In the name of Allah

A Systematic Study Of Complete Fusion And Multinucleon Transfer Reactions with heavy ion beams of ^{48}Ca and ^{40}Ar Using MASHA Apparatus.

Presented By

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Introduction

- **Flerov Laboratory of Nuclear Reactions (FLNR)**

Flerov Laboratory of Nuclear Reactions is one of the world's leading research centers in the field of nuclear physics.

The main activity of the lab is research in heavy-ion physics focuses on three major areas:

- ❑ Synthesis and properties of nuclei at the limits of stability.
- ❑ Accelerator complex of ion beams of stable and radioactive nuclides (DRIBs-III).
- ❑ Radiation effects and physical bases of nanotechnology, radioanalytical and radioisotope investigations at the FLNR accelerators.

- **Dr. V. Vedeneev** - Research Scientist at JINR, Dubna, Russia. *(Project supervisor)*

Introduction

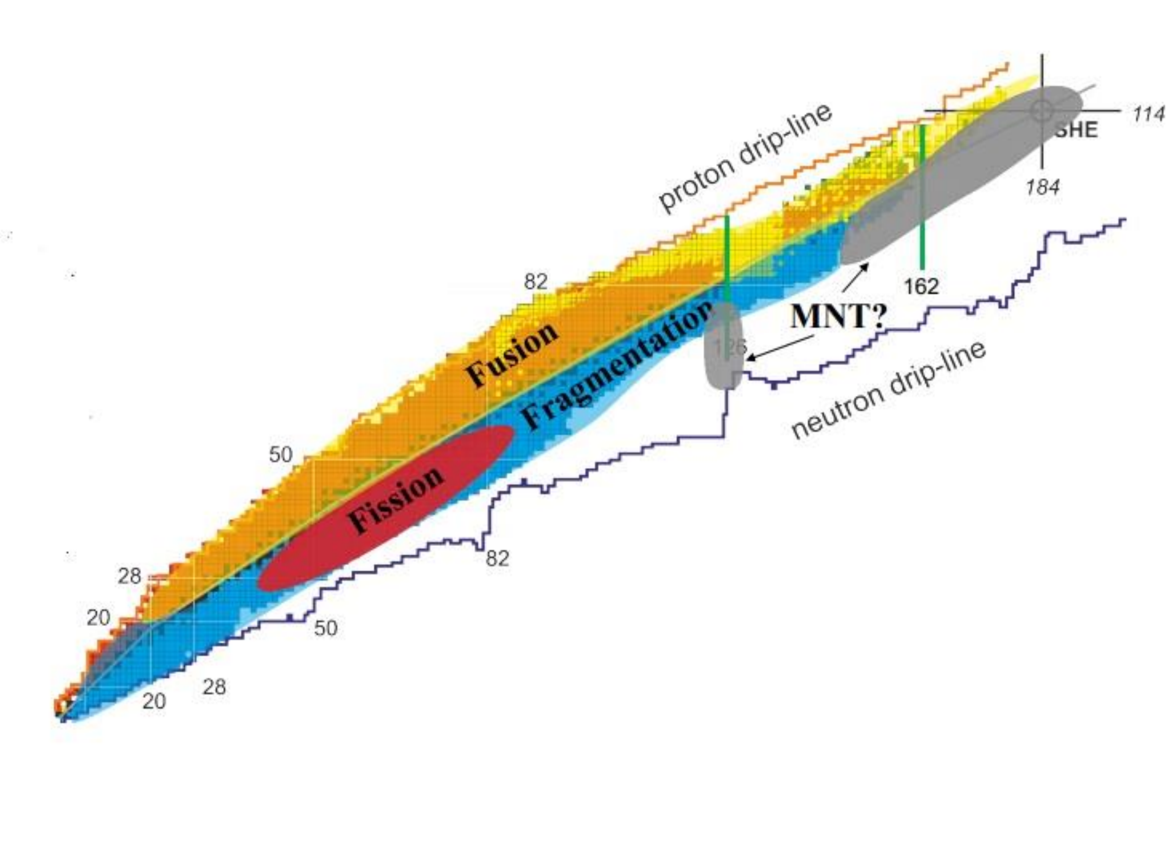
Methods of synthesis of new nuclei :-

- Fusion:
  + any element (question of probability)
  - lack of neutrons

- Fragmentation:
  + very efficient and universal
  - products are lighter than ^{238}U

- Fission:
  + neutron-rich products
  - products are much lighter than ^{238}U

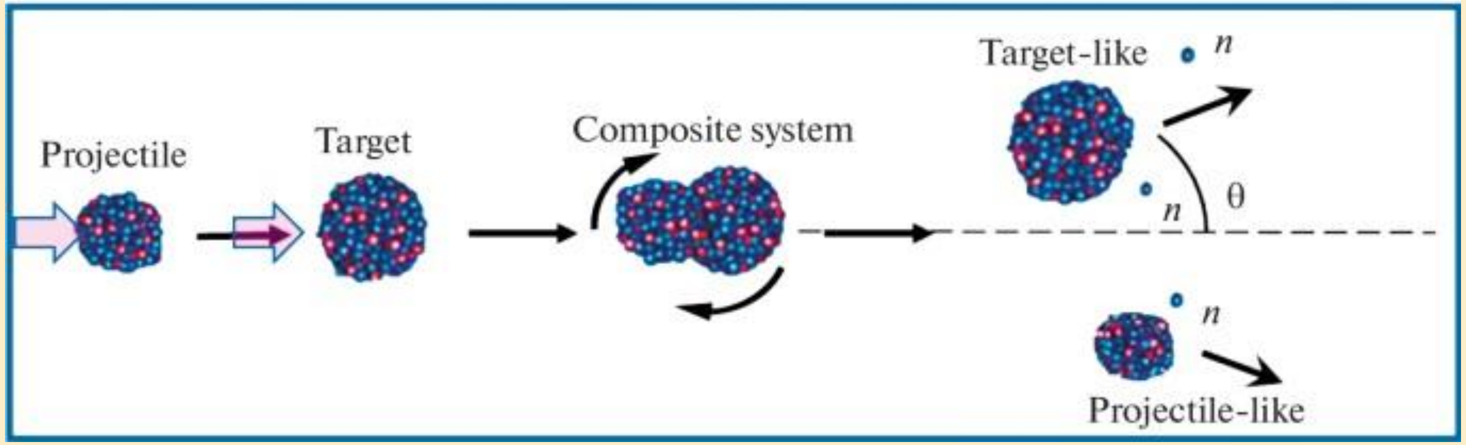
- Multinucleon transfer (MNT):
  + a way to unknown regions
  - Variety of outputs



Introduction

Multinucleon transfer (MNT): :-

This kind of reactions happens between heavy ions with some aiming parameter at energies around the Coulomb barrier and are characterized by the exchange of many nucleons between the target and the projectile.
They have been extensively used in the last decades to populate moderately neutron-rich mid-mass nuclei with cross sections large enough to study their structure.



$$^{A_x}_{Z_x}X + ^{A_Y}_{Z_Y}Y \xrightarrow{MNT} {}^{A_x+A_Y-A_{PLN}-xn}_{Z_{TLN}}TLN + Xn + PLN$$

Aim of the Project

- The project has been denoted to the analysis evaporation residues collected from reactions of complete fusion and multi-nucleon transfer reactions of

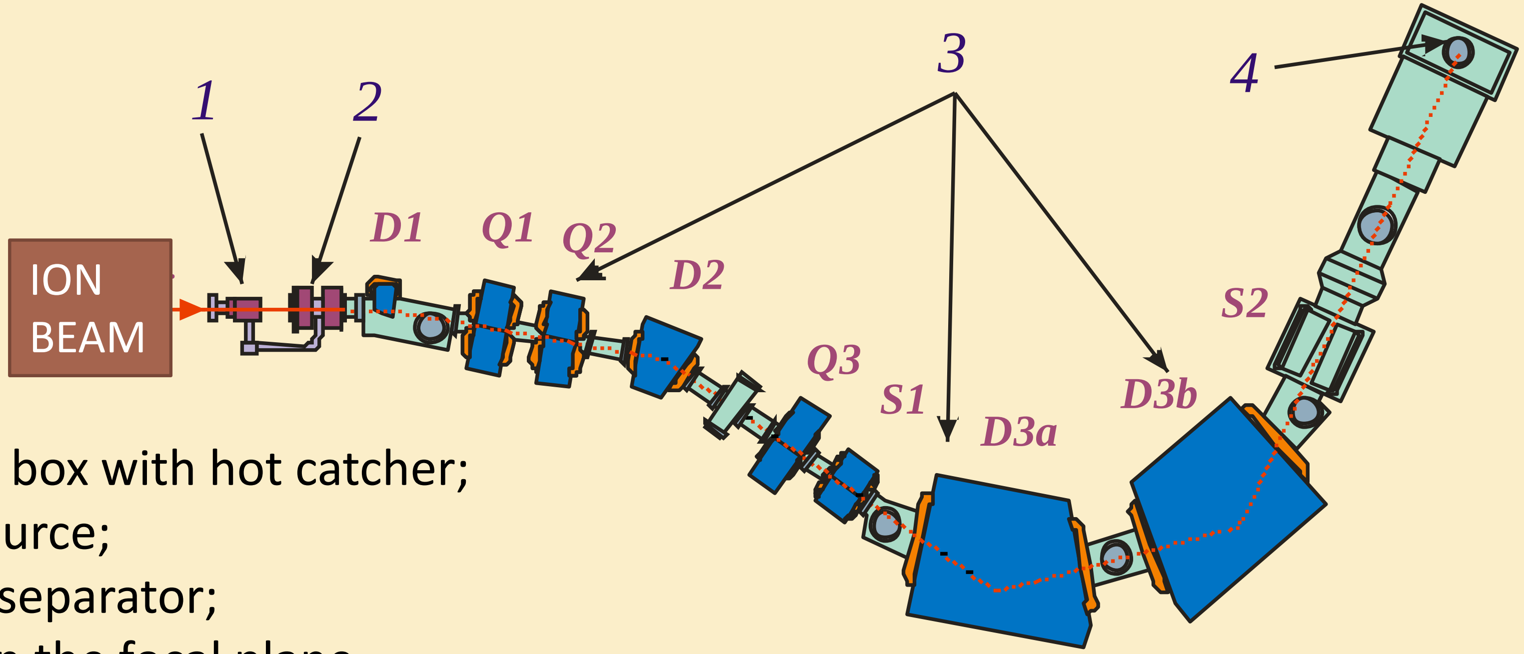
  - $^{40}Ar + ^{144}Sm \rightarrow ^{186-xn}Hg + xn$
  - $^{40}Ar + ^{166}Er \rightarrow ^{220-xn}Rn + xn$
  - $^{48}Ca + ^{242}Pu \xrightarrow{MNT} ^{220-xn}Rn + xn$

- The products of these reactions were separated by using the methodic of Isotope Separation OnLine (ISOL), and they have been detected by multi-channel Si detector based in the main focal plane of the MASHA installation.

Facility Description - MASHA

The **MASHA** setup stands for **M**ass **A**nalyzer of **S**uper **H**eavy **A**toms. The apparatus has a resolving power of about 1700 by mass and uses the so-called ISOL (**I**sotope **S**eparation **O**n-**L**ine) method to separate the reaction products.

Facility Description - MASHA



1 – Target box with hot catcher;
2 – Ion source;
3 – Mass separator;
4 – DAQ in the focal plane.

The proposed setup is a combination of the so-called ISOL method of synthesis and separation of radioactive nuclei with the classical method of mass analysis, allowing mass identification of the synthesized nuclides in the wide mass range (A = 1-450 u).

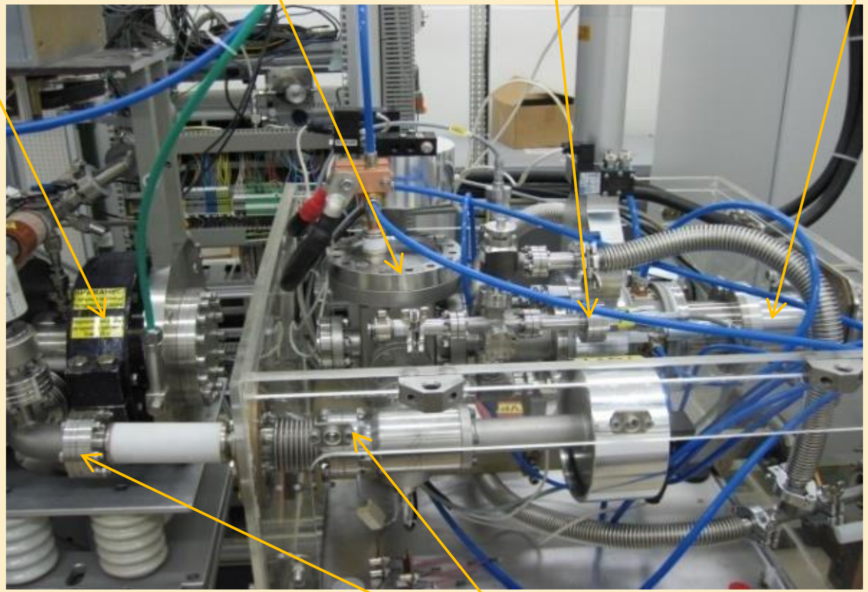
Project Design

ECR
ion source

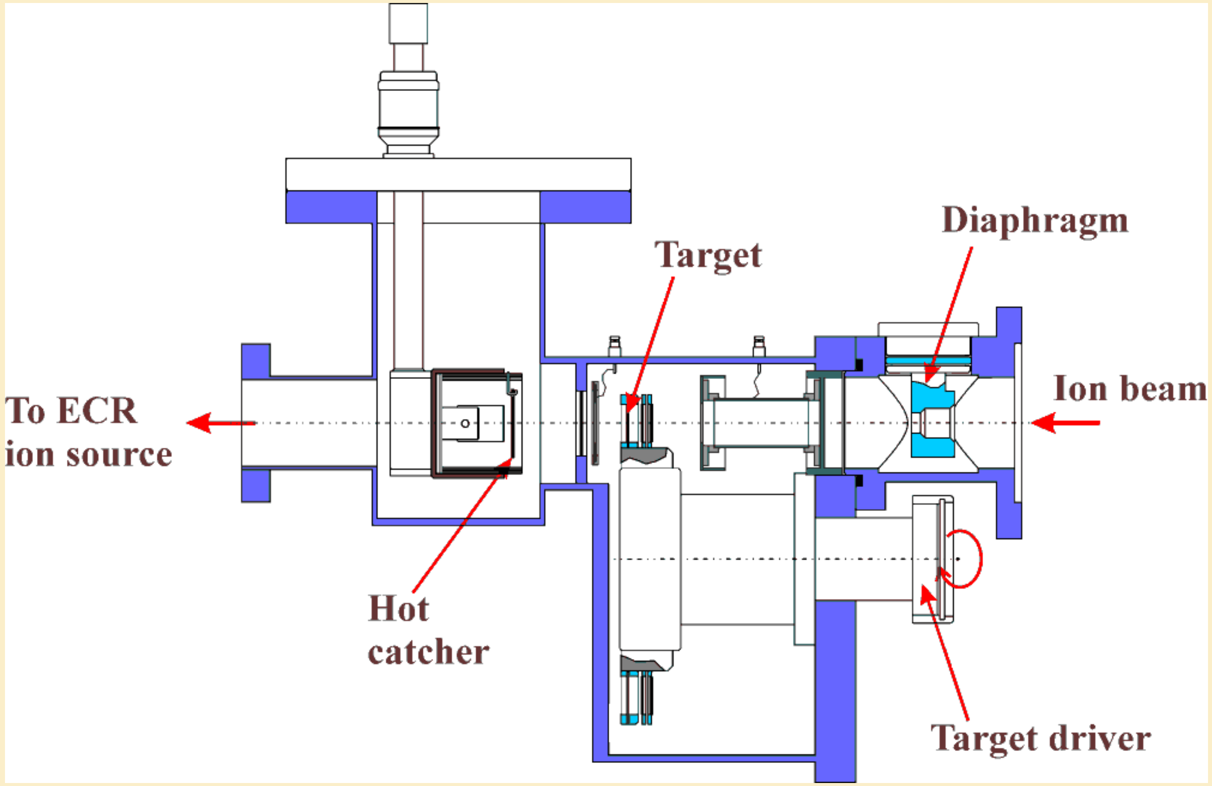
Hot catcher

Target

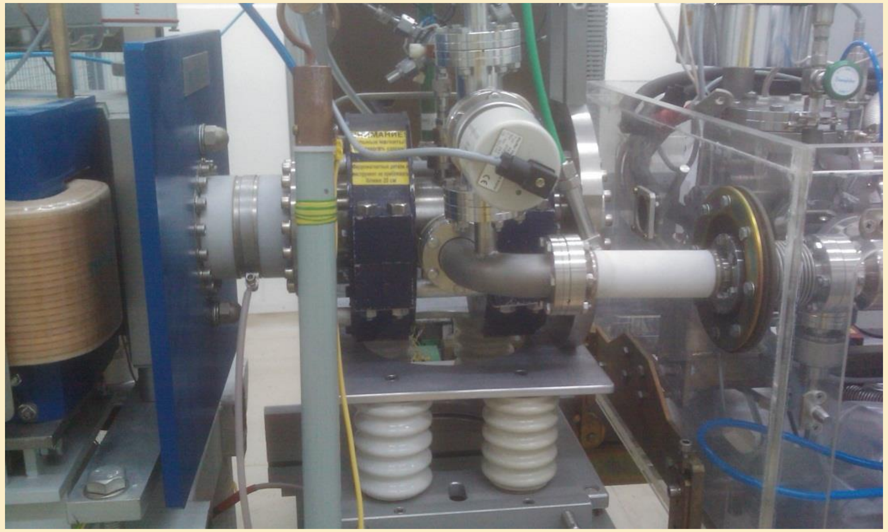
Beam line



Recoil transport



Project Design



Ion source + Hot catcher

Nuclear reaction products escape from the target, pass through the separating foil, and are stopped in the graphite absorber. In the form of atoms, the products diffuse from the graphite absorber to the vacuum volume of the hot catcher and, moving over the pipeline, reach the ECR source, where are ionized to charge state Q = +1 and accelerated with the aid of the three-electrode system.

Project Design

Focal plane silicon multi strip detector

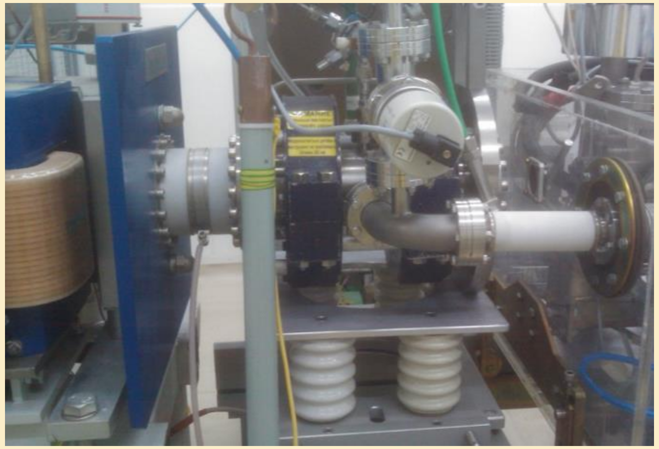
Silicon detector well-type:

Side: 4 crystals each side 16 strips. Pitch 5 mm;

Front: 3 crystals 64 strips each. Pitch 1.25 mm;

Latter: 1 crystal like side ones.

Project Design



Results

- The collision between ^{40}Ar (projectile) and a target of ^{148}Sm occurs within the MASHA system

$$^{40}Ar + ^{148}Sm \rightarrow ^{188-xn}Hg + xn$$

$$^{40}Ar + ^{148}Sm \rightarrow ^{180}Hg + 8n \quad (2.58\ S)$$

$$^{40}Ar + ^{148}Sm \rightarrow ^{181}Hg + 7n \quad (3.54\ S)$$

$$^{40}Ar + ^{148}Sm \rightarrow ^{182}Hg + 6n \quad (10.84\ S)$$

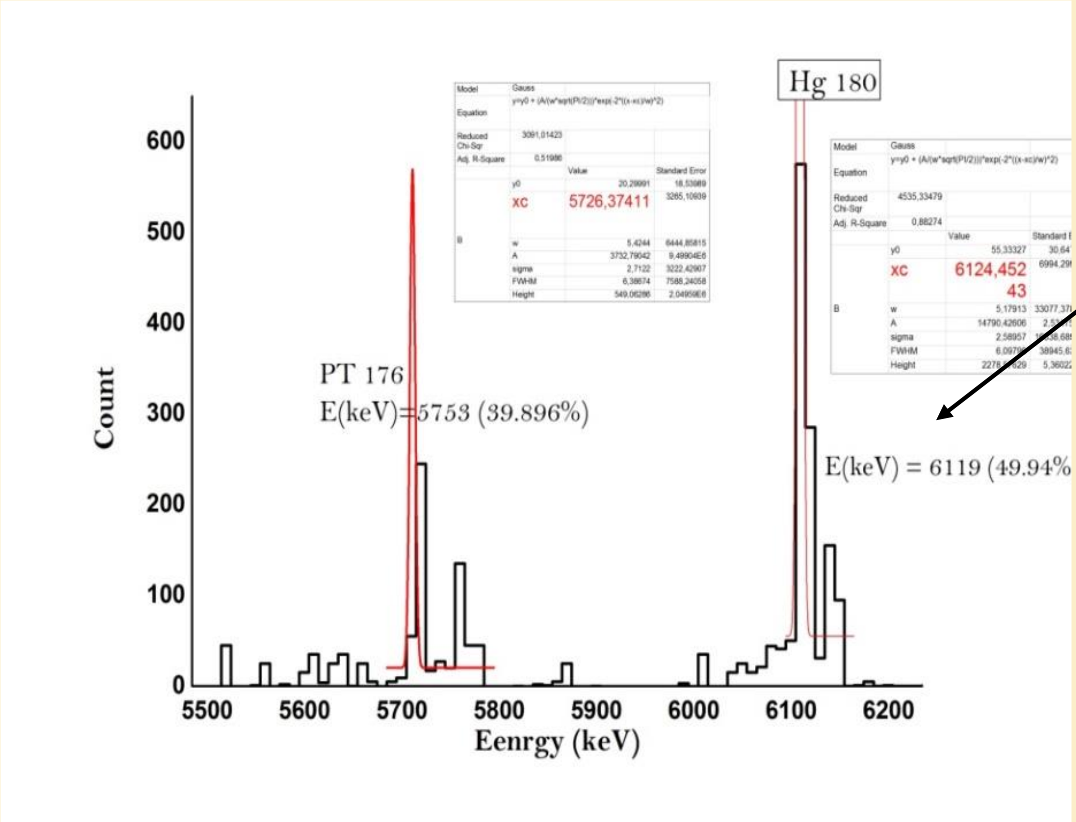
$$^{40}Ar + ^{148}Sm \rightarrow ^{183}Hg + 5n \quad (9.4\ S)$$

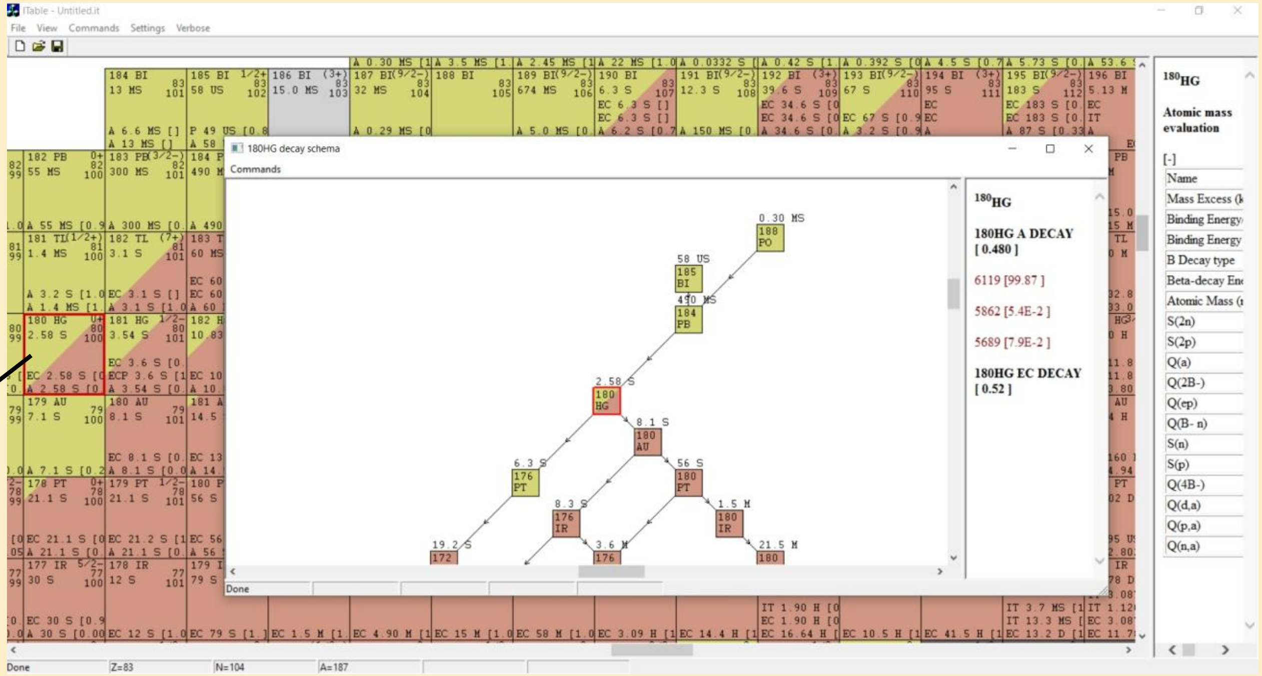
$$^{40}Ar + ^{148}Sm \rightarrow ^{184}Hg + 4n \quad (30.9\ S)$$

$$^{40}Ar + ^{148}Sm \rightarrow ^{185}Hg + 3n \quad (49.1\ S)$$

Results

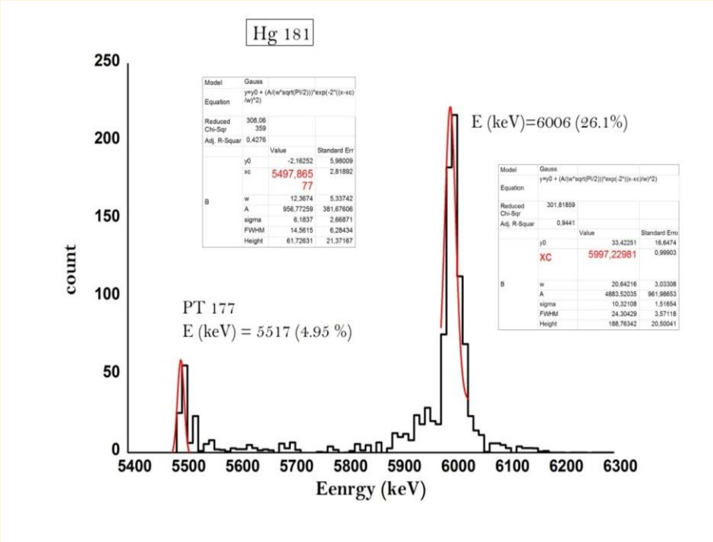
Energy calibration curve of ^{180}Hg isotope

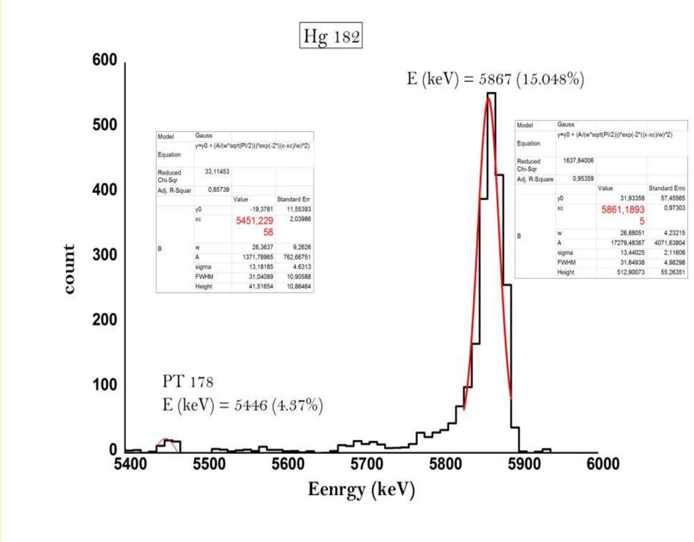


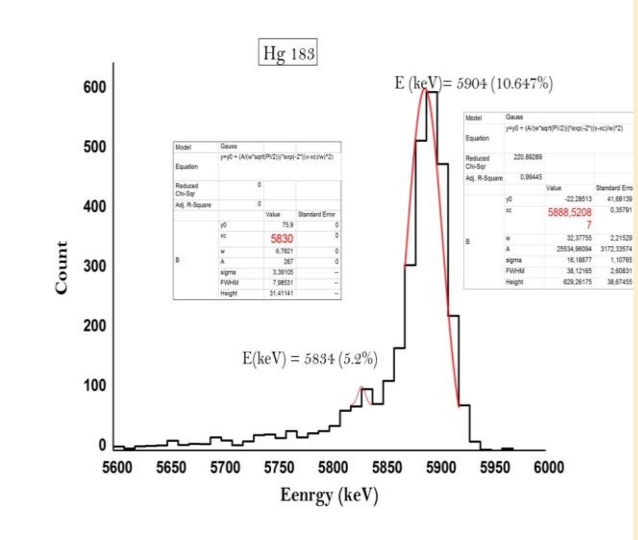


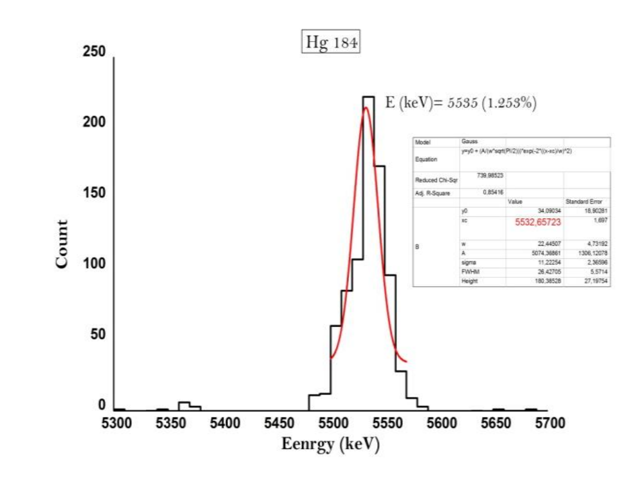
Scheme of the chain reactions of ^{180}Hg isotope

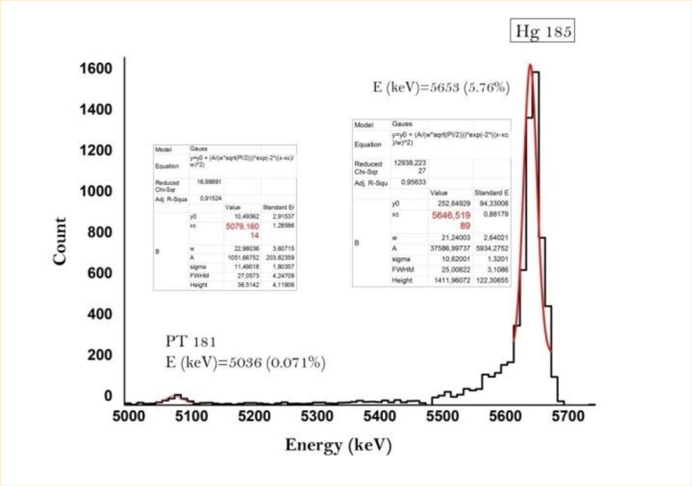
Results


Hg 181
E (keV)=6006 (26.1%)
PT 177
E (keV) = 5517 (4.95 %)
count
Eenrgy (keV)


Hg 182
E (keV) = 5867 (15.048%)
PT 178
E (keV) = 5446 (4.37%)
count
Eenrgy (keV)

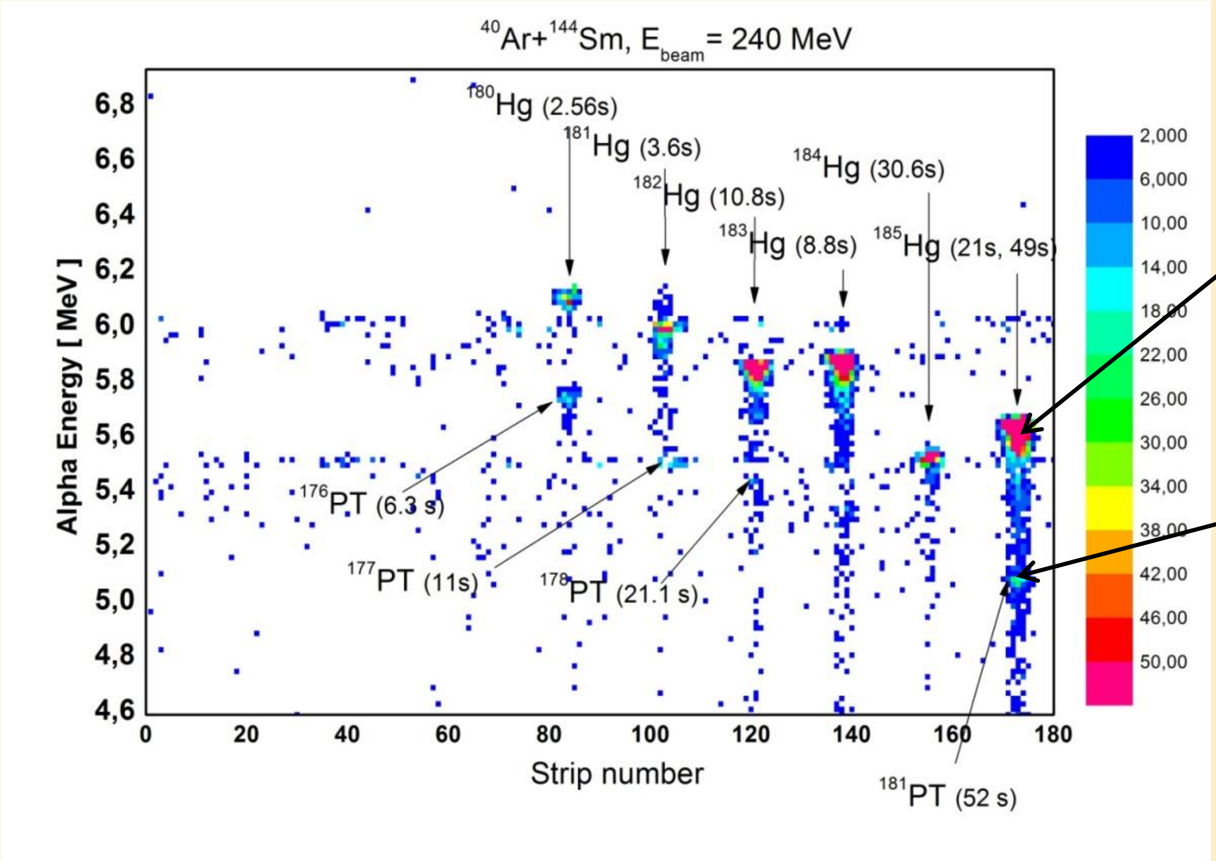

Hg 183
E (keV)= 5904 (10.647%)
E(keV) = 5834 (5.2%)
Count
Eenrgy (keV)

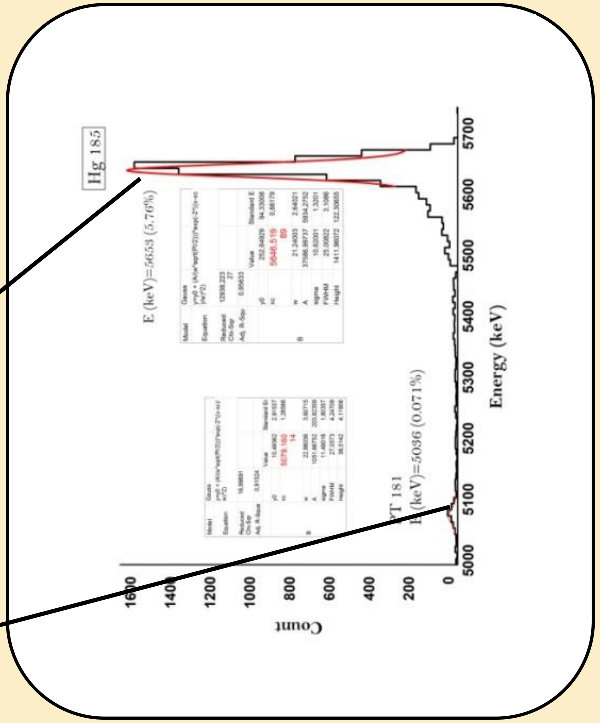

Hg 184
E (keV)= 5535 (1.253%)
Count
Eenrgy (keV)


Hg 185
E (keV)=5653 (5.76%)
PT 181
E (keV)=5036 (0.071%)
Count
Energy (keV)

Results

The mass-energy spectra (heat map) of the mercury isotopes (Hg 180-185) by Origin.





Results

- The collision between ^{40}Ar (projectile) and a target of ^{166}Er occurs within the MASHA system

$^{40}Ar + ^{166}Er \rightarrow ^{206-xn}Rn + xn$

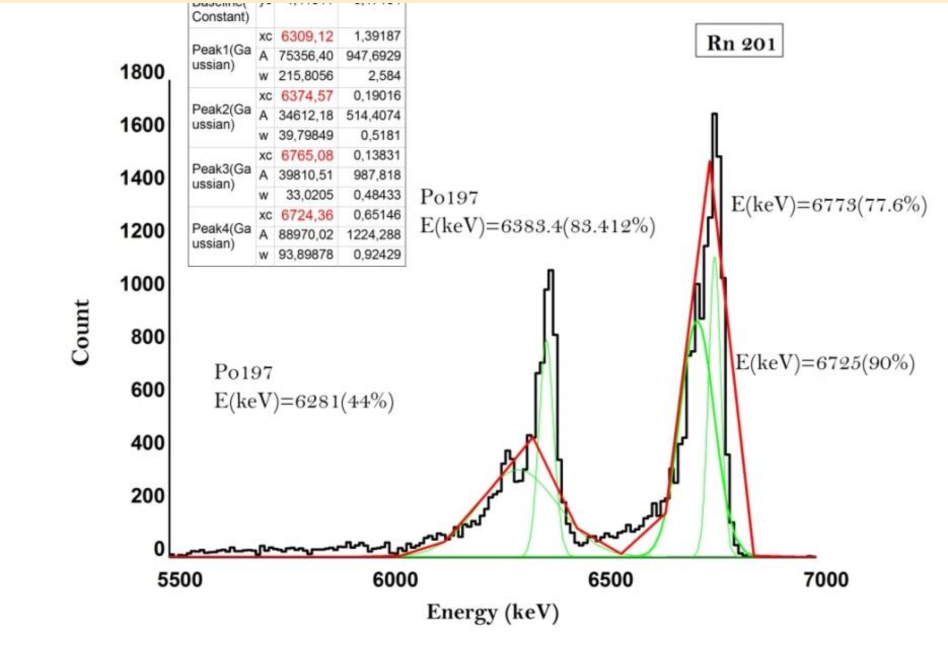
$^{40}Ar + ^{166}Er \rightarrow ^{201}Rn + 5n$ (1.06 s)

$^{40}Ar + ^{166}Er \rightarrow ^{202}Rn + 4n$ (3.8 s)

$^{40}Ar + ^{166}Er \rightarrow ^{203}Rn + 3n$ (9.85 s)

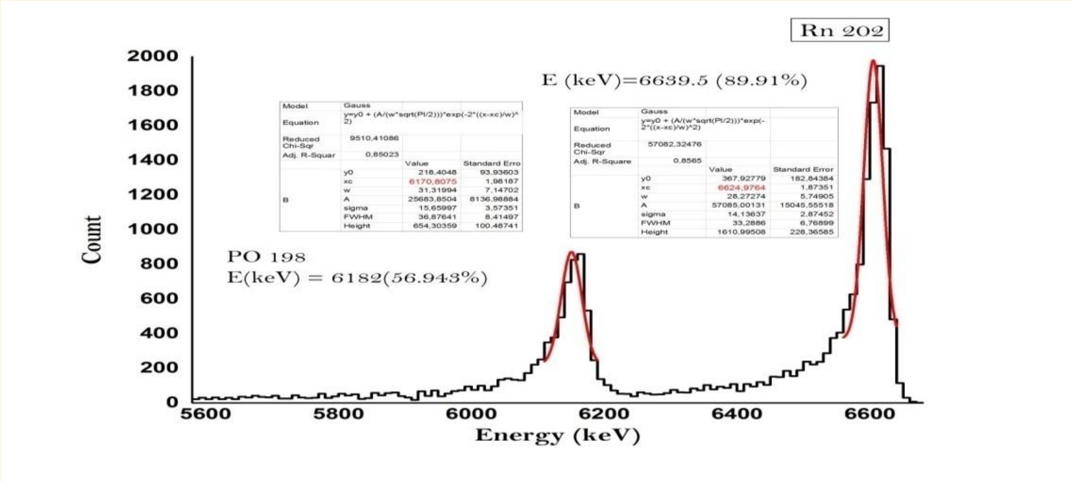
$^{40}Ar + ^{166}Er \rightarrow ^{204}Rn + 2n$ (28 s)

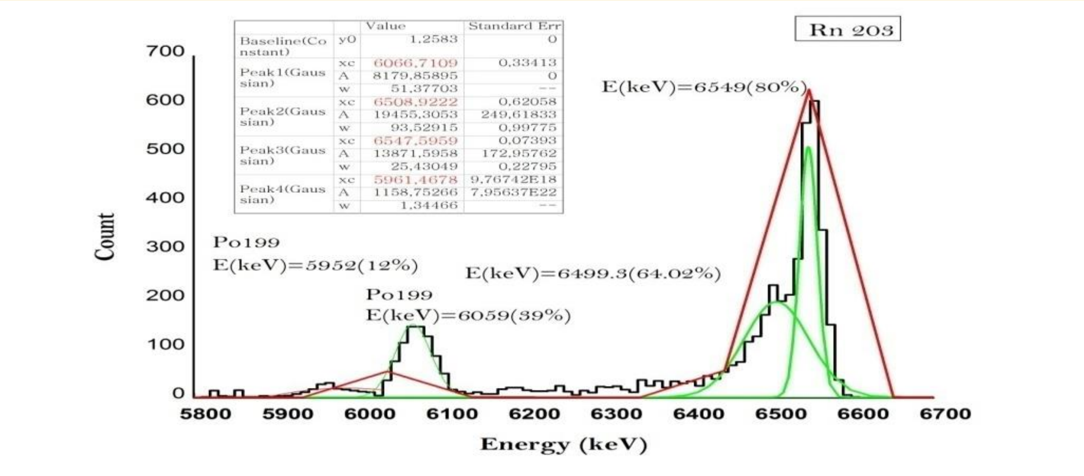
$^{40}Ar + ^{166}Er \rightarrow ^{205}Rn + n$ (1.24 m)

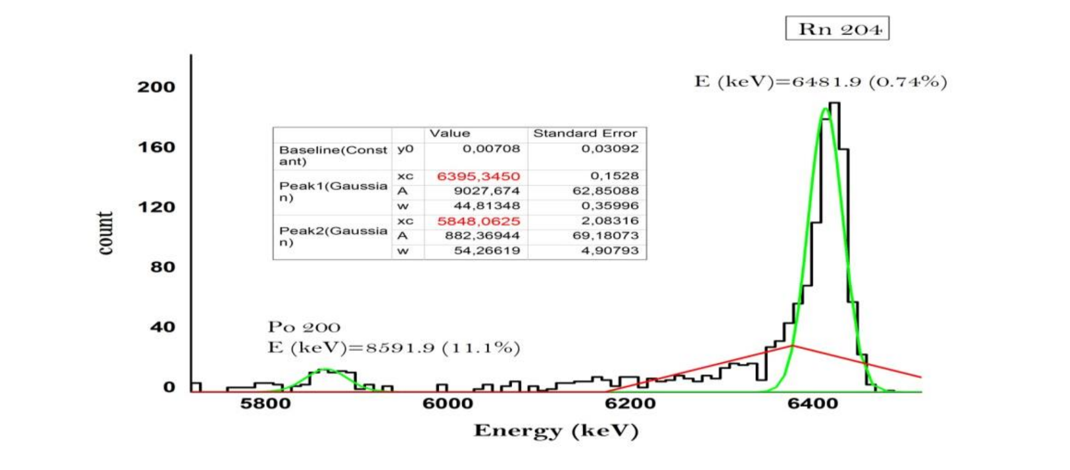


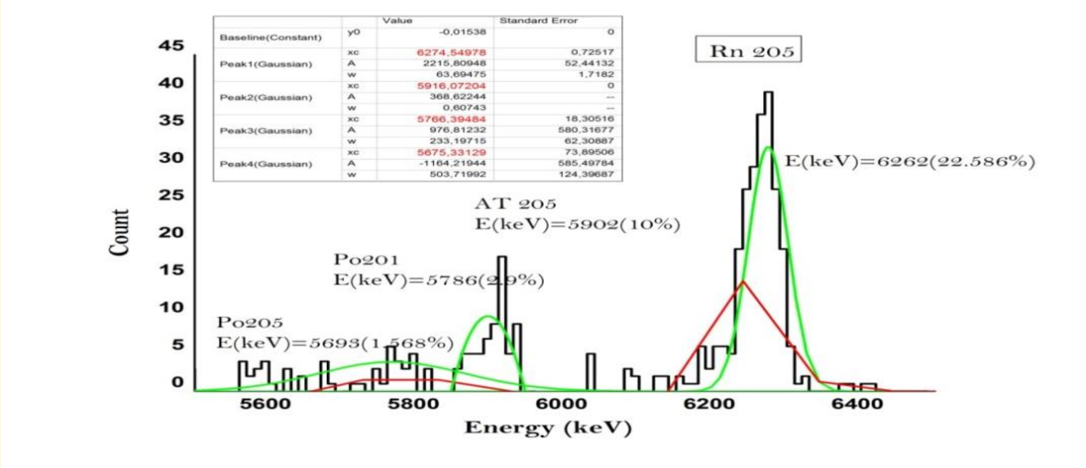
Energy calibration curve of ^{201}Rn Isotope

Results



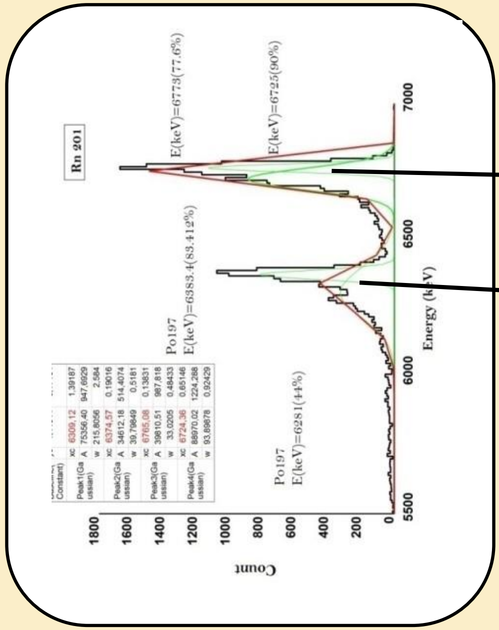


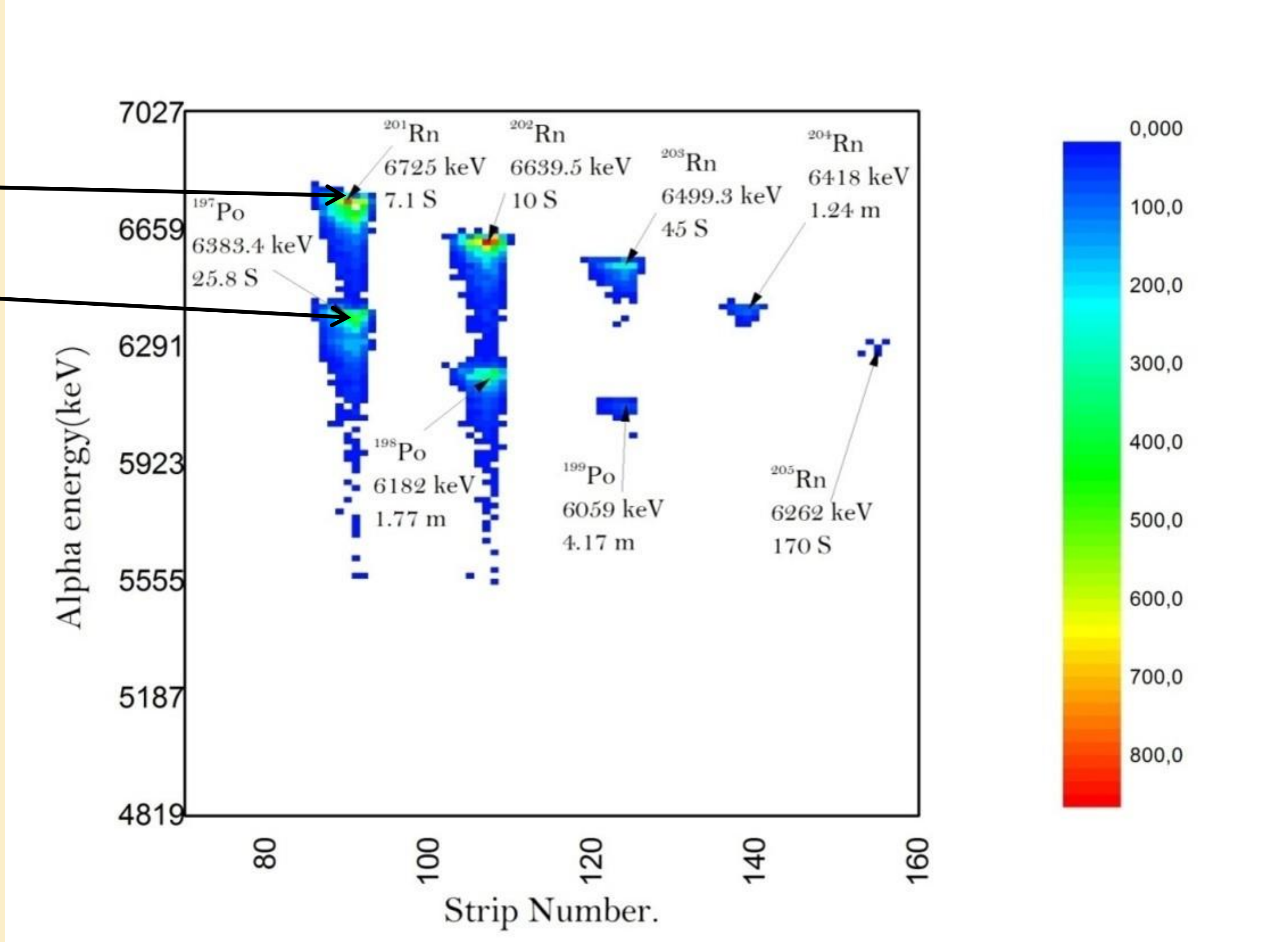




Energy calibration curve of ^{202}Rn, ^{203}Rn, ^{204}Rn and ^{205}Rn Isotopes

Results





The mass-energy spectra (heat map) of the radon isotopes (Rn 201-205) by Origin.

Results

$^{48}Ca + ^{242}Pu \rightarrow ^{290-xn}Fl + xn \rightarrow Rn$

Here was another type of reactions were occurred, MNT (Multi Nucleon Transfer), so radon is the volatile product.

^{212}Rn (23.9 m)

^{213}Rn (25 ms)

^{214}Rn (0.27 µs)

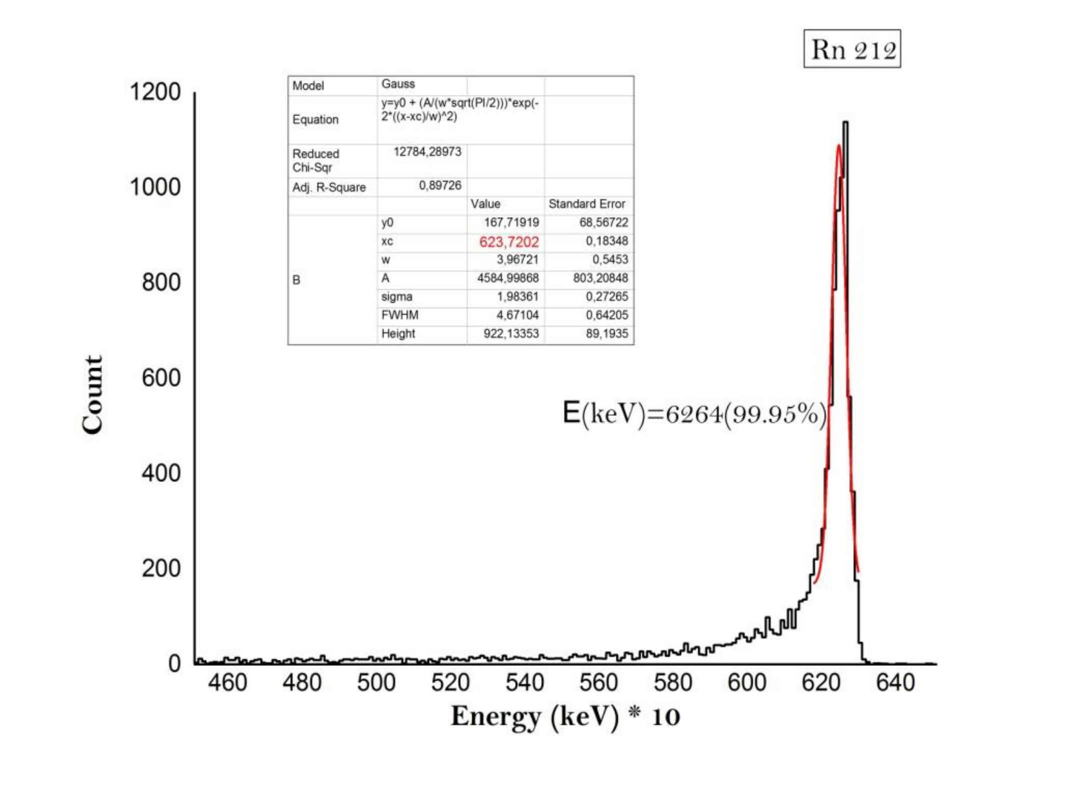
^{215}Rn (2.3 µs)

^{216}Rn (45 µs)

^{217}Rn (0.54 ms)

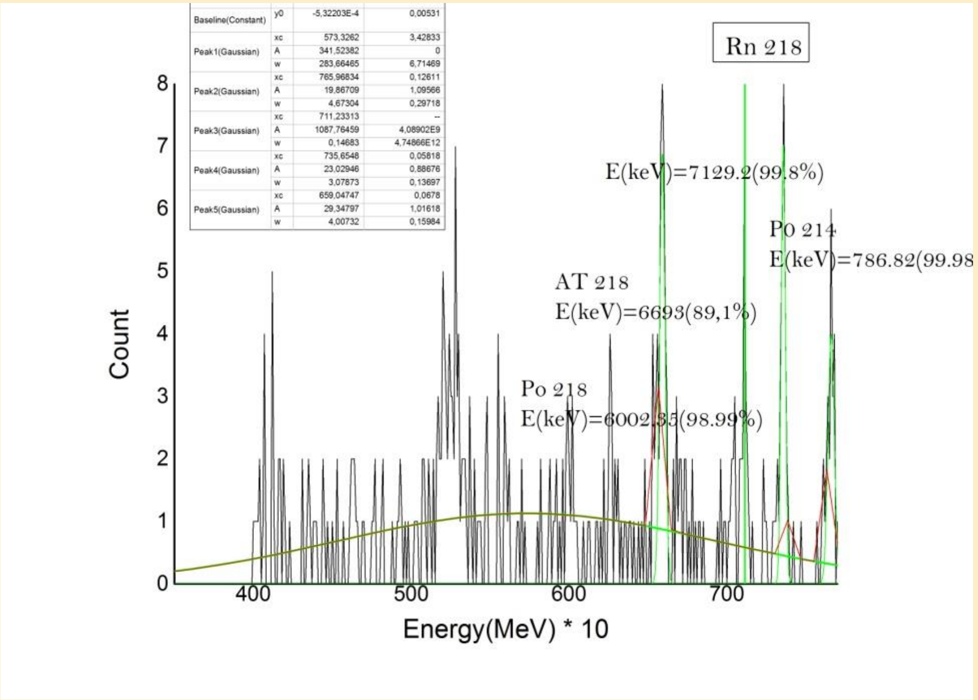
^{218}Rn (35 ms)

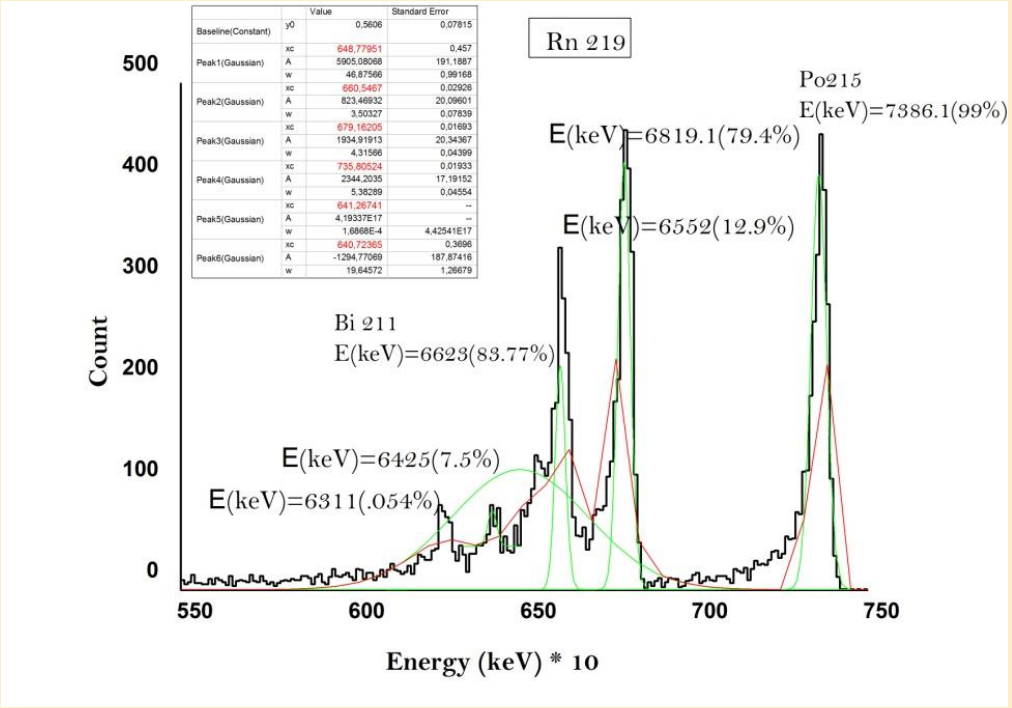
^{219}Rn (3.96 s)



Energy calibration curve of ^{212}Rn Isotope

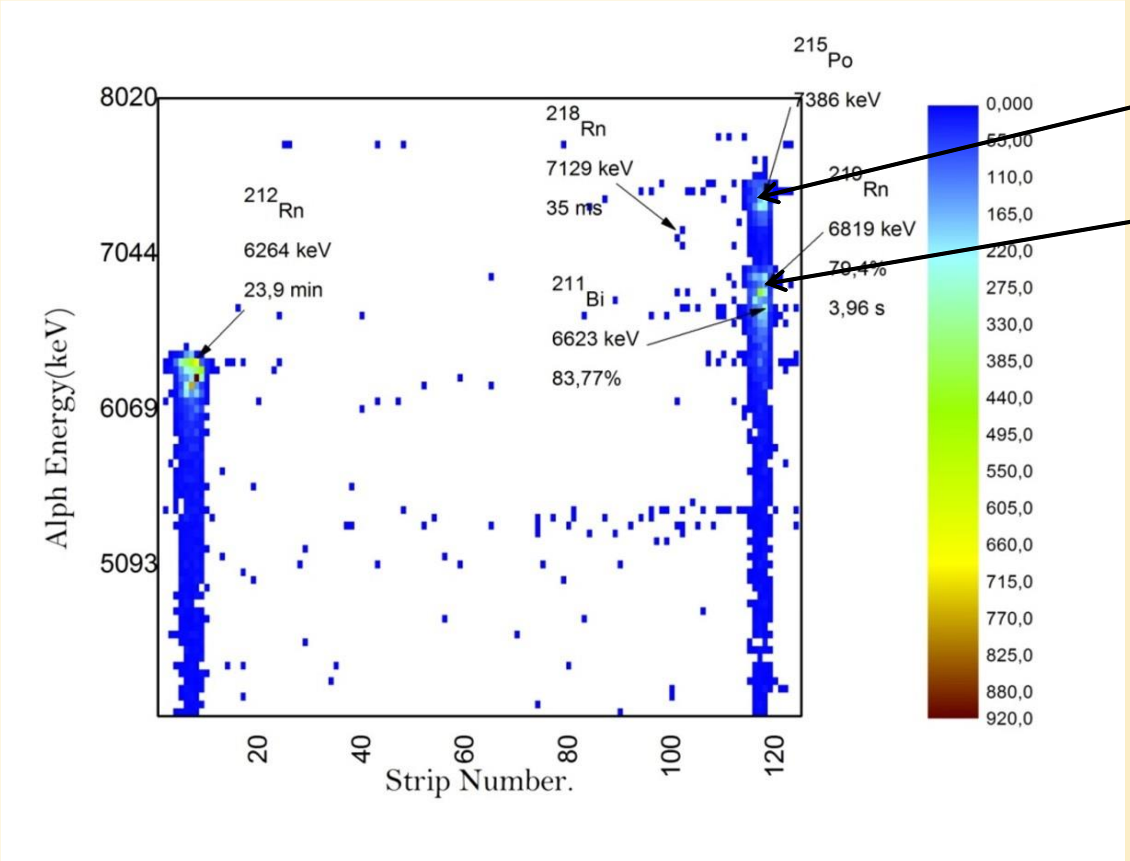
Results

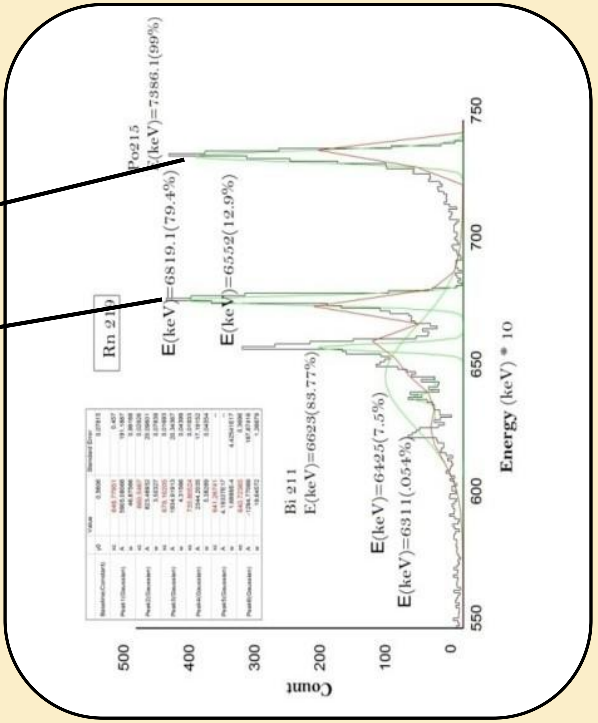




Energy calibration curve of ^{218}Rn and ^{219}Rn Isotopes

Results





The mass-energy spectra (heat map) of the radon isotopes (Rn 212, 218, 219) by Origin.

Conclusion

- ✓ The literature overview of new neutron-rich isotopes near N=126 shell closure and the literature overview about the MASHA mass spectrometer has been performed.
- ✓ The data analysis of $^{180-185}Hg$, $^{201-205}Rn$ and $^{212,218,219}Rn$ was made using α-decay spectrometry.
- ✓ Origin Software was used to find and fit the peaks and drawing the heat maps
- ✓ The results of the data analysis was shown. The calibrations of 2D-spectra were performed. They have been compared to the values provided by the Nuclear Chart, and no deviations were found.

Thank You for your attention …

منجيلكمش ف حاجة وحشة …