Workshop on Progress on J-PARC hadron physics in 2014
30 Nov.-2 Dec., 2014

Experiments of charmed baryons at J-PARC

H. Noumi (RCNP, Osaka University)
2 December, 2014

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2. Charmed Baryon Spectroscopy via (π-,D*-)
   Mass Spectrum, Production, and Decay
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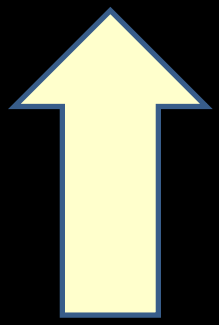
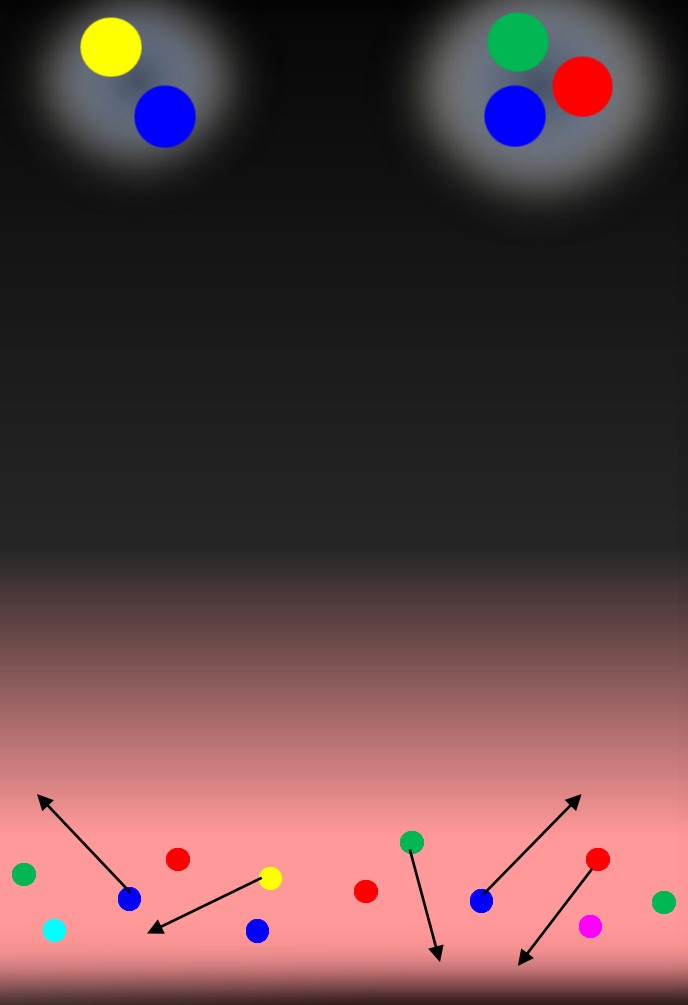
How are hadrons formed?

Hadron



?

Current Quark



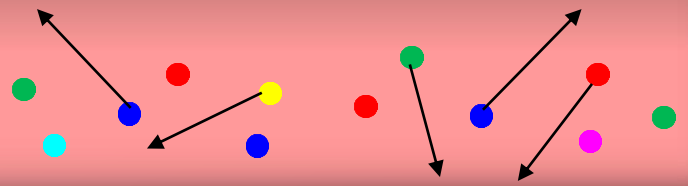
How are hadrons formed?

Hadron

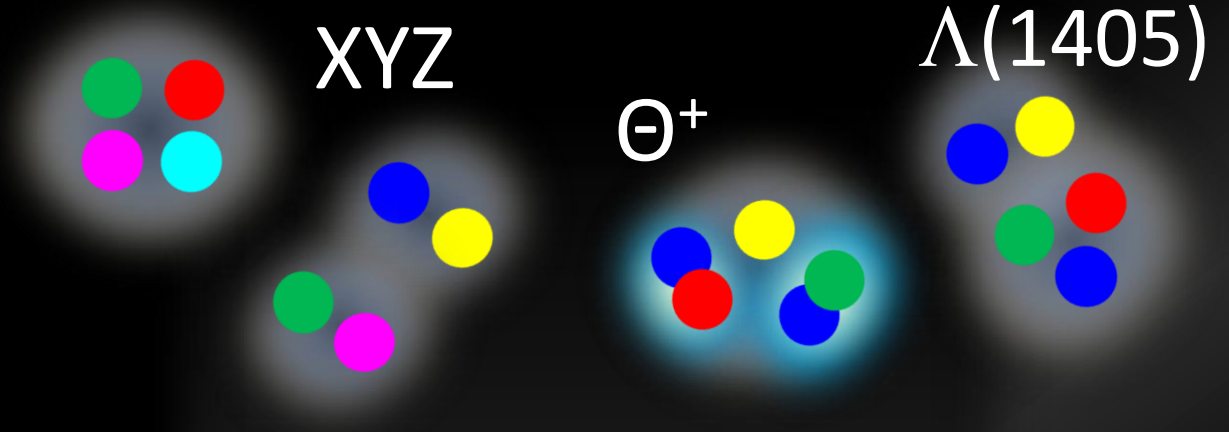
"Building Block"

Current Quark

Constituent Quark

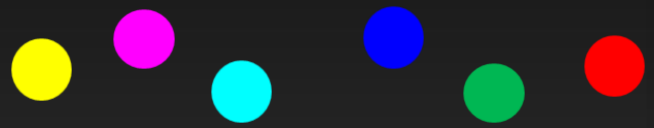


How are hadrons formed from quarks?



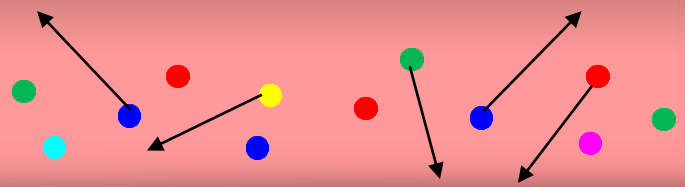
New Hadrons

"Building Block"



Constituent Quark

Current Quark



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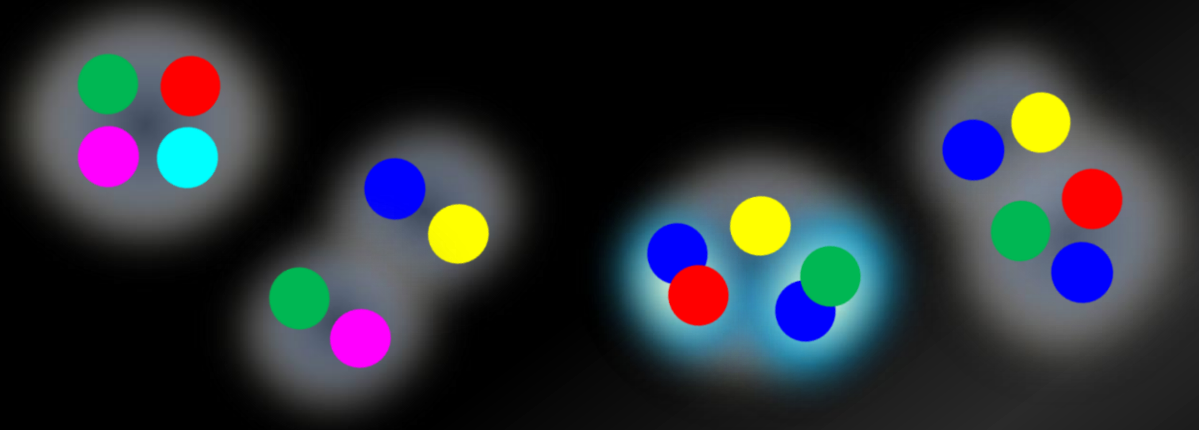
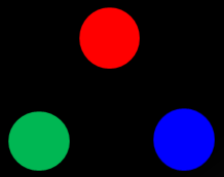


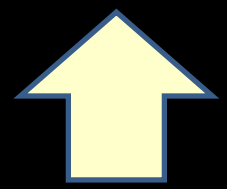
“Building Block”

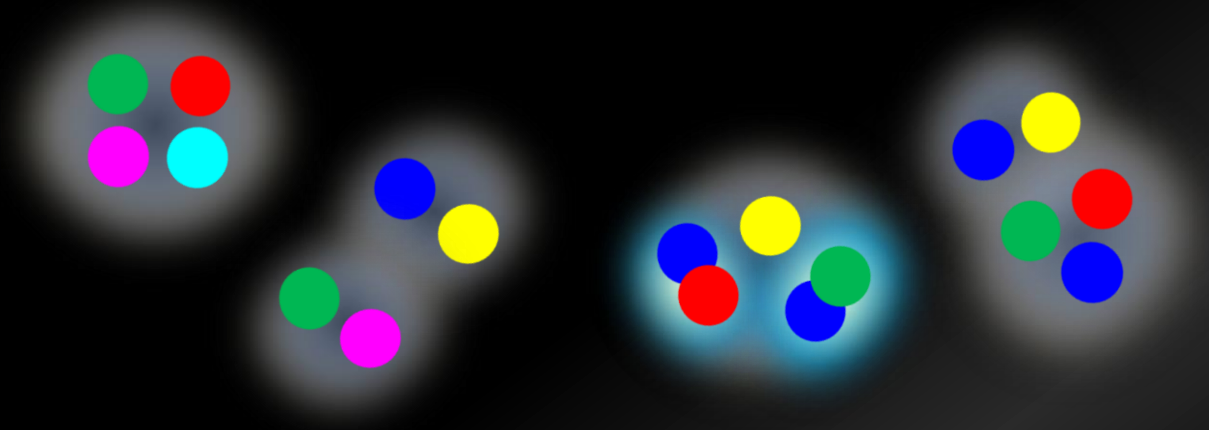


Constituent Quark

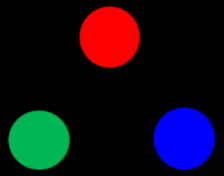
How are hadrons formed from quarks?

New Hadrons

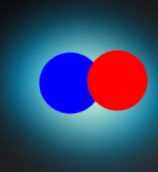




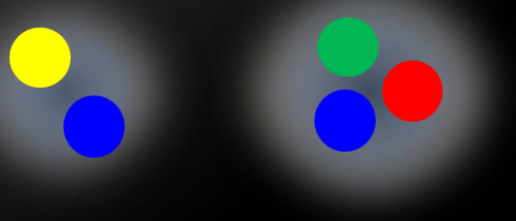
"New Building Blocks"



Constituent Quark



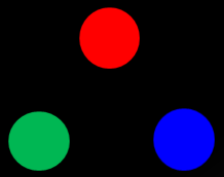
Diquark



Hadrons

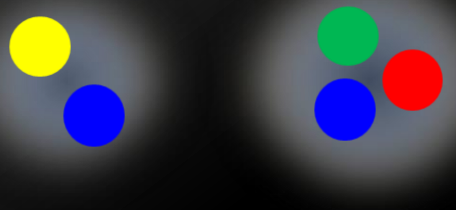
Hadrons

"Characteristic Quasi-Particle"



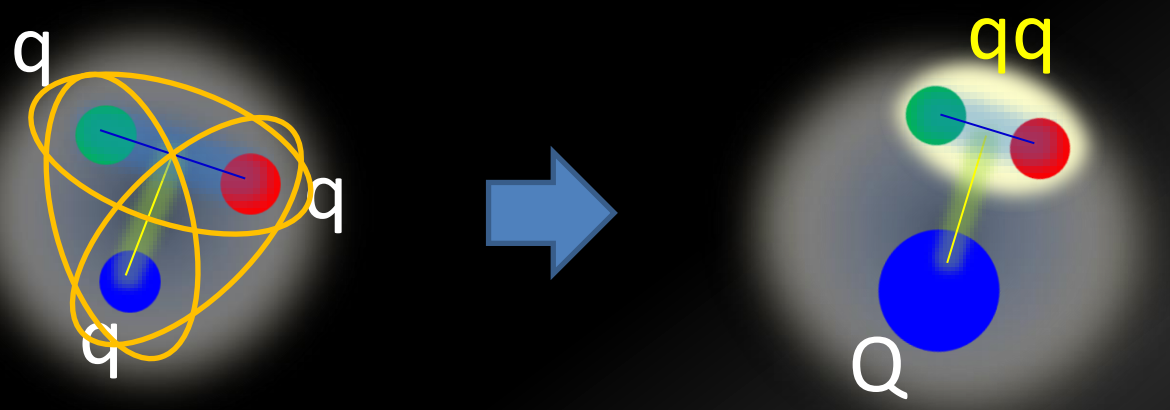
Constituent Quark

Diquark



Hadrons

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
- Properties are expected to depend on a Q mass.

Hadron Spectroscopy in H.E. Exp.

- e+e-(Belle), pp(LHCb), RHI(RHIC/LHC), …
  - Invariant Mass Spectroscopy

    mass reconstructed from F. S. Particles
- Production from Vacuum/QGP
  - $e^+e^- \rightarrow q\bar{q} \rightarrow q\bar{q} + q\bar{q}, qqq+\bar{q}\bar{q}\bar{q}, \ldots$

    $[q\bar{q}][\bar{q}q] + q\bar{q}, \ldots$
  - $gg \rightarrow q\bar{q} \rightarrow \ldots\ldots$
  - QGP $\rightarrow q\bar{q}, qqq, \ldots$

    $[qq]q, [q\bar{q}][\bar{q}q], [\bar{q}q]qqq, \bar{q}[qq][qq], \ldots$

Hadron Spectroscopy at J-PARC

- Unique approach
  - Missing Mass Spectroscopy in M-B collisions.

    $q\bar{q} + q[qq] \rightarrow q\bar{Q} + Q[qq]$

    in addition to mass, width, and spin/parity
    - Production Cross Section
    - Decay Property : Decay Branching Ratios

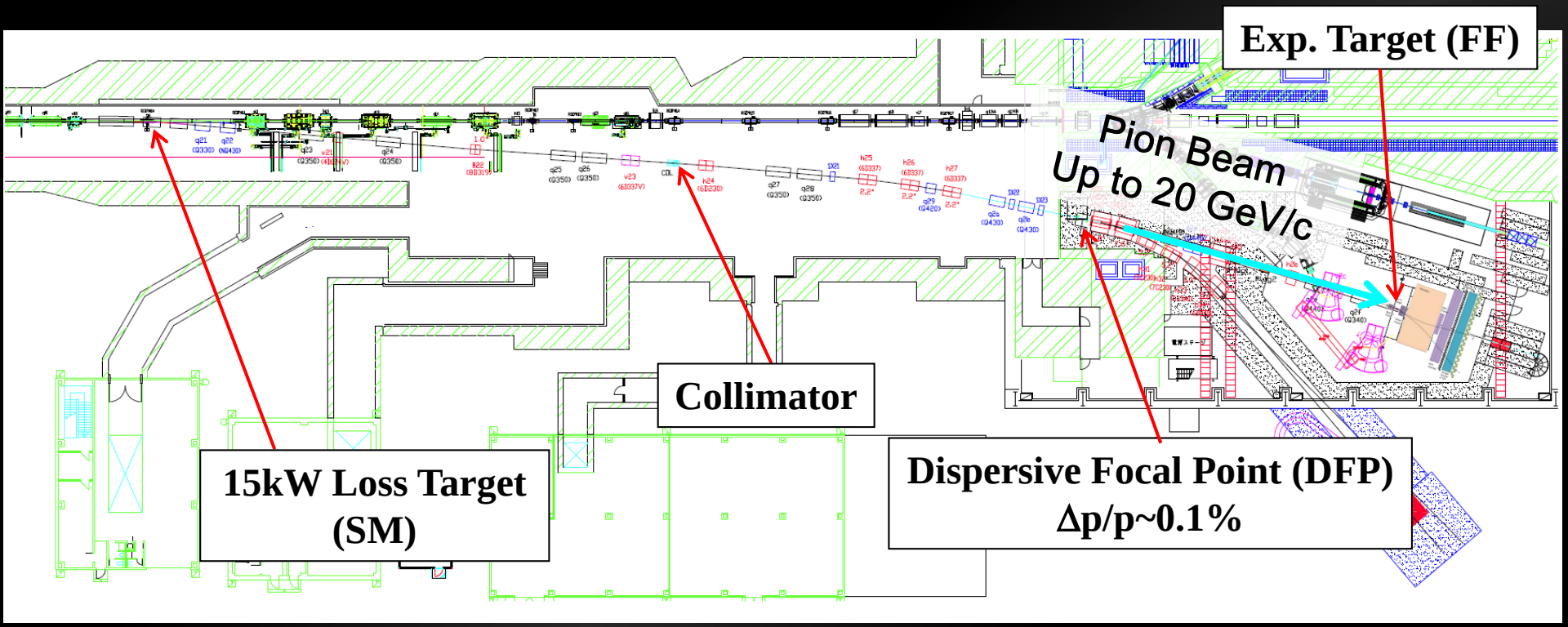
      … reflect Quark-Diquark config. of Baryons

      → baryons with heavy flavors

High-res., High-momentum Beam Line

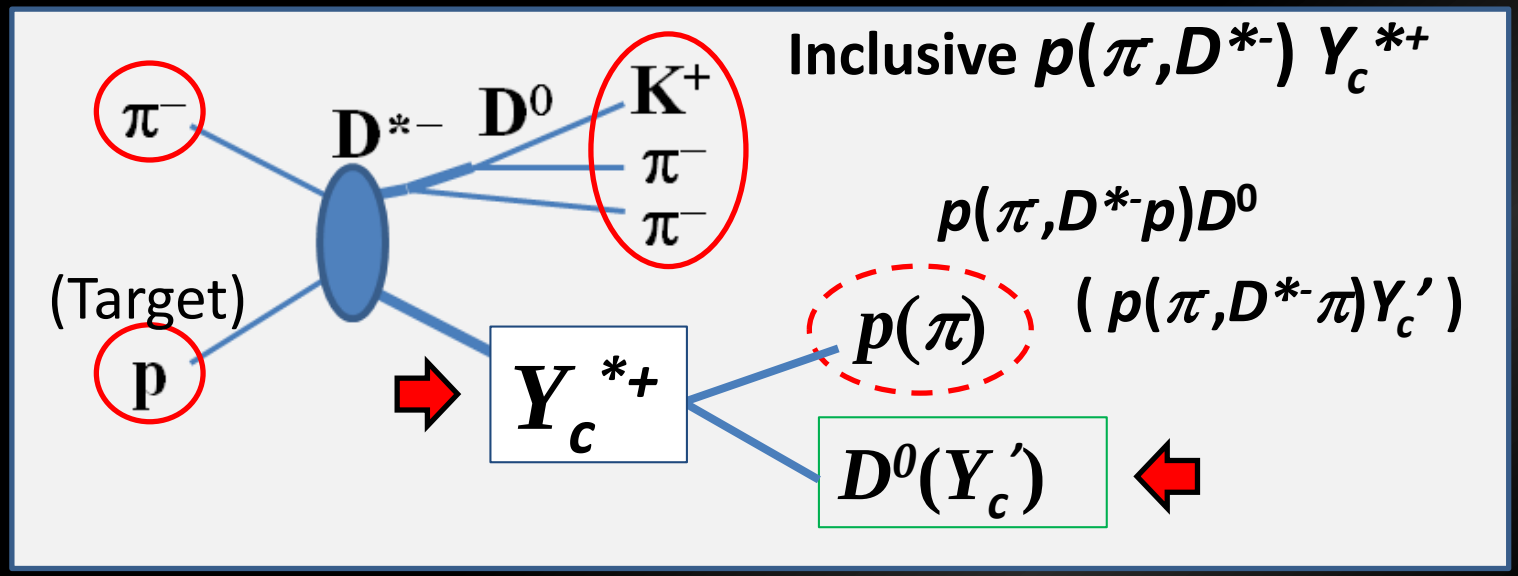
- High-intensity secondary Pion beam
  - >1.0 x 10^7 pions/sec @ 20GeV/c
- High-resolution beam: $\Delta p/p$~0.1%

Open a new platform for hadron physics



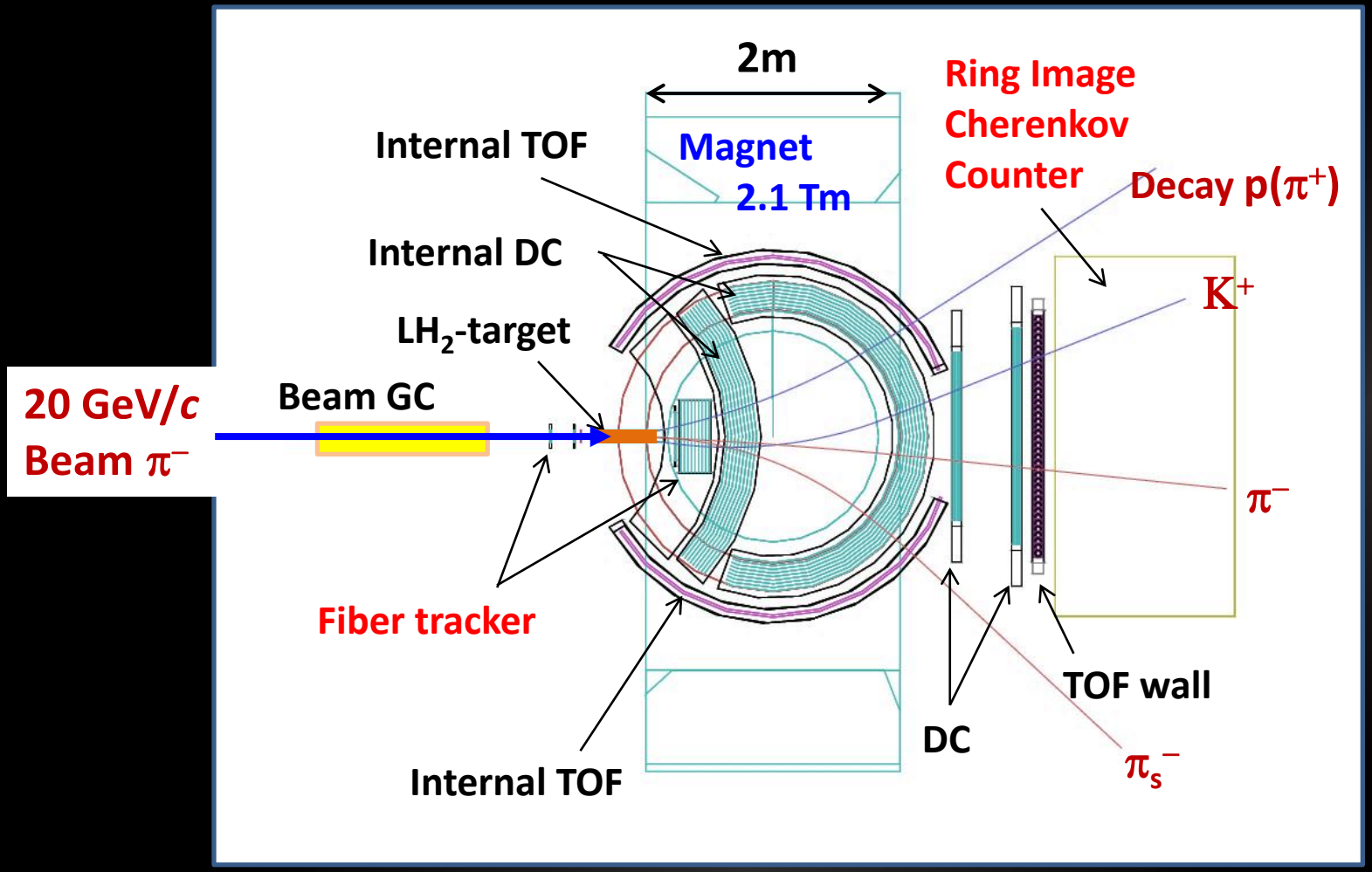
Charmed Baryon Spectroscopy

Using Missing Mass Techniques



Conducted by the E50 experiment at J-PARC

Large Acceptance Spectrometer

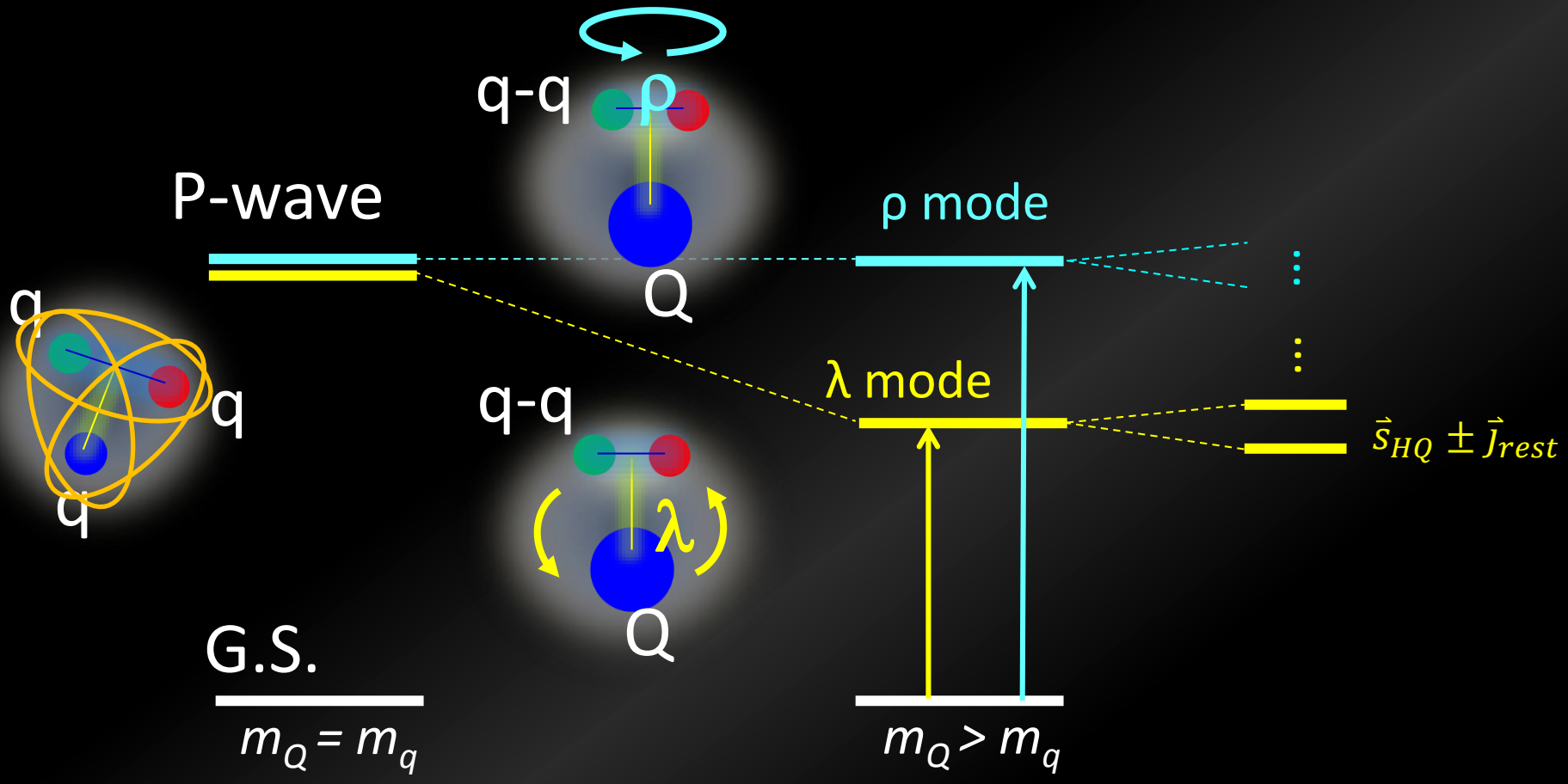


Acceptance: ~ 60% for D^*, ~80% for decay π^+

Resolution: $\Delta p/p$~0.2% at ~5 GeV/c （Rigidity：~2.1 Tm)

Schematic Level Structure of Heavy Baryons

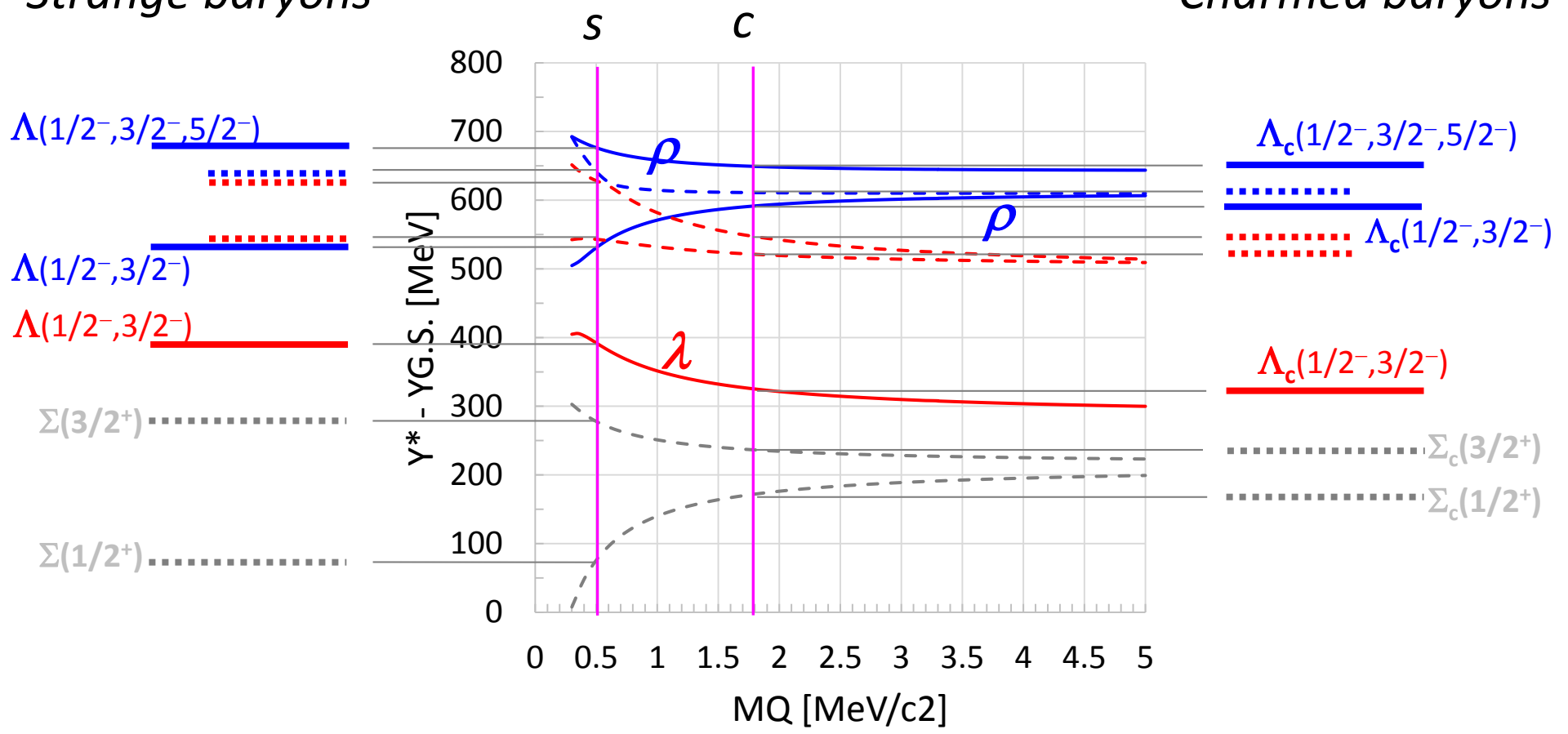
- λ and ρ motions split (Isotope Shift)
- HQ spin multiplet（$\vec{s}_{HQ} \pm \vec{J}_{rest}$）



CQM calculation (Lambda)

Strange baryons

Charmed baryons



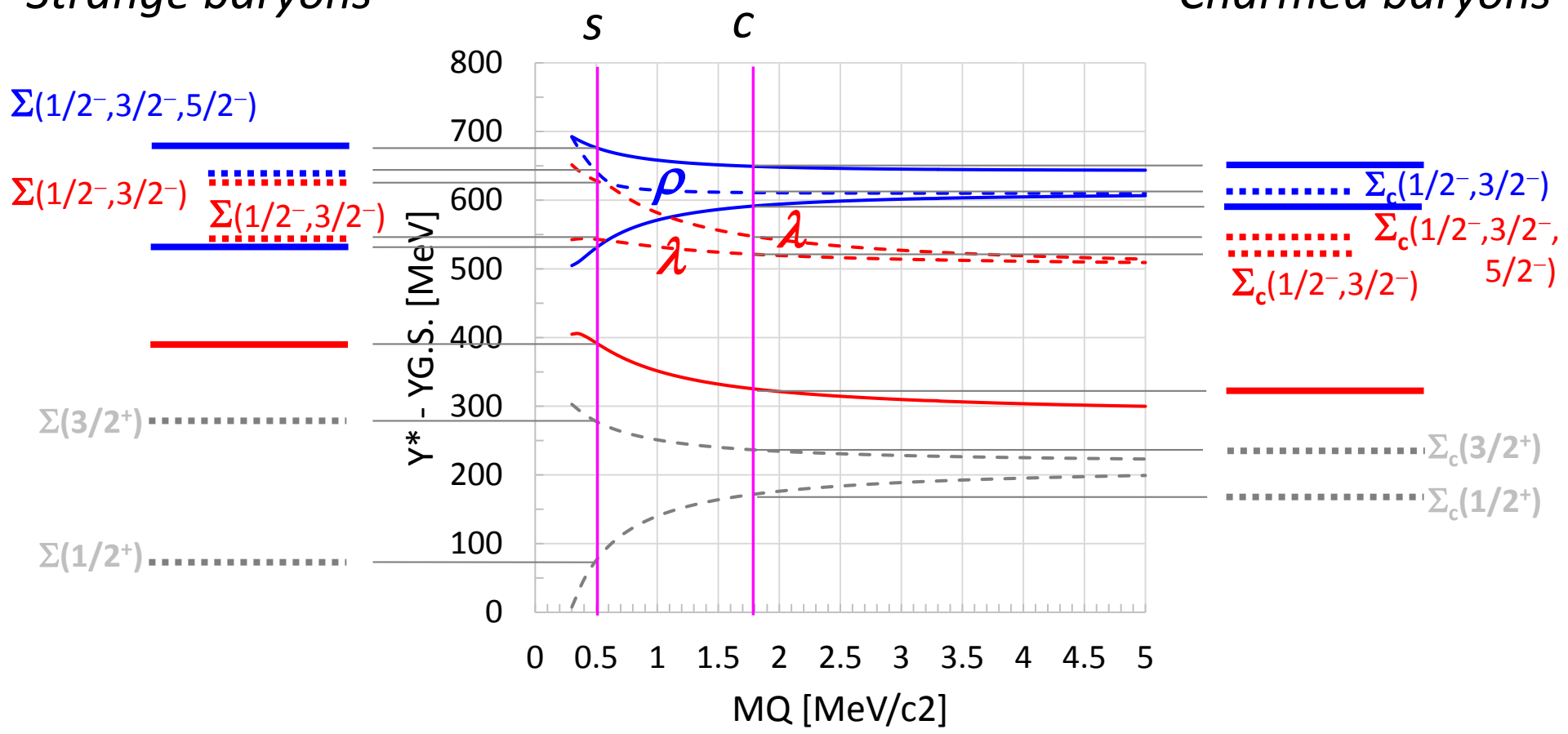
non-rel. QM: $H=H_0+V_{conf}+V_{SS}+V_{LS}+V_T$

ρ–λ mixing (cal. By T. Yoshida)

CQM calculation (Sigma)

Strange baryons

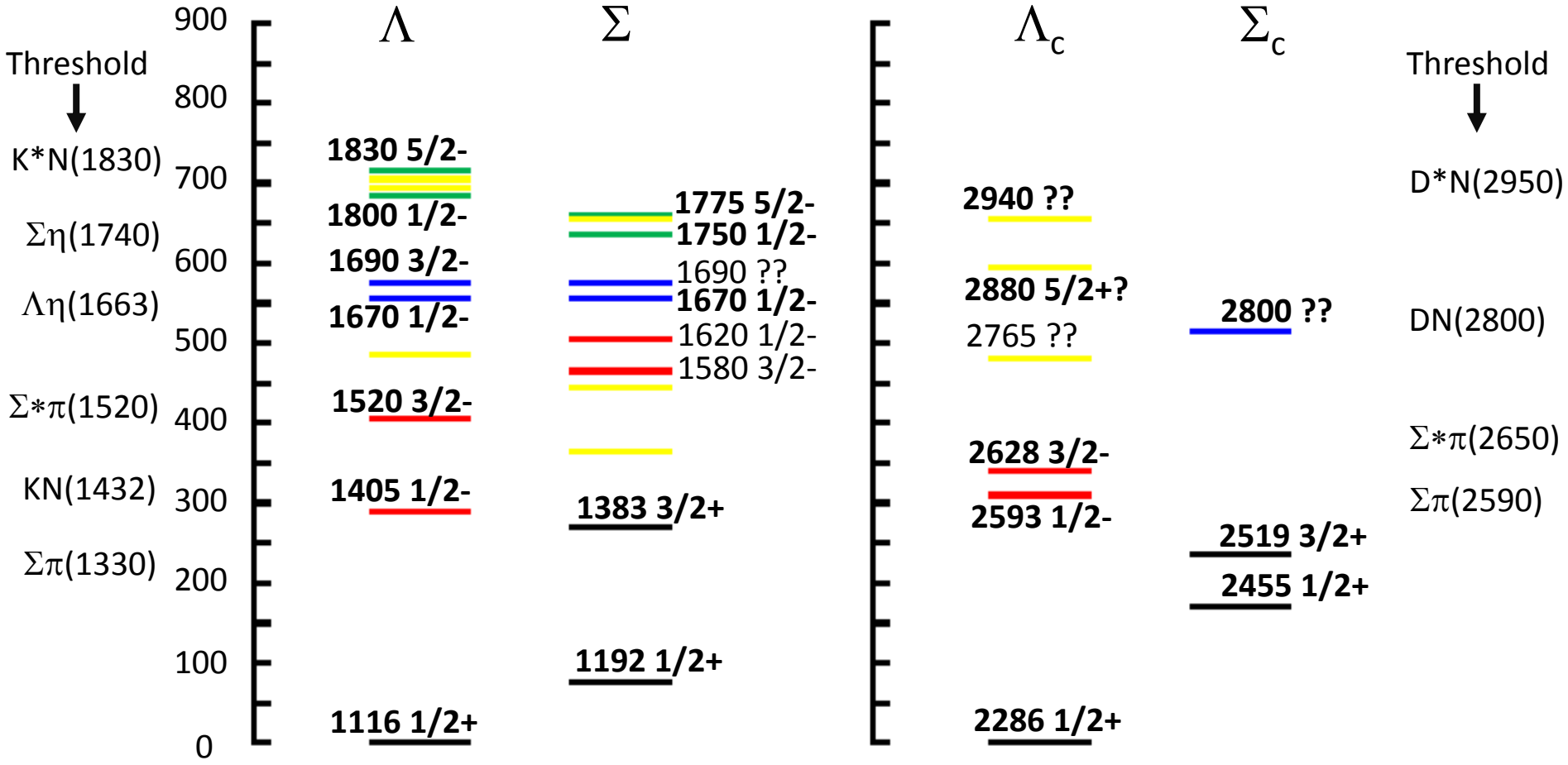
Charmed baryons



non-rel. QM: $H=H_0+V_{conf}+V_{SS}+V_{LS}+V_T$

ρ–λ mixing (cal. By T. Yoshida)

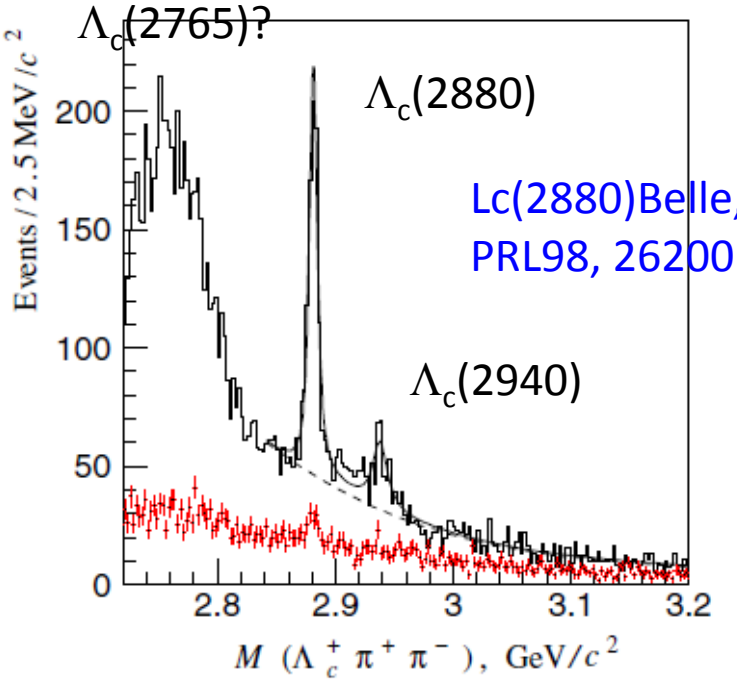
Level structure (Exp.)



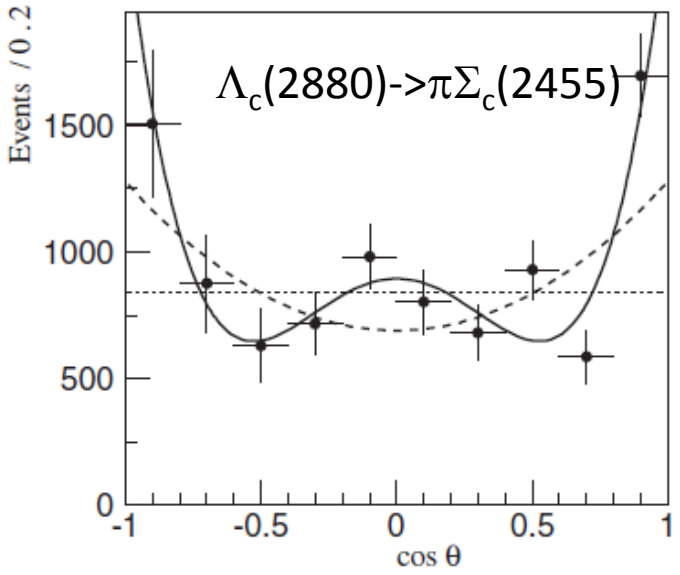
- ✓ λ / ρ mode assignment is not established yet.
- ✓ Level structure of Υ_c is little known.

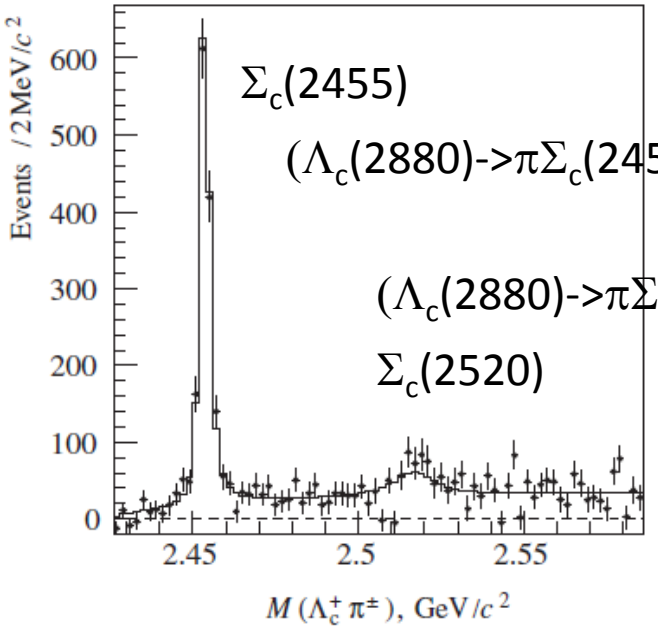
Experimental Situation in Charm Baryons

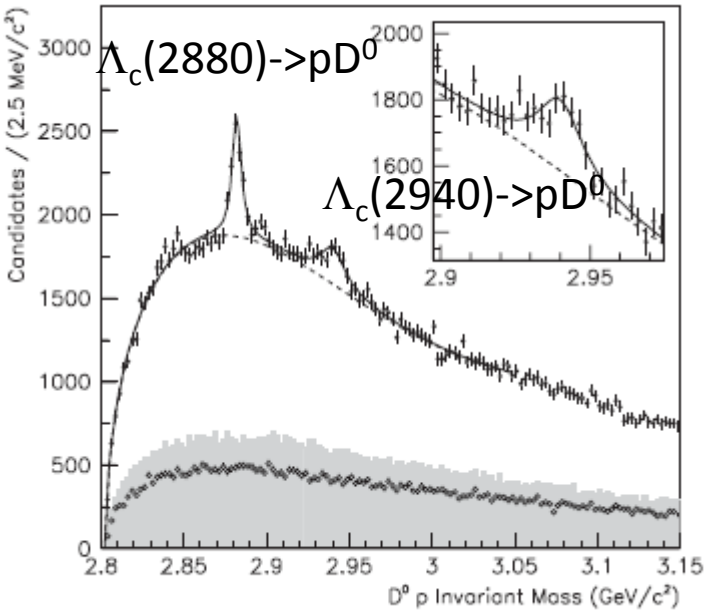
- Experimental information is limited.
  - Many states in excited states have yet to be observed.
  - Spin/Party, (Isospin) still not determined
- $\Lambda(2880)/\Lambda(2940)$ and beyond
  - Orbital Angular momentum is still unclear.
  - λ /ρ mode assignments are important.



Lc(2880)Belle,
PRL98, 262001('07)



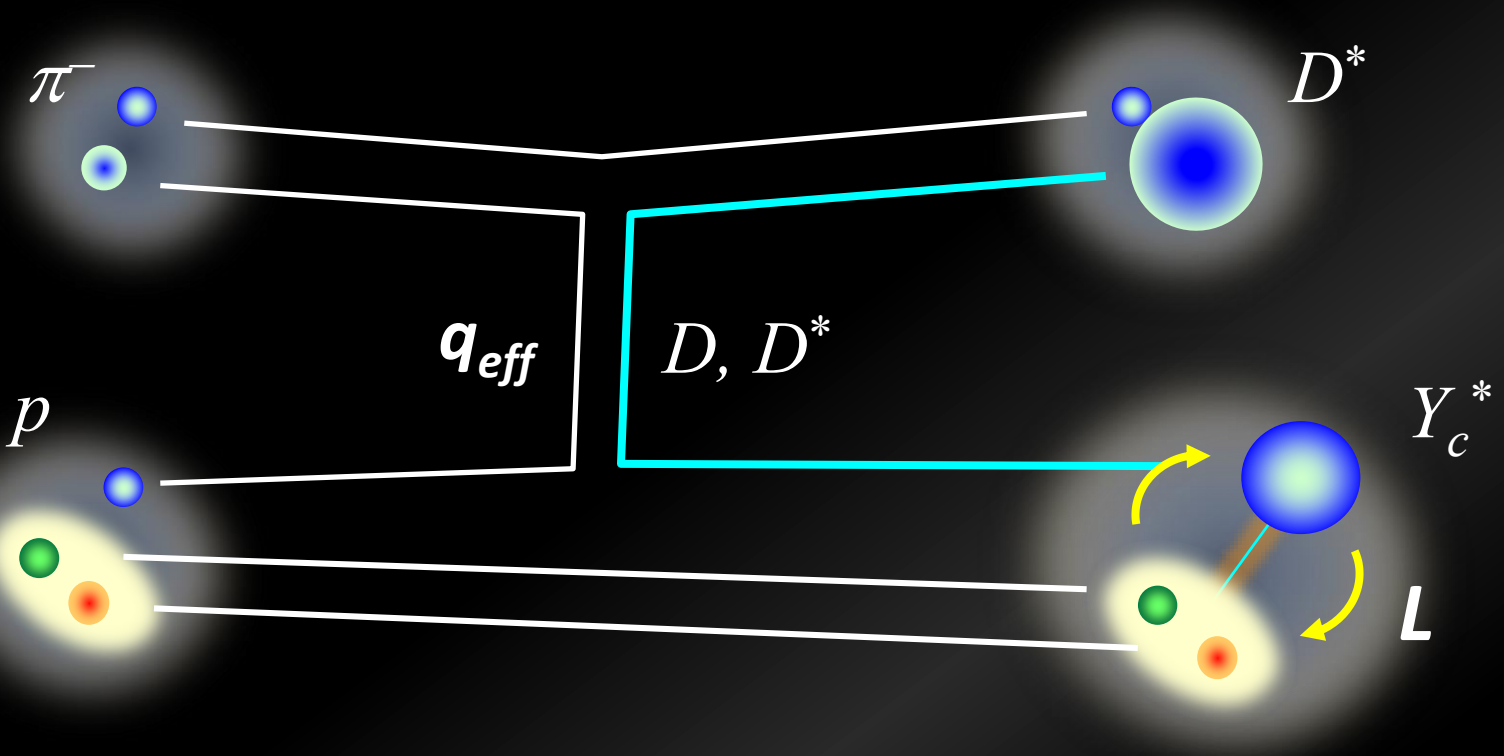




Babar, PRL98, 012001('07)

Production Rate

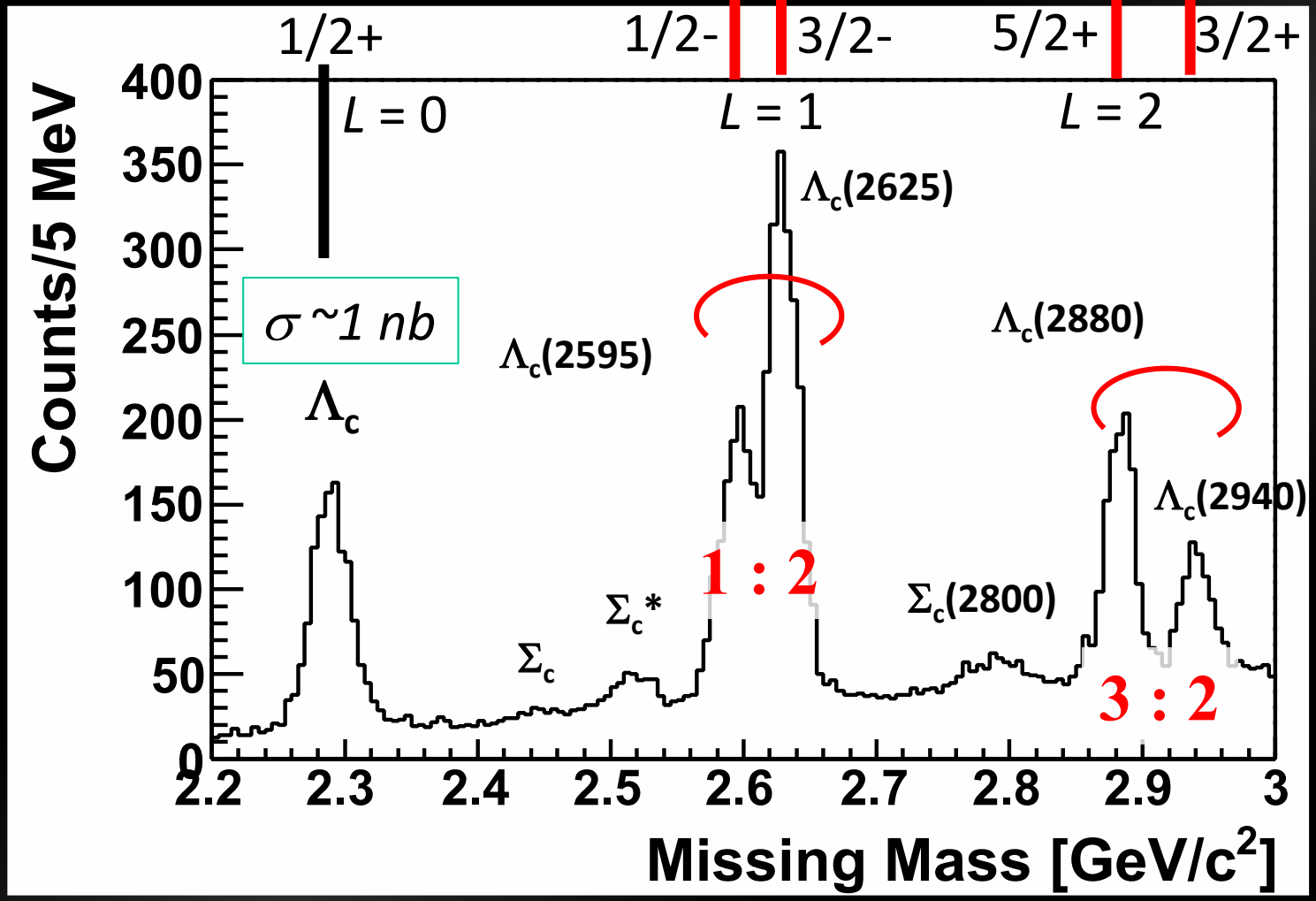
S.H. Kim, A. Hosaka, H.C. Kim, HN, K. Shirotori, PTEP, 103D01, 2014.



- ✓ 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



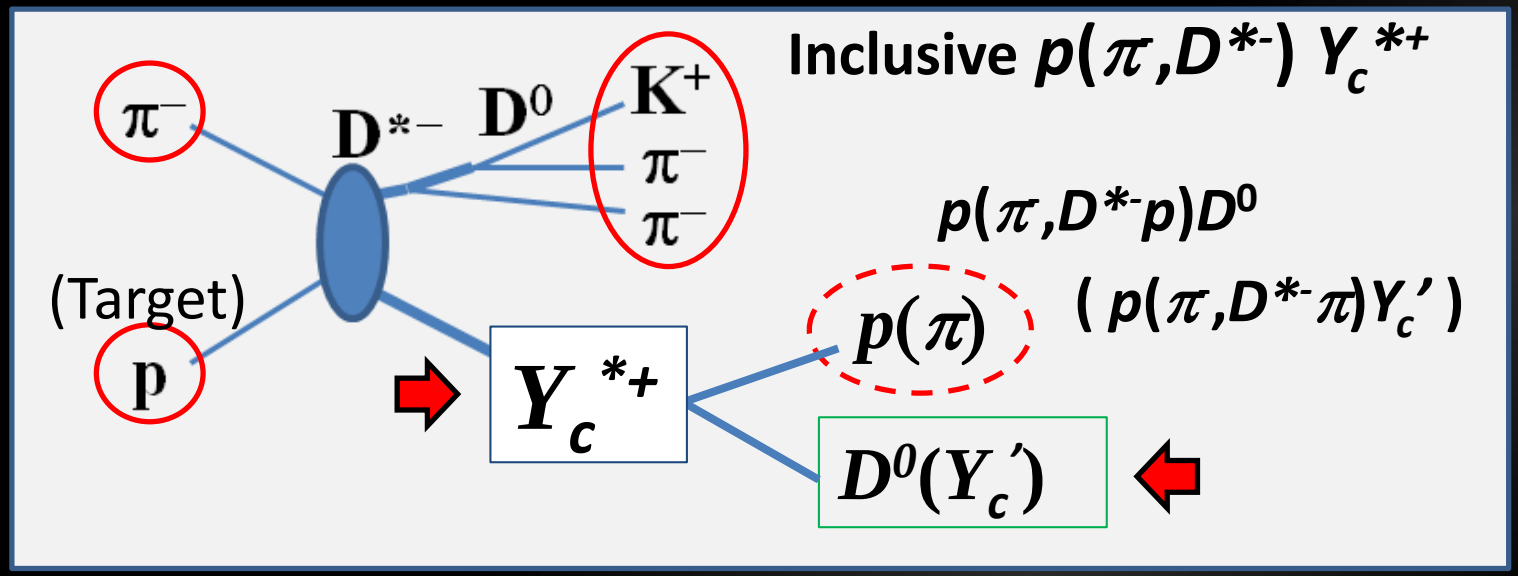
Production rate

- Note on HQ doublet states:
  - If they are LS partners, $j_>=L+1/2$ and $j_<=L-1/2$

    Prod. Ratio of $j_>$ to $j_<$ = $(L+1)/L$
  - Spin(/Parity) of the HQ doublets can be determined from the Prod. Rates (Spins/Parities of Y^*_c's are not established experimentally…)
  - *c.f.* $\Lambda(2880)=5/2+$, as reported by Belle, will be able to examined with its LS partner if it is an L=2 λ-mode state

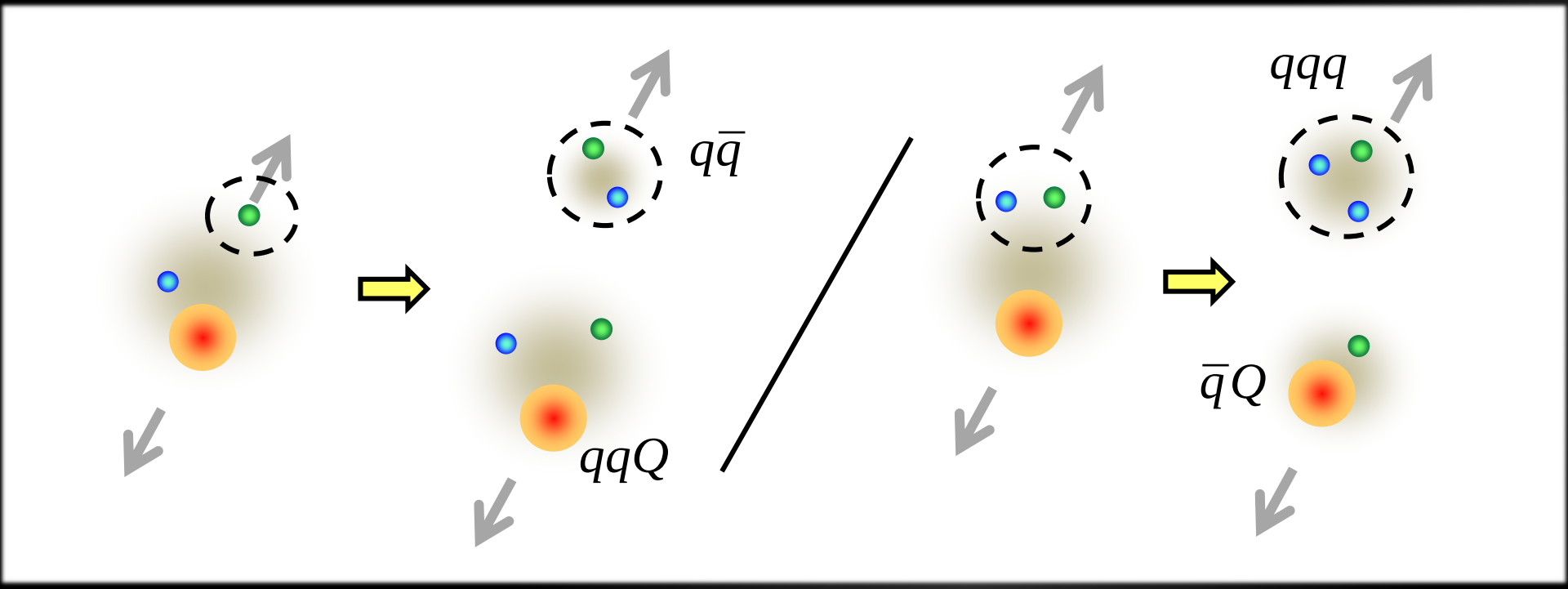
Charmed Baryon Spectroscopy

Using Missing Mass Techniques



Conducted by the E50 experiment at J-PARC

Decay Properties



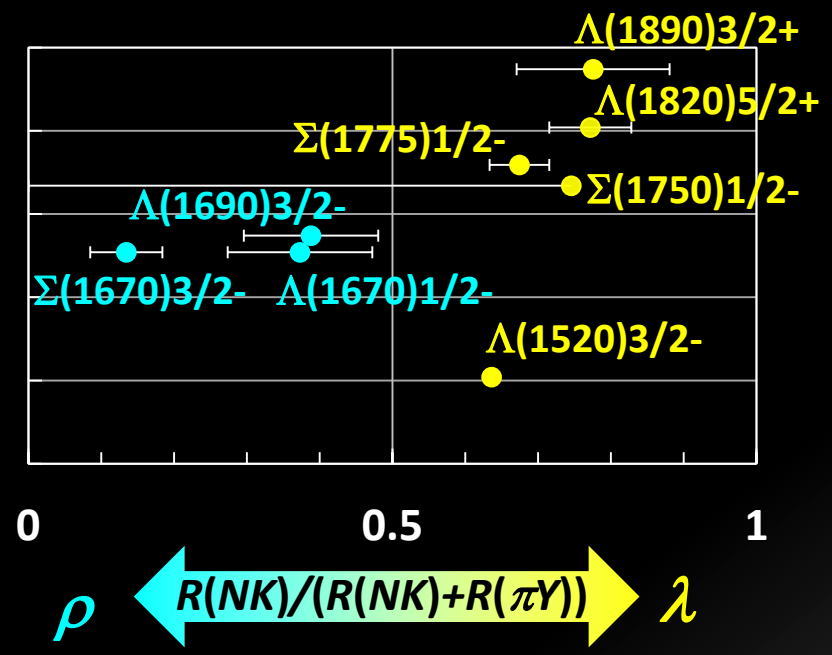
ρ mode (qq)

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

λ mode [qq]

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

Hint in $R(NK)/R(\pi Y)$



* Phase space factor: p^{2L+1} corrected

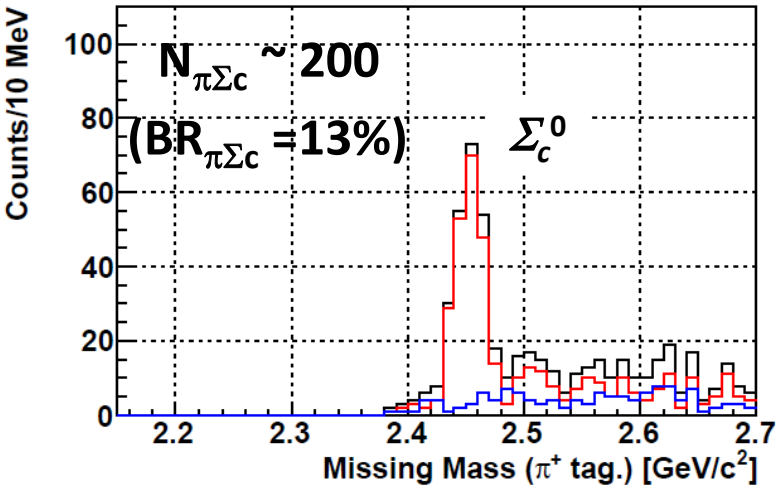
- Decay ratios in known hyperons SUGGEST the λ/ρ mode states
- λ/ρ mode ID by Prod. Rates correlate w/ Decay Ratios
  → to be established

More clearly identified in charmed baryons

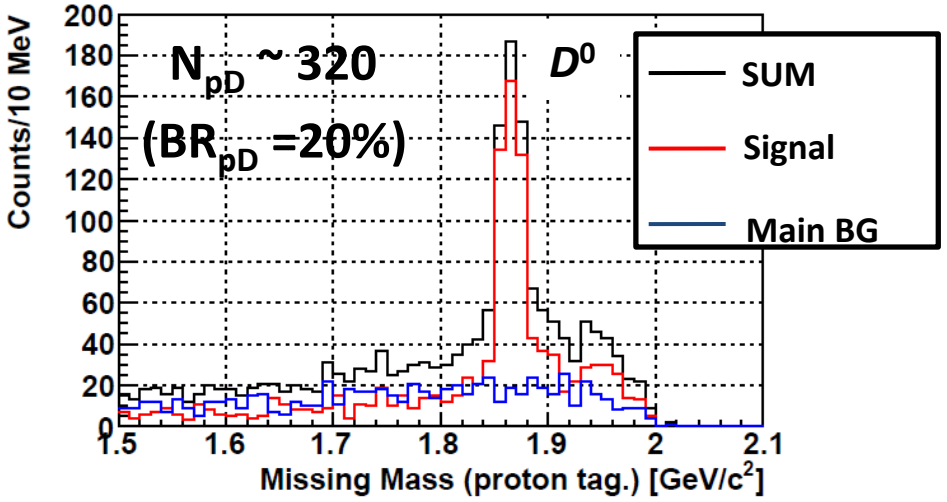
Decay Products

$\Lambda_c(2940) \rightarrow \Sigma_c^0 \pi^+$

with $\Lambda_c^+ \pi^+ \pi^-$ selected

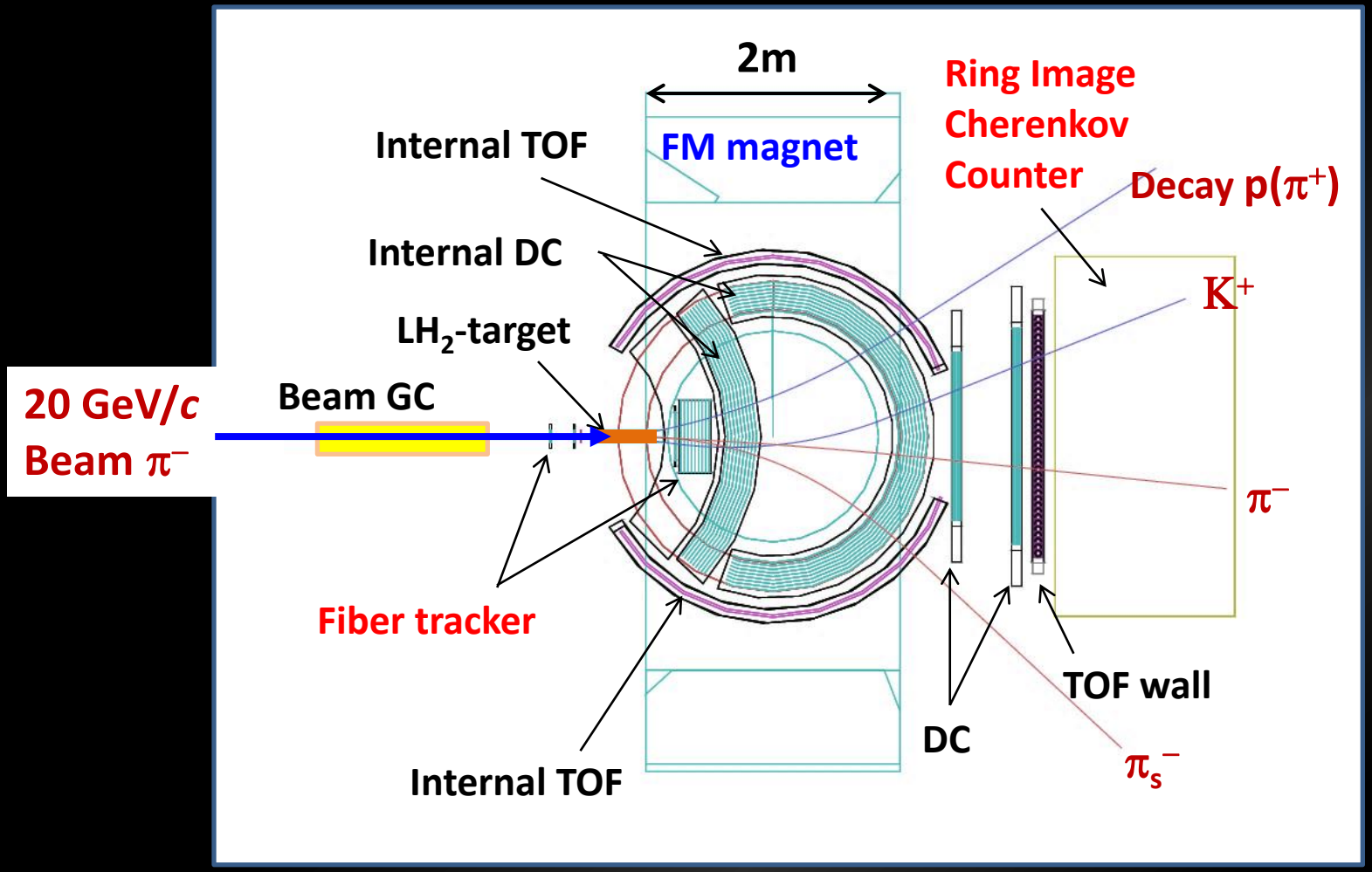


$\Lambda_c(2940) \rightarrow p\ D^0$



* Decay products can be seen clearly owing to the large acceptance.
* Decay meas. strongly assists the missing mass spectroscopy.
  - Branching ratios: Diquark corr. affects $\Gamma(\Lambda_c^* \rightarrow pD)/\Gamma(\Lambda_c^* \rightarrow \Sigma_c \pi)$.
  - Angular distribution: Spin, Parity

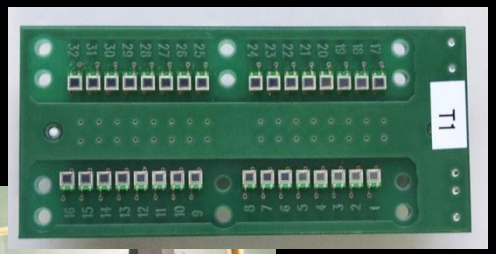
Detector R&D are issues…

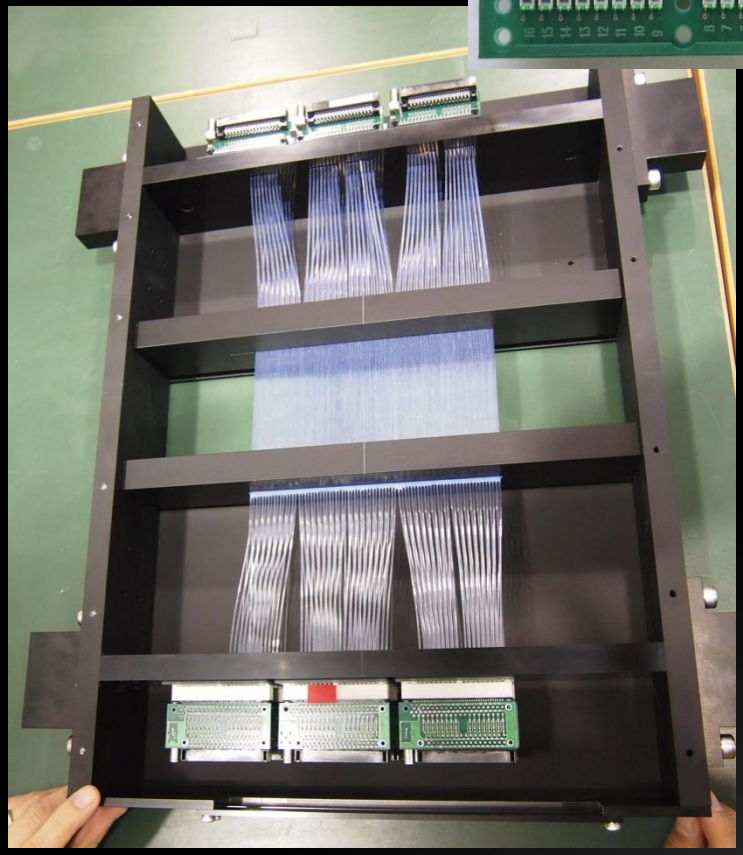


Acceptance: ~ 60% for D^*, ~80% for decay π^+

Resolution: $\Delta p/p$~0.2% at ~5 GeV/c （Rigidity：~2.1 Tm)

High rate BFT at K1.8



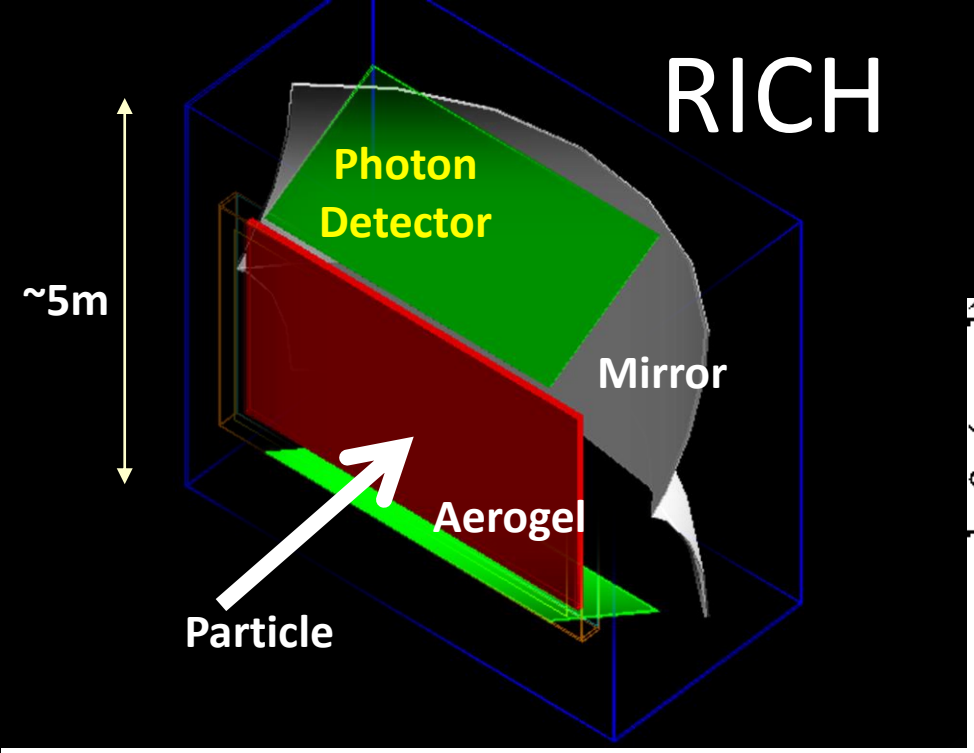


To be Enlarged for E50

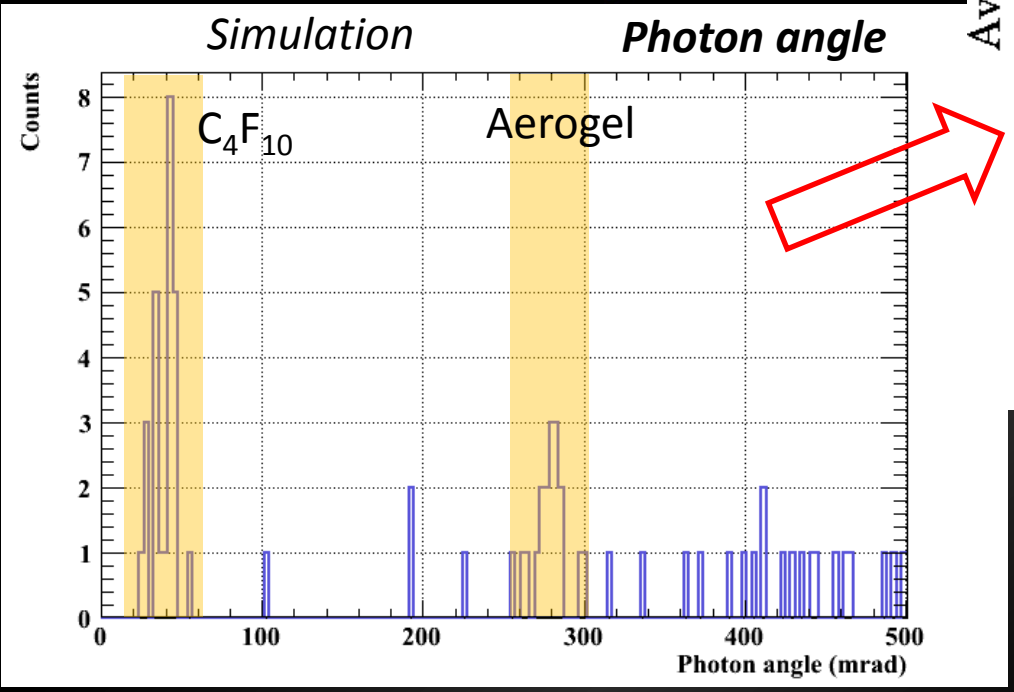
K. Miwa et al., Tohoku U.

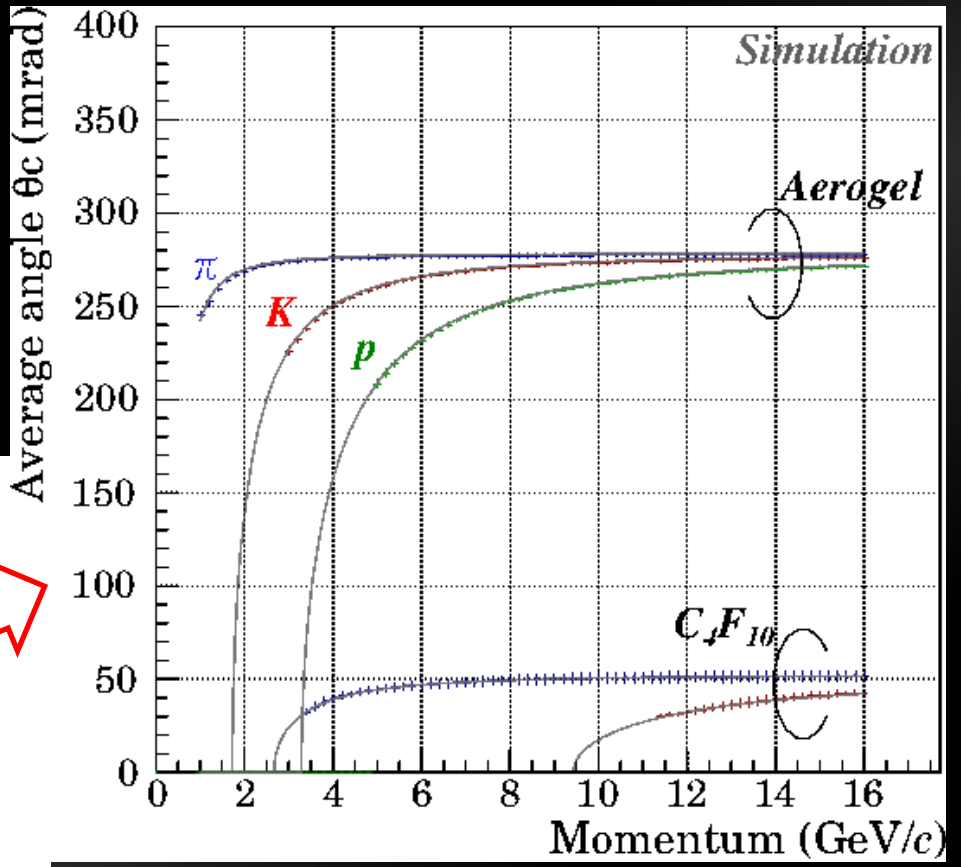
- Beamline Fiber Tracker
  - Can operate stably under a high intensity beam.
  - Structure
    - 320 ch of 1mm ϕ fibers
    - Two staggered layers
    - MPPC readout
      - We designed the high density MPPC PCB.
- We have finished the design. Detector and MPPC PCB are being produced now.
- We will use 10 EASIROC test board to operate 320 MPPCs, because we want to install this detector as soon as possible.

RICH



T. Yamaga
HUA Master Thesis Award 2014



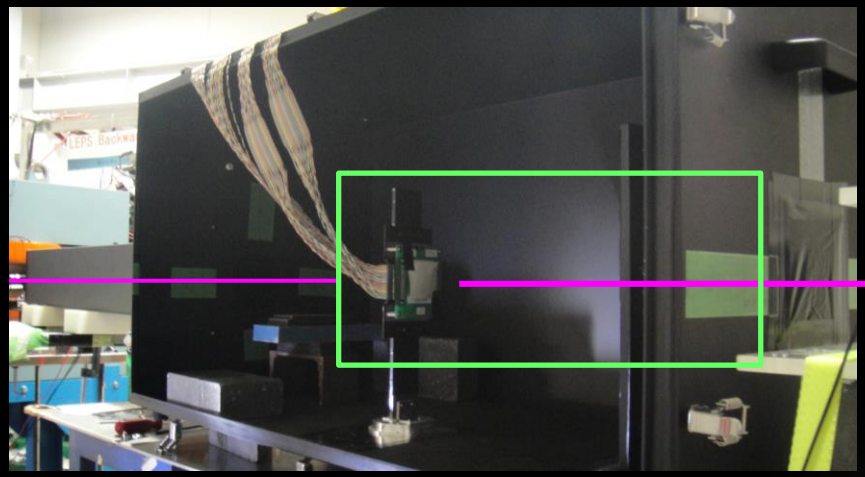


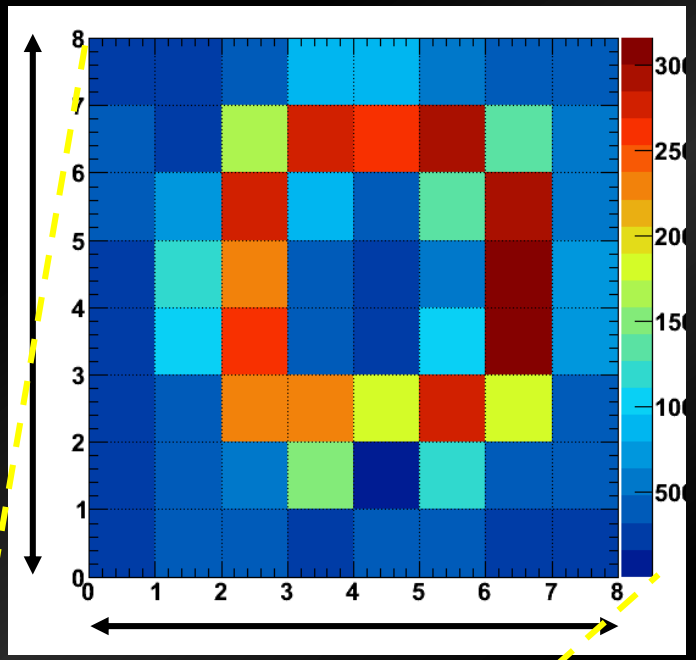
Conceptual Design: Done!
-> Test Experiment

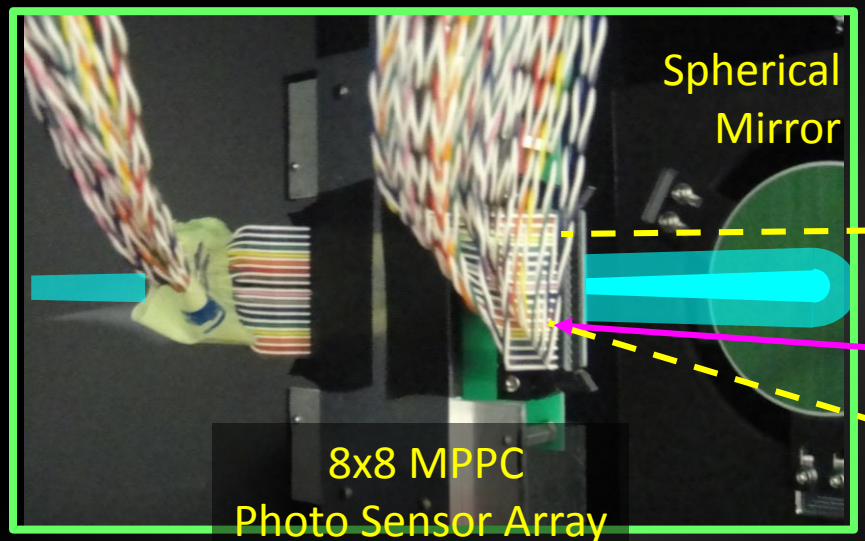
RICH R&D is in progress

Measured RING IMAGE
by 8x8 MPPC Array

Electron
0.75 GeV/c







Summary

- What can we learn from heavy baryons…
  1. Quark-diquark structure of heavy baryons
     - Mass spectrum
     - Production Rate
     - Decay Branching ratio
  2. Diquark is an essential degree of freedom?
     - Information to access “wave function” in the con
- Detector R&D are in Progress
  - High Rate Trackers
  - RICH PID counters
  - High Speed Electronics/DAQ

We welcome your join!

E50 collaboration:

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