Physics at the new π20 beamline in J-PARC

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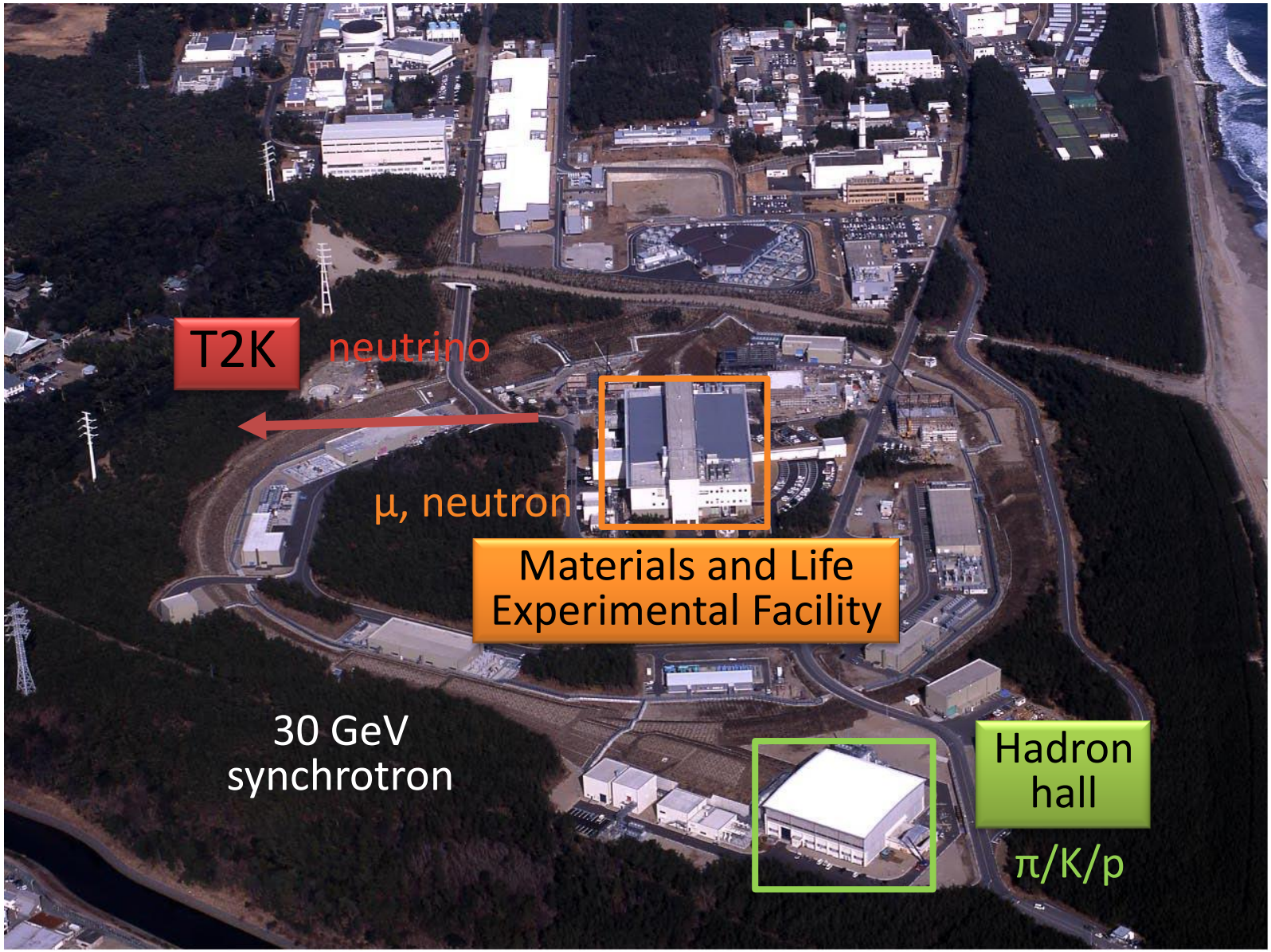
2022/Jul/21
Towards improved hadron femtography with hard exclusive reactions

J-PARC

Japan Proton Accelerator Research Complex



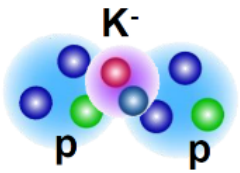
Hadron hall

2010-

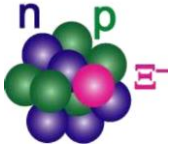
Separated K/π ~1.0 GeV/c

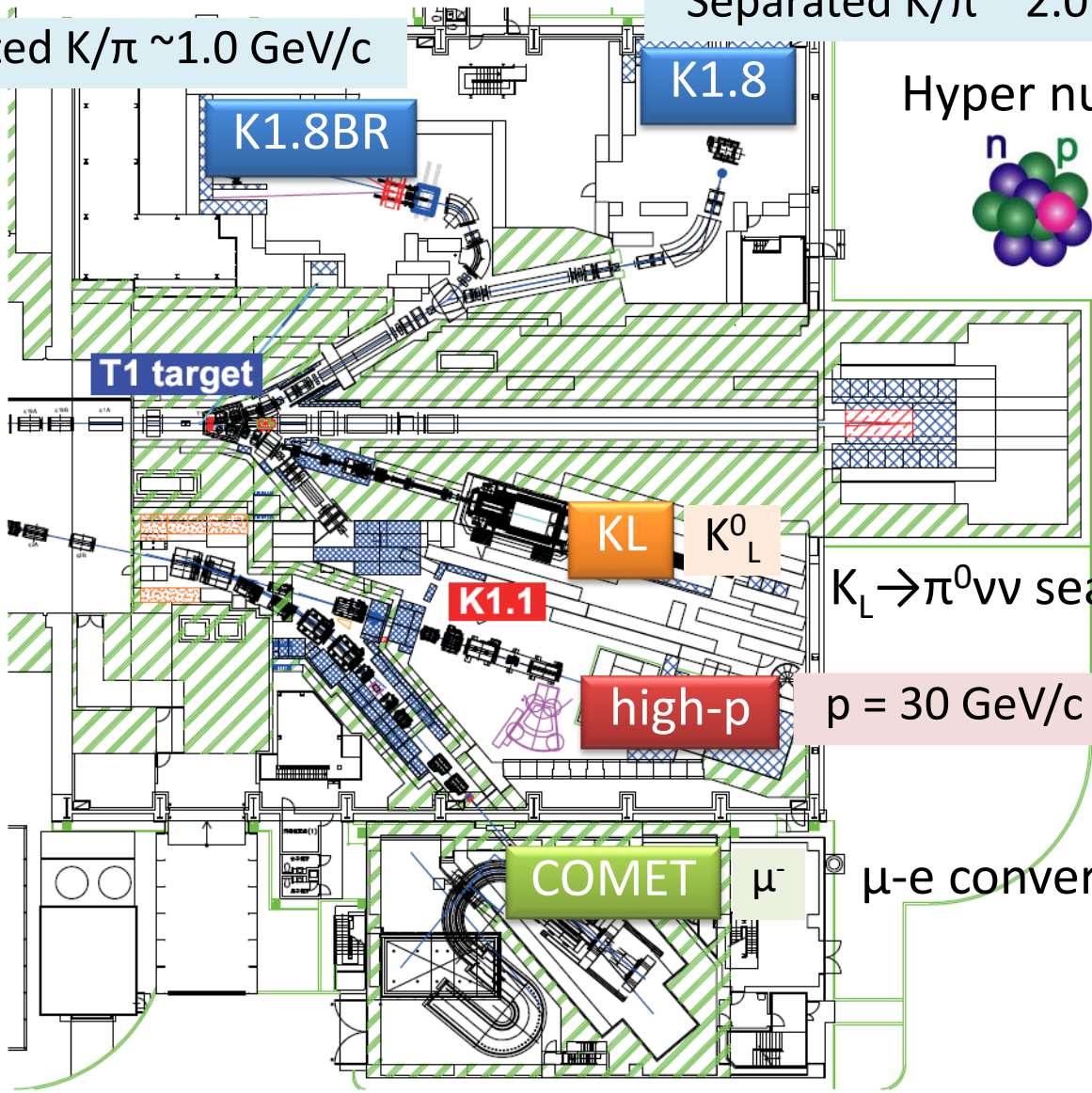
Separated K/π ~ 2.0 GeV/c

Kaonic nuclei



Hyper nuclei





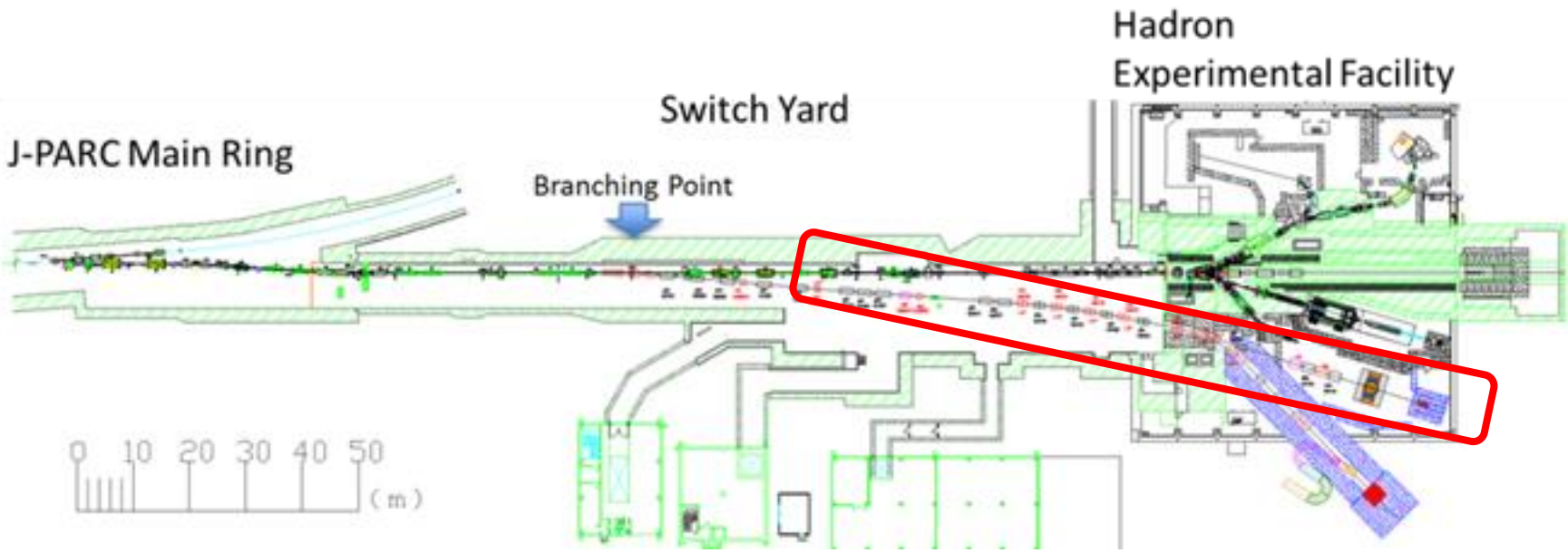
$K_L \rightarrow \pi^0 \nu\nu$ search

p = 30 GeV/c

μ-e conversion

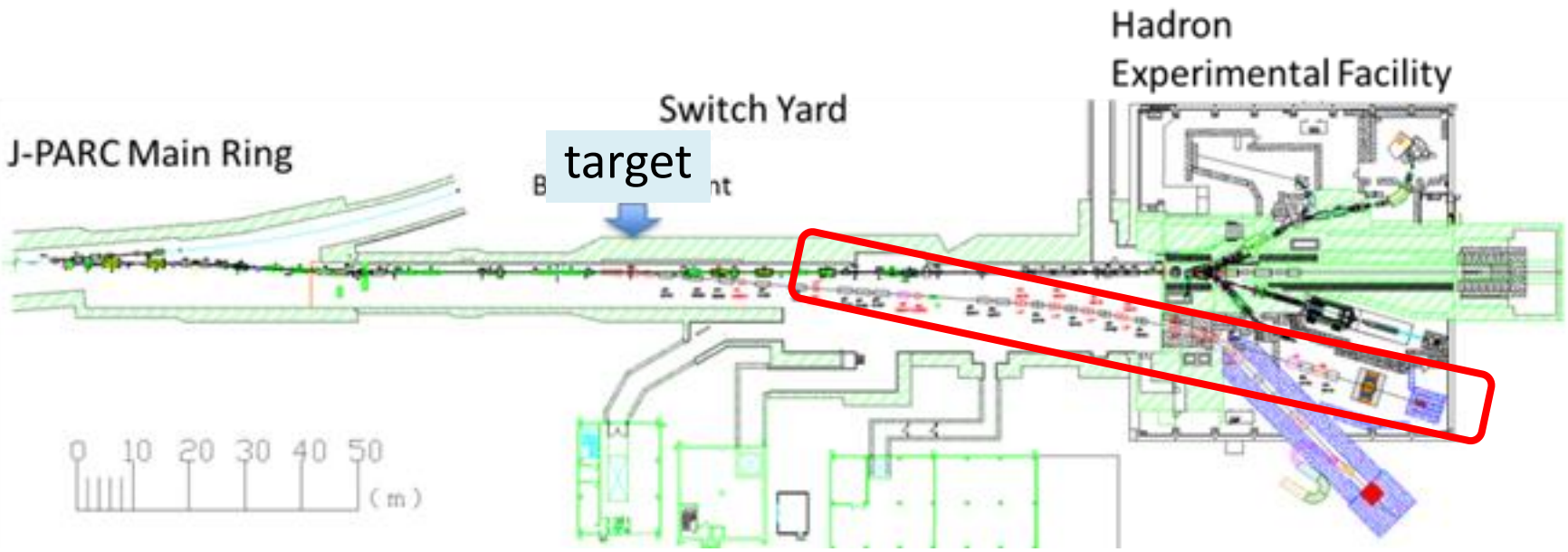
arXiv:2110.04462
[nucl-ex]

high momentum (high-p) beamline



- 2020 first beam
- Derive primary proton beam (30 GeV)
- 10^{10} proton/spill (5.2 s)
- Study of Φ meson mass modification in nuclei (E16)
    - $p + A \rightarrow \Phi + X$
    - $\Phi \rightarrow e^+e^-$

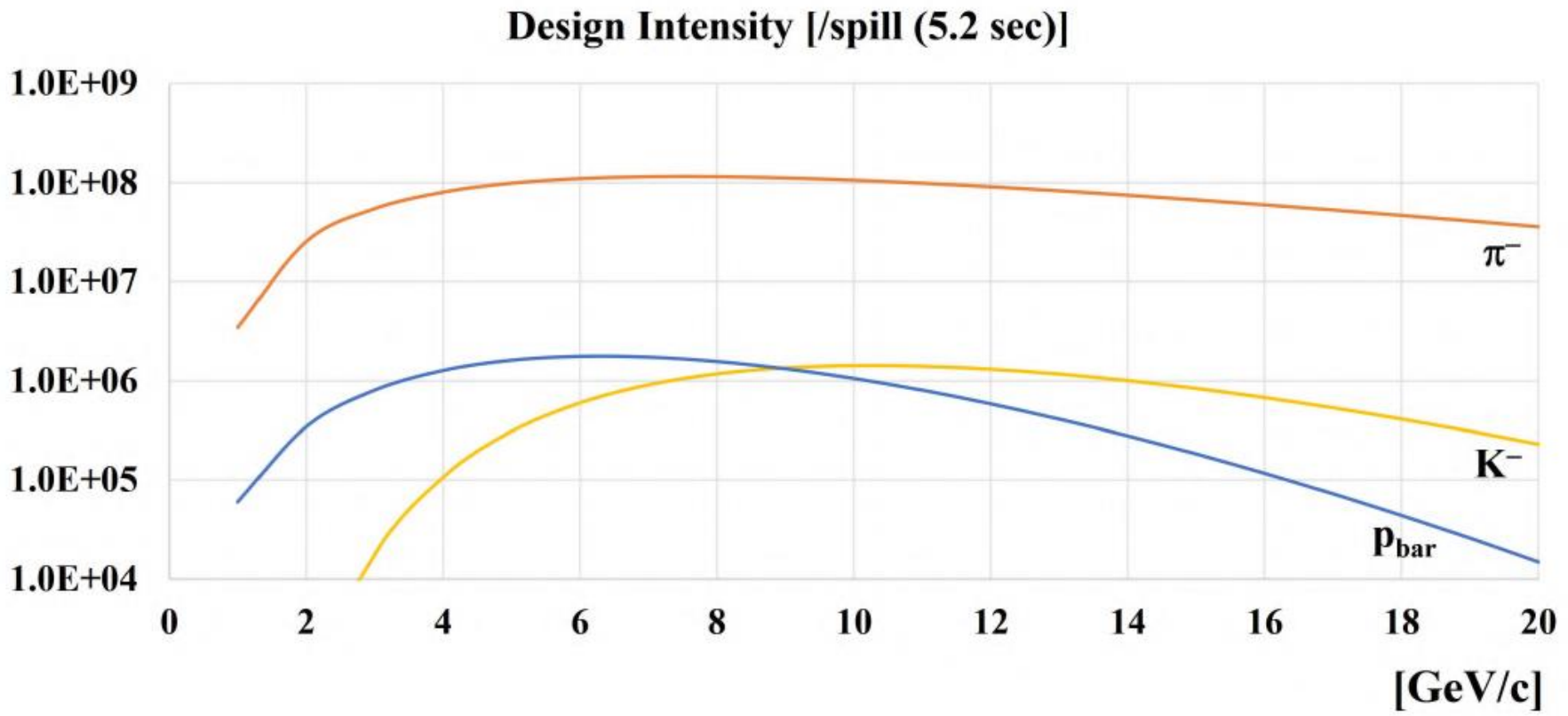
π20 beamline



- Derive secondary beam ($\pi/K/p_{bar}$) to the high-p beamline
- Place a target at the branching point
- Install polarity change devices, focusing magnets in the high-p beamline
  (positive proton beam → negative secondary beam)

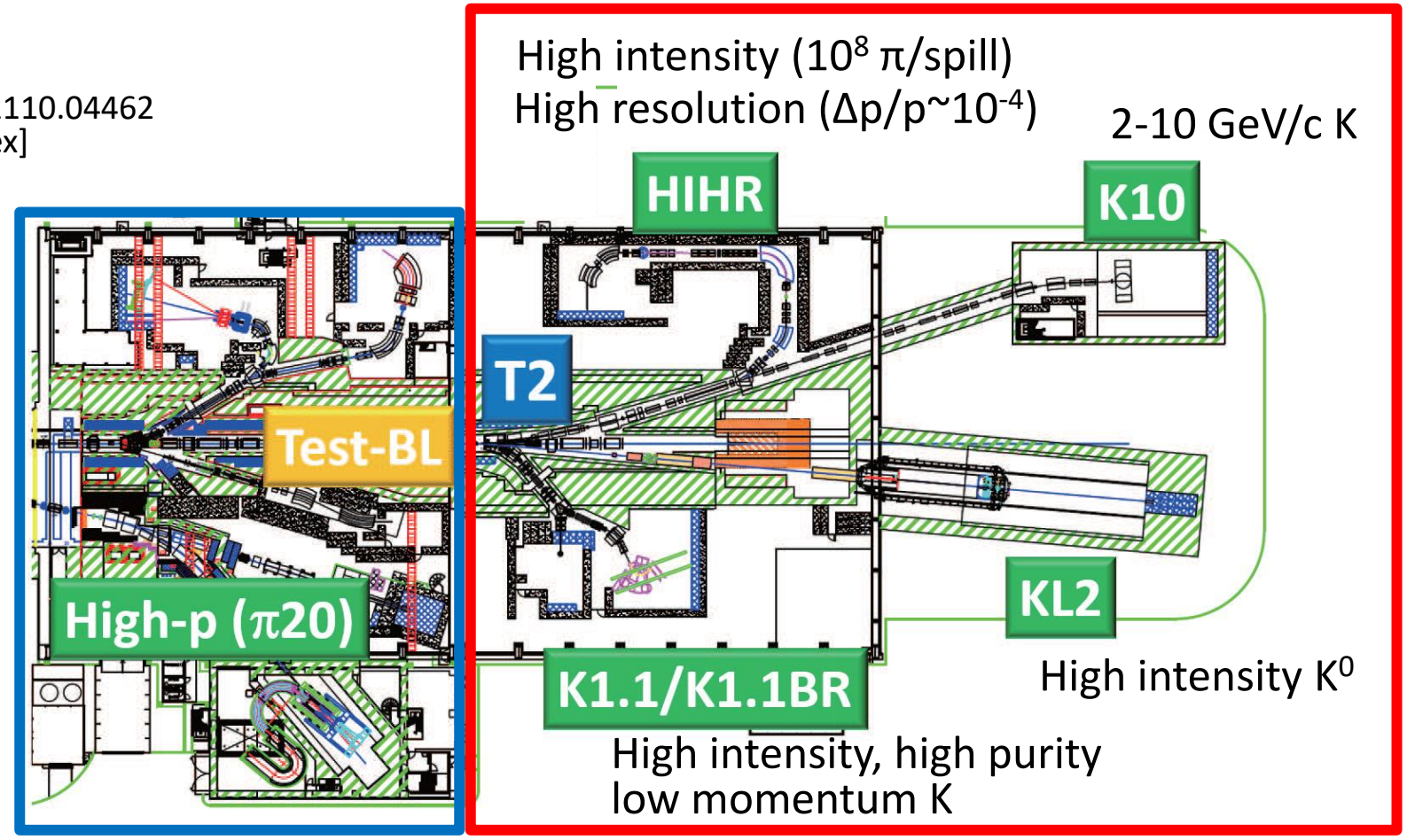
π20 beamline

- High intensity : $\pi^- > 10^7$ Hz
- High momentum resolution : $\Delta p/p \sim 0.1\%$ (RMS)
- Unseparated beam : π/K/pbar identification by beam PID detectors



Hadron hall extension

arXiv:2110.04462
[nucl-ex]



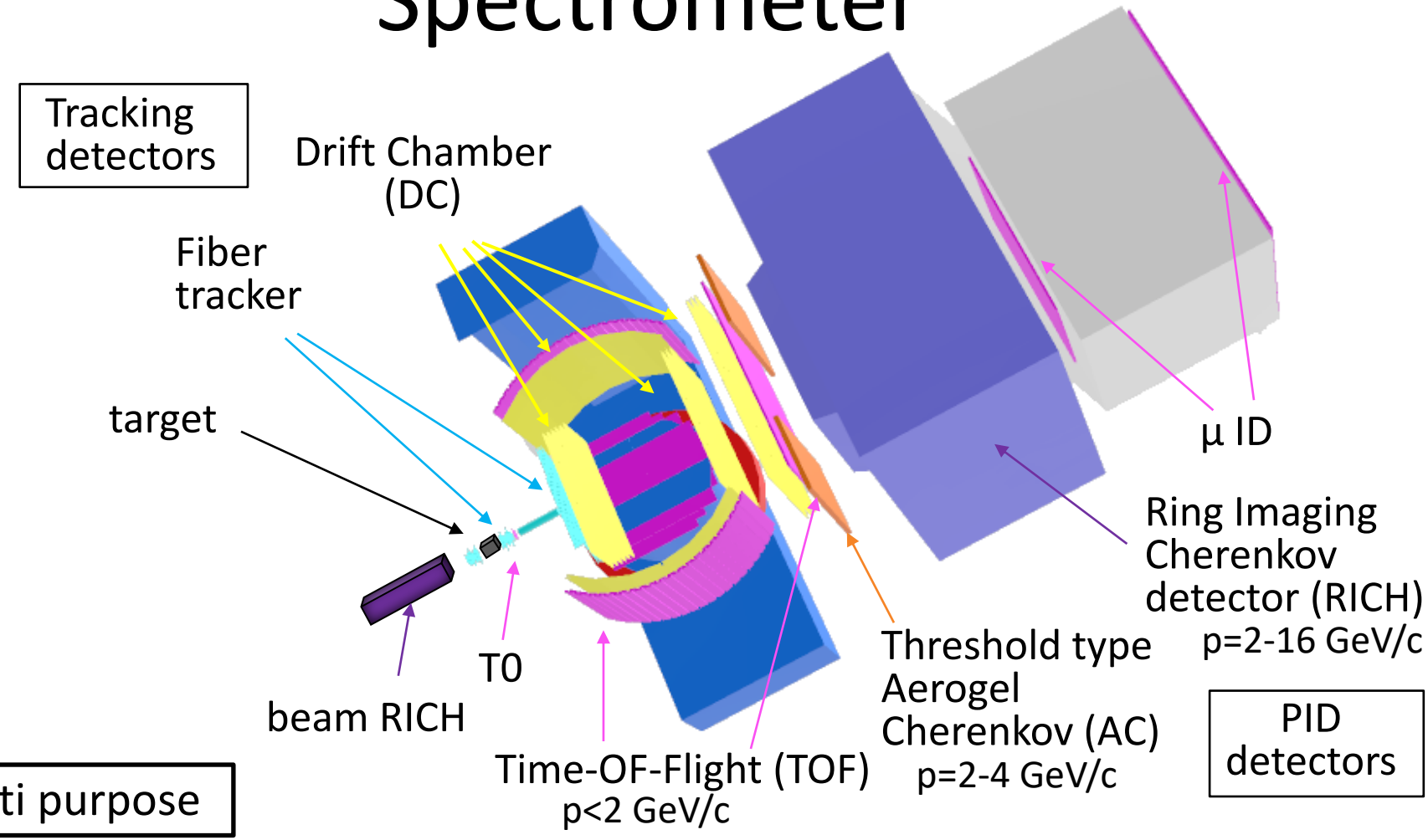
- Selected as the 1st priority project of KEK in 2022-2027
- π20 beamline construction together with the extension

Physics programs at π20 beamline

- Hadron structure
  - Exclusive Drell-Yan (GPDs) (LoI)
  - Charmed baryon spectroscopy (E50)
  - Ξ baryon spectroscopy (LoI)
  - High isospin dibaryon search (E79)
- Λp scattering cross section (LoI)
- Φ production (Proposal submitted)

Carry out experiments with a common setup :
multi-purpose spectrometer

Spectrometer



- Streaming DAQ : no hardware trigger R. Honda et al., PTEP 123H01 (2021)
- High rate stability : 1MHz/1 mm @ center
- Large acceptance • High momentum resolution

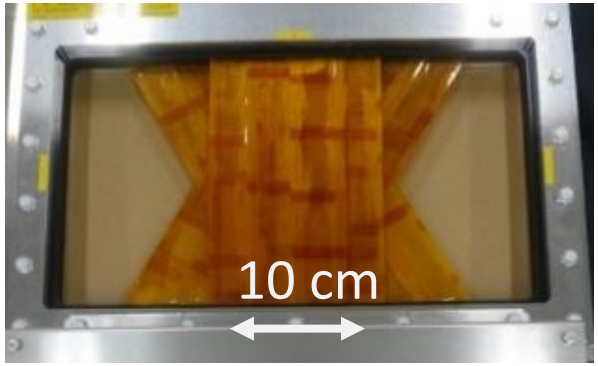
Suited for exclusive measurements

Tracking detectors

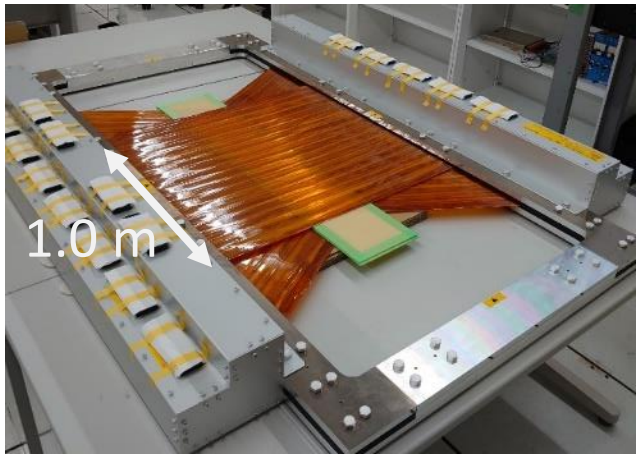
Fiber Trackers

- High rate : 1 MHz/mm
- Fiber scintillators

Beam Fiber Tracker (0.5 mm Φ)



Scattered Fiber Tracker (1.0 mm Φ)

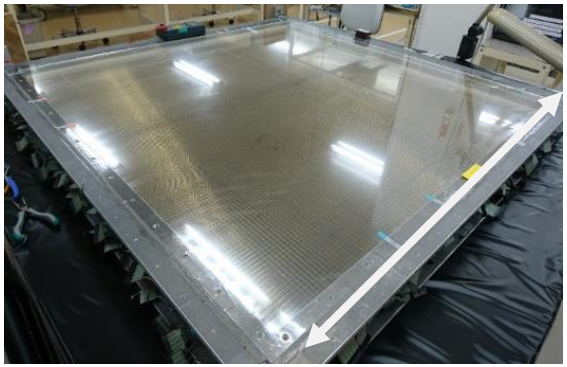


x6 : Ready

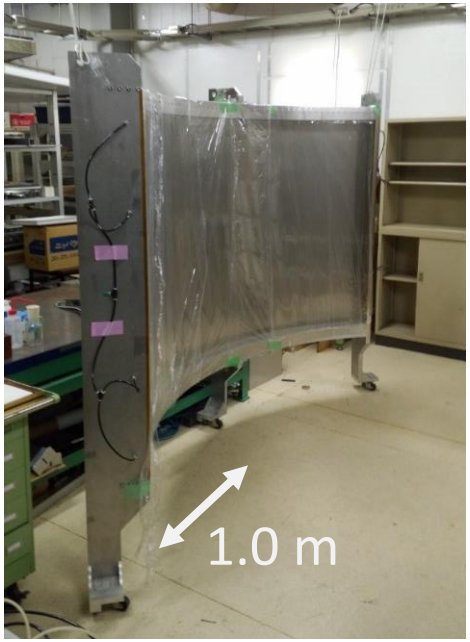
Drift Chamber (DC)

- Large acceptance

Target Downstream DC



Inner DC

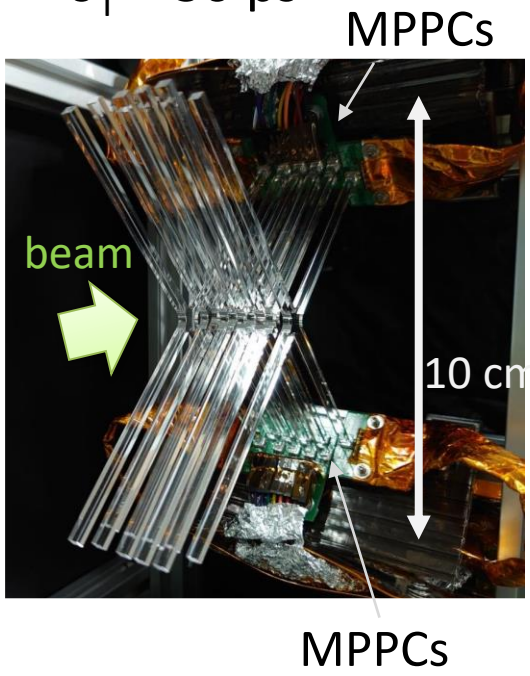


x4 : ready
x1 : start construction in 2022
x1 : planned

TOF detectors

T0

- Cherenkov + MPPC
- Suppression of dark currents using shot key barrier diode
- σ_T ~ 30 ps



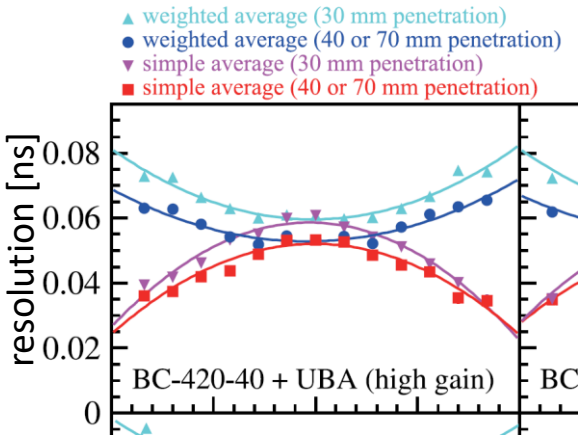
Ready

Forward TOF

- 1.8 m-long scintillator + PMT

T. Ishikawa et al.,
NIM A 1039 (2022)
167164

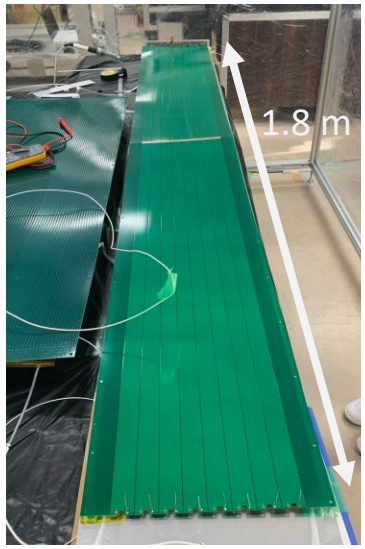
Production in 2022



Side TOF

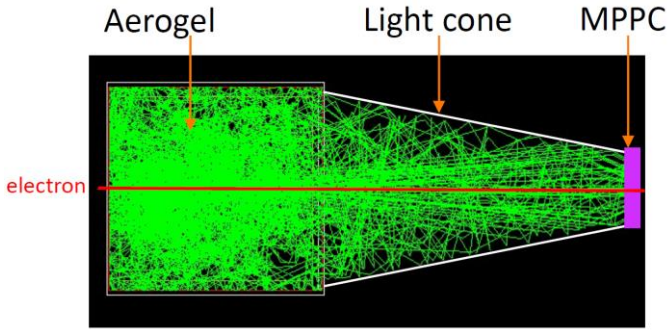
- 1.8 m-long Resistive Place Chamber (RPC)

Prototype test in 2022



PID detectors

Threshold type Aerogel Cherenkov

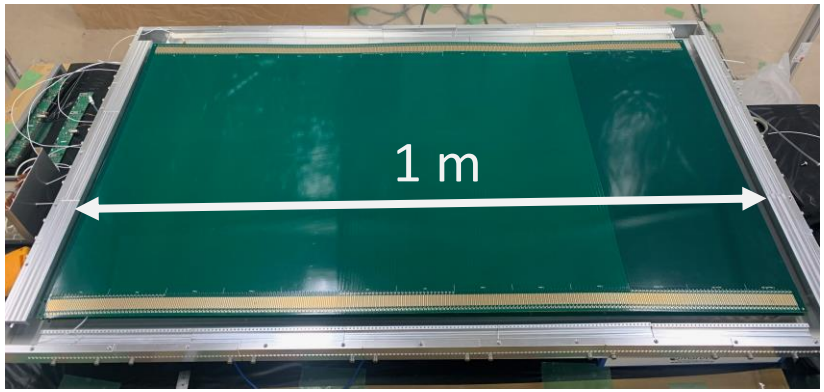


Geant4 simulation

Light cone + MPPC : design completed

μ ID tracker

- Resistive Plate Chamber (RPC) based tracker



Prototype test in 2022

Ring Imaging Cherenkov detector (RICH)

- MPPC + light guide cone

Prototype test in 2022

Electronics

ASAGI

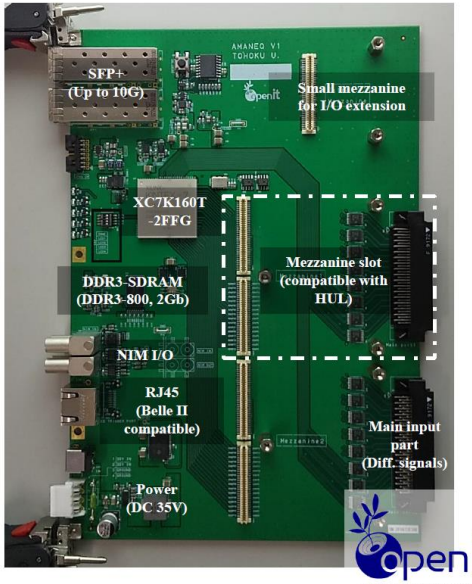
- Amp-Shaper-Discriminator Card for DCs
- Testing a prototype board

CIRASAME

- Multi MPPC readout card for Fiber Trackers and Cherenkov counters
- Testing a prototype board

AMANEQ

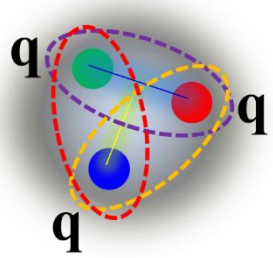
- The main electronics board for the trigger less data acquisition system
  - Mezzanine card
    - HR-TDC
    - LR-TDC
    - Clock distribution
- Ready



Charmed baryon spectroscopy

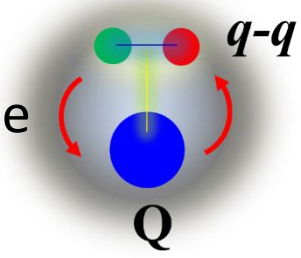
- Study of **the effective degree of freedom** of hadrons in low energy QCD
- Probe **di-quark correlation**

Light quark baryon

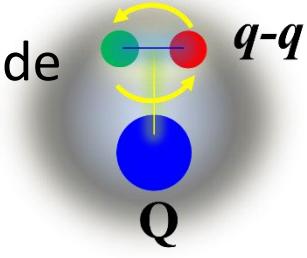


Charmed baryon

λ-mode



ρ-mode

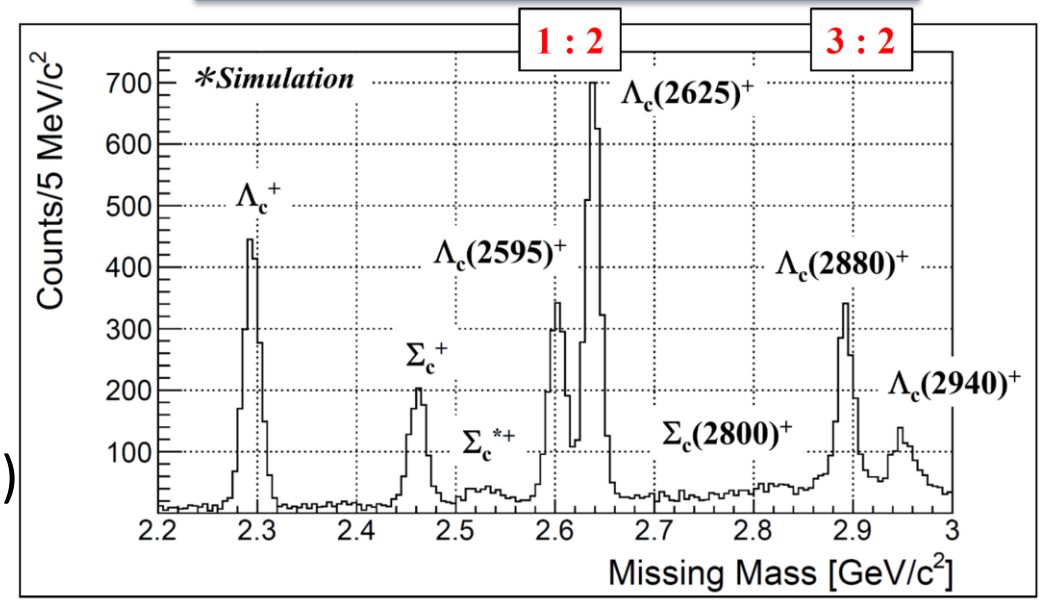


First missing mass spectroscopy of charmed baryons

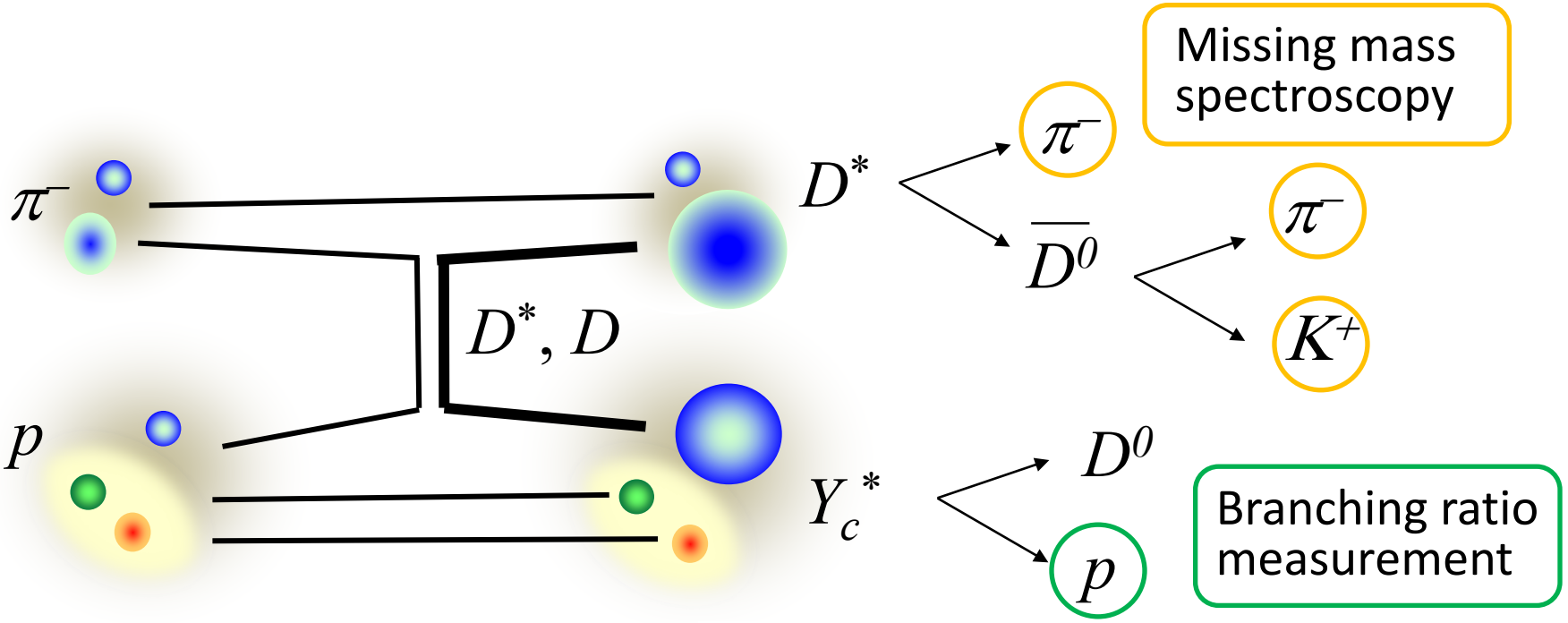
- Probe di-quark correlation from the ratio of the production cross section / branching fraction of excited states

⇔ Collider experiments (LHCb, belle)
(Invariant mass measurement)

Expected missing mass spectra



Charmed baryon spectroscopy

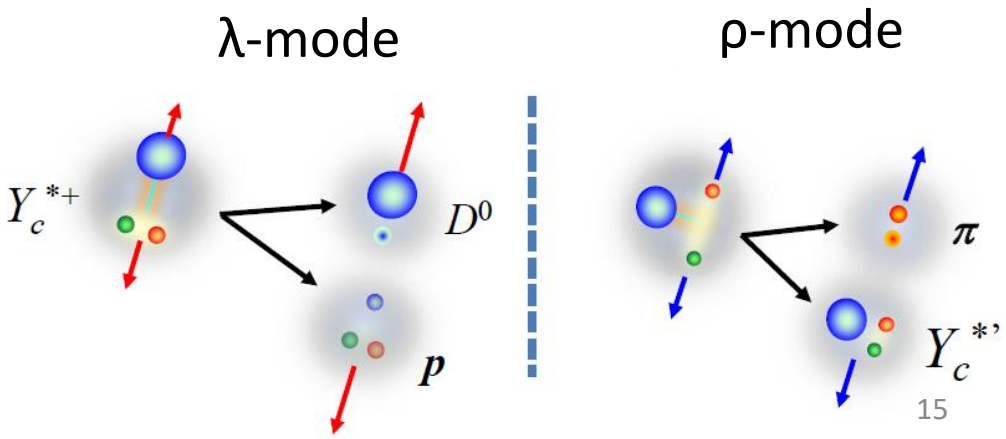


Theoretical studies

S.H. Kim et al, Phys.Rev . D92 (2015) 094021

S.H. Kim et al, PTEP 10 (2014) 103D01

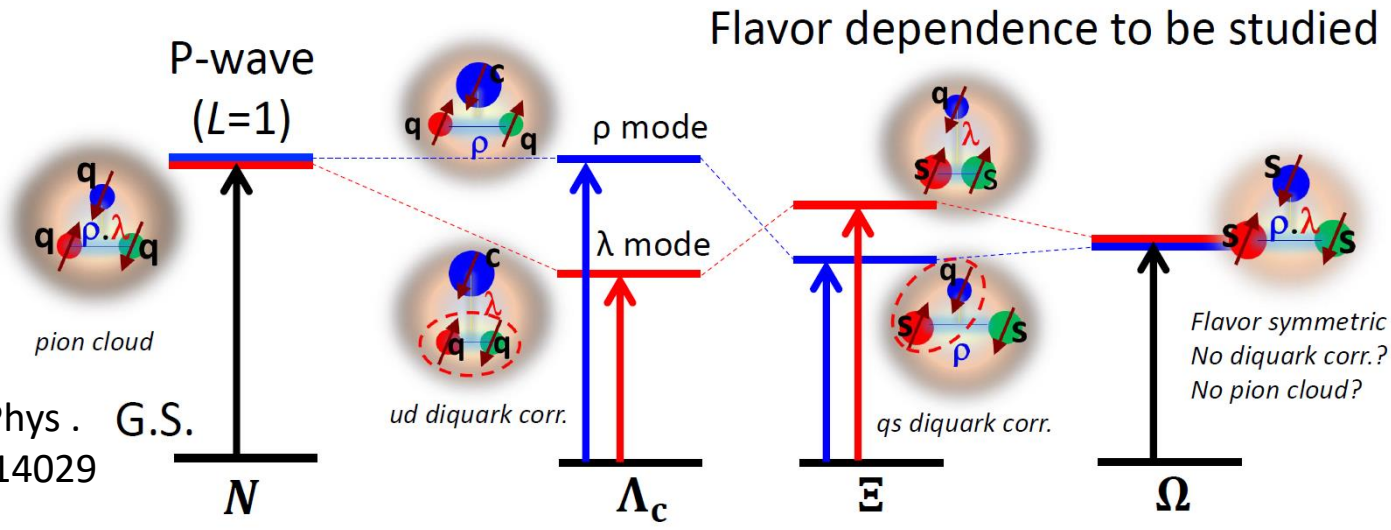
S.I Shim, et al, PTEP 2020, (2020) 5, 053D01



Ξ (s=-2) baryon spectroscopy

$K^-p \rightarrow K^+\Xi^{*-}$

$K^-p \rightarrow K^{*0}\Xi^{*0}$

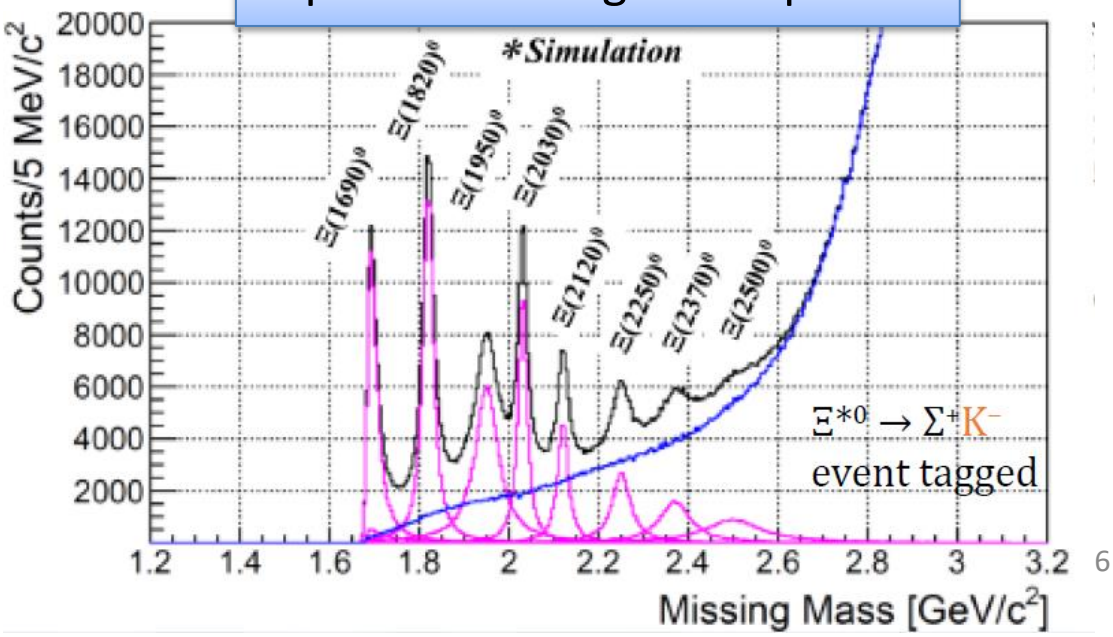


T. Yoshida, et al., Phys . Rev. D 92 (2015) 114029

PDG

Particle	J^P	Overall status
Ξ(1318)	1/2+	****
Ξ(1530)	3/2+	****
Ξ(1620)		*
Ξ(1690)		***
Ξ(1820)	3/2−	***
Ξ(1950)		***
Ξ(2030)		***
Ξ(2120)		*
Ξ(2250)		**
Ξ(2370)		**
Ξ(2500)		*

Expected missing mass spectra



I=3 dibaryon search

- Dibaryon : 2 baryons ?, 6 quarks ?
- D_{IJ} : Dibaryon with I=isospin, J=spin

This exp

J. Dyson and N.-H. Xuong, PRL 13 (1964) 815

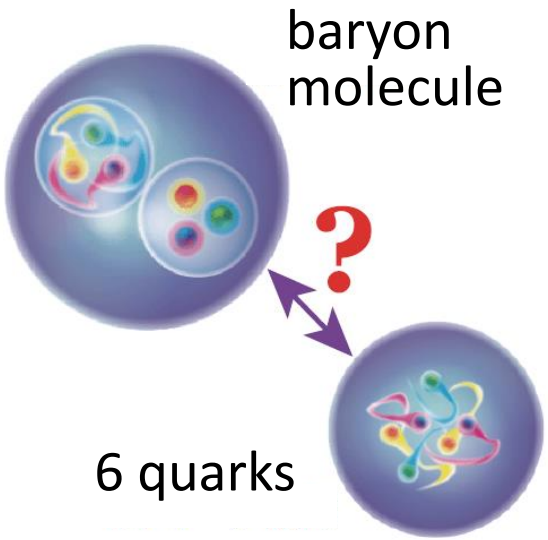
dibaryon	$\mathcal{D}_{01}$	$\mathcal{D}_{10}$	$\mathcal{D}_{12}$	$\mathcal{D}_{21}$	$\mathcal{D}_{03}$	$\mathcal{D}_{30}$
component	NN	NN	ΔN	ΔN	$\Delta\Delta$	$\Delta\Delta$

Deuteron

d*(2380)

H. Clement Prog. Part. Nucle. Phys. 93 (2017) 195

- $m_{D30} \sim m_{D03}$ => baryon molecular
- $m_{D30} >> m_{D03}$ => 6 quarks



- $p+p \rightarrow \pi^-+\pi^-+D_{30}$
  - ↳ $\pi^++\pi^++{}^2He$
    - ↳ $p+p$

Λp scattering

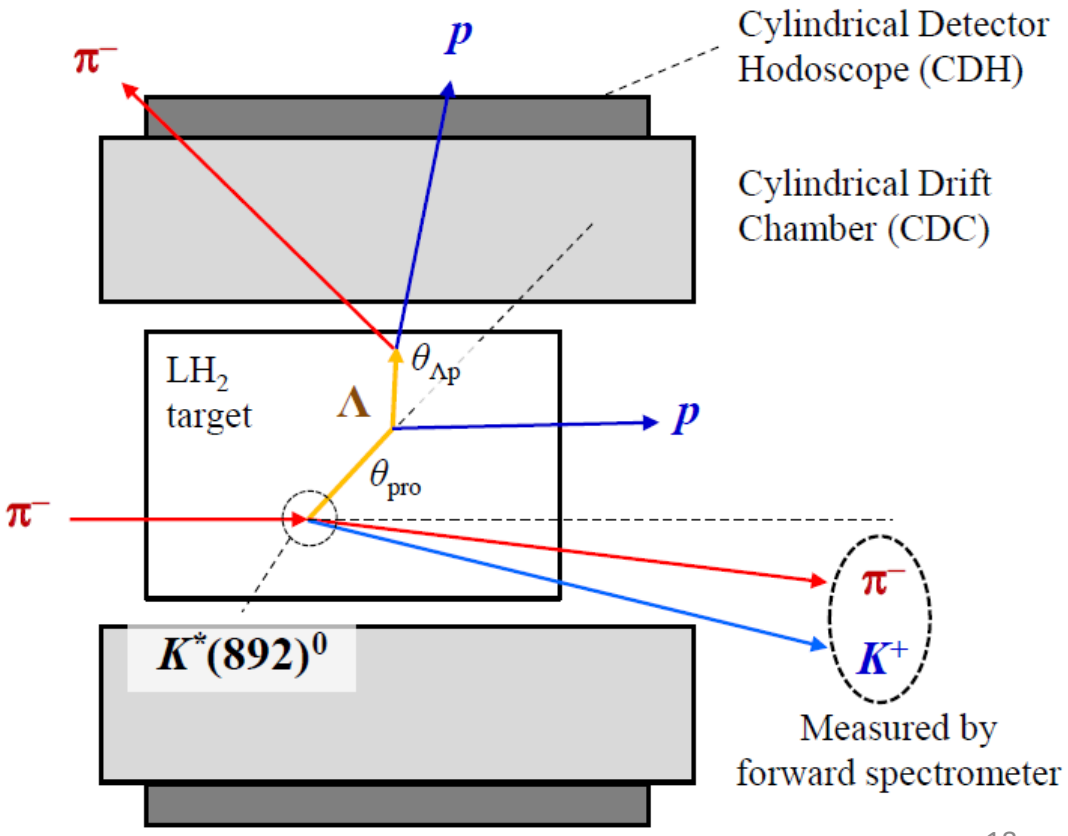
- Λ(uds)-p scattering cross section : basic information to understand baryon-baryon interaction including hyperons
- Short life time of Λ : $\tau = 2.6 \times 10^{-12}$ s, $c\tau = 7.9$ cm
- No differential cross section measurement up to now

Background-free Λ tag

$\pi^- p \rightarrow \Lambda K^{*0}$

$K^{*0} \rightarrow K^+ \pi^-$

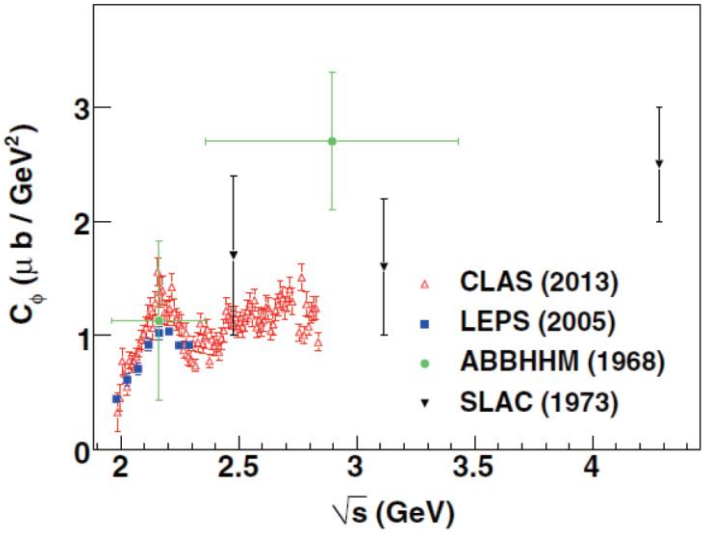
Measurement of differential Λp scattering cross section at $0.4 < p_\Lambda < 1.4$ GeV/c



Φ production

- Φ(s$\bar{s}$) : weak interaction with nucleons
  => No nucleon resonances coupled to ΦN?

- A bump observed in γp→Φp reaction <= t-channel dominant



Dey et al., PRC 89 (2014) 055208

- Measurement of $\pi^- p \to \Phi n$ => s-channel dominant
  → suited to study ΦN resonances

- The early stage experiment at the π20 beamline with low intensity π^-

Summary

- High momentum secondary beamline is planned at J-PARC
  20 GeV/c π/K/pbar π20 beamline
- Detectors for multi-purpose spectrometer is under construction
  - High momentum resolution
  - Large acceptance
  - High rate capability

  Suited for precise exclusive measurements
- Variety of physics programs are expected
  - Exclusive Drell-Yan (GPDs)
  - Charmed baryon spectroscopy
  - Ξ baryon spectroscopy
  - High isospin dibaryon search
  - Λp scattering cross section
  - Φ production

Proposals/LoIs : https://j-parc.jp/researcher/Hadron/en/Proposal_e.html

Thank you for your attention !