

ORTEC[®]

FRAM-BW
Plutonium and Uranium Isotopic Analysis Software
Software User's Manual
Software Version 5.2

Advanced Measurement Technology, Inc.

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Safeguards Science and Technology
Group N-1

Nuclear Nonproliferation Division

FRAM, Version 5

User Manual

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FRAM, Version 5

User Manual

1. Introduction

This section contains general information about the FRAM program, the prerequisites for running that program, and the contents of the distribution kit.

1.1. General

This manual describes the use of version 5 of the FRAM gamma-ray isotopic analysis software developed in the Safeguards Science and Technology Group, N-1, Nuclear Nonproliferation Division, Los Alamos National Laboratory. The software analyzes the gamma ray spectrum from plutonium-bearing items and determines the isotopic distribution of the plutonium, ^{241}Am content, and concentration of other isotopes in the item. The software can also determine the isotopic distribution of uranium isotopes in items containing only uranium.

The body of this manual describes the generic version of the code.

The software can analyze data that is stored in a file on disk. It understands five common storage formats and an ASCII text format. The software can also control data acquisition using an MCA and then store the results in a file on disk for later analysis or analyze the spectrum directly after the acquisition. The software currently supports the control of ORTEC systems. Support for the Canberra's Genie-2000 Spectroscopy Systems exists in version 5 provided the user has installed the Genie-2000 software.

A versatile parameter database structure governs all facets of the data analysis. User editing of the parameter sets allows great flexibility in handling data with different isotopic distributions, interfering isotopes, and different acquisition parameters such as energy calibration, and detector type.

The maximum number of data channels allowable in FRAM v.5 is 32K. The maximum energy range for analysis extends to 10 MeV.

1.2. Audience

This manual is intended for the system supervisor or the local user who is to be the resident expert. Excerpts from this manual may also be appropriate for the system operator who will routinely use the instrument.

1.3. Other Documentation

Various manuals for commercially available electronic and computer components of the data acquisition and analysis system may be required to support other aspects of data acquisition and analysis. These manuals are supplied only if the FRAM software is delivered as part of a complete data acquisition system.

1.4. Conventions Used in this Document

The pictures in this document were captured on a system running Windows XP Professional (SP3). Most of the text and all of the headings in this document are written with the Times New Roman font.

Names of the menu choices will be written using the Arial font, for example, **File, Measure, Parameter, Analyze, etc.**

Placing a vertical bar between the individual choices will denote a sequence of menu selections. For example, choose the **File | Open File** option.

Directory and file names will be written in bold using the Courier New font, for example, **c:\FRAMdata** and **FRAM.INI**.

Text that is reproduced from a text file will be written using the Courier New font.

Text that is displayed on the screen either as a message, a dialog box title, or prompt for a control within a dialog box will be written using the Arial font.

Key combinations are indicated with a plus sign, e.g. Shift+Tab or Ctrl+F4.

1.5. Definitions and Acronyms

CAM	Configuration Access Method
CPU	Central Processing Unit
DLL	Dynamic Link Library.
FRAM	<u>F</u> ixed energy, <u>R</u> esponse function <u>A</u> nalysis with <u>M</u> ultiple efficiencies. Also, a word of Scandinavian origin meaning “forward” or “onward.”
FWHM	Full Width at Half Maximum.
MCA	Multi-Channel Analyzer.
MCB	Multi-Channel Buffer.
NIM	Nuclear Instrumentation Module.
Parameter Set	The group of parameters, constants, and text strings that govern all facets of the analysis. Each parameter set is stored in the FRAM database during analysis.
Parameter File	A parameter set may be exported as ASCII text to a disk file. This disk file is called a parameter file. It has a default file extension of .par. The standard extension .txt for a text file may also be used and is often preferred when transmitting parameter files between facilities.
PC	Personal Computer, an IBM (or compatible) computer with an Intel-based CPU.
RAM	Random Access Memory.
UMCBI	Unified MCB Interface.

1.6. New Features in Version 5

The users familiar with version 4 of FRAM will note the following new features and upgrades in version 5.

1. **User Interface.** FRAM v.5 has a totally new User Interface that, for simplicity, provides a single interface for all data displays. This new interface will be described in detail in this manual.
2. **Menu Information.** The main FRAM v.5 menu consists of six selections: **File, Measure, User, Parameter, Param Edit, and Help.** Most commands are “sticky” (they remember their previous selection) so there is no need for the Default option of FRAM v.4.
3. **Analysis Improvements.** Analysis improvements are made in many areas:
 - Pu 100-keV region analysis,
 - U 100-keV region analysis,
 - Provision for inclusion of systematic uncertainties in output results,
 - Maximum channel range extended to 32K channels,
 - Maximum energy range for physical model efficiency extended to ~ 10 MeV,
 - Improved energy calibration peak search,
 - Improved ^{236}U correlation,
 - Error bars and error band for relative efficiency points and fit,
 - Interactive, real-time parameter editing,
 - Improved compatibility with commercial formats for multiple spectra,
 - Excel-compatible results file for multiple spectra analysis and comparison,
 - Improved parameter set version control,
 - Fill and line spectrum display modes.
 - Very extensive auto-analysis.
4. **FRAM v.4 Capabilities Removed.** Some capabilities present in v.4 have been removed for the sake of improved simplicity.
 - Dual language capability removed,
 - Capability to display multiple analysis results windows removed,
 - Generic detector efficiency model built in. No choice of detector type required.
5. **New command options in Application Constants.** Many of the changes in the FRAM v.5 can be turned on or off with the built-in commands in the Application Constants section of the parameter set.
 - Correction for peaks in 100-keV region,
 - Systematic uncertainties,
 - Sum peak correction option,
 - Improved ^{236}U correlation option,
 - Number of iterations.
6. **New Help Menu Options with Extensive User Help Features.**
7. **New Command-Line Mode of Operation.** The Command-Line Operation mode is meant for users who want to incorporate FRAM into their own applications. This mode allows the user to make a very simple interface to the FRAM analysis engine.
8. **New Measure-Compare Option.** This option allows the user to directly compare the results of an analysis with a decay-corrected declared value. The differences between the measured and declared values are expressed in terms of the standard deviations of the measured and declared values.

1.7. System Requirements

FRAM v.5 is designed to run under all currently supported (2010) Windows operating systems. This includes Windows XP, Windows Vista, and Windows 7.

FRAM v.5 should run successfully on any computer compatible with these operating systems.

A math coprocessor is required.

1.8. Distribution Kit

FRAM v.5 is distributed as a single executable file, **FRAM51setup.exe**.

1.9. Installation Instructions

Run the executable file **FRAM51setup.exe**.

The file will install FRAM v.5 into **C:\Program Files** (you can change the installation folder if preferred). The FRAM program folder is created as **C:\Program Files\FRAM51** and the installation process installs the FRAM v.5 icon on the desktop.

The installation process will also create the **C:\FRAMdata** directory containing the folders **FRAM51**, **Params**, **References**, **Results**, **Spectra**, and **Testspec**.

FRAM51	Contains FRAM database .
Params	Contains FRAM parameter files .
References	Contains FRAM manual and other reference files .
Results	Default folder for storage of analysis results.
Spectra	Default folder for spectral data storage.
Testspec	Contains test spectra from well characterized sources and the certified isotopic values of the sources.

1.10. Configuration

There is a configuration file, **FRAM.INI** that contains much of the default information needed for running FRAM. All the information in this file can be accessed and modified within the FRAM program. The file is in text format and can be edited directly by using Windows Notepad or WordPad programs.

The user authorization file contains a list of authorized users, their passwords (in encrypted form), and the level of access granted to each. The information in this file can be modified by means of the **User | Change Password** and **User | Edit User List** options (cf. Section 3.5).

2. Getting Started

This section describes the steps required for installing and configuring FRAM for the first time. These initial actions seldom require any changes once the software is in operation. In this section references are made to other sections of the manual that contain more detailed information.

2.1. Before Running FRAM

The first step is to install the software. These instructions are reproduced from section 1.9.

Run the executable file **FRAM51setup.exe**.

The file will install FRAM v.5 into **C:\Program Files** (you can change the installation folder if preferred). The FRAM program folder is created as **C:\Program Files\FRAM51** and the installation process installs the FRAM v.5 icon on the desktop.

The installation process will also create the **C:\FRAMdata** directory containing the folders **FRAM51**, **Params**, **References**, **Results**, **Spectra**, and **Testspec**.

FRAM51	Contains FRAM database.
Params	Contains FRAM parameter files.
References	Contains FRAM manual and other reference files.
Results	Default folder for storage of analysis results.
Spectra	Default folder for spectral data storage.
Testspec	Contains test spectra from well characterized sources and the certified isotopic values of the sources.

2.2. Running FRAM for the First Time

FRAM has two modes of operation: **Normal Operation** and **Command-Line Operation**.

Normal Operation

When FRAM is run without any argument (such as double clicking the **FRAM.exe** file or the shortcut pointing to **FRAM.exe**), it will operate in the normal mode. This mode of operation will open a window with all the necessary menus to assist in the execution of the FRAM measurement and analysis.

Command-Line Operation

When FRAM is run with a string argument it will switch to the command-line operation mode. This mode of operation will execute the commands supplied in the argument and when the analysis is completed will automatically terminate. It will not open a window.

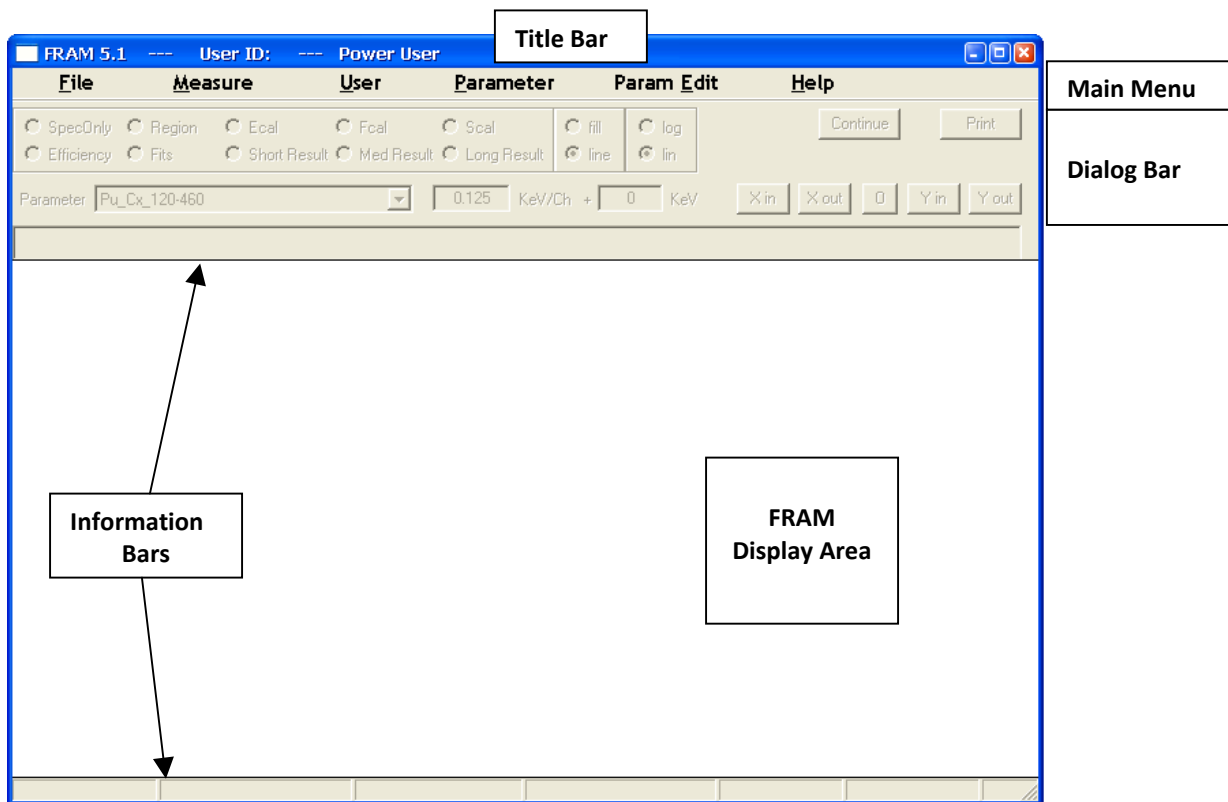
The Command-Line Operation mode is meant for users who want to incorporate FRAM into their own applications. This mode allows the user to make a very simple interface to the FRAM analysis engine. The commands for this mode are listed in Appendix E.

The remainder of this section deals with the **Normal Operation** of FRAM.

Run FRAM by double clicking on its icon that was established during the installation procedure. The following blank FRAM window will appear on the screen. The FRAM window provides a single interface for all FRAM data display. All analysis output results are also displayed in the FRAM window.

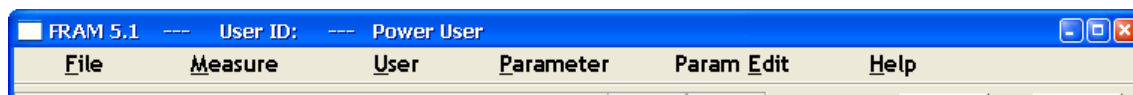
All actions start from the FRAM Main Menu. The Dialog Bar contains options that enable the user to check all aspects of a spectrum acquisition or an analysis without leaving the FRAM window.

An overview of the six Main Menu options is provided in section 2.2.1 below and discussed in detail in chapter 3. Similarly, an overview of the Dialog Bar options is provided in section 2.2.2 below. The Dialog Bar options are presented in detail in chapter 4.



2.2.1. Main Menu Overview

Presented below is a brief description of the functions provided by FRAM’s main menu.



File This menu allows you to open a spectral data file and read it into memory and to save spectral data into a file on disk. It allows you to access previous results files from within the program or switch between previous and current results. It also allows you to exit from FRAM.

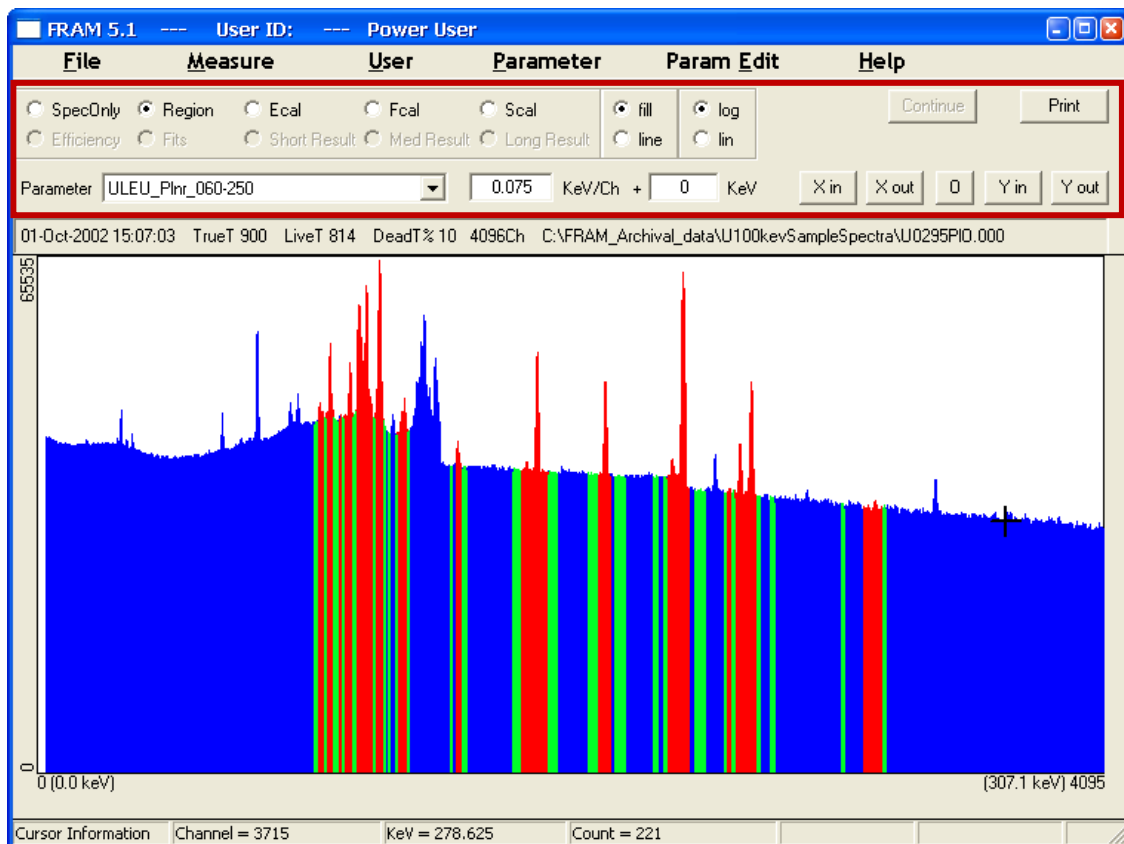
Measure This menu allows you to acquire a spectrum from a multi-channel analyzer under the control of the FRAM program followed by storage of the acquired spectrum on disk. These operations require the installation of the appropriate hardware and its associated software drivers. This menu also allows you to analyze spectra from a disk file or a series of disk files. This menu combines the two functions allowing a FRAM-controlled data acquisition followed immediately by an analysis.

Additionally this menu allows the user to access the ISOPOW plutonium isotopic composition decay correction program and also to make a comparison of the FRAM analysis result with a declared value.

- User** This option allows you to view and modify the information about the user accounts that is stored in the User Authorization File. The options under this menu are password-protected.
- Parameter** This menu allows you to export and import, open, save, print, and rename or delete parameter sets
- Param Edit** This menu allows you to view and/or edit the five categories of parameters that govern an analysis.
- Help** This menu provides information on the options and sub options under the five main menu items. This menu allows you to see a screen with the name and version number of the program along with copyright information.

2.2.2. Dialog Bar Overview

The dialog bar outlined below controls all aspects of spectrum and results display making it easy for the user to check on the quality of the data or analysis without leaving the FRAM main window. A brief description of the functions provided follows.



<input type="radio"/> SpecOnly	Displays the spectrum.
<input type="radio"/> Region	Displays the spectrum's regions of analysis. The peak regions are shown in red and the background regions are shown in green.
<input type="radio"/> Ecal	The peaks used for Energy calibration are shown in red on the background of a blue spectrum.
<input type="radio"/> Fcal	The peaks used for FWHM calibration are shown in red on the background of a blue spectrum.
<input type="radio"/> Scal	The peaks used for Shape calibration are shown in red on the background of a blue spectrum.
<input type="radio"/> Efficiency	Shows the relative efficiency curve of the analysis.
<input type="radio"/> Fits	Shows the fits of the analysis regions. When Fits is selected the "Region" scroll bar becomes active allowing the user to scroll and display all the regions.
<input type="radio"/> Short Result	Displays the short output (1 page) of results in the FRAM window.
<input type="radio"/> Med Result	Displays the medium output (~ 4 pages) of results in the FRAM window.
<input type="radio"/> Long Result	Displays the long output (~10 pages) of results in the FRAM window.
<input type="radio"/> fill	Fills the spectrum from the baseline to the data points with solid blue color.
<input type="radio"/> line	Displays the spectrum by connecting the data points with a blue line.
<input type="radio"/> log	Displays the spectrum with a logarithmic vertical scale.
<input type="radio"/> lin	Displays the spectrum with a linear vertical scale.
Parameter	The combo box allows the user to access the parameter sets in the database. The energy gain and offset allow the user to change the energy calibration of a parameter set to match the energy calibration of the spectrum.
Continue	When acquiring data, this button switches between Acq. Stop and Continue to allow for stopping and continuing the acquisition.
Print	Prints the information displayed in the FRAM Display Area. When the acquisition is stopped by pressing the Acq. Stop button then this Print button is changed to Restart to allow for restarting the acquisition.
X in	Adjusts the horizontal scale to view half the channels of the current spectrum display.
X out	Adjusts the horizontal scale to view twice the channels of the current spectrum display.
O	Returns the spectrum to its full scale in both horizontal and vertical scales.
Y in	Contracts the vertical display by one-half. Makes peaks taller.
Y out	Expands the vertical display by a factor of 2. Makes peaks shorter.

2.2.3. Built-In Parameter Sets

The FRAM installation process installs a set of built-in parameter sets. These parameter sets should be sufficient for analysis of spectra of most common plutonium and uranium materials obtained with typical HPGe detectors (including the planar, coaxial, N-type, and P-type HPGe). The names of the built-in parameter sets are capitalized, and they cannot be changed or removed. This process greatly strengthens the ability to control the versions of the parameter sets. Users can still create and modify their own parameter sets, and those parameter sets are saved with lower-case characters.

The parameter sets in FRAM v.5 are backward compatible with the parameter sets of earlier versions of FRAM.

Importing and Exporting parameter sets is described later in the discussion of the **Parameter** main menu option in section 3.6.

Editing of parameter sets is described in section 3.7. Temporary editing of built-in parameter sets is discussed in section 3.9.8.

The optimum application of the built-in parameter sets is described in Appendix C.

2.2.4. Setting Passwords/User Names

There are four levels of password protection in FRAM v.5: Manager or Administrator has full access to everything; Supervisor or Power User can do everything except assign users; Operator or Normal User cannot edit parameter sets; and Limited User, a feature new to v.5, cannot even select which parameter set to use and can only push the button to analyze. Limited User is the same as not being logged in.

When FRAM is installed and started for the first time, it will create an authorization file containing five users: "administrator" with the Administrator access level; "manager" with the Administrator access level; "supervisor" with the Power User access level; "operator" with the Normal User access level; and NULL (no characters or blank entry), with the Power User access level. The "administrator" user is created with a NULL password. The other passwords are the same as the user names.

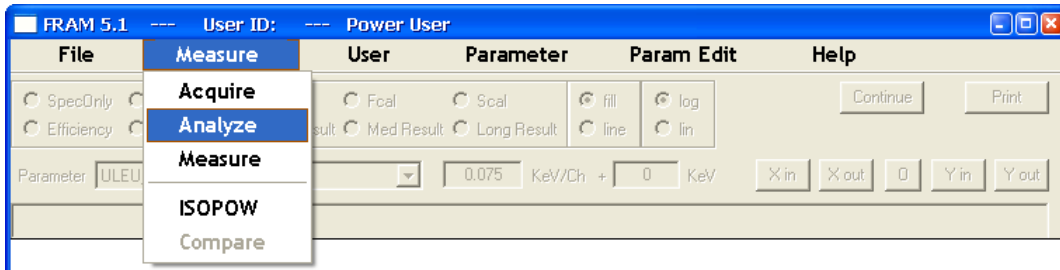
After FRAM is installed the system administrator should change the default passwords/user names to enhance system security. To do this the system administrator should: Select **User | Login** . Login as a user with Administrator level access. Then select **User | Change Password** and/or **User | Edit User List** to change user names and/or passwords to reflect your desired configuration.

The **User** menu option is discussed in more detail in section 3.5.

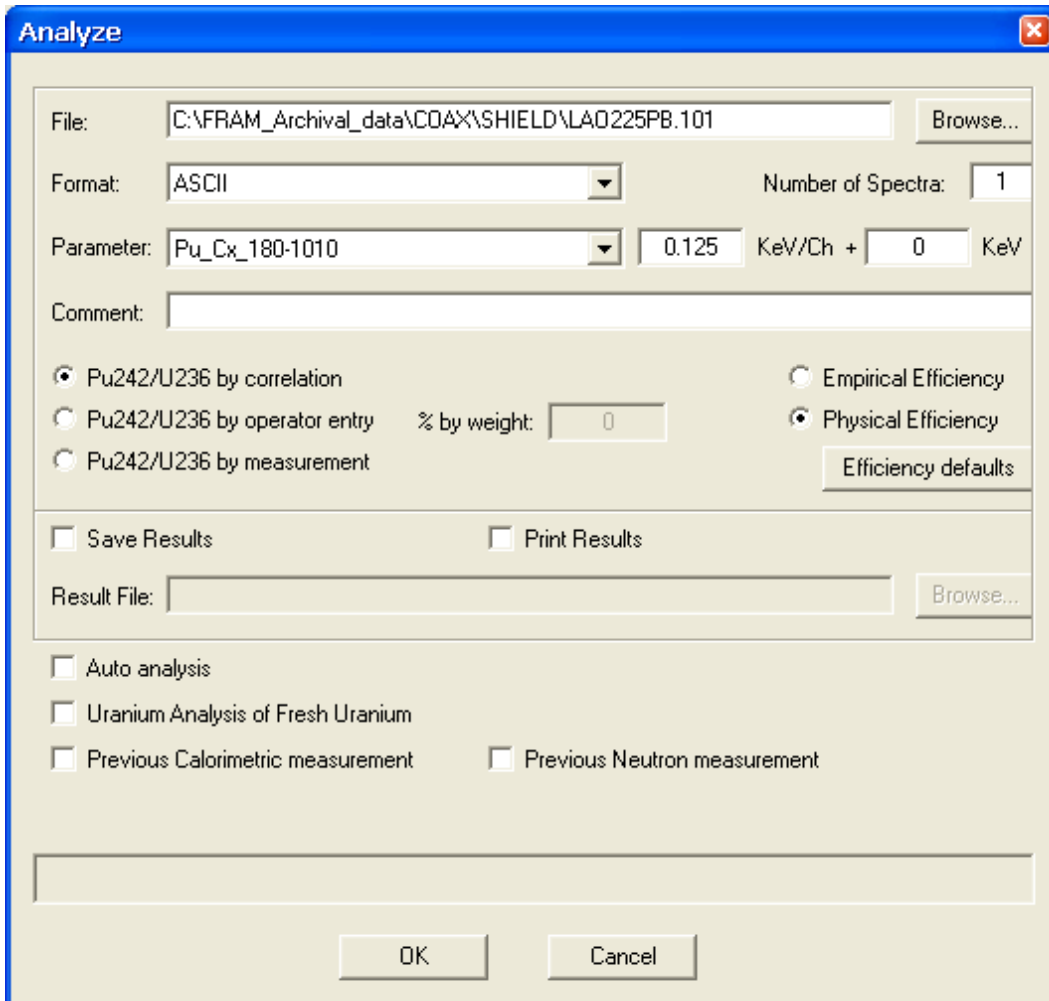
2.3. Analyzing Spectral Data

The following procedure shows how to analyze a spectrum stored in a disk file. It is assumed that you will use one of the standard, built-in parameter sets installed with FRAM.

Choose the **Measure | Analyze** option.



The **Analyze** dialog box will appear on the screen. The initial settings of the parameters may vary depending on how the system has previously been used.



Enter the filename in the **File:** box or click on the **Browse...** button to find the filename for the spectrum to be analyzed.

Choose the data storage **Format** from the pull down list.

Choose the **Parameter Set** appropriate for the spectrum type and data acquisition conditions from the pull down list.

Enter a comment, if desired.

This completes the minimum required information to analyze data from a disk file. The short output that appears on the screen will be described later.

The choices below the comment line are sticky and will reflect the last use of the **Measure | Analyze** option (even through code restart). The user should check these choices to see if they are appropriate for the desired analysis. These choices are described more thoroughly in the discussion of the **Measure | Analyze** option in section 3.4.2.

To proceed with the analysis click on the **OK** button. Just above this button you will see information about the analysis as it progresses. When the analysis is done, a summary of the results will be displayed on the screen in the FRAM window.

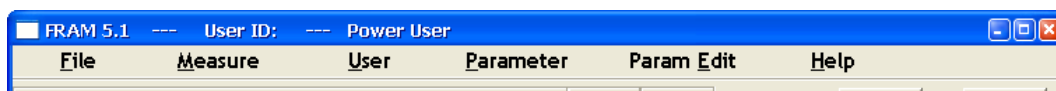
3. Operations Reference—Main Menu

3.1. Startup

To invoke the program from the desktop, double-click on the icon that was established during the installation procedure. The alternative is to use Explorer to locate the file **FRAM.exe** in your working directory and then double clicking on that entry.

3.2. Software Controls

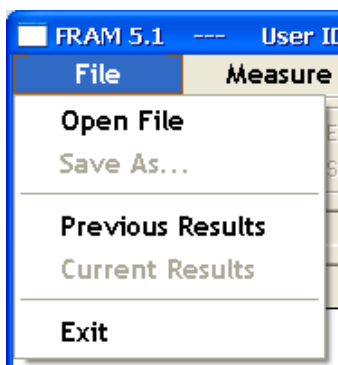
The major software controls provided by the program are implemented in terms of a menu system. You may choose any of the options presented by the menus. These options are grouped into six top-level menu headings. The following is the top-level menu structure presented to you after invoking the program.



The main features of the five top-level menu options have been discussed in section 2.2.1. The sections below describe these options in detail.

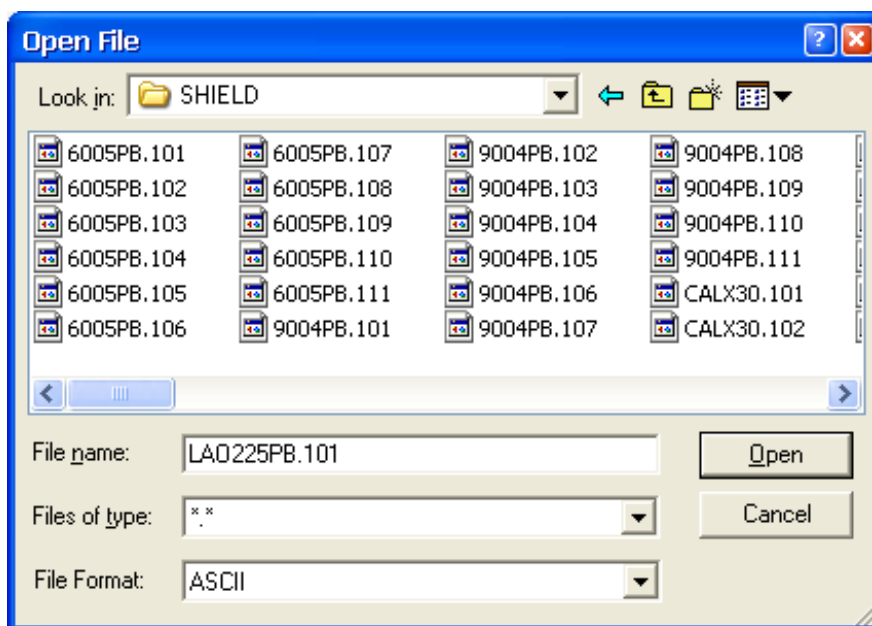
3.3. File

The **File** menu can be expanded by clicking on the word **File** with the mouse or by pressing the key combination Alt+F. The following picture shows the options available under the **File** menu.

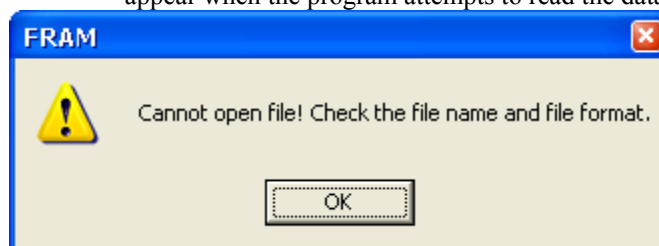


3.3.1. File | Open File

This option allows you to read spectral data from a disk file into memory and display the spectrum in the FRAM window. The **Open File** dialog box will appear on the screen. The path and entries reflect entries from the last time a file was opened or analyzed.



- Look in:** Use the standard Windows dialog to search for the file to be opened.
- File name:** File name of the file chosen to be opened.
- Files of type:** The drop down menu allows the user to display only the file type selected or all file types with *.* selected. It is likely that the user will want to select *.* so that all files are displayed, regardless of format or extension.
- File Format:** You must select the data storage format of the selected file from the choices given. If the wrong format is chosen an error message will appear when the program attempts to read the data from the file.

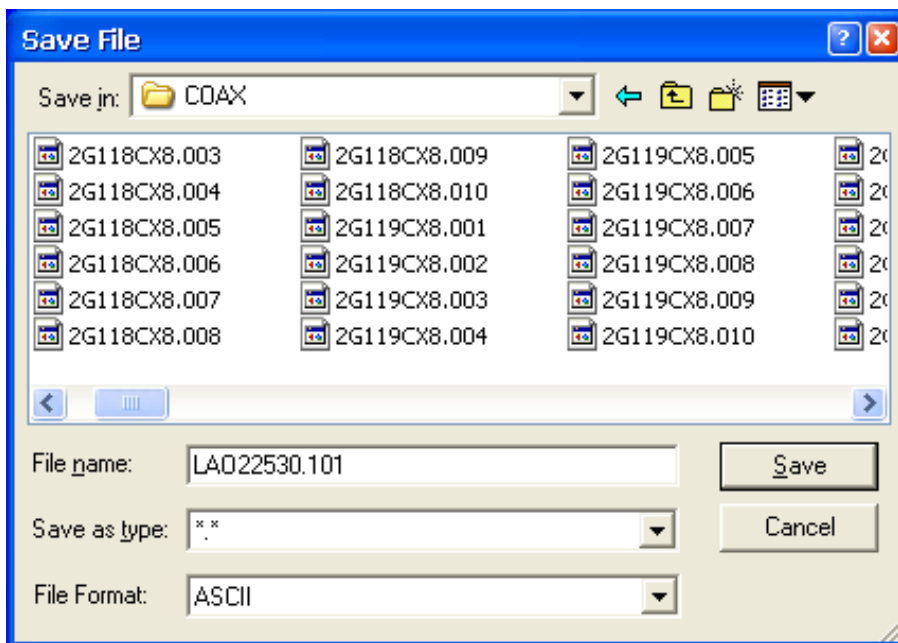


Dismiss the error message window by clicking on **OK**. FRAM will return to the main FRAM window and the user will need to invoke the **File | Open File** option again.

- Open** Click on this button to open the specified data file. If there is an error in opening the file, a message will appear. If the file is opened successfully the spectrum will appear in the FRAM window. Acquisition information and the path to the stored file appear in the Information Bar above the plotted spectrum. The pointer can be used to place a cursor (cross hair) in the spectrum. Cursor information is shown in the Information Bar at the bottom of the window. See chapter 4 for more description of the spectrum display controls in the FRAM window.

3.3.2. File | Save As

This option allows you to write spectral data from memory to a disk file with a user-specified file name. If a data file has been read into memory and displayed in the FRAM window the **File | Save As...** becomes active. Selecting this option brings up the **Save File** dialog box.



Save in: Use the standard Windows dialog to search for the location where the file is to be stored. The default directory and file format will be those of the last saved spectrum.

File Name: Enter the file name and extension of the file to be stored. If the file extension of the opened file is one of the FRAM file types (chn, spc, mca, cnf, spe, dat, and txt) then the default extension of the File | Save As format will be added automatically to the file name. Otherwise, the extension of the opened file is used.

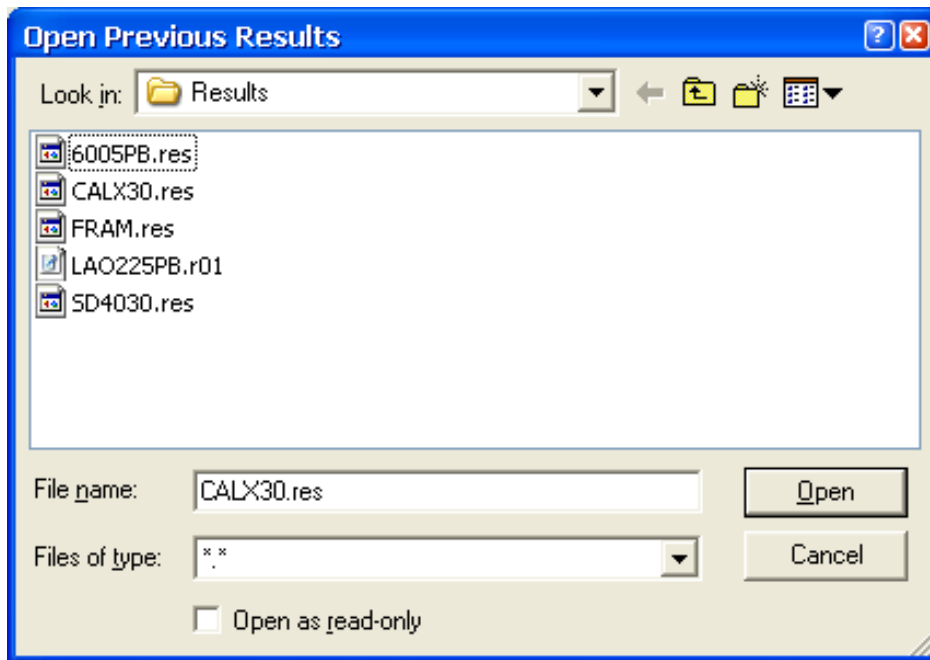
Save as type: The drop down menu allows the user to display only the file type selected or all file types with *.* selected.

File Format Select the data storage format of the selected file from the choices given. The **Save As** option allows you to use the program as a data format translation utility among supported formats.

Save Click on this button to save the specified data file. Acquisition information and the path to the stored file appear in the line above the plotted spectrum of the stored file.

3.3.3. File | Previous Results

This option brings up the **Open Previous Results** dialog box. This option defaults to **C:\FRAMdata\Results** after a new installation of FRAM but because the path is “sticky” it will reflect the search for the last previous results file.



Look in: Use the standard Windows dialog to search for the file to be opened.

File name: File name of the results file chosen to be opened.

Files of type: The drop down menu allows the user to display only the file type selected or all file types with *.* selected. It is likely that the user will want to select *.* so that all files are displayed, regardless of extension. The default results file names are *.res for single file and *.r* for multiple files.

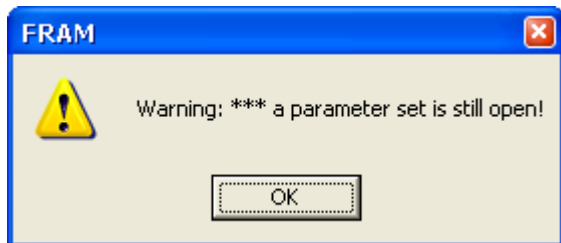
Open Click on this button to open the specified results file in the FRAM window. On opening the results are initially displayed as a **Short Result** but can be displayed as a **Med Result**, or **Long Result** using the options in the FRAM Dialog Bar.

3.3.4. File | Current Results

The Current Results option becomes active after a Previous Results file has been displayed. It allows the user to return to the display of the just analyzed results which still remain in the database. The results can be displayed as **Short Result**, **Med Result**, or **Long Result** using the options in the FRAM Dialog Bar.

3.3.5. File | Exit

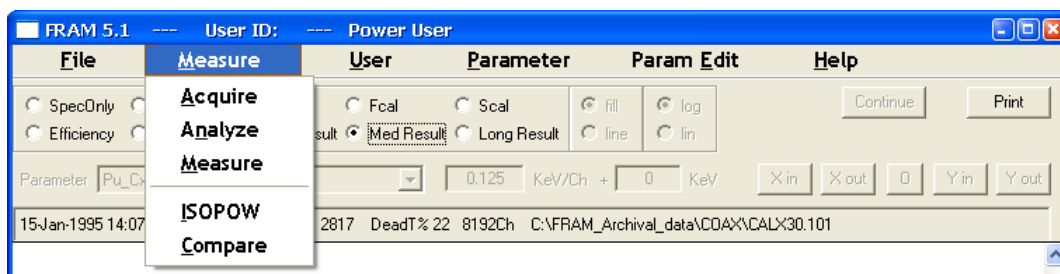
This option closes the FRAM code and returns you to the Windows Desktop. There are three alternatives to closing FRAM in addition to the **File | Exit** command. You may click on the **X** in the upper right hand corner of the window. You may also click on the small box in the upper left-hand corner of the window to bring up a small system menu and then choose the **Close** option. Alternatively you may use the Alt+F4 keyboard shortcut. None of these options will succeed if you have opened a parameter set under the **Parameter** menu option. Instead the following message will appear on the screen.



In this case you must get back into the **Parameter** menu option and exit in the normal way before exiting FRAM.

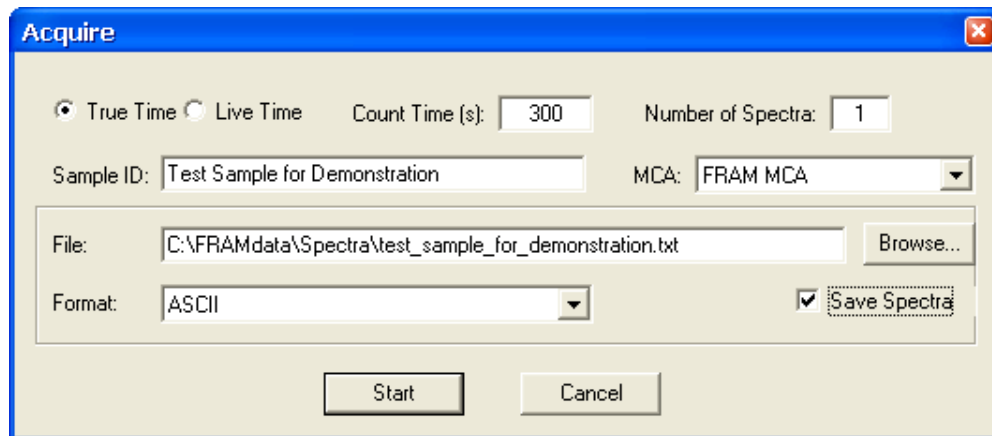
3.4. Measure

The Measure menu can be expanded by clicking on the word **M**easure with the mouse or by pressing the key combination Alt+M. The following picture shows the options available under the **M**easure menu.



3.4.1. Measure | Acquire

This option controls all aspects of a data acquisition with data storage, but no analysis. The following dialog box will appear on the screen.



Count Time (s): Enter the data acquisition time in seconds. Choose whether the count is to be preset on Live Time or True Time.

Live Time The amount of time during which the analyzer is actively engaged in counting pulses from the detector/preamplifier. The time during which the analyzer is unable to count pulses is referred to as “dead time”.

True Time The elapsed clock time during the data acquisition. This is the sum of the live time and the dead time.

Number of Spectra: Enter the number (between 1 and 1000) of repeated data acquisition and storage cycles. The acquisition and data storage cycles will be repeated without operator intervention. See below for discussion of filename structure and its interaction with the **Number of Spectra**.

Sample ID: You should enter a character string (up to 39 characters in length) identifying the sample being measured.

If **Save Spectra** is checked, the name of the **File:** to be saved is defaulted to the **Sample ID**. If the **Number of Spectra** is 1, the default output file name is **SampleID.xyz** where **xyz** is the standard extension for the chosen file format. If the **Number of Spectra** is >1 then the output file name is **SampleIDXXX.xyz** where **XXX** is the sequence number of the acquired spectrum.

If the **Sample ID** contains characters that do not conform to allowed Windows filenames (*, |, /, \, :, “, <, >, comma, ?), the un-allowed characters will be ignored in the output filename. Also, the “space” character will be replaced by “_”.

MCA: Choose the MCA for data acquisition from the pull down menu of available MCA choices. One of the menu choices is **Simulation**. The simulation MCA option generates data from a previously acquired spectrum using the Poisson distribution. If the **Simulation** option is selected, an **Open Simulating Spectrum** dialog box will appear after clicking on **Start**, allowing you to choose the simulating spectrum. To shorten the measurement time, the simulation clock is run

at ten times the rate of the actual clock. This function can be used for training purposes when no MCA is connected.

Save Spectra

Checking the **Save Spectra** activates the **File:** and **Format:** boxes. **C:\FRAMdata\Spectra** was established during the FRAM installation as the default data storage path. The **Browse...** button may be used to select other paths for spectral data storage. The default file name, path, file type and file format will be those of the last saved spectrum.

File:

The user chooses the path and the filename for storage of the acquired spectrum using the **Browse...** button. For multiple spectrum acquisitions (**Number of Spectra** > 1), several filename-number of spectra-file extension combinations are available to accommodate standard commercial file naming conventions.

To save 1-100 spectra, the filename format can be **Filename.X##** where **##** is a 2 digit number from 00 to 99, and **X** can be any character or number. This form is compatible with FRAM v.4 where **X** = S (for Spectrum), although other characters can also be used. The data format of the stored spectral data is specified by the entry in the **Format:** box described below.

To save up to 1000 spectra, the filename format must be **Filename###.XXX** where **###** is a 3 digit number from 000 to 999 and **XXX** can be any extension such as .CHN, .CNF but not limited to standard extensions. This naming convention is compatible with several commercial data acquisition software packages. One advantage of using the standard commercial extensions is that the recognized icon will be used to display the file name. The data format of the stored spectral data is specified by the entry in the **Format:** box described below. The default file name and path will be that of the last saved spectrum.

Format:

The data format of the stored spectral data. This entry controls the data format of the stored data, irrespective of the extension entered for the filename. The default format will be that of the last saved spectrum. The supported data formats are:

Ortec 'chn'

Ortec 'spc'

Canberra S100

Canberra CAM

IAEA MMCA

ASCII Two columns (channel, counts)

Start

Click on this button to start the measurement.

Cancel

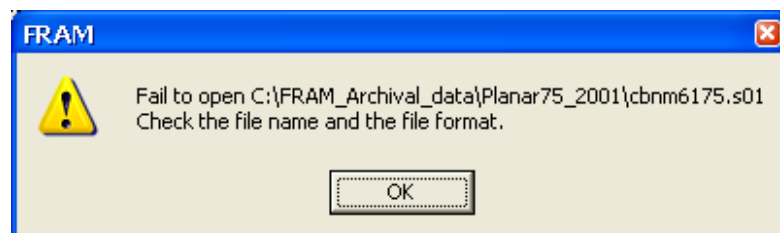
Click on this button to cancel the measurement and return to FRAM's main menu.

3.4.2. Measure | Analyze

This option allows you to analyze spectral data files stored on disk. The single dialog box below allows analysis of either plutonium or uranium spectral data.

File: Enter the file to be analyzed, including complete path and extension. You may click on the **Browse...** button and use the standard Windows dialog to search for the file to be analyzed. The default file name and path will be that of the last analyzed spectrum.

Format: You must select the data storage format of the selected file from the choices given. If the wrong format is chosen an error message window will appear when the program attempts to read the data from the file. Dismiss the error message by clicking **OK** and FRAM will return to the **Analyze** window. The default file format will be that of the last opened file.



- Number of Spectra:** The number of files with sequential filenames/extensions to be analyzed starting with the entered file. The supported formats for sequential file filenames/extensions are discussed in section 3.4.1 above.
- Parameter:** You must select an analysis parameter set from the choices given. They represent the sets that currently exist in the database. If you select an inappropriate parameter set, you may encounter difficulties in the analysis. The default gain (**KeV/Ch**) and offset (**KeV**) of the chosen parameter set are displayed. This assists in the choice of a proper parameter set. The default parameter set and energy calibration will be those most recently used.
- Comment:** Enter a comment (a character string up to 59 characters in length) that is reproduced on the output. Comments are optional.

Other Selections

☉ Pu242/U236 by correlation

Calculate Pu242 (or U236, depending upon the analysis) by a correlation.

The correlation used for Pu242 is of the form

$$\text{Pu242} = A * [(\text{Pu238})^B * (\text{Pu239})^C * (\text{Pu240})^D * (\text{Pu241} + \text{Am241})^E]$$

where the constants A, B, C, D, and E are Application Constants in the selected parameter set and are entered or changed in the **Param Edit** menu option.

The correlation used for U236 is of the form

$$\text{U236} = A * [(\text{U235})^B * (\text{U238})^C] + D * [(\text{U235})^E * (\text{Th228})^F]$$

where the constants A, B, C, D, E, and F are Application Constants in the selected parameter set and are entered or changed in the **Param Edit** menu option. If Th228 is not present as an isotope in the parameter set, the correlation uses just the first term.

☉ Pu242/U236 by operator entry % by weight

When this button is selected the % by weight box becomes active to accept an operator entry of a known or estimated wt% of Pu242 or U236. This entry is sticky.

☉ Pu242/U236 by measurement

Selection of this option will allow Pu242 or U236 to be measured directly from analysis of peaks in the gamma ray spectrum. If this option is selected and the parameter file does not contain any Pu242/U236 peaks the result for the measurement of that isotope will be 0.0.

- ☉ **Empirical Efficiency** Choose this option to use the empirical (polynomial) model for determining the relative efficiency. See Chapter 5 and Appendix A for a description of the model.

- Physical Efficiency** Choose this option to use the physics-based model for determining the relative efficiency. See Chapter 5 and Appendix A for a description of the model.

Efficiency defaults

This button will be activated only when the **Physical Efficiency** model is chosen and **Auto analysis** is not checked. Click on this button to view and/or modify the efficiency parameters as shown in the window below. These parameters are taken from the Application Constants in the parameter set chosen. If the parameter set has no efficiency information, built-in default values are used for **U – Pu Maximum** and **Cd Maximum** values (see section 5.3). See section 5.2–5.4 for a description of the use of the dialog box resulting from the selection of this button. Any modification of the Efficiency defaults is noted in the header block of the output where the Efficiency model will say **Physical Efficiency (Mod. Eff.)**.

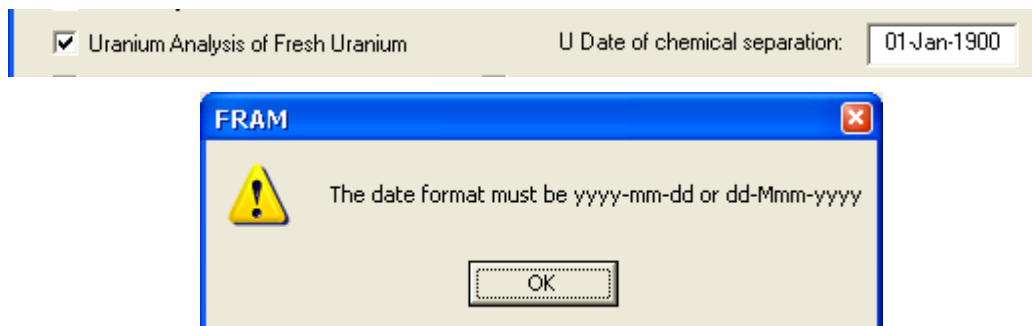
Parameter	Unit	Minimum	Maximum
U - Pu	g/cm ²	0.001	20.000
Cd	mm	0.00	5.00

- Save Results** When this box is checked the **Result File:** entry and **Browse...** button become active allowing the user to specify the path and filename for storage of the results file. Default values for the Result File are: **C:\FRAMdata\Results\filename.res** where **filename** is the name of the analyzed data file. The path **C:\FRAMdata\Results** was established during the FRAM installation.
- Print Results** When this box is checked a short output (see section 7.1) is printed on the system printer at the end of the analysis.

Other Analysis Choices

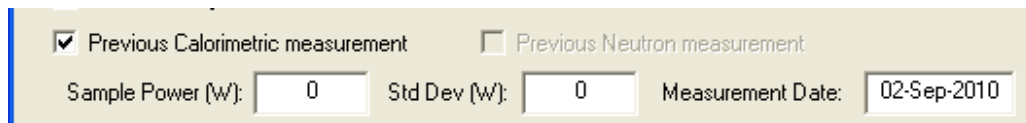
- Auto analysis** Check this box if you wish to have the spectrum automatically re-analyzed depending on the results of the current analysis and the directions encoded into the Application Constants in the chosen parameter set. See chapter 6 for more information on how this feature works.
- Uranium Analysis of Fresh Uranium** Check this box if you are analyzing fresh uranium (less than 6 months since chemical removal of thorium and protactinium from the uranium). Checking this box brings up an entry box to enter the date of chemical separation. The date format for the measurement date can be either the American date format (dd-Mmm-yyyy) or the ISO 8601

international date format (yyyy-mm-dd). A wrong date format would activate the following warning message reminding you to use the correct format.



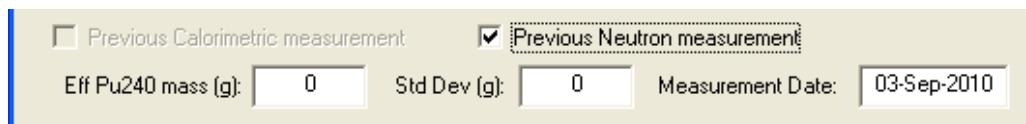
Previous Calorimetric measurement

Checking this box brings up additional entry boxes allowing the entry of results from a prior calorimetry measurement. The calorimetry results are combined with the current isotopic results to obtain the total plutonium mass. The date format for the measurement date can be either the American date format (dd-Mmm-yyyy) or the ISO 8601 international date format (yyyy-mm-dd). A wrong date format would activate the above warning message reminding you to use the correct format.



Previous Neutron measurement

Checking this box brings up additional entry boxes allowing the entry of results from a prior neutron measurement to obtain the total plutonium mass. The date format for the measurement date can be either the American date format (dd-Mmm-yyyy) or the ISO 8601 international date format (yyyy-mm-dd). A wrong date format would activate the above warning message reminding you to use the correct format. This function has no effect on uranium measurements.



Start

Click on this button to start the analysis.

Cancel

Click on this button to cancel the analysis and return to FRAM's main menu.

Parameter:

You must select an analysis parameter set from the choices given. They represent the sets that currently exist in the database. If you

select an inappropriate parameter set, you may encounter difficulties in the analysis. The default gain (**KeV/Ch**) and offset (**KeV**) of the chosen parameter set are displayed. This assists in the choice of a proper parameter set.

Comment: Enter a comment (a character string up to 59 characters in length) that is reproduced on the output. Comments are optional.

.CSV Files

When a spectrum is analyzed, FRAM v.5 will append one-line results to the **Uranium.csv** or **Plutonium.csv** file (depending on the analysis) whether or not the **Save Results** option is checked. The files, which are in the **FRAMdata** folder, can be opened by Excel. If the file does not exist, FRAM will create it the first time a spectrum is analyzed. When the file grows too large, it will be saved as **Uranium###.csv** or **Plutonium###.csv**, where **###** starts from 000 and a new **Uranium.csv** or **Plutonium.csv** file is created. This feature is designed to be used in analyzing and comparing multiple spectral analyses.

For plutonium the results saved are the ^{238}Pu – ^{242}Pu , ^{241}Am , P_{eff} , and $^{240}\text{Pu}_{\text{eff}}$ values and their one-sigma uncertainties. Other parameters saved are the file name or sample ID of the analyzed data, the acquisition date, the analysis date, the parameter set, the efficiency model, and the default gain and zero of the analysis. For plutonium the P_{eff} and $^{240}\text{Pu}_{\text{eff}}$ values are the values calculated for all the isotopes in the isotope list, not just the plutonium isotopes listed in the **Plutonium.csv** file.

For uranium the results saved are the ^{234}U , ^{235}U , ^{236}U , ^{238}U , Specific Power, and their one-sigma uncertainties. Other parameters saved are the file name or sample ID of the analyzed data, the acquisition date, the analysis date, the parameter set, the efficiency model, and the default gain and zero of the analysis. For uranium the Specific Power values are the values calculated for all the isotopes in the isotope list, not just the uranium isotopes listed in the **Uranium.csv** file.

3.4.3. Measure | Measure

This option governs all aspects of a measurement including data acquisition, data analysis, and spectral data and results file generation. Spectral analysis, spectrum storage, results generation and storage proceed immediately upon completion of data acquisition without user intervention. Selection of this option will bring up the following dialog box. This dialog box basically combines the **Acquire** and **Analyze** dialog boxes under the **Measure** option.

- Count Time (s):** Enter the data acquisition time in seconds. Choose whether the count is to be preset on Live Time or True Time.
- Live Time** The amount of time during which the analyzer is actively engaged in counting pulses from the detector/preamplifier. The time during which the analyzer is unable to count pulses is referred to as “dead time”.
- True Time** The elapsed clock time during the data acquisition. This is the sum of the live time and the dead time.
- Number of Spectra:** Enter the number (between 1 and 1000) of repeated data acquisition and storage cycles. The acquisition and data storage cycles will be repeated without operator intervention. See below for discussion of filename structure and its interaction with the **Number of Spectra**.
- Sample ID:** You must enter a character string (up to 39 characters in length) identifying the sample being measured.
- If **Save Spectra** is checked, the name of the **File:** to be saved is defaulted to the **Sample ID**. If the **Number of Spectra** is 1, the default output file name is **sampleID.xyz** where **xyz** is the standard extension for the chosen file format. If the **Number of Spectra** is >1 then the output file name is **sampleIDXXX.xyz** where **XXX** is the sequence number of the acquired spectrum.
- If the **Sample ID** contains characters that do not conform to allowed Windows filenames (*, |, /, \, :, “, <, >, comma, ?), the unallowed

characters will be ignored in the output filename. Also, the “space” character will be replaced by “_”.

MCA:

Choose the MCA for data acquisition from the pull down menu of available MCA choices. One of the menu choices is Simulation. The simulation MCA option generates data from a previously acquired spectrum using the Poisson distribution. The Simulation MCA is described in section 3.4.1.

 Save Spectra

Checking the **Save Spectra** activates the **File:** and **Format:** boxes. **C:\FRAMdata\Spectra** was established during the FRAM installation as the default data storage path. The output filename defaults to the **Sample ID** as discussed above. The **Browse...** button may be used to select other paths for spectral data storage.

File:

The user chooses the path and the filename for storage of the acquired spectrum using the **Browse...** button. For multiple spectrum acquisitions (**Number of Spectra** > 1), several filename-number of spectra-file extension combinations are available to accommodate standard commercial file naming conventions.

To save 1-100 spectra, the filename format can be **Filename.X##** where **##** is a 2 digit number from 00 to 99, and **X** can be any character or number. This form is compatible with FRAM v.4 where **X = S** (for Spectrum), although other characters can also be used. The data format of the stored spectral data is specified by the entry in the **Format:** box described below.

To save up to 1000 spectra, the filename format must be **Filename###.XXX** where **###** is a 3 digit number from 000 to 999 and **XXX** can be any extension such as .CHN, .CNF but not limited to standard extensions. This naming convention is compatible with several commercial data acquisition software packages. One advantage of using the standard commercial extensions is that the recognized icon will be used to display the file name. The data format of the stored spectral data is specified by the entry in the **Format:** box described below.

Format:

The data format of the stored spectral data. This entry controls the data format of the stored data, irrespective of the extension entered for the filename. The supported data formats and their default extensions are:

Ortec 'chn'	.chn
Ortec 'spc'	.spc
Canberra S100	.mca
Canberra CAM	.cnf
IAEA MMCA	.spe
ASCII (2 col, channel, count)	.txt

Parameter:

You must select an analysis parameter set from the choices given. They represent the sets that currently exist in the database. If you

select an inappropriate parameter set, you may encounter difficulties in the analysis.

Unlike the **Measure | Analyze** option, by design, there are no default gain (**KeV/Ch**) and offset (**KeV**) entry boxes in the **Measure | Measure** dialog window for you to adjust. If the energy calibration of the system does not match that of the parameter set then you should adjust the gain and offset of the MCA so that the acquired spectrum's energy calibration will match that of the parameter set. If you do not want to adjust the electronics then you can select a different parameter set or acquire and save the spectrum and use the **Measure | Analyze** option to analyze the data.

Comment: Enter a comment (a character string up to 59 characters in length) that is reproduced on the output. Comments are optional.

Other Selections

- ⊙ **Pu242/U236 by correlation** Calculate Pu242 (or U236, depending upon the analysis) by a correlation.

The correlation used for Pu242 is of the form

$$\text{Pu242} = A * [(\text{Pu238})^B * (\text{Pu239})^C * (\text{Pu240})^D * (\text{Pu241} + \text{Am241})^E]$$

where the constants A, B, C, D, and E are Application Constants in the selected parameter set and are entered or changed in the **Param Edit** menu option.

The correlation used for U236 is of the form

$$\text{U236} = A * [(\text{U235})^B * (\text{U238})^C] + D * [(\text{U235})^E * (\text{Th228})^F]$$

where the constants A, B, C, D, E, and F are Application Constants in the selected parameter set and are entered or changed in the **Param Edit** menu option. If Th228 is not present as an isotope in the parameter set, the correlation uses just the first term.

- ⊙ **Pu242/U236 by operator entry % by weight**

When this button is selected the % by weight box becomes active to accept an operator entry of a known or estimated wt% of Pu242 or U236. This entry is sticky.

- ⊙ **Pu242/U236 by measurement**

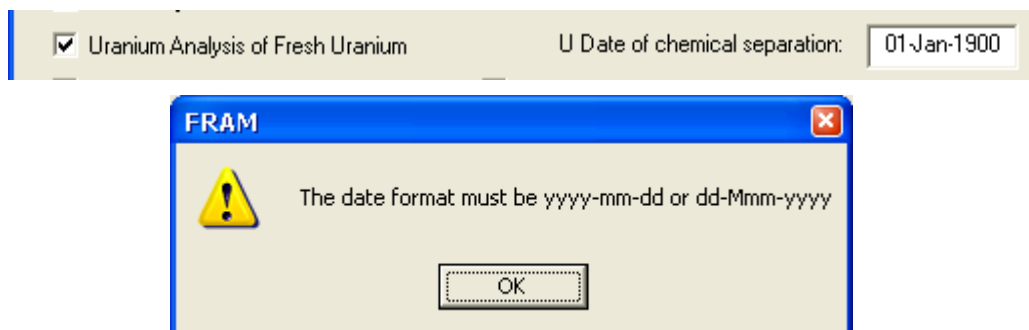
Selection of this option will allow Pu242 or U236 to be measured directly from analysis of peaks in the gamma ray spectrum. If this option is selected and the parameter file does not contain any Pu242/U236 peaks the result for the measurement of that isotope will be 0.0.

- ⊙ **Empirical Efficiency** Choose this option to use the empirical (polynomial) model for determining the relative efficiency. See Chapter 5 and Appendix A for a description of the model.

- Physical Efficiency** Choose this option to use the physics-based model for determining the relative efficiency. See Chapter 5 and Appendix A for a description of the model.
- By design, there is no Efficiency Defaults entry box in the **Measure | Measure** dialog window. If the user wants to adjust the Efficiency Defaults then he/she should acquire and save the spectrum and use the **Measure | Analyze** option to analyze the data. The default parameters from the applications constants in the selected parameter set are used.
- Save Results** When this box is checked the **Result File:** entry and **Browse...** button become active allowing the user to specify the path and filename for storage of the results file. Default values for the **Result File** are: **C:\FRAMdata\Results\filename.res** where **filename** is the name of the analyzed data file. The path **C:\FRAMdata\Results** was established during the FRAM installation.
- Print Results** When this box is checked a short output (see section 7.1.) is printed on the system printer at the end of the analysis.

Other Analysis Choices

- Auto analysis** Check this box if you wish to have the spectrum automatically re-analyzed depending on the results of the current analysis and the directions encoded into the Application Constants in the chosen parameter set. See chapter 6 for more information on how this feature works.
- Uranium Analysis of Fresh Uranium**
- Check this box if you are analyzing fresh uranium (less than 6 months since chemical removal of thorium and protactinium from the uranium). Checking this box brings up an entry box to enter the date of chemical separation. The date format for the measurement date can be either the American date format (dd-Mmm-yyyy) or the ISO 8601 international date format (yyyy-mm-dd). A wrong date format would activate the following warning message reminding you to use the correct format.



Previous Calorimetric measurement

Checking this box brings up additional entry boxes allowing the entry of results from a prior calorimetry measurement. The calorimetry results are combined with the current isotopic results to obtain the total plutonium mass. The date format for the measurement date can be either the American date format (dd-Mmm-yyyy) or the ISO 8601 international date format (yyyy-mm-dd). A wrong date format would activate the above warning message reminding you to use the correct format.

 Previous Neutron measurement

Checking this box brings up additional entry boxes allowing the entry of results from a prior neutron measurement to obtain the total plutonium mass. The date format for the measurement date can be either the American date format (dd-Mmm-yyyy) or the ISO 8601 international date format (yyyy-mm-dd). A wrong date format would activate the above warning message reminding you to use the correct format.

Start

Click on this button to start the measurement.

Cancel

Click on this button to cancel the measurement and return to FRAM's main menu.

.CSV Files

When a spectrum is analyzed, FRAM v.5 will append one-line results to the **Uranium.csv** or **Plutonium.csv** file (depending on the analysis) whether or not the **Save Results** option is checked. The files, which are in the **FRAMdata** folder, can be opened by Excel. If the file does not exist, FRAM will create it the first time a spectrum is analyzed. When the file grows too large, it will be saved as **Uranium###.csv** or **Plutonium###.csv**, where **###** starts from 000 and a new **Uranium.csv** or **Plutonium.csv** file is created. This feature is designed to be used in analyzing and comparing multiple spectral analyses.

For plutonium the results saved are the ^{238}Pu – ^{242}Pu , ^{241}Am , P_{eff} , and $^{240}\text{Pu}_{\text{eff}}$ values and their one-sigma uncertainties. Other parameters saved are the file name or sample ID of the analyzed data, the acquisition date, the analysis date, the parameter set, the efficiency model, and the default gain and zero of the analysis. For plutonium the P_{eff} and $^{240}\text{Pu}_{\text{eff}}$ values are the values calculated for all the isotopes in the isotope list, not just the plutonium isotopes listed in the **Plutonium.csv** file.

For uranium the results saved are the ^{234}U , ^{235}U , ^{236}U , ^{238}U , Specific Power, and their one-sigma uncertainties. Other parameters saved are the file name or sample ID of the analyzed data, the acquisition date, the analysis date, the parameter set, the efficiency model, and the default gain and zero of the analysis. For uranium the Specific Power values are the values calculated for all the isotopes in the isotope list, not just the uranium isotopes listed in the **Uranium.csv** file.

3.4.4. Measure | ISOPOW

This option allows you to decay correct the isotopic ratios, including ^{241}Am , of a plutonium sample from any arbitrary date to any other date, either forward or backward in time. The following dialog box will appear on your screen.

Initial		Final	Sample ID
0.00550	w% Pu238	0.00512	84000cx.s01
94.05570	w% Pu239	94.08266	
5.84190	w% Pu240	5.83951	Initial Pu date 13-Aug-2001
0.06810	w% Pu241	0.04399	Initial Am date 13-Aug-2001
0.02870	w% Pu242	0.02872	Final Date 03-Sep-2010
0.00000	w% Pu244	0.00000	
0.41130	w% Am241	0.42957	
100	grams Pu	99.9453	Calculate
2.73117	Spec Power mW/gPu	2.74942	Exit
0.27312	Power W	0.27479	
5.90398	%Pu240 Eff	5.90066	
99.99990	sum of Pu fractions	100.00000	Print

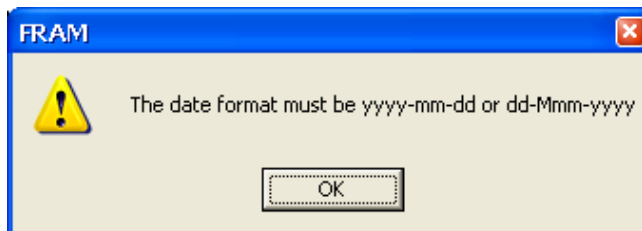
In the **Initial** column, you need to enter the starting values of the Pu isotopic ratios in wt%, the Am241 ratio in wt% with respect to total Pu, and the total amount of Pu in grams, if known. Default values are provided from the most recent analysis. If the total amount of Pu is not known, a nominal value of 100 will suffice. Decay-corrected values for all these quantities will appear in the final column.

Initial Pu date

Enter the date of the values in the column labeled **Initial**. The date format for the measurement date can be either the American date format (dd-Mmm-yyyy) or the ISO 8601 international date format (yyyy-mm-dd). A wrong date format would activate the following warning message reminding you to use the correct format

Initial Am date

Enter the date of the **w%Am241** value in the column labeled **Initial**. This date may be different from that for the Pu isotopic. The date format for the measurement date can be either the American date format (dd-Mmm-yyyy) or the ISO 8601 international date format (yyyy-mm-dd). A wrong date format would activate the following warning message reminding you to use the correct format.

**Final date**

Enter the final date for decay correcting the ratios. The date format for the measurement date can be either the American date format (dd-Mmm-yyyy) or the ISO 8601 international date format (yyyy-mm-dd). A wrong date format would activate the above warning message reminding you to use the correct format.

Calculate

Click on this button to perform the decay corrections. The results for the **Final date** will appear in the column labeled **Final**. The sum of the initial Pu isotopic w% values appears at the bottom of the **Initial** column. If this sum deviates from 100% by more than 0.1%, an error message will appear and you should check the initial values.

Print

Click on this button to print out the results of the decay corrections.

Exit

Click on this button to dismiss the 'ISOPOW' dialog box and return to FRAM's main menu.

Print

Click on this button to print the 'ISOPOW' results.

Sample ID

Enter a string of up to 31 characters which will identify the sample. This string will appear on a print out if you click on the **Print** button. Otherwise it is ignored.

Specific Power

This box will be filled in with the computed value of the specific power for the sample on both the initial and the final date. The units are milliWatts per gram of Pu.

Sample Power

This box will be filled in with the computed value for the total power of the sample (in Watts) on the both the initial and final date based on the value for the total grams of Pu. It is the product of the specific power and the final value for the total amount of Pu.

Percent Pu240 Effective

This box will be filled in with the computed value for the effective ²⁴⁰Pu fraction expressed as wt%.

3.4.5. Measure | Compare

The **Measure | Compare** option enables the user to compare the result from a just-completed analysis to the Operator-declared or certified values of the isotopic fractions. The command becomes

active after an analysis has been completed with either the **Measure | Analyze** or **Measure | Measure** options. The comparison can be done for either plutonium or uranium analyses; FRAM makes the choice automatically.

Plutonium Measurement

After completing a Measurement or an Analysis the user selects **Measure | Compare** from the main menu. For a plutonium measurement the **Compare Plutonium Results** dialog box will appear as below.

	Measured		Declared	
	Value	Sigma	Value	Sigma
w% Pu238	0.0070	0.0011	0	0
w% Pu239	93.7573	0.1653	0	0
w% Pu240	6.0328	0.1656	0	0
w% Pu241	0.1781	0.0005	0	0
w% Pu242	0.0247	0.0020	0	0
w% Am241	0.1962	0.0015	0	0
Pu date	15-Jan-1995		17-Feb-2011	
Am date	15-Jan-1995		17-Feb-2011	
Source	CALX30.101			
sum fractions	99.9999		0.0000	
Comment	Illustration of Measure Compare Option			

Final date: 15-Jan-1995 Load Declared Values Compare Exit Print Save

	Measured		Declared		Measured - Declared		# Sigma's
	Value	Sigma	Value	Sigma	Value	Sigma	
w% Pu238							
w% Pu239							
w% Pu240							
w% Pu241							
w% Pu242							
w% Am241							
Spec Power mW/gPu							
%Pu240 Eff							

Measured

The **Value** and **Sigma** columns are automatically filled with the **mass%** and **sigma** values from the most recent measurement.

Pu date, Am date

Automatically filled with the date of the Measured/Analyzed spectrum.

Source

Filename for an Analyzed spectrum or Sample ID for a Measured spectrum.

Declared	The user enters the declared or certified values and absolute one-sigma uncertainty (if available) of the plutonium isotopic fractions in the same units as the Measured column.
Pu date, Am date	The Pu date and Am date in the Declared columns is the date of the declared or certified values and must be either in the American date format (dd-Mmm-yyyy) or the ISO 8601 international date format (yyyy-mm-dd). A warning appears if you enter the date in the wrong format. The date fields are preloaded with the current date but will almost always have to be changed to the date of the declaration or certification.
Source	An informative box giving the user-entered source of the Declared values.
sum fractions	The sum of the plutonium fractions must be in the range 99.9% to 100.1%.
Comment	This box is preloaded with the comment : field from the analysis and also may be edited in the Compare window.
Final date	The Final date is preloaded with the date of the Measured values but may be changed to any desired date for purposes of comparison. The date format must be either the American date format (dd-Mmm-yyyy) or the ISO 8601 international date format (yyyy-mm-dd).
Compare	After all the information is entered for the Declared values, clicking the Compare button will decay correct the measured and declared values to the Final date and compare them. The Final dialog box will look like:

Compare Plutonium Results

	Measured		Declared	
	Value	Sigma	Value	Sigma
w% Pu238	0.0070	0.0011	0.0100	0.0003
w% Pu239	93.7573	0.1653	93.7336	0.0013
w% Pu240	6.0328	0.1656	5.8564	0.0018
w% Pu241	0.1781	0.0005	0.3712	0.0008
w% Pu242	0.0247	0.0020	0.0290	0.0007
w% Am241	0.1962	0.0015	0.0061	0.0008
Pu date	15-Jan-1995		25-May-1979	
Am date	15-Jan-1995		25-May-1979	
Source	CALX30.101		Calex1 Report of Analysis	
sum fractions	99.9999		100.0002	
Comment	Illustration of Measure Compare Option			

Final date: 15-Jan-1995 Load Declared Values Compare Exit Print Save

	Measured		Declared		Measured - Declared		
	Value	Sigma	Value	Sigma	Value	Sigma	# Sigma's
w% Pu238	0.0070	0.0011	0.0089	0.0003	-0.0019	0.0011	-1.64
w% Pu239	93.7574	0.1653	93.9259	0.0013	-0.1685	0.1653	-1.02
w% Pu240	6.0328	0.1656	5.8614	0.0018	0.1714	0.1656	1.04
w% Pu241	0.1781	0.0005	0.1748	0.0004	0.0033	0.0006	5.32
w% Pu242	0.0247	0.0020	0.0291	0.0007	-0.0044	0.0021	-2.06
w% Am241	0.1962	0.0015	0.2006	0.0009	-0.0044	0.0017	-2.50
Spec Power mW/gPu	2.5056	0.0138	2.5121	0.0018	-0.0065	0.0139	-0.47
%Pu240 Eff	6.0919	0.1657	5.9325	0.0023	0.1594	0.1657	0.96

Print

After the comparison is made the **Print** button becomes active allowing the user to print the results. The print output will have the header information similar to that of the short, medium, or long result print out and all the comparison results seen in this **Compare Plutonium Results** dialog box.

Load Declared Values

Instead of typing in the declared values in the **Compare Plutonium Results** dialog box, you can load them in by clicking the **Load Declared Values** button. It will display the **Declared Plutonium Isotopic Composition** dialog box. You can click on a sample and then click OK to close the dialog box and return to the **Compare Plutonium Results** dialog, which now has all the declared values from the selected sample loaded. You can also type in the new values for new samples and save them for later use by clicking **OK**. The Title Bar for the **Declared Plutonium Isotopic Composition** dialog box contains the file name/Sample ID of the results in the Measured column of the **Compare Plutonium Results** dialog box.

Several features in the **Declared Plutonium Isotopic Composition** window allow the user to order the samples in

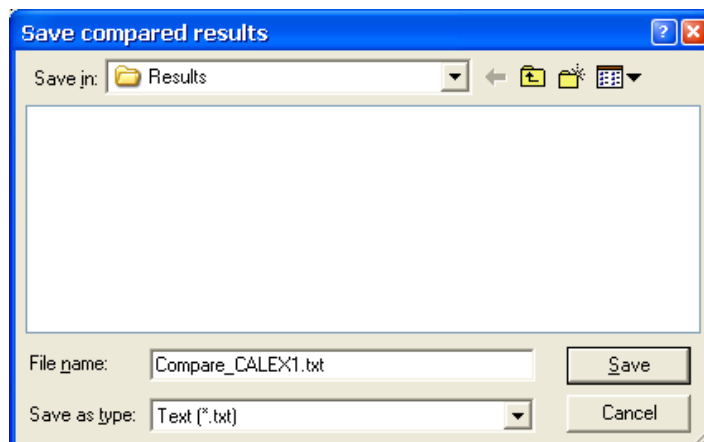
groupings meaningful and useful for the user. You can use the **Sample Name** field, by adding prefixes or other identifiers, to group samples by like categories such as material type, facility, burnup, or the like. Then you can use the **Insert**, **Delete**, and **Move** buttons at the right of the window to order the samples within the groups and add dummy rows between groups for easier visual identification.

Sample Name	Pu Date	Am Date	Pu238	Pu239	Pu240	Pu241	Pu242	Am241	
1	CBNM Pu93	20-Jun-1986	20-Jun-1986	0.0117	93.4123	6.3131	0.2235	0.0395	0.1047
2	Calex I	25-May-1979	25-May-1979	0.0100	93.7336	5.8564	0.3712	0.0290	0.0061
Sigma			0.0003	0.0013	0.0018	0.0008	0.0007	0.0008	

The date format in the **Declared Plutonium Isotopic Composition** dialog box is the current default date format that may be either the American date format (dd-Mmm-yyyy) or the ISO 8601 international date format (yyyy-mm-dd) and cannot be changed. Also, note the horizontal scroll bar at the bottom of the dialog box. Scrolling here will display the **Sigma** values.

Save

This option saves the compared results from the **Compare Plutonium Results** window in the same format as they appear after invoking the **Print** option. Selecting **Save** brings up the **Save compared results** dialog box allowing the user to select the path and filename for storage.



The saved compared results file appears just as it would have if you had printed it directly using the **Print** button in the **Compare Plutonium Results** window. You can view the text file in Notepad or any word-processing program as seen below.

```

FRAM 5.1 Plutonium Compare Results -- CALX30.101 -- 10-Mar-2011
*****
PC FRAM (5.1)      Isotopic Analysis      10-Mar-2011 14:55:41
(Fixed energy Response function Analysis with Multiple efficiencies)
Operator ID:

spectrum source:  C:\FRAMdata\Spectra\CALX30.101
spectrum date:    15-Jan-1995 14:07:24
live time:        2817 s
true time:        3600 s
num channels:     8192

parameter set:    Pu_Cx_120-460 (2011.03.03 14:35)
                  Pu Coax, Equilibrium, 120-460keV
                  Physical Efficiency, Gain 0.125 keV/ch, Offset 0 keV
comment:          Illustration of Measure | Compare Option

-----
Declared Source:  Calex 1 Report of Analysis

                    Measured                Declared
                    Value   Sigma          Value   Sigma
                    -----   -----          -----   -----
wt% Pu238           0.0070  0.0011          0.0100  0.0003
wt% Pu239           93.7573  0.1653          93.7336  0.0013
wt% Pu240           6.0328  0.1656          5.8564  0.0018
wt% Pu241           0.1781  0.0005          0.3712  0.0008
wt% Pu242           0.0247  0.0020          0.0290  0.0007
wt% Am241           0.1962  0.0015          0.0061  0.0008
                    -----   -----          -----   -----
Initial Pu Date:    15-Jan-1995                25-May-1979
Initial Am Date:    15-Jan-1995                25-May-1979

-----

                    Measured                Declared                Measured-Declared
                    Value   Sigma          Value   Sigma          Value   Sigma #Sigma's
                    -----   -----          -----   -----          -----   -----
wt% Pu238           0.0070  0.0011          0.0089  0.0003          -0.0019  0.0011  -1.64
wt% Pu239           93.7574  0.1653          93.9259  0.0013          -0.1685  0.1653  -1.02
wt% Pu240           6.0328  0.1656          5.8614  0.0018           0.1714  0.1656   1.04
wt% Pu241           0.1781  0.0005          0.1748  0.0004           0.0033  0.0006   5.32
wt% Pu242           0.0247  0.0020          0.0291  0.0007          -0.0044  0.0021  -2.06
wt% Am241           0.1962  0.0015          0.2006  0.0009          -0.0044  0.0017  -2.50
                    -----   -----          -----   -----          -----   -----
SpecPower mW/gPu    2.5056  0.0138          2.5121  0.0018          -0.0065  0.0139  -0.47
%Pu240 Effective    6.0919  0.1657          5.9325  0.0023           0.1594  0.1657   0.96

Final Date:         15-Jan-1995                15-Jan-1995
    
```

Uranium Measurement

After completing a Measurement or an Analysis the user selects **Measure | Compare** from the main menu. For a uranium measurement the **Compare Uranium Results** dialog box will appear as below.

	Measured		Declared		Measured - Declared		
	Value	Sigma	Value	Sigma	Value	Sigma	# Sigma's
w% U234	0.0366	0.0011	0	0			
w% U235	4.4326	0.0297	0	0			
w% U236	0.0204	0.0018	0	0			
w% U238	95.5104	0.0302	0	0			
Spec Power uW/gPu	0.0767	0.0020					
Source	U0446PI0.000						
sum fractions	100.0000		0.0000				
Comment	Illustrate Measure Compare Option						

Buttons: Load Declared Values, Compare, Exit, Print, Save

This dialog box is similar to but simpler than the Compare Plutonium Results dialog box because no decay corrections are performed.

- Measured** The **Value** and **Sigma** columns are automatically filled with the **mass%** and **sigma** values from the most recent measurement.
- Source** Filename for an Analyzed spectrum or Sample ID for a Measured spectrum.
- Declared** The user enters the declared or certified values and absolute one-sigma uncertainty (if available) of the uranium isotopic fractions in the same units as the **Measured** column.
- Source** An informative box giving the user-entered source of the Declared values.
- sum fractions** The sum of the uranium fractions must be in the range 99.9% to 100.1%.
- Comment** This box is preloaded with the **comment :** field from the analysis and also may be edited in the Compare window.
- Compare** After all the information is entered, clicking the **Compare** button will compare the **Measured** and **Declared** values. The Final dialog box will look like (below) where we have illustrated the common situation where uncertainties in the Declared values are not available. The **Print** button will now become active and allow the user to print the results. The print output will have the header information similar to that of the

short, medium, or long result print out and all the comparison results seen in this **Compare Uranium Results** dialog box.

	Measured		Declared		Measured - Declared		
	Value	Sigma	Value	Sigma	Value	Sigma	# Sigma's
w% U234	0.0366	0.0011	0.03591	0	0.0007	0.0011	0.63
w% U235	4.4326	0.0297	4.4623	0	-0.0297	0.0297	-1.00
w% U236	0.0204	0.0018	0.00685	0	0.0136	0.0018	7.53
w% U238	95.5104	0.0302	95.4949	0	0.0155	0.0302	0.51
Spec Power uW/gPu	0.0767	0.0020	0.0753	0.0000	0.0015	0.0020	0.74
Source	U0446PID.000		NBS-446 certified values				
sum fractions	100.0000		100.0000				
Comment	Illustrate Measure Compare Option						

Buttons: Load Declared Values, Compare, Exit, Print, Save

Load Declared Values

Instead of typing in the declared values, you can load them in by clicking the **Load Declared Values** button. It will display the **Declared Uranium Isotopic Composition** dialog box. You can click on a sample and then click **OK** to close the dialog box and return to the **Compare Uranium Results** dialog, which now has all the declared values loaded. You can also type in the new values for new samples and save them for later use by clicking **OK**.

Several features in the **Declared Uranium Isotopic Composition** window allow the user to order the samples in groupings meaningful and useful for the user. You can use the Sample Name field, by adding prefixes or other identifiers, to group samples by like categories such as material type, facility, burnup, or the like. Then you can use the **Insert**, **Delete**, and **Move** buttons at the right of the window to order the samples within the groups and add dummy rows between groups for easier visual identification.

FRAM 5.1 Uranium Compare Results -- U0446PlO.000 -- 09-Mar-2011

PC FRAM (5.1) Isotopic Analysis 09-Mar-2011 10:48:11
 (Fixed energy Response function Analysis with Multiple efficiencies)
 Operator ID:

spectrum source: C:\FRAM_Archival_data\U100kevSampleSpectra\U0446PlO.000
 spectrum date: 25-Sep-2002 13:31:03
 live time: 799 s
 true time: 900 s
 num channels: 4096

parameter set: ULEU_Plnr_060-250 (2011.03.03 14:57)
 U Only, Enrichment <=20, 0.075 keV/ch, Planar Detector
 Physical Efficiency, Gain 0.075 keV/ch, Offset 0 keV
 comment: Illustrate Measure | Compare Option

 Declared Source: NBS-446 certified values

	Measured		Declared		Measured-Declared		
	Value	Sigma	Value	Sigma	Value	Sigma	#Sigma's
wt% U234	0.0366	0.0011	0.0359	0.0000	0.0007	0.0011	0.63
wt% U235	4.4326	0.0297	4.4623	0.0000	-0.0297	0.0297	-1.00
wt% U236	0.0204	0.0018	0.0069	0.0000	0.0136	0.0018	7.53
wt% U238	95.5104	0.0302	95.4949	0.0000	0.0155	0.0302	0.51
SpecPower uW/gPu	0.0767	0.0020	0.0753	0.0000	0.0015	0.0020	0.74

3.5. User

This option allows the user to log in with a user name and password. The user name will appear as the **User ID** in the FRAM title bar. This option allows a user with appropriate access credentials to view and modify the information about the user accounts that is stored in the User Authorization File. This option is protected by the password mechanism. Selecting the **U**ser option on the main menu brings up the following menu.



The User Authorization File contains a list of authorized users, their passwords (in encrypted form), and the level of access granted to each. The following records are present in this file when first created. A screen display of this information is shown in section 3.5.3.

User Name	Password	Access Level
administrator	“null”	Administrator (can edit list of users)
manager	manager	Administrator (can edit list of users)
supervisor	supervisor	Power User (can edit parameters)
operator	operator	Normal User
“null”	“null”	Power User (can edit parameters)

where “null” means a string with no characters in it. User names and passwords are case sensitive.

The “manager”, “supervisor”, and “operator” users are created for compatibility with version 4 of FRAM.

For best security if a system is to be used by multiple users, accounts should be created for the different users. In addition the Administrator should assign a password to the “administrator” user and delete the “manager”, “supervisor”, “operator” and “null” users.

3.5.1. User | Login

When FRAM is started the user must “sign in” by selecting **User | Login**. This brings up the **User Validation** window where the user enters his/her **User name:** and **Password:**. This **User name:** field is sticky and the **User name:** reflects the last user name signed in. The current user edits the User name appropriately and enters his/her Password. If access is permitted the **User Validation** window is dismissed and the user is returned to the FRAM window. The user name will appear as the User ID in the Title bar of the FRAM window.

The 'User Validation' dialog box has a title bar with a close button. It contains a text box at the top left, an 'OK' button at the top right, and a 'Cancel' button below it. Below these are two input fields: 'User name:' with the text 'manager' and 'Password:' with an empty field.

Entries for **User name** and **Password** that are not in the User Authorization File produce error messages (**No such user name in list.** and **Invalid password.**) in the box to the left of the OK button as shown below.

The 'User Validation' dialog box shows an error message 'Invalid password.' in the text box at the top left. The 'User name:' field contains 'supervisor' and the 'Password:' field contains 'xxxx'.

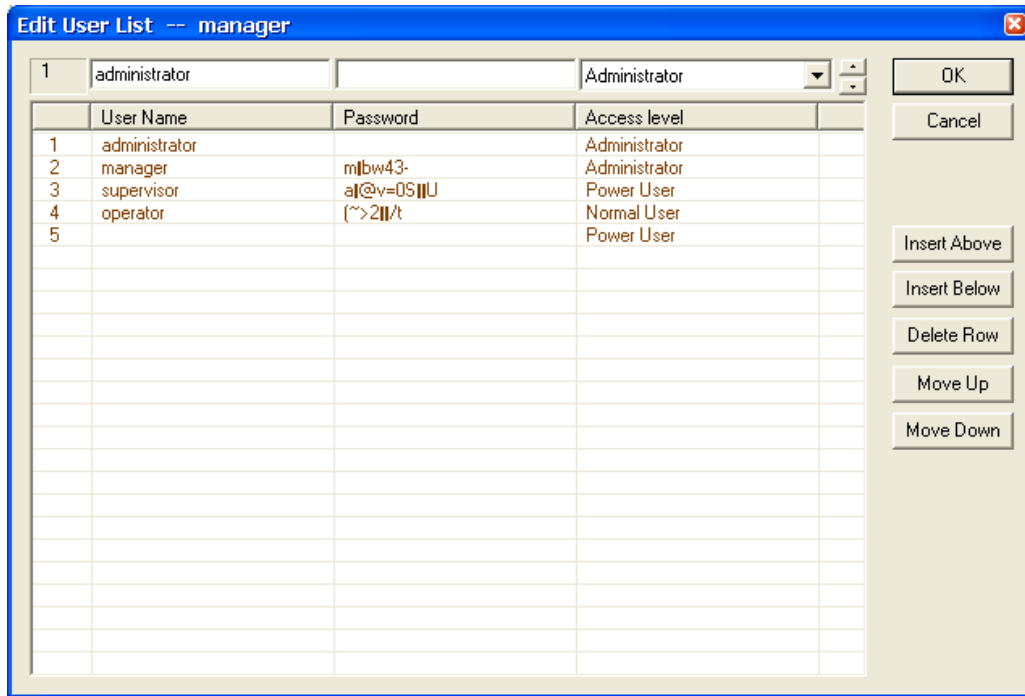
3.5.2. User | Change Password

A user who is logged in to FRAM may change his/her password by invoking the **User | Change Password** option which brings up the window below.

The 'Change Password' dialog box has a title bar with a close button. It contains a text box at the top left, an 'OK' button at the top right, and a 'Cancel' button below it. Below these are three input fields: 'Old Password:', 'New Password:', and 'Verification:'.

3.5.3. User | Edit User List

This option allows you to view and modify the information about the user accounts that is stored in the User Authorization File. This option is protected by the password mechanism and the user must be signed on with Administrator level privileges. The **Edit User List** below is the table as first installed in a new FRAM v.5 installations with five default User Names and Passwords.



The first column in the table displays an index, which serves as a row number for the table. Row 1 at the top of the window is used to enter new **User Name/Password/Access level** information or to edit existing information in the table. Clicking on a row in the table selects it for editing, the normal red text turns blue and the row contents are placed in Row 1 above the table for editing.

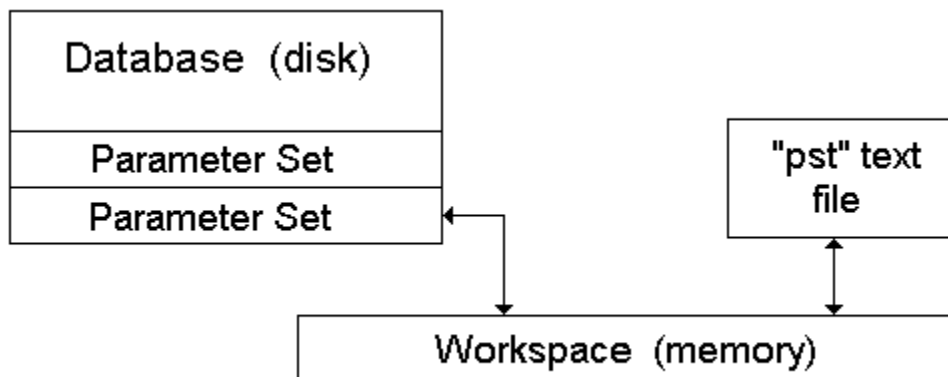
Note! User Name and Password are case sensitive.

- User Name** This column contains the name associated with each user account
- Password** This column contains the encrypted password associated with each user account.
- Access level** Use the drop down menu in the row above the table to select from four access levels.
 - Limited User** Can only make measurements or analyze data but does not have access to selecting or editing parameter sets.
 - Normal User** Can make measurements, analyze data and select parameter sets but cannot edit parameter sets.
 - Power User** Can do everything except assign users.
 - Administrator** Has access to all FRAM features.

Insert Above	Insert a new blank row above the selected row.
Insert Below	Insert a new blank row below the selected row.
Delete Row	Delete the selected row.
Move Up	Move the selected row up one row.
Move Down	Move the selected row down one row.

3.6. Parameter

The Parameter option coupled with the Param Edit option gives you access to all the parameters that control an analysis. A complete group of parameters necessary for an analysis is called a **Parameter Set**. All parameter sets are stored in a single database, which resides in the **C:\FRAMdata\FRAM51** directory. The Parameter option allows you to augment the database with a new parameter set, delete a parameter set from the database and also allows you to export the information in a parameter set to a text file and subsequently import that information back into the database. This allows for sharing of parameter sets between different FRAM systems. The basic mechanism used to implement all of this is a data structure in memory which is called the workspace. Parameter sets can be transferred back and forth from the database to the workspace. Parameter sets can also be transferred back and forth from the workspace to a text file. The following diagram illustrates the overall design structure and may help to clarify all the various actions performed by the Parameter option.

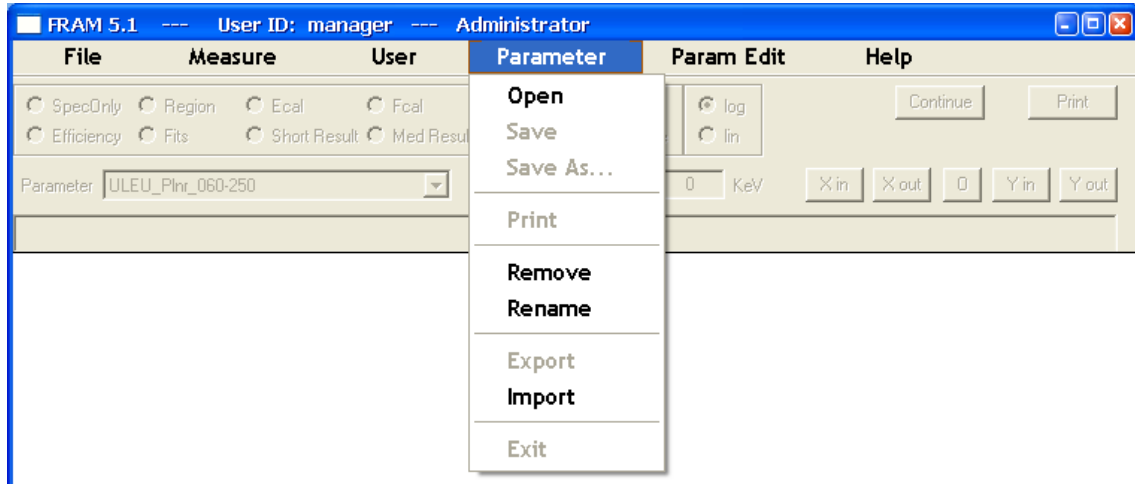


Each parameter set has a name that must conform to the Windows conventions for file names. Only characters conforming to Windows file naming conventions are allowed. If the parameter set name contains characters that do not conform to allowed Windows filenames (*, |, /, \, :, “, <, >, comma, ?), the un-allowed characters will be ignored in the stored parameter set name. Also, the “space” character will be replaced by “_”.

The FRAM installation process installs a set of built-in parameter sets. These parameter sets should be sufficient for analysis of spectra of most common plutonium and uranium materials obtained with typical HPGe detectors (including the planar, coaxial, N-type, and P-type HPGe). The names of the built-in parameter sets are capitalized, and they cannot be changed or removed. This process greatly strengthens the ability to control the versions of the parameter sets. Users can still create and modify their own parameter sets, and those parameter sets are saved with lower-case characters.

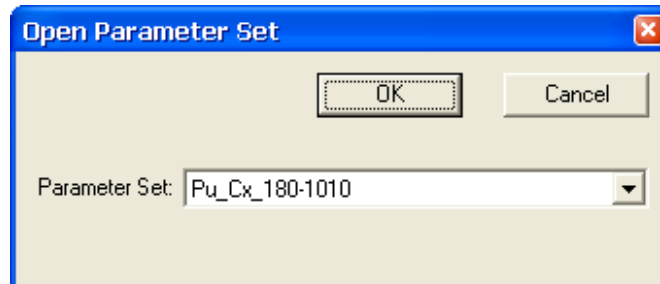
The **Parameter** option is indirectly password protected through the **User** option which allows only users with Administrator or Power User access rights to access the **Parameter** option.

When the **Parameter** option is selected the following menu appears.



3.6.1. Parameter | Open

This option allows you to open an existing parameter set and read it into memory. The opened parameter set may be viewed and/or edited in the **Param Edit** option. The following dialog box will appear on the screen.



Parameter Set:

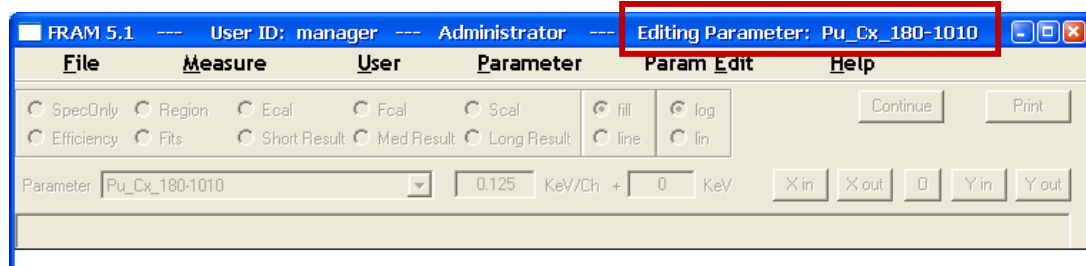
Select one of the parameter set from the drop-down list. These are the parameter sets that currently reside in the database. The default parameter set appearing in the **Parameter Set:** box is the one currently in use.

OK

Click on this button to open the selected parameter set and dismiss this dialog box. Opening a parameter set causes its information to be transferred from the database to a worksheet in memory. After a parameter set is opened, its name will be displayed in the title bar of the window as shown below. Only one parameter can be open at any one time. Viewing and editing of the opened parameter set is carried out in the **Param Edit** option.

Cancel

Click on this button to dismiss the dialog box without opening any parameter set.



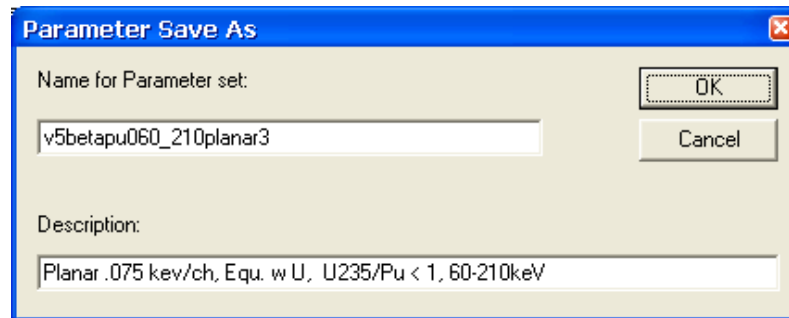
NOTE! The display of the parameter set name in the title bar is the key to the user that a parameter set is open.

3.6.2. Parameter | Save

This option saves the opened parameter set. It writes the contents of the worksheet to the database replacing the old records for this parameter set with new ones. This option is inactive if the name of the opened parameter set is capitalized.

3.6.3. Parameter | Save As...

This option makes a copy of the current worksheet and writes it to the database as a parameter set with the name and description specified by the user. This operation also updates the name of the parameter set in the worksheet to the “new” parameter set name so you may continue editing the “new” parameter set without taking any additional actions. The following dialog box will appear on the screen.



Name for Parameter set: Enter a name (up to 31 characters in length) for the new parameter set. Only characters conforming to Windows file naming conventions are allowed. If the **Name for Parameter set** contains characters that do not conform to allowed Windows filenames (*, |, /, \, :, “, <, >, comma, ?), the unallowed characters will be ignored in the stored parameter set name. Also, the “space” character will be replaced by “_”.

Description: Enter a description for the new parameter set. This serves as a short description of the type of spectral data this parameter set is designed to handle. This string of characters will truncate if longer than 59 characters. The date and time of the edit is appended to the **Description** on the analysis output.

OK

Click on this button to save the parameter set and dismiss this dialog box. If the name you gave matches the name of a parameter set already in the database a message box will appear on the screen with the message: **The parameter set “xxx” already exists in the database. Do you want to replace it?** If you click on the **Yes** button, the current worksheet will replace that parameter set in the database. If you click on the **No** button you are returned to the **Parameter Save As** window. If you click on the **Cancel** button, the save operation will be cancelled.

Cancel

Click on this button to dismiss the dialog box without saving the worksheet in the database.

NOTE! Saving a worksheet with a new name creates a copy of that worksheet in the database with that name. This operation also updates the name of the file in the worksheet to the new “Save As...” parameter set name. The “old” parameter set is still available in the database, but the worksheet is now populated with the “new” parameter set and you can continue to edit the new parameter set and now use the **Save** option to save your edits.

This is changed from the way FRAM v.4 worked and is now like the way standard word-processing programs work.

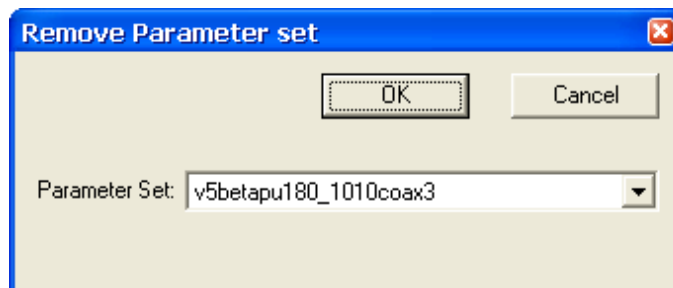
3.6.4. Parameter | Print

This option will write the contents of the worksheet to a text file and then have that file printed on the system printer. The standard Windows Print dialog box will appear to direct the printing.

Examples and descriptions of the printout are presented in chapter 7.

3.6.5. Parameter | Remove

This option removes all the information in a single parameter set from the database. Selection of this option brings up the **Remove Parameter set** dialog box and the parameter set to be removed is chosen from the drop down list.

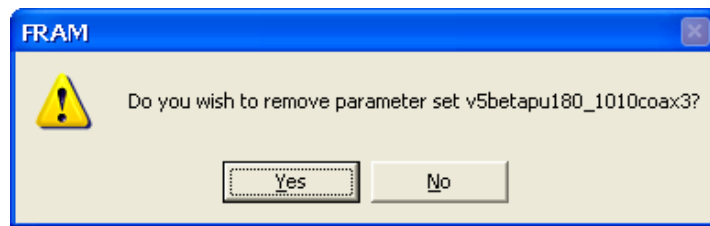
**Parameter Set:**

Select the parameter set from this drop-down list. These are the parameter sets that currently reside in the database. The built-in parameter sets (with capitalized name) cannot be removed. A warning message will alert you if you try to remove them.

OK

Click on this button to bring up a verification dialog, **Do you wish to remove parameter set “xxx”?**, shown below. Clicking on **Yes**

will remove the parameter set from the database. Clicking **No** will return the user to the main FRAM window.

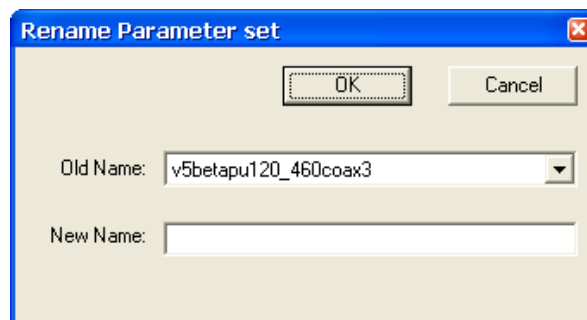


Cancel

Click on this button to dismiss the dialog box without changing the database.

3.6.6. Parameter | Rename

This option allows you to change the name of a parameter set in the database. The following dialog box will appear on the screen.



Old Name:

Select the parameter set from this drop-down list. These are the parameter sets that currently reside in the database. The built-in parameter sets (with capitalized name) cannot be renamed. A warning message will alert you if you try to rename them.

New Name:

Enter a name (up to 31 characters in length) for the new parameter set. Only characters conforming to Windows file naming conventions are allowed. If the **Name for Parameter set** contains characters that do not conform to allowed Windows filenames (*, |, /, \, ;, “, <, >, comma, ?), the unallowed characters will be ignored in the stored parameter set name. Also, the “space” character will be replaced by “_”.

OK

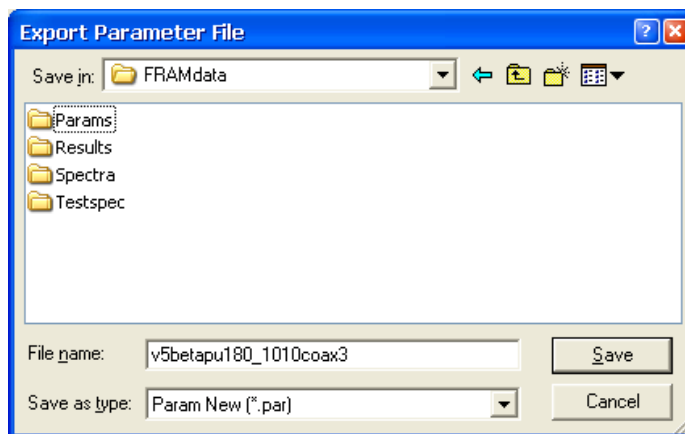
Click on this button to dismiss the dialog box and have the parameter set renamed. If you specify a new name that matches the name of another parameter set in the database, an error message window will appear.

Cancel

Click on this button to dismiss the dialog box without renaming the parameter set.

3.6.7. Parameter | Export

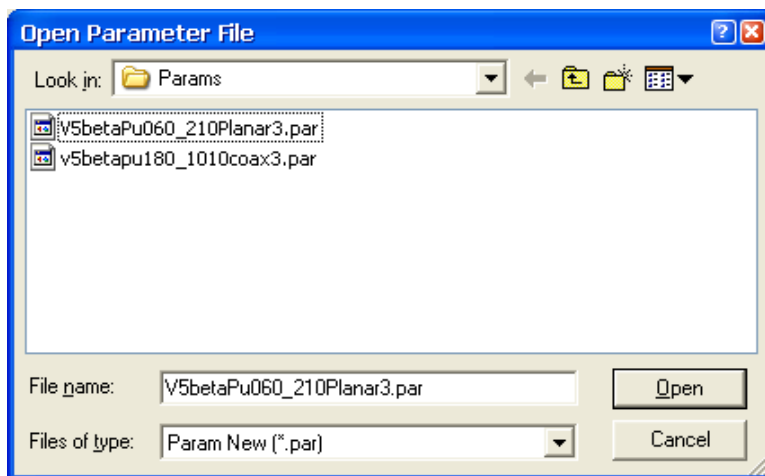
This option takes the contents of the current worksheet, formats the information, then writes it to a text file on the disk. This can be used to transfer parameter sets between different FRAM systems. The following dialog box will appear on the screen.



- Save in:** Search for the desired path where the parameter set information will be stored using the Windows standard icons to the right of the **Save in** box. The path is sticky and will reflect the path used the last time the **Save** option was invoked.
- File name:** This can be any legal filename, up to 158 characters in length, that is accepted by Windows.
- Save as type:** The drop down menu presents three options for the extension for the exported parameter file .
- | | |
|--------------------------|---|
| Param New (*.par) | default FRAM v.5 parameter file extension |
| Text (*.txt) | standard text file extension |
| All Files (*.*) | user chosen extension |
- Choosing **Text** or **Param New** automatically appends the extension. If you choose **All Files** you will see all of the files in the storage folder and will have to append your chosen extension in the **File name:** box before saving.
- Save** Click on this button to dismiss the dialog box and have the parameter set information stored in textual form.
- Cancel** Click on this button to dismiss the dialog box without saving the parameter set information.

3.6.8. Parameter | Import

This option reads the information present in a text file resulting from a previous **Export** command and places it in the current worksheet. The following dialog box will appear on the screen. At installation **Parameter | Import** defaults to **C:\FRAMdata\Params** to look for parameter files. This option is sticky and subsequent uses will reflect the last path used in the **Parameter | Import** option.



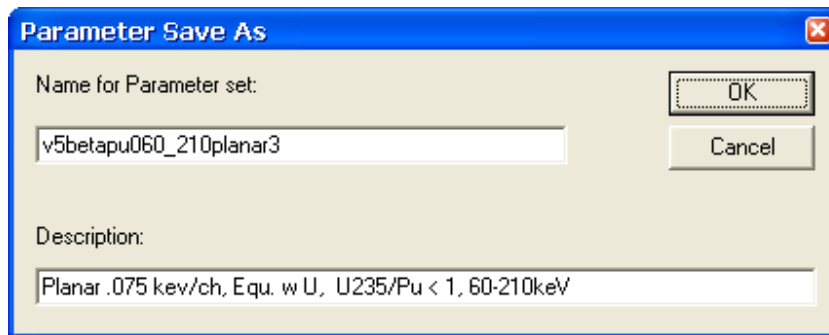
Look in: At installation **Parameter | Import** defaults to **C:\FRAMdata\Params** to look for parameter files. This option is sticky and subsequent uses will reflect the last path used in the **Parameter | Import** option. Use the Windows icons to the right of the **Look in:** box to find the location of the parameter file to be imported.

File name: This can be any legal filename, up to 158 characters in length, that is accepted by Windows.

Files of type: The drop down menu allows display of files with extensions

Param New (*.par)	default FRAM v.5 parameter file extension
Param Old (*.pst)	default FRAM v.4 parameter file extension
Text (*.txt)	standard text file extension
All Files (*.*)	display all files

Open Clicking on **Open** brings up the **Parameter Save As** dialog box.



Name for Parameter set: Enter the name of the parameter set to be saved. This must be a Windows compatible filename. You may accept the name of the imported parameter file or choose your own name. FRAM prevents the use of capital letters in the parameter set name to avoid conflict with the naming convention for the build-in parameter sets.

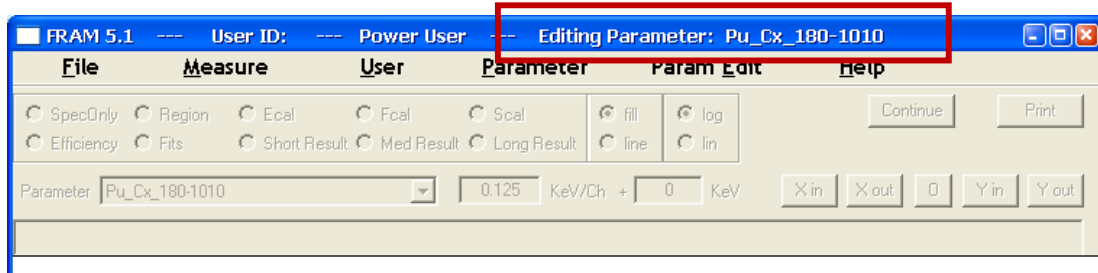
- Description:** Description of the characteristics of the parameter set. You may accept the description of the imported parameter file or choose your own description.
- OK** Click on this button to save the parameter set and dismiss this dialog box. If the name you gave matches the name of a parameter set already in the database a message box will appear on the screen with the message: **The parameter set “xxx” already exists in the database. Do you want to replace it?** If you click on the **Yes** button, the current worksheet will replace that parameter set in the database. If you click on the **No** button you are returned to the **Parameter Save as** window. If you click on the **Cancel** button, the save operation will be cancelled.
- Cancel** Click on this button to dismiss the dialog box without saving the worksheet in the database.

3.6.9. Parameter | Exit

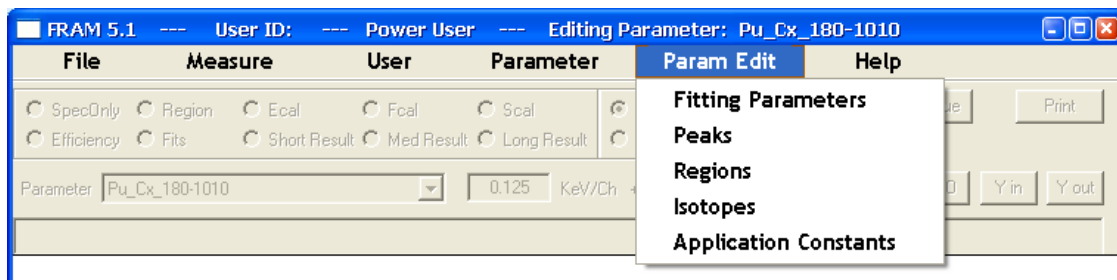
Select this option to close the open parameter set and return to the main FRAM window. If changes have been done to the parameter set, a message box will appear on the screen with the message: **Do you want to save the modified parameter set?** Clicking on the **Yes** button will save the parameter set, **No** button will not save it, and **Cancel** button will return you the Parameter editing mode.

3.7. Param Edit

The **Param Edit** option becomes active after a parameter set has been opened with the **Parameter | Open** option (see section 3.6.1). The active, open parameter set is indicated in the title bar of the FRAM window.



The choices that appear when the **Param Edit** option in the menu is selected refer to various groups of editable parameters in the open parameter set. These choices are illustrated in the picture below.



3.7.1. Param Edit | Fitting Parameters

This option displays the default parameters used to describe the energy calibration and the peak shapes. It also displays a description of the parameter set. The following dialog box will appear on the screen.

Edit Fitting Parameters -- Pu_Cx_180-1010

Default Energy Calibration

Gain (KeV/Ch) = Offset (keV) =

Fixed

Default FWHM Constants

$fwhm(ch) = \sqrt{A1 + A2 \cdot E + A3/E}$

A1 (ch²) = A2 (ch²/KeV) = A3 (ch²*keV) =

Fixed

Default Tailing Constants

$tail(ch) = H \cdot \exp((T1 + T2 \cdot E) + (T3 + T4 \cdot E) \cdot (ch - x0)) \cdot [1 - \exp(-C \cdot (ch - x0)^2)]$

T1 = T2 = T3 = T4 =

Fixed

Description:

Last modified on 14-Feb-2011

The software is fairly tolerant regarding these initial values. Appropriate starting values for use here may be obtained from the medium (or long) printouts from a successful analysis. The starting values that are provided with the existing parameter sets should be adequate for nearly all purposes.

It is important that the Default Energy Calibration constants be accurate. This enables the code to find the peaks selected for the final energy calibration and to convert from channel number to energy for setting region boundaries. The default energy calibration should predict the actual peak positions to within the limits of the channel-dependent peak search window which is: $\pm (6 \text{ channels} + 0.0016 \cdot \text{peak centroid})$.

If the **Default Energy Calibration** is not correct for a spectrum, you can still temporarily change the energy calibration to match the spectrum in the **Parameter** dialog box on the Dialog Bar or in the **Measure | Analyze** window.

The **Default FWHM Constants** use a formula with the final result $fwhm(ch)$ in units of channels whereas the input energy values are in keV. The first two terms in the formula for $fwhm(ch)$ are physics based, while the last term is an empirical correction to account for the observation that many curves of $FWHM^2$ vs. energy deviate from a straight line at low energy. The Application Constant

(see section 3.7.5.) **restrict_fwhm_model** enables the user to fit FWHM^2 vs. energy with only the first two physical terms.

The **Default tailing Constants** describe an exponential tail on the low energy side of the peak and allow for both the amplitude and slope of the tail to be a linear function of *energy*. We have observed that these tail parameters are not easily parameterized, with their observed behavior depending on the type of detector and even the detector manufacturer. Therefore we typically set the constant T4 to zero and use the customary form where the amplitude is a linear function of *energy* and the slope is a constant

NOTE! One may encounter conditions where good peaks, for the internal calibration of the shape parameters, are not available in the spectrum. The program allows you to fix the parameters at their default values, which can be obtained from a previous analysis with good statistical precision. This may be the best procedure for very weak spectra with poor counting statistics. If the parameters are to be fixed, it is best to obtain the fixed values from a spectrum acquired under conditions as near as possible to those from the acquisition of the unknown. The FWHM constants, in particular, will be count rate dependent. *We find it very useful to fix the tailing constants for poor quality spectra.* It is usually not necessary to fix the FWHM constants.

Cancel	Closes the Edit Fitting Parameters window without saving any changes.
OK	Temporarily saves the changes to the parameter set and closes the Edit Fitting Parameters window. These changes are applied to the following analyses but are not permanent. To make the changes permanent select Parameter Save or Parameter Exit which will ask if you want to save the parameter set before you exit.

3.7.2. Param Edit | Peaks

This option displays, in a new window in tabular form, necessary information about the peaks to be used in an analysis. An example of such a table appears below.

Edit Peak Information -- Pu_Cx_180-1010

	isotope	pk energy	Lwidth	branching ratio	fix to	eff	act	ecal	fcal	scal
1	U235	185.715	0.0	5.7000e-001	0	N	Y	N	N	N
2	U235	202.110	0.0	1.0980e-002	1	N	N	N	N	N
3	Pu239	203.545	0.0	5.7400e-006	0	Y	Y	N	N	N
4	Am241	204.040	0.0	2.9000e-008	31	N	N	N	N	N
5	U235	205.311	0.0	5.0300e-002	1	N	N	N	N	N
6	Pu241	208.000	0.0	5.3920e-006	0	Y	Y	Y	Y	Y
7	Am241	208.000	0.0	7.9540e-006	31	N	N	N	N	N
8	Am243	209.750	0.0	3.4200e-002	11	N	N	N	N	N
9	Am243	226.360	0.0	2.8000e-003	11	N	N	N	N	N
10	Am243	227.810	0.0	5.1000e-003	11	N	N	N	N	N
11	Am243	228.160	0.0	1.0760e-001	0	N	Y	N	N	N
12	Am243	254.400	0.0	1.1000e-003	11	N	N	N	N	N
13	Pu239	255.380	0.0	7.9900e-007	0	Y	Y	N	N	N
14	Pu239	263.930	0.0	2.4980e-007	0	N	N	N	N	N
15		264.850	0.0	0.0000e+000	0	N	N	N	N	N
16	Pu239	265.700	0.0	1.5070e-008	14	N	N	N	N	N
17	Pu241	267.540	0.0	1.7860e-007	0	Y	Y	N	N	N
18	Am241	267.540	0.0	2.6350e-007	31	N	N	N	N	N
19	Pu239	311.700	0.0	2.6170e-007	36	N	N	N	N	N
20	Np237	311.900	0.0	3.8600e-001	0	N	Y	N	N	N
21	Pu239	319.828	0.0	4.5450e-008	0	N	N	N	N	N
22	Pu239	320.868	0.0	5.0260e-007	0	N	N	N	N	N
23	Am241	322.526	0.0	1.4980e-006	0	N	Y	N	N	N
24	Pu239	323.828	0.0	5.3770e-007	0	N	N	N	N	N

Buttons: OK, Cancel, Insert Above, Insert Below, Delete Row, Move Up, Move Down

When the table first appears, the text boxes (editing row) on top display the information of the first row in the table.

The first column (unlabeled) displays an index number for each gamma ray in the table. Clicking anywhere in a row selects and highlights (blue text) that row and places the row contents in the editing row at the top of the window.

The five buttons at the right of the window (**Insert Above, Insert Below, Delete Row, Move Up, Move Down**) control the ordering of the table and the addition or removal of table rows to accommodate the addition or removal of gamma ray peaks in the analysis. The code will automatically reorder the peaks by energy when you exit the table. This means that using the **Move Up** and **Move Down** options will have no effect in the end.

The buttons operate with respect to a row that has been selected by clicking anywhere in the row.

To edit a peak information entry the user should first select the row to be edited by clicking anywhere in the row. This action places the selected row's contents into the editing row at the top of the window. All editing is done in the editing row. Scroll buttons at the end of the editing row aid in finding the desired row to edit.

NOTE! To change the database, you must click the **OK** button to preserve the changes made on the screen into the worksheet. Then you must choose the **Save** option from the **Parameter** menu to write the contents of the worksheet into the database. If you are editing one of the built-in parameter sets only the **Save As . . .** option will be active to prevent overwriting the built-in parameter sets.

isotope	<p>This column displays the name of the gamma ray's assigned isotope usually in the form XXnnn where XX is the standard two letter abbreviation for the isotope and nnn is its atomic mass number. The isotope name may have up to 7 characters so names other than XXnnn are permitted. A peak does not have to have an isotope assignment; this column may be left blank. An unassigned peak may be used for energy, shape, and FWHM calibrations.</p> <p>A peak may also be assigned to a "pseudo isotope" and given a name that is <u>not</u> in the isotope list. This is the same as leaving the isotope blank or NULL. A peak from a pseudo isotope may have a branching ratio and be a free peak or be fixed to other peaks from the same pseudo isotope. This has been done in parameter files for plutonium in the 100 keV region by assigning fluorescence Pu X rays the isotope name PuXray.</p>
pk energy	<p>This column displays the energy of each gamma ray in keV. Various sources are used for the gamma ray energies used in the built-in parameter sets. Some of the values have been adjusted from the published data because the adjusted values gave better fits. It is appropriate to adjust published values if it improves the fitting results. Because energy calibrations are done on a piecewise linear basis, system nonlinearity and the exact choice of energy calibration peaks may force this adjustment. It is more important that the energies be internally consistent than it is for the energies to match any particular published data set. One can select Fits in the FRAM Dialog Bar (section 4.5.2) to examine the peak fits to see if this is necessary.</p>
Lwidth	<p>This column displays the line width in eV of x-ray peaks. This column should be used only in parameter sets that analyze x-rays in the 100 keV region. Otherwise, this column should be filled with zeros.</p>
branching ratio	<p>This column displays the branching ratio of each gamma ray which is the fraction of all decays of the assigned isotope that yield the gamma ray in question. For parent-daughter gamma rays, you should consider all branches between the parent and daughter if you wish the daughter to represent the parent. For example, the ^{237}U branching ratios for gamma rays at 164, 208, 267 keV and other energies, are the product of the branching ratio of the decay of ^{237}U to ^{237}Np and the alpha decay branching fraction of $2.46\text{e-}5$ for the decay of ^{241}Pu to ^{237}U. These gamma rays are labeled as Pu241 in the Pu_Cx_180-1010 parameter set example because of the assumed decay equilibrium between ^{241}Pu and ^{237}U.</p>
Columns six through eight display information about how the peaks are used in the analysis.	
fix to	<p>This column indicates when a peak area is to be determined by ratio of relative efficiency, branching ratio, and activity from a second peak rather than being determined as a free parameter in the response</p>

function fitting. Such a process is used to extract interfering peaks from a complex of several peaks by reference to a more easily determined peak nearby. Peaks fixed to another peak in the same region are used together in a composite response function. Peaks that are fixed to another peak outside the region are subtracted or stripped from the net count array before the response function fitting is performed. Peaks fixed to other peaks should not be used for activity peaks because they do not provide independent information.

Enter the peak number of the peak to be fixed to or a zero if the peak is free.

eff

This column designates the peaks to be used in the relative efficiency curve calculation. One typically chooses a series of strong peaks from a single isotope that spans the range of the analysis. Peaks from other isotopes can also be included, although, because of normalization, additional isotopes must have two or more peaks to contribute. The principal isotope in the relative efficiency calculation is usually the first isotope in the isotope list (see later discussion on the isotope list). We usually use ^{239}Pu and ^{241}Pu - ^{237}U peaks for the relative efficiency curve in the 120-450 keV range for plutonium analysis. If you want to use the peak in the efficiency calculation, click on the **Eff** box in the editing row. If you do not want to use the peak in the efficiency calculation and the box is selected, click on the box to remove selection.

act

This column designates the peaks to be used in the calculation for relative activity. We do not use all of the peaks from a given isotope for relative activity determination. Only the strongest peaks will contribute significantly in the weighted least squares process used. Also, we do not use peaks that have been fixed to other peaks in this analysis because the fixed peaks are not independent. If you want to use the peak in the activity calculation, click on the **Act** box in the editing row. If you do not want to use the peak in the relative activity calculation and the box is selected, click on the box to remove selection.

Internal Calibration Peaks

The last three columns indicate the selection of peaks used for the internal calibrations. It is not necessary for these peaks to belong to a particular isotope, or to have any isotope name at all. These peaks typically are clean, single, well-resolved peaks with good statistics. While different peaks may be used for these calibrations, one usually uses many of the same peaks for all the calibrations.

ecal

This column indicates the selection of peaks used for the energy calibration. While any peak in the list may be used, the peak should be strong, have good counting statistics, a well-defined peak position, a well-known energy, and be free from neighboring interferences over the range from 75% of the peak maximum on the low energy side to 25% of the maximum on the high energy side. At a minimum, two energy calibration peaks are needed. When more peaks are used, the

calibration is a piecewise linear calibration between adjacent calibration peaks. If you want to use the peak in the internal energy calibration, click on the **Ecal** box in the editing row. If you do not want to use the peak in the energy calibration calculation and the box is selected, click on the box to remove selection.

fcal

This column designates the peaks to be used for the full-width-at-half-max (FWHM) vs. energy calibration. The peaks used for this internal calibration need to have the same characteristics as those used for the energy calibration and must be used for energy calibration. At least three and two FWHM peaks must be specified for full and restricted FWHM models, respectively. If you want to use the peak in the internal FWHM calibration, click on the **Fcal** box in the editing row. If you do not want to use the peak in the internal FWHM calibration and the box is selected, click on the box to remove the selection.

scal

This column designates the peaks to be used for the shape calibration, (the determination of the peak tailing parameters). The peaks used must be free of interferences in the range from 0.5 FWHM to 1.5 FWHM on the low energy side of the peak and must be used for energy and FWHM calibrations. If you want to use the peak in the internal shape calibration, click on the **Scal** box in the editing row. If you do not want to use the peak in the internal shape calibration and the box is selected, click on the box to remove the selection.

If a sufficient number of high quality peaks are not available for ecal, fcal, or scal, those parameter values may be fixed at the default values. Do this by returning to the FRAM main menu (keeping the desired parameter set open) and selecting **Param Edit | Fitting Parameters**. In the window that comes up, click on the appropriate check box on the left-hand side, which is labeled **Fixed**.

Cancel

Closes the **Edit Peak Information** window without saving any changes.

OK

Temporarily saves the changes to the parameter set and closes the **Edit Peak Information** window. These changes are applied to the following analyses but are not permanent. To make the changes permanent select **Parameter | Save** or **Parameter | Exit** which will ask if you want to save the parameter set before you exit.

If the Dialog Bar is in the display **Ecal**, **Fcal**, or **Scal** calibration mode and you add a new **ecal**, **fcal**, or **scal** calibration peak then right after you exit the parameter editing mode, you can immediately see the new calibration peak marked red on the screen.

Peaks are arranged by energy. If a peak is placed out of order, it will be automatically reordered when you exit the Peak-editing mode.

3.7.3. Param Edit | Regions

Selection of these options opens a new window displaying in tabular form all the information about the regions (groupings of peaks) to be used in an analysis. Region parameters are entered and displayed in energy units (keV). An example of the **Edit Energy Region Information** table appears below.

1	ROI beg	ROI end	BG1 beg	BG1 end	BG2 beg	BG2 end	BG3 beg	BG3 end	BG4 beg	BG4 end	BG type
1	184.10	186.90	183.40	184.10	187.00	187.60	0.00	0.00	0.00	0.00	linear
2	226.30	229.30	223.10	223.90	229.60	230.40	0.00	0.00	0.00	0.00	linear
3	201.80	205.40	201.00	201.50	201.50	202.00	204.90	205.40	0.00	0.00	linear
4	205.30	210.30	205.10	205.70	211.70	212.40	212.70	213.40	0.00	0.00	linear step
5	253.90	256.70	252.70	253.20	253.30	253.80	257.10	257.60	0.00	0.00	linear
6	262.60	269.50	261.90	262.60	269.60	270.20	270.40	270.90	0.00	0.00	linear step
7	310.10	313.70	309.20	309.70	313.90	314.40	0.00	0.00	0.00	0.00	linear
8	318.70	325.20	317.50	318.00	318.00	318.50	325.40	325.90	326.10	326.60	flat step
9	339.50	347.30	328.80	329.40	329.50	330.10	347.80	348.40	348.80	349.40	flat step
10	502.70	505.40	501.80	502.60	505.50	506.30	0.00	0.00	0.00	0.00	linear
11	330.00	339.00	328.80	329.40	329.50	330.10	347.80	348.40	348.80	349.40	flat step
12	373.00	378.00	363.80	364.40	364.50	365.10	385.50	386.10	386.20	386.80	flat step
13	365.30	372.90	363.80	364.40	364.50	365.10	385.50	386.10	386.20	386.80	flat step
14	409.20	417.20	404.00	404.60	404.90	405.50	432.20	432.80	433.00	433.60	flat step
15	449.10	453.10	448.20	448.90	456.00	456.50	0.00	0.00	0.00	0.00	flat step
16	656.60	665.90	628.50	629.20	635.20	635.90	671.60	672.40	682.40	683.60	linear step
17	635.90	649.60	628.50	629.20	635.20	635.90	648.50	649.00	649.10	649.60	linear step
18	715.80	724.20	711.60	712.20	713.60	714.20	733.20	733.80	734.00	734.60	flat step
19	762.90	777.50	762.90	763.50	775.60	776.50	776.80	777.50	0.00	0.00	flat step
20	997.80	1003.60	996.10	997.60	1004.50	1006.00	0.00	0.00	0.00	0.00	linear

The first column (unlabeled) displays an index number for each energy region in the table. Clicking anywhere in a row selects and highlights (blue text) that row and places the row contents in the editing row at the top of the window.

The start and end of each region are displayed in the next two columns. The start and end of each of four background regions are displayed in the next 8 columns. The units of the display are energy (keV). The shape of the background continuum to be extrapolated underneath the peaks in the region is displayed in the last column.

Up to four different “sub regions” labeled **BG1** through **BG4** can be used to define the background continuum underneath the region. The background regions may be placed anywhere in the spectrum, inside or outside the peak region and do not have to be in order. The regions may overlap or be empty. The placement of the background regions must be done carefully with full cognizance of interferences that may appear in other spectra to be analyzed with the same parameter set. The wide intensity variation of peaks from ²⁴¹Am must especially be recognized in this regard.

NOTE! The selection of the proper parameters for the peak and background regions may be the most important set up feature in the code.

The five buttons at the right of the window (**Insert Above, Insert Below, Delete Row, Move Up, Move Down**) control the ordering of the table and the addition or removal of table rows to accommodate the addition or removal of analysis regions. The order of the energy region information is important. The regions are analyzed in the order listed starting with region 1. It is possible (and often desirable) to analyze a higher energy region before a lower energy region.

The buttons operate with respect to a row that has been selected by clicking anywhere in the row.

To edit a peak information entry the user should first select the row to be edited by clicking anywhere in the row. This action places the selected row’s contents into the editing row at the top of the window. All editing is done in the editing row. Scroll buttons at the end of the editing row aid in finding the desired row to edit.

NOTE! To change the database, you must click the **OK** button to preserve the changes made on the screen into the worksheet. Then you must choose the **Save** option from the **Parameter** menu to write the contents of the worksheet into the database. If you are editing one of the built-in parameter sets only the **Save As . . .** option will be active to prevent overwriting the built-in parameter sets.

Region Numbers:	Regions are analyzed in the order they are presented in the table. The regions need not be in order of energy and, indeed, it is sometimes desirable to have them out of order so a region having a peak that a second region fixes to is analyzed first. Note the discussion in Appendix A. The regions are not reordered when the window is reentered.
ROI beg ROI end	The boundaries in keV of the analysis region.
BGn beg BGn end	Up to four different “sub regions” labeled BG1 through BG4 can be used to define the background continuum underneath the region. The background regions maybe any size and may be placed anywhere in the spectrum, inside or outside the peak analysis region. The region beginning (BGn beg) and ending (BGn end) boundaries are in keV. All the counts in a background region are averaged to produce a single value per region for use in the background calculation. Hence, the different BG type functions have different requirements for the number of BG regions required to be defined.
BG type	Click on the arrow at the right hand side of this box in the editing row to display a list of the permissible background types. Select one of the eight choices in the list. Here is a brief description of the background types.
none	no background subtraction, requires no BG region.
flat	a straight line with zero slope, requires at least 1 BG region.
linear	a sloping straight line, requires at least 2 BG regions.
quadratic	use with care as poor background ROI choices may produce an unphysical background, requires at least 3 BG regions.
exponential	gives a mildly curving background, requires at least 3 BG regions.
flat step	a smoothed step function with zero slope at the ends, requires at least 2 BG regions.
linear step	a smoothed step function superimposed on a sloping straight line, requires at least 3 BG regions.
bilinear step	a linear step with different sloping straight lines allowed above and below the region (use with care), requires 4 BG regions.

To judge the appropriateness of a particular background form for a particular region, perform an analysis using this parameter set, then use the **Fits** option on the FRAM Dialog Bar to view the computed backgrounds.

- Cancel** Closes the **Edit Energy Region Information** window without saving any changes.
- OK** Temporarily saves the changes to the parameter set and closes the **Edit Energy Region Information** window. These changes are applied to the following analyses but are not permanent. To make the changes permanent select **Parameter | Save** or **Parameter | Exit** which will ask if you want to save the parameter set before you exit.

3.7.4. Param Edit | Isotopes

Selecting this option opens a new window and displays in tabular form all the necessary information about the isotopes to be used in an analysis. An example of such a table appears below.

	isotope	half-life (years)	mass	Power mW/g	Pu240 coef	Eff func
1	Pu239	2.41190e+004	239.05220	1.92880e+000	0.0000	1
2	Pu241	1.43480e+001	241.05690	3.41120e+000	0.0000	1
3	Pu238	8.77400e+001	238.04961	5.67570e+002	2.5200	1
4	Pu240	6.56400e+003	240.05380	7.08240e+000	1.0000	1
5	Pu242	3.76300e+005	242.05874	1.15900e-001	1.6800	1
6	Am241	4.33600e+002	241.05679	1.14200e+002	0.0000	1
7	U235	7.03800e+008	235.04390	5.99600e-005	0.0000	1
8	U238	4.46800e+009	238.05080	8.51000e-006	0.0000	1
9	Np237	2.14000e+006	237.04817	2.07200e-001	0.0000	1
10	Am243	7.37000e+003	243.06140	6.43500e+000	0.0000	1

The first column (unlabeled) displays an index number for each isotope in the table. Clicking anywhere in a row selects and highlights (blue text) that row and places the row contents in the editing row at the top of the window.

The five buttons at the right of the window (**Insert Above**, **Insert Below**, **Delete Row**, **Move Up**, **Move Down**) control the ordering of the table and the addition or removal of table rows to accommodate the addition or removal of isotopes in the analysis. The buttons operate with respect to a row that has been selected by clicking anywhere in the row.

To edit an isotope entry the user should first select the row to be edited by clicking anywhere in the row. This action places the selected row's contents into the editing row at the top of the window. All editing is done in the editing row. Scroll buttons at the end of the editing row aid in finding the desired row to edit.

- isotope** The isotope name can contain up to 7 characters. Usually this column displays the name of the **isotope** in the form **XXnnn** where **XX** is the standard two-letter abbreviation for the isotope and **nnn** is its atomic mass number. **The first isotope in the list is important because all the other isotopes ratios are calculated relative the first one.** Thus,

in the example above, the fundamental isotopic ratios calculated by the code are $^{241}\text{Pu}/^{239}\text{Pu}$, $^{241}\text{Am}/^{239}\text{Pu}$, $^{238}\text{Pu}/^{239}\text{Pu}$, $^{240}\text{Pu}/^{239}\text{Pu}$, ... $^{243}\text{Am}/^{239}\text{Pu}$. After the first isotope the order of the isotopes is not important.

In the 100 keV region the uranium analysis uses U x rays. The x rays are treated as an isotope and given the isotope name **UXray**.

half-life (years)

The values of the **half-life (years)** used are those from ASTM C 1458-00, "Standard Test Method for Nondestructive Assay of Plutonium, Tritium and ^{241}Am by Calorimetric Assay," (ASTM International, West Conshohocken, PA, 2000).

mass

The Atomic Mass in AMUs.

Power (mW/g)

This is the specific power of the isotope in milliWatts/g isotope used for interpretation of calorimetry results. The values also come from ASTM C 1458-00.

Pu240 coef

This parameter is the coefficient multiplying the isotope mass in the expression for ^{240}Pu effective mass, (or effective fraction) used to interpret neutron coincidence counting. Currently accepted values are highlighted below.

$$^{240}\text{Pu}_{\text{eff}}(\text{mass}) = 2.52 * ^{238}\text{Pu}(\text{mass}) + 1.00 * ^{240}\text{Pu}(\text{mass}) + 1.68 * ^{242}\text{Pu}(\text{mass})$$

Eff func

A different **Eff func** is given to isotopes in a different matrix or isotopes that suffer different attenuation at the same gamma energy than the first isotope in the isotope list. The number of efficiency functions is not limited, but we only have experience with two functions. You must be sure that there are enough relative efficiency points to define additional efficiency functions.

Cancel

Closes the **Edit Isotope Information** window without saving any changes.

OK

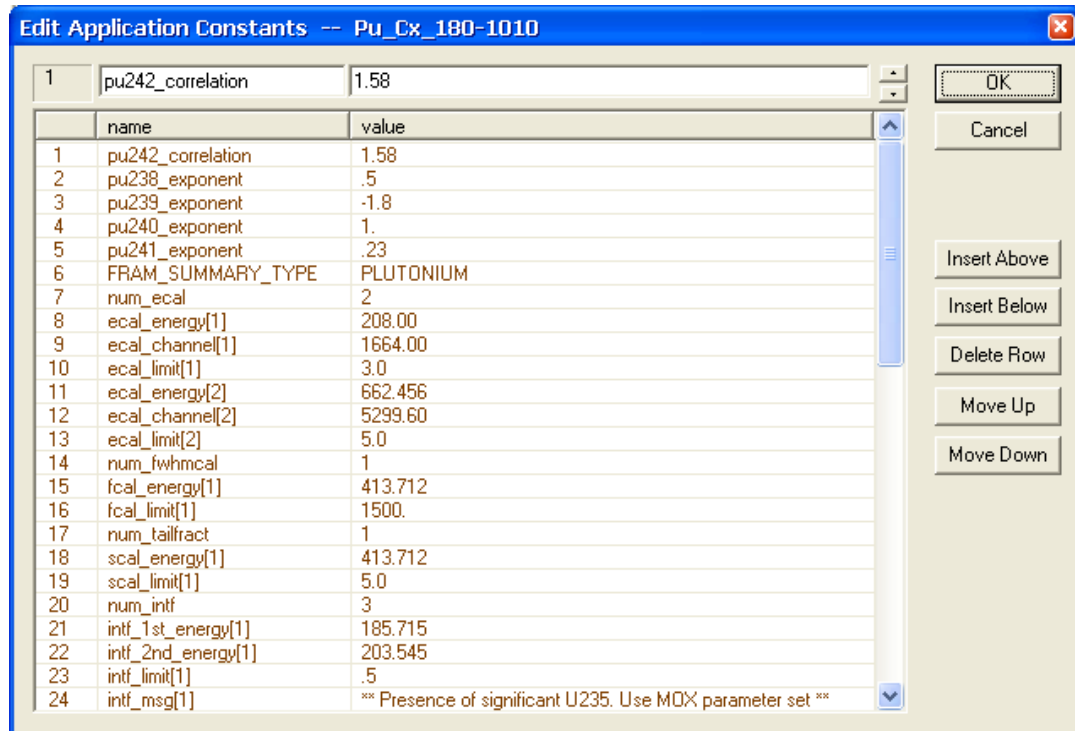
Temporarily saves the changes to the parameter set and closes the **Edit Isotope Information** window. These changes are applied to the following analyses but are not permanent. To make the changes permanent select **Parameter | Save** or **Parameter | Exit** which will ask if you want to save the parameter set before you exit.

NOTE! To change the database, you must click the **OK** button to preserve the changes made on the screen into the worksheet. Then you must choose the **Save** option from the **Parameter** menu to write the contents of the worksheet into the database. If you are editing one of the built-in parameter sets only the **Save As . . .** option will be active to prevent overwriting the built-in parameter sets.

3.7.5. Param Edit | Application Constants

Selecting this option opens a new window and displays in tabular form all the information about the application constants to be used in an analysis. These constants, for the most part, govern the

diagnostic tests and analysis control flags in FRAM. These tests are flexible and can be added, deleted, or customized to suit specific measurement conditions.



The number of possible Application Constants is large. They are described in several tables below and are also listed and described in Appendix F.

The first column (unlabeled) displays an index for each application constant, which serves as a row number for the table.

name This column contains a string, which is the name of the application constant. The program, when searching for a constant name, examines only the characters in the column up to the first blank. You may append other information such as assumed units to the name as long as there is one or more blanks separating the two.

value This column contains a string which can be decoded into the value for that constant.

Row Operations

Rows may be added, deleted, or shifted in the Application Constants list. The five buttons at the right of the window (**Insert Above**, **Insert Below**, **Delete Row**, **Move Up**, **Move Down**) control the ordering of the table and the addition or removal of table rows to accommodate the addition or removal of Application Constants. However, the position of an Application Constant in the table is not important; only the presence or absence of the Application Constant is considered. Thus the ordering of the table rows is usually performed for the convenience of ordering and keeping like Application Constants together.

Many of the constant names have indices. You are permitted to test as many peaks or quantities as desired. The indices *must* be entered in brackets [...]. Parentheses will not work.

Tests may be added to or deleted from the list to suit the analysis characteristics of the specific parameter set. A test is not performed if its corresponding application constant is not listed.

A description of the permitted Application Constants names follows. Unless otherwise noted the Application Constants are valid in FRAM v.5 and earlier versions. There are two additional groups of Application Constants. These two groups of constants control the application of the physical model for the relative efficiency determination (see chapter 5) and the **Auto analysis** automated parameter file selection (see chapter 6). These groups of Application Constants are described in the referenced chapters.

pu242_correlation	<p>The correlation constant A in the expression for the ^{242}Pu correlation, which has the form</p> $^{242}\text{Pu} = A * [(^{238}\text{Pu})^B * (^{239}\text{Pu})^C * (^{240}\text{Pu})^D * (^{241}\text{Pu} + ^{241}\text{Am})^E]$ <p>The units are mass fraction. ^{241}Am is added back to the ^{241}Pu as shown before the correlation is calculated. This correlation can be tailored to most any of the specific models that have been published in the literature.</p>
pu238_exponent	The value of B in the ^{242}Pu correlation above.
pu239_exponent	The value of C in the ^{242}Pu correlation above.
pu240_exponent	The value of D in the ^{242}Pu correlation above.
pu241_exponent	The value of E in the ^{242}Pu correlation above.
u236_correlation	<p>The correlation constant A in the expression for the ^{236}U correlation, which has the form</p> $^{236}\text{U} = A * ^{235}\text{U}^B * ^{238}\text{U}^C + D * ^{235}\text{U}^E * ^{228}\text{Th}^F$ <p>There is evidence that the ^{236}U fraction depends upon the amount of ^{232}U because they are both created in the reactor. Because ^{232}U decays to ^{228}Th the correlation contains the ^{228}Th term. If ^{228}Th is not quantified in the analysis, the second term in the correlation is ignored.</p>
u235_exponent	The value of B in the ^{236}U correlation above.
u238_exponent	The value of C in the ^{236}U correlation above.
u236_correlation2	The value of D in the ^{236}U correlation above. Valid only in FRAM v.5.
u235_exponent2	The value of E in the ^{236}U correlation above. Valid only in FRAM v.5.
th228_exponent	The value of F in the ^{236}U correlation above. Valid only in FRAM v.5.
FRAM_SUMMARY_TYPE	The value designates the type of output results. Allowed values are the text strings (in caps): PLUTONIUM or URANIUM . The default value is PLUTONIUM .

num_ecal	The number of peaks to be checked for peak centroid position. This check assures that the energy calibration has been maintained. Failure is usually not a problem unless the peaks are so far out of position that the internal energy calibration routine cannot find them.
ecal_energy[.]	The energy in keV of a peak to be checked for peak centroid position. This energy should appear in the peak list.
ecal_channel[.]	The channel number including decimal fractions, if desired, of the peak centroid for the peak at ecal_energy [.] .
ecal_limit[.]	The allowable deviation in channels of the observed peak position of the peak at ecal_energy from its specified location at ecal_channel . If the observed peak centroid position is outside the region from location minus limit to location plus limit, a warning message will be printed.

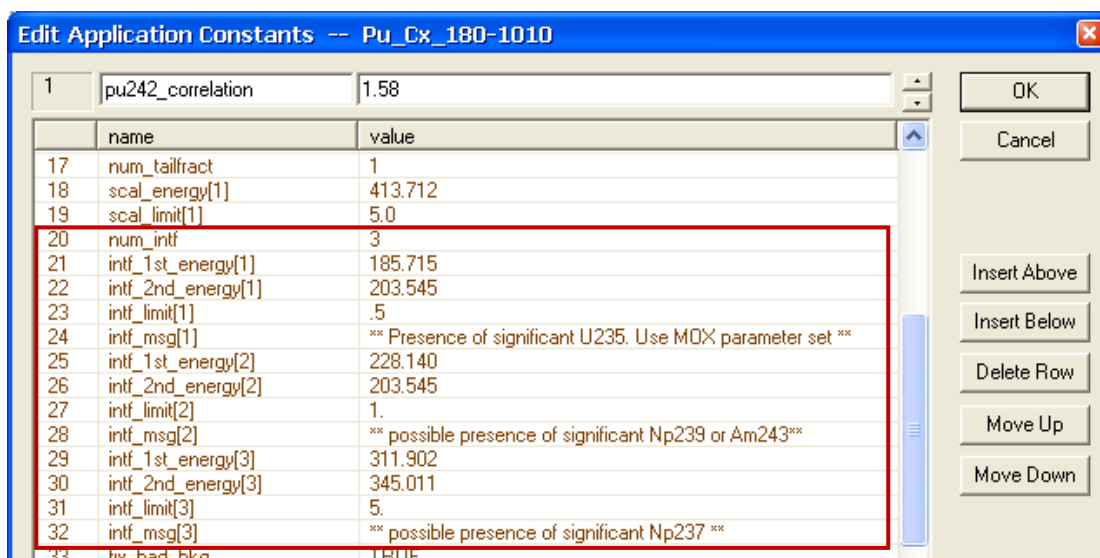
Example: The acceptable peak positions for **ecal_energy[1]** at 208.00 keV lie between channels 1661.00 and 1667.00 in the above table from parameter set **Pu_Cx_180-1010**.

num_fwhmcal	The number of peaks to be checked for Full Width at Half Maximum (FWHM). This test is usually performed to see that the detector resolution is within reasonable bounds.
fcal_energy[.]	The energy in keV of a peak to be checked for FWHM. This energy should appear in the peak list.
fcal_limit[.]	The FWHM of the peak at fcal_energy[.] must be less than this limit, in eV or a warning message will be printed.

Example: The acceptable FWHM of the **fcal_energy[1]** peak at 413.712keV is < 1500 eV in the above table from parameter set **Pu_Cx_180-1010**.

num_tailfract	The number of peaks to be used to check for the percentage of the total peak area falling in the tail. This test is performed to look for possible neutron damage causing excessive peak tailing.
scal_energy[.]	The energy in keV of a peak to be checked for its tailing percentage. This energy should appear in the peak list.
scal_limit	The percentage of the total peak area permitted to fall under the tail. A warning message will be printed if the tail percentage is greater than this number.

Example: The acceptable tailing percentage of the **scal_energy[1]** peak at 413.712 keV is < 5 % in the above table from parameter set **Pu_Cx_180-1010**.

**num_intf**

The number of interference peaks to be checked. Interference peaks are peaks that are somewhat likely to appear in a spectrum but may not be accounted for in the parameter set. Their presence, when not accounted for in the parameter set, may bias the analysis.

intf_1st_energy[.]

To check for the presence of an interference peak we search for the peak at **intf_1st_energy[.]** and ratio its gross area including background to that of an expected peak at **intf_2nd_energy[.]**.

intf_2nd_energy[.]

The peak area ratio must be less than **intf_limit[.]**. The **intf_limit[.]**'s are set empirically. When a peak interference is found, the text from **intf_msg[.]** is printed. The message should be less than 80 characters

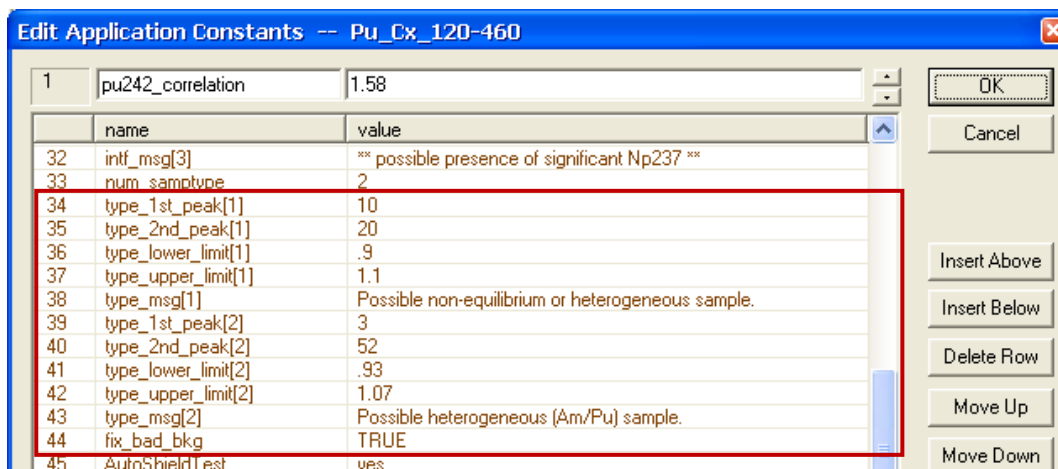
intf_limit[.]**intf_msg[.]**

If this diagnostic is triggered one should visually examine the spectrum and, if necessary, reanalyze the spectrum with another parameter set, which includes the appropriate interference peaks.

Example: In the display above three interference peak tests are listed in lines 20 to 32. All three tests are performed because **num_intf = 3**. If **num_intf** would have been **1** only the first test would have been performed.

Counting statistics at the 2-sigma level are considered in the interference test.

The next listing below illustrates the Sample Type tests. A different built-in parameter set has been used to illustrate these tests.

**num_samptype**

The number of Sample Type tests to be performed. The Sample Type test checks peak activity ratios and can be used for various diagnostic tests. Most often it is used to test if one isotope is heterogeneous (in a different matrix) with respect to another.

type_1st_peak[.]**type_2nd_peak[.]****type_lower_limit[.]****type_upper_limit[.]****type_msg[.]**

An activity ratio is the isotopic activity for the **type_1st(2nd)_peak[.]** ratioed to the activity for the first isotope in the isotope list. When this activity ratio is formed for two type peaks and ratioed, one has formed a ratio between the activities found from the two type peaks. This ratio must be between **type_lower_limit[.]** and **type_upper_limit[.]** or the **type_msg[.]** will be printed. The value for **type_1st(2nd)_peak[.]** in the table above is the number of the peak in the **Peaks** list.

Counting statistics at the 2-sigma level are considered in the Sample Type tests.

Lines 33 to 43 illustrate two Sample Type tests. Both tests will be performed because **num_samptype = 2**. The parameter set **Pu_Cx_120-460**, not shown here, contains the following information.

First isotope in the isotope list:	Pu-239
Peak no.10:	Pu-241, 148.567 keV
Peak no. 20:	Pu-241 (U-237), 164.597 keV
Peak no. 3:	Am-241, 125.29 keV
Peak no. 52:	Am-241, 335.43 keV

Sample Type test [1] forms the activity ratio of Pu-241, determined from the 148.567 keV peak (peak 10), to the activity of Pu-239 and ratios this activity ratio to the ratio of the activity of 164.597 keV peak 20 from U-237 to Pu-239. This ratio of ratios produces the Pu-241/U-237 ratio. If this ratio is unity then U-237 is in secular equilibrium with its parent, Pu-241. If it falls outside the limits of $0.9 < \text{ratio} < 1.1$, then the error message **Possible non-equilibrium or heterogeneous sample** is printed.

Sample Type test [2] forms the activity ratio of Am-241, determined from the 125.29 keV peak (peak 3), to the activity of Pu-239 and ratios this activity ratio to the ratio of the activity of 335.4 keV peak 52 from Am-241 to Pu-239. This ratio of ratios produces the Am-241(125 keV)/Am-241(335 keV) ratio. The ratio of the activity determined from a high energy Am gamma ray to that determined from a low energy Am gamma ray should be unity if the Am and Pu are attenuated in the same manner. If these two isotopes are in different matrices they will experience different attenuation and their ratio will not be unity. If this ratio falls outside the limits of $0.93 < \text{ratio} < 1.07$, then the error message **Possible heterogeneous [Am/Pu] sample** is printed.

The limits of these tests are determined empirically. The structure of this test is flexible enough that you may find applications other than those illustrated.

NOTE! Moving a co-energetic peak up or down, changing a peak's energy, or adding or removing peaks from a parameter set may change the peak numbers of the peaks used in the Sample Type tests. The peak numbers in the Sample Type tests do NOT update after this action. After making changes to the peaks in the Param Edit | Peaks section, the user should review the Sample Type tests to see that they are using the intended peaks and make any necessary corrections.

The **type_1st(2nd)_peak[.]** constants have a setback that whenever a peak is added or removed, you have to remember to check the type peaks and correct them as necessary. FRAM v5 introduces a new Sample Type Peak that does not require reviewing when you make changes to the Peak Edit. The listing below from the modified parameter set shows the new Sample type peak constants.

id	name	value
1	pu242_correlation	1.58
32	intf_msg[3]	*** possible presence of significant Np237 ***
33	num_samptype	2
34	type_1st_energy[1]	148.567
35	type_2nd_energy[1]	164.597
36	type_lower_limit[1]	.9
37	type_upper_limit[1]	1.1
38	type_msg[1]	Possible non-equilibrium or heterogeneous sample.
39	type_1st_energy[2]	125.292
40	type_2nd_energy[2]	335.432
41	type_lower_limit[2]	.93
42	type_upper_limit[2]	1.07
43	type_msg[2]	Possible heterogeneous [Am/Pu] sample.

type_1st_energy[.]
type_2nd_energy[.]

The Type peaks at the 1st and 2nd energies are searched for the same way as those of the interference peaks. The activity ratio of these two **type_1st(2nd)_energy[.]** peaks is done the same way as that of the two **type_1st(2nd)_peak[.]** peaks.

Two groups of Application Constants provide quality checks on the fitting in the low and high energy tail regions of a peak. These checks are helpful when the tail parameters have been fixed or conditions exist that could cause a distorted peak shape such as a poor pole-zero setting, very high count rates or excessive neutron damage to the detector. These tests check for the quality of the fit in the low and high energy tailing regions of a peak and produce a warning message if the fit is poor. The warning message is meant to notify the user to correct the problem causing the excessive tailing

- num_tailLowE** The number of peaks to be checked for quality of the least squares fit of the low energy tail. A maximum of four peaks is allowed. The peaks must be clean, single, isolated peaks to at least 3 sigma below the peak centroid.
- tailLowE_energy[.]** The energy in keV of a peak to be checked for quality of the fit of the low energy tail. The energy must appear in the peak list.
- tailLowE_limit[.]** The permitted percent deviation of the fit of the low energy tail. If the absolute difference (relative to the total peak area) between the data and the fit in the region from 2 to 3 sigma's left of the peak centroid is larger than the limit, then a warning message will be printed. (Sigma = FWHM/2.355).
- num_tailHighE** The number of peaks to be checked for quality of the least squares fit of the high energy tail. A maximum of four peaks is allowed. The peaks must be clean, isolated peaks to at least 3 sigma above the peak centroid.
- tailHighE_energy[.]** The energy in keV of a peak to be checked for quality of the fit of the high energy tail. The energy must appear in the peak list
- tailHighE_limit[.]** The permitted percent deviation of the fit of the high energy tail. If the absolute difference (relative to the total peak area) between the data and the fit in the region from 2 to 3 sigma's right of the peak centroid is larger than the limit, then a warning message will be printed.

The above tailing fit quality tests are included in all of the built-in parameter sets. The tests in parameter set Pu_Cx_120-460 are shown below.

	name	value
1	pu242_correlation	1.58
42	type_upper_limit[2]	1.07
43	type_msg[2]	Possible heterogeneous (Am/Pu) sample.
44	num_tailLowE	3
45	tailLowE_energy[1]	129.294
46	tailLowE_limit[1]	.5
47	tailLowE_energy[2]	208.00
48	tailLowE_limit[2]	.5
49	tailLowE_energy[3]	345.011
50	tailLowE_limit[3]	.5
51	num_tailHighE	3
52	tailHighE_energy[1]	129.294
53	tailHighE_limit[1]	.4
54	tailHighE_energy[2]	208.00
55	tailHighE_limit[2]	.4
56	tailHighE_energy[3]	345.011
57	tailHighE_limit[3]	.4
58	AutoShieldTest	yes
59	AutoShieldPass	Pu_Cx_180-1010
60	Shield_LowEnergy	129.294
61	Shield_HighEnergy	413.712
62	Shield_HighToLowLimit	20
63	AutoHeteroTest	yes
64	AutoHeteroPass	PuHetero_Cx_120-460
65	Hetero_AmLimit	0.01

fix_bad_bkg	This parameter can be set to TRUE or FALSE . It controls whether the background fitting is redone with an alternate function if the program senses that an unphysical background has been calculated. The default value is TRUE which means that the backgrounds are automatically recalculated even if this parameter is omitted from the Application Constants list. For example, a linear step background applied to a region with a positively sloping background continuum may produce unphysical smoothed steps for the calculated background. The program will recalculate the background with a linear background if the fix_bad_bkg parameter is TRUE or if the fix_bad_bkg parameter is omitted from the list. If the fix_bad_bkg parameter is FALSE the designated background fit is not changed.
restrict_fwhm_model	If TRUE set $A_3 = 0$ in fitting the equation: $\text{FWHM}(\text{ch}) = \sqrt{A_1 + A_2 * E + A_3 / E}$. See section 3.7.1. The allowed values are TRUE or FALSE . The default value is FALSE . In FRAM v5 (but not v4), when the least squares fit using the full FWHM model fails, the code will set the FWHM model to restricted and then refit the data.

New Application Constants Valid only in FRAM v.5.

fix_100kev_plutonium	If TRUE correct the bias due to the large tail and FWHM in the 100-keV region analysis of plutonium. It has no effect for analysis in the energy region above 120 keV. Allowed values are TRUE or FALSE . The default value is FALSE .
fix_100kev_uranium	If TRUE correct the bias due to the large tail and FWHM in the 100-keV region analysis of uranium. It has no effect for analysis in the energy region above 120 keV. Allowed values are TRUE or FALSE . The default value is FALSE .
syst_error_pu238	A user-designated systematic error component for Pu238. A positive number represents the relative percent uncertainty. A negative number invokes the built-in bias. (See <i>Duc Vo, "FRAM version 5.1's Bias," LANL document LA-UR-11-02958</i> for the determination of the built-in bias.) The absolute value of the negative number is the multiplication factor of the built-in bias. The default value is 0—no systematic error component used. The systematic uncertainty is combined in quadrature with the statistical uncertainty. When the syst_error_xxyyy Application Constants are included in the parameter set, the final isotopic analysis results are recalculated and listed in the Med Result output titled Isotopic Results with Systematic errors included . This result immediately follows the normal isotopic result whose uncertainties come from counting statistics only.

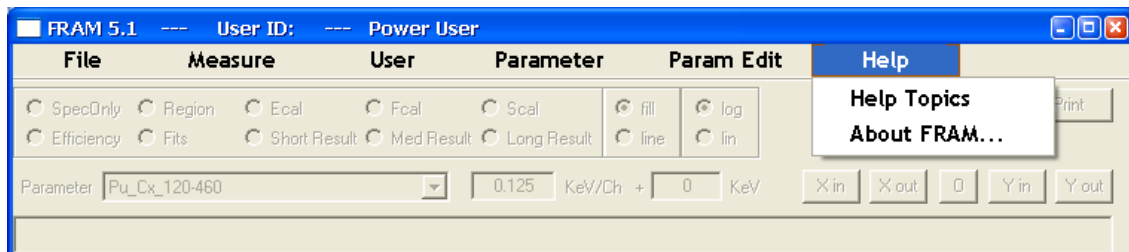
syst_error_pu239	For Pu239. See description for Pu238.
syst_error_pu240	For Pu240. See description for Pu238.
syst_error_pu241	For Pu241. See description for Pu238.
syst_error_pu242	For Pu242. See description for Pu238.
syst_error_am241	For Am241. See description for Pu238.
syst_error_u234	<p>A user-designated systematic error component for U234. A positive number represents the relative percent uncertainty. A negative number invokes the built-in bias. (See <i>Duc Vo, "FRAM version 5.1's Bias," LANL document LA-UR-11-02958</i> for the determination of the built-in bias.) The absolute value of the negative number is the multiplication factor of the built-in bias. The default value is 0—no systematic error component used. The systematic uncertainty is combined in quadrature with the statistical uncertainty.</p> <p>When the syst_error_xxyyy Application Constants are included in the parameter set, the final isotopic analysis results are recalculated and listed in the Med Result output titled Isotopic Results with Systematic errors included. This result immediately follows the normal isotopic result whose uncertainties come from counting statistics only.</p>
syst_error_u235	For u235. See description for u234.
syst_error_u236	For u236. See description for u234.
syst_error_u238	For u238. See description for u234.
correct_u_sumpeaks	Correct for the intensities of the U238 peaks that undergo coincidence summing. This command has no meaning for analysis in the 100-keV energy region. Allowed values are TRUE or FALSE . Default value is TRUE .
num_iterations	The number of times that the background, relative efficiency, peak area, and isotopic results calculations are repeated. In FRAM v.4 and earlier versions, this value was set in the General Defaults setup and was applied for every analysis. In FRAM v.5, this value is set in the parameter set and is applied for only that parameter set. The default value is 3.
restrict_tail_model	Fix T2 to its default value (Param Edit Fitting Parameters) in fitting the equation: <p style="text-align: center;">$Tail(ch) = H * exp((T1 + T2 * E) + (T3 + T4 * E) * (ch - x0)) * [1 - exp(-C * (ch - x0)^2)]$</p> <p>Also, when the least squares fit using the full tail model fails, the code will set the tail model to restricted and then refit the data. Allowed values are TRUE or FALSE. Default value is FALSE.</p>
restrict_efficiency_model	If TRUE set c5 = 0 in fitting the empirical relative efficiency curve: <p style="text-align: center;">$ln(eff) = c1 + c2/E^2 + c3 * ln(E) + c4 * [ln(E)]^2 + c5 * [ln(E)]^3 + c_i + c_j/E$</p>

This command has no effect on the physical model efficiency curve fit. Allowed values are **TRUE** or **FALSE**. The default value is **FALSE**.

There are two additional groups of Application Constants described elsewhere. These two groups of constants control the application of the physical model for the relative efficiency determination (see chapter 5) and the Auto analysis automated parameter file selection (see chapter 6).

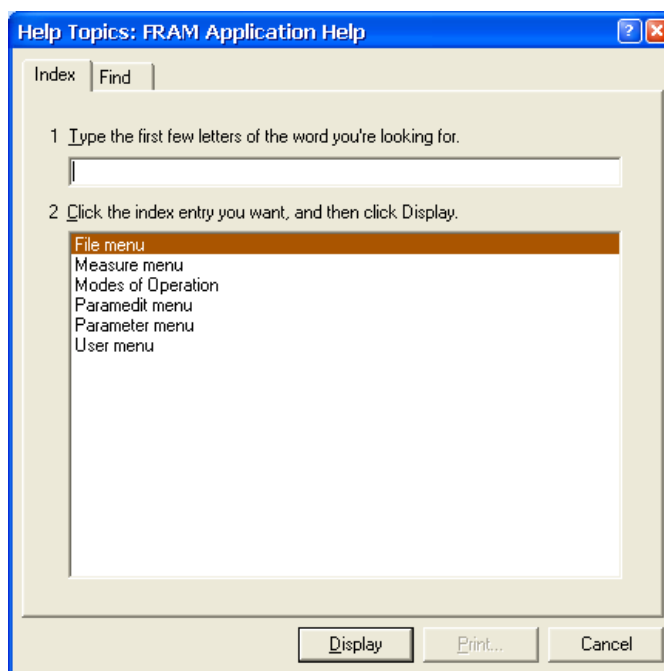
3.8. Help

The **Help** menu can be expanded by clicking on the word **Help** with the mouse or by pressing the key combination Alt+H.



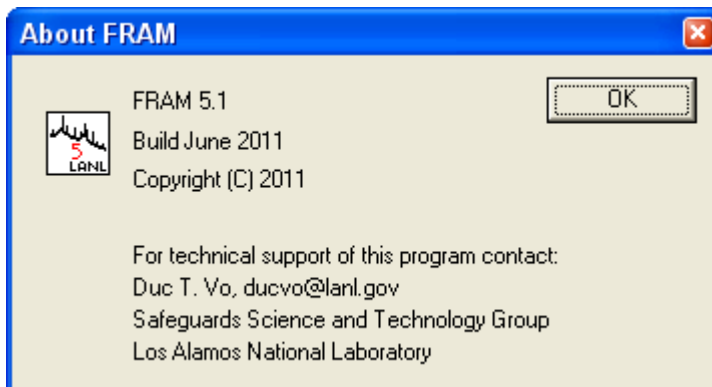
3.8.1. Help | Help Topics

This menu option provides online Help for the FRAM v.5 software that is initiated from the **Help Topics: FRAM Application Help** window. Note: this online Help may not work with Windows Vista or Windows 7 unless the user has downloaded and installed the WinHelp viewer from Microsoft's website. As an alternate, the user can run the FRAM Help (HTML) from the FRAM51 program group.



3.8.2. Help | About FRAM. . .

This option brings up a window displaying the FRAM version, copyright, and support information.



3.9. Modifying Parameter Sets for Special Applications

The FRAM installation process installs a suite of built-in parameter sets. These parameter sets should be sufficient for analysis of spectra of most common plutonium and uranium materials obtained with typical HPGe detectors (including the planar, coaxial, N-type, and P-type HPGe). The names of the built-in parameter sets are capitalized, and they cannot be changed or removed. This process greatly strengthens the ability to control the versions of the parameter sets. Users can still create and modify their own parameter sets, and those parameter sets are saved with lower-case characters. The discussion below describes the general process to use to extensively modify a parameter set for a special application.

3.9.1. General Approach to Parameter Set Modification

The user has password-protected control over five groups of parameters that have been discussed above.

- **Fitting Parameters**
- **Peaks**
- **Regions**
- **Isotopes**
- **Application Constants**

User editing of these groups of parameters allows the construction of a new parameter set appropriate to the special application at hand.

3.9.2. Begin with an Existing Parameter Set

One begins by choosing an existing parameter set that has properties that are nearest to the desired new parameter set. Open this parameter set by **Parameter | Open**. Save the parameter set with the **Parameter | Save As. . .** option. Rename the parameter set to reflect the new application. You may now edit the renamed parameter set with the **Param Edit** option.

3.9.3. Set Energy Calibration Defaults and Isotopes for Analysis

The default energy calibration is accessed by **Param Edit | Fitting Parameters**. Set the **Gain (KeV/ch)** and **Offset (keV)** to match the spectra being analyzed. The other default values for the fwhm parameters and tailing parameters can usually remain at their default values as long as the new energy calibration is not significantly different from the old one. If the change is more than 50%, new values should be obtained from the medium printout of the analysis of a good quality spectrum where all fitting parameters are NOT Fixed.

Designate the isotopes to be used in the analysis by selecting (**Param Edit | Isotopes**).

3.9.4. Edit Gamma-Ray Peaks for Analysis

Next the user enters the information on the peaks to be analyzed after selecting (**Param Edit | Peaks**).

3.9.5. Define Regions for Analysis

The boundaries of the regions for analysis and the background regions are entered next. The selection of region boundaries is somewhat of an art. It is not difficult to do for a single specific spectrum and can be done in many, equally acceptable ways in this case. It does become more difficult if one wants to make the new parameter file applicable to a wider range of samples. In this case one must be especially aware of the positioning of the background ROIs. An ROI that is satisfactory for one spectrum may not be applicable to another spectrum that has additional interference isotopes present.

Changing ^{241}Am concentrations can be troublesome in this regard and it is best to guide your region setup using a spectrum with the highest ^{241}Am concentration available.

3.9.6. Define Peaks for Internal Calibrations

The user now designates the peaks to be used in the internal calibrations although this can also be done when the peaks were selected. This is a critical part of the parameter file setup because poor internal calibrations will quickly invalidate an analysis. Sometimes this is all that has to be done to modify a parameter file. Peaks chosen for internal calibration of energy, fwhm, and peak shape should be, to the greatest extent possible, clean single peaks. Peaks selected for the internal shape calibration should be completely free from interferences to at least 1.5 fwhm below the peak centroid.

The piecewise linear internal energy calibration requires a minimum of two peaks. The fwhm calibration requires a minimum of two peaks, preferably sampling the extremes of the analysis range. The shape calibration should also come from peaks at high and low energies. Two peaks are sufficient but they should be intense peaks so that the tailing can be pulled out of the noise. The shape calibration requirements are often the most difficult to satisfy and lead to our recommendation of fixing the shape parameters for some analyses.

One can recalibrate the shape parameters off line if they seem to have changed. You observe this by examining the peak by selecting the **Fits** button on the Dialog Bar. Poor fits in the tail region are a signal that the shape calibration should be updated. Acquire several spectra with good counting statistics and analyze them with the shape parameters set to be free (remove the check in the **Fixed** box for the **Default Tailing Constants, Param Edit | Fitting Parameters**). Updating of shape parameters should be infrequent but will probably need to be done as the detector ages and absorbs neutron damage over its lifetime. Enter the new parameters obtained from a medium printout, and continue analysis, fixing the new parameters if required by the new spectra.

3.9.7. Edit Application Constants

The user can edit the Application Constants last as most of these constants do not affect the analysis. To clean up the application constants the user should first make sure that the peak channels in the diagnostic tests agree with the default energy calibration as the diagnostic test channels are not linked to the default energy calibration. One should check that the interference peaks are appropriate for the data to be analyzed. The user will usually not change the isotopic correlation constants for ^{242}Pu or ^{236}U or change the **FRAM SUMMARY TYPE**.

The penalty for not changing the application constants is often a large number of error messages. The messages usually do not signify that anything is wrong with the analysis but are very disconcerting to a customer or an auditor looking over formal measurement results. Be sure to clean up the application constants before any new parameter file is put into formal use.

3.9.8. Temporary Editing of Built-In Parameter Sets

Two sets of parameters in a built-in parameter set may be edited “on the fly” for a one-off analysis or a series of analyses requiring analysis parameters different from those in the built-in parameter set. The parameters that may be changed for an individual analysis are the gain (**KeV/Ch**) and zero (**KeV**) in the **Parameter** line of the **Analyze** window and also the **Efficiency defaults** in the same window.

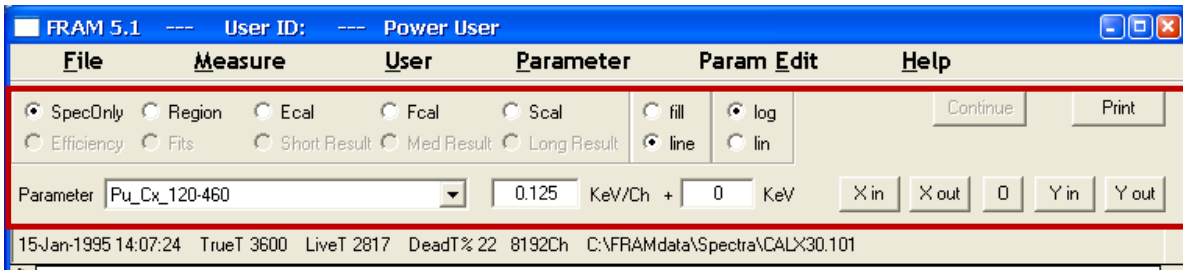
These parameters are changed, if desired, in the **Measure | Analyze** window. The user should note the changes in the **Comment:** box of the window for future reference. If the gain or zero is changed the new values are listed in the header block of the analysis output on the line listing the efficiency model used. If changes are made in the **Efficiency defaults** then the header block output for the efficiency model will read **Physical Efficiency (Mod. Eff.)**. The modified Physical Efficiency is also reported in the **.CSV** file as "**ModEff Physical**".

If the default energy calibration gain (**KeV/Ch**) and/or zero (**KeV**) are temporarily edited in this manner, the resulting analysis will very likely display diagnostic error messages from the energy calibration (**ecal**) diagnostic test set up in the Application Constants. The channel numbers in the diagnostic test do not update when the default energy calibration is changed. The temporary editing allowed for a Built-In parameter set does not allow this parameter to be changed. The user should recognize the reason for the diagnostic message and ignore it.

This editing is temporary and is not saved into the built-in parameter set.

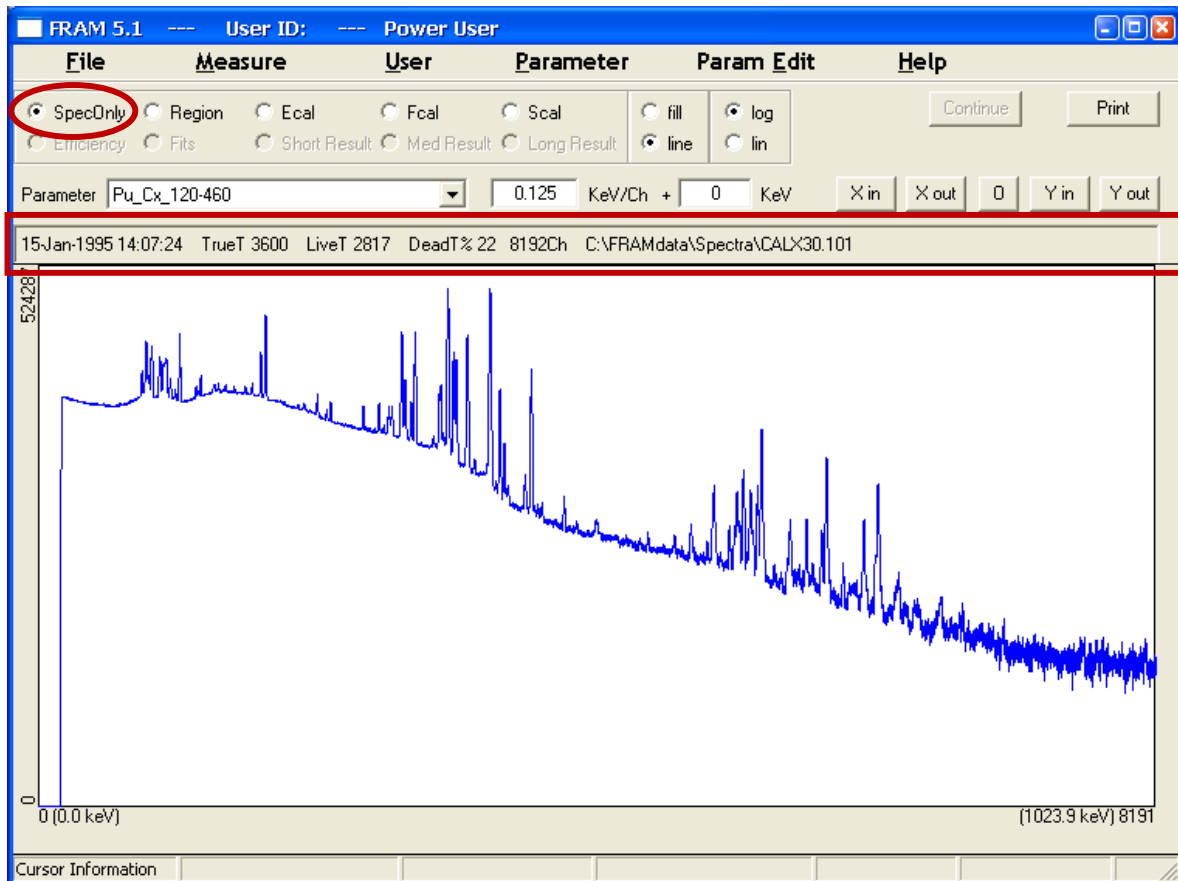
4. Operations Reference – FRAM Dialog Bar

The dialog bar outlined below controls all aspects of spectrum and results display making it easy for the user to check on the quality of the data or analysis without leaving the FRAM main window. It also controls the printing and display of spectral data and results displayed in the FRAM window. These options have been described briefly in section 2.2.2 and will be discussed in more detail in this chapter.



The FRAM main window displays the spectral data from a data acquisition or from an opened spectral data file by clicking the **SpecOnly** button. The window below shows spectral data read from a stored disk file.

SpecOnly Displays the spectrum.



4.1. FRAM Information Bars

Information about the data file is listed in the Information Bar (outlined) at the top of the FRAM Display Area in the spectrum above. Included are date and time of acquisition, True Time (seconds), Live Time (seconds), % Dead Time, No. of Channels, data storage path.

At the bottom of the FRAM Display Area we see on the horizontal axis the channel and energy for the beginning and end of the display. These parameters are obtained from the energy calibration for the displayed **Parameter** set in the Dialog Bar.

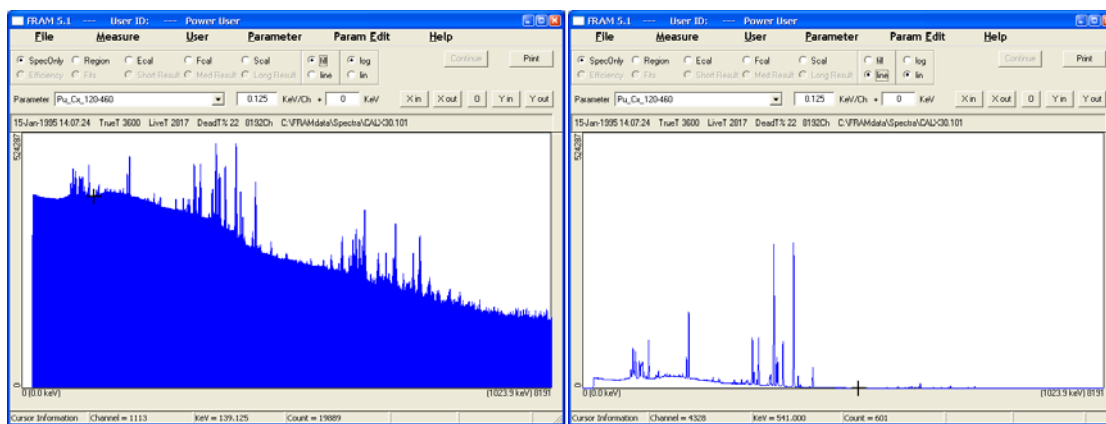
Parameter	The combo box allows the user to access the parameter sets in the database. The energy gain and offset allow the user to change the energy calibration of a parameter set to match the energy calibration of the spectrum.
------------------	--

4.2. Spectral Display Options

The following display option buttons control the appearance of the spectrum in the Display Area. As you can see, the spectrum above is displayed with a log scale and a line plot.

fill	Fills the spectrum from the baseline to the data points with solid blue color.
line	Displays the spectrum by connecting the data points with a blue line.
log	Displays the spectrum with a logarithmic vertical scale.
lin	Displays the spectrum with a linear vertical scale.

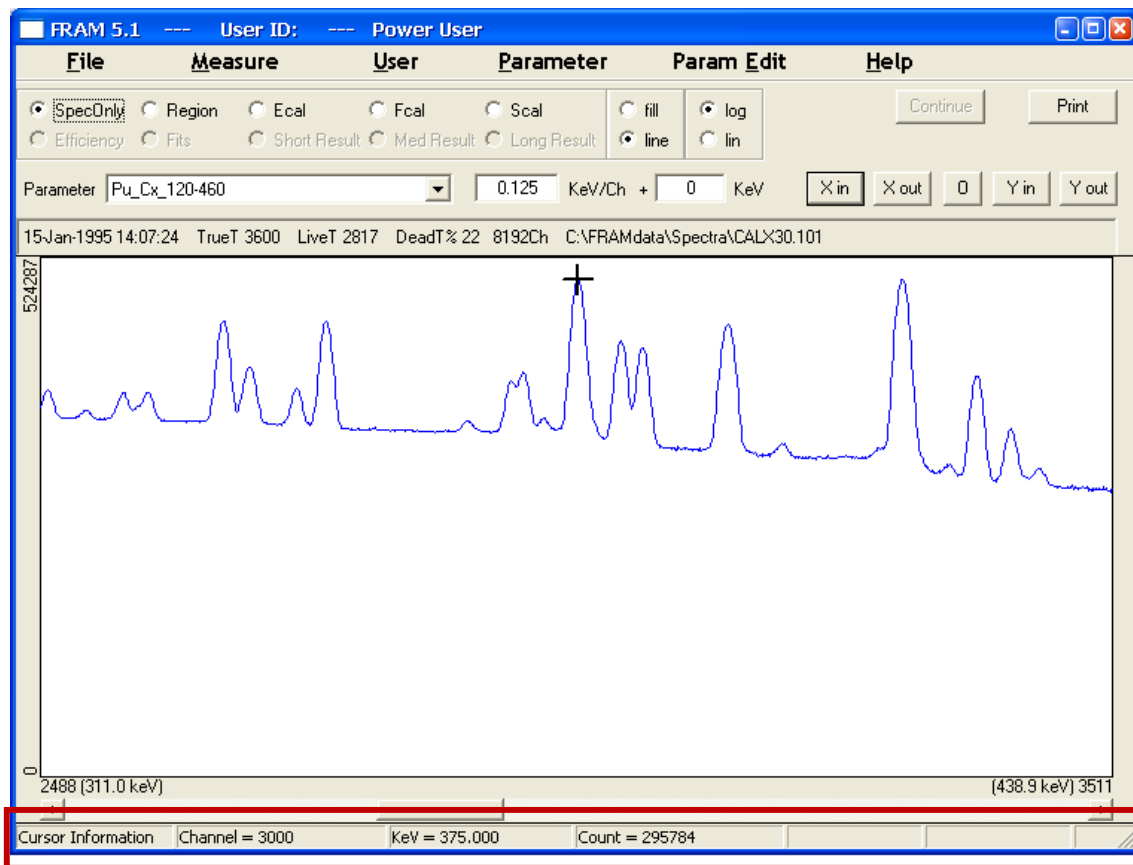
The spectral displays below show fill and log on the left and line and lin on the right for the same data.



Clicking inside the display area will place a cursor cross hair in the spectrum at the x coordinate of the cursor. You can then use the vertical and horizontal scale adjust buttons to examine the spectrum in more detail. The horizontal scale buttons **x in** and **x out** expand or contract about the position of the cursor which moves to the center of the display. The cursor may be moved through the spectrum with the ← and → keys. The cursor location, energy, and channel counts are displayed in the Information Bar at the bottom of the window.

X in	Adjusts the horizontal scale to view half the channels of the current spectrum display.
X out	Adjusts the horizontal scale to view twice the channels of the current spectrum display.
O	Returns the spectrum to its full scal in both horizontal and vertical scales.
Y in	Contracts the vertical display by one-half.
Y out	Expands the vertical display by a factor of 2.

The scale adjust buttons have been used to expand the display above as shown in the picture below. Horizontal expansion takes place about the location of the cursor. **Cursor Information –Channel, KeV, and Count** are shown in the bottom Information Bar outlined below.



4.3. Display Information Options

These four radio buttons at the top of the FRAM Dialog Bar control what is plotted in addition to the spectrum itself.

- Region** Displays the spectrum's regions of analysis. The peak regions are shown in red and the background regions are shown in green. The regions displayed are from the parameter set chosen in the **Parameter** combo box. This allows you to judge the appropriateness of the region

data for the chosen parameter set. For example, you might scan through the spectrum and note whether the defined background regions of interest truly represent the background continuum and are not on top of an unexpected peak. The default energy calibration displayed in the parameter combo box is used to calibrate the x-axis.

⊙ **Ecal**

The peaks used for the internal Energy calibration are shown in red on the background of a blue spectrum. Use **fill** or **line** according to your preference.

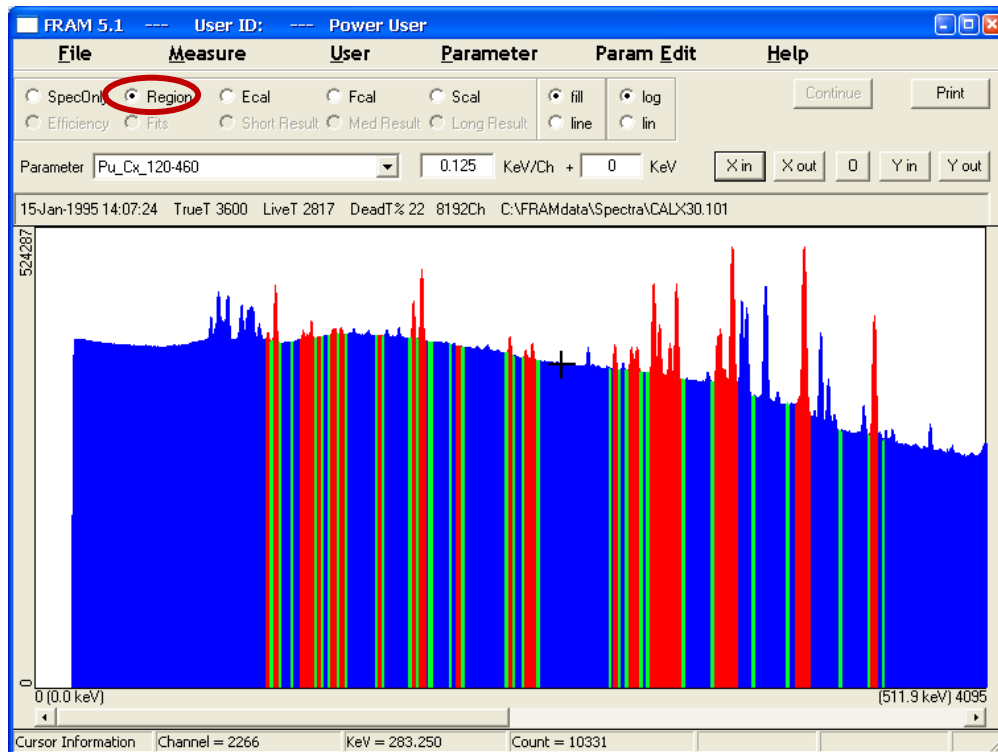
⊙ **Fcal**

The peaks used for the internal FWHM calibration are shown in red on the background of a blue spectrum. Use **fill** or **line** according to your preference.

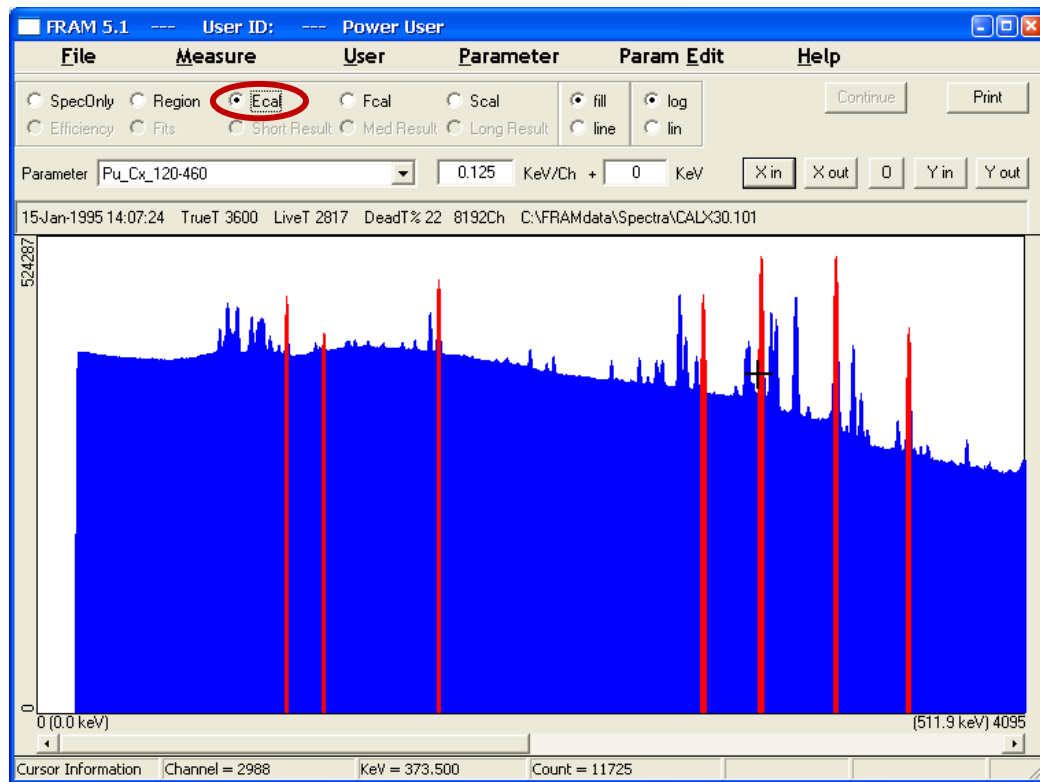
⊙ **Scal**

The peaks used for the internal Shape calibration are shown in red on the background of a blue spectrum. Use **fill** or **line** according to your preference.

The spectrum below illustrates the selection of the **Region** radio button showing the red peak regions and the green background regions for the analysis of a plutonium spectrum in the 120-460 keV energy region.



The next display below shows the same spectrum with the selection of the **Ecal** radio button showing the red peak regions used for the internal energy calibration. That the red **Ecal** peaks coincide with clean, strong, single peaks is an indication that the energy calibration peaks have been properly chosen for analysis of this spectrum.

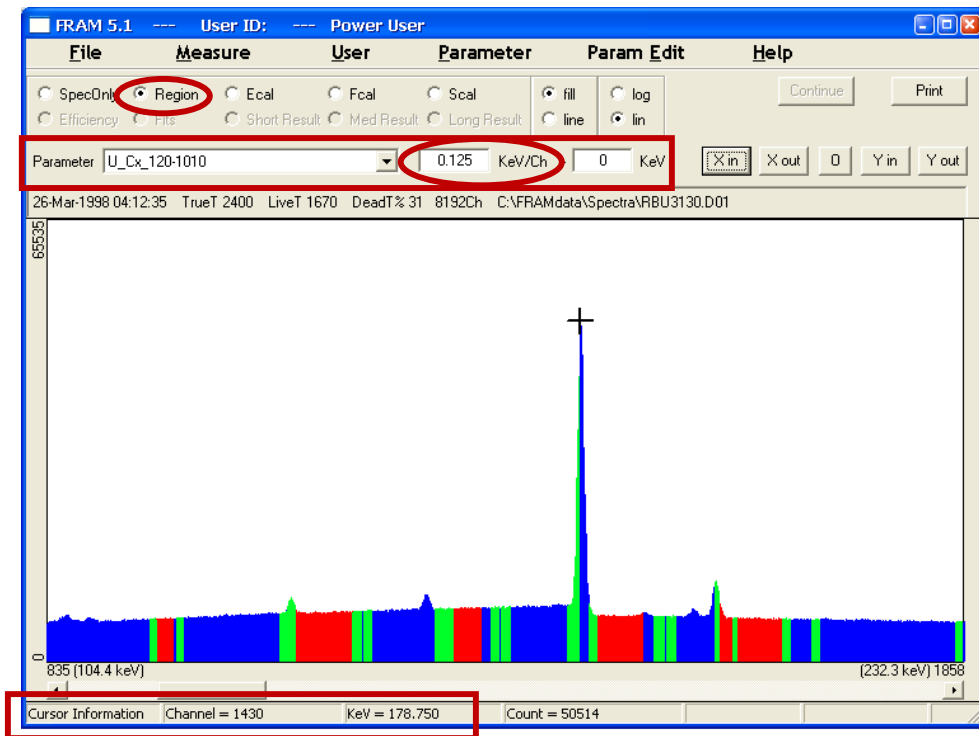


4.4. Parameter Set-Spectral Display Interactive Features

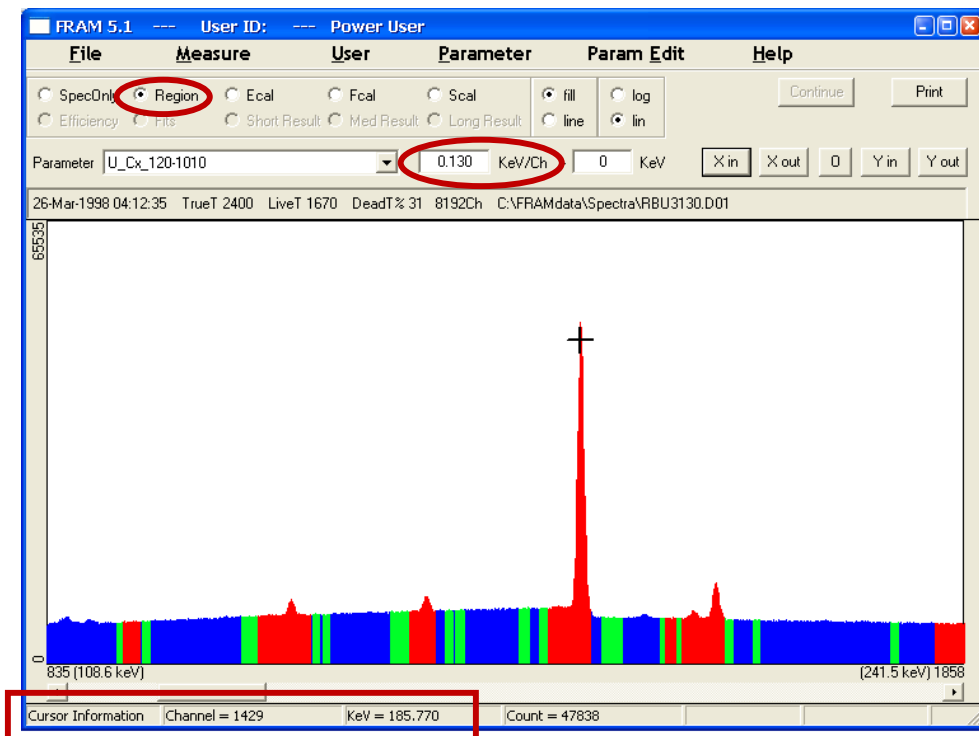
The FRAM Dialog Bar allows near real-time interaction between the parameter set selected in the **Parameter** combo box, the selected parameter set's gain and zero, and the spectral display. This allows nearly instant adjustment of the default gain (keV/Ch) in the parameter set showing its effects on the **Region**, **Ecal**, **Fcal**, and **Scal** peak/region locations in the spectrum.

An example would be the analysis of a spectrum with a parameter set whose default gain is different from the gain of the spectral data. One would overlay the regions of the selected parameter set onto the spectrum by selecting the **Region** radio button. Close examination of the spectrum/region display in the FRAM Display window would immediately show that the parameter set regions were not appropriate for the spectral data. One would then adjust the **KeV/Ch** input in the **Parameter** combo box to the correct value of the spectrum gain. Then simply click in the display window and the regions will shift to their new positions corresponding to the adjusted **KeV/Ch** parameter set gain. This adjustment carries over to the **Measure | Analyze** option for immediate analysis of the spectral data with the adjusted gain.

The window below shows a portion of a low-enriched uranium spectrum centered around the 185 keV peak. The standard parameter set for analysis of this spectrum has a default gain of 0.125 keV/ch, displayed in the **Parameter** combo box. The Information Bar at the bottom of the window shows the energy of the cursor channel (on top of the 185 keV ^{235}U peak) to be 178.875 keV. We also note that the red peak regions and green background regions do not match the spectrum.



By changing 0.125 KeV/Ch in the Parameter combo box to a value of 0.130 KeV/Ch and clicking in the FRAM Display Window the spectral display updates to (spectrum below) showing proper regions and correct energy for 185 keV peak.



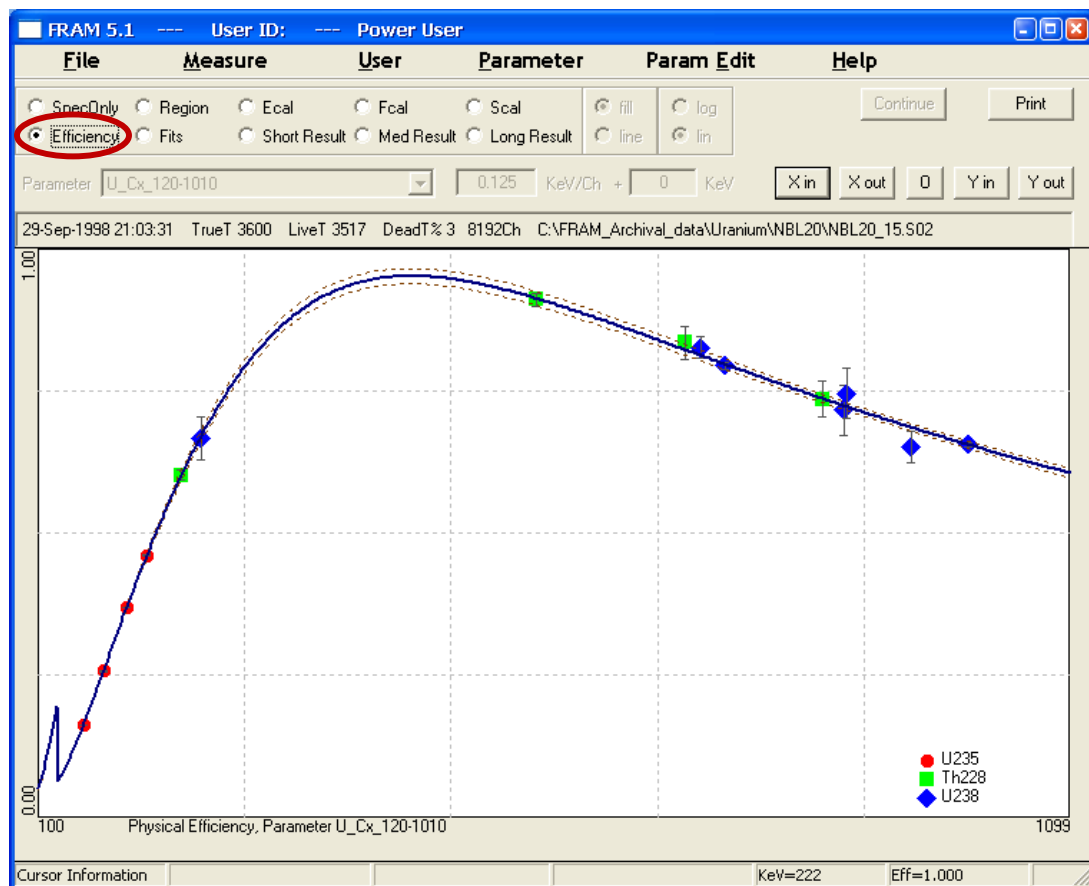
4.5. Analyzed Results Features

After a spectrum analysis the group of radio buttons in the second row of the FRAM Dialog Bar becomes active.

- Efficiency** Shows the relative efficiency curve of the analysis.
- Fits** Shows the fits of the analysis regions. When Fits is selected the “Region” scroll bar becomes active allowing the user to scroll and display all the regions.
- Short Result** Displays the short output (1 page) of results in the FRAM window.
- Med Result** Displays the medium output (~ 4 pages) of results in the FRAM window.
- Long Result** Displays the long output (~10 pages) of results in the FRAM window.

4.5.1. Efficiency

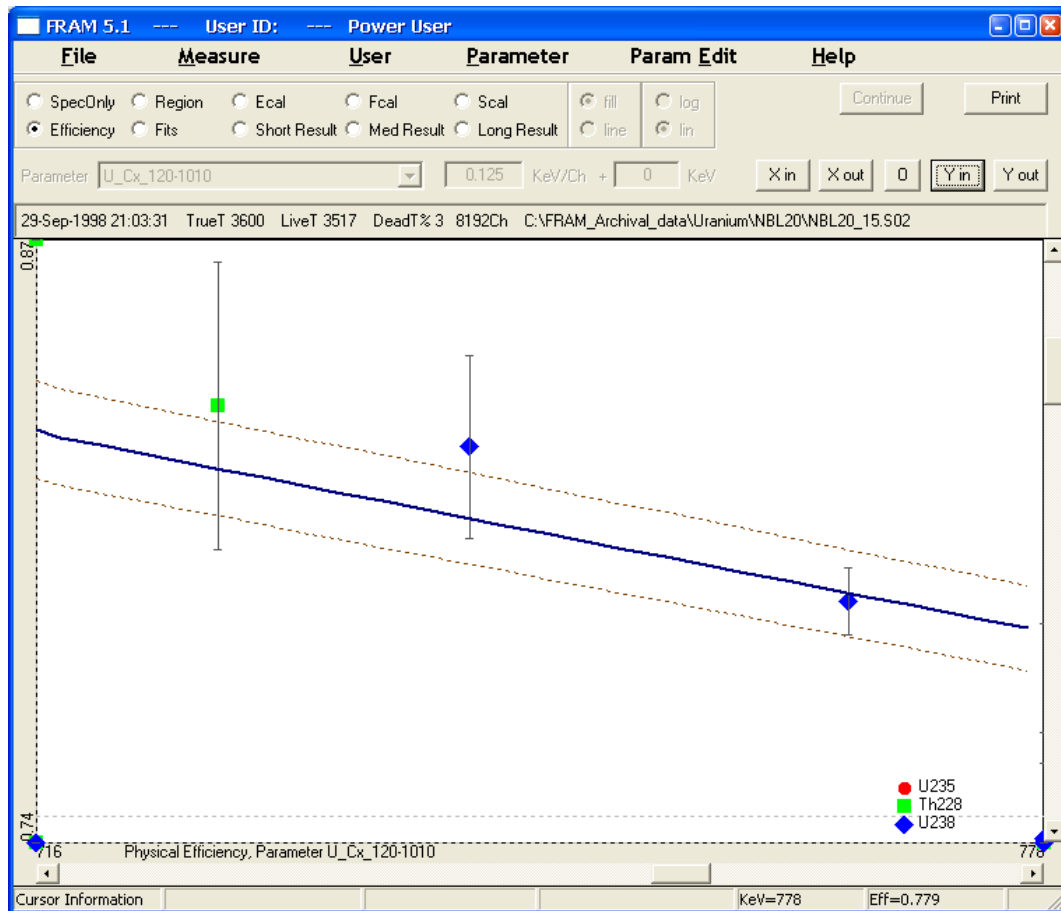
Clicking on the **Efficiency** radio button shows the relative efficiency curve of the just-completed analysis. The relative efficiency curve from the analysis of a coaxial detector spectrum from 200 g of U_3O_8 enriched to 20% ^{235}U is shown below.



Some of the features of this presentation are:

- Statistical (1 sigma) error bars on the points. Where they are not visible, they are smaller than the point but may be seen by expanding the vertical scale (**Y in**) and scrolling the display.
- Statistical error band (at the 1 sigma level) from the fitting is displayed as dotted brown lines.
- Placing the cursor on a point in the display allows the read out of the energy and efficiency at the cursor location.

An expanded portion of the above relative efficiency curve shows the error bars and error band in a better fashion.



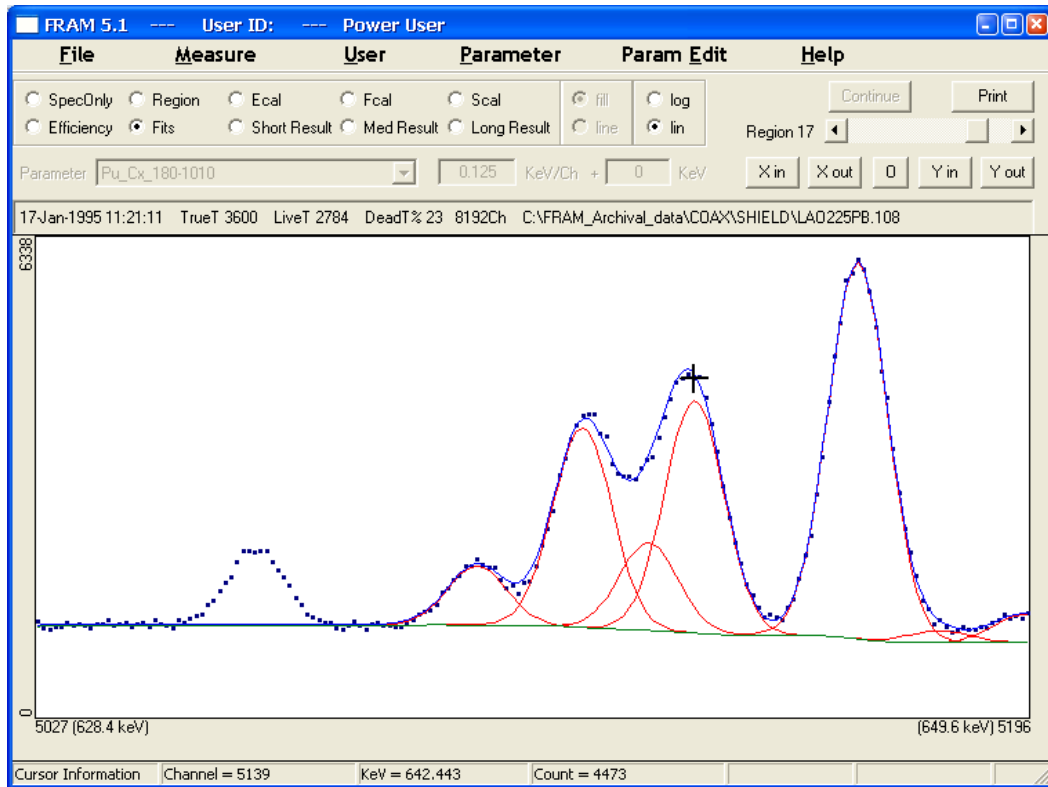
4.5.2. Fits

When the **Fits** radio button is selected the **Region** slider bar becomes active. The user can now scan through and closely inspect the detailed fits in each fitting region.

- The initial display window is defined by lowest and highest channels in the fitting region.
- The display window can be expanded, contracted and scrolled to view the fits in close detail.
- The data is displayed as blue points.

- The individual peak components are in red.
- The envelope of the total response function fit is a blue line.
- The background fit is a green line.

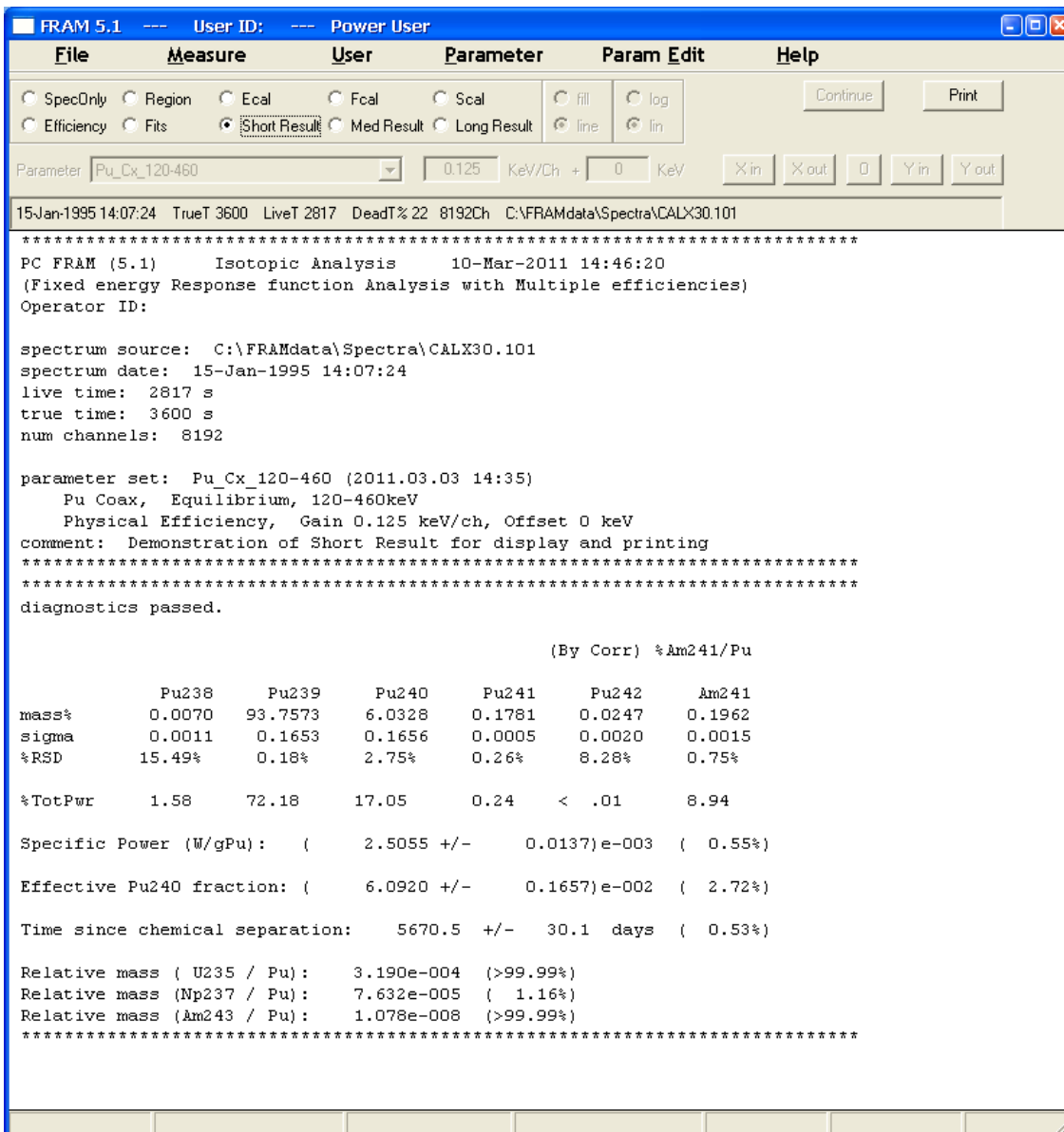
An expanded **Fits** region showing the fitting in the 640 keV region from the spectrum of a 1 kg PuO₂ sample with 16% ²⁴⁰Pu.



4.5.3. Results Display Options

- ⊙ **Short Result** Displays the short output (1 page) of results in the FRAM window.
- ⊙ **Med Result** Displays the medium output (~ 4 pages) of results in the FRAM window.
- ⊙ **Long Result** Displays the long output (~10 pages) of results in the FRAM window.

Selecting one of the results display options displays the selected output result in the FRAM window. A Short Result output is shown below. The output listings are described in detail in chapter 7.



4.5.4. Control and Printing Options

Continue

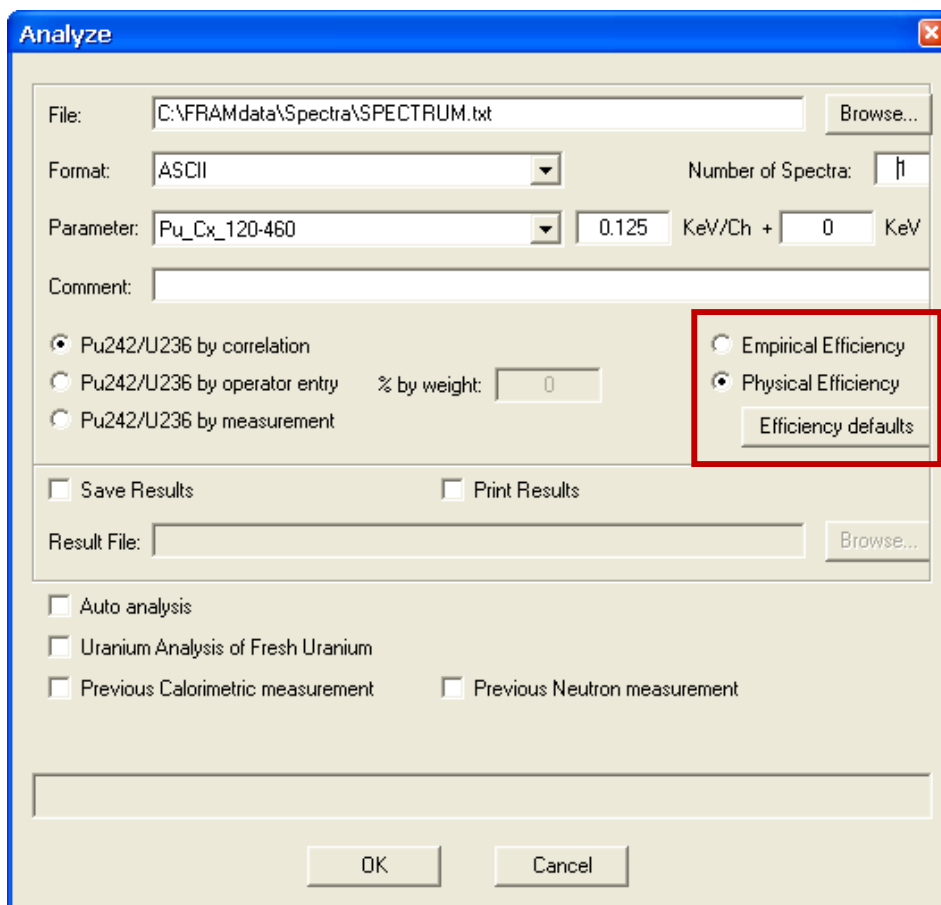
When acquiring data, this button switches between “Acq. Stop” and “Continue” to allow for stopping and continuing the acquisition. This option would be used, for instance, to stop data acquisition to fill a detector with LN₂ and continue the acquisition after the filling was completed.

Print

Selecting this option prints the information being displayed in the FRAM window. When acquiring data and then stopping, this button switches to “Restart” to allow the restarting of the data acquisition. This option is useful for adjusting the input rate or dead-time and then restarting the acquisition.

5. Relative Efficiencies

The **Measure | Measure** and **Measure | Analyze** options allow the user to choose between two types of relative efficiency functions, a physical efficiency model and an empirical efficiency model. The choice of efficiency functions is outlined in the **Measure | Analyze** dialog box is shown below.



For high quality spectral data with good counting statistics, the two models work equally well for analysis employing only the peaks above the K-edge. The empirical model calculates faster because the physical model must use iterative non-linear least squares fitting but the difference is not significant on modern computers.

The empirical model will sometimes give unphysical results if the spectra have poor counting statistics or if the efficiency curve is extrapolated outside its range of definition, although the Application Constant **restrict_efficiency_model** may be invoked to mitigate these effects. The empirical model requires a minimum of five relative efficiency points, more if additional isotopes are used or if an isotope is determined to be physically heterogeneous with respect to the first isotope in the isotope list. The iterative nature of the calculation of the physical relative efficiency curve does not require that the number of relative efficiency points be equal to or greater than the number of unknowns. The physical relative efficiency curve can produce acceptable results with fewer relative efficiency points than the number of unknowns.

The physical model is to be preferred if the relative efficiency function is to be extrapolated outside the range of definition.

5.1. Empirical Model

The empirical efficiency model is the same model that has been used in previous versions of FRAM.

$$\ln(\text{Area}/BR) = c_1 + c_2/E^2 + c_3(\ln E) + c_4(\ln E)^2 + c_5(\ln E)^3 + c_i + c_j/E$$

where E is the energy in MeV. Each c_i is associated with isotopes beyond the first one. Each c_j is associated with an efficiency function beyond the first one.

The **restrict_efficiency_model** Application Constant when set to **TRUE** will set $c_5 = 0$ removing the cubic term from the model. This will make the model behave in a more physical manner when the spectrum has poor statistics and/or if the model is being extrapolated outside the range of the relative efficiency data points (although the latter extrapolation is not recommended).

5.2. Physical Model

The relative efficiency is represented by a model that considers the principal physical processes taking place in the sample/detector system. These processes include self-absorption within the sample, absorption in the sample container, absorption in any filters or shielding between the sample and the detector, and the efficiency of the detector itself.

This model is given by the following formula.

$$RE = [(1 - \exp(-\mu_0 x_0)) / \mu_0 x_0]^* \\ [\exp(-\mu_1 x_1) \exp(-\mu_2 x_2) \exp(-\mu_3 x_3)]^* \\ [A_i][\exp(c_j / E)][DetectorEfficiency][CorrectionFactor]$$

The first term accounts for self absorption within the sample. μ_0 is the absorption coefficient for plutonium and uranium while x_0 is the corresponding thickness. The unknown thickness x_0 is determined in the fitting process.

The three terms in the second line account for attenuation in up to three different materials interspersed between the sample and the detector. μ_i is the absorption coefficient for the i^{th} absorber material while x_i is the corresponding thickness. The software permits these three materials to be chosen from Al, Fe, Cd, Er, Pb, U, concrete, and H₂O. The absorption coefficients for these materials are parameterized in the software. The (up to) three unknown thicknesses x_i are determined during the fitting process.

The terms in the third line are:

A_i	Isotope activity
$\exp(c_j / E)$	Term for multiple efficiency functions
<i>DetectorEfficiency</i>	Generic detector efficiency built into the software. A single generic detector efficiency curve is used for all detector types.
<i>CorrectionFactor</i>	Modified Hoerl function ($E^b * c^{1/E}$).

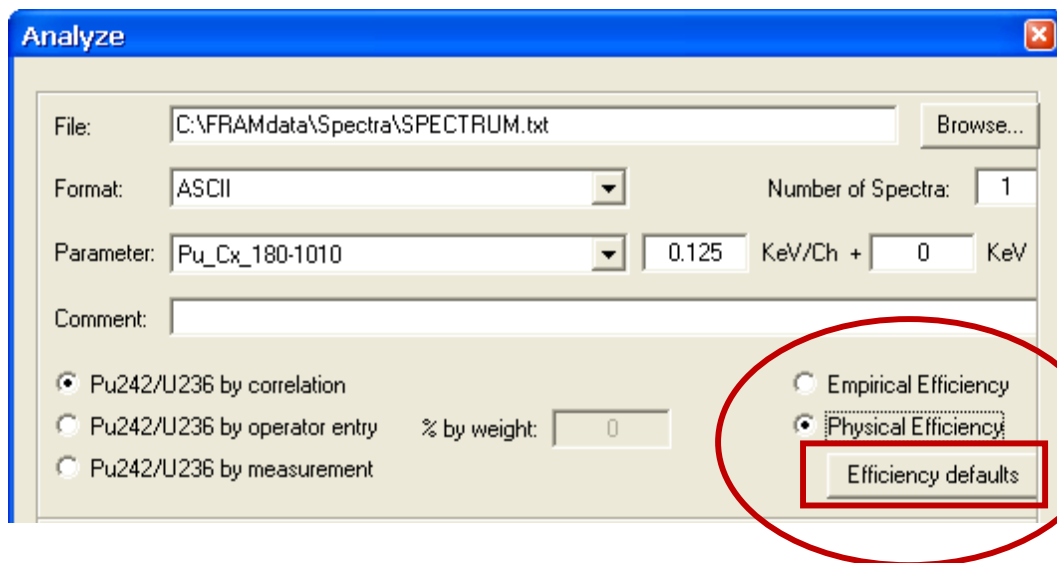
Corrects for differences between the actual detector efficiency and matrix and the chosen generic *DetectorEfficiency*. The constants b and c are determined in the fitting process.

The relative efficiency function is fit to the selected relative efficiency data points by non-linear least squares using the Levenberg-Marquardt method. Because the fitting process is non-linear least squares, the number of data points may be less than the number of free parameters.

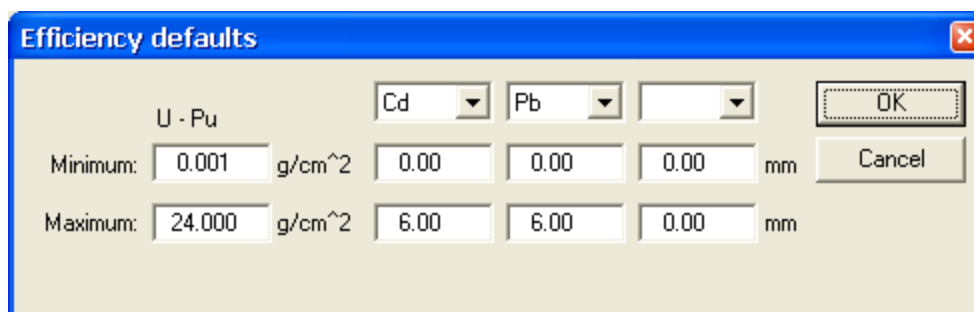
The generic detector efficiency and attenuation coefficients parameterized in the software are defined for all materials up to 10 MeV increasing the range of application of FRAM v.5 over that of FRAM v.4.

5.3. Parameters for Physical Model

The parameters needed to describe the physical efficiency model are specified by Application Constants in the selected parameter set. The **Efficiency defaults** button becomes active in the **Measure | Analyze** window when the **Physical Efficiency** model is chosen.



When **Efficiency defaults** is selected the following window appears allowing adjustment of the Efficiency Defaults in the current parameter set for the current analysis. This adjustment is temporary, and applies only to the current analysis, and does not change the value of the Application Constants in the parameter set. The fact that an adjustment has been made is indicated in the header block of the output. The efficiency model will read **Physical Efficiency (Mod. Eff.)**



If the current parameter set does not contain any Application Constants for **Efficiency defaults**, the following hard-wired values are used in the **Physical Efficiency** curve fitting.

U – Pu Minimum	0.001
U – Pu Maximum	20
Cd Minimum	0
Cd Maximum	6

The specific parameters in the **Efficiency defaults** window are described below.

Absorber material	In each of the three drop-down lists you may select an absorber material. The choices of materials are: none (blank), Aluminum (Al), Iron (Fe), Cadmium (Cd), Erbium (Er), Lead (Pb), Uranium (U), water (H ₂ O), and concrete (Con). These materials represent commonly encountered materials plus additional materials spaced throughout the periodic table to approximate materials not specifically listed. Plutonium and Uranium are represented by the same set of absorption parameters built into the software.
Minimum	You must select a minimum thickness in g/cm ² for Uranium and Plutonium in the sample and in mm for each of the absorber materials chosen above. These values help define the range for the iterative least-squares calculations.
Maximum	You must select a maximum thickness in g/cm ² for Uranium and Plutonium in the sample and in mm for each of the absorber materials chosen above. These values help define the range for the iterative least-squares calculations.
OK	Click on this button to have the modified values used in the current analysis. Efficiency parameters found in the Application Constants in a parameter set are never altered through this dialog box. They can only be changed with the Parameter Param Edit option.
Cancel	Click on this button to dismiss the dialog box without changing the efficiency parameters.

5.4. Application Constants for Physical Model

eff_upu_min	This indicates the minimum thickness in gm/cm ² for the sample in order to determine self-absorption.
eff_upu_max	This indicates the maximum thickness in gm/cm ² for the sample in order to determine self-absorption.
eff_abs_name[.]	Indicates the material used in the absorber. A total of 3 different absorbers can be used. The choices of the absorbers are: none (blank), Aluminum (Al), Iron (Fe), Cadmium (Cd), Erbium (Er), Lead (Pb), Uranium (U), water (H2O), and concrete (Con).
eff_abs_min[.]	Specifies the minimum thickness in mm of the absorber.
eff_abs_max[.]	Specifies the maximum thickness in mm of the absorber.

The Application Constants for the physical efficiency parameters in the Pu_Cx_180-1010 parameter set illustrated above are shown below as they appear in FRAM.

	name	value
1	pu242_correlation	1.58
33	fix_bad_bkg	TRUE
34	AutoUnshieldTest	yes
35	AutoUnshieldPass	Pu_Cx_120-460
36	Unshield_LowEnergy	203.54
37	Unshield_HighEnergy	769.25
38	Unshield_LowToHighLimit	.2
39	AutoMoxTest	yes
40	AutoMoxPass	Mox_Cx_180-1010
41	Mox_U235Limit	0.1
42	eff_upu_min	.001
43	eff_upu_max	24
44	eff_abs_name[1]	Cd
45	eff_abs_min[1]	0
46	eff_abs_max[1]	6
47	eff_abs_name[2]	Pb
48	eff_abs_min[2]	0
49	eff_abs_max[2]	6
50	syst_error_pu238	-1.
51	syst_error_pu239	-1.
52	syst_error_pu240	-1.
53	syst_error_pu241	-1.
54	syst_error_pu242	-1.
55	syst_error_am241	-1.

6. Auto Analysis

A parameter set containing all the parameters necessary to complete an analysis drives the analysis in FRAM. Some of the parameters that can be specified for the analysis include:

- Defaults for energy calibration and peak shape parameters,
- Isotope name, mass, and half-life,
- Effective specific power and $^{240}\text{Pu}_{\text{eff}}$ constants of all isotopes,
- Designation of an isotope to be heterogeneous with respect to the principal isotope,
- Specification of peaks, peak energies, branching ratios,
- Specification of use of peaks in internal calibrations,
- Specification of boundaries of regions for analysis,
- Specification of background region boundaries,
- Specification of functional form of background under a region,
- Specification of $^{242}\text{Pu}/^{236}\text{U}$ correlation parameters, and
- Specification of parameters of various diagnostic tests.

A single parameter file is not adequate for all commonly encountered measurements, given the very wide range of applicability of FRAM. Numerous parameter files have been developed and are provided with FRAM for most commonly encountered measurement situations. Sometimes the user's lack of knowledge of the characteristics of the measured item prevents the use of the optimum parameter file for the analysis. In these cases the user may have to manually reanalyze the data using a different parameter file.

The main characteristics that broadly govern the choice of a parameter file are:

- Detector characteristics such as optimum energy range, efficiency, and most importantly, resolution.
- Presence or absence of shielding around the measured item that prevents lower energy gamma rays from being recorded in the spectrum.
- Presence of ^{241}Am in a different matrix and a different physical distribution than the plutonium in the sample. This is the so-called "Heterogeneous Am/Pu" case.
- Presence of very high concentrations of ^{241}Am (> 10-20% relative to plutonium).
- Presence of uranium such as in MOX materials and the $^{235}\text{U}/\text{Pu}$ ratio in the MOX.
- Burnup of plutonium and enrichment of uranium.
- Presence of intense peaks from interference isotopes.

While parameter sets are designed to be as insensitive as possible to the wide range of variables that affect the analysis, it is impossible to make a single parameter set that encompasses all variables. The **Auto analysis** feature in FRAM allows automatic reanalysis of the spectrum depending upon the results of the current analysis and directions encoded into the Application Constants in the chosen parameter set.

In FRAM v5, the **Auto analysis** can start with any parameter set and works with both plutonium and uranium in all the energy ranges. The user has the freedom to program the analysis (by means of the Application Constants in the parameter set) to determine the properties of the material such as: shielded, MOX, plutonium burnup, uranium enrichment, interference isotope, or heterogeneous. The direction of the checking can be either forward or backward or both at the same time. For example, after an analysis of the mid energy region (120-500 keV) of a plutonium spectrum, it can check both the lower energy (~100 keV) and higher energy (~700 keV) regions to see if those regions are more favorable.

The order of precedence of the auto analysis is:

1. Peak efficiency ratio (for shielded sample)
2. Peak efficiency ratio (for non-shielded sample)
3. U235/Pu ratio (for MOX)
4. Isotope ratio (for burnup and enrichment)
5. Peak area ratio (for interference isotope)
6. Peak activity ratio (for heterogeneous sample)
7. Peak activity ratio (for fresh plutonium sample)
8. Am241/Pu ratio (for high Am/Pu)

“Best results” is subjective and depends upon the user’s specific application. For that reason, when a test passes and a second analysis is performed, both sets of analysis results are output and stored allowing the user to choose the best result for the application at hand. After the second analysis the Efficiency and Fits options will reflect the results of the second analysis. The Efficiency and Fits displays from the first analysis are not available.

6.1. Tests for Auto analysis

The tests for Auto analysis all take the same general form, usually with five variables.

Perform test name	yes/no
Parameter set name	next test parameter set if test passes
Parameter 1 in test	
Parameter 2 in test	
Test limit	

NOTE! The FRAM Auto analysis tests include 2 sigma statistical limits. The tests are of the form [upper limit < value / (1 + 2*sigma/value)] or [lower limit > value + 2*sigma].

FRAM v.5 contains eight (8) Auto analysis tests. Three of the tests carry over from v.4 and five of the tests are new to v.5. The three tests that carry over from FRAM v.4 are:

Test for Shielded Sample

This test forms the ratio of the relative efficiency of a peak at high energy relative to one at low energy from the same isotope. The ratio is tested against an empirical limit. If the ratio is < the limit, the sample is not shielded, if it is > the limit, the sample is shielded. This test is based on the fact that absorbers attenuate low energy peaks (and hence decrease the relative efficiency) more than at high energies. For FRAM v.4, the peaks must be real and in the peak list. For FRAM v.5, the peaks need not to be real. They must be within the energy range of the displayed efficiency curve. To extend the range of the efficiency curve, a dummy peak at very high or very low energy may be inserted into the peak list. The lower end of the efficiency curve is the multiple of 100 keV below the smallest energy peak and the upper end of the efficiency curve is the multiple of 100 keV above the highest energy peak.

Command	Type	Default	Description
AutoShieldTest	yes/no	no	Indicate whether a test for a shielded sample is to be performed.
AutoShieldPass	String	""	Name of the parameter set that is to be used next if the test for the shielded sample passes.
Shield_LowEnergy	Real	0.	FRAM v4: Energy of a peak in the region that would be affected by shielding of the sample. This peak must be in the peak list and from the same isotope as the Shield_HighEnergy peak. FRAM v5: Energy of a peak in the energy range covered by the efficiency curve. Peak needs not be real.
Shield_HighEnergy	Real	0.	FRAM v4: Energy of a peak in the region that would be affected by shielding of the sample. This peak must be in the peak list and from the same isotope as the Shield_LowEnergy peak. FRAM v5: Energy of a peak in the energy range covered by the efficiency curve. Peak needs not be real.
Shield_HighToLowLimit	Real	0.	FRAM v4: The ratio of the peak area divided by branching ratio for the high-energy peak to the low-energy peak is calculated. If it exceeds this limiting amount, the test for a shielded sample passes. FRAM v5: The ratio of the efficiency at the energy of the high-energy peak to the efficiency at the energy of the low-energy peak. If it exceeds this limiting amount, the test for a shielded sample passes.

Test for Heterogeneity

For FRAM v4, this test forms the ratio of Am/Pu from a low energy peak to Am/Pu from a high-energy peak. If americium and plutonium are in the same matrix, this ratio should be unity. If americium is in a different matrix (heterogeneous Am/Pu) than the plutonium, the ratio will differ from unity because of the different attenuation suffered by americium and plutonium gamma rays at the same gamma-ray energy. The test also accounts for the statistical uncertainties in the two Am/Pu ratios. When Am/Pu heterogeneity is detected, the spectrum is reanalyzed with a second relative efficiency curve assigned to americium.

For FRAM v5, this test is applied to any isotope, not just the Am/Pu heterogeneity. That is, it compares the ratio of any pair of isotopes from a low energy peak to the ratio from a high energy peak.

Command	Type	Default	Description
AutoHeteroTest	yes/no	no	Indicate whether a test for a heterogeneous sample is to be performed.
AutoHeteroPass	String	""	Name of the parameter set that is to be used next if the test for the heterogeneous sample passes.
Hetero_Energy[1]	Real	0.	Energy of the free, low-energy peak to be compared. This peak must be in the peak list.
Hetero_Energy[2]	Real	0.	Energy of the free, high-energy peak to be compared. This peak must be in the peak list.
Hetero_LowerLimit	Real	0.	If the ratio of the activities of the low-energy peak to high-energy peak is below this limit then the test for a heterogeneous sample passes.
Hetero_UpperLimit	Real	0.	If the ratio of the activities of the low-energy peak to high-energy peak is greater than this limit then the test for a heterogeneous sample passes.

Test for High Americium

This test compares the measured Am/Pu fraction against a user-defined limit. A different parameter file is used for high americium because of the additional americium peaks appearing in the spectrum that are not visible for lower concentrations.

Command	Type	Default	Description
AutoHighAmTest	yes/no	no	Indicate whether a test for high americium is to be performed.
AutoHighAmPass	String	""	Name of the parameter set that is to be used next if the test for high americium sample passes.
Hetero_AmLimit	Real	0.	If the %Am241/Pu exceeds this limit, then the test for high americium passes.

The next five Auto analysis tests are valid only in FRAM v.5.

Test for Unshielded Sample

This is the inverse of the Test for Shielded Sample above. If the test passes the sample is unshielded.

Command	Type	Default	Description
AutoUnshieldTest	yes/no	no	Indicate whether a test for an unshielded sample is to be performed.
AutoUnshieldPass	String	""	Name of the parameter set that is to be used next if the test for the unshielded sample passes.
Unshield_LowEnergy	Real	0.	Energy of a peak in the energy range covered by the efficiency curve. Peak needs not be real.
Unshield_HighEnergy	Real	0.	Energy of a peak in the energy range covered by the efficiency curve. Peak needs not be real.
Unshield_LowToHighLimit	Real	0.	The ratio of the efficiency at the energy of the low-energy peak to the efficiency at the energy of the high-energy peak. If it exceeds this limiting amount and the FWHM of the low energy peak is below the required FWHM (see below) then the test for an unshielded sample passes.
Unshield_LowEnergyFWHM	Real	100000.	The FWHM upper limit in eV. If the FWHM of the low energy peak is below this limit and the Unshield_LowToHighLimit ratio (see above) is passed then the test for an unshielded sample passes.

Test for MOX

This test compares the U235/Pu ratio against a limit. If the ratio exceeds the limit MOX is present and the spectrum is reanalyzed with a parameter set designed specifically for MOX.

Command	Type	Default	Description
AutoMoxTest	yes/no	no	Indicate whether a test for a MOX sample is to be performed in the plutonium analysis. U235 must be in the isotope list.
AutoMoxPass	String	""	Name of the parameter set that is to be used next if the test for the MOX sample passes.
Mox_U235Limit	Real	0.	If U235/Pu exceeds this limit, then the test for the MOX sample passes.

Isotope Ratio Test

This test compares the mass ratio of two isotopes against a limit and switches to a new parameter set if the test passes.

Command	Type	Default	Description
AutoIsotopeRatioTest	yes/no	no	Indicate whether a test for the ratio of the activities of 2 isotopes is to be performed.
AutoIsotopeRatioPass	String	""	Name of the parameter set that is to be used next if the test for the Isotope ratio passes.
First_Isotope	String	""	Name of the first isotope. This isotope must be in the isotope list.
Second_Isotope	String	""	Name of the second isotope. This isotope must be in the isotope list.
FirstToSecondIsoLimit	Real	0.	The test forms the ratio of the mass of the first isotope to the mass of the second isotope. If the ratio exceeds this limiting amount, the test for the isotope ratio passes.

Peak Area Ratio Test

This test may be used to flag an interference peak and direct the analysis to a parameter set that includes the interference peak.

Command	Type	Default	Description
AutoPeakRatioTest	yes/no	no	Indicate whether a test for the ratio of the peak areas of 2 peaks is to be performed.
AutoPeakRatioPass	String	""	Name of the parameter set that is to be used next if the test for the Peak ratio passes.
First_Peak	Real	0.	Energy of the first peak. This peak must be in the peak list and free.
Second_Peak	Real	0.	Energy of the second peak. This peak must be in the peak list and free.
FirstToSecondPeakLimit	Real	0.	The ratio of the first peak area to the second peak area. If it exceeds this limiting amount, the test for the peak ratio passes.

Fresh Plutonium Sample Test

This test checks to see if ^{241}Pu – ^{237}U decay equilibrium has been attained. If these two isotopes are in decay equilibrium ^{237}U peaks can be used to determine the activity of ^{241}Pu . Ninety-nine (99) percent of decay equilibrium is attained in 45 days after a chemical separation of uranium from plutonium

Command	Type	Default	Description
AutoFreshPuTest	yes/no	no	Indicate whether a test for fresh plutonium sample is to be performed.
AutoFreshPuPass	String	""	Name of the parameter set that is to be used next if the test for the fresh plutonium sample passes.
FreshPu_1stPeak	Real	0.	Energy of the 1st peak (normally of Pu241 decay) to be used in the fresh plutonium test. This peak must be in the peak list and free.
FreshPu_2ndPeak	Real	0.	Energy of the 2nd peak (normally of U237 decay) to be used in the fresh plutonium test. This peak must be in the peak list and free.
FreshPu_1stTo2ndLimit	Real	0.	The ratio of the normalized [Area/(BR*Eff)] 1st peak to the 2nd peak is calculated. If it exceeds this limiting amount, the test for a fresh plutonium sample passes.

6.2. Examples of Application Constants for Auto analysis Tests

6.2.1. AutoShieldTest in Pu_Plnr_060-230

The **AutoShieldTest** in **Pu_Plnr_060-230** will switch the analysis from the 100 keV region of **Pu_Plnr_060-230** to the higher energy region analysis (120–420 keV) of the **Pu_Plnr_120-420** parameter set if the test shows that the 100 keV region is attenuated too much for a good analysis. The test compares the relative efficiency at 104 keV, which is the energy of the only peak used for Pu240 activity in the low energy region analysis, and 160 keV, which is the energy of the only peak used for Pu240 activity in the medium energy region analysis. The test limit is empirically determined.

Because the **Pu_Plnr_060-230** parameter set is configured for a gain of 0.075 keV/ch, the tested spectrum must contain at least 8192 channels so that the 120-420 keV region is available in case the test passes and the **Pu_Plnr_120-420** parameter set is used. If the test passes and the spectrum has only 4096 channels which does not cover the energy range used by the **Pu_Plnr_120-420** parameter set then the analysis with the **Pu_Plnr_120-420** parameter set will not be performed.

The test as it appears in the Application Constants of the **Pu_Plnr_060-210** parameter set is shown below outlined in red..

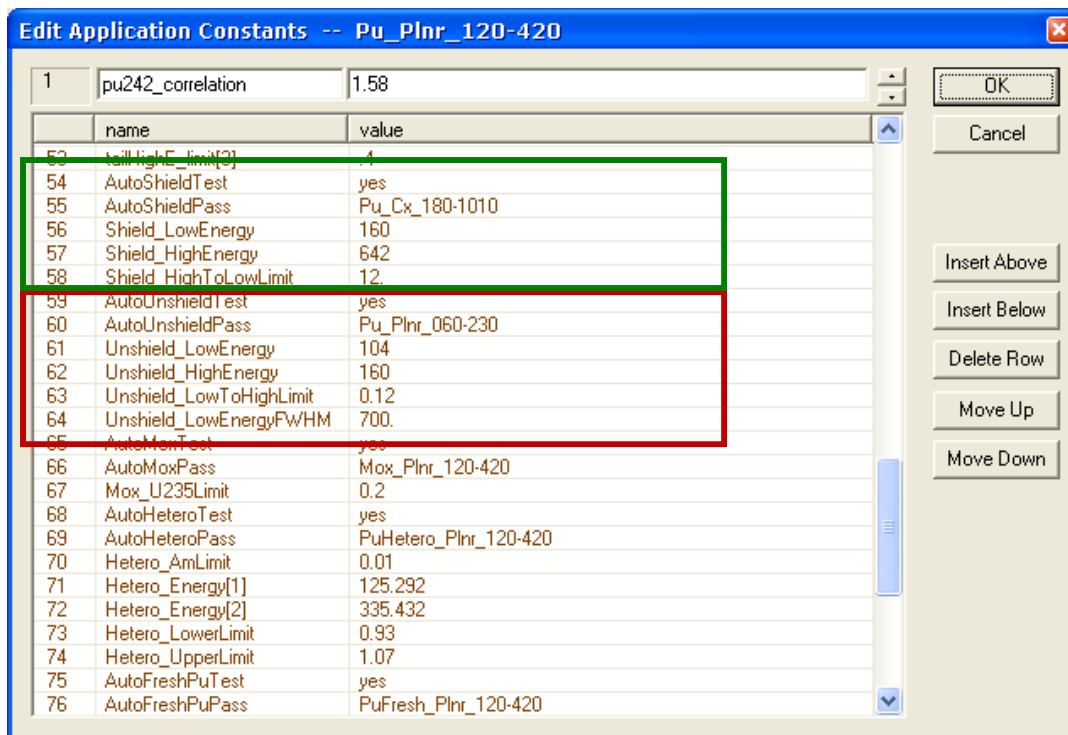
id	name	value
1	pu242_correlation	1.58
44	tailHighE_limit[1]	.4
45	tailHighE_energy[2]	129.294
46	tailHighE_limit[2]	.4
47	tailHighE_energy[3]	208.00
48	tailHighE_limit[3]	.4
49	required_phys_eff_msg	**This analysis requires physical efficiency**
50	fix_100kev_plutonium	TRUE
51	AutoShieldTest	yes
52	AutoShieldPass	Pu_Plnr_120-420
53	Shield_LowEnergy	104
54	Shield_HighEnergy	160
55	Shield_HighToLowLimit	12
56	AutoMoxTest	yes
57	AutoMoxPass	Mox_Plnr_060-230
58	Mox_U235Limit	0.2
59	AutoFreshPuTest	yes
60	AutoFreshPuPass	PuFresh_Plnr_060-230
61	FreshPu_1stPeak	148.567
62	FreshPu_2ndPeak	164.597
63	FreshPu_1stTo2ndLimit	1.1
64	eff_upu_min	0.001
65	eff_upu_max	8
66	eff_abs_name[1]	Cd
67	eff_abs_min[1]	.0

6.2.2. AutoUnshieldTest in Pu_Plnr_120-420

The **AutoUnshieldTest** is the complement of the **AutoShieldTest** above. If the 129 keV ^{239}Pu peak is strong enough when compared to the 414 keV ^{239}Pu peak the test passes and the spectrum is reanalyzed in the 100 keV region with the **Pu_Plnr_060-230** parameter set.

These two tests enable the user to find the best analysis from a single 8k ch planar detector spectrum with a gain of 0.075 keV/ch, regardless of which parameter set is chosen for the analysis.

The test as it appears in the Application Constants of the **Pu_Plnr_120-420** parameter set is shown below outlined in red..



Note: The **Pu_Plnr_120-420** parameter set also performs the **AutoShieldTest** (see rows 54-58 inside the green box above) and if it passes the test then it will switch to the high energy region analysis using the **Pu_Cx_180-1010** parameter set. The energy calibration of the **Pu_Cx_180-1010** parameter set with a gain of 0.125 keV/ch will be temporarily changed to the energy calibration used in the first analysis which is 0.075 keV/ch (or the gain and zero values set in the Analyze dialog box). The spectrum would need to contain 16k channels in order to be analyzed with the **Pu_Cx_180-1010** parameter set. Also note that the maximum useful peak in the **Pu_Plnr_120-420** parameter set is less than 420 keV. So in order to use the efficiency at 642 keV, which is the energy of the only peak used for Pu240 activity in the high energy region analysis, you would need to add dummy peak between 600-700 keV to extend the efficiency range to above 642 keV as shown below.

68	Pu239	413.712	0.0	1.4690e-005	0	Y	Y	Y	Y	Y
69		414.800	0.0	0.0000e+000	0	N	N	N	N	N
70	Np237	415.743	0.0	1.6820e-002	44	N	N	N	N	N
71	sumpk	415.348	0.0	0.0000e+000	0	N	N	N	N	N
72	dummy	601.000	0.0	0.0000e+000	0	N	N	N	N	N

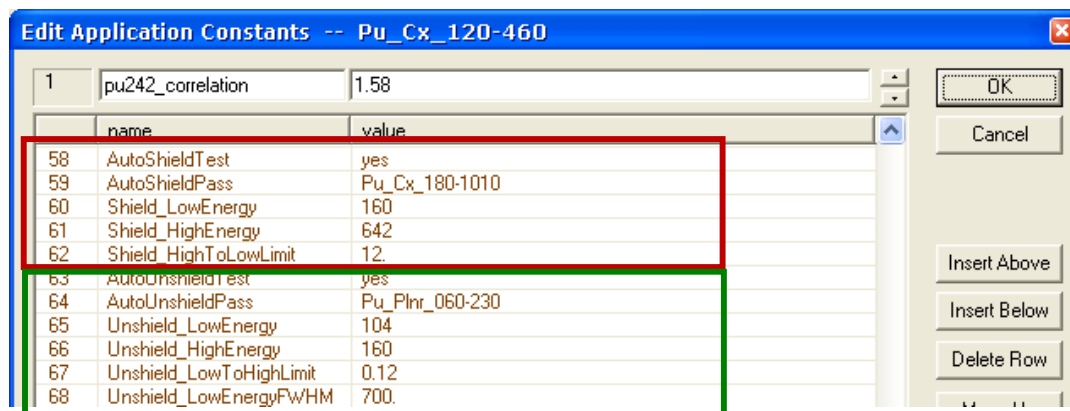
6.2.3. AutoShield/Unshield Tests for Coax Spectra in the 120-1010 keV Range

The same two tests can be used to switch between the **Pu_Cx_120-460** and **Pu_Cx_180-1010** parameter sets. These two parameter sets are used to analyze a plutonium spectrum acquired in 8192 ch (or more) at a gain of 0.125 keV/ch spanning the energy range from 0–1024 keV.

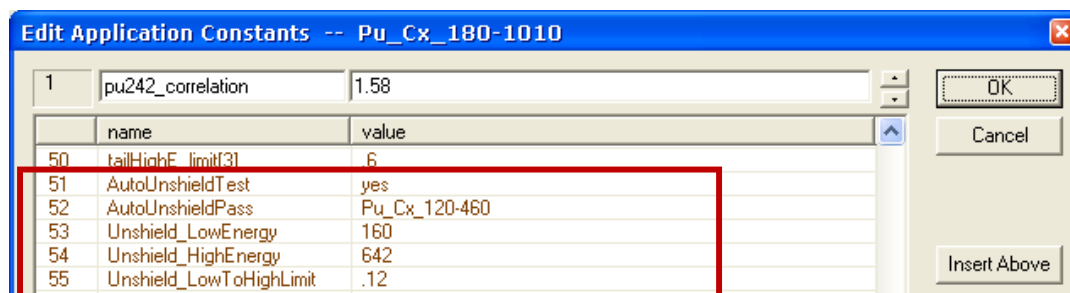
When the lower energy portion of the plutonium spectrum is attenuated with thick absorbers usually only the region above 180 keV is available for analysis. However, when the full spectrum is available, it is not clear, a priori, which region, 120–460 or 180–1010, is best for the analysis. In many cases the spectra from large quantities of plutonium analyze better in the higher energy range even though the specific gamma ray activity is lower.

The figures below illustrate these two tests as implemented in the built-in plutonium coaxial detector parameter sets. Also note the **AutoUnshieldTest** in **Pu_Cx_120-460** (in green box) switching to the planar parameter set.

AutoShieldTest in Pu_Cx_120-460



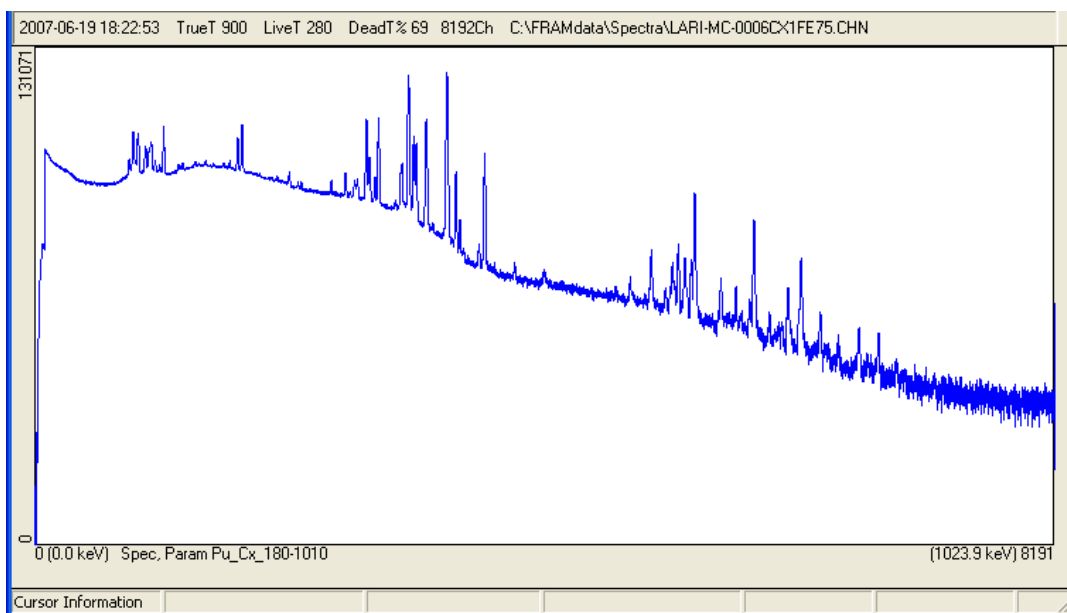
AutoUnshieldTest in Pu_Cx_180-1010



6.3. Analysis Examples using Auto Analysis

6.3.1. PuO₂, >1 kg, 6% ²⁴⁰Pu, Coaxial Detector Analysis

This unshielded item can be classified as fairly large giving rise to the question of which analysis region would be best, 120–460- or 180–1080 keV. Because the item is unshielded analysis is initiated with the **Pu_Cx_120-460** parameter set with **Auto analysis** enabled. The spectrum of this item in the 0–1024 keV range is below.



The Auto analysis **AutoShieldTest** in **Pu_Cx_120-460** passes and a second analysis with **Pu_Cx_180-1010** proceeds. This is documented in the **Med Result** output as:

Auto analysis:

(0) Test for shielded sample passed.
 (0) Efficiency Ratio (642.00keV/160.00keV) = 13.775 +- 0.561, Limit = 12.000
 Next parameter set: Pu_Cx_180-1010
 Next level: 1

Portions of the short output from the two analyses are reproduced below.

Initial Parameter Set

```

parameter set: Pu_Cx_120-460 (2011.05.11 18:25)
  Pu Coax, Equilibrium, 120-460keV
  Physical Efficiency, Gain 0.125 keV/ch, Offset 0 keV
comment: Auto Analysis Example, >1 kg PuO2, unshielded
*****
*****
diagnostics passed.
    
```

	(By Corr) %Am241/Pu					
	Pu238	Pu239	Pu240	Pu241	Pu242	Am241
mass%	0.0070	93.6429	6.2405	0.0840	0.0256	0.2916
sigma	0.0031	0.4440	0.4445	0.0007	0.0060	0.0038
%RSD	43.90%	0.47%	7.12%	0.79%	23.23%	1.31%
%TotPwr	1.51	68.84	16.85	0.11	< .01	12.69
Specific Power (W/gPu):	(2.6236	+/-	0.0372)e-003	(1.42%)
Effective Pu240 fraction:	(6.3011	+/-	0.4447)e-002	(7.06%)

```

Second Parameter Set

parameter set: Pu_Cx_180-1010 (2011.05.10 16:43)
Pu Coax, Equilibrium, 180-1010keV
Physical Efficiency, Gain 0.125 keV/ch, Offset 0 keV
comment: Auto Analysis Example, >1 kg PuO2, unshielded
*****
*****
diagnostics passed.

                                     (By Corr) %Am241/Pu

mass%      Pu238      Pu239      Pu240      Pu241      Pu242      Am241
sigma      0.0088     93.8957   5.9841     0.0842     0.0273     0.2815
%RSD      23.81%     0.35%     5.58%     0.76%     13.31%     0.64%

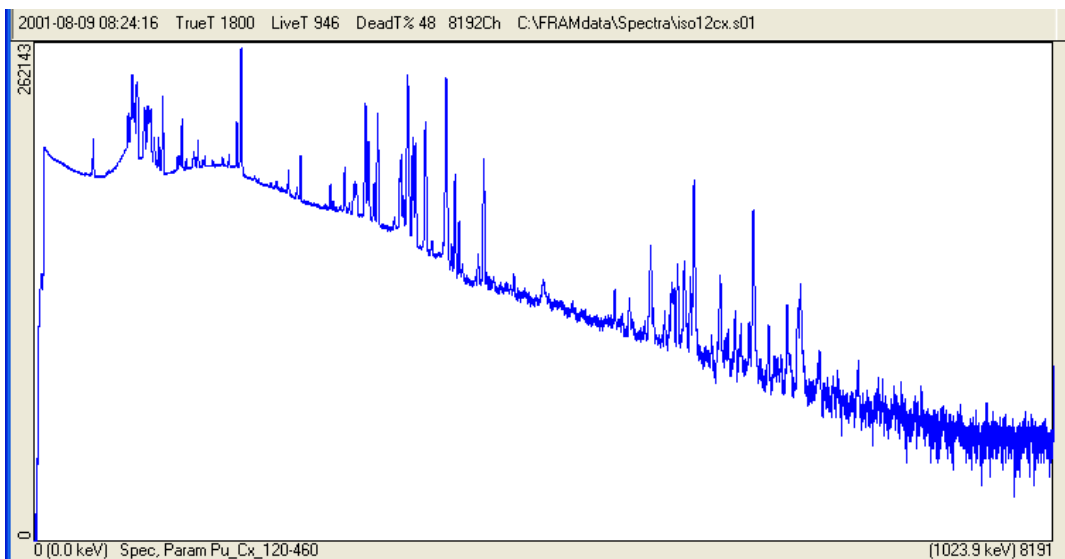
%TotPwr    1.90      69.42     16.24     0.11     < .01     12.32

Specific Power (W/gPu):  ( 2.6089 +/- 0.0273)e-003 ( 1.05%)
Effective Pu240 fraction: ( 6.0520 +/- 0.3338)e-002 ( 5.52%)
    
```

One sees that the second result, with analysis at higher energies, exhibits better precision for all the isotopes even though the sample was unshielded.

6.3.2. PuO₂, ~ 10 g, 12% ²⁴⁰Pu, Coaxial Detector Analysis

This unshielded item is fairly small. We use this example to demonstrate the **AutoUnshieldTest** in **Pu_Cx_180-1010**. This analysis is initiated with the **Pu_Cx_180-1010** parameter set with **Auto analysis** enabled. The spectrum in the 0–1024 keV range is shown below.



The **AutoUnshieldTest** in **Pu_Cx_180-1010** passes and the spectrum is automatically reanalyzed with the **Pu_Cx_120-460** parameter set. This is documented in the **Med Result** output as:

Auto analysis:

(0) Test for unshielded sample passed.
 (0) Efficiency Ratio (160.00keV/642.00keV) = 0.254 +- 0.105, Limit = 0.120
 FWHM(160.00keV) = 1002 ev [? < 100000]
 Next parameter set: Pu_Cx_120-460
 Next level: 1

Portions of the short output from the two analyses are reproduced below.

Initial Parameter Set

```
parameter set: Pu_Cx_180-1010 (2011.05.10 16:43)
Pu Coax, Equilibrium, 180-1010keV
Physical Efficiency, Gain 0.125 keV/ch, Offset 0 keV
comment: Auto Analysis example of AutoUnshieldTest
*****
*****
diagnostics passed.
```

	(By Corr) %Am241/Pu					
	Pu238	Pu239	Pu240	Pu241	Pu242	Am241
mass%	0.0542	87.4004	11.8920	0.4572	0.1962	0.6226
sigma	0.0023	0.2974	0.2997	0.0019	0.0070	0.0026
%RSD	4.28%	0.34%	2.52%	0.41%	3.58%	0.42%
%TotPwr	8.63	47.32	23.64	0.44	< .01	19.96
Specific Power (W/gPu):	(3.5623 +/-		0.0258)e-003		(0.72%)	
Effective Pu240 fraction:	(12.3582 +/-		0.3000)e-002		(2.43%)	

Second Parameter Set

```
parameter set: Pu_Cx_120-460 (2011.05.11 18:25)
Pu Coax, Equilibrium, 120-460keV
Physical Efficiency, Gain 0.125 keV/ch, Offset 0 keV
comment: Auto Analysis example of AutoUnshieldTest
*****
*****
diagnostics passed.
```

	(By Corr) %Am241/Pu					
	Pu238	Pu239	Pu240	Pu241	Pu242	Am241
mass%	0.0510	87.4160	11.8847	0.4579	0.1904	0.6266
sigma	0.0012	0.1702	0.1715	0.0011	0.0038	0.0025
%RSD	2.27%	0.19%	1.44%	0.25%	2.00%	0.39%
%TotPwr	8.16	47.51	23.72	0.44	< .01	20.17
Specific Power (W/gPu):	(3.5486 +/-		0.0145)e-003		(0.41%)	
Effective Pu240 fraction:	(12.3331 +/-		0.1717)e-002		(1.39%)	

The results from the Auto analysis indicates that the second parameter set provides an analysis with much better statistical precision than the initial parameter set.

7. Output Display and Listings

Three levels of output display (**Short Result**, **Med Result**, and **Long Result**) may be selected in the FRAM Dialog Bar and displayed in the FRAM window for all analysis results from the **Measure | Analyze** and **Measure | Measure** options. A screen copy of the **Short Result** is automatically sent to the monitor after each analysis.

You may print the displayed results by selecting **Print** in the FRAM Dialog Bar. You can print or display results from the latest analysis or a previously saved results file at any of the above levels. To copy the information on the screen, you can left click and drag to highlight the lines to be copied and then right click to bring up the "Copy" menu. Left click on the "Copy" menu will copy the lines to the Clipboard. The copied information now can be pasted into other applications such as Excel, Word, or Notepad.

7.1. Short Result Output

7.1.1. Plutonium

A short output from a plutonium measurement with a **Previous Calorimetric measurement** is shown below.

```
*****
PC FRAM (5.1)      Isotopic Analysis      2011-05-12 10:42:42
(Fixed energy Response function Analysis with Multiple efficiencies)
Operator ID:

spectrum source:  C:\FRAMdata\Spectra\CALX30.101
spectrum date:    1995-01-15 15:07:24
live time:        2817 s
true time:        3600 s
num channels:     8192

parameter set:    Pu_Cx_120-460 (2011.05.11 18:25)
  Pu Coax, Equilibrium, 120-460keV
  Physical Efficiency, Gain 0.125 keV/ch, Offset 0 keV
comment: Demonstration of Short Result with Previous Calorimetric me
*****
*****
diagnostics passed.

                                     (By Corr) %Am241/Pu

      Pu238      Pu239      Pu240      Pu241      Pu242      Am241
mass%    0.0070    93.5948    6.1949    0.1778    0.0255    0.1963
sigma    0.0011    0.1637    0.1641    0.0005    0.0021    0.0014
%RSD     15.44%    0.17%     2.65%     0.26%     8.22%     0.74%

%TotPwr   1.58     71.81     17.45     0.24     < .01     8.92

Specific Power (W/gPu):  (    2.5139 +/-    0.0136)e-003 ( 0.54%)
Effective Pu240 fraction: (    6.2553 +/-    0.1641)e-002 ( 2.62%)
Time since chemical separation:  5679.2 +/- 29.8 days ( 0.52%)

Relative mass ( U235 / Pu):  3.187e-004 (>99.99%)
Relative mass (Np237 / Pu):  7.609e-005 ( 1.16%)
Relative mass (Am243 / Pu):  1.075e-008 (>99.99%)
*****
*****
Total Pu Mass:      397.79 +/-    2.30 ( 0.58%) grams
Sample Power:      1.00000 +/-    0.00200 ( 0.20%) Watts
```

Specific Power: 2.5139 +/- 0.0136 (0.54%) milliWatts per gram Pu
 Date: 1995-01-15

- Header Block Information** FRAM version number and date printed.
 Operator Identification
 Spectrum source, date, and acquisition conditions
 Parameter set name, description, date of last edit, Relative Efficiency model, and the default gain and zero used in the analysis.
 Path to results file storage (if any)
 Optional comment
- diagnostics passed** A report from any failed spectrum quality, spectrum type diagnostic tests as established in the Application Constants list is appended here. The report includes the value of the tested parameter and the limits compared against.
- Pu242** This is labeled as (**By Corr**) if from the correlation specified in the Application Constants in the parameter set used for the analysis, or (**OpEntry**) if entered by the operator in the dialog box for the **Measure** options. If Pu242 was measured directly the output value is labeled (**Measure**).
- Am241** This isotopic ratio is expressed as mass % Am241 with respect to the total plutonium.
- mass%** The isotopic percentage by weight relative to total plutonium.
- sigma** The absolute uncertainty representing one standard deviation propagated from counting statistics, closely representing the standard deviation that is observed from repeated measurements.
- % RSD** The relative standard deviation expressed as a percentage. It is calculated as $(\text{sigma}/\text{mass\%}) * 100$.
- %TotPwr** The percentage of the total power (Watts) from the sample that is contributed by the indicated isotope. It is calculated from the known Watts/gram for each isotope weighted by the measured fraction of that isotope in the sample. If additional isotopes in the Isotope List have measurable power, the percentage of the total power for the indicated isotopes will not sum to 100%. This parameter is listed only for information purposes.
- Specific Power (W/gPu)** The sum over all heat producing isotopes in the Isotope List of the product of the Watts/gram for each isotope times the measured isotope fraction (relative to plutonium) in the sample. It is used to interpret a calorimetry measurement of the total sample power in Watts.
- Effective Pu240 fraction** $2.52 * \text{mass\%}(\text{Pu238}) + 1.00 * \text{mass\%}(\text{Pu240}) + 1.68 * \text{mass\%}(\text{Pu242})$
 This parameter is used to convert neutron coincidence counting measurements of Effective Pu240 mass to total plutonium mass. The coefficients in this equation are entered as **Pu240 coef** through the **Param Edit | Isotopes** option on the FRAM main menu.

NOTE the exponents on the **Specific Power (W/gPu):** and **Effective Pu240 fraction:**. The uncertainties from counting statistics for these quantities are absolute one sigma (within the first parentheses) and one relative standard deviation expressed as a percentage (in the second parentheses).

Time since chemical separation The time in days since the last chemical separation of ²⁴¹Am and ²³⁷U from the sample. It is calculated from the equation

$$time(days) = 7819.176 * \ln(0.9669335 * R + 1)$$

where R is the ²⁴¹Am/²⁴¹Pu abundance ratio.

Relative mass (IsotopeXXX / Pu): The mass ratio to total Pu for all isotopes in the Isotope List that have not been listed in the plutonium isotopic report above . Note the exponent in the result. The uncertainty (in parenthesis) is 1 RSD in percent from counting statistics.

Calorimetry Report (optional) If you enter a calorimeter wattage and date in the dialog box associated with the **Measure | Measure** or the **Measure | Analyze** option, FRAM appends a report of the total plutonium mass in the sample as of the date of the calorimetry measurement. If a calorimetry wattage is not entered, this report is not printed. The uncertainty on the **Total Pu Mass** is propagated in quadrature from the uncertainties in the **Sample Power** and **Specific Power**. It is one relative standard deviation expressed as a percent.

Neutron Report (optional) If you enter an effective Pu240 mass and date in the dialog box associated with the **Measure | Measure** or the **Measure | Analyze** option, FRAM appends a report of the total plutonium mass in the sample as of the date of the neutron coincidence measurement. If an effective Pu240 mass is not entered, this report is not printed. The uncertainty on the **Total Pu Mass** is propagated in quadrature from the uncertainties in the **Effective Pu240 mass** and **Effective Pu240 fraction**. It is one relative standard deviation expressed as a percent.

7.1.2. Uranium

The **Short Result** for an uranium analysis is shown below.

```
*****
PC FRAM (5.1)      Isotopic Analysis      2011-05-12 10:54:46
(Fixed energy Response function Analysis with Multiple efficiencies)
Operator ID:

spectrum source:  C:\FRAMdata\Spectra\U0295P10.000
spectrum date:    2002-10-01 15:07:03
live time:        814 s
true time:        900 s
num channels:     4096

parameter set:    ULEU_Plnr_060-250 (2011.04.13 17:57)
      U Only, Enrichment <=20%, 0.075 keV/ch, Planar Detector
      Physical Efficiency, Gain 0.075 keV/ch, Offset 0 keV
comment: Demonstration of Short Result for display and printing
*****
*****
diagnostics passed.
```

(By Corr)

	U234	U235	U236	U238
mass%	0.0281	2.9600	0.0097	97.0021
sigma	0.0010	0.0187	0.0008	0.0190
%RSD	3.48%	0.63%	8.56%	0.02%
%TotPwr	81.24	2.86	0.27	15.62

```
Specific Power (W/gU):      (    0.0621 +/-    0.0018)e-006  (  2.83%)
Relative mass (Th228 / U):  4.504e-015  (>99.99%)
Relative mass (Uxray / U):  8.918e-002  (  0.41%)
*****
```

Header Block Information FRAM version number and date printed.
 Operator Identification
 Spectrum source, date, and acquisition conditions
 Parameter set name, description, date of last edit, Relative Efficiency model, and the default gain and zero used in the analysis.
 Path to results file storage (if any)
 Optional comment

diagnostics passed A report from any failed spectrum quality, spectrum type diagnostic tests as established in the Application Constants list is appended here. The report includes the value of the tested parameter and the limits compared against.

U236 This is labeled as (**By Corr**) if from the correlation specified in the Application Constants in the parameter set used for the analysis, or (**OpEntry**) if entered by the operator in the dialog box for the **Measure** options. No label means the U236 was measured directly.

mass% The isotopic percentage by weight relative to total plutonium.

sigma The absolute uncertainty representing one standard deviation propagated from counting statistics, closely representing the standard deviation that is observed from repeated measurements.

% RSD The relative standard deviation expressed as a percentage. It is calculated as **(sigma/mass%)*100.**

%TotPwr The percentage of the total power (Watts) from the sample that is contributed by the indicated isotope. It is calculated from the known Watts/gram for each isotope weighted by the measured fraction of that isotope in the sample. This parameter is listed only for information purposes.

Specific Power (W/gU) The sum over all heat producing isotopes in the Isotope List of the product of the Watts/gram for each isotope times the measured isotope fraction (relative to uranium) in the sample. It is used to interpret a calorimetry measurement of the total sample power in Watts.

NOTE the exponents on the **Specific Power (W/gU):**. The uncertainty from counting statistics for this quantity is absolute one sigma (within the first parentheses) and one relative standard deviation expressed as a percentage (in the second parentheses).

Relative mass (IsotopeXXX / Pu): The mass ratio to total U for all isotopes in the Isotope List that have not been listed in the uranium isotopic report above. Note the exponent in the result. The uncertainty (in parenthesis) is 1 RSD in percent from counting statistics.

The UXray “isotope” in the above output listing is established as an isotope in the Isotope List because U x-ray peaks are used in the relative efficiency curve. The value of the relative mass ratio represents the relative amount of

fluorescence x rays emitted by the sample which is a function of enrichment, sample size, shape, and composition.

Calorimetry Report (optional) If you enter a calorimeter wattage and date in the dialog box associated with the **Measure | Measure** or the **Measure | Analyze** option, FRAM appends a report of the total uranium mass in the sample as of the date of the calorimetry measurement. If a calorimetry wattage is not entered, this report is not printed. The uncertainty on the **Total U Mass** is propagated in quadrature from the uncertainties in the **Sample Power** and **Specific Power**. It is one relative standard deviation expressed as a percent. Calorimetry on uranium is currently feasible only on kg quantities of highly enriched uranium. See the plutonium output example in section 7.1.1. for an example of the form of the output.

7.2. Med Result Output

A medium printout (shown below for plutonium without Auto Analysis or calorimetry report) begins with the Short Result just described, appends a second Short Result with Systematic errors included, and then finishes with about a half dozen pages of detailed intermediate calculational results. Description of some of the features of this output follows the example.

```

*****
PC FRAM (5.1)      Isotopic Analysis      2011-05-12 10:58:32
(Fixed energy Response function Analysis with Multiple efficiencies)
Operator ID:

spectrum source:  C:\FRAMdata\Spectra\CALX30.101
spectrum date:   1995-01-15 15:07:24
live time:       2817 s
true time:       3600 s
num channels:    8192

parameter set:   Pu_Cx_120-460 (2011.05.11 18:25)
                Pu Coax, Equilibrium, 120-460keV
                Physical Efficiency, Gain 0.125 keV/ch, Offset 0 keV
comment:         Demonstration of Med Result for display and printing
*****
*****
diagnostics passed.

                                (By Corr) %Am241/Pu

      Pu238    Pu239    Pu240    Pu241    Pu242    Am241
mass%    0.0070    93.5948    6.1949    0.1778    0.0255    0.1963
sigma    0.0011    0.1637    0.1641    0.0005    0.0021    0.0014
%RSD     15.44%    0.17%     2.65%    0.26%    8.22%    0.74%

%TotPwr   1.58     71.81     17.45     0.24     < .01     8.92

Specific Power (W/gPu):  (    2.5139 +/-    0.0136)e-003 (  0.54%)
Effective Pu240 fraction: (    6.2553 +/-    0.1641)e-002 (  2.62%)
Time since chemical separation:  5679.2 +/-  29.8 days (  0.52%)

Relative mass ( U235 / Pu):  3.187e-004 (>99.99%)
Relative mass ( Np237 / Pu):  7.609e-005 (  1.16%)

```

Relative mass (Am243 / Pu): 1.075e-008 (>99.99%)

Isotopic Results with Systematic errors included:

(By Corr) %Am241/Pu

	Pu238	Pu239	Pu240	Pu241	Pu242	Am241
mass%	0.0070	93.5948	6.1949	0.1778	0.0255	0.1963
sigma	0.0012	0.1764	0.1767	0.0026	0.0034	0.0046
%RSD	17.11%	0.19%	2.85%	1.45%	13.51%	2.33%

%TotPwr 1.58 71.81 17.45 0.24 < .01 8.92

Specific Power (W/gPu): (2.5139 +/- 0.0155)e-003 (0.62%)

Effective Pu240 fraction: (6.2553 +/- 0.1768)e-002 (2.83%)

Time since chemical separation: 5679.2 +/- 110.4 days (1.94%)

Relative mass (U235 / Pu): 3.187e-004 (>99.99%)

Relative mass (Np237 / Pu): 7.609e-005 (1.17%)

Relative mass (Am243 / Pu): 1.075e-008 (>99.99%)

Table used for energy calibration:

	centroid	energy
1	1034.218	129.294
2	1188.401	148.567
3	1664.014	208.000
4	2760.022	345.011
5	3000.379	375.042
6	3309.667	413.712
7	3611.826	451.474

FWHM parameter in the formula:

$$fwhm = \text{SQRT}(A1 + A2 * E + A3 / E)$$

A1 = 4.192e+001 sigma = 2.404e+001
 A2 = 1.576e-001 sigma = 4.507e-002
 A3 = 8.878e+002 sigma = 2.437e+003

Qfit = 5.424e+000 R**2 = 0.99957 Cond = 7.298e+005

	energy	centroid	interp. fwhm	fitted fwhm	% rsd	formula	ratio
1	129.294	1034.232	8.3966	8.3102	0.56%	8.3160	0.9993
2	208.000	1664.028	8.9761	8.9106	0.50%	8.8859	1.0028
3	345.011	2760.026	9.8625	9.8749	0.37%	9.9426	0.9932
4	413.712	3309.675	10.5368	10.4825	0.18%	10.4525	1.0029
5	451.474	3611.830	10.7859	10.6258	0.45%	10.7250	0.9908

Shape parameters in the formula:

$$\log(\text{tail}[j]/\text{hght}/\text{roll_off}) = (T1+T2 * E) + (T3+T4 * E) * (x-x0)$$

T1 = -1.534e+000 sigma = 4.563e+000
 T2 = -6.109e-003 sigma = 1.343e-002
 T3 = 2.089e-001 sigma = 1.977e-001

T4 = 0.000e+000 sigma = 0.000e+000
 Qfit = 1.189e+001 R**2 = 0.97348 Cond = 9.320e+002

	energy	amp	slope
1	129.294	9.794066e-002	2.088740e-001
2	208.000	6.055546e-002	2.088740e-001
3	345.011	2.622155e-002	2.088740e-001

Calibration Diagnostics:

check energy calibration:

1 at 129.294 keV, centroid = 1034.218 [1032.400 < ? < 1036.400]
 2 at 413.712 keV, centroid = 3309.667 [3305.700 < ? < 3313.700]

check fwhm calibration:

3 at 208.000 keV, fwhm = 1111. ev [? < 1300.]

check shape calibration:

4 at 208.000 keV, tail fraction = 0.84 [? < 5.00]

check for interferences:

5 (185.715, 203.545) peak area ratio = 0.000 +- 0.002 [? < 0.500]
 6 (228.140, 203.545) peak area ratio = 0.001 +- 0.002 [? < 1.000]
 7 (311.902, 345.011) peak area ratio = 0.097 +- 0.001 [? < 5.000]

Results of efficiency calculations:

coefficient	sigma	
5.73124e-001	1.27615e-001	(b : E^b)
-4.05381e-001	9.07689e-002	(ln(c) : c^(1/E))
7.84251e-001	4.13245e-001	(U/Pu g/cm2)
7.39705e-001	9.74885e-002	(Cd mm)
0.00000e+000	0.00000e+000	(mm)
0.00000e+000	0.00000e+000	(mm)
2.95229e+001	4.60636e-002	(Pu239)
3.06756e+001	4.62866e-002	(Pu241)

Chisq = 15.55

pk	isotope	energy	area	% rsd	branch	log(A/Br)	predicted	exp(dif)
1	4 Pu239	129.294	715243	0.15%	6.2900e-005	23.154	23.154	1.0001
2	10 Pu241	148.567	135092	0.61%	1.8940e-006	24.991	24.994	0.9967
3	20 Pu241	164.597	49965	1.65%	4.6630e-007	25.398	25.414	0.9837
4	25 Pu239	203.545	391774	0.25%	5.7400e-006	24.946	24.947	0.9999
5	28 Pu241	208.000	1236018	0.11%	5.3920e-006	26.158	26.158	1.0005
6	35 Pu239	255.380	91641	0.75%	7.9900e-007	25.466	25.470	0.9951
7	39 Pu241	267.540	69769	0.91%	1.7860e-007	26.691	26.710	0.9810
8	57 Pu239	345.011	1018885	0.11%	5.5330e-006	25.939	25.939	1.0005
9	66 Pu239	375.042	3146927	0.06%	1.5540e-005	26.034	26.035	0.9993
10	70 Pu239	413.712	3287621	0.06%	1.4690e-005	26.134	26.133	1.0010
11	74 Pu239	451.474	456180	0.15%	1.8980e-006	26.205	26.209	0.9967

isotope	beta
Pu239	0.00000
Pu241	0.00000
Pu238	0.00000
Pu240	0.00000
Pu242	0.00000

```
Am241    0.00000
U235     0.00000
Np237    0.00000
Am243    0.00000
```

Results of efficiency calculations: (Empirical Efficiency Model)

```
coefficient      sigma
-----
 2.64898e+001    5.72612e-001  (Pu239)
-3.67637e-002    1.23813e-001  (1/E**2)
-1.96528e-001    2.00155e+001  (log(E))
-4.33018e-001    2.87972e+000  (log(E)**2)
-3.19482e-002    5.06354e-001  (log(E)**3)
 1.15246e+000    6.01217e-002  (Pu241)
```

Qfit = 3.076e+000 R**2 = 1.00000 Cond = 2.836e+004

pk	isotope	energy	area	% rsd	branch	log(A/Br)	predicted	exp(dif)
1	4 Pu239	129.294	715243	0.15%	6.2900e-005	23.154	23.154	1.0003
2	10 Pu241	148.567	135092	0.61%	1.8940e-006	24.991	24.999	0.9920
3	20 Pu241	164.597	49942	1.65%	4.6630e-007	25.397	25.418	0.9794
4	25 Pu239	203.545	391773	0.25%	5.7400e-006	24.946	24.947	0.9996
5	28 Pu241	208.000	1235755	0.11%	5.3920e-006	26.158	26.157	1.0006
6	35 Pu239	255.380	91641	0.75%	7.9900e-007	25.466	25.469	0.9967
7	39 Pu241	267.540	69760	0.91%	1.7860e-007	26.691	26.708	0.9828
8	57 Pu239	345.011	1018888	0.11%	5.5330e-006	25.939	25.938	1.0008
9	66 Pu239	375.042	3146925	0.06%	1.5540e-005	26.034	26.035	0.9992
10	70 Pu239	413.712	3287622	0.06%	1.4690e-005	26.134	26.133	1.0009
11	74 Pu239	451.474	456181	0.15%	1.8980e-006	26.205	26.208	0.9974

```
isotope      beta
-----
Pu239        0.00000
Pu241        0.00000
Pu238        0.00000
Pu240        0.00000
Pu242        0.00000
Am241        0.00000
U235         0.00000
Np237        0.00000
Am243        0.00000
```

Results of activity calculations:

isotope ratio	activity ratio	mass ratio	% rsd of numerator	isotope
Pu239/Pu239	1.00000e+000	1.00000e+000	0.060%	
Pu241/Pu239	3.16695e+000	1.89977e-003	0.180%	
Pu238/Pu239	2.05794e-002	7.45498e-005	15.442%	
Pu240/Pu239	2.42193e-001	6.61890e-002	2.823%	
Pu242/Pu239	0.00000e+000	0.00000e+000	>99.999%	
Am241/Pu239	1.15690e-001	2.09727e-003	0.716%	
U235/Pu239	1.18683e-008	3.40514e-004	>99.999%	

Np237/Pu239 9.23997e-007 8.12959e-005 1.139%
 Am243/Pu239 3.69727e-008 1.14872e-008 >99.999%

Qfit = 2.888e+000 R**2 = 0.99942 Cond = 1.000e+000

Individual ratios:

pk	isotope	energy	area	% rsd	activity ratios	mass ratios
4	Pu239	129.294	715243	0.15%	1.00009e+000	1.00009e+000
25	Pu239	203.545	391774	0.25%	9.99874e-001	9.99874e-001
35	Pu239	255.380	91641	0.75%	9.95067e-001	9.95067e-001
57	Pu239	345.011	1018885	0.11%	1.00050e+000	1.00050e+000
66	Pu239	375.042	3146927	0.06%	9.99306e-001	9.99306e-001
70	Pu239	413.712	3287621	0.06%	1.00096e+000	1.00096e+000
74	Pu239	451.474	456180	0.15%	9.96699e-001	9.96699e-001
10	Pu241	148.567	135092	0.61%	3.15666e+000	1.89359e-003
20	Pu241	164.597	49965	1.65%	3.11543e+000	1.86886e-003
28	Pu241	208.000	1236018	0.11%	3.16845e+000	1.90066e-003
39	Pu241	267.540	69769	0.91%	3.10692e+000	1.86376e-003
13	Pu238	152.720	4911	15.43%	2.05794e-002	7.45498e-005
16	Pu240	160.308	30842	2.77%	2.42193e-001	6.61890e-002
3	Am241	125.292	46247	1.63%	1.18177e-001	2.14235e-003
45	Am241	322.526	29418	2.51%	1.16414e-001	2.11039e-003
52	Am241	335.432	99275	0.93%	1.14691e-001	2.07915e-003
62	Am241	368.605	48845	1.90%	1.16147e-001	2.10555e-003
23	U235	185.715	353	>99.99%	1.18683e-008	3.40514e-004
42	Np237	311.902	57269	1.13%	9.23997e-007	8.12959e-005
33	Am243	228.160	362	>99.99%	3.69727e-008	1.14872e-008

Summary of peak information:

pk	isotope	energy	area	% rsd	eff	hfac	mass ratios		
1	Pu239	124.490	13276	5.85%	0.0918	1.0000	2.4100e+000		
2	Pu239	125.200	6265	0.15%	0.0949	1.0000	1.0004e+000	F	
3	Am241	125.292	46247	1.63%	0.0953	1.0000	2.1423e-003	A	
4	Pu239	129.294	715243	0.15%	0.1137	1.0000	1.0001e+000	EA	QWT
5	Pu239	143.350	3434	1.25%	0.1920	1.0000	9.9050e-001	F	
6	U235	143.760	25	>99.99%	0.1946	1.0000	3.4043e-004	F	
7	Pu239	144.211	56473	1.25%	0.1974	1.0000	9.9050e-001		
8	Pu239	146.077	25391	1.25%	0.2094	1.0000	9.9048e-001	F	
9	Am241	146.557	11227	7.20%	0.2126	1.0000	1.8590e-003		
10	Pu241	148.567	135092	0.61%	0.2260	1.0000	1.8936e-003	EA	Q
11	Am241	150.113	971	87.07%	0.2365	1.0000	9.8314e-004		
12	U235	150.930	0	>99.99%	0.2421	1.0000	3.4042e-004	F	
13	Pu238	152.720	4911	15.43%	0.2547	1.0000	7.4550e-005	A	
14	Pu241	159.970	6460	0.61%	0.3080	1.0000	1.8937e-003	F	
15	Pu239	160.180	1606	2.12%	0.3096	1.0000	1.0173e+000	F	
16	Pu240	160.308	30842	2.77%	0.3106	1.0000	6.6189e-002	A	
17	Pu239	161.482	39961	2.12%	0.3196	1.0000	1.0173e+000		
18	Am241	161.540	23	1.63%	0.3201	1.0000	2.1408e-003	F	
19	U235	163.360	20	>99.99%	0.3342	1.0000	3.4044e-004	F	
20	Pu241	164.597	49965	1.65%	0.3439	1.0000	1.8689e-003	EA	
21	Am241	164.597	2794	1.63%	0.3439	1.0000	2.1409e-003	F	

22	Am241	165.930	1150	73.16%	0.3545	1.0000	2.5567e-003		
23	U235	185.715	353	>99.99%	0.5218	1.0000	3.4051e-004	A	
24	U235	202.110	9	>99.99%	0.6695	1.0000	3.4056e-004	F	
25	Pu239	203.545	391774	0.25%	0.6826	1.0000	9.9987e-001	EA	
26	Am241	204.040	235	1.63%	0.6872	1.0000	2.1416e-003	F	
27	U235	205.311	42	>99.99%	0.6988	1.0000	3.4057e-004	F	
28	Pu241	208.000	1236018	0.11%	0.7235	1.0000	1.9007e-003	EA	QWT
29	Am241	208.000	67985	1.63%	0.7235	1.0000	2.1417e-003	F	
30	Am243	209.750	94	>99.99%	0.7396	1.0000	1.1486e-008	F	
31	Am243	226.360	9	>99.99%	0.8922	1.0000	1.1487e-008	F	
32	Am243	227.810	17	>99.99%	0.9055	1.0000	1.1487e-008	F	
33	Am243	228.160	362	>99.99%	0.9087	1.0000	1.1487e-008	A	
34	Am243	254.400	5	>99.99%	1.1441	1.0000	1.1488e-008	F	
35	Pu239	255.380	91641	0.75%	1.1526	1.0000	9.9507e-001	EA	
36	Pu239	263.930	31318	1.95%	1.2266	1.0000	1.0221e+000		
37		264.850	44	>99.99%	1.2344	1.0000	0.0000e+000		
38	Pu239	265.700	1913	1.95%	1.2417	1.0000	1.0221e+000	F	
39	Pu241	267.540	69769	0.91%	1.2573	1.0000	1.8638e-003	EA	
40	Am241	267.540	3915	1.63%	1.2573	1.0000	2.1419e-003	F	
41	Pu239	311.737	41203	0.11%	1.6086	1.0000	1.0005e+000	F	
42	Np237	311.902	57269	1.13%	1.6099	1.0000	8.1296e-005	A	
43	Pu239	319.828	7798	8.33%	1.6676	1.0000	1.0288e+000		
44	Pu239	320.868	86452	0.72%	1.6751	1.0000	1.0269e+000		
45	Am241	322.526	29418	2.51%	1.6869	1.0000	2.1104e-003	A	
46	Pu239	323.828	90898	0.68%	1.6962	1.0000	9.9666e-001		
47	Pu241	332.387	169315	0.85%	1.7559	1.0000	1.9476e-003		
48	Am241	332.387	30328	0.93%	1.7559	1.0000	2.0792e-003	F	
49	Pu239	332.850	862366	0.11%	1.7590	1.0000	1.0005e+000	F	
50	Am243	334.310	135	>99.99%	1.7690	1.0000	1.1487e-008	F	
51	Pu241	335.432	13498	0.85%	1.7767	1.0000	1.9476e-003	F	
52	Am241	335.432	99275	0.93%	1.7767	1.0000	2.0792e-003	A	
53	Pu239	336.112	203880	0.11%	1.7813	1.0000	1.0005e+000	F	
54		337.720	3639	20.36%	1.7921	1.0000	0.0000e+000		
55		340.450	5351	12.54%	1.8104	1.0000	0.0000e+000		
56	Pu239	341.495	120061	0.11%	1.8174	1.0000	1.0005e+000	F	
57	Pu239	345.011	1018885	0.11%	1.8406	1.0000	1.0005e+000	EA	QWT
58	U235	345.870	1	>99.99%	1.8462	1.0000	3.4059e-004	F	
59	Pu239	367.054	170559	0.49%	1.9791	1.0000	1.0033e+000		
60	Pu239	368.534	178635	0.06%	1.9880	1.0000	9.9931e-001	F	
61	Pu241	368.605	6546	0.11%	1.9884	1.0000	1.9007e-003	F	
62	Am241	368.605	48845	1.90%	1.9884	1.0000	2.1055e-003	A	
63	Pu241	370.934	17661	3.30%	2.0023	1.0000	1.9262e-003		
64	Am241	370.934	11755	0.93%	2.0023	1.0000	2.0791e-003	F	
65		372.450	5583	8.96%	2.0112	1.0000	0.0000e+000		
66	Pu239	375.042	3146927	0.06%	2.0265	1.0000	9.9931e-001	EA	Q
67	Np237	375.300	1272	1.13%	2.0280	1.0000	8.1292e-005	F	
68	Am241	376.610	41125	5.34%	2.0356	1.0000	2.4095e-003		
69	Pu239	410.990	10222	9.16%	2.2221	1.0000	9.1999e-001		
70	Pu239	413.712	3287621	0.06%	2.2358	1.0000	1.0010e+000	EA	QW
71		414.800	31196	8.00%	2.2413	1.0000	0.0000e+000		
72	Np237	415.743	3490	1.13%	2.2460	1.0000	8.1292e-005	F	
73		415.940	14079	10.83%	2.2470	1.0000	0.0000e+000		
74	Pu239	451.474	456180	0.15%	2.4114	1.0000	9.9670e-001	EA	QWT
75	Am241	452.450	665	0.93%	2.4156	1.0000	2.0792e-003	F	
76		601.000	0	>99.99%	2.8966	1.0000	0.0000e+000		

Efficiencies are divided by 1.0e+011

- E - this peak is used to determine relative efficiencies.
- A - this peak is used to determine relative activities.
- F - this peak is fixed to another peak.
- S - this peak is summed with another peak.
- Q - this peak is used to determine the energy calibration.
- W - this peak is used to determine the fwhm calibration.
- T - this peak is used to determine the shape calibration.

Check sample types:

1 (148.567, 164.597) mass ratio = 1.013 +- 0.018 [0.900 < ? < 1.100]
 2 (125.292, 335.432) mass ratio = 1.030 +- 0.019 [0.930 < ? < 1.070]

check low energy tail of peak fit:

1 at 129.294 keV, low E tail %(meas-fit)/area = 0.088 +- 0.059 [? < 0.500]
 2 at 208.000 keV, low E tail %(meas-fit)/area = 0.012 +- 0.036 [? < 0.500]
 3 at 345.011 keV, low E tail %(fit-meas)/area = 0.008 +- 0.032 [? < 0.500]

check high energy tail of peak fit:

1 at 129.294 keV, high E tail %(meas-fit)/area = 0.028 +- 0.057 [? < 0.400]
 2 at 208.000 keV, high E tail %(meas-fit)/area = 0.113 +- 0.035 [? < 0.400]
 3 at 345.011 keV, high E tail %(fit-meas)/area = 0.018 +- 0.031 [? < 0.400]

Auto analysis:

(0) Test for shielded sample failed.
 (0) Efficiency Ratio (642.00keV/160.00keV) = 9.598 +- 0.094, Limit = 12.000
 (0) Test for unshielded sample failed.
 (0) Efficiency Ratio (104.00keV/160.00keV) = 0.216 +- 0.064, Limit = 0.120
 FWHM(104.00keV) = 1022 ev [? < 700]
 (0) Test for MOX sample failed.
 (0) U235/Pu = 0.0003 +- 0.0008, Limit = 0.1000
 (0) Test for heterogeneous sample failed.
 (0) Am241/Pu = 0.00196 +- 0.00005, Limit = 0.01000
 (0) Test for Fresh Pu sample failed.
 (0) Mass ratio (148.57keV/164.60keV) = 1.013 +- 0.018, Limits = 1.100
 Next parameter set:
 Next level: 1

Output Header Block

The **Med Result** listing begins with the same Header Block as for the **Short Result**. It then lists the **Short Result** followed by the Short Result with Systematic errors included.

Isotopic Results with Systematic errors included:

These results display the **Short Result** with recomputed measurement uncertainties if the **sys_error_XXyyy** Application Constants are included in the analysis parameter set. See section 3.7.5 for a description of the **sys_error_XXyyy** Application Constants. A description of the methodology behind the systematic error calculation may be found in a paper in the **References** folder.

The detailed intermediate calculations listed include the following:

Table used for energy calibration:

This table lists the centroid in channels of the peaks designated as energy calibration peaks. The energy calibration is a piecewise linear calibration between adjacent pairs of energy calibration peaks.

FWHM parameters in formula:

In the table displaying the results of the FWHM fitting, the heading **interp.fwhm** gives the FWHM from a simple linear interpolation and is used only as a check on the other values. **fitted fwhm** lists the

values from the FWHM fitting which are input to a least squares fit to obtain the formula. **formula** gives the value from the formula and fitted parameters **A1** . . . **A3**. The formula values are used in the response function fitting. **ratio** is **fitted fwhm** divided by **formula**. The units of the formula coefficients are such that **fwhm** is in channels when **E** (energy) is in keV.

The Application Constant **restrict_fwhm_model** when set to **TRUE** fixes **A3** = 0 in fitting the equation $FWHM(ch) = \sqrt{A1+A2*E+A3/E}$.

Shape parameters in formula:

We customarily set **T4** to zero in the expression for parametrizing the energy dependence of the tailing parameters.

Calibration Diagnostics:

This section displays the results from some of the diagnostic tests set up in the Application Constants dialog. If any of these tests fail, the complete diagnostic will be displayed on the short output listing.

Results of efficiency calculations:

Two efficiency calculations are shown above. The first shows the output when the Physical Efficiency model is used. The first two coefficients are the parameters of the Hoerl correction factor. The third coefficient is the thickness of the plutonium in the measured item. The next three coefficients are the thicknesses of the (up to three) absorbers allowed in the efficiency function. The next coefficient represents the first isotope in the isotope list. Following this are any other isotopes in the isotope list used to determine the relative efficiency curve. If an isotope included in the relative efficiency curve is heterogeneous with respect to the first isotope in the isotope list, it is indicated by **XXnnn 1/E**.

The relative efficiency calculation for the same data using the Empirical Efficiency model is inserted in the medium printout in a shaded box. The coefficients correspond to the constants in the expression for the Empirical relative efficiency given in Chapter 5. The first coefficient represents the first isotope in the isotope list. All relative activity calculations are performed relative to this isotope. **predicted** is the fitted value of $\log(A/Br)$ where **A** is the peak area and **Br** is the branching ratio and **ratio** is $\log(A/Br)/\text{predicted}$.

The **Chisq** value shows how well the relative efficiency model fits the data points.

beta will be nonzero only for isotopes declared in the isotope list to have a different relative efficiency curve from that for the first isotope.

The Application Constant **restrict_efficiency_model** when set to **TRUE** sets $c5 = 0$ in fitting the empirical relative efficiency curve $\ln(\text{eff})=c1+c2/E^2+c3*\ln(E)+c4*[\ln(E)]^2+c5*[\ln(E)]^3+c_i+c_j/E$. This command has no effect on the physical model efficiency curve fit.

Results of Activity Calculation:

This section gives the calculated results for the fundamental quantities computed in FRAM

FRAM may be used to measure isotopic ratios other than from plutonium or uranium. While a standard printout format is used for plutonium and uranium, no such formal output exists at this time for other than

uranium and plutonium. The final answers for measured isotopic ratios for samples without uranium or plutonium would be obtained here.

The remainder of this section shows the individual activity ratios for each peak designated as an activity peak. All the peaks for a given isotope should have the same activity ratio, within statistical uncertainties, for all gamma rays. A peak consistently out of conformance with others from the same isotope may indicate the need for a branching ratio adjustment or close examination of the fitting parameters in that region. It could also indicate the presence of an unidentified interference.

Summary of Peak Information:

This section presents the final peak areas and uncertainties (**error** at the one RSD level), scaled relative efficiency values (**eff**), and the heterogeneity factor (**hfac** = $\exp(\beta/E)$). **mass ratios** (ratio relative to first isotope in the isotope list) are given for all peaks whether or not they were designated as an activity peak. The letter codes at the right are keyed at the bottom of the section.

Check Sample Types:

Displays the results from some of the diagnostic tests set up in the Application Constants dialog. If any of these tests fail, the complete diagnostic will be displayed on the short output listing. The tests listed in this section can diagnose non-equilibrium ^{241}Pu - ^{237}U decay and Am/Pu heterogeneity.

Auto analysis:

This section displays the results of any **Auto analysis** results encoded into the parameter set when **Auto analysis** is selected in the **Measure | Analyze** and **Measure | Measure** options.

7.3. Long Result Output

A **Long Result** output inserts a **Summary of the results for each region** into the **Med Result** output previously shown. The **Summary of the results for each region** is inserted after the **check for interferences** and before **Results of efficiency calculations**. This section displays statistical parameters from the response function fit to each region. Normally one expects **Qfit** to be near unity for a good fit. For very intense peaks **Qfit** will often be $\gg 1$ representing our inability to perfectly model the peak shape within counting statistics. **R²** will be near unity for a good fit. **Cond** is a parameter that describes the nearness to singularity of the inverted matrix. The larger the number, the more nearly the matrix is to being singular. This section also provides information about each of the peaks in the given region. The following information is listed: peak index, name of the associated **isotope**, **energy**, **centroid**, full-width at half-max (**fwhm**), tailing amplitude (**tamp**), tailing slope (**tslp**), **area**, **error** associated with the area, the group index (**fn**) of the peak, and the area **factor**. Each free peak is assigned a unique group index while the other peaks are assigned the group index of the free peak that they are fixed to. The area **factors** are the weights assigned to the functional form of each peak when constructing a composite response for all the peaks in a single group.

Only the **Summary of the results for each region:** portion of the **Long Result** Output is shown below. The remainder of the printout is identical to the **Med Result** output.

Summary of the results for each region:

```

-----
region 1 from channel 1021 to 1048    ( 127.600 keV to 131.000 keV)
-----

total net counts =      713845.
Qfit = 6.519e-001    R**2 = 0.99991    Cond = 1.000e+000

pk isotope  energy  centroid  fwhm  tamp  tslp      area  % rsd  fn  factor
-----
  4  Pu239  129.294  1034.232  8.316  0.098  0.209    715243  0.15%  1  1.0000
-----

region 2 from channel 993 to 1012    ( 124.200 keV to 126.500 keV)
-----

total net counts =      57710.
Qfit = 1.123e+000    R**2 = 0.98340    Cond = 1.645e+000

pk isotope  energy  centroid  fwhm  tamp  tslp      area  % rsd  fn  factor
-----
  1  Pu239  124.490  995.786  8.286  0.101  0.209    13276  5.85%  1  1.0000
  2  Pu239  125.200  1001.466  8.291  0.100  0.209     6265  0.15%  0  0.0088
  3  Am241  125.292  1002.202  8.291  0.100  0.209    46247  1.63%  2  1.0000
-----

region 3 from channel 1473 to 1495    ( 184.100 keV to 186.900 keV)
-----

total net counts =         855.
Qfit = 9.832e-002    R**2 = -.27993    Cond = 1.000e+000

pk isotope  energy  centroid  fwhm  tamp  tslp      area  % rsd  fn  factor
-----
 23  U235  185.715  1485.678  8.716  0.069  0.209     353 >99.99%  1  1.0000
-----

region 4 from channel 1141 to 1209    ( 142.700 keV to 151.100 keV)
-----

total net counts =     231382.
Qfit = 5.304e-001    R**2 = 0.99808    Cond = 1.399e+000

pk isotope  energy  centroid  fwhm  tamp  tslp      area  % rsd  fn  factor
-----
  5  Pu239  143.350  1146.665  8.408  0.090  0.209     3434  1.25%  1  0.0608
  6  U235  143.760  1149.945  8.411  0.090  0.209      25 >99.99%  0  0.0719
  7  Pu239  144.211  1153.553  8.414  0.089  0.209    56473  1.25%  1  1.0000
  8  Pu239  146.077  1168.481  8.427  0.088  0.209    25391  1.25%  1  0.4496
  9  Am241  146.557  1172.321  8.430  0.088  0.209    11227  7.20%  2  1.0000
 10  Pu241  148.567  1188.401  8.444  0.087  0.209   135092  0.61%  3  1.0000
 11  Am241  150.113  1200.772  8.455  0.086  0.209     971  87.07%  4  1.0000
 12  U235  150.930  1207.311  8.461  0.086  0.209      0 >99.99%  0  0.0006
-----

region 5 from channel 1207 to 1231    ( 150.900 keV to 153.900 keV)
-----

total net counts =         5060.
Qfit = 3.741e-001    R**2 = 0.67085    Cond = 1.000e+000

pk isotope  energy  centroid  fwhm  tamp  tslp      area  % rsd  fn  factor
-----
 12  U235  150.930  1207.311  8.461  0.086  0.209      0 >99.99%  0  0.0006
 13  Pu238  152.720  1221.635  8.473  0.085  0.209     4911  15.43%  1  1.0000
-----

```

 region 6 from channel 1302 to 1334 (162.800 keV to 166.700 keV)

total net counts = 50734.
 Qfit = 3.069e-001 R**2 = 0.99548 Cond = 1.142e+000

pk	isotope	energy	centroid	fwhm	tamp	tslp	area	% rsd	fn	factor
19	U235	163.360	1306.782	8.549	0.080	0.209	20	>99.99%	0	0.0567
20	Pu241	164.597	1316.681	8.558	0.079	0.209	49965	1.65%	1	1.0000
21	Am241	164.597	1316.681	8.558	0.079	0.209	2794	1.63%	0	0.0604
22	Am241	165.930	1327.348	8.568	0.078	0.209	1150	73.16%	2	1.0000

 region 7 from channel 1272 to 1307 (159.000 keV to 163.400 keV)

total net counts = 71844.
 Qfit = 6.299e-001 R**2 = 0.98847 Cond = 1.269e+000

pk	isotope	energy	centroid	fwhm	tamp	tslp	area	% rsd	fn	factor
14	Pu241	159.970	1279.653	8.525	0.081	0.209	6460	0.61%	0	0.0478
15	Pu239	160.180	1281.334	8.526	0.081	0.209	1606	2.12%	2	0.0402
16	Pu240	160.308	1282.358	8.527	0.081	0.209	30842	2.77%	1	1.0000
17	Pu239	161.482	1291.753	8.536	0.080	0.209	39961	2.12%	2	1.0000
18	Am241	161.540	1292.217	8.536	0.080	0.209	23	1.63%	0	0.0005
19	U235	163.360	1306.782	8.549	0.080	0.209	20	>99.99%	0	0.0567

 region 8 from channel 1810 to 1834 (226.300 keV to 229.300 keV)

total net counts = 723.
 Qfit = 1.731e-001 R**2 = -.07864 Cond = 1.000e+000

pk	isotope	energy	centroid	fwhm	tamp	tslp	area	% rsd	fn	factor
31	Am243	226.360	1810.883	9.028	0.054	0.209	9	>99.99%	1	0.0256
32	Am243	227.810	1822.482	9.039	0.054	0.209	17	>99.99%	1	0.0472
33	Am243	228.160	1825.282	9.042	0.054	0.209	362	>99.99%	1	1.0000

 region 9 from channel 1614 to 1643 (201.800 keV to 205.400 keV)

total net counts = 391073.
 Qfit = 7.213e-001 R**2 = 0.99973 Cond = 1.000e+000

pk	isotope	energy	centroid	fwhm	tamp	tslp	area	% rsd	fn	factor
24	U235	202.110	1616.879	8.841	0.063	0.209	9	>99.99%	0	0.0247
25	Pu239	203.545	1628.363	8.852	0.062	0.209	391774	0.25%	1	1.0000
26	Am241	204.040	1632.324	8.855	0.062	0.209	235	1.63%	0	0.0051
27	U235	205.311	1642.495	8.865	0.062	0.209	42	>99.99%	0	0.1182

 region 10 from channel 1642 to 1682 (205.300 keV to 210.300 keV)

total net counts = 1239680.
 Qfit = 2.368e+000 R**2 = 0.99979 Cond = 1.000e+000

pk	isotope	energy	centroid	fwhm	tamp	tslp	area	% rsd	fn	factor
27	U235	205.311	1642.495	8.865	0.062	0.209	42	>99.99%	0	0.1182
28	Pu241	208.000	1664.028	8.886	0.061	0.209	1236018	0.11%	1	1.0000

```

29 Am241 208.000 1664.014 8.886 0.061 0.209      67985  1.63%  0  1.4700
30 Am243 209.750 1678.013 8.899 0.060 0.209      94 >99.99%  0  0.2587

```

```

-----
region 11 from channel 2032 to 2054      ( 254.000 keV to 256.800 keV)
-----

```

```

total net counts =      90794.
Qfit = 5.296e-001      R**2 = 0.99822      Cond = 1.000e+000

```

pk	isotope	energy	centroid	fwhm	tamp	tslp	area	% rsd	fn	factor
34	Am243	254.400	2035.187	9.246	0.046	0.209	5	>99.99%	0	0.0129
35	Pu239	255.380	2043.026	9.254	0.045	0.209	91641	0.75%	1	1.0000

```

-----
region 12 from channel 2101 to 2156      ( 262.600 keV to 269.500 keV)
-----

```

```

total net counts =      101380.
Qfit = 1.333e+000      R**2 = 0.99082      Cond = 1.627e+000

```

pk	isotope	energy	centroid	fwhm	tamp	tslp	area	% rsd	fn	factor
36	Pu239	263.930	2111.421	9.320	0.043	0.209	31318	1.95%	1	1.0000
37		264.850	2118.781	9.328	0.043	0.209	44	>99.99%	2	1.0000
38	Pu239	265.700	2125.580	9.334	0.043	0.209	1913	1.95%	1	0.0611
39	Pu241	267.540	2140.299	9.348	0.042	0.209	69769	0.91%	3	1.0000
40	Am241	267.540	2140.299	9.348	0.042	0.209	3915	1.63%	0	0.0846

```

-----
region 13 from channel 2488 to 2510      ( 311.000 keV to 313.700 keV)
-----

```

```

total net counts =      55428.
Qfit = 7.464e-001      R**2 = 0.99440      Cond = 1.000e+000

```

pk	isotope	energy	centroid	fwhm	tamp	tslp	area	% rsd	fn	factor
41	Pu239	311.737	2493.850	9.690	0.032	0.209	41203	0.11%	0	0.0404
42	Np237	311.902	2495.169	9.691	0.032	0.209	57269	1.13%	1	1.0000

```

-----
region 14 from channel 2550 to 2602      ( 318.700 keV to 325.200 keV)
-----

```

```

total net counts =      213687.
Qfit = 6.612e-001      R**2 = 0.99794      Cond = 1.499e+000

```

pk	isotope	energy	centroid	fwhm	tamp	tslp	area	% rsd	fn	factor
43	Pu239	319.828	2558.573	9.751	0.031	0.209	7798	8.33%	1	1.0000
44	Pu239	320.868	2566.892	9.759	0.030	0.209	86452	0.72%	2	1.0000
45	Am241	322.526	2580.155	9.772	0.030	0.209	29418	2.51%	3	1.0000
46	Pu239	323.828	2590.571	9.782	0.030	0.209	90898	0.68%	4	1.0000

```

-----
region 15 from channel 2716 to 2778      ( 339.500 keV to 347.300 keV)
-----

```

```

total net counts =      1144589.
Qfit = 1.158e+000      R**2 = 0.99986      Cond = 2.176e+000

```

pk	isotope	energy	centroid	fwhm	tamp	tslp	area	% rsd	fn	factor
55		340.450	2723.537	9.908	0.027	0.209	5351	12.54%	1	1.0000
56	Pu239	341.495	2731.896	9.916	0.027	0.209	120061	0.11%	2	0.1178

```

57 Pu239 345.011 2760.026 9.943 0.026 0.209 1018885 0.11% 2 1.0000
58 U235 345.870 2766.897 9.949 0.026 0.209 1 >99.99% 0 0.0019

```

```

-----
region 16 from channel 2640 to 2712 ( 330.000 keV to 339.000 keV)
-----

```

```

total net counts = 317130.
Qfit = 1.205e+000 R**2 = 0.99671 Cond = 2.754e+000

```

pk	isotope	energy	centroid	fwhm	tamp	tslp	area	% rsd	fn	factor
47	Pu241	332.387	2659.038	9.847	0.028	0.209	169315	0.85%	1	1.0000
48	Am241	332.387	2659.038	9.847	0.028	0.209	30328	0.93%	2	0.3055
49	Pu239	332.850	2662.741	9.851	0.028	0.209	862366	0.11%	0	0.8464
50	Am243	334.310	2674.420	9.862	0.028	0.209	135	>99.99%	0	0.3745
51	Pu241	335.432	2683.396	9.870	0.028	0.209	13498	0.85%	1	0.0797
52	Am241	335.432	2683.396	9.870	0.028	0.209	99275	0.93%	2	1.0000
53	Pu239	336.112	2688.835	9.875	0.028	0.209	203880	0.11%	0	0.2001
54		337.720	2701.698	9.887	0.027	0.209	3639	20.36%	3	1.0000

```

-----
region 17 from channel 2984 to 3024 ( 373.000 keV to 378.000 keV)
-----

```

```

total net counts = 3191025.
Qfit = 9.035e+000 R**2 = 0.99975 Cond = 3.487e+000

```

pk	isotope	energy	centroid	fwhm	tamp	tslp	area	% rsd	fn	factor
66	Pu239	375.042	3000.379	10.168	0.022	0.209	3146927	0.06%	1	1.0000
67	Np237	375.300	3002.443	10.170	0.022	0.209	1272	1.13%	0	0.0222
68	Am241	376.610	3012.920	10.179	0.022	0.209	41125	5.34%	2	1.0000

```

-----
region 18 from channel 2922 to 2983 ( 365.300 keV to 372.900 keV)
-----

```

```

total net counts = 240933.
Qfit = 1.659e+000 R**2 = 0.99781 Cond = 1.863e+000

```

pk	isotope	energy	centroid	fwhm	tamp	tslp	area	% rsd	fn	factor
59	Pu239	367.054	2936.446	10.108	0.023	0.209	170559	0.49%	1	1.0000
60	Pu239	368.534	2948.291	10.119	0.023	0.209	178635	0.06%	0	0.0568
61	Pu241	368.605	2948.860	10.120	0.023	0.209	6546	0.11%	0	0.0053
62	Am241	368.605	2948.860	10.120	0.023	0.209	48845	1.90%	2	1.0000
63	Pu241	370.934	2967.500	10.137	0.022	0.209	17661	3.30%	3	1.0000
64	Am241	370.934	2967.500	10.137	0.022	0.209	11755	0.93%	0	0.1184
65		372.450	2979.634	10.148	0.022	0.209	5583	8.96%	4	1.0000

```

-----
region 19 from channel 3274 to 3338 ( 409.200 keV to 417.200 keV)
-----

```

```

total net counts = 3345848.
Qfit = 7.572e+000 R**2 = 0.99978 Cond = 6.649e+000

```

pk	isotope	energy	centroid	fwhm	tamp	tslp	area	% rsd	fn	factor
69	Pu239	410.990	3287.896	10.433	0.018	0.209	10222	9.16%	1	1.0000
70	Pu239	413.712	3309.675	10.452	0.017	0.209	3287621	0.06%	2	1.0000
71		414.800	3318.372	10.460	0.017	0.209	31196	8.00%	3	1.0000
72	Np237	415.743	3325.918	10.467	0.017	0.209	3490	1.13%	0	0.0609
73		415.940	3327.494	10.469	0.017	0.209	14079	10.83%	4	1.0000

region 20 from channel 3593 to 3625 (449.100 keV to 453.100 keV)

```

-----
total net counts =      455212.
Qfit = 2.888e+000      R**2 = 0.99942      Cond = 1.000e+000

pk isotope  energy  centroid  fwhm  tamp  tslp      area  % rsd  fn  factor
--  -----  -
74  Pu239   451.474  3611.830 10.725 0.014 0.209   456180 0.15%  1  1.0000
75  Am241   452.450  3619.634 10.732 0.014 0.209     665 0.93%  0  0.0067
    
```


Appendix A. Analysis Methods

The analysis of a gamma-ray pulse-height spectrum by the FRAM code can be conveniently described in two parts, 1) The Internal Calibration, 2) The Analysis Of The Spectral Data

The discussion below assumes that the spectral data is in computer memory.

A.1. Internal Calibration

The internal calibration uses selected peaks in the spectrum under analysis to provide an internal calibration of energy vs. channel, FWHM vs. channel, and peak shape (tailing parameters) vs. channel. This means that the analysis does not depend on parameters determined from other measurements that may have been taken with different conditions of count rate, resolution, or electronic adjustment. The internal calibration is performed with the same unknown spectrum that is under analysis.

There may be special cases where the spectral quality or the absence of strong peaks to use for calibration precludes using the unknown spectrum for its own peak calibrations. In these cases one can fix the peak calibration parameters to their initial values in the parameter set. The appropriate portion of the internal calibration is bypassed in this case.

A.1.1. Energy Calibration:

The first portion of the internal calibration procedure calibrates energy vs. channel number from a list of peaks, usually strong singlets, in the parameter set. A piecewise linear calibration between pairs of peaks is used for the energy calibration. The peaks are located using the default gain (keV/ch) and zero (keV at channel 0) in the parameter set. The algorithm locates the peak at the maximum count found in an energy dependent region of width $\pm(6 \text{ channels} + 0.0016 * \text{peak channel})$ on either side of the default peak position. This position is found using the default gain and zero.

The centroid is found using a least squares fit of a quadratic function to the logarithm of the counts. If there is an error in the calculation the peak is not used in the calibration. Calibration outside the range of the peaks in the parameter set is extrapolated from the nearest two points.

A.1.2. Initial Background:

A background is now calculated for all peak regions defined in the parameter set using the background shape for each region that is specified in the parameter set.

A.1.3. FWHM Calibration:

The full width at half maximum (FWHM) of the FWHM peaks in the parameter set is calculated from the net data after a channel by channel subtraction of the initial background. The FWHM is calculated from a least-squares fit of a quadratic to logarithm of the net counts. The fit is over a range of channels in which the counts exceed 75% of the peak maximum on the low-energy side and exceed 50% of the peak maximum on the high-energy side. This fit also yields the peak centroid and if there is a match with an energy calibration peak (very likely) the centroid of the energy calibration peak is updated.

The FWHM as a function of energy used in calculating the response function of an arbitrary fitted peak is found from a least squares fit to the function:

$$FWHM(E) = \sqrt{A_1 + A_2 E + A_3 / E}.$$

A.1.4. Shape /Tail Calibration

The shape of a gamma-ray peak in the spectrum is described by a central Gaussian component with a single exponential tail on the low energy side of the peak:

$$Y(J) = H \exp(\alpha(J - x_0)^2) + Tail(J)$$

where

$Y(J)$ is the net count in channel J

H is the peak height at the peak centroid x_0

$\alpha = 2.77259/FWHM^2$ the peak width parameter

and the tailing parameter $Tail(J)$ is given by

$$Tail(J) = H \exp((T_1 + T_2 E) + (T_3 + T_4 E)(J - x_0)) (1 - \exp(-0.4\alpha(J - x_0)^2))$$

Here we have allowed both the amplitude and slope of the tailing function to be a function of energy.

In practice we set T_4 to zero reducing the number of unknowns to three. After subtracting the Gaussian portion of the peak (known because we have calibrations for energy and FWHM), we combine the data from all the FWHM peaks on the low energy side of the peak from 1.8 to 0.7 FWHMs from the peak center to determine the slope and amplitude constants in a least squares fit.

At this point we have completed the internal calibration and have all the parameters necessary to calculate the shape of a gamma ray peak at any location in the spectrum.

A.2. Analysis of the Spectral Data

The analysis proceeds on a region-by-region basis in the order that the regions are presented in the parameter set. The program makes a number (set in parameter set, usually 3) of passes or iterations through all the regions. The regions are generally analyzed in order of increasing energy, however, if a region has a peak fixed to a second peak outside of the region, it is desirable to analyze the second region first so all peaks fit in a given region use the most current data. You do this ordering when constructing the regions in the parameter set.

The analysis starts by subtracting the background to get the net counts in a region. The background for the first iteration is available from the initial background calculation done during the calibration phase.

These are the steps taken during each iteration of the analysis phase:

A.2.1. Calculate Peak Areas

For each of the regions defined in the parameter set being used, perform the following:

Establish the start of the region, the end of the region, and the number of peaks in the region.

Make sure that a background has been calculated for the region that uses all the latest information.

Allocate enough dynamic memory for a least squares fitting of the response functions. Then initialize all the arrays used in this analysis. In particular, set the values of the output array to the net counts in the region.

Construct a set of response functions by examining each peak that contributes to this region. There will be as many response functions as there are free peaks in the region, and each one of the response functions will have the form

$$\sum_i f_i R_i(x)$$

where each R_i is a unit area function describing the shape of a photo peak and f_i is the associated area factor. One of the terms in this sum will correspond to a given free peak; its area factor is set to one. The other terms in the sum will correspond to peaks, which are fixed to this free peak. If peak i is fixed to peak j , the area factor will be

$$f_i = \frac{BR_i}{BR_j} \frac{RE_i}{RE_j} \frac{RA_i}{RA_j}$$

where BR = branching ratio, RE = relative efficiency, and RA = relative activity. This defines the ratio of the area of peak i to the area of peak j . The relative activity is the ratio of the activity of the given isotope to that of the first isotope in the isotope list in the parameter set. The relative activity ratio above is set to unity for the first iteration.

If a peak in the region is fixed to one outside the region, its photo peak function $R(x)$ is multiplied the product of the area factor and the previously determined area of that other peak. These values are then subtracted from the values in the output array. Thus, this peak is effectively stripped off or removed from the spectrum.

Compute the final weights to be used in the least squares fitting.

Perform the weighted least squares fitting of the response fingerprints for the free peaks to the adjusted (adjusted for stripped peaks) net counts. If the area of any of the peaks turn out to be negative, perform another least-squares analysis, forcing them to be zero this time around. The coefficients resulting from the analysis will be the areas of the free peaks.

Calculate the predicted responses and save for display and output.

Calculate from the coefficients the areas of all the peaks and appropriate values for their errors.

If this is not the last iteration, use the results so far to update the background offsets.

A.2.2. Calculate Relative Efficiencies

From the parameter set determine how many peaks are to be used in calculating the relative efficiency curve. This will be the number of data points used in the least-squares analysis.

A.2.2.1. Empirical Model

Determine the number of isotopes, N , represented by the above peaks. Determine the number of efficiency functions, M , represented by these isotopes. The number of parameters used in the least squares analysis will be $5 + (N-1) + (M-1)$.

Set up the arrays for a least-squares analysis. The design matrix is constructed to reflect the model

$$\ln(\text{Area} / BR) = c_1 + c_2 / E^2 + c_3 \ln E + c_4 (\ln E)^2 + c_5 (\ln E)^3 + c_i + c_j / E$$

where E is the energy in MeV. Each c_j is associated with isotopes beyond the first one; i ranges in value from 6 to $5+(N-1)$. Each c_j is associated with an efficiency function beyond the first one; j ranges in value from $6+(N-1)$ to $5+(N-1)+(M-1)$

Each weight is set to the reciprocal of the square of the relative error in the associated peak area.

Each output array value is the logarithm of the associated peak area divided by its branching ratio.

Perform the least-squares analysis.

For every peak in the parameter set, compute a relative efficiency by using the first $5+(N-1)$ terms in the above model. In addition, if a peak is associated with an isotope which is assigned an efficiency function other than one, compute its heterogeneity factor, $h = \exp(c_j/E)$, then multiply its relative efficiency by h.

A.2.2.2. Physical Model

Determine the number of isotopes, N, represented by the above peaks. Determine the number of efficiency functions, M, represented by these isotopes. The number of parameters used in the least squares analysis will be $6 + (N-1) + (M-1)$.

Set up the arrays for a least-squares analysis. The design matrix is constructed to reflect the model

$$\ln(\text{Area} / \text{BR}) = [(1 - \exp(-\mu_0 x_0)) / \mu_0 x_0]^* \\ [\exp(-\mu_1 x_1) \exp(-\mu_2 x_2) \exp(-\mu_3 x_3)]^* \\ [A_i][\exp(c_j / E)][\text{DetectorEfficiency}][\text{CorrectionFactor}]$$

where E is the energy in MeV. μ_0 and x_0 refer to the absorption coefficient and thickness of plutonium or uranium in the sample. For $i = 1, 2, \text{ or } 3$, μ_i and x_i refer to the absorption coefficient and thickness of the i th absorber material. Each A_i is associated with isotopes beyond the first one; if there are any, i ranges in value from 7 to $6+(N-1)$. Each c_j is associated with an efficiency function beyond the first one; if there are any, j ranges in value from $6+(N-1)$ to $5+(N-1)+(M-1)$.

Each output array value is the logarithm of the associated peak area divided by its branching ratio.

Perform the non-linear least-squares analysis.

For every peak in the parameter set, compute a relative efficiency by using the first $5+(N-1)$ terms in the above model. In addition, if a peak is associated with an isotope which is assigned an efficiency function other than one, compute its heterogeneity factor, $h = \exp(c_j/E)$, then multiply its relative efficiency by h.

A.2.3. Calculate Relative Activities

The relative activity of a peak is $A_i = \text{Area}_i(\text{BR}_i)(\text{RE}_i)$ where Area_i is the area of the peak i , BR_i is the branching ratio of the peak i , and RE_i is the relative efficiency at the peak i 's energy. The relative activity of an isotope is the average in logarithm of the activities of the individual peaks of the isotope.

$$\ln(A) = \text{ave}(\ln(A_i)) = \frac{\sum_i \ln(A_i) w_i}{\sum_i w_i}$$

where $w_i = (A_i/\delta A_i)^2$ is the reciprocal of the square of the error associated with $\ln(A_i)$, δA_i is the uncertainty of the relative activity of peak i .

Two different ways are used to calculate the uncertainty of the logarithm of the relative activity of the isotope.

1. The standard way $\delta(\ln(A)) = \sqrt{1/\sum_i w_i}$
2. The standard deviation of the individual relative activities of the peaks

$$\delta(\ln(A)) = \sqrt{\frac{\sum_i (\ln(A_i) - \ln(A))^2 w_i}{n \sum_i w_i}}$$

where n is the number of the peaks used.

The uncertainty of the logarithm of the relative activity of the isotope is taken to be the larger of the two $\delta(\ln(A))$ values. And finally, the uncertainty of the relative activity of the isotope is $\delta A = A\delta(\ln(A))$.

A.2.4. Calculate Isotopic Fractions

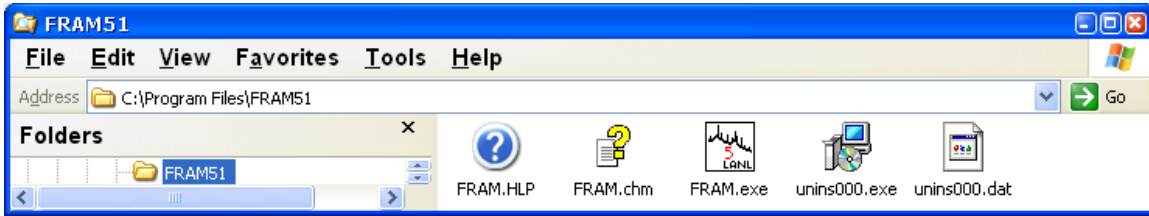
After the third iteration is complete the final relative masses (relative to the first isotope in the isotope list) are combined to give the absolute isotopic fractions without ^{242}Pu . The fractions are renormalized accounting for ^{242}Pu computed by correlation or fixed by operator entry. Non Pu isotopes are quantified relative to total Pu when analyzing Pu-bearing samples. For samples (except uranium only) containing no plutonium the final results are the relative masses themselves.

Auxiliary results such as effective specific power and effective ^{240}Pu fraction are computed from the plutonium isotopic fractions and appropriate constants in the parameter set.

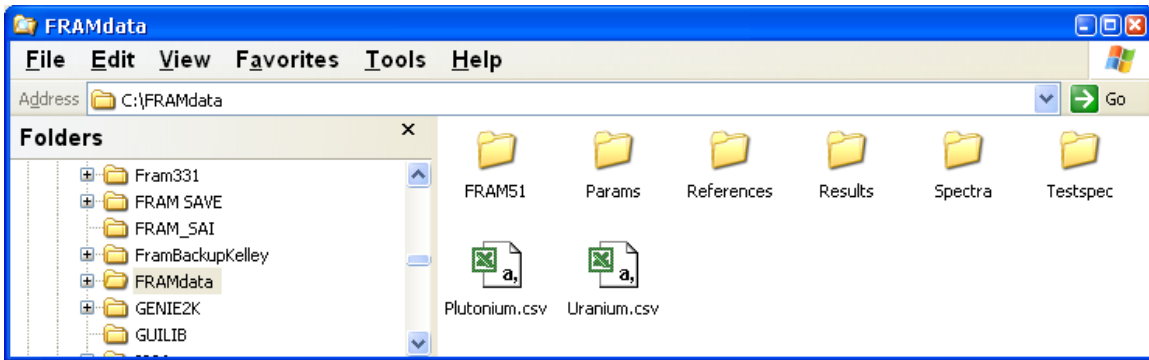
Appendix B. Files for FRAM

This appendix describes all the important files associated with FRAM.

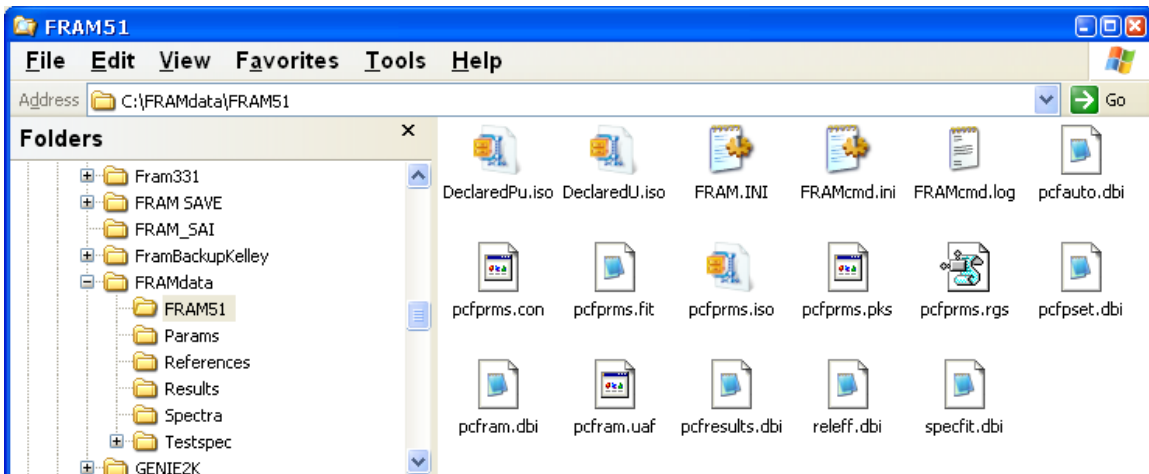
The screen below shows FRAM files after installing FRAM v.5 on a Windows XP system following the instructions in section 1.9 in this manual and then operating the system exercising all the options. The files in **C:\Program Files\FRAM51** are created at installation.



In **C:\FRAMdata** the six folders are created at installation and the **Uranium.csv** and **Plutonium.csv** files are created after the first analysis of the indicated isotope.



These files are created at installation.



B.1. FRAM Software

B.1.1. **FRAM.exe**

The FRAM executable. A shortcut to this executable file is placed on the desktop during installation.

B.1.2. **FRAM.HLP**

The FRAM Help file accessed from the main menu by **Help | Help Topics** and from the FRAM51 program group.

B.1.3. **FRAM.chm**

The FRAM Help file for Windows Vista and Windows 7 accessed from the FRAM51 program group.

B.1.4. **unins000.exe & unins000.dat**

Files associated with removing (uninstalling) FRAM from your system. Removal of FRAM is accessed through the **Control Panel | Add or Remove Programs** system commands (Windows XP).

B.2. Input Files

This section describes all the files that are created external to the software but are used by the software.

B.2.1. **FRAM.INI**

Configuration file: This file is provided in the distribution kit. Initially it contains a minimal amount of information about the system. Every time the defaults are modified and saved, however, this file gets overwritten with the most recent settings.

This file is also used to store default responses for all the major dialog boxes presented to you when invoking menu options. Every time these defaults are modified and saved, this file gets overwritten with the most recent values.

Reprinted below is a copy of the file that comes with the distribution kit.

```
; file fram.ini

[configuration]
prior_x=0
prior_y=0
prior_width=800
prior_height=600
prior_log_lin=0
prior_specfill=0

[file]
MainParam=9
```

```

File_Open=C:\FRAMdata\Spectra\Fram.chn
File_Save=C:\FRAMdata\Spectra\Fram.chn
File_PreviousResults=C:\FRAMdata\Results\Fram.res
File_Param=C:\FRAMdata\Params\Pu_Cx_120-460.par
[analyze]
analyze_resultfilename=C:\FRAMdata\Results\Fram.res
analyze_resultcompare=C:\FRAMdata\Results\Compare.txt
[acquire]
acquire_fileSimulate=C:\FRAMdata\Spectra\Fram.chn

```

B.2.2. **FRAMcmd.ini**

The configuration file for the FRAM Command Line Interpreter. Reprinted below is a copy of the file that comes with the distribution kit.

```

[CmdLineConfig]
/i = c:\FRAMdata\Spectra\fram.chn
/p = Pu_Cx_120-460
/o = test.res
/a = 0
/g = 0
/m = 1.2
/u = 1.1e-1
/d = 2011-01-02

```

B.2.3. **pcfprms.con**

Database file: this file contains all the records storing information about the application constants for each parameter set.

B.2.4. **pcfprms.fit**

Database file: this file contains all the fitting parameters for each parameter set.

B.2.5. **pcfprms.iso**

Database file: this file contains all the records storing information about the isotopes for each parameter set.

B.2.6. **pcfprms.pks**

Database file: this file contains all the records storing information about the gamma-ray peaks for each parameter set.

B.2.7. **pcfprms.rgs**

Database file: this file contains all the records storing information about the regions of interest for each parameter set.

B.2.8. **Parameter files**

Each of these files contains a sample set of parameters. Each one is a text file and has an extension of “.par”, “.txt”, or “.pst” for compatibility with v.4. In order to get the information in a file into the

database, you need to make use of the **Parameter | Import** option on the main FRAM menu. The Built-In parameter sets are already installed in the database when FRAM is installed. Any other parameter files delivered with the system are found in **C:\FRAMdata\Params**.

B.2.9. **DeclaredPu.iso**

This file contains the declared or certified isotopic values for plutonium samples used in the **Measure | Compare** option.

B.2.10. **DeclaredU.iso**

This file contains the declared or certified isotopic values for uranium samples used in the **Measure | Compare** option.

B.3. **Output Files**

This section describes all the files that are generated by the software that are intended to be used by other software.

B.3.1. **saved spectra**

When spectral data is stored, it is written to a binary file in the storage format specified by you. If the data is saved from the **Measure | Acquire** option or the **Measure | Measure** option and the number of cycles was set to one, the name of the file specified by you will be used. A sticky default path is provided. For multiple spectrum acquisitions (Number of Spectra > 1), several filename-number of spectra-file extension combinations are available to accommodate standard commercial file naming conventions.

To save 1-100 spectra, the filename format can be **Filename.X##** where **##** is a 2 digit number from 00 to 99, and **X** can be any character or number. This form is compatible with FRAM v.4 where **X = S** (for Spectrum), although other characters can also be used. The data format of the stored spectral data is specified by the entry in the **Format:** box. To save up to 1000 spectra, the filename format must be **Filename###.XXX** where **###** is a 3 digit number from 000 to 999 and **XXX** can be any extension such as .CHN, .CNF but not limited to standard extensions. The data format of the stored spectral data is specified by the entry in the **Format:** box described below. The default file name and path will be that of the last saved spectrum.

B.3.2. **saved results**

The user may specify the path and filename for storage of the results file. Default values for the Result File are: **C:\FRAMdata\Results\filename.res** where **filename** is the name of the analyzed data file. The path **C:\FRAMdata\Results** was established during the FRAM installation.

B.3.3. **Plutonium.csv**

The principal isotopic results of every plutonium analysis are written to this Excel spreadsheet which is found in **C:\FRAMdata**.

B.3.4. **Uranium.csv**

The principal isotopic results of every uranium analysis are written to this Excel spreadsheet which is found in **C:\FRAMdata**.

B.4. Internal Files

In this section we describe all the files created by and used by the software for internal operations.

B.4.1. **pcfram.uaf**

The user authorization file. This contains information about the users, their passwords, and the authorizations granted to them.

B.4.2. **pcfram.dbi**

The results of every analysis are stored in this file. This file is overwritten whenever a new analysis is performed. This file is used when you ask for a display of the results of the last analysis.

B.4.3. **specfit.dbi**

The results of the fitting process during every analysis are stored in this file. This file is overwritten whenever a new analysis is performed. This file is used when you ask for a display of the fits achieved in the last analysis.

B.4.4. **pcfpset.dbi**

This file stores, in text form, the values of the analysis parameters that were last retrieved from the database.

B.4.5. **pcfresults.dbi**

This file contains the FRAM output that is being displayed on the screen.

B.4.6. **releff.dbi**

This file contains the results of the relative efficiency curve fit and the relative efficiency data points.

B.5. Additional Files

After FRAM has been used additional files are created when the referenced options are invoked..

B.5.1. **FRAM.GID**

This file is part of the FRAM **Help** option.

B.5.2. **pcfauto.dbi**

This file contains the results of all of the analyses in an **Auto analysis** sequence.

B.6. Reference Documents

The installation process installs the reference documents into the directory **C:\FRAMdata\References**. The FRAM manual which you are reading at the moment also resides in the **C:\FRAMdata\References**.

Most reference documents can be accessed through the FRAM51 program group.

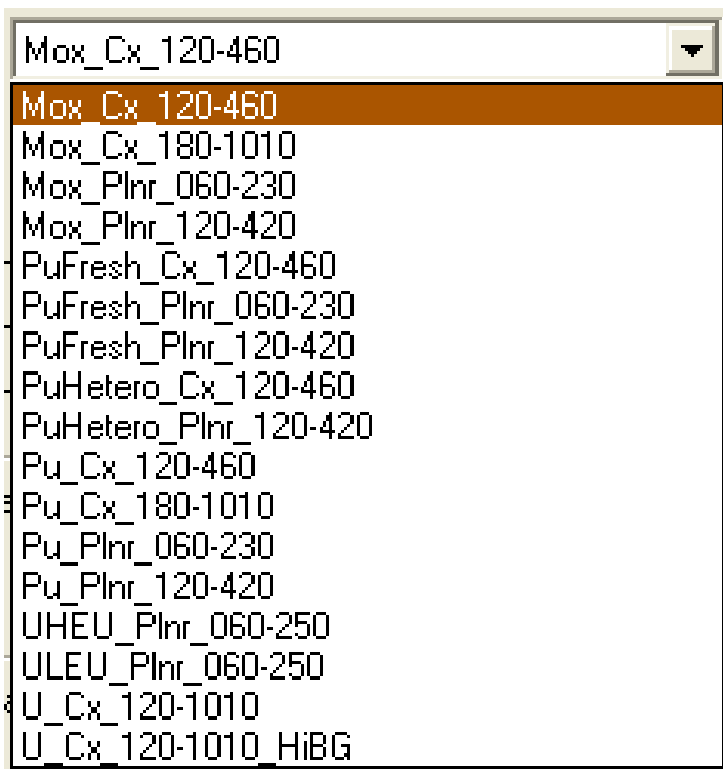
Appendix C. FRAM Built-In Parameter Set Descriptions

The versatility of the FRAM code allows it to be used with parameter sets tailored for different applications. FRAM is delivered and installed with a set of Built-In parameter sets. These parameter sets should be sufficient for analysis of spectra of most common plutonium and uranium materials obtained with typical HPGe detectors (including the planar, coaxial, N-type, and P-type HPGe). The names of the Built-In parameter sets are capitalized, and they cannot be changed or removed.

The Built-In parameter sets have a relatively standardized name format to assist in choosing the best parameter set for the application at hand. Most of the Built-In parameter sets have a name of the form

Isotope (Pu, U, Mox)_Detector type(Cx for coaxial, Plnr for planar)_Energy range in keV_Version no. or special application.

The drop down menu of the Built-In parameter sets is shown below.



Below we describe the Built-In parameter sets and their optimum application.

C.1. Built-In Parameter Sets for Planar Detectors

Pu_Plnr_060-230

The **Pu_Plnr_060-230** parameter set is the standard parameter set for planar detectors analyzing plutonium spectra in the energy range from 60 keV to 230 keV. These parameters apply best to a high resolution planar detector (typically 25 mm dia. by 15mm deep) with a low rate resolution at 122 keV of ≤ 600 eV. This is the so-called “100 keV region” analysis. This parameter set can also analyze spectra from semi-planar type detectors with resolution as large as 700 eV at 122 keV.

- The default gain is 0.075 keV/ch. The spectrum must contain at least 8192 ch of data at this gain so the spectrum may be reanalyzed in the 120–420 keV region if shielding is found.
- The parameter set must be used with the Physical Relative Efficiency.
- This parameter set analyzes for ^{235}U , up to 20% $^{235}\text{U}/\text{Pu}$, and ^{238}U on every analysis.
- A Cd absorber is assumed present.
- Americium/plutonium homogeneity and ^{241}Pu - ^{237}U equilibrium are assumed.
- The sample type tests in the application constants are set to detect nonequilibrium ^{241}Pu - ^{237}U .
- Interference tests for ^{239}Np and ^{235}U (MOX) are performed.
- The high and low energy tail-fitting tests are performed.
- **Fix_100kev_plutonium model** Application Constant is set to **TRUE**.
- The **AutoShieldTest** for shielding is performed. If shielding is found the spectrum is reanalyzed in the 120–420 keV region.
- The **AutoMoxTest** is performed. If Mox ($^{235}\text{U}/\text{Pu} > 20\%$) is found the spectrum is reanalyzed with **Mox_Plnr_060-230**.
- The **AutoFreshPuTest** is performed. If Fresh Pu is found the spectrum is reanalyzed with **PuFresh_Plnr_060-230**.

This parameter set has been used with ^{240}Pu fractions ranging from 2% to 38% and ^{241}Am to above 5%.

PuFresh_Plnr_060-230

The **PuFresh_Plnr_060-230** parameter set is used with a planar HPGe detector for analysis of unshielded samples of fresh plutonium in the 60-230 keV region. Fresh plutonium is plutonium freshly separated (uranium removed) where the ^{241}Pu - ^{237}U decay equilibrium has not been established. Ninety-nine (99) percent of equilibrium is established in approximately 45 days after a chemical separation of uranium.

- The default gain is 0.075 keV/ch. The spectrum must contain at least 8192 ch of data at this gain so the spectrum may be reanalyzed in the 120–420 keV region if shielding is found.
- The parameter set must be used with the Physical Relative Efficiency.
- This parameter set analyzes for ^{235}U , ^{238}U , ^{243}Am , and ^{237}U on every analysis.
- A Cd absorber is assumed present.

- Americium/plutonium homogeneity is assumed.
- Interference tests for ^{239}Np and ^{235}U (MOX) are performed.
- The high and low energy tail-fitting tests are performed.
- Pu-241 isotopic fraction is determined solely from the 148.6 keV gamma ray. U-237 is treated as a separate isotope and is not tied to ^{241}Pu . U-237 gamma rays are used for relative efficiency.
- **Fix_100kev_plutonium** Application Constant is set to **TRUE**.
- The **AutoShieldTest** for shielding is performed. If shielding is found the spectrum is reanalyzed in the 120–420 keV region.
- The **AutoisotopeRatioTest** is performed on ^{241}Pu and ^{237}U to test for equilibrium. If equilibrium is found the spectrum is reanalyzed with **Pu_Plnr_060-230**.

Mox_Plnr_060-230

The **Mox_Plnr_060-230** parameter set has been established to measure mixed uranium/plutonium oxides. It is used with a planar detector in the 100 keV region under the same conditions as **Pu_Plnr_060-230**. It is applicable for $^{235}\text{U}/\text{Pu}$ ratios between 0.2 and 20. Biases in the $^{235}\text{U}/\text{Pu}$ ratio may be present if the two oxides have different particle sizes.

- The default gain is 0.075 keV/ch. The spectrum must contain at least 8192 ch of data at this gain in case it needs to be reanalyzed in the 120–420 keV region.
- The parameter set must be used with the Physical Relative Efficiency.
- A Cd absorber is assumed present.
- Americium/plutonium homogeneity and ^{241}Pu - ^{237}U equilibrium are assumed.
- The sample type tests in the application constants are set to detect nonequilibrium ^{241}Pu - ^{237}U .
- The parameter set will analyze for ^{243}Am , ^{235}U and ^{238}U .
- The parameter set is applicable for $0.2 < ^{235}\text{U}/\text{Pu} < 20$.
- An interference test for ^{239}Np is performed.
- Interference tests are performed to flag $^{235}\text{U}/\text{Pu}$ above or below its desirable measurement range.
- The high and low energy tail-fitting tests are performed.
- **Fix_100kev_plutonium** Application Constant is set to **TRUE**.
- The **AutoShieldTest** for shielding is performed. If shielding is found the spectrum is reanalyzed in the 120–420 keV region.
- The **AutoisotopeRatioTest** is performed on the Pu239/U235 ratio. The spectrum is reanalyzed with **Pu_Plnr_060-230** if the U235 is too small.

Pu_Plnr_120-420

The **Pu_Plnr_120-420** parameter set is the standard parameter set for planar detectors analyzing plutonium spectra in the energy range from 120 keV to 420 keV. These parameters apply to a high resolution planar detector (typically 25 mm dia. by 15mm deep) with a low rate resolution at 122 keV of ≤ 600 eV. This parameter set will also operate successfully with detectors with resolution > 600 eV at 122 keV.

- The default gain is 0.075 keV/ch so the spectrum must contain at least 8192 ch of data.
- It can be used with either the Physical or Empirical Relative Efficiency model.
- Americium/plutonium homogeneity and ^{241}Pu - ^{237}U equilibrium are assumed.
- The parameter set analyzes for ^{235}U , up to 20% $^{235}\text{U}/\text{Pu}$, ^{237}Np , and ^{243}Am - ^{239}Np on every analysis.
- A Cd absorber is assumed present.
- The sample type tests in the application constants are set to detect non-equilibrium ^{241}Pu - ^{237}U and heterogeneous $^{241}\text{Am}/\text{Pu}$.
- Interference tests for ^{243}Am - ^{239}Np and ^{235}U are performed.
- The high and low energy tail-fitting tests are performed.
- The **AutoShieldTest** is performed. If shielding is found the spectrum is reanalyzed in the 180–1,010 keV region with the **Pu_Cx_180-1010** parameter set.
- The **AutoUnshieldTest** is performed. If shielding is not found the spectrum is reanalyzed in the 60–230 keV region with the **Pu_Plnr_060-230** parameter set.
- The **AutoMoxTest** is performed. If Mox ($^{235}\text{U}/\text{Pu} > 20\%$) is found the spectrum is reanalyzed with the **Mox_Plnr_120_420** parameter set.
- The **AutoHeteroTest** is performed. If Am/Pu heterogeneity is found the spectrum is reanalyzed with the **PuHetero_Plnr_120-420** parameter set.
- The **AutoFreshPuTest** is performed. If the test passes the spectrum is reanalyzed with the **PuFresh_Plnr_120-420** parameter set.

This parameter set has been used with ^{240}Pu fractions ranging from 2% to 38% and ^{241}Am to above 5%.

PuFresh_Plnr_120-420

The **PuFresh_Plnr_120-420** parameter set is used with a planar HPGe detector for analysis of unshielded samples of fresh plutonium in the 120-420 keV region. Fresh plutonium is plutonium freshly separated (uranium removed) where the ^{241}Pu - ^{237}U decay equilibrium has not been established. Ninety-nine (99) percent of equilibrium is established in approximately 45 days after a chemical separation of uranium.

- The default gain is 0.075 keV/ch. This parameter set is used with at least 8k channels.
- It can be used with either the Physical or Empirical Relative Efficiency model.
- This parameter set analyzes for ^{235}U , ^{237}Np , ^{243}Am , and ^{237}U on every analysis.

- A Cd absorber is assumed present.
- Americium/plutonium homogeneity is assumed. A sample type test for Am/Pu heterogeneity is performed.
- Interference tests for ^{243}Am - ^{239}Np and ^{235}U are performed.
- The high and low energy tail-fitting tests are performed.
- Pu-241 isotopic fraction is determined solely from the 148.6 keV gamma ray, the only measurable direct ^{241}Pu gamma ray above the 100 keV region.
- U-237 is treated as a separate isotope and is not tied to ^{241}Pu . U-237 gamma rays are used for relative efficiency.
- The **AutoUnshieldTest** is performed. If shielding is not found the spectrum is reanalyzed in the 60–210 keV region with the **PuFresh_Plnr_060-230** parameter set..
- The **AutoisotopeRatioTest** is performed on ^{241}Pu and ^{237}U to test for equilibrium. If equilibrium is found the spectrum is reanalyzed with **Pu_Plnr_120-420**.

Note: This parameter set may also be used for samples with ^{241}Pu - ^{237}U decay equilibrium with some loss in precision for ^{241}Pu because only a single gamma ray is used to quantify ^{241}Pu .

Mox_Plnr_120-420

The **Mox_Plnr_120-420** parameter set has been established to measure mixed uranium/plutonium oxides. It is used with a planar detector in the 120–420 keV region under the same conditions as the **Pu_Plnr_120-420** parameter set. It is applicable for $^{235}\text{U}/\text{Pu}$ ratios between 0.2 and 50. Biases in the $^{235}\text{U}/\text{Pu}$ ratio may be present if the two oxides have different particle sizes.

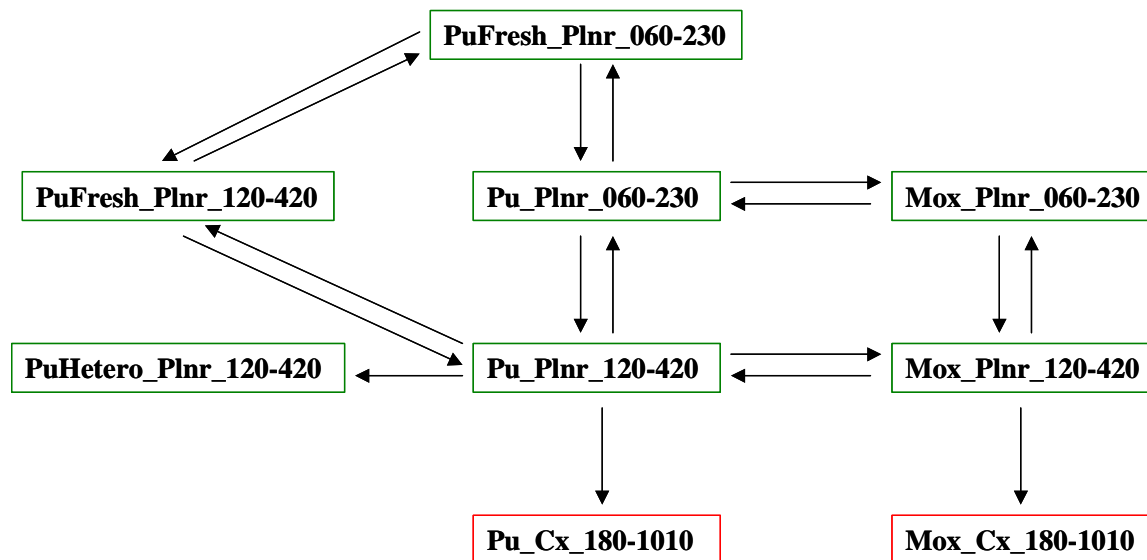
- The default gain is 0.075 keV/ch. The spectrum must contain at least 8192 ch of data at this gain.
- It can be used with either the Physical or Empirical Relative Efficiency model.
- A Cd absorber is assumed present.
- Americium/plutonium homogeneity and ^{241}Pu - ^{237}U equilibrium are assumed.
- Sample type tests are performed for americium/plutonium homogeneity and ^{241}Pu - ^{237}U equilibrium
- The parameter set will analyze for both ^{235}U , ^{237}Np , and ^{243}Am ,
- The parameter set is applicable for $0.2 < ^{235}\text{U}/\text{Pu} < 50$.
- Interference tests for ^{243}Am - ^{239}Np and ^{235}U are performed.
- The high and low energy tail-fitting tests are performed.
- The **AutoShieldTest** is performed. If shielding is found the spectrum is reanalyzed in the 180–1,010 keV region with the **Mox_Cx_180-1010** parameter set.
- The **AutoUnshieldTest** for shielding is performed. If shielding is not found the spectrum is reanalyzed in the 60–230 keV region with the **Mox_Plnr_060-230** parameter set.
- The **AutoisotopeRatioTest** is performed to test for the $^{235}\text{U}/^{239}\text{Pu}$ ratio. If this ratio is too small, the spectrum is reanalyzed with the **Pu_Plnr_120-420** parameter set..

PuHetero_Plnr_120-420

The **PuHetero_Plnr_120-420** parameter set is used with a planar HPGe detector for analysis of unshielded plutonium-bearing samples with ^{241}Am -Pu heterogeneities. The analysis takes place in the 120-420 keV region. Heterogeneity occurs when ^{241}Am and plutonium occur in different matrices such that the gamma ray attenuation at the same energy depends upon whether the gamma ray originated from ^{241}Am or plutonium. The classic example of this are the residues from a pyrochemical purification process. These residues have the Am present in a chloride matrix while the plutonium in the residue is in the form of metal. The analysis is treated by assigning a second relative efficiency curve to Am, related to the primary plutonium relative efficiency curve by the factor $\exp(-\beta/E)$ where E is energy and β is a fitted parameter..

- The default gain is 0.075 keV/ch. This parameter set is used with at least 8k channels.
- It can be used with either the Physical or Empirical Relative Efficiency model.
- Americium/plutonium heterogeneity is assumed.
- A sample type test is performed for ^{241}Pu - ^{237}U equilibrium.
- The high and low energy tail-fitting tests are performed.
- This parameter set analyzes for ^{235}U , ^{243}Am , and ^{237}Np on every analysis.
- A Cd absorber is assumed present.
- Interference tests for ^{243}Am - ^{239}Np and ^{235}U are performed.
- Am-241 is assigned a second relative efficiency curve.

The Auto analysis tests for the seven plutonium-planar detector parameter sets (0.075 keV/ch) are represented schematically below. The Auto analysis also test for the very shielded samples to be analyzed with the coaxial parameter sets (red boxes).



UHEU_Plnr_060-250

The parameter set **UHEU_Plnr_060-250** analyzes uranium spectral data in the energy range 60–250 keV. These parameters apply to a high resolution planar detector (typically 25 mm dia. By 15mm deep) with a low rate resolution at 122 keV of ≤ 600 eV. This parameter set has been tested for ^{235}U enrichment from 2% to 93% and works best for ^{235}U enrichments $> 10\%$.

- The default gain is 0.075 keV/ch. The spectrum must contain at least 4096 ch of data at this gain.
- The parameter set must be used with the Physical Relative Efficiency.
- A Cd absorber is assumed present.
- The high and low energy tail-fitting tests are performed.
- The parameter set analyzes for ^{228}Th on every analysis.
- The **restrict_fwhm_model** Application Constant is set to **TRUE**.
- The **fix_100kev_uranium** Application Constant is set to **TRUE**.
- The **AutoisotopeRatioTest** is performed. If ^{235}U is $< \sim 10\%$ the spectrum is reanalyzed with the **ULEU_Plnr_060-250** parameter set.

The applicability of this parameter set is for ^{235}U enrichments above 10%. The enrichment range between 10% and 20% can be analyzed by both this parameter set and the **ULEU_Plnr_060-250** parameter set.

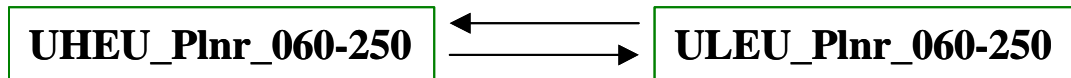
ULEU_Plnr_060-250

The parameter set **ULEU_Plnr_060-250** analyzes uranium spectral data in the energy range 60–250 keV. These parameters apply to a high resolution planar detector (typically 25 mm dia. By 15mm deep) with a low rate resolution at 122 keV of ≤ 600 eV. This parameter set has been tested for ^{235}U enrichment from 0.3% to 20%.

- The default gain is 0.075 keV/ch. The spectrum must contain at least 4096 ch of data at this gain.
- The parameter set must be used with the Physical Relative Efficiency.
- A Cd absorber is assumed present.
- The high and low energy tail-fitting tests are performed.
- The parameter set analyzes for ^{228}Th on every analysis.
- The **restrict_fwhm_model** Application Constant is set to **TRUE**.
- The **fix_bad_bkg** Application Constant is set to **TRUE**.
- The **fix_100kev_uranium** Application Constant is set to **TRUE**.
- The **AutoisotopeRatioTest** is performed. If ^{235}U is $> \sim 20\%$ the spectrum is reanalyzed with the **UHEU_Plnr_060-250** parameter set.

The applicability of this parameter set is for ^{235}U enrichments below 20%. The enrichment range between 10% and 20% can be analyzed by both this parameter set and the **UHEU_Plnr_060-250** parameter set.

The Auto analysis tests for the two uranium-planar detector parameter sets (0.075 keV/ch) are represented schematically below.



C.2. Built-In Parameter Sets for Coaxial Detectors

Pu_Cx_120-460

The parameter set **Pu_Cx_120-460** is the standard parameter set for use with a coaxial HPGe detector for analysis of unshielded samples of plutonium in the 120-460 keV region. We have extensive experience with modest-sized, good resolution, coaxial detectors, 20-30% efficiency, with resolutions < 1.75 keV at 1332 keV and <750 eV at 122 keV at low rates. This parameter set has also been used with detectors up to 100% relative efficiency.

- The default gain is 0.125 keV/ch. This parameter set is used with at least 8k channels so we can attempt analysis of the same spectrum at higher energies with a more appropriate parameter set if shielding is present.
- It can be used with either the Physical or Empirical Relative Efficiency model.
- Americium/plutonium homogeneity and ^{241}Pu - ^{237}U equilibrium are assumed.
- This parameter set analyzes for ^{235}U , ^{237}Np , and ^{243}Am - ^{239}Np on every analysis.
- A Cd absorber is assumed present.
- The sample type tests in the application constants are set to detect non-equilibrium ^{241}Pu - ^{237}U and heterogeneous ^{241}Am /Pu.
- Interference tests for ^{243}Am - ^{239}Np , ^{237}Np , and ^{235}U are performed.
- The high and low energy tail-fitting tests are performed.
- The **AutoShieldTest** for shielding is performed. If shielding is found the spectrum is reanalyzed in the 180–1010 keV region with the **Pu_Cx_180-1010** parameter set.
- The **AutoUnshieldTest** is performed. If shielding is not found the spectrum is reanalyzed in the 60–230 keV region with the **Pu_Plnr_060-230** parameter set.
- The **AutoMoxTest** is performed. If $\text{U235}/\text{Pu} > 0.1$ is found the spectrum is reanalyzed with **Mox_Cx_120-460**.

- The **AutoHeteroTest** is performed on ^{241}Am peaks at 125.3- and 335.4 keV. If the test passes the spectrum is reanalyzed with **PuHetero_Cx_120-460**.
- The **AutoFreshPuTest** is performed. If the test passes the spectrum is reanalyzed with the **PuFresh_Cx_120-460** parameter set.

PuFresh_Cx_120-460

The **PuFresh_Cx_120-460** parameter set is used with a coaxial HPGe detector for analysis of unshielded samples of fresh plutonium in the 120-460 keV region. Fresh plutonium is plutonium freshly separated (uranium removed) where the ^{241}Pu - ^{237}U decay equilibrium has not been established. Ninety-nine (99) percent of equilibrium is established in approximately 45 days after a chemical separation of uranium.

- The default gain is 0.125 keV/ch. This parameter set is used with at least 8k channels.
- It can be used with either the Physical or Empirical Relative Efficiency model.
- This parameter set analyzes for ^{235}U , ^{237}Np , ^{243}Am - ^{239}Np , and ^{237}U on every analysis.
- A Cd absorber is assumed present.
- Americium/plutonium homogeneity is assumed. A sample type test for Am/Pu heterogeneity is performed.
- Interference tests for ^{243}Am - ^{239}Np , ^{237}Np , and ^{235}U are performed.
- The high and low energy tail-fitting tests are performed.
- Pu-241 isotopic fraction is determined solely from the 148.6 keV gamma ray, the only measurable direct ^{241}Pu gamma ray above the 100 keV region.
- U-237 is treated as a separate isotope and is not tied to ^{241}Pu . U-237 gamma rays are used for relative efficiency.
- The **AutoUnshieldTest** is performed. If shielding is not found the spectrum is reanalyzed in the 60–230 keV region with the **PuFresh_Plnr_060-230** parameter set.
- The **AutoIsotopeRatioTest** is performed on ^{241}Pu and ^{237}U to test for equilibrium. If equilibrium is found the spectrum is reanalyzed with **Pu_Cx_120-460**.

Note: The **AutoShieldTest** is *not* performed. If shielding were present there is no higher energy gamma ray than the 148.6 keV peak to use to quantify ^{241}Pu .

Note: This parameter set may also be used for samples with ^{241}Pu - ^{237}U decay equilibrium with some loss in precision for ^{241}Pu because only a single gamma ray is used to quantify ^{241}Pu .

Mox_Cx_120-460

The parameter set **Mox_Cx_120-460** is for use with a coaxial HPGe detector for analysis of unshielded samples of MOX (mixed uranium-plutonium oxide) in the 120-460 keV region. This parameter set is used with a coaxial detector at a gain of 0.125 keV/channel with zero offset. We have experience with modest-sized, good resolution, coaxial detectors, 20-30% efficiency, with resolutions < 1.75 keV at 1332 keV and < 750 eV at 122 keV at low rates. Larger volume coaxial detectors will also produce satisfactory results. It

has been shown to operate over a range of $^{235}\text{U}/\text{Pu}$ from 0.1 to 20 although the plutonium analysis quality deteriorates for ratios above four or five because of the very intense ^{235}U interferences. The Application Constants contain defaults for the physical relative efficiency curve.

- The default gain is 0.125 keV/ch. This parameter set is used with at least 8k channels so we can attempt analysis of the same spectrum at higher energies with the **Mox_Cx_180-1010** parameter set if shielding is present.
- It can be used with either the Physical or Empirical Relative Efficiency model.
- Americium/plutonium homogeneity and ^{241}Pu - ^{237}U equilibrium are assumed.
- Sample type tests are performed for americium/plutonium homogeneity and ^{241}Pu - ^{237}U equilibrium
- This parameter set analyzes for ^{235}U , ^{237}Np , and ^{243}Am - ^{239}Np on every analysis.
- Interference tests for ^{243}Am - ^{239}Np , ^{237}Np , and ^{235}U are performed and the user is warned if only small amounts of ^{235}U are present.
- The high and low energy tail-fitting tests are performed.
- A Cd absorber is assumed present.
- The **AutoShieldTest** for shielding is performed. If shielding is found the spectrum is reanalyzed in the 180–1010 keV region with the **Mox_Cx_180-1010** parameter set.
- The **AutoUnshieldTest** is performed. If shielding is not found the spectrum is reanalyzed in the 60–230 keV region with the **Mox_Plnr_060-230** parameter set.
- The **AutolotopeRatioTest** is performed to test for the $^{235}\text{U}/^{239}\text{Pu}$ ratio. If this ratio is too small, the spectrum is reanalyzed with the **Pu_Cx_120-460** parameter set..

PuHetero_Cx_120-460

The **PuHetero_Cx_120-460** parameter set is used with a coaxial HPGe detector for analysis of unshielded plutonium-bearing samples with ^{241}Am -Pu heterogeneities. The analysis takes place in the 120-460 keV region. Heterogeneity occurs when ^{241}Am and plutonium occur in different matrices such that the gamma ray attenuation at the same energy depends upon whether the gamma ray originated from ^{241}Am or plutonium. The classic example of this are the residues from a pyrochemical purification process. These residues have the Am present in a chloride matrix while the plutonium in the residue is in the form of metal. The analysis is treated by assigning a second relative efficiency curve to Am, related to the primary plutonium relative efficiency curve by the factor $\exp(-\beta/E)$ where E is energy.

- The default gain is 0.125 keV/ch. This parameter set is used with at least 8k channels.
- It can be used with either the Physical or Empirical Relative Efficiency model.
- Americium/plutonium heterogeneity is assumed.
- A sample type test is performed for non-equilibrium ^{241}Pu - ^{237}U .
- This parameter set analyzes for ^{235}U , ^{237}Np , and ^{243}Am - ^{239}Np on every analysis.
- The parameter set tests for significant interferences from ^{235}U , ^{237}Np , and ^{243}Am - ^{239}Np on every analysis.
- The high and low energy tail-fitting tests are performed.

- A Cd absorber is assumed present.
- Am-241 and ^{243}Am - ^{239}Np are assigned a second relative efficiency curve.

Pu_Cx_180-1010

The parameter set **Pu_Cx_180-1010** is the standard parameter set for use with a coaxial HPGe detector to analyze spectra taken in 8192 (or greater) channels at a gain of 0.125 keV/channel. It is the standard parameter file used to analyze data in the region from 200 keV to 780 keV for spectra with no peaks below 200 keV. Such spectra may arise from plutonium in shielded or very heavy-walled containers. Analysis for ^{240}Pu is done at 642.5 keV while ^{238}Pu is obtained at 766.4 keV. Analysis can be done for shielding up to at least 6 mm of lead or until the 203- and 208 keV peaks are no longer visible.

- The default gain is 0.125 keV/ch. This parameter set is used with at least 8k channels.
- It can be used with either the Physical or Empirical Relative Efficiency model.
- Americium/plutonium homogeneity and ^{241}Pu - ^{237}U equilibrium are assumed.
- This parameter set analyzes for ^{235}U , ^{238}U , ^{237}Np , and ^{243}Am - ^{239}Np on every analysis. The analysis for ^{235}U is at 185 keV and may not be reliable for a shielded sample.
- Interference tests are performed for ^{235}U , ^{243}Am - ^{239}Np , and ^{237}Np .
- A Cd absorber and a Pb absorber are assumed present.
- The high and low energy tail-fitting tests are performed.
- The **AutoUnshieldTest** is performed. If shielding is not found the spectrum is reanalyzed in the 120–460 keV region with parameter set **Pu_Cx_120-460**.
- The **AutoMoxTest** is performed. If Mox is found the spectrum is reanalyzed with the **Mox_Cx_180-1010** parameter set.

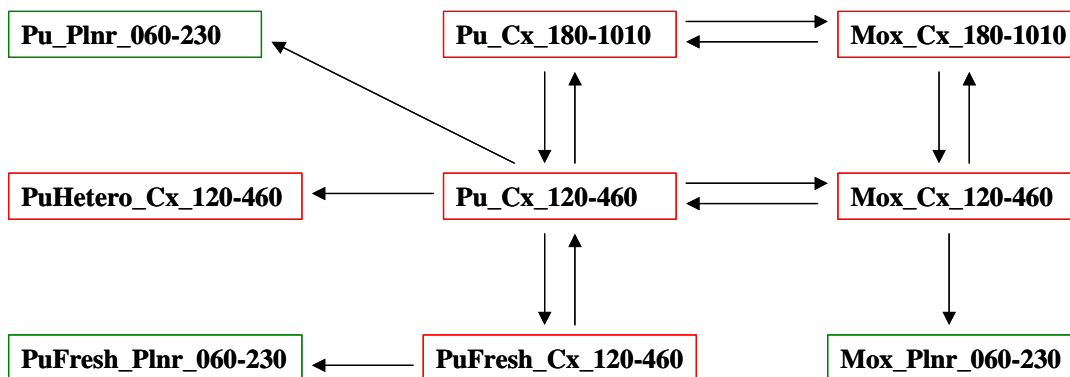
Mox_Cx_180-1010

The parameter set **Mox_Cx_180-1010** uses a coaxial detector spectrum taken in 8192 channels or greater at a gain of 0.125 keV/channel. It is used to analyze data in the region from 180 keV to 1001 keV for spectra from MOX (mixed uranium-plutonium oxide). Analysis for ^{240}Pu is done at 642.5 keV while ^{238}Pu is obtained at 766.4 keV. U-235 is obtained at 185.7 keV and ^{238}U is obtained at 1001 keV. Plutonium analysis can be done for shielding up to at least 6 mm of lead or until the 203- and 208 keV peaks are no longer visible. The analysis for ^{235}U at 185.7 keV may not always be possible, depending upon the shielding present and the amount of ^{235}U in the sample. This parameter file is designed to operate over a U235/Pu range of 0.1–50. The Application Constants contain defaults for the physical relative efficiency curve.

- The default gain is 0.125 keV/ch. This parameter set is used with at least 8k channels so we can attempt analysis of the same spectrum at lower energies with the **Mox_Cx_120-460** parameter set if shielding is not found
- It can be used with either the Physical or Empirical Relative Efficiency model.

- Americium/plutonium homogeneity and ^{241}Pu - ^{237}U equilibrium are assumed.
- This parameter set analyzes for ^{235}U , ^{238}U , ^{237}Np , and ^{243}Am - ^{239}Np on every analysis.
- Interference tests are performed for ^{235}U , ^{243}Am - ^{239}Np , and ^{237}Np .
- The high and low energy tail-fitting tests are performed.
- A Cd absorber and a Pb absorber are assumed present.
- The **AutoUnshieldTest** for shielding is performed. If shielding is not found the spectrum is reanalyzed in the 120–460 keV region with the **Mox_Cx_120-460** parameter set.
- The **AutolotopeRatioTest** is performed to test for the $^{235}\text{U}/^{239}\text{Pu}$ ratio. If this ratio is too small, the spectrum is reanalyzed with the **Pu_Cx_180-1010** parameter set.

The Auto analysis tests for the six plutonium-coaxial detector parameter sets (0.125 keV/ch) are represented schematically below.



U_Cx_120-1010

The parameter set **U_Cx_120-1010** is used to obtain ^{234}U , ^{235}U , ^{236}U (by correlation) and ^{238}U in samples that contain only uranium (no plutonium). It analyzes data from 120 keV to 1001 keV taken at a gain of 0.125 keV/channel with the same class of coaxial detector that has been described for plutonium. It is designed to work over the entire enrichment range and has been tested from 0.2%-97% ^{235}U . The Application Constants contain defaults for the physical relative efficiency curve and parameters for the ^{236}U correlation.

- The default gain is 0.125 keV/ch. This parameter set is used with at least 8k channels.
- It can be used with either the Physical or Empirical Relative Efficiency model.
- The parameter set analyzes for ^{228}Th on every analysis.
- The parameter set uses peaks from ^{228}Th daughters to supplement relative efficiency peaks from ^{235}U and $^{234\text{m}}\text{Pa}$ (^{238}U daughter).

- The ^{234m}Pa (^{238}U daughter) peaks are strongest for low ^{235}U enrichments and the ^{228}Th daughter peaks contribute mainly for higher ^{235}U enrichments.
- A Cd absorber is assumed present.
- The high and low energy tail-fitting tests are performed.
- A sample type test for ^{228}Th heterogeneity is performed.
- The **AutoHeteroTest** is performed for ^{228}Th daughter peaks. This test detects if significant ^{228}Th daughter contributions are coming from natural background as opposed to the sample. If the test passes the spectrum is reanalyzed with the **U_Cx_120-1010_HiBG** parameter set that considers ^{228}Th daughter peaks heterogeneous with respect to uranium.
- The **restrict_efficiency_model** Application Constant is set to **TRUE**.

U_Cx_120-1010_HiBG

The parameter set **U_Cx_120-1010_HiBG** is the heterogeneous (Th/U) analog to **U_Cx_120-1010** above. This parameter set should be used in place of the **U_Cx_120-1010** parameter set when the detector is not very well shielded and/or the input rate is low.

- The default gain is 0.125 keV/ch. This parameter set is used with at least 8k channels.
- It can be used with either the Physical or Empirical Relative Efficiency model.
- The parameter set analyzes for ^{228}Th on every analysis.
- Th-228 daughters are assumed to be heterogeneous with respect to uranium. This occurs when significant intensity of ^{228}Th daughters arises from background relative to that from the sample.
- The parameter set uses peaks from ^{228}Th daughters to supplement relative efficiency peaks from ^{235}U and ^{234m}Pa (^{238}U daughter).
- The ^{234m}Pa (^{238}U daughter) peaks are strongest for low ^{235}U enrichments and the ^{228}Th daughter peaks contribute mainly for higher ^{235}U enrichments.
- A Cd absorber is assumed present.
- The high and low energy tail-fitting tests are performed.
- The **restrict_efficiency_model** Application Constant is set to **TRUE**.

The Auto analysis tests for the two uranium-coaxial detector parameter sets (0.125 keV/ch) are represented schematically below.



Appendix D. ASCII File Description

You can save spectral data in a text file by selecting the **File | Save As. . .** option then choosing ASCII as the **File Format:**.

The first 48 lines of such a text file are shown on the next page. This was produced by opening the file U0071PIO.000 and then performing a **File | Save As. . .** with the **File Format: ASCII**. The file format is in two columns, **ch, counts**, separated by a comma. The resulting text file was opened with Microsoft Word, and then the first page was printed.

The first line in the output file displays the name of the original file (before conversion to ASCII) in which the data resides. The next two lines display information that is usually found in the header portion of the spectral data file. In the second line, between the commas, are numbers representing the date and time associated with that spectrum. The numbers, in order, indicate the year, month, day, hour, minute, second, millisecond, and time zone offset. The third line indicates the live time and true time used in collecting the spectral data. The fourth line is blank. The fifth line consists of the string “ch” followed by the comma separator character followed by the string “counts.” The remaining lines present the spectral data with a channel number, comma, followed by a count.

When you choose to open a data file and select ASCII as the storage format, FRAM attempts to read the header information: date, time, live time, and true time. If this fails, it proceeds to the spectral data. Thus, the header information in lines 1-3 need not be present in the file. But **the line with the strings “ch” and “counts” must be present**. FRAM looks for the character between these two strings and assumes that this will be the delimiter between each column of numbers in the succeeding lines. As the channel counts are being read the channel numbers actually read are checked against what they ought to be in order to ensure the integrity of the data.

Spectral data from C:\FRAM_Archival_data\U100kevSampleSpectra\U0071P10.000
2002,9,24,9,43,30,0,8
Live time: 838 True time: 900

ch,counts

0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0
8,0
9,0
10,0
11,0
12,0
13,0
14,0
15,0
16,0
17,0
18,0
19,0
20,0
21,0
22,0
23,0
24,0
25,0
26,0
27,0
28,0
29,0
30,0
31,0
32,857
33,953
34,985
35,1003
36,974
37,982
38,954
39,975
40,931
41,982
42,980
43,965
44,945
45,947
46,967
47,949

Appendix E. FRAM Command Line Operation

E.1. Introduction

When FRAM is run with a string argument it will switch to the command-line operation mode. This mode of operation will execute the commands supplied in the argument and when the analysis is completed will automatically terminate. It will not open a window.

The Command-Line Operation mode is meant for users who want to incorporate FRAM into their own applications. This mode allows the user to make a very simple interface to the FRAM analysis engine.

In the command-line mode, FRAM will not APPEND the one-line results to the Uranium.csv or Plutonium.csv file as in the normal operation mode. Instead it will WRITE the one-line results to the FRAMcmd.log file. This file resides in the database directory.

E.2. Command Descriptions

- **/I Init File** Open the INI file and read the commands in the file. The default directory is the directory containing the FRAM database, **C:\FRAMdata\FRAM51**.
- **/p Parameter set** Required. Parameter set must be in the FRAM database. Parameter sets' names are case sensitive.
- **/i Input file** Required. The default directory is **C:\FRAMdata\Spectra**. The commands **/i Uran\file1.txt** is equivalent to **/i C:\FRAMdata\Spectra\Uran\file1.txt**. If there is "space" in the file name or directory then the whole file name, including the directory, must be enclosed between double quotes. The inclusion of space in the filename is discouraged.
- **/o Output file** The default is NULL. The default directory is **C:\FRAMdata\Results**. The commands **/o Uran\file1.res** is equivalent to **/o C:\FRAMdata\Results\Uran\file1.res**. If there is "space" in the file name or directory then the whole file name, including the directory, must be enclosed between double quotes. The inclusion of space in the filename is discouraged.
- **/f Input file format** If the input file has the extension *chn*, *spc*, *mca*, *cnf*, *spe*, or *txt* then the file format will be automatically assigned to the Ortec *chn*, Ortec *spc*, Canberra S100, Canberra Cam, IAEA MMCA, or FRAM Ascii, respectively. If the input file format is not one of those then this **/f** command option is required. The acceptable formats are *chn*, *spc*, *mca*, *cnf*, *spe*, and *txt*. The **/f** command option will override the file format extracted from the extension of the input file name.
- **/e Rel. Efficiency** **0** or **1**. **0** means Physical model and **1** means Empirical model. The default is **0**.

- **/c Pu242/U236** Real number. A negative number means that the Pu242 or U236 value is determined by correlation. A value from 0 to less than 100 represents the operator declared %Pu242 or %U236. A value greater than or equal 100 means that the Pu242 or U236 value is determined by measurement. The default is -1.
- **/s U separation date** Default is "1900-01-01". The date must be in either the international "yyyy-mm-dd" format or the American "dd-Mmm-yyyy" format.
- **/a Auto Analysis** *0* or *1*. *0* stands for normal analysis and *1* stands for auto analysis. The default is *0*.
- **/g E calibration gain** The default is the energy calibration gain from the parameter set.
- **/z E calibration zero** The default is the energy calibration intercept (or zero) from the parameter set.
- **/m Prev. Calorimetry** The sample power (Watts) of the previous calorimetric measurement. The default is NULL. This command will add an extra line containing the calorimetric measurement information and the resulted plutonium or uranium mass to the FRAMcmd.log file.
- **/n Prev. Neutron** The effective Pu240 mass (grams) of the previous neutron measurement. The default is NULL. This command will add an extra line containing the neutron measurement information and the resulted plutonium mass to the FRAMcmd.log file. If both commands **/m** and **/n** are present then **/n** will be ignored.
- **/u Prev. Uncertainty** The one sigma uncertainty for either previous calorimetric measurement or neutron measurement. The unit is either Watt or gram. The default is 0.0.
- **/d Prev. Meas. Date** The date of the previous calorimetric measurement or neutron measurement. The date must be in either the ISO 8601 international format (yyyy-mm-dd) or the American format (dd-Mmm-yyyy). The default date is the current date.
- **/x Hide Results** *0* or *1* where *0* means the results are written to the standard DBI files (releff.dbi, pcfram.dbi, etc.) and *1* means no results are written to the DBI files; only one-line results are written to the FRAMcmd.log file the end of the analysis. This command also invalidate the **/o** command. The default is *0*.

The order of the commands is not important.

FRAM /i FRAM.spe /p Pu_Plnr_120-420 /e 1
is equivalent to

FRAM /I FRAMcmd.ini

where FRAMcmd.ini is a text file containing the following statements:

```
[CmdLineConfig]
```

```
/i = FRAM.spe
```

```
/p = Pu_Plnr_120-420
```

```
/e = 1
```

In the example above, FRAM will analyze the file C:\FRAMdata\Spectra\FRAM.spe using the parameter set Pu_Plnr_120-420, the empirical efficiency model, the IAEA MMCA file format, and the correlation for the determination of Pu242. The statement [CmdLineConfig] must be at the beginning, before any command line.

For every analysis, the full results are saved in the **pcfram.dbi** file and the **pcfauto.dbi** (if auto analysis is used) file and the short results (1 line) is saved in the **FRAMcmd.log** file. All these 3 files reside in the directory containing the FRAM database. If the /o option is used then the full results are also saved in the specified output file.

Appendix F. Permitted Application Constant Names

A description of the permitted Application constant names follows. These are valid for FRAM v5 and earlier.

Command	Type	Default	Description
pu242_correlation	Real	0.	The correlation constant A in the expression for the Pu242 correlation, which has the form $Pu242=A*Pu238^B*Pu239^C*Pu240^D*(Pu241+Am241)^E$. The units are mass fraction.
pu238_exponent	Real	0.	The value of B in the Pu242 correlation above.
pu239_exponent	Real	0.	The value of C in the Pu242 correlation above.
pu240_exponent	Real	0.	The value of D in the Pu242 correlation above.
pu241_exponent	Real	0.	The value of E in the Pu242 correlation above.
u236_correlation	Real	0.	The correlation constant A in the expression for the U236 correlation, which has the form $U236=A*U235^B*U238^C+D*U235^E*Th228^F$. The units are mass fraction.
u235_exponent	Real	0.	The value of B in the U236 correlation above.
u238_exponent	Real	0.	The value of C in the U236 correlation above.
num_ecal	Integer	0	The number of peaks to be checked for peak centroid position. This check assures that the energy calibration has been maintained.
ecal_energy[.]	Real	0.	The energy in keV of a peak to be checked for peak centroid position. This energy should appear in the peak list.
ecal_channel[.]	Real	0.	The channel number including decimal fractions, if desired, of the peak centroid for the peak at ecal_energy [.]
ecal_limit[.]	Real	0.	The allowable deviation in channels of the observed peak position of the peak at ecal_energy from its specified location at ecal_channel. If the observed peak centroid position is outside the region from location minus limit to location plus limit, a warning message will be printed.
num_fwhmcal	Integer	0	The number of peaks to be checked for FWHM. This test is usually performed to see that the detector resolution is within reasonable bounds.
fcal_energy[.]	Real	0.	The energy in keV of a peak to be checked for FWHM. This energy should appear in the peak list.
fcal_limit[.]	Real	0.	The FWHM of the peak at fcal_energy[.] must be less than this limit, in eV or a warning message will be printed.

num_tailfract	Integer	0	The number of peaks to be used to check for the percentage of the total peak area falling in the tail. This test is performed to look for possible neutron damage causing excessive peak tailing.
scal_energy[.]	Real	0.	The energy in keV of a peak to be checked for its tailing percentage. This energy should appear in the peak list.
scal_limit[.]	Real	0.	The percentage of the total peak area permitted to fall under the tail. A warning message will be printed if the tail percentage is greater than this number.
num_intf	Integer	0	The number of interference peaks to be checked. Interference peaks are peaks that are somewhat likely to appear in a spectrum but are not accounted for in the parameter set. Their presence, when not accounted for in the parameter set, may bias the analysis.
intf_1st_energy[.]	Real	0.	The energy in keV of the 1st peak to be searched for.
intf_2nd_energy[.]	Real	0.	The energy in keV of the 2nd peak to be searched for.
intf_limit[.]	Real	0.	The ratio limit. If the ratio of the 1st peak area to the 2nd peak area is greater than the ratio limit then the 1st peak is the interference peak.
intf_msg[.]	String	""	Message to be printed if an interference peak is found.
num_samptype	Integer	0	The type test checks peak activity ratios and can be used for various diagnostic tests.
type_1st_peak[.]	Integer	0	Peak number (in the peak list).
type_2nd_peak[.]	Integer	0	Peak number (in the peak list).
type_lower_limit[.]	Real	0.	The lower limit of the activity ratio range.
type_upper_limit[.]	Real	0.	The upper limit of the activity ratio range.
type_msg[.]	String	""	If the activity ratio of the 1st and 2nd peaks are outside the lower-upper limit range then the message will be printed.
fix_bad_bkg	BOOL	TRUE	Control whether the background fitting is redone with an alternate function if the program senses that an unphysical background has been calculated.
restrict_fwhm_model	BOOL	FALSE	Set $A_3 = 0$ in fitting the equation $FWHM(ch) = \sqrt{A_1 + A_2 * E + A_3 / E}$
eff_use_dflts			<i>This command has no effect for FRAM v5</i>
eff_det_type			<i>This command has no effect for FRAM v5</i>

eff_upu_min	Real	0.	Indicates the minimum thickness in gm/cm ² for the sample in order to determine self-absorption.
eff_upu_max	Real	0.	Indicates the maximum thickness in gm/cm ² for the sample in order to determine self-absorption.
eff_abs_name[.]	String	""	Indicates the material used in the absorber. A total of 3 different absorbers can be used. The choices of the absorbers are: none (blank), Aluminum (Al), Iron (Fe), Cadmium (Cd), Erbium (Er), Lead (Pb), Uranium (U), water (H ₂ O), and concrete (Con).
eff_abs_min[.]	Real	0.	Specifies the minimum thickness in mm of the absorber.
eff_abs_max[.]	Real	0.	Specifies the maximum thickness in mm of the absorber.
AutoShieldTest	yes/no	no	Indicate whether a test for a shielded sample is to be performed.
AutoShieldPass	String	""	Name of the parameter set that is to be used next if the test for the shielded sample passes.
Shield_LowEnergy	Real	0.	FRAM v4: Energy of a peak in the region that would be affected by shielding of the sample. This peak must be in the peak list and from the same isotope as the Shield_HighEnergy peak. FRAM v5: Energy of a peak in the energy range covered by the efficiency curve. Peak needs not be real.
Shield_HighEnergy	Real	0.	Same as the Shield_LowEnergy peak above.
Shield_HighToLowLimit	Real	0.	FRAM v4: The ratio of the peak area divided by branching ratio for the high-energy peak to the low-energy peak is calculated. If it exceeds this limiting amount, the test for a shielded sample passes. FRAM v5: The ratio of the high-energy peak efficiency to the low-energy peak efficiency. If it exceeds this limiting amount, the test for a shielded sample passes.
AutoHeteroTest	yes/no	no	Indicate whether a test for a heterogeneous sample is to be performed.
AutoHeteroPass	String	""	Name of the parameter set that is to be used next if the test for the heterogeneous sample passes.
Hetero_AmLimit	Real	0	If the test is for Am ²⁴¹ /Pu heterogeneity and the Am ²⁴¹ /Pu ratio exceeds this limit, then the test will continue onto comparing the peaks. If it is below this limit then the AutoHetero test fails. If the test is for other isotopes then the Hetero_AmLimit command will have no effect and the AutoHetero test will continue onto comparing the peaks. Note: this command is the same as that of the AutoHighAm Test."
Hetero_Energy[1]	Real	0.	Energy of the low-energy peak to be compared. This peak must be in the peak list.
Hetero_Energy[2]	Real	0.	Energy of the high-energy peak to be compared. This peak must be in the peak list.

Hetero_LowerLimit	Real	0.	If the ratio of the activities of the low-energy peak to high-energy peak is below this limit then the test for a heterogeneous sample passes.
Hetero_UpperLimit	Real	0.	If the ratio of the activities of the low-energy peak to high-energy peak is greater than this limit then the test for a heterogeneous sample passes.
AutoHighAmTest	yes/no	no	Indicate whether a test for high americium is to be performed.
AutoHighAmPass	String	""	Name of the parameter set that is to be used next if the test for high americium sample passes.
Hetero_AmLimit	Real	0.	If the Am241/Pu ratio exceeds this limit, then the test for high americium passes. Note: this command is the same as that of the AutoHetero Test

In addition to those commands above, FRAM v5 adds a number of new commands. The commands below are valid for FRAM v5 only.

Command	Type	Default	Description
num_tailLowE	Integer	0.	The number of peaks to be checked for quality of the least square fit of the low energy tail. Maximum 4 peaks.
tailLowE_energy [.]	Real	0.	The energy in keV of a peak to be checked for quality of the fit of the low energy tail. This energy must appear in the peak list.
tailLowE_limit [.]	Real	0.	The permitted percent deviation of the fit of the low energy tail. If the absolute difference (relative to the total peak area) between the data and the fit in the region from 2 to 3 sigma's left of the peak centroid is larger than the limit then a warning message will be printed. (sigma = FWHM/2.355)
num_tailHighE	Integer	0.	The number of peaks to be checked for quality of the least square fit of the high energy tail. Maximum 4 peaks.
tailHighE_energy [.]	Real	0.	The energy in keV of a peak to be checked for quality of the fit of the high energy tail. This energy must appear in the peak list.
tailHighE_limit [.]	Real	0.	The permitted percent deviation of the fit of the high energy tail. If the absolute difference (relative to the total peak area) between the data and the fit in the region from 2 to 3 sigma's right of the peak centroid is larger than the limit then a warning message will be printed. (sigma = FWHM/2.355)
required_phys_eff_msg	String	""	If the analysis spans the K-edge is done with the empirical relative efficiency curve fit then the message will be printed.
fix_100kev_plutonium	BOOL	FALSE	Correct the large bias due to the large tail and FWHM in the 100-keV region analysis of plutonium. It has no effect for analysis in the energy region above 120 keV.

fix_100kev_uranium	BOOL	FALSE	Correct the large bias due to the large tail and FWHM in the 100-keV region analysis of uranium. It has no effect for analysis in the energy region above 120 keV.
syst_error_pu238	Real	0.	Systematic uncertainty of Pu238. A positive number represents the percent uncertainty. A negative number would invoke the built-in bias. The absolute value of the negative number is the multiplication factor of the built-in bias.
syst_error_pu239	Real	0.	Systematic uncertainty of Pu239. See description for Pu238 above.
syst_error_pu240	Real	0.	Systematic uncertainty of Pu240. See description for Pu238 above.
syst_error_pu241	Real	0.	Systematic uncertainty of Pu241. See description for Pu238 above.
syst_error_pu242	Real	0.	Systematic uncertainty of Pu242. See description for Pu238 above.
syst_error_am241	Real	0.	Systematic uncertainty of Am241. See description for Pu238 above.
syst_error_u234	Real	0.	Systematic uncertainty of U234. A positive number represents the percent uncertainty. A negative number would invoke the built-in bias. The absolute value of the negative number is the multiplication factor of the built-in bias.
syst_error_u235	Real	0.	Systematic uncertainty of U235. See description for U234 above.
syst_error_u236	Real	0.	Systematic uncertainty of U236. See description for U234 above.
syst_error_u238	Real	0.	Systematic uncertainty of U238. See description for U234 above.
correct_u_sumpeaks	BOOL	TRUE	Correct for the intensities of the U238 peaks that undergo the sum peak problem. This command has no meaning for analysis in the 100-keV energy region.
u236_correlation2	Real	0.	The value of D in the U236 correlation $U236=A*U235^B*U238^C+D*U235^E*Th228^F$. The units are mass fraction.
u235_exponent2	Real	0.	The value of E in the U236 correlation above.
th228_exponent	Real	0.	The value of F in the U236 correlation above.
num_iterations	Integer	3	The number of times that the background, relative efficiency, peak area, and isotopic results calculations are repeated or iterated. In FRAM v.4 and earlier versions, this value is set in the General Default setup and is applied for every analysis. In FRAM v.5, this value is set in the parameter set and is applied for that parameter set only.

restrict_tail_model	BOOL	FALSE	Fix T2 to the default value in fitting the equation $\text{tail}(ch) = H * \exp((T1 + T2 * E) + (T3 + T4 * E) * (ch - x0)) * [1 - \exp(-C * (ch - x0)^2)]$. Also, when the least square fit using the full tail model fails then the code will set the tail model to restricted and then refit the data.
restrict_efficiency_model	BOOL	FALSE	Set $c5 = 0$ in fitting the empirical relative efficiency curve $\ln(\text{eff}) = c1 + c2/E^2 + c3 * \ln(E) + c4 * [\ln(E)]^2 + c5 * [\ln(E)]^3 + c6 + c7/E$. This command has no effect on the physical model efficiency curve fit.
AutoUnshieldTest	yes/no	no	Indicate whether a test for an unshielded sample is to be performed.
AutoUnshieldPass	String	""	Name of the parameter set that is to be used next if the test for the unshielded sample passes.
Unshield_LowEnergy	Real	0.	Energy of a peak in the energy range covered by the efficiency curve. Peak needs not be real.
Unshield_HighEnergy	Real	0.	Energy of a peak in the energy range covered by the efficiency curve. Peak needs not be real.
Unshield_LowToHighLimit	Real	0.	The ratio of the high-energy peak efficiency to the low-energy peak efficiency. If it exceeds this limiting amount, the test for an unshielded sample passes.
Unshield_LowEnergyFWHM	Real	100000.	The FWHM upper limit in eV. If the FWHM of the low energy peak is below this limit and the Unshield_LowToHighLimit ratio (see above) is passed then the test for an unshielded sample passes.
AutoMoxTest	yes/no	no	Indicate whether a test for a MOX sample is to be performed in the plutonium analysis. U235 must be in the isotope list.
AutoMoxPass	String	""	Name of the parameter set that is to be used next if the test for the MOX sample passes.
Mox_U235Limit	Real	0.	If U235/Pu exceeds this limit, then the test for the MOX sample passes.
AutoisotopeRatioTest	yes/no	no	Indicate whether a test for the mass ratio of 2 isotopes is to be performed.
AutoisotopeRatioPass	String	""	Name of the parameter set that is to be used next if the test for the Isotope ratio passes.
First_Isotope	String	""	Name of the first isotope. This isotope must be in the isotope list.
Second_Isotope	String	""	Name of the second isotope. This isotope must be in the isotope list.
FirstToSecondIsoLimit	Real	0.	The test forms the ratio of the mass of the first isotope to the mass of the second isotope. If the ratio exceeds this limiting amount, the test for the isotope ratio passes.

AutoPeakRatioTest	yes/no	no	Indicate whether a test for the ratio of the peak areas of 2 peaks is to be performed.
AutoPeakRatioPass	String	""	Name of the parameter set that is to be used next if the test for the Peak ratio passes.
First_Peak	Real	0.	Energy of the first peak. This peak must be in the peak list.
Second_Peak	Real	0.	Energy of the second peak. This peak must be in the peak list.
FirstToSecondPeakLimit	Real	0.	The ratio of the first peak are to the second peak area. If it exceeds this limiting amount, the test for the peak ratio passes.
AutoFreshPuTest	yes/no	no	Indicate whether a test for fresh plutonium sample is to be performed.
AutoFreshPuPass	String	""	Name of the parameter set that is to be used next if the test for the fresh plutonium sample passes.
FreshPu_1stPeak	Real	0.	Energy of the 1st peak (normally of Pu241 decay) to be used in the fresh plutonium test. This peak must be in the peak list.
FreshPu_2ndPeak	Real	0.	Energy of the 2nd peak (normally of U237 decay) to be used in the fresh plutonium test. This peak must be in the peak list.
FreshPu_1stTo2ndLimit	Real	0.	The ratio of the normalized $[Area/(BR*Eff)]$ 1st peak to the 2nd peak is calculated. If it exceeds this limiting amount, the test for a fresh plutonium sample passes.
FRAM_SUMMARY_TYPE	SNM	PLUTONIUM	There are 2 summary types: PLUTONIUM & URANIUM. This command was used in FRAM v2 and v3 but not v4. It is again implemented in FRAM v5.

Appendix G. Nuclear Data

FRAM uses nuclear data in its various calculations.

The nuclear data (half lives and specific powers) for the plutonium isotopes and ^{241}Am used in the ISOPOW decay corrections comes from ASTM C 1458-00, "Standard Test Method for Nondestructive Assay of Plutonium, Tritium and ^{241}Am by Calorimetric Assay." These values are hard-wired into the FRAM software. The **Measure | Compare** option uses these same hardwired values.

Each parameter set also contains user editable values for half-life, Atomic Mass, Specific Power, and the $^{240}\text{Pu}_{\text{eff}}$ coefficient. The Built-In parameter sets use the ASTM C 1458 values for the plutonium isotopes. The uranium half lives come from the 8th Ed of the Table of Isotopes. The uranium specific powers are calculated from the decay schemes.

The hard-wired values in ISOPOW and the values for the same parameters in the parameter set are not connected. Changing a value in the parameter set will not affect the same parameter in ISOPOW.

The initial values in the Built-In parameter sets and the hardwired values in ISOPOW and **Measure | Compare** are the same. The two screens below display this data for the most commonly encountered isotopes.

Isotope data in the **Mox_Cx_180-1010** Built-In parameter set.

	isotope	half-life (years)	mass	Power mW/g	Pu240 coef
1	Pu239	2.41190e+004	239.05220	1.92880e+000	0.0000
2	Pu241	1.43480e+001	241.05690	3.41200e+000	0.0000
3	Pu238	8.77400e+001	238.04961	5.67570e+002	2.5200
4	Pu240	6.56400e+003	240.05380	7.08240e+000	1.0000
5	Pu242	3.76300e+005	242.05874	1.15900e-001	1.6800
6	Am241	4.33600e+002	241.05679	1.14200e+002	0.0000
7	U235	7.03800e+008	235.04390	5.99600e-005	0.0000
8	U238	4.46800e+009	238.05080	8.51000e-006	0.0000
9	Np237	2.14000e+006	237.04817	2.07200e-001	0.0000
10	Am243	7.37000e+003	243.06140	6.43500e+000	0.0000

Isotope data in the **U_Cx_120-1010** Built-In parameter set.

	isotope	half-life (years)	mass	Power mW/g	Pu240 coef
1	U235	7.03800e+008	235.04390	5.99600e-005	0.0000
2	U238	4.46800e+009	238.05080	8.51000e-006	0.0000
3	U234	2.45500e+005	234.04090	1.79200e-001	0.0000
4	U236	2.34200e+007	236.04560	1.75400e-003	0.0000
5	Th228	1.91310e+000	228.02873	1.84600e+005	0.0000

Appendix H. Technical Support

Questions, comments, and trouble reports for this program should be directed to:

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