Seminars at FEFU, Vladivostok

II. Charmed baryons

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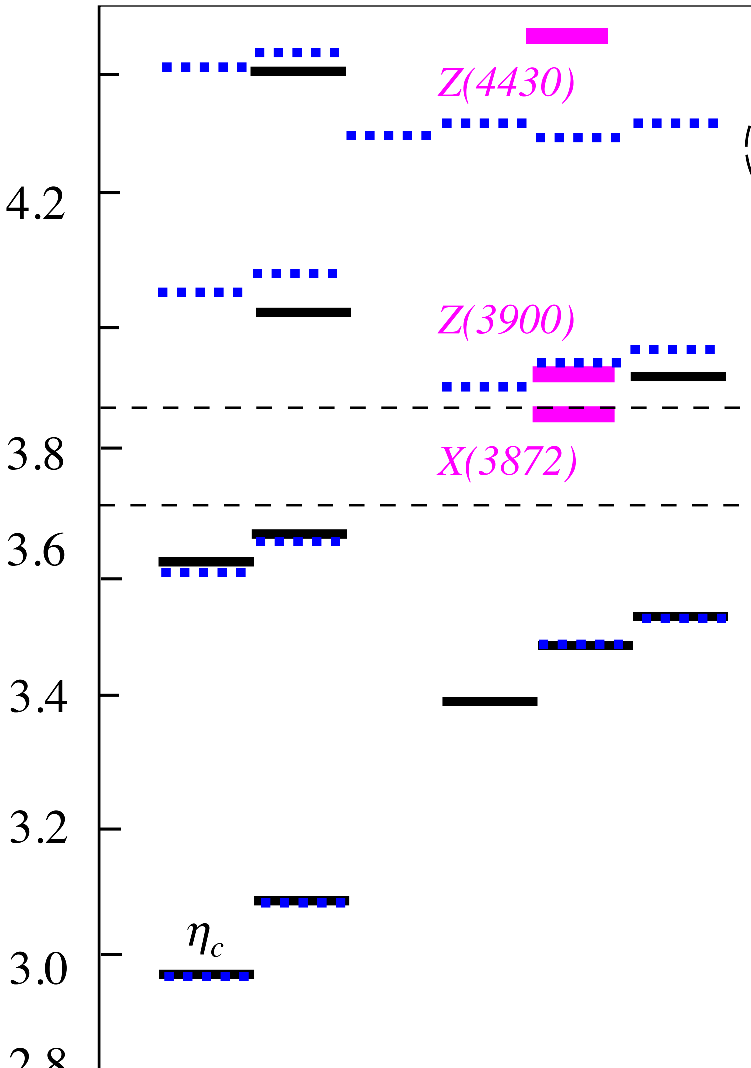
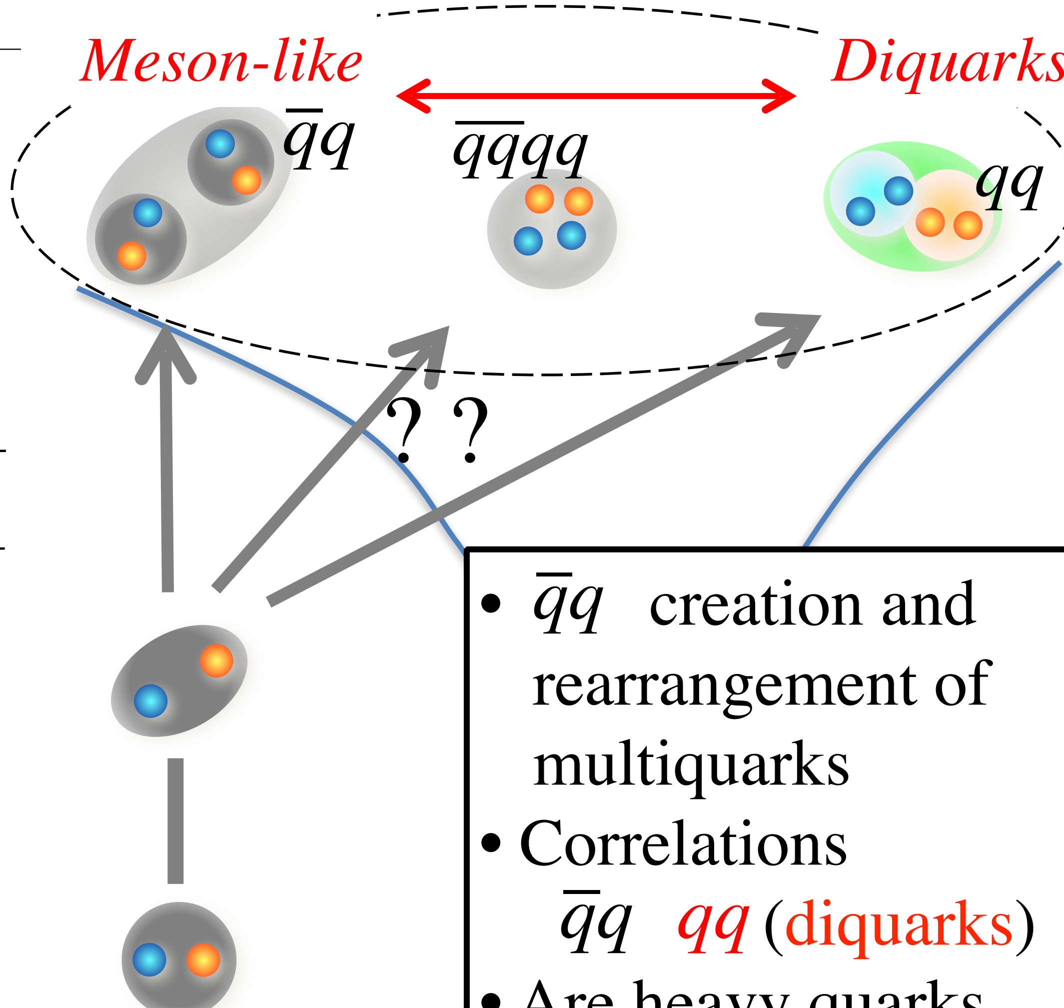
Quarkonium like states and excitations



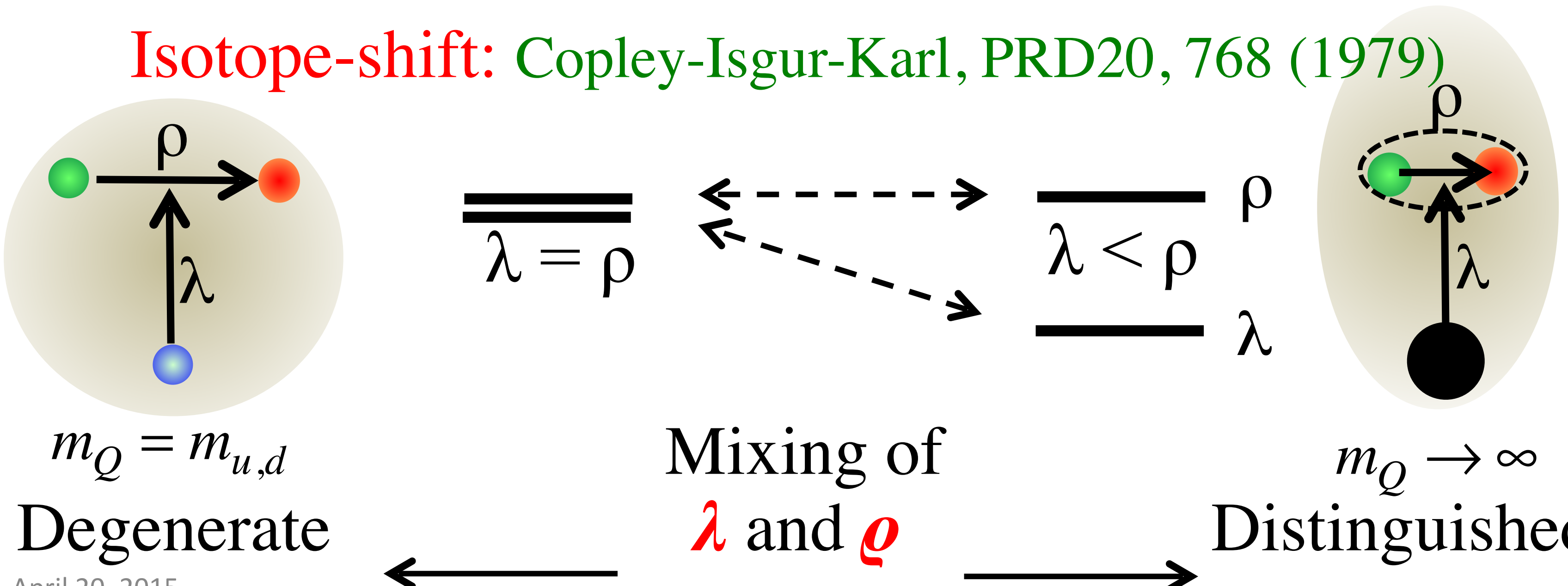


- $\bar{q}q$ creation and rearrangement of multiquarks
- Correlations
  $\bar{q}q$ qq (diquarks)
- Are heavy quarks useful to know it?

1. ρ, λ modes and diquark motions

A heavy quark may disentangle
the fundamental modes ***λ*** and ***ρ***
➔ place to look at diquark correlations

Isotope-shift: Copley-Isgur-Karl, PRD20, 768 (1979)



$m_Q = m_{u,d}$
Degenerate

Mixing of
λ and ***ρ***

$m_Q \to \infty$
Distinguished

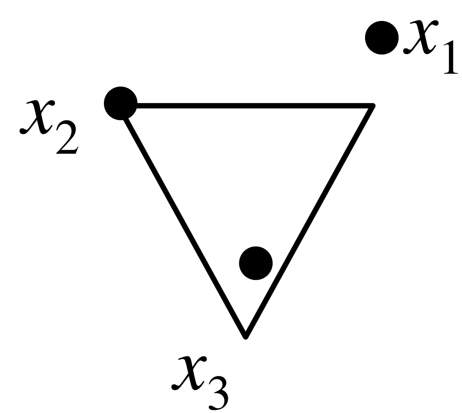
April 20, 2015

λ excitation < ρ excitation

Harmonic oscillator

$$H = \frac{p_1{}^2}{2m} + \frac{p_2{}^2}{2m} + \frac{p_3{}^2}{2M} + \frac{k}{2}\left((x_1 - x_2)^2 + (x_2 - x_3)^2 + (x_3 - x_1)^2\right)$$

$$= \frac{p_\rho{}^2}{2m_\rho} + \frac{p_\lambda{}^2}{2m_\lambda} + \frac{k_\rho \rho^2}{2} + \frac{k_\lambda \lambda^2}{2}$$



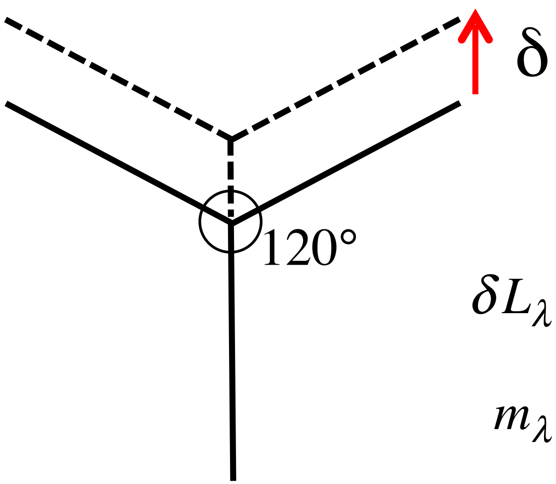
$$m_\rho = \frac{m}{2}, \quad m_\lambda = \frac{2mM}{M + 2m}$$

$$k_\rho = \frac{3}{2}k, \quad k_\lambda = 2k$$

$$\omega_\lambda = \sqrt{\frac{M + 2m}{M}}\omega \quad < \quad \omega_\rho = \sqrt{3}\omega$$

String: $V \sim \sigma L$

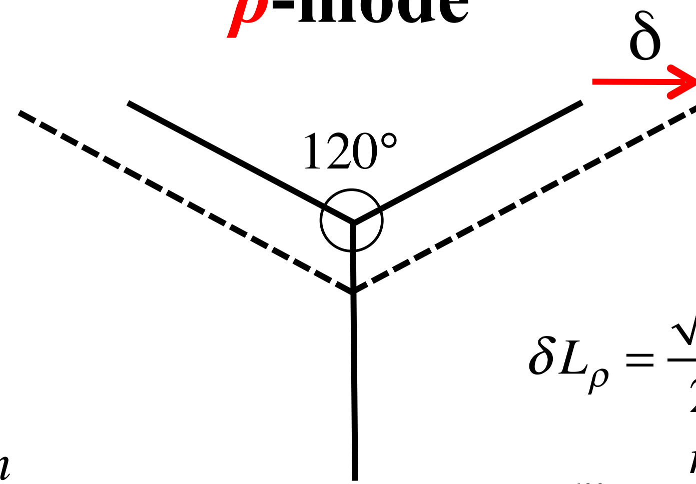
λ-mode



$$\delta L_\lambda = \delta$$

$$m_\lambda = \frac{2mM}{M+2m} \to 2m$$

ρ-mode



$$\delta L_\rho = \frac{\sqrt{3}}{2}\delta$$

$$m_\rho = \frac{m}{2}$$

$$\omega_\lambda \to \left(\frac{1}{2}\right)^{1/3}\left(\frac{\sigma^2}{m}\right)^{1/3} \quad < \quad \omega_\rho = \left(\frac{\sigma^2}{m}\right)^{1/3} \to \left(\frac{3}{2}\right)^{1/3}\left(\frac{\sigma^2}{m}\right)^{1/3}$$

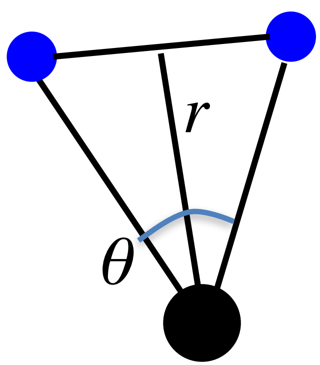
Diquark correlations

Alexandrou, deForcrand, Lucini
PRL 97, 222002 (2006)

$$C_\Gamma(\mathbf{r}_u, \mathbf{r}_d, t) = \langle 0 | J_\Gamma(\mathbf{0}, 2t) J_0^u(\mathbf{r}_u, t) J_0^d(\mathbf{r}_d, t) J_\Gamma^\dagger(\mathbf{0}, 0) | 0 \rangle$$

$$J_0^f(\mathbf{r}, t) = :\bar{f}(\mathbf{r}, t)\gamma_0 f(\mathbf{r}, t):, \; f = u, d,$$

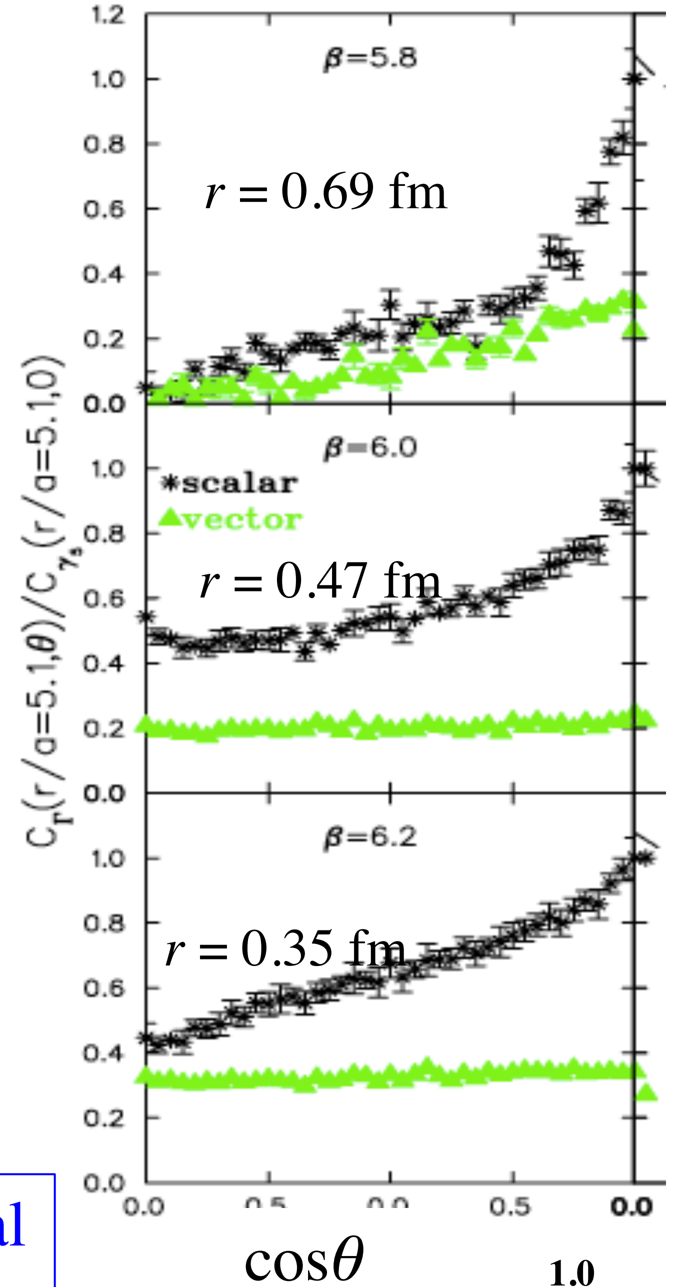
$$J_\Gamma(x) = \epsilon^{abc}[u^T{}_a(x) C\Gamma d_b(x) \pm d^T{}_a(x) C\Gamma u_b(x)] s_c(x),$$



Good diquark

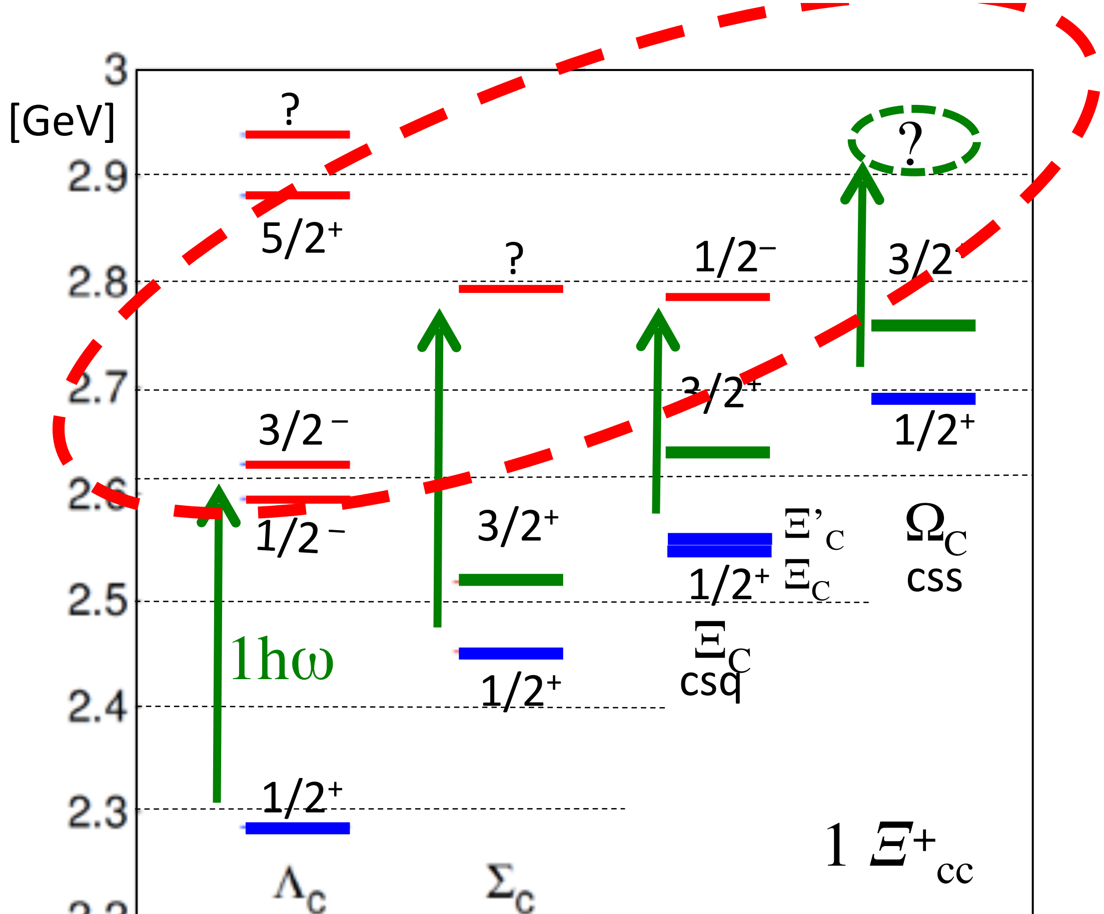
Bad diquark

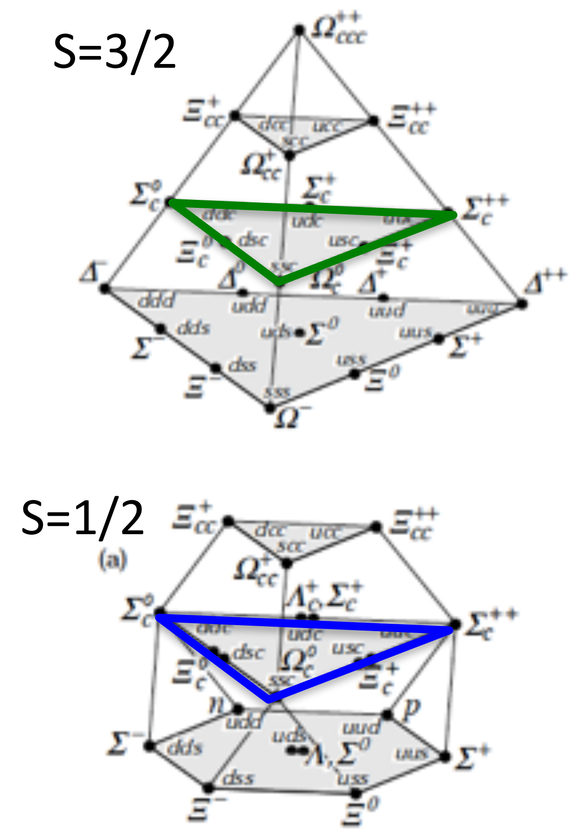
Indicates significant attraction between quarks in good diquark pair



See also recent ***QCD sum rule study***, Chen et al arXiv:1502.01103 [hep-ph], To appear in PRD

Spectroscopy: More states at J-PARC





- Excited energies, decay widths are smaller
- Two distinct modes may be different

Quark model calculations

Roberts-Pervin, IJMPA, 23, 2817 (2008)

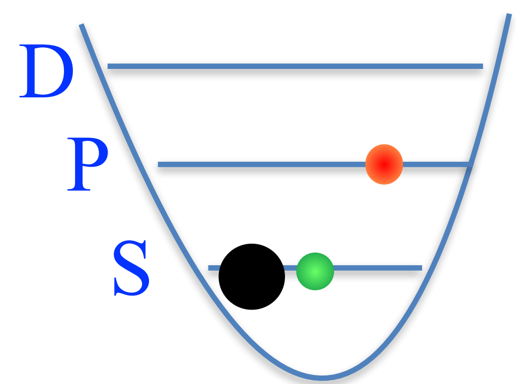
Yoshida, Hiyama, Hosaka, Oka, Phys.Rev. D92 (2015) no.11, 114029

- Hamiltonian

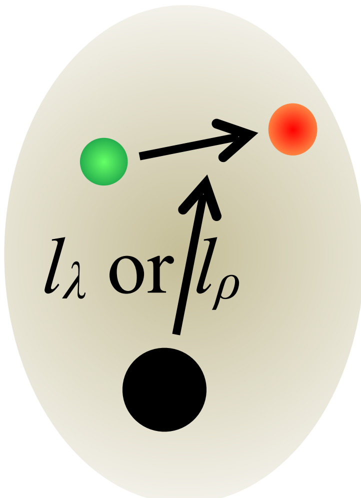
$$H = \frac{p_1^2}{2m_q} + \frac{p_2^2}{2m_q} + \frac{p_3^2}{2M_Q} - \frac{P^2}{2M_{tot}}$$
$$+ V_{conf}(HO) + V_{spin-spin}(Color - magnetic) + \ldots$$

- Solved by the **Gaussian expansion** method

- Quark excitations of
  P ($l = 1$), D ($l = 2$), … waves
  Many …



Classifications; p-wave



$$S_{qq} + l = j \text{ (Brown muck)}$$

$$j + 1/2_Q = J_{\text{tot}}$$

$S_{\text{qq}} = 0$ or 1, l_λ or l_ρ, $j = 0, 1, \ldots$
$J = 1/2, 3/2, \ldots$

Brown muck

(l_λ, l_ρ)	(l_λ, l_ρ)	diquark		J_{tot}
$(0, 1)$	$(0, 0)$	d^0	1^-	$(1/2, 3/2)^-$
$(0, 0)$	$(0, 1)$	d^1	0^-	$1/2^-$
			1^-	$(1/2, 3/2)^-$
			2^-	$(3/2, 5/2)^-$

⬅ **7 states** for Λ and Σ

Only few of them are observed

<u>QM wave functions</u>

charm spin

λ mode

$$\Lambda_c(J^-;\lambda) = \left[\left[\psi_1(\vec{\lambda})\psi_0(\vec{\rho}), d^0\right]^1, \chi_c\right]^{J=\frac{1}{2},\frac{3}{2}} D^0 c$$

H.O.(gauss)

flavor

$$\Sigma_c(1/2^+) = \left[\left[\psi_0(\vec{\lambda})\psi_0(\vec{\rho}), d^1\right]^1, \chi_c\right]^{\frac{1}{2}} D^1 c$$

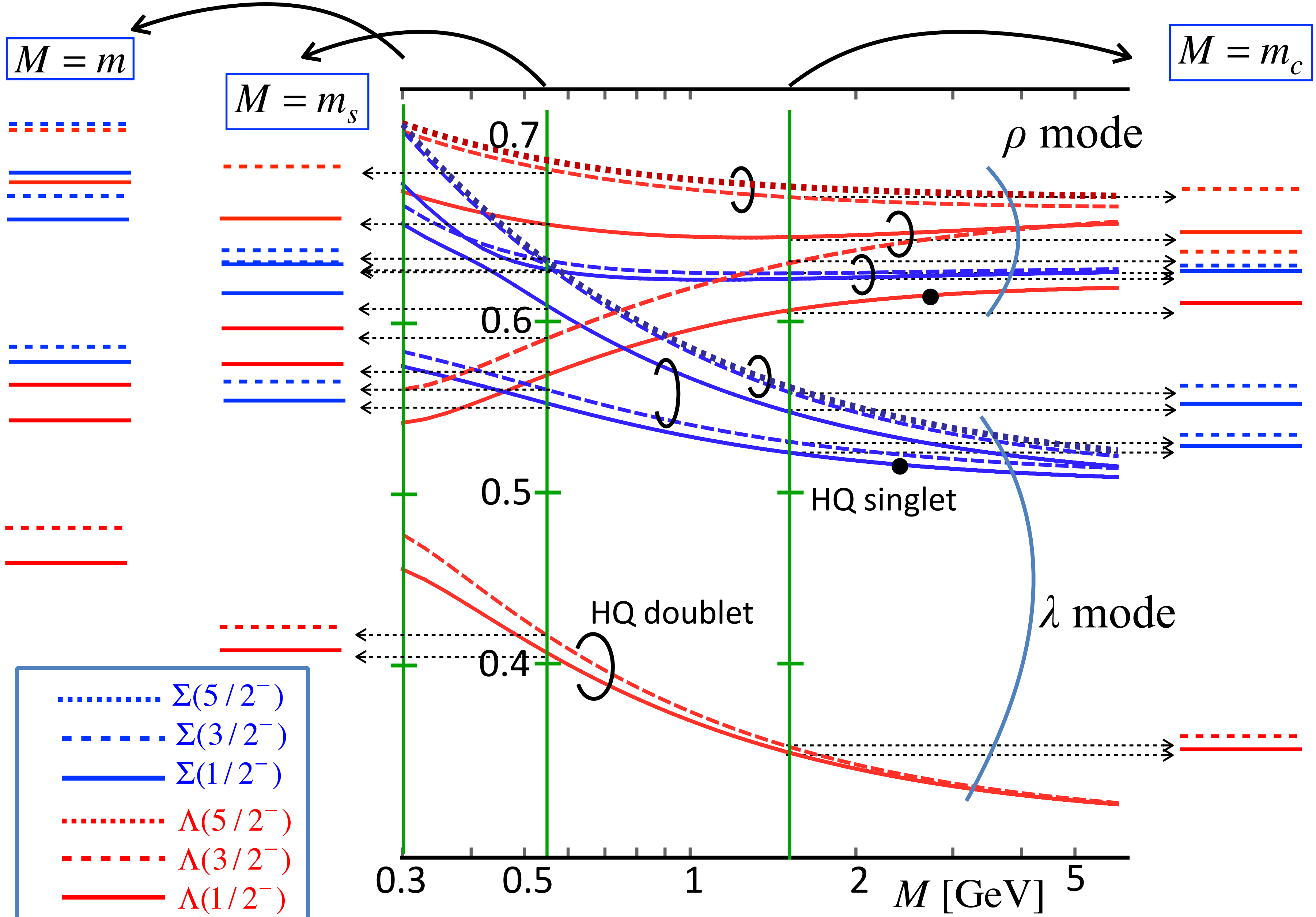
etc.

di-quark spin

Similarly for $\boldsymbol{\rho}$ mode

And mixing of λ and ρ modes

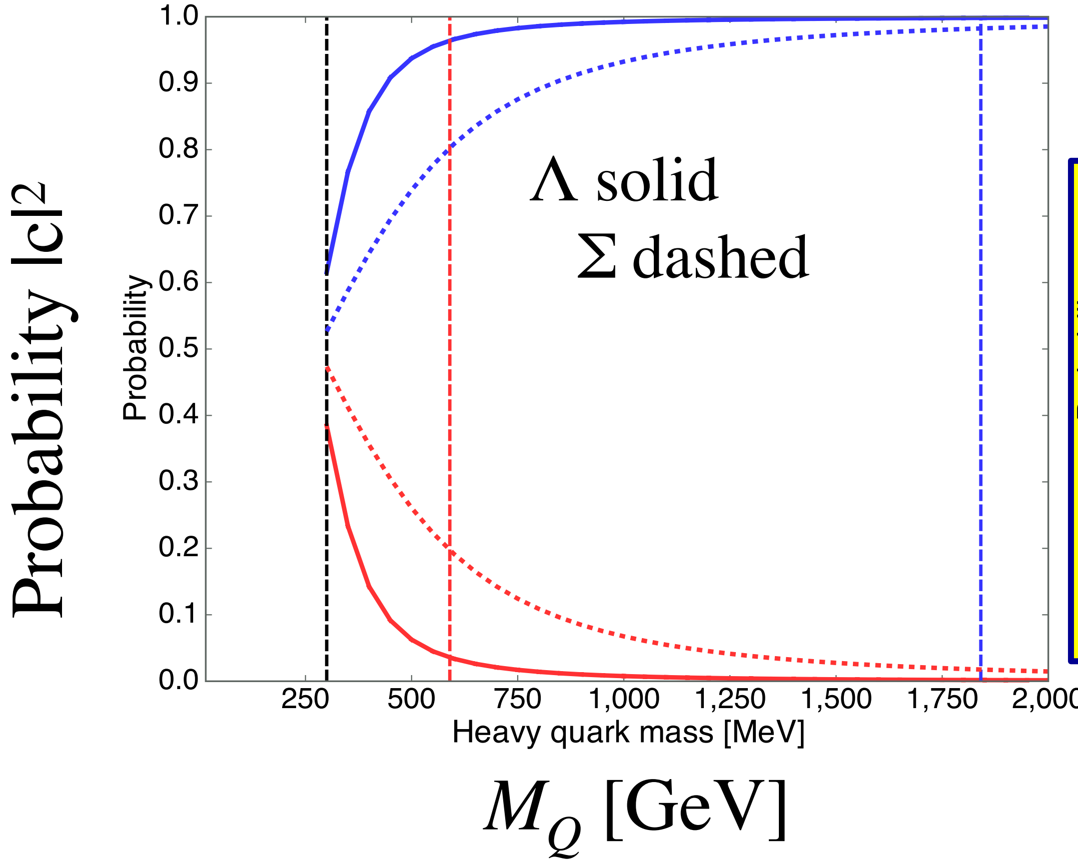
P-wave excitations - $1/2^-$, $3/2^-$



$\lambda\rho$ mixing in the wave functions

Mixing of $\Lambda(\text{phys}) = c_\lambda \Lambda(^2\lambda) + c_\rho \Lambda(^2\rho)$

e.g. λ-mode dominant state: How much the other mode mixes?



Λ_c^* is almost pure $\boldsymbol{\lambda}$ mode
➔
Reflect more ***qq*** nature

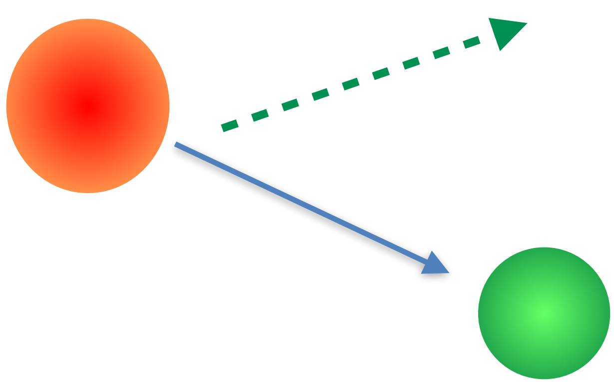
Decays —Pion emission—

On going, Nagahiro, Yasui, …

To know the structure,
We study transitions (decay and productions)

Quarks are confined
Only transitions through photons, hadrons are available

See the structure that invisible particles form



Decays —Pion emission—

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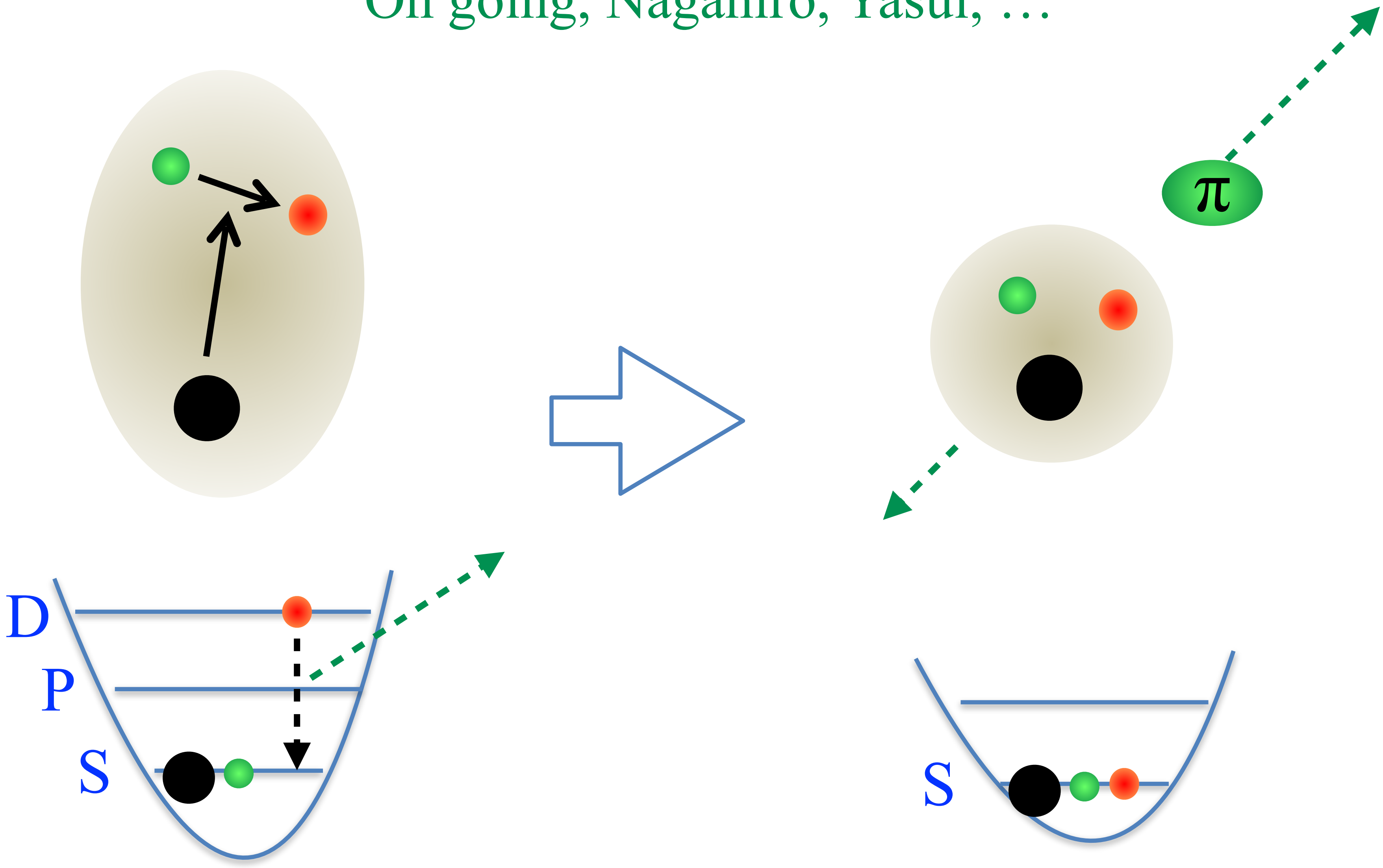
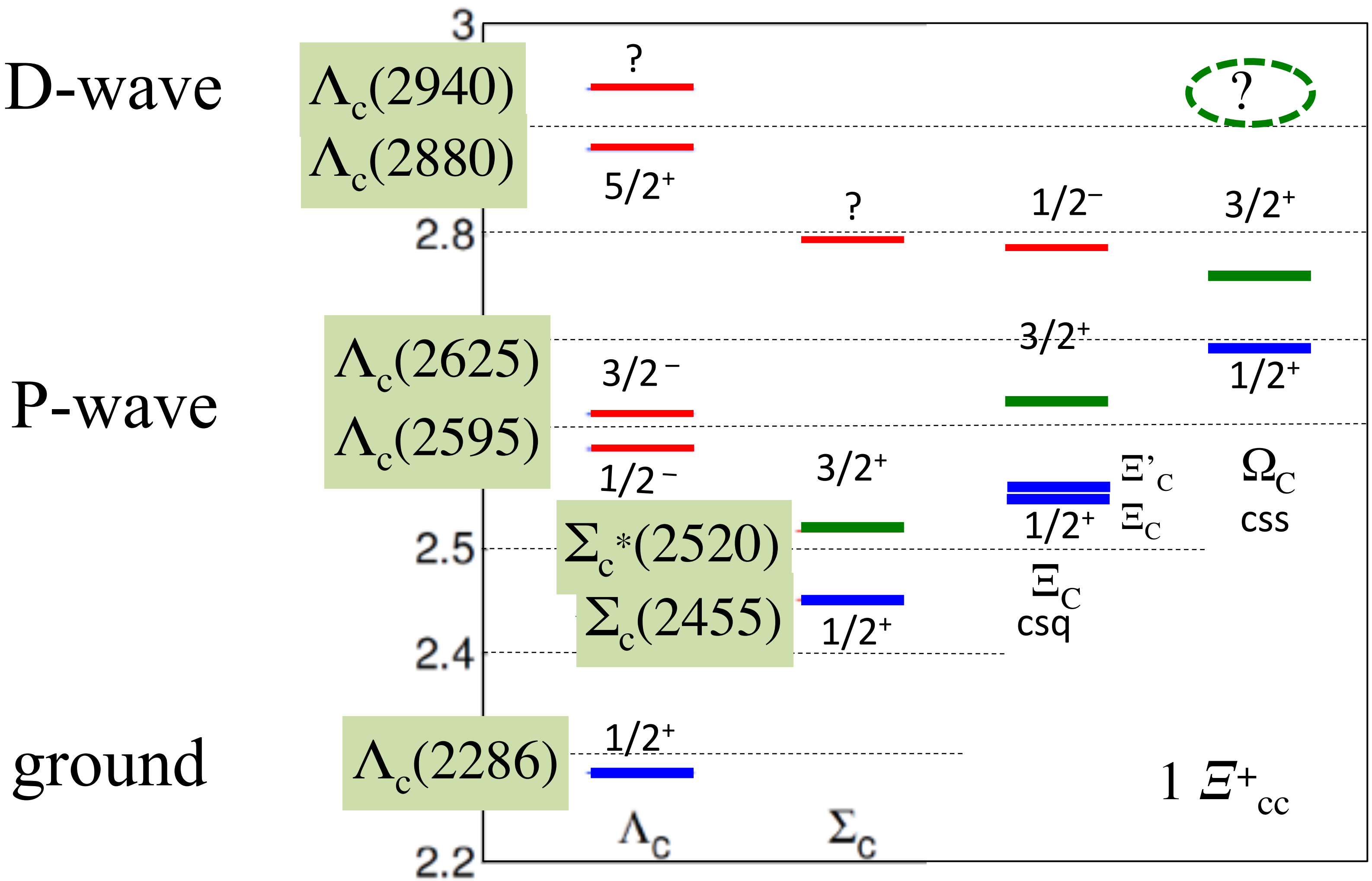


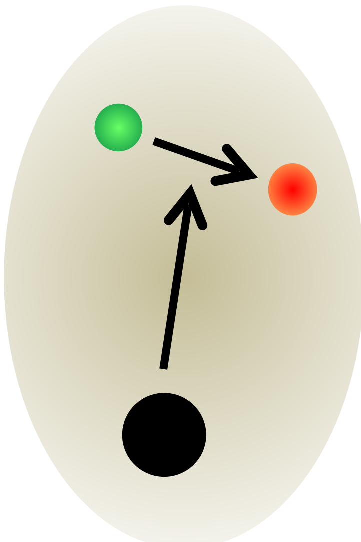
Excited states

Ground state

Known spectrum so far



Λ^*

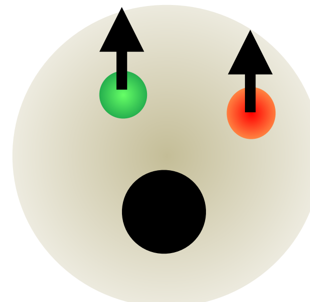


good diquark

$[[ud]_{S=0,I=0}\ c]$

$l = 1$

Σ, Σ^*

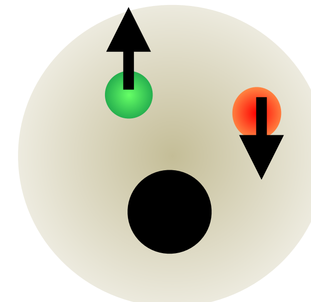


bad diquark

$[[uu]_{S=1,I=1}\ c]$

$l = 0$

Λ

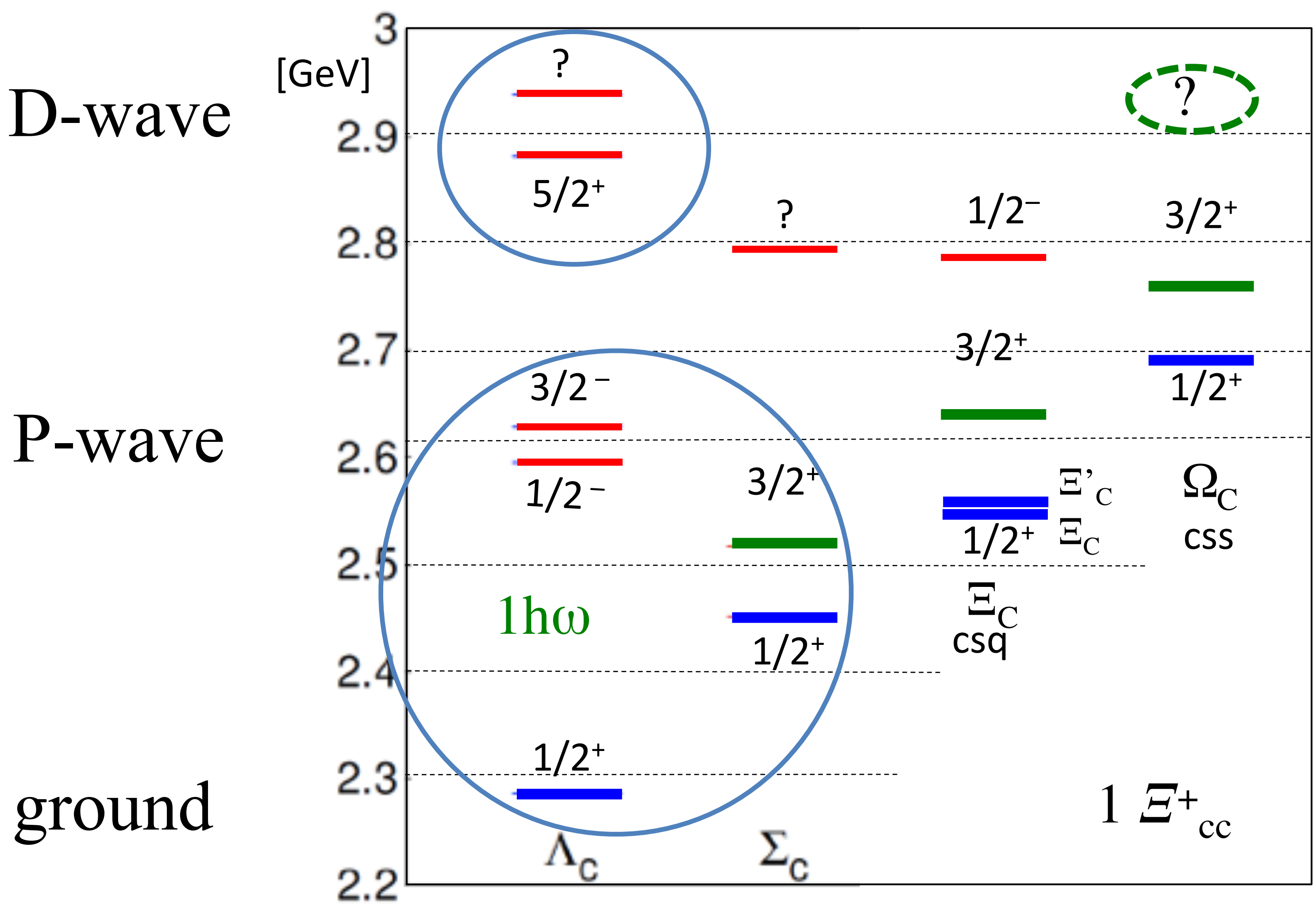


good diquark

$[[ud]_{S=0,I=0}\ c]$

$l = 0$

Known spectrum so far



Transitions between lower states

Excited
$\Lambda_c(2625, 3/2^-)$
$\Lambda_c(2595, 1/2^-)$

u↑ d↓ **c**

good diquark
in p-wave

Ground
$\Sigma_c(2520, 3/2^+)$
$\Sigma_c(2455, 1/2^+)$

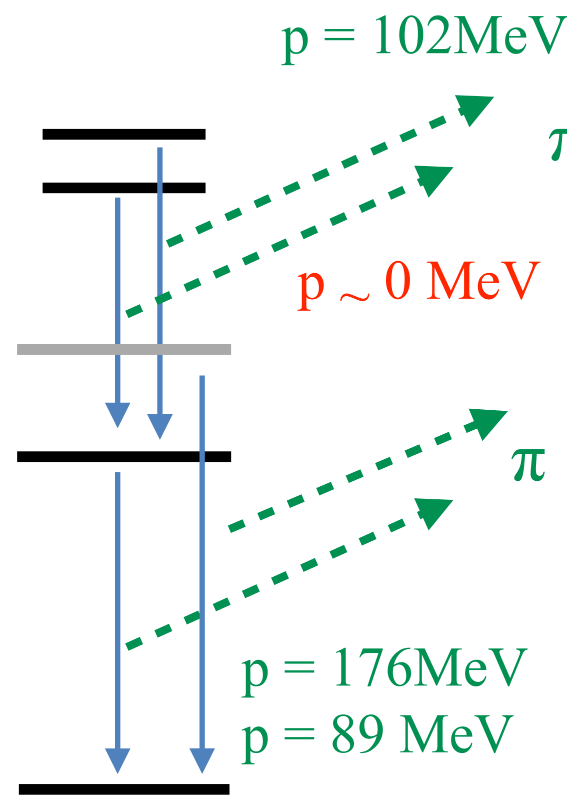
u↑ d↑ **c**

bad diquark

$\Lambda_c(2286, 1/2^+)$

u↑ d↓ **c**

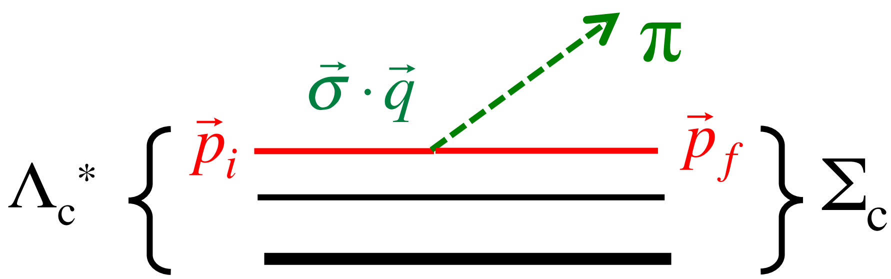
good diquark



low energy
cf: p(Δ->πN)=229 MeV

Pion coupling

- Place to look at the ***two independent*** operators

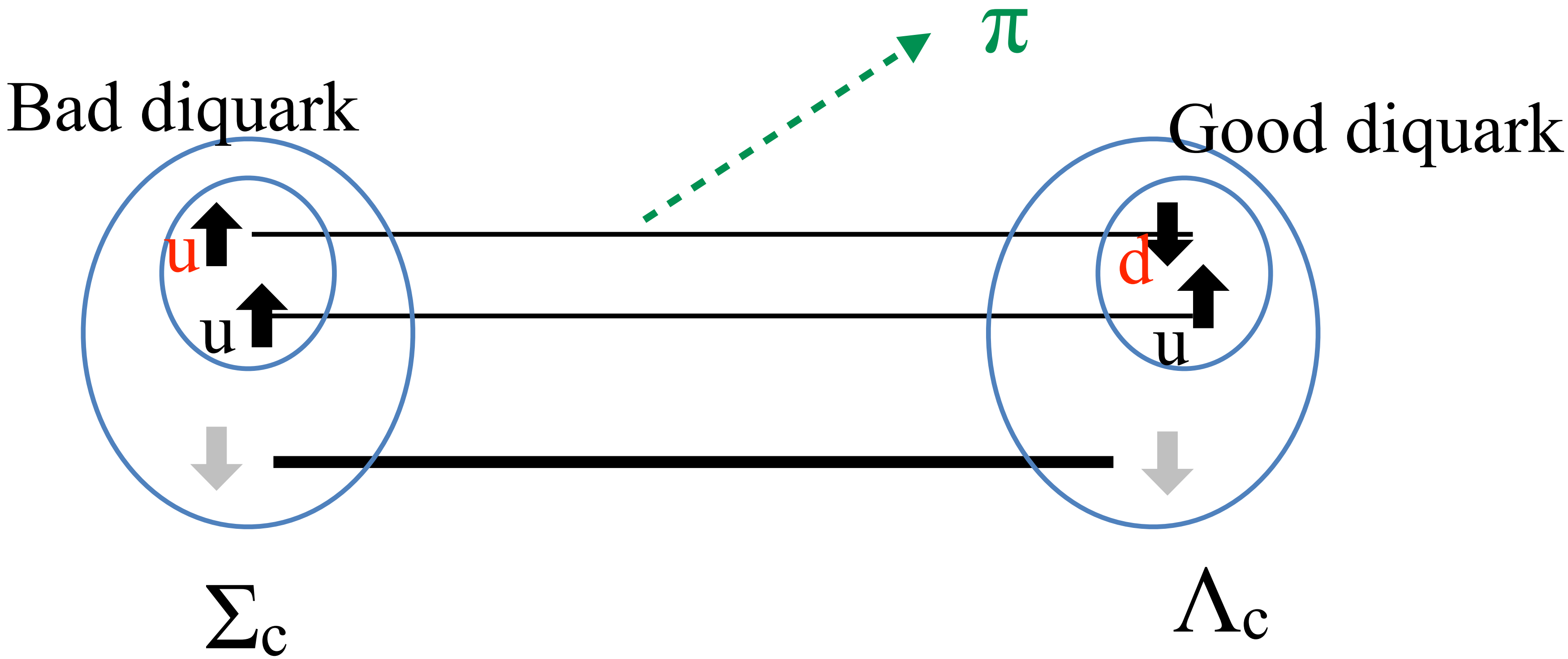


$\vec{\sigma}\cdot\vec{p}_i,\ \vec{\sigma}\cdot\vec{p}_f$

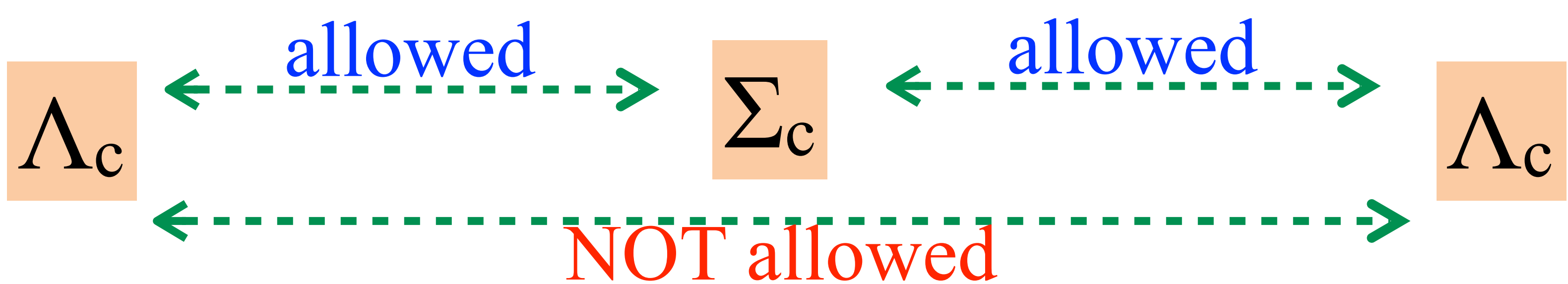
$\bar{q}\gamma_5 q\phi_\pi,\ \bar{q}\gamma^\mu\gamma_5 q\,\partial_\mu\phi_\pi$

Chiral dynamics of the NG bosons

0^-: $\boldsymbol{\sigma}\cdot\boldsymbol{p}$



- spin-isospin flip between diquark
- charm quark is a spectator



Ground → ground transitions

$\Lambda_c(2625, 3/2^-)$
$\Lambda_c(2595, 1/2^-)$

u↑ d↓ **c**

good diquark
in p-wave

$\Sigma_c(2520, 3/2^+)$
$\Sigma_c(2455, 1/2^+)$

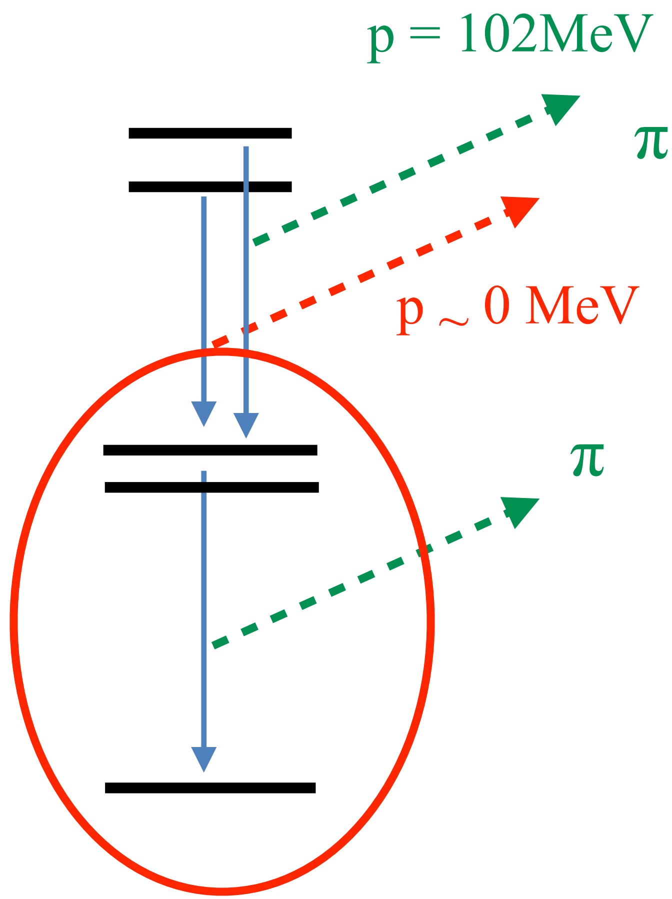
u↑ d↑ **c**

bad diquark

$\Lambda_c(2286, 1/2^+)$

u↑ d↓ **c**

good diquark

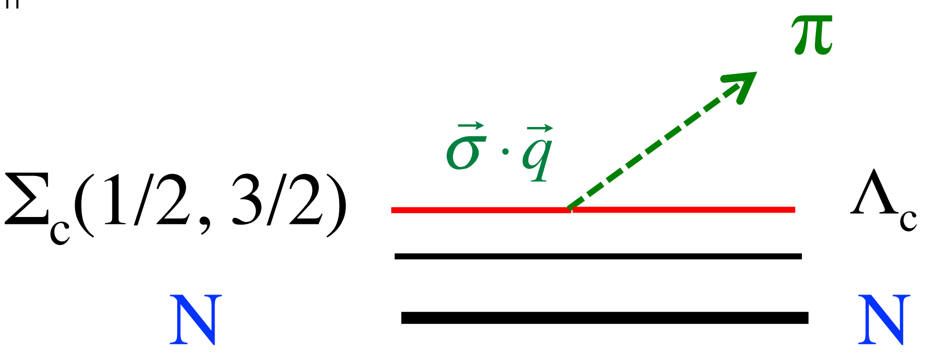


Preliminary results

Ground (1/2, 3/2$^+$) –> Ground (1/2$^+$)

$B_i J^P$ (MeV)	$\Gamma_{\rm exp}^{\rm full}(\Gamma_i)$ (MeV)	q (MeV)	$\Gamma_{\rm th}(\Sigma_c(J^+)^{++} \to \Lambda_c^{gs}(1/2^+;2286)^+\pi^+)$ (MeV)
$\Sigma_c(2455)$ $1/2^+$ (2453.98) ($\omega_\pi = 0$ limit)	2.26 (2.26) (2.26)	89	4.27–4.33
$\Sigma_c(2520)$ $3/2^+$ (2517.9) ($\omega_\pi = 0$ limit)	14.9 (14.9)	176	30.0–31.2

$$g_A{}^q = 1 \;\longrightarrow\; g_A{}^N = 5/3$$



Excited → ground transitions

$\Lambda_c(2625, 3/2^-)$
$\Lambda_c(2595, 1/2^-)$

u↑ d↓ c

good diquark
in p-wave

$\Sigma_c(2520, 3/2^+)$
$\Sigma_c(2455, 1/2^+)$

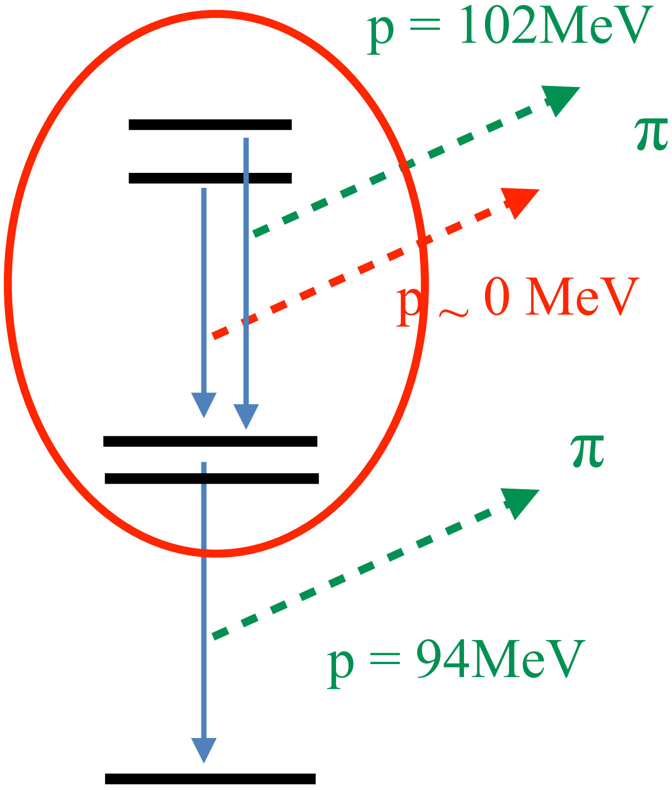
u↑ d↑ c

bad diquark

$\Lambda_c(2286, 1/2^+)$

u↑ d↓ c

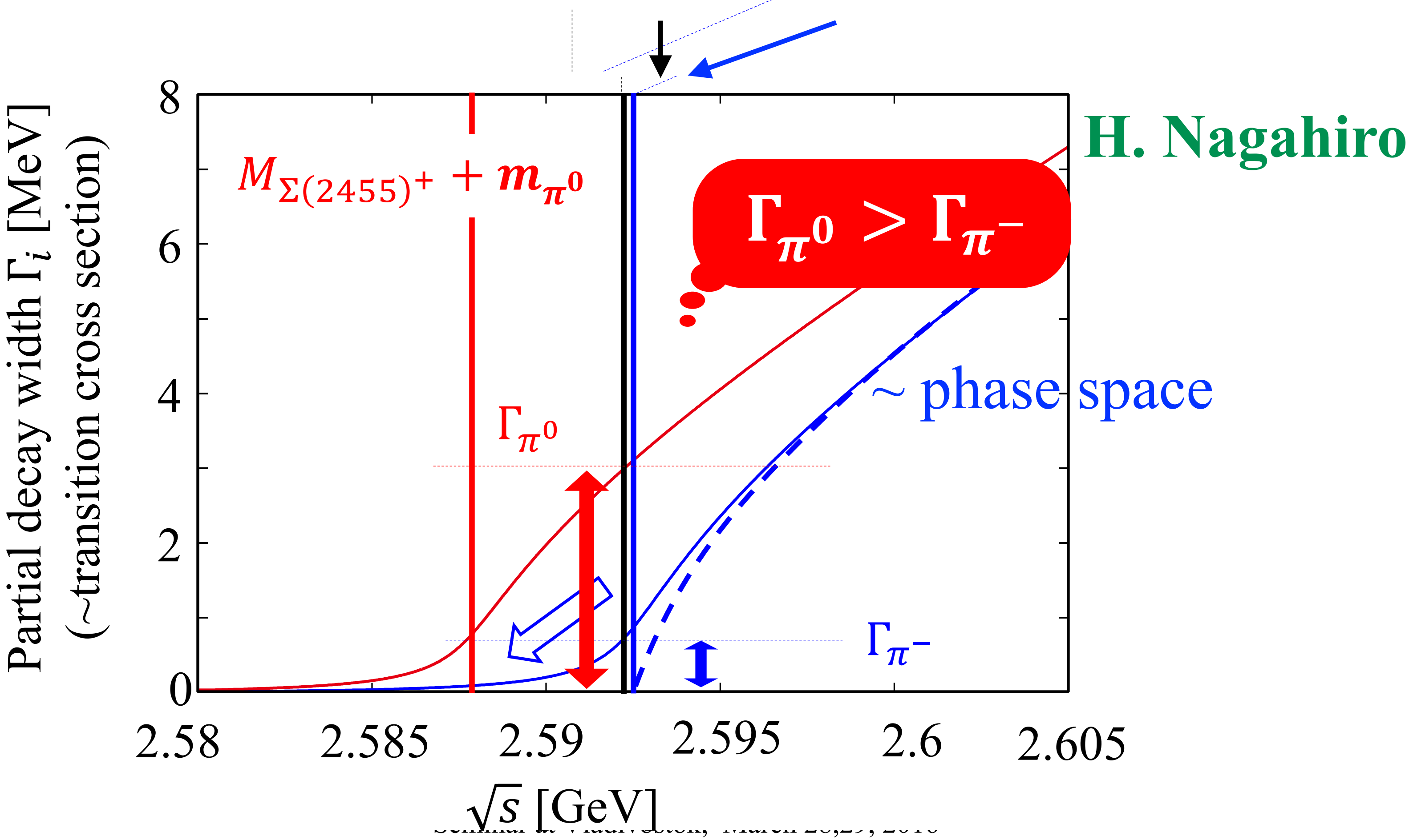
good diquark



$\Lambda_c(2595, 1/2^-) \rightarrow \Sigma_c(2455, 1/2^+)$

Isospin breaking right on the threshold

$M_{\Lambda(2595)} < M_{\Sigma(2455)^{++}} + m_{\pi^-} \implies \Gamma_{\pi^-} = 0$?



Preliminary results

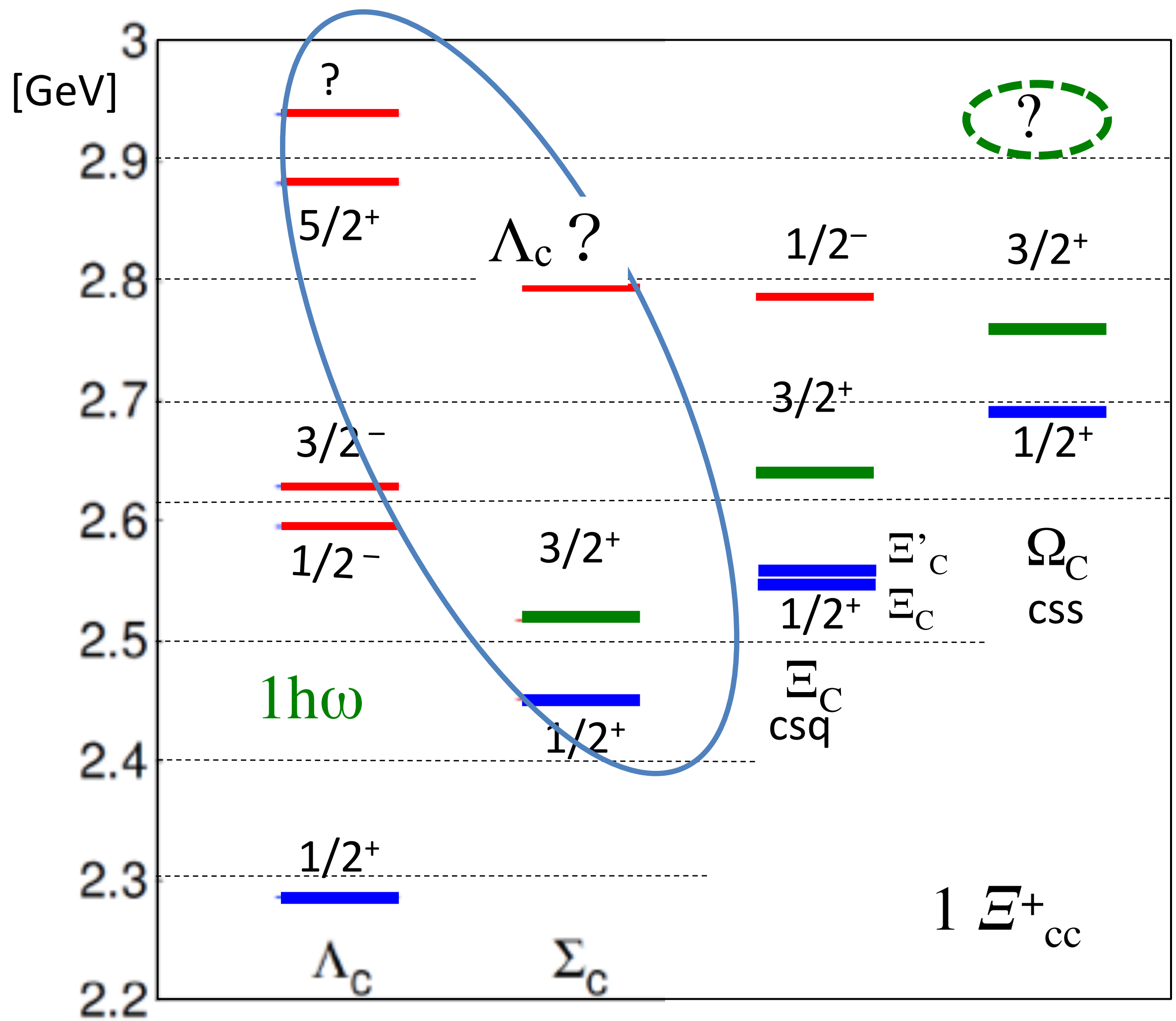
P-wave excitation –> Ground ($1/2^+$)

			$\Lambda_c(2592; 1/2^-)$	$\Lambda_c(2625; 3/2^-)$
PDG value Γ_{tot} [MeV] (3body含む)			2.6 ± 0.26	< 0.95
Γ^{theo} ($\Sigma_c \pi$) [MeV]	λ-mode	$1/2^-$	**1.7 – 3.2**	18.3 – 44.4
		$3/2^-$	-	**0.075 – 0.14**
	ρ-mode	$1/2^-$ ($j = 0$)	0	0
		$1/2^-$ ($j = 1$)	7.3 – 13.1	80 - 188
		$3/2^-$ ($j = 1$)	-	0.036 – 0.66
		$3/2^-$ ($j = 2$)	-	0.078 – 0.12
		$5/2^-$ ($j = 2$)	-	0.030 – 0.053

⇧ **7 states**

Decays —Pion emission—

On going, Nagahiro, Yasui, …



$\Lambda_c(2765), \Lambda_c(2880), \Lambda_c(2940) \to \Sigma_c\pi, \Sigma_c^*\pi$ decay widths ?

in PDG, BR($\Sigma_c^{(*)}\pi$/total) are not shown

$\to$ sum-up $\Sigma_c\pi + \Sigma_c^*\pi$ decay widths and compare to Γ_{tot}^{PDG}

			$\Lambda_c(2765)?^?$	$\Lambda_c(2880)5/2^+$	$\Lambda_c(2940)?^?$
PDG value total Γ [MeV]			50	5.8 ± 1.1	17^{+8}_{-6}
This work $\Gamma_{\Sigma\pi} + \Gamma_{\Sigma^*\pi}$ [MeV]	**λ-mode J^-**	**$1/2^-$**	**65 – 146**	**112 – 255**	**145 – 314**
		$3/2^-$	**52 – 104**	**129 – 249**	**182 – 332**
	ρ-mode J^-	**$1/2^-$ (j = 0)**	**0**	**0**	**0**
		$1/2^-$ (j = 1)	**325 – 675**	**503 – 1130**	**558 – 1301**
		$3/2^-$ (j = 1)	**211 – 414**	**440 – 921**	**537 – 1155**
		$3/2^-$ (j = 2)	**9 – 13**	**53 – 68**	**96 – 119**
		$5/2^-$ (j = 2)	**6 – 9**	**42 – 55**	**80 – 101**
	λ-mode J^+	**$1/2^+$ (j = 0)**	**1.6 – 4.4**	**3.7 – 13.5**	**3.8 – 17.5**
		$3/2^+$ (j = 2)	**4.6 – 10.8**	**16.2 – 39.2**	**24.8 − 61.4**
		$5/2^+$ (j = 2)	**1.9 − 4.3**	**11.1 − 26.1**	**19.8 − 46.5**

$\Lambda_c(2765), \Lambda_c(2880), \Lambda_c(2940) \to \Sigma_c\pi, \Sigma_c^*\pi$ decay widths ?

in PDG, BR($\Sigma_c^{(*)}\pi$/total) are not shown

$\to$ sum-up $\Sigma_c\pi + \Sigma_c^*\pi$ decay widths and compare to $\Gamma_{\rm tot}^{\rm PDG}$

			$\Lambda_c(2765)?^?$	$\Lambda_c(2880)5/2^+$	$\Lambda_c(2940)?^?$
PDG value total Γ [MeV]			50	5.8 ± 1.1	17^{+8}_{-6}
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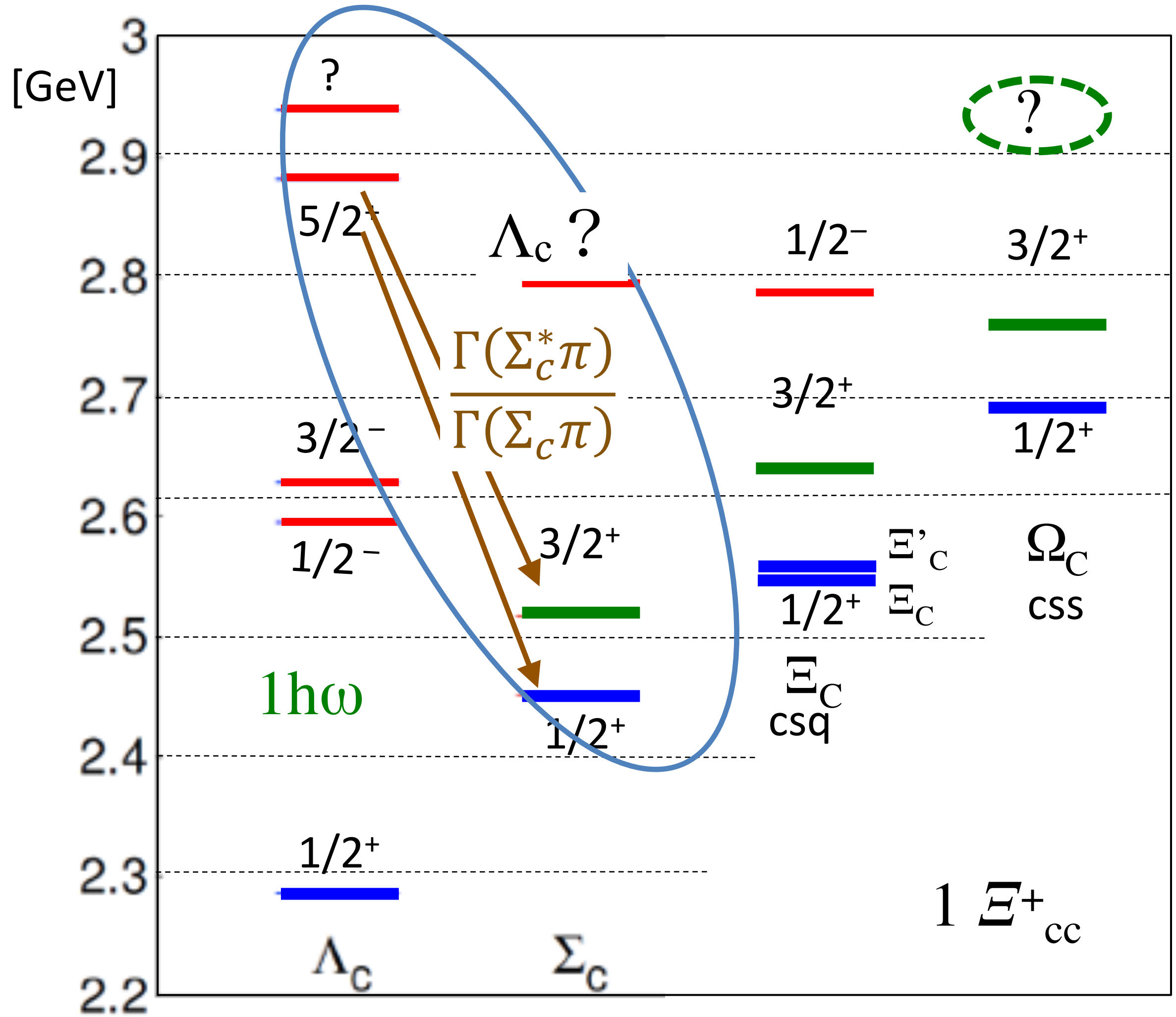
		$3/2^-$	52 – 104	~~129 – 249~~	~~182 – 332~~
	ρ-mode J$^-$	$1/2^-$ (j = 0)	0	0	0
		$1/2^-$ (j = 1)	~~325 – 675~~	~~503 – 1130~~	~~558 – 1301~~
		$3/2^-$ (j = 1)	~~211 – 414~~	~~440 – 921~~	~~537 – 1155~~
		$3/2^-$ (j = 2)	9 – 13	~~53 – 68~~	~~96 – 119~~
		$5/2^-$ (j = 2)	6 – 9	~~42 – 55~~	~~80 – 101~~
		$^+$ (j = 0)	1.6 – 4.4	3.7 – 13.5	3.8 – 17.5
		$^+$ (j = 2)	4.6 – 10.8	16.2 – 39.2	24.8 – 61.4
		$/2^+$ (j = 2)	1.9 – 4.3	11.1 – 26.1	19.8 – 46.5

$\frac{\Gamma(\Sigma_c^*\pi)}{\Gamma(\Sigma_c\pi)}$ are different

Decays —Pion emission—

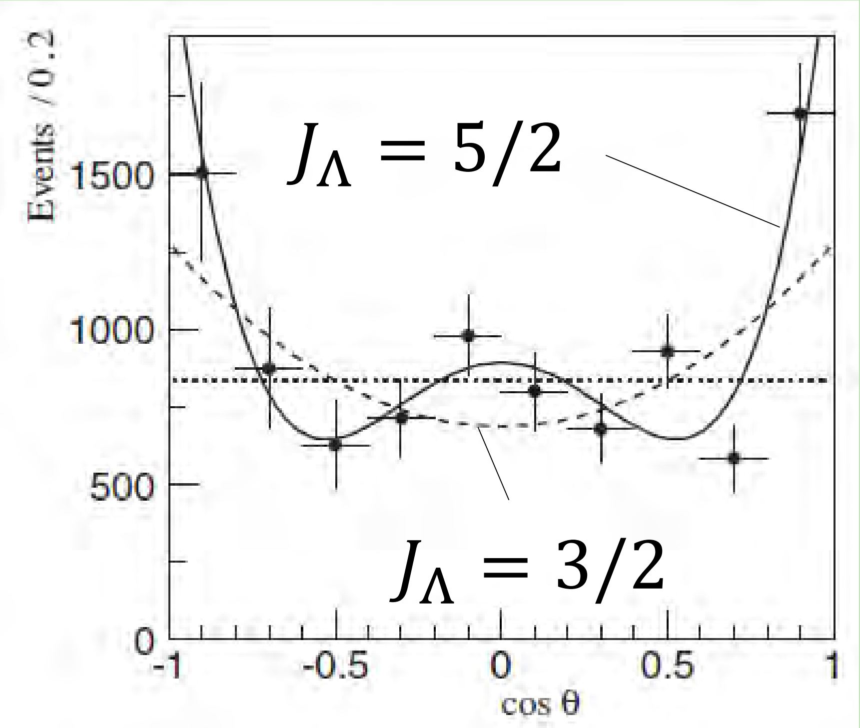
On going, Nagahiro, Yasui, …



Spin and parity of Λ(2880)

- Spin ⬅ decay angular distribution

$$\Lambda_c(2880) \to \Sigma_c(2455)\pi$$



[Mizuk et al., (Belle), PRL98(07)262001, FIG. 3]

- Parity ⬅ decay ratio

$$R = \frac{\Gamma[\Lambda_c(2880, 5/2^P) \to \Sigma_c^*(2520, 3/2^+)\pi]}{\Gamma[\Lambda_c(2880, 5/2^P) \to \Sigma_c^*(2455, 1/2^+)\pi]}$$

$$= \frac{\Gamma[F\text{ wave}] + \Gamma[P\text{ wave}]}{\Gamma[F\text{ wave}]}$$

Ignoring P wave and use the HQ symmetry

Isgur-Weise, PRL66(91)1130
Cheng et al., PRD75(07)014006

$$R = \frac{\Gamma[F\text{ wave}] + \cancel{\Gamma[P\text{ wave}]}}{\Gamma[F\text{ wave}]} \sim 0.23_{HQ}$$

$$\sim 0.225 \pm 0.062 \pm 0.025_{EXP}$$

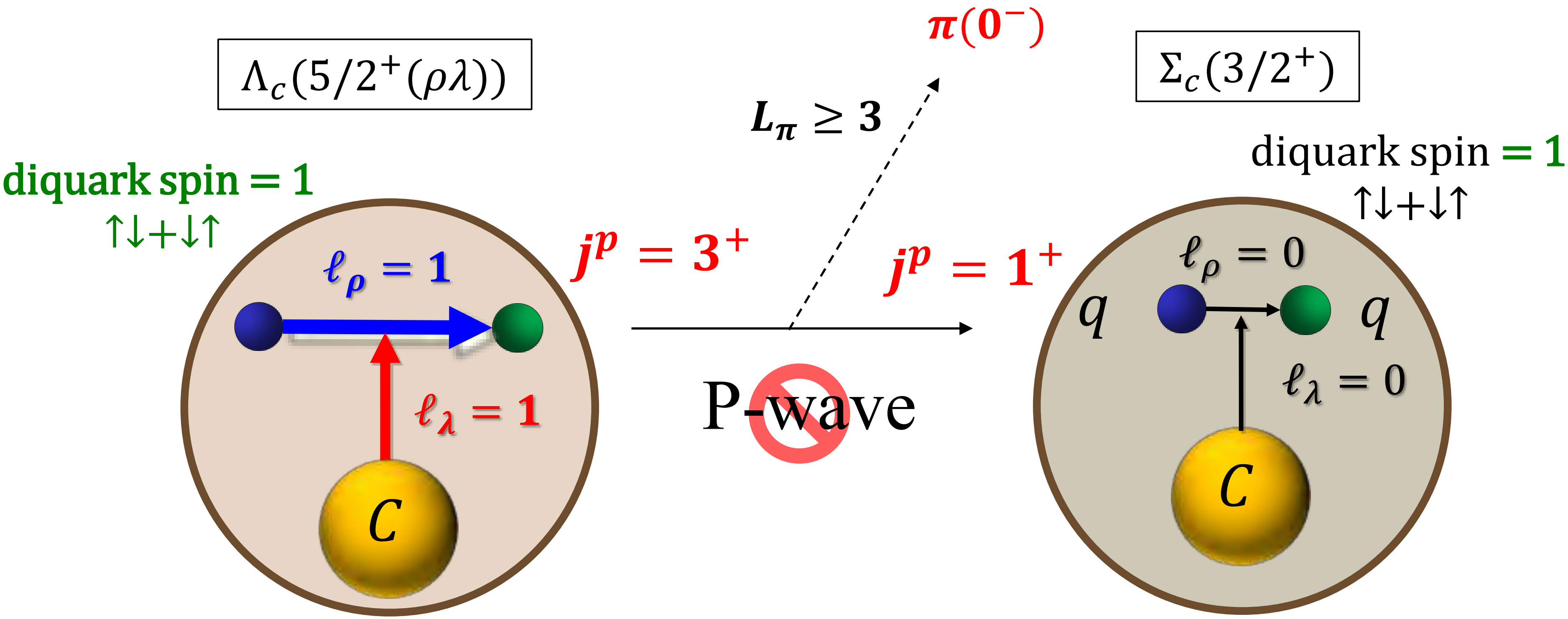
Generally, however, *P* wave exists and is larger than *F* wave term ➡ How can we explain data?

j … Brown muck spin

				$\Lambda_c(2880)5/2^+$	
				Γ (MeV)	$\boldsymbol{R = \Gamma(\Sigma_c^*\pi)/\Gamma(\Sigma_c\pi)}$
Experimental values (Belle(07))				5.8 ± 1.1	$0.225 \pm 0.062 \pm 0.025$
	$(\ell_\lambda, \ell_\rho)$	$J^P_\Lambda(j)$	$(\ell_\lambda + \ell_\rho)$		
This work	(0, 1)	$5/2^-(2)$	1	**42 –55**	**1.6 – 1.7**
	(2, 0)	$5/2^+(2)$	2	**11 – 26**	**8.2 – 8.5**
	(0, 2)	$5/2^+(2)$	2	**28 – 52**	**19.0 – 19.1**
	(1, 1)	$5/2^+(2)$	2	**52 – 110**	**27.7 – 30.4**
			1	**0.63 – 1.7**	(∞)
		$5/2^+(3)$	2	**2.8 – 5.7**	**0.41 – 0.43**

This is the only configuration to explain

Selection rule due to the brown muck (diquark)

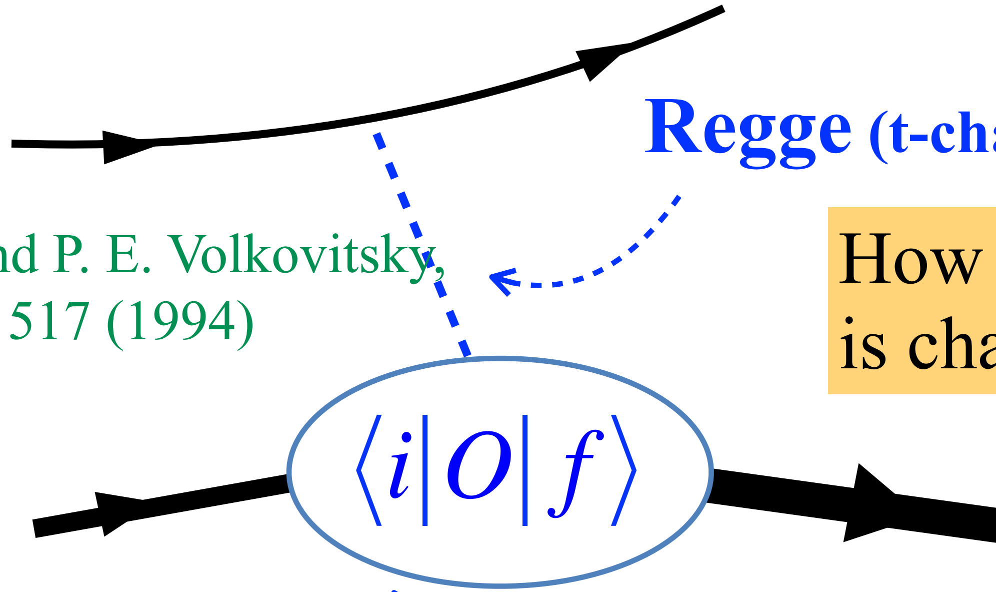


Productions

- How much $\begin{cases} \text{charm} \\ \text{excited states} \end{cases}$ are produced
- Can we study structure?

Productions

$$\pi + N \rightarrow D^* + \Lambda_c$$



Regge (t-channel) model

A. B. Kaidalov and P. E. Volkovitsky,
B. Z. Phys. C 63, 517 (1994)

How much
is charm produced?

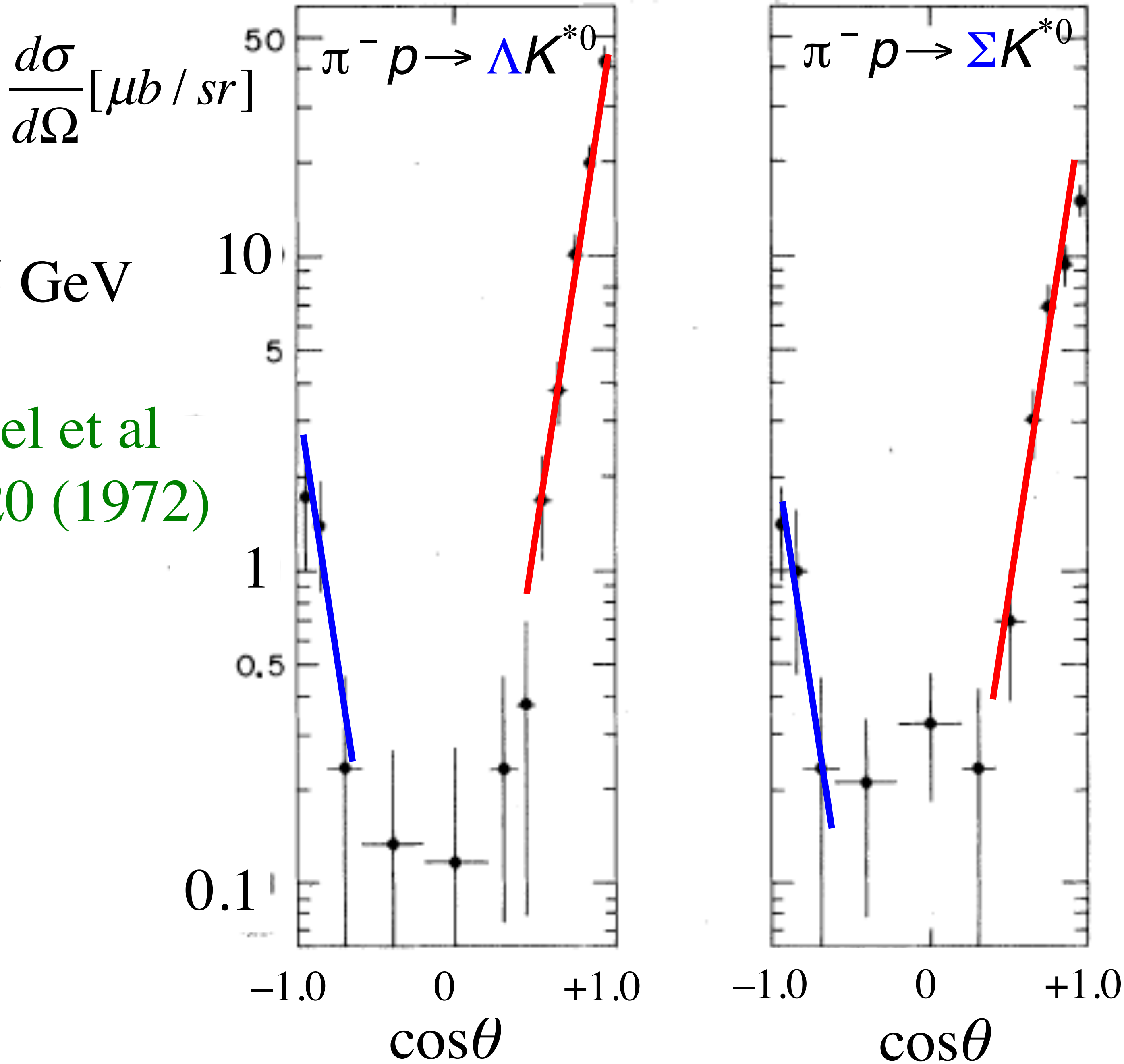
Quark model

Kim, Kim, Noumi, Shirotori, Hosaka
PTEP 2014 (2014) 10, 103D01,
PRD92 (2015) 9, 094021

How are they related to
internal structure of Λ_c*?

$p_{\pi,\,\mathrm{Lab}} = 4.5$ GeV

D.J. Krennel et al
PRD6, 1220 (1972)

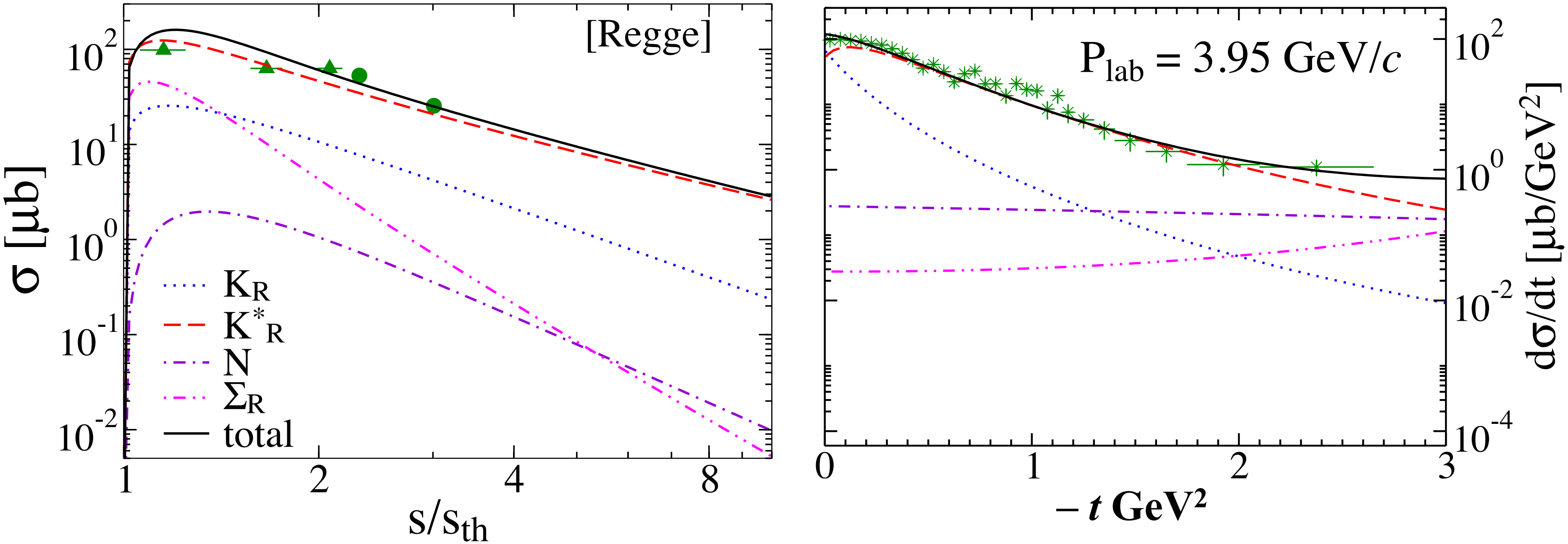


How much is charm produced?

Regge model description

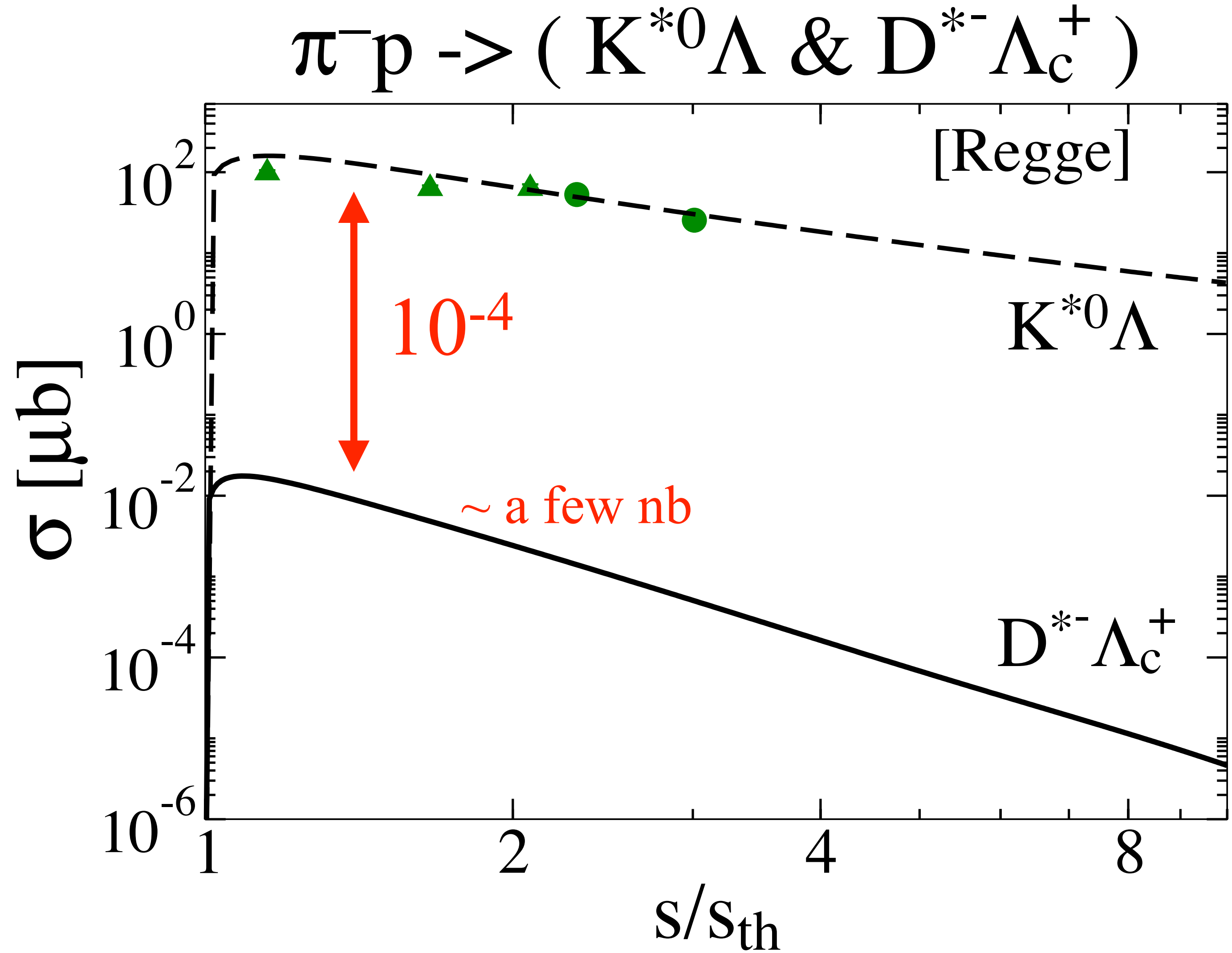
Kim Hosaka Kim Noumi, arXiv:1509.03567

$$\pi^- + N \rightarrow K^{*0} + \Lambda$$



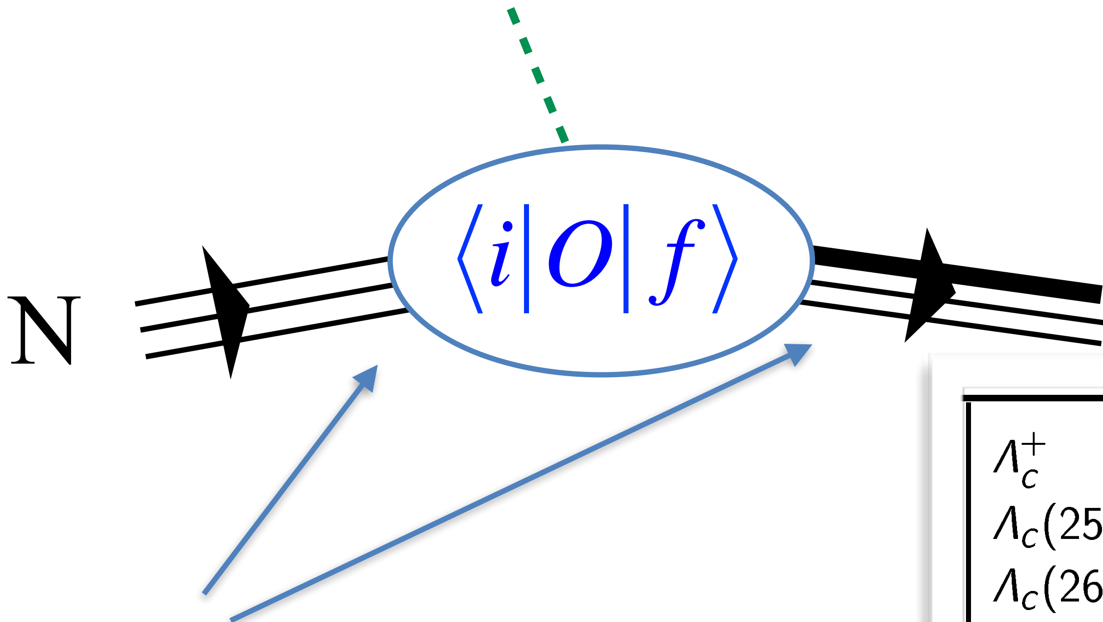
- Vector-Reggeon dominance with some pseudoscalar
- Energy dependence is also well produced

Prediction to the charm production



How are they related to internal structure?

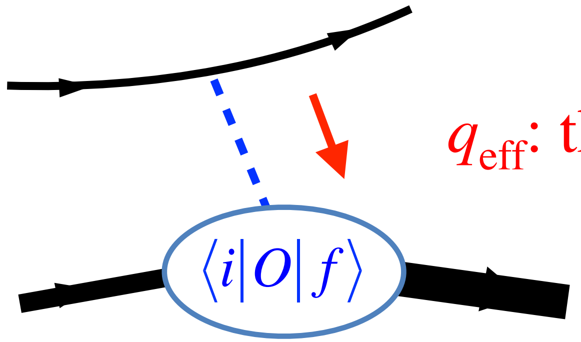
PTEP 2014 (2014) 10, 103D01



Various Y_C

Λ_c^+	****
$\Lambda_c(2595)^+$	***
$\Lambda_c(2625)^+$	***
$\Lambda_c(2765)^+$	*
$\Lambda_c(2880)^+$	***
$\Lambda_c(2940)^+$	***
$\Sigma_c(2455)$	****
$\Sigma_c(2520)$	***
$\Sigma_c(2800)$	***

Quark model wave functions
(Harmonic oscillator)



q_{eff}: the momentum transfer ~ Large

GS $\quad \langle B_c(\text{S-wave})|\vec{e}_\perp\cdot\vec{\sigma}e^{i\vec{q}_{\mathit{eff}}\cdot\vec{x}}|N(\text{S-wave})\rangle_{\mathit{radial}} \sim 1\times\exp\left(-\frac{q_{\mathit{eff}}^2}{4A^2}\right)$

Excited states

$$\langle B_c(P\text{-wave})|\vec{e}_\perp\cdot\vec{\sigma}e^{i\vec{q}_{\mathit{eff}}\cdot\vec{x}}|N(\text{S-wave})\rangle_{\mathit{radial}} \sim \left(\frac{q_{\mathit{eff}}}{A}\right)^1\times\exp\left(-\frac{q_{\mathit{eff}}^2}{4A^2}\right)$$

$$\langle B_c(D\text{-wave})|\vec{e}_\perp\cdot\vec{\sigma}e^{i\vec{q}_{\mathit{eff}}\cdot\vec{x}}|N(\text{S-wave})\rangle_{\mathit{radial}} \sim \left(\frac{q_{\mathit{eff}}}{A}\right)^2\times\exp\left(-\frac{q_{\mathit{eff}}^2}{4A^2}\right)$$

Transitions to excited states are not suppressed!

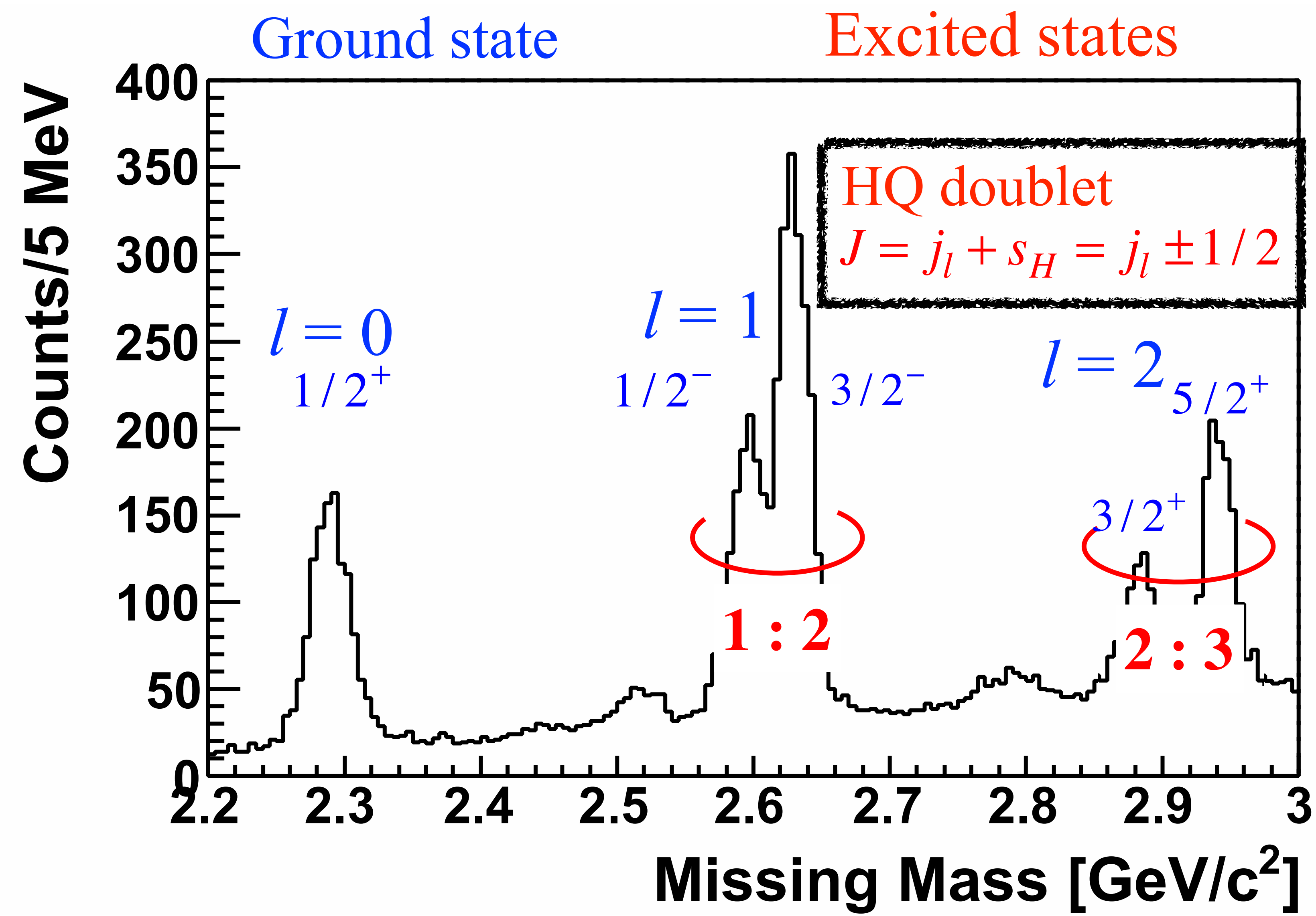
Charm $k_\pi^{CM} = 2.71$ [GeV] , $k_\pi^{Lab} = 16$ [GeV]

$l=0$	$\Lambda_c(\frac{1}{2}^+)$ 1.00	$\Sigma_c(\frac{1}{2}^+)$ 0.02	$\Sigma_c(\frac{3}{2}^+)$ 0.16					
$l=1$	$\Lambda_c(\frac{1}{2}^-)$ 0.90	$\Lambda_c(\frac{3}{2}^-)$ 1.70	$\Sigma_c(\frac{1}{2}^-)$ 0.02	$\Sigma_c(\frac{3}{2}^-)$ 0.03	$\Sigma'_c(\frac{1}{2}^-)$ 0.04	$\Sigma'_c(\frac{3}{2}^-)$ 0.19	$\Sigma'_c(\frac{5}{2}^-)$ 0.18	
$l=2$	$\Lambda_c(\frac{3}{2}^+)$ 0.50	$\Lambda_c(\frac{5}{2}^+ -)$ 0.88	$\Sigma_c(\frac{3}{2}^+)$ 0.02	$\Sigma_c(\frac{5}{2}^+)$ 0.02	$\Sigma'_c(\frac{1}{2}^+)$ 0.01	$\Sigma'_c(\frac{3}{2}^+)$ 0.03	$\Sigma'_c(\frac{5}{2}^+)$ 0.07	$\Sigma'_c(\frac{5}{2}^+)$ 0.07

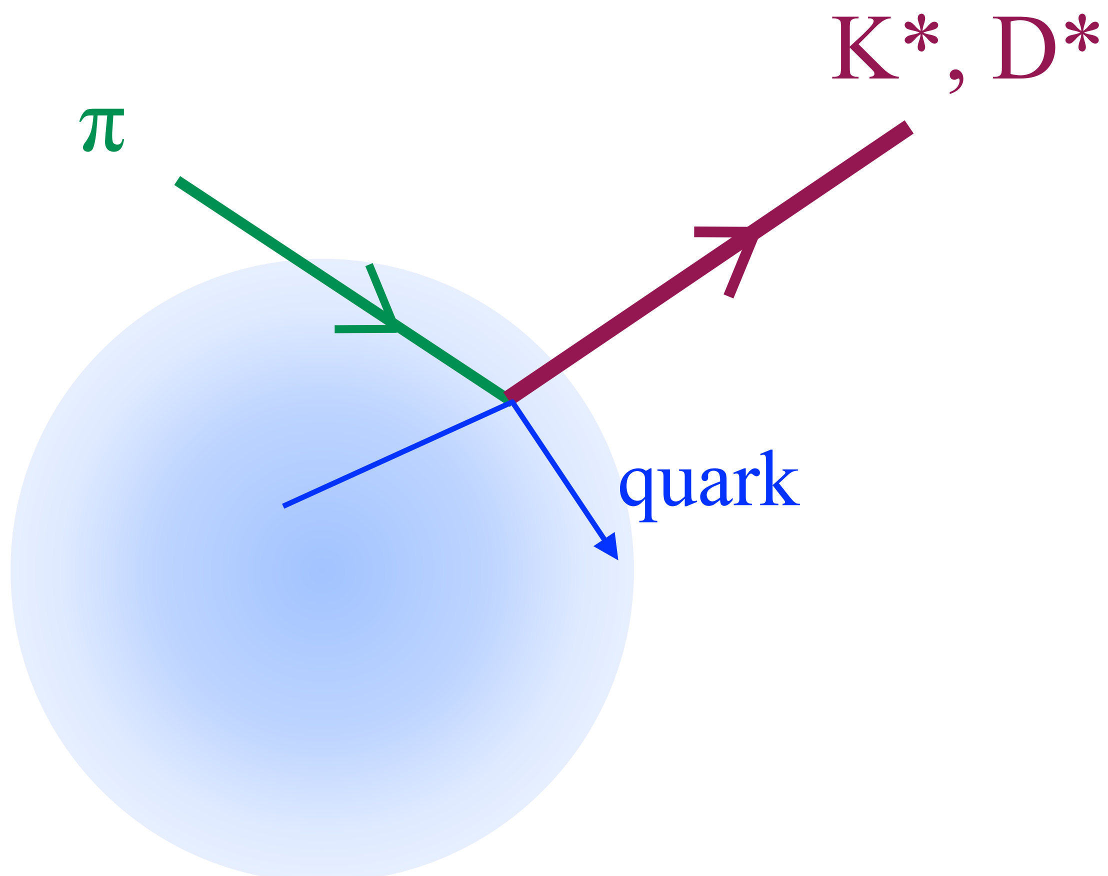
Strange $k_\pi^{CM} = 1.59$ [GeV], $k_\pi^{Lab} = 5.8$ [GeV]

$l=0$	$\Lambda(\frac{1}{2}^+)$ 1.00	$\Sigma(\frac{1}{2}^+)$ 0.067	$\Sigma(\frac{3}{2}^+)$ 0.44					
$l=1$	$\Lambda(\frac{1}{2}^-)$ 0.11	$\Lambda(\frac{3}{2}^-)$ 0.23	$\Sigma(\frac{1}{2}^-)$ 0.007	$\Sigma(\frac{3}{2}^-)$ 0.01	$\Sigma'(\frac{1}{2}^-)$ 0.01	$\Sigma'(\frac{3}{2}^-)$ 0.07	$\Sigma'(\frac{5}{2}^-)$ 0.067	
$l=2$	$\Lambda(\frac{3}{2}^+)$ 0.13	$\Lambda_c(\frac{5}{2}^+ -)$ 0.20	$\Sigma(\frac{3}{2}^+)$ 0.007	$\Sigma(\frac{5}{2}^+)$ 0.01	$\Sigma'(\frac{1}{2}^+)$ 0.004	$\Sigma'(\frac{3}{2}^+)$ 0.02	$\Sigma'(\frac{5}{2}^+)$ 0.038	$\Sigma'(\frac{5}{2}^+)$ 0.04

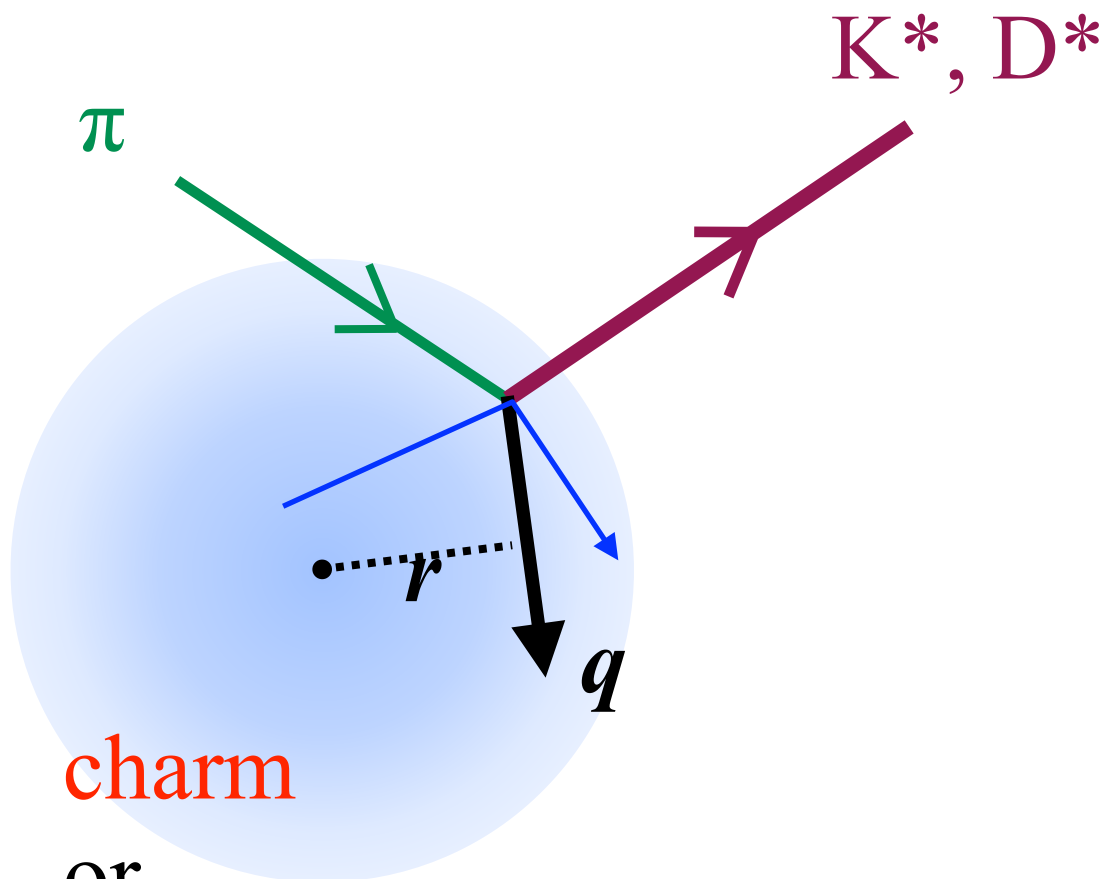
Charm production spectrum



Angular momentum dependence



Angular momentum dependence

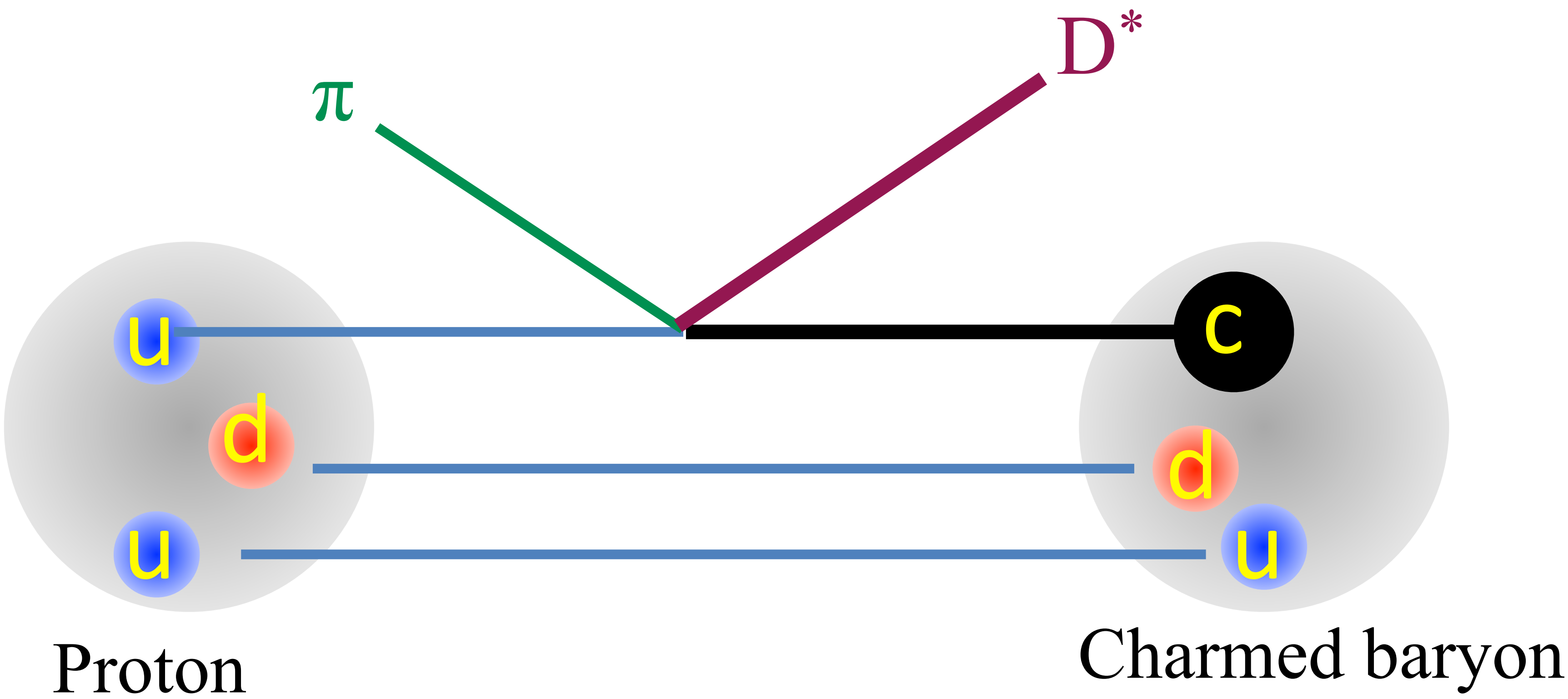


$\Delta L \sim rq \sim$ 1.5 charm

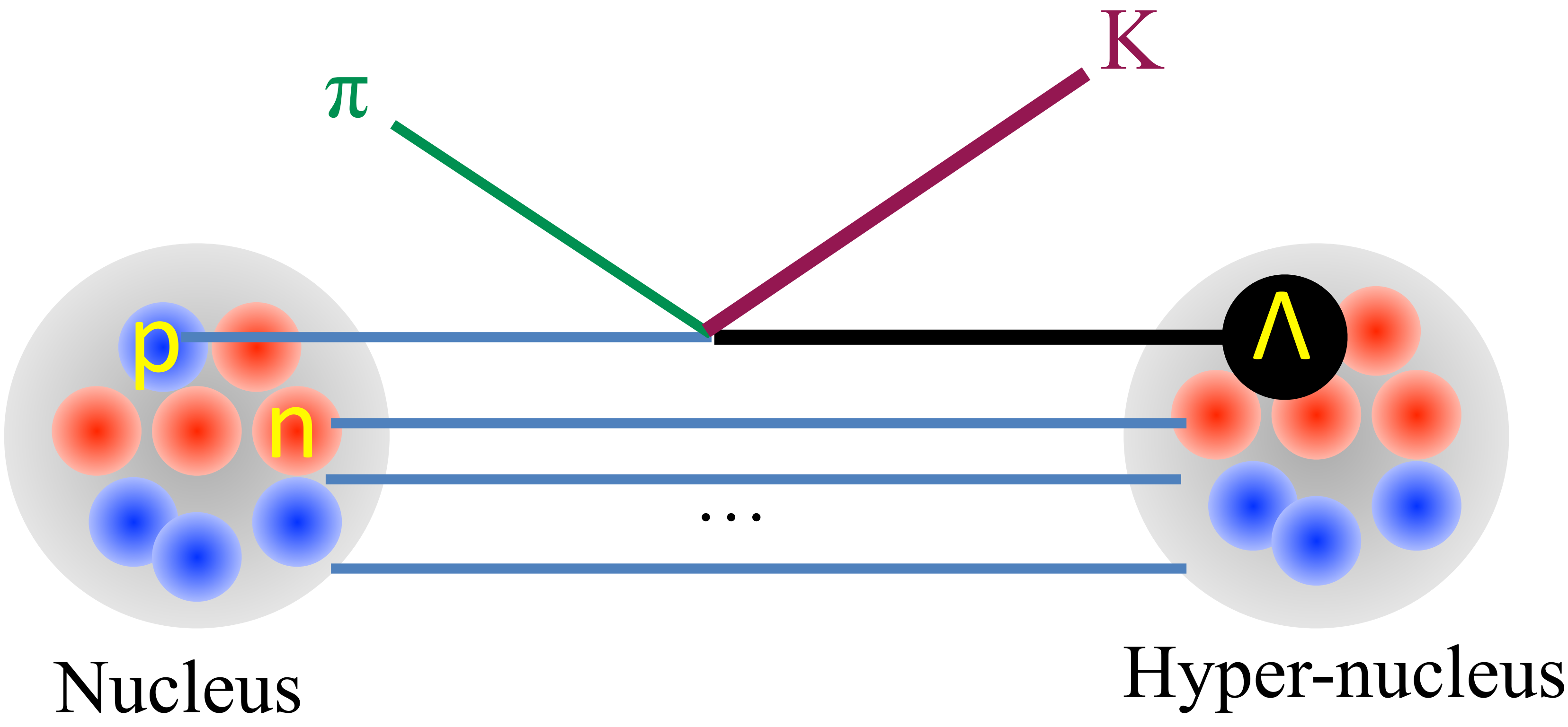
or or

0.4 strangeness

Analogy to the hyper nucleus production



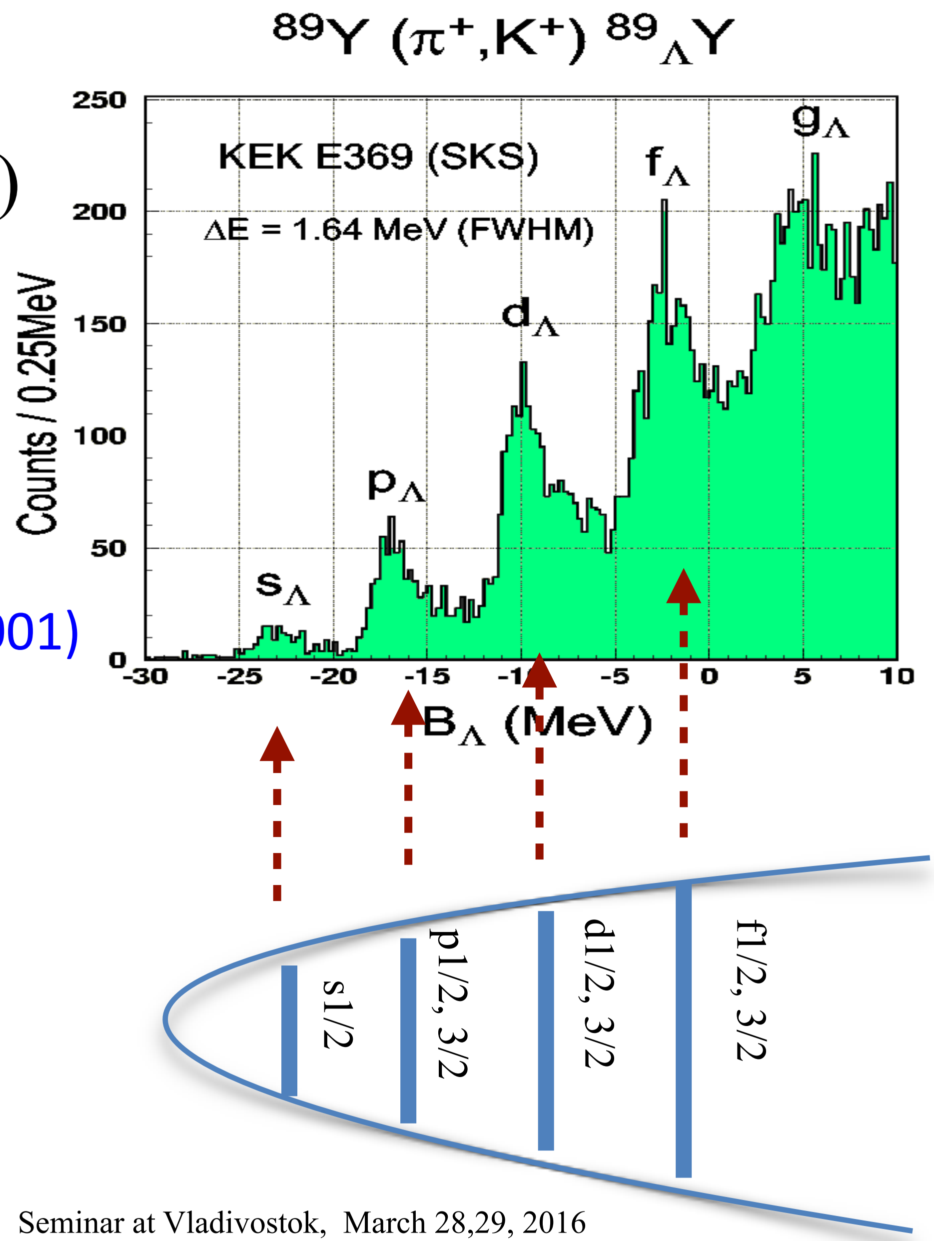
Analogy to the hyper nucleus production



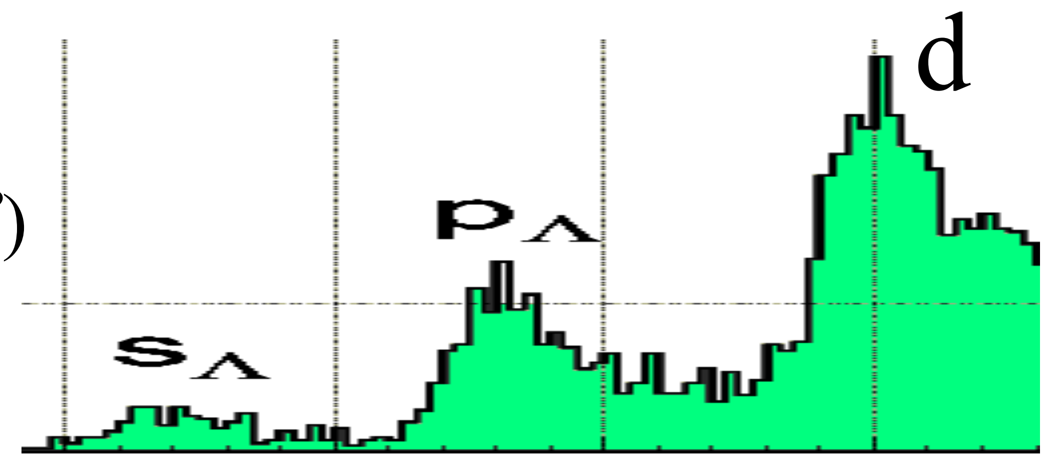
Analogy to the hyper nucleus production

$$\pi^+ + {}^{89}\mathrm{Y} \rightarrow \mathrm{K}^+ + {}^{89}{}_{\Lambda}\mathrm{Y}(J^P)$$

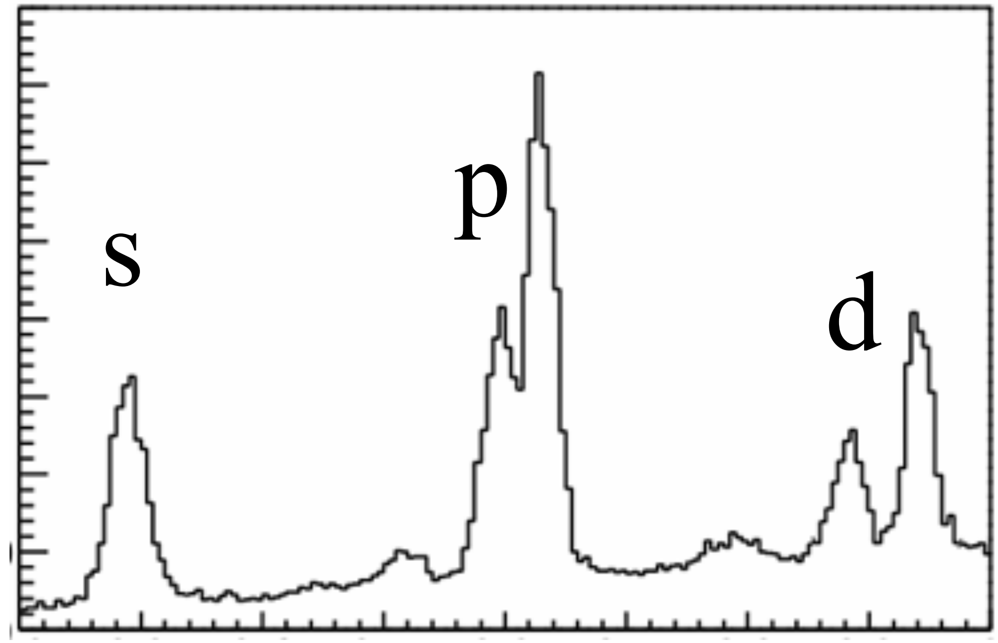
H. Hotch *et al.*,
Phys. Rev. C64, 044302(2001)



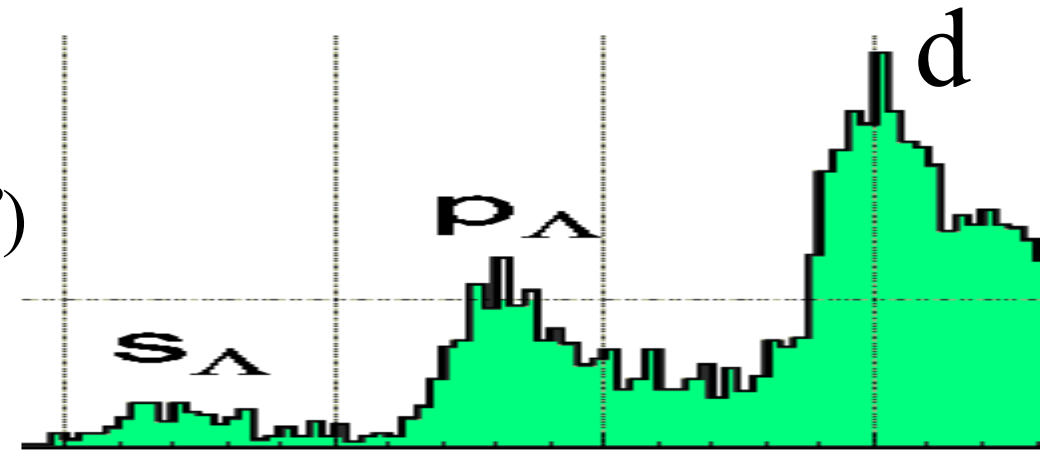
$$\pi^+ + {}^{89}\mathrm{Y} \rightarrow \mathrm{K}^+ + {}^{89}{}_{\Lambda}\mathrm{Y}(J^P)$$



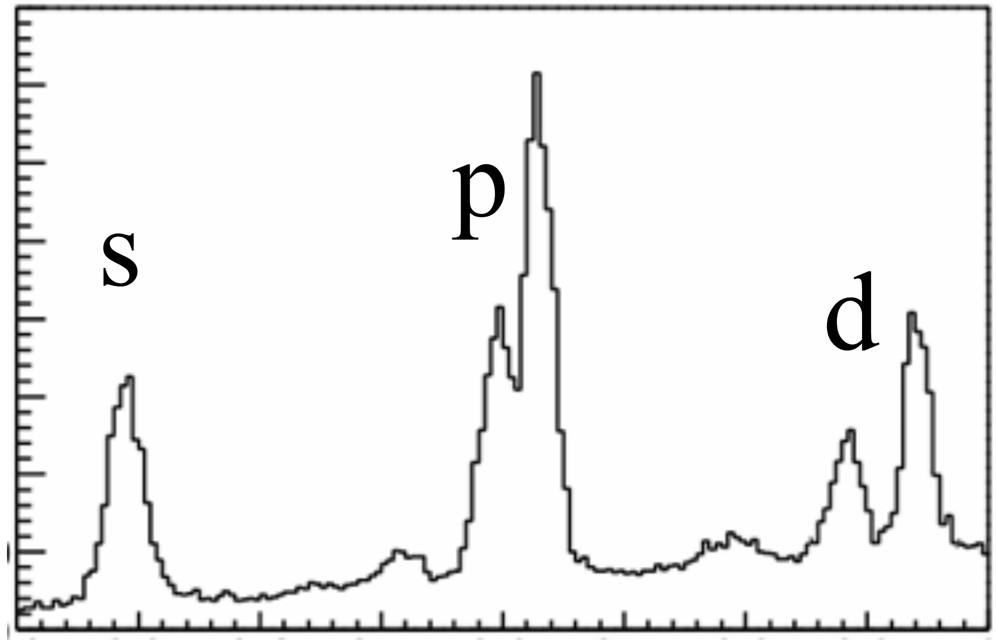
$\pi + p$
$\rightarrow D^* + B_c^*(J^P)$



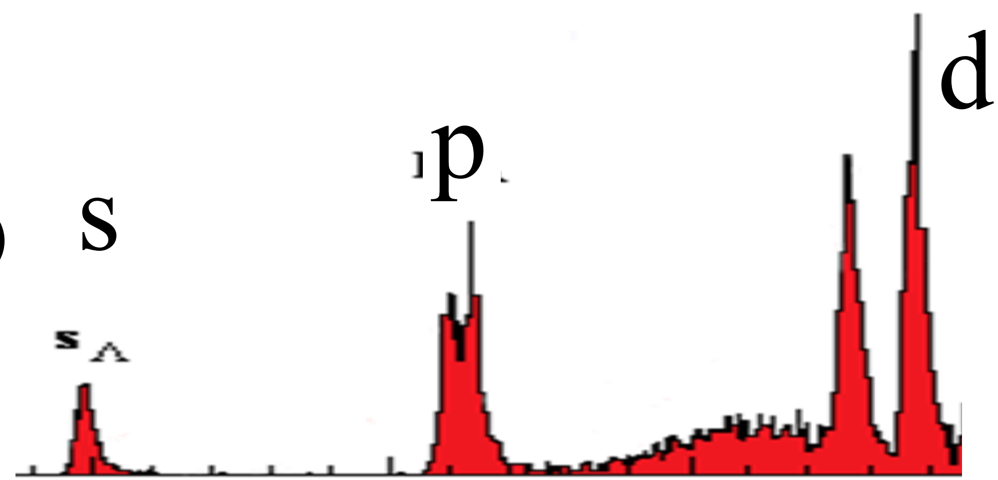
$\pi^+ + {}^{89}\mathrm{Y}$
$\rightarrow \mathrm{K}^+ + {}^{89}{}_{\Lambda}\mathrm{Y}(J^P)$



$\pi + p$
$\rightarrow D^* + B_c{}^*(J^P)$



$\pi^+ + {}^{89}\mathrm{Y}$
$\rightarrow \mathrm{K}^+ + {}^{89}{}_{\Lambda}\mathrm{Y}(J^P)$



Summary

- Heavy quarks identify and disentangle different modes of baryons, ρ and λ modes => diquark dynamics?
- Decays are useful to further understand the structure and fundamental nature of hadron physics = QCD
- Productions are useful for structure study
  A similar feature with hyper nuclei
- Charm baryons could be abundantly produced

Further studies at J-PARC