High-rate axial-field ionization chamber for particle identification of radioactive beams

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To resolve beam contaminants by ΔE-TOF in a radioactive beam at high rates:

- Use a transmission ionization chamber -- good energy resolution and resistance to radiation damage.
- Employ axial field design with central anode to minimize electron drift distance (~ 1cm).
- Utilize CF₄ as detector gas based upon its high electron drift velocity.

![Diagram of beam and drift](image)

This detector is called the Rare Ion Purity Detector (RIPD).

Axial field ionization chamber

Detector characteristics:

- Use of axial field with central anode minimizes the charge collection time.
- Integrated charge sensitive amplifier close to central anode minimizes the impact of detector capacitance.
- The anode is doubly aluminized mylar (0.5 µm thick) and 2 cm in diameter.
- Extremely thin windows (0.5 µm mylar) minimizes energy loss and straggling introduced by detector.
- Aluminization of windows allows them to also serve as cathodes.

A: Window plate
B: Anode foil ring
C: PCB for charge sensitive amplifier
D: Detector body
E: Window plate

To test the detector with an alpha source ($^{241}\text{Am}$) operation at high pressure was necessary.

The thin windows were replaced with high pressure caps that contained the $^{241}\text{Am}$ source (A) and a surface barrier silicon detector (F).

Thin foils (B,E) were placed, after the source and before the surface barrier detector, to define the electric field and the energy loss in the windows.

Risetime: $\sim 60$ ns
Return to baseline: $\sim 300$ ns
S/N= 5.7

Fast shaping amplifier/Timing filter amplifier/Discriminator

- Single width NIM module
- 8 channels of:
  - shaping amplifier
  - timing filter amplifier
  - leading edge discriminator
- OR output of discriminators
- Coarse Gain controlled by two 4-bit stages
- Fine gain adjusted with 12 bit DAC
- Shaping time 100 ns – 800 ns
- Slow and fast signals multiplexed for inspection
- TFA outputs available at front panel
- Gain, threshold, pole-zero, and polarity all adjustable under USB control

S/N = 31 with fast shaping amplifier
For deposited energies up to ~2 MeV the energy resolution is constant at ~220 keV indicating that electronic noise dominates the total noise.

Above 2 MeV the energy deposit in the gas impacts the measured resolution.

At an energy deposit of 3.5 MeV, the relative energy resolution is ~7.5%

\[ ^{241}\text{Am} \]

Performance with beam

- Used ReA3 facility at MSU-NSCL
- ReA3 is 80 MHz linac

- Count rate provided by a ExB design microchannel plate detector (100 $\mu$g/cm$^2$ thick carbon foil)
- At low beam intensity ($< 10^3$ ions/s), the beam energy is measured by inserting a surface barrier silicon detector
- The RIPD detector is inserted and the resultant energy loss is measured.

For both $E/A = 2.5$ MeV and 4 MeV the same dependence of resolution on deposited energy is observed.

Consistent with the $\alpha$ source measurements for $E_{\text{RIPD}} > 4$ MeV a resolution of $< 10\%$ is determined.

With increasing instantaneous rate a worsening in the resolution is observed. At instantaneous rates above $1 \times 10^5$ ions/s the resolution exceeds 10%.

Also observed with increasing instantaneous rate is a decrease in the peak position of the peak. This behavior is due to charge recombination in the high ionization density trail of the beam. For higher energy beams, use of a tilted electrode can mitigate this problem.

Resolving beam contaminants with $\Delta E$-TOF in a $^{47}$K beam

The radioactive beam of $^{47}$K contains the contaminant $^{36}$Ar (~5%) with the same velocity after acceleration.

Due to the RIPD detector the ions experience different energy loss so that they manifest different TOF.

$P_{CF_4} = 25$ torr
Conclusions

- A fast axial field ionization chamber suitable for resolving radioactive contaminants in a low-energy RIB has been designed, built, and tested with beam.

- For an energy deposit of \(\sim 4 \text{ MeV}\) and an instantaneous rate of \(< 1 \times 10^5 \text{ } ^{39}\text{K} \text{ ions/s}\) an energy resolution of \(\leq 10\%\) is obtained.

- At instantaneous rates above \(1 \times 10^5 \text{ ions/s}\) the high ionization along the beam path leads to charge recombination resulting in charge collection that is beam intensity dependent.