9 th APCTP-BLTP JINR Joint WS at Kazakhstan
28 June - 3 July, 2015

New Platform for Hadron Physics at RCNP

H. Noumi (RCNP, Osaka University)
29 June, 2015

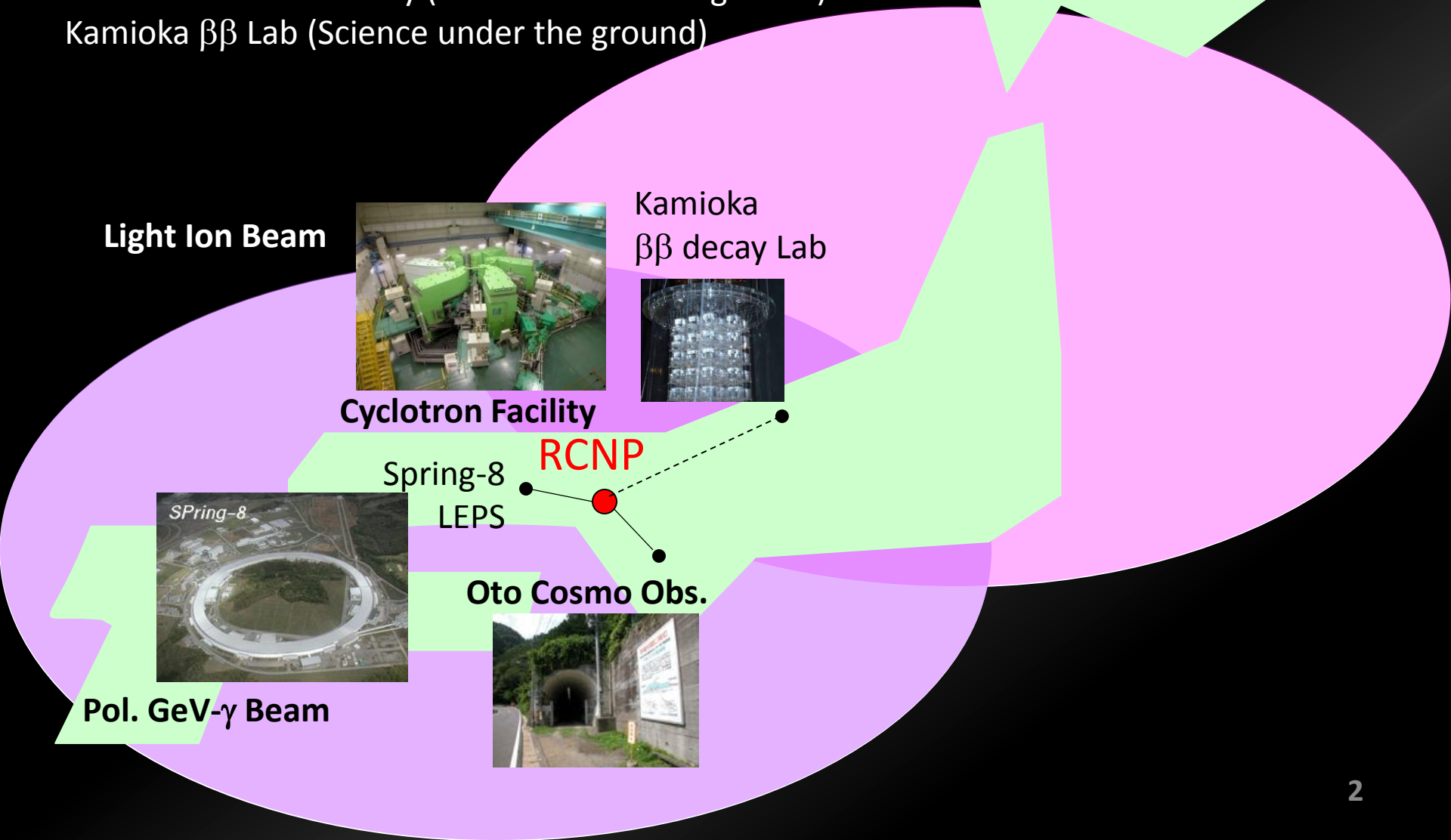
Contents:

1. Activities of Nuclear Hadron Physics at RCNP
2. A new platform of RCNP for hadron physics
   - High Resolution, High Momentum Bean Line at J-PARC
3. Baryon Spectroscopy with Heavy Flavors
   - Charmed Baryon
   - Double-Strange Baryon
4. Summary

RCNP：User Based Research Center for Nuclear Physics

Founded in 1971

- Cyclotron Facility（AVF, RING・G-RAIDEN)
- Laser Electron Photon Facility at SPring-8（LEPS)
- Oto Cosmo Observatory (Science under the ground)
- Kamioka ββ Lab (Science under the ground)



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Light Ion Beam

Cyclotron Facility

Kamioka
ββ decay Lab

ELPH

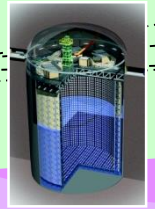
Neutrino Beam

JAEA
J-PARC
KEK

Kaon Factory

RCNP

Spring-8
LEPS



RIKEN

Pol. GeV-γ Beam

Oto Cosmo Obs.

Super-
Kamiokande

Heavy Ion Beam
RI Beam Facility

B Factory
KEKB/Belle

RCNP CYCLOTRON FACILITY

CAGRA spectrometer

Clover-type Ge Detector Array

Radioisotope Beam
UCN source

Ring Cyclotron
K=400 MeV

2 World Bests
Energy spread <0.01%
Stability of Mag. Field <0.001%

100m
Neutron TOF

Grand Raiden Spectrometer

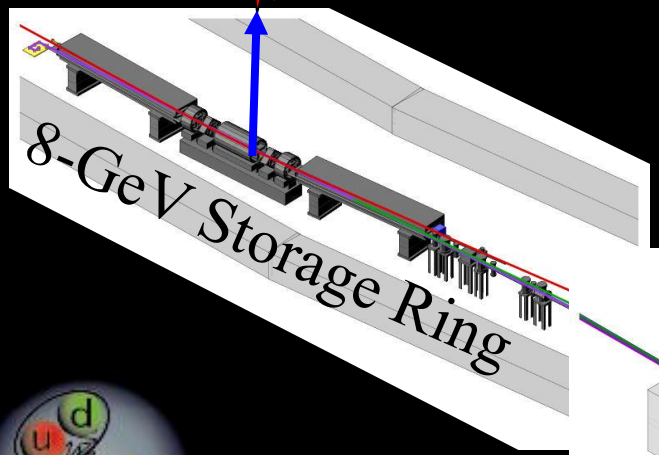
Resolution (World Best)
$\Delta p/p$~0.0027% at E=400 MeV

MUSIC

Muon Source
for Material Science

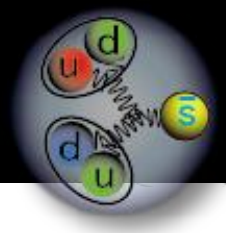
AVF Cyclotron
K=140 MeV

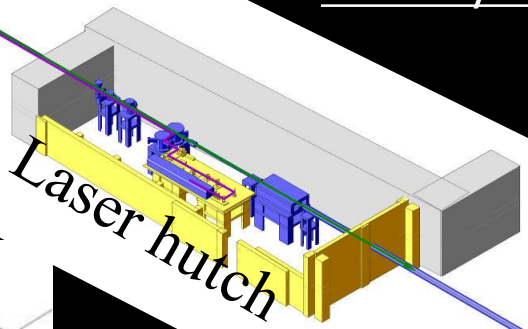
Laser Electron Photon Facility at SPring-8



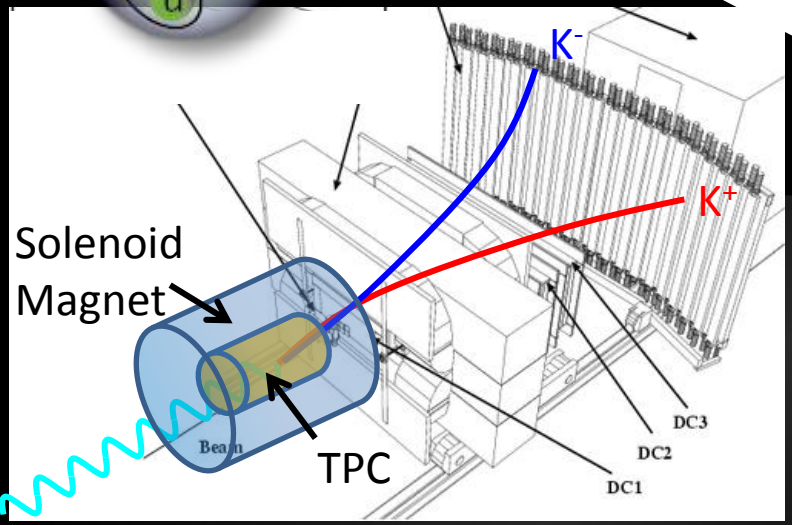
Backward-Compton scattering

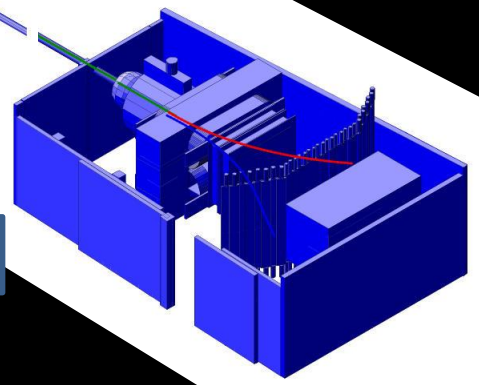
- ✓ Laser 257/266 nm → up to 3 GeV γ
- ✓ Linearly Polarized Photon Beam





Experimental hutch

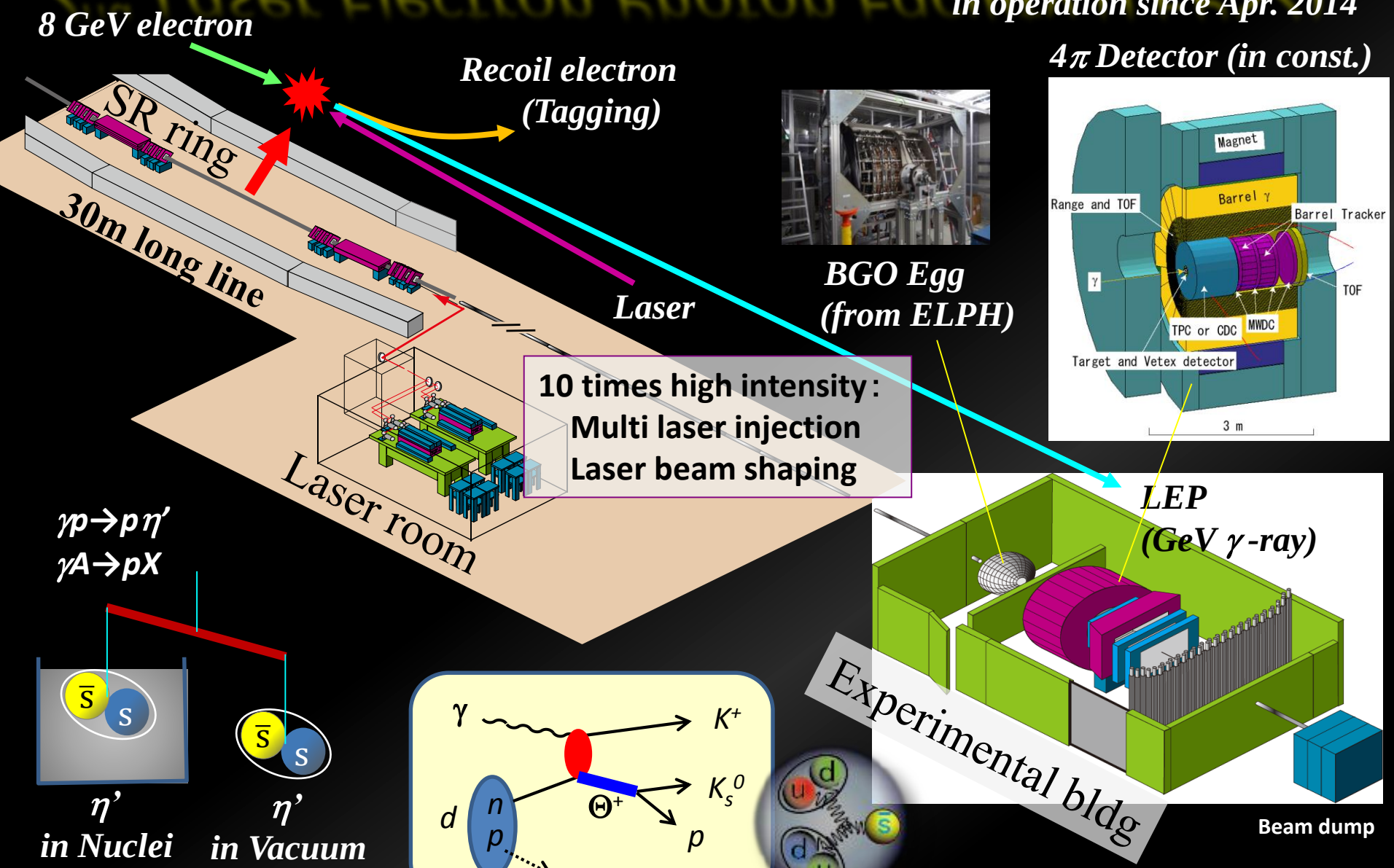




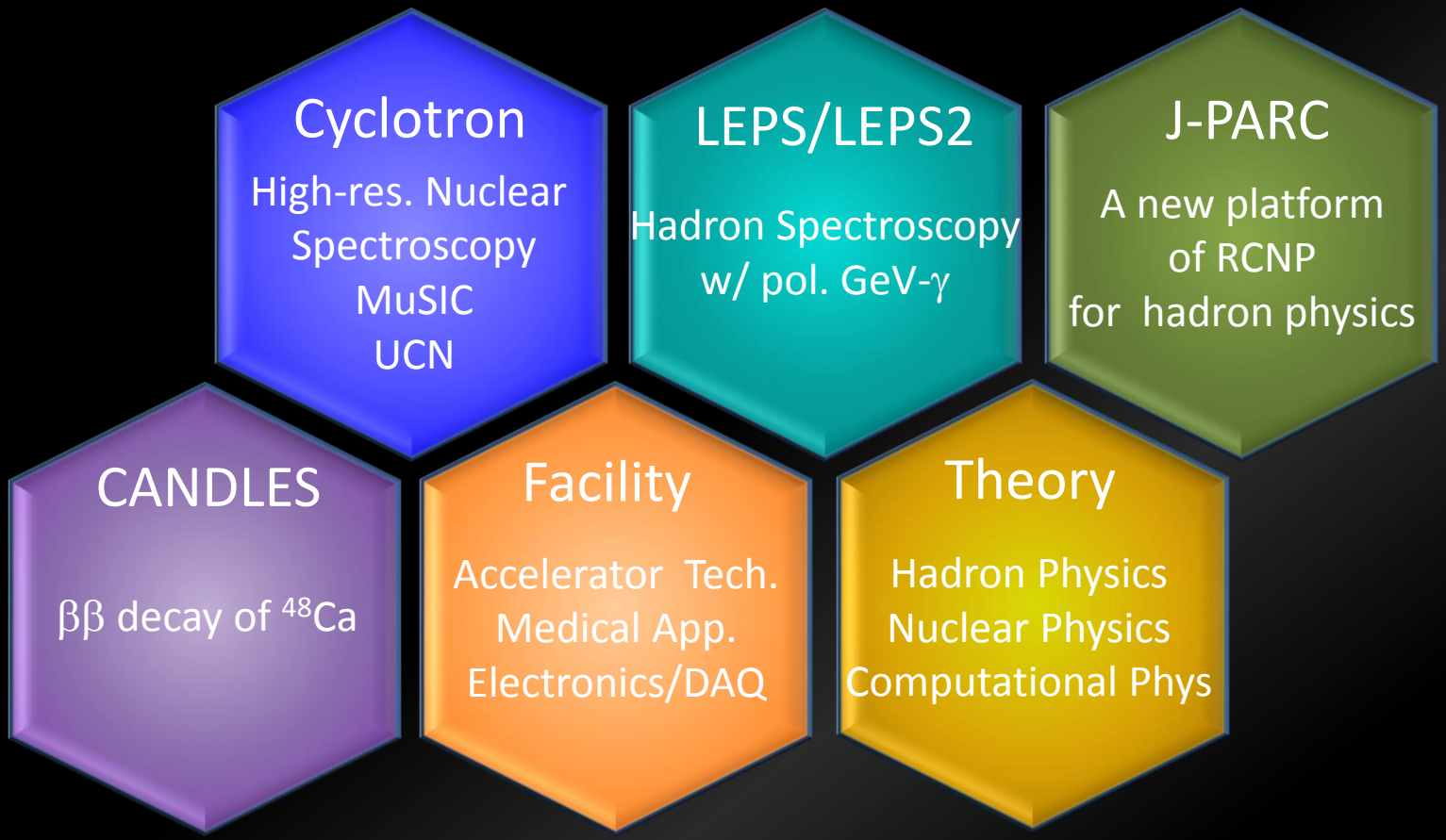
LEPS Spectrometer

2nd Laser Electron Photon Facility (LEPS2)

in operation since Apr. 2014

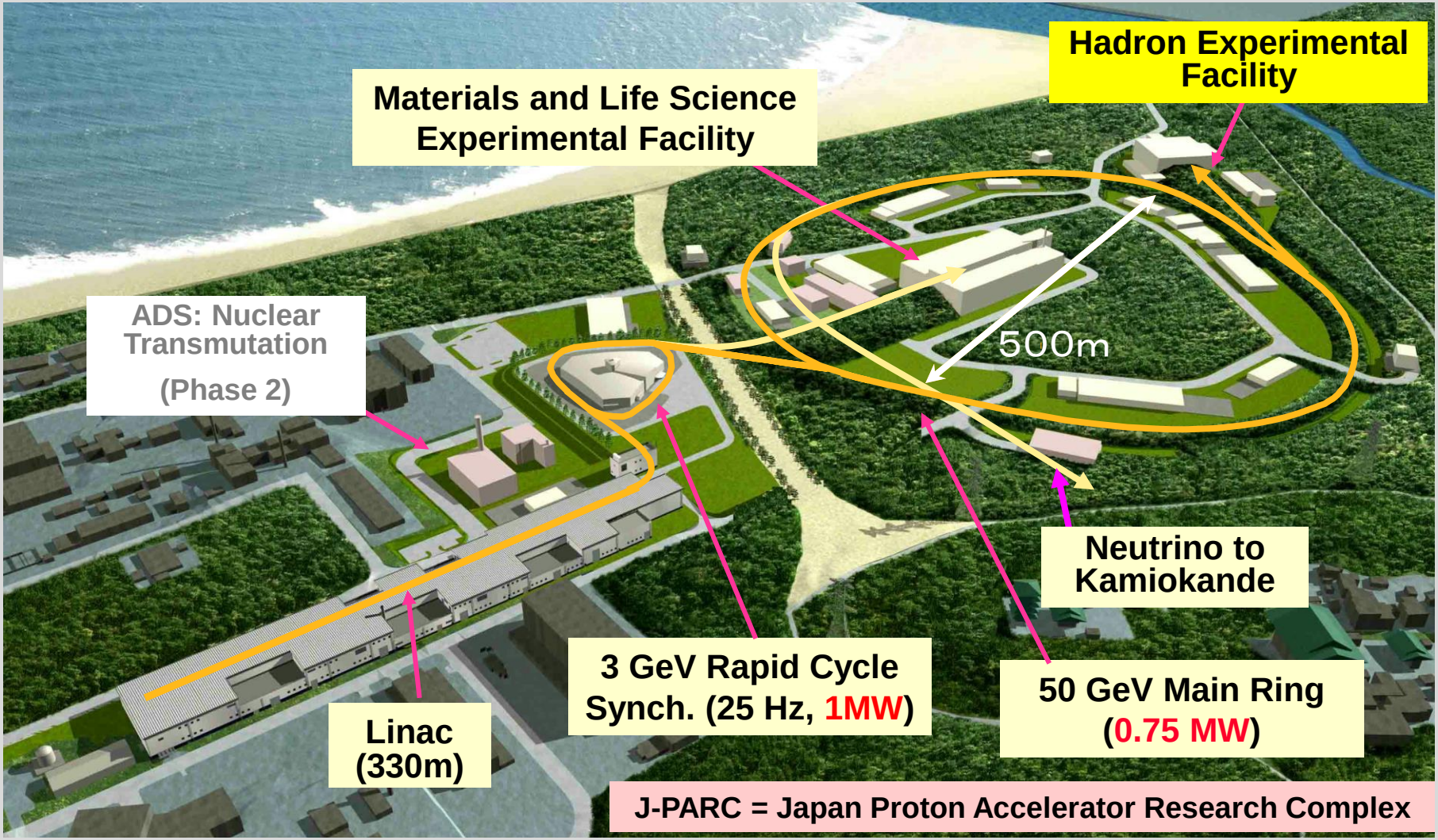


RCNP Activity

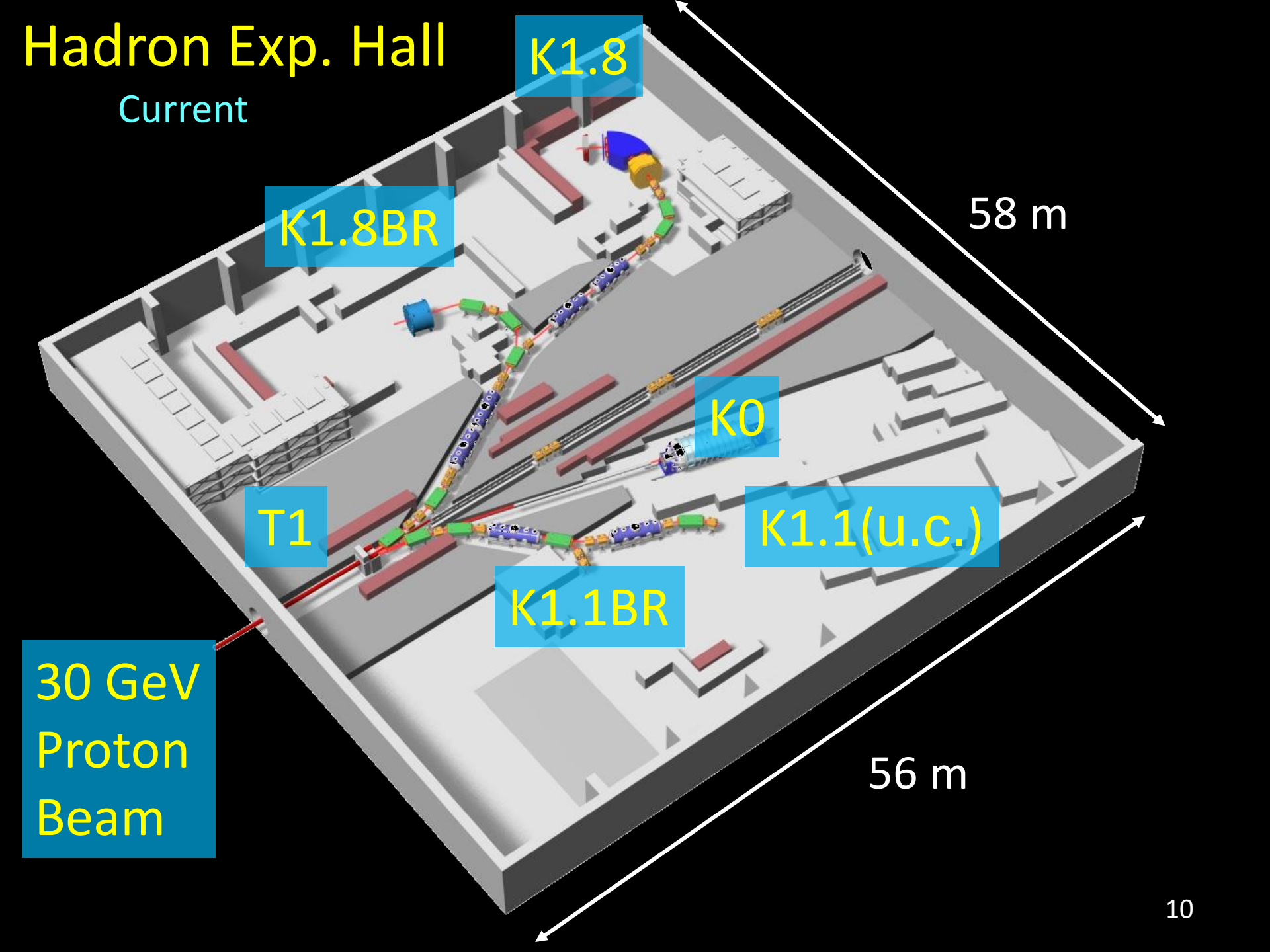


A new platform of RCNP for hadron physics at J-PARC

J-PARC Facility



Joint Project between KEK and JAEA since 2001

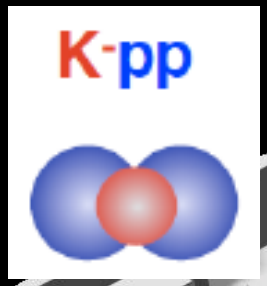

Hadron Exp. Hall
Current
K1.8
K1.8BR
58 m
K0
T1
K1.1(u.c.)
K1.1BR
30 GeV
Proton
Beam
56 m

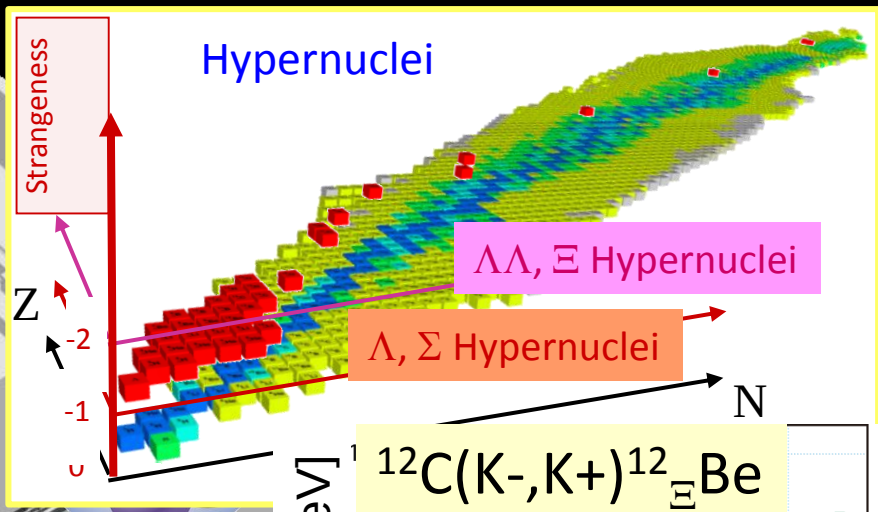
Hadron Exp. Hall

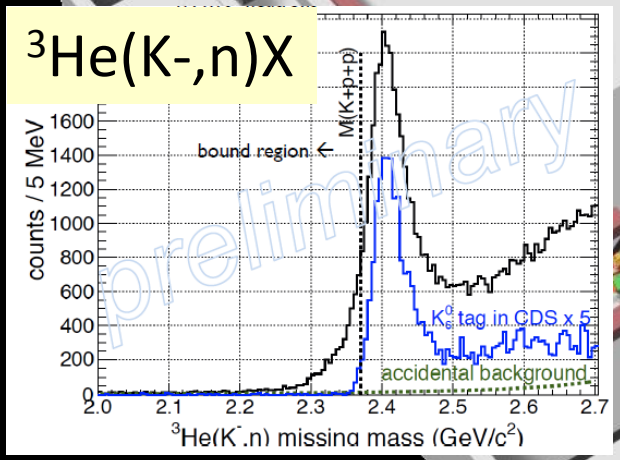
Current

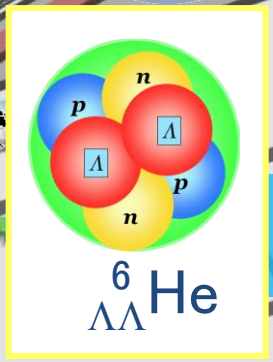
K1.8

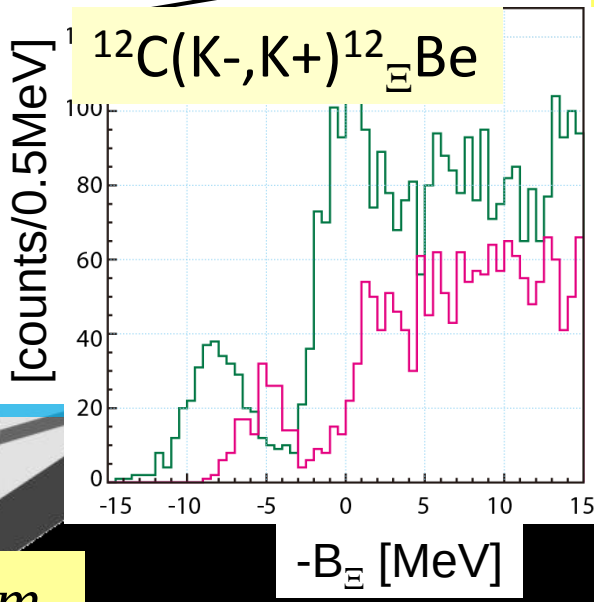
K1.8BR

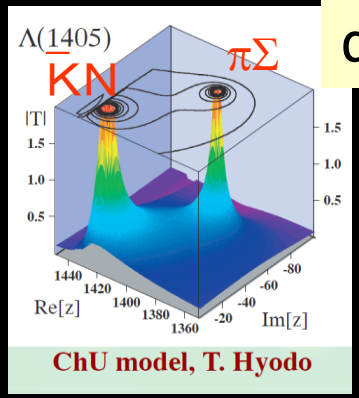






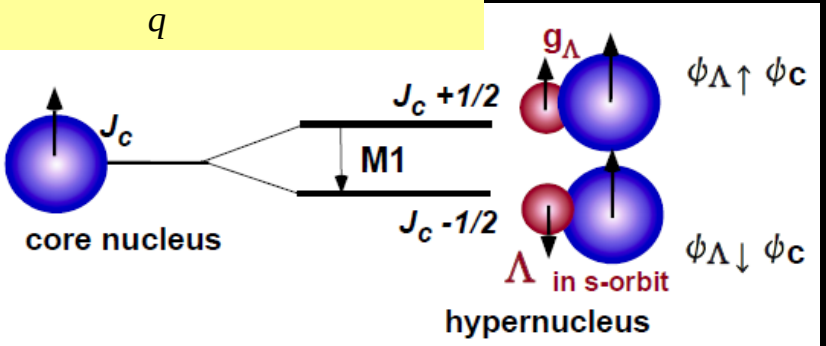






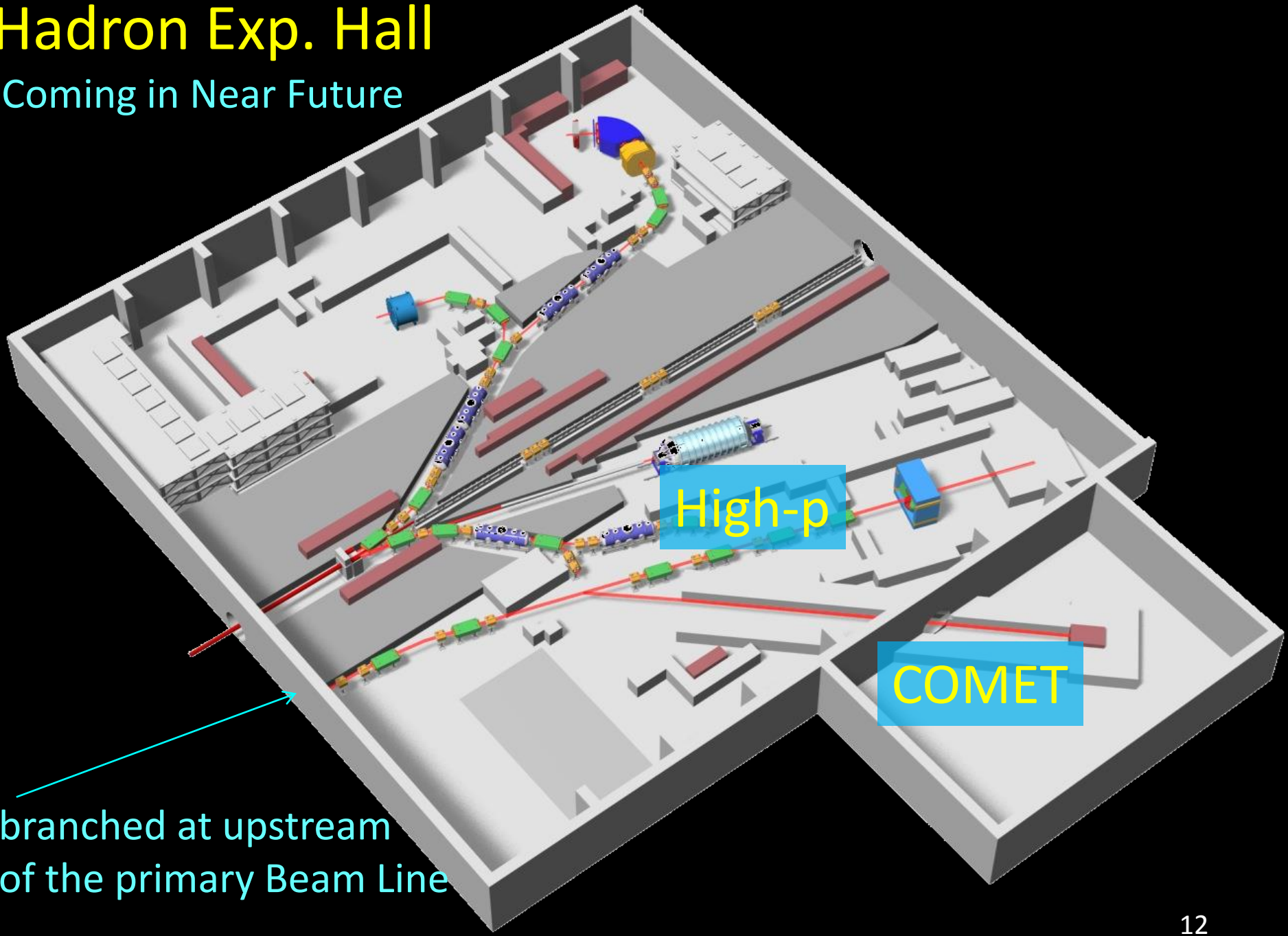
d(K⁻,n)Λ(1405)

$$\hat{\mu}_z = \sum_q q_q s_z^q \hbar / m_q$$



Hadron Exp. Hall

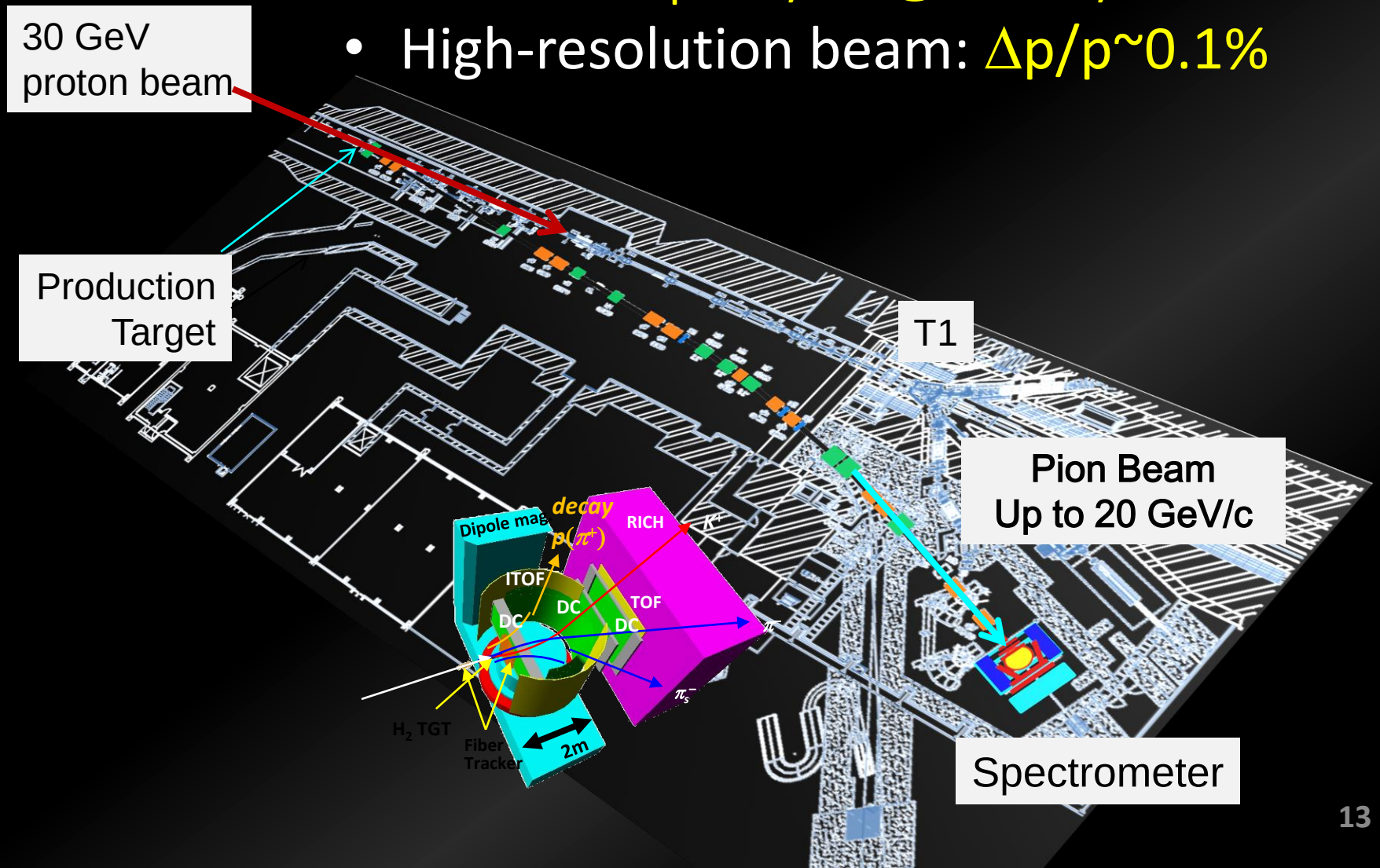
Coming in Near Future



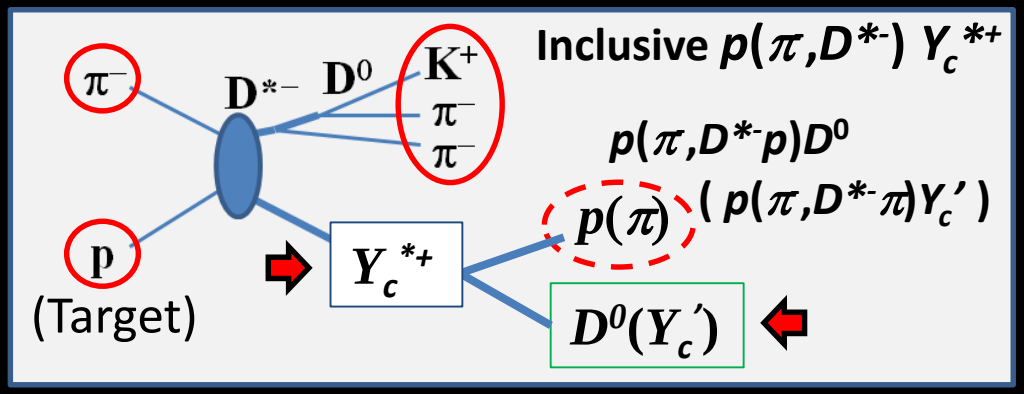
branched at upstream
of the primary Beam Line

High-res., High-momentum Beam Line

- High-intensity secondary Pion beam
  - 1.0×10^7 pions/sec @ 20GeV/c
- High-resolution beam: $\Delta p/p \sim 0.1\%$



CHARM Spectrometer Design



Cross Section:

$\sigma(\Lambda_c) \sim$ **1 nb** (no meas.)

Acceptance:

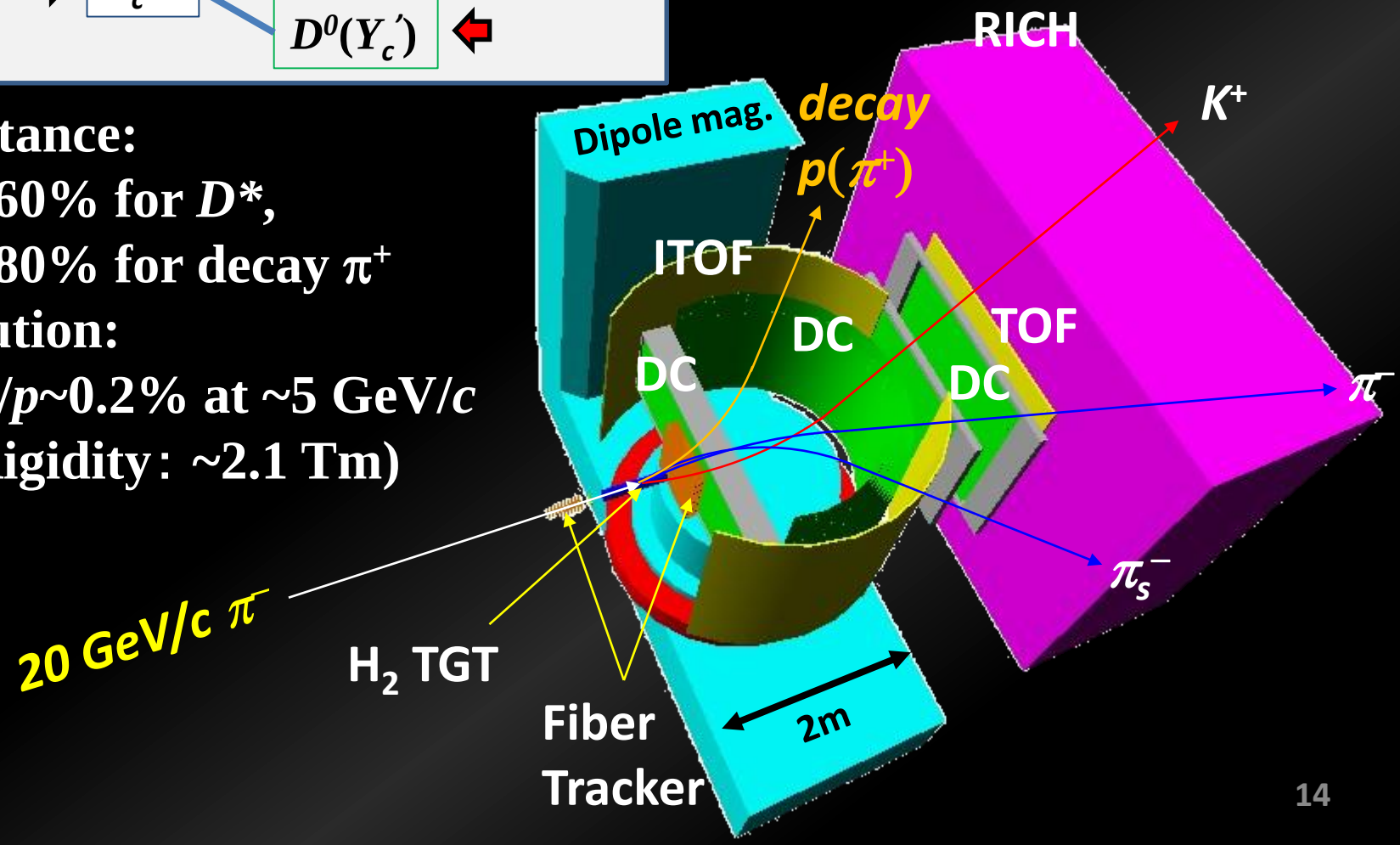
~ 60% for D^*,

~ 80% for decay π^+

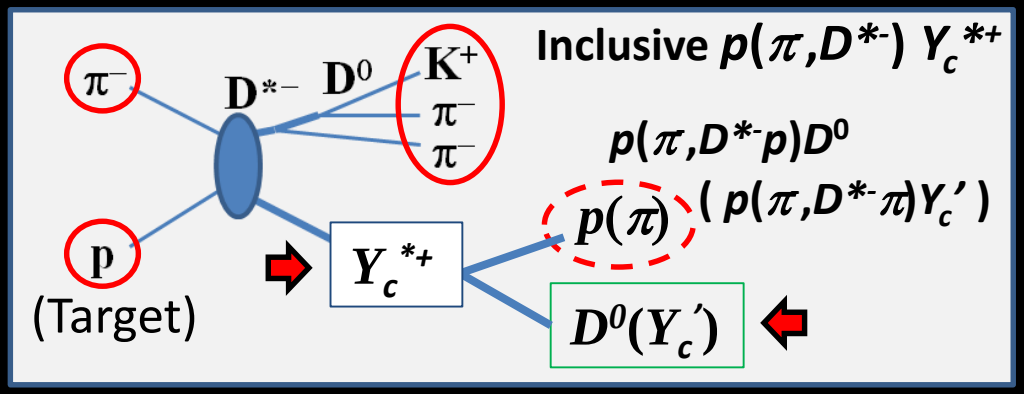
Resolution:

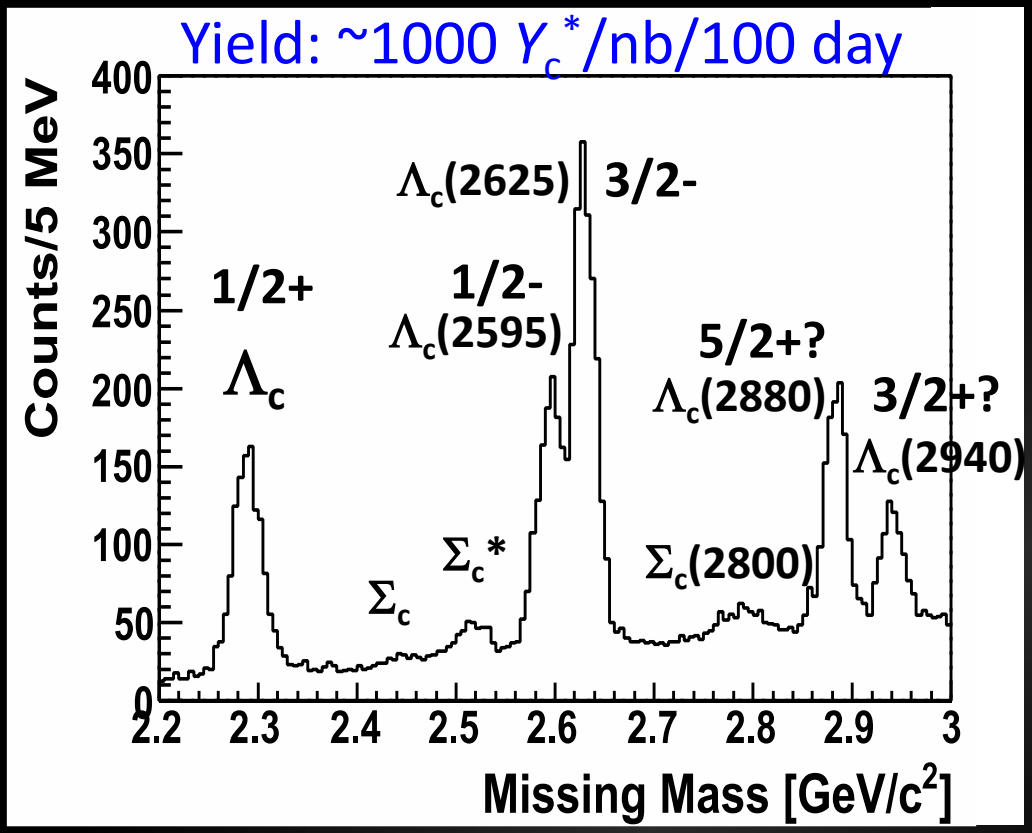
$\Delta p/p$~0.2% at ~5 GeV/c

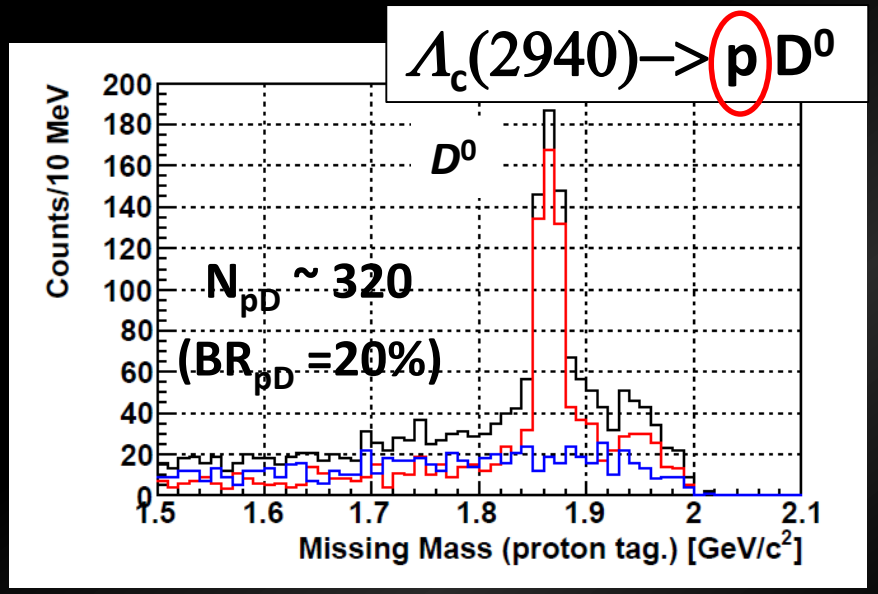
(Rigidity: ~2.1 Tm)

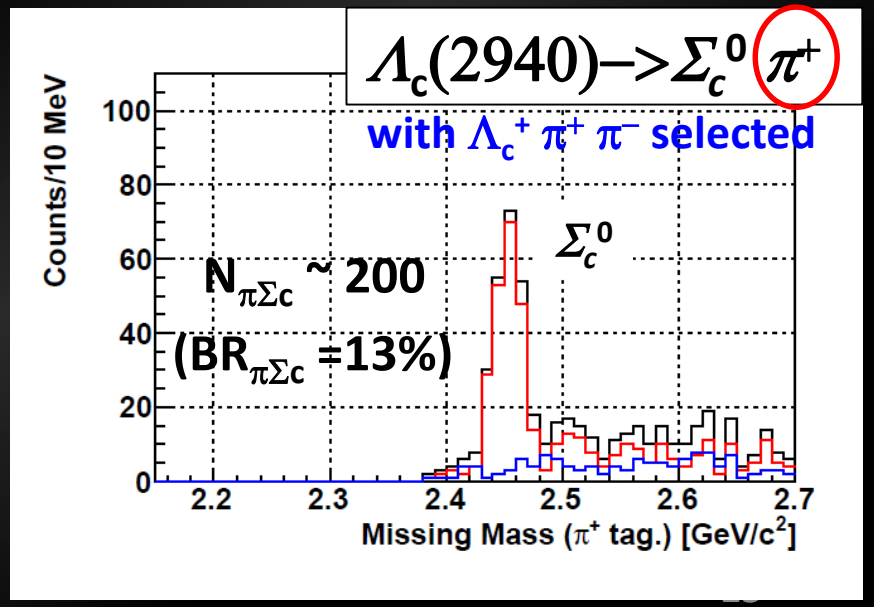


Inclusive Spectrum and Decay Mode ID (Sim.)









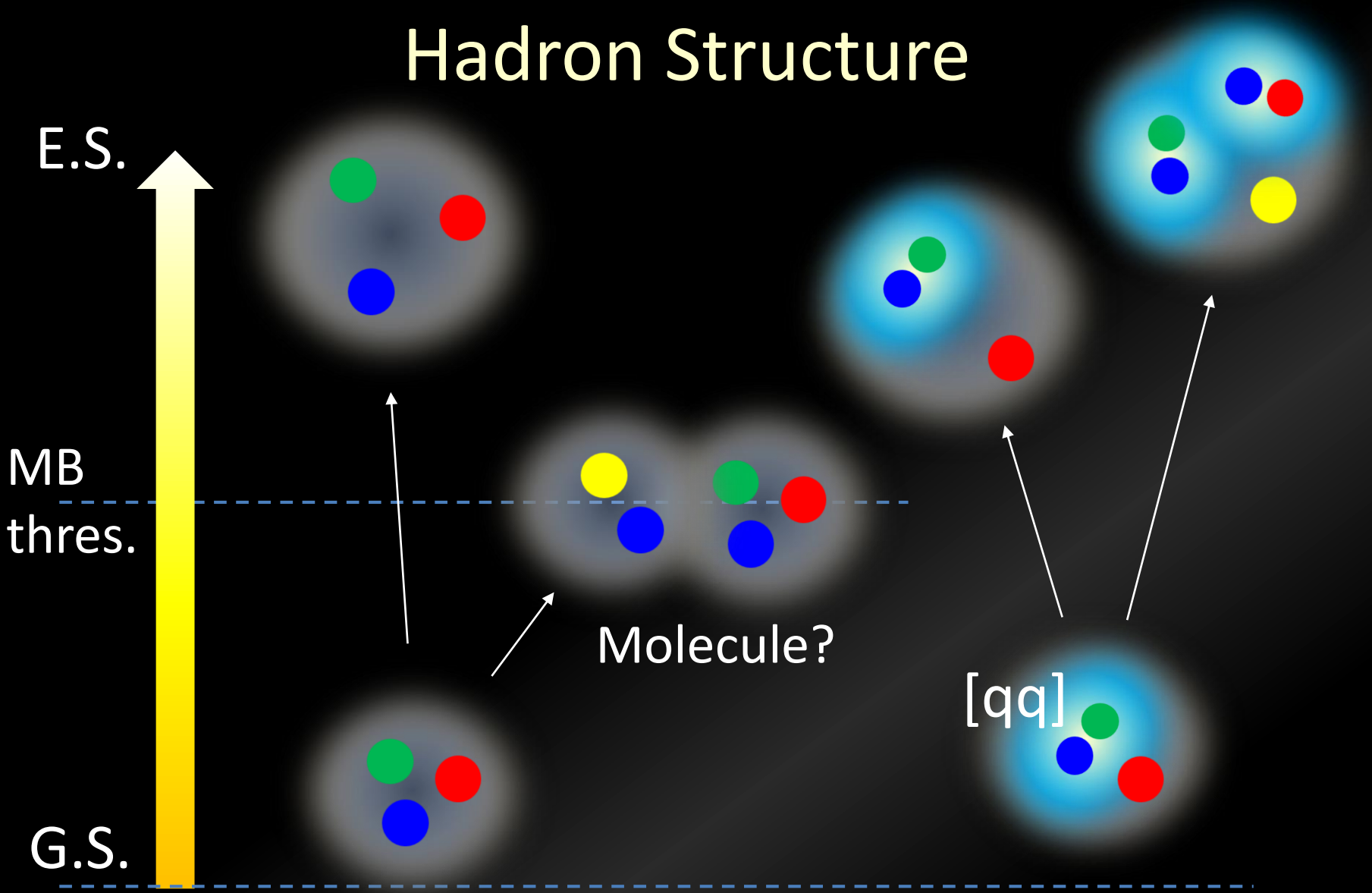
A new research project in High-res., High-p Beam Line at J-PARC

- MOU on research cooperation btwn RCNP, IPNS/KEK, and the J-PARC Center
- RCNP conducts in cooperation w/ J-PARC:
  - collection of research ideas and collaborators
  - introduction of new methods/techniques
    - High-resolution, high-p Secondary Beam Line
    - Multi-particle Spectrometer
- Proposal E50: "Charmed Baryon Spectroscopy via the (π^-,D^{*-}) reaction", stage-1 approval in the 18th PAC (May, 2014)

  http://www.j-parc.jp/researcher/Hadron/en/Proposal_e.html#1301

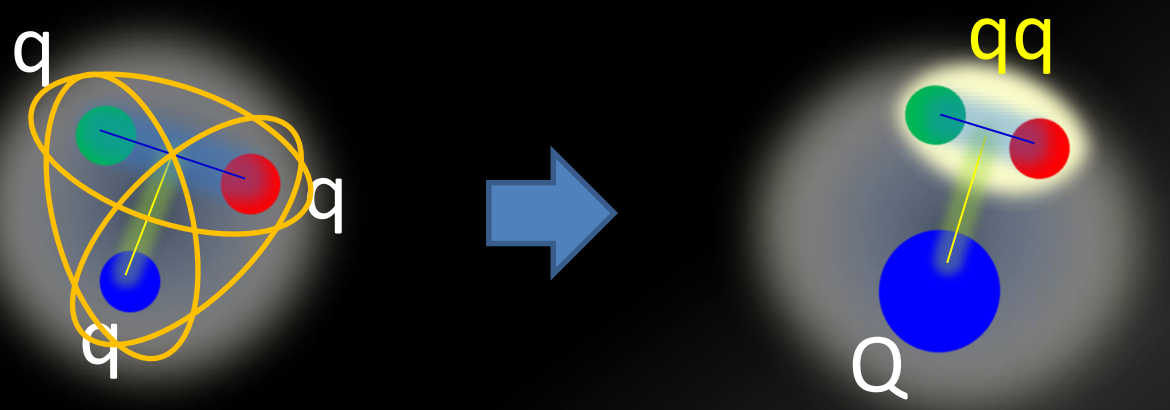
Baryon Spectroscopy with Heavy Flavors

Hadron Structure



EDoF | Quark | Hadron (Colorless) | Diquark (Color)

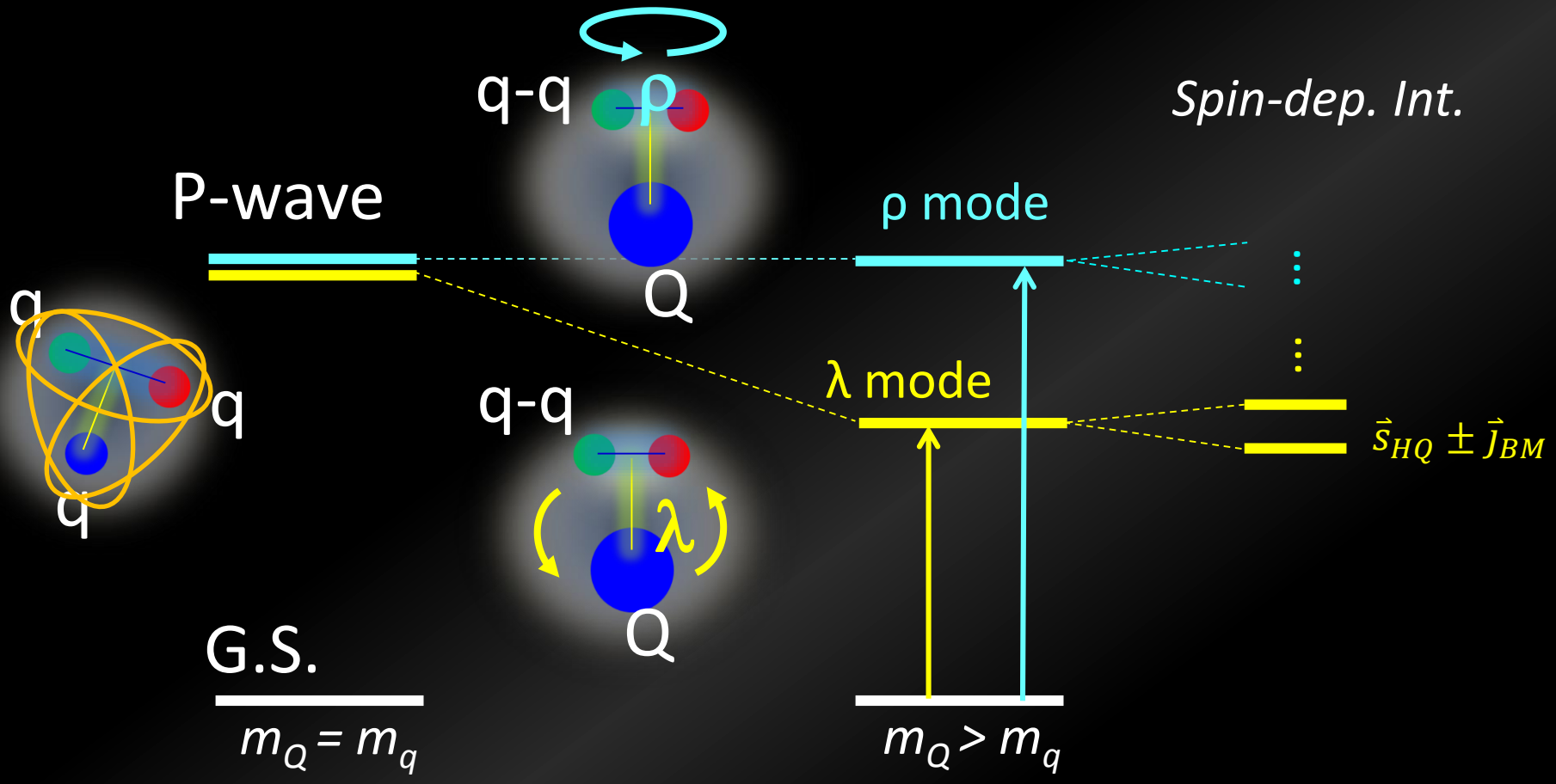
What we can learn from baryons with heavy flavors



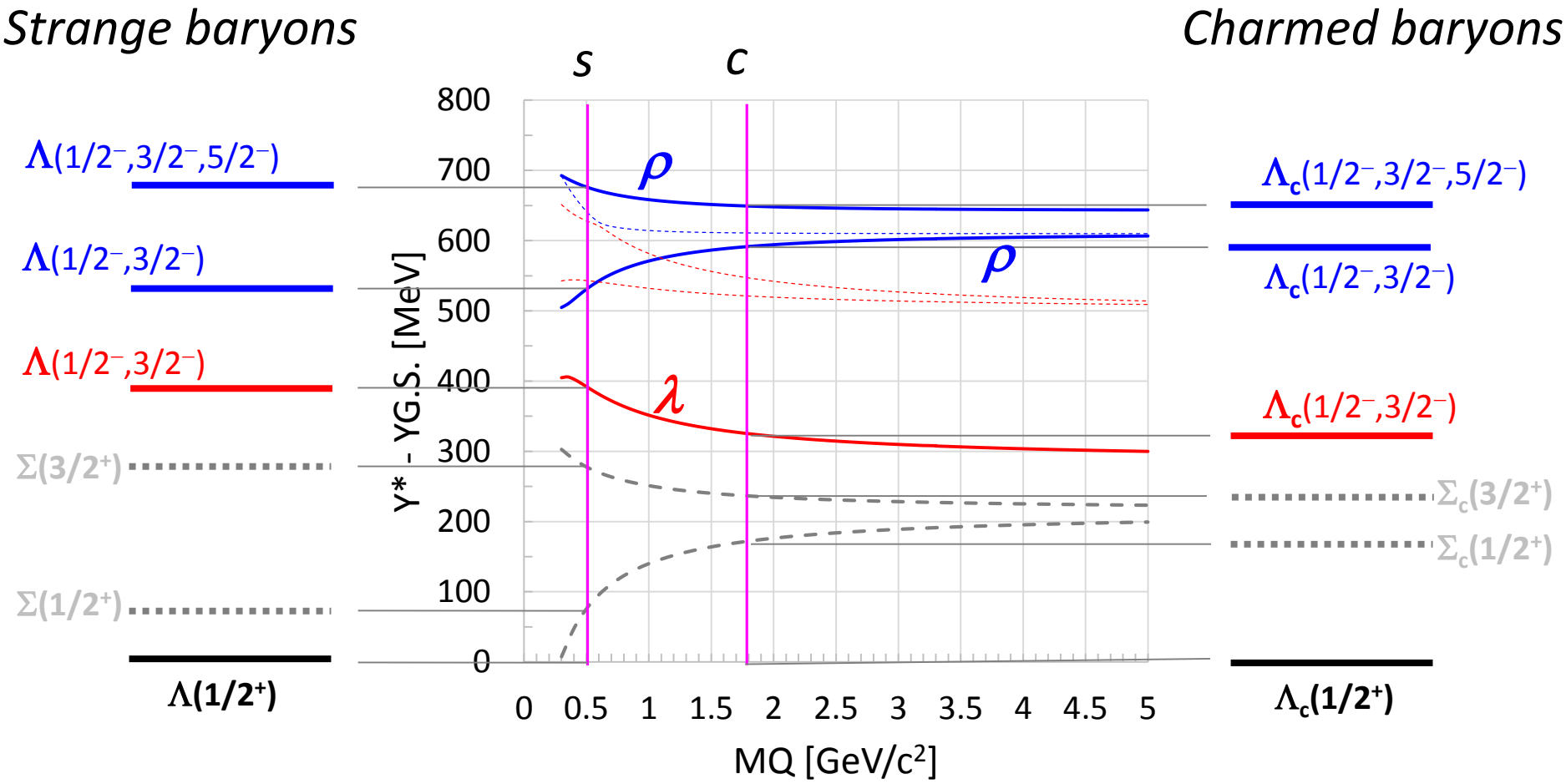
- Quark motion of “qq” is singled out by a heavy Q
  - Diquark correlation
- Level structure, Production rate, Decay properties
  - sensitive to the internal quark(diquark) WFs.
- Properties are expected to depend on a Q mass.

Schematic Level Structure of Heavy Baryons

- λ and ρ motions split (Isotope Shift)
- HQ spin multiplet（$\vec{s}_{HQ} \pm \vec{J}_{Brown\ Muck}$）

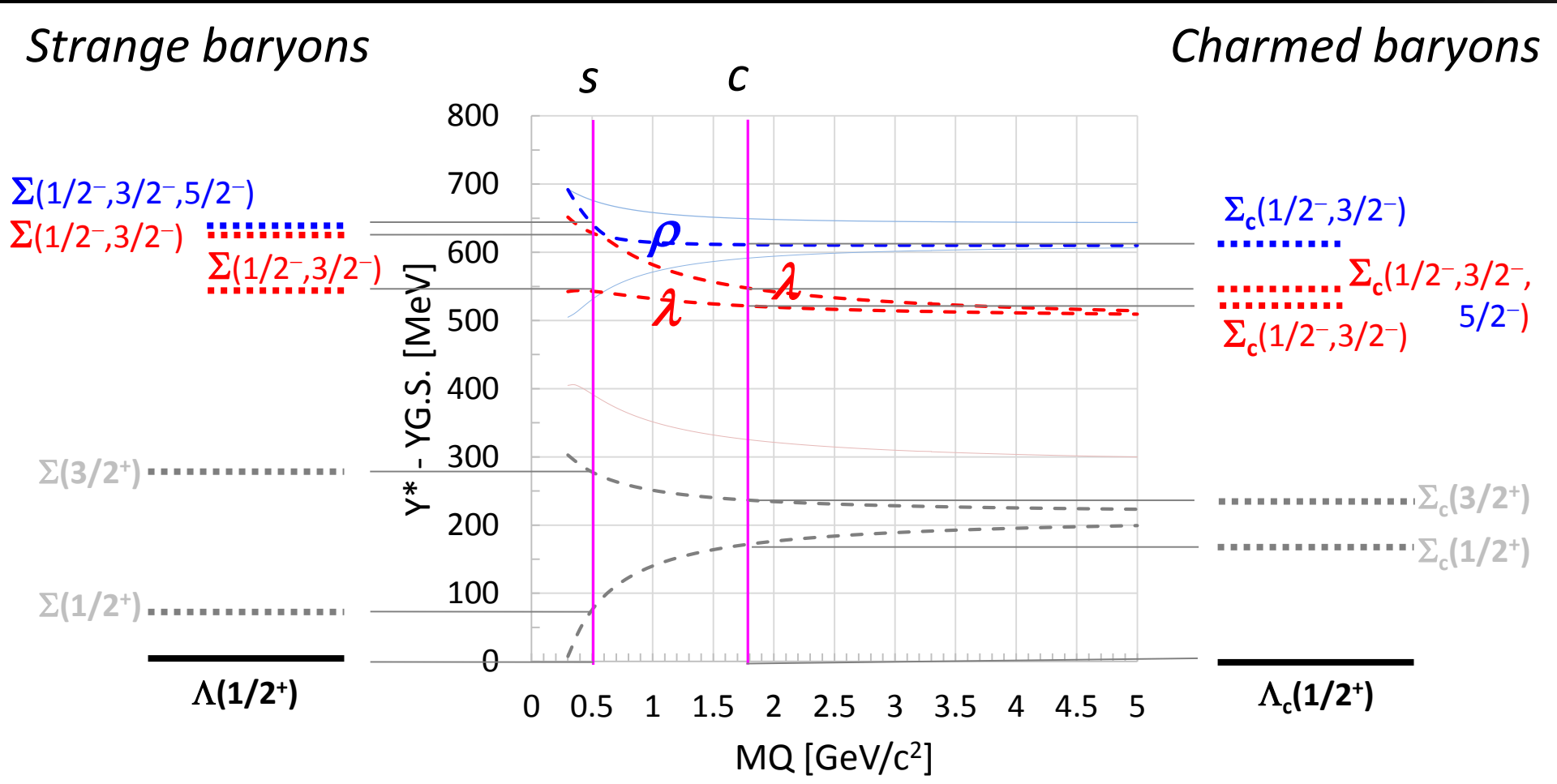


CQM calculation (P-wave Lambda)



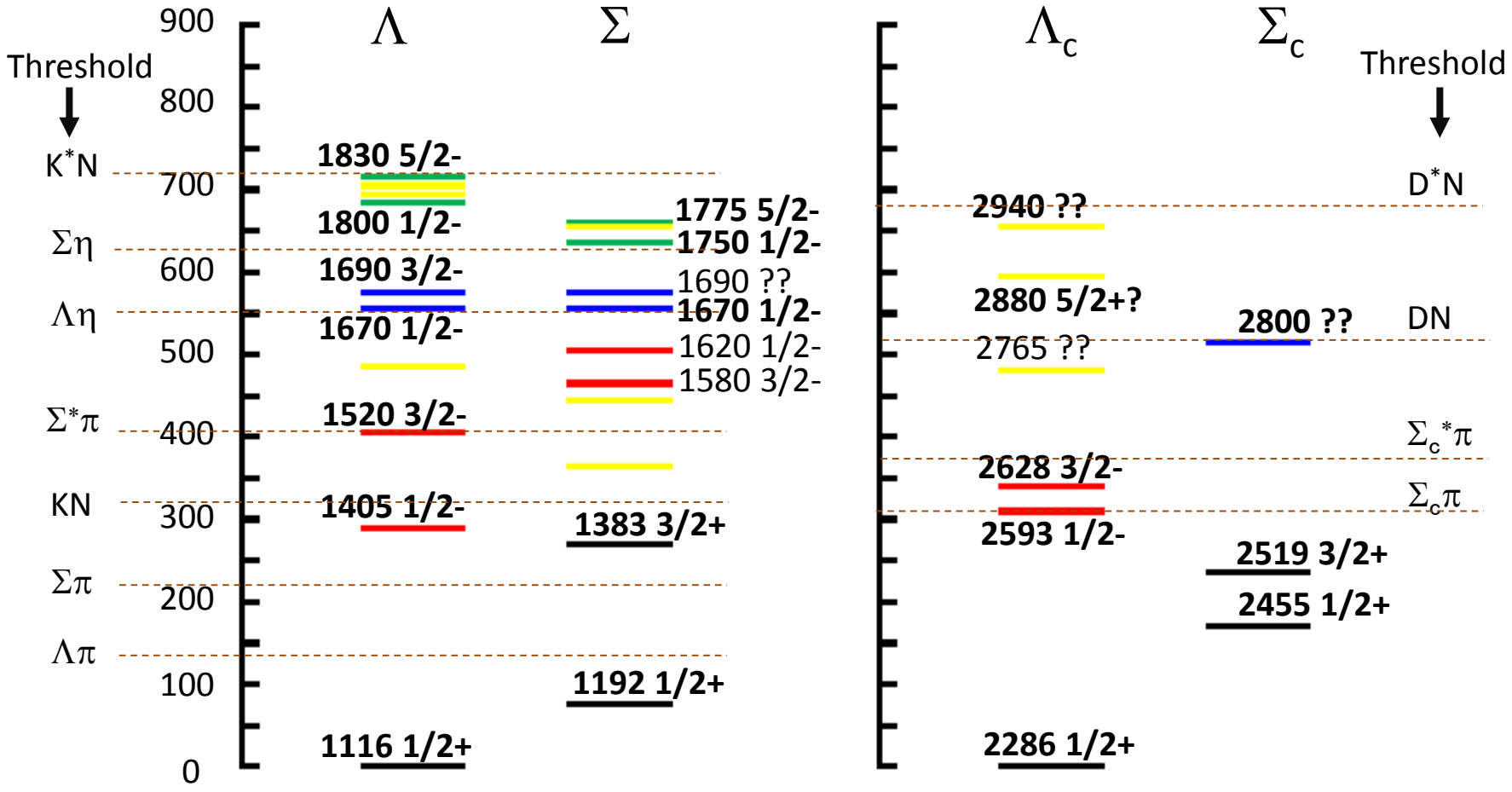
non-rel. QM: $H=H_0+V_{conf}+V_{SS}+V_{LS}+V_T$
ρ–λ mixing (cal. By T. Yoshida (Tokyo I. Tech.)

CQM calculation (P-wave Sigma)



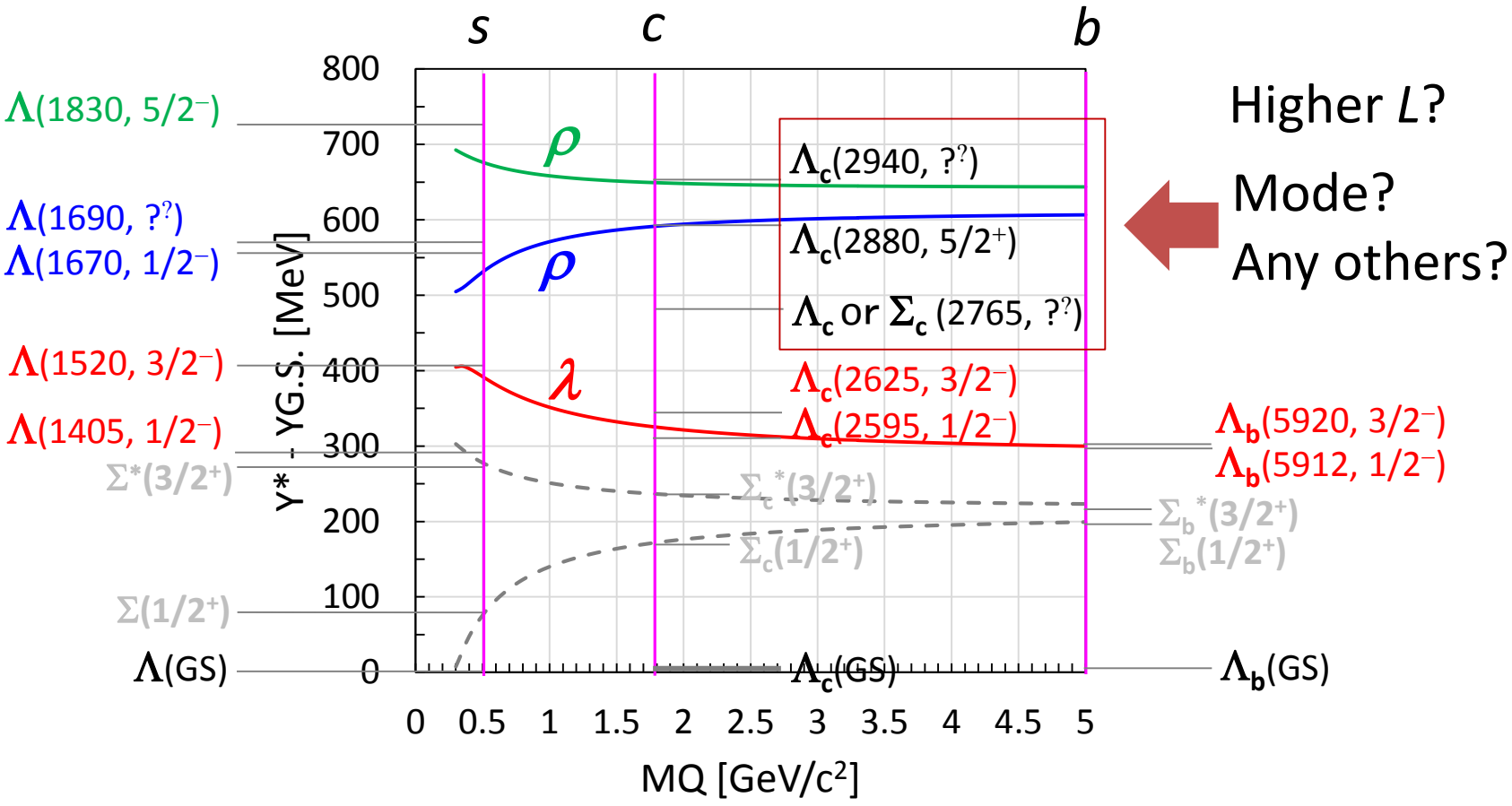
non-rel. QM: $H=H_0+V_{conf}+V_{SS}+V_{LS}+V_T$
ρ–λ mixing (cal. By T. Yoshida)

Level structure (Exp.)



- ✓ Classification based on λ / ρ mode has yet to be established.
- ✓ Little of Y_c is known.

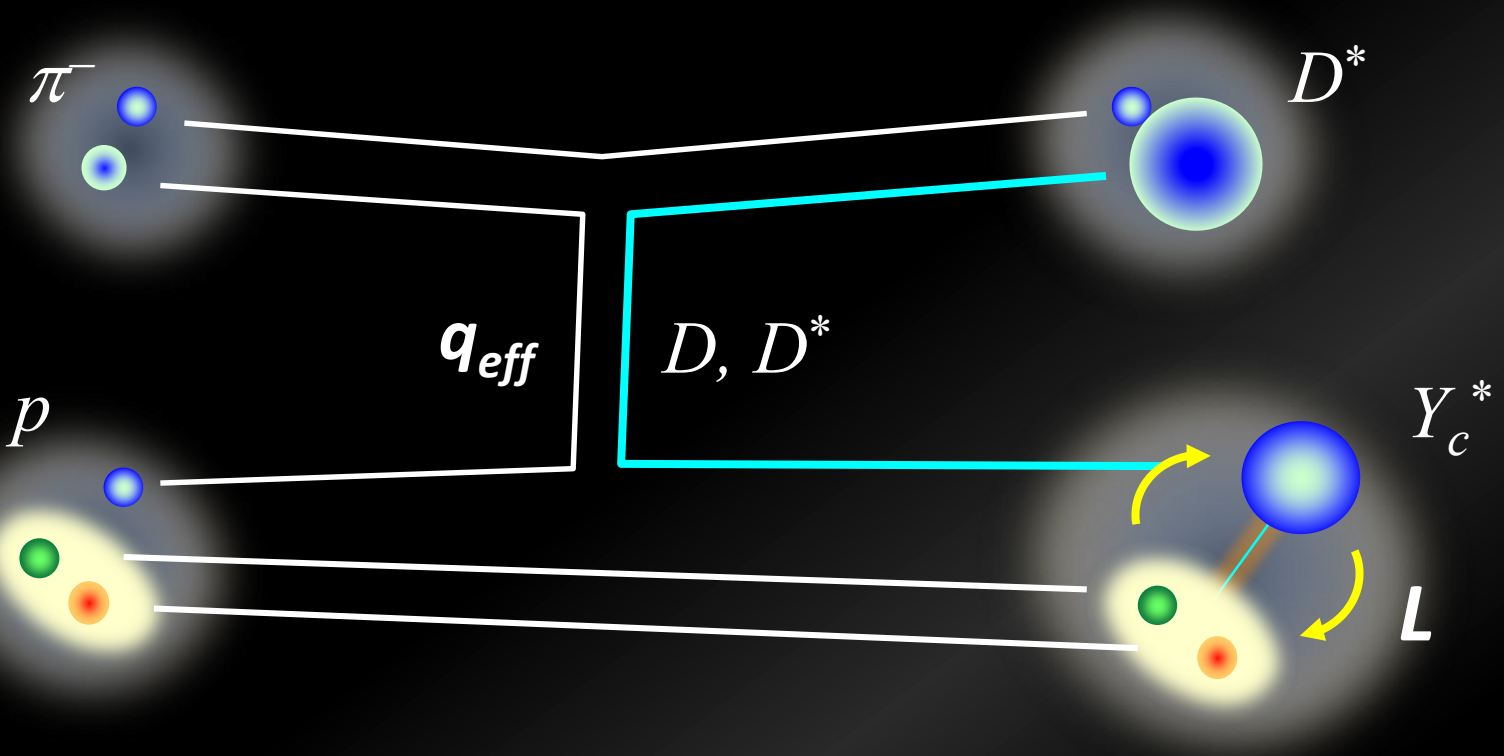
Lambda Baryons



non-rel. QM: $H=H_0+V_{conf}+V_{SS}+V_{LS}+V_T$
ρ–λ mixing (cal. By T. Yoshida)

Production Rate

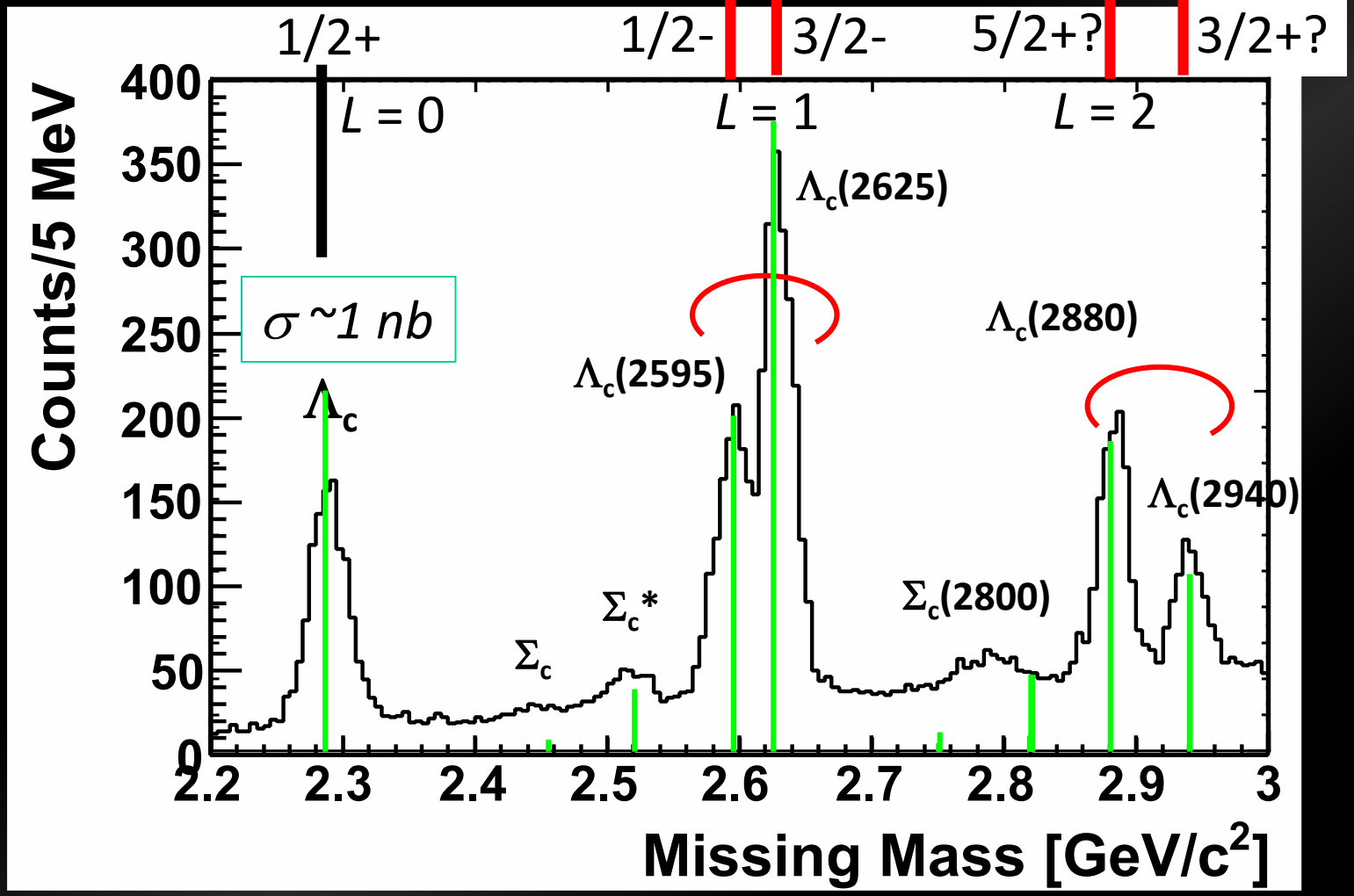
S.H. Kim, A. Hosaka, H.C. Kim, HN, K. Shirotori, PTEP, 103D01, 2014.



- ✓ C.S. DOES NOT go down at higher L when q_{eff} >1 GeV/c
- ✓ λ modes are excited by a simple mechanism

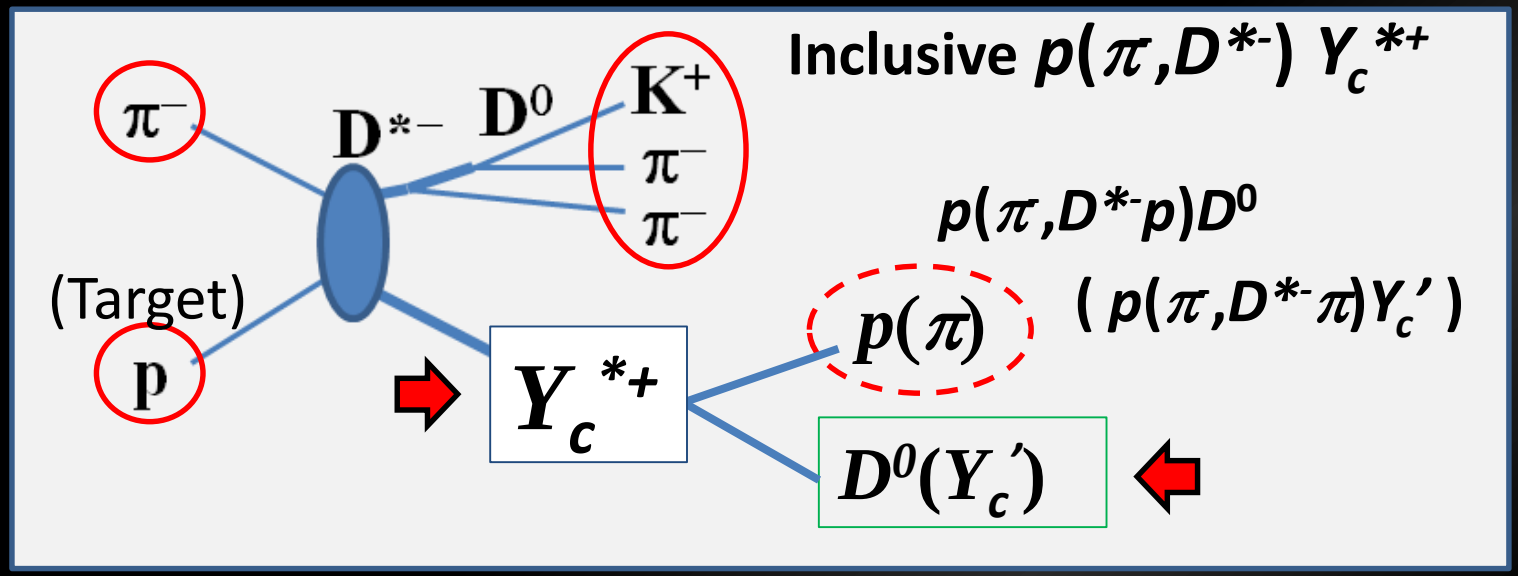
Missing Mass Spectrum (Sim.)

- ~1000 Y_c^*/nb/100 days
- Sensitivity: σ~0.1 nb for Y_c^* w/ Γ=100 MeV



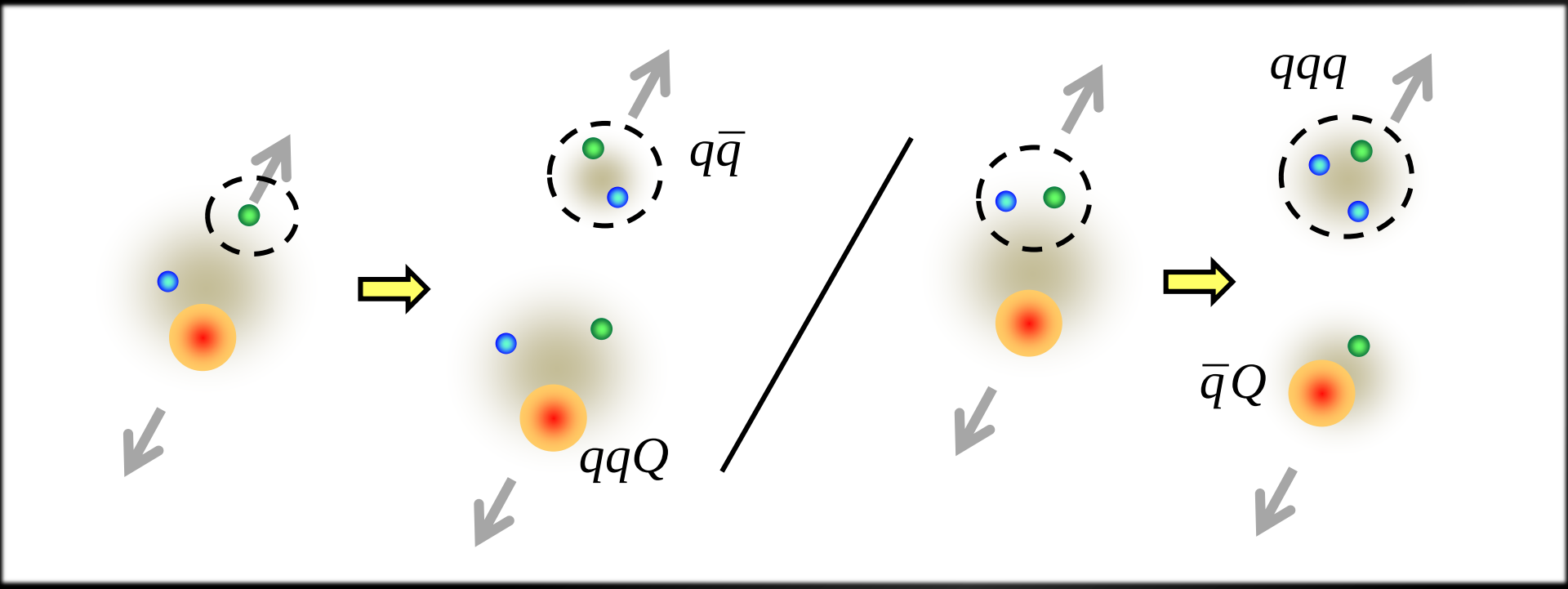
Charmed Baryon Spectroscopy

Using Missing Mass Techniques



Conducted by the E50 experiment at J-PARC

Decay Properties



ρ mode (qq)

$\Gamma(\Sigma_c\pi) > \Gamma(pD)$

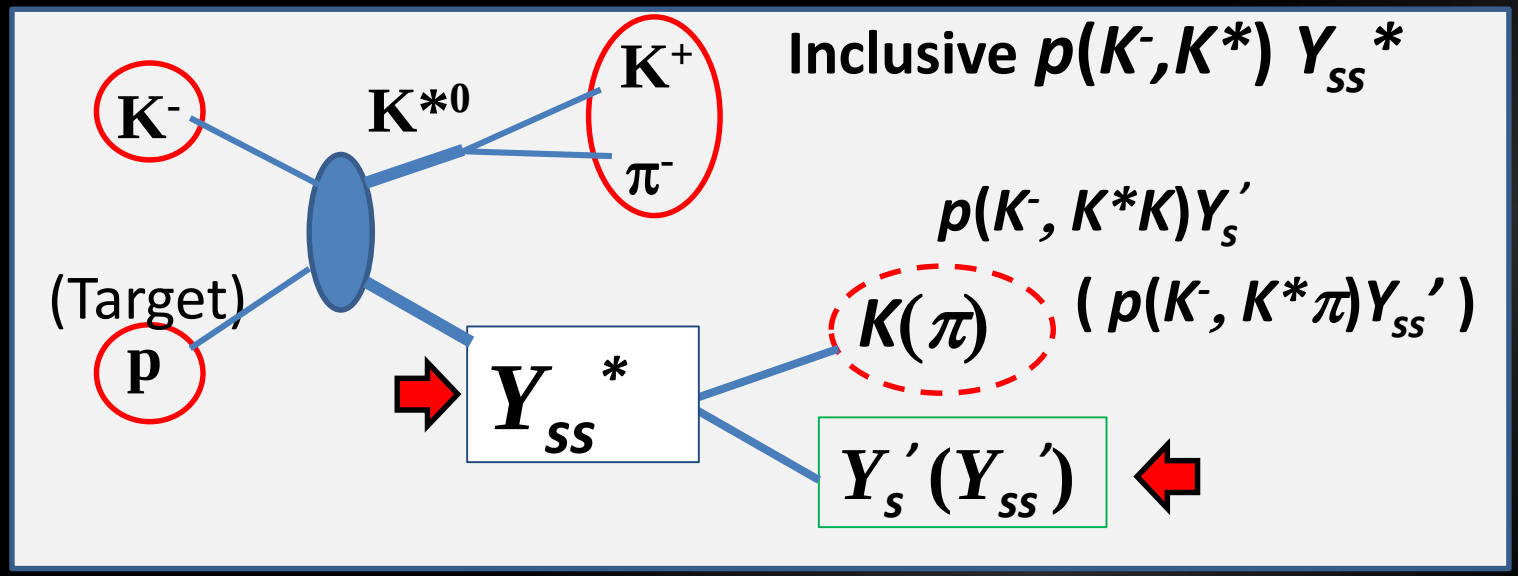
λ mode [qq]

$\Gamma(\Sigma_c\pi) < \Gamma(pD)$

Strange Hyperons

Double-Strange Baryon Spectroscopy

Using Missing Mass Techniques



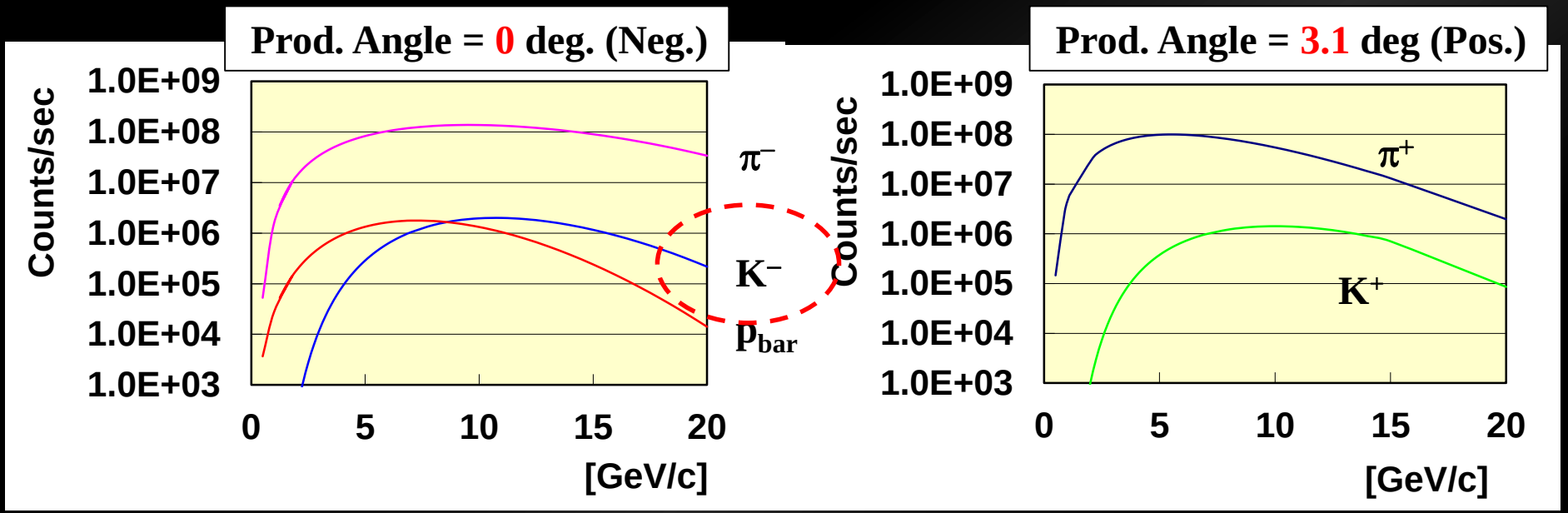
- S=-1 Hyperon *by* $p(\pi^-,K^*)$, $Y^*\rightarrow pK,\ \ \pi Y$
- S=-2 Hyperon *by* $p(K^-,K^*)$, (K^-,K), (π,KK^*), $\Xi^*\rightarrow YK,\ \pi\Xi$

x1000~10000 better statistics than Y_c^*

High-res., High-momentum Beam Line

- High-intensity secondary Pion beam
  - >1.0 x 10^7 pions/sec @ 20GeV/c
- High-resolution beam: $\Delta p/p \sim 0.1\%$

Intense K beams are available w/ a good KID counter.

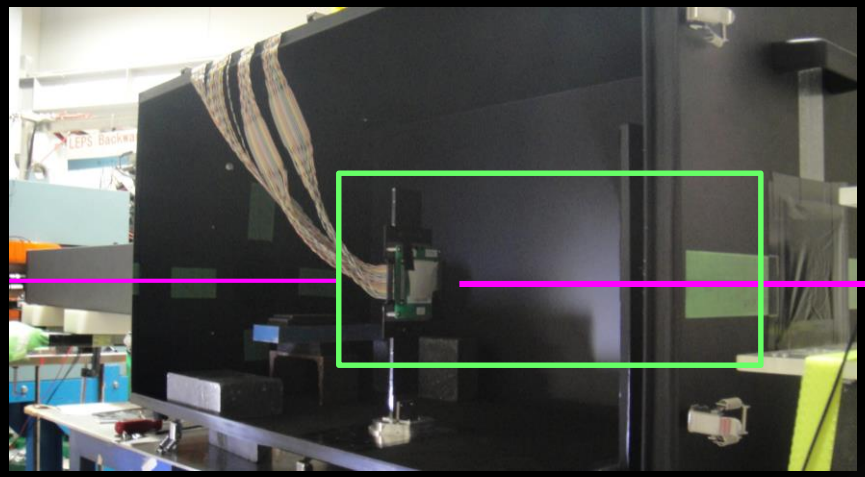


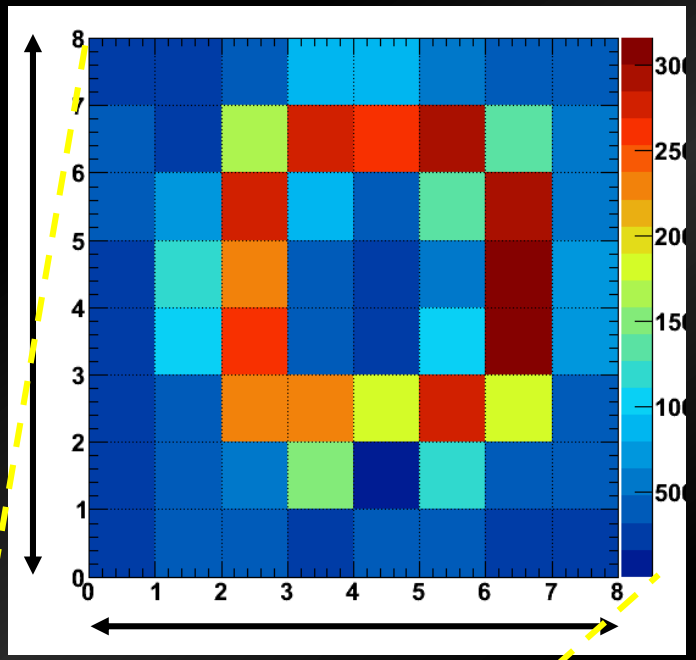
* Sanford-Wang:15 kW Loss on Pt, Acceptance :1.5 msr%, 133.2 m

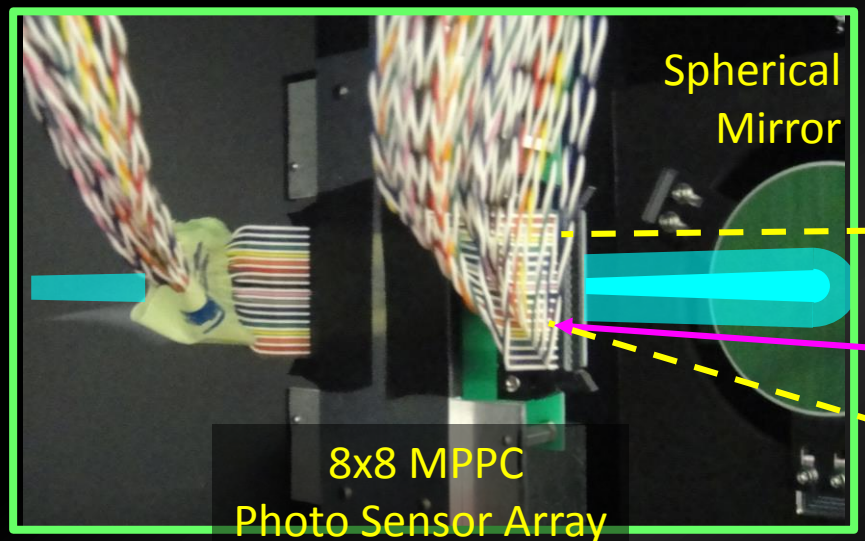
RICH R&D is in progress

Measured RING IMAGE
by 8x8 MPPC Array

Electron
0.75 GeV/c

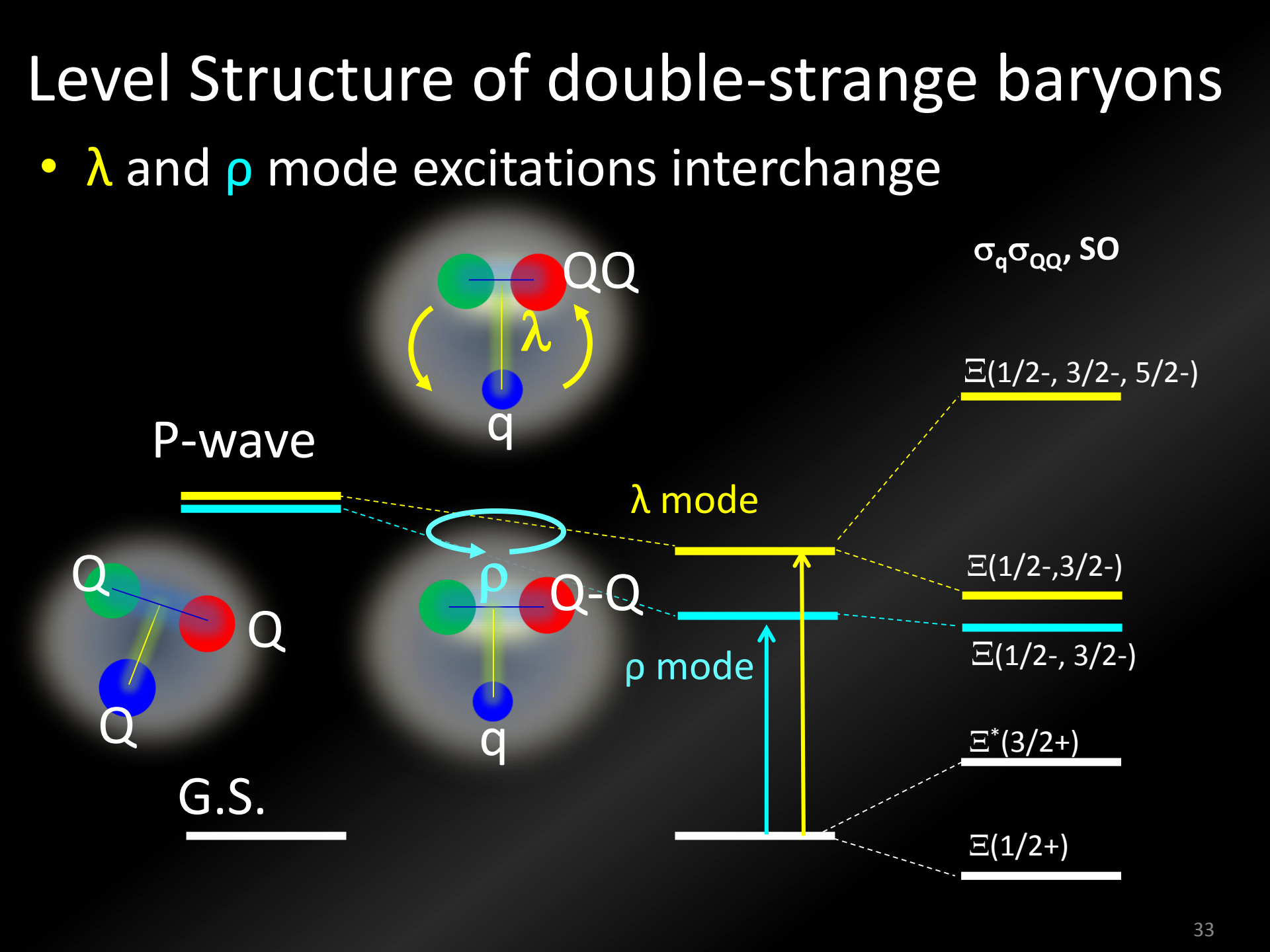




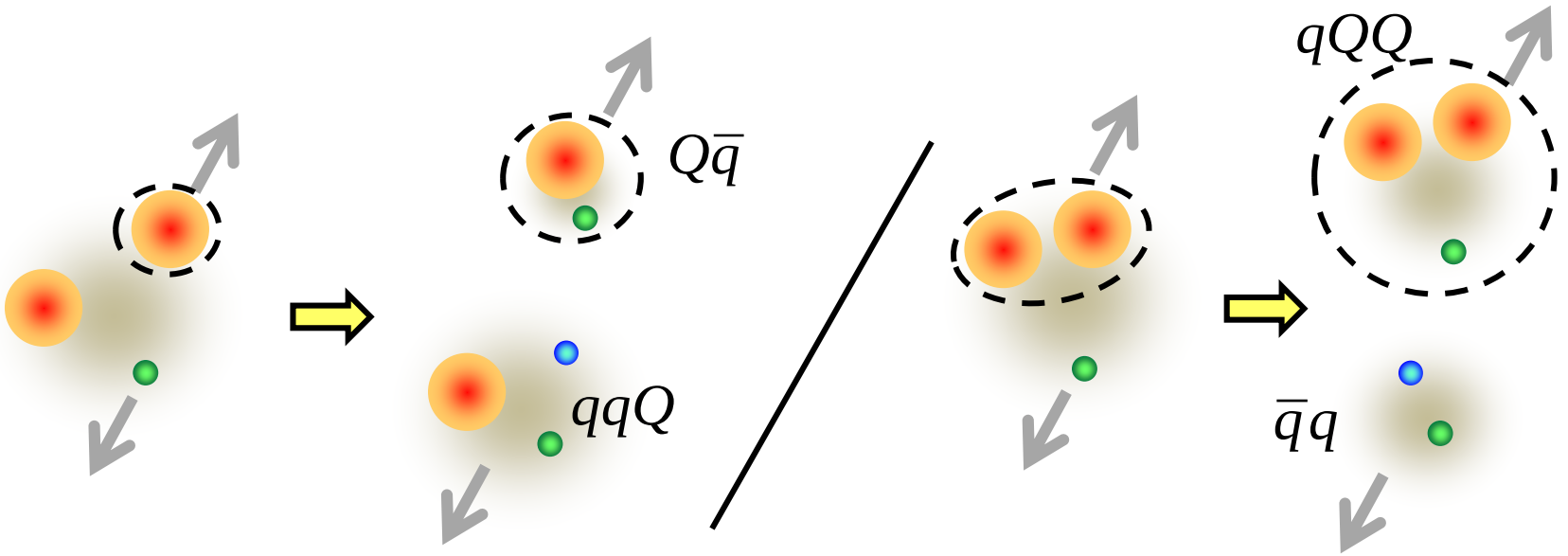


Level Structure of double-strange baryons

- λ and ρ mode excitations interchange



Structure and Decay Partial Width



ρ mode (QQ)

$\Gamma(\Xi\pi) < \Gamma(YK^{bar})$

λ mode [QQ]

$\Gamma(\Xi\pi) > \Gamma(YK^{bar})$

Measured Ξ (PDG)

Threshold

$\Omega\overline{K}(2166)$

$\Sigma\overline{K}^{*}(1983)$

$\Sigma^{*}\overline{K}(1878)$ $\Lambda\overline{K}^{*}(1908)$

$\Xi^{*}\pi(1665)$ $\Sigma\overline{K}(1685)$

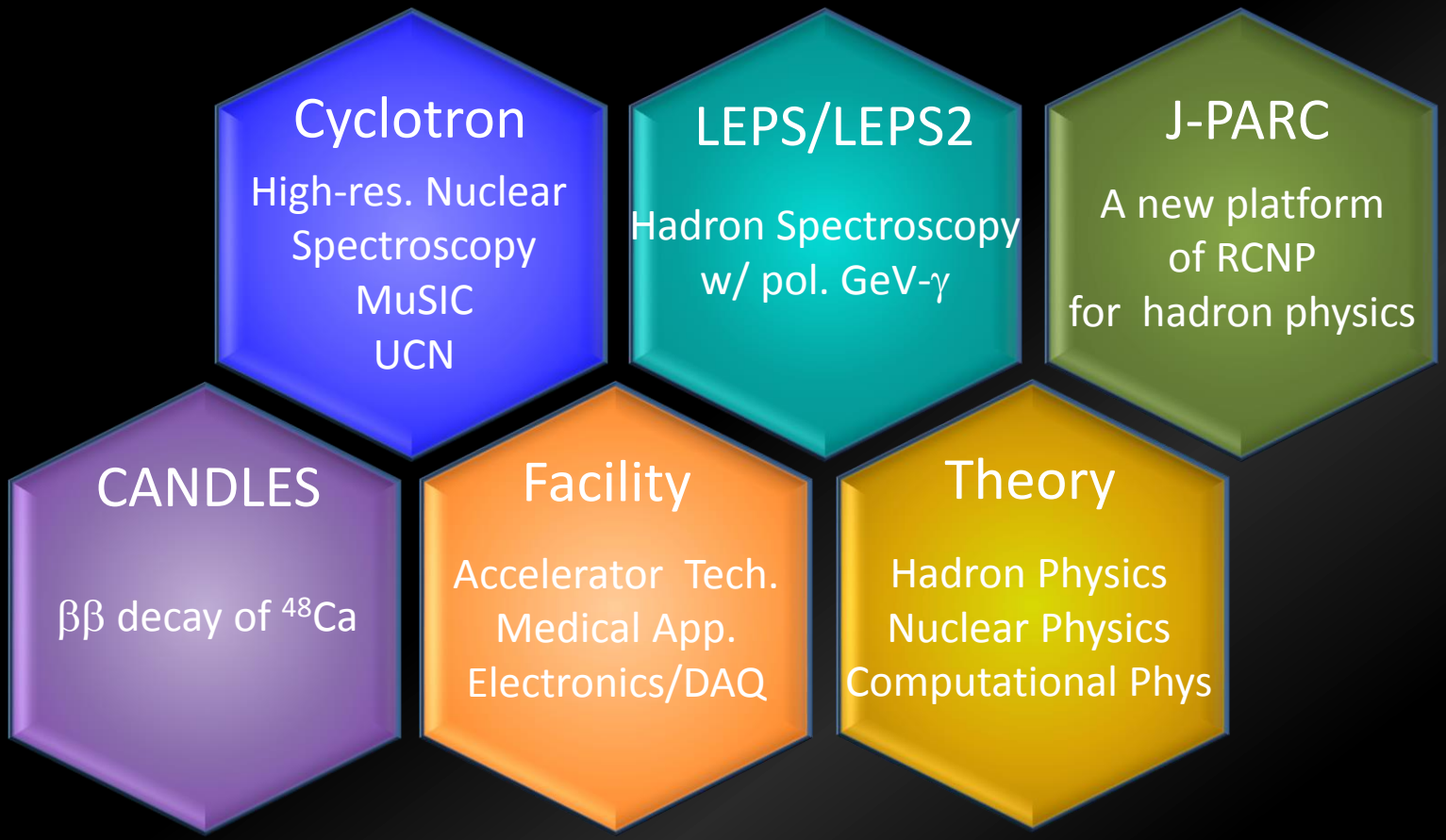
$\Lambda\overline{K}(1610)$

$\Xi\pi(1450)$

	JP	rating	Width [MeV]	→Ξπ [%]	→ΛK [%]	→ΣK [%]	
Ξ(2500)	??	1*	150?				
Ξ(2370)	??	2*	80?				ΩK~9±4
Ξ(2250)	??	2*	47+-27?				
Ξ(2120)	??	1*	25?				
Ξ(2030)	>=5/2?	3*	20^{+15}_{-5}	small	~20	~80	Why ΣK?
Ξ(1950)	??	3*	60+-20	seen	seen		
Ξ(1820)	3/2-	3*	24^{+15}_{-10}	small	Large	Small	
Ξ(1690)	??	3*	<30	seen	seen	seen	
Ξ(1620)	??	1*	20~40?				
Ξ(1530)	3/2+	4*	19	100			

- ✓ *Most of spins/parities have NOT been determined yet.*
- ✓ *Why the* Ξ^{*} -> $\pi\Xi$ decay seems to be suppressed?
  - ✓ expected to reflect QQq configuration.

RCNP Activity



Summary

- RCNP will conduct a new platform for hadron physics at the High-p Beam Line of J-PARC.
  - Hadron beam and γ-beam
  - Strangeness and charm
- Strong collaborations of experiment and theory are important to attack problems on hadron physics
- RCNP can provide a lot of opportunities to study nuclear hadron physics in Japan.
  - APCTP are expected to play an important role to strengthen mutual collaborations.