HypTPC読み出しシステム開発の現状

原研　先端基礎研究センター
細見　健二

計測システム研究会＠J-PARC 2014/11/20

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- 対象実験
  - J-PARC E42/E45
- 検出器
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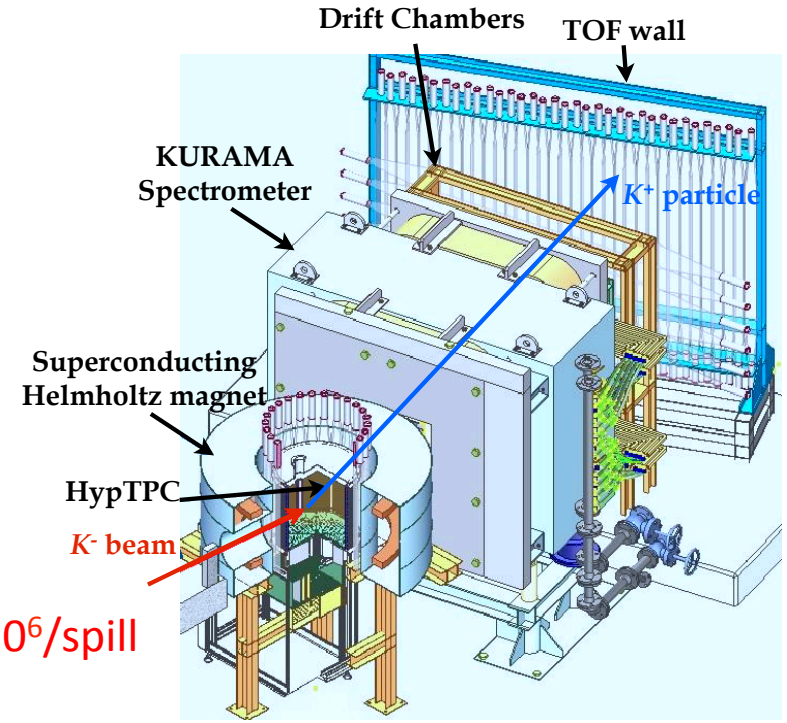
  - GET test bench @ JAEA
- まとめ

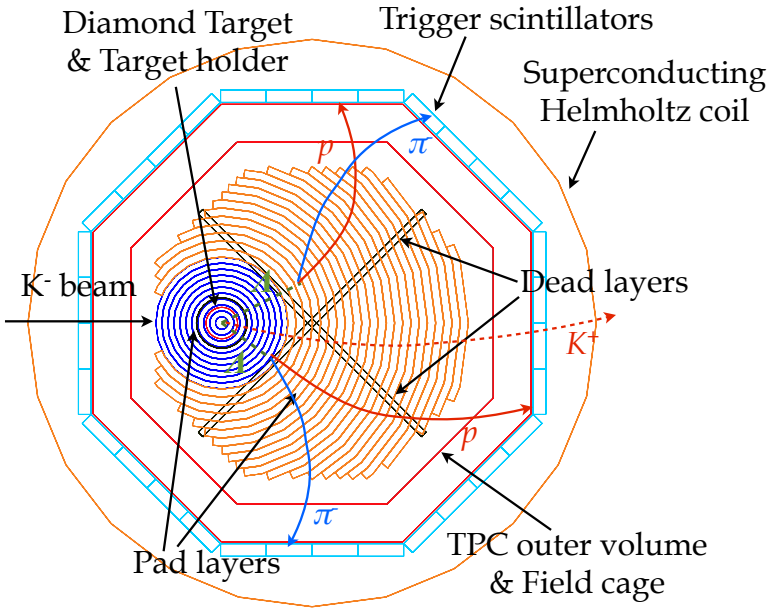
J-PARC E42

Search for H-dibaryon 6-quark (uuddss) state in $^{12}C(K^-, K^+)X$ at 1.6 GeV/c

$$H \rightarrow 2\Lambda \rightarrow \pi^-\pi^- pp$$

$$H \rightarrow \Lambda p\pi^-$$





J-PARC E45

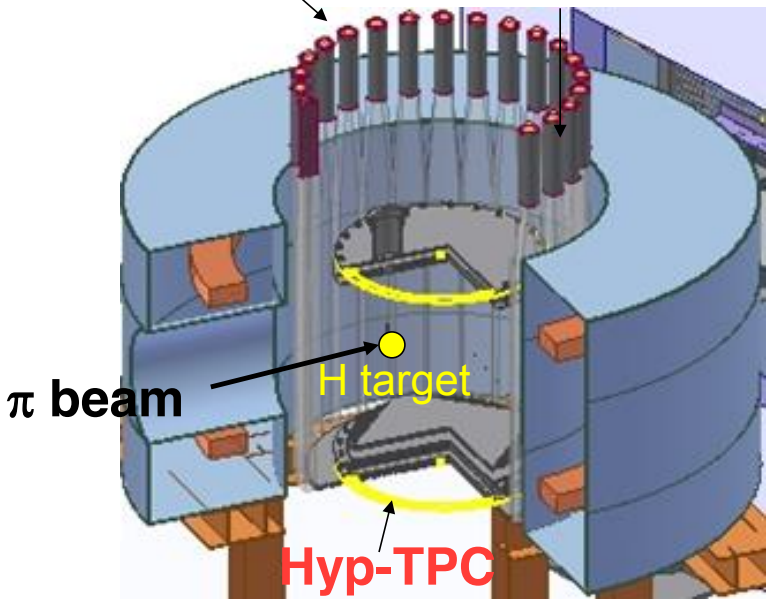
Measure p(π, 2π)N to study baryon resonances and search for hybrid baryon (qqqg)

$\pi^- p \rightarrow \pi^+ \pi^- n$, $\pi^0 \pi^- p$
$\pi^+ p \rightarrow \pi^0 \pi^+ p$, $\pi^+ \pi^+ n$

2 charged particles + 1 neutral particle
→missing mass technique

Trigger with hodoscope

π^{+-} beam on liquid-hydrogen target
(p= 0.73 – 2.0 GeV/c)



Hyp(Hyperon)TPC

Shared by J-PARC E42 and E45

Requirements

- Large acceptance
  - Target inside TPC

- High-rate operation (10^6 Hz/cm^2 beams)

  GEM and Gating Grid

  Suppression of ion backflow causing E-field distortions to less than5%

- Good position resolution ~ 0.3mm rms

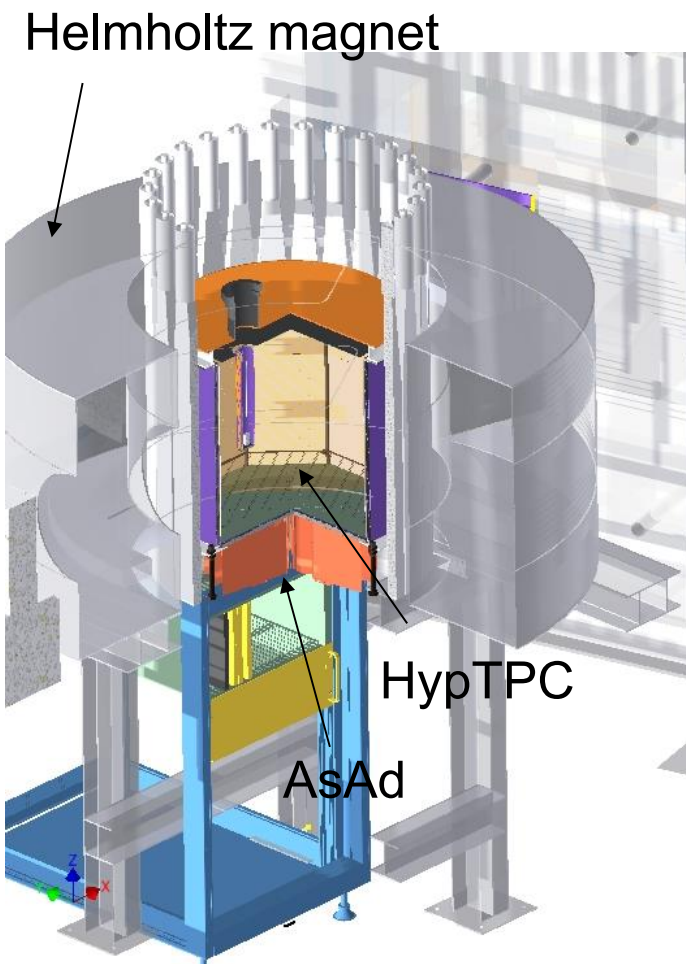
  E and B in parallel

  small pad size ~2.5 mm x 10 mm

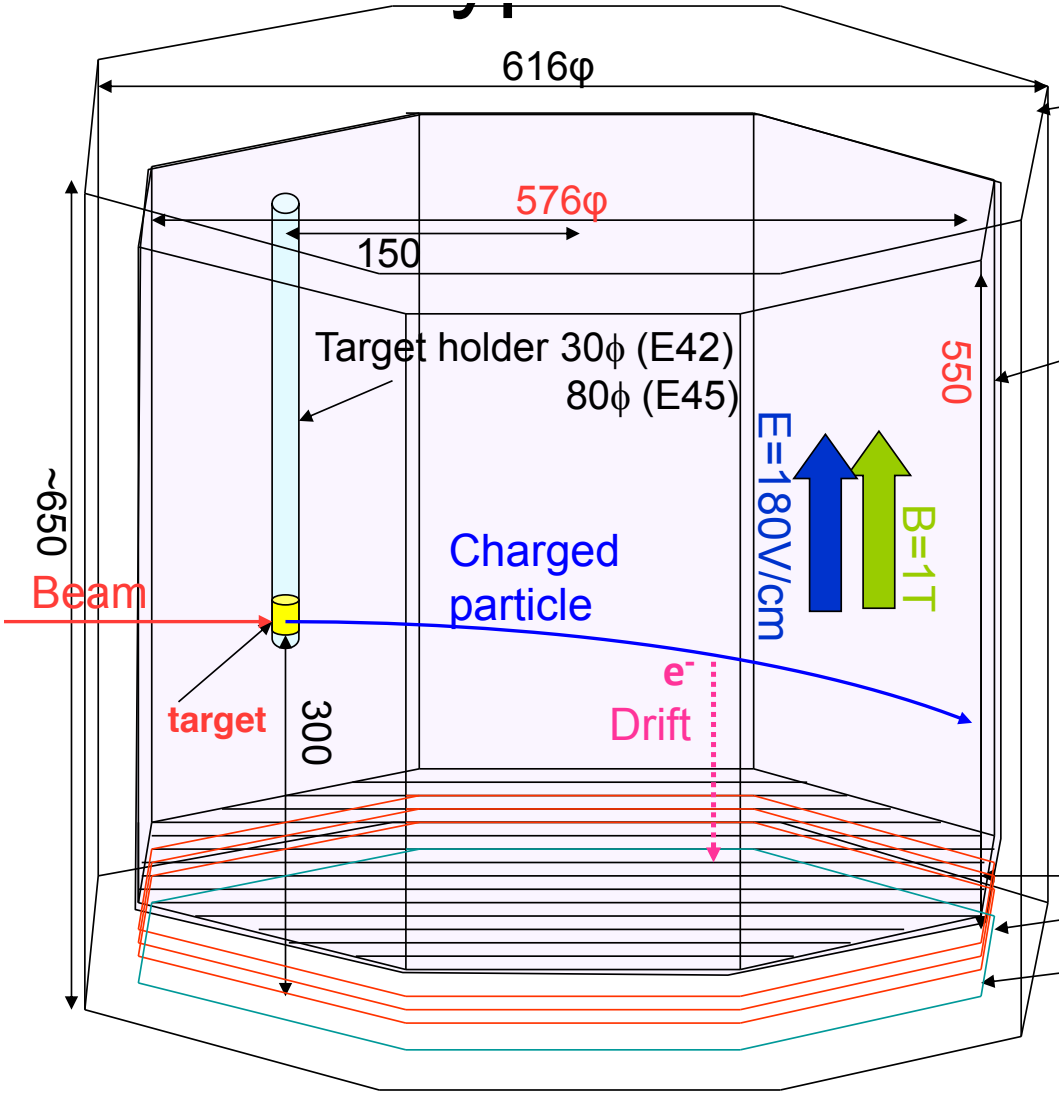
- π/K/p separation

  Good dE/dx resolution
  - large number of pad planes 32

  dE/dx dynamic range ~ 10



HypTPC structure



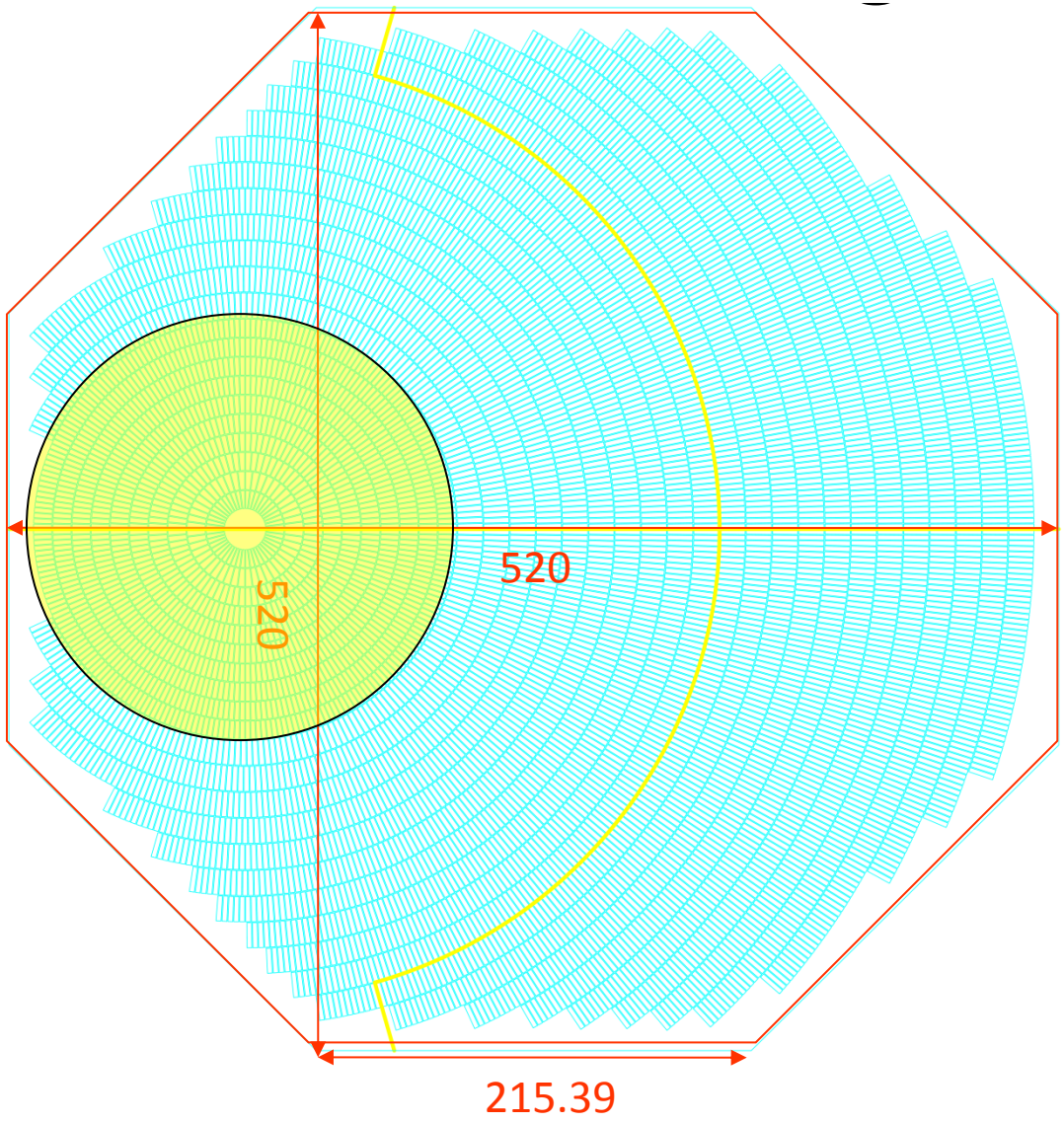
Gas vessel

Field cage (sensitive volume)

Gas : Ar:CH_4 90:10
Drift velocity = 5.5cm/μs
Max drift length = 55cm
Max drift time = 10μs
Sampling freq 40MHz
512 SCA cell→12.8μs

Gating Grid wire
GEM (3-layers)
Pad plane

Readout pads configuration



- Inner planes (rings)

2.1~2.7x9mm^2

#plane=10

- Outer planes (rings)

2.3~2.4x12.5mm^2

#plane=22

Total #pad 5768

- Average charge sharing

= 3 pads / hit

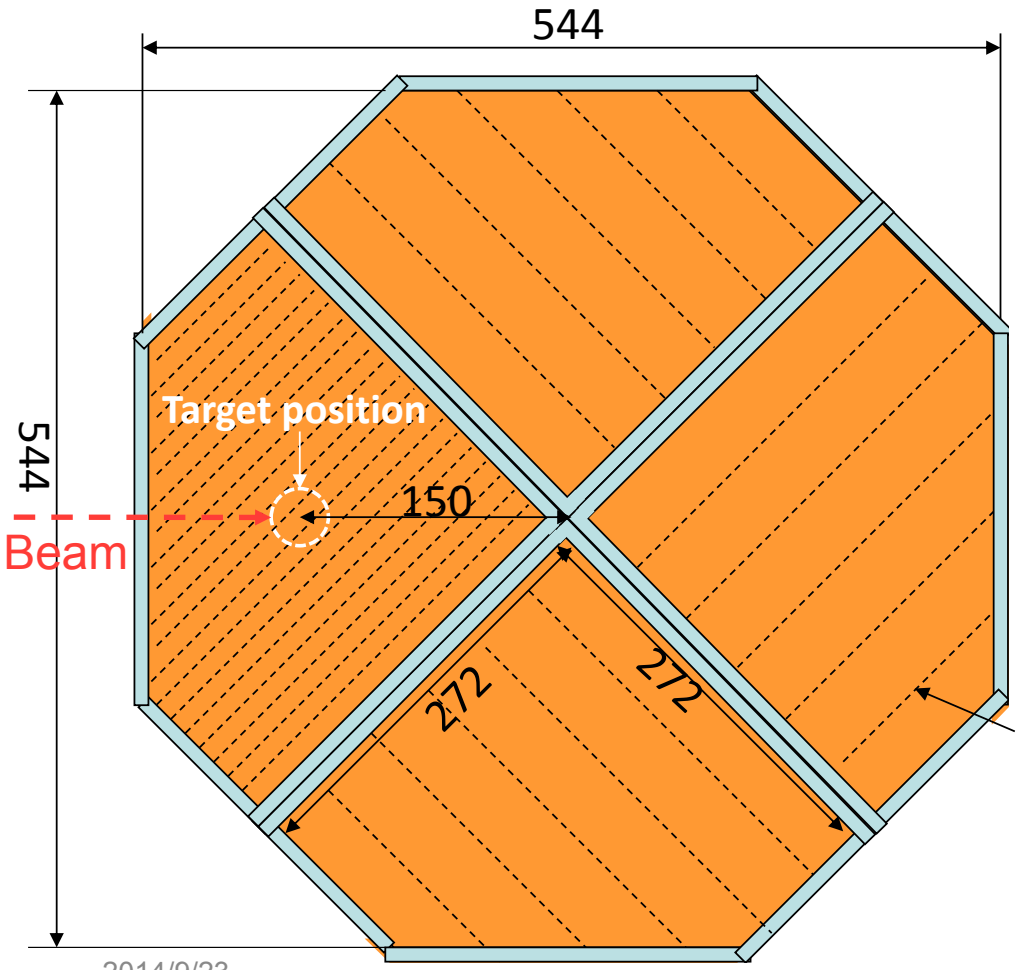
- Horizontal position resolution at B=1T

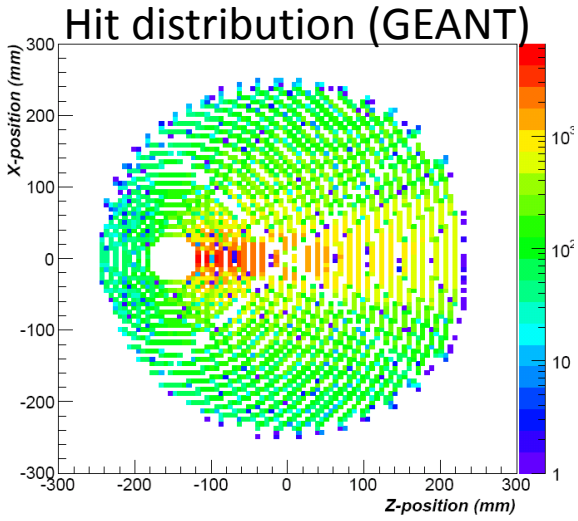
< 0.3 mm

(at drift length>10cm)

GEM configuration

- 4 GEMs (277x277mm^2)
- 3-layer GEM (50μm+50μm+100μm)



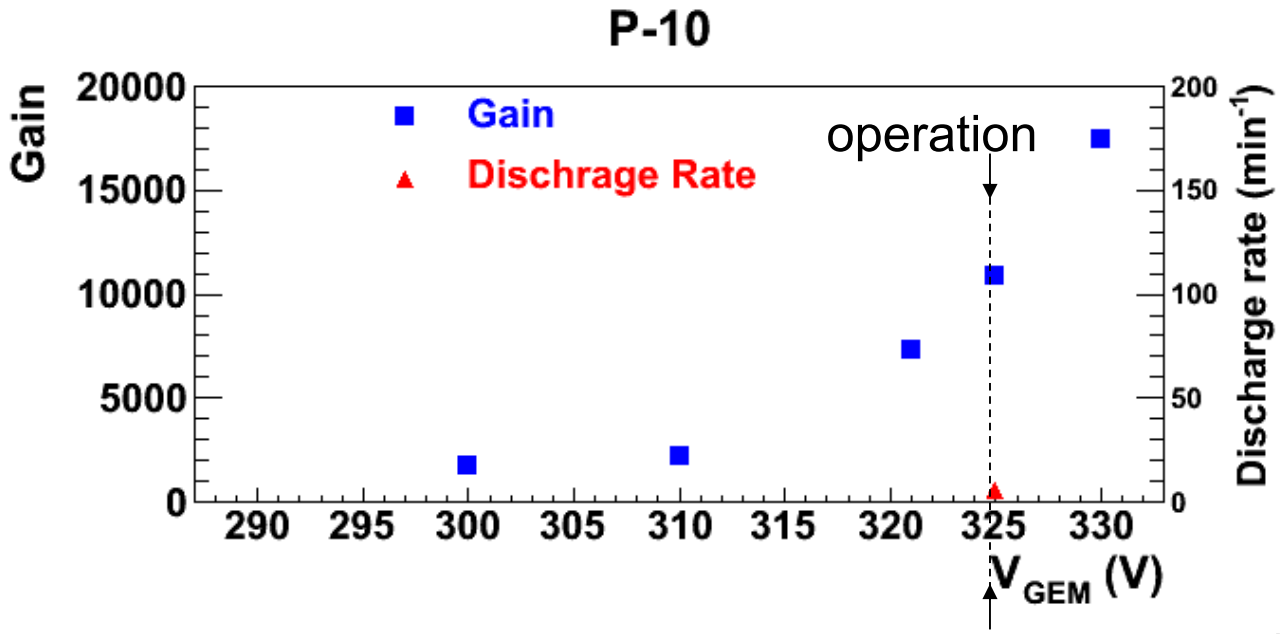


Electrode division

- 12.5 mm width (20 div.) 1 sheet
- 41mm width (6 div.) 3 sheets

- Suppress discharge rate
- Minimize acceptance reduction in case an electrode is broken

GEM gain and discharge rate



Discharge rate <= 10 / min
(between Cu foils within a GEM)

GEM Gain~10^4

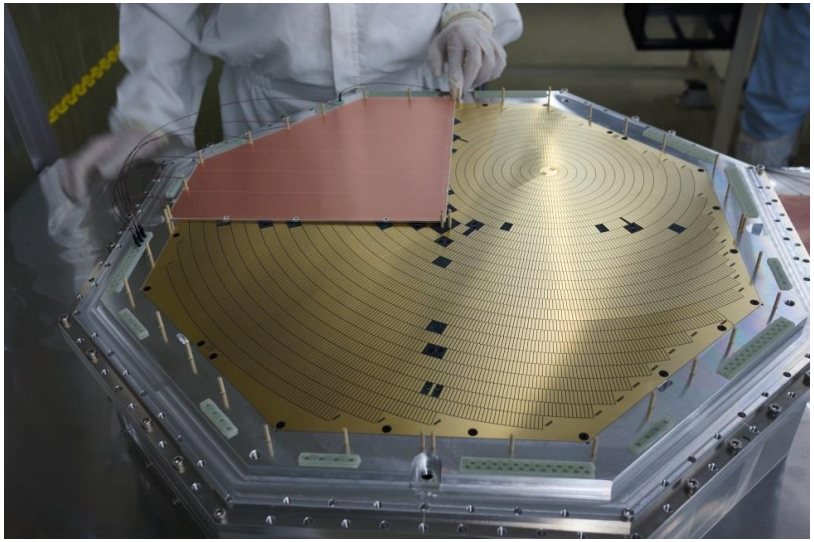
Charge on pad (1cm length)

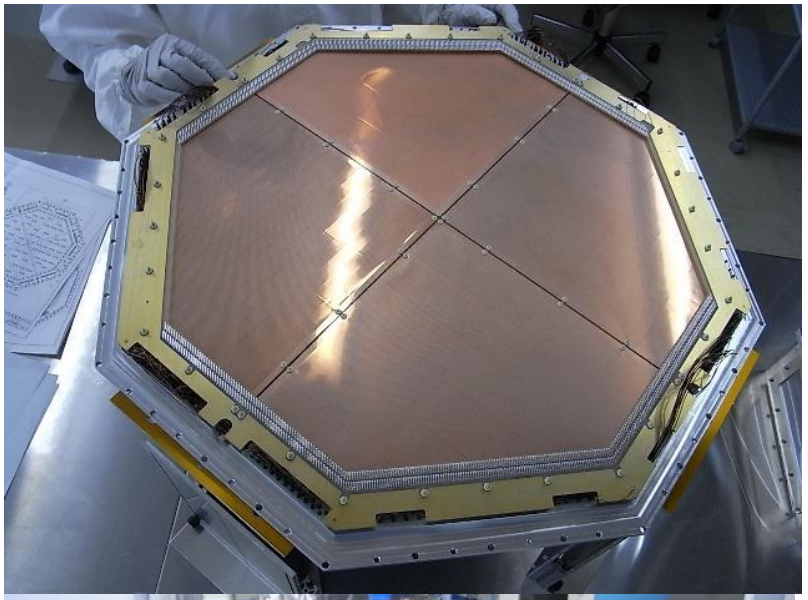
=100x1.6x10^{-19}x10^4 x 0.6(charge sharing)

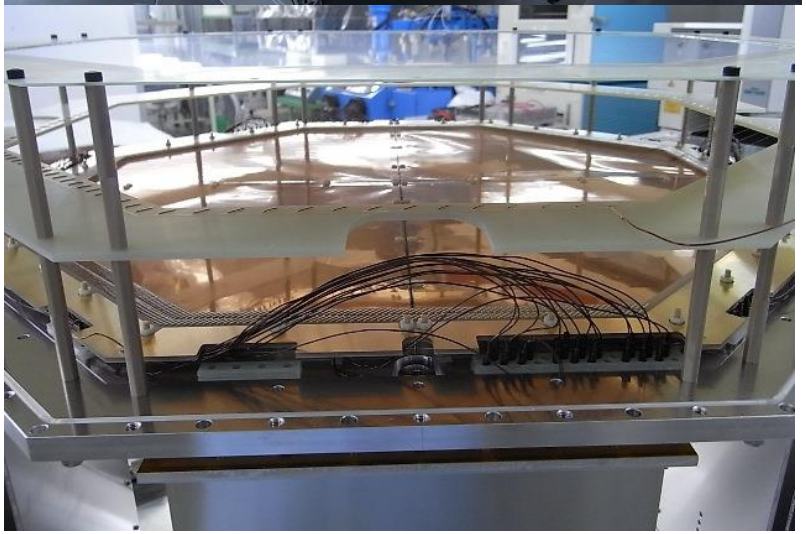
~100fC

1.0pC range (AGET) → Dynamic range=10

HypTPC construction

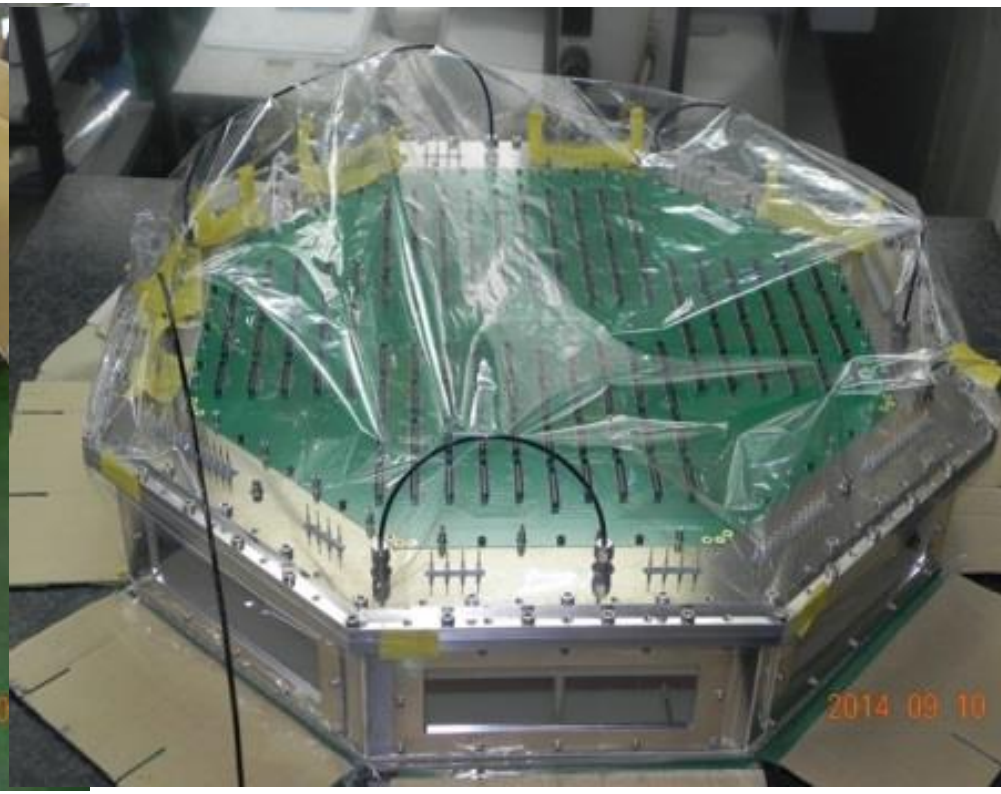






- Assembly at REPIC at Tateyama (Aug-Sep 2014)
- Completed (Sep 5)

HypTPC test



- Gas leak test and HV test (cathode plane, field wire, gating grid wires) complete (Sep 19)

Requirements for HypTPC readout

- Readout ch: 5768
- Input charge: 100 – 1000 fC
- Drift time: 10us (55cm)
- ADC, TDC -> waveform sampling
- ~1kHz DAQ rate

GET readout system

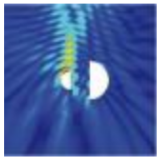
GET

- The General Electronics for Time projection chambers
- Developers

CEA
Commissariat à lEnergie Atomique et aux Energies Alternatives

CENBG
Centre d'Etudes Nucléaires de Bordeaux Gradignan

GANIL
Grand Accélérateur National d'Ions Lourds



NSCL
The NSCL (National Superconducting Cyclotron Laboratory) at Michigan State University

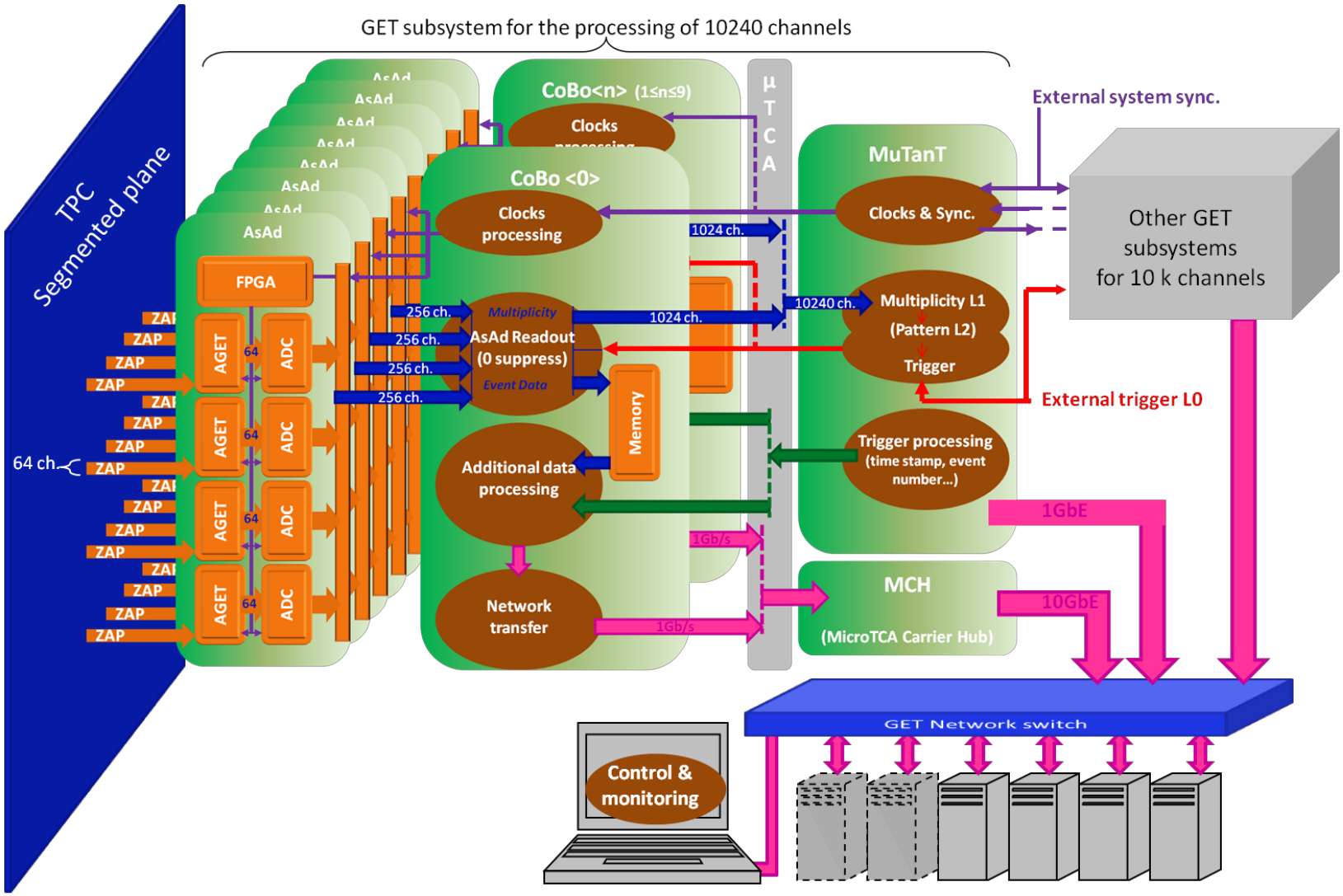
- Users (Japan)
  - JAEA HypTPC, RIKEN Samurai-TPC

GET people

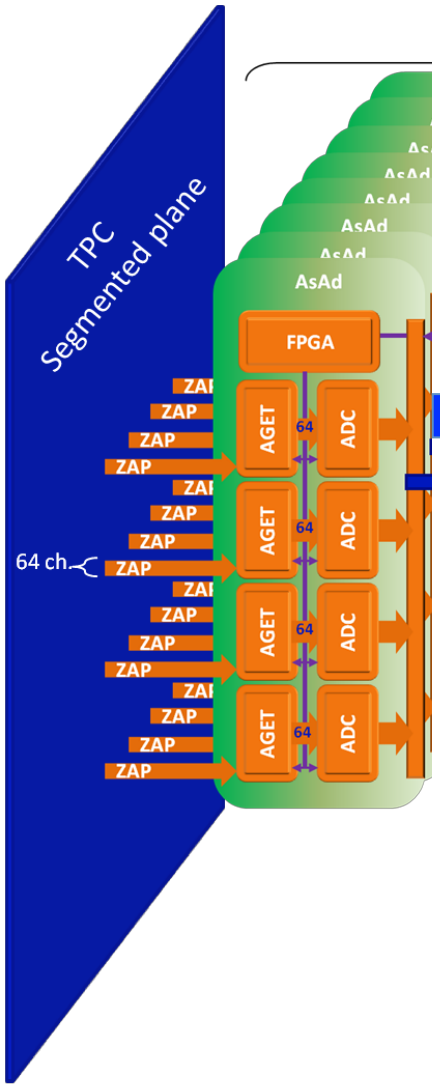
June, 2014 @ RIKEN

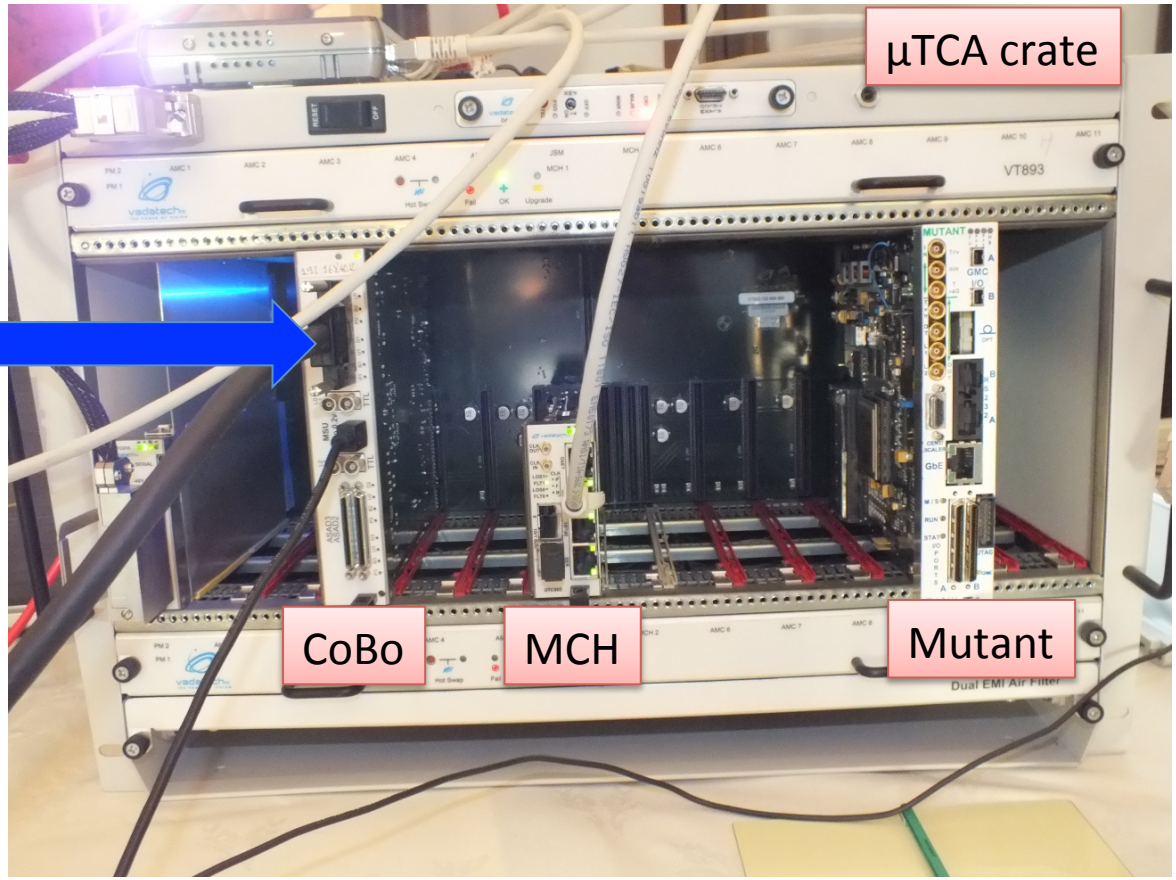
Sep, 2014 @ France

GET components



GET components





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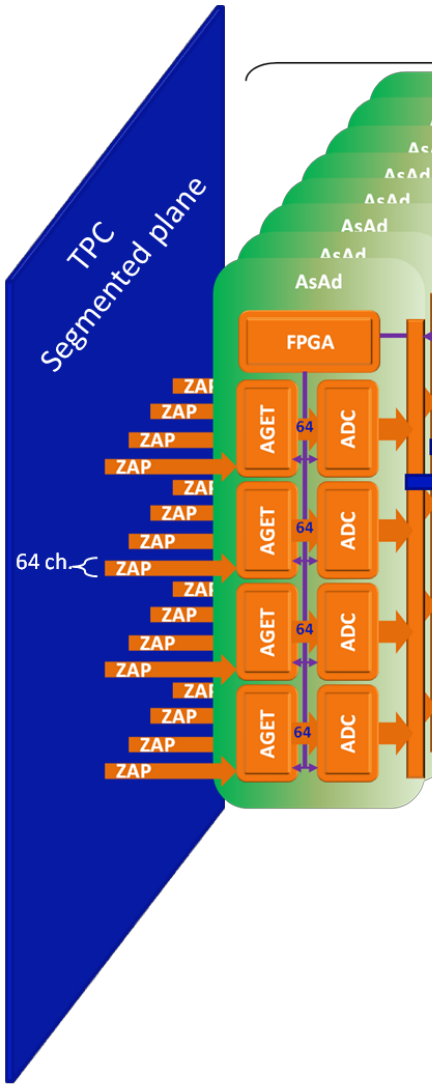
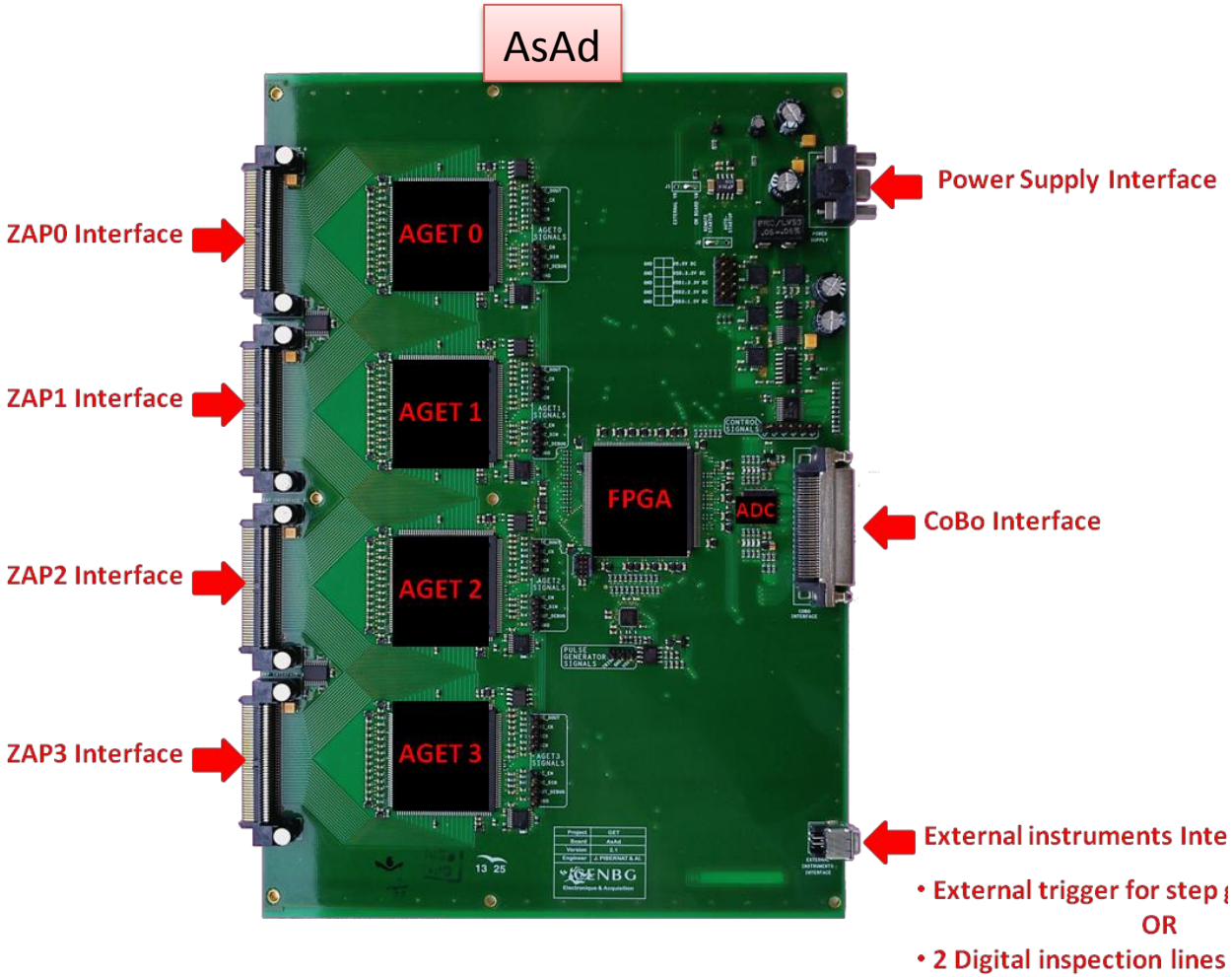




AGET ASIC

❖ Mean features

Input current polarity: positive **or** negative

64 (72) analog channels

4 charge ranges/channel: 120 fC, 240 fC, 1 pC & 10 pC

16 peaking time values: 50 ns(100 ns) to 1(2) µs

512 (511) analog memory cells / channel

Fsampling: 1 MHz to 100 MHz; Fread: 25(20) MHz

Auto triggering : discriminator + threshold (DAC)

Multiplicity signal: analog OR of the 72 discri. outputs

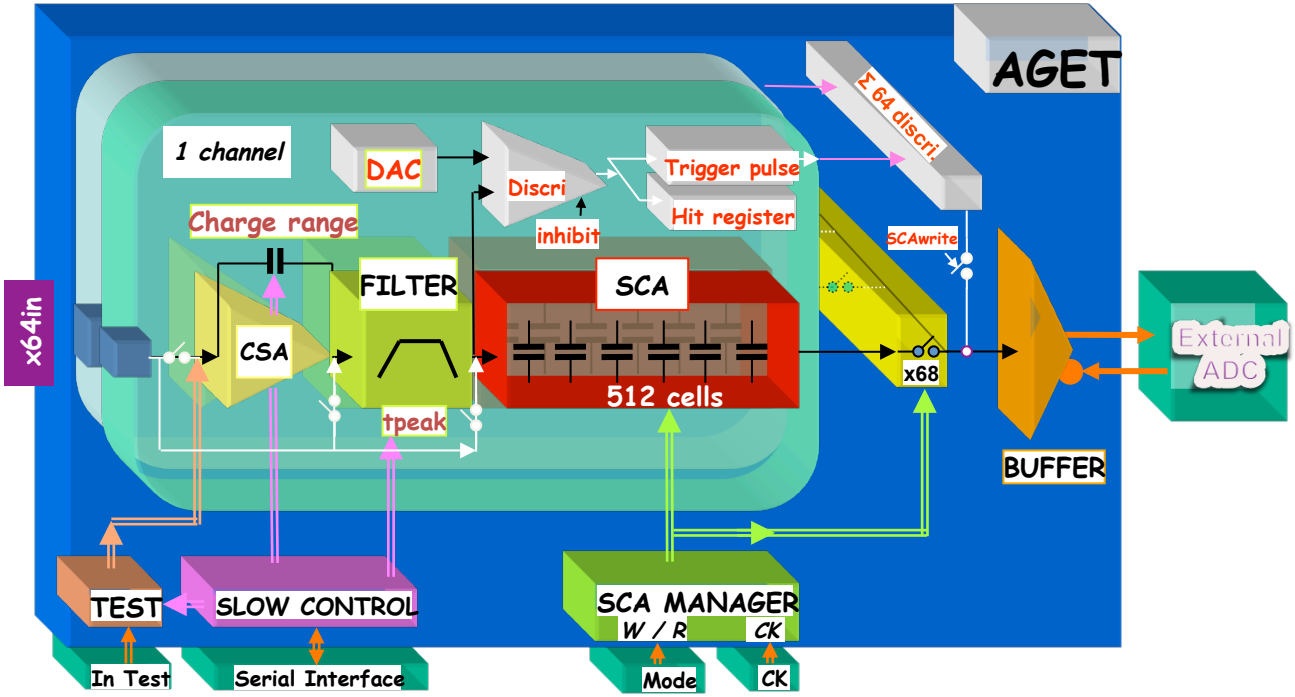
❖ Main features for the readout

- Address of the hit channel(s)
- 3 readout modes:

All, hit or specific channels

- Predefined number of analog cells / trigger (1 to 512)

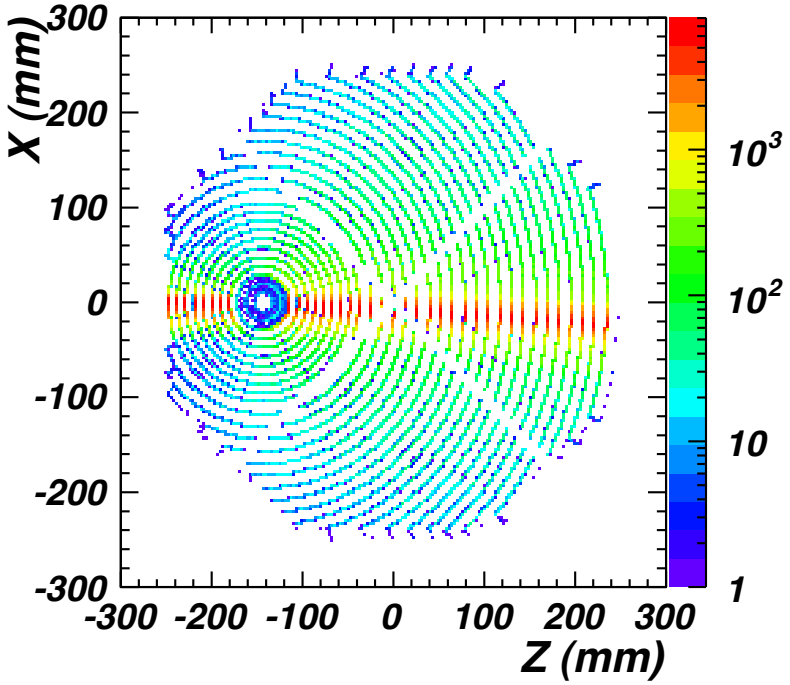
- Possibility to bypass the internal CSA and to enter directly into the filter or SCA inputs



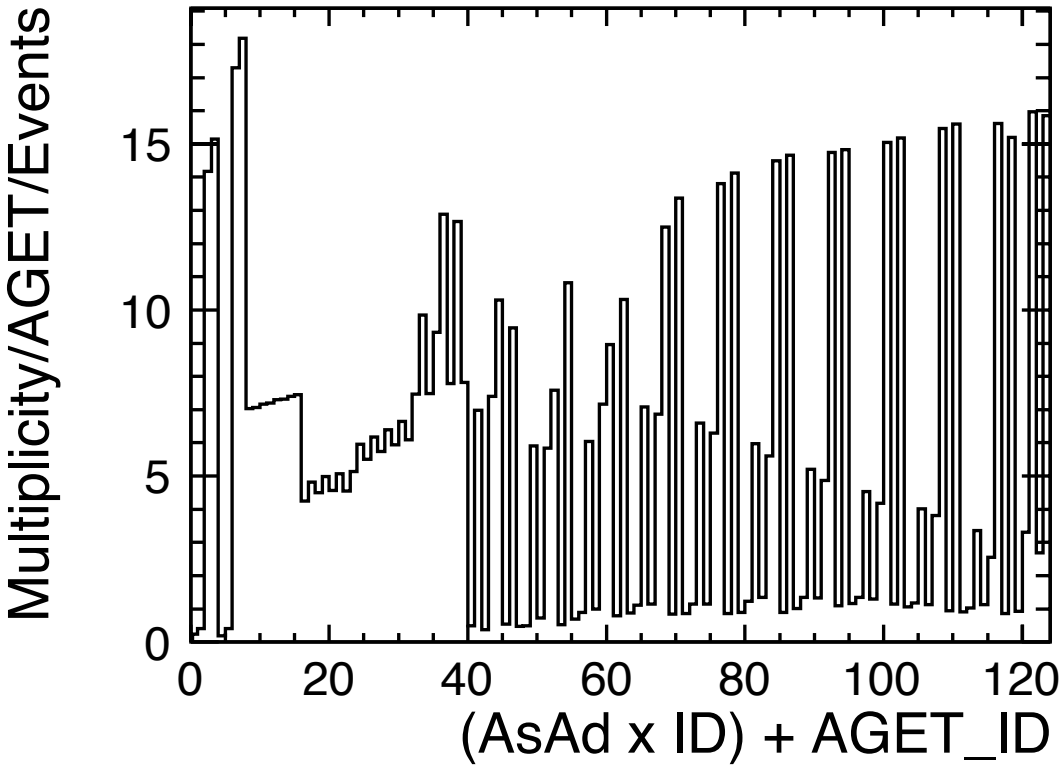
external 12-bit ADC [*ADS6422*]

Multiplicity

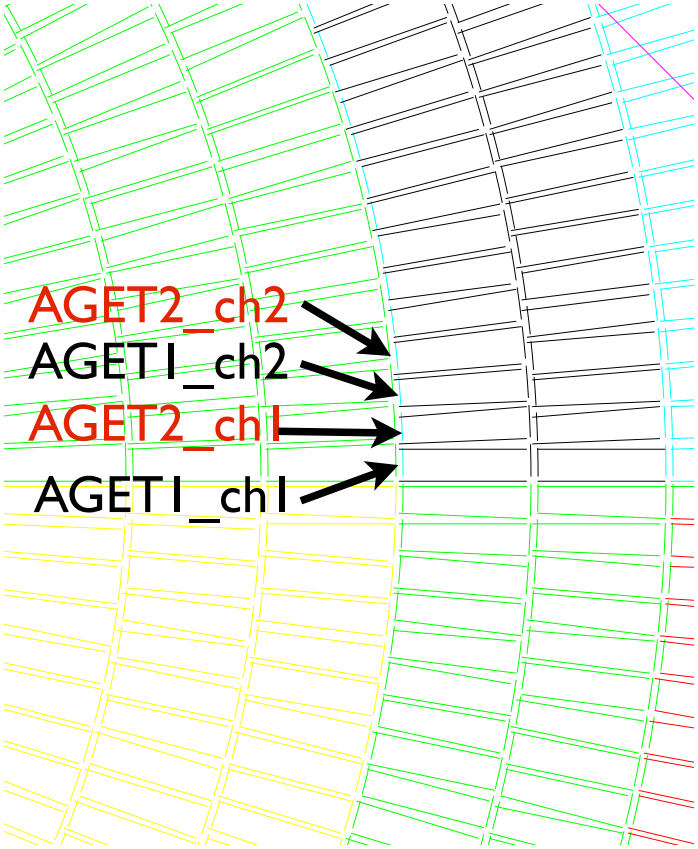
10^6 K^- beam/spill, 10-beam backgrounds with 10 us drift time.

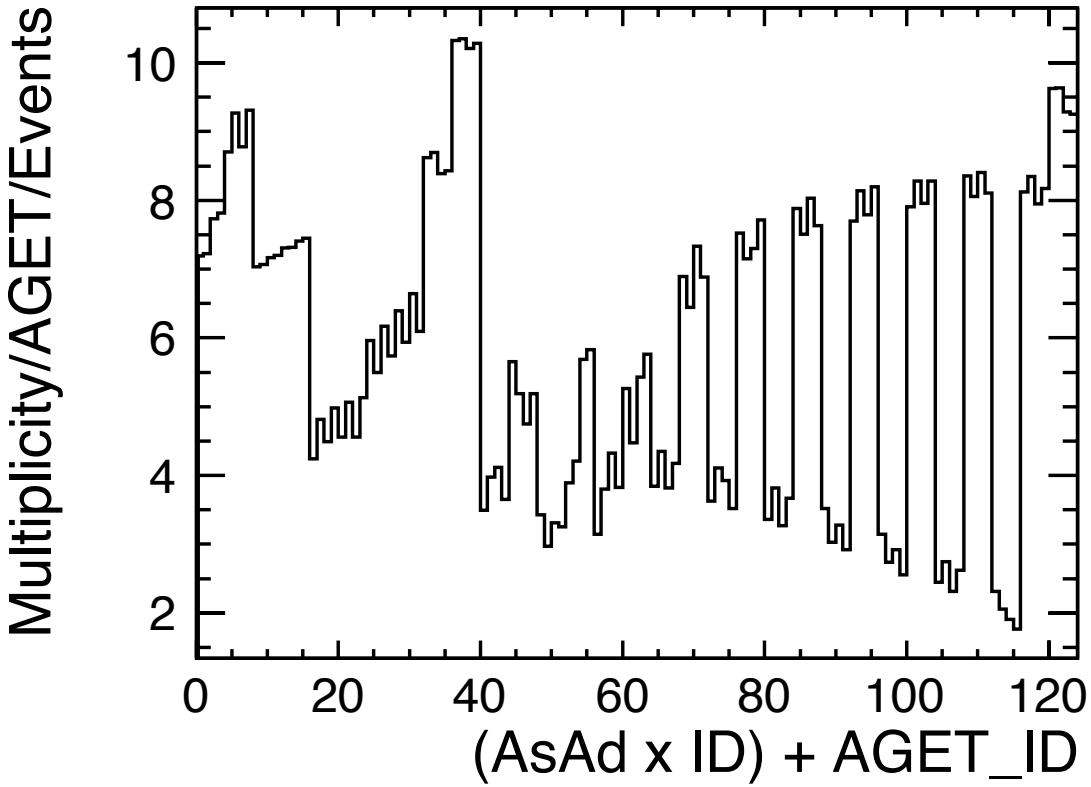


Hit pattern
(1 signal with 10 beams)



Multiplicity



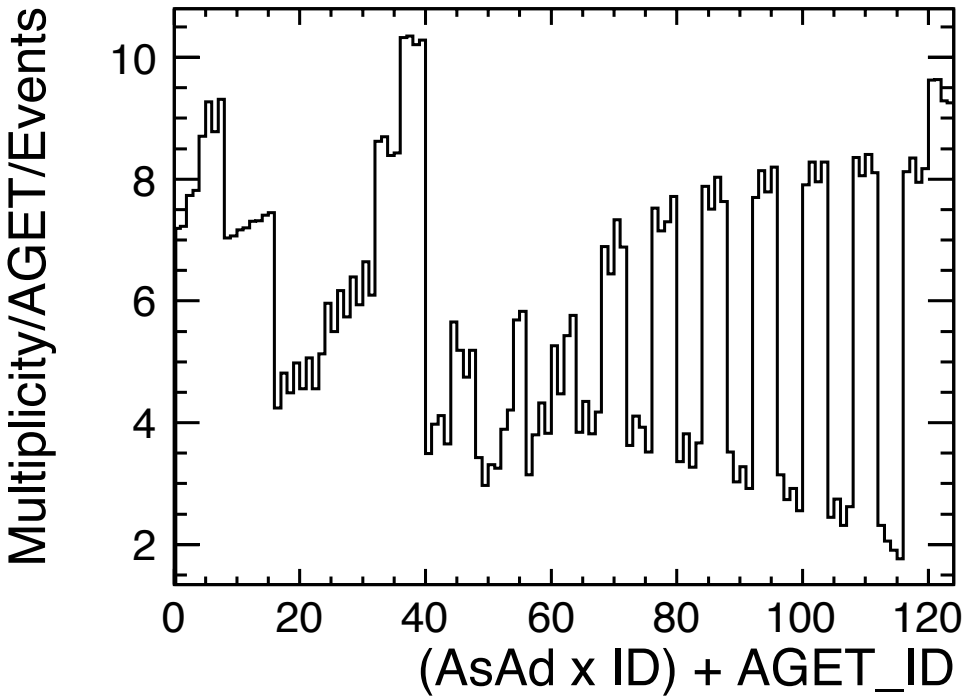


Average multiplicity is less than 10 hits/AGET

Dead time estimation

Maximum multiplicity per AGET : 10
Readout cells: 512
ADC readout rate: 40nsec (25MHz)

512cells x 40 nsec x (10ch + 2ch (noise test)) = 246 usec / event



Fast clear function

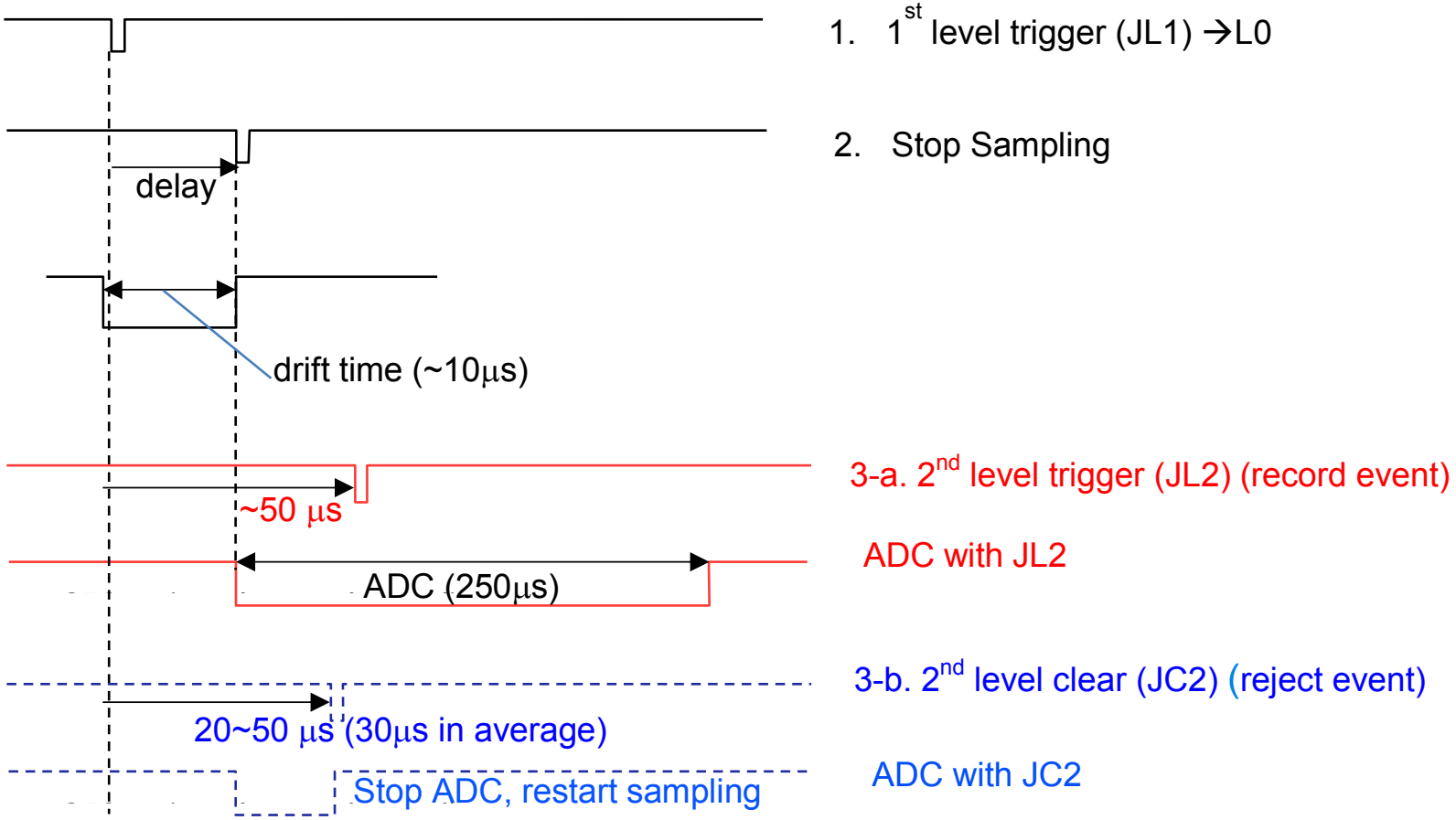


Fig. 1: An ideal timing chart in J-PARC E42 experiment.

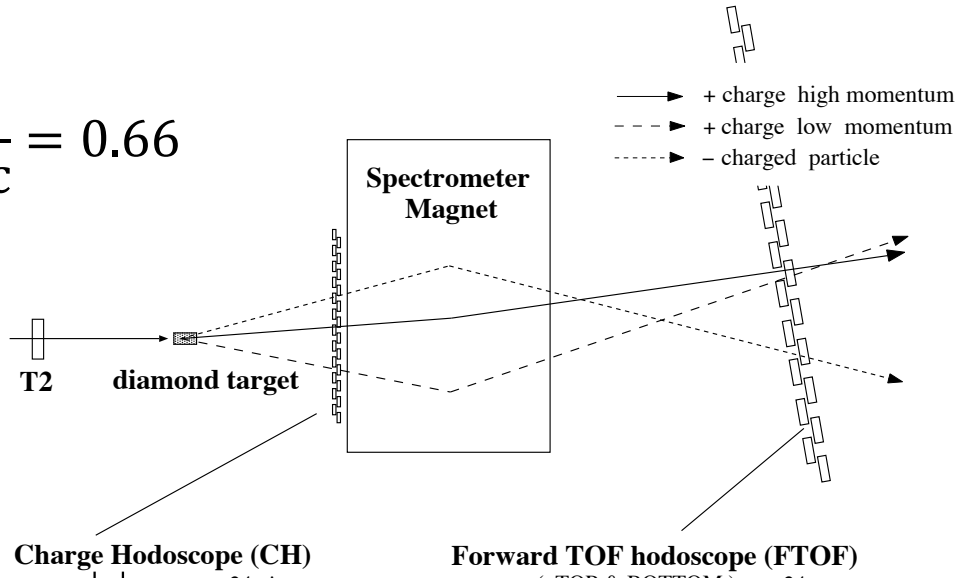
DAQ efficiency estimation

- (K^-,p) elastic : dominant background 5-10 kHz

$$\epsilon_0 = \frac{1}{1 + 9\mathrm{k} \cdot 250\mu\mathrm{sec} + 1\mathrm{k} \cdot 250\mu\mathrm{sec}} = 0.29$$

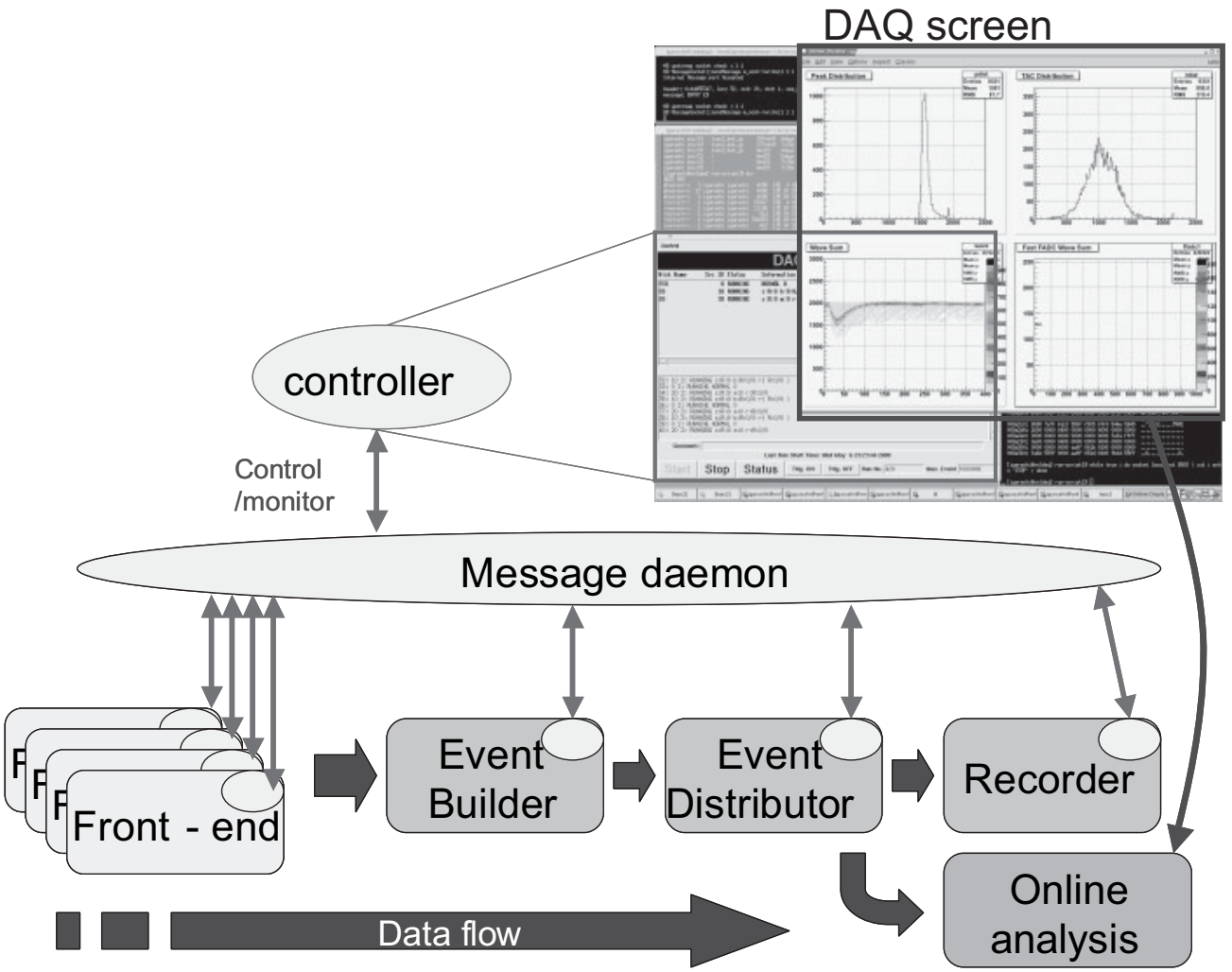
- w/ 2nd level trigger (fast clear)
  - Rough mass selection for scattering particles

$$\epsilon_A = \frac{1}{1 + 9\mathrm{k} \cdot 30\mu\mathrm{sec} + 1\mathrm{k} \cdot 250\mu\mathrm{sec}} = 0.66$$

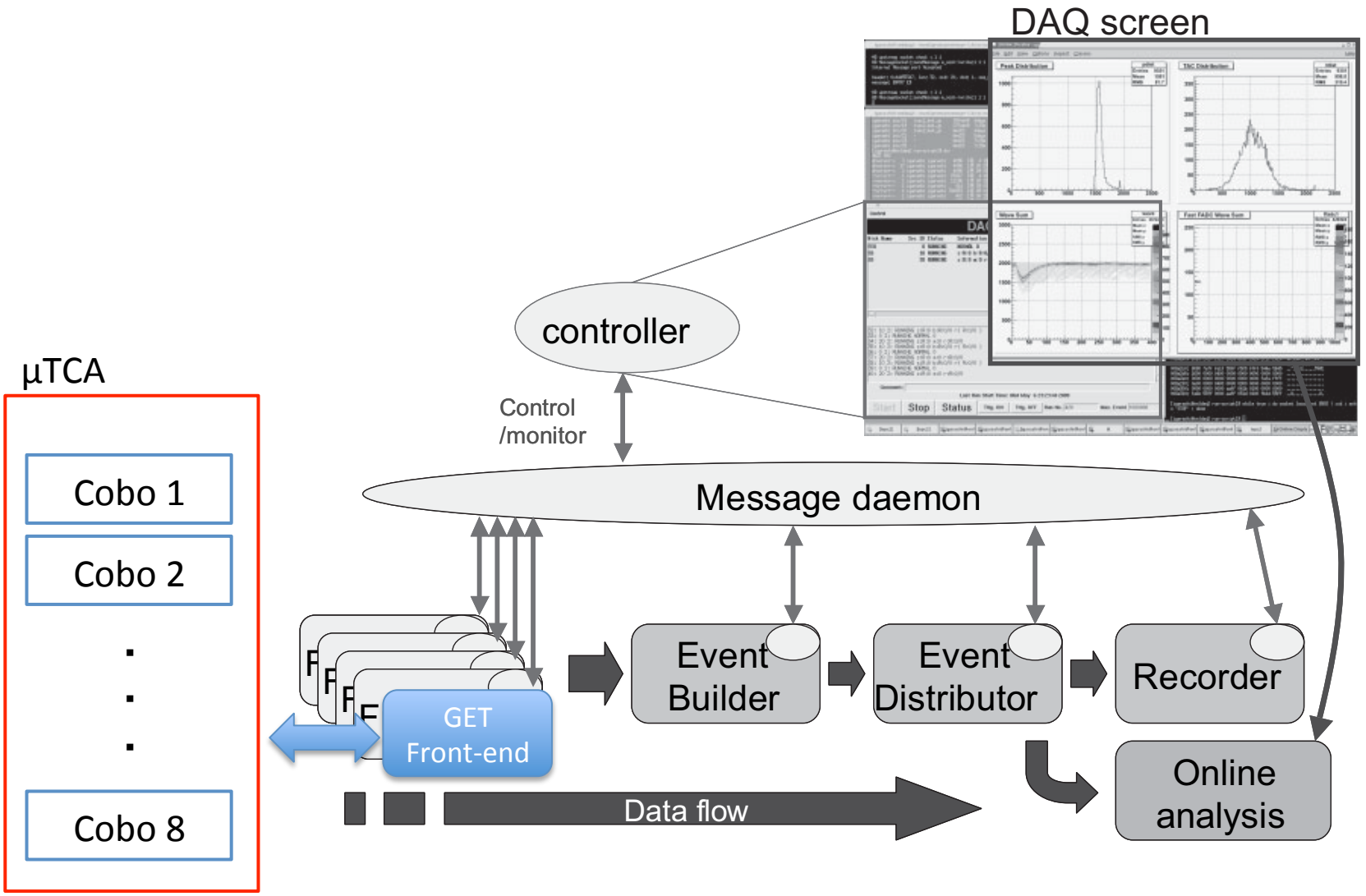


J-PARC DAQへのGet system組み込み

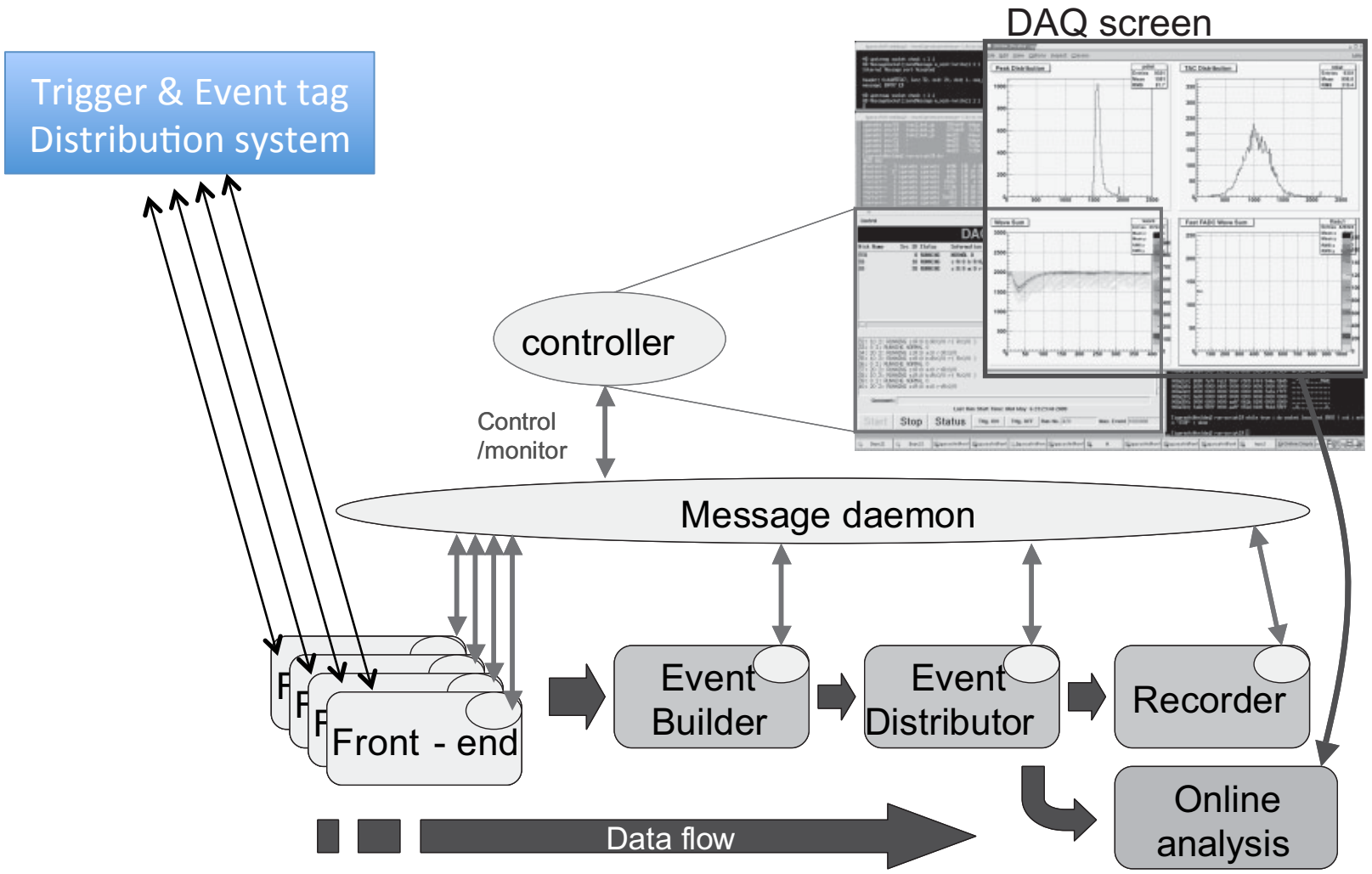
Overview of the HD DAQ



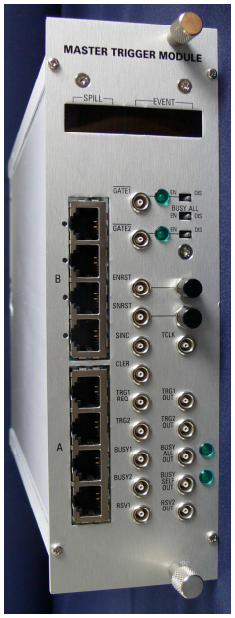
Overview of the HD DAQ



Overview of the HD DAQ



J-PARC Trigger/Tag distribution system



Master Trigger Module (NIM)

RJ45 x2

Repeater

TRIGGER

TAG (20bit serial encoded)

BUSY

RJ45 x2

RJ45 x2

SMP

COPPER
COPPER
COPPER
COPPER
KEK-VME RM

VME module
VME module
KEK-VME RM
VME bus

GONG
TKO RM
SCH

CAMAC C.C.
CAMAC/FERA RM
CAMAC module
CAMAC module
Data way

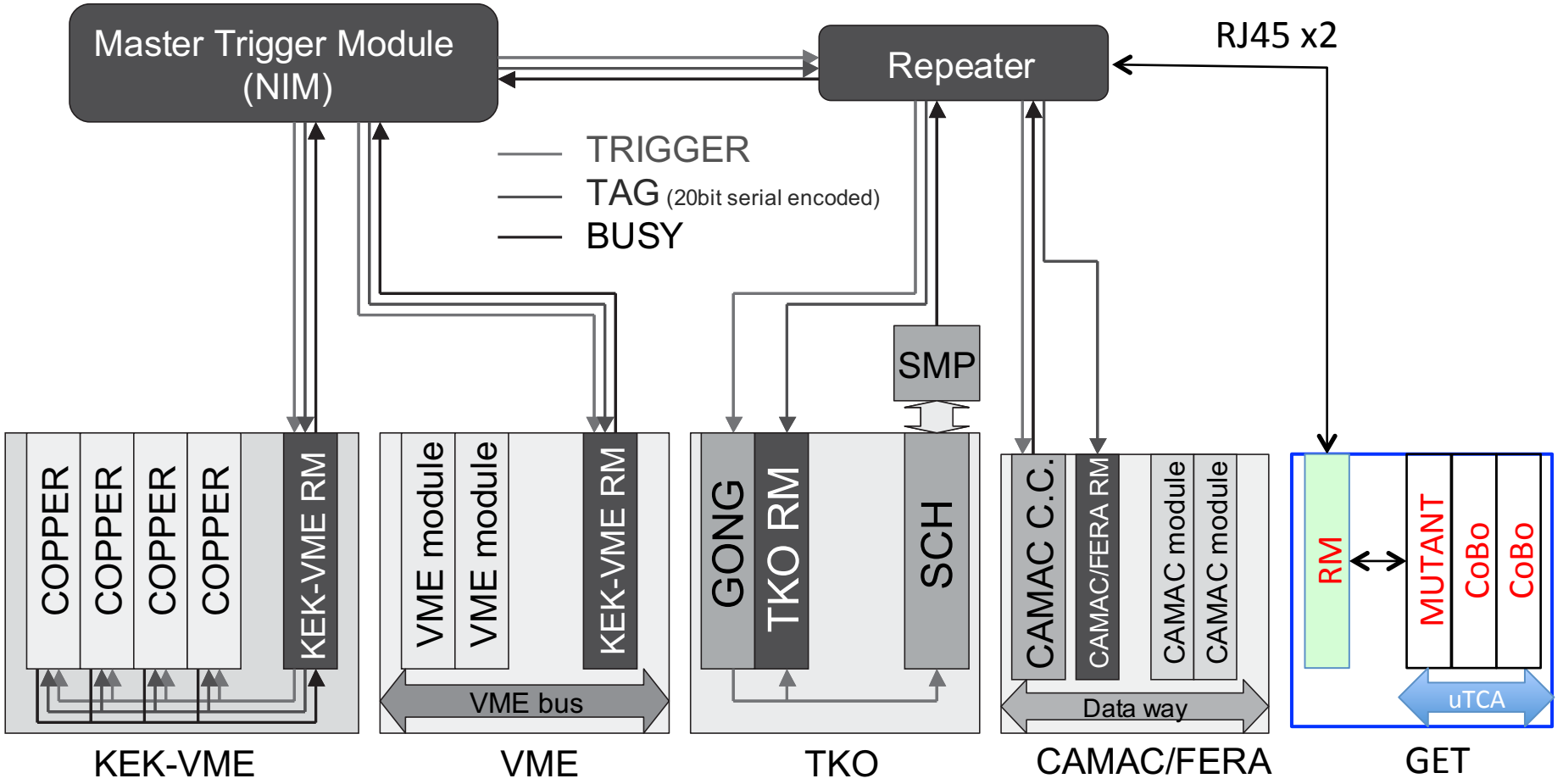
KEK-VME

VME

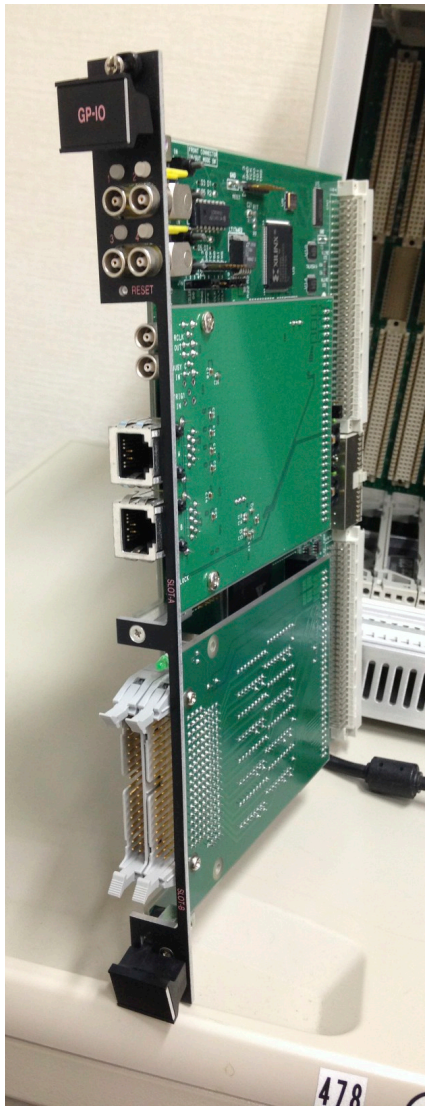
TKO

CAMAC/FERA

J-PARC Trigger/Tag distribution system



Receiver module for the GET system

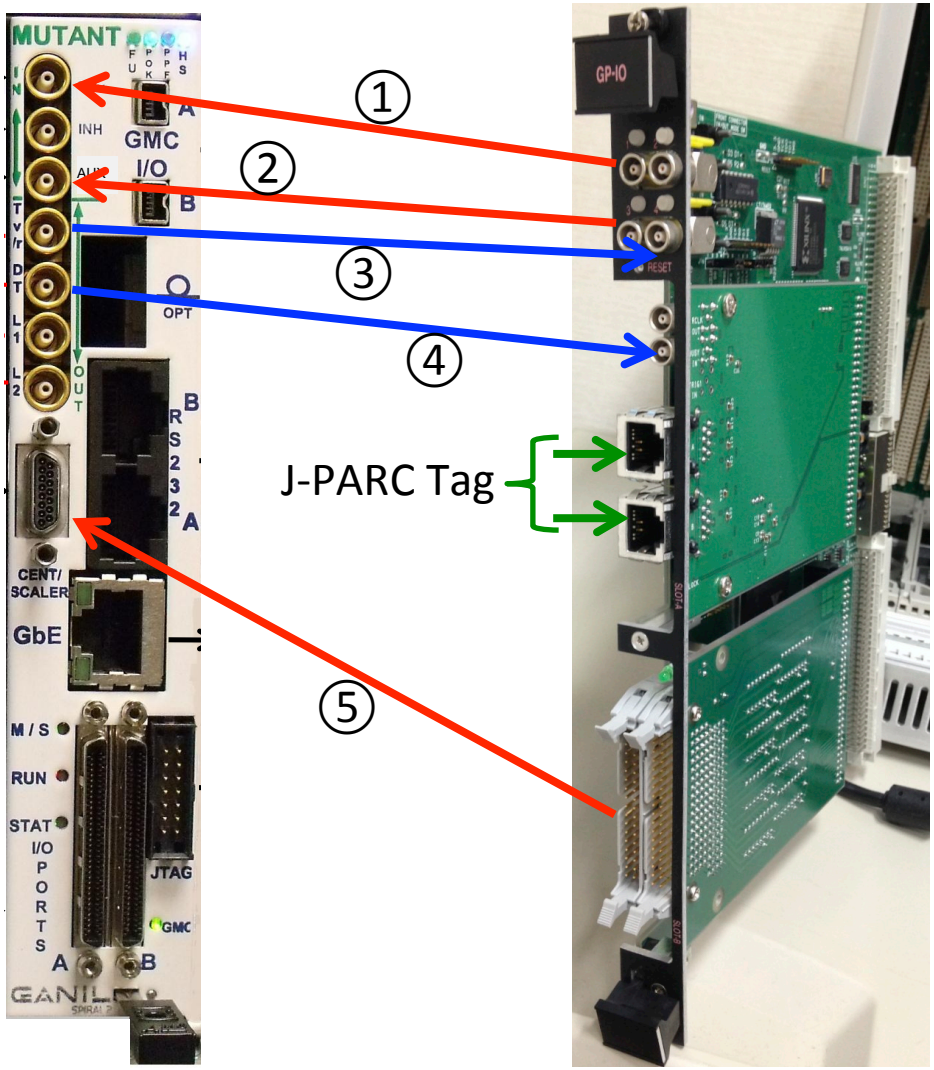


- VME GP-IO module
  - FPGA for multi purpose
  - CPLD for VME access
- Additional daughter card
  - J-PARC Tag receiver (RJ45 x2)
  - 16ch x 2 ECL out put
- FPGA firmware modification
  - Current: MTM --- RM --- VME
  - Mod: MTM --- RM --- CENTRUM interface on MUTANT

Connection

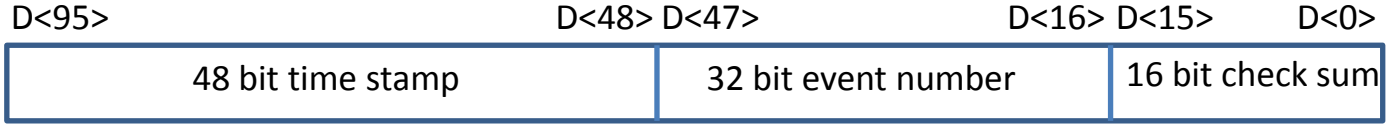
Signal Assignments

MUTANT	J-PARC
1: L0	Trigger 1
2:	Fast Clear
3:	Trigger Request
4: Dead Time	Busy
5:	96bit event tag

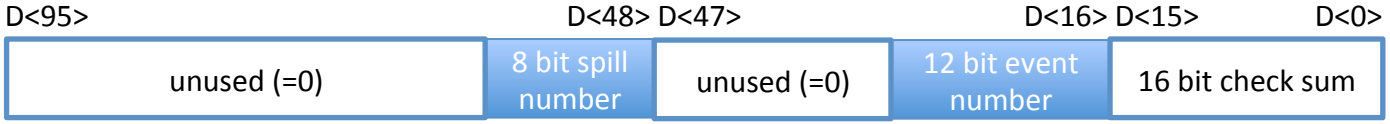


CERNTRUM interface on MUTANT

ORIGINAL CENTRUM information is based on a 96 bit frame

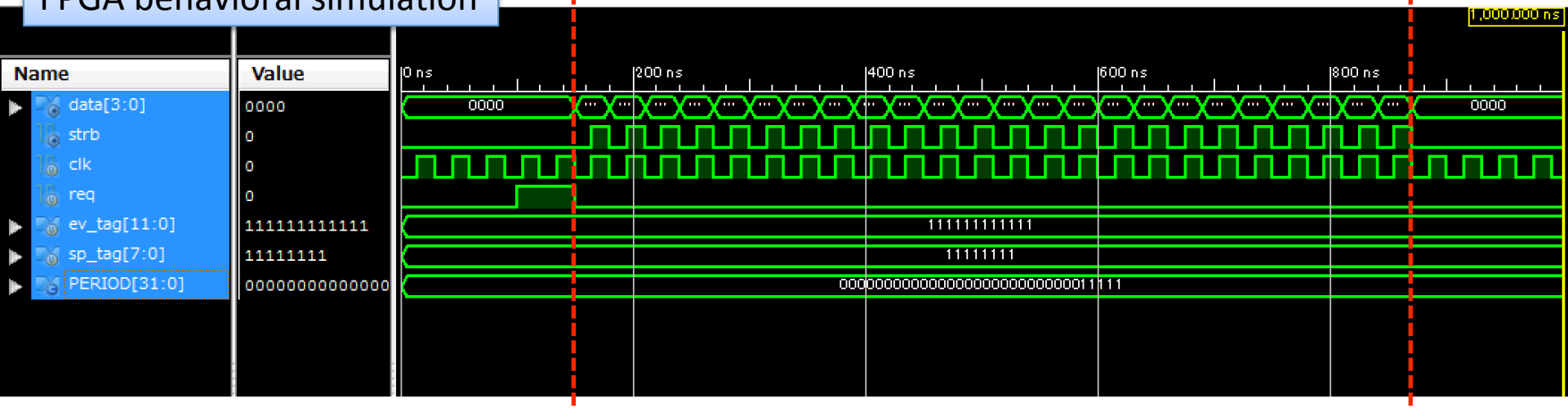


J-PARC event tag after converting to the CERNTRUM structure



Chronograph for data transfer

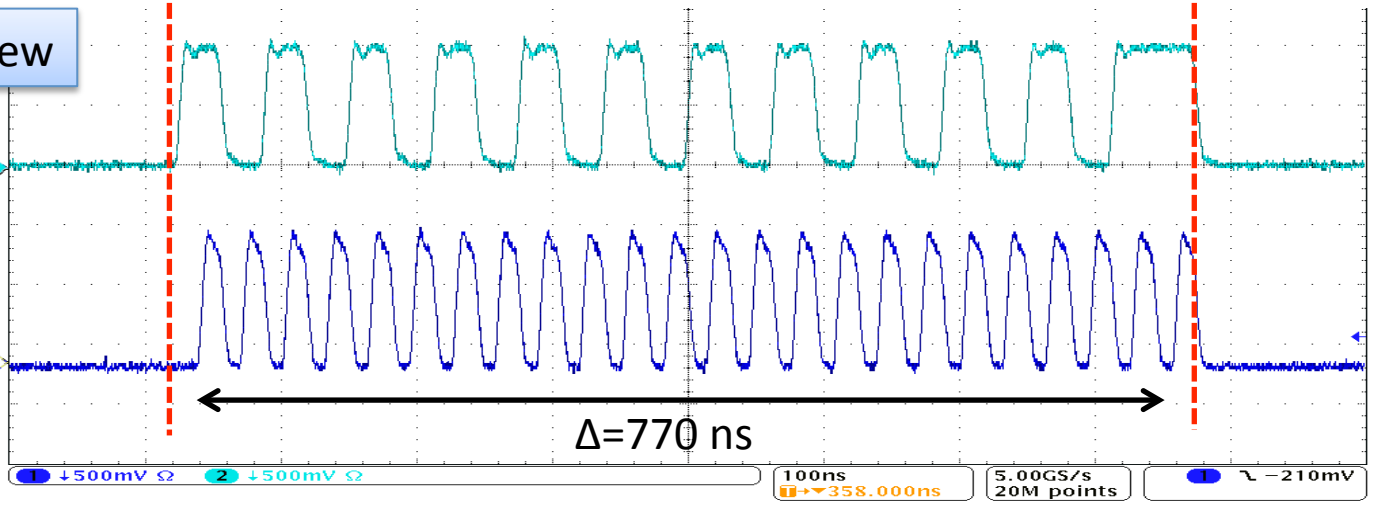
FPGA behavioral simulation



Oscilloscope view

data[3:0]: LSB

write strobe

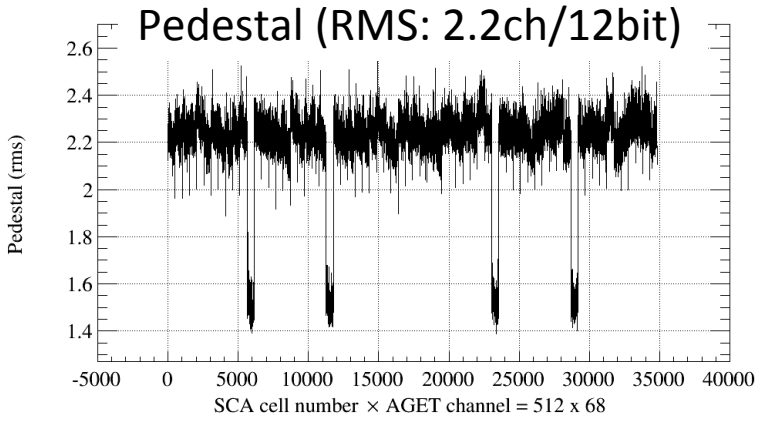


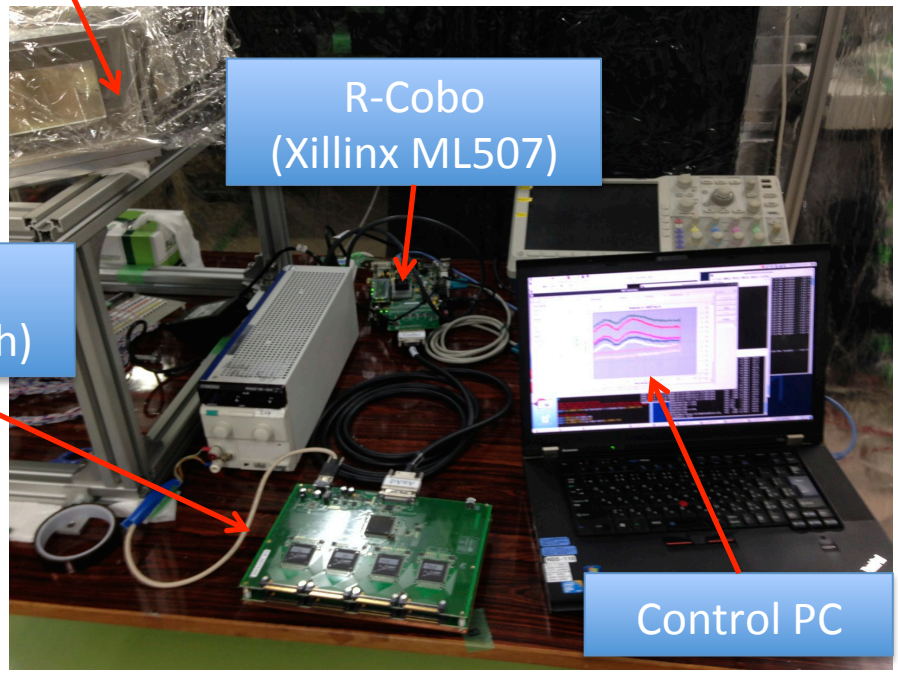
GET test bench @ JAEA

HypTPC

ZAP (protection diodes)

AsAd
(4AGET chips, 256ch)





R-Cobo
(Xillinx ML507)

Control PC

Summary

- We designed and developed a GEM-TPC with the gating grid (HypTPC) for J-APRC E42/E45
  - 1 MHz K^- beam is directly injected into the TPC.
- The GET system is adopted for HypTPC readout.
  - CH mapping for moderate hit multiplicity <- done
  - Fast clear function <- done
  - J-PARC Event Tag Receiving <- done
  - Frontend software <- under development
- TPC test with full GET system
  - July, 2015 -