Experimental study of chiral properties in a finite density medium at J-PARC

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Introduction
E16 experiment at J-PARC
Possible upgrades of E16
Status of E16
Summary

Study of Quark and Hadron Phases

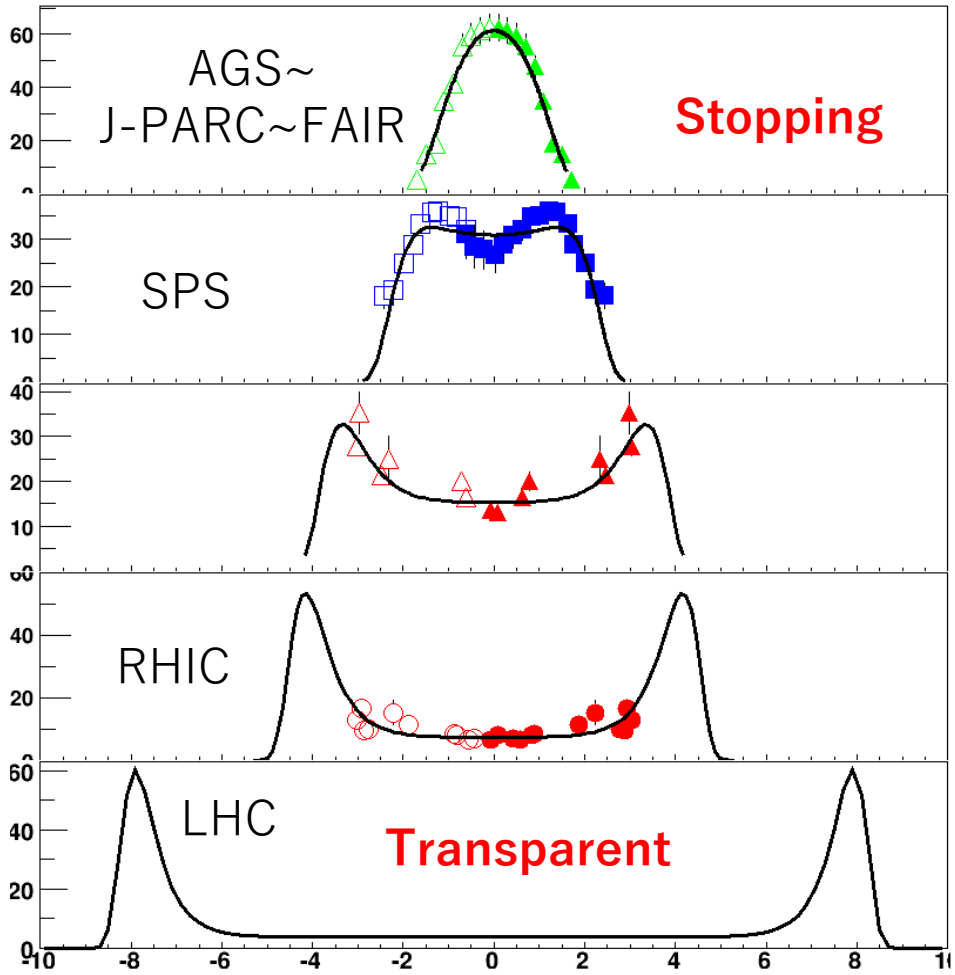
- At RHIC and LHC,
  - Generation and study of a quark phase
  - Understandings using hydrodynamics
  - Characteristics properties of parton energy loss

- Still, we need further studies
  - Quark correlations and condensates in a medium
  - Study of interactions with strange and heavy quarks and generations of exotic hadrons

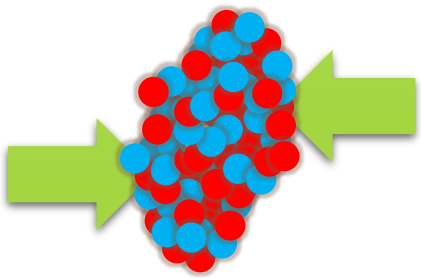
- New Goal:
  - Study of Cold Quark Matter in a high-density medium

Heavy Ion collisions at J-PARC

S. Esumi, QM06

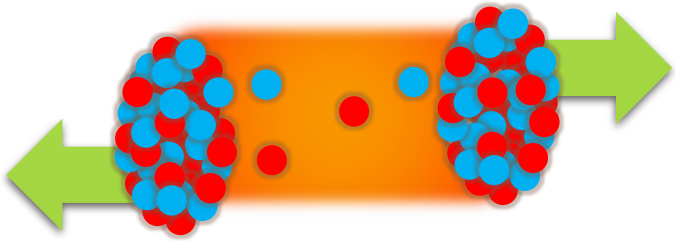


Net-Proton as a function of rapidity



J-PARC energy is suitable to generate a high-density medium

Heavy ion acc. and experiments are proposed at J-PARC



Figures by M. Kitazawa

Even in proton-nucleus collisions

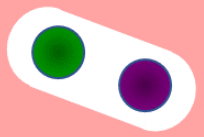
- Nucleus as a finite density matter
  - Quark condensates in nucleus
    - Main purpose of J-PARC E16 experiment
  - Precursory phenomenon of high-density matter?
    - Hadron-quark cross over
      - T. Schaefer, F. Wilczek, PRL 82, 3956
      - N. Yamamoto, M. Tachibana, T. Hatsuda, G. Baym, PRL97, 122001, and PRD76, 074001
      - T. Hatsuda, M. Tachibana, N. Yamamoto, PRD78, 011501
    - Lepton production and a color super conductivity
      - M. Kitazawa, JPS 2019 Fall presentation
      - T. Kunihiro, M. Kitazawa, Y. Nemoto, arXiv:0711.4429

- Reference measurements for Heavy Ion collisions
  - Missing measurements at AGS
    - Di-lepton
    - Higher order correlations
    - Event-by-event fluctuations

J-APRC E16: Quark condensate in a finite density medium

Vacuum

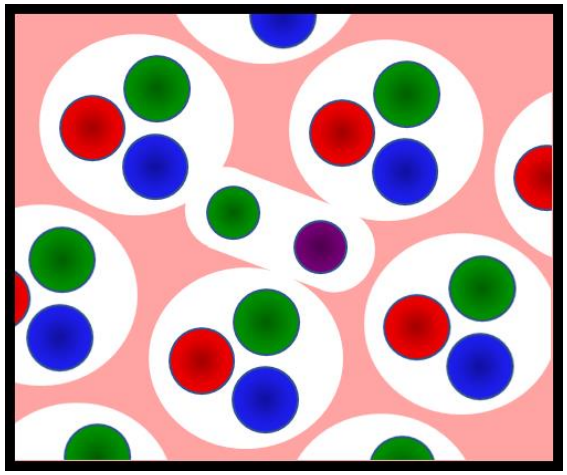
Quark Condensates



ϕ meson:
which contains quark and anti-quark

Change of quark condensates and modifications of mass spectrum

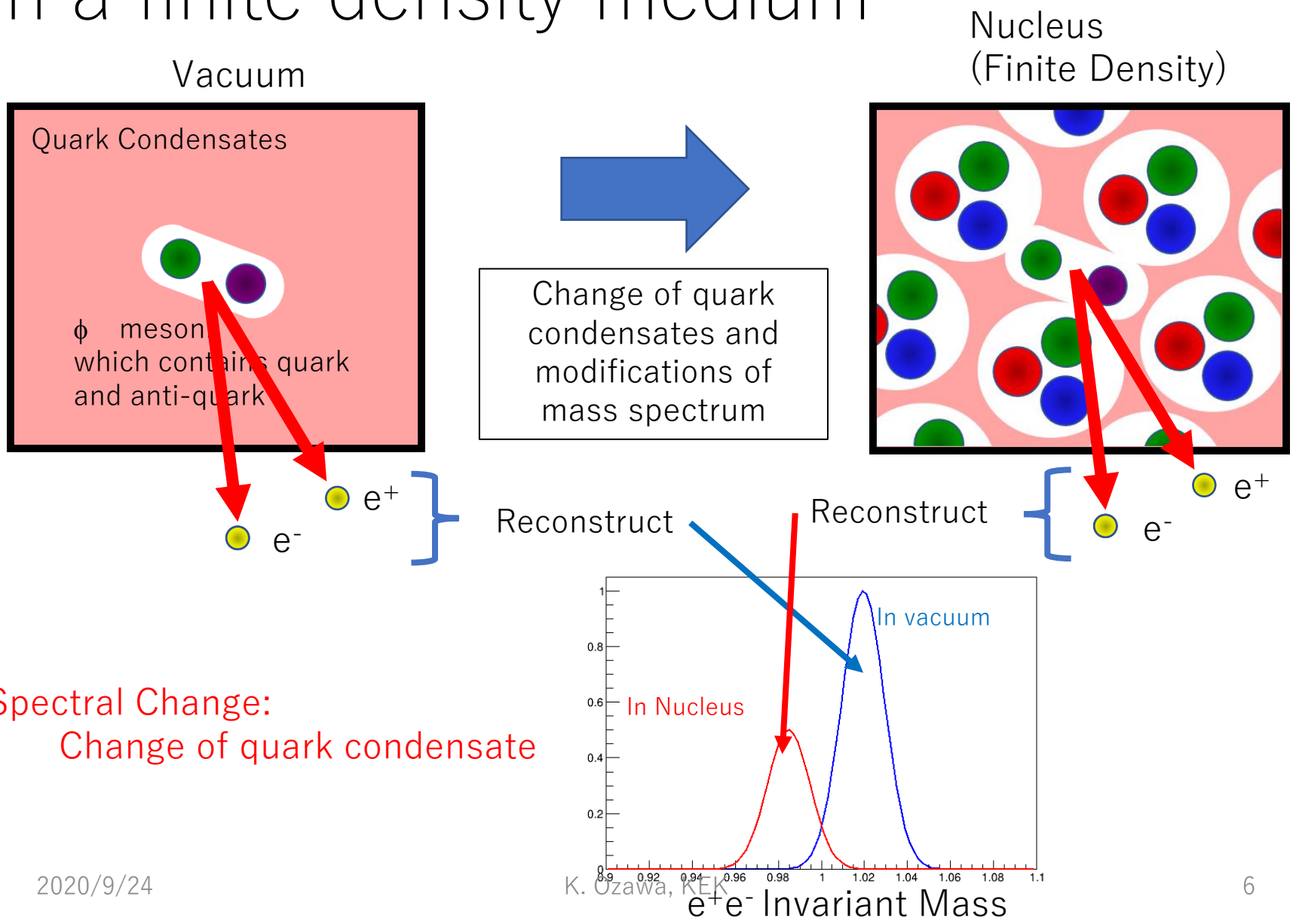
Nucleus
(Finite Density)



As a physics view,

Hadrons can be understood as excitation states from “QCD vacuum”
Amount of mass modifications corresponds to
amount of restoration of the symmetry and
amount of quark condensate

J-APRC E16: Quark condensate in a finite density medium



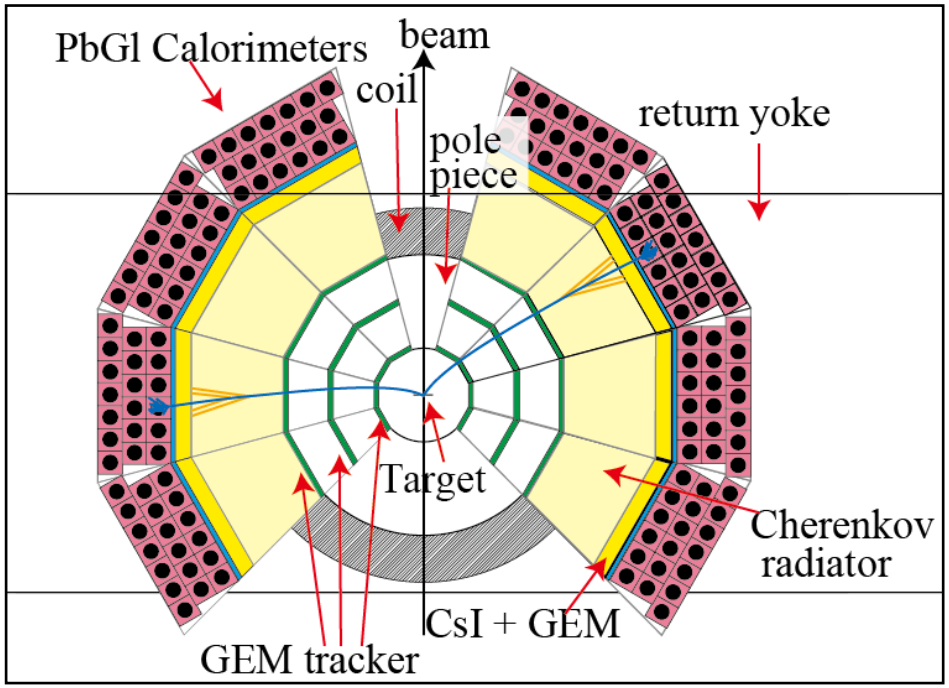
Spectral Change:
Change of quark condensate

J-PARC E16

- Measurements of vector meson mass spectra in nucleus
  - Mass spectra of vector mesons are reflected amounts of quark condensate in a medium
  - Use **p + A → ρ/ω/ϕ → e+e-**
  - Di-electron mass spectra are obtained

- Features of the experiment
  - High Intensity beam
    - High rate capability
  - Large acceptance

High Statistics



Possible upgrades for further study

- Nucleus as a finite density matter
  - Quark condensates in nucleus
    - Currently, we focus on ϕ meson
    - Trigger system upgrades for ρ/ω mesons with higher statistics
    - Low momentum proton detectors for collision geometry determination – Density dependence
  - Precursory phenomenon of high-density matter?
    - Additional detectors for low-mass regions in e^+e^- invariant mass spectra
    - Trigger-less high-statistics DAQ
- Reference measurements for Heavy Ion collisions
  - Higher order correlations
  - Event-by-event fluctuations
    - Additional detectors in the forward region
    - Hadron Identification

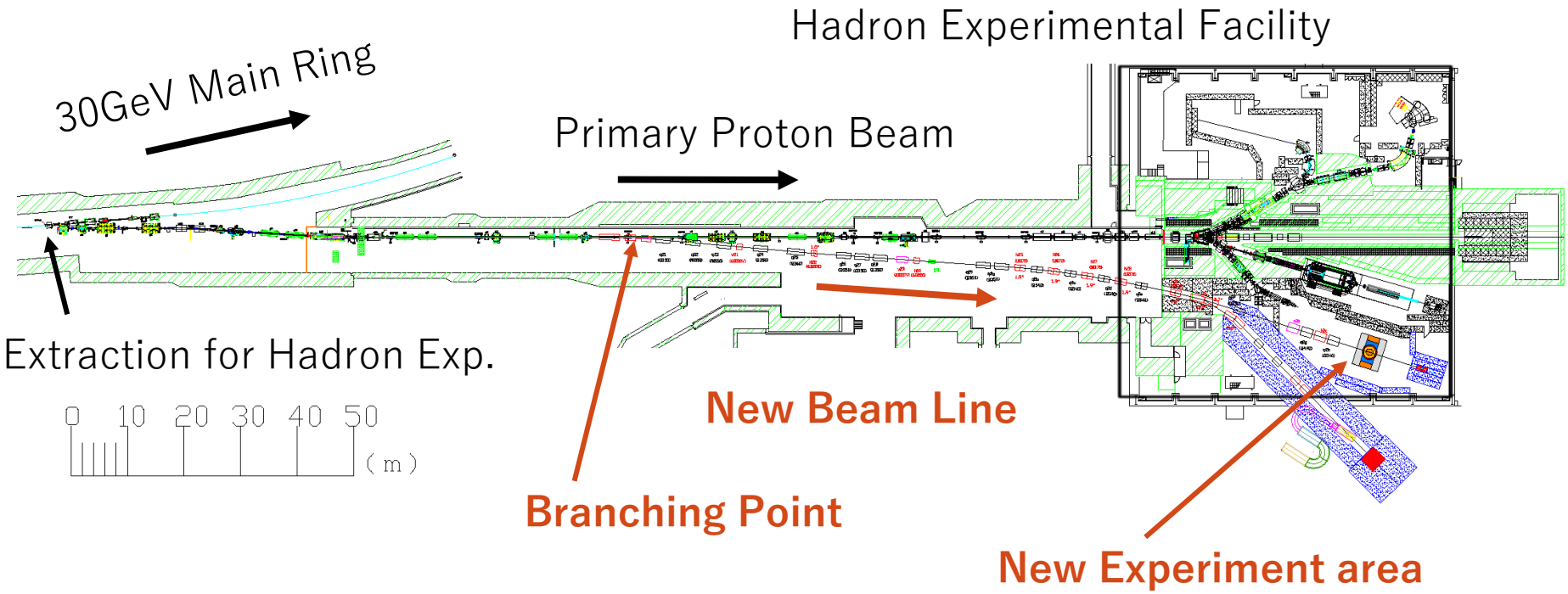
Status of E16

- The First User Beam Time from Jun 4 to Jun 21
  - Beam tuning starts on May 24
- Data acquisitions are done with several beam, detector, and trigger conditions
  - For Calibrations, test, adjustments
  - Beam intensity, FM magnet field, beam positions

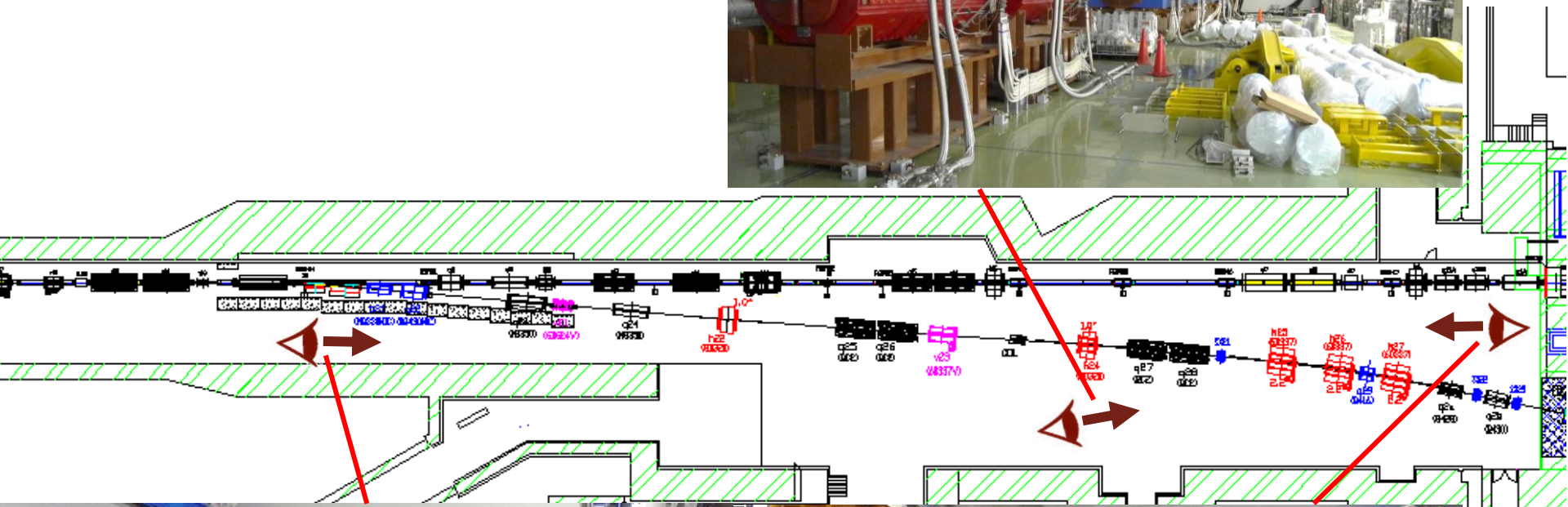
								備考	user	BL/ACC	BL	nominal								Ieiri-sum
	37.0	4.0	31.0	73.5	10.5	2.0	158.0	3.5			調整	start	end	141:37	01:53	20:38	08:02	12:30		127:23
	1e8	5e8	1e9	5e10	1e10	areawork		1e10BL							最初の	down-a	down<3	30分以上のdown		
2020-06-04	11.0						11.0		1e8 FM0	1st day, KL-1H(not-downtime		10:28	21:55	11:27	00:00	01:32	01:32			
2020-06-05	8.0						8.0		1e8 FM0	acc-tuning-not-works		11:00	22:20	11:20	00:02	05:13	02:37	02:36		
2020-06-06	3.0						3.0		1e8 FM+	beam tune/acc-tuning-	10H	20:00	23:00	03:00	00:00	00:29	00:29			
2020-06-07	7.5						7.5		1e8 FMscan	FMunstable		10:00	18:00	08:00	00:22	00:43	00:43			
2020-06-08	7.5	4.0	4.0				15.5		1e8FMscan, 5e8,1e9			10:00	02:00	16:00	00:20	00:38	00:38			
2020-06-09				6.0	6.0		12.0		1st 1e10 (4e9→8e9)			10:00	01:00	15:00	00:18	03:54	00:54	03:00		
2020-06-10							0.0			maintenance24H		0:00	00:00	00:00	00:00	00:00	00:00			
2020-06-11			12.0				12.0		1e9 wire	tune 1e10, width x1.5	8H	17:40	06:00	12:20	00:00	00:09	00:09			
2020-06-12			6.0	5.5			11.5	1.0	1e9FM0, 5e9FM+	radiation 1e10FM0		18:00	06:00	12:00	00:12	00:40	00:40			
2020-06-13				11.5			11.5		5e9			17:30	07:00	13:30	00:07	02:07	00:07	02:00		
2020-06-14				9.5			9.5		5e9			17:00	07:30	14:30	00:08	05:00	00:00	05:00		
2020-06-15				9.0	4.5	1.0	14.5		5e9,1e10,1Hwork			17:00	07:30	14:30	00:13	00:12	00:12			
2020-06-16				10.0			10.0	2.0	5e9FM0, FM+	morino activation		17:00	03:00	10:00	00:11	00:01	00:01			127:23
2020-06-17			3.0	1.0			4.0	0.5	5e9,1e9	komatsu-spill	7H	0:25	04:41	04:16	00:00	00:36	00:36		04:16	131:39
2020-06-18			6.0	3.5		1.0	10.5		1e9,5e9, 1Hwork	vac.		17:00	06:00	13:00	00:14	03:38	00:43	02:55	10:05	141:44
2020-06-19				12.5			12.5		5e9 ee/pipi	haloMonitor off		17:30	06:00	12:30	00:13	00:13	00:13		12:30	154:14
2020-06-20				5.0			5.0		5e9 ee	empty target		18:00	23:15	05:15	00:20	00:21	00:21		05:15	159:29
														176:38	02:40	25:26	09:55	15:31		

NEW PRIMARY BEAM LINE

A small fraction of primary protons (10^{10} per spill, 0.1% of the main beam) is delivered to the experimental area



TRANSPORT MAGNET



EXPERIMENT AREA

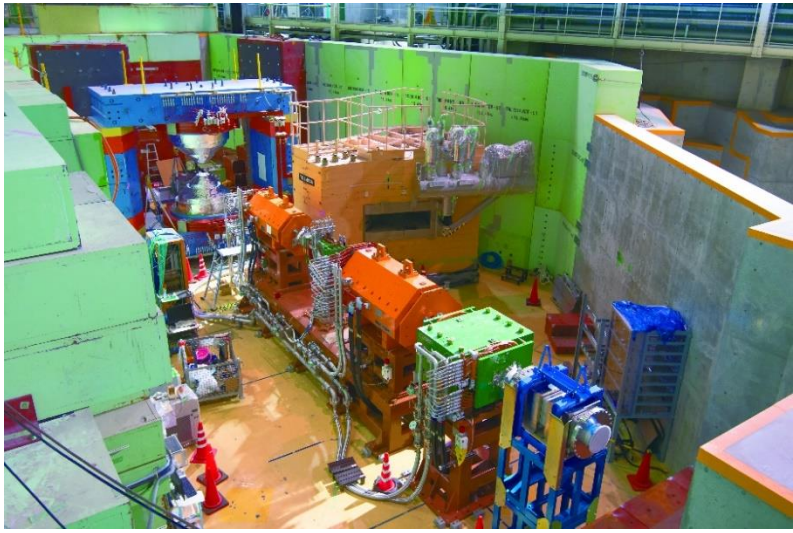
FM magnet

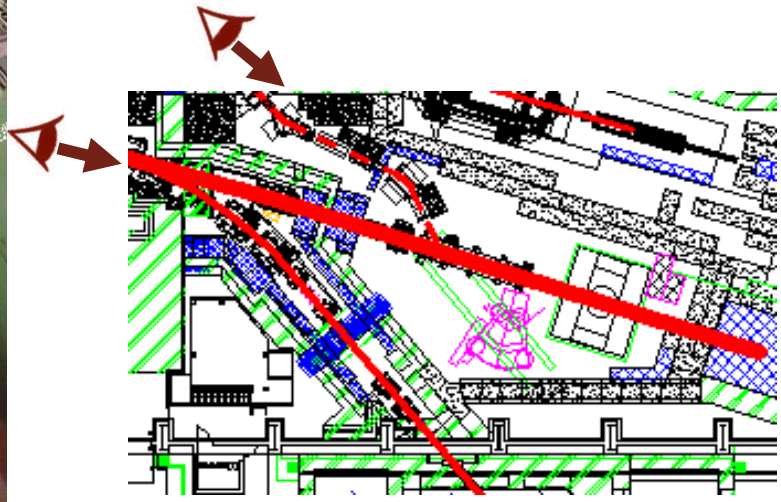
beam dump

B line

C line

2019.09.18





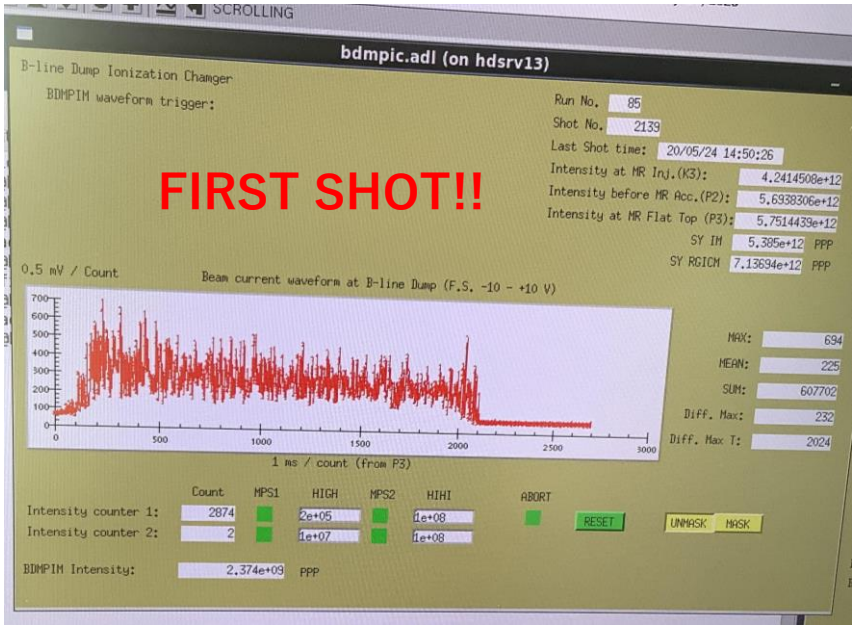
South part of the Hall

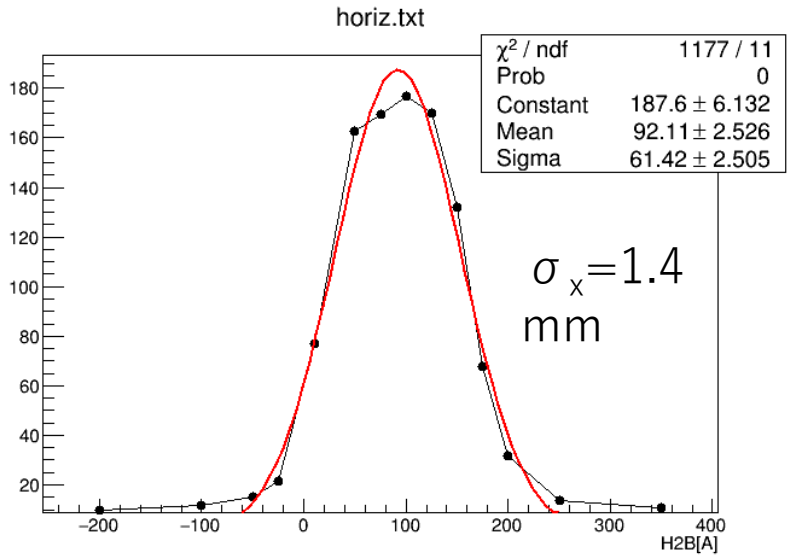
Beam Properties

- First Shot on May 24!!

- Beam profile
  - Measured by a scattering method at the target point
  - Beam width is consistent with an expectation

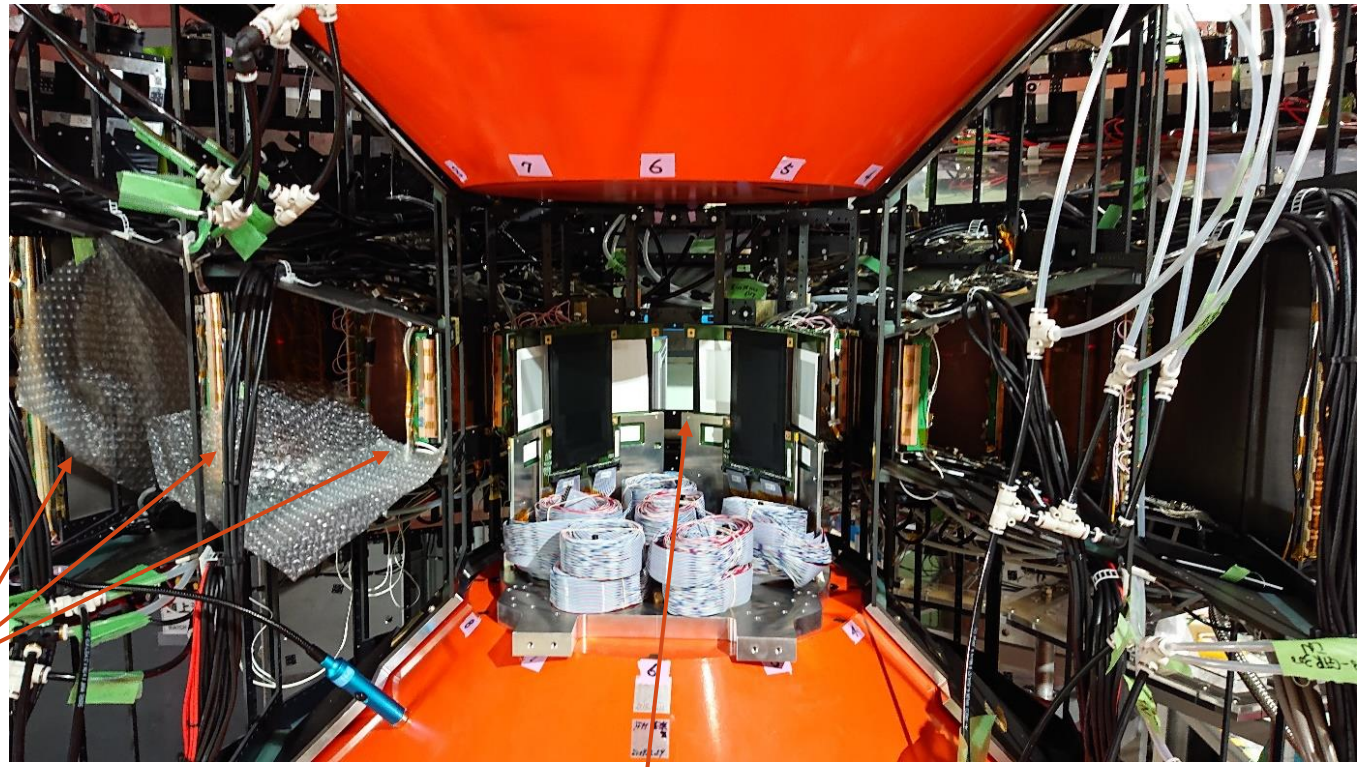
- Beam intensity in a spill
  - High intensity at the beginning
  - It can be corrected by changing the magnet current during the spill





TRACKING DETECTORS

One layer of Silicon Strip Detector (SSD)
Three layers of Gas Electron Multiplier (GEM) Tracker

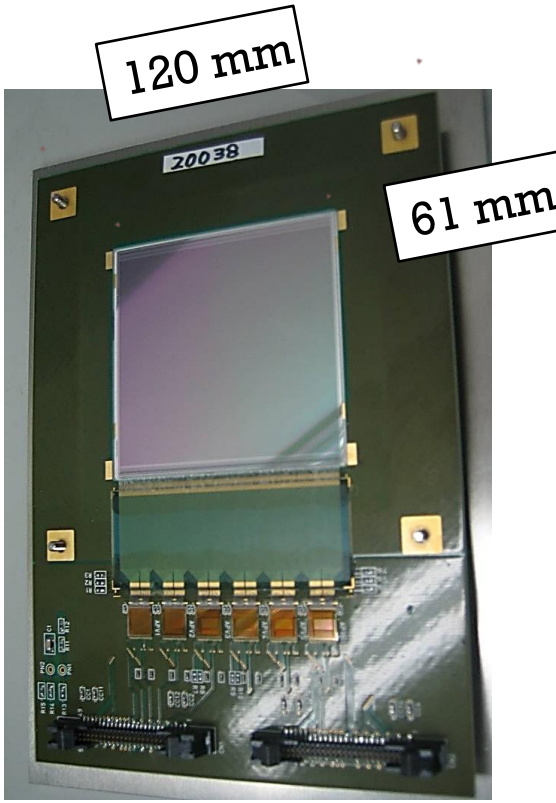


GEM Tracker

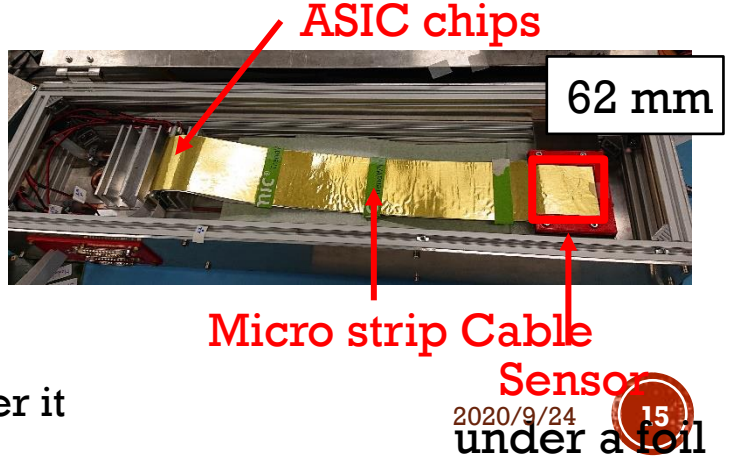
SSD

Silicon Strip Detector

- Run0
  - Existing 6 SSDs used for another J-PARC experiment.
    - ATLAS sensor
    - Sensitive area: 61 mm x 62mm
    - Strip pitch 80 um. (1D)
    - Timing Resolution 4ns
    - It has large unwanted frame.
    - The readout ASIC is APV-25

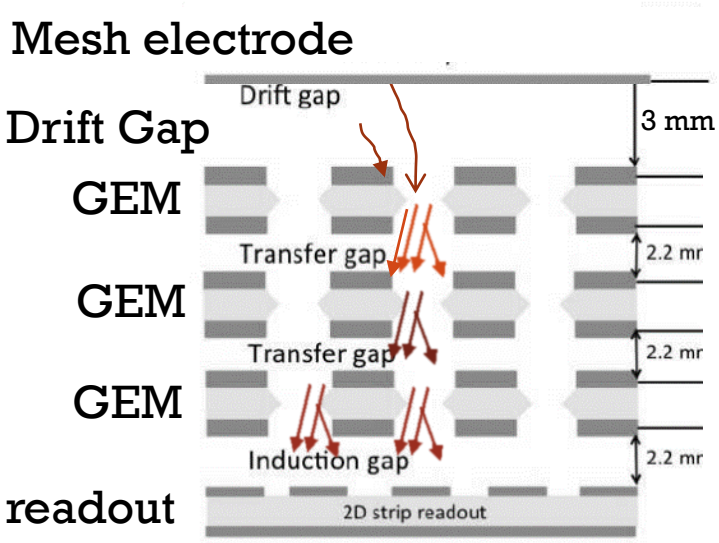


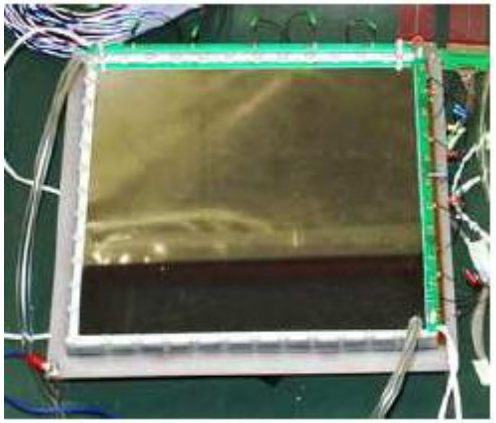
- Run1
  - Starting collaboration with FAIR-CBM
    - CBM developed sensor
    - Sensitive area: 60 mm x 60 mm
    - Strip pitch 50um (Double sides)
    - Almost no frame
    - The readout ASIC is a CBM special chip
    - Developed for the streaming DAQ, however it can be used for a triggered DAQ



GEM TRACKER

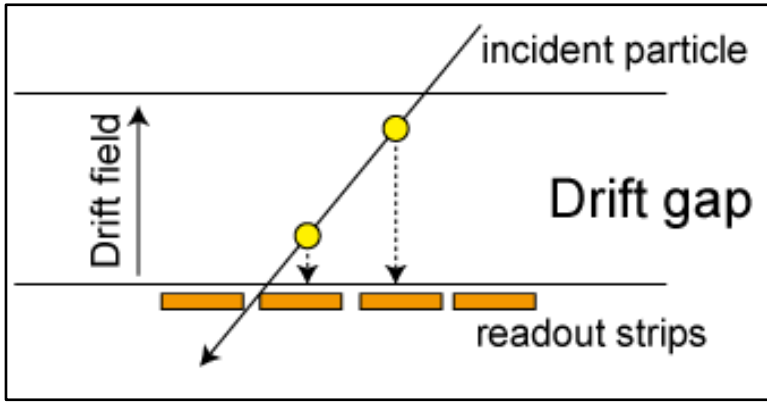
- Ionization electrons in the drift gap are collected and amplified by GEMs.
- Gas Electron Multiplier (GEM)
  - Many small holes
    - ϕ 50μm, pitch 140μm
  - Electro nodes in both sides and make strong electric fields in holes
- 2D strip readout
  - X: 350um pitch
    - Sensitive to bending direction.
    - 100 um resolution required.
  - Y: 1400um pitch
- Trigger signal is generated from the bottom side of the last GEM foil
  - A new ASIC is developed for a trigger signal as a Open-IT project





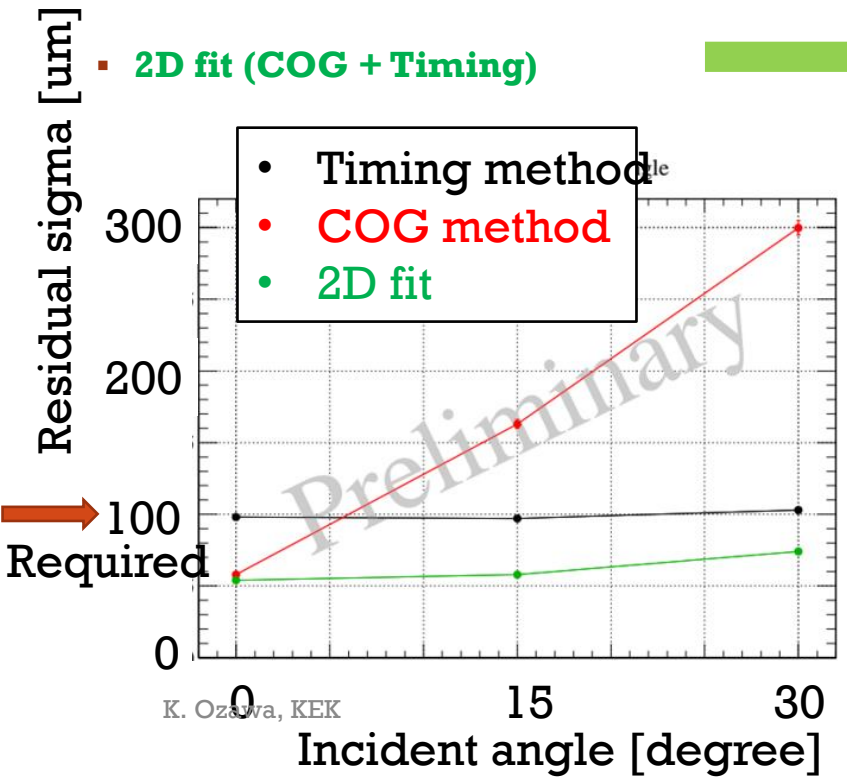
GTR PERFORMANCE

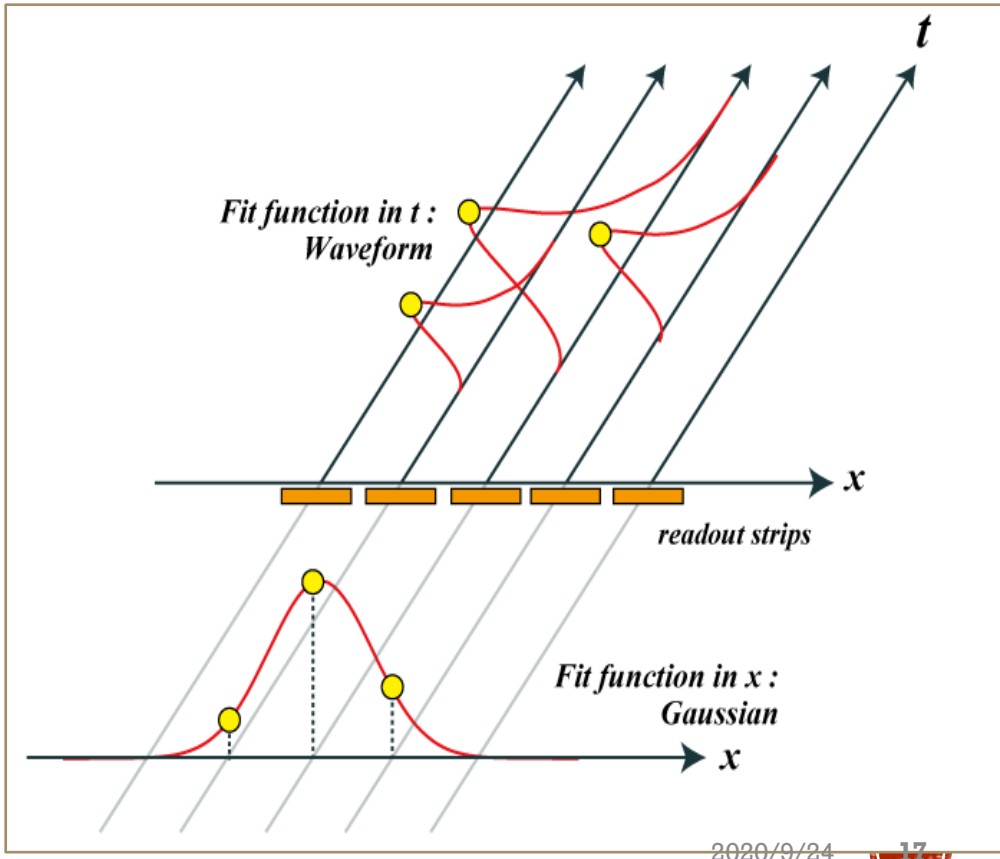
- Center Of Gravity (COG) Method
  - Ordinal analysis method
  - ~ 60 μm @ 0 degree of incident angle
  - Worse results for inclined tracks



- Timing method
  - Distance in drift field dir. Can be obtained using flight time like mini-TPC
  - ~ 100 μm for all tracks

- 2D fit (COG + Timing)





IDENTIFICATION OF ELECTRON

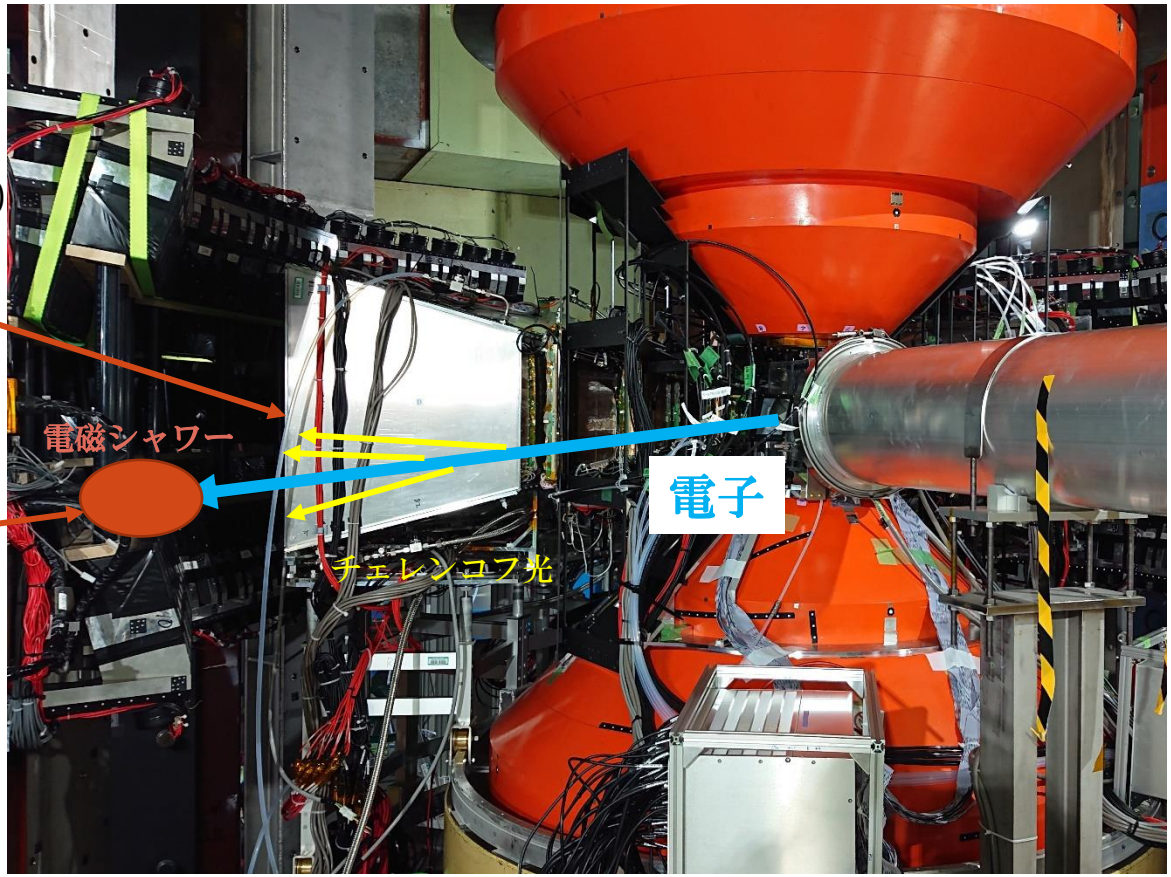
Identify electrons and reject hadrons

Gas Cherenkov Detector
（Hadron Blind Detector, HBD）

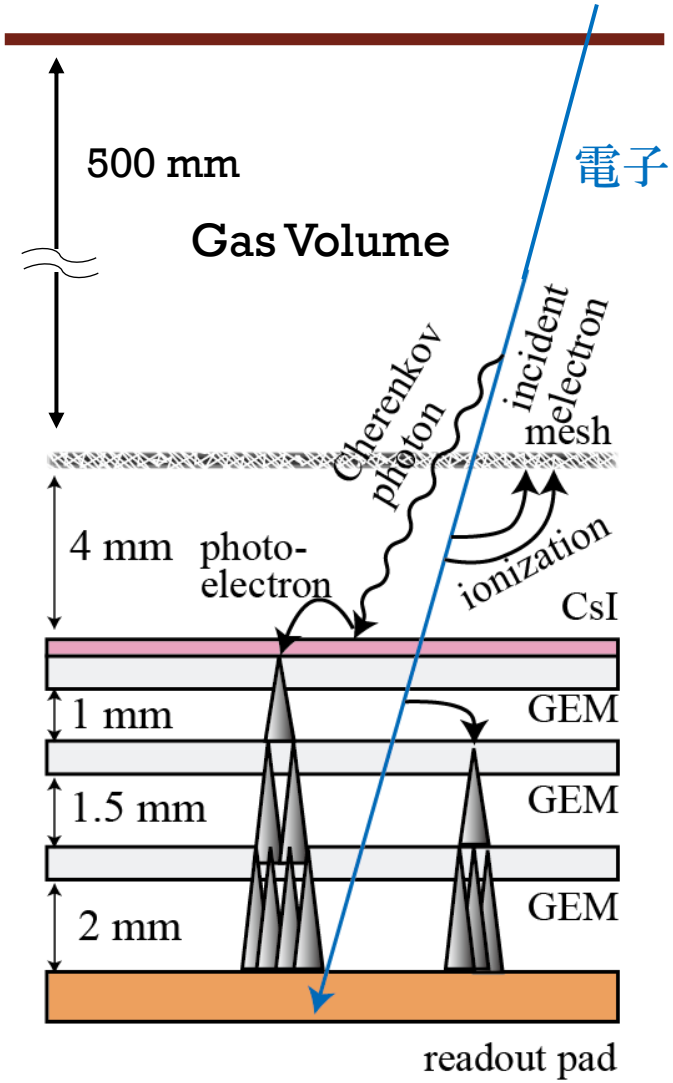
Using Cherenkov radiation emitted by electron in a radiation gas

Lead Glass Detecotr

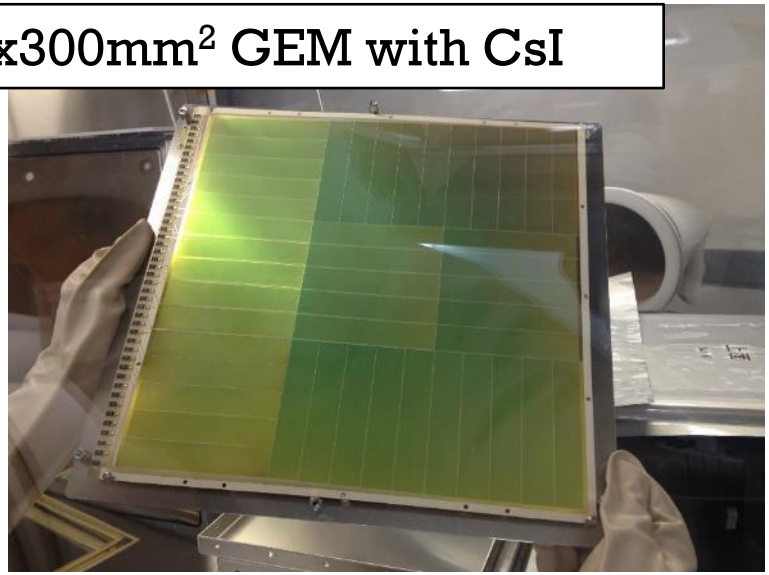
Using electro magnetic shower generated by electron

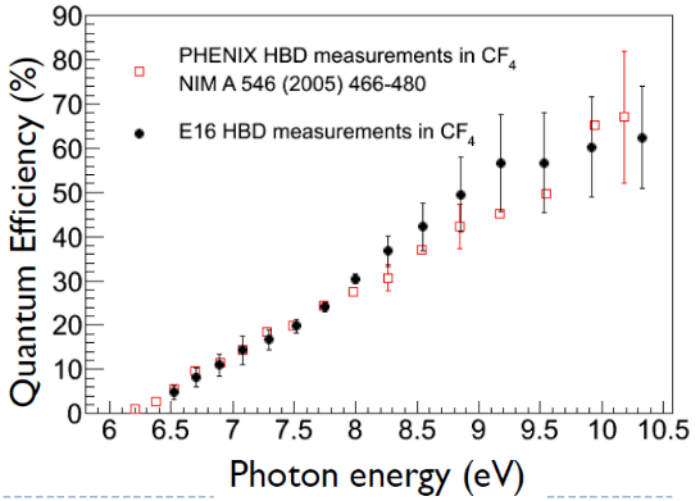


HADRON BLIND DETECTOR（HBD）



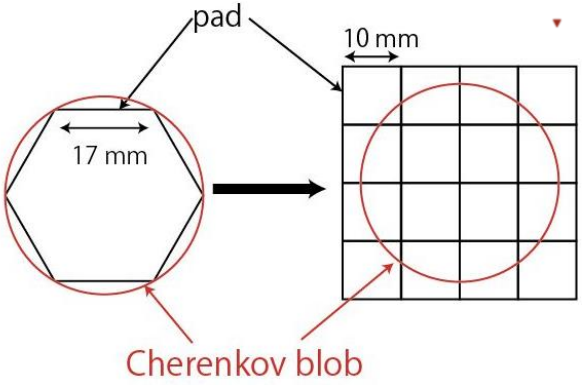
300x300mm^2 GEM with CsI

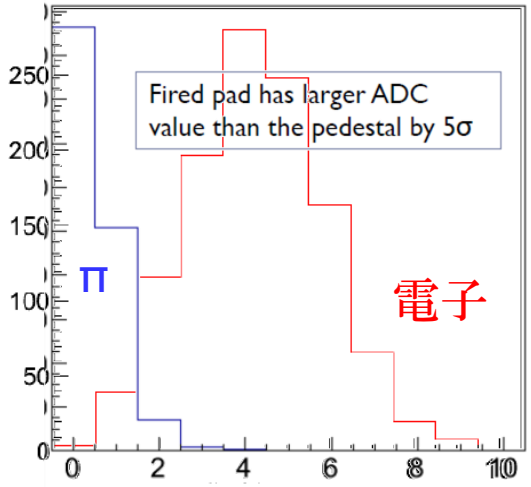




PERFORMANCE OF HBD

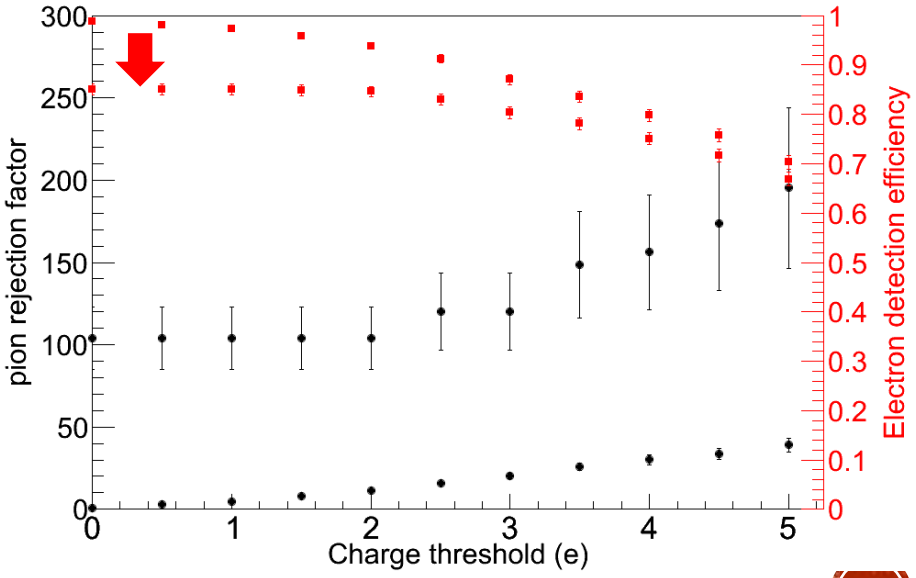
Analysis using Cluster size are established in detector tests





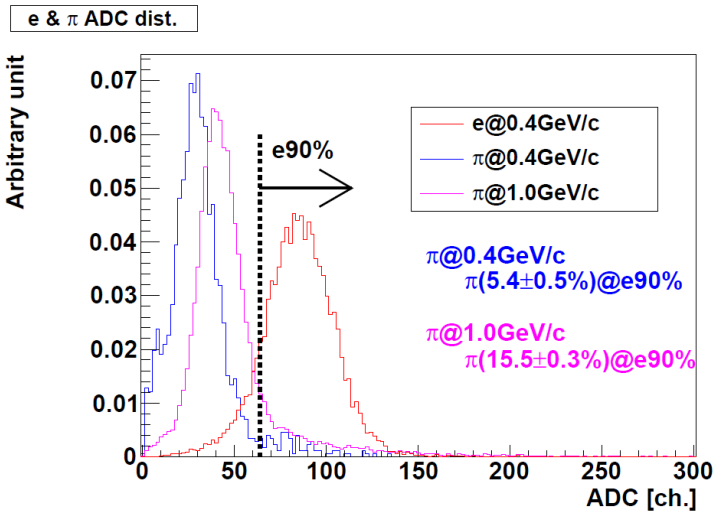
Cluster size - 1

- Rejection of π mesons: 1/100
  - For electron detection efficiency of 80n %



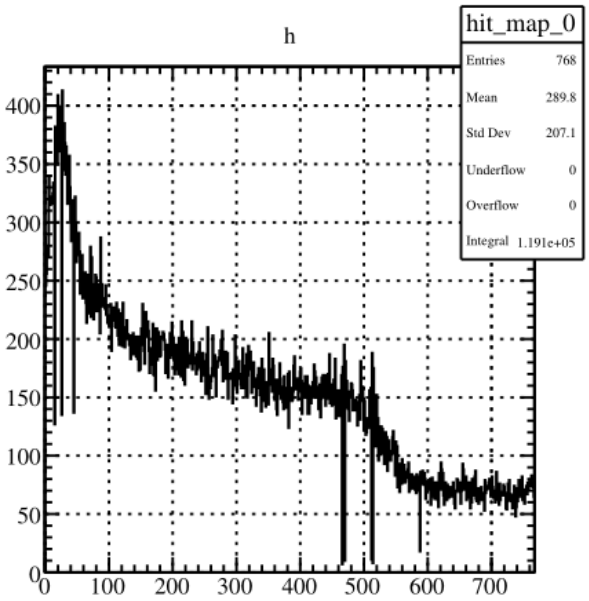
LEAD GLASS DETECTOR

- ✓ Reuse of TRISTAN-TOPAZ
  - ✓ ~300 at the 1st stage.
  - ✓ ~1000 in total
- ✓ Π rejection factor
  - ✓ ~25 offline (energy dep. th.)
  - ✓ ~10 online (fixed th.)



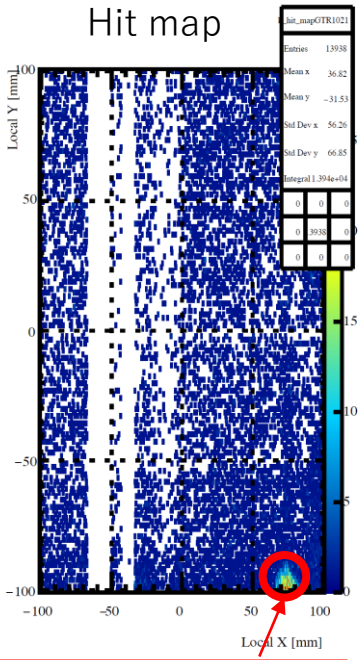
Snapshots of detector online monitor

- We have for detectors, SSDs, GEM trackers, Hadron Blind Detectors, LG calorimeters



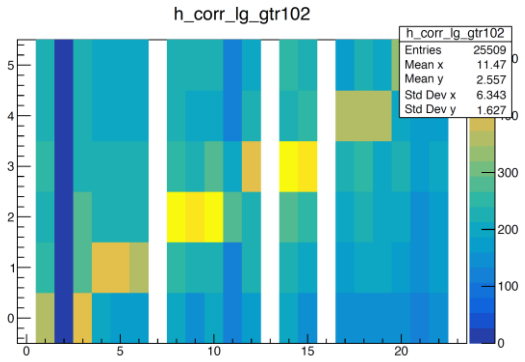
SSD Profile

GEM Tracker
Hit map



Corresponds to a trigger scinti

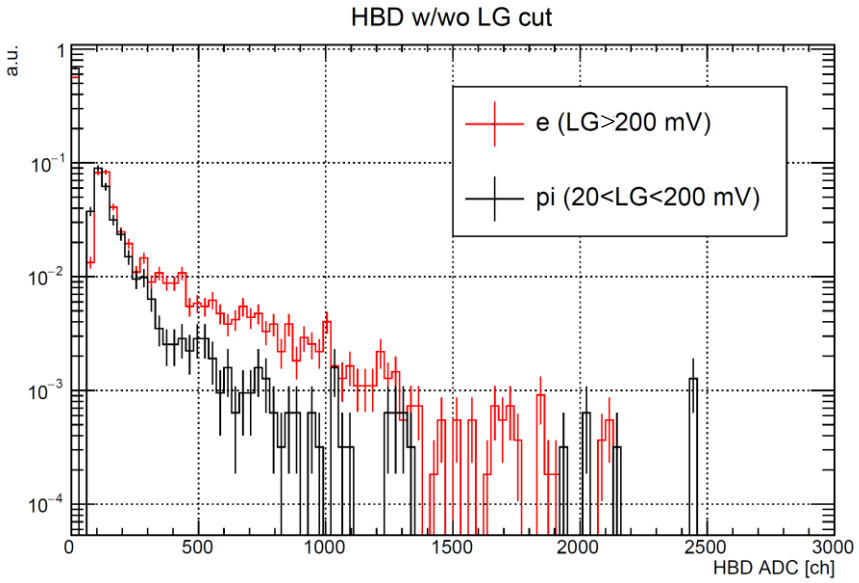
GEM Tracker
Trigger signal from a GEM foil



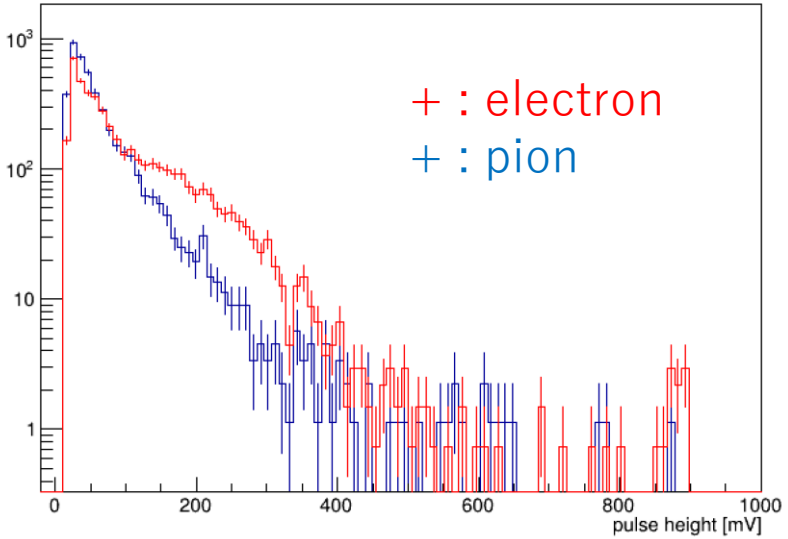
GEM-LG trigger signal correlation

Snapshots (cont'd)

- Electron identification
  - Hadron Blind Detectors and Lead Glass calorimeter



HBD Pulse height distribution



Lead Glass Pulse height distribution

We can see an electron enhancement in an online-analysis
We will improve electron identifications using track information in offline

Summary

- Study of quark and hadron phases in a high-density region is an important topics in coming few years

- The J-PARC E16 experiment aims to measure mass spectra of vector mesons in a nucleus to study quark condensates in a finite density medium

- The E16 experiment started in this June and went well. Upgrade plans of the experiment to extend capabilities of measurements are under discussions