Determination of masses of the super heavy elements in the experiments on synthesis of Cn and Flusing the reactions 48Ca + 242Pu and 48Ca + 244Pu

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JINR Interest Training program (1st Wave)

2020

Abstract

the separation efficiency of mercury could predict the separation efficiency of super heavy elements and thus predict its expected yields. The calculation of super heavy elements (SHE) by their mass-to-charge ratios, being by MASHA analysis, it is observed that the full fusion reactions are very low due to its low cross-sections of several nanobarns and leading to Hg and Rn.

Introduction:

MASHA (Mass Analyzer of Super Heavy Atoms), has been designed at the Flerov Laboratory JINR Dubna to separate and measure masses of nuclei, the unique property of this mass-spectrometer: is ability to measure masses of the synthesized super heavy isotopes simultaneously with registration of their α-decay or spontaneous fission. Thus, electromagnetic mass separators are used very frequently in nuclear physics to separate mixtures of radioactive isotopes, and the fusion evaporation reaction will be: $^{40}Ar+^{nat}Sm$, $^{40}Ar+^{166}Er$.

Installation (Main Parts and Description):

1. Ion-Optical Layout:

The analyzer has four dipole magnets (D1, D2, D3a, D3b), three quadrupole lenses (Q1, Q2, Q3), two sextupole, lenses (S1, S2) and a focal plane detector system. it describes separate units of the facility and presents the results of measuring their basic parameters. [1]

2. Hot Catcher and ECR Ion source:

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. [1,2]

3. Detectors and control system:

a. Focal plane silicon multi strip detector: Configuration – well type, which consists of number of the focal strips – 192 (step– 1.25 mm), number of the back side strips – 160 (step – 5 mm), and the total efficiency – more than 90%.

b. TIMEPIX detector: It consists of an array of 256x256 square pixels of pitch size 55µm for full sensitive area 14x14 mm^2. Silicon sensor of 300 µm width, it can detect any type of radiation: α-, β-particles, fission fragments and electromagnetic radiation (γ- and X-rays). [1,2]

Method:

- The 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 precise mass measurements of the synthesized nuclides in the wide mass range.[1]
- Synthesized in nuclear reactions nuclides are emitted from an ECR ion source at energy E =40 keV and charge state Q= + 1. Then they pass the following steps of separation and analysis: the first section of rough

separation, the second section of separation and mass analysis and the final section of separation with a constant voltage on the plates of an electrostatic deflector, the deflector was installed in the U400M cyclotron injection channel. In the focal plane of the device, the positions (masses) of studied nuclei have determined. [1,3]

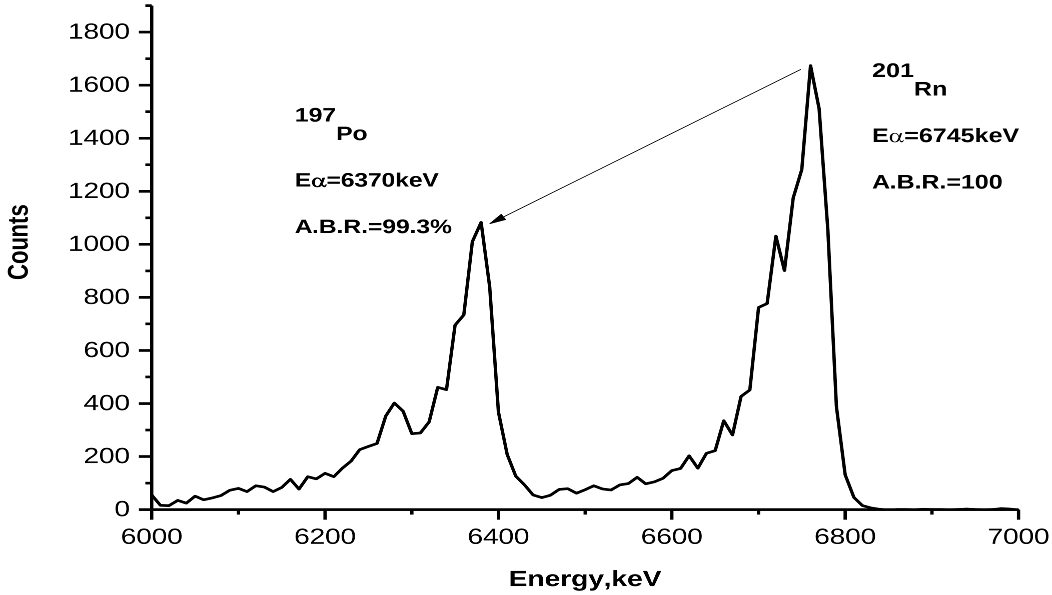
Task:

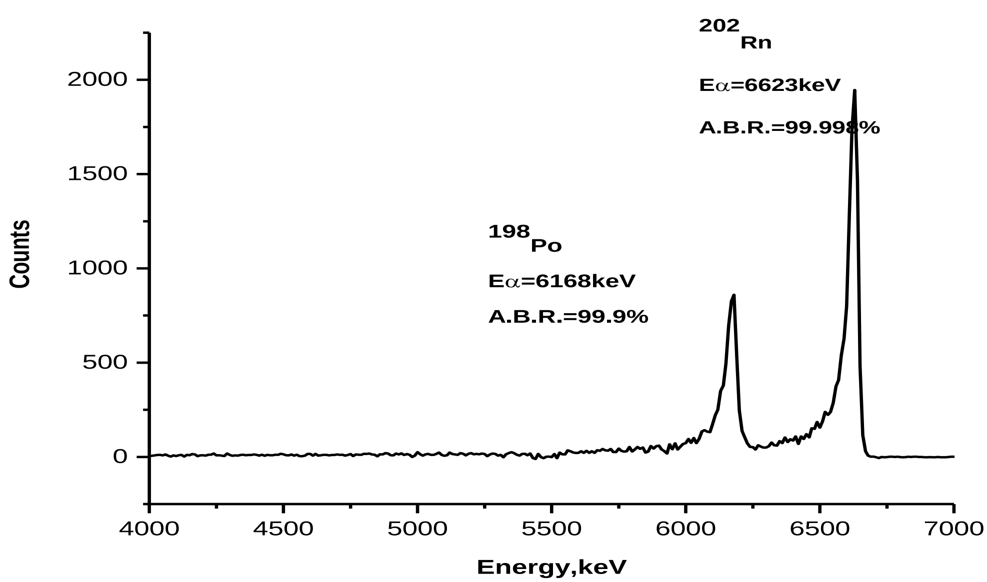
Determine the alpha branching ratios and alpha decay energy for every possible alpha emitter for three different reactions that obtained at the MASHA facility. doing the calibration of the strip detectors and graphing the results as a heat map.

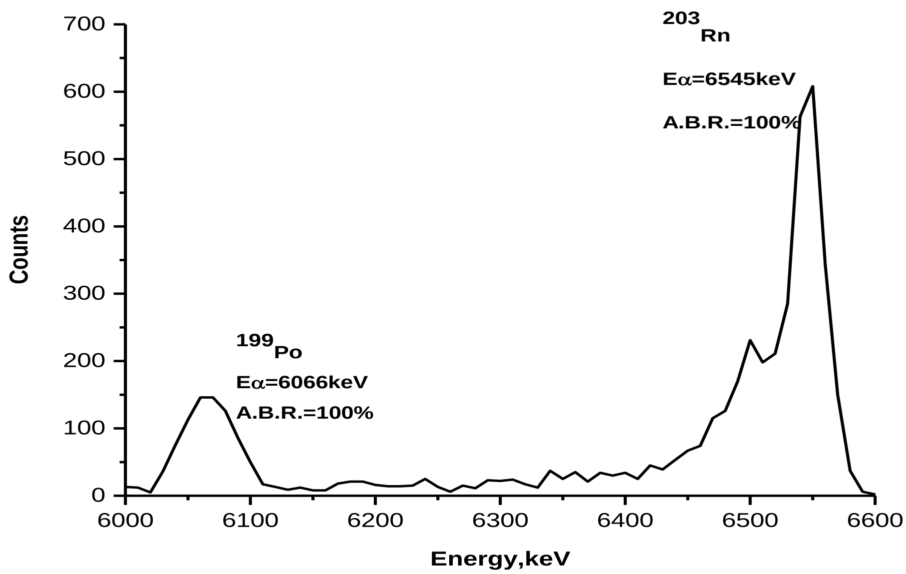
Results:

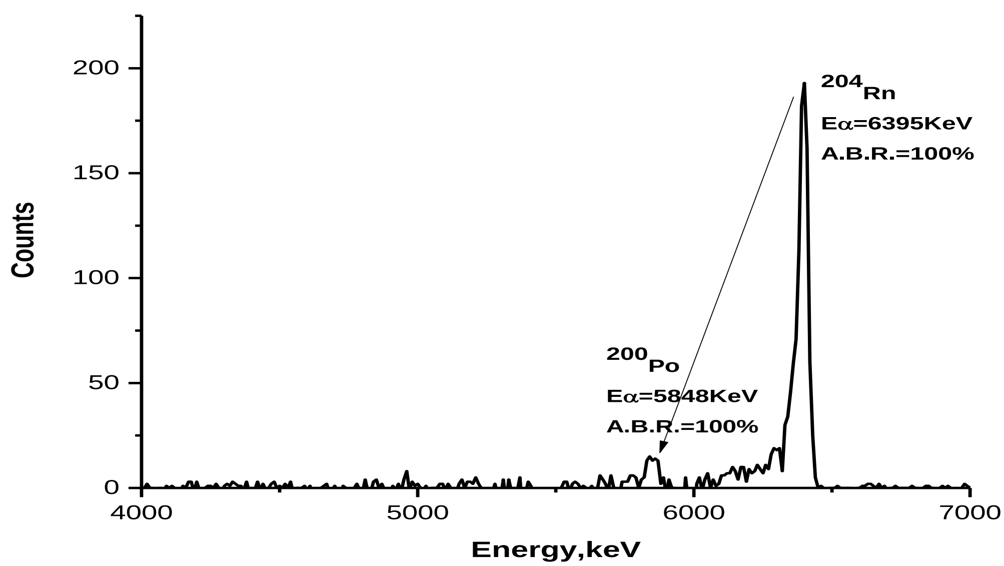
$^{40}Ar+^{166}Er$ reaction:

1-Dimensional spectra for Radon isotopes

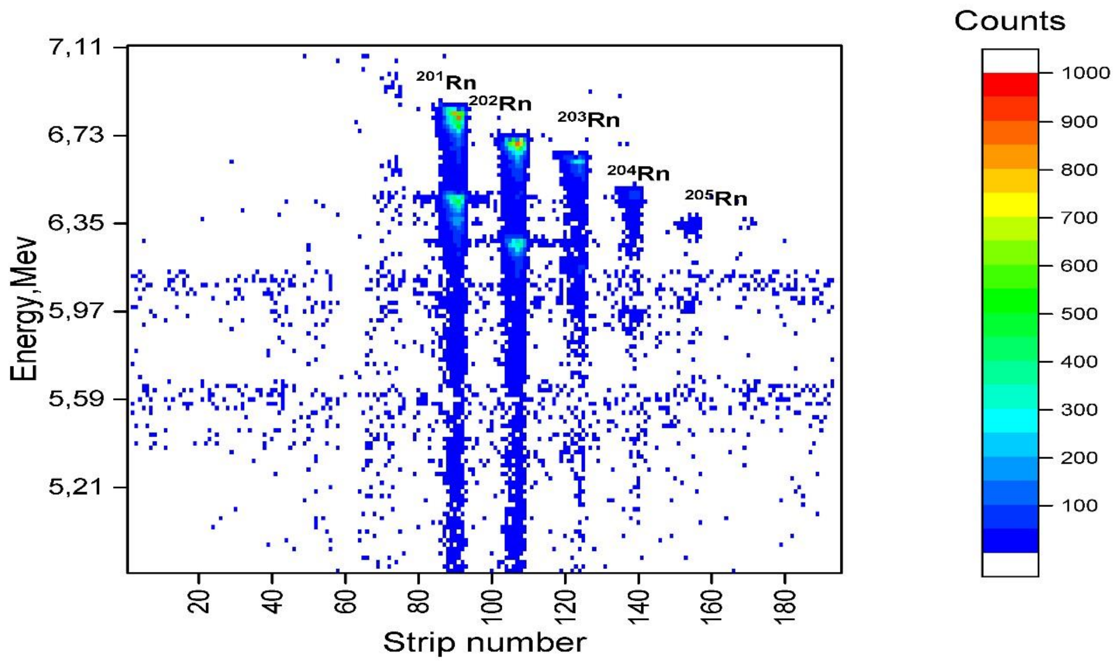

Counts
1800
1600
1400
1200
1000
800
600
400
200
0
6000
6200
6400
6600
6800
7000
Energy,keV
197Po
Eα=6370keV
A.B.R.=99.3%
201Rn
Eα=6745keV
A.B.R.=100


Counts
2000
1500
1000
500
0
4000
4500
5000
5500
6000
6500
7000
Energy,keV
198Po
Eα=6168keV
A.B.R.=99.9%
202Rn
Eα=6623keV
A.B.R.=99.998%



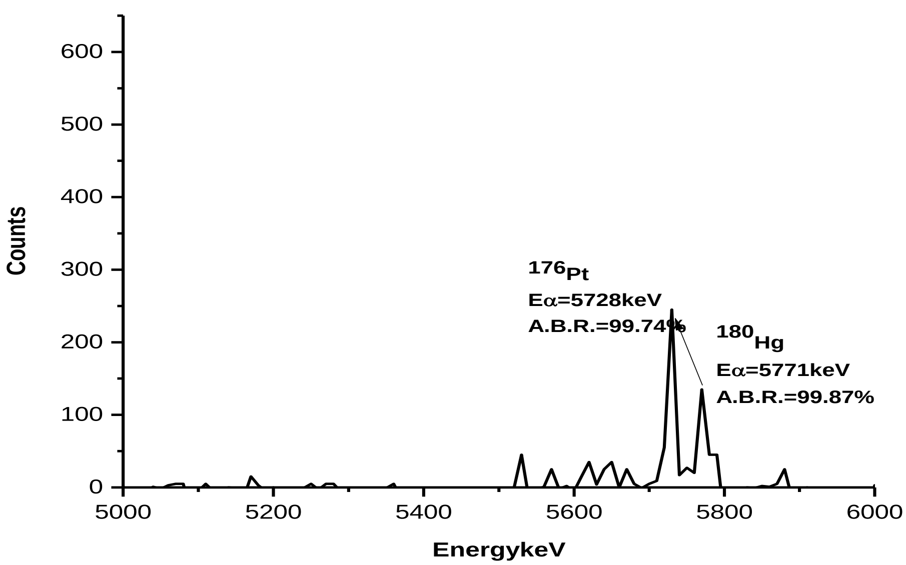


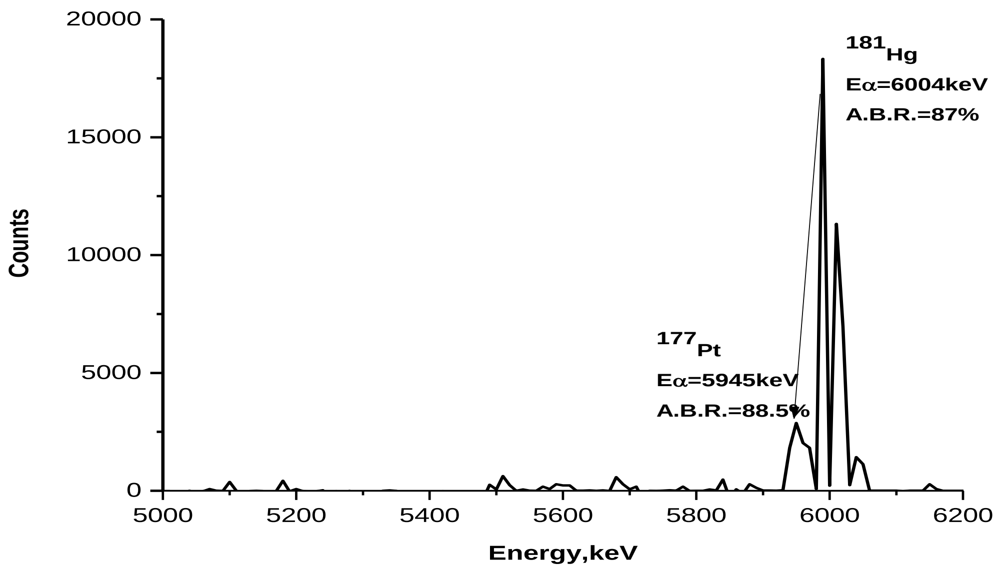
2-dimensional plot of alpha particle energies



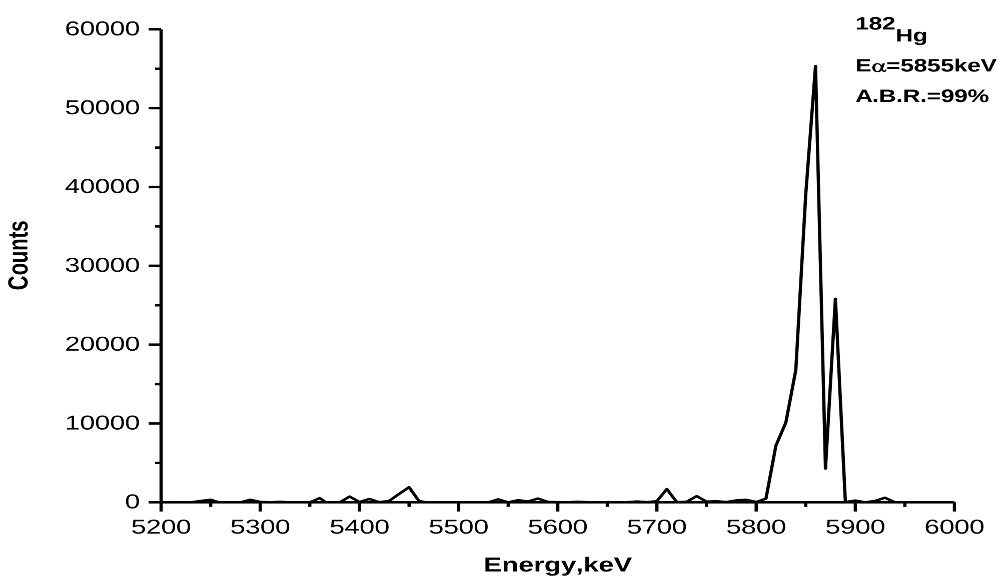
^{40}Ar+^{148}Sm reaction

1-Dimensional spectra of mercury isotopes

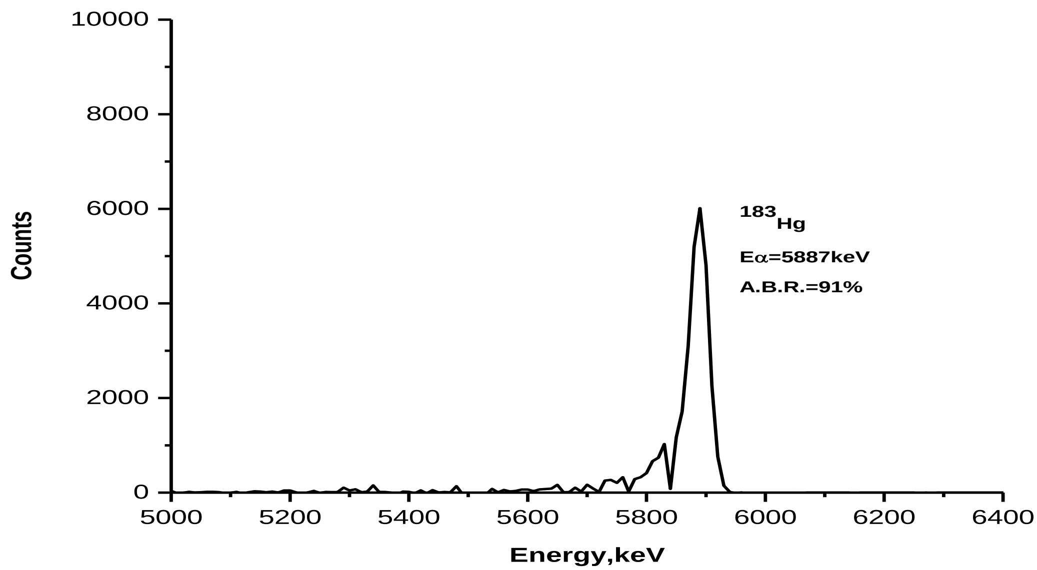


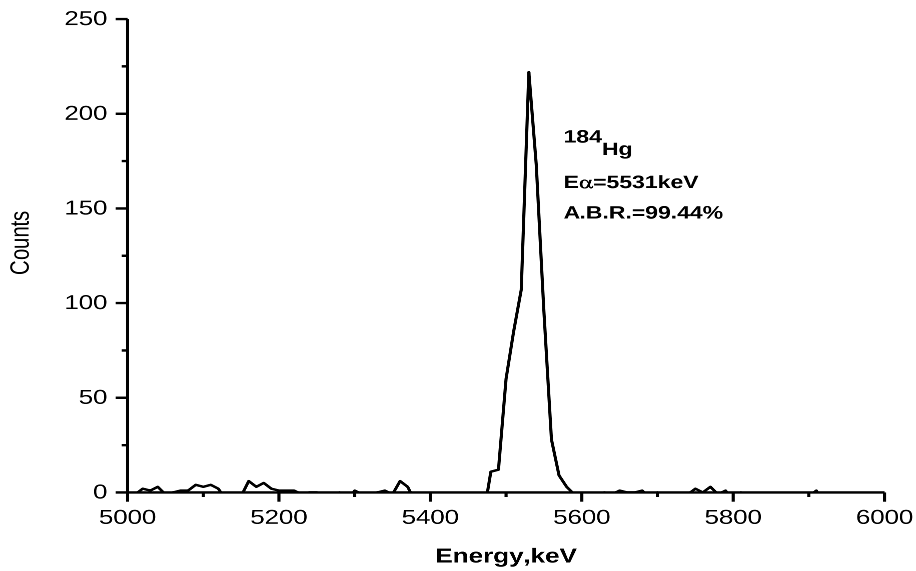


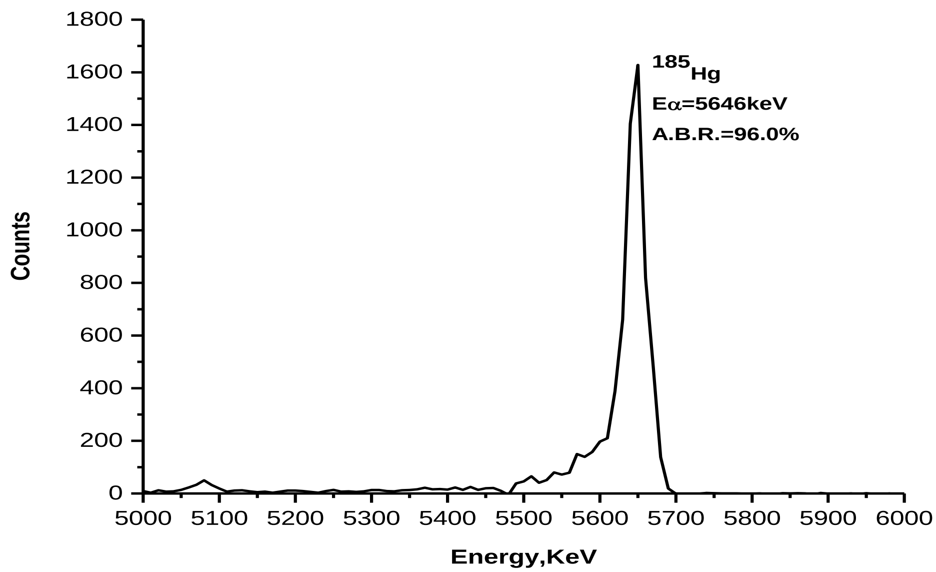
181Hg
Eα=6004keV
A.B.R.=87%
177Pt
Eα=5945keV
A.B.R.=88.5%
Counts
Energy,keV



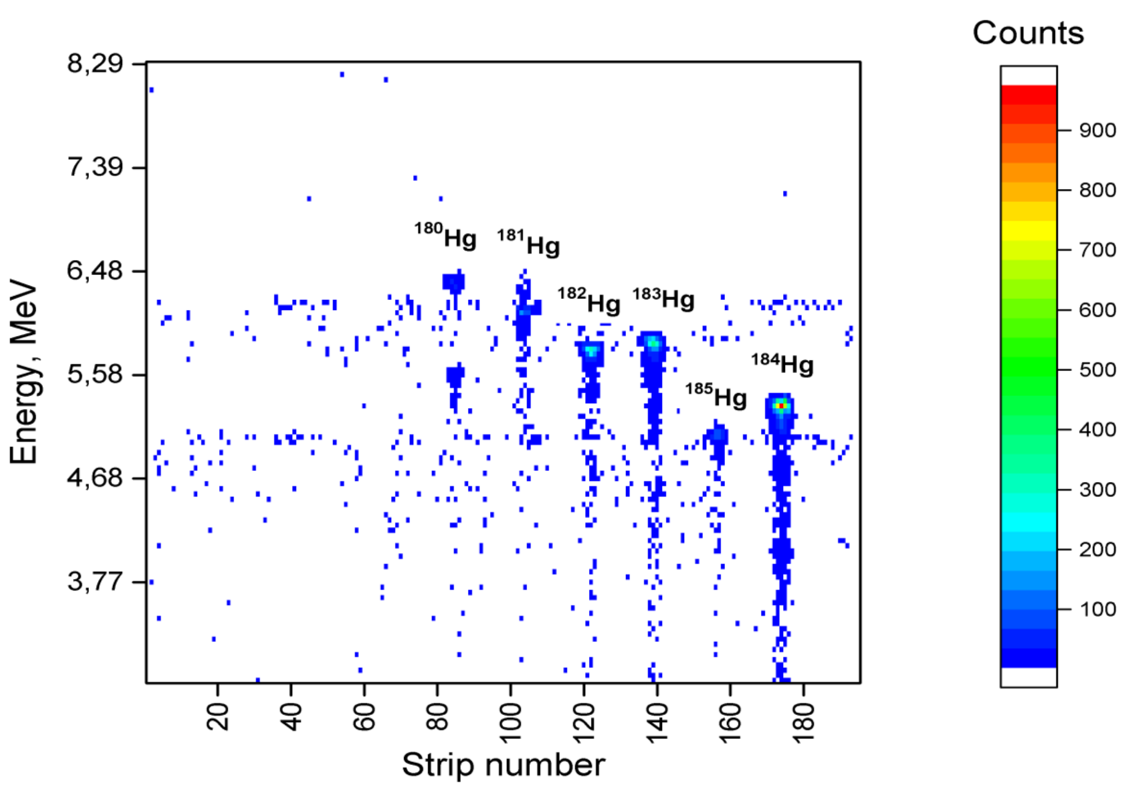
182Hg
Eα=5855keV
A.B.R.=99%
Counts
Energy,keV


183Hg
Eα=5887keV
A.B.R.=91%
Counts
Energy,keV
0
2000
4000
6000
8000
10000
5000
5200
5400
5600
5800
6000
6200
6400

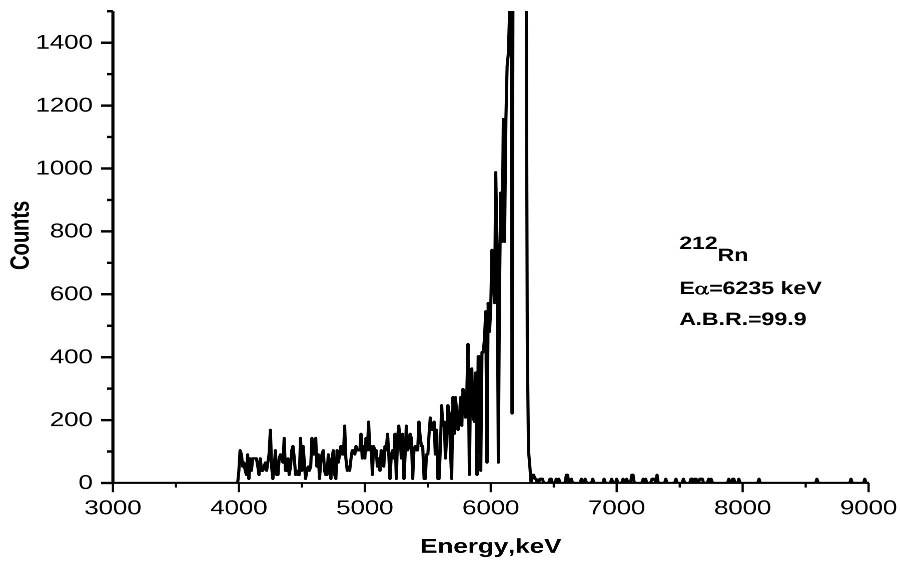

184Hg
Eα=5531keV
A.B.R.=99.44%
Counts
Energy,keV
0
50
100
150
200
250
5000
5200
5400
5600
5800
6000

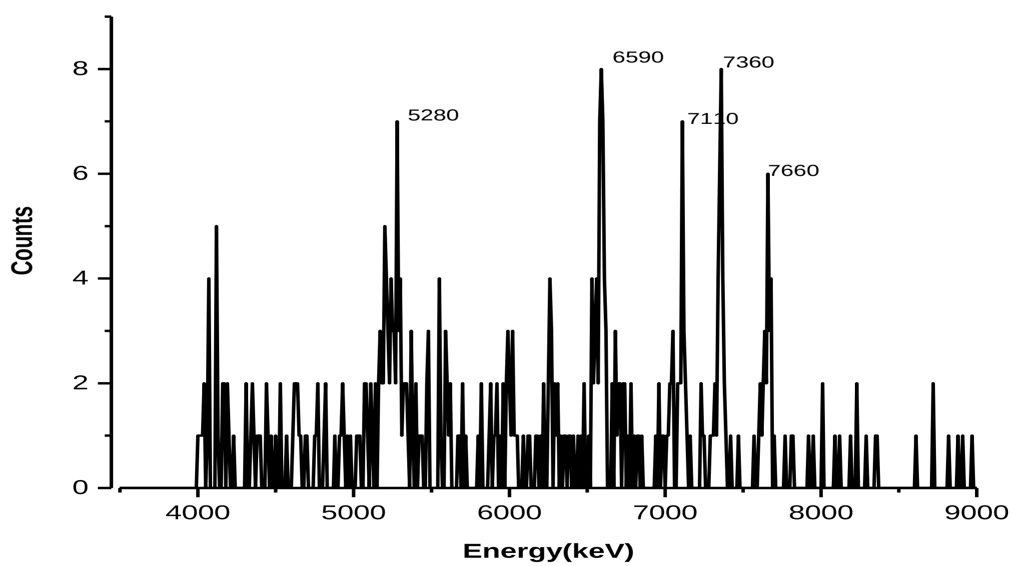


2-dimensional plot of alpha particle energies



$^{48}Ca+^{242}Pu$:



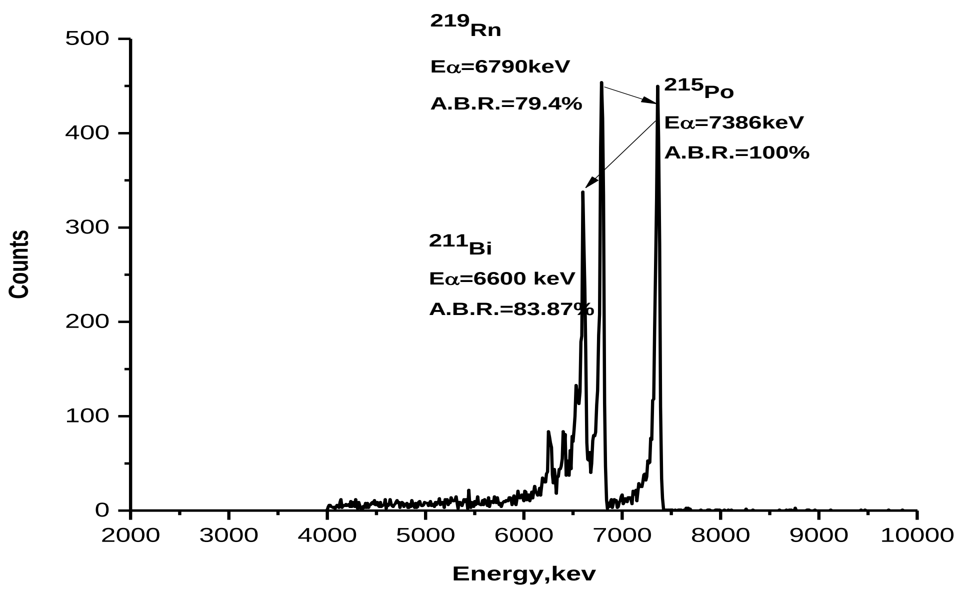


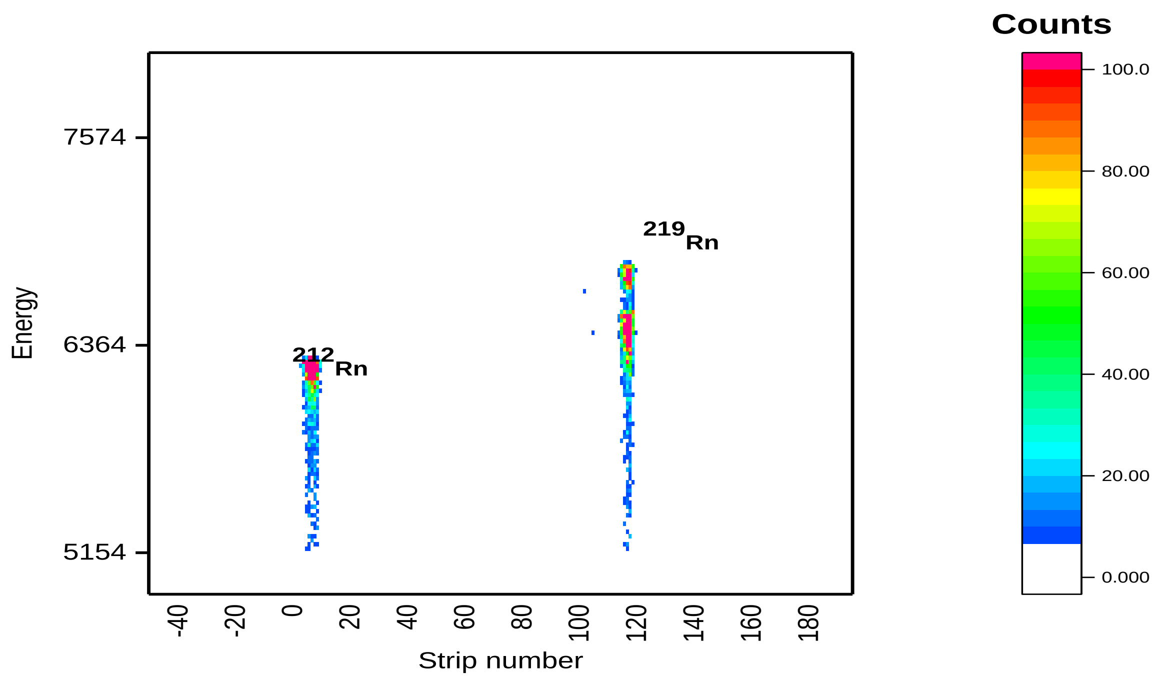
Alpha Decay Energy [Rn 218]:7110 Alpha Branching Ratio: 99.89

Alpha Decay Energy [^{218}Rn]:6590 Alpha Branching Ratio: 0.127

Alpha Decay Energy [^{214}Po]:7660 Alpha Branching Ratio: 99.9895

Alpha Decay Energy [^{210}Po]:5280 Alpha Branching Ratio: 100





Descriptions**:**

In the last heat map $^{213-217}$ Rn do not exist in the matrix graph because their half-lives are less than 0.5 ms [4].

Conclusion:

Mass-spectrometer MASHA at the beam line of the cyclotron U-400M is used to identify the superheavy elements by their mass-to-charge ratio and getting additional details by using the detector system. After a fusion reaction that happen between the beam and target which placed in the hot catcher, the energy spectra of the escaped α-particles were measured at the focal plane via the silicon detector system. The reaction products get ionized in the vacuum tube till they reach the detectors.

Acknowledge:

I have to thank the team of the INTEREST JINR training project for allowing me to work on this data and to gain more experience about the latest update for MASHA setup, in addition to this, the project provided in-depth overview of working with superheavy elements, detection and data analysis.

References:

1. Separation efficiency of the MASHA facility for short-lived mercury isotopes.
2. Oganessian Yu. Ts., Dmitriev S. N. Superheavy elements in D I Mendeleev's Periodic table. Russ. Chem. Rev. 2009.V.78, No 12.P.1077-1087
3. MASHA Separator on the Heavy Ion Beam for Determining Masses and NuclearPhysical Properties of Isotopes of Heavy and Superheavy Elements
4. CHEMICAL IDENTIFICATION OF DUBNIUM AS A DECAY PRODUCT OFELEMENT 115 PRODUCED IN THE REACTION 48Ca+ 243Am.
5. Oganessian Yu. Heaviest nuclei from ^{48}Ca-induced reactions. J. Phys. G: Nucl. Parrt. Phys. 2007. V.34, P.165-242.
6. Stavsetra L., Gregorich K.E., Dvorak Jet al. independent verification of the element 114 Production in the ^{48}Ca+Pu Reaction. Phys. Lett. 2009. V. 103, P.132502.