Study of the nonleptonic decay $\Xi_c^0 \to \Lambda_c^+\pi^-$ in the CCQM

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Abstract

The nonleptonic decay $\Xi_c^0 \to \Lambda_c^+\pi^-$ with $\Delta C = 0$ is systematically studied in the framework of the covariant confined quark model (CCQM) with account for both short and long distance effects. The short distance effects are induced by four topologies of external and internal weak $W^\pm$ exchange, while long distance effects are saturated by an inclusion of the so-called pole diagrams with an intermediate $\frac{1}{2}^+$ and $\frac{1}{2}^-$ baryon resonances. The contributions from $\frac{1}{2}^+$ resonances are calculated straightforwardly by account for single charmed Σ_c^0 and $\Xi_c'^+$ baryons whereas the contributions from $\frac{1}{2}^-$ resonances are calculated by using the well-known soft-pion theorem in the current-algebra approach. It allows to express the parity-violating S-wave amplitude in terms of parity-conserving matrix elements. It is found that the contribution of external and internal W-exchange diagrams is significantly suppressed by more than one order of magnitude in comparison with data. The pole diagrams play the major role to get consistency with experiment.

Nonleptonic decay $\Xi_c^0 \to \Lambda_c^+\pi^-$

The effective Hamiltonian needed for the calculation of the $\Xi_c^0 \to \Lambda_c^+ + \pi^-$ decay is written down

$$\begin{aligned}\mathcal{H}_{\rm eff}^{\Delta S=1} &= \frac{G_F}{\sqrt{2}}\Big[\, V_{us}^* V_{ud}\Big(C_1^{(u)}(\mu_u)Q_1^{(u)} + C_2^{(u)}(\mu_u)Q_2^{(u)}\Big) \\ &\qquad + V_{cs}^* V_{cd}\Big(C_1^{(c)}(\mu_c)Q_1^{(c)} + C_2^{(c)}(\mu_c)Q_2^{(c)}\Big) + \text{H.c.}\Big],\end{aligned}$$

where Q_1 and Q_2 is the set of flavor-changing effective four-quark operators given by

$$\begin{aligned}Q_1^{(u)} &= (\bar s_a O_L^\mu u_b)(\bar u_b O_{\mu L} d_a), \qquad Q_2^{(u)} = (\bar s_a O_L^\mu u_a)(\bar u_b O_{\mu L} d_b),\\ Q_1^{(c)} &= (\bar s_a O_L^\mu c_b)(\bar c_b O_{\mu L} d_a), \qquad Q_2^{(c)} = (\bar s_a O_L^\mu c_a)(\bar c_b O_{\mu L} d_b).\end{aligned}$$

Here $O_L^\mu = \gamma^\mu(1-\gamma_5)$ is the left-handed chiral weak matrix. One has to note that we adopt that the C_2Q_2 means the leading order, whereas the C_1Q_1 is for subleading order. The numerical values of the Wilson coefficients C_1 and C_2 are being equal to

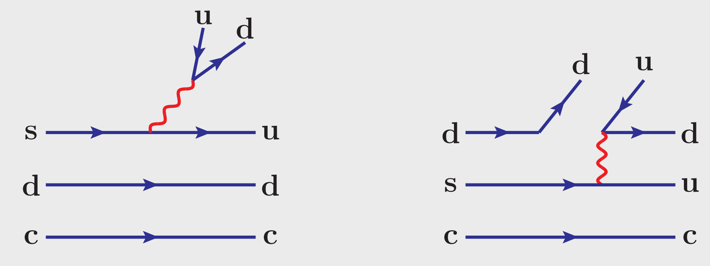
$$\begin{aligned}C_1^{(u)}(\mu_u) &= -0.625, \qquad C_2^{(u)}(\mu_u) = 1.361, \quad (\mu_u = O(1\,\text{GeV})),\\ C_1^{(c)}(\mu_c) &= -0.621, \qquad C_2^{(c)}(\mu_c) = 1.336, \quad (\mu_c = O(m_c)).\end{aligned}$$

The numerical values of the CKM matrix elements needed in our calculations are taken from PDG:

$$\begin{aligned}&|V_{ud}| = 0.97373 \pm 0.00031, \qquad |V_{us}| = 0.2243 \pm 0.0008,\\ &|V_{cd}| = 0.221 \pm 0.004, \qquad |V_{cs}| = 0.975 \pm 0.006,\end{aligned}$$

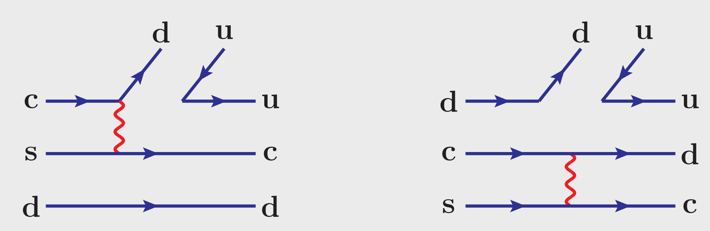
that approximately give $V_{\rm CKM}^{(u)} \approx 0.218$ and $V_{\rm CKM}^{(c)} \approx -0.215$.

Matrix elements



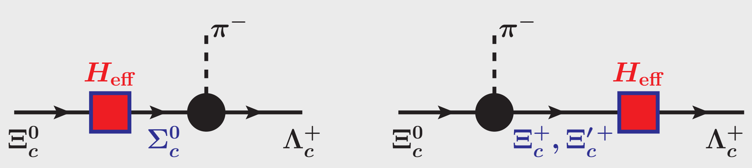
Ia IIb

$\Xi_c^0 \to \Lambda_c^+\pi^-$ via $s \to u(d\bar u)$ transitions.



IIa III

$\Xi_c^0 \to \Lambda_c^+\pi^-$ via $sc \to dc$ transitions.



The matrix elements corresponding to the decay are written down

$$M(\Xi_c^0 \to \Lambda_c^+\pi^-) = \frac{G_F}{\sqrt{2}}\bar u(p_2)\Big(\Big(A_{\rm SD} + A_{\Sigma_c^0} + A_{\Xi_c'^+}\Big) + \gamma_5\Big(B_{\rm SD} + B_{\Sigma_c^0} + B_{\Xi_c'^+}\Big)\Big)u(p_1).$$

Numerical results

Table I. SD, LD and full amplitudes in units of GeV^2.

Amplitudes	SD	LD	SD + LD
A-ampl.	0.0156	-0.0751	-0.0595
B-ampl.	0.166	-5.378	-5.212

Table II. Comparison of our findings with other approaches.

Approach	BR($\Xi_c^0 \to \Lambda_c^+\pi^-$)%	Asymmetry
Our model	0.54 ± 0.11	-0.75
LHCb [1]	$0.55 \pm 0.02 \pm 0.1$	—
Belle [2]	$0.54 \pm 0.05 \pm 0.12$	—
Voloshin [3]	$> 0.025 \pm 0.015$	—
Gronau and Rosner [4] (construc)	0.194 ± 0.070	—
Gronau and Rosner [4] (destruc)	< 0.01	—
Faller and Mannel [5]	< 0.39	—
Cheng et al. [6]	0.72 ± 0.07	0.46 ± 0.05
Niu et al. [7]	0.58 ± 0.21	-0.16

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Branching