Application of an electronic spreadsheet package and a dedicated spectral analysis software for the calibration of a gamma-ray spectrometer

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PRESENTATION OUTLINE

- Introduction
- Focus of this study
- Crucial role of full energy peak efficiency of detectors in analytical accuracy
- Efficiency calibration with spectral analysis software
- Efficiency calibration with Microsoft Excel electronic spreadsheet package
- Efficiency computation and fitting with electronic spreadsheet for GEM 30195 at 2cm & 15cm geometries
- Comparison of the FEPE calibration results obtained from both approaches (spreadsheet and k_0_IAEA)
- Results & discussion
- Conclusion

Centre for Energy Research and Training (CERT) NAA laboratories

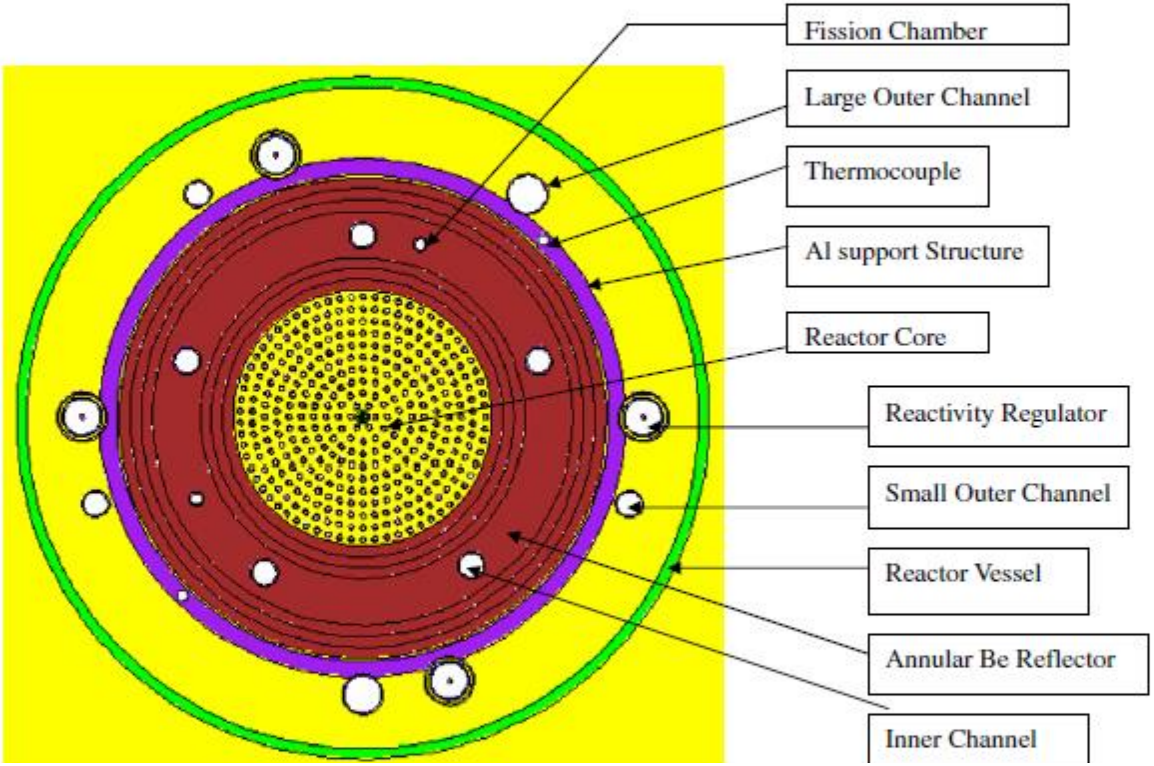
Strategic Utilization Plan for NIRR-1

This study was carried out as part of the strategic development plans for the optimum utilization of the Nigeria Research Reactor-1 (NIRR-1) since it was installed and commissioned in 2004.

It was specifically designed for use in

- neutron activation analysis (NAA) and
- limited radioisotope production.

NIRR-1 DESIGN SPECIFICATIONS



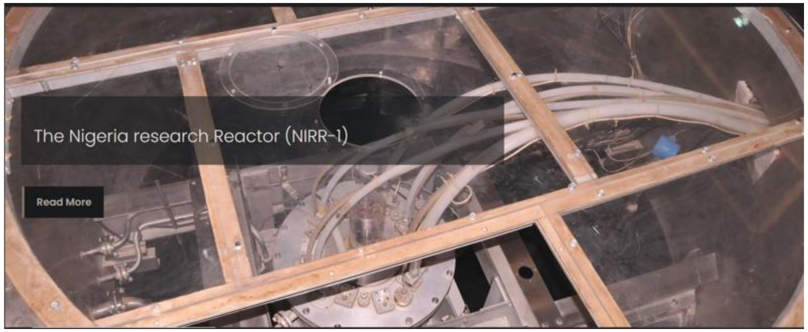
A geometric diagram of NIRR-1 core mid-plane from MCNP code

(NIRR-1) is a low-power Miniature Neutron Source Reactor (MNSR) designed by China Institute of Atomic Energy (CIAE) with a tank-in-pool structural configuration and a nominal thermal power rating of 31 kW at thermal neutron flux setting of 5×10^{11} n cm^{-2} s^{-1}

NIRR-1 CONVERSION FROM HEU TO LEU

Conversion from 90% to 12% uranium-235 enrichment

NIRR-1



Reactor Hall

Reactor Core

NIRR-1 Control Room

INTRODUCTION

- Instrumental Neutron Activation Analysis (INAA) is a nuclear analytical technique with high sensitivity and multi-elements capability.

- Results from k_0-standardized INAA labs depend on accurate efficiency calibration of detectors at specific counting positions called geometries which must be known in advance. (De Corte et al., 2004)

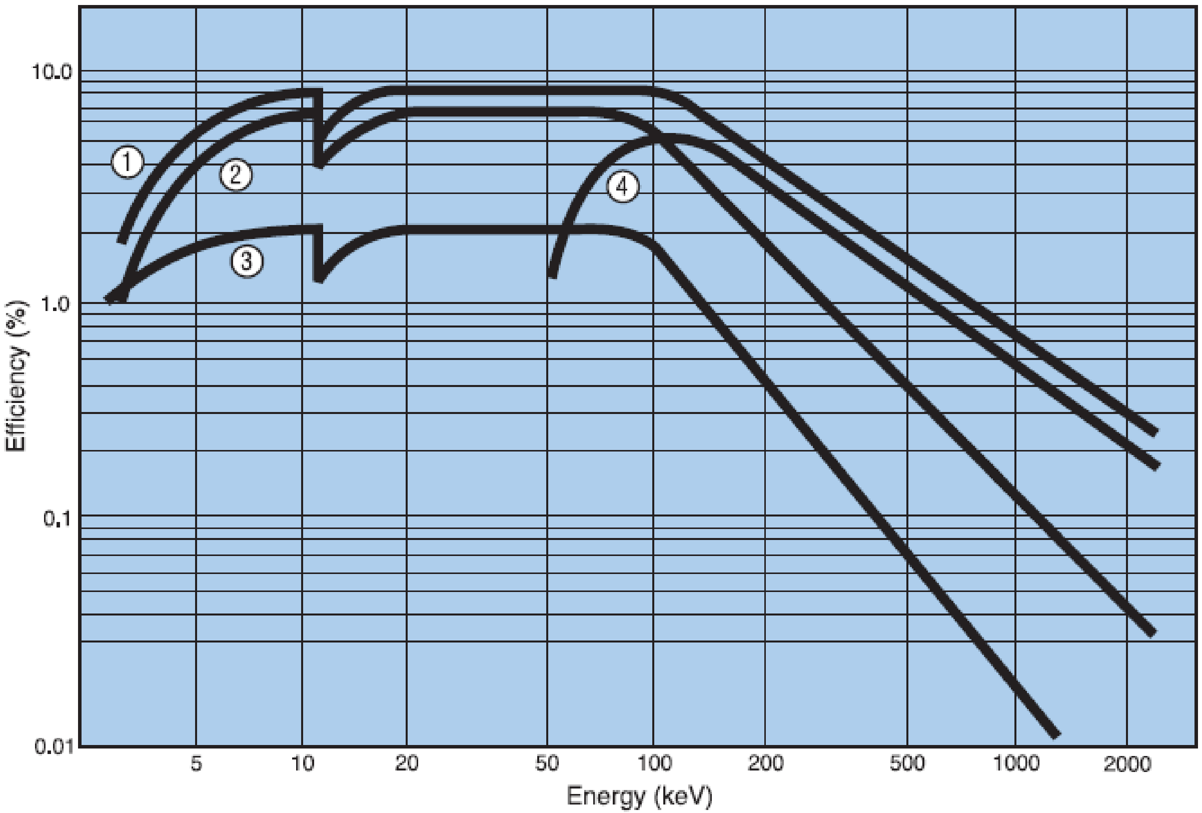
- The ultimate goal of detector calibrations is in carrying out routine analysis of samples.

FOCUS OF THIS STUDY

To use a novel method that does not rely on spectral analysis software to generate full-energy peak detection efficiency data and fitted curve for gamma rays within the energy range of 59.54 – 2447.71 KeV for a High Purity Germanium (HPGe) detector using electronic spreadsheet package. This covers the entire range over which the spectrometer is to be used.

The result was compared with the one obtained from a dedicated proprietary spectral analysis software.

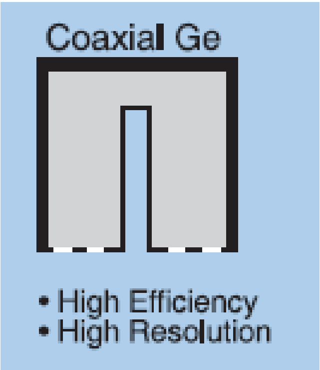
FOCUS OF THIS STUDY



Typical absolute efficiency curves for various Ge detectors with 2.5 cm source to end-cap spacing

Code:

1. REGe, 15% Relative Efficiency
   XtRa, 15% Relative Efficiency
2. LEGe, 10 cm^2 x 15 mm thick
3. Planar, 200 mm^2 x 10 mm thick
4. Coaxial Ge, 10% Relative Efficiency



KEY STEPS INVOLVED IN THE IMPLEMENTATION OF THE k_0-STANDARDIZATION METHOD OF NAA

- Characterization of the irradiation facility
- Calibration of the detectors

- The two processes are done once because

(i) One of the hallmarks of MNSRs such as NIRR-1 is their neutron flux stability.

(ii) Detectors' efficiency re-calibration would only be necessary if the detector is etched.

FULL ENERGY PEAK EFFICIENCY OF DETECTORS AS CRUCIAL COMPONENT IN THE ANALYTICAL RESULT

- Full energy peak efficiency of detectors is used in evaluation of the peak area of elements of interest in a sample, hence determining the activity of either Naturally Occurring Radioactivity in Materials (NORMS) or induced radioactivity from matrices irradiated in a research reactor.

- This activity forms the basis for quantifying the elements of interest in the sample. (Jonah et al., 2006).

k_0-NAA STANDARDIZATION METHOD

The formula for computing the analyte mass fraction c_a is:

$$C_a = \frac{\left(\dfrac{N_P / t_m}{SDCW}\right)_a}{\left(\dfrac{N_P / t_m}{SDCW}\right)_{Au}} \times \frac{1}{\left(k_{0,Au}\right)_a} \times \frac{\varepsilon_{P,Au}}{\varepsilon_{P,a}} \times \frac{f_i + Q_{0,Au}(\alpha)}{f_i + Q_{0,a}(\alpha)}$$

1st term describes the results of the gamma-ray spectrometry measurements,

2nd term is the corresponding k_0 factor,

3rd term is related to the full energy peak efficiency calibration of detector

4th term accounts for the contribution of the epithermal activation (reactor-dependent).

CHARACTERIZING OF IRRADIATION FACILITY

The irradiation facility is characterized by the following neutron flux parameters:

- Φ_{th} - thermal neutron flux and its uncertainty.
- $f = \frac{\Phi_{th}}{\Phi_{epi}}$ - the thermal to epithermal neutron flux ratio.
- Φ_{f} – the fast neutron flux and its uncertainty.
- α – shape factor of the epithermal neutron flux
- T – the temperature of the Maxwell-Boltzmann velocity distribution that describes the thermal component of the neutron spectrum.
- f_T - the ratio of the thermal to fast neutron flux

NEUTRON SPECTRUM PARAMETERS FOR FOUR NIRR-1 IRRADIATION CHANNELS

Parameter	Inner		Outer	
	A1	B2	A2	B4
α	-0.046 ± 0.005	-0.052 ± 0.002	0.024 ± 0.002	0.029 ± 0.003
f	18.4 ± 0.3	19.2 ± 0.5	49.5 ± 0.1	48.3 ± 3.3
$\Phi_{th}/\Phi_f(f_T)$	5.2 ± 0.2	5.0 ± 0.2	15.0 ± 0.8	15.5 ± 0.9
$T_n(^oC)$	52.3 ± 2.6	60.6 ± 3.7	40.4 ± 2.4	44.5 ± 2.7
$\Phi_{th}(cm^{-2}s^{-1})$	5×10^{11}	5×10^{11}	2.5×10^{11}	2.5×10^{11}

Routine irradiation and measuring regimes for NIRR-1 facilities (Optimized protocol)

Neutron flux/irradiation channel	Procedure	T_{irr}	T_d	T_m	Activation products
2.5 x 10^{11} n/cm^{2}s/outer irradiation channels (B4)	S1	1 min	10 – 15 min	10 min	^{27}Mg, ^{28}Al, ^{49}Ca, ^{51}Ti, ^{52}V, ^{66}Cu,
2.5 x 10^{11} n/cm^{2}s/outer irradiation channels (B4)	S2	1 min	3 - 4 h	10 min	^{42}K, ^{56}Mn, ^{165}Dy,
5 x 10^{11} n/cm^{2}s/inner irradiation channels (B2 and B3)	L1	6 h	4 – 5 d	30 min	^{24}Na, ^{72}Ga, ^{76}As, ^{140}La, ^{153}Sm, ^{238}U,
5 x 10^{11} n/cm^{2}s/inner irradiation channels (B2 and B3)	L2	6h	11 – 12 d	60 min	^{46}Sc, ^{51}Cr, ^{59}Fe, ^{60}Co, ^{65}Zn, ^{86}Rb, ^{131}Ba, ^{134}Cs, ^{152}Eu, ^{177}Lu, ^{181}Hf, ^{182}Ta, ^{232}Th

PART A – Energy and Efficiency calibration with spectral analysis software

TOOLS REQUIRED FOR THE SPECTRAL ACQUISITION & ANALYSIS

- High-Purity Germanium detectors (HPGe 30195)
- Analog to digital converter (ADC)
- Digital gamma-ray spectrometer hardware DSPEC jr 2.0
- MAESTRO-32 gamma-ray data acquisition software
- Multi-channel analyzer (MCA) emulation software
- A personal computer and associated electronic modules
- Standard calibration sources
- k_0-IAEA software for spectral analysis.
- WINSPAN 2004 spectral analysis software

Courtesy of Ortec.

CONTROL OF THE SPECTRAL ACQUISITION & ANALYSIS

The detector is coupled to the integrated digital gamma-ray spectrometer hardware DSPEC jr 2.0 which is completely computer-controlled with the MAESTRO-32 multi-channel analyzer (MCA) emulation software. Complete computer control of the front end electronics means there are no knobs to turn or buttons to push, eliminating the possibility of accidental misadjustment. Precise adjustment of all front end electronics is accomplished via emulated controls - right on the screen. The DSPEC jr 2.0 is connected via a USB port to the host personal computer which is used for configuring the hardware settings (such as high voltages, presets and amplifier gain) through the multichannel buffer (MCB) interface of the MAESTRO-32 software. (DSPEC jr 2.0 Hardware User's Manual)

DATA ACQUISITION

MCA plug-in card and MAESTRO-32 gamma ray data acquisition and MCA emulation software for control of the MCA functions.

SPECTRAL ANALYSIS

Version 5.00 of the ***k*$_0$-IAEA program** was used for the calibration of the detector.

Freely distributed gamma spectroscopy software developed by The International Atomic Energy Agency, Vienna, Austria.

CALIBRATIONS OF THE DETECTOR IN k_0-IAEA PROGRAM

(1) Storing of background spectrum

(2) Peak shape calibration

(3) Energy calibration

(4) Efficiency curve calibration

(a) Peak-to-total ratio

(for only the farthest geometry)

(b) Full-energy peak efficiency curves

(for all detector-source distances to be used)

THE COAXIAL HPGE DETECTOR MODEL NUMBER “GEM-30195” USED

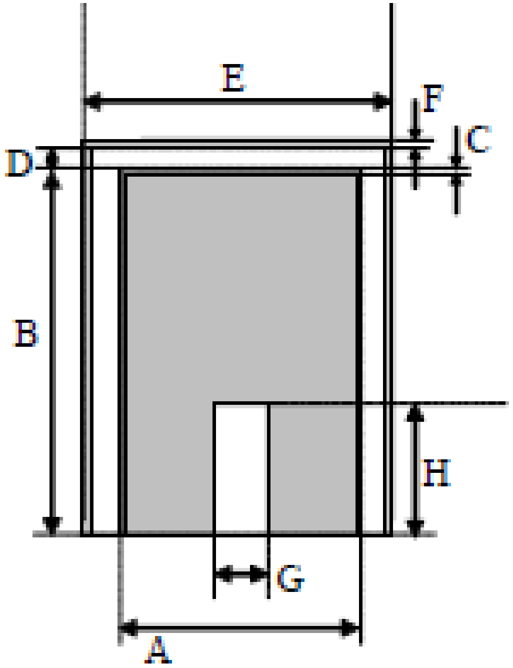
GEM 30195 detector mounted on 30-liter liquid nitrogen dewar for cooling to cryogenic temperatures (77K or -196°C) and surrounded by lead shield to reduce the background caused by sources other than the sample.

THE TECHNICAL/PERFORMANCE SPECIFICATIONS OF GEM-30195 FROM THE CERTIFICATE

	Warranted	Measured	Amplifier Time constant
Resolution (FWHM) at 1.33 MeV, ^{60}Co	1.95KeV	1.80KeV	6μs
Peak-to-Compton Ratio, ^{60}Co	54	70.7	6μs
Relative Efficiency at 1.33 MeV, ^{60}Co	30%	43.4%	6μs
Peak Shape (FWTM/FWHM), ^{60}Co	1.98	1.88	6μs
Peak Shape (FWFM/FWHM), ^{60}Co	2.98	2.51	6μs

High-purity coaxial germanium detector (HPGe) 30195 with **relative efficiency of 30% and a resolution of 1.95 keV** (FWHM) for the 1.33 MeV gamma line of ^{60}Co.

DETECTOR'S DIMENSIONS (SPECIFICATIONS OF GEM-30195 FROM THE CERTIFICATE)



Detector type	Coaxial	Well-type
A	Crystal diameter	Crystal diameter
B	Crystal length	Crystal length
C	Dead layer thickness	Not used
D	End cap to crystal	Not used
E	Top cover diameter	Not used
F	Top cover thickness	Cover thickness
G	Core diameter	Well diameter
H	Core height	Well depth

DATA ACQUISITION

Digital Spectrometer (DSPEC jr 2.0) connected to desktop compute

Coupled with MCA plug-in card and MAESTRO-32 gamma ray data acquisition software and MCA emulation software for control of the MCA functions.

EVOLUTION OF SPECTRAL ACQUISITION SYSTEM

Modern digital Spectrometer connected to desktop computer and coupled with MCA plug-in card and MCA emulation software for control of the MCA functions.

Hardwired MCA with its own user interface - today the MCA interface is emulated in computer software.

ESSENTIAL FEATURES OF THE SPECTRAL ANALYSIS PROGRAM (k_0-IAEA) FOR ENERGY CALIBRATION

(1) Peak search – using a peak-search algorithm to find full-energy peaks above the background in a spectrum. (The peaks are superposed on the continuum)

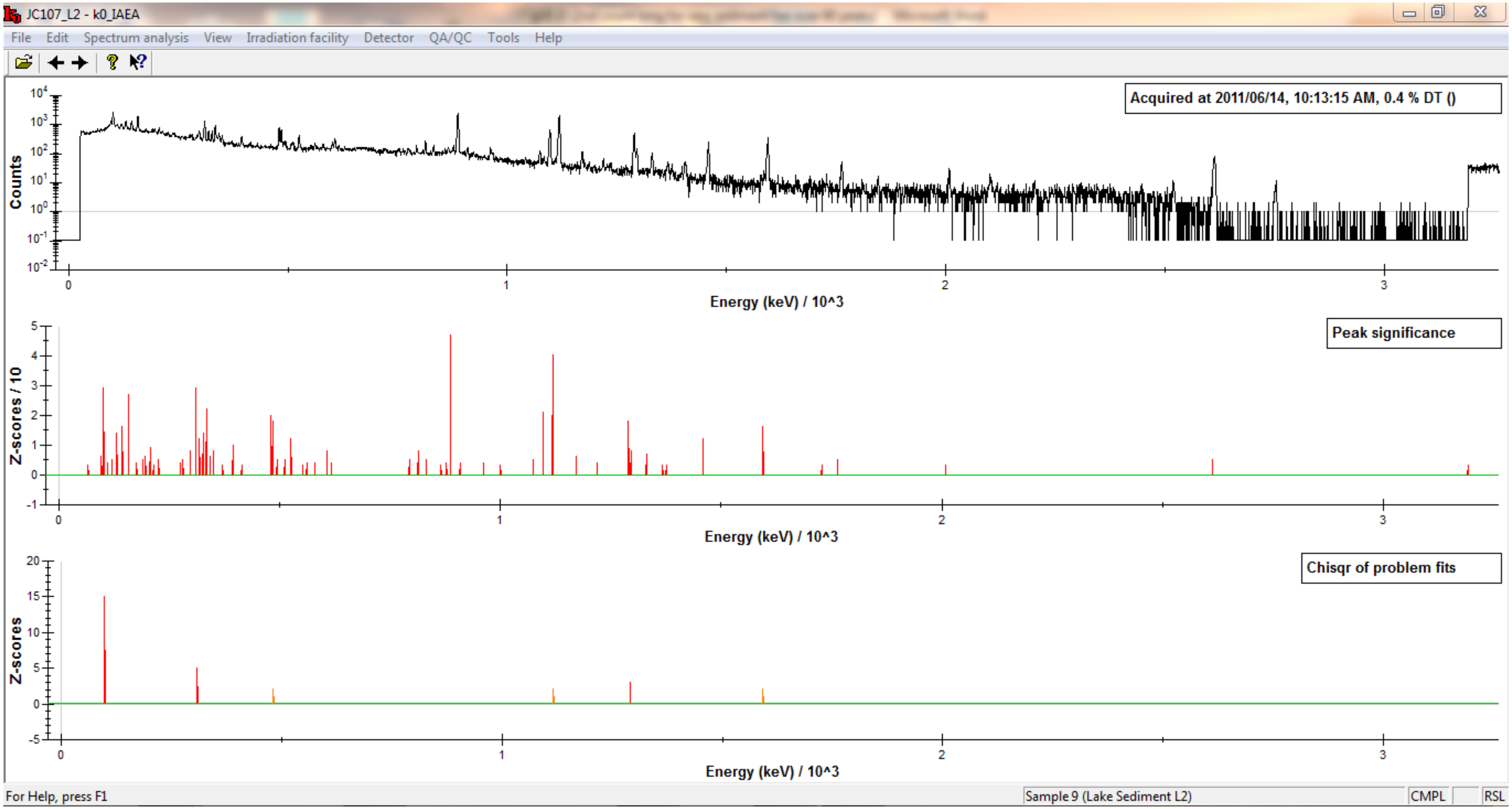
(2) Assignment of energy - to each detected peak using the Energy calibration. Peaks in all channels.

(3) Peak match – nuclide identification, determining the element to which each peak belongs using the computer based nuclear data library. Identifying particular γ-rays with specific nuclides.

(4) Net peak area calculation - to determine activity and subsequently the elemental concentration.

Typical gamma-ray spectrum as recorded by HPGe 30195 detector and displayed k_0-IAEA software

(With 62 detected peaks by version 5.00 of the k0-IAEA program)



ENERGY CALIBRATION

Routine energy calibration of the MAESTRO-32 spectrum acquisition software has to be carried out once a week or every two weeks using a mixed energy gamma ray calibration sources e.g. ^{137}Cs, ^{60}Co and ^{88}Y.

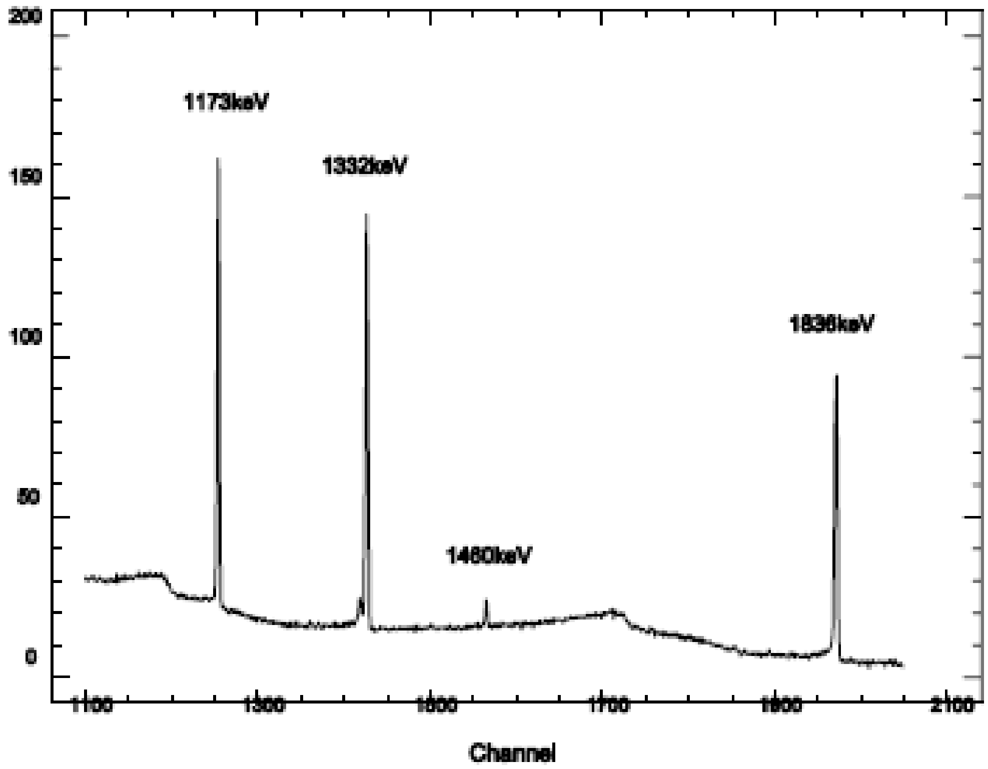
The spectrum is acquired long enough to clearly identify the positions of the pure photopeaks in the spectrum. This usually takes about five minutes.

ENERGY CALIBRATION

For the point sources used - ^{137}Cs, ^{60}Co and ^{88}Y, the corresponding peaks could be seen prominently at 661.6 KeV, 1173 keV, 1332 keV and 1836 keV respectively. Good spread and cover almost the entire range over which the spectrometer is to be used.

The calibration is carried out by replacing the channel number placeholders for these peaks on the horizontal axis of the spectrum plot with the well known actual values of the expected peak energies from these calibration sources.

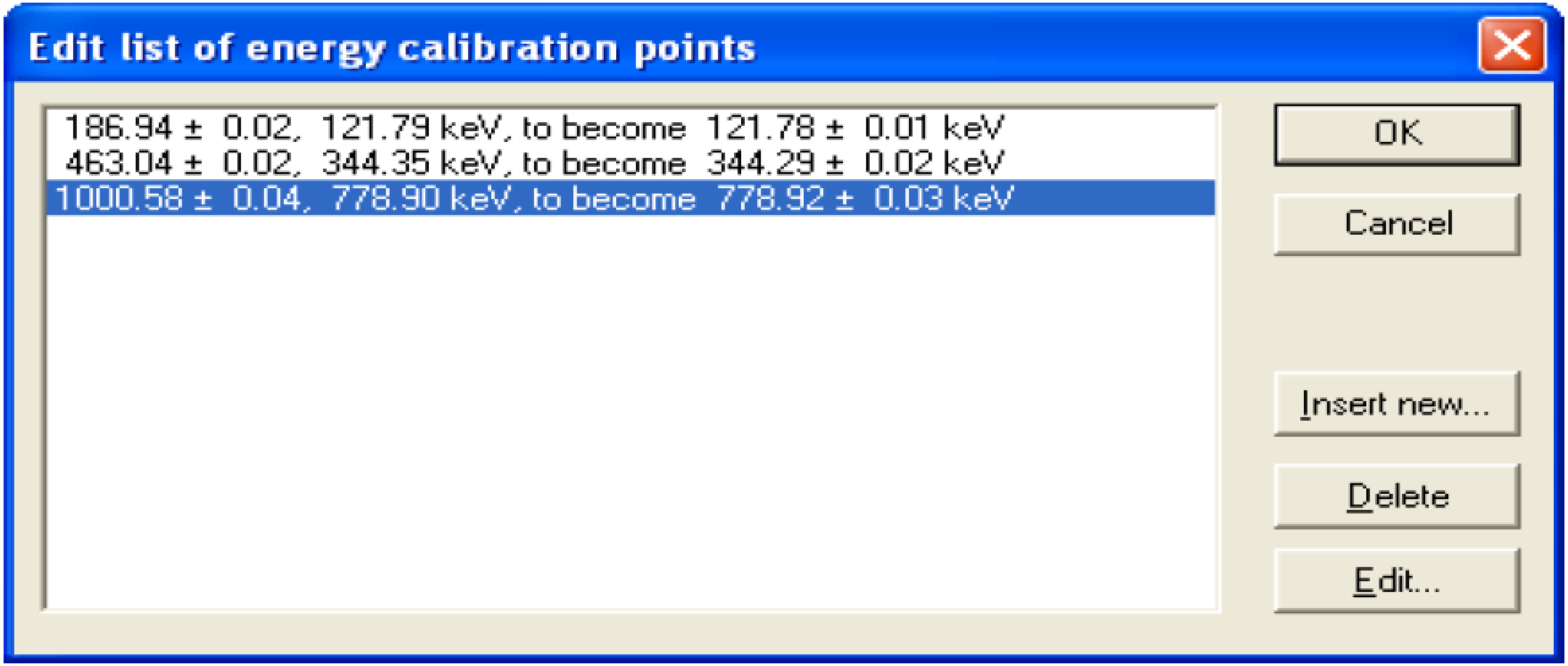
ENERGY CALIBRATION



γ-ray spectrum segment showing energy calibration (^{60}Co [1173, 1332 keV], ^{88}Y [1836 keV]) and impurity (^{40}K [1460 keV]) peaks.

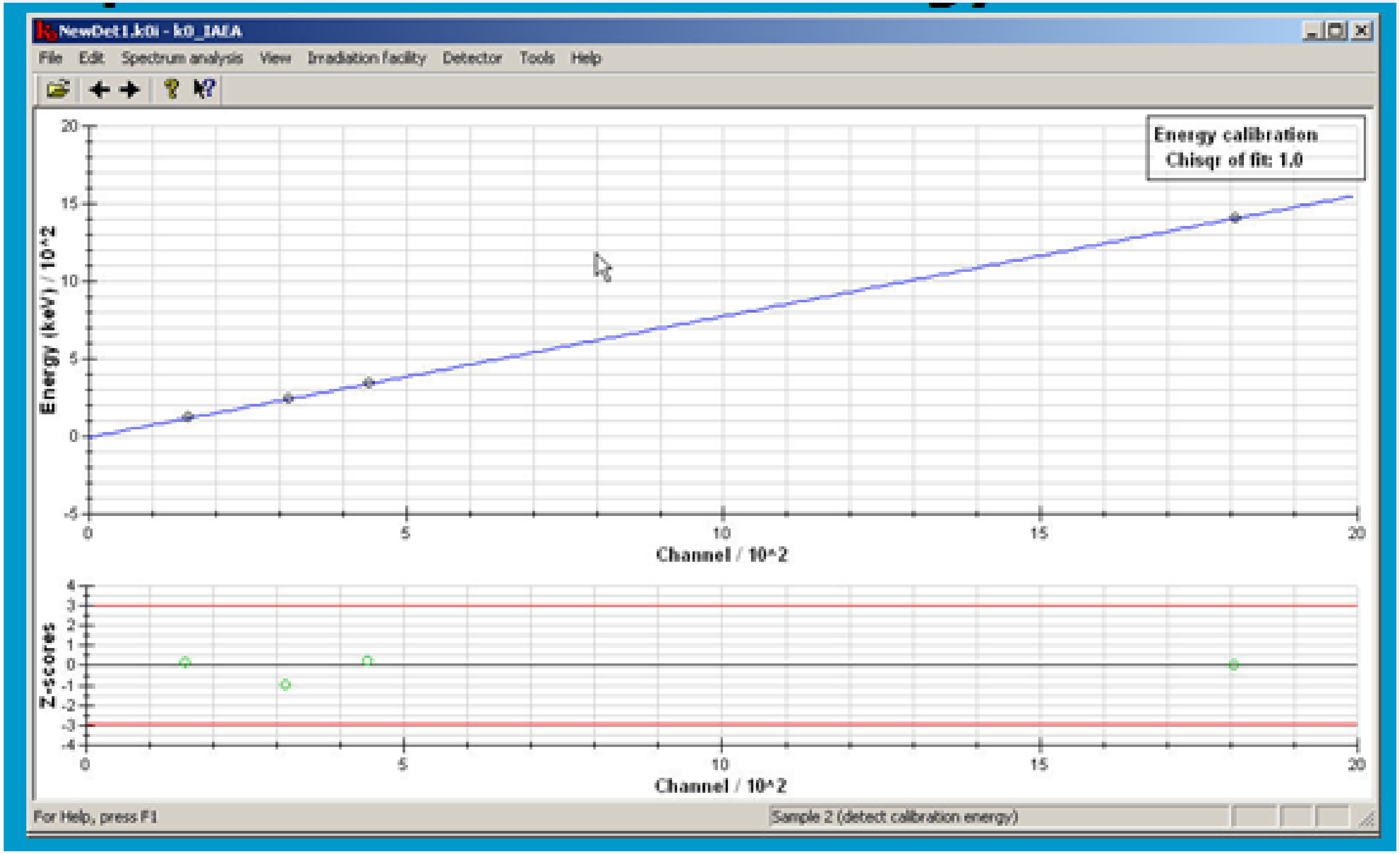
Courtesy of IAEA-TECDOC-1401

ENERGY CALIBRATION WITH Eu-152 SPECTRUM ANALYSED IN k_0-IAEA PROGRAM



Window of the menu “Spectrum analysis/Energy calibration” with typical values of data entered for energy calibration with Eu-152 spectrum analysed.

TYPICAL ENERGY CALIBRATION CURVE WITH k_0-IAEA PROGRAM



FULL-ENERGY PEAK EFFICIENCY CALIBRATION

The efficiency calibration establishes the relationship between the peak energy and the probability of the detector recording a count in the full energy peak.

This is done once for a detector and stored in the permanent database of the software except it is etched, then the calibration has to be repeated.

Efficiency calibration datapoints for GEM 30195 at 2 cm source-detector geometry with k_0-IAEA program

GEM 30195 - k0_IAEA

File Edit Spectrum analysis View Irradiation facility Detector QA/QC Tools Help

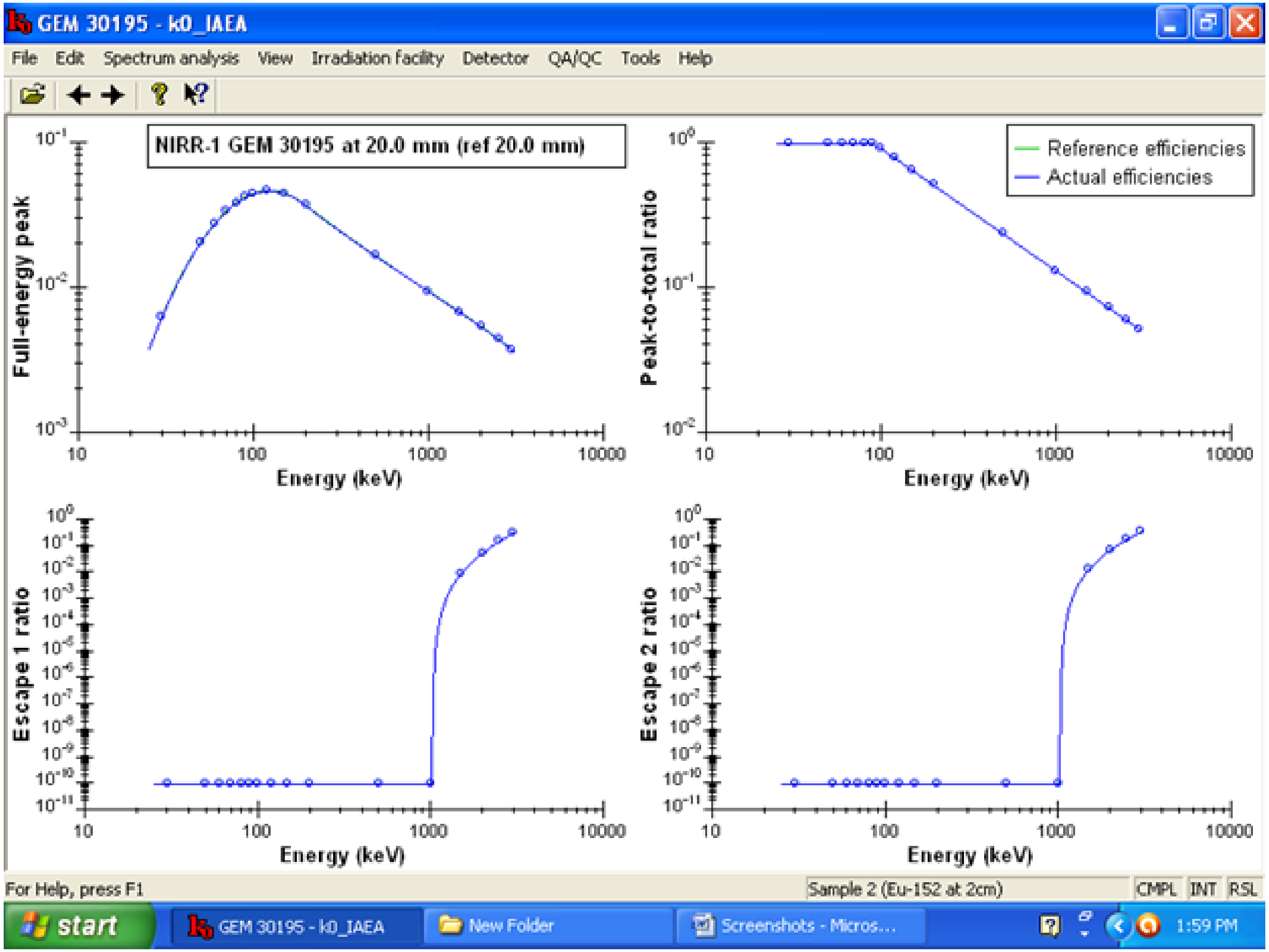
Results calculated just now:

E(keV)	measured effic, tc correction			fitted eff, z		p/t ratio	Esc1ratio	Esc2ratio
45.40	2.230E-004	+/- 7.004E-005	0.912	1.708E-004	0.7	9.990E-001	0.000E+000	0.000E+000
121.78	4.444E-002	+/- 1.513E-003	0.925	3.800E-002	4.3	7.748E-001	0.000E+000	0.000E+000
147.96	1.102E-001	+/- 2.774E-002	0.919	3.499E-002	2.7	6.573E-001	0.000E+000	0.000E+000
244.69	2.807E-002	+/- 9.024E-004	0.916	2.632E-002	1.9	4.299E-001	0.000E+000	0.000E+000
295.93	3.634E-002	+/- 1.098E-002	0.901	2.289E-002	1.2	3.662E-001	0.000E+000	0.000E+000
344.29	2.262E-002	+/- 7.047E-004	0.949	2.032E-002	3.3	3.223E-001	0.000E+000	0.000E+000
411.12	1.730E-002	+/- 8.582E-004	0.903	1.761E-002	-0.4	2.775E-001	0.000E+000	0.000E+000
443.89	1.853E-002	+/- 9.065E-004	0.920	1.655E-002	2.2	2.601E-001	0.000E+000	0.000E+000
488.61	1.209E-002	+/- 4.653E-003	0.899	1.531E-002	-0.7	2.398E-001	0.000E+000	0.000E+000
564.01	1.220E-002	+/- 2.893E-003	0.985	1.364E-002	-0.5	2.125E-001	0.000E+000	0.000E+000
678.59	7.650E-003	+/- 2.115E-003	0.881	1.178E-002	-2.0	1.818E-001	0.000E+000	0.000E+000
688.67	1.300E-002	+/- 1.571E-003	0.987	1.164E-002	0.9	1.795E-001	0.000E+000	0.000E+000
755.41	(sum peak)							
778.92	1.131E-002	+/- 4.138E-004	0.941	1.057E-002	1.8	1.618E-001	0.000E+000	0.000E+000
810.45	1.024E-002	+/- 1.915E-003	1.043	1.025E-002	-0.0	1.565E-001	0.000E+000	0.000E+000
867.38	1.102E-002	+/- 5.026E-004	0.922	9.722E-003	2.6	1.478E-001	0.000E+000	0.000E+000
919.39	6.957E-003	+/- 1.748E-003	0.938	9.292E-003	-1.3	1.407E-001	0.000E+000	0.000E+000
926.31	6.566E-003	+/- 1.826E-003	0.973	9.238E-003	-1.5	1.398E-001	0.000E+000	0.000E+000
964.11	9.235E-003	+/- 5.851E-004	0.969	8.956E-003	0.5	1.352E-001	0.000E+000	0.000E+000
989.16	(sum peak)							
1005.26	1.053E-002	+/- 1.255E-003	0.924	8.669E-003	1.5	1.305E-001	0.000E+000	0.000E+000
1085.89	6.578E-003	+/- 2.993E-004	1.009	8.163E-003	-5.3	1.222E-001	3.618E-005	5.100E-005
1112.07	1.064E-002	+/- 7.500E-004	0.984	8.012E-003	3.5	1.198E-001	9.730E-005	1.371E-004
1212.93	8.262E-003	+/- 7.344E-004	0.924	7.483E-003	1.1	1.113E-001	8.019E-004	1.127E-003
1233.85	(sum peak)							
1249.95	1.388E-002	+/- 6.171E-003	1.075	7.307E-003	1.1	1.086E-001	1.300E-003	1.824E-003
1299.16	7.764E-003	+/- 4.294E-004	0.941	7.086E-003	1.6	1.051E-001	2.200E-003	3.077E-003
1529.78	(sum peak)							

Results stored for this sample in series database:
Curves must be stored in permanent database using Detector/Store menu option

For Help, press F1 | Sample 2 (Eu-152 at 2cm) | CMPL | INT | RSL

EFFICIENCY CALIBRATION CURVE OF GEM 30195 AT 2cm WITH k_0-IAEA PROGRAM



FULL-ENERGY PEAK EFFICIENCY CALIBRATION

The efficiency calibration was carried out for GEM 30195 at 2cm and 15 cm source-detector geometry with Eu-152 calibration source.

2 cm and 15 cm are the two optimum source-detector distances for the counting with the GEM 30195 detector.

PART B – Energy and Efficiency calibration with Microsoft Excel electronic spreadsheet package

FULL-ENERGY PEAK EFFICIENCY CALCULATION

$$Measured\ Activity = \frac{Peak\ \text{Net Area}}{Live\ \text{Time}} \text{ .... 1}$$

$$Actual\ \text{Activity A} = \text{A}_o e^{-\lambda t} \text{ ....2}$$

$$Decay\ \text{constant}\ \lambda = \frac{\log_e 2}{\text{T}_{\frac{1}{2}}} = \frac{0.693}{\text{T}_{\frac{1}{2}}} \text{............ 3}$$

$$Efficiency = \frac{Experimental\ \text{value of activity measured with detector}}{(Activity\ \text{of calibration source}) \times (\text{Branching ratio of gamma rays})} \text{....4a}$$

$$Efficiency = \frac{Net\ \text{peak area}}{(Live\ \text{Time}) \times (\text{Activity}) \times (\text{Yield})} \text{.........................4b}$$

POST SPECTRAL ACQUISITION DATA ANALYSIS

- The graph of efficiency versus gamma-ray energy was plotted using the Microsoft Excel on a log-log scale.

- Since a non-linear relationship was obtained, a polynomial function of degree 3 was fitted to the experimental data points of the detector’s efficiency curve.

CURVE FITTING TO THE EXPERIMENTAL DATA

- An interpolation of efficiency at any required gamma-ray energy between two tabulated and plotted data points could then be calculated using the equation obtained from the trend line and regression analysis.

- Non-linear least square method was used as a criterion for determining the best fitting curve which is as close as possible to the experimental data.

- The correlation coefficient given by the electronic spreadsheet is a measure of how the two variables relate.

COMBINED CALIBRATION SOURCES USED IN THE EFFICIENCY WITH ELECTRONIC SPREADSHEET

- 3 calibration sources (Am-241, Eu-152 & Ra-226) were combined to cover the low, intermediate, and high energy regions under investigation.

- Combined multiple calibration sources also reduces the energy gaps which may lead to large uncertainties in the efficiency during analysis due to interpolations in the fitted curves.

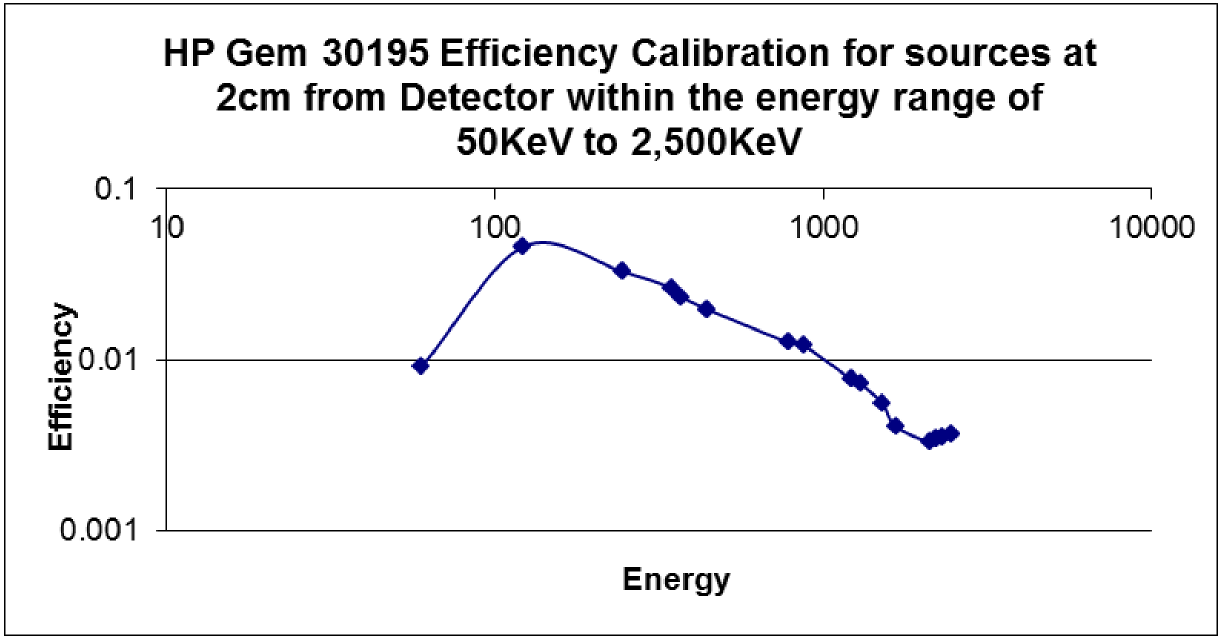
EVALUATION OF THE NET FULL ENERGY PEAK COUNTS FOR EACH PHOTON OF INTEREST

- After accumulating sufficient counts by a MCA for each of the sources, MAESTRO emulation software was used to evaluate the net full energy peak (background subtracted) counts for each photon of interest.
- The activity for each source was normalized to the measurement date before obtaining the full energy peak efficiency through the calculation of the net peak count rate per photon emission rate, using the emission probability table of Erdmann and Soyka, (1979).

EFFICIENCY COMPUTED AND FITTED WITH ELECTRONIC SPREADSHEET FOR GEM 30195 WITH SOURCES AT 2 CM FROM DETECTOR END CAP

Nuclide	Energy (KeV)	Efficiency
Am-241	59.54	0.009084383
Eu-152	121.78	0.045945262
Eu-152	244.7	0.032750254
Eu-152	344.28	0.026325629
Eu-152	367.76	0.023403456
Eu-152	444	0.019739155
Eu-152	778.9	0.012700505
Eu-152	867.38	0.012206212
Eu-152	1212.94	0.00773334
Eu-152	1298.7	0.007228203
Ra-226	1509.19	0.005574393
Ra-226	1661.28	0.004065313
Ra-226	2118.54	0.003298883
Ra-226	2204.12	0.003446851
Ra-226	2293.36	0.003573887
Ra-226	2447.71	0.003721455

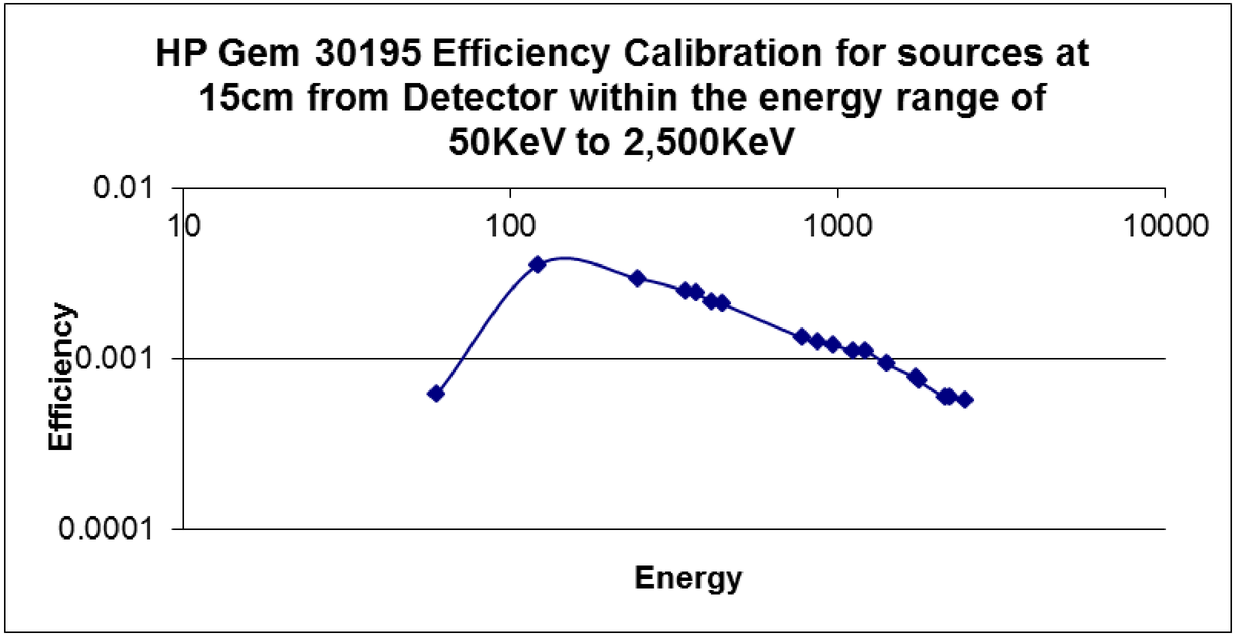
EFFICIENCY COMPUTED AND FITTED WITH ELECTRONIC SPREADSHEET FOR GEM 30195 WITH SOURCES AT 2 CM FROM DETECTOR END CAP



EFFICIENCY COMPUTED AND FITTED WITH ELECTRONIC SPREADSHEET FOR GEM 30195 WITH SOURCES AT 15 CM FROM DETECTOR END CAP

Nuclide	Energy (KeV)	Efficiency
Am-241	59.54	0.000613337
Eu-152	121.78	0.003553117
Eu-152	244.7	0.00295213
Eu-152	344.28	0.002491134
Eu-152	367.76	0.002412776
Eu-152	411.3	0.00216846
Eu-152	444	0.002089715
Eu-152	778.9	0.00132318
Eu-152	867.38	0.001252362
Eu-152	964	0.001204472
Eu-152	1112	0.001111782
Eu-152	1212.94	0.001109479
Eu-152	1408.03	0.000931153
Ra-226	1729.6	0.000770708
Ra-226	1764.51	0.000740934
Ra-226	2118.54	0.000589674
Ra-226	2204.12	0.000595507
Ra-226	2447.71	0.000574499

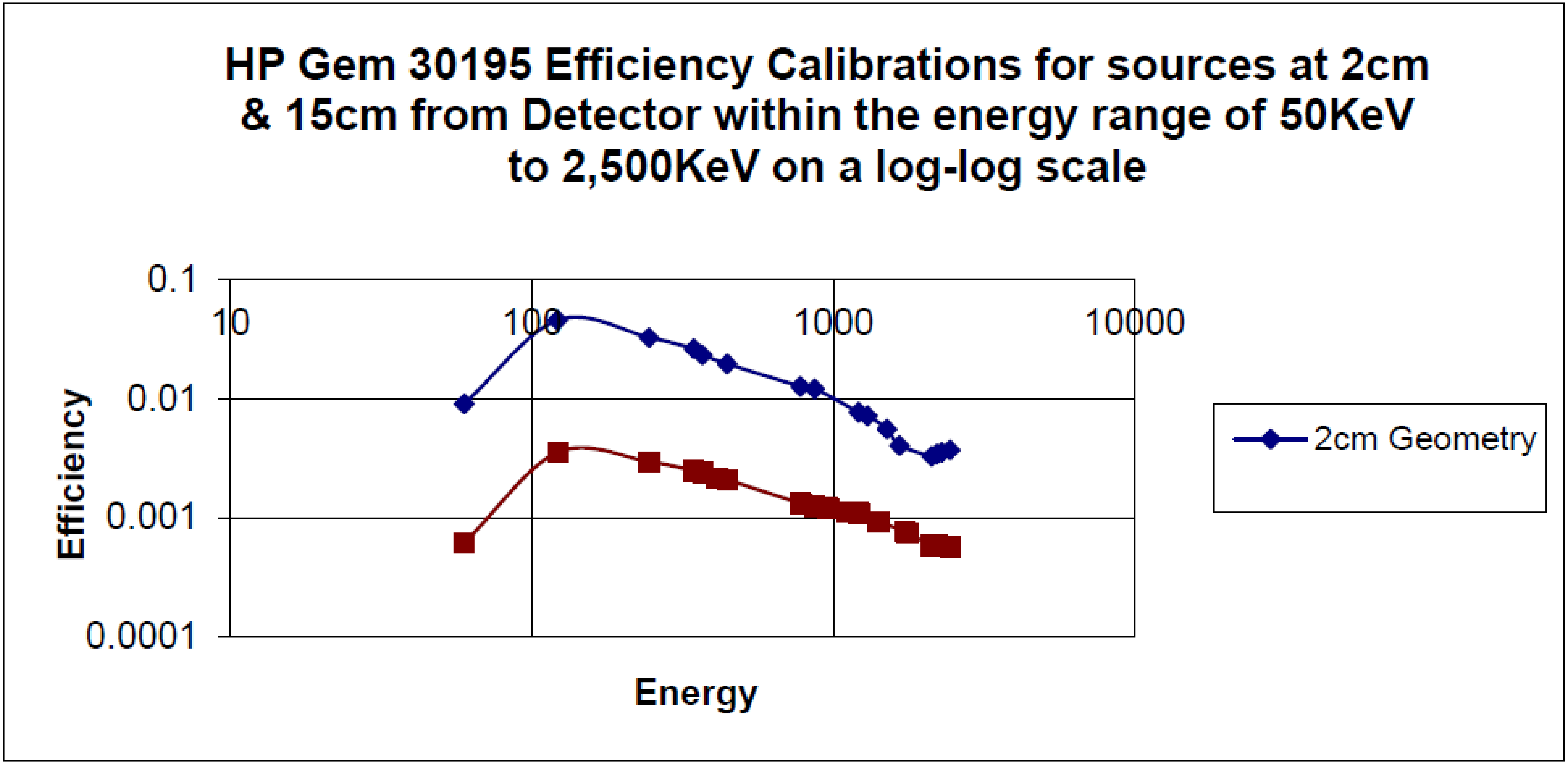
EFFICIENCY COMPUTED AND FITTED WITH ELECTRONIC SPREADSHEET FOR GEM 30195 WITH SOURCES AT 15 CM FROM DETECTOR END CAP



IMPORTING AND STORING OF THE CALCULATED EFFICIENCY IN THE DATABASE OF SPECTRAL ANALYSIS SOFTWARE

Because of the large data set and measurements involved in NAA implementation, there was the need to import the efficiency data generated using this novel, alternative approach into a proper spectral analysis software and stored in its database for future use during routine analysis of samples.

EFFICIENCY COMPUTED AND FITTED WITH ELECTRONIC SPREADSHEET FOR GEM 30195

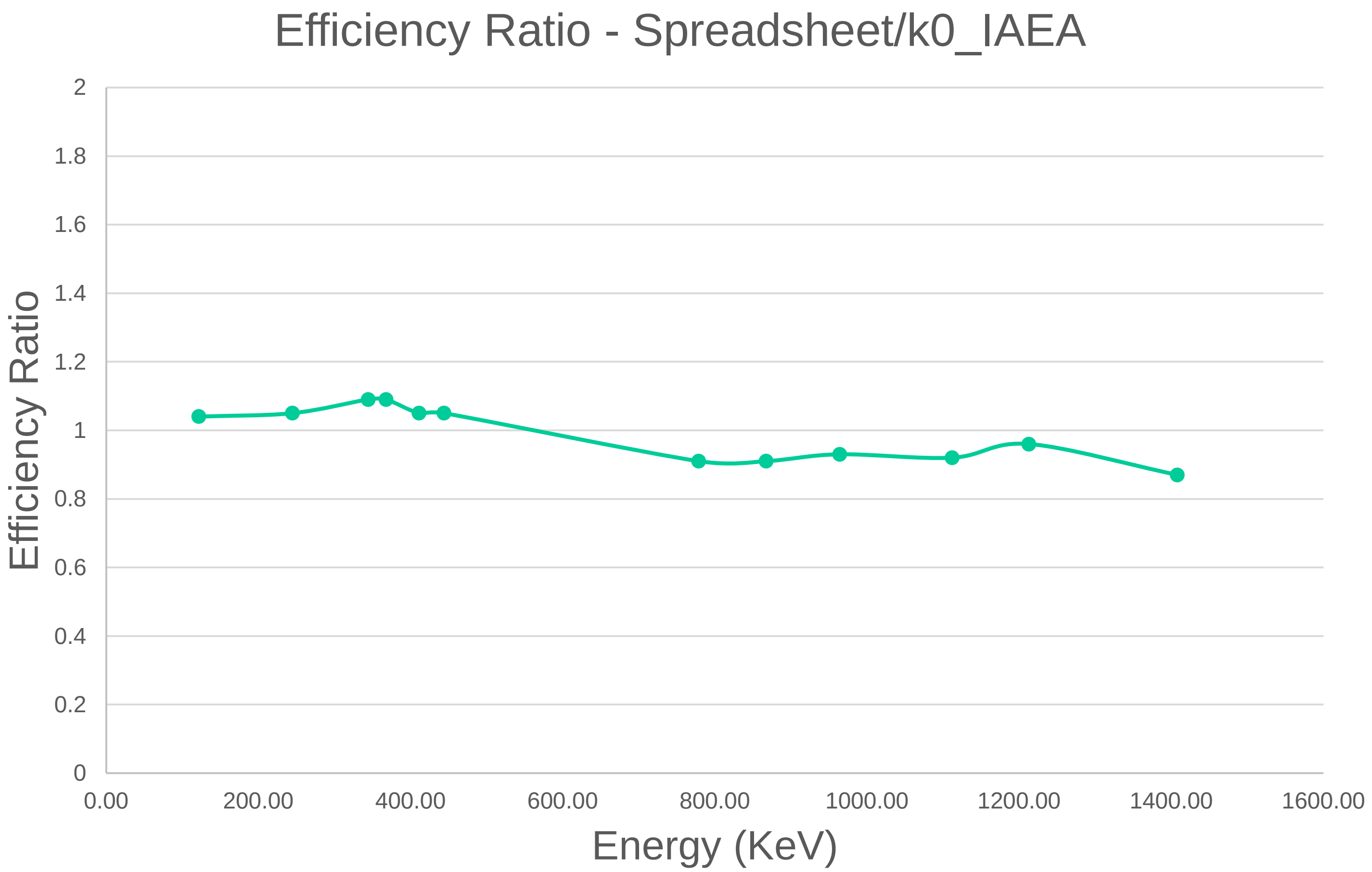


RESULTS & DISCUSSION

COMPARISON OF THE FULL-ENERGY PEAK EFFICIENCY CALIBRATION RESULTS OBTAINED FROM SPREADSHEET AND K_0_IAEA SOFTWARE FOR 15 CM SOURCE-DETECTOR DISTANCE

Energy (KeV)	Efficiency		Ratio Spreadsheet/k_0_IAEA
	Spreadsheet	k_0_IAEA	
121.78	3.553E-03	3.415E-03	1.04
244.7	2.952E-03	2.818E-03	1.05
344.28	2.491E-03	2.294E-03	1.09
367.76	2.413E-03	2.207E-03	1.09
411.3	2.168E-03	2.071E-03	1.05
444	2.090E-03	1.983E-03	1.05
778.9	1.323E-03	1.457E-03	0.91
867.38	1.252E-03	1.376E-03	0.91
964	1.204E-03	1.302E-03	0.93
1112	1.112E-03	1.208E-03	0.92
1212.94	1.109E-03	1.155E-03	0.96
1408.03	9.312E-04	1.069E-03	0.87

COMPARISON OF THE FULL-ENERGY PEAK EFFICIENCY CALIBRATION RESULTS OBTAINED FROM SPREADSHEET AND K_0_IAEA SOFTWARE FOR THE 15 CM SOURCE-DETECTOR DISTANCE



COMPARISON OF THE ANALYTICAL RESULTS USING WINSPAN 2004 AND K_0_IAEA 5.00 PROGRAM WITH CERTIFIED VALUES FOR LAKE SEDIMENT IAEA-SL-3

ELEMENT	k_0_IAEA Program	C.V. (Range)	WINSPAN-2004
	IAEA-SL-3 Lake Sediment [mg/kg]		
Al	24500 ± 953	23300 – 25700	24530 ± 491
As	3.03 ± 0.41	3.0 – 3.4	2.5 ± 0.2
Ba	256 ± 64	-----	231 ± 28
Br	5.27 ± 0.43	4.8 – 6.4	5.2 ± 1.3
Ca	116700 ± 13887	107200 – 115000	127000 ± 4699
Ce	-----	43.8 – 47.2	-----
Co	4.21 ± 0.40	-----	3.4 ± 0.4
Cr	-----	-----	29 ± 3
Cs	BDL	1.24 – 1.52	1.4 ± 0.3
Dy	1.66 ± 0.47	1.65 – 2.79	2.9 ± 0.5
Eu	BDL	0.64 – 0.68	1.1 ± 0.1
Fe	14660 ± 733	-----	11480 ± 230
Hf	8.80 ± 0.58	8.5 – 9.7	8.8 ± 0.3
K	9031 ± 1117	7910 – 9570	8975 ± 323
La	20.0 ± 1.0	21.5 – 23.5	16.6 ± 0.8
Lu	-----	0.27 – 0.33	0.30 ± 0.03
Mg	24910 ± 5206	24600 – 29400	20440 ± 1553
Mn	539 ± 28	-----	435 ± 2
Na	6550 ± 263	6360 – 7020	648 ± 1
Rb	-----	36.9 – 40.7	37.2 ± 4.2
Sb	0.72 ± 0.09	0.46 – 0.66	7.2 ± 0.4
Sc	3.92 ± 0.31	3.64 – 4.18	3.87 ± 0.05
Sm	3.58 ± 0.50	3.53 – 4.13	2.97 ± 0.003
Ta	0.71 ± 0.23	0.65 – 0.75	0.6 ± 0.1
Tb	0.51 ± 0.15	0.44 – 0.54	-----
Th	7.94 ± 0.65	6.5 – 7.5	6.9 ± 0.2
Ti	2731 ± 489	2300 – 2920	2117 ± 385
U	1.41 ± 0.40	2.08 – 2.52	1.4 ± 0.2
V	21.4 ± 4.5	-----	25 ± 4
Yb	1.84 ± 0.49	1.77 – 2.01	1.8 ± 0.2
Zn	-----	-----	BDL

BDL = Below Detection Limit

----- = Not Analysed

ADVANTAGE OF THE ALTERNATIVE APPROACH

- This alternative approach to the efficiency data generation in Neutron Activation Analysis has advantage of increasing the range of the calibration from e.g. **from 1408 KeV to 2447.71 KeV**, hence broadening the range of elements that could be analysed with the spectrometer at the laboratory.

- In terms of performance, this methodology has performed fairly well in comparison to the conventional proprietary software counterpart.

THE DOWNSIDE OF THE ALTERNATIVE APPROACH

- The calculations of the efficiency and the fitting of the curve has to be done semi-manually in electronic spreadsheet approach. Whereas these procedures are automated in dedicated proprietary spectrum analysis software.

- The large data set and complexities of the calculation involved in the implementation of the k_0-INAA necessitated the computerization of the procedures making use of electronic spreadsheet very tedious and time-consuming.

- Spectrum analysis software such as k_0-IAEA program has modules for storage of background spectrum, shape calibration, energy calibration and efficiency calibration after acquiring and analyzing the spectrum of the relevant calibration point sources.

THE DOWNSIDE OF THE ALTERNATIVE APPROACH 2

- The peak-to-total ratio has not been taken into account in this efficiency curve fitting via the electronic spreadsheet approach.

- The peak-to-total ratio which is required for true coincidence effect correction is especially important when the source-detector distance becomes small such as the 2cm geometry in this case.

RESEARCH FINDINGS

- On the whole, the two methods and corresponding software are at par in terms of accuracy and effectiveness. However, k_0-INAA holds out great prospects with exciting possibilities given its several advantages over relative method which have been earlier enumerated.

RECOMMENDATIONS

- For the k0_IAEA software, the following improvements are suggested:
- Enhancement of the code to make it capable of resolving multiplet or overlapping peaks into individual components for accurate net peak area determination without the user intervention. Hence reducing the manual selection of the region of interest (ROI) for some photopeaks before peak area analysis. Taking into consideration the fact that even high resolution detectors and MCA do sometimes select a gate for energy range which includes more than one gamma line.
- Integration of the two key aspects of a spectroscopy application, which is data acquisition and spectra analysis, into a unified platform by using the same software for both the acquisition and analysis of spectra used for the implementation of the k0-INAA.
- Integration of the installation files into a single one-step setup file, rather than the present four.
- Backward compatibility of the software so that users will not have to manually backup the permanent data and restore it each time after installing a newer version or an update.

CONCLUSION

Two approaches (k_0_IAEA software and electronic spreadsheet) for calculating the full-energy peak efficiency for the high purity germanium detector GEM 30195 have been compared.

On the whole, the performance of the two approaches in terms of accuracy and effectiveness are close at higher geometries with less than 10% variation.

However, the proprietary software has several routines in its suite for automating most of the calibration procedures which makes it more suitable for spectral analysis than the electronic spreadsheet.

FURTHER WORK???

Major challenge is lack of access to research facility. As of now, Kaduna is the epicenter of the kidnapping in Nigeria.

I therefore solicit

- Collaborations
- Access to research facilities of fellow participants
- Donation of old, but abandoned detectors etc. Especially portable ones for in-situ measurements o the field.

ACKNOWLEDGEMENT

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FOR YOUR ATTENTION!