First results of imaging properties and testbeam for Resistive μ-PIC

Atsuhiko Ochi, Fumiya Yamane, Yusuke Ishitobi,
Keisuke Ogawa, Kohei Matayoshi
Kobe University

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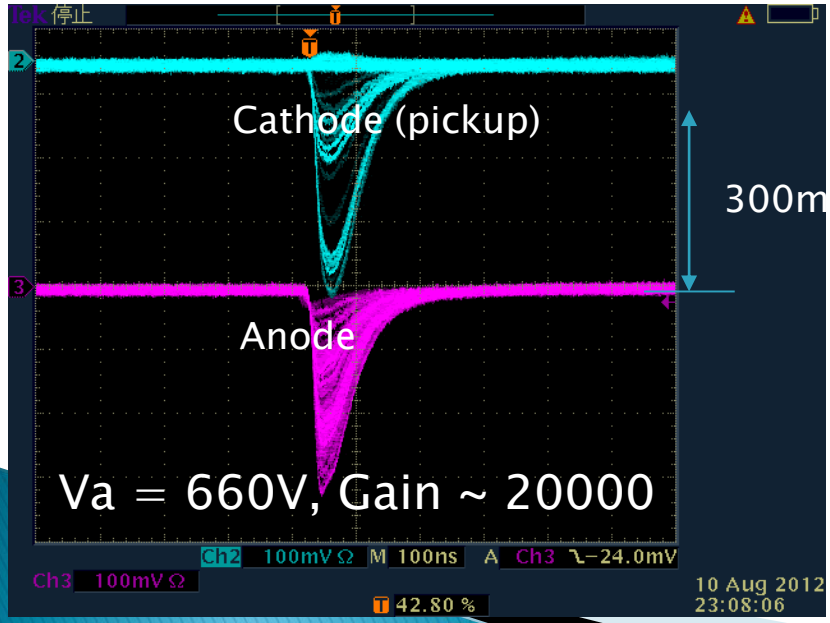
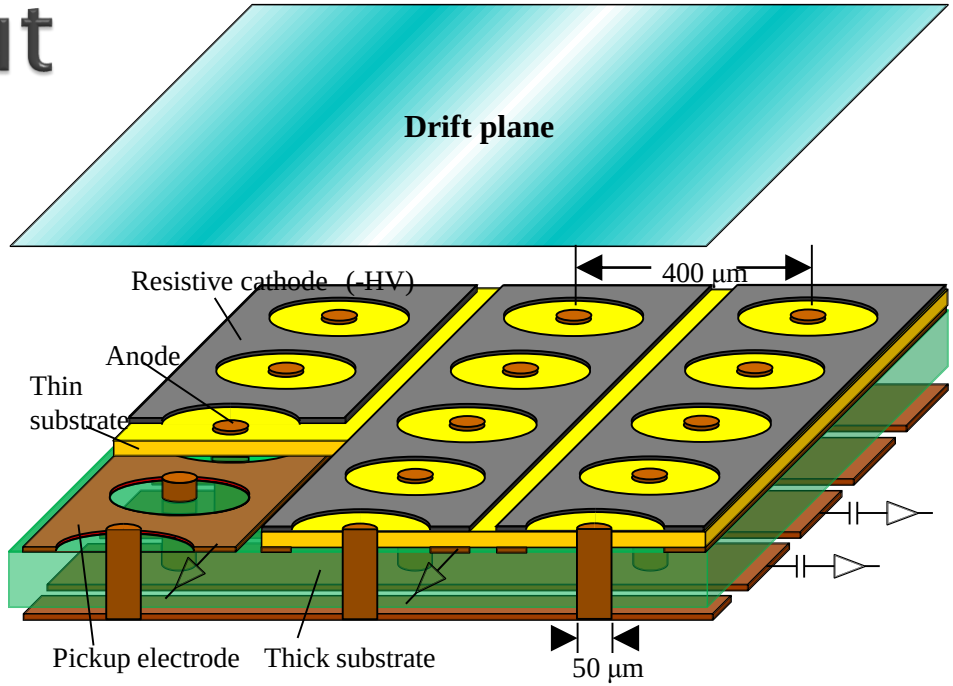
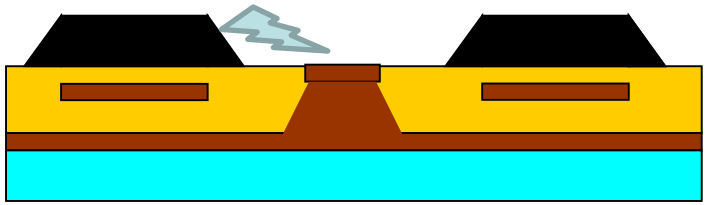
μ-PIC with resistive cathode and capacitive readout

- Detector design
  - All cathodes are made from carbon-polyimide
  - Pickup electrodes are lied under cathodes and insulator
  - We have two dimensional signals



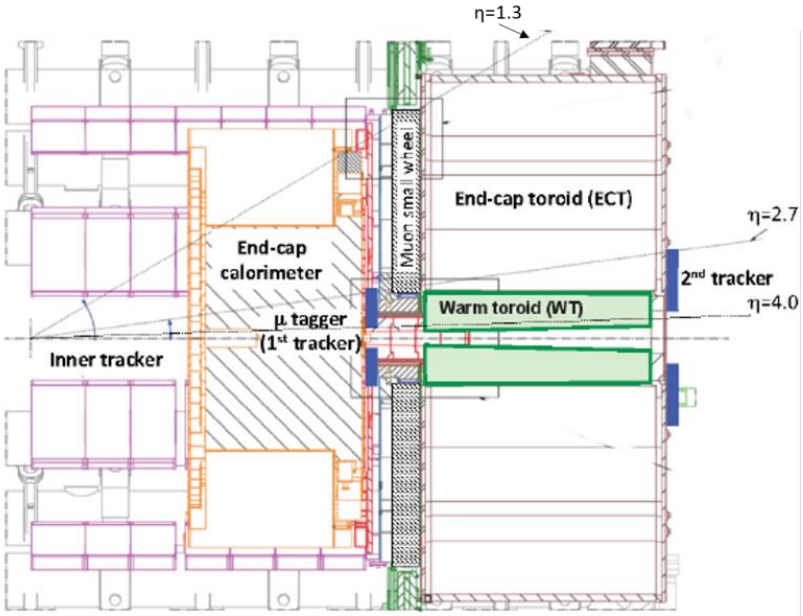




- Cathode signal on oscilloscope is inverted
- Two dimensional signal is induced on opposite sign.
- Not charge shareing.

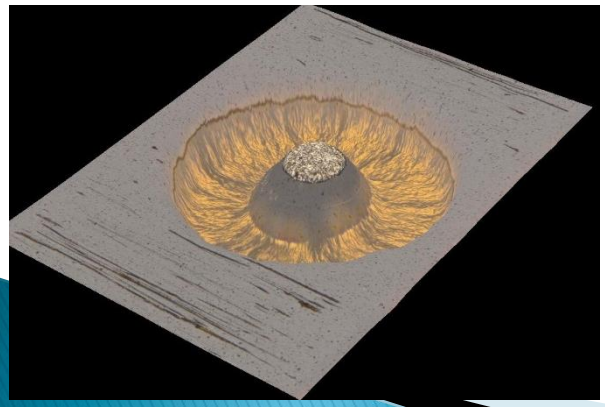
Main R&D target

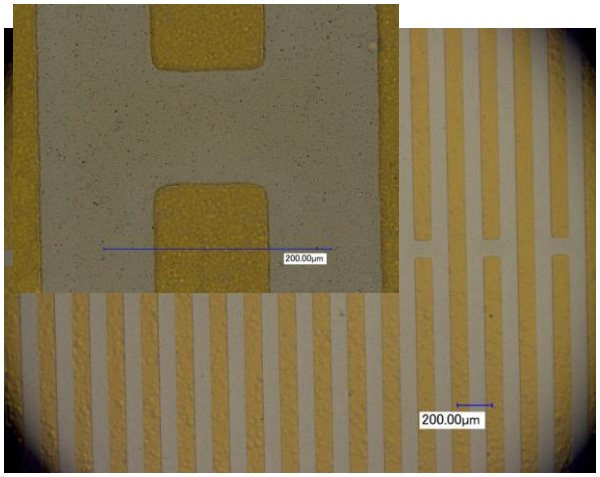
- For ATLAS muon tagger (High eta muon detector)
  - Proposed for Phase II upgrade 2023~
  - Need high position resolution ~ 0.1mm
  - BG rate > 10MHz/cm^2 (HIP, gamma) @ $\eta = 4.0$
- Rate tolerant
- 2 dimensional readout needed
- Muon TDR for phase II has just been approved
  - Four technology for muon tagger are described:
    - μ-PIC
    - Embedded MM
    - μ-RPWELL
    - Silicon



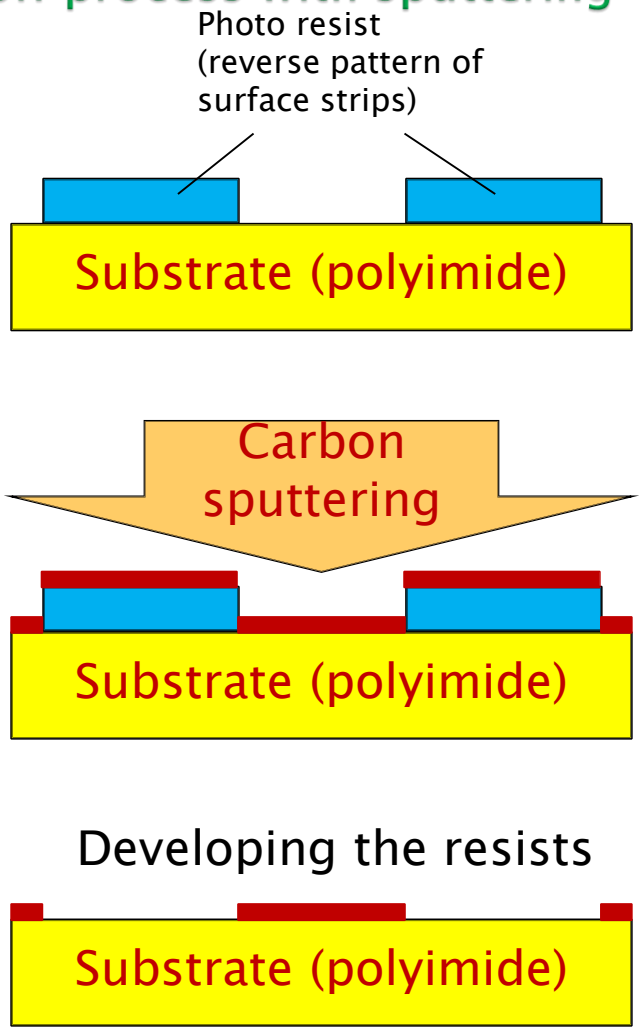
Resistive electrodes with DLC

- On beginning of 2013, we have developed resistive electrodes by DLC
  - Initially, it was developed for ATLAS MM resistive foils
  - Fine micro-patterning (um order) available → applying it for u-PIC electrodes



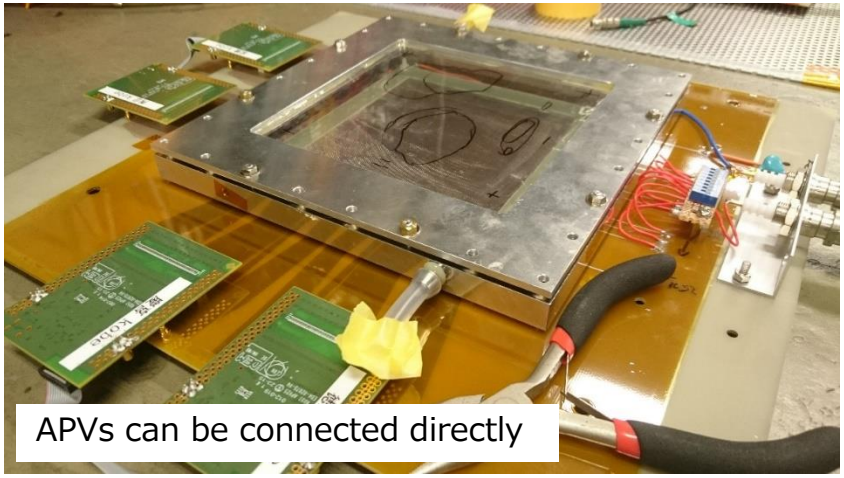


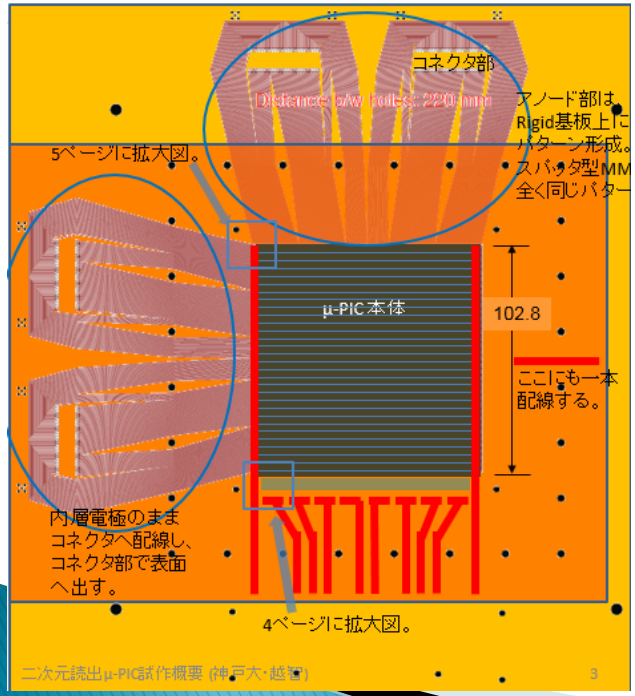
Liftoff process with sputtering

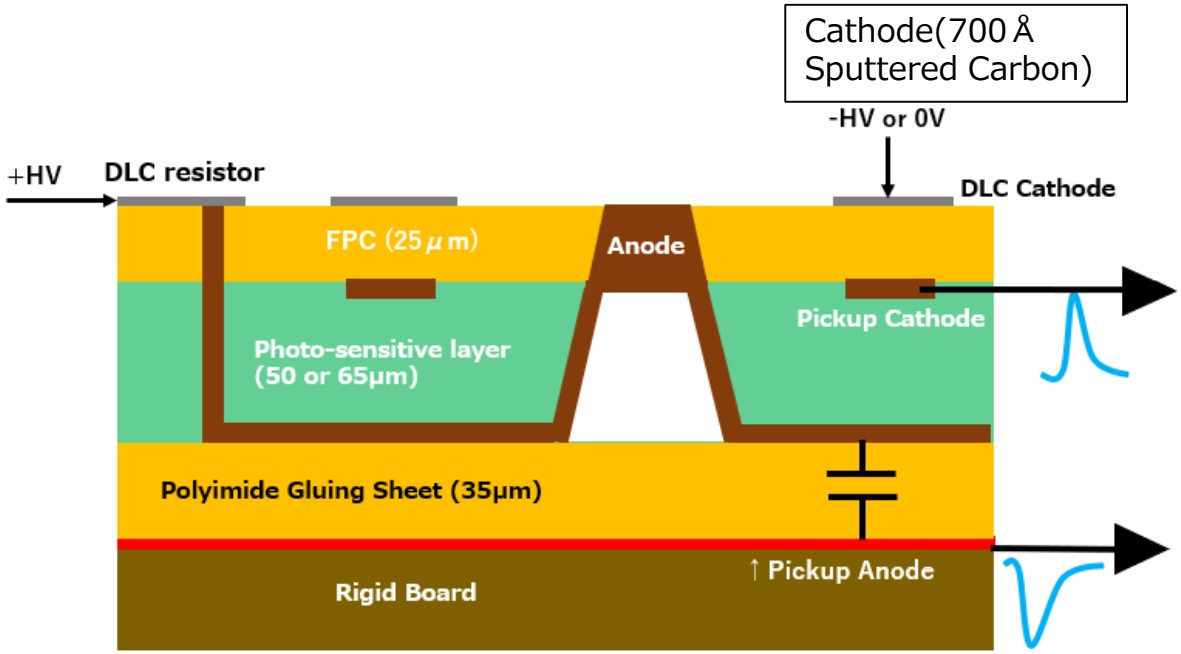


Prototype design

- To adopt SRS readout
  - Cathode signal is read by induced charge
  - For anodes, bias resister and coupling capacitor are needed for each channel.
- CR parts correspond to 512 strips are all put in the μ-PIC board

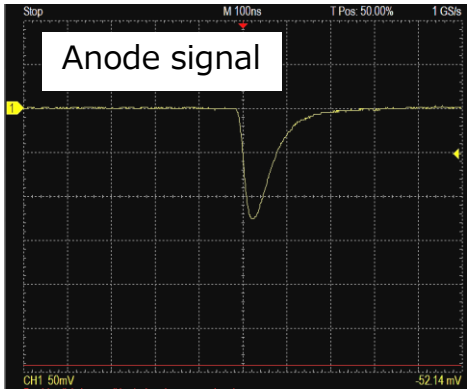


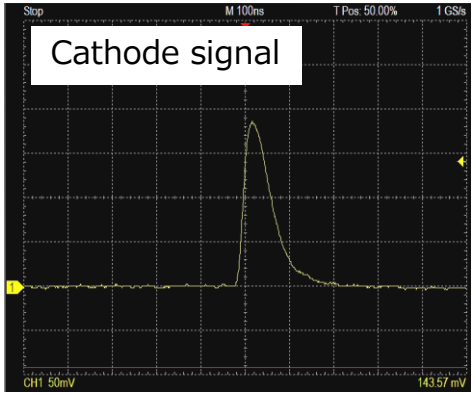


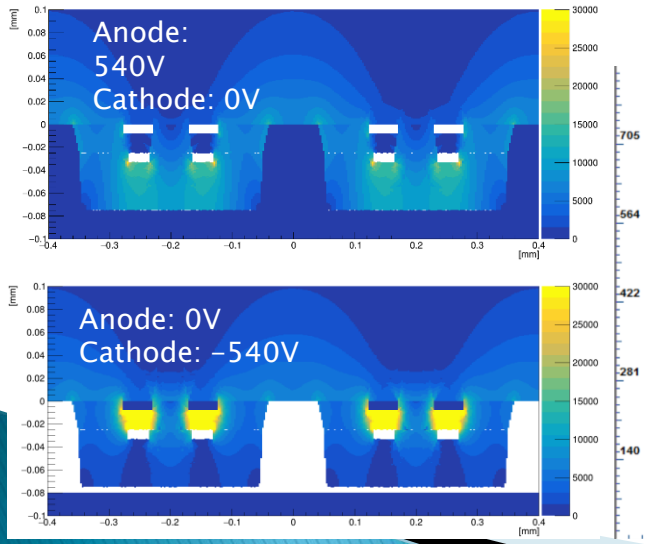


Signal from anode and cathode

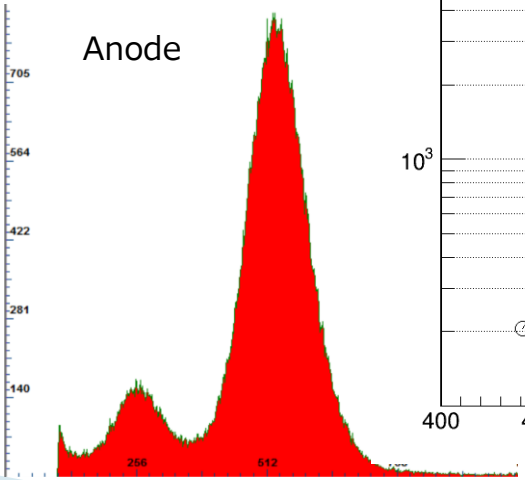
- ^{55}Fe
  - Gas: Ar:C_2H_6 = 90:10
  - Both Anodes and Cathode signal found
- Operation voltage parameter
  - Both anodes and cathode (resistive) can be applied HV, while pickup electrodes are 0V.
  - We can study to avoid the charge-up effect

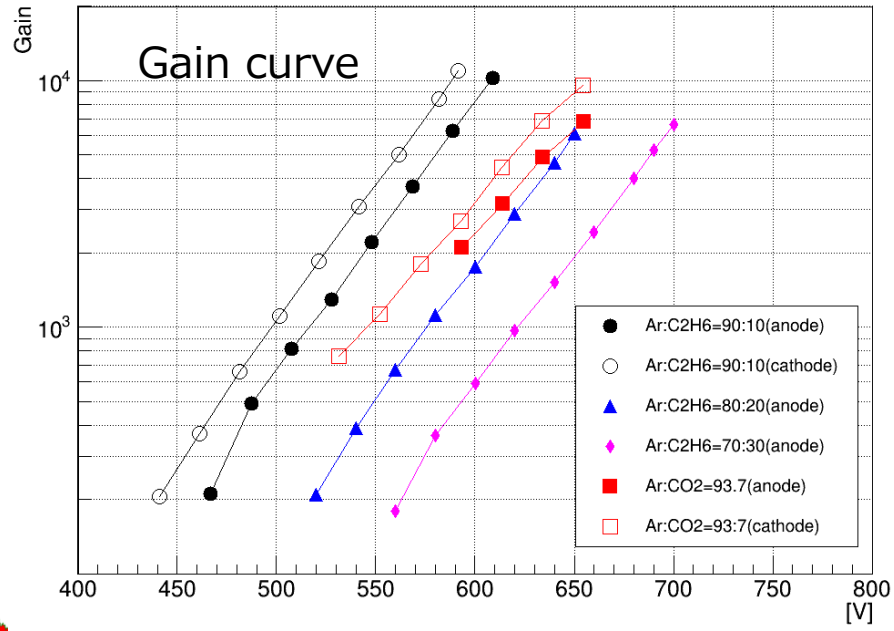






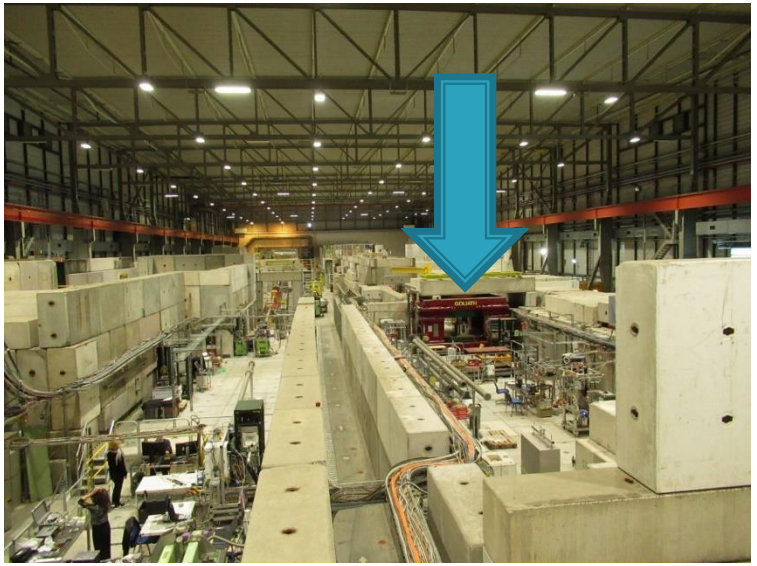
^{55}Fe spectrum

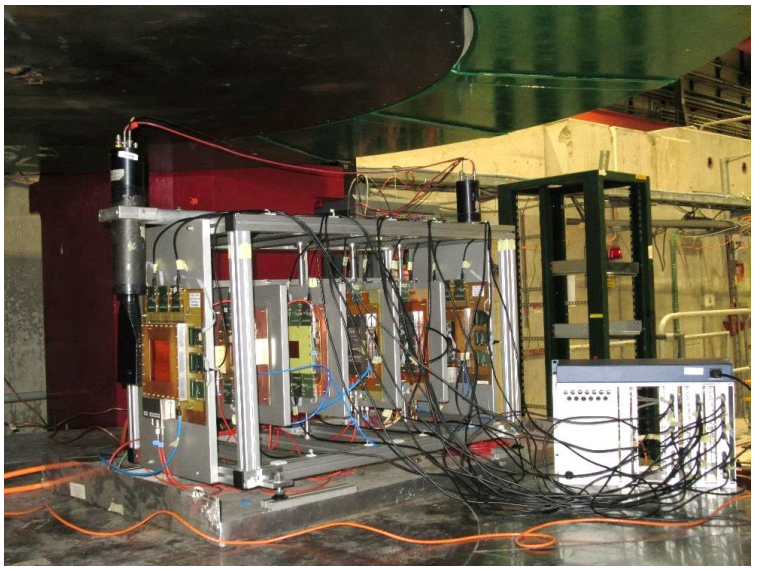


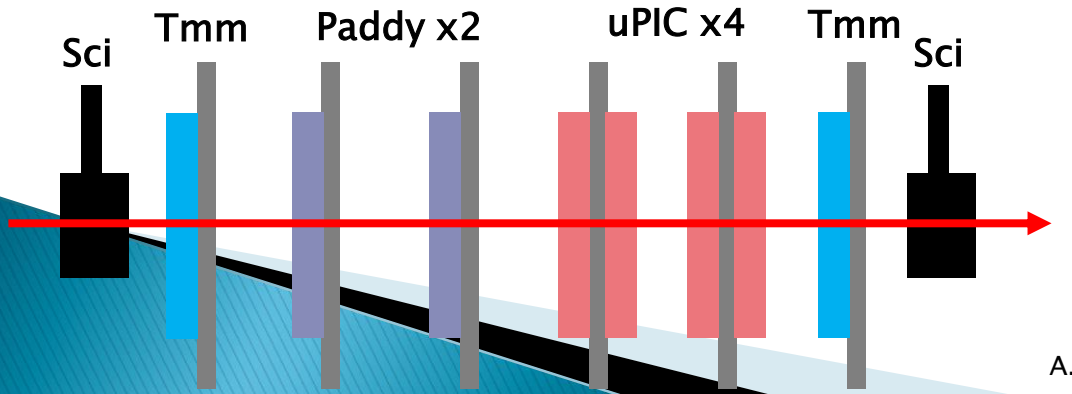


Testbeam of 150GeV μ/π (SPS H4 beamline)

- Tracking test for MIP
- Beamtime: 9-16 October, 2017
- CERN-SPS/H4 (RD51 line)
- 150GeV/c μ/π (~4sec./spill)
  - Muon: ~10^5 /spill, ~8cmx8cm, 390Hz/cm^2
  - Pion: ~3x10^5 /spill, ~1cmx1cm or ~1cmx6cm, 75kHz/cm^2 or 12.5kHz/cm^2
- Detectors:
  - Trigger: Plastic scintillator x2
  - Telescope: Tmm (2D MM, 250umpitch, 10x10cm)
  - Test chambers: Resistive u-PIC x4, Paddy x 2
- U-PIC operation conditions
  - Gas: Ar 93% + CO_2 7% or Ar 70% + C_2H_6 30%
  - Readout: SRS with APV25

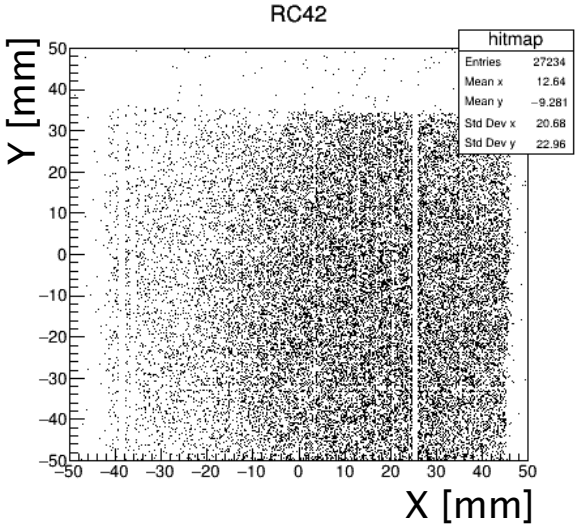




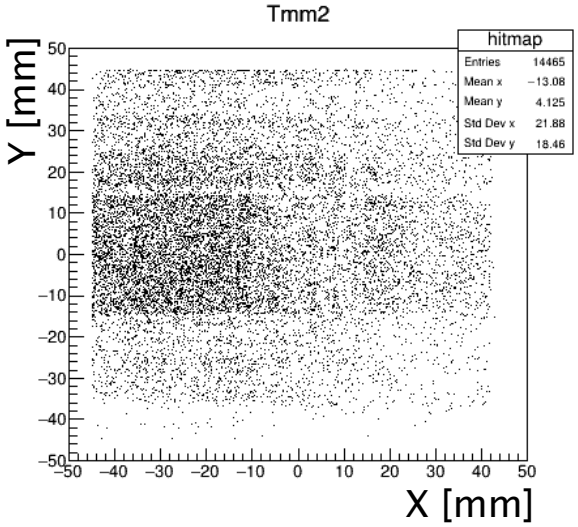


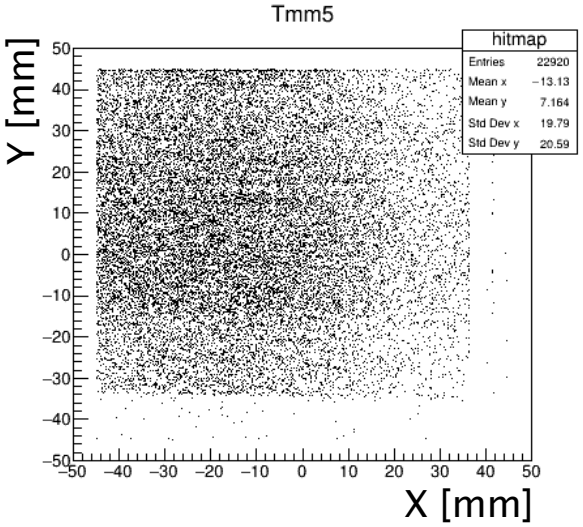
2D hitmap (Muon run)

μ-PIC

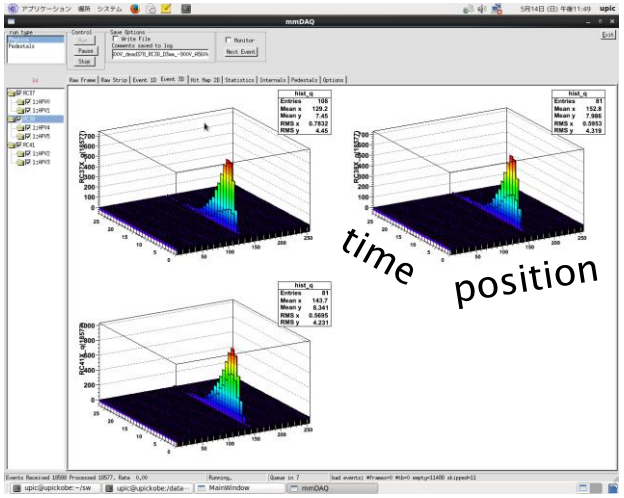


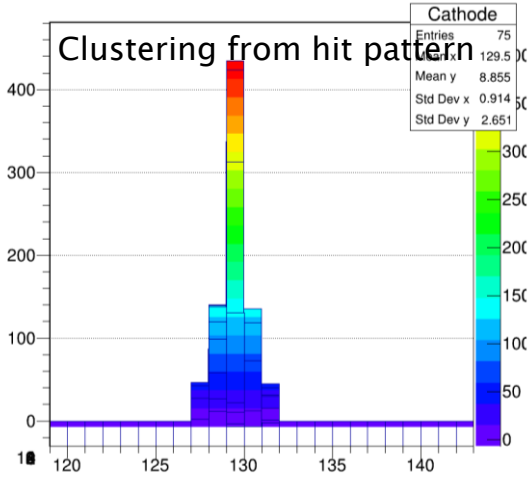
Telescope MMs





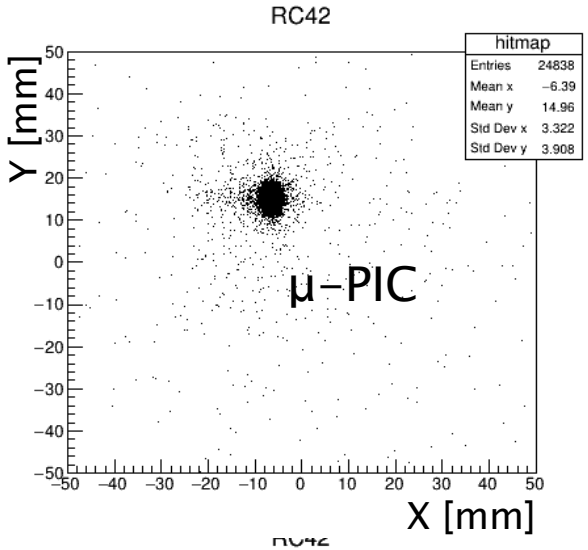
- Hit position:
  centroid of mass
  = Σ(x*qmax)/Σqmax
- (qmax means maximum ADX value

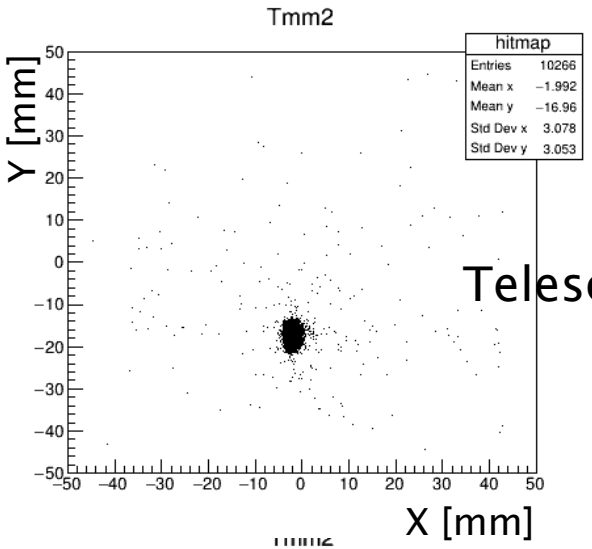


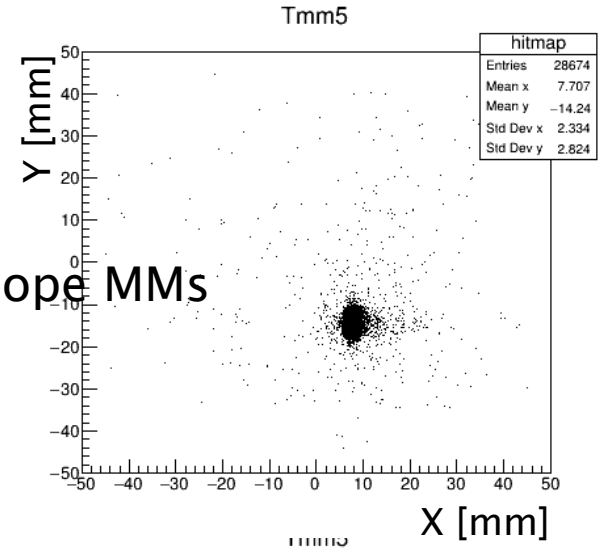


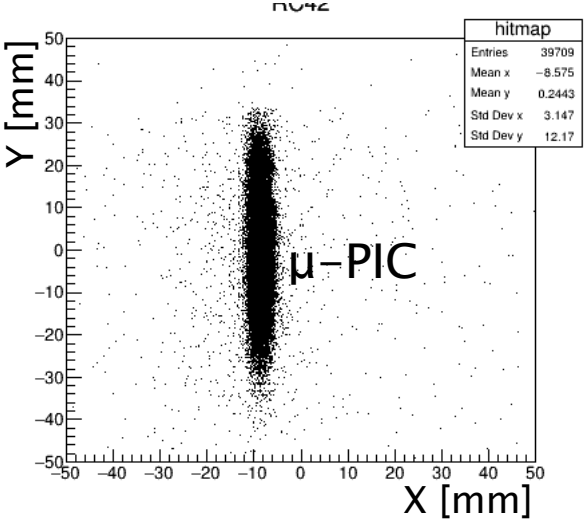
2D hitmap (Pion run)

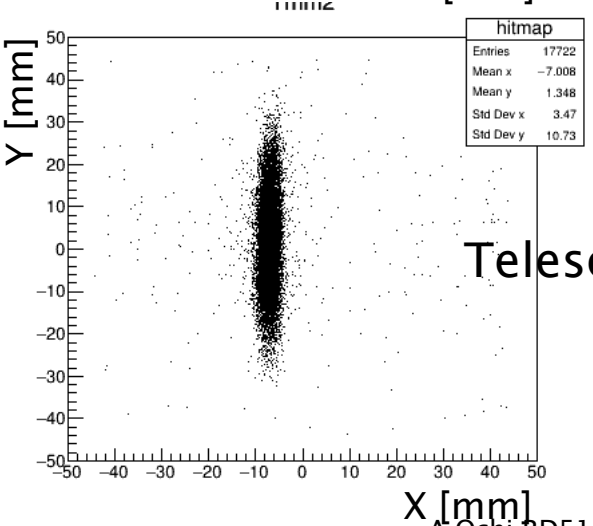
- Squeezed beam and deforcused (Y axis) beam

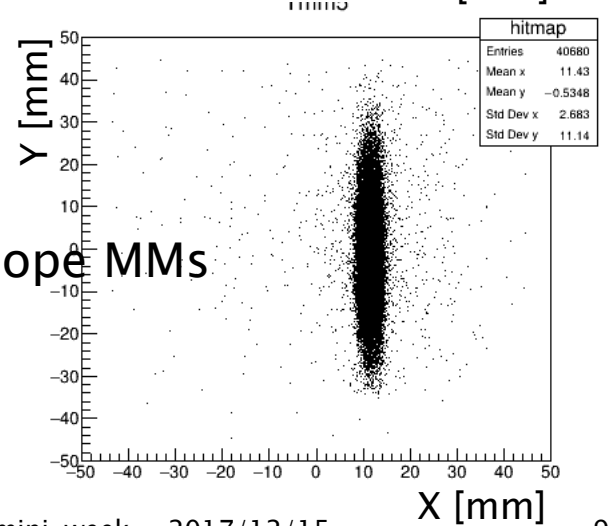




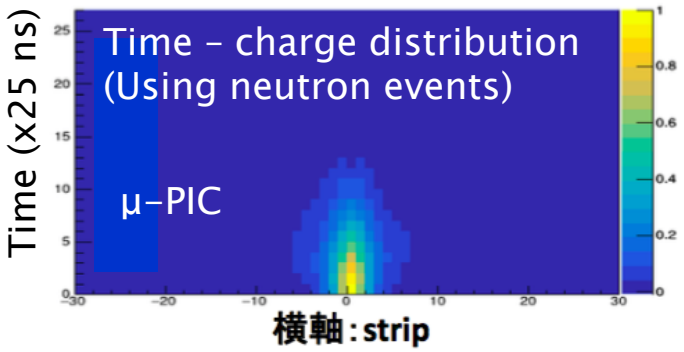


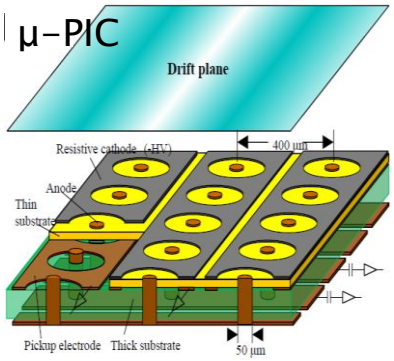


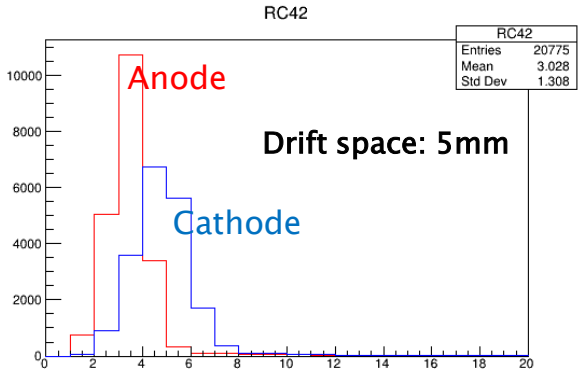


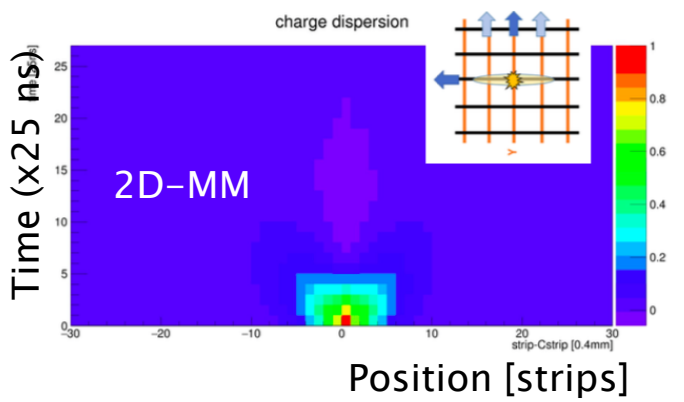


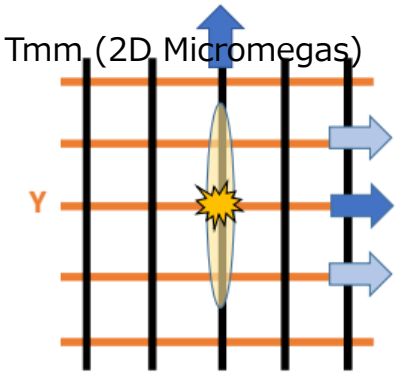
Charge distribution over the strips

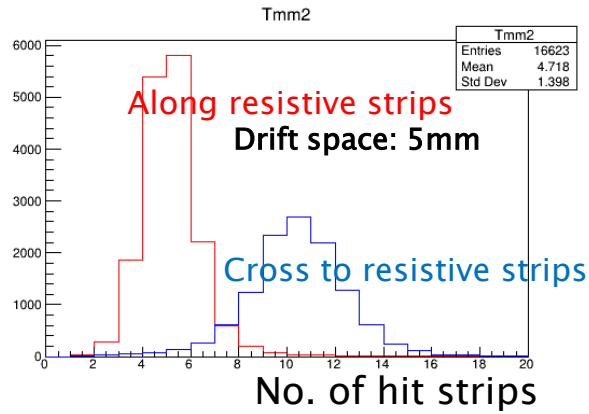








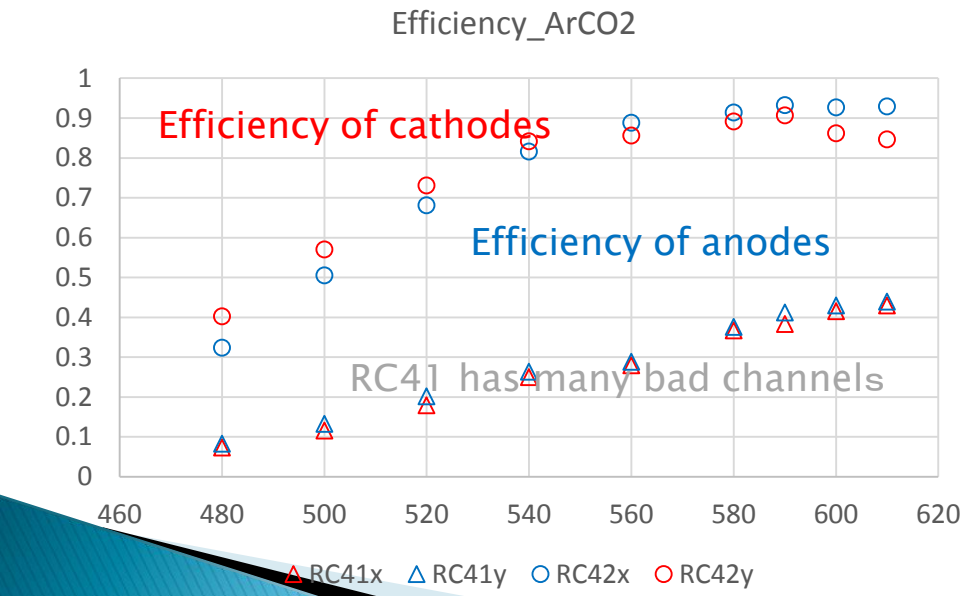


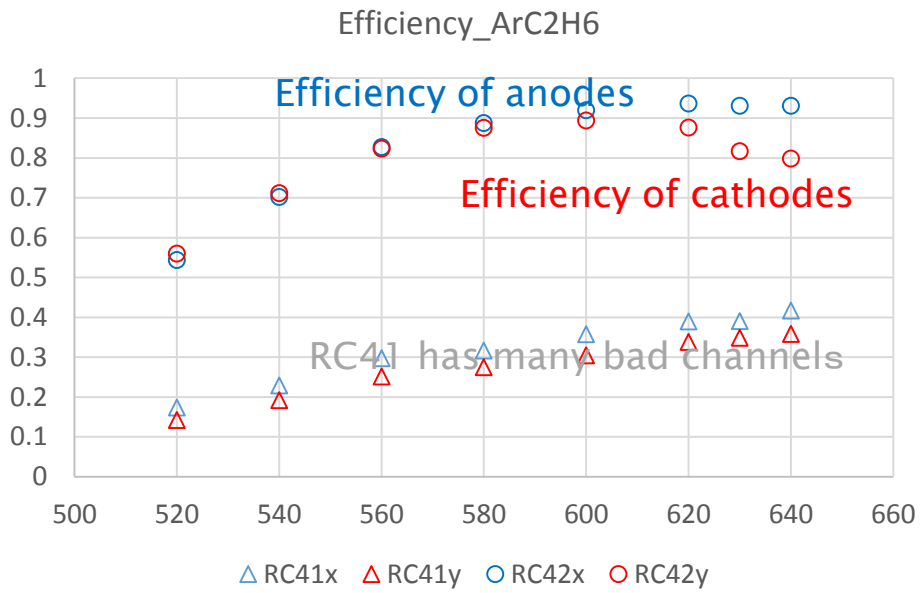


- The charge will be distributed on resistive strips (plane).
- There are no major differences of signal spread between X and Y on μ-PIC.
- For Micromegas, Y-axis readouts are spread due to charge dispersion along the resistive strips.

Efficiency for muons

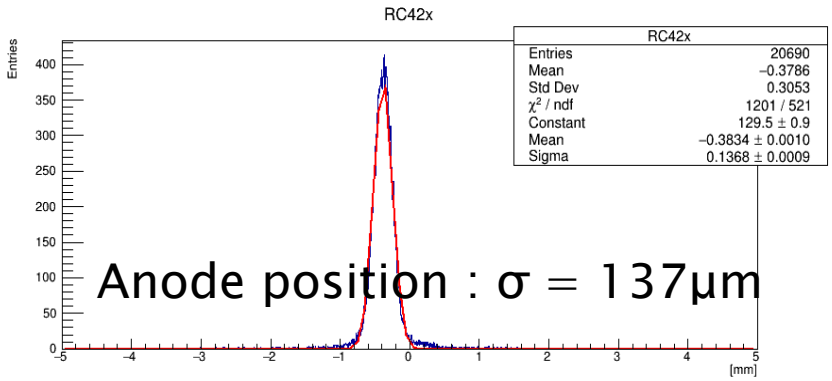
- Tracking efficiency using muon
  - Those are preliminary results.
  - Efficiency =(uPIC∧Tmm2∧Tmm5)/(Tmm2∧Tmm5)
  - Maximum efficiency is 94% in both Ar/CO2 and Ar/C2H6
  - At least 2% of efficiency loss are caused from dead strips.
  - Anode shows plateau of efficiency in higher operation voltage, however, cathode shows degradation of it. → Under investigation

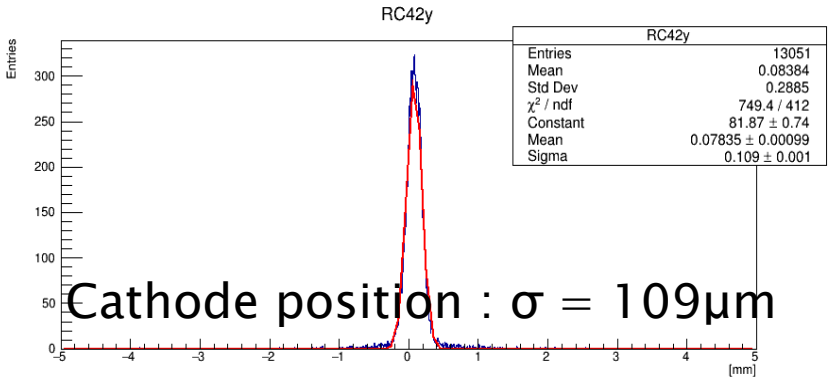




Position resolution (muon)

- Residual distributions are measured from two telescope MMs. (Doesn't including MM's resolution)
  - Anode: 137um, Cathode: 109um were obtained as resolution.

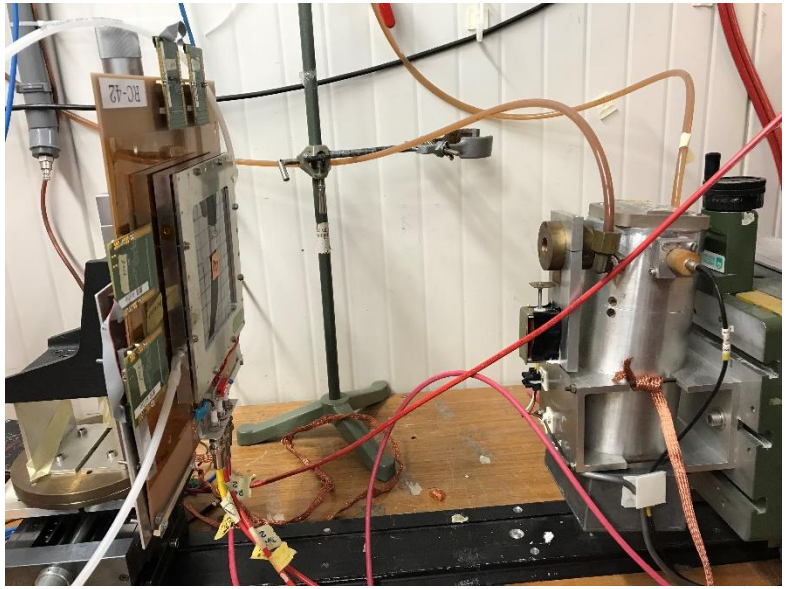


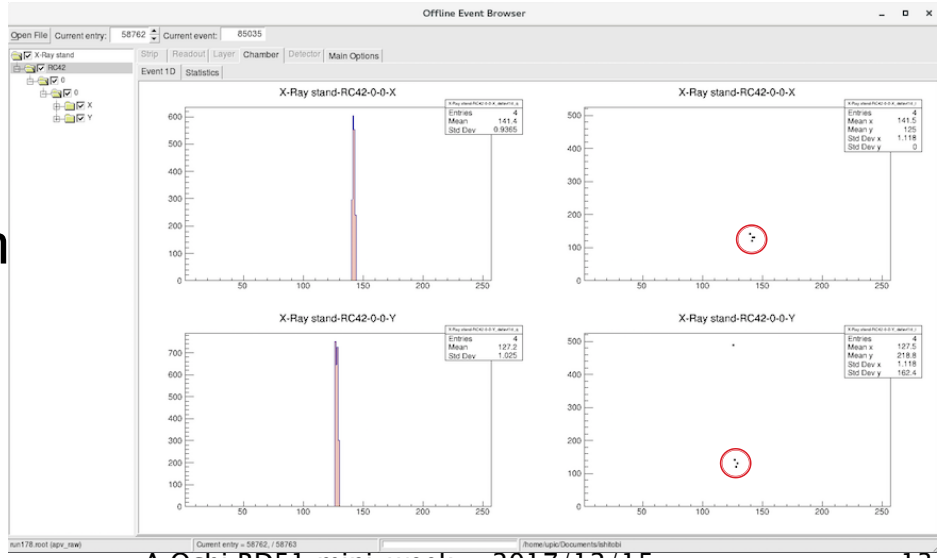


- Using self residual with two μ-PICs, we found 80 μm of resolution minimum.

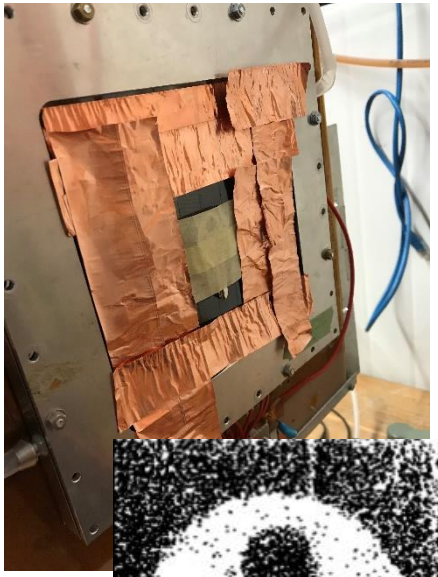
Imaging test (X-ray)

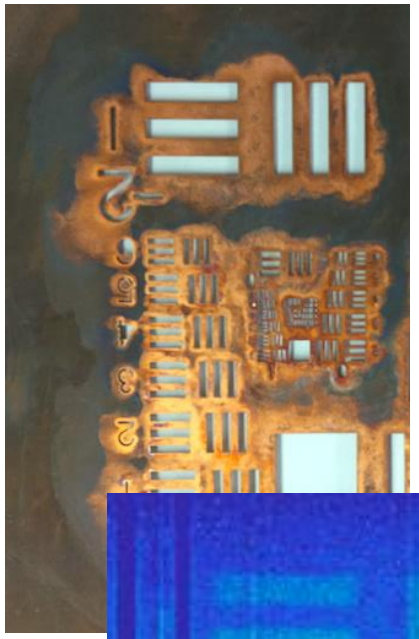
- X-ray 2D images were taken in RD51 labo.
  - November, 2017
- SRS with random trigger is used for data taking
  - Signal efficiency ~ 0.1% !
- Operation condition:
  - Gas: Ar 93% + CO2 7%
  - V_anode = +280V
  - V_cathode = -270V
  - V_drift = -770V (gap=5m
  - X-ray: 16kV, Cu target

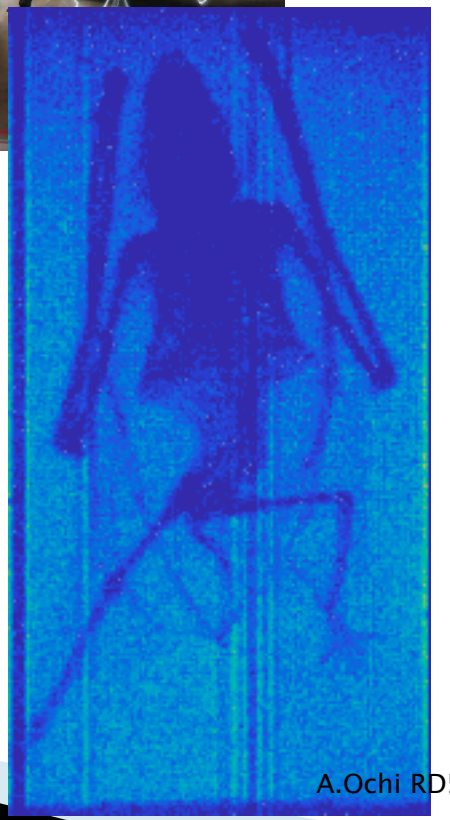


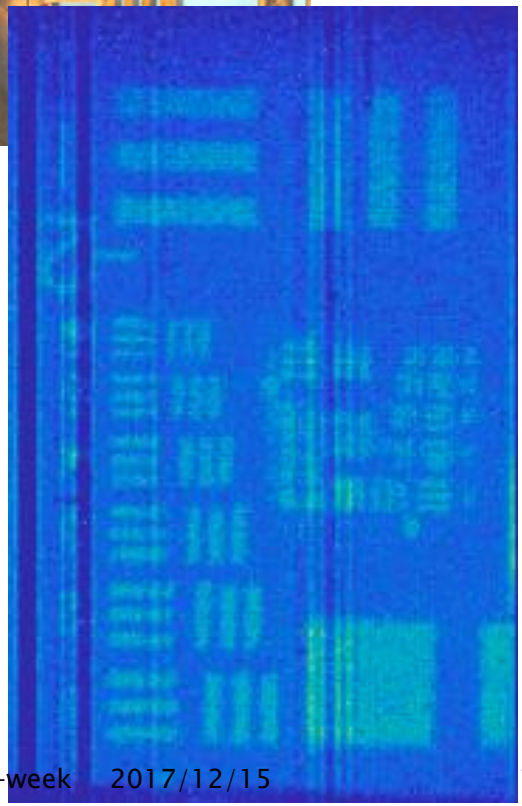


Imaging samples



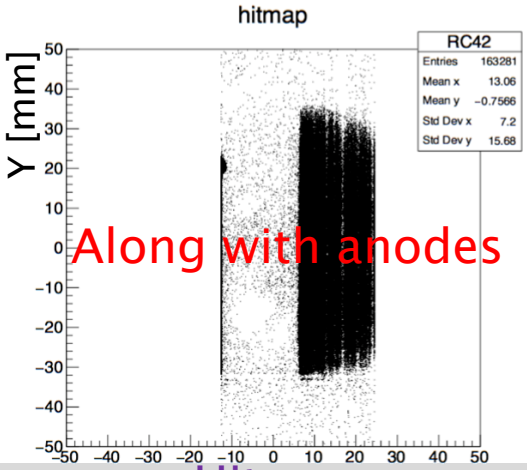


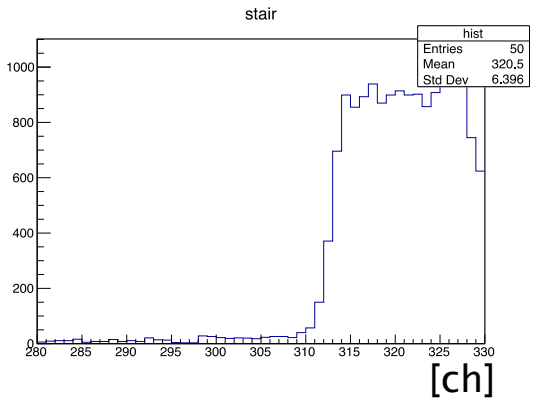


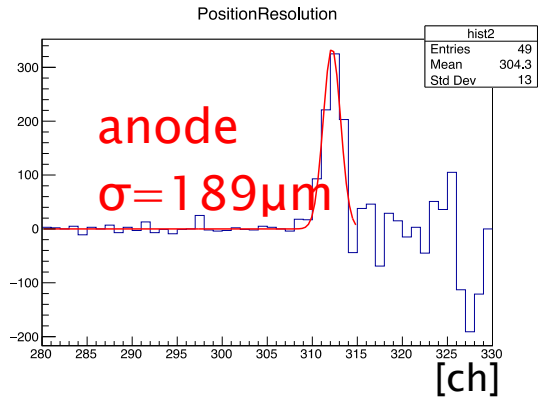


Position resolutions for imaging

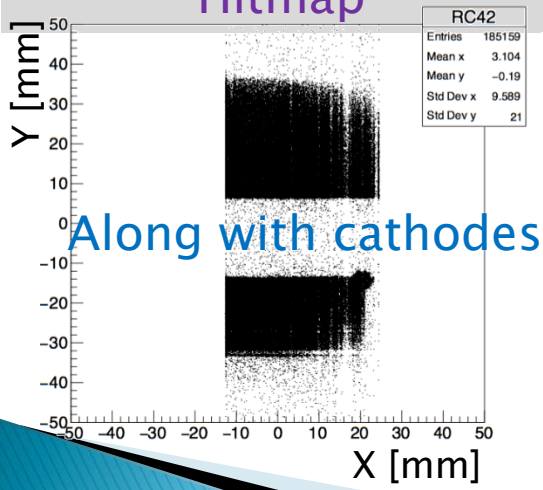
- Knife edge method

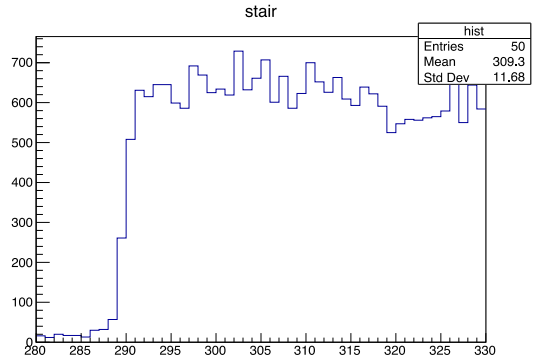


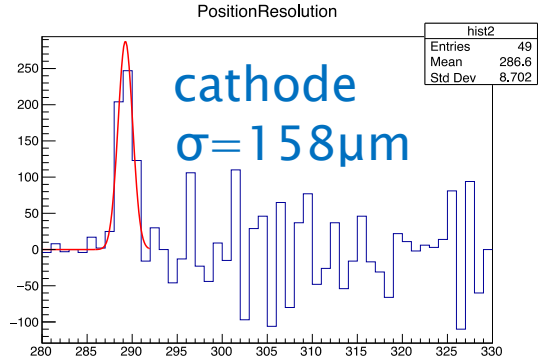




Hitmap | Projection histogram | Differential of projection



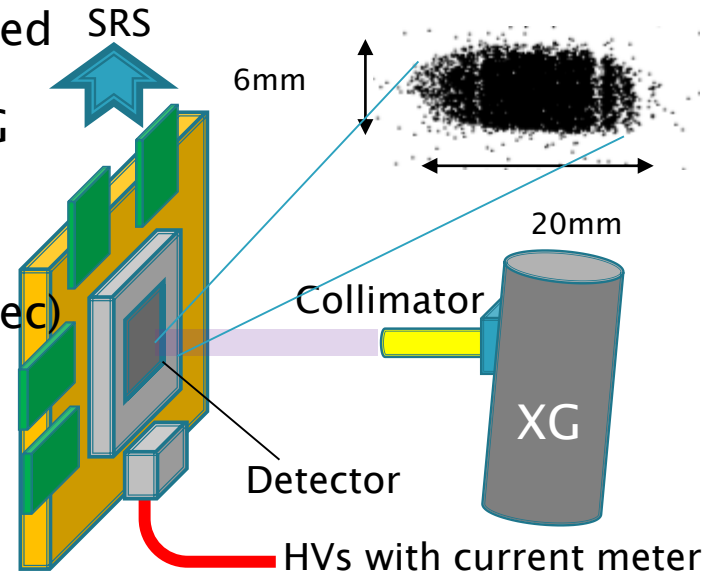


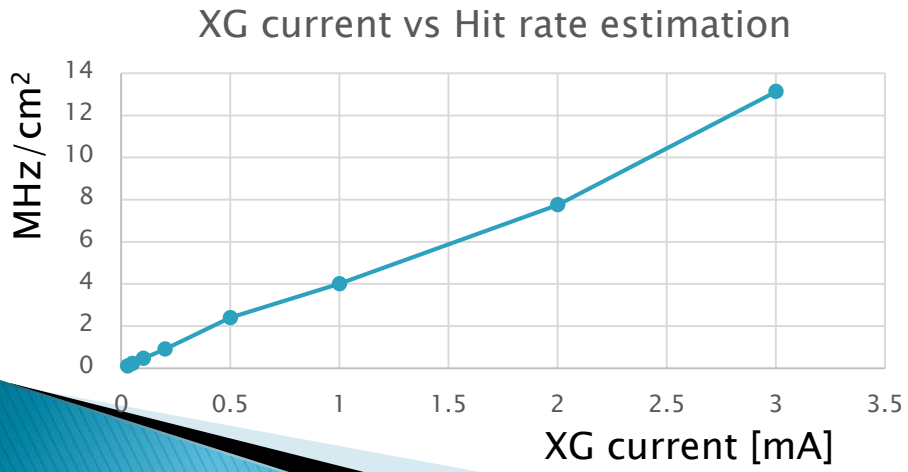


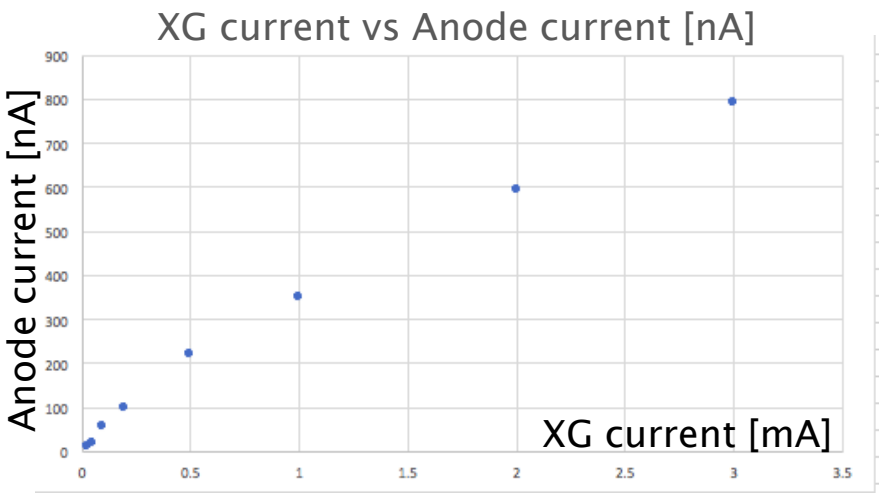
A little bit worse than test beam results
→ we have to take account to diffusion of primary photo electrons from Cu Kα (8keV)

Operation tests in intense X-ray

- Direct collimated beam from XG was irradiated to detector.
- Relative X-ray intensity was controlled by XG current
  - 0.03mA → 3mA
- X-ray intensity is estimated by event appearance rate of SRS event frame (~500nsec)
- Relative gain of chamber is estimated by current monitor of anode HV.
- No significant gain drop found up to 13MHz/cm^2







Summary

- Performance of 2-dimensional resistive μ-PIC has been measured using H4 testbeam and X-ray generator
- Our preliminary results show very good 2D position resolutions (137μm/109μm) and efficiency (94%) for MIPs.
- 2D X-ray images were taken with good quality (189μm/158μm of position resolution)
- No significant gain drop more than 10MHz/cm^2 X-ray irradiation
- Those results meet the requirements for high-eta muon detector in HL-LHC.