Korea-China joint workshop for rare isotope physics

Jeju Island, Jul 6-10, 2025

A GEM-Based TPC (HypTPC) for Hadron Experiments at J-PARC

Shin Hyung Kim

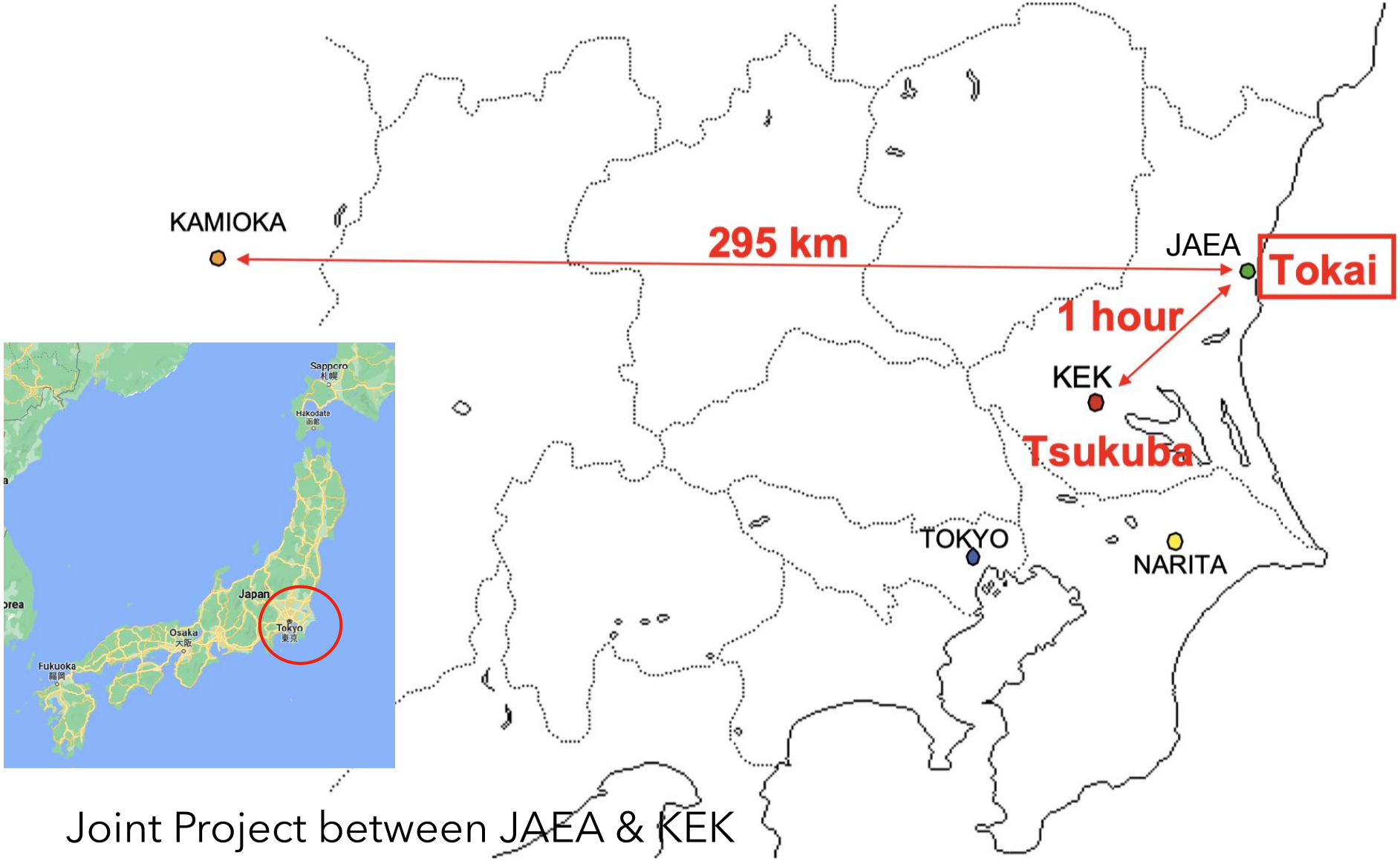
(Kyungpook National University)

KNU KYUNGPOOK NATIONAL UNIVERSITY

J-PARC HypTPC Collaboration

J-PARC (**J**apan **P**roton **A**ccelerator **R**esearch **C**omplex)

- the world's top class high-energy and high-intensity proton beam



Joint Project between JAEA & KEK

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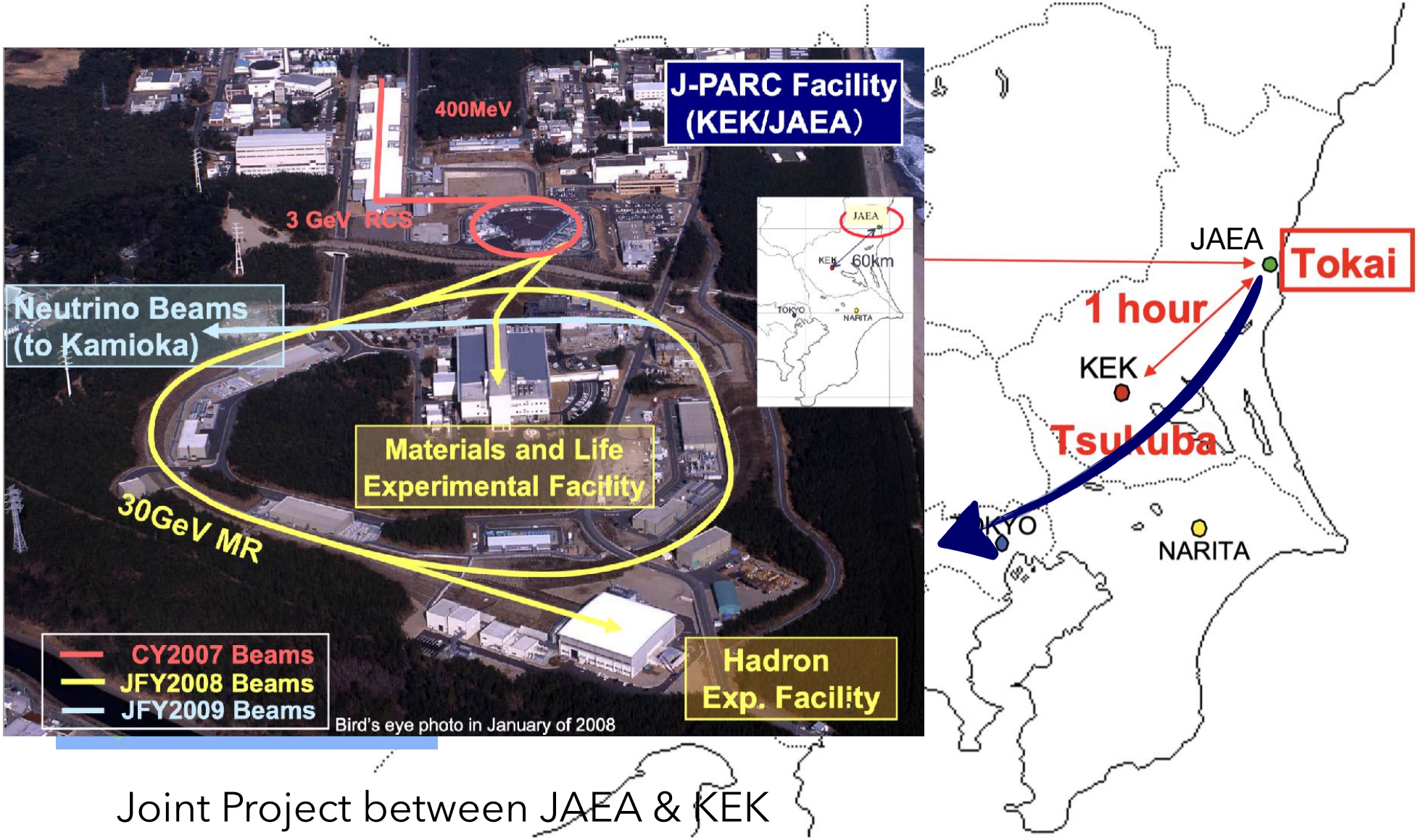
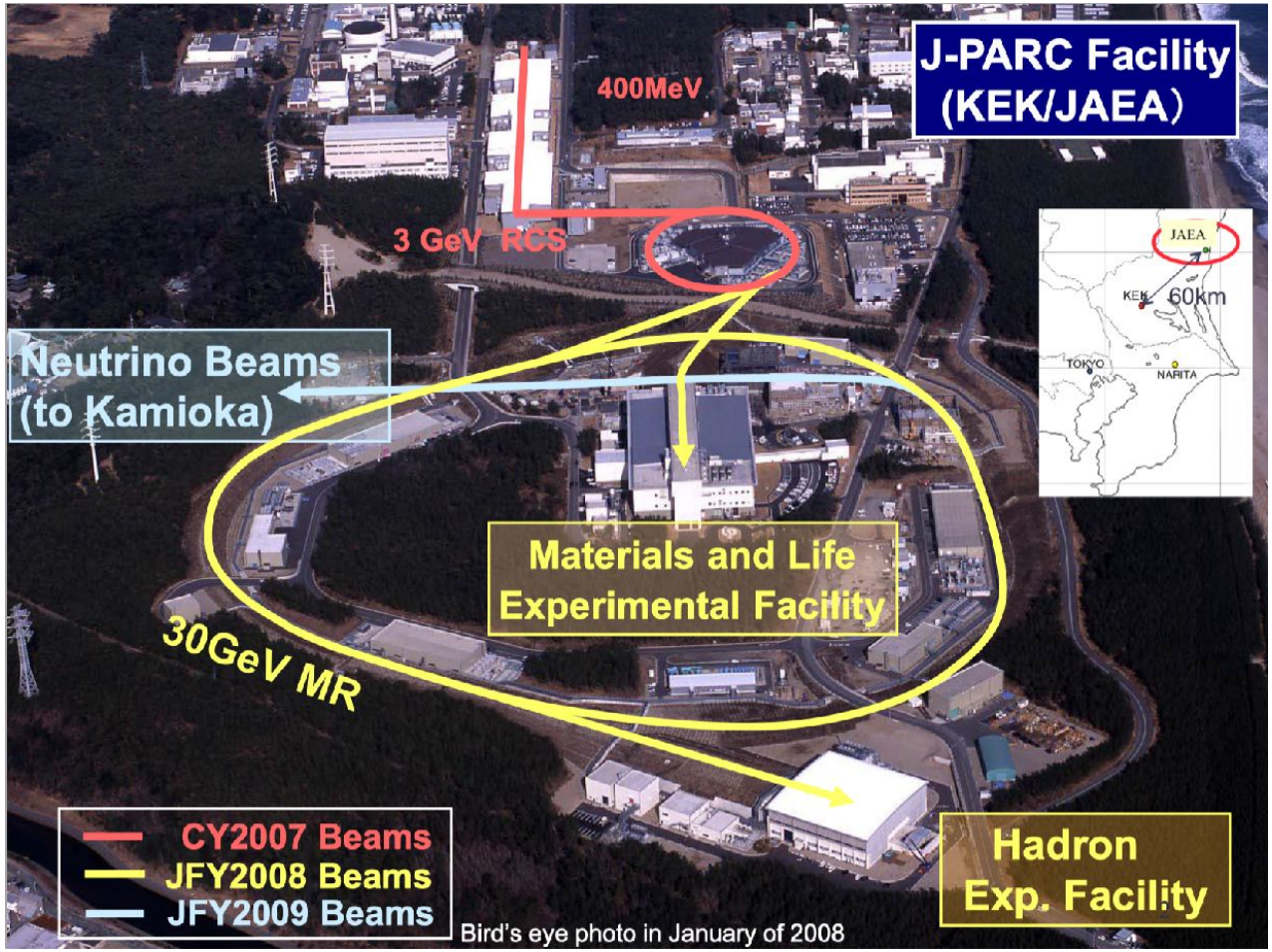
- the world's top class high-energy and high-intensity proton beam

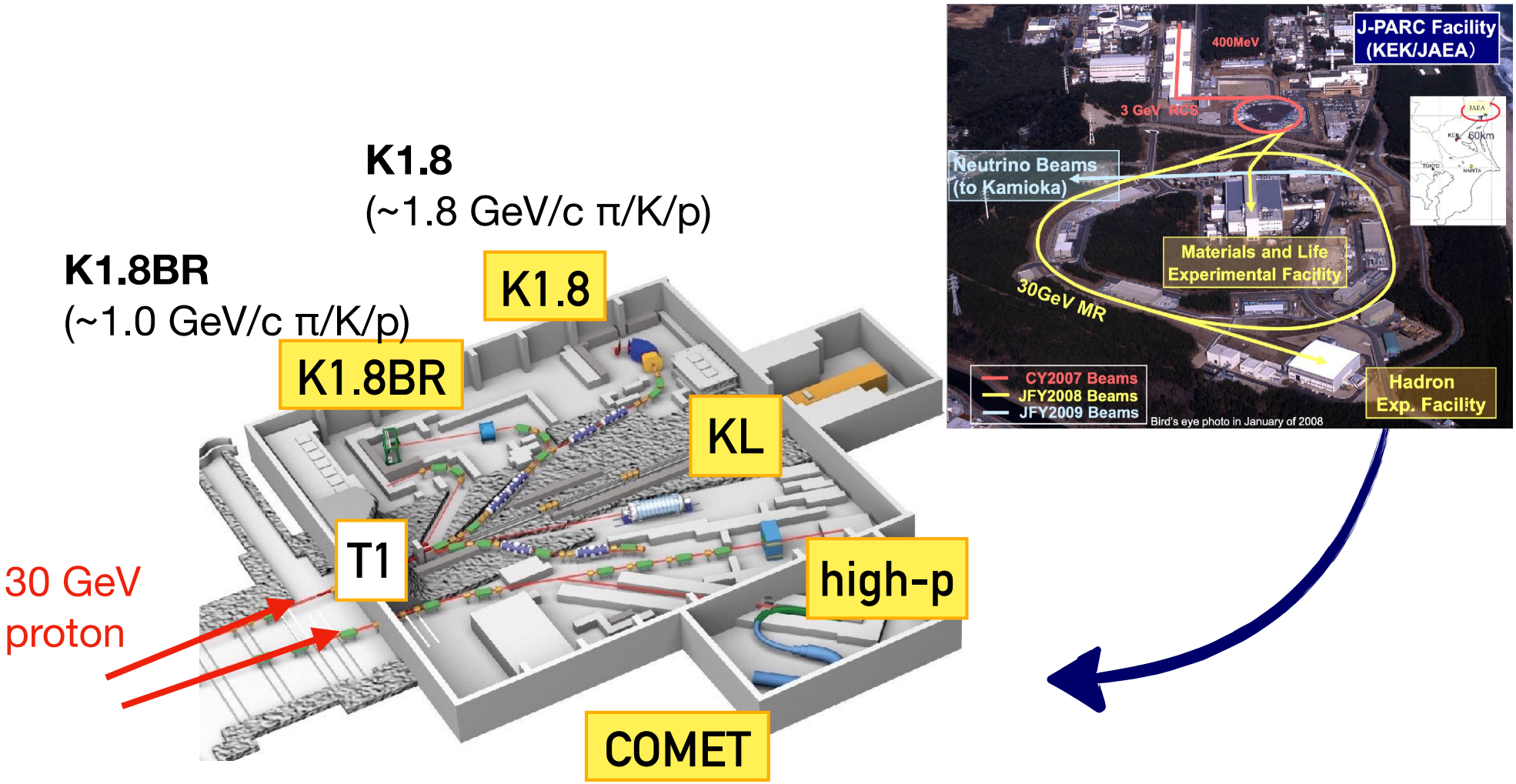


Joint Project between JAEA & KEK

J-PARC Hadron Experimental Facility



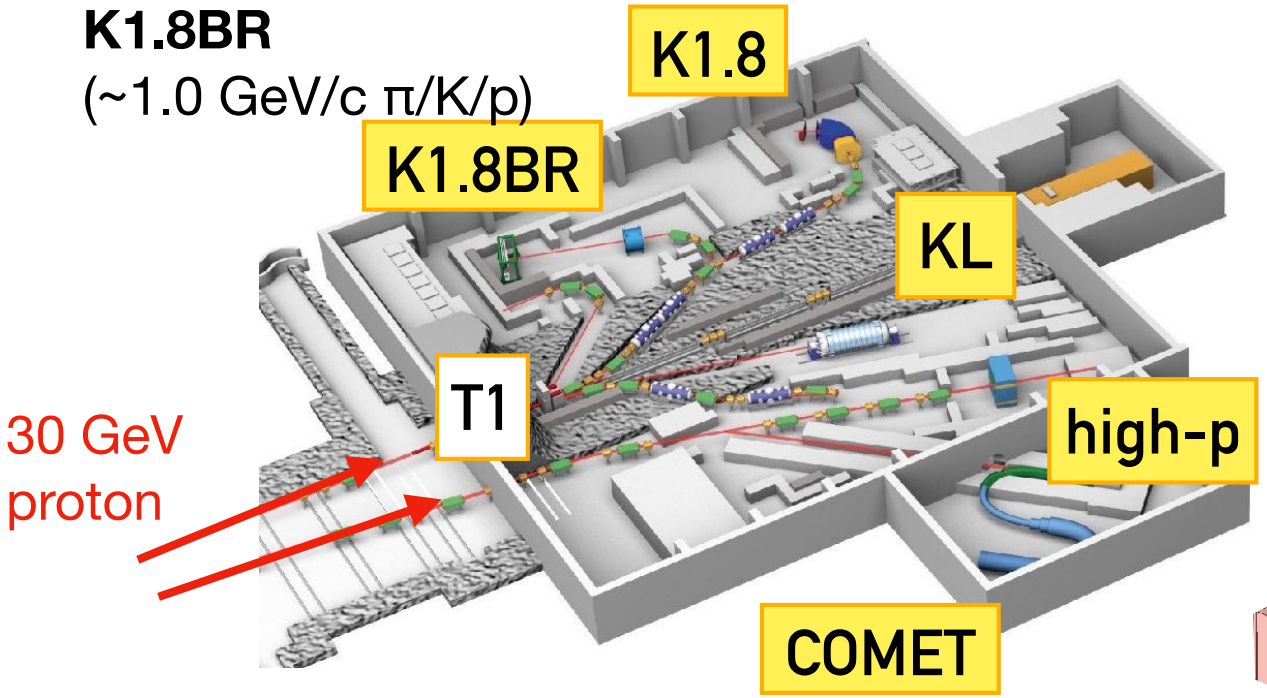
J-PARC Hadron Experimental Facility

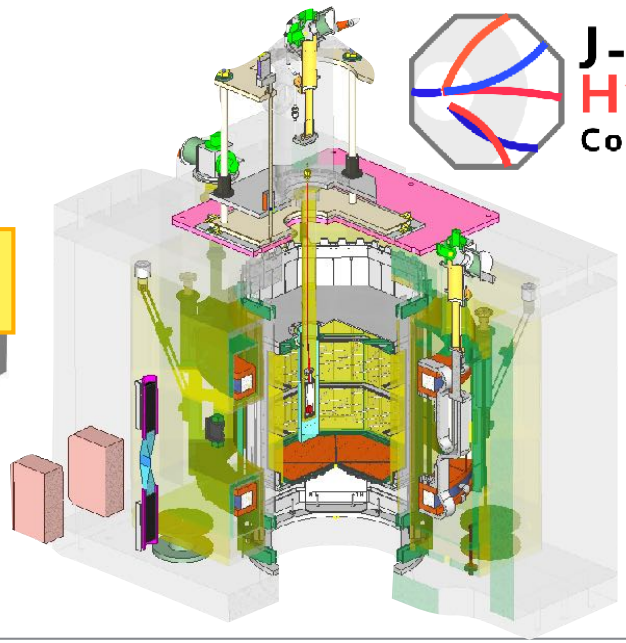


HypTPC Experiments at J-PARC

K1.8
(~1.8 GeV/c π/K/p)

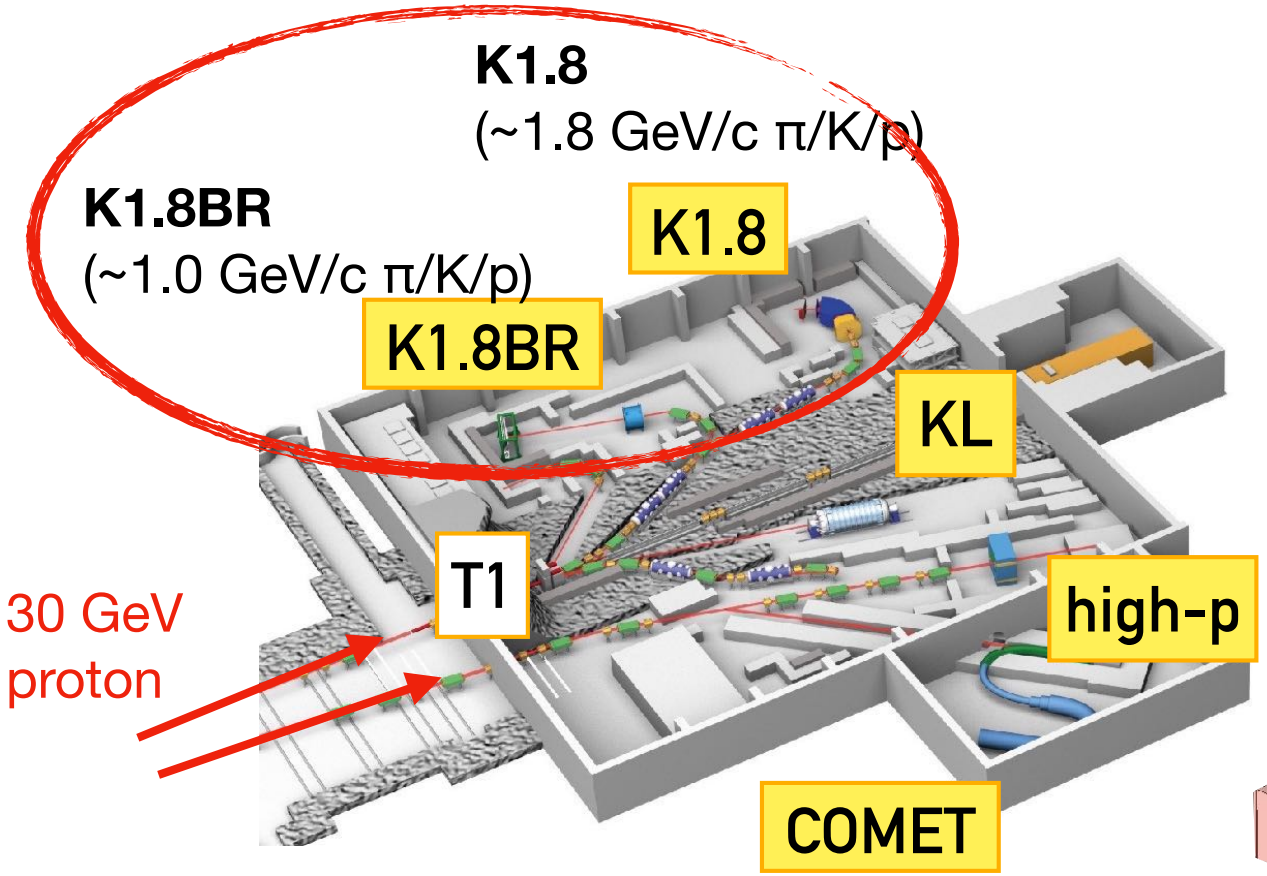
K1.8BR
(~1.0 GeV/c π/K/p)

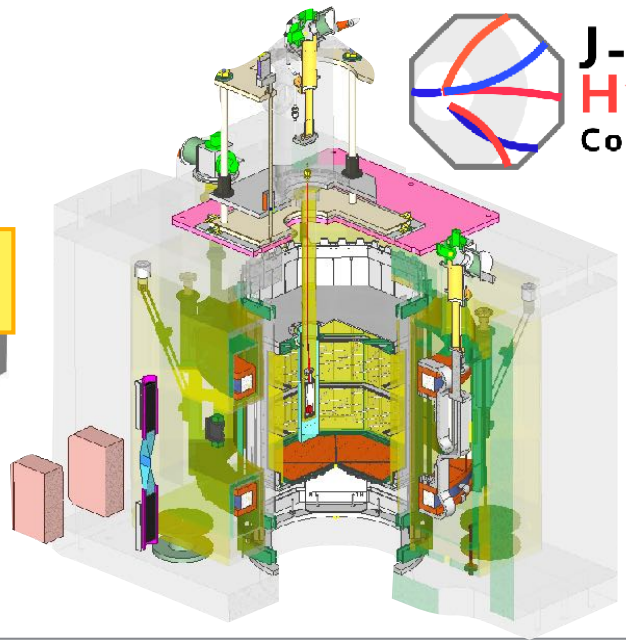




J-PARC HypTPC Collaboration

HypTPC Experiments at J-PARC



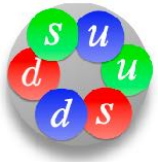


J-PARC HypTPC Collaboration

HypTPC Experiments at J-PARC

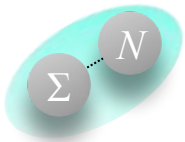
E72

Narrow Λ* search



E42 *H*-dibaryon search

E45 N* spectroscopy



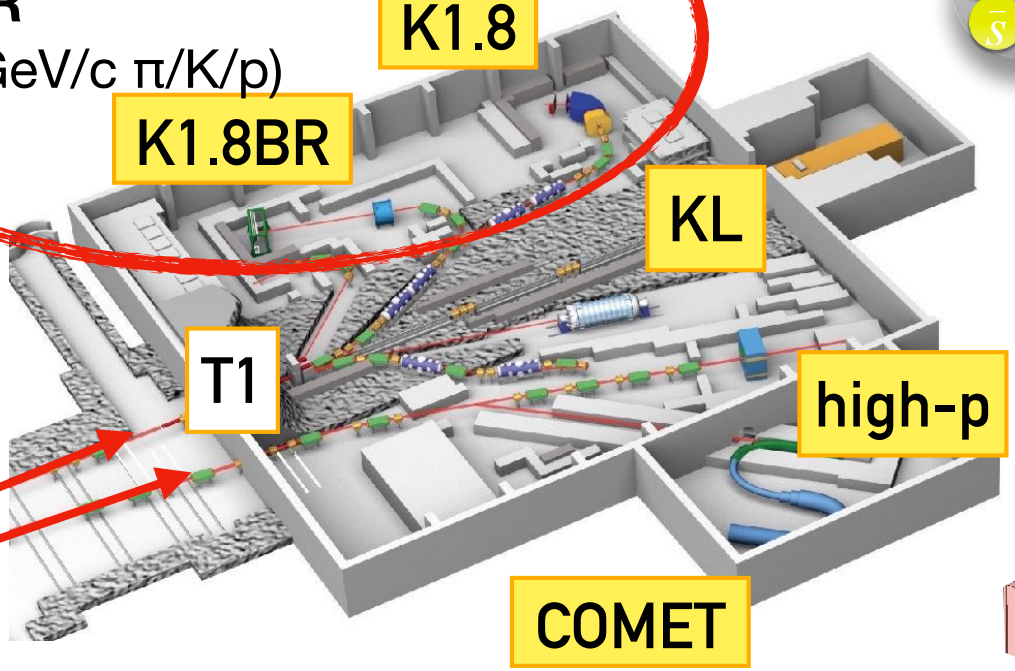
E90 ΣN cusp

E104 $\bar{p}p \rightarrow \phi\phi$ reaction

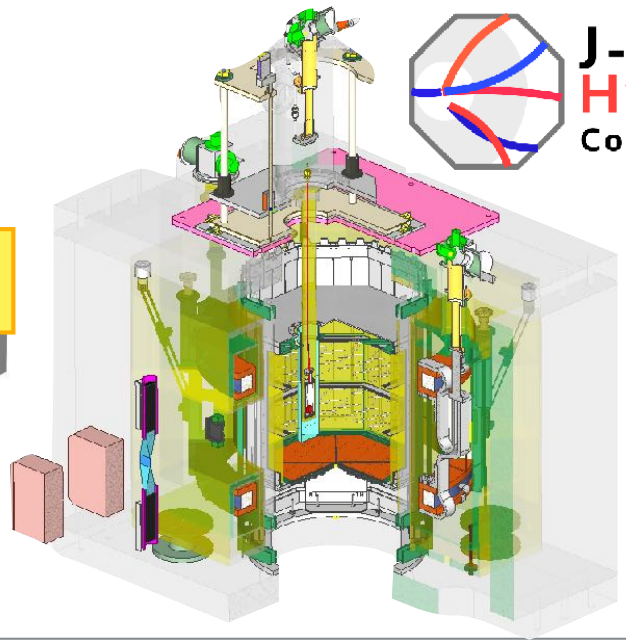
L0I Θ⁺ search in $K^+d \rightarrow K^0pp$ reaction

K1.8
(~1.8 GeV/c π/K/p)

K1.8BR
(~1.0 GeV/c π/K/p)



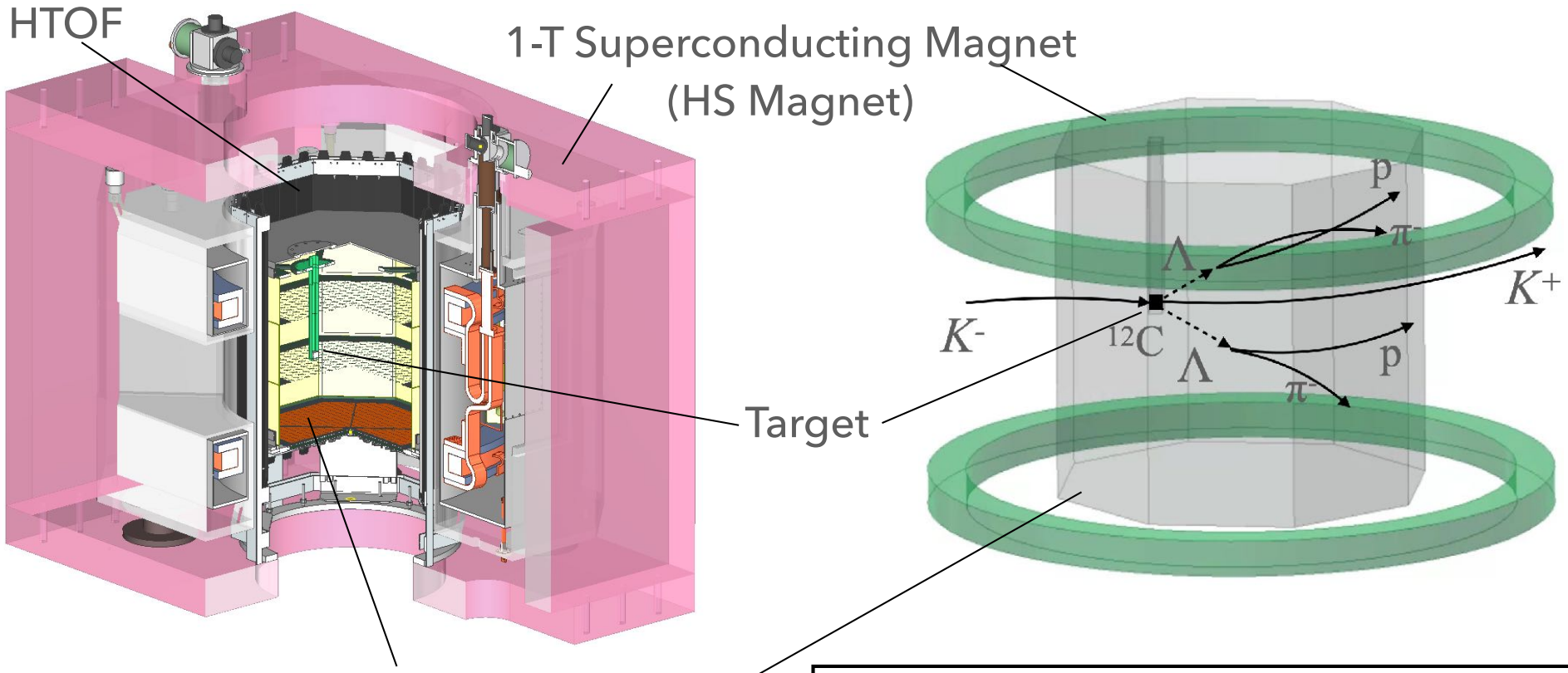
30 GeV proton



J-PARC HypTPC Collaboration

Hyperon Spectrometer

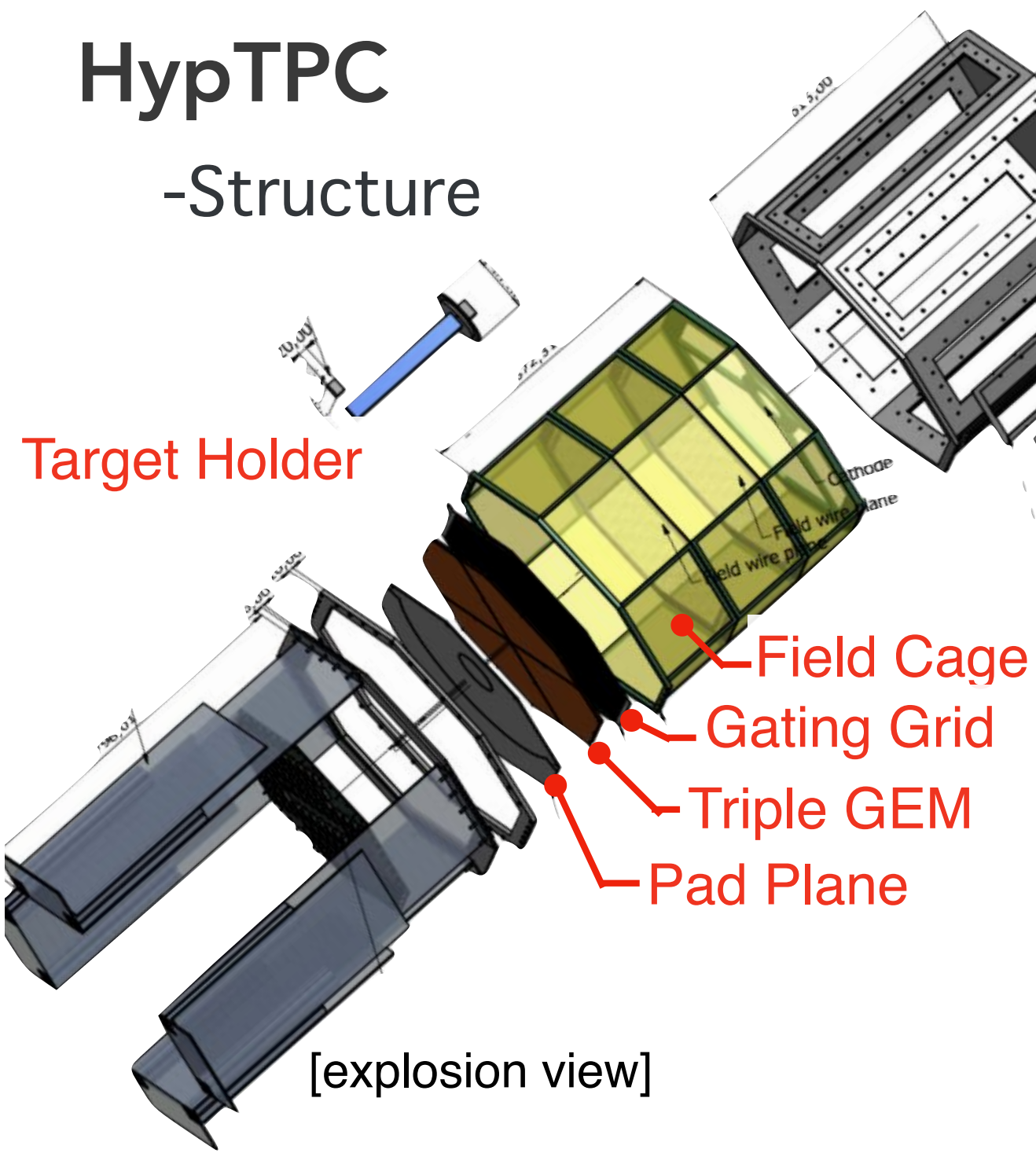
- A new type of detector system for hadron experiments at J-PARC
- Visualize all charged particles' trajectories in 3D with a large acceptance



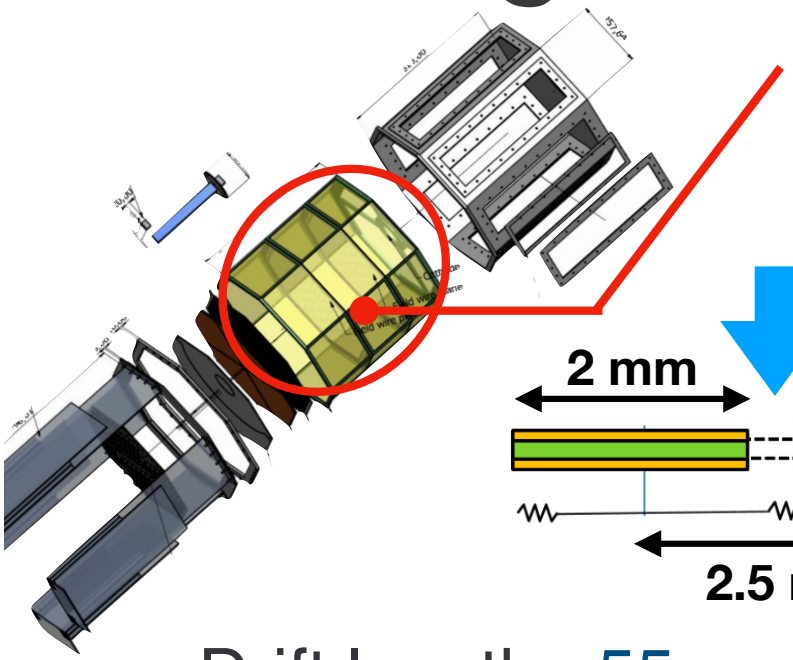
- High rate capability (~10^6 cps)
- High resolution (σ <300 μm)

HypTPC

-Structure

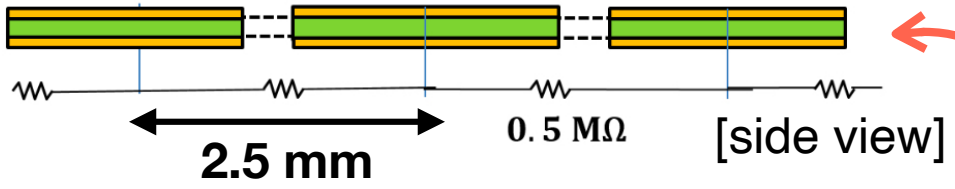


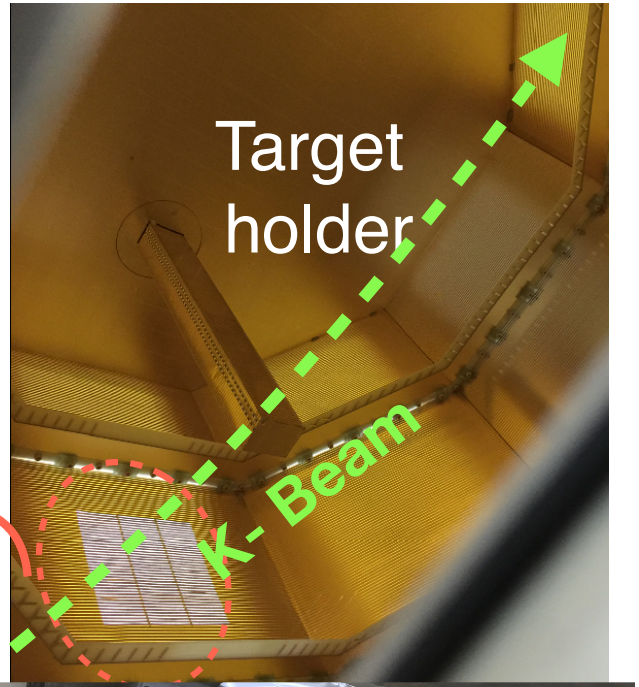
Field Cage Structure



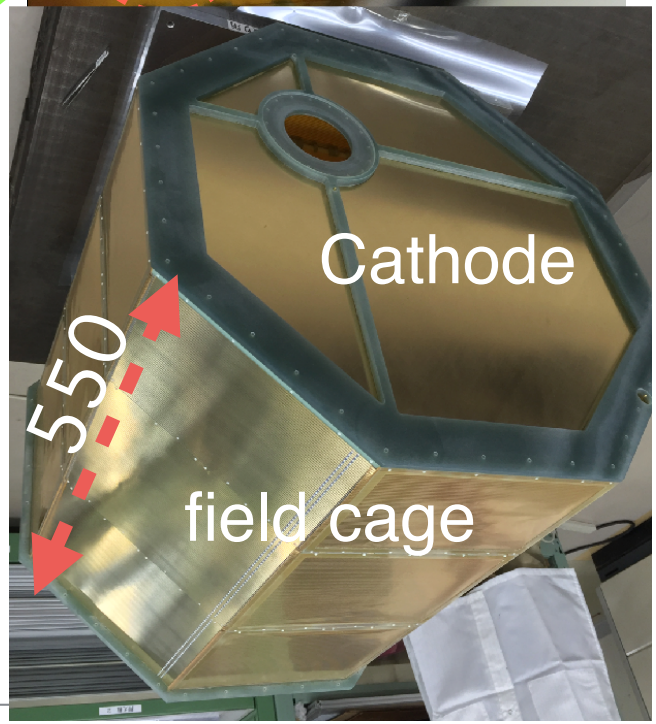
Drift Region

Field Strip Structure

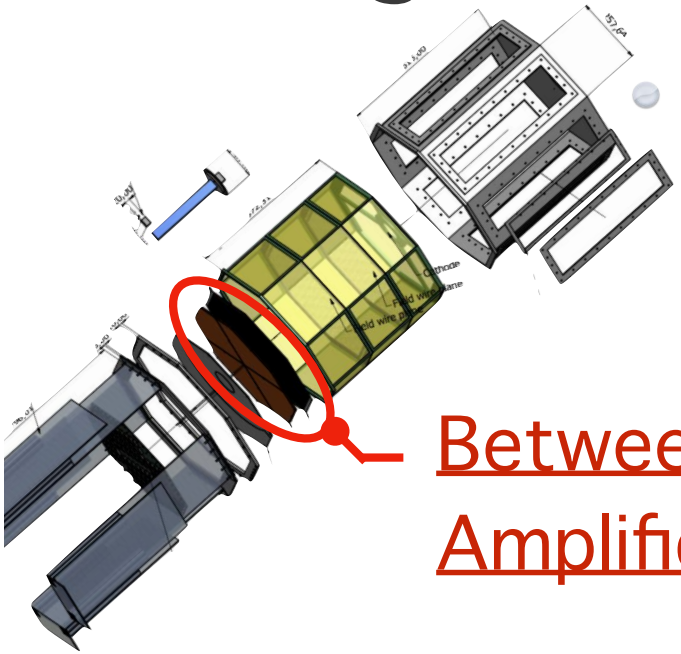




- Drift length : 55 cm
- 1 atm P-10 gas, 130 V/cm
- Target inside drift volume for a large acceptance
- Beam slits to avoid charge build-up on the field cage in high rate beam.

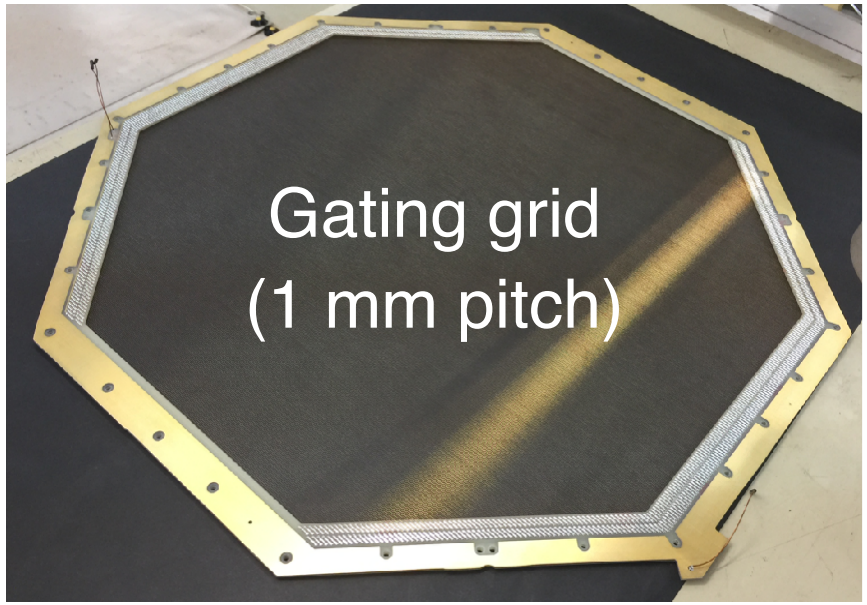


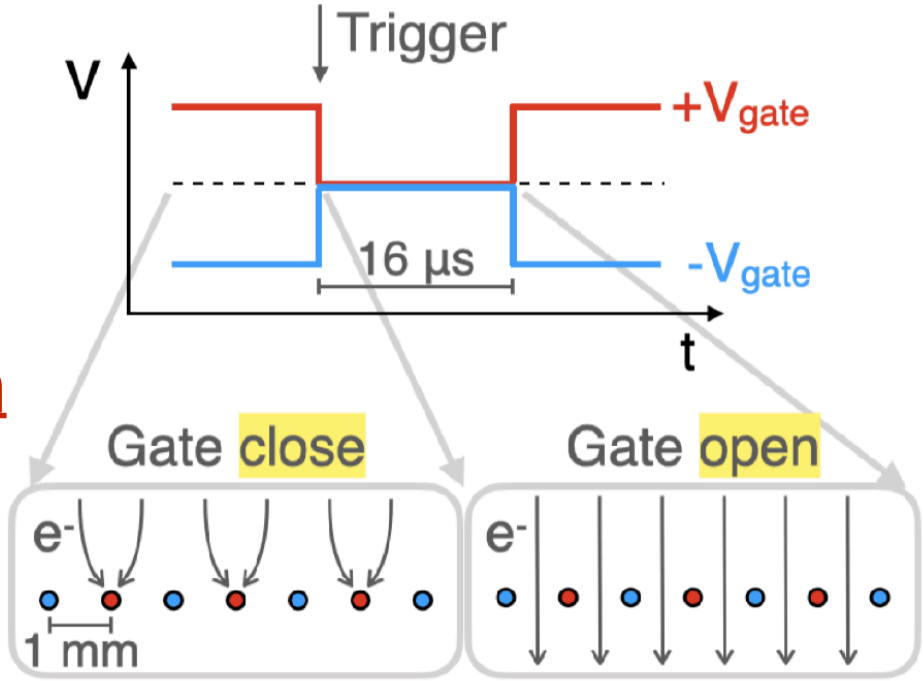
Gating Grid Plane

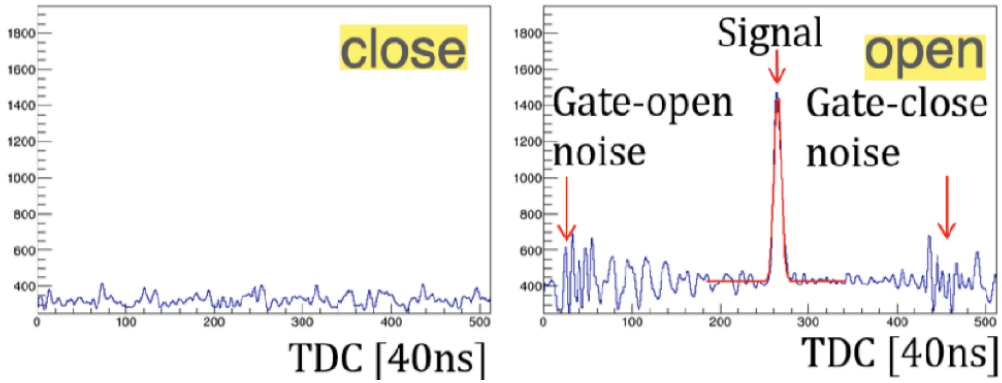


- Gate operation to suppress the ion backflow

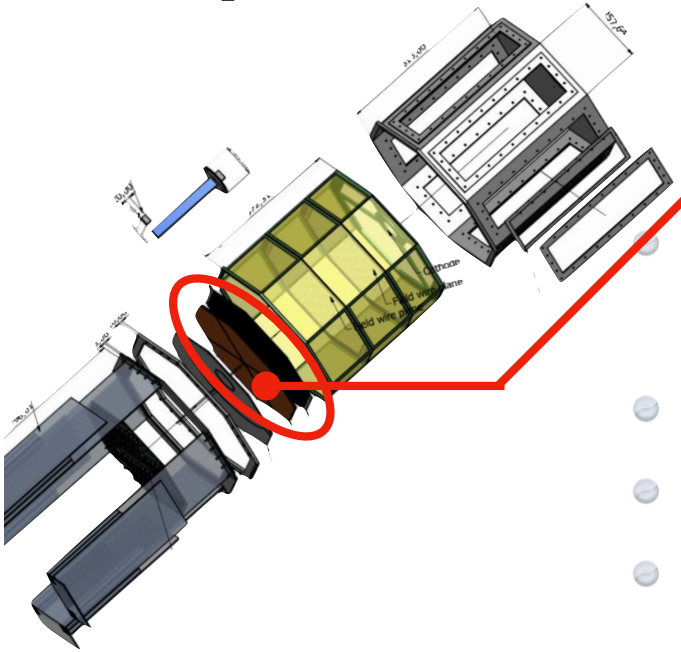
Between Drift & Amplification Region





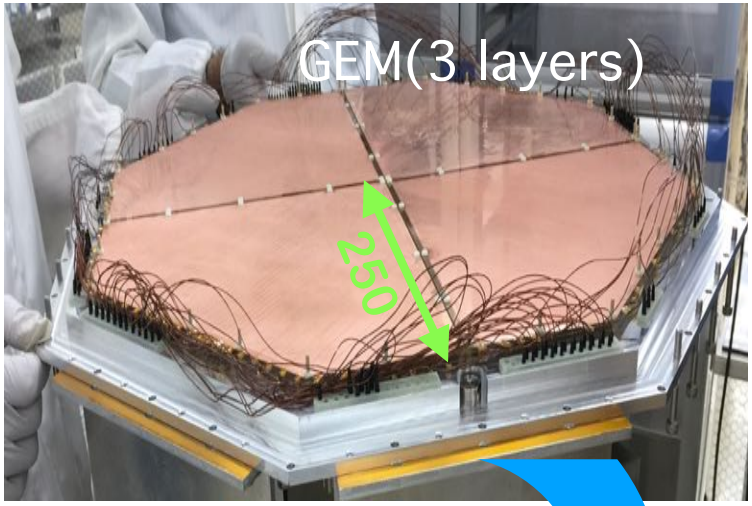


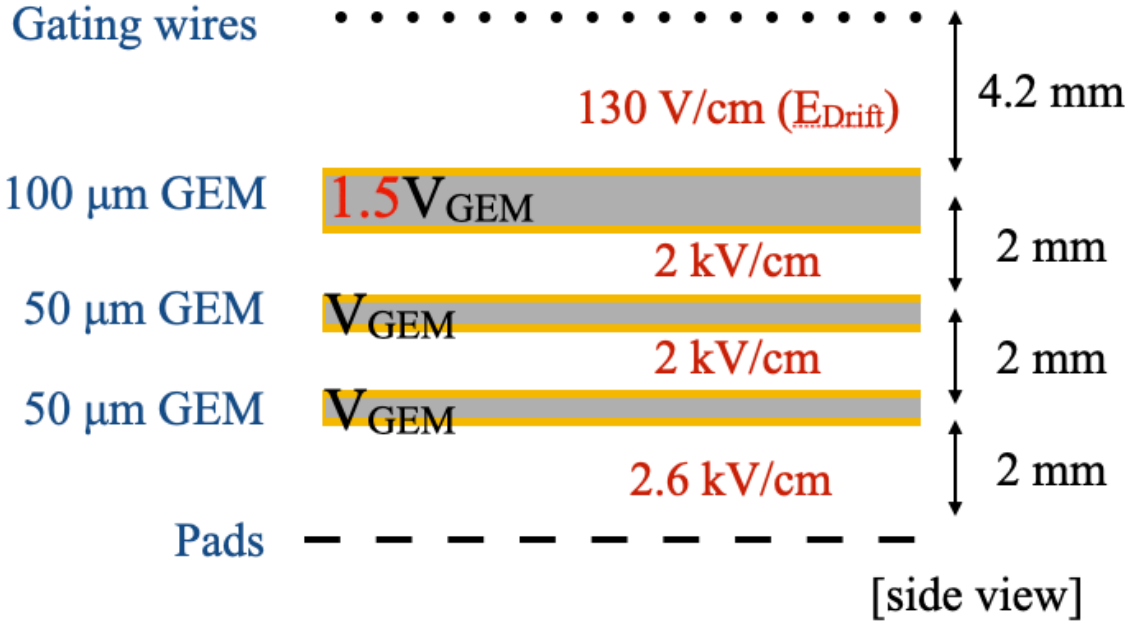
Triple GEM Layer

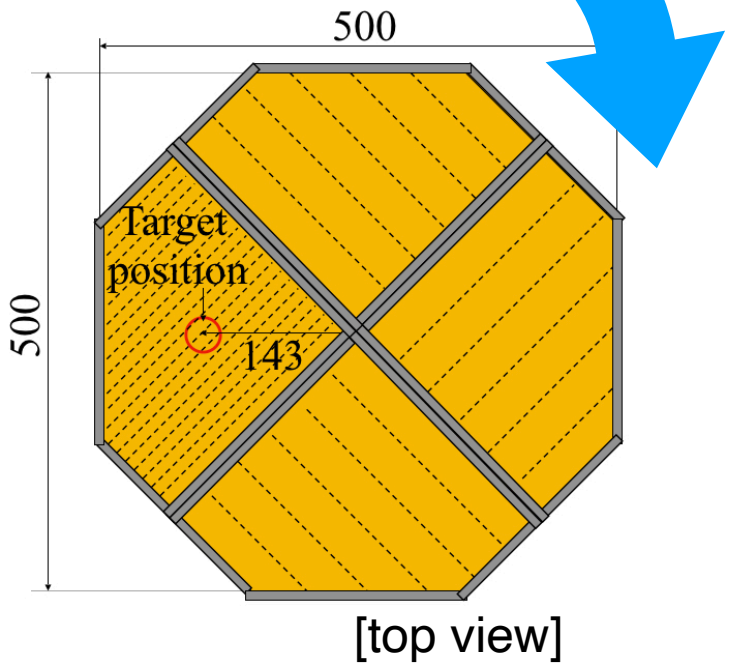


Amplification Region

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

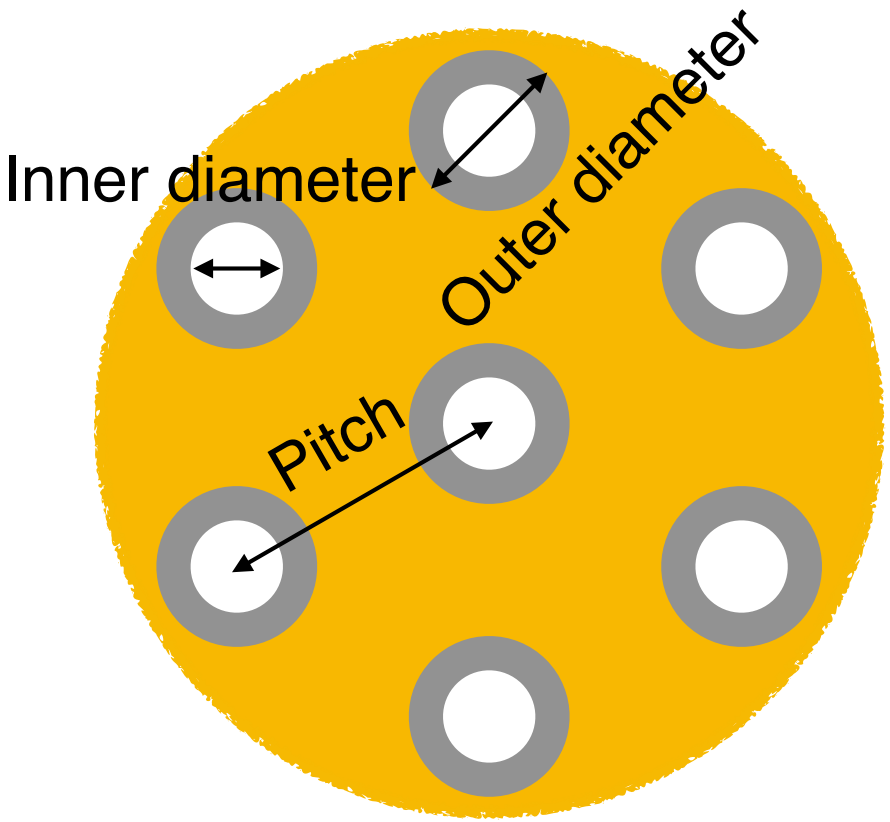


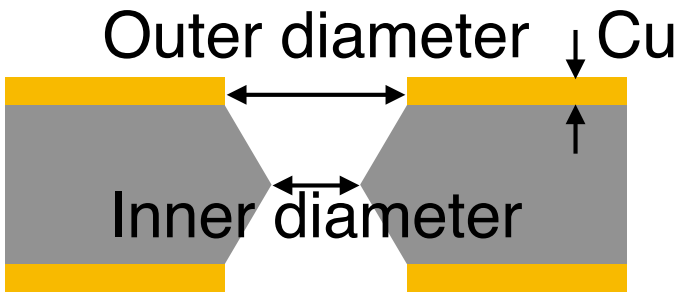




GEM Specification

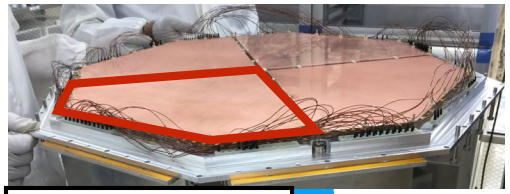
	50 μm GEM	100 μm GEM
Manufacturer	Raytech*	Raytech*
Insulator	Polyimide (PI)	Liquid Crystal Polymer (LCP)
Etching method	Wet	Laser
Cu thickness	4 μm	9 μm
Pitch	140 μm	140 μm
Inner diameter	25 ± 10 μm	35 ± 10 μm
Outer diameter	55 ± 5 μm	65 ± 5 μm





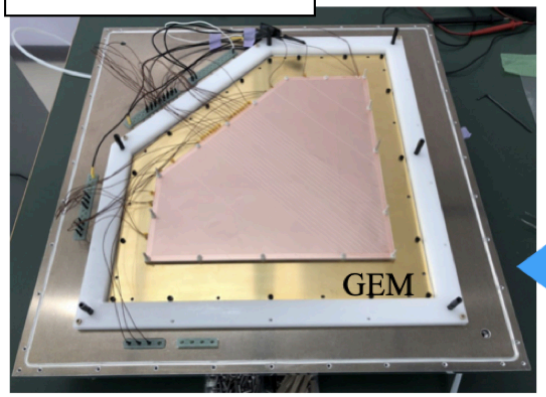
*Raytech company is now merged into Toray company.

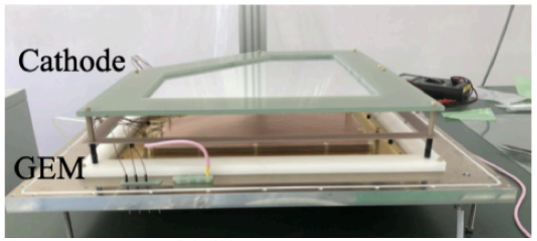
GEM Study



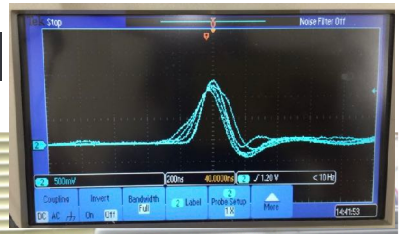
HypTPC

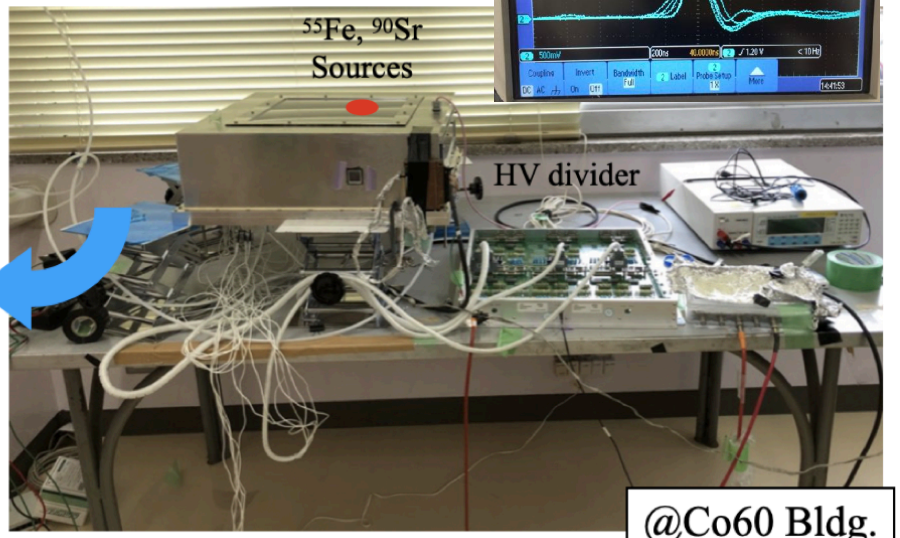
Test chamber



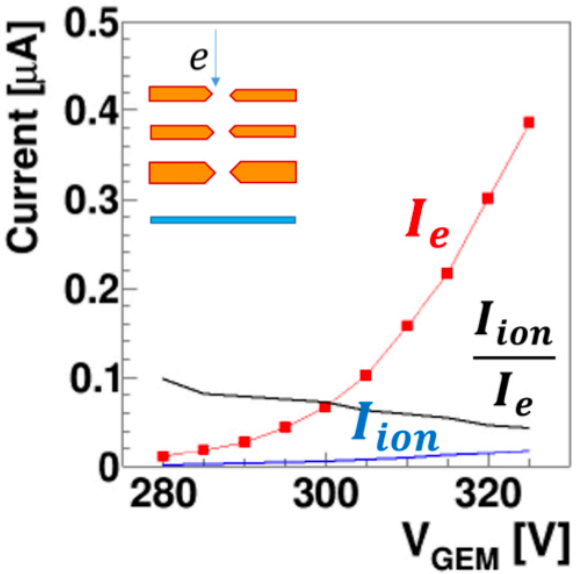


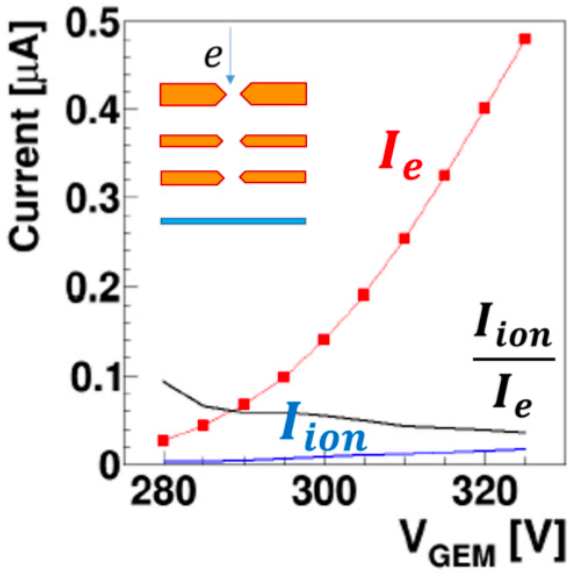
^{90}Sr signal



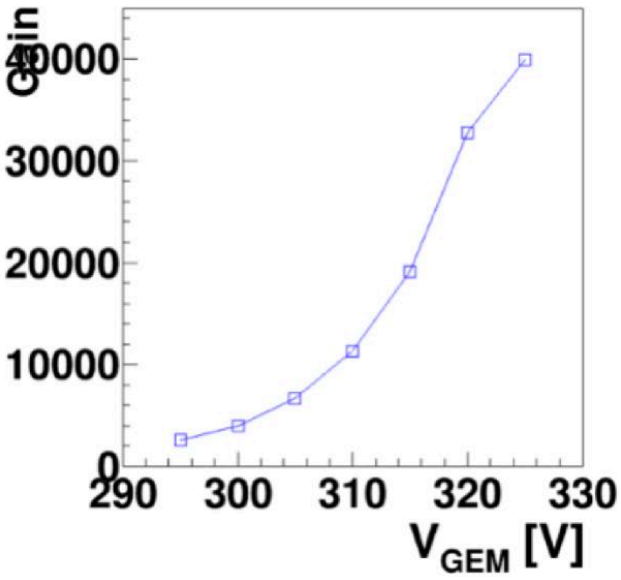


- Ion Backflow

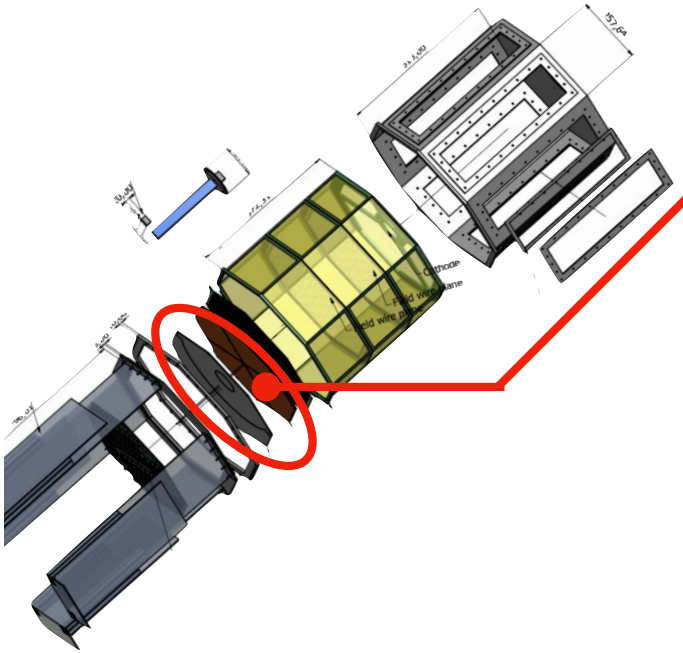




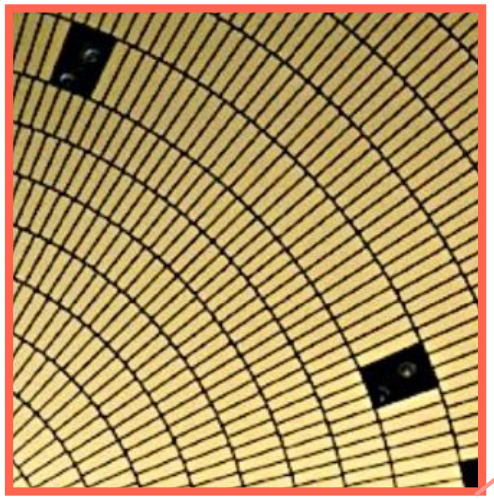
- Gain

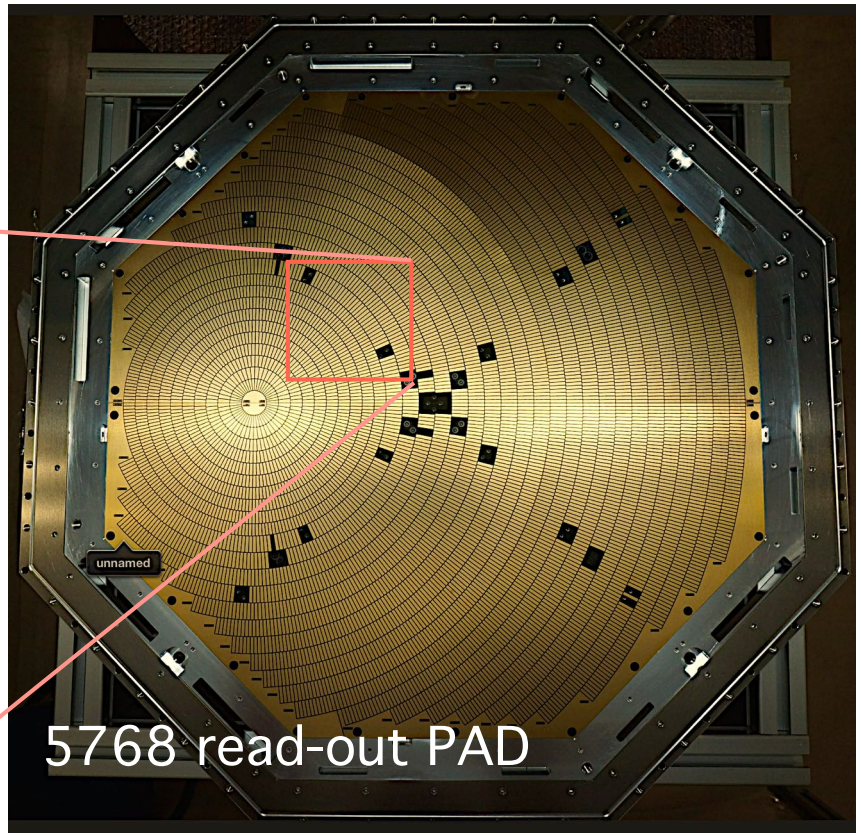


Pad Plane

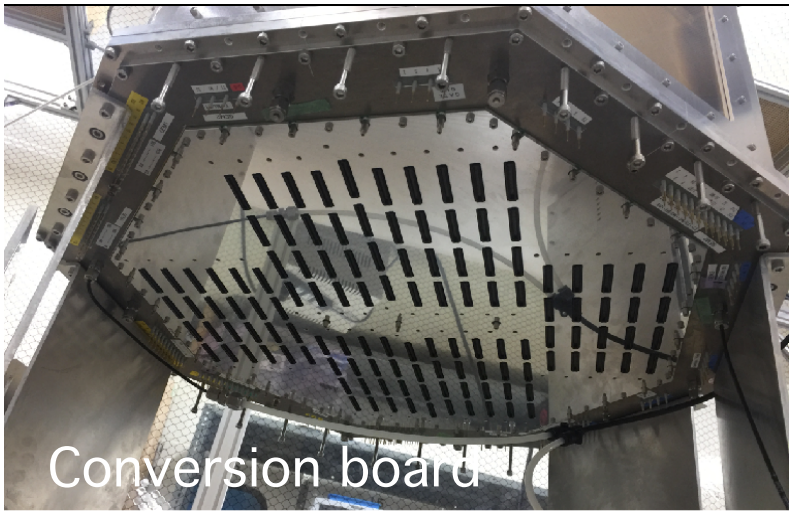


Readout Pads



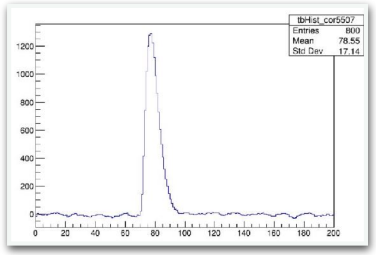


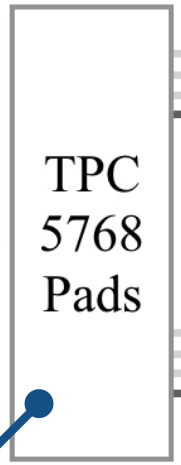
- 5768 readout pads
- Concentric configuration around the target
- 10 inner layers: 2.1-2.7 × 9 mm²
- 22 outer layers: 2.3-2.4 × 12.5 mm²

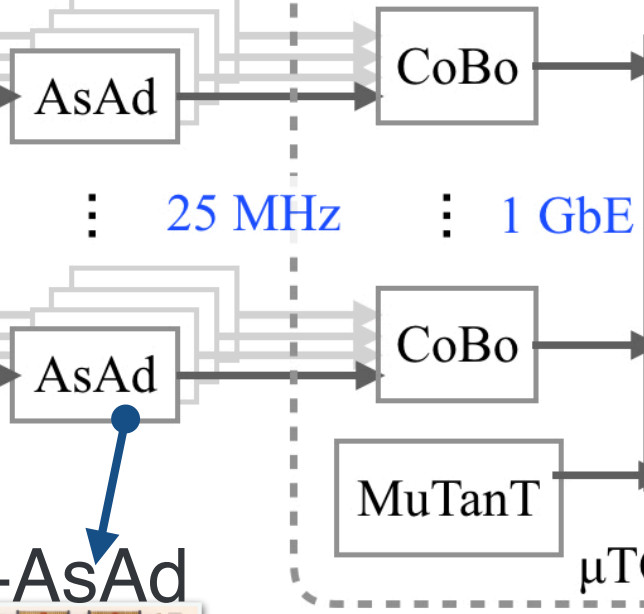


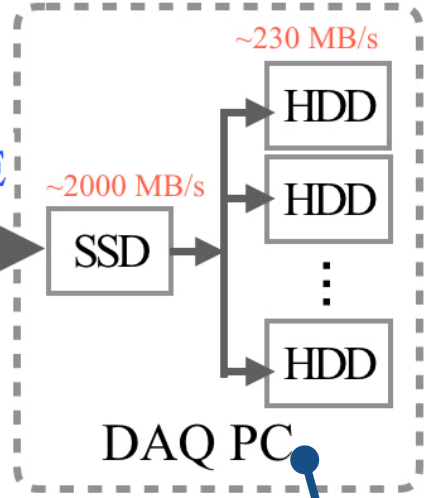
GET(General Electronics for TPCs)

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







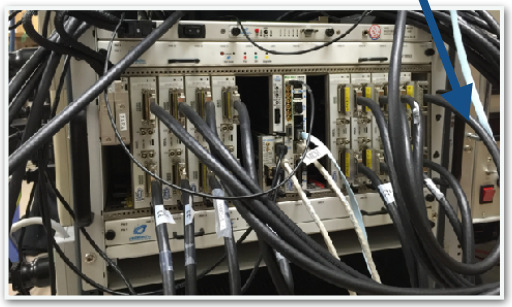


HypTPC

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

ZAP+AsAd



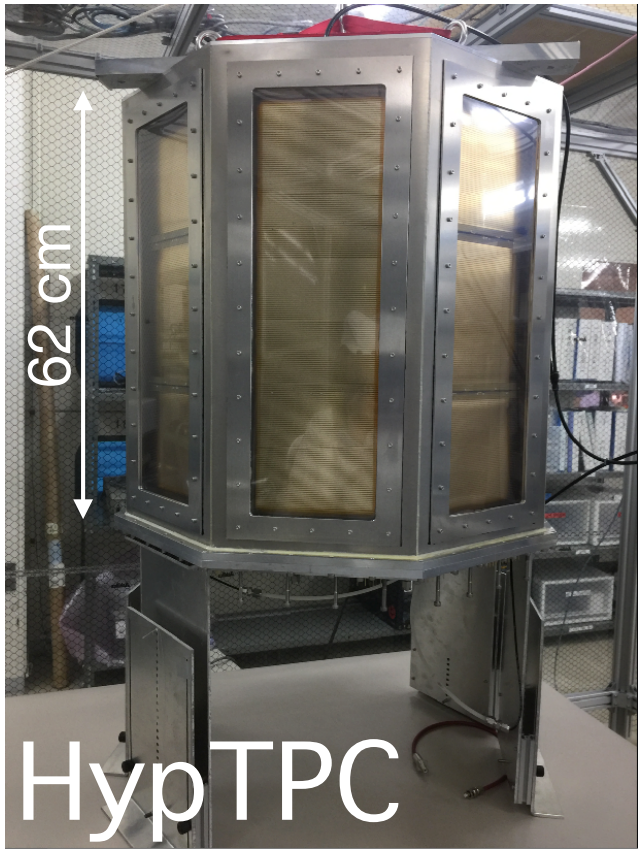
CoBo
- Data processing
- Data formatting

MuTanT
- synchronous trigger

MCH(µTCA Carrier Hub)

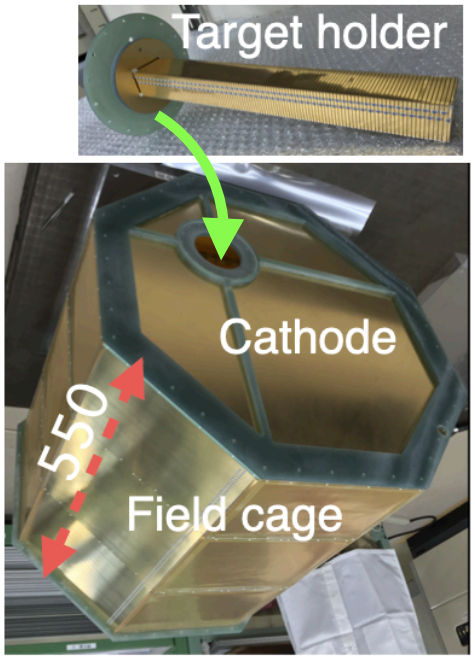
DAQ PC
- Run control
- Data flow manage
- Data storage

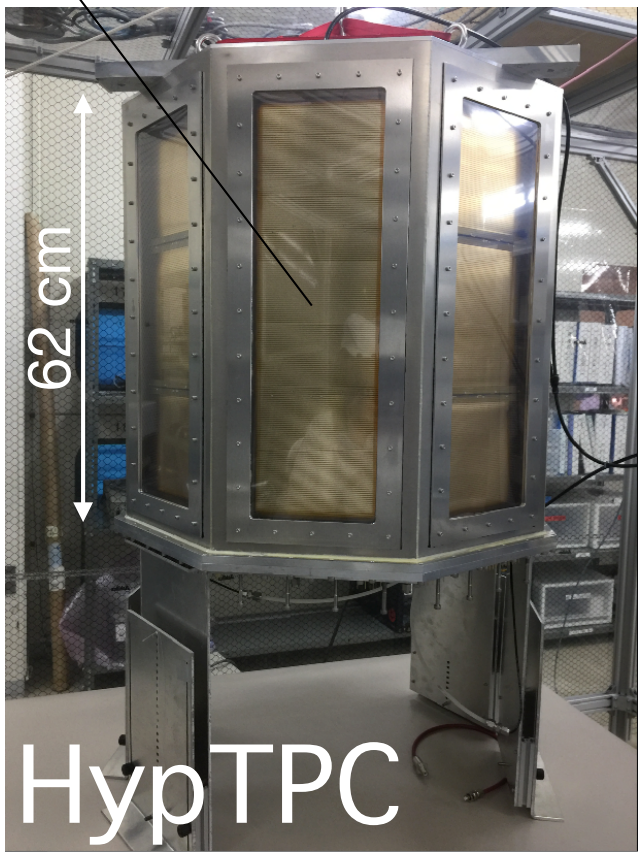
HypTPC



HypTPC

- 1. Drift region





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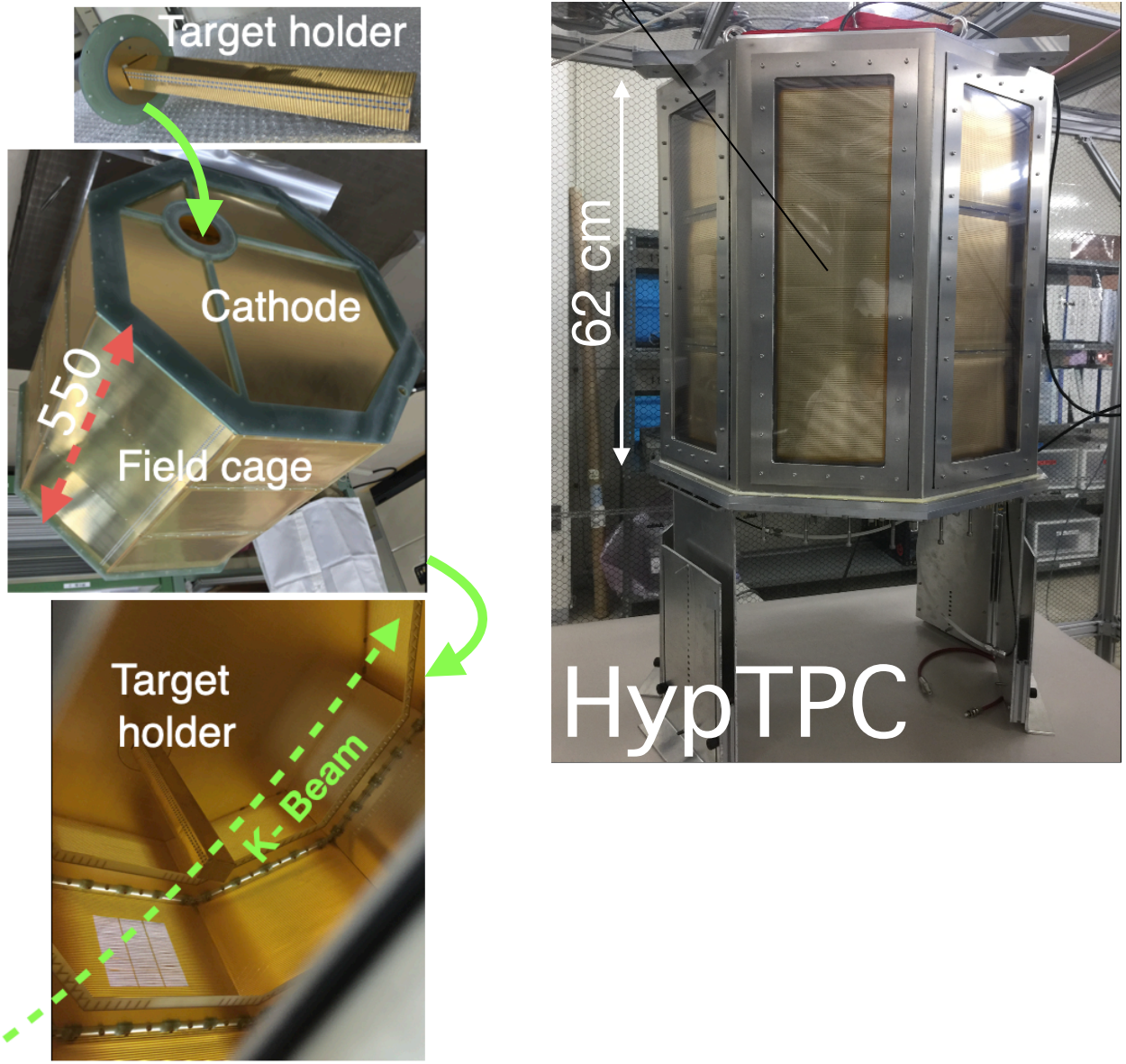

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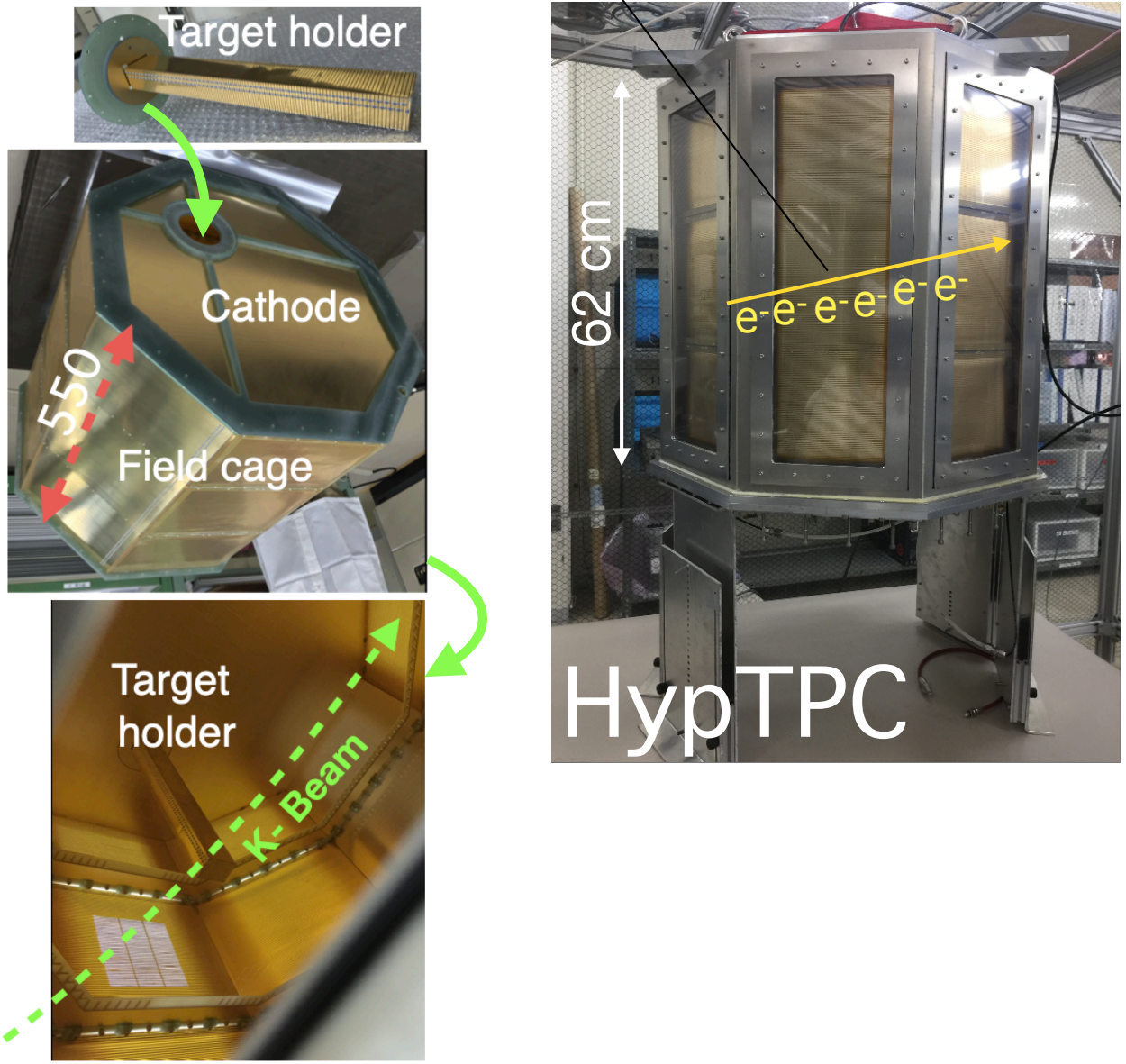

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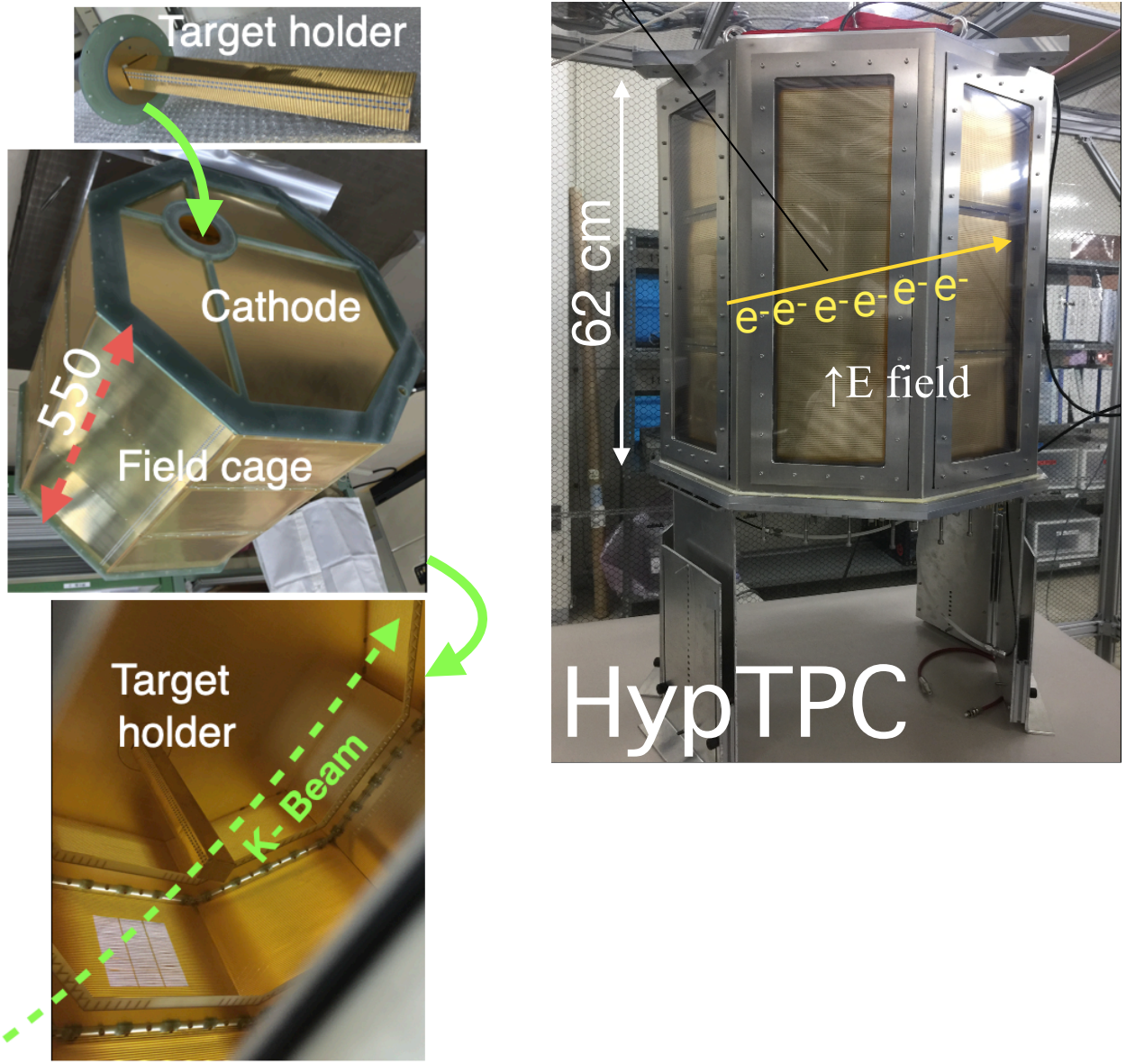

HypTPC

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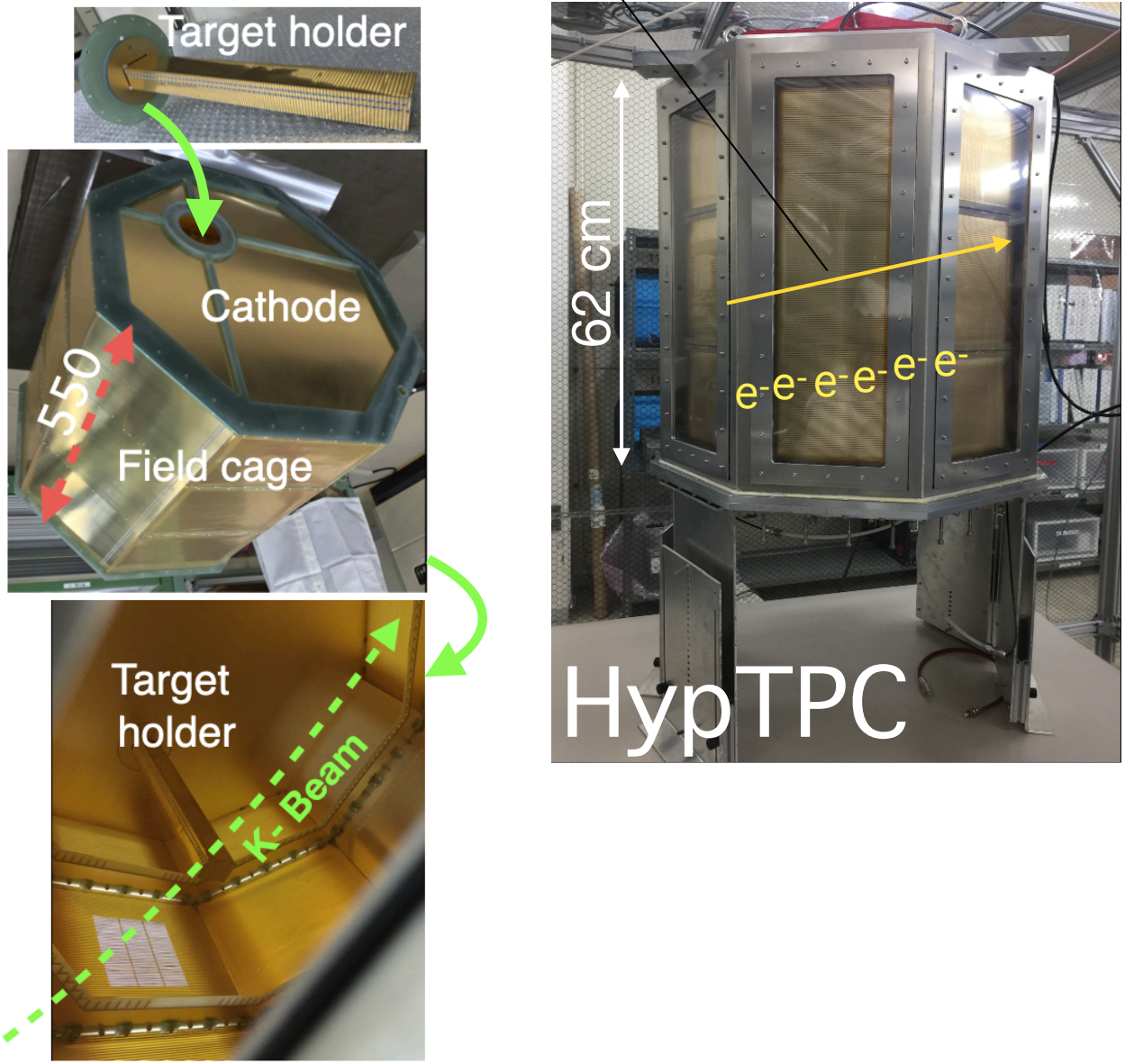
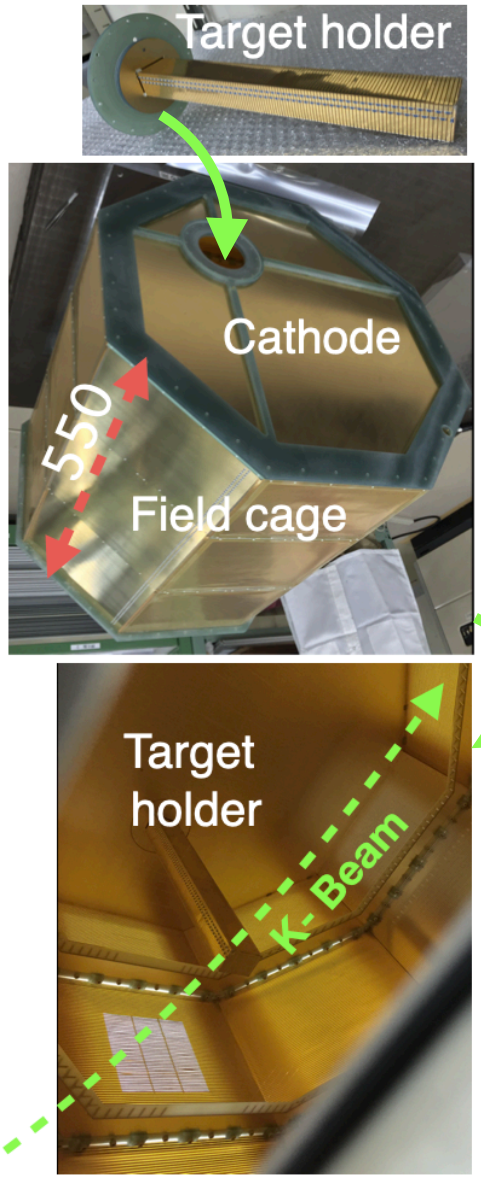
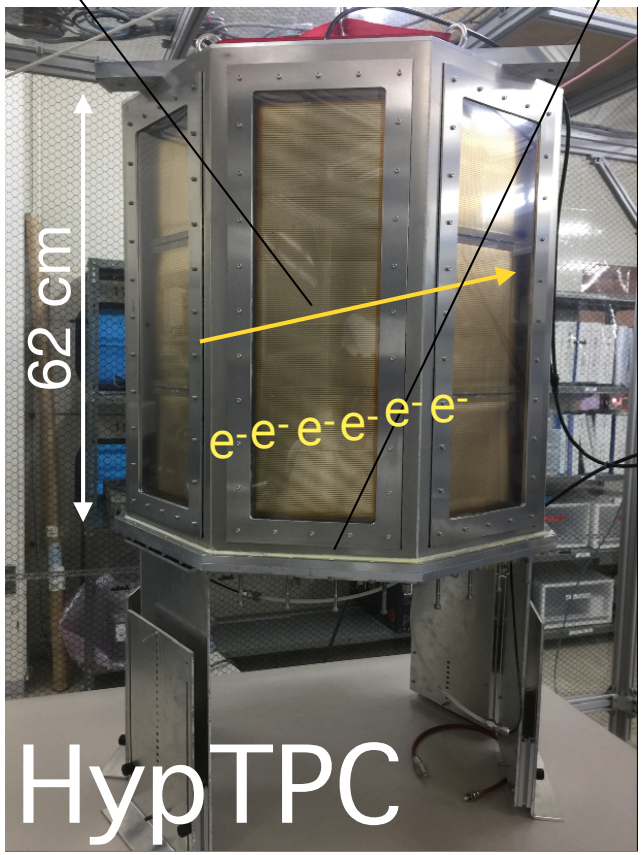
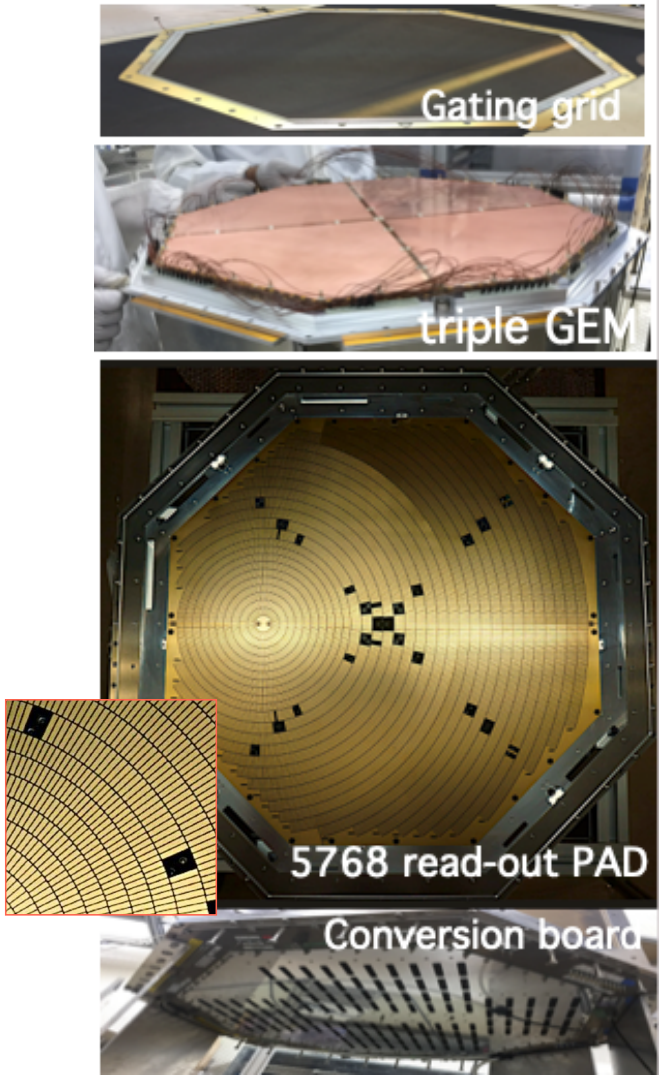


HypTPC

- 1. Drift region
- 2. Amplification Region







HypTPC

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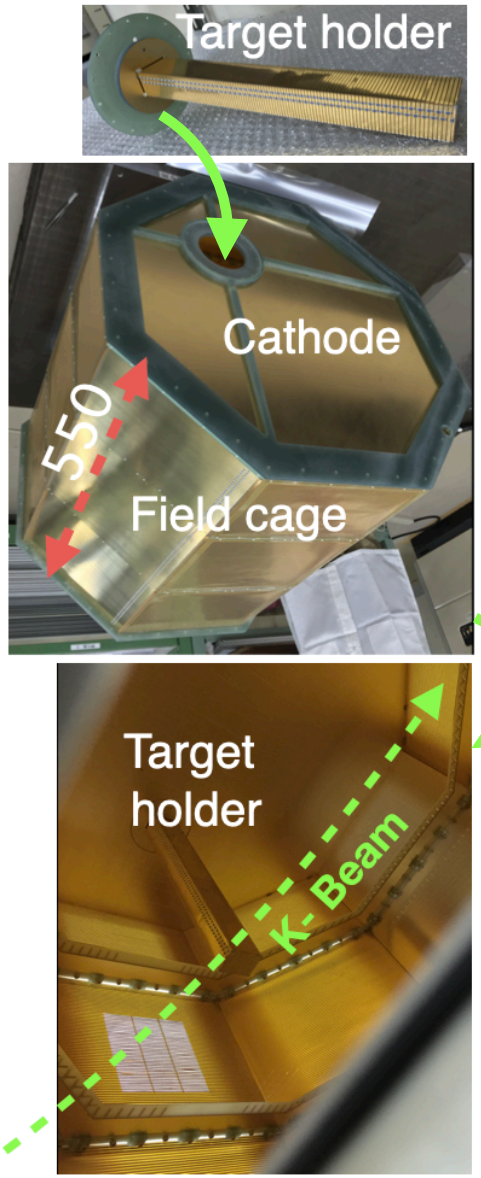
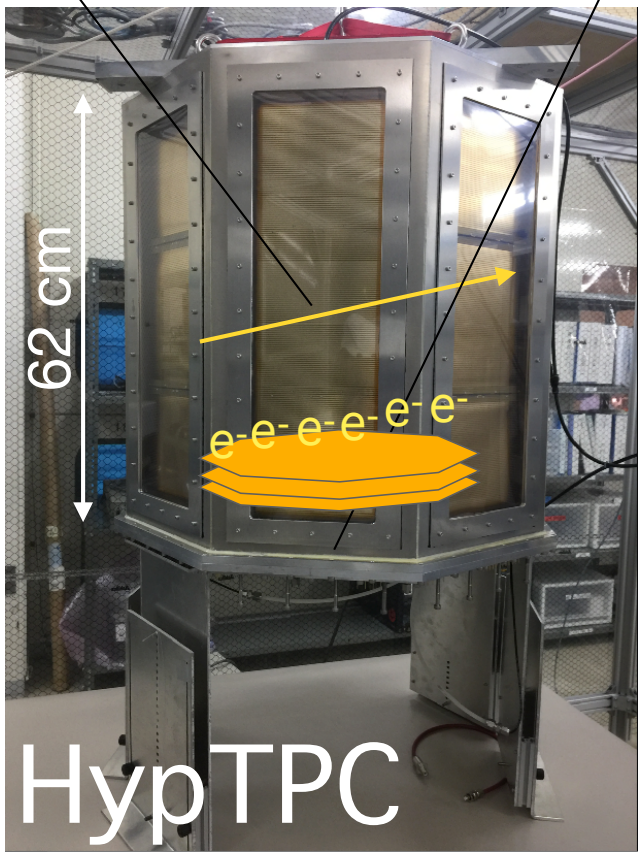
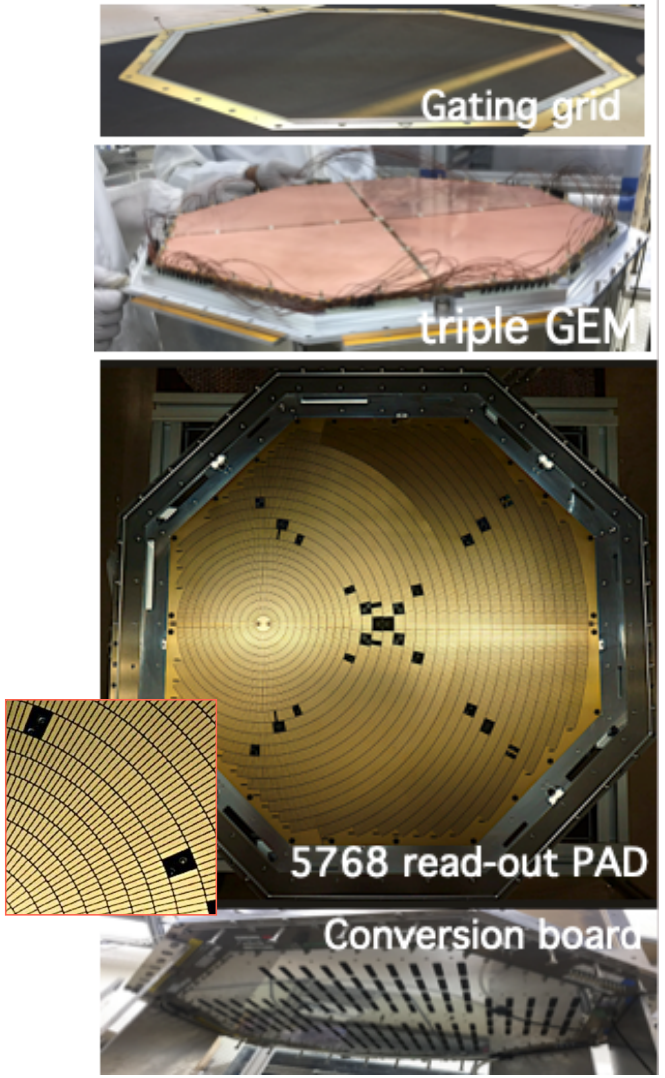
- 2. Amplification Region

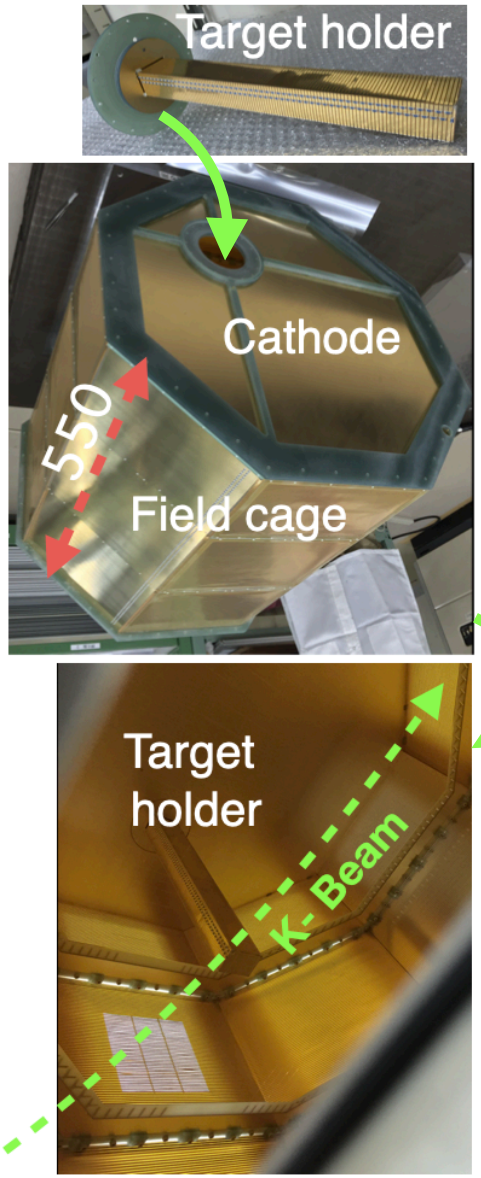


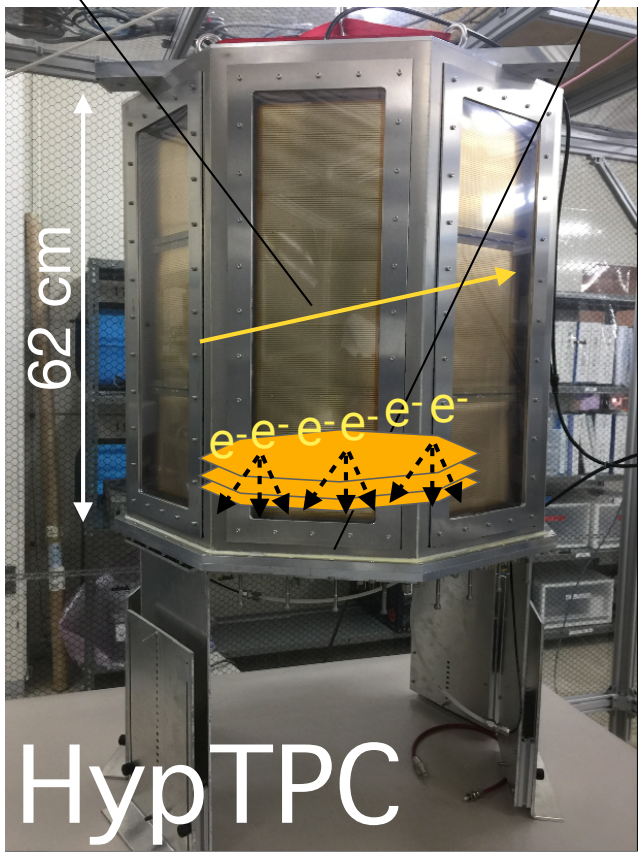


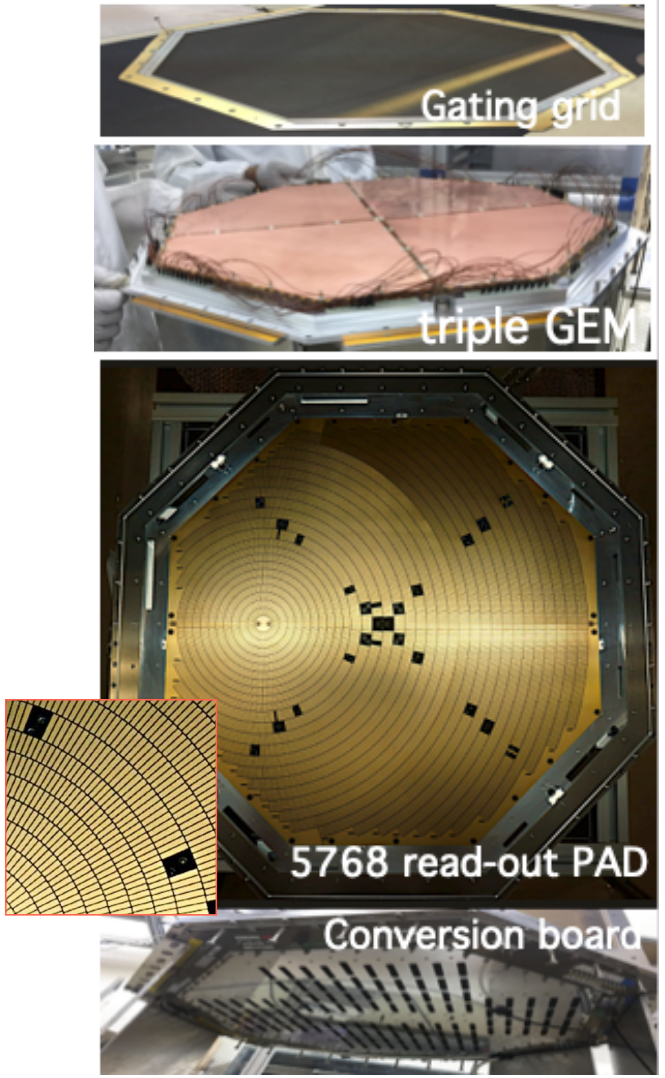


HypTPC

- 1. Drift region
- 2. Amplification Region







HypTPC

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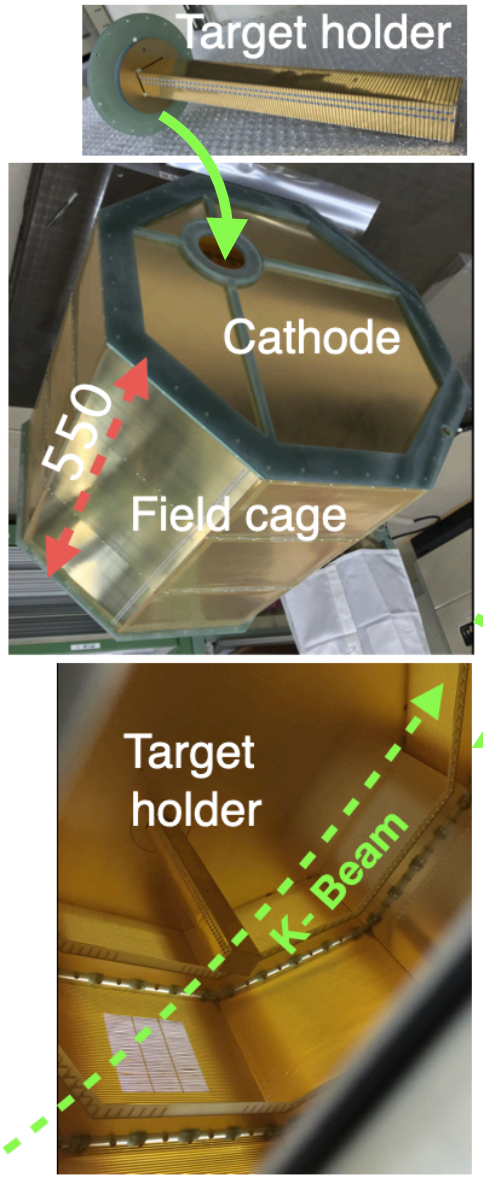
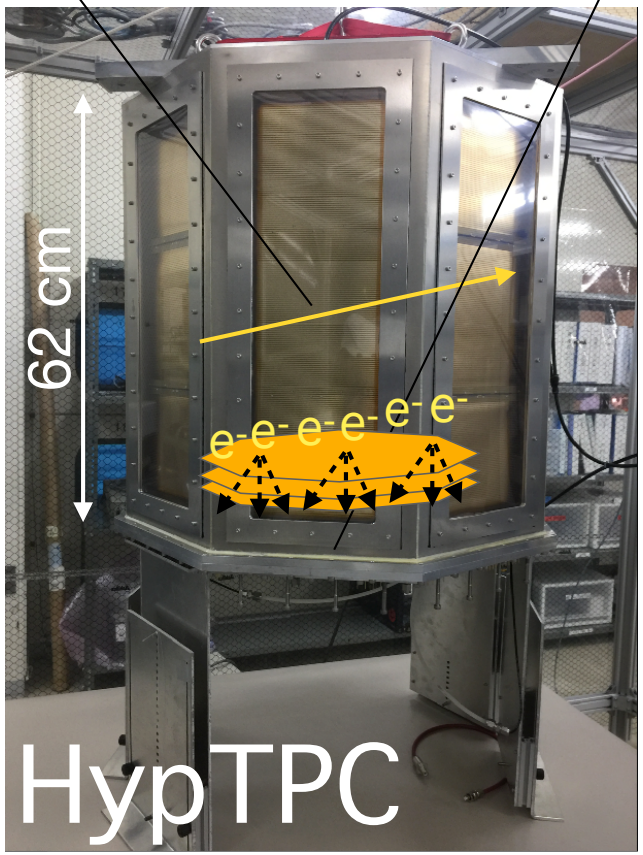
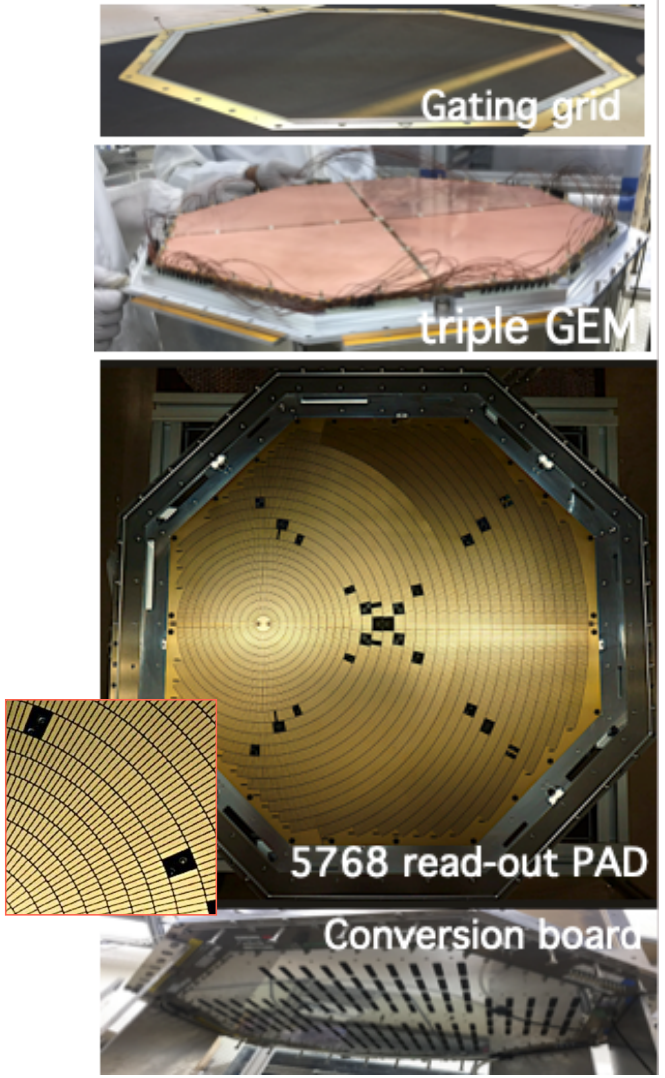


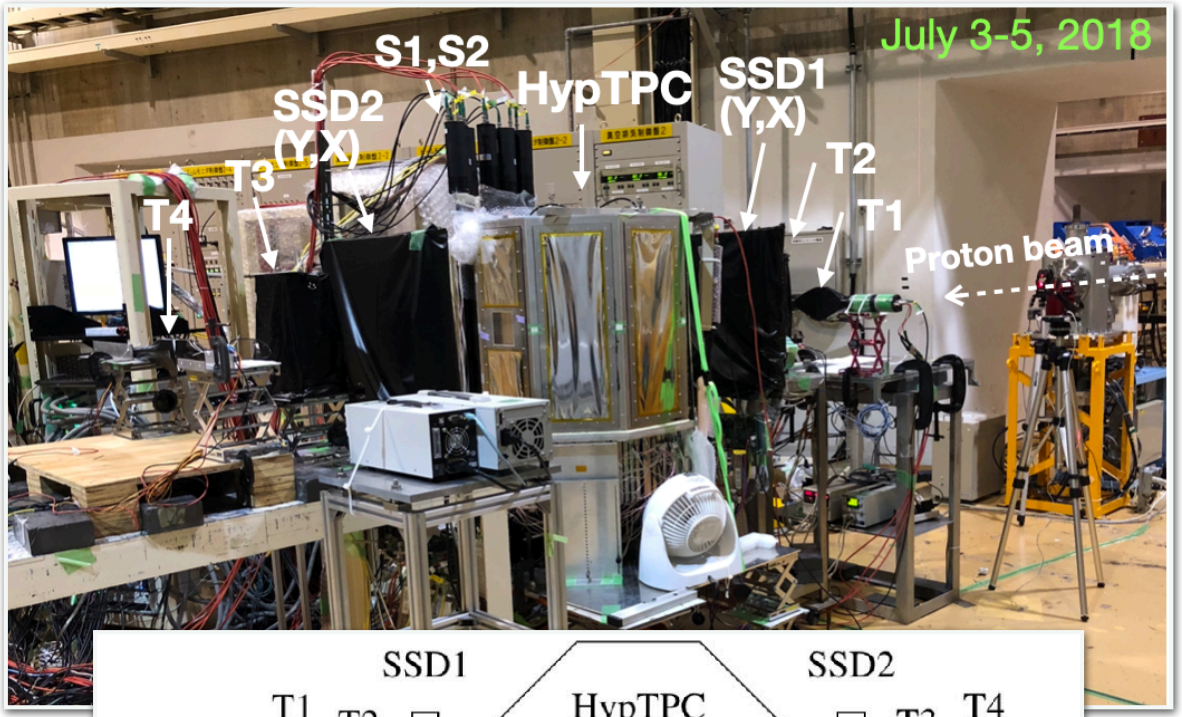


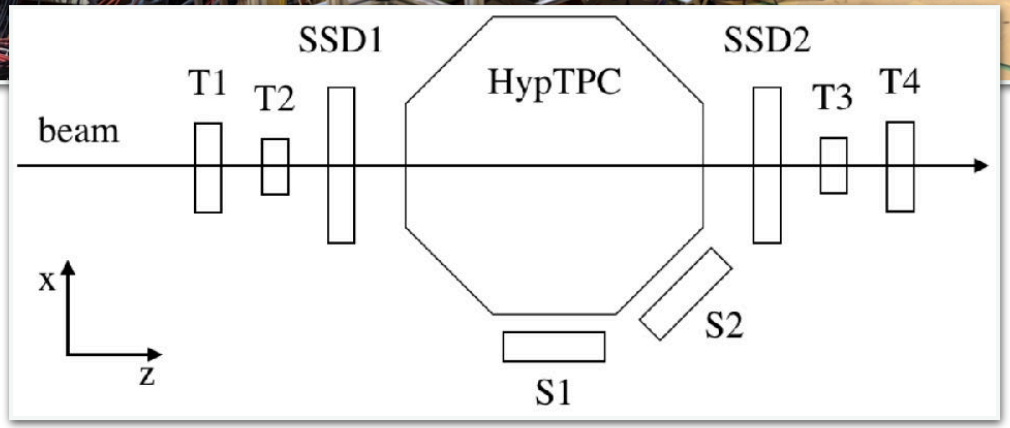


- 3. Read-out Electronics

HypTPC Commissioning at HIMAC

- To confirm the basic performance and high rate capability of HypTPC





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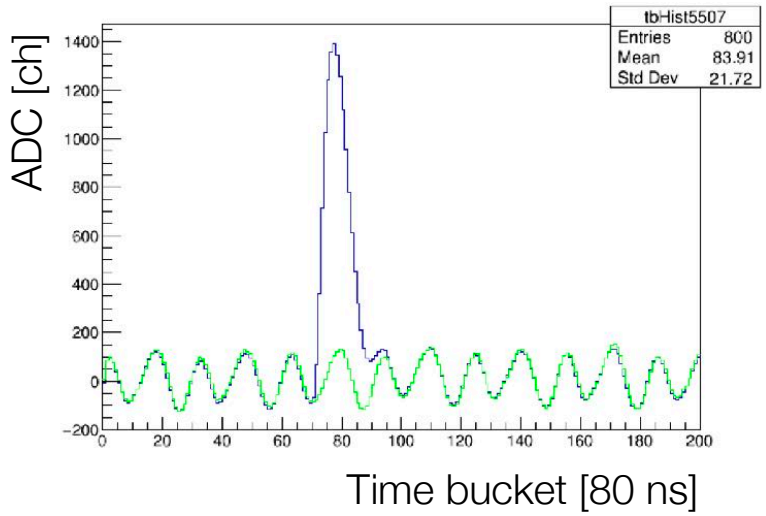
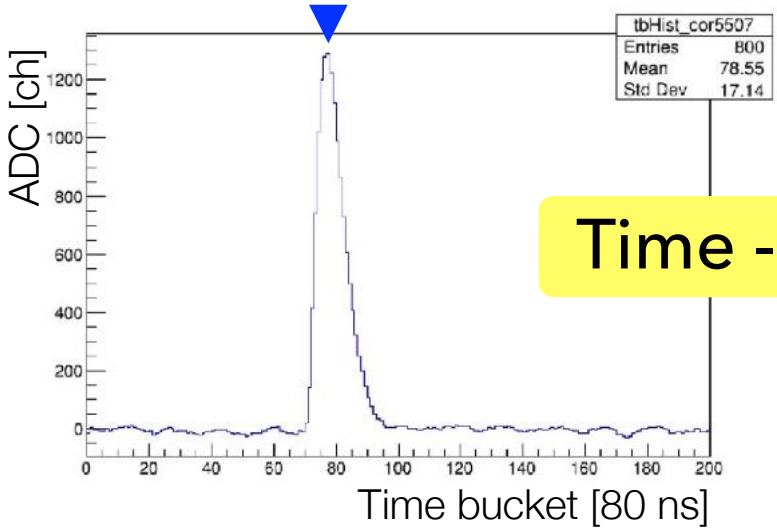
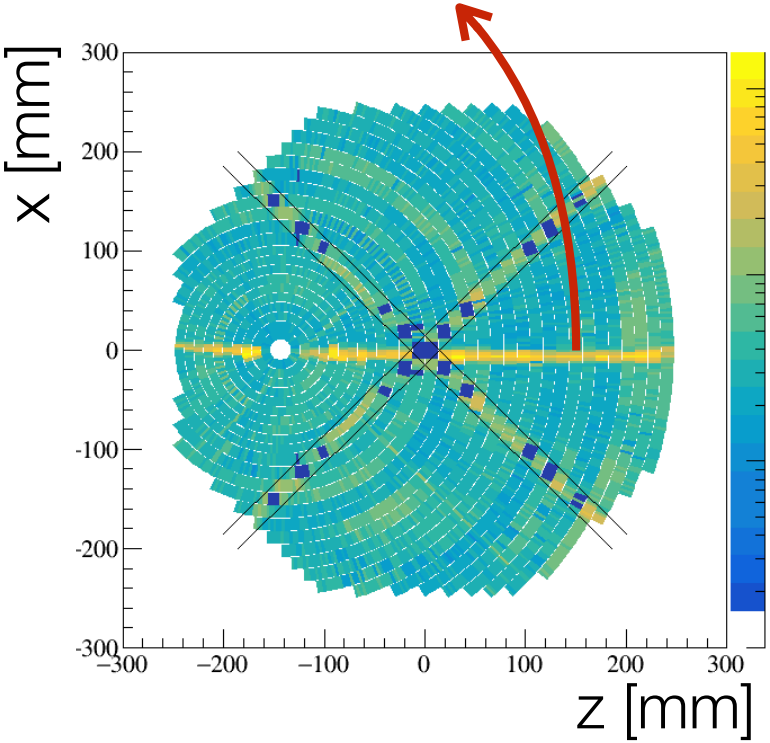
Beam Event



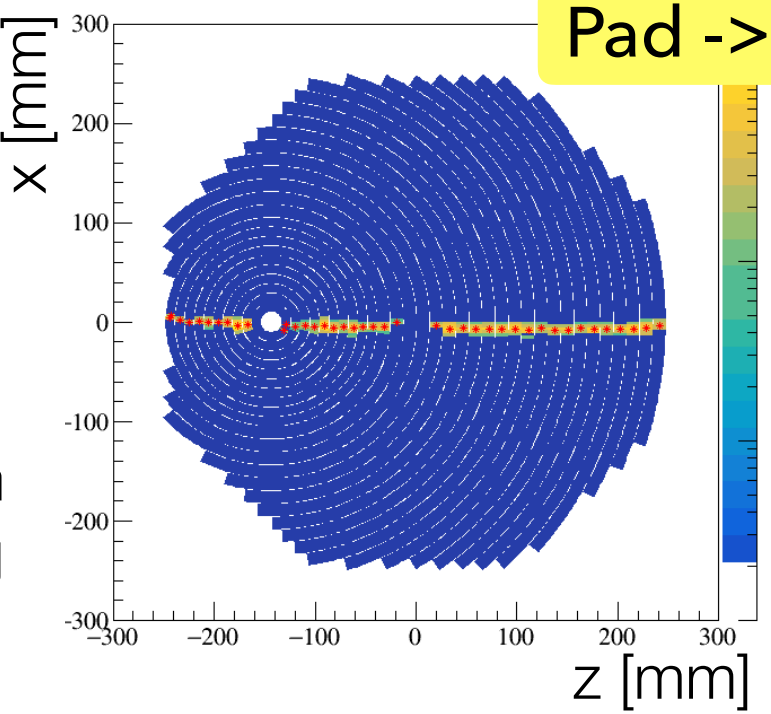
Baseline Correction



Time -> y



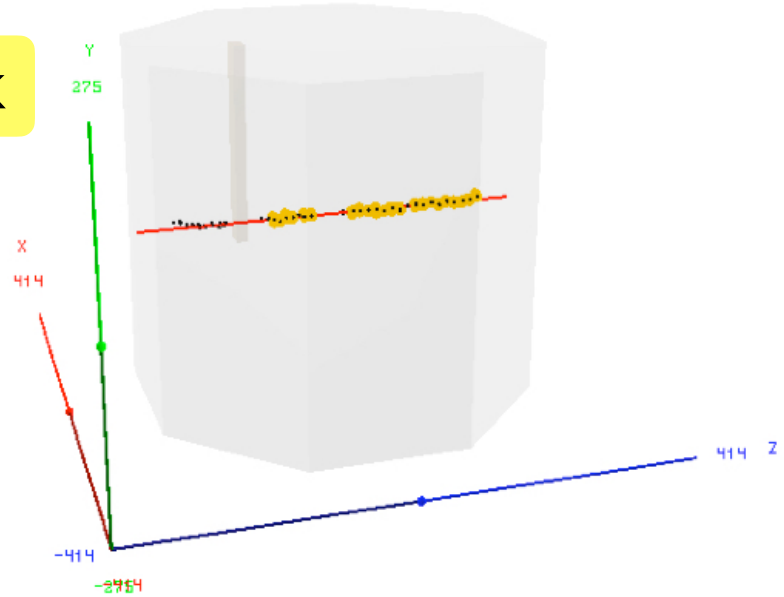
Hit Selection & Clustering



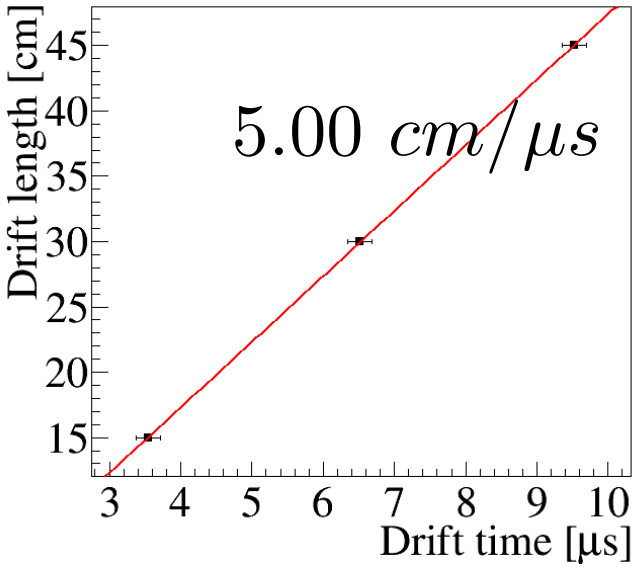
Pad -> x,z

Basic Performance

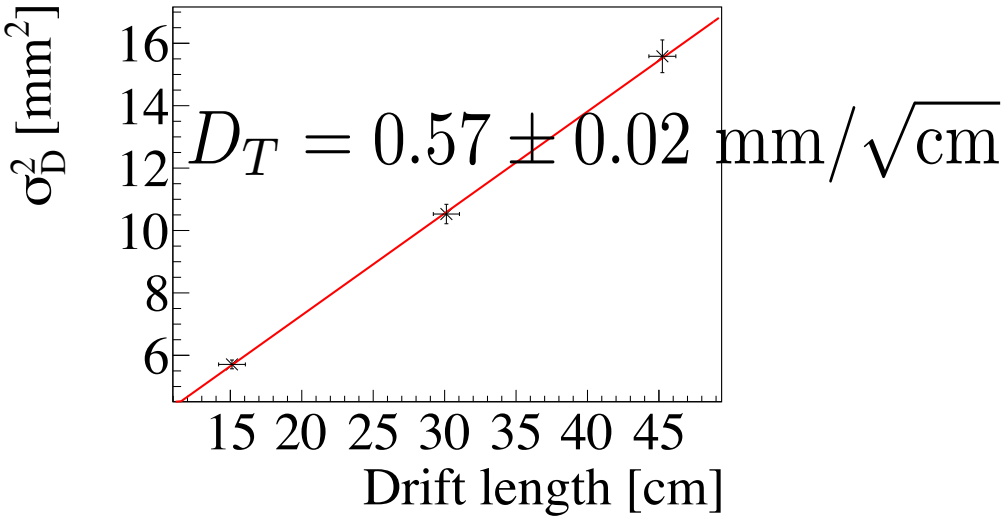
3D track



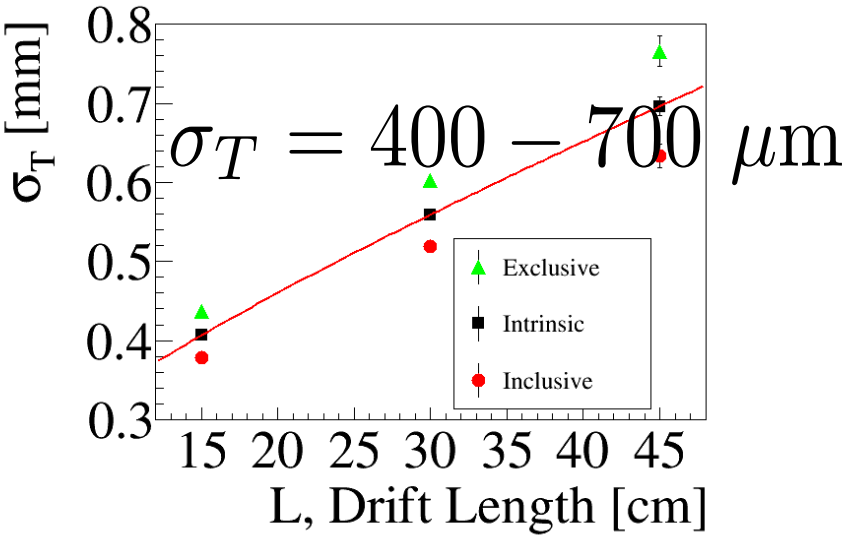
- Drift velocity



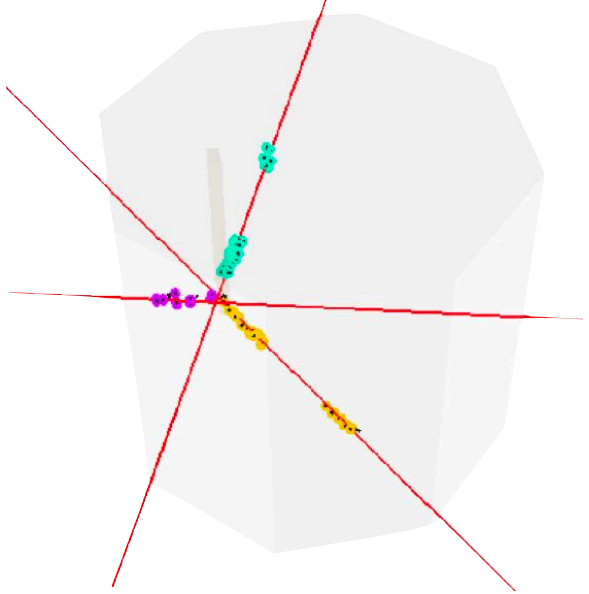
- Diffusion coefficient



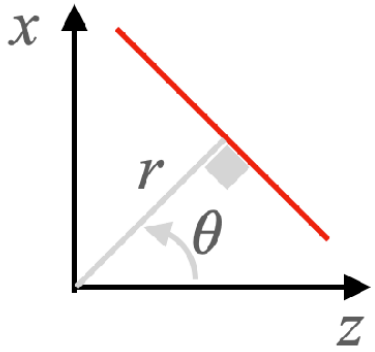
- Spatial resolution



Scattering Event

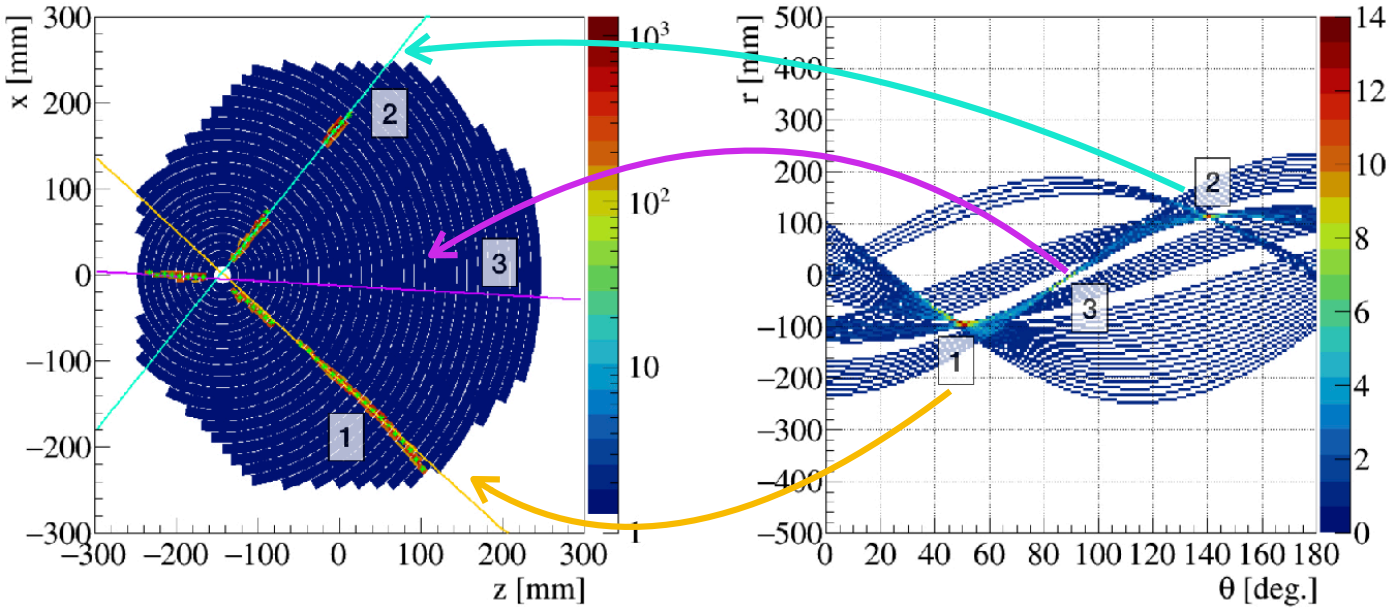


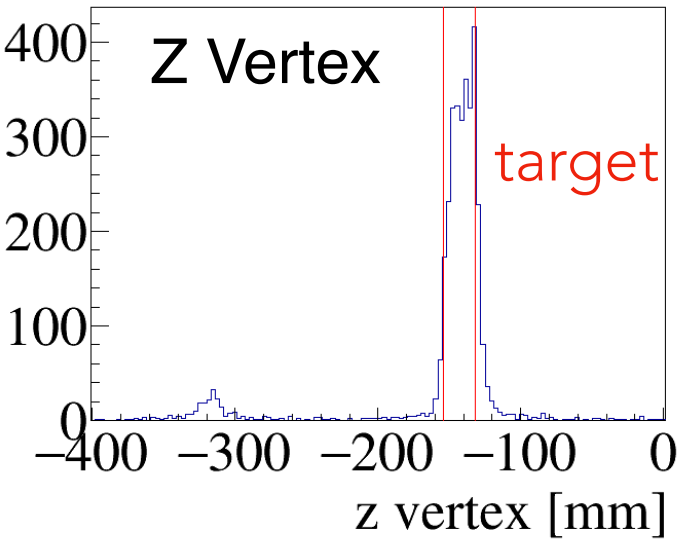
$$r = z \cdot \cos\theta + x \cdot \sin\theta$$



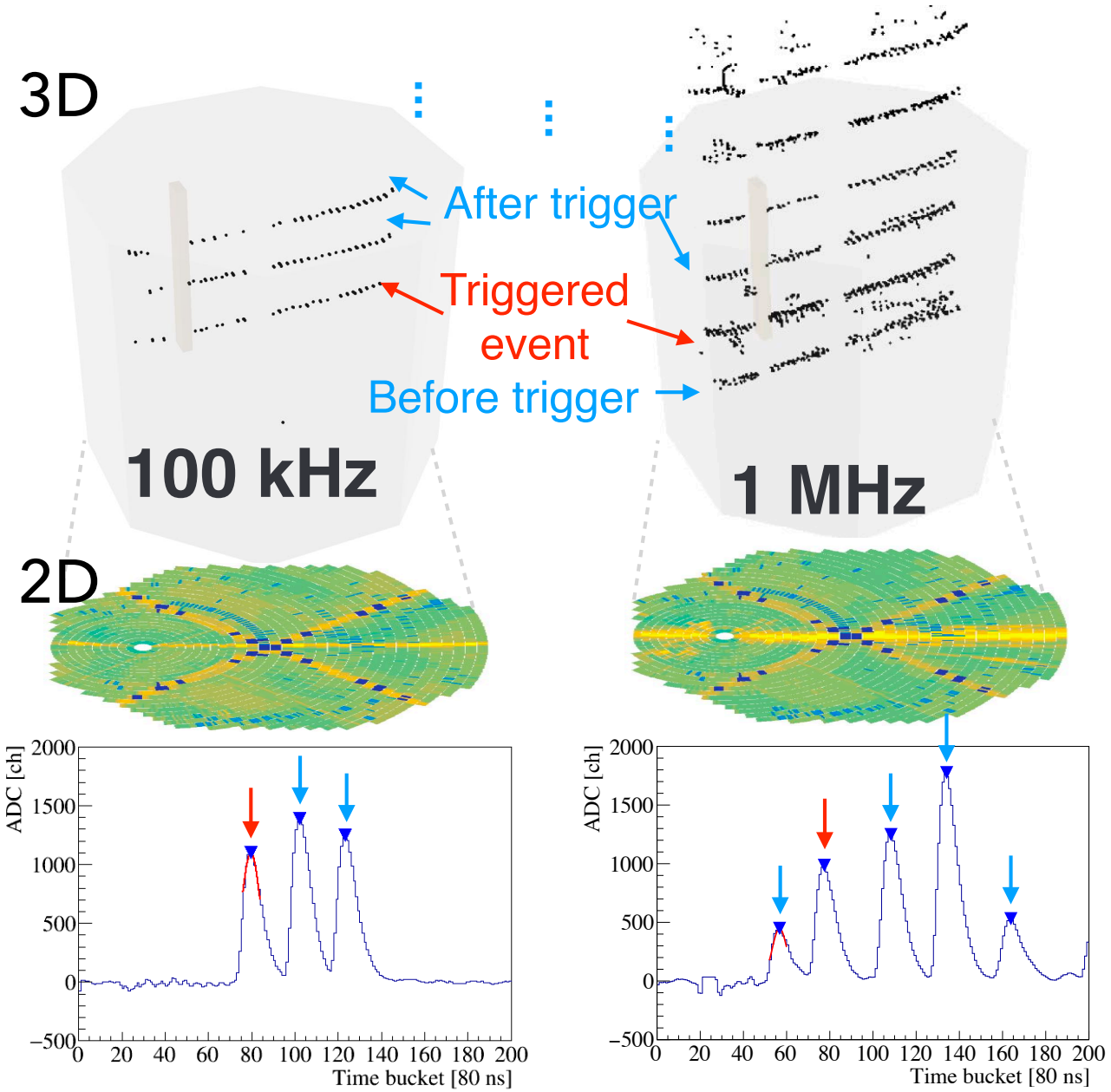
(z, x) Space

(r, θ) Hough Space

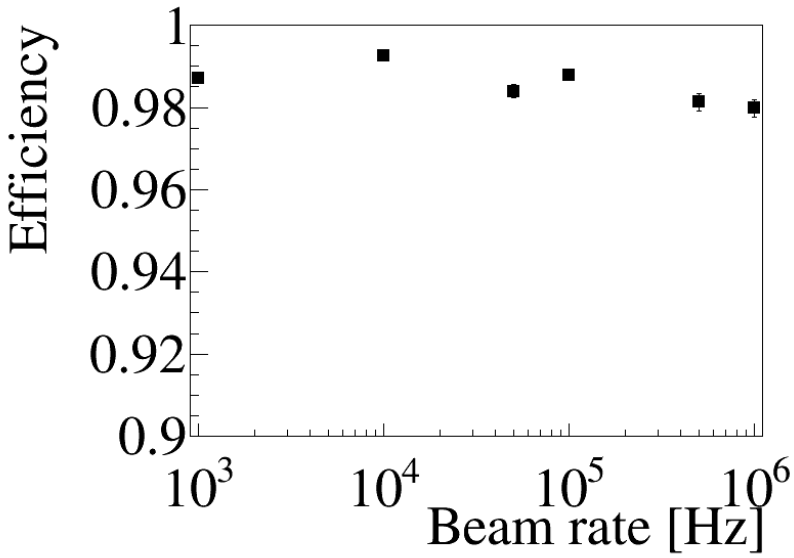




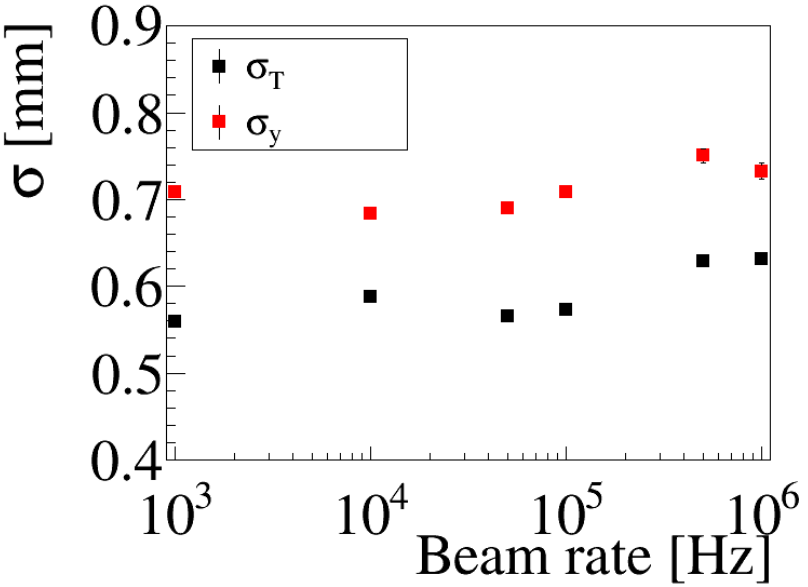
High-rate Capability



- Pad efficiency

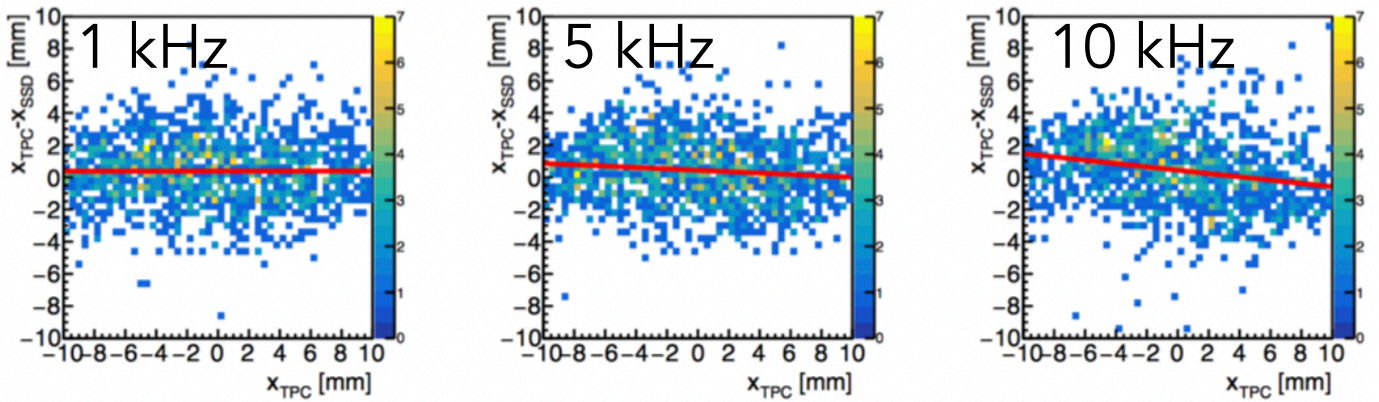


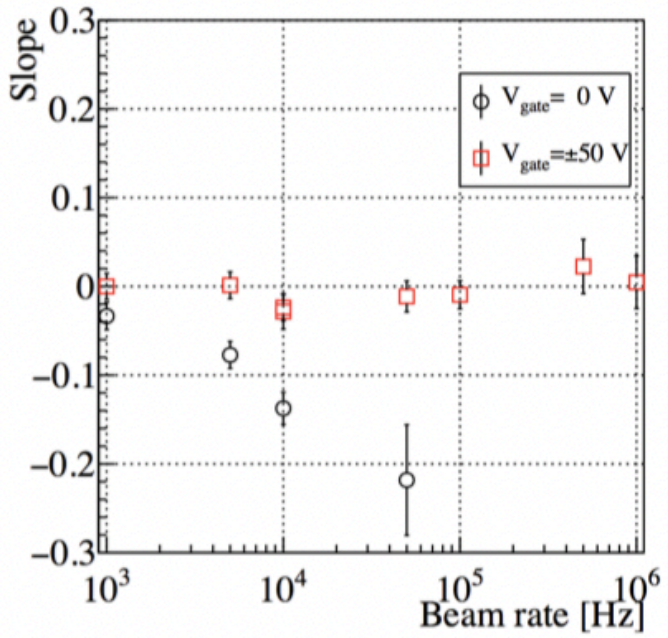
- Spatial resolution

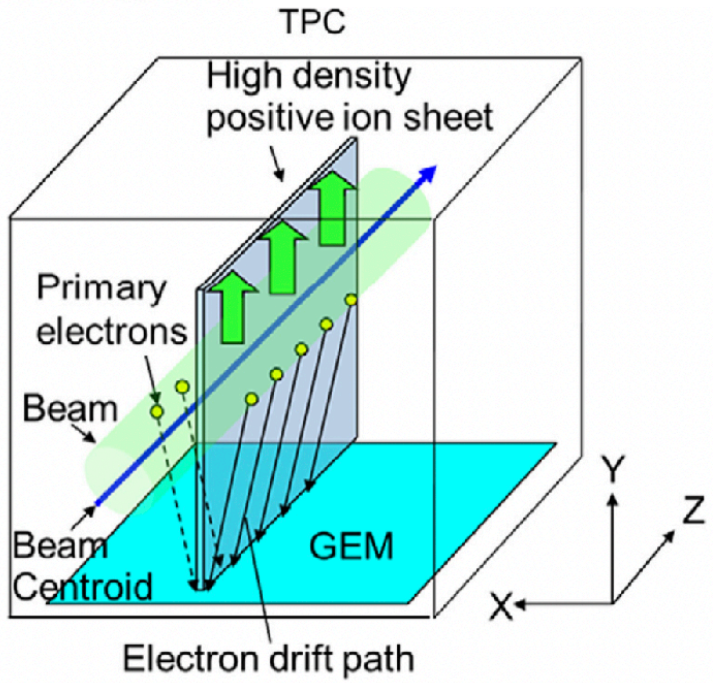


Ion Backflow Suppression w/ gate op.

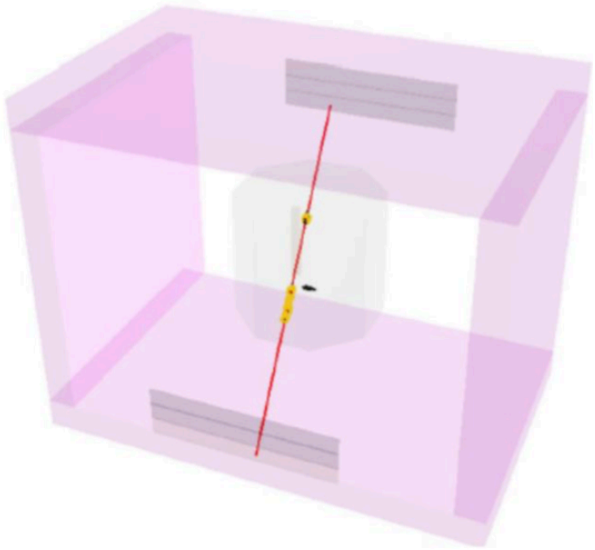
- X residual w/o gate operation



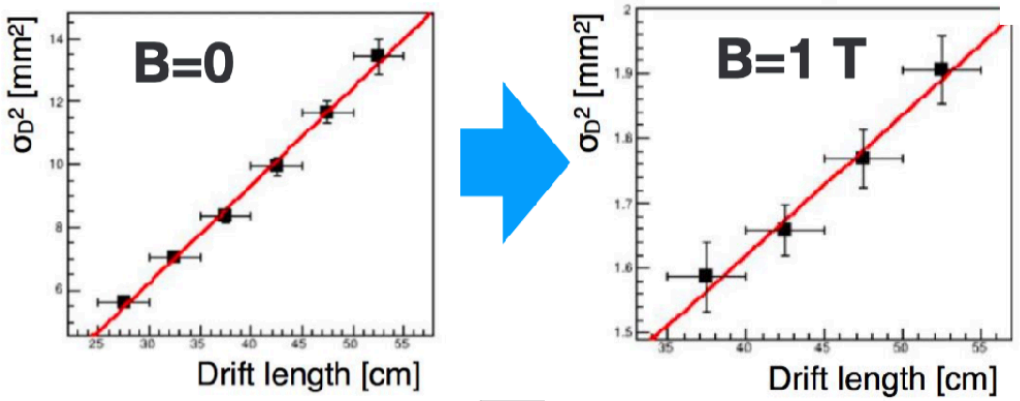




HypTPC Test in Magnetic Field

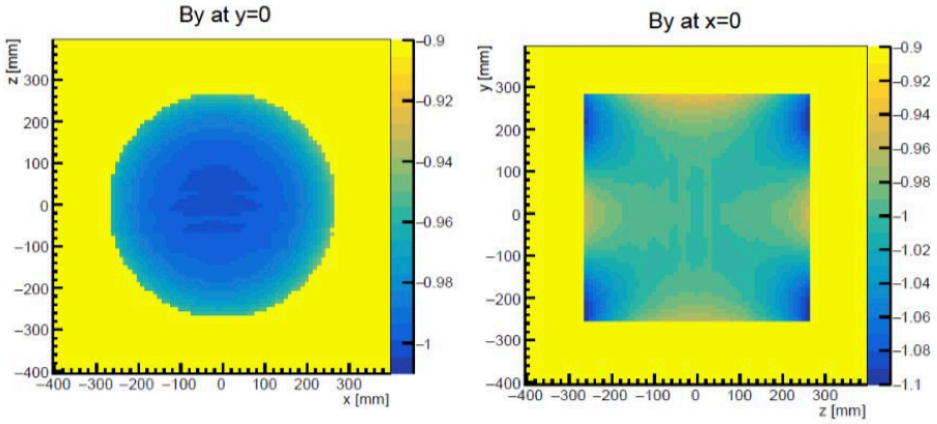


- Diffusion size



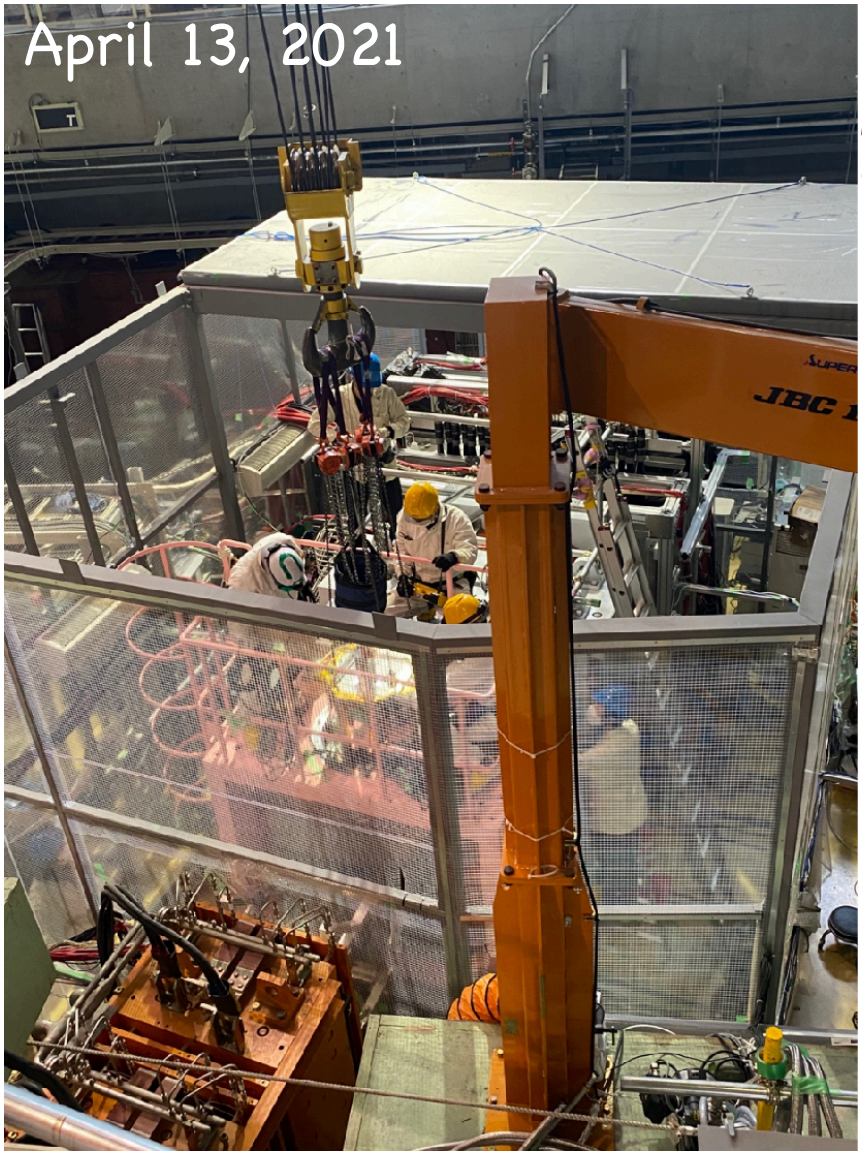
$D_T = 0.56 \pm 0.04\ mm/\sqrt{cm}$ $0.15 \pm 0.02\ mm/\sqrt{cm}$

- Field mapping



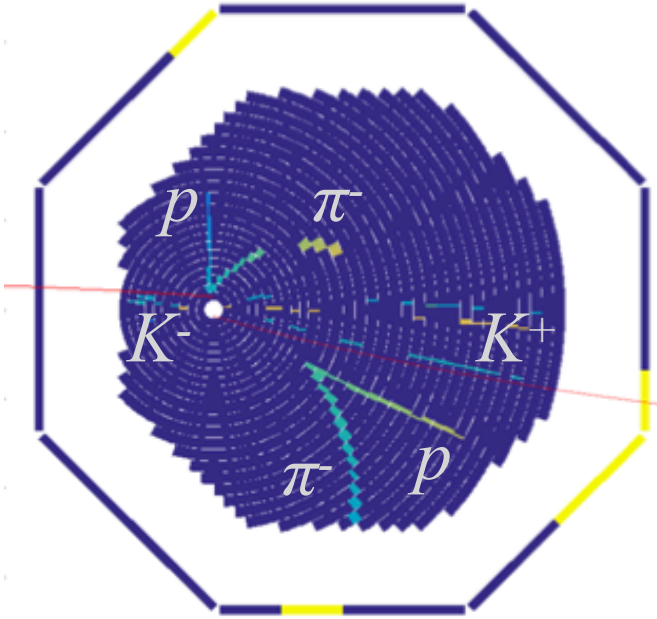
<2% uniformity

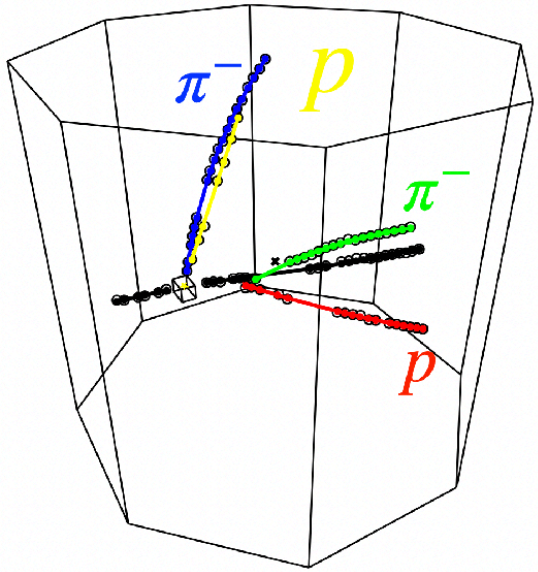
Hyperon Spectrometer at K1.8 Beam Line



J-PARC E42 Completed

- E42: Search for H-dibaryon via $^{12}C(K^-,K^+)$ reactions at 1.8 GeV/c
- Event display

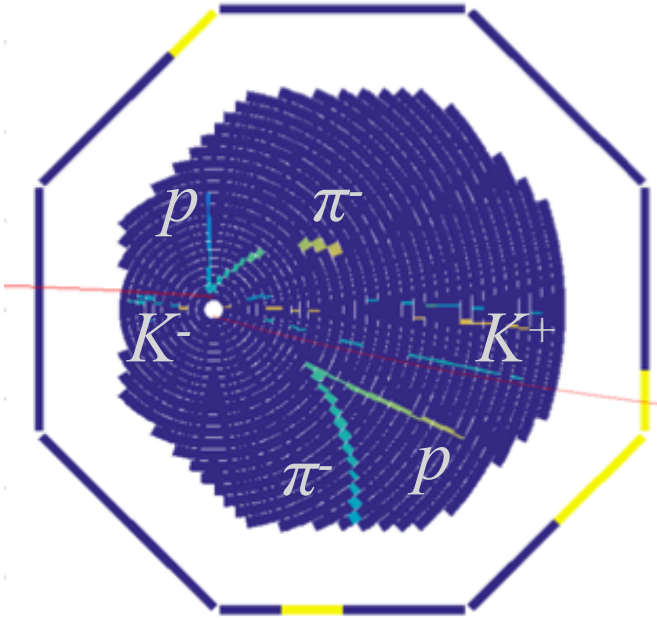


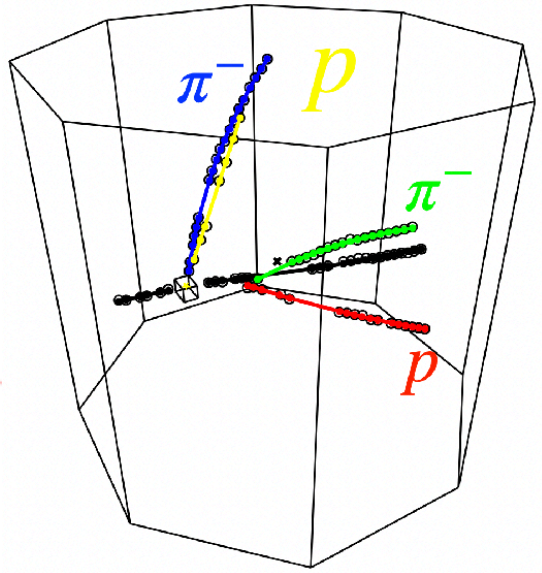


J-PARC E42 Completed

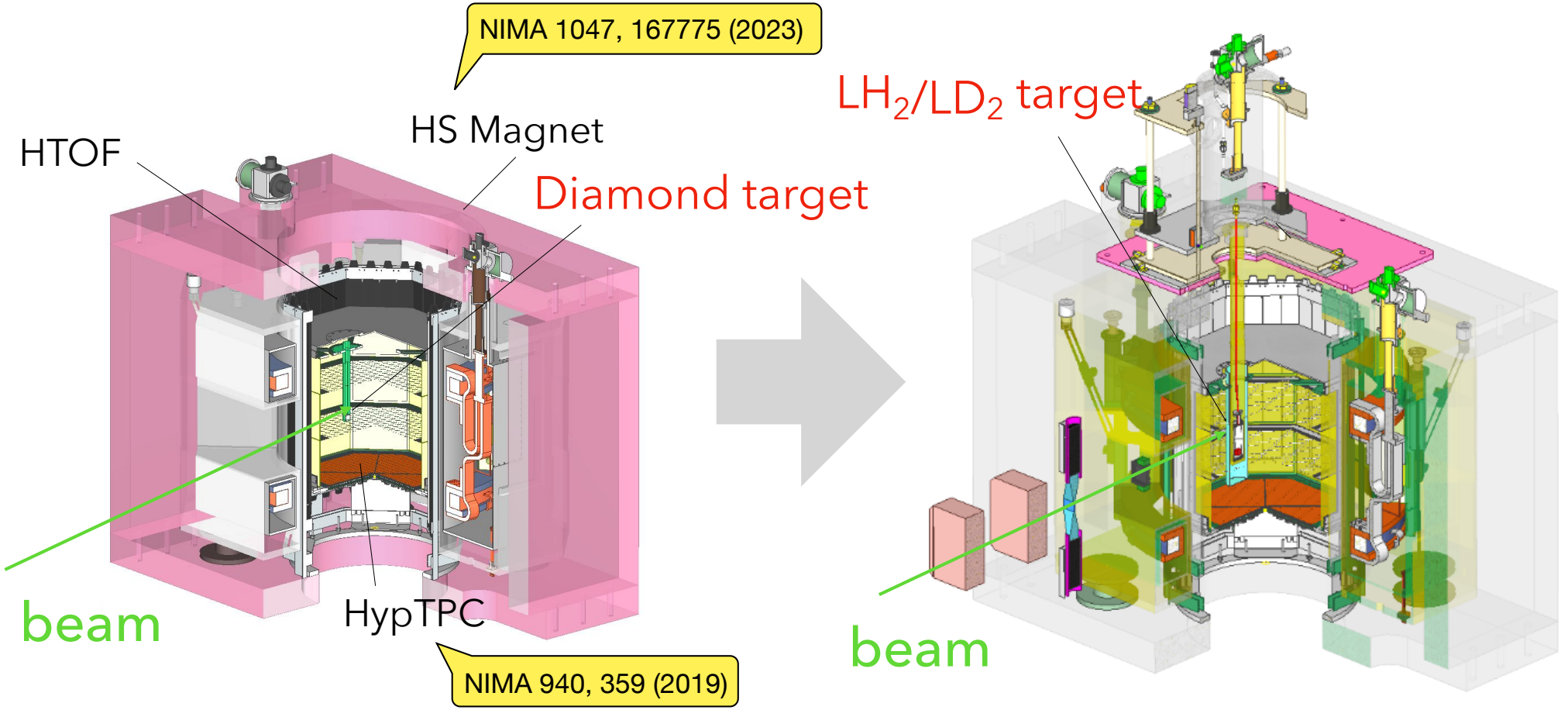
- E42: Search for H-dibaryon via $^{12}C(K^-,K^+)$ reactions at 1.8 GeV/c
- Event display

Related talks:
Jul 7th W. Jung, B. Kang





HypTPC Upgrade



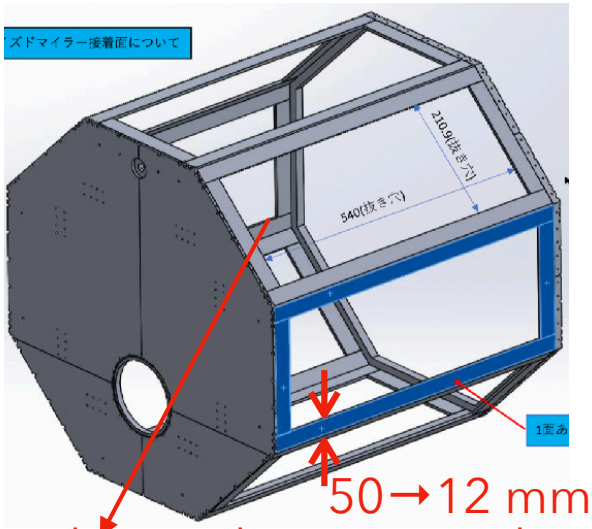
E42

May-Jun 2021

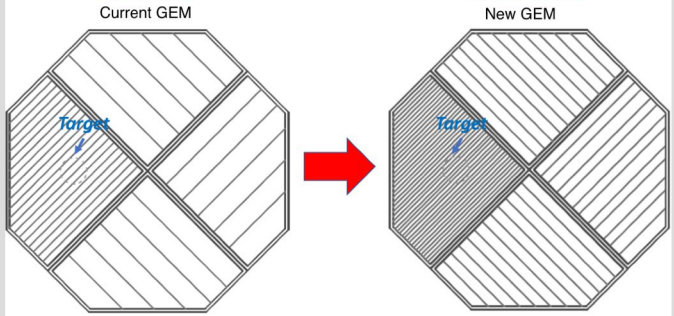
E45/E72/(E90)/E104

HypTPC Upgrade

- Gas Vessel



- Washed/New GEMs

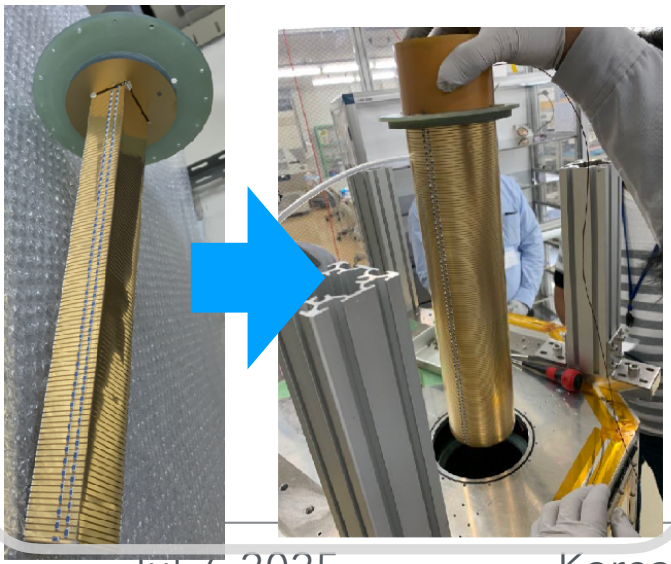


Finer segmentation
for bottom GEMs

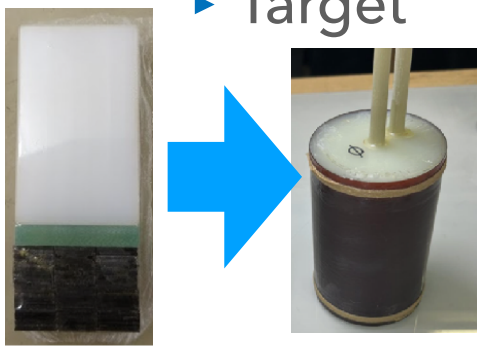
- Modified gate pulser

For higher trigger rate

- Target holder



- Target

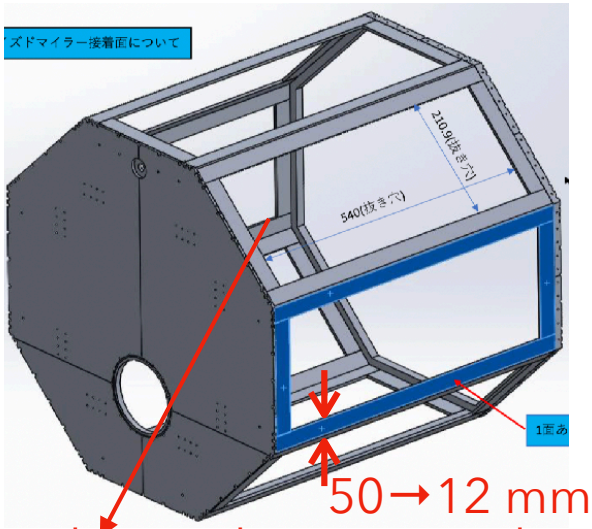


Target cooling system

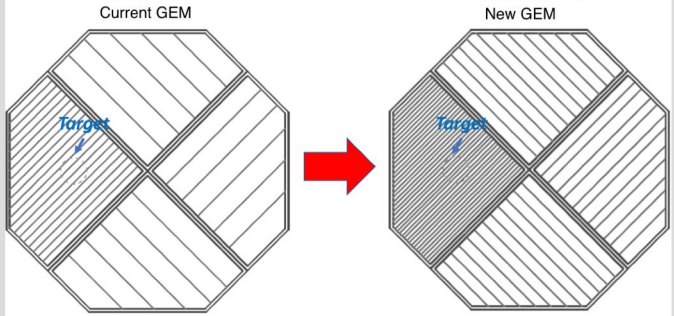
- New Electronics
  GET ➔ SPADI Alliance
- Glass GEM R&D

HypTPC Upgrade

- Gas Vessel



- Washed/New GEMs



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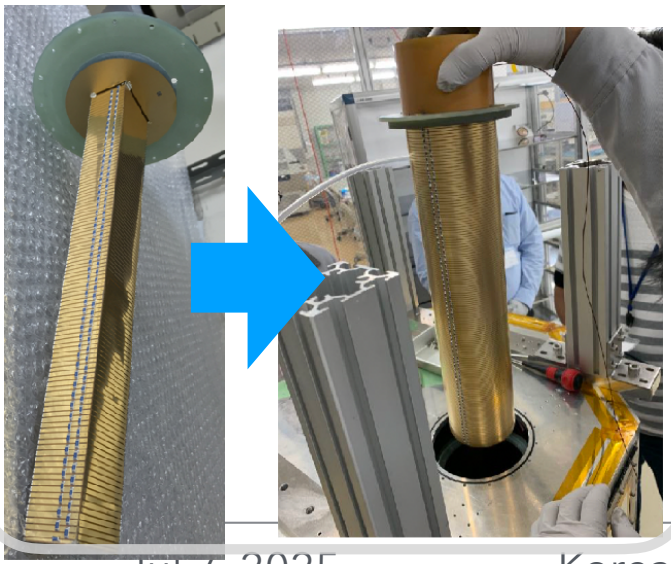
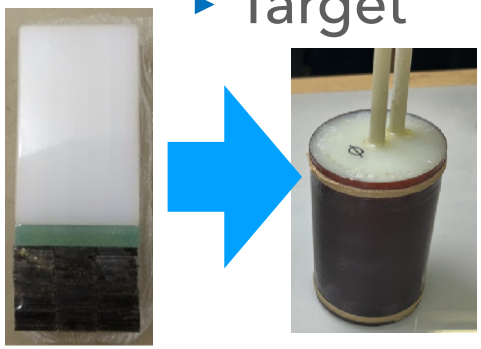


- Target



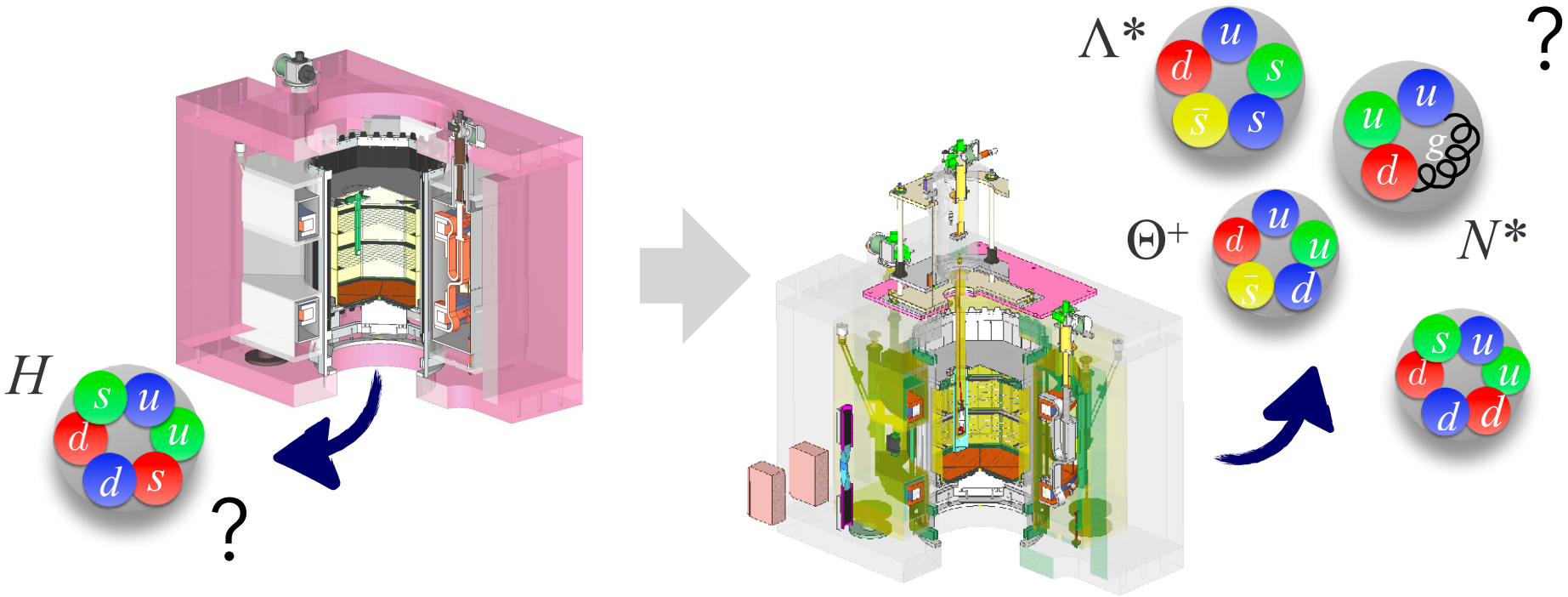
Target cooling system

- New Electronics
  GET → SPADI Alliance
- Glass GEM R&D

Jul 8th J. Lee

Summary

- We have developed the HypTPC for various hadron experiments at J-PARC.
- I hope this workshop provides a great opportunity to share ideas and insights related to TPC development.



Thank you for your attention!