Status of PID detectors at BigRIPS

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2016/8/31 Expert Meeting @Gland Rapids

PID detectors at BigRIPS

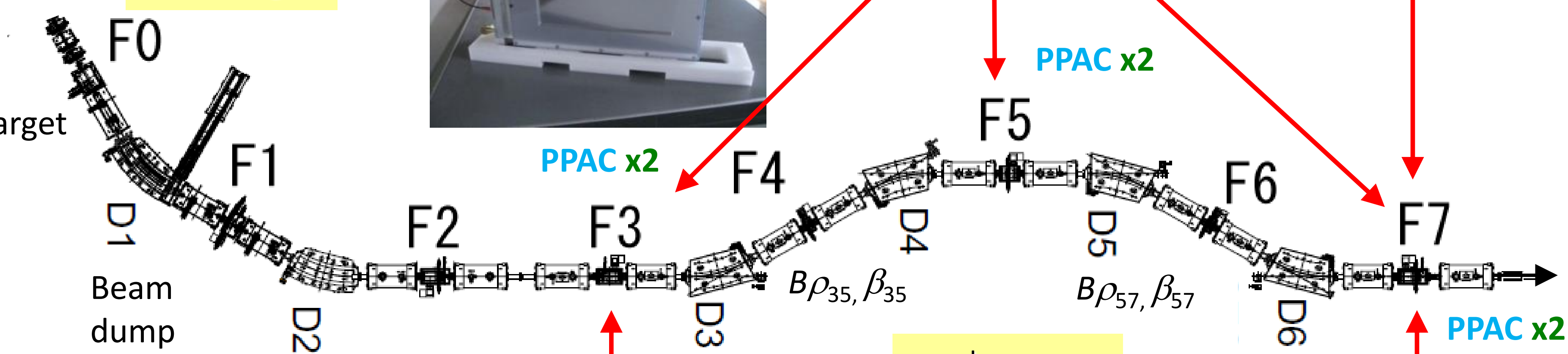
Particle identification → TOF-$B\rho$-ΔE method with track reconstruction

TOF, $B\rho$, ΔE → Z, A/Q

TOF: Time of flight
$B\rho$: Magnetic rigidity
ΔE: Energy loss

$B\rho$ with track reconstruction

ΔE: MUSIC, Si
Isomer tagging: Ge



TOF: β

Plastic scintillator

Trajectories at focuses are measured for track reconstruction by using two double PPACs to improve A/Q resolution.

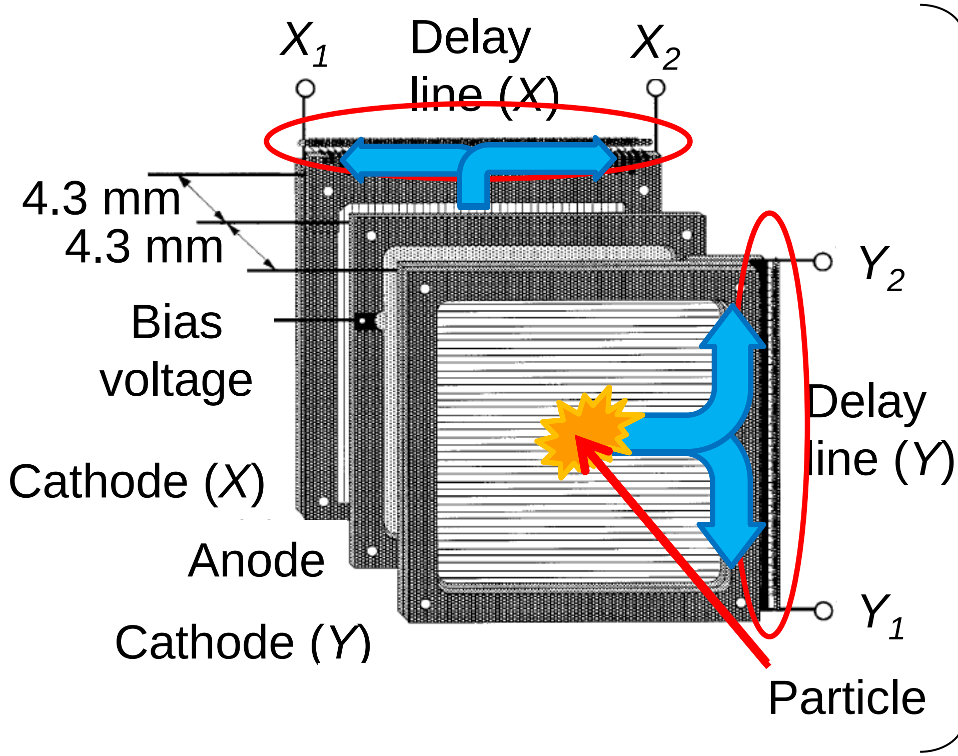
PPAC

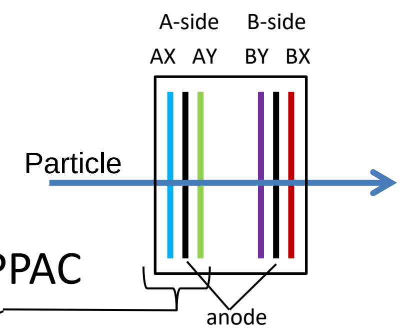
Parallel Plate Avalanche Counter : PPAC → 2D position sensitive detector

H. Kumagai et al., NIMB 317(2013)717-727.

- isobutane (C_4H_{10}), 10 Torr
- ~150V/mm electric field
- Electron avalanche

\+ **Delay-Line read-out**





high efficiency

240x150 double PPAC

Today's items

Recent topics on the PPAC

1. Discharge problem
   - ✓ Change of the material of the electrode
   - ✓ Development of the anti-discharge unit
2. Endurance test with high-rate beams
   - ✓ Efficiency
   - ✓ Position resolution
3. Fabrication of the electrodes
   - ✓ Clear strip gap
   - ✓ Damage problem

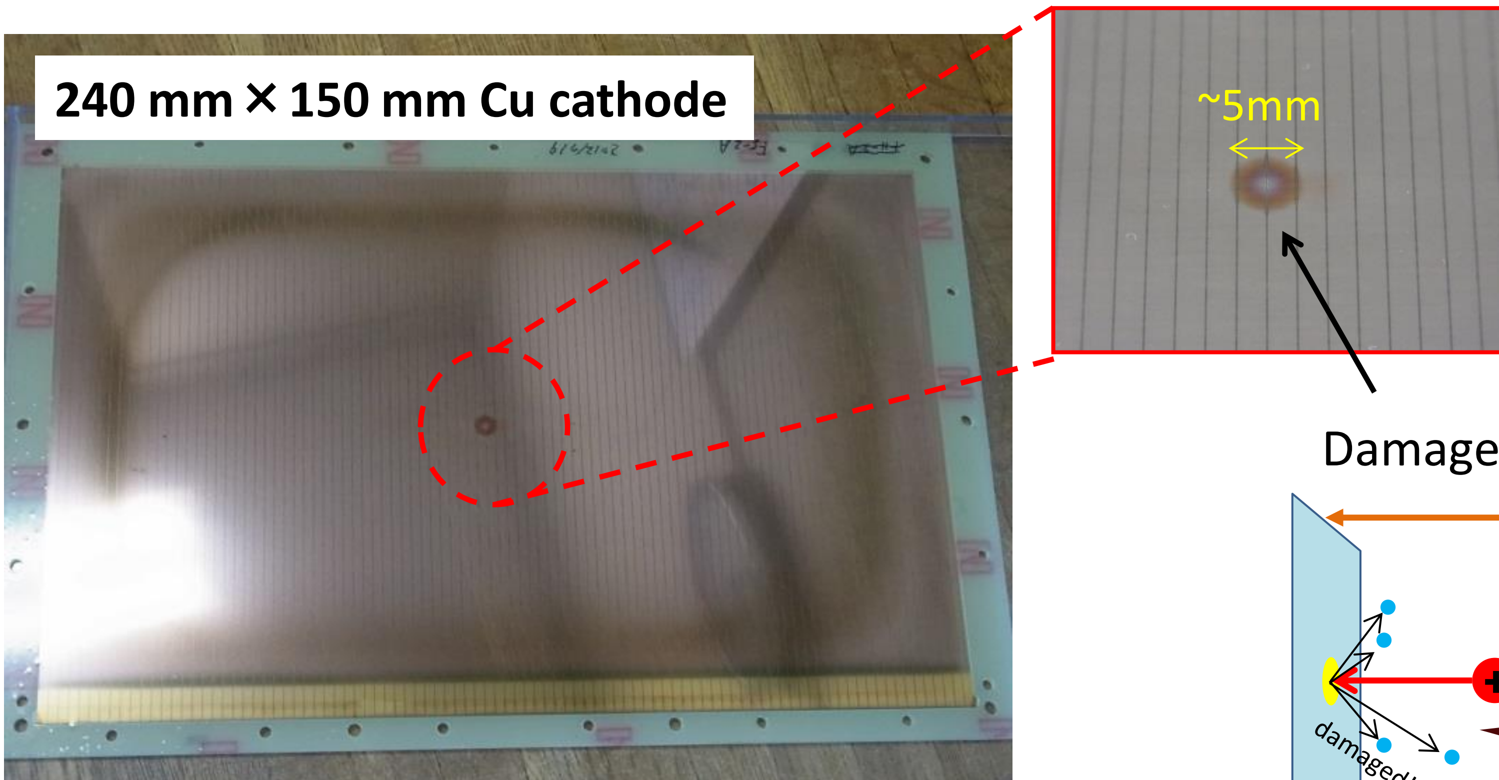
1. Discharge problem

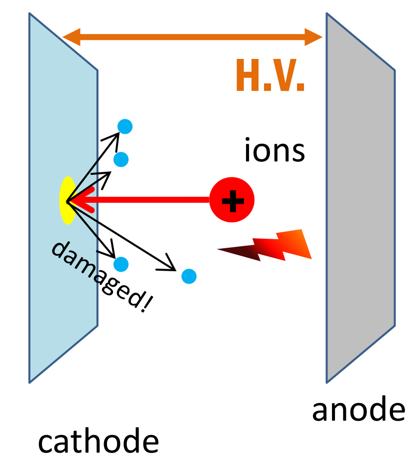
1. Damage due to discharge

Electrical discharge sometimes occur with several tens of kHz of beams.

Trip of H.V. modules frequently happens.

Damage on the cathode electrodes can be seen.



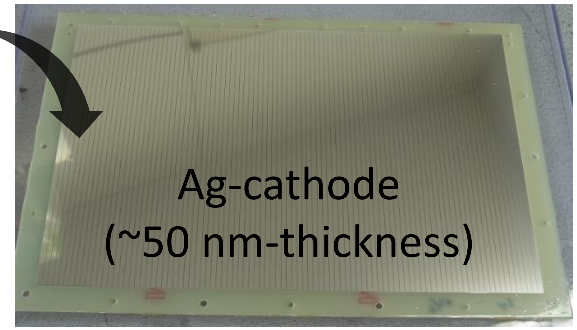


The occurrence of the damage must be avoided.

Change the electrode materials

The occurrence of the discharge depends on the material of electrodes.

Au, Al, Cu → *Ag*



Empirically, silver electrode is more tolerant to the discharge than the others.

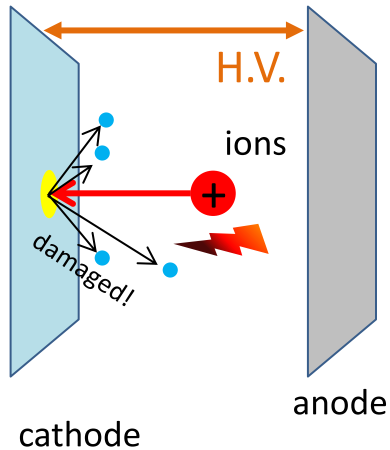
- Small electrical resistivity : Al > Au > Cu > Ag
- Large thermal conductivity : Al < Au < Cu < Ag

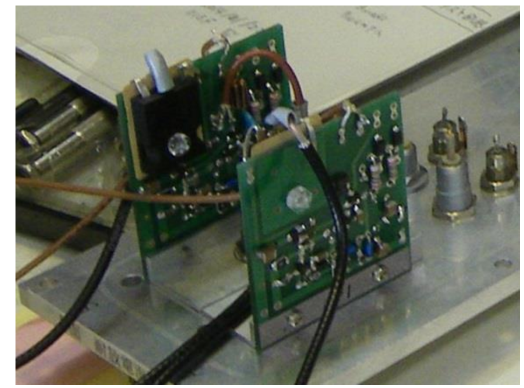
	Resistivity [μΩ cm]		Thermal conductivity [W m^{-1} K^{-1}]	
	0℃	100℃	0℃	100℃
Al	2.5	3.55	236	240
Au	2.05	2.88	319	313
Cu	1.55	2.23	403	395
Ag	1.47	2.08	428	422

Anti-discharge unit

Anti-discharge unit (ADU) is being developed by Kumagai-san.

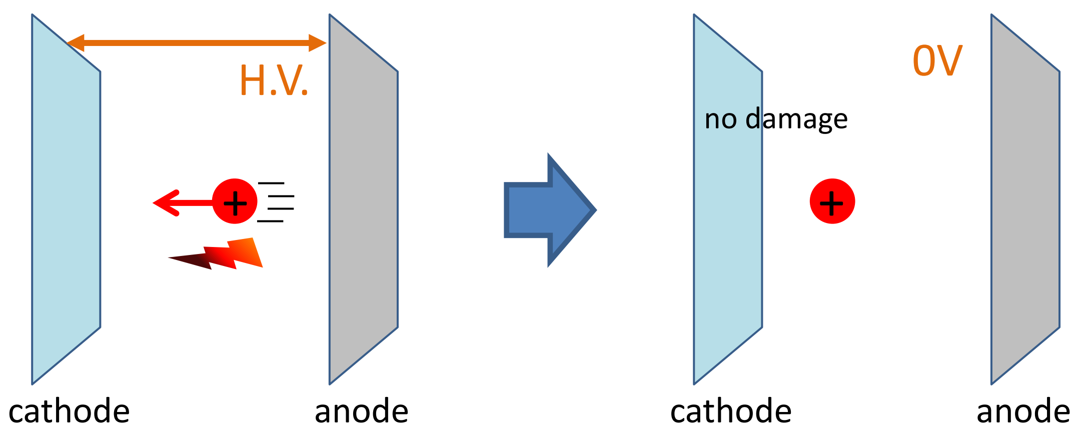
without anti-discharge unit





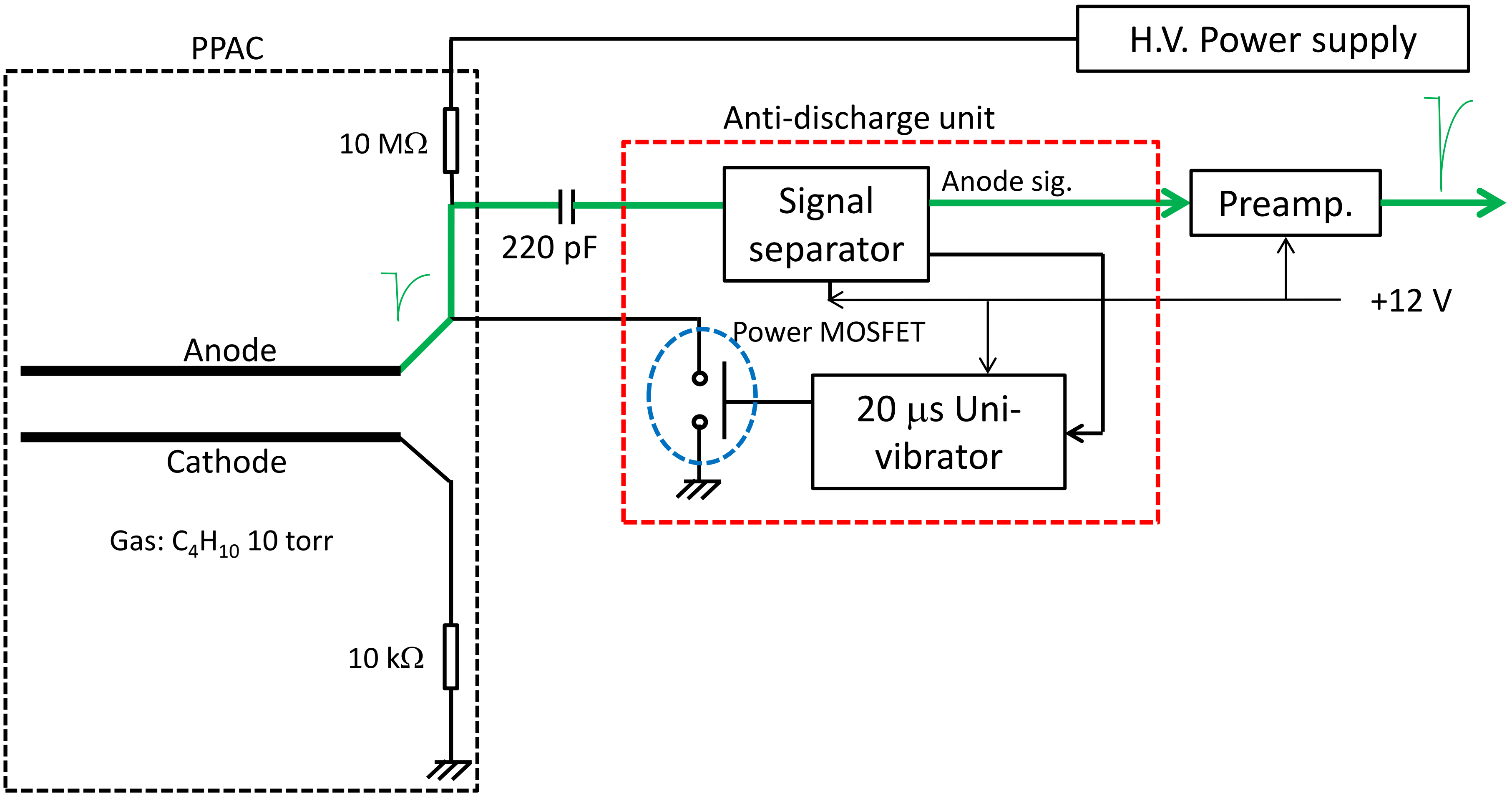
H.V. is forced to become 0V to stop the discharge before ions hit the cathode electrode.

with anti-discharge unit



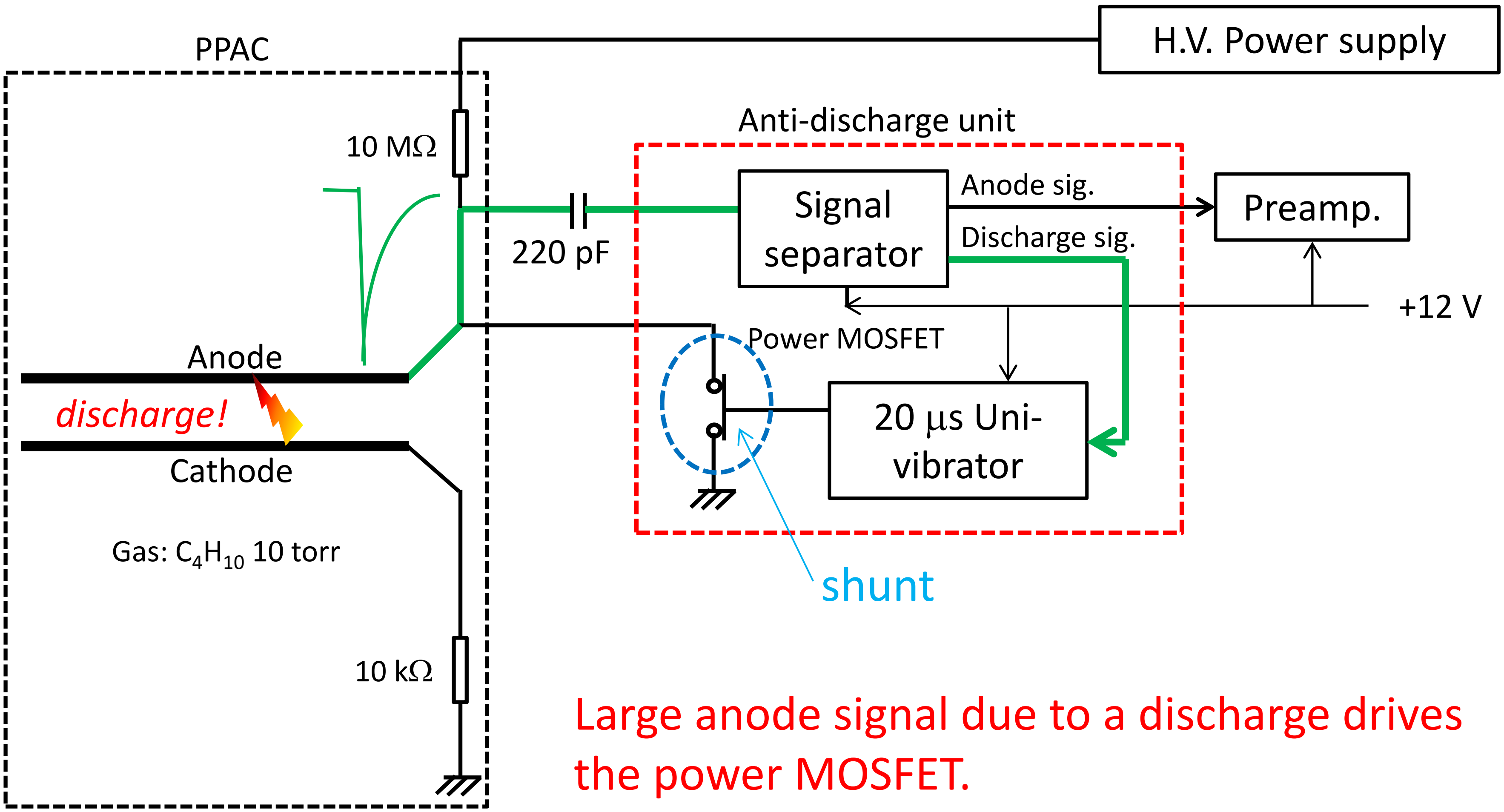
Function of the ADU

No discharge



Function of the ADU

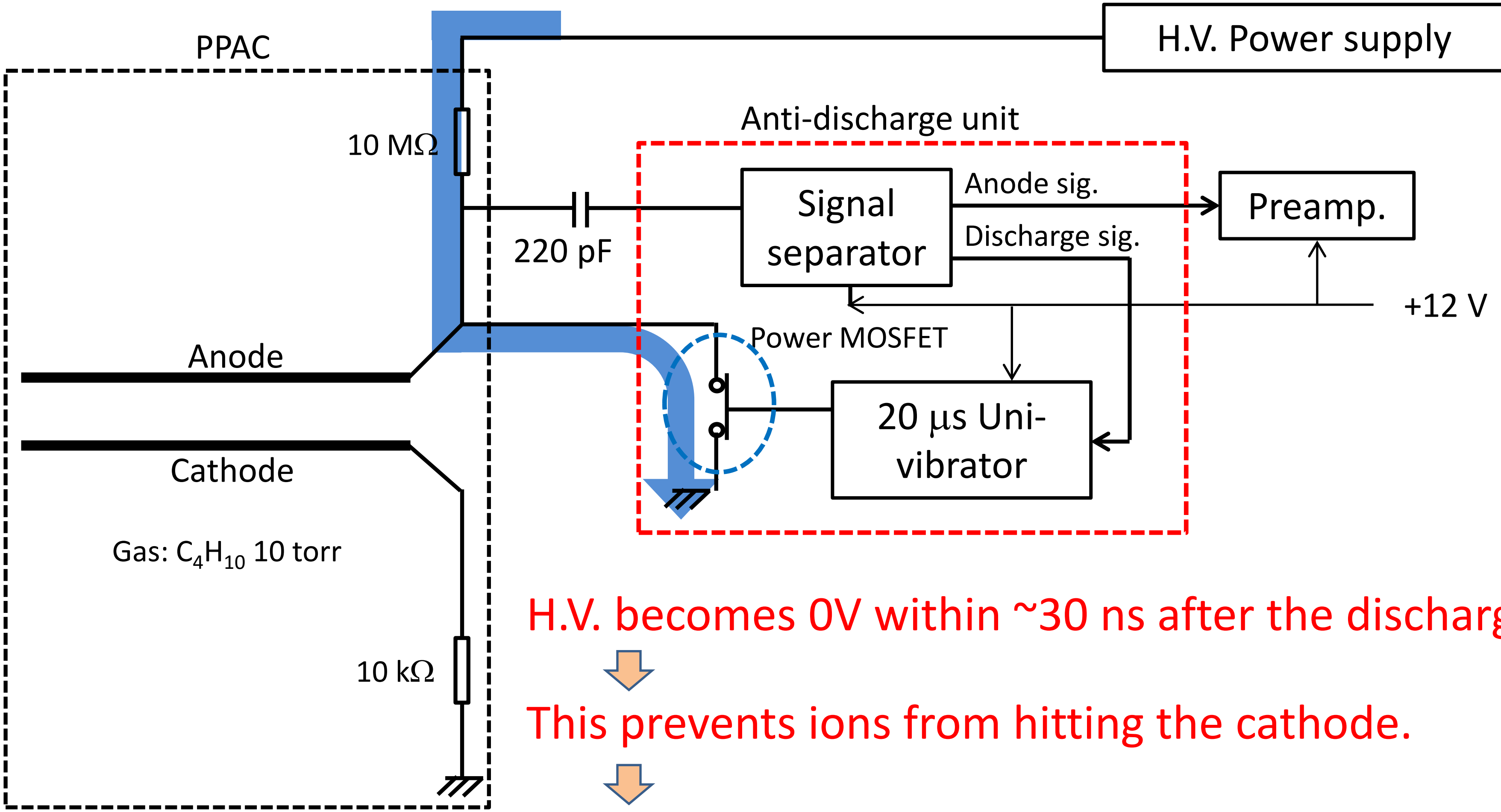
Discharge occurs



Large anode signal due to a discharge drives the power MOSFET.

Function of the ADU

H.V. becomes 0V



H.V. becomes 0V within ~30 ns after the discharge.

⇩

This prevents ions from hitting the cathode.

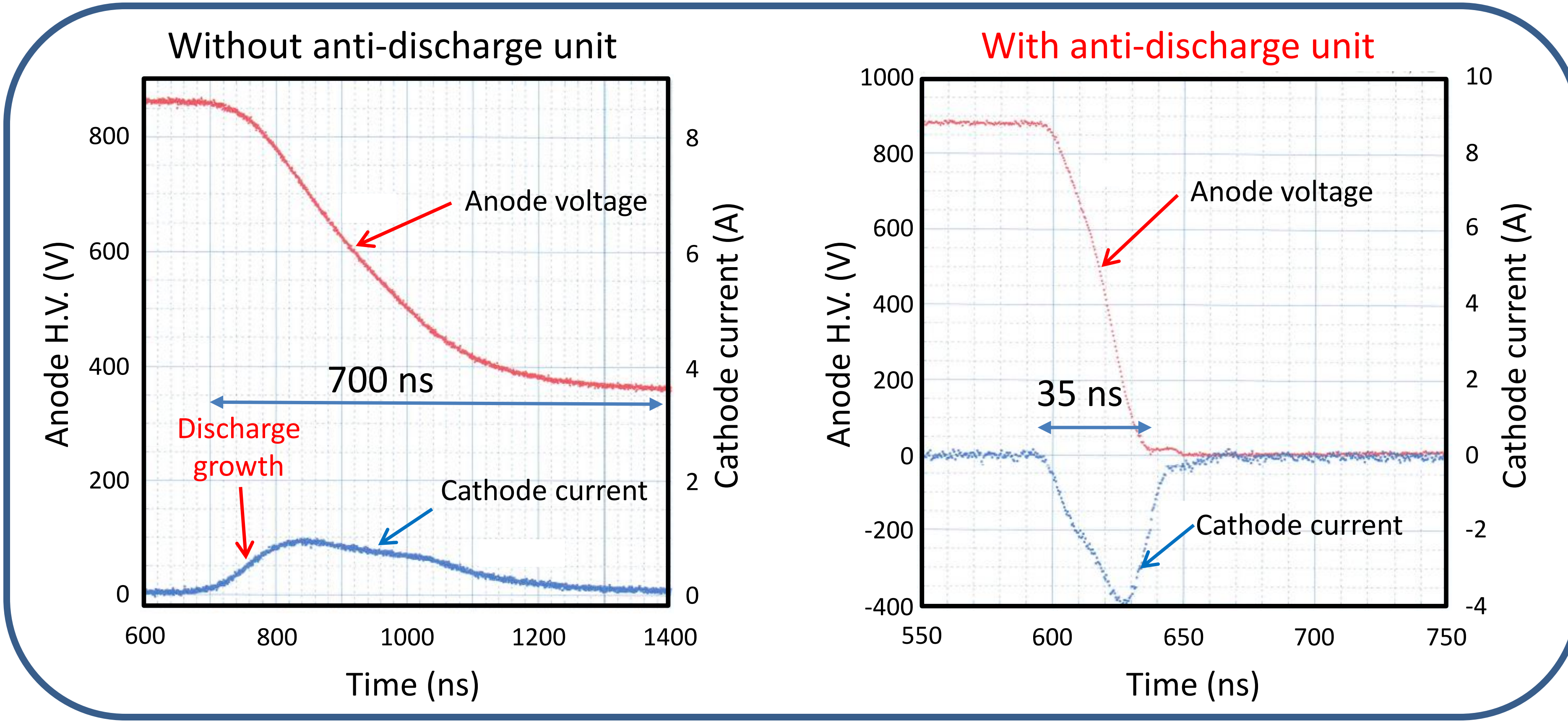
⇩

Reduce the damage on the cathode electrodes.

(H.V. recovers in ~5 ms.)

Test of the ADU

Discharge was induced using ^{241}Am-alpha by applying the too large bias voltage, intentionally.



The anode voltage (H.V.) was forcibly 0V by the anti-discharge unit.

Prevent damages on the cathode electrodes

2. endurance test with high-rate beams

2. Test with high-rate beams

➢ Ag electrodes

First test with RI-beams for Ag electrode

- *2012* ● ~160 kHz of Ni (Z=28) ions for 1 hour
- *2014* ● ~50 kHz of Cs (Z=55) ions for 2.5 days.
- ● ~70 kHz of Z~60-70 ions for ~5 hours.
- *Apr. 2015* ● ~400 kHz of Sn (Z=50) ions for ~40 min.

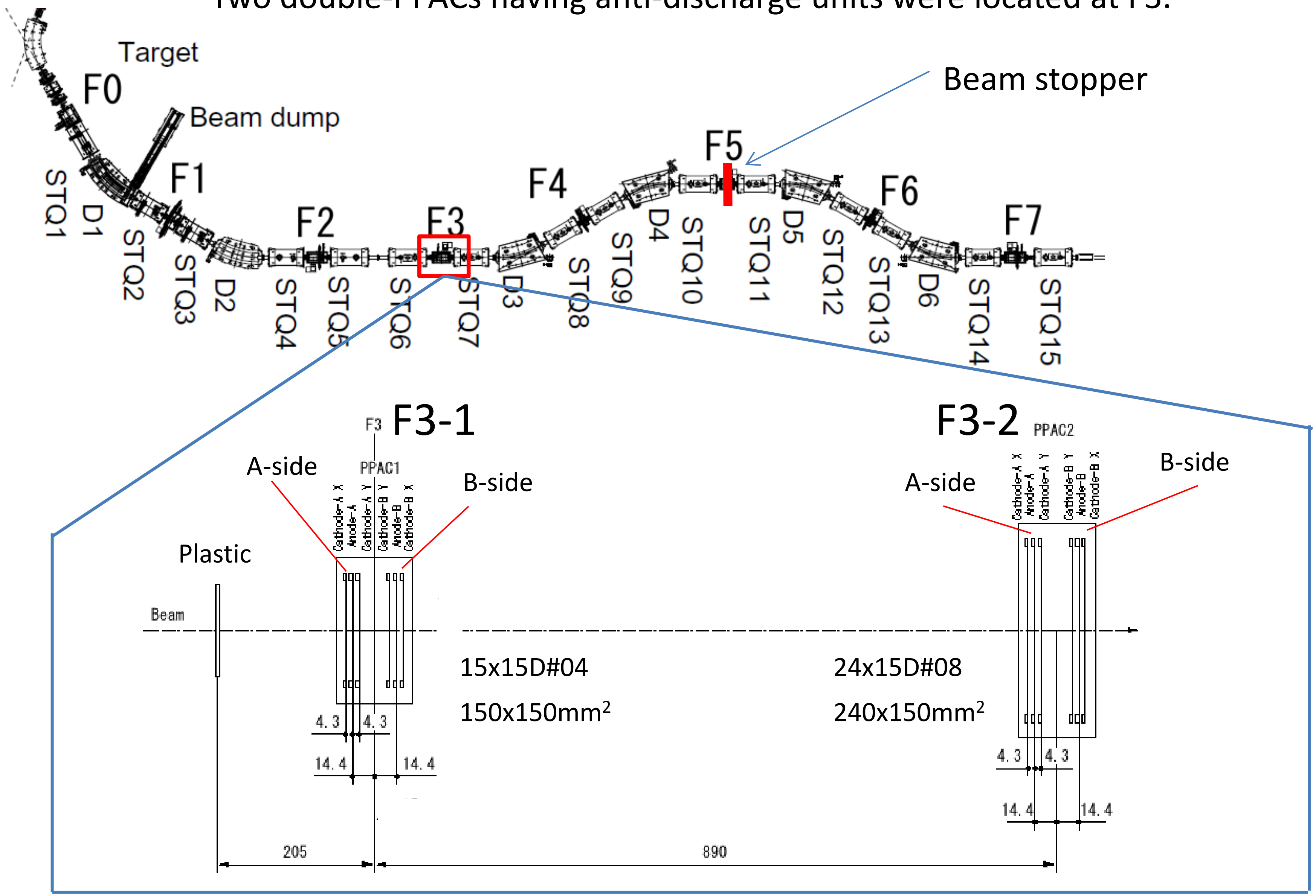
} No damage

➢ Anti-discharge unit

An endurance test of the PPAC against high-rate beams (Z~50) was carried out in Nov. 2015.

Location of the PPACs

Two double-PPACs having anti-discharge units were located at F3.

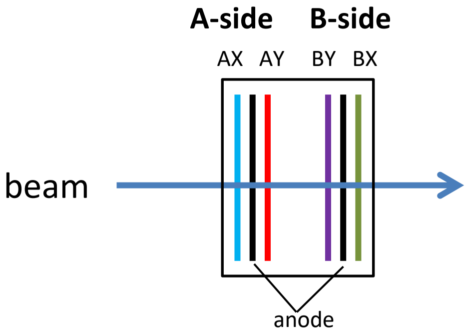


RI beams

Z~50 beams were used.

^{132}Sn (Z=50) purity: 6%
^{133}Sb (Z=51) purity: 20%
^{134}Te (Z=52) purity: 31%
^{135}I (Z=53) purity: 12%

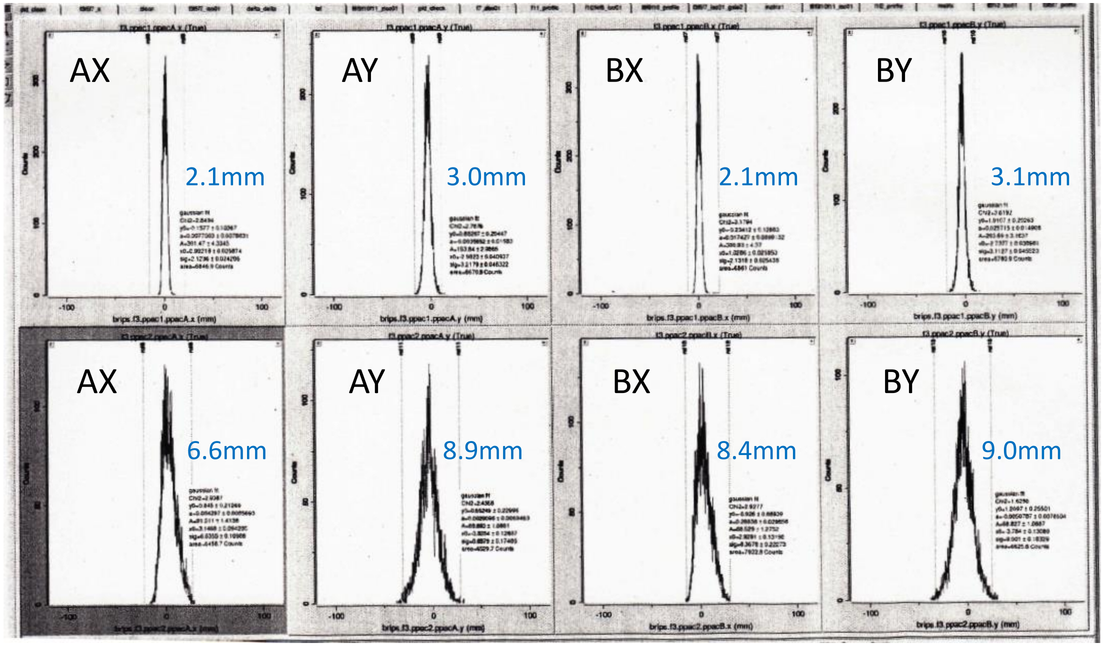
E~220 MeV/u @F3



Beam spot (σ)

@F3-1

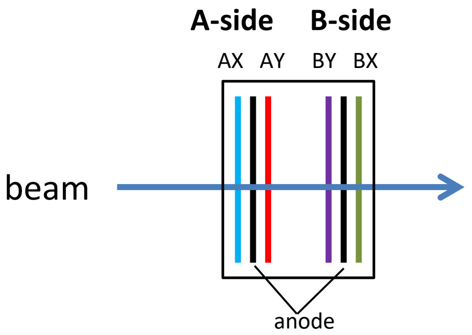
@F3-2

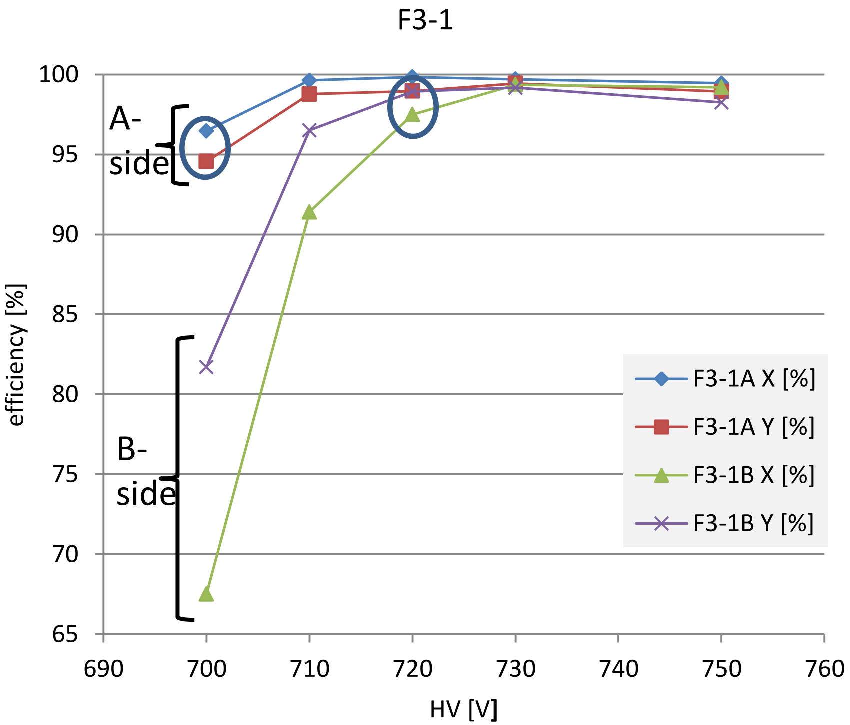


Bias voltage adjustment

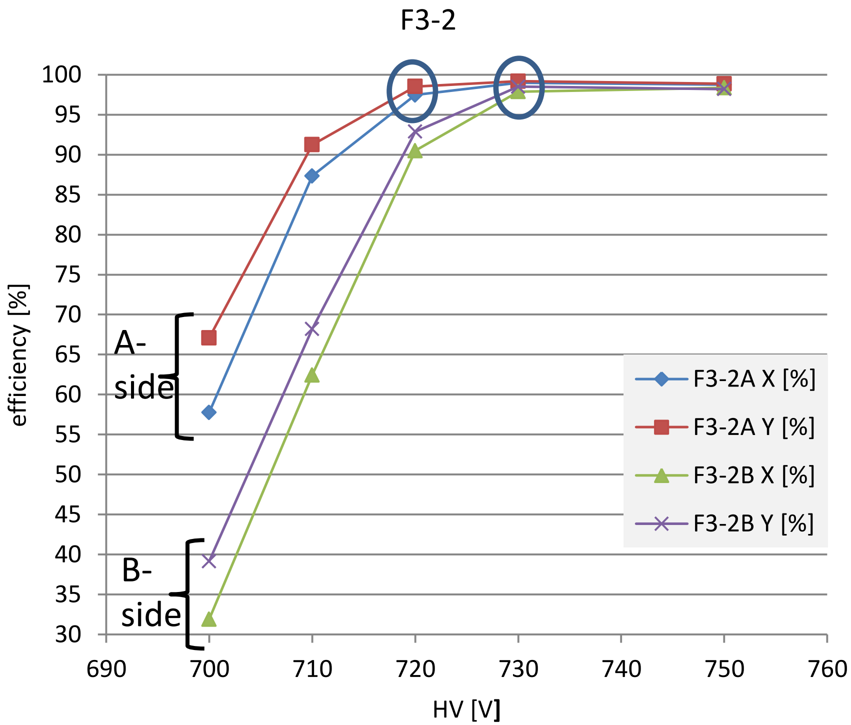
Before irradiating the PPACs with intense beams, the HV dependence of detection efficiency for each cathode was measured with a 1kHz beam.

The bias voltage was adjusted for all cathodes so as to realize the efficiency of ~95% in order to reduce unnecessary voltage.





F3-1 A-side:700V
B-side:720V



F3-2 A-side:720V
B-side:730V

Beam rate

Rate of the beams @F3 was increased step by step as follows:

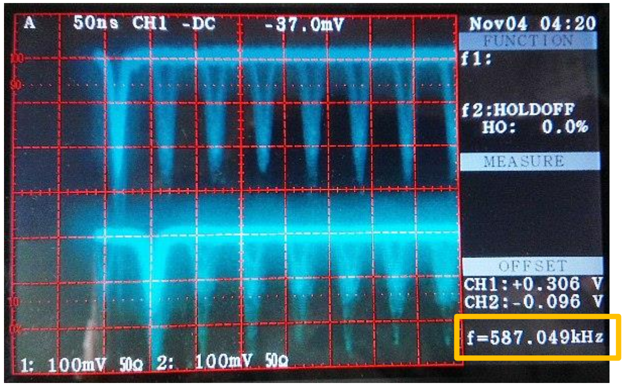
1.3 kcps (5min)
↓
49 kcps (10min)
↓
100 kcps (10min)
↓
200 kcps (10min)
↓
400 kcps (10min)
↓
600 kcps (70min)
↓
1 kcps (5min)
↓
1000 kcps (60min)
↓
1 kcps (5min)

Results: Endurance

- 600kcps 70min → **No trip** of HV modules for both PPACs

F3-1A anode

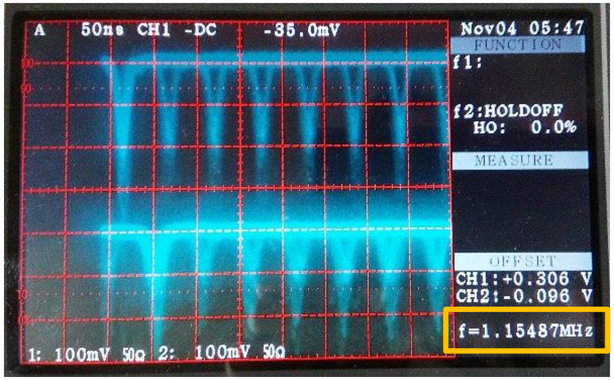
y2



- 1Mcps 60min → **No trip** of the HV modules for both PPACs

F3-1A anode

y2



Results: Efficiency

Tendency of the total efficiency was measured.

$$Eff_{X\,total} = \{1-(1-Eff_{F3-1AX})(1-Eff_{F3-1BX})\}\{1-(1-Eff_{F3-2AX})(1-Eff_{F3-2BX})\}$$

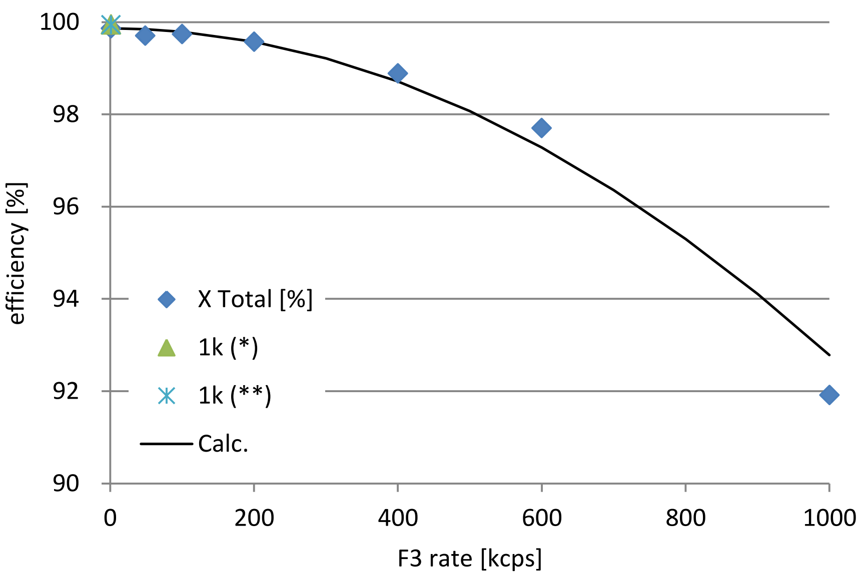
Total efficiency

Efficiency of each cathode

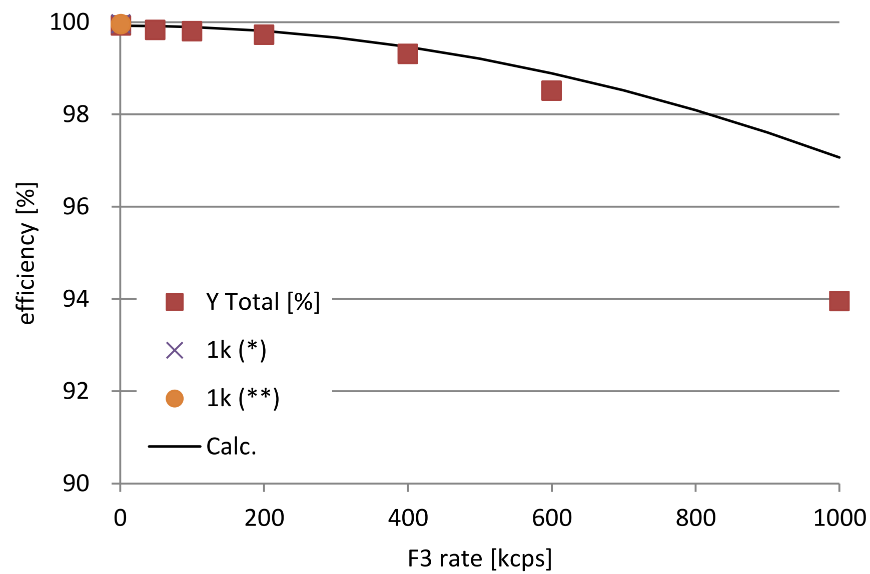
Order of the measurements

rate [kcps]	X Total [%]	Y Total [%]
1.3	99.86	99.92
49	99.70	99.83
100	99.74	99.80
200	99.57	99.72
400	98.89	99.30
600	97.70	98.51
1 (*)	99.95	99.96
1000	91.92	93.93
1 (**)	99.94	99.95

total efficiency: X-direction



total efficiency: Y-direction



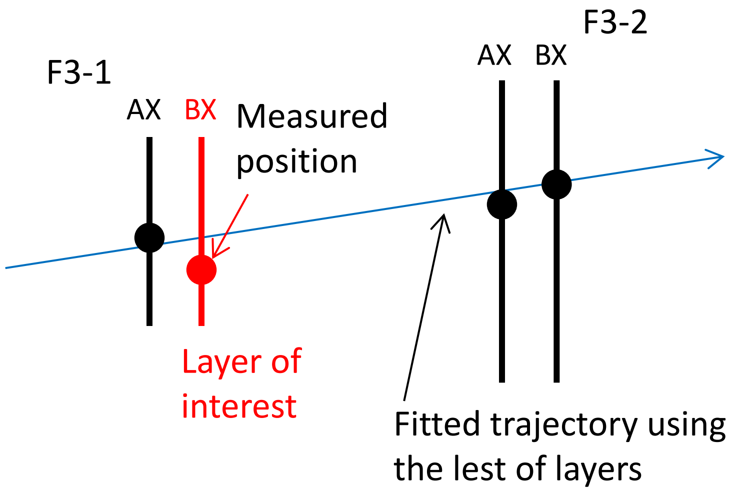
The efficiency obtained with 1k(*) and 1k(**) just after high-rate beams reproduce the values obtained with the 1.3k (first run).

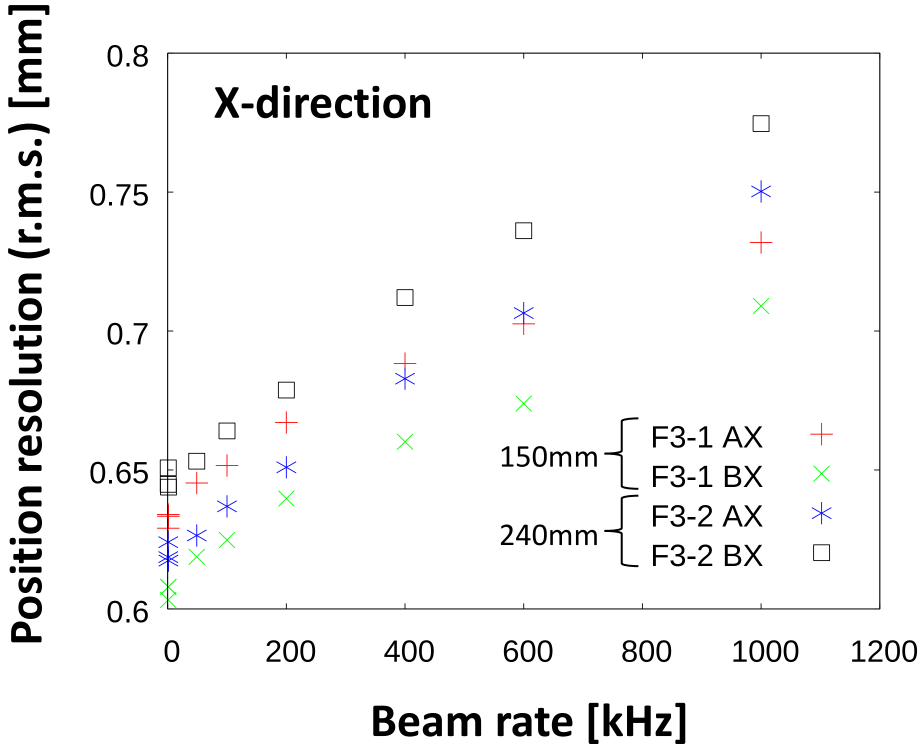
The tendency of the efficiency change can be explained by the dead time of the PPAC: delay time is 192 ns for X and 118 ns for Y.

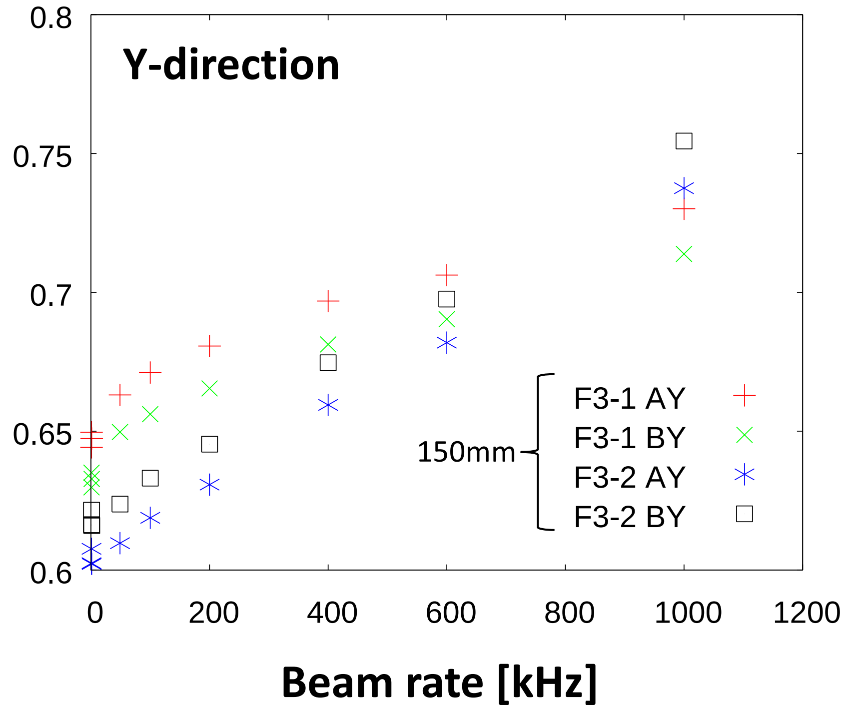
➡ Electrodes were not damaged with 1Mcps beams for 60 minutes.

Results: Position resolution

The position resolution is deduced for the layer of interest with respect to the trajectory that was obtained by fitting the measured positions using the rest of layers.



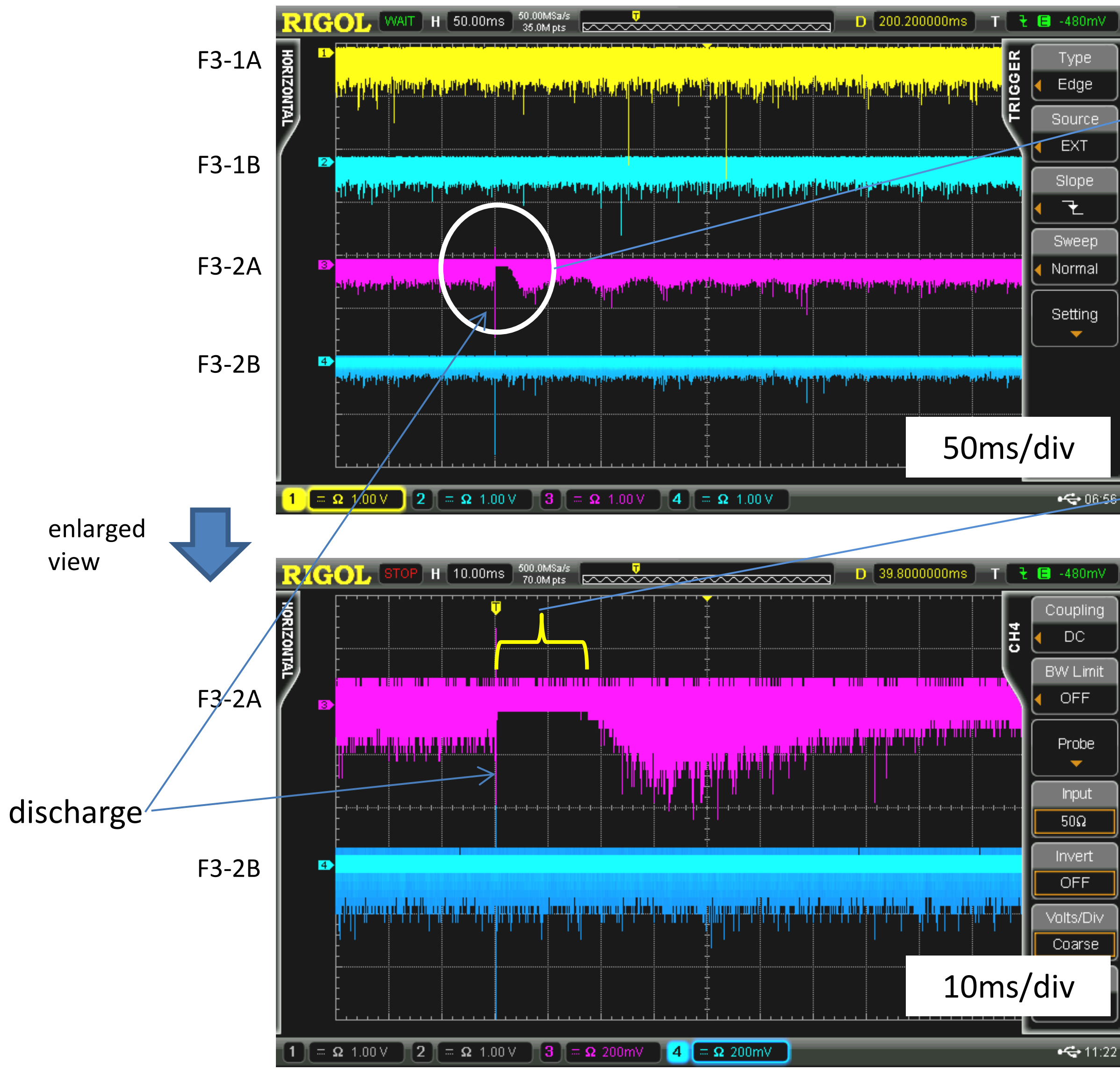




Results: action of the ADU

We increased the bias voltage of F3-2A up to 750V @1MHz beam, and a discharge happened on F3-2A.

Signal from X cathodes



The anti-discharge unit was operated.

Bias voltage was shutdown and recover.

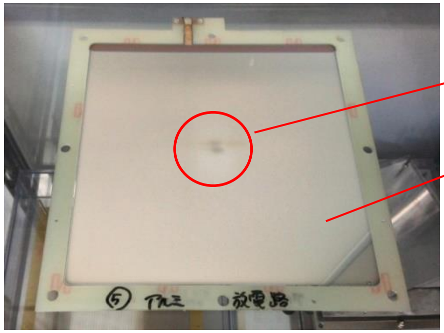
16ms

Unresolved discharge problems

From the data of the efficiency, we found that the electrodes were not damaged. So, we think that the combination of the Ag electrode and the ADU is effective.

- Damage on the anode appears because the lifetime of the cathode becomes longer by using the anti-discharge unit.

  - ✓ The ADU cannot stop the electrons which are running to the anode.
  - ✓ We prepared the anodes which have thicker Ag layer (50nm → 100nm).
  - ✓ We will test them on the beamline.



damage

Anode electrode (Al)

Same kind of damages are seen in the case of Ag.

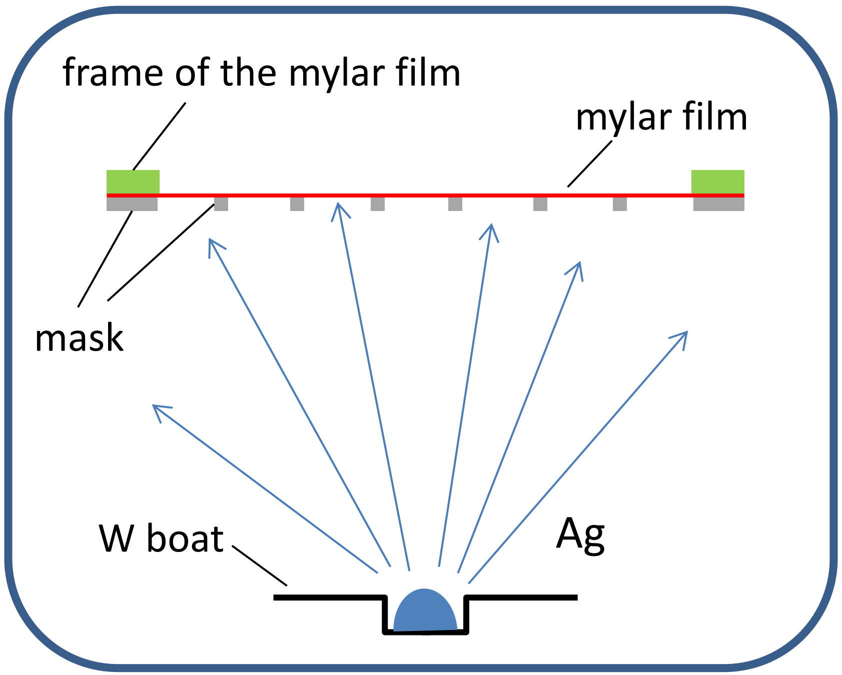
- Discharge happens with high-rate light beams because higher bias voltage should be applied for enough efficiency.

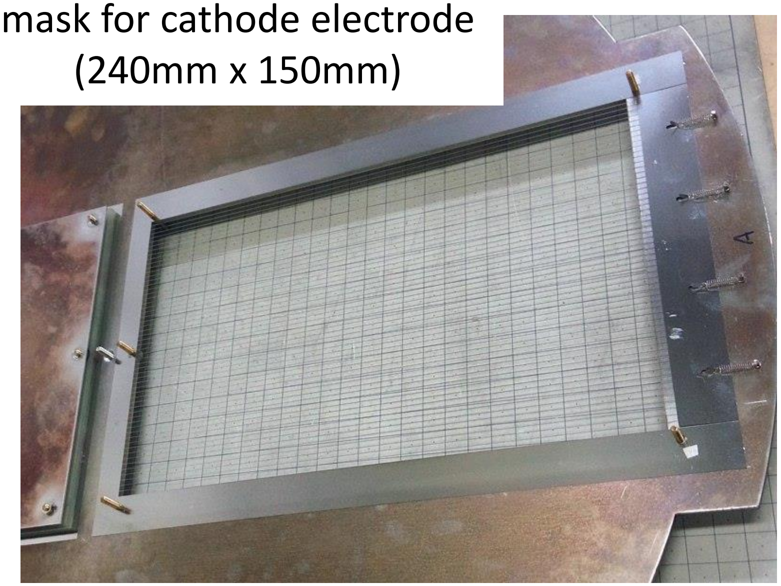
3. Fabrication of the electrodes

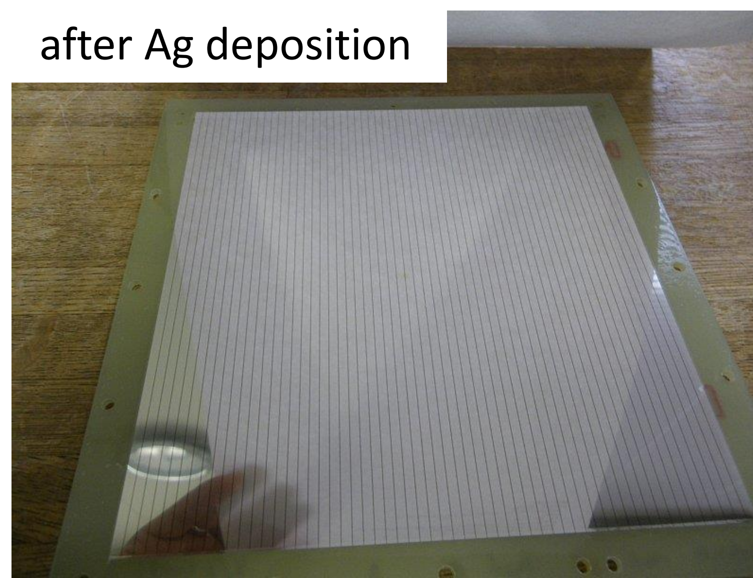
3. Fabrication of the electrodes

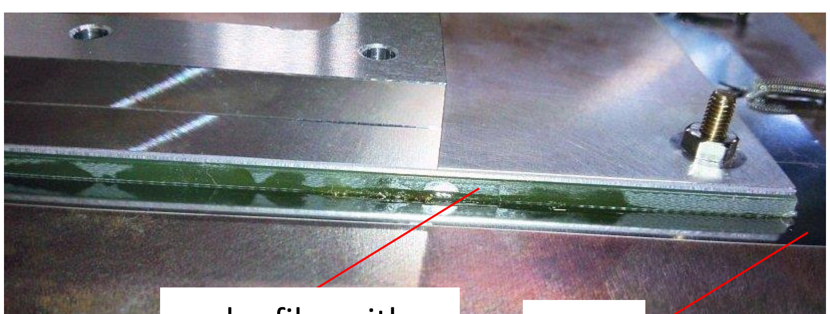
Ag electrodes are fabricated by using vacuum evaporation.

Side view





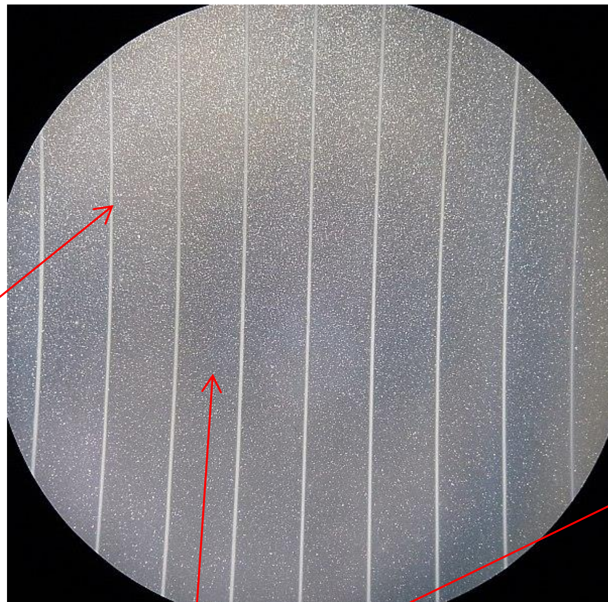


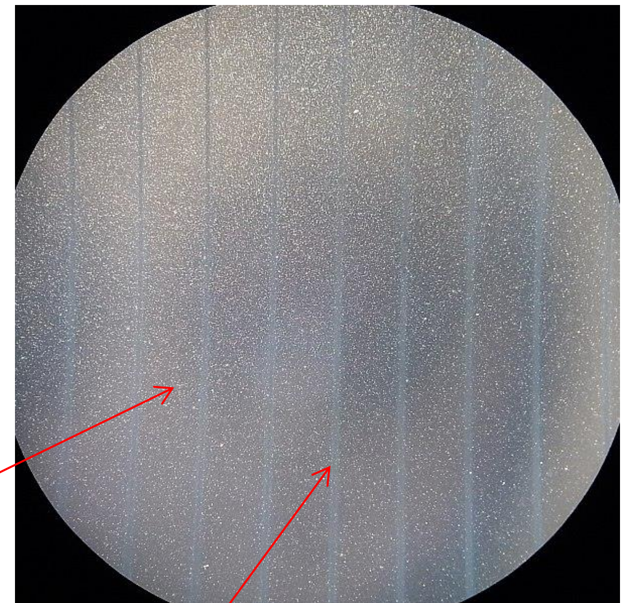


Non-clear strip gaps

Sometimes, non-clear strip gaps are seen after depositing Ag.

Microscopic view

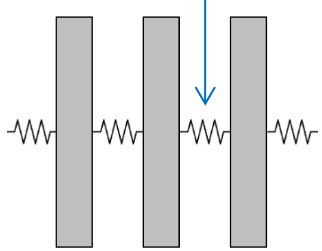




Clear gap
(0.15mm)

Ag strip
(2.4mm)

Non-clear gap ← thin Ag layer

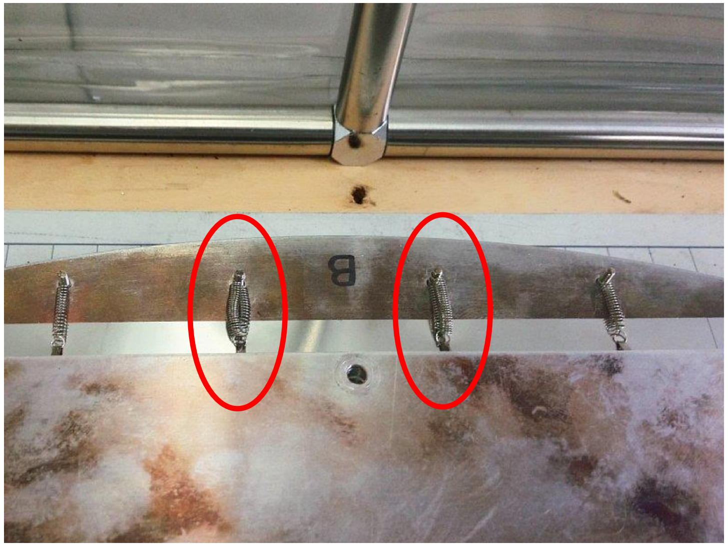


Each strips are connected !
→
Such electrode cannot be used !

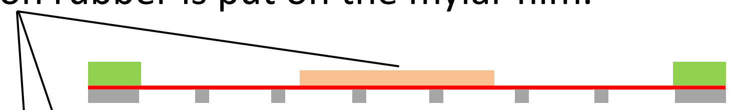
Non-clear strip gaps

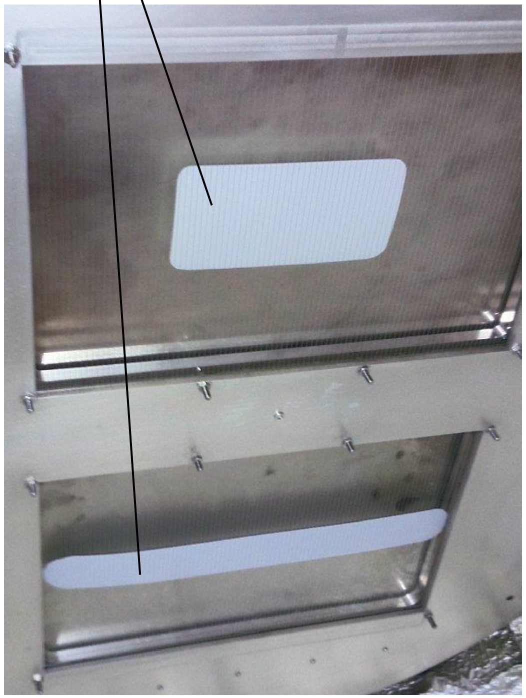
Non-clear strip gaps comes from the imperfect contact between the mylar film and the mask wire.

- Add the spring to apply more tension to the mask wire.



- Silicon rubber is put on the mylar film.





View from downside

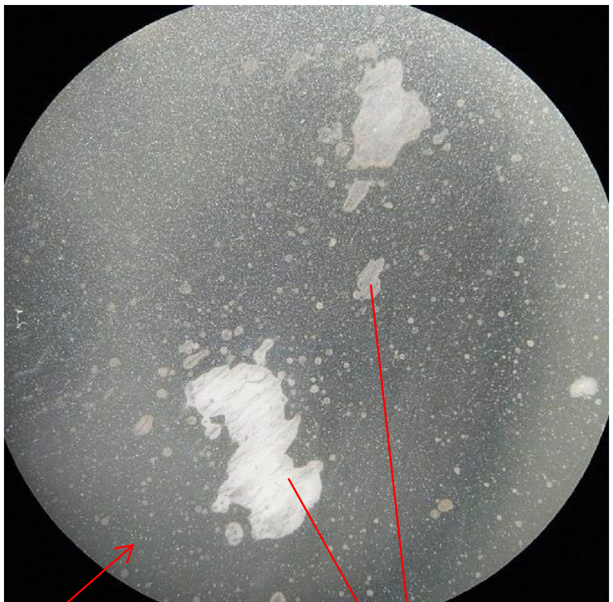
Production yield: ~50% → 100%!

Damage on the Ag films

After depositing Ag on the mylar film, sometimes damages (colored arer of the Ag) has been seen.

Examples

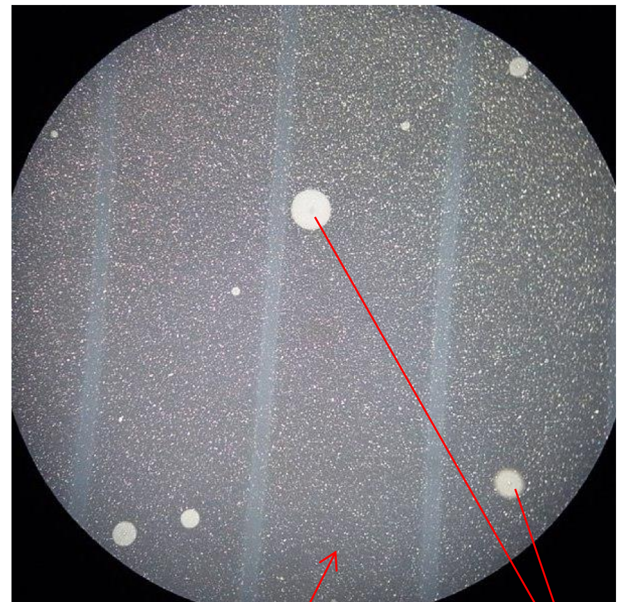
anode electrode



Ag

Damage (~mm)

cathode electrode



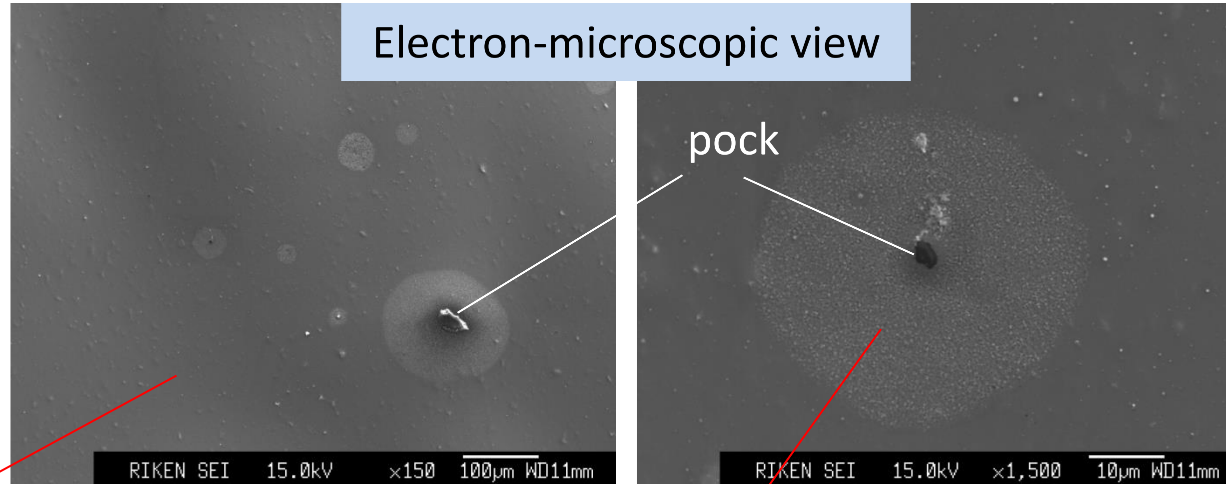
Ag

Damage (~200μm)

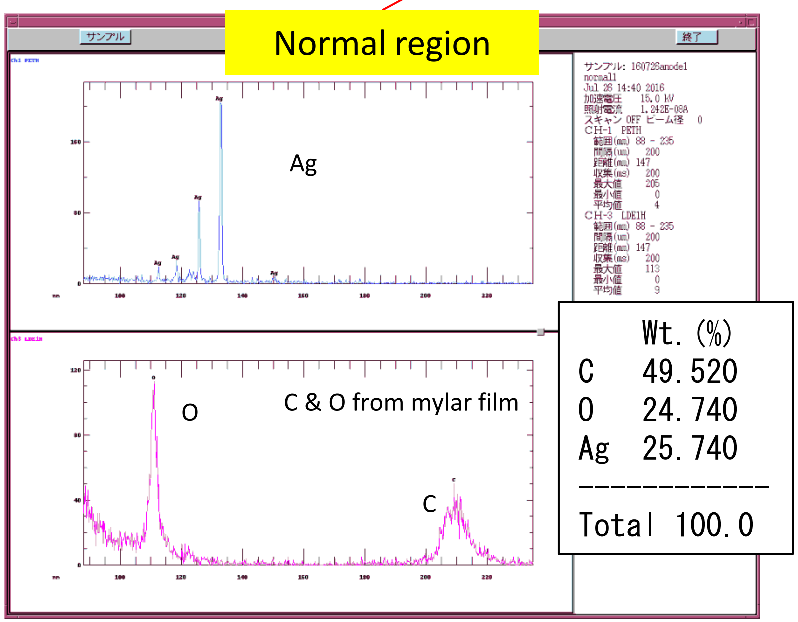
- ✓ Sometimes, they appear immediately after finishing the deposition.
- ✓ Sometimes, they appear several days after.

Component analysis with EPMA

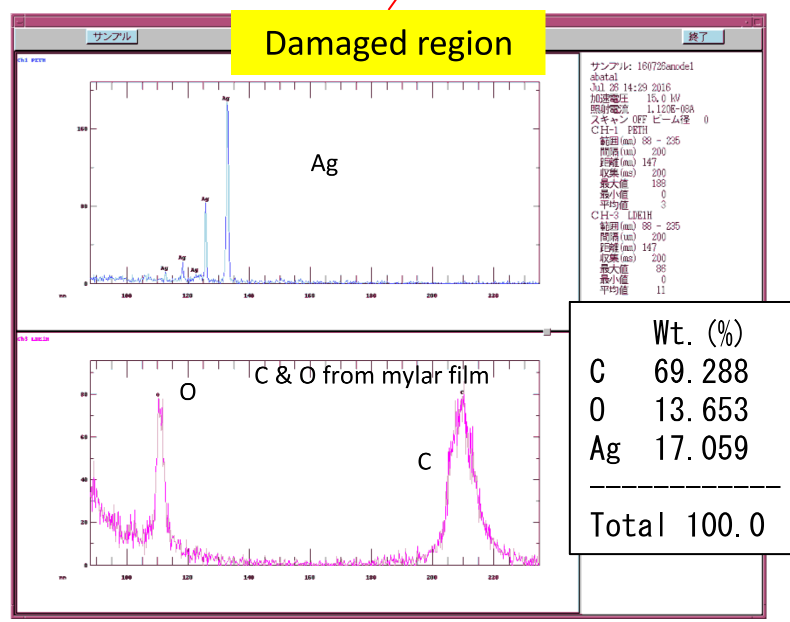
The component analysis of the damaged area was done by using Electron Probe Micro Analyzer.



Spectrum of character X-rays

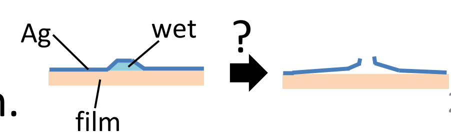


	Wt. (%)
C	49.520
O	24.740
Ag	25.740
Total	100.0



	Wt. (%)
C	69.288
O	13.653
Ag	17.059
Total	100.0

There are no contaminants in the damaged area.
We consider that the reason of the damage is due to the wet on the film.



Summary

Development of the PPAC is reported.

1. Material of the electrodes was changed (Au, Cu, Al → Ag).

2. Anti-discharge unit is being developed by Kumagai-san.

3. PPAC worked with 1MHz beams (Z~50) for 60min.

4. There are unresolved problems: one is the damage on the anode and another is the discharge with high-rate light beams.

5. Fabrication technique for Ag electrodes has been modified. Investigation of the damage on the Ag films is continued. (We got a new air conditioner in this summer !!)