Overview and developments of BigRIPS detectors:

issues on high rates and resolution

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Detector team

Main topics

Fundamental characteristics and performances of

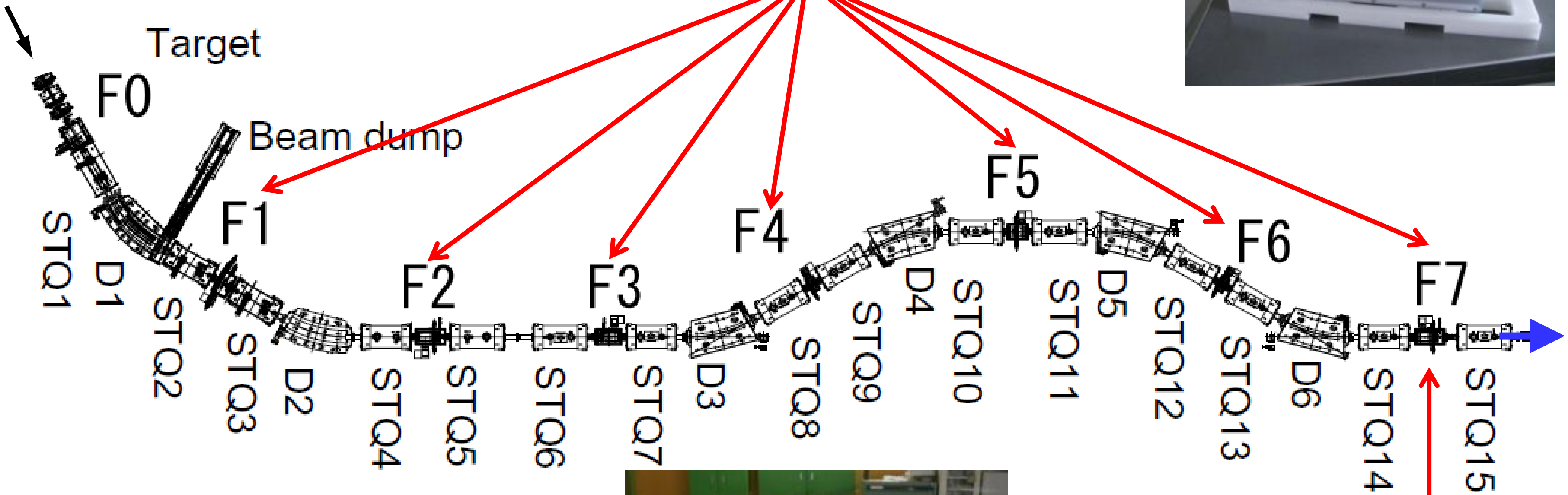
Multiple Sampling Ionization Chamber : MUSIC

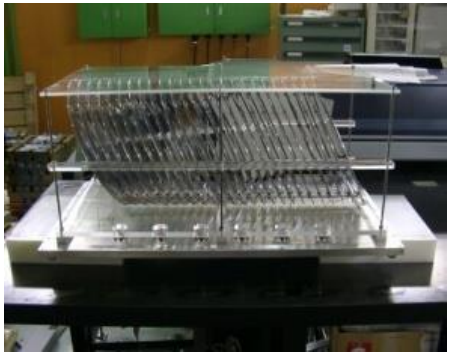
and

Parallel Plate Avalanche Counter : PPAC.

MUSIC and PPACs

PPAC: Position detector





MUSIC: ΔE detector

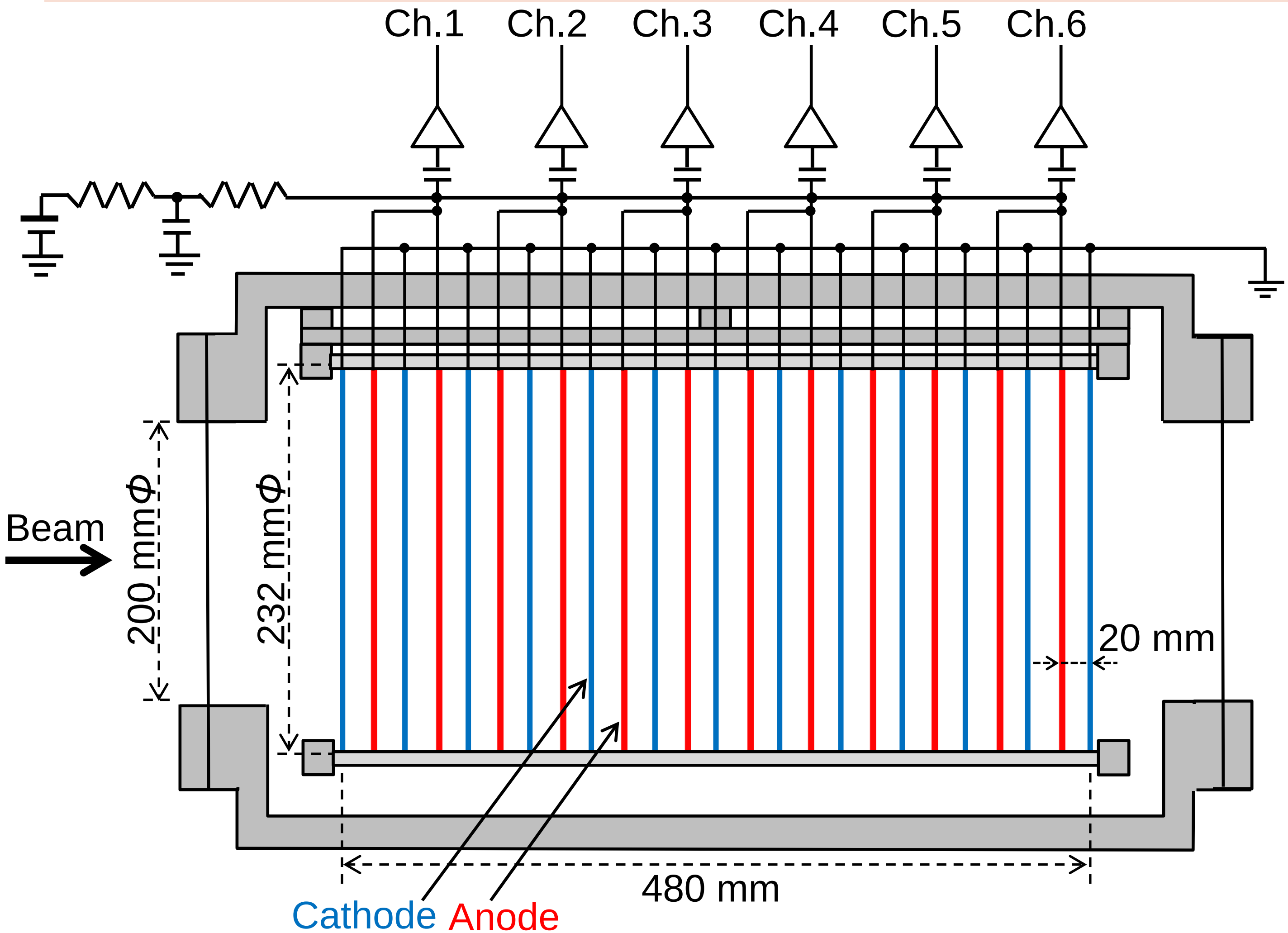
MUSIC and PPACs are gas detectors.

MUSIC → ΔE detector

PPAC → Position measurement

Multiple Sampling Ionization Chamber : MUSIC

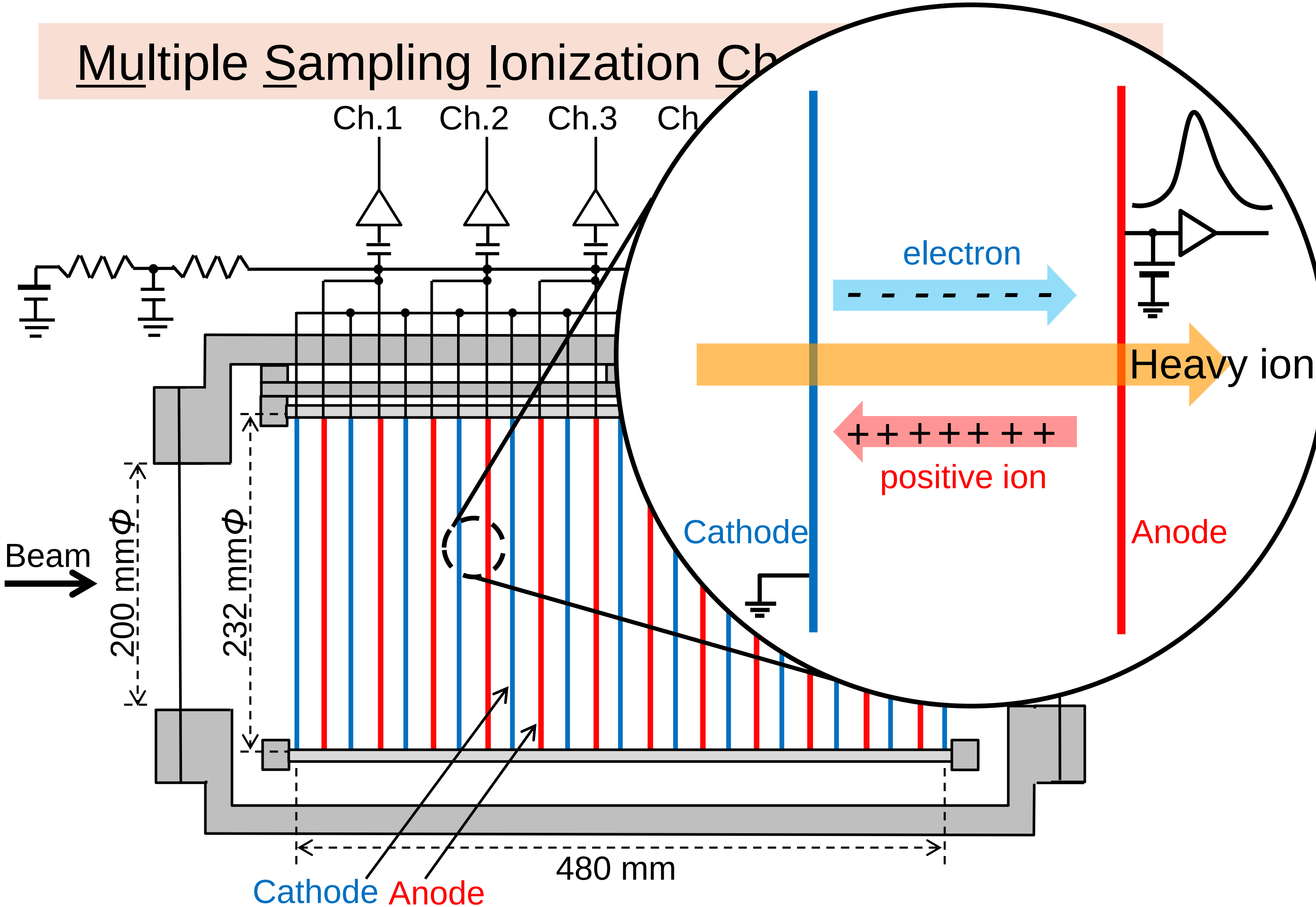
Multiple Sampling Ionization Chamber : MUSIC



13 cathodes and 12 anodes (2-μm-thick aluminized mylar foils)

- Gas: Ar+CH_4 (90%:10%), 760 torr
- Anode bias 500~550 V

Multiple Sampling Ionization Ch



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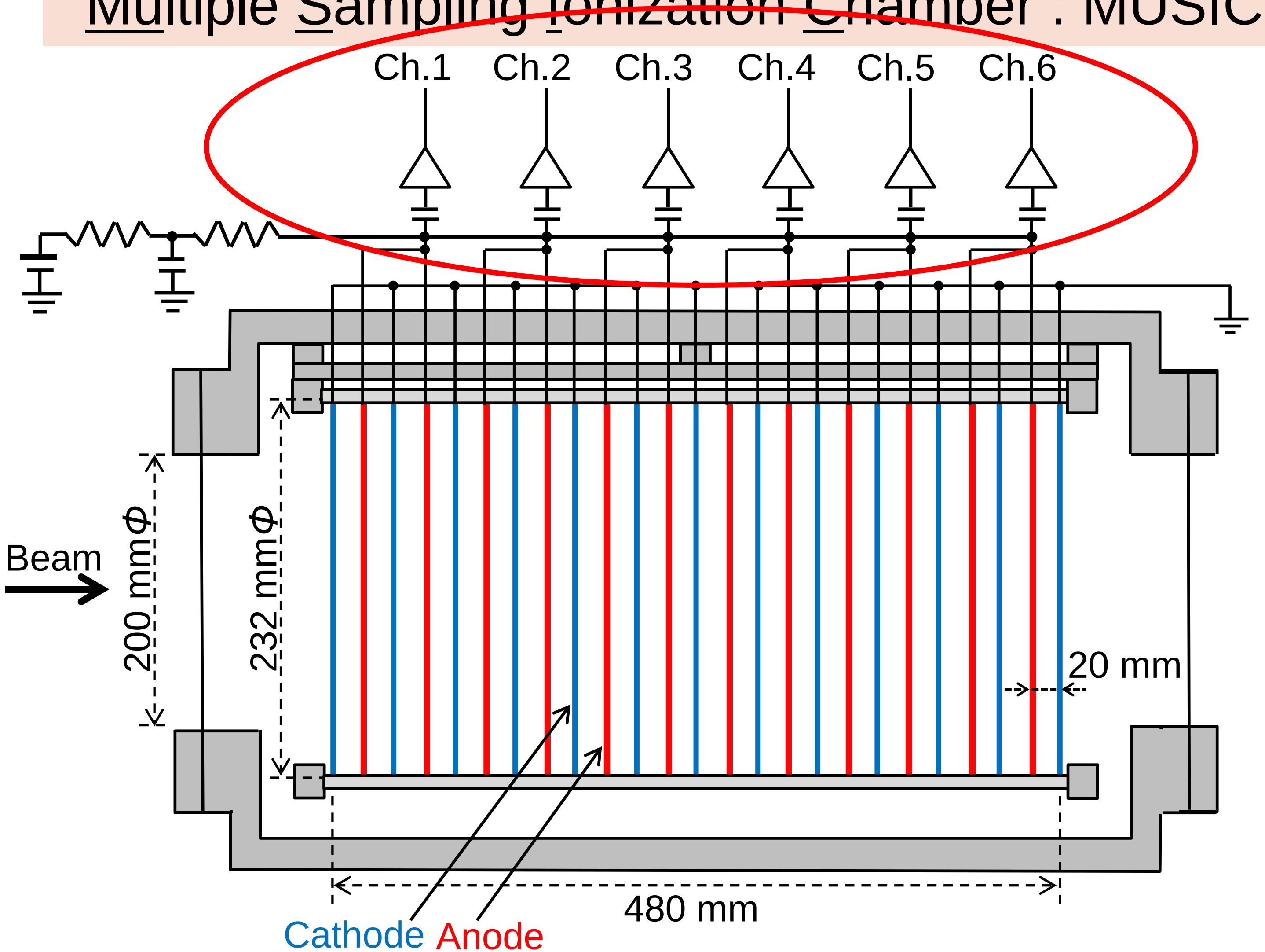
Multiple Sampling Ionization Chamber : MUSIC

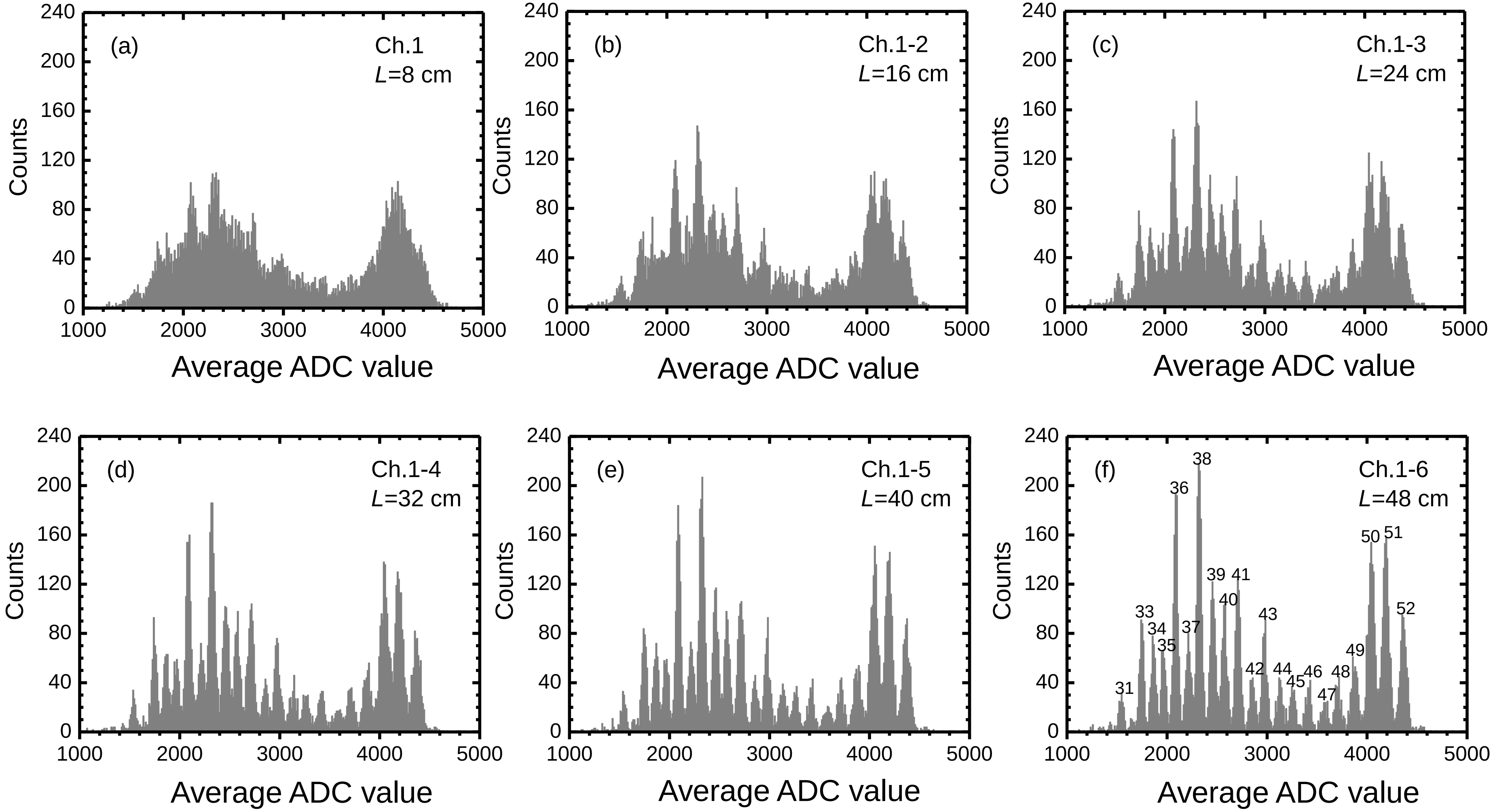


13 cathodes and 12 anodes (2-μm-thick aluminized mylar foils)

Tow anode electrodes are connected to a charge-sensitive preamplifier.

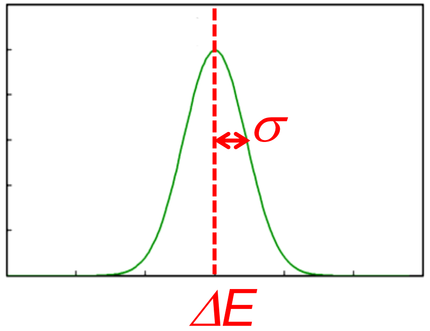
1 channel : 8 cm → 6 channels : 48 cm

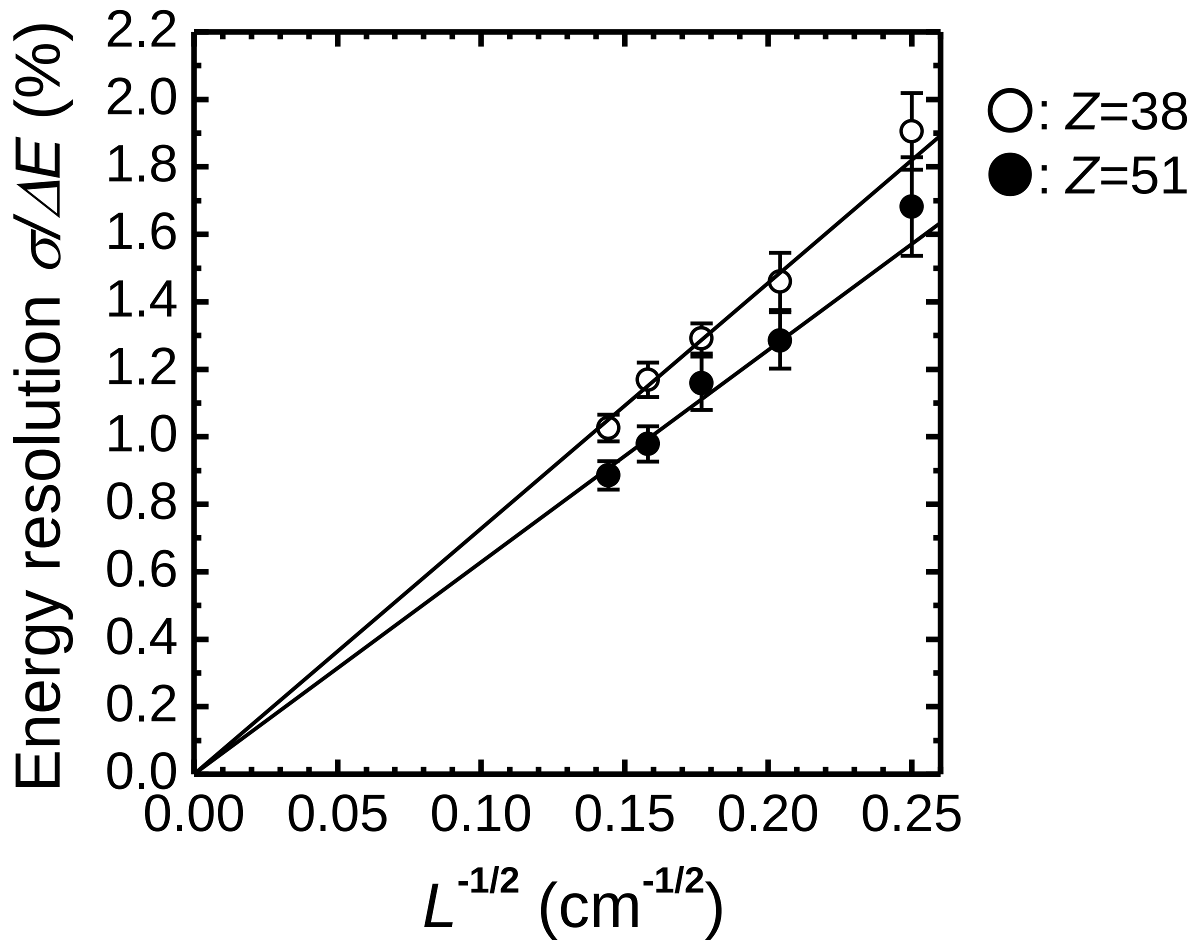
Energy spectra for heavy ions produced from in-flight fission of ^{238}U at 345 MeV/nucleon.



The resolving power increased with gas thickness.

Energy resolution as a function of the gas thickness





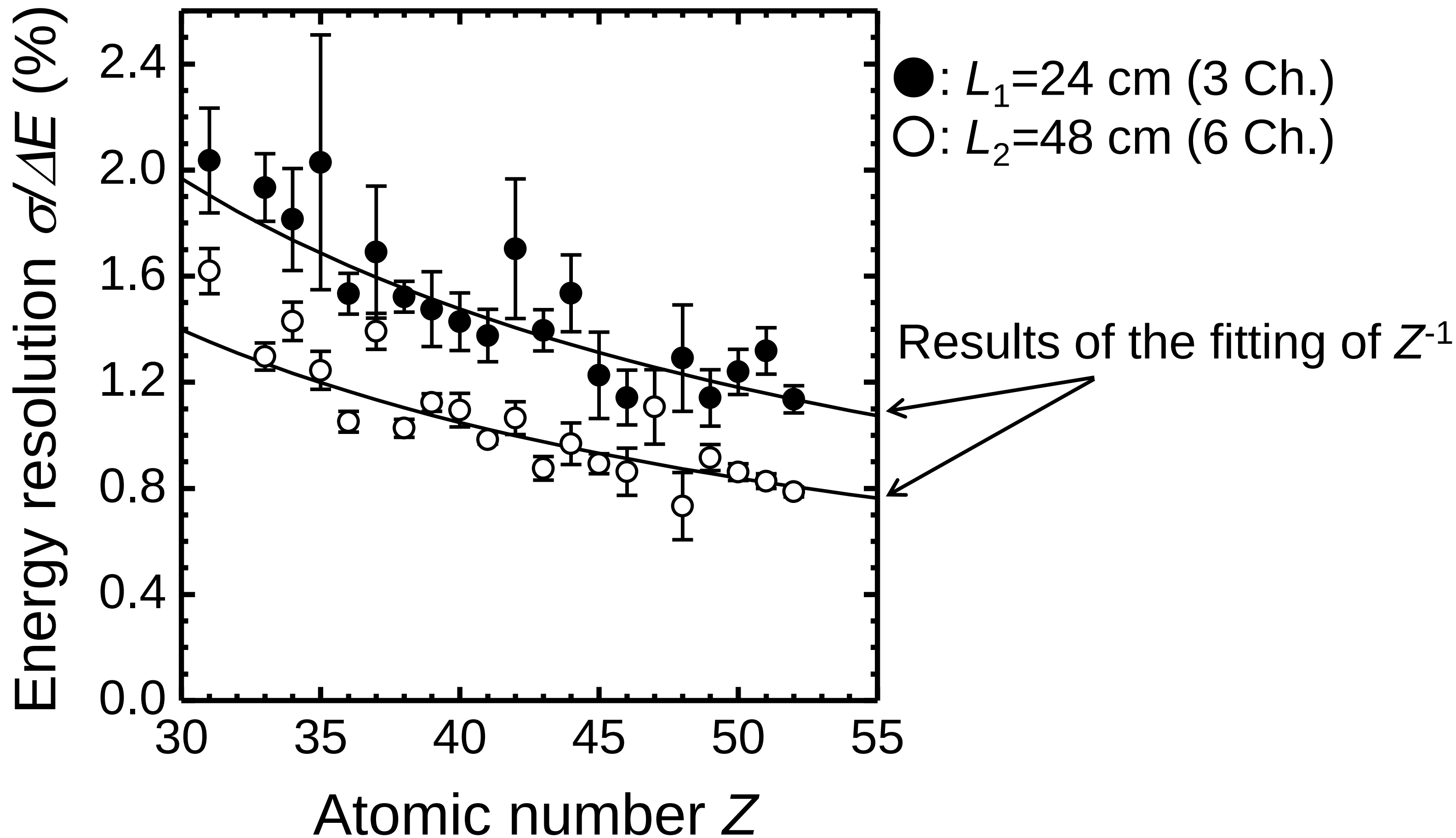
Consider only energy straggling, then

$\sigma \propto L^{1/2}$ (Bohr expression) and $\Delta E \propto L$ (Bethe-Bloch formula)

thus

$\sigma / \Delta E \propto L^{-1/2}$.

Energy resolution as a function of the atomic number of heavy ions



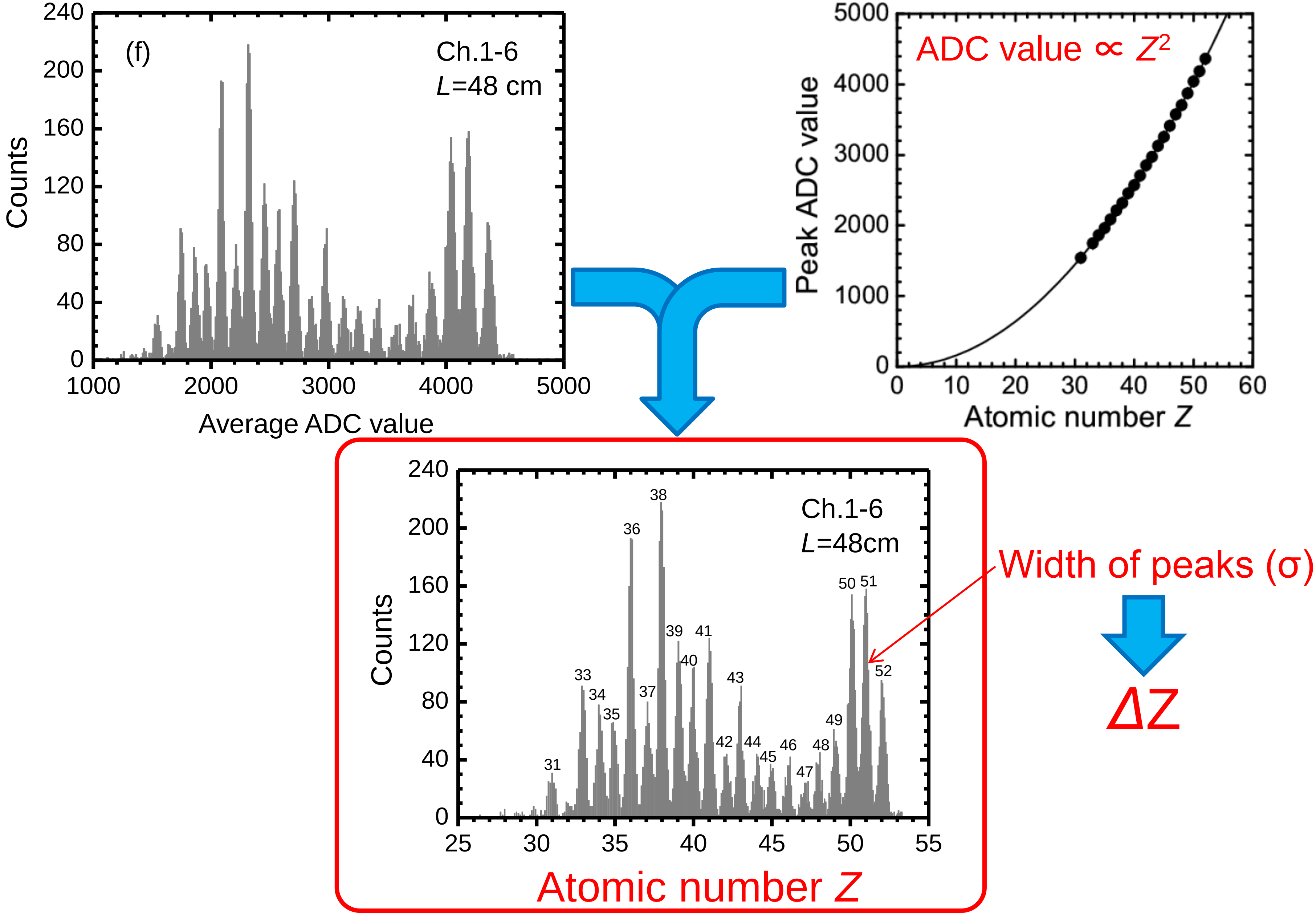
Consider only energy straggling, then

$\sigma \propto Z$ (Bohr expression) and $\Delta E \propto Z^2$ (Bethe-Bloch formula)

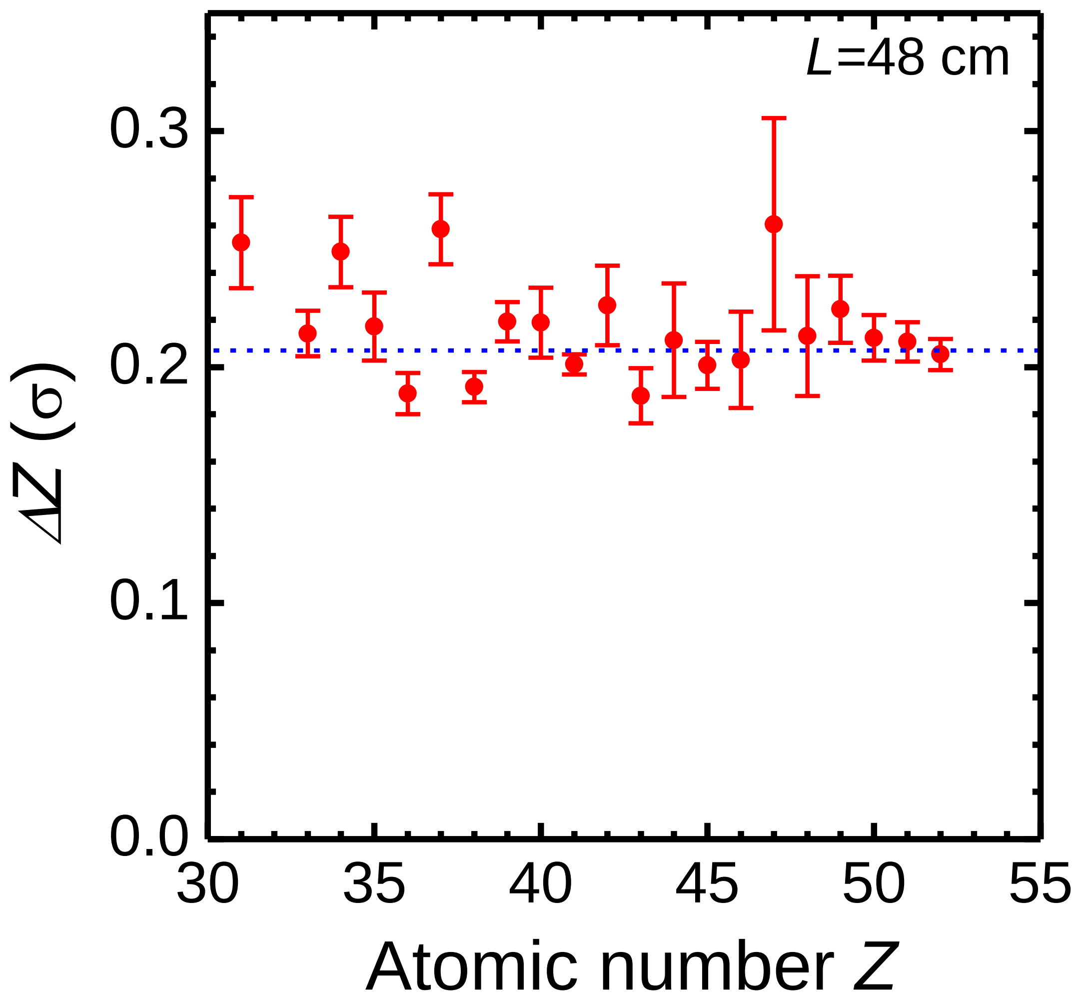
thus

$\sigma/\Delta E \propto Z^{-1}$.

Z resolution (ΔZ)



Z resolution as a function of the atomic number of heavy ions

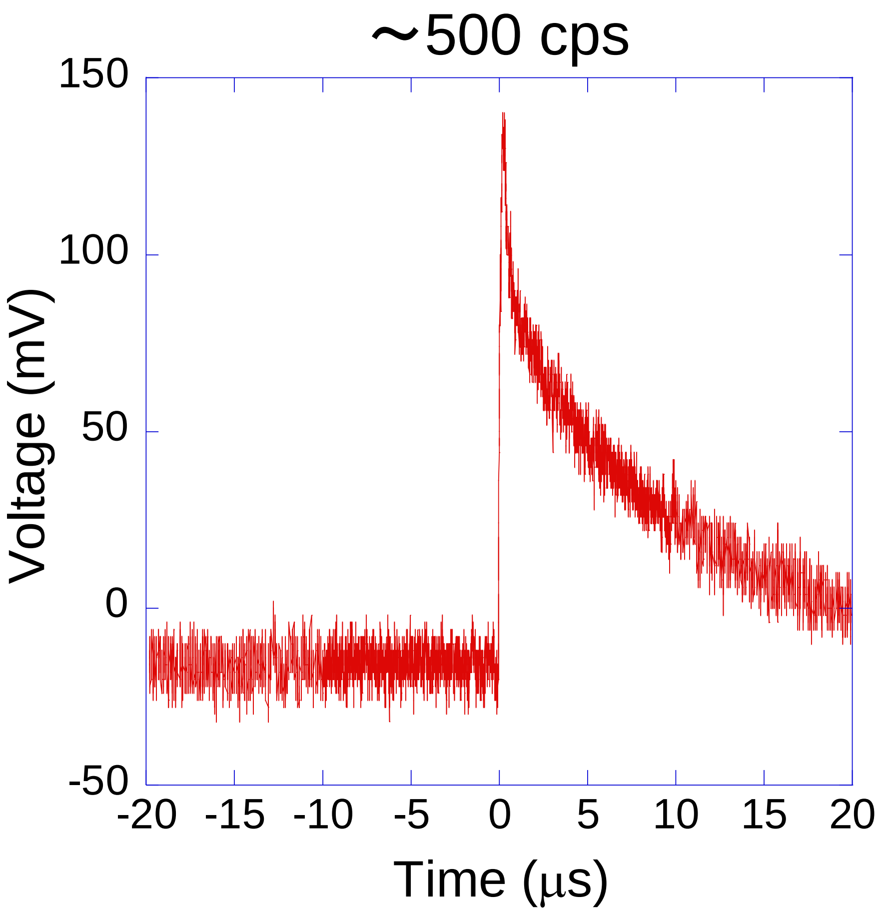


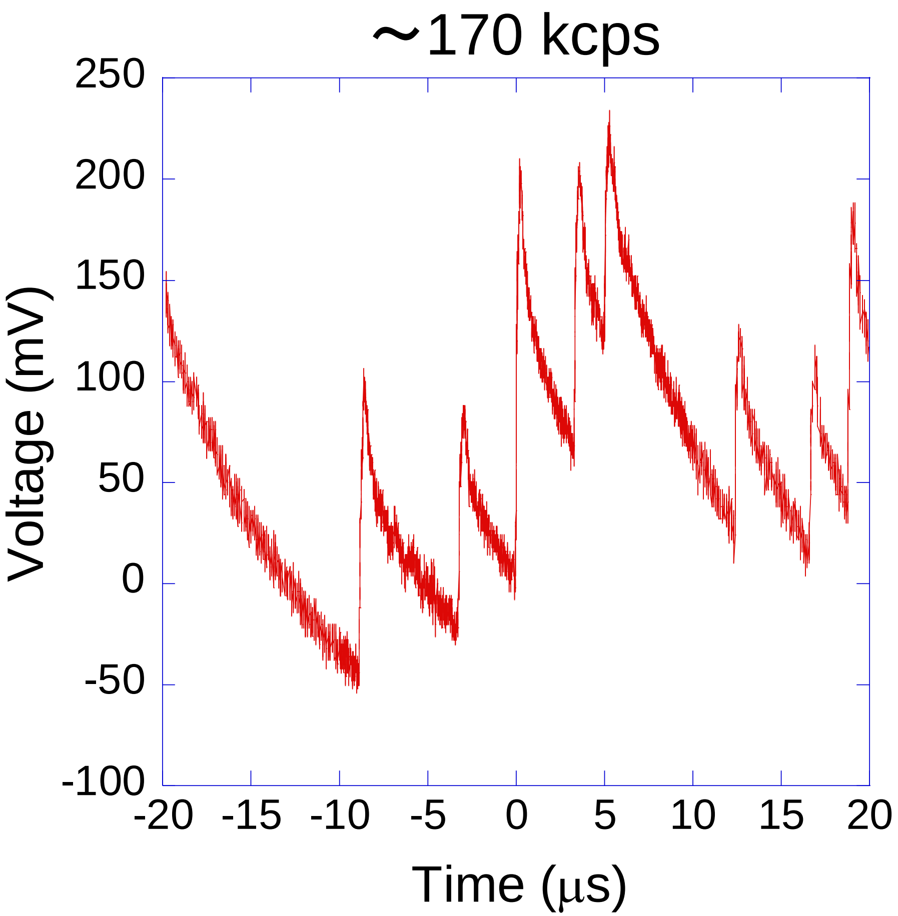
Z resolutions : $\Delta Z \approx 0.21$

Performance decline is not observed up to *Z*=52 below 1 kcps.

Ionization chamber (@ F7) Pre. Amp. OUT

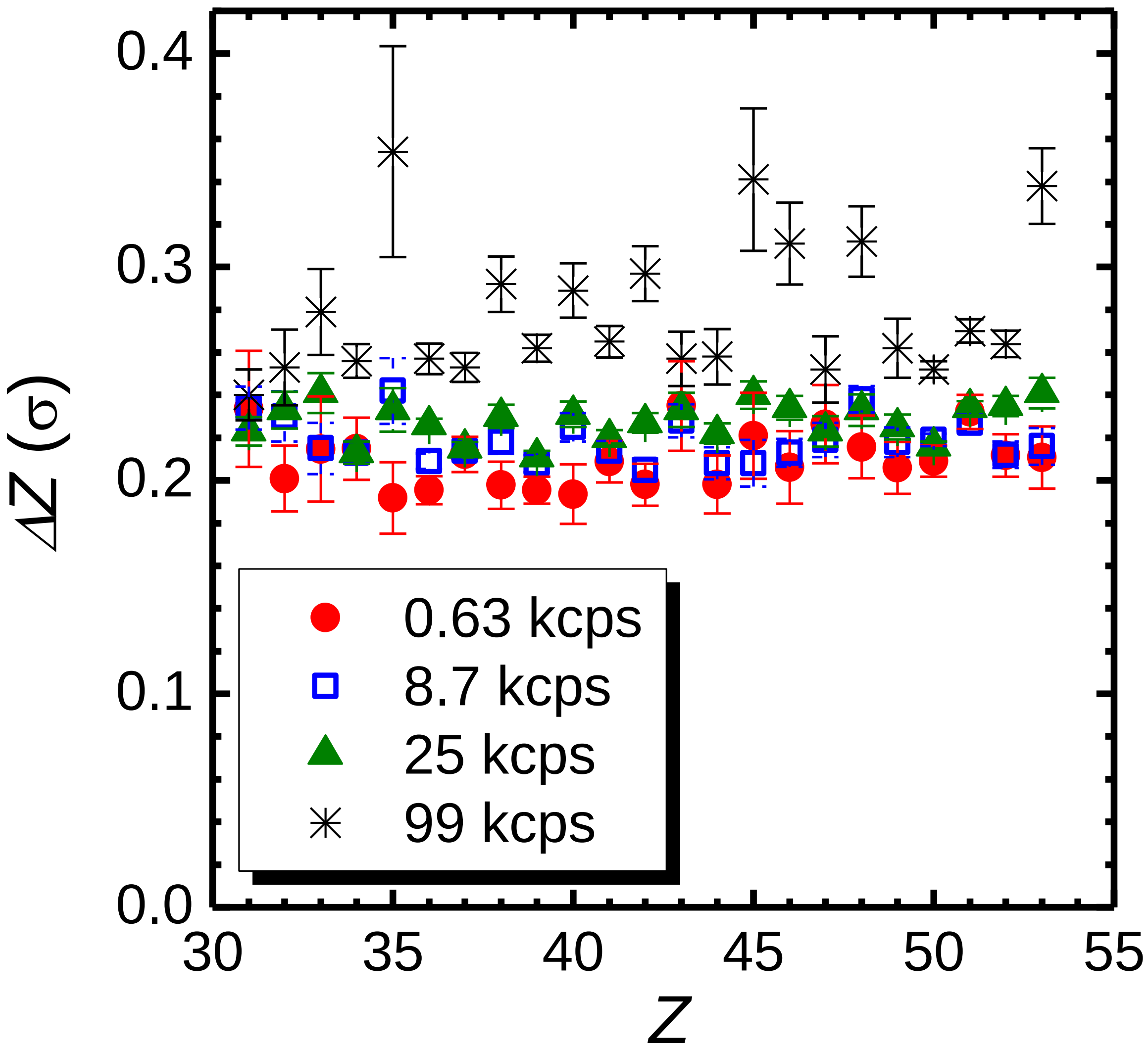
PreAmp : Mesytec MPR-16 PreAmp (10 μs decay)





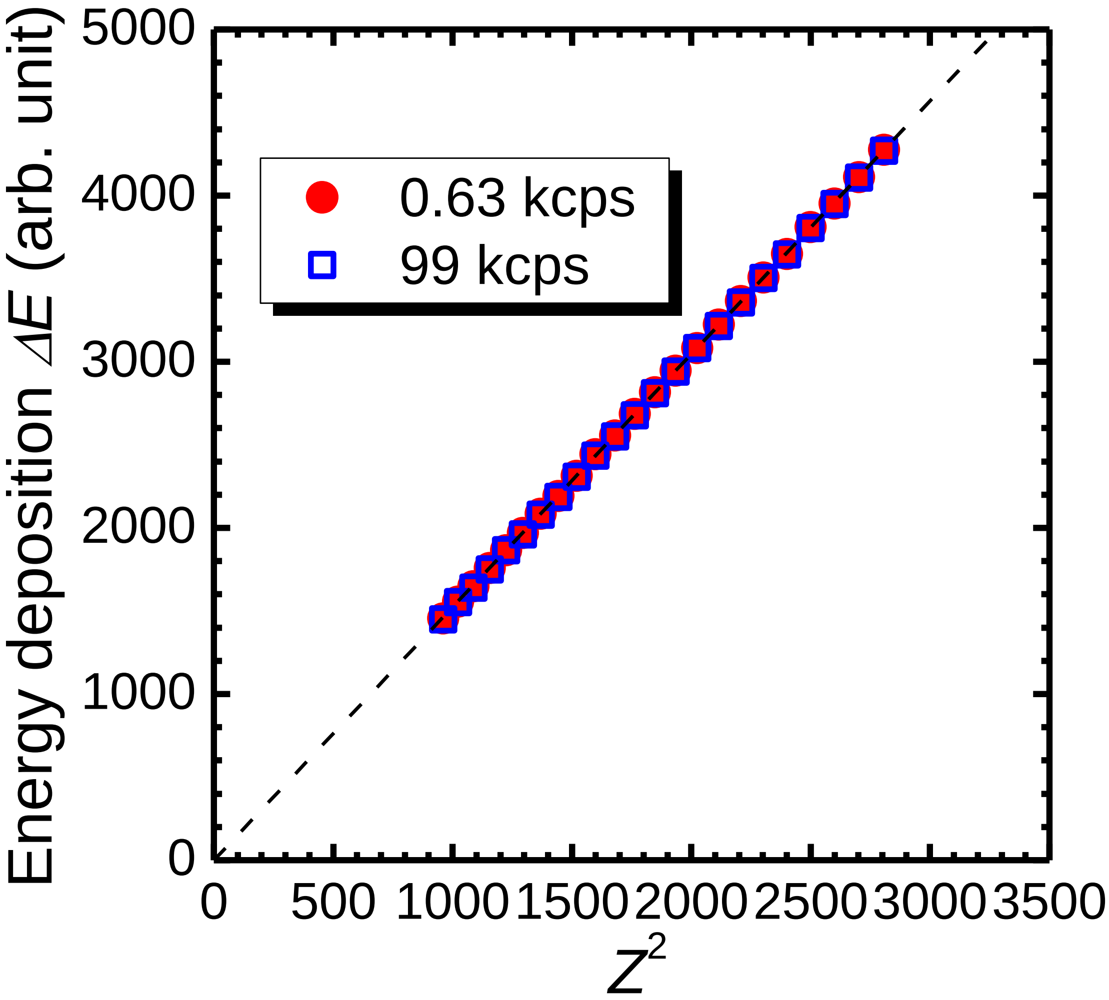
Many pile-up events !!

Rate dependence of *Z* resolution



Z resolutions decreased above several tens of kcps.

Dependence of energy deposition on atomic number



Recombination of electrons and positive ions is negligibly small.

→ Decline of ΔZ was caused by the measurement system (pile-up events).

Summary of MUSIC

● Energy resolution $\sigma/\Delta E$ for fragment heavy ions produced from in-flight fission of ^{238}U at 345 MeV/nucleon was discussed.

$$\sigma/\Delta E \propto Z^{-1} \text{ and } \sigma/\Delta E \propto L^{-1/2}$$

● Z resolution did not decrease up to Z=52 below 1 kcps,

$$\Delta Z \approx 0.21$$

● Z resolutions decreased above several tens of kcps.

● Recombination of electrons and positive ions was not observed up to ~100 kcps.

New measurement system is necessary for high-rate conditions.

Parallel Plate Avalanche Counter : PPAC

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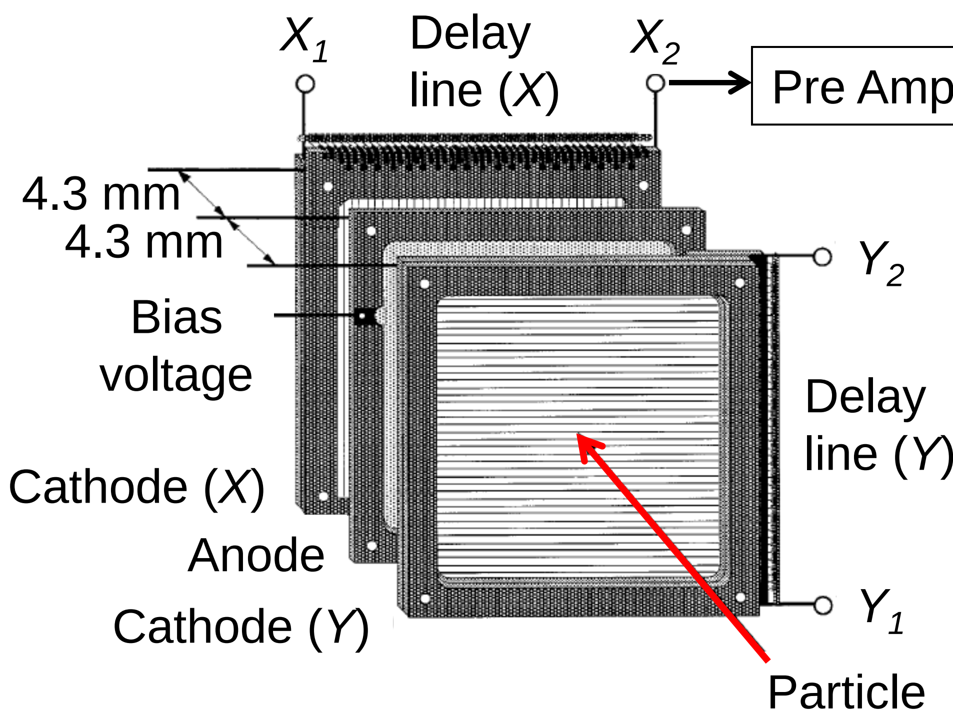
➡ 2D position sensitive detector

- iso−C_4H_{10}, C_3F_8, 10〜50 torr
- 〜100V/mm electric field
- Electron avalanche

\+ **Delay-Line read-out**
H. Kumagai et. al., NIMA 2001



$$P_X = k_X \times \frac{T_{X1} - T_{X2}}{2} \quad \text{(mm)}$$

$$P_Y = k_Y \times \frac{T_{Y1} - T_{Y2}}{2} \quad \text{(mm)}$$

k_X, k_Y: slope factors

Parallel Plate Avalanche Counter : PPAC

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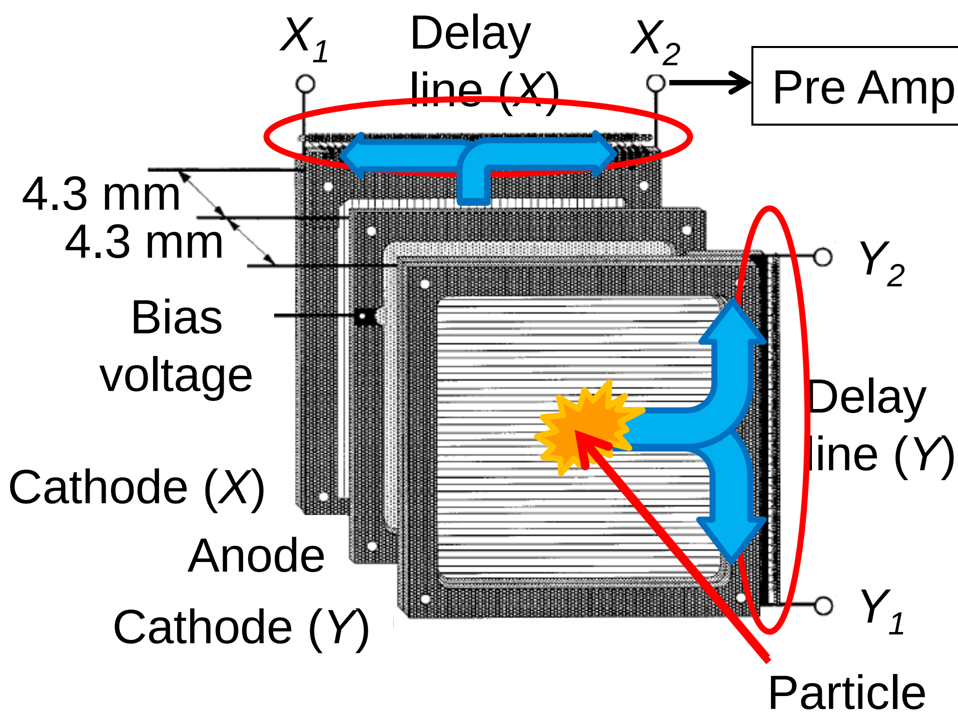


X_2 → Pre Amp. → Fast Amp. → CFD $\equiv T_{X2}$

$$P_X = k_X \times \frac{T_{X1} - T_{X2}}{2} \ \text{(mm)}$$

$$P_Y = k_Y \times \frac{T_{Y1} - T_{Y2}}{2} \ \text{(mm)}$$

k_X, k_Y: slope factors

Photos of PPAC detector

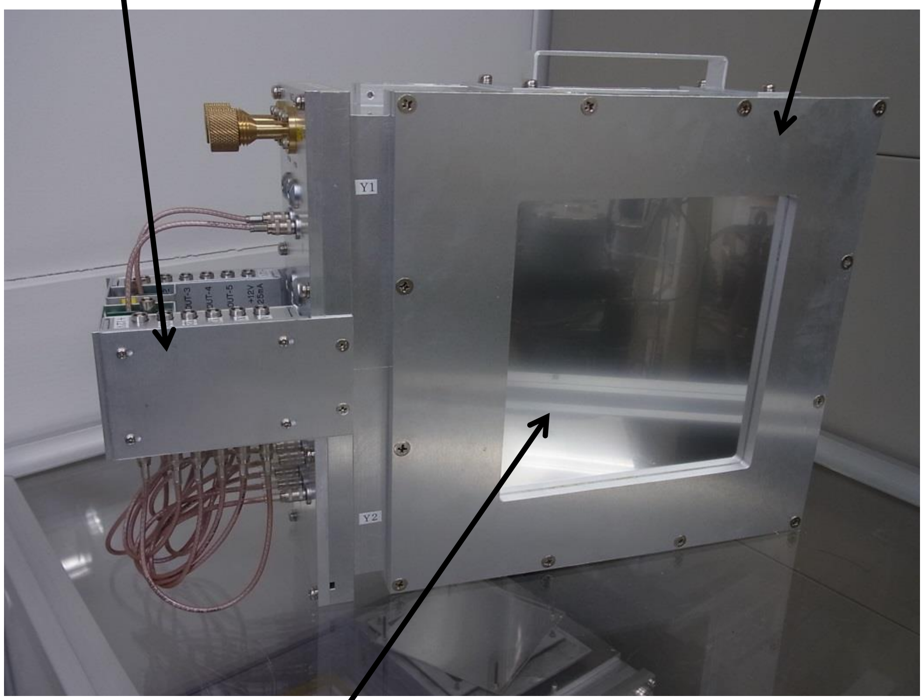
● 240 mm × 150 mm
● 150 mm × 150 mm

Prepared

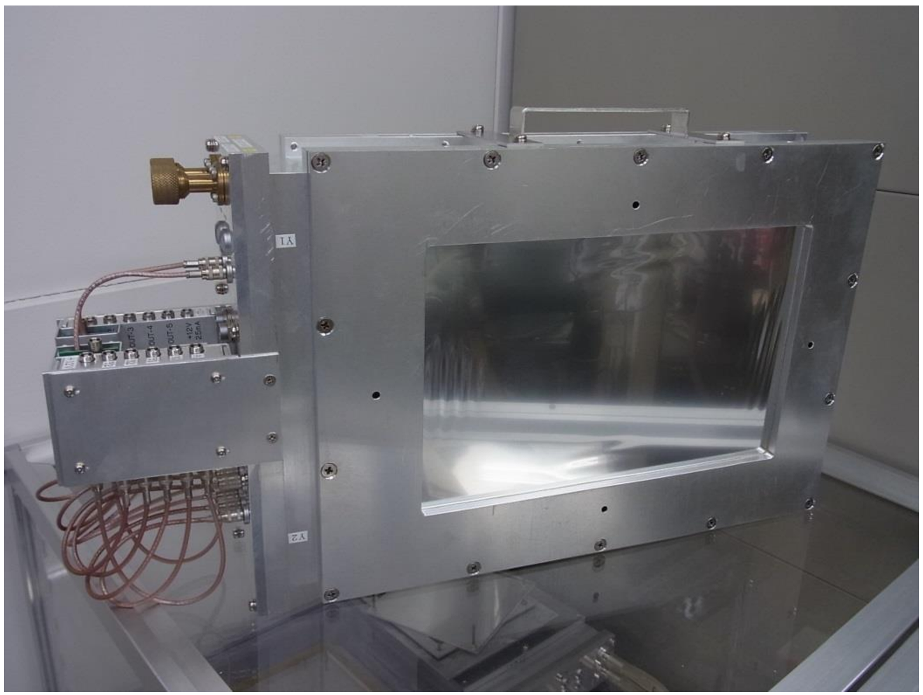
Pre. amp.

Al case

150 mm × 150 mm

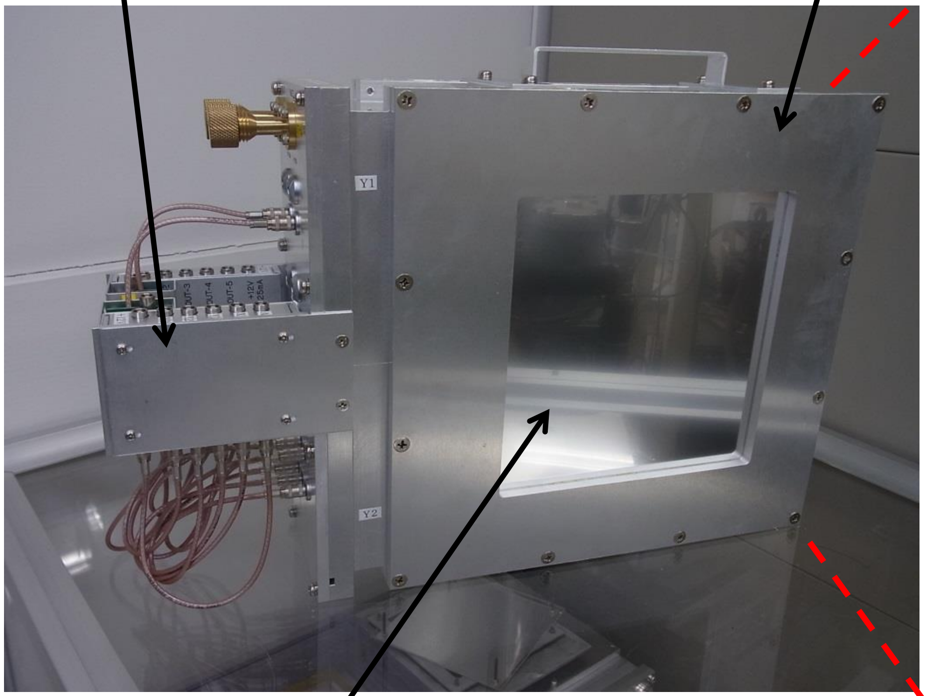


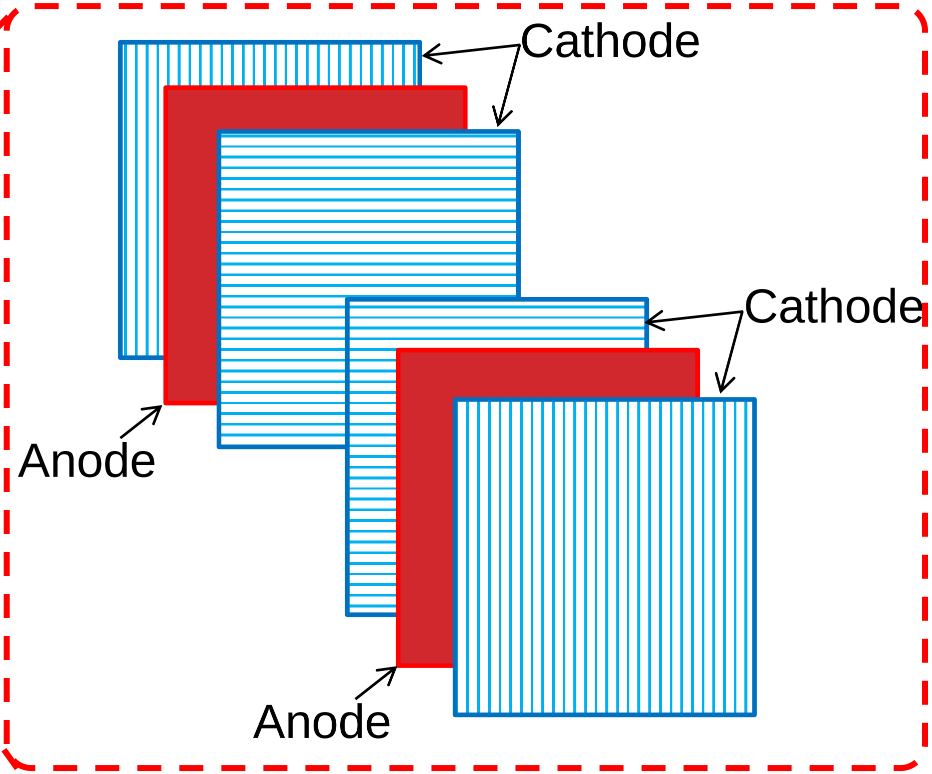
240 mm × 150 mm



Entrance window
(Aluminized mylar: 12 μm)

Photos of PPAC detector

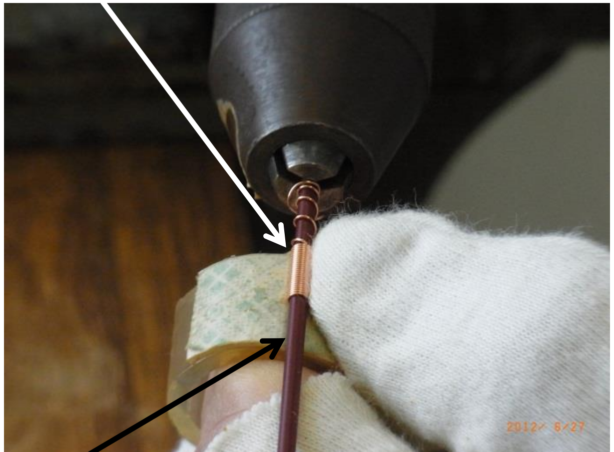


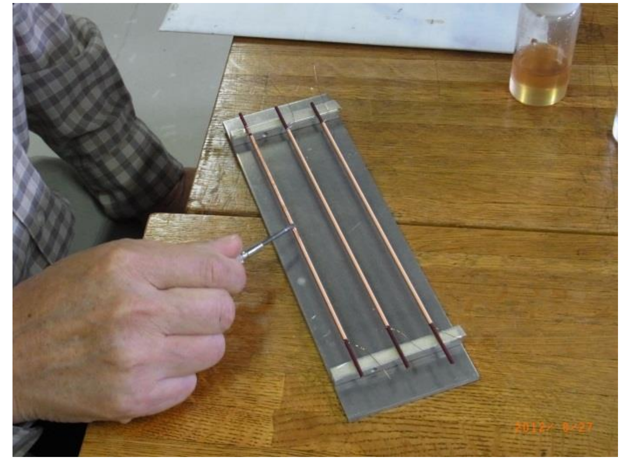


Double PPAC
for BigRIPS

Delay-line fabrication

Cu wire coated by polyurethane



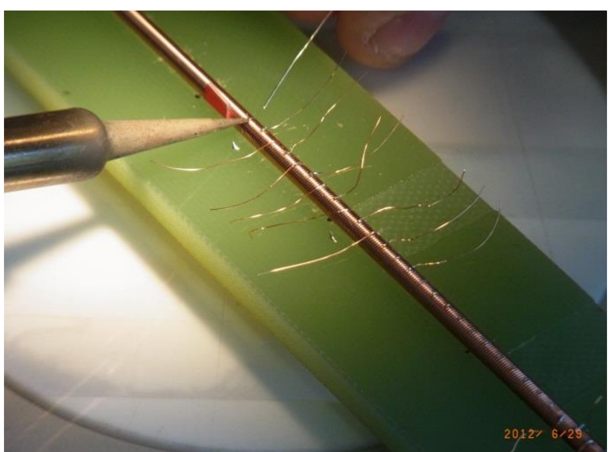


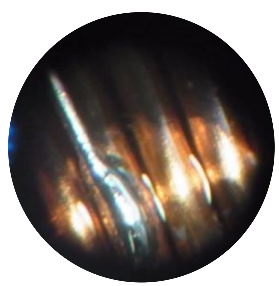
2 mmφ bakelite rod

Cu wire is wound.

Wound wires are coated with epoxy resin.

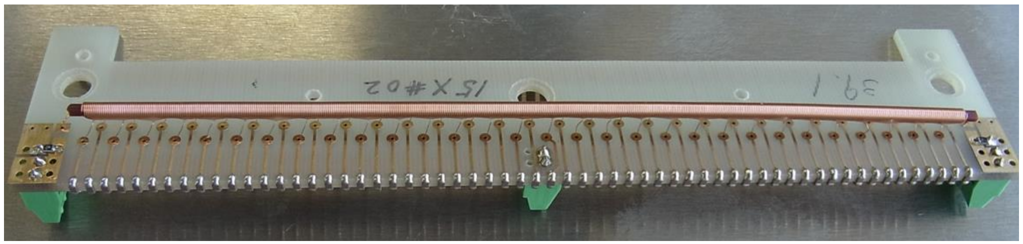
Read-out lines are soldered.

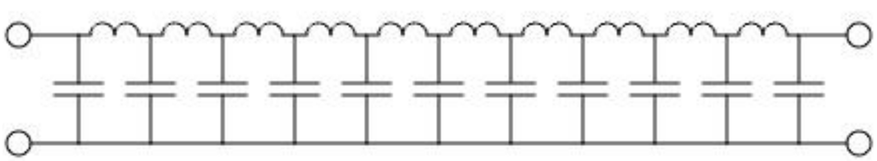


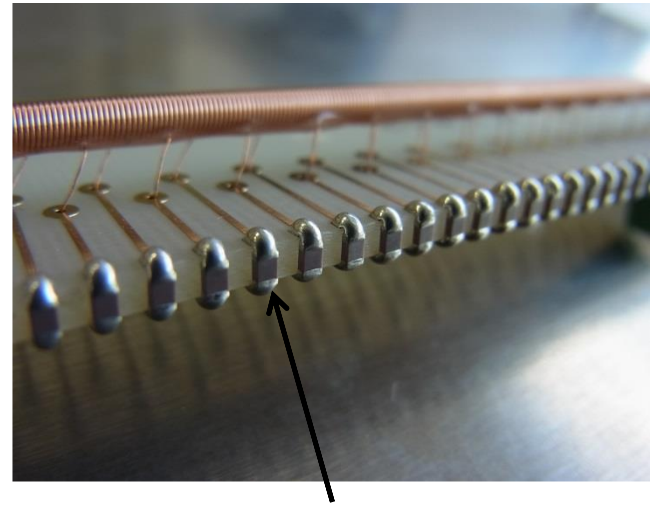


Delay-line fabrication

Mounted on printed board.







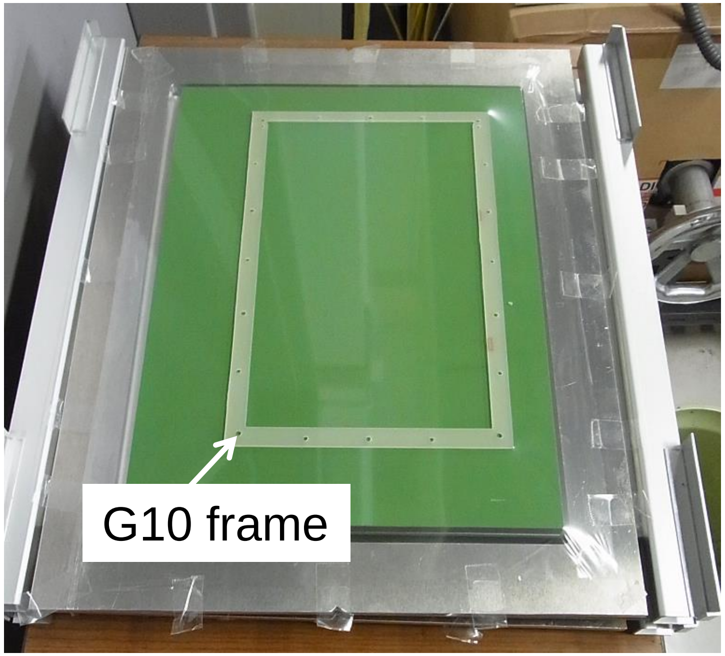
Chip capacitors (~40 pF)

LC delay-line

- Z_0=50 Ω (Matching with input impedance of the pre-amplifier)
- Delay : 0.81 ns/mm

Electrode-foil fabrication

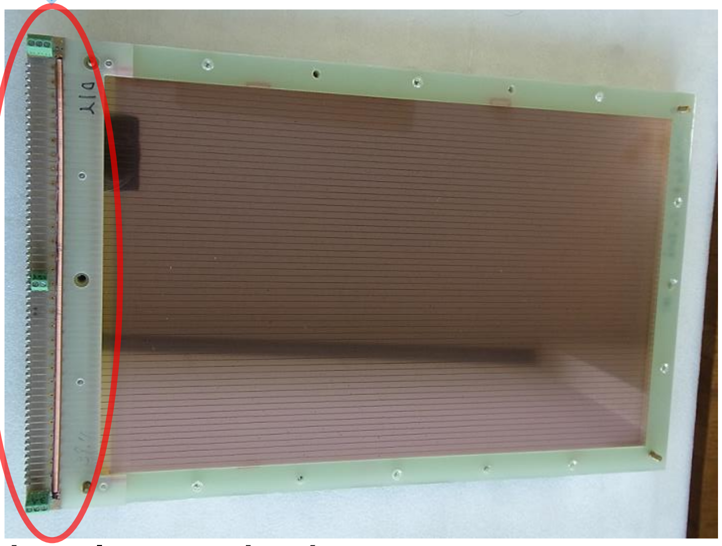
4 μm-thick-mylar is pasted and stretched on the G10 frame.



+

Evaporation mask

Vacuum metalizing

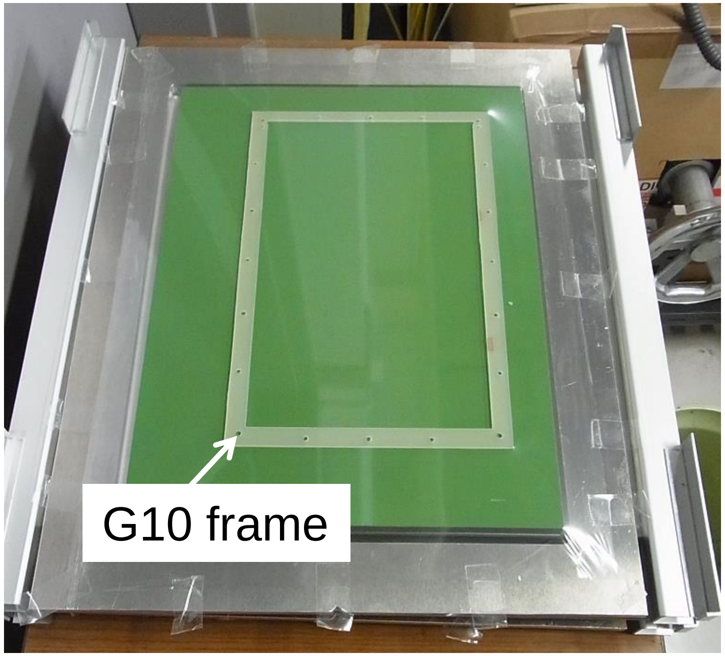


Delay line was attached.

Cathode electrode (240 mm × 150 mm Y-axis)

Electrode-foil fabrication

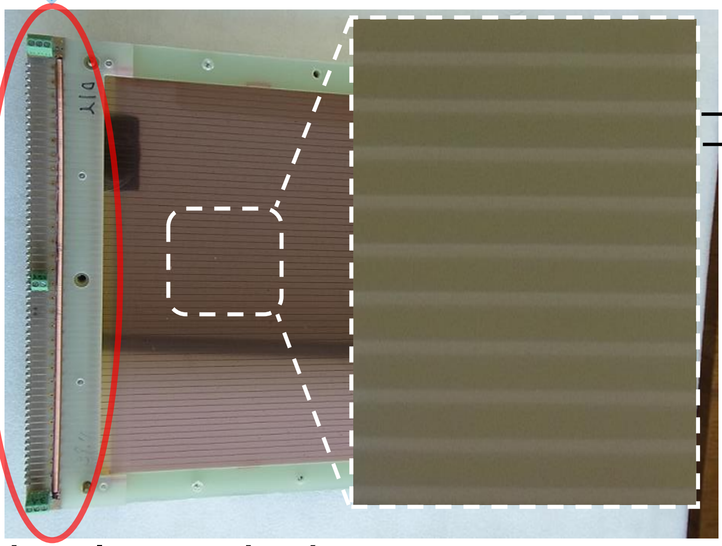
4 μm-thick-mylar is pasted and stretched on the G10 frame.



Evaporation mask

+

Vacuum metalizing



2.4 mm

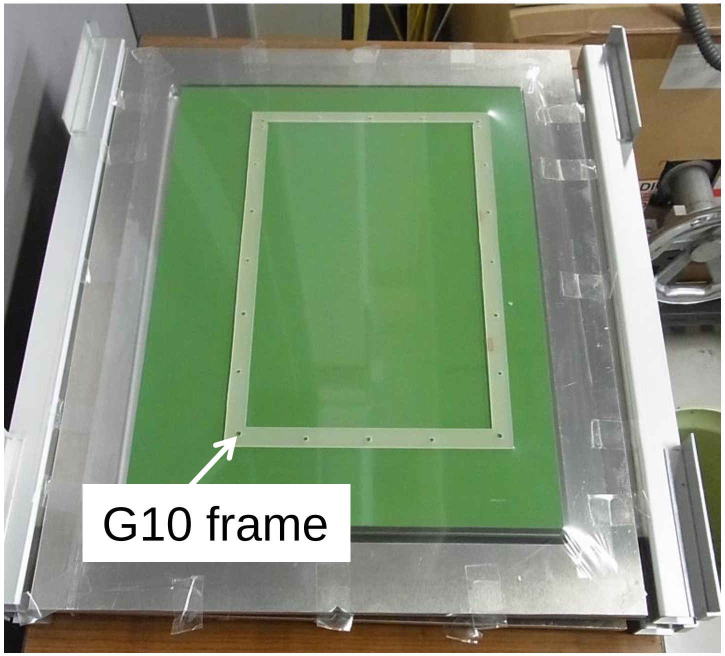
gap:
0.15 mm

Delay line was attached.

Cathode electrode (240 mm × 150 mm Y-axis)

Electrode-foil fabrication

4 μm-thick-mylar is pasted and stretched on the G10 frame.



+

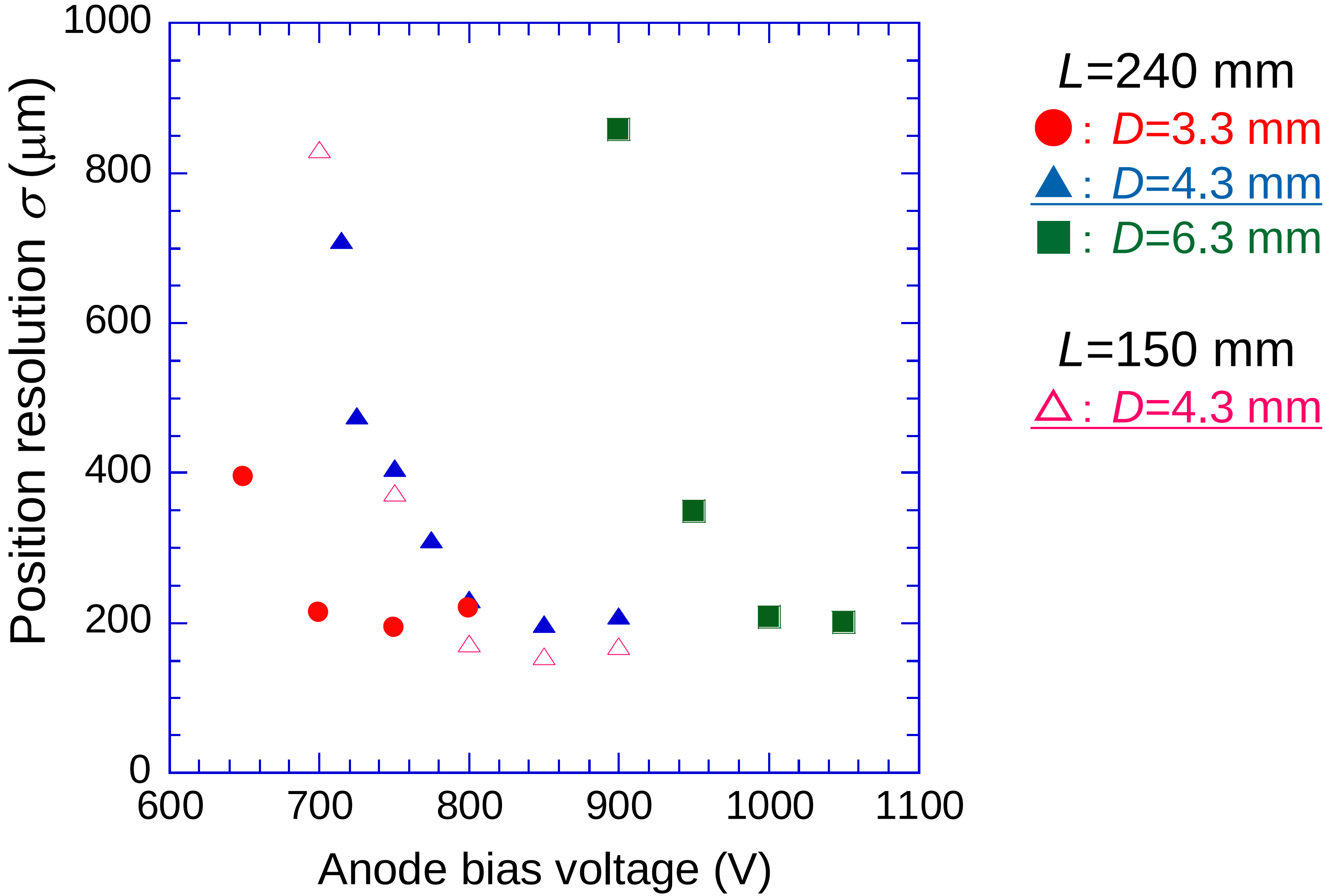
Evaporation mask

Vacuum metalizing

Delay line was attached.

Cathode electrode (240 mm × 150 mm Y-axis)

Position resolution for ^{241}Am-α particles



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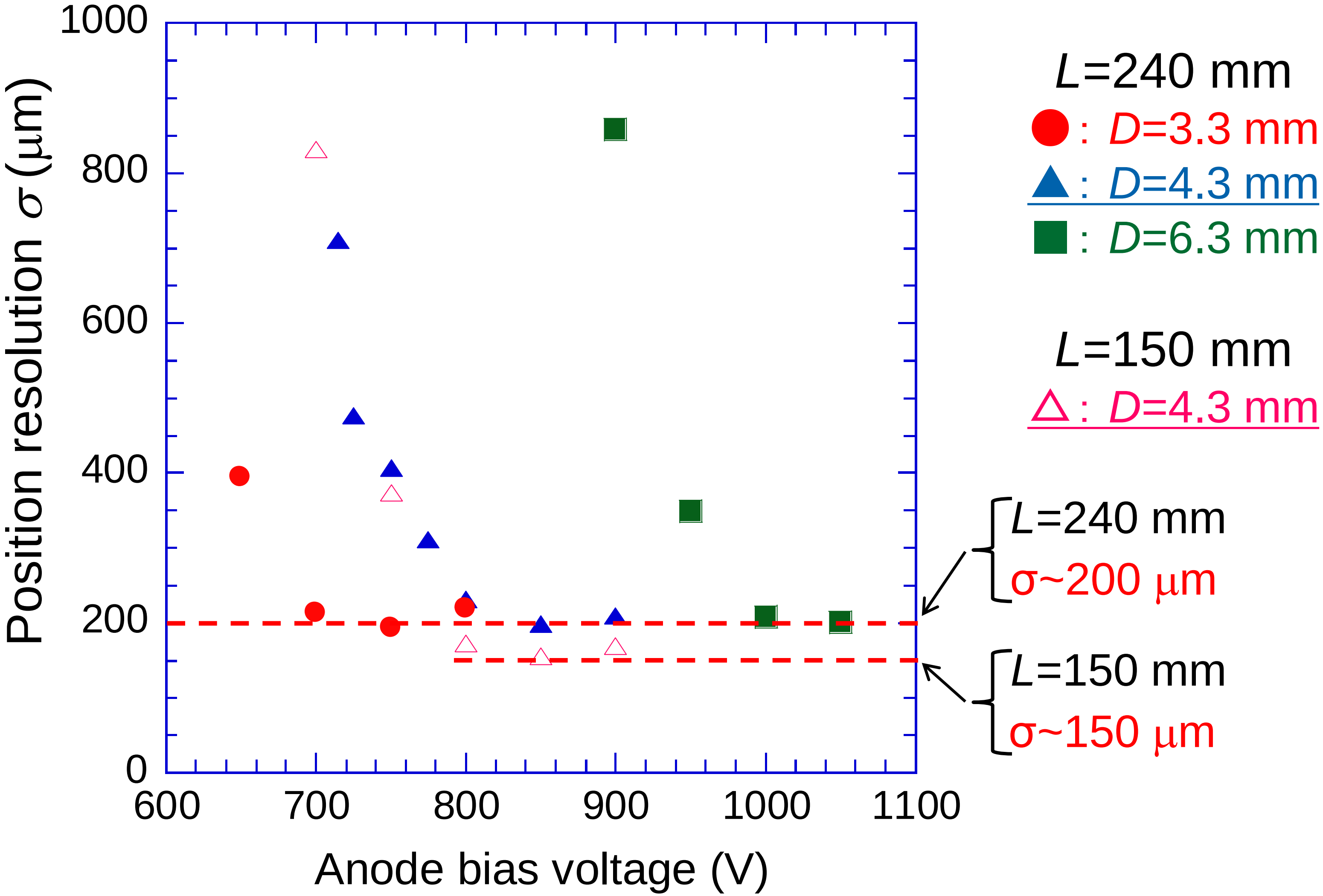
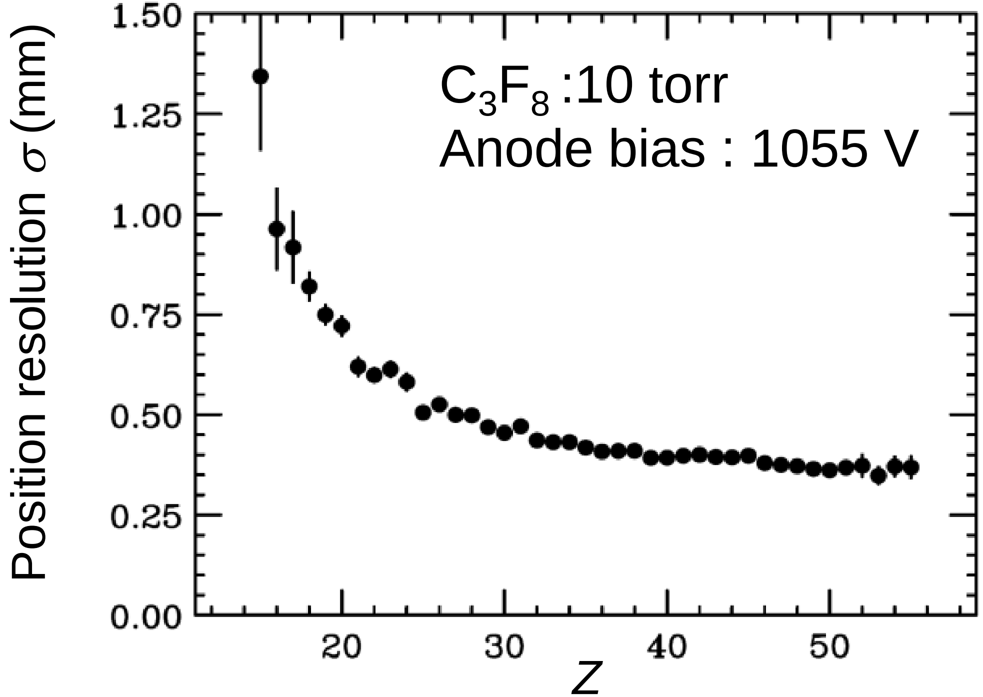
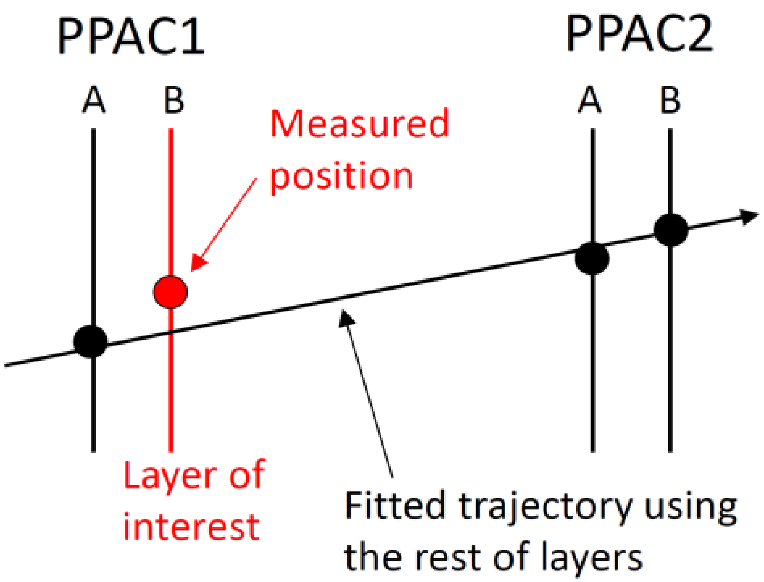


Reachable position resolutions does not depend on the electrode distance.

Position resolution for heavy ions

Fragment ions (reaction: $^{238}U + {}^{9}Be$ at 345 MeV/nucleon)





Signal intensities are increasing.
($Q \propto Z^2$)

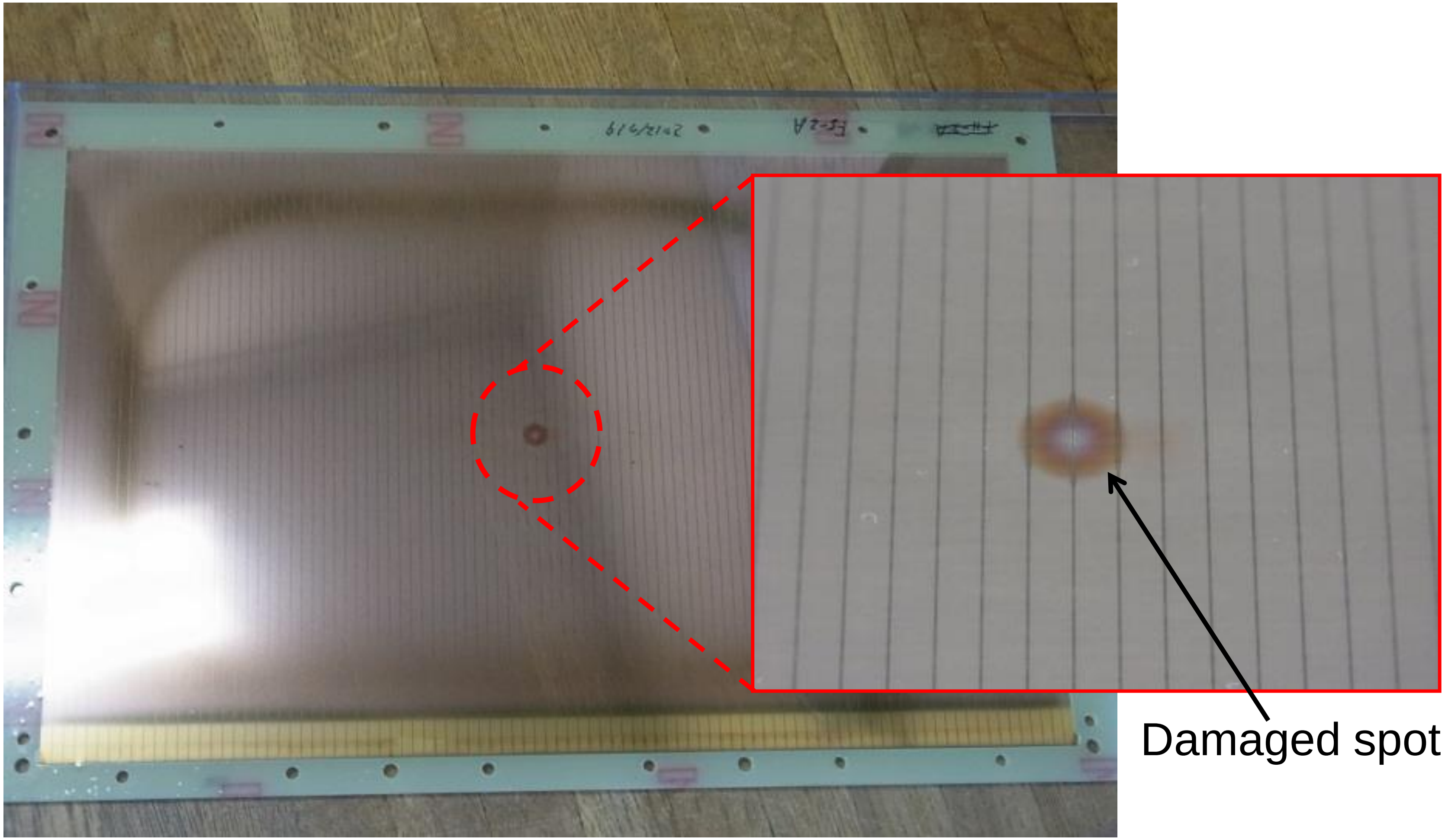
Position resolutions improved.

σ~350 μm at Z≈50 ions.

H. Kumagai NIMB 2013

Damage on cathode electrode due to the discharge

- *Z*~10 ions are measurable up to 1 Mcps.
- Electrical discharge was sometimes occur above several tens of kcps beam rate for *Z*~50 ions.

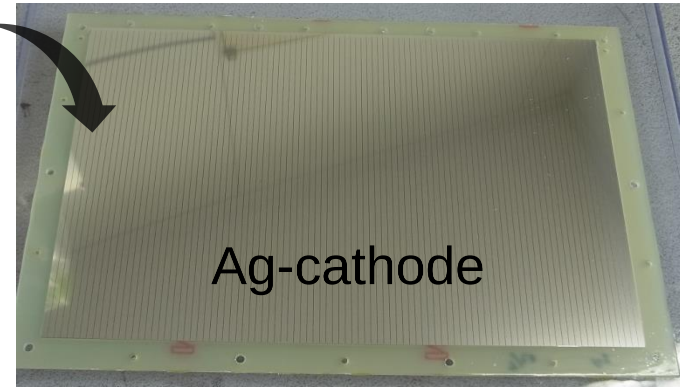


240 mm×150 mm Cu cathode

Solution 1

Changing the electrode materials.

Au, Al, Cu ➡ *Ag*



- Large thermal conductivity : Al < Au < Cu < Ag
- Small electrical resistivity : Al > Au > Cu > Ag

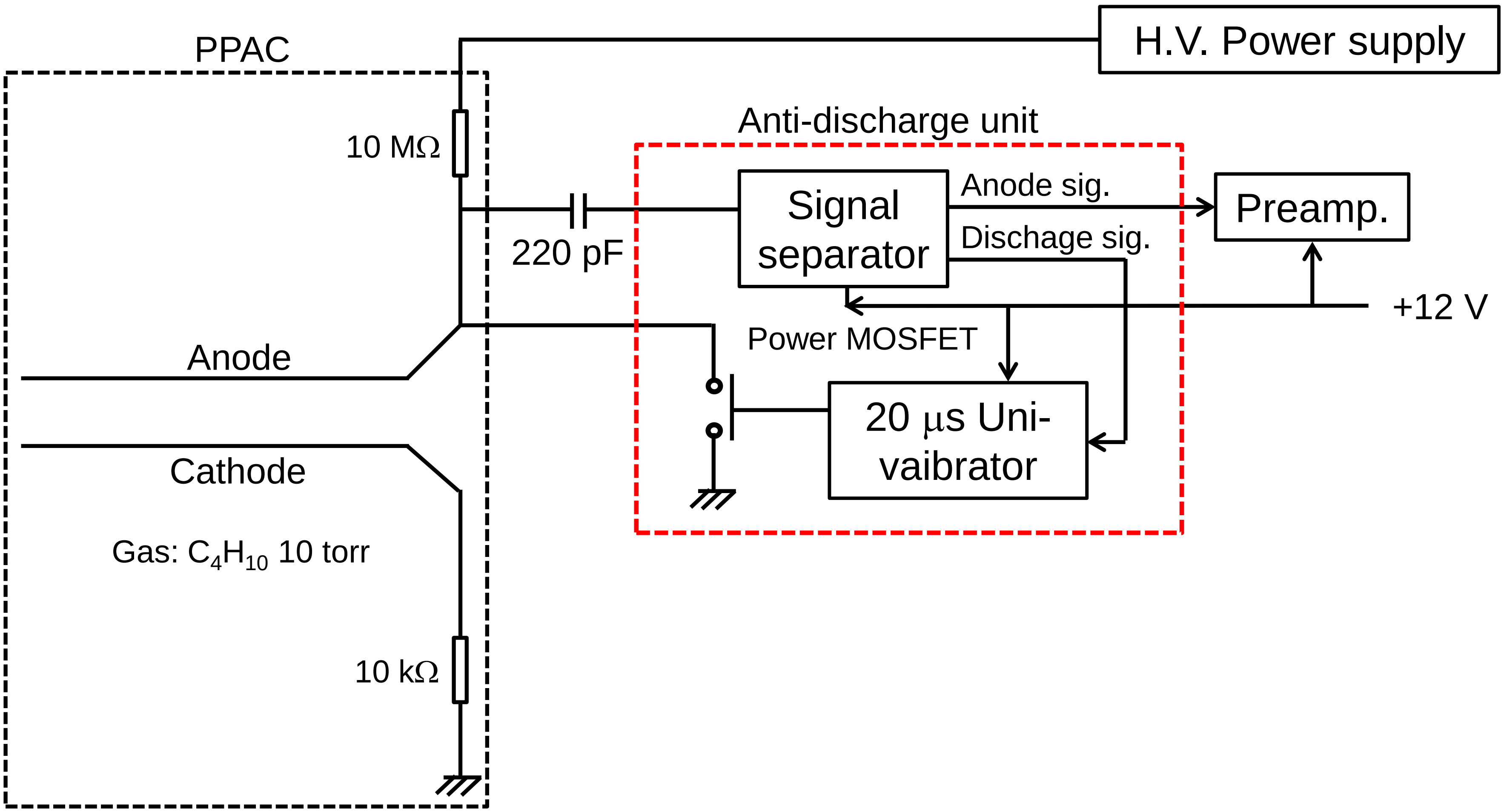
In the first half-year of 2014…

- ~50 kcps of Cs (*Z*=55) ions for 2.5 days.
- ~70 kcps of *Z*~60-70 ions for ~5 hours.

➡ No discharge
No damage

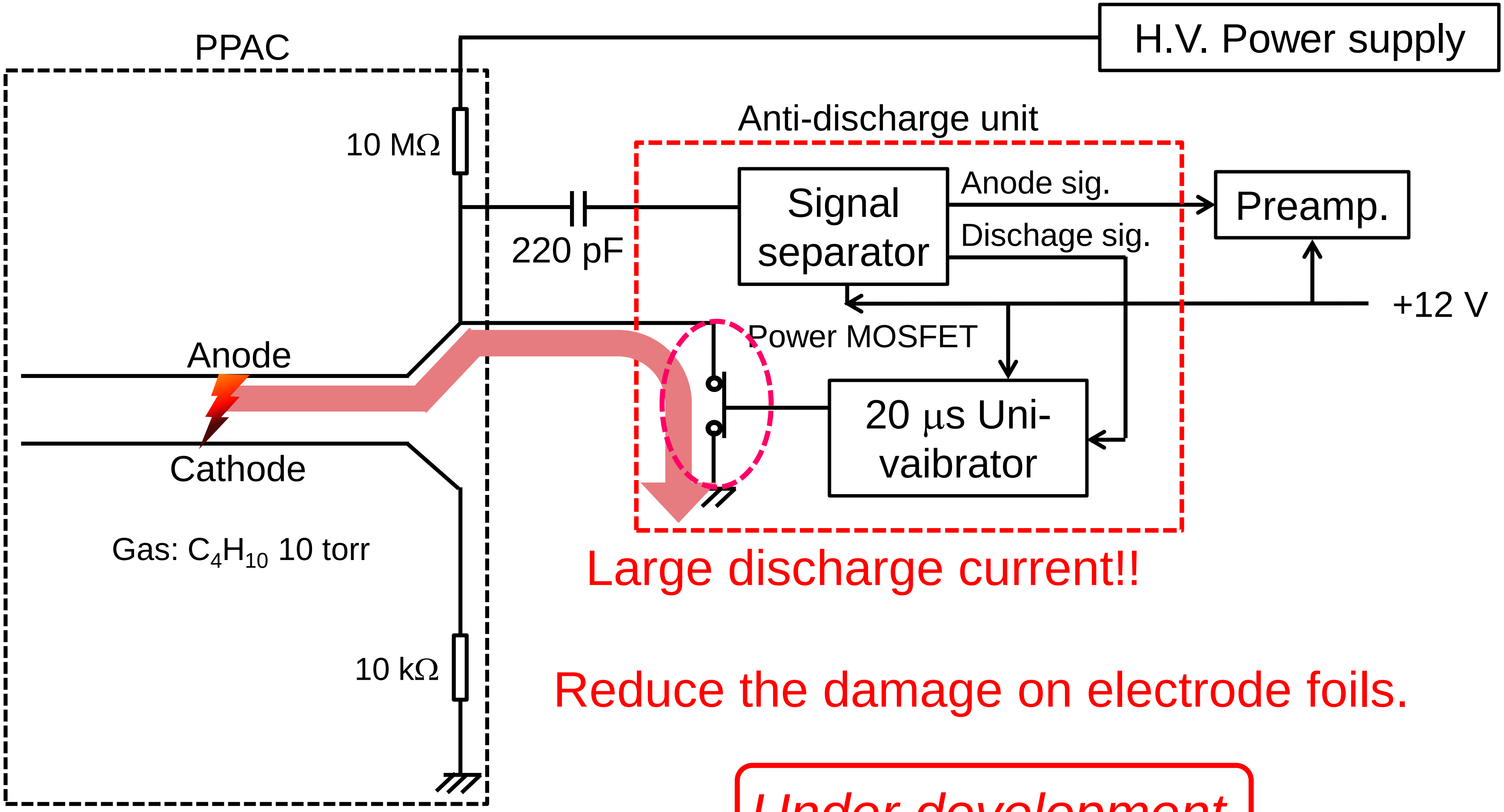
Solution 2

Development of anti-discharge unit.



Solution 2

Development of anti-discharge unit.



Large discharge current!!

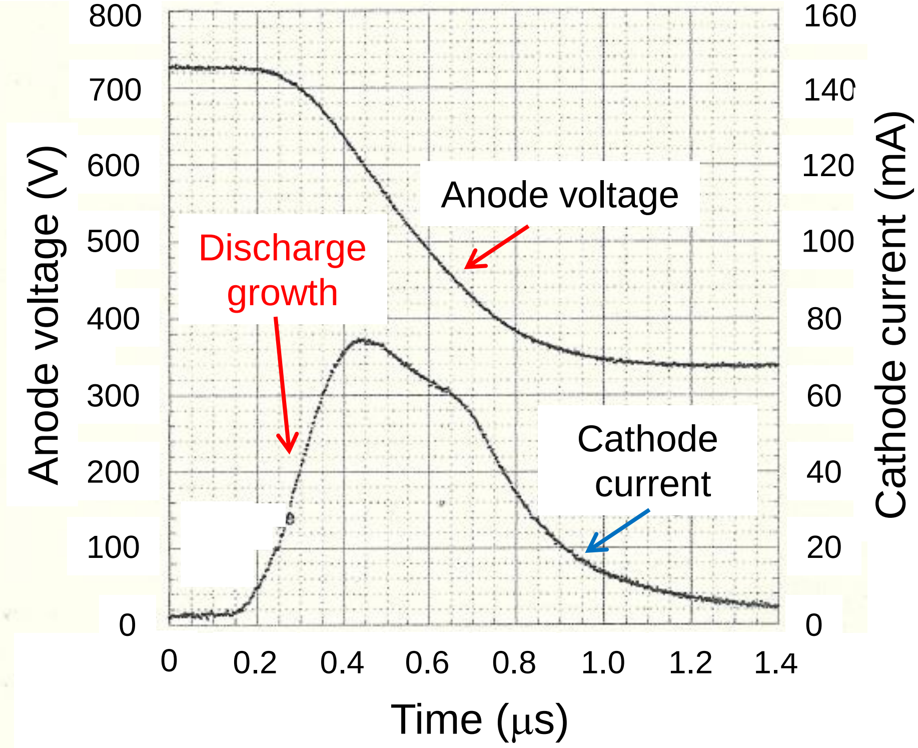
Reduce the damage on electrode foils.

Under development

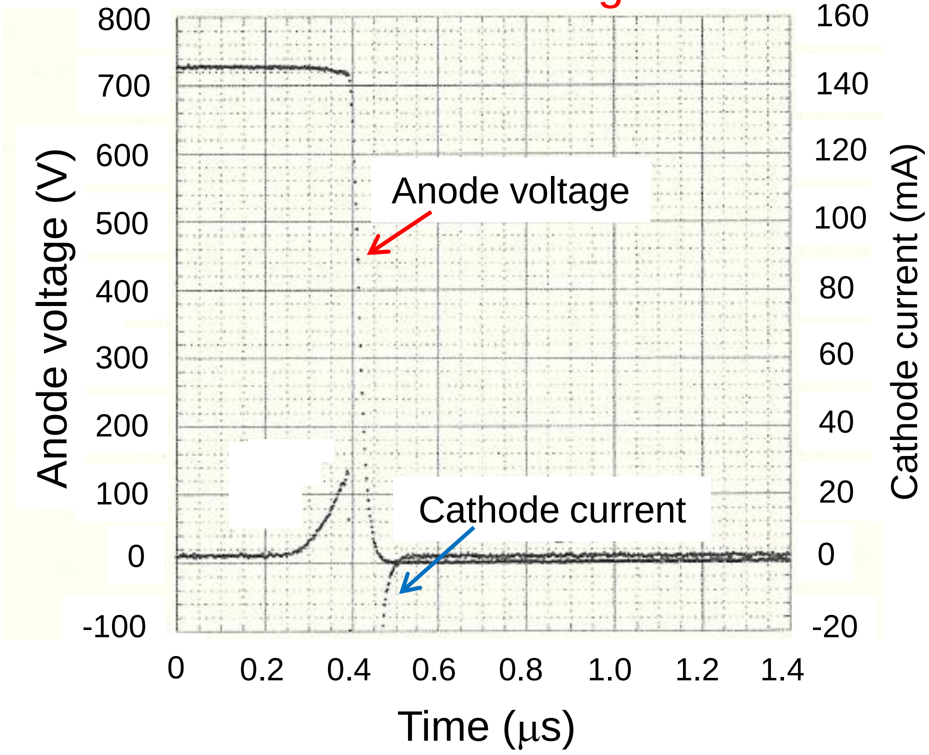
Operation test

Example: Discharge induced using ^{241}Am-α by applying the too large bias voltage, intentionally.

Without anti-discharge unit



With anti-discharge unit



The anode voltage was forcibly grounded using the anti-discharge unit.

➡ Discharge current was suppressed.

➡ Preventing damages on electrodes.

Summary of PPAC

- The delay-line and electrode-foil are made by hand work.

- The position resolution improves with the signal intensity.

  ~200 μm for alpha particles
  ~350 μm for $Z \approx 50$ heavy ions

- The durability against electric discharge was improved by using Ag electrodes.

  ~50 kcps of Cs (Z=55) ions for more than 2.5 days.
  ~70 kcps of Z~60 ions for 10 hours.

- Anti-discharge unit is under development.
  Suppress the discharge current and prevent damage on electrodes.

fin.