Dilepton measurement at J-PARC high-momentum beamline

– Activities at new beamline –

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at Hadron2021
2021/7/30

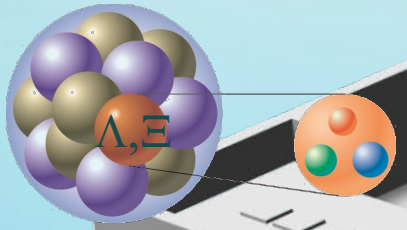
Outline

- Introduction
  - J-PARC Hadron Facility
  - high momentum beamline
- Current physics program at high-p
  - Dilepton measurement
- Near future activity
  - Baryon spectroscopy
- Summary

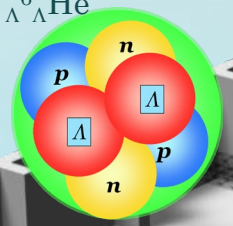
Physics at J-PARC intense kaon beam

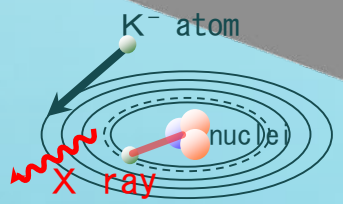
Strangeness Physics

multi-strangeness hypernuclei

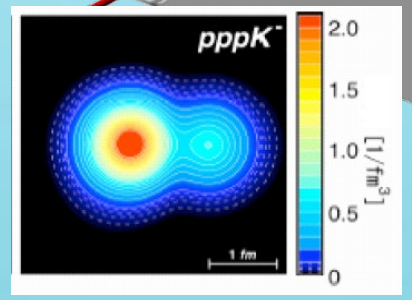


double-Λ ${}^{6}_{\Lambda\Lambda}$He





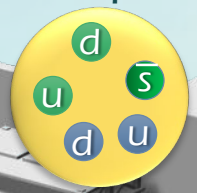
kaonic atom



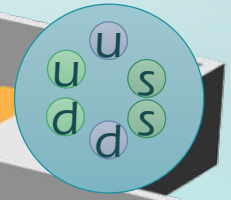
kaonic nuclei

Exotic Hadrons

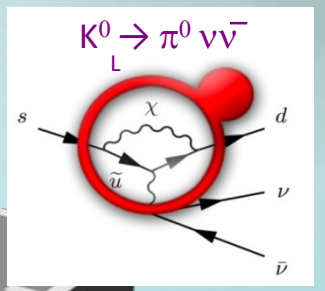
Pentaquark Θ⁺



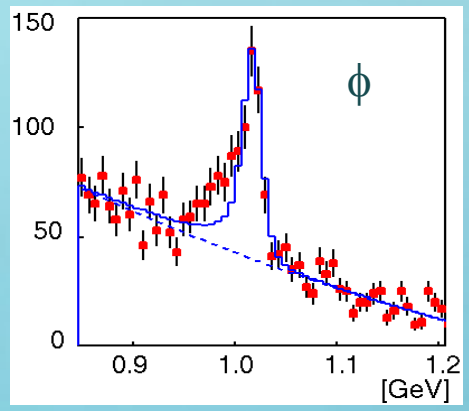
H dibaryon



CP violation



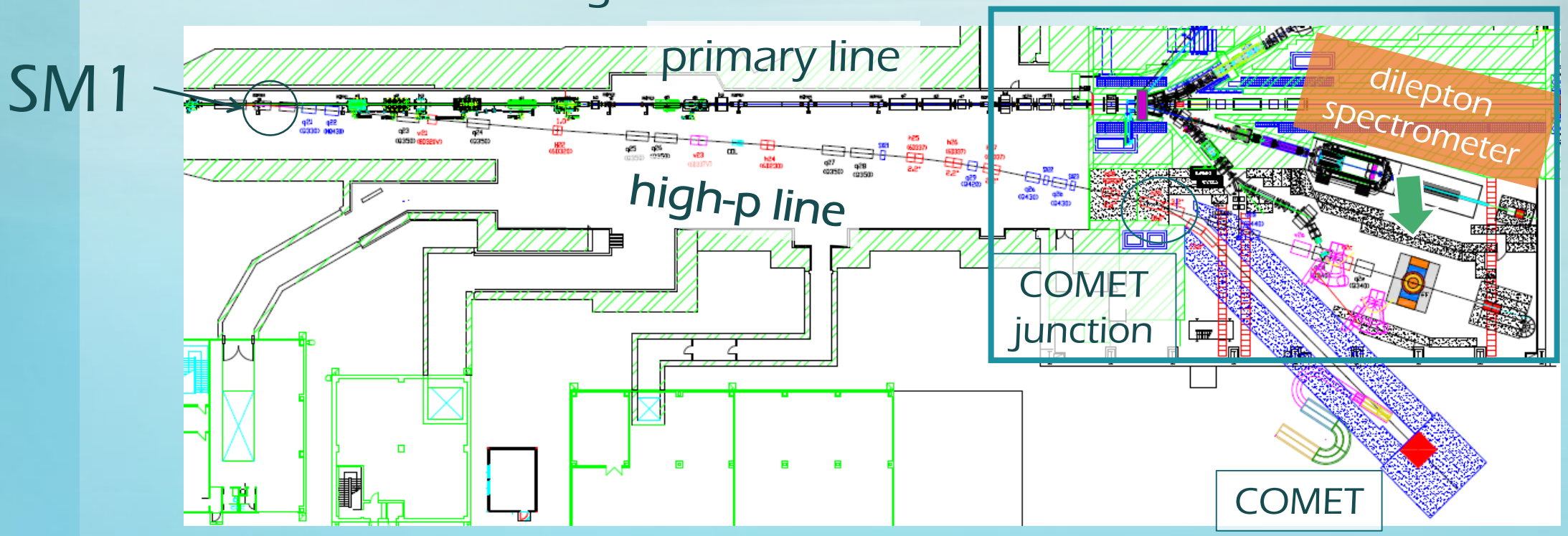
Hadron Mass in medium



Baryon spectroscopy

High-momentum beamline at J-PARC

branch angle : 5°



at SM1 high-p beam branches off from the primary line

- **30 GeV primary proton (10^{10}/pulse)**
- 8 GeV primary proton for COMET
- secondary particles like π, K up to 20 GeV/c

Beam line specifications

Name	Particles	P_{max}	Intensity
K1.8	π, K	2.0 GeV/c	10^6 K^- 's
K1.8BR	π, K	1.1 GeV/c	10^6 K^- 's
KL	neutral K		
K1.1BR	π, K	0.8 GeV/c	10^6 K^- 's
High-p	**proton**	**31 GeV/c**	10^{10} p
High-p secondary	**π/K** (unseparated.)	**20 GeV/c**	10^6 K^- 's
K1.1	π, K	1.1 GeV/c	10^6 K^- 's

→ 2020 May~

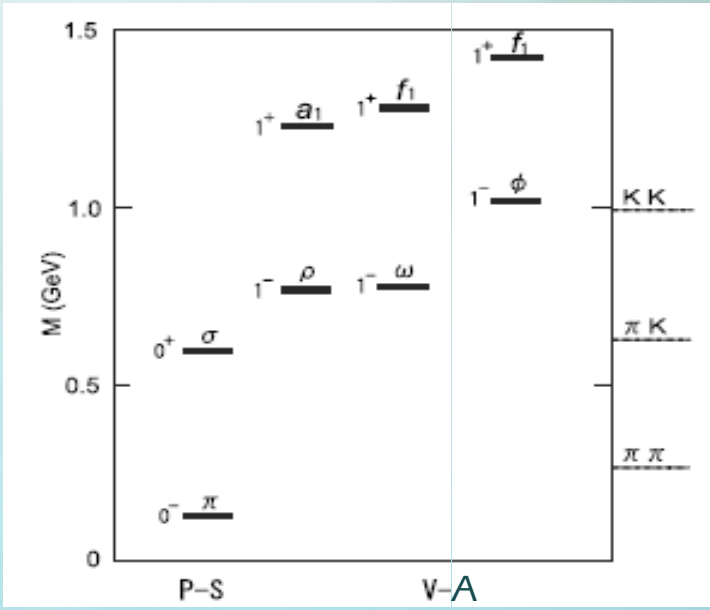
planned

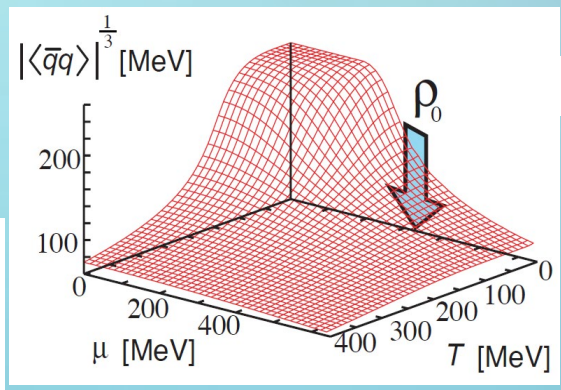
$\sqrt{s}$ =2.2 GeV → $\sqrt{s}$ = 6.2 GeV in 20GeV/c πp/Kp reactions

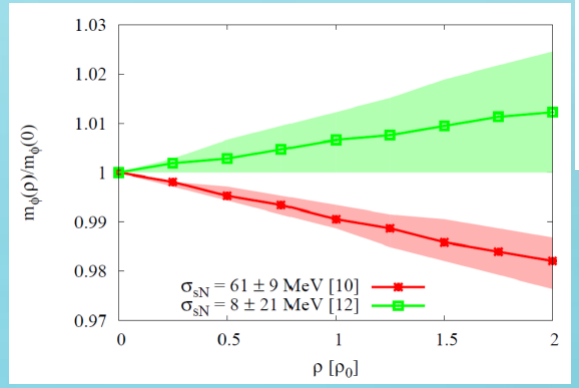
Dilepton measurement

In-medium Spectral Information on Vector Mesons - E16 -

- Explore the world of light quarks
  - determine quark and gluon condensations
  - key symmetry – chiral symmetry
- Leptonic probe – di-lepton
  - clean signal from complicated hadronic systems
- Next-generation experiment
  - catch up e+/e− pairs produced in 30 GeV p+A interactions
  - w/ J-PARC intense beam & state-of-the-art experimental techniques







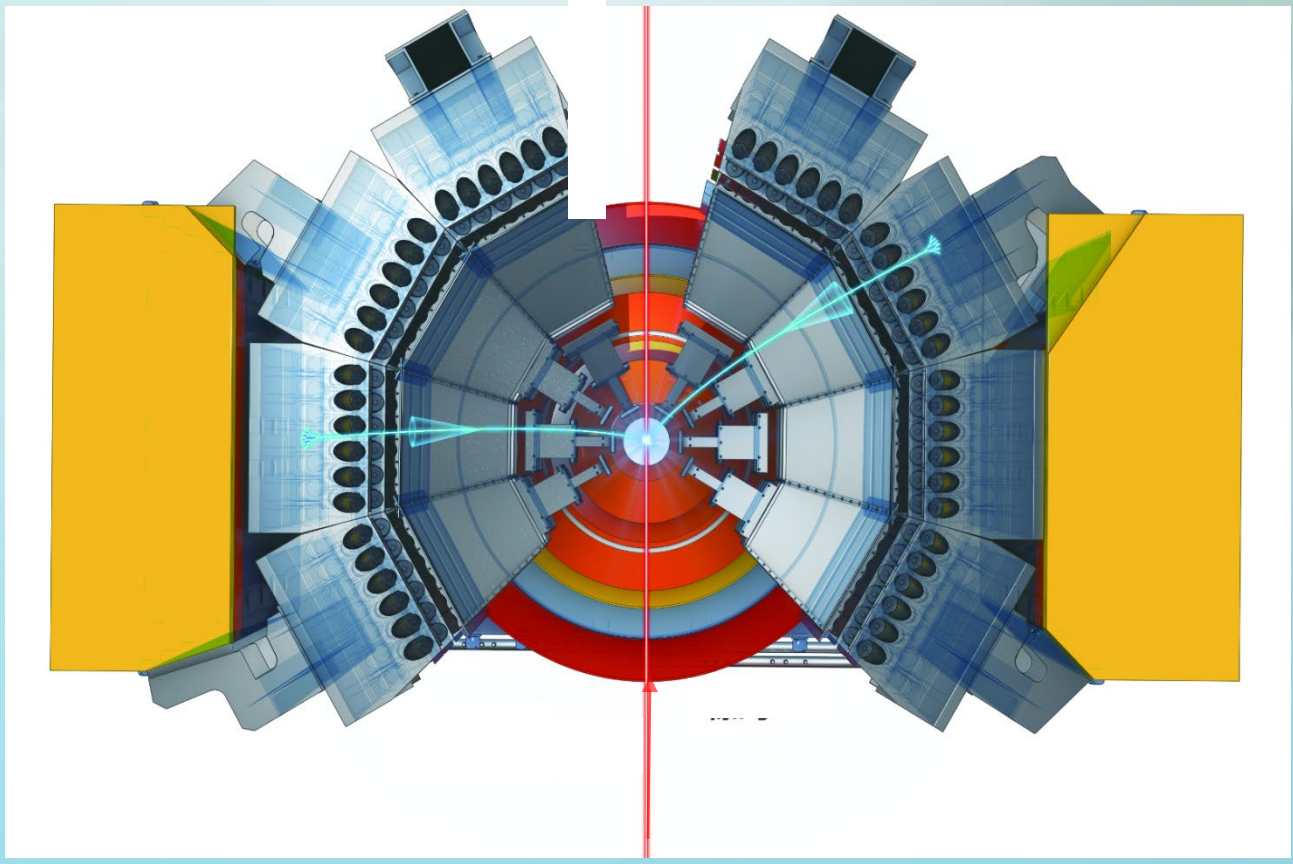
P. Gubler and K. Ohtani, Phys. Rev. D 90, 094002 (2014).

Dilepton measurement at J-PARC (E16)

- φ produced in 30 GeV pA reactions
- $\varphi \rightarrow e^+e^-$

	mass	width
ρ	770	149.2
ω	782	8.44
φ	**1020**	**4.26**

- systematic studies
  - High statistics
    - 10^{10} p/spill (2 seconds) x 0.1% targets (C,Cu,Pb)
    - high rate capability 100k channel
  - High mass resolution ΔM = 7 MeV

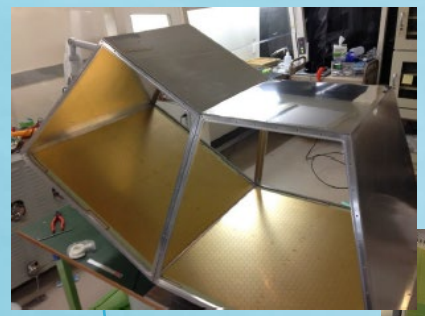


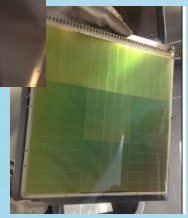
proton beam

spectrometer

- Tracking devices
  - SSD
  - GEM Tracker (GTR)
- double-stage Electron ID counters
  - Hadron Blind Detector (HBD)
  - Lead-glass calorimeter (LG)

Hadron Blind Detector (HBD)

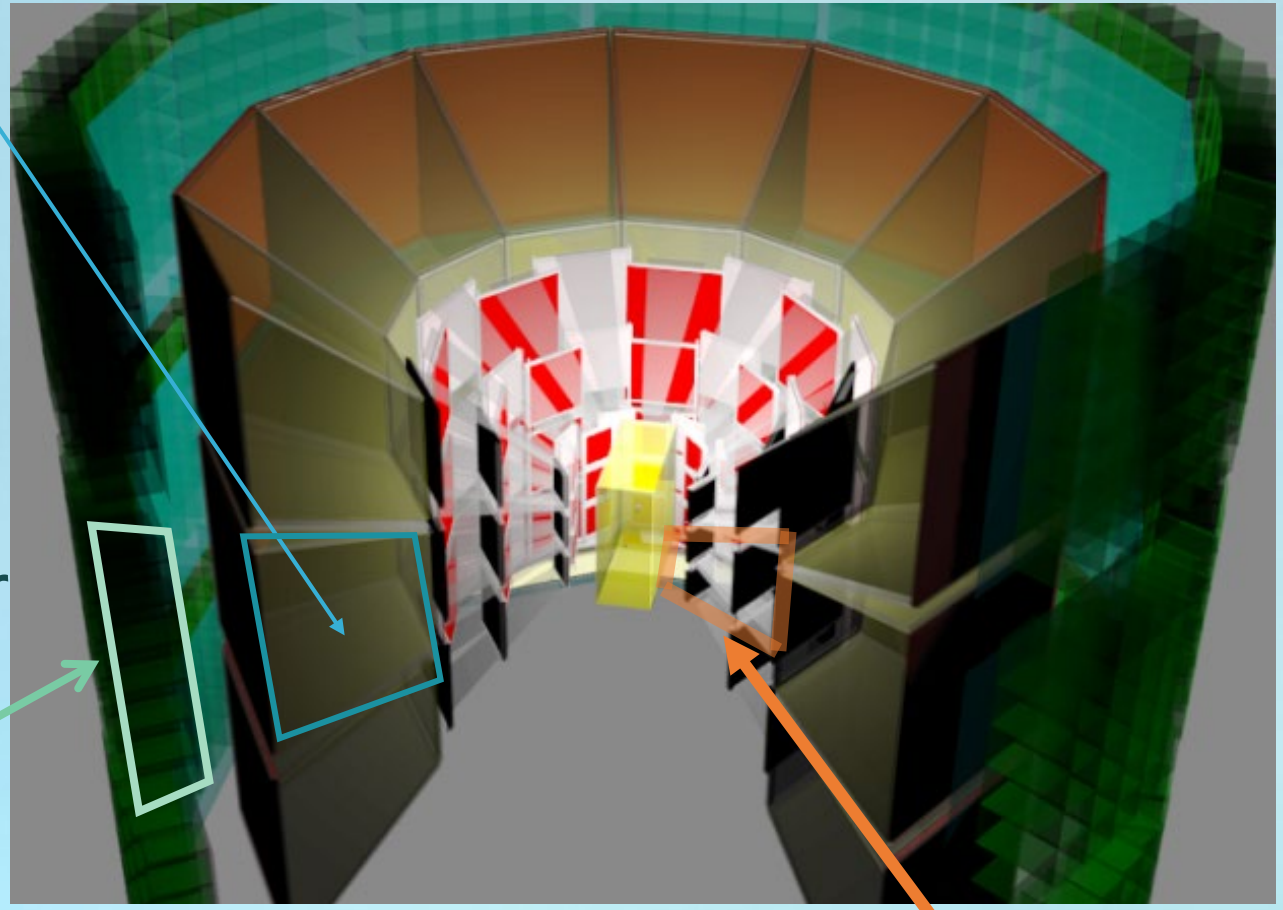




CsI evaporated GEM
(inside the gas chamber)

Lead-glass calorimeter

PbWO4 crystals

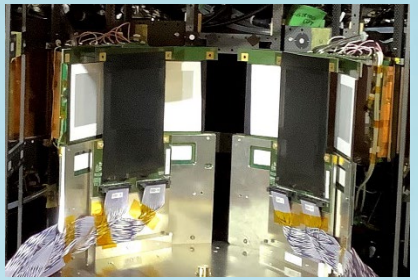


rejection power :
3x10-4

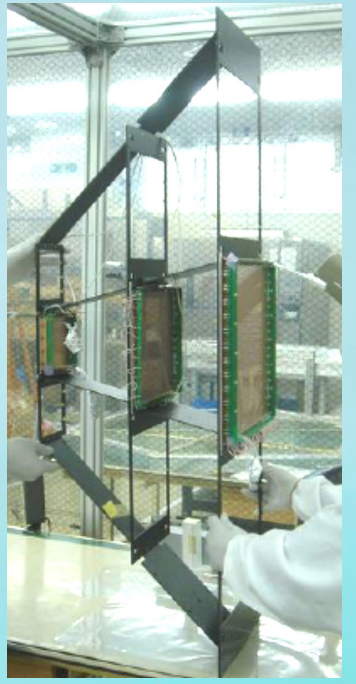
GEM Tracker)

3 size of GEM
(10, 20 and 30 cm^2)

SSD

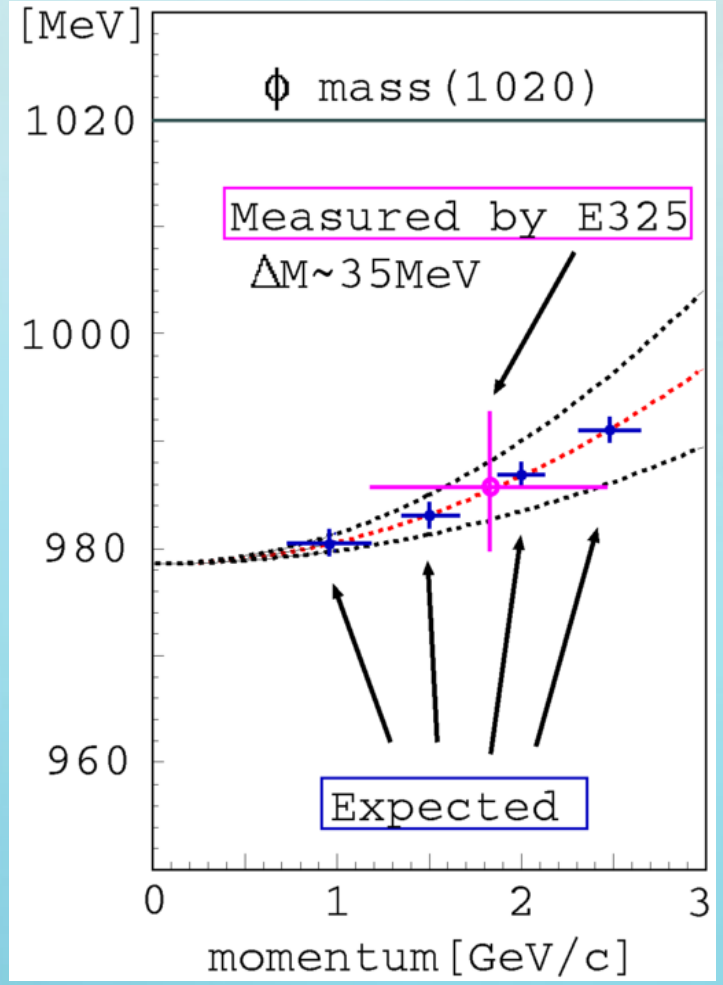


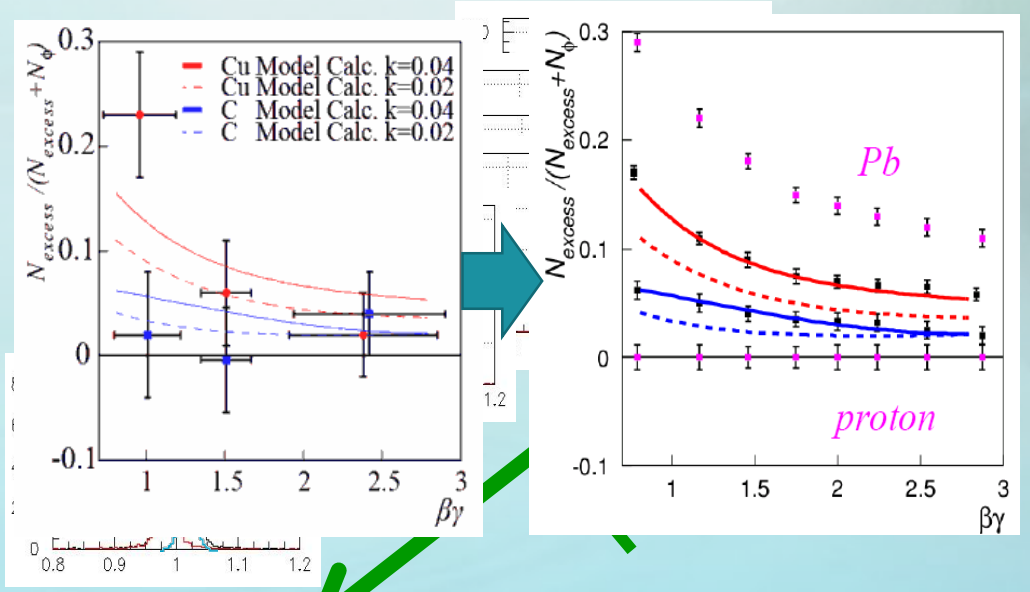
1 module

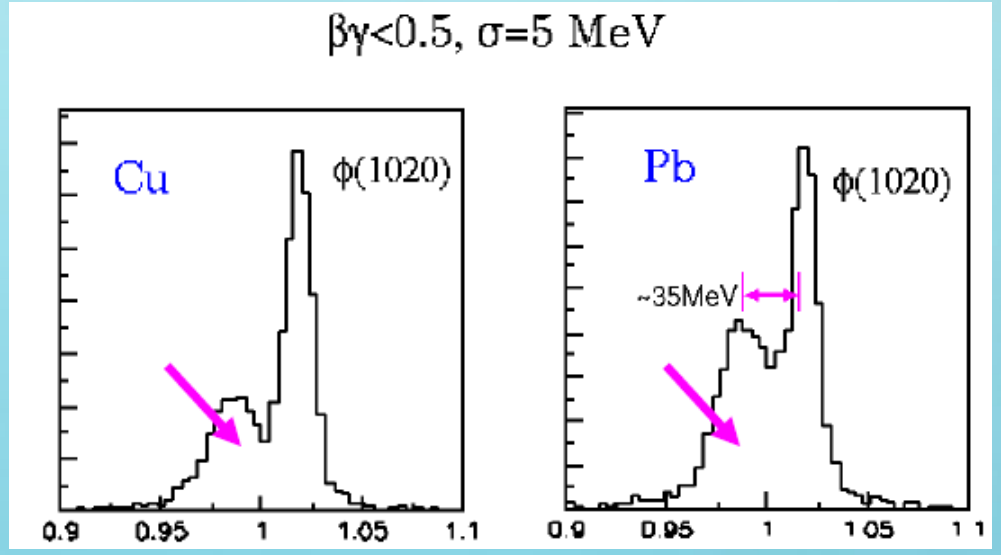


Expected Signal

momentum dependence of mass



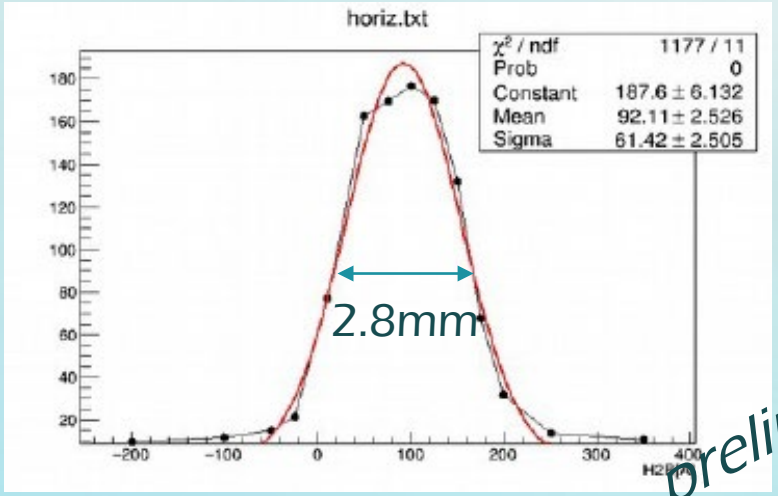




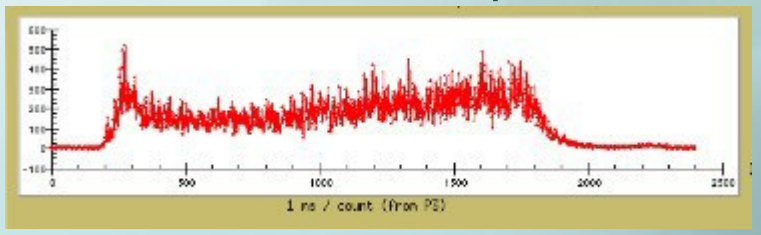
Current status

- quality of extracted primary beam
  - xy profiles: as expected
  - global time structure: OK
- detector performance
  - wire successfully reconstructed from SSD & GTR
  - electrons are identified with 2-stage PID counter

beam profile

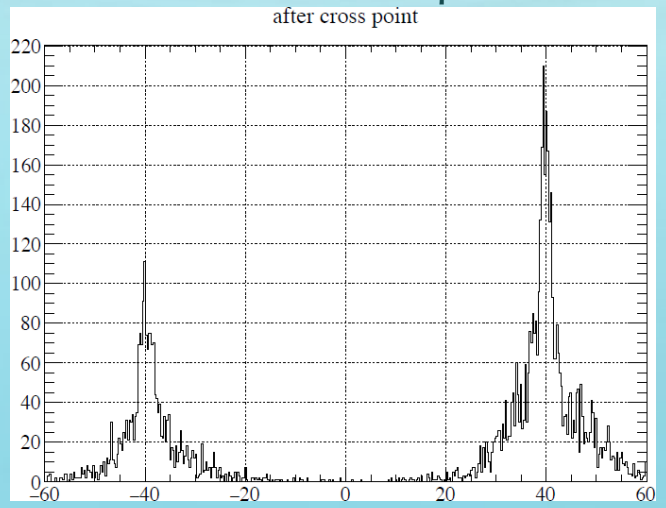


time structure of spill

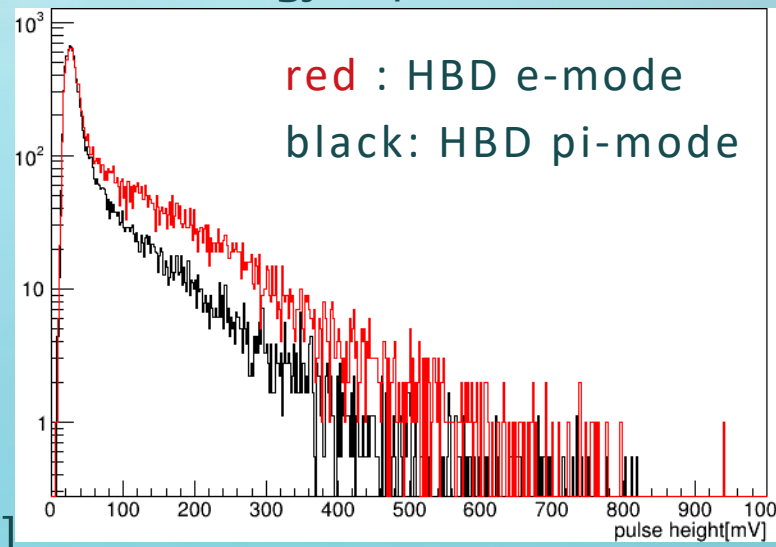


preliminary

reconstructed wire positions



energy deposit of LG

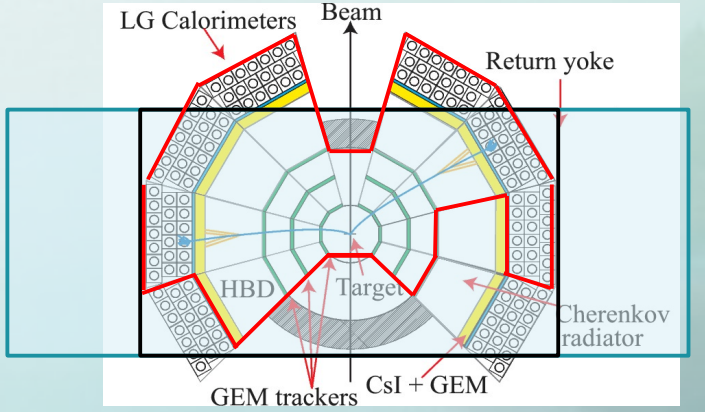


Schedule

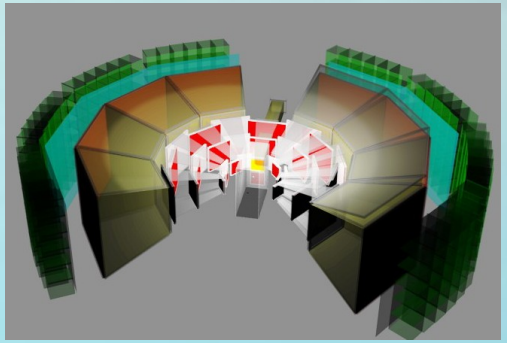
- 2020-2021 RUN0 – 320 hours, C/Cu targets
  - Beamline / Detector commissioning

we are ready

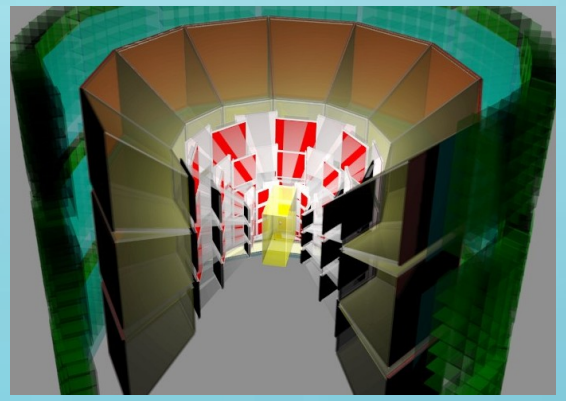
- 2022 RUN1 – 1280 hours, C/Cu targets
  - Physics run 15k of ϕ mesons
- 2023~ RUN2 – 2560 hours, C/Cu/Pb targets
  - nuclear size & velocity dependences



RUN 1 (8 modules)



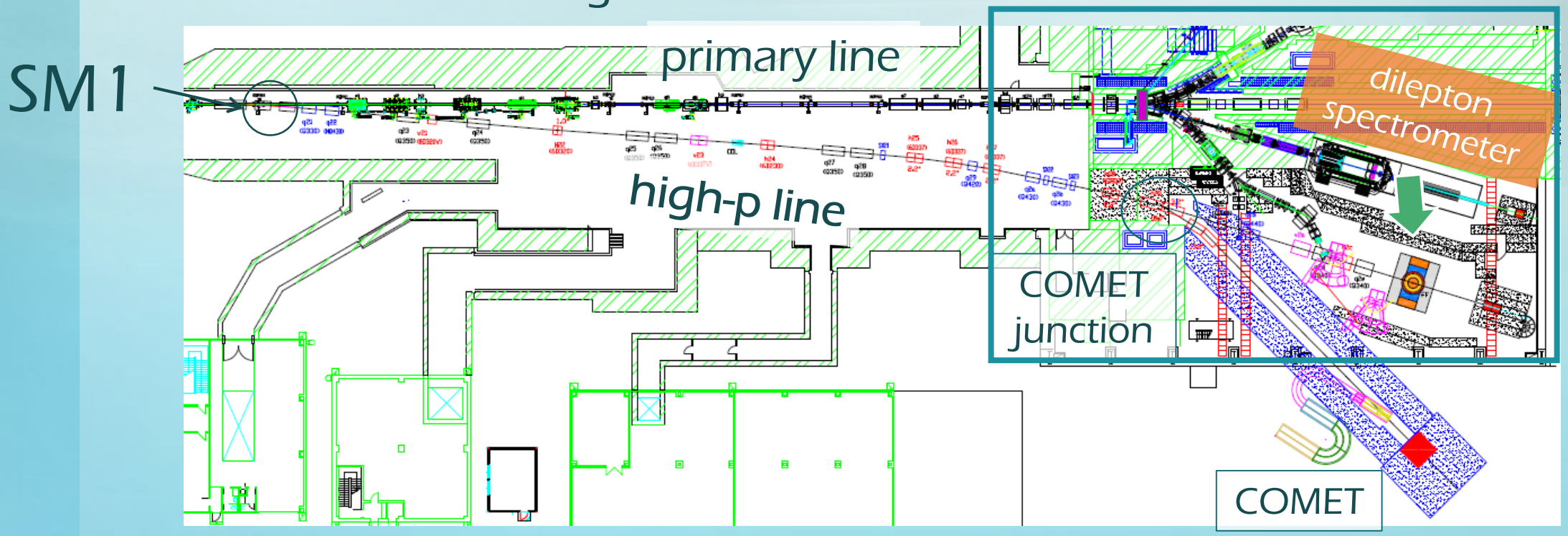
RUN 2 (26 modules)



Baryon spectroscopy

High-momentum beamline at J-PARC

branch angle : 5°



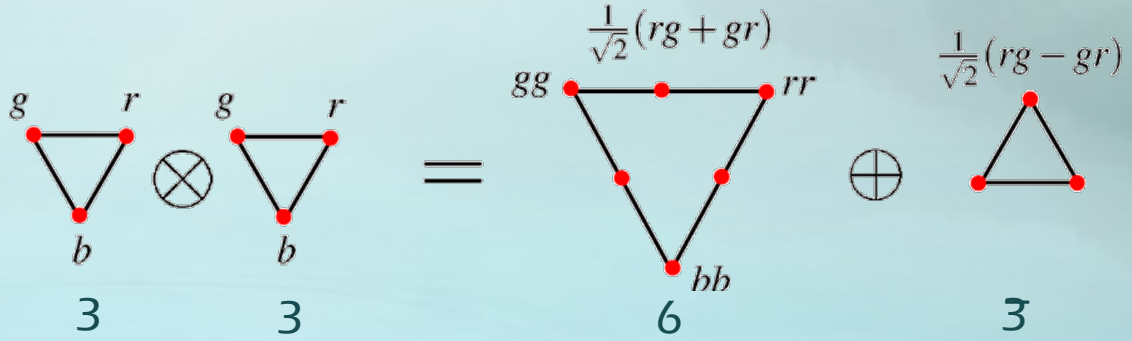
at SM1 high-p beam branches off from the primary line

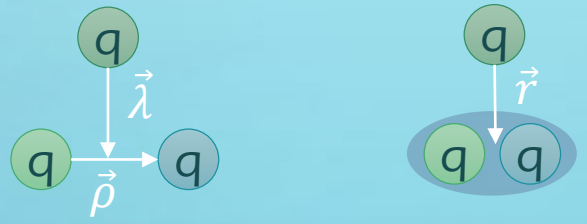
- **30 GeV primary proton (10^{10}/pulse)**
- 8 GeV primary proton for COMET
- **secondary particles like π, K up to 20 GeV/c**

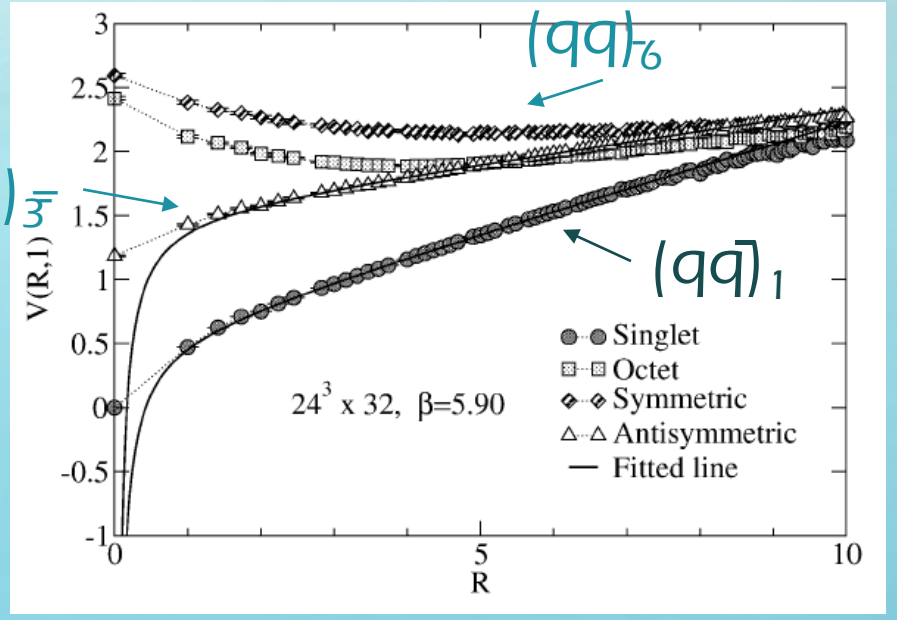
Diquark as key component of hadrons

- diquark interaction
  - color-magnetic (OGE)
  - color-electric (confinement)
    - ✓ $(qq)_{\bar{3}}$:strong attractive force
  - Cornell potential : $-\frac{4}{3}\frac{\alpha_s}{r} + \sigma r$

(OGE) (confinement)



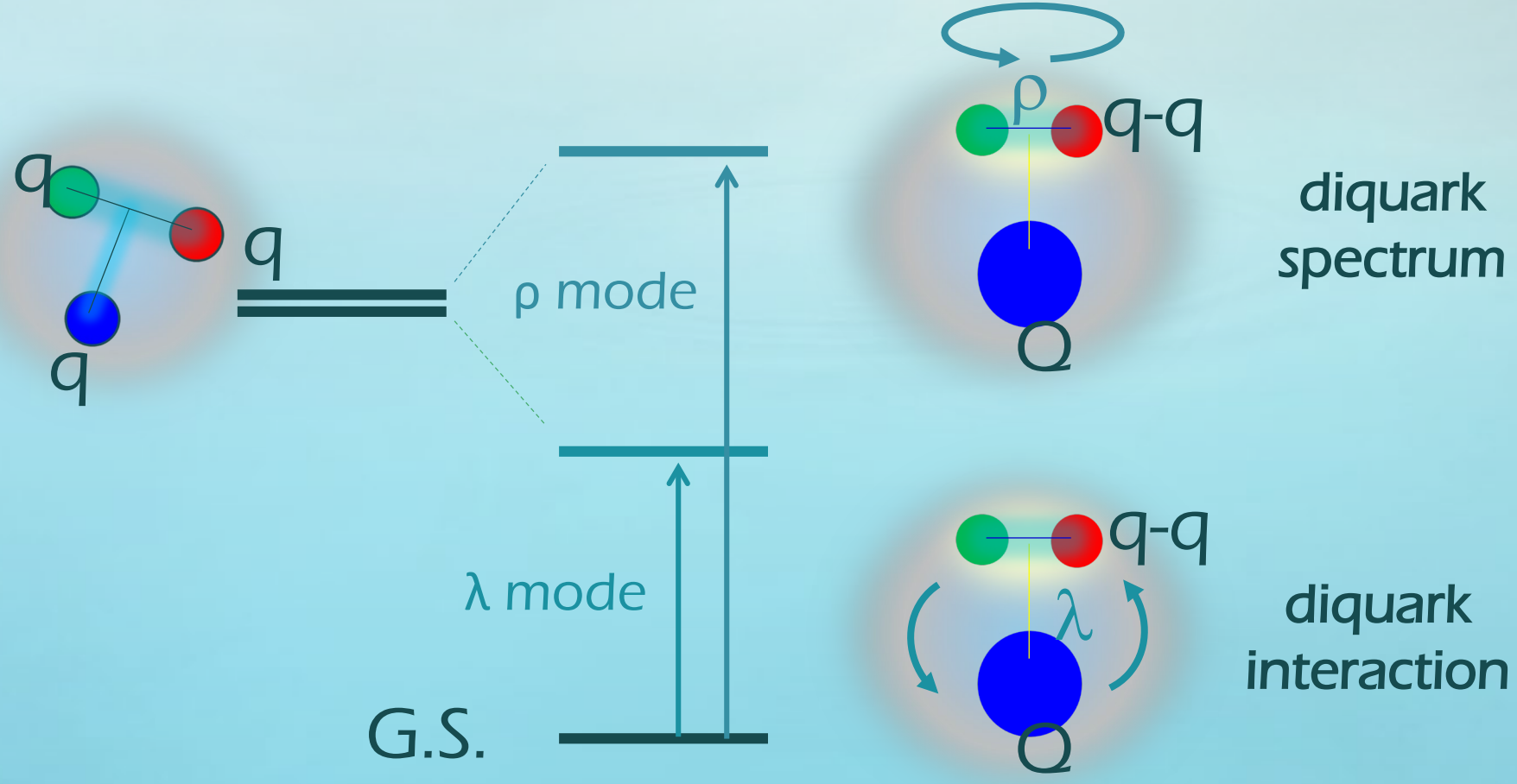




q LQCD, Nakamura & Saito, PLB621(2005)171

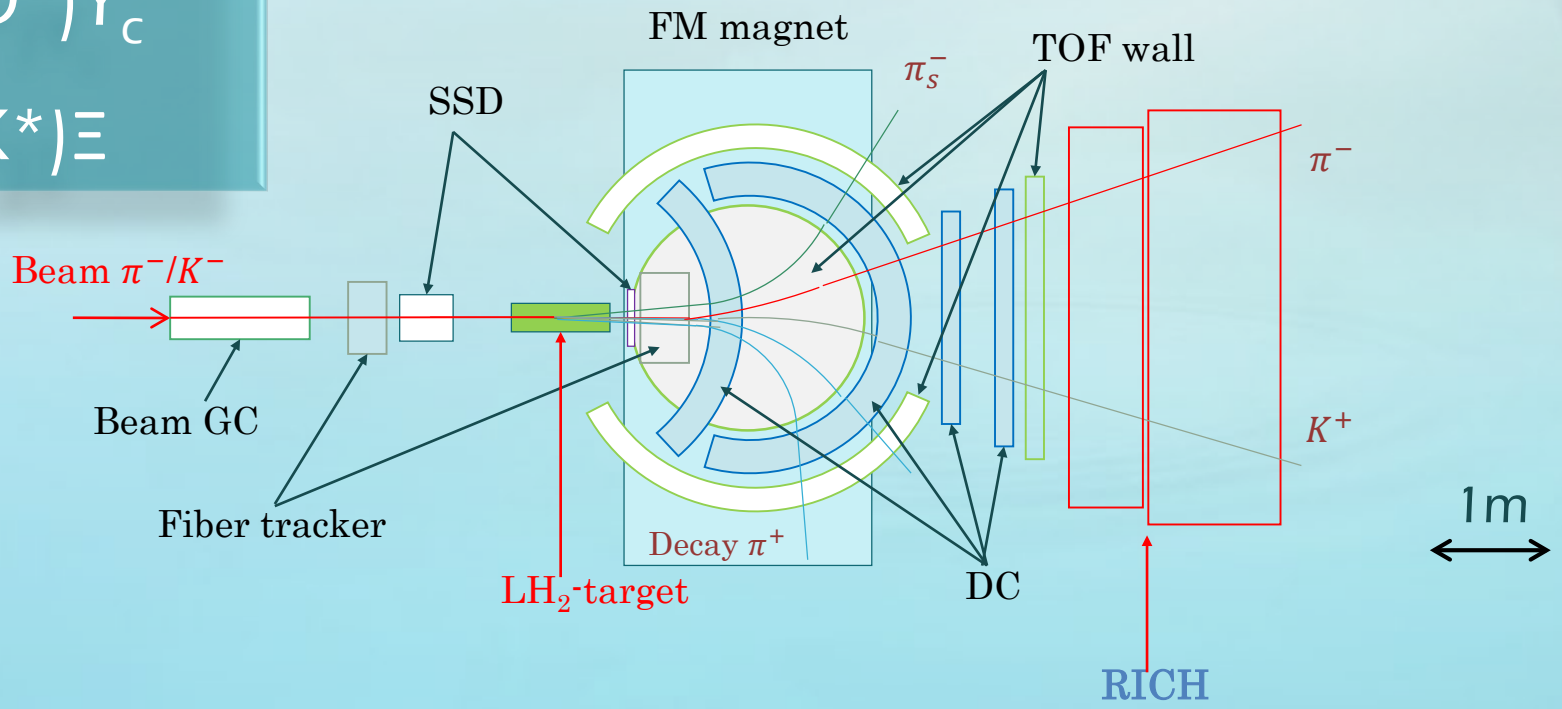
Charm baryon spectroscopy

- λ and ρ motions split in heavy baryons



Multi Purpose Spectrometer

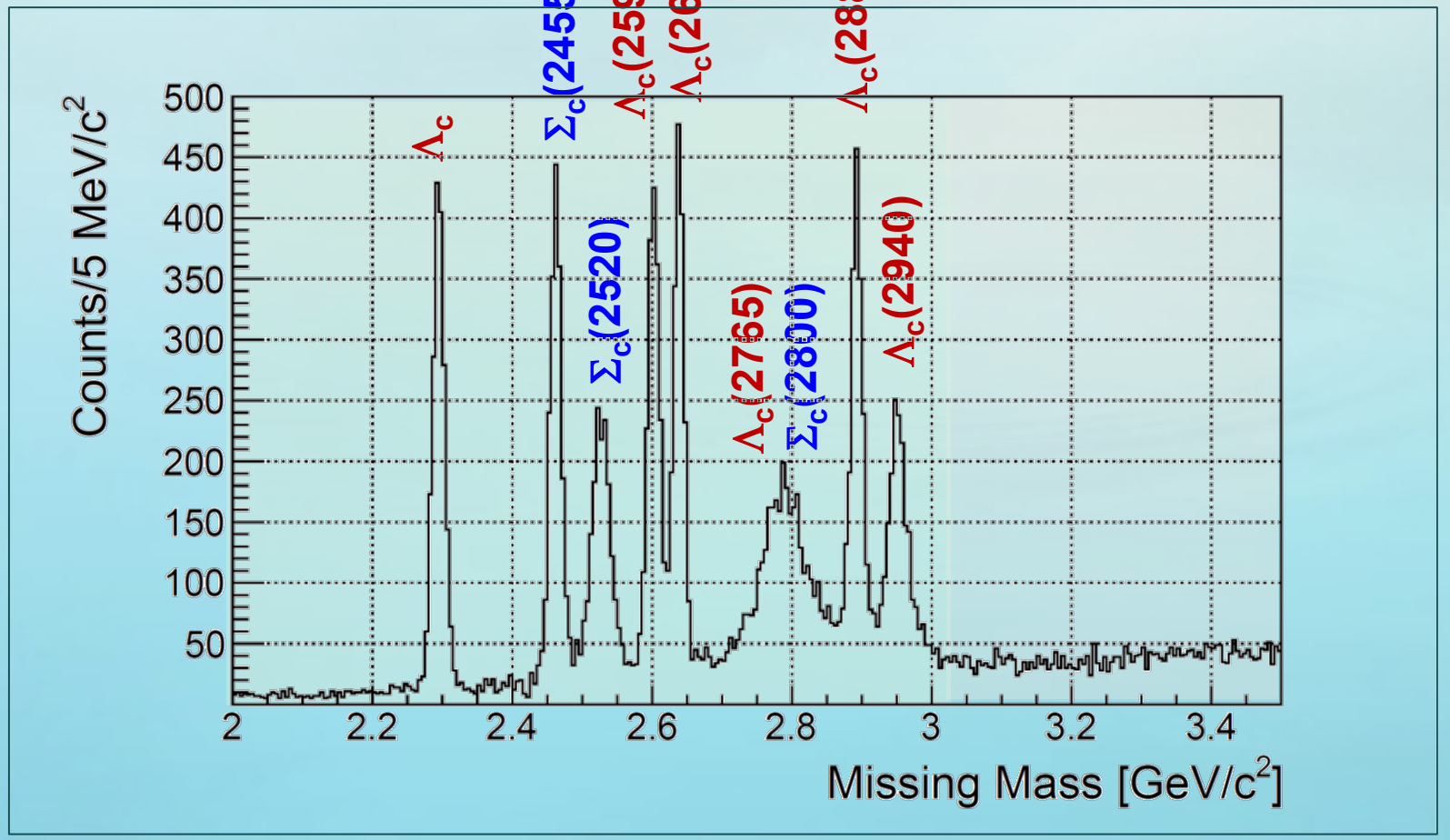
- $p(\pi,D^*)Y_c$
- $p(K,K^*)\Xi$



High resolution & Large acceptance spectrometer

- Large acceptance (50% for K* / 60% for D*)
- Detector configuration for high-resolution (dp/p=0.2%)
  - Possible decay mode measurement: $Y_c^* \rightarrow Y_c + \pi$...
- Multi-particle detection in the high rate environment

Expected spectrum: σ(πp→D*⁻Yc) = 1 nb



10M π beam + LH2

N(Yc*)~1000 events/1nb/100 days
Sensitivity: ~0.1 nb (3σ, Γ~100 MeV)

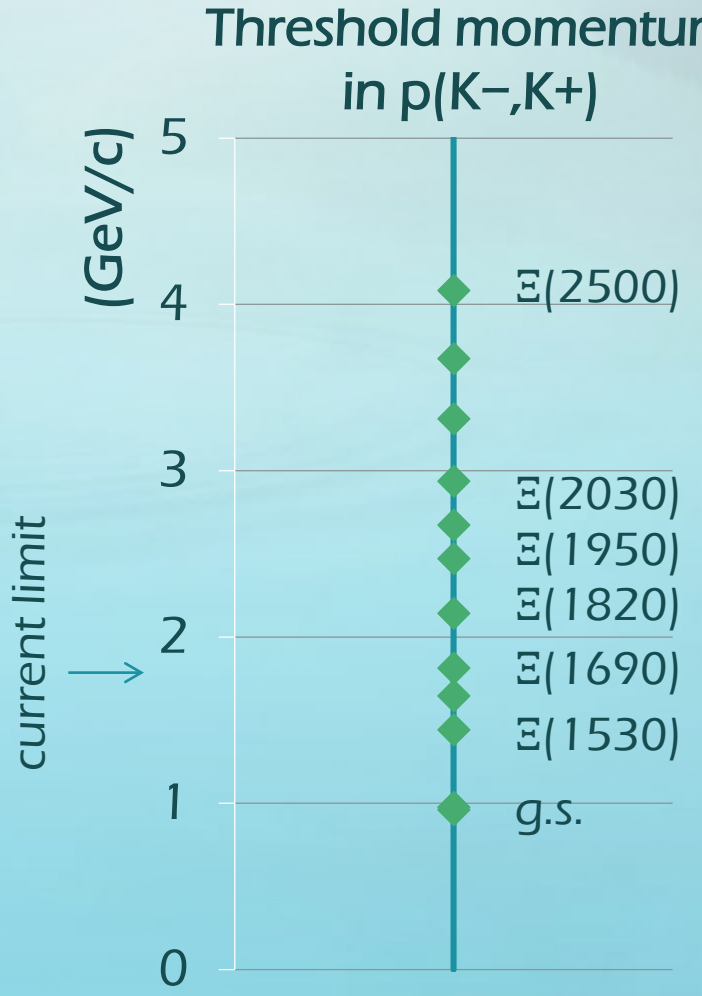
Ξ Spectroscopy with kaon beam

- Missing & Invariant Mass Spectroscopy
- 5 GeV/c K− p reaction up to 2.5 GeV Ξ
  - * by K* tagging, threshold momentum for 2.5 GeV Ξ production is 5.5 GeV/c.

Yield Estimation

$I_K = 10^6$/spill
$\sigma = 1\mu b$
$d\Omega/4\pi = 50\%$
$4 g/cm^2$ LH2 target

→ $Y \sim 10^4$/day
$S/N \gtrsim 10$



LoI: Ξ Baryon Spectroscopy with High-momentum Secondary Beam

Summary

- At the high-momentum beamline, 30 GeV primary proton beam is now available at J-PARC
- The experiment to measure dilepton spectra has been successfully launched. Beamline/detector commissioning were done, first physics data will be taken in autumn 2022.
- Ξ and charm baryon spectroscopy will be performed with π/K beams at mid-energy region.