Ion detector for Accelerator Mass Spectrometry based on low-pressure TPC with THGEM 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.

Radioactive isotopes used in AMS

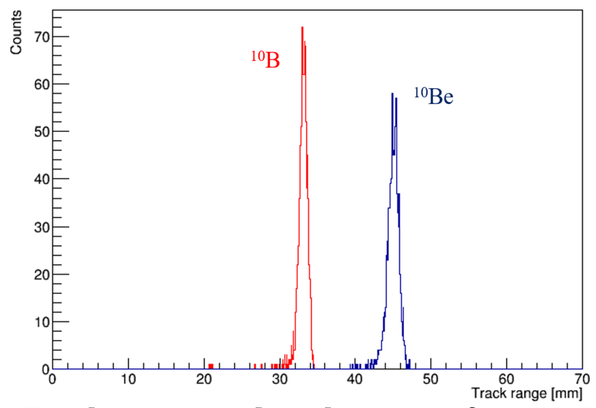
Analyzed isotope	Half life	Stable isotope	Stable isobar
^{10}Be	1.39 million years	^{9}Be	^{10}B
^{14}C	5730 years	^{12,13}C	^{14}N
^{26}Al	717 thousand years	^{27}Al	^{26}Mg
^{36}Cl	301 thousand years	^{35,37}Cl	^{36}Ar, ^{36}S
^{41}Ca	102 thousand years	^{40,42,43,44}Ca	^{41}K
^{129}I	15.7 million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

Time intervals of dating:

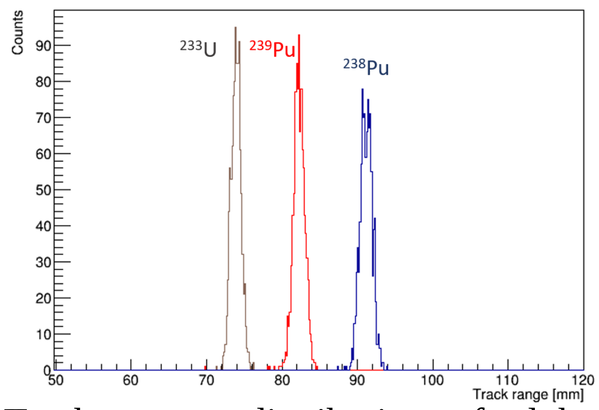
- ➢ **^{14}C** from 300 years to 40-60 thousand years
- ➢ **^{10}Be** from 1 thousand years to 10 million years

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 track ranges using a low-pressure TPC with THGEM readout.

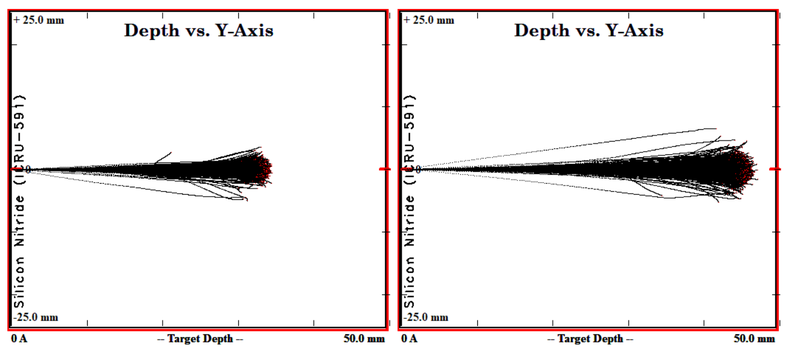
2. SRIM simulation



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



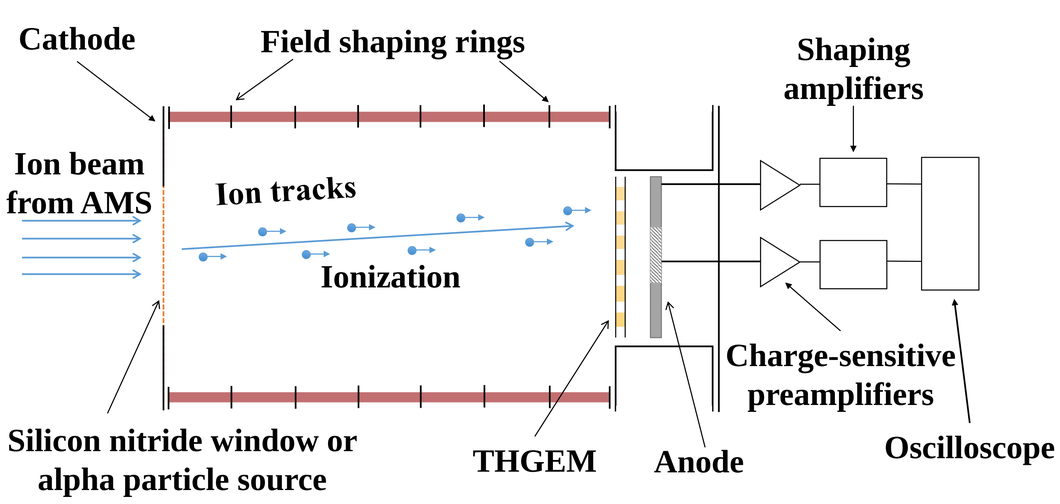
Track ranges distribution of alpha particles with different energies in 120 torr isobutane, obtained using the SRIM simulation

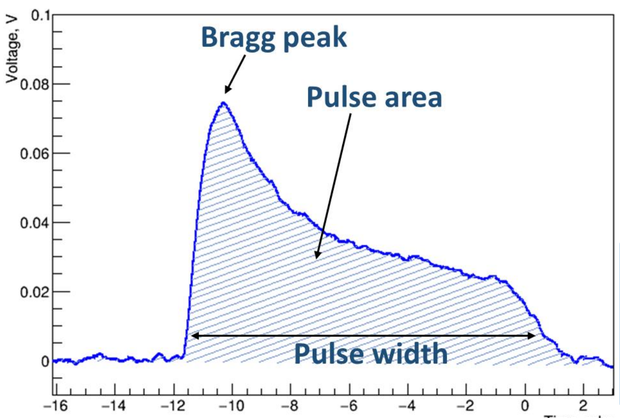


Tracks of ^{10}B and ^{10}Be respectively for 200 nm silicon nitride and 50 torr isobutane, obtained using the SRIM simulation

- ➢ 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

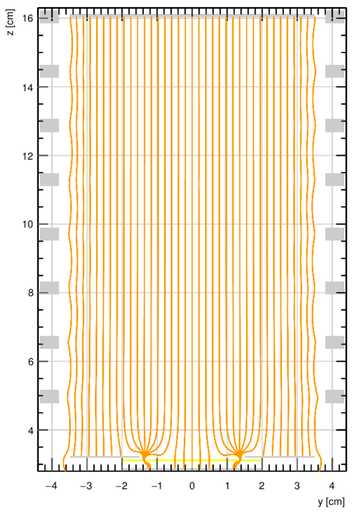




- ➢ Diameter - 76 mm
- ➢ Length - 130 mm
- ➢ Gas filled – Isobutane
- ➢ Operating pressure – 50÷160 torr

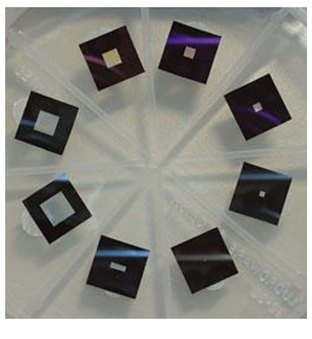
Signal waveform from alpha particle:

pulse width ~ track range
pulse area ~ energy



Calculated electric field lines in the low-pressure TPC

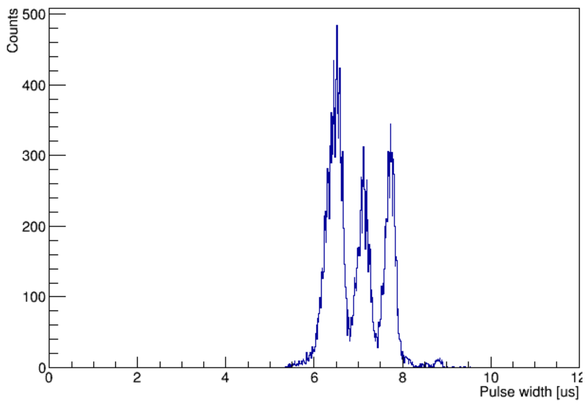
- ➢ As can be seen the lines of electric field are uniform
- ➢ The electric field strength is 50 V/cm

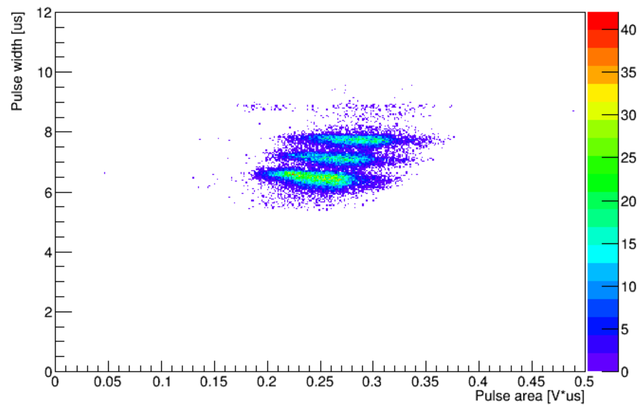


The membrane of silicon nitride will be used as entrance window

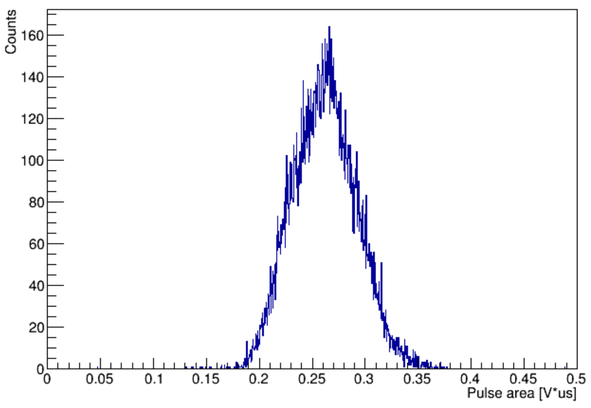
- ➢ A frame of 14 mm × 14 mm and 525 μm thick, a membrane of 10 mm × 10 mm and 100 nm thick will be used.
- ➢ Advantages of silicon nitride membrane: high strength, high fracture toughness, the much lower energy loss straggling respect to other materials.

4. Results





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 120 torr and THGEM gain of 220



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

Source	Amplifier shaping time	THGEM gain	Pressure	Sigma/Range
3 isotopes	500 ns	40	120 torr	3.2 %
3 isotopes	200 ns	40	120 torr	2.2 %
3 isotopes (different geometry)	100 ns	220	120 torr	1.4 %

5. Conclusion

- ➢ The track ranges of alpha particles were measured in the low-pressure TPC with THGEM readout with a high accuracy, reaching 1.4% precision level.
- ➢ On the basis of these results and the SRIM code simulation, one may conclude that the isobaric boron and beryllium ions (having range difference of 32%) can be effectively separated coupling the TPC to AMS, at a level exceeding 10 sigma, by measuring the ion track ranges.
- ➢ 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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