Determination of the isotopic composition of a Uranium target using alpha-Spectrometry

JINR Student Practice 2019

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Goal : determination of the isotopic composition

Actions

1. Assembly and tuning of the alpha spectrometer.
2. Spectrometer calibration using a known alpha emitter.
3. Energy measurement of the unknown source.
4. Data analysis.
5. Results.

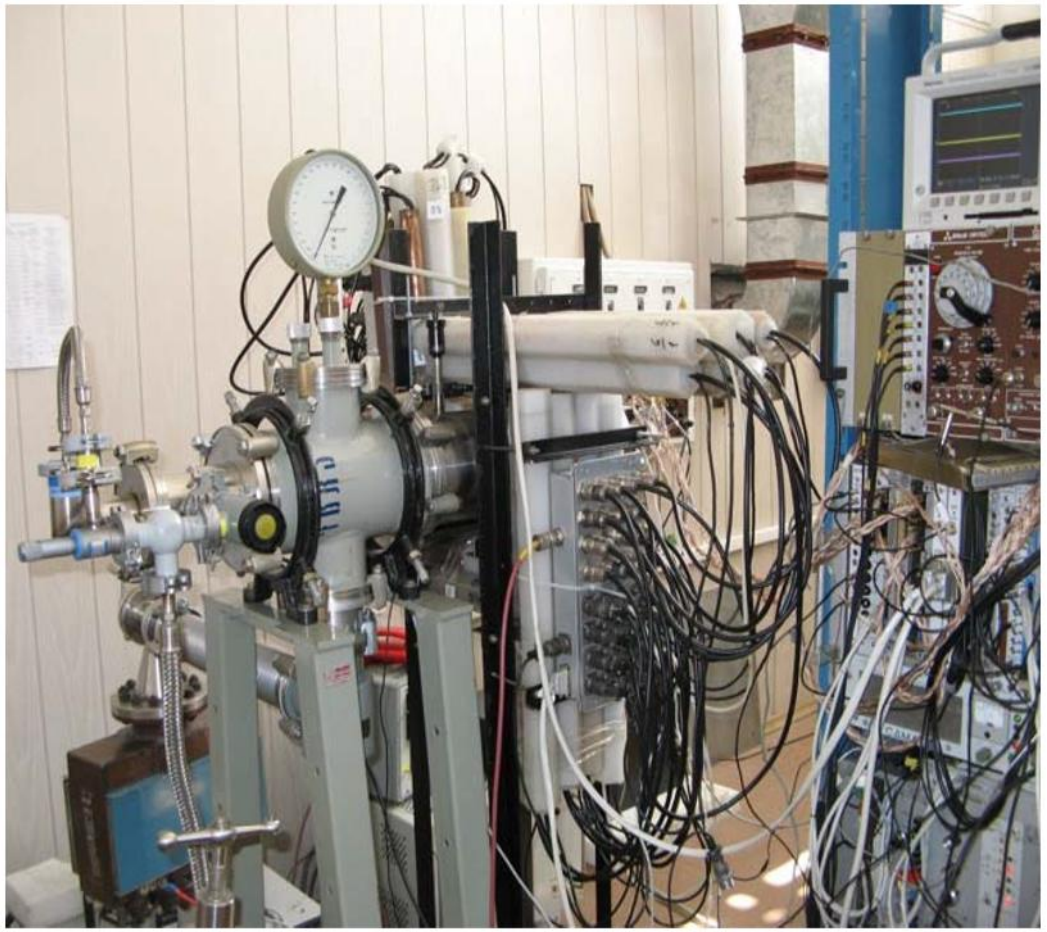
How this project relates with the work the group is doing

The practice was performed in group №1 “Fission of low excited nuclei" of sector №5 of the FLNR JINR.

The aim of the group is to study the various manifestations of clustering in heavy low excited nuclei, and the group strives to obtain experimental information about such phenomena and trying to explain them.

The experiments are performed on two-arm time-of-flight spectrometers COMETA, COMETA-R, LIS, VEGÀ for 252Cf(sf) è 235U(nth,ff) reactions. (COrrelation Mosaic E-T Array, index -R is "Reactor" for experiment on IBR-2, LIS is light ion spectrometer, VEGA is Velocity-Energy Guided Array). In experiments, the 2V2E registration method is used, i.e. measuring the time of flight and energy of all fixed fragments in order to restore their mass.

At the moment, an experiment is being prepared to study the reaction ^{235}U (nth, ff) at the IBR-2 reactor. The aim of the present work is to determine the isotopic composition of the target, which will be used in the upcoming experiment.



COMETA setup

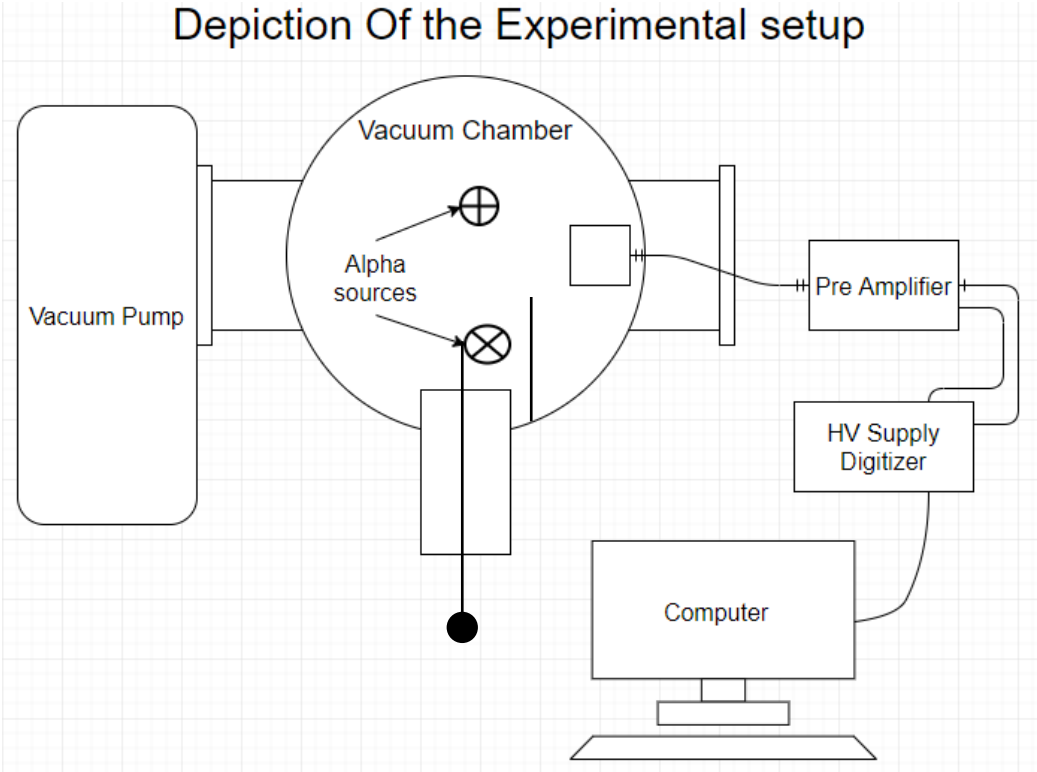
Experimental Method

Equipment Used:

- Vacuum Chamber (at about 1e-5 hPa)
- An Alpha Emitter with a known composition (In this case it was a target consisting of ^{238}Pu, ^{239}Pu and ^{233}U)
- PIN (p-type, intrinsic, n-type) diode semiconductor detector
- The unknown Uranium alpha emitter

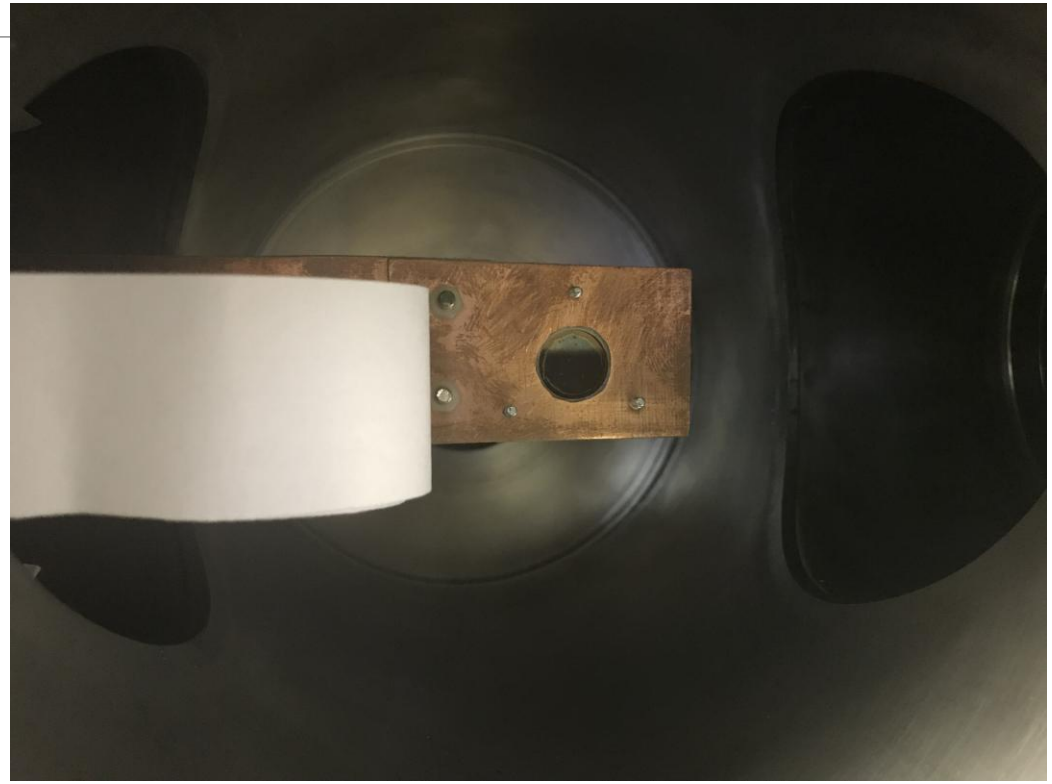
Electronics consisted of:

- Pre-Amplifier
- CAEN HV supply and digitizer
- CAEN mc^2 analyser software



Vacuum chamber at the top

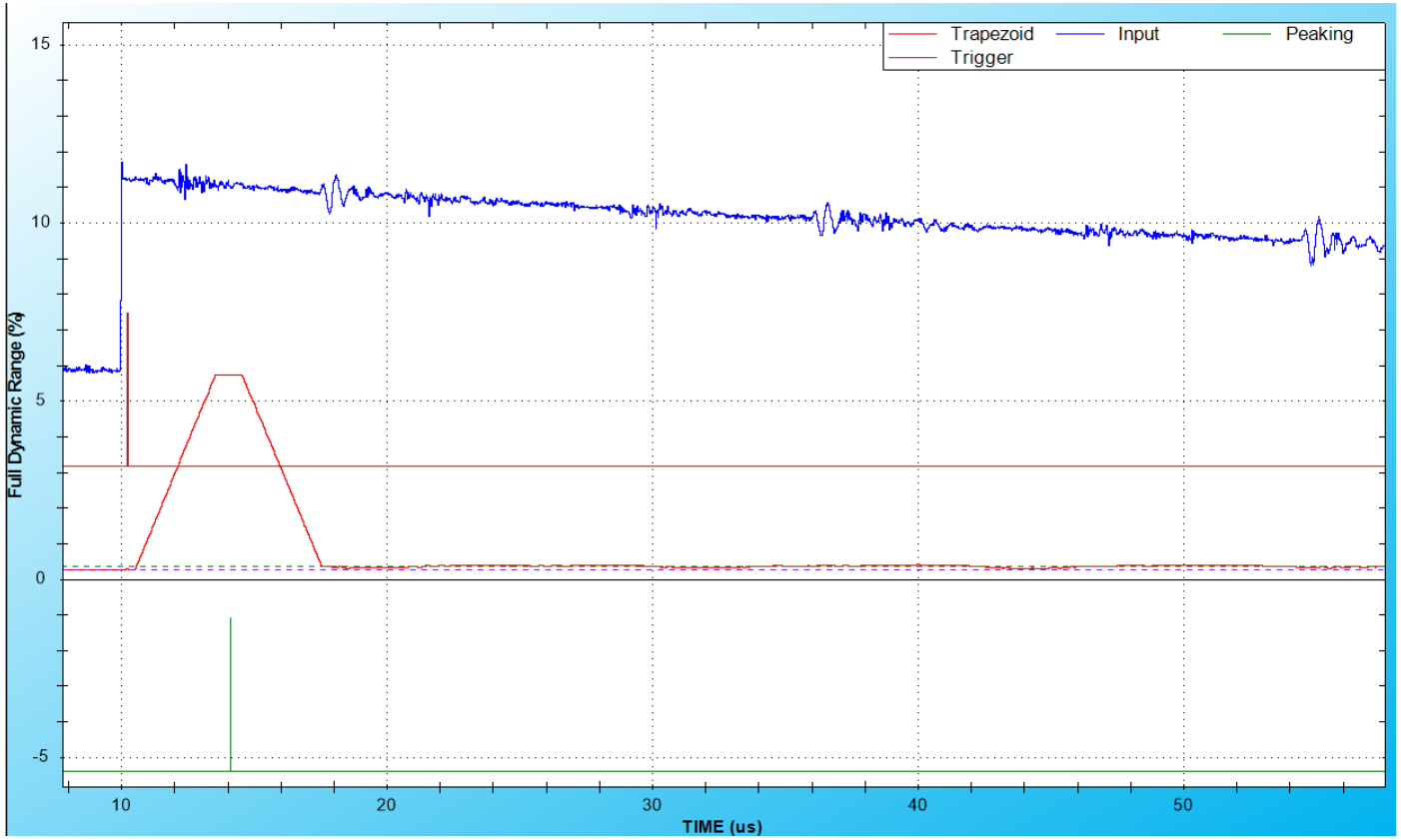
Vacuum pumps on the shelf below it



Inside of the Vacuum chamber, with known alpha emitter

Tuning the spectrometer

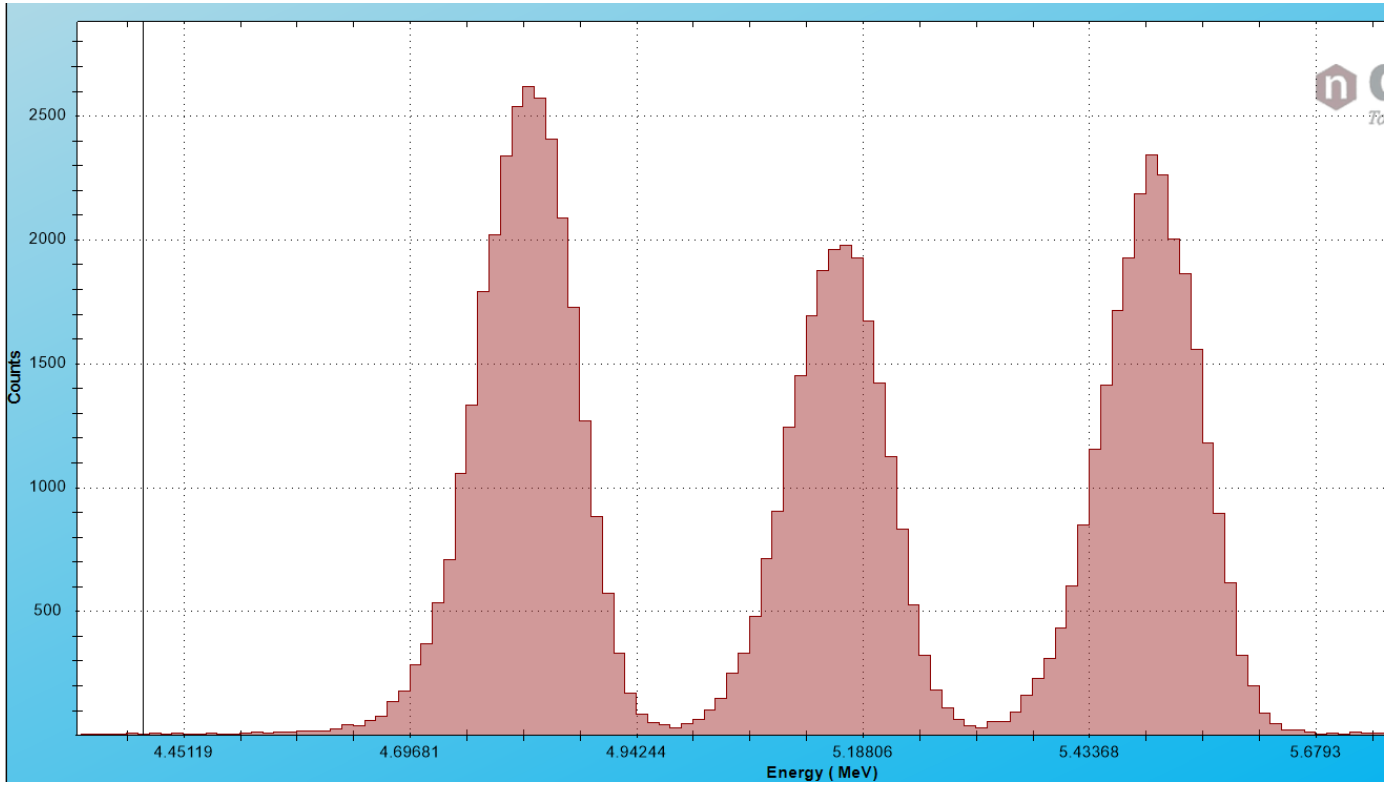
Energy of alpha particles is proportional to the amplitude of the pulse from the detector. To reduce the noise and increase E resolution the trapezoidal filter was used in mc^2 software.



The Experiment

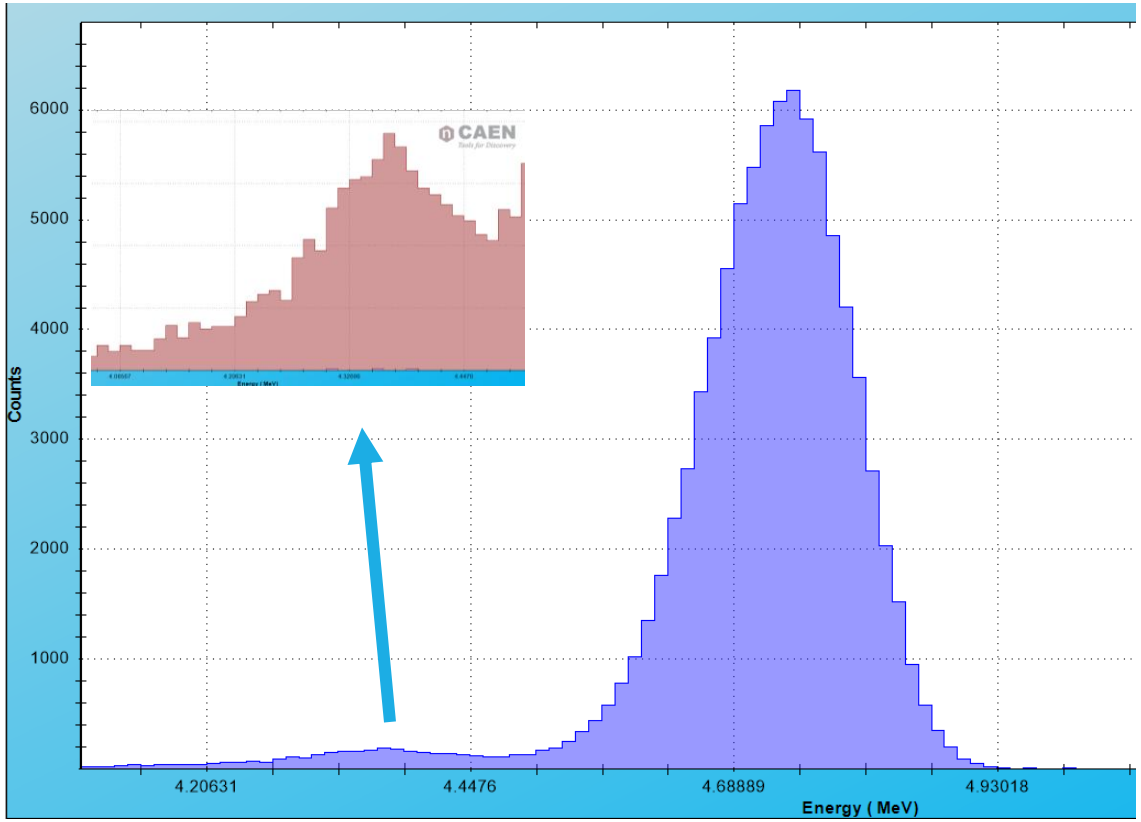
Known alpha Emitter		
Isotope	Energy [MeV]	Probability [%]
^{238}Pu	5,49921	72
^{238}Pu	5,4565	28
^{239}Pu	5,1554	73
^{239}Pu	5,1429	15,1
^{239}Pu	5,1046	11,5
^{233}U	4,8236	84

Histogram of the spectrum obtained from the calibration alpha source



Data Analysis

Histogram of the spectrum of the unknown alpha emitter



- Two peaks are visible in the spectrum.
- One with peak at 4,36 MeV.
- Second with peak at 4,74 MeV.

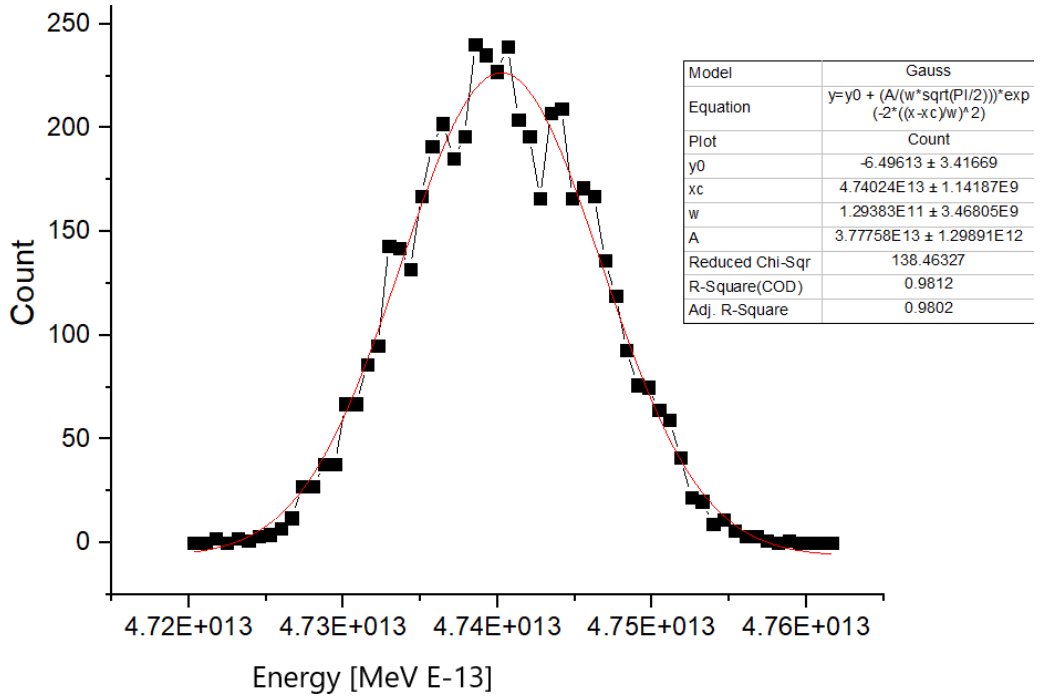
These energies are close to the alpha signatures of ^{235}U and ^{234}U having, 4.3978(13) MeV and 4.7746(7) MeV respectively.

However energies measured are lower than those from literature because the target has thickness.

Data Analysis

SRIM -> Origin

Plot showing the simulated deviation in energy of alpha particles as they pass through Uranium



Model	Gauss
Equation	y=y0 + (A/(w*sqrt(PI/2)))*exp(-2*((x-xc)/w)^2)
Plot	Count
y0	-6.49613 ± 3.41669
xc	4.74024E13 ± 1.14187E9
w	1.29383E11 ± 3.46805E9
A	3.77758E13 ± 1.29891E12
Reduced Chi-Sqr	138.46327
R-Square(COD)	0.9812
Adj. R-Square	0.9802

Using SRIM software the thickness was estimated as 150 ug\cm2 of U material.

Using the amount of events in each peak and duration of the experimental run, you can calculate activity (R)

$$N = \frac{R t_{1/2}}{0{,}693}$$

R – reaction rate [decays/year]

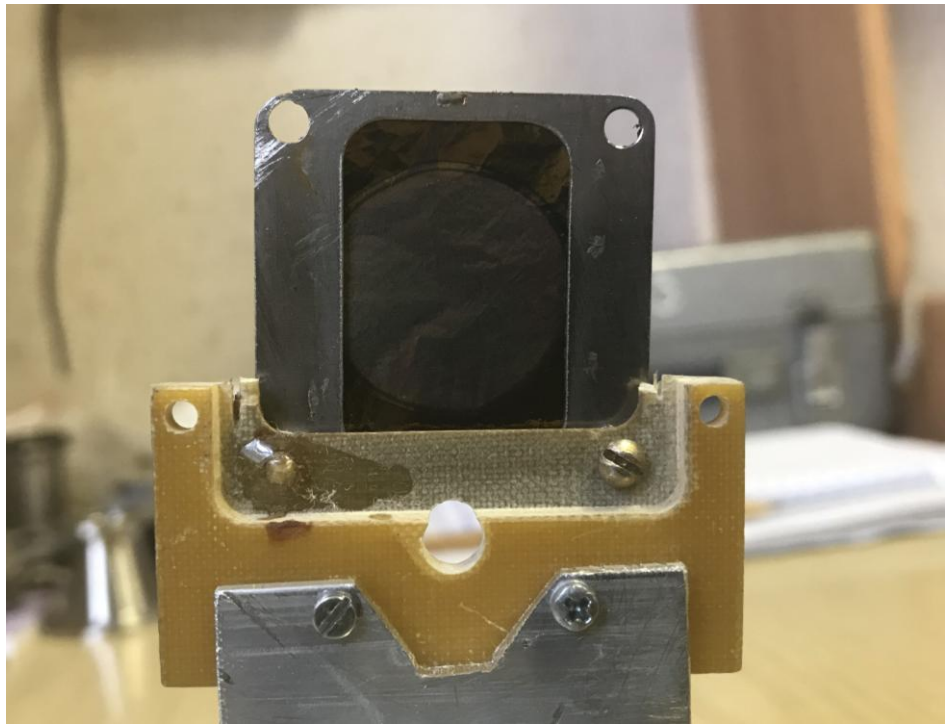
$t_{1/2}$ – Half life [year]

N – Number of nuclei

With this equation I could calculate the isotopic composition of the Uranium target

Results

The unknown target consisted of 98.94% ^{235}U and 1.06% ^{234}U



Some additional comments:

There is a third peak visible in the spectrum close to 4,198 MeV.

This peak would suggest the presence of ^{238}U

There are too few data point in this peak to make a statistically reliable conclusion.

Rough calculation estimates an experimental run of 38 days would produce useable results.

Due to the low activity/low amount of ^{238}U