ORTEC®

Multi-Group Analysis
MGA++

The U235 Program
Uranium Isotopic Abundance by Gamma-Ray Spectroscopy

U235View
Part 2 of MGA-B32

Software User's Manual

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Advanced Measurement Technology, Inc.

a/k/a/ ORTEC®, a subsidiary of AMETEK®, Inc.

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NOTE!

We assume that you are thoroughly familiar with 32-bit Microsoft® Windows® usage and terminology. If you are not fully acquainted with the Windows environment, including the use of the mouse, ***we strongly urge you to read the Microsoft documentation supplied with your Windows software and familiarize yourself with a few simple applications before proceeding.***

The convention used in this manual to represent actual keys pressed is to enclose the key label within angle brackets; for example, **<F1>**. For key combinations, the key labels are joined by a + within the angle brackets; for example,

1. INTRODUCTION

The U235View program uses gamma-ray and x-ray emissions to analyze and report on the isotopic abundances of plutonium and other actinides in a sample. This nondestructive technique has been in use since1974,[1] and has been constantly refined and improved since then. The analysis methods and algorithms used in this program have been developed for analyzing gamma-ray spectra from a germanium detector, and are used here under license.[2] The program accurately determines the relative abundances of several different uranium isotopes in a sample. The methods require only an energy and peak-shape calibration, and are thus suited to measure any shape or size of uranium sample. Measurement times can be as short as a few minutes. With proper care, measurement accuracies can be within 1% of the stated value.

U235View, in conjunction with MAESTRO™-32, controls the MCB hardware and the acquisition of one or two spectra, sets the analysis parameters, analyzes the spectrum (or spectra), produces a report, and stores the results in a Microsoft Access®-format database. The spectra are stored in ORTEC format with complete analysis and available hardware settings stored in the file. The spectra can be re-analyzed at anytime, either by U235View, MGAView, or GammaVision®-32.

To ensure consistent results, the physical parameters of all the relevant isotopes (such as gamma-ray or x-ray energy, yield, and half-life) are stored in the program.

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[1]R. Gunnink, J.B. Niday, and P.D. Siemens, *A System for Plutonium Analysis by Gamma-Ray Spectrometry*, LLNL, Livermore, CA, UCRL-51577 (1974).

[2]U235View is the subject of a cooperative research and development agreement (CRADA TSV-1368-96) and license (License Number TL-1375-96) between ORTEC and the University of California under which ORTEC is integrating those programs into the ORTEC software environment to enhance usability.

2. SYSTEM REQUIREMENTS

Due to the complexity of the spectrum, the U235View software requires the following minimum hardware specifications, which can be met with normal, commercial components.

2.1. Detector Specifications

A germanium detector with a resolution (full width half maximum [FWHM]) less than 550 eV at 122 keV is recommended. Detectors with resolutions of 600 keV or above may not produce results with sufficient precision. Where the count rate is high, the detector can be a relatively small-volume planar detector. For counting small or low-count-rate samples, large-volume detectors can be used, but attention must be given to maintain as good a resolution as possible.

The peak shape of the net counts in the full-energy peak should be as Gaussian as can be obtained. The amount of low-energy tailing should not be detectable at 10% of the peak height and should be insignificant at 2% of the peak height. The amount of high-energy tailing should not be detectable at all, but may appear at high count rates. If high-energy tailing is noticed, reduce either the count rate or the shaping time. The count rate can be reduced with cadmium or copper absorbers to reduce the low-energy counts.

The ORTEC Model "SG" Series Safeguards Detectors are optimized for this application.

2.2. Signal Processing

Spectrum analysis for actinide isotopic ratios is an extremely difficult procedure. Good quality nuclear electronics are required for the best analysis results. If analog electronics such as the Model 92X-II or DART® are used, a shaping time constant of 1 µs for high count rates (20k to 40k counts/s) and a shaping time constant of 2 µs for low count rates (<20k counts/s) are needed. When a high energy (coaxial) detector is used, shaping times of less than 2 µs are not likely to give satisfactory results. For DSP systems such as the DSPEC®, similar equivalent shaping times are needed, although the time constants can be increased (to obtain better resolution) and still maintain the pulse throughput without peak-shape deterioration.

The electronics should also include pulse-pileup rejection to reject coincidence or summed peaks, and baseline restoration to maintain detector resolution. The system must be stable with regard to zero level and gain over the expected temperature range or have zero and gain stabilizers.

The multichannel analyzer (MCA, also called the multichannel buffer or MCB) must have a conversion gain of at least 4096 channels. Some special applications will require a conversion gain of 8192 channels. For high count rate applications, consideration should be given to the

limit placed on the maximum throughput by ADC speed and amplifier shaping time[3]. The MCB must have a sufficiently low conversion time that the dead time of the analysis is low. The MCB must also have good differential and integral linearity. All of these requirements are met by ORTEC MCBs such as the portable DART and the DSPEC.

2.3. Computer

The operator interface program, U235View, and the analysis module, U235, are 32-bit applications that must be run under Windows 95 or Windows NT®. Any PC that will run Windows 95/NT is sufficient to run U235View. A high-capacity hard disk for spectrum storage is useful, and a color monitor is recommended.

U235View communicates with the MCB hardware and is ***CONNECTIONS-32*** compliant. This means that it will communicate with any supported MCA using the ORTEC Dual-Port Memory Interface (such as the 92X), the printer port interface (such as the DART), the Ethernet interface (such as the DSPEC), and the serial port interface (such as the LANL M^{3}CA or the MCA166 by GBS).

[3]"High-Count-Rate Spectroscopy with Germanium Detectors: Quantitative Evaluation of the Performance of High-Rate Systems," T.R. Twomey, R.M. Keyser, M.L. Simpson, and S.E. Wagner, *Radioact. Radiochem.*, Vol. 2, No. 3, 1991.

3. GETTING STARTED

The following procedure outlines the steps needed to start U235View and analyze a sample. Detailed instructions for all of the U235View functions are in Chapter 5.

3.1. Software Installation

The installation program installs both MGAView and U235View, and configures the system. Before installing MGAView/U235View, connect the MCBs to the PC and power them on; otherwise the configuration program will not locate the MCBs, and configuration will have to be performed at a later time. Until configuration is completed, the user will not be able to access the MCBs by computer to set them up for data acquisition. The hardware is set up in the following section using the MAESTRO software, which needs a completed configuration to access the MCBs.

MAESTRO should be installed according to the instructions included with the MAESTRO software. The Windows 95/NT version is required. MAESTRO is used for the MCA setup. Once the setup is complete, MAESTRO can be removed.

Put Disk 1 in drive A: and click on **Start**, then **Run...**. Enter **`A:SETUP`** in the **Run** dialog and click on **OK**.

3.1.1. Installation Options

Typical This is the standard installation which includes graphics and database. If this is a reinstallation, this option will ask if you want to overwrite your database. ***Make sure you have a backup of any prior U235View database before allowing that database to be overwritten!***

Custom This option allows you to install the database but disable the graphics display by unmarking the graphics option.

Compact This setup does not install the database or graphics. Use this should you need to reinstall U235View.

To disable U235View's (and MGAView's) graphics capability, see Appendix F.1.

3.1.2. To Complete Installation

Restart the PC.

If the MCBs were not connected during the installation of MGAView/U235View, run the MCB Configuration program by going to the Windows Taskbar and clicking on **Start**, **Programs**,

MGA, then **MCB Configuration**. A list of the connected detectors will be shown. The default detector names (descriptions) are based on the physical hardware names. These can be changed to more personalized descriptions in the MCB Configuration program. Complete details are in Appendix G.

3.2. Hardware Setup

The detectors, signal electronics, MCBs, and computer should be connected and setup according to the manufacturer's instructions for each part. A gamma-emitting radioactive source of any type is needed for setup of the MCBs and amplifiers.

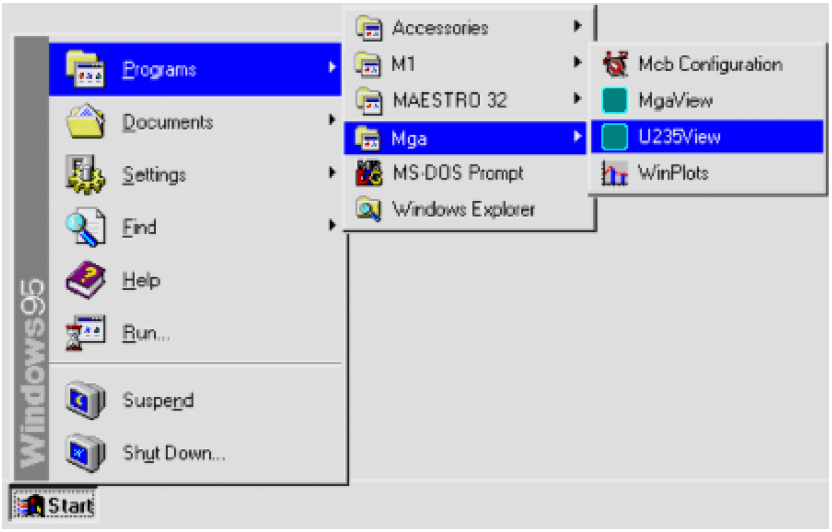

Fig. 1. Starting U235View.

Start U235View by going to the Taskbar and clicking on **Start**, **Programs**, **Mga**, and **U235View** (see Fig. 1). Figure 2 shows the initial U235View screen. Its features are discussed in detail in Chapter 4.

There is a field on the right half of the *Spectrum Toolbar* (located just above the display area). It contains a drop-down list of the MCBs connected to the PC. Click on the field (or the down arrow beside it), then click on the desired MCB. The toolbars can be turned off, so the display may not look exactly like this.

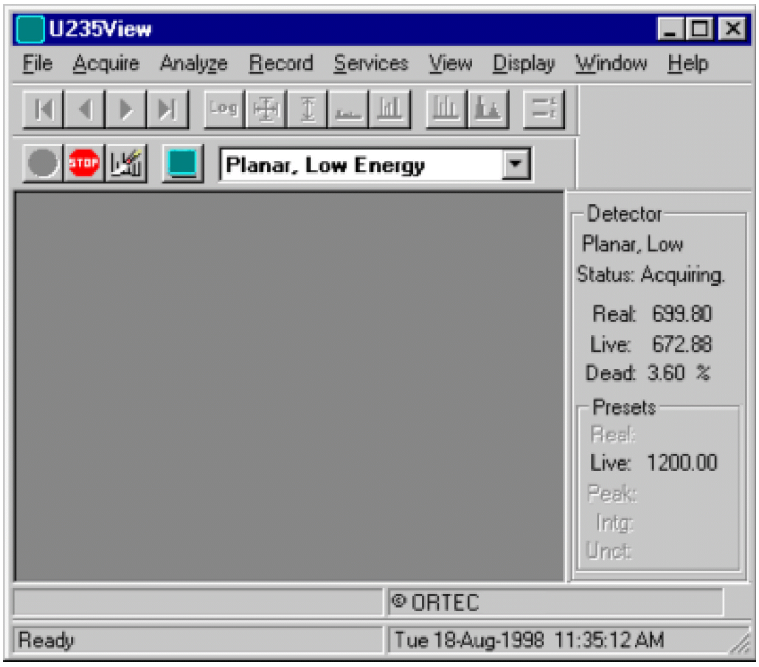

Fig. 2. The U235View Screen.

3.2.1. Hardware Adjustment

Start MAESTRO-32 by clicking on the **Run MAESTRO** toolbar button. In MAESTRO, display the spectrum for the same MCB by using **Display/Detector...**, then clicking on the MCB name.

Go to **Acquire/Adjust Controls...**. If the MCB has software-controlled polarity, set it to the correct polarity. Otherwise, set the hardware to the correct polarity. Set the amplifier input polarity to the polarity required by the detector. Turn on the high voltage. Click on **OK** to leave the **Adjust Controls...** dialog.

Now select **Acquire/ADC Setup...** to set the ADC conversion gain to 4096 channels. Click on **OK** to leave the **ADC Setup...** dialog.

Put the radioactive source in front of the detector and start the acquisition by selecting **Acquire/Start**. A spectrum should begin accumulating on the display. Set the display to **Log** mode if needed.

Select **Acquire/Adjust Controls...** to show the MCB control dialog. If using a DSPEC, set up the controls according to the "Adjust DSPEC Controls" section of the MAESTRO manual and click on **Optimize**. For other MCBs, select the shaping time desired and click on the **Pole Zero** button. For manual systems, manually select the shaping time and perform the pole zero.

NOTE A near Gaussian peak shape is required for a good analysis. This is only possible if the pole zero adjustment is correctly done. For manual pole zero systems, perform the pole zero carefully and verify that it is correct. For automatic pole zero, verify that it has been done according to the procedure in the manual.

To be certain that the adjustment is correct, collect a spectrum of a simple source such as ^{57}Co and use the MAESTRO **Calculate** function to verify the peak shape. The FW.1M/FWHM ratio for a perfect Gaussian peak is 1.83; the FW.02M/FWHM ratio is 2.38.

The peak shape calibration is discussed in Section 5.2.10 and below.

Adjust the coarse and fine gain until a calibration of about 0.075 keV/channel is obtained. The gain should be within 5% of this value. Table 1 shows the channel number for some energies with this gain. This is best done with a source with only a few energies.

Table 1.

Nuclide	Energy	Channel
Am-241	59.5	794
Cd-108	88	1173
Co-57	122.1	1627
Ce-139	165.8	2210
U-237	208	2773

Next, perform an exact calibration on the MCB using the calibration feature of MAESTRO. The MAESTRO-32 *Software User's Manual* provides complete details, but here is an outline of the steps:

1. Mark the known peaks as ROIs by putting the marker on each peak and pressing the <**Insert**> key.

2. Put the marker in the lowest-energy ROI.

3. Click on **Calculate/Calibrate** and enter the energy of the peak.

4. Press **<Shift + →>** to go to the next higher ROI, click on **Calculate/Calibrate**, and enter the energy of the peak.

5. Repeat this for all the ROIs in the spectrum. This calibration will be stored in the MCB and in each spectrum file acquired with this MCB until it is recalibrated.

6. Check the resolution at this time by double-clicking in the ROI. The FWHM and FW(1/10)M will be displayed for the peak. If FW(1/10)M is not shown, go to **Calculate/Settings** and change the "**x**" to 10. Verify that the FWHM agrees with the detector specifications.

7. Now exit MAESTRO by clicking on the × box in the upper-right-hand corner.

8. In U235View, set the preset time for the collection using **Acquire/Preset Limits**.

Now select **Acquire/Calibrate** and perform the Peak Shape Calibration according to the methods in Section 5.2.10.

The system is now ready to collect and analyze a sample spectrum. Put the sample in front of the detector and select **Acquire**, then **Start/Save/Report**. The sample spectrum will be collected, stored on disk, analyzed, and the results printed and stored in the database.

4. DISPLAY FEATURES

This chapter covers U235View's display features, discusses the role of the mouse and keyboard, covers the use of the toolbar buttons and fields, and shows how to change to different disk drives and folders.

4.1. Main Screen Features

Figure 3 shows U235View's principal screen features.

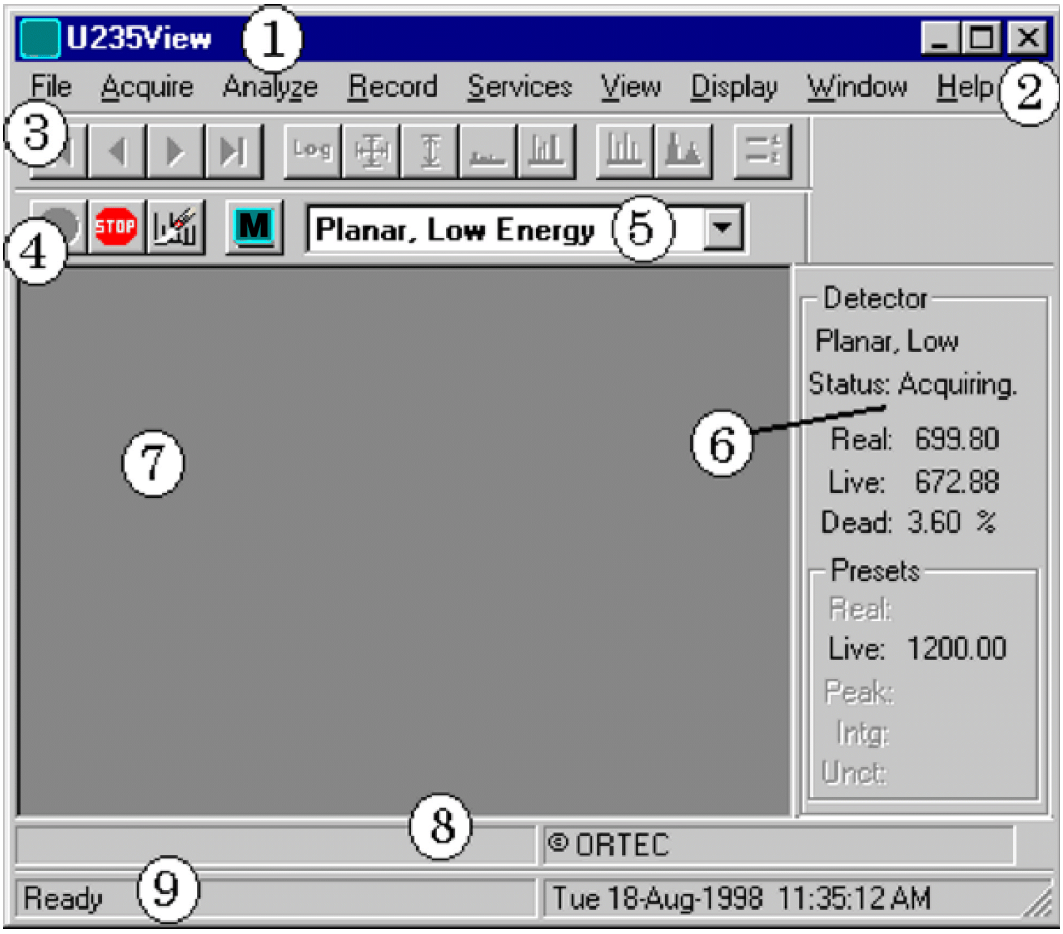

Fig. 3. U235View Main Display.

1. **Main title bar**, contains the Minimize, Maximize, and Close buttons on the far right. If one of the windows in the display area is maximized, the contents of its title bar are shown in the main title bar.

2. **Menu bar**, shows the commands that can be selected with the mouse or keyboard; see Chapter 5.

3. **Analysis (or Standard) Toolbar**, beneath the menu bar, contains speed buttons for indexing through the records in the various database tables, and adjusting a spectrum's vertical and horizontal scale.

4. **Spectrum Toolbar** contains speed buttons for starting and stopping data acquisition, clearing the current spectrum from the display, starting MAESTRO, and selecting an MCB for acquisition.

5. **Detector field**, provides a drop-down pick list of the available MCBs, and lists the currently selected MCB.

6. **Detector sidebar** displays the current status of the MCB, including the real time, live time, dead time, and presets.

7. **Display area** can display several windows at once, showing the spectrum being acquired/analyzed, as well as one or more analysis results tables (selected using the **View** menu [Section 5.6]). These windows can be moved, sized, minimized, maximized, and closed with the mouse; and cascaded or tiled from the **Window** menu.

8. **Hardware status line**, beneath the display area, showing the present state of the MCB, error messages, etc.

9. **System status line**, beneath the hardware status line, displaying *tool tips* when the mouse is over a button or icon, error messages, etc.

4.2. Analysis Toolbar

The first four buttons on this toolbar allow you to move through the records in the analysis results database. They are active only when a database table is open in the display area. The remaining eight buttons control the spectrum scaling and legend, and are active only when a spectrum window is open.

Move to First Record jumps to the first record in the results database.

Move to Previous Record steps to the previous record in the results database.

Move to Next Record steps to the next record in the results database.

Move to Last Record jumps to the last record in the results database.

Log/Linear Display switches between logarithmic and linear scaling.

Automatic reads the data set and adjusts the X and Y axes so the entire plot fills the maximum space available to it on-screen (scaling up a small graph and scaling down a "too-big" graph).

Automatic Y adjusts the Y axis so the currently displayed peaks fill the maximum vertical space available.

Shorter switches the spectrum display to a linear vertical scale and increases the full-scale value, making the peaks appear shorter. Only active when display is zoomed in.

Taller switches the spectrum display to a linear vertical scale and decreases the full-scale value, making the peaks appear taller. Only active when display is zoomed in.

Narrower increases the horizontal full scale of the spectrum window so that the peaks appear narrower. Only active when display is zoomed in.

Wider decreases the horizontal full scale of the spectrum window so that the peaks appear wider. Only active when display is zoomed in.

Legend On/Off toggle displays or hides the legend box for the spectrum in the active display window.

4.3. Spectrum Toolbar

These speed buttons control data acquisition.

Start Acquisition starts data acquisition in the current detector(s).

Stop Acquisition stops data collection.

Clear the Detector clears the detector data from the window.

Run MAESTRO starts MAESTRO-32.

The right half of the toolbar contains a drop-down list of the available detectors (Fig. 4). To select a detector, click in the field or on the down-arrow beside it to open the list, then click on the desired detector. The detector sidebar will update to show the values for the selected detectors. (To display the spectrum, select **Spectrum** from the **View** menu; see Section 5.6.4.)

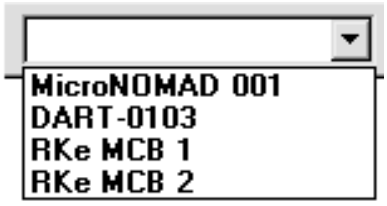

Fig. 4. Detector List on Spectrum Toolbar.

4.3.1. Spectrum and Table Window Features

Each window in the display area has a title bar with an icon indicating the window type — spectrum ( ) or table ( ) — and lists the detector/disk file description or the table name, respectively. If a window is maximized, the contents of its title bar are shown in the main U235View title bar.

Each window has its own Minimize, Maximize, and Close buttons, which, respectively, reduce the active window to a short title bar (Planar, Low...) at the bottom of the display area, fully expand the window to occupy the entire display area, and close the window. (Refer also to your Windows 95/NT documentation.) Note that when you maximize a window, these three buttons move to the far right of the menu bar.

Only one spectrum window can be open at a time. If you choose another MCB from the list, its spectrum will replace the previous MCB's spectrum in the spectrum window. However, one or more results database tables and spectrum analysis windows can be open at the same time.

4.3.2. Zooming In on an Area of Interest in a Spectrum

In spectrum windows, the mouse pointer is shaped like a "magnifying glass." Use this to draw a *rubber rectangle* around an area of interest and zoom in on it. Position the mouse on one corner of the desired area, press the left mouse button and drag the mouse diagonally across the area to be magnified (see Fig. 5). When you release the mouse button, the graph axes will scale up to the approximate extent of the rubber rectangle and the area of interest will enlarge accordingly. Use the **Automatic** button on the Analysis Toolbar to restore the graph to its original scaling.

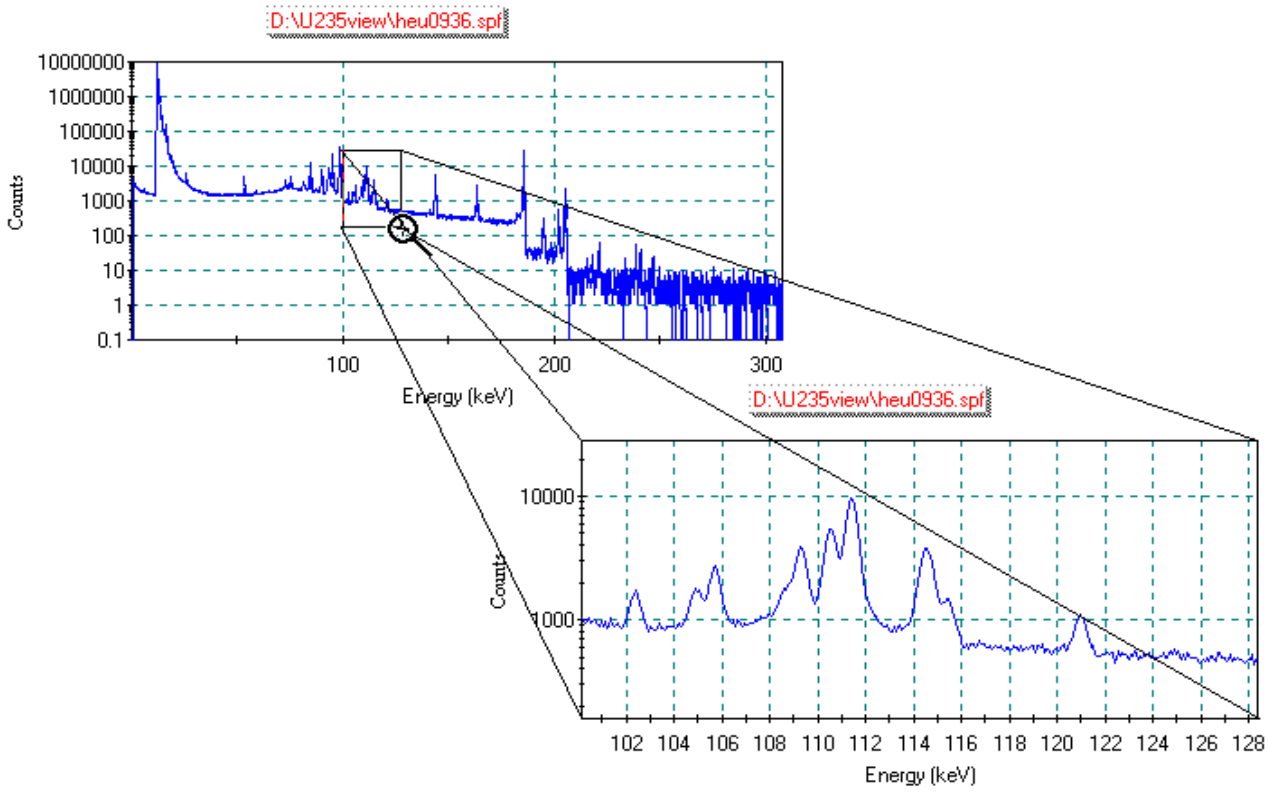

Fig. 5. Zooming In on an Area of Interest.

4.4. Buttons and Boxes

This section describes U235View's radio buttons and checkboxes. To activate a button or box, just click on it.

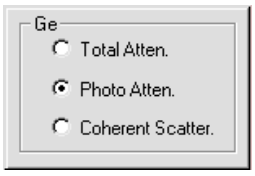

Fig. 6. Radio Buttons.

Radio buttons (Fig. 6) allow the user to switch between *mutually exclusive choices.*

Checkboxes (Fig. 7) indicate that the user can choose *one or more options* at one time.

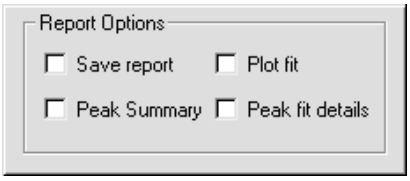

Fig. 7. Checkboxes.

4.5. Using the File Recall/Save Dialogs

U235View provides a consistent user interface for all functions that involve reading files from or writing files to disk. The standard file recall/save dialog (an example of which is shown in Fig. 8) includes a **Look in:** or **Save in:** box that allows the user to specify the drive and pathname, a list-of-files box, a **File name:** box, a **Files of type:** box, and, on certain dialogs, a **Show Description** checkbox that allows the user to display a sample description, if available.

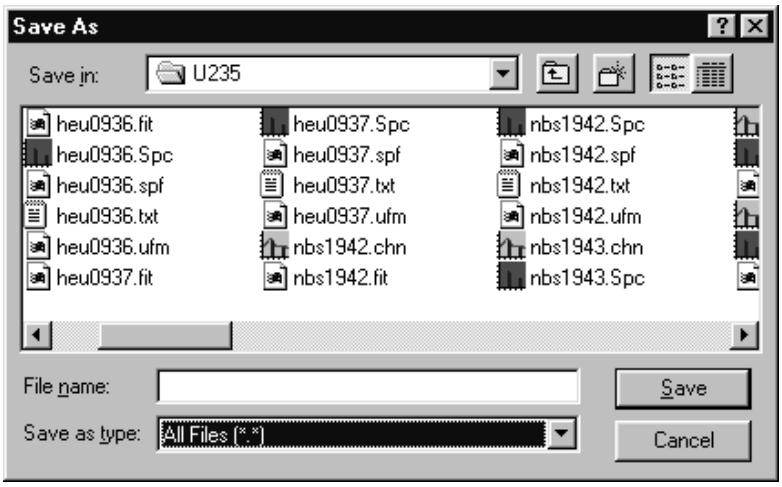

Fig. 8. Standard File Save Dialog.

Any extension or filename can be entered in the **File name:** field. If this entry contains wildcards (* or ?) and the user clicks on **OK**, the list-of-files box will show the list of all files for the current drive and path that meet the wildcard requirements.

The default list of files is set to the appropriate file type for the function being performed. For example, in **Analyze/Display Analysis Results**, if you leave the default filename criterion, **Background fit files (.spf)**, in the **Files of type:** field, the list-of-files box will display *only* the files that have the extension **`.SPF`**. In addition to typing in a wildcard search, you can also click on the **File of type:** field to open its drop-down list, then choose one of its file extensions/types.

To recall an existing file, double-click on its filename in the list-of-files box; or enter its filename in the **File name:** field, then press **<Enter>** or click on **Open**.

In some cases, you will be saving new data for which no file exists yet. To do this, enter the new filename in the **File name**: field and click on press **<Enter>** or click on **Save**.

The **Save As** dialog also allows you to "reuse" an existing filename by saving new data into an existing file. *Note that this completely overwrites (destroys) the previous data*. To do this, double-click on a filename from the list-of-files box or enter one of those existing filenames into the **File name:** field, then press **<Enter>** or click on **Save**. The system will display a message saying, "**This file already exists. Replace existing file?**" Click on **Yes** to save the new data or **No** to cancel the **Save As** operation.

4.5.1. Changing Drive and Pathname

There are two ways to change to another directory and/or drive: click on the **Look in:**/**Save in:** field to open a drop-down list of all drives and subdirectories connected to your PC (see Fig. 9); or click on the **Up One Level** button (just right of the **Look in:**/**Save in:** field) to move, one level at a time, to higher- and higher-level directories. In both cases, movement through the drives and directories is similar to using Windows 95/NT Explorer.

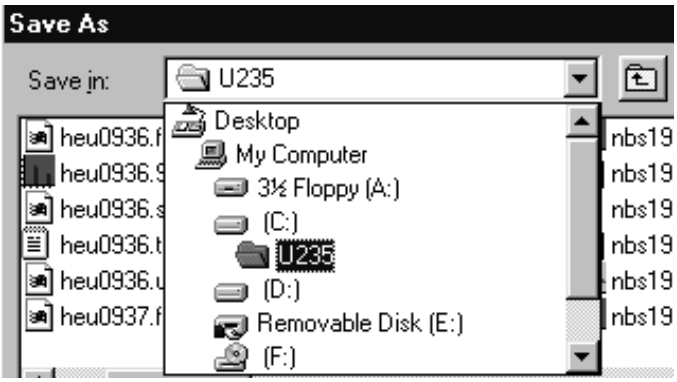

Fig. 9. Changing Drive and Pathname with the Drop-Down List.

5. MENU COMMANDS

This chapter describes all the U235View menu functions and their associated dialogs. As is customary for Windows menus, the accelerator(s) (if any) are shown to the right of the menu function they duplicate. Also, the underlined letter in the menu item indicates a key that can be used together with the **<Alt>** key for quick access in the menu. (So, for example, the **Settings...** dialog under the **Acquire** menu can be reached by the following key sequence: **<Alt + A>**, **<Alt + S>**.) The ellipsis (**...**) following a menu selection indicates that a dialog is displayed to complete the function. Finally, a small arrow ("▸") following a menu selection means a submenu with more selections will be shown. The menus covered in this section, in the order they appear on the menu bar, are as follows:

File
- Exit

Acquire
- Preset Limits...
- Settings...
- Count rate...
- Start <Alt + 1>
- Start/Save/Report
- Stop <Alt + 2>
- Clear <Alt + 3>
- Save
- Re-start/Save/Report
- Calibrate

Analyze
- Settings...
- Spectrum on Disk...
- Spectrum in MCB
- Display Background Fit
- Display Analysis Results

Record
- First Record
- Previous Record
- Next Record
- Last Record

Services
- Lock/Unlock detector...
- Edit detector List...
- Run MAESTRO

View
- Detector Bar
- Analysis Toolbar
- Spectrum Toolbar
- Status Bar
- Analysis Table
- Acquisition Table
- By Isotope
- Spectrum

Display
- Taller
- Shorter
- Automatic Y-Axis
- Automatic
- Logarithmic
- Narrower
- Wider
- Legend

Window
- Cascade
- Tile
- Arrange Icons

Help
- Help Topics
- About U235View...

NOTE To prevent the MCB parameters, such as gain or pole zero, from being changed, you may remove MAESTRO-32 from the PC after hardware setup is completed. From the Windows Taskbar, click on **Start**, **Settings**, **Control Panel**, and **Add/Remove Programs**. On the list of installed programs, click on **MAESTRO for Windows**, click on the **Add/Remove** button, and answer any prompts.

5.1. File

The only menu item for **File** is **Exit**, as shown in Fig. 10. This closes U235View. This will abort any Start/Stop/Report in progress, but will not stop the data collection.

Fig. 10.

5.2. Acquire

The **Acquire** menu is shown in Fig. 11. These functions control spectrum acquisition.

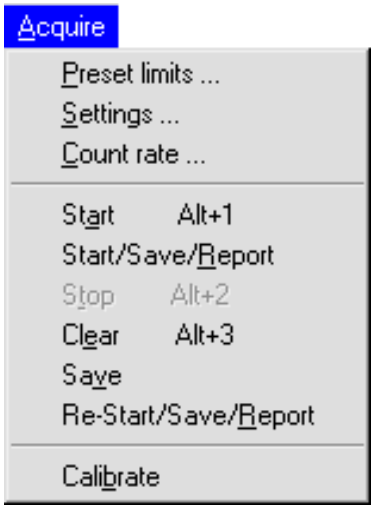

Fig. 11. Acquire Menu.

5.2.1. Preset Limits...

The **Preset** dialog is shown in Fig. 12. Any or all of the presets can be used at the same time. If a preset type is not valid for the selected MCB, it is not shown. This function is available only on MCBs that are not acquiring data.

The **Real Time** and **Live Time** fields are used to enter the real-time and live-time presets, respectively (in units of seconds and fractions of a second). These values are stored internally with a resolution of 20 milliseconds (ms), since the MCB clock increments by 20 ms. *Real time* means elapsed time or clock time. *Live time* refers to the amount of time that the MCB is available to accept another pulse (i.e., is not busy), and is equal to the real time minus the *dead time* (the time the MCB is not available).[4]

The **ROI Peak** field is used to enter the ROI peak count preset (in counts). With this preset condition, the MCB stops counting when any ROI channel reaches this value, unless there are no ROIs marked in an MCB, in which case that MCB continues counting until the count is manually stopped.

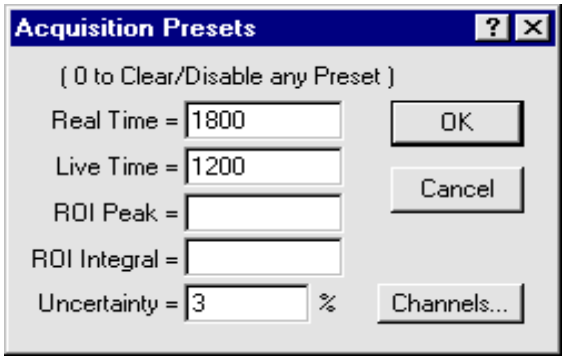

Fig. 12. The Acquisition Presets Dialog.

The **ROI Integral** field is used to enter the ROI integral preset value (in counts). With this preset condition, the MCB stops counting when the sum of all counts in all channels for this MCB marked with an ROI reaches this value, unless no ROIs are marked in the MCB.

[4]Isotopic Ratio Analysis does not require good dead time correction accuracy since it is based on relative peak amplitudes in a single spectrum or on two spectra collected at the same time.

The **Uncertainty** preset (DSPEC, DART, and 92X-II only) is used to stop acquisition when the statistical or counting uncertainty of a user-selected net peak reaches the value entered by the user. The value is entered as percent uncertainty at 1 sigma of the net peak area. The user has complete control over the selected peak region. As the uncertainty is calculated approximately every 30 seconds, the uncertainty achieved for a high count rate sample may be better than the preset value.

The 1-sigma **Uncertainty** is entered as percent in the **Acquisition Presets** dialog. The range is from 99% to 0.1% in 0.1% steps. The peak region is selected by clicking on the **Channels...** button.

The **Uncertain Peak Channels** dialog (Fig. 13) allows the user to enter the channel limits directly.

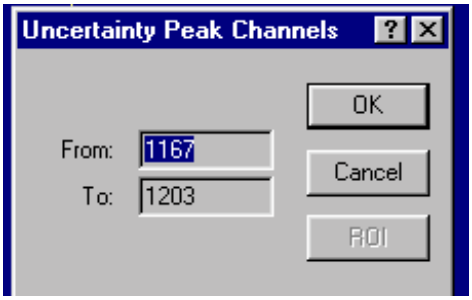

Fig. 13. Peak Region Selection.

The net peak area and statistical uncertainty are calculated in the same manner as in the **Peak Info** calculation (see the MAESTRO user manual).

To disable any preset, enter a value of zero (which the MCB interprets as “infinity”). If all preset conditions are disabled, data acquisition continues until manually stopped.

Any or all of the presets can be enabled at one time. When more than one preset is set to a non-zero value, the first condition met during the acquisition causes the Detector to stop. This can be useful when samples of widely varying activity are analyzed and the general activity is not known before counting. For example, the **Live Time** preset can be set so that sufficient counts can be obtained for proper calculation of the activity in the sample with the least activity. But if the sample contains a large amount of this or another nuclide, the dead time may be high, resulting in a long counting time for the sample. By setting the **ROI Peak** preset in addition to the **Live Time** preset, the low-level samples will be counted to the desired fixed live time while the very active samples will be counted for the ROI peak count. Therefore, the **ROI Peak** preset can be viewed as a “safety valve.”

The values of all presets currently loaded into the selected MCB are shown in the detector sidebar to the right of the spectrum display. These values are not changed by the entry of new values in the **Acquisition Presets** dialog until the user clicks on **OK**. To keep the current presets and discard any changes, click on **Cancel** or press **<Esc>**.

5.2.2. Settings...

The settings dialog is shown in Fig. 14. This dialog allows the user to set the spectrum file name and sample ID, and displays the current energy MCB calibration(s).

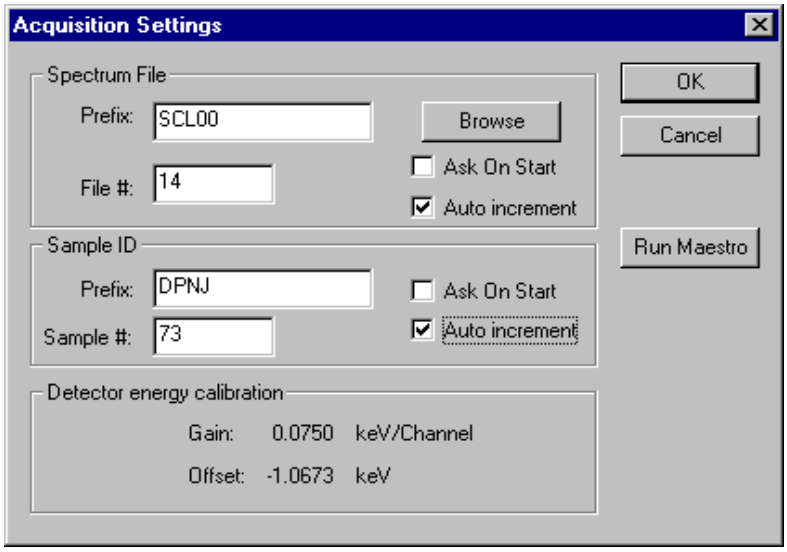

Fig. 14. Acquisition Settings.

5.2.2.1. Spectrum File

When a spectrum is saved on disk, the filename is constructed from the prefix and the file number. The **Prefix** can be any valid Windows name without extension. If the drive letter and path are included, the spectrum will be stored in that place. If only the base name is entered, the spectrum will be stored in the default directory. The total number of characters in the filename will include the file number (**File #**), which is at least one digit. For example, if "SCLOO" is entered for the **Prefix** and "10" is entered for the **File #**, the first spectrum saved will be **`SCLOO10.SPC`**.

Click on **Browse** to locate an existing filename; in this way, the complete filename can be entered easily and reliably. Click once on the desired filename and it will display in the **File name** field.

If **Ask on Start** is checked, the filename **Prefix** is entered whenever acquisition is started from the **Acquire** menu or the Spectrum Toolbar.

If **Auto increment** is checked, **File #** is incremented each time a spectrum is stored to disk.

The spectrum names are stored in the database and included on the report.

5.2.2.2. Sample ID

When a spectrum is saved on disk, the **Sample ID** field is constructed from the **Prefix** and the **Sample #**. The **Prefix** can include any keyboard characters, and the **Sample #** is at least 1 digit. The maximum length of the **Sample ID**, including the **Sample #**, is 26 characters. For example, if "uranium" is entered for the **Prefix** and "10" is entered for the **Sample #**, the **Sample ID** will be uranium10.

If **Ask on Start** is checked, the sample ID **Prefix** is entered whenever acquisition is started from the **Acquire** menu or the Spectrum Toolbar.

If **Auto increment** is checked, **Sample #** is incremented each time a spectrum is stored to disk.

The **Sample ID** is stored in the database and included in the report.

5.2.2.3. Calibration

The current calibration stored with the MCB is displayed (this is the calibration done by MAESTRO; see Chapter 3). It is also stored with the spectrum file and used in the analysis.

5.2.2.4. OK or Cancel

When the inputs are finished, click on **OK** to return to the main screen. Click on **Cancel** to ignore the inputs and return to the original settings.

5.2.2.5. Run MAESTRO

MAESTRO can be used to view the spectrum or change the energy calibration, as well as to perform many other functions. To use it, click on **Run MAESTRO.** This duplicates the **Run MAESTRO** button on the Spectrum Toolbar. If MAESTRO has been disabled, this button does not function.

5.2.3. Count rate...

The count rate must be kept within reasonable limits. To reduce the count rate, absorbers such as cadmium or copper can be mounted between the detector and the sample to reduce the low-energy gamma rays. To monitor the count rate in the MCB, select **Count rate...** to open the dialog shown in Fig. 15. It shows the count rate for the energy range selected. The count rate is the integral of the counts for a short time in the selected range, divided by the elapsed live time since the last reading.

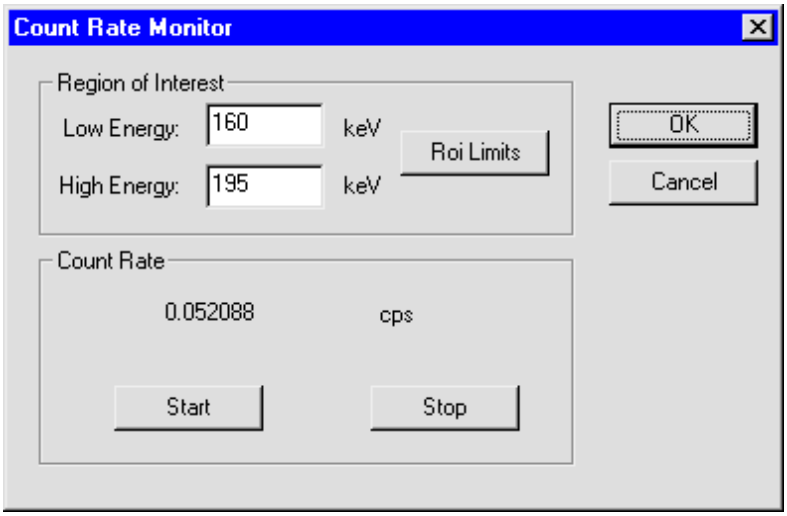

Fig. 15. Monitor Count Rate.

Region of Interest — The count-rate region is specified in energy, so the MCB must be energy-calibrated using MAESTRO. The energy limits can be specified exactly. Also, if an ROI is set in the MCB with MAESTRO, these limits can be selected by clicking on the **ROI Limits** button. The limits are stored and used the next time.

The **Count Rate** section shows the actual count rate, in counts per second (cps), in the MCB. To start data collection, click on **Start**. To stop the data collection, click on **Stop**. In stop mode, the total count rate is shown.

Click on **OK** to apply any new inputs and close the dialog; click on **Cancel** to ignore the changes.

5.2.4. Start

This starts data collection in the selected MCB. Any warnings arising from problems detected at the hardware level will be displayed in a message box or on one of the status lines at the bottom of the display. The MCB can also be started with **<Alt + 1>** or the **Start Acquisition** button on the Spectrum Toolbar. If the MCB is already started, this entry is grayed.

5.2.5. Start/Save/Report

This function performs all three functions without operator intervention. The **Start** is the same as **Acquire/Start**, **Save** is the same as **Acquire/Save** (using the filename in the **Acquire/Settings...** dialog), and **Report** is the same as specified in **Analyze/Settings...**.

5.2.6. Stop

Stop terminates data collection in the selected MCB. If the MCB is not active, the entry is grayed. The MCB can also be stopped with **<Alt+ 2>** or the **Stop Acquisition** button on the Spectrum Toolbar.

5.2.7. Clear

Clear erases the MCB spectral data and the descriptors (real time, live time, start time, etc.) for the selected MCB. The presets are not altered. (This function may not operate on some types of MCBs when they are collecting data.) The data can also be cleared with **<Alt+ 3>** or the **Clear Spectrum** button on the Spectrum Toolbar.

5.2.8. Save

Use this to save the data in the MCB to disk using the filename(s) specified in **Acquire/Settings...**. The file type is the ORTEC **`.SPC`** spectrum file, which saves the U235 analysis parameters.

5.2.9. Re-Start/Save/Report

This will restart data collection, wait for the preset condition, then save and analyze the spectrum. It operates the same way as the **Start/Save/Report** except that the data are not cleared before starting. The presets need to be changed before selecting this option.

This is used when the initial spectrum did not produce adequate results and the user wishes to continue the count. If **Auto increment** is enabled in the **Spectrum File** section under **Settings...** (Section 5.2.2), this will save the spectra with new names, so the first (shorter time) spectra will also be saved.

5.2.10. Calibrate

The peak analysis requires accurate modeling of the peak shape. The peak shape parameters are automatically calculated in this process. When this command is selected, the dialog shown in Fig. 16 is displayed to warn the user that this step should be done with care.

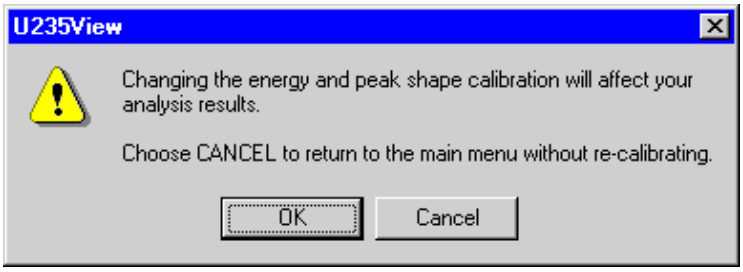

Fig. 16. Calibration Warning.

The calibration is performed on the spectrum stored in the MCB. After calibration, the user is shown the results and has the option of keeping them or repeating the process. If the parameters are kept, they are stored internally. The peak shape parameters can be viewed and modified (see Section 5.3.1.3).

To do the calibration, first collect the spectrum of the calibration sample. The calibration sample can be a mixed isotope standard or a uranium sample. The spectrum should be collected for a long enough period of time to get peaks with small statistical error. Now start the calibration operation. The first display in the calibration sequence is shown in Fig. 17. This gives the information on the spectrum just collected in the MCB.

```
 Welcome to the CZTU/U235 peak Calibration routine.
-----------------------------------------------------------
Data Counted on:          =  8/18/1998 for     33.2 min.
Analyzer deadtime         =   9.73 %
Count rate                = 1.1657E+05 [counts/min]
Total Counts              = 3.8741E+06 [counts]

Observed peak width:   .3720 < data in peak parameter

Total peaks detected =   27; Doubles =   5
```

Fig. 17. Beginning of the Calibration Process.

After the peaks have been located in the spectrum, the list shown in Fig. 18. The peak energy column (Peak_En) gives the energy of the peak using the current calibration. This should be accurate (or close) because U235 operates with the gain setting of 0.075 keV per channel.

Pick two peaks in this list that are isolated and high counts (Peak_ct) and record the peak number (Pk #). This number will be needed later. Press Enter when finished reviewing the list.

Now the current gain and offset are shown as in Fig. 19. If these values need to be recalculated, answer the question with a **Y.** Now enter the peak number (from the above list) and the actual energy of that peak for the low energy point and the high energy point. The peak number and the

Pk #	Peak_En	Peak_ct	Pk_width	Bkg	Dble
1	1.447	62099.1	.000	11316.9	0.
2	12.345	3013.2	.543	3028.9	0.
3	15.193	490.8	.465	1238.2	0.
4	17.869	101.4	.471	1126.5	0.
5	22.304	13344.7	.436	56191.7	0.
6	25.157	3319.1	.420	17396.2	0.
7	27.441	214.2	.298	1170.5	0.
8	31.829	209.3	.000	857.7	1.
9	33.451	2077.1	1.042	756.6	0.
10	36.618	68.7	.286	573.8	0.
11	37.875	535.1	.727	584.1	0.
12	49.759	268.7	.967	958.0	0.
13	59.650	10297.2	.755	1086.9	0.
14	60.384	387.0	.000	815.0	1.
15	72.987	192.8	.750	824.6	0.
16	88.141	12012.9	.798	814.9	0.
17	89.015	195.9	.000	628.1	1.
18	121.225	349.3	.000	522.7	1.
19	122.178	5217.4	.827	509.7	0.
20	136.610	608.0	.770	360.8	0.
21	165.085	501.9	.000	370.1	1.
22	165.975	4332.2	.925	368.8	0.
23	199.269	39.4	1.208	237.6	0.
24	238.688	58.9	.132	201.9	0.
25	255.359	127.0	.699	178.0	0.

Press Enter to Continue

Fig. 18. Peak List in Calibration.

energy are separated by a comma (**,**) with the "." used in the energy value. When the second value is entered, the gain and offset are recalculated using these two peak fitted centroids and the entered energies. The peak list of Fig. 18 is redisplayed. The number of peaks in the list may change due to the change in the energy calibration. Select two peaks to be used for the peak shape calculation.

```
 Input Gain =      .0761 [keV/ch]
 Input Zero =    -1.2180 [keV]

 Maximum Energy of data =   310.6758 [keV]
Do you want to adjust GAIN and ZERO? [Y/N]: y

Data GAIN and ZERO Calibration [Separate input with: , ]
 [For only one peak: Enter other Pk # as 0]
 [Reference peaks must have a "reasonable" width
 and be single, isolated, peaks.]

  Enter Low En [keV] ref: Pk #, Energy, [Ex. 12,195.715]: 13, 59.5
  Enter Hi  En [keV] ref: Pk #, Energy, [Ex. 34,195.715]: 22, 165.85
```

Fig. 19. Gain and Offset Adjustment.

The current peak parameters are shown in Fig. 20. The FWHM, amplitude and slope of the short tailing term, and the amplitude and slope of the long tailing term are shown for the two peaks used. The long tailing term is not used in U235.

```
 Peak Shape Parameters

 59.500,    .771,                  En, FWHM [keV]
165.850,    .929,                  En, FWHM [keV]
 59.500,    .061,                  En, AMP short
165.850,    .049,                  En, AMP short
 59.500,    .922,                  En, Slope short [1/keV]
165.850,   1.000,                  En, Slope short [1/keV]
 59.500,    .000,                  En, AMP long
 59.500,    .000,                  En, Slope long [1/keV]


 Do you want to adjust/check peak SHAPE data? [Y/N]: y
```

Fig. 20. Initial Peak Shape Parameters.

If the peak parameters are to be changed, enter **Y**. This will start the process for developing new peak parameters, as shown in Fig. 27. Two peak numbers from the list shown in Fig. 21 are entered now to specify the peaks to be used. In the figure, peak 13 and peak 22 have been selected.

Next the peak type of either gamma ray or x ray is specified for these two peaks.

Next the source for the peak parameters is selected from Setup file, Data fits, or keyboard. To use the current spectrum, select Data fits. To enter the parameters directly, select keyboard. The direct entry is better done on the Peak Shape Parameters Tab (see Section 5.3.1.3).

```
Two peaks are required to find peak parameters.
   [Separate input with commas; Enter 0 to EXIT]
ENTER Peak #,s: Low En #, High En #  [Ex. 12,34]: 13,22

ENTER peak TYPEs? gammas=0, X-ray=1     [Ex. 0,0]: 0,0

Use Peak Parameters From? Setup File=1, Data fits=2, Keybd=3
Enter Choice: 2
```

Fig. 21. Specifying Peak Parameter Inputs.

After selecting Data fits, the spectrum peaks are fit and the process is shown in Fig. 22. The number of iterations depends on how quickly the fitting converges. When the fitting has converged, the final peak parameters are displayed.

```
      Peak Summary for  59.500 keV Fit Iterations
      ------------------------------------------
E[keV]     FWHM    Amp_S   Slp_S   Amp_L   Slp_L     Rchi
 59.504    .771   .0605   .9228   .0000   .0000  .9661        100
 59.504    .770   .0605   .8932   .0000   .0000  .9706        101
 59.505    .770   .0628   .9228   .0000   .0000  .9713        110
 59.504    .771   .0577   .8718   .0000   .0000  .9954        111
=========================================
      Peak Summary for 165.850 keV Fit Iterations
      ------------------------------------------
E[keV]     FWHM    Amp_S   Slp_S   Amp_L   Slp_L     Rchi
165.848    .942   .0010  1.0000   .0000   .0000  1.762        100
165.850    .937   .0010   .6944   .0000   .0000  1.803        101
165.853    .929   .0495  1.0000   .0000   .0000  .9945        110
165.851    .933   .0279   .6500   .0000   .0000  1.101        111
=========================================
```

Fig. 22. Peak Shape Parameter Fitting.

At this time, the dialog in Fig. 23 is shown. If the parameters are acceptable, then press **N** to retain them. If **Y** is entered, the dialog in Fig. is shown to redo the parameters. To retain the peak parameters to be used in subsequent analyses, enter **Y** to the Save question. Entering **N** here will discard these parameters and return to the starting parameters. In both cases, control returns to the main screen.

```
 Peak Shape Parameters

 59.500,    .771,                  En, FWHM [keV]
165.850,    .929,                  En, FWHM [keV]
 59.500,    .061,                  En, AMP short
165.850,    .049,                  En, AMP short
 59.500,    .923,                  En, Slope short [1/keV]
165.850,   1.000,                  En, Slope short [1/keV]
 59.500,    .000,                  En, AMP long
 59.500,    .000,                  En, Slope long [1/keV]


 Do you want to adjust/check peak SHAPE data? [Y/N]: n

 Do you want to save/use new Peak Parameters? [Y/N]: Y
```

Fig. 23. Ending the Peak Shape Parameter Entry.

5.3. Analyze

The **Analyze** menu is shown in Fig. 24.

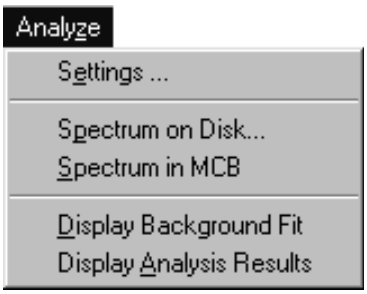

Fig. 24. Analyze Menu.

5.3.1. Settings...

This dialog (Fig. 25) has five tabs (sub-screens) for defining the sample-type definition file. All of the entries on all the **Settings...** tab are stored in this file. Users can create an unlimited number of sample-type definition files.

5.3.1.1. Sample Type

On this tab are specified the file name and description of the sample-type definition file.

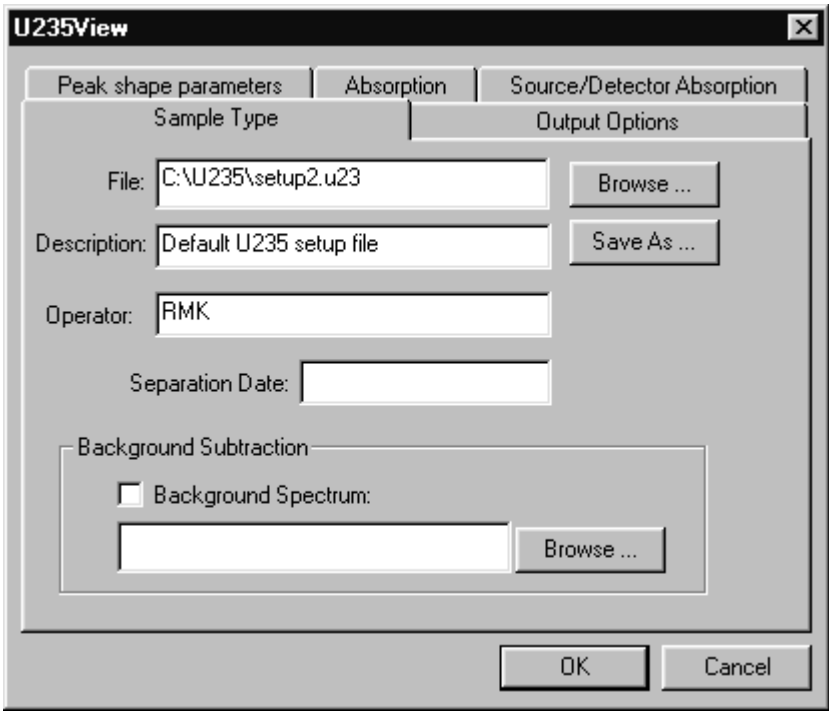

Fig. 25. Settings Dialog; Sample Type Tab.

File — The name of the sample type file is specified in this entry. Click on **Browse...** to find existing files or to specify the total path for the new file.

Description — This is the description of the sample-type file. It is used to help distinguish the different files from one another. It is recommended that you enter a fairly comprehensive description to save time and confusion as you accumulate these files.

Operator — This is the operator name; it appears in the database and on the output report.

Separation Date — This is the date that the uranium separation was performed. If no date is given, the program assumes the sample is in equilibrium.

Background Subtraction — If the **Background Spectrum** checkbox is marked, the file entered in the field is subtracted from the spectrum before the analysis. Use **Browse...** to locate the file. A background subtraction is usually not needed for the analysis. The program determines an appropriate background and only in a very few circumstances is background subtraction in this manner beneficial.

NOTE The Background Subtraction option only applies when a spectrum is analyzed from disk and the "Use current analysis options" is chosen.

5.3.1.2. Output Options

This tab is shown in Fig. 26. The output report options are selected here.

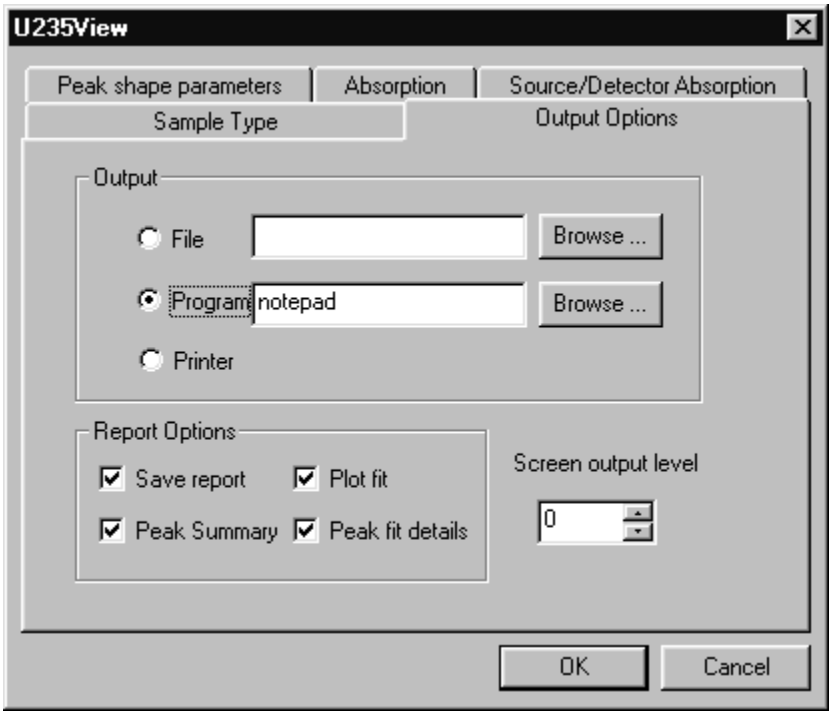

Fig. 26. Output Options.

Output — The ASCII output can be sent to a **File**, a **Program**, or the Windows default **Printer**. The filename can be specified. If no name is specified, the spectrum name is used with the extension **`.RPT`**.

The ASCII output can be sent to a **Program** for further processing. A common program is Windows Notepad (**`Notepad.exe`**). When Notepad is specified, the analysis report is displayed on the screen when the analysis is complete.

When **Printer** is selected, the output file is automatically sent to the Windows default printer.

Report options — To save the report as a text file (even if it is also being sent to the printer or to a program), check the **Save report** box. Marking the **Peak Summary** checkbox adds this section to the report. The **Plot fit** option creates a **`.FIT`** file of values that is used to make the output plot. **Peak fit details** adds the numeric details to the report.

The **Screen output level** field controls the output to the analysis window during the analysis. It defaults to 0 (zero), the normal value except during debugging.

5.3.1.3. Peak Shape Parameters

This tab (Fig. 27) shows the peak-shape parameters used in the program to describe the peak. The values are given for two energies, as selected in the calibration. The peak is shown in Fig. 63 (Section 6.3).

The three components are added to give the total peak. The formula for the peak uses parameter values which are fitted to these values to give the peak shape as a function of energy.

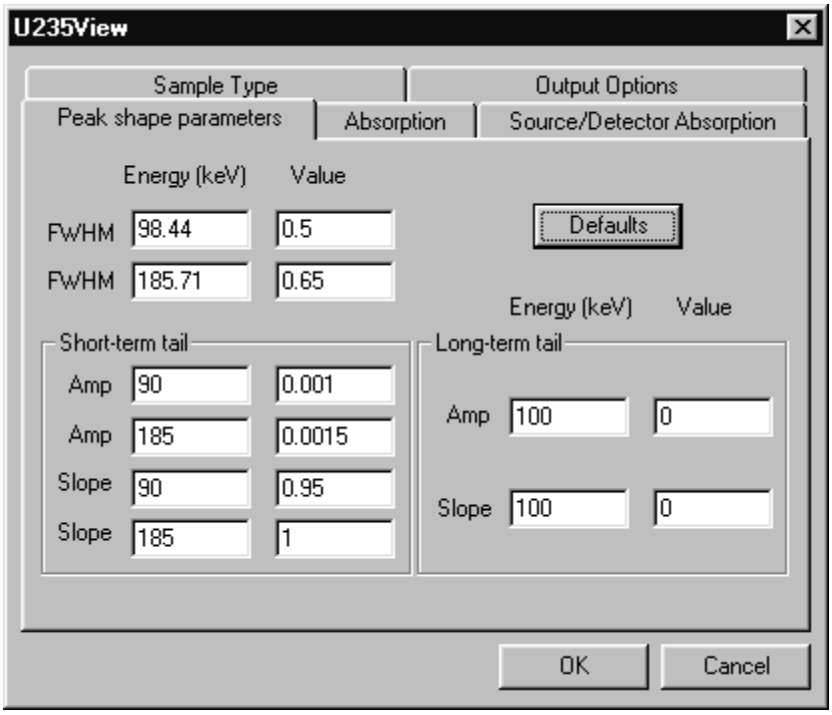

Fig. 27. Peak Shape Calibration Parameters.

5.3.1.4. Absorption

This tab (Fig. 28) is used to specify the absorber (e.g., the container walls between the source and the detector. These inputs are used in the program to calculated the attenuation of gamma rays due to these materials.

The list of available elements is shown. If the element is to be included, check the **Material** box for that element. Enter the density and length for the elements included. The **Length** is the thickness of the sample in the direction perpendicular to the detector. That is, length is the expected (average) path length of gamma rays from the far side of the sample, through the sample, to the detector.

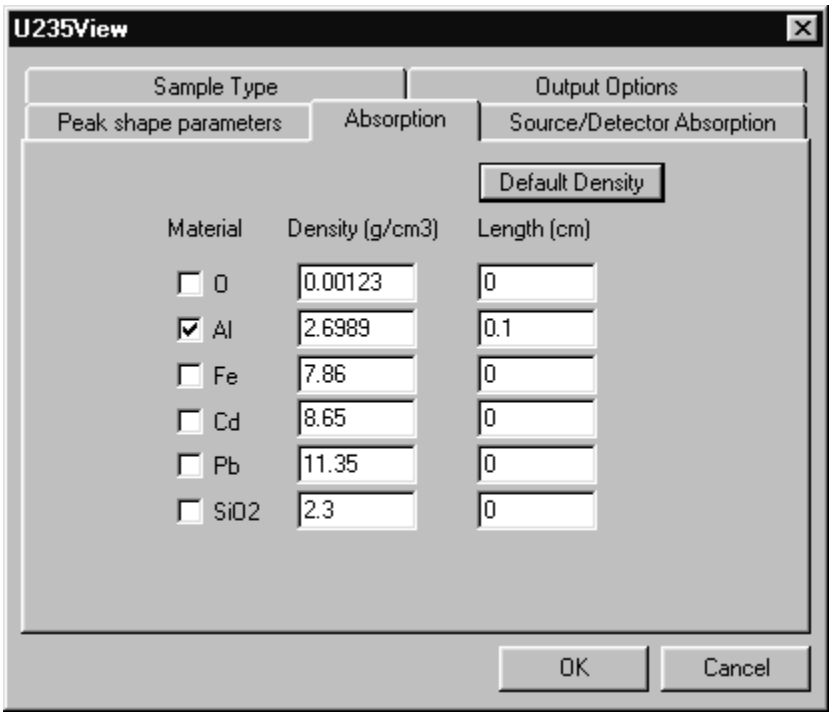

Fig. 28. Absorption Parameters.

The **Default Density** button is used to set all the densities to fixed values. These can be used if no other values are known.

5.3.1.5. Source/Detector Absorption

This tab (Fig. 29) is used to specify the sample material to correct for self-absorption in the sample and detector. The corrections can be turned on or off by marking or unmarking the **On** checkbox. If on, the chemical composition can also be selected.

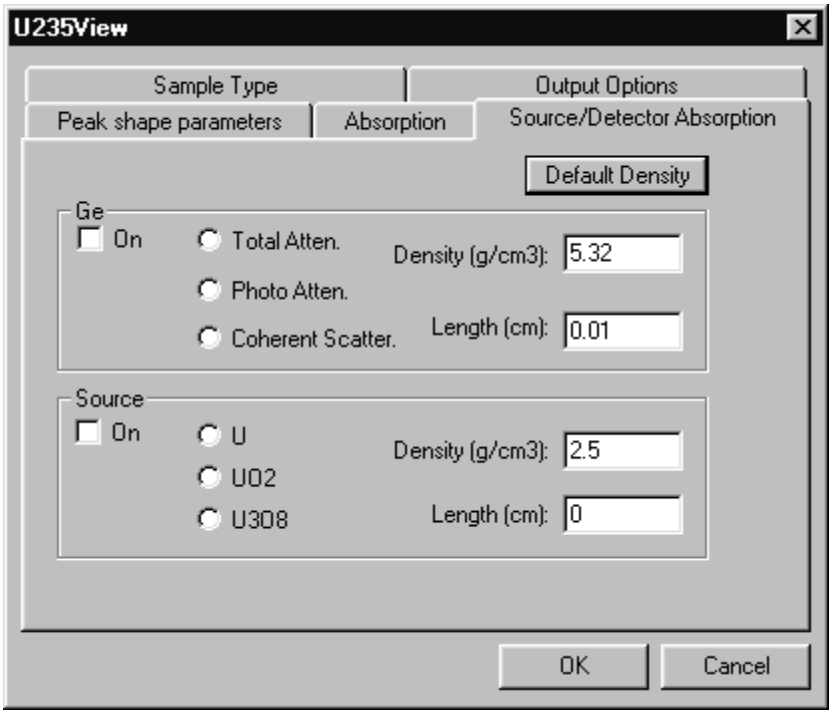

Fig. 29. Source and Detector Absorption Parameters.

The physical form (e.g., metal or powder) is indicated by the **Length** and **Density** inputs in the source description. The **Length** is the thickness of the sample in the direction perpendicular to the detector. That is, length is the expected (average) path length of gamma rays from the far side of the sample, through the sample, to the detector. The **Density** is the average density of the sample. The **Default Density** value can be used if the actual density is not known. The default is the density for powder.

The absorber corrections are used to give better fits to the data. The program will determine the "best" values based on the fitting process, but exact values entered here for the known absorbers usually improves the fitting.

5.3.2. Spectrum on Disk

This is used to analyze previously collected spectra stored on disk. The dialog is shown in Fig. 30.

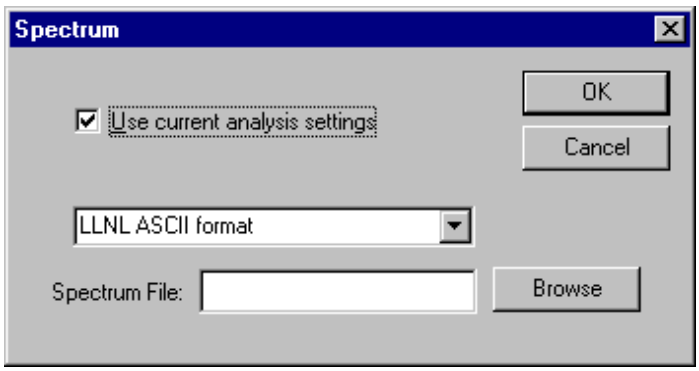

Fig. 30. Select Spectrum File to Analyze.

Use current analysis settings — The analysis settings used in the analysis can be either the settings in the spectrum file or the currently selected settings (see **Analyze/Settings...**, Section 5.3.1.1). Some file formats do not have

the analysis settings stored internally. In this case the currently selected values are used. Checking this box will use the current settings in all cases.

File format — Several different file formats are supported. The list is shown in Fig. 31.

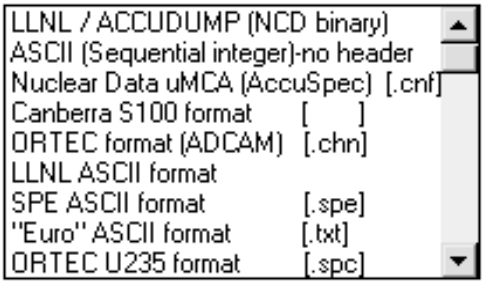

Fig. 31. Spectrum File Formats.

Spectrum File — This is the filename for the spectrum. Use the **Browse...** button to find and specify the filename.

5.3.3. Spectrum in MCB

This analyzes the spectrum in the MCB using the current **Analyze/Settings...** parameters (Section 5.3.1), and saves the spectrum to disk with the analysis settings using the filename selected in **Acquire/Settings...** (Section 5.2.2). If **Auto increment** under the **Spectrum File** section (see Section 5.2.2.1) was not selected, the old files may be overwritten.

5.3.4. Display Background Fit

This command displays the spectrum, background, and fitted spectrum for the total energy range of the spectrum (see Fig. 32) from a background fit (**.SPF**) file. Each of the curves is shown in a different color. The user can also access the corresponding results database tables.

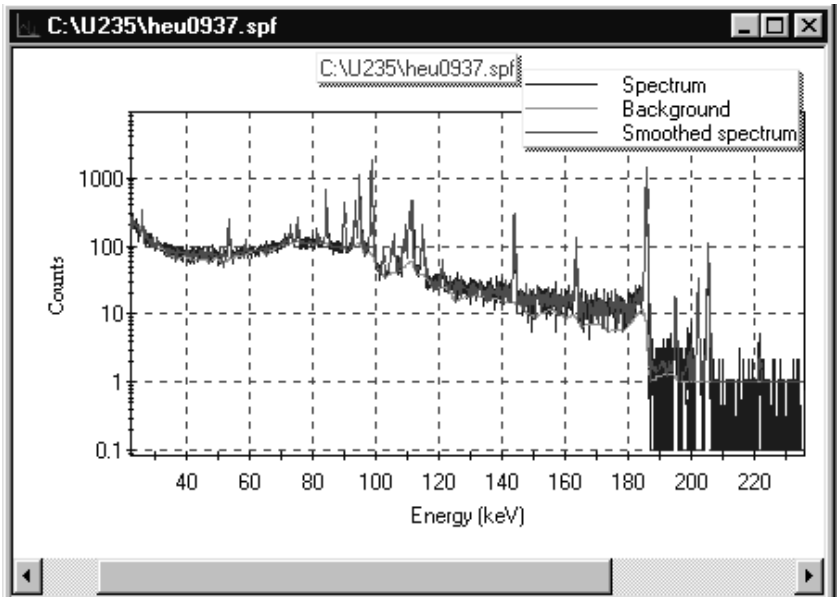

Fig. 32. Display Analysis Results.

Use the Analysis (Standard) Toolbar buttons to adjust the horizontal and vertical scale, and the zoom tool to expand any regions of interest (see Section 4.2). To maximize the screen area; the Spectrum Toolbar, detector sidebar, and status bar can be hidden (see Section 5.6).

5.3.5. Display Analysis Results

This displays the spectrum data, individual peaks, background, and residuals for the energy range of 85 to 101 keV. The peaks can be plotted by energy, as shown in Fig. 33, or by isotope, as

shown in Fig. 34. Each of the curves is shown in a different color with different symbols. The sidebar shows the possible variables to plot. The check box shows the variables plotted.

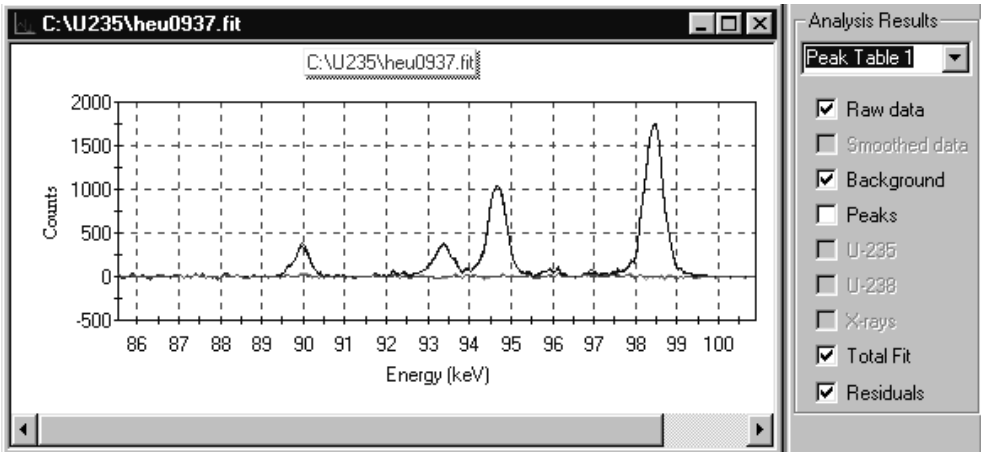

Fig. 33. Display Peaks Plotted by Energy.

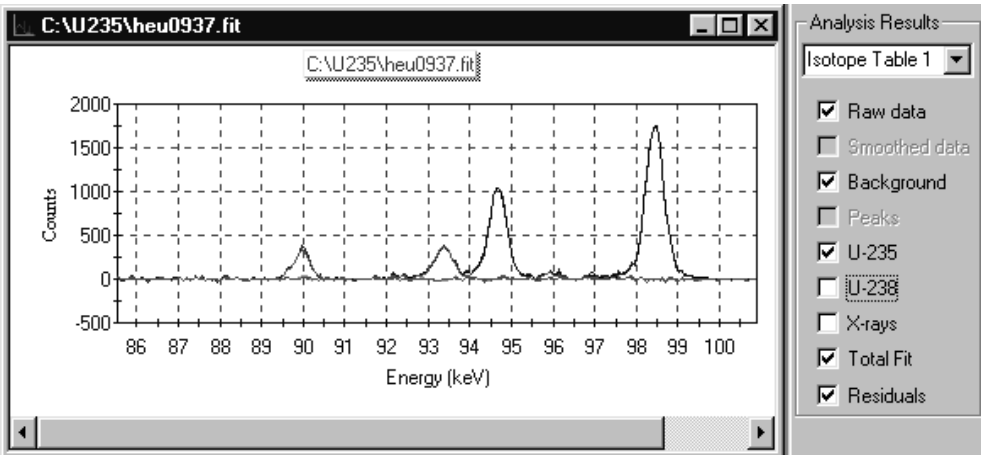

Fig. 34. Display Peaks Plotted by Isotope.

To remove a curve, click in the check box.

To add the curve, click again.

Use the Analysis (Standard) Toolbar buttons to adjust the horizontal and vertical scale, and the zoom tool to expand any regions of interest (see Section 4.2). To maximize the screen area; the Spectrum Toolbar, detector sidebar, and status bar can be hidden using the commands on the **View** menu (see Section 5.6).

5.4. Record

When the results database is displayed, the commands on this menu (Fig. 35) allow the user to index through the tables of the results database. These functions duplicate the arrow buttons on the Analysis Toolbar.

Fig. 35. Record Menu.

5.4.1. First Record

This jumps to the first record in the table.

5.4.2. Previous Record

This moves to the record before the current record in the table.

5.4.3. Next Record

This moves to the record after the current record in the table.

5.4.4. Last Record

This jumps to the last record in the table.

5.5. Services

This menu (Fig. 36) contains three hardware control functions.

Fig. 36. Services Menu.

5.5.1. Lock/Unlock detector...

This command allows the user to protect an MCB from destructive access (e.g., **Start**, **Stop**, **Clear**, etc.) by any program on the PC or network. While any program can *view* the data and read the contents of any MCB in the system — locked or unlocked — the contents of a locked MCB cannot be changed without knowing the password.

NOTE ***There is no master password.*** If the password is lost, contact ORTEC Customer Service for assistance in unlocking the MCB.

Fig. 37. Entering Name/Password to Lock an MCB.

If the MCB is currently unlocked, selecting **Lock/Unlock** will show the dialog displayed in Fig. 37. Enter the **Owner** name. Then enter a password in the **Password** field, and re-enter it in the **Verify** field (the two entries must agree).

Click on **OK**. The password is not case-sensitive (that is, uppercase and lowercase letters are treated the same).

If the MCB is currently locked, selecting **Lock/Unlock** will display the dialog in Fig. 38. Enter the correct password to unlock the MCB.

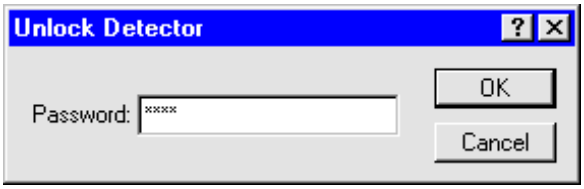

Fig. 38. Unlocking an MCB.

Each time destructive access to an MCB is attempted while it is locked, the **Locked Detector** dialog (see Fig. 39) will ask for the password. In addition, the owner of the MCB will be displayed on the Status line, as in Fig. 40.

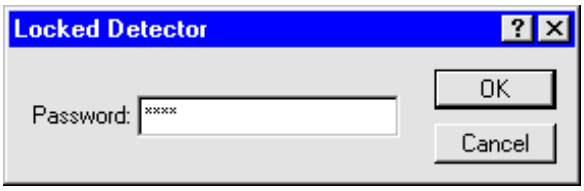

Fig. 39. Password for Accessing Locked MCB.

If the incorrect password is entered in either the **Unlock** or **Locked Detector** dialog, the dialog will reappear, waiting for the correct password. If the password is not known, click on **Cancel** to abort the access attempt.

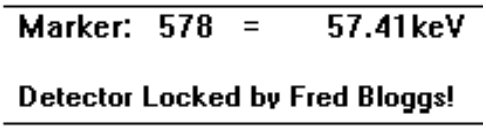

Fig. 40. Name of Person Who Locked MCB.

5.5.2. Edit Detector List...

This allows the user to select those MCBs on the system that are to be available in U235View on this PC. Other applications (e.g., GammaVision, AlphaVision, ScintiVision™) on the same PC can have their own lists. In this way, the different MCBs on the network can be segregated by function or type.

Figure 41 shows the **Detector List Editor** dialog. On the left is the **Master Detector List** of all MCBs on the system. This is created by the MCB Configuration program (which can be run automatically during MGAView/U235View installation or from the **MGA** menu started from the Windows Taskbar). The default descriptions are derived from the hardware and can be changed by running the configuration program.

On a single-PC system, the U235View installation program initially sets the available MCB list identical to the master list. On a networked system, the system configuration program (rather than the installation program) sets the MCB list identical to the master list. The **Master Detector List**, including the MCB descriptions, are the same for all ORTEC ***CONNECTIONS-32*** programs running on all PCs connected to the workgroup.

To add an MCB to the U235View **Pick List** for this PC, click on the name in the master list, then click on **Add**. To add all the MCBs on the **Master Detector List**, click on **All**.

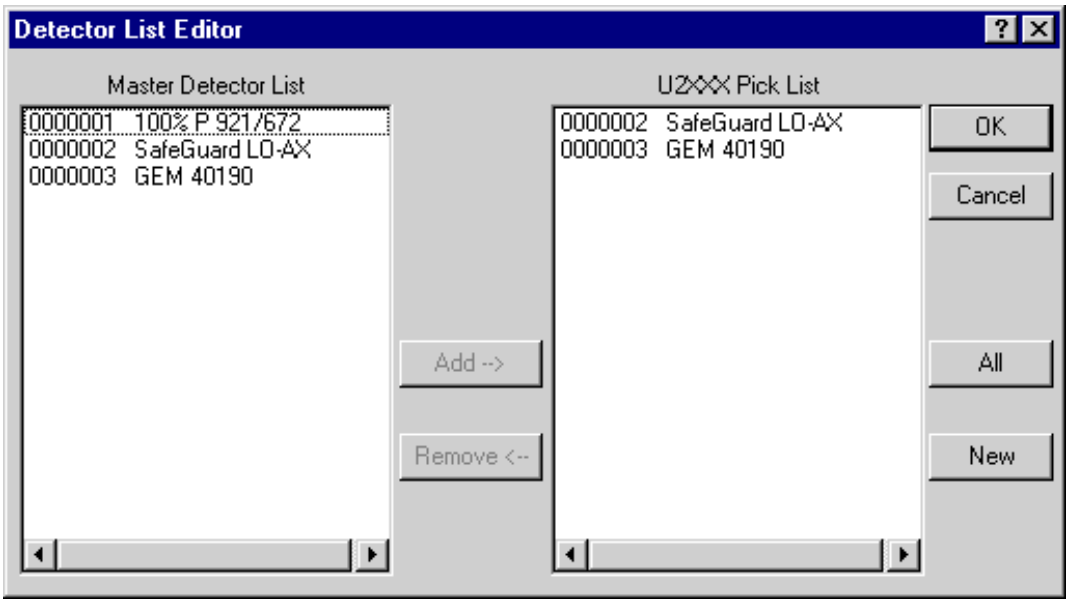

Fig. 41. Detector List Editor Dialog.

To remove an MCB from this local pick list, click on the name in the **Pick List** and click on **Remove**. To remove all the MCBs, click on **New**.

When MCB selection is complete, click on **OK**. These selections will be saved to disk and used by U235View until changed on this screen or until the entire network is reconfigured.

5.5.3. Run Maestro

This starts MAESTRO, which can be used to view the spectrum or change the energy calibration, as well as for many other functions. This duplicates the **Run MAESTRO** button on the Spectrum Toolbar.

NOTE To prevent the MCB parameters, such as gain or pole zero, from being changed, you may remove MAESTRO-32 from the PC after hardware setup is completed. From the Windows Taskbar, click on **Start, Settings**, **Control Panel**, and **Add/Remove Programs**. On the list of installed programs, click on **MAESTRO for Windows**, click on the **Add/Remove** button, and answer any prompts.

5.6. View

Use the commands on the **View** menu, Fig. 42, to select what will be displayed on the main screen. The check marks beside the toolbar names indicate that all of the toolbars are currently displayed (as shown in Fig. 3). Click beside an item to unmark it and U235View will hide it.

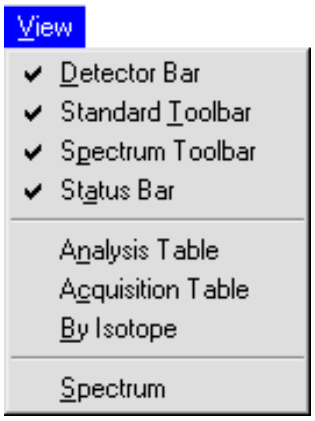

Fig. 42. View Menu and Toolbar Submenu.

5.6.1. Analysis Table

The Analysis Table menu item displays this table from the database in the display window. The table shows the analysis parameters in the database for the selected analysis. When this table is displayed the Record Advance toolbar buttons are active.

The table is shown in Fig 43. This shows the results of some of the calculations for one analysis.

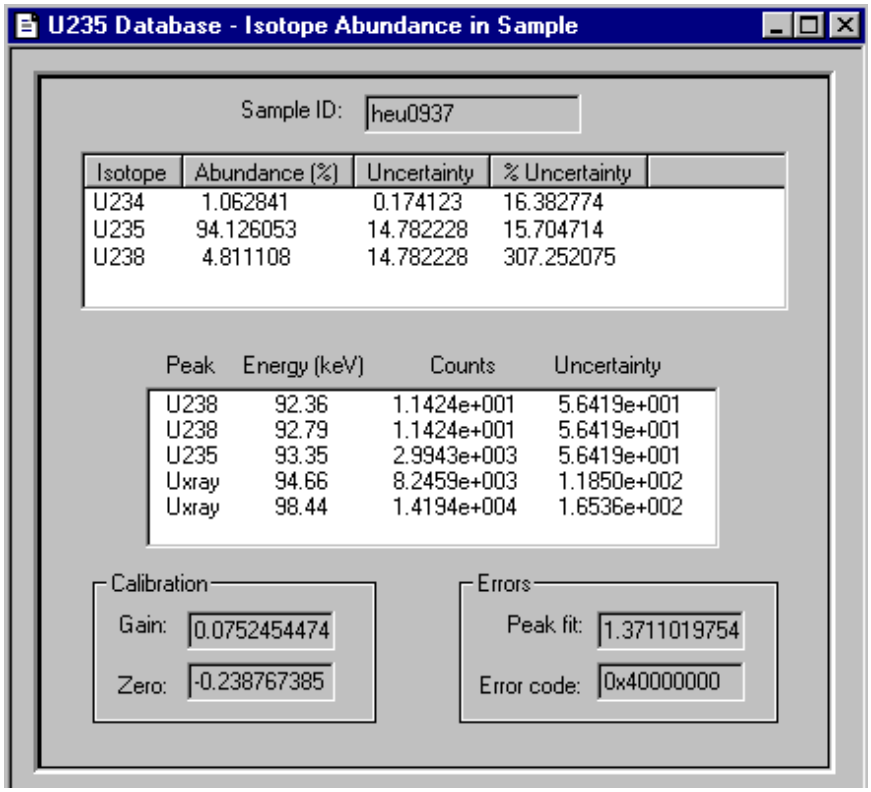

Fig. 43. Isotope Database Table.

5.6.2. Acquisition Table

The Acquisition Table menu item displays this table from the database in the display window. The table shows the type of sample, the time of data collection and the spectrum name (or

names) in the database for the selected analysis. When this table is displayed the Record Advance toolbars buttons are active.

The table display is shown in Fig. 44.

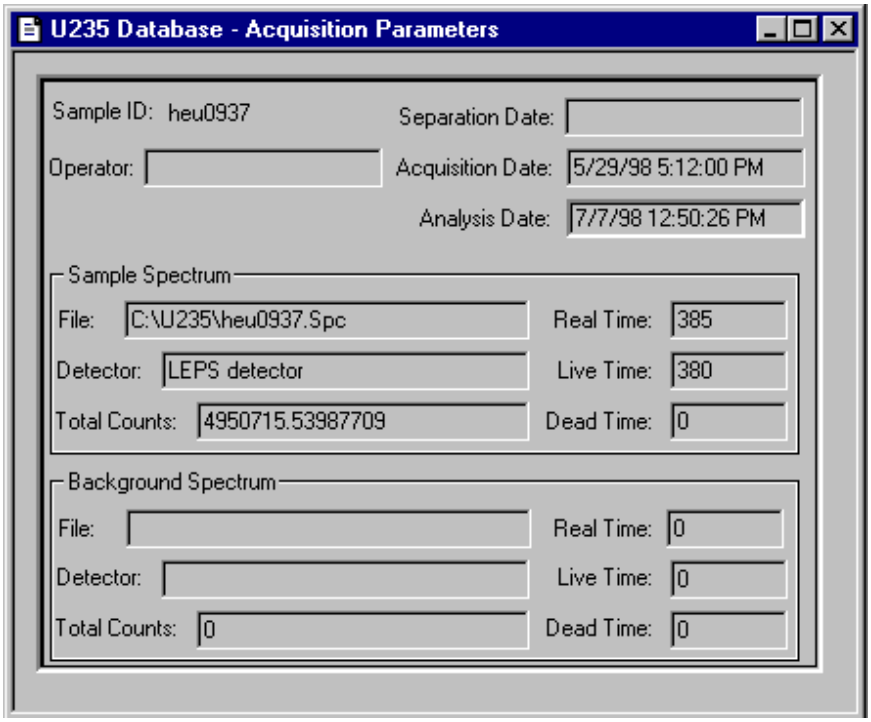

Fig. 44. Database Acquisition Table.

5.6.3. By Isotope

This menu item displays the table of analysis results for all the uranium isotopes for all the analyzed spectra between the selected dates from the database in the display window.

The display is shown in Fig. 45. The time and date for the analysis is entered directly in the fields shown. All of the analysis results for the selected time span are shown.

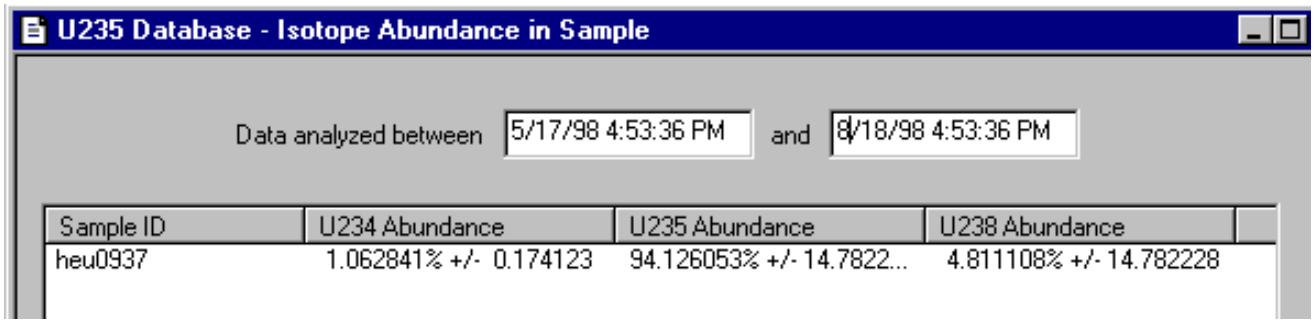

Fig. 45. Database Display by Isotope.

See Section 4.3.1 for more information on spectrum and table window features.

5.6.4. Spectrum

Use **Spectrum** to display the spectrum in the MCB (see example in Fig. 46). The spectrum window is display-only; the MCB functions cannot be changed here.

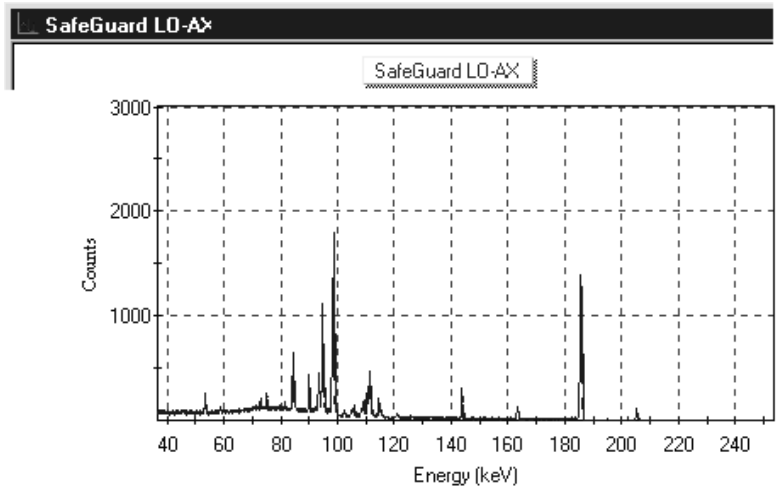

Fig. 46. Spectrum Window.

NOTE	To prevent the MCB parameters, such as gain or pole zero, from being changed, you may remove MAESTRO-32 from the PC after hardware setup is completed. From the Windows Taskbar, click on **Start, Settings, Control Panel,** and **Add/Remove Programs**. On the list of installed programs, click on **MAESTRO for Windows**, click on the **Add/Remove** button and answer any prompts.

5.7. Display

Figure 47 shows the **Display** menu, which contains commands for changing the horizontal and vertical scaling of a spectrum, and for hiding or displaying the legend.

Fig. 47. Display Menu.

5.7.1. Taller and Shorter

Taller and **Shorter** switch the spectrum display to a linear vertical scale and, respectively, increase or decrease the full-scale value. These commands are duplicated by the **Taller** and **Shorter** buttons on the Analysis Toolbar.

5.7.2. Automatic Y-Axis

Automatic Y switches the spectrum window from logarithmic to linear vertical scale and adjusts the Y axis so the tallest currently displayed peak fills the maximum space available without overflowing the display. This function is duplicated by the **Automatic Y-Axis** button on the Analysis Toolbar.

5.7.3. Automatic

Automatic switches the spectrum window from logarithmic to linear vertical scale and adjusts the X and Y axes so the entire plot fills the maximum space available without overflowing the display (scaling up a small graph and scaling down a “too-big” graph). This function is duplicated by the **Automatic** button on the Analysis Toolbar.

5.7.4. Logarithmic

Logarithmic toggles the vertical scale of the spectrum display between the logarithmic and linear modes. This function is duplicated by the **Log/Linear Display** button on the Analysis Toolbar.

5.7.5. Narrower and Wider

Narrower and **Wider** increase and decrease the horizontal full scale of the spectrum window so that the peaks appear respectively narrower and wider. These commands are duplicated by the **Narrower** and **Wider** buttons on the Analysis Toolbar.

5.7.6. Legend

This displays or hides the graph legend box; it duplicates the **Legend** button on the Analysis Toolbar.

5.8. Window

This menu, shown in Fig. 48, contains the standard Windows **Cascade** and **Tile** commands for arranging the open windows on the screen (refer to the Windows 95/NT documentation). **Arrange Icons** aligns any minimized windows icons. If any spectrum or table windows are open, they are listed on the lower portion of the menu, with a check mark beside the active window. To switch to a different window, press **<Alt + W>** **<Alt +** [window number]**>**, click on the window name on the menu list, or click anywhere on the window you wish to activate.

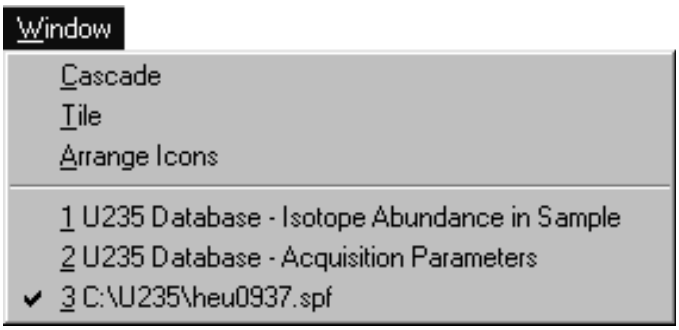

Fig. 48. Window Menu.

5.9. Help

The **Help** menu is shown in Fig. 49. This accesses U235View help.

The **About** box is shown in Fig. 50. This dialog contains version information that will be useful should you require technical support.

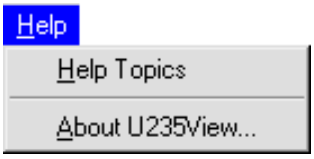

Fig. 49. Help Menu.

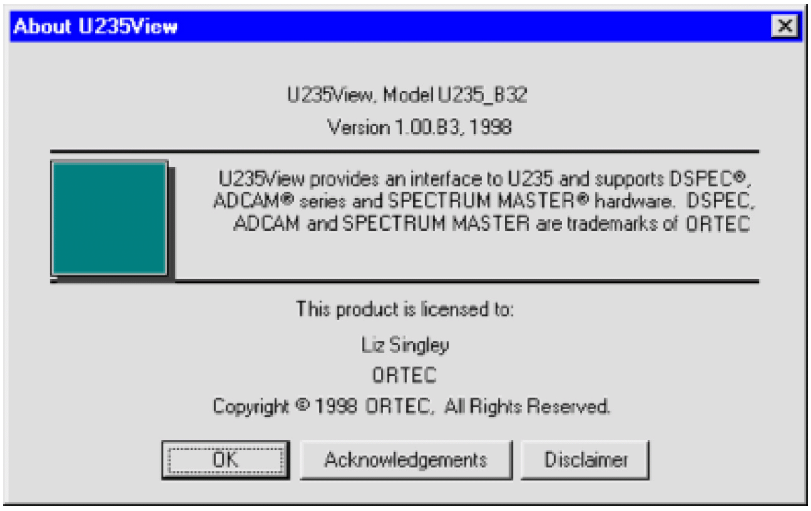

Fig. 50. About U235View.

6. ANALYSIS METHODS[5]

6.1. Discussion of Fundamentals

The U235 program accurately determines uranium isotopic ratios from very low ^{235}U concentrations (depleted sources) to very high ^{235}U concentration (enriched) sources. Presently the program works for uranium samples that are 0.05% ^{235}U to 95% ^{235}U.

There are several potential energy regions in the uranium gamma ray spectra that can be used to calculate isotopic abundance ratios. In this program only gamma- and x-rays less than 300 keV are used. This energy region is measured by a typical low energy Ge detector set with a gain of .075 keV/channel and 4096 channels of data. The only serious limitation this energy range imposes is the relative few ^{238}U (and daughters) peaks less than 300 keV. Fortunately there are two relatively strong ^{238}U/ ^{234}Th lines at 92.365 and 92.790 keV and a relatively strong IC x-ray at 93.356 keV ^{235}U/Th-Kα_1 (see Appendix A). One of the disadvantages of using gammas in the 80 to 300 keV range is their limited transmission through "thick" material. This restricts the applicability of the analysis procedures to homogenous sources or "thin" heterogeneous uranium sources.

6.1.1. Basis of Gamma Ray Methods

Gamma ray spectrometry can be used to determine uranium isotopic abundance ratios. This method is more accurate and complicated than the so-called "enrichment meter" method.[6]

Accurate analysis of a radioactive sample by spectrometry requires correct information on the gamma-ray and x-ray branching ratios for the radionuclides in the sample. ^{235}U and ^{238}U sample analysis is complicated in that the gammas observed often come from their radioactive daughters produced by successive alpha and beta decays. In addition to gamma decay, these elements decay by internal conversion, IC, and subsequent emission of daughter-product x rays. For example, when ^{235}U alpha decays, the result is a radioactive ^{231}Th nucleus. This thorium isotope decays by both gamma emission and IC. IC results in an electron being ejected — usually from the K-shell, but L-, M- etc. shell conversions are also possible. This ejected electron gives rise to the thorium x-ray spectrum associated with the decay.

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[5]This section based on "U235: A Gamma-Ray Analysis Code for Uranium Isotopic Determination," DeLynn Clark, UCRL-ID-125727, 1996

[6]The "standard" uranium enrichment meter relies on making standards of the various sample types of interest, then analyzing these standards with mass spectrometry to find the appropriate calibration factors to calibrate out all the unknowns in the counting scheme. The strong ^{235}U gamma peak at 185.712 keV can then be counted with a "simple" two-channel analyzer to find the peak counts and background. The net 185.715 counts are used to calculate the enrichment. This technique works well but has the draw back that new "standards" have to be made for each different geometry and analyzed by mass spectrometry. This calibration process is often very time consuming and costly as well as being limited to "calibrated" geometries.

In addition, x-rays are produced by gamma rays interacting (via the photoelectric effect) in the material itself, the so-called fluorescent x rays. In the case of a pure uranium sample, these will be uranium x rays. IC processes give rise to characteristic x rays of the daughter product (not the parent), and are not proportional to the amount of material in the sample (the amount of thorium in a decaying sample of purified uranium is very small). IC-induced x rays are proportional to the number of decays; i.e., each decay has a fractional output of x rays of the daughter product regardless of the parent material present in the sample. This fact makes these x rays usable for isotopic analysis if the sample has a very low concentration of daughter material (Th). To accurately use these IC x-ray peaks requires that the thorium present in very old natural uranium samples be removed. X rays induced by the photoelectric effect (fluorescent x rays) have energies characteristic of the bulk material and are proportional to the mass of material present in the source. The observed x rays, from both fluorescent and internally converted sources, must originate near the surface to be easily observed.

Branching ratio and gamma, x-ray energy data have been published in various places[7,8,9,10] for ^{235}U and ^{238}U and some of their daughter products; but this data is sometimes incomplete, or of inadequate accuracy. The current status of this data are summarized in Appendix A.

Figure 51 shows the main decay scheme for ^{235}U and ^{238}U.

Pure ^{238}U emits only a 49.55 keV gamma that is too weak to be useful for analysis (see Fig. 52). Fortunately, ^{238}U alpha (and beta) decays so that in within a few months it is in equilibrium with the ^{238}U decay and there are gammas from ^{234}Th, ^{234}Pa, and ^{234}U available for analysis. (see Appendix E for a discussion of equilibrium). The small percentage (0.0057%) of natural ^{234}U typically observed is due to the constant decay of ^{238}U. Similarly, ^{235}U relatively quickly decays to equilibrium with its daughters, ^{231}Th and ^{231}Pa. Samples of uranium that have been enriched or separated can be analyzed for their ^{235}U concentrations by using these daughter product decays in all cases except very fresh (<2-month-old) samples. At present the only way to accurately measure “fresh” samples before equilibrium is established is to use mass spectrometry.

[7]Firestone, B. F. ed., *Table of Isotopes*, 8th Edition, Lawrence Berkeley Laboratory, John Wiley & Sons, 1996.

[8]*Decay Data of the Transactinium Nuclides*, Technical Report 261, IAEA, 1986.

[9]Roy, J. C., et. al. *Int. J. Appl. Radiation Isotopes*, 35, pg 899, 1984.

[10]Lammer, M. and O. Schwerer, *Handbook of Nuclear Data for Safeguards*, INDC (NDS)-248, IAEA, 1991.

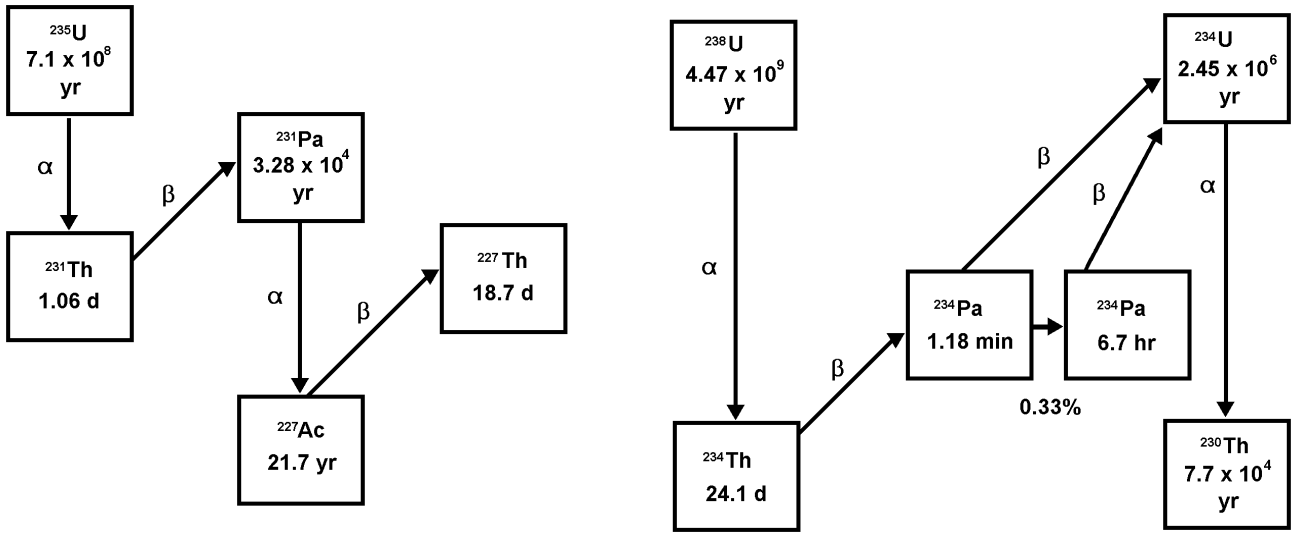

Fig. 51. ^{235}U and ^{238}U Decay Scheme Showing Their Principal Daughters and Half Lives.

Alternately, using high resolution gamma spectrometers, the spectra can be measured and the ^{235}U/ ^{238}U ratio determined by finding the peak intensities of neighboring gamma (or x-ray) peaks from each isotope. By taking intensity ratios on gamma peaks very close to the same energy, the detector efficiency and gamma attenuation differences in the sample will be small and to first order cancel.

When referring to the ^{238}U peaks in the following discussion the assumption is made that the gamma spectrum is in equilibrium with daughters ^{234}Th (24.1 d), ^{234}Pa (6.70 hr), and ^{234m}Pa (1.17 min), but not ^{234}U (2.457×10^5 yr) and its daughters. Similarly, the ^{235}U spectrum is assumed to be in equilibrium with its daughter ^{231}Th (25.52 hr), but not ^{231}Pa (3.276×10^4 yr) and its daughters.

The isotopic abundance is related to the observed peak intensities by the following relation:

$$I_1 = \lambda_1 A_1 B_1 \Omega_1 \varepsilon_1 \tau_1 \quad (counts/sec)$$

where:

I_1 = measured peak intensity of isotope *1*
λ_1 = $0.6932/T_1$, the decay constant of isotope *1*
T_1 = material half-life (in seconds) of isotope *1*
A_1 = number of atoms of isotope *1*
B_1 = branching ratio of isotope *1*
Ω_1 = factional solid angle of detector
ε_1 = gamma counting efficiency of isotope *1*
τ_1 = gamma transmission to detector

The isotopic ratio is given by the following equation:

$$\frac{A_1}{A_2} = \frac{I_1}{I_2} \times \frac{\varepsilon_2 \tau_2}{\varepsilon_1 \tau_1} \times \frac{\lambda_2 B_2}{\lambda_1 B_1}$$

where:

A_1/A_2 = isotopic ratio
λ_i = $0.6932/T_i$, decay constant for isotope *i*
I_i = measured peak intensities from isotope *i*
T_i = half life, in the same time units, of isotope *i*
ε_i = gamma counting efficiencies of isotope *i*
B_i = branching ratios for characteristic gamma rays of isotope *i*

Analysis is greatly simplified by the following observations:

- $\varepsilon_2\tau_2/\varepsilon_1\tau_1 \approx 1$ if the two gammas are close to the same energy.
- $\Omega_1 = \Omega_2$. The fractional solid angle of detector is the same for both gammas and cancels out.
- T_i is known from the previously measured half lives.
- B_i is known from the previously measured branching ratios.
- I_i has to be determined extremely accurately to get precise isotopic ratios.

The analysis proceeds on the assumptions that the solid-angle terms cancel out and the half-lives and branching ratios of the respective gamma- and x-rays can be determined. The efficiencies for detecting gamma rays are harder to determine, involving the intrinsic detector efficiencies and the overall detector and counting geometry used to obtain the data. Gamma- and x-ray transmissions are nearly equal for energies close to each other. Fortunately for gammas and x-rays close in energy, the ratio of these terms, $\varepsilon_2\tau_2/\varepsilon_1\tau_1$ is approximately 1. Approximate detector efficiencies and gamma-transmission corrections are used to make first-order corrections to this ratio. The accuracy of determining the isotopic ratio, A_1/A_2, is largely determined by the accuracy of determining the respective peak intensities, I_1/I_2. The U235 code determines these peak intensities as accurately as possible then applies the second-order corrections for efficiency and transmission differences between the ratio-ed peaks to get a more accurate answer.

The program very precisely subtracts the “background” signal, and fits the observed peak shapes. X-rays are fit with a Voight profile, the shape resulting from the Lorentzian profile emitted by the x-rays and the Gaussian detector response. Gammas are fitted with a Gaussian profile and a low-energy exponential tail (see Figs. 55, 56, and 57 for examples of these profiles). The complex peak multiplets in the spectra are unfolded using mathematical

descriptions of the peak shapes and Taylor series minimization to fit the observed data as accurately as possible.

6.2. Useful Energy Regions

6.2.1. The 20–80-keV Energy Region

Fig. 52 is a plot of a 99.983% ^{238}U spectrum from 20–80 keV. It clearly shows the only gamma directly associated with the ^{236}U decay — the 49.369-keV peak. The ^{238}U peak at 49.550 keV is normally too weak to be seen. The strongest line in this region is the ^{238}U to ^{234}Th daughter line at 63.29 keV. The first number on the peak labels above shows their energy, the second number gives their approximate peak counts, and the third gives their origin.

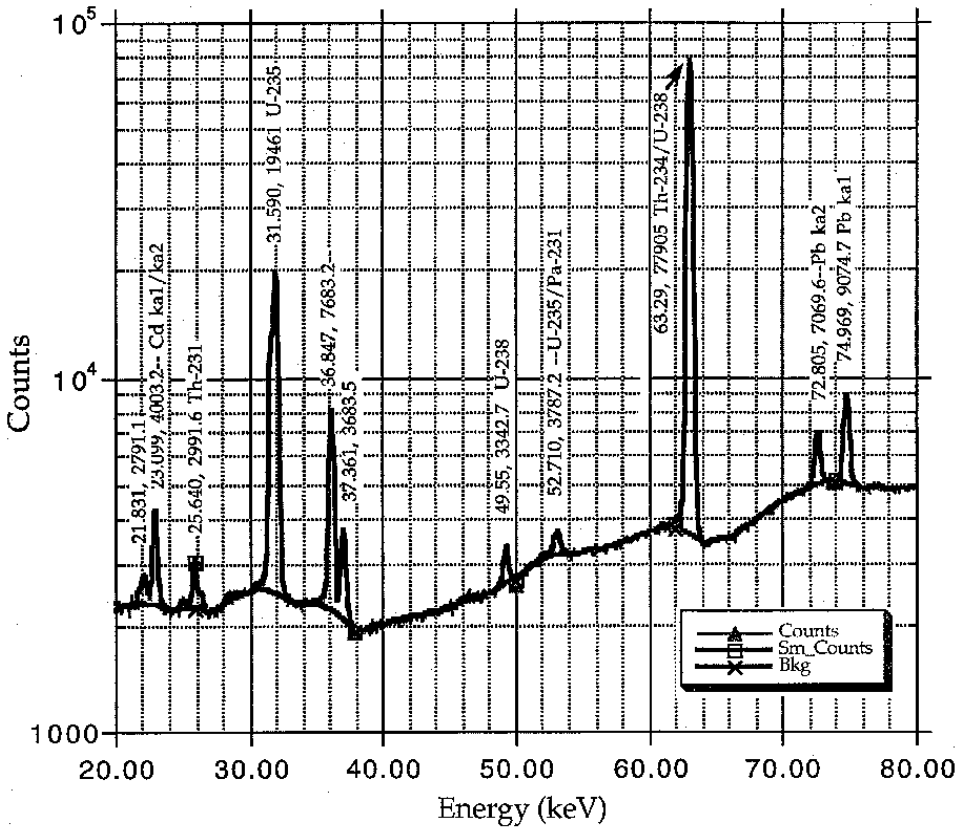

Fig. 52. Plot of a 99.983% ^{238}U Spectrum from 20–80 keV.

Fig. 53 shows the spectrum from a 99.1% sample of ^{235}U. It is considerably different than the ^{238}U spectrum shown above. There are no strong lines from ^{235}U or its daughters in this region. The lead $K\alpha_1$ and $K\alpha_2$ x-ray lines are a typical spectral contaminant resulting from fluorescent x-rays in the collimator.

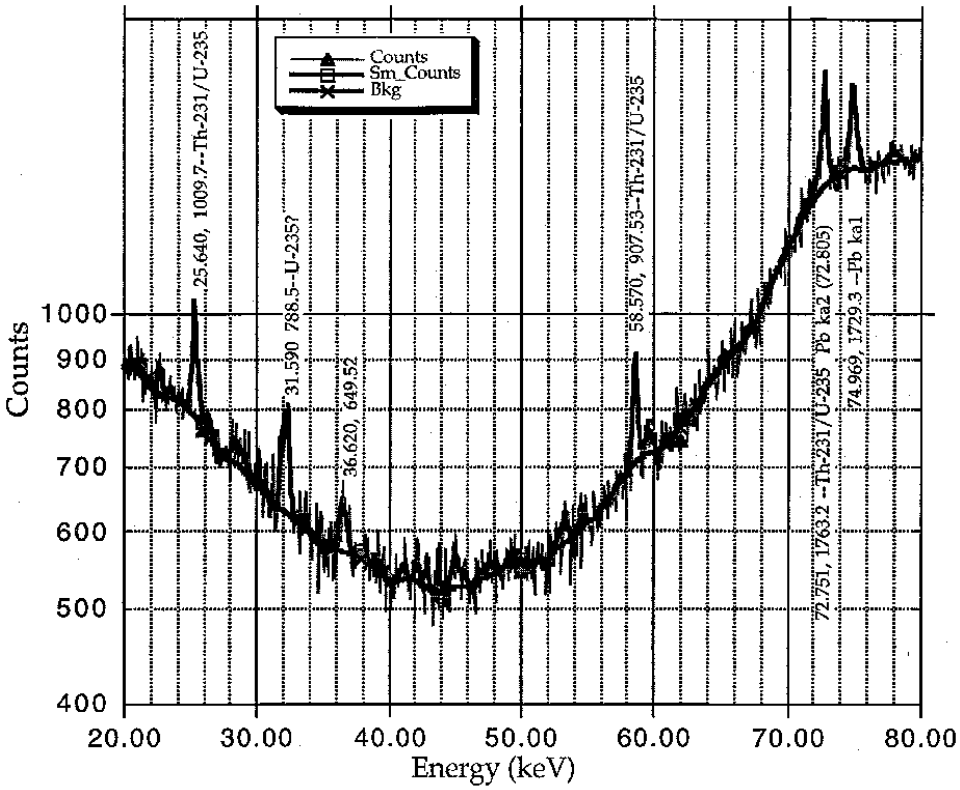

Fig. 53. Spectrum from a 99.1% Sample of ^{235}U, from 20–80 keV.

Fig. 54 shows a 10.075% ^{235}U/89.975% ^{238}U spectrum from 20–80 keV. In this region is found the only pure ^{236}U peak at 49.369-keV. The ^{238}U peak at 49.550 keV is normally too weak to be seen. Samples that have been in a reactor will often have a much higher ^{236}U peak.

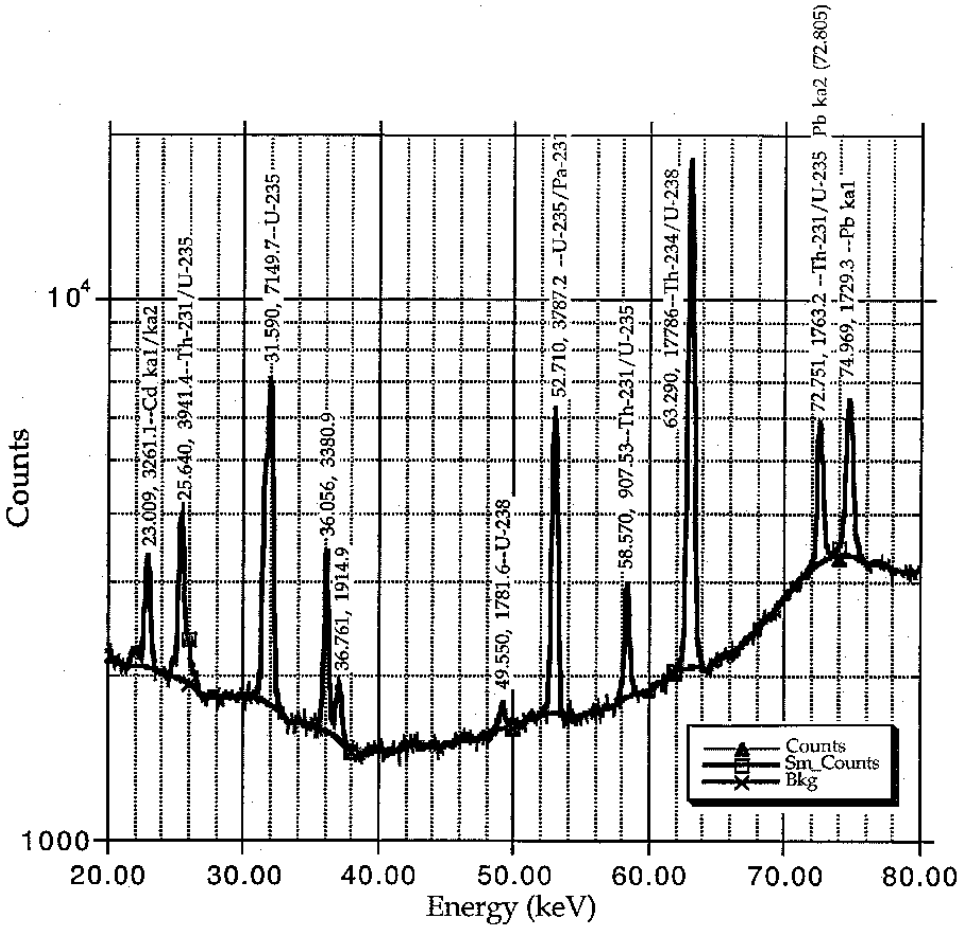

Fig. 54. Plot of a 10.075% ^{235}U/89.975% ^{238}U Spectrum from 20–80 keV.

6.2.2. The 80–85 keV Energy Region

The lowest energy range of practical use is the 80–85-keV region. It contains peaks due to ^{235}U (81.228, 82.087, and 84.214 keV) as well as a 83.300-keV peak due to ^{238}U/ ^{234}Th decay. Fig. 54 shows the spectrum of a 10.075% ^{235}U sample. Even though the lead x-rays are weak, they are a typical contaminant to spectra in this region and have to be accounted for in making accurate peak intensity determinations. The 83.30-keV ^{238}U/ ^{234}Th peak is quite weak making its accurate determination difficult.

Fig. 55 shows the net (background subtracted) uranium spectrum (10.075% ^{235}U) from 80 to 87 keV. As can be seen, the ^{238}U / ^{234}Th 83.300-keV peak is quite weak, making good peak intensity measurements difficult for this sample and samples with lower concentrations of ^{238}U.

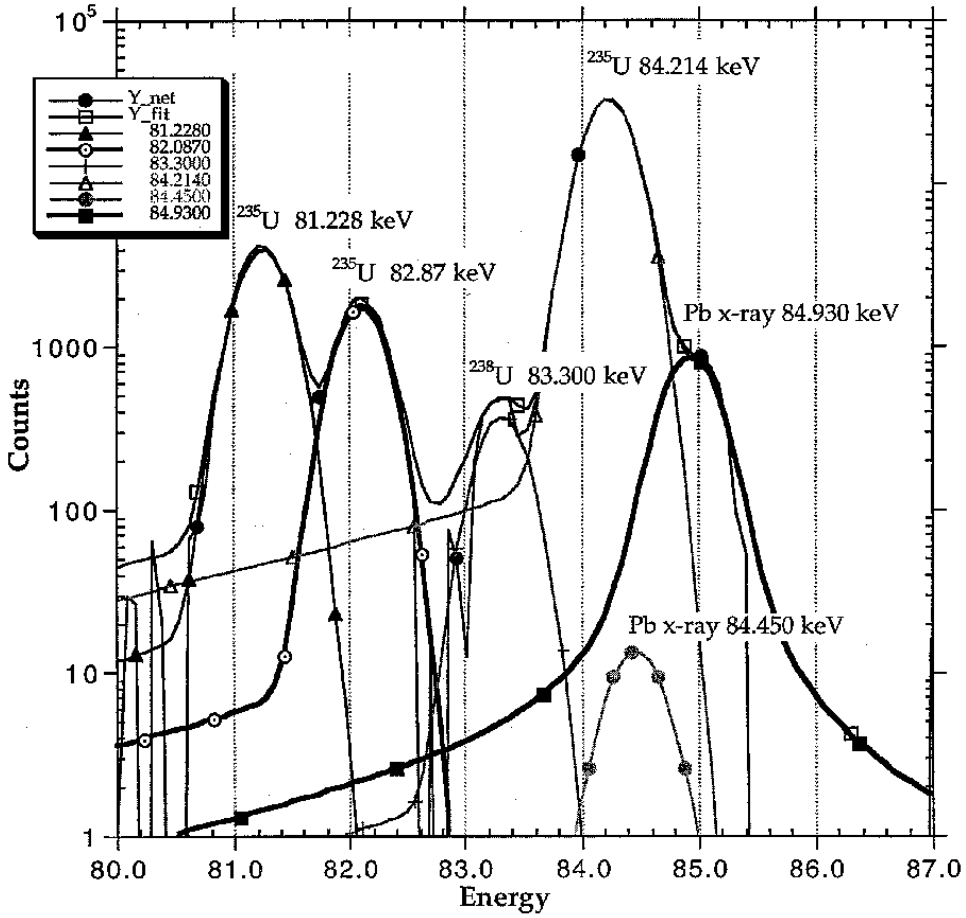

Fig. 55. The Net (Background-Subtracted) Uranium Spectrum (10.075% ^{235}U) from 80 to 87 keV.

6.2.3. The 87-100-keV Energy Region

This region has three peaks due to ^{238}U, a number of ^{235}U peaks and the two strong uranium Kα_1 and Kα_2 x-ray peaks. The tight clustering of peaks requires careful peak fitting and analysis. For most concentrations, this is the region of primary interest since the 92.365- and 92.790-keV ^{238}U/^{234}Th peaks are very near the 93.356 keV Th-Kα_1/ ^{235}U peak. The thorium Kα_1 and Th Kα_2 x-ray peaks, due to ^{235}U decay, bracket the ^{238}U doublet. The ^{238}U 95.85-keV peak is so weak and has so much interference from the Pa Kα_1 95.89-keV peak that it is virtually useless as a diagnostic tool. The main limitations on using this energy range are that at high ^{235}U concentrations, the signals of the ^{238}U peaks are too small to be accurately determined, and at low ^{235}U concentrations the ^{235}U peaks are too small.

Fig. 56 shows all 13 peaks used in fitting the data in the 86-102 keV region. Appendix A gives the identification of each of the energies and where they come from. Clearly seen is the gamma-ray profile of the ^{238}U peaks and the much broader Voight x-ray profile of the ^{235}U/Th x-ray daughter peaks and the uranium x-rays.

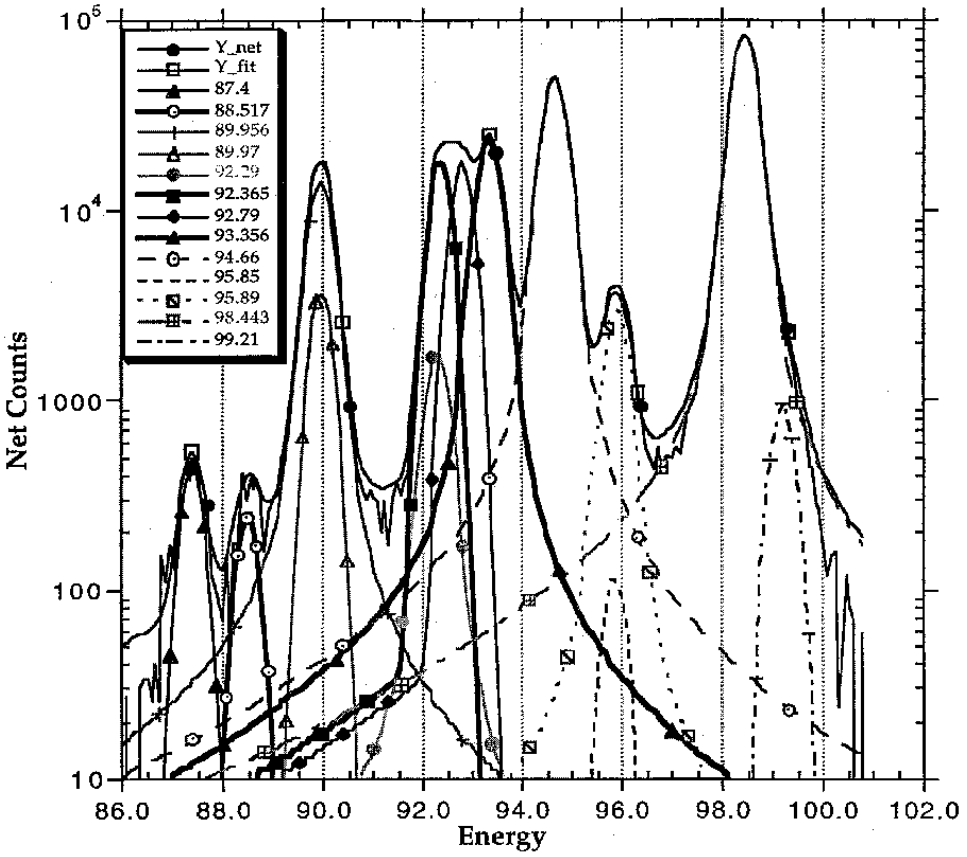

Fig. 56. The 13 Peaks Used in Fitting the Data in the 86-102-keV Region.

Fig. 57 shows the net count spectrum from 86 to 102 keV of a 10.075% ^{235}U sample with the peaks grouped into their respective components. At this ^{235}U concentration, the ^{235}U and ^{238}U peaks are approximately equal. The fitting process uses both the protactinium and thorium x-rays from the ^{235}U daughters to find the best fit to the combined ^{235}U and ^{238}U spectrum.

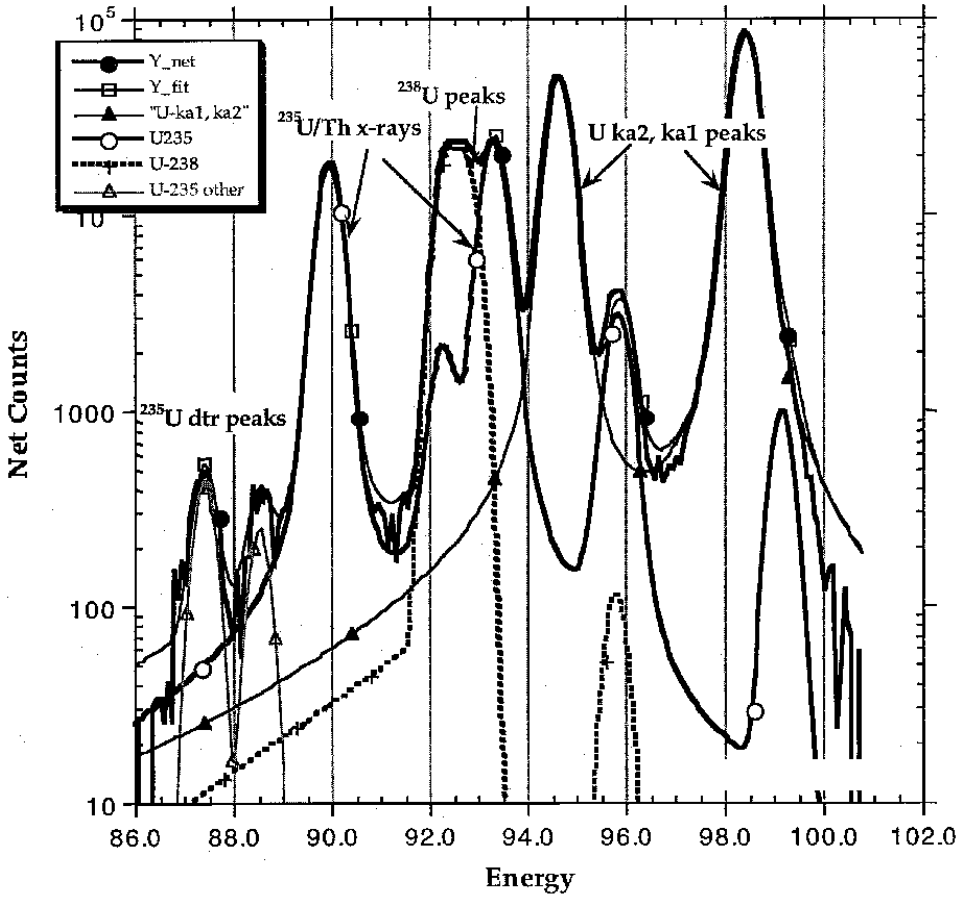

Fig. 57. Net Count Spectrum from 86 to 102 keV of a 10.075% ^{235}U Sample.

6.2.4. The 100–118-keV Energy Region

This region is very complex with 21 peaks containing all the Kβ x-rays of U, Th and Pa plus a 109.2-keV gamma from ^{235}U and a 112.82-keV peak from ^{238}U. The large number of peaks and the overlap of peaks due to the wide Voight profile of the x-ray signals make extracting useful peak ratios difficult. The thorium and protactinium x-ray peaks are tied to the ^{235}U decay and cannot be used because good branching ratio values are not available.

Fig. 58 shows the different x-ray multiplets in this region (each the sum of six x-ray peaks) and the two gamma rays. This energy region is not used in the analysis due to the difficult nature of the signals and the poor information available on branching ratios.

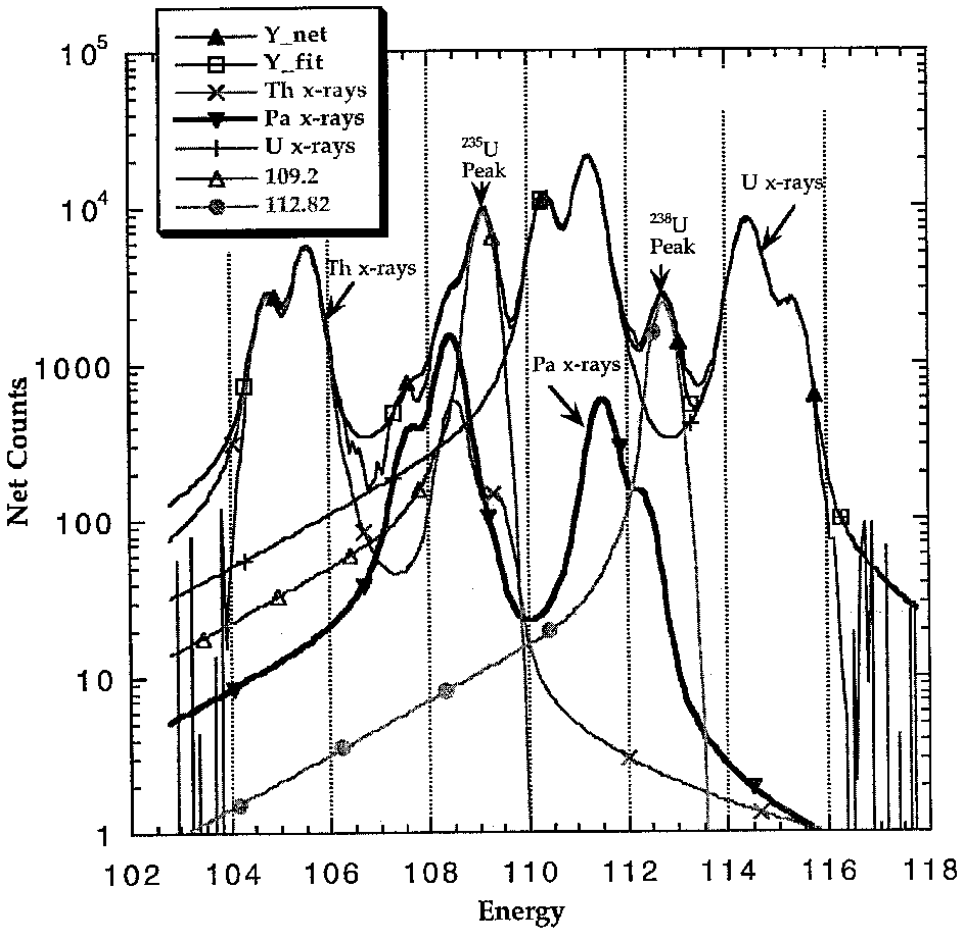

Fig. 58. Net Count Spectrum from 102 to 118 keV of a 10.075% ^{235}U Sample.

6.2.5. The 118-180 keV Energy Region

The 118–180-keV region has relatively few peaks. The usually clean 120.90-keV peak of ^{234}U is useful for obtaining an estimate of that isotope. This peak is usually weak (sometimes too weak to analyze), giving poor statistic answers, and there are no nearby peaks to ratio it to. For good accuracy the 120.90-keV peak intensity needs to be corrected for efficiency and gamma transmission.

There are usually no ^{238}U or daughter peaks of sufficient intensity to be of interest in this region. The only exception is for depleted uranium spectra where the normally weak 131.300-keV ^{238}U/ ^{234}Pa peak is enhanced and the 143.760 keV ^{235}U peak is one of the cleanest ^{235}U peaks available (see Fig. 60). Extracting the peak area of the 93.35-keV ^{235}U/Th x-ray peak from the 82-102 spectral region is very inaccurate at very low ^{235}U concentrations. These isolated ^{235}U and ^{238}U/daughter peaks in the 118–180-keV region can be more accurately analyzed. The 143.76- and 163.33-keV ^{235}U peaks can be used to establish the average material thickness in the sample by analyzing their relative intensities. Both of these techniques are utilized in the U235 code for low ^{235}U concentrations and transmission corrections.

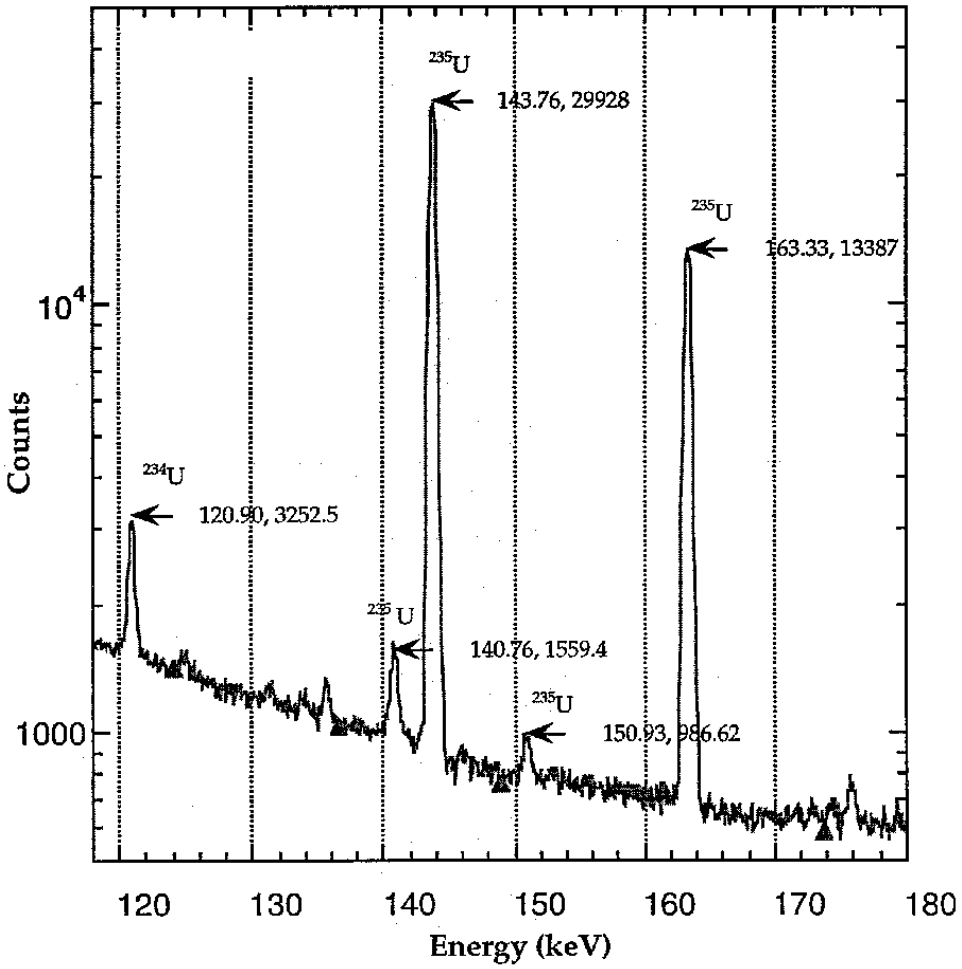

Fig. 59. The Gamma Spectrum from 118 to 180 keV of a 10.075% ^{235}U Sample.

Fig. 59 is the gamma spectrum from 118 to 180 keV of a 10.075% ^{235}U sample. Peaks are rather sparse in this region with usable ^{238}U peaks mainly showing up at low ^{235}U concentrations. The ^{234}U peak at 120.90 keV is usually quite weak but can still be analyzed because of its isolation. Lack of good statistics on this peak may limit its accuracy.

Fig. 60 shows the same 118–180-keV range for a 0.017% ^{235}U sample. The ^{238}U peaks are enhanced, but the low count rate makes getting decent statistics for analysis very time consuming. The ^{234}U 120.90-keV peak is normally too weak to analyze at low ^{235}U concentrations.

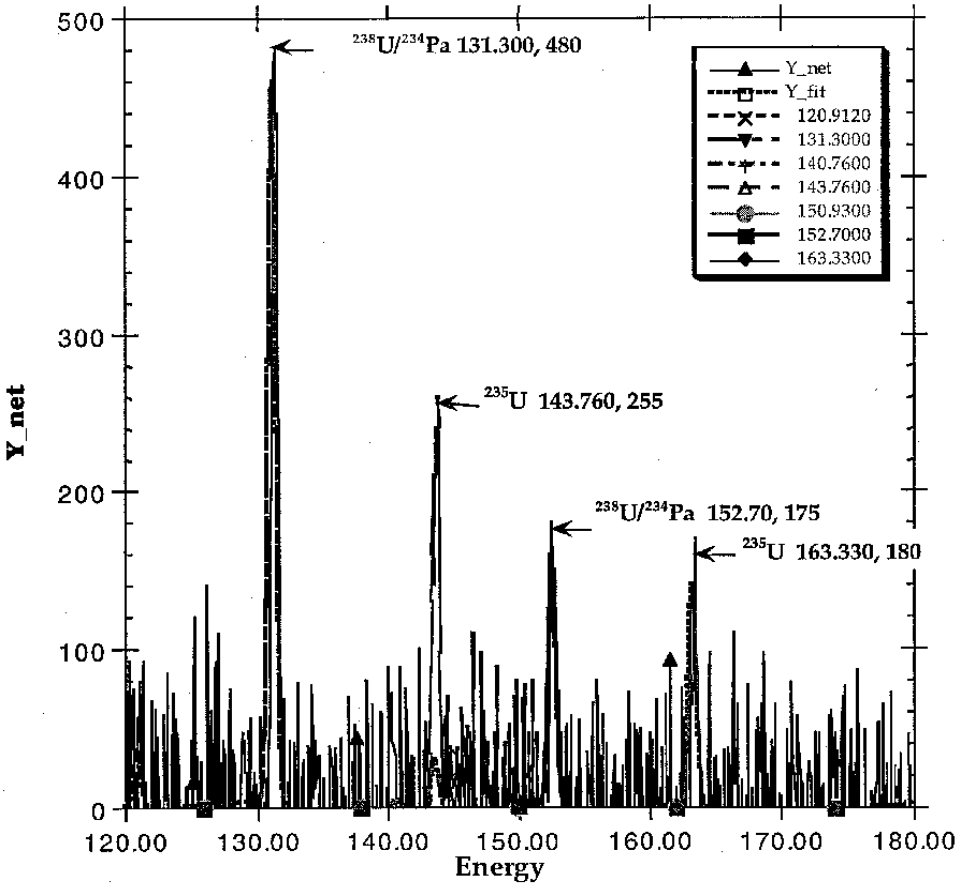

Fig. 60. Spectrum for 118–180-keV Range for a 0.017% ^{235}U Sample.

6.2.6. The 180–210-keV Energy Region

The 180-210 keV region has several prominent ^{235}U peaks including the most intense ^{235}U peak at 185.715 keV. This peak, in conjunction with the 98.443 keV uranium x-ray peak, is used to determine a more accurate gain and zero for the spectrum and to verify that ^{235}U is present in the spectrum. There are no easily observable ^{238}U peaks in this region. The only major uncertainty here is the 185.712 keV peak which has several other weak peaks around it that must be accounted for to get a good 185.715 keV peak intensity. One of the significant variations observed in this region is the 185.715 keV peak height to 188 keV background ratio. This ratio is found to vary from about 1000 at 90% enrichment to 1 at .02% enrichment. This change is attributed to the high energy gamma rays in ^{238}U decay and the contribution they make to the Compton continuum in this energy region. A spectrum with a high 185.712-to-188-keV ratio has almost certainly a “high” ^{235}U enrichment. Conversely a weak 185.715 peak with a high Compton continuum has a low ^{235}U enrichment.

Fig. 61 shows the net count spectrum from 180 to 210 keV of a 10.075% ^{235}U sample. In this region there are typically no ^{238}U peaks intense enough for any peak analysis.

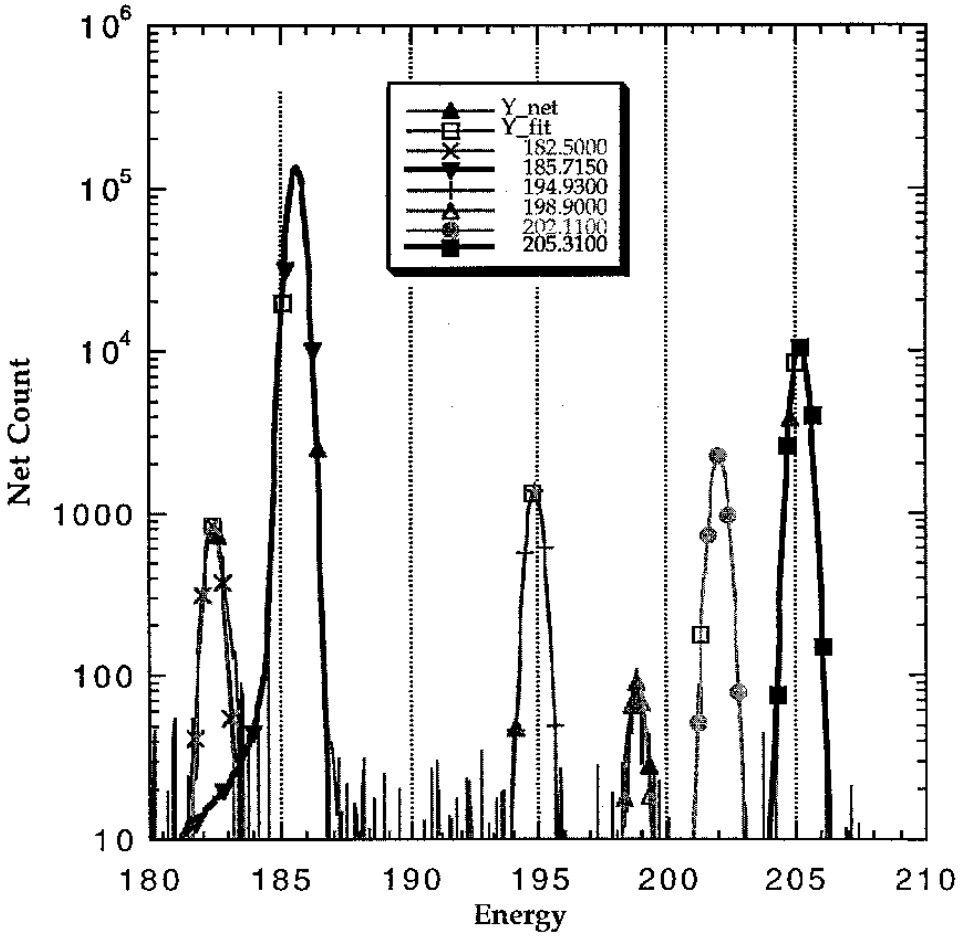

Fig. 61. The Net Count Spectrum from 180 to 210 keV of a 10.075% ^{235}U Sample.

6.2.7. The 210–300-keV Energy Region

The 210–300-keV region only has one strong ^{238}U/ ^{234m}Pa peak at 258.2 keV. This peak is too weak to be of any great interest. The overall low intensity of this region lowers its utility in analyzing isotopic ratios.

Fig. 62 is the net count spectrum from 210 to 300 keV of a 10.075% ^{235}U sample. In this region there is only one ^{238}U peak of interest, and a few ^{235}U peaks.

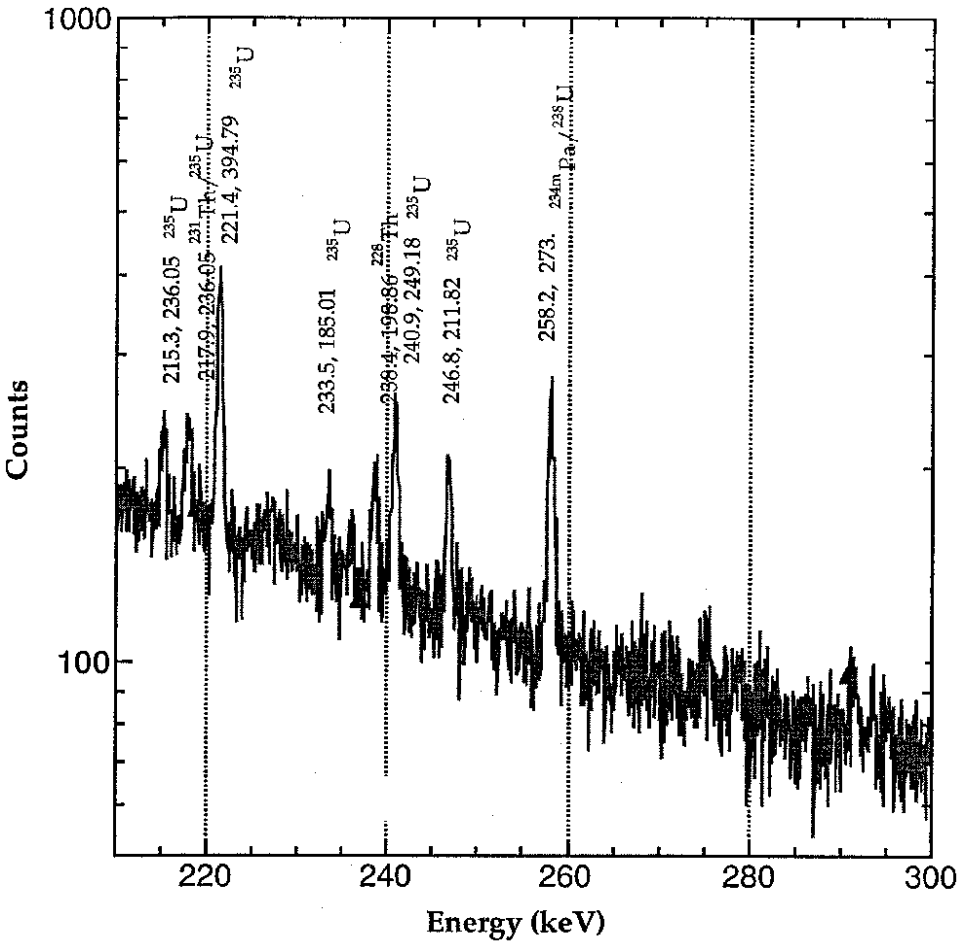

Fig. 62. The Net Count Spectrum from 210 to 300 keV of a 10.075% ^{235}U Sample.

6.3. Describing the Peak Shape[11]

Some peaks in uranium spectra are well enough resolved that their intensity can be simply determined by integrating the counts in selected channels and subtracting related backgrounds to obtain the net peak areas. However, the peaks in other regions overlap severely, requiring a more involved procedure to interpret the data. To start, one must have an analytic function or algorithm that adequately describes the shapes of the peaks in the regions of interest. This shape is mainly described by a Gaussian function; however, some tailing does occur, particularly on

[11]Adapted from "*MGA: A Gamma-Ray Spectrum Analysis Code for Determining Plutonium Isotopic Abundances*," Vol. 1 and 2, R. Gunnick, W. D. Ruhter, UCRL-LR-103220, 1990.

the low-energy side. Therefore, the following equation is used to fit a peak,[12] as shown in Fig. 63, with a central Gaussian component and a "short-term" (and sometimes a "long-term") tailing component:

$$y_i = y_0(e^{\alpha(x_i - x_0)^2} + T(x_i)) \quad \textbf{(3)}$$

where

y_i = net counts in channel x_i
y_0 = peak height at the peak position, x_0
α = peak-width parameter
$T(x_i)$ = tailing function

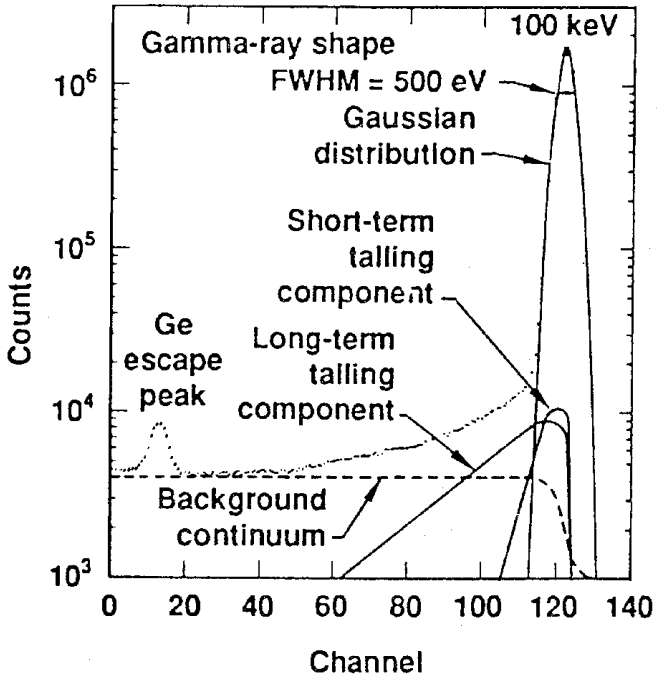

Fig. 63. The principal shape components of a gamma-ray peak are described by a central Gaussian distribution and two tailing components.

[12] *Computerized Quantitative Analysis by Gamma-Ray Spectrometry. Vol. 1, Description of the GAMANAL Program,* R. Gunnink and J. B. Niday, Lawrence Livermore National Laboratory, Livermore, Calif., UCRL-51061 (1972).

The tailing function is given by

$$T(x) = (Ae^{Bx} + Ce^{Dx})(1 - e^{0.4x^2})\delta \quad \textbf{(4)}$$

where

x = $x_i - x_o$
$A\,e^{Bx}$ = short-term tailing
$C\,e^{Dx}$ = long-term tailing.
δ = 1 for $x < x_0$
= 0 for $x \geq x_0$

The *A* and *C* are referred to as "tailing-amplitude parameters," while *B* and *D* are parameters that describe the two tailing slopes. The final term involving δ reduces the effect of *T(x)* to zero at the peak position to limit the tailing contributions only to the low-energy side of a peak.

These equations are used to unfold the data in complex peak regions, as discussed below. For now, it is important to note that some of the variables are linear in the equations (such as *yo*, *A*, and *C*), whereas the others are in the exponents. The variables appearing in the exponents can be predetermined and therefore are treated as constants. The equations are then linear in form so that they can be solved by a one-pass least-squares calculation rather than by iterative calculations. The peak-shape characterization is done in the calibration step. Also, the parameters can be entered by the operator in the analysis settings dialogs.

The peak resolution parameter, α, is related to the peak width, σ_t, by the equation

$$\alpha = -1/2\,\sigma_t^2 \quad \textbf{(5)}$$

where σ_t is given by

$$\sigma_t^2 = \sigma_n^2 + \sigma_s^2 \quad \textbf{(6)}$$

and where

σ_t = the total peak width at half-maximum
σ_n = contributions due to the system "noise"
σ_s = detector contribution related to the statistical process of electron-hole production

Because σ_n is a constant for a given spectrum and σ_s is directly related to the energy,[12] **Eq. (6)** can be written as

$$\sigma_t^2 = S_1 + S_2E \quad \textbf{(7)}$$

The shape constants S_1 and S_2 are determined by measuring the peak width of two "clean" peaks in a spectrum during the calibration.

Although **Eqs. (3)** and **(4)** are useful for describing gamma-ray peak shapes, they do not accurately describe the observed distribution of K-series x-ray peaks associated with the actinide elements.[13] Because of the short lifetime of the virtual x-ray state associated with the electron conversion process, the Lorentzian distribution of K x-rays emitted have an FWHM of about 100 eV. When this energy distribution of radiations is convoluted with the instrumental dispersion, the resulting peak shape, as shown in Fig. 64, is substantially different from that of an equivalent-energy gamma ray. The algorithms reported in footnote 13 are used to compute the altered response.

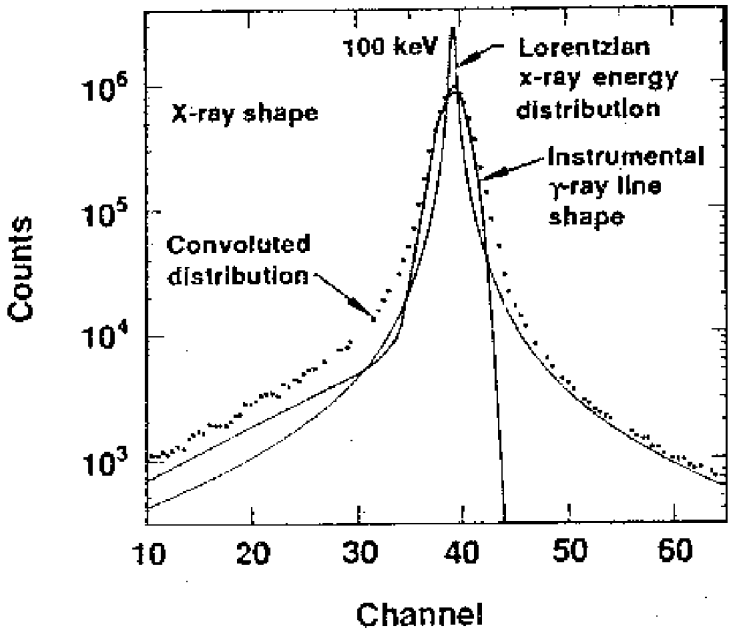

Fig. 64. The Lorentzian-broadened energy distribution of x rays both increases the FWHM of a peak and significantly alters its line shape.

The above equations are adequate for describing peaks in a spectrum taken at modest counting rates. Additional peak-shape distortions may occur when using high counting rates. These manifest themselves as protrusions or tails on the high-energy side of the peaks. The magnitude and shape of this distortion is not predictable. However, a relatively simple procedure has been implemented to account for this distortion when generating peak shape profiles. In this procedure, the Gaussian portion of the 59- and 208-keV peaks is first stripped out. The net counts remaining on the high-energy side of these peaks are used to determine an approximate magnitude and shape of any distortion caused by pulse pileup. This profile is stored and used when calculating the shape responses of the peaks in the 94- to 104-keV region.

The program determines and uses the constants, A, B, C, D, S_1 and S_2 from the Peak Shape Parameters entered or calculated in the calibration. The Voight profile is used in fitting peaks that are identified as x-rays.

[13]"An Algorithm for Fitting Lorentzian-Broadened, K-Series X-Ray Peaks of the Heavy Elements," R. Gunnink, *Nucl. Instrum. Meth.* **143**, 145 (1977).

7. REPORT

7.1. Standard Report

The standard report is shown in Fig. 65. This is the normal report, which includes several measurement and bookkeeping parameters as well as the analysis results.

The top of the report contains version information, analysis time, data collection time, and sample details.

The next section shows the peak summary for each peak in the analysis. This section is included or not depending on the output settings. The **FWHM**, **Slpsh**, and **Pkht** are the peak parameters for the tail and the main peak.

The next section shows the 92- to 98-keV region peak areas and the reduced chi-square for this region.

The next section shows the isotopic abundance for the three uranium isotopes and the uncertainty associated with each value.

The last section shows the file name of the spectrum and the results files. The results files are needed for the graphic display of the analysis results.

Any errors in the analysis are shown at the end of the report.

```
               U235 Calculation Summary

  File = C:\U235\heu0936.Spc   Analyzed:  6/17/1998 @: 14:21
-----------------------------------------------------------
  Data Counted on:        =  5/29/1998 for    121.3 min.
  Analyzer deadtime       =   1.11 %
  Count rate              = 7.8081E+05 [counts/min]
  Total Counts            = 9.4751E+07 [counts]

  Calculated gain         =    .0752 [keV/channel]
  Calculated zero         =   -.2384 [keV]
  Number of data channels =   4096
=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=
        Peak Summary for Individual Peaks

        --------------------------------
  E[in]   E[fit] FWHM  Ampsh Slpsh      Pkht    Tot_cts     +/-    Rchisq
  185.71  185.71  .617  .001  .650   26645.7  .2343E+06     693.9   4.116
  120.90  120.91  .525  .001  .616     532.2  3798.         135.3   1.317
  129.30  129.71  .000  .000  .000      39.7  61.87          7.9    .000
  143.76  143.77  .547  .001  .628    5539.3  .4303E+05     298.2   2.723
  163.33  163.35  .594  .001  .639    2455.2  .2105E+05     209.6   1.314
  205.30  205.31  .657  .002  .661    2176.0  .2088E+05     186.8  35.649
  111.30  111.30  .489  .001  .608    8357.8  .7256E+05     323.5   4.305
=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=

 U238 92.36  keV peak     =      220.4 +/-      269.3 [cts]
 U238 92.79  keV peak     =      224.4 +/-      269.3 [cts]
 U235 93.35  keV peak     =    57703.0 +/-      269.3 [cts]
 U 94.66 keV X-ray peak   =   162918.3 +/-      572.2 [cts]
 U 98.44 keV x-ray peak   =   269663.8 +/-      814.2 [cts]

        Rchisq =       6.0096

=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=
         URANIUM ISOTOPE ANALYSIS RESULTS
 U-Isotope Abundance(%)  Uncertainty        (%)
   U234       .801        +/-   .093   (   11.623)
   U235     94.278        +/-  3.586   (    3.804)
   U238      4.920        +/-  3.586   (   72.881)

   Data corrected for absorber; [ Z  (g/cm**3)  Thx(cm)]
                                 13.  2.6989   .2000
   Data and fit have POOR statistics
     "Answers" should be used with CAUTION
       Total peak fit error >=  120.1 %

=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=
 ERROR WARNINGS:  3 Possible ERRORS reported.
=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=

  Fit 185.715 peak RCHISQ =      4.
     Possible GAIN, ZERO or STATISTICS problems

  Fit of 85-100 keV peak region RCHISQ =       6.0
     FIT did NOT converge well!
     Possible GAIN, ZERO or STATISTICS problems

 Possible SPURIOUS peak(s) detected in fit residual data.
   Set Output Level = 6; to examine data in; [ ].fit file.
     Possible GAIN, ZERO, BACKGROUND or STATISTICS problems
=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=
```

Fig. 65. U235 Standard Report.

8. WINPLOTS

This program makes a hardcopy output of any type of ORTEC spectrum file in a fixed format with many user-set optional variations (such as grid lines) available. The plotting output devices include the full range of graphics- capable printing devices supported by Windows (i.e., hardcopy is not limited only to plotters). WINPLOTS allows the user to select and set up the printer. In the interactive mode, a preview of the spectrum plot is automatically displayed on the screen and updated as changes are made to the display parameters. The operator can select the start and stop channels or energy range for the plot, the printer to be used, whether the plot will be in logarithm mode or linear mode, and whether to specify the scale maximum in linear mode or use automatic scaling. If a color printer is used, the colors of the different parts of the plot can be selected.

The sample, detector, and acquisition descriptions in the file can be plotted or suppressed. ROIs can be plotted when stored in the spectrum (**`.SPC`**) file or in a separate ROI file.

To start WINPLOTS, click on **Start** on the Windows Taskbar, then **Programs**, **Mga**, and **WinPlots** (see Fig. 66). WINPLOTS can also be run in command-line mode for use in **`.JOB`** files, or directly from other Windows programs (see Section 8.3). In this mode, the settings can be specified or the defaults can be used.

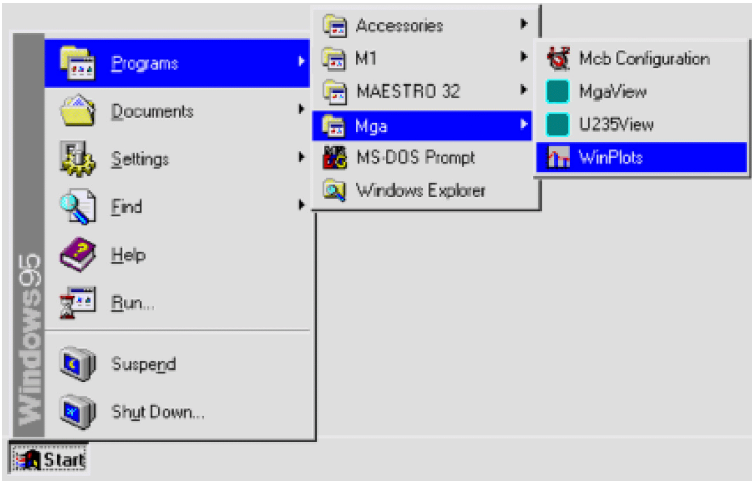

Fig. 66. Starting WINPLOTS.

The spectrum files are associated with WINPLOTS by the installation program, so double-clicking on a spectrum filename within Windows Explorer will start WINPLOTS and display that spectrum.

The main WINPLOTS display is shown in Fig. 67.

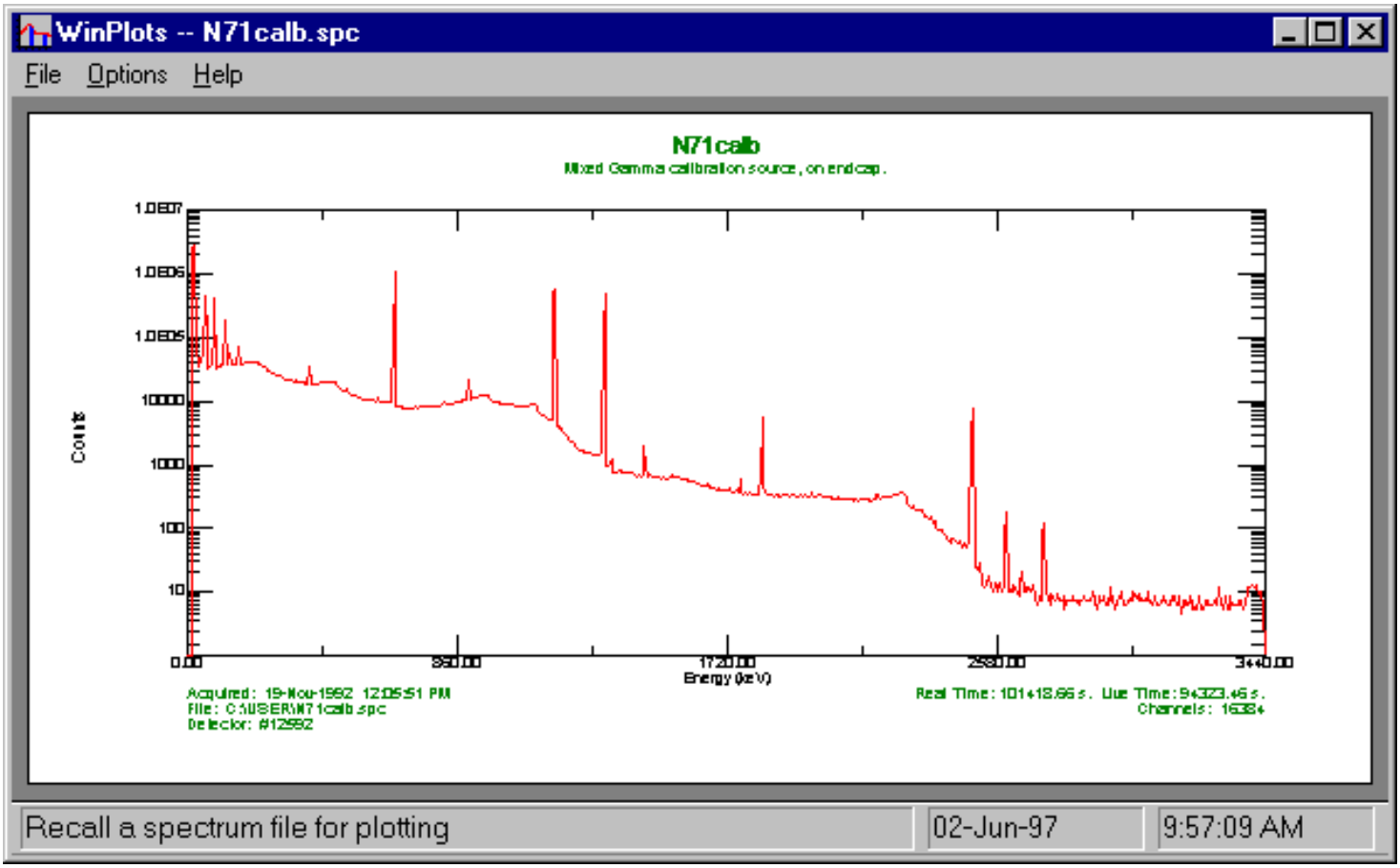

Fig. 67. The Main WINPLOTS Display.

8.1. File

Fig. 68 shows the **File** menu. These menu items select the spectrum and ROI to be displayed, read and write the settings file, and actually make the plot.

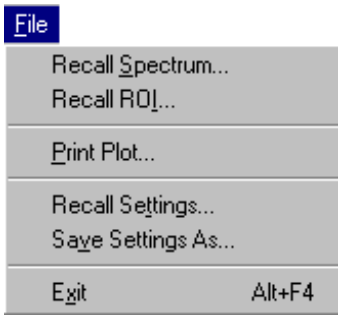

Fig. 68. The File Menu.

Once a file has been selected using the **Recall Spectrum...** function (see the file-open dialog shown in Fig. 69), it is automatically previewed using the current settings. This is the exact plot that will be printed. There are minor differences between display and printer fonts and colors.

The sample description, format, and number of channels are shown at the bottom of the dialog to aid in selecting the correct file.

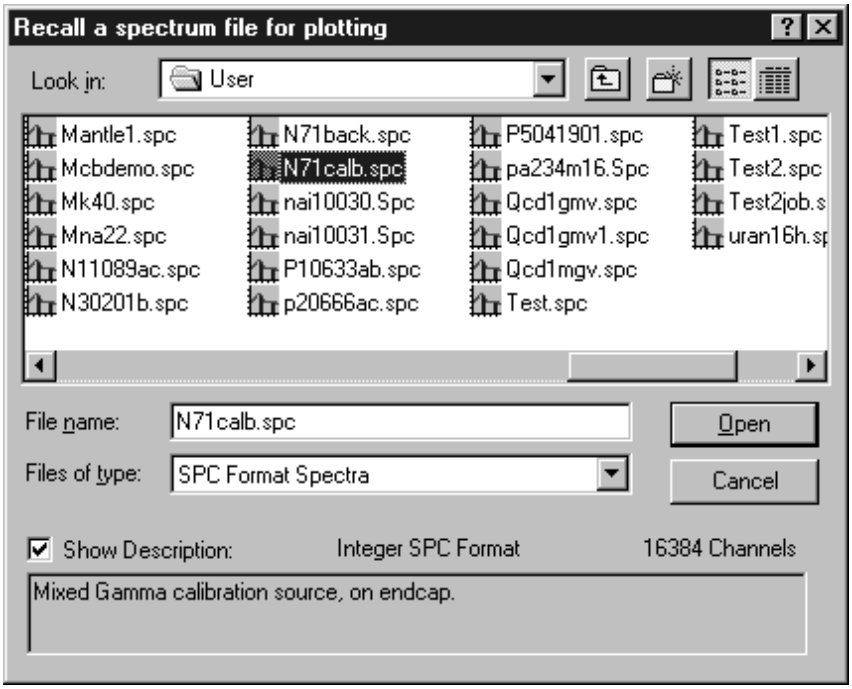

Fig. 69. The Recall Spectrum File for Plotting Dialog.

Figure 70 shows the **Recall a settings file** dialog. All of the settings specified on the **Options**/**Plot...** dialog can be saved in the settings file. The file is saved in the **Save Settings** menu item. Various groups of settings can be saved and recalled here to make the desired plots or to be used in the command line mode.

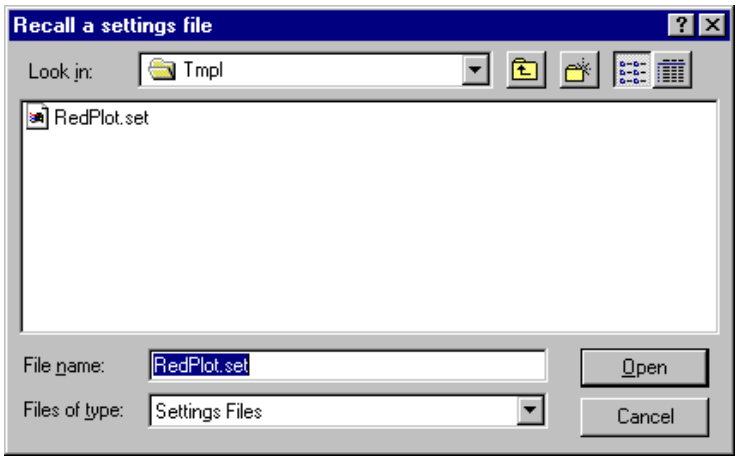

Fig. 70. The Recall a Settings File Dialog.

The **Print Plot...** dialog (Fig. 71) allows you to choose a printer from the **Name** droplist. Click on **Properties** to adjust the settings for the current printer.

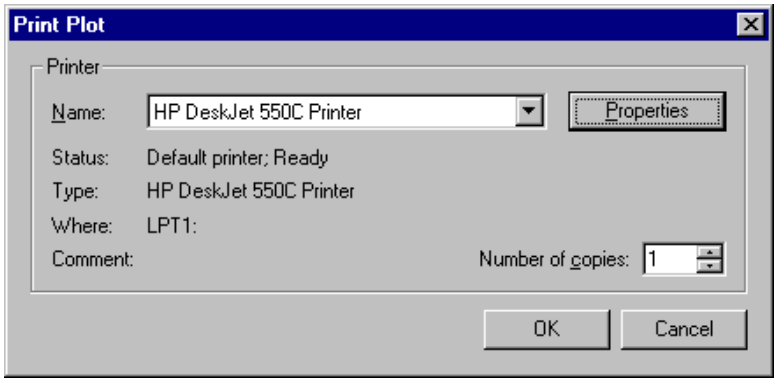

Fig. 71. The Print Plot Dialog.

8.2. Options

The **Options** menu is shown in Fig. 72. These menu items control the plot settings and WINPLOTS operation.

Fig. 72. The Options Menu.

8.2.1. Plot...

The **Plot Options** dialog is shown in Fig. 73. These settings are all stored in the default settings file and reloaded when WINPLOTS is next started. The **Title** is printed at the top of every plot (just above the sample description). If no title is specified, a default title is generated which is composed of the spectrum and ROI file names. The **Printer** is selected from the list of available printers in Windows.

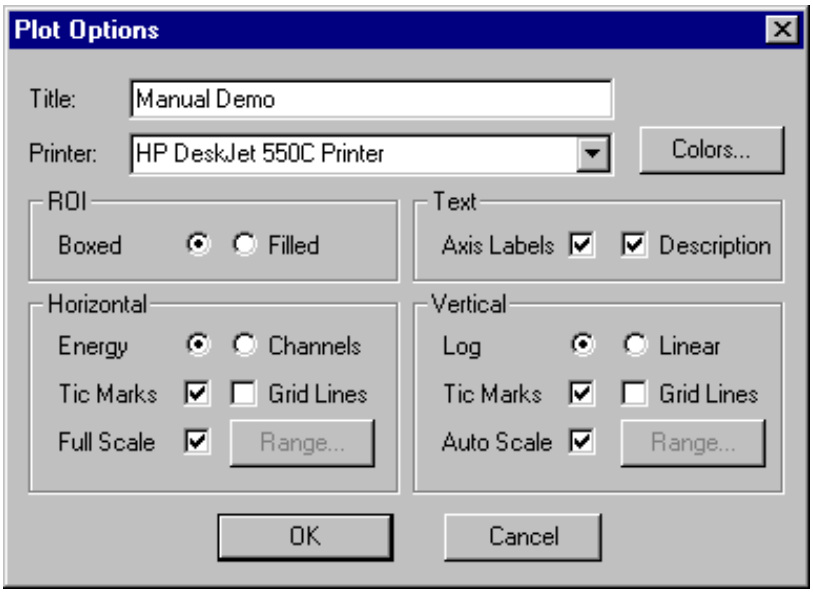

Fig. 73. The Plot Options Dialog.

If the printer supports color printing, the **Colors...** button will be enabled. Clicking on it will display the color options dialog, Fig. 74. If monochrome prints are desired from a color printer, check the **Monochrome** box. The five different plot areas can have different colors. Select the desired color from the drop down list for each area. These are the Windows colors defined for the selected printer and may not duplicate the actual colors printed.

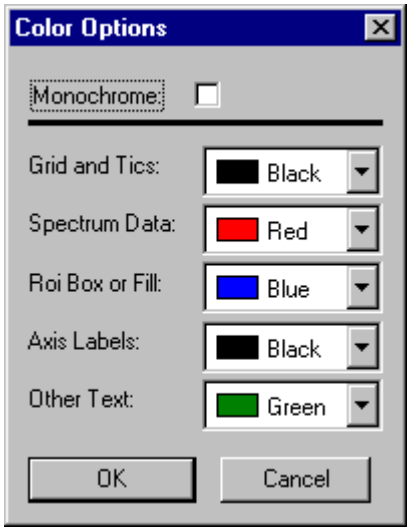

Fig. 74. The Color Options Dialog.

8.2.1.1. ROI

The ROIs can be **Boxed**, that is, represented as "boxes" drawn from the start to the stop channel (or energy) and from the baseline to above the spectrum. The **Filled** selection will "fill" the region under the spectrum data with a cross hatch. It is not completely filled in and does not extend above the data.

8.2.1.2. Text

The **Axis Labels** and the text **Description** from the file can be printed. The description includes the sample, detector, and acquisition description.

8.2.1.3. Horizontal

If the spectrum to be plotted is calibrated, the plot can be either in **Energy** or **Channel** numbers. If the spectrum is not calibrated, this value is set to channel and cannot be altered.

Tic Marks (small lines indicating the scale on the axes) can be included. Including them makes the plot more readable. **Grid Lines** can also be included. The grid lines are lines across the complete width of the plot at the major tic marks.

The plot can either be the complete spectrum or any part of the spectrum. Unmarking **Full Scale** will enable the **Range** button. Selecting **Range** will open the dialog shown in Fig. 75, where the limits for the plot are set. The range of the plot can be either in **Channels** or **Energy** (independent of the plot labeling). In order to easily compare spectra, the energy can be set to values below the first channel in the spectrum. In this case the data below channel 0 are plotted as 0.

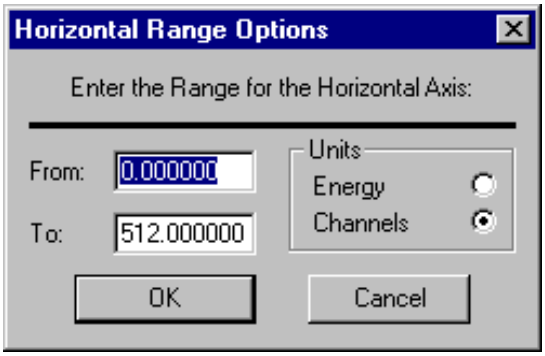

Fig. 75. Horizontal Range Options Dialog.

8.2.1.4. Vertical

One of the two choices, **Log** and **Linear**, can be selected by clicking on the appropriate radio button. The linear scale is set by clicking on **Range...**.

Tic Marks (small lines indicating the scale on the axes) can be included. Including them makes the plot more readable. **Grid Lines** can also be included. The grid lines are lines across the complete height of the plot at the major tic marks.

When **Auto Scale** is selected, the plot vertical axis is adjusted so that the largest count in the spectrum is near the top of the plot region.

When **Auto Scale** is clicked off, the **Range** button is enabled. Clicking on **Range** will display the dialog shown in Fig. 76. The value entered will be the value for the top of the plotted region. Any counts above this value will be plotted at this value.

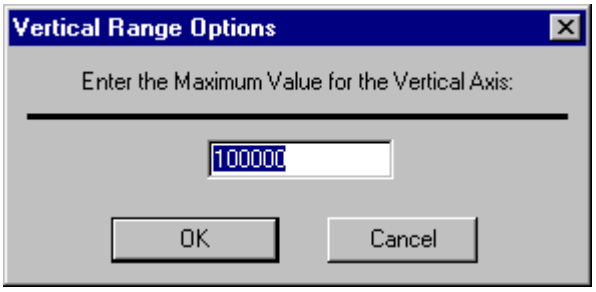

Fig. 76. Vertical Range Options Dialog.

8.3. Command Line Interface

The Command Line Interface will support options available in the interactive mode as shown below:

```
WINPLT32 <spectrum> -R <roi_file> -S <set_file> -P
```

Where:

<spectrum> Specifies the spectral data file (**.SPC**, **.An1** or **.CHN**). The extension must be included.

-R <roi_file> Specifies the **.ROI** file. The extension must be included.

-S <set_file> Specifies the settings file. The extension must be included.

-P Causes the program to print the plot and exit automatically. Used mainly in **.JOB** files or the Export function.

9. ERROR MESSAGES

The following lists the U235 error flags. These message numbers are displayed by the analysis engine, U235, if a problem occurs in the analysis.

In the database, the first four digits of the error are the errnum value, and the second four are the warnum value.

=Errnum (Hexadecimal)	**Meaning**
1	The peak parameter shapc(1) = 0 in: PKFIT
2	The fit MATRIX is singular in: PKFIT
4	Tried to read beyond EOF OF INPUT file in: RDBLK
8	LIVETIME NOT found in header, Approximate LIVETIME value calculated.
10	Data TYPE set to -1, Cannot read INPUT data of this type.
20	GAIN, ZERO appear to be incorrect in Setup file? Use C=Calibrate, to check or change.
40	Total counts VERY HIGH. Possible IO or data problems
80	Total counts VERY LOW. Possible IO, statistics or data problems
100	Livetime = Realtime in Header record, Possible IO or data problems
200	Analyzer DEADTIME VERY HIGH = Possible IO or data problems
400	Fit 185.715 peak RCHISQ = *value*. Possible GAIN, ZERO or STATISTICS problems
800	Fit of 85-100 keV peak region RCHISQ = *value*. FIT did NOT converge well! Possible GAIN, ZERO or STATISTICS problems
1000	U-235 185.715 keV peak VERY LOW or non-existent. U235 may NOT be present for analysis or; Possible GAIN, ZERO or STATISTICS problems
2000	Fit Matrix is SINGULAR in PKFIT; cannot fit data. Possible GAIN, ZERO or STATISTICS problems

4000 Possible SPURIOUS peak(s) detected in fit residual data. Set Output Level = 6; to examine data in; [ ].fit file. Possible GAIN, ZERO, BACKGROUND or STATISTICS problems

8000 Uranium 98.443 keV X-ray peak VERY LOW or non-existent. U235 may NOT be present for analysis or; Possible GAIN, ZERO or STATISTICS problems

warnum

1 Requested Material Cross Section: NOT in database. Transmission correction in ERROR.

2 A peak was found near 129.3 keV, Pu-239 may be present. Possible source contamination--Analysis may be Inaccurate.

4 Input Energy out of cross section range in material: *value*)

8 Invalid inputs in Peak Parameters. Check SETUP file; or: Examine Analysis Settings. Possible errors include zero energies or widths that are too small.

10 Uranium X-ray peaks at 94.65 or 111.298 keV appear to be Calculated incorrectly. No Correction to data applied. Possible GAIN, ZERO or STATISTICS problems.

20 Code was unable to resolve very weak U-238 peaks; percentage U235 is probably 90% . Possible inadequate count

40 Gain calculation error. Unable to calculate gain or zero. Possible input GAIN, ZERO or STATISTICS problems.

80 Low U235 185.715 keV peak signal; Possible input GAIN, ZERO or STATISTICS problems

APPENDIX A. ^{235}U AND ^{238}U DECAY

A.1. Gamma- and X-Ray Decay of ^{235}U and ^{238}U and their Daughters from 49–300 keV

The gamma-ray energies listed in bold are used with the branching ratios listed in column three to determine $^{235}U/\ ^{238}U/\ ^{234}U$ ratios by the U235 code. All x-rays listed as IC-decay are internally converted in the isotope and decay with the isotope's decay characteristics, half-life, and isotopic composition. All x-rays labeled as fluorescence are caused (nearly completely) by photoelectric absorption in the material and subsequent L–K shell electron decay. These x-rays are characteristic of the physical properties of the material and not its isotopic composition. Gamma rays and x-rays are listed by energy. This should allow quicker identification of observed spectra and may help pinpoint potential interference in a given measurement. Only the "strongest" lines are listed; many other gammas in this range are normally too weak to observe. These lines will occur with different intensity depending on the isotopic concentration being observed. The branching ratios listed in column three are the ones presently used at LLNL.

Group No.	E (keV)	Branch Ratio BR×100	G or X	Source	Parent	URADOS[c] Branch Ratio BR×100	IAEA[a] Branch Ratio ×100
Group-1							
1	49.550	0.064	G	U-238	U-238		0.064±0.008
2	53.200	0.123	G	U-234			0.123±0.002
3	58.570	0.500	G	Th-231	U-235	0.46 ± 0.060	0.5 ± 0.05
4	63.290	4.470	G	Th-234	U-238	3.94 ± 0.010	4.47 ± 0.88
5	72.751	0.260	G	Th-231	U-235		0.26 ± 0.02
6	72.804	27.700	X	Pb-Kα2	fluorescence		
7	73.920	0.202	G	Pa-234m	U-238		
8	74.000	0.036	G	Pa-234	U-238		
9	74.910	0.510	G	U-235	U-235		
10	74.969	46.200	X	Pb-Kα1	fluorescence		
11	81.228	0.850	G	Th-231	U-235		0.85 ± 0.03
12	82.087	0.370	G	Th-231	U-235		0.37 ± 0.02
13	83.300	0.073	G	Th-234	U-238	0.064 ± 0.10	0.073
14	**84.214**	**6.710**	**G**	Th-231	U-235		6.71 ± 0.1
15	84.450	5.580	X	Pb-Kβ3	fluorescence		
16	84.930	10.700	X	Pb-Kβ1	fluorescence		
17	87.300	3.910	X	Pb-Kβ2	fluorescence		
Group-2							
1	**87.700**	**0.050**	G	Pa-231	Th-231/U-235		
2	**88.500**	**0.030**	G	Th-227	U-235		
3	**89.956**	**3.360**	X	Th Kα2	U-235 IC-decay	3.17 ± 0.08	3.4 ± 0.8

Group No.	E (keV)	Branch Ratio BR×100	G or X	Source	Parent	URADOS[c] Branch Ratio BR×100	IAEA[a] Branch Ratio ×100
4	**89.970**	**0.742**	G	Th-231	U-235	0.97 ± 0.05	
5	**92.290**	**0.470**	X	Pa Kα2	U-235 IC-decay	0.451 ±0.036	0.39 ± 0.03
6	**92.365**	**2.600**	G	Th-234	U-238	2.52 ± 0.06	2.60 ± 0.53
7	**92.790**	**2.560**	G	Th-234	U-238	2.50 ± 0.06	2.56 ± 0.52
8	**93.356**	**5.500**	X	Th Kα1	U-235 IC-decay	5.22 ± 0.14	5.6 ± 1.3
9	**94.660**	**9.161**	X	U Kα2	fluorescence	61.2 (norm)	28.2 ± 0.6
10	**94.700**	**0.0321**		Pa-234	U-238		
11	**95.850**	**0.0024**	G	Th-234	U-238		
12	**95.860**	**0.880**	X	Pa Kα1	U-235 IC-decay	0.776 ± 0.043	0.63 ± 0.05
13	**98.443**	**14.800**	X	U Kα1	fluorescence	100.0 (norm)	45.1 ± 0.9
14	**99.270**	**0.400**	G	Th-231	U-235	0.14 ± .03	
Group-3							
1	102.270	0.400	G	Th-231	U-235		0.40 ± 0.02
2	104.819	0.137	X	Th Kβ3	IC-decay		
3	105.604	0.262	X	Th Kβ1	IC-decay		
4	106.239	0.009	X	Th Kβ5	IC-decay		
5	107.595	0.022	X	Pa Kβ3	IC-decay		
6	108.422	0.042	X	Pa Kβ1	IC-decay		
7	108.582	0.100	X	Th Kβ2	IC-decay		
8	108.955	0.003	X	Th Kβ4	IC-decay		
9	109.072	0.002	X	Pa Kβ5	IC-decay		
10	109.160	1.540	G	U-235	U-235		1.54 ± 0.05
11	109.442	0.022	X	Th KO2_3	IC-decay		
12	110.480	0.555	X	U Kβ3	fluorescence		
13	110.500	.0043	X	U-238	U-238		
14	111.350	1.000	X	U Kβ1	fluorescence		
15	111.486	0.017	X	Pa Kβ2	IC-decay		
16	111.870	0.001	X	Pa Kβ4	IC-decay		
17	111.964	0.037	X	U Kβ5	fluorescence		
18	112.380	0.004	X	Pa KO2_3	IC-decay		
19	112.820	0.040	G	Th-234	U-238		0.256 ± 0.054
20	114.540	0.388	X	U Kβ2	fluorescence		
21	114.844	0.011	X	U Kβ4	fluorescence		
22	114.900	0.0064	G	Pa-234m	U-238		
23	115.377	0.089	X	U KO23	fluorescence		
Group-4							
1	**120.900**	**0.0342**	G	U-234		0.041 ± 0.006	0.0342± 0.0005
2	124.914	0.0600	G	Th-231	U-235		0.06 ± 0.003

Group No.	E (keV)	Branch Ratio BR×100	G or X	Source	Parent	URADOS[c] Branch Ratio BR×100	IAEA[a] Branch Ratio ×100
3	**131.300**	**0.0286**		Pa-234	U-238		
4	134.030	0.0250	G	Th-231	U-235		0.025 ± 0.005
5	135.664	0.0840	G	Th-231	U-235		0.084 ± 0.007
6	**140.760**	**0.2200**	G	U-235			0.22 ± 0.02
7	**143.760**	**10.9600**	G	U-235		10.95 ± 0.15	10.96 ± 0.08
8	**150.930**	**0.0800**	G	U-235			.08 ± 0.02d
9	**152.700**	**0.0083**		Pa-234	U-238		
10	**163.330**	**5.0800**	G	U-235		5.11 ± 0.05	5.08 ± 0.04
Group-5							
1	**182.610**	**0.3400**	G	U-235		0.37 ± 0.02	0.34 ± 0.02
2	**183.500**	**0.0329**	G	U-235			.0329
3	**184.800**	**0.2200**	G	Th-234	U-238		
4	**185.715**	**57.2000**	G	U-235		57.2 ± 0.02	57.2 ± 0.5
5	**185.900**	**0.0039**	G	Pa-234	U-238		3.89E-3
6	194.940	0.6300	G	U-235			0.630 ± 0.01
7	198.900	0.0420	G	U-235			0.042
8	202.110	1.0800	G	U-235			1.080 ± 0.02
9	205.311	5.0100	G	U-235			5.010 ± 0.05
Group-6							
1	215.30	0.0288	G	U-235			
2	217.94	0.0370	G	Th-231	U-235		0.037 ± 0.001
3	221.38	0.1200	G	U-235			0.12 ± 0.01
4	226.63	0.0059	G	Pa-234	U-238		
5	227.17	0.0055	G	Pa-234	U-238		
6	233.50	0.0290	G	U-235			
7	238.50	0.0092	G	Th-231	U-235		
8	240.85	0.0540	G	U-235			
9	246.84	0.0530	G	U-235			
10	258.20	0.0730	G	Pa-234m	U-238		
11	291.63	0.0180	G	U-235			
12	293.90	0.0039	G	Pa-234	U-238		

[a] "Handbook of Nuclear Data for Safeguards," INDC (NDS)-248, IAEA, 1991
[b]GAMGEN code LLNL
[c]Presented in CEA meeting by DAMPRI-LPRI May 1996
[d] "Decay Data of the Transactinium Nuclides," Report # 261, IAEA, 1986

A.2. ^{238}U and Daughters ^{234}Pa and ^{234}Th

GAMGEN calculation showing gammas/second/gram of ^{238}U (g/s/gm) at five years since separation and the implied branching ratio (branching ratio normalized to 2.60% at 92.3 keV).

E(keV)	g/s/gm	G or X	BR x100	Source	Parent 1	Emiter 2	Parent 2
62.9	2.36	G	0.0182	Th-234	U-238		
73.9	1.36	G	0.0105	Pa-234m	U-238		
74.0	5.30	G	0.0408	Th-234	U-238		
83.3	8.71	G	0.0670	Th-234	U-238		
92.3	338.0	G	2.6000	Th-234	U-238		
92.8	335.0	G	2.5769	Th-234	U-238		
94.7	21.6	G	0.1662	Pa-234m	U-238	Pa-234	U-238
95.9	1.62	G	0.0125	Th-234	U-238		
110.5	2.98	G	0.0229	U-238	U-238		
114.9	4.32	G	0.0332	Pa-234m	U-238	Pa-234	U-238
131.3	3.23	G	0.0248	Pa-234	U-238		
152.7	1.08	G	0.0083	Pa-234	U-238		
184.8	1.49	G	0.0115	Th-234	U-238		
258.2	9.02	G	0.0694	Pa-234m	U-238		

APPENDIX B. X-RAYS

B.1. Uranium and Daughter X-Rays[14]

Th X rays		Pa X rays		U X rays		
E (keV	%[a]	E (keV)	%	E (keV)	%	
93.350	45.400	95.863	45.3	93.434	45.1	Kα1
89.957	28.100	92.282	28.1	94.654	28.2	Kα2
105.604	10.700	108.422	10.7	111.298	10.7	Kβ1
108.582	4.100	111.486	4.163	114.445	4.15	Kβ2
104.819	5.610	107.595	5.64	110.421	5.65	Kβ3
108.955	0.110	111.870	0.11	114.844	0.12	Kβ4
106.239	0.380	109.072	0.389	111.964	0.397	Kβ5
109.442	0.900	112.380	0.93	115.377	0.95	K02_3

[a]% refers to percent decay per 100 k-shell vacancies.

B.2. X-rays Associated with Uranium Decay, Sorted by Energy

Uranium x-ray fluorescence intensity is set to 1.00 for U-Kα_1 in this comparison. The other branching ratios are derived from the observed decay of ^{235}U. The Pa branching ratios determined from the protactinium fluorescent decay ratios normalized to a 0.042 branching ratio for the Pa Kβ_1 line at 108.422 keV. The thorium branching ratios determined from the Th fluorescent decay ratios normalized to a .503 branching ratio for the Th Kα_1 line at 93.350 keV.

E (keV)	%	Branch Ratio			Type X Ray
89.957	28.100	0.3113	**Th**	**Kα2**	IC-decay
92.282	28.100	0.1103	**Pa**	**Kα2**	IC-decay
93.350	45.400	0.5030	**Th**	**Kα1**	IC-decay
94.654	28.200	0.6253	**U**	**Kα2**	fluorescence
95.863	45.300	0.1778	**Pa**	**Kα1**	IC-decay
98.434	45.100	1.0000	**U**	**Kα1**	fluorescence
104.819	5.610	0.0622	**Th**	**Kβ3**	IC-decay
105.604	10.700	0.1185	**Th**	**Kβ1**	IC-decay
106.239	0.380	0.0042	**Th**	**Kβ5**	IC-decay
107.595	5.640	0.0221	**Pa**	**Kβ3**	IC-decay
108.422	10.700	0.0420	**Pa**	**Kβ1**	IC-decay
108.582	4.100	0.0454	**Th**	**Kβ2**	IC-decay
108.955	0.110	0.0012	**Th**	**Kβ4**	IC-decay

[14]Browne, E. and R. Firestone, "Table of Radioactive Isotopes," *LBL*, 2986, p. C-23.

E (keV)	%	Branch Ratio			Type X Ray
109.072	0.389	0.0015	**Pa**	**Kβ5**	IC-decay
109.442	0.900	0.0100	**Th**	**k02_3**	IC-decay
110.421	5.650	0.1253	**U**	**Kβ3**	fluorescence
111.298	10.700	0.2373	**U**	**Kβ1**	fluorescence
111.486	4.163	0.0163	**Pa**	**Kβ2**	IC-decay
111.870	0.110	0.0004	**Pa**	**Kβ4**	IC-decay
111.964	0.397	0.0088	**U**	**Kβ5**	fluorescence
112.380	0.930	0.0037	**Pa**	**k02_3**	IC-decay
114.445	4.150	0.0920	**U**	**Kβ2**	fluorescence
114.844	0.120	0.0027	**U**	**Kβ4**	fluorescence
115.377	0.950	0.0211	**U**	**k02_3**	fluorescence

E (keV)	Th X rays measured[a]	Norm. meas.	Intensity %	Scofield[b] Calculation	Th X rays %		Calc. Meas. % diff.
93.350	93.348	100	45.4	100	45.40	**Kα1**	0
89.957	89.957	61	27.694	61.9	28.10	**Kα2**	0
105.604	105.606	19	8.626	22.35	10.70	**Kβ1**	2.47
108.582	108.471	10	4.54	8.5601	4.10	**Kβ2**	2.5
104.819	104.822			11.466	5.61	**Kβ3**	3.53
108.955					0.11	**Kβ4**	
106.239				0.8247	0.38	**Kβ5**	0.68
109.442					0.90	**k02_3**	
Pa X-rays							
95.863	95.867	100	45.3	100	45.300	**Kα1**	0
92.282	92.284	62	28.086	62.2	28.100	**Kα2**	-0.1
108.422	108.418	24	10.872	22.45	10.700	**Kβ1**	2.36
111.486			0	8.6882	4.163	**Kβ2**	2.62
107.595	107.586	11	4.983	11.472	5.640	**Kβ3**	3.86
111.870					0.110	**Kβ4**	
109.072				0.8441	0.389	**Kβ5**	0.78
112.380					0.930	**k02_3**	
U X-rays							
98.434	98.435			100	45.100	**Kα1**	0
94.654	94.656			62.5	28.200	**Kα2**	0.02
111.298	111.300			22.6	10.700	**Kβ1**	2.25

E (keV)	Th X rays measured[a]	Norm. meas.	Intensity %	Scofield[b] Calculation	Th X rays %		Calc. Meas. % diff.
114.445				8.7462	4.150	**Kβ2**	2.35
110.421	110.416			11.549	5.650	**Kβ3**	3.82
114.844					0.120	**Kβ4**	
111.964	112.043			0.8656	0.397	**Kβ5**	0.77
115.377					0.950	**k02_3**	

	Kα2/Kα1	Kβ1/Kα1	Kβ3/Kβ1	Kβ5/Kβ1
Th	0.619	0.224	0.513	0.0369
Pa	0.622	0.225	0.512	0.0376
U	0.625	0.226	0.511	0.0383

[a]Barreau, G. et al., "*Z. Phys. A. Atoms and Nuclei*," 308, 209–213 (1982).

[b]Scofield, J. D. "Relativistic Hartree-Slater Values of the K and L X-ray Emission," *Atomic Data and Nuclear Data Tables* **14**, 121–137 (1974).

APPENDIX C. DAUGHTER GAMMA AND X-RAYS

C.1. ^{235}U-Daughter ^{231}Th Gamma Rays, Pa X-Rays, and Branching Ratios

E (keV)	±ΔE	IAEA E(keV)	G or X	* Rel. Int b	±ΔI	Notes	Branch Ratio (IAEA)	Imp. Branch Ratio[a]
26.560		25.640	G	202	20		0.146	0.135542
44.100	0.3		G	0.06	0.04			4.03E-05
58.470	0.05	58.570	G	7.2	0.7		0.005	0.004831
63.700	0.2		G	0.68	0.14			0.000456
72.660	0.06	72.751	G	4	0.4		0.0026	0.002684
73.000	0.1		G	0.1	0.04			6.71E-05
81.180	0.05	81.228	G	14.2	1.4		0.0085	0.009528
82.020	0.06	82.087	G	7.2	0.7		0.0037	0.004831
84.170		84.214	G	100		Reference a	0.0671	0.067100
89.940	0.05		G	15.3	1.5			0.010266
92.230	0.05		X	6	0.6	Pa Kα2		0.004026
93.300	0.1		G	0.5	0.05			0.000336
95.870	0.05		X	10.3	1	Pa Kα1		0.006911
99.300	0.05		G	2.1	0.2			0.001409
102.300	0.05	102.270	G	6.7	0.7		0.004	0.004496
105.730	0.1		G	0.14	0.02			9.39E-05
106.580	0.1		G	0.34	0.04			0.000228
107.620	0.1		X	1.29	0.14	Pa Kβ3		0.000866
108.490	0.1		X	2.43	0.24	Pa Kβ1+5		0.001631
111.590	0.1		X	0.9	0.1	Pa Kβ2		0.000604
112.460	0.1		X	0.34	0.04	Pa k_0		0.000228
115.500	0.2		G	0.04	0.01			2.68E-05
116.910	0.05		G	0.39	0.04			0.000262
125.100	0.05	124.914	G	0.95	0.09		0.0006	0.000637
134.140	0.08	134.030	G	0.42	0.05		0.00025	0.000282
135.770	0.06	135.664	G	1.3	0.1		0.00084	0.000872
136.780	0.2		G	0.09	0.03			6.04E-05
145.150	0.3		G	0.12	0.03			8.05E-05
146.000	0.07		G	0.58	0.06			0.000389
163.160	0.06		G	2.6	0.03			0.001745

E (keV)	±ΔE	IAEA E(keV)	G or X	* Rel. Int b	±ΔI	Notes	Branch Ratio (IAEA)	Imp. Branch Ratio[a]
164.940	0.1		G	0.06	0.03			4.03E-05
169.580	0.1		G	0.03	0.01			2.01E-05
174.190	0.08		G	0.31	0.03			0.000208
183.470	0.07		G	0.57	0.06			0.000382
188.770	0.2		G	0.08	0.01			5.37E-05
218.000	0.07	217.94	G	0.67	0.07		0.00037	0.00045
236.170	0.07		G	0.18	0.02			0.000121
240.400	0.2		G	0.005	0.0005			3.36E-06
242.600	0.1		G	0.013	0.0006			8.72E-06
249.800	0.3		G	0.01	0.002			6.71E-06
250.500	0.3		G	0.011	0.002			7.38E-06
267.800	0.07		G	0.023	0.0006			1.54E-05
308.900	0.3		G	0.008	0.001			5.37E-06
311.000	0.1		G	0.054	0.005			3.62E-05
318.000	0.4		G	0.002	0.0002			1.34E-06
320.200	0.3		G	0.004	0.0003			2.35E-06

[a]Normalized to 0.0671 for 84.17 keV transition.
[b]Browne, E and F. Asaro, *Phys. Rev. C*, **7**(6), 2545; the 84.17-keV transition branching ratio = 0.070 ±0.003.

C.2. ^{235}U and Daughters Gammas

keV	Branch ratio[a]	g/s/gm	Emitter 1	Parent 1	Emitter 2	Parent 2
11.400	0.03050	2.40E+03	Th-231	U-235		
13.000	0.22367	1.76E+04	U-235	U-235	Ac-227	U-235
13.700	0.49817	3.92E+04	Th-231	U-235		
14.500	0.00224	1.76E+02	U-235	U-235	Ac-227	U-235
15.000	0.00407	3.20E+02	Th-231	U-235		
16.100	0.15250	1.20E+04	U-235	U-235		
16.600	0.37617	2.96E+04	Th-231	U-235		
17.200	0.00224	1.76E+02	Th-231	U-235		
19.100	0.02643	2.08E+03	U-235	U-235		
19.800	0.07523	5.92E+03	Th-231	U-235		
25.600	0.14869	1.17E+04	Th-231	U-235		
42.000	0.00061	4.80E+01	U-235	U-235		
42.800	0.00059	4.64E+01	Th-231	U-235		

keV	Branch ratio[a]	g/s/gm	Emitter 1	Parent 1	Emitter 2	Parent 2
58.600	0.00488	3.84E+02	Th-231	U-235		
72.700	0.00112	8.80E+01	U-235	U-235		
72.800	0.00255	2.01E+02	Th-231	U-235		
74.800	0.00061	4.80E+01	U-235	U-235		
81.200	0.00915	7.20E+02	Th-231	U-235		
84.200	0.06710	5.28E+03	Th-231	U-235		
90.000	0.03419	2.69E+03	U-235	U-235		
90.000	0.00956	7.52E+02	Th-231	U-235		
92.300	0.00397	3.12E+02	Th-231	U-235		
93.400	0.05592	4.40E+03	U-235	U-235		
95.900	0.00641	5.04E+02	Th-231	U-235		
96.200	0.00087	6.88E+01	U-235	U-235		
99.300	0.00122	9.60E+01	Th-231	U-235		
102.300	0.00417	3.28E+02	Th-231	U-235		
105.400	0.02008	1.58E+03	U-235	U-235		
108.200	0.00231	1.82E+02	Th-231	U-235		
109.000	0.00671	5.28E+02	U-235	U-235		
109.200	0.01563	1.23E+03	U-235	U-235		
111.900	0.00077	6.08E+01	Th-231	U-235		
116.100	0.00071	5.60E+01	U-235	U-235		
124.900	0.00057	4.48E+01	Th-231	U-235		
135.700	0.00079	6.24E+01	Th-231	U-235		
140.800	0.00224	1.76E+02	U-235	U-235		
143.800	0.11133	8.76E+03	U-235	U-235		
150.900	0.00081	6.40E+01	U-235	U-235		
163.100	0.00158	1.24E+02	Th-231	U-235		
163.300	0.05160	4.06E+03	U-235	U-235		
182.600	0.00346	2.72E+02	U-235	U-235		
185.700	0.58077	4.57E+04	U-235	U-235		
194.900	0.00641	5.04E+02	U-235	U-235		
198.900	0.00427	3.36E+02	U-235	U-235		
202.100	0.01098	8.64E+02	U-235	U-235		
205.300	0.05096	4.01E+03	U-235	U-235		
221.400	0.00122	9.60E+01	U-235	U-235		
240.900	0.00055	4.32E+01	U-235	U-235		

[a]Normalized to .0671 at 84.214 keV.

C.3. ^{238}U and Daughter Gamma Rays

E (keV)[a]	Branch Ratio %[a]	uncert. %[a]	g/s/gm	Emitter 1	Parent 1
63.24	3.6000	3	4.73E+02	Th-234	U-238
131.31	0.0286	1.4	3.23E+00	Pa-234	U-238
152.76	0.0083	3.7	1.08E+00	Pa-234	U-238
203.12	0.0027	8	3.37E-01	Pa-234	U-238
226.85	0.0167	1.3	9.54E-01	Pa-234	U-238
249.21	0.0035	4.7	4.53E-01	Pa-234	U-238
258.26	0.0730	0.46	9.02E+00	Pa-234m	U-238
272.20	0.0018	9.1	1.62E-01	Pa-234	U-238
293.74	0.0049	3.1	6.31E-01	Pa-234	U-238
369.52	0.0044	3.5	4.69E-01	Pa-234	U-238
372.02	0.0023	6.9	2.10E-01	Pa-234	U-238
450.96	0.0030	5.2	3.36E-01	Pa-234m	U-238
453.58	0.0019	8.4	2.71E-01	Pa-234m	U-238
458.63	0.0020	8	2.43E-01	Pa-234	U-238
468.44	0.0023	6.8	2.63E-01	Pa-234m	U-238
475.75	0.0023	6.5	3.18E-01	Pa-234m	U-238
506.70	0.0035	5.5	2.59E-01	Pa-234	U-238
543.98	0.0036	4.7	4.14E-01	Pa-234m	U-238
569.30	0.0203	1.3	1.73E+00	Pa-234	U-238
654.37	0.0022	7.6	9.70E-02	Pa-234	U-238
666.42	0.0015	9.8	2.59E-01	Pa-234	U-238
669.64	0.0017	8.9	2.26E-01	Pa-234	U-238
691.08	0.0090	2.1	8.75E-01	Pa-234m	U-238
699.02	0.0059	2.6	7.44E-01	Pa-234	U-238
702.05	0.0071	2.4	8.59E-01	Pa-234m	U-238
705.90	0.0065	2.4	9.16E-01	Pa-234	U-238
733.38	0.0115	1.5	1.39E+00	Pa-234	U-238
737.88	0.0021	8.3	1.62E-01	Pa-234	U-238
739.95	0.0118	2.1	1.13E+00	Pa-234m	U-238
742.77	0.0946	0.7	9.38E+00	Pa-234m	U-238
755.00	0.0021	8.1	1.62E-01	Pa-234	U-238
766.37	0.3220	0.65	3.29E+01	Pa-234m	U-238
781.73	0.0078	2.2	8.43E-01	Pa-234m	U-238
786.25	0.0554	0.93	5.67E+00	Pa-234m	U-238
796.42	0.0054	4.3	6.14E-01	Pa-234	U-238

E (keV)[a]	Branch Ratio %[a]	uncert. %[a]	g/s/gm	Emitter 1	Parent 1
805.74	0.0088	1.8	1.04E+00	Pa-234	U-238
808.20	0.0026	10	3.60E-01	Pa-234m	U-238
819.21	0.0037	3.9	4.20E-01	Pa-234	U-238
824.94	0.0068	2.6	6.47E-01	Pa-234	U-238
831.39	0.0078	1.9	8.89E-01	Pa-234	U-238
851.57	0.0070	2	6.88E-01	Pa-234m	U-238
875.94	0.0042	3	6.47E-01	Pa-234	U-238
880.45	0.0212	0.9	1.46E+00	Pa-234	U-238
883.22	0.0211	0.9	2.13E+00	Pa-234	U-238
887.28	0.0071	1.8	8.27E-01	Pa-234m	U-238
898.52	0.0059	2.2	6.63E-01	Pa-234	U-238
921.70	0.0127	1.1	1.32E+00	Pa-234m	U-238
924.98	0.0142	1.2	1.78E+00	Pa-234	U-238
926.61	0.0192	1.1	1.60E+00	Pa-234	U-238
941.94	0.0025	4.2	3.45E-01	Pa-234m	U-238
945.90	0.0335	0.86	2.44E+00	Pa-234	U-238
947.43	0.0031	4.4	1.29E+00	Pa-234	U-238
980.42	0.0045	3	4.85E-01	Pa-234	U-238
984.09	0.0030	4.2	3.07E-01	Pa-234	U-238
994.93	0.0057	2.1	4.61E-01	Pa-234m	U-238
1000.99	0.839	0.56	1.03E+02	Pa-234m	U-238
1041.70	0.0012	8	1.54E-01	Pa-234m	U-238
1061.89	0.0023	5.2	2.23E-01	Pa-234m	U-238
1084.25	0.0012	7.5	2.22E-01	Pa-234	U-238
1124.93	0.0042	3.1	3.34E-01	Pa-234m	U-238
1193.69	0.0135	0.96	1.43E+00	Pa-234m	U-238
1220.37	0.0009	10.2	1.11E-01	Pa-234m	U-238
1237.24	0.0053	1.8	5.73E-02	Pa-234m	U-238
1292.66	0.0009	11.2	9.70E-02	Pa-234	U-238
1352.80	0.0019	4.1	2.75E-01	Pa-234	U-238
1393.57	0.0039	2.5	4.85E-01	Pa-234	U-238
1413.88	0.0023	4.2	2.39E-01	Pa-234m	U-238
1434.13	0.0097	1.3	9.07E-01	Pa-234m	U-238
1452.63	0.0012	7.3	1.62E-01	Pa-234	U-238
1510.20	0.0129	1.2	1.45E+00	Pa-234m	U-238
1527.27	0.0024	3.7	2.47E-01	Pa-234m	U-238
1548.12	0.0014	5.9	2.07E-01	Pa-234m	U-238

E (keV)[a]	Branch Ratio %[a]	uncert. %[a]	g/s/gm	Emitter 1	Parent 1
1553.74	0.0081	1.6	1.00E+00	Pa-234m	U-238
1570.67	0.0011	7.8	1.21E-01	Pa-234m	U-238
1591.65	0.0019	5.2	4.30E-01	Pa-234m	U-238
1593.88	0.0027	3.6	9.70E-02	Pa-234	U-238
1668.44	0.0012	6.2	1.94E-01	Pa-234	U-238
1694.08	0.0013	5.9	1.94E-01	Pa-234	U-238
1737.73	0.0212	1.1	2.26E+00	Pa-234m	U-238
1759.81	0.0014	4.4	2.55E-01	Pa-234m	U-238
1765.44	0.0087	1.4	9.71E-01	Pa-234m	U-238
1809.04	0.0037	2.1	4.77E-01	Pa-234m	U-238
1819.69	0.0009	7.3	1.32E-01	Pa-234m	U-238
1831.36	0.0172	1.3	1.78E+00	Pa-234m	U-238
1863.09	0.0012	4.3	1.35E-01	Pa-234m	U-238
1867.68	0.0092	1.4	8.43E-01	Pa-234m	U-238
1874.85	0.0082	1.5	8.75E-01	Pa-234m	U-238
1877.21	0.00165	3.4	3.07E-02	Pa-234	U-238
1893.50	0.00219	2.9	2.39E-01	Pa-234m	U-238
1911.17	0.0063	1.6	5.89E-01	Pa-234m	U-238
1925.42	0.0005	10.1	8.08E-02	Pa-234	U-238
1937.01	0.0029	2.3	3.34E-01	Pa-234m	U-238

[a]Scott, H. L. and K. W Marlow., NIM A286, (1990) 549–55.

C.4. ^{238}U and Daughters ^{234}Pa and ^{234}Th

E(keV)	g/s/gm	Emitter	Parent 1	Emitter 2	Parent 2
62.9	2.36	Th-234	U-238		
73.9	1.36	Pa-234m	U-238		
74.0	5.30	Th-234	U-238		
83.3	8.71	Th-234	U-238		
92.3	338.0	Th-234	U-238		
92.8	335.0	Th-234	U-238		
94.7	21.6	Pa-234m	U-238	Pa-234	U-238
95.9	1.62	Th-234	U-238		
110.5	2.98	U-238	U-238		
114.9	4.32	Pa-234m	U-238	Pa-234	U-238
131.3	3.23	Pa-234	U-238		
152.7	1.08	Pa-234	U-238		

E(keV)	g/s/gm	Emitter	Parent 1	Emitter 2	Parent 2
184.8	1.49	Th-234	U-238		
258.2	9.02	Pa-234m	U-238		

C.5. 238U Daughter Protactinium: Gammas and Branching Ratios

234mPa IC-decay[a]			
IC-decay prob%			
E (keV)	**×1000**	**Uncert. ±**	
257.90	57.000	0.230	Pa234m
691.00	5.500	0.500	Pa234m
701.60	5.400	0.500	Pa234m
740.10	7.100	0.700	Pa234m
743.00	56.600	0.230	Pa234m
766.60	207.800	0.800	Pa234m
782.30	5.300	0.500	Pa234m
786.40	34.200	0.130	Pa234m
887.50	5.200	0.500	Pa234m
922.30	8.300	0.800	Pa234m
946.30	7.000	0.700	Pa234m
1001.20	590.000		Pa234m
1738.20	14.200	0.600	Pa234m
1831.50	11.200	0.400	Pa234m
1868.20	5.300	0.500	Pa234m
1911.80	3.700	0.400	Pa234m
1937.70	2.100	0.200	Pa234m

NORMALIZED 1001. = 590 (0.59% × 1000)

[a]Ardisson G. and C. Marsol, Nuovo Chimie, 11v28A, 155 (1975).

234mPa IC-decay[a] IC-decay prob%		
E (keV)	**×1000**	**Uncert. ±**
63.0	4.10	Pa 234
131.3	20.00	Pa 234
153.0	6.60	Pa 234

234mPa IC-decay[a] IC-decay prob%		
E (keV)	**×1000**	**Uncert. ±**
226.9	11.50	Pa 234
569.3	13.80	Pa 234
699.1	4.75	Pa 234
805.5	3.10	Pa 234
824.7	3.70	Pa 234
831.1	5.10	Pa 234
926.7	16.80	Pa 234
945.8	18.40	Pa 234
980.5	3.90	Pa 234
1394.1	2.40	Pa 234

[a]*Radiochem. Radioanal Lett.*, **357** (75), 221.

APPENDIX D. OUTPUT FILES

D.1. Report File

D.1.1. Isotopic Ratio File for Post-processing

D.1.1.1. Output UFM file

(Unformatted U235 file)

- UFM Record
- U235 analysis records taken from **.SPC** file
- CALREC record taken from **.SPC** file
- Analysis results records

UFM record

Variable	Description	Variable Type	Position
sFormat	Must be 1	INTEGER*2	1
sType	Must be 4096	INTEGER*2	2
LREC	Last used record	INTEGER*2	3
LSPCREC	Spc file names record pointer (long record)	INTEGER*2	4
LOWEDES	Low energy detector description record	INTEGER*2	5
HIGHEDES	High energy detector description record	INTEGER*2	6
AN1REC	First U235 analysis record	INTEGER*2	7
AN2REC	Second U235 analysis record for low energy detector	INTEGER*2	8
LAN3REC	Third U235 analysis record (long record)	INTEGER*2	9
AN4RECAL	Fourth SPC analysis record A for low energy detector	INTEGER*2	10
AN4RECBL	Fourth SPC analysis record B for low energy detector	INTEGER*2	11
AN4RECAH	Fourth SPC analysis record A for high energy detector	INTEGER*2	12
AN4RECBH	Fourth SPC analysis record B for high energy detector	INTEGER*2	13
CALDESL	Low energy calibration description		14
CALRECL	Low energy calibration record		15
CALDESH	High energy calibration description		16
CALRECH	High energy calibration record	INTEGER*2	17
CLRREC	Calibration results record	INTEGER*2	18
ISOREC1	First isotope record	INTEGER*2	19
ISORECL	Last isotope record	INTEGER*2	20
NISOREC	Number of isotopes	INTEGER*2	21

Variable	Description	Variable Type	Position
PUREC	Pu 242 record	INTEGER*2	22
AMREC	Am 241 record	INTEGER*2	23
PKREC1	First peak record	INTEGER*2	24
PKRECL	Last peak record	INTEGER*2	25
Extra		INTEGER*2 [39]	26–64

SPC Record

Variable	Description	Variable Type	Position
SPC1ID	Low energy spectrum name	CHAR*256	1–123
SPC2ID	High energy spectrum name	CHAR*256	124–256
SampleTupe	Sample type	CHAR*26	257–282
Extra		INTEGER*2 [243]	292–512

First Analysis Record (Also in .SPC File)

Variable	Description	Type	Position
wU235 Type	U235 type flag 1=MGA++, 2=U235, 4=CZTU	INTEGER*2	1
bFreshSample	Freshly separated sample	INTEGER*2	2
bUPresent	Uranium present	INTEGER*2	3
bThPresent	Th x-rays present	INTEGER*2	4
bAm241Heterogeneous	Am241 Heterogeneous	INTEGER*2	5
bPuFixed	Fixed Pu abundance	INTEGER*2	6
dPuThickness	Pu thickness	REAL*8	7–10
dSolutionArea	Solution area	REAL*8	11–14
dCell	Cell to detector distance	REAL*8	15–18
dConc	Solution concentration	REAL*8	19–22
dDepth	Solution depth	REAL*8	23–26
bSolution	Sample is a solution	INTEGER*2	27
bTwoDetectors	Two detector analysis	INTEGER*2	28
bHighEnergy	High energy detector SPC file flag	INTEGER*2	29
dFeThickness	Steel sample container thickness	REAL*8	30–33

Variable	Description	Type	Position
wOutputDevice	1=file 2=screen 3=printer	INTEGER*2	34
bLongPrint	Long printout	INTEGER*2	35
bPrintPeaks	Print peak information	INTEGER*2	36
bPrintRatio	Print Pu241 ratio	INTEGER*2	37
Extra		INTEGER*2 (27)	38–64

Second analysis record (also in SPC file)

Variable	Description	Type	Position
wPuAbundance	Pu abundance calculation flag	INTEGER*2	1
dPuAbundance	Operator entered Pu value	REAL*8	2–5
dColtm	Collection time	REAL*8	6–9
dCoeff	Pu abundance calculation coefficient	REAL*8	10–13
dE2421	Pu calculation coefficient	REAL*8	14–17
dE2422	Pu calculation coefficient	REAL*8	18–21
dE2423	Pu calculation coefficient	REAL*8	22–25
dE2424	Pu calculation coefficient	REAL*8	26–29
lChannel	Number channels in spectrum	INTEGER	30–31
dDepth	Detector depth	REAL*8	32–35
dVolume	Detector volume	REAL*8	36–39
dPbThickness	Lead thickness	REAL*8	40–43
dCdThickness	Cd thickness	REAL*8	44–47
dCdFrac	Fraction Cd in second gamma path (low energy detector only)	REAL*8	48–51
dCd2	Cd thickness in second gamma path (low energy detector only)	REAL*8	52–55
wU235Cal	0: read detector calibration from SPC file 1: Use default calibration	INTEGER*2	56
Extra		INTEGER*2 (6)	57–64

Third analysis record (also in SPC file)

Variable	Description	Type	Position
cOutputFile	Report file name	CHAR*256	1–128
cRpgPgm	Report program name	CHAR*256	129–256
szOperator	Operator name	CHAR*64	257–320
szSampID	Sample ID (Unique)	CHAR*26	321–333
szSampleType	Sample Type	CHAR*26	334–346
szU235Ver	U235++ Version	CHAR*8	347–350
wExtra	extra	INTEGER*2 (2)	351–352
szDecDat	Declared date	CHAR*12	353–358
szAnlDat	Analysis date	CHAR*12	359–364
szAcqDat	Acquisition date	CHAR*12	365–370
szU235Ver	U235 Version	CHAR*8	371–374
Extra		INTEGER*2 (136)	375–512

Calibration results record

Variable	Description	Type	Position
PUGPSC	PU absorption g/cm^2	REAL*8	1–4
CDABS	CD absorption g/cm^2	REAL*8	5–8
ANS(ICMP(13))	tailing amplitude	REAL*8	9–12
RSLP	residual slope	REAL*8	13–16
SHAPC(10)	100 keV background slope	REAL*8	17–20
SHAPC(2)	resolution slope	REAL*8	21–24
IW122	FWHM at 122 keV	INTEGER	25–26
IW208	FWHM at 208 keV	INTEGER	27–28
QFIT	Reduced chi^2	REAL*8	29–32
RMSD	Intensity normalized chi^2	REAL*8	33–36
Counts	Number of counts in low energy detector	REAL*8	37–40
HighECounts	Number of counts in high energy detector	REAL*8	41–44
TIME	Low energy live time	REAL*8	45–48
RLTIME	Low energy real time	REAL*8	49–52
TIM	High energy live time	REAL*8	53–56
RLTIM2	High energy real time	REAL*8	57–60

Variable	Description	Type	Position
IDT1	Low energy dead time	INTEGER	61–62
IDT2	High energy dead time	INTEGER	63–64

Isotope record

Variable(s)	Description	Type	Position
ISONAM	Isotope name	CHAR*8	1–4
GRMS	relative abundance	REAL*8	5–8
ER	% uncertainty	REAL*8	9–12
ER2	%* uncertainty	REAL*8	13–16
PCT1	isotopic analysis by weight % of Pu	REAL*8	17–20
ER1	1 sigma uncertainty	REAL*8	21–24
SPPOW	specific power (milliwatts/g)	REAL*8	25–28
	Declared abundance	REAL*8	29–32
ISONAM1	Isotope name	CHAR*8	33–36
GRMS1	relative abundance	REAL*8	37–40
ER01	% uncertainty	REAL*8	41–44
ER201	%* uncertainty	REAL*8	45–48
PCT101	isotopic analysis by weight % of Pu	REAL*8	49–52
ER101	1 sigma uncertainty	REAL*8	53–56
SPPOW01	specific power (milliwatts/g)	REAL*8	57–60
	Declared abundance	REAL*8	61–64

Pu 242 record

Variable	Description	Type	Position
NPU	Pu 242 algorithm flag: <0 = New 0 = Old >0 = entered by operator	INTEGER	1–2
Extra		INTEGER	3–4
PU242C	isotopic analysis by weight % of Pu 242	REAL*8	5–8
SP242	specific power (milliwatts/g) of Pu 242	REAL*8	9–12
CPU242	User input of Pu 242 abundance	REAL*8	13–16

Variable	Description	Type	Position
POW	Uncertainty in Ratio	REAL*8	17–20
SGPOW	Total (power?)	REAL*8	21–24
UPU	U/Pu ratio by fluorescence (approx)	REAL*8	25–28
ERUPU	Error in U/Pu ratio	REAL*8	29–32
RDPM	Related to U237 separation date (calculate days from it)	REAL*8	33–36
PEFF	Pu-240 effective	REAL*8	37–40
EPEFF	Error in Pu-240 effective	REAL*8	41–44
CONC	Pu solution concentration	REAL*8	45–48
SIG	Error in pu solution concentration	REAL*8	49–52
CDFCT	Pu solution concentration correction factor	REAL*8	53–56
R4139	Pu241/239 ratio based on 148/129 keV peaks		57–60
D4139	Difference between R4139 and isotope calculation (%)		61–64

Am241 record

Variable	Description	Type	Position
RAM241	Am/Pu241 weight ratio	REAL*8	1–4
ERRAM	Error in Am/Pu241 weight ratio	REAL*8	5–8
STDDEV	Number standard deviations 100–622 Am241 peak results differ by	REAL*8	9–12
PCTDIF	% 100–622 Am241 peak results differ by	REAL*8	13–16
AM100	Zero-time weight % derived from 100 (300, 600) keV peak	REAL*8	17–20
AM300	Zero-time weight % derived from 100 (300, 600) keV peak	REAL*8	21–24
AM600	Zero-time weight % derived from 100 (300, 600) keV peak	REAL*8	25–28
DM100*PCT(5)/ER1(5)	Error in zero-time weight % derived from 100 keV peak	REAL*8	29–32
DM300*PCT(5)/ER1(5)	Error in zero-time weight % derived from 300 keV peak	REAL*8	33–36
DM600*PCT(5)/ER1(5)	Error in zero-time weight % derived from 600 keV peak	REAL*8	37–40
AA(2)	Beta	REAL*8	41–44
CA106	Am243–Np239 flag	REAL*8	45–48

Variable	Description	Type	Position
TZ	Current date – Am241 separation date (years)	REAL*8	49–52
ERRTZ	Error in tz	REAL*8	53–56
Extra		INTEGER*2 (8)	57–64

Peak Record

Variable	Description	Size	Position
ENRG	Energy (keV)	REAL*8	1–4
YNET	Net counts	REAL*8	5–9
RM	Residuals	REAL*8	10–12
ENRG1	Energy (keV)	REAL*8	13–16
YNET1	Net counts	REAL*8	17–20
RM1	Residuals	REAL*8	21–24
ENRG2	Energy (keV)	REAL*8	25–28
YNET2	Net counts	REAL*8	29–32
RM2	Residuals	REAL*8	33–36
ENRG3	Energy (keV)	REAL*8	37–40
YNET3	Net counts	REAL*8	41–44
RM3	Residuals	REAL*8	45–48
ENRG4	Energy (keV)	REAL*8	49–52
YNET4	Net counts	REAL*8	53–56
RM4	Residuals	REAL*8	57–60

APPENDIX E. DATABASE TABLES

E.1. Acquisition Table

U235 Variable	Database Column	Description	Variable Type
ItemID	SampleID	Unique analysis results identifier	
SPC1ID	LowESpectrum	Low energy spectrum name	CHAR*256
DETID	LowEDetector	Low energy detector name	CHAR*26
RLTIME	LowERealTime	Low energy real time	
TIME	LowELiveTime	Low energy live time	
IDT1	LowEDeadTime	Low energy dead time	
SPC2ID	HighESpectrum	High energy spectrum name	CHAR*256
DETID(14:26)	HighEDetector	High energy detector name	CHAR*26
RLTIM2	HighERealTime	High energy real time	
TIME2	HighELiveTime	High energy live time	
IDT2	HighEDeadTime	High energy dead time	
OPRNAM	Operator	Operator name	CHAR*64
STYPES	SampleType	Sample type (Freshly separated, Aged, or U/Pu)	CHAR*26
ACQDAT	AcquisitionDate	Acquisition date	CHAR*12
ANLDAT	AnalysisDate	Analysis date	CHAR*12
DECDAT	DeclaredDate	Declared date	CHAR*12

E.2. Analysis Results Table

U235 Variable	Database Column	Description	Type
ItemID	SampleID	Unique analysis results identifier	
ANLDAT	AnalysisDate	Analysis Date	
PUGPSC	PuAbs	PU absorption g/cm^2	REAL*8
CABS	CdAbs	CD absorption g/cm^2	REAL*8
IW122	IW122	FWHM at 122 keV	INTEGER
IW208	IW208	FWHM at 208 keV	INTEGER
QFIT	QFit	Reduced chi^2	REAL*8
RMSD	NormQFit	Intensity normalized chi^2	REAL*8
UPU	UPu	U/Pu ratio	REAL*8
ERUPU	ErrUpu	Error in UPu	REAL*8

U235 Variable	Database Column	Description	Type
RAM241	RAmPu241	Am241/Pu241 ratio	REAL*8
ERRAM	ErrRAmPu241	Error in RAmPu241	REAL*8
TZ	Tz	Separation time (years ago)	REAL*8
ERRTZ	ErrTz	Error in Tz	REAL*8
PEFF	Pu240Eff	Pu-240 effective	REAL*8
EPEFF	ErrPu240Eff	Error in Pu240Eff	REAL*8

E.3. Isotope Table

U235 Variable	Database Column	Description	Type
ItemID	SampleID	Primary Key Unique analysis results identifier	
ANLDAT	AnalysisDate	Analysis date	
ISONAM	Isotope	Isotope name	CHAR*8
GRMS	RelAbundance	relative abundance	REAL*8
ER	PerUncert	% uncertainty	REAL*8
ER2	Per*Uncert	%* uncertainty	REAL*8
PCT1	Percent	isotopic analysis by weight % of Pu	REAL*8
ER1	SigmaUncert	1 sigma uncertainty	REAL*8
SPPOW	SpecificPower	specific power (milliwatts/g)	REAL*8

APPENDIX F. MGAVIEW FILES

Files in the default directory, **c:\mga**:

setup.mga Contains the information that appears in the Analyze/Settings... fields. This is an ASCII text file and can be edited with Windows Notepad or other text processors.

235Rpt.mdb The U235View database, which should be backed up regularly. ORTEC strongly recommends that users not manipulate this database outside of the U235View program (copy the database and manipulate the copy).

Files in **c:\Program files\Mga**

If any of these files are missing or corrupt, default values will be used.

U235br.txt Contains the default branching ratios. While it is strongly recommended that users not edit this ASCII text file, follow its format to create customized branching-ratio files.

setu23.txt Contains the setup files keys. This file can be translated into another language, and the **.u23** files will be written in it.

u235msg.txt Contains the U235View messages and FORMAT statements that are used to write the report file. Included for translation.

F.1. Disabling and Enabling U235View's Graphics

To disable graphics on a PC with the **Typical** U235View installation, go to the Windows Taskbar and click on **Start**, **Run**. On the command line of the **Run** dialog, enter:

```
regsvr32  /u  gsx.ocx
```

("regsvr32", a space, a forward slash and a "u", a space, and "gsx.ocx") and press <**Enter**>.

To re-enable graphics on this PC, click on **Start**, **Run**, then enter

```
regsvr32  gsx.ocx
```

(no "slash-u") and press <**Enter**>.

F.2. Analysis Command Line Options

The analysis engine may be run in command line mode for use by other programs or directly. The command line is:

```
U235 lowfilename [/O /M parfilename /n]
```

Where:

`U235` is the program name of the analysis engine, normally located in **`c:\program files\mga`**.

`Lowfilename` is the filename of the low energy spectrum, it must always be present.

`/O` Turns on the debugging output, default is off

`/M parfilename` Reads the analysis parameters from parfilename. The default is to read the parameters from the spectrum file, if possible. If not possible, internal parameters are used. The file has the same format as **`setup.U23`**.

`/n` is the spectrum file format index. The default is 9.

1 LLNL/ACCUDUMP
2 ASCII (sequential integer) no header
3 Nuclear Data, Accuspec, (.cnf)
4 Canberra S100 format
5 ORTEC format (.chn)
6 LLNL ASCII format
7 SPE ASCII format (.spe)
8 Euro ASCII format (.txt)
9 ORTEC format (.spc)

APPENDIX G. MCB CONFIGURATION

G.1. Initial Configuration

The initial configuration is determined by the program MCBCON32, which is either run by SETUP or run manually and set to the Master Detector List for MAESTRO.

When MCBCON32 is run, it searches the PC and the network (if any) for MCBs. After this search is complete, the list of Detectors is displayed (Fig. 77). The Detectors are listed in alphanumeric order by server name, hardware MCB number, and segment or device number.

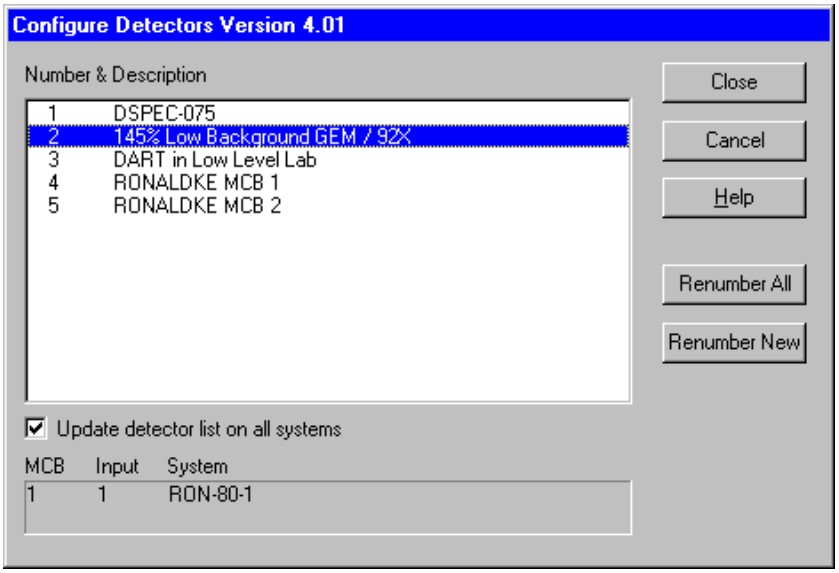

Fig. 77. Detector Numbering.

The first time the system is configured, Fig. 78 will be displayed to remind you of the Detector numbering scheme.

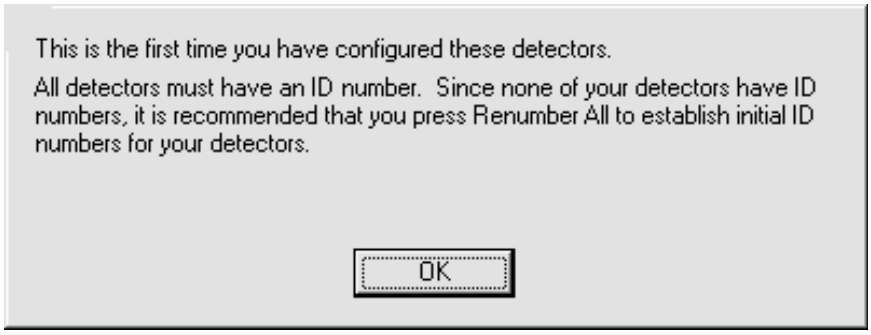

Fig. 78. Detector Numbering First Time.

The PC hardware description for a particular Detector can be viewed by clicking once on the Detector from the **Number & Description** list with the mouse. The description will then be displayed in the lower edit box.

When a configuration is performed, the result is normally broadcast to all PCs on the network. This can be stopped by removing the checkmark from the **Update detector list on all systems** checkbox under the detector list. If this box is not checked, the configuration is only saved to the local PC.

If the Detector numbers are not in the desired order, click on **Renumber All** to assign new numbers in sequence, or **Renumber New** to renumber only the new detectors. Figure 79 will be displayed if the list is a mixture of old and new numbers.

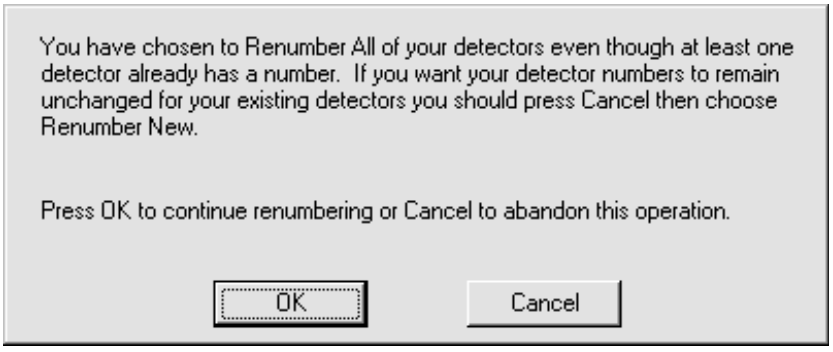

Fig. 79. Renumbering Warning.

To change the detector number or description, double-click on the Detector entry in Fig. 77. This will display the dialog box shown in Fig. 80. This shows the physical detector location and allows the description and number to be changed.

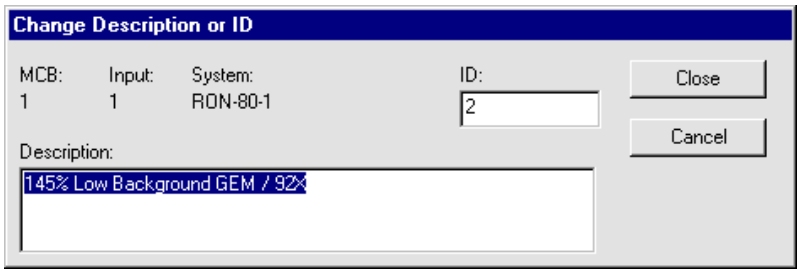

Fig. 80. Change Detector Description or ID.

Click on **Help** to display the information screen shown in Fig. 81.

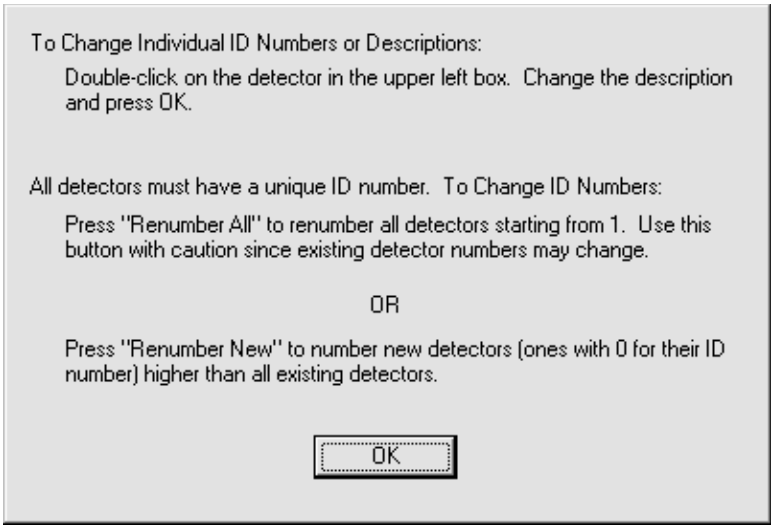

Fig. 81. Detector Renumbering Help.

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