Strange and Charm Hadron Physics at J-PARC in Future

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1. High-p BL and CHARM Spectrometer
2. Hadron Spectroscopy w/ heavy flavors
3. Summary

High-res., High-momentum Beam Line

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

30 GeV proton beam

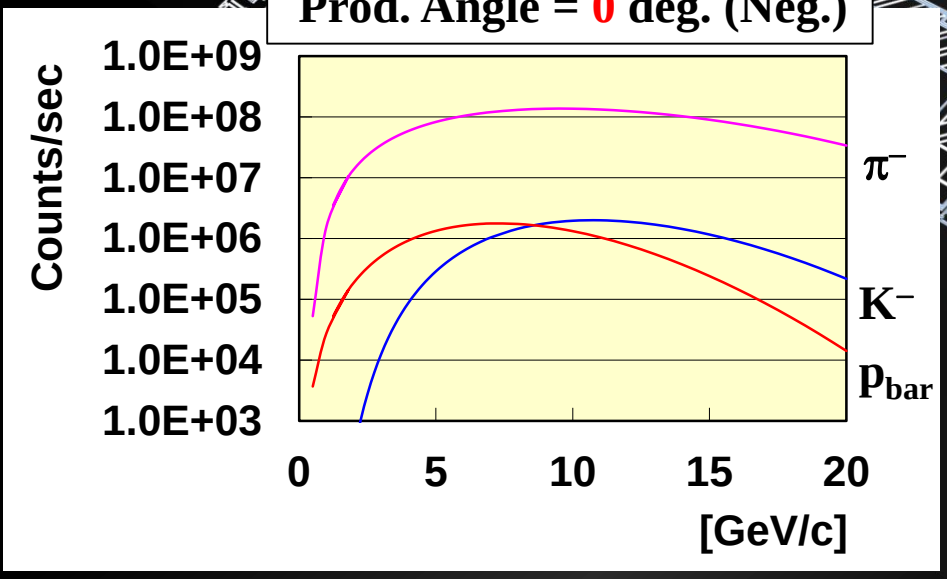
Production Target

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

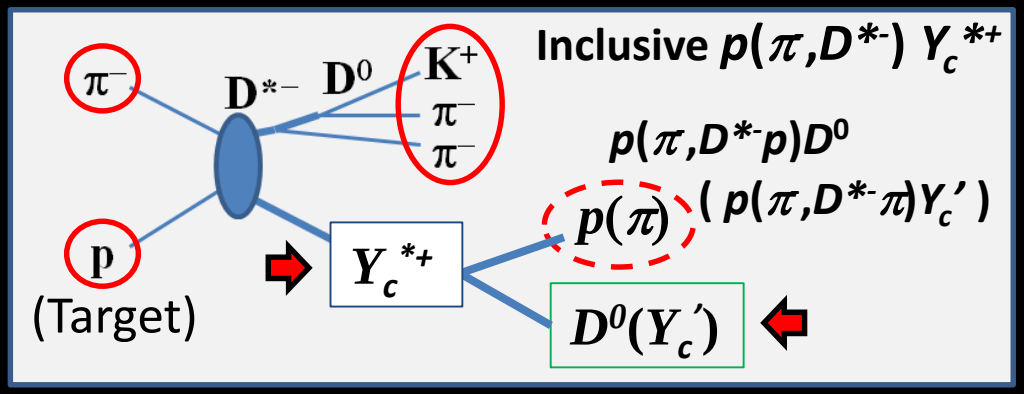
T1

Pion Beam
Up to 20 GeV/c

Spectrometer



CHARM Spectrometer Design



Cross Section:

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

Acceptance:

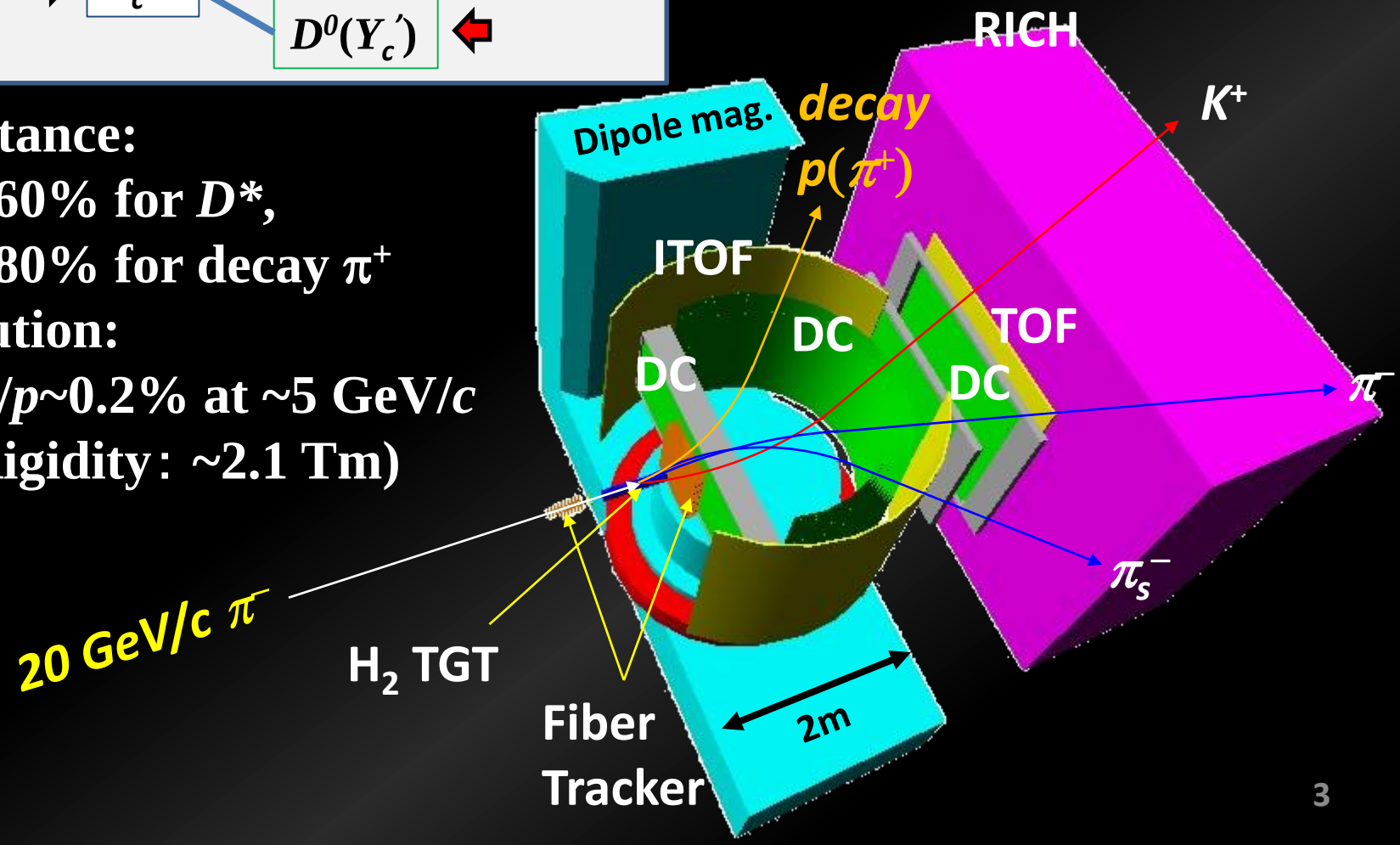
~ 60% for D^*,

~ 80% for decay π^+

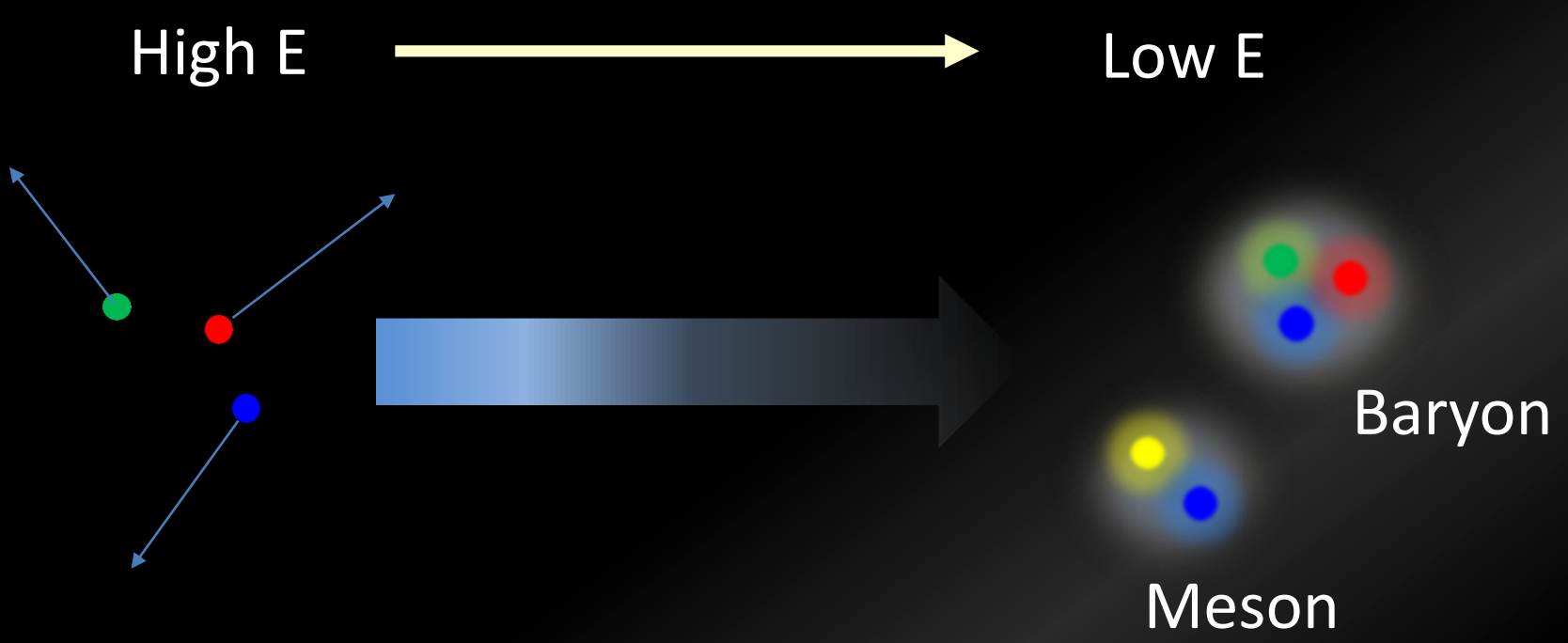
Resolution:

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

(Rigidity: ~2.1 Tm)

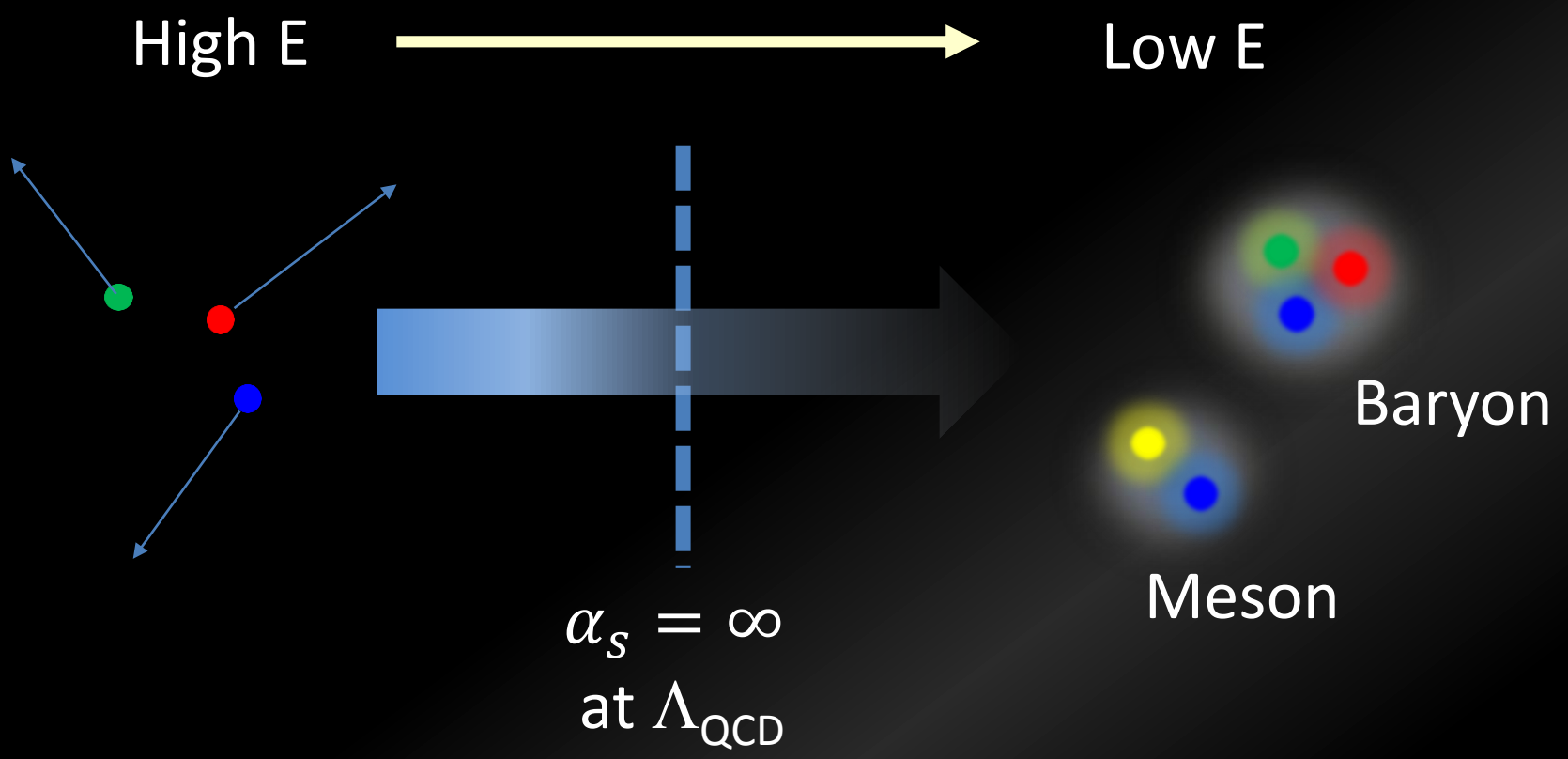


How Hadrons are formed?



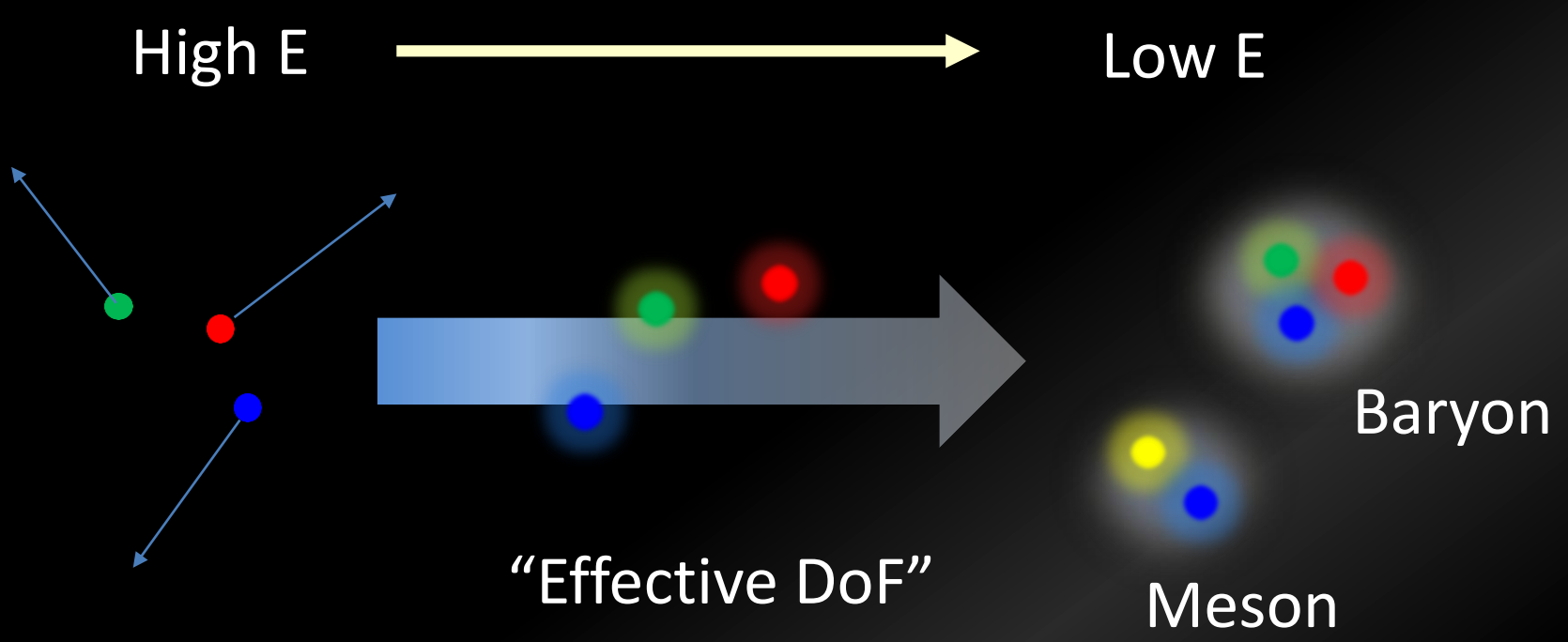
It seems still unclear to answer a question how hadrons form current quarks.

How Hadrons are formed?



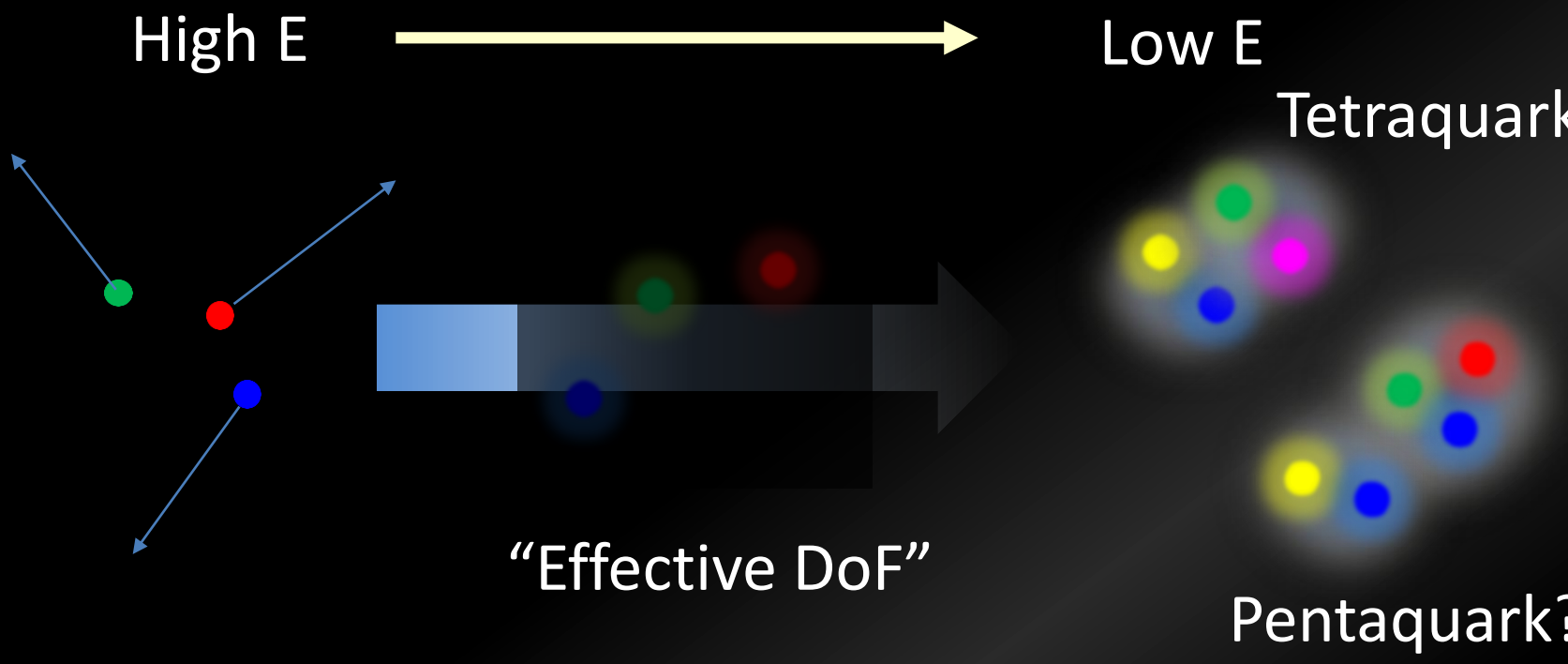
Quarks drastically change themselves below Λ_{QCD}.

How Hadrons are formed?



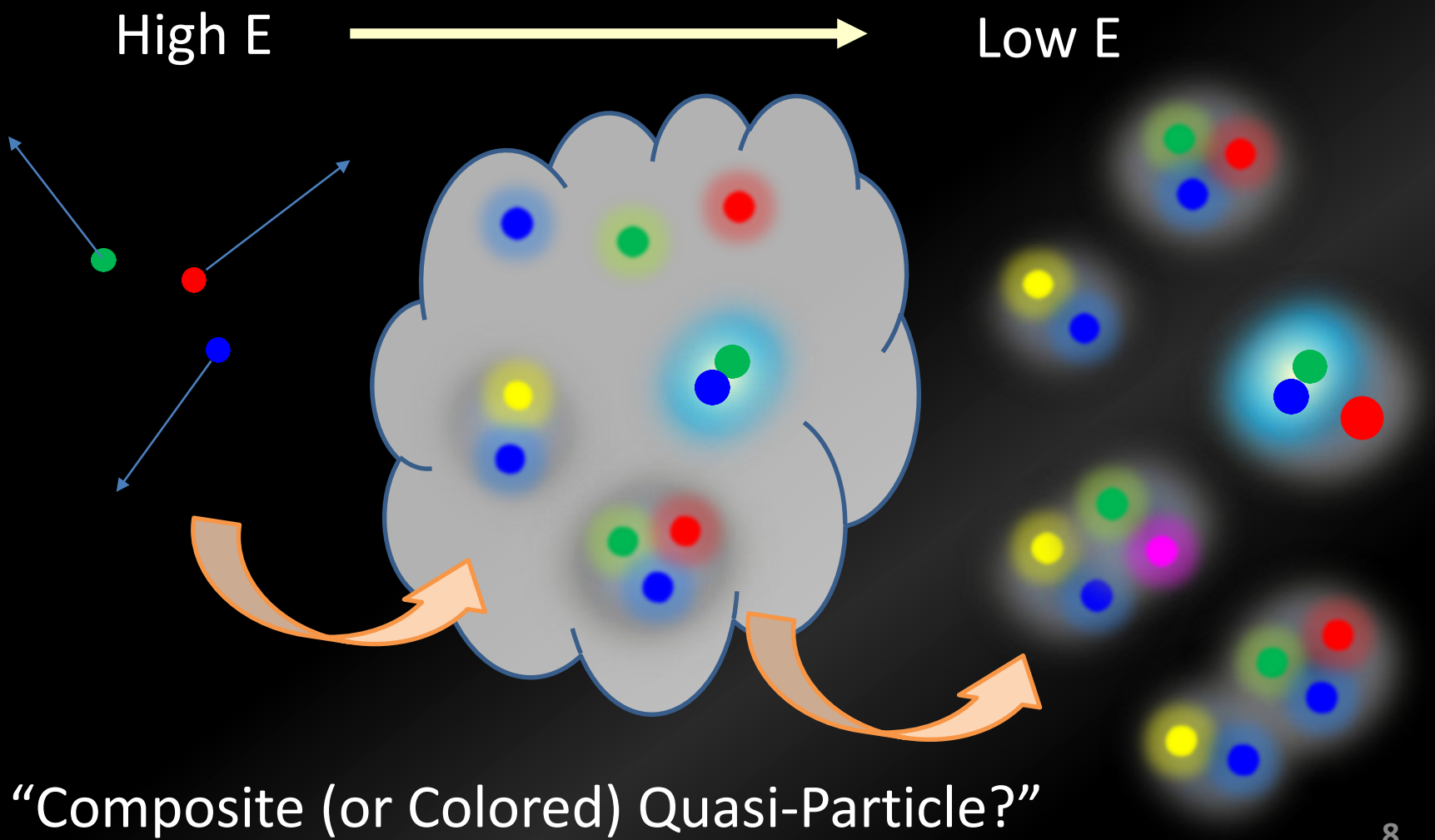
"Constituent Quarks" seem to work rather well
as good building blocks of hadrons…

How Hadrons are formed?



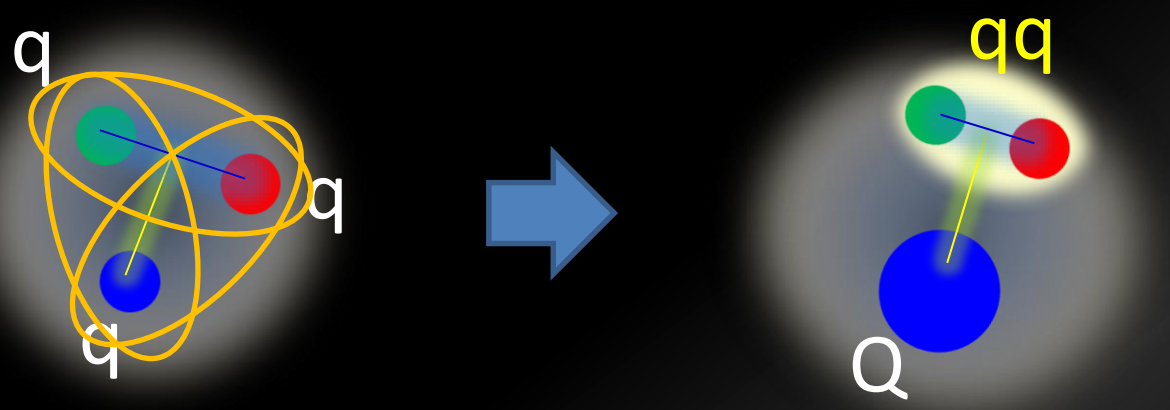
"Exotic hadrons" require a new aspect
in describing hadrons beyond the "standard picture".

How Hadrons are formed?



"Composite (or Colored) Quasi-Particle?"

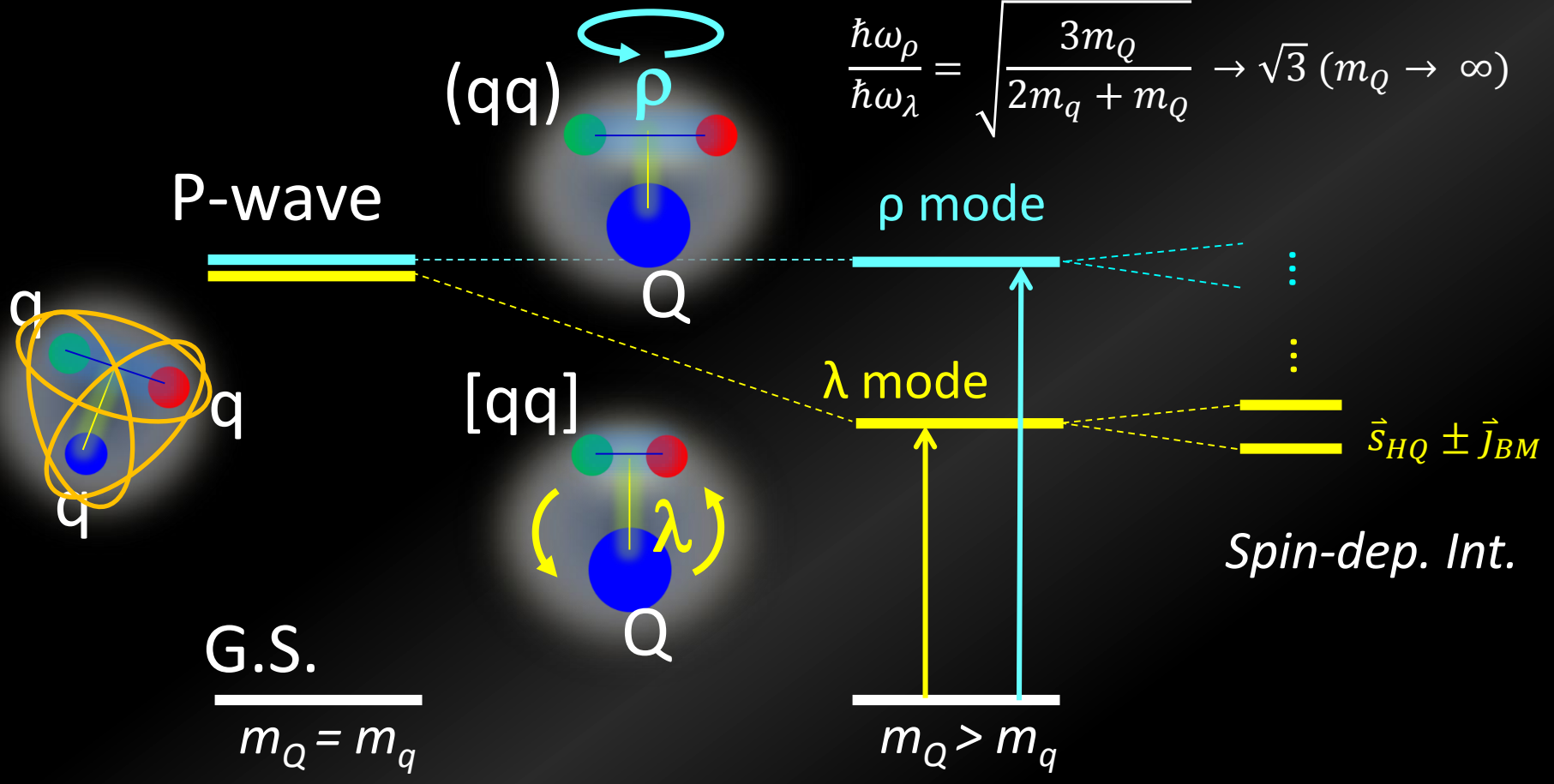
What we can learn from baryons with heavy flavors



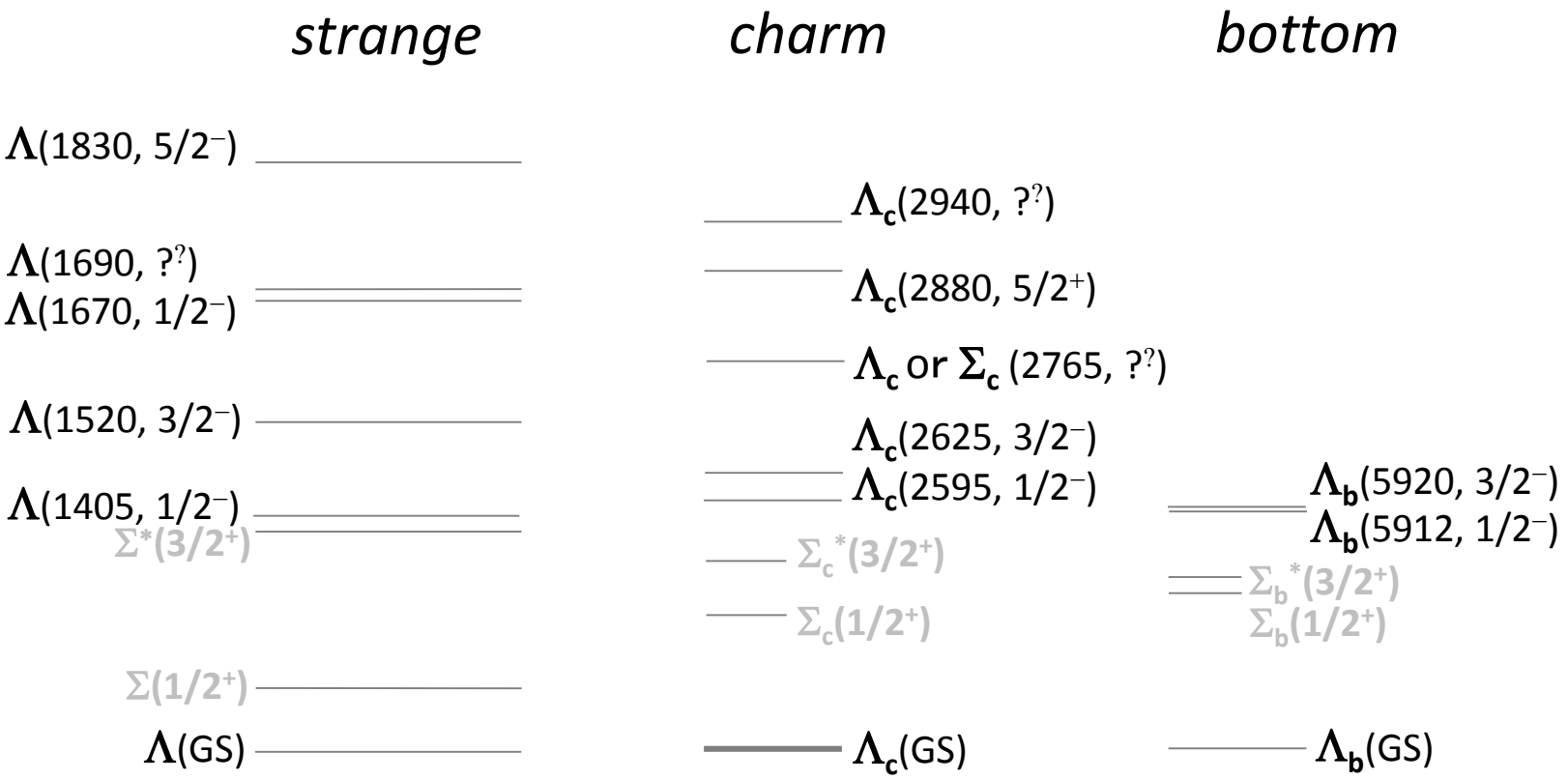
- Quark motion of “qq” is singled out by a heavy Q
  - Diquark correlation
- Level structure, Production rate, Decay properties
  - sensitive to the internal quark(diquark) WFs.
- Properties are expected to depend on a Q mass.

Schematic Level Structure of Heavy Baryons

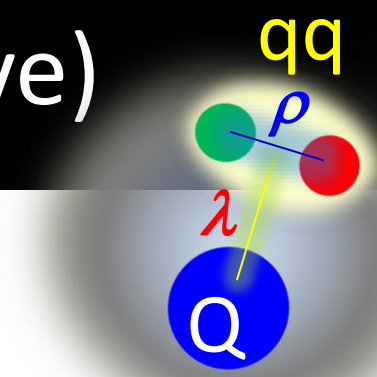
- λ and ρ motions split (Isotope Shift)
- HQ spin multiplet（$\vec{s}_{HQ} \pm \vec{J}_{Brown\ Muck}$）

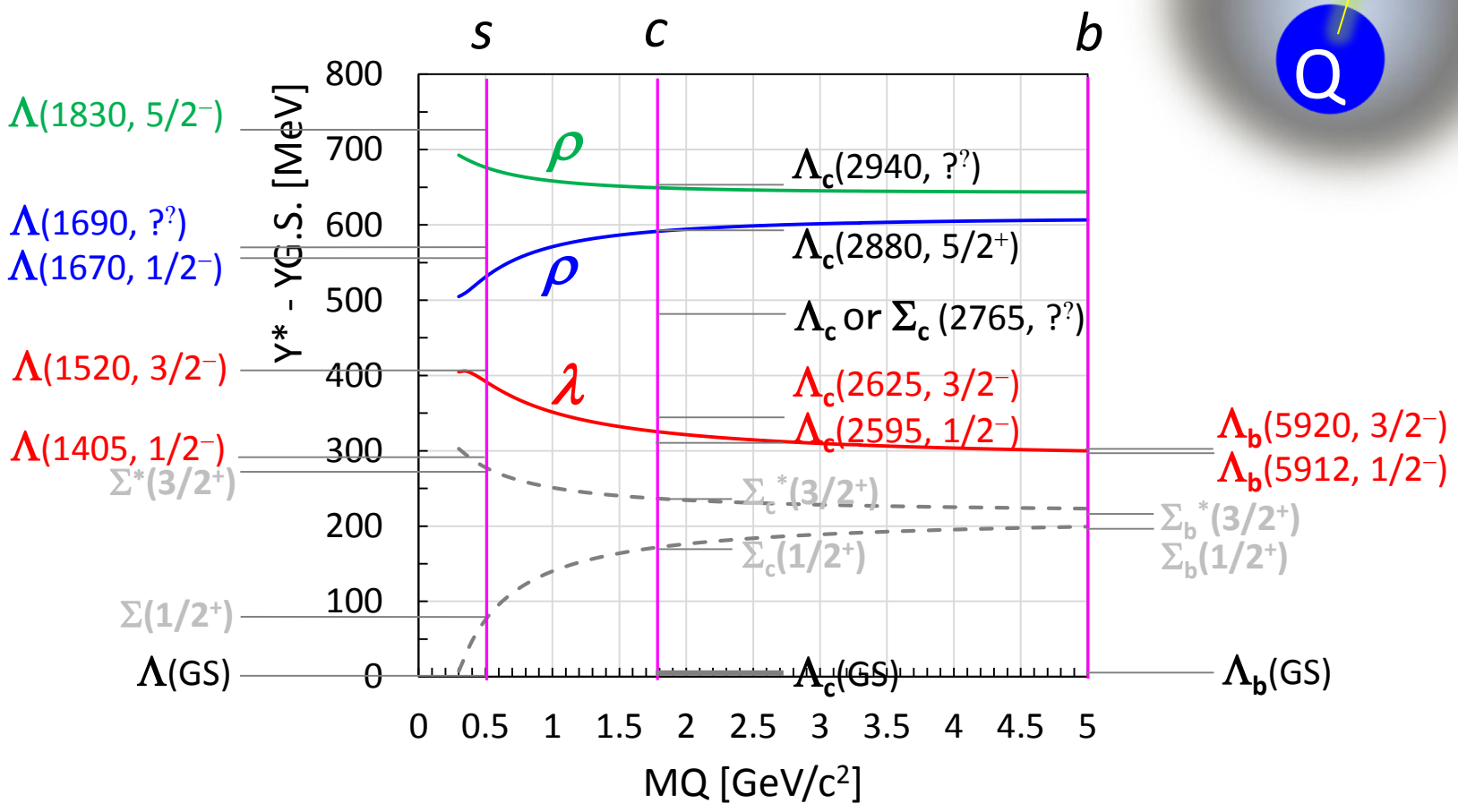


Lambda Baryons (P-wave)



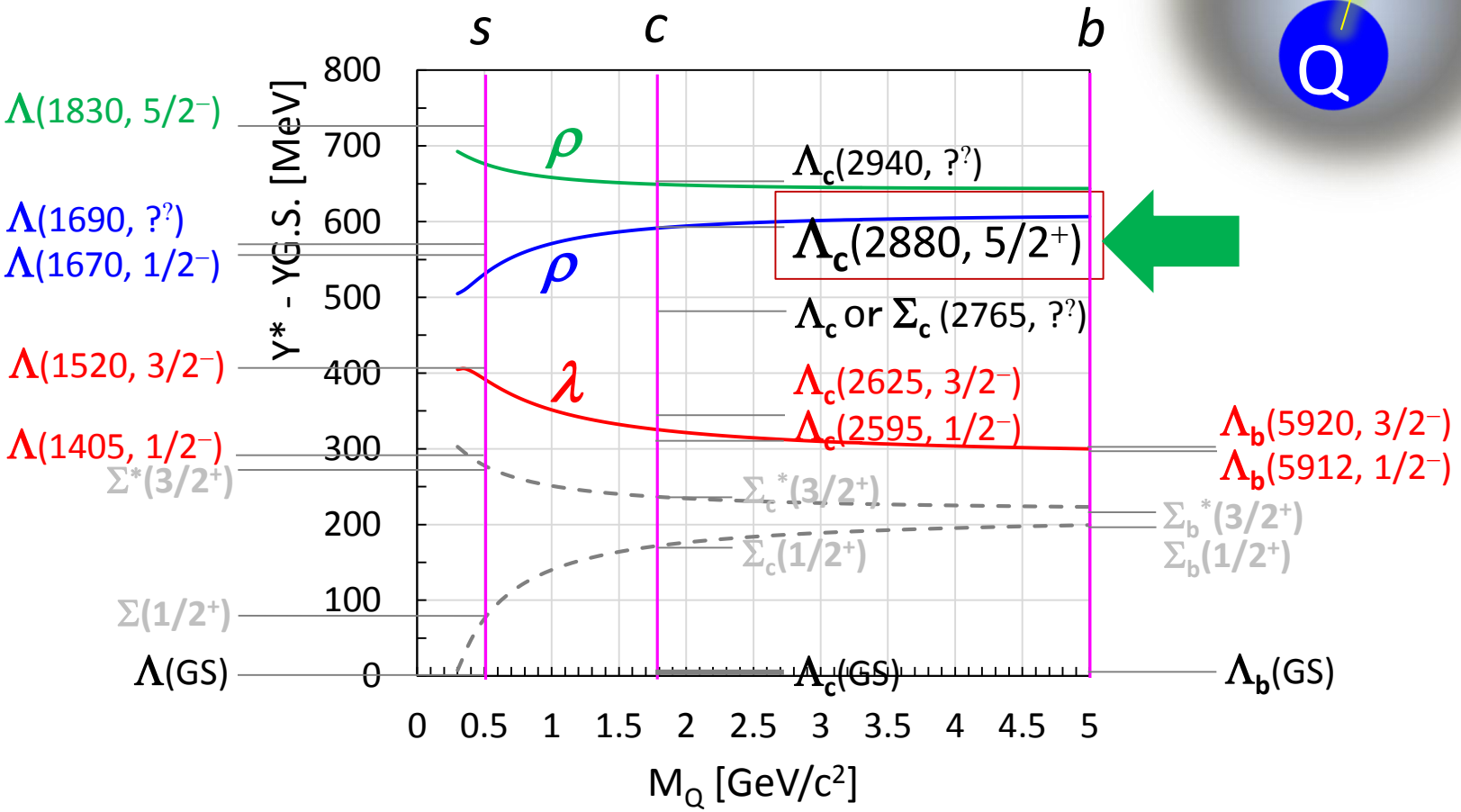
Lambda Baryons (P-wave)





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

Lambda Baryons (P-wave)



non-rel. QM: $H=H_0+V_{conf}+V_{SS}+V_{LS}+V_T$
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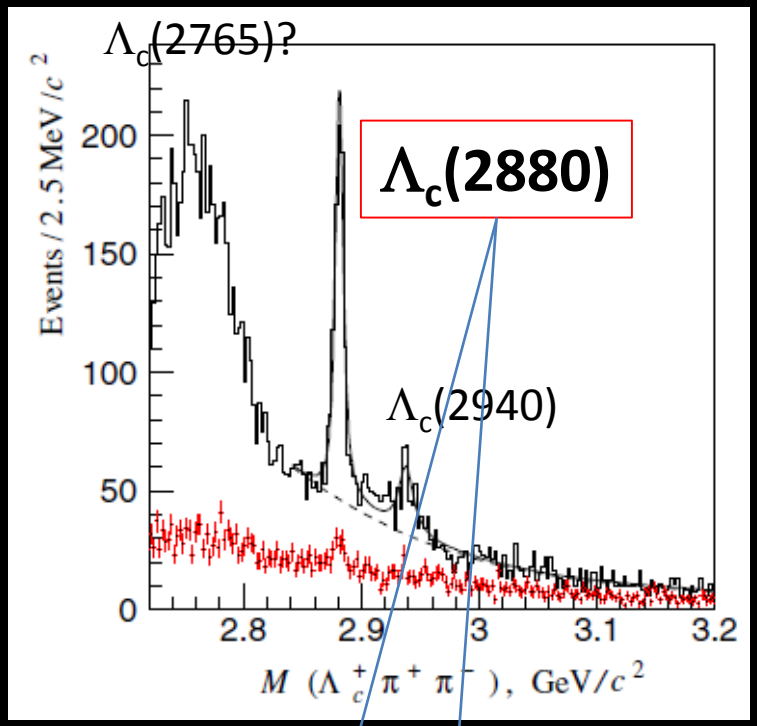
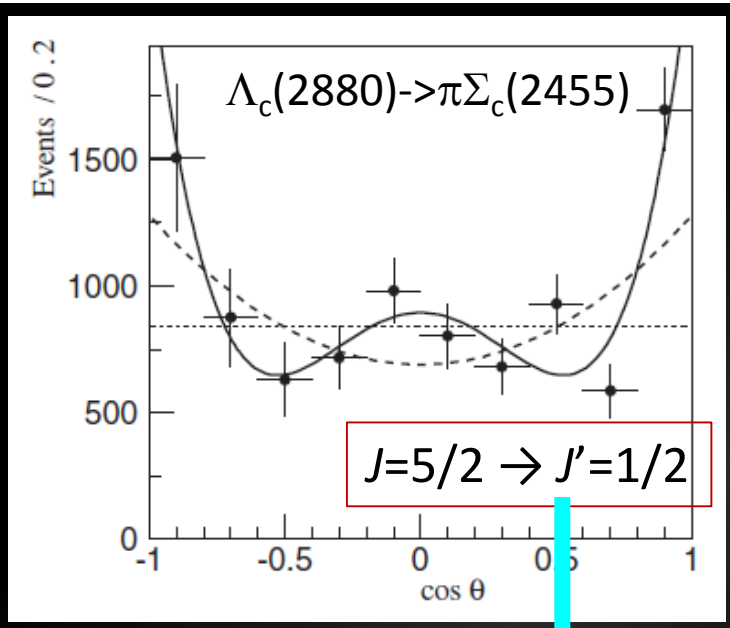
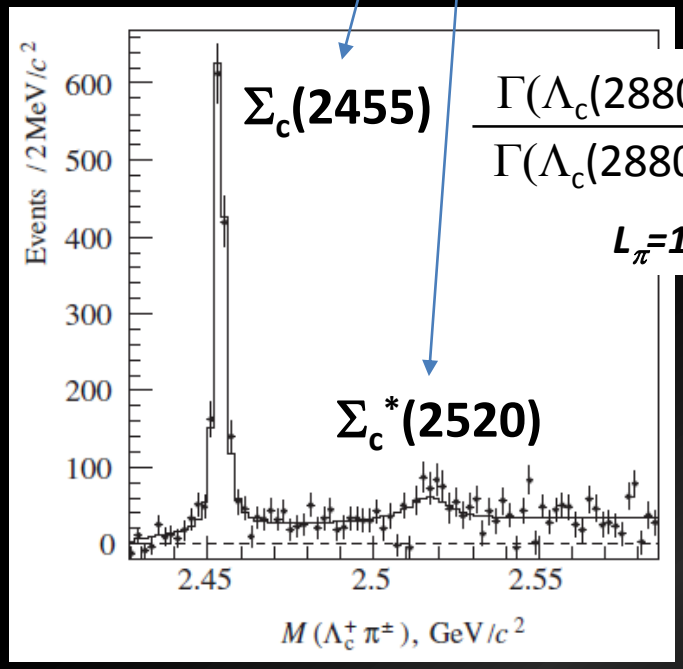
Lc(2880)Belle, PRL98, 262001('07)







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

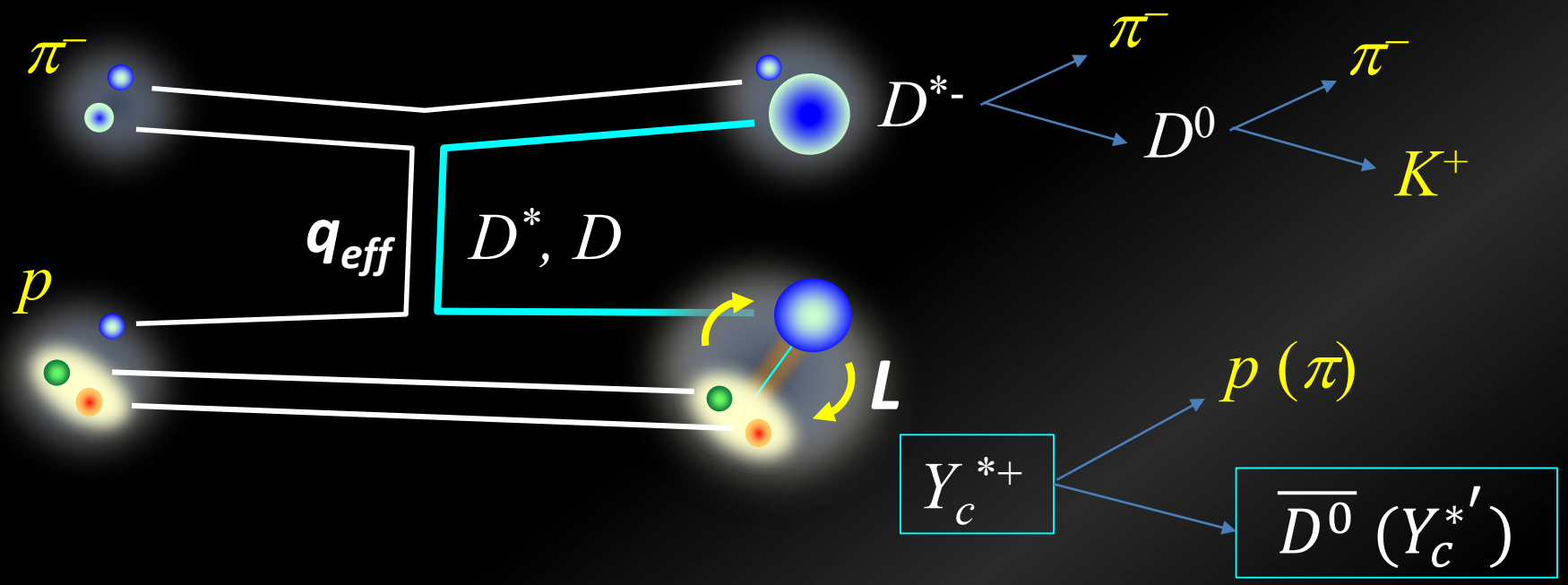
L_π=3 transition

L_π=1 contribution may affect…

$J^P=5/2^+$ for $\Lambda_c(2880)$

Is it a D-wave Lambda-c Baryon?
If so, where is a spin partner ?

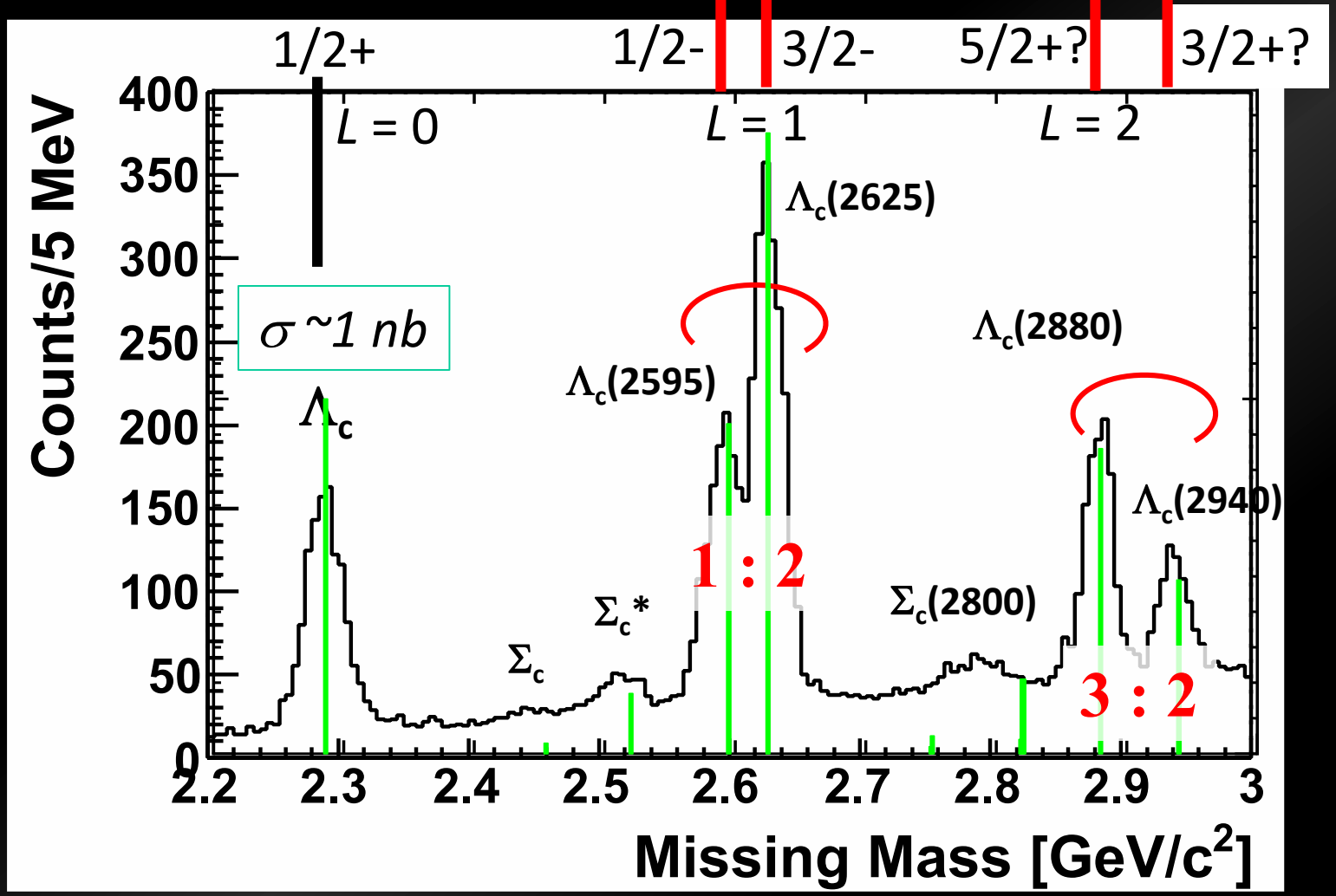
Charmed Baryon Spectroscopy Using Missing Mass Techniques



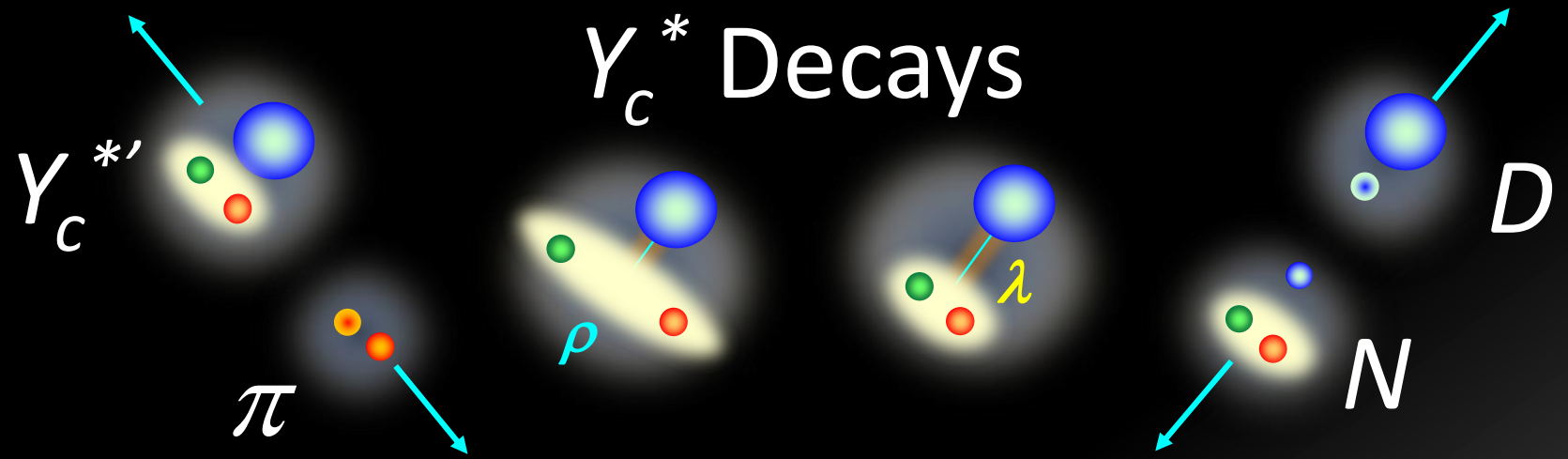
- ✓ Production and Decay reflect [qq] correlation…
- ✓ C.S. DOES NOT go down at higher *L* when q_{eff}>1 GeV/c.

Missing Mass Spectrum (Sim.)

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

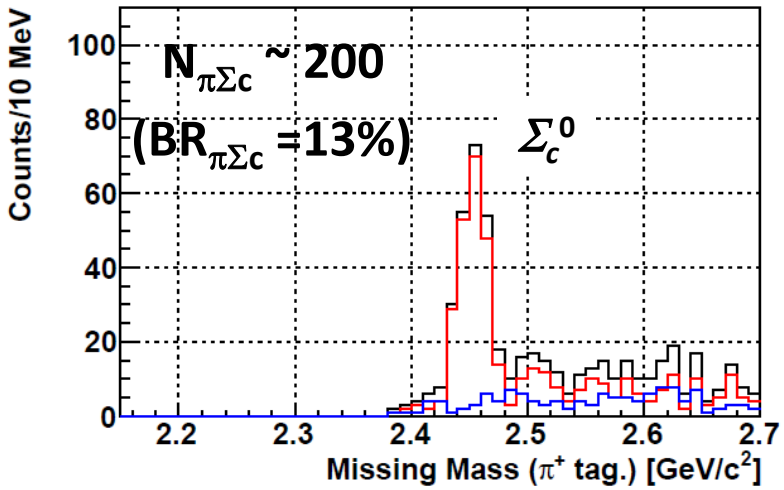


Y_c^* Decays

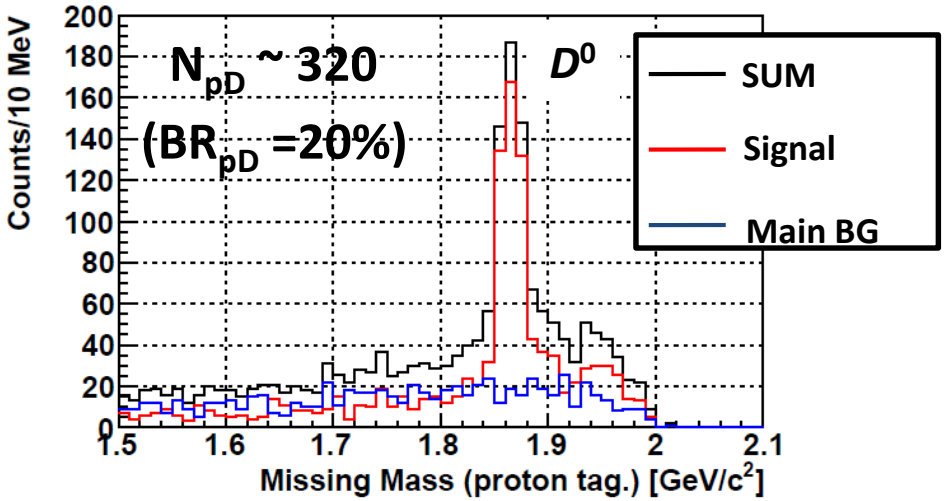


$\Lambda_c(2940) \rightarrow \Sigma_c^0 \pi^+$

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

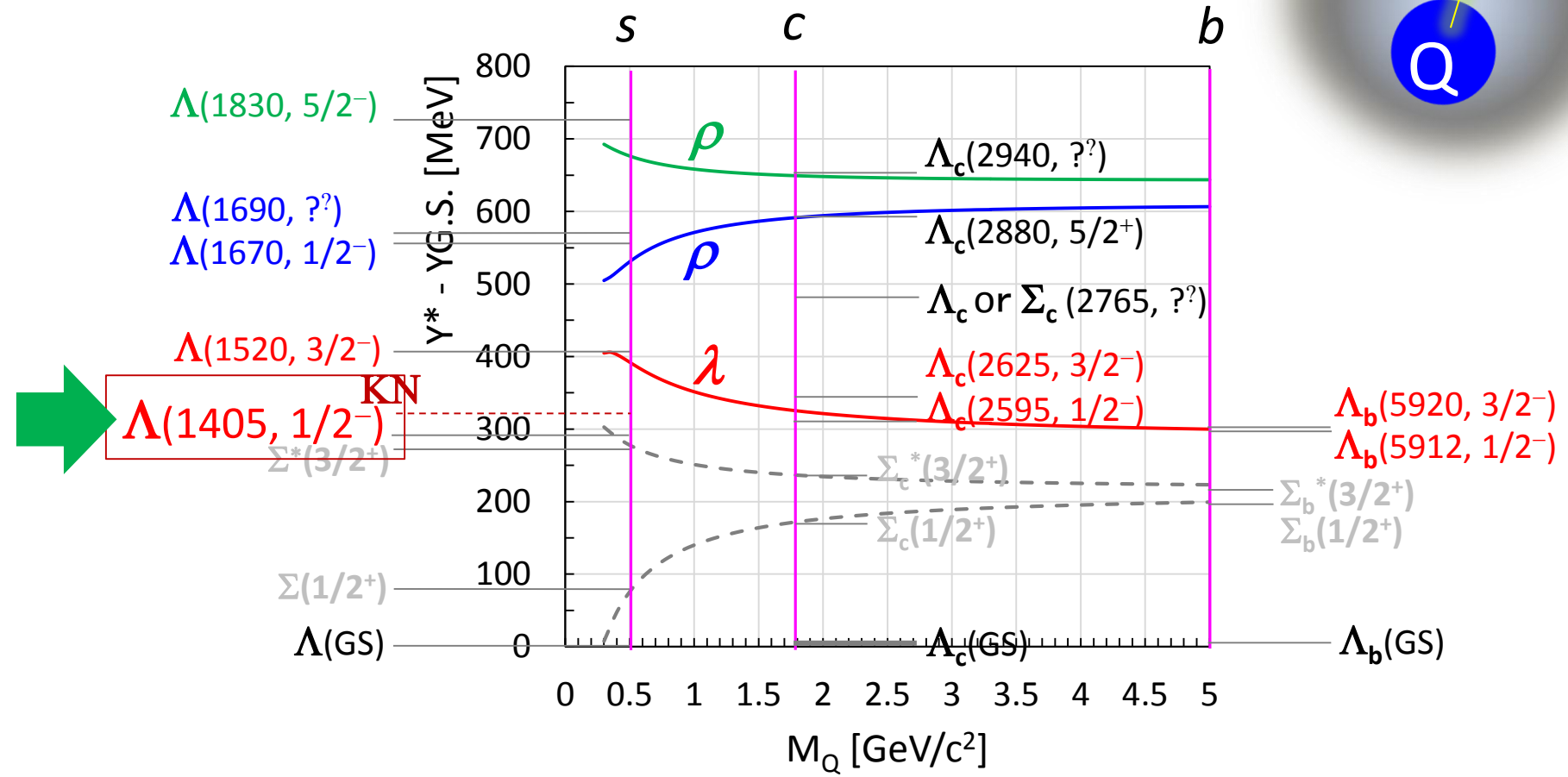


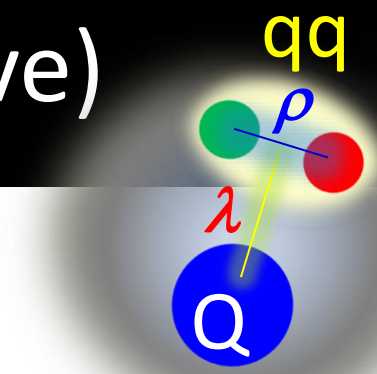
$\Lambda_c(2940) \rightarrow p\ D^0$



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

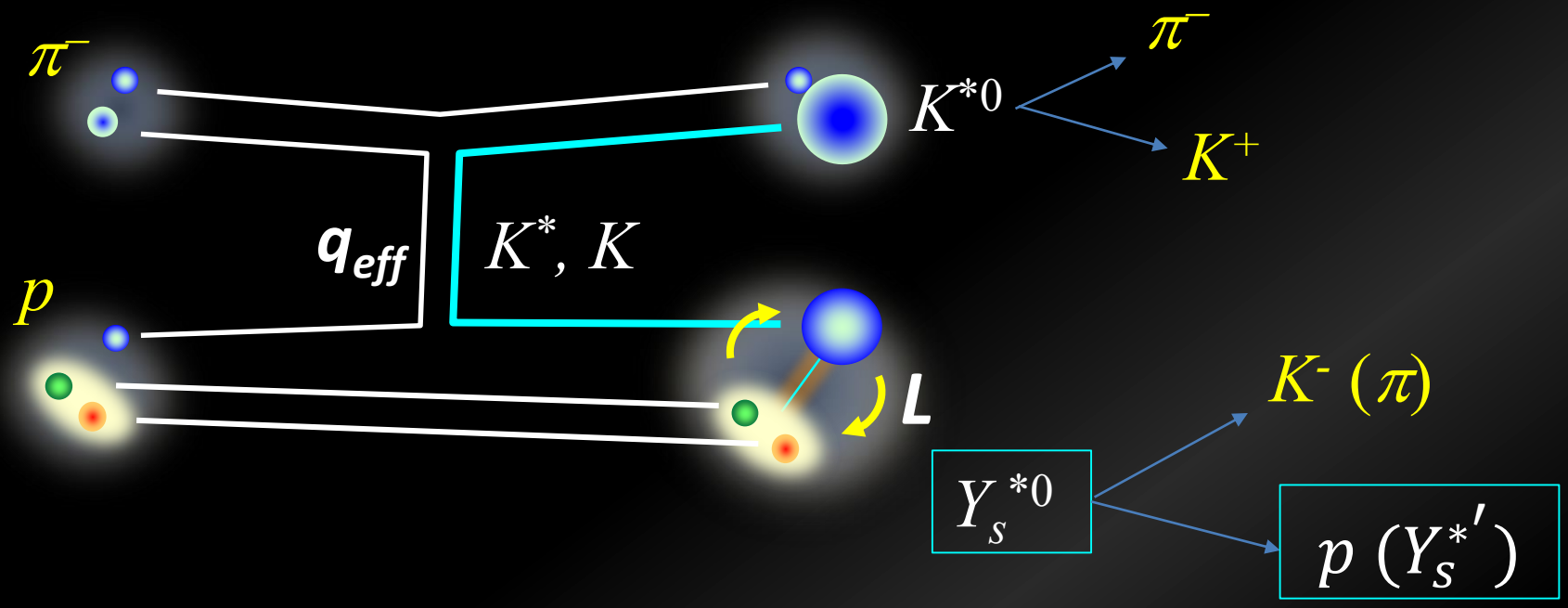
Lambda Baryons (P-wave)





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

Strange Baryon Spectroscopy Using Missing Mass Techniques

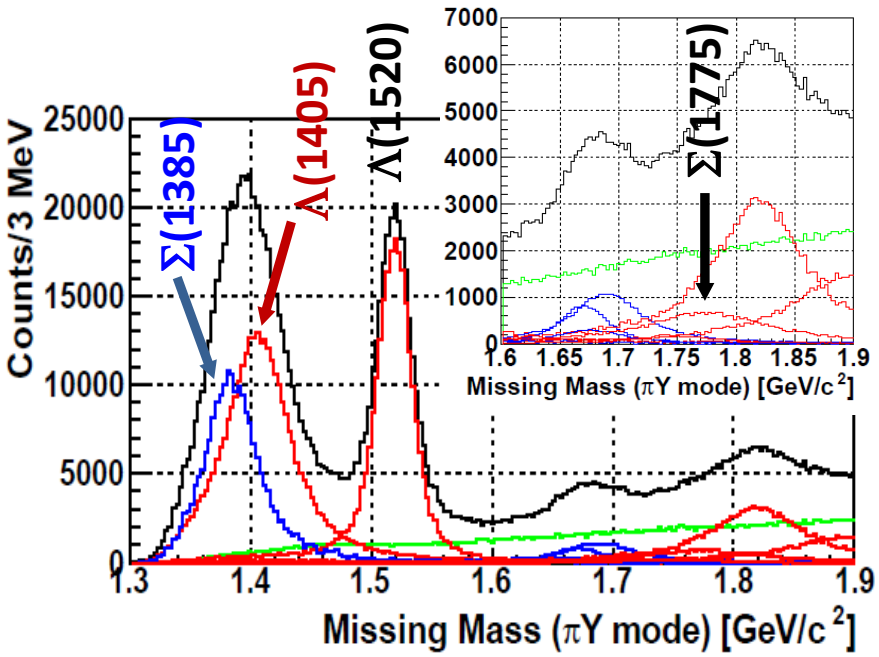


✓ Production and Decay reflect [qq] correlation…

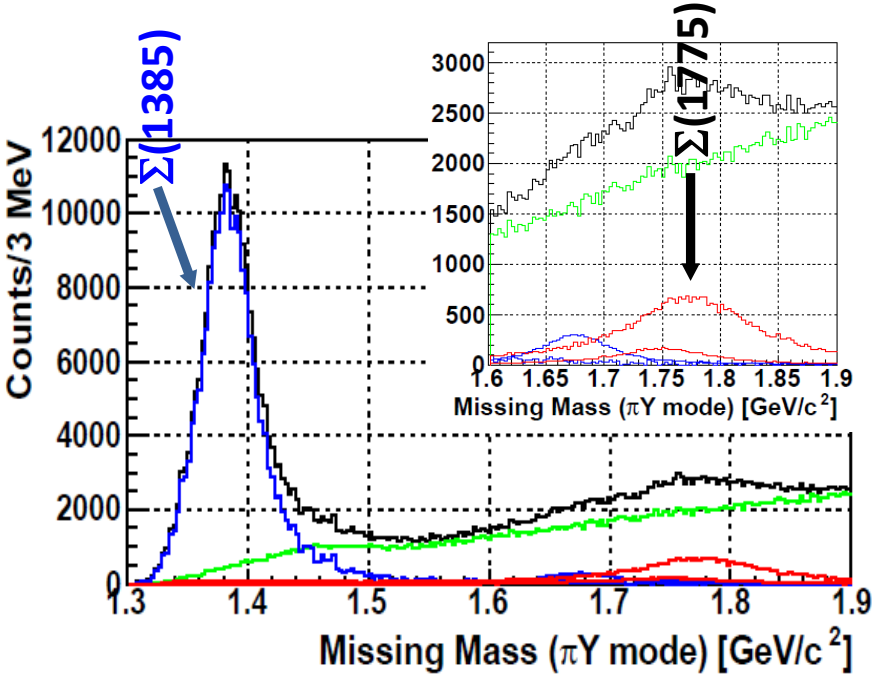
$\Lambda(1405)$

$I = 0, 1$ $I = 1$ only

(a)(π^-,K^{*0}) w/ $\pi\Sigma$ decay



(b)(π^+,K^{*+}) w/ $\pi\Sigma$ decay



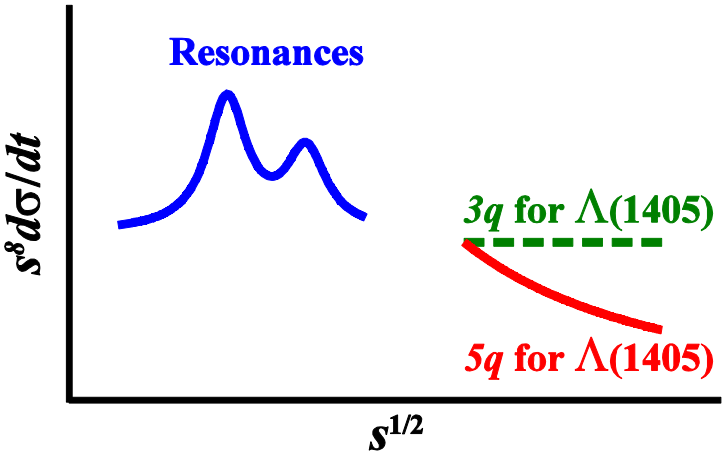
- ✓ Production rate tells how $\Lambda(1405)/\Lambda(1520)$ deviates from/follows the quark-diquark configuration.

Quark counting rule in hadron reactions

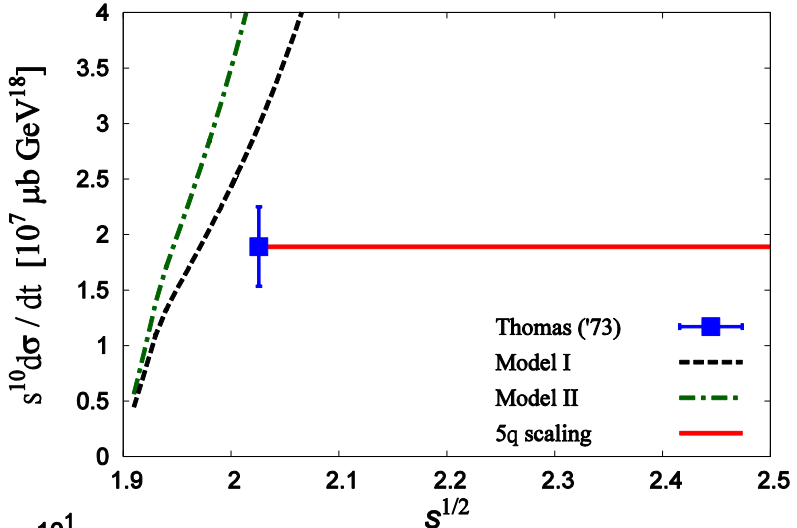
H. Kawamura, et al., PRD 88, 034010 (2013)

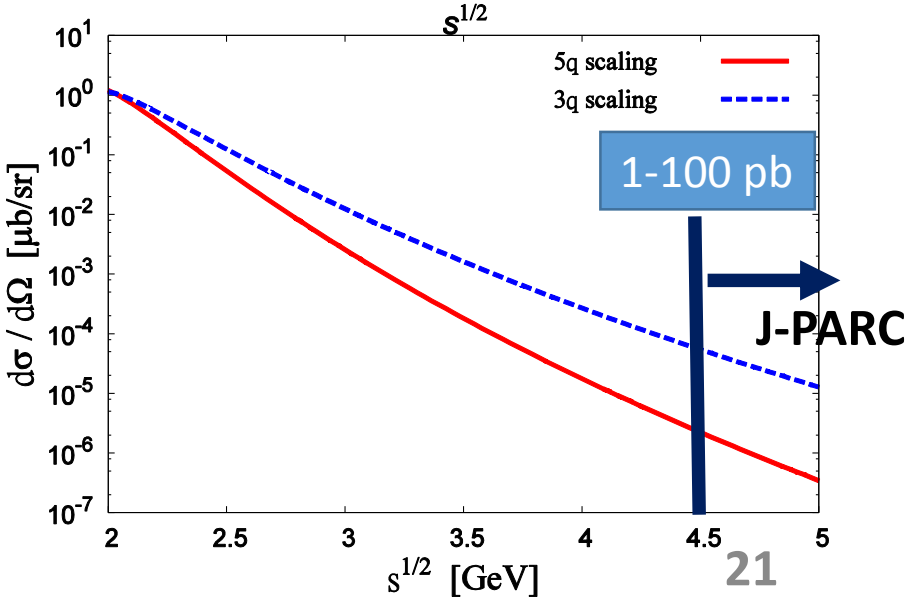
$$\frac{d\sigma}{d\Omega} \sim 1/s^{n-2}$$

$$\pi^- + p \rightarrow \mathrm{K}^0 + \Lambda(1405)$$



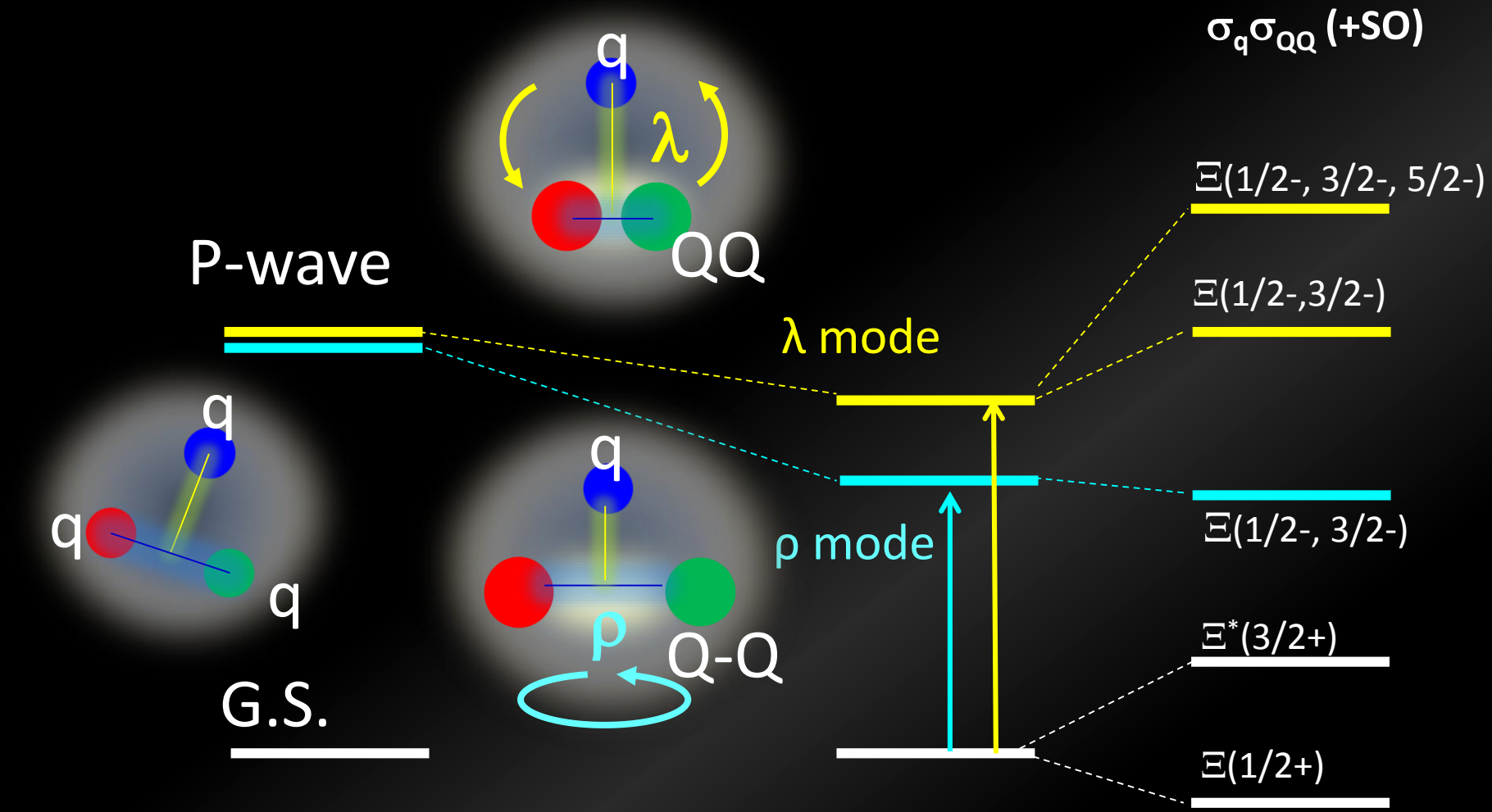
Taken from T. Sekihara's Slide



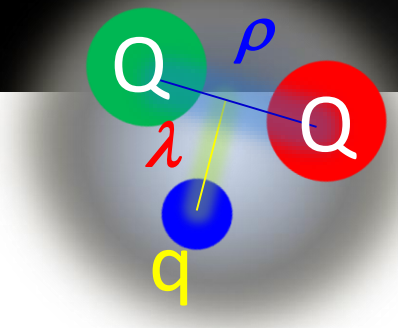


Level Structure of double-Q baryons

- λ and ρ mode excitations interchange



Xi Baryons



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

Little is known for Ξ

Threshold

ΩK(2166)

ΣK*(1983)

Σ*K(1878) ΛK*(1908)

Ξ*π(1665) ΣK(1685)

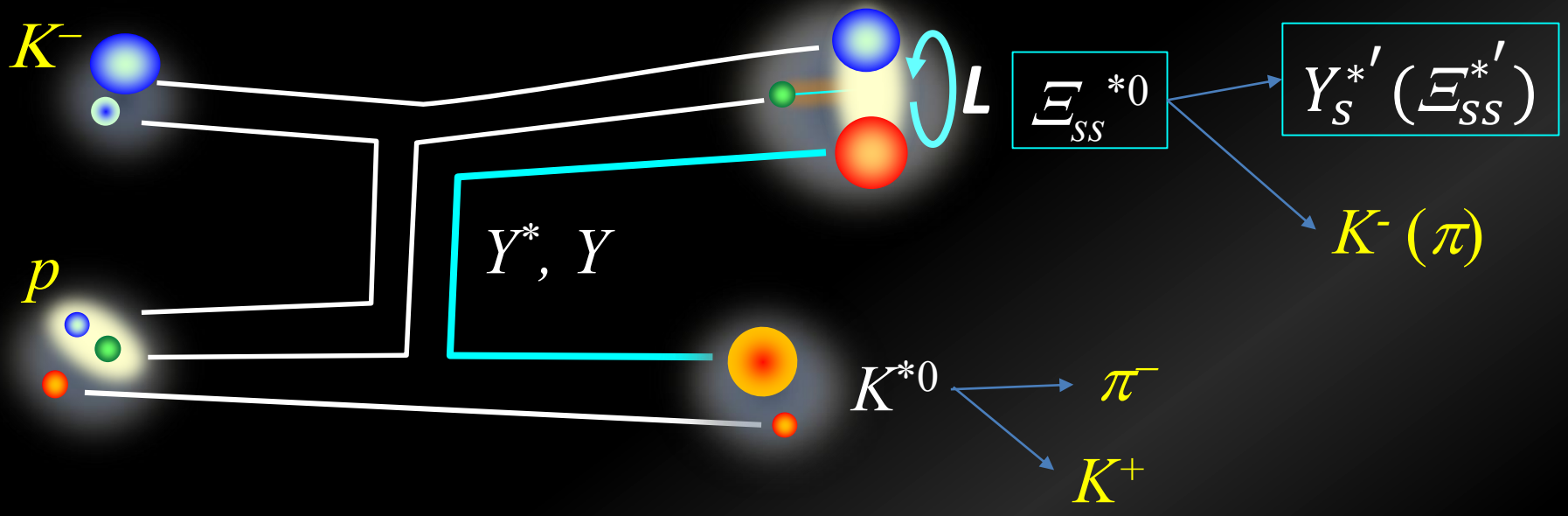
ΛK(1610)

Ξπ(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	
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			

- Narrow width: ~ a few 10 MeV
- Large production cross section: ~ 1 μb

Double Strange Baryon Spectroscopy Using Missing Mass Techniques



- ✓ Production and Decay reflect [QQ] correlation…
- ✓ *U-channel production may be dominant…*

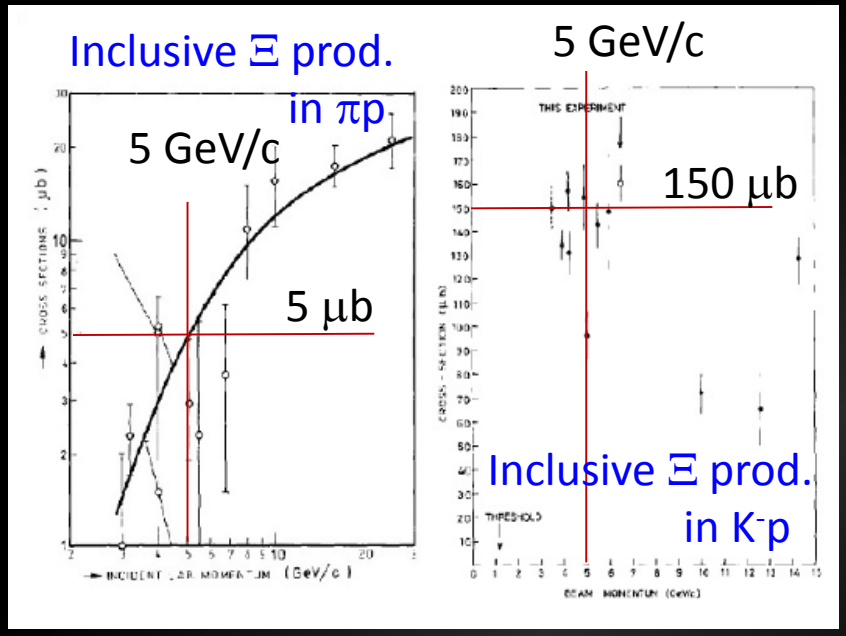
Ξ Baryon Spectroscopy w/ the High-p Secondary Beam

LoI submitted by M. Naruki and K. Shirotori

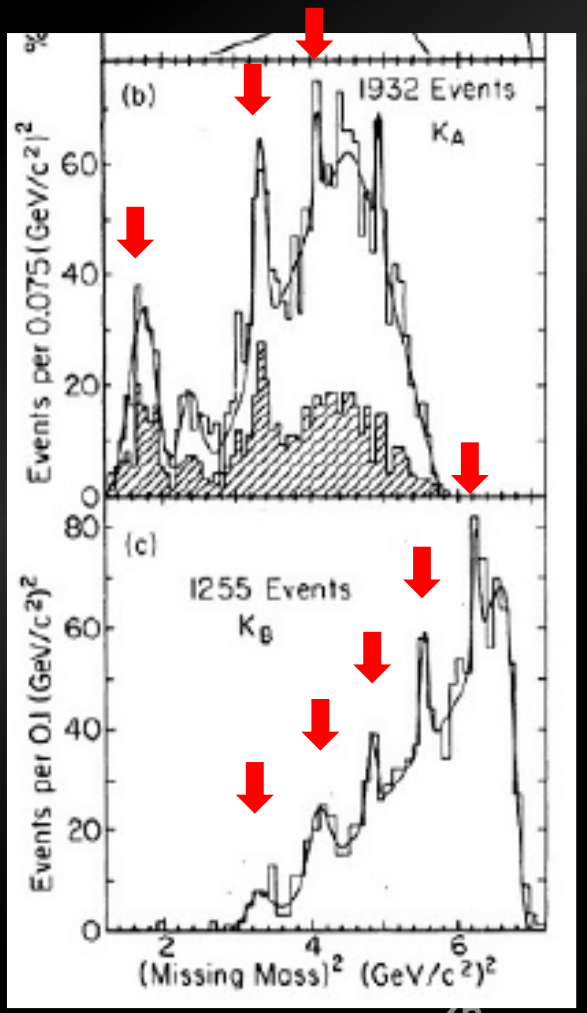
- Sizable yields are expected for a month.

Reaction	σ [μb]	Beam [/spill]	B.R.	Acceptance [%]	Y_{Total}	$Y_{Decay/bin}$
$K^-p \to \Xi^{*-}K^+$	1.0	10^6	1.0	50	3.1×10^5	2500
$K^-p \to \Xi^{*-}K^{*+}$	1.0	10^6	0.23	50	0.7×10^5	580
$K^-p \to \Xi^{*0}K^{*0}$	1.0	10^6	0.67	50	2.1×10^5	1700
$\pi^-p \to \Xi^{*-}K^{*0}K^+$	0.1	10^7	0.67	50	3.1×10^5	2500

- Past exp. C.M. Jenkins et al., PRL51, 951(1983) →

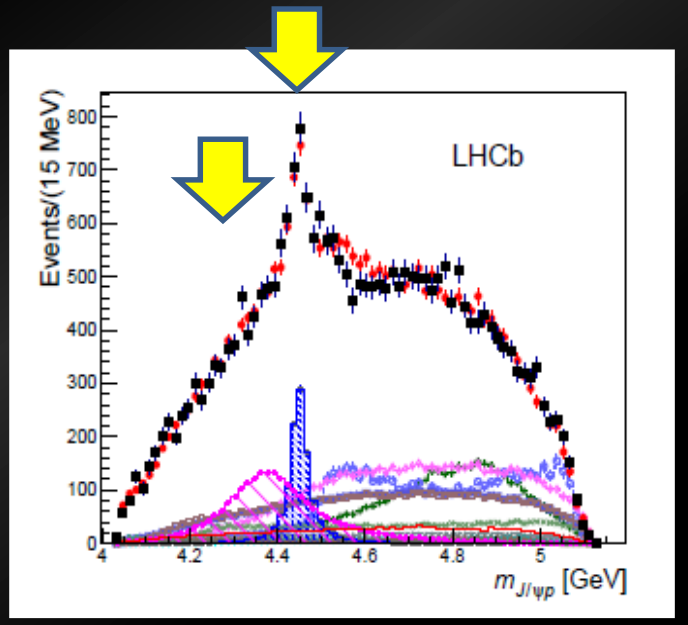


p(K-,K+) spectra



$P_c(4380), P_c(4450)$

- Is P_c^+ the N* with a hidden c-cbar?
- P_c can be excited on its mass with 10 GeV/c pion beam at J-PARC.
- Its decay modes to $Y_c + \overline{D}$.
- Its family?



Summary

1. A general purpose spectrometer at the J-PARC High-p BL
   - CHARM spectrometer will open a new platform to study hadron physics.
2. Quark-diquark structure of heavy baryons
   - Mass spectrum, Production Rate, and Decay Branching ratio
   - Information to access “wave function” of quark/diquark in baryons
3. Systematic studies with different flavors may help to understand the light baryon system
   - Meson-baryon coupling may modify mass spectrum/width
   - Relation btw charmed and strange baryons are useful.