Parallel plate avalanche counter (PPAC) development and performance test for Rare Isotope Science Project (RISP)

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RISP, IBS

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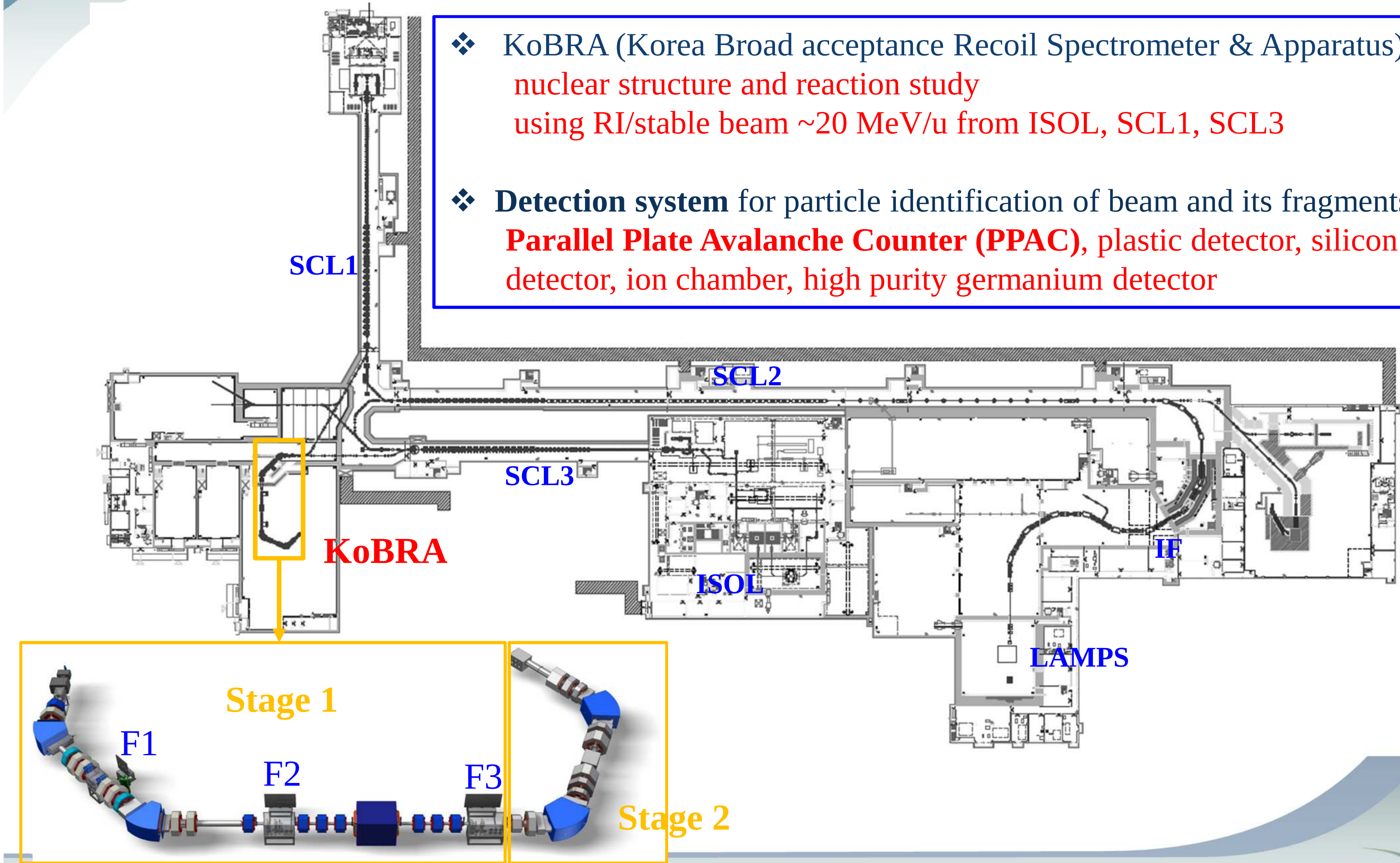
Content

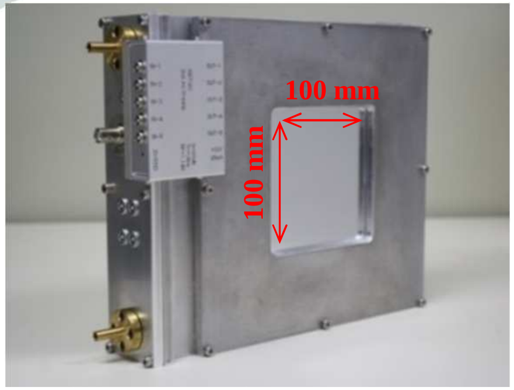
- ❖ RAON facility & KoBRA layout
- ❖ Detection system & PPAC
- ❖ PPAC structure
  - Delayboard, electrode and its assembly
- ❖ Performance test & analysis status
  - α of ^{241}Am, 3 MeV/u ^{12}C and ^{16}O beam
- ❖ Summary and outlook

RAON facility Layout

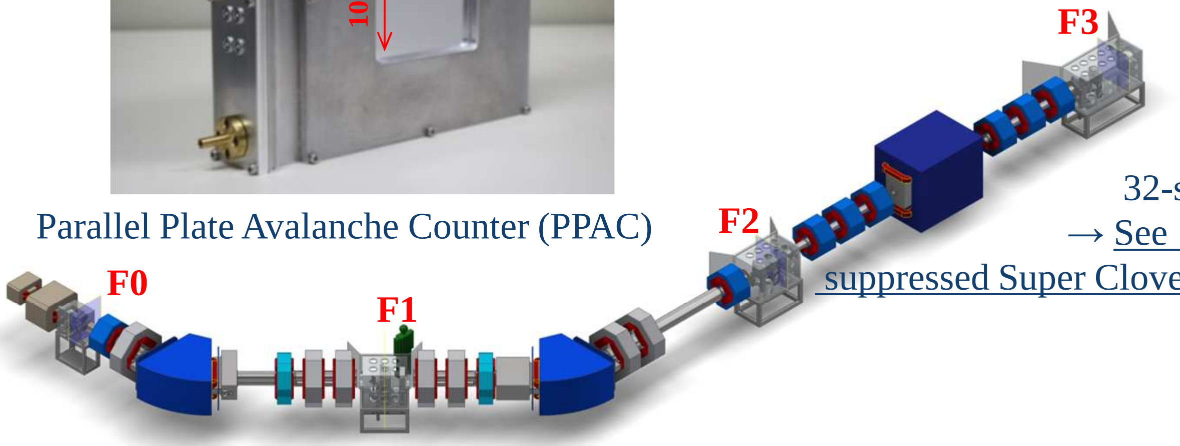
- KoBRA (Korea Broad acceptance Recoil Spectrometer & Apparatus); nuclear structure and reaction study using RI/stable beam ~20 MeV/u from ISOL, SCL1, SCL3
- **Detection system** for particle identification of beam and its fragments; **Parallel Plate Avalanche Counter (PPAC)**, plastic detector, silicon detector, ion chamber, high purity germanium detector

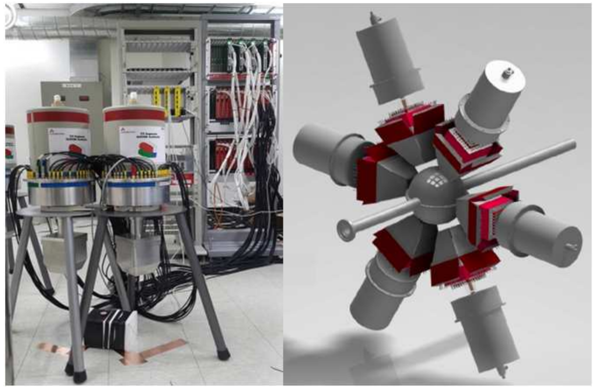


KOBRA detection system

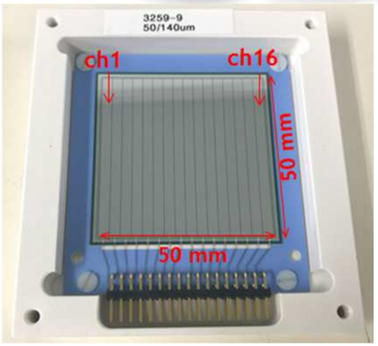


Parallel Plate Avalanche Counter (PPAC)

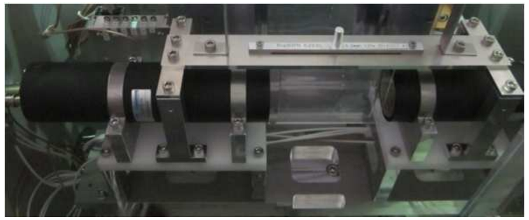




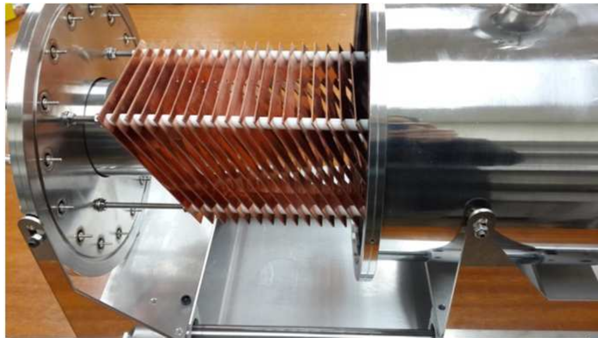
32-segmented high purity germanium detector
→ See 'PA-53: Development Status of Compton-suppressed Super Clover Detector Array in RISP' @ Poster session



16 ch. silicon detector



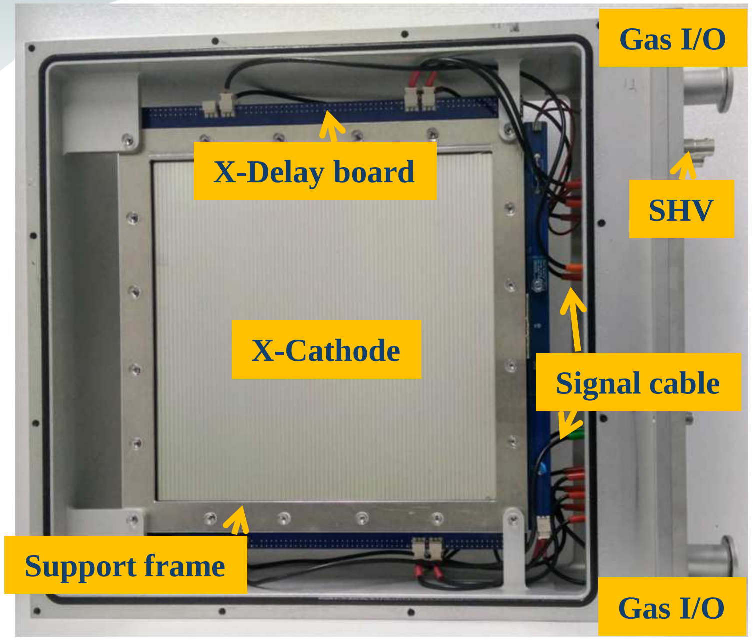
Plastic detector



Ionization chamber

❖ Detectors measure beam position, time, energy for particle identification of Bρ-TOF-ΔE method;
PPAC: position for Bρ, Plastic detector: time for TOF, Silicon detector: ΔE
← 10×10 cm^2, 20×20 cm^2, 40×20 cm^2 active area PPACs are developed

PPAC structure



Inside of PPAC
(covers opened)

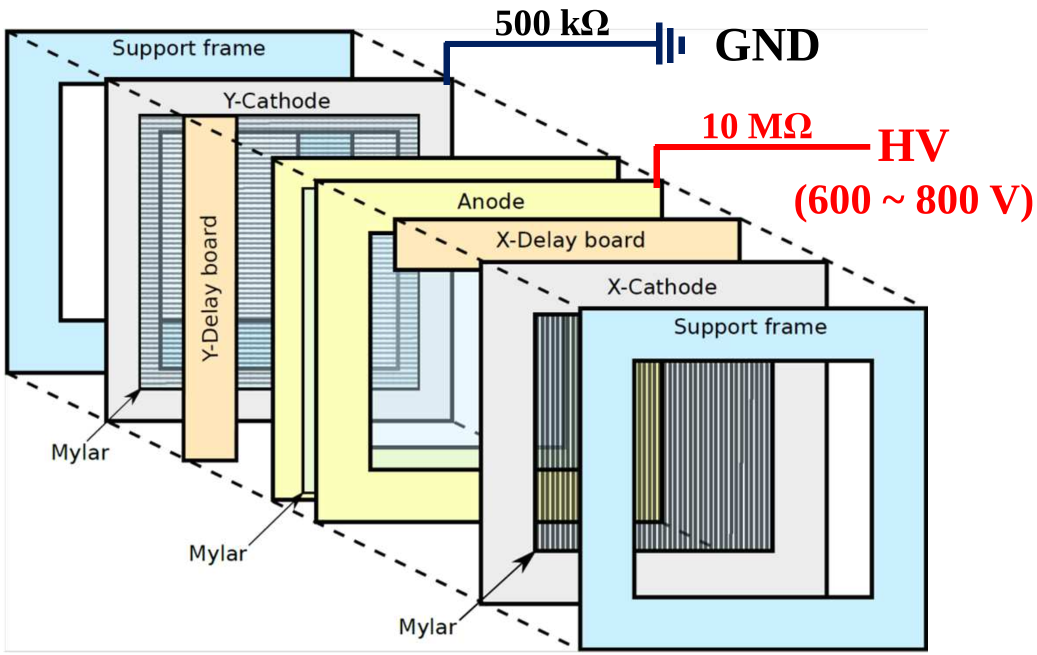


Diagram of a board layers

- PPAC is a gas detector using electron avalanche between electrodes
- It has fast response of ~few ns using fast electron
  → shows good performance even for the high beam intensity
- It operates for low energy experiment
  → needs to minimize interference in beam path;
  thin Mylar of 2~3.5 μm for the electrodes
  low gas pressure mode less than 10 Torr

Operating conditions

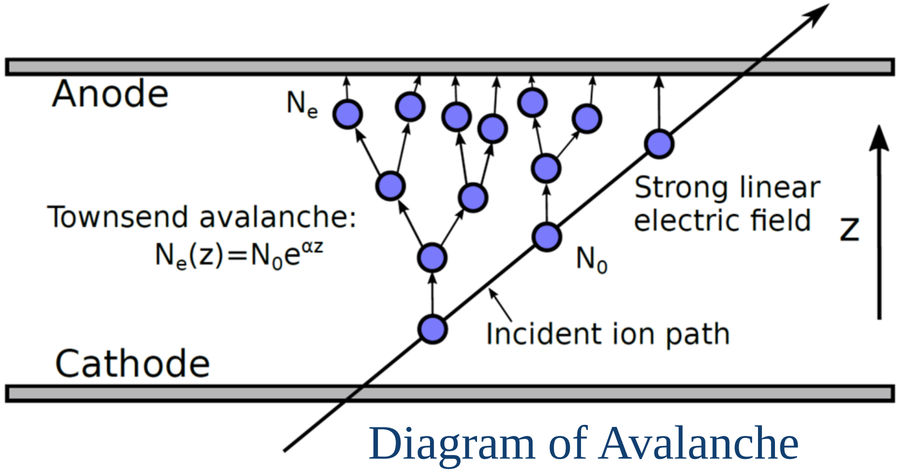
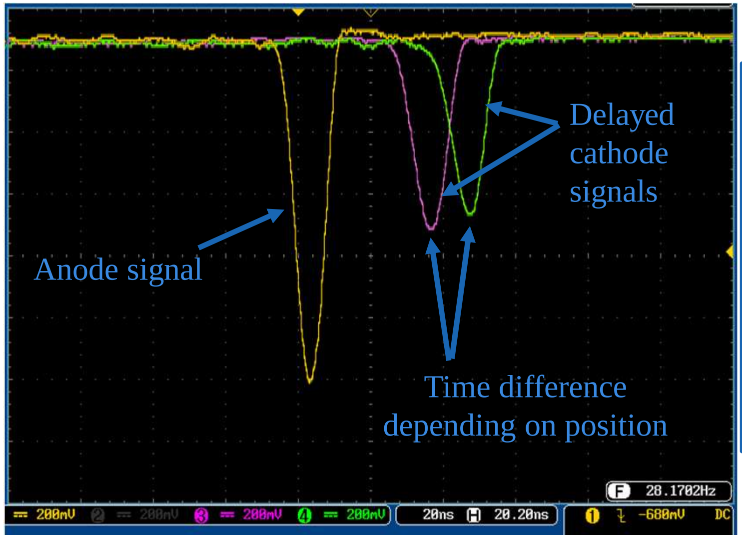


Diagram of Avalanche

- <u>Gas available;</u>
  Need pure quenching gas of C_4H_{10}(W = 23.7 eV), C_3F_8(W = 34.4 eV)
  due to lack of quenching properties at low gas pressure
- <u>HV;</u> ≥ 100 V/mm, adjustable by beam energy & mass
- Read out avalanche signals from anode and cathode;
  <u>Anode for time</u> & triggering, <u>cathode for position</u> measurement

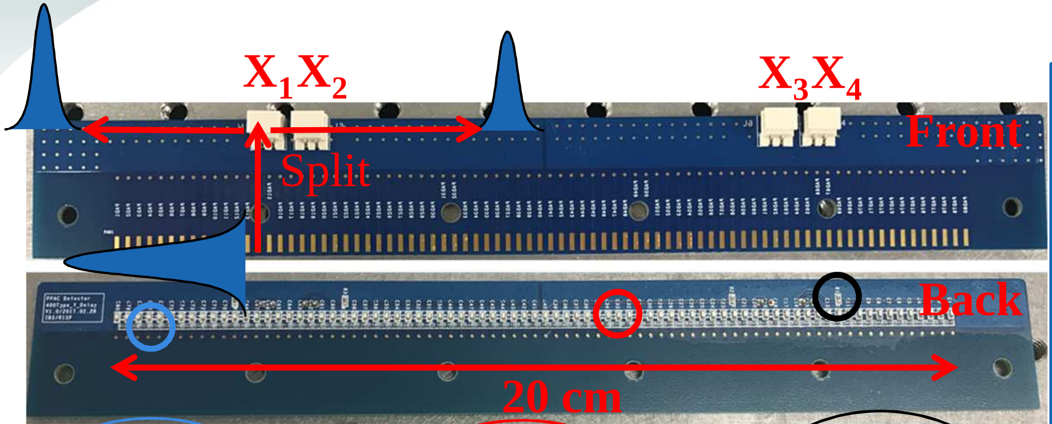


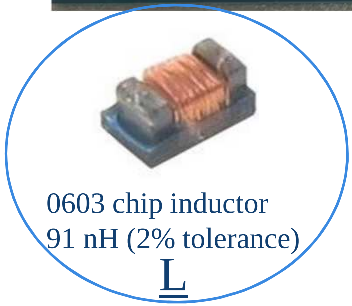
Signal example after amplifier

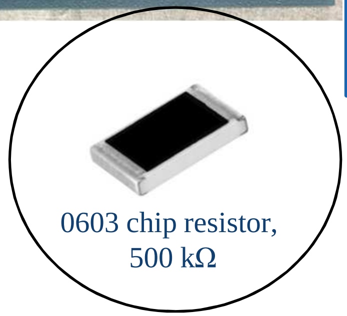
<u>Readout method</u>

- Charge division;
  Resistive arrays gives charge difference, but few μs shaping time
  → charge pile-up effect at few kHz beam rate
- **Delay line;**
  LC delay makes time difference from either end using fast ns signal
  → fast measurement for few <u>MHz beam rate</u>

Delay line readout

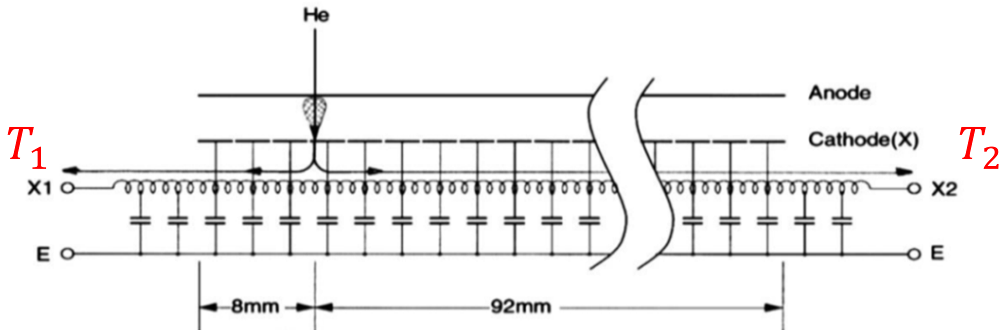




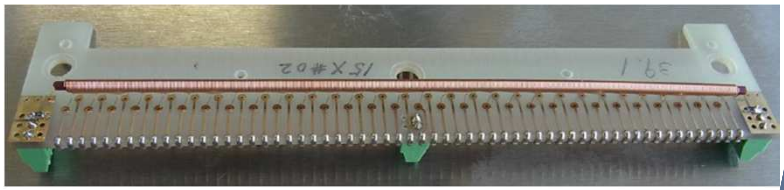


For 20 cm area PPAC;

- 2.5 mm/tap makes 80 LC taps, 2 ns tap delay,
  → 160 ns delay in total
- Impedence, Z0 = $\sqrt{\frac{L}{C}}$ = 48 Ω
- 2 separate sections to reduce signal attenuation
- Precise chip inductor, capacitor of ~ 2% tolerance, negligible compared to detector resolution



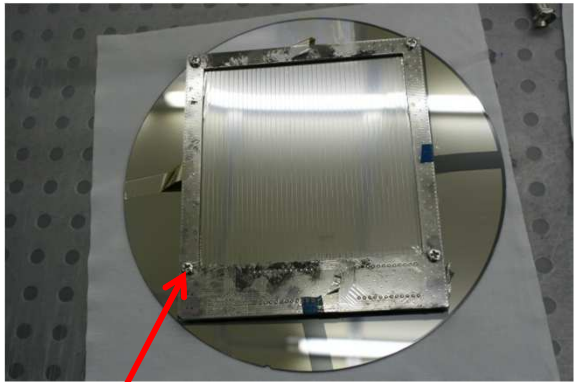
LC chain signal flow

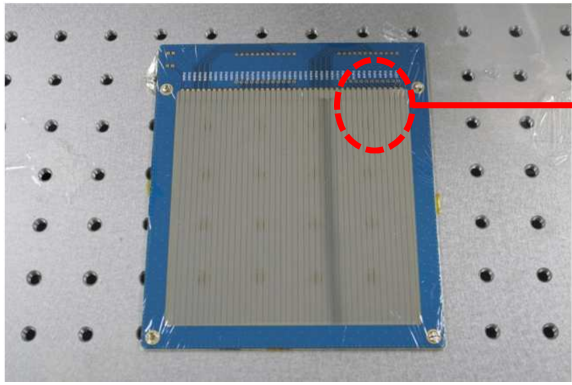


cf) delay line of RIKEN PPAC by coiling
- hard to control and produce

Position extracted by $x = k(T_2 - T_1) + x_0$

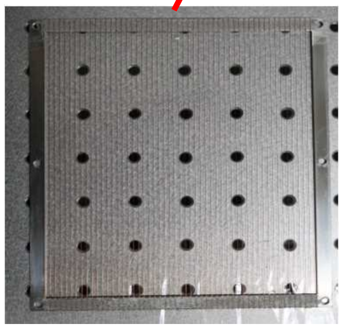
Electrode evaporation - cathode





Zoom-in

Ag evaporation on Mylar for cathode strip

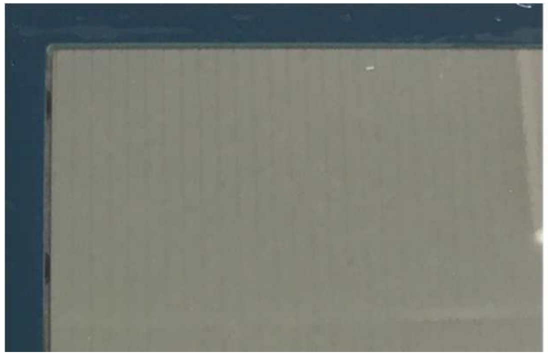


Mechanical masking frame

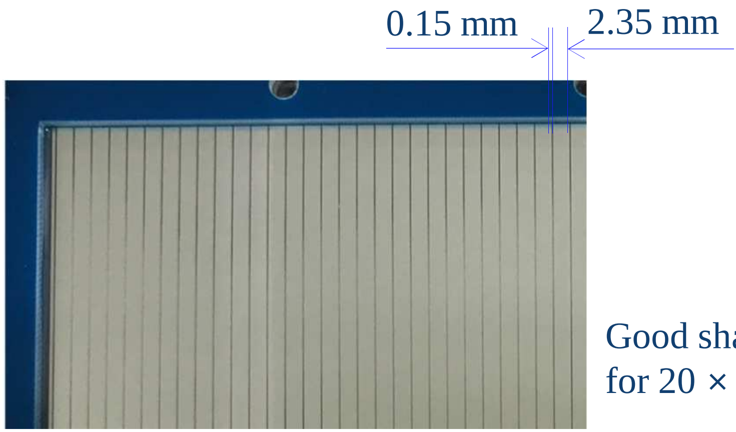
- Cathode contacts to delay line, needs strip pattern to separate hit position
- Evaporate Ag/Al on the masking frame
- Take off the masking after evaporation
- This method is available for 10 × 10 cm^2 cathode

- It gets tricky technically for large area electrode
- Mechanical masking frame gets distorted larger than 20 × 20 cm^2

Large area electrode



Cathode strip by
mechanical masking
-blurred, electrically connected



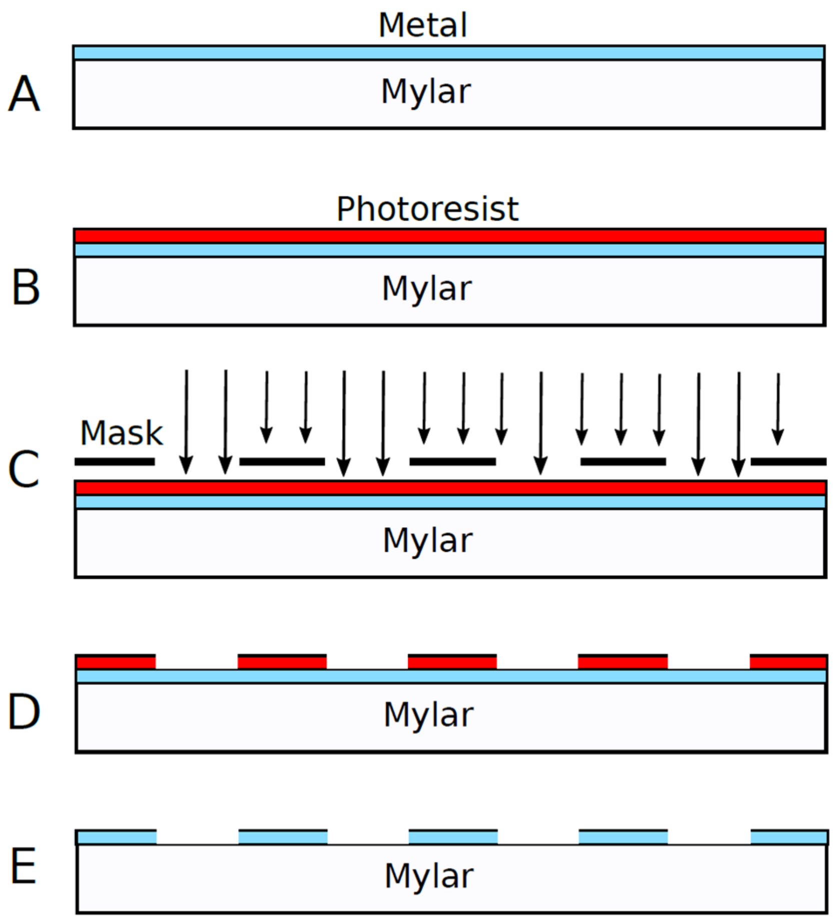
Cathode strip by
Photolithography,
newly tired method

Good shape obtained
for 20 × 20 cm^2 and 40 × 20 cm^2

Large area cathode electrode

Largest electrode tried for PPAC
Technically possible up to
50 × 50 cm^2

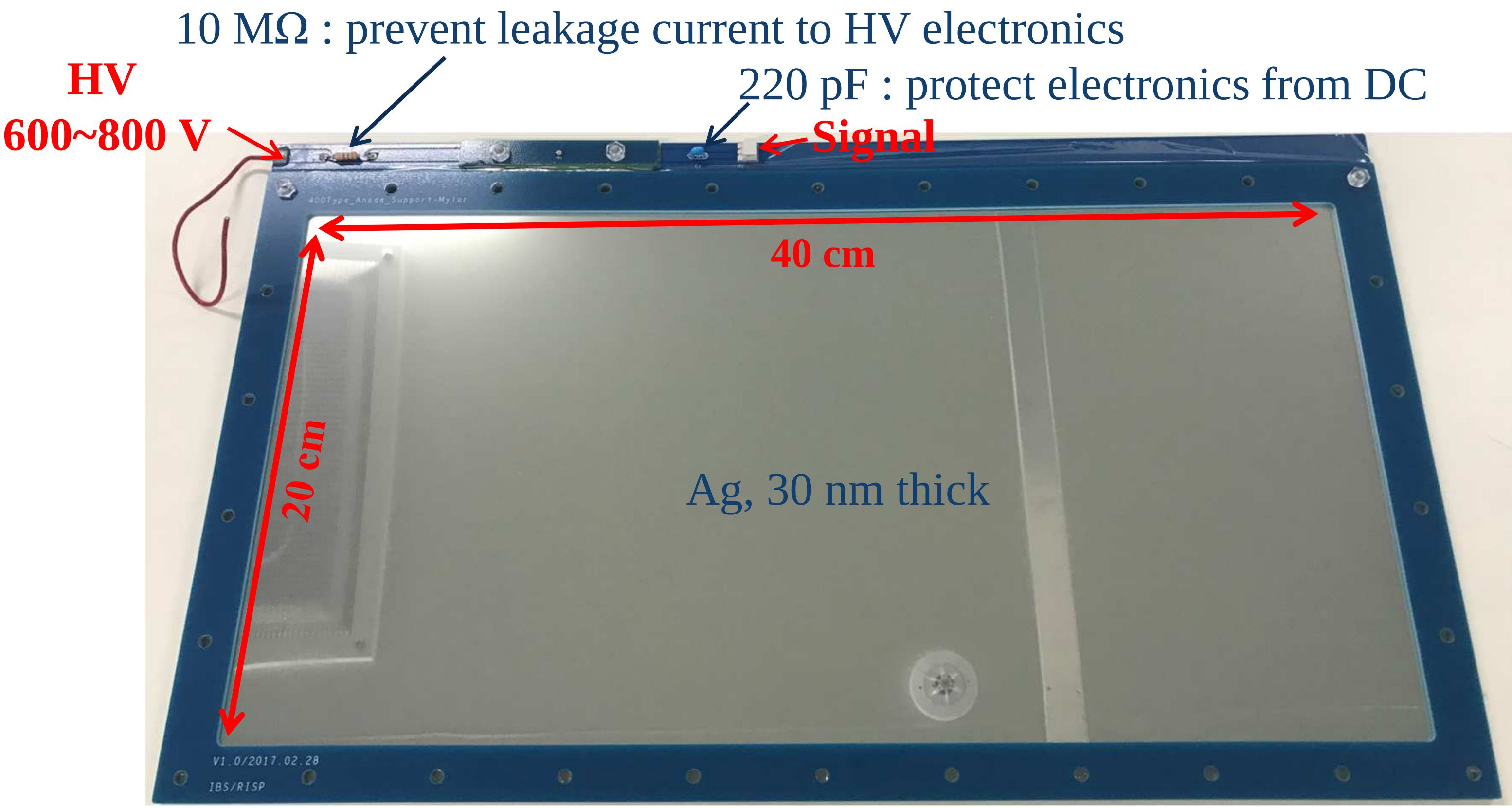
Large area electrode - Photolithography



- Evaporate Ag/Al 30 nm on top of 3.5 μm thick Mylar for 40 × 20 cm^2,
  2.5 μm thick Mylar for 20 × 20 cm^2
  (~3 nm thickness uncertainty)
- Coat with photoresist & bake for dry
- Mount film mask, expose UV light
  - Outside of mask, photoresist becomes soluble
- Develop and remove photoresist exposed to UV light
- Etch as pattern and remove the remaining photoresist

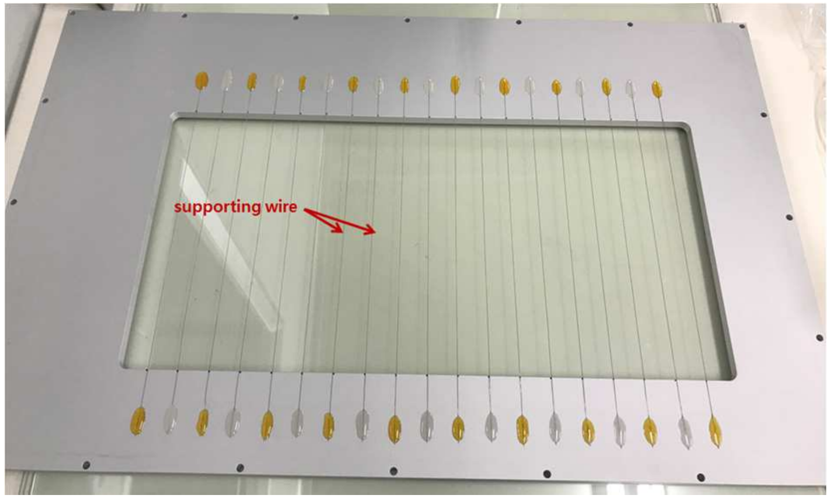
* Photolithography is a technique for complex integrated circuit, ~ few μm precision

Anode electrode

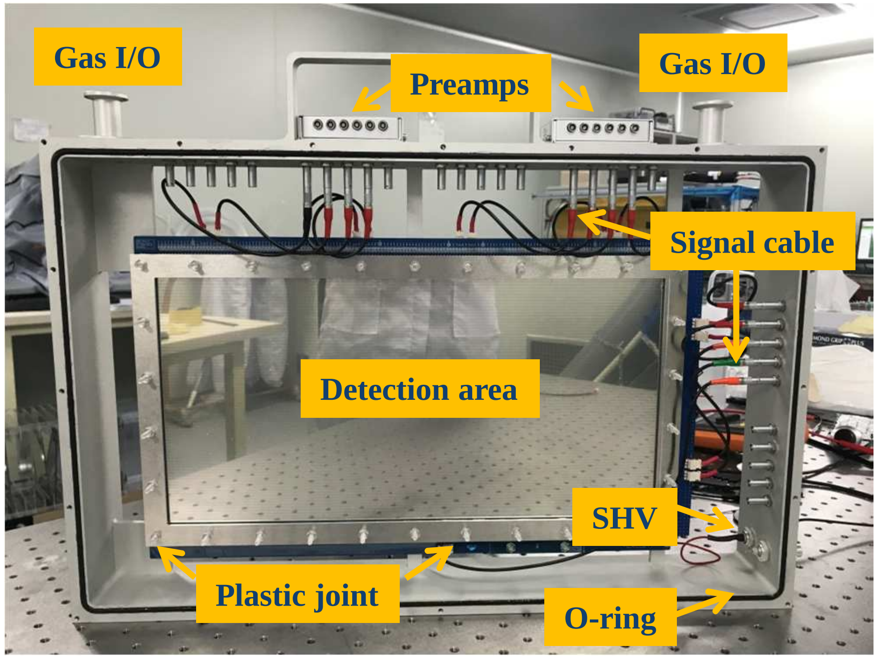


❖ Uniformity of surface is quite important to prevent discharge

Detector assembly



Cover with supporting wire, 40 × 20 cm^2 PPAC



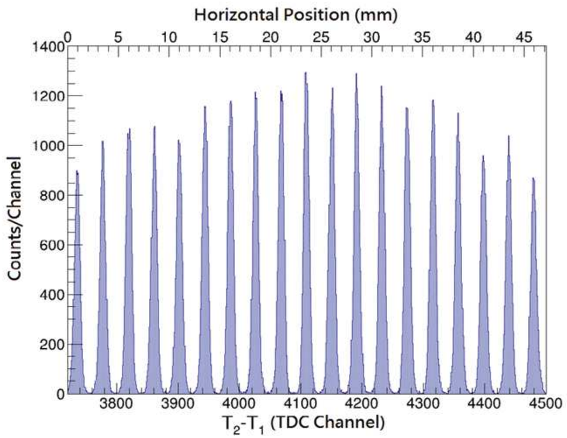
Inside of PPAC, 40 × 20 cm^2 PPAC
(covers opened)

- ❖ Single gap or double gap can be assembled
- ❖ Plastic bolts and nuts are used for electric insulation
- ❖ Housing has O-ring for gas shielding
- ❖ Peamps are put close at PPAC housing to reduce signal noise

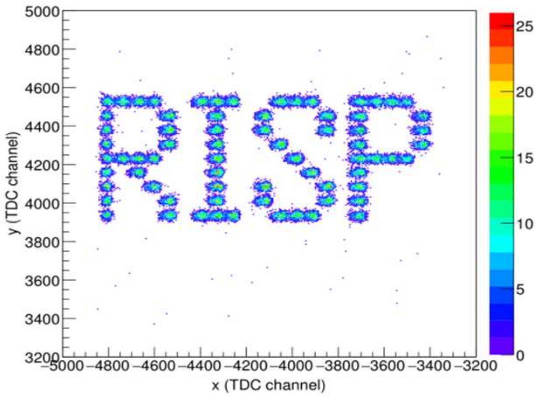
^{241}Am source test

❖ ^{241}Am source test of 10 × 10 cm^2 PPAC
- Position resolution ~ 0.55 mm (FWHM) (KoBRA requirement; ~1.00 mm (σ))
- Time resolution ~ 450 ps (FWHM)
- Efficiency > 99%

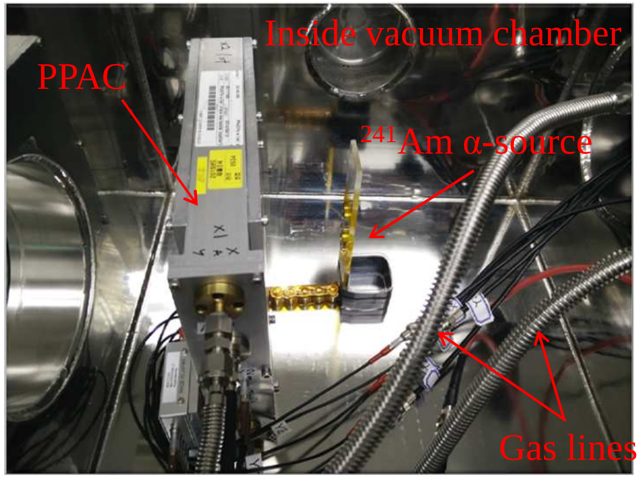
C. Akers, et al., JKPS 70 (2017) 682-696



Position structure from 2.5 mm pitch 0.5 mm width silt mask



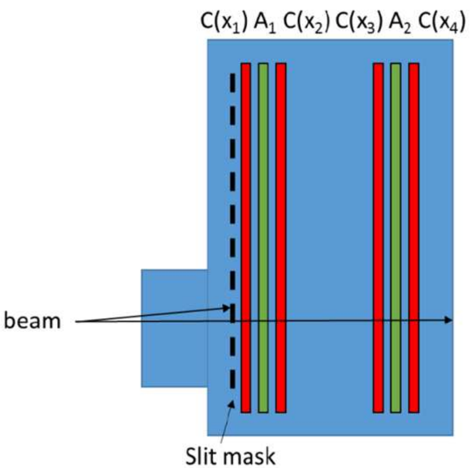
2D position spectrum displaying lettering of 'RISP'



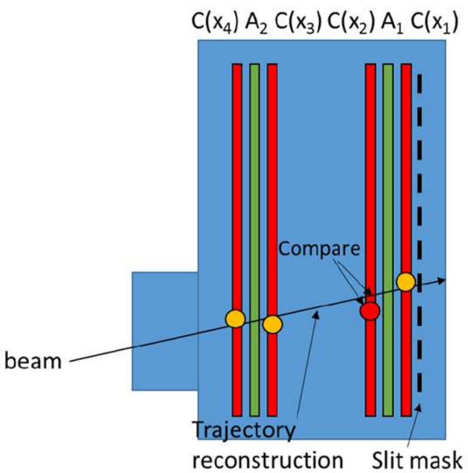
Vacuum chamber test

Beam test configuration

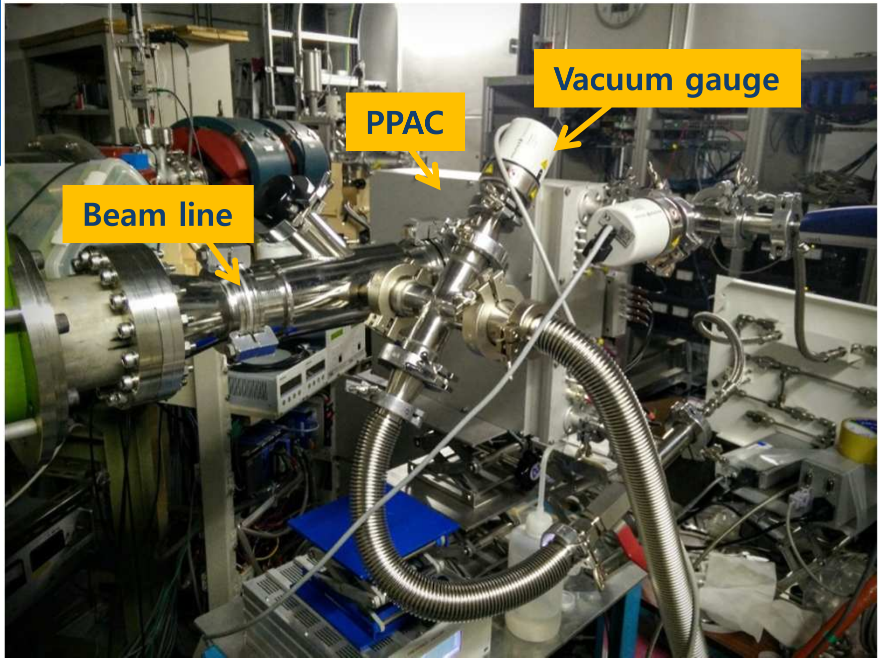
❖ Beam test of 20 × 20 cm^2 PPAC
- Tested at tandem accelerator of Kyushu University
- ^{12}C and ^{16}O beam @ 3 MeV/u
- Intensity up to 2 × 10^5 pps for ^{12}C and 2 × 10^6 pps for ^{16}O



Measurement with slit



Track fitting without slit

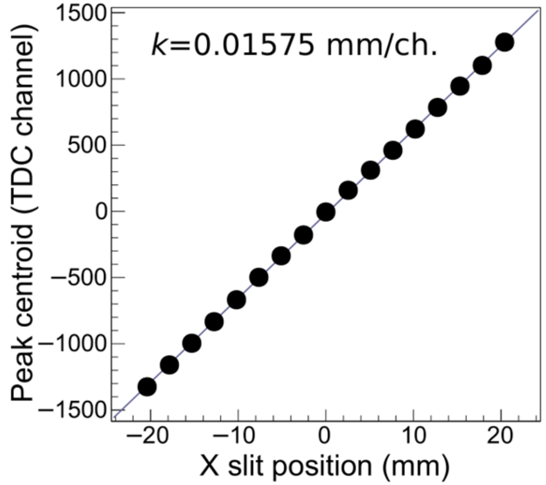


Picture of experiment configuration

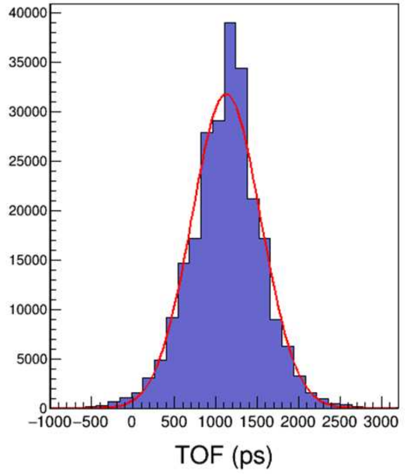
❖ Took two datasets from two configurations
❖ Double layer for track fitting & efficiency measurement

Beam test analysis

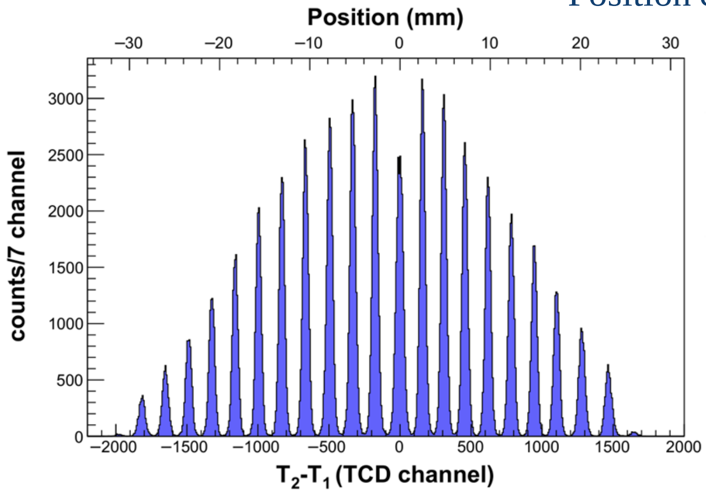
- Used slit mask to calibrate position spectrum
- Width of peaks gave position resolution
- Observed position resolution of 1 mm (FWHM) at beam intensity of 2 x 10^5 pps ^{12}C
- TOF between anodes gave time resolution of 700 ps (FWHM) at 2 x 10^6 pps ^{16}O
- Very high efficiency: 99% at 2 x 10^5 pps ^{12}C, 95% at 2 x 10^6 pps ^{16}O
- Track fitting data at 2 x 10^6 pps beam is being analyzed



Position calibration graph



TOF between two andoes



Position distribution with slit mask

Summary and outlook

- Large area PPAC adopted photolithographic method for cathode electrode, for the first time
- 10×10 cm^2, 20×20 cm^2 and 40×20 cm^2 PPACs have been developed successfully
- Large area PPAC worked stably at high beam intensity of 2×10^6 pps ^{16}O

- PPAC and detection system will be commissioned in ~2019
- Day-1 experiment at KoBRA facility is planned in ~2020