Spectroscopic Study of Charmed Baryons at J-PARC

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Contents:

Hierarchy of Matter in the Universe

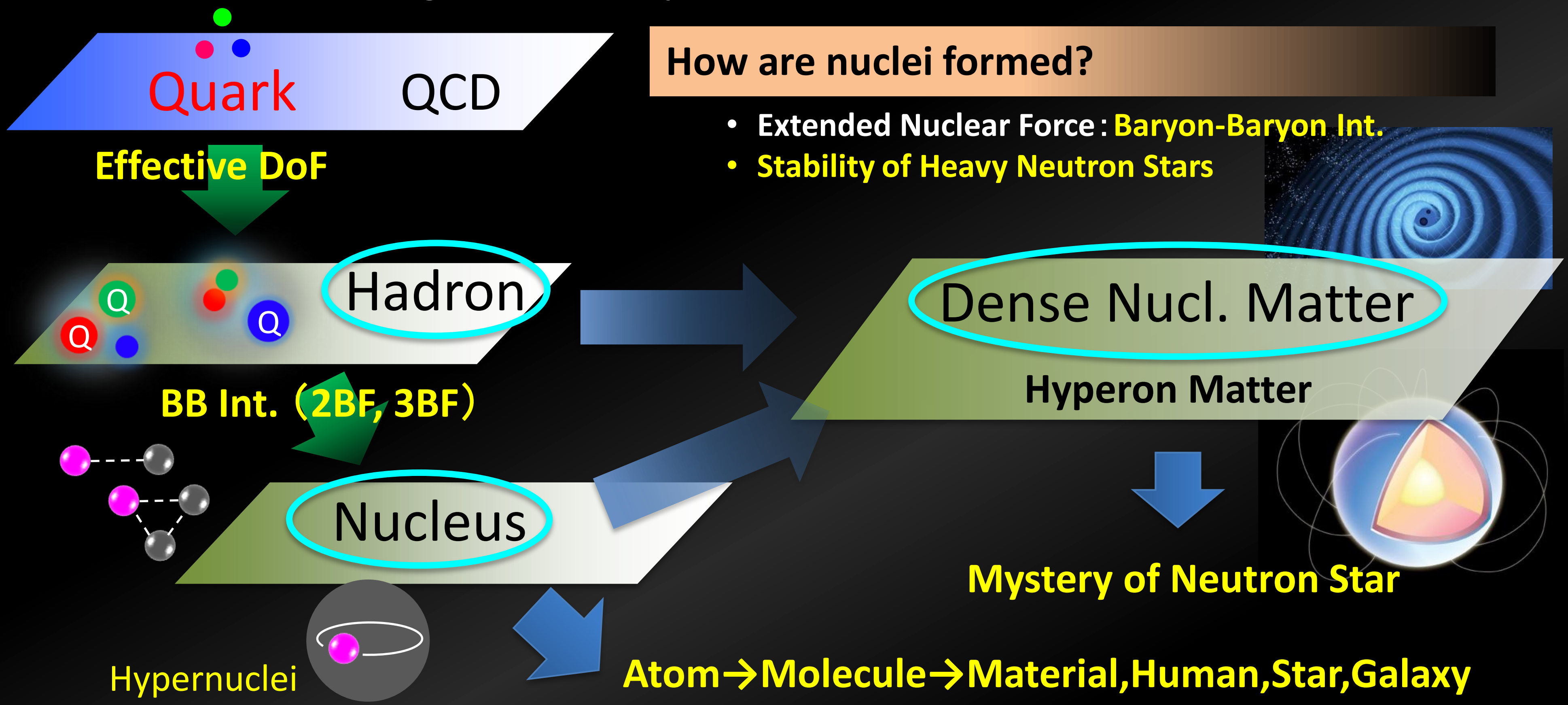
Matter Evolution from Quark to Hadron, Nucleus, and Neutron Star

How QCD works in Hadron?

- Effective DoF (building blocks) to describe hadrons
- Change of Hadron Properties in Matter

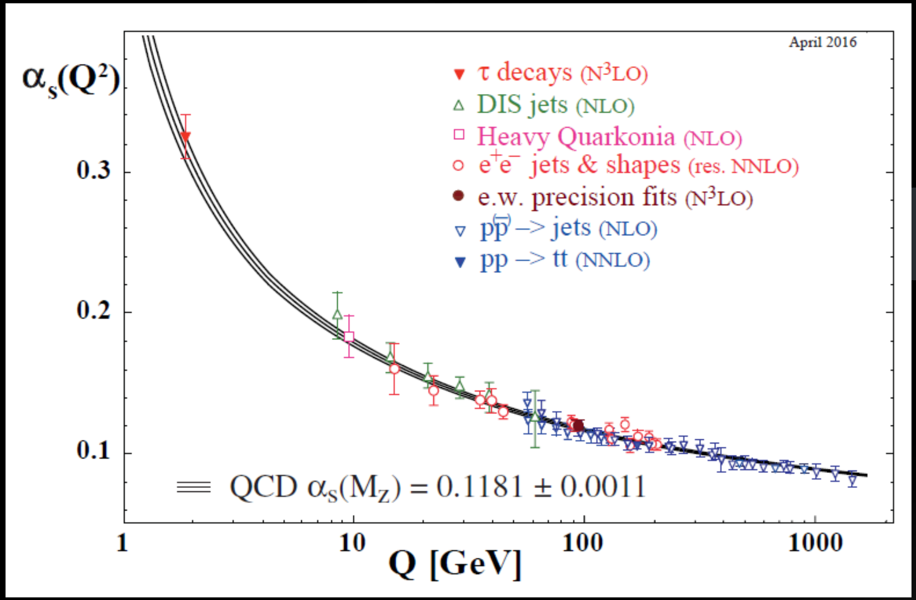
How are nuclei formed?

- Extended Nuclear Force : Baryon-Baryon Int.
- Stability of Heavy Neutron Stars

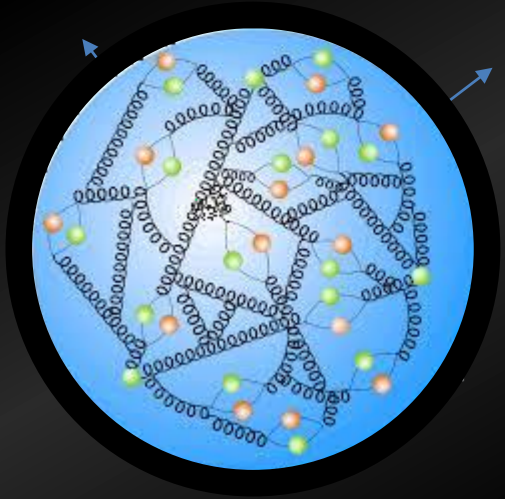


Form of Hadrons

Low E ← High E



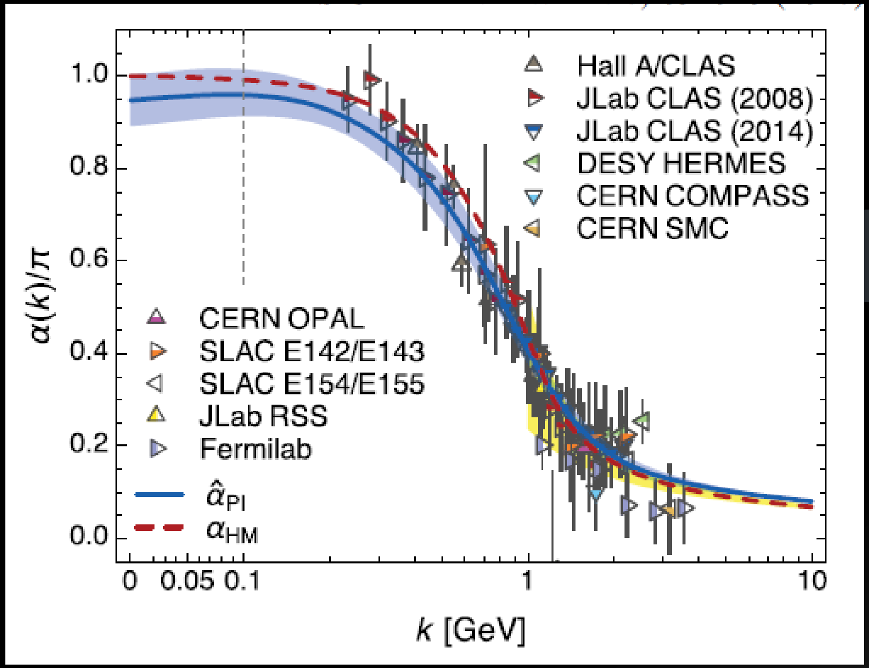
$\alpha_s = \infty$
at Λ_{QCD}



Quark-Gluon

Form of Hadrons

Low E ← High E



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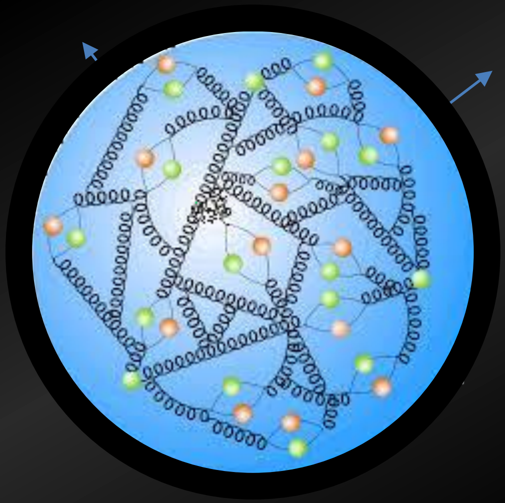

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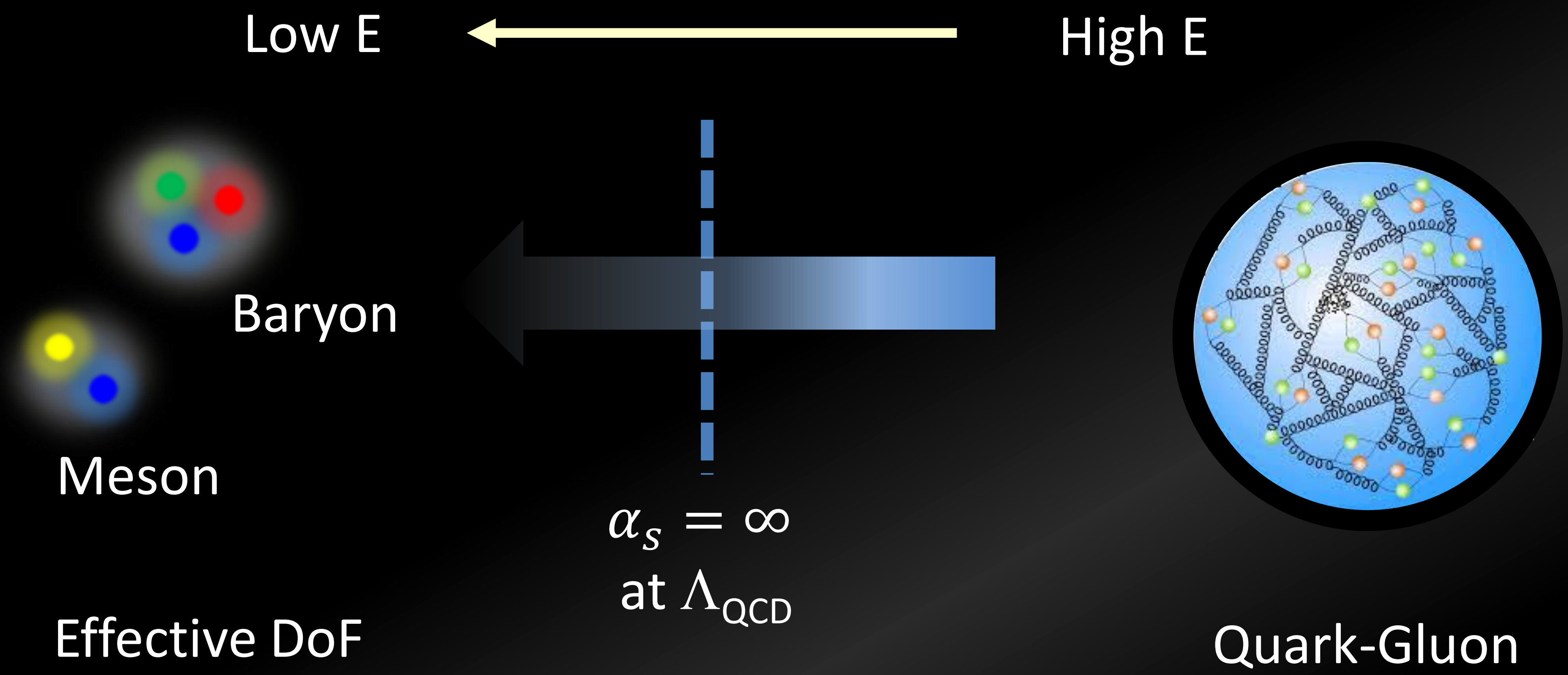
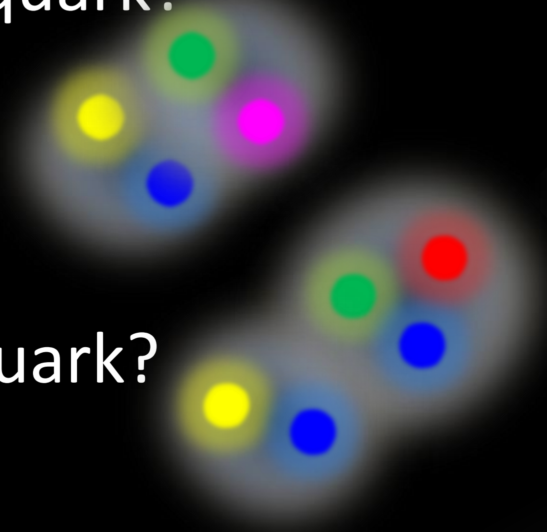


Form of Hadrons

Low E ← High E

Tetraquark?



Pentaquark?

$\alpha_s = \infty$

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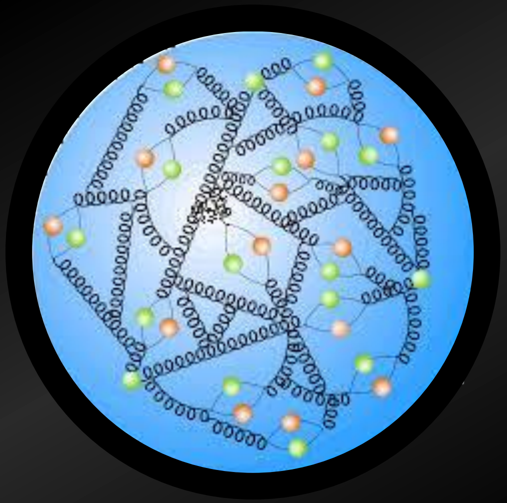
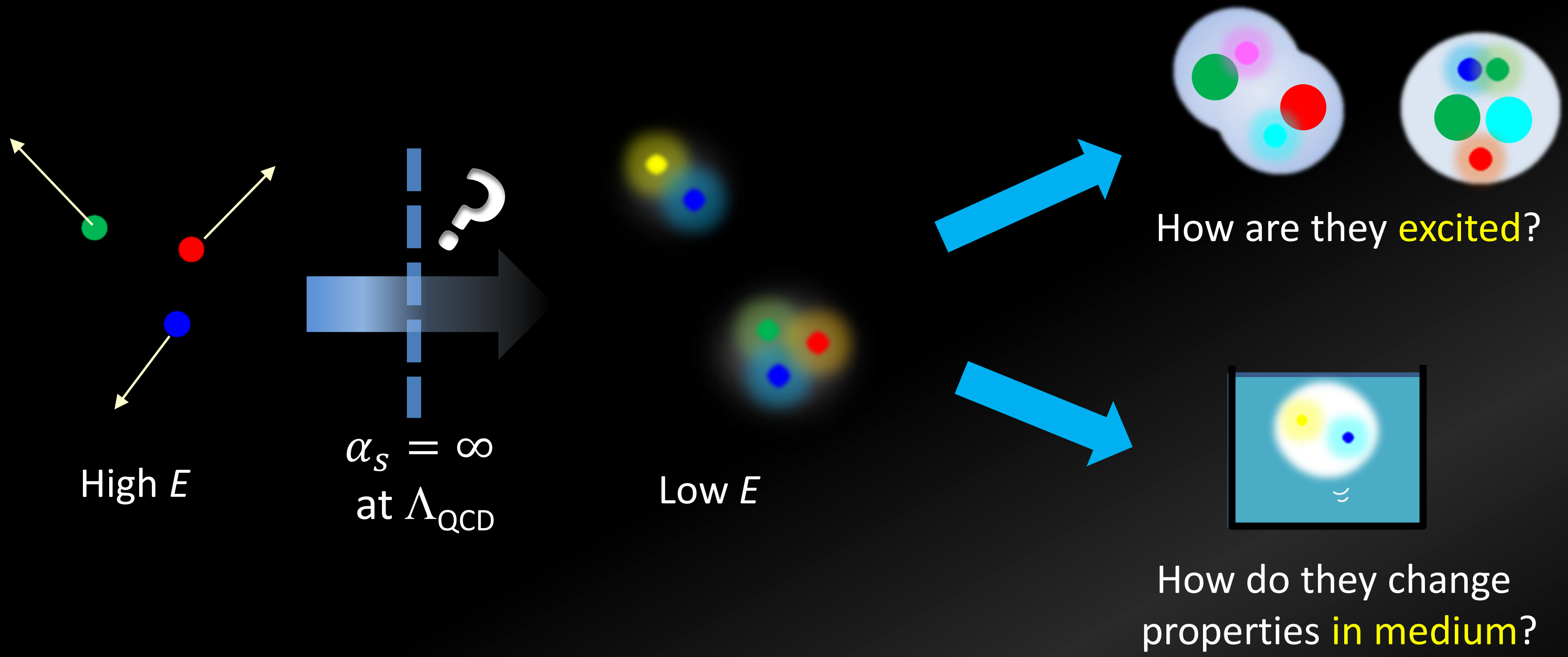


Effective DoF

Quark-Gluon

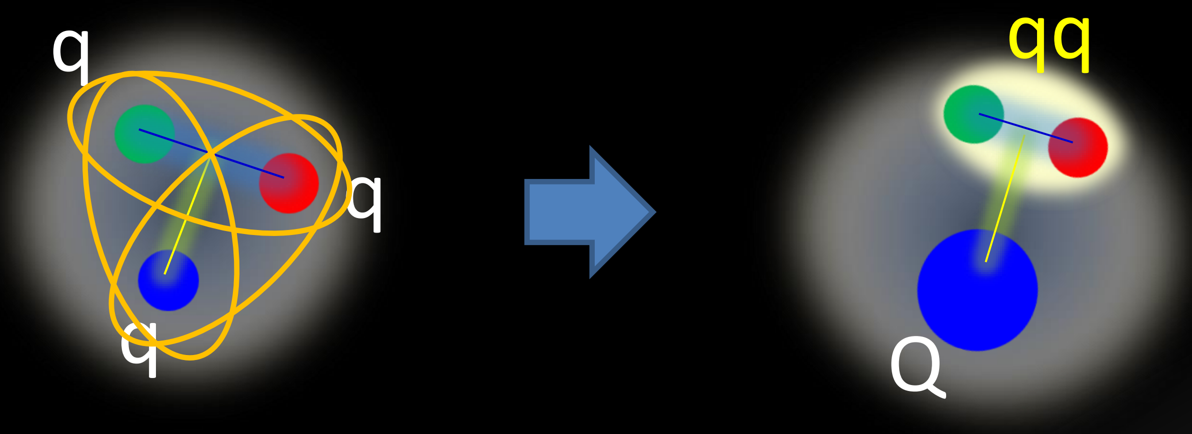
“Exotic hadrons” require a new aspect
in describing hadrons beyond the “standard picture”.

Hadron Physics at J-PARC



- Quasi-Particles (= Effective DoF) emerging at Low E describe hadron properties effectively.
- QP could play a role to form hadrons in early Universe.

Roles of Heavy Flavors



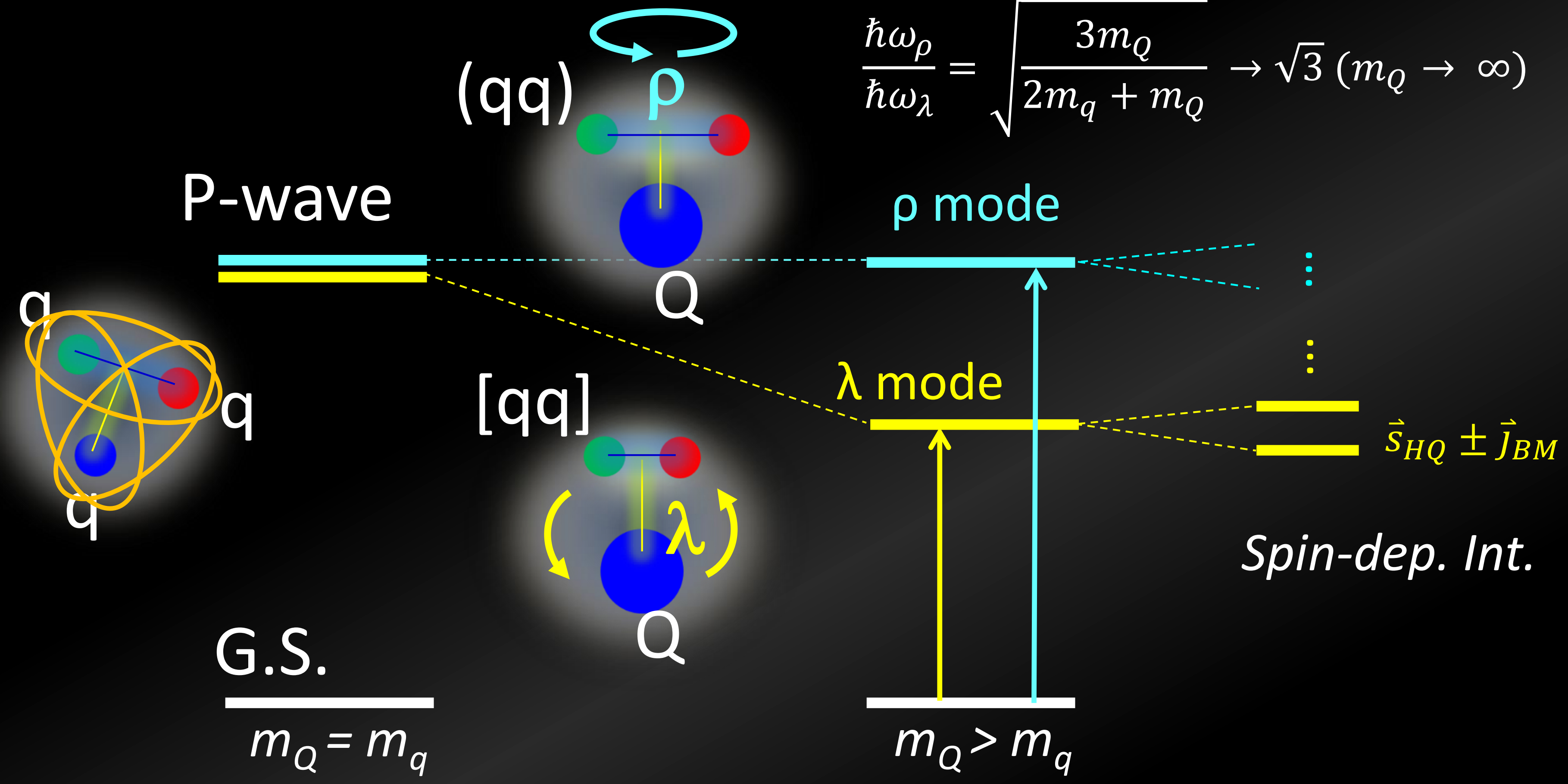
$$V_{CMI} \sim [\alpha_s/(m_i m_j)]*(\lambda_i,\lambda_j)(\sigma_i,\sigma_j)$$
$$\to 0 \text{ if } m_{i,j} \to \infty$$

$$V_{CMI}(^1S_0, \bar{3}_c) = 1/2*V_{CMI}(^1S_0, 1_c)$$
$[qq]$ $[\bar{q}q]$

- 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 $(\vec{s}_{HQ} \pm \vec{j}_{Brown\ Muck})$



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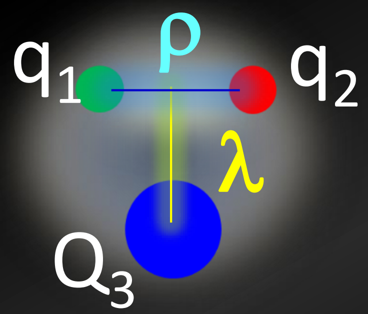
Essence of

Non-relativistic Formulation in CQM

$$H = H_0 + V_c + V_{ss} + V_{SO} + V_T \ldots$$

- H_0: kinematic term
- V_c: confinement potential
- V_{ss}: spin-spin interaction
- V_{SO}: spin-orbit interaction (LS force)
- V_T: Tensor interaction



Coordinate: r_1, r_2, r_3

$\rho = (r_1 - r_2)/\sqrt{2}$

$\lambda = (r_1 + r_2 - 2r_3)/\sqrt{6}$

$\mu_\rho = m_q$

$\mu_\lambda = 3m_q m_Q/(2m_q + m_Q)$

Confinement

- $H = H_0 + V_c + V_{ss} + \cdots$

  $\Psi \sim \psi_\ell \chi_S \phi_I (color) \rightarrow$ symmetrize (anti-symm.)

- $V_c = k/2 \sum r_{ij}^2 \rightarrow$ analytic (<-> Cornell potential $\sum(\frac{a}{r_{ij}} + br_{ij}$))

$$\omega_{\lambda,\rho} = \sqrt{3k/m_{\lambda,\rho}}, \quad \left(m_\lambda = \frac{3m_q m_Q}{2m_q + m_Q}, m_\rho = m_q \right)$$

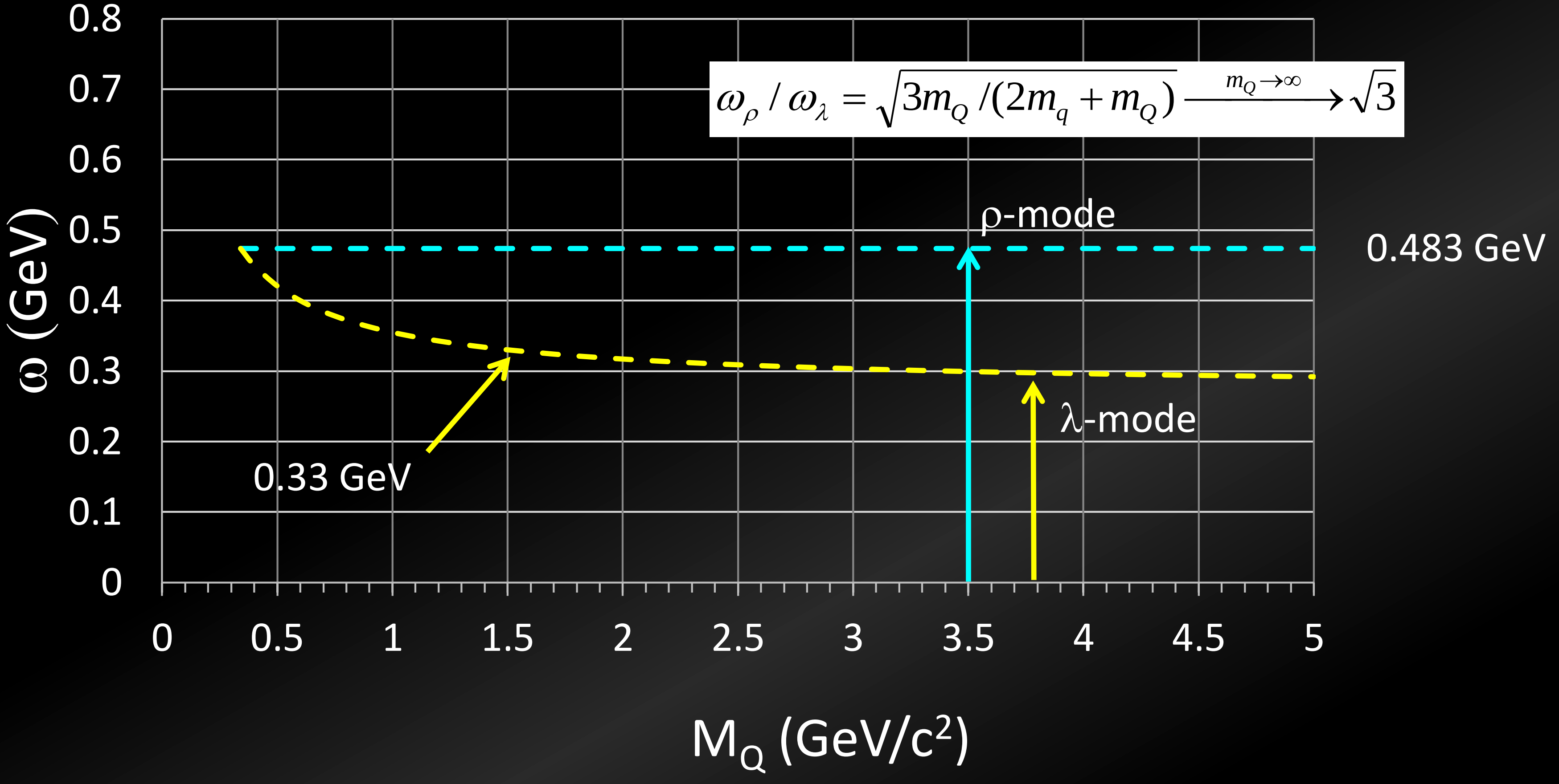
$k = 0.33^2 m_\lambda/3,\ at\ m_Q = 1.5\ \mathrm{GeV}/c^2$

$c.f.\ 1\hbar\omega_\lambda \sim \frac{\Lambda_c\left(\frac{1}{2}^-\right) + 2\Lambda_c\left(\frac{3}{2}^-\right)}{3} - \Lambda_c\left(\frac{1}{2}^+\right) \sim 0.33\ \mathrm{GeV}/c^2$ @charm sector

$1\hbar\omega_\rho \sim \hbar\sqrt{3k/m_q}$~0.483 GeV (independent of m_Q)

P-wave (ρ, λ-mode excitations)

isotope shift



Spin-spin Interaction

- $H = H_0 + V_c + V_{ss} + \cdots$

  $\Psi \sim \psi_\ell \chi_S \phi_I (color)$ → symmetrize (anti-symm.)

- $V_c = k/2 \sum r_{ij}^2$

$$\omega_{\lambda,\rho} = \sqrt{3k/m_{\lambda,\rho}}, \qquad \left(m_\lambda = \frac{3m_q m_Q}{2m_q + m_Q}, m_\rho = m_q \right)$$

- $V_{ss} = c_s \sum \frac{\sigma_i \cdot \sigma_j}{m_i m_j} \delta(r_{ij})$ $\quad \langle \chi_S | V_{ss} | \chi_S \rangle$:

$$\Lambda\left(\frac{1}{2}^+\right) = \omega_0 - 3c_s/m_q^2$$

(S, χ^ρ) : "qq"-spin anti-symm.

$$\Sigma\left(\frac{1}{2}^+\right) = \omega_0 + c_s\left(\frac{1}{m_q^2} - \frac{4}{m_q m_Q}\right)$$

(S, χ^λ) : "qq"-spin symm., $[qqQ]^{1/2}$

$$\Sigma^*\left(\frac{3}{2}^+\right) = \omega_0 + c_s\left(\frac{1}{m_q^2} + \frac{2}{m_q m_Q}\right)$$

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$$\Sigma^*\left(\tfrac{3}{2}^+\right) = \omega_0 + c_s\left(\frac{1}{m_q^2} + \frac{2}{m_q m_Q}\right)$$

$$\rightarrow \frac{\Sigma + 2\Sigma^*}{3} - \Lambda = c_s \frac{4}{m_q^2} \sim 0.2 \text{ GeV}/c^2$$

Spin-spin Interaction

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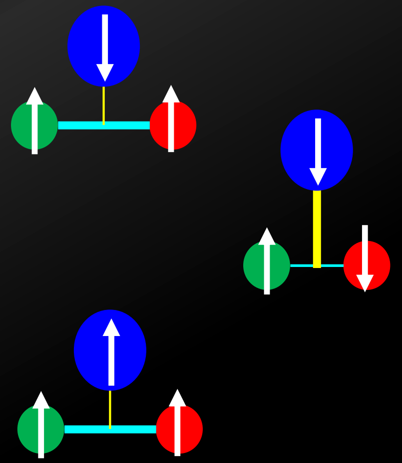
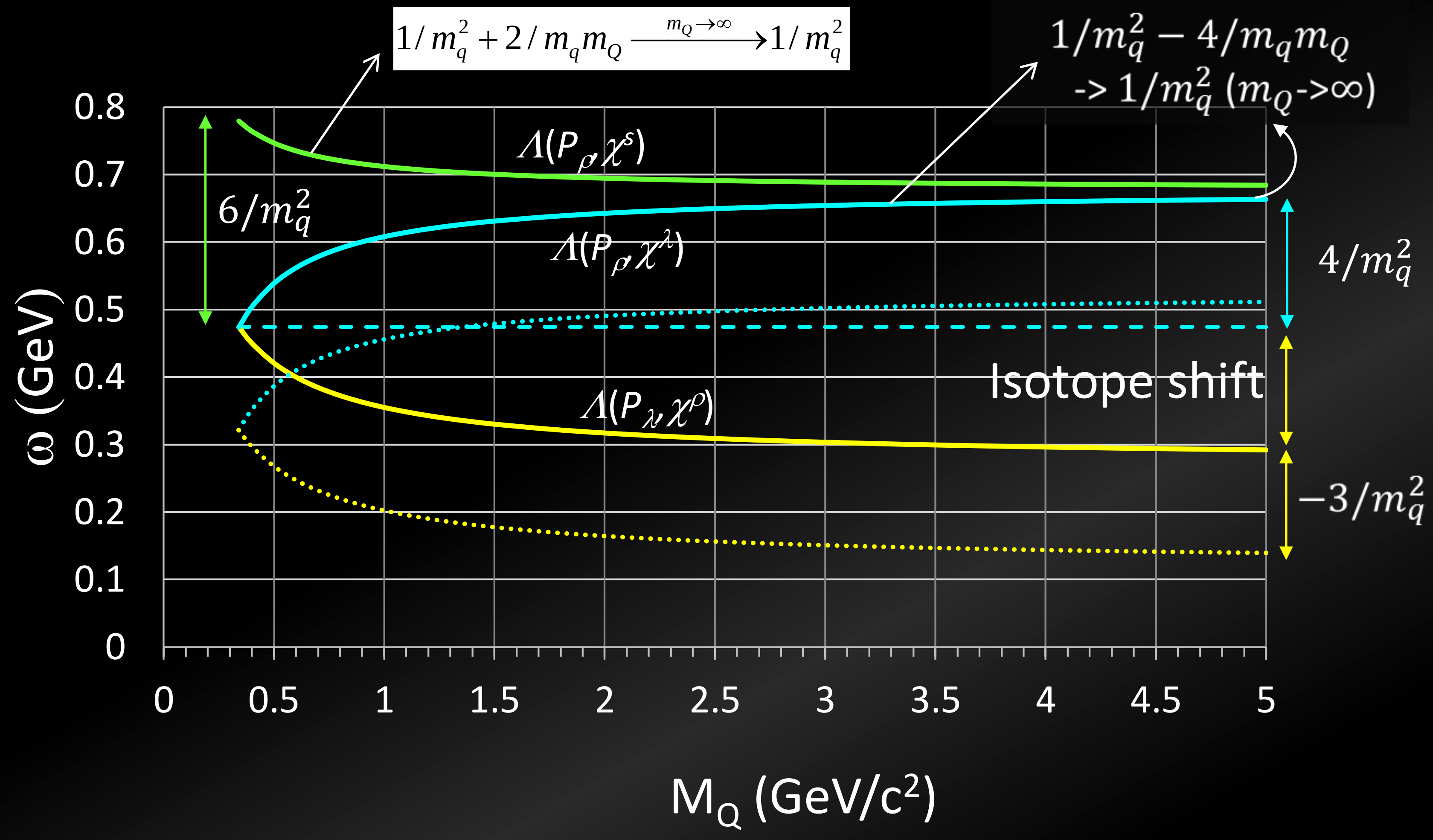
$$\Lambda\left(\frac{1}{2}^-, \frac{3}{2}^-\right) = \begin{cases} \omega_\rho + c_s \left(\frac{1}{m_q^2} - \frac{4}{m_q m_Q} \right) & (\ell_\rho = 1, \chi^\lambda) \\ \omega_\lambda - 3c_s/m_q^2 & (\ell_\lambda = 1, \chi^\rho) \end{cases}$$

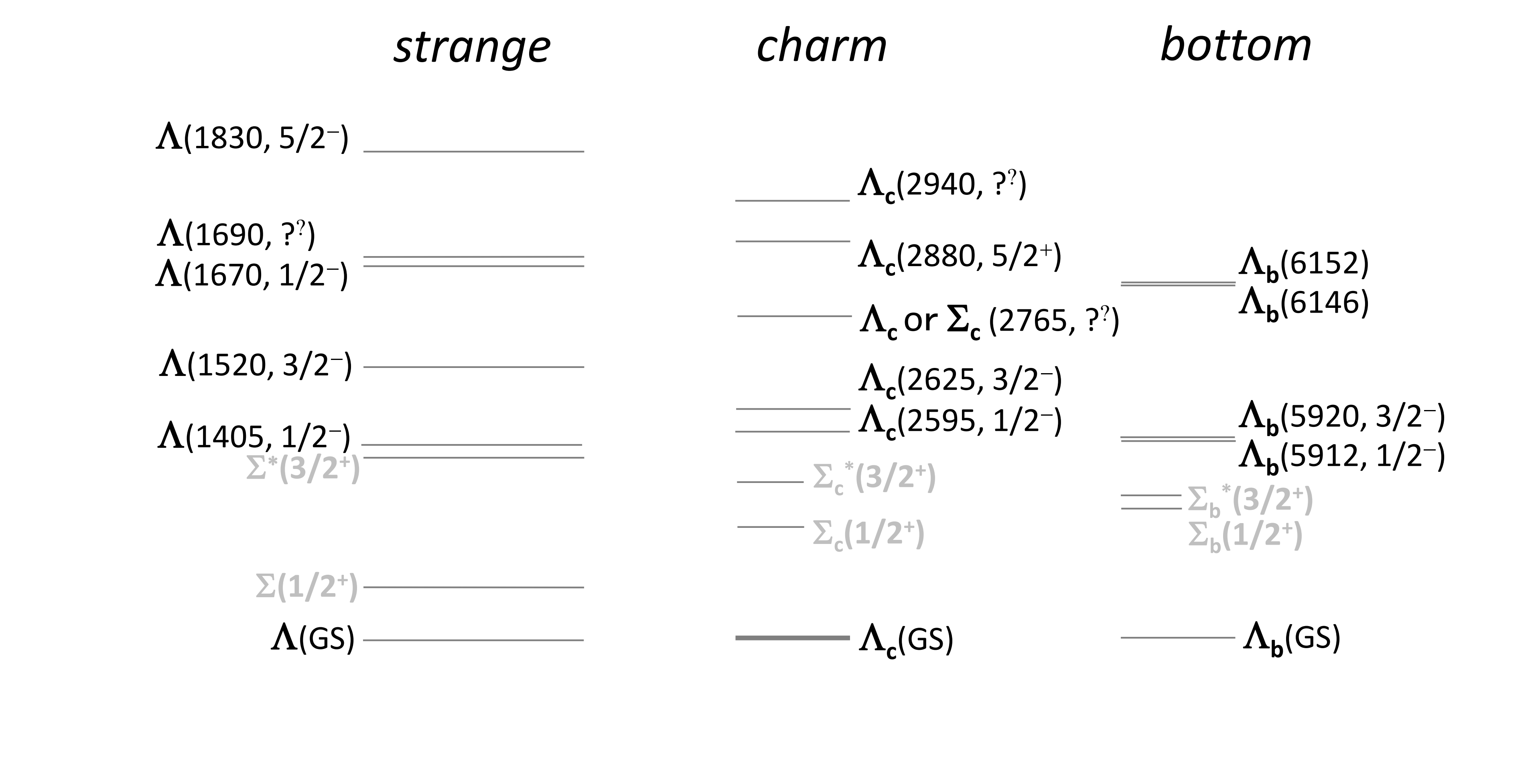
$$\Lambda\left(\frac{1}{2}^-, \frac{3}{2}^-, \frac{5}{2}^-\right) = \omega_\rho + c_s \left(\frac{1}{m_q^2} + \frac{2}{m_q m_Q} \right) (\ell_\rho = 1, \chi^s)$$



$\Lambda(P,\chi)$ (ρ, λ-mode excitations w/ V_{ss})



Lambda Baryons



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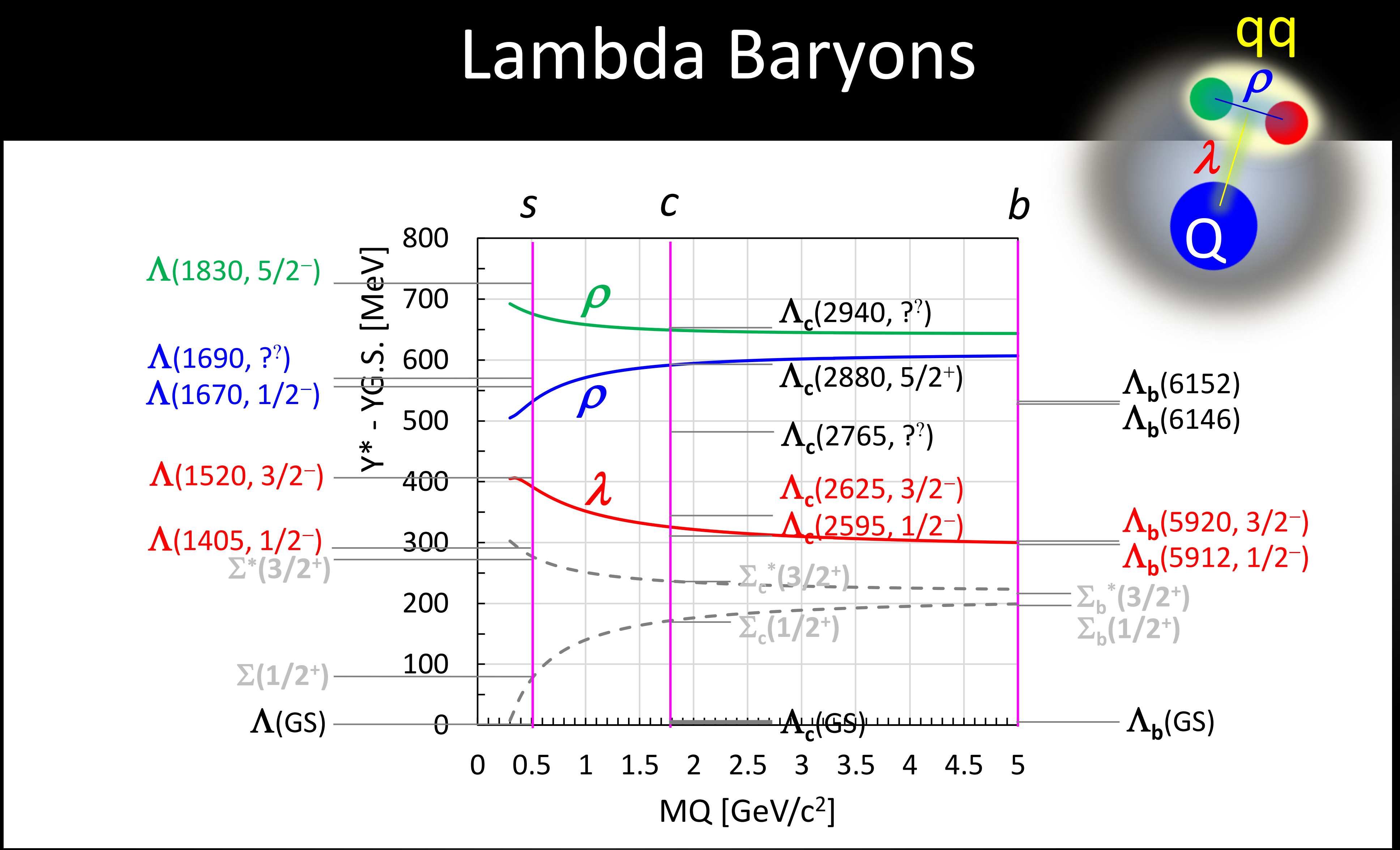
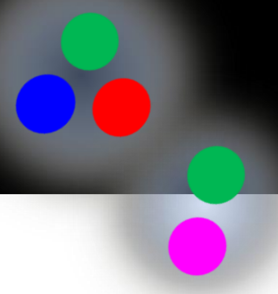
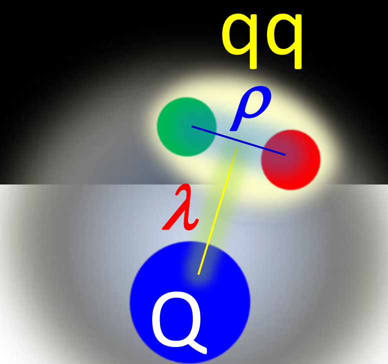


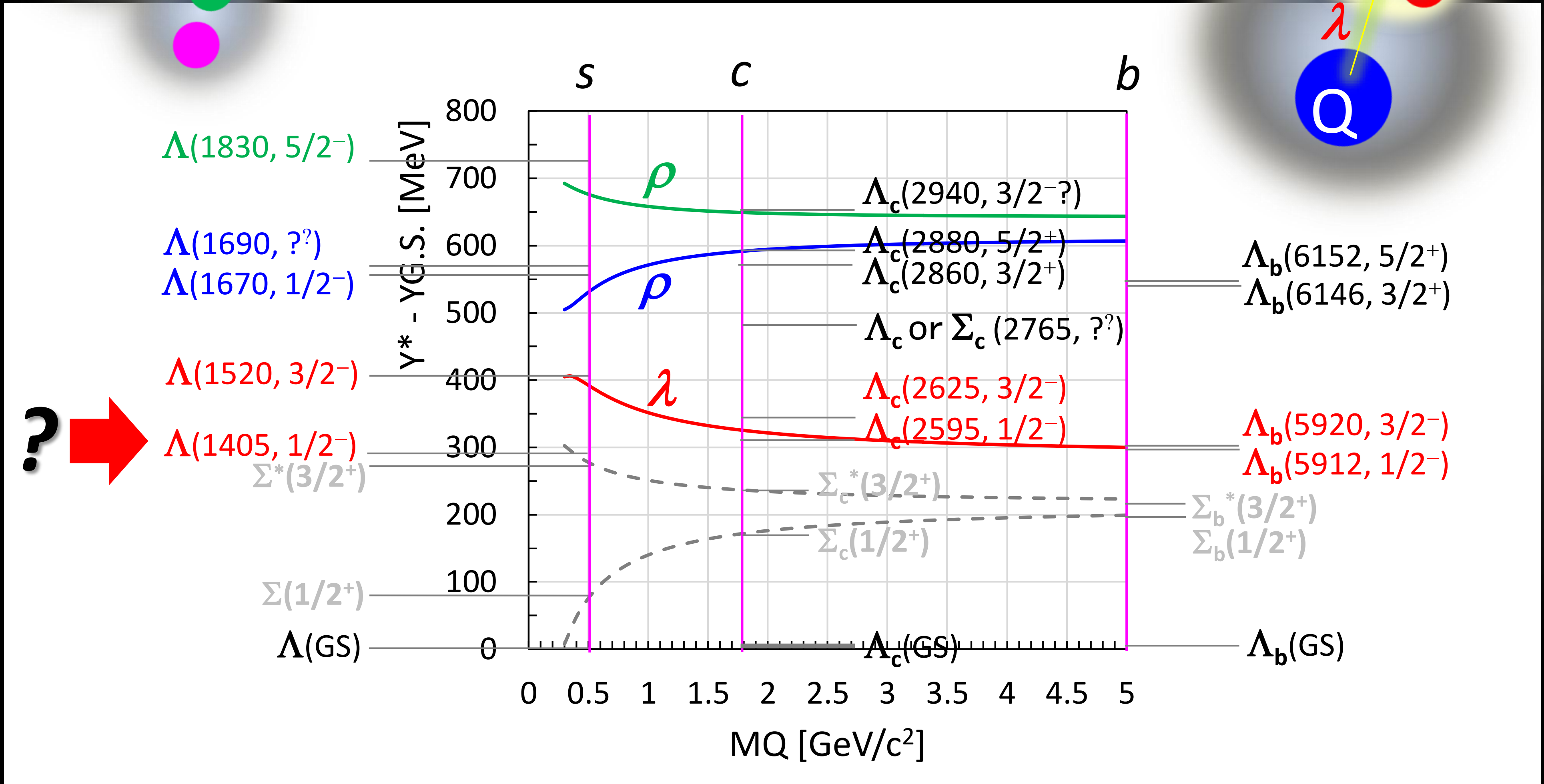
non-rel. QM: $H=H_0+V_{conf}+V_{SS}+V_{LS}+V_T$
ρ–λ mixing (cal. By T. Yoshida)

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

Lambda Baryons







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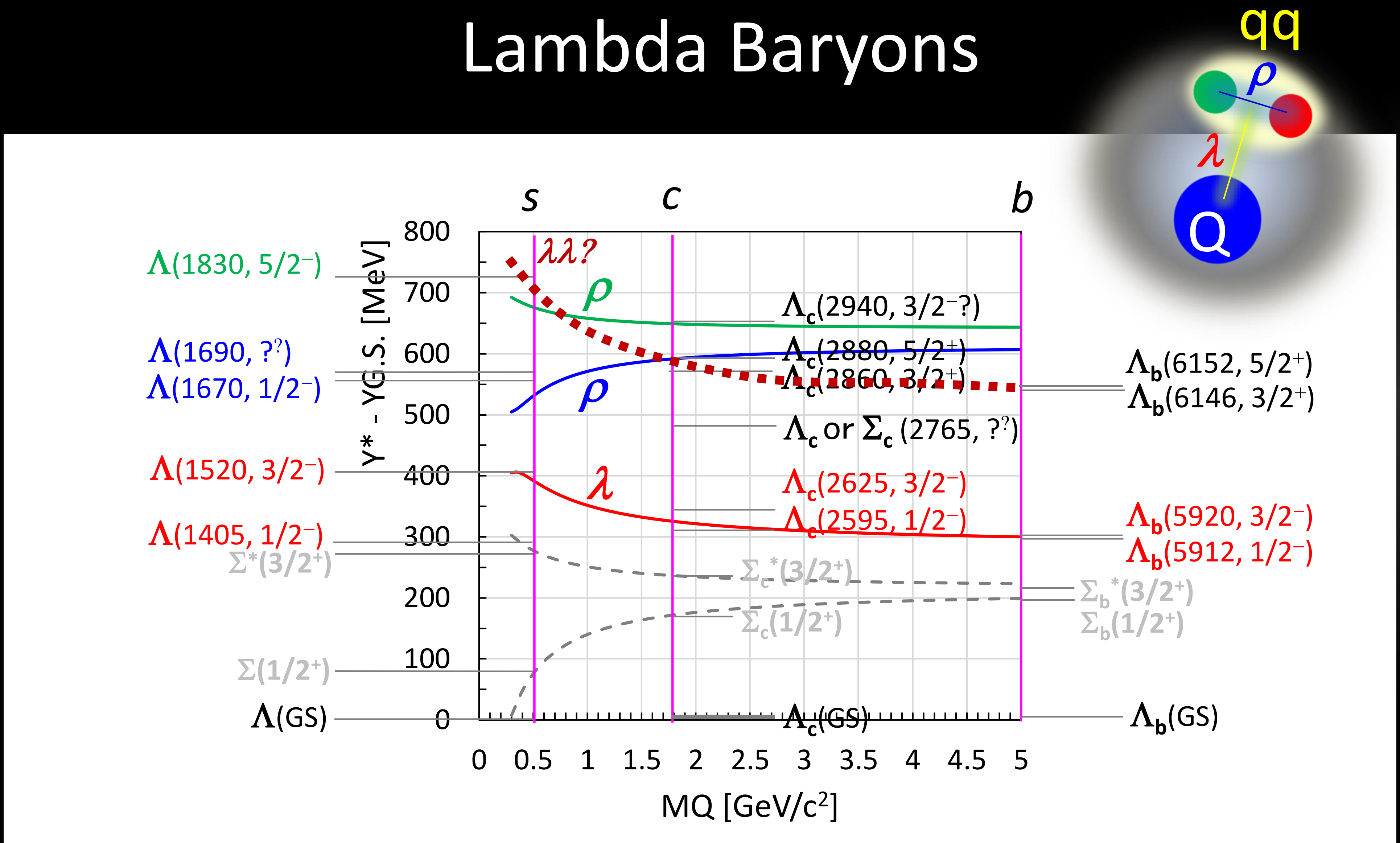

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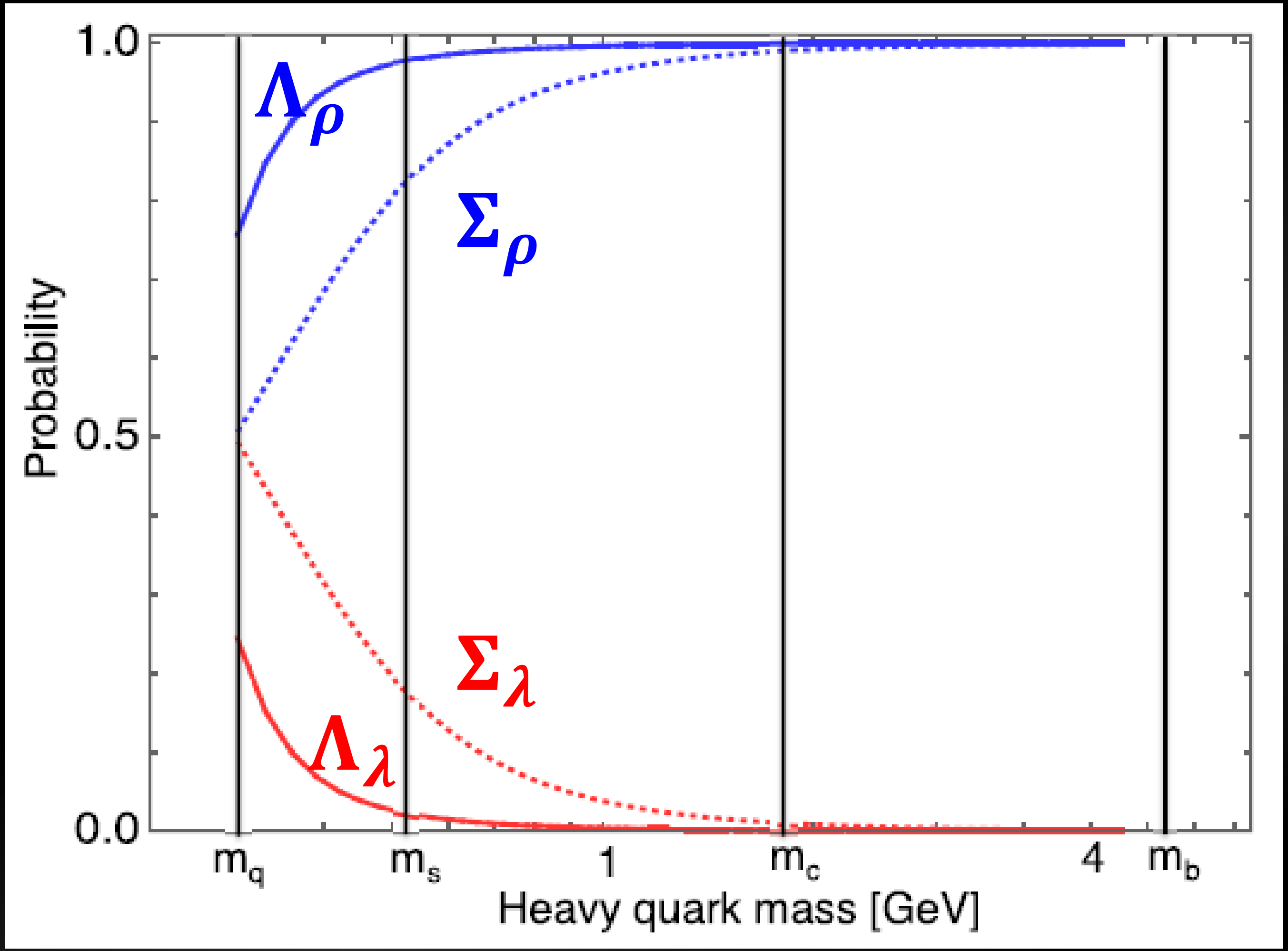
$\Lambda,\Sigma(P,\chi)$ (ρ, λ-mode mixing w/ V_{ss})



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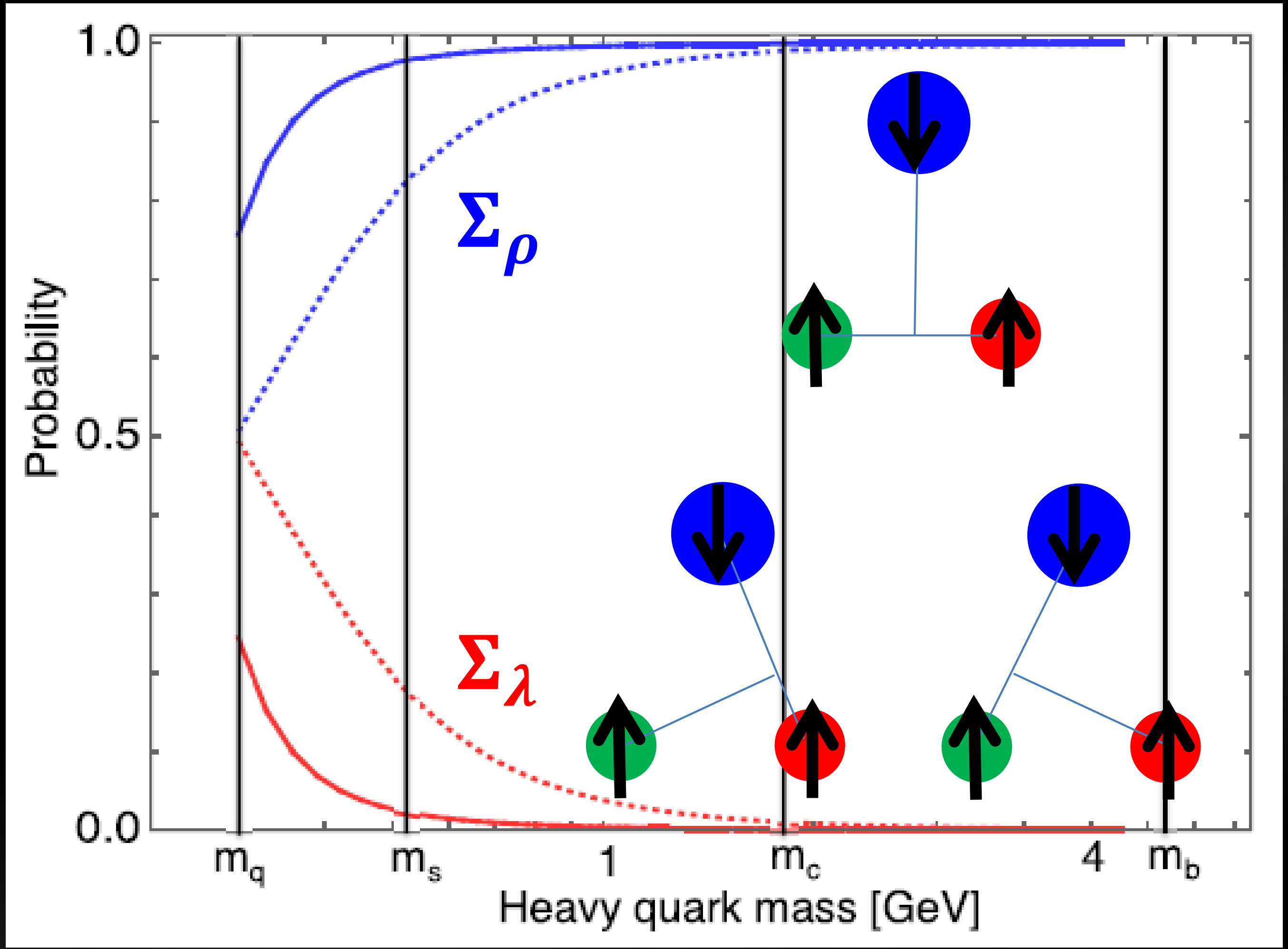

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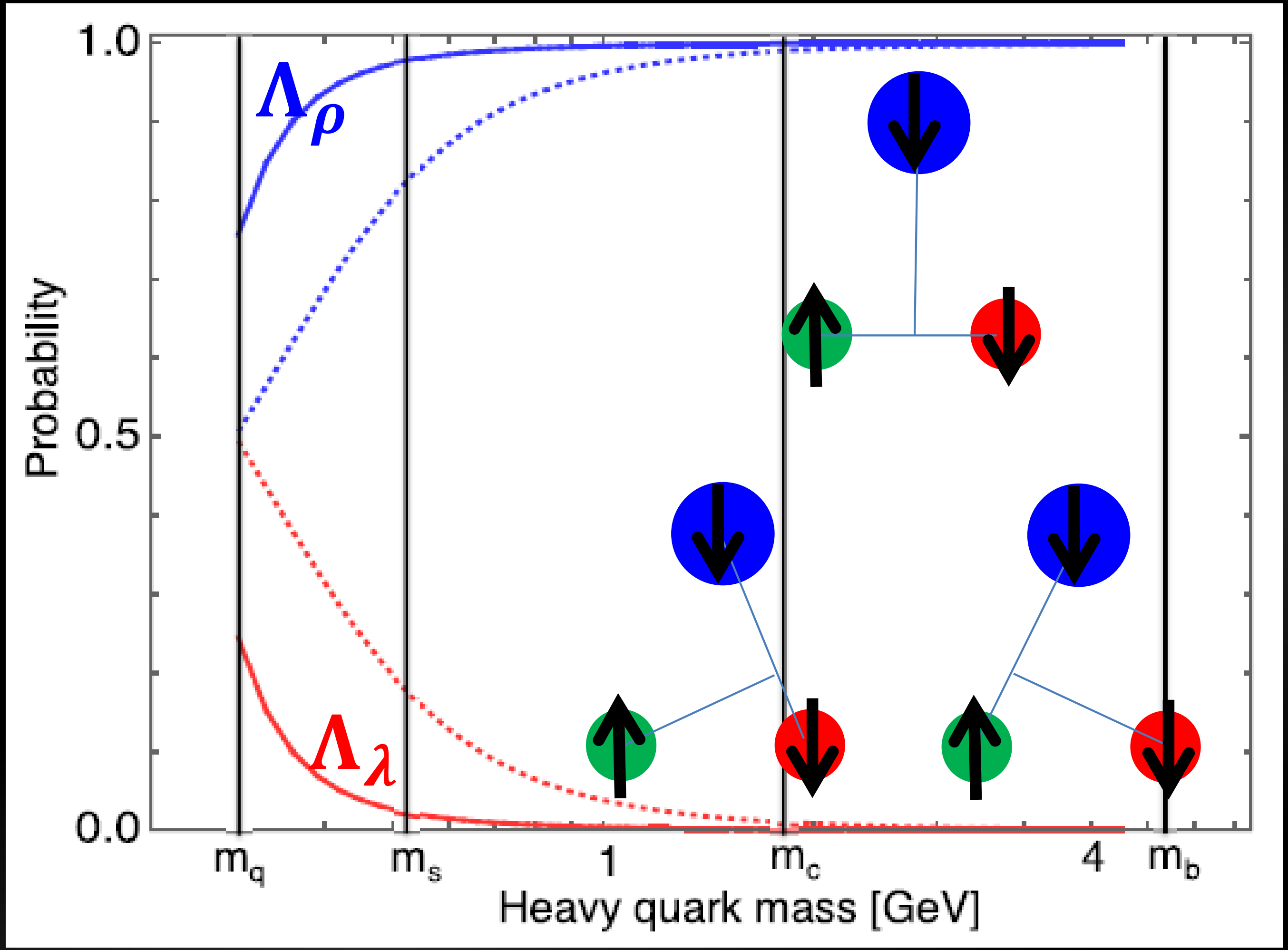

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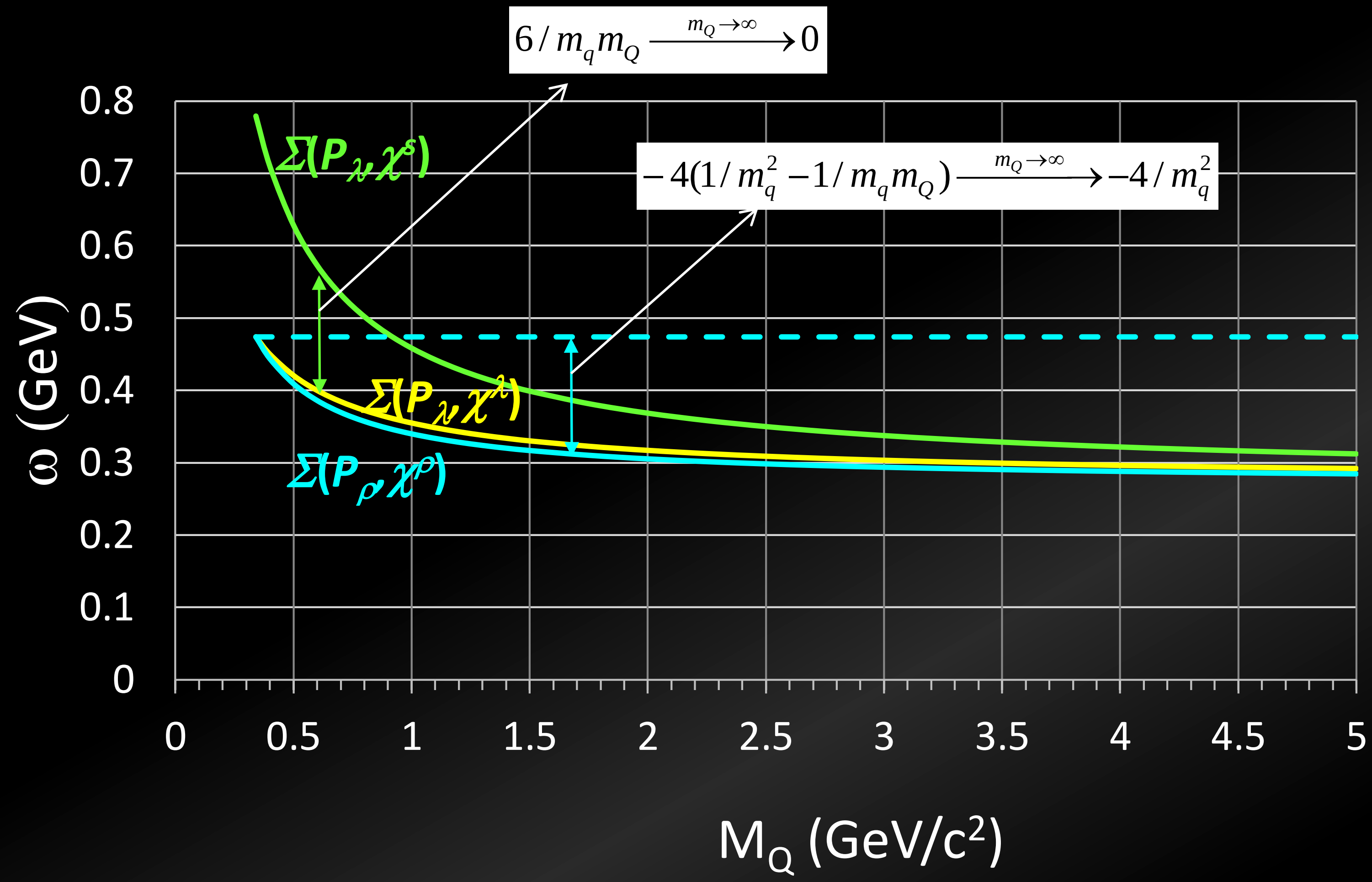
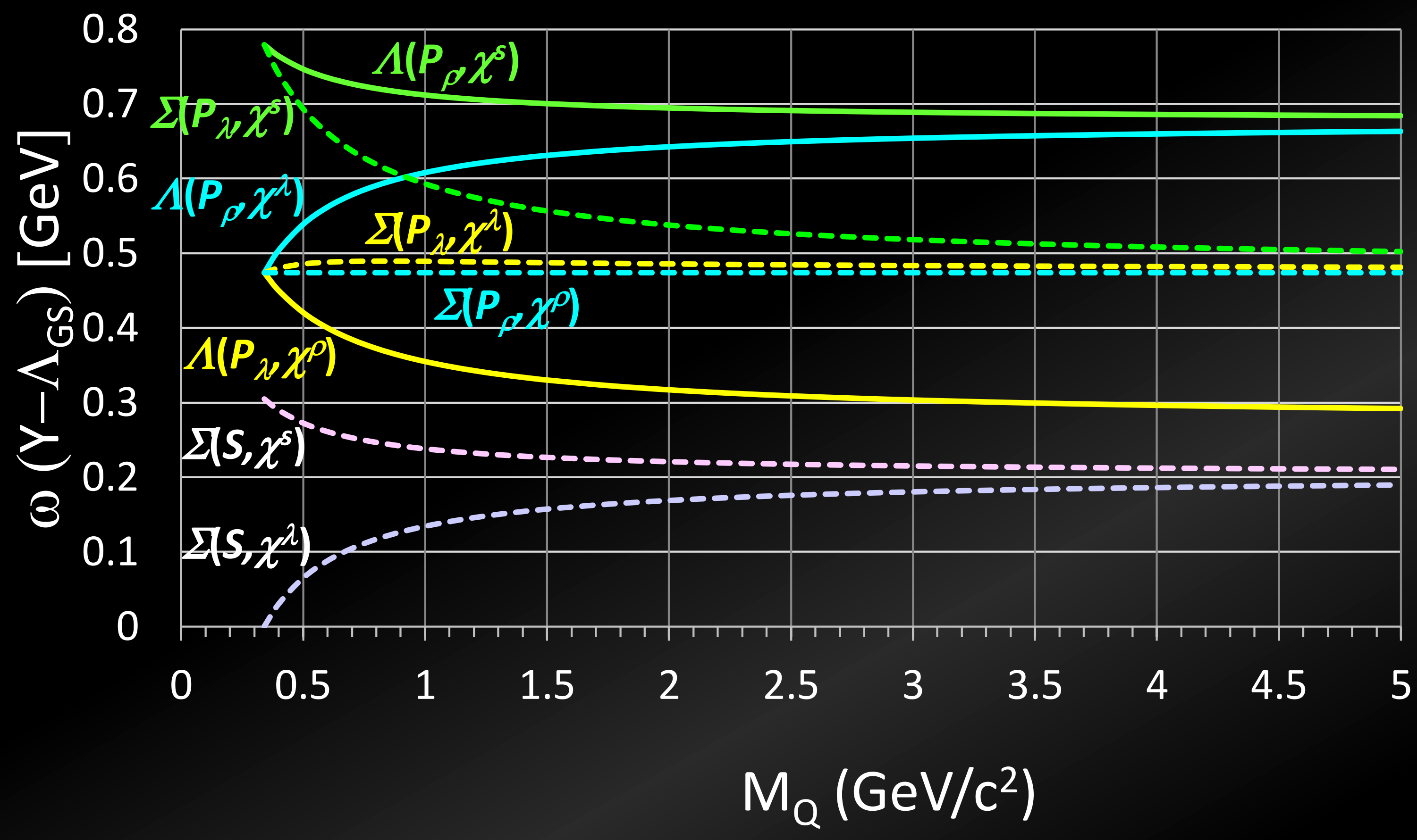
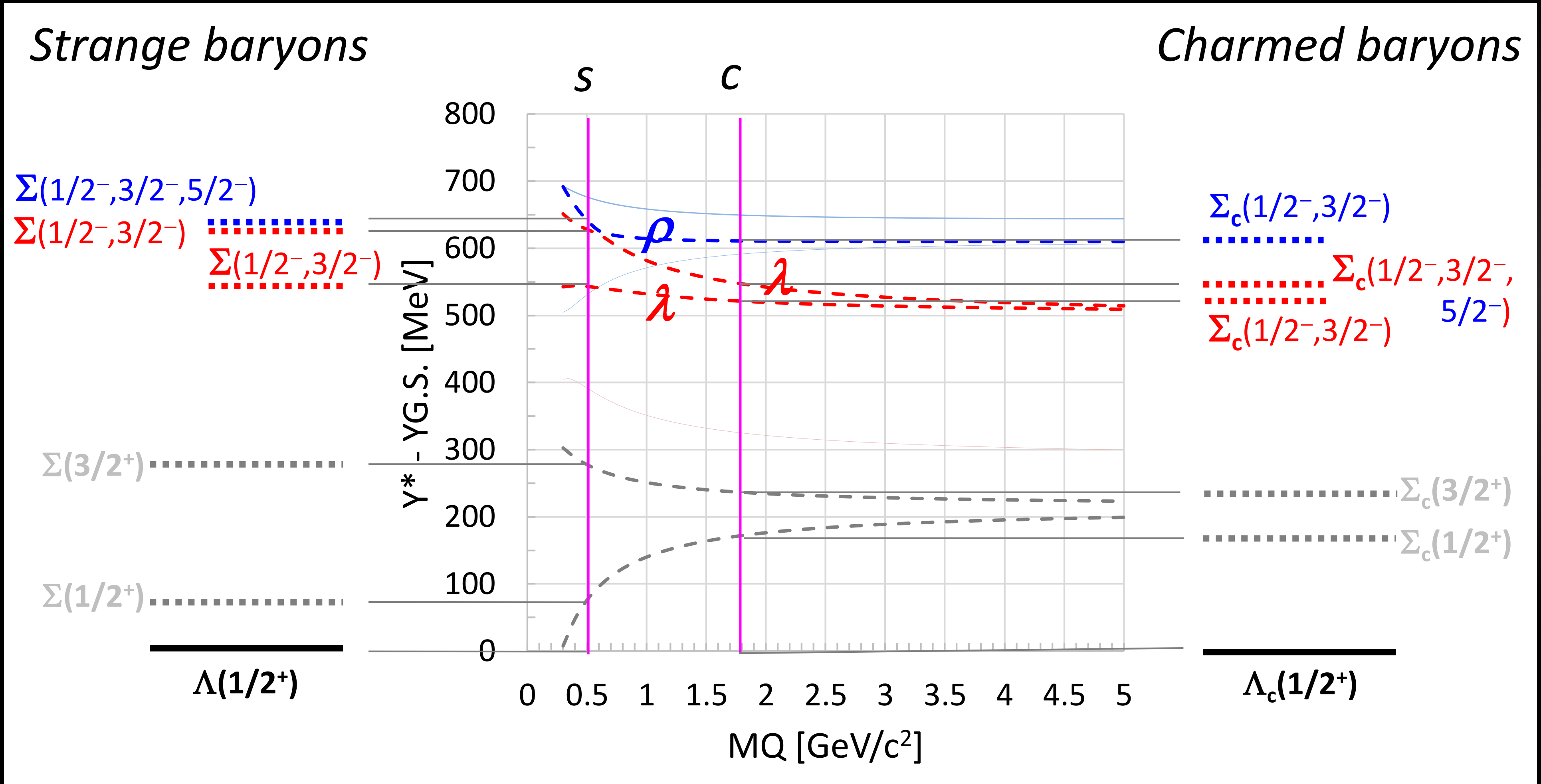


Λ,Σ(1/2-) (ρ, λ-mode excitations w/ V_{ss})



CQM calculation (P-wave Sigma)



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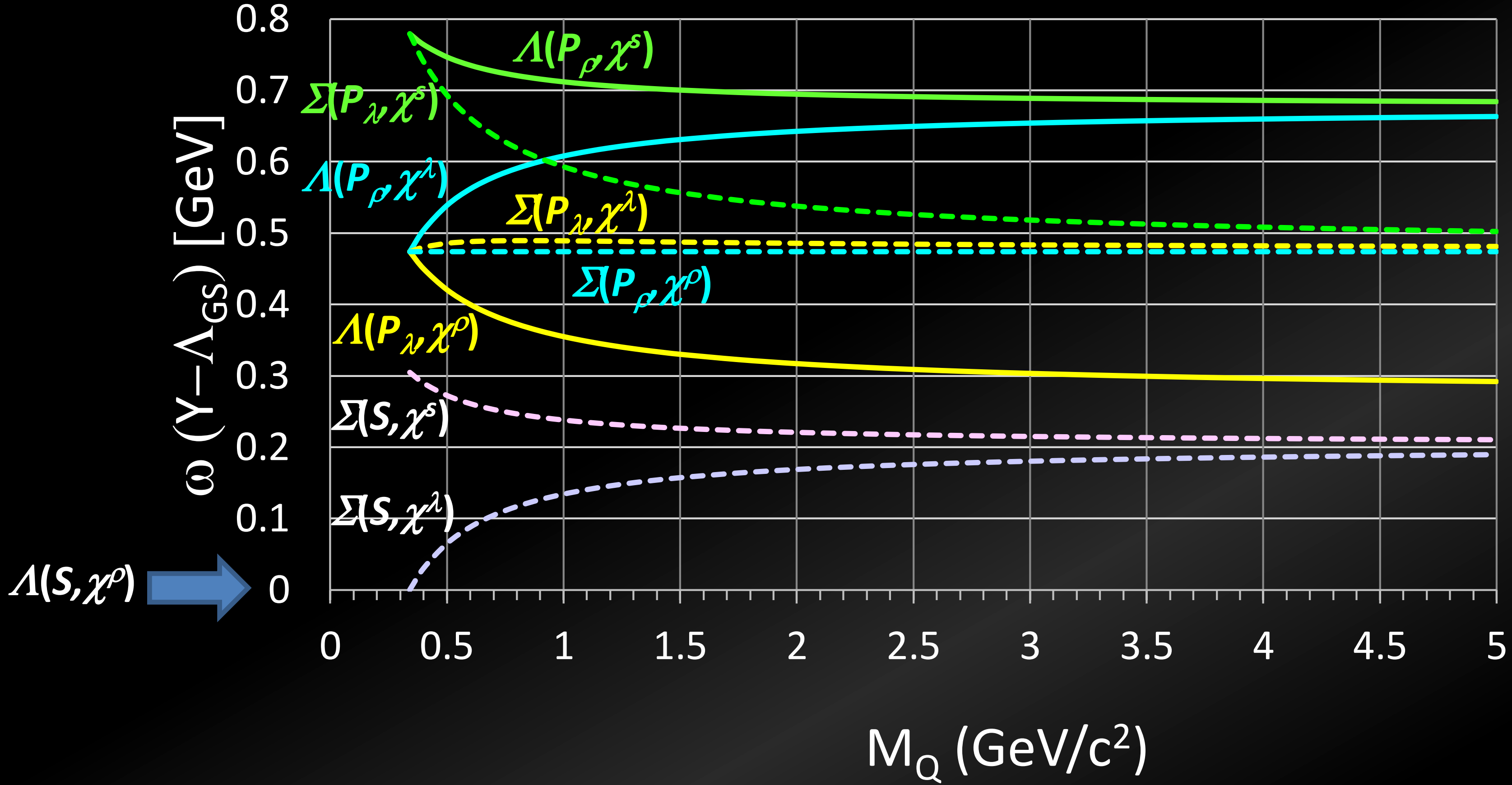
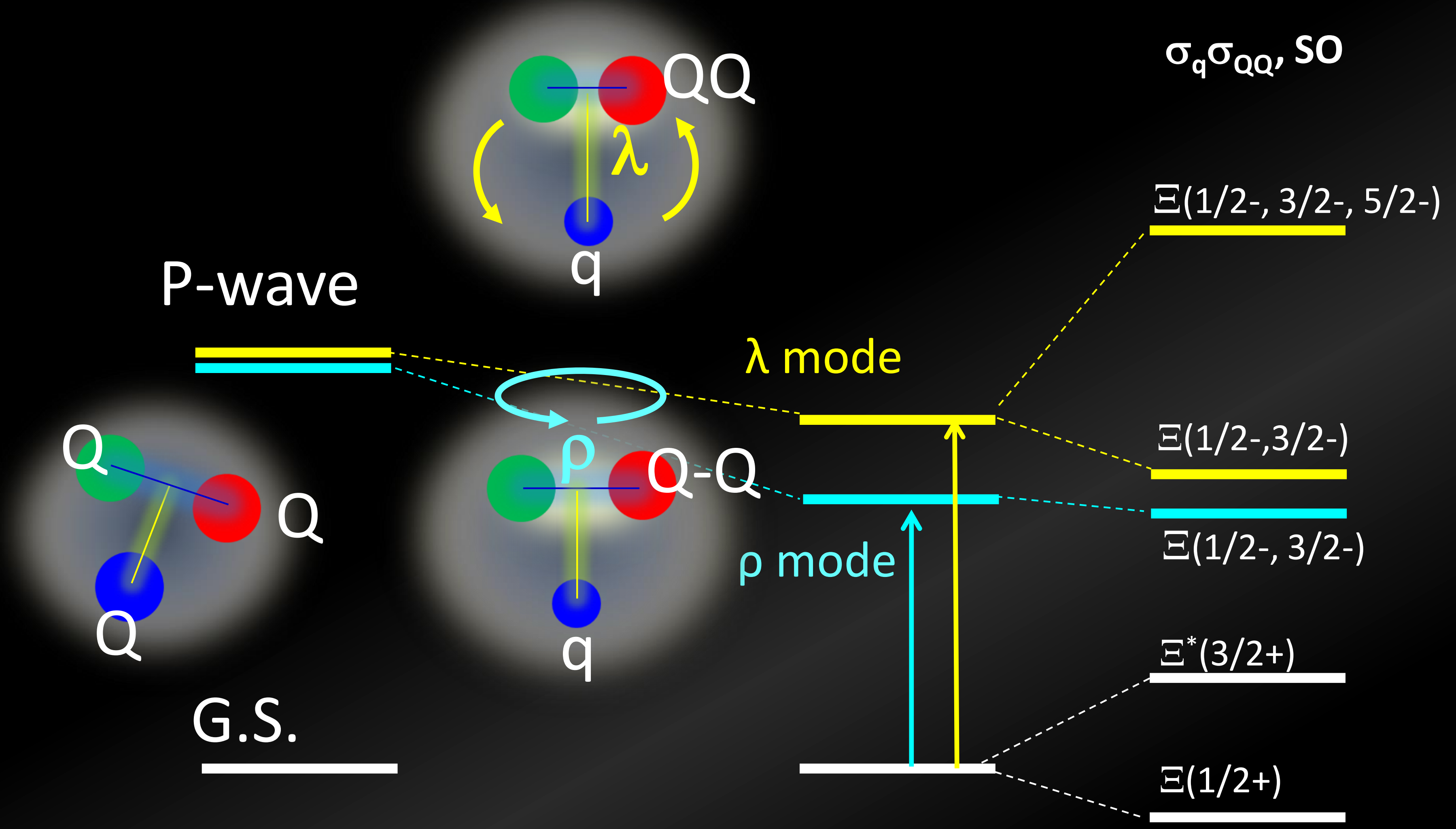


QQq

Level Structure of double-strange baryons

- λ and ρ mode excitations interchange



Confinement

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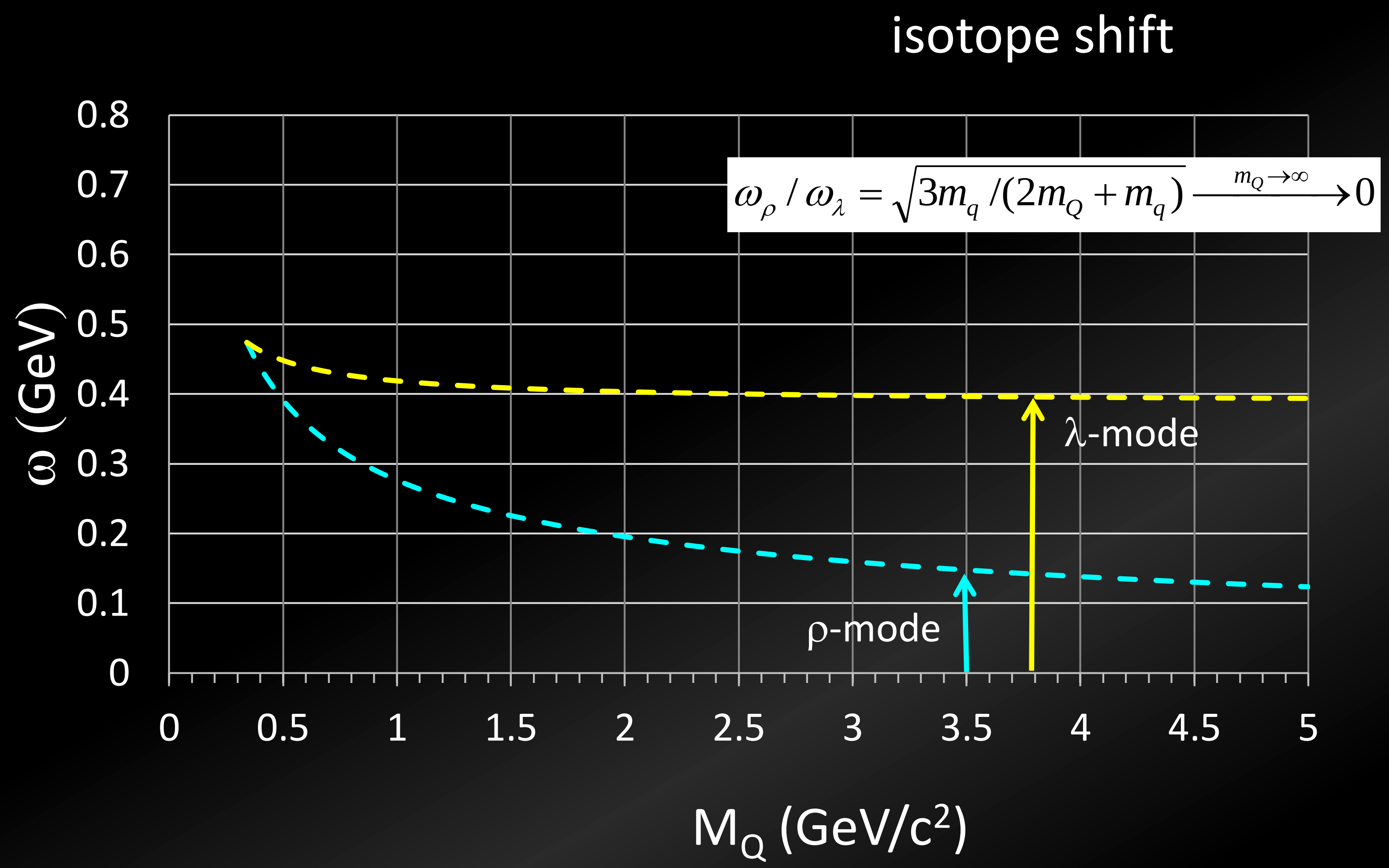
P-wave (ρ, λ-mode excitations)



Spin-spin Interaction

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$$\Xi\left(\frac{1}{2}^+\right) = \omega_0 + c_s \left(\frac{1}{m_Q^2} - \frac{4}{m_q m_Q} \right)$$

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$$\Xi^*\left(\frac{3}{2}^+\right) = \omega_0 + c_s \left(\frac{1}{m_Q^2} + \frac{2}{m_q m_Q} \right)$$

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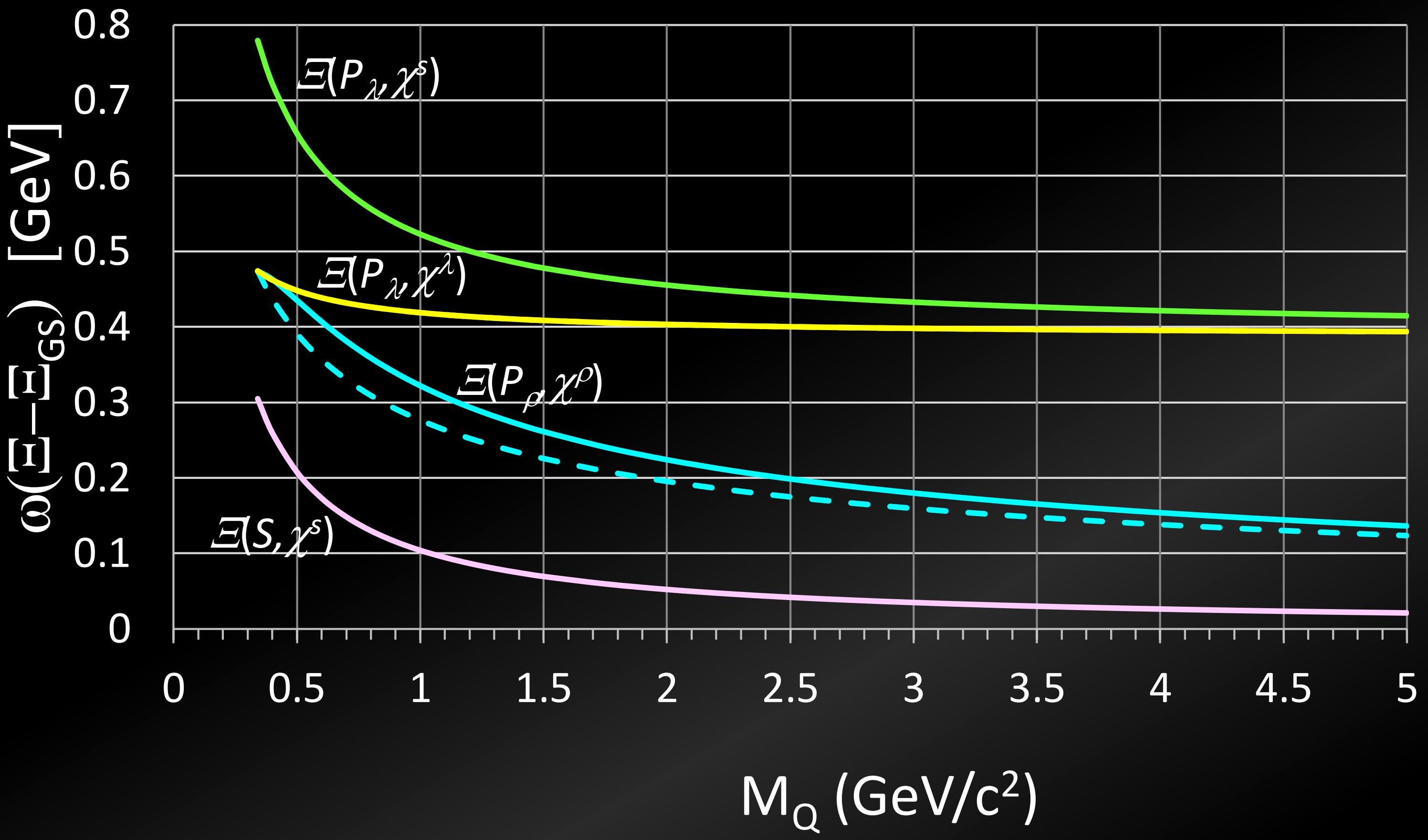
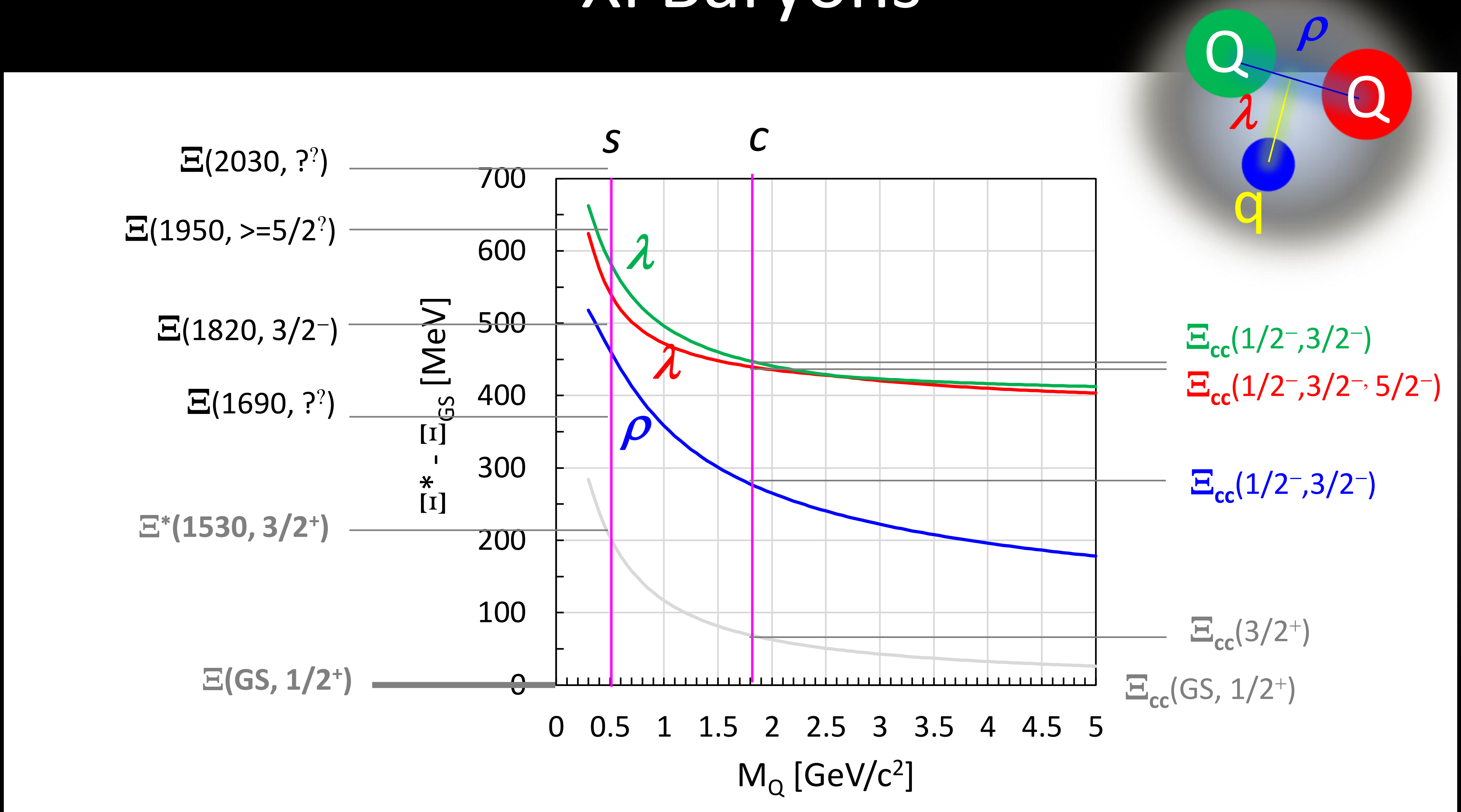
$$\Xi\left(\frac{1}{2}^-, \frac{3}{2}^-, \frac{5}{2}^-\right) = \omega_\lambda + c_s\left(\frac{1}{m_Q^2} + \frac{2}{m_q m_Q}\right) (\ell_\lambda = 1, \chi^s)$$

Ξ (ρ, λ-mode excitations w/ V_{ss})



Xi Baryons



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

ρ–λ mixing (cal. By T. Yoshida)

T. Yoshida et al.,
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Measured Ξ (PDG)

Threshold

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

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

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

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

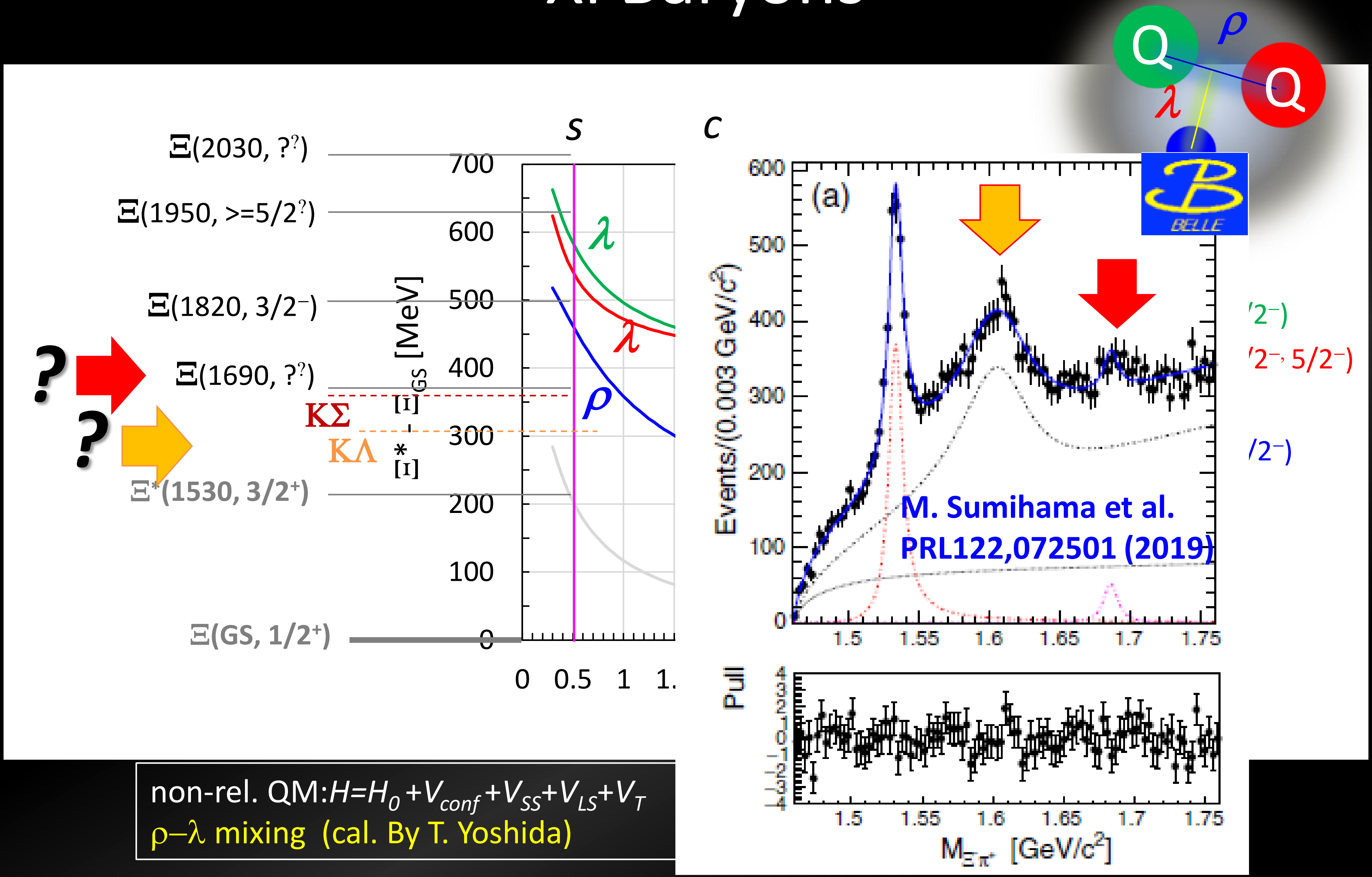
$\Lambda\bar{K}$(1610)

$\Xi\pi$(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* $\Sigma\bar{K}$	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.

Xi Baryons



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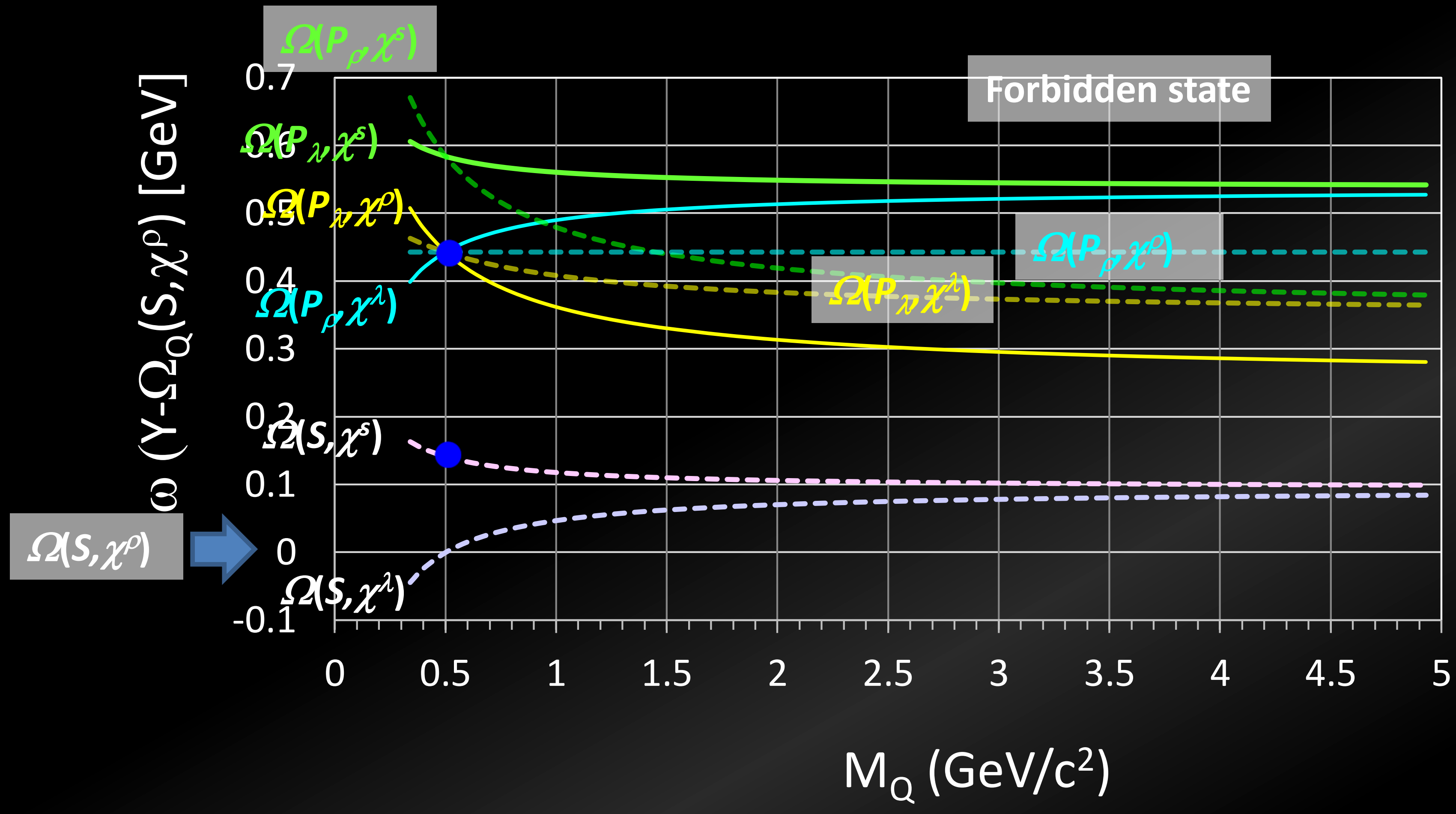
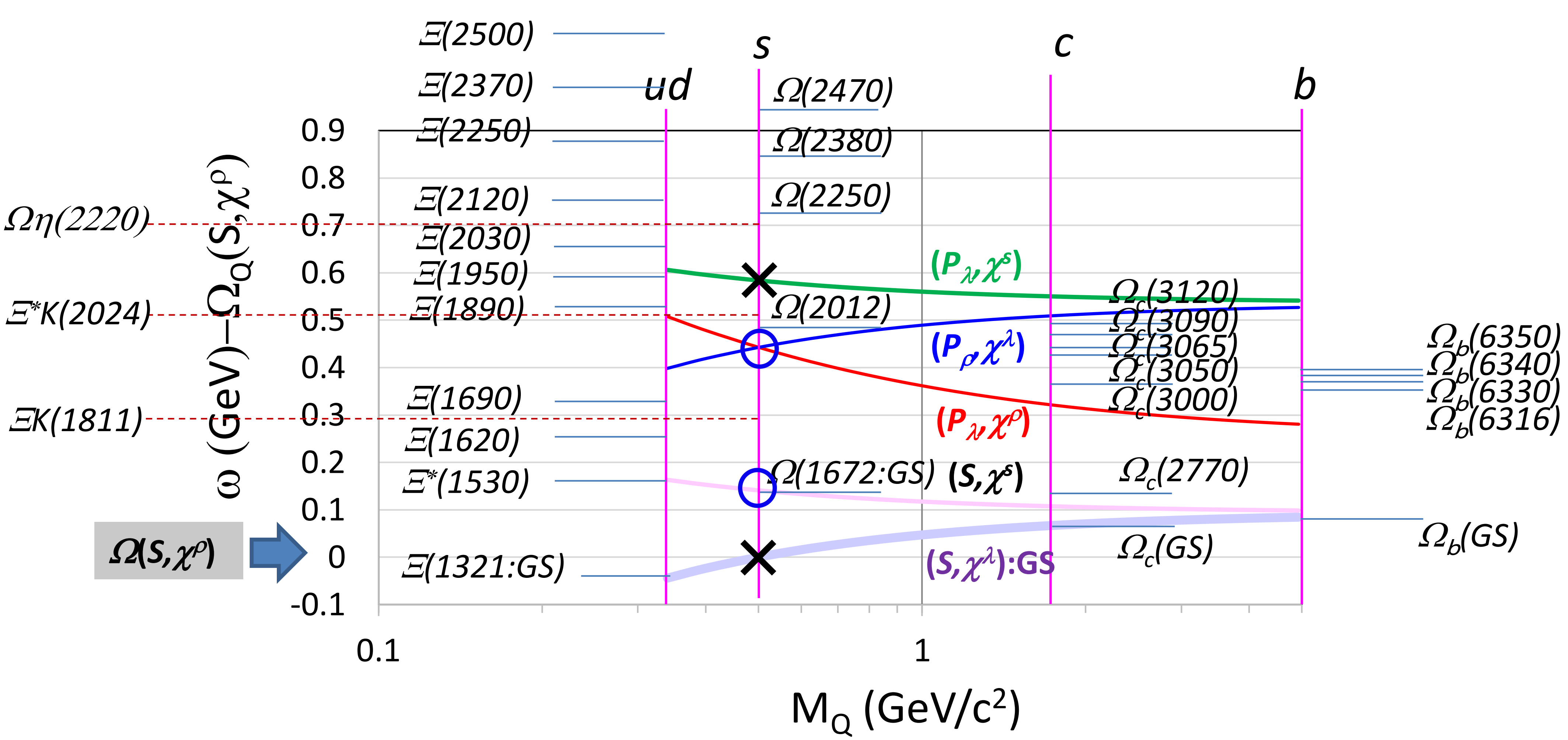
Qss

Ω(S,P) (ρ, λ-mode excitations w/ V_{ss}) when m_q=m_s



Omega Baryon



Measured Ω (PDG)

Threshold

Ξ0K*- 2109

Ξ0*K- 2024

Ξ0K-π0 1956

Ωπ0π0 1942

Ξ0K- 1811

(Ωπ0 1807)

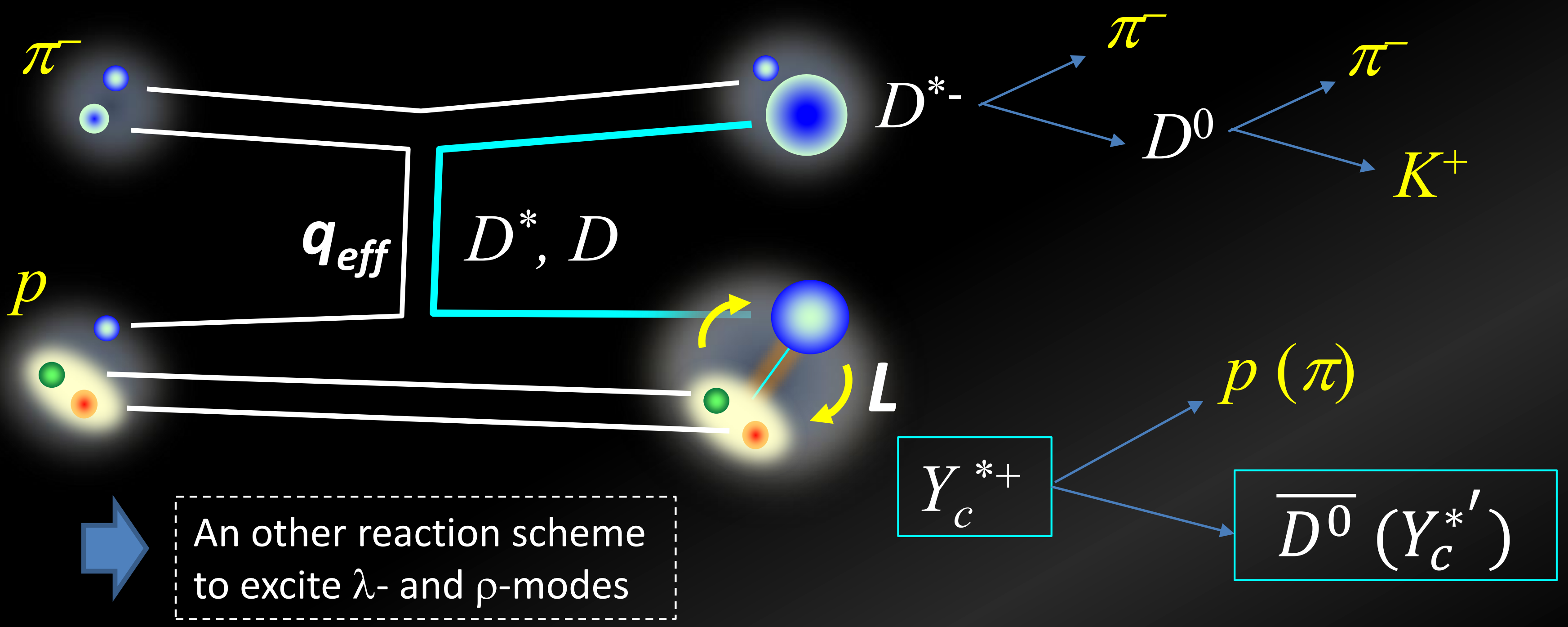
	JP	rating	Width [MeV]	→ΞK (1)	→Ξ*K (2)	→ΞK* (3)	→ΞKπ (4)	→Ωππ (5)	
Ω(2470)	??	2*	72+-33					seen	LASS (113MK-,11GeV/c) (290+-90)/(5) nb
Ω(2380)	??	2*	26+-23		<0.44 to (4)	0.5+-0.3 to (4)			Xi Beam
Ω(2250)	??	3*	55+-18		0.7+-0.2 to (4)		Seen		Xi Beam LASS (113MK-, 11GeV/c) (630+-180)/(2) nb
Ω(2012)	?-	3*	$6.4^{+2.5}_{-2.0}$ +-1.6	1.2+-0.3 (=Ξ0/Ξ–)	<0.119 /(1)				->Ξ*K dominant if Ξ*K mol?
Ω(1672)	3/2+	4*	-						

✓ *Most of spins/parities/decay branches have yet to be determined.*

✓ *What the production Ξ* -> Ω*K* and *Ω** decay modes tell us *Ω**'s internal structure.

Charmed Baryon Spectroscopy

Charmed Baryon Spectroscopy Using Missing Mass Techniques



- ✓ Production and Decay reflect [qq] correlation in Excited Y_c*
- ✓ C.S. DOES NOT go down at higher *L* when q_{eff}>1 GeV/c.

S.H. Kim, A. Hosaka, H.C. Kim, and HN, PTEP, (2014) 103D01,
S.H. Kim, A. Hosaka, H.C. Kim, and HN, Phys.Rev. D92 (2015) 094021

discussed with A. Hosaka

Revisit the Regge Theory

- shows the typical s-dependence of binary reaction cross sections at the large s region;

$$\frac{d\sigma}{dt} = \frac{1}{64\pi s (p_\pi^{cm})^2} \left| \langle f | T | i \rangle \right|^2 \quad \langle f | T | i \rangle = g_1 g_2 \Gamma(-\alpha(t))(s/s_0)^{\alpha(t)}$$

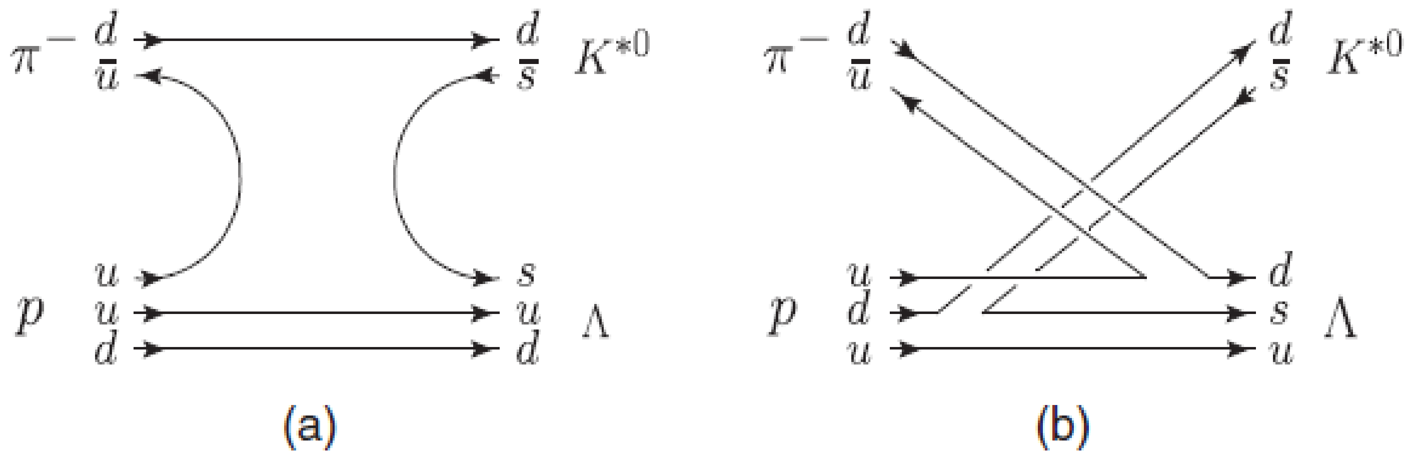
  - Regge trajectory: $\alpha(t) = \alpha(0) - \gamma[\sqrt{T} - \sqrt{t-T}]$
  - scale parameter s_0 :

    s at the threshold energy of the reaction AB → CD

    (*In Kaidalov's Model: $s_0^{2(\alpha_{D^*}(0)-1)} = s_{CD}^{\alpha_\rho(0)-1} * s_{CD}^{\alpha_{J/\psi}(0)-1}$

    $s_{AB} = (\Sigma m_i)_A * (\Sigma m_j')_B$, m_i:transversal masses of the consituent quark)

Amplitude

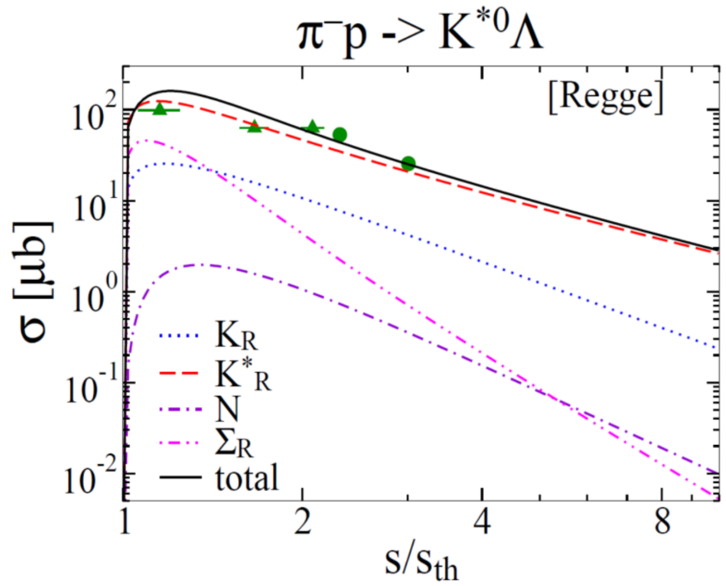


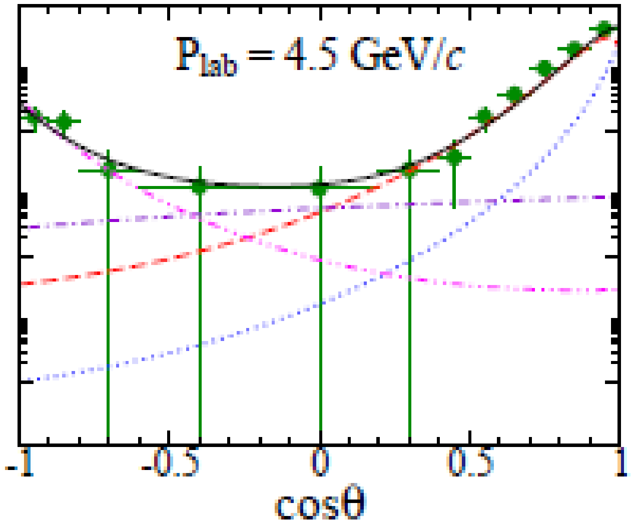
$$P_K^{\mathrm{R}}(s,t) = \begin{pmatrix} 1 \\ e^{-i\pi\alpha_K(t)} \end{pmatrix} \left(\frac{s}{s_K}\right)^{\alpha_K(t)} \Gamma[-\alpha_K(t)]\alpha'_K,$$

$$P_{K^*}^{\mathrm{R}}(s,t) = \begin{pmatrix} 1 \\ e^{-i\pi\alpha_{K^*}(t)} \end{pmatrix} \left(\frac{s}{s_{K^*}}\right)^{\alpha_{K^*}(t)-1} \Gamma[1-\alpha_{K^*}(t)]\alpha'_{K^*},$$

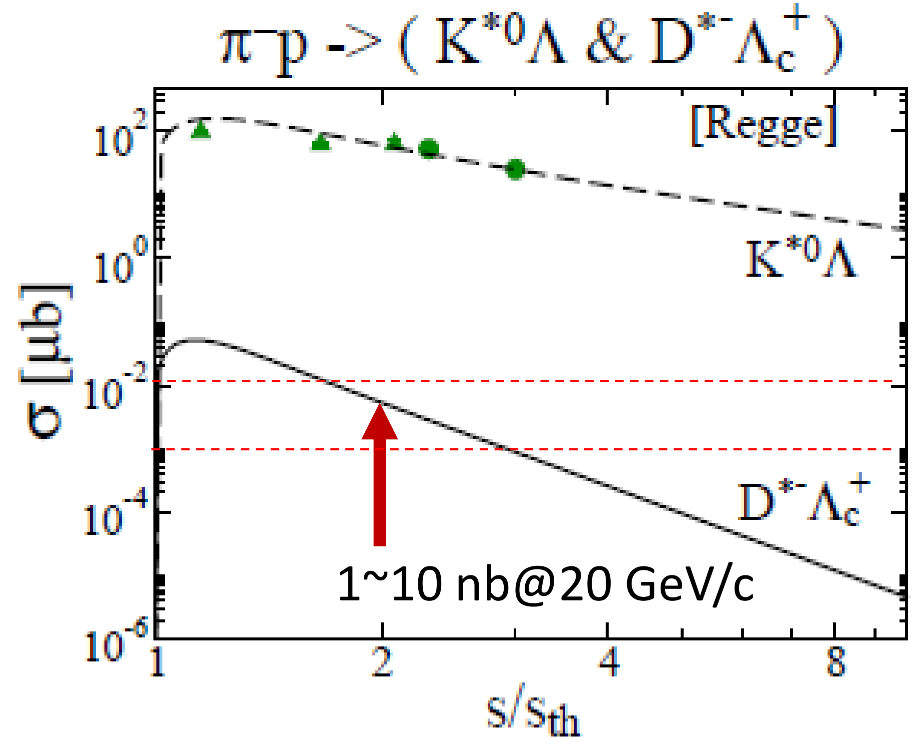
$$P_{\Sigma}^{\mathrm{R}}(s,u) = \begin{pmatrix} 1 \\ e^{-i\pi\alpha_\Sigma(u)} \end{pmatrix} \left(\frac{s}{s_\Sigma}\right)^{\alpha_\Sigma(u)-\frac{1}{2}} \Gamma\left[\frac{1}{2}-\alpha_\Sigma(u)\right]\alpha'_\Sigma,$$

Production Cross Section



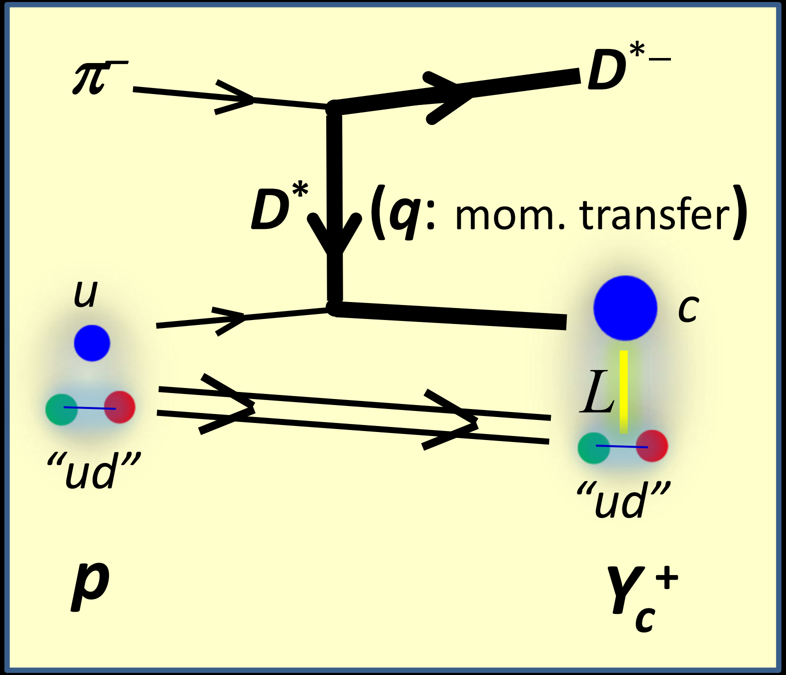


S.H. Kim, A. Hosaka, H.C. Kim, and HN
PRD92, 094021(2015)



Production Rate:

$$R \sim \left\langle \varphi_f \left| \sqrt{2}\sigma_- \exp(i\vec{q}_{eff}\vec{r}) \right| \varphi_i \right\rangle$$



- *t*-channel *D** *Reggeon* at a forward angle

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

1. Momentum transfer (q_{eff})

$$I_L \sim (q_{eff}/A)^L \exp(-q_{eff}^2/2A^2)$$

q_{eff}~1.4 GeV/c A~0.4 GeV ([Baryon size]$^{-1}$)

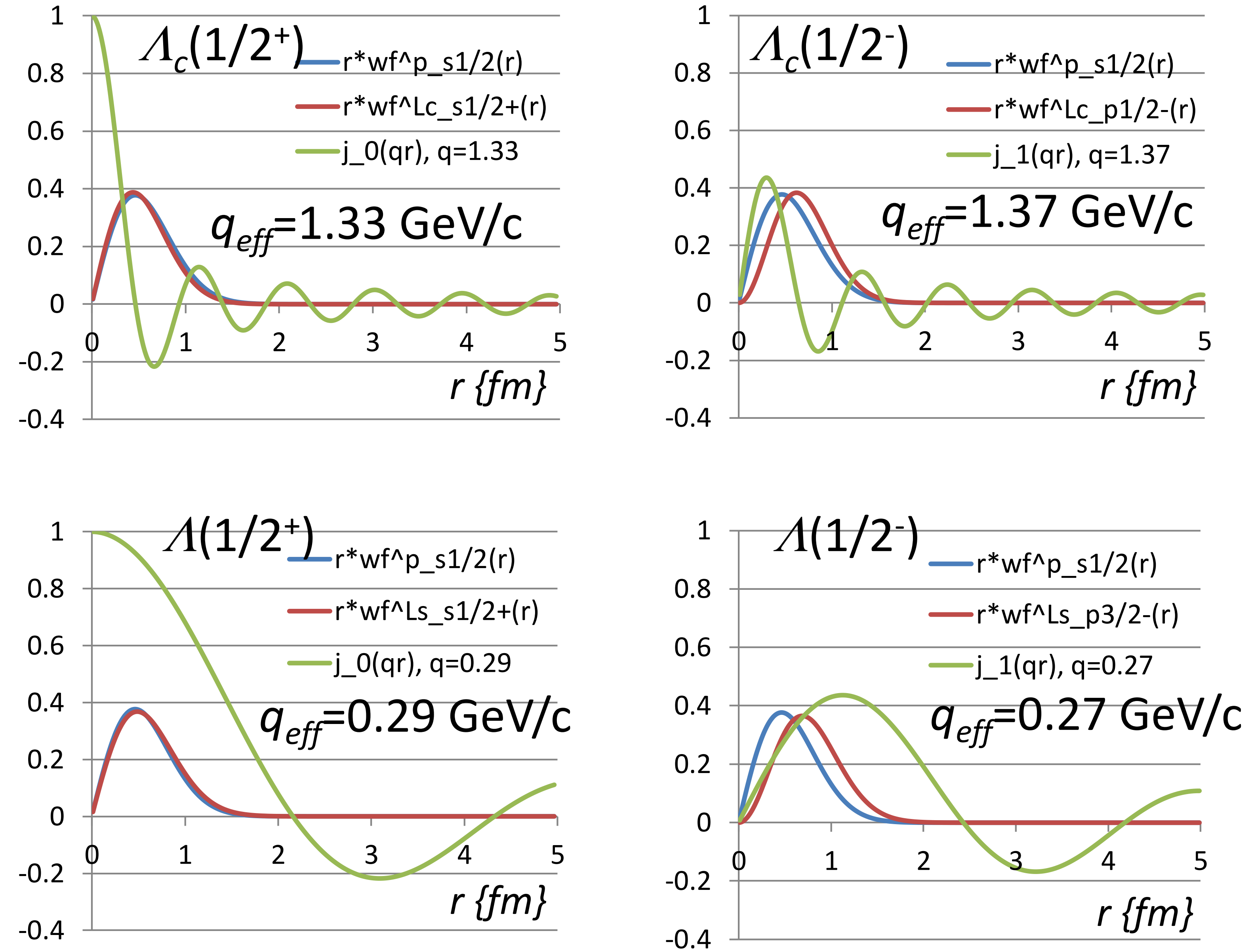
2. Population shared among HQ-spin multiplet

$$J_{BM} - s_{HQ} : J_{BM} + s_{HQ} = L : L + 1$$

3. Spectroscopic Factor ("ud" configulation)

γ=1/2 for Λ_c's, =1/6 for Σ_c's charm

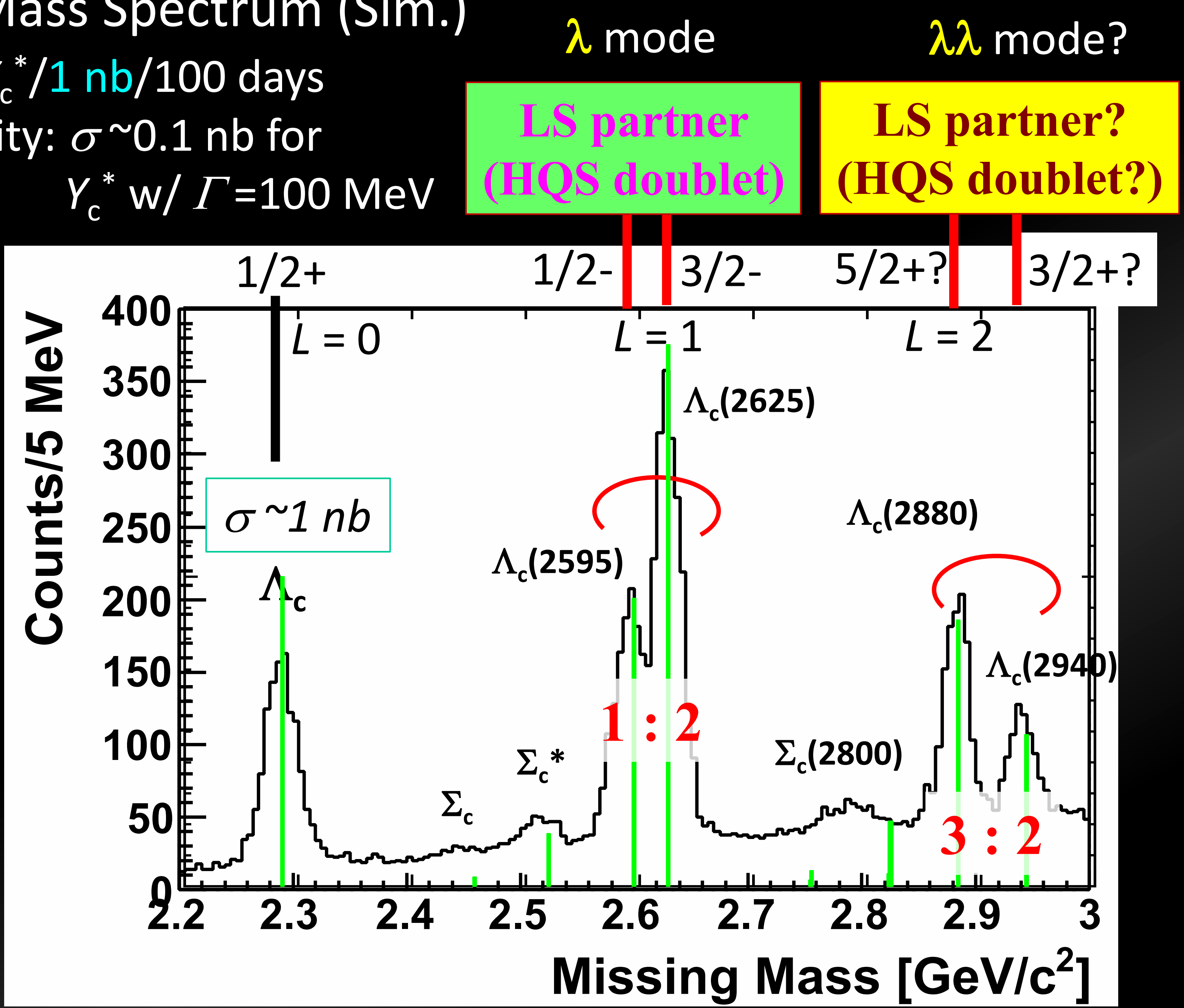
strange



L=0 *L*=1

Missing Mass Spectrum (Sim.)

- ~1000 Y_c^*/1 nb/100 days
- Sensitivity: σ~0.1 nb for Y_c^* w/ Γ=100 MeV



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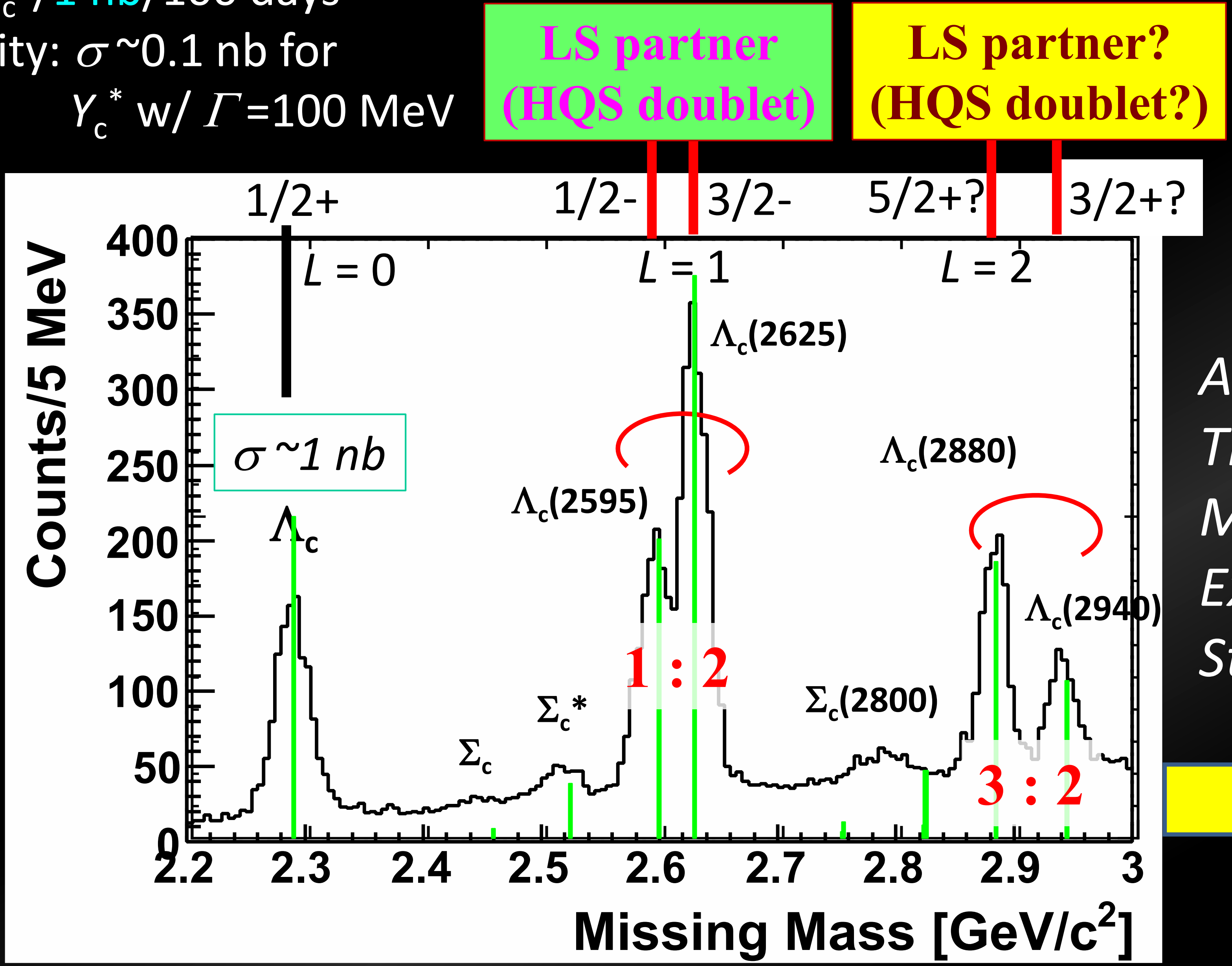
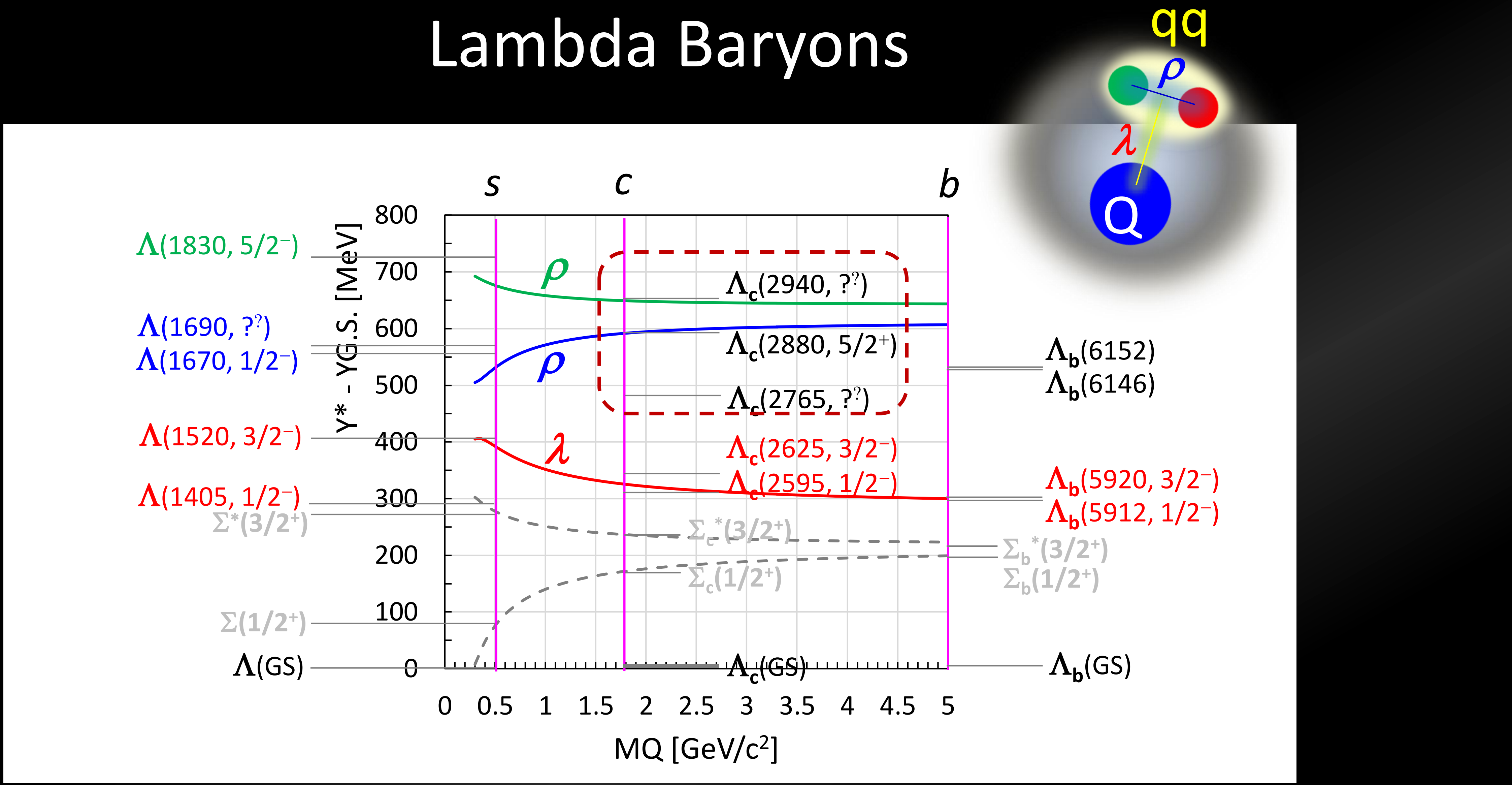


Are There More Excited States?

Lambda Baryons



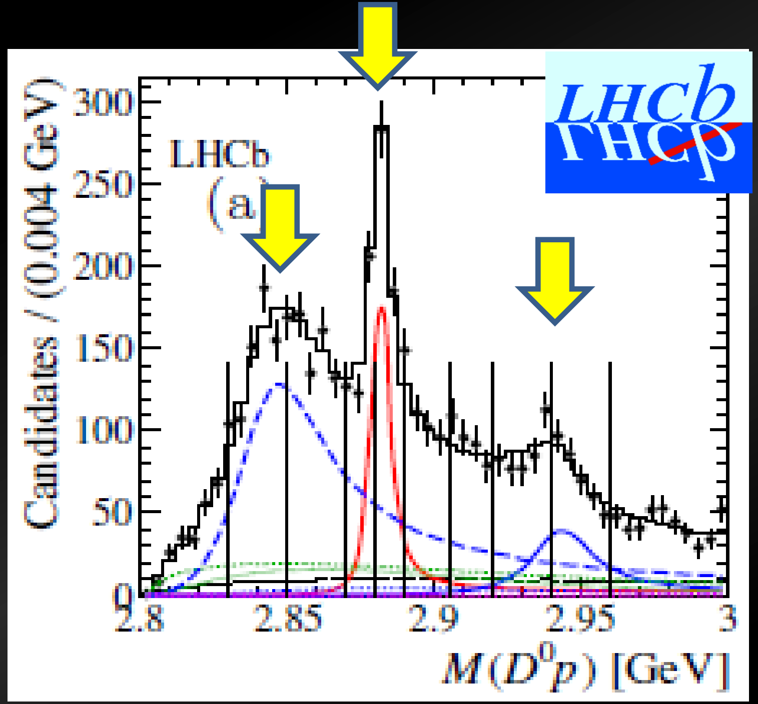
non-rel. QM: $H=H_0+V_{conf}+V_{SS}+V_{LS}+V_T$
ρ–λ mixing (cal. By T. Yoshida)

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

LHCb data in Λ_c^*

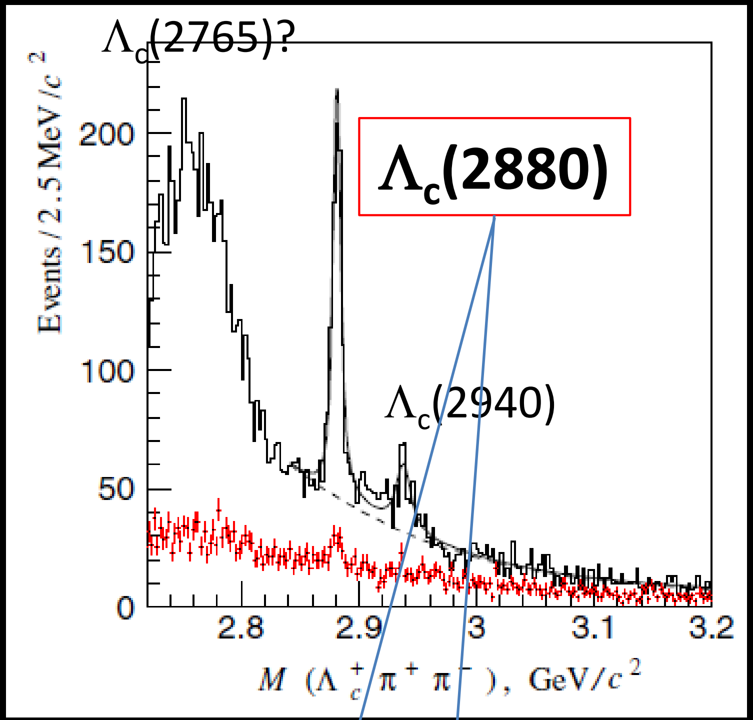
J. High Energ. Phys. (2017) 2017

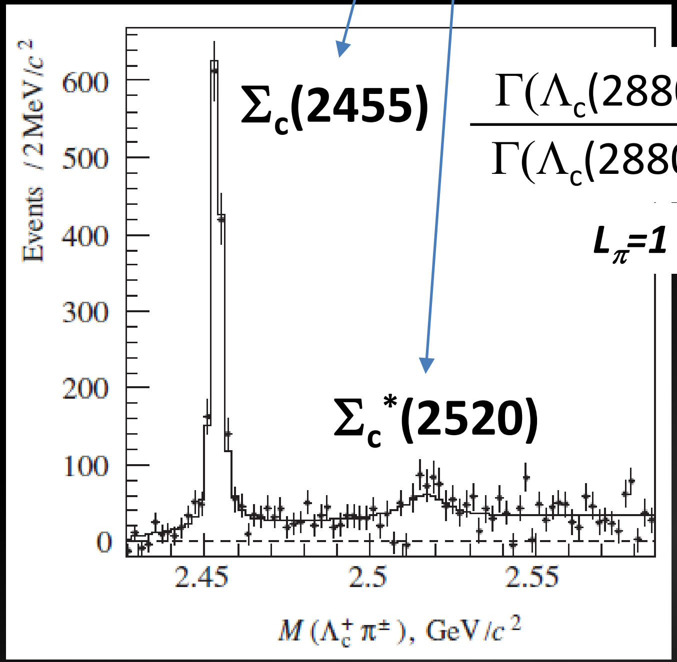
- $D^0 p$ invariant mass in $\Lambda_b \to D^0 p \pi^-$
  - $\Lambda_c(2940)$: known
    - likely 3/2-, (acceptable 1/2, 7/2)
  - $\Lambda_c(2880)$: known
    - 5/2+ confirmed
  - $\Lambda_c(2860)$: new
    - likely 3/2+, D-wave (*L*=2) resonance?



- Questions arise;
  - Is $\Lambda_c(2940)$ an *L*=3 state (λ mode)?
  - Are $\Lambda_c(2880)$ and $\Lambda_c(2860)$ *LS* partners of *L*=2 (λ modes)?
- Production rates in p(π^-,D^{*-})Y_c^* will give answer.

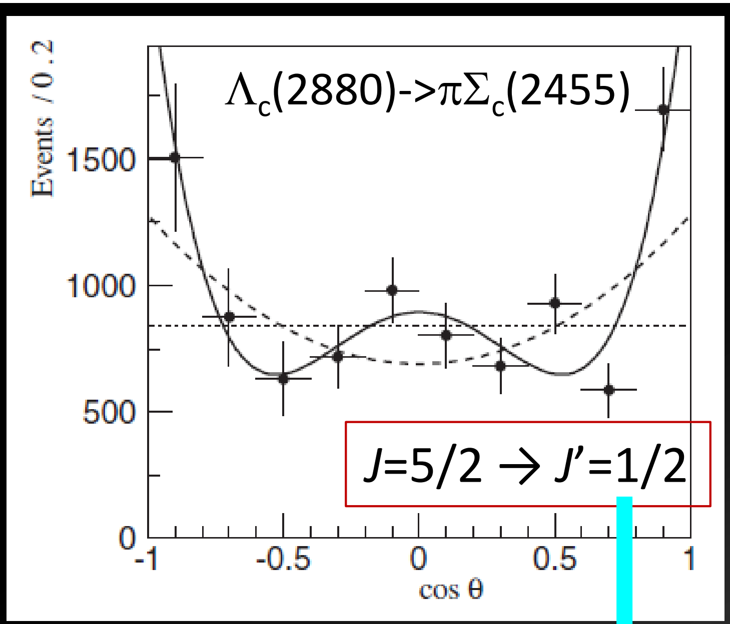
Lc(2880)Belle, PRL98, 262001('07)





$$\frac{\Gamma(\Lambda_c(2880)\to\pi\Sigma_c^*(2520))}{\Gamma(\Lambda_c(2880)\to\pi\Sigma_c(2455))} = \mathbf{0.23}$$

L_π=1 contribution may affect…



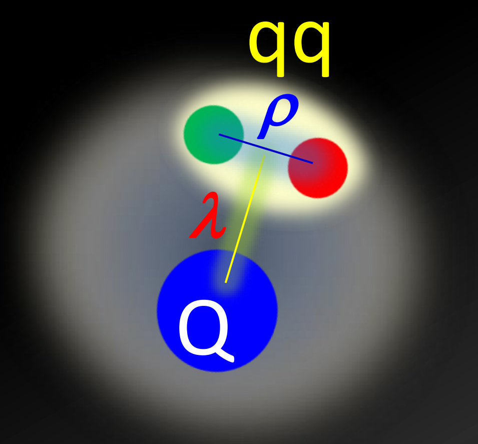
L_π=3 transition

J^P=5/2⁺ for $\Lambda_c(2880)$

Is it a D-wave Lambda-c Baryon?

If so, where is a spin partner ?

Λ(2880) likely to be $\lambda\rho$ mode?



H. Nagahiro et al., PRD95 (2017) no.1, 014023

- P-wave transition seems to be suppressed in

$$\Lambda_c(2880)\frac{5}{2}^+ \rightarrow \Sigma_c^*(2520)\frac{3}{2}^+ + \pi(0^-).$$

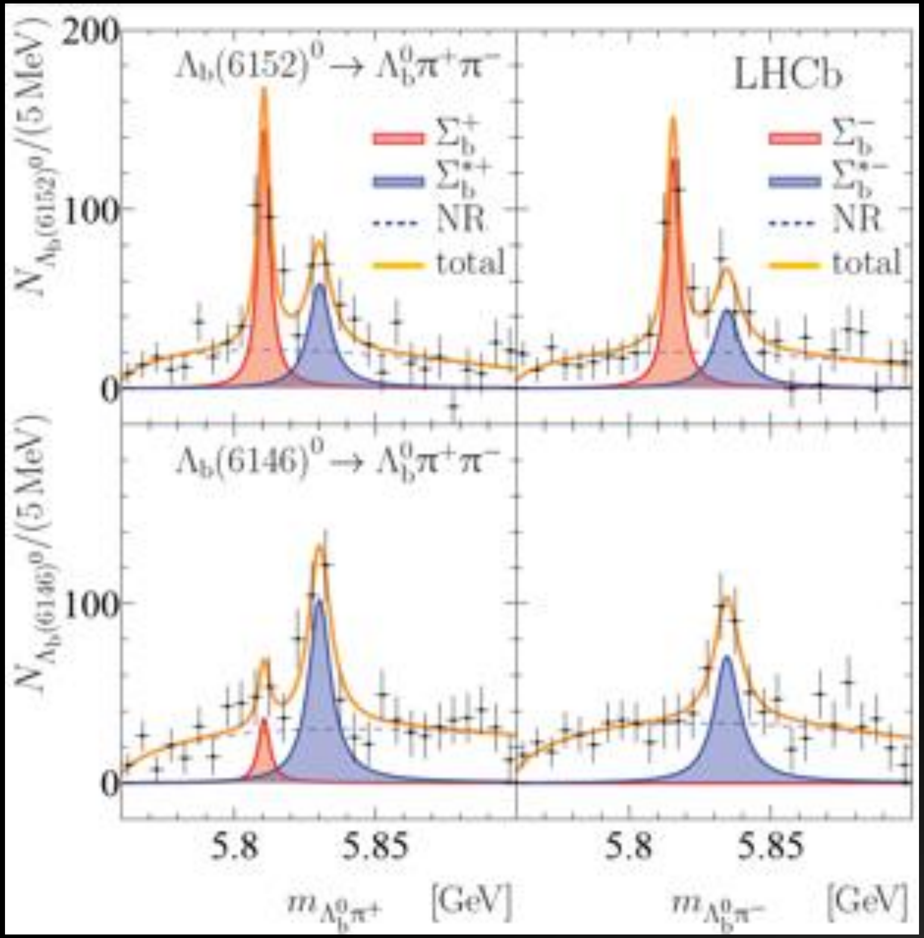
- It would be forbidden only in the case of $J_{BM}^P = 3^+$: "5/2-" state have large widths.
- $\Lambda_c(2880)\frac{5}{2}^+$ is likely to be a $\lambda\rho$ mode (λ=1, ρ=1) state.

Λ_c(2880) 5/2+	$\lambda\lambda$	$\lambda\rho$	$\rho\rho$
color		Asymm.	
Isospin		Asymm. (I=0)	
Diquark spin Diquark orbit	Asymm. 0 Symm. 0	Symm. 1 Asymm. 1	Asymm. 0 Symm, 2
Lambda orbit	2	1	0
J_{BM}^P	2+	1+, 2+, **3+**	2+

Σ_c^*(2520) 3/2+
Asymm
Symm. (I=1)
Symm. 1 Symm, 0
0
1+

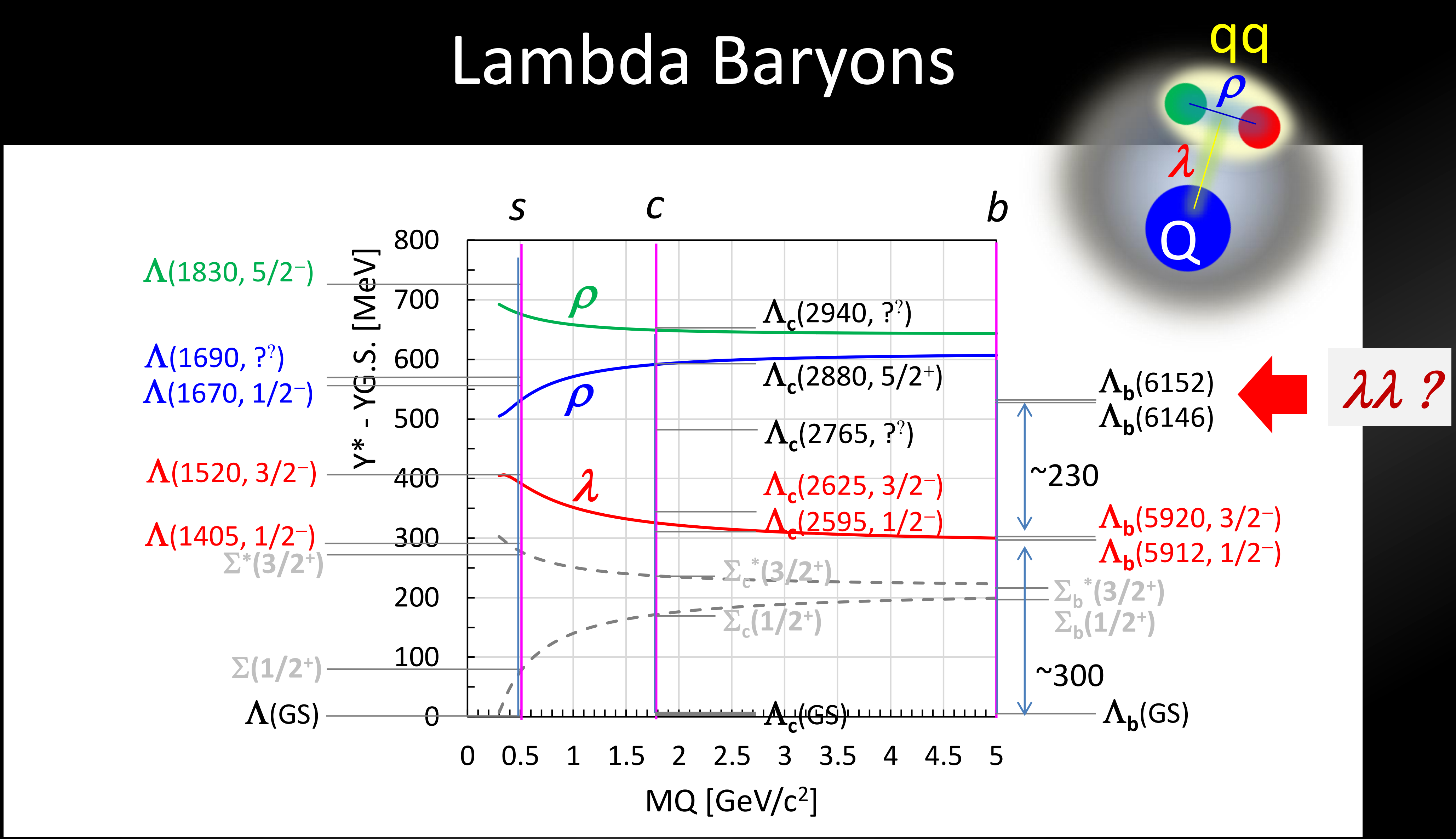
To be confirmed by measuring the prod. ratio

Lambda_b(6146/6152) Phys. Rev. Lett. 123, 152001



- A new doublet Λ_b^* states decaying into $\Lambda_b\pi^+\pi^-$ have been observed.
  - $M_{\Lambda_b(6146)} = 6146.17 \pm 0.33 \pm 0.22 \pm 0.16$ MeV
  - $M_{\Lambda_b(6152)} = 6152.51 \pm 0.26 \pm 0.22 \pm 0.16$ MeV
  - $\Gamma_{\Lambda_b(6146)} = 2.9 \pm 1.3 \pm 0.3$ MeV
  - $\Gamma_{\Lambda_b(6146)} = 2.1 \pm 0.8 \pm 0.3$ MeV
- They are likely to be λ-mode with L=2…
- $\Lambda_b(6146)$ dominantly decays to Σ_b?
  - Similar to the case of $\Lambda_c(2880, 5/2^+)$

Lambda Baryons



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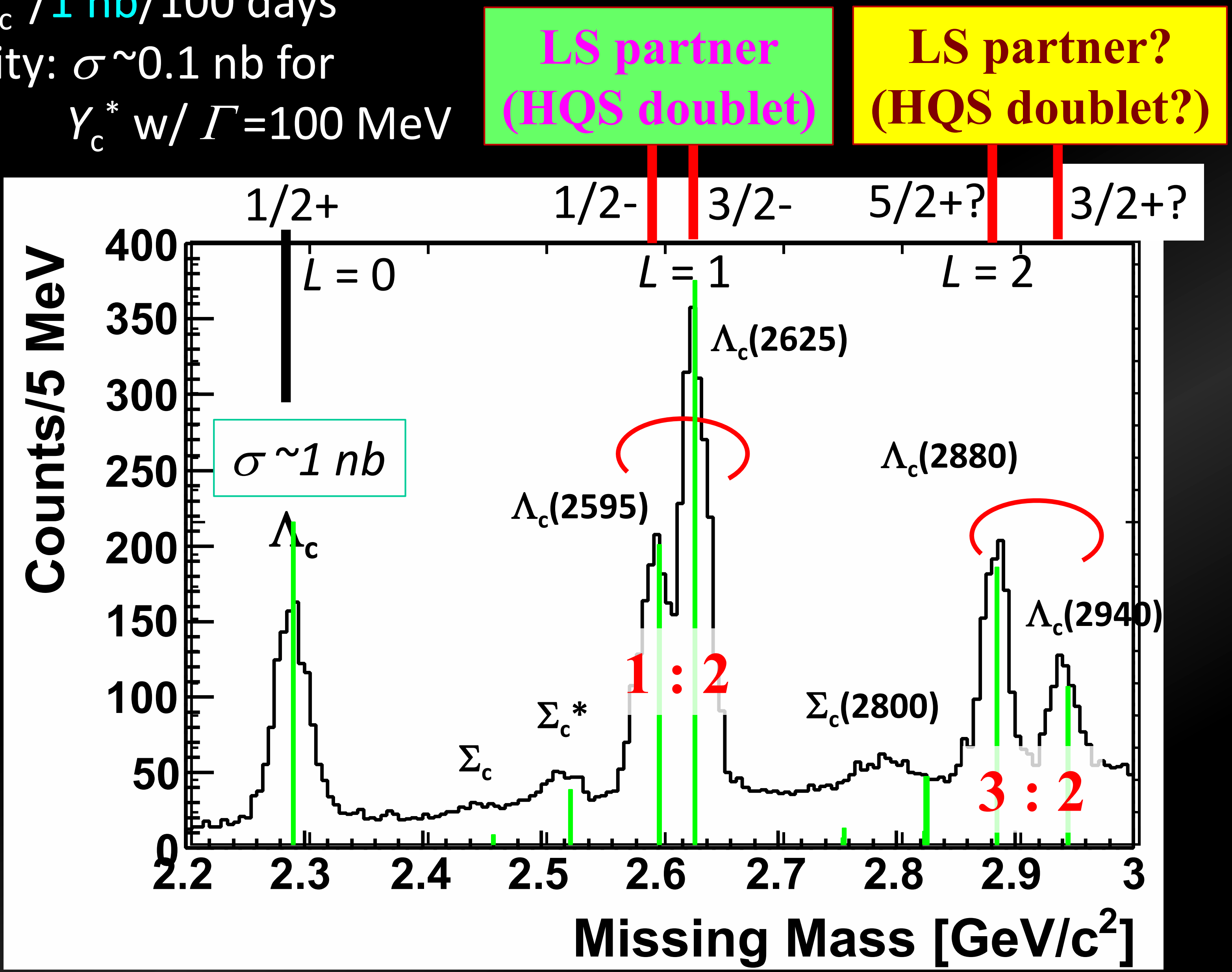
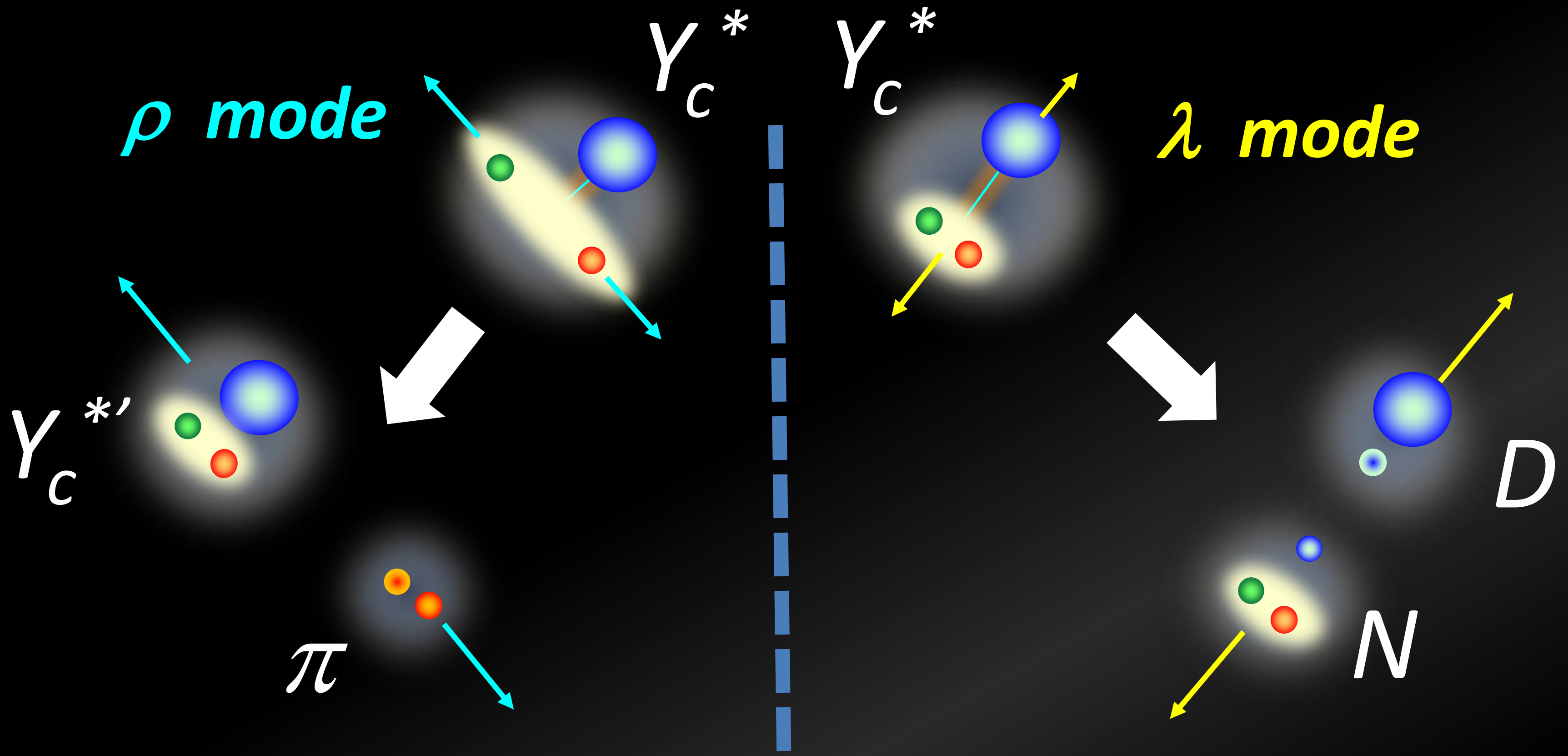
T. Yoshida et al.,
Phys. Rev. D**92**, 114029(2015)

Missing Mass Spectrum (Sim.)

- ~1000 Y_c^*/1 nb/100 days
- Sensitivity: σ~0.1 nb for Y_c^* w/ Γ=100 MeV



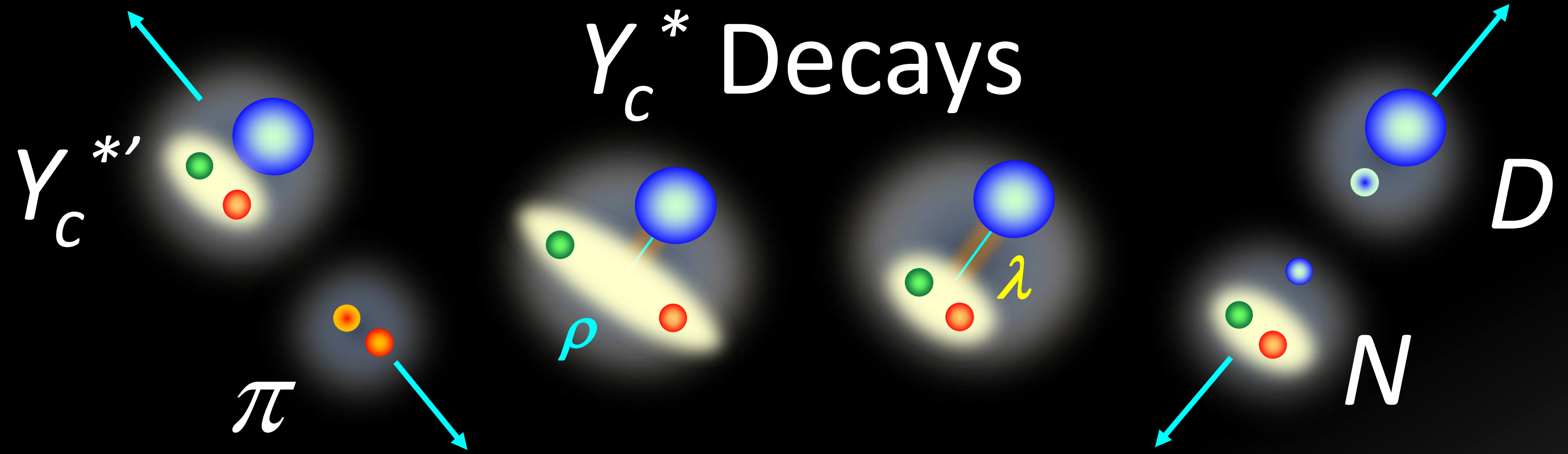
Y_c^* Decay Branching Ratio

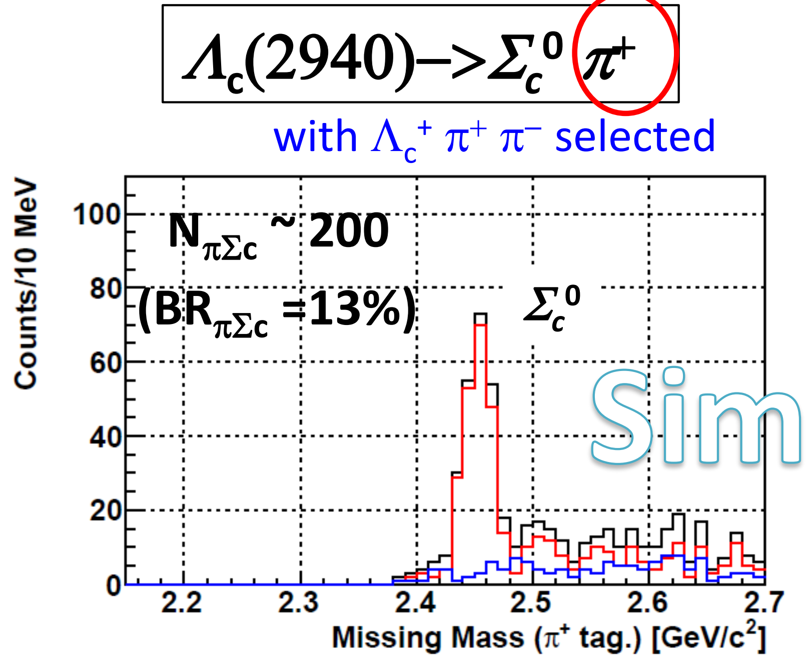


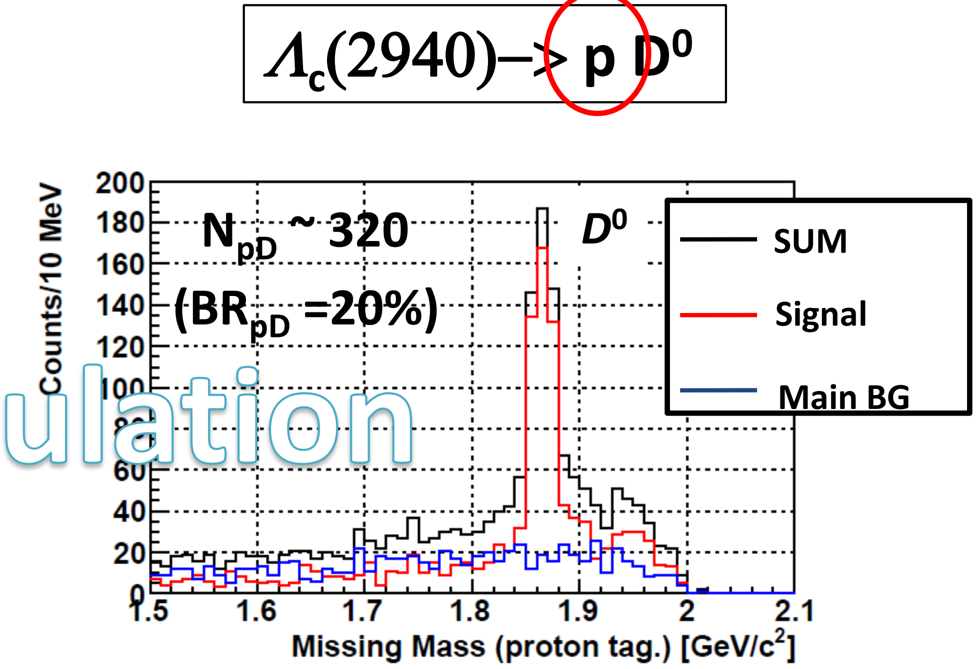
$\Gamma(Y\pi) > \Gamma(DN)$

$\Gamma(DN) > \Gamma(Y\pi)$

Y_c^* Decays

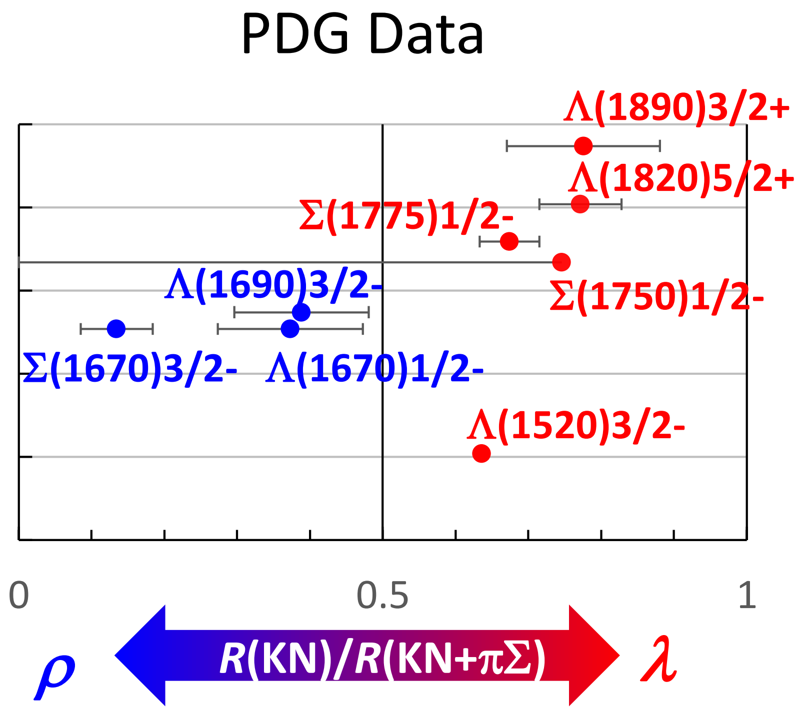






* Branching ratios: Diquark corr. affects $\Gamma(\Lambda_c^* \to pD)/\Gamma(\Lambda_c^* \to \Sigma_c\pi)$.

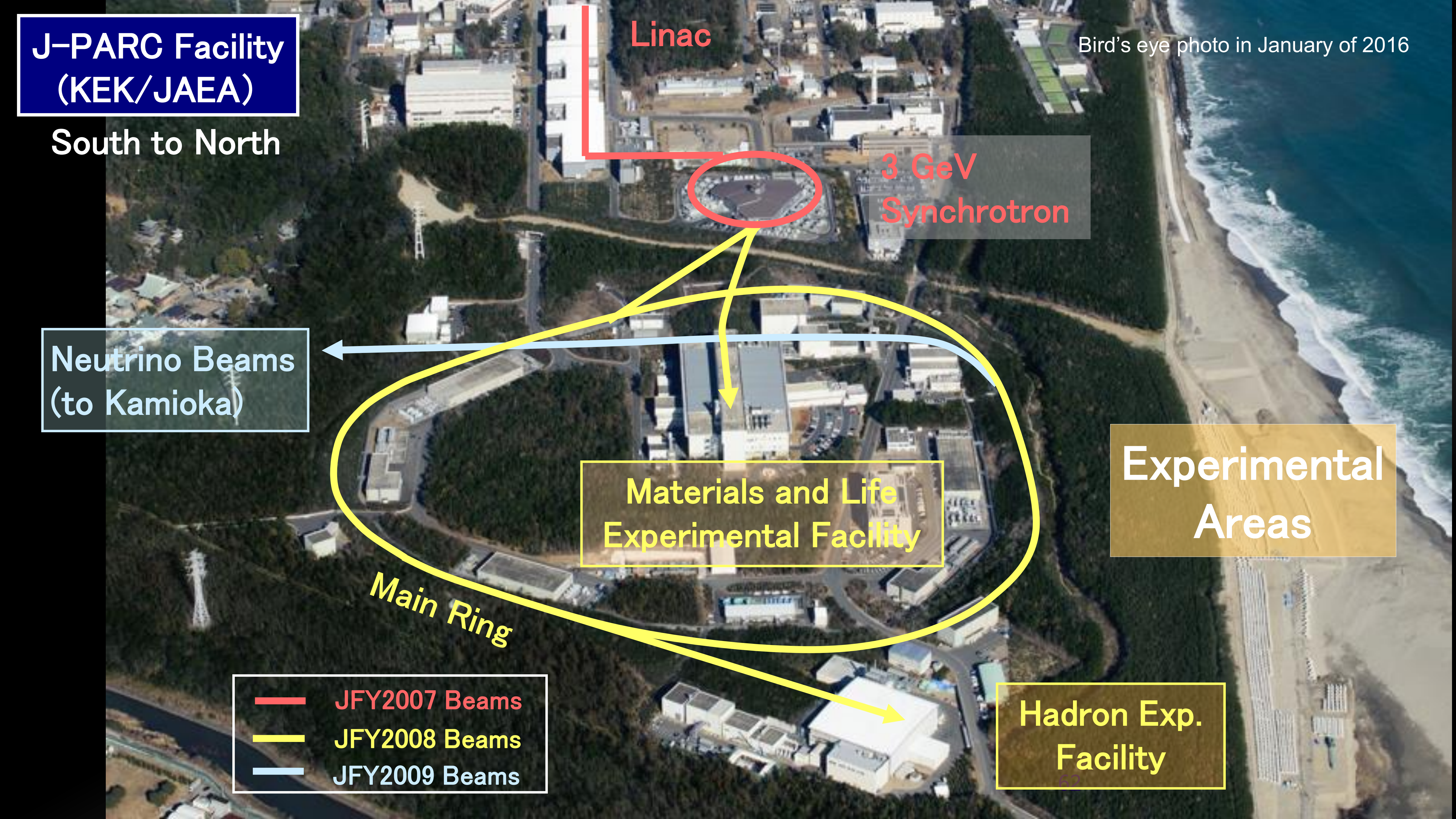
Hint in $R(NK)/R(\pi\Sigma)$



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

- Hyperon data indicate mode dependence
  → Errors should be improved.
- No data in charmed baryons

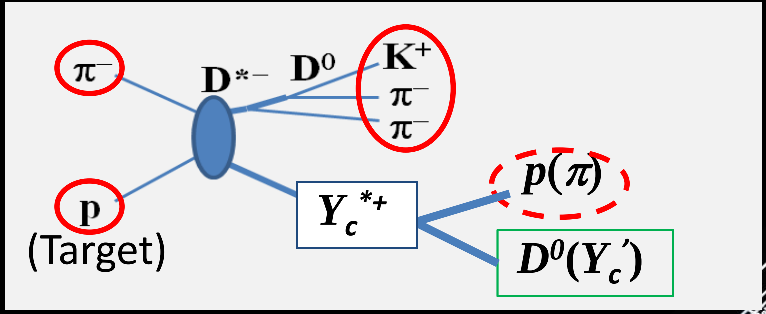
New Platform of Hadron Physics at J-PARC

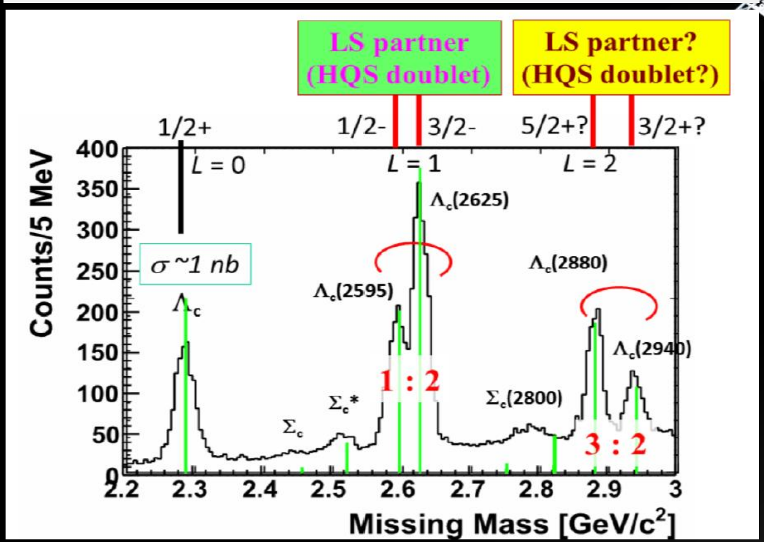


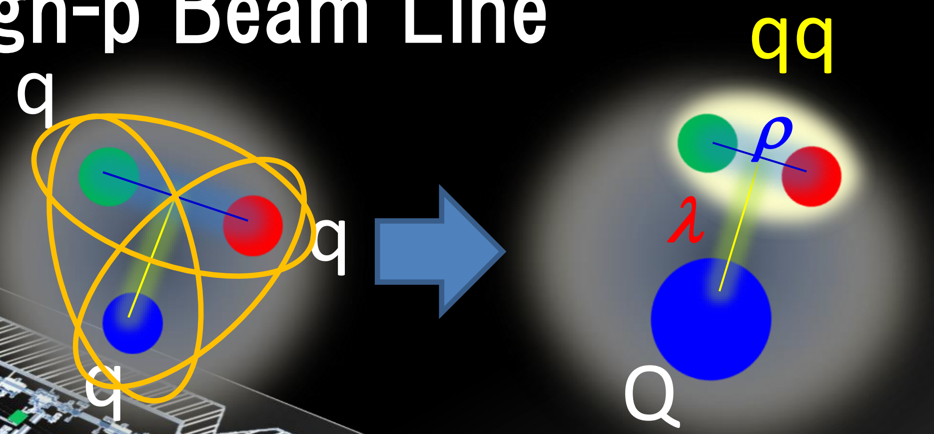
J-PARC Facility
(KEK/JAEA)
South to North
Linac
Bird's eye photo in January of 2016
3 GeV
Synchrotron
Neutrino Beams
(to Kamioka)
Materials and Life
Experimental Facility
Experimental
Areas
Main Ring
Hadron Exp.
Facility
JFY2007 Beams
JFY2008 Beams
JFY2009 Beams

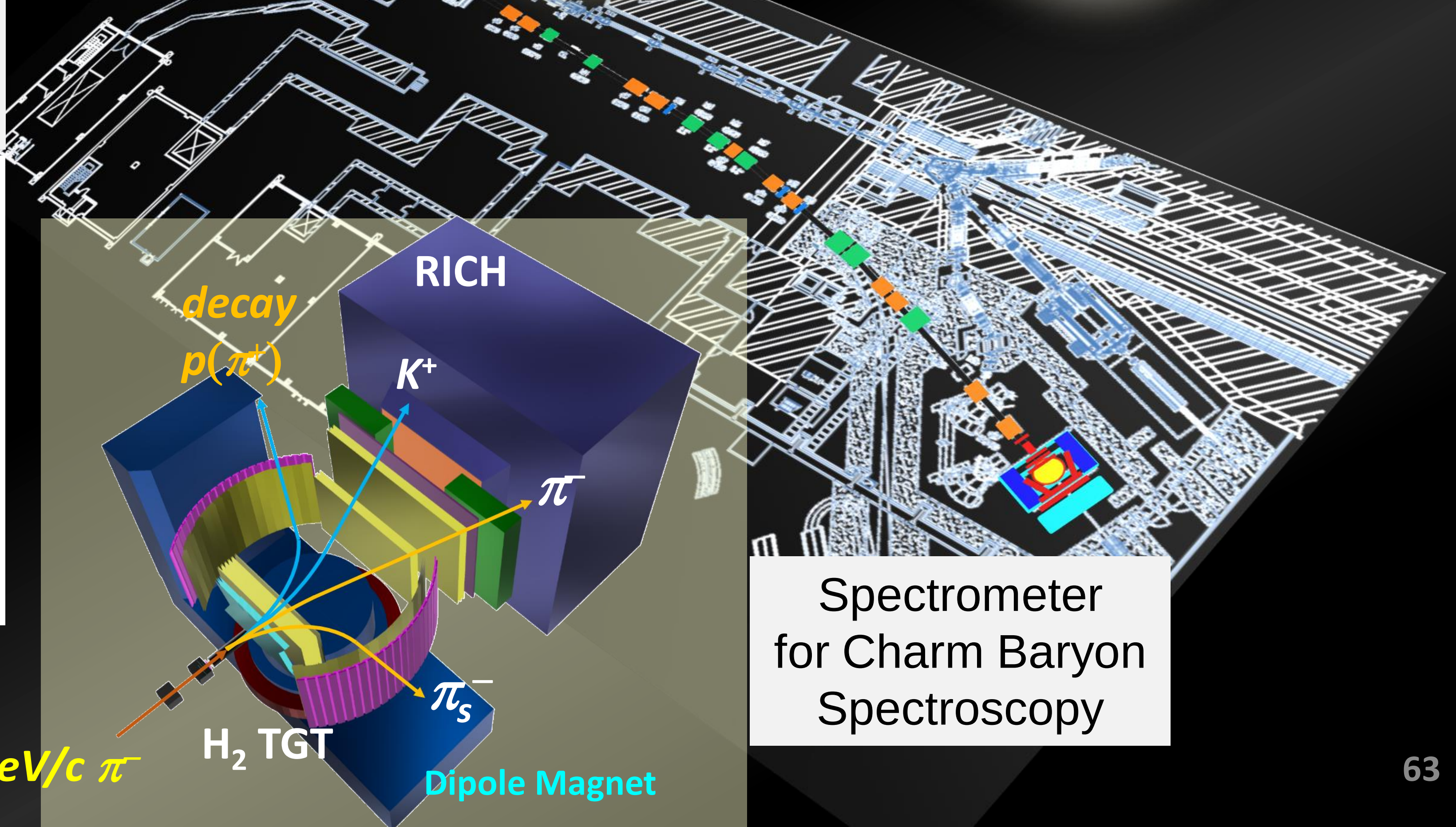
Hadron Physics at the High-p Beam Line

- π20 beam line :
  - 1.0 x 10^7 pions/sec @ 20GeV/c
  - Δp/p~0.1%





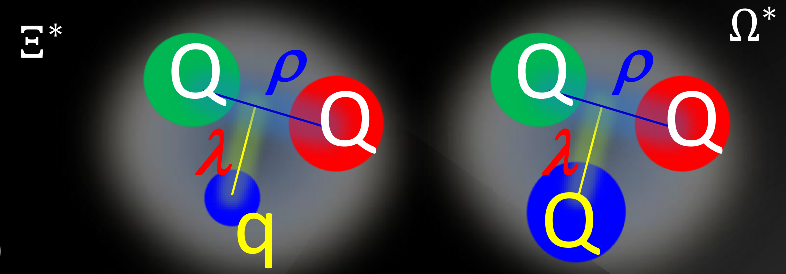


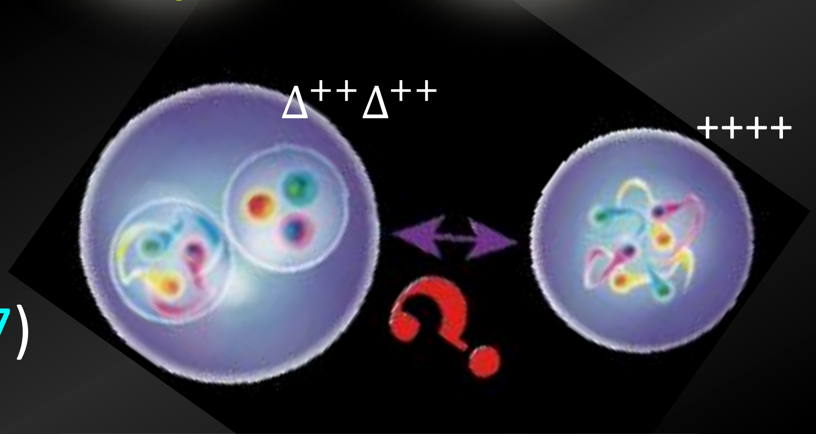


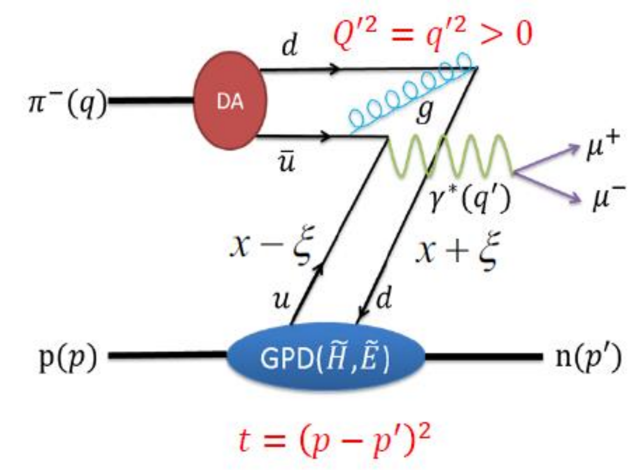
Spectrometer
for Charm Baryon
Spectroscopy

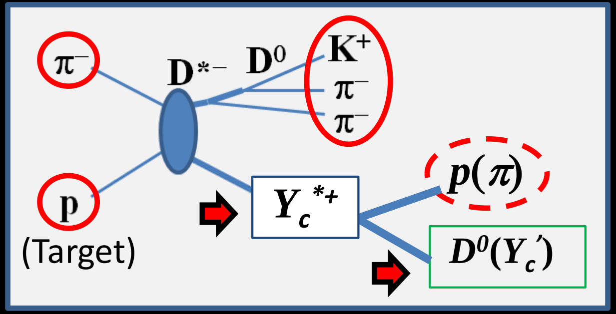
Hadron Physics at High-p BL

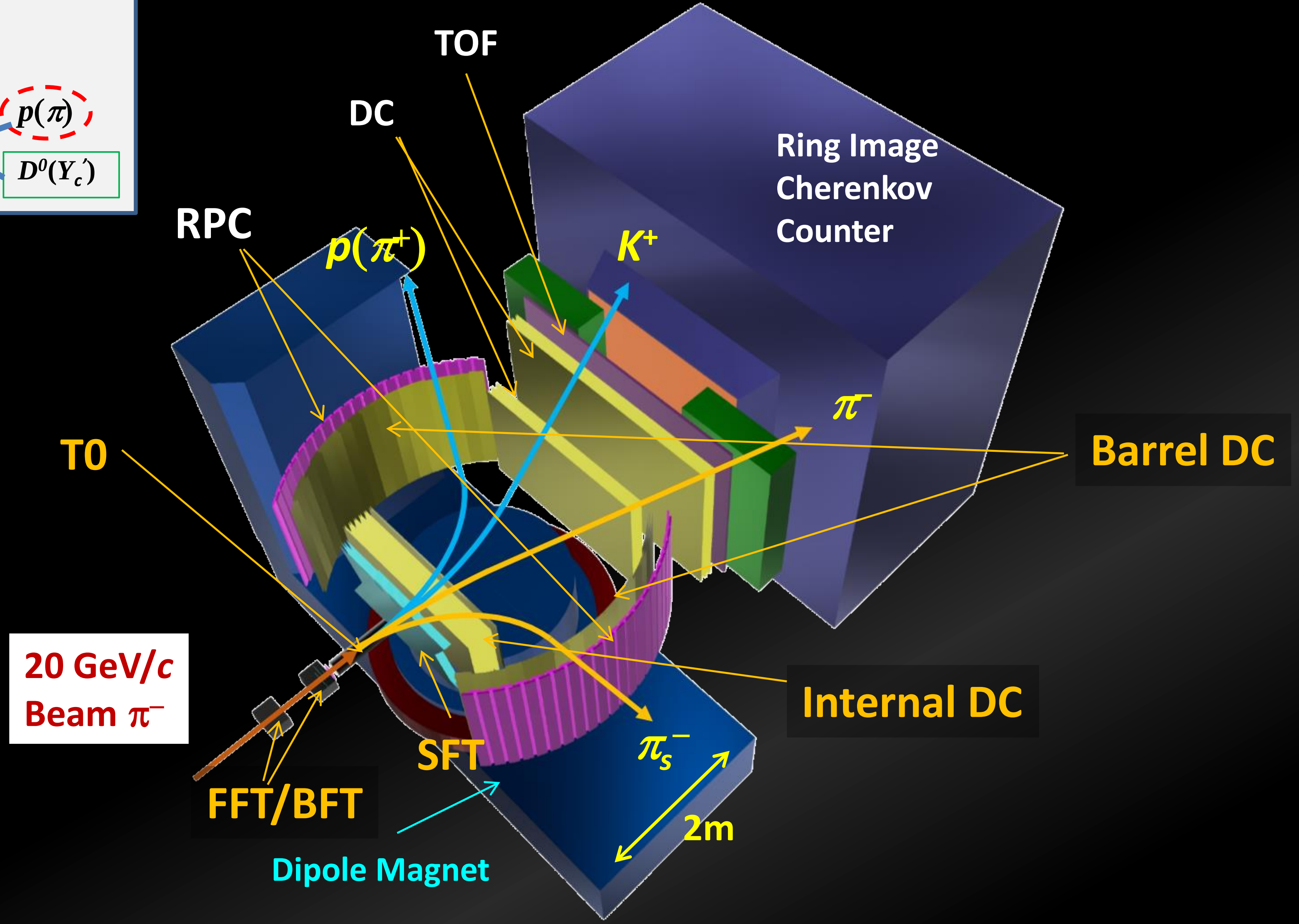
- Baryon Spectroscopy
  - p(π^-,D^{*-})Y$_c$* (E50)
  - p(K$^-$,K*)Ξ*, p(K$^-$,K$^+$K*)Ω* (LoI:KEK/J-PARC-PAC 2014-4)
  - Search for D_{30} Dibaryon State in $pp \to \pi^-\pi^- D_{30}$ (E79)
  - p(π^-,K*)Λ(1405) at large *s*, *t* (to be proposed)
- Hadron Tomography
  - Exclusive DY, $\pi^- p \to \mu^-\mu^+ n$ (LoI: KEK/J-PARC-PAC 2019-7)
- For Strangeness Nuclear Physics
  - Λp Scattering for the study of high-dense nuclear matter (LoI: KEK/J-PARC-PAC 2020-08)
- For Neutrino Physics
  - Hadron Production for neutrino beams









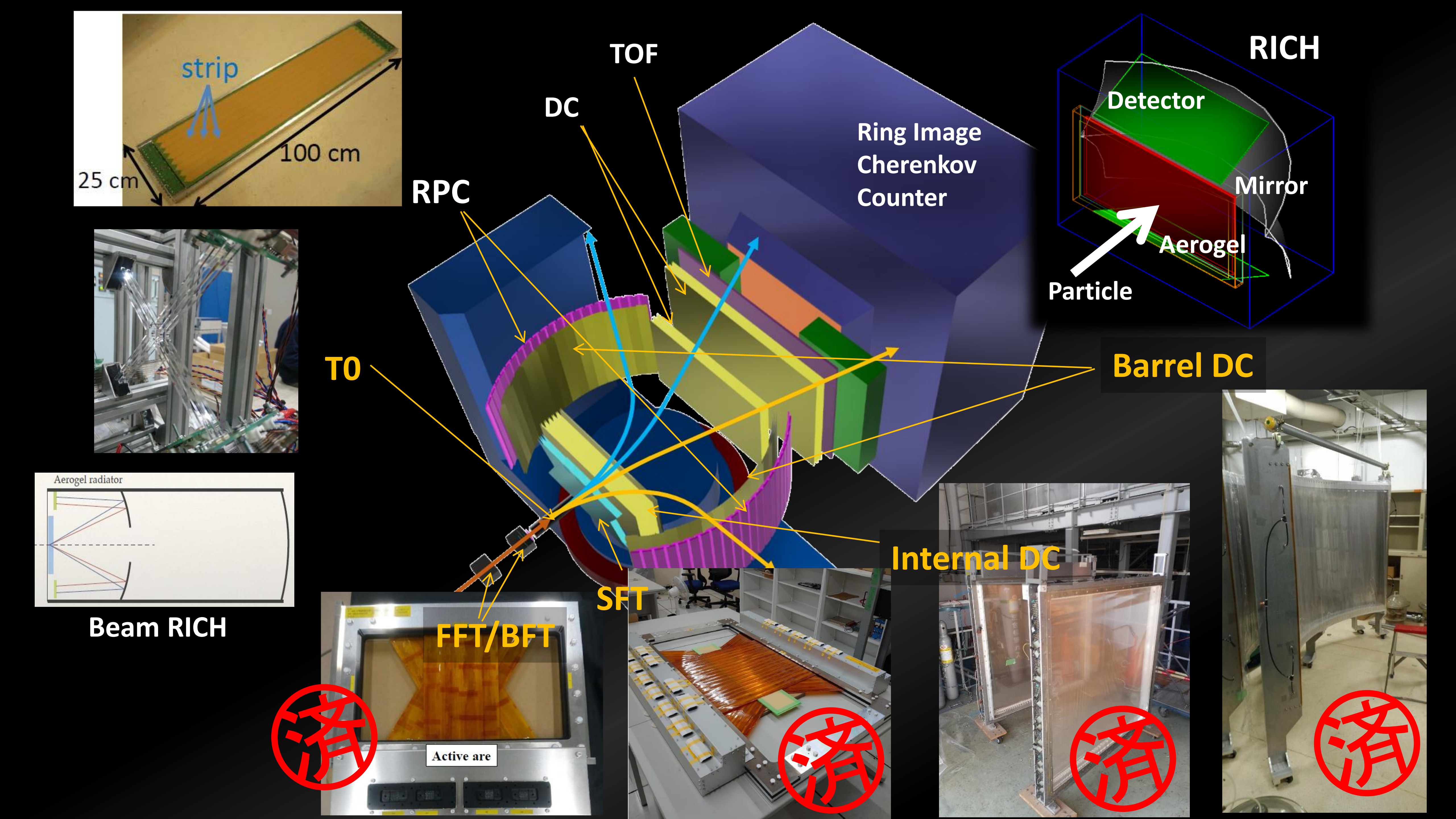


Acceptance: ~ 60% for D^*, ~ 80% for decay π^+

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

R&D Works

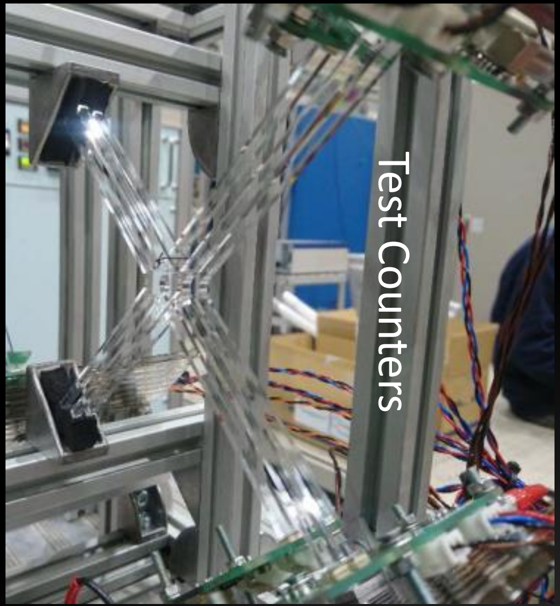
- Particle Identification (Osaka/Kyoto/Tohoku/RIKEN…)
  - Timing counters
    - T-Zero (Osaka): Cherenkov type ~50 ps
    - Resistive Plate Chamber (RCNP/ELPH/Taiwan/Kyoto/JAEA/Tsukuba): Large Size~60 ps
  - Ring Image Cherenkov Detector
    - BeamRICH/RICH (Tohoku/KEK/Osaka/Kyoto/RIKEN/…)
  - Muon ID (Academia Sinica)
- Trackers (Tohoku/RCNP/RIKEN…)
  - SciFi Tracker (Focal Plane/Beam/Scattered particle)
  - DC (Forward, Barrel)
- High-speed DAQ system (RCNP/Tohoku/Taiwan/KEK/RIKEN…)
  - PC cluster-based DAQ scheme
    - Flexible "trigger": not only (π^-,D*) but also (K^-,K*),…


strip
100 cm
25 cm
TOF
DC
RPC
Ring Image
Cherenkov
Counter
RICH
Detector
Mirror
Aerogel
Particle
Barrel DC
T0
Internal DC
SFT
FFT/BFT
Aerogel radiator
Beam RICH
Active are
済
済
済
済

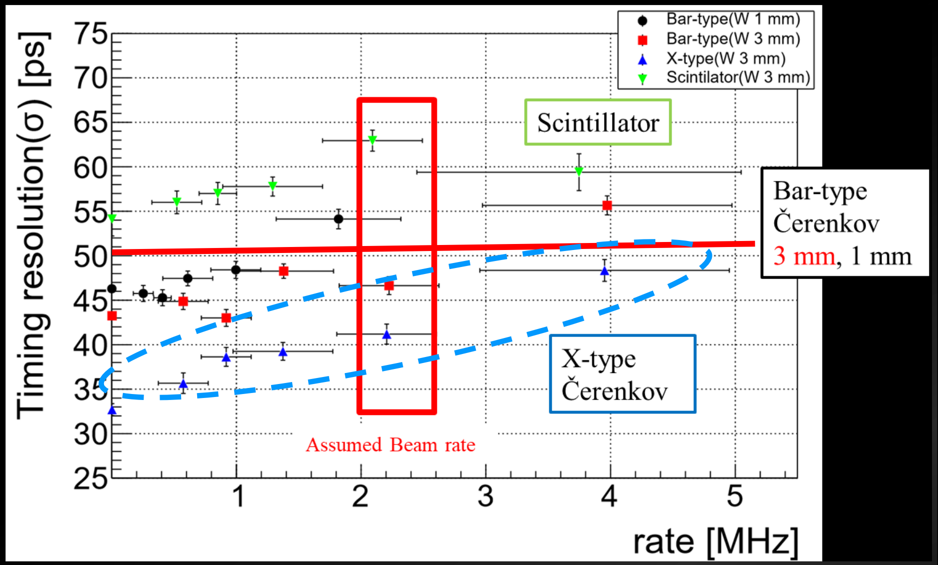
Time Zero Counter

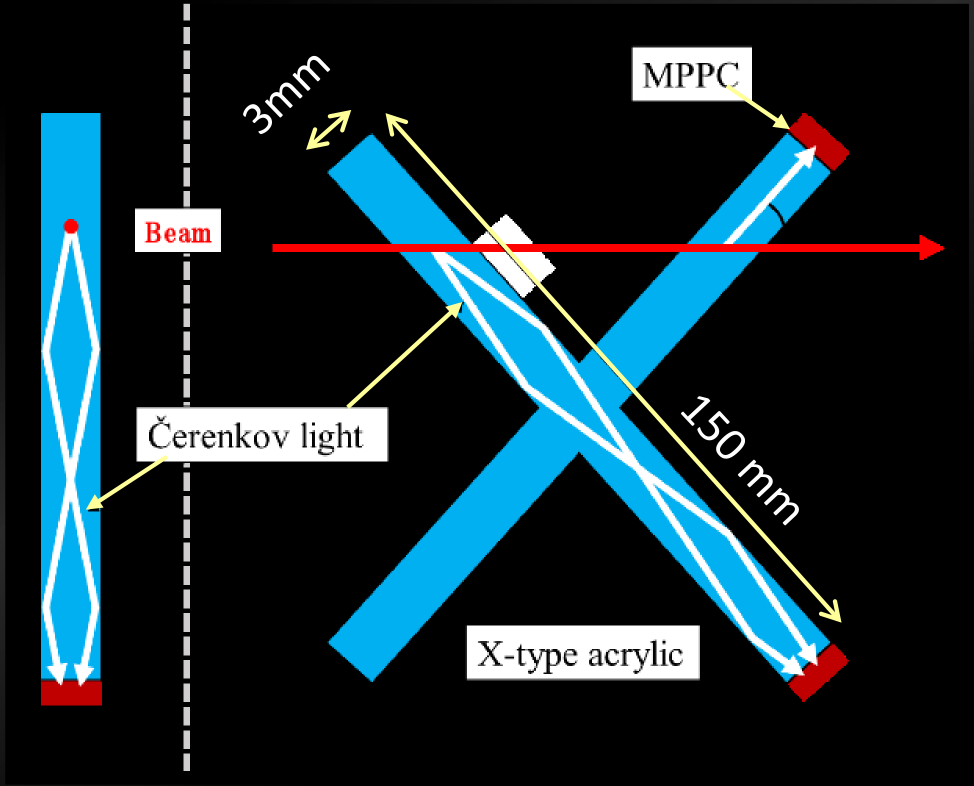
- Hodoscope w/ Cherenkov Radiator for a Beam Rate: 60 M/spill (30 MHz)
  - X-shape to cancel position dependence by taking mean time
  - σ<50 ps at 3-5 MHz

By T. Akaishi, K. Shirotori et al.



Measured Performance for MIPs



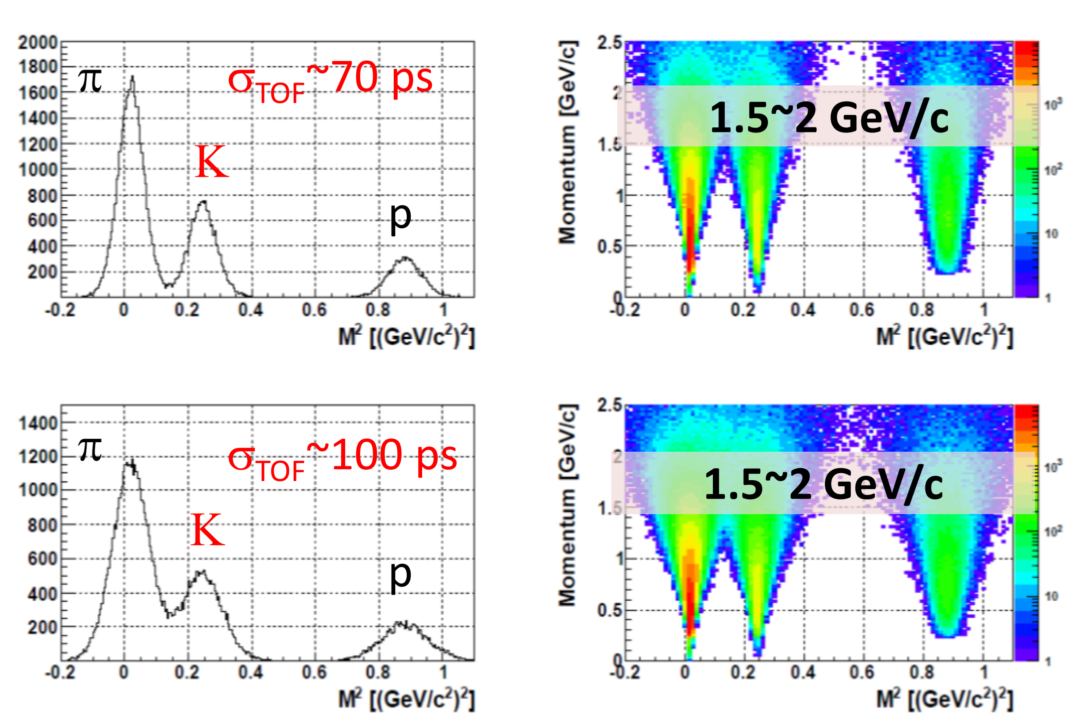


Resistive Plate Chamber

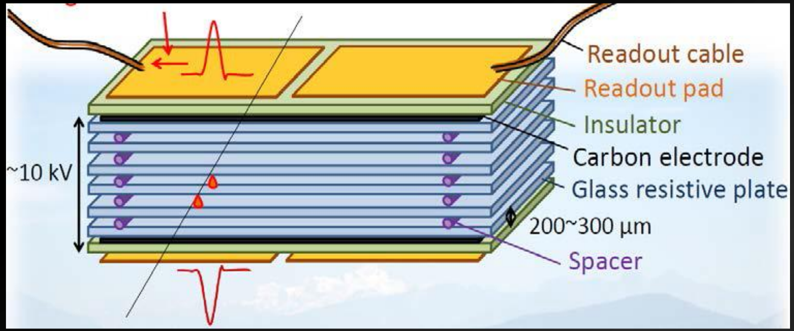
- TOF meas. for Scattered Particles
  - Developed in LEPS
  - σ~60 ps

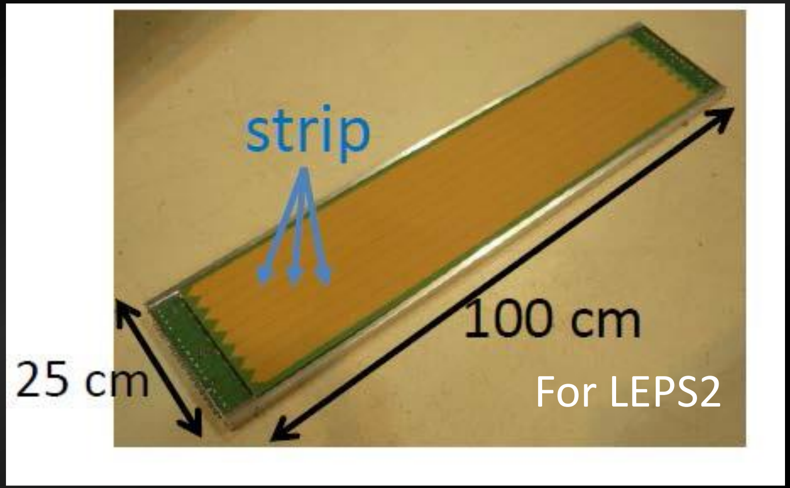
By N. Tomida, H. Ohnishi et al.

Simulation



Expected PID performance w/ TOF vs Mom.

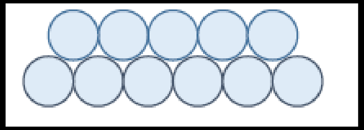


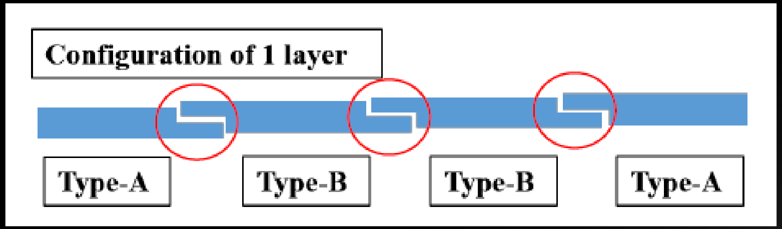


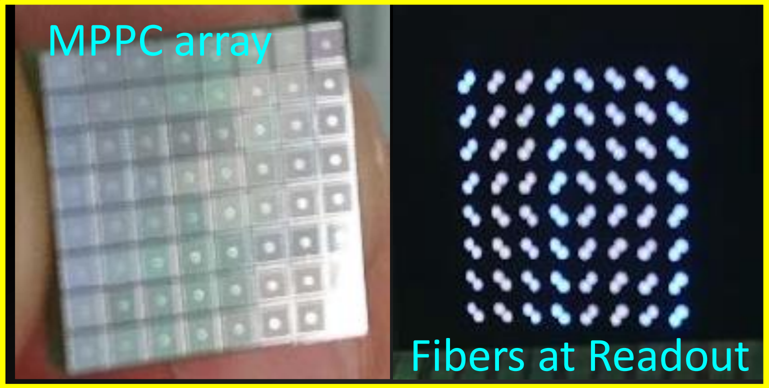
Fiber Tracker

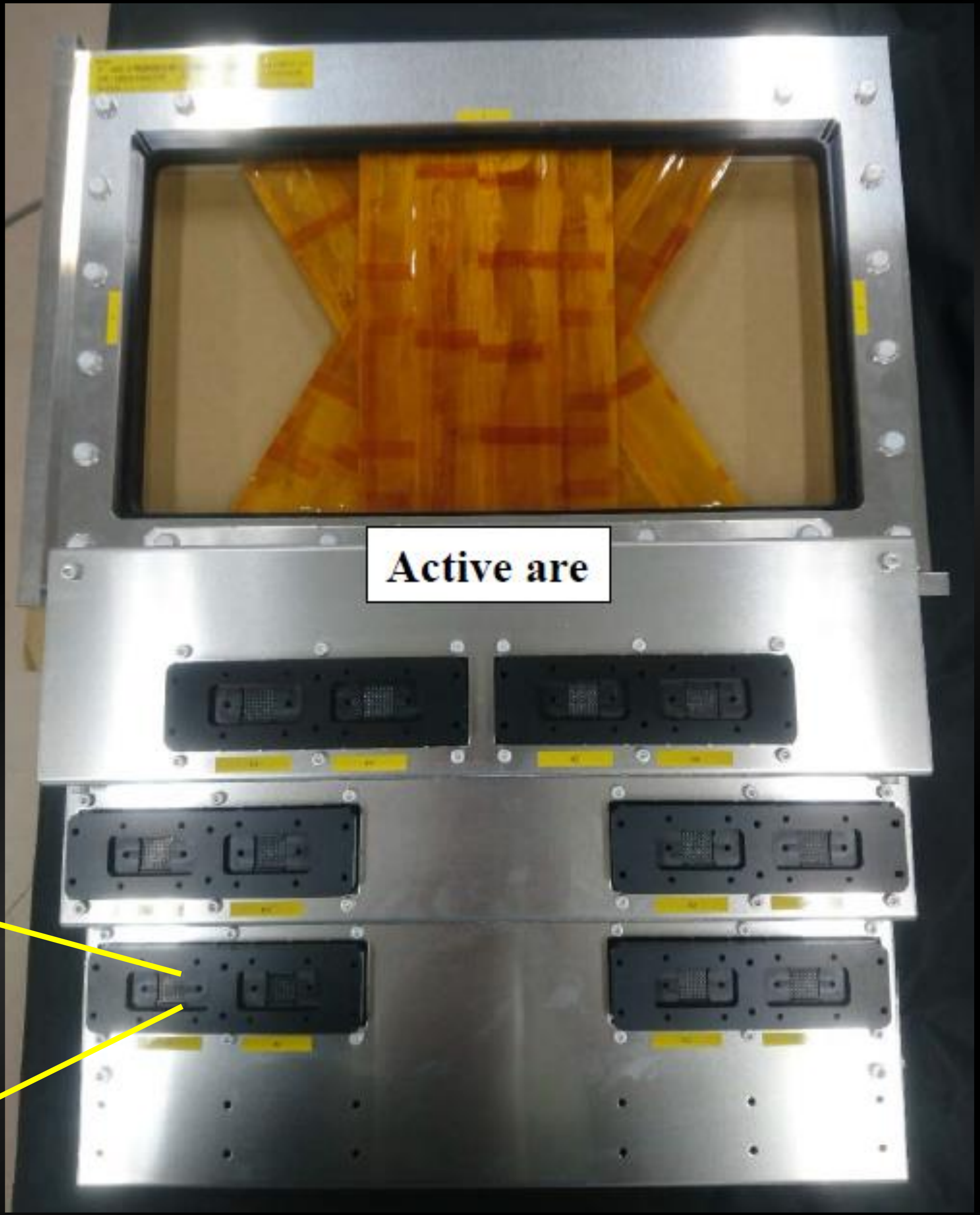
By K. Shirotori et al.

- Faster Responding Trackers are needed for a Beam Rate: 60 M/spill (30 MHz)
  - Focal plane: XUV 1 set w/ ϕ1mm fiber
  - Beam Trackers: XUV 2 sets w/ ϕ0.5mm fiber
  - Scattered Particle Trackers : in Fabrication









Drift Chamber

- Barrel DC (Side DC) for backward-emitted, low mom. particles
  - Two arms are ready and waiting for FEEs.
- Front/Forward DC for Forward-emitted particles
  - To be prepared
  - still missing pieces for better redundancy

High-speed DAQ system

Streaming DAQ(~50 GB/spill)

Frontend modules
* Signal digitalization
  – Pipelined system

Buffer PCs
* Data accumulation
  – Several 10 GB memories

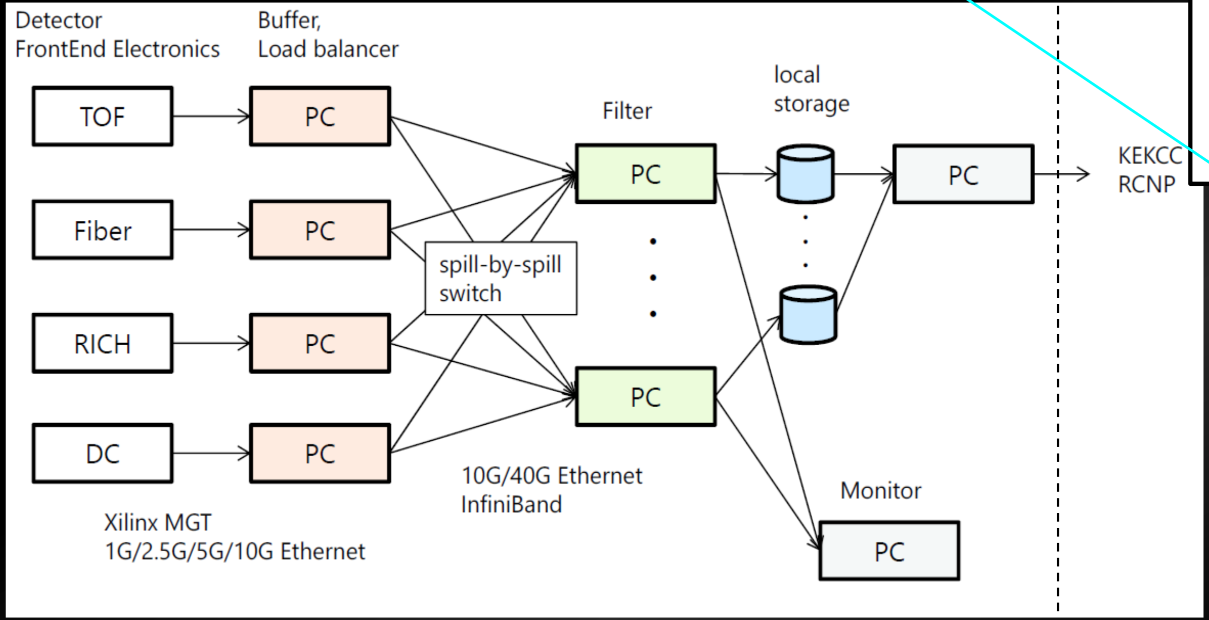
~50 GB/spill

* High-speed data link (Local)

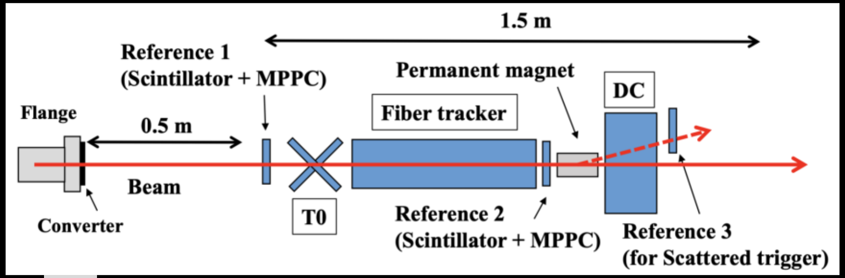
Filter PCs
* Event reconstruction
  – 100–200 CPUs

<0.5 GB/spill

Storage
– Local storage
– Transferred to KEKCC/RCNP

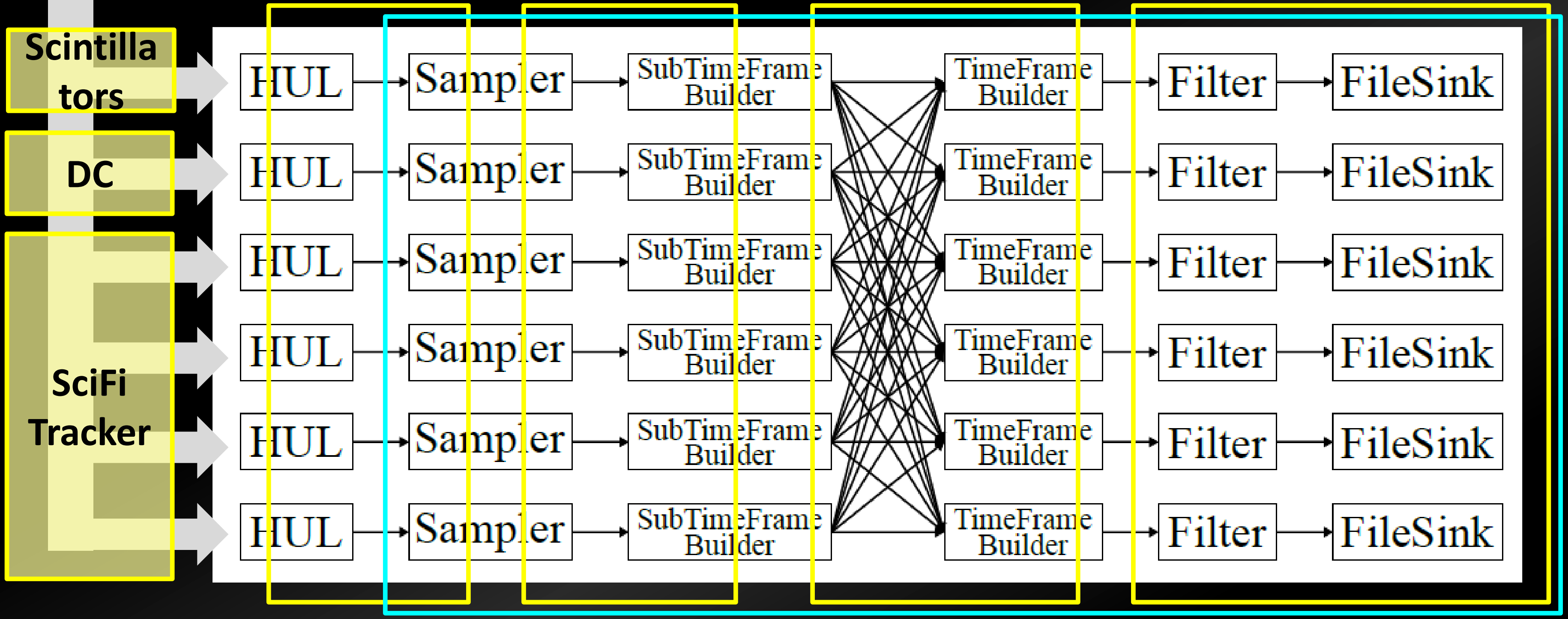


Demonstration of High-speed DAQ



under the Highest Throughput (SiTCP: GbE)

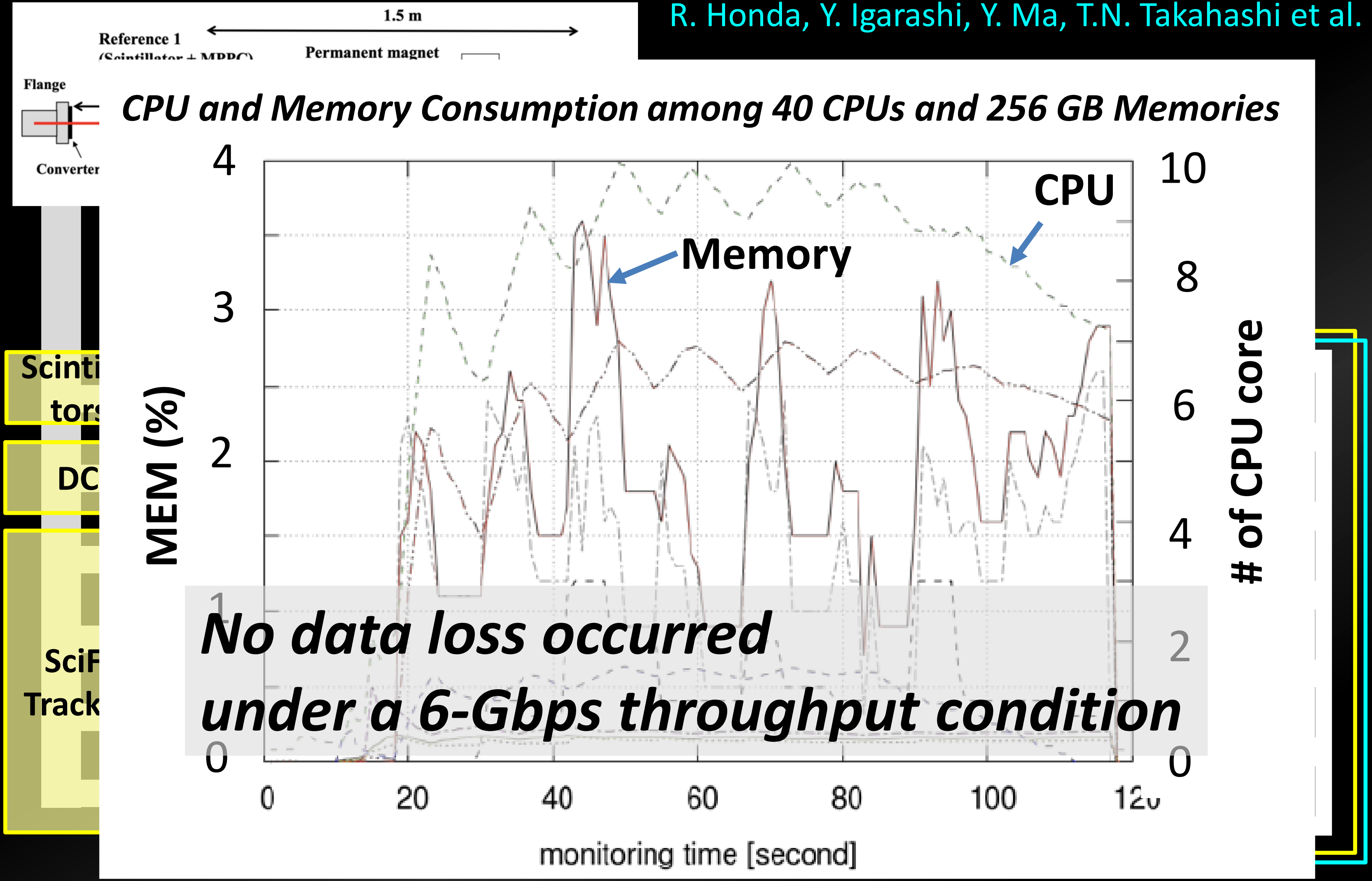
R. Honda, Y. Igarashi, Y. Ma, T.N. Takahashi et al. (paper in preparation)



40 CPUs and 256 GB Memories

Demonstration of High-speed DAQ

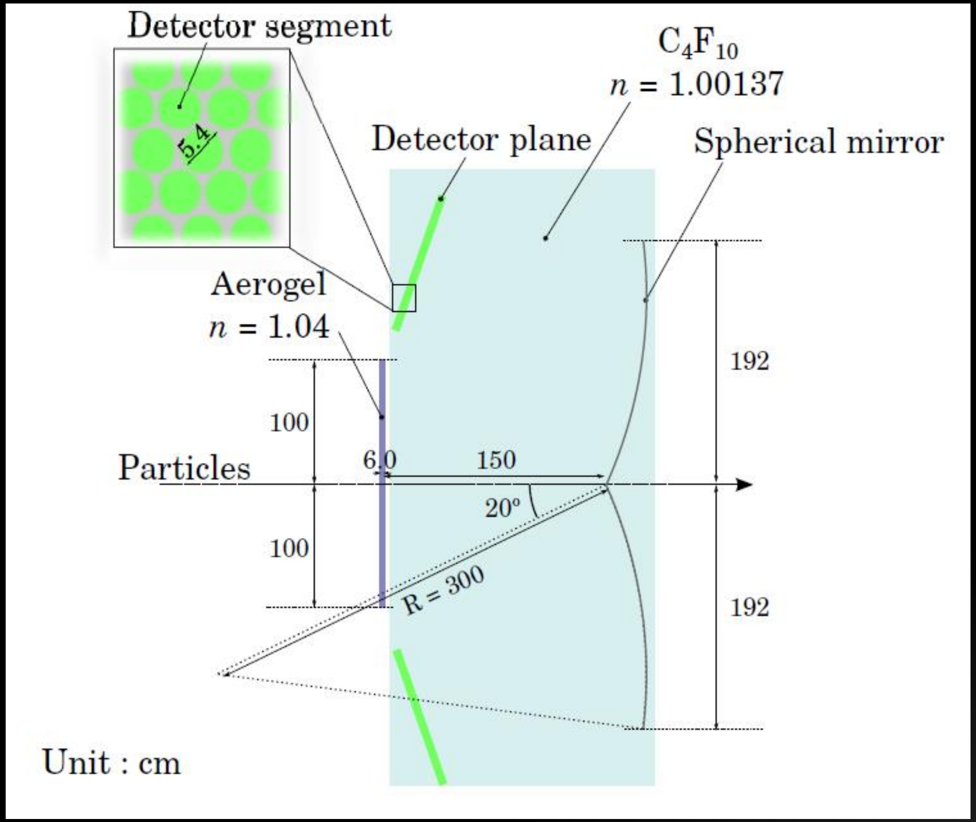
R. Honda, Y. Igarashi, Y. Ma, T.N. Takahashi et al.

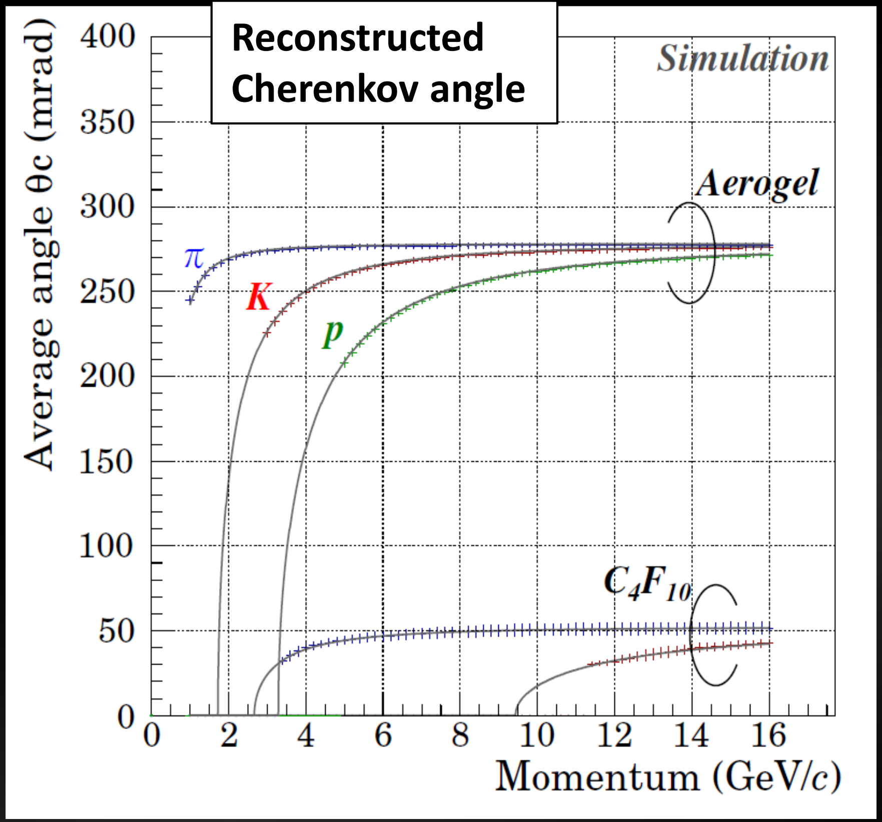


40 CPUs and 256 GB Memories

Ring Image CHerenkov detector

By T. Yamaga





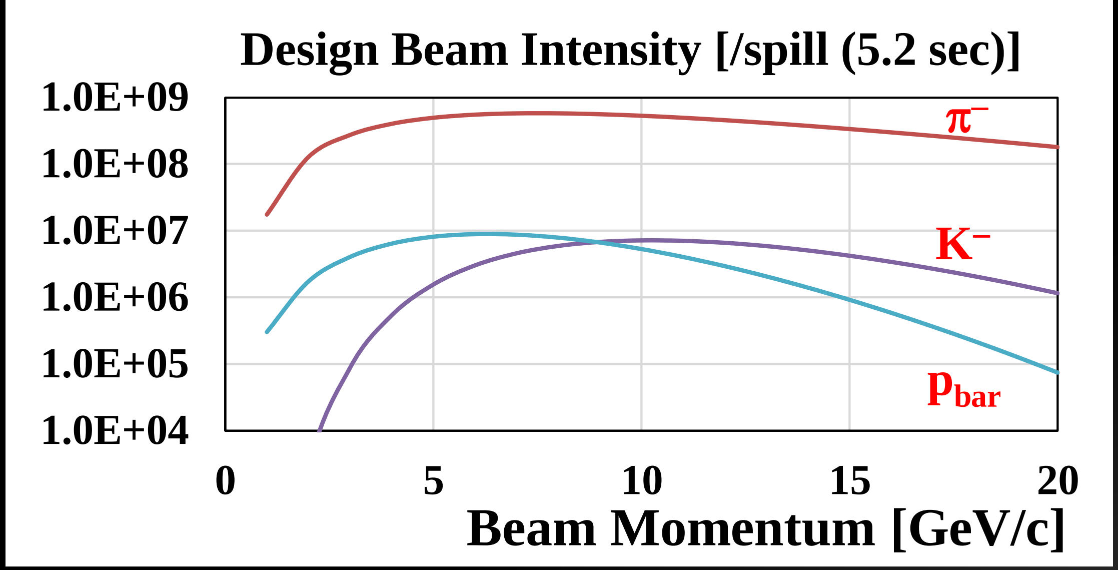
- High-momentum PID
  - Mom. range: 2-16 GeV/c

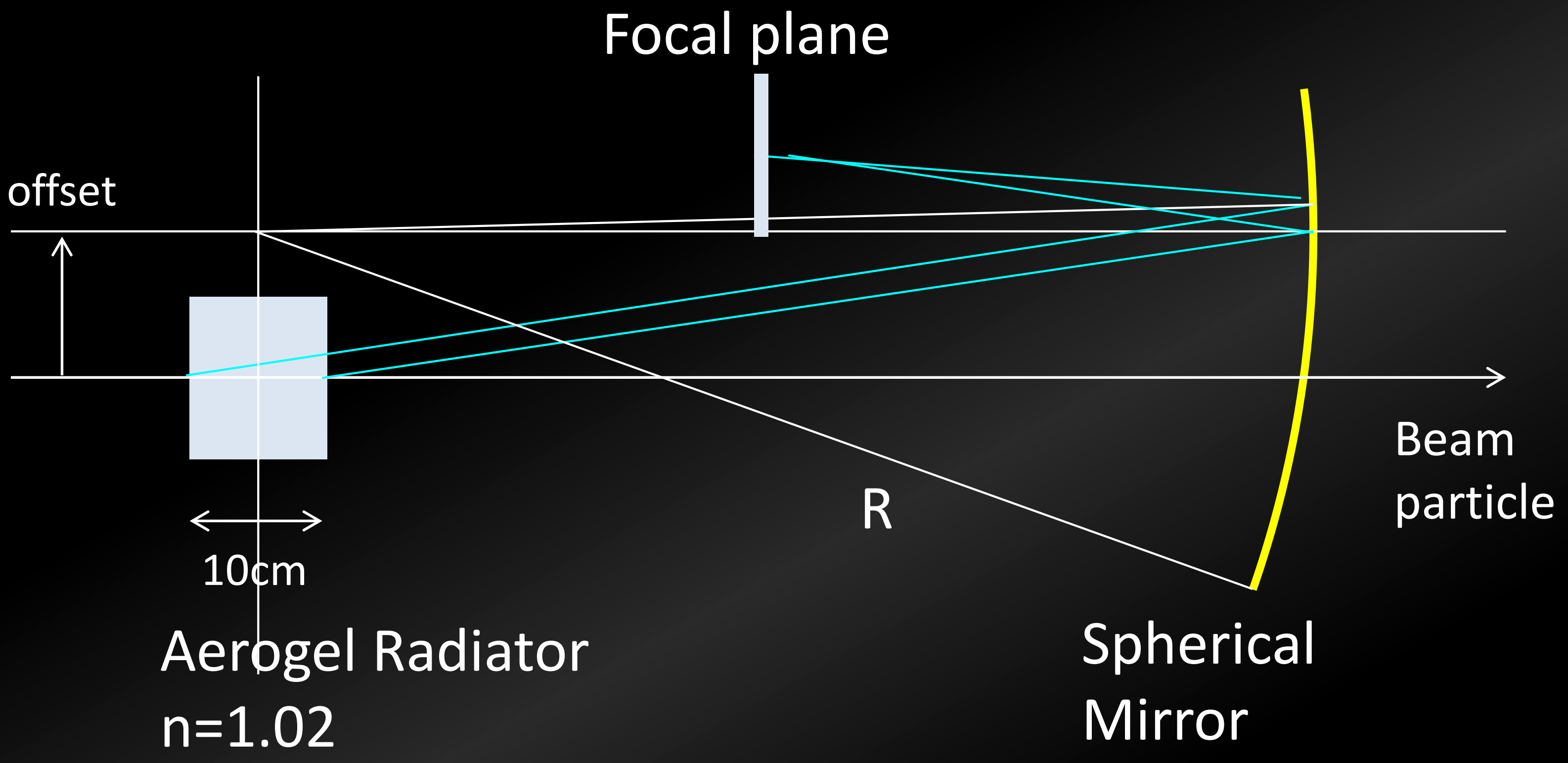
⇒ Hybrid RICH
  - Aerogel + C_4F_{10} gas
  - MPPC detector plane
  - Spherical mirror

- Design Performances
  - Efficiency: ~99%
  - Wrong PID: 0.10~0.14%

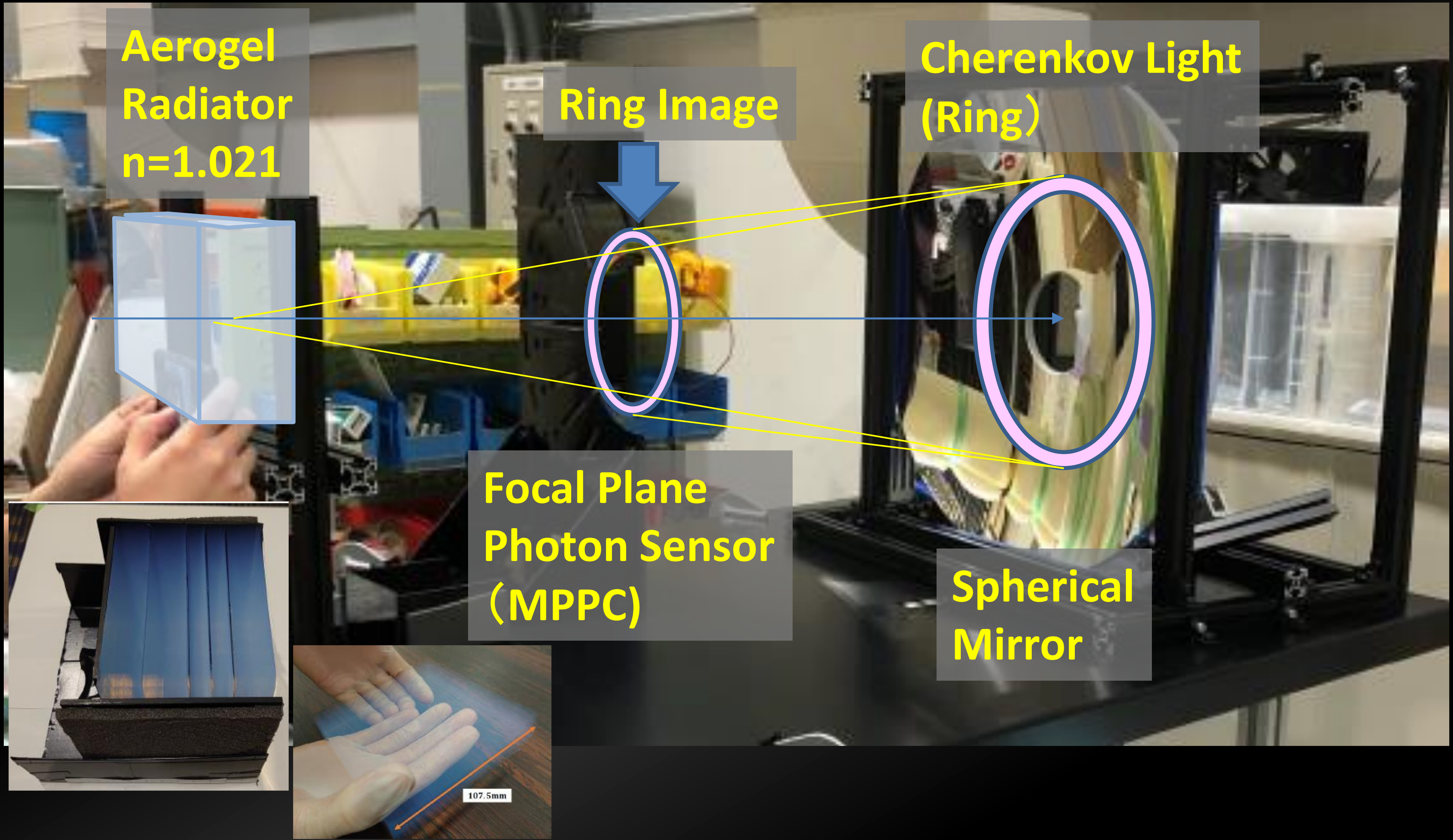
⇒ Background level × 1.05

S. Kajikawa
Master Thesis
2021 Tohoku Univ.



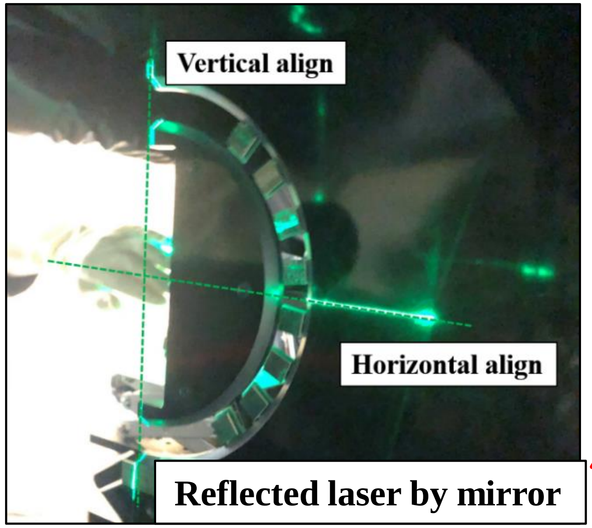


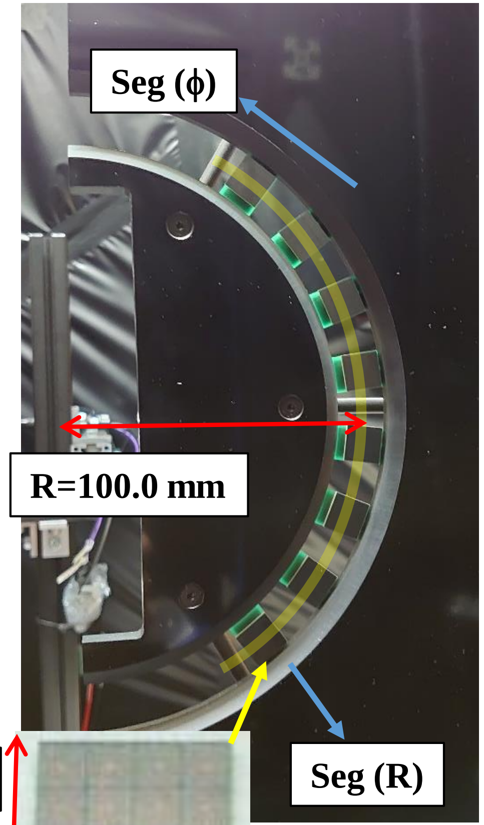
Beam RICH: test w/ electron@LEPS

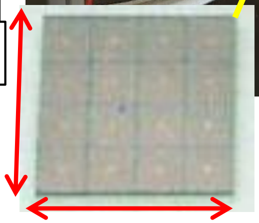


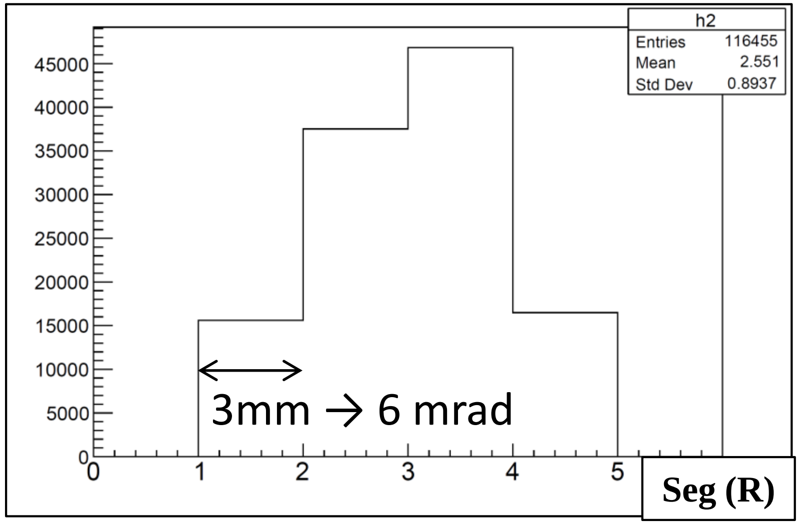
Hit pattern on detector plane

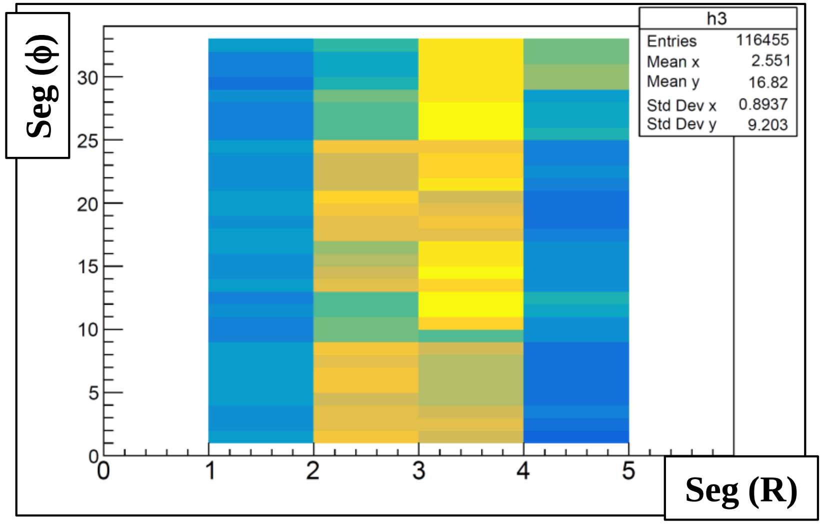
- **MPPC segment configuration (3-mm 4×4 array, 8 sets)**
  - **Seg(R): 1–4 seg**
  - **Seg(ϕ): 1–32 seg (half a full space)**
- **Clear hit pattern**
  - **Alignment: OK**









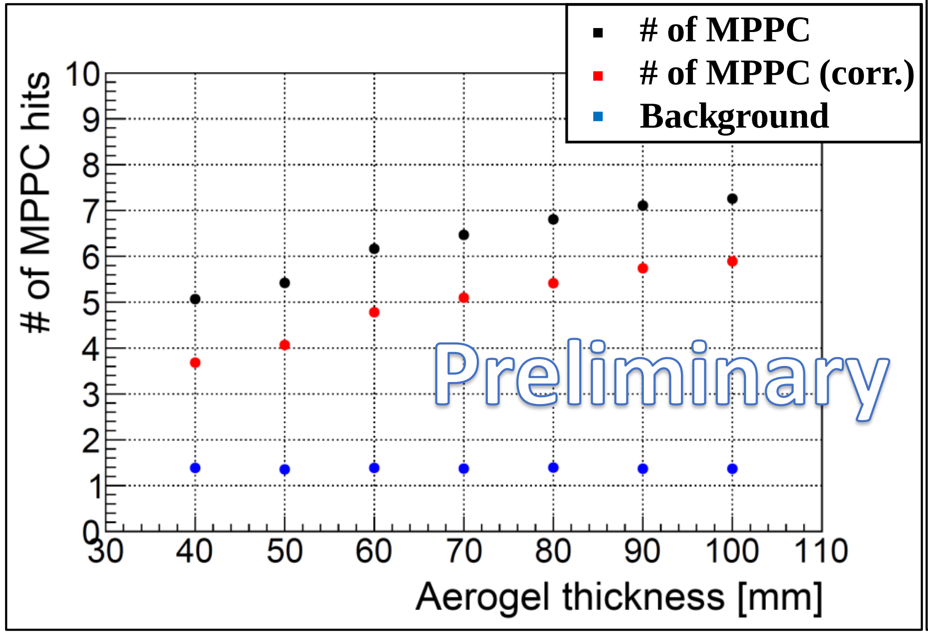


MPPC S13361-3050: 3-mm 4x4 array

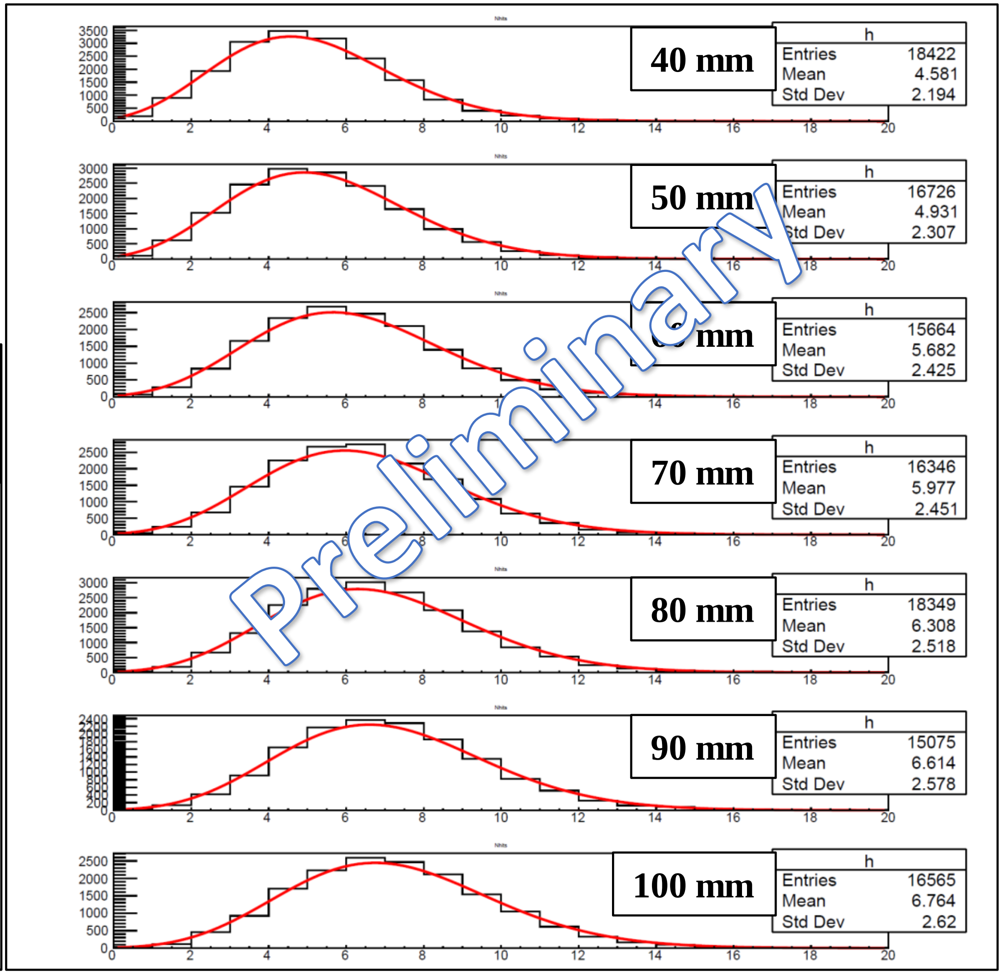
Number of MPPC hits (# of photons) : Aerogel thickness dependence

※1 p.e. Vth operation of MPPC has been confirmed.

- 1 MPPC hit = 1 p.e.
- Poisson fitting
- V_{ov} = 54.0 V (+3.0V)
- Background: Side band of TOF
  - 30 ns rough time gate



Estimation: ~5 p.e. (100 mm)



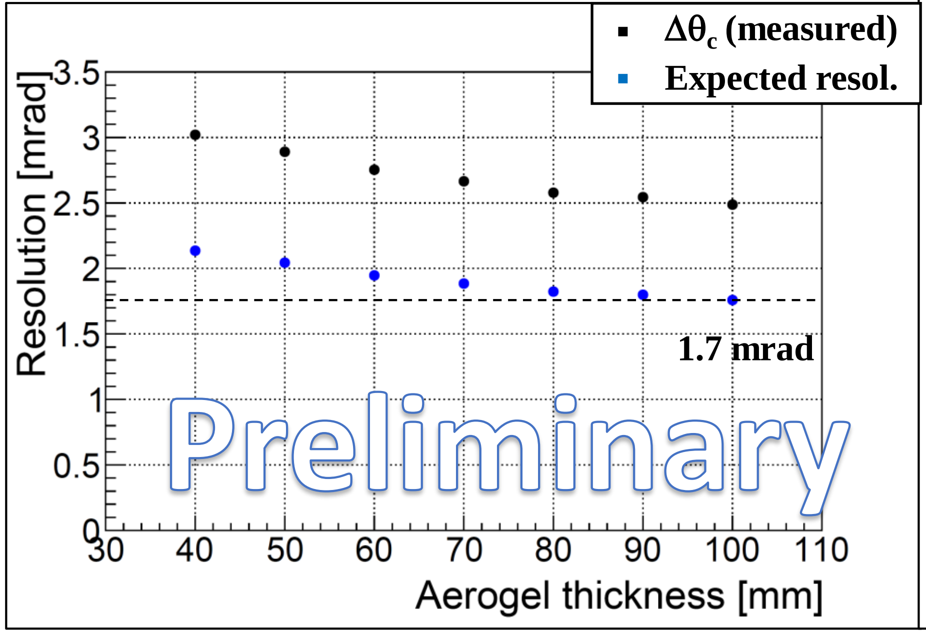
Cherenkov angle resolution: Aerogel thickness dependence

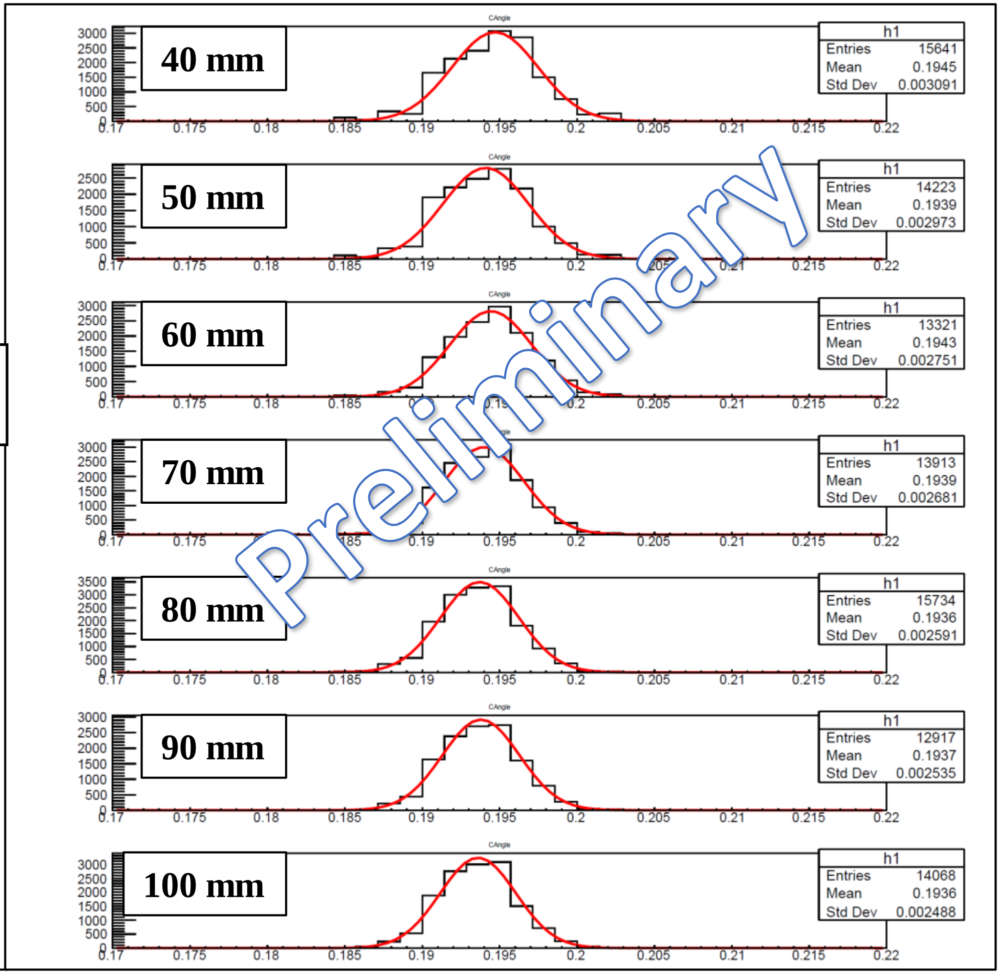
- V_{ov} = 54.0 V (+3V)
- Gaussian fitting resolution:
- **Expected performance achieved: σ_{θ_C} ~ 2.5 mrad**

  ⇒ # of MPPCs can be double

  2.5/√2 ~ 1.7 mrad

※Aerogel is sufficiently transparent up to 100 mm.





Summary

- A heavy quark plays an inert particle in a hadron and is quite helpful to investigate internal motions and/or correlations of quarks.
  - Excitation Energy, Production Rate, and Decay Branching Ratio
- We conduct charmed baryon spectroscopy by means of missing mass technique at the J-PARC high-momentum beam line, where the intense pion beams up to 20 GeV/c will be delivered.
  - New platform of hadron physics will be covered owing to the general purpose spectrometer