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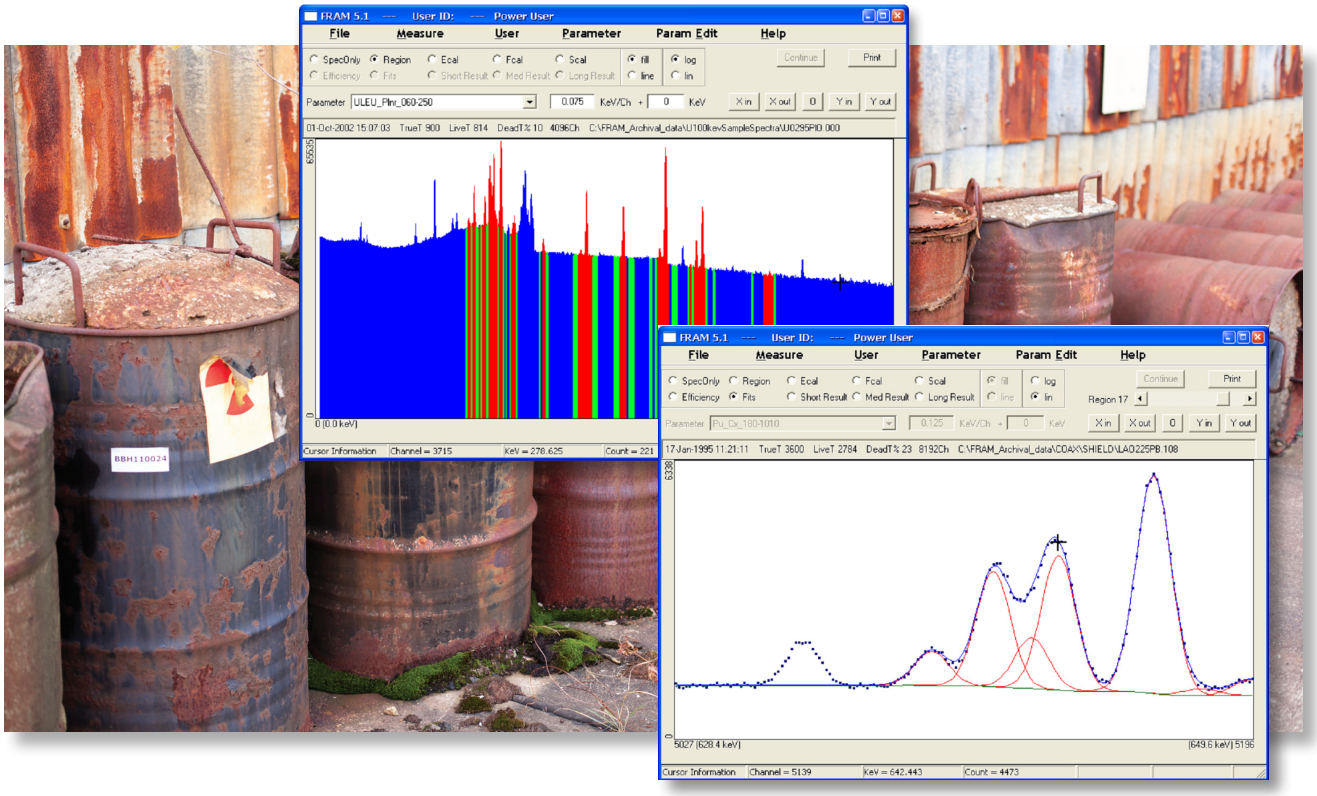
FRAM V7.1

Plutonium and Uranium Isotopic Analysis Software

Advanced Isotopic Ratio Analysis Software for Gamma-Ray Spectra



- Analyzes Pu, and a wide variety of heterogeneous samples containing Pu, Am, U, and other nuclides including ^{242}Pu.
- Operates with LaBr3, CZT, and HPGe detectors, including ORTEC Detective and trans-SPEC families.
- Reads N42 file format.
- No calibration standards necessary.
- Works with shielded samples.
- Select from a large number of supplied sample/geometry conditions or add more types.
- Auto-analysis function for samples of unknown characteristics.
- Command-line mode of operation allows easy incorporation into other applications.
- Automatically reads ORTEC ‘chn’, ORTEC ‘spc’, Canberra ‘cnf, Canberra ‘mca’, IAEA ‘spe’, and ASCII ‘txt’ files.
- Shift spectra from one energy calibration to a different energy calibration and convert multiple spectra from one format to another format.
- Windows 64-bit and 32-bit compatible.
- Significant enhancements over previous versions.

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The Fixed-energy Response-function Analysis with Multiple efficiency (FRAM) code works with high resolution Germanium (HPGe) detectors and now, with the new Version 7.1, FRAM works with pixelated CZT medium-resolution gamma-ray spectrometer (MRGS) detectors. CZT detectors operate at room temperature, are more compact, and are easy to use and maintain. With FRAM Version 7.1, they are now capable of isotopic analysis of uranium and plutonium samples which can be very useful in safeguards applications.

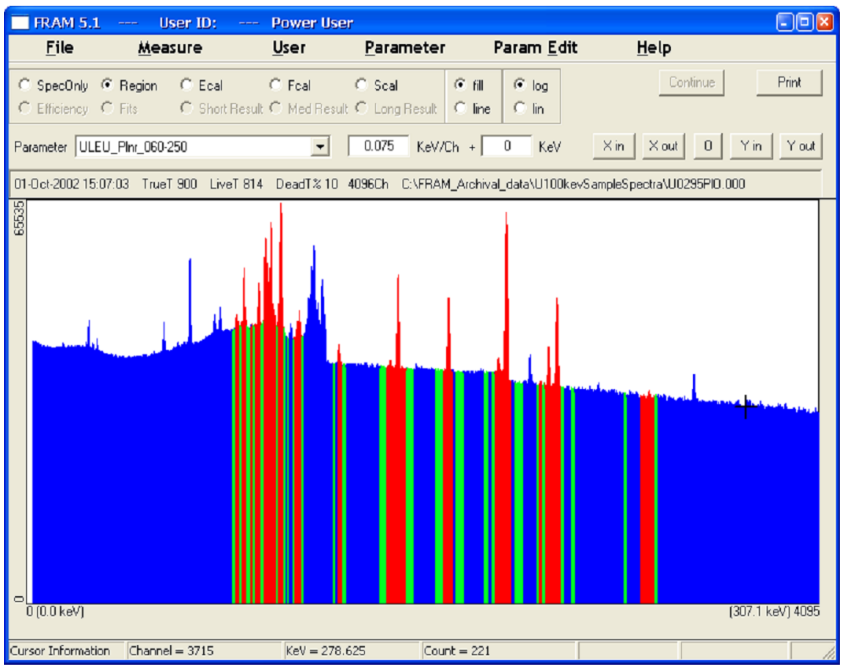
FRAM V7.1 is a minor upgrade from V6.1, which was released in 2020. In addition to the capability to analyze pixelated CZT spectra, FRAM V7.1 implements new features that improve usability, sustainability, compatibility, and maintainability.

The FRAM code has been under evolutionary development at Los Alamos National Laboratory since the mid-1980s. It analyzes the gamma-ray spectrum taken with a germanium, LaBr3, or CZT detector, of items containing plutonium or uranium, or both and quantifies the distribution of plutonium or uranium isotopes. ^{241}Am and other transuranic isotopes (including uranium in mixed uranium-plutonium oxides) that contribute measurable gamma rays to the spectrum can also be quantified relative to plutonium.

It also analyzes spectra from items containing only uranium and can quantify the uranium isotopic distribution. These measurements can be performed on samples of any size, geometry, and physical and chemical composition.

Easy-to-Use Windows User Interface

ORTEC FRAM is a member of the ORTEC CONNECTIONS family of products. It operates within the ORTEC CONNECTIONS network spectroscopy architecture, giving greater flexibility in choice of MCA hardware, including the latest DSPEC 50/50A and DSPEC 502/502A digital spectrometers, and fully integrated spectrometers such as the Detective, trans-SPEC and IDM series.



The highly graphical FRAM user interface complies with the latest Windows conventions and is easy to use. A single interface is provided for all data displays. A single dialog bar controls all aspects of spectrum and results display, making it easy for the user to verify the quality of the data or analysis without leaving the FRAM main window.

FRAM provides acquisition control of all MCA hardware supported by ORTEC CONNECTIONS. The ORTEC MAESTRO-PRO MCA software program is used for hardware system setup prior to use and can be removed from the PC to secure the MCB from changes.

FRAM Analysis Capabilities

Sample Type

The versatility of FRAM and its ability to analyze a wide variety of samples stems from its reliance upon generic analysis algorithms. Specific information needed to guide the analysis is encoded into a set of parameters and stored in a database. This information includes the regions and peaks to be examined, the isotopes to be used in the analysis, and special information for performing a number of diagnostic tests on the spectrum. For analysis of well characterized "routine" samples, a single analysis parameter set may be easily constructed; for less well-known samples, an automatic mode is provided in which the optimum sample parameter set is determined iteratively in an automated fashion.

The parameter sets in V7.1 are backward compatible with the parameter sets of earlier versions of FRAM.

Material Categories Analyzed:

- 2–95% ^{240}Pu
- 0.01–50% ^{241}Am
- Interferences from ^{243}Am–^{239}Np, ^{237}Np, and ^{244}Cm
- 80% ^{238}Pu
- Shielded samples (>13mm Pb for Pu, >16mm Steel for U)
- Heterogeneous Am/Pu
- Nonequilibrium ^{241}Pu–^{237}U
- MOX: ^{235}U/Pu from 0.005–35
- Pu with 80–95% ^{242}Pu
- ^{235}U/^{238}U in pure U (no Pu)
- ^{235}U: ^{241}Am: Pu = 24:1:1

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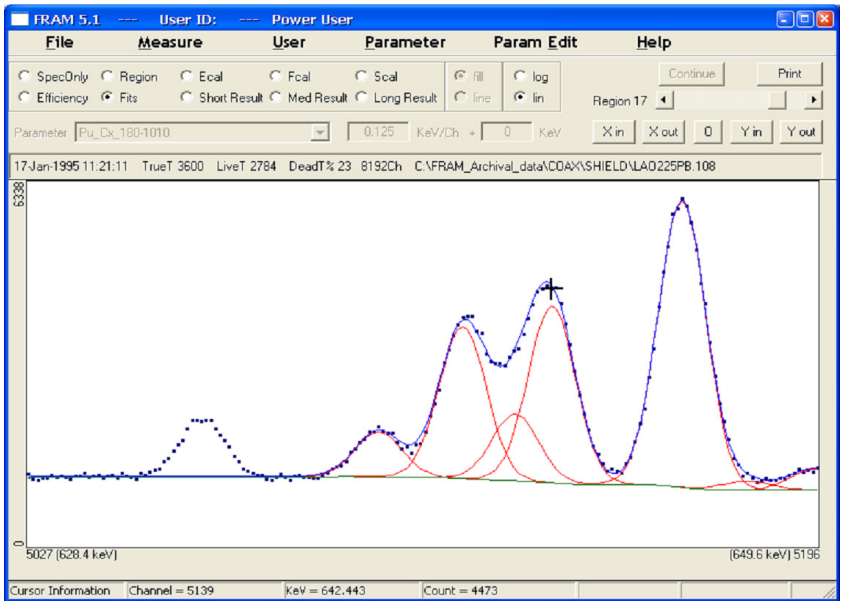
Analysis Methods

FRAM analyzes photopeaks from the spectrum of plutonium or uranium gamma rays. The spectrum contains peaks from the plutonium isotopes ^{238}Pu to ^{241}Pu, ^{241}Am, and often other isotopes such as ^{235}U or ^{237}Np. FRAM combines this information to produce isotopic ratios independent of sample size, shape, physical and chemical composition, measurement geometry, and container characteristics. The results are obtained using only the spectral data and known fundamental nuclear constants. Calibration with standards is NOT necessary.

Peak Area Determination

FRAM uses response function methods to determine all peak areas, fitting a Gaussian with a single exponential on the low-energy side to model the gamma-ray peak shapes and uses a Lorentzian to model x-ray peaks.



Fitting in the 640 keV region from the spectrum of a 1 kg Pu^{O2} sample with 16% ^{240}Pu.

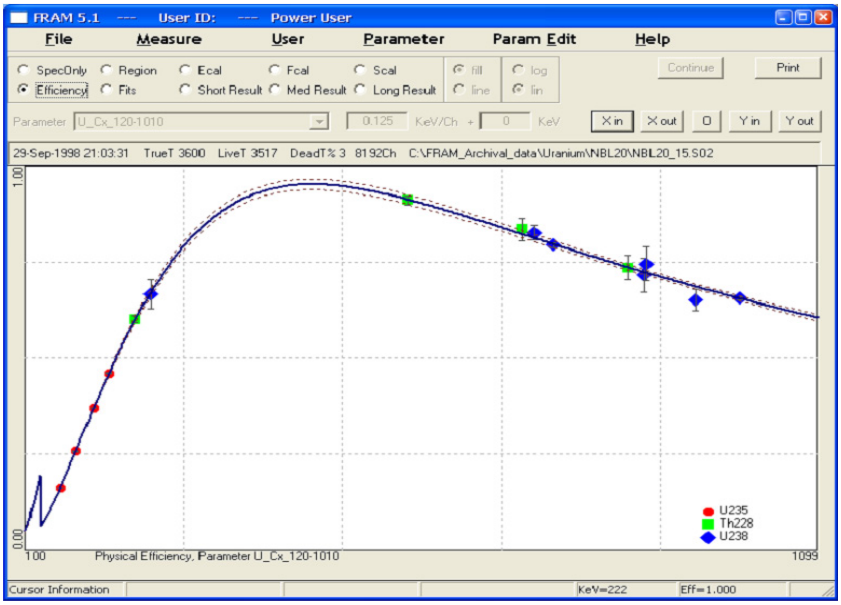
Relative Efficiency

FRAM uses a separate efficiency curve for each isotope. This allows it to measure the specific power of pyrochemical residues with biases that are reduced by as much as a factor of ten from analyses that do not use multiple efficiency curves.

The multiple efficiency feature of FRAM may also be used for other heterogeneous samples. The physical and chemical characteristics of the sample may not be uniform or even well known. Items may contain mixtures of solids and powders with no ill effect so long as the plutonium is isotopically uniform. Both physical and empirical efficiency models are provided.

Analysis for Isotopic Ratios

The approach used is that of finding a least squares solution to a set of linear equations involving peak areas, relative efficiency, and isotope ratios as unknowns. The method allows use of multiple peaks in the analysis with resulting improved measurement precision.



A relative efficiency curve plot from the analysis of a coaxial detector spectrum from 200 g of U^{3O8} enriched to 20% ^{235}U.

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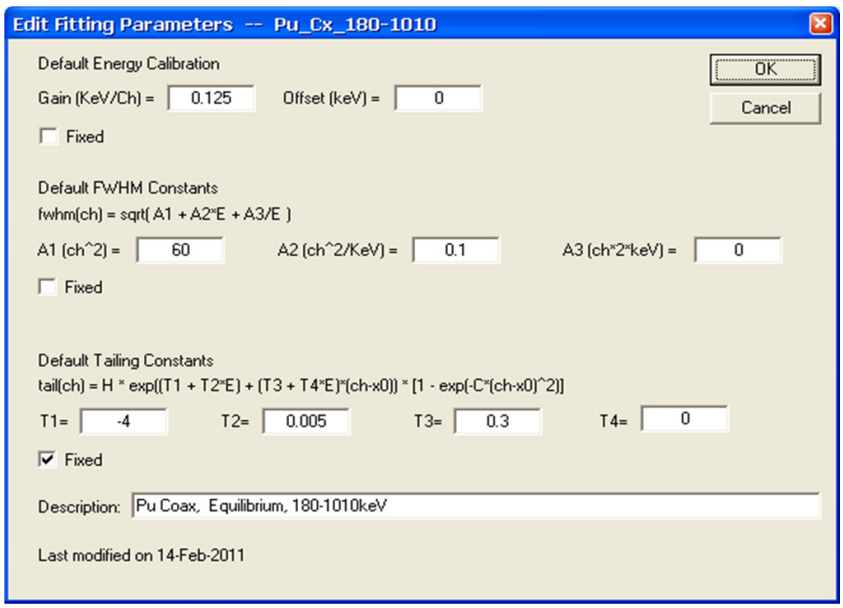
Analysis Parameters Database

The analysis parameters database is important in the power and flexibility of FRAM. These parameter sets are grouped into five categories: peak fitting parameters, gamma-ray peaks to be searched for, energy regions to be searched, isotopes to be used, and special application constants. Multiple parameter sets can be easily accommodated.



Analysis Parameters.

Auto-Analysis Feature

The auto analysis feature in FRAM allows automatic reanalysis of the spectrum, with changed parameters, based upon the current results. Auto analysis can start with any parameter set and works with both plutonium and uranium in all the energy ranges. The user has the freedom to program the analysis (by means of the Application Constants in the parameter set) to determine the properties of the material such as shielded, MOX, plutonium burnup, uranium enrichment, interference isotope, or heterogeneous. For example, after an analysis of the mid energy region (120–500 keV) of a plutonium spectrum, it can check both the lower energy (~100 keV) and higher energy (~700 keV) regions to see if those regions are more favorable.

Plutonium or Uranium Analysis

A parameter set can be set up for uranium (only) spectra. In this case, different isotopic ratios are calculated, and the summary is formatted differently.

Estimation of ^{242}Pu

The estimation of ^{242}Pu is done via a correlation model using an industry standard formula with user specified parameters. Their values may be stored in any one of the parameter sets used for analysis. This model accommodates most of the commonly proposed correlations for ^{242}Pu.

Decay Correction of Isotopic Fractions

For samples which are at least 5 years old, the 14.35-year half-life of ^{241}Pu can lead to a significant change in the ^{242}Pu fraction, which, if unaccounted for, can lead to (relative) errors on the order of 4% in the ^{239}Pu fraction.

FRAM can decay correct the isotopic fractions of Pu and Am.

Command-Line Mode of Operation

The Command-Line Operation mode is intended for users who want to incorporate FRAM into their own applications. This mode allows the user to make a very simple interface to the FRAM analysis engine.

Measure-Compare Option

This option allows the user to directly compare the results of an analysis with a decay-corrected declared value. The differences between the measured and declared values are expressed in terms of the standard deviations of the measured and declared values.

Analysis Improvements in FRAM Version 7.1

- Ability to fit peaks and analyze pixelated CZT spectra.
- Option to enter and use an actual detector efficiency curve in its analysis. Together with the source dimension information, the source-to detector distance, and the self and external attenuation at all energies calculated by the analysis, the code can determine the mass of the item
- New parameter set, HPGe_Pu_060-230, for plutonium analysis in the low energy region. This parameter set has 0.075 keV/ch default energy calibration and requires spectra with good resolution such as those of a planar HPGe detector.
- Two parameter sets to analyze low-enriched uranium (LEU) and high-enriched uranium (HEU) employing the low-energy region and named them HPGe_ULEU_060-250 and HPGe_UHEU_060-250, respectively. The parameter set HPGe_ULEU_060-250 can analyze uranium with enrichment below 40% and the parameter set HPGe_UHEU_060-250 can analyze uranium with enrichment greater than 10%.

Germanium Detector Requirements

FRAM can perform a complete isotopic analysis using either a single planar or a single coaxial detector. The benefits of being able to operate with a single HPGe detector are obvious: cost, space, convenience, ease of use, and reliability. When used with the “traditional” single planar detector, it is used often (but not always) to collect and analyze data in the 120–420 keV range.

The most common energy range used in conjunction with a coaxial detector is 0–1024 keV. Various analysis modes can be used in this wide data range. If the 120–200 keV range is available, FRAM will work best analyzing in the range of 120–450 keV. If this is not possible (for example, if the sample is shielded or in a thick-walled container), FRAM can still obtain a complete analysis using only those gamma rays above 200 keV from a single coaxial detector.

The optimum choice of detector depends on the applications expected to be encountered. A planar detector is usually the detector of choice if all measured items are unshielded or are in thin-walled containers. If shielded containers, thick-walled containers, or a mixture of all container types are encountered, a single coaxial detector is optimum. The ORTEC Safeguards Series HPGe detectors are highly recommended.

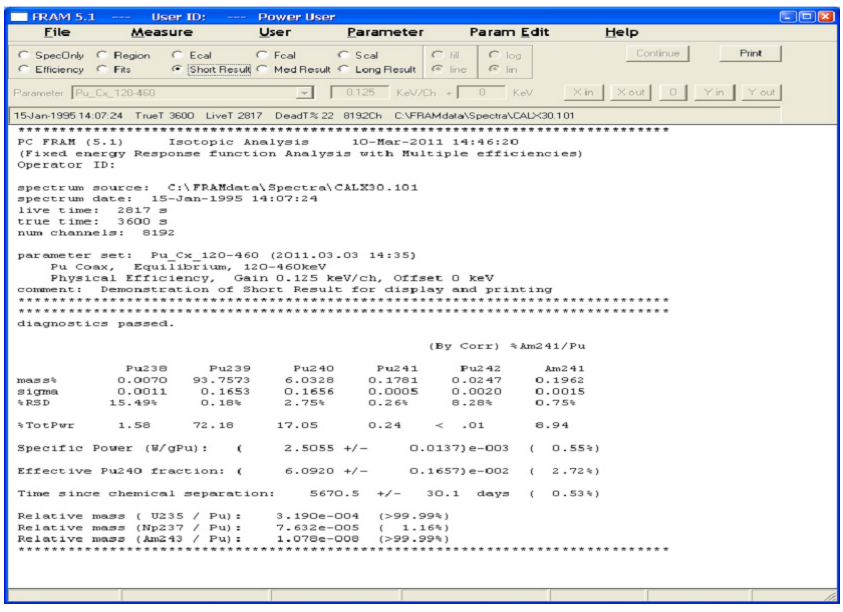
In many applications the ORTEC Detective and trans-SPEC portable spectrometers have proven highly effective. FRAM software includes starting analysis parameter sets for the ORTEC Detective.

Password Protection and Security

An access control system within FRAM stores a list of users, their passwords, and access rights granted to them. Three of the items listed in the Edit menu are protected by this mechanism: the Parameters option, the General Defaults option, and the User List. When all these options are in operation, the user will be asked to supply a name and a password. If the security check fails, control returns to the main menu.

Output Display and Listings

Three levels of output display (Short Result, Med Result, and Long Result) may be selected in the FRAM dialog bar and displayed in the FRAM window for all analysis results. A screen copy of the Short Result is automatically sent to the monitor after each analysis.



Example Short Display.

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Prerequisites

As a CONNECTIONS family member, FRAM-BW will operate correctly on any system supporting CONNECTIONS compatible hardware. The software operates under all currently supported Windows operating systems. Windows 7 64-bit hardware compatibility is available for all ORTEC instruments that use USB and TCP/IP connectivity. These instruments, as well as other legacy hardware, are also supported with Windows 7 and XP 32-bit operating systems.

Ordering Information

Model	Description
FRAM-BW	FRAM-BW Version 7.1 Gamma-Ray Isotopic Analysis Software. Includes MAESTRO-PRO MCA Emulation software.
FRAM-GW	Documentation for FRAM-BW
FRAM-UW	Update for FRAM-BW

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