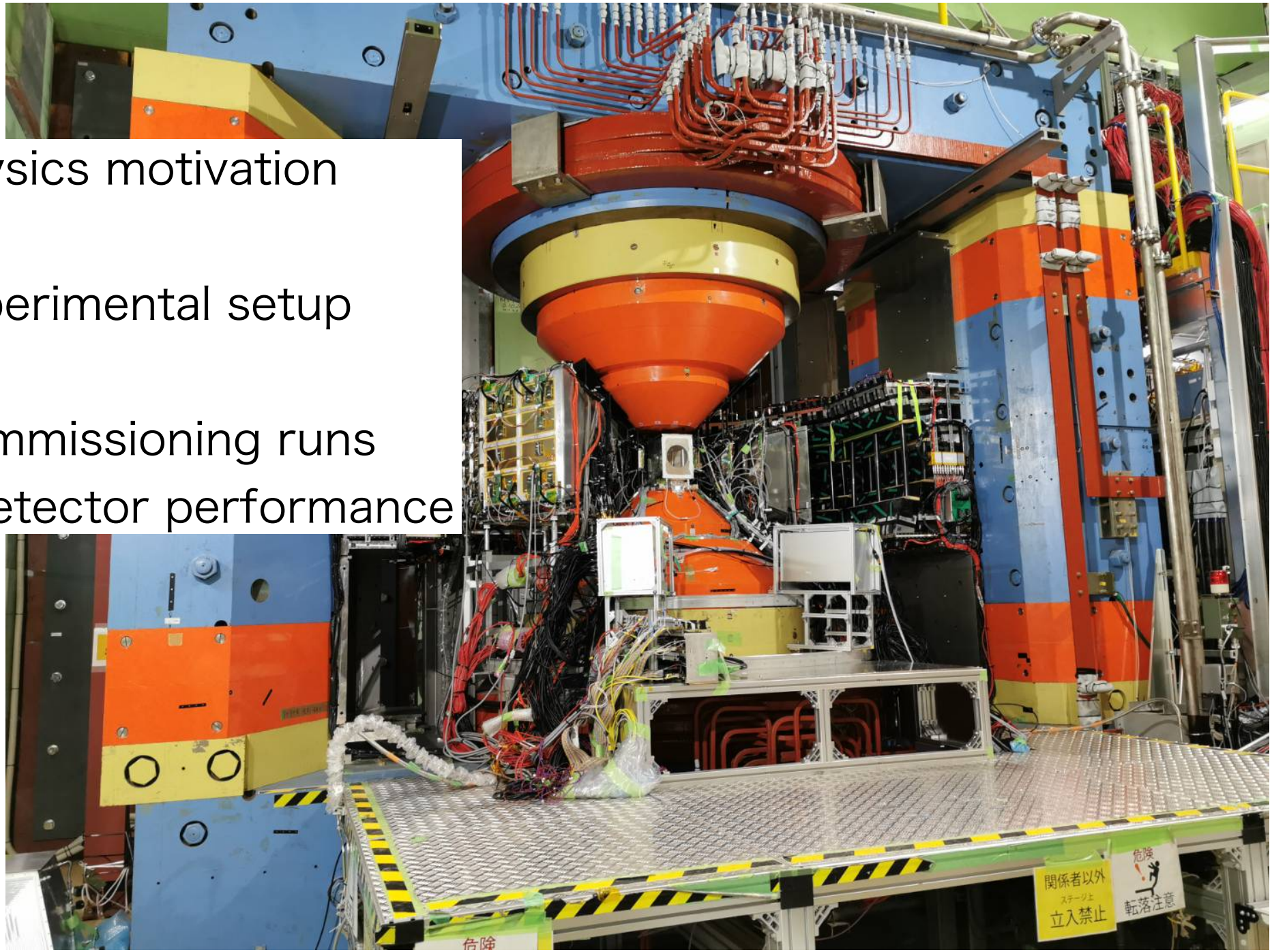
Commissioning Runs of J-PARC E16 Experiment

M. Ichikawa, for the J-PARC E16 collaboration
Kyoto Univ., JAEA
2022.4.7

Outline



- Physics motivation
- Experimental setup
- Commissioning runs
  - Detector performance

J-PARC E16 collaboration

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JASRI	A. Kiyomichi
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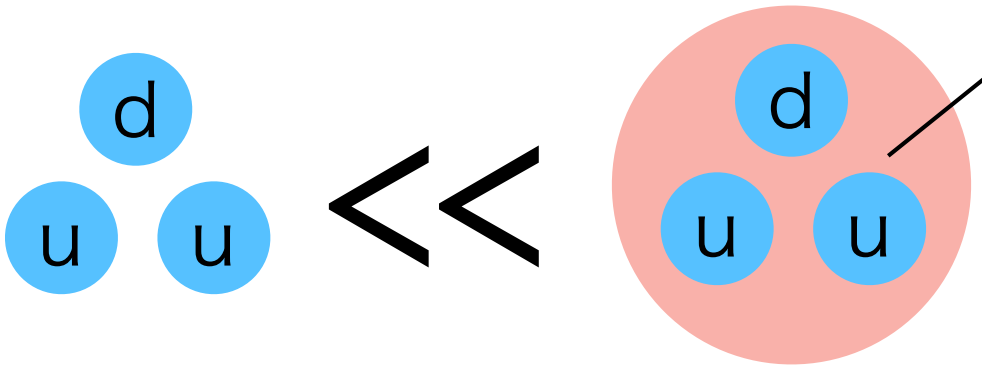
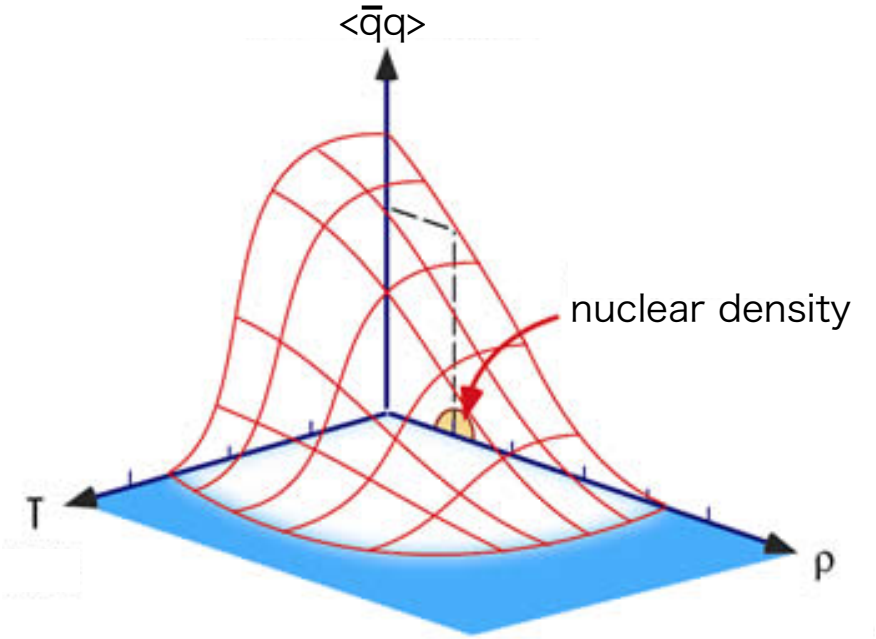
Physics motivation

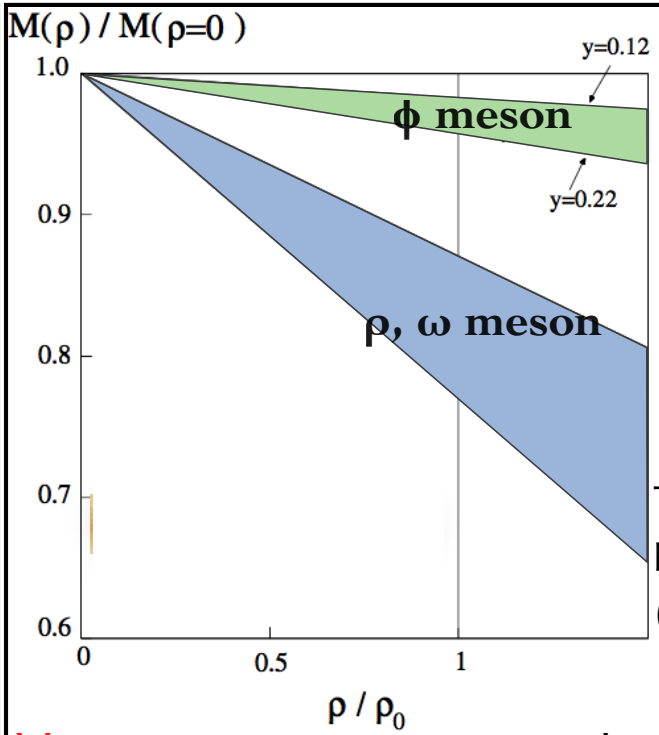
Current quark ~ MeV/c^2 Hadron ~GeV/c^2 Contribution of Higgs mechanism is a few percent



Spontaneous breaking of chiral symmetry



Chiral symmetry breaking is suggested to be restored at nuclear density.



T. Hatsuda and S. H. Lee, Phys. Rev. C 46, R34 (1992)

Vector meson mass and quark condensate are linked by theoretical calculation (QCD sum rule).

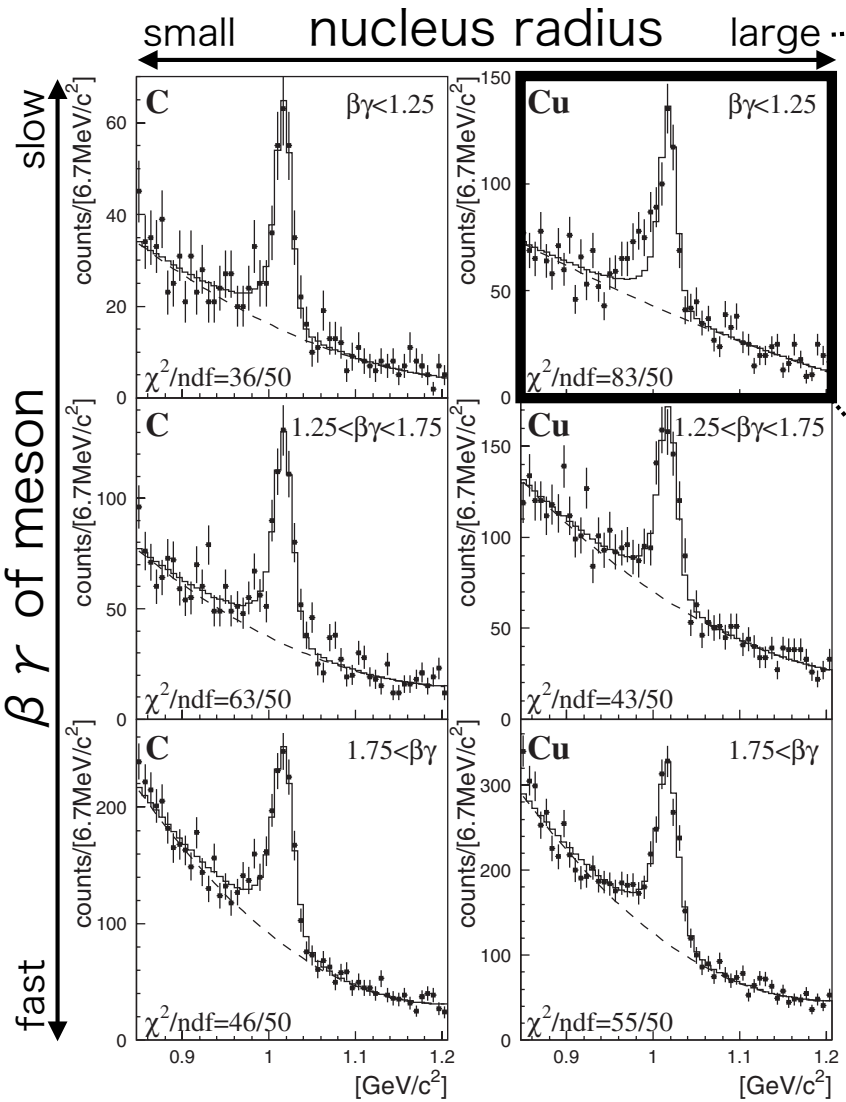
Previous experiment

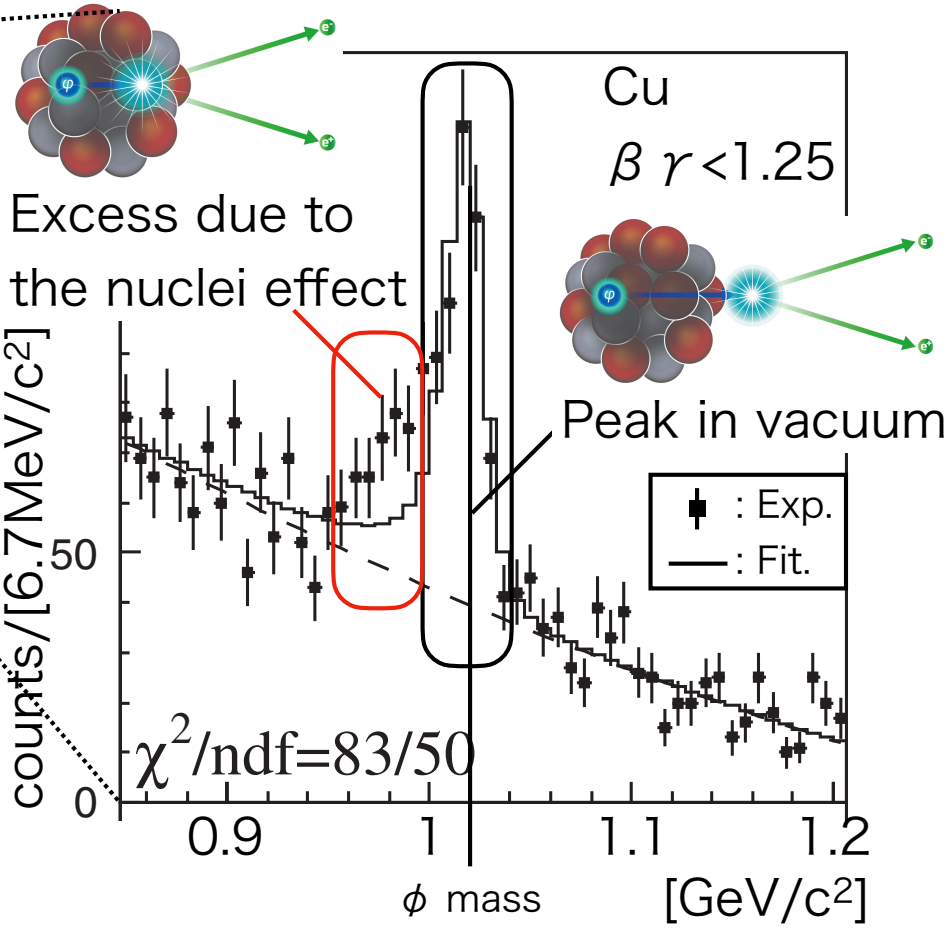
○KEK-PS E325

- 12 GeV p+A->(ρ, ω, ϕ)+X

  (ρ, ω, ϕ)->e^+e^- (almost free from final state interaction)

- Low background and static environment compared to HI.





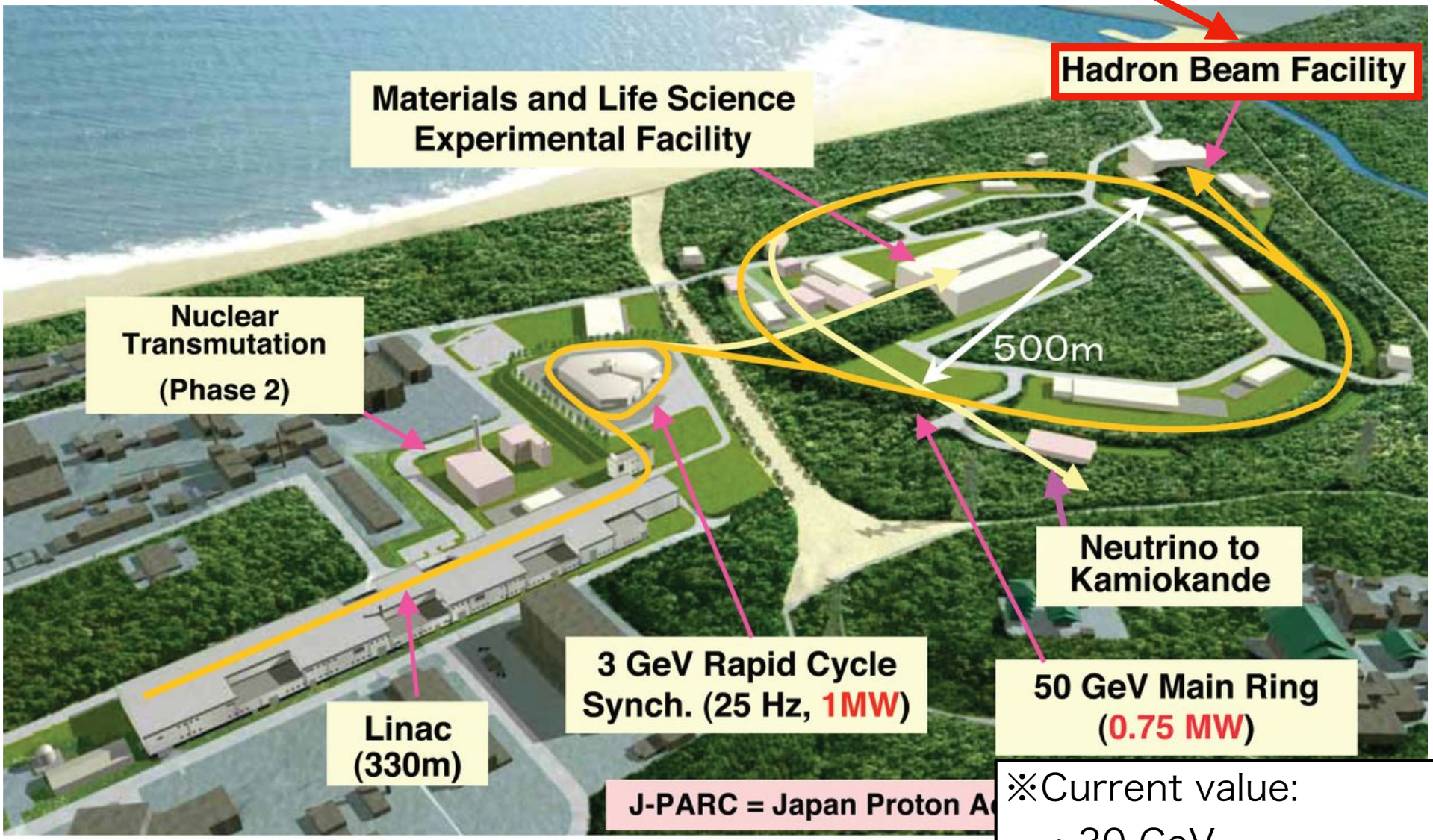
It is important to establish the spectral modification with enough high statistics.

R. Muto, et. al., Phys. Rev. Lett., 98, 042501(2007)

J-PARC

Japan Proton Accelerator Research Complex

・30 GeV proton, 7.0 × 10^{13} /spill (for hadron experiment, 2021)



※Current value:

- 30 GeV
- 64.5 kW (for hadron)
- 515 kW (for neutrino)

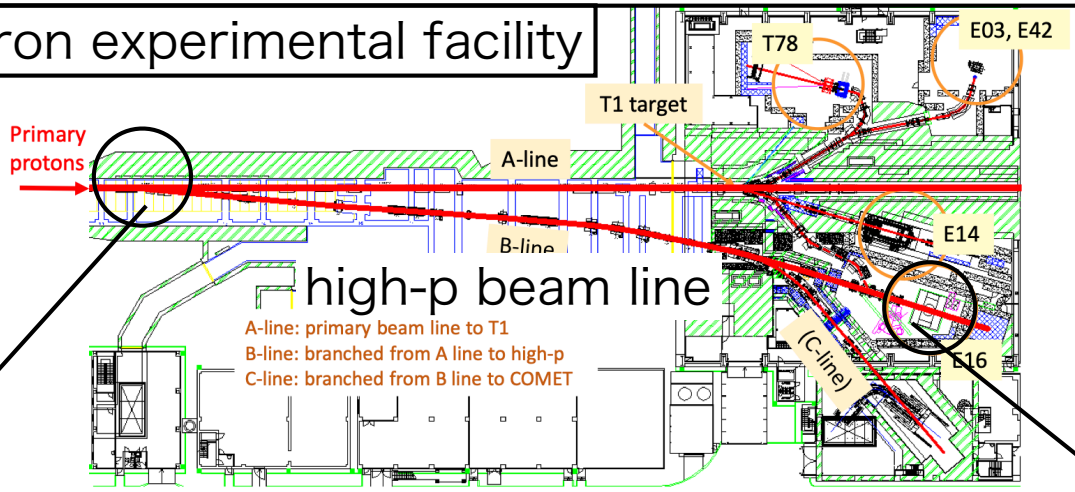
J-PARC E16 experiment

Measurement of vector meson in nuclei

@J-PARC hadron experimental facility, B-line (high-p beam line).

- Started operation in 2020. E16 is the first experiment.
- 30 GeV primary proton, 1.0×10^{10} /spill (2 s)
- Available at the same time as other beam lines

J-PARC hadron experimental facility



Septum magnet

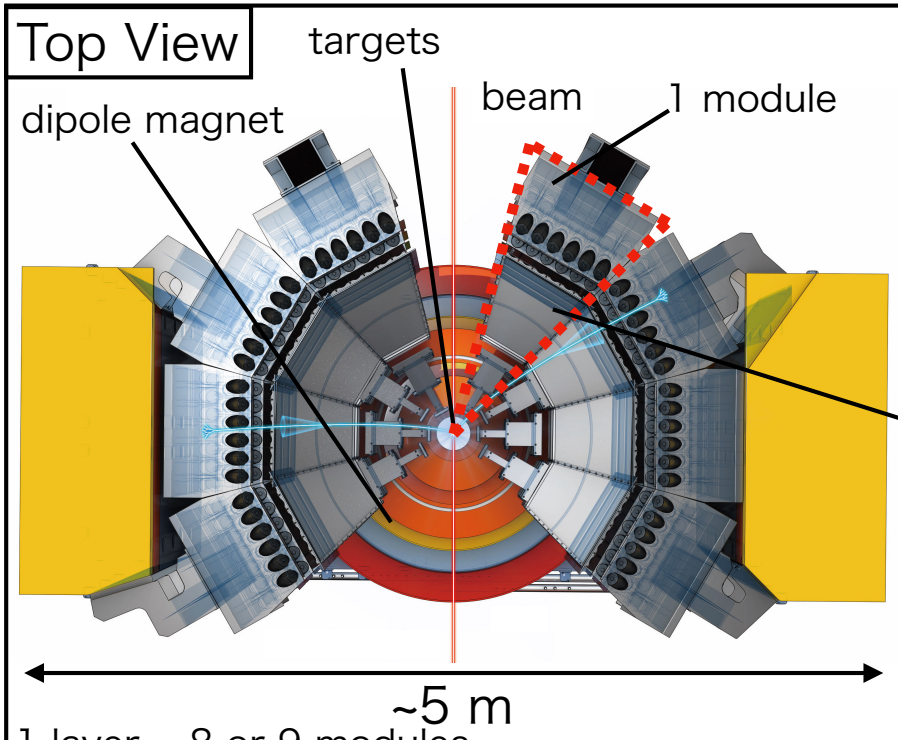
0.02 % are transferred to high-p.

high-p experimental area

- p + (C, Cu, Pb, CH_2) -> (ρ, ω, ϕ) + X
- p + A interaction rate: 10 MHz (10 times higher than KEK E325)
- Measuring vector mesons via e^+e^- decay.
- 100 times higher statistics than KEK E325

Spectrometer

Top View



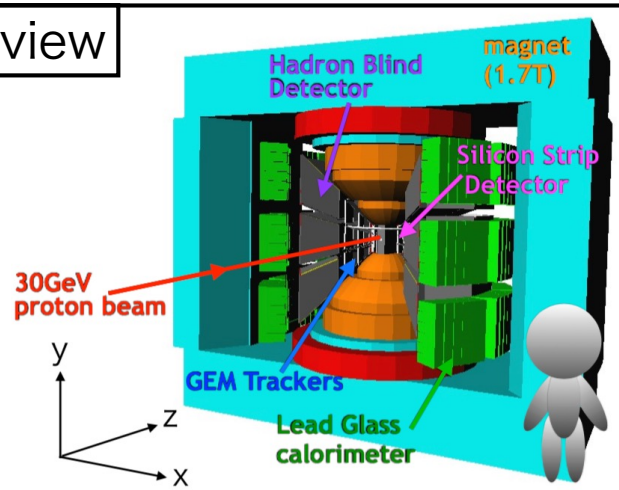
1 layer = 8 or 9 modules

Total (upper, middle, lower): 26 modules

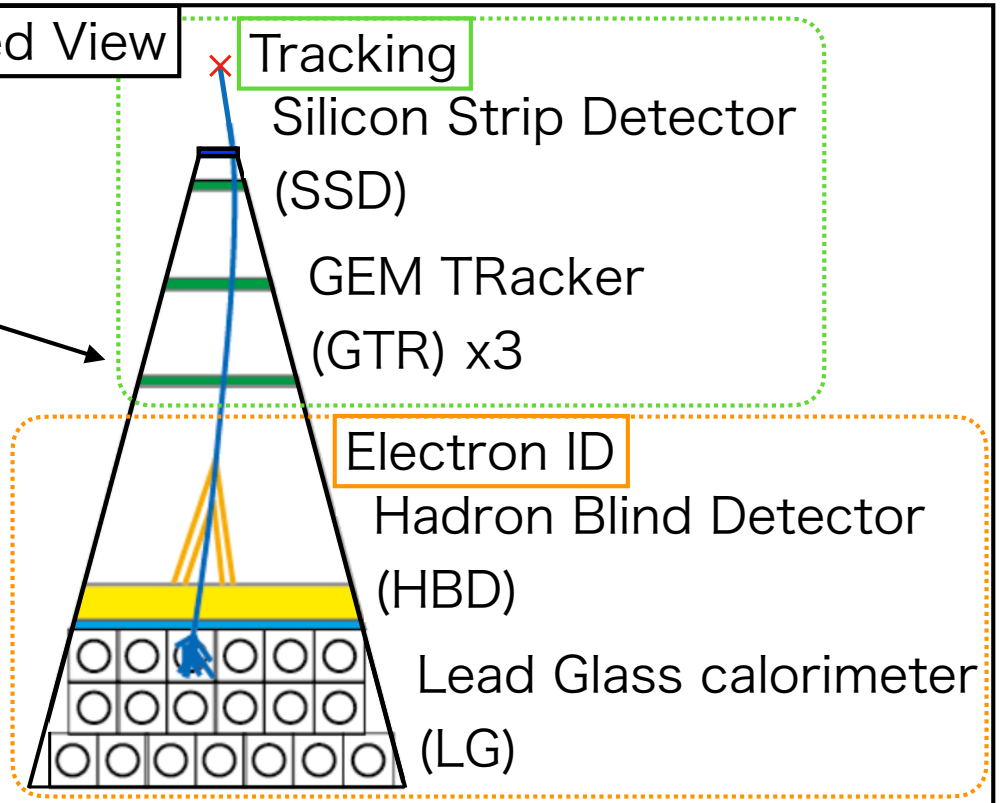
(Except for 1 module on the beam orbit)

Horizontal: ±135°, Vertical: ±45°

Side view



Enlarged View



Number of channels: ~110,000 ch

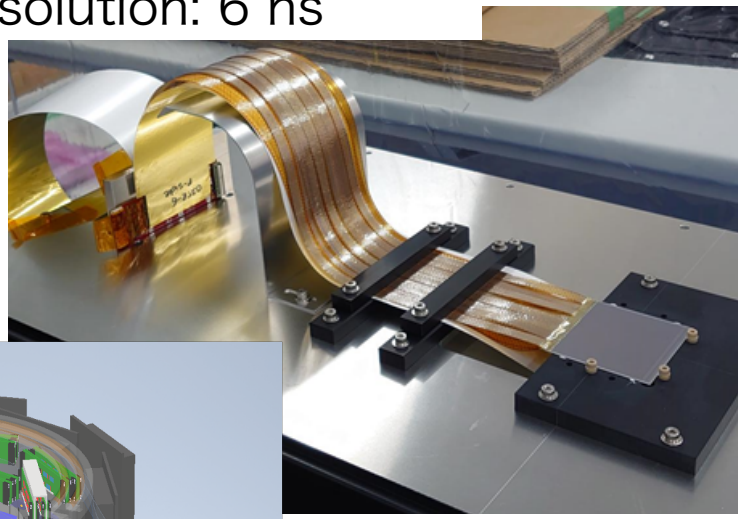
○Design value

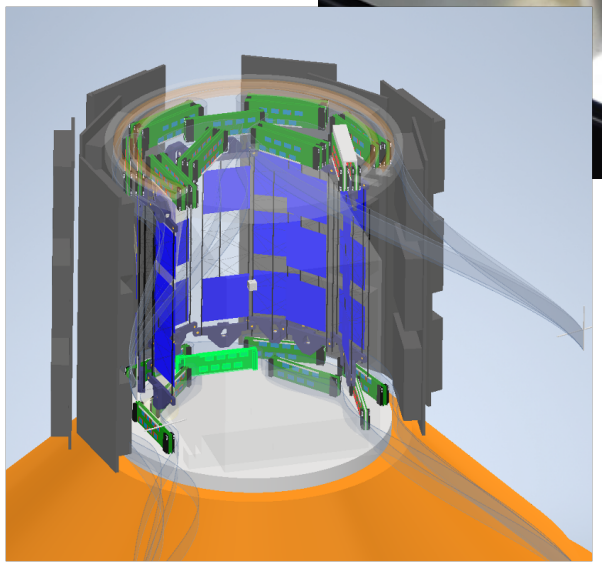
- Mass resolution: 5.8 MeV/c^2 for slow ϕ ($\beta\gamma$ <1.25)
- electron efficiency: 57 %
- π rejection: 99.97 %

Tracking detectors

○Silicon Strip Detector (SSD)

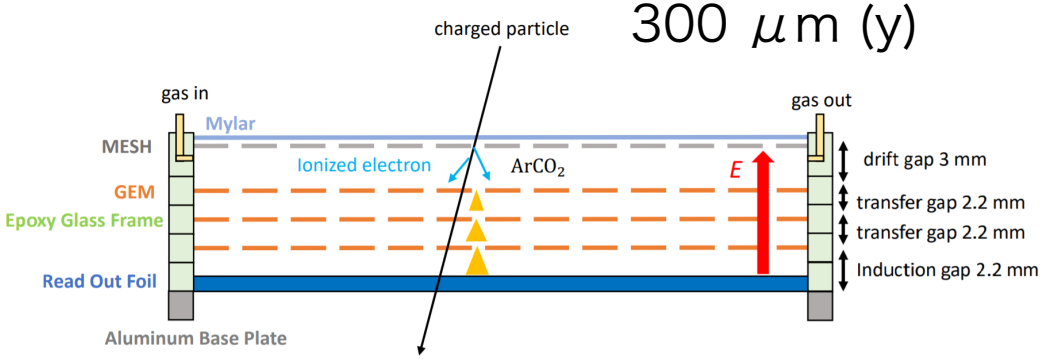
- Developed at GSI/FAIR
- From next beam time.
- Strip configuration: XU
  (stereo angle : 7.5°)
- Size: 60 mm
- Position resolution: 25 μm
- Time resolution: 6 ns

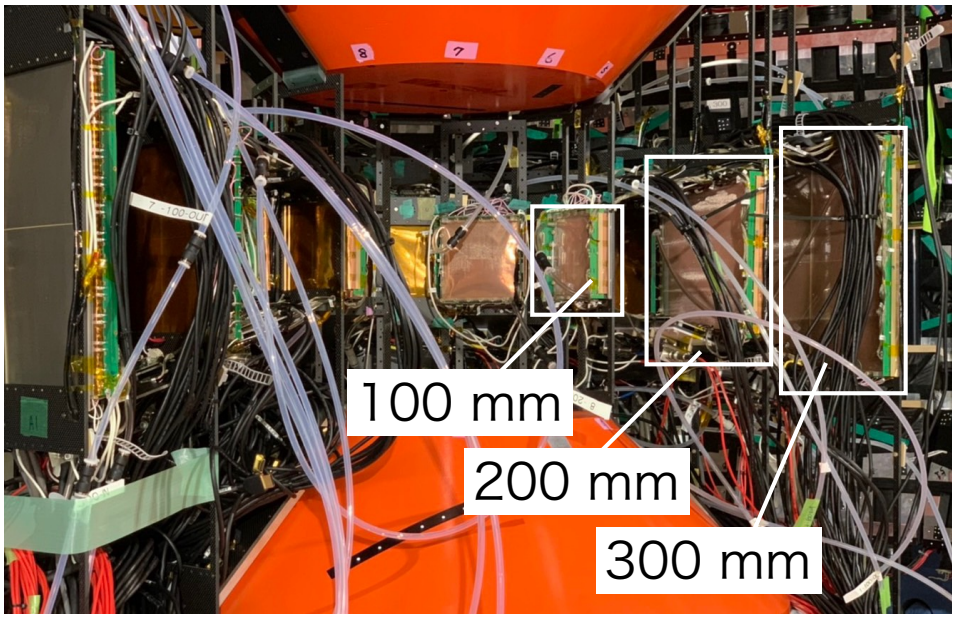




○GEM Tracker (GTR)

- 3 chambers
  with Gas Electron Multiplier (GEM)
- Strip configuration: XY
- Size: 100 / 200 / 300 mm
- Position resolution: 100 μm (x)
  300 μm (y)

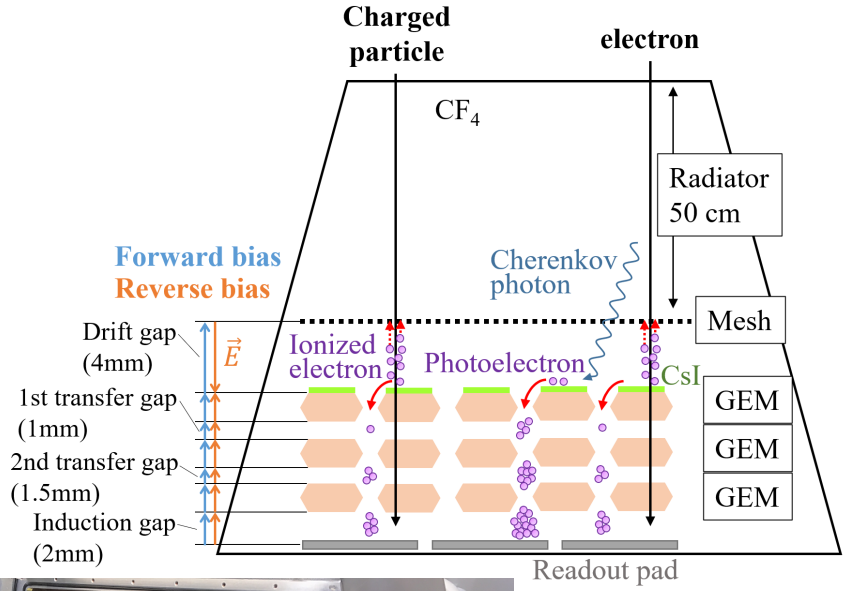


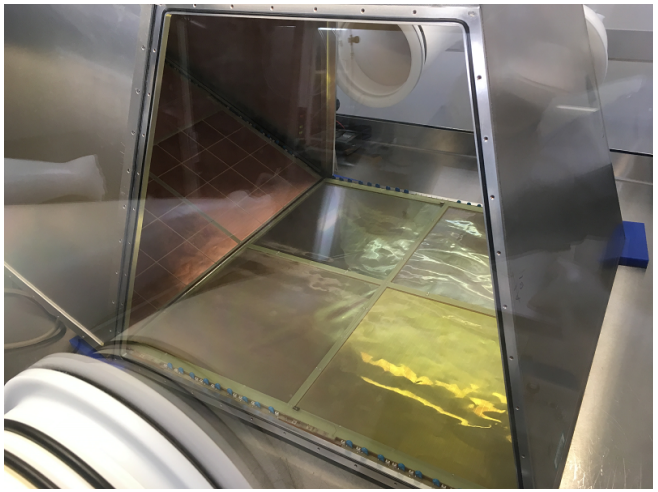


Electron ID counters

○Hadron Blind Detector (HBD)

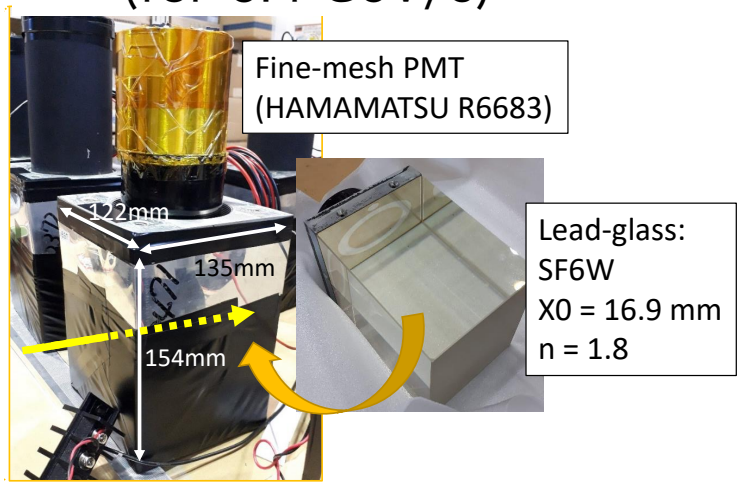
- Gas type Cherenkov detector using GEM
- π rejection: 99.4 % (offline)
- electron efficiency: 63 % (offline)

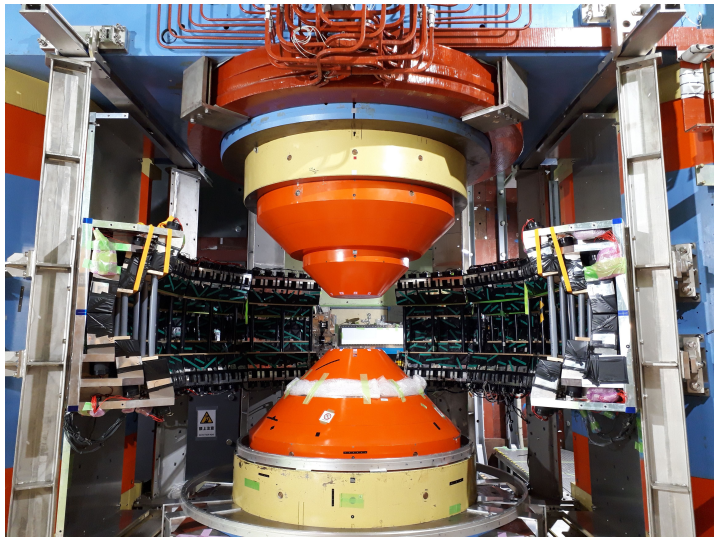




○Lead Glass Calorimeter (LG)

- Used under strong magnetic field (0.5 T)
- π rejection: 95 % (offline)
- electron efficiency: 90 % (offline) (for 0.4 GeV/c)





Trigger system

◯Signal

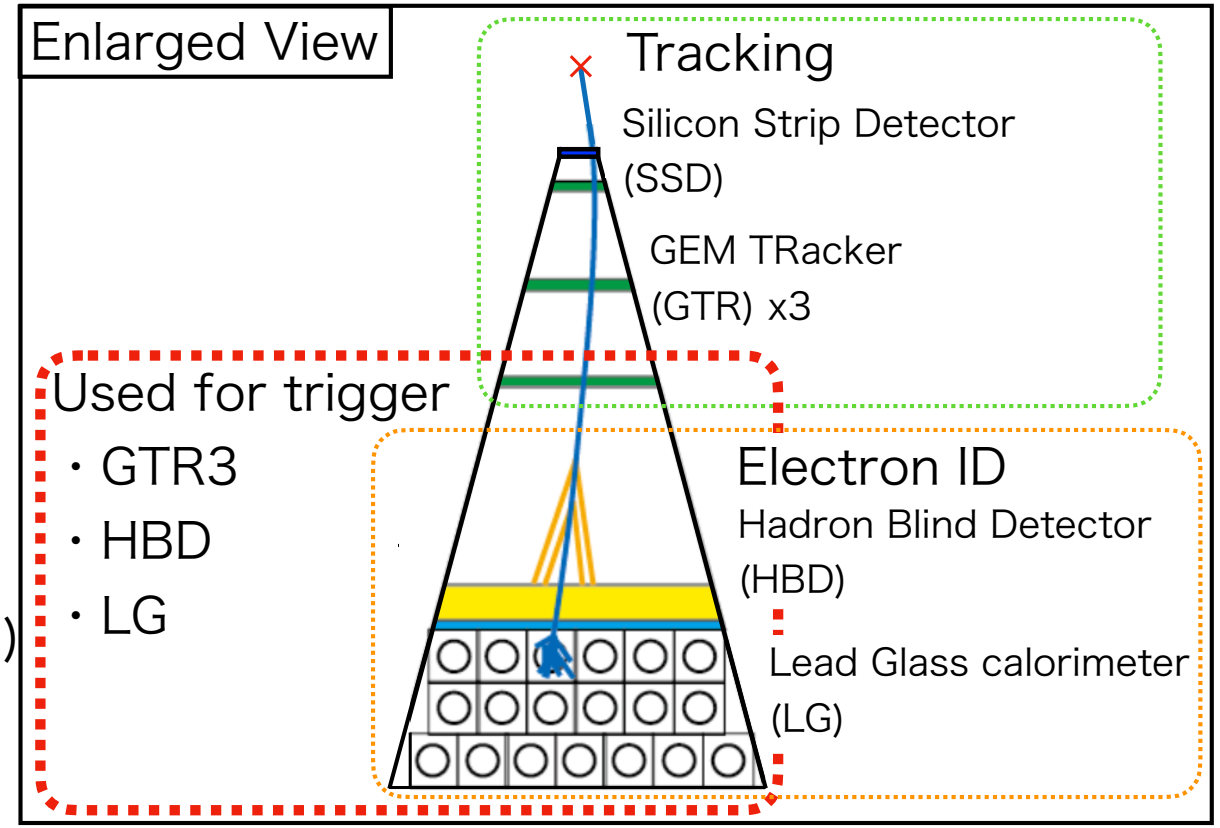
- (ρ, ω, ϕ) -> e^+e^-
  Branching Ratio: 3×10^{-4} (ϕ)

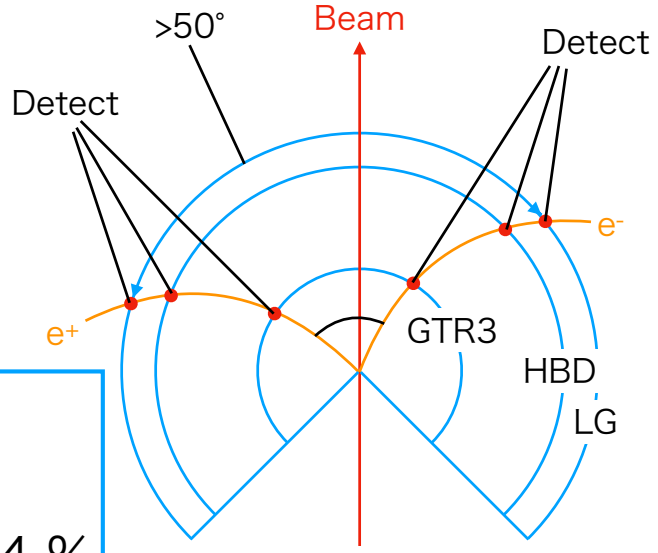
◯Background

- π^0 -> $e^+e^-\gamma$
- π^0 -> 2γ, γ -> e^+e^-
- $\pi^\pm$ miss ID
  (~100 times larger than electron)

◯Trigger Logic

- Require 2 electron candidates
- Candidate is selected
  by GTR3 × HBD × LG
  (~2,600 ch, ~1 MHz/ch)
- Require large opening angle
  for rejecting Dalitz decays.





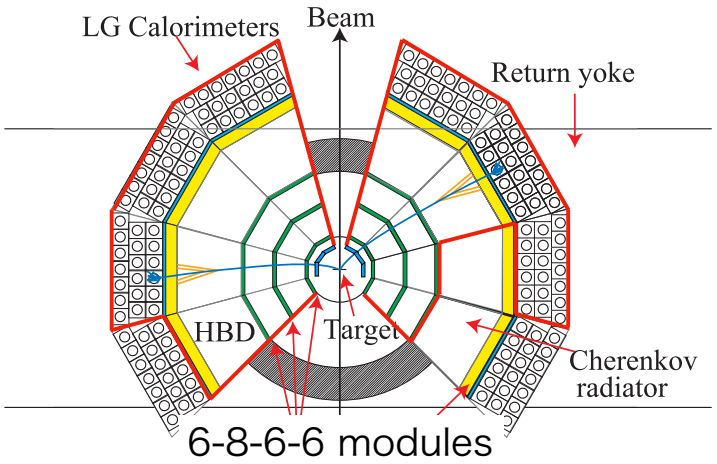
◯Expected value

- Trigger rate: 1 kHz
- ϕ surviving ratio: 74 %

Staging strategy

○Run0 (Jun. 2020, Feb. 2021, Jun. 2021)

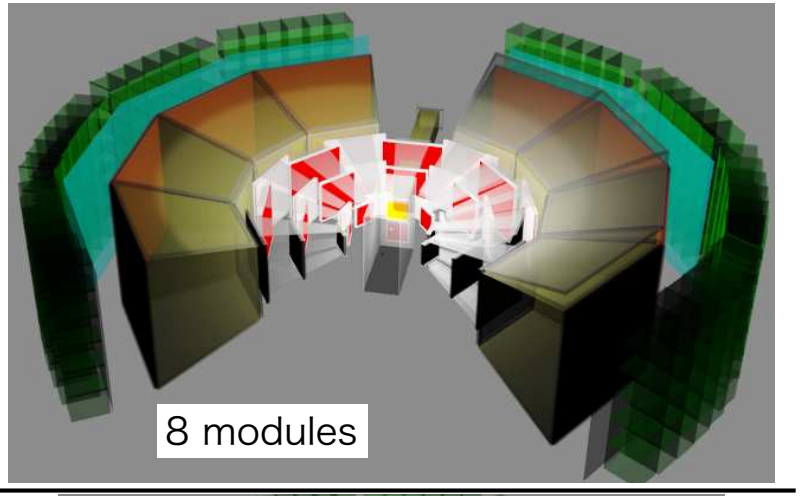
- Beam line and detectors commissioning
- Finished
- C, Cu targets
- 403 hours



○Run1 (Planned in the beginning of 2023)

- First physics run
- C, Cu targets
- 15k ϕ mesons (E325 × 6)
- 1,280 hours

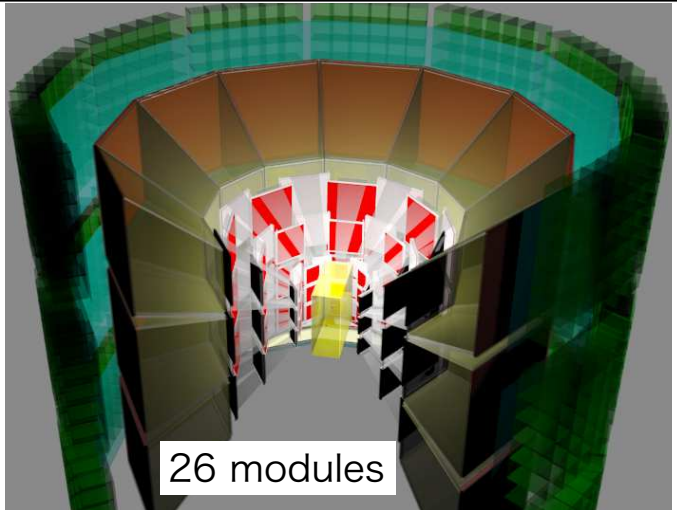
(・Approval by PAC is required.)



○Run2 (Planned in 2024 or later)

- Main physics run
- C, Cu, Pb, CH_2 targets
- 2,560 hours

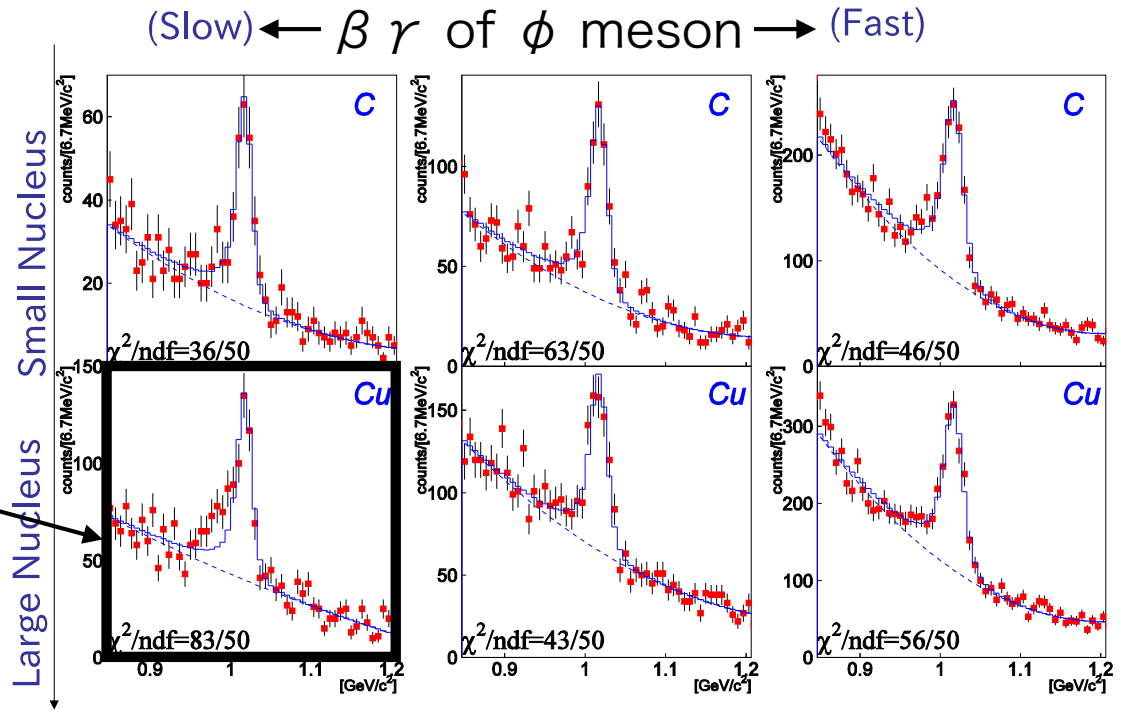
Run0 was finished in June 2021.
Run1 is planned to start in 2023.



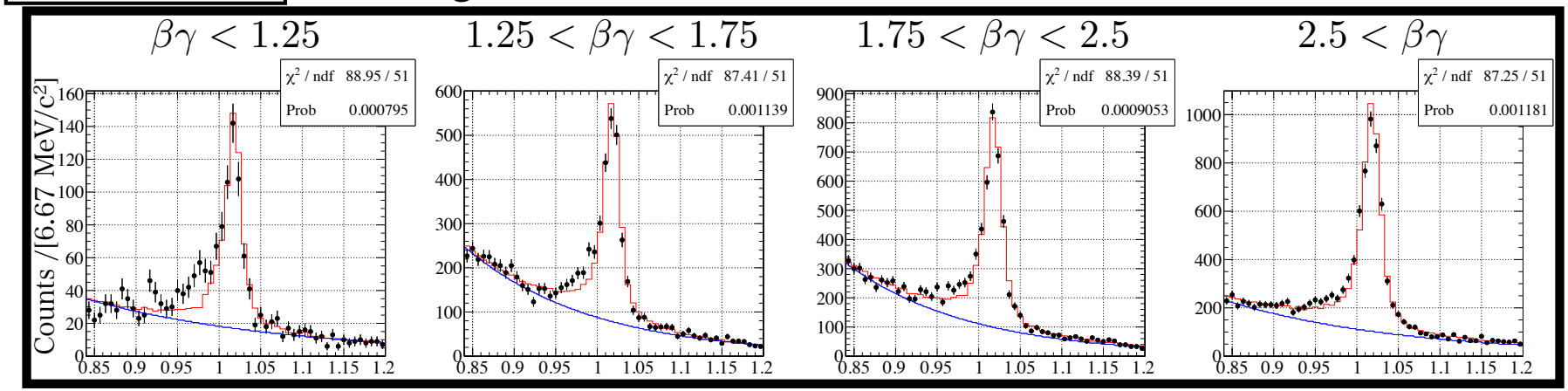
Expected result: $\beta\gamma$ dependence

KEK-PS E325

Spectral modification was only seen
in the single spectrum
with the largest proportion
of ϕ mesons decaying in nuclei.



J-PARC E16 Cu target



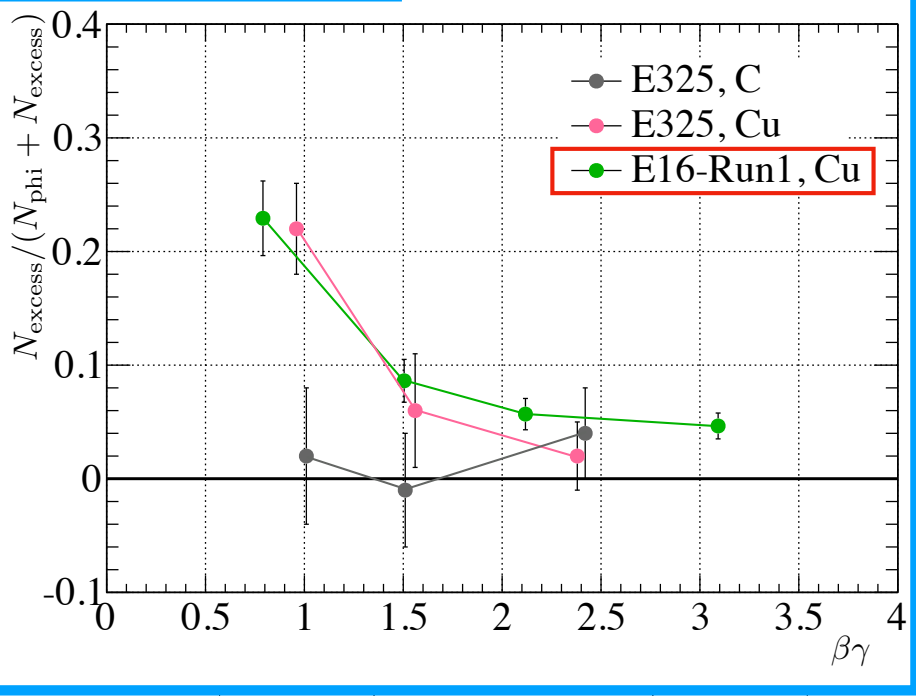
Spectral modification will be observed in all $\beta\gamma$ regions
because of large statistics and better resolution.

Expected result: $\beta\gamma$ dependence

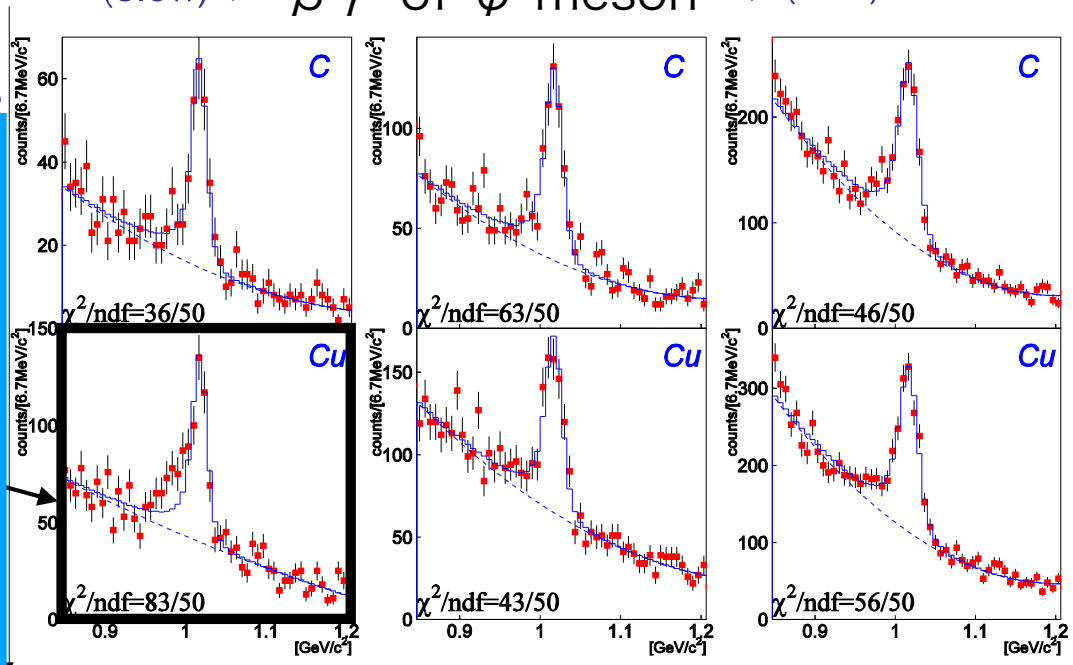
KEK-PS E325

Spectral modification was only seen in wi… of …

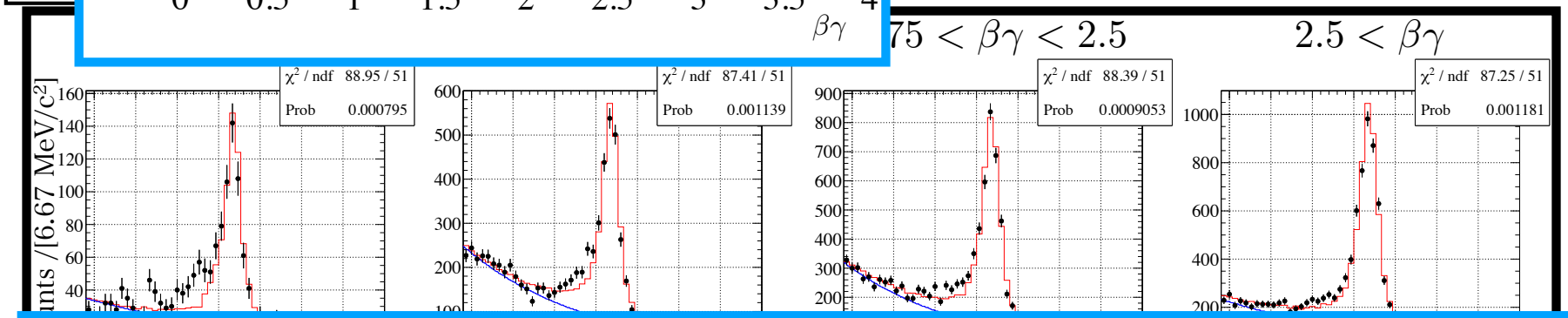
Ratio of excess



(Slow) ← $\beta\gamma$ of ϕ meson → (Fast)

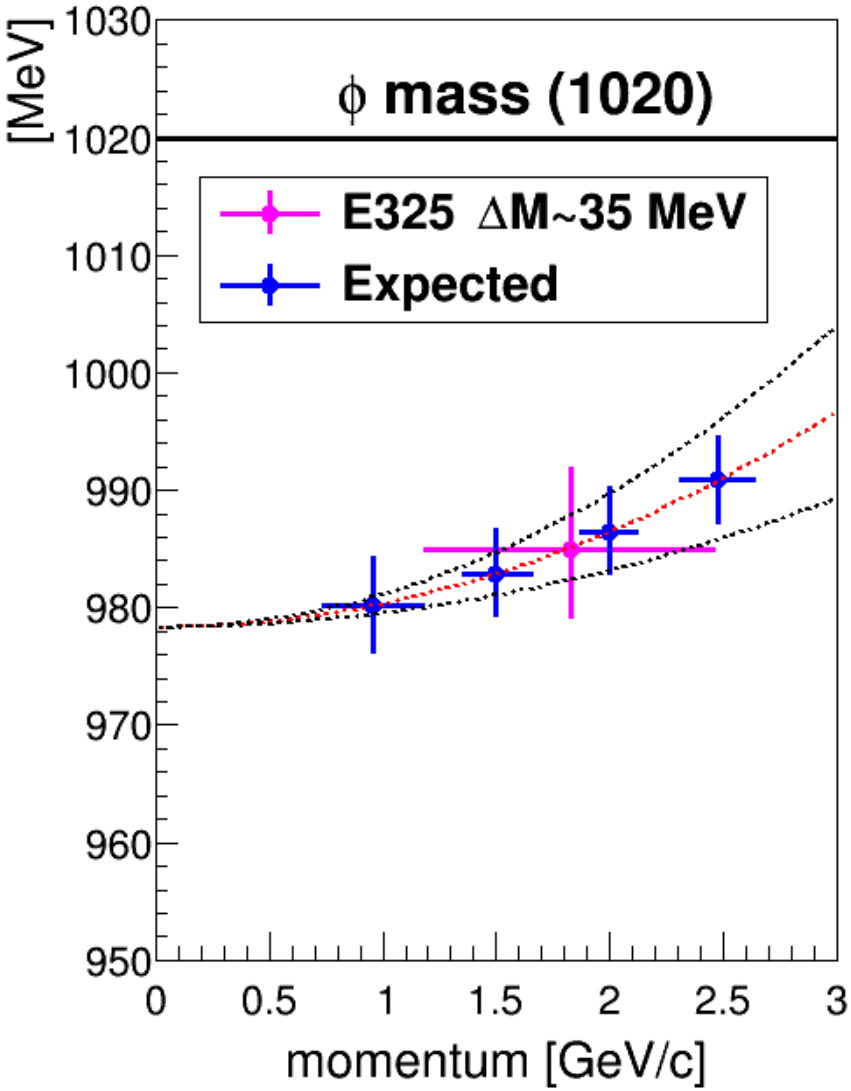


J-P…



By studying the $\beta\gamma$ and target dependences of the modification probability, the existence of the relation between spectral modification and decaying in nuclei will be established.

Expected result: Dispersion relation



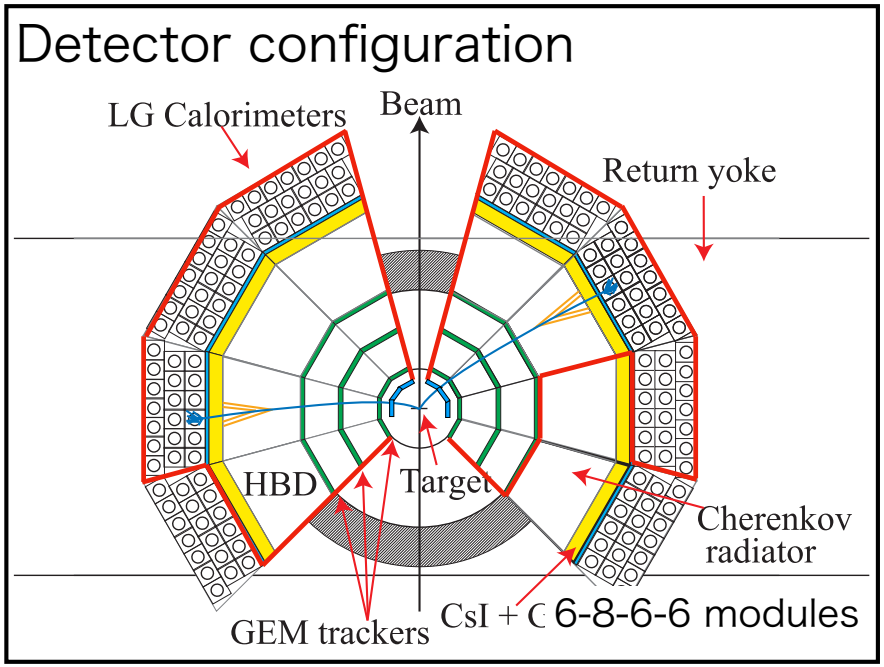
※10 times larger statistics than KEK E325

Curve: Lee's prediction (Phys. Rev. C 57 927 (1998))

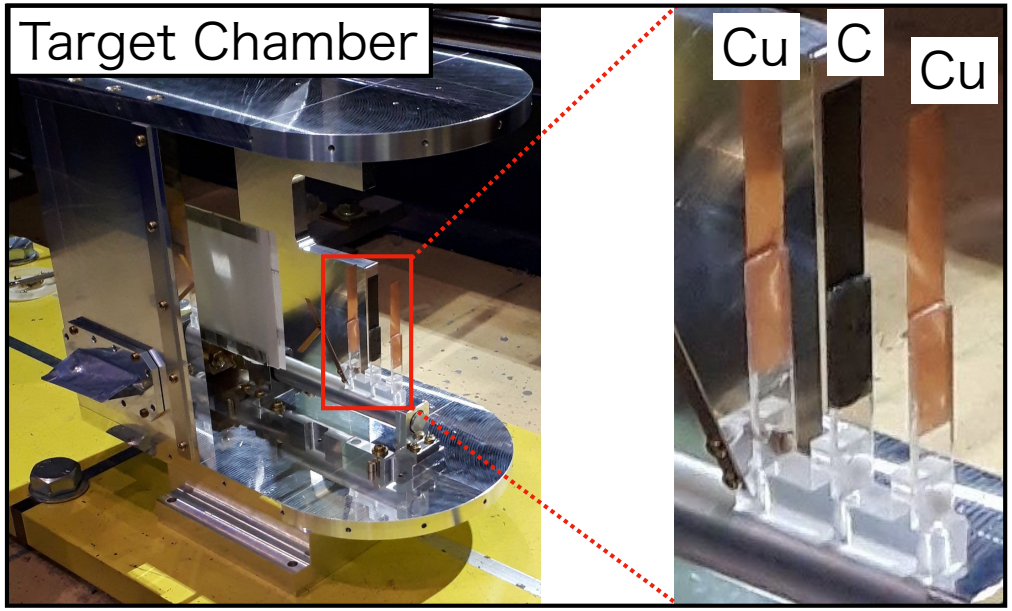
In-medium dispersion relation in QCD will be observed for the first time.

Commissioning run

- Carried out in Jun. 2020, Feb. 2021, Jun. 2021
- Beam time: 403 hours
- Beam intensity: 1.0×10^{8} - 1.2×10^{10} /spill
- Target: Cu - C - Cu (From upstream)
  C : 400 μm (0.1 % interaction, 0.2 % X_0)
  Cu: 80 μm (0.05 % interaction, 0.5 % X_0)

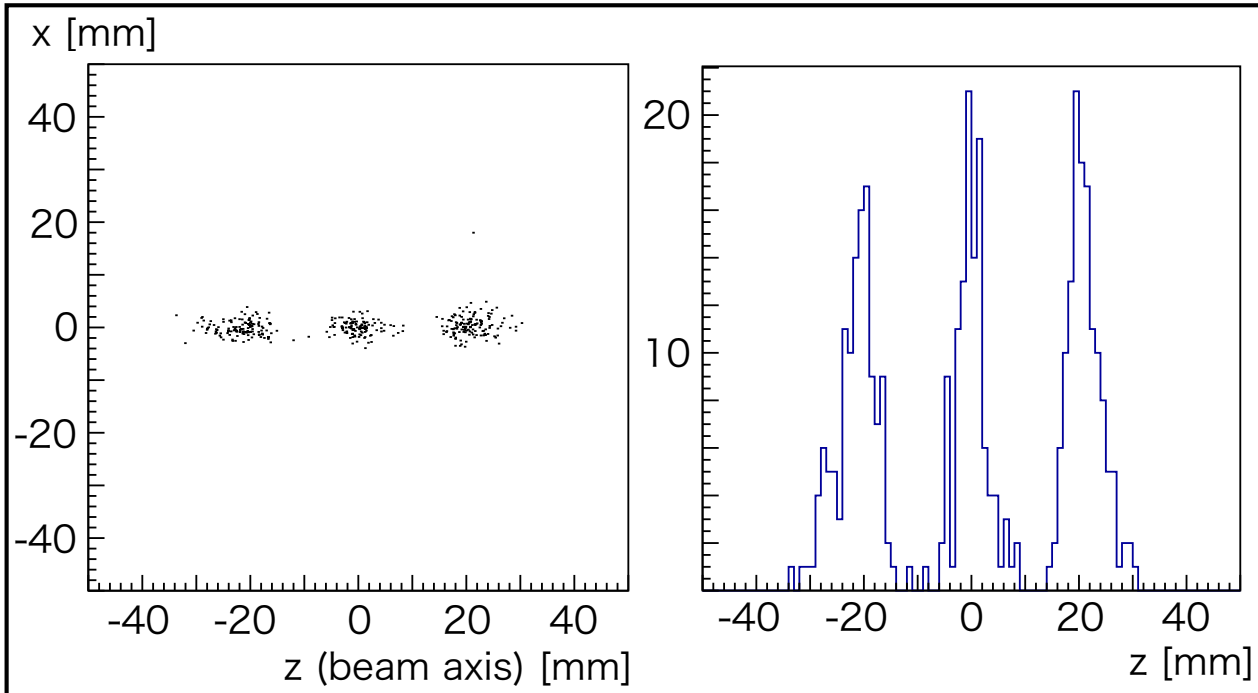


- Started up of beam line and detectors
- Acquired data for
  - Detector study
  - Trigger study
  - Yield study

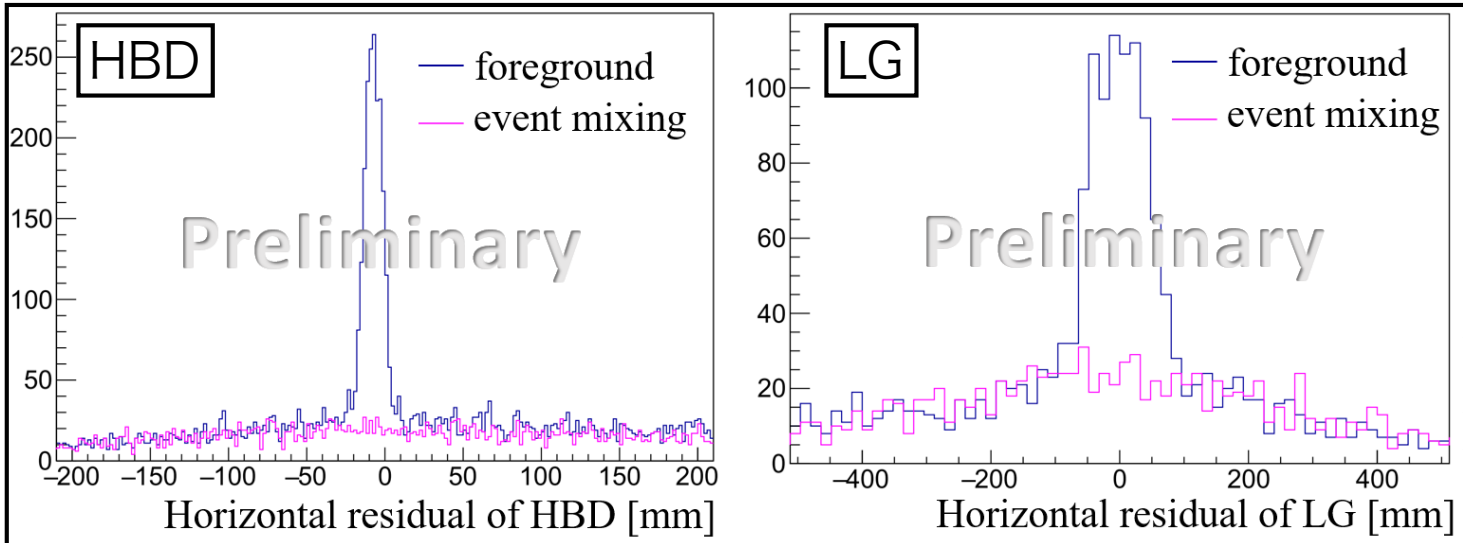


- Unexpected micro time structure of beam was found.
  - DAQ performance was deteriorated: live time 75 % -> 15 %
  - It will be improved in the next beam time by upgrade of power supply of accelerator magnets and beam line optics.

Performance of tracking detectors



- Vertex distribution reconstructed by 2 tracks
- 3 targets (-20, 0, 20 mm) are clearly seen.

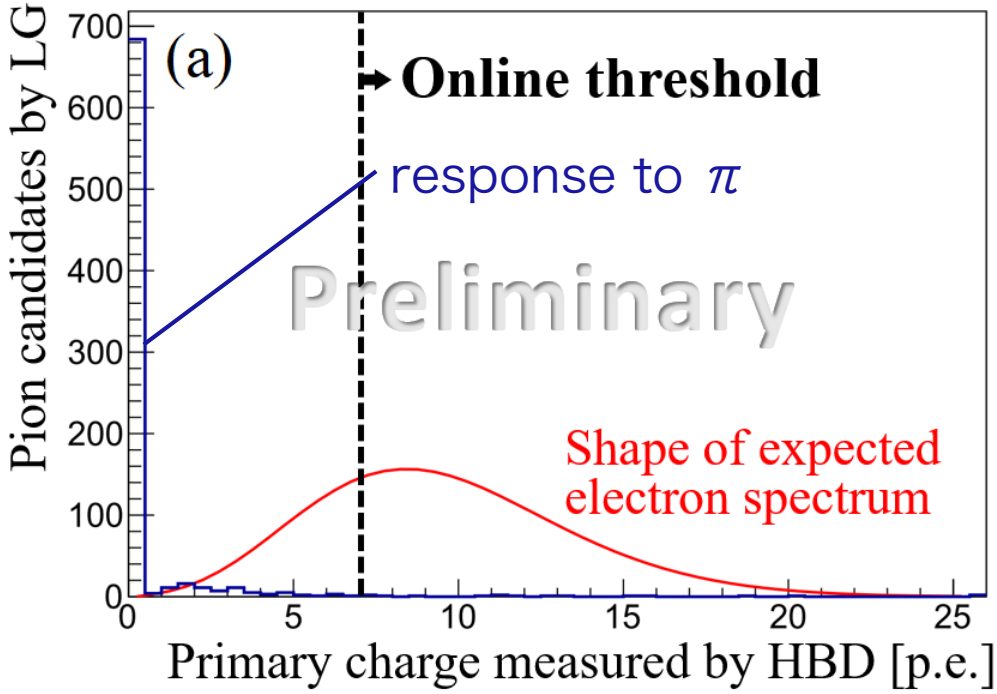


HBD pad pitch: 15.4 mm
LG block pitch: 124 mm

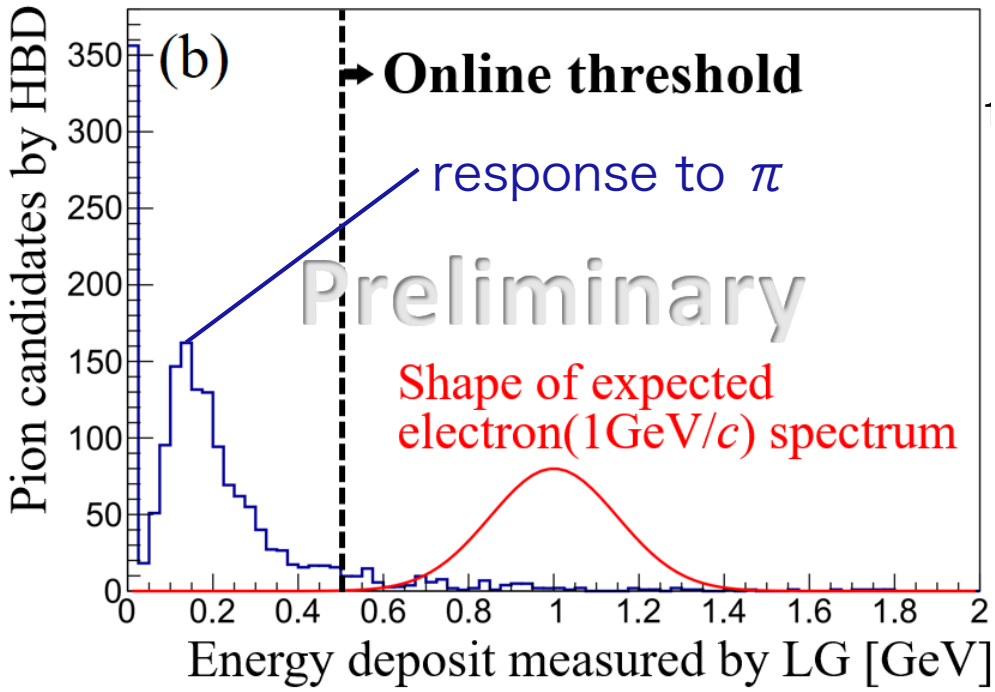
- Residual between HBD or LG hit and track projection
- Reconstructed tracks match well with eID counters.

Performance of online π rejection

HBD responce to π



LG responce to π



HBD π rejection for trigger

・Achieved : 97.6 ± 0.6 %

・Design Value: 98 %

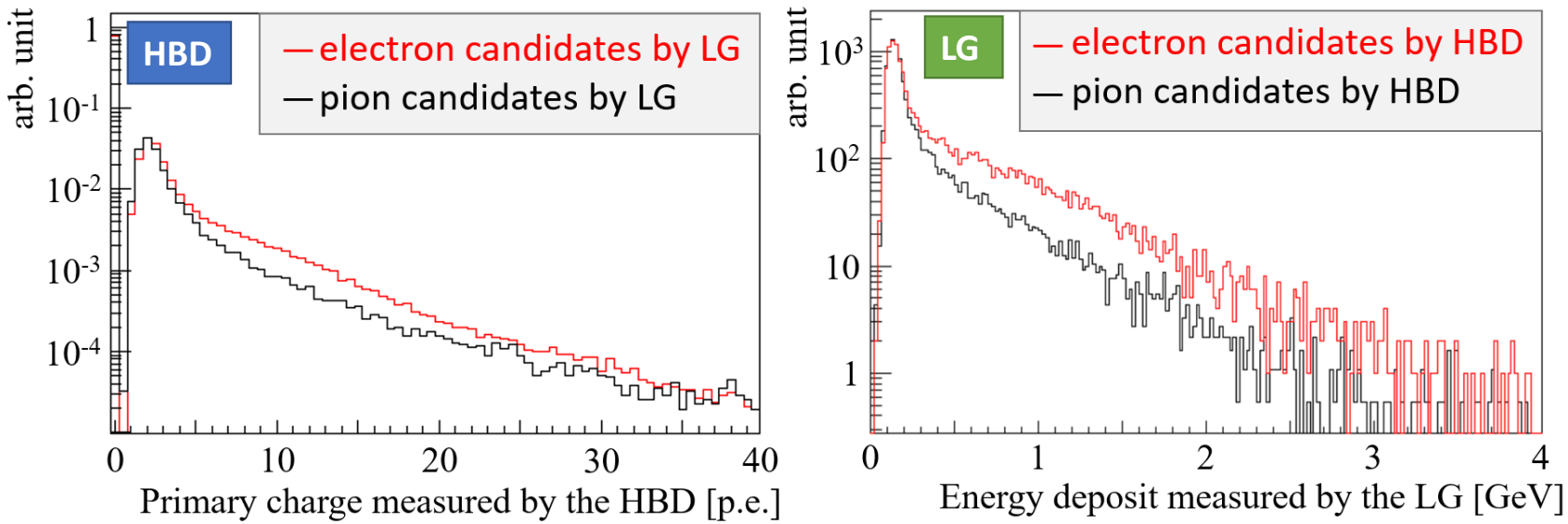
LG π rejection for trigger

・Achieved : 91.2 ± 0.7 %

(・Design Value: 90 %)

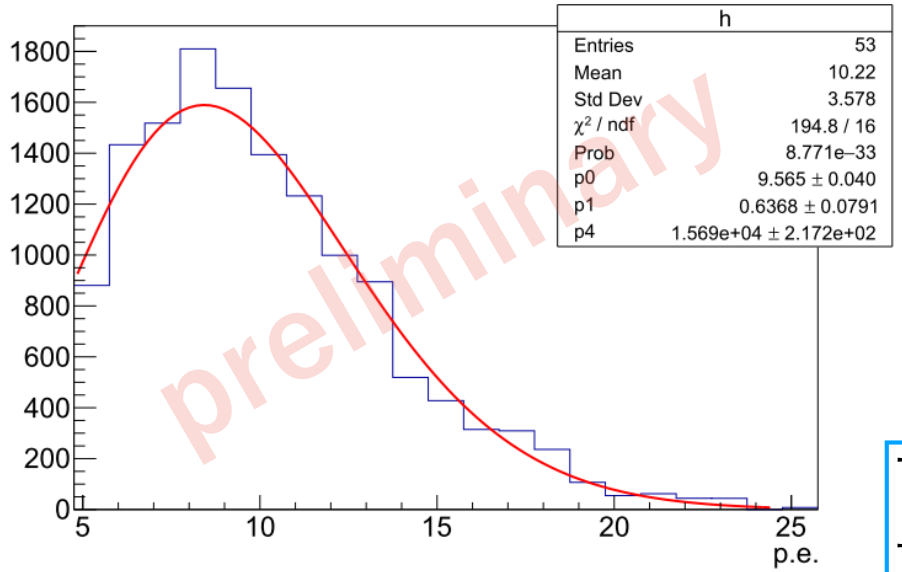
Both HBD and LG signal for pions were suppressed.
The performance is consistent with the design.

Performance of electron detection



Both the detectors show the electron enhancement.

Response of HBD to electrons



—: Data

—: Fit (Poisson distribution convoluted with a Polya distribution)

Response of HBD to electrons is consistent with expectation.

- Achieved : 10 ± 2 p.e.
- Design Value: 11 p.e.

The performance of HBD and LG is enough to separate electrons from pions.

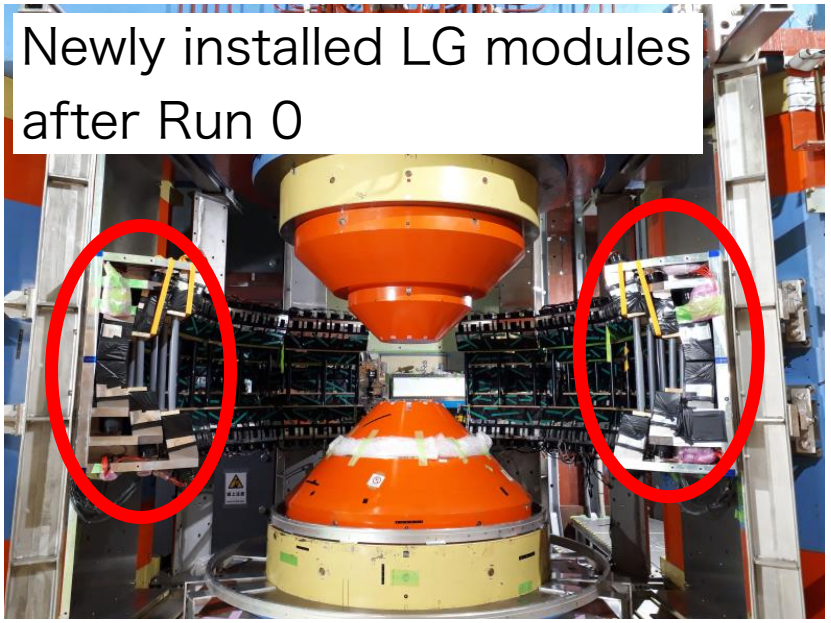
Summary

○J-PARC E16 experiment

- Measurement of vector meson in nuclei.
- J-PARC high-p beam line established in 2020

○Commissioning run

- Carried out in 06/2020, 02/2021, 06/2021
- Max beam intensity: 1.2×10^{10} /spill
- Acquired pilot data
- Unexpected beam micro structure was found.
  -> Improvement is expected.



○Analysis

- Tracking, π rejection and electron ID worked well.
- Improvement of tracking is still ongoing.

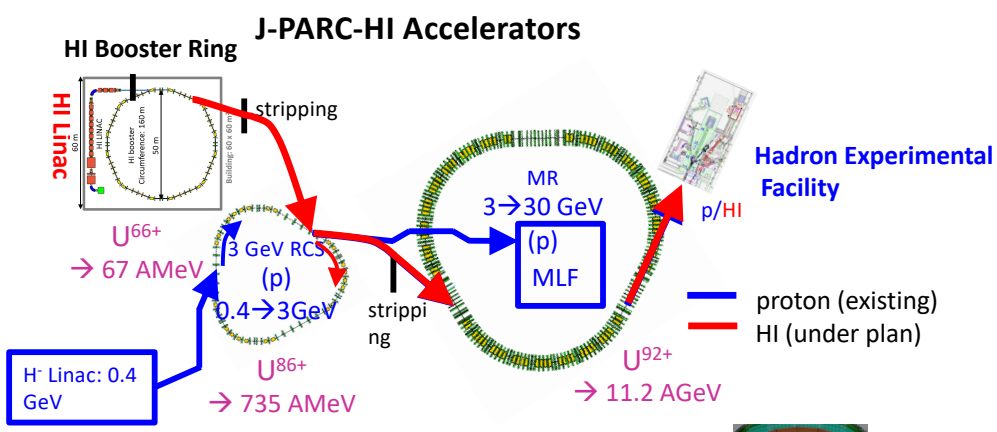
○For the Run1

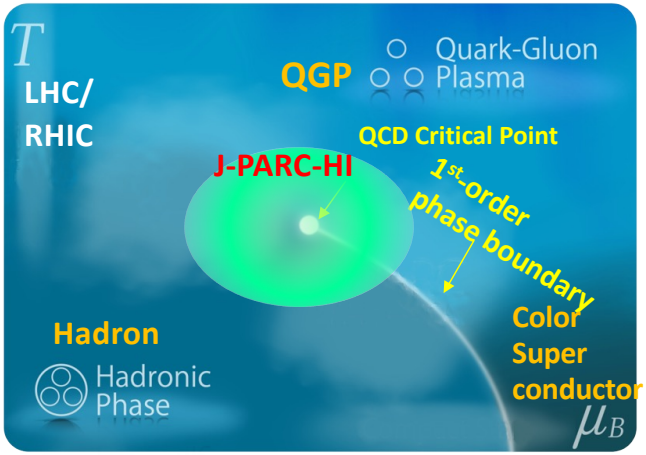
- Planned in 2023
- New detector modules are under construction.
- 8 modules will be operated. 15k ϕ mesons will be obtained.

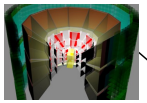
J-PARC Heavy-Ion Project

J-PARC-HI (J-PARC Heavy-Ion Project)

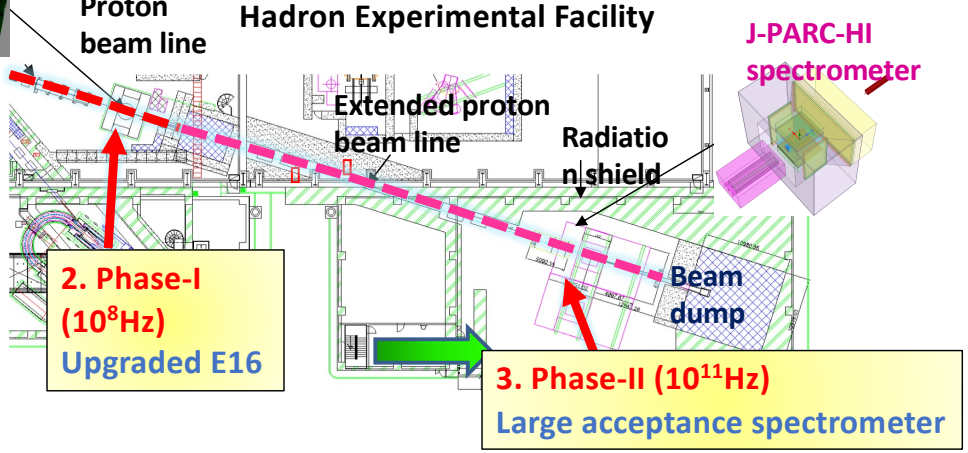
Poster: Apr. 8, 3T 15-1







E16 spectrometer



- Explore QCD phase diagram at high density regime
- Studies of multi-strangeness system
- HI beam rate ~10^{11} Hz
- $\sqrt{s_{NN}}$ (U) = 1.9-4.9 GeV

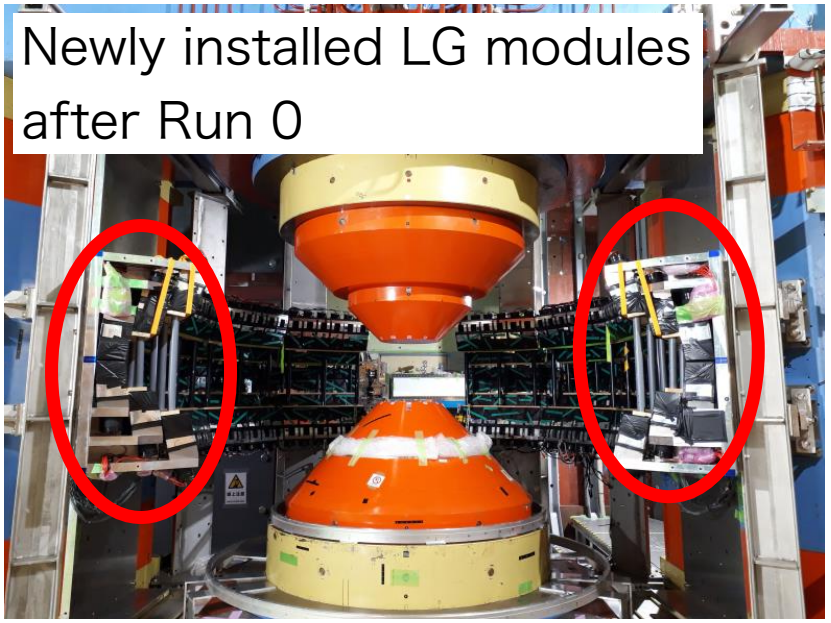
○Related posters (Poster session 3, 4/8 14:00-15:00)

- T15_1 (#324): Studying high-density baryonic matter at J-PARC Heavy-Ion Project (H. Sako)
- T15_2 (#785): A new experiment of di-electron measurement at the 1st stage of J-PARC Heavy-Ion Project (Y. Morino)
- T11_1 (#325): Study of ϕ mass modification with K^+K^- decay in p+A collisions at J-PARC (S. Sato)

Summary

○J-PARC E16 experiment
- Measurement of vector meson in nuclei
- J-PARC high-p beam line established in 2020

○Commissioning run
- Carried out in 06/2020, 02/2021, 06/2021
- Max beam intensity: 1.2 × 10^{10} /spill
- Acquired pilot data
- Unexpected beam micro structure was found.
  -> Improvement is expected.



○Analysis
- Tracking, π rejection and electron ID worked well.
- Improvement of tracking is still ongoing.

○Posters about J-PARC HI Project
(4/8 14:00-15:00)
- T15_1: J-PARC HI Project (H. Sako)
- T15_2: 1st stage of J-PARC HI (Y. Morino)
- T11_1: ϕ->K^+K^- @high-p (S. Sato)

○For the Run1
- Planned in 2023
- New detector modules are under construction.
- 8 modules will be operated. 15k ϕ mesons will be obtained.