測定器開発テストビームライン（電子ビームとハドロンビーム）の現状と見通し

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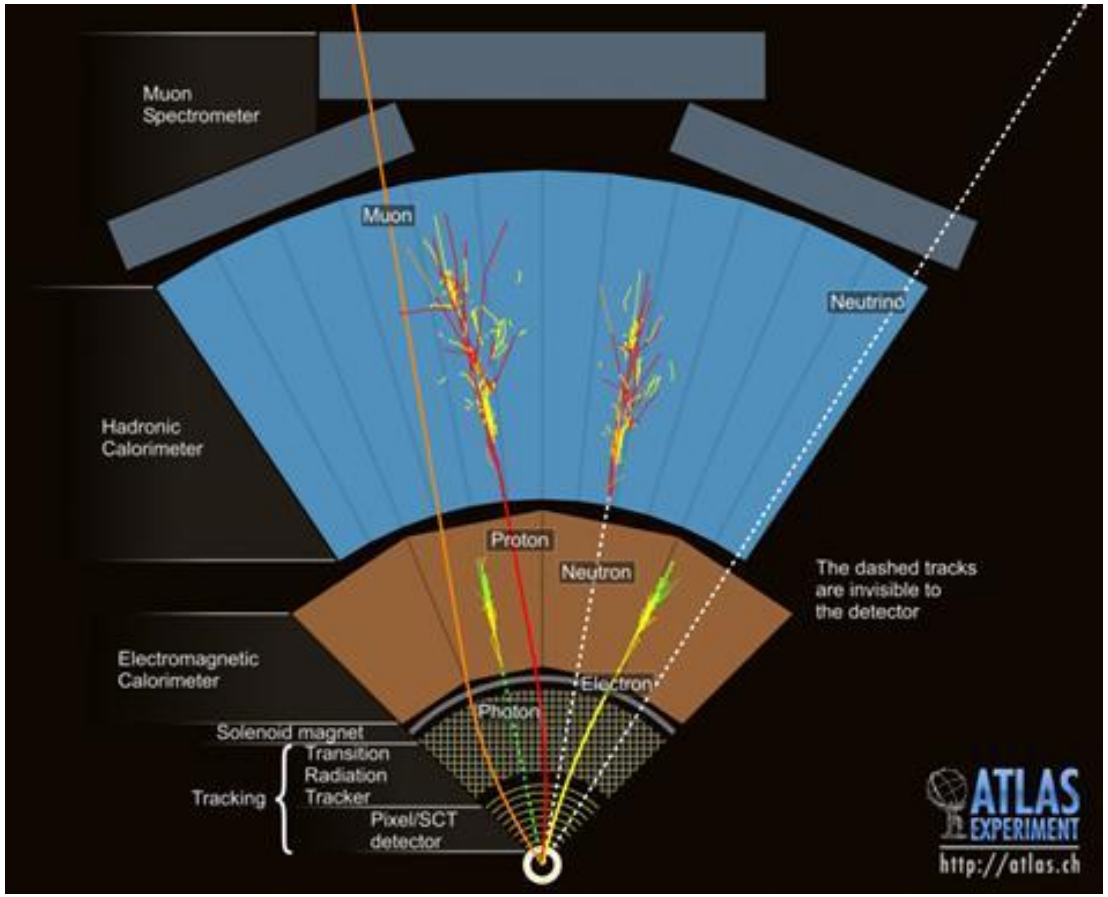
測定器開発センター
Instrumentation Technology Development Center

計測システム研究会2025@J-PARC
2025 / Nov / 18th

What we do at test beam line?



- Measuring particle property
  - High energy particle interact with material and deposit energy.
  - Convert it into electric signal and readout.
- To determine particle property
  - Position : σ ~ a few μm
  - Time : σ ~10 ps
  - Energy : σ ~ a few %
  - Spices of particle
    - e, μ, π, K, p, n

are necessary.

Test beam line can provide particles which could determine these parameters with enough precision.

Test beam line in the world

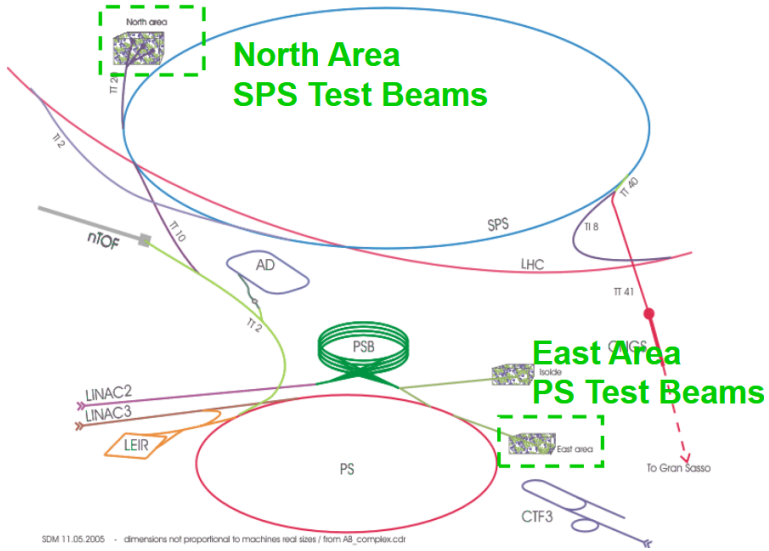
High energy particle beam for **instrumentation development**

- PS
- SPS

Secondary beam: 1 – 15 GeV
Electrons, hadrons, muons.
5 beam lines

5-400 GeV proton
Secondary particles
4 lines for fixed target exp. and test beam.
Total 7 lines.

Test Beam Facilities at CERN



Fermilab

- 120 GeV proton
  - 1~ 300 kHz
- Secondary particle
  - Down to 1 GeV.

DESY.

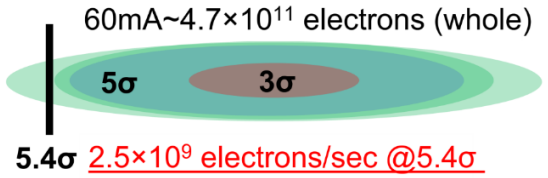
- Electron / positron
- < 1000 particles / cm^2
- 1 GeV to 6 GeV
- 4 lines.

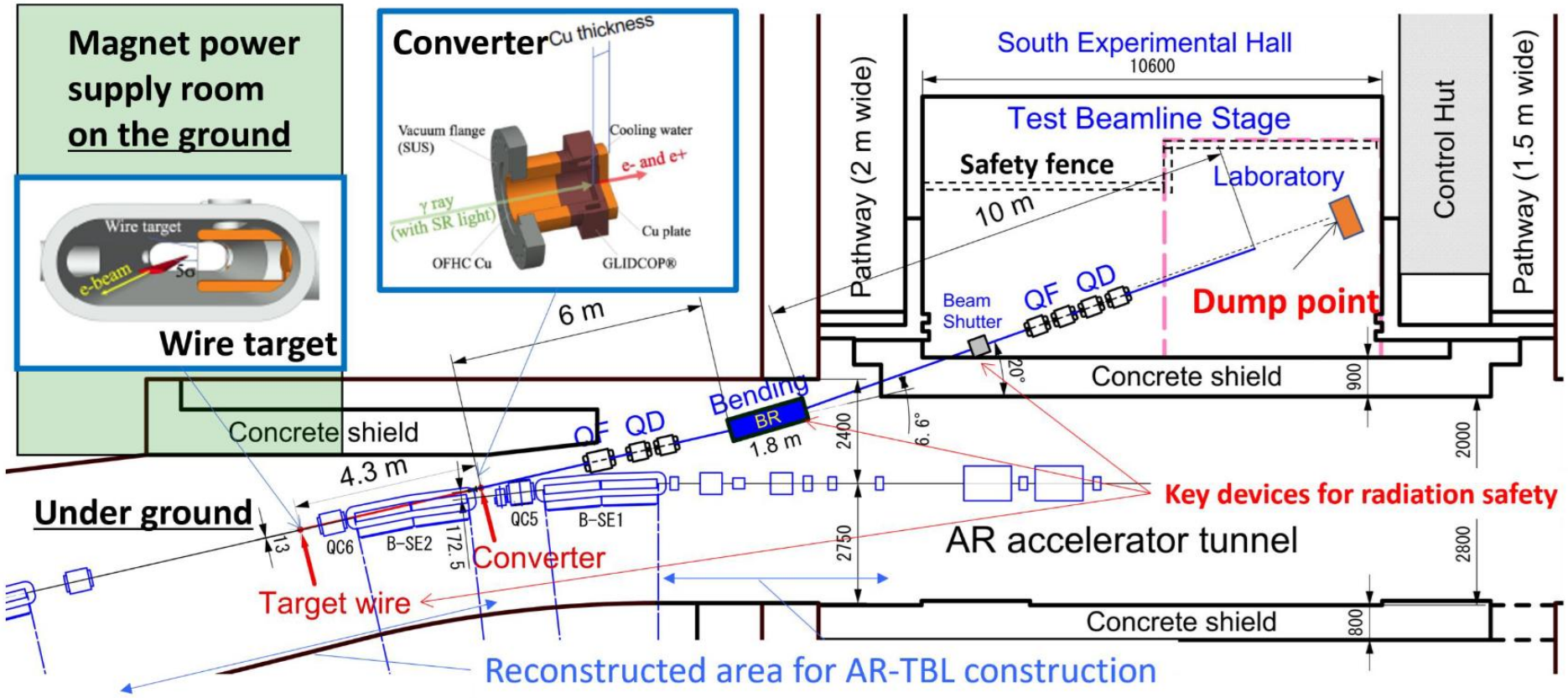
Electron test beam from PF-AR @ KEK

Electron in AR ring

Single Bunch with 50 mA

βx = 20.6 [m], εx = 290 [nmrad]
beam size $1\sigma_x$ = 2.4 [mm] $1\sigma_y$=0.1[mm]



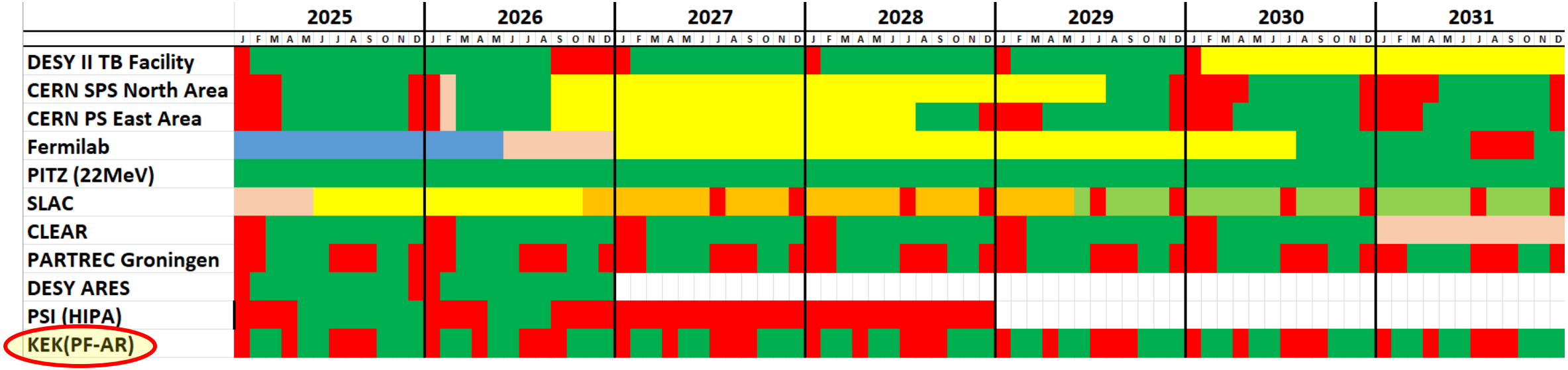


- Photon emission by wire target (Graphene)
- Inject photon to a converter (16 mm Cupper plate) to make pair creation.
- Transfer electron with Di-pole and Quadra-pole magnets to the test stage.

Electron Test Beam @ KEK Tsukuba campus

- Electron test beam line with momentum up to 5.8 GeV.
  - Officially from 2024 at KEK Tsukuba campus.
  - About 5.5 months per year
  - Available over CERN TBL shutdown period

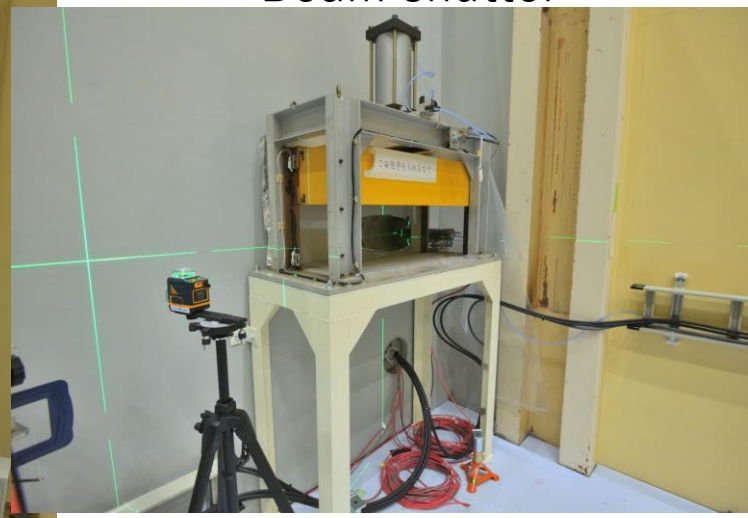
Table from this link



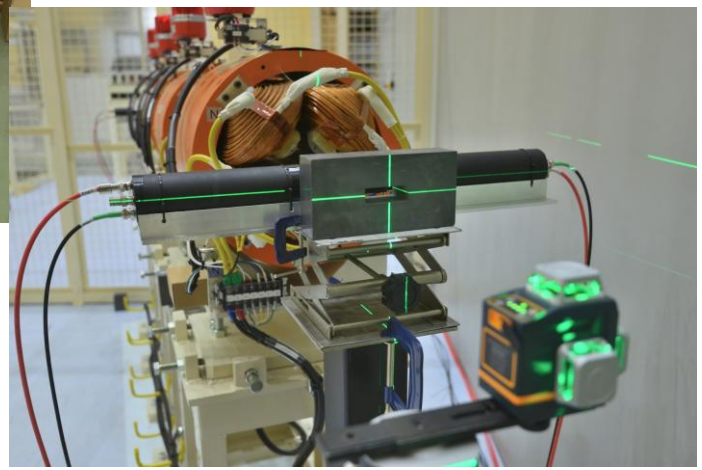
The electron test beam line at KEK PF-AR

Counting room

Beam shutter



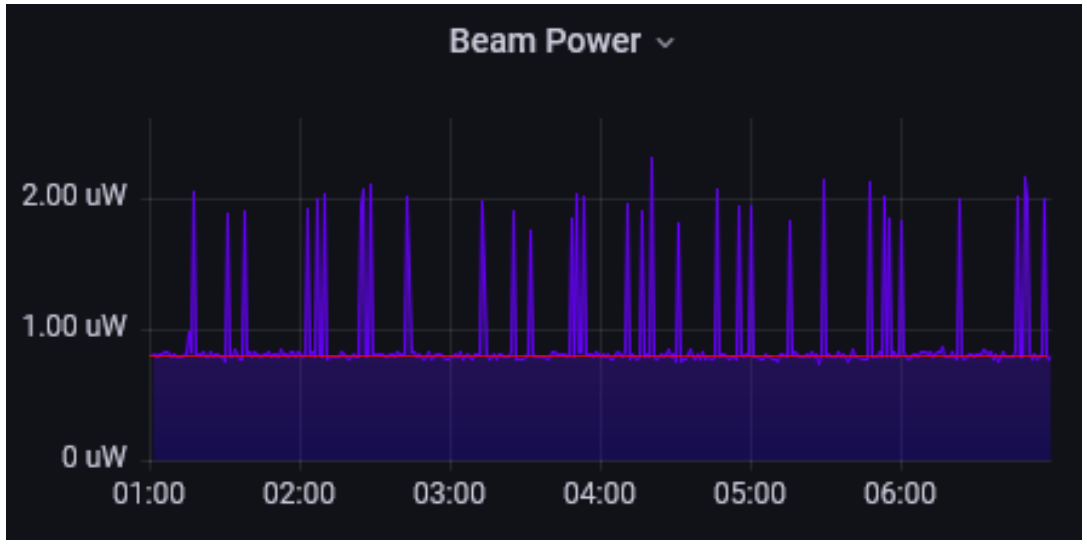
Sensor Stage



Trigger counters

Operation

- Real “24 hours” stable running.
- Top up mode: inject electrons to the bunch every 5 ~ 10 min



Instability during the Top-up:
- very high rate for a few turn.
- 155 k Hits per Top-up.

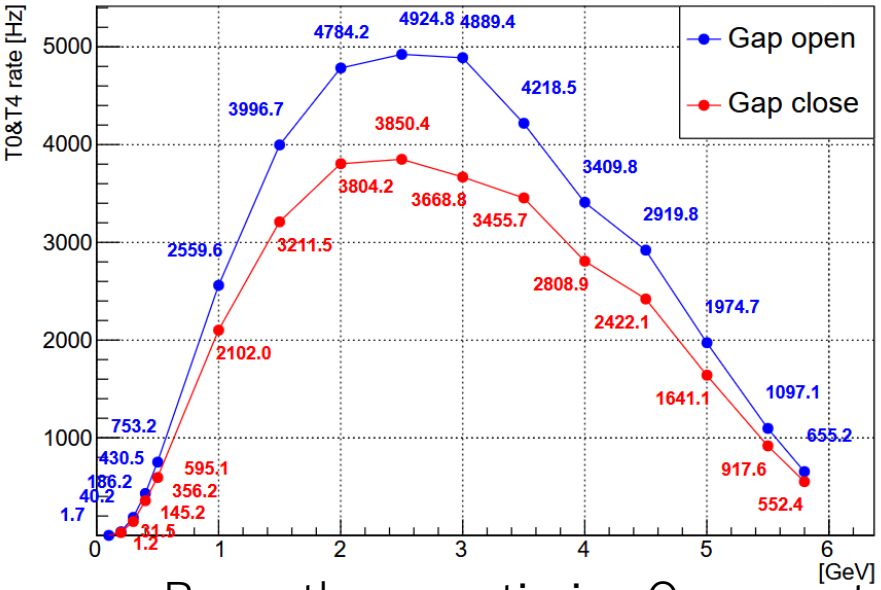
→ Try to reduce the instability next year.
(kicker system will be improved.)

Test beam rate and profile

Rate:

Overall rate is 2.5~4.5 kHz
Highest rate around 2.5 GeV.

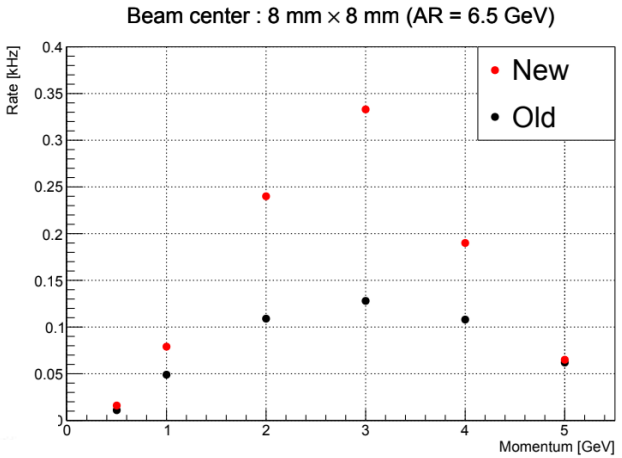
With AR beam @ 6.5 GeV

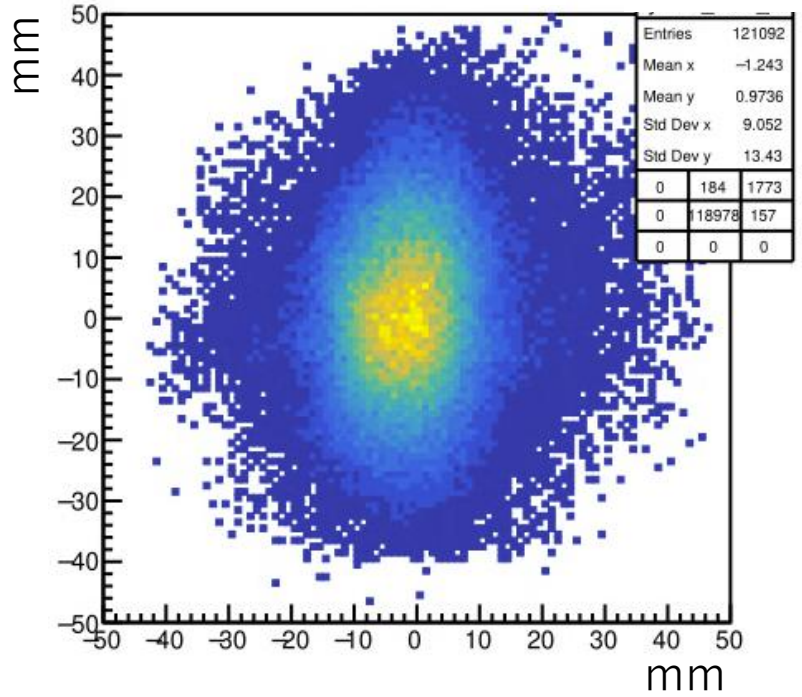


Recently we optimize Q-magnet
New: after optimization.
Δp/p ~ 10%.

- Beam profile at 3 GeV
  - ~ 4 mm in sigma
    - Wide in x direction.
  - Beam rate with 10 mm x 10mm:

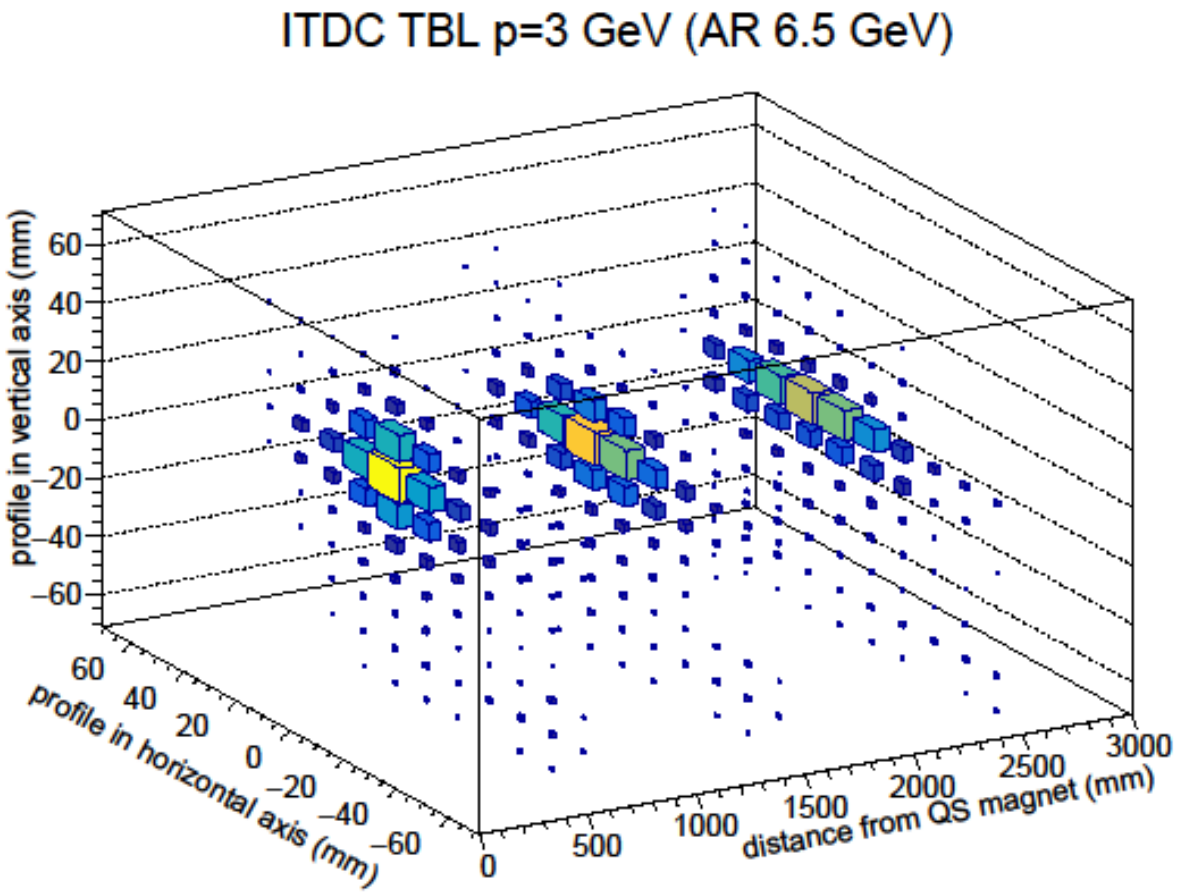
    ~ 350 Hz.



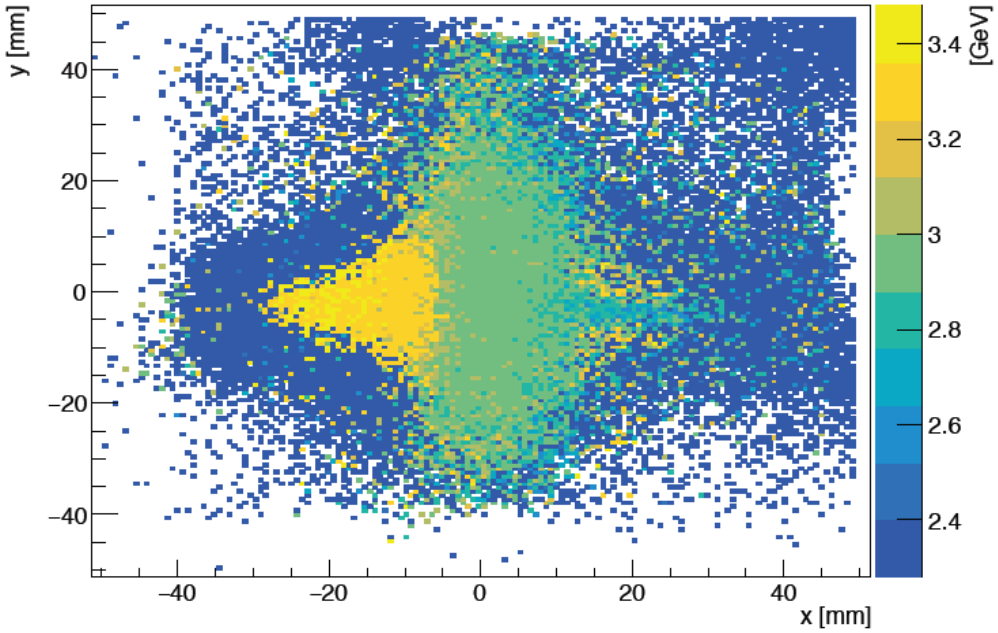


Beam profile in beam axis direction

Beam width in sigma (gaussian fit) in beam axis direction
Z=0 is at the edge of the last quadrupole magnet.



Relation of position and energy.

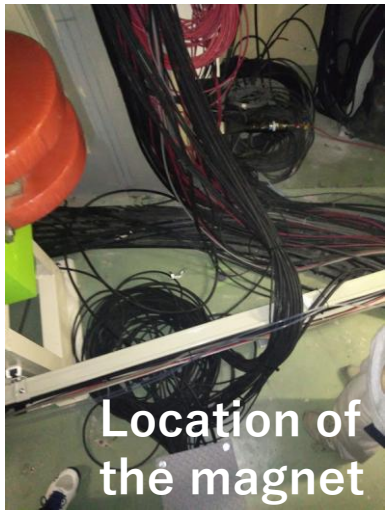


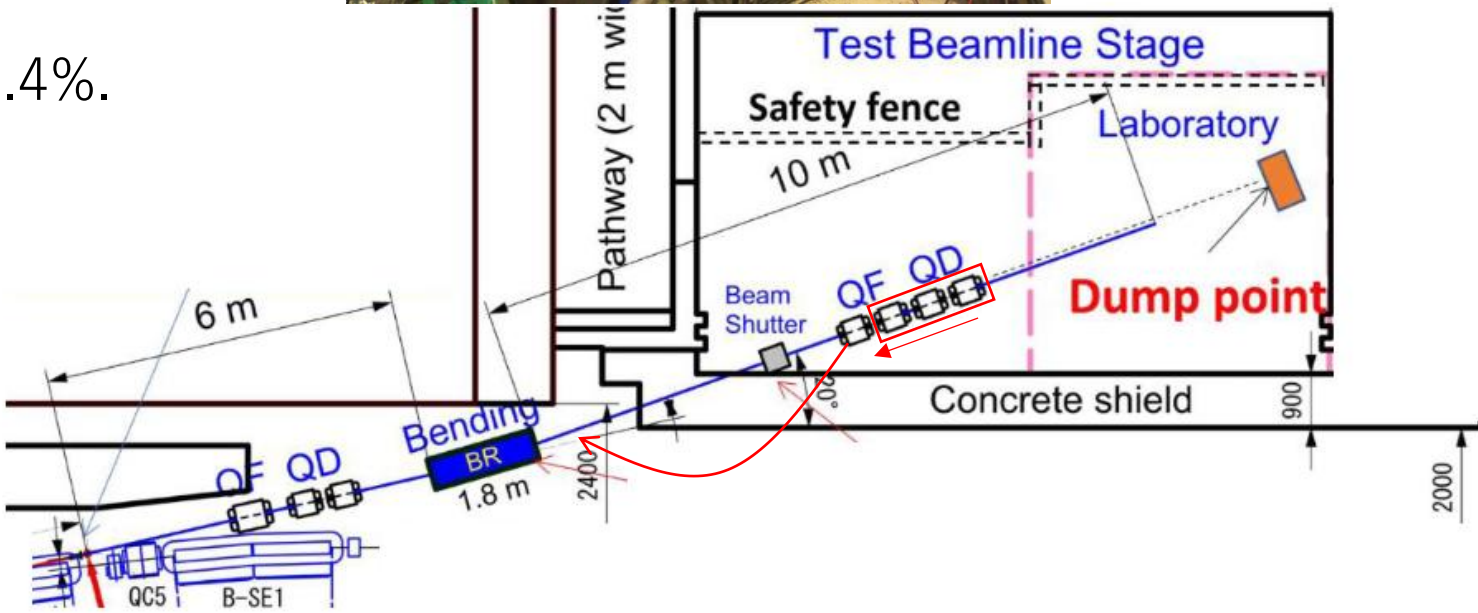
Narrow energy spread of ~5% would be possible.

To have higher rate by the beam transfer

- Position of Quadrupole magnets can be improved.
- Set them upper stream side.
  - Move one of QF just after Dipole magnet
  - Move forward rest of Quadrupoles by 1 m.

  → The rate increased by 1.8
  momentum spread: 2.8% → 3.4%.

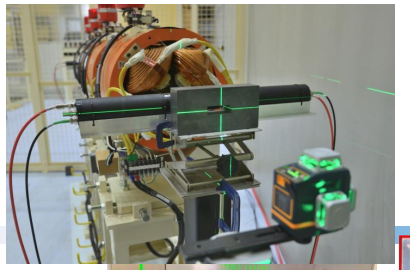


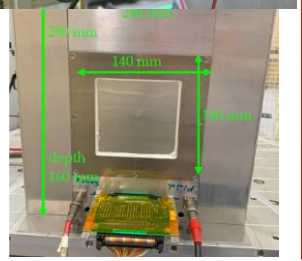


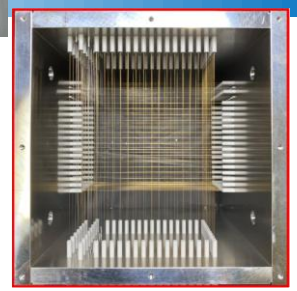
2025 Nov~

: Beam power has been increased by **1.4**!
- in case collimated beam: stay same level.

Beamline setup: status and plan

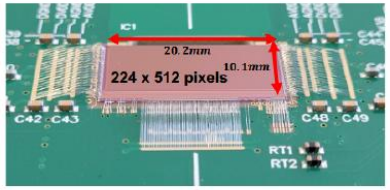




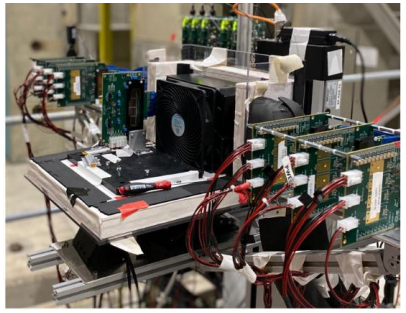


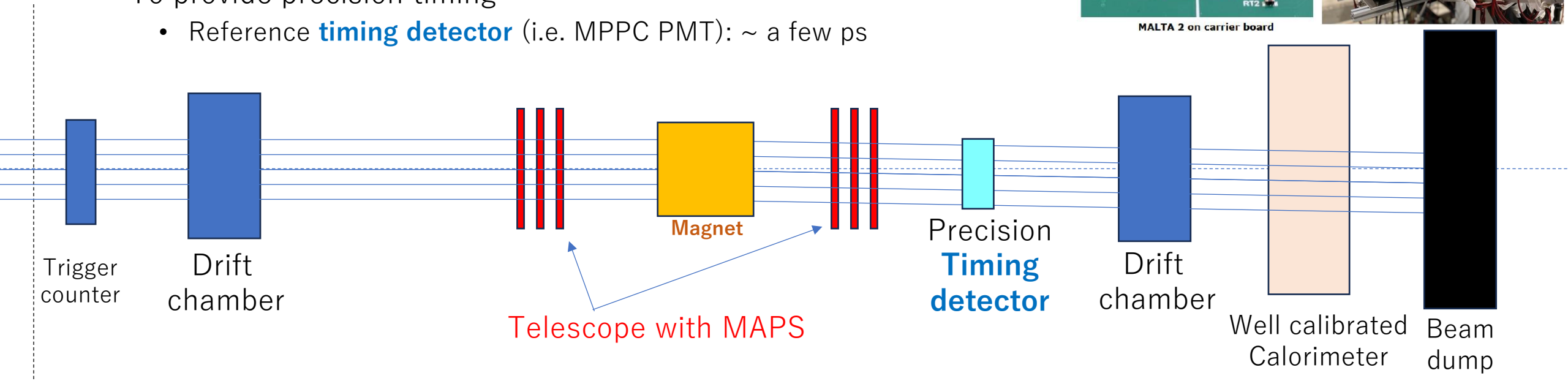
- Already available
  - Trigger counter, Drift chamber for beam profile measurement
- Plan:
  - To have High position resolution
    - Telescope with MAPS: interpolate position resolution: ~ μm
  - To provide precise energy scale
    - Combine with Telescope and **permanent magnet**: Energy scale a few %.
  - To provide precision timing
    - Reference **timing detector** (i.e. MPPC PMT): ~ a few ps

Your contribution is very welcome!
Contact: yuji.enari@kek.jp

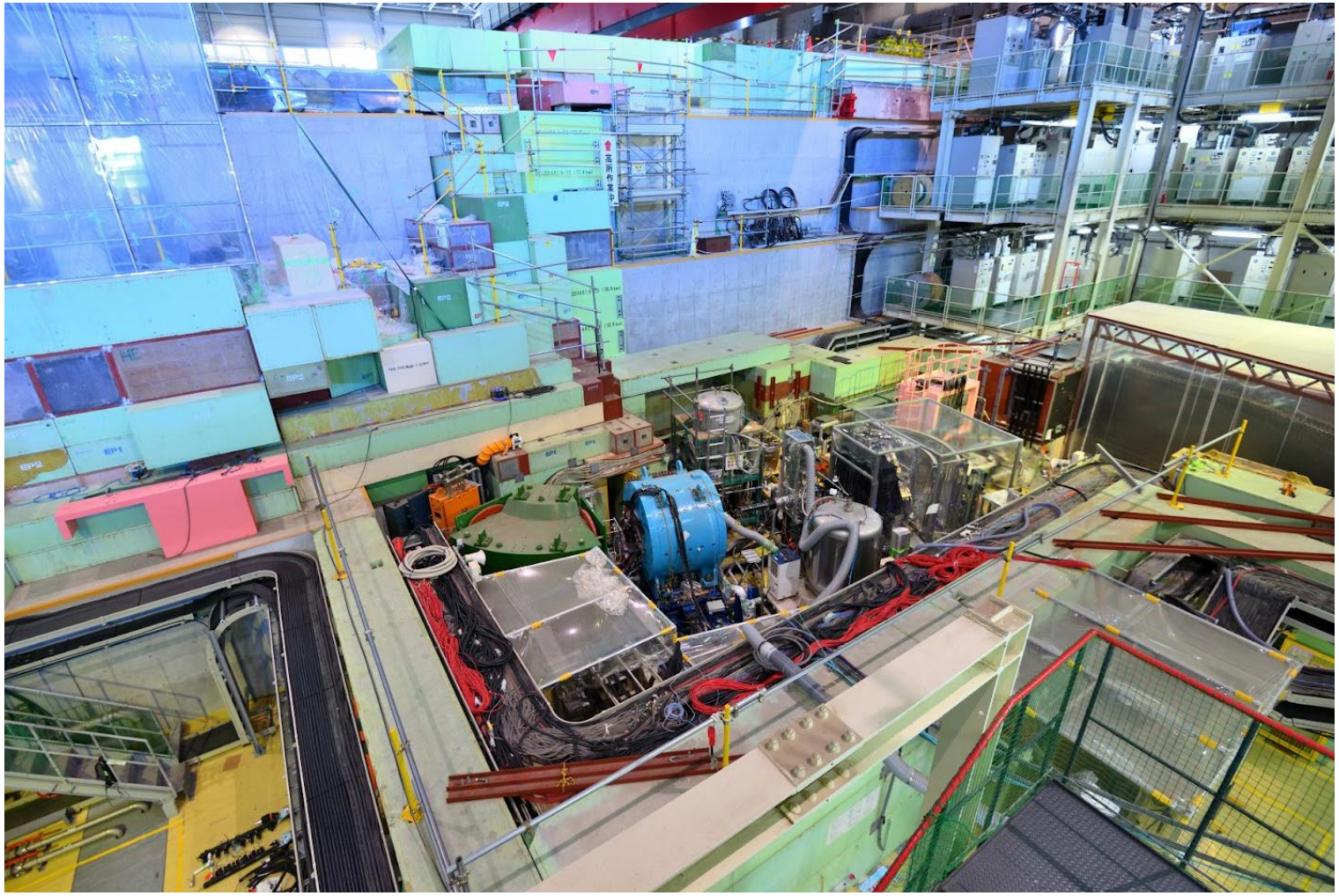


MALTA 2 on carrier board



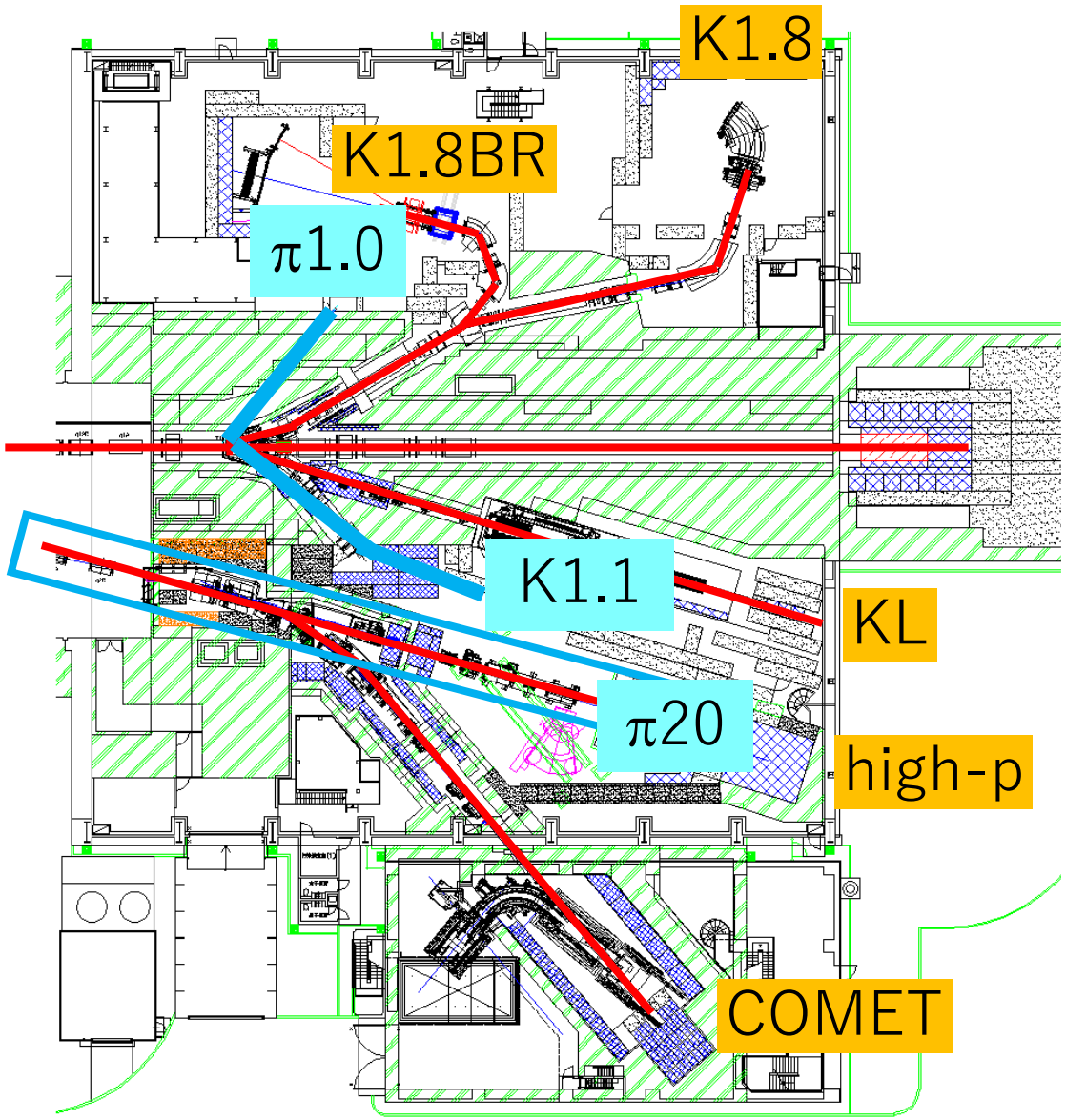


Possibilities of Hadron test beam in J-PARC

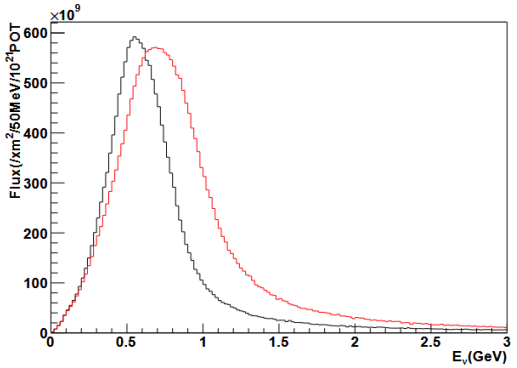


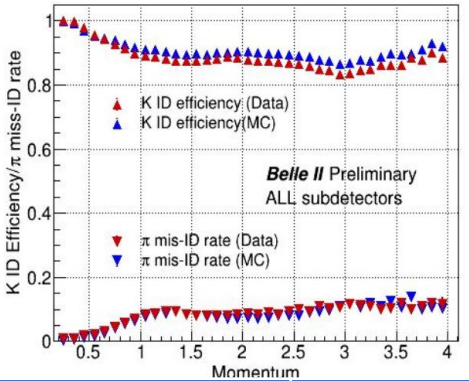
J-PARC Hadron experimental hall @ KEK Tokai campus

Possibility of Hadron Test beam line @ J-PARC



We need hadron test beam!





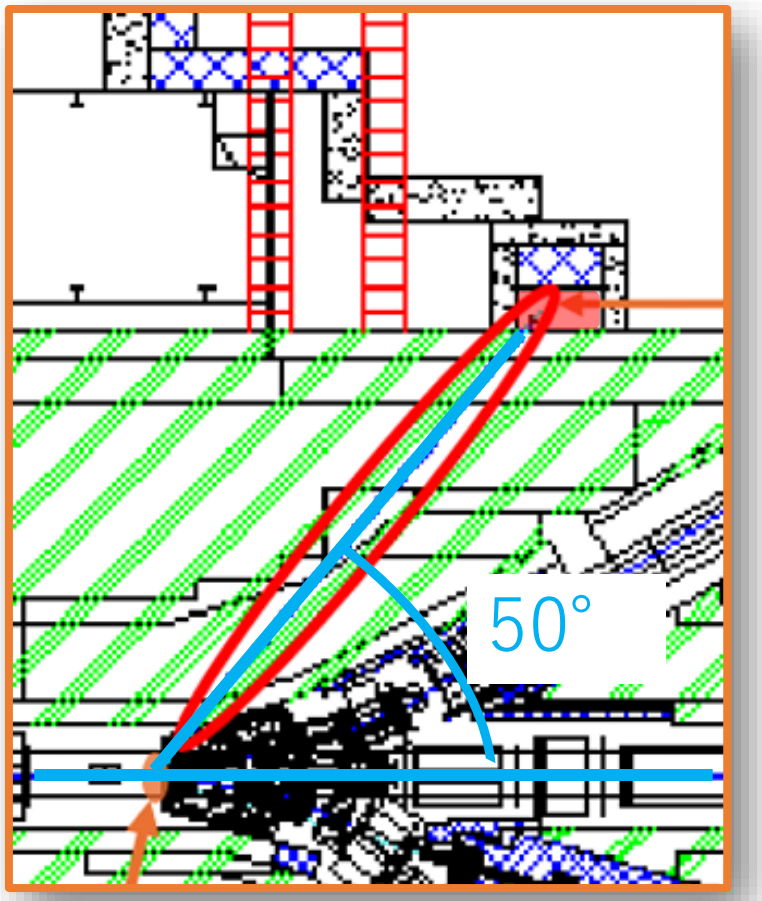
	π1.0	K1.1	π20
Max. Momentum	< 1.0 GeV/c	< 1.1 GeV	< 20 GeV
Rate (# of particle/spill)	10^3	10^7	10^6
Separator	No	Yes	No
Conflict	Parallel with Physics	Parallel with Physics	Time sharing

This is a study on the π1.0 beam line.

→ trying to measure the rates of particles.

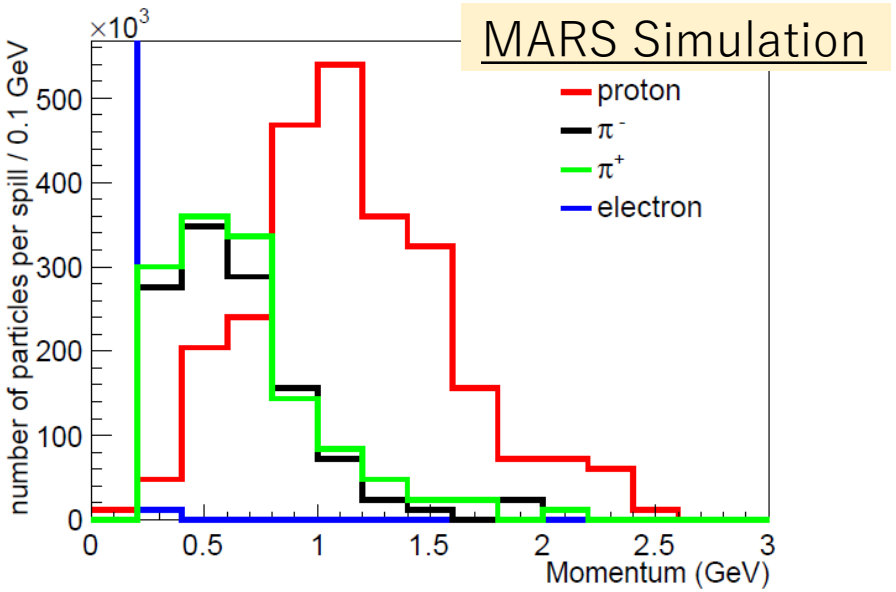
Location of the π1.0 beam pipe

- There is a pipe from production target to π1.0 area.
  - A space of 1 m x 1 m x 2 m for beam monitoring



T105 experiment

Proposal submitted: 2024 Sep
Install setup : 2024 Dec
Data taking : 2025 Jan / Feb, 2025 Apr / May



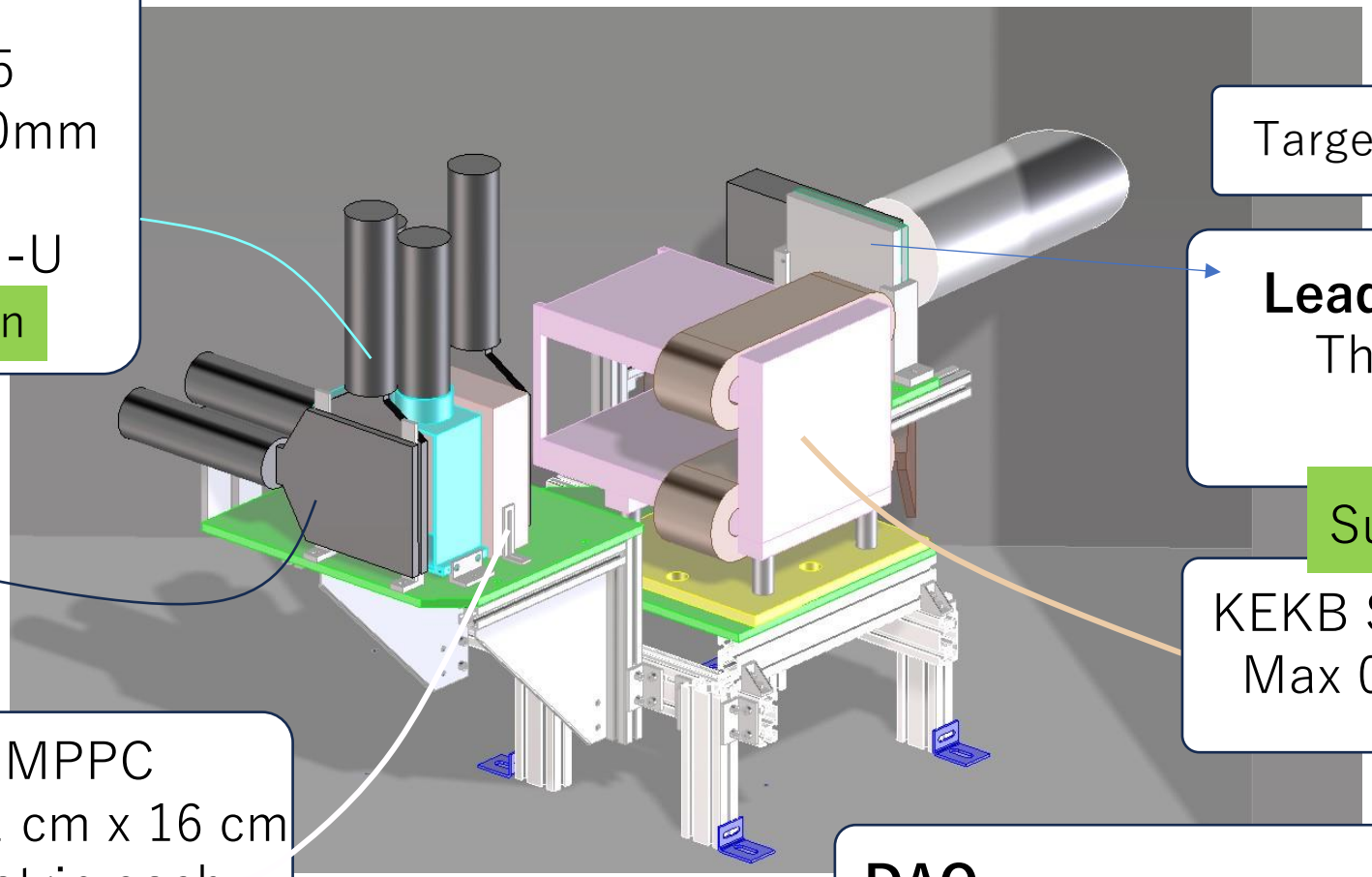
Experimental setup

Proposal submitted: 2024 Sep
Install setup : 2024 Dec
Data taking : 2025 Jan / Feb / Apr / May

Aerogel counter
Reflective Index: 1.045
60 mm x 160mm x 160mm
Four HPK H1161
supported by Kyushu-U
Separate proton and pion

Count charged particles

Scinti. Counter
Scinti + PMT
3 sets



Target Monitor

Lead plate
Thickness 1.5 cm
~2.7X_0

Suppress γ, e

KEKB Steering **Magnet**
Max 0.039 T@ 5 A

Scinti. strip + MPPC
strip size: 1 cm x 16 cm
x and y 16 strip each
Total 32 ch
supported by Kobe-U

DAQ
Trigger less readout with AMANEQ
ITDC E-sys group

DAQ

Slide of Kakeru Tanaka
from Kyushu-U

【RAYRAW】
Wave form digitizer

【PC】

【Trigger Scintillation × 3 】

【Aerogel Cherenkov Counter × 4 】

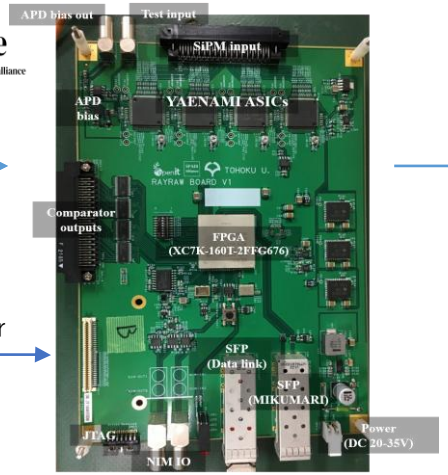
【Scintillation Pad (MPPC × 32)】

Analog

Trigger

Input to Discriminator

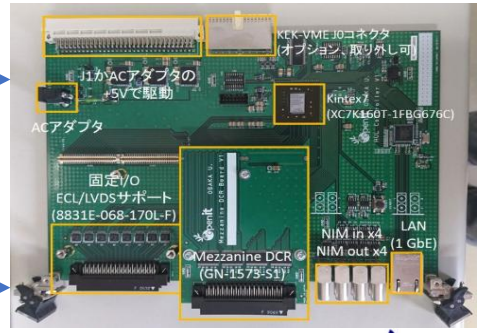
Input to EASIROC



【NIM Module】

flat cable
(LVDS)

flat cable



【HUL】
Logic module

Input Signa to Logic modulel	Output
Trigger Scintillation (3)	7
Scintillation Pad (16×16)	35
Aerogel Cherenkov Counter (4)	5
Coincidence outputs	13
Rayraw common stop	1

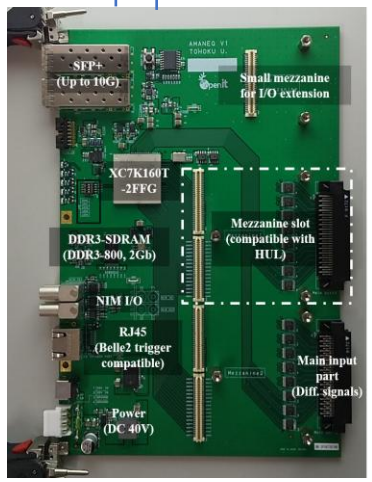
1. ADC：Digitized wave form

2. Scaler：
Number of hits

3. TDC：
Timing information of hits

Logic output
(64ch)

64ch



【AMANEQ】
FPGA readout board

2025/3/21

DAQ and Output

【Trigger Scintillation × 3 】

【Aerogel Cherenkov Counter × 4 】

【Scintillation Pad (MPPC × 32)】

Input to Discriminator

Input to EASIROC

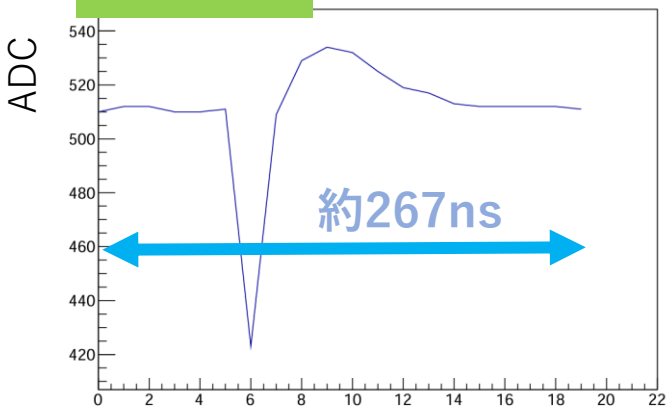
【NIM Module】

flat cab
(LVDS

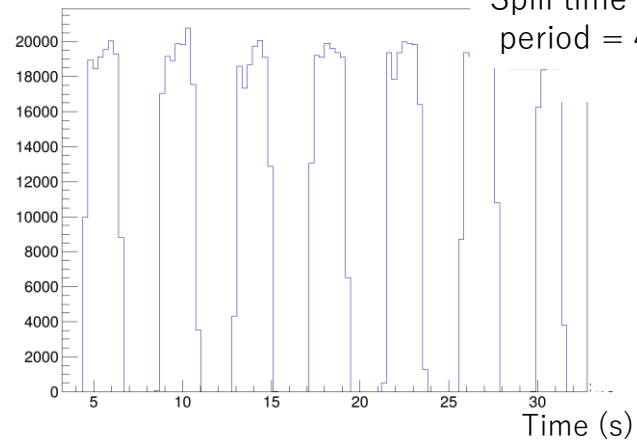
flat ca

【 RAYRAW】
Wave form digitizer

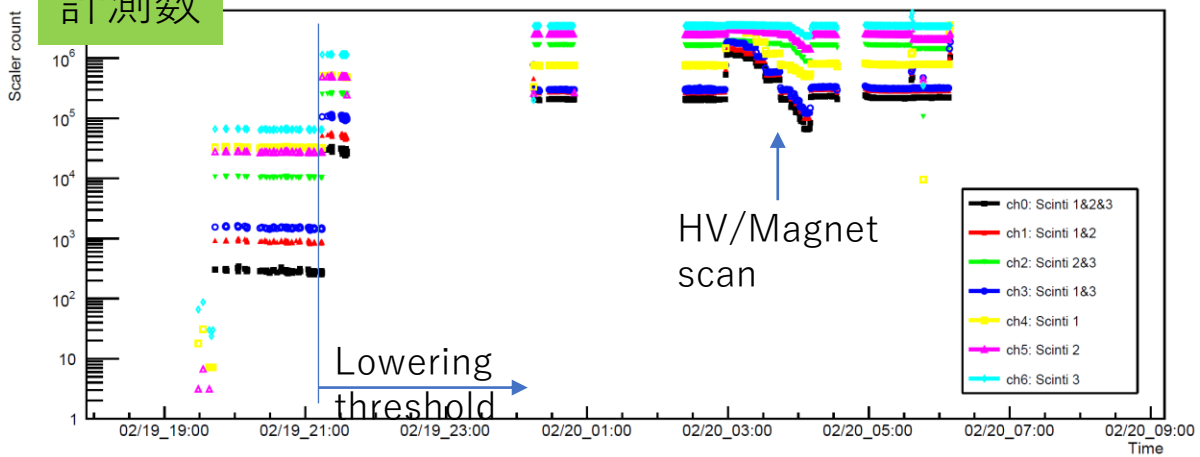
ADC分布



連続読み出しTDC



計測数



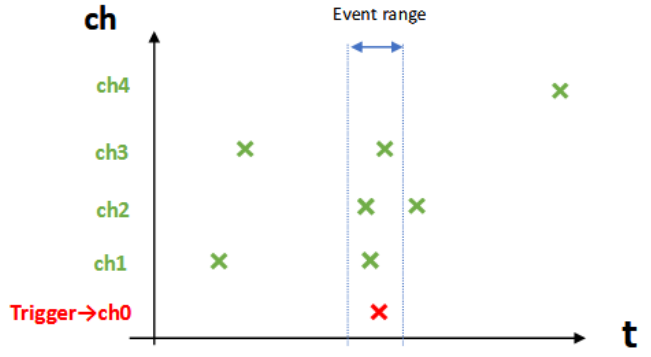
【AMANEQ】
FPGA readout board

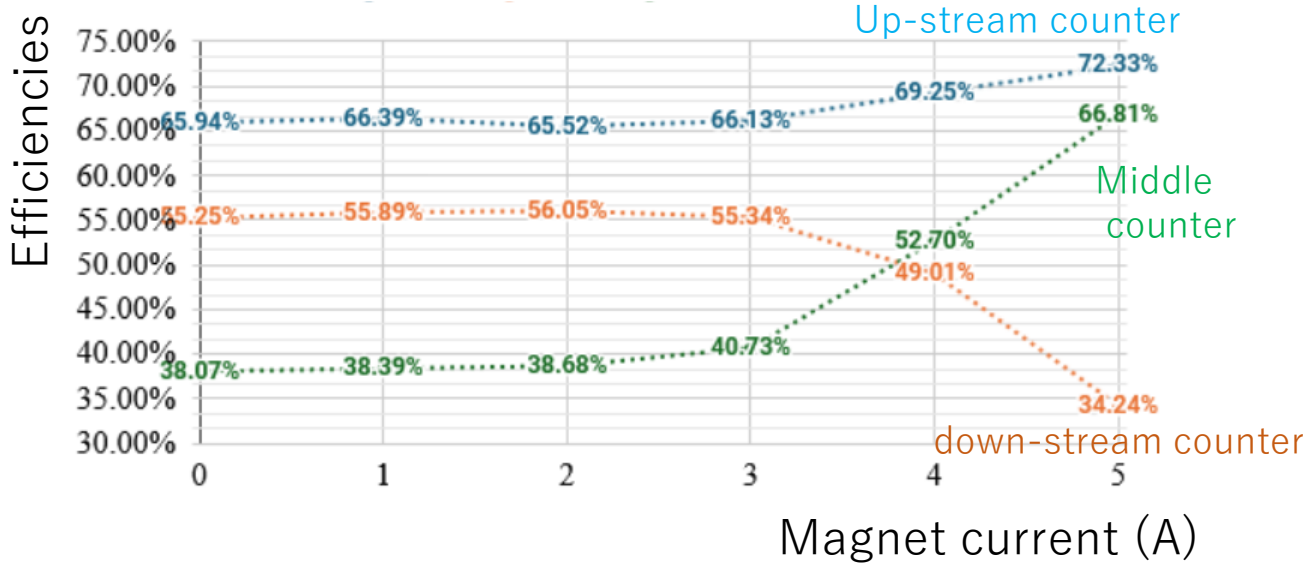
2025/3/21

Analyzing TDC data with continuous readout

by Kakeru Tanaka from Kyushu-U

- Need to define an event





- Issue observed due to high rate
  - Observed coincidence, but no individual hit
    - The width of logic signal is 20 ns,
    - coincidence window is 20 ns.

    → Due to high rate, relevant individual hit shifted and out of coincidence.
  - Dependence of measured efficiencies
    - As function of current of the magnet
    - At 0 A: no effect of magnetic field

      → Highest gain, efficiencies suppose to be highest.

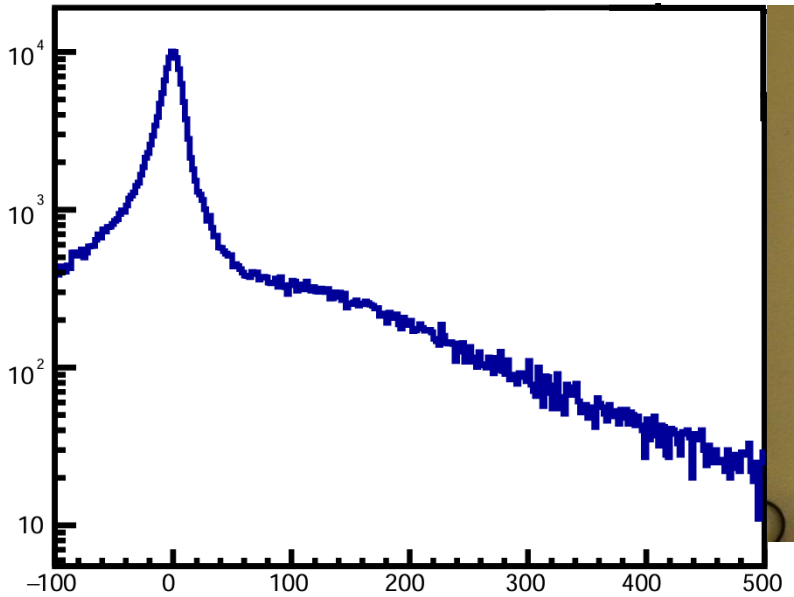
      Not for two counters in up-stream

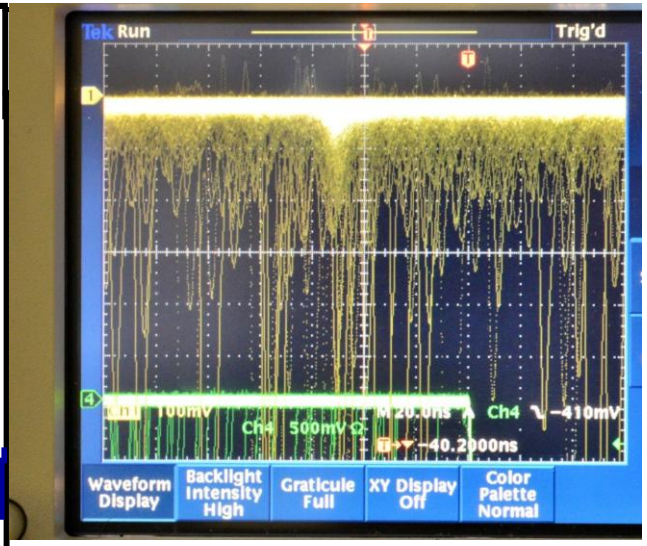
Possible explanation:
Voltage drop due to a high counting rate
(efficiency recovered with smaller signal due to magnetic field.)

Response of Aerogel counter

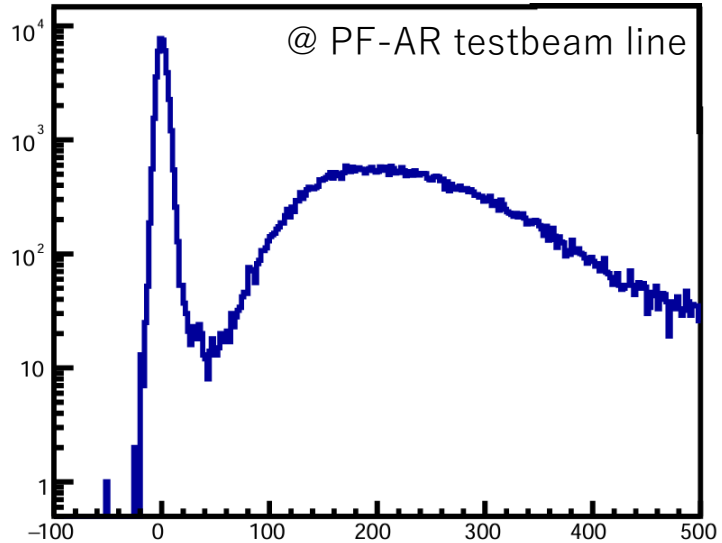
by Yuta Tochi from Kyushu-U

Output of Hadron Hall (T105)





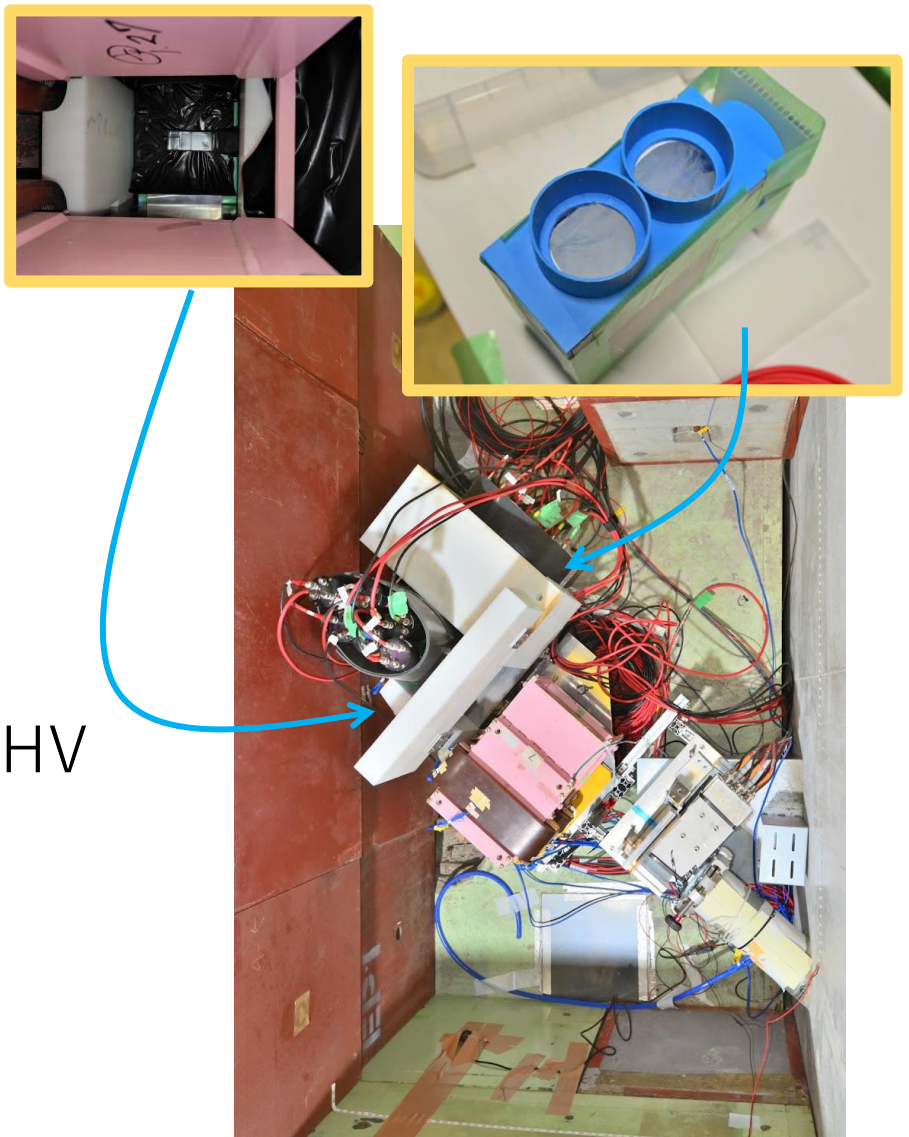
Reference taken with electron beam



- At π1.0 line, observed
  - beam related background with high rate (2 M hits per spill / PMT)
  - Not so clear indication of peak of Cherenkov light.
  - Due to high rate hits from beam related background? (neutron?)
- Check Aerogel counter performance with 3 GeV electron beam
  - Taken before hadron hall setup
  - The efficiency is ~ 90 % with ADC > 50 ADC count.

Updates on configuration @ 2025 Apr

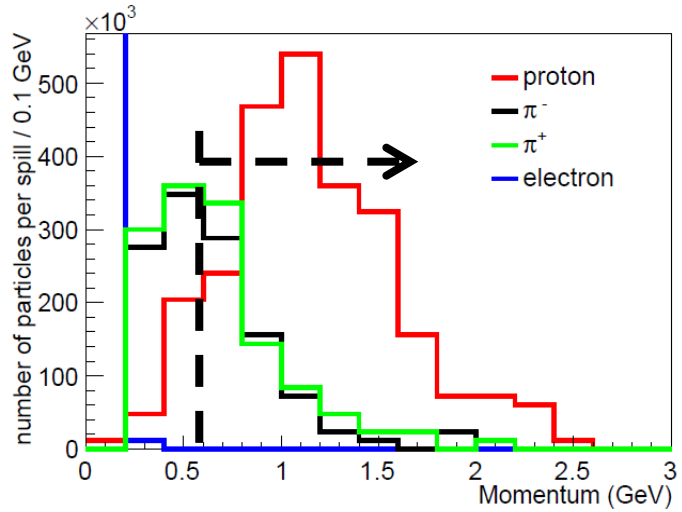
- Changes on detector
  - Remove Scinti-pad+MPPC
  - Insert small Scintillation counter
  - Insert 2nd Aerogel counter
  - Insert light shielded PMT
- Shielding for neutron background
  - Polyethylene blocks
  - PMTs covered by Boron sheet
- Readout
  - Introduce analog amp for PMT readout to lower HV
  - Optimize threshold level
  - Update on AMANEQ FW
    - Adjust readout channels
    - Fix small bugs

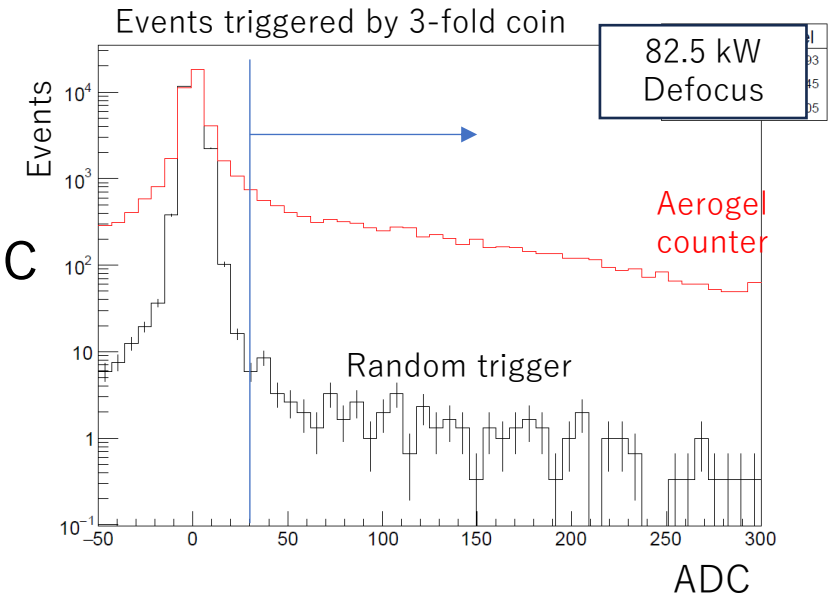


Results after updates

by Kakeru Tanaka from Kyushu-U

- Rate and efficiencies
  - Before: Feb 19th : 400 kHits / spill @ 82.5 kW
  - After : May 13th: **1.5 MHits / spill** @ 92.1 kW
    - Fake hit is negligible thanks to the 3-fold coincidence
    - The efficiency correction factor is 1.5 ~ 3.0.
      - Large variation in different conditions
- The fraction of pion
  - The hit fraction of the aerogel counter
    - 10～20% (large variation observed)
- Result: rate of π- in 0.9 GeV/c < p < 1 .0GeV/c
  - > 14 kHits / spill
    - Assuming distribution of MARS simulation
    - Expectation by MARS simulation : 110 kHis / spill

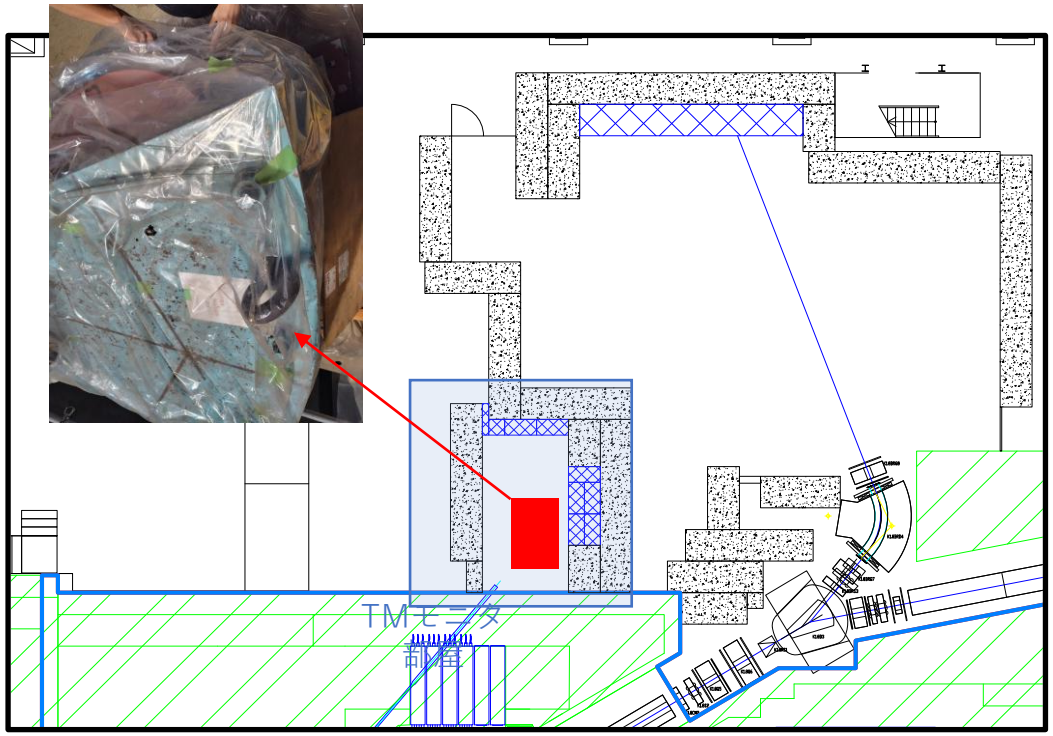




Next step

Use opportunity of the modification of K1.8BR area

- Plan to enlarge area and introduce magnet.
  - 1 m x 2 m → 5 m x 2.7 m
  - Bend charged particle by 45 degree
    - Max 1.6 T @ 1060 A
- Measure charged particle rate
  - Suppress large amount of neutrals.
- Detectors
  - Scintillation counter
    - Need to readout under magnetic filed
  - PID device
    - Aerogel / Gas Cherenkov?
  - Position sensitive
    - DLC-RPC K. Ieki *et al., NIM A 1064, (2024), 169375* M. Takahashi *et al., NIM A 1066, (2024), 169509*
  - Current team members from
    - Kobe U, Kyushu U, Osaka U, ITDC



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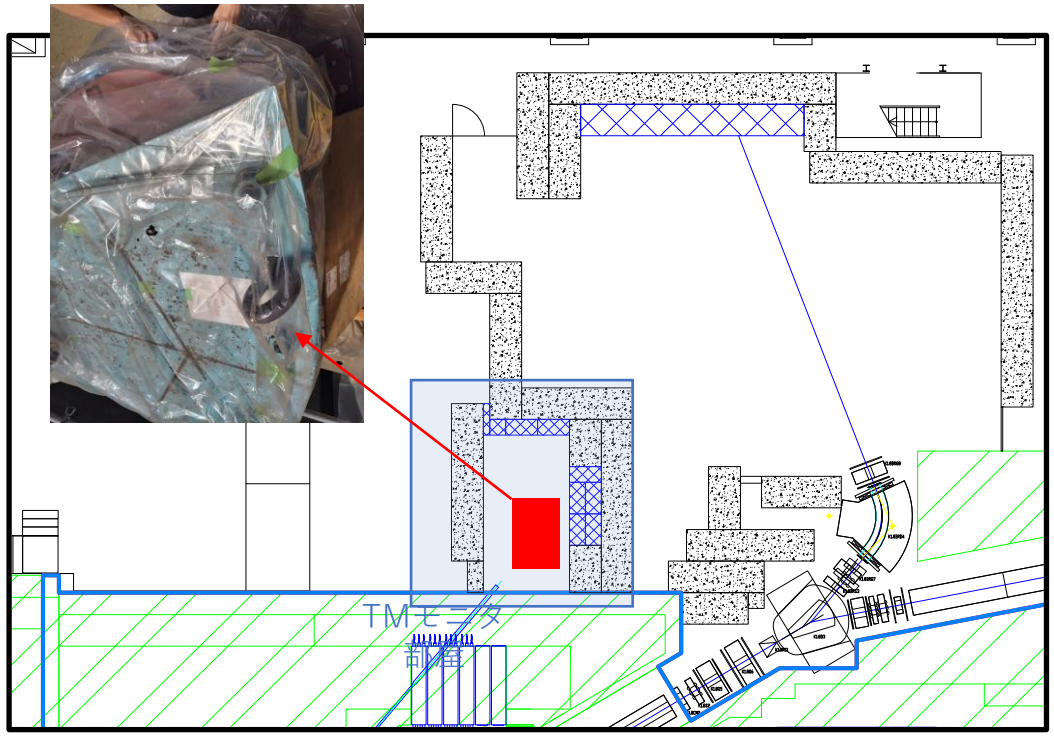
  - DEC-RPC M. Takahashi *et al., NIM A 1066, (2024), 169509*
- Current team members from
  - Kobe U, Kyushu U, ITDC

The site will be modified from 2026 May.
Your contribution is very welcome!
Please contact
yuji.enari@kek.jp



Summary

- Electron test beam is available at KEK Tsukuba campus
  - May-July, Oct-Dec, Feb-Mar, about 5.5 months per year.
  - Momentum up to 5.8 GeV/c, 3.5 kHz @ 2~3 GeV/c
  - https://itdc.kek.jp/testBeamLine/index.html
  - Please use the test beam line!
    - very welcome to efforts improving TBL system (beam, telescope system)
- Possibility on a Hadron test beam in J-PARC hadron hall is under evaluation
  - pi1.0 beam line is realistic plan.
  - Rate measurement is on-going.
    - $>$ 1.5 M hits per spill by charged particle. Pion fraction 10~20%.
    - Plan to introduce bending magnet to suppress neutral particles to the rate measurement.
      - Now designing measurement system. Your participation is very welcome!

Contact: yuji.enari@kek.jp