JOINT INSTITUTE FOR NUCLEAR RESEARCH
Veksler and Baldin laboratory of High Energy Physics

FINAL REPORT ON THE INTEREST PROGRAMME

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

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Abstract

Due to radioactivity and short half-lives of super heavy elements, mass spectrometers have proven to be effective at measuring mass, identifying super heavy nuclei, giving better understanding of chemical properties of super heavy elements. MASHA facility, constructed at FLNR, JINR combining solid state ISOL method for synthesizing with classical mass-spectrometry methods for identifying reaction products, is aimed at studying super heavy elements through their decay chains (mainly α-decay).

This project is focused on reactions (40Ar+148Sm, 40Ar+166Er 48Ca+242Pu), producing Hg and Rn, which are homologues to super heavy elements, giving a better understanding of super heavy nuclei properties.

1. Introduction

1.1. Super heavy elements

Super heavy elements (SHEs), most of them having half-lives less than minutes, have only been synthesized in laboratories. Theoretical existence of the island of stability shows a great interest for scientist, as it can mean existence of SHEs in nature and provide a deeper understanding of heavy nuclei's properties. Otherwise called 'Island of super heavy elements', island of stability is a predicted set of isotopes around proton number 114 and neutron number 184, which are estimated to have half-lives up to 10^9s due to their stability against nuclear decay. [1]

Notable SHEs include rutherfordium and dubnium, stable isotopes (^{267}Rf and ^{268}Db) having half-lives of 48 minutes and 16 hours respectively, greatly extending opportunities for research. Element 112 also poses a great interest: due to relativistic effects taking place in SHEs, it differs from its lighter homologue Hg, possessing some gas-like qualities, being closer to Rn. [2]

1.2. MASHA setup

MASHA (Mass Analyzer of Super Heavy Atoms) was designed with the main goal of identifying super heavy elements. The specifics of MASHA setup allow not only for measuring SHEs' masses, but for simultaneously recording their α-decays and spontaneous fissions.

MASHA setup main parts include: a target box with a hot catcher, ECR (electron cyclotron resonance) ion source, followed up by a magneto-optical analyzer and detection system.

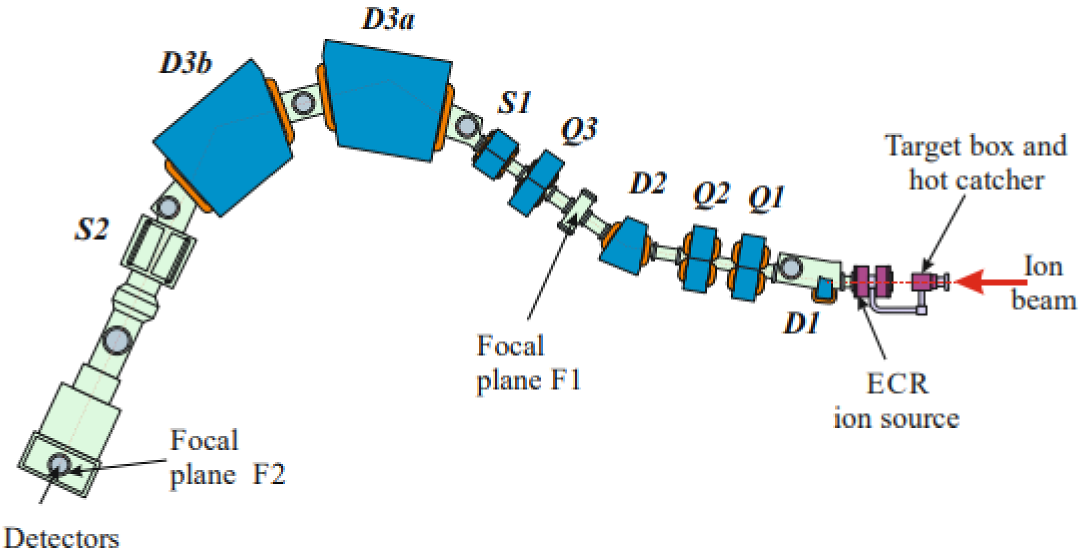


Figure 1. MASHA setup

Firstly, target+catcher system uses the block of rotating targets, assembled into cassettes, allowing for better heat distribution. Currently, MASHA uses thermally expanded graphite heated directly by current and graphite foil, removing heating losses and irregularities.

Schematic overview of MASHA's target and hot catcher system is shown in Figure 2.

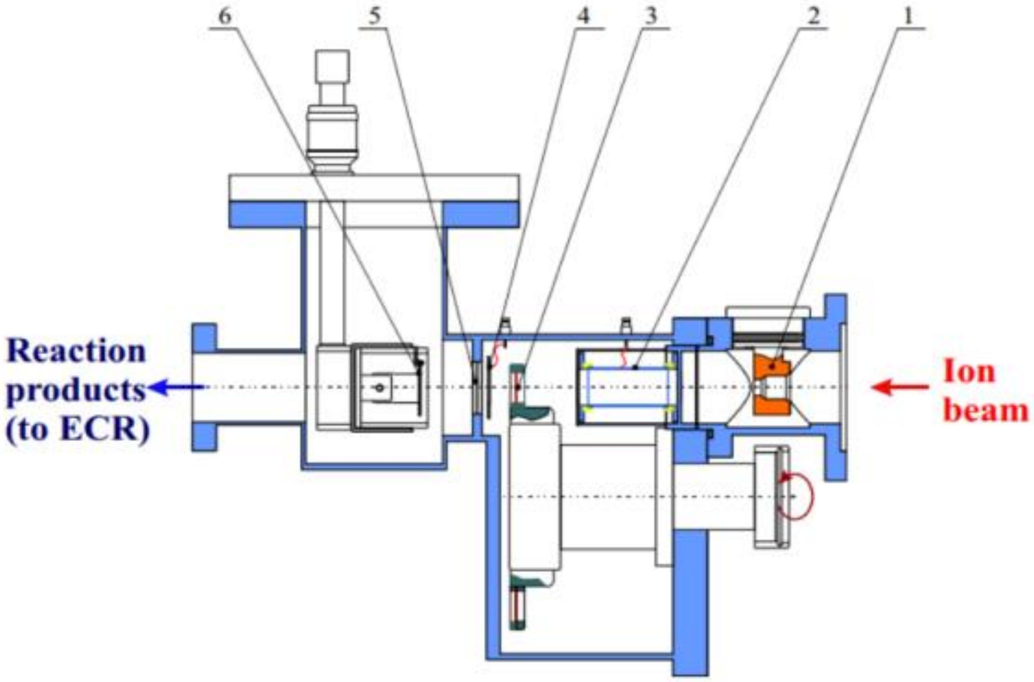


Figure 2. Schematic overview of the target-hot catcher system. Here: (1) diaphragm; (2) pick-up sensor; (3) target on the wheel; (4) electron emission beam monitor; (5) separating foil; (6) hot catcher.

After that ion source, containing a 2.45 GHz Microwave oscillator, ionizes atoms, previosly generated by the nuclear fusion reaction, that are later accelerated to energies up to 38 KeV with three-electrode electrostatic lenses, mass-to-charge separator forming them into beams.

Current MASHA setup uses silicon strip well-type detector, that contains front, side and lateral detectors in order to cover as much area as possible, front detector consisting of 192 strips, while side detectors have 64 strips.

TIMEPIX pixel detector system has also been used at MASHA. With detector consisting of a full sensitive area of 14 x 14 mm^2 and having an array of 256 x 256 pixels on it, TIMEPIX has 65536 channels and each has individual ADC and preamplifier, which allows to detect even single β^- and α-particles, as well as nuclear fragments and electromagnetic γ - or X-rays. [3]

2. Project Goals

Main goal of the project is analysis of α-decays of Hg and Rn isotopes, obtained through following reactions:

1) 40Ar + 148Sm (isotopes 180Hg, 181Hg, 182Hg, 183Hg, 184Hg, 185Hg)
2) 40Ar + 166Er (isotopes 201Rn, 202Rn, 203Rn, 204Rn, 205Rn)
3) 48Ca + 242Pu (isotopes 212Rn, 218Rn, 219Rn)

3. Methods

As stated previously, this project aims to study properties of SHEs, specifically element 112 (Copernicium). This is achieved by looking at α-decays of its homologue Hg along with Rn, as copernicium exhibit some gas-like behaviors.

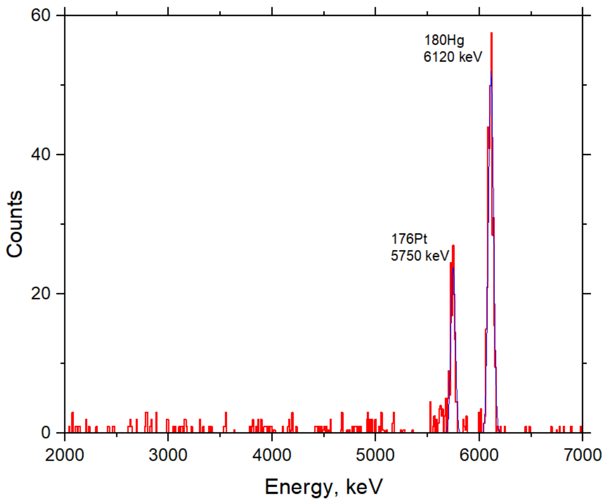
Following reactions have been performed at MASHA: 40Ar + 148Sm for Hg isotopes, 40Ar + 166Er and 48Ca +242Pu for Rn isotopes.

Obtained experiment data later had been later processed through Origin software, graphs showing α-decay energies for each isotope and heat maps for each of three reactions being made.

4. Results

Figure 3 to 5 show spectrums for each isotope, allowing us to identify their α-decay energies, as well as α-decay energies of some next elements in their respective chains. As well as that, heat maps for each of three reactions are also presented below.

4.1. 40Ar + 148Sm



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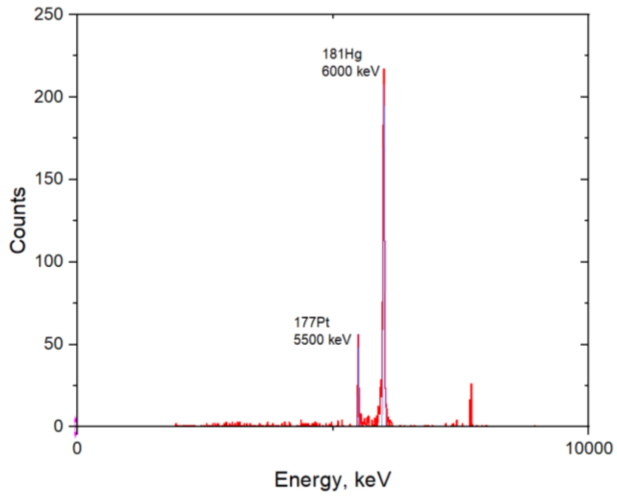

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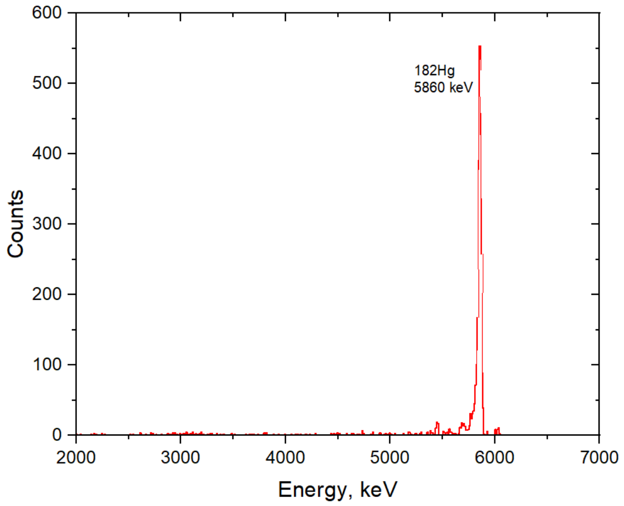

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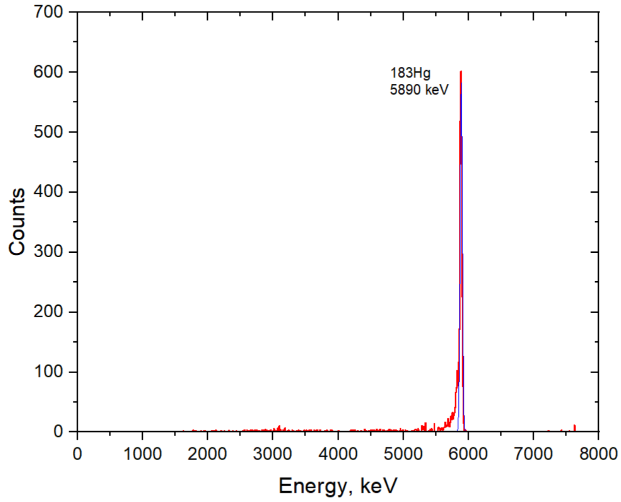

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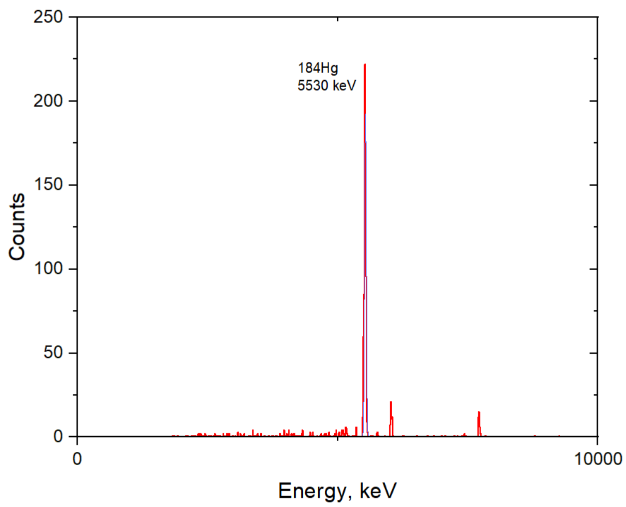

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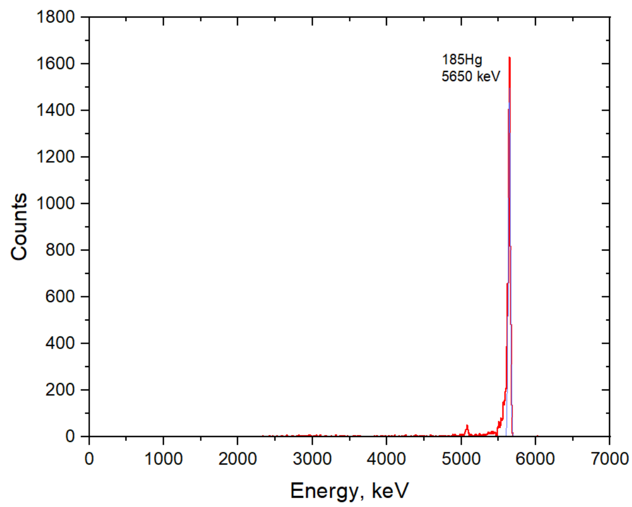

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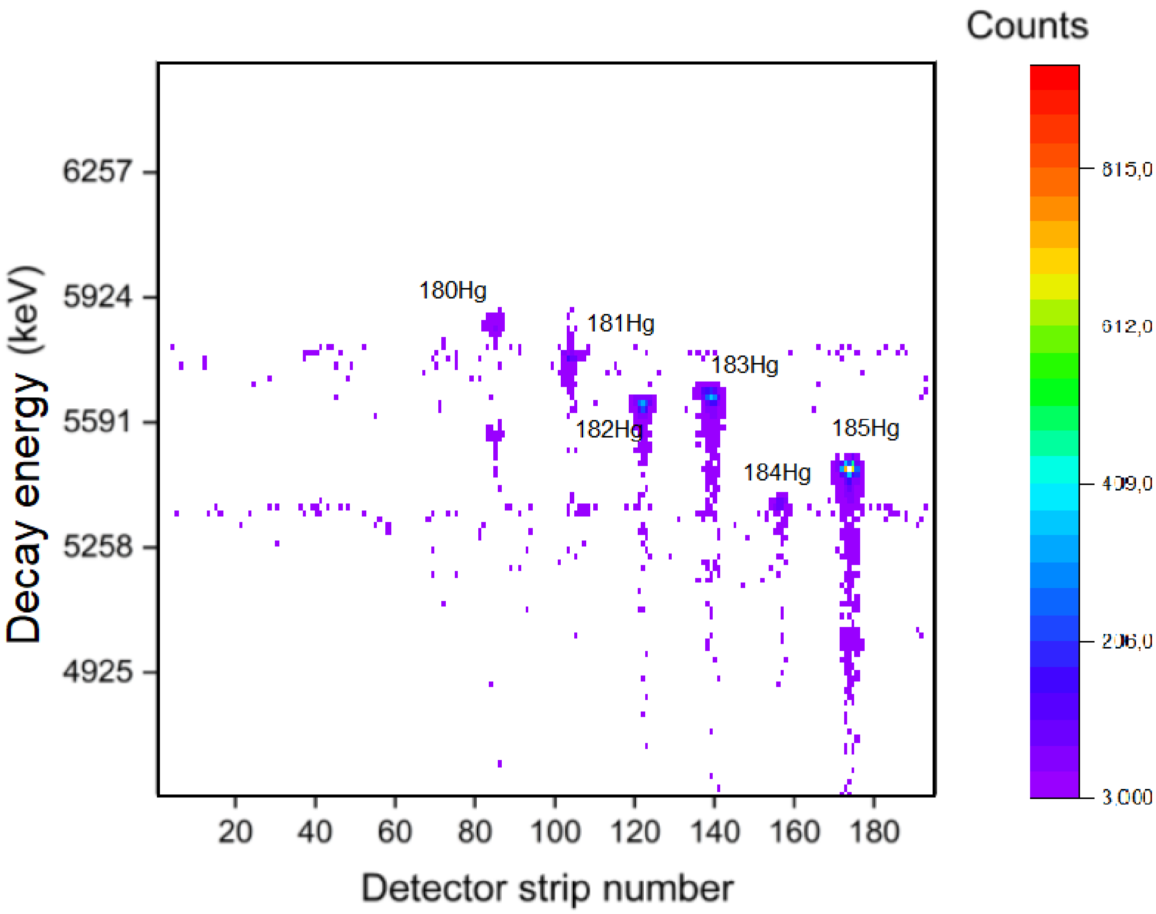
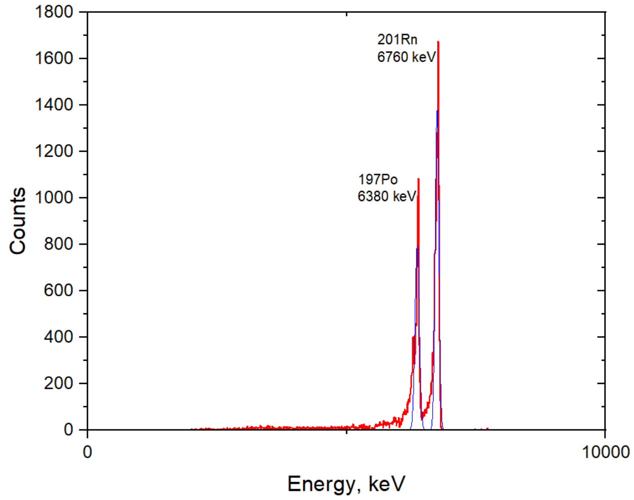


Figure 3. Hg alpha decay

4.2. 40Ar + 166Er



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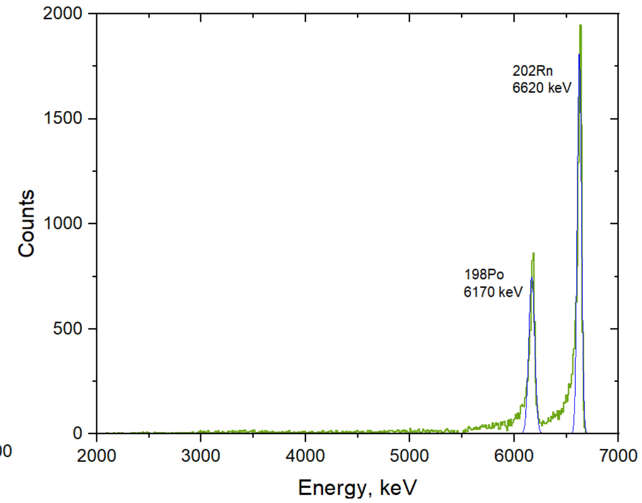

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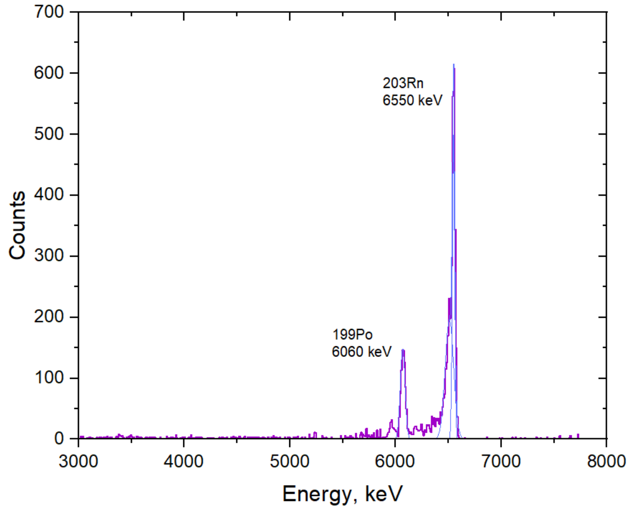

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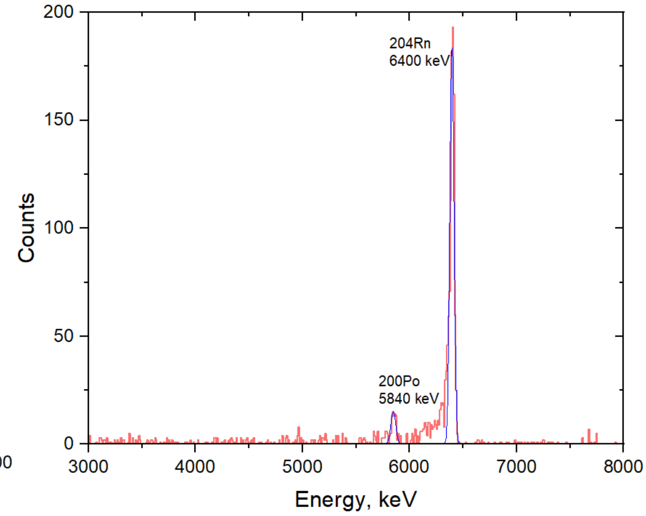

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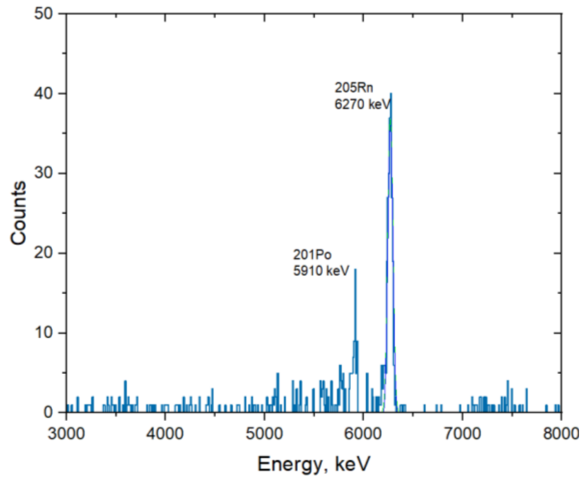

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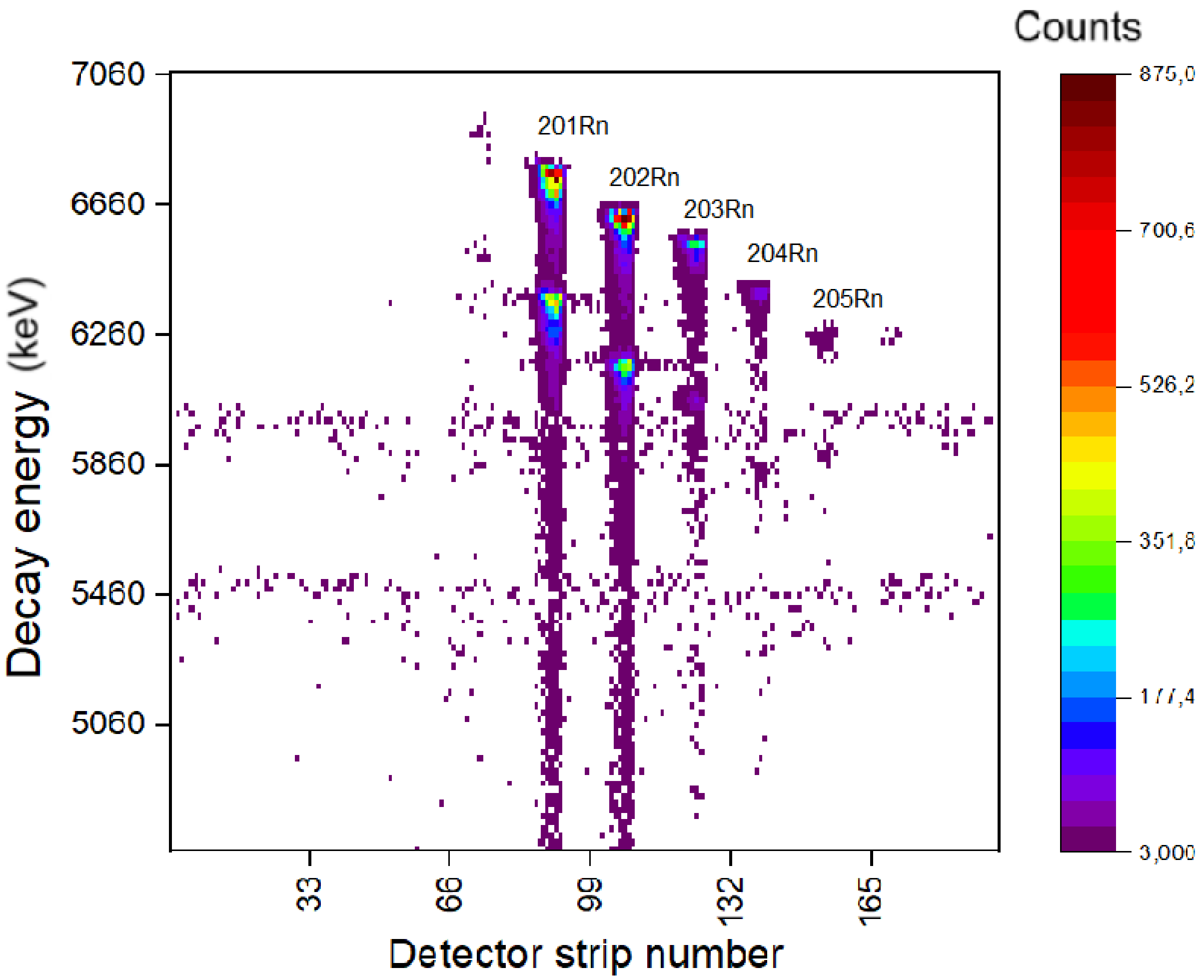

Figure 4. Rn alpha decay

4.3. 48Ca + 242Pu

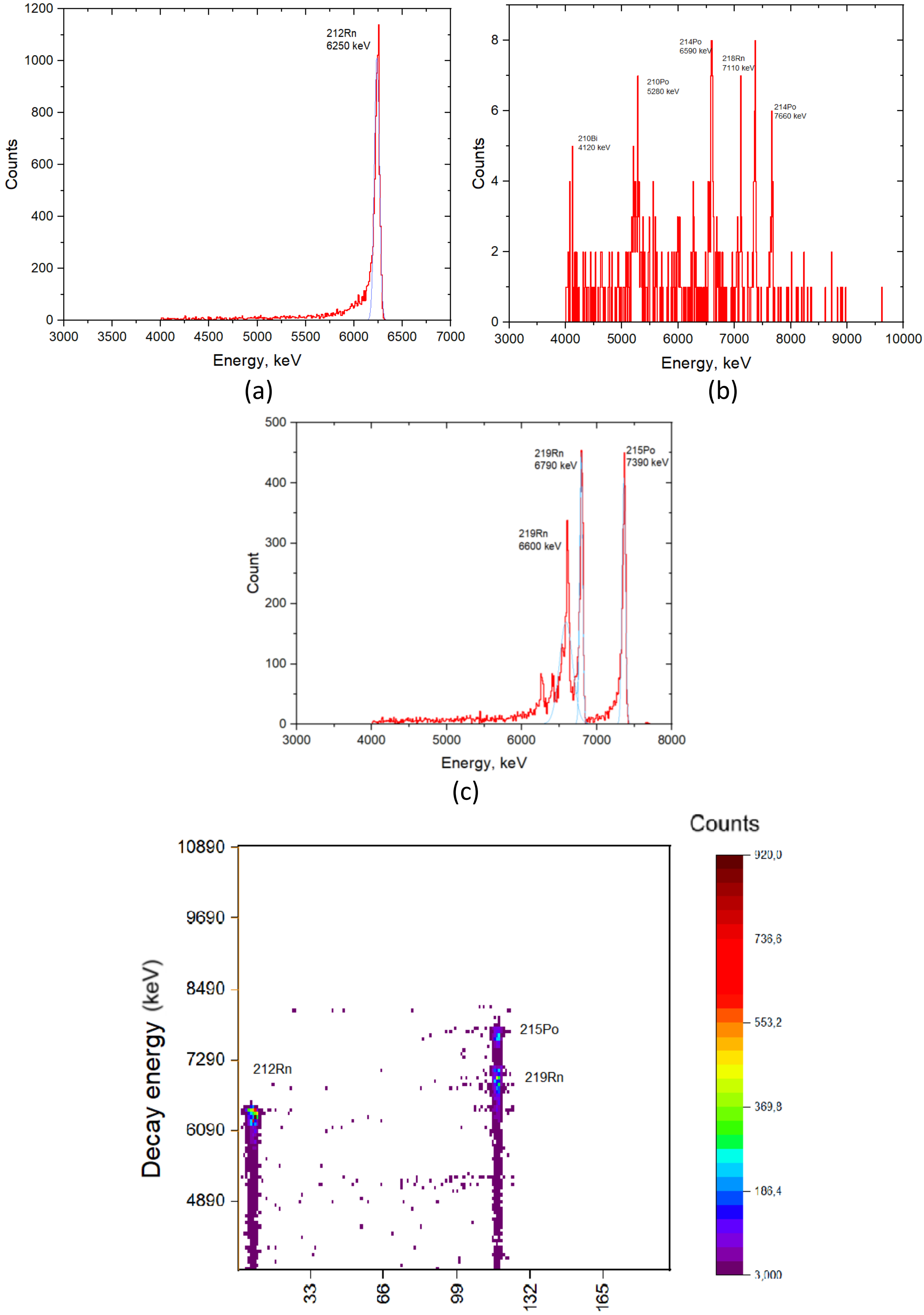

Figure 5. Rn alpha decay

5. Conclusion

During this project, following reactions have been studied: 40Ar+148Sm (producing isotopes 180Hg, 181Hg, 182Hg, 183Hg, 184Hg, 185Hg); 40Ar + 166Er (producing isotopes 201Rn, 202Rn, 203Rn, 204Rn, 205Rn); 48Ca + 242Pu (producing isotopes 212Rn, 218Rn, 219Rn). Radon and mercury had been chosen as they exhibit qualities similar to element 112, mercury being its homologue.

Copernicium itself is a product of element 114 nuclear decay, element 114 in its turn being the closest to the island of stability, as its existence is predicted for isotopes with proton number around 114 and neutron number around 184.

This project along with other studies [3, 4] shows potential of MASHA setup along with TIMEPIX in the field of super heavy elements studies. Further studying of element 112 and 114 can also get physicists closer to experimentally finding island of stability, thus providing further inside into super heavy elements' properties and their possible existence in nature.

6. Acknowledgements

I would like to thank INTEREST programme at JINR for providing such an incredible opportunity, my project supervisor, Mr Viacheslav Vedeneev, as well as my professors and university for providing me with skills and knowledge, necessary for completing this project.

7. References

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