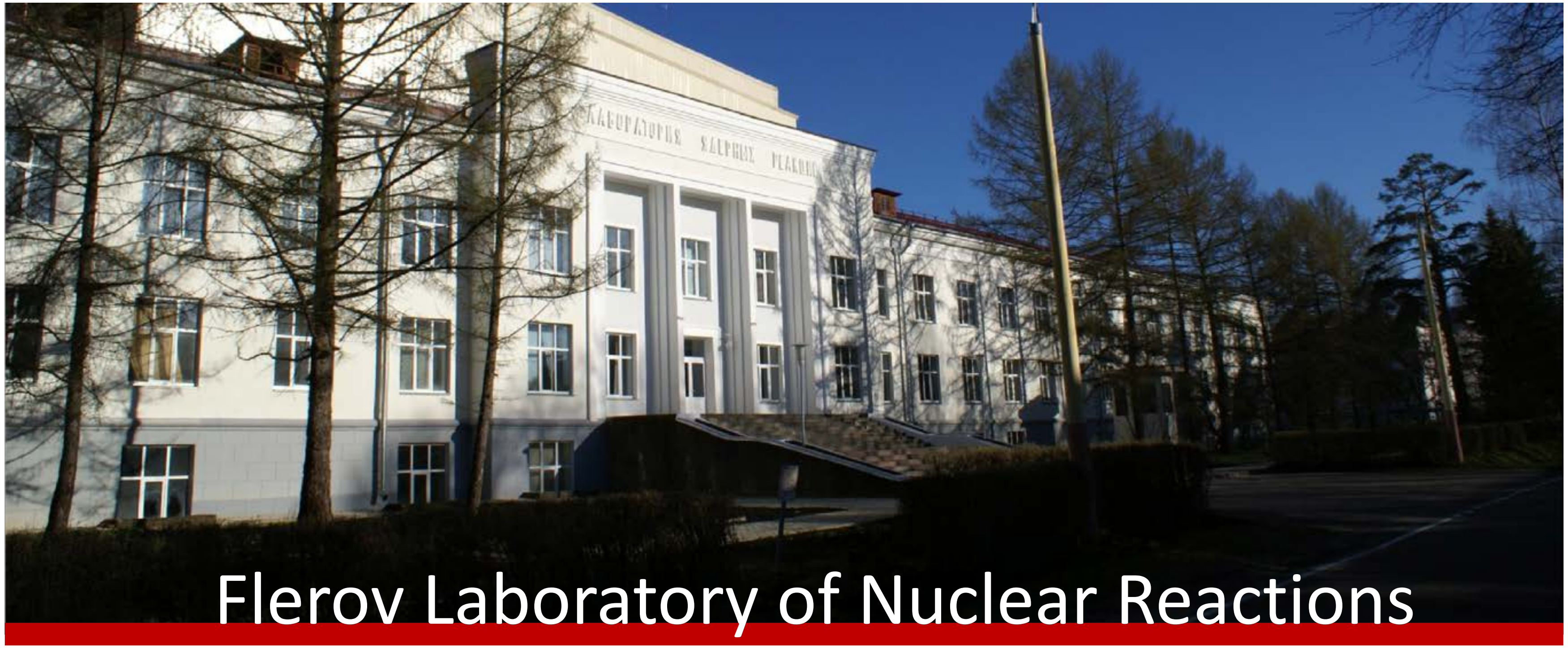
STAGE 3 INTERNATIONAL STUDENT PRACTICE 2018



The Joint Institute for Nuclear Research in Dubna

Joint Institute for Nuclear Research
Flerov Laboratory of Nuclear Reactions
University Center

PROJECT TITLE

- Ge(Li) – detector for energy measurements of gamma-activity
- Study of the operation principles of X-ray detectors
- Moseley's Law in Action
- Alpha Spectroscopy

SPEAKERS

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Introduction

3 Types of semiconductor detectors

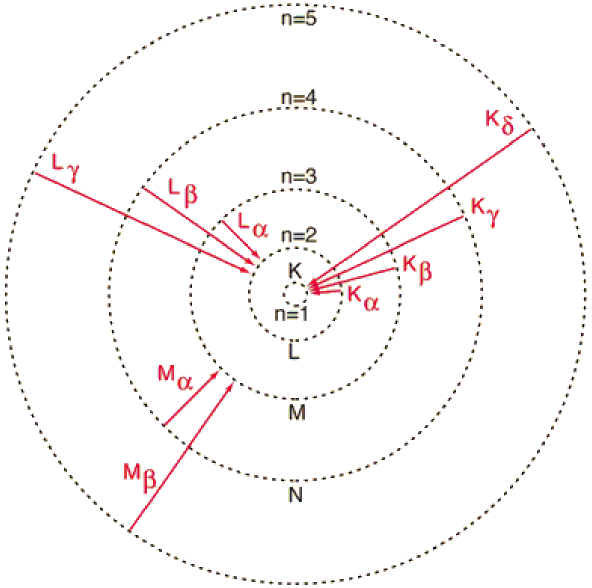
1. X-ray Ge(Li) detector

2. Ge(Li) Gamma detector

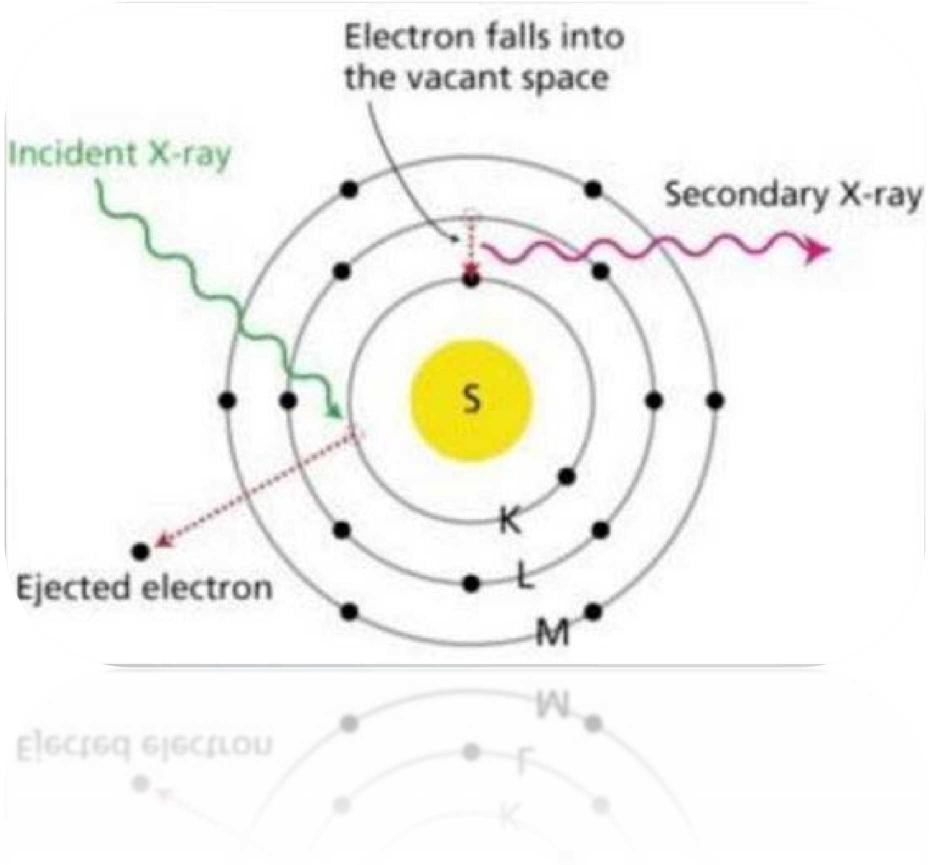
3. Si Alpha spectroscopy detector

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.



X-ray transitions



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

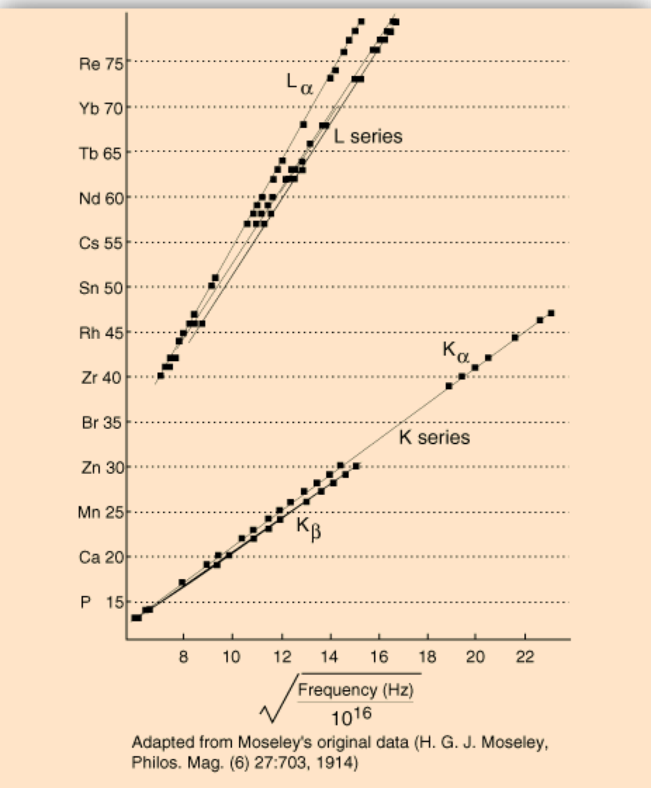
$$E = a\,(Z - b)^2$$

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.

Moseley Plot of characteristic X-rays

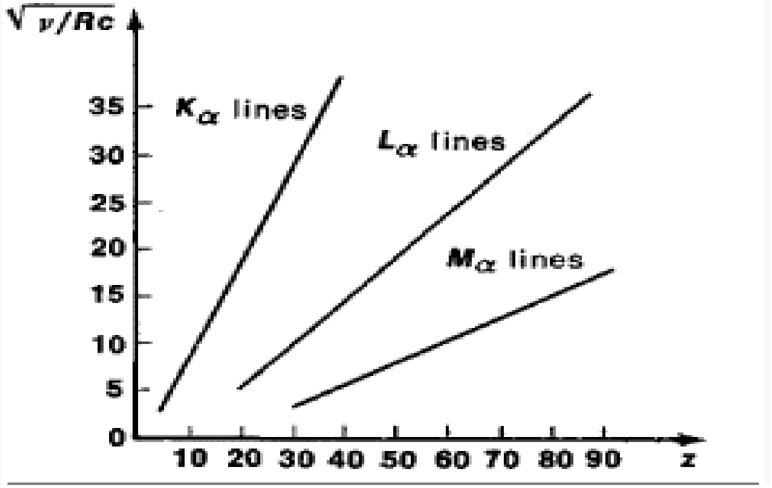
- His data Moseley plot is still standard feature of physics textbooks (Figure 1).



Moseley plot of characteristic X-rays

$$\sqrt{f} = a(Z - b)$$

$\sqrt{f}$ is proportional to Z a particular line (say, K_α- line).



Applications of Moseley’s Law

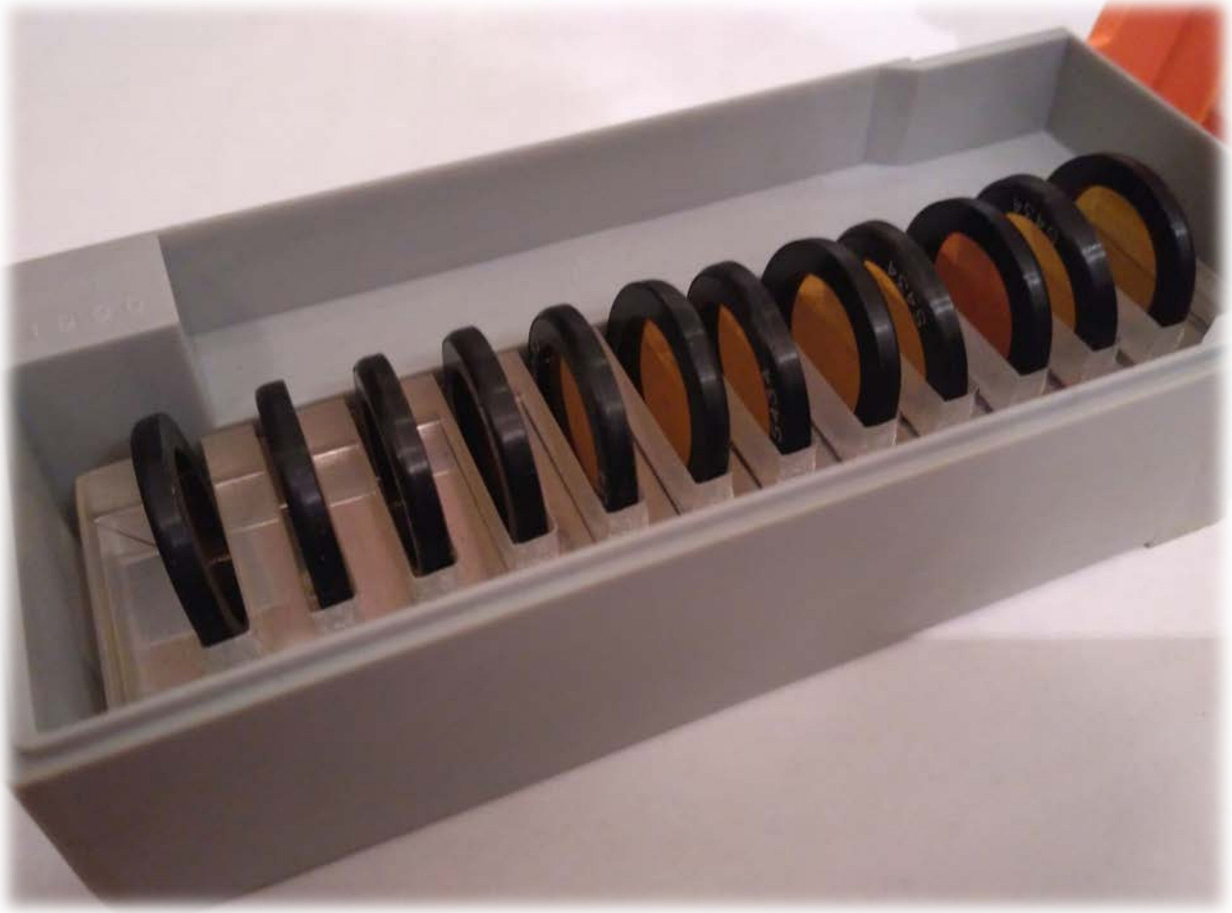
- Any discrepancy in the order of the elements in the periodic table can be removed by Moseley's law by arranging the elements according to the atomic numbers and not according to the atomic weights.

- 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.

General view of the X-ray spectrometer

Source



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.
4. Find a Z number of an unknown source.

Moseley Law in action

Element Z (Atomic No.)	Energy (keV) K(α)	Energy (keV)K(β)
Y 39	14.1	15.8
Cd 48	22.0	24.9
Sn 50	24.2	27.2
Ce 58	33.4	37.8
Eu 63	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.

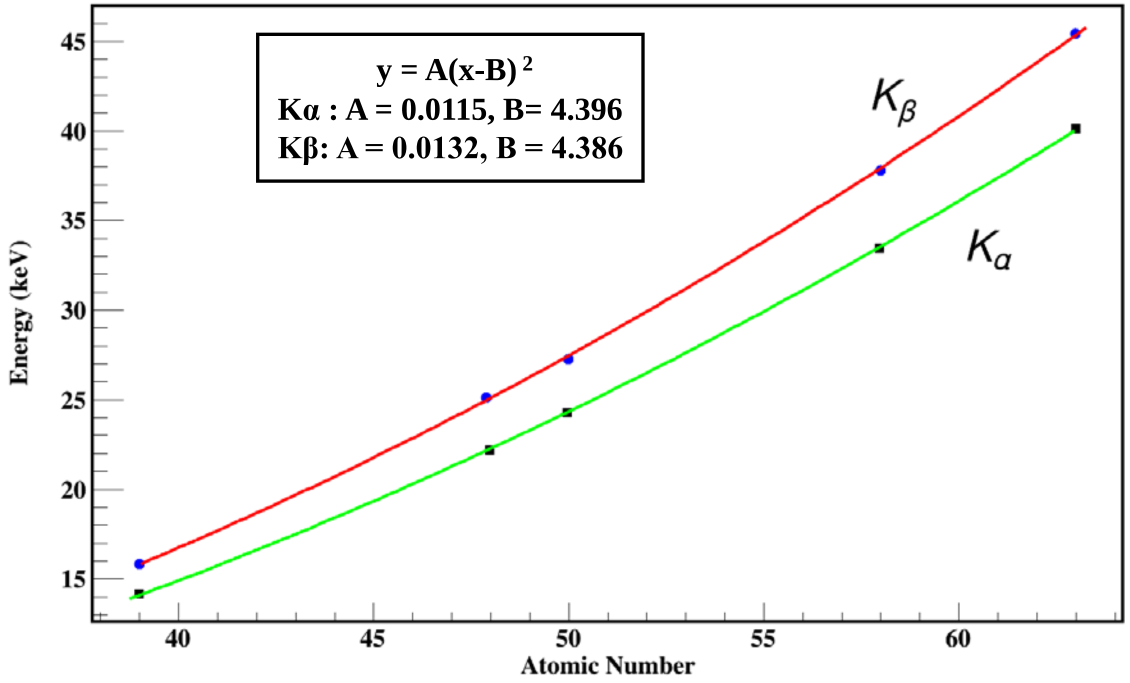
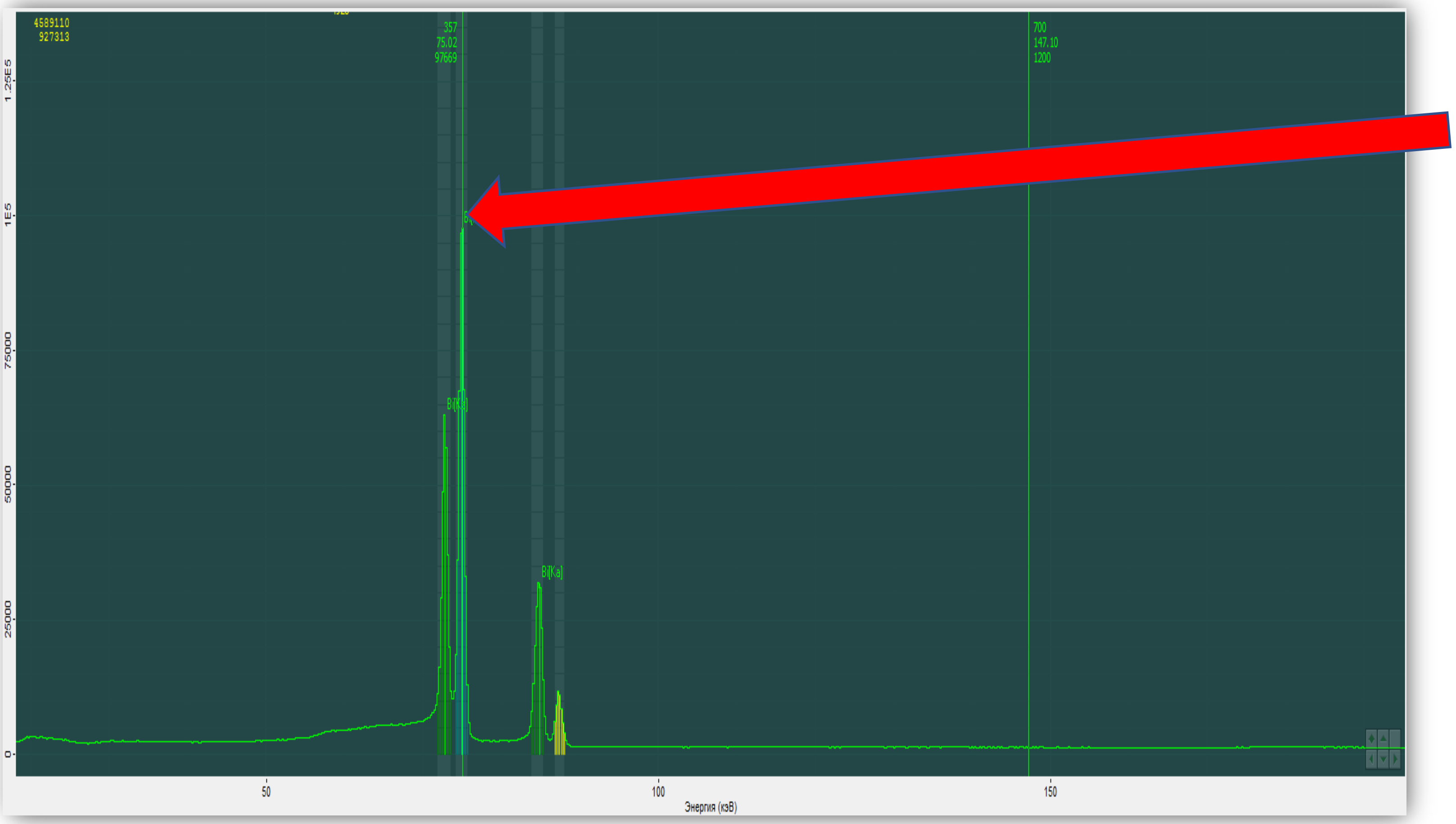


Figure 4: K (α) and K (β) lines fit to Moseley's Law. We confirm the functional form of the law but different values for the constants (a & b).

Spectra from X-ray detector of unknown source



Calculation and results.

E = 74.956 keV

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

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

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

$$= \frac{\sqrt{74.956}}{0.0115} + 4.0137$$

$$= 83.66$$

Nuclear data: Z = 83

Element is Bi

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JINR

CENTIS
Centro de Isótopos

Ge(Li) semiconductor detector

- **Germanium detector**

is a solid state detector with P-n juction structure

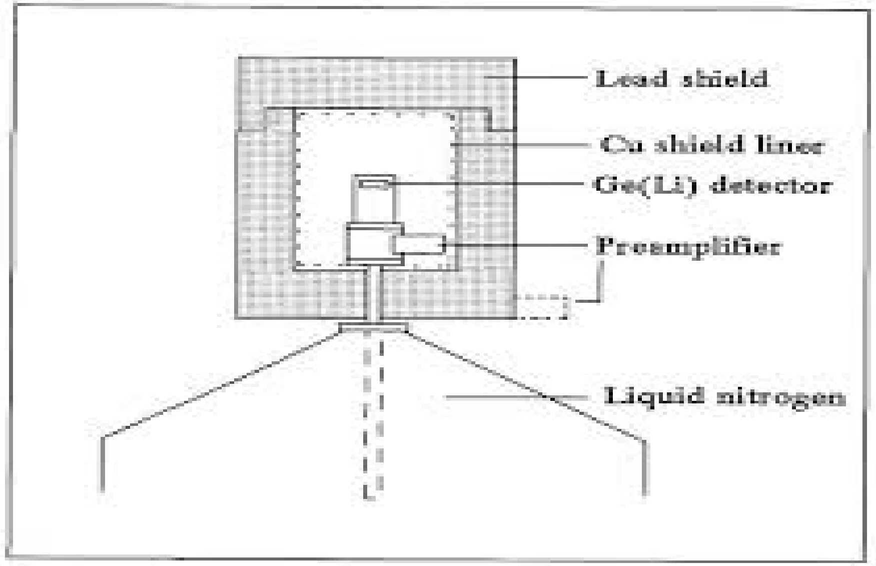
In which the built in area is sensitive to ionizing radiation.

- **It consists of:**

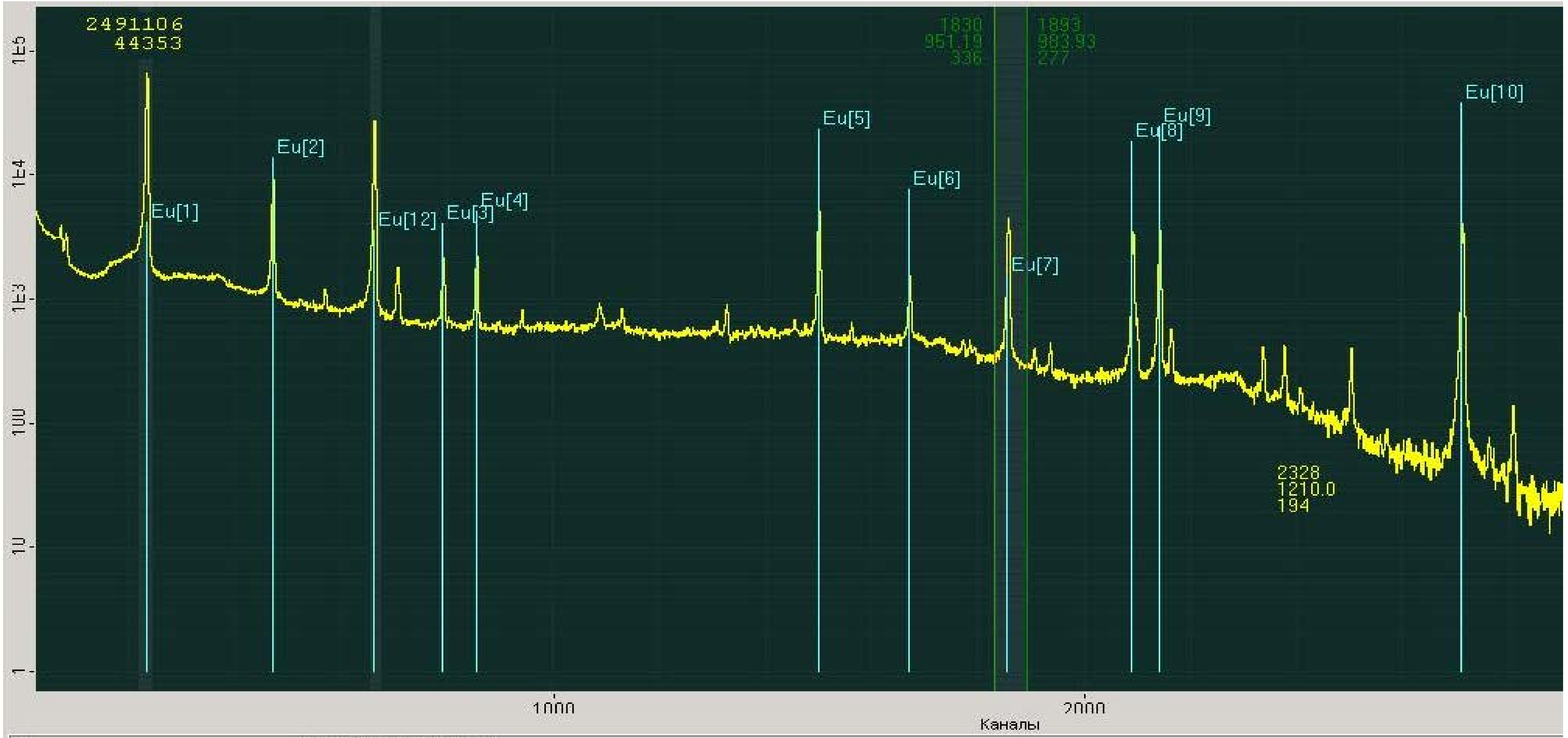
Semiconductor detector crystal.

Pre amplifier unit.

Data spectra analyzing system.



Gamma spectra calibration



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]

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[2] *Department of Physics, Lund University, Sweden*

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

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:

WWW Table of Radioactive Isotopes

Radiation search

Energy: ± 1 keV Search

Type: Alpha Gamma

Parent:

T1/2: s - s

Mass number: 152 - 152

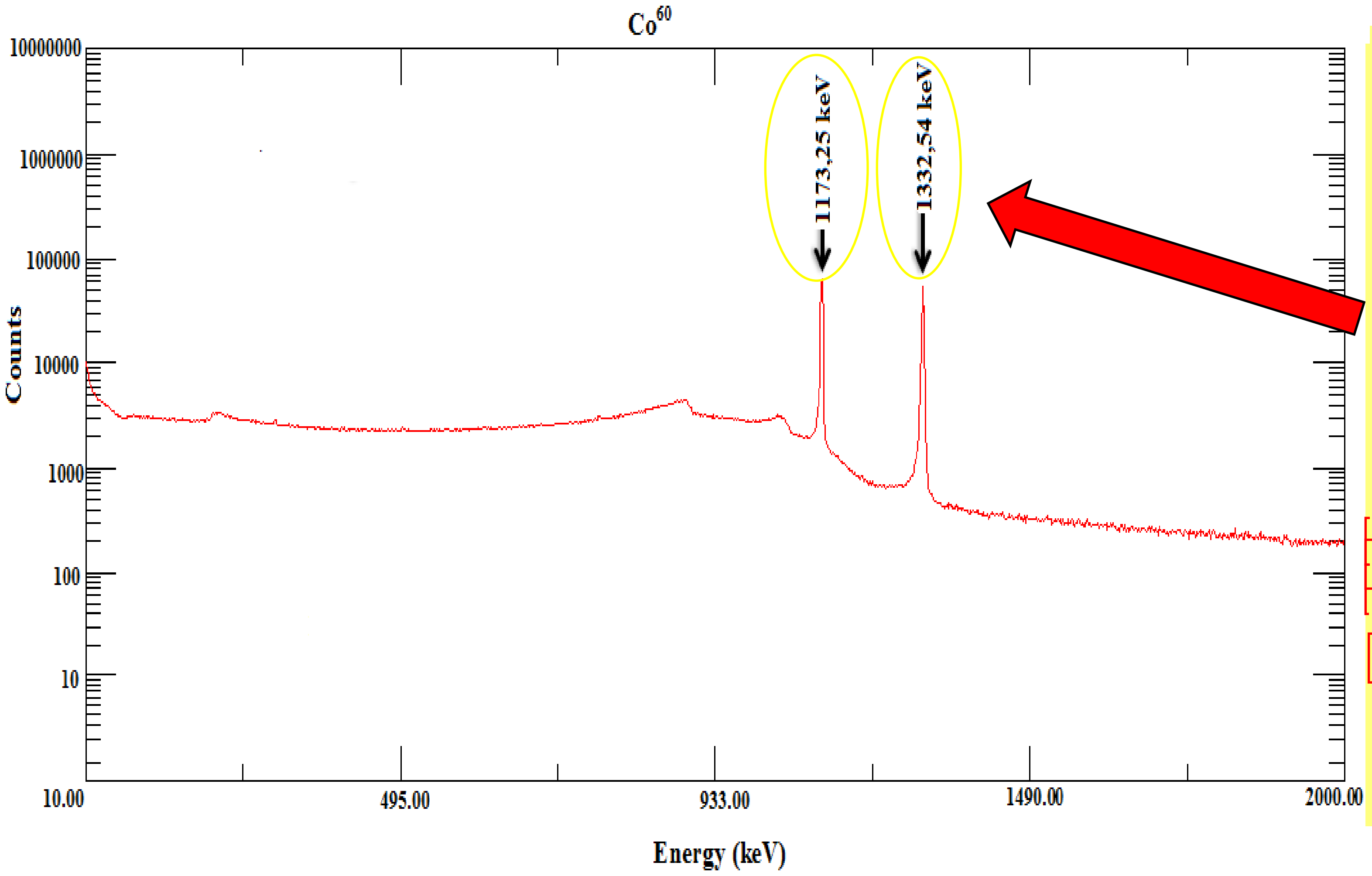
Z: 63 or Element: Eu

N:

Sort by: Energy, Intensity A, Z Reset form

Main page | Nuclide search

Gamma spectra of unknown source



ToRI

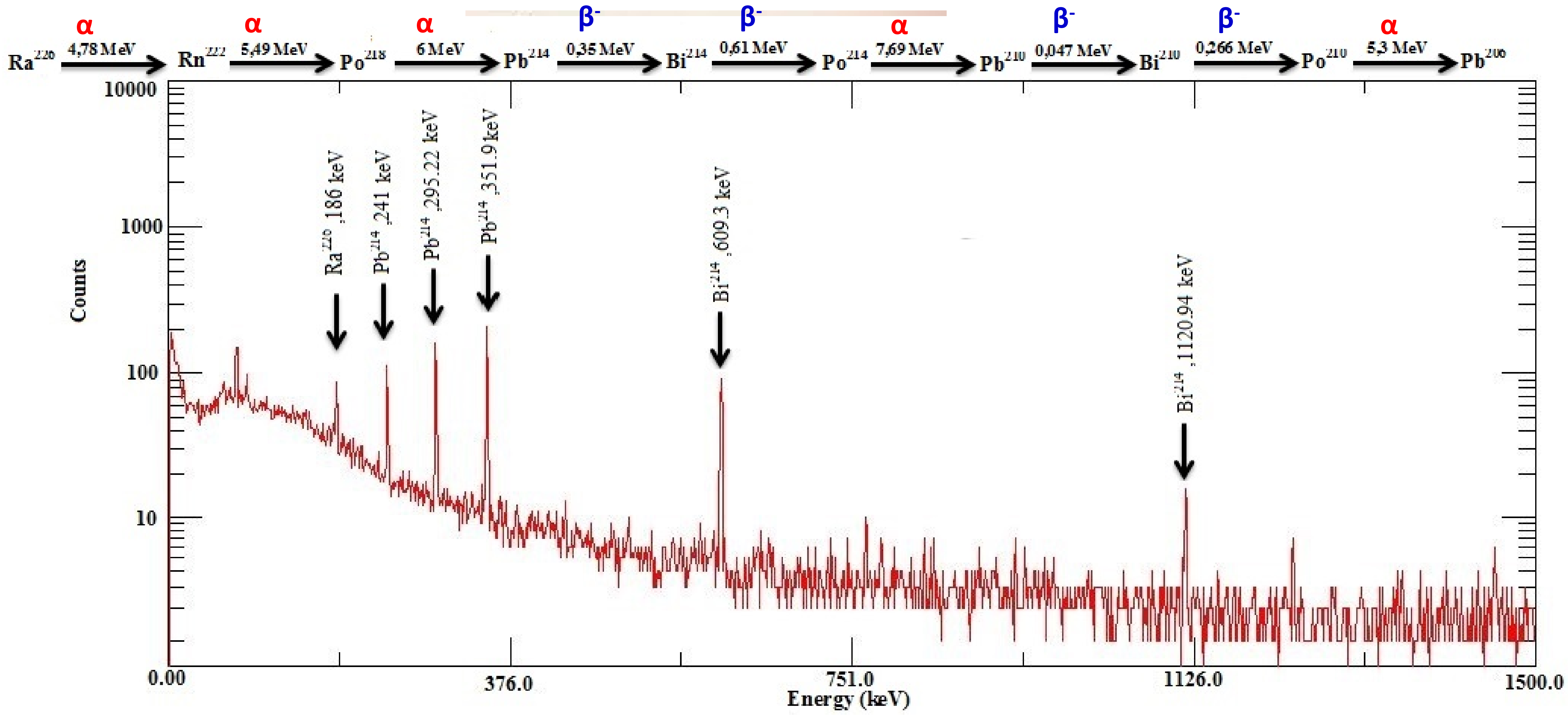
WWW Table of Radioactive Isotopes

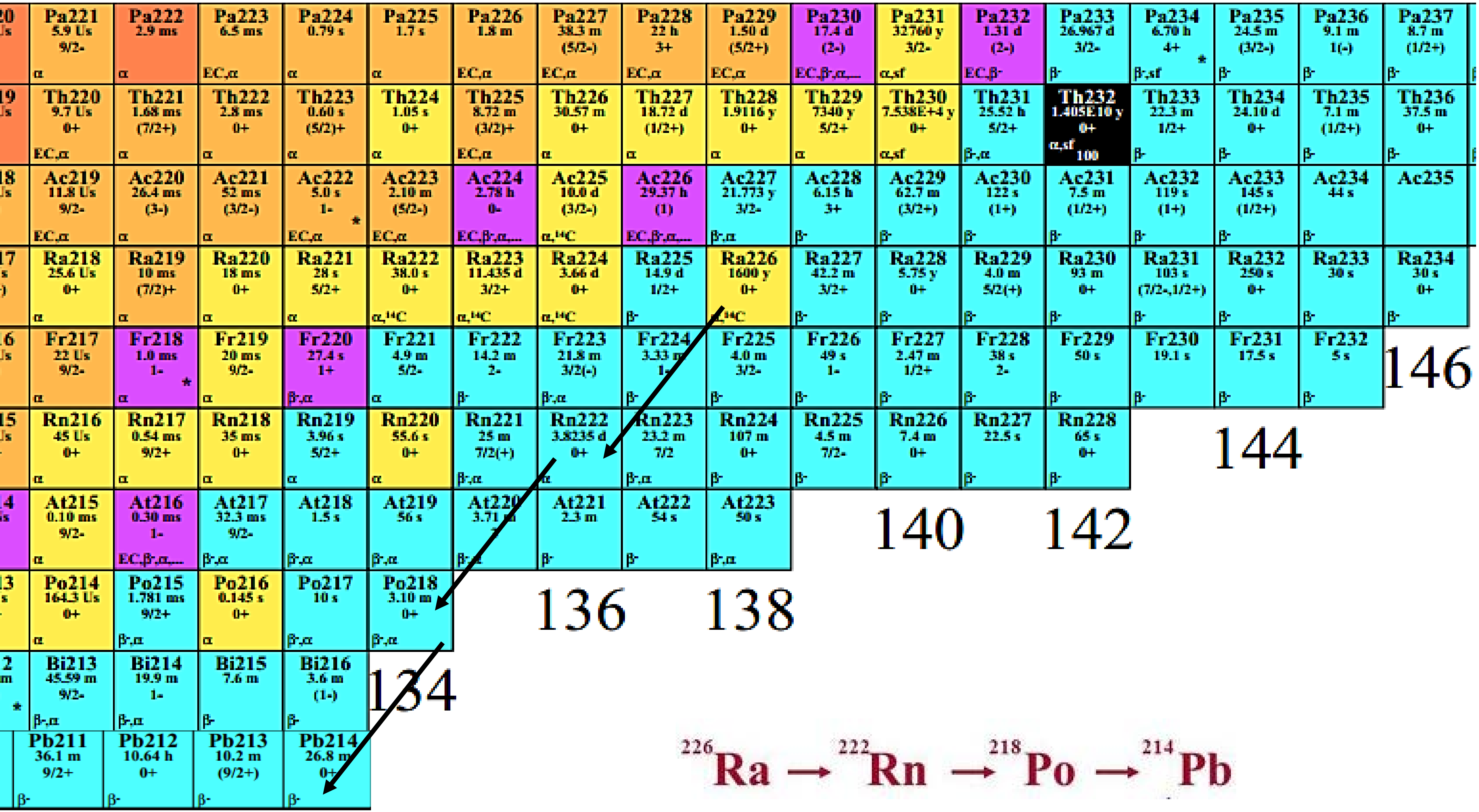
Gamma energy search

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

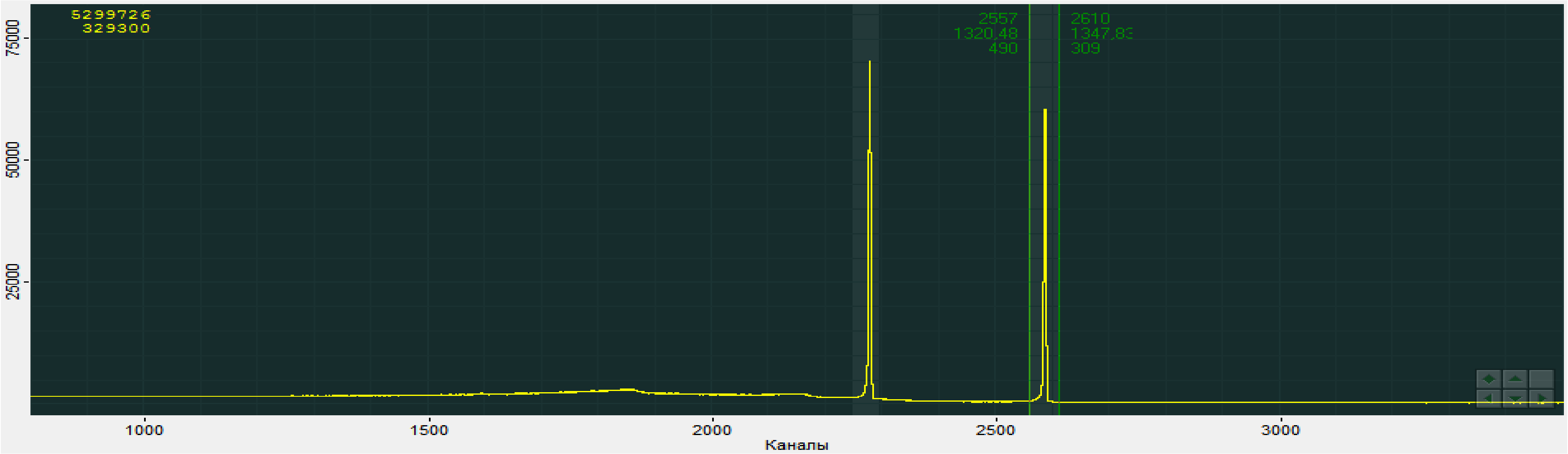
Disintegration chain of ^{226}Ra



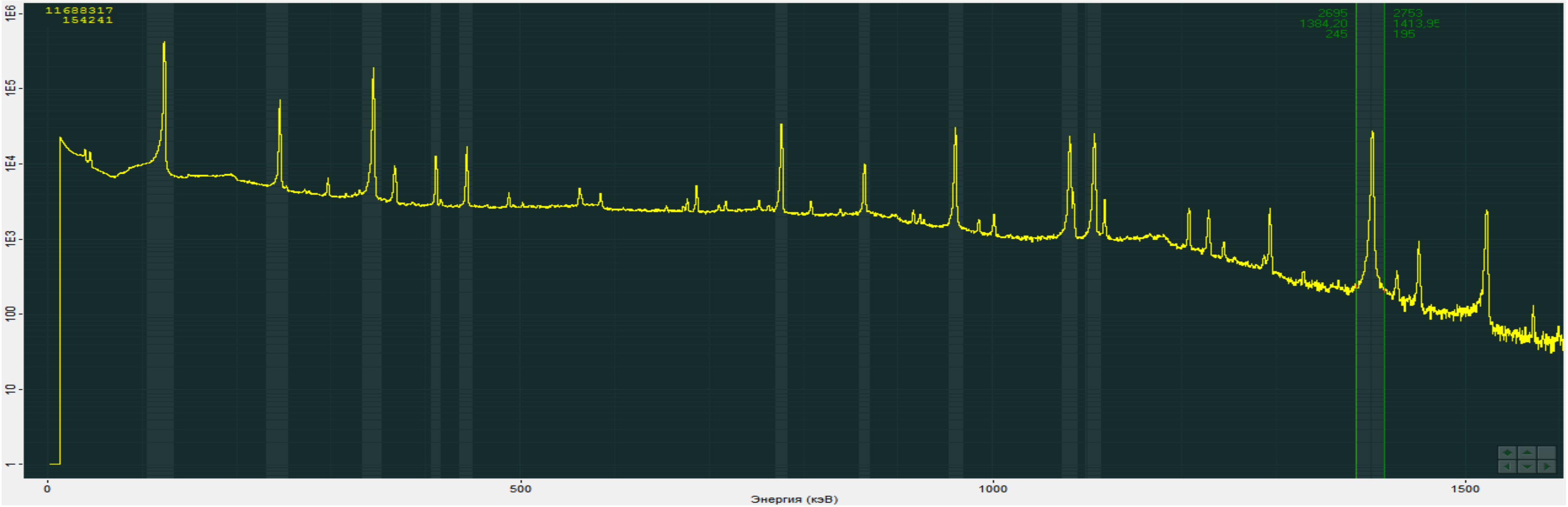


$$^{226}Ra \rightarrow {}^{222}Rn \rightarrow {}^{218}Po \rightarrow {}^{214}Pb$$

Determination of the efficiency



^{60}Co spectra



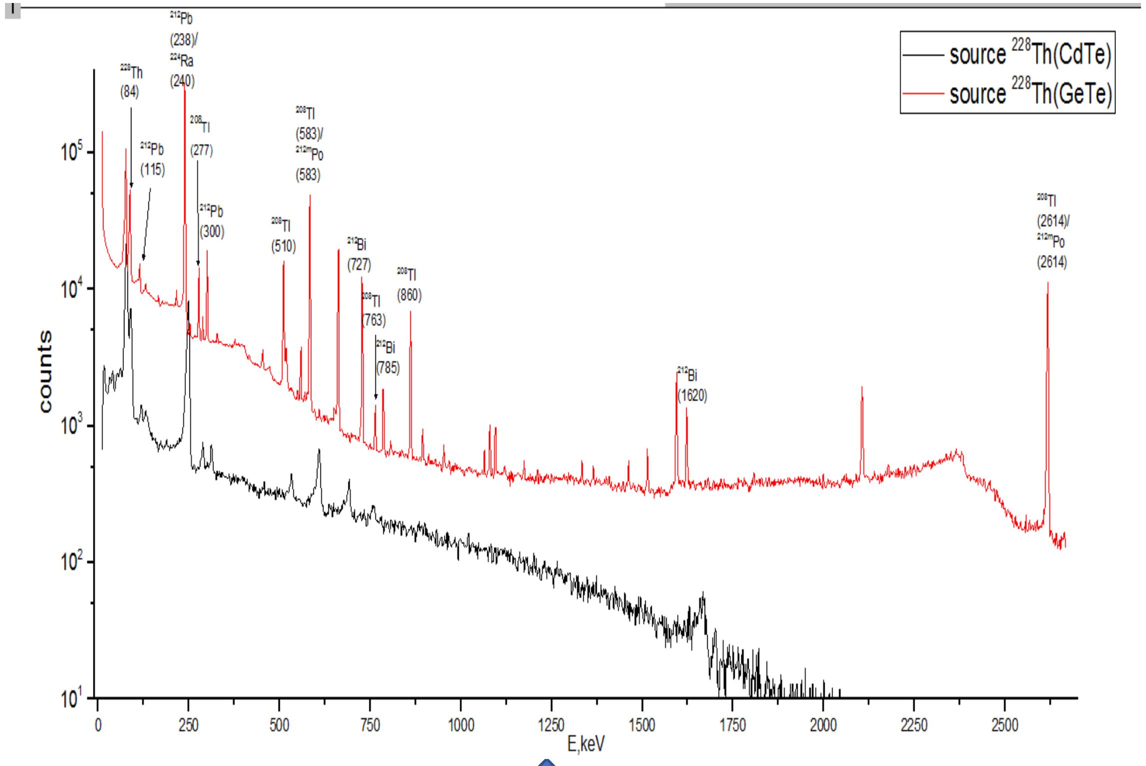
^{152}Eu spectra

Now we calculate the absolute efficiency and internal efficiency by using these equations

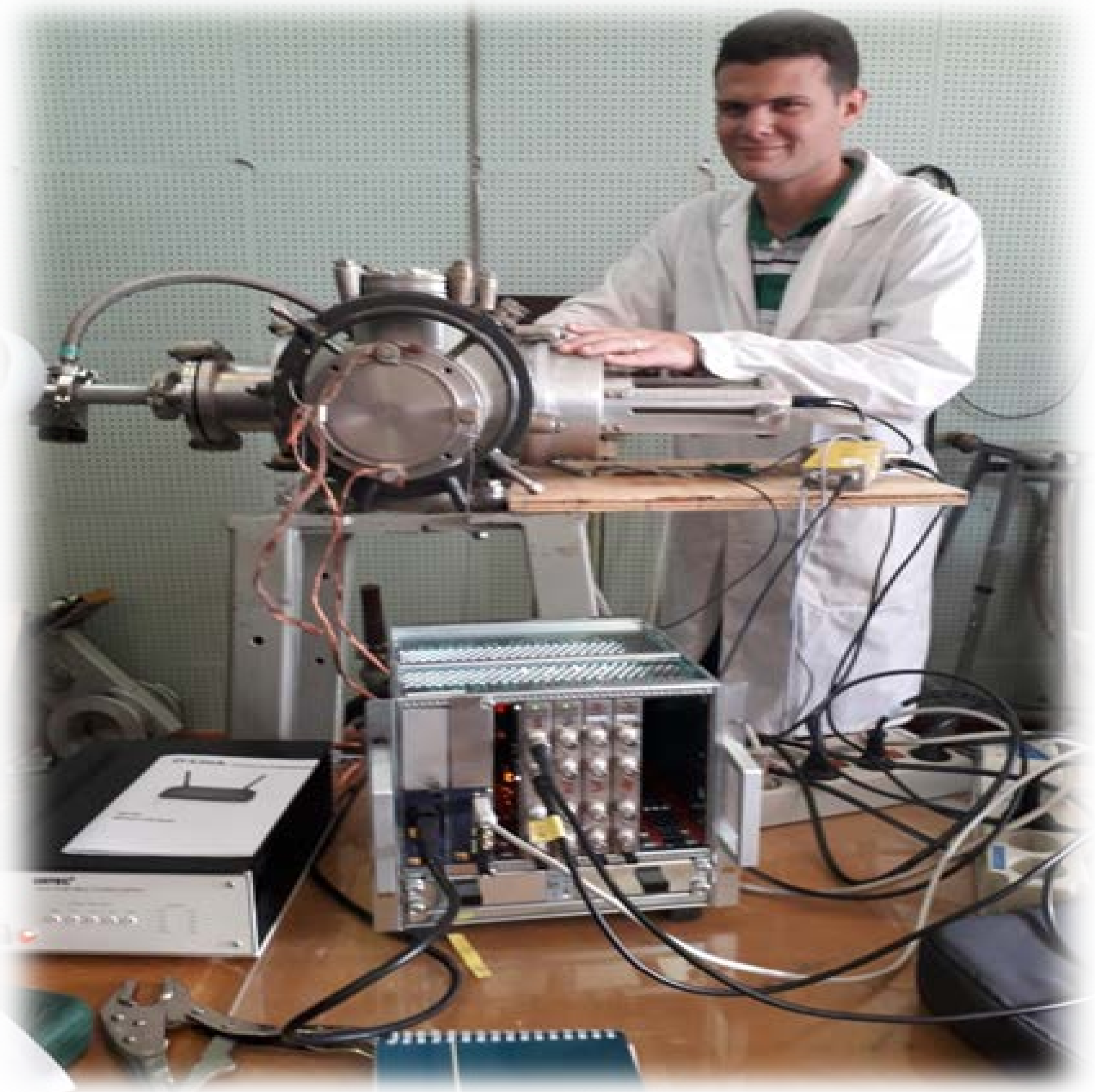
	$\sum_{absolute} = N_{det} / N_{em}$	$\sum_{internal} = N_{det} / N_{fl}$
For Co-60	22.30%	53.4%
For Ba-133	20.8%	49.86%

Comparison of detectors

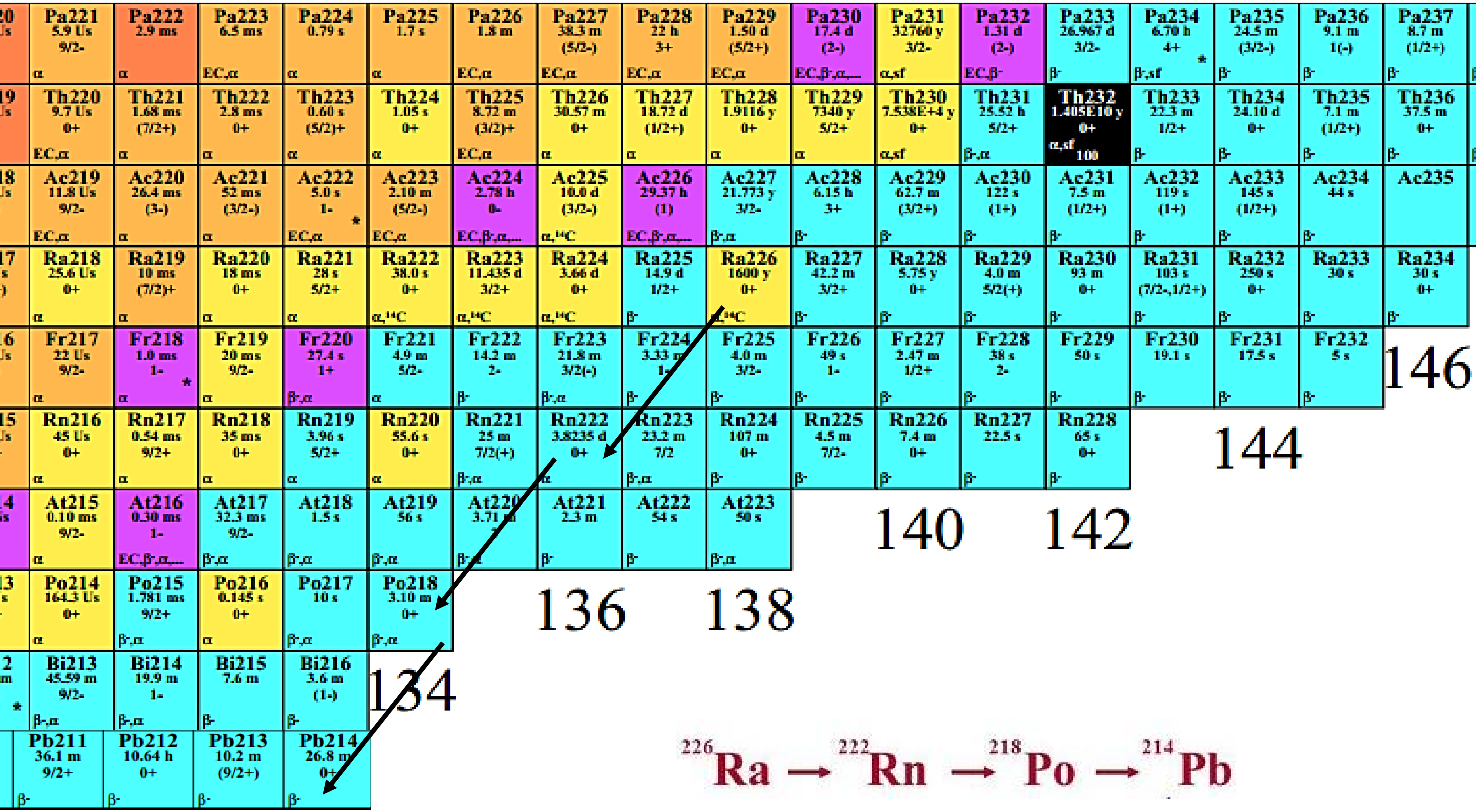
	Ge(Li)detector	CdZn(Te)detector
Size	Huge	Very compact
Cooling System	Need	No Need
Efficiency	More	Lower
Resolution	More	Lower



Resolution and efficciency comparison

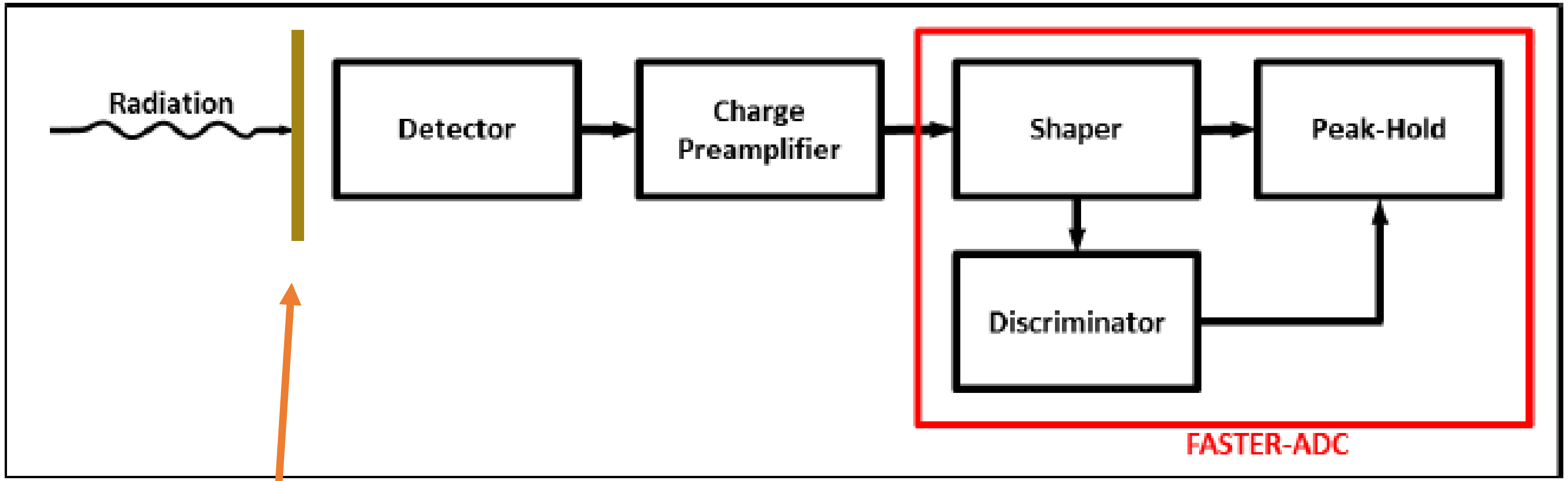


ALPHA SPECTROMETRY WITH Si DETECTOR



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

Silicon detector

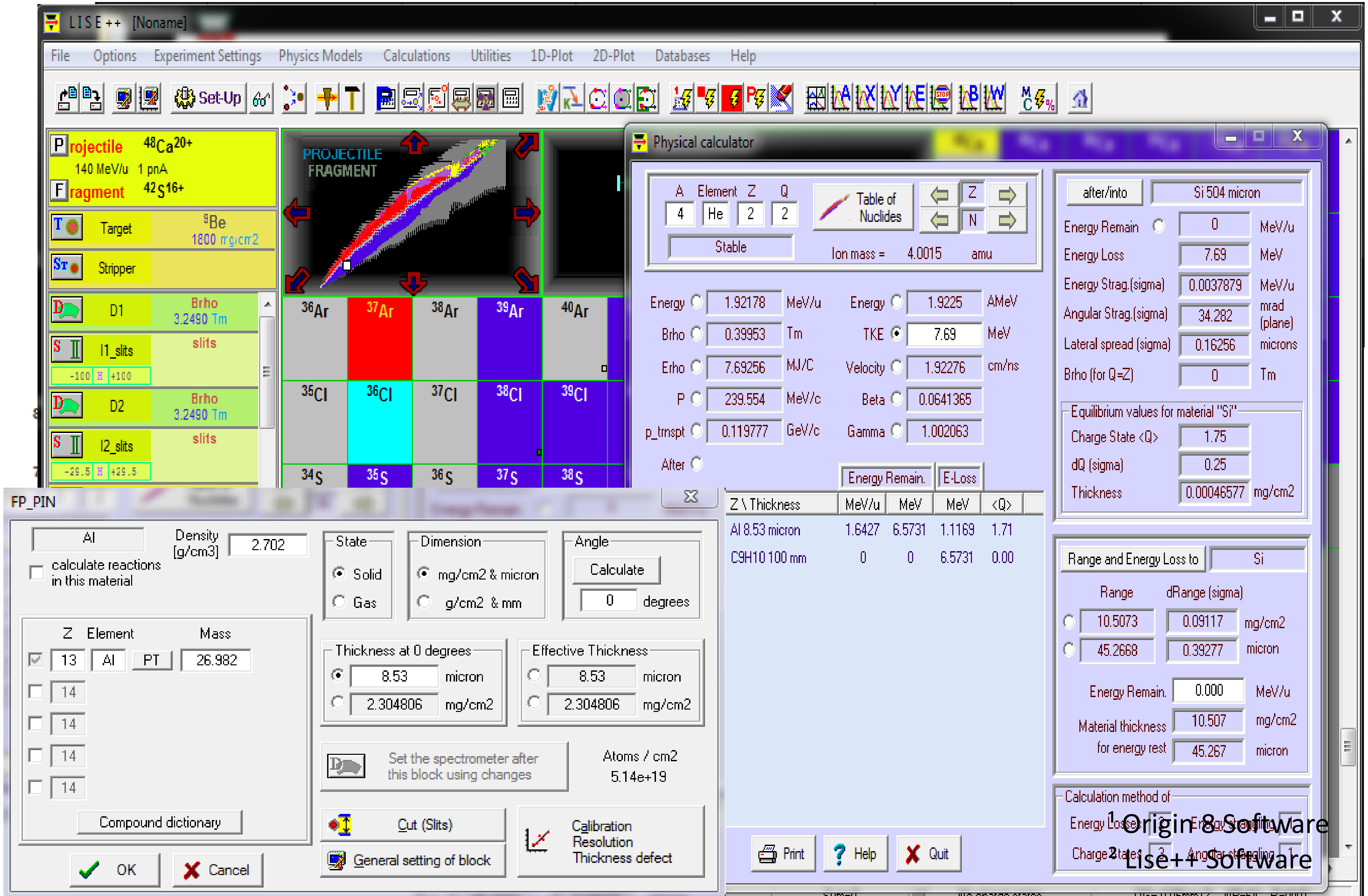


Measurement of thickness of Aluminium foil

^{226}Ra ^{222}Rn ^{218}Po ^{214}Pb

^{226}Ra Source

Measurement of thickness of Al-foil (d)



Calculations of error

$$\left(\frac{\delta x}{x}\right) = \sqrt{\sigma^2 + \left(\frac{\Delta E}{E}\right)^2}$$

$$\sigma = \sqrt{\frac{(d_1-\bar{d})^2+(d_2-\bar{d})^2+(d_3-\bar{d})^2+(d_4-\bar{d})^2}{4}}$$

$$\bar{d} = \frac{d_1 + d_2 + d_3 + d_4}{4}$$

Measurement of thickness of Al-foil by balance weighting

L= 28,9 cm

H= 7,8 cm

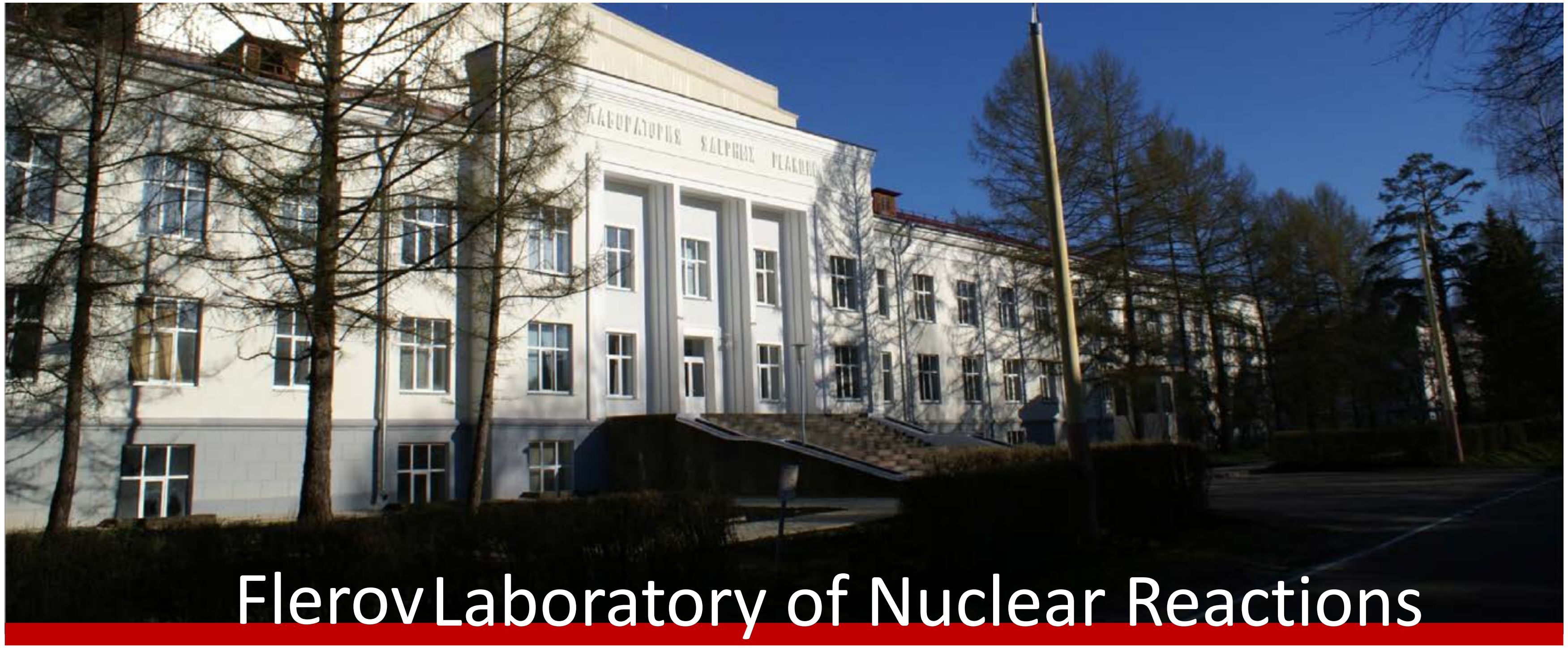
M= 0,5287 g

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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THANK YOU FOR YOUR ATTENTION.