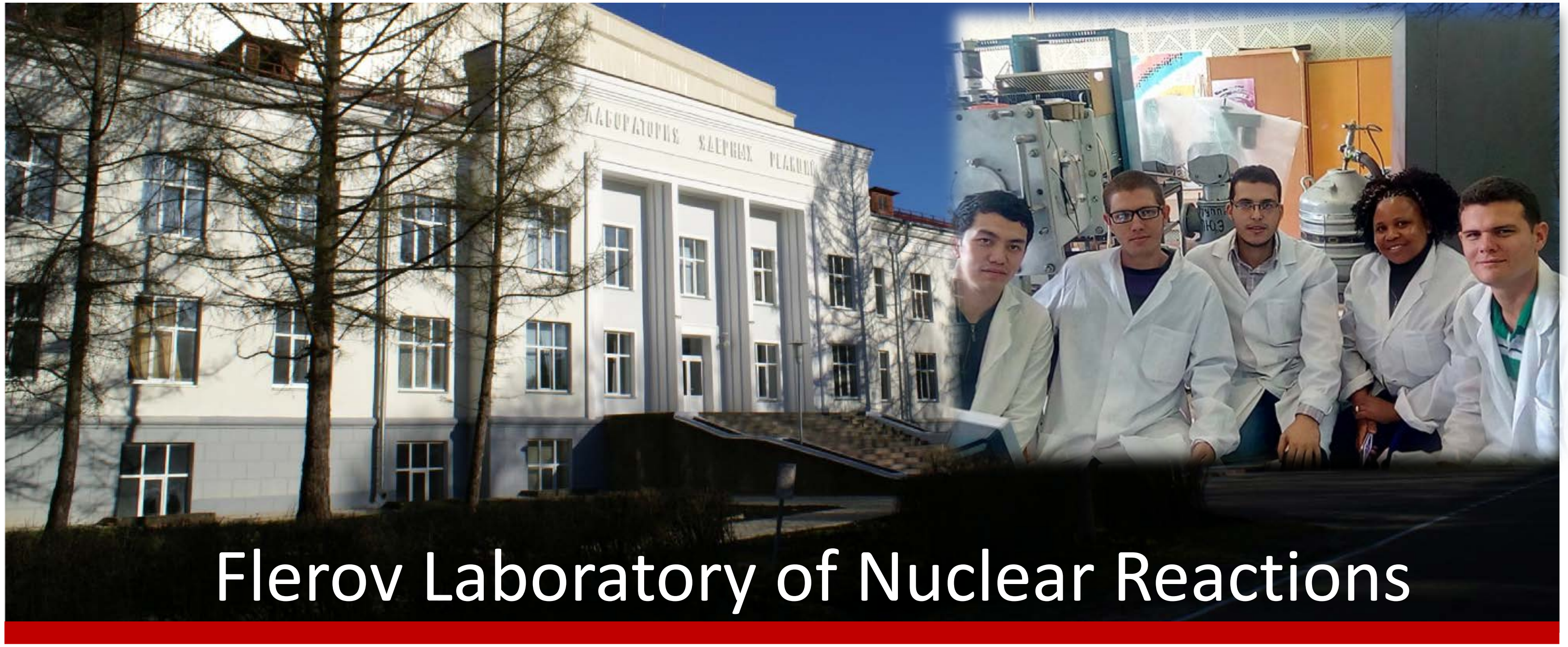
STAGE 3 INTERNATIONAL STUDENT PRACTICE 2017



Joint Institute for
Nuclear Research in Dubna

Joint Institute for Nuclear Research

Flerov Laboratory of Nuclear Reactions

University Center

PROJECT TITLE

- HpGe – detector for energy measurements of gamma-activity
- Study of the operation principles of X-ray detectors
- Moseley’s Law in Action
- Alpha Spectroscopy

SPEAKERS

Aurelia Genu – RSA
Igor Moroz – Belarus
Madian Pino Peraza – Cuba
Luis Enrique Llanes Montesino - Cuba

SUPERVISORS

S. Lukyanov
K. Mendibaev

Introduction

3 Types of semiconductor detectors

1. X-ray HpGe detector

2. HpGe Gamma detector

3. Alpha Si spectroscopy detector

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History of Moseley's Law

Henry G.J. Moseley's
1887 - 1915

- In his early 20's, he measured and plotted x-ray frequencies for about 40 elements of the periodic table and was described by Rutherford as his most talented student.

- Based on his experiments, this is known as Moseley's law

$$E = a\,(Z - b)^2$$

where *a* and *b* are constants depending upon the particular spectral line, E is the energy of characteristic x-ray and Z atomic number.

- Moseley volunteered for combat duty during World War I and was killed in action at the age of 27 during the attack on the Gallipoli in the Dardenelles.

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Moseley Plot of characteristic X-rays

- His data Moseley plot is still standard feature of physics textbooks (Figure 1).
- Photographic recording of Kα and Kβ x-ray emission lines for a range of elements (Figure 2).

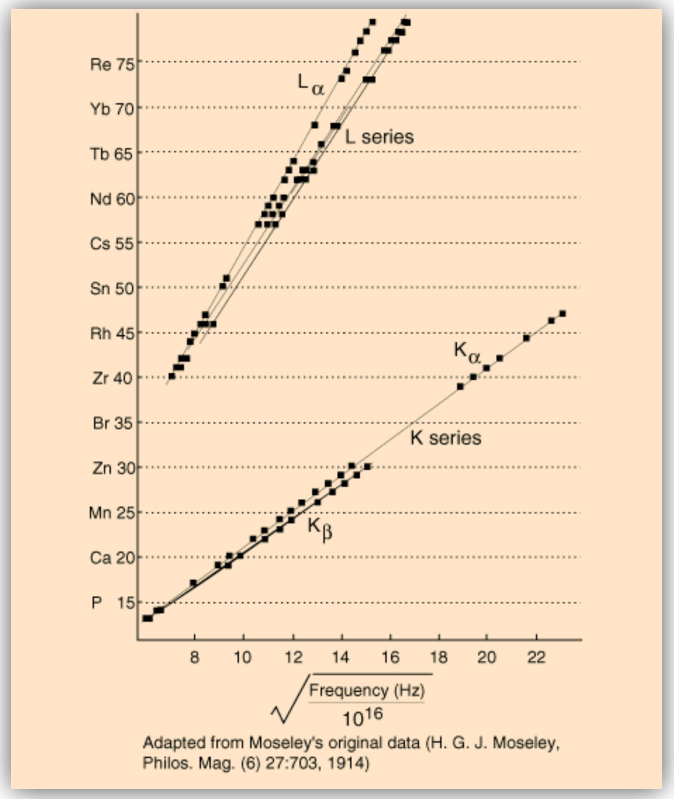


Fig. 1 Moseley plot of characteristic X-rays

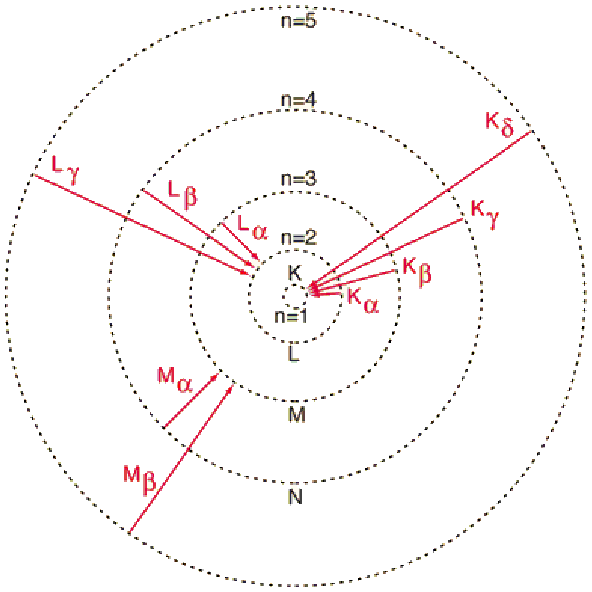


Fig. 3 X-ray transitions

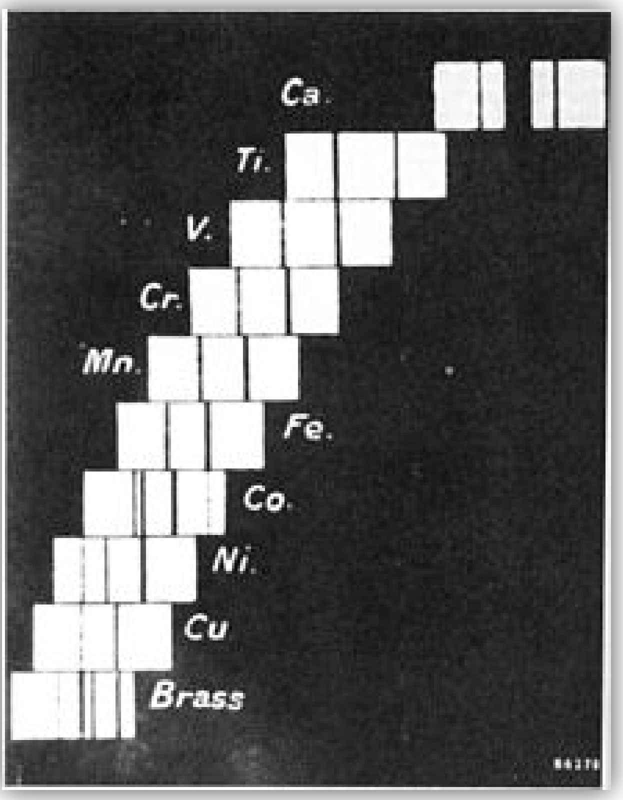


Fig. 2 Moseley step ladder of elements

Applications of Moseley’s Law

- Any discrepancy in the order of the elements in the periodic table can be removed by Moseley's law by arranging the elements according to the atomic numbers and not according to the atomic weights.

- Moseley's law has led to the discovery of new elements like hafnium (72), technetium (43), rhenium (75) etc.

- This law has been helpful in determining the atomic number of rare earths, thereby fixing their position in the periodic table.

Moseley Law in action

Element Z (Atomic No.)	Energy (keV) K(α)	Energy (keV) K(β)
$_{38}$Sr	14.1	15.8
$_{47}$Ag	22.0	24.9
$_{49}$In	24.2	27.2
$_{57}$La	33.4	37.8
$_{62}$Sm	40.1	45.4

Table 1: Energies of K (α) and K (β) transitions in keV and elements listed with increasing atomic number obtained from nuclear data.

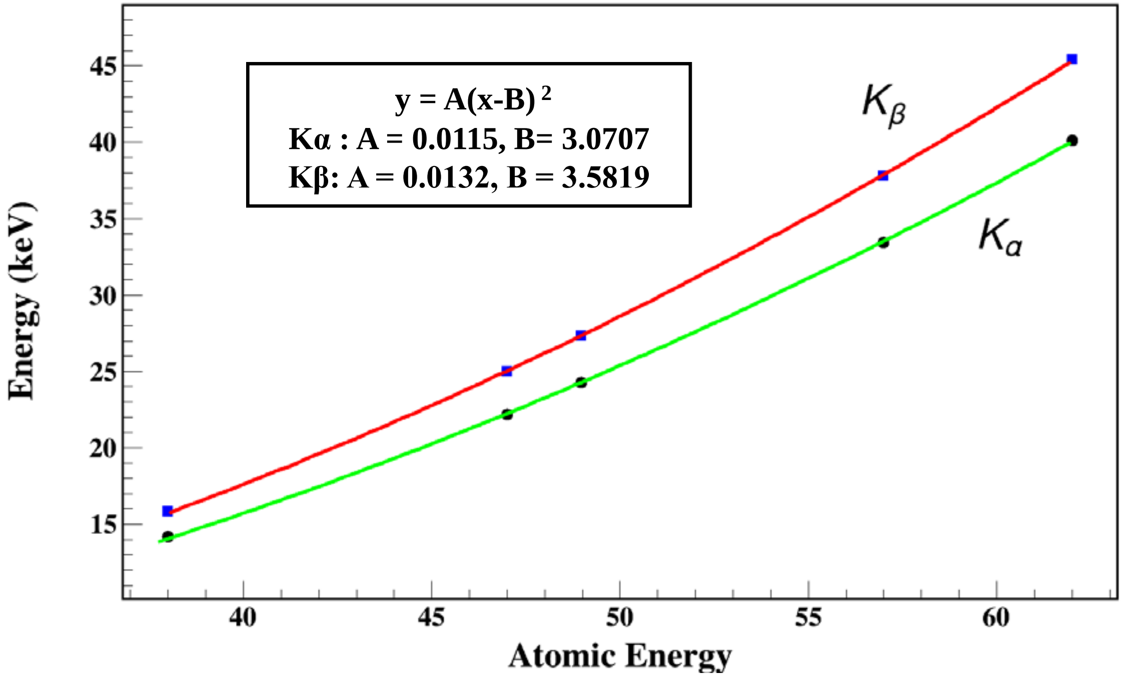
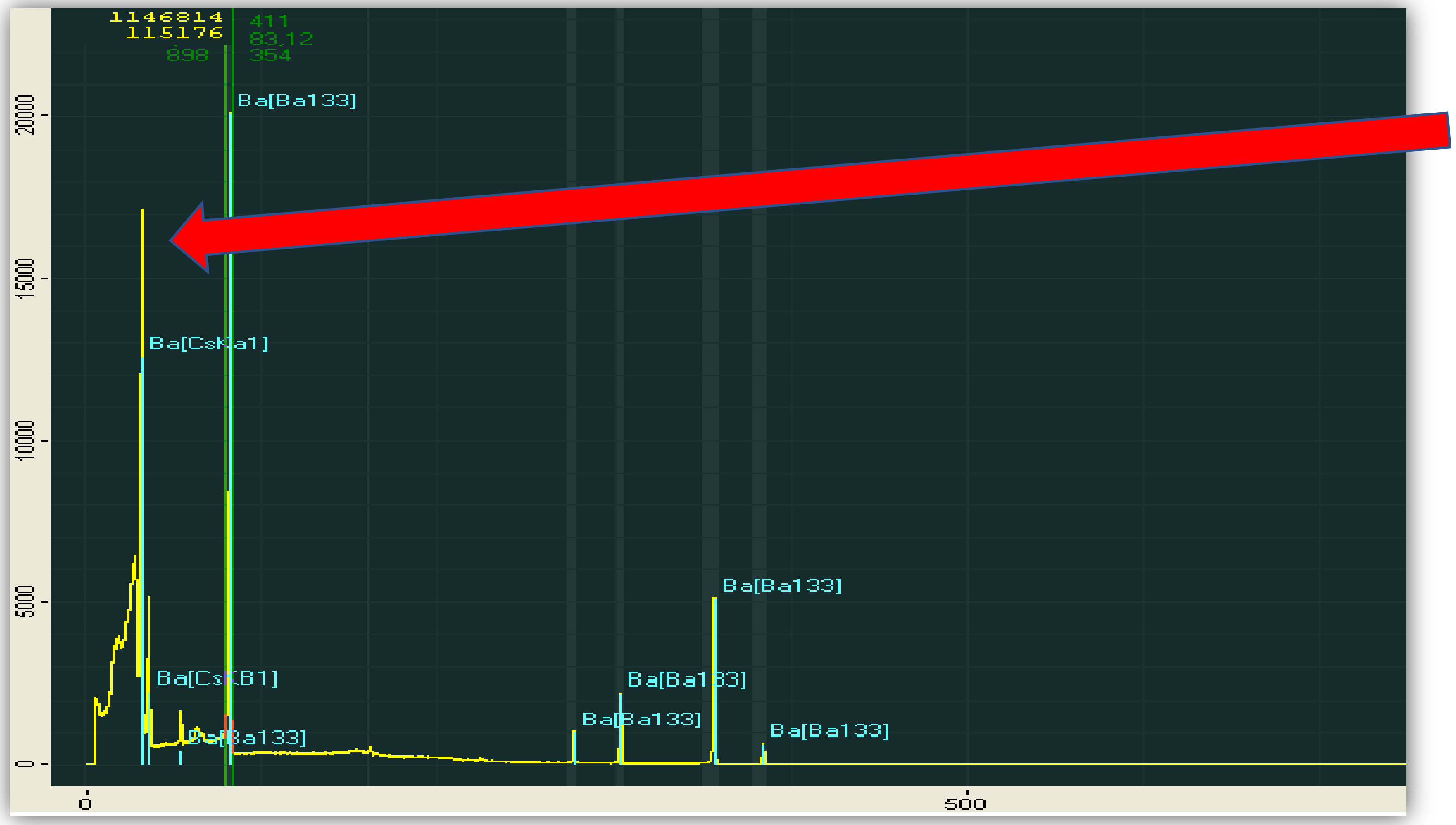


Figure 4: K (α) and K (β) lines fit to Moseley's Law. We confirm the functional form of the law but different values for the constants (a & b).

Spectrum from X-ray detector



Calculation and results.

E = 30.97 keV
A & B = constants obtained from Kα Moseley's plot.

$$E = a\,(Z - b)^2$$

$$Z = \sqrt{\frac{E}{a}} + b$$

$$= \sqrt{\frac{30.97}{0.0115}} + 3.0706$$

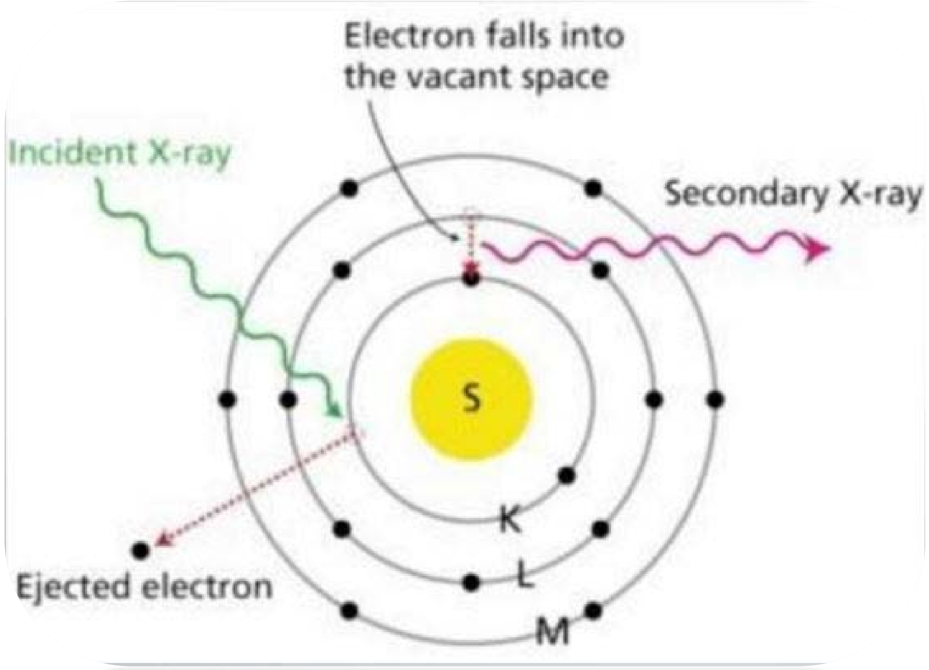
$$= 54.9$$

Nuclear data: Z = 55
Element is Cs

X-rays

X-rays are emitted when outer-shell electrons fill a vacancy in the inner shell of an atom, releasing X-rays in a pattern that is "characteristic" to each element.

Detectors are manufactured with thin face and side contacts. The area of the rear contact is less than the total area, so the capacitance of such a detector is small. And this means that the resolution will be high at low and medium energies than detectors of other geometries.



General view of the X-ray spectrometer

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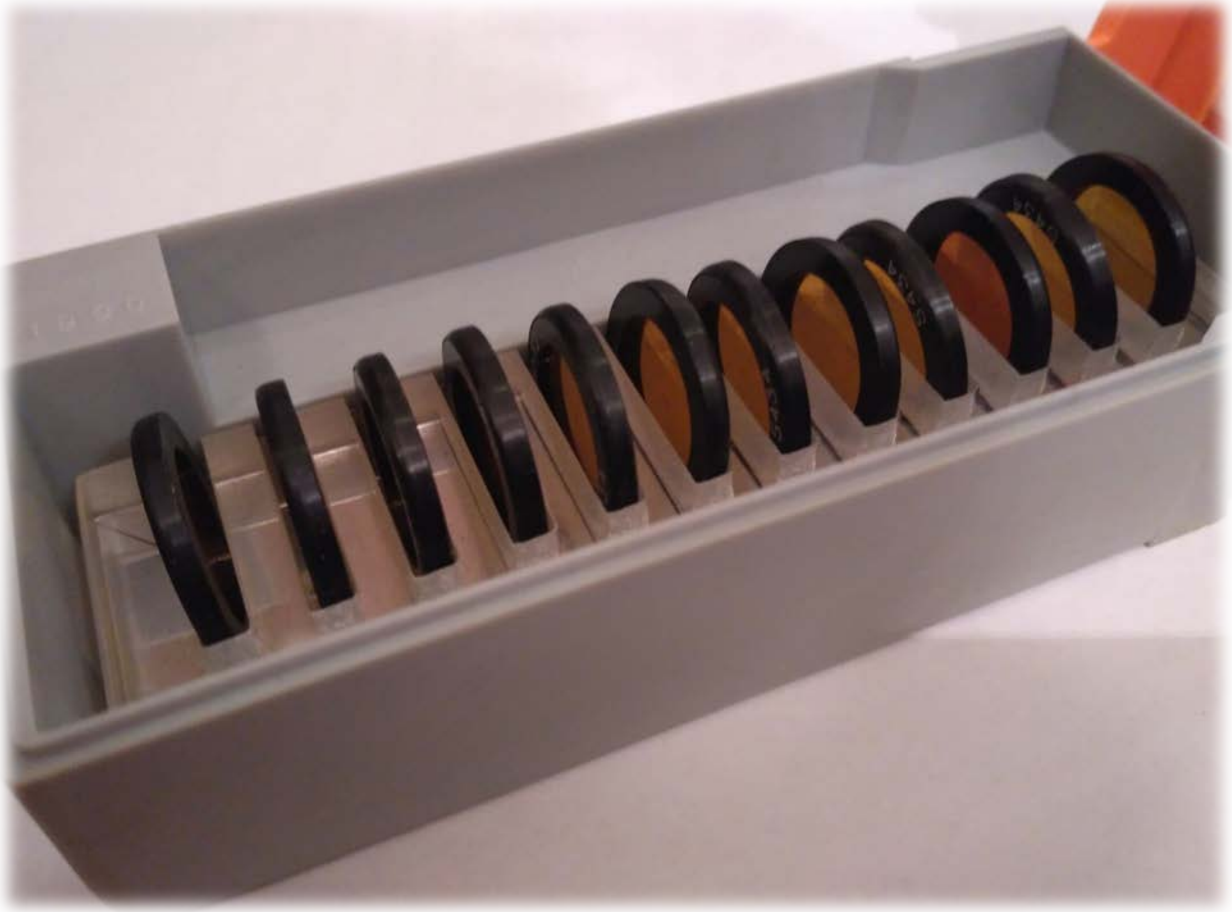
Preparation for measurement

1. Cool the detector, fill the vessel with liquid nitrogen.
2. Place a calibration source in the detector.
3. Calibrate the energy X-ray spectrometer.

Source



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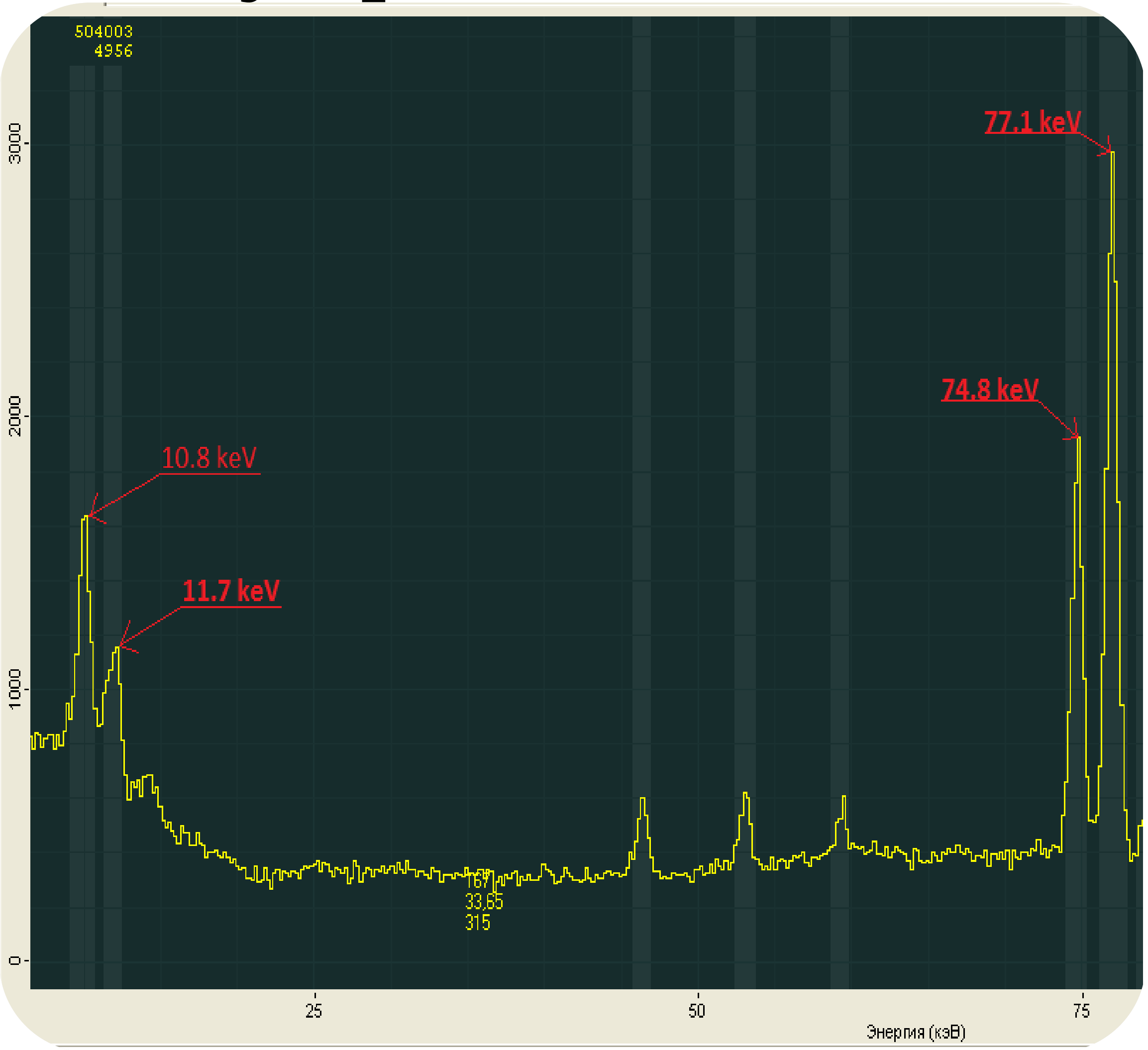
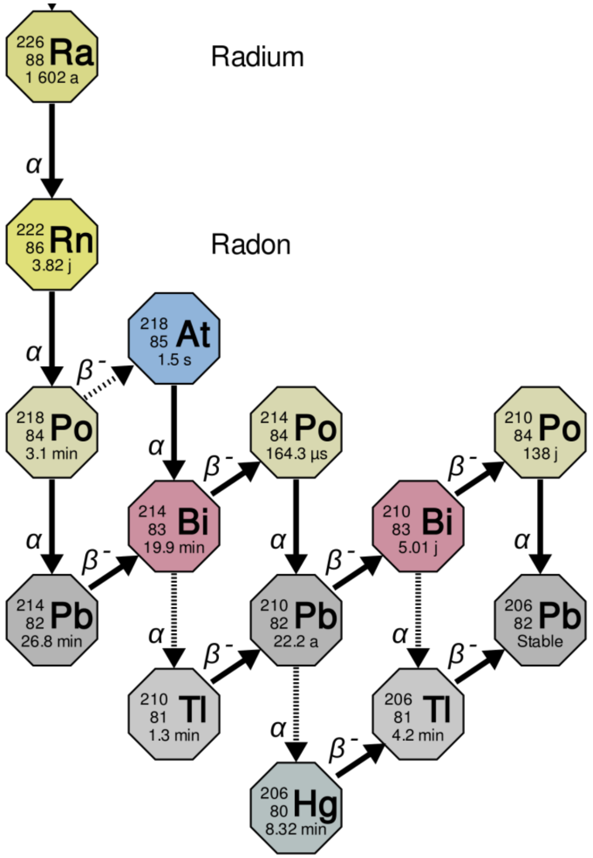
X-ray specter Ra-226





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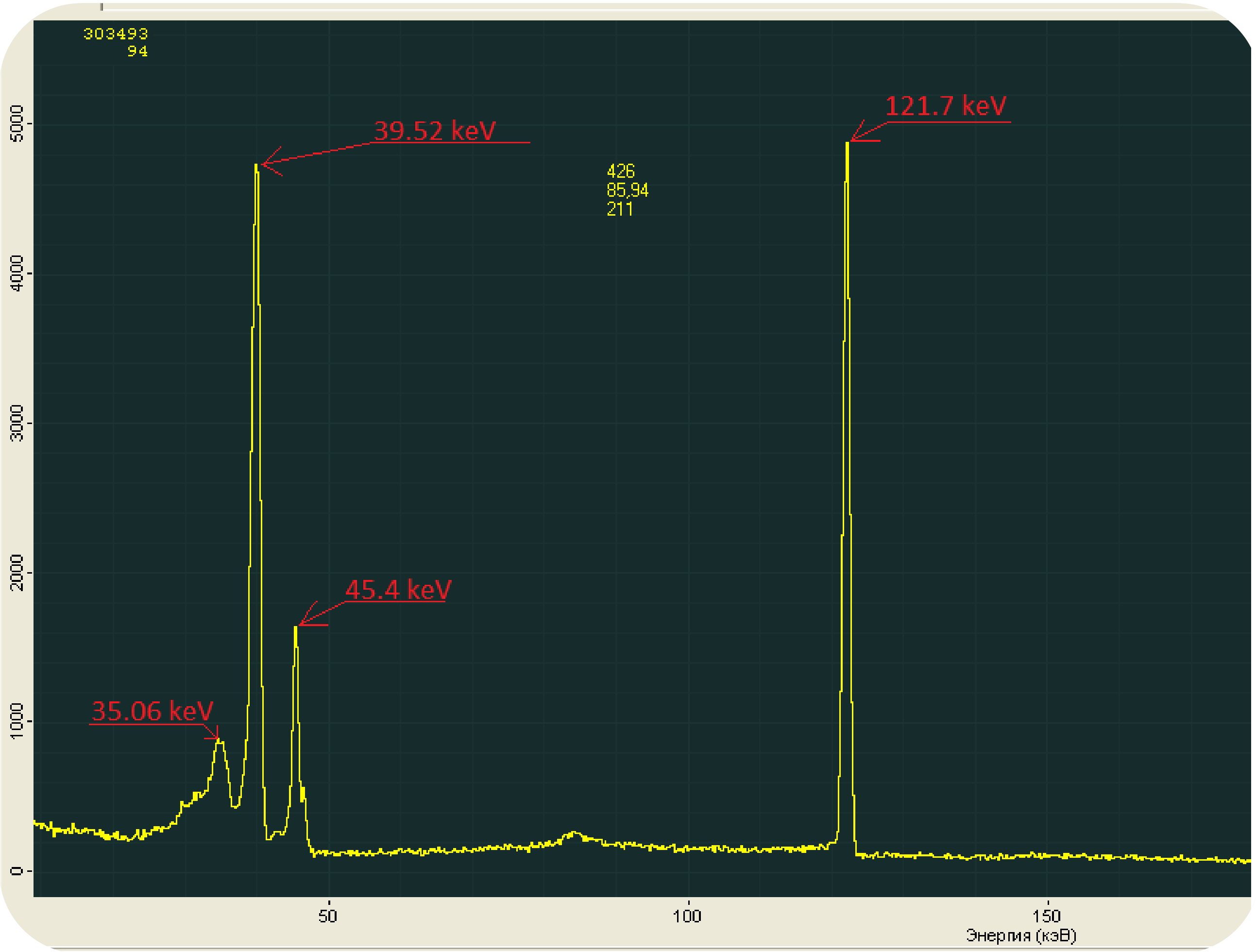
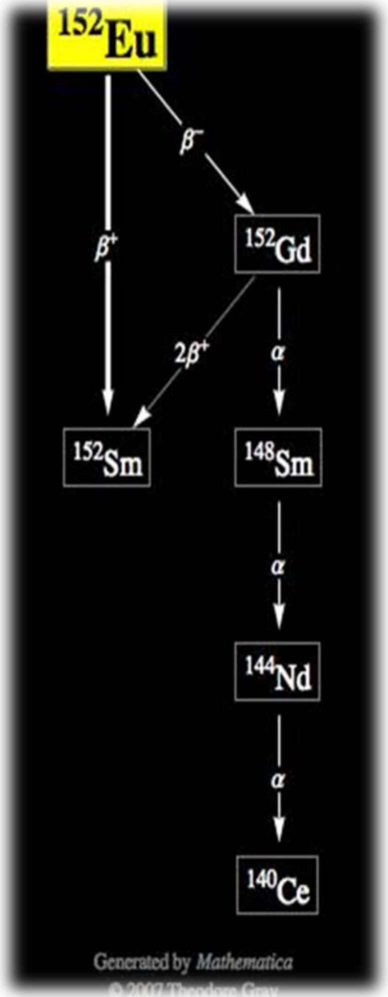
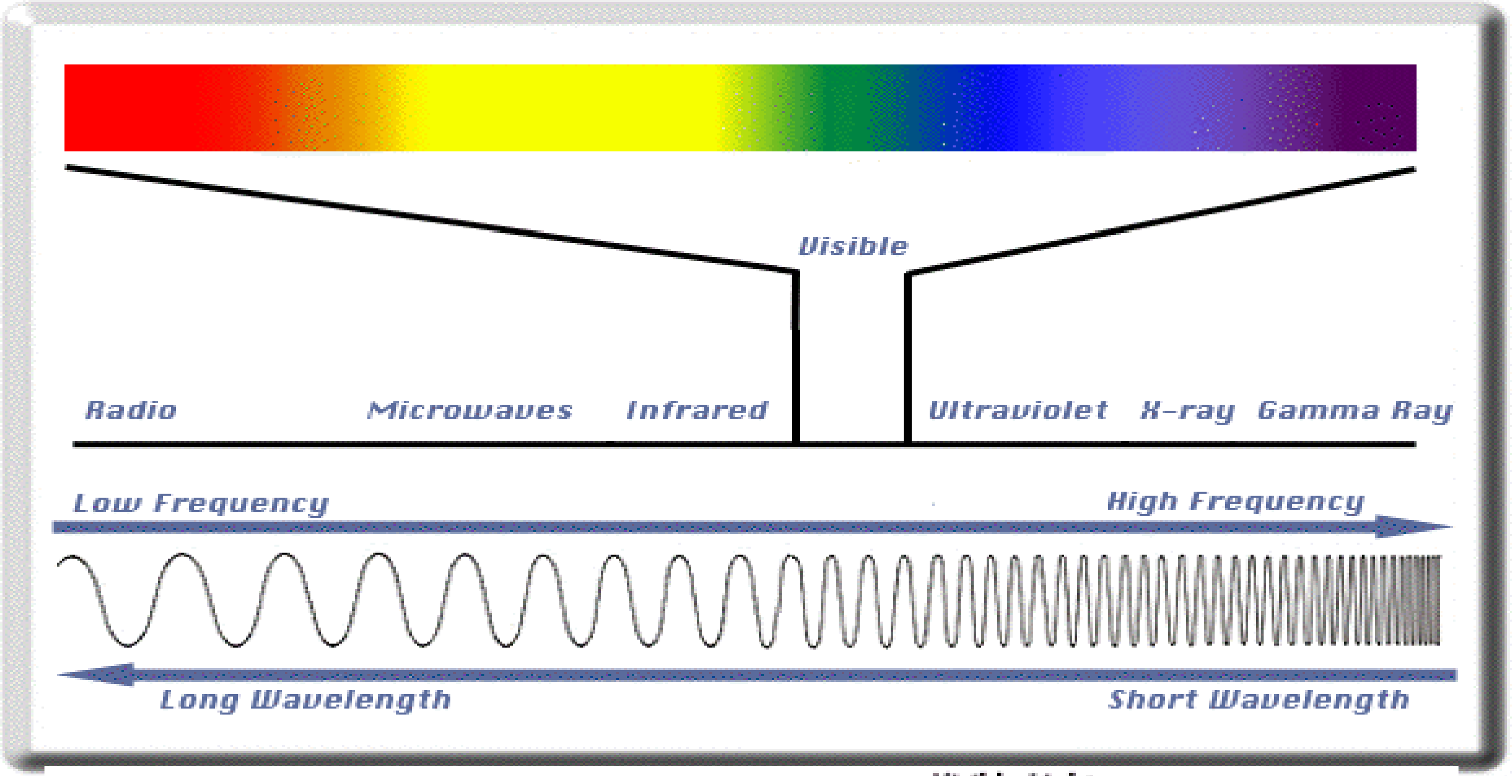
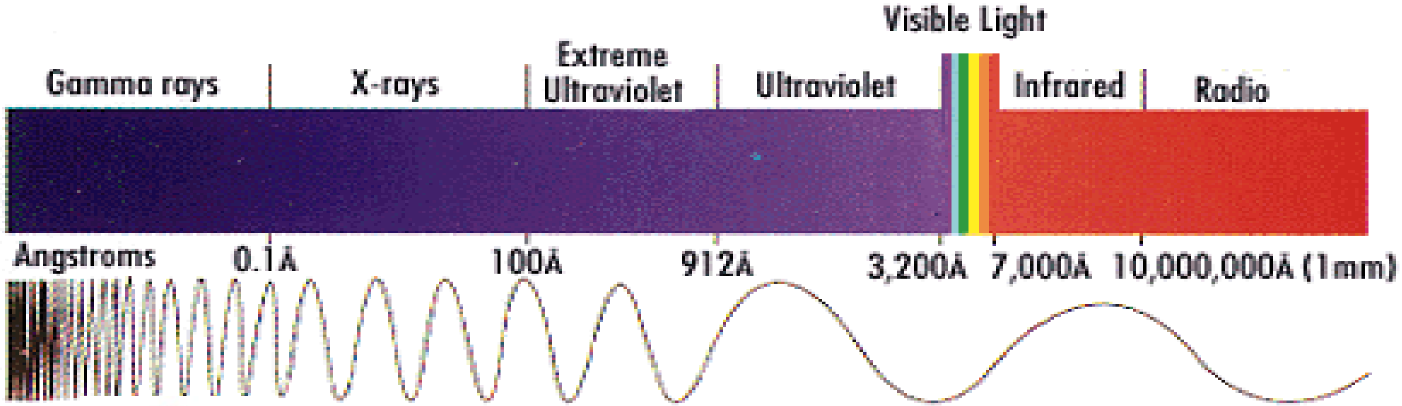
X-ray specter Eu-152









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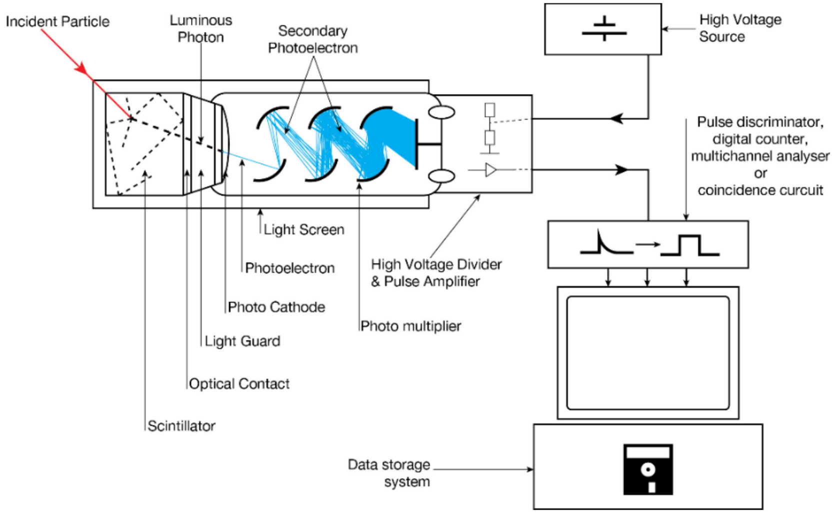
Main detectors used for gamma

➢**Scintillators detectors**

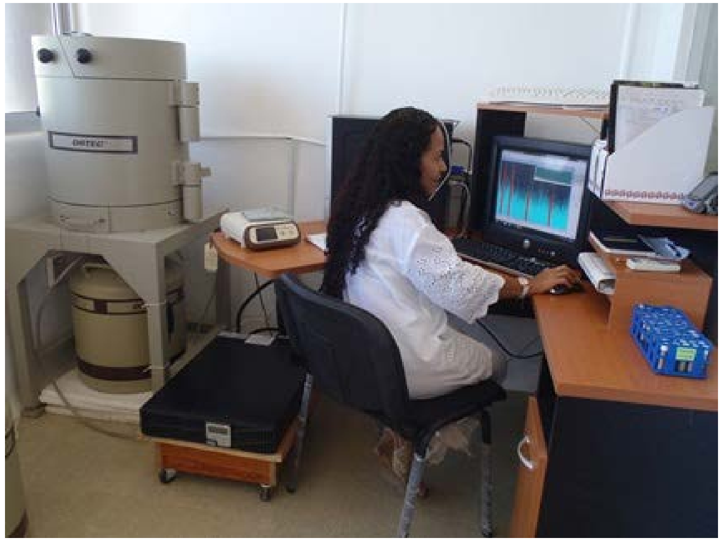
Organic (plastic, organic cristal, liquids)

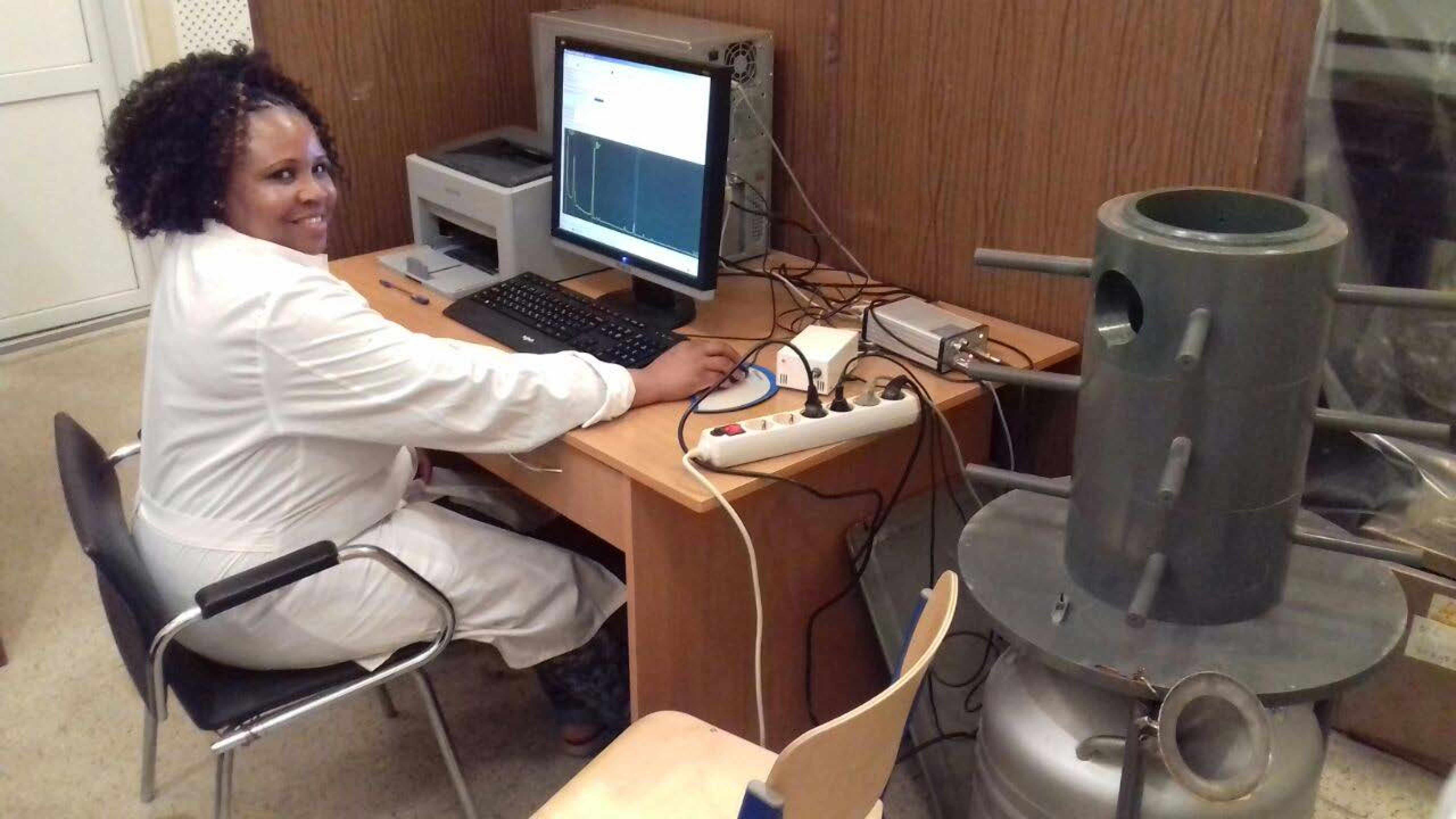
Inorganic (NaI(Tl), CsI(Tl), BaF2, BGO, etc)



➢**Solid State detectors**

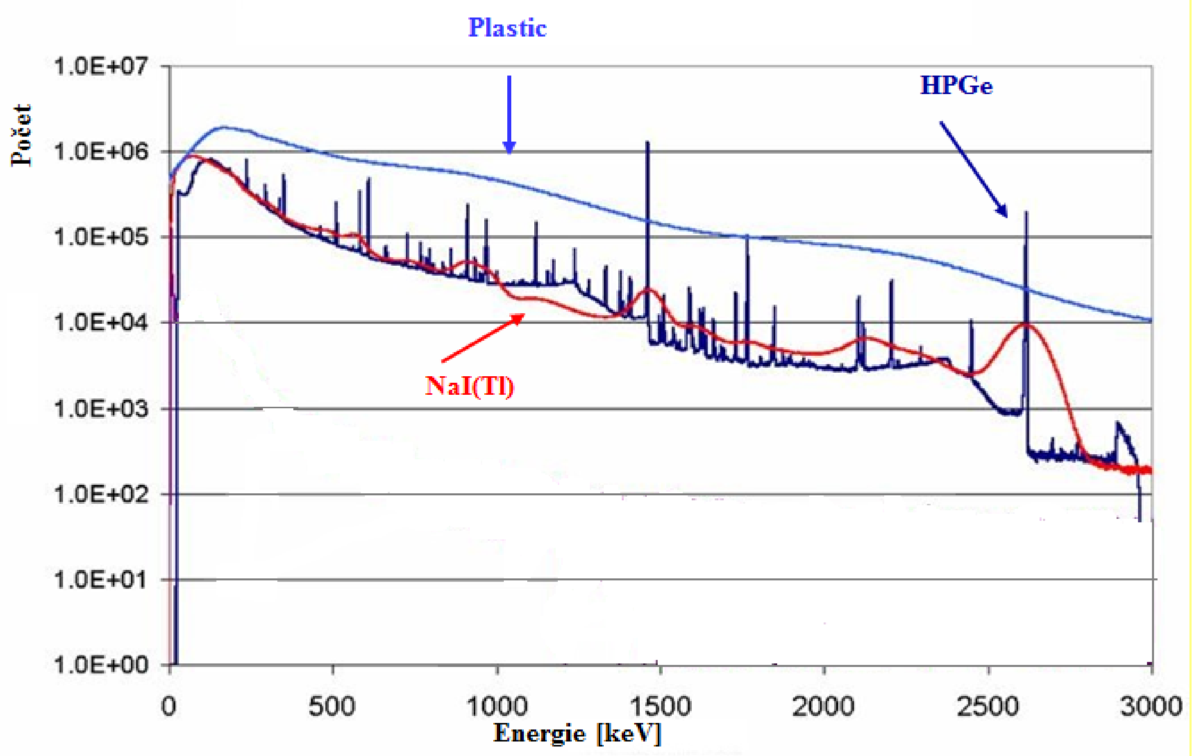
HPGe detector, Si





Comparison of detectors

	Pure Ge-detector	Plastic Scintillator
	Price	Chipper
Size	Restricted a few cm^3	No size limitation
Neutron-gamma separation	No need	Need
Efficiency	Less 10 %	Large due to Z and size
Resolution	1 keV	Worst resolution



Resolution comparison

Use of Nuclear Data Search

The Lund/LBNL Nuclear Data Search

Version 2.0, February 1999

S.Y.F. Chu[1], L.P. Ekström[1,2] and R.B. Firestone[1]

[1] *LBNL, Berkeley, USA*
[2] *Department of Physics, Lund University, Sweden*

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WWW Table of Radioactive Isotopes

- Radiation search
- Nuclide search
- Atomic data (X-rays and Auger electrons, very preliminary!)
- Periodic chart interface to the nuclides
- Summary drawings for A=1-277 (PDF)
- Nuclear charts (PDF, 333 kbyte)
- Database status

ToI

***Table of Isotopes* (ToI)**

- About this service
- ToI home page

The data are properly referenced as given in the database status panel. *Please give your **feedback** on the usefulness of and suggestions on how to improve the ToI service.*

Help and instructions are given with a "pop-up help" system:

ToRI

WWW Table of Radioactive Isotopes

Radiation search

Energy: ± 1 **keV** Search

Type: Alpha Gamma

Parent:

T1/2: s - s

Mass number: 152 - 152

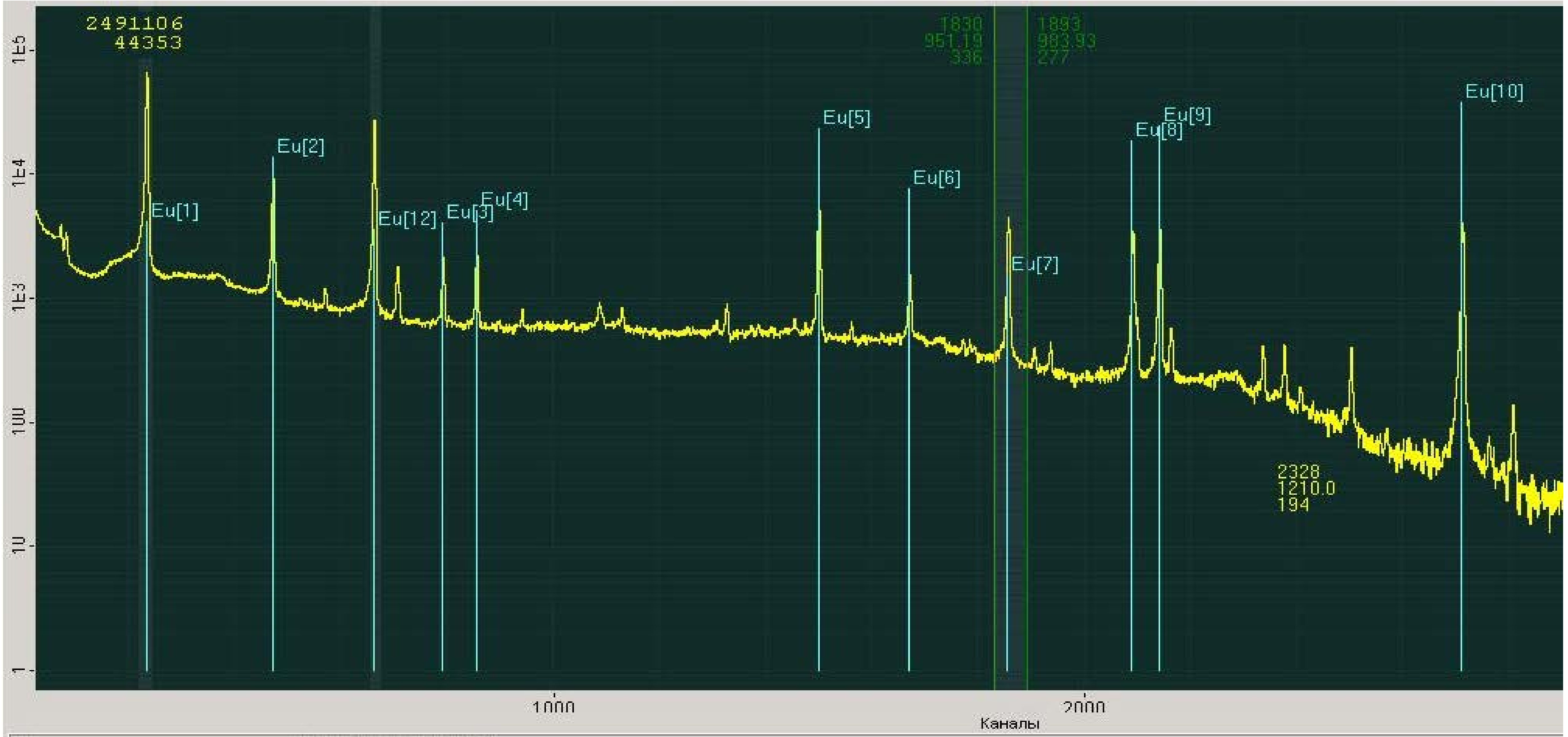
Z: 63 **or Element:** Eu

N:

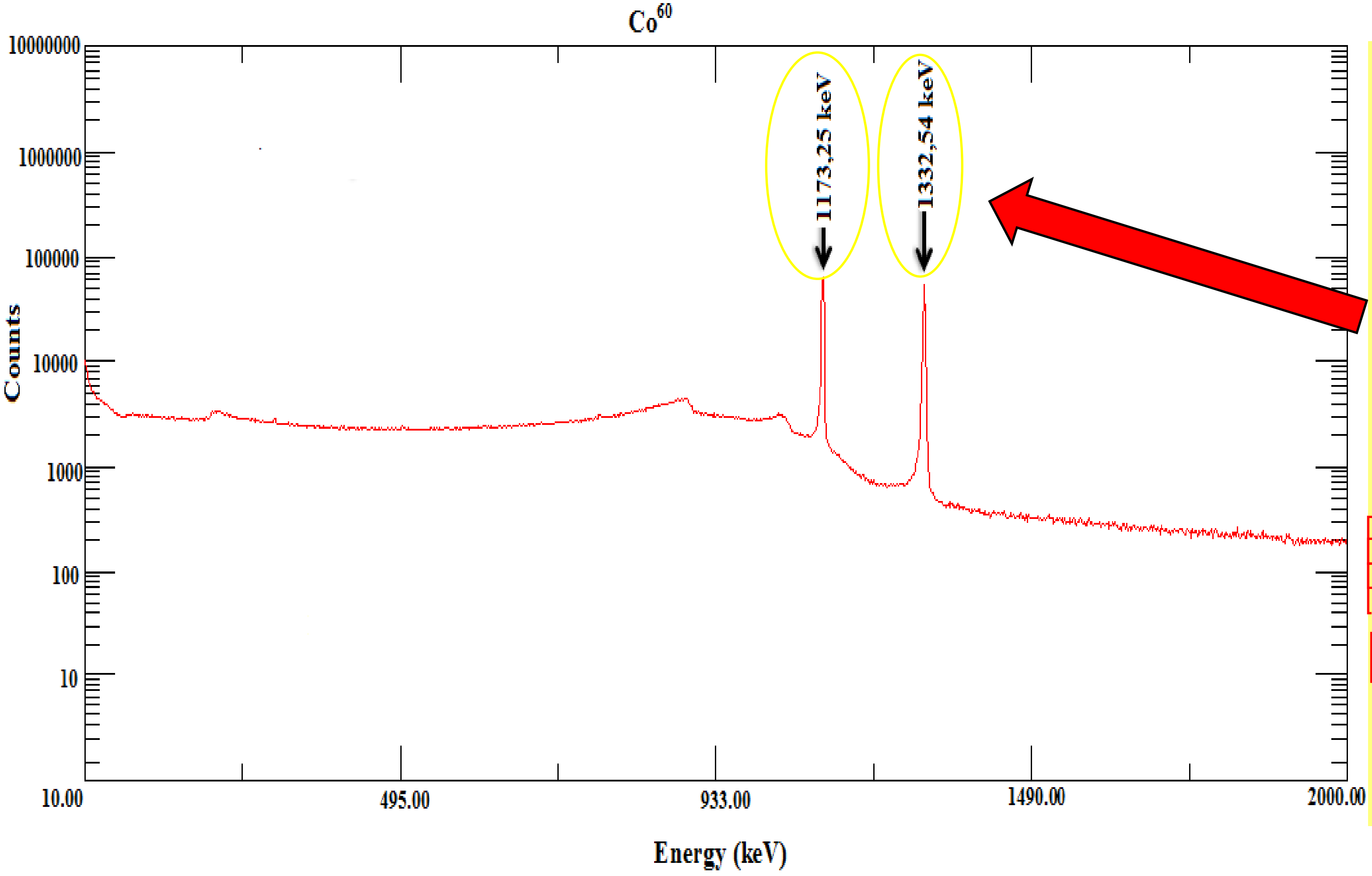
Sort by: Energy, Intensity A, Z Reset form

Main page | Nuclide search

Gamma spectra calibration



Gamma spectra of unknown source



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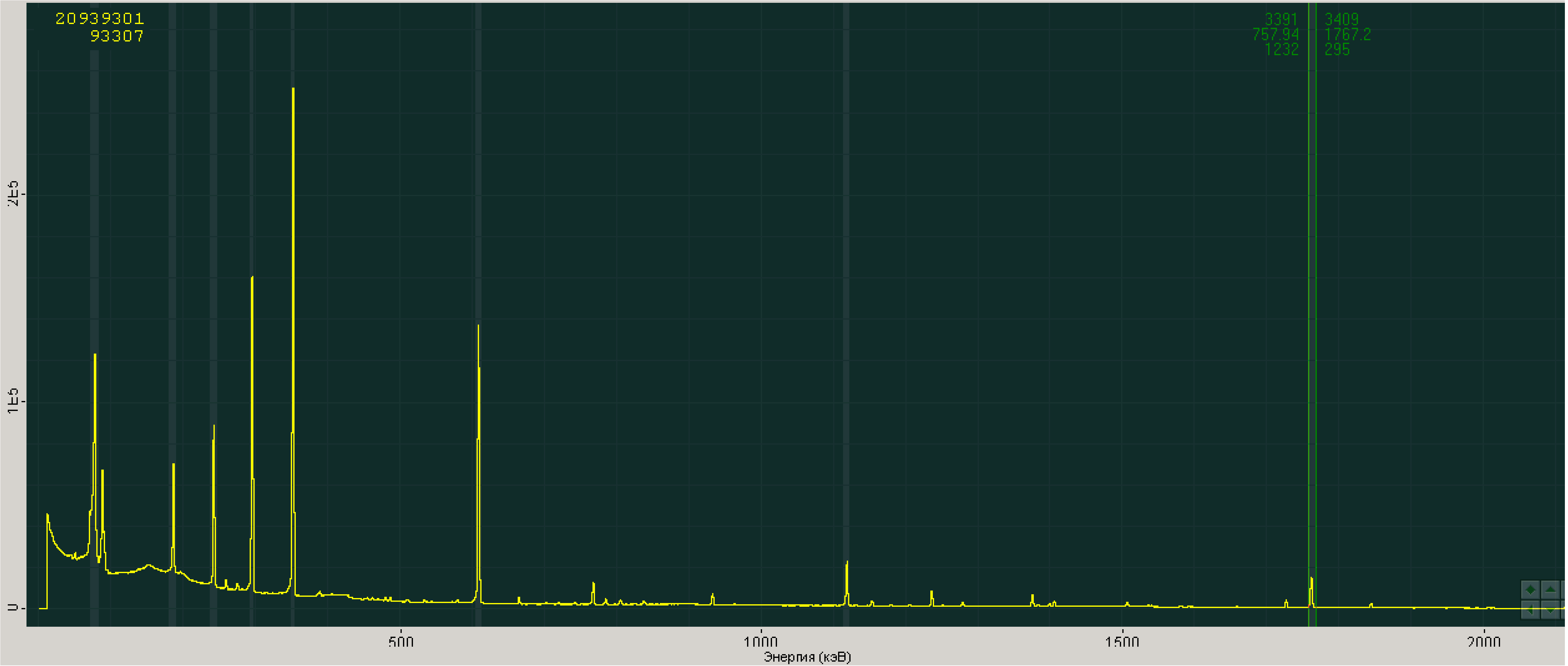
WWW Table of Radioactive Isotopes

Gamma energy search

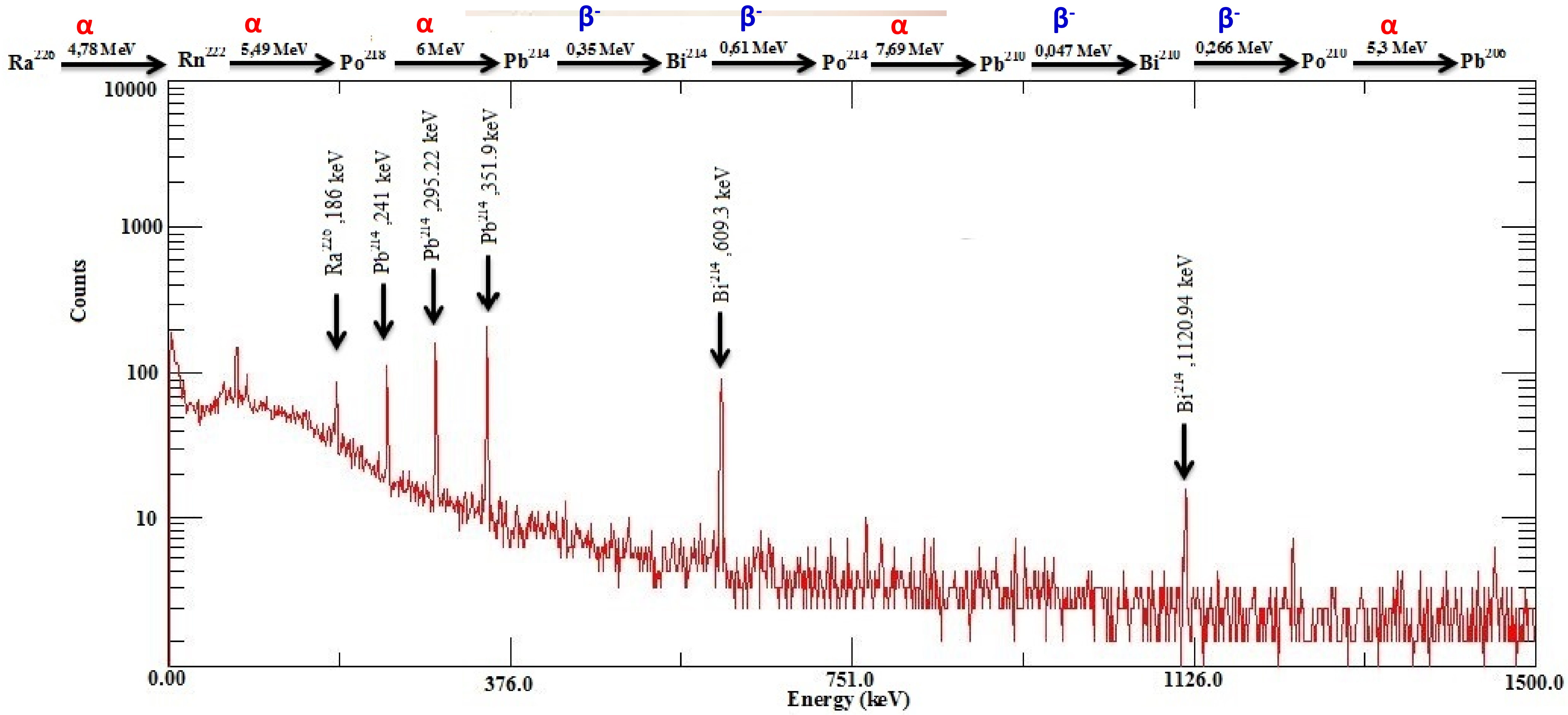
A=60;

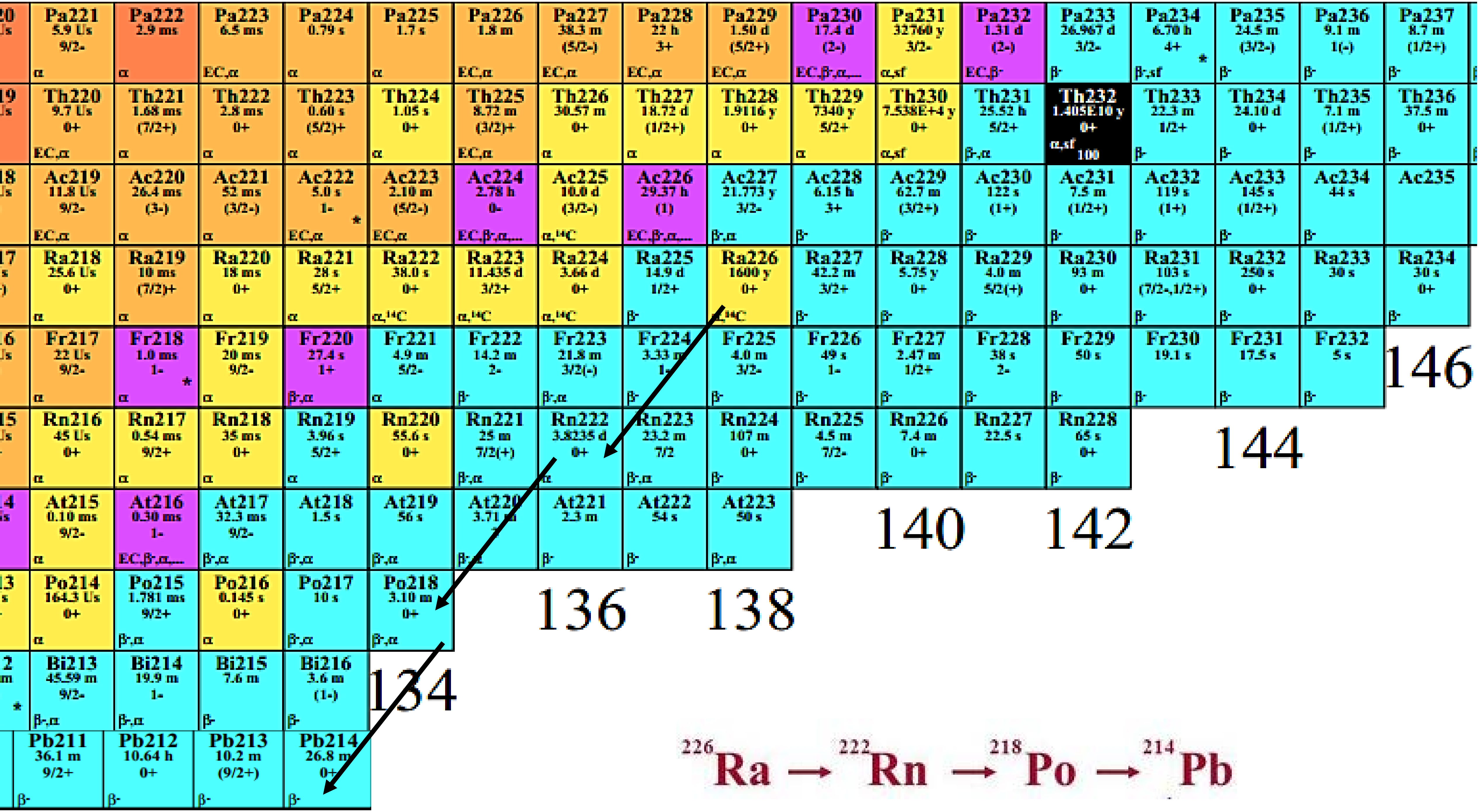
Eg (keV)	Ig (%)	Decay mode	Half life	Parent
58.603 7	2.0	IT	10.467 m 6	^{60m}Co
346.93 7	0.0076 5	b^-	5.2714 y 5	^{60}Co
826.06 3	0.0076 8	b^-	5.2714 y 5	^{60}Co
826.06 3	~0.008	b^-	10.467 m 6	^{60m}Co
1173.237 4	99.9736 7	b^-	5.2714 y 5	^{60}Co
1332.501 5	0.24	b^-	10.467 m 6	^{60m}Co
1332.501 5	99.9856 4	b^-	5.2714 y 5	^{60}Co
2158.57 10	~0.0007	b^-	10.467 m 6	^{60m}Co
2158.57 10	0.00111 18	b^-	5.2714 y 5	^{60}Co
2505	2.0E-6 4	b^-	5.2714 y 5	^{60}Co

Gamma spectra of 2-nd unknown source



Disintegration chain of ^{226}Ra





$$^{226}Ra \rightarrow {}^{222}Rn \rightarrow {}^{218}Po \rightarrow {}^{214}Pb$$

Alpha-spectroscopy
Silicon detector

^{222}Rn

^{214}Pb

^{226}Ra

^{218}Po

^{226}Ra Source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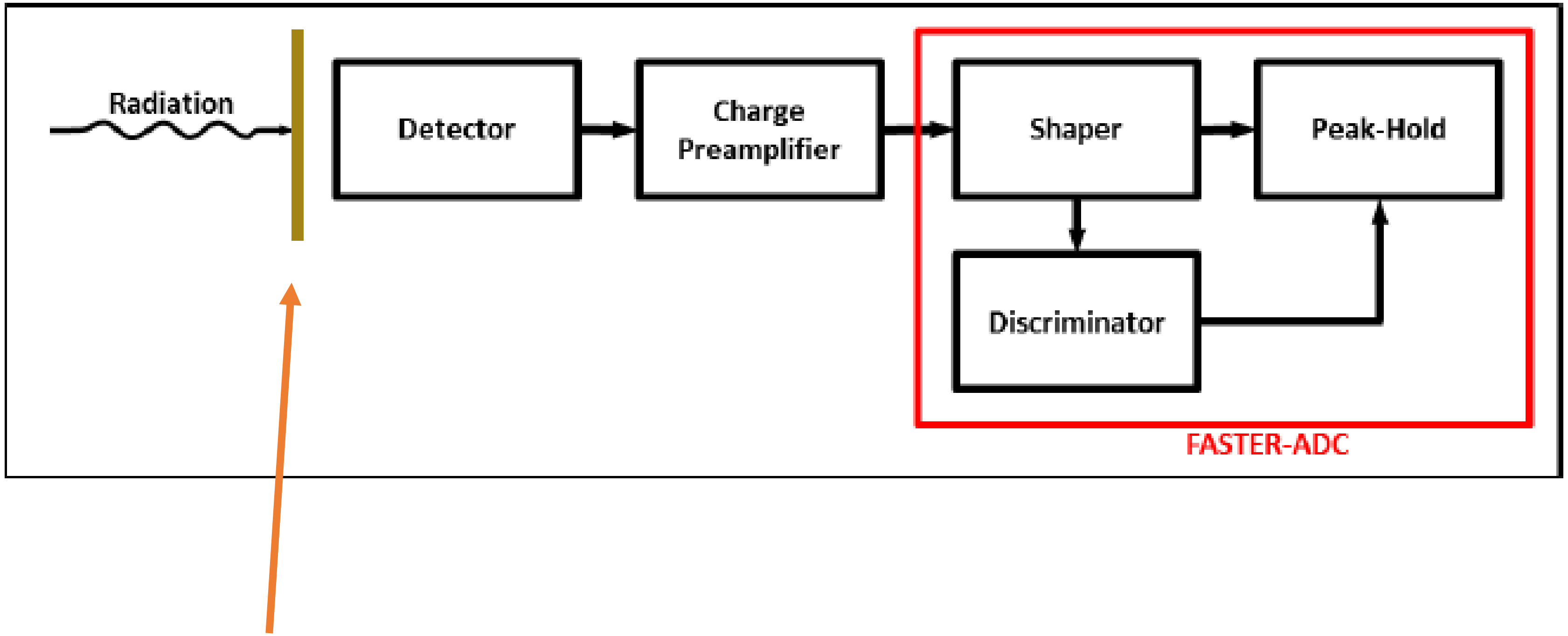
Silicon detector



Measurement
of thickness of
Aluminium foil

Measurement of thickness of Al-foil by balance weighting

L= 28,9 cm

H= 7,8 cm

M= 0,5287 g

S= L*H= 225,42 cm^2

D= M/S= 2,345 mg/cm^2

ρ= 2698,4 mg/cm^3

D/ρ= 8,69 μm

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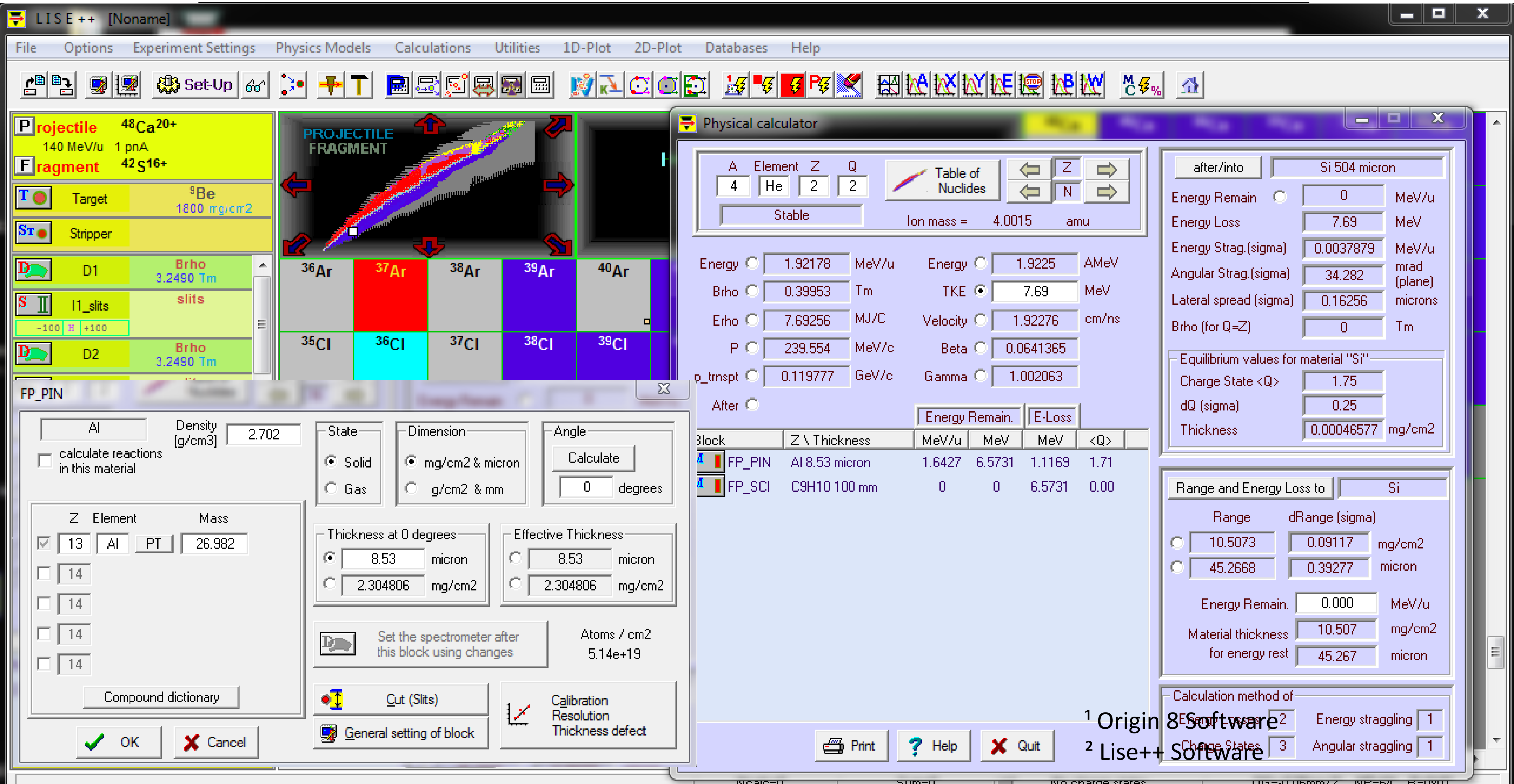
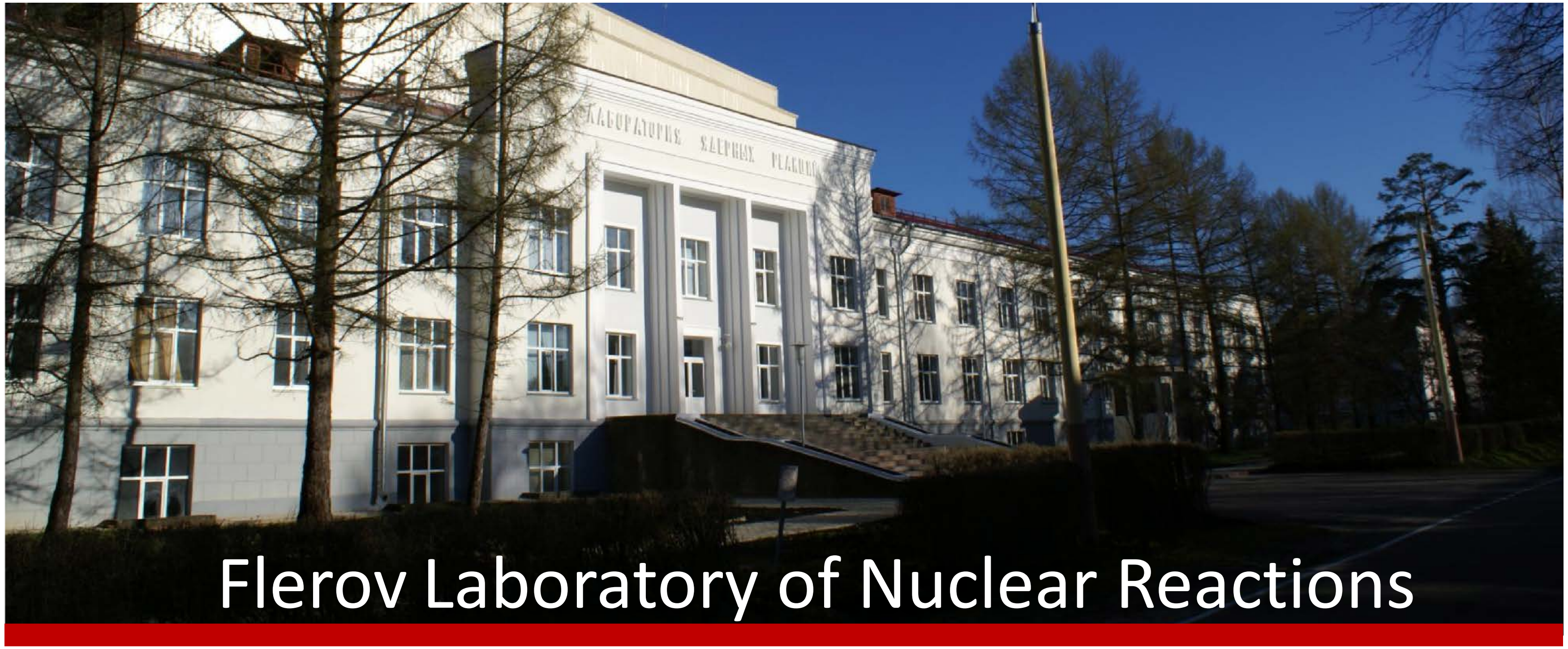
Measurement of thickness of Al-foil (d)



[1] Origin 8 Software

[2] Lise++ Software



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