Hadron Physics at J-PARC

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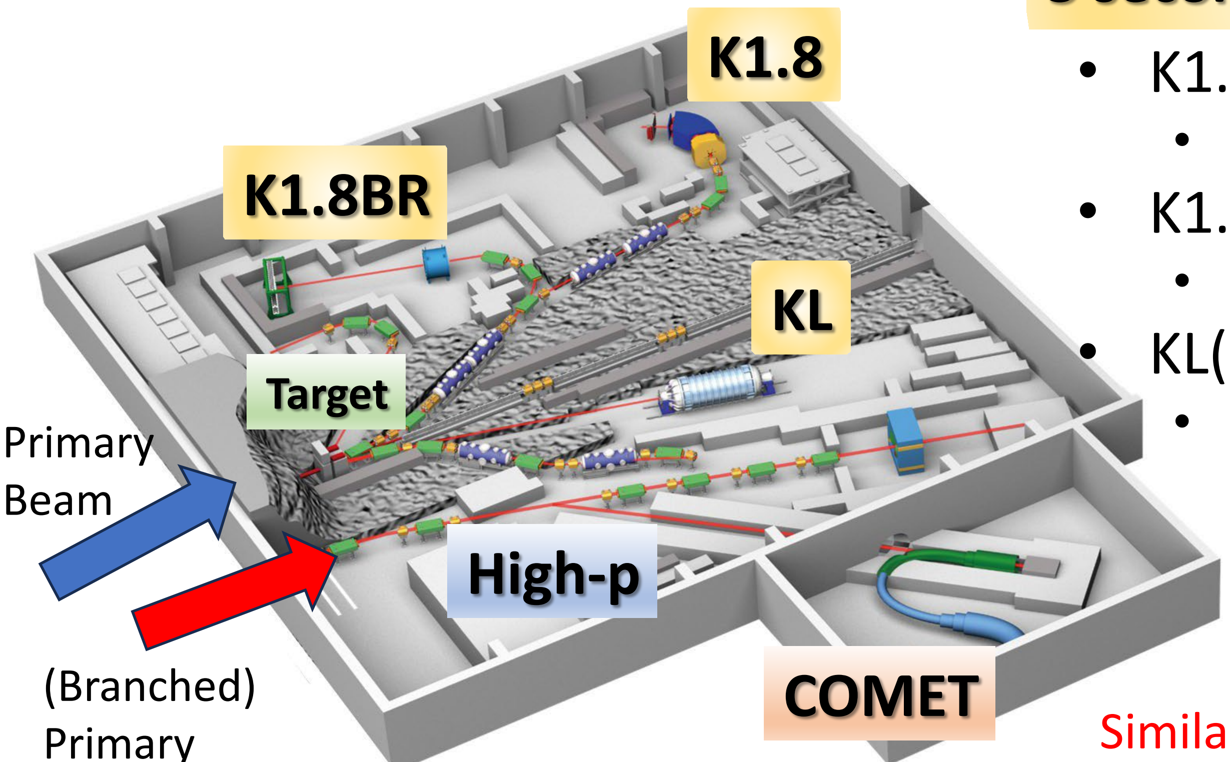
1. J-PARC hadron hall introduction
2. Strange nuclear physics
3. Hadron physics
4. Future plan & Summary

1. J-PARC hadron hall introduction

Current Status(2024) of J-PARC Hadron Hall

Slow extracted Primary Proton beam::30GeV, 2/(4.2-5.2)s cycle, 7×10^{13}protons/spill



3 secondary beamline

- K1.8(nucl phys)
  - ～$1 \times 10^6 K^-$/spill, <2GeV/c
- K1.8BR(nucl phys)
  - ～$0.5 \times 10^6 K^-$/spill, <1.1GeV/c
- KL(part phys)
  - ～$1 \times 10^7 K^0$/spill, ～2GeV/c

1 branched primary beamline

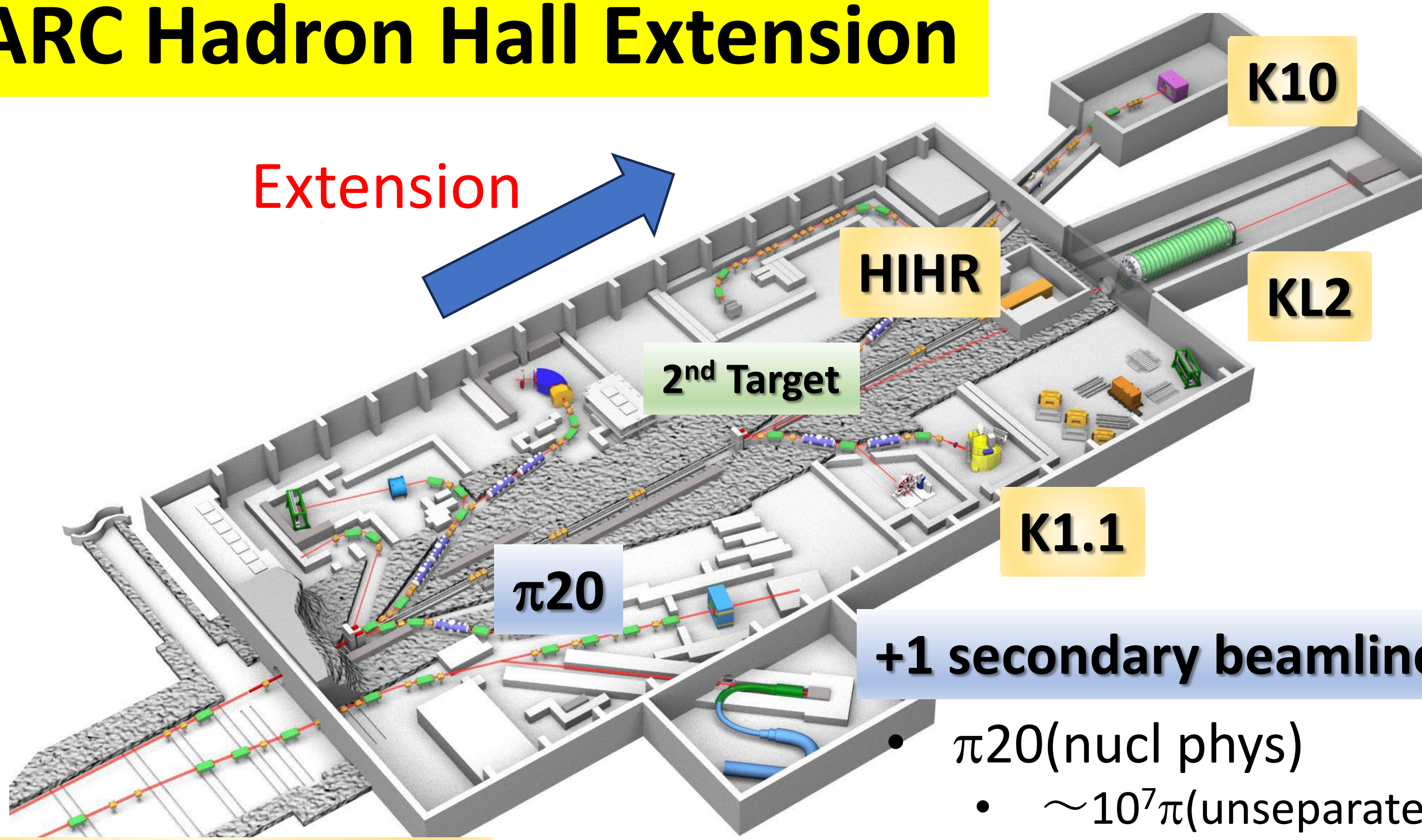
- High-p(nucl phys)
  - ～1×10^{10}proton/spill, 30GeV

Similar SIS100 Proton

1 primary beamline

- COMET(part phys)
  - ～10^{12}proton/spill, 8GeV

J-PARC Hadron Hall Extension



+1 secondary beamline

- π20(nucl phys)
  - ～$10^7\pi$(unseparated)/spill ～20GeV/c

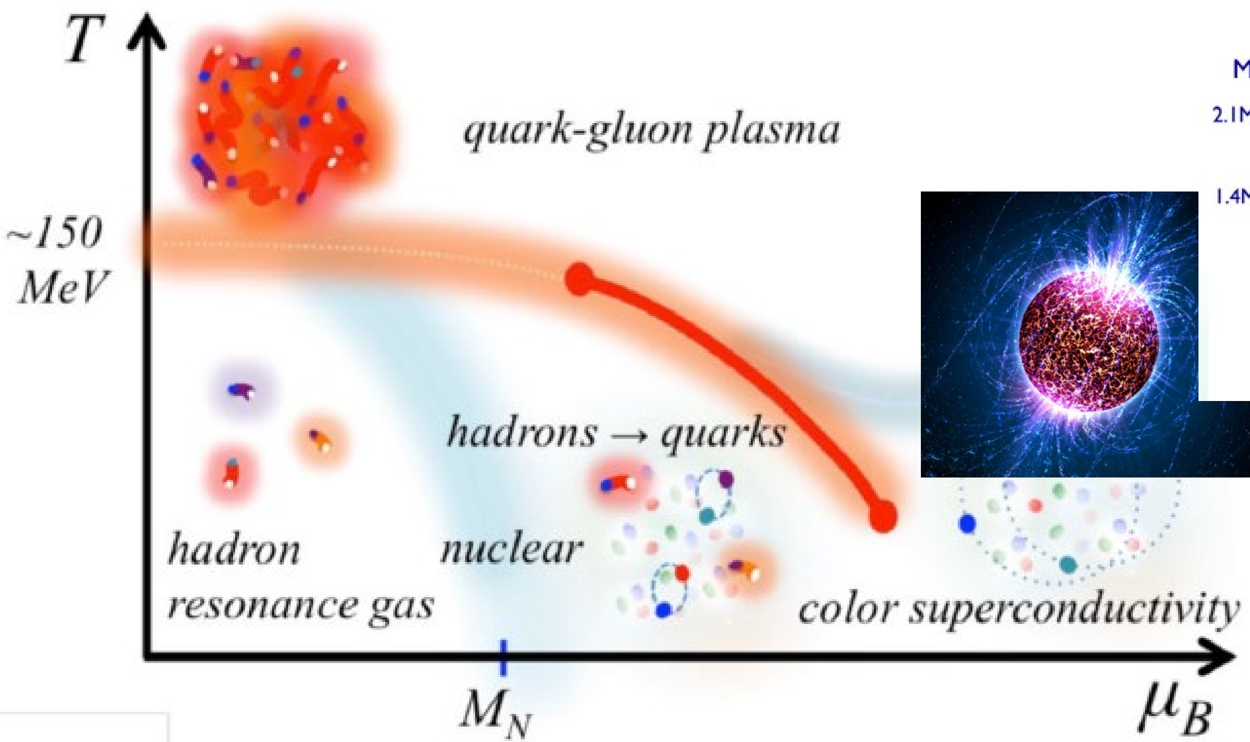
+4 secondary beamline

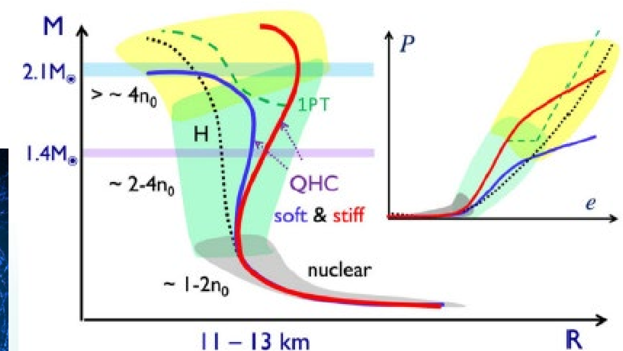
- HIHR(nucl phys)
  - $\Delta p/p$～0.01%, >$10^8\pi$/spill, <2GeV/c
- K10(nucl phys)
  - $\Delta p/p$～0.1%, >10^6K/spill, ～10GeV/c
- K1.1(nucl phys)
  - Separated K ～1.1GeV/c
- KL2(part phys)
  - x～3 intensity than KL

High density QCD matter(My interest)

- Why $\sim 2M_{\odot}$ exists?
- What a kind of phase at the core?

One of the solution is accumulation of microscopic information.
Understanding of QCD nature will help the answer for above questions





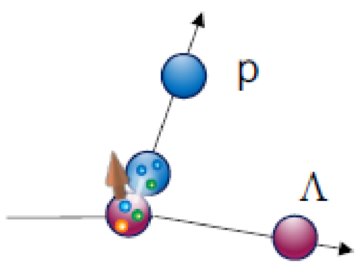
2. Strange nuclear physics

High Density Baryonic Matter

Key issue of neutron star EOS

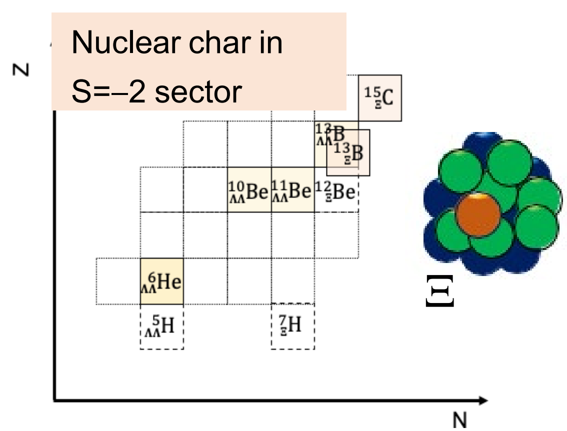
- Establishment of generalized baryon-baryon interaction
- Density dependance of B-B interaction
  (including 3-body or higher interaction)

Experimental approaches at J-PARC

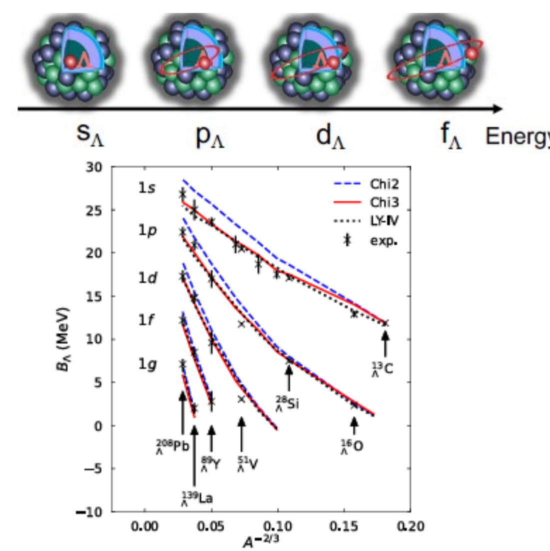


Hyperon scattering experiments

Extension hyper-nuclei chart to S=-2



Systematic study of deep bound hypernuclei

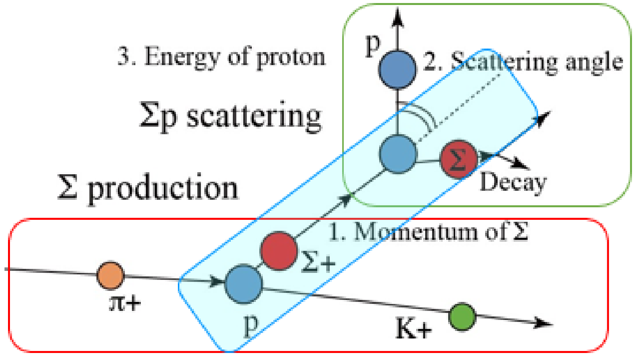


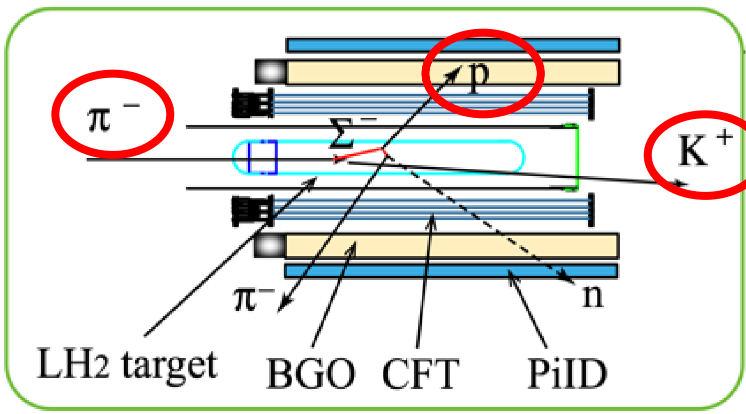
PRC108 065803

Hyperon scattering

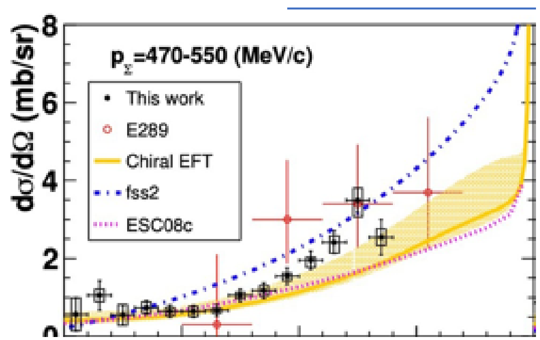
PRC 104, 045204
PRL 128, 072501
arXiv:2203.08393

$\pi\, p \rightarrow \Sigma^{+-}$ $\Sigma^{+-}\, p \rightarrow \Sigma^{+-}\, p$

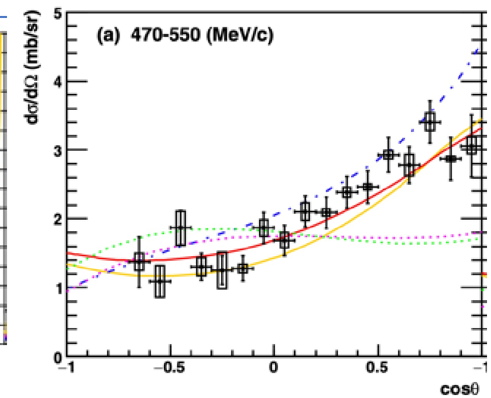




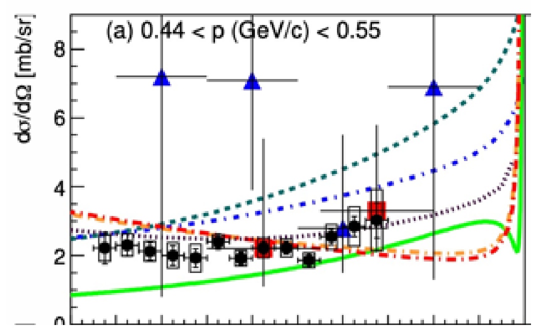
$\Sigma^{-}\, p \rightarrow \Sigma^{-}\, p$



$\Sigma^{-}\, p \rightarrow \Lambda\, n$



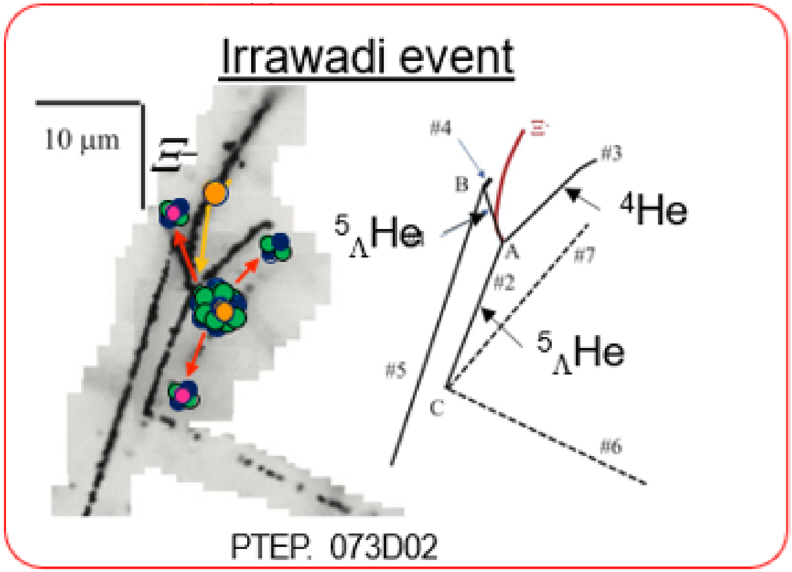
$\Sigma^{+}\, p \rightarrow \Sigma^{+}\, p$



Fundamental & Important info for understanding of B-B forces!

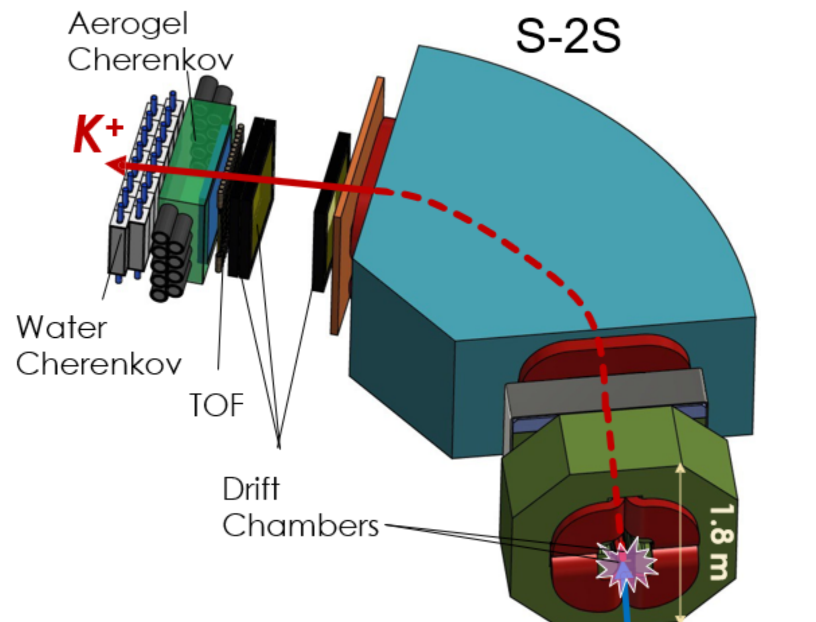
In future, polarized Λ p scattering will be measured with similar setup.
Consideration of low momentum extension is on going.

Ξ Hypernuclei



Emulsion has excellent resolution.
J-PARC emulsion experiment has been found 2 bound state.
(BE～1MeV & BE～6MeV)
ΞN interaction sees to be attractive.

Coming soon experiment



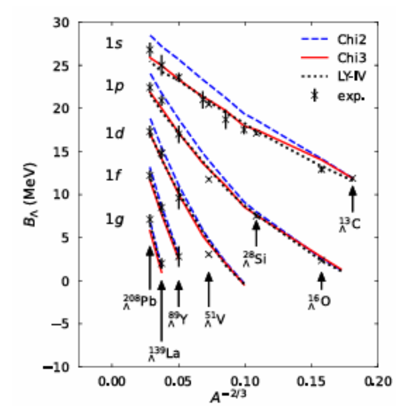
$$\frac{\Delta p}{p} = 5.5\times10^{-4} \text{ (FWHM)}$$

Ξ hypernuclei study via missing mass method become possible soon with newly constructed “S-2S” spectrometer with good resolution

Systematic study of deep bound hypernuclei

HIHR beamline will be constructed in hadron extension project.

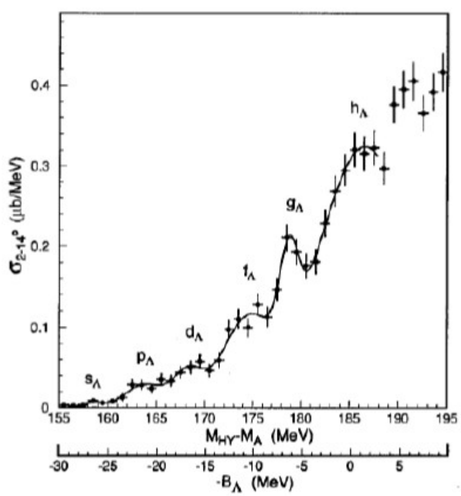
Momentum dispersion matching
→ high intensity (～$10^8\pi$/spill)
& high resolution($\Delta p/p$～0.01%)

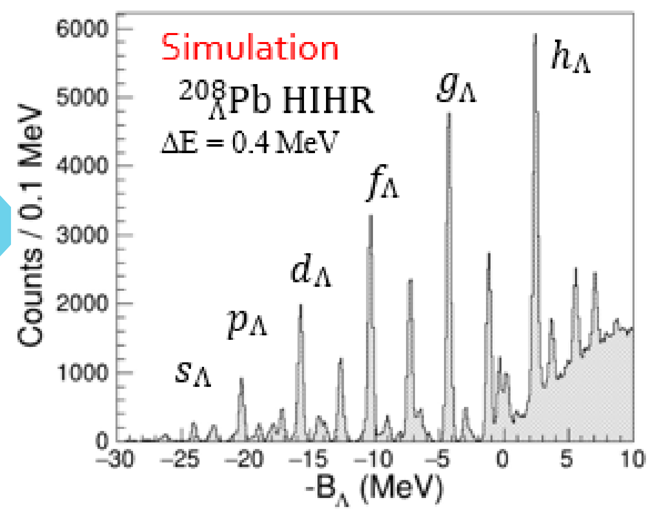


PRC108 065803

HIHR expectation

KEK
E369





3body force
will be determined
presisely

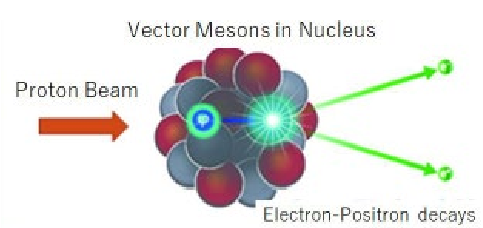
3. Hadron physics

Baryon to Quark

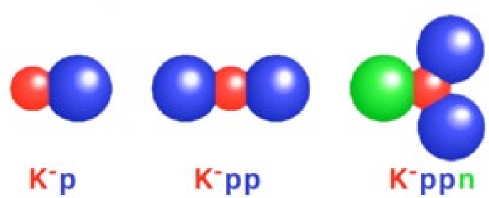
Quark matter may emerge at the core of neutron star
Detail of phase structure has strong model & parameter dependance.
→Improvement of effective theory is necessary.

- Hadron property in dense medium. How mass generated?
- Diquark degree and its property
- KMT interaction

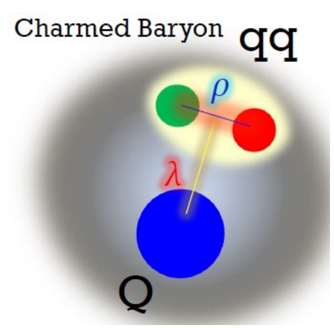
Experimental approaches at J-PARC



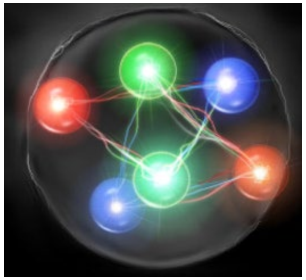
Vector meson in nuclei



Systematic study of KN system

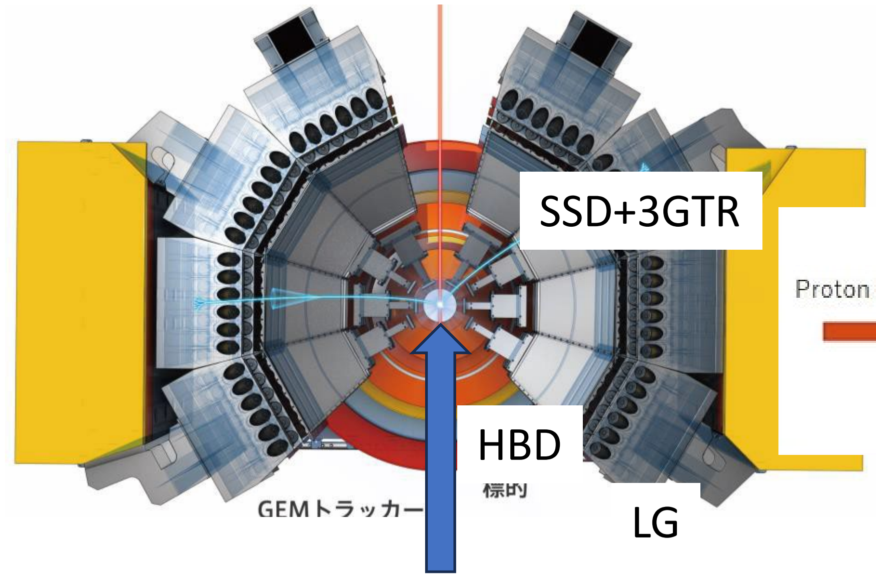


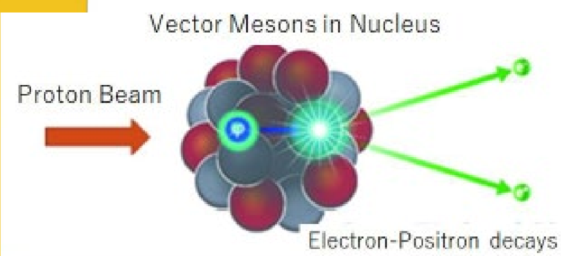
Heavy baryon spectroscopy

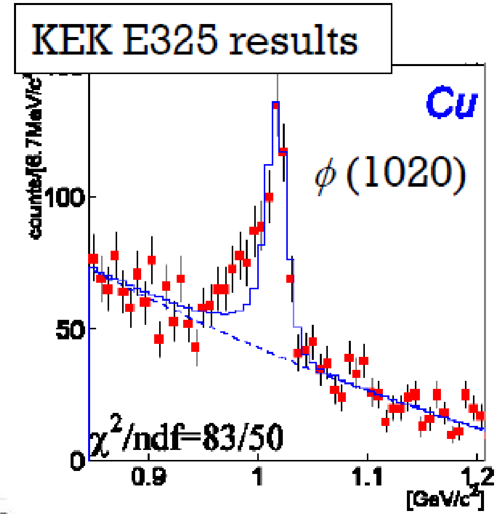


Exotic states

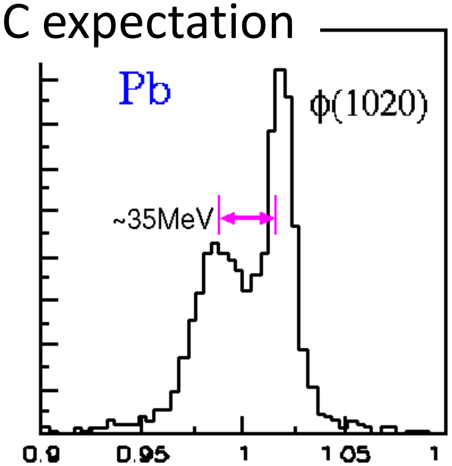
Vector Meson in Nuclei







J-PARC expectation

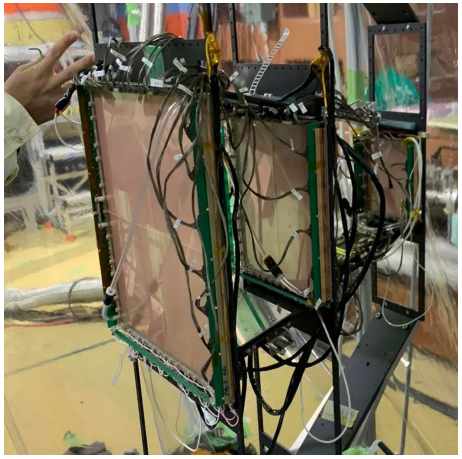


Branched primary proton beam
(～10^{10}p/spill, 30GeV)
p A → ρ/ω/ϕ X → e^+e^- X
Most high rate experiment at hadron hall

By using high statistics & good resolution,
systematic study(target, momentum)
of spectral change will be performed.
It will reveal density dependance of generated mass.
Experiment is under commissioning.

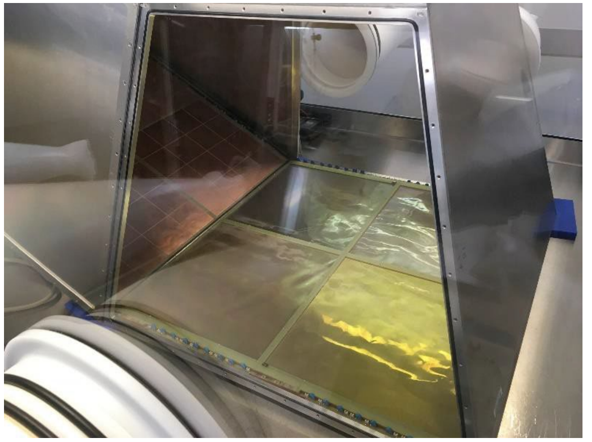
I am mainly working on this project…

GTR(GEM tracker)



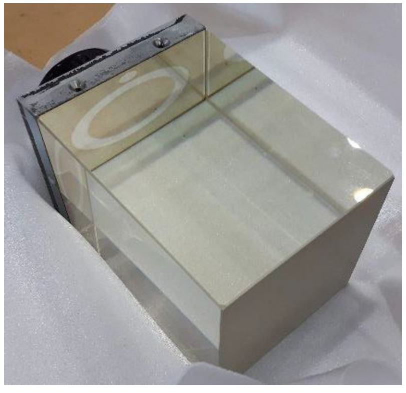
2 strip readout
σx:100um σy:300um

HBD(Hadron blind detector)



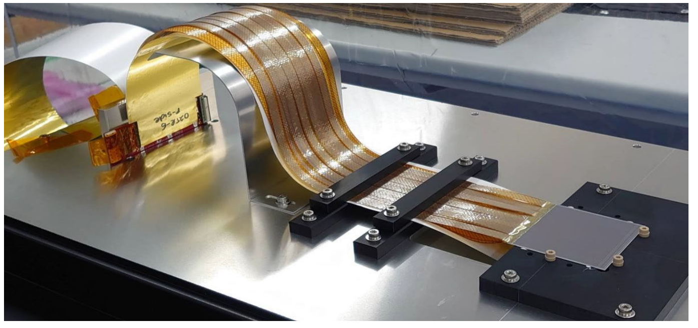
Cherenkov detector with CF4 radiator
～200 rejection power with 65% efficiency

LG(Lead Glass)



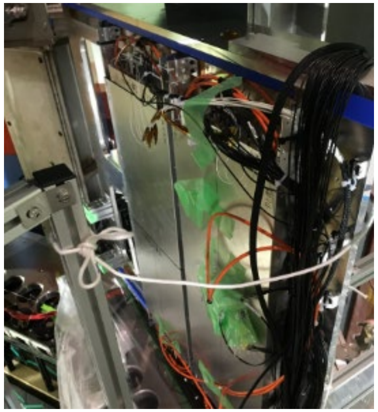
～10 rejection power with 90% efficiency

CBM SSD(STS)

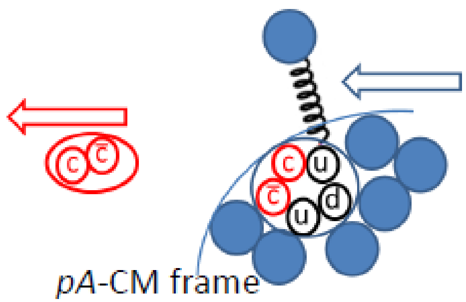


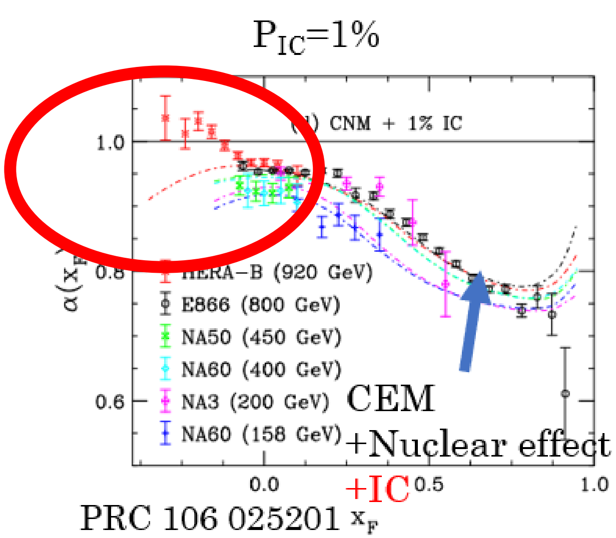
Position resolution: 25 um
Time resolution: 6 ns

Related experiments are planning



MRPC
TOF for
K ID





@branched primary beamline

- p A→ ϕ X → K^+ K^- X

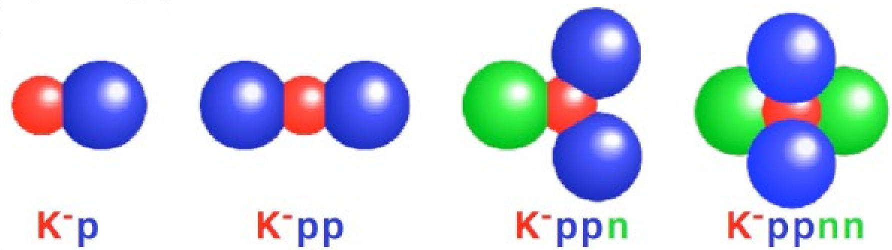
Good comparison with ϕ → e^+ e^-
Effect of final state interaction(K N) will be studied

- p A→ J/ψ X → e^+ e^- X

Target nuclei dependances of J/ψ cross section at mid & backward rapidity

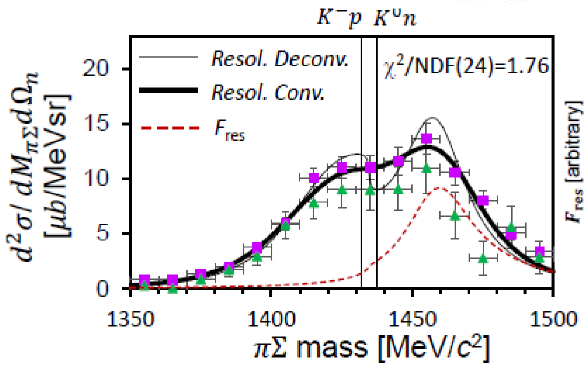
The effect of charm component in nuclei (intrinsic charm) will be seen also in backward region

Systematic study for KN system



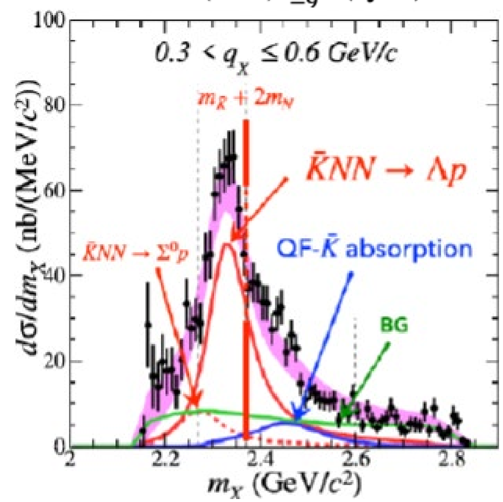
PLB837, 137867
PRC100, 044002

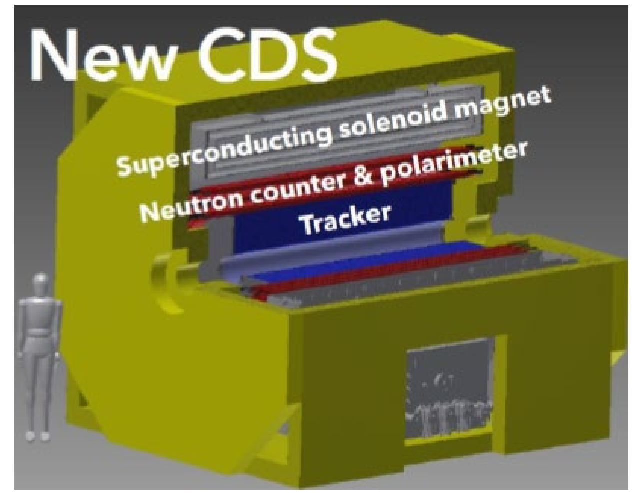
Subthrehold KN scattering

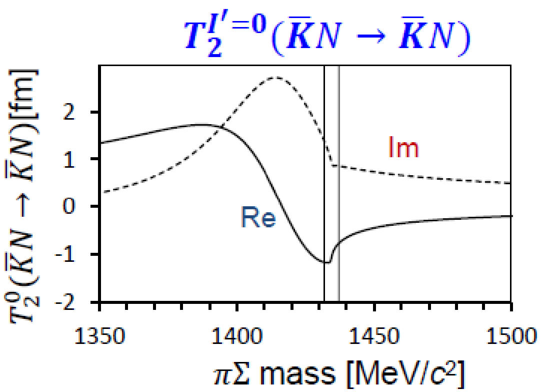


$BE = 42 \pm 3$ (stat.) $^{+3}_{-4}$ (syst.) MeV

$\Gamma = 100 \pm 7$ (stat.) $^{+19}_{-9}$ (syst.) MeV





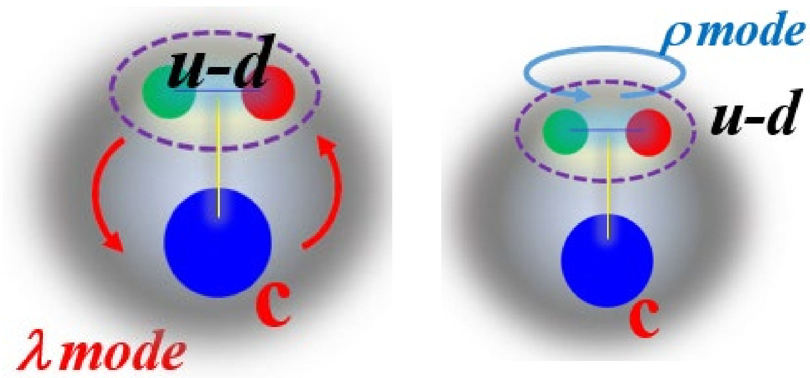


Resonance pole

$1417.7^{+6.0}_{-7.4}\ {}^{+1.1}_{-1.0} + [-26.1^{+6.0}_{-7.9}\ {}^{+1.7}_{-2.0}]i\ \mathrm{MeV}/c^2$

Systematic study for KN system will reveal property of K in nuclear medium.
→density dependence of KN interaction

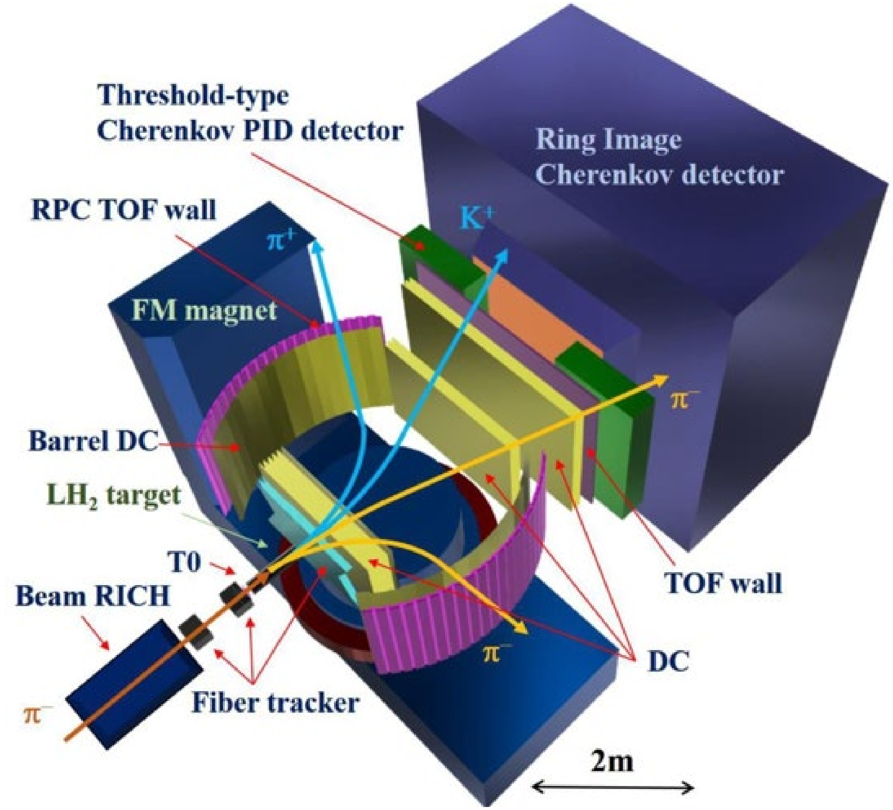
diquark degrees of freedom in baryon



$$V_{CMI} \sim [\alpha_S/(m_i m_j)] \cdot (\lambda_i \lambda_j)(\sigma_i \sigma_j)$$

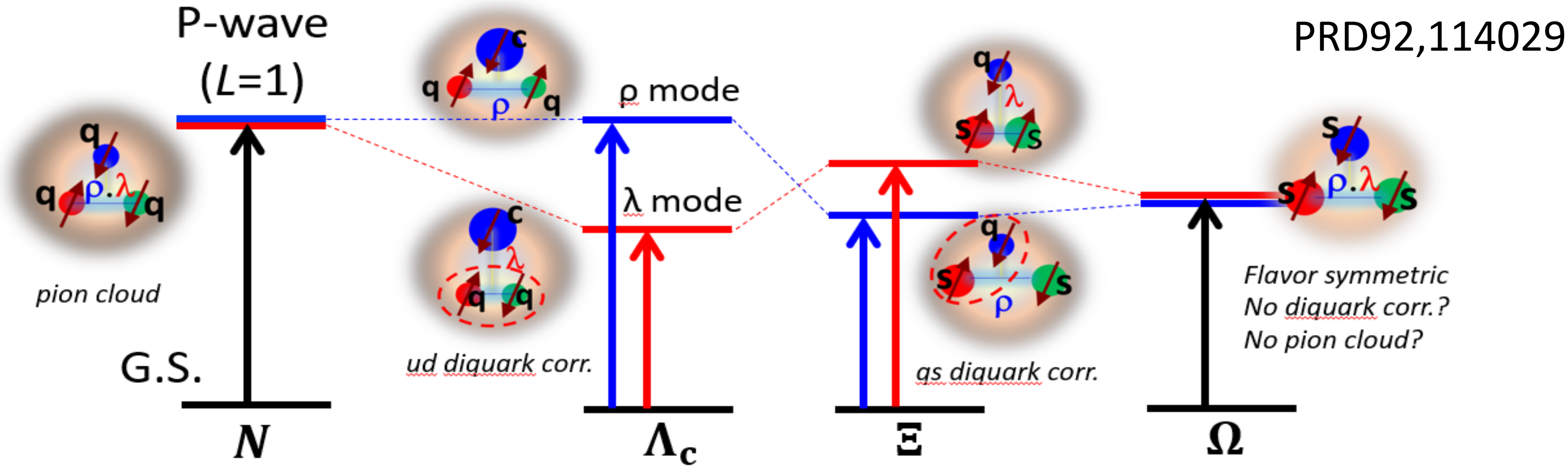
Single heavy baryon
→di-quark will be isolated
→di-quark motion can be identified in excited spectrum

Confirmation of di-quark degrees & study for di-quark property!

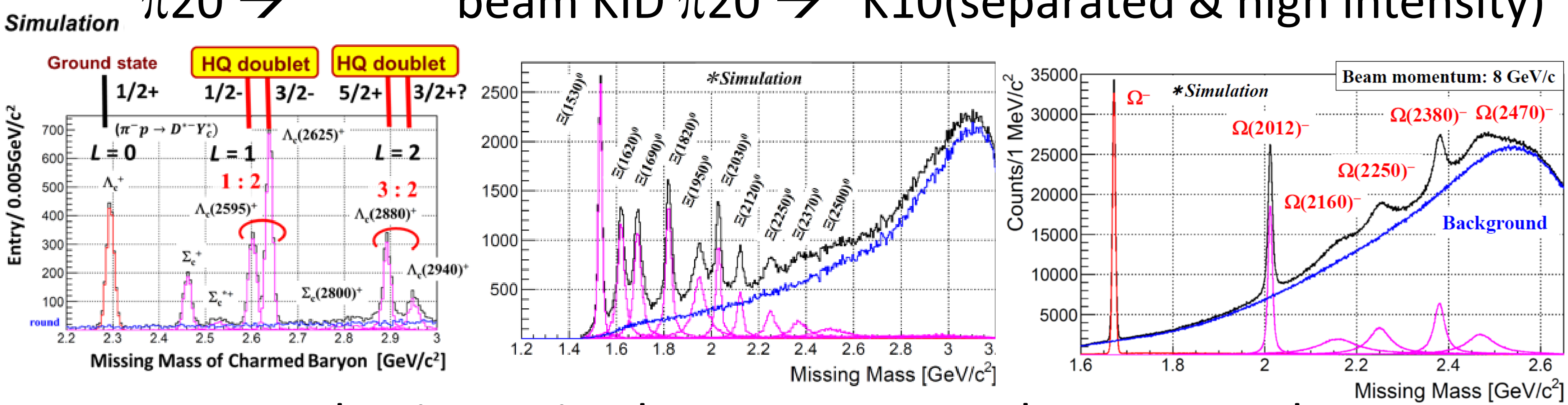


π20 beamline
(next stage of branched primary beamline)
Δp/p～0.1%, several 10^7π/spill
Missing mass spectroscopy

Flavor systematic study



π20 → beam KID π20 → K10(separated & high intensity)

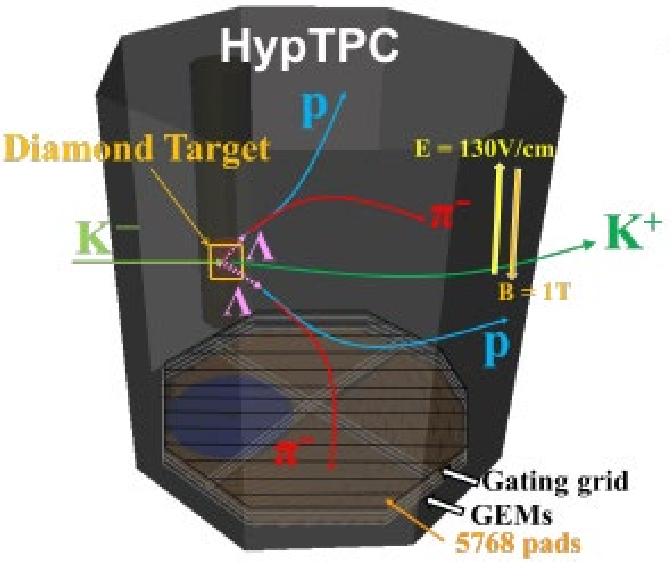


Mass, production ratio, decay pattern can be measured

Systematic spectroscopy will reveal di-quark property

& has possibility to access instanton induced interactions

H dibaryon & missing resonances

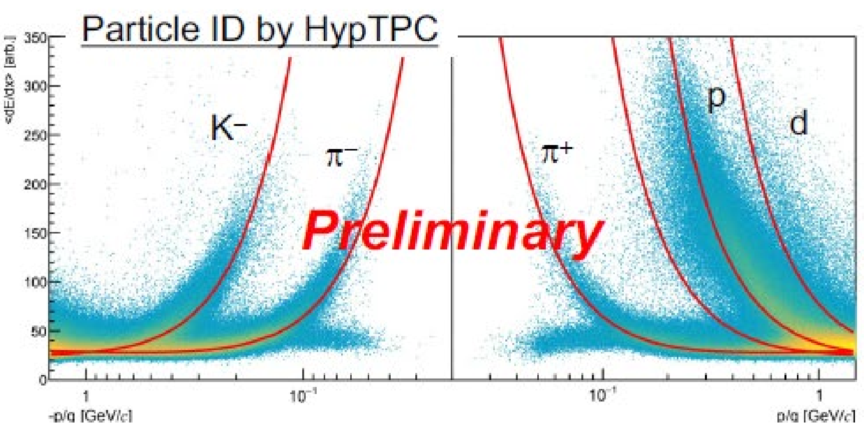


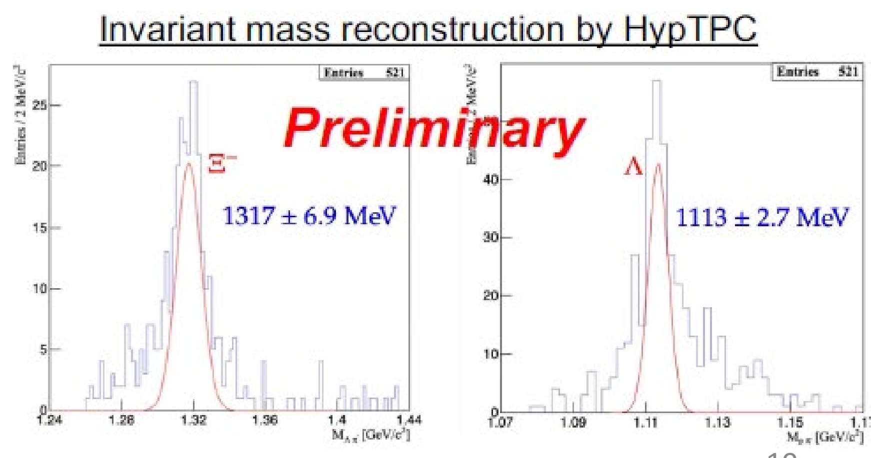
The existence of H dibaryon

- $K^- C \rightarrow K^+ H X \rightarrow K^+ \Lambda\Lambda X$

In future, LH2 target will be installed
Spin&parity of $\Lambda*$
Missing $N*/\Delta*$
Experiments are ready/in preparation

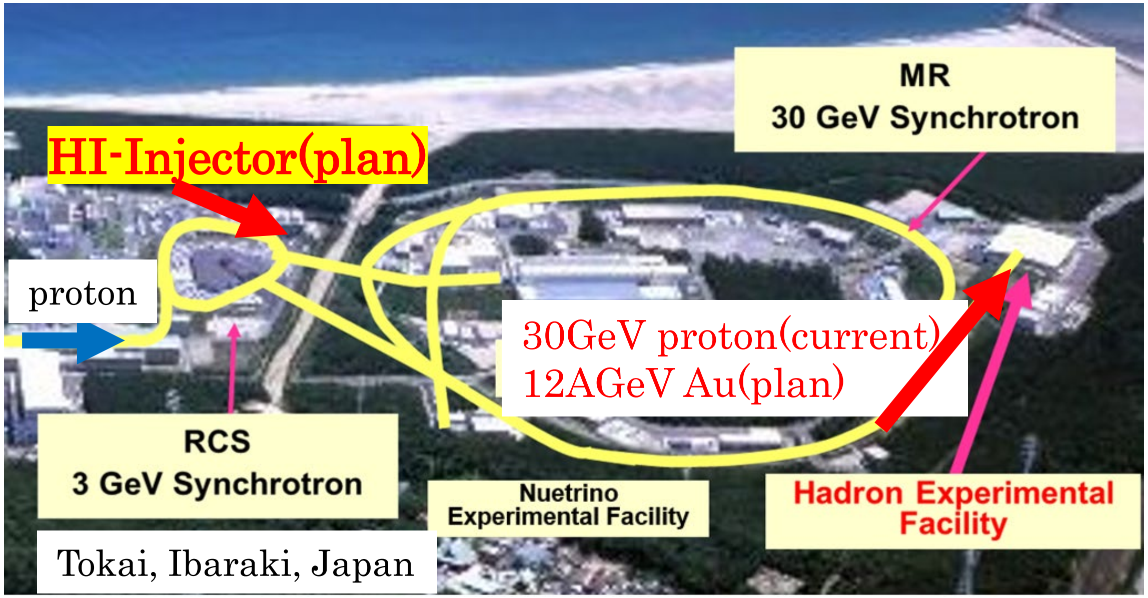
Analysis is on going





4. Future plan & summary

J-PARC-HI Project

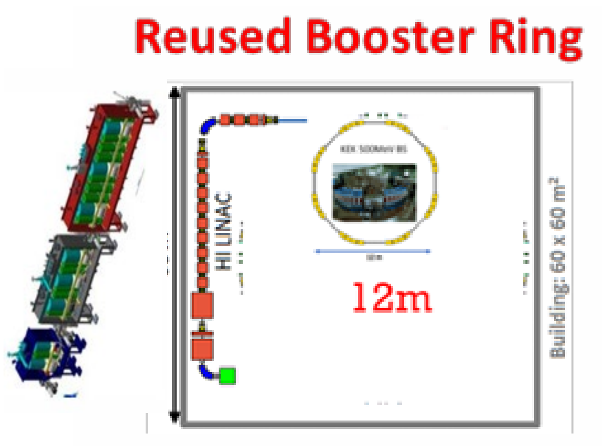


J-PARC-HI
→fixed target A+A experiment
with high intensity HI beam

Phase1 ～10^8Hz 12AGeV Au beam
Target: 1st Phase transion search at high density region via dielectron

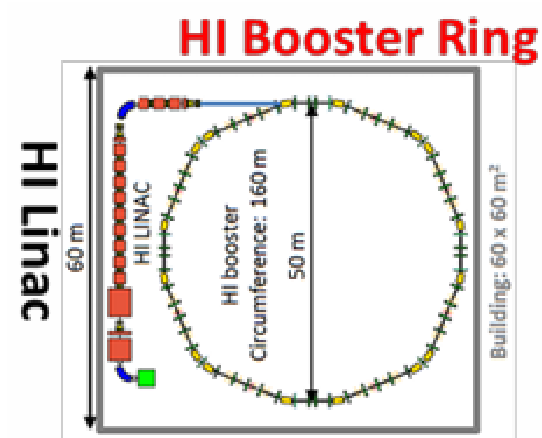
Phase2 ～10^{11}Hz(!) 12AGeV Au beam
Target: precise study for the extreme high density matter via various probe

1st PHASE



～10^8/spill

2nd PHASE



～10^{11}/spill

Summary

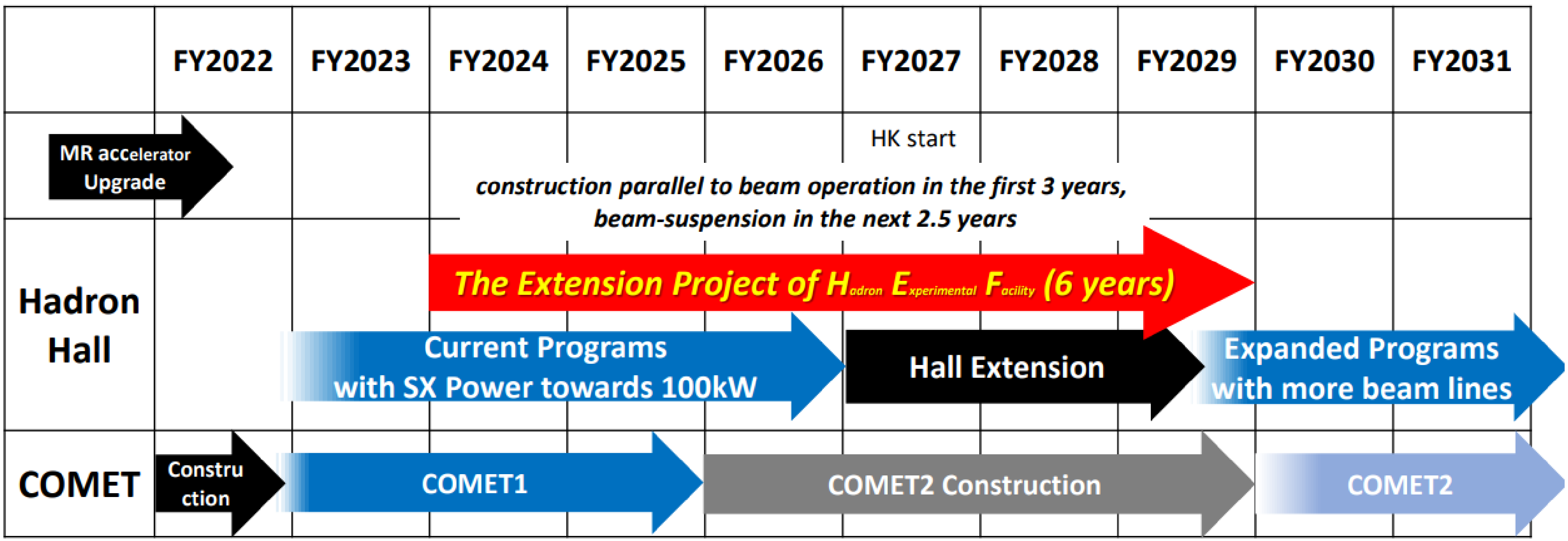
- J-PARC is using 30GeV proton beam.
- Secondary beam is mainly used for experiments.
- Now, primary beam can be used for experiments.
- I think the physics goal is similar with SIS100.
- Experimental approach is slightly different.
- We should be complemental.

Thank you

backup

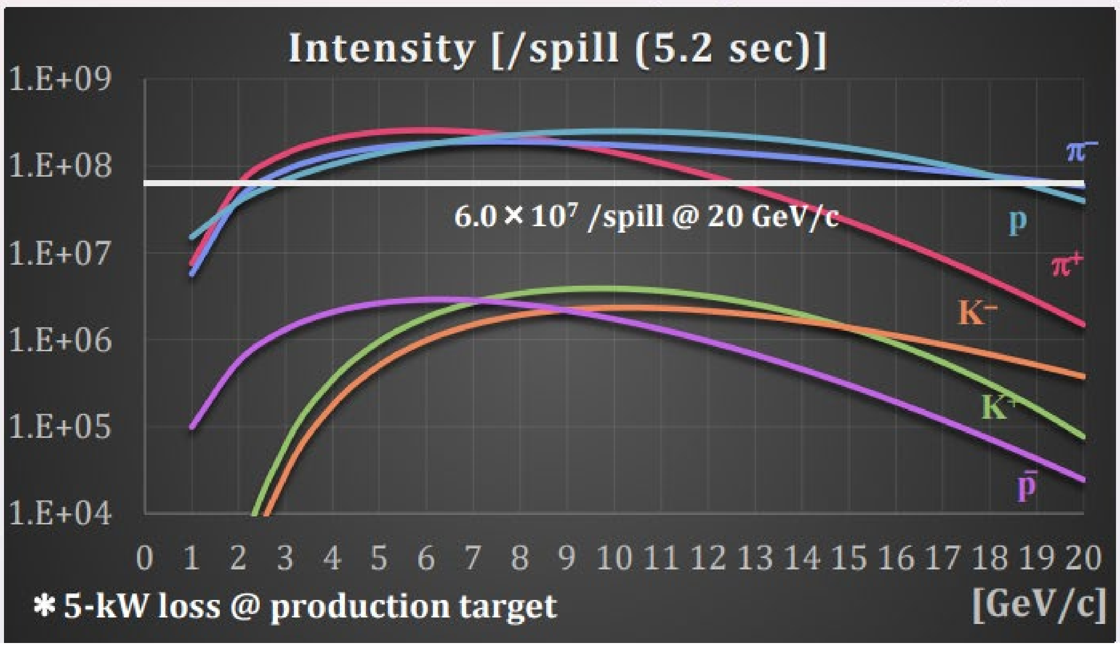
2022 ver

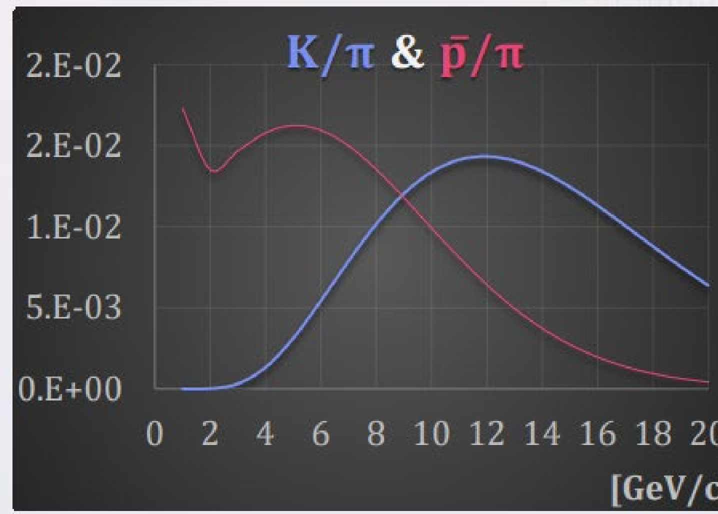
Timeline of the Project



BEAM INTENSITY AT HIGH-P SECONDARY BL

- Unseparated beam
- 5 kW loss target
- Beam intensity: 6×10^5 K^- /spill at beam momentum: 8 GeV/c
  - Maximum beam intensity expected in E50 ($\pi^- p$ reaction) : 6×10^7 /spill





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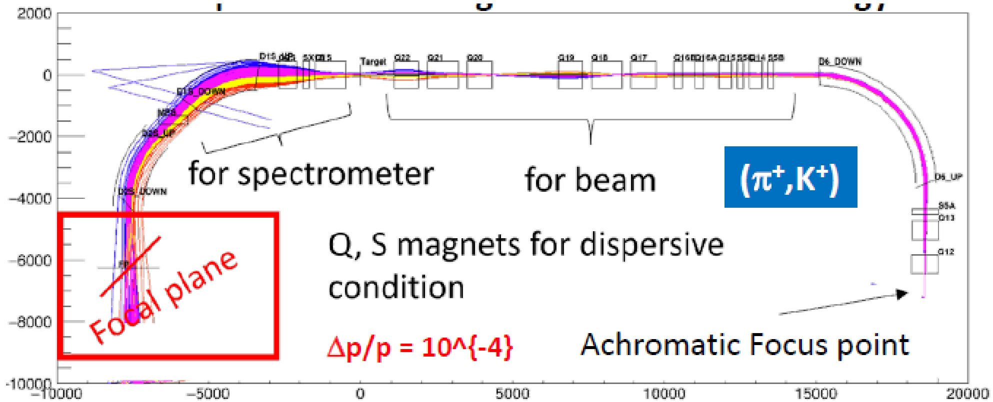
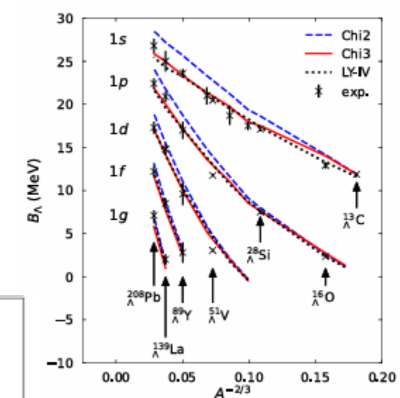
Systematic study of deep bound hypernuclei

High Intensity High Resolution (HIHR) beamline



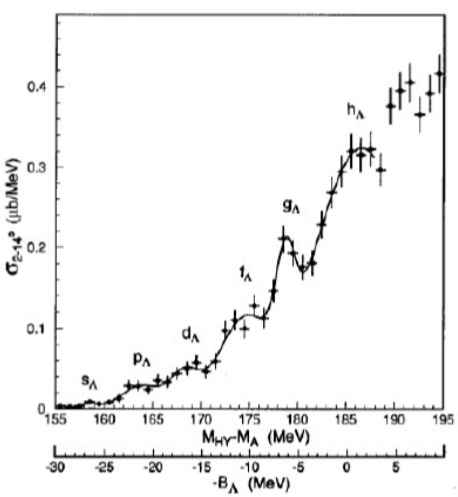
HIHR beamline will be constructed in hadron extension project.

Momentum dispersion matching
→ high intensity ($\sim 10^8 \pi$/spill)
& high resolution($\Delta p/p \sim 0.01\%$)

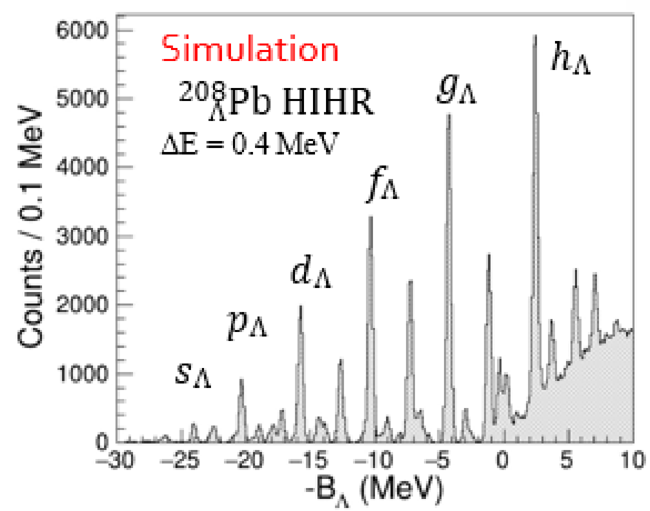


PRC108 065803

KEK E369



HIHR expectation



3body force will be determined presisely

K10 beam line specification

- Beam Intensity: Several 10^6 /spill (2-second extraction)
  - High-purity K^- beam ($K/\pi \sim 1/2$)
- Beam-spectrometer resolution: $\Delta p/p \sim 0.1\%(\sigma)$
  - By QQDDQ magnet configuration for analyzing beam momentum

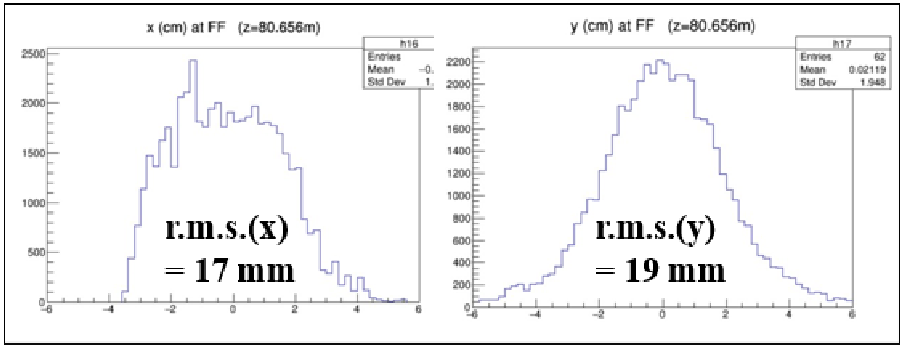
K^- intensity [$\times 10^6$ /spill]
(Purity: K^-/π^-)

- Primary proton beam power: 50 kW
- Production target: 50% loss
- Spill cycle: 5.2sec

	7 GeV/c	8 GeV/c	9 GeV/c	10 GeV/c
QQDDQ (central stopper)	8.3 (1/2.1)	7.9 (1/2.1)	6.7 (1/2.1)	4.7 (1/2.5)

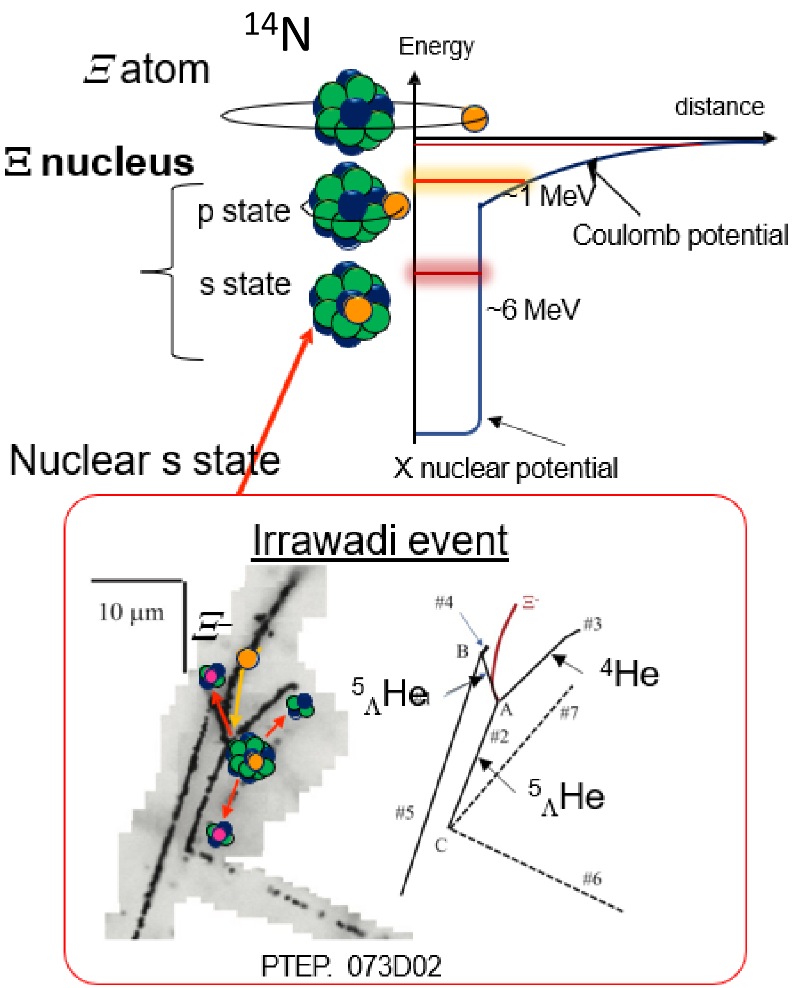
＊Purity K^-/π^- = 1/2 case
＊ 8.0 M/spill (K^-) w/ 16 M/spill (π^-)
Total = 24 M/spill (12 Mcps)

Beam profiles @ experimental target



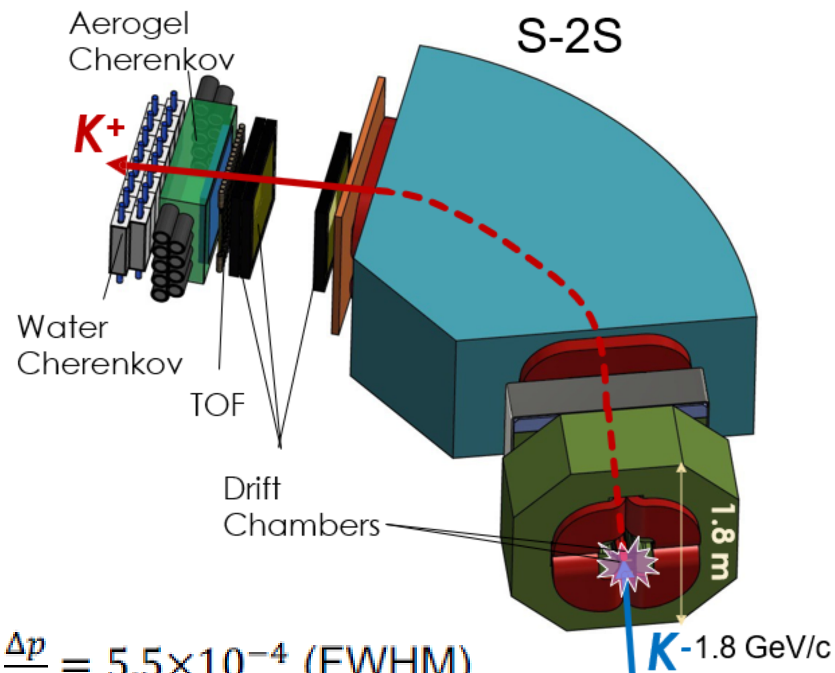
100 mm × 100 mm size (Similar to high-p BL conditions)

Ξ Hypernuclei



Emulsion experiment found
the deeply bound s state(BE～6MeV) !!
ΞN interaction sees to be attractive.

Coming soon experiment

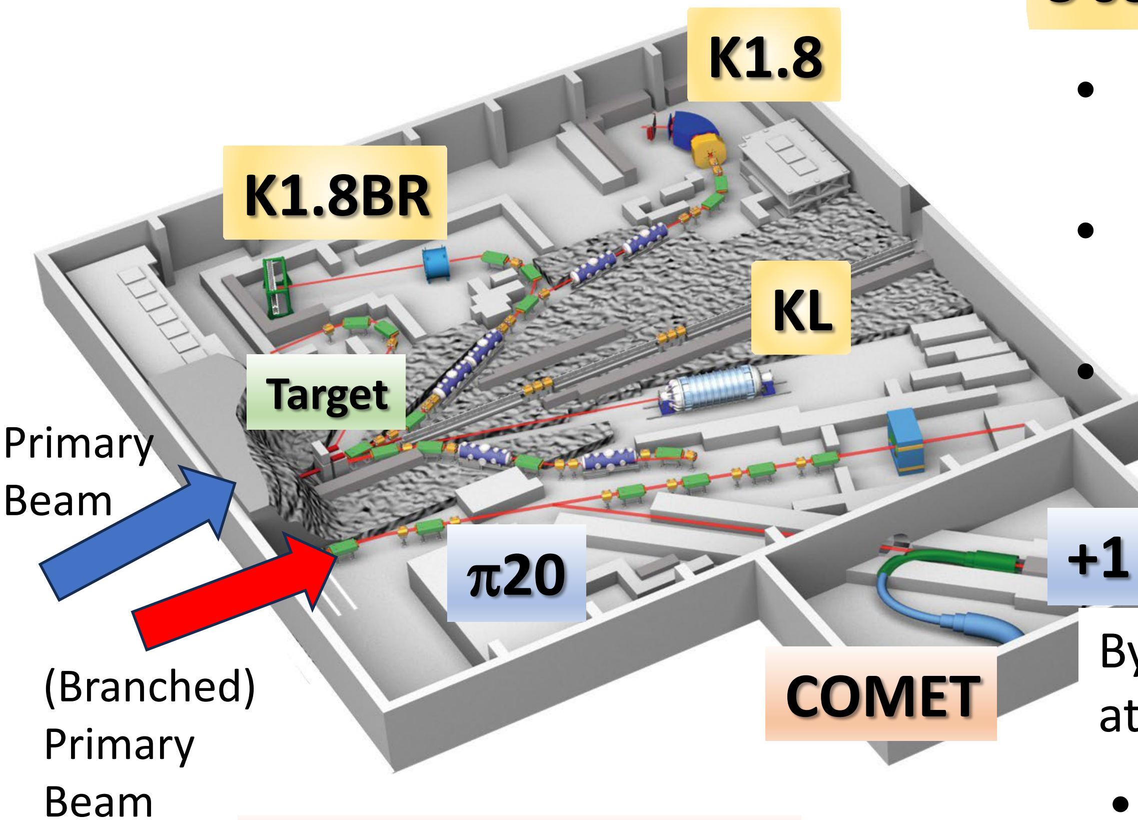


$$\frac{\Delta p}{p} = 5.5\times10^{-4}\ \text{(FWHM)}$$

Ξ hypernuclei study via missing mass method become possible soon with newly constructed “S-2S” spectrometer with good resolution

Next Stage of J-PARC Hadron Hall

Slow extracted Primary Proton beam::30GeV, 2/(4.2-5.2)s cycle, 7×10^{13}protons/spill



3 secondary beamline

- K1.8(nucl phys)
  - ～$1 \times 10^6 K^-$/spill, <2GeV/c
- K1.8BR(nucl phys)
  - ～$0.5 \times 10^6 K^-$/spill, <1.1GeV/c
- KL(part phys)
  - ～$1 \times 10^7 K^0$/spill, ～2GeV/c

+1 secondary beamline

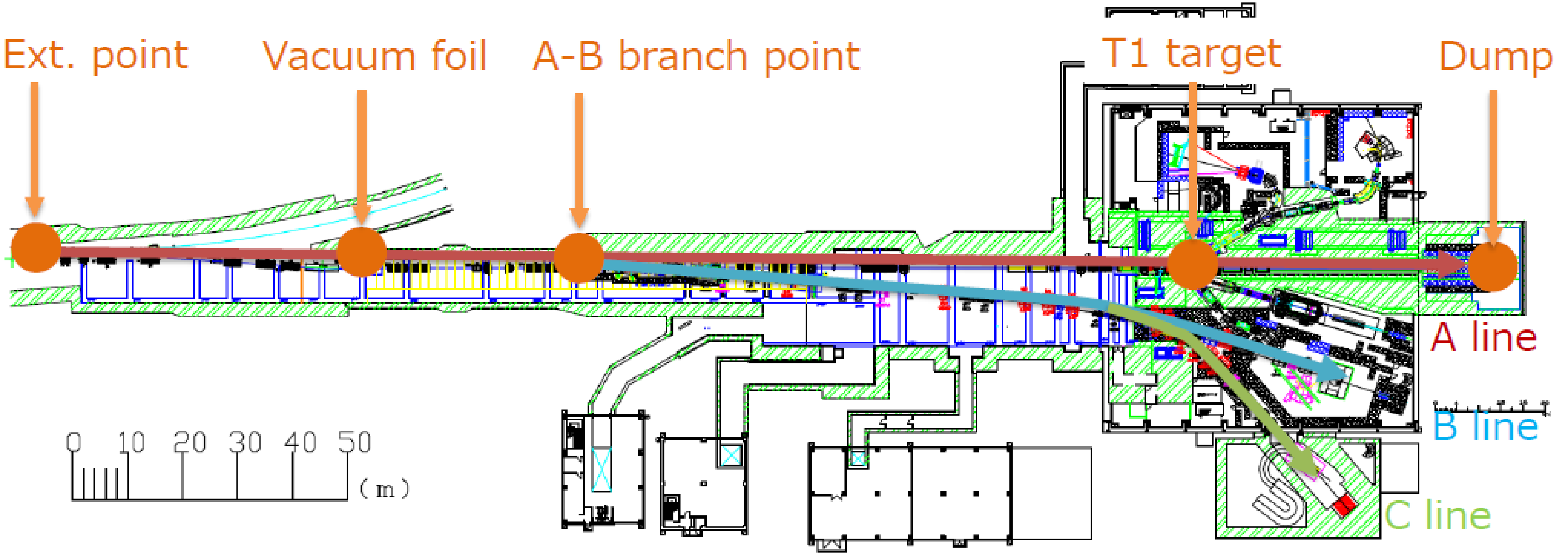
By newly installing 2nd target at upstream branching point

- π20(nucl phys)
  - ～$10^7 \pi$(unseparated)/spill ～20GeV/c

1 primary beamline

- COMET(part phys)
  - ～10^{12}proton/spill, 8GeV

J-PARC Hadron Primary Beamline



- A line 30 GeV 65 kW (7.0 x 10^{13} protons/spill)
  - 3 experimental areas using secondary beam from the T1 target
- B line 30 GeV 24 W (2.6 x 10^{10} protons/spill)
  - Branching out part of A line beam.
  - 1 experimental area using primary proton beam directly
- C line 8 GeV 0.33 kW (2.5 x 10^{12} protons/spill, 9.6 s cycle, 0.5 s spill length)
  - Bunched slow extraction beam
  - 1 experimental area using secondary muon beam from the target