New technique of ion identification in Accelerator Mass Spectrometry using low-pressure TPC with GEM readout

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1. Introduction

Accelerator mass spectrometry (AMS) is an ultra-sensitive method of counting individual atoms, usually rare radioactive atoms with a long half-life. There are about 140 AMS operating in the worldwide, two of which are located in Novosibirsk.

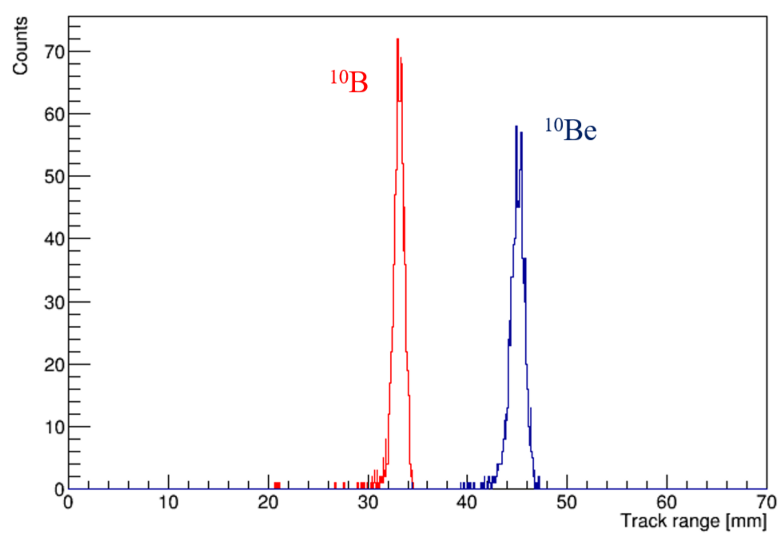
Radioactive isotopes used in AMS

Analyzed isotope	Stable isotope	Stable isobar	Half life	Time intervals of dating
^{10}Be	^{9}Be	^{10}B	1.39 million years	from 1 thousand to 10 million
^{14}C	^{12,13}C	^{14}N*	5730 years	from 300 to 40–60 thousand
^{26}Al	^{27}Al	^{26}Mg*	717 thousand years	from 10 thousand to 10 million
^{36}Cl	^{35,37}Cl	^{36}Ar*, ^{36}S	301 thousand years	from 1 thousand to 1 million
^{41}Ca	^{40,42,43,44}Ca	^{41}K	102 thousand years	from 20 thousand to 500 thousand

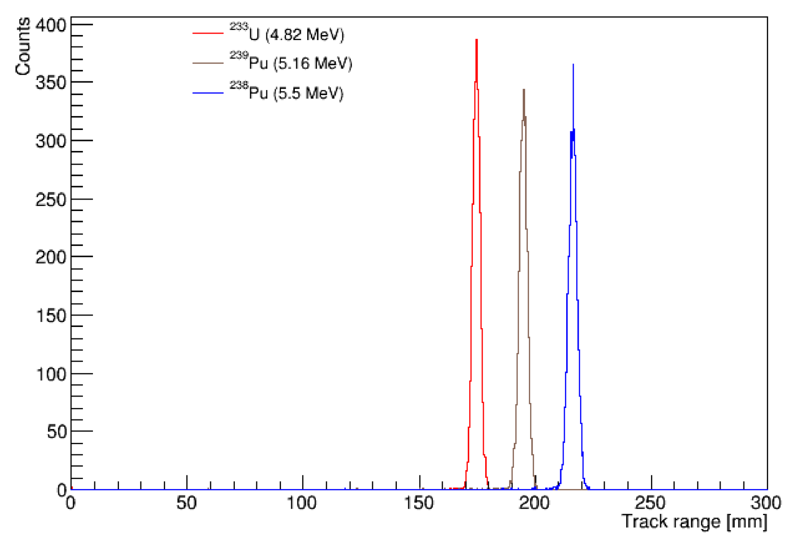
** isobars that do not form stable negative ions therefore they can be separated in AMS.*

At AMS in Novosibirsk, there is a problem to separate isobar ions of different chemical elements that have the same atomic mass. The typical example is radioactive isotopes ^{10}Be and ^{10}B that are used to date geological objects at a time scale of ten million years. To solve this problem, a new ion identification technique, namely that based on measuring both ion track ranges and ion energies in low-pressure TPCs with GEM readout, has been developed.

2. SRIM simulation



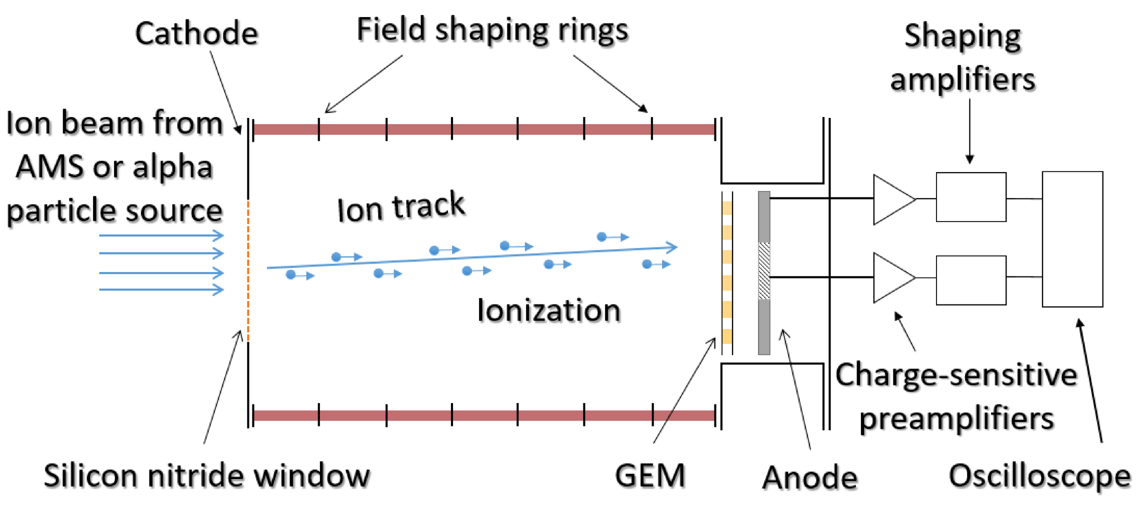
Track ranges distribution of 4 MeV ^{10}Be and ^{10}B for 200 nm silicon nitride window and 50 torr isobutane, obtained using SRIM simulation



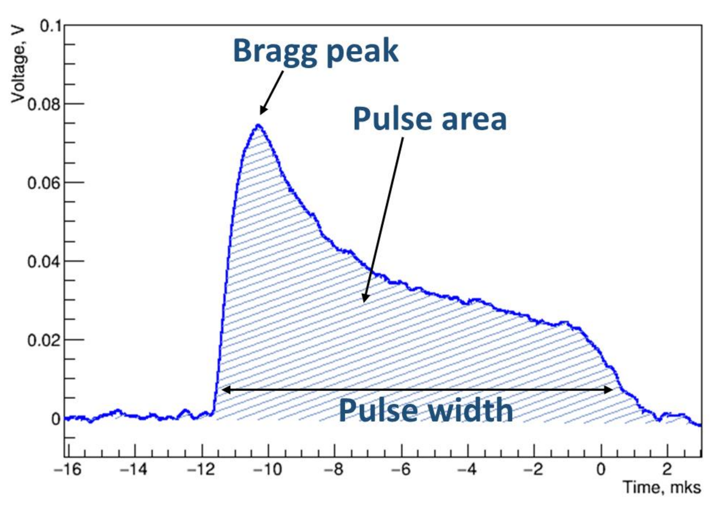
Track ranges distribution of alpha particles with different energies for 200 nm silicon nitride window and 50 torr isobutane, obtained using SRIM simulation

To study this technique we used a low-pressure TPC and triple alpha particle source (^{233}U, ^{238}Pu and ^{239}Pu).

3. Experimental setup

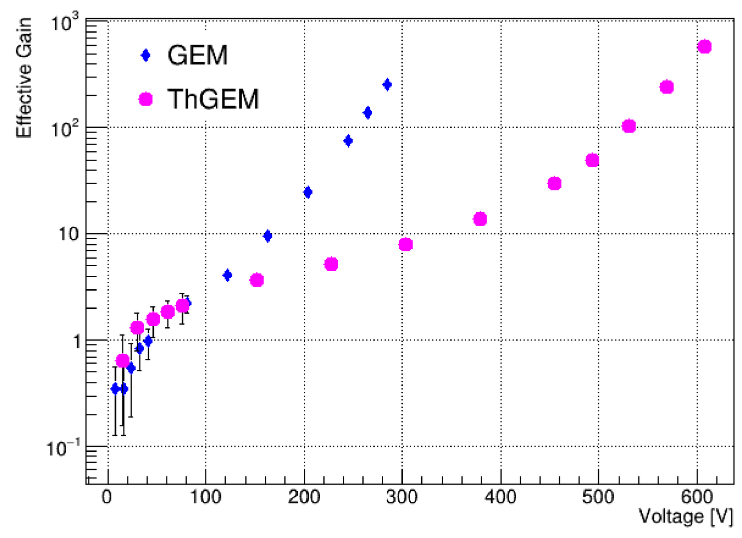


- Diameter - 178 mm
- Length - 300 mm
- Gas filled - isobutane
- Operating pressure 40 ÷ 300 torr



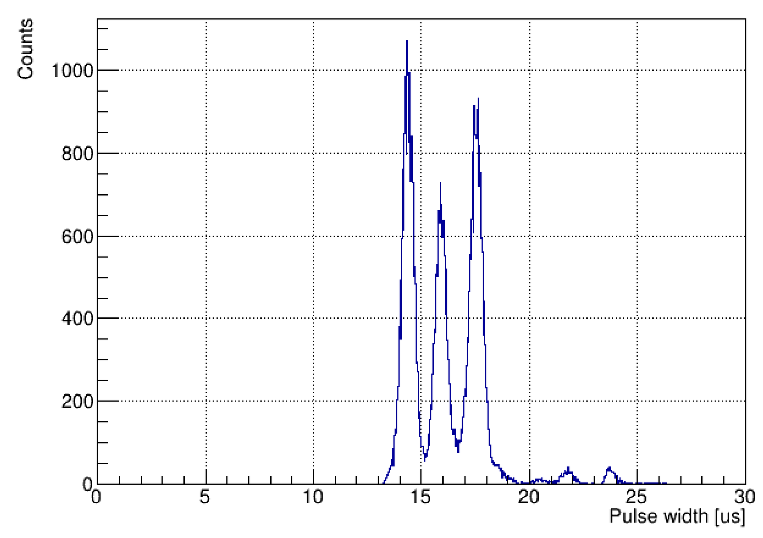
Signal waveform from alpha particle:
pulse width ~ track range
pulse area ~ energy

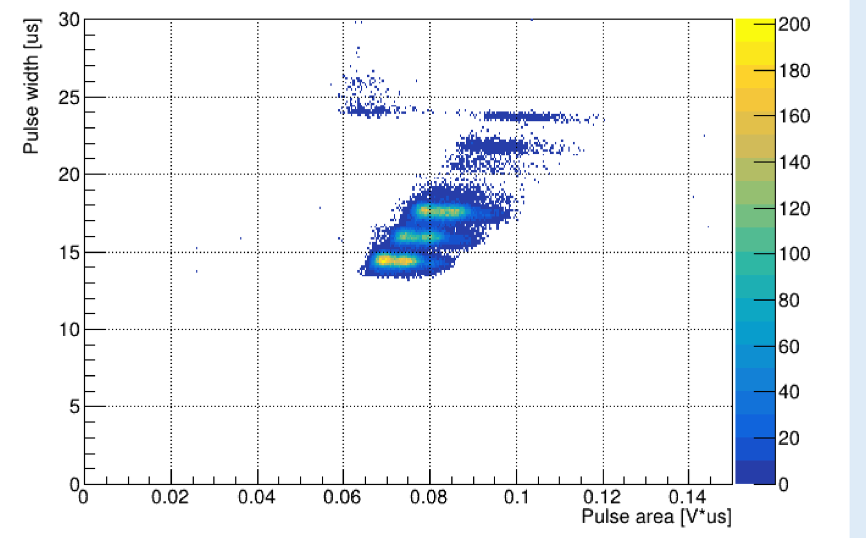
4. Results



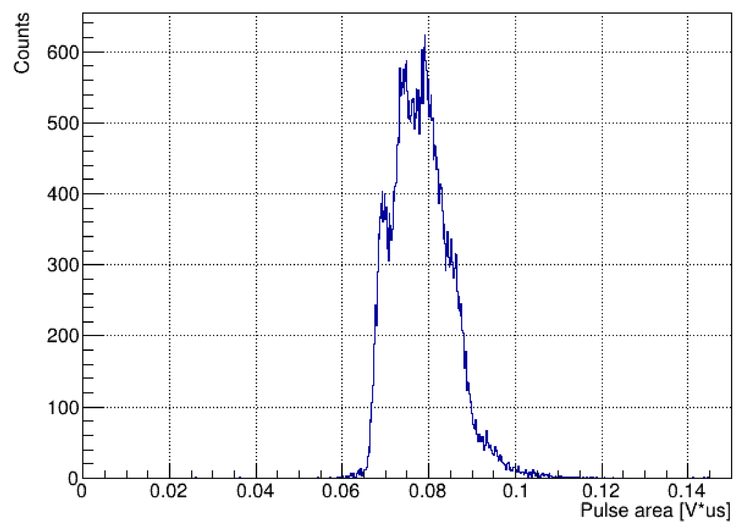
Effective gain as function of voltage across electrodes for GEM and THGEM in low-pressure TPC in isobutane at 50 torr

THGEM

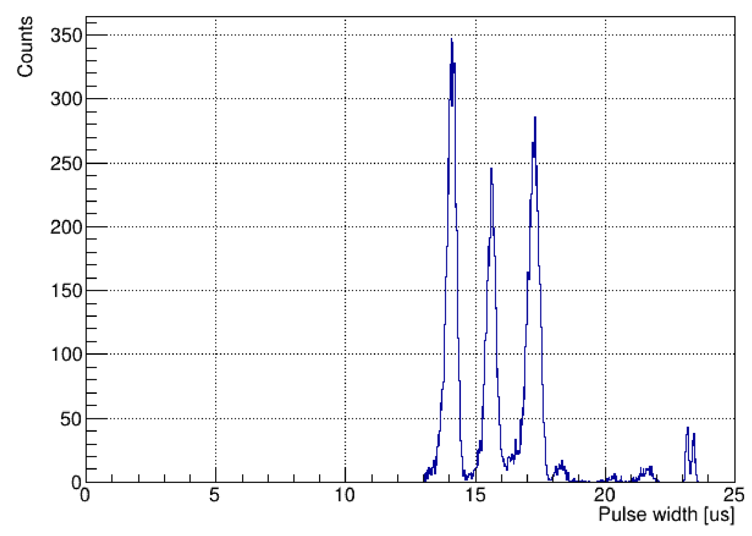


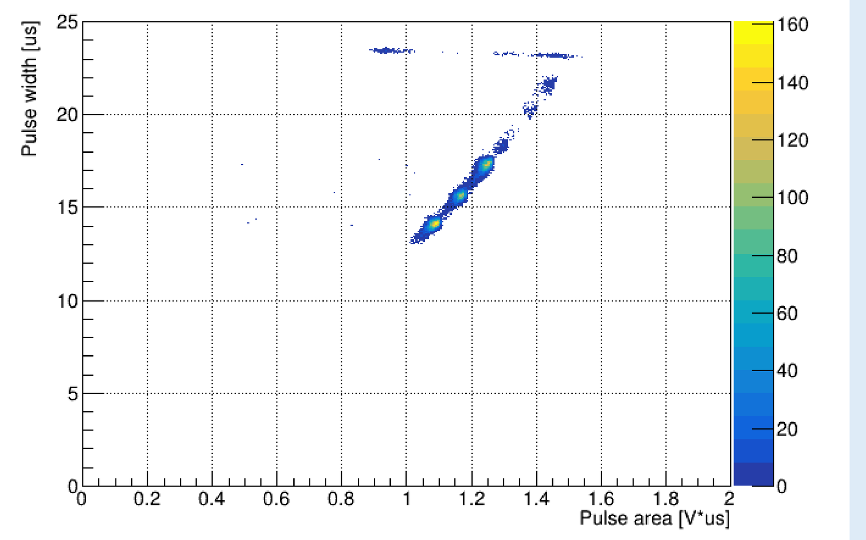


2D plot of pulse width versus pulse area and their axis projection spectra for alpha particles from ^{233}U (4.8 MeV), ^{239}Pu (5.2 MeV) and ^{238}Pu (5.5 MeV) source, measured in low-pressure TPC in isobutane at 50 torr and THGEM gain of 320

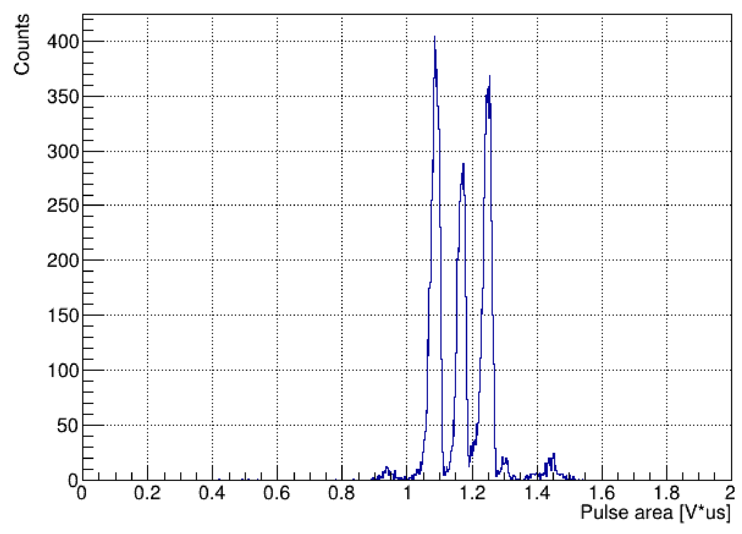


GEM





2D plot of pulse width versus pulse area and their axis projection spectra for alpha particles from ^{233}U (4.8 MeV), ^{239}Pu (5.2 MeV) and ^{238}Pu (5.5 MeV) source, measured in low-pressure TPC in isobutane at 50 torr and GEM gain of 230



One can see that the use of GEM instead of THGEM substantially improve the energy resolution at a nominal pressure (50 torr).

5. Conclusion

- ✓ We have developed and successfully tested TPC with GEM readout for AMS.
- ✓ A new ion identification technique, namely that based on measuring both ion track ranges and ion energies in low-pressure TPCs has been developed.
- ✓ Using these results and SRIM code simulations, it is shown that isobaric boron and beryllium ions can be effectively separated at AMS at a level 5 sigma, providing efficient dating on a scale of 10 million years.
- ✓ This technique will be applied in the AMS facility in Novosibirsk in the near future for dating geological objects, in particular for geochronology of Cenozoic Era.

References

1. A. Bondar et al 2020 NIM A 958 162780
2. A. Bondar et al 2020 JINST 15 C07025