Construction and performance testing of PPAC detectors at RAON

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Introduction

- RAON planned to be built near Daejeon by 2021
- Produce Rare Isotope (RI) beam using both ISOL and In Flight methods
- 70 MeV proton cyclotron driver for ISOL system
- 3 super conducting linacs (SCL)
- Combine both ISOL and IF to produce very exotic beams

T. Shin et al., Sae Mulli 66 (2016) 1500-1510
Introduction

- Why do we need a PPAC?
- KOBRA will produce and separate RI beams in flight
- Nucleon transfer ~10-20 MeV/u
- Significant beam impurities expect in this method however
- We must then conduct PID on the beam in flight
- Required intensity of nuclei of interest is $>10^5$ pps
- Beam contaminants 10-100 times more abundant
- If low cross section reactions are to be observed we need detection rate of $>10^6$ pps
Particle Identification

- Bp-ΔE-TOF method
- Bp -> Position detector (PPAC)
- TOF -> Timing detector (Scint., PPAC)
- ΔE -> Energy loss detector (Si, IC)
- This method allows for the identification of many different rare isotopes in a single beam

BigRIPS PID\(^1\):

Required Performance

- Need position information, event by event
- Minimal beam interference
- Position resolution in x and y of <1 mm (FWHM)
- Efficiency close to 100% for low energy heavy ion beams up to $10^6$ pps
- Active area up to 40x20 cm$^2$ at F1
- (MW)PPACs only current detectors that can provide all of these
PPAC Concept

- Parallel plate avalanche counter
- PPACs first developed in the 1960s, well known technology
- Three parallel surfaces, metalized Mylar or thin wires form electrodes
- Central electrode biased, forming strong electric field between gap

![Diagram of Parallel Plate Avalanche Counter (PPAC)](image)

- Strong linear electric field
- \(-1-4\) mm gap

\[ \text{anode} \quad +V \quad \text{cathode} \]
PPAC Concept

- Pure quencher gas flowed through gap to produce avalanche region
- Reduced field strength of ~15-50 V/mm/Torr
- Electrodes only a few mm apart
- This design allows for a very compact detector
- Also minimizes material in beam path, electrodes and window only a few μm thick
PPAC Concept

- Incident ion ionizes $\sim 10^{2-3}$ primary electrons ($n_0$) in sensitive gas volume.
- $n_0$ depends on ion species, energy, gas type and pressure.
- Each primary electron is accelerated by strong field and can cause a secondary ionization event, etc.
- Causes cascade of electron generation; exponential growth.

Townsend avalanche:
$$n_e(d) = n_0 e^{\alpha d}$$
PPAC Signal

- Good timing properties:
- Entire gap between electrodes is avalanche region
- Most electrons formed close to anode
- Fast e- signal have rise times of <10 ns
- Avalanche process degrades energy resolution however, poor $\Delta E$ resolution

PPAC signal:

- Fast e- <10 ns
- Slow ion ~1 μs
Current Design

- D. v Harrach and H J Specht\(^1\), and Kumagai et al.\(^2\) developed delay-type PPACs that used fast e- signals for continuous position determination.
- Cathode is segmented into strips, each strip has separate delay.
- Signal split and time difference between pulses gives position information (T2-T1).
- 2 cathodes, orthogonal, give X and Y information.
- Use low tolerance LC elements for good position uniformity.
- 50 \(\Omega\) impedance to match coaxial cables.

\(1\) D. v Harrach and H.J. Specht, NIM 164 (1979) 477-490
\(2\) H. Kumagai et al., NIM A 470 (2001) 562-570
Large PPAC

- KOBRA requires a large detection active area
- We have designed and fabricated a larger PPAC with 20x20 cm² wide Mylar electrodes
- Also fabricated 40x20 cm² cathodes
- To our knowledge, largest area finely stripped evaporated electrodes ever made for PPACs
Electrode Manufacturing

- Previously mechanical mask was mounted before evaporation
- Could not use this method for larger sizes however
- Heat from evaporation distorts mask shape
- Found improved manufacturing method using photolithography
- We may then control the strip pitch to within ~1 μm
- Even larger active area (40x20 cm²) was possible
Testing

- Made ‘Double PPAC’ so we essentially have 2 detectors in a single case
- Beam test with 3 MeV/u $^{12}\text{C}$ and $^{16}\text{O}$ beam
- Up to $2 \times 10^6$ pps intensity
- Kyushu University tandem accelerator
- Mounted slit mask for position calibration and resolution
Results

- Used slit mask to calibrate position spectrum
- Width of peaks gave position resolution
- Observed position resolution of 1 mm (FWHM) at beam intensity of $2 \times 10^5$ pps $^{12}$C
- TOF between layers gave time resolution of 700 ps (FWHM) at $2 \times 10^6$ pps $^{16}$O
- Very high efficiency: 99% with $2 \times 10^5$ pps $^{12}$C
  95% with $2 \times 10^6$ pps $^{16}$O
- Did not use slits with $2 \times 10^6$ pps beam, no position resolution measurement yet
Conclusions

- Up to beam intensities of $2 \times 10^5$ pps observed high efficiency, 99%, and good position resolution, 1 mm FWHM
- Up to $2 \times 10^6$ pps observed detection efficiency of 95%
- New production technique, photolithography, makes the production of larger cathodes possible
Thank you for your attention!