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Ξ resonances in the weak decay of Ξ_c

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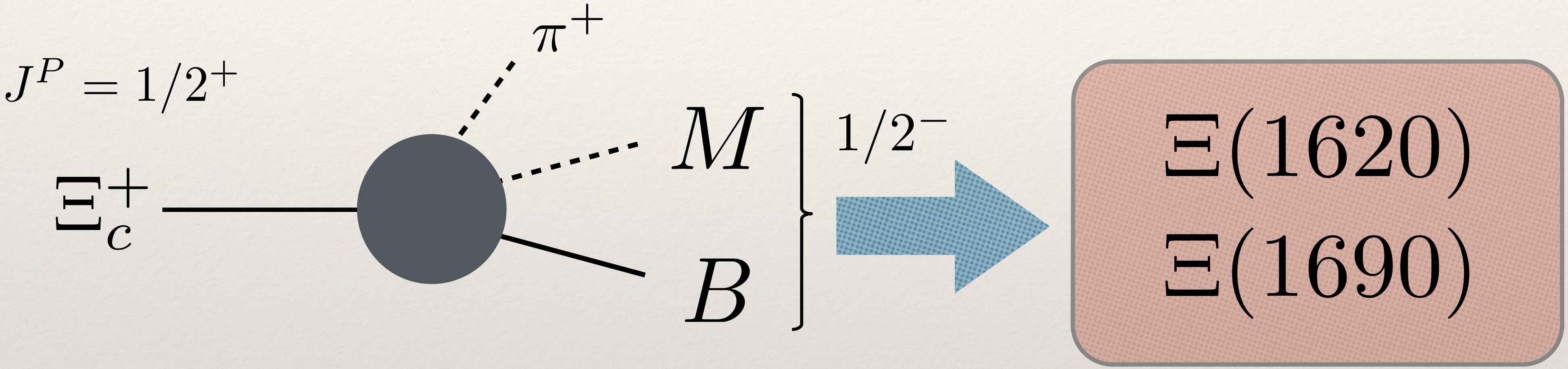
Introduction

Ξ_c -decay



- Weak decay
- $\bar{q}q$ creation
- Final State Interaction

exp.) Belle, BESIII, …

- existence…?
- J^P…?
- theoretically controversial

❖ Ξ resonances

- a small number of measured Ξ*
- poor information about J^P

❖ Ξ(1620)

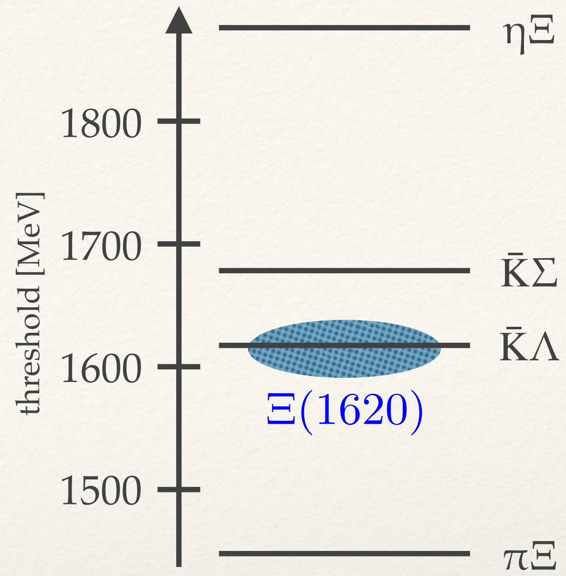
— one-star in PDG

— $J^P = ?^?$

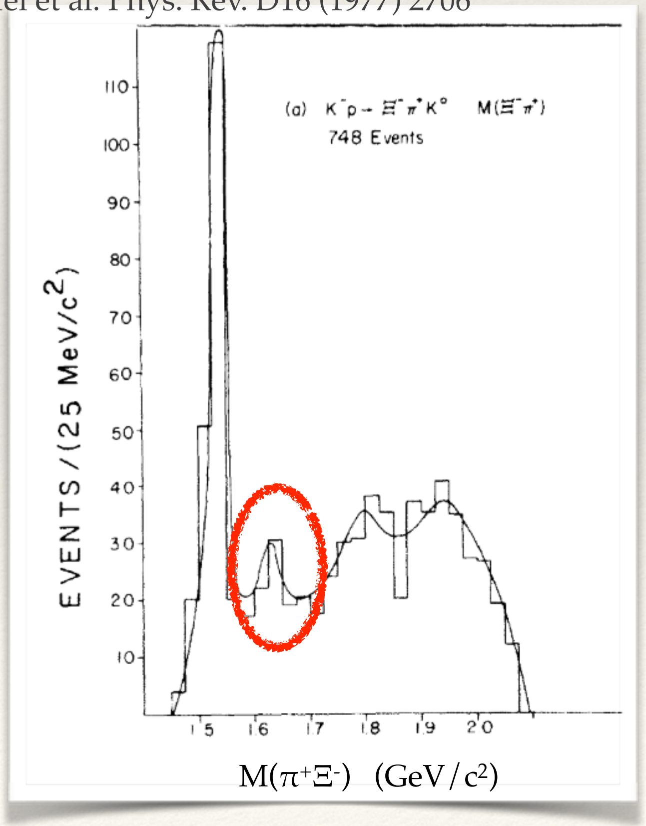
exp.) $K^- p \to K^0\ (\pi^+ \Xi^-)$

theory) mainly coupled to
$\pi\Xi$ and $\bar{K}\Lambda$ channels

Ramos, Oset, Benhold, Phys. Rev. Lett. 89 (2002) 252001



Briefel et al. Phys. Rev. D16 (1977) 2706

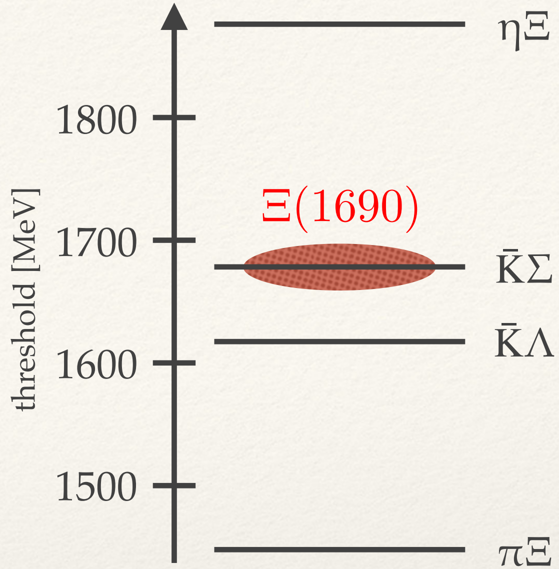


❖ Ξ(1690) resonance

— three-star in PDG

— $(M, \Gamma) = (1690 \pm 10, < 30)$ MeV

— $J^P = ?^?$



theory)

- J^P assignment is controversial
- mainly coupled to
  K̄Σ and ηΞ channels

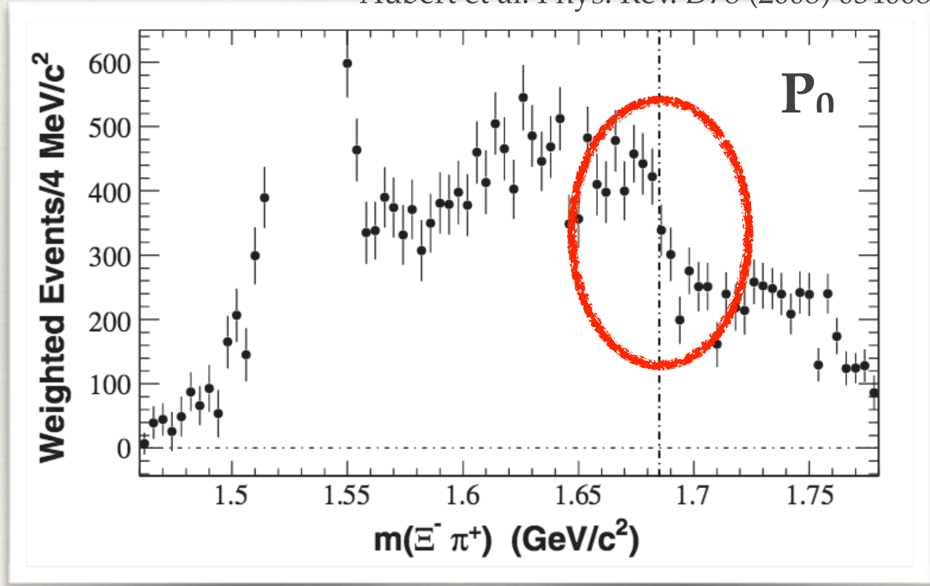
Garcia-Recio, Lutz, Nieves, Phys. Lett. B 582 (2004) 49

exp.)

- K^-, hyperon + nucleon
  → (K̄Σ), (K̄Λ), (πΞ) distribution
- $\Lambda_c \to K^+$ (K̄Λ), (K̄Σ), (πΞ)

some evidence of $J^P=1/2^-$

Aubert et al. Phys. Rev. D78 (2008) 034008



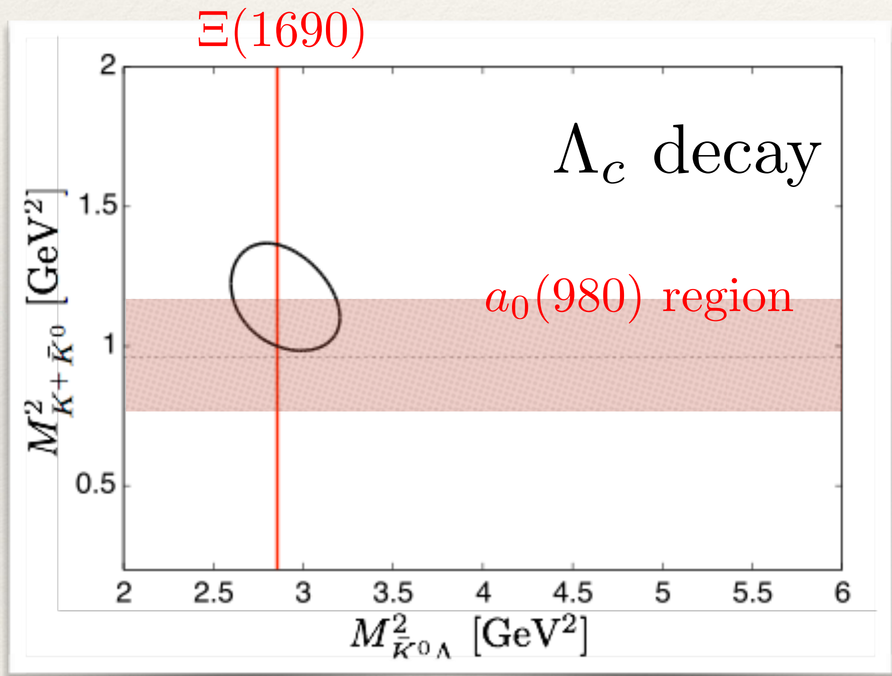
Legendre polynomial moment :

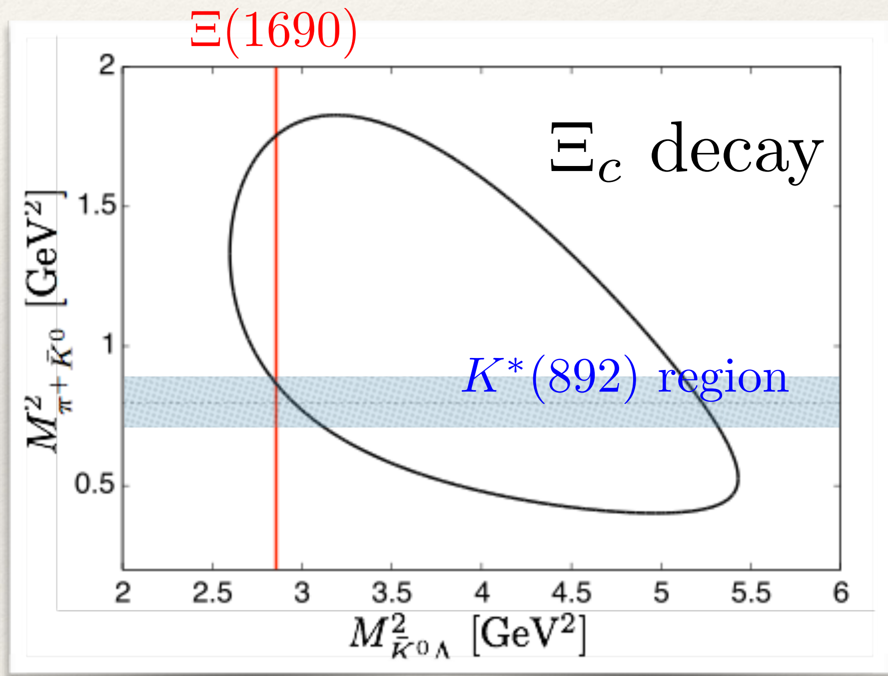
$$P_0 = \frac{1}{N}\int_{-1}^{1}\frac{dN}{d\cos\theta_{\Xi^-}}P_0(\cos\theta_{\Xi^-})d\cos\theta_{\Xi^-}$$

$$= \frac{1}{\sqrt{2}}\left[|S^{1/2}|^2 + |P^{1/2}|^2 + |P^{3/2}|^2 + |D^{3/2}|^2 + |D^{5/2}|^2\right]$$

❖ Ξ (1690) exp.

- Ξ(1690) coupling to $\pi\Xi$ channel is too weak.
  → $\bar{K}\Lambda$, $\bar{K}\Sigma$ are the ideal channels
- In $\Lambda_c \to K^+ (\bar{K}\Lambda)$ reaction, $a_0(980)$ contribution is obstructive.





In Ξc → π^+ ($\bar{K}\Lambda$) process,

other interaction effect is relatively small.

❖ Ξ (1690) exp.

- Ξ(1690) coupling to $\pi\Xi$ channel is too weak.
  $\rightarrow$ $\bar{K}\Lambda$, $\bar{K}\Sigma$ are the ideal channels
- In $\Lambda_c \rightarrow K^+ (\bar{K}\Lambda)$ reaction, $a_0(980)$ contribution is obstructive.

$$\Xi_c^+ \rightarrow \pi^+ (\bar{K}^0\Lambda)$$

I_3 : +1 +1/2

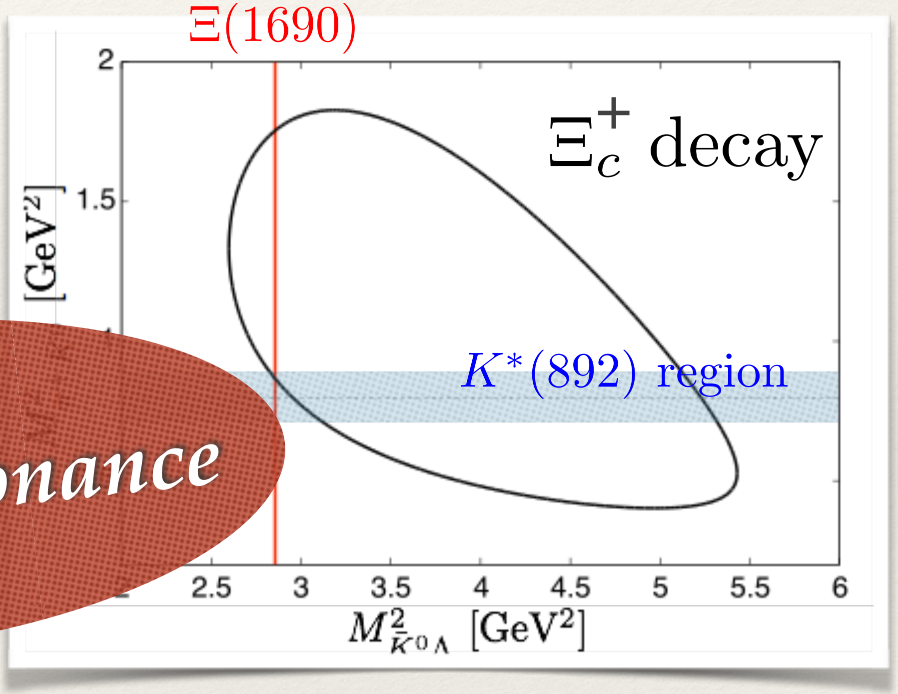
$\rightarrow$ $I = 3/2$ only

cf)

$$\Xi_c^0 \rightarrow \pi^+ (K^-\Lambda)$$

$I = 1/2, 3/2$

no meson resonance

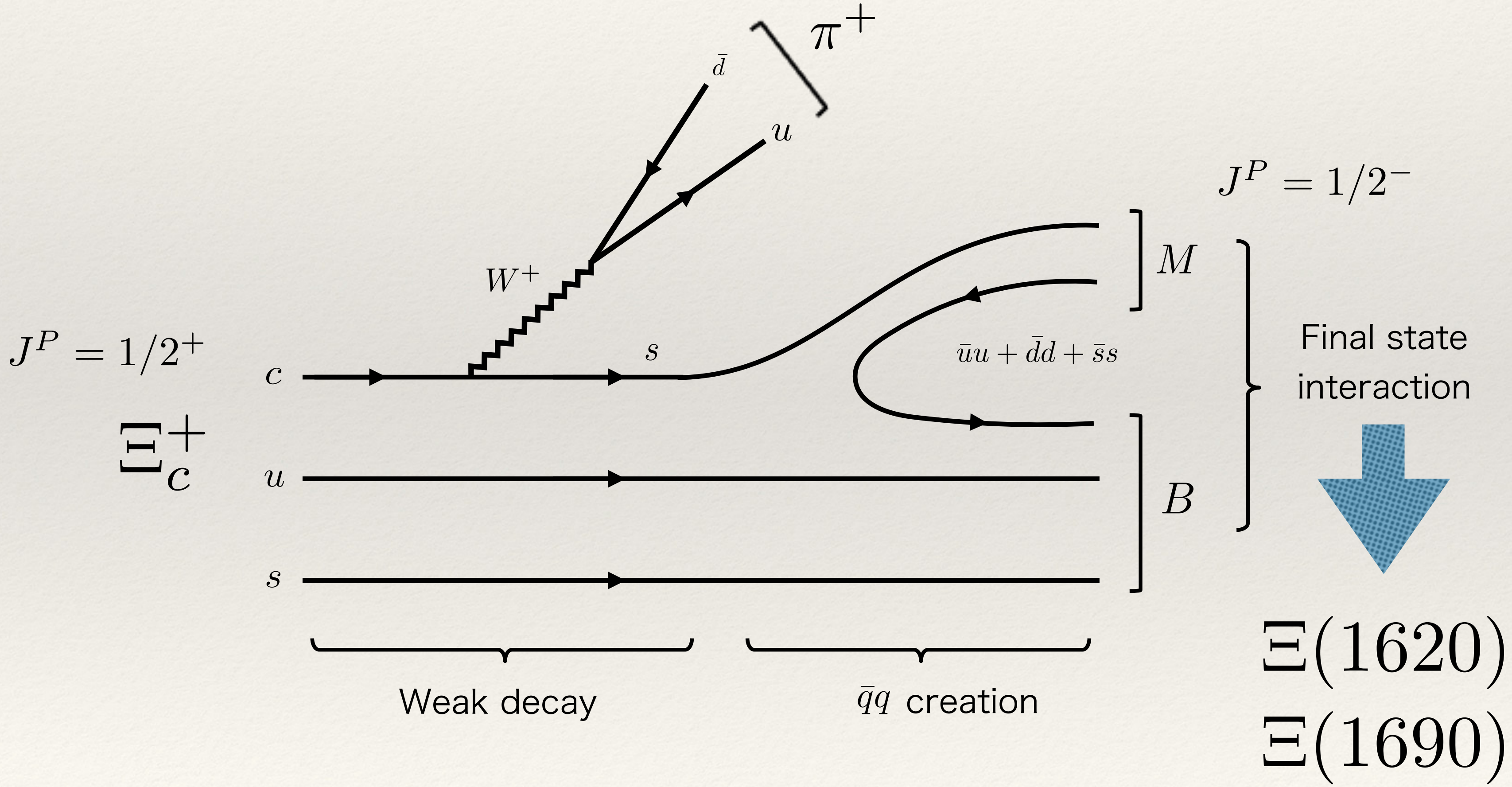


In $\Xi_c \rightarrow \pi^+ (\bar{K}\Lambda)$ process,

other interaction effect is relatively small.

Formalism

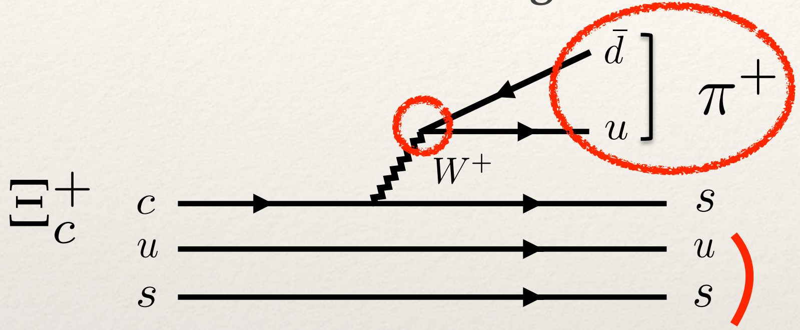
Considering Cabibbo-Kobayashi-Maskawa matrix and diquark correlation, the following diagram is favored.



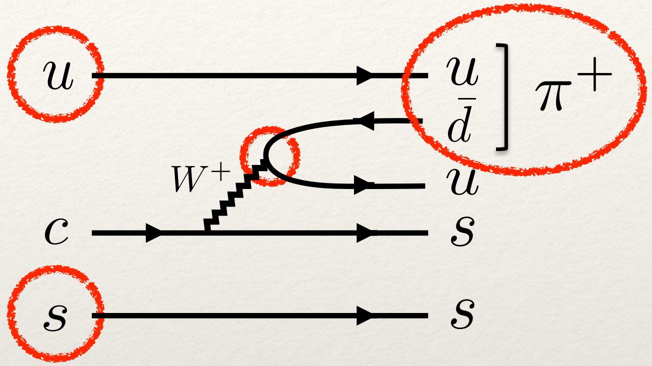
Weak decay

Cabibbo favored diagrams

high momentum



(a) $|\{qq\}\bar{\mathbf{3}}_c(A)\bar{\mathbf{3}}_f(A)0^+(A)\rangle$



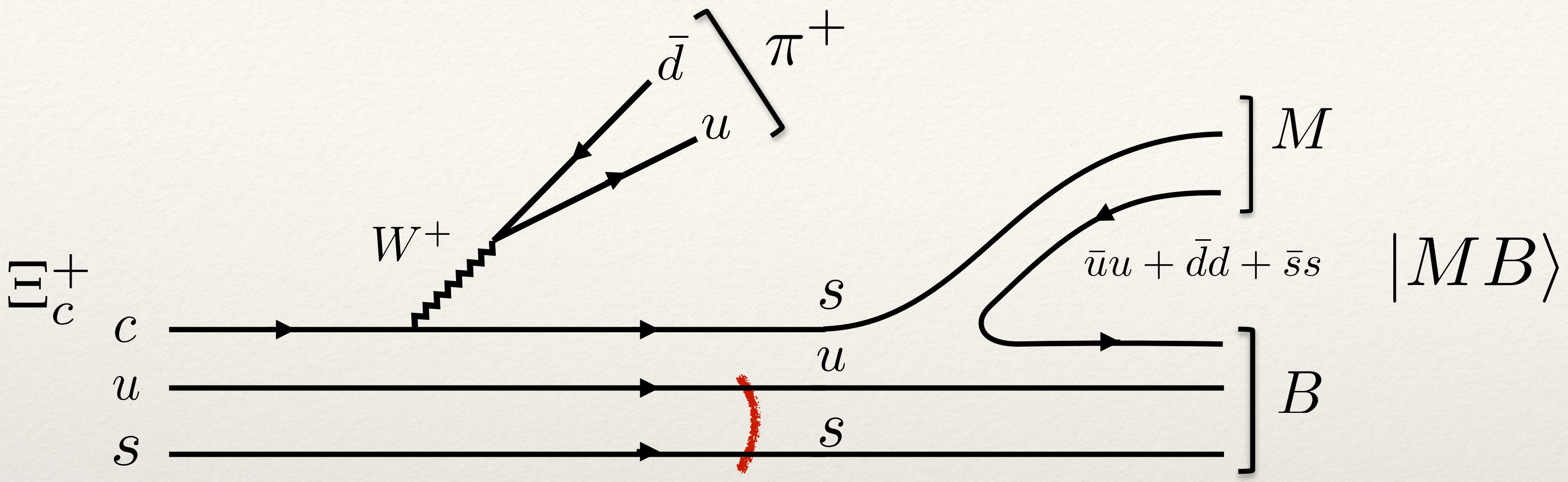
(b)

" good diquark " Jaffe, Phys. Rept. 409, 1 (2005)

	color	diquark	kinematics
(a)	○	○	○
(b)	×	×	×

Diagram(a) is the most favored

❖ q̄q creation



$$|\{qq\}\bar{\mathbf{3}}_c(A)\bar{\mathbf{3}}_f(A)0^+(A)\rangle$$

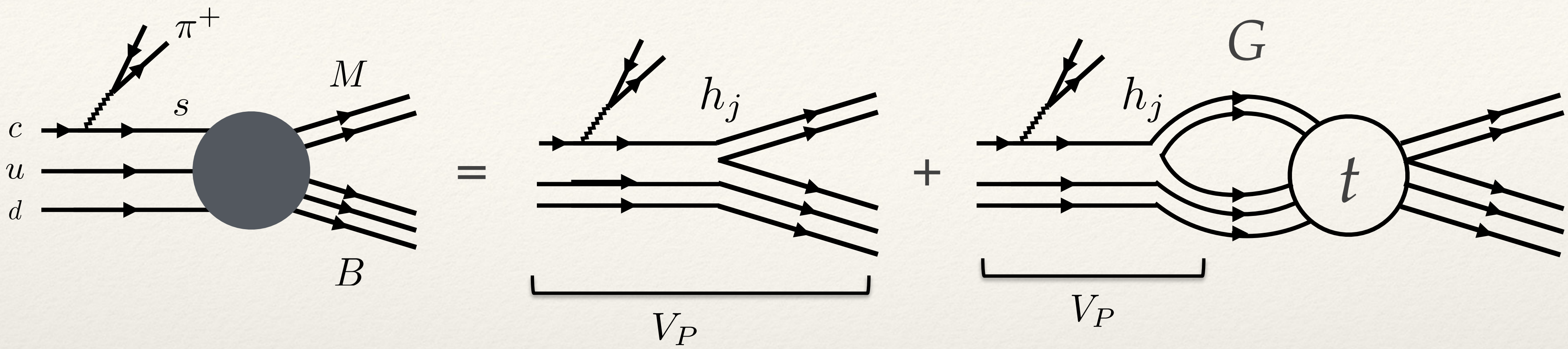
“ good diquark “

Jaffe, Phys. Rept. 409, 1 (2005)

With the hadron degrees of freedom,

$$|MB\rangle = -\frac{1}{\sqrt{6}}|\bar{K}\Lambda\rangle - \sqrt{\frac{3}{2}}|\bar{K}\Sigma\rangle + \frac{1}{\sqrt{3}}|\eta\Lambda\rangle$$

Final State Interaction



$$\mathscr{M}_j = V_P \left(h_j + \sum_i h_i G_i(M_{\rm inv}) t_{ij}(M_{\rm inv}) \right)$$

$$\frac{d\Gamma_j}{dM_{\rm inv}} = \frac{1}{(2\pi)^3} \frac{p_{\pi^+} p_j M_{\Lambda_c^+} M_j}{M_{\Lambda_c^+}^2} |\mathscr{M}_j|^2$$

coefficients can be determined from |*MB*>

$$\left(\begin{array}{l} h_{\pi\Xi} = 0,\ h_{\bar{K}\Lambda} = -\frac{1}{\sqrt{6}}, \\ h_{\bar{K}\Sigma} = -\sqrt{\frac{3}{2}},\ h_{\eta\Xi} = \frac{1}{\sqrt{3}}. \end{array} \right.$$

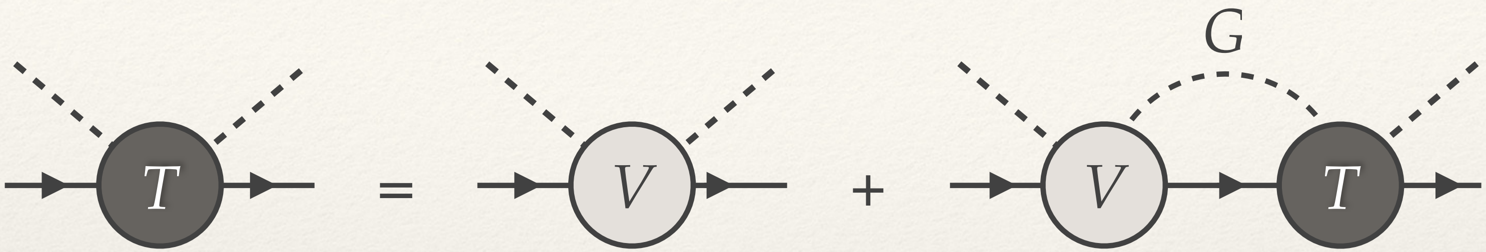
G_i : meson-baryon loop function

t_{ij} : meson-baryon scattering matrix

chiral unitary approach

- chiral unitary approach
  - non-perturbative treatment
    (bound state, resonance state)

chiral unitary approach



$$T = V + VGT = V + VGV + VGVGV + \cdots$$

$$= (V^{-1} - G)^{-1}$$: pole ⟷ **resonance state**

$$G(W) = i\int \frac{d^4q}{(2\pi)^4} \frac{2M}{(P-q)^2 - M^2 + i\epsilon} \frac{1}{q^2 - m^2 + i\epsilon}$$

dimensional regularization ⟶ **subtraction constant**

free parameter

fit scattering data ⟶ **well describe resonance state**

Results

ROB

$\Xi(1620) : (M, \Gamma) = (1606, 132)$ MeV

$\Xi(1690) :$ no pole

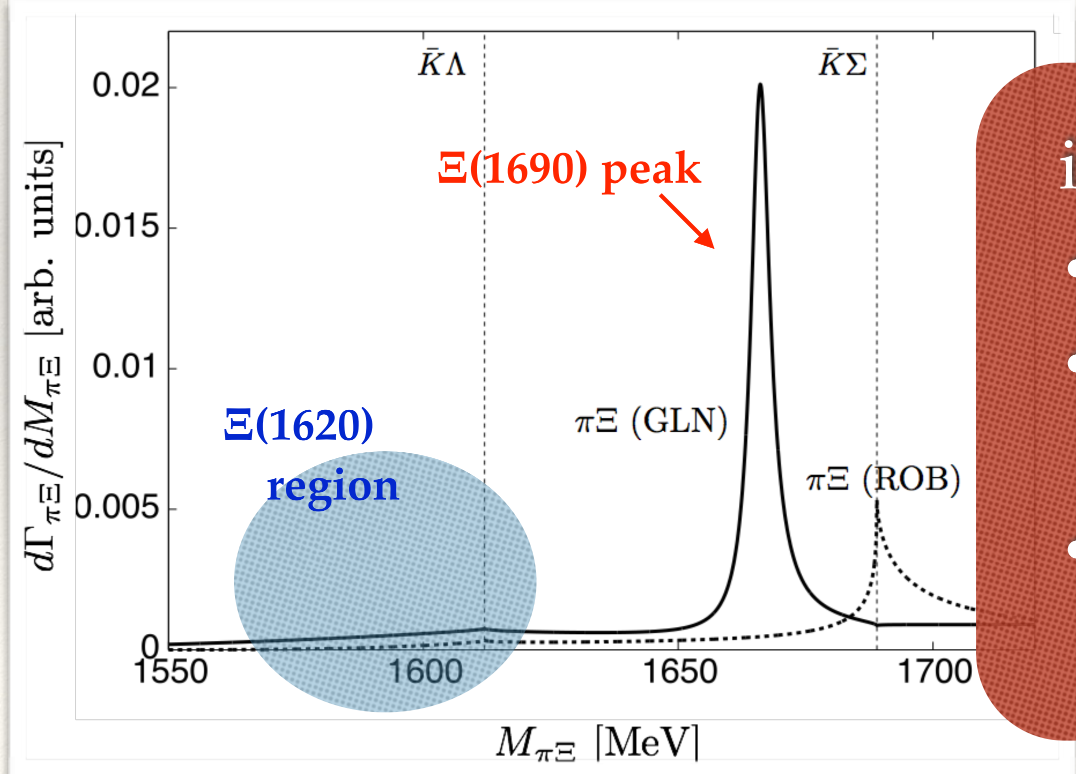
Ramos, Oset, Benhold, Phys. Rev. Lett. 89 (2002) 252001

GLN

$\Xi(1620) : (M, \Gamma) = (1568, 252)$ MeV

$\Xi(1690) : (M, \Gamma) = (1667, 4)$ MeV

Garcia-Recio, Lutz, Nieves, Phys. Lett. B 582 (2004) 49



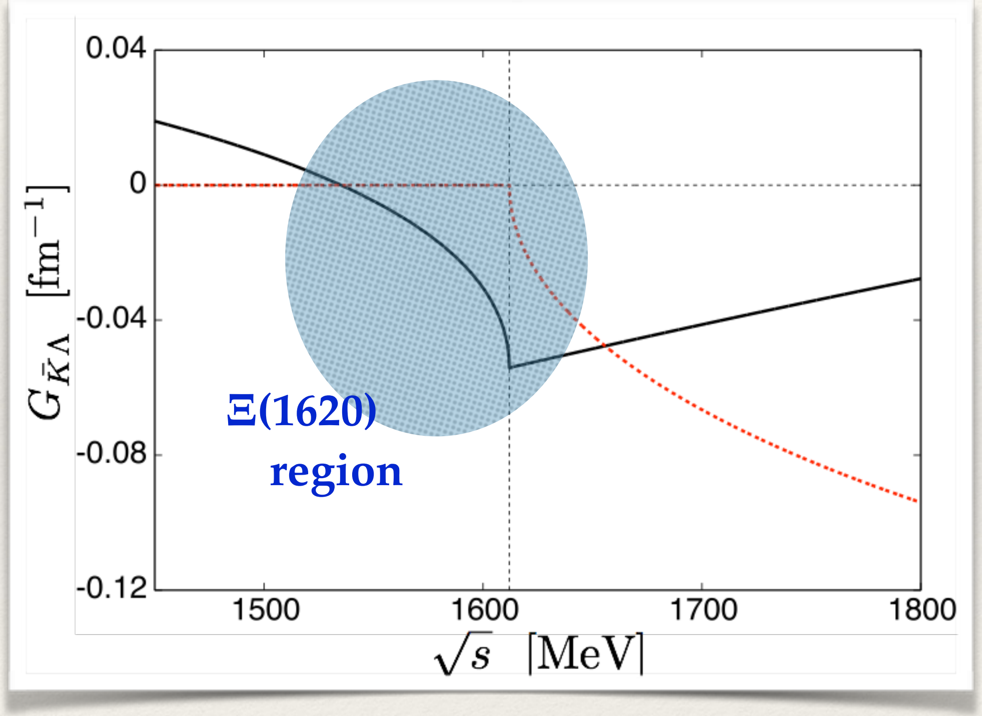
in $\pi\Xi$ channel

- $\Xi(1620)$ peak cannot be seen.
- $\Xi(1690)$ peak can be seen clearly.
- $\bar{K}\Sigma$ threshold also gives the peak-like structure

Discussion

$\Xi(1620)$ mainly coupleds to $\pi\Xi$ and $\bar{K}\Lambda$ channel

$$\mathscr{M}_{\pi\Xi} \sim -V_P \frac{1}{\sqrt{6}} G_{\bar{K}\Lambda}(M_{\rm inv}) t_{\bar{K}\Lambda,\pi\Xi}({\rm inv})$$



- |MB> does not include the $\pi\Xi$ channel.
- $\bar{K}\Lambda$ loop function is small around the $\Xi(1620)$ region below the $\bar{K}\Lambda$ threshold.

In $\Xi_c^+ \rightarrow \pi^+$ (MB) reaction, $\Xi(1620)$ is difficult to see.

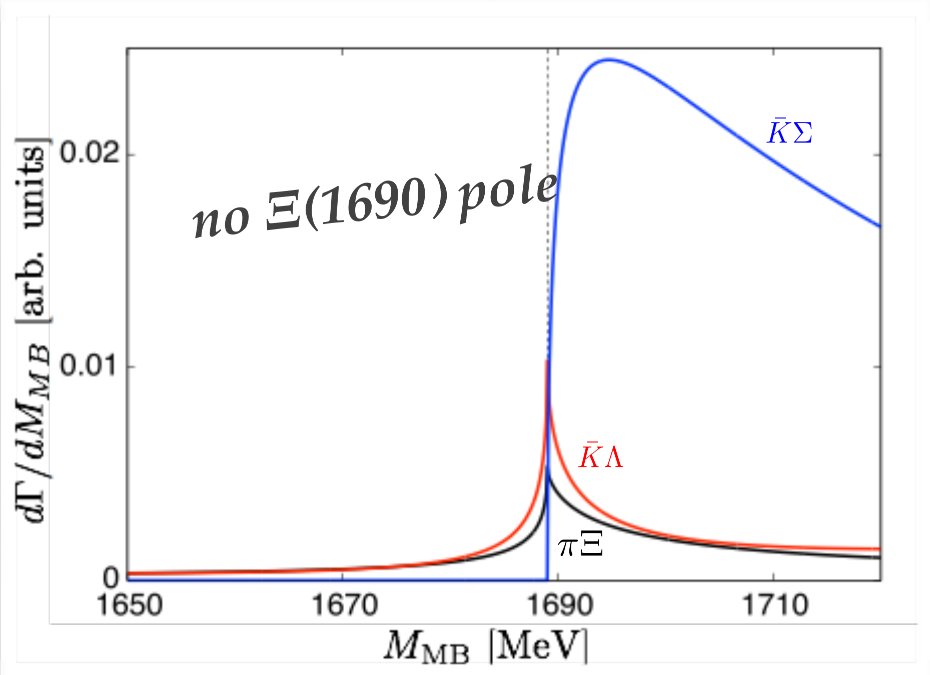
❖ Discussion

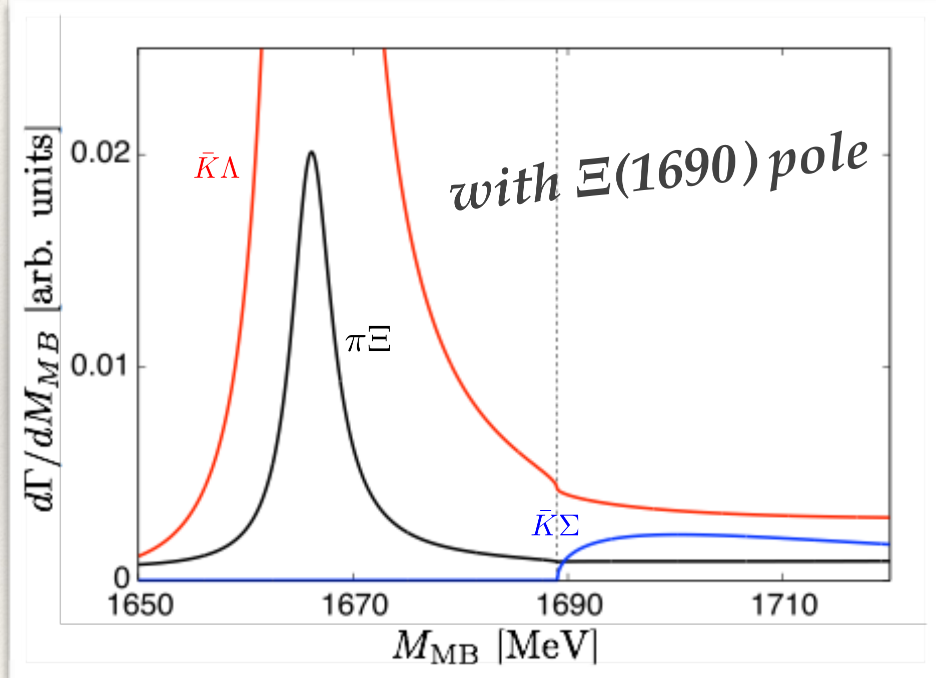
ROB

$\Xi(1690)$: no pole

GLN

$\Xi(1690)$: $(M, \Gamma) = (1667, 4)$ MeV

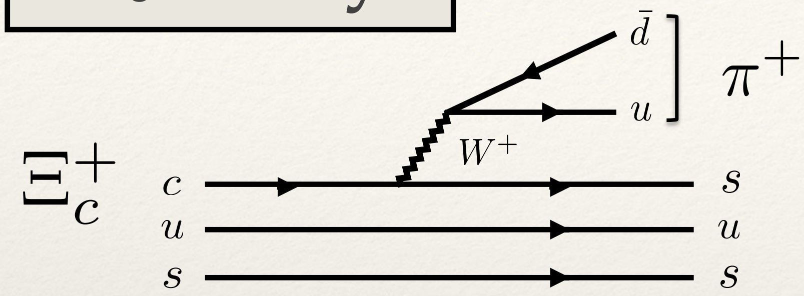


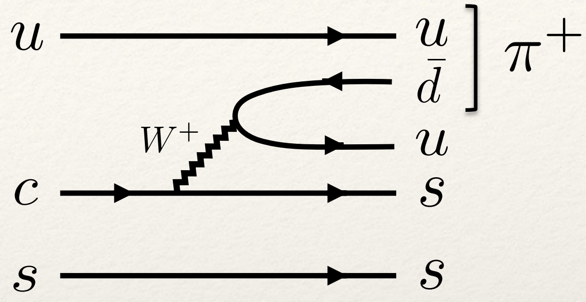


The ratios of the decay fractions may be useful.

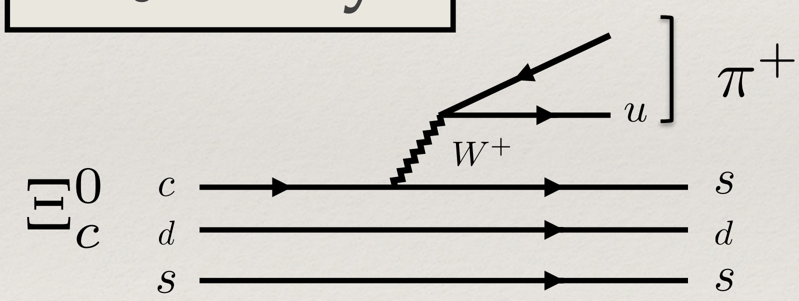
Discussion

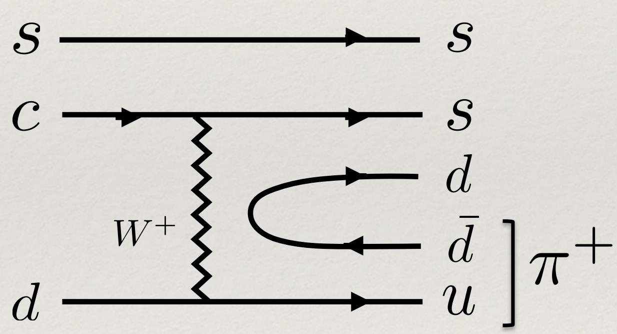
Ξ_c^+ decay





Ξ_c^0 decay





Comparison between Ξ_c^+ and Ξ_c^0 decays may clarify the effect of other diagrams.

Summary

- We have studied $\Xi(1620)$ and $\Xi(1690)$ resonances from Ξ_c-decay.
- Considering CKM matrix, color factor, diquark correlation, and kinematics, we have chosen the most favored diagram.
- It has been found that the $\Xi(1620)$ peak is difficult to see in Ξ_c decay.
- $\Xi(1690)$ peak has been seen clearly. The decay fraction may be useful to distinguish the resonance peak from the threshold effect.