Low-pressure TPC with THGEM readout for ion identification in Accelerator Mass Spectrometry

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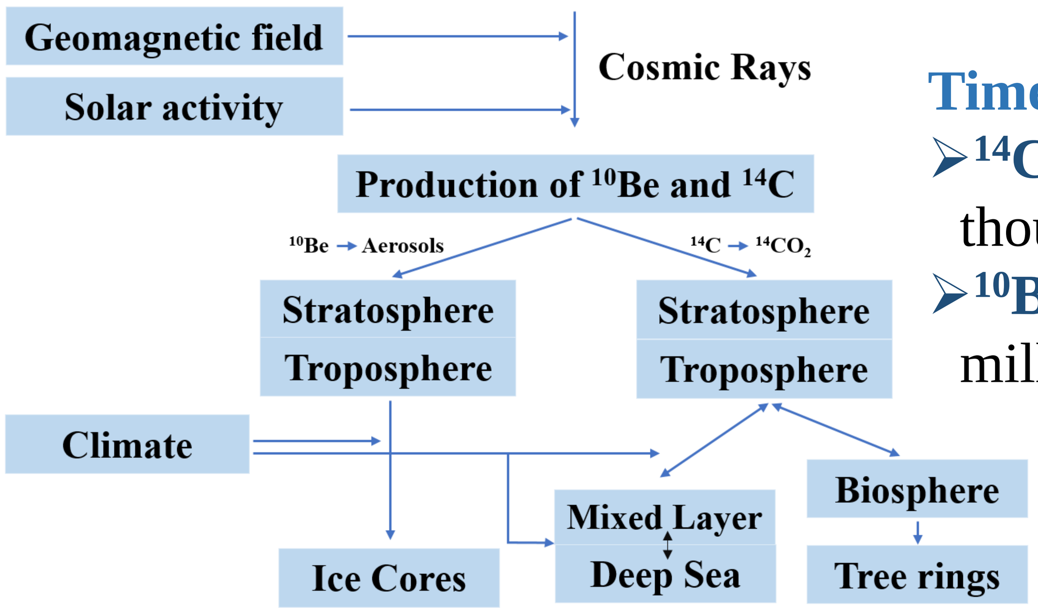
1. Introduction

Accelerator mass spectrometry (AMS) is an ultra-sensitive means of counting individual atoms. The atoms to be countered are radioactive with a long half-life, and are rare. The archetypal example is ^{14}C which has a half-life of 5730 years and an abundance in living organisms of 10^{-12} relative to stable ^{12}C. The utility of AMS is not limited to ^{14}C alone, however, and many other isotopes are amenable to the technique, the most important of which are ^{10}Be, ^{26}Al, ^{36}Cl and ^{129}I.

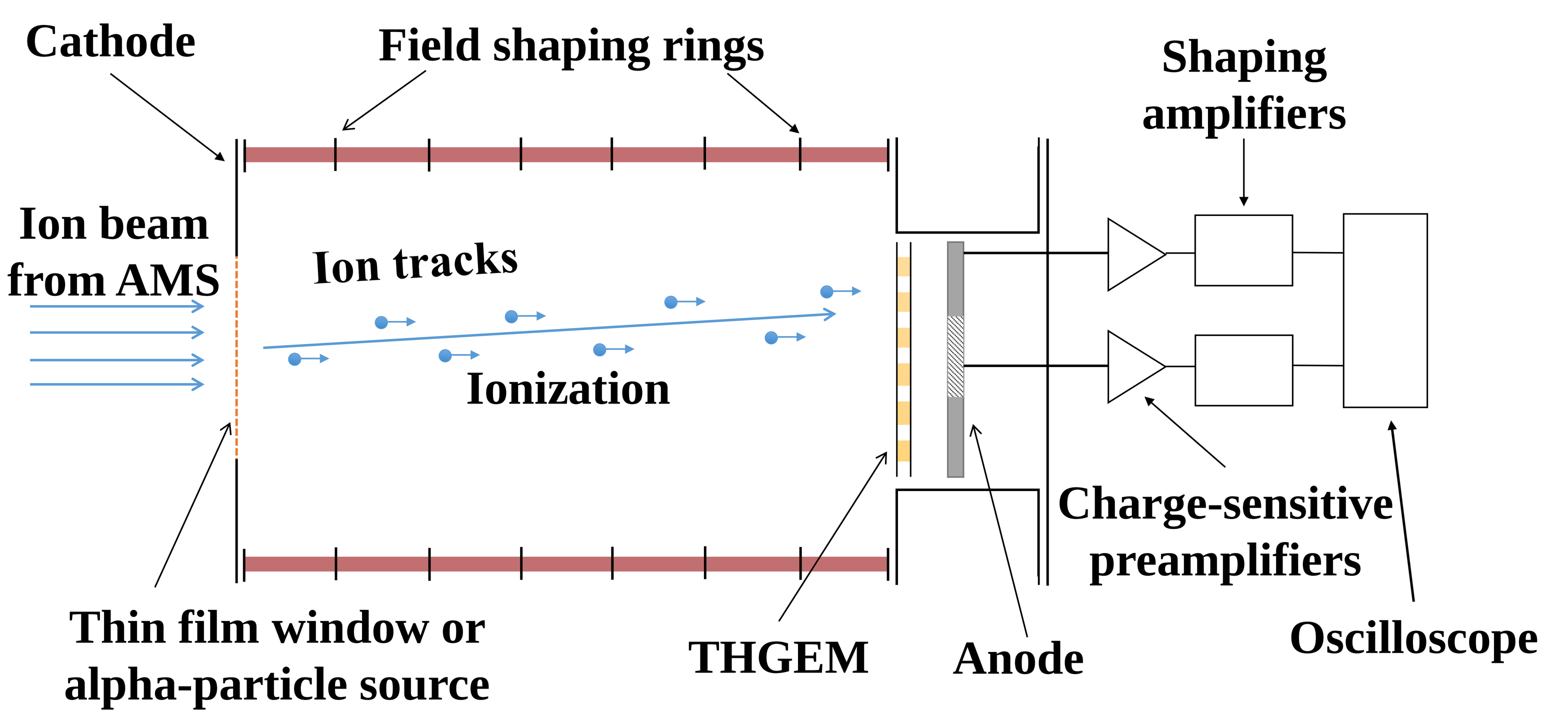


Time intervals of dating:

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

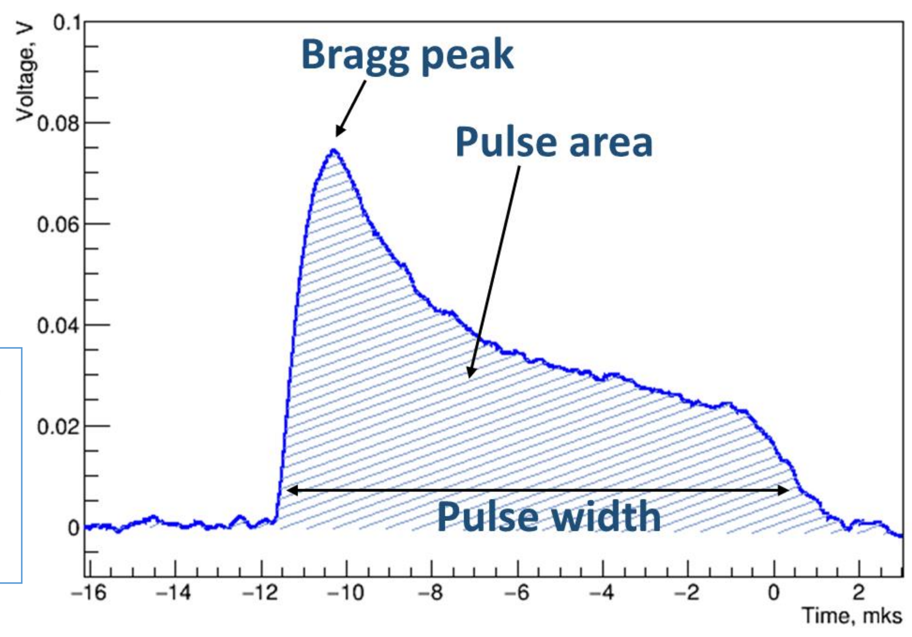
AMS facilities operate in more than 100 physical laboratories worldwide, one of which is located in Novosibirsk at Geochronology of the Cenozoic Era Center for Collective Use. There is a serious problem of separating the radioactive isotope ^{10}Be used for geochronology from isobar ^{10}B. To solve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

2. Experimental setup

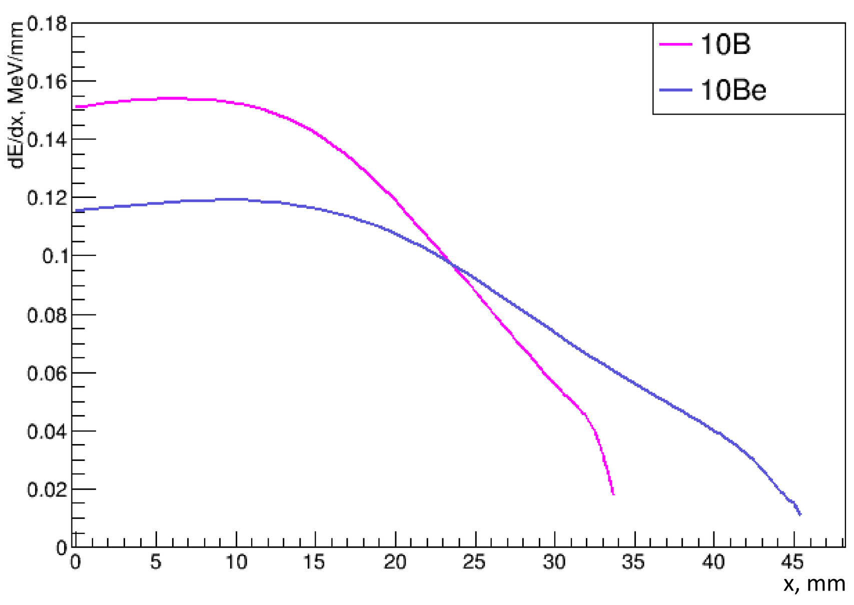


- Diameter - 76 mm
- Length - 130 mm
- Gas filled – Isobutane
- Operating pressure – 50÷160 torr

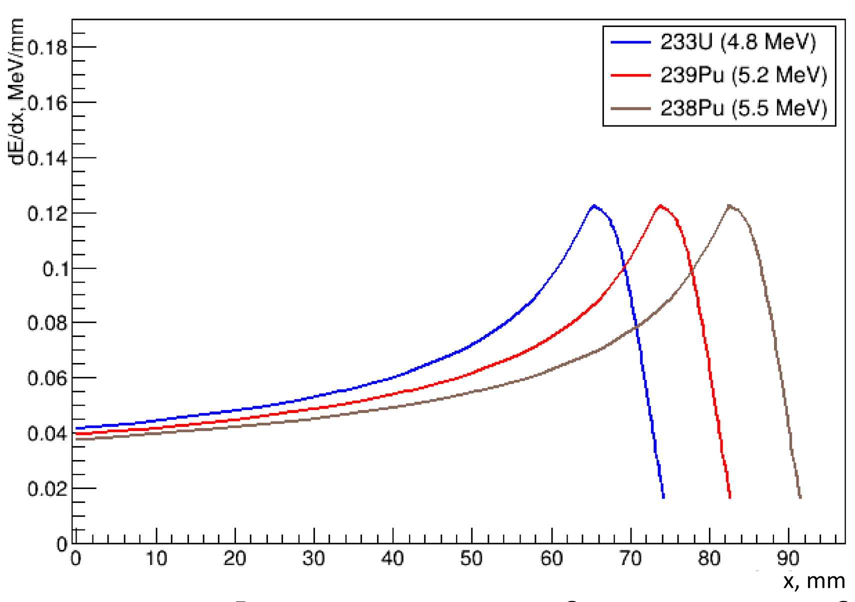
Signal waveform from alpha-particle
energy ~ pulse area
track range ~ pulse width



3. SRIM simulation



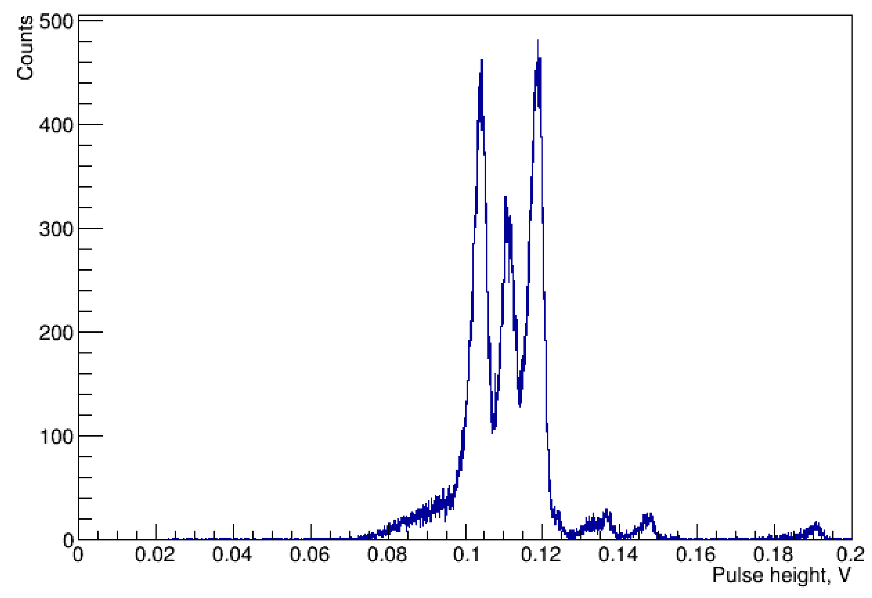
Energy loss as a function of distance in Isobutane for 4.0 MeV ^{10}B and ^{10}Be ions at 50 torr



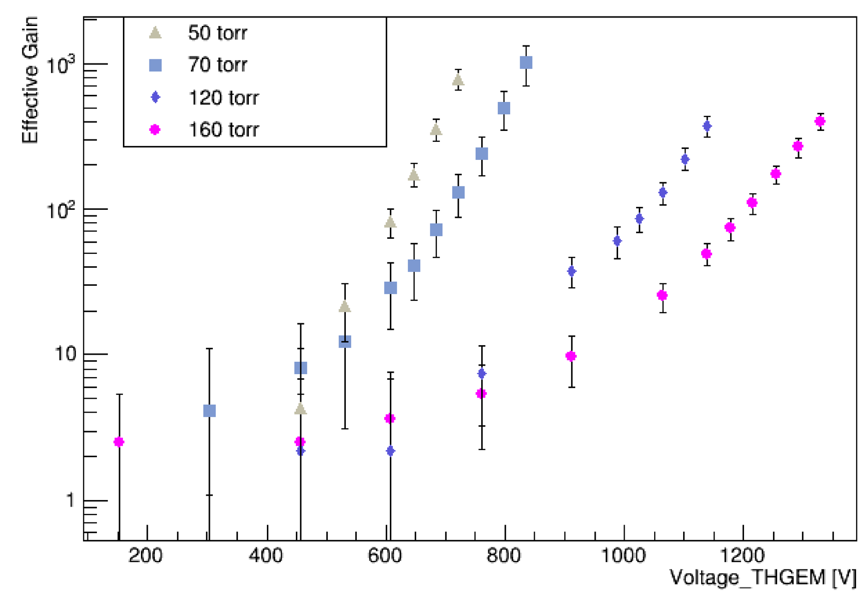
Energy loss as a function of distance in Isobutane for alpha-particles with different energy at 120 torr

- The track ranges for boron and beryllium are rather different: accordingly, the ions can be effectively separated by measuring the track ranges.
- To study this technique, we used a low-pressure TPC and triple alpha-particle source (^{233}U, ^{238}Pu and ^{239}Pu).

4. Results

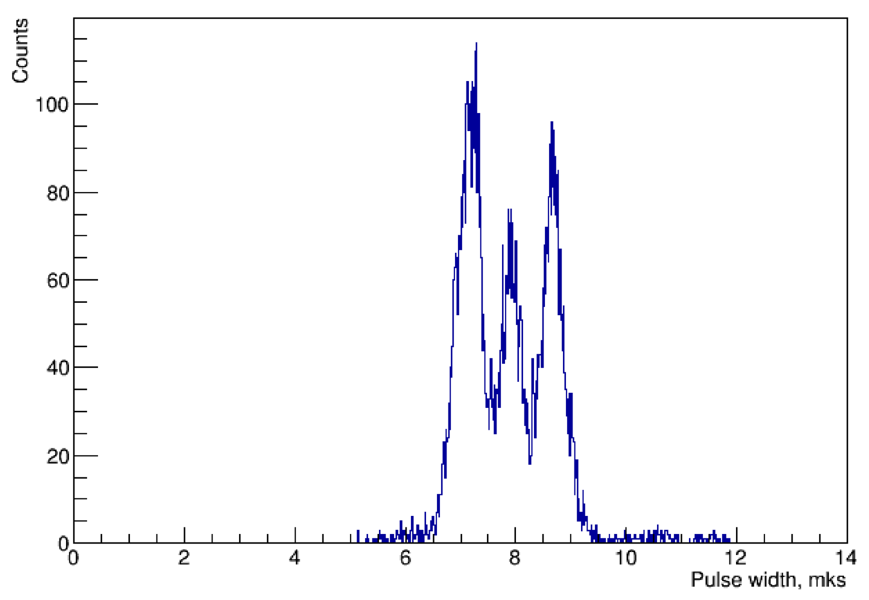


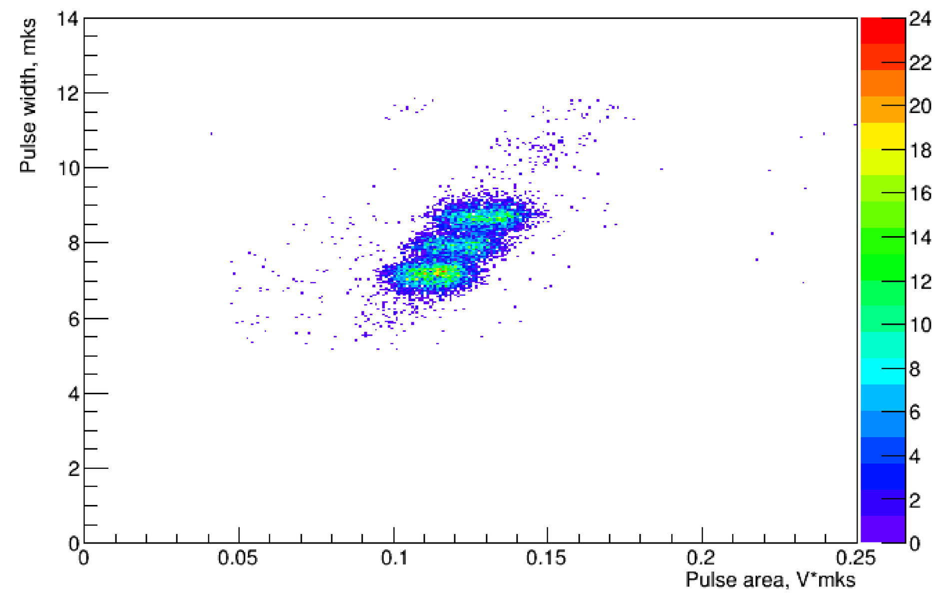
Energy spectra of alpha-particles from ^{233}U (4.8 MeV), ^{239}Pu (5.2 MeV) and ^{238}Pu (5.5 MeV) sources, measured using semiconductor detector



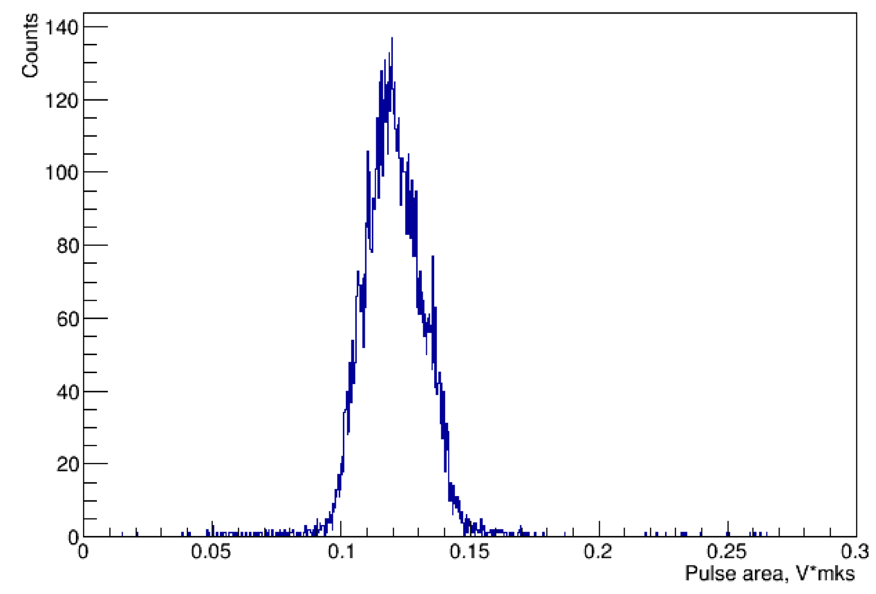
THGEM effective gain as function of voltage in low-pressure TPC in Isobutane at pressures varying from 50 torr to 160 torr

Note that the semiconductor detector cannot separate ^{10}Be and ^{10}B isobars since their energies are equal in AMS.





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 40. The pulse width and pulse area spectra reflect those of the track range and energy.



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

5. Conclusion

- The track ranges of alpha-particles has been measured in a low-pressure TPC with THGEM readout with a rather high accuracy, reaching 2%.
- Based on these results and SRIM code simulation, one may conclude that the isobaric boron and beryllium ions (having range difference of 32%) can be effectively separated in AMS, at the >10 sigma level, by measuring the ion track ranges in low-pressure TPC.
- This technique is expected to be applied in the AMS facility in Novosibirsk for dating geological objects, in particular for geochronology of Cenozoic Era.

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