Production and spectroscopic analysis of isotopes in full fusion and multinucleon transfer reactions at MASHA facility, JINR.

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JINR; Dubna, Russia

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Outline

- Objectives
- Introduction
- Results
- Conclusion
- Acknowledgement

Objectives

- The present status of the mass-spectrometer MASHA (Mass Analyzer of Super Heavy Atoms) designed for determination of the masses of super heavy elements. The mass-spectrometer is connected to the U-400M cyclotron of the FLNR, JINR, Dubna.
- Results of the test experiments on the mass-spectrometer MASHA aimed at the study of the reactions 40Ar+148Sm; 48Ca+166Er and 48 Ca+242Pu.
- Production and spectroscopic investigation of neutron-rich isotopes, produced in mutinucleon transfer reactions, near the neutron N = 126 shell closures. Test experiments.
- Determination of masses of super heavy elements in the experiments on synthesis of 112 and 114 elements by using the reactions 48Ca+242Pu. The beam energy is Ebeam ~ 5 MeV/n.
- The program of future investigations using the technique of a gas catcher is discussed.

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Introduction

- The synthesis of the new super heavy elements stimulated works on the development of methods of their identification by means of the technique called Isotope Separation On-Line (ISOL).

- Thereto, FLNR (JINR) designed and put into commissioning the mass spectrometer MASHA - Mass Analyzer of Super Heavy Atoms.

- The uniqueness of this mass spectrometer consists in ability to measure "on line" the masses of the synthesized isotopes of the Super Heavy Elements simultaneously with detection of their alpha decays and(or) spontaneous fission.

- In the mass spectrometry the overall extraction efficiency and the extraction time are very crucial parameters.

Introduction

- A possible application of the mass-separator MASHA would be related to studying the neutron-rich nuclei near the N=126 neutron shell.

- These nuclei are planned to be produced in the multi-nucleon transfer reactions with mass-to-charge ratio separation of the target-like fragments. The target+catcher system using Isotope Separation On-Line (ISOL), where the target material is solved in the catcher material will be used in this type of reactions.

- This has to be in favour of increasing the yield of fragments.

- It is also expected that a prior determination of masses of the nuclei under investigation will essentially facilitate the analysis of their decays using the focal plane silicon multi strip detector.

General ion-optical parameters of "MASHA" with gas catcher ($\varepsilon_{X(Y)} \leq 2\pi \cdot mm \cdot mrad$)

Parameters	ECR ion source	Gas catcher
Range of energy variation, keV	15-40	15-40
Range of Bρ variation, Tm	0.08-0.5	0.08-0.5
Mass acceptance, %	2.8	2.8
Angular spread, mrad	14	5
Diameter the ion source exit hole, mm	**5.0**	**1.0**
Horizontal magnification at F1/F2	**0.39/0.68**	**0.24/0.90**
Vertical magnification at F1/F2	**2.4/3.13**	**1.5/1.25**
Linear mass resolution at F1	75	420
Mass resolution at F2	**1150**	**3000**

^{242}Pu targets before and after irradiation

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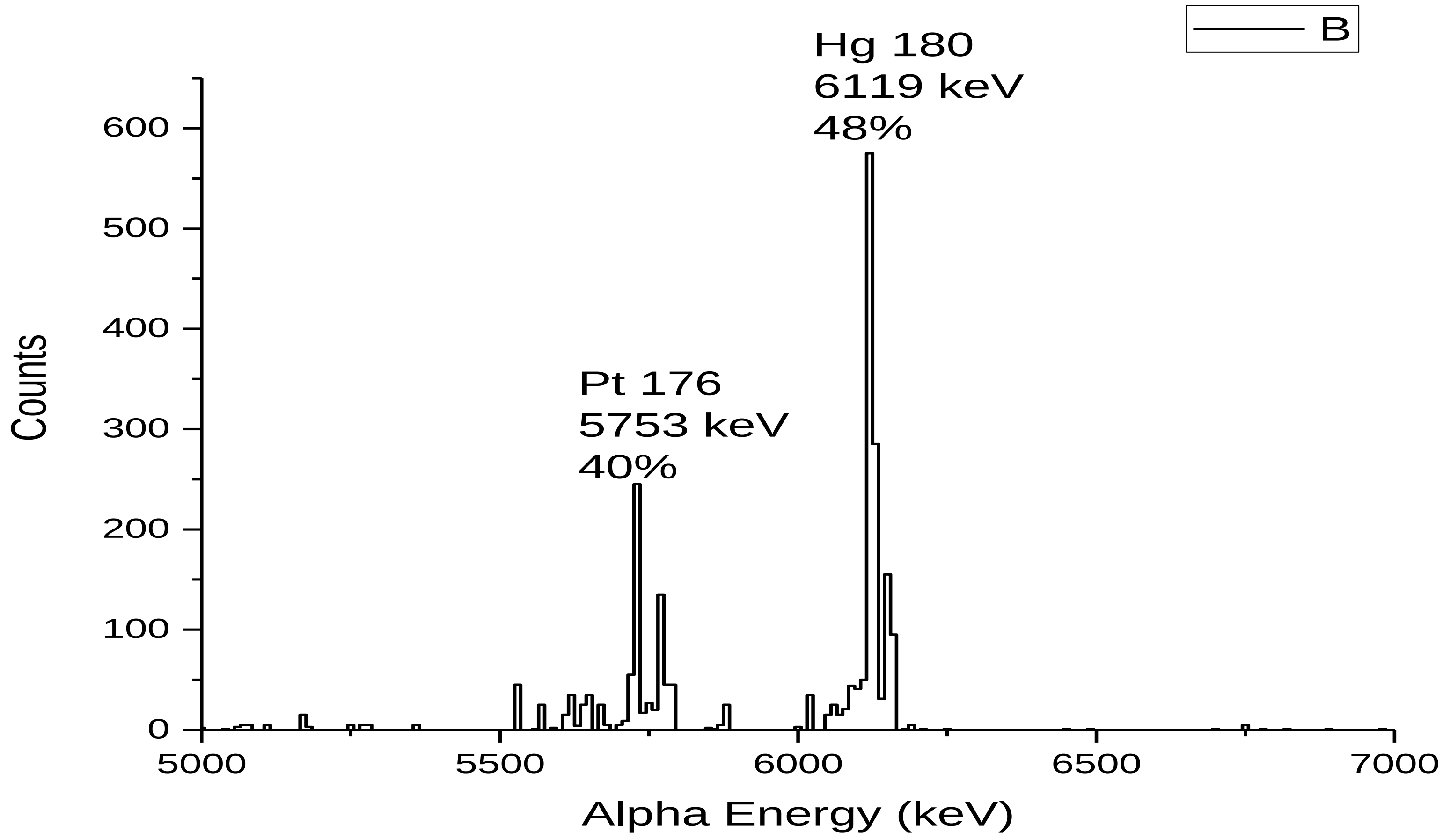
Focal plane silicon multi strip detector

Configuration – well type
Number of the focal strips – 192 (step – 1.25 mm)
Number of the back side strips – 160 (step – 5 mm)
Total efficiency – more than 90%
Energy resolution – 20 keV

Experimental reactions

- $^{40}Ar+^{148}Sm \Rightarrow Hg$, $E_{beam} = 5\text{-}7$ MeV/n
- $^{48}Ca+^{166}Er \Rightarrow Rn$, $E_{beam} = 5\text{-}7$ MeV/n
- $^{48}Ca+^{242}Pu \Rightarrow Rn$, $E_{beam} = 5\text{-}7$ MeV/n

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



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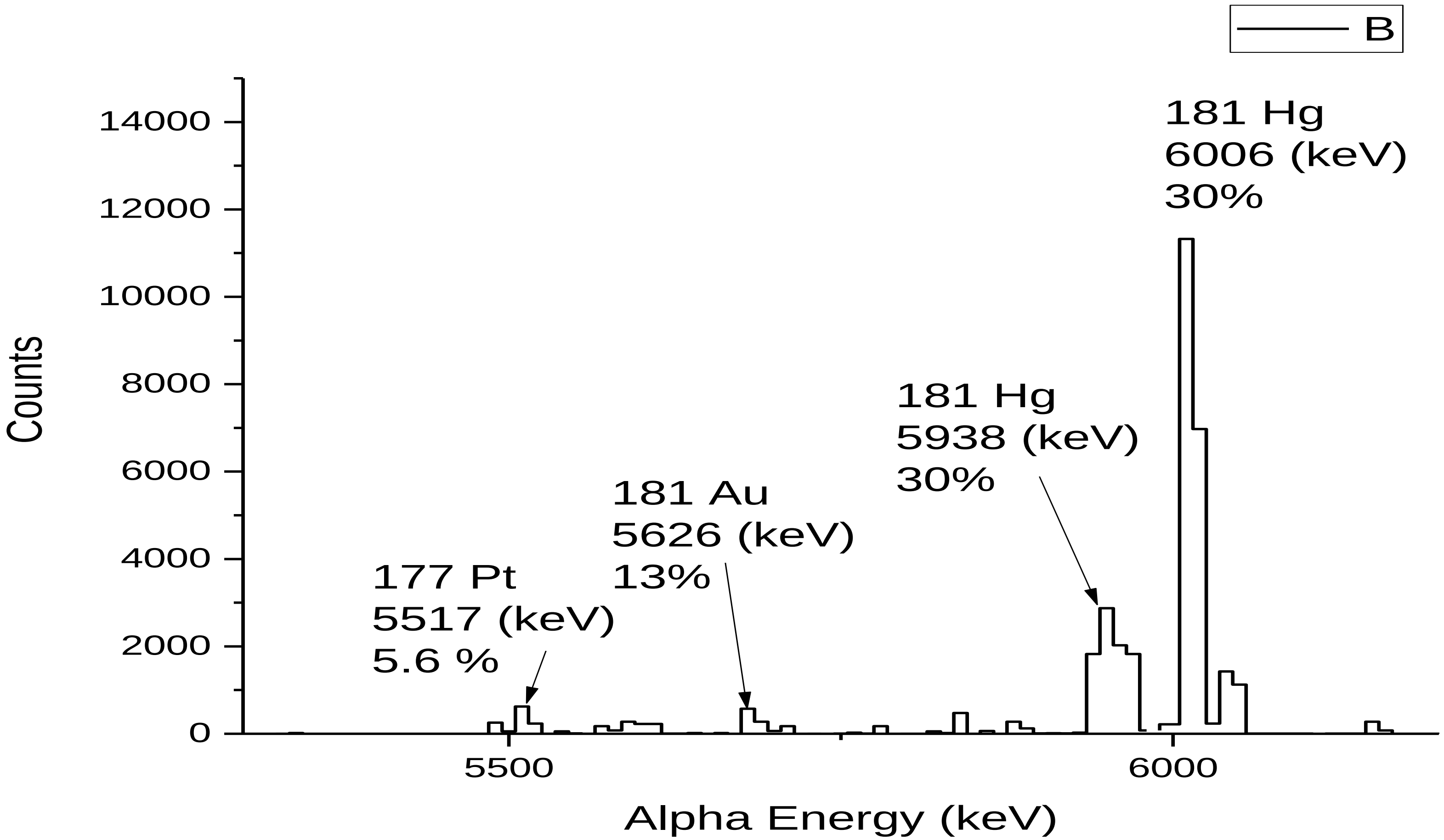

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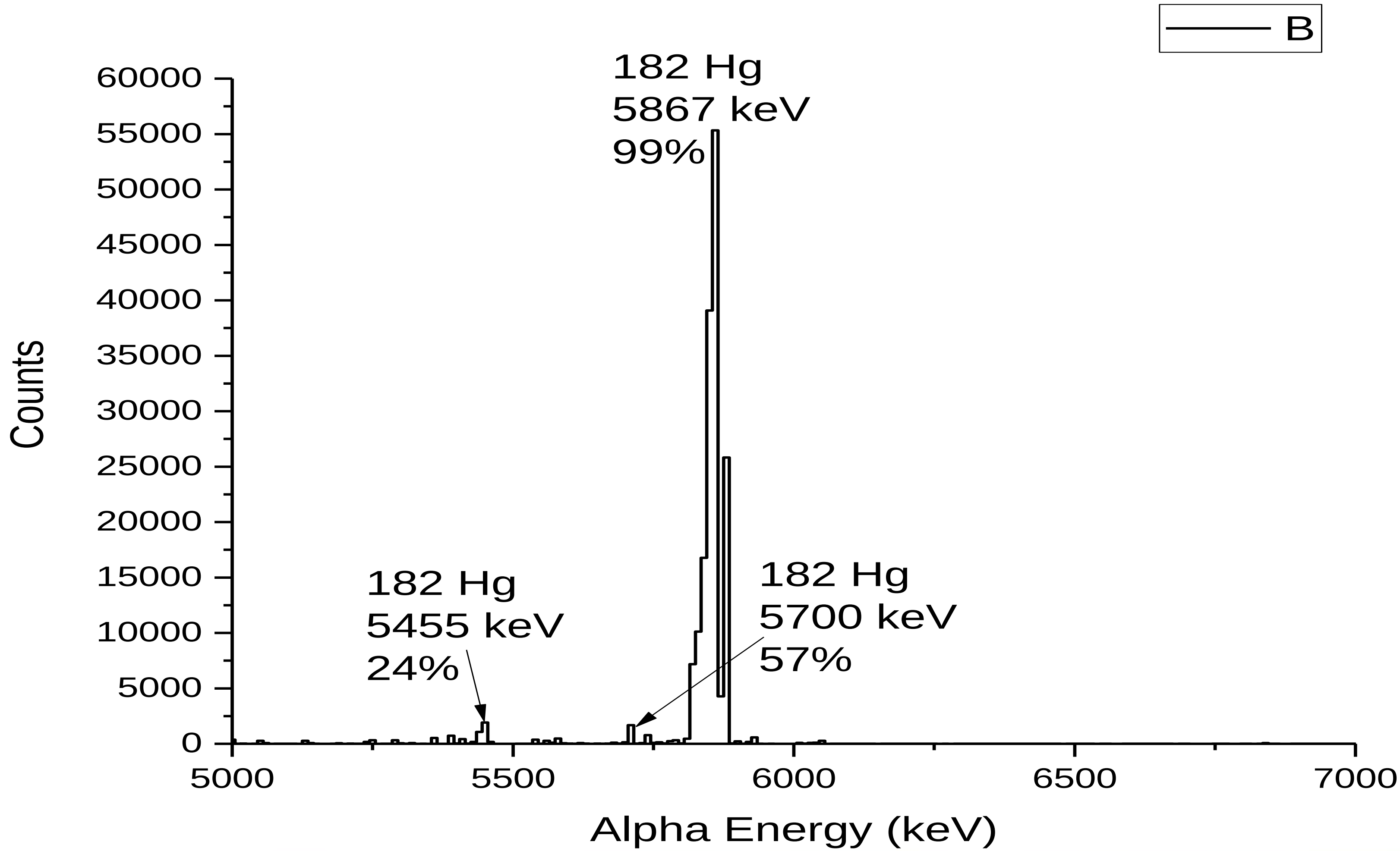

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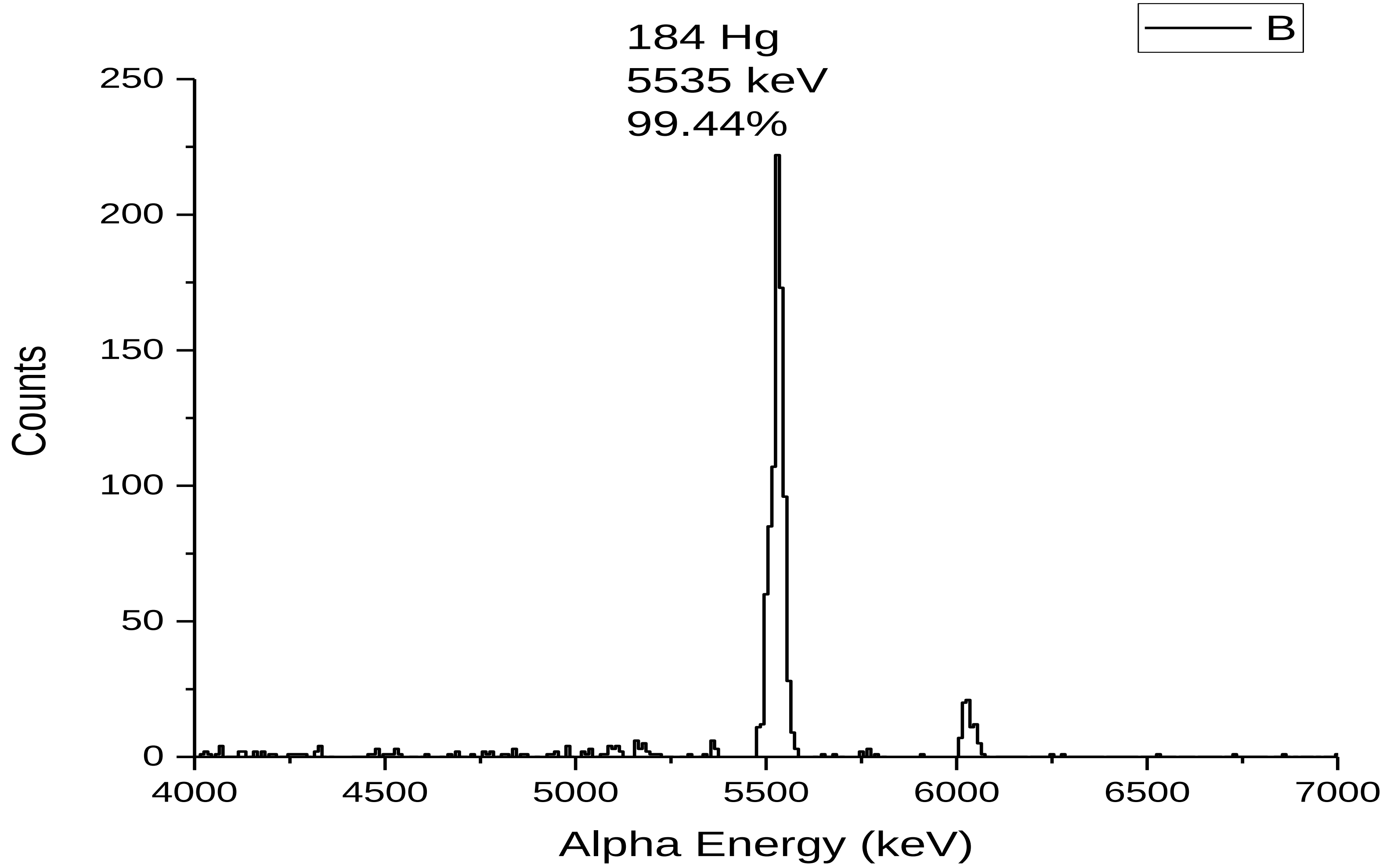

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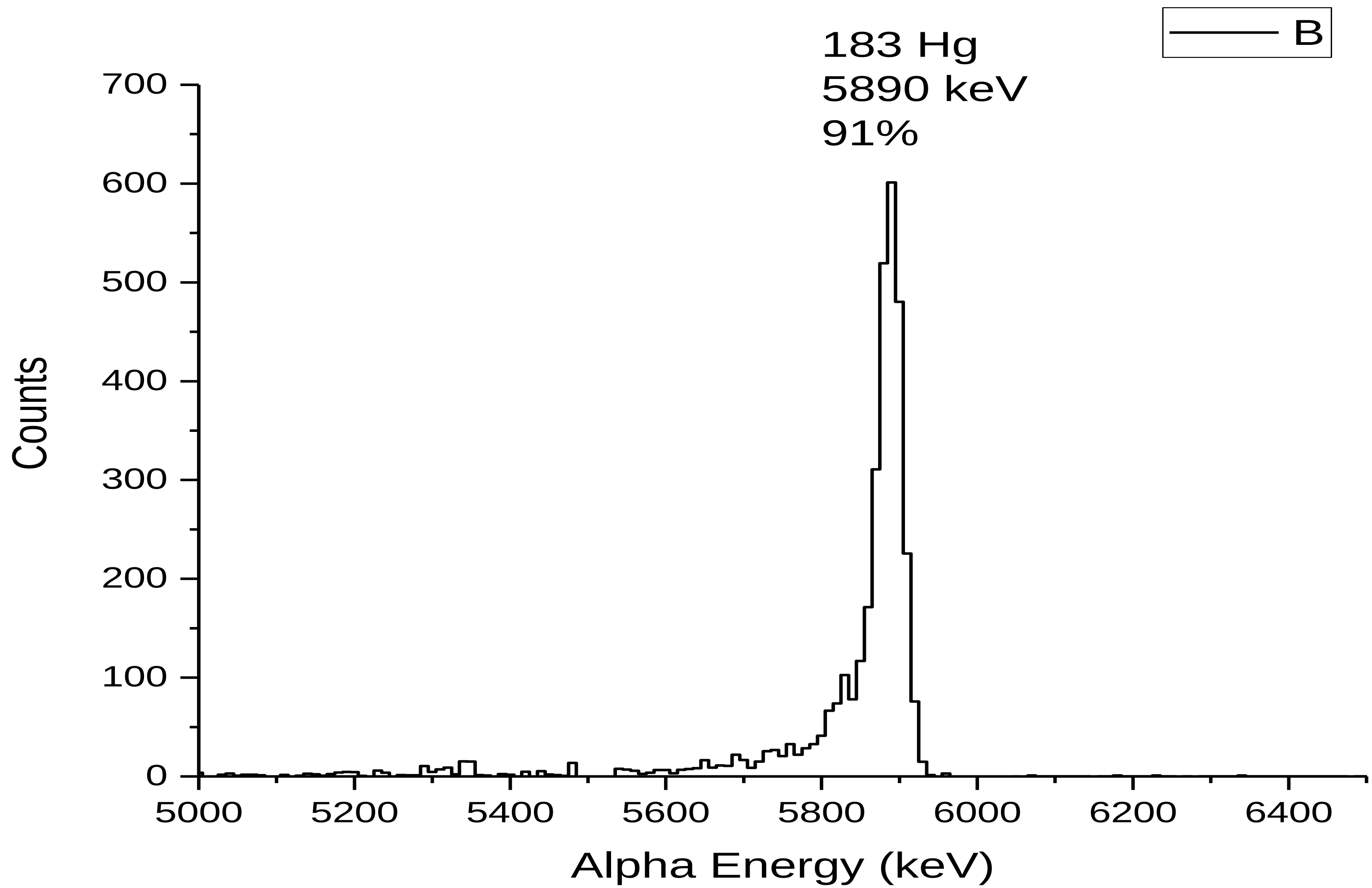

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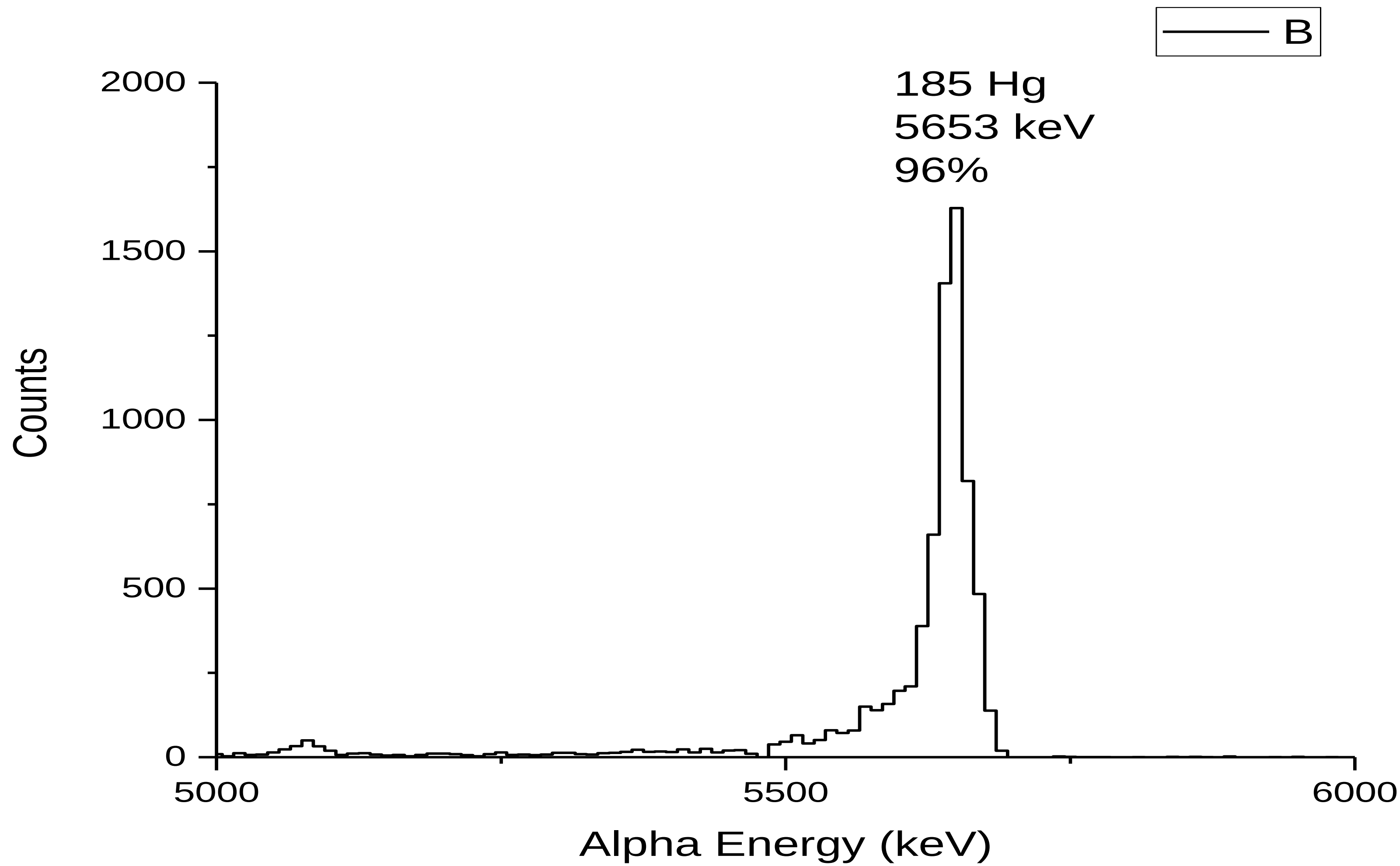

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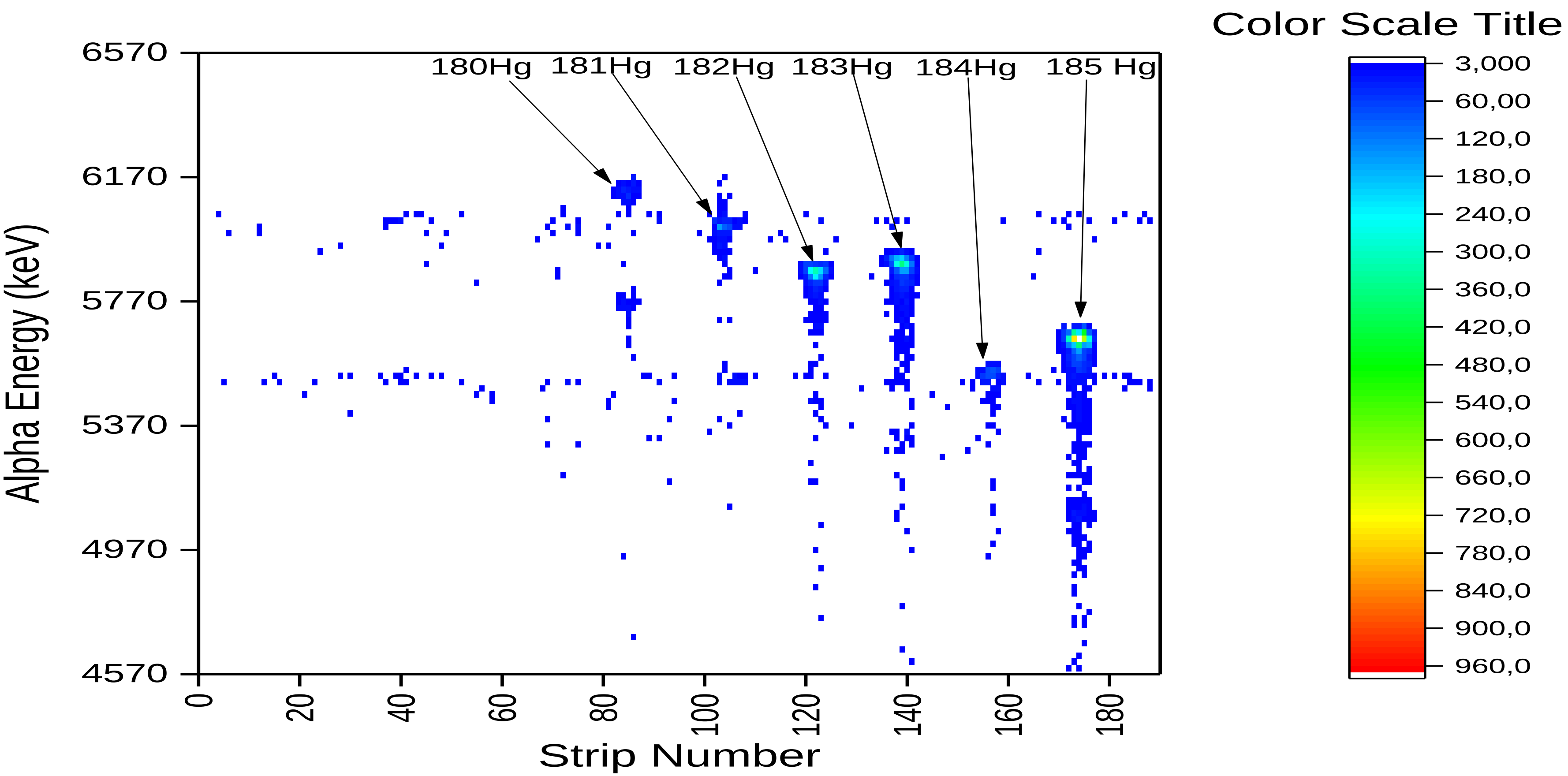

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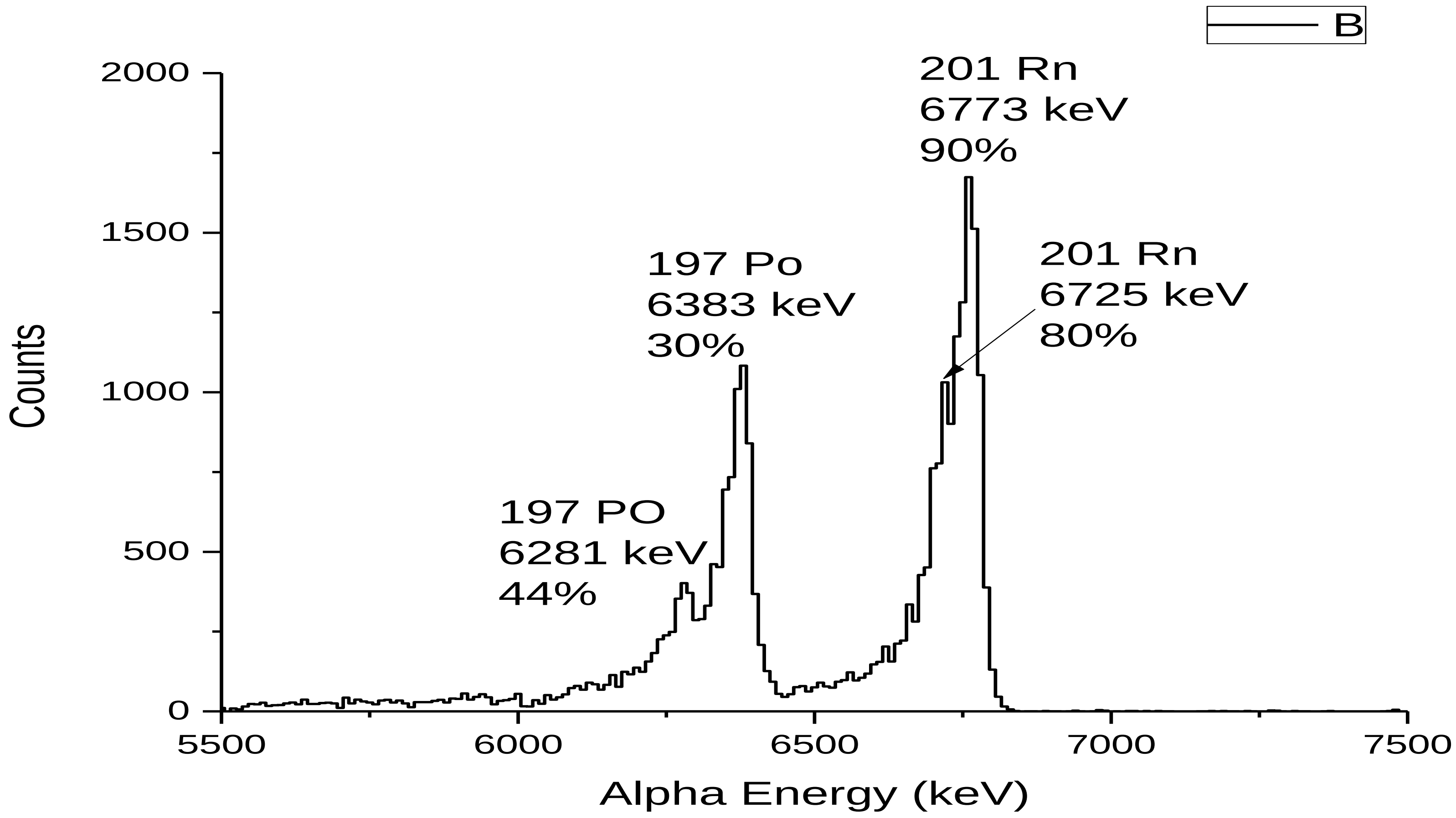

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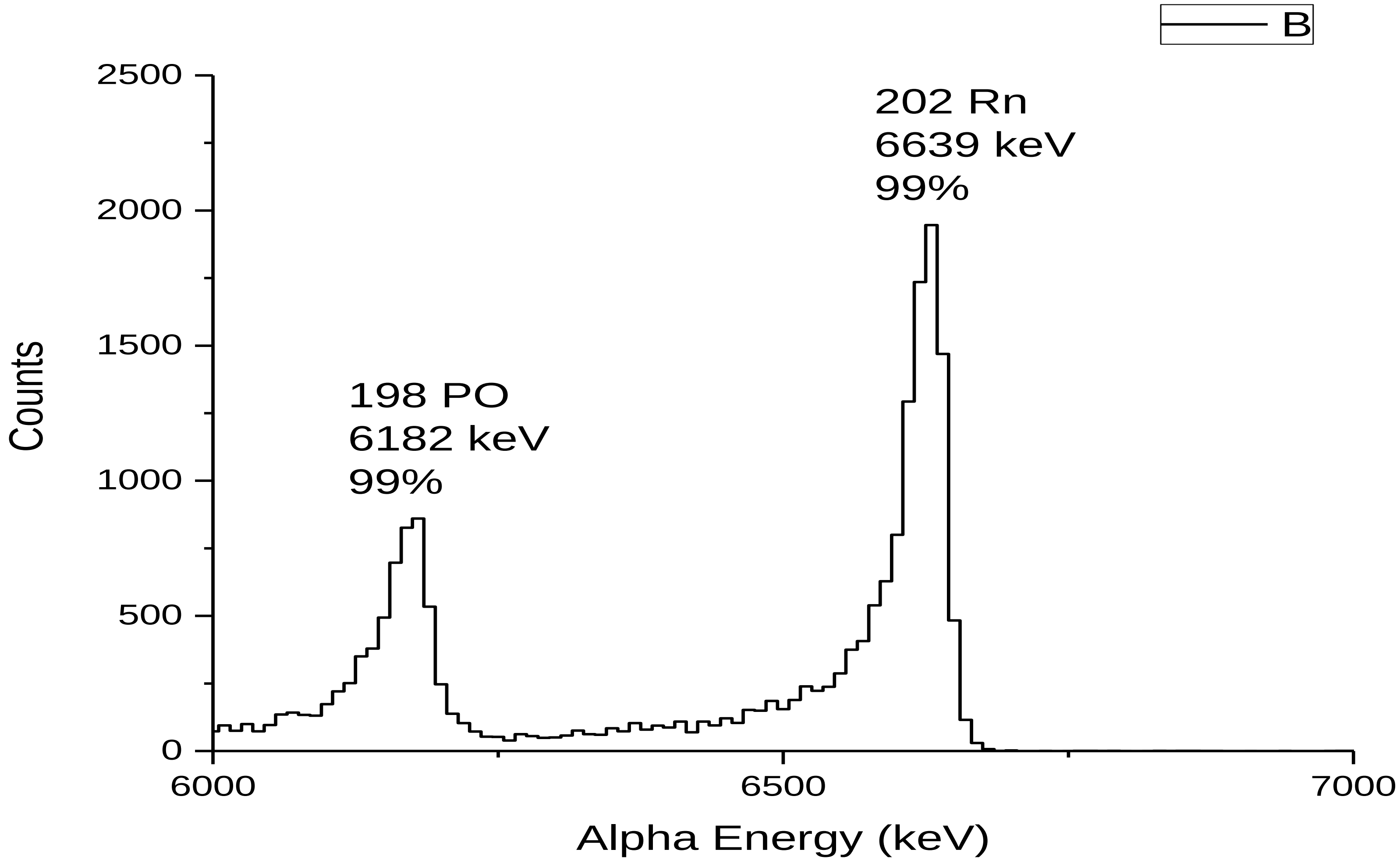

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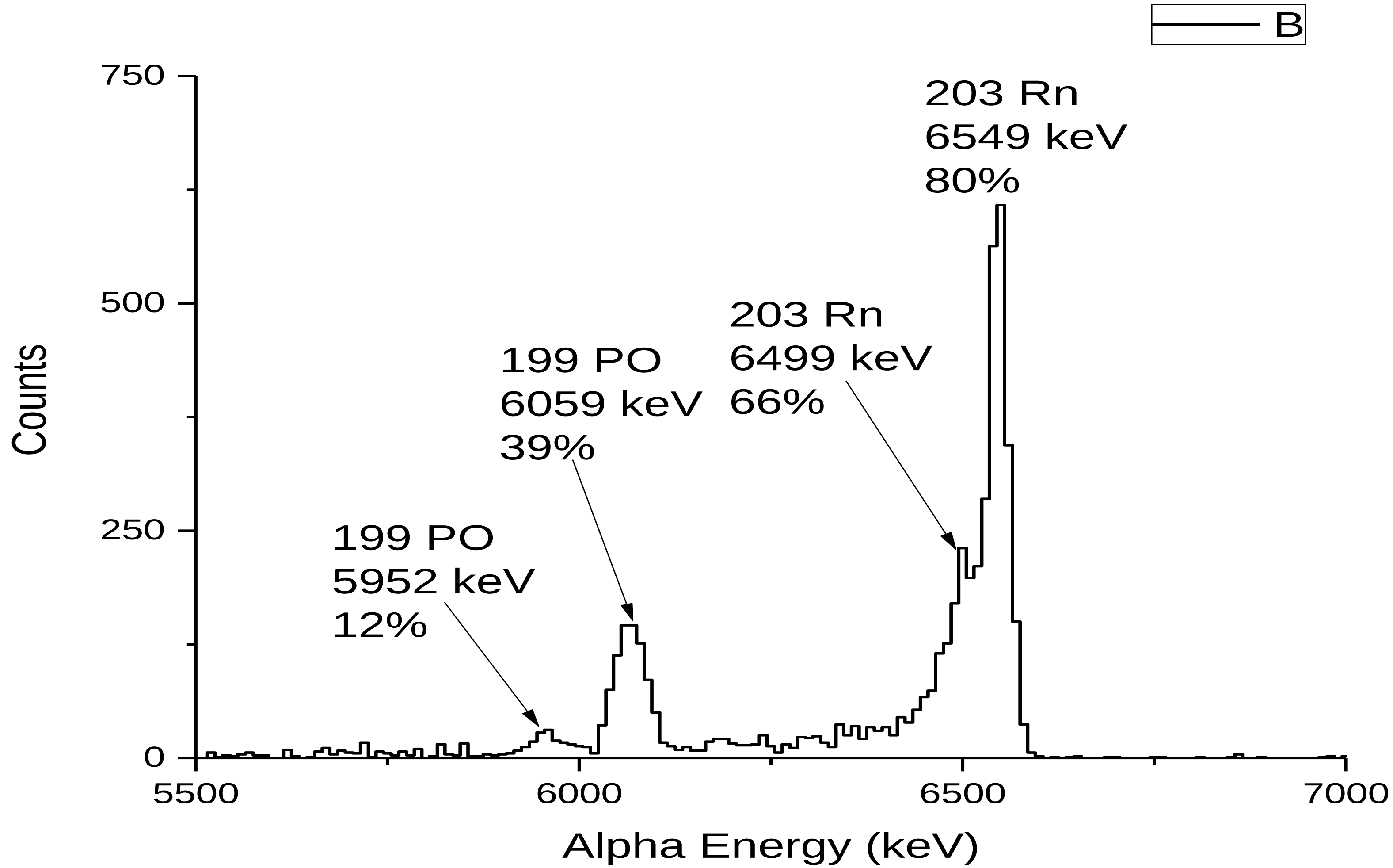

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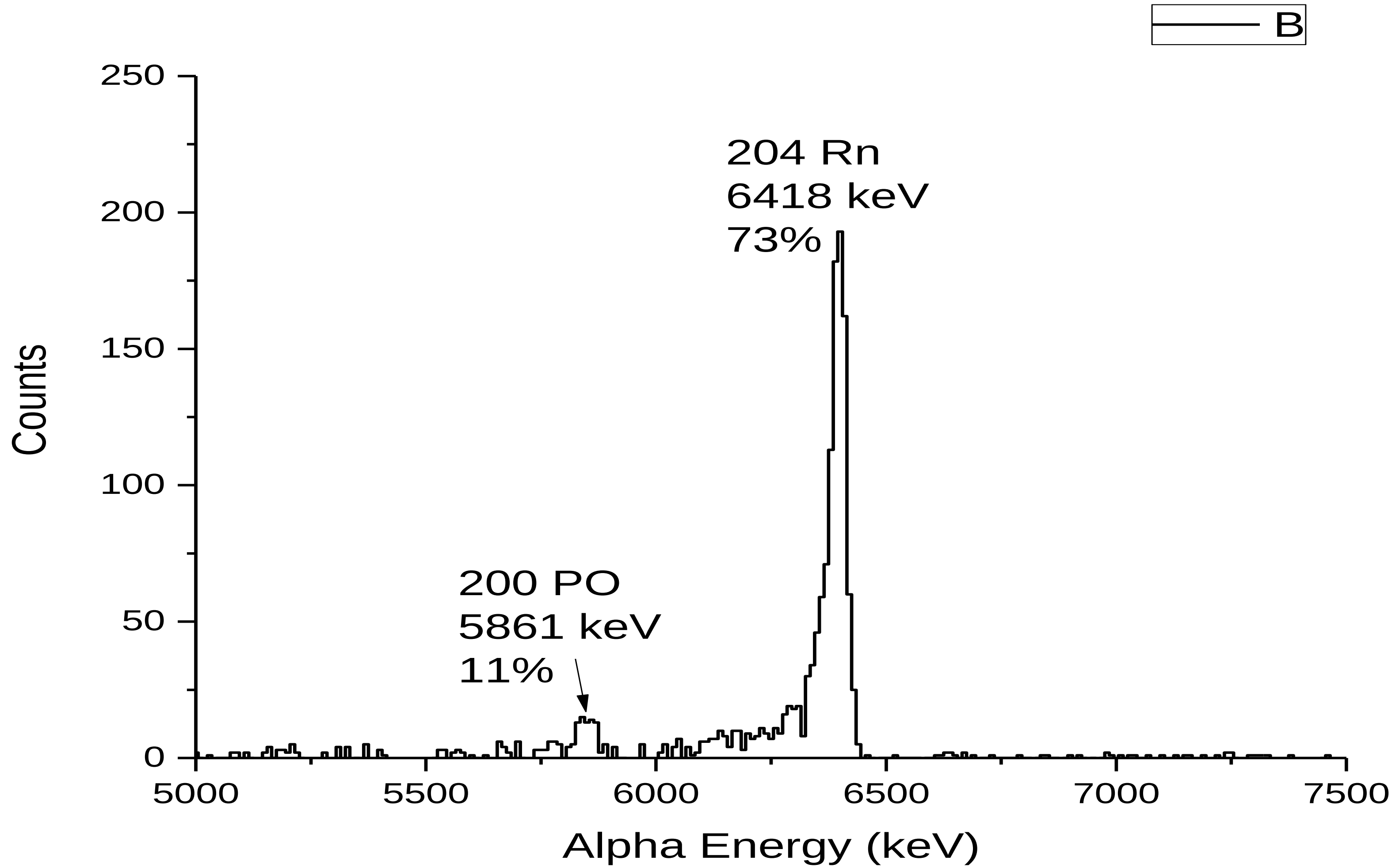

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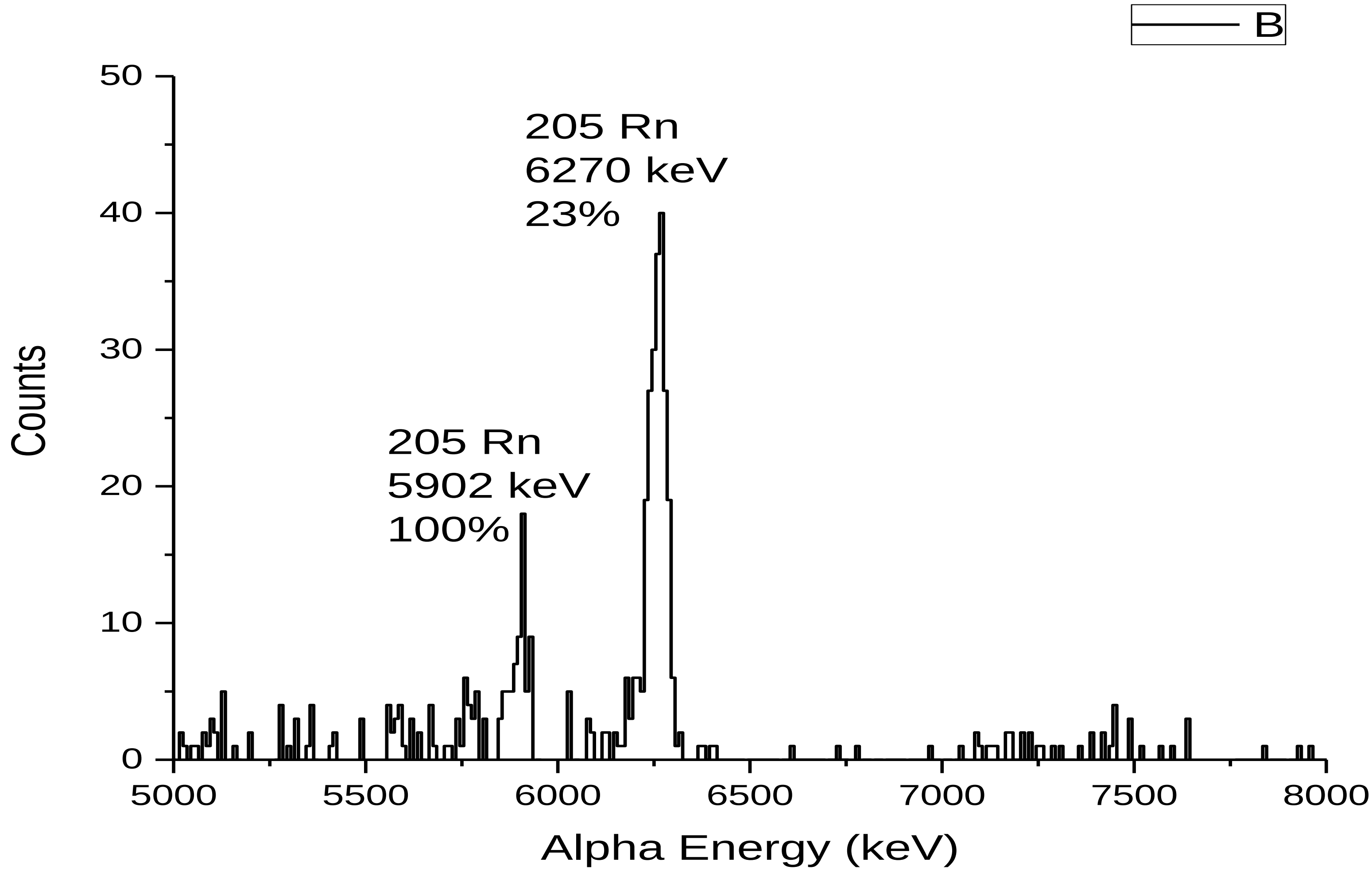

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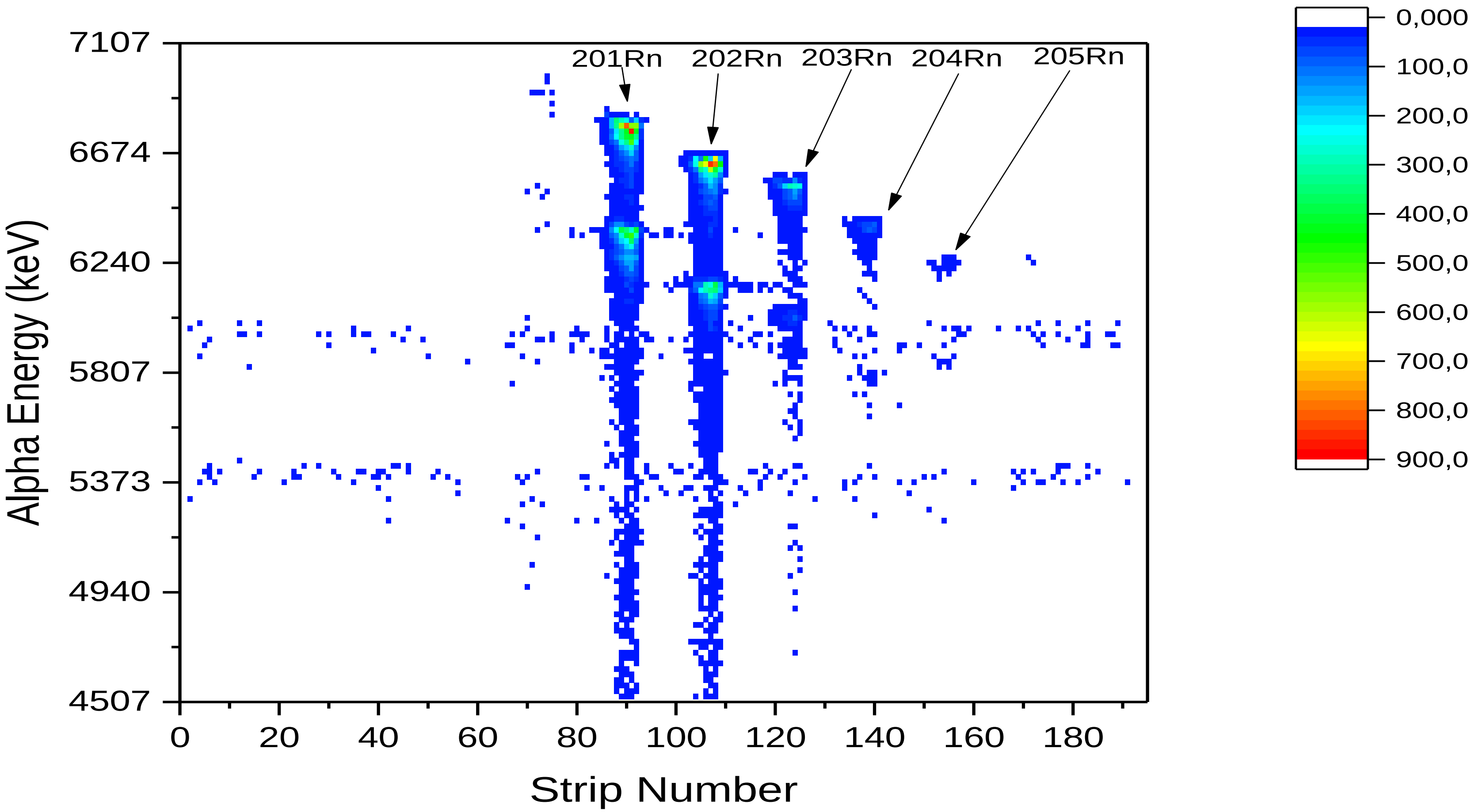

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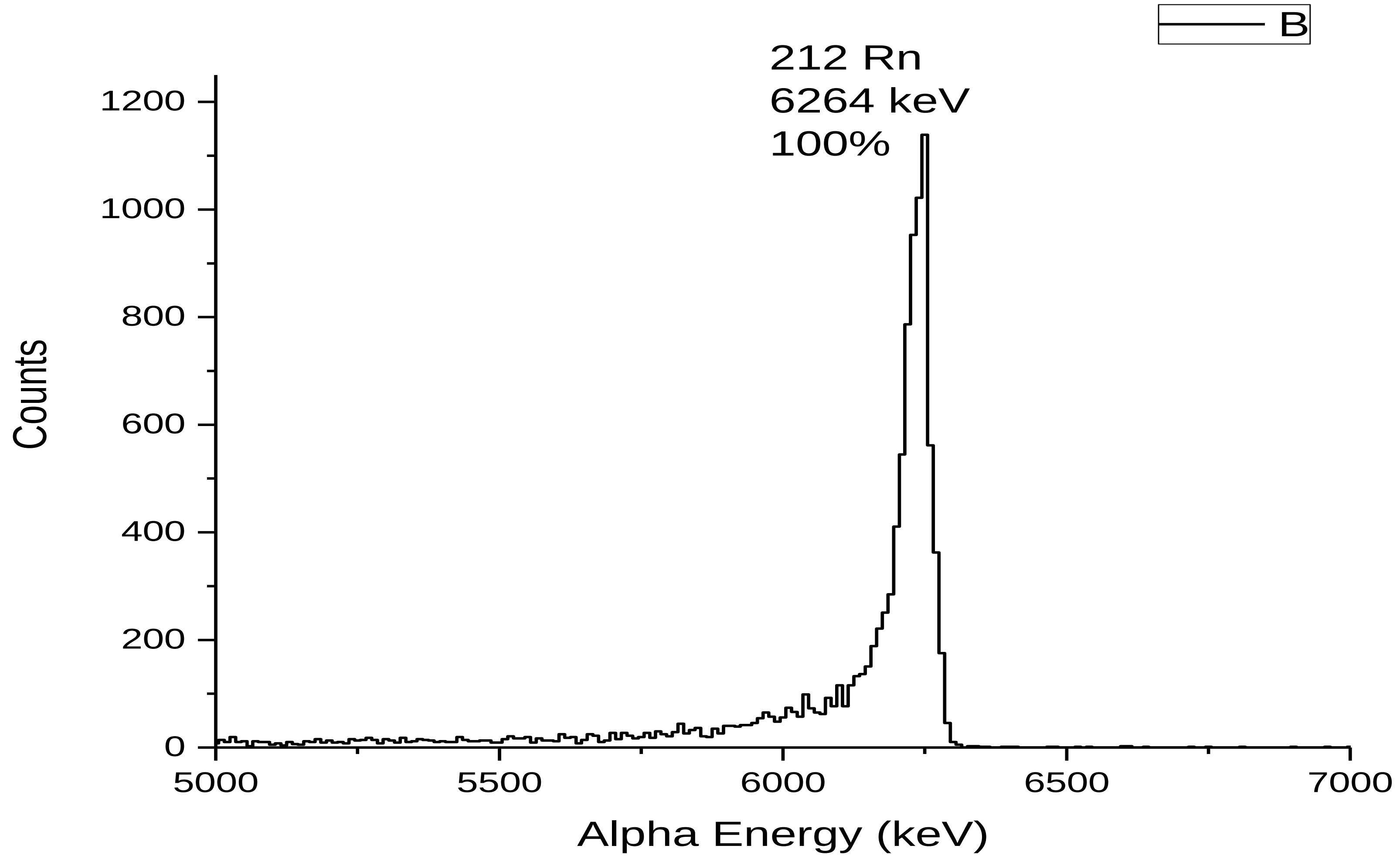

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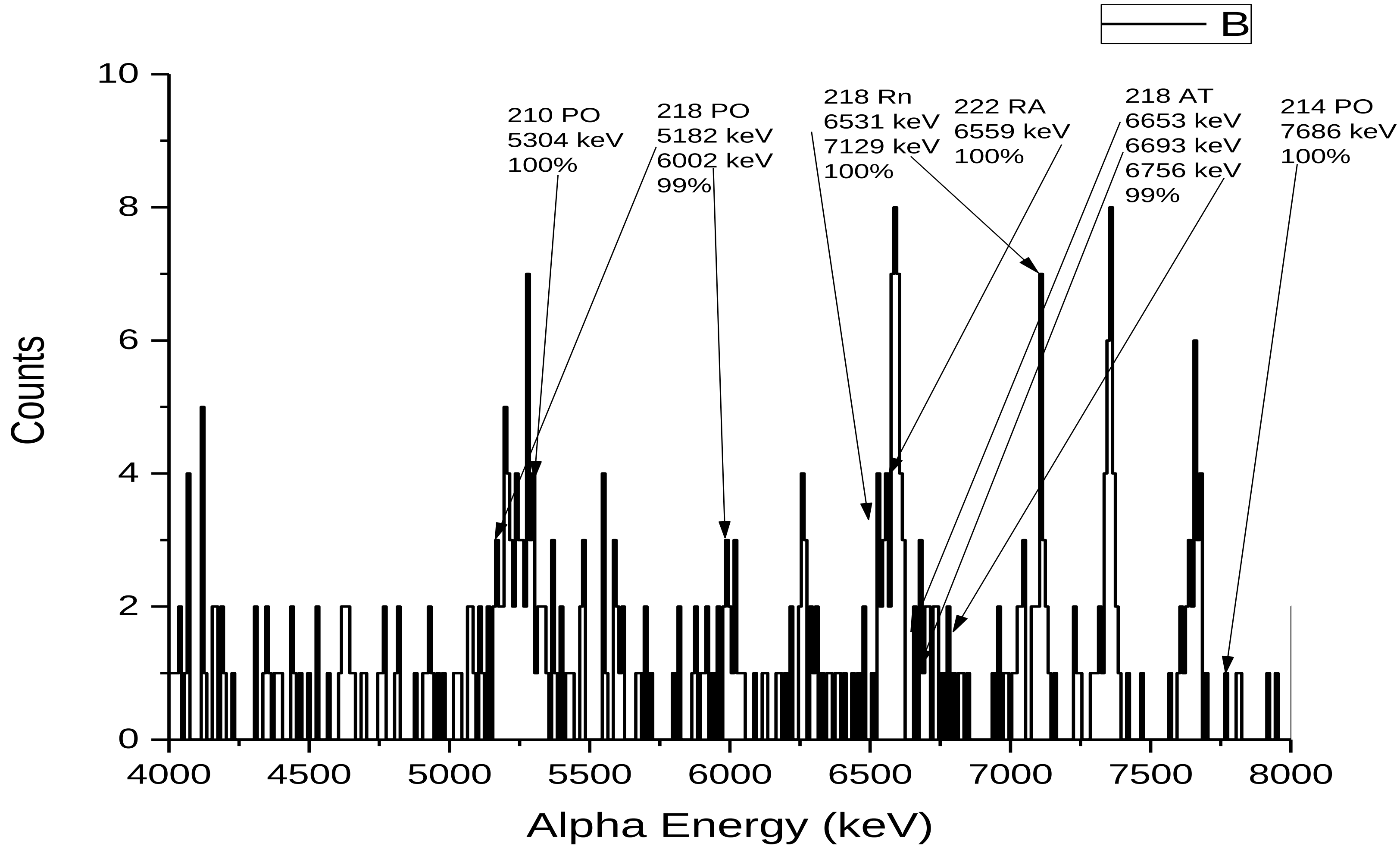

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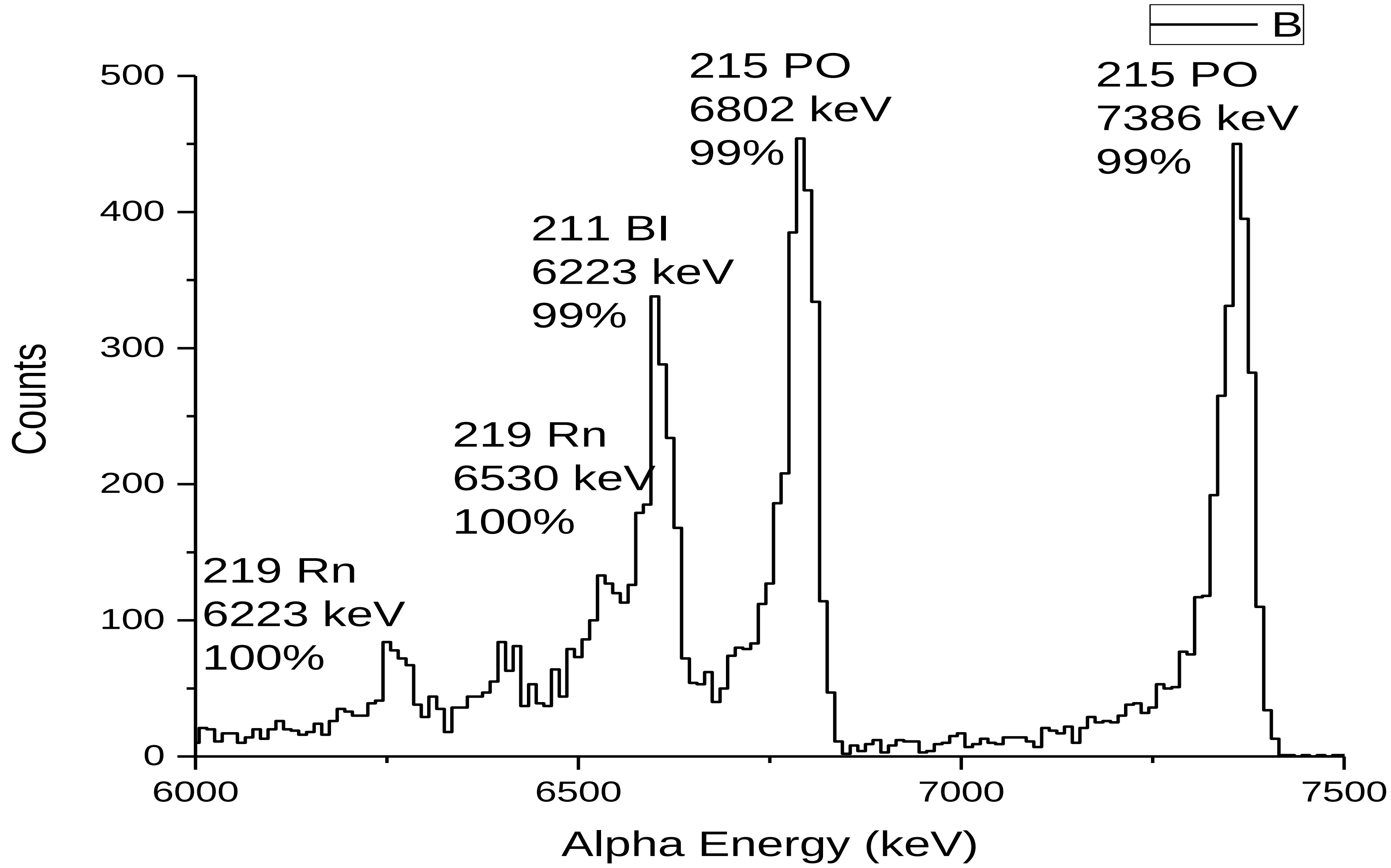

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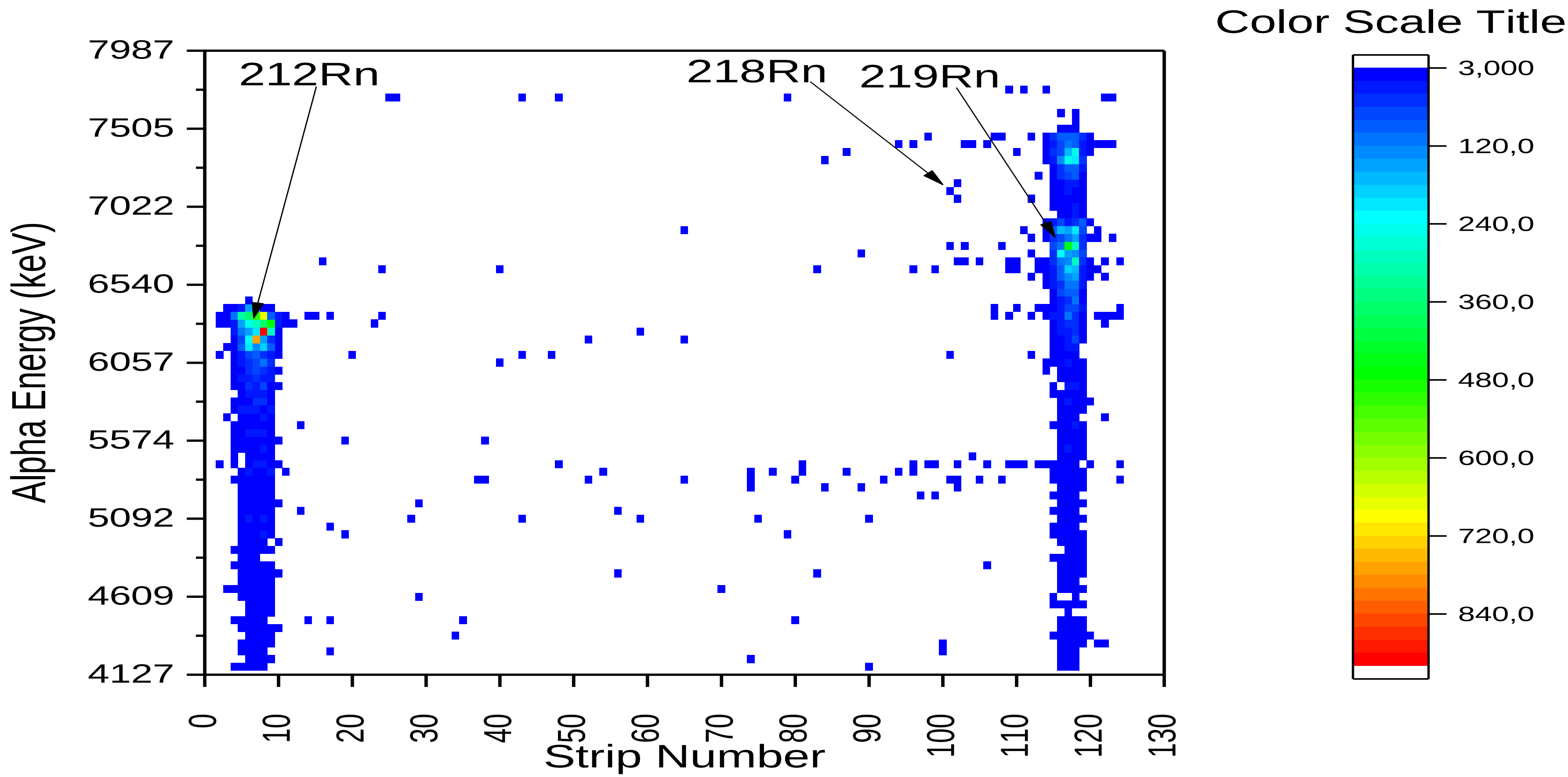

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Conclusion

- There are two important parameters in mass-spectrometric investigation isotopes which lacks stability: the overall extraction efficiency and the extraction time.

- However, an assembly combining a hot catcher and ECR source allows only ionization of the volatile elements with lifetime of least 2s, thus, strongly limiting the experimental possibilities. In the last several years, gas catchers are widely used for production of radioactive beams and turn out to be more perspective.

- The main advantages of the gas catchers are namely:

    - The technique does not suffer from any dependence on chemical and physical properties of the nuclides whose beams are formed in the catcher.
    - It provides an essentially faster extraction time ($\tau \sim 10$ ms) than a hot stopper ($\tau \sim 1.8$ s).
    - There is no need of ionization.
    - It is possible to reach a high total efficiency for transformation (up to 40%) of the initial nuclear reaction products to a low energy beam for mass-spectrometric analysis.

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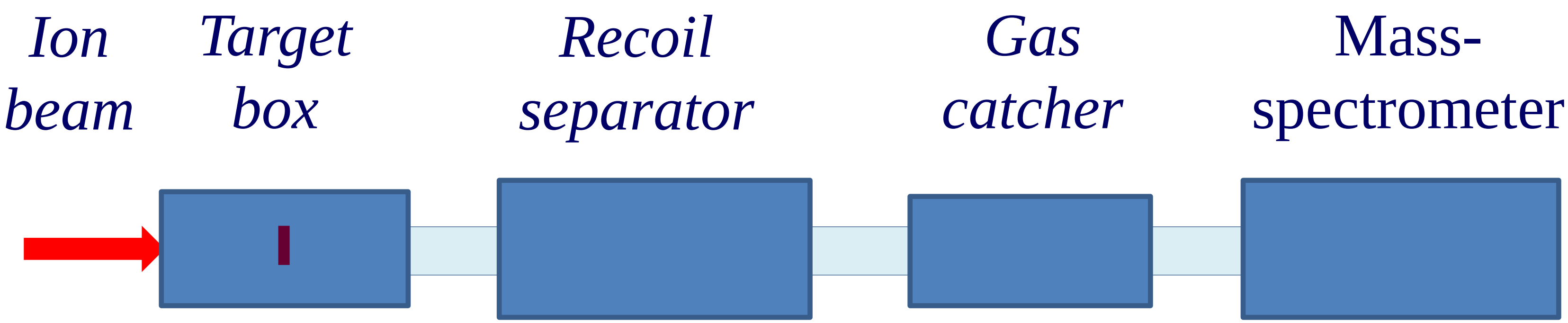
Conclusion

- During the experiment, a detailed study of efficiency and reliability of all systems was also carried out.

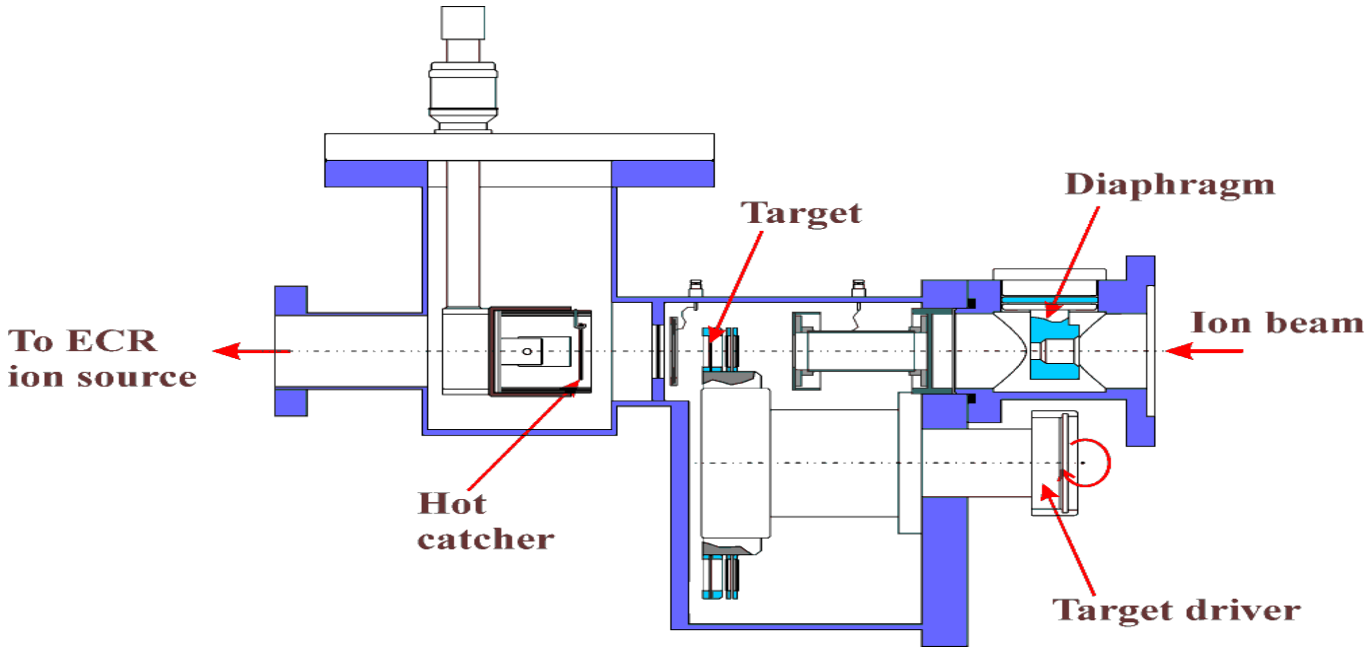
- It turned out that the separation efficiency of MASHA setup is not stable during the experiment in the case of high beam intensity (typically 10 mkA of 48Ca).

- The high beam intensity corrupts the “Hot Catcher” and the separation efficiency of the “Hot Catcher” decreases by almost ten times during a few days.

Experimental facility

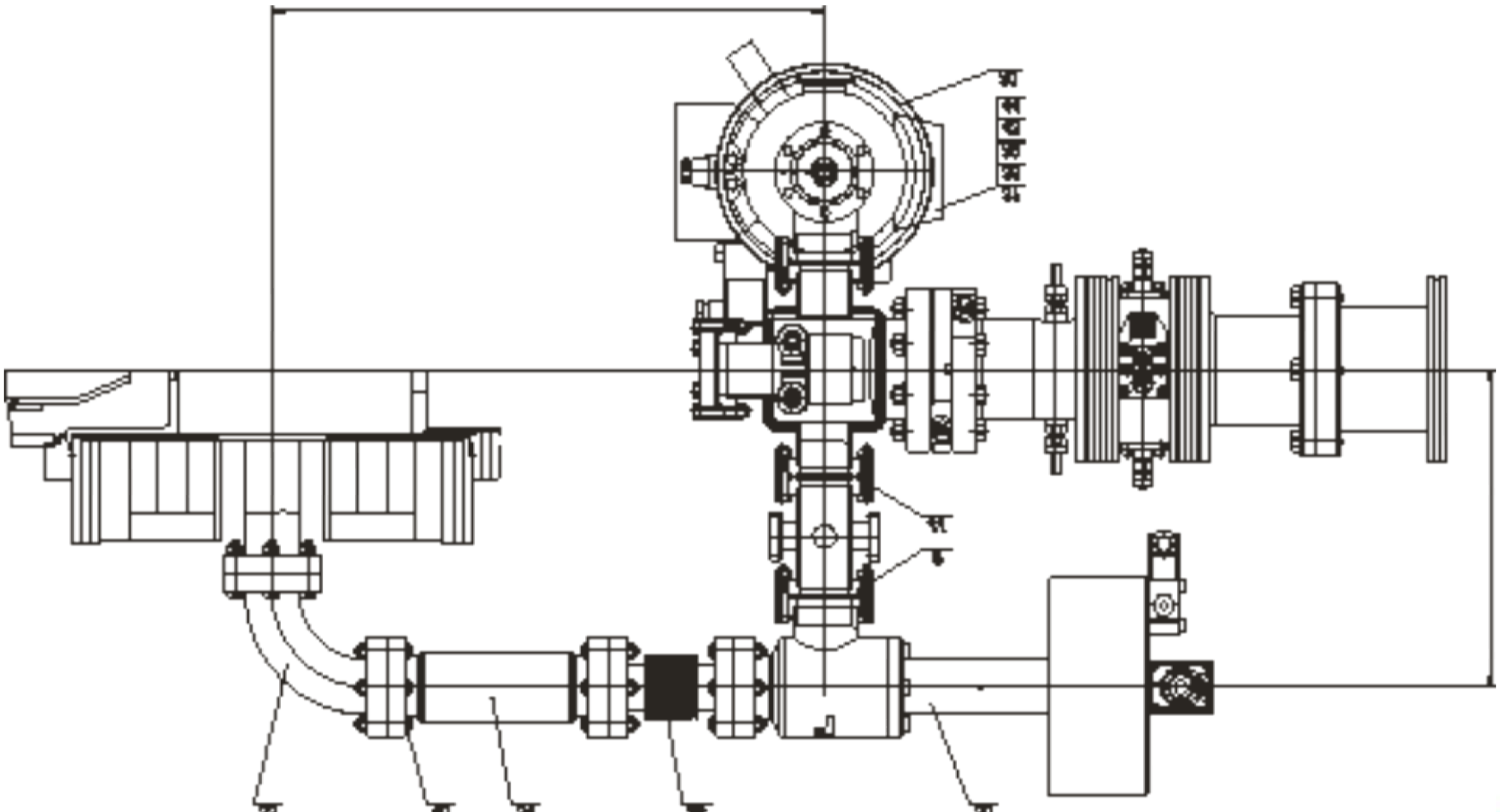


Hot catcher scheme

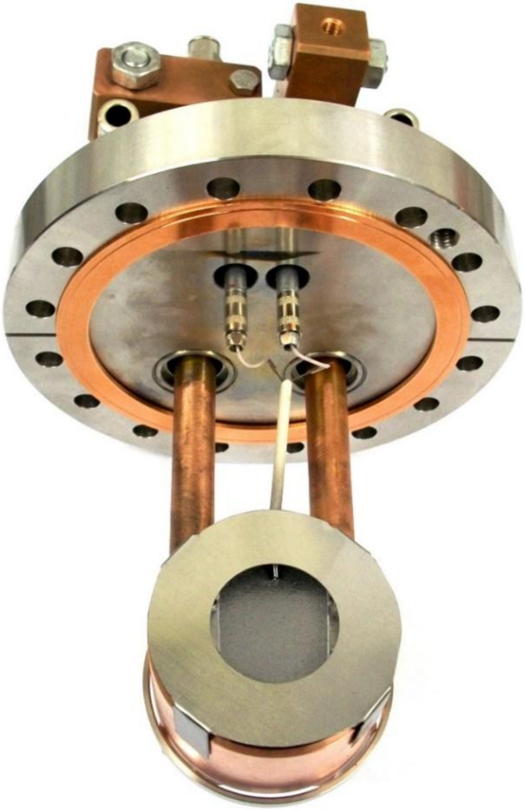


Material of the catcher – flexible graphite, density of 1 g/cm3, a thickness of 0.6 mm and shaped as a 30 mm diameter disk.
Operating temperature of hot catcher – 1800-2000 ^{0}C.
Delivery time of nuclides to the ECR ion source < 1.8 s.

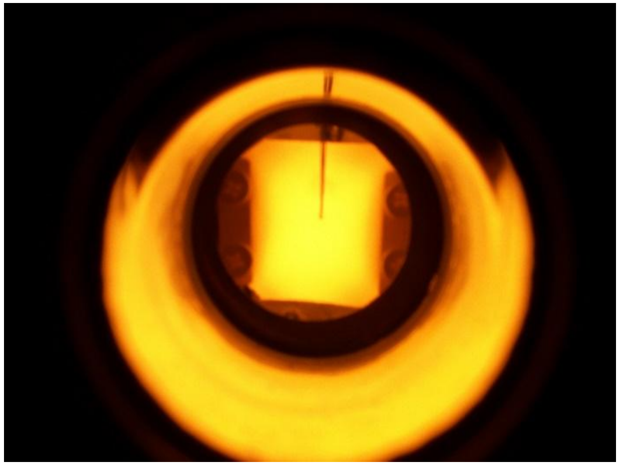
Ion source + Hot catcher (top view)



Hot Catcher



Heating up to 1800 ^{o}C



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- FLNR MASHA staff
- Student Practice organizing committee

Spasibo!

(Kea Leboga)