Development of a fast response PPAC for high-intensity heavy-ion beams

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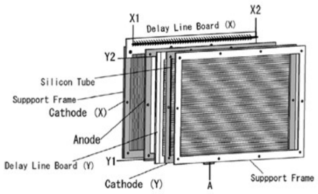
Background

Position measurement is essential for RI beam experiment

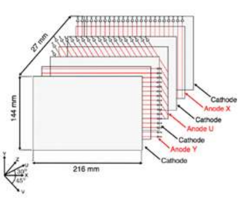
- the beam position is corresponding to magnetic rigidity
  => lateral and angular momentum measurement
- the beam profile such as emittance

The conventional beamline position detectors

Delay-line PPAC [1]



Multi-Wire Drift Chamber [2]



	For high-rate beams	material thickness	position resolution	Timing detection
Delayline PPAC (DL-PPAC)	Not good for ～1MHz And wide spread beam	Only counter gas	typically 500μm (FWHM)	OK
Multi-Wire Drift Chamber (MWDC)	Good	Anode and potential wires	typically 300μm (FWHM)	NG

DL-PPAC is generally used in the beamline in some accelerator facilities such as RI beam Factory in RIKEN. It has very thin and uniform material thickness but not good efficiency for high intensity beam due to the pileup. MWDC has very good position resolution but the wires inside of the detector cause the multiple scattering and it will not negligible for low energy beam.

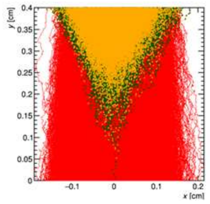
In this research, our goal is to develop

(i) fast-response (high efficiency for ～ 1MHz)
(ii) thin and uniform thickness
(iii) high resolution

position detector.

Strip Readout PPAC (SR-PPAC)

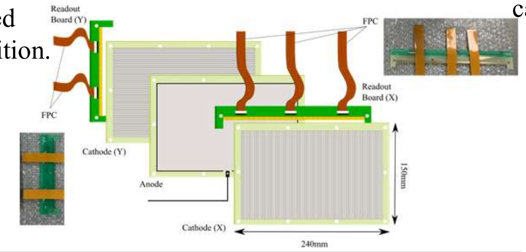
Parallel Plate Avalanche Counter (PPAC) use the signal of electrons amplified in the process of electron avalanche. The figure in the middle show the simulation of electron avalanche using Garfield++ code. The orange line is track of electrons and the red is ions'. PPAC potentially has fast response because the mobility of electron is fast (20 cm/us => 20 ns in 4 mm, typical gap of electrodes). The DL-PPAC collect the signal from striped cathode and the signal is delayed through the delay-line. Therefore, PPAC can realize the fast response if the signals from each strips are collected directly and independently. We have developed Strip-Readout PPAC (SR-PPAC) based on this idea.



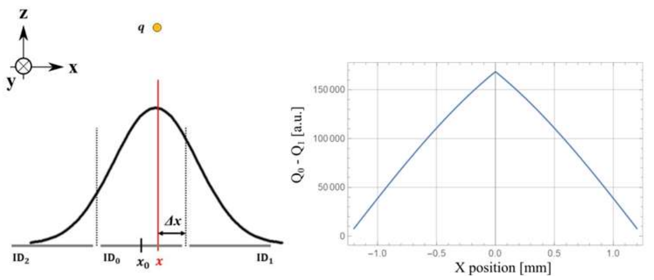
The readout board was newly designed and replaced instead of delay-line. The DL-PPAC extracts the position information by calculating difference Between timing of signals collected from both ends of electrode. For the SR-PPAC, we developed New method to deduce the position.

Table 1. Configration of SR-PPAC

Sensitive area [mm^2]	240 (X) × 150 (Y)
Gap of Electrodes [mm]	4.3
Strip width [mm]	2.55 (X), 2.58 (Y)
Number of strips	94 (X), 58 (Y)



✓ How to get position information



We calculate the induced charge on the cathode using Townsend's theory of electron-avalanche[3]. There is a clear correlation between the position and charge difference between two strips (right figure).

Difference between highest charge (Q0) and 2nd highest (Q1) can be converted to position inner side of a strip as

Conversion function Δq (Q0-Q1) to Δx

$$k(\Delta q) = \frac{\int_0^{\Delta q} f(u)du}{\int_0^{Q} f(u)du}$$

Q: maximum value of Δq

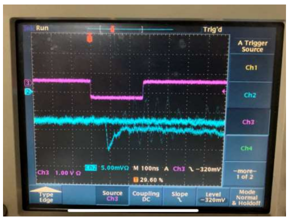
Δx is calculated as

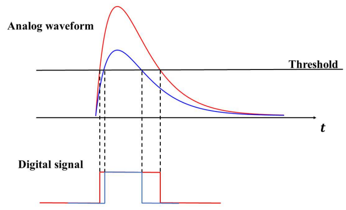
$$\Delta x = \frac{s}{2} \times k(\Delta q)$$

s: strip width

✓ How to get charge

The Time-over-Threshold method enables to quickly acquire pulse-height information, which corresponding to the amount of charge comparing to the charge integration technique, Flash ADC etc.





Performance evaluation

We performed test experiment at HIMAC, Japan.

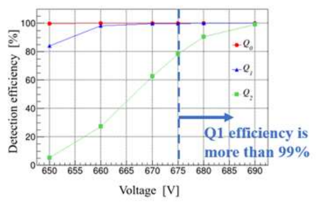
Detection Efficiency and position resolution of SR-PPAC were evaluated.

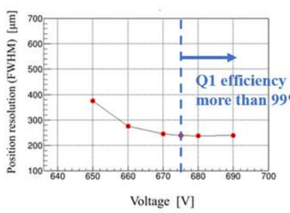
The beam we used was ^{132}Xe 115 MeV/u. The counter gas i-C4H10 and the pressure was 10 Torr.

The left figure shows the bias dependence of detection efficiency and the right figure shows the bias dependence of position resolution.

We check the bias dependence of the efficiency and the position resolution shows the same bias dependence as the efficiency because the position is calculated using the Q0 and Q1 charge information as mention above.

The best position resolution was 240 μm (FWHM) and it was 295 μm (FWHM) even for the beam with intensity of 770 kppp (particle per pulse).





Conclusion

We developed a fast response PPAC for high intensity beams. We achieve more than 99% detection efficiency and better than 300μm position resolution even for 770 kppp beam, which is comparable to typical resolution of MWDC.

Reference [1] H.Kumagai, et al., Nucl. Instrum. Meth Phys. Res., Sect. A, **470** (2001) 562
[2] H.Kumgai, et al., Nucl. Instrum. Meth Phys. Res., Sect. B, **317** (2013) 717. [3] J.S.Townsend, Phil. Mag. **6-1** (1901) 198.