Application of GET System for J-PARC HypTPC Experiments

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for the J-PARC E42/45 Collaboration

Outline

- J-PARC Experiments
- Hyperon Spectrometer
- GET System for HypTPC
- HypTPC Commissioning
- Things to do
- Summary

Where is J-PARC?
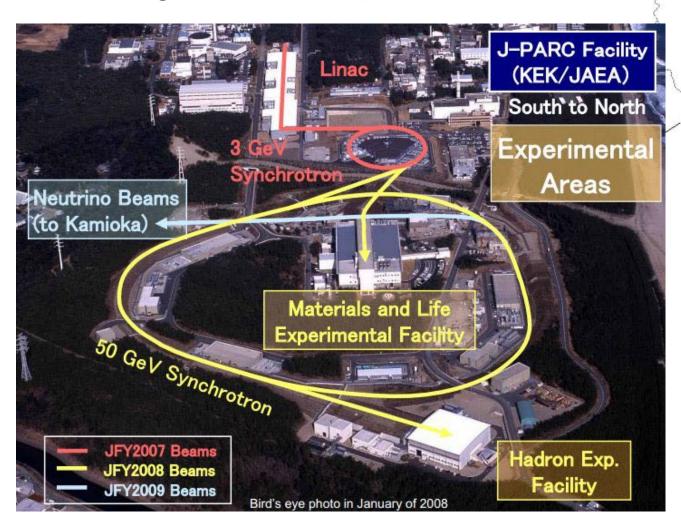
J-PARC

Japan **P**roton **A**ccelerator
Research **C**omplex
World highest intensity proton beam

Hadron Hall
K1.8 Beam Line
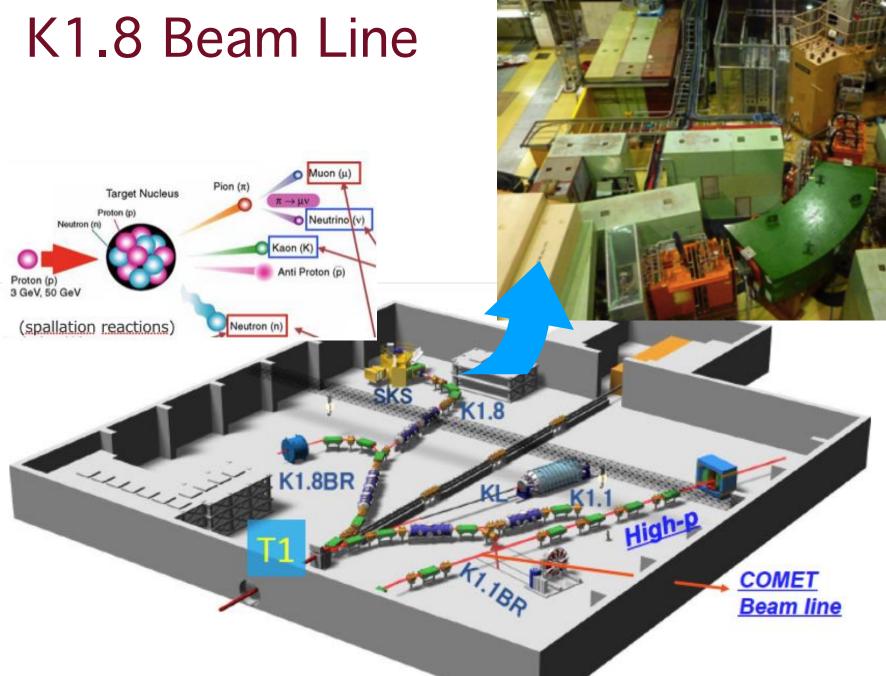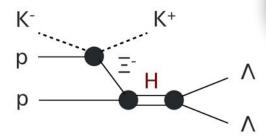
J-PARC E42 Experiment

H Di-baryon

?

uudd**ss**
$I=0$, $J^{\pi}=0^+$

K^- K^+

p Ξ^-

p   H Λ

     Λ

- high statistics
- high resolution

HypTPC
SC Magnet

Helmholtz coil   -HV plane

p

K^+

π^-

K^- π^- p

P-10 gas   triple GEMs Read-out

E=150 V/cm   B=1 T

Hyperon Spectrometer

KURAMA Spectrometer

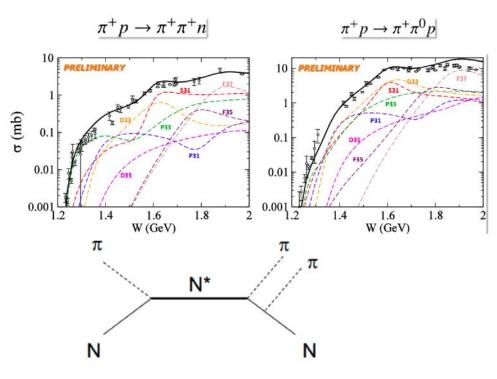K1.8 Beam Line Spectrometer

10^6/spill
K^- beam

K^+
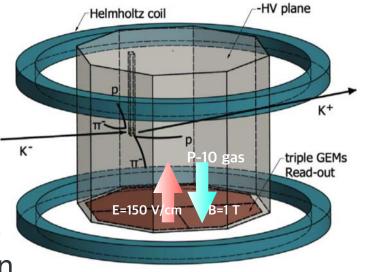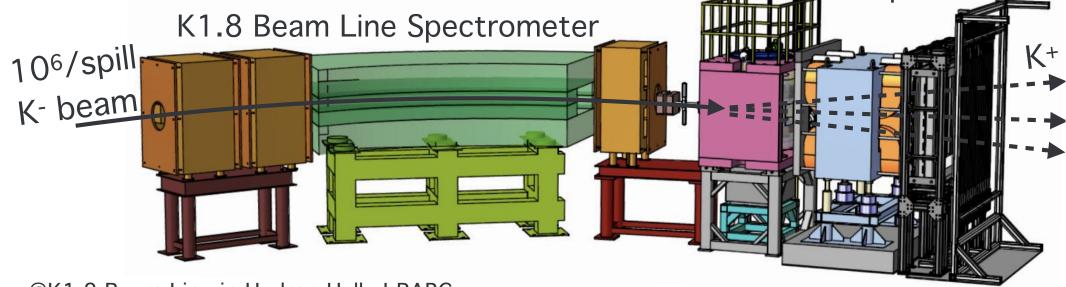
@K1.8 Beam Line in Hadron Hall, J-PARC

Other Experiments with Hyperon Spectrometer

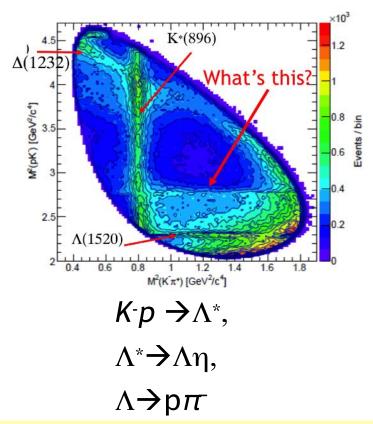## <J-PARC E45>

- A baryon spectroscopy with $(\pi, 2\pi)$ reaction

$$\pi p \to \pi^+\pi n,\ \pi^0\pi p$$
$$\pi^+ p \to \pi^0\pi^+ p,\ \pi^+\pi^+ n$$

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

<J-PARC E72>

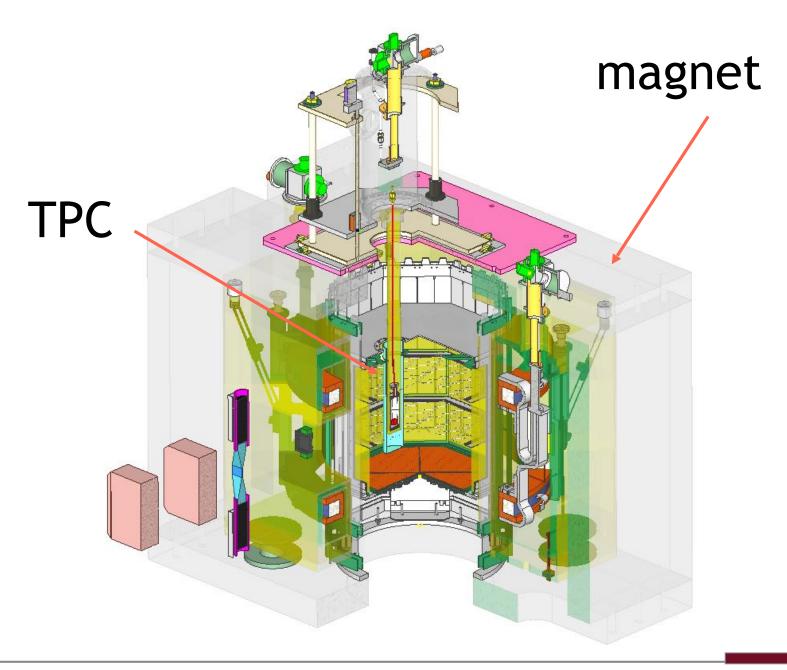- A new Λ resonance search near $\Lambda\eta$ threshold

$$K^-p \to \Lambda^*,$$
$$\Lambda^* \to \Lambda\eta,$$
$$\Lambda \to p\pi$$

S. B. Yang et al., Phys. Rev. Lett. 117, 011801 (2016)
K. Tanida et al., J-PARC Proposal E72

Hyperon Spectrometer

magnet

TPC
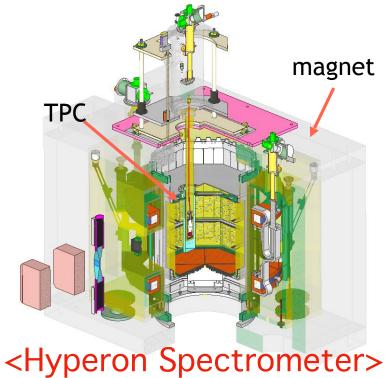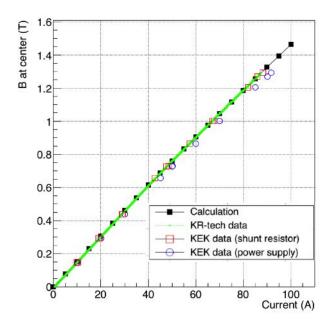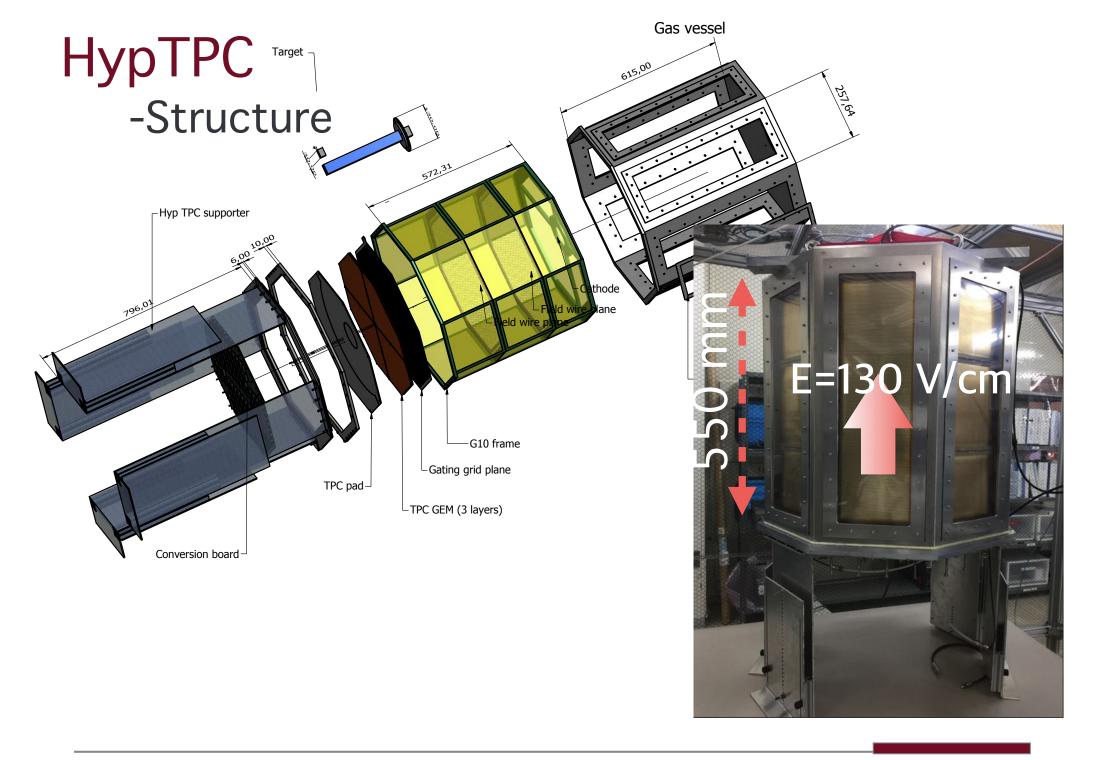
Superconducting Magnet

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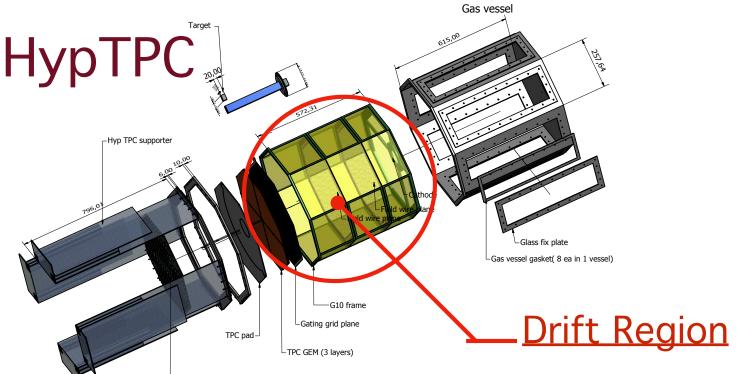- 1.5 T Max. @ 103 A
- $\Delta By/B_0$<3 % in TPC volume

TPC

magnet

<Hyperon Spectrometer>

SC magnet@KEK

HypTPC
-Structure

Target

Gas vessel

615,00

257,64

572,31

Hyp TPC supporter

6,00   10,00

796,01

Cathode

Field wire plane

Field wire plane

G10 frame

Gating grid plane

TPC pad

TPC GEM (3 layers)

Conversion board

550 mm

E=130 V/cm

HypTPC

Target

Gas vessel

Hyp TPC supporter

Cathode

Field wire plane

Field wire plane

G10 frame

Gating grid plane

TPC pad

TPC GEM (3 layers)

Conversion board

Glass fix plate

Gas vessel gasket(8 ea in 1 vessel)

Drift Region

E=130 V/cm

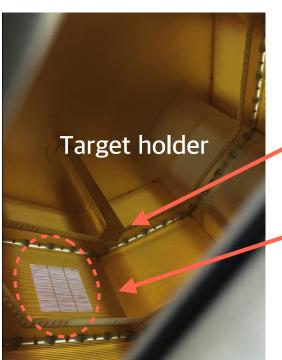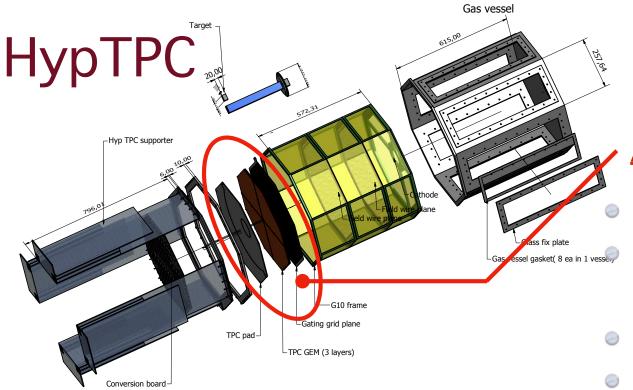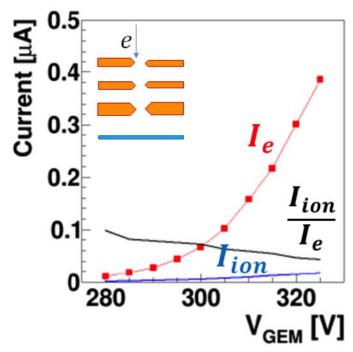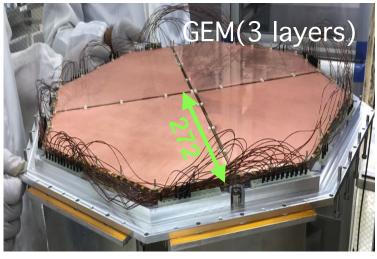550 mm

target holder

field cage

Cathode

Target holder

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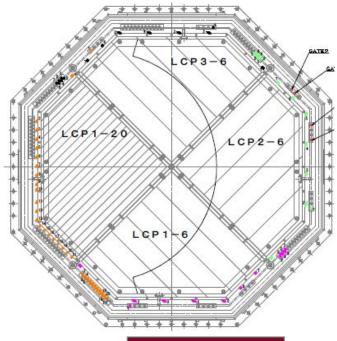- Beam slits to avoid charge build-up on the field cage in high rate beam.
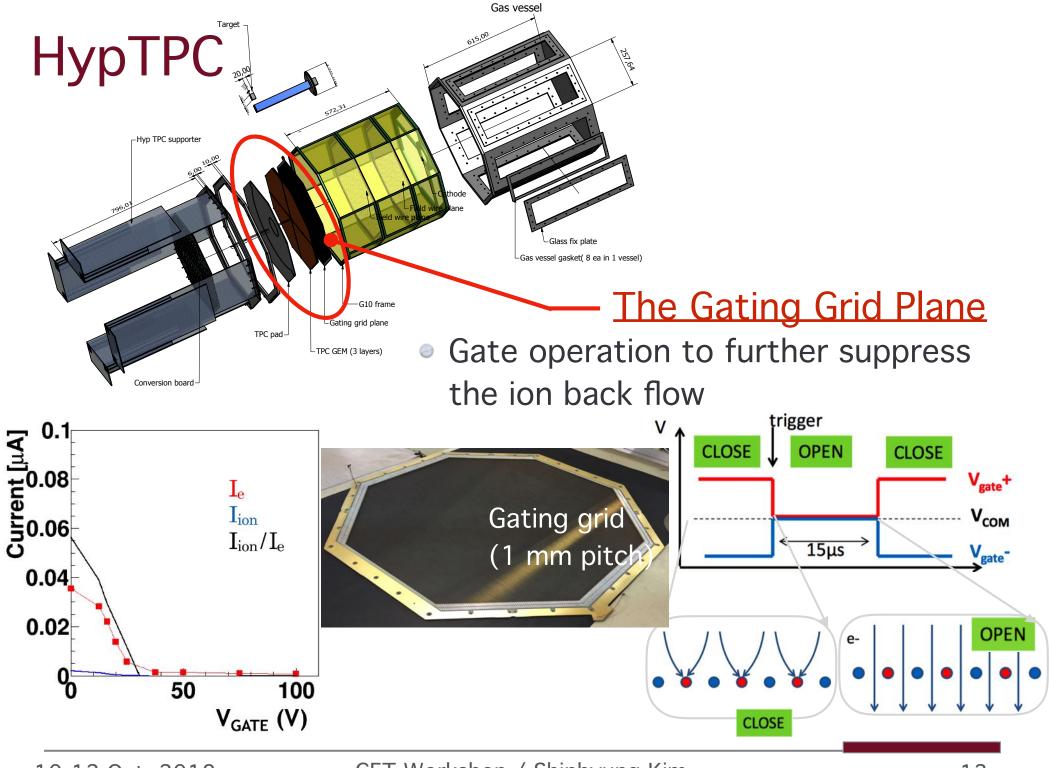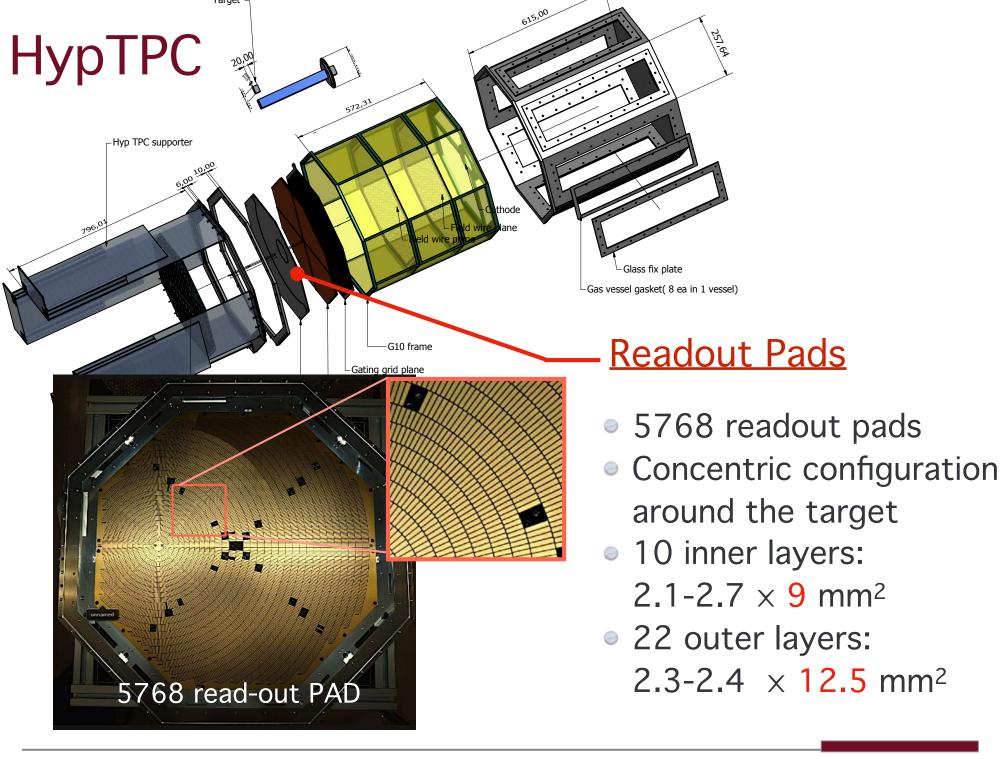
HypTPC

Amplification Region

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

GEM(3 layers)

272

LCP3-6
LCP1-20
LCP2-6
LCP1-6

HypTPC

The Gating Grid Plane

- Gate operation to further suppress the ion back flow

Gating grid
(1 mm pitch)

HypTPC

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

5768 read-out PAD

GET(General Electronics for TPCs)

HypTPC
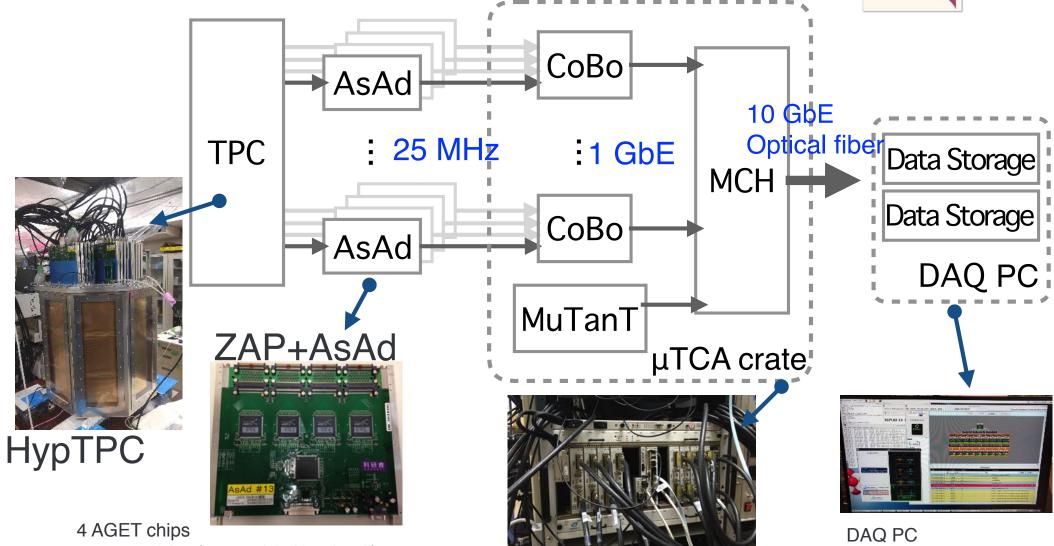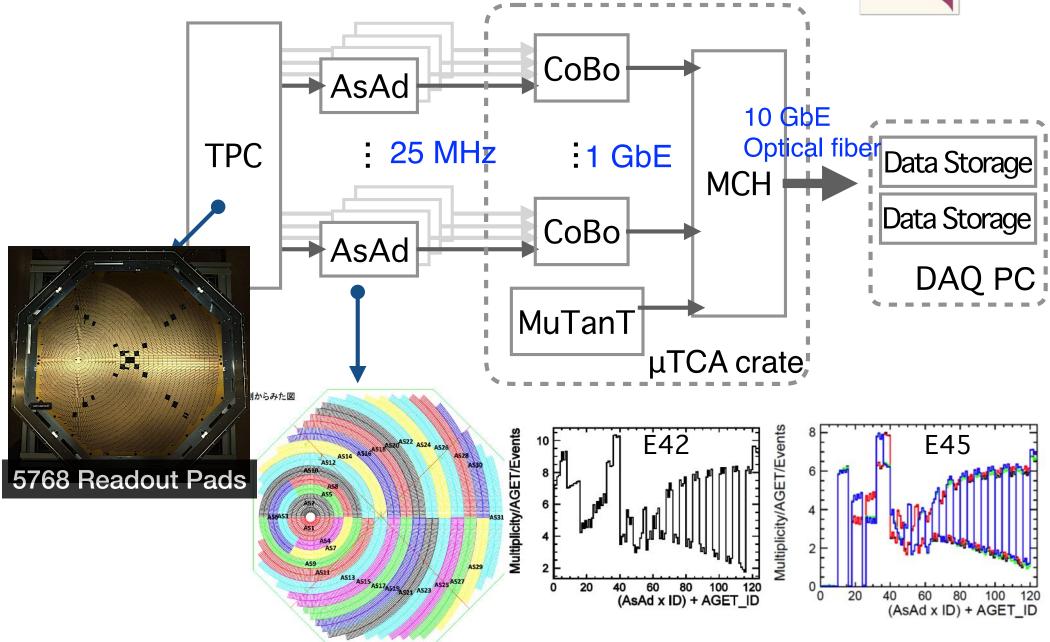
ZAP+AsAd

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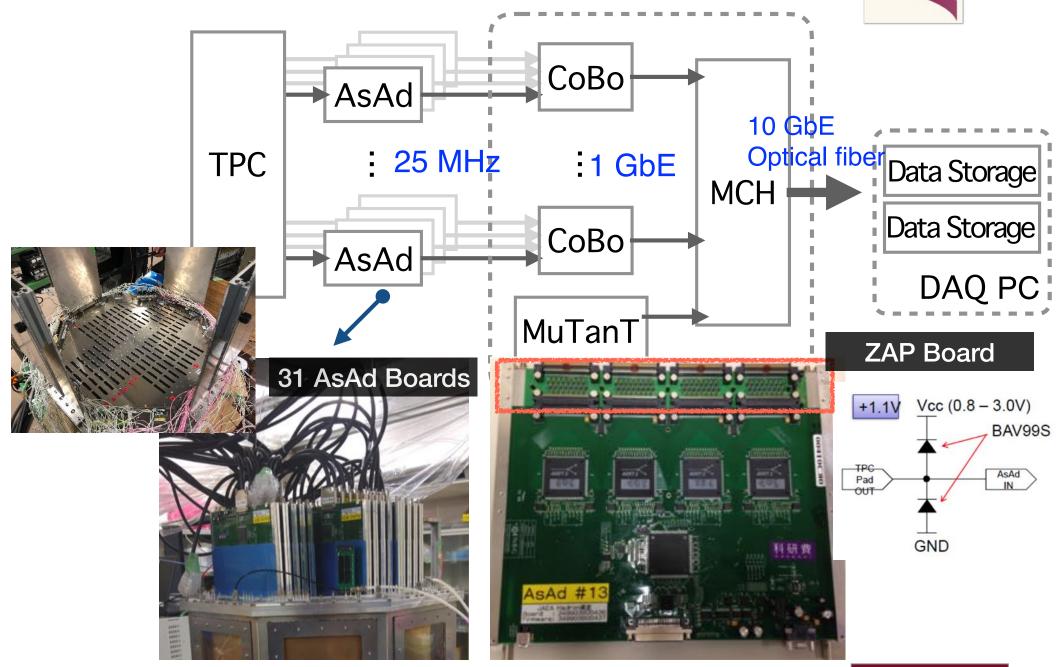- Circular Buffer(sampling rate 1 MHz-100 MHz)

12-bit ADC

CoBo
- Data processing
- Data formatting

MuTanT
- synchronous trigger

MCH(μTCA Carrier Hub)

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

GET(General Electronics for TPCs)

TPC

AsAd

: 25 MHz

AsAd

CoBo

: 1 GbE

CoBo

MuTanT

MCH

10 GbE
Optical fiber

Data Storage

Data Storage

DAQ PC

µTCA crate

5768 Readout Pads

E42

Multiplicity/AGET/Events

(AsAd x ID) + AGET_ID

E45

Multiplicity/AGET/Events

(AsAd x ID) + AGET_ID

GET(General Electronics for TPCs)

10 GbE
Optical fiber

TPC · 25 MHz · 1 GbE

31 AsAd Boards

ZAP Board

+1.1V   Vcc (0.8 – 3.0V)

BAV99S

TPC Pad OUT   AsAd IN

GND

GET(General Electronics for TPCs)

TPC → AsAd ⋮ 25 MHz → CoBo ⋮ 1 GbE → MCH — 10 GbE Optical fiber → Data Storage / Data Storage (DAQ PC)

AsAd → CoBo

MuTanT → MCH

µTCA crate

HypTPC Commissioning at HIMAC

- To study the basic performance and the high rate capability of TPC
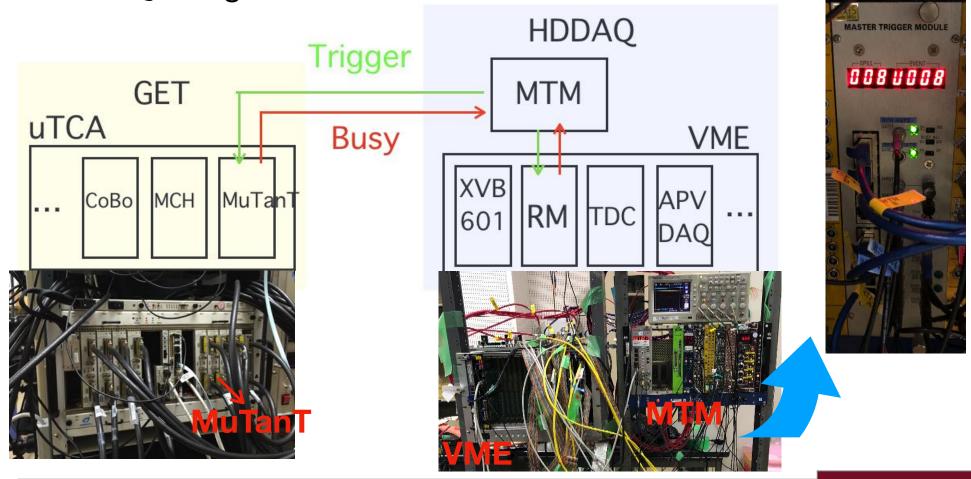
DAQ System at HIMAC(GET + HDDAQ)

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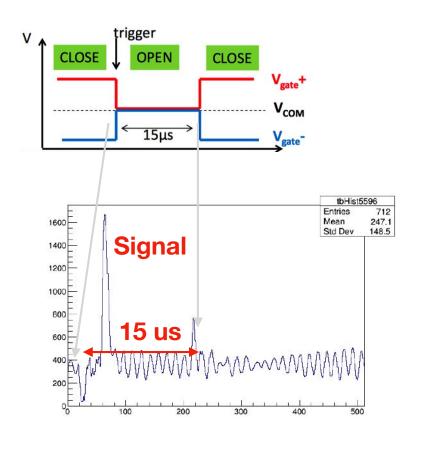- The GET(TPC DAQ) shares the trigger and busy signal with HDDAQ using MuTanT module.
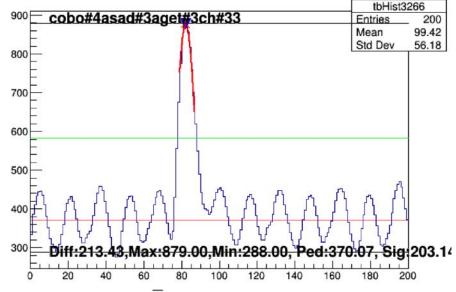
DAQ Performance

- 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.
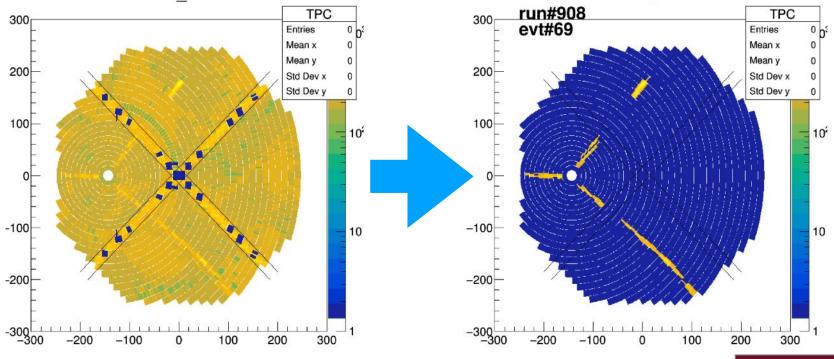
Hit Selection
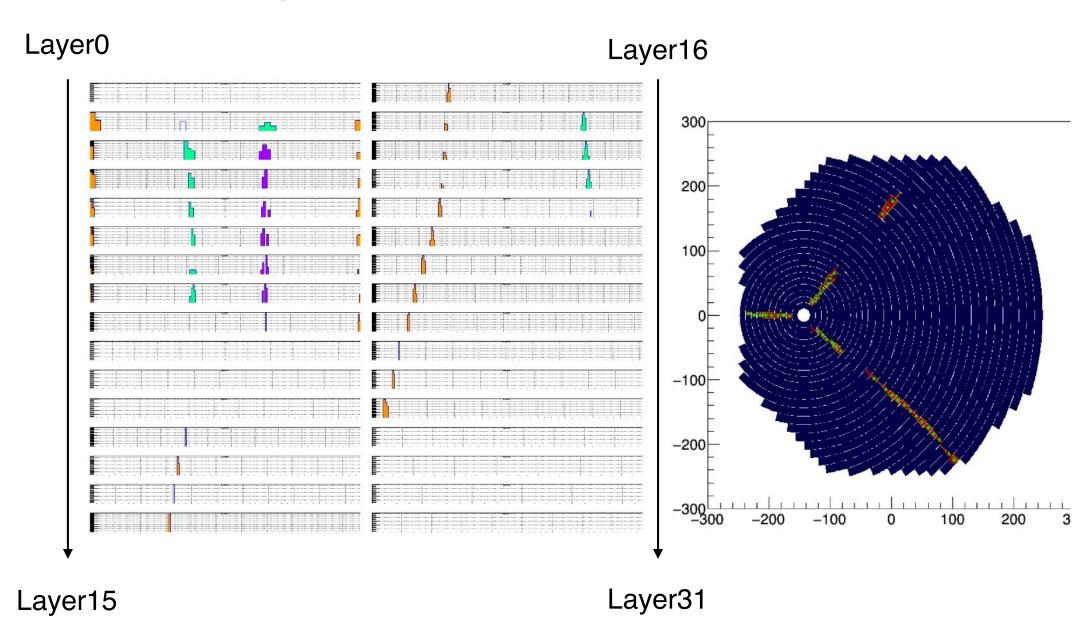

Gain: 120 fC
Peaking time: 502 ns
Sampling freq.: 12.5 MHz
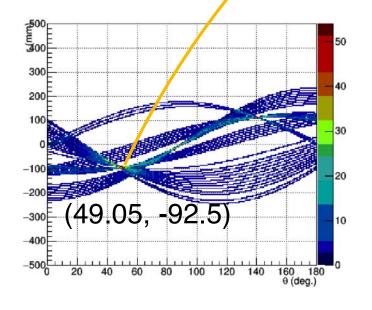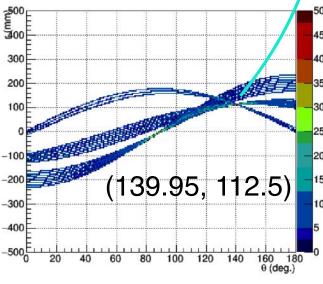Readout depth : 200
(80 ns X 200 = 16 us)

Clustering

Layer0

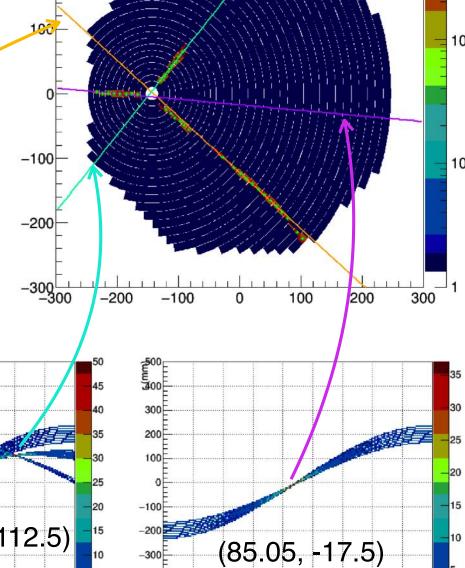Layer16

Layer15

Layer31

Track Finding

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

(x, y) -> (θ, r)

Hough Space

(49.05, -92.5)
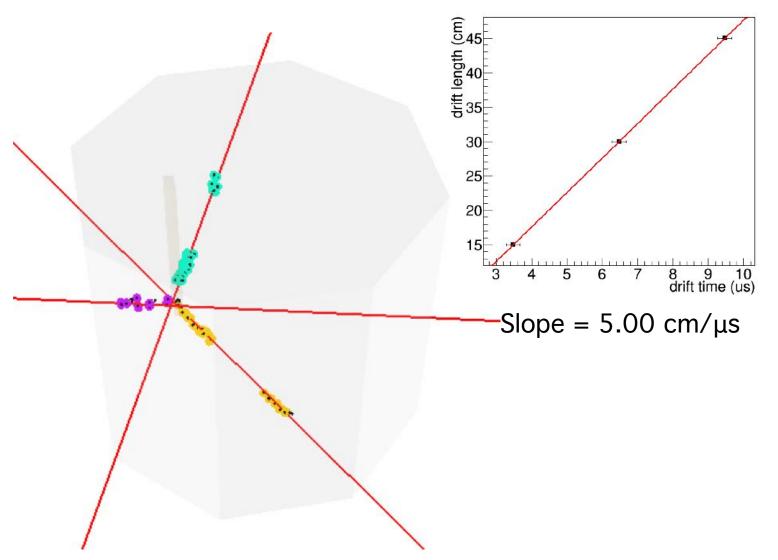
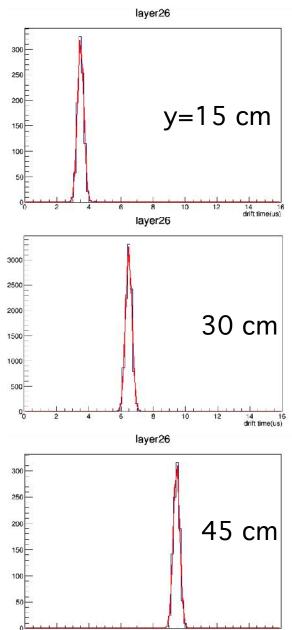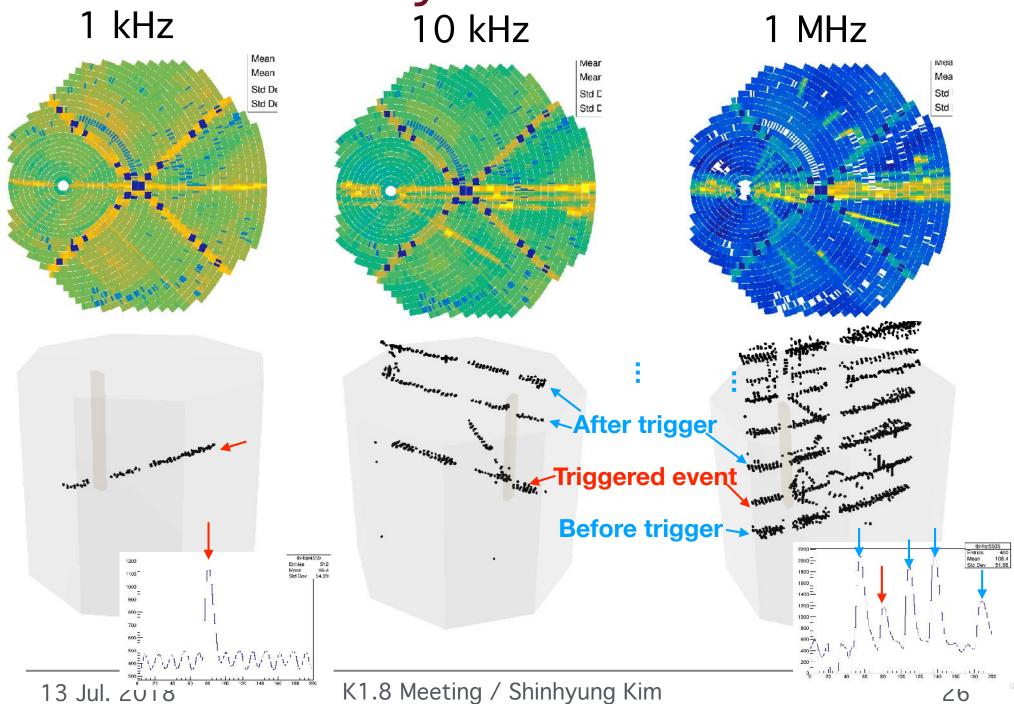(139.95, 112.5)

(85.05, -17.5)

3D Track Reconstruction

Slope = 5.00 cm/μs

y=15 cm

30 cm

45 cm

Beam Rate Study

1 kHz   10 kHz   1 MHz

After trigger

Triggered event

Before trigger
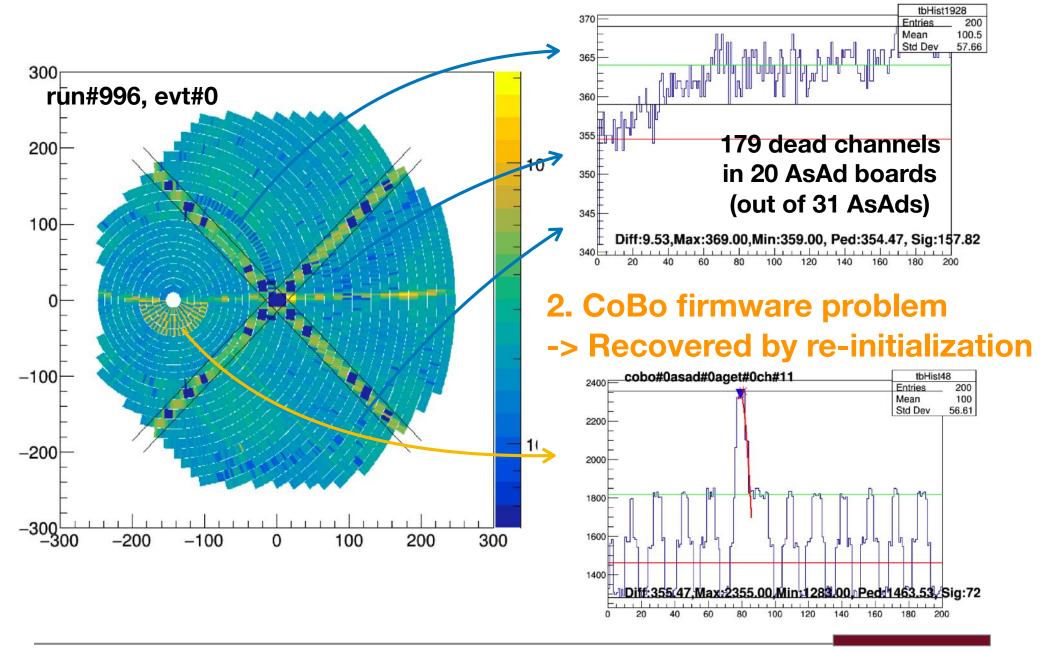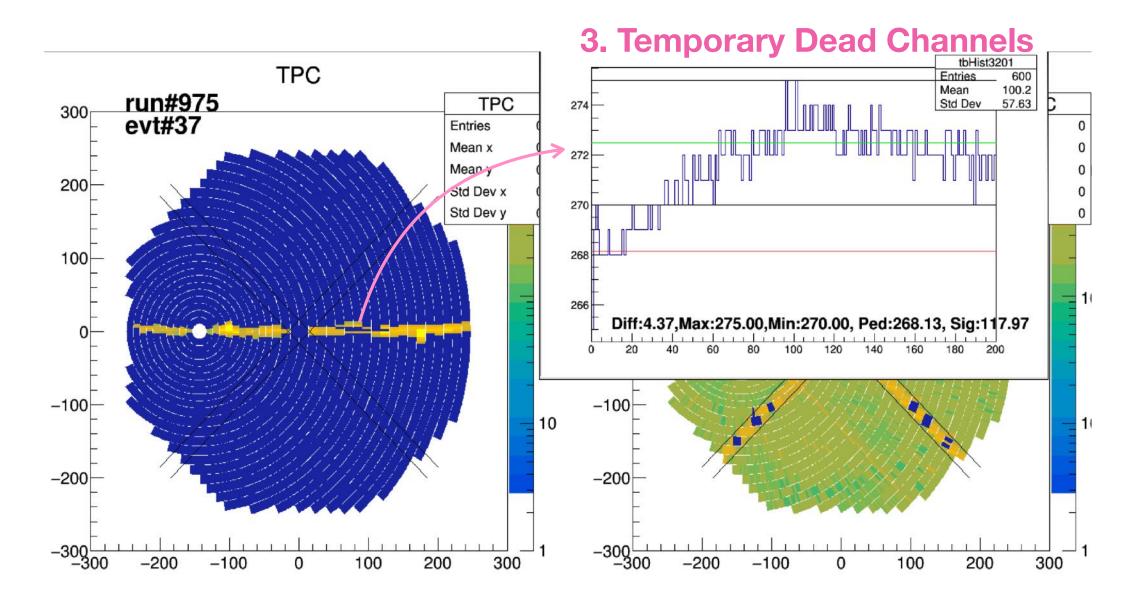
Several Issues
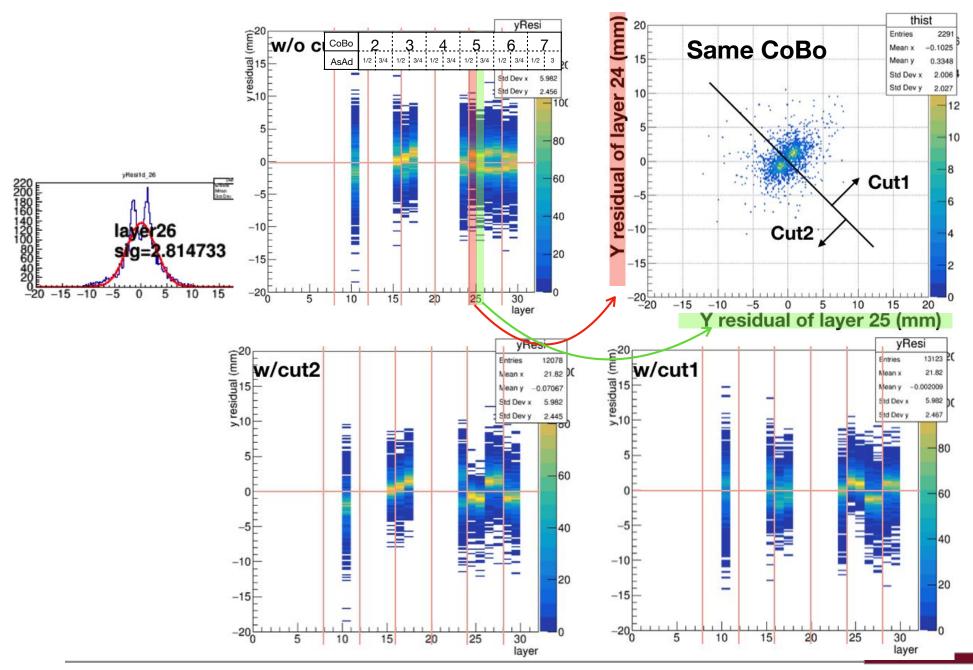
1. Permanently Dead Channels

run#996, evt#0

**179 dead channels
in 20 AsAd boards
(out of 31 AsAds)**

Diff:9.53,Max:369.00,Min:359.00, Ped:354.47, Sig:157.82

**2. CoBo firmware problem
-> Recovered by re-initialization**

cobo#0asad#0aget#0ch#11

Diff:355.47,Max:2355.00,Min:1283.00, Ped:1463.53, Sig:72

Several Issues

3. Temporary Dead Channels
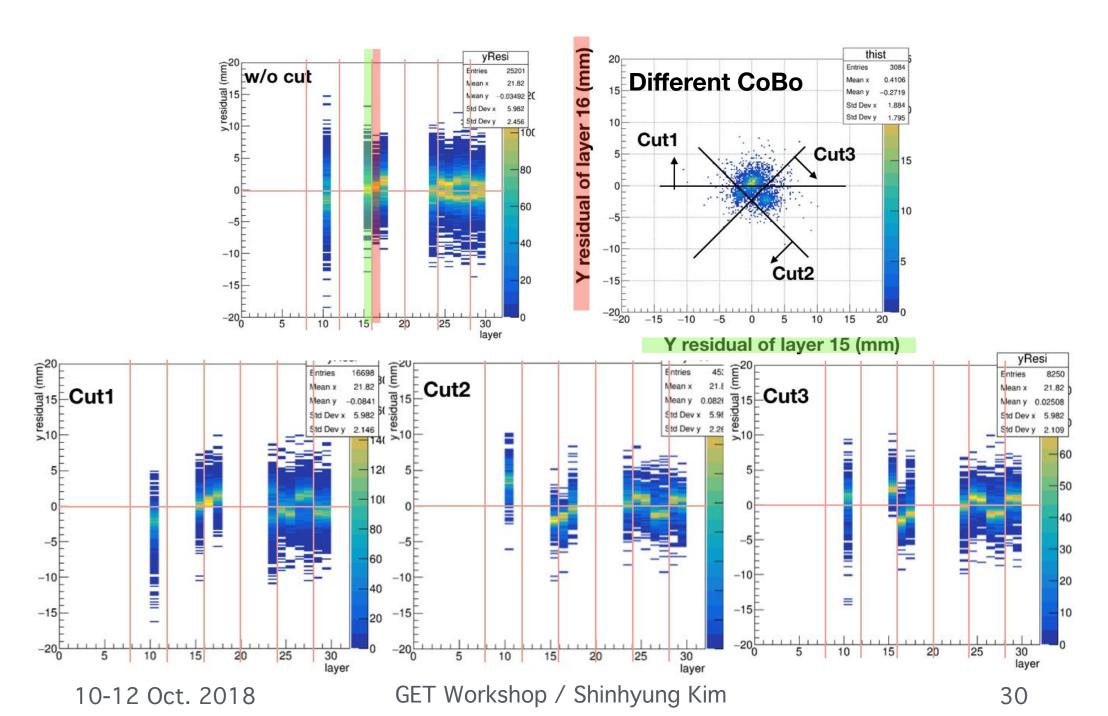
Y Residual Problem
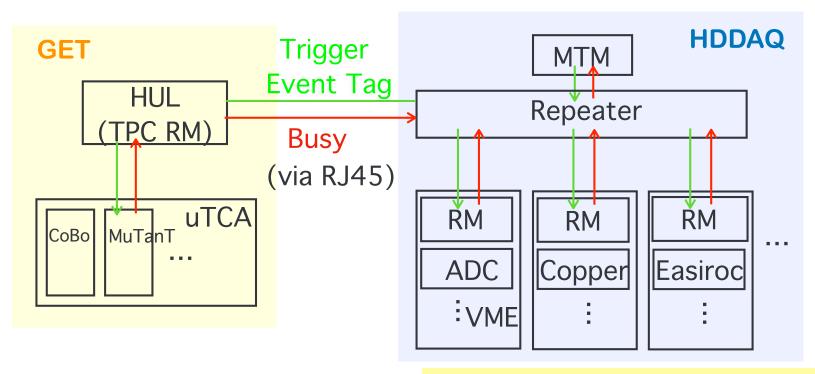
Y Residual Problem

Toward the Real Experiments

- We will run the GET(TPC DAQ) system with the existing HDDAQ (J-PARC K1.8 beamline DAQ system).
- The trigger/busy signal and the event tag will be shared via an HUL(Hadron Universal Logic) module.

Y. Igarashi et al., IEEE Trans. Nucl. Sci. 57, 618 (2010)

TPC RM

Hadron Universal Logic (HUL) module

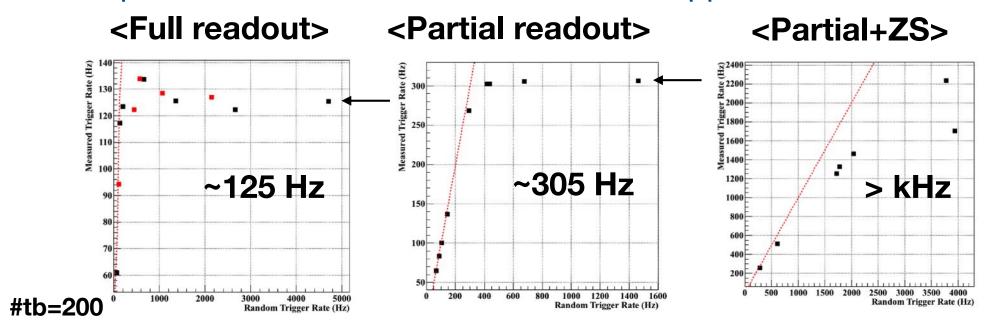## MuTanT

http://openit.kek.jp/project/HUL/HUL

High Trigger Rate

- The expected trigger rate for J-PARC experiments are ~500 Hz (E42/E72) and ~1.5-3 kHz (E45).
- The dead time of the HDDAQ is measured as ~30 us.
- In order to achieve the high trigger rate, it is essential to utilize the partial readout mode with the zero suppression.
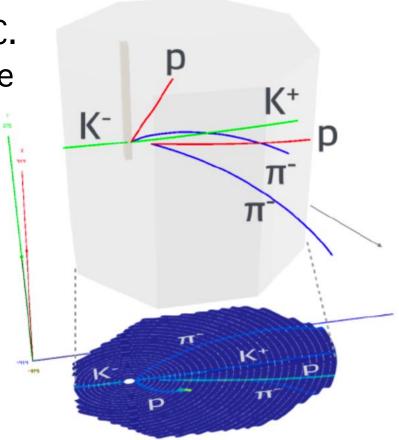
<Full readout> **<Partial readout>** **<Partial+ZS>**

~125 Hz ~305 Hz > kHz

#tb=200

- The gain calibration with ^{55}Fe source using the multiplicity trigger of GET should be done to determine the partial readout threshold.

Summary

- A time projection chamber(HypTPC) has been newly developed for the various hadron experiments at J-PARC.
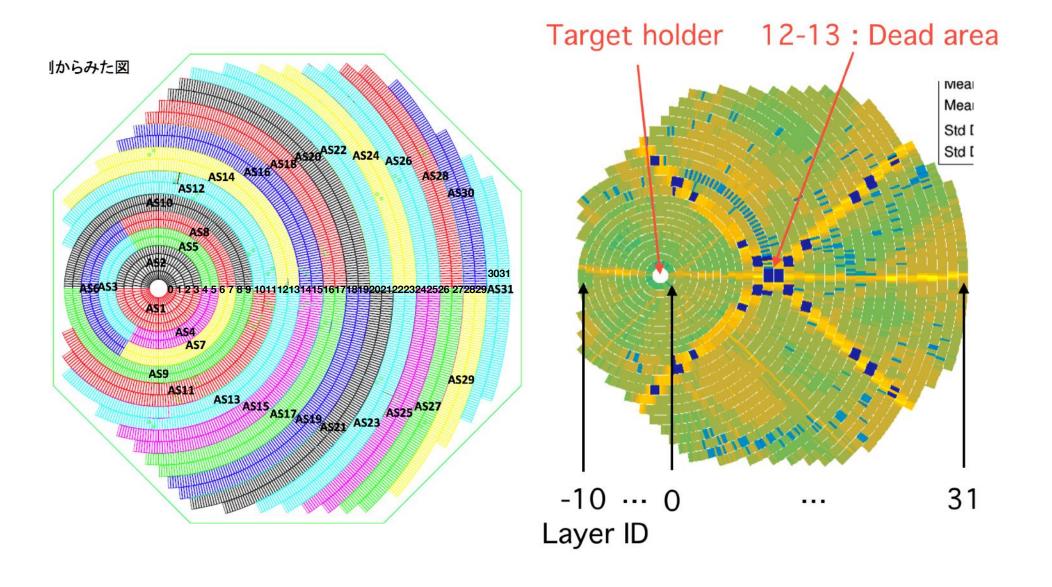- The GET electronics is adopted for the data acquisition of HypTPC.

- The proton beam commissioning of HypTPC with the GET system was successfully done at HIMAC.
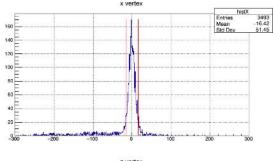- The first physics experiment with HypTPC (E42) is scheduled in 2020.
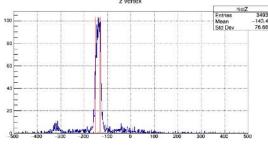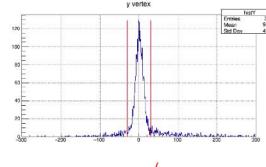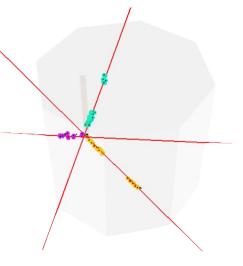
Stay tuned!

Backup

HypTPC Pad Layers

Preliminary Results of HIMAC

\<Vertex distribution\>

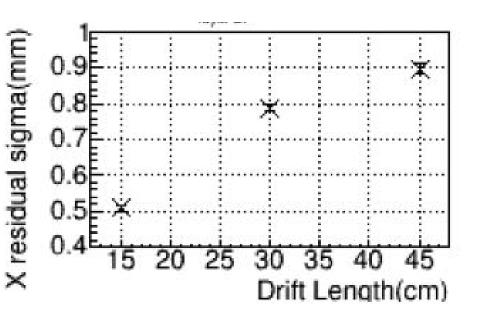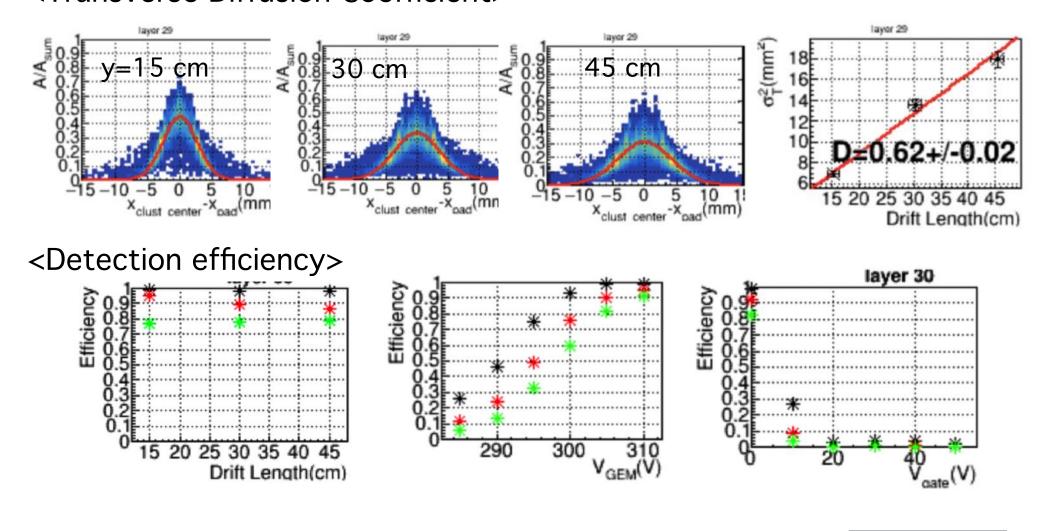**\<X position resolution\>**

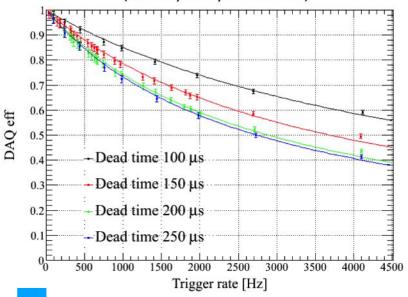# Preliminary Results of HIMAC

<Transverse Diffusion Coefficient>

<Detection efficiency>
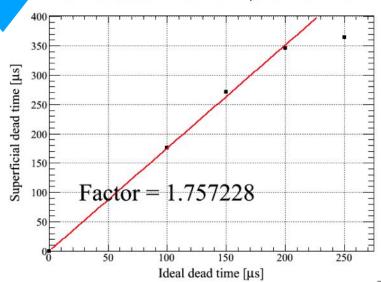
Beam Spill Structure at J-PARC
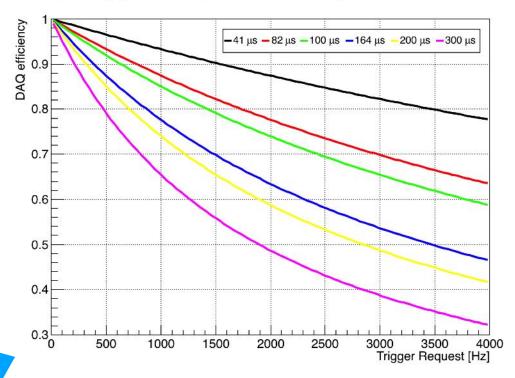
Relation between the dead time of DAQ and trigger rate.
(Taken by S. Hayakawa in E05)

Dead time 100 μs
Dead time 150 μs
Dead time 200 μs
Dead time 250 μs

Relation between the ideal and superficial dead time.

Factor = 1.757228

Eff = 1/(1+ req*deadtime)

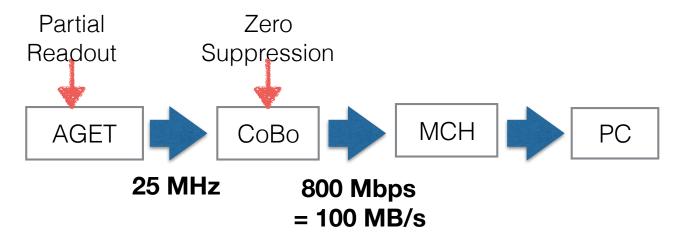— 41 μs — 82 μs — 100 μs — 164 μs — 200 μs — 300 μs

At 100 us busy time
1300/spill with 90 % DAQ efficiency
2900/spill with 80 % DAQ efficiency

DAQ speed

Partial readout + Zero suppression mode
10 hits per AGET, 256 time bin depth, 13 time bins in pulse width

Partial
Readout

Zero
Suppression

AGET ➡ CoBo ➡ MCH ➡ PC

25 MHz

**800 Mbps
= 100 MB/s**

AGET->CoBo data transfer

   40 ns X 10 hits X 256 time bin = <u>100 us</u>

CoBo->MCH data transfer (considering beam spill structure)

   Total data size we can take in 2 s (spill-on)
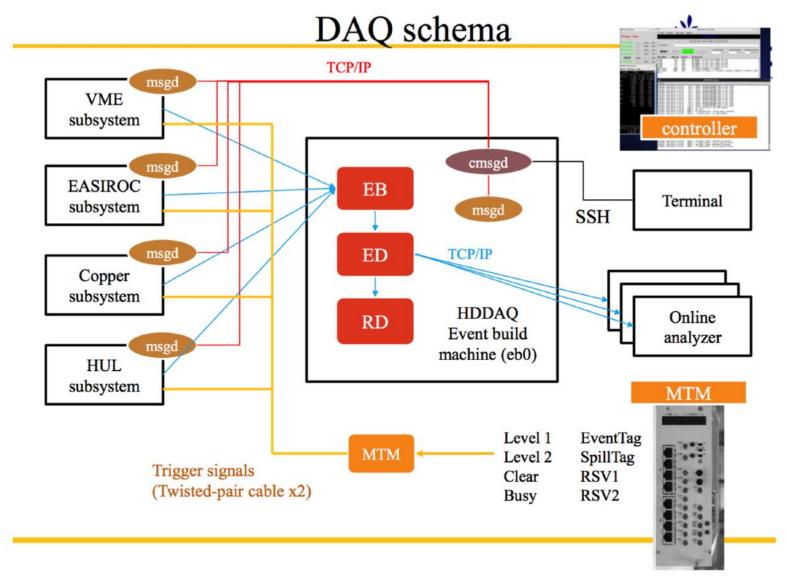
     D = 100 MB/s X 2s + 126 MB (CoBo buffer) = 326 MB

   All buffered data can be released in 3.5 s(spill-off) at 100 MB/s

   Data size per 1 CoBo per 1 event

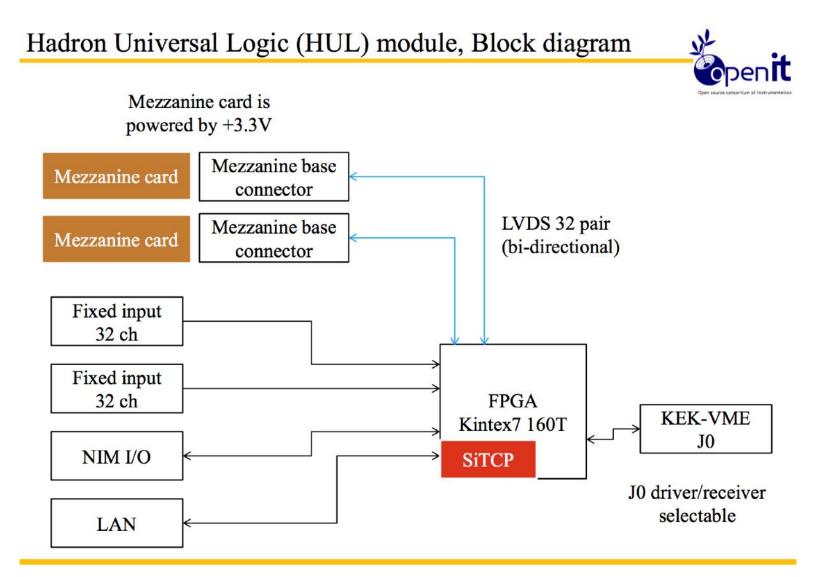   d = (256B + 4B X (10+4) X 13 X 4) X 4 = 12.4 kB

     d/(D/2s) = <u>74 us</u>

J-PARC K1.8 Beam Line DAQ(HDDAQ)

Credit: R. Honda

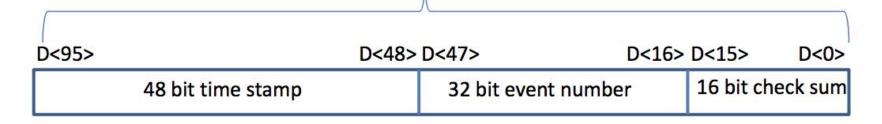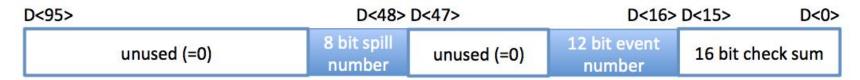# Hadron Universal Logic(HUL) Module

Hadron Universal Logic (HUL) module, Block diagram

Credit: R. Honda

CERNTRUM interface on MUTANT

ORIGINAL CENTRUM information is based on a 96 bit frame

D<95>	D<48> D<47>	D<16> D<15>	D<0>
48 bit time stamp	32 bit event number	16 bit check sum	

J-PARC event tag after converting to the CERNTRUM structure

D<95>		D<48> D<47>		D<16> D<15>	D<0>
unused (=0)	8 bit spill number	unused (=0)	12 bit event number	16 bit check sum	

Credit: K. Hosomi