MPGD19, La Rochelle, 5-10 May 2019

A GEM-Based Time Projection Chamber for J-PARC Hadron Physics Program

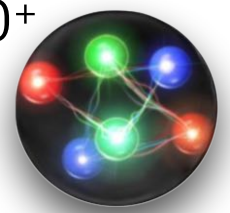
Kim, Shin Hyung (Korea Univ.)
for the J-PARC E42/45 Collaboration

<u>Outline</u>

- Motivation (J-PARC Experiments)
- Introduction of HypTPC
- High-Rate Beam Test Results

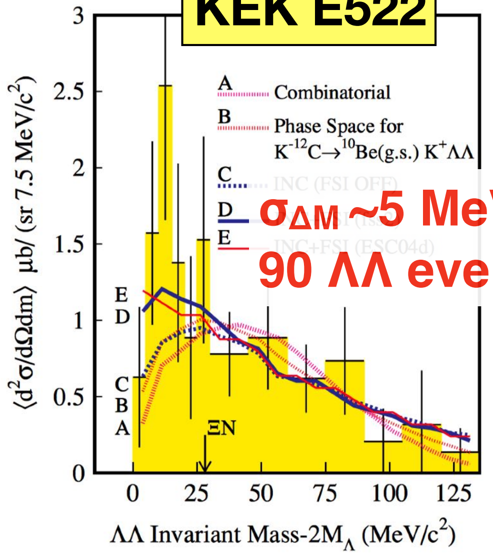
J-PARC E42 Experiment

uuddss
I=0, $J^{\pi}=0^{+}$
?



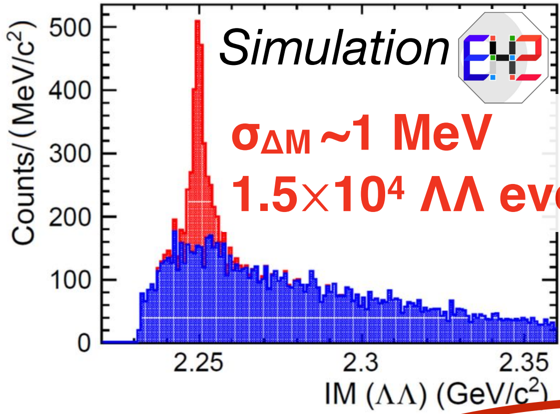
- Search for H-dibaryon via $^{12}C(K^-,K^+)$ reactions

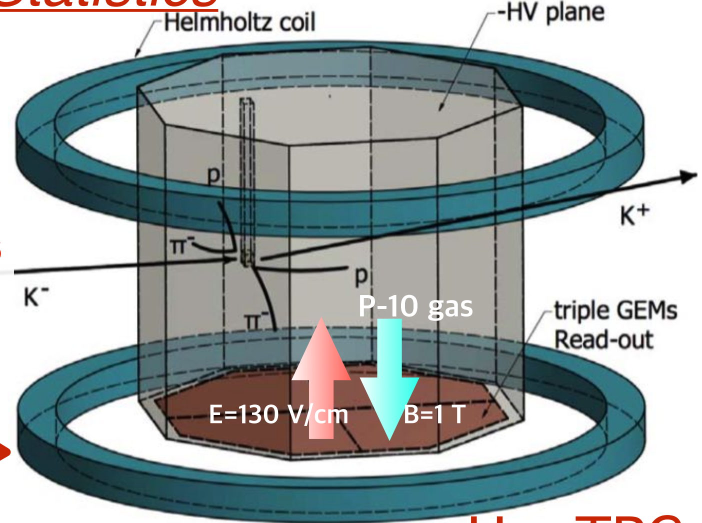
KEK E522



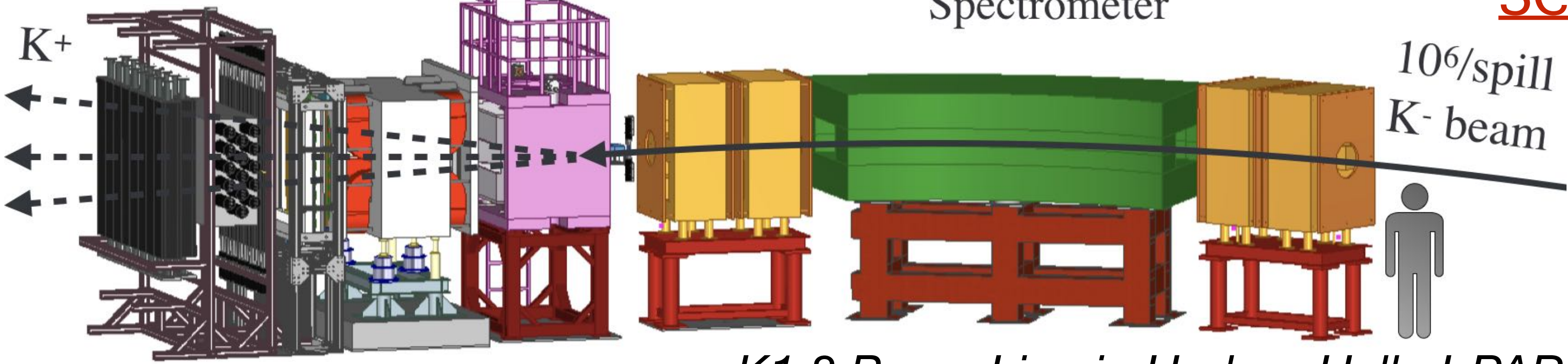
J-PARC E42

High Resolution
High Statistics



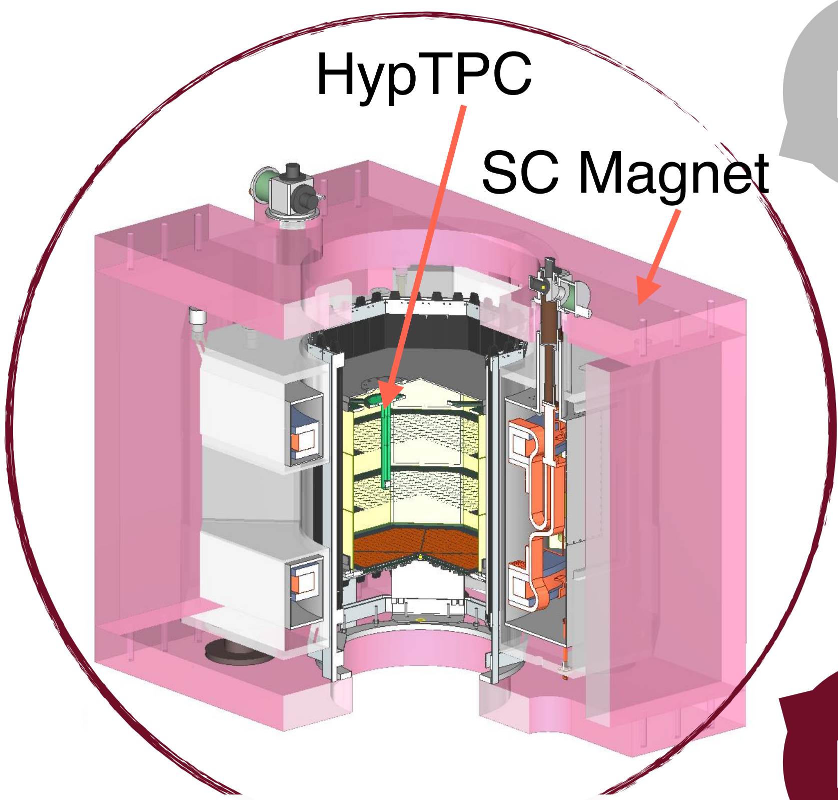


HypTPC
SC Magnet



K1.8 Beam Line in Hadron Hall, J-PARC

J-PARC Hadron Experiments with HypTPC



E42

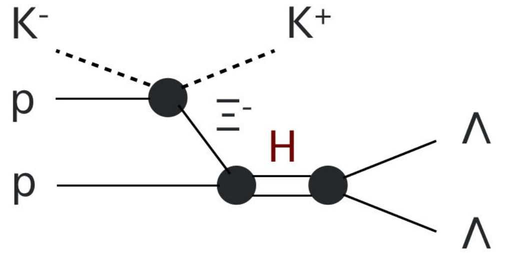
E45

E72

<Hyperon Spectrometer>

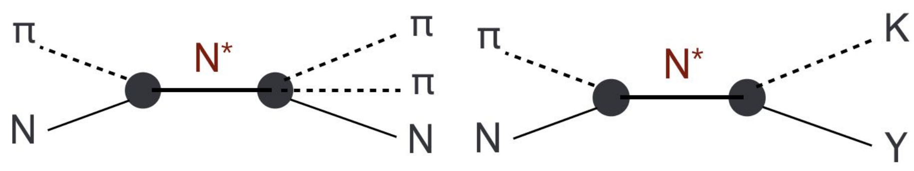
- Main tracking device

H-Dibaryon Search



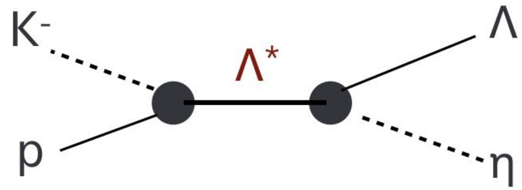
J.K. Ahn et al., J-PARC Proposal E42

N* Baryon Spectroscopy



H. Sako et al., J-PARC Proposal E45

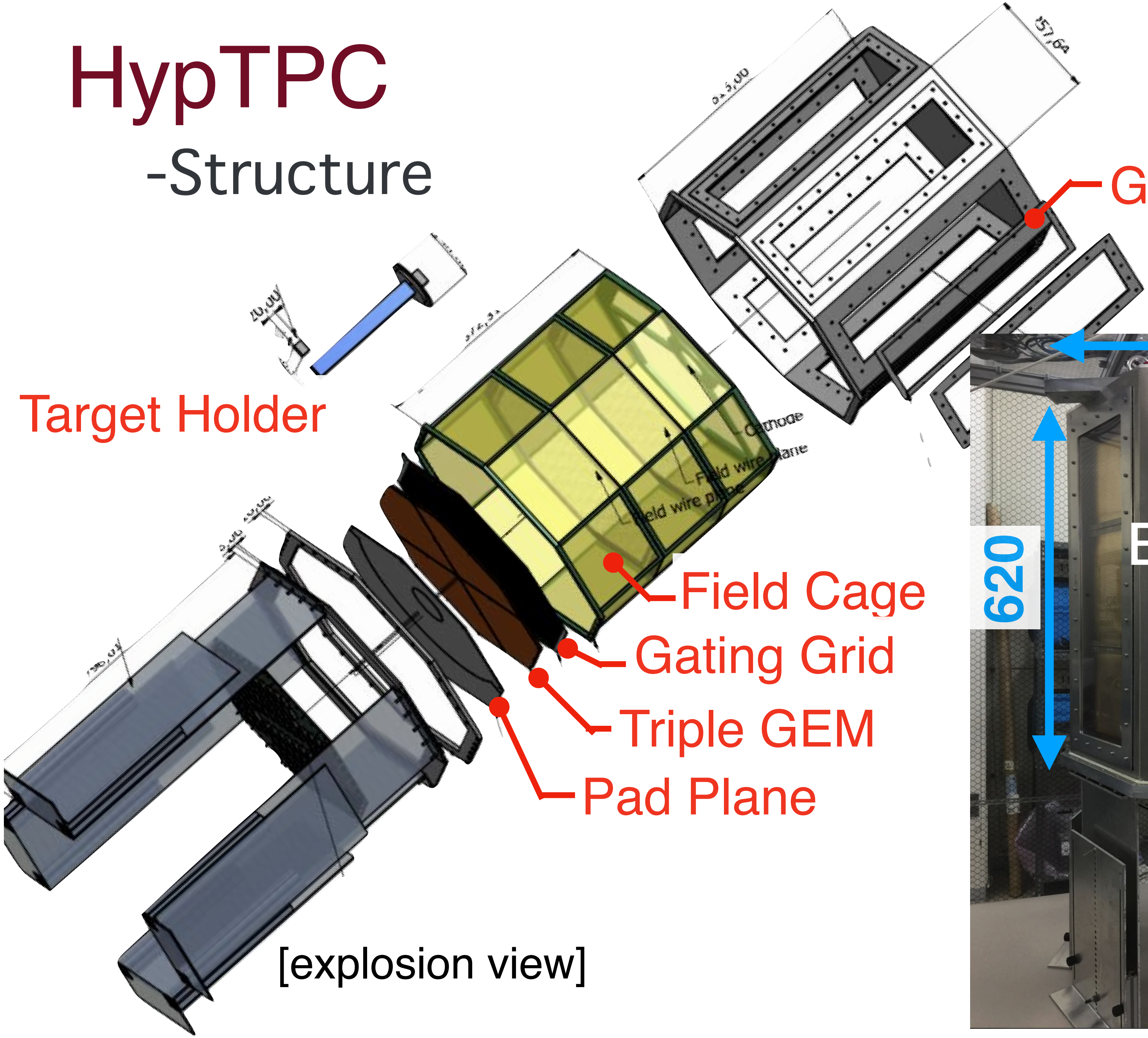
New Λ* Resonance Search near Λη Threshold



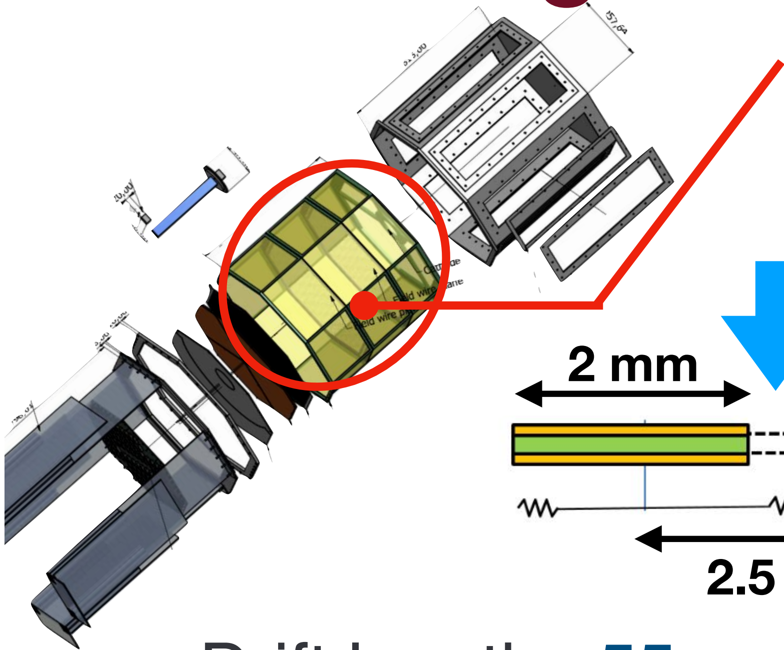
K. Tanida et al., J-PARC Proposal E72

HypTPC

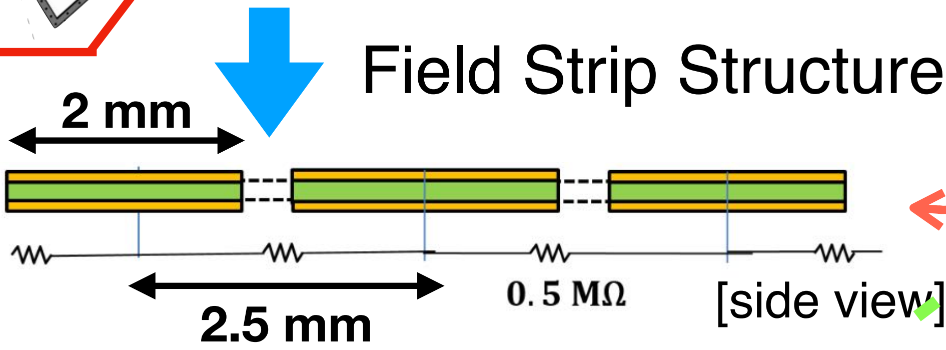
-Structure

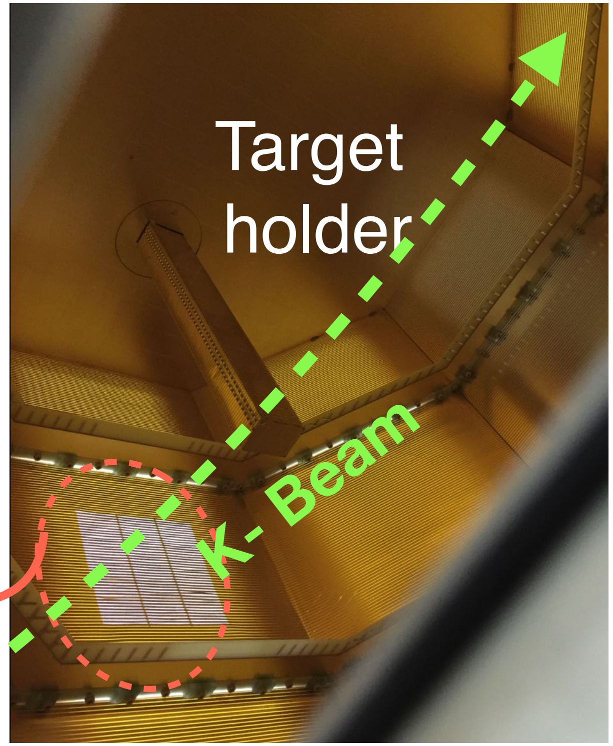


Field Cage Structure

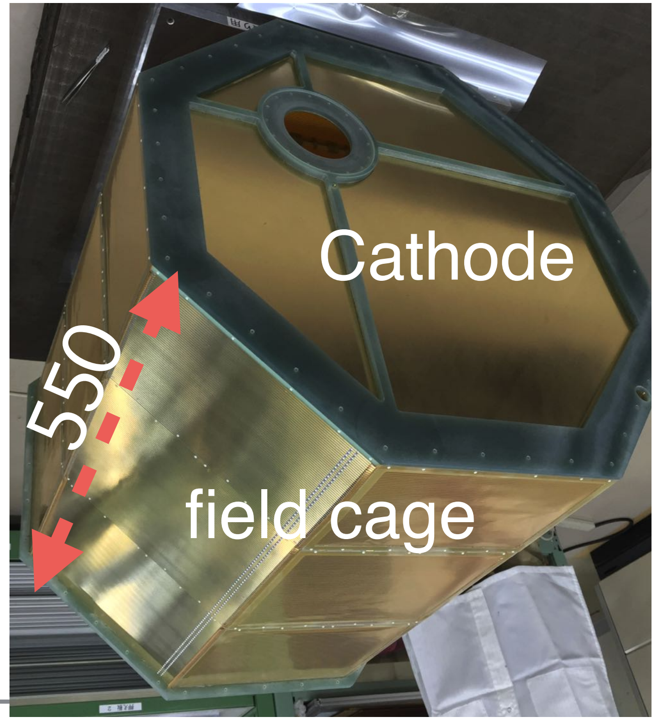


Field Strip Structure

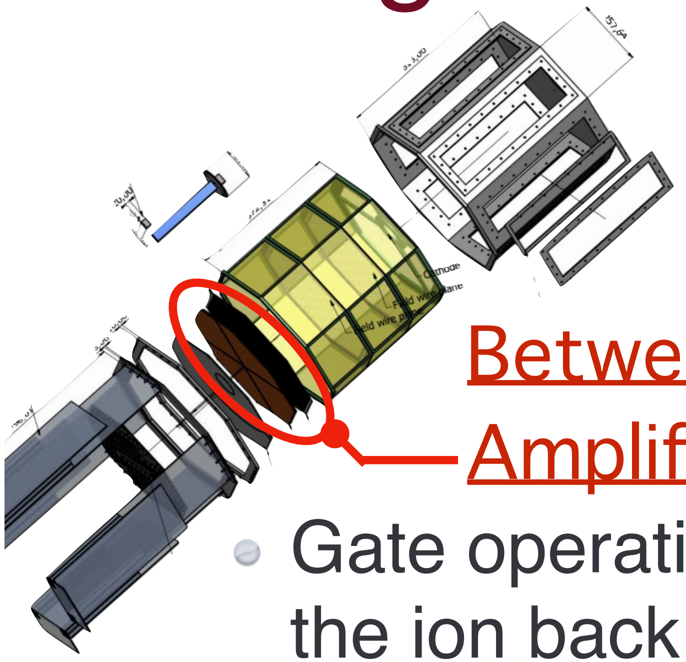




- Drift length : 55 cm
- 1 atm P-10 gas, 130 V/cm
- Target inside drift volume for a large acceptance
- Beam slits to avoid charge build-up on the field cage in high rate beam.

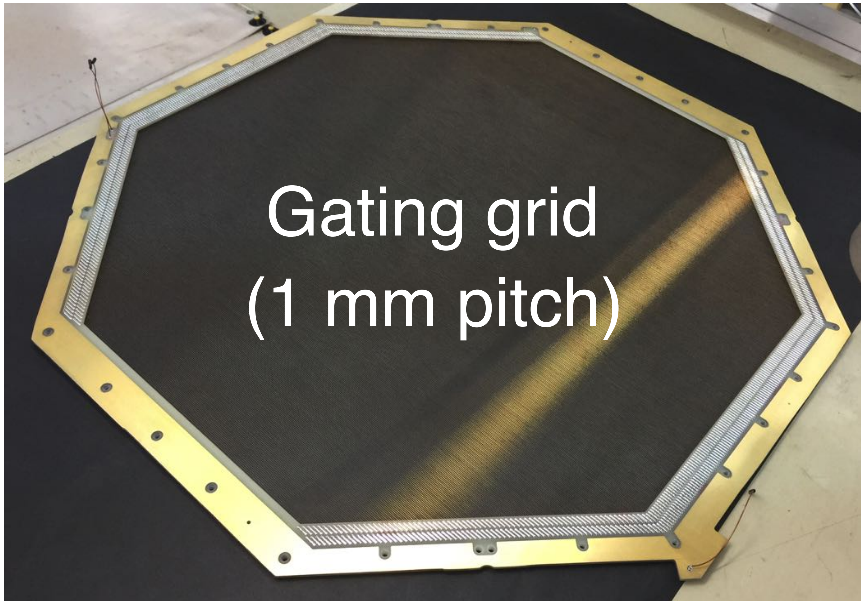


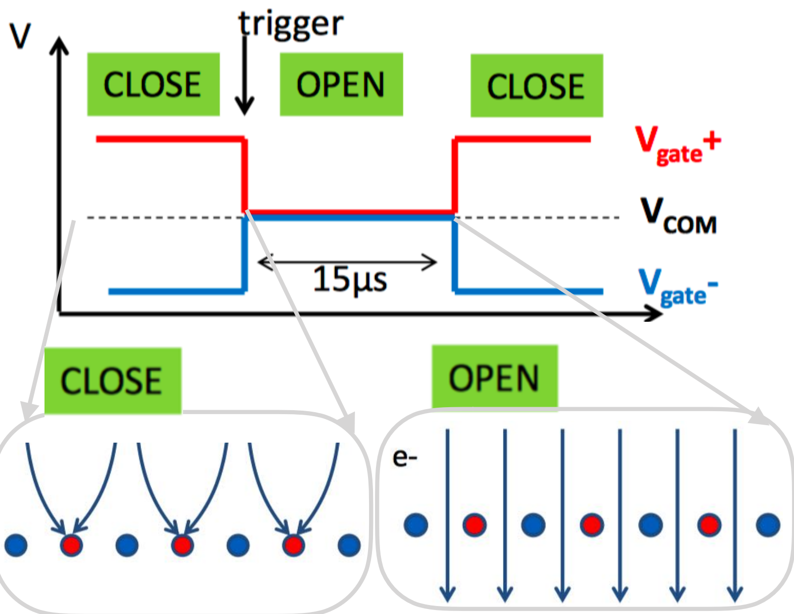
Gating Grid Plane



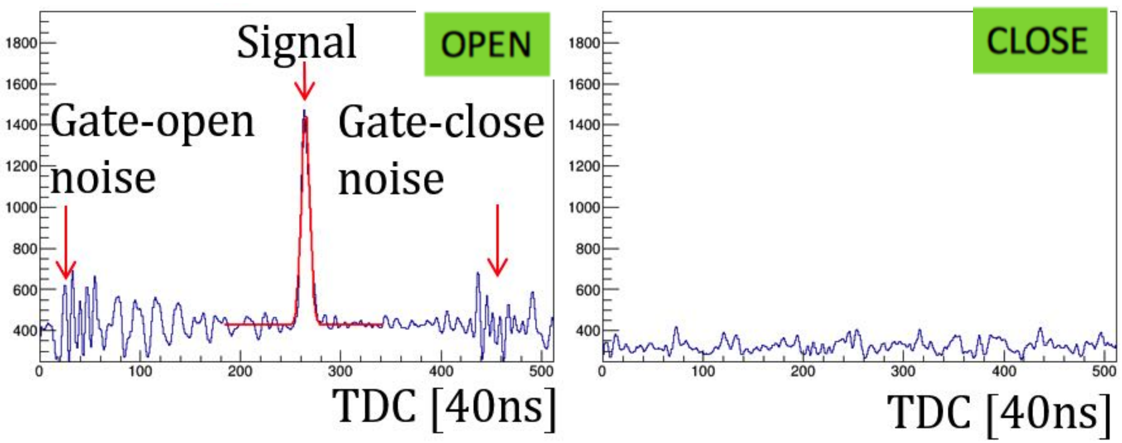
Between Drift & Amplification Region

- Gate operation to suppress the ion back flow

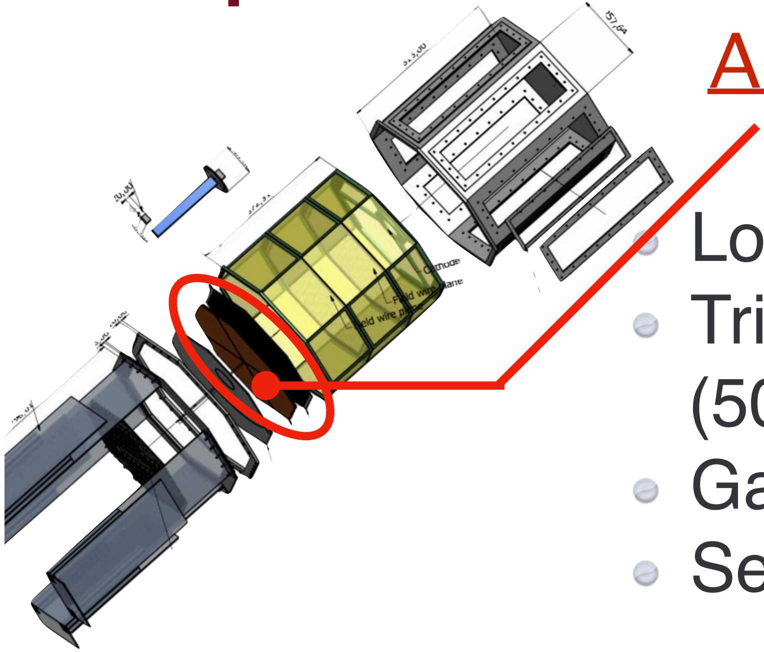




- Gate Operation with V_{Gate}=±25 V

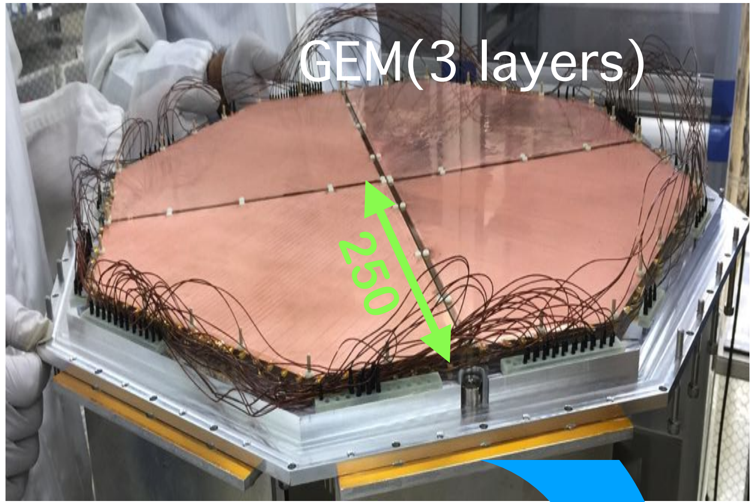


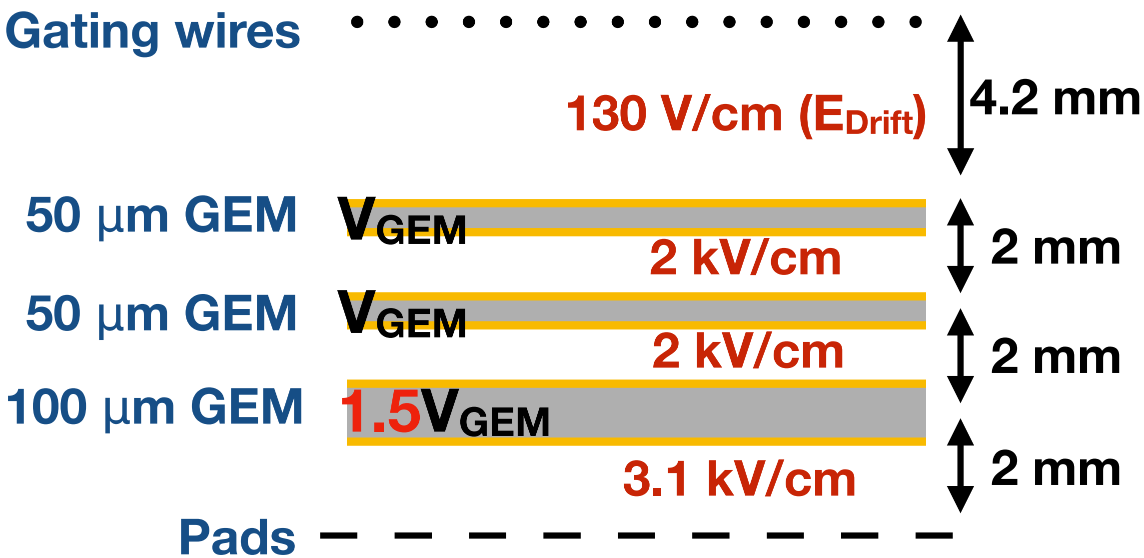
Triple GEM Layer



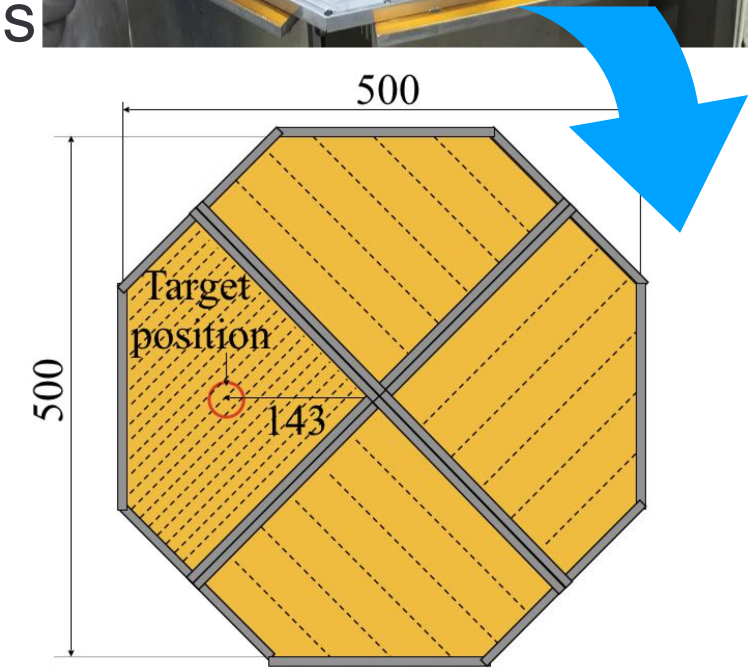
Amplification Region

- Low ion back flow rate
- Triple GEM layers (50+50+100 um)
- Gain ~10^4
- Segmented electrodes





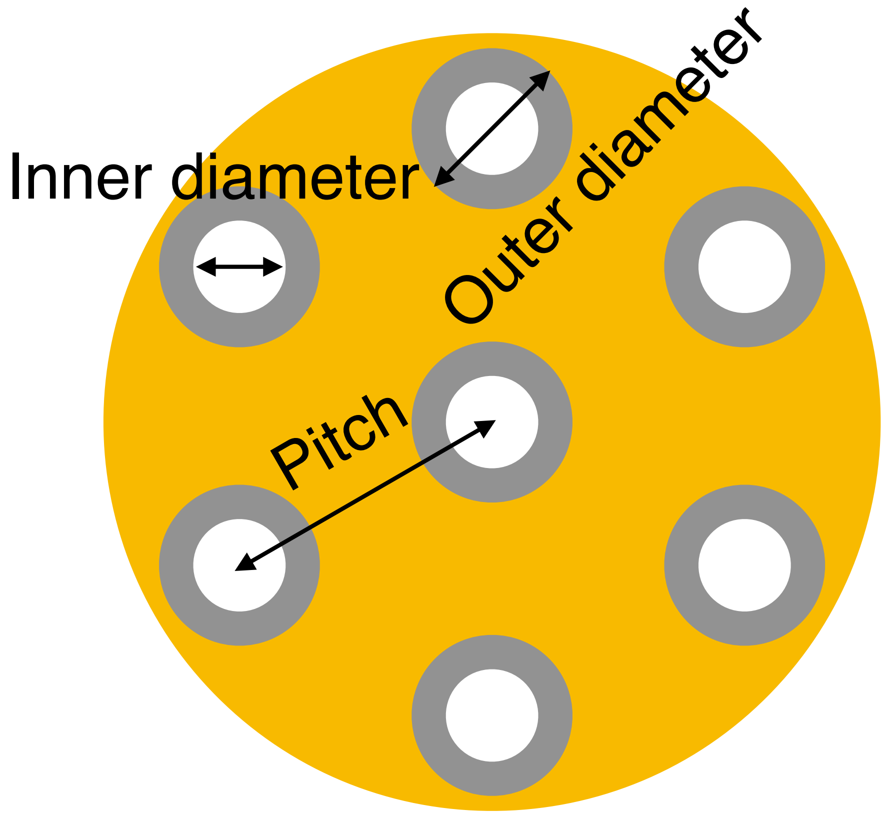
[side view]

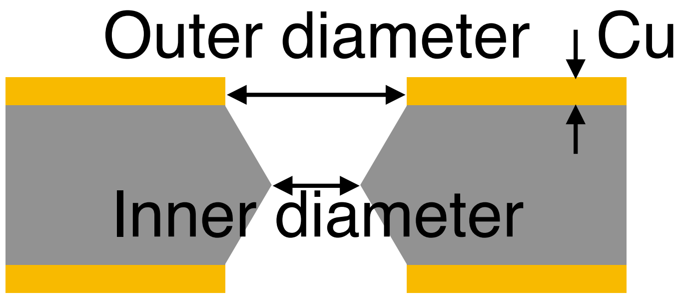


[top view]

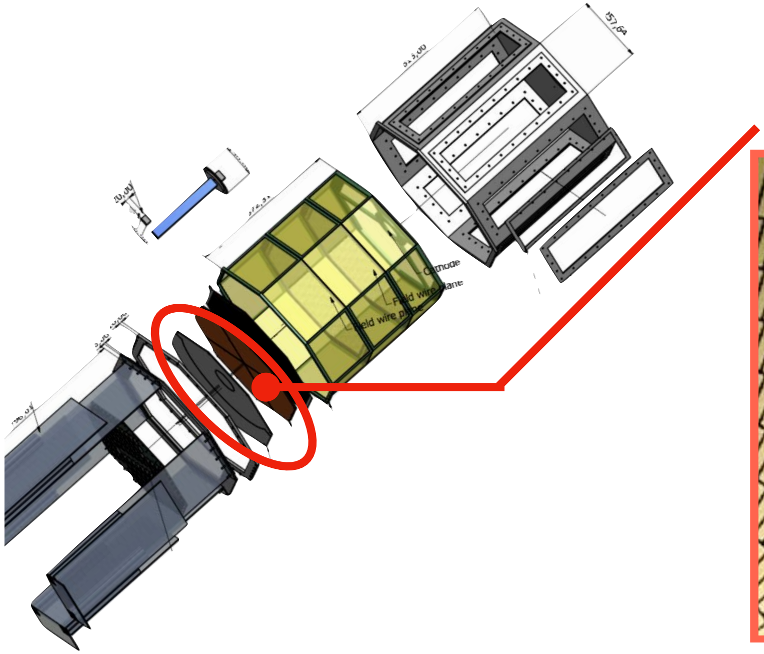
GEM Specification

	50 µm GEM	100 µm GEM
Manufacturer	Raytech	Raytech
Insulator	Polyimide (PI)	Liquid Crystal Polymer (LCP)
Etching method	Wet	Laser
Cu thickness	4 µm	9 µm
Pitch	140 µm	140 µm
Inner diameter	25 ± 10 µm	35 ± 10 µm
Outer diameter	55 ± 5 µm	65 ± 5 µm

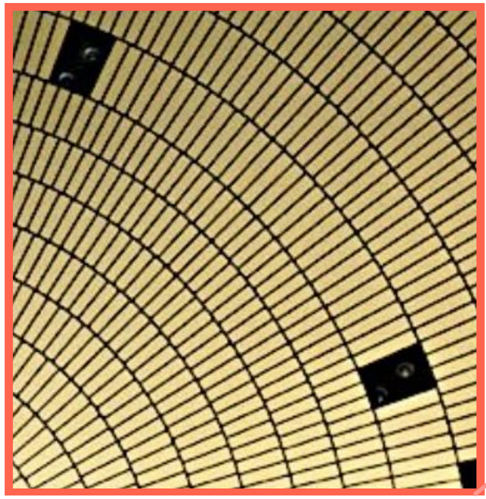


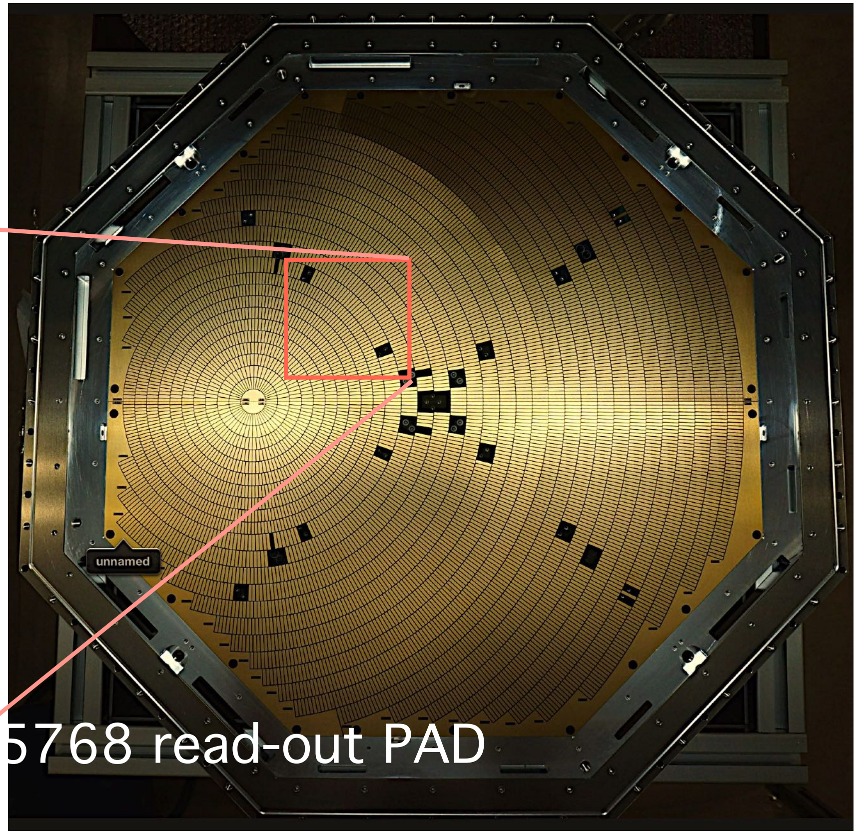


Pad Plane



Readout Pads

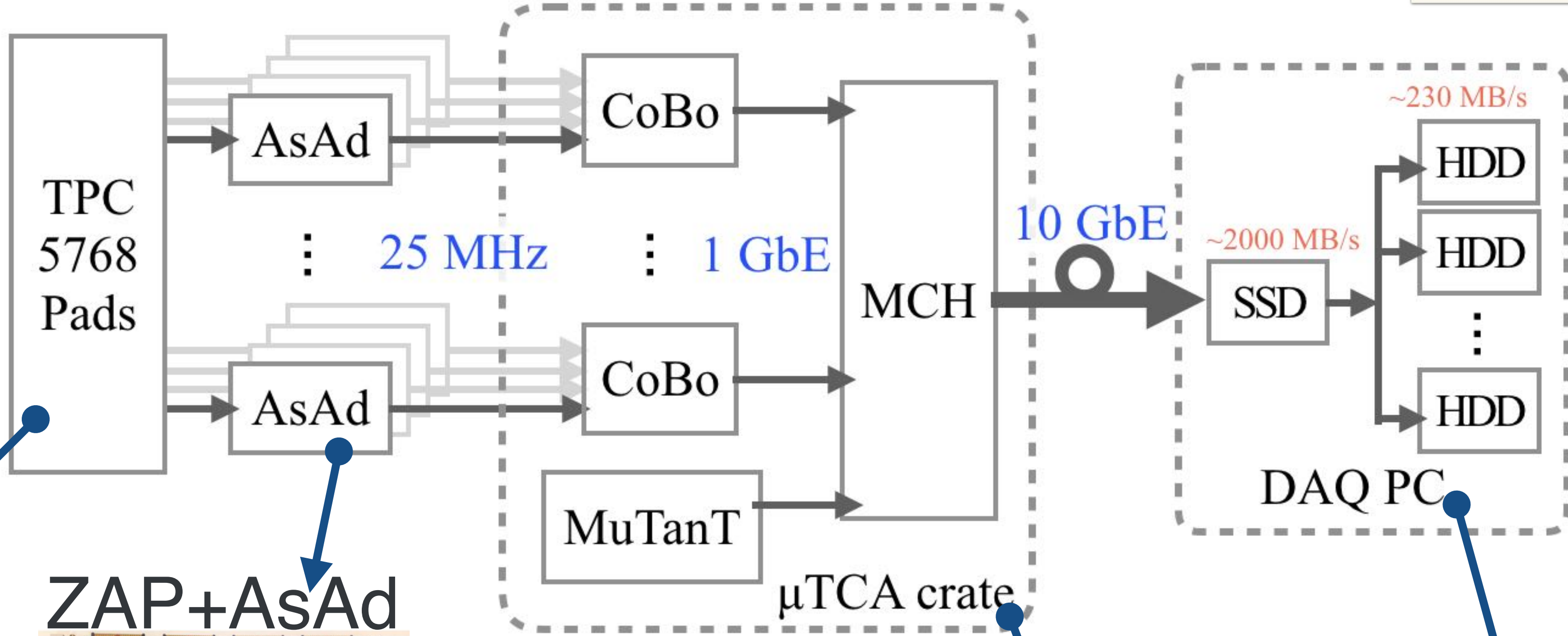




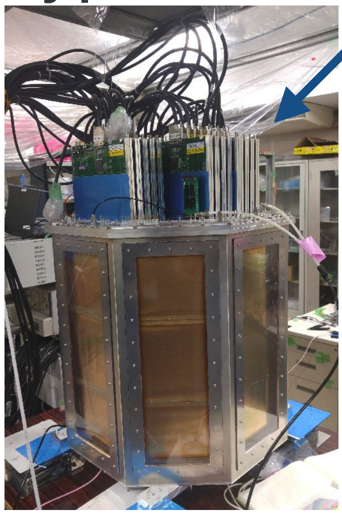
- 5768 readout pads
- Concentric configuration around the target
- 10 inner layers: 2.1-2.7 × 9 mm²
- 22 outer layers: 2.3-2.4 × 12.5 mm²

GET(General Electronics for TPCs)

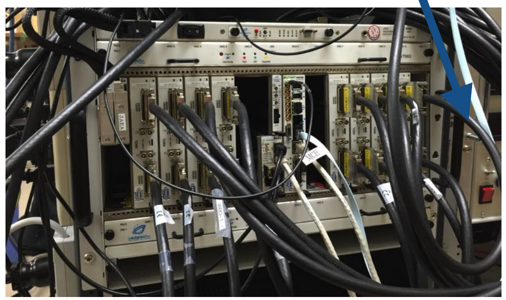
E. Pollacco et al., NIMA 887 (2018) 81

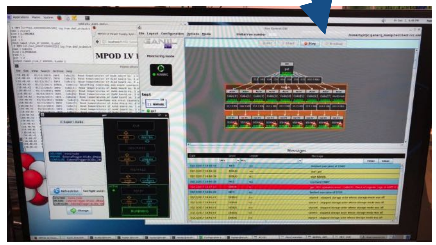


HypTPC



ZAP+AsAd





4 AGET chips
- Preamplifier(gain 120 fC-10 pC)
- Shaper(peaking time 50 ns-1 μs)
- Circular Buffer(sampling rate 1-100 MHz)

12-bit ADC

CoBo
- Data processing
- Data formatting

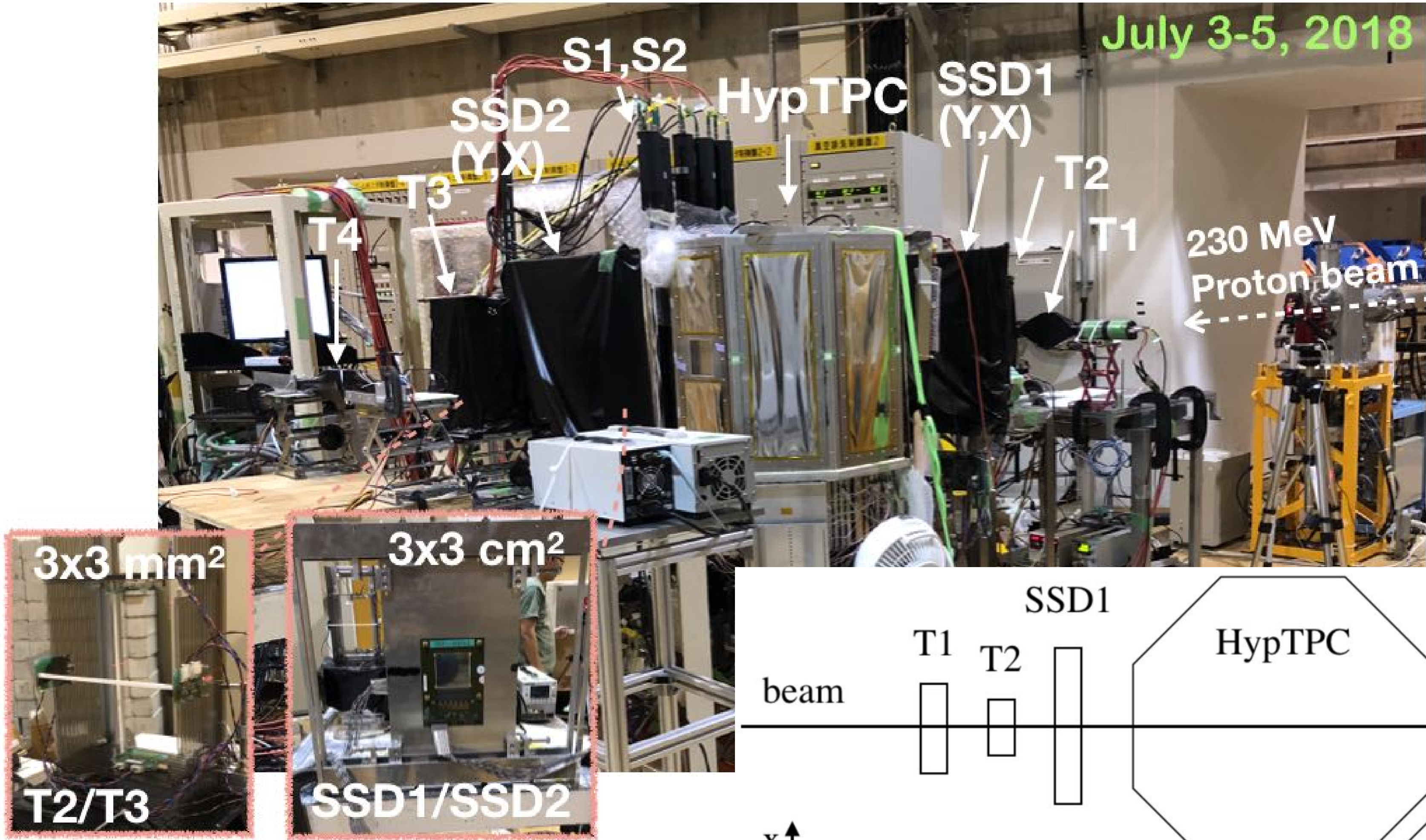
MuTanT
- synchronous trigger

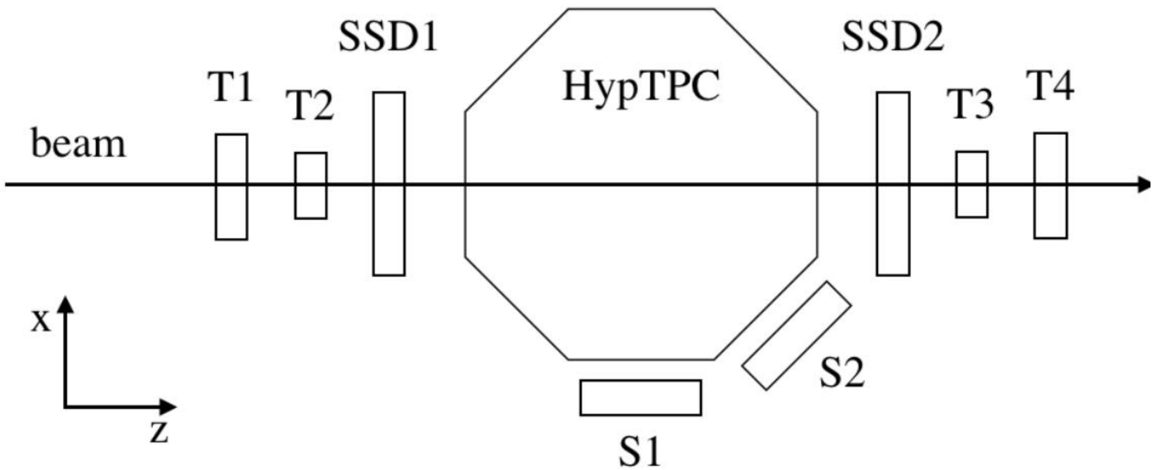
MCH(μTCA Carrier Hub)

DAQ PC
- Run control
- Data flow manage
- Data storage

HypTPC Commissioning at HIMAC

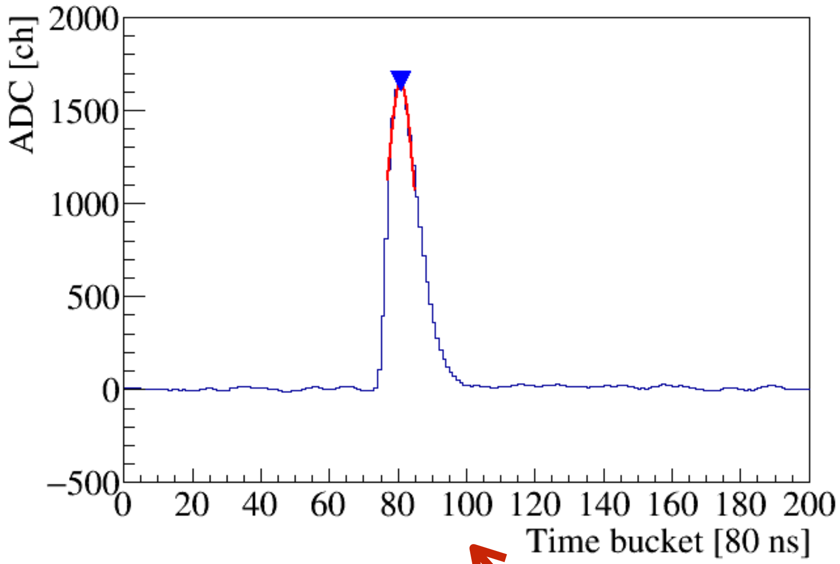
- To study the basic performance and the high rate capability of TPC





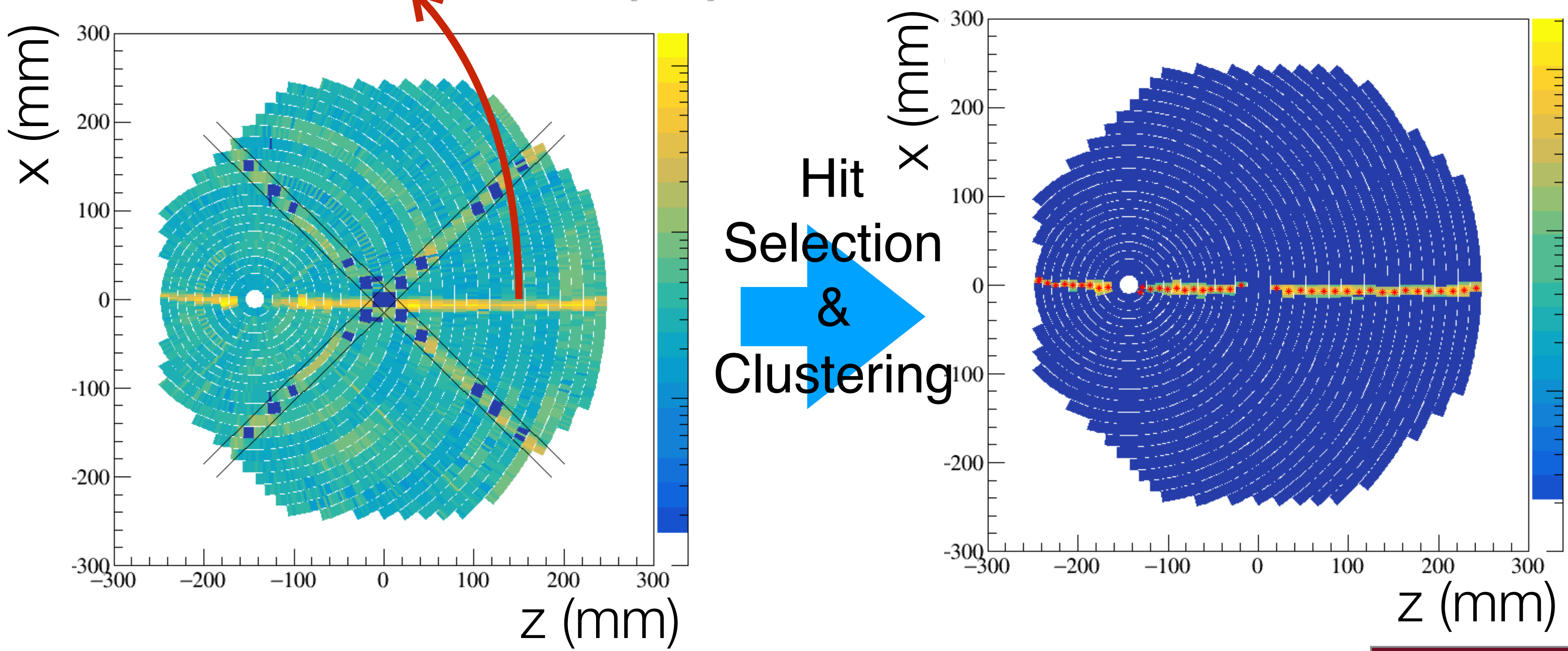
<u>Submitted to NIMA</u>

Beam Event



- Sampling freq.: 12.5 MHz
- Readout depth : 200
  (80 ns X 200 = **16 μs**)

- Δ=(Max+Min)/2-Ped > 20
- GEM frame region pads excluded



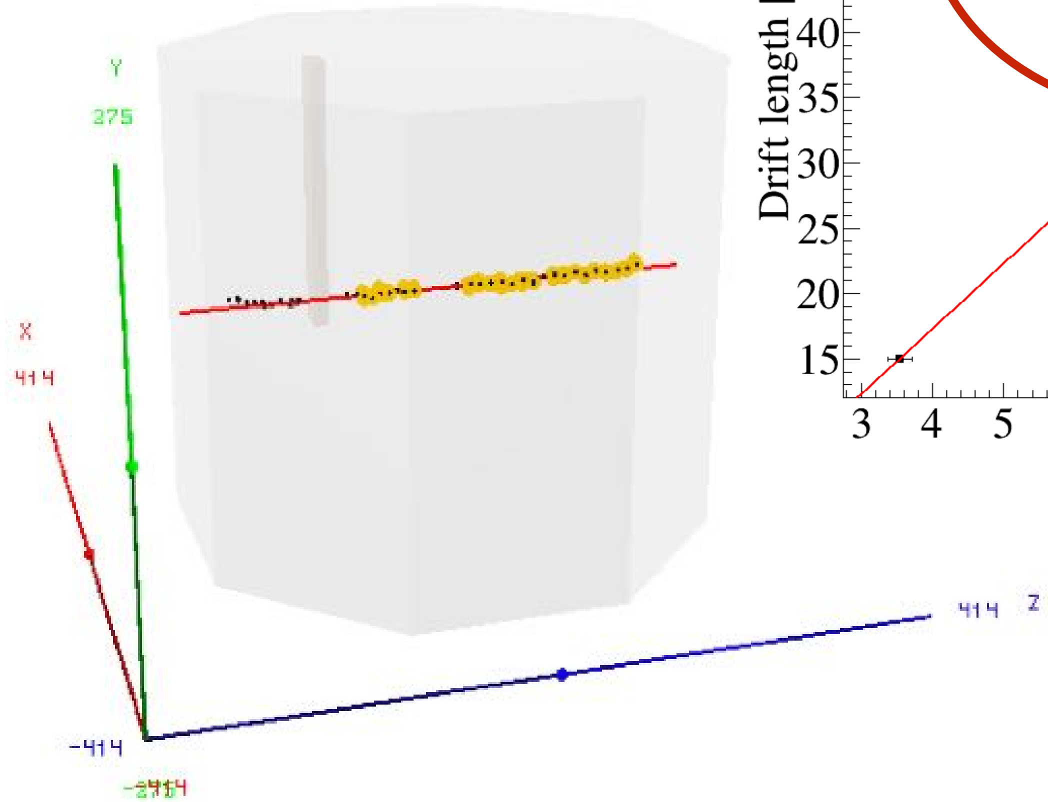
3D Track Reconstruction

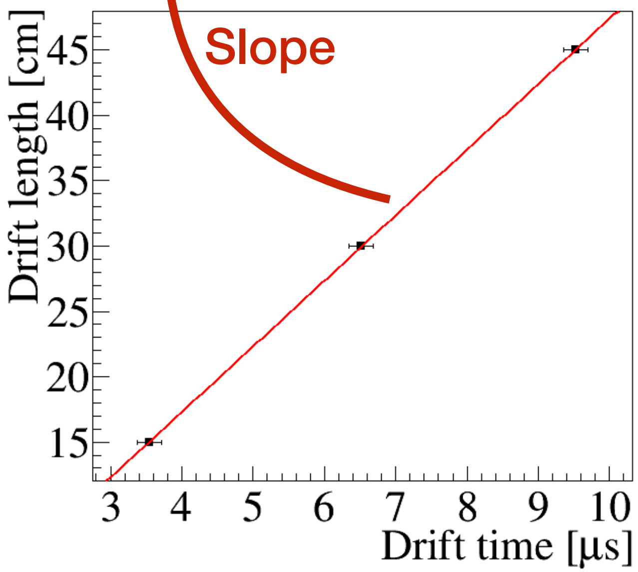
At E=130 V/cm in P-10 gas,

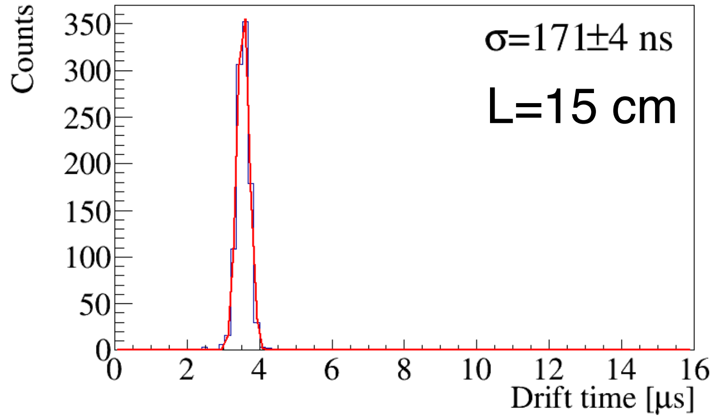
Drift Velocity = **5.00 cm/μs**

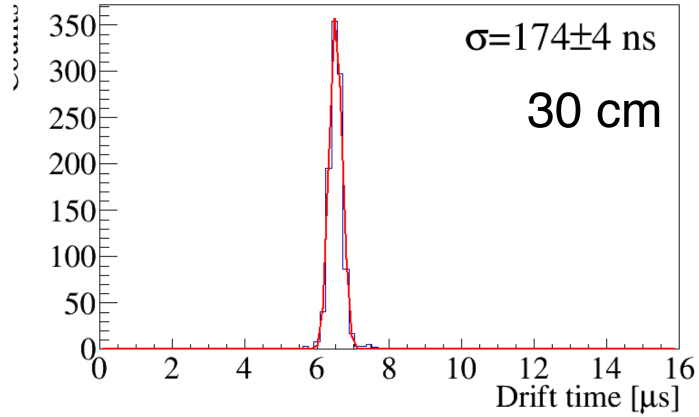
x,z <- Pad plane

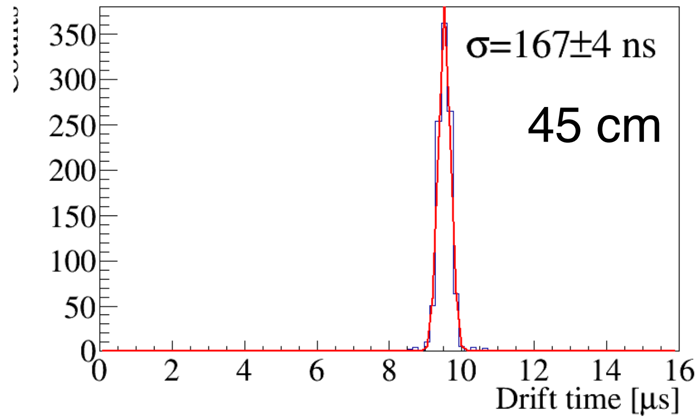
y <- Time





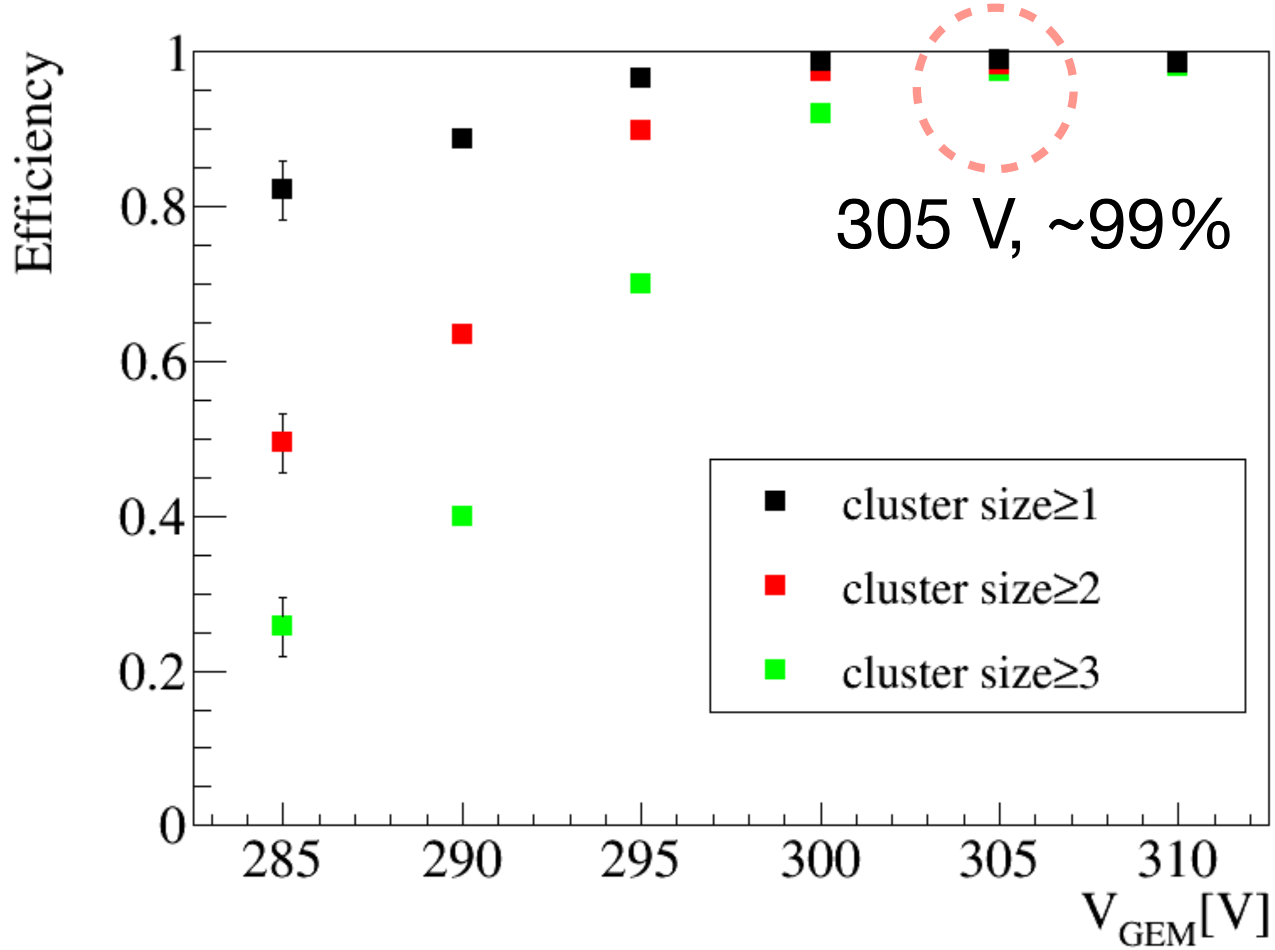






Pad Detection Efficiency

$$\text{Efficiency} = \frac{\#\text{ of clusters with the size} \geq N}{\#\text{ of tracks}}$$

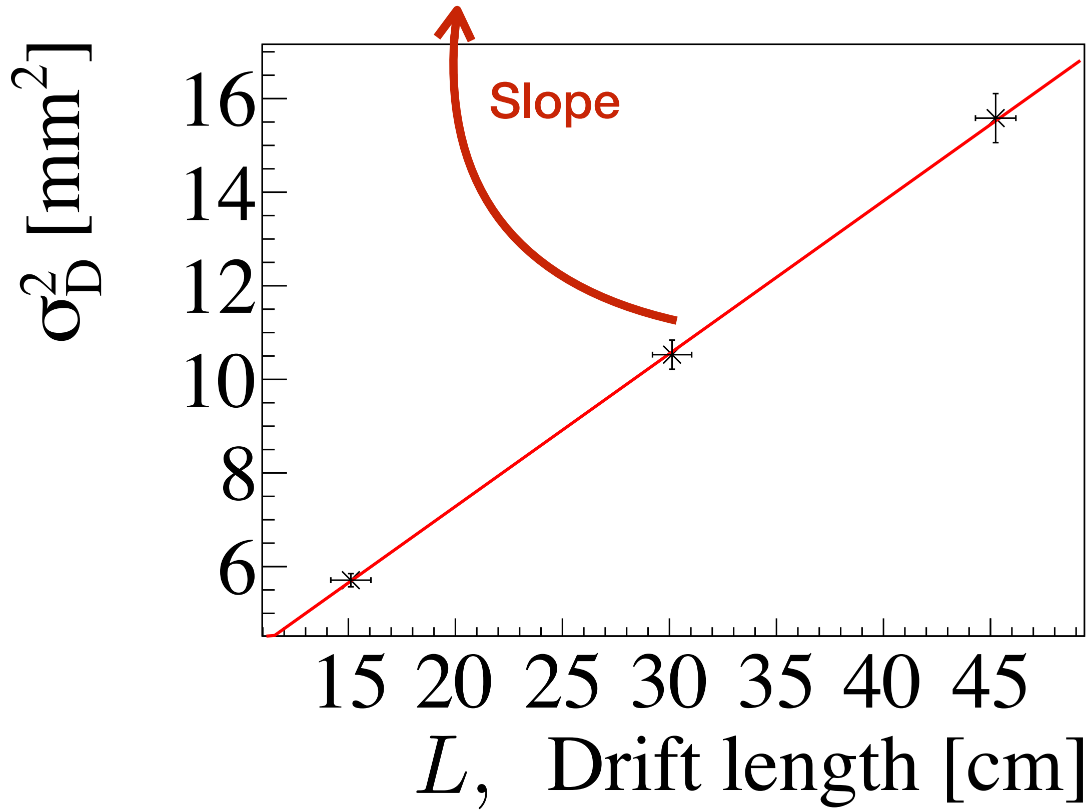


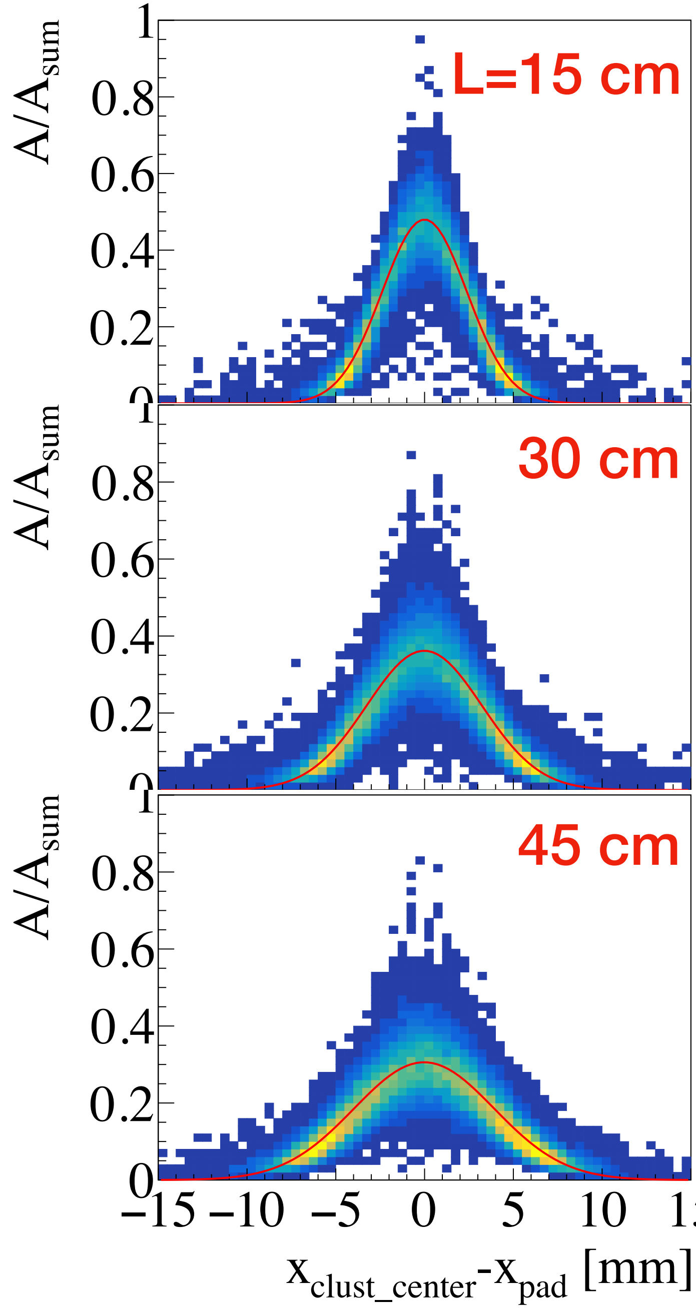
Transverse Diffusion Coefficient, D_T

$$\sigma_D(L) = \sqrt{\sigma_0^2 + D_T^2 L}$$

At E=130 V/cm, B=0 in P-10 gas,

$$D_T = 0.57 \pm 0.02\ \mathrm{mm}/\sqrt{\mathrm{cm}}$$

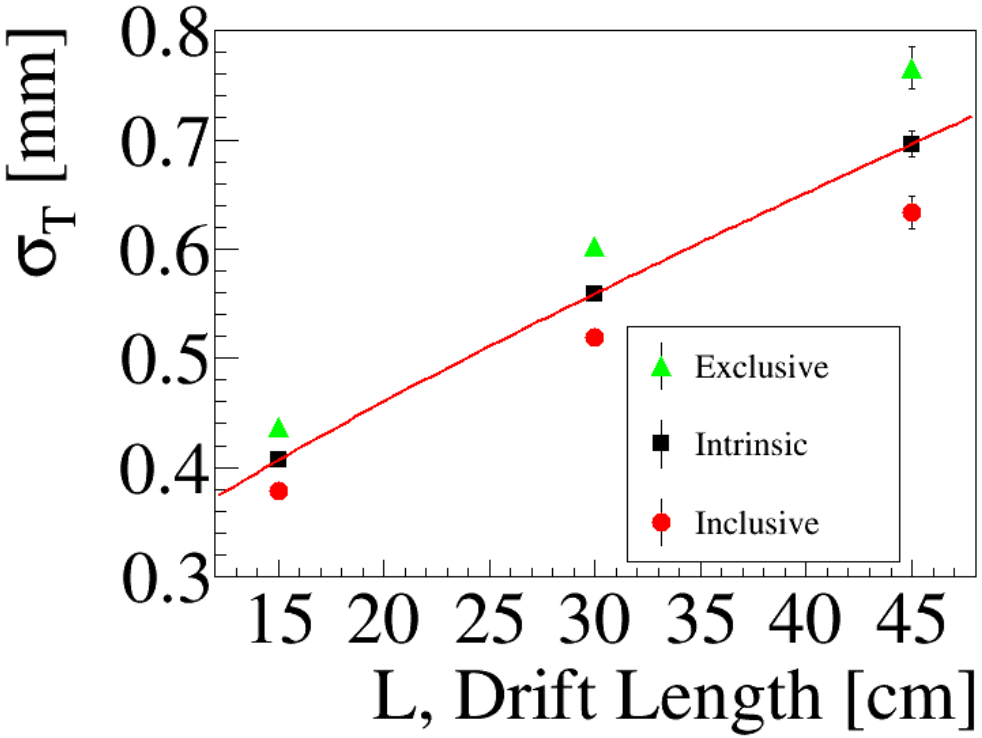


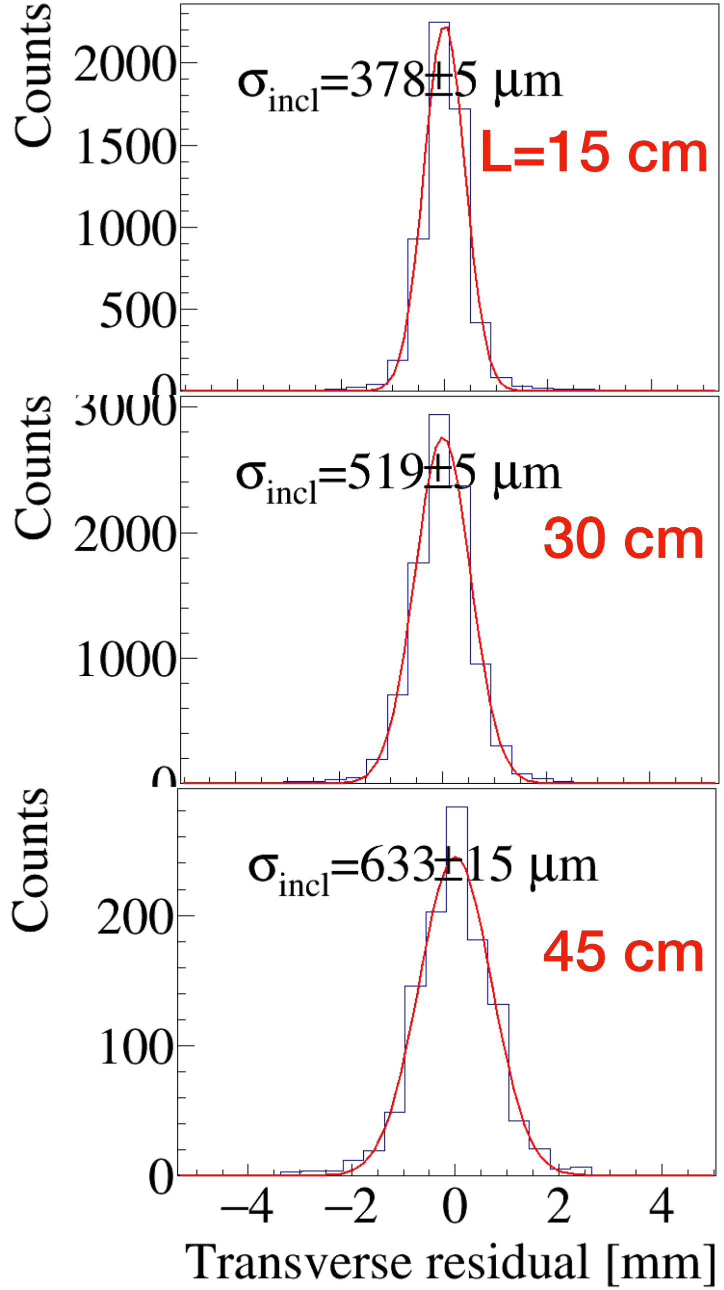


Transverse Spatial Resolution, σ_T

E=130 V/cm, B=0, P-10 gas

$$\sigma = \sqrt{\sigma_{incl} \cdot \sigma_{excl}}$$





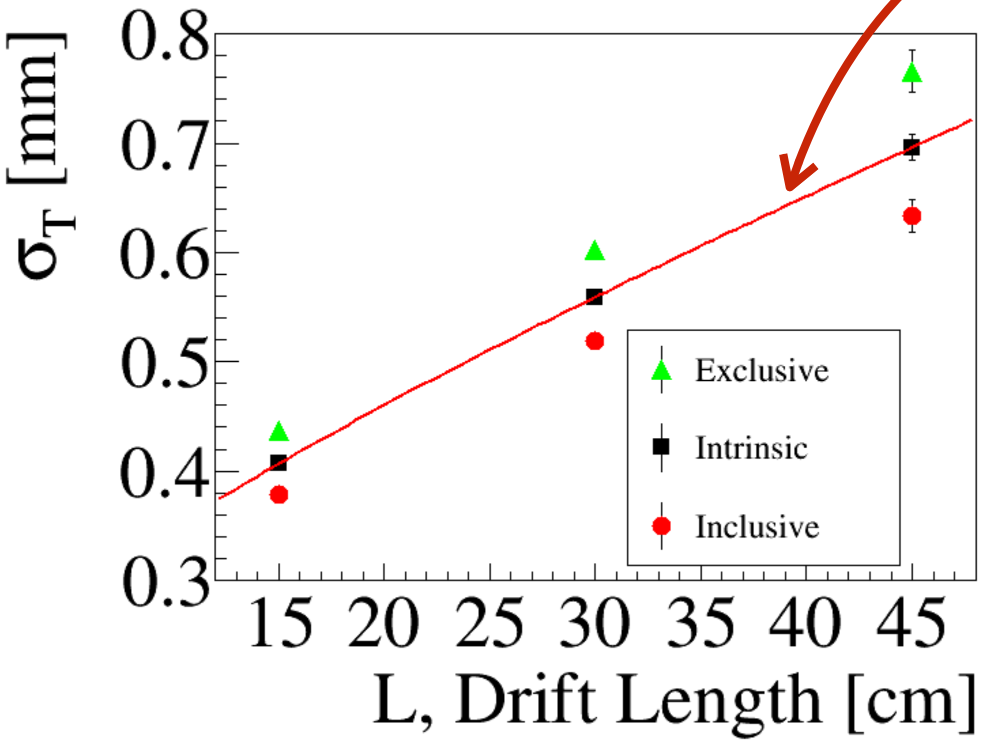
$$\sigma_T = 400 - 700\ \mu m$$

Expected σ_T under the B Field

D. Attié et al., NIMA 856 (2017) 109

E=130 V/cm, B=0, P-10 gas

$$\sigma = \sqrt{\sigma_{\text{incl}} \cdot \sigma_{\text{excl}}}$$



$$\sigma_T^2 = \sigma_0^2 + \frac{D_T^2}{N_{\text{eff}} \cdot e^{-AL}} L$$

with $D_T = 0.57\ \text{mm}/\sqrt{\text{cm}}$

$$\sigma_0 = 199 \pm 40\ \mu m$$
$$N_{\text{eff}} = 42.1 \pm 8.1$$
$$A = 0.55 \pm 0.42\ \text{m}^{-1}$$

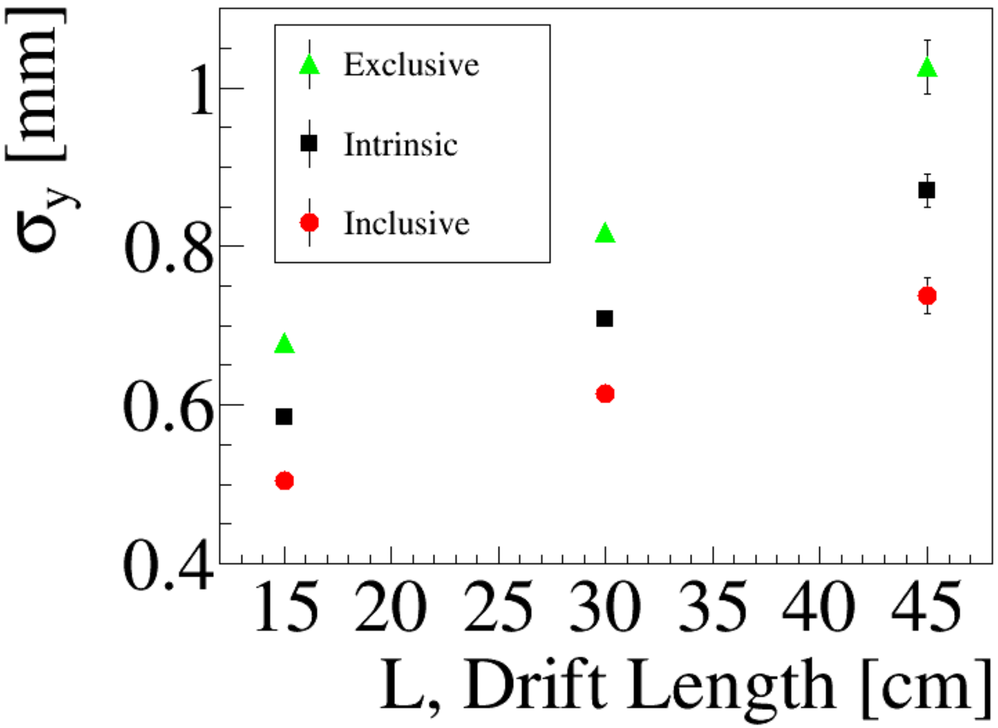
with $D_T = 0.18\ \text{mm}/\sqrt{\text{cm}}$ at $B = 1\ T$

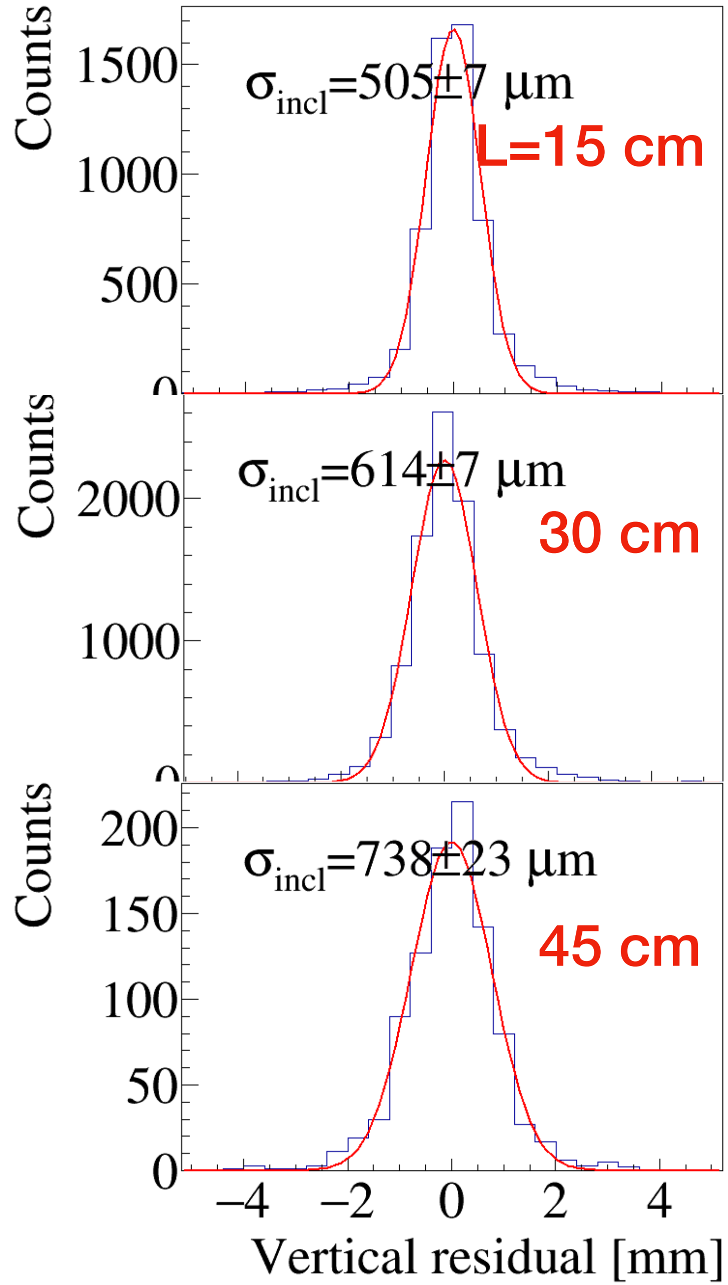
$$\sigma_T = 230 - 300\ \mu m$$

Vertical Spatial Resolution, σ_y

E=130 V/cm, B=0, P-10 gas

$$\sigma = \sqrt{\sigma_{\text{incl}} \cdot \sigma_{\text{excl}}}$$



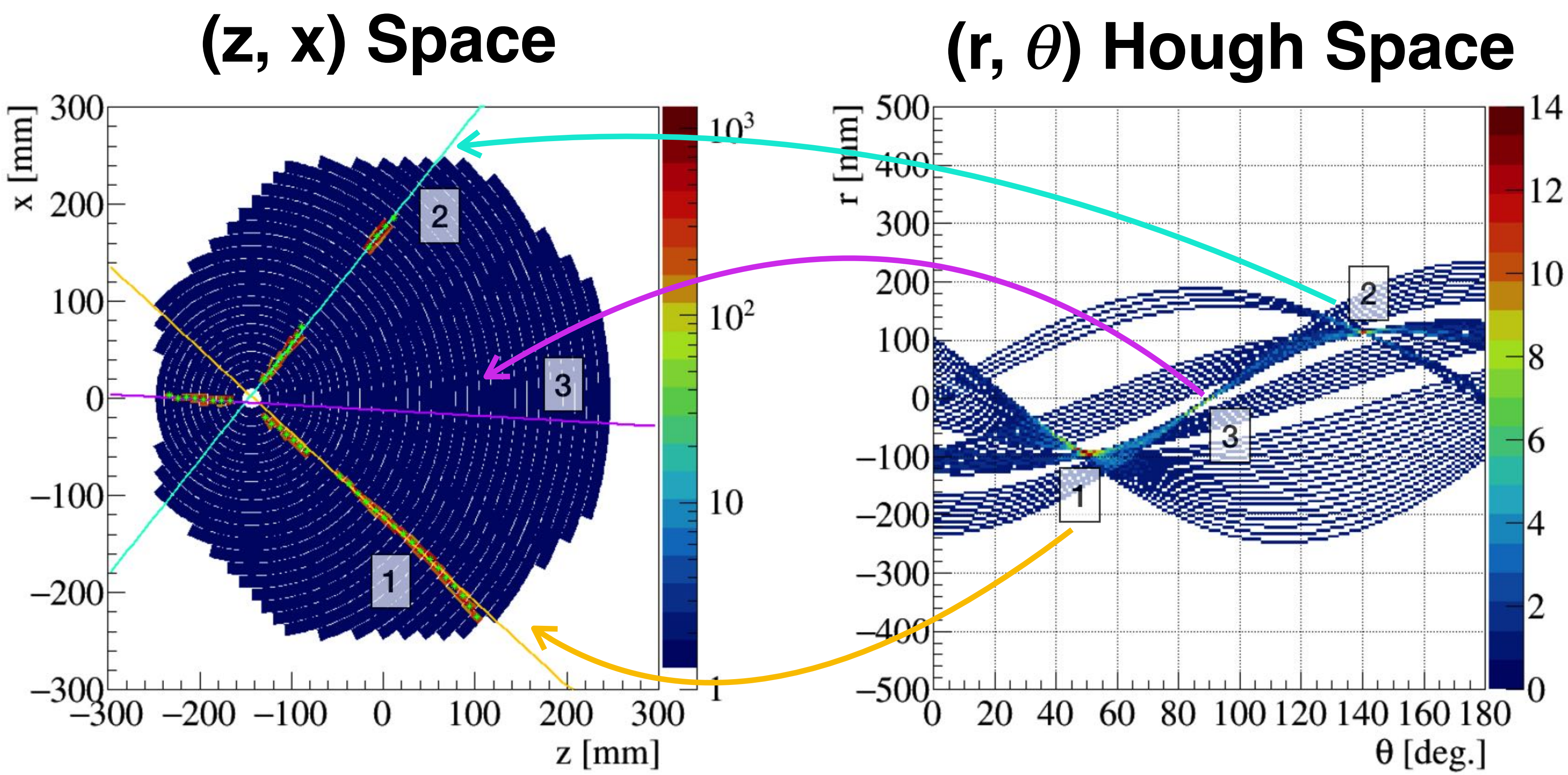


$$\sigma_y = 500 - 800\ \mu m$$

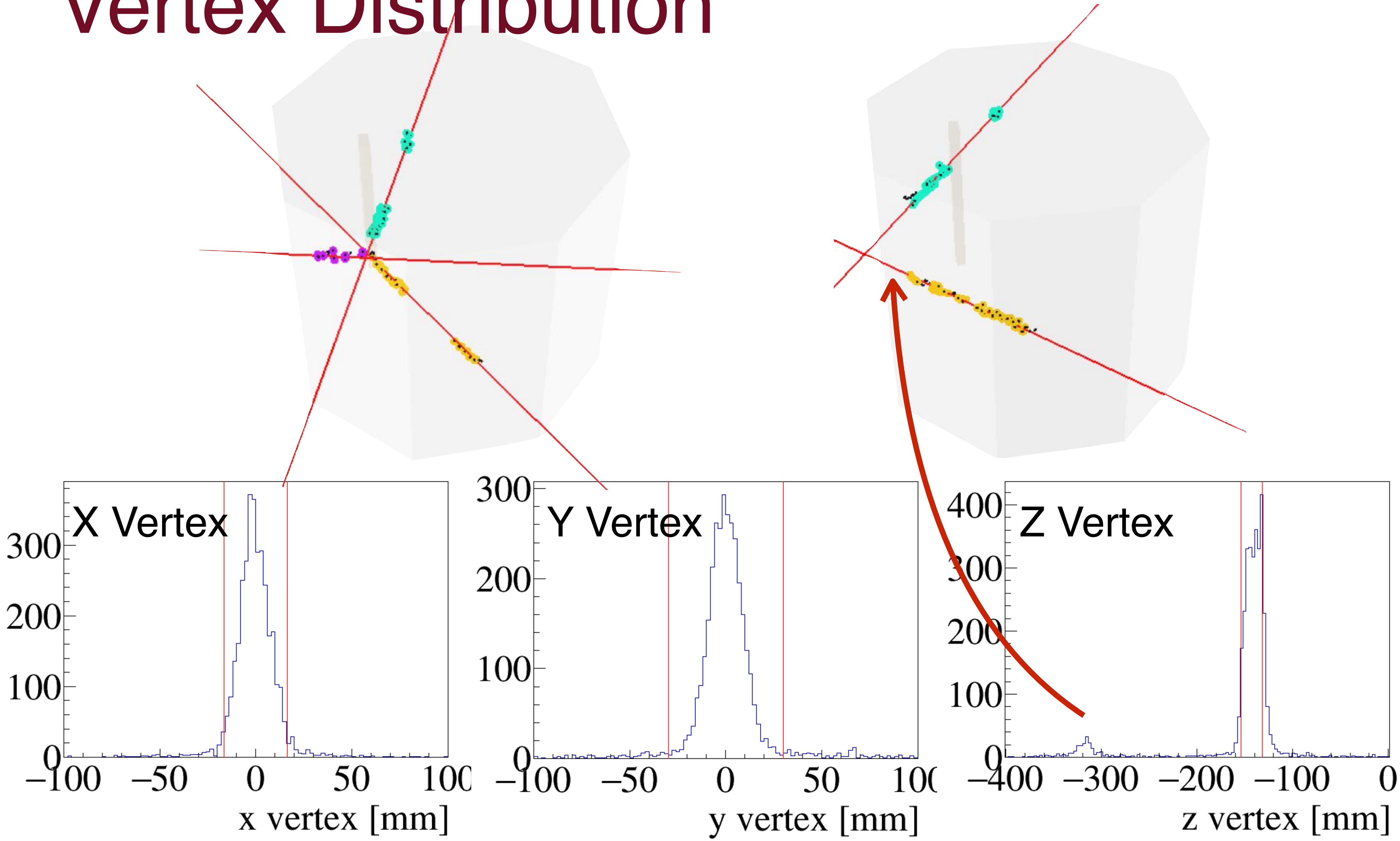
Scattering Event

- Hough Transform from the (z, x) plane

$$r = z \cdot \cos\theta + x \cdot \sin\theta$$

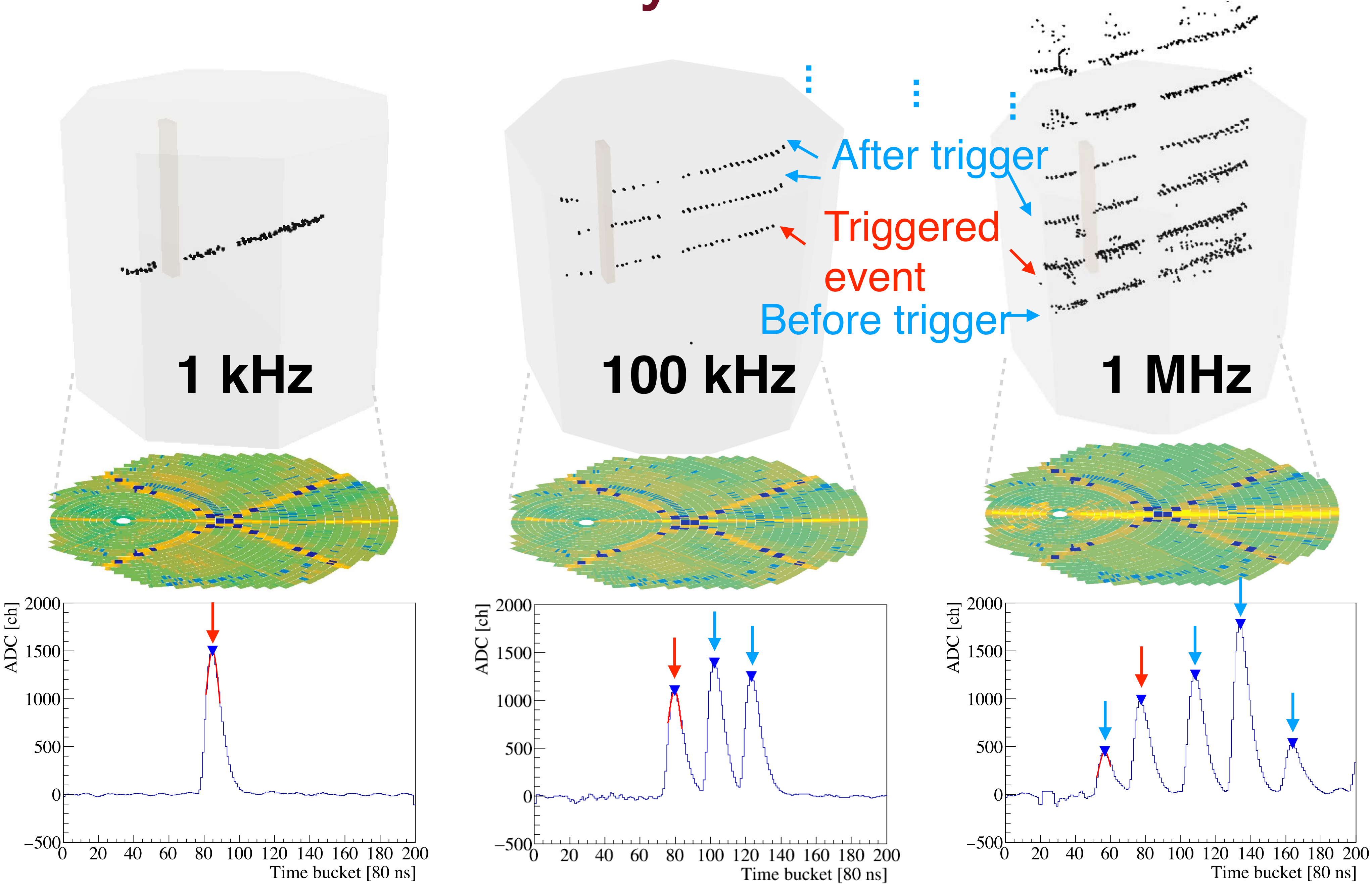


Vertex Distribution



CH_2 Target size : 3 cm (x) x 6 cm (y) x 2 cm (z)

Beam Rate Study

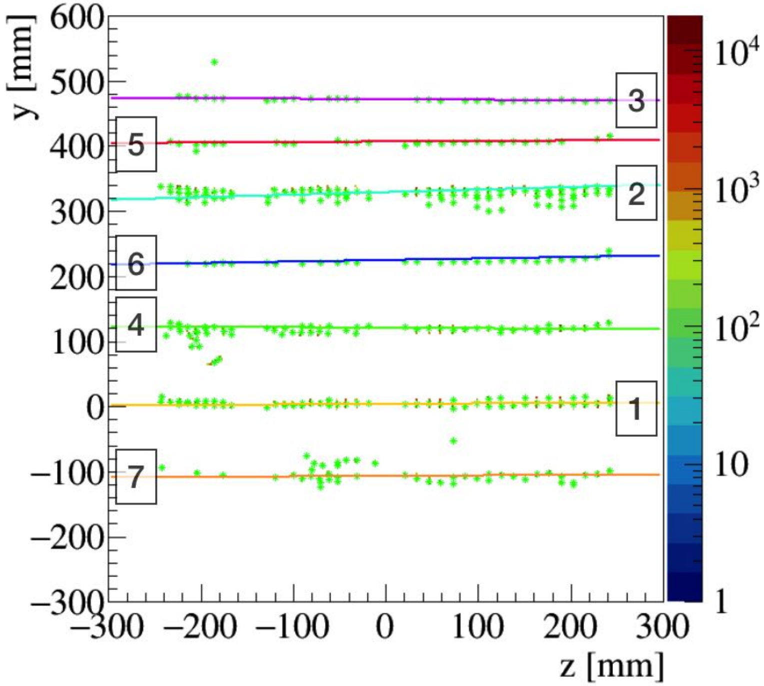


Beam Event at High-Rate Beam

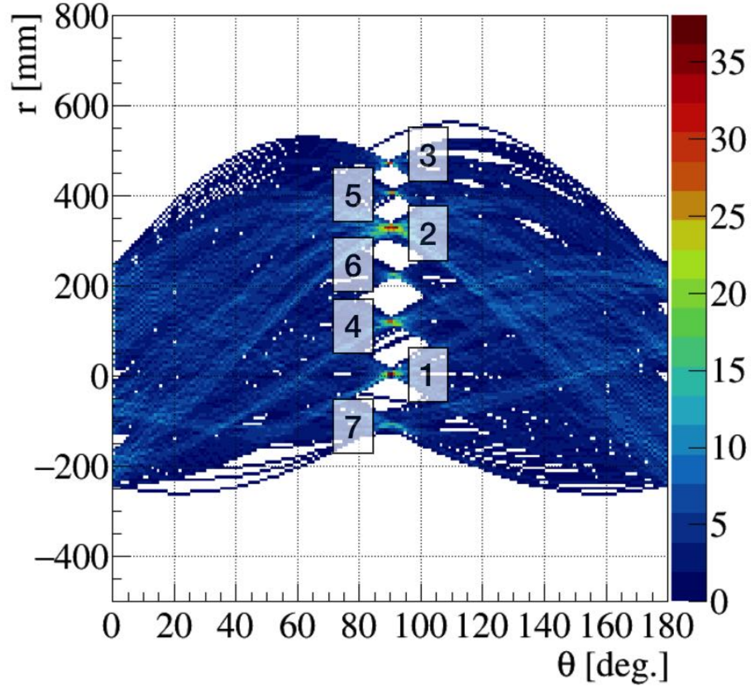
- Hough Transform from the (z, y) plane

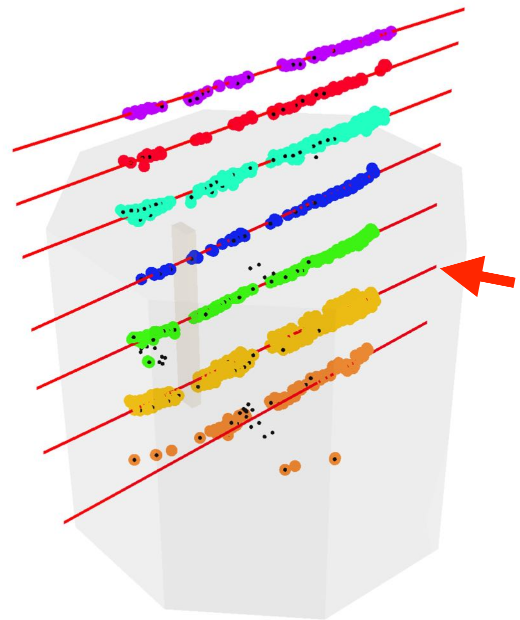
$$r = z \cdot \cos\theta + y \cdot \sin\theta$$

(z, y) Space



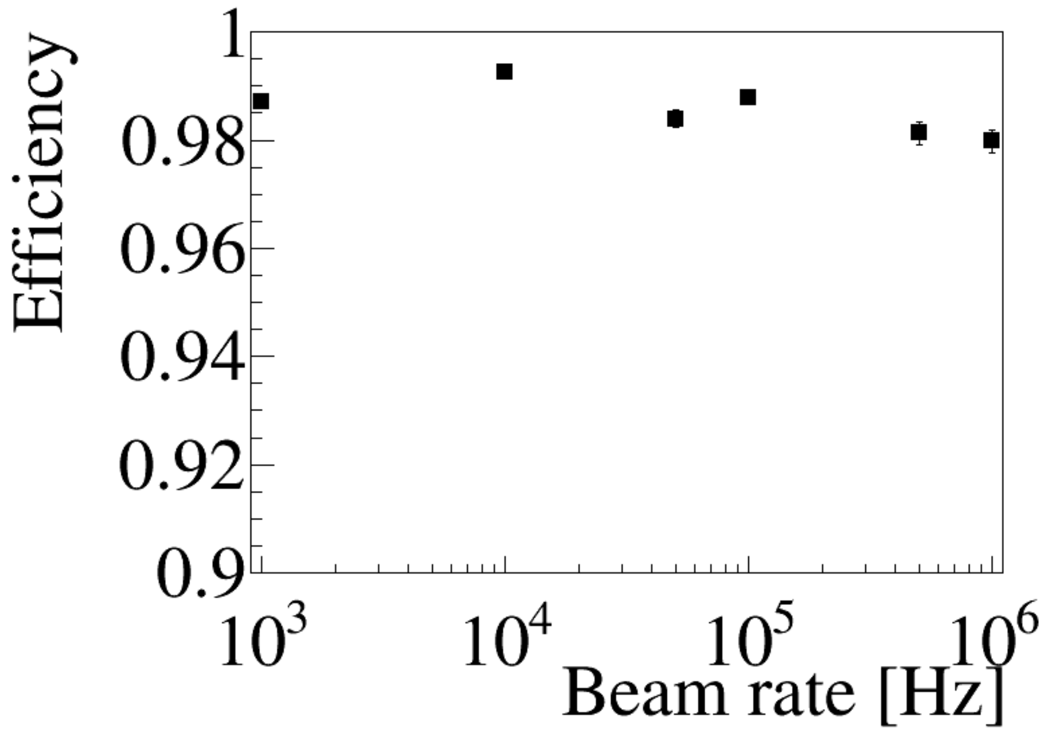
(r, θ) Hough Space



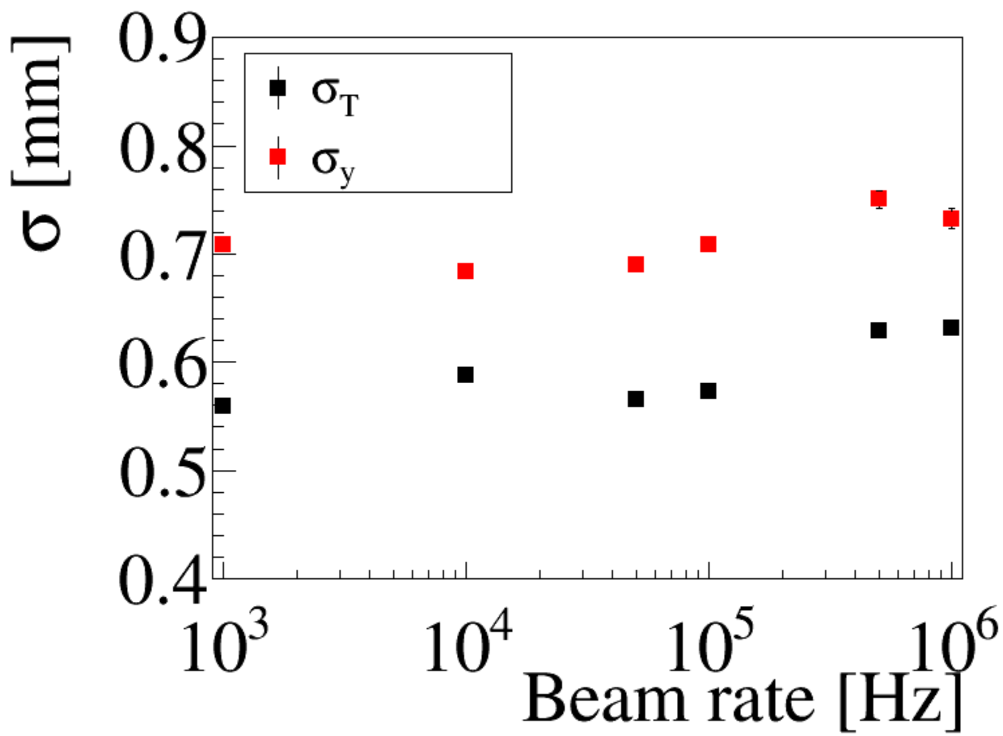


TPC Performance at High-Rate Beam

- **Pad Efficiency**



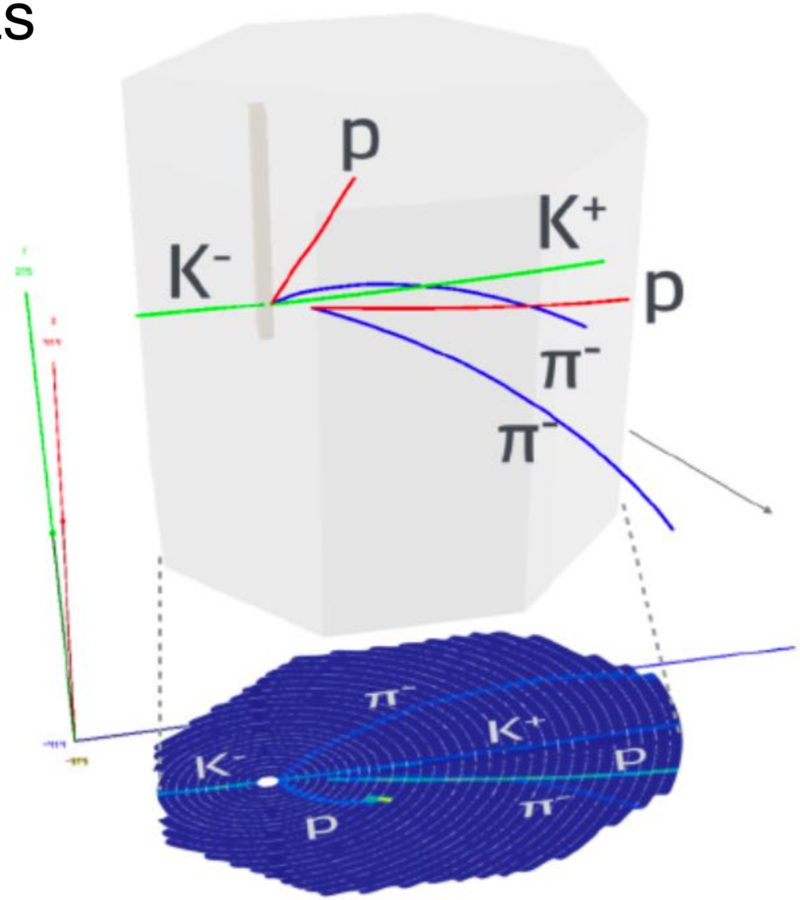
- **Spatial Resolution**



Summary

- A time projection chamber(HypTPC) has been newly developed for the various hadron experiments at J-PARC.
- We confirmed the basic performance and the high rate capability of HypTPC in the proton beam test at HIMAC.
- The first physics experiment with HypTPC (E42) is envisioned in 2020.

Stay tuned!



Backup

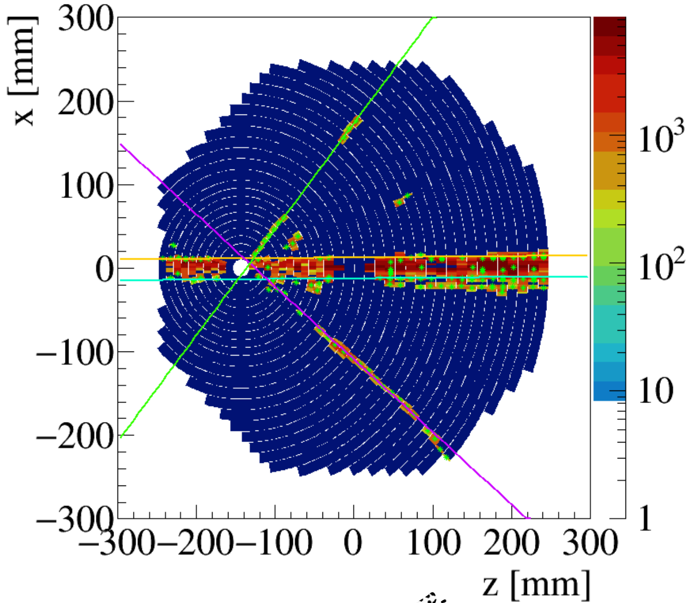
Scattering Events at 1 MHz Beam

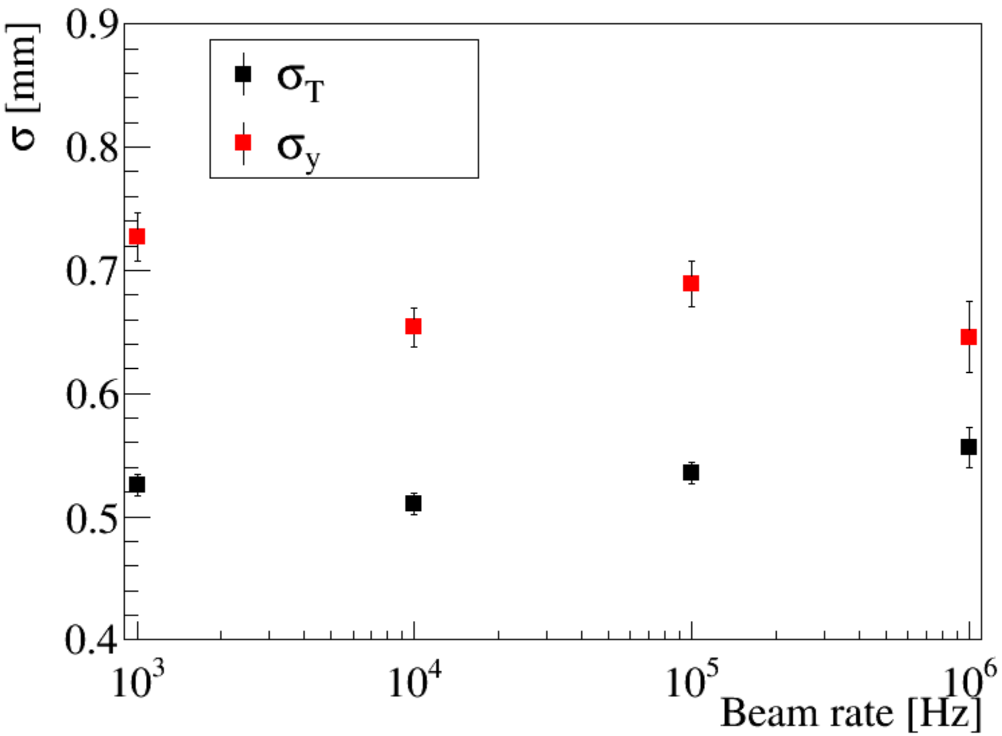
- Hough Transform from the **(z, y)** space to separate the accidental beam events

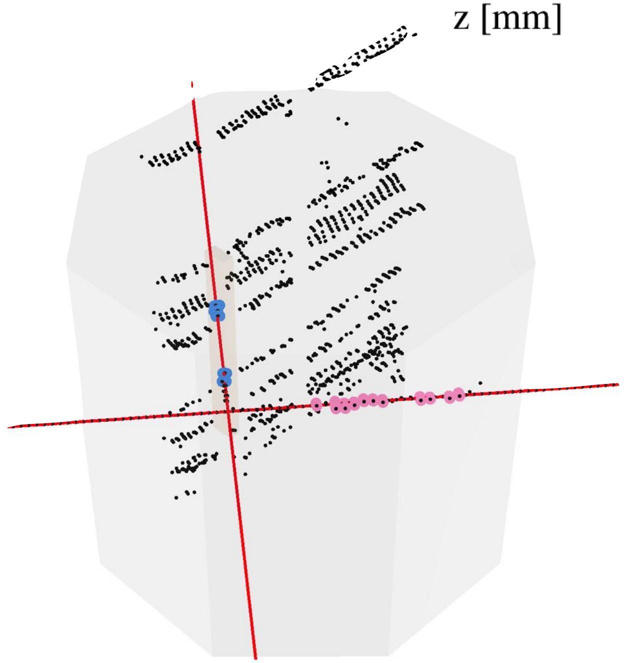
$$r = z \cdot \cos\theta + y \cdot \sin\theta$$

- Hough Transform from the **(z, x)** space to separate the scattered particle tracks

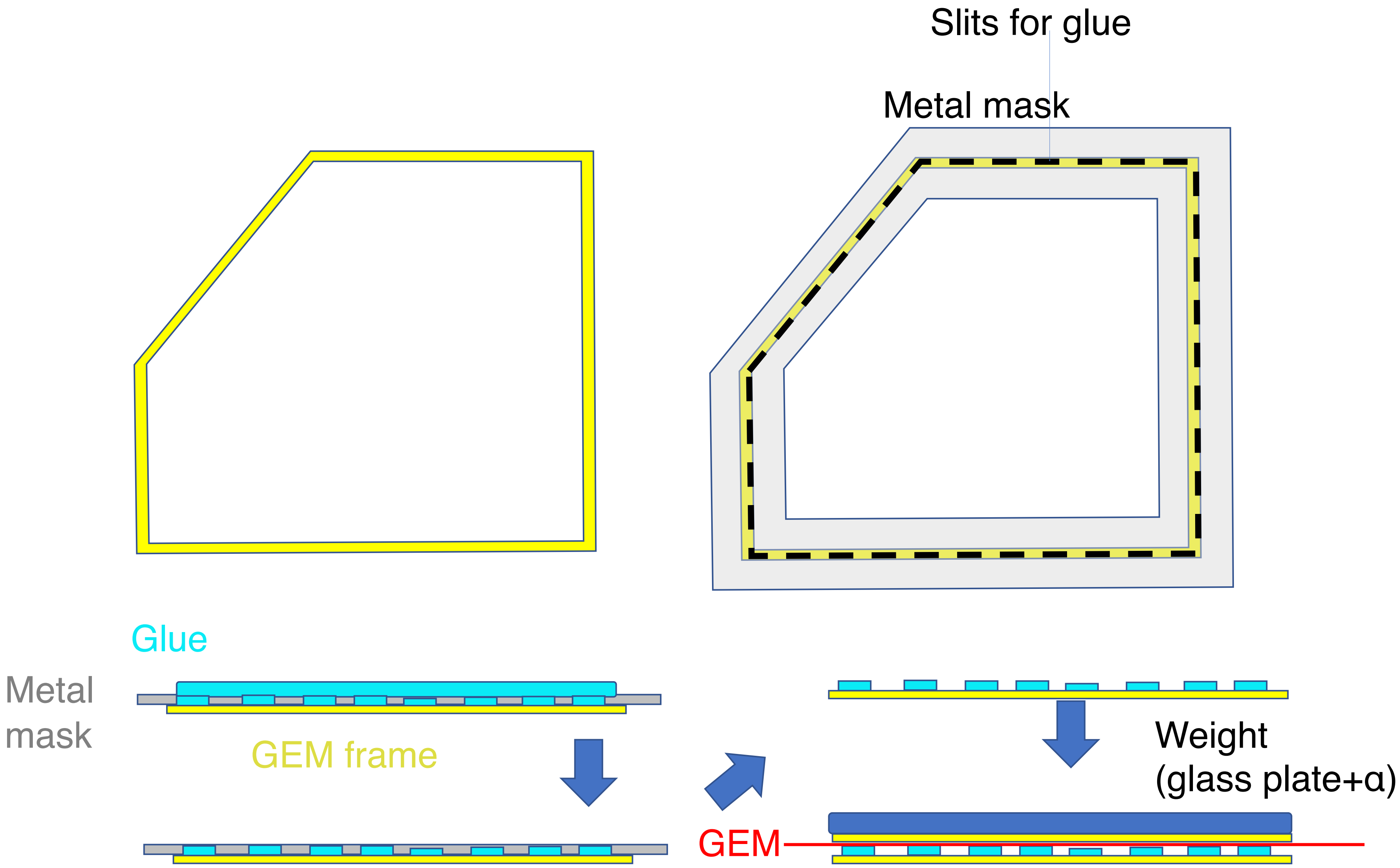
$$r = z \cdot \cos\theta + x \cdot \sin\theta$$

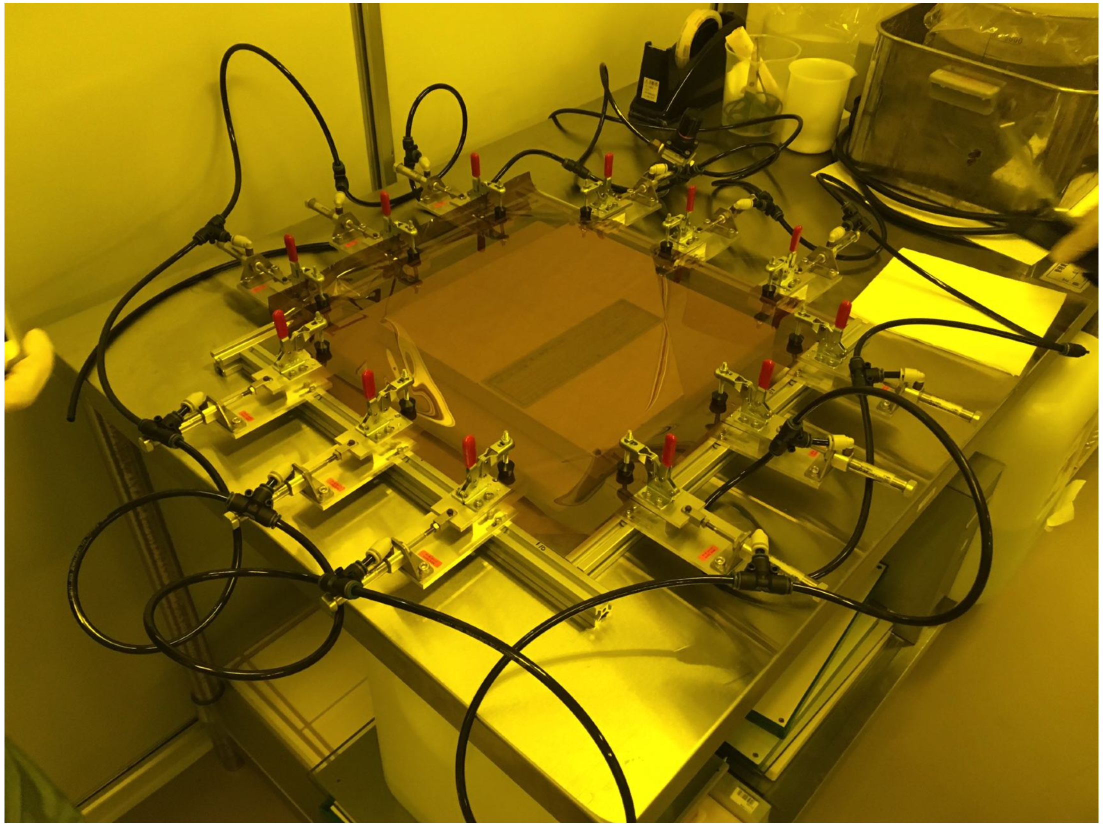




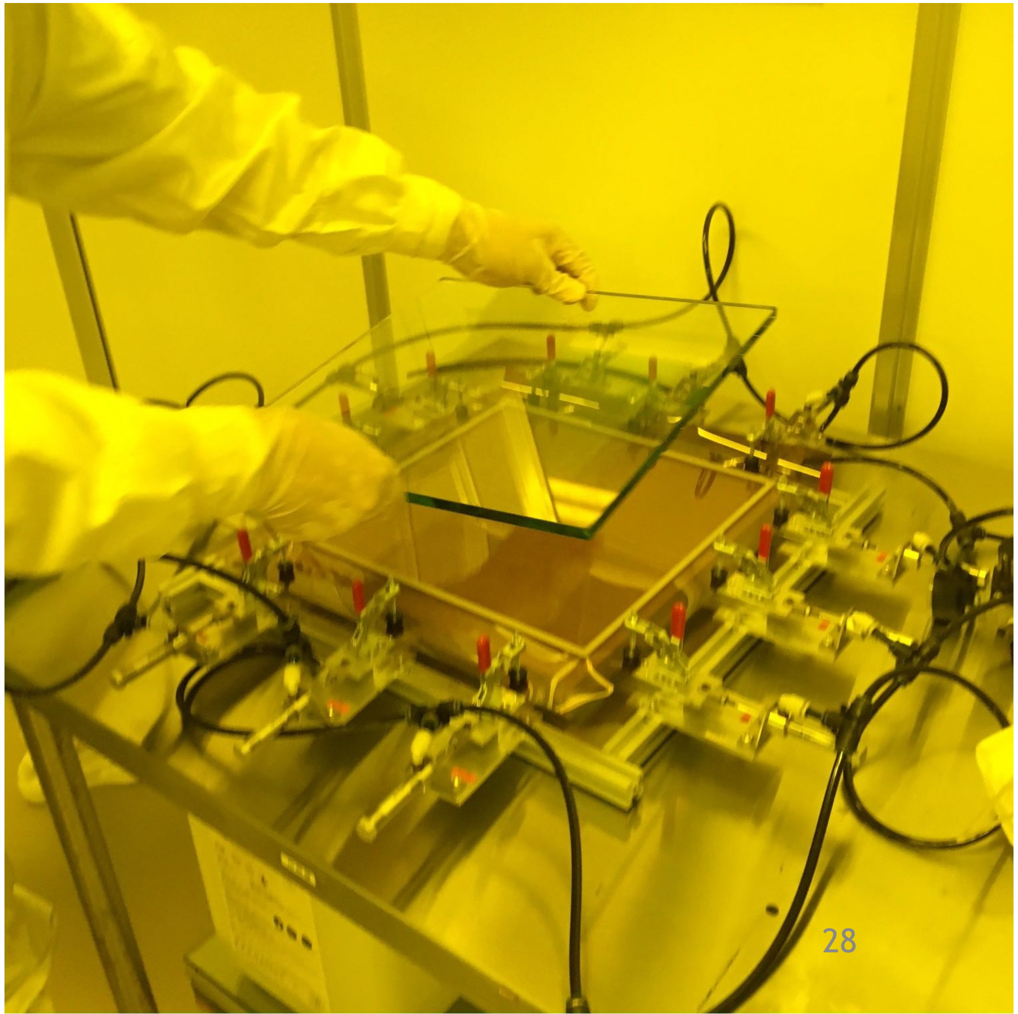


How To Attach GEM Frame



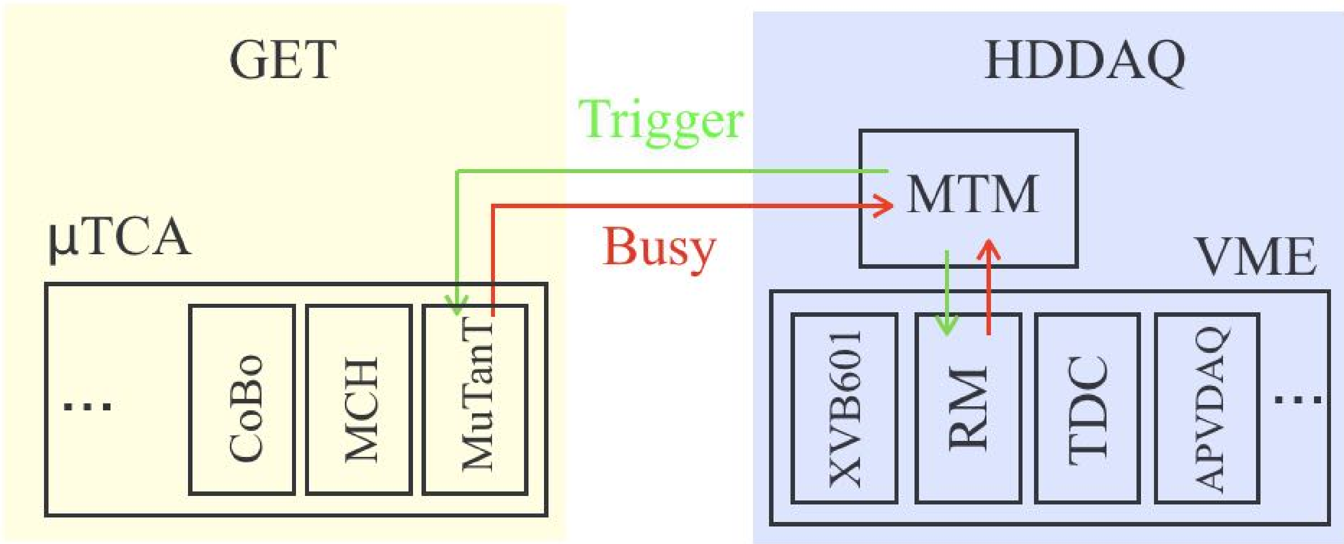


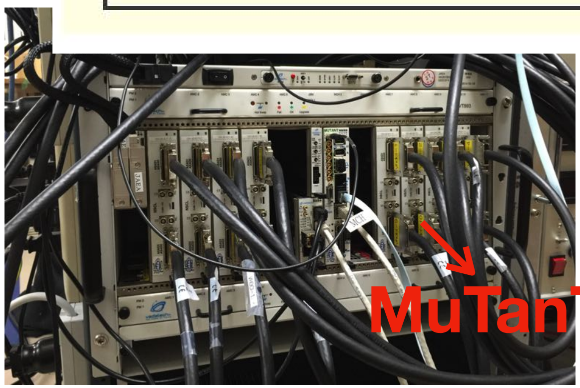
Tension of 0.24 Pa with 12 cylinders

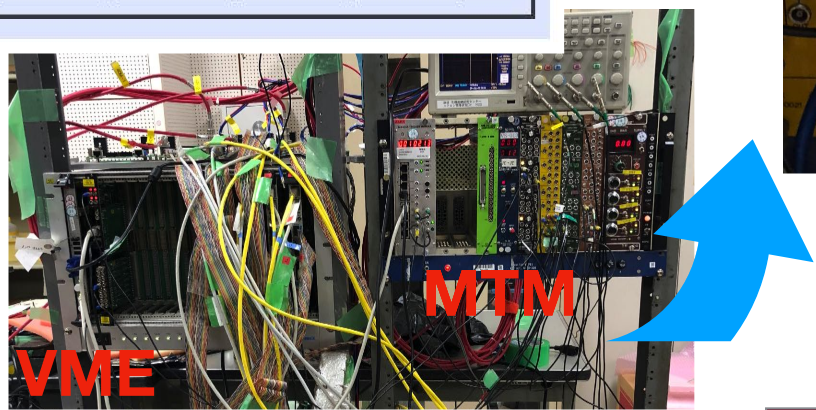


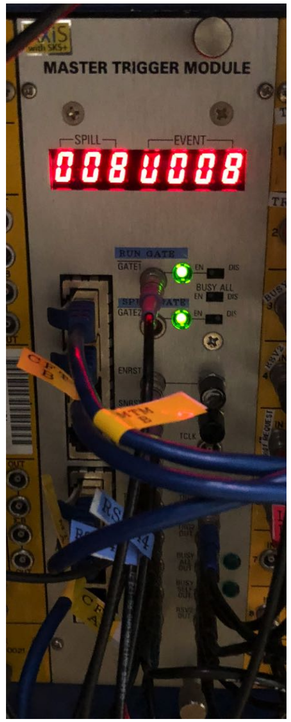
DAQ System at HIMAC(GET + HDDAQ)

- The HDDAQ(K1.8 beam line DAQ) was used for the data acquisition of the trigger counters and the SSDs.
- The GET(TPC DAQ) shares the trigger and busy signal with HDDAQ using MuTanT module.



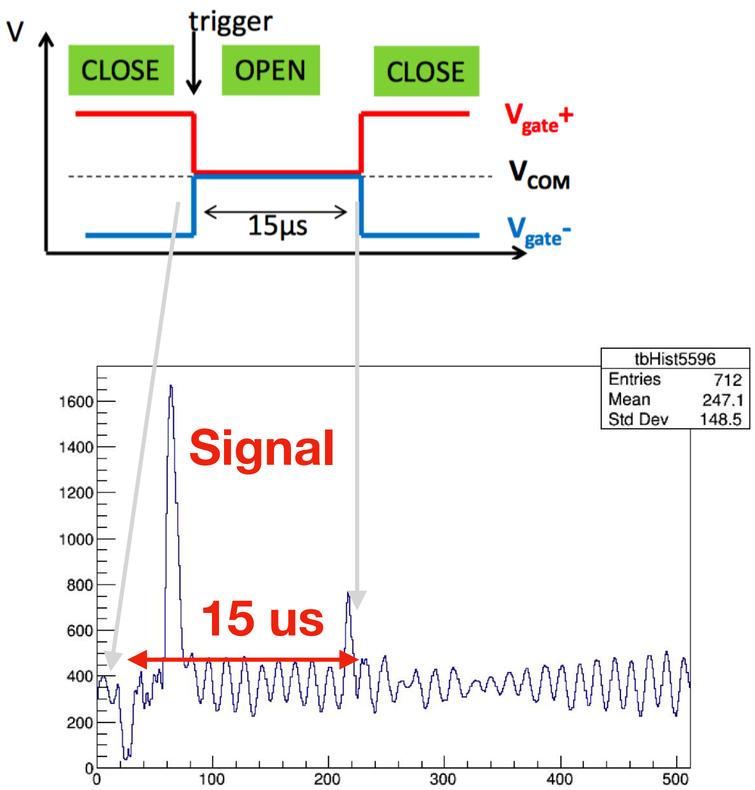






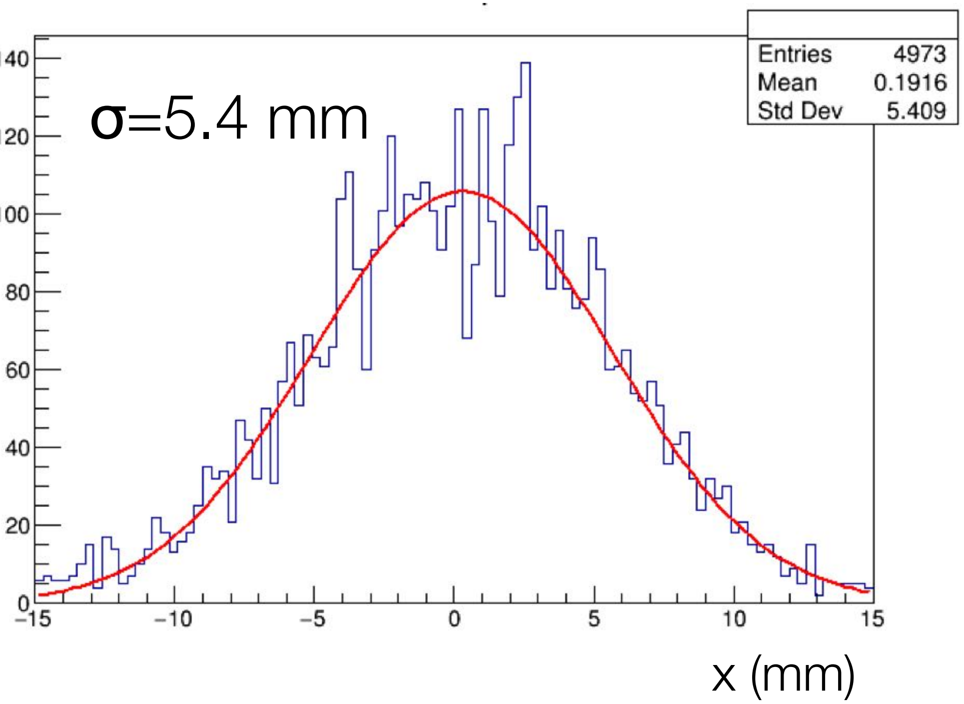
DAQ Performance

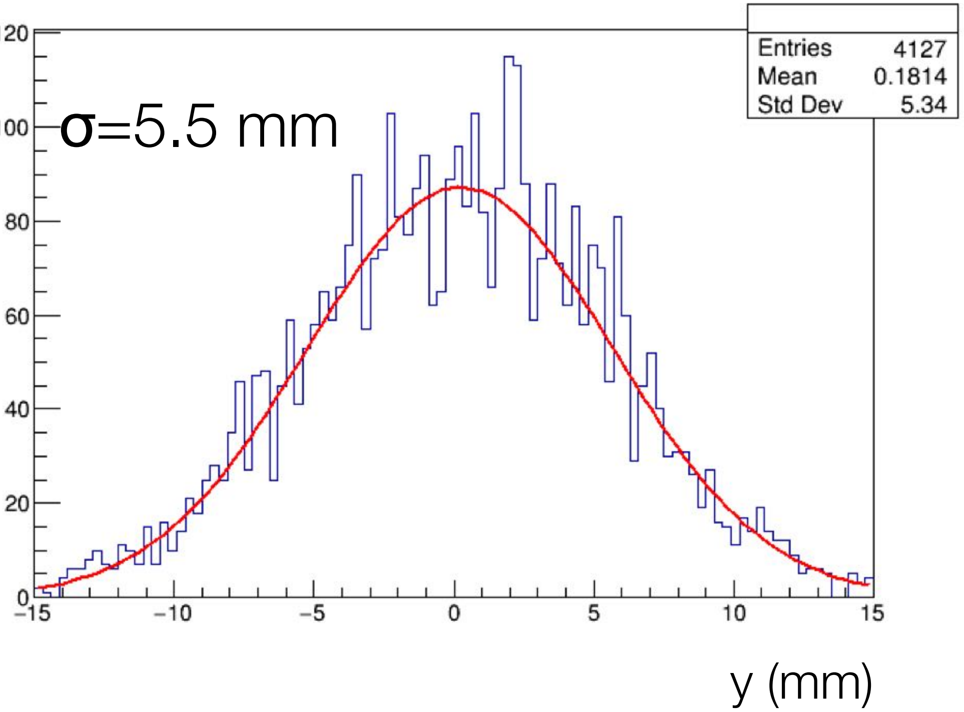
- Due to the gate noise, the full readout mode was used.
- The data size/CoBo for each event in the full readout mode with 200 time buckets was 426 kB and the measured data transfer speed for each CoBo was ~420 Mbps.



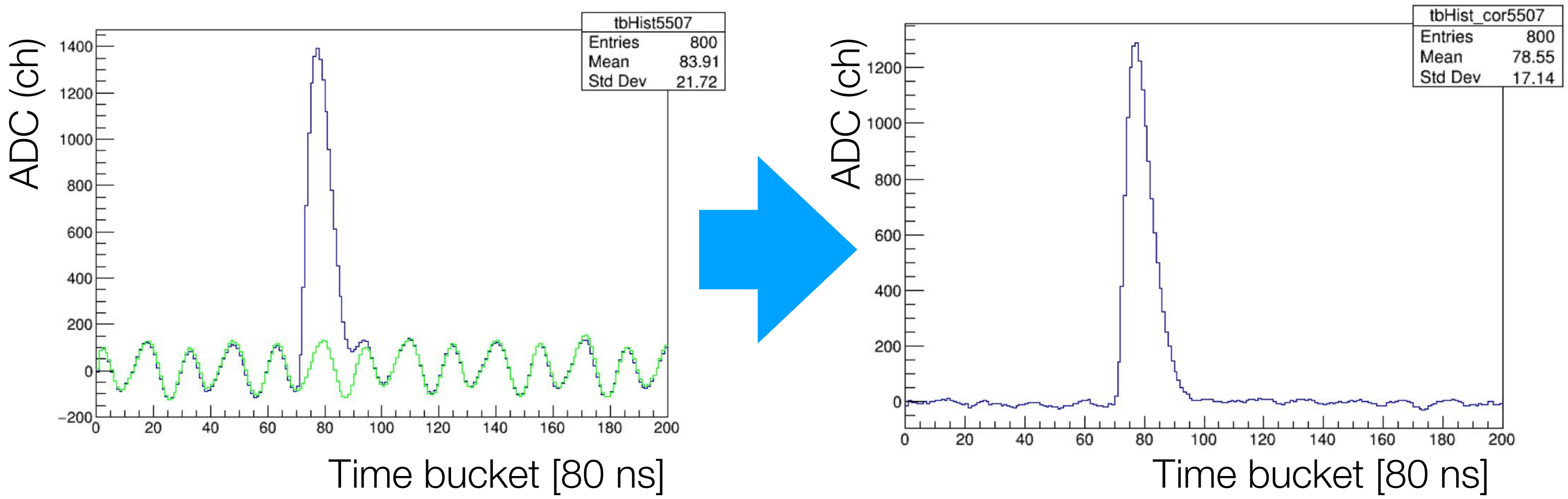
- The HIMAC beam had a spill structure with ~1 sec length in every ~3.3 sec cycle.
- The beam rate was varied in a range of 10^3 - 10^6 cps.
- We used the pre-scaled trigger rate of ~230 Hz with ~100 % DAQ efficiency.

Upstream SSD Beam Profile



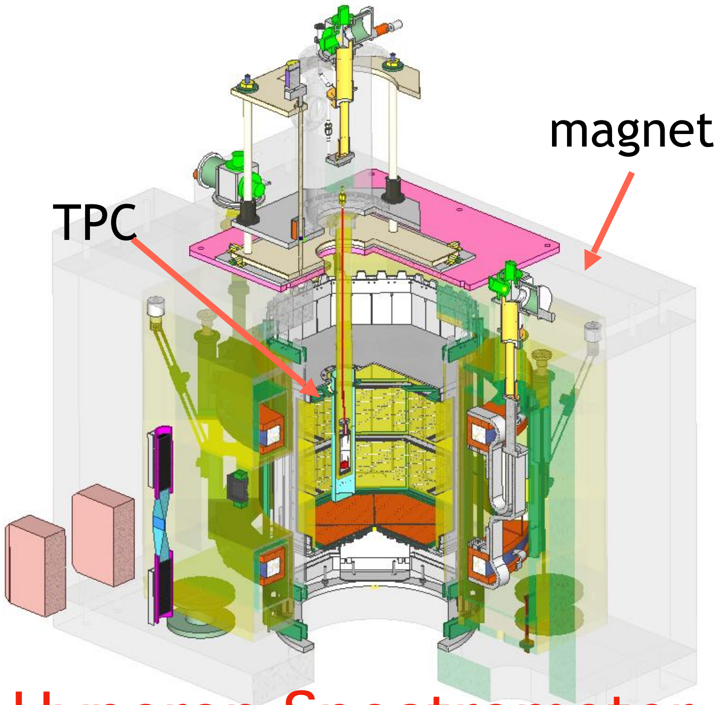


Baseline Correction

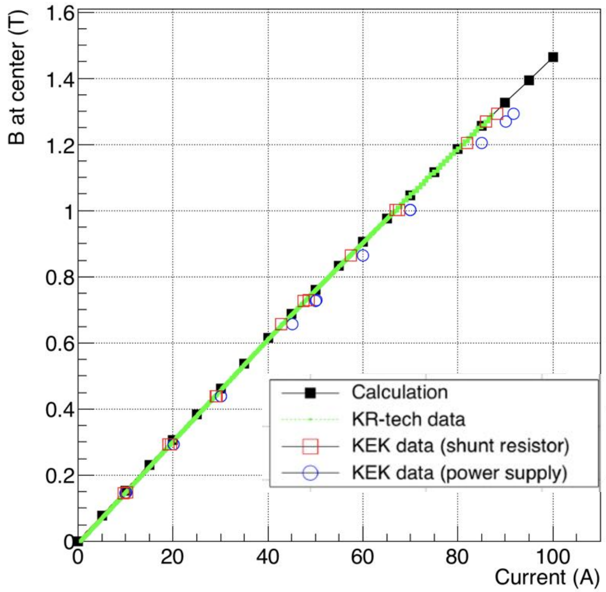


Superconducting Magnet

- Helmholtz-typed Magnet
- NbTi(T_c=9 K), Cu/SC = 2.4
- 1.5 T Max. @ 103 A
- $\Delta B_y/B_0$<3 % in TPC volume

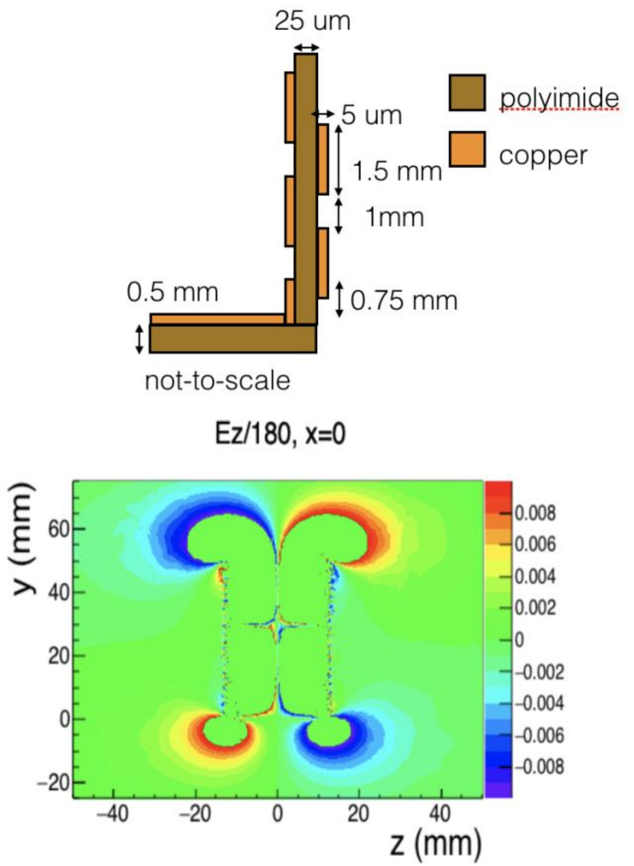


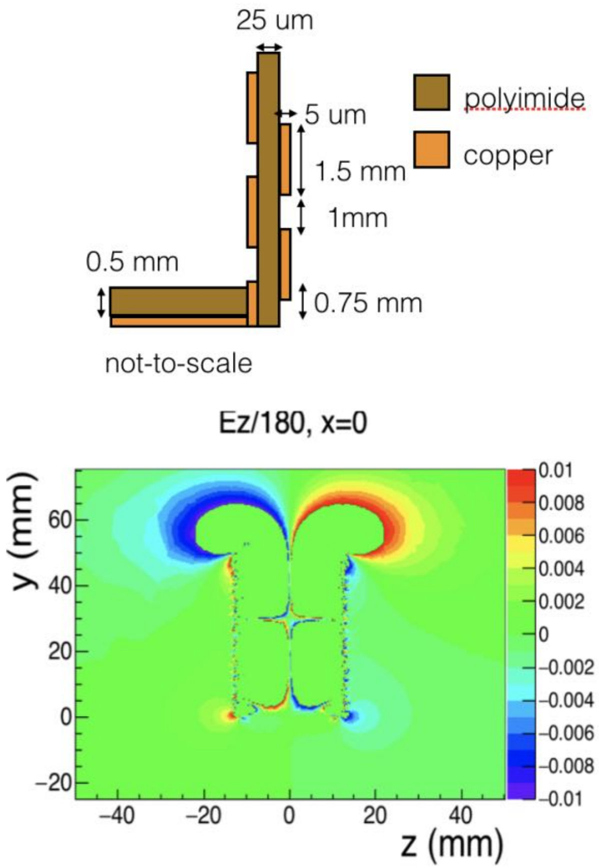
<Hyperon Spectrometer>



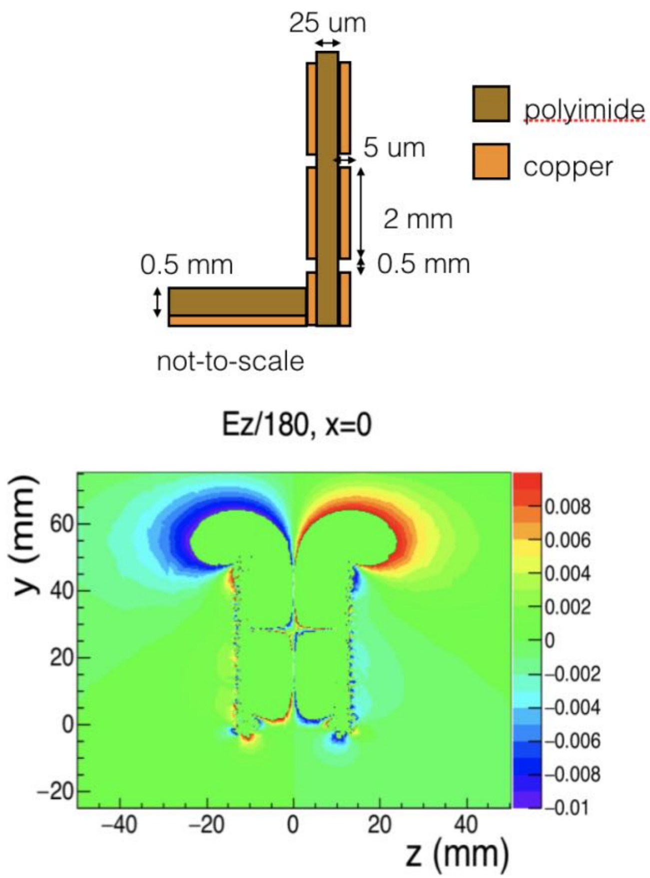
E Field Calculation

Staggered Field Strip

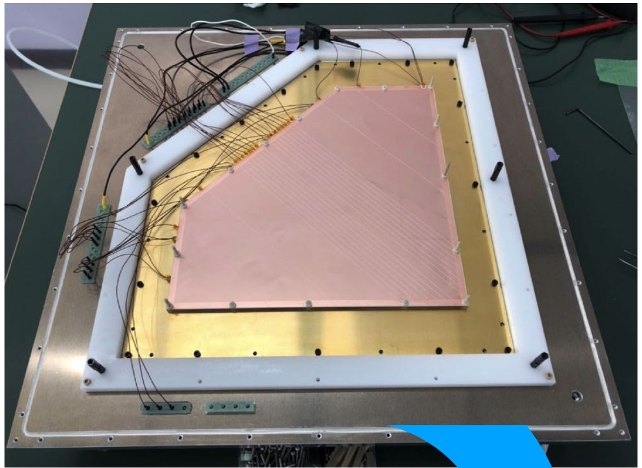


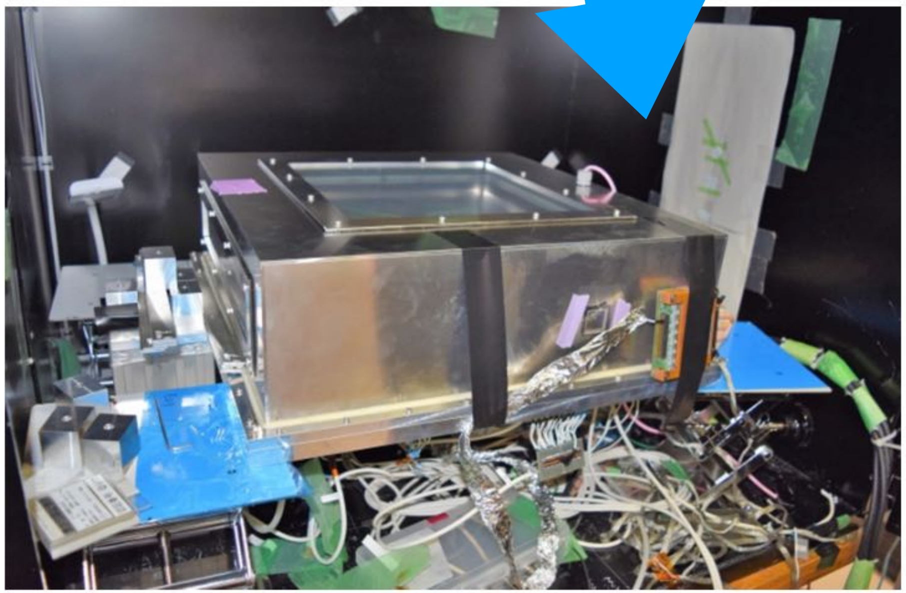


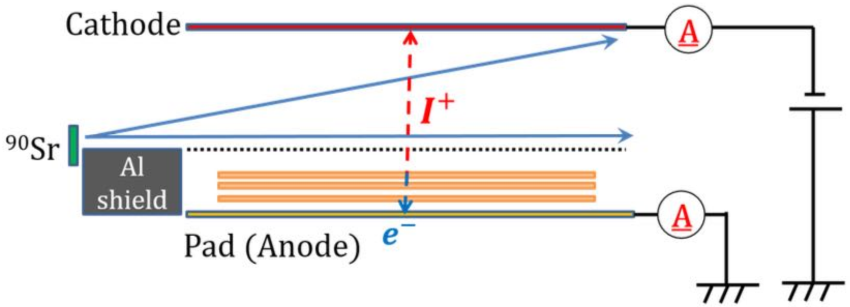
Non-staggered

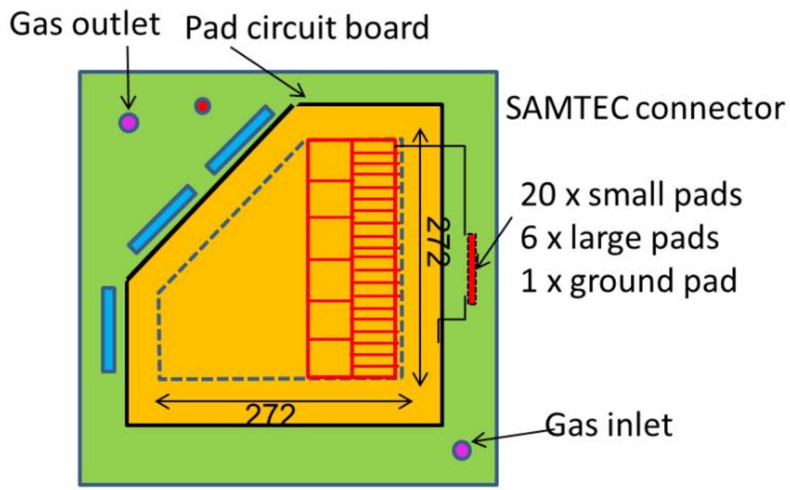


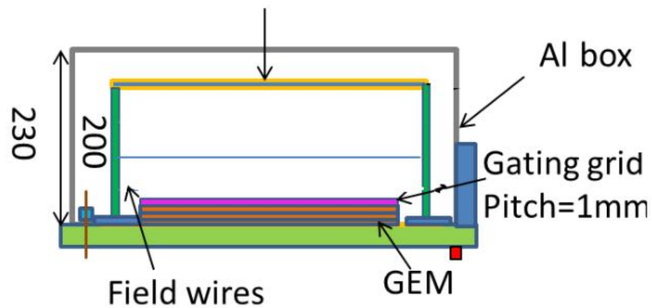
GEM Q/A with Test Chamber











GEM Q/A with Test Chamber