Theoretical interpretation of the Ξ(1620) and Ξ(1690) resonances seen in $\Xi_c^+ \to \Xi^- \pi^+ \pi^+$ decay

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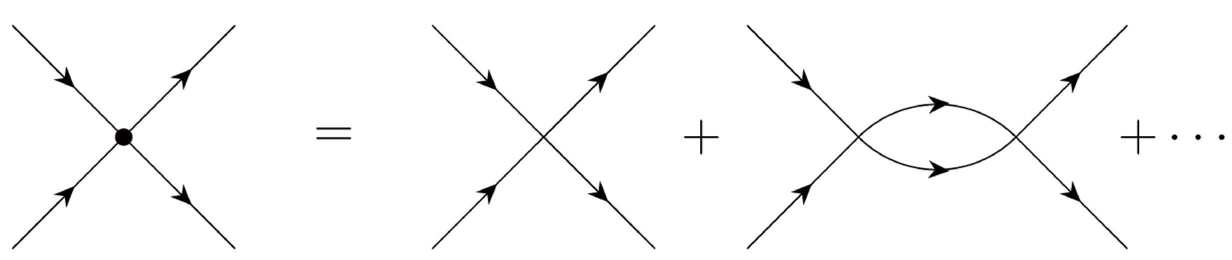
Introduction: We study the Belle reaction $\Xi_c^+ \to \Xi^- \pi^+ \pi^+$, focusing on the $\pi^+\Xi$ mass distribution. Signals of the Ξ(1620) and Ξ(1690) resonances are observed. These resonances are dynamically formed through interactions in coupled channels like $\pi\Xi$, $\bar{K}\Lambda$, $\bar{K}\Sigma$, and $\eta\Xi$, using the chiral unitary approach. The weak decay process doesn't directly create the $\pi\pi\Xi$ state, but transitions between channels produce the resonances. Including the $\Xi^*(1530)$ and background contributions, our model matches the experimental mass distribution, confirming the molecular nature of the Ξ(1620) and Ξ(1690) resonances with spin-parity $J^P = \frac{1}{2}^-$.

Generation of the Ξ(1620) and Ξ(1690) states

The chiral unitary approach:

coupled channels: $\pi\Xi, \bar{K}\Lambda, \bar{K}\Sigma, \eta\Xi$



$$T = [1 - VG]^{-1}\, V,$$

$$G_l = \int_{|\vec{q}|<q_{\max}} \frac{d^3q}{(2\pi)^3}\, \frac{1}{2\, w_l(\vec{q})}\, \frac{M_l}{E_l(\vec{q})}\, \frac{1}{\sqrt{s} - w_l(\vec{q}) - E_l(\vec{q}) + i\epsilon},$$

Table 1: Poles of the T matrix with different values of $q_{\max}$. (in MeV)

$q_{\max}$	630	700	750	770
poles	$1569.4 + 125.7i$	$1563.7 + 106.1i$	$1558.0 + 94.0i$	$1555.6 + 89.7i$
	$1687.9 + 0.7i$	$1681.8 + 1.8i$	$1674.8 + 2.3i$	$1671.5 + 2.4i$

Table 2: Couplings of the two generated states to different channels (with $q_{\max} = 630$ MeV). The bold face numbers indicate the pole position of the states.

1569.4 + i125.7	$\pi\Xi$	$\bar{K}\Lambda$	$\bar{K}\Sigma$	$\eta\Xi$
g_i	$-2.0 - 1.6i$	$1.9 + 0.9i$	$0.7 + 0.5i$	$-0.1 - 0.4i$
$\lvert g_i\rvert^2$	6.6	4.5	0.6	0.1
1687.9 + i0.7	$\pi\Xi$	$\bar{K}\Lambda$	$\bar{K}\Sigma$	$\eta\Xi$
g_i	$0.1 - 0.1i$	$0.2 + 0.1i$	$-1.2 + 0.2i$	$-0.8 + 0.1i$
$\lvert g_i\rvert^2$	0.01	0.04	1.5	0.6

The $\Xi_c^+ \to \pi^+\pi^+\Xi^-$ reaction

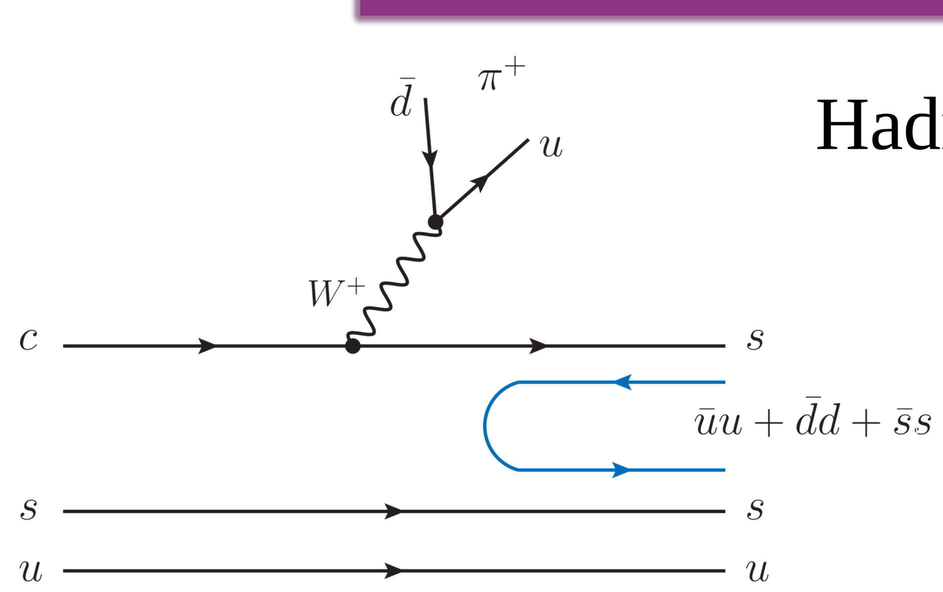


Figure 1: Feynman diagram at quark level for the first step of the $\Xi_c^+ \to \Xi^-\pi^+\pi^+$ decay.

Hadronization process:

$$K^-\Sigma^+ - \frac{1}{\sqrt{2}}\bar{K}^0\Sigma^0 + \frac{1}{\sqrt{6}}\bar{K}^0\Lambda - \frac{1}{\sqrt{3}}\eta\,\Xi^0,$$

Rescattering:

$$t = V_P \sum_{i=1}^{4} h_i\, G_i(M_{\rm inv})\, t_{i,\pi^+\Xi^-},$$

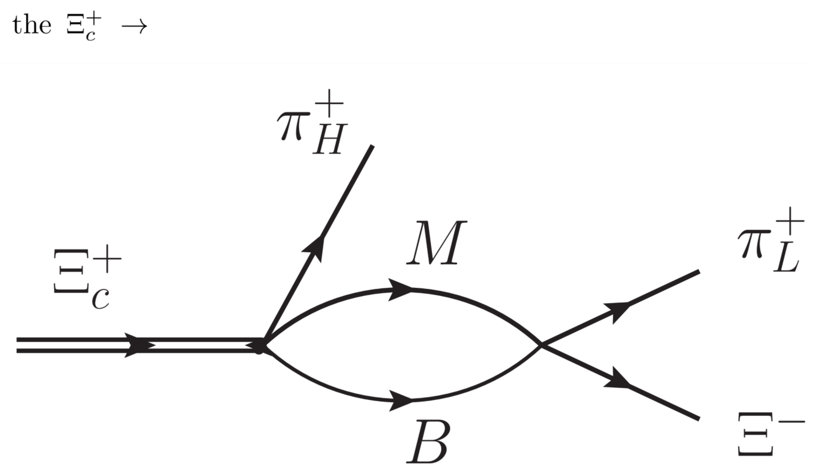
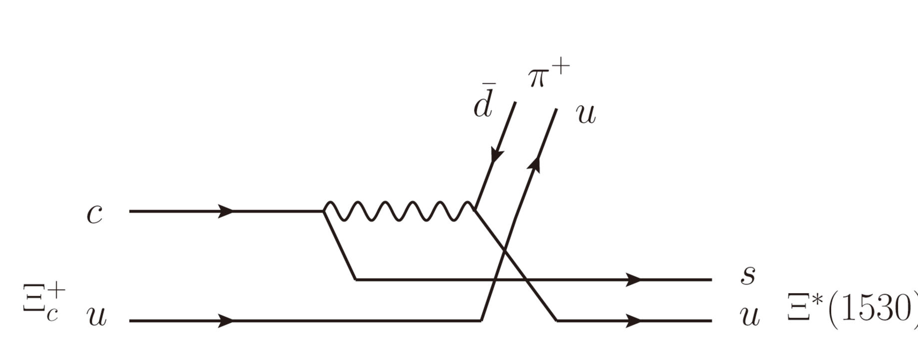


Figure 2: The rescattering mechanism for $\Xi_c^+ \to \pi^+\pi^+\Xi^-$ decay.

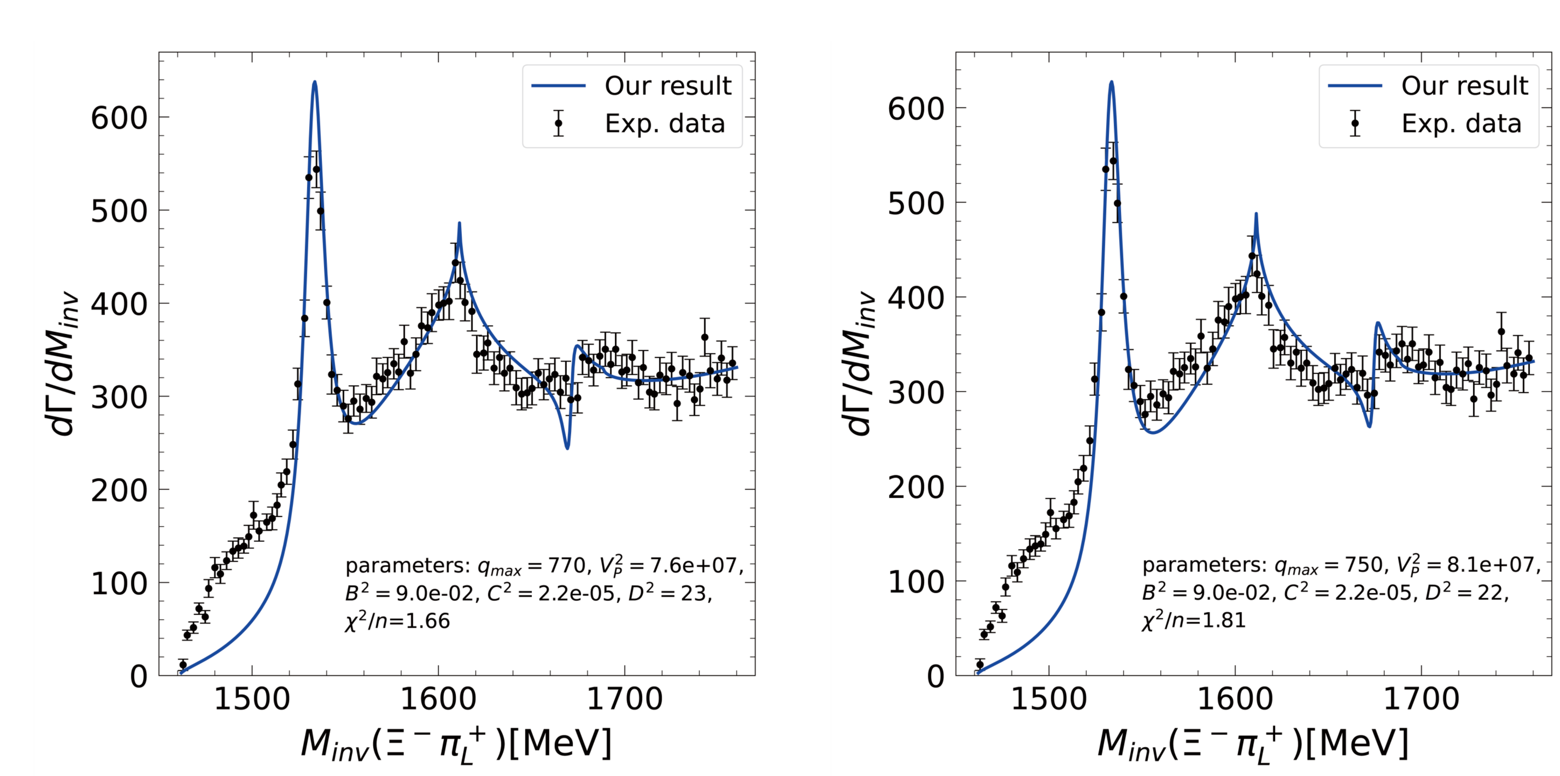
Background:



$$B^2\, |\vec{p}_{\pi^+}|^2\, |\tilde{p}_{\pi^+}|^2 \left[\left| \frac{1}{M_{\rm inv} - M_{\Xi(1530)} + i\Gamma_{\Xi(1530)}/2} \right|^2 + C^2 \right] + D^2 |\tilde{p}_{\pi^+}|^2.$$

Result

$$\frac{d\Gamma}{dM_{\rm inv}} = \frac{1}{(2\pi)^3}\, \frac{1}{4\, M_{\Xi_c}^2}\, p_{\pi^+}\, \tilde{p}_{\pi^+}\, |t|^2,$$



In this work, we have studied $\Xi^-\pi_L^+$ invariant mass distribution for $\Xi_c^+ \to \pi_H^+\pi_L^+\Xi^-$ decay, considering the Ξ(1620) and Ξ(1690) as meson-baryon molecular states, under the framework of the chiral unitary approach.

We take into account contributions from $\Xi^*(1530)$ and other backgrounds, and get the $\Xi^-\pi_L^+$ invariant mass distribution for $\Xi_c^+ \to \pi_H^+\pi_L^+\Xi^-$ decay. Results in comparison with experimental data strongly support that the Ξ(1620) and Ξ(1690) are molecular states, with spin-parity being both $\frac{1}{2}^-$.

References:
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