Recent results on low-pressure TPC for Accelerator Mass Spectrometry

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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, used in dating of biological and geological objects.

Radioactive isotopes used in AMS

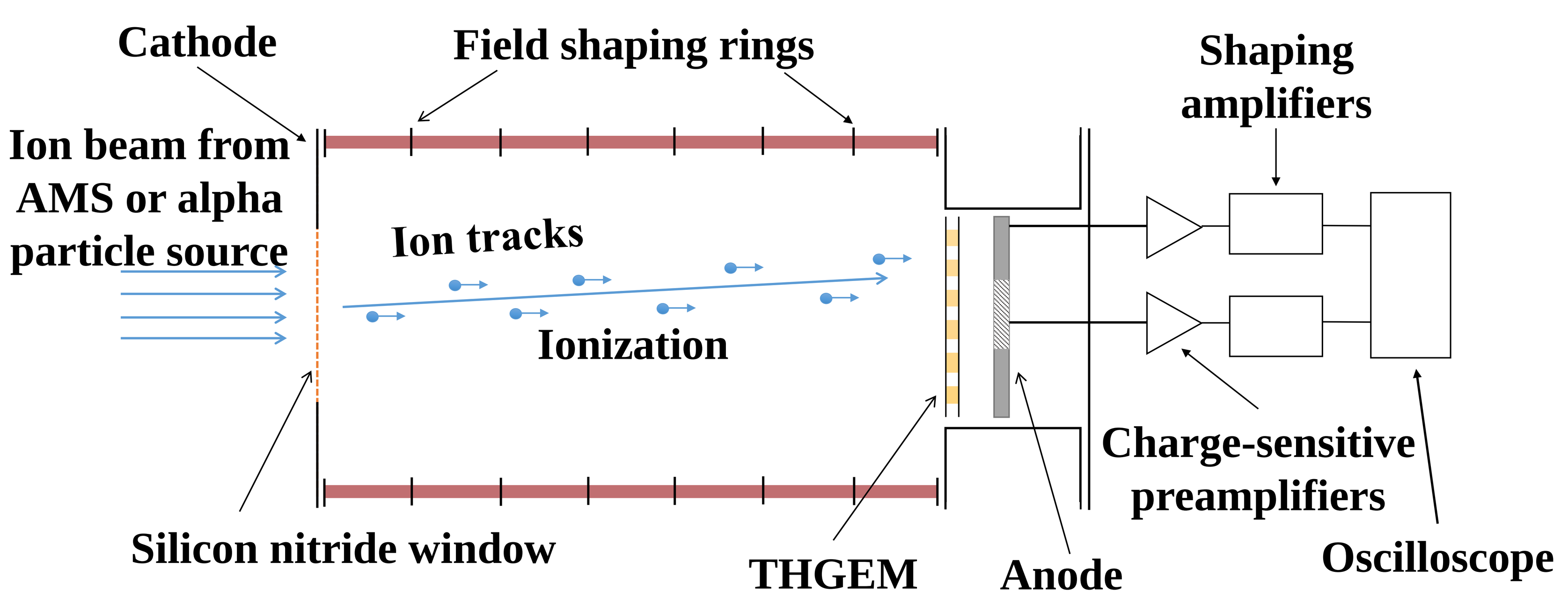
Analyzed isotope	Half life	Stable isotope	Stable isobar
^{10}Be	1.39 million years	^{9}Be	^{10}B
^{14}C	5730 years	^{12,13}C	^{14}N
^{26}Al	717 thousand years	^{27}Al	^{26}Mg
^{36}Cl	301 thousand years	^{35,37}Cl	^{36}Ar, ^{36}S
^{41}Ca	102 thousand years	^{40,42,43,44}Ca	^{41}K
^{129}I	15.7 million years	^{127}I	^{129}Xe

Time intervals of dating:

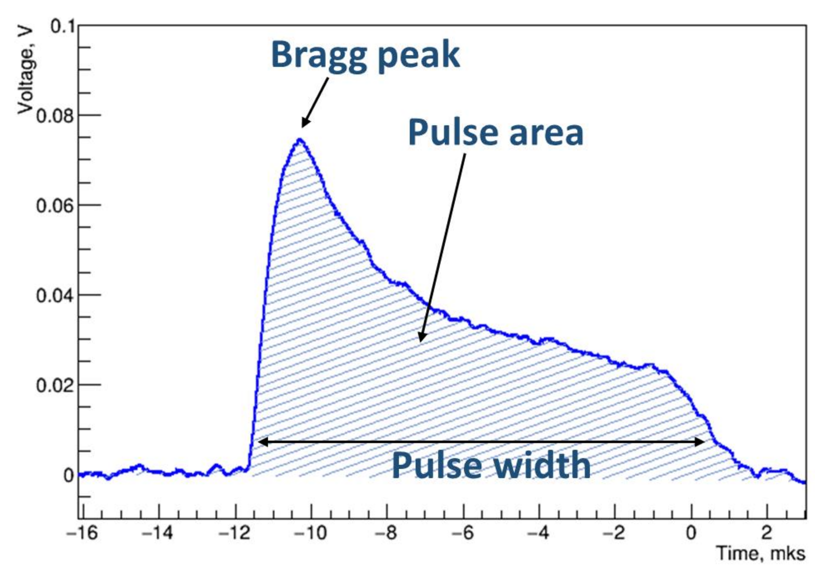
- **^{14}C** from 300 years to 40-60 thousand years
- **^{10}Be** from 1 thousand years to 10 million years

AMS facilities operate in more than 100 physical laboratories worldwide, one of which is located in Novosibirsk at Geochronology of the Cenozoic Era Center for Collective Use. There is a serious problem of separating the radioactive isotope ^{10}Be, used for geochronology, from isobar ^{10}B. To solve this problem, we propose a new technique for ion identification, namely by measuring the ion ranges using a low-pressure TPC with THGEM readout.

2. Experimental setup

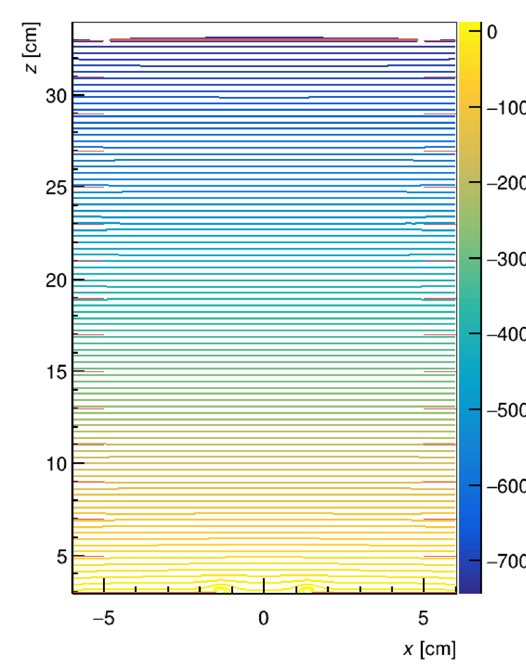


- **The concept: ions are identified by measuring their ranges and energies**
- The proof of concept was demonstrated in low-pressure TPC using triple alpha-particle source (^{233}U, ^{238}Pu and ^{239}Pu)



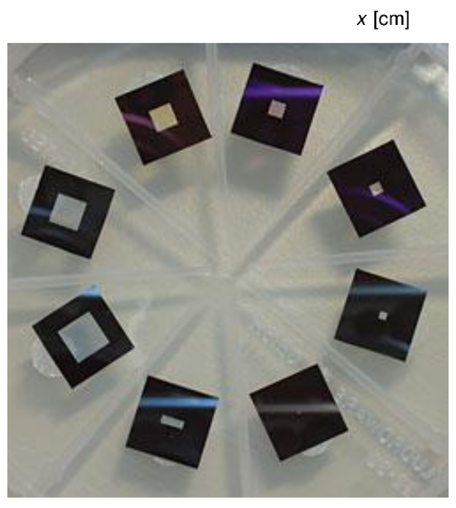
Diameter - 178 mm
Length - 300 mm
Gas filled – isobutane
Operating pressure – 40÷300 torr

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



Calculated electric field in the low-pressure TPC

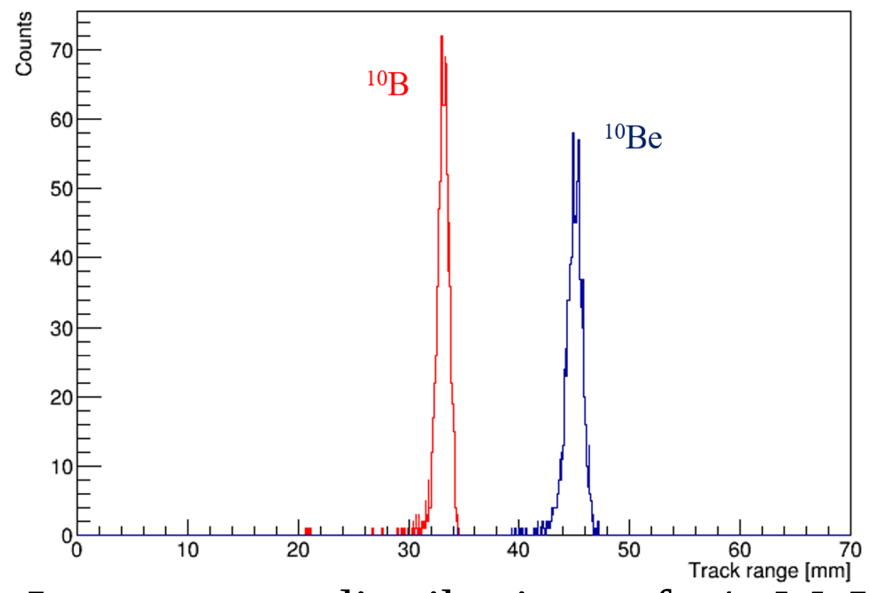
- Gmsh, Elmer and Garfield++ were used to calculate the electric field
- As can be seen the equipotential lines of electric field are uniform
- The electric field strength is 25 V/cm



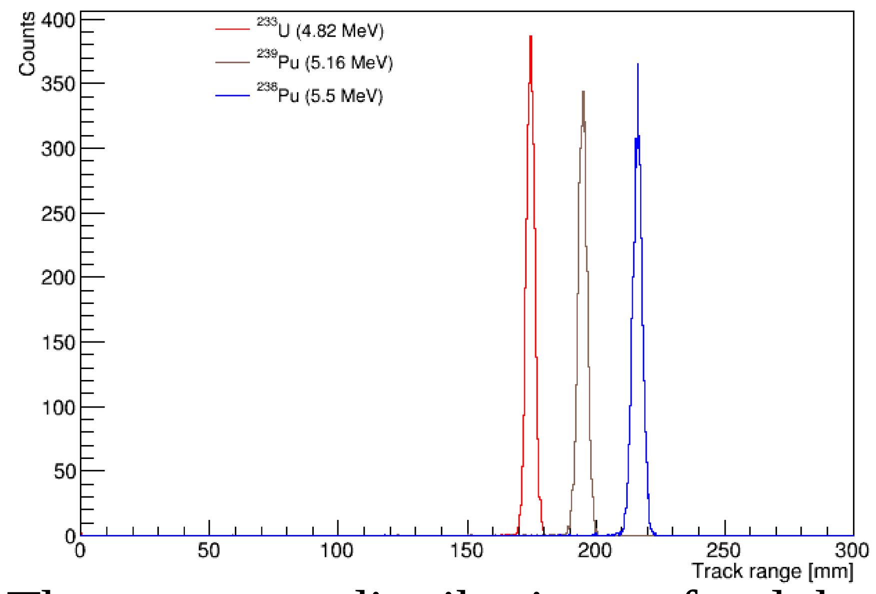
The thin film of silicon nitride is used as entrance window

- A 200 nm thick Si_3N_4 film of 10x10 mm^2 is used, mounted on Si frame.
- Advantages of Si_3N_4 window: high strength, high fracture toughness, much lower energy loss straggling respect to other materials.

3. SRIM simulation of ion ranges in low-pressure TPC

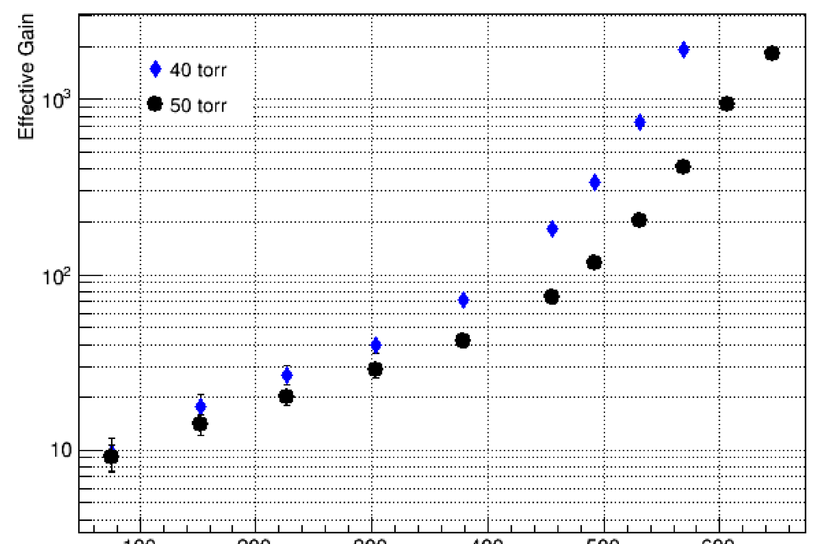


Ion ranges distribution of 4 MeV ^{10}Be and ^{10}B for 200 nm Si_3N_4 window and 50 torr isobutane gas filling, obtained using SRIM simulation

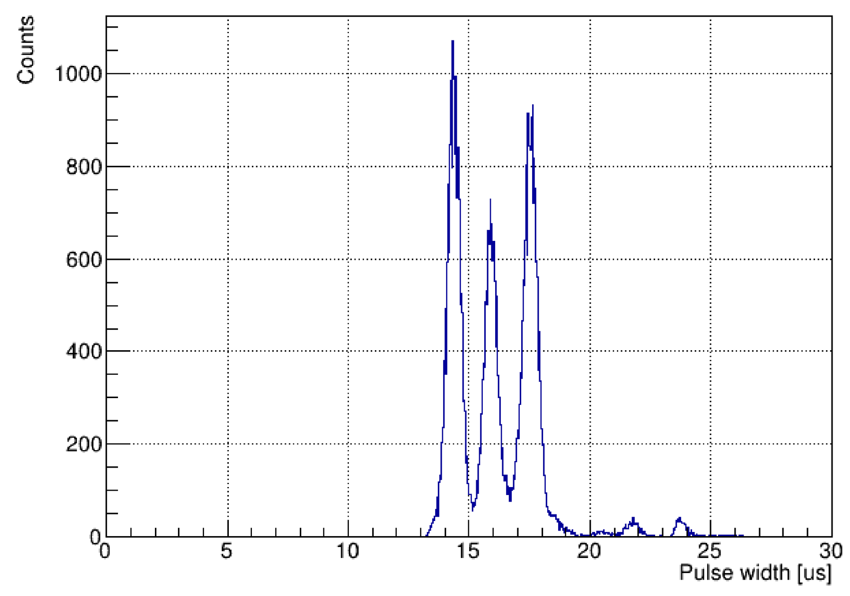


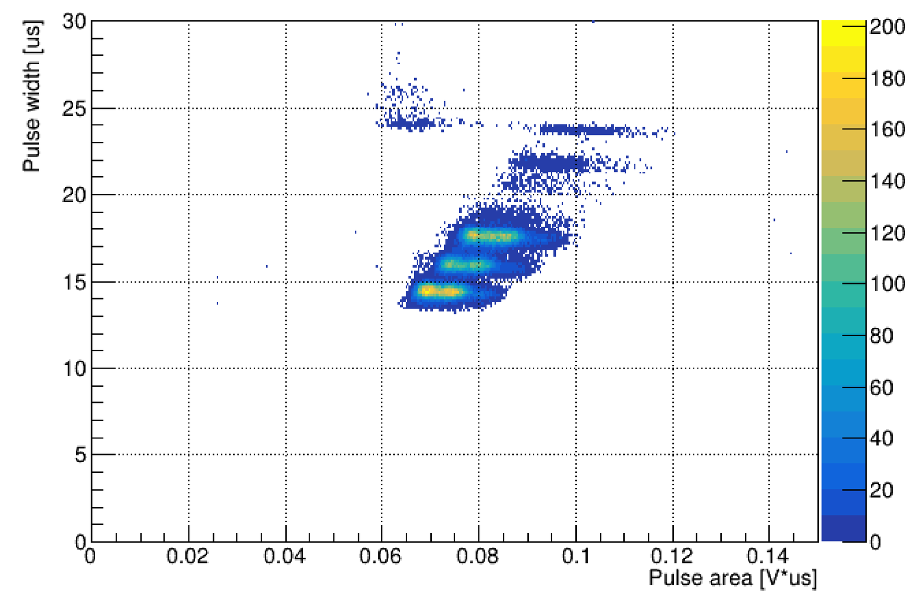
The ranges distribution of alpha particles with different energies for 200 nm Si_3N_4 window and 50 torr isobutane gas filling, obtained using SRIM simulation

4. Results

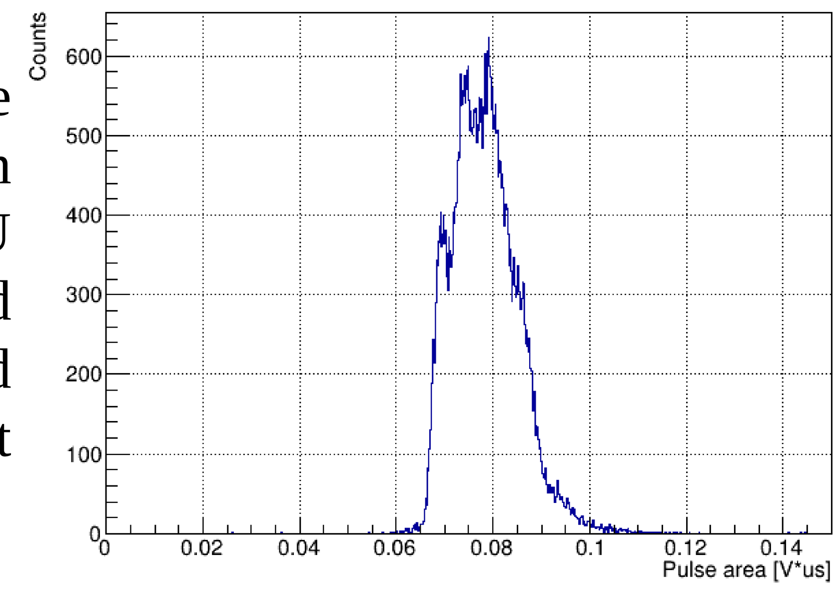


THGEM effective gain as function of voltage in low-pressure TPC in isobutane at pressures of 40 torr and 50 torr





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 410



Ion range resolution measured in low-pressure TPC

Source	THGEM gain	Pressure	Sigma/Range
3 isotopes	40	120 torr	2.23 %
3 isotopes	220	120 torr	2.08 %
3 isotopes	410	50 torr	1.68 %

One can see that in low-pressure TPC the alpha particle lines can be effectively separated by pulse width (ion ranges). On the other hand, these can hardly be separated by pulse area (energy).

5. Conclusion

- In this work we developed a new, larger version of the low-pressure TPC, with a dedicated thin Si_3N_4 window for efficient passage of ions.
- The THGEM gain was measured and the improved resolution for measuring the ranges of alpha particles was obtained at the nominal TPC pressure (50 Torr). Using these results and SRIM code simulations, it is shown that isobaric boron and beryllium ions can be effectively separated on AMS at a level 10 sigma.
- It is expected that this technique will be applied in the AMS facility in Novosibirsk for dating geological objects, in particular for geochronology of Cenozoic Era.

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