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SU(3) predictions for charmed-baryon decays

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The charmed baryons Λ_c^+, Ξ_{c1}^+, Ξ_{c1}^0 and Ω_c^0 can only weakly decay to lower-mass baryons and mesons. We derive relations between the decay rates of these particles based on flavor SU(3). Two-body and three-body nonleptonic decays are explored along with semileptonic decays.

INTRODUCTION

Measurements of the branching fractions for many exclusive decay modes of charmed baryons are starting to be made. Although the weak decays of the Λ_c^+, $\Xi_{c1}^{0,+}$, and Ω_c^0 have been observed, only the decays of the Λ_c^+ have been studied in any detail. The large event sample of B-meson decays that will be collected in the near future will allow for the study of the decay modes of all the charmed baryons. Charmed baryons belong to one of two representations of flavor SU(3): a $\bar{3}$ or a **6**. The Λ_c^+, Ξ_{c1}^+, and Ξ_{c1}^0 constitute the $\bar{3}$ and the Ω_c^0, Ξ_{c2}^+, Ξ_{c2}^0, Σ_c^{++}, Σ_c^+, and Σ_c^0 comprise the **6**. Only the Ω_c^0 and the members of the $\bar{3}$ decay weakly; the other members of the **6** decay strongly or electromagnetically to the $\bar{3}$. It has been shown that the flavor-SU(3) representations of charmed baryons are a good approximation to their mass eigenstates.[1]

The masses of five of the particles have been measured to be (for a review see Ref. 2)

$$\begin{aligned} M_{\Lambda_c^+} &= 2285.4 \pm 0.9 \text{ MeV}/c^2 , \\ M_{\Xi_{c1}^+} &= 2467 \pm 3 \text{ MeV}/c^2 , \\ M_{\Xi_{c1}^0} &= 2472 \pm 3 \text{ MeV}/c^2 , \\ M_{\Omega_c^0} &= 2740 \pm 20 \text{ MeV}/c^2 , \\ M_{\Sigma_c^{++}} &= 2452.8 \pm 1.7 \text{ MeV}/c^2 . \end{aligned} \tag{1a}$$

The lifetimes of the four weakly decaying charmed baryons have been measured as

$$\begin{aligned} &\tau_{\Lambda_c^+} = 0.196 \pm 0.016 \text{ ps}, \quad \tau_{\Xi_{c1}^+} = 0.57 \pm 0.14 \text{ ps} , \\ &\tau_{\Xi_{c1}^0} = 0.082 \pm 0.06 \text{ ps}, \quad \tau_{\Omega_c^0} = 0.79 \pm 0.34 \text{ ps} . \end{aligned} \tag{1b}$$

Flavor-SU(3) symmetry typically works at the 30% level in low-energy physics. The quantity f_K/f_π is predicted to be unity in the limit of exact SU(3) but is experimentally determined to be ~ 1.28. However, SU(3) predictions for D-meson decays are found not to work well at all.[3,4] An example is $\Gamma(D^0 \to K^+K^-)/\Gamma(D^0 \to \pi^+\pi^-)$, which is predicted to be unity in the SU(3) limit but is measured to be 3.5 ± 1.2.[5] Decay amplitudes factorize in the large-N_c limit[6] (also, the leading $1/N_c$ terms cancel[7]), so we can phenomenologically modify the SU(3) prediction for $\Gamma(D^0 \to K^+K^-)/\Gamma(D^0 \to \pi^+\pi^-)$ by $(f_K/f_\pi)^2 \sim 1.7$. The phase space available to the two final states is different giving rise to modification in the SU(3) prediction of ~ 0.7. These two effects essentially cancel leaving the SU(3) prediction unchanged. It is unlikely that SU(3) is this badly broken at the weak-interaction vertex, and hence there must be a large contribution from final-state interactions[8] (FSI's). For instance, if there were a resonance in the K^+K^- system (and not the $\pi^+\pi^-$) with a mass near the D-meson mass then this could give rise to the observed deviation between theory and experiment. On the other hand, there are cases where SU(3) works much better than at the 30% level (for instance, the hyperon-nucleon axial-vector-current matrix elements).

Since the origin of the deviation from the SU(3) predictions in D decays is not well understood, it is possible that SU(3) may work much better for charmed-baryon decay rates. Even if FSI's are important for charmed-baryon decays (the energy of the decay lies in the midst of the baryon resonances), their effect can be removed (as in D-meson decays[8]) and the modified amplitudes can be compared with the predictions from SU(3). Since SU(3) is a better symmetry for baryons than for mesons it is possible that the effect of FSI's will not be as dramatic for charmed baryons and then the deviations from the SU(3) predictions will be significantly smaller than for the D mesons. Therefore, we feel it is useful to tabulate the predictions of SU(3) for the decay of charmed baryons.

In the standard six-quark model the coupling of the quarks to the W boson is given by

$$\mathcal{L} = \frac{g_2}{2\sqrt{2}} (\bar{u},\bar{c},\bar{t}) \gamma^\mu (1-\gamma_5) K \begin{bmatrix} d \\ s \\ b \end{bmatrix} W_\mu^+ + \text{H.c.} , \tag{2}$$

where g_2 is the $SU(2)_L$ gauge coupling and K is the Kobayashi-Maskawa matrix,[9] which can be parametrized as

$$K = \begin{bmatrix} c_1 & -s_1 c_3 & -s_1 s_3 \\ s_1 c_2 & c_1 c_2 c_3 - s_2 s_3 e^{i\delta} & c_1 c_2 s_3 + s_2 c_3 e^{i\delta} \\ s_1 s_2 & c_1 s_2 c_3 + c_2 s_3 e^{i\delta} & c_1 s_2 s_3 - c_2 c_3 e^{i\delta} \end{bmatrix} , \tag{3}$$

where $c_i = \cos(\theta_i)$ and $s_i = \sin(\theta_i)$. The angles θ_i are all chosen to lie in the first quadrant where their sines and cosines are positive. With this convention the phase δ has physical significance and must be fixed by experiment.

Experimental information from nuclear β decay, semileptonic hyperon decay, and kaon decay yields[5]

$$s_1 \sim 0.22 \ . \tag{4a}$$

The angles θ_2 and θ_3 are small and experimental information from B-meson decays gives, to leading order in small angles,

$$(s_2^2+s_3^2+2s_2s_3c_\delta)^{1/2} \sim 0.05 \ , \tag{4b}$$

and

$$s_3 < 0.05 \ . \tag{4c}$$

This paper is divided into two sections: nonleptonic and semileptonic decays. In Sec. I we examine the flavor-SU(3) predictions for the decay of charmed baryons in the $\overline{3}$ and **6** representation to $\frac{1}{2}^+$ or $\frac{3}{2}^+$ uncharmed baryons and one or two mesons. Section II deals with the semileptonic decay of charmed baryons in both representations to $\frac{1}{2}^+$ and $\frac{3}{2}^+$ uncharmed baryons, a (l^+,ν_l) lepton pair, and zero or one meson. The matrix elements for the decay processes are tabulated in terms of unknown reduced matrix elements.

I. NONLEPTONIC DECAYS

It is the interaction Lagrangian density in Eq. (2) that determines the transformation properties of the effective Hamiltonian for the weak decay of charmed baryons under flavor SU(3). The $\Delta c=-1$ nonleptonic decays arise from weak Hamiltonians with flavor quantum numbers $(c\overline{s})(d\overline{u})$ for Cabibbo-allowed decays, $s_1[(c\overline{d})(d\overline{u})-(c\overline{s})(s\overline{u})]$ for Cabibbo-suppressed decays, and $s_1^2(c\overline{d})(s\overline{u})$ for doubly Cabibbo-suppressed decays. These operator are three different components of the same Hamiltonian which can be decomposed into irreducible representations of flavor SU(3). An example of this is the decomposition of the component of the operator responsible for Cabibbo-allowed decays [denoted with a superscript (a)]:

$$(c\overline{s})(d\overline{u})=\mathcal{O}_6^{(a)}+\mathcal{O}_{\overline{15}}^{(a)} \ , \tag{5a}$$

where

$$\mathcal{O}_6^{(a)}=\tfrac{1}{2}[(c\overline{s})(d\overline{u})-(c\overline{u})(d\overline{s})] \tag{5b}$$

transform as a **6** under flavor SU(3) and

$$\mathcal{O}_{\overline{15}}^{(a)}=\tfrac{1}{2}[(c\overline{s})(d\overline{u})+(c\overline{u})(d\overline{s})] \tag{5c}$$

transforms as a $\overline{15}$ under flavor SU(3). The Cabibbo-suppressed operator has a similar decomposition into $\mathcal{O}_6^{(s)}$ and $\mathcal{O}_{\overline{15}}^{(s)}$, as does the doubly Cabibbo-suppressed operator into $\mathcal{O}_6^{(ds)}$ and $\mathcal{O}_{\overline{15}}^{(ds)}$. Perturbative QCD corrections arising from momentum scales between the W-boson mass and the charmed-quark mass give rise to an enhancement of the coefficient of $\mathcal{O}_6$ over the coefficient $\mathcal{O}_{\overline{15}}$ by

$$\left[\frac{\alpha_s(m_b)}{\alpha_s(m_W)}\right]^{18/23}\left[\frac{\alpha_s(m_c)}{\alpha_s(m_b)}\right]^{18/25} \sim 2.5 \ , \tag{5d}$$

in the effective weak Hamiltonian.[10] Consequently it is possible, analogous to octet dominance in the decay of strange particles, that the sextet component of the Hamiltonian may dominate charmed-baryon decays.

The operator $\mathcal{O}_{\overline{15}}$ can be represented in tensor notation as $H_{bc}^a(\overline{15})$, which is traceless and symmetric on its lower two indices with nonzero elements

$$H_{13}^2(\overline{15})=H_{31}^2(\overline{15})=+1 \tag{6a}$$

for Cabibbo-allowed decays,

$$H_{12}^2(\overline{15})=H_{21}^2(\overline{15})=-H_{13}^3(\overline{15})=-H_{31}^3(\overline{15})=s_1 \tag{6b}$$

for Cabibbo-suppressed decays, and

$$H_{12}^3(\overline{15})=H_{21}^3(\overline{15})=-s_1^2 \tag{6c}$$

for doubly Cabibbo-suppressed decays. Similarly, $\mathcal{O}_6$ can be represented in tensor notation as $H^{ab}(\mathbf{6})$ which is symmetric on its upper two indices and has nonzero elements

$$H^{22}(\mathbf{6})=+2 \tag{7a}$$

for Cabibbo-allowed decays,

$$H^{23}(\mathbf{6})=H^{32}(\mathbf{6})=-2s_1 \tag{7b}$$

for Cabibbo-suppressed decays, and

$$H^{33}(\mathbf{6})=+2s_1^2 \tag{7c}$$

for doubly Cabibbo-suppressed decays. [These can be written with the same tensor structure as the $\overline{15}$ by contracting with the totally antisymmetric Levi-Civita tensor ϵ_{abc} to give $H_{13}^2(\mathbf{6})=-H_{31}^2(\mathbf{6})=-1$ for Cabibbo-allowed decays, $H_{12}^2(\mathbf{6})=-H_{21}^2(\mathbf{6})=-H_{13}^3(\mathbf{6})=H_{31}^3(\mathbf{6})=-s_1$ for Cabibbo-suppressed decays, and $H_{12}^3(\mathbf{6})=-H_{21}^3=s_1^2$ for doubly Cabibbo-suppressed decays.]

A. Two-body final states

First we examine the process $T\to BM$, where T denotes the $\overline{3}$ representation of charmed baryons, B is the lowest-lying $\frac{1}{2}^+$ baryon octet, and M is the lowest-lying pseudoscalar meson octet. Some of the SU(3) predictions for this set of decays have been considered before in Ref. 4. The effective Hamiltonian for the process is given by

$$\begin{aligned}H_{\text{eff}}=&\,aH_{bc}^a(\overline{15})T^b\overline{B}\,{}^c_d M_a^d+bH_{bc}^a(\overline{15})T^b M_d^c\overline{B}\,{}^d_a\\&+cH_{bc}^a(\overline{15})\overline{B}\,{}^b_d M_a^c T^d\\&+dH_{bc}^a(\overline{15})M_d^b\overline{B}\,{}^c_a T^d+eH^{ab}(\mathbf{6})T_{ac}\overline{B}\,{}^c_d M_b^d\\&+fH^{ab}(\mathbf{6})T_{ac}M_d^c\overline{B}\,{}^d_b+gH^{ab}(\mathbf{6})\overline{B}\,{}^c_a M_b^d T_{cd} \ ,\end{aligned} \tag{8}$$

where a,b,c,d,e,f,g are unknown reduced matrix elements, T^a is the charmed-baryon antitriplet

$$T^a=(\Xi_{c1}^0,-\Xi_{c1}^+,\Lambda_c^+), \quad T_{ab}=\epsilon_{abc}T^c \ , \tag{9a}$$

B is the baryon octet given by

$$B_b^a=\begin{bmatrix} \frac{1}{\sqrt{6}}\Lambda^0+\frac{1}{\sqrt{2}}\Sigma^0 & \Sigma^+ & p \\ \Sigma^- & \frac{1}{\sqrt{6}}\Lambda^0-\frac{1}{\sqrt{2}}\Sigma^0 & n \\ \Xi^- & \Xi^0 & -\sqrt{2/3}\Lambda^0 \end{bmatrix}, \tag{9b}$$

and M is the lowest-lying pseudoscalar octet

$$M_b^a=\begin{bmatrix} \frac{1}{\sqrt{6}}\eta^0+\frac{1}{\sqrt{2}}\pi^0 & \pi^+ & K^+ \\ \pi^- & \frac{1}{\sqrt{6}}\eta^0-\frac{1}{\sqrt{2}}\pi^0 & K^0 \\ K^- & \bar{K}^0 & -\sqrt{2/3}\eta^0 \end{bmatrix}. \tag{9c}$$

The square of the matrix elements for Cabibbo-allowed processes are shown in Table I. We see that there is only one relation between the matrix elements of Cabibbo-allowed decays,

$$|M(\Lambda_c^+\to\Sigma^0\pi^+)|^2=|M(\Lambda_c^+\to\Sigma^+\pi^0)|^2\ , \tag{10}$$

and this is a result of the SU(2)-isospin subgroup of SU(3).

There are several relations between squares of matrix elements for Cabibbo-suppressed decays, as can be seen from Table II. They are

$$|M(\Xi_{c1}^0\to\Sigma^-\pi^+)|^2=|M(\Xi_{c1}^0\to\Xi^-K^+)|^2\ , \tag{11a}$$

$$|M(\Xi_{c1}^0\to n\bar{K}^0)|^2=|M(\Xi_{c1}^0\to\Xi^0K^0)|^2\ , \tag{11b}$$

$$|M(\Xi_{c1}^0\to\Sigma^+\pi^-)|^2=|M(\Xi_{c1}^0\to pK^-)|^2\ , \tag{11c}$$

$$|M(\Xi_{c1}^+\to p\bar{K}^0)|^2=|M(\Lambda_c^+\to\Sigma^+K^0)|^2\ , \tag{11d}$$

$$|M(\Xi_{c1}^+\to\Xi^0K^+)|^2=|M(\Lambda_c^+\to n\pi^+)|^2\ , \tag{11e}$$

$$|M(\Xi_{c1}^0\to\Lambda^0\eta^0)|^2=|M(\Xi_{c1}^0\to\Sigma^0\pi^0)|^2\ , \tag{11f}$$

TABLE I. Squared matrix elements for Cabibbo-allowed decays $T\to BM$ in terms of the reduced matrix elements a, b, c, d, e, f, and g.

Process	Squared matrix element
$\Lambda_c^+\to\Lambda^0\pi^+$	$\frac{1}{6}\lvert a+b-2c-2e-2f-2g\rvert^2$
$\Lambda_c^+\to\Sigma^0\pi^+$	$\frac{1}{2}\lvert a-b-2e+2f+2g\rvert^2$
$\Lambda_c^+\to\Sigma^+\pi^0$	$\frac{1}{2}\lvert -a+b+2e-2f-2g\rvert^2$
$\Lambda_c^+\to\Sigma^+\eta^0$	$\frac{1}{6}\lvert a+b-2d-2e-2f+2g\rvert^2$
$\Lambda_c^+\to p\bar{K}^0$	$\lvert a+c-2e\rvert^2$
$\Lambda_c^+\to\Xi^0K^+$	$\lvert b+d-2f\rvert^2$
$\Xi_{c1}^0\to\Xi^-\pi^+$	$\lvert a+c+2e\rvert^2$
$\Xi_{c1}^0\to\Xi^0\pi^0$	$\frac{1}{2}\lvert -a+d-2e+2g\rvert^2$
$\Xi_{c1}^0\to\Xi^0\eta^0$	$\frac{1}{6}\lvert a-2b+d+2e-4f-2g\rvert^2$
$\Xi_{c1}^0\to\Lambda^0\bar{K}^0$	$\frac{1}{6}\lvert -2a+b+c-4e+2f+2g\rvert^2$
$\Xi_{c1}^0\to\Sigma^+K^-$	$\lvert b+d+2f\rvert^2$
$\Xi_{c1}^0\to\Sigma^0\bar{K}^0$	$\frac{1}{2}\lvert -b+c-2f-2g\rvert^2$
$\Xi_{c1}^0\to\Xi^0\pi^+$	$\lvert -c-d-2g\rvert^2$
$\Xi_{c1}^+\to\Sigma^+\bar{K}^0$	$\lvert -c-d+2g\rvert^2$

TABLE II. Squared matrix elements for Cabibbo-suppressed decays $T\to BM$ in terms of the reduced matrix elements a, b, c, d, e, f, and g.

Process	Squared matrix element (mod s_1^2)
$\Lambda_c^+\to\Lambda^0K^+$	$\frac{1}{6}\lvert -a+2b+2c+3d+2e-4f+2g\rvert^2$
$\Lambda_c^+\to\Sigma^0K^+$	$\frac{1}{2}\lvert -a-d+2e-2g\rvert^2$
$\Lambda_c^+\to\Sigma^+K^0$	$\lvert -a+d+2e-2g\rvert^2$
$\Lambda_c^+\to p\eta^0$	$\frac{1}{6}\lvert 2a-b+3c+2d-4e+2f-2g\rvert^2$
$\Lambda_c^+\to p\pi^0$	$\frac{1}{2}\lvert -b-c+2f+2g\rvert^2$
$\Lambda_c^+\to n\pi^+$	$\lvert -b+c+2f+2g\rvert^2$
$\Xi_{c1}^0\to\Sigma^-\pi^+$	$\lvert a+c+2e\rvert^2$
$\Xi_{c1}^0\to\Lambda^0\pi^0$	$\frac{1}{12}\lvert -a-b-c+3d-2e-2f+4g\rvert^2$
$\Xi_{c1}^0\to\Sigma^0\pi^0$	$\frac{1}{4}\lvert a+b-c-d+2e+2f\rvert^2$
$\Xi_{c1}^0\to\Lambda^0\eta^0$	$\frac{1}{4}\lvert -a-b+c+d-2e-2f\rvert^2$
$\Xi_{c1}^0\to\Sigma^0\eta^0$	$\frac{1}{12}\lvert -a-b+3c-d-2e-2f-4g\rvert^2$
$\Xi_{c1}^0\to n\bar{K}^0$	$\lvert a-b+2e-2f-2g\rvert^2$
$\Xi_{c1}^0\to\Xi^-K^+$	$\lvert -a-c-2e\rvert^2$
$\Xi_{c1}^0\to\Xi^0K^0$	$\lvert -a+b-2e+2f+2g\rvert^2$
$\Xi_{c1}^0\to\Sigma^+\pi^-$	$\lvert b+d+2f\rvert^2$
$\Xi_{c1}^0\to pK^-$	$\lvert -b-d-2f\rvert^2$
$\Xi_{c1}^+\to\Lambda^0\pi^+$	$\frac{1}{6}\lvert -a-b-c-3d+2e+2f-4g\rvert^2$
$\Xi_{c1}^+\to\Sigma^0\pi^+$	$\frac{1}{2}\lvert -a+b+c+d+2e-2f\rvert^2$
$\Xi_{c1}^+\to\Sigma^+\pi^0$	$\frac{1}{2}\lvert a-b+c+d-2e+2f\rvert^2$
$\Xi_{c1}^+\to\Sigma^+\eta^0$	$\frac{1}{6}\lvert -a-b-3c-d+2e+2f+4g\rvert^2$
$\Xi_{c1}^+\to p\bar{K}^0$	$\lvert -a+d+2e-2g\rvert^2$
$\Xi_{c1}^+\to\Xi^0K^+$	$\lvert -b+c+2f+2g\rvert^2$

which are all a consequence of the full SU(3) symmetry. From Table III we see that there are no relations between squared matrix elements of doubly Cabibbo-suppressed decays. However, there are relations between the squares of Cabibbo-allowed, -suppressed, and doubly Cabibbo-suppressed matrix elements. They are

TABLE III. Squared matrix elements for the doubly Cabibbo-suppressed decays $T\to BM$ in terms of the reduced matrix elements a, b, c, d, e, f, and g.

Process	Squared matrix element (mod s_1^4)
$\Lambda_c^+\to pK^0$	$\lvert c+d-2g\rvert^2$
$\Lambda_c^+\to nK^+$	$\lvert c+d+2g\rvert^2$
$\Xi_{c1}^0\to\Sigma^-K^+$	$\lvert a+c+2e\rvert^2$
$\Xi_{c1}^0\to\Lambda^0K^0$	$\frac{1}{6}\lvert a-2b+c+2e+4f-4g\rvert^2$
$\Xi_{c1}^0\to\Sigma^0K^0$	$\frac{1}{2}\lvert -a+c-2e\rvert^2$
$\Xi_{c1}^0\to n\eta^0$	$\frac{1}{6}\lvert -2a+b+d-4e+2f+4g\rvert^2$
$\Xi_{c1}^0\to p\pi^-$	$\lvert b+d+2f\rvert^2$
$\Xi_{c1}^0\to n\pi^0$	$\frac{1}{2}\lvert -b+d-2f\rvert^2$
$\Xi_{c1}^+\to\Lambda^0K^+$	$\frac{1}{6}\lvert -a+2b-c+2e-4f-4g\rvert^2$
$\Xi_{c1}^+\to\Sigma^0K^+$	$\frac{1}{2}\lvert -a+c+2e\rvert^2$
$\Xi_{c1}^+\to\Sigma^+K^0$	$\lvert -a-c+2e\rvert^2$
$\Xi_{c1}^+\to p\eta^0$	$\frac{1}{6}\lvert 2a-b-d-4e+2f+4g\rvert^2$
$\Xi_{c1}^+\to p\pi^0$	$\frac{1}{2}\lvert -b+d+2f\rvert^2$
$\Xi_{c1}^+\to n\pi^+$	$\lvert -b-d+2f\rvert^2$

$$|M(\Xi_{c1}^0 \to \Xi^- K^+)|^2 = s_1^2 |M(\Xi_{c1}^0 \to \Xi^- \pi^+)|^2 , \tag{12a}$$

$$|M(\Xi_{c1}^0 \to \Sigma^+ \pi^-)|^2 = s_1^2 |M(\Xi_{c1}^0 \to \Sigma^+ K^-)|^2 , \tag{12b}$$

$$|M(\Xi_{c1}^+ \to \Sigma^+ K^0)|^2 = s_1^4 |M(\Lambda_c^+ \to p\bar{K}^0)|^2 , \tag{12c}$$

$$|M(\Xi_{c1}^+ \to n\pi^+)|^2 = s_1^4 |M(\Lambda_c^+ \to \Xi^0 K^+)|^2 , \tag{12d}$$

$$|M(\Xi_{c1}^0 \to \Sigma^- K^+)|^2 = s_1^4 |M(\Xi_{c1}^0 \to \Xi^- \pi^+)|^2 , \tag{12e}$$

$$|M(\Xi_{c1}^0 \to p\pi^-)|^2 = s_1^4 |M(\Xi_{c1}^0 \to \Sigma^+ K^-)|^2 , \tag{12f}$$

$$|M(\Lambda_c^+ \to nK^+)|^2 = s_1^4 |M(\Xi_{c1}^+ \to \Xi^0 \pi^+)|^2 , \tag{12g}$$

$$|M(\Lambda_c^+ \to pK^0)|^2 = s_1^4 |M(\Xi_{c1}^+ \to \Sigma^+ \bar{K}^0)|^2 . \tag{12h}$$

Unlike B-meson decays, where the final-state masses are small compared to the energy released in the decay, the sum of the masses of the products from charmed-baryon decay is not always negligible compared to the energy release. Therefore, SU(3) relations between decay rates, derived from relations between the square of matrix elements, have significant phase-space corrections. The exception to this is when a relation is due to isospin, where the difference between the sum of the final-state masses is small. To find the relation between the decay rates from the square of the matrix elements we can use the expression

$$d\Gamma(a \to bc) = \frac{1}{32\pi^2} |M(a \to bc)|^2 \frac{|\mathbf{p}_b|}{m_a^2} d\Omega , \tag{13}$$

where m_a is the mass of the decaying particle, $\mathbf{p}_b$ is the momentum of one of the final-state particles, $d\Omega$ is its solid angle, and $M(a \to bc)$ is the matrix element for the decay $a \to bc$. There is also an additional factor of $|\mathbf{p}_b|^{2l}$ occurring in the squared matrix element for decays with final-state angular momentum l. Any mass dependence in the matrix element is not corrected for as this is due to explicit SU(3) violation and not a kinematical effect. Consequently we find that, for instance,

$$\frac{\Gamma_l(\Xi_{c1}^0 \to \Sigma^- \pi^+)}{\Gamma_l(\Xi_{c1}^0 \to \Xi^- K^+)} = \left\{ \frac{\left[1 - \left[\frac{M_{\Sigma^-} + M_{\pi^+}}{M_{\Xi_{c1}^0}}\right]^2\right]\left[1 - \left[\frac{M_{\Xi^-} - M_{\pi^+}}{M_{\Xi_{c1}^0}}\right]^2\right]}{\left[1 - \left[\frac{M_{\Xi^-} + M_{K^+}}{M_{\Xi_{c1}^0}}\right]^2\right]\left[1 - \left[\frac{M_{\Xi^-} - M_{K^+}}{M_{\Xi_{c1}^0}}\right]^2\right]} \right\}^{l+1/2} , \tag{14}$$

where l is the angular momentum of the decay channel and Γ_l is its contribution to the rate. For this process both $l=0$ and $l=1$ partial waves can contribute. The angular distribution of the decay products from a polarized charmed baryon can be decomposed to yield the relative magnitude of the $l=0$ and $l=1$ partial waves, to which the phase-space corrections can be applied accordingly. If, however, the angular distribution information is not available (which is probably the case), then the best estimate of the phase-space correction is to say that it lies somewhere in the range between its value for $l=0$ and $l=1$. Thus the flavor-SU(3) prediction for the above process is

$$1.2\Gamma(\Xi_{c1}^0 \to \Xi^- K^+) < \Gamma(\Xi_{c1}^0 \to \Sigma^- \pi^+) < 1.7\Gamma(\Xi_{c1}^0 \to \Xi^- K^+) .$$

The only decay mode that has been observed is $B(\Lambda_c^+ \to p\bar{K}^0) = (1.5 \pm 0.6) \times 10^{-2}$,[11–13] from which we predict that $B(\Xi_{c1}^+ \to \Sigma^+ K^0) \sim 3 \times 10^{-5}$. These expressions can easily be carried over to decays involving baryons and vector mesons, $T \to BV$. Unlike the pseudoscalar mesons, the isoscalar diagonal element of the octet and the singlet of SU(3) are not the vector-meson mass eigenstates ω and ϕ. Consequently relations found between decays with pseudoscalar mesons in the final state are preserved for vector mesons in the final state except for those decays involving η^0. An example of this is

$$|M(\Xi_{c1}^0 \to \Sigma^- \rho^+)|^2 = |M(\Xi_{c1}^0 \to \Xi^- K^{*+}(892))|^2 . \tag{15}$$

One of the branching ratios for final states containing a vector meson has been measured $B(\Lambda_c^+ \to p\bar{K}^{*0}(892)) = (5.6 \pm 3) \times 10^{-3}$,[12,14] from which we predict that $B(\Xi_{c1}^+ \to \Sigma^+ K^{*0}(892)) \sim 1 \times 10^{-5}$.

Next we look at the process $T \to h^* M$, where h^* is the decuplet of $\frac{3}{2}^+$ baryon resonances with elements

$$\begin{aligned} &h^{*111} = \Delta^{++}, \quad h^{*112} = \frac{1}{\sqrt{3}}\Delta^+, \quad h^{*113} = \frac{1}{\sqrt{3}}\Sigma^{*+} , \\ &h^{*122} = \frac{1}{\sqrt{3}}\Delta^0, \quad h^{*133} = \frac{1}{\sqrt{3}}\Xi^{*0} , \\ &h^{*123} = \frac{1}{\sqrt{6}}\Sigma^{*0}, \quad h^{*222} = \Delta^-, \quad h^{*223} = \frac{1}{\sqrt{3}}\Sigma^{*-} , \\ &h^{*233} = \frac{1}{\sqrt{3}}\Xi^{*-}, \quad h^{*333} = \Omega^- . \end{aligned} \tag{16}$$

The effective Hamiltonian for the process is

$$\begin{aligned} H_{\text{eff}} = &\alpha \bar{h}^{*abc} T_{ad} H_{bc}^e(\overline{15}) M_e^d + \beta \bar{h}^{*abc} T_{ad} H_{be}^d(\overline{15}) M_c^e \\ &+ \gamma \bar{h}^{*abc} H_{ab}^d(\overline{15}) M_c^e T_{de} + \delta \bar{h}^{*abc} H_{ag}^e(6) T_{be} M_c^g , \end{aligned} \tag{17}$$

where α, β, γ, and δ are unknown reduced matrix elements. The rates for Cabibbo-allowed decay processes in terms of these reduced matrix elements are given in Table IV. There are four relations between Cabibbo-allowed decay rates. They are

TABLE IV. Squared matrix elements for Cabibbo-allowed decays $T \to h^* M$ in terms of the reduced matrix elements α, β, γ, and δ.

Process	Squared matrix element
$\Lambda_c^+ \to \Sigma^{*+}\pi^0$	$\frac{1}{6}\lvert -2\alpha+\beta-2\gamma-\delta\rvert^2$
$\Lambda_c^+ \to \Sigma^{*+}\eta^0$	$\frac{1}{18}\lvert 2\alpha-\beta-2\gamma-3\delta\rvert^2$
$\Lambda_c^+ \to \Sigma^{*0}\pi^+$	$\frac{1}{6}\lvert -2\alpha+\beta-2\gamma-\delta\rvert^2$
$\Lambda_c^+ \to \Delta^{++}K^-$	$\lvert\beta+\delta\rvert^2$
$\Lambda_c^+ \to \Delta^+\bar{K}^0$	$\frac{1}{3}\lvert\beta+\delta\rvert^2$
$\Lambda_c^+ \to \Xi^{*0}K^+$	$\frac{1}{3}\lvert\beta-2\gamma-\delta\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*+}\bar{K}^0$	$\frac{4}{3}\lvert\alpha\rvert^2$
$\Xi_{c1}^+ \to \Xi^{*0}\pi^+$	$\frac{4}{3}\lvert\alpha\rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*0}\bar{K}^0$	$\frac{1}{6}\lvert 2\alpha-\beta+2\gamma-\delta\rvert^2$
$\Xi_{c1}^0 \to \Xi^{*0}\pi^0$	$\frac{1}{6}\lvert 2\alpha-\beta+\delta\rvert^2$
$\Xi_{c1}^0 \to \Xi^{*0}\eta^0$	$\frac{1}{18}\lvert -2\alpha+\beta-4\gamma+3\delta\rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*+}K^-$	$\frac{1}{3}\lvert -\beta+2\gamma-\delta\rvert^2$
$\Xi_{c1}^0 \to \Xi^{*-}\pi^+$	$\frac{1}{3}\lvert -\beta+\delta\rvert^2$
$\Xi_{c1}^0 \to \Omega^-K^+$	$\lvert -\beta+\delta\rvert^2$

$$|M(\Lambda_c^+ \to \Sigma^{*+}\pi^0)|^2 = |M(\Lambda_c^+ \to \Sigma^{*0}\pi^+)|^2 , \tag{18a}$$

$$|M(\Lambda_c^+ \to \Delta^{++}K^-)|^2 = 3|M(\Lambda_c^+ \to \Delta^+\bar{K}^0)|^2 , \tag{18b}$$

which are due to isospin and

$$|M(\Xi_{c1}^+ \to \Sigma^{*+}\bar{K}^0)|^2 = |M(\Xi_{c1}^+ \to \Xi^{*0}\pi^+)|^2 , \tag{18c}$$

$$|M(\Xi_{c1}^0 \to \Omega^-K^+)|^2 = 3|M(\Xi_{c1}^0 \to \Xi^{*-}\pi^+)|^2 , \tag{18d}$$

which are due to the full SU(3) symmetry. Again, phase-space-correction factors must be applied to these equalities giving, for example,

$$\Gamma(\Xi_{c1}^0 \to \Omega^-K^+) \sim \Gamma(\Xi_{c1}^0 \to \Xi^{*-}\pi^+) , \tag{19}$$

a modification of $(0.69)^3$ due to the differing final-state masses and the fact that the decay is P wave (neglecting possible D-wave contributions).

There are several relations between the squares of Cabibbo-suppressed matrix elements, as seen in Table V. They are

$$|M(\Lambda_c^+ \to \Delta^0\pi^+)|^2 = |M(\Xi_{c1}^+ \to \Xi^{*0}K^+)|^2 , \tag{20a}$$

$$|M(\Lambda_c^+ \to \Sigma^{*+}K^0)|^2 = |M(\Xi_{c1}^+ \to \Delta^+\bar{K}^0)|^2 , \tag{20b}$$

$$|M(\Lambda_c^+ \to \Sigma^{*0}K^+)|^2 = |M(\Xi_{c1}^+ \to \Sigma^{*0}\pi^+)|^2 , \tag{20c}$$

$$|M(\Lambda_c^+ \to \Delta^{++}\pi^-)|^2 = |M(\Xi_{c1}^+ \to \Delta^{++}K^-)|^2 , \tag{20d}$$

$$|M(\Xi_{c1}^0 \to \Sigma^{*-}\pi^+)|^2 = |M(\Xi_{c1}^0 \to \Xi^{*-}K^+)|^2 , \tag{20e}$$

$$|M(\Xi_{c1}^0 \to \Delta^0\bar{K}^0)|^2 = |M(\Xi_{c1}^0 \to \Xi^{*0}K^0)|^2 , \tag{20f}$$

$$|M(\Xi_{c1}^0 \to \Sigma^{*0}\pi^0)|^2 = 3|M(\Xi_{c1}^0 \to \Sigma^{*0}\eta^0)|^2 , \tag{20g}$$

$$|M(\Xi_{c1}^0 \to \Sigma^{*+}\pi^-)|^2 = |M(\Xi_{c1}^0 \to \Delta^+K^-)|^2 , \tag{20h}$$

which are all full SU(3) relations.

There are also relations between doubly Cabibbo-suppressed matrix elements as seen from Table VI. They are

TABLE V. Squared matrix elements for Cabibbo-suppressed decays $T \to h^* M$ in terms of the reduced matrix elements α, β, γ, and δ.

Process	Squared matrix element (mod s_1^2)
$\Lambda_c^+ \to \Delta^+\pi^0$	$\frac{2}{3}\lvert -\alpha-\gamma-\delta\rvert^2$
$\Lambda_c^+ \to \Delta^+\eta^0$	$\frac{2}{9}\lvert\alpha+\beta-\gamma\rvert^2$
$\Lambda_c^+ \to \Delta^0\pi^+$	$\frac{1}{3}\lvert -2\alpha+\beta-2\gamma-\delta\rvert^2$
$\Lambda_c^+ \to \Sigma^{*+}K^0$	$\frac{1}{3}\lvert -2\alpha+\beta+\delta\rvert^2$
$\Lambda_c^+ \to \Sigma^{*0}K^+$	$\frac{1}{6}\lvert 2\alpha+\beta-2\gamma-\delta\rvert^2$
$\Lambda_c^+ \to \Delta^{++}\pi^-$	$\lvert\beta+\delta\rvert^2$
$\Xi_{c1}^+ \to \Delta^+\bar{K}^0$	$\frac{1}{3}\lvert 2\alpha-\beta-\delta\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*0}\pi^+$	$\frac{1}{6}\lvert -2\alpha-\beta+2\gamma+\delta\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*+}\eta^0$	$\frac{1}{18}\lvert 4\alpha+\beta+2\gamma+3\delta\rvert^2$
$\Xi_{c1}^+ \to \Xi^{*0}K^+$	$\frac{1}{3}\lvert 2\alpha-\beta+2\gamma+\delta\rvert^2$
$\Xi_{c1}^+ \to \Delta^{++}K^-$	$\lvert -\beta-\delta\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*+}\pi^0$	$\frac{1}{6}\lvert -\beta+2\gamma+\delta\rvert^2$
$\Xi_{c1}^0 \to \Delta^0\bar{K}^0$	$\frac{1}{3}\lvert 2\alpha-\beta+2\gamma-\delta\rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*0}\pi^0$	$\frac{1}{12}\lvert 2\alpha-\beta-2\gamma+3\delta\rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*0}\eta^0$	$\frac{1}{36}\lvert 2\alpha-\beta-2\gamma+3\delta\rvert^2$
$\Xi_{c1}^0 \to \Xi^{*0}K^0$	$\frac{1}{3}\lvert 2\alpha-\beta+2\gamma-\delta\rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*+}\pi^-$	$\frac{1}{3}\lvert -\beta+2\gamma-\delta\rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*-}\pi^+$	$\frac{4}{3}\lvert -\beta+\delta\rvert^2$
$\Xi_{c1}^0 \to \Xi^{*-}K^+$	$\frac{4}{3}\lvert -\beta+\delta\rvert^2$
$\Xi_{c1}^0 \to \Delta^+K^-$	$\frac{1}{3}\lvert -\beta+2\gamma-\delta\rvert^2$

$$|M(\Lambda_c^+ \to \Delta^+K^0)|^2 = |M(\Lambda_c^+ \to \Delta^0K^+)|^2 , \tag{21a}$$

$$|M(\Xi_{c1}^+ \to \Delta^{++}\pi^-)|^2 = 3|M(\Xi_{c1}^+ \to \Sigma^{*+}K^0)|^2 , \tag{21b}$$

$$|M(\Xi_{c1}^0 \to \Delta^-\pi^+)|^2 = 3|M(\Xi_{c1}^0 \to \Sigma^{*-}K^+)|^2 , \tag{21c}$$

$$|M(\Xi_{c1}^+ \to \Delta^+\eta^0)|^2 = |M(\Xi_{c1}^0 \to \Delta^0\eta^0)|^2 . \tag{21d}$$

TABLE VI. Squared matrix elements for the doubly Cabibbo-suppressed decays $T \to h^* M$ in terms of the reduced matrix α, β, γ, and δ.

Process	Squared matrix element (mod s_1^4)
$\Lambda_c^+ \to \Delta^+K^0$	$\frac{4}{3}\lvert\alpha\rvert^2$
$\Lambda_c^+ \to \Delta^0K^+$	$\frac{4}{3}\lvert\alpha\rvert^2$
$\Xi_{c1}^+ \to \Delta^+\eta^0$	$\frac{2}{9}\lvert -2\alpha+\beta-\gamma\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*0}K^+$	$\frac{1}{6}\lvert -2\alpha+\beta-2\gamma-\delta\rvert^2$
$\Xi_{c1}^+ \to \Delta^{++}\pi^-$	$\lvert\beta+\delta\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*+}K^0$	$\frac{1}{3}\lvert\beta+\delta\rvert^2$
$\Xi_{c1}^+ \to \Delta^0\pi^+$	$\frac{1}{3}\lvert\beta-2\gamma-\delta\rvert^2$
$\Xi_{c1}^+ \to \Delta^+\pi^0$	$\frac{2}{3}\lvert\gamma+\delta\rvert^2$
$\Xi_{c1}^0 \to \Delta^0\eta^0$	$\frac{2}{9}\lvert -2\alpha+\beta-\gamma\rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*0}K^0$	$\frac{1}{6}\lvert -2\alpha+\beta-2\gamma+\delta\rvert^2$
$\Xi_{c1}^0 \to \Delta^+\pi^-$	$\frac{1}{3}\lvert\beta-2\gamma+\delta\rvert^2$
$\Xi_{c1}^0 \to \Delta^-\pi^+$	$\lvert\beta-\delta\rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*-}K^+$	$\frac{1}{3}\lvert\beta-\delta\rvert^2$
$\Xi_{c1}^0 \to \Delta^0\pi^0$	$\frac{2}{3}\lvert\gamma-\delta\rvert^2$

Several relations between Cabibbo-allowed, -suppressed, and doubly Cabibbo-suppressed decay modes are found. They are

$$|M(\Lambda_c^+\to\Delta^0\pi^+)|^2=2s_1^2|M(\Lambda_c^+\to\Sigma^{*+}\pi^0)|^2\ , \tag{22a}$$

$$|M(\Lambda_c^+\to\Delta^{++}\pi^-)|^2=s_1^2|M(\Lambda_c^+\to\Delta^{++}K^-)|^2\ , \tag{22b}$$

$$2|M(\Xi_{c1}^+\to\Sigma^{*+}\pi^0)|^2=s_1^2|M(\Lambda_c^+\to\Xi^{*0}K^+)|^2\ , \tag{22c}$$

$$|M(\Xi_{c1}^0\to\Delta^0\overline{K}^0)|^2=2s_1^2|M(\Xi_{c1}^0\to\Sigma^{*0}\overline{K}^0)|^2\ , \tag{22d}$$

$$|M(\Xi_{c1}^0\to\Sigma^{*+}\pi^-)|^2=s_1^2|M(\Xi_{c1}^0\to\Sigma^{*+}K^-)|^2\ , \tag{22e}$$

$$|M(\Xi_{c1}^0\to\Sigma^{*-}\pi^+)|^2=4s_1^2|M(\Xi_{c1}^0\to\Xi^{*-}\pi^+)|^2\ , \tag{22f}$$

$$|M(\Xi_{c1}^+\to\Sigma^{*0}K^+)|^2=s_1^4|M(\Lambda_c^+\to\Sigma^{*+}\pi^0)|^2\ , \tag{22g}$$

$$|M(\Xi_{c1}^+\to\Delta^{++}\pi^-)|^2=s_1^4|M(\Lambda_c^+\to\Delta^{++}K^-)|^2\ , \tag{22h}$$

$$|M(\Xi_{c1}^+\to\Delta^0\pi^+)|^2=s_1^4|M(\Lambda_c^+\to\Xi^{*0}K^+)|^2\ , \tag{22i}$$

$$|M(\Lambda_c^+\to\Delta^+K^0)|^2=s_1^4|M(\Xi_{c1}^+\to\Sigma^{*+}\overline{K}^0)|^2\ , \tag{22j}$$

$$|M(\Xi_{c1}^0\to\Sigma^{*0}K^0)|^2=s_1^4|M(\Xi_{c1}^0\to\Sigma^{*0}\overline{K}^0)|^2\ , \tag{22k}$$

$$|M(\Xi_{c1}^0\to\Delta^+\pi^-)|^2=s_1^4|M(\Xi_{c1}^0\to\Sigma^{*+}K^-)|^2\ , \tag{22l}$$

$$|M(\Xi_{c1}^0\to\Delta^-\pi^+)|^2=s_1^4|M(\Xi_{c1}^0\to\Omega^-K^+)|^2\ . \tag{22m}$$

One of these decay modes has been observed with a branching ratio of[14]

$$B(\Lambda_c^+\to\Delta^{++}K^-)=(5.3\pm2.7)\times10^{-3}\ , \tag{23}$$

and hence we can predict, neglecting possible D-wave contributions, that $B(\Lambda_c^+\to\Delta^{++}\pi^-)\sim(3.8\pm2.0)\times10^{-4}$ [$\sim(4.8\pm2.5)\times10^{-4}$ for a purely D-wave process] and that $B(\Xi_{c1}^+\to\Delta^{++}\pi^-)\sim2.3\times10^{-5}$ ($\sim3.8\times10^{-5}$ for a purely D-wave process).

Next we look at the two-body decays $S\to BM$, where S denotes the **6** representation of charmed baryons. The element $S_{33}=\Omega_c^0$ is the only member of the **6** that decays weakly, the $\Sigma_c^{++,+,0}$ decay strongly to the Λ_c^+ in the $\overline{\mathbf{3}}$ (e.g., $\Sigma_c^{++}\to\Lambda_c^+\pi^+$), and the $\Xi_{c2}^{+,0}$ decay electromagnetically (e.g., $\Xi_{c2}^0\to\Xi_{c1}^0\gamma$). By inspection of the Ω_c^0 flavor wave function we see that the only Cabibbo-allowed final state is $\Xi^0\overline{K}^0$. We therefore look for relations between Cabibbo-allowed and -suppressed decay rates. The effective Hamiltonian for the process is

$$\begin{aligned}H_{\rm eff}=&a\epsilon^{abf}\overline{B}\,{}^c_fH^d_{ac}(\overline{\mathbf{15}})S_{be}M^e_d+b\epsilon^{abf}\overline{B}\,{}^c_fH^d_{ae}(\overline{\mathbf{15}})S_{bc}M^e_d+c\epsilon^{abf}\overline{B}\,{}^c_fH^d_{ae}(\overline{\mathbf{15}})S_{bd}M^e_c\\&+d\epsilon^{abf}\overline{B}\,{}^c_fH^d_{ac}(\overline{\mathbf{15}})S_{de}M^e_b+e\epsilon^{abf}\overline{B}\,{}^c_fH^d_{ae}(\overline{\mathbf{15}})S_{cd}M^e_b+f(\overline{B}\,{}^a_bM^b_a)[H^{cd}(\mathbf{6})S_{cd}]\\&+g\overline{B}\,{}^a_bM^b_cH^{cd}(\mathbf{6})S_{ad}+hM^a_b\overline{B}\,{}^b_cH^{cd}(\mathbf{6})S_{ad}+k\overline{B}\,{}^a_bM^c_dH^{bd}(\mathbf{6})S_{ac}+l\epsilon^{abf}\overline{B}\,{}^c_fH^d_{ce}(\overline{\mathbf{15}})M^e_dS_{bd}\ .\end{aligned} \tag{24}$$

The squared matrix elements resulting from this effective Hamiltonian are found in Table VII. We see that there are no relations between any of the decay rates involving Cabibbo-allowed, -suppressed, or doubly-Cabibbo-suppressed decays.

If we look at the isospin structure of the doubly Cabibbo-suppressed sextet component of the Hamiltonian $\mathcal{O}_6^{(ds)}=\frac{1}{2}[(c\overline{d})(s\overline{u})-(c\overline{u})(s\overline{d})]$, we see that it is an $I=0$ operator, whereas $\mathcal{O}_{\overline{15}}^{(ds)}$ is an $I=1$ operator. Since Ω_c^0 has $I=0$, we expect that the decay to $\Lambda^0\eta^0$ proceeds via $\mathcal{O}_6$

TABLE VII. Squared matrix elements for the decays $S\to BM$ in terms of the reduced matrix elements a, b, c, d, e, f, g, h, and k.

Process	Squared matrix element
$\Omega_c^0\to\Xi^0\overline{K}^0$	$\|-a-b+2k\|^2$
$\Omega_c^0\to\Sigma^0\overline{K}^0$	$s_1^2\frac{1}{2}\|2a-c+d+2h-l\|^2$
$\Omega_c^0\to\Xi^0\eta^0$	$s_1^2\frac{1}{6}\|-2a-3b-2c-2d-3e-2g+4h+4k+l\|^2$
$\Omega_c^0\to\Xi^0\pi^0$	$s_1^2\frac{1}{2}\|b-e+2g+l\|^2$
$\Omega_c^0\to\Xi^-\pi^+$	$s_1^2\|b+e-2g-l\|^2$
$\Omega_c^0\to\Sigma^+K^-$	$s_1^2\|c-d-2h+l\|^2$
$\Omega_c^0\to\Lambda^0\overline{K}^0$	$s_1^2\frac{1}{6}\|c+3d+2e+4g-2h+4k-l\|^2$
$\Omega_c^0\to\Sigma^0\eta^0$	$s_1^4\frac{1}{3}\|-2a+c-2d+l\|^2$
$\Omega_c^0\to\Xi^0K^0$	$s_1^4\|-b-c-2f-e-2g\|^2$
$\Omega_c^0\to\Xi^-K^+$	$s_1^4\|b+c-2f+e-2g\|^2$
$\Omega_c^0\to\Lambda^0\pi^0$	$s_1^4\frac{1}{3}\|c+2e-l\|^2$
$\Omega_c^0\to\Sigma^-\pi^+$	$s_1^4\|c-2f+l\|^2$
$\Omega_c^0\to\Sigma^+\pi^-$	$s_1^4\|c+2f+l\|^2$
$\Omega_c^0\to n\overline{K}^0$	$s_1^4\|d-2f-2h\|^2$
$\Omega_c^0\to pK^-$	$s_1^4\|d+2f+2h\|^2$
$\Omega_c^0\to\Lambda^0\eta^0$	$s_1^4\frac{4}{9}\|3f+2g+2h+2k\|^2$
$\Omega_c^0\to\Sigma^0\pi^0$	$s_1^4 4\|f\|^2$

only, and similarly for the $\Sigma^0\pi^0$ final state, since the weak Hamiltonian does not have an $I=2$ component. Therefore, by measuring the relative rate for an $I=1$ decay, for example, the $\Sigma^0\eta^0$ or $\Lambda^0\pi^0$ final state compared to an $I=0$ decay, an estimate of the relative contributions from $\mathcal{O}_6$ and $\mathcal{O}_{\overline{15}}$ can be made. This will not be a strong set of the perturbative QCD prediction since there could be cancellations between the reduced matrix elements contributing to the decays, but it will give a rough estimate of the relative contributions. Unfortunately, since these are doubly Cabibbo-suppressed decays, they will probably be the last to be measured and hence their predictive power is somewhat limited.

Consider now the process $S\to h^*M$. The only two possible Cabibbo-allowed final states are $\Omega^-\pi^+$ and $\Xi^{*0}\overline{K}^0$. The effective Hamiltonian for the decay is

$$H_{\text{eff}}=\alpha\bar{h}^{*abc}H^d_{ab}(\overline{15})S_{ce}M^e_d+\beta\bar{h}^{*abc}H^d_{ac}(\overline{15})S_{bc}M^e_d+\gamma\bar{h}^{*abc}H^d_{ae}(\overline{15})S_{bd}M^e_c$$
$$+\delta\bar{h}^{*abc}H^d_{ab}(\overline{15})S_{de}M^e_c+\lambda\epsilon_{adf}\bar{h}^{*abc}H^{de}(6)M^f_bS_{ce}+\eta\epsilon_{adf}\bar{h}^{*abc}H^{de}(6)M^f_eS_{bc}\ . \tag{25}$$

The resulting squared matrix elements are shown in Table VIII. We see that there are no relations between any of the Cabibbo-allowed or -suppressed decay modes. However, there are two relations involving doubly Cabibbo-suppressed processes; they are

$$|M(\Omega^0_c\to\Delta^+K^-)|^2=|M(\Omega^0_c\to\Delta^0\overline{K}^0)|^2\ , \tag{26a}$$

$$|M(\Omega^0_c\to\Xi^{*-}K^+)|^2=s^2_1\tfrac{1}{3}|M(\Omega^0_c\to\Omega^-K^+)|^2\ . \tag{26b}$$

B. Three-body final states

In this subsection we will be considering decays of charmed baryons to final states containing a baryon (either in the lowest-lying $\frac{1}{2}^+$ octet or the $\frac{3}{2}^+$ decuplet) and two octet mesons M. As far as SU(3) is concerned the two meson octets are identical and consequently the Hamiltonian must be symmetrized if the mesons are in a relatively even angular momentum state or antisymmetrized if they are in a relatively odd angular momentum state. When the Hamiltonian is expanded in terms of the individual particle operators, and matrix elements are taken, there are symmetry factors that must be included. This is demonstrated most simply by an example. Consider the Hamiltonian

$$H_{\text{eff}}=\pi^+\pi^-+\pi^0\pi^0\ , \tag{27}$$

of which matrix elements can be formed to yield

$$\langle 0|H_{\text{eff}}|\pi^+\pi^-\rangle=1\ , \tag{28a}$$

and

$$\langle 0|H_{\text{eff}}|\pi^0\pi^0\rangle=2\ , \tag{28b}$$

due to the two possible ways of annihilating the two neutral pions. When we form a rate from these matrix elements there is an additional factor of $\frac{1}{2}$ multiplying the $\pi^0\pi^0$ phase-space integrals from Bose statistics. In the tables this factor of $\frac{1}{2}$ has been omitted and so to obtain rate relations from the squared matrix elements a factor of $\frac{1}{2}$ must be included for processes involving identical particles. Also, in obtaining rate relations from the matrix elements, phase-space-correction factors must be included just as for the two-body decay modes. However since these factors depend upon the momentum configuration of the final state we will not calculate them in this work. Any processes that are not energetically allowed are not included in the tables.

The first three-body decay process examined is $T\to BMM$, for which there are 19 reduced matrix elements. The operator $\mathcal{O}_{\overline{15}}$ contributes 11 reduced matrix elements and $\mathcal{O}_6$ contributes eight. The Hamiltonian for the process is

TABLE VIII. Squared matrix element for the decays $S\to h^*M$ in terms of the reduced matrix elements α, β, γ, δ, λ, and η.

Process	Squared matrix element
$\Omega^0_c\to\Xi^{*0}\overline{K}^0$	$\frac{1}{3}|2\alpha+\beta+2\eta|^2$
$\Omega^0_c\to\Omega^-\pi^+$	$|\beta-2\eta|^2$
$\Omega^0_c\to\Sigma^{*0}\overline{K}^0$	$s^2_1\frac{1}{6}|2\alpha-\gamma-2\delta-2\lambda|^2$
$\Omega^0_c\to\Xi^{*0}\eta^0$	$s^2_1\frac{1}{18}|4\alpha+3\beta+\gamma+4\delta+6\lambda+6\eta|^2$
$\Omega^0_c\to\Xi^{*0}\pi^0$	$s^2_1\frac{1}{6}|-\beta-\gamma+2\lambda-2\eta|^2$
$\Omega^0_c\to\Xi^{*-}\pi^+$	$s^2_1\frac{1}{3}|\beta-\gamma+2\lambda-2\eta|^2$
$\Omega^0_c\to\Omega^-K^+$	$s^2_1|-\beta-\gamma+2\lambda+2\eta|^2$
$\Omega^0_c\to\Sigma^{*+}K^-$	$s^2_1\frac{1}{3}|\gamma+2\delta+2\lambda|^2$
$\Omega^0_c\to\Sigma^{*0}\eta^0$	$s^4_1\frac{1}{9}|-2\alpha+\gamma-2\delta|^2$
$\Omega^0_c\to\Xi^{*0}K^0$	$s^4_1\frac{1}{3}|\beta+\gamma+2\lambda+2\eta|^2$
$\Omega^0_c\to\Xi^{*-}K^+$	$s^4_1\frac{1}{3}|\beta+\gamma-2\lambda-2\eta|^2$
$\Omega^0_c\to\Sigma^{*+}\pi^-$	$s^4_1\frac{1}{3}|\gamma+2\lambda|^2$
$\Omega^0_c\to\Sigma^{*-}\pi^+$	$s^4_1\frac{1}{3}|\gamma-2\lambda|^2$
$\Omega^0_c\to\Delta^+K^-$	$s^4_1\frac{4}{3}|\delta|^2$
$\Omega^0_c\to\Delta^0\overline{K}^0$	$s^4_1\frac{4}{3}|\delta|^2$
$\Omega^0_c\to\Sigma^{*0}\pi^0$	$s^4_1\frac{4}{3}|\lambda|^2$

$$
\begin{aligned}
H_{\text{eff}} = {} & A_f T^a \bar{B}\,{}^b_a H^d_{bc}(\overline{15}) M^e_d M^c_e + B_f T^a \bar{B}\,{}^b_a H^e_{cd}(\overline{15}) M^c_e M^d_b + C_f T^a \bar{B}\,{}^b_c H^c_{ad}(\overline{15}) M^e_b M^d_e \\
& + D_f T^a \bar{B}\,{}^b_c H^d_{ab}(\overline{15}) M^c_e M^e_d + E_f [T^a \bar{B}\,{}^b_c H^c_{ab}(\overline{15})](M^e_f M^f_e) + F_f T^a \bar{B}\,{}^b_c H^d_{ae}(\overline{15}) M^c_b M^e_d \\
& + G_f T^a \bar{B}\,{}^b_c H^d_{ae}(\overline{15}) M^c_d M^e_b + I_f T^a \bar{B}\,{}^b_c H^c_{bd}(\overline{15}) M^e_a M^d_e + J_f T^a \bar{B}\,{}^e_c H^c_{bd}(\overline{15}) M^b_a M^d_e \\
& + K_f T^a \bar{B}\,{}^b_c H^d_{be}(\overline{15}) M^c_a M^e_d + L_f T^a \bar{B}\,{}^b_c H^d_{be}(\overline{15}) M^e_a M^c_d + A_s [T_{ab} \bar{B}\,{}^a_c H^{bc}(6)](M^d_e M^e_d) \\
& + B_s T_{ab} \bar{B}\,{}^a_c H^{cd}(6) M^b_e M^e_d + C_s T_{ab} \bar{B}\,{}^a_c H^{bd}(6) M^c_e M^e_d + D_s T_{ab} \bar{B}\,{}^a_c H^{de}(6) M^b_d M^c_e \\
& + F_s T_{ab} \bar{B}\,{}^c_d H^{ad}(6) M^b_e M^e_c + I_s T_{ab} \bar{B}\,{}^d_c H^{ae}(6) M^b_d M^c_e + J_s T_{ab} \bar{B}\,{}^c_d H^{ae}(6) M^b_e M^d_c + K_s T_{ab} \bar{B}\,{}^c_d H^{de}(6) M^a_c M^b_e \ .
\end{aligned} \tag{29}
$$

The matrix elements resulting from this Hamiltonian are *not* tabulated in this paper as there are ~ 121 possible decay modes for either angular momentum state.

Despite this large number of operators there are still relations between some matrix elements for various decay modes. The relations between Cabibbo-allowed decays are all due to isospin, examples of which are

$$
|M(\Xi^0_{c1} \to \Xi^- \pi^0 \pi^+)_{(L=0,2,\ldots)}|^2 = |M(\Xi^+_{c1} \to \Xi^0 \pi^0 \pi^+)_{(L=0,2,\ldots)}|^2 \ , \tag{30a}
$$

$$
|M(\Lambda^+_c \to \Sigma^0 \pi^0 \pi^+)_{(L=1,3,\ldots)}|^2 = |M(\Lambda^+_c \to \Sigma^+ \pi^+ \pi^-)_{(L=1,3,\ldots)}|^2 \ , \tag{30b}
$$

for even and odd angular momentum channels, respectively, and

$$
|M(\Lambda^+_c \to \Sigma^0 \eta^0 \pi^+)|^2 = |M(\Lambda^+_c \to \Sigma^+ \eta^0 \pi^0)|^2 \ , \tag{30c}
$$

$$
|M(\Lambda^+_c \to \Sigma^0 \pi^0 \pi^+)|^2 \geq \tfrac{1}{4} |M(\Lambda^+_c \to \Sigma^- \pi^+ \pi^+)|^2 \ , \tag{30d}
$$

which are independent of the relative angular momentum between the mesons. The inequality arises from the fact that processes involving identical mesons in the final state can only proceed through even angular momentum channels. There is a relation between a Cabibbo-allowed process and -suppressed process that holds only for odd relative angular momentum states which is

$$
|M(\Xi^+_{c1} \to \Xi^- K^+ \pi^+)_{(L=1,3,\ldots)}|^2 = s_1^2 |M(\Lambda^+_c \to \Xi^- K^+ \pi^+)_{(L=1,3,\ldots)}|^2 \ . \tag{30e}
$$

More interesting are the Cabibbo-suppressed decays where there are relations due to the full SU(3) symmetry which are independent of the relative angular momentum between the mesons. They are

$$
|M(\Lambda^+_c \to \Sigma^+ K^+ \pi^-)|^2 = |M(\Xi^+_{c1} \to p K^- \pi^+)|^2 \ , \tag{31a}
$$

$$
|M(\Lambda^+_c \to p \bar{K}^0 K^0)|^2 = |M(\Xi^+_{c1} \to \Sigma^+ \bar{K}^0 K^0)|^2 \ , \tag{31b}
$$

$$
|M(\Lambda^+_c \to n \bar{K}^0 K^+)|^2 = |(M(\Xi^+_{c1} \to \Xi^0 K^0 \pi^+)|^2 \ , \tag{31c}
$$

$$
|M(\Xi^+_{c1} \to \Sigma^- \pi^+ \pi^+)|^2 \leq \frac{s_1^2}{2} |M(\Lambda^+_c \to \Xi^- K^+ \pi^+)|^2 \ , \tag{31d}
$$

$$
|M(\Xi^0_{c1} \to p \bar{K}^0 \pi^-)|^2 = |M(\Xi^0_{c1} \to \Sigma^+ K^- K^0)|^2 \ , \tag{31e}
$$

$$
|M(\Xi^0_{c1} \to n K^- \pi^+)|^2 = |(M \Xi^0_{c1} \to \Xi^0 K^+ \pi^-)|^2 \ , \tag{31f}
$$

$$
|M(\Xi^0_{c1} \to \Sigma^- \bar{K}^0 K^+)|^2 = |M(\Xi^0_{c1} \to \Xi^- K^0 \pi^+)|^2 \ , \tag{31g}
$$

$$
|M(\Xi^0_{c1} \to \Sigma^0 \bar{K}^0 K^0)|^2 = |M(\Xi^0_{c1} \to \Lambda^0 \bar{K}^0 K^0)|^2 \ . \tag{31h}
$$

Experimentally, branching ratios for some of these processes have been measured, $B(\Lambda^+_c \to p K^- \pi^+) = (2.6 \pm 0.9) \times 10^{-2}$ (Ref. 5) and $B(\Lambda^+_c \to \Sigma^+ \pi^+ \pi^-) = (10 \pm 8) \times 10^{-2}$ (Ref. 16) of which the latter appears in an isospin relation between Cabibbo-allowed decays.

There are 29 reduced matrix elements contributing to the process $S \to BMM$, 20 of which are from $\mathcal{O}_{\overline{15}}$ and the remaining nine from $\mathcal{O}_6$. Only two relations are found:

$$
|M(\Omega^0_c \to \Sigma^+ \bar{K}^0 K^-)|^2 \geq 2 |M(\Omega^0_c \to \Sigma^0 \bar{K}^0 \bar{K}^0)|^2 \ , \tag{32a}
$$

$$
|M(\Omega^0_c \to p \bar{K}^0 K^-)|^2 \geq \tfrac{1}{4} |M(\Omega^0_c \to n \bar{K}^0 \bar{K}^0)|^2 \ . \tag{32b}
$$

The first is between Cabibbo-allowed decays and the second between Cabibbo-suppressed decays. They are both consequences of isospin. The matrix elements for the various decay modes are not tabulated.

We consider now the process $T \to h^* MM$. There are 12 reduced matrix elements contributing to the decays. The effective Hamiltonian for the process is given by

$$
\begin{aligned}
H_{\text{eff}} = {} & A_f \bar{h}^{*abc} H^d_{bc}(\overline{15}) M^e_d M^g_a T_{eg} + B_f \bar{h}^{*abc} H^d_{ab}(\overline{15}) M^e_d M^g_e T_{cg} + C_f \bar{h}^{*abc} H^d_{ga}(\overline{15}) M^e_b M^g_c T_{de} \\
& + D_f [\bar{h}^{*abc} H^d_{bc}(\overline{15}) T_{ad}](M^e_g M^g_e) + E_f \bar{h}^{*abc} H^d_{eb}(\overline{15}) M^e_d M^g_c T_{ag} + F_f \bar{h}^{*abc} H^d_{gb}(\overline{15}) M^e_d M^g_c T_{ae} \\
& + G_f \bar{h}^{*abc} H^d_{eg}(\overline{15}) M^e_b M^g_c T_{ad} + I_f \bar{h}^{*abc} H^d_{ab}(\overline{15}) M^e_g M^g_c T_{de} + C_s \bar{h}^{*abc} H^d_{ga}(6) M^e_b M^g_c T_{de} \\
& + E_s \bar{h}^{*abc} H^d_{eb}(6) M^e_d M^g_c T_{ag} + F_s \bar{h}^{*abc} H^d_{gb}(6) M^e_d M^g_c T_{ae} + G_s \bar{h}^{*abc} H^d_{eg}(6) M^e_b M^g_c T_{ad} \ .
\end{aligned} \tag{33}
$$

The results for Cabibbo-allowed decays with the mesons in an even (odd) angular momentum state are shown in Table IX (Table X). Cabibbo-suppressed decays with the mesons in an even (odd) angular momentum state are shown in Table XI (Table XII). We see that there are many relations between squared matrix elements for various processes. For Cabibbo-allowed decays, we find that there are relations between matrix elements when the mesons in an even or odd angular momentum state. They are

$$|M(\Xi_{c1}^{+}\to\Xi^{*0}\pi^{0}\pi^{+})_{(L=0,2,\ldots)}|^2=\tfrac{1}{8}|M(\Xi_{c1}^{+}\to\Xi^{*-}\pi^{+}\pi^{+})_{(L=0,2,\ldots)}|^2$$
$$=\tfrac{1}{6}|M(\Xi_{c1}^{+}\to\Omega^{-}K^{+}\pi^{+})_{(L=0,2,\ldots)}|^2$$
$$=|M(\Xi_{c1}^{0}\to\Xi^{*-}\pi^{0}\pi^{+})_{(L=0,2,\ldots)}|^2\,, \tag{34a}$$

$$|M(\Xi_{c1}^{0}\to\Delta^{+}\bar{K}^{0}K^{-})_{(L=1,3,\ldots)}|^2=\tfrac{1}{3}|M(\Xi_{c1}^{+}\to\Delta^{++}\bar{K}^{0}K^{-})_{(L=1,3,\ldots)}|^2\,, \tag{34b}$$

$$|M(\Lambda_{c}^{+}\to\Xi^{*-}K^{+}\pi^{+})_{(L=1,3,\ldots)}|^2=\tfrac{1}{3}|M(\Xi_{c1}^{+}\to\Omega^{-}K^{+}\pi^{+})_{(L=1,3,\ldots)}|^2\,. \tag{34c}$$

TABLE IX. Squared matrix elements for the Cabibbo-allowed decays $T\to h^{*}MM$ where the mesons are in a relatively even angular momentum state in terms of the reduced matrix elements A_f, B_f, C_f, D_f, E_f, F_f, G_f, I_f, C_s, E_s, F_s, and G_s.

Process	Squared matrix element
$\Lambda_c^+\to\Sigma^{*+}\pi^0\pi^0$	$\frac{1}{3}\lvert 2A_f+2B_f-C_f+4D_f-F_f-2I_f+C_s+F_s\rvert^2$
$\Lambda_c^+\to\Sigma^{*+}\pi^0\eta^0$	$\frac{1}{9}\lvert -2B_f+F_f-2G_f-2I_f+2C_s+F_s\rvert^2$
$\Lambda_c^+\to\Sigma^{*+}\pi^-\pi^+$	$\frac{1}{3}\lvert 2A_f+2B_f+4D_f+E_f-2I_f-E_s\rvert^2$
$\Lambda_c^+\to\Sigma^{*0}\pi^0\pi^+$	$\frac{1}{3}\lvert -C_f-E_f-F_f+C_s+E_s+F_s\rvert^2$
$\Lambda_c^+\to\Sigma^{*0}\pi^+\eta^0$	$\frac{1}{9}\lvert -2B_f+F_f-2G_f-2I_f+2C_s+F_s\rvert^2$
$\Lambda_c^+\to\Xi^{*0}K^+\pi^0$	$\frac{2}{3}\lvert A_f-C_f-\frac{1}{2}F_f-I_f+C_s+\frac{1}{2}F_s\rvert^2$
$\Lambda_c^+\to\Xi^{*0}K^0\pi^+$	$\frac{1}{3}\lvert 2A_f+E_f-2I_f-E_s\rvert^2$
$\Lambda_c^+\to\Delta^{++}K^-\pi^0$	$\frac{1}{2}\lvert -C_f-F_f+2G_f-C_s-F_s\rvert^2$
$\Lambda_c^+\to\Delta^{+}K^-\pi^+$	$\frac{1}{3}\lvert -C_f-F_f+2G_f-C_s-F_s\rvert^2$
$\Lambda_c^+\to\Delta^{+}\bar{K}^0\pi^0$	$\frac{1}{6}\lvert -C_f-2E_f-F_f+2G_f-C_s-2E_s-F_s\rvert^2$
$\Lambda_c^+\to\Delta^{0}\bar{K}^0\pi^+$	$\frac{1}{3}\lvert -C_f-E_f-F_f+2G_f-C_s-E_s-F_s\rvert^2$
$\Lambda_c^+\to\Sigma^{*-}\pi^+\pi^+$	$\frac{4}{3}\lvert -C_f-E_f-F_f+C_s+E_s+F_s\rvert^2$
$\Lambda_c^+\to\Xi^{*-}\pi^+K^+$	$\frac{1}{3}\lvert -2C_f-E_f-F_f+2C_s+E_s+F_s\rvert^2$
$\Lambda_c^+\to\Delta^{++}\pi^-\bar{K}^0$	$\lvert E_f+E_s\rvert^2$
$\Xi_{c1}^+\to\Sigma^{*+}\pi^0\bar{K}^0$	$\frac{1}{6}\lvert -2A_f-2B_f-E_f+F_f-E_s-F_s\rvert^2$
$\Xi_{c1}^+\to\Sigma^{*+}\eta^0\bar{K}^0$	$\frac{1}{18}\lvert -2A_f-2B_f-3E_f-F_f-3E_s-3F_s\rvert^2$
$\Xi_{c1}^+\to\Sigma^{*+}K^-\pi^+$	$\frac{1}{3}\lvert 2A_f+2B_f+E_f-E_f-E_s-F_s\rvert^2$
$\Xi_{c1}^+\to\Sigma^{*0}\pi^+\bar{K}^0$	$\frac{2}{3}\lvert E_s+F_s\rvert^2$
$\Xi_{c1}^+\to\Xi^{*0}\eta^0\pi^+$	$\frac{1}{18}\lvert -4A_f-4B_f-3E_f+F_f+3E_s+3F_s\rvert^2$
$\Xi_{c1}^+\to\Delta^{++}K^-\bar{K}^0$	$\lvert E_f+F_f+E_s+F_s\rvert^2$
$\Xi_{c1}^+\to\Delta^{+}\bar{K}^0\bar{K}^0$	$\frac{4}{3}\lvert E_f+F_f+E_s+F_s\rvert^2$
$\Xi_{c1}^+\to\Xi^{*0}\pi^0\pi^+$	$\frac{1}{6}\lvert -E_f-F_f+E_s+F_s\rvert^2$
$\Xi_{c1}^+\to\Xi^{*-}\pi^+\pi^+$	$\frac{4}{3}\lvert -E_f-F_f+E_s+F_s\rvert^2$
$\Xi_{c1}^+\to\Omega^{-}K^+\pi^+$	$\lvert -E_f-F_f+E_s+F_s\rvert^2$
$\Xi_{c1}^0\to\Sigma^{*+}\pi^-\bar{K}^0$	$\frac{1}{3}\lvert -2A_f-E_f+2I_f-E_s\rvert^2$
$\Xi_{c1}^0\to\Sigma^{*+}K^-\pi^0$	$\frac{1}{6}\lvert -2A_f+C_f+F_f-2G_f+2I_f-C_s+F_s\rvert^2$
$\Xi_{c1}^0\to\Sigma^{*+}K^-\eta^0$	$\frac{1}{18}\lvert 2A_f-3C_f-F_f-2G_f-2I_f-5C_s-F_s\rvert^2$
$\Xi_{c1}^0\to\Sigma^{*0}\bar{K}^0\pi^0$	$\frac{1}{12}\lvert -2B_f+C_f+E_f+2F_f-2G_f-2I_f-C_s+E_s\rvert^2$
$\Xi_{c1}^0\to\Sigma^{*0}\bar{K}^0\eta^0$	$\frac{1}{4}\lvert -\frac{2}{3}B_f-C_f-E_f-\frac{2}{3}F_f-\frac{2}{3}G_f-\frac{2}{3}I_f-\frac{5}{3}C_s-E_s-\frac{4}{3}F_s\rvert^2$
$\Xi_{c1}^0\to\Xi^{*0}\eta^0\pi^0$	$\frac{1}{9}\lvert 2A_f+2B_f-C_f-F_f+2G_f+C_s-F_s\rvert^2$
$\Xi_{c1}^0\to\Delta^{++}K^-K^-$	$4\lvert C_f+C_s\rvert^2$
$\Xi_{c1}^0\to\Delta^{+}K^-\bar{K}^0$	$\frac{1}{3}\lvert 2C_f+E_f+F_f+2C_s+E_s+F_s\rvert^2$
$\Xi_{c1}^0\to\Sigma^{*-}\pi^+\bar{K}^0$	$\frac{1}{3}\lvert C_f+E_f+F_f-2G_f-C_s-E_s-F_s\rvert^2$
$\Xi_{c1}^0\to\Xi^{*-}\pi^+\eta^0$	$\frac{1}{18}\lvert -2C_f-3E_f-F_f+4G_f+2C_s+3E_s+F_s\rvert^2$
$\Xi_{c1}^0\to\Sigma^{*0}\pi^+K^-$	$\frac{1}{6}\lvert 2B_f+C_f+E_f-2G_f+2I_f-C_s-E_s\rvert^2$
$\Xi_{c1}^0\to\Delta^{0}\bar{K}^0\bar{K}^0$	$\frac{4}{3}\lvert C_f+E_f+F_f+C_s+E_s+F_s\rvert^2$
$\Xi_{c1}^0\to\Xi^{*0}\pi^+\pi^-$	$\frac{1}{3}\lvert -2B_f-4D_f-E_f+E_s\rvert^2$
$\Xi_{c1}^0\to\Xi^{*-}\pi^0\pi^+$	$\frac{1}{6}\lvert E_f+F_f-E_s-F_s\rvert^2$
$\Xi_{c1}^0\to\Omega^{-}K^0\pi^+$	$\lvert -E_f+E_s\rvert^2$
$\Xi_{c1}^0\to\Xi^{*0}\pi^0\pi^0$	$\frac{1}{3}\lvert -2B_f-4D_f+F_f-F_s\rvert^2$
$\Xi_{c1}^0\to\Omega^{-}K^+\pi^0$	$\frac{1}{2}\lvert F_f-F_s\rvert^2$

There are also many relations that are independent of the relative angular momentum between the mesons; they are

$$|M(\Lambda_c^+\to\Delta^{++}K^-\pi^0)|^2=\tfrac{3}{2}|M(\Lambda_c^+\to\Delta^+K^-\pi^+)|^2\ , \tag{34d}$$

$$|M(\Lambda_c^+\to\Sigma^{*+}\eta^0\pi^0)|^2=|M(\Lambda_c^+\to\Sigma^{*0}\eta^0\pi^+)|^2\ , \tag{34e}$$

$$|M(\Lambda_c^+\to\Sigma^{*0}\pi^0\pi^+)|^2\geq\tfrac{1}{4}|M(\Lambda_c^+\to\Sigma^{*-}\pi^+\pi^+)|^2\ , \tag{34f}$$

$$|M(\Xi_{c1}^+\to\Delta^{++}\bar{K}^0K^-)|^2\geq\tfrac{3}{4}|M(\Xi_c^+\to\Delta^+\bar{K}^0\bar{K}^0)|^2\ , \tag{34g}$$

$$|M(\Xi_{c1}^+\to\Xi^{*0}\pi^0\pi^+)|^2=\tfrac{1}{6}|M(\Xi_{c1}^+\to\Omega^-K^+\pi^+)|^2 \geq\tfrac{1}{8}|M(\Xi_{c1}^+\to\Xi^{*-}\pi^+\pi^+)|^2\ . \tag{34h}$$

Turning now to the Cabibbo-suppressed decays, again there are many relations between squared matrix elements. All except one of the relations between the squared matrix elements are independent of the relative angular momentum between the mesons. The relations are

$$|M(\Xi_{c1}^0\to\Delta^0K^-\pi^+)|^2=|M(\Xi_{c1}^0\to\Xi^{*0}K^+\pi^-)|^2\ , \tag{35a}$$

$$|M(\Lambda_c^+\to\Sigma^{*+}K^+\pi^-)|^2=|M(\Xi_{c1}^+\to\Delta^+K^-\pi^+)|^2\ , \tag{35b}$$

$$|M(\Lambda_c^+\to\Sigma^{*-}K^+\pi^+)|^2=|M(\Xi_{c1}^+\to\Xi^{*-}K^+\pi^+)|^2\ , \tag{35c}$$

$$|M(\Lambda_c^+\to\Delta^+\pi^0\eta^0)_{(L=1,3,\dots)}|^2 =|M(\Xi_{c1}^+\to\Sigma^{*+}\pi^0\eta^0)_{(L=1,3,\dots)}|^2\ . \tag{35d}$$

TABLE X. Squared matrix elements for the Cabibbo-allowed decays $T\to h^*MM$, where the two mesons are in a relatively odd angular momentum state in terms of reduced matrix elements A_f', B_f', C_f', D_f', E_f', F_f', G_f', I_f', C_s', E_s', F_s', and G_s'.

Process	Squared matrix element
$\Lambda_c^+\to\Sigma^{*+}\pi^0\eta^0$	$\frac{1}{9}\lvert 2A_f'+C_f'+C_s'+2F_s'+2G_s'\rvert^2$
$\Lambda_c^+\to\Sigma^{*+}\pi^-\pi^+$	$\frac{1}{3}\lvert -2A_f'-2B_f'-E_f'+2I_f'+E_s'\rvert^2$
$\Lambda_c^+\to\Sigma^{*0}\pi^0\pi^+$	$\frac{1}{3}\lvert 2A_f'+2B_f'+E_f'-2I_f'-E_s'\rvert^2$
$\Lambda_c^+\to\Sigma^{*0}\pi^+\eta^0$	$\frac{1}{9}\lvert 2A_f'+C_f'+C_s'+2F_s'+2G_s'\rvert^2$
$\Lambda_c^+\to\Xi^{*0}K^+\pi^0$	$\frac{1}{6}\lvert 2A_f'-F_f'-2I_f'+F_s'\rvert^2$
$\Lambda_c^+\to\Xi^{*0}K^0\pi^+$	$\frac{1}{3}\lvert 2A_f'+E_f'-2I_f'-E_s'\rvert^2$
$\Lambda_c^+\to\Delta^{++}K^-\pi^0$	$\frac{1}{2}\lvert C_f'+F_f'+C_s'+F_s'+2G_s'\rvert^2$
$\Lambda_c^+\to\Delta^+K^-\pi^+$	$\frac{1}{3}\lvert C_f'+F_f'+C_s'+F_s'+2G_s'\rvert^2$
$\Lambda_c^+\to\Delta^+\bar{K}^0\pi^0$	$\frac{1}{6}\lvert -C_f'+2E_f'-F_f'-C_s'+2E_s'-F_s'-2G_s'\rvert^2$
$\Lambda_c^+\to\Delta^0\bar{K}^0\pi^+$	$\frac{1}{3}\lvert -C_f'+E_f'-F_f'-C_s'+E_s'-F_s'-2G_s'\rvert^2$
$\Lambda_c^+\to\Delta^{++}\pi^-\bar{K}^0$	$\lvert E_f'+E_s'\rvert^2$
$\Lambda_c^+\to\Xi^{*-}K^+\pi^+$	$\frac{1}{3}\lvert -E_f'-F_f'+E_s'+F_s'\rvert^2$
$\Xi_{c1}^+\to\Sigma^{*+}\pi^0\bar{K}^0$	$\frac{1}{6}\lvert -2A_f'+2B_f'-E_f'+F_f'-E_s'-F_s'\rvert^2$
$\Xi_{c1}^+\to\Sigma^{*+}\eta^0\bar{K}^0$	$\frac{1}{18}\lvert 2A_f'+6B_f'+3E_f'+F_f'+3E_s'+3F_s'\rvert^2$
$\Xi_{c1}^+\to\Sigma^{*+}K^-\pi^+$	$\frac{1}{3}\lvert 2A_f'+2B_f'+E_f'-F_f'-E_s'-F_s'\rvert^2$
$\Xi_{c1}^+\to\Sigma^{*0}\pi^+\bar{K}^0$	$\frac{2}{3}\lvert -2A_f'-E_f'+F_f'\rvert^2$
$\Xi_{c1}^+\to\Xi^{*0}\eta^0\pi^+$	$\frac{1}{18}\lvert -4A_f'-3E_f'+F_f'+3E_s'+3F_s'\rvert^2$
$\Xi_{c1}^+\to\Delta^{++}K^-\bar{K}^0$	$\lvert E_f'+F_f'+E_s'+F_s'\rvert^2$
$\Xi_{c1}^+\to\Xi^{*0}\pi^0\pi^+$	$\frac{1}{6}\lvert -4B_f'-E_f'-F_f'+E_s'+F_s'\rvert^2$
$\Xi_{c1}^+\to\Omega^-K^+\pi^+$	$\lvert -E_f'-F_f'+E_s'+F_s'\rvert^2$
$\Xi_{c1}^0\to\Sigma^{*+}\pi^-\bar{K}^0$	$\frac{1}{3}\lvert -2A_f'-E_f'+2I_f'-E_s'\rvert^2$
$\Xi_{c1}^0\to\Sigma^{*+}K^-\pi^0$	$\frac{1}{6}\lvert -2A_f'-C_f'+F_f'-2I_f'+C_s'+F_s'+2G_s'\rvert^2$
$\Xi_{c1}^0\to\Sigma^{*+}K^-\eta^0$	$\frac{1}{18}\lvert 2A_f'-C_f'-F_f'-6I_f'+C_s'-F_s'+2G_s'\rvert^2$
$\Xi_{c1}^0\to\Sigma^{*0}\bar{K}^0\pi^0$	$\frac{1}{12}\lvert 4A_f'+2B_f'+C_f'+E_f'-2I_f'-C_s'+E_s'-2F_s'-2G_s'\rvert^2$
$\Xi_{c1}^0\to\Sigma^{*0}\eta^0\bar{K}^0$	$\frac{1}{36}\lvert 4A_f'+6B_f'-C_f'+3E_f'-6I_f'+C_s'-3E_s'+2F_s'+2G_s'\rvert^2$
$\Xi_{c1}^0\to\Xi^{*0}\eta^0\pi^0$	$\frac{1}{9}\lvert 2A_f'+C_f'-C_s'-2F_s'-2G_s'\rvert^2$
$\Xi_{c1}^0\to\Sigma^{*-}\pi^+\bar{K}^0$	$\frac{1}{3}\lvert C_f'-E_f'+F_f'-C_s'+E_s'-F_s'-2G_s'\rvert^2$
$\Xi_{c1}^0\to\Xi^{*-}\eta^0\pi^+$	$\frac{1}{18}\lvert -2C_f'+3E_f'-F_f'+2C_s'-3E_s'+F_s'+4G_s'\rvert^2$
$\Xi_{c1}^0\to\Delta^+K^-\bar{K}^0$	$\frac{1}{3}\lvert E_f'+F_f'+E_s'+F_s'\rvert^2$
$\Xi_{c1}^0\to\Sigma^{*0}K^-\pi^+$	$\frac{1}{6}\lvert -2B_f'+C_f'-E_f'+2I_f'-C_s'+E_s'-2G_s'\rvert^2$
$\Xi_{c1}^0\to\Xi^{*0}\pi^-\pi^+$	$\frac{1}{3}\lvert -2B_f'-E_f'+E_s'\rvert^2$
$\Xi_{c1}^0\to\Xi^{*-}\pi^0\pi^+$	$\frac{1}{6}\lvert E_f'-F_f'-E_s'+F_s'\rvert^2$
$\Xi_{c1}^0\to\Omega^-K^0\pi^+$	$\lvert -E_f'+E_s'\rvert^2$
$\Xi_{c1}^0\to\Omega^-K^+\pi^0$	$\frac{1}{2}\lvert F_f'-F_s'\rvert^2$

TABLE XI. Squared matrix elements for the Cabibbo-suppressed decays $T \to h^* MM$, where the mesons are in a relatively even angular momentum state in terms of reduced matrix elements A_f, B_f, C_f, D_f, E_f, F_f, G_f, I_f, C_s, E_s, F_s, and G_s.

Process	Squared matrix element (mod s_1^2)
$\Lambda_c^+ \to \Delta^+ \pi^0 \pi^0$	$\frac{4}{3}\lvert A_f+B_f+2D_f+E_f-G_f-I_f+C_s+E_s+F_s\rvert^2$
$\Lambda_c^+ \to \Delta^+ \pi^0 \eta^0$	$\frac{1}{9}\lvert 2B_f+C_f+3E_f+F_f+2I_f-C_s+3E_s+F_s\rvert^2$
$\Lambda_c^+ \to \Delta^+ \pi^+ \pi^-$	$\frac{1}{3}\lvert 2A_f+2B_f-C_f+4D_f+E_f-F_f+2G_f-2I_f-C_s-E_s-F_s\rvert^2$
$\Lambda_c^+ \to \Delta^+ K^+ K^-$	$\frac{1}{3}\lvert 4D_f+F_f-2I_f+F_s\rvert$
$\Lambda_c^+ \to \Delta^+ \bar{K}^0 K^0$	$\frac{1}{3}\lvert 2B_f+4D_f-F_f-F_s\rvert$
$\Lambda_c^+ \to \Delta^0 \pi^0 \pi^+$	$\frac{1}{6}\lvert -C_f-E_f-F_f-2G_f+3C_s+3E_s+3F_s\rvert$
$\Lambda_c^+ \to \Delta^0 \pi^+ \eta^0$	$\frac{1}{18}\lvert -4B_f-3C_f-3E_f-F_f+2G_f-4I_f+C_s-3E_s-F_s\rvert$
$\Lambda_c^+ \to \Delta^0 \bar{K}^0 K^+$	$\frac{1}{3}\lvert -2B_f+F_f-2I_f+F_s\rvert$
$\Lambda_c^+ \to \Sigma^{*0} K^+ \pi^0$	$\frac{1}{12}\lvert 4A_f+2B_f-C_f+3E_f-2G_f-2I_f+3C_s-E_s\rvert^2$
$\Lambda_c^+ \to \Sigma^{*0} K^0 \pi^+$	$\frac{1}{6}\lvert 4A_f+2B_f-C_f+E_f-2F_f+2G_f-2I_f-C_s-E_s\rvert^2$
$\Lambda_c^+ \to \Sigma^{*+} K^+ \pi^-$	$\frac{1}{3}\lvert -2A_f-2B_f-C_f-E_f+2G_f-C_s+E_s\rvert^2$
$\Lambda_c^+ \to \Sigma^{*+} K^0 \pi^0$	$\frac{1}{6}\lvert 2A_f+2B_f-C_f-E_f-2F_f+2G_f-C_s-E_s\rvert^2$
$\Lambda_c^+ \to \Delta^{++} \pi^- \pi^0$	$\frac{1}{2}\lvert -C_f-E_f-F_j+2G_f-C_s-E_s-F_s\rvert^2$
$\Lambda_c^+ \to \Delta^{++} K^- K^0$	$\lvert F_f+F_s\rvert^2$
$\Lambda_c^+ \to \Delta^{++} \eta^0 \pi^-$	$\frac{1}{6}\lvert -C_f+3E_f+F_f+2G_f-C_s+3E_s+F_s\rvert^2$
$\Lambda_c^+ \to \Delta^- \pi^+ \pi^+$	$4\lvert -C_f-E_f-F_f+C_s+E_s+F_s\rvert^2$
$\Lambda_c \to \Sigma^{*-} K^+ \pi^+$	$\frac{4}{3}\lvert C_f-C_s\rvert^2$
$\Xi_{c1}^+ \to \Delta^+ \bar{K}^0 \pi^0$	$\frac{1}{6}\lvert -2A_f-2B_f+C_f-E_f-2G_f+C_s-E_s-2F_s\rvert^2$
$\Xi_{c1}^+ \to \Delta^+ \bar{K}^0 \eta^0$	$\frac{1}{18}\lvert -2A_f-2B_f+C_f+3E_f+4F_f-2G_f+C_s+3E_s+2F_s\rvert^2$
$\Xi_{c1}^+ \to \Delta^+ K^- \pi^+$	$\frac{1}{3}\lvert 2A_f+2B_f+C_f+E_f-2G_f+C_s-E_s\rvert^2$
$\Xi_{c1}^+ \to \Delta^0 \bar{K}^0 \pi^+$	$\frac{1}{3}\lvert C_f+E_f+F_f-2G_f+C_s-E_s-F_s\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*0} \bar{K}^0 K^+$	$\frac{1}{6}\lvert -4A_f-2B_f+C_f-E_f+2F_f-2G_f+2I_f+C_s+E_s\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*0} \eta^0 \pi^+$	$\frac{1}{9}\lvert -4A_f-2B_f-3E_f+2G_f+2I_f-2C_s-F_s\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*+} K^- K^+$	$\frac{1}{3}\lvert -2A_f-2B_f+C_f-4D_f-E_f+F_f-2G_f+2I_f+C_s+E_s+F_s\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*+} \eta^0 \pi^0$	$\frac{1}{9}\lvert -2A_f+F_f+2G_f+2I_f-2C_s-F_s\rvert^2$
$\Xi_{c1}^+ \to \Delta^{++} K^- \pi^0$	$\frac{1}{2}\lvert C_f-E_f-2G_f+C_s-E_s\rvert^2$
$\Xi_{c1}^+ \to \Delta^{++} K^- \eta^0$	$\frac{1}{6}\lvert C_f+3E_f+2F_f-2G_f+C_s+3E_s+2F_s\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*+} \pi^0 \pi^0$	$\frac{1}{3}\lvert C_f-4D_f+E_f+2I_f-C_s+E_s\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*0} \pi^0 \pi^+$	$\frac{1}{3}\lvert C_f-C_s+E_s+F_s\rvert^2$
$\Xi_{c1}^+ \to \Xi^{*0} K^+ \pi^0$	$\frac{1}{6}\lvert 2B_f+2C_f+2E_f+F_f+2I_f-2C_s-F_s\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*-} \pi^+ \pi^+$	$\frac{4}{3}\lvert C_f-E_f-F_f-C_s+E_s+F_s\rvert^2$
$\Xi_{c1}^+ \to \Xi^{*-} K^+ \pi^+$	$\frac{4}{3}\lvert C_f-C_s\rvert^2$
$\Xi_{c1}^+ \to \Delta^{++} \bar{K}^0 \pi^-$	$\lvert F_f+F_s\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*+} \bar{K}^0 K^0$	$\frac{1}{3}\lvert -2B_f-4D_f+F_f+F_s\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*+} \pi^- \pi^+$	$\frac{1}{3}\lvert -4D_f-F_f-F_s+2I_f\rvert^2$
$\Xi_{c1}^+ \to \Xi^{*0} K^0 \pi^+$	$\frac{1}{3}\lvert 2B_f-F_f+2I_f-F_s\rvert^2$
$\Xi_{c1}^0 \to \Delta^+ \bar{K}^0 \pi^-$	$\frac{1}{3}\lvert -2A_f+2C_f+F_f+2I_f+2C_s+F_s\rvert^2$
$\Xi_{c1}^0 \to \Delta^+ K^- \pi^0$	$\frac{1}{6}\lvert -2A_f-C_f-E_f-2G_f+2I_f-3C_s-E_s\rvert^2$
$\Xi_{c1}^0 \to \Delta^+ K^- \eta^0$	$\frac{1}{18}\lvert 2A_f+3C_f+3E_f+2F_f-2G_f-2I_f+C_s+3E_s+2F_s\rvert^2$
$\Xi_{c1}^0 \to \Delta^0 \bar{K}^0 \pi^0$	$\frac{1}{6}\lvert -2B_f-C_f-E_f-2G_f-2I_f-3C_s-E_s-2F_s\rvert^2$
$\Xi_{c1}^0 \to \Delta^0 \bar{K}^0 \eta^0$	$\frac{1}{18}\lvert -2B_f+3C_f+3E_f+4F_f-2G_f-2I_f+C_s+3E_s+2F_s\rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*0} \bar{K}^0 K^0$	$\frac{2}{3}\lvert -2A_f-2B_f+C_f-4D_f+F_f+2I_f+C_s+F_s\rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*0} \pi^0 \eta^0$	$\frac{1}{18}\lvert 4A_f+2B_f+C_f+3E_f+2F_f$ $2G_f-2I_f+3C_s+3E_s\rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*+} K^- K^0$	$\frac{1}{3}\lvert -2A_f+2C_f+F_f+2I_f+2C_s+F_s\rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*+} \pi^- \eta^0$	$\frac{1}{18}\lvert -4A_f-3C_f-3E_f-F_f-2G_f+4I_f-5C_s-3E_s-F_s\rvert^2$
$\Xi_{c1}^0 \to \Delta^{++} K^- \pi^-$	$4\lvert C_f+C_s\rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*+} \pi^- \pi^0$	$\frac{1}{6}\lvert C_f+E_f+F_f-2G_f-C_s+E_s+F_s\rvert^2$
$\Xi_{c1}^0 \to \Delta^0 K^- \pi^+$	$\frac{1}{3}\lvert 2B_f+C_f+E_f-2G_f+2I_f-C_s-E_s\rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*0} K^- K^+$	$\frac{1}{6}\lvert -2B_f+C_f-8D_f-E_f-2G_f+2I_f-C_s+E_s\rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*0} \pi^0 \pi^0$	$\frac{1}{6}\lvert -2B_f-C_f-8D_f-E_f+2G_f+2I_f+C_s-E_s-2F_s\rvert^2$

TABLE XI. (*Continued*).

Process	Squared matrix element (mod s_1^2)
$\Xi_{c1}^0 \to \Sigma^{*0}\pi^-\pi^+$	$\frac{1}{6}\lvert -2B_f+C_f-8D_f-E_f-2G_f+2I_f-C_s+E_s\rvert^2$
$\Xi_{c1}^0 \to \Delta^-\bar{K}^0\pi^+$	$\lvert C_f+E_f+F_f-2G_f-C_s-E_s-F_s\rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*-}\bar{K}^0K^+$	$\frac{1}{3}\lvert C_f-E_f+F_f-2G_f-C_s+E_s-F_s\rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*-}\pi^+\eta^0$	$\frac{1}{18}\lvert -C_f-3E_f+F_f+2G_f+C_s+3E_s-F_s\rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*-}\pi^0\pi^+$	$\frac{1}{6}\lvert -C_f+E_f+F_f+2G_f+C_s-E_s-F_s\rvert^2$
$\Xi_{c1}^0 \to \Xi^{*0}K^+\pi^-$	$\frac{1}{3}\lvert 2B_f+C_f+E_f-2G_f+2I_f-C_s-E_s\rvert^2$
$\Xi_{c1}^0 \to \Xi^{*0}K^0\pi^0$	$\frac{1}{6}\lvert -2B_f+C_f+E_f+2F_f-2G_f-2I_f-C_s+E_s\rvert^2$
$\Xi_{c1}^0 \to \Xi^{*-}K^+\pi^0$	$\frac{1}{6}\lvert -C_f-E_f+F_f+2G_f+C_s+E_s-F_s\rvert^2$
$\Xi_{c1}^0 \to \Xi^{*-}K^0\pi^+$	$\frac{1}{3}\lvert C_f-E_f+F_f-2G_f-C_s+E_s-F_s\rvert^2$

TABLE XII. Squared matrix elements for the Cabibbo-suppressed decays $T\to h^*MM$, where the mesons are in a relatively odd angular momentum state in terms of reduced matrix elements A_f', B_f', C_f', D_f', E_f', F_f', G_f', I_f', C_s', E_s', F_s', and G_s'.

Process	Squared matrix element (mod s_1^2)
$\Lambda_c^+ \to \Delta^+\pi^0\eta^0$	$\frac{1}{9}\lvert 2A_f'-C_f'+3E_f'-F_f'-C_s'+3E_s'+F_s'-2G_s'\rvert^2$
$\Lambda_c^+ \to \Delta^+\pi^+\pi^-$	$\frac{1}{3}[2A_f'+2B_f'-C_f'+E_f'-F_f'-2I_f'\rvert -C_s'-E_s'-F_s'-2G_s'\rvert^2$
$\Lambda_c^+ \to \Delta^+K^+K^-$	$\frac{1}{3}\lvert F_f'-2I_f'+F_s'\rvert$
$\Lambda_c^+ \to \Delta^+\bar{K}^0K^0$	$\frac{1}{3}\lvert 2B_f'+F_f'+F_s'\rvert$
$\Lambda_c^+ \to \Delta^0\pi^0\pi^+$	$\frac{1}{6}\lvert 4A_f'+4B_f'-C_f'+3E_f'-F_f'-4I_f'-C_s'-E_s'-F_s'-2G_s'\rvert$
$\Lambda_c^+ \to \Delta^0\pi^+\eta^0$	$\frac{1}{18}\lvert 4A_f'-C_f'+3E_f'-3F_f'-C_s'+3E_s'+F_s'-2G_s'$
$\Lambda_c^+ \to \Delta^0\bar{K}^0K^+$	$\frac{1}{3}\lvert -2B_f'-F_f'+2I_f'-F_s'\rvert$
$\Lambda_c^+ \to \Sigma^{*0}K^+\pi^0$	$\frac{1}{12}\lvert 2B_f'+C_f'+E_f'+2F_f'+2I_f'$ $+C_s'-3E_s'-2F_s'+2G_s'\rvert^2$
$\Lambda_c^+ \to \Sigma^{*0}K^0\pi^+$	$\frac{1}{6}\lvert 2B_f'+C_f'-E_f'+2I_f'+C_s'+E_s'+2F_s'+2G_s'\rvert^2$
$\Lambda_c^+ \to \Sigma^{*+}K^+\pi^-$	$\frac{1}{3}\lvert 2A_f'+2B_f'+C_f'+E_f'+C_s'-E_s'+2G_s'\rvert^2$
$\Lambda_c^+ \to \Sigma^{*+}K^0\pi^0$	$\frac{1}{6}\lvert 2A_f'+2B_f'+C_f'+E_f'+C_s'+E_s'+2F_s'+2G_s'\rvert^2$
$\Lambda_c^+ \to \Delta^{++}\pi^-\pi^0$	$\frac{1}{2}\lvert C_f'+E_f'+F_f'+C_s'+E_s'+F_s'+2G_s'\rvert^2$
$\Lambda_c^+ \to \Delta^{++}K^-K^0$	$\lvert F_f'+F_s'\rvert^2$
$\Lambda_c^+ \to \Delta^{++}\eta^0\pi^-$	$\frac{1}{6}\lvert C_f'-3E_f'-F_f'+C_s'-3E_s'-F_s'+2G_s'\rvert^2$
$\Lambda_c^+ \to \Sigma^{*-}K^+\pi^+$	$\frac{4}{3}\lvert E_f'+F_f'-E_f'-F_s'\rvert^2$
$\Xi_{c1}^+ \to \Delta^+\bar{K}^0\pi^0$	$\frac{1}{6}\lvert 2A_f'-2B_f'+C_f'-E_f'+C_s'-E_s'+2F_s'+2G_s'\rvert^2$
$\Xi_{c1}^+ \to \Delta^+\bar{K}^0\eta^0$	$\frac{1}{18}\lvert -2A_f'-6B_f'-C_f'-3E_f'-C_s'-3E_s'-2F_s'-2G_s'\rvert^2$
$\Xi_{c1}^+ \to \Delta^+K^-\pi^+$	$\frac{1}{3}\lvert -2A_f'-2B_f'-C_f'-E_f'-C_s'+E_s'-2G_s'\rvert^2$
$\Xi_{c1}^+ \to \Delta^0\bar{K}^0\pi^+$	$\frac{1}{3}\lvert 4A_f'+C_f'+E_f'-F_f'+C_s'-E_s'+F_s'+2G_s'\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*0}\bar{K}^0K^+$	$\frac{1}{6}\lvert 2B_f'+C_f'-E_f'+2I_f'+C_s'+E_s'+2F_s'+2G_s'\rvert$
$\Xi_{c1}^+ \to \Sigma^{*0}\eta^0\pi^+$	$\frac{1}{9}\lvert -C_f'-2F_f'-C_s'+3E_s'+F_s'-2G_s'\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*+}K^-K^+$	$\frac{1}{3}\lvert 2A_f'+2B_f'-C_f'+E_f'-F_f'$ $-2I_f'-C_s'-E_s'-F_s'-2G_s'\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*+}\eta^0\pi^0$	$\frac{1}{9}\lvert 2A_f'-C_f'+3E_f'-F_f'-C_s'+3E_s'+F_s'-2G_s'\rvert^2$ $-6I_f'-2C_s'-F_s'-4G_s'\rvert^2$
$\Xi_{c1}^+ \to \Delta^{++}K^-\pi^0$	$\frac{1}{2}\lvert -C_f'+E_f'-C_s'+E_s'-2G_s'\rvert^2$
$\Xi_{c1}^+ \to \Delta^{++}K^-\eta^0$	$\frac{1}{6}\lvert -C_f'-3E_f'-2F_f'-C_s'-3E_s'-2F_s'-2G_s'\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*0}\pi^0\pi^+$	$\frac{1}{12}\lvert -4B_f'-2E_f'-4I_f'+2F_s'\rvert^2$
$\Xi_{c1}^+ \to \Xi^{*0}K^+\pi^0$	$\frac{1}{6}\lvert 2B_f'+F_f'-2I_f'-2E_s'-F_s'\rvert^2$
$\Xi_{c1}^+ \to \Xi^{*-}K^+\pi^+$	$\frac{4}{3}\lvert E_f'+F_f'-E_s'-F_s'\rvert^2$
$\Xi_{c1}^+ \to \Delta^{++}\bar{K}^0\pi^-$	$\lvert F_f'+F_s'\rvert^2$
$\Xi_{c1}^+ \to \Sigma^{*+}\bar{K}^0K^0$	$\frac{1}{3}\lvert 2B_f'+F_f'+F_s'\rvert$
$\Xi_{c1}^+ \to \Sigma^{*+}\pi^-\pi^+$	$\frac{1}{3}\lvert F_f'-2I_f'+F_s'\rvert^2$
$\Xi_{c1}^+ \to \Xi^{*0}K^0\pi^+$	$\frac{1}{3}\lvert 2B_f'+F_f'-2I_f'+F_s'\rvert^2$
$\Xi_{c1}^0 \to \Delta^+\bar{K}^0\pi^-$	$\frac{1}{3}\lvert 2A_f'-F_f'-2I_f'-F_s'\rvert^2$

TABLE XII. (*Continued*).

Process	Squared matrix element (mod s_1^2)
$\Xi_{c1}^0 \to \Delta^+ K^- \pi^0$	$\frac{1}{6}\lvert 2A_f' + C_f' + E_f' + 2I_f' - C_s' + E_s' - 2G_s' \rvert^2$
$\Xi_{c1}^0 \to \Delta^+ K^- \eta^0$	$\frac{1}{18}\lvert -2A_f' + C_f' - 3E_f' - 2F_f' + 6I_f' - C_s' - 3E_s' - 2F_s' - 2G_s' \rvert^2$
$\Xi_{c1}^0 \to \Delta^0 \overline{K}{}^0 \pi^0$	$\frac{1}{6}\lvert 4A_f' + 2B_f' + C_f' + E_f' - 2I_f' - C_s' + E_s' - 2F_s' - 2G_s' \rvert^2$
$\Xi_{c1}^0 \to \Delta^0 \overline{K}{}^0 \eta^0$	$\frac{1}{18}\lvert -4A_f' - 6B_f' + C_f' - 3E_f' + 6I_f' - C_s' - 3E_s' - 2F_s' - 2G_s' \rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*+} K^- K^0$	$\frac{1}{3}\lvert 2A_f' - F_f' - 2I_f' - F_s' \rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*+} \pi^- \pi^0$	$\frac{1}{18}\lvert 4A_f' + C_f' + 3E_f' + F_f' - C_s' + 3E_s' + F_s' - 2G_s' \rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*+} \pi^- \pi^0$	$\frac{1}{6}\lvert -C_f' + E_f' + F_f' - 4I_f' + C_s' + E_s' + F_s' + 2G_s' \rvert^2$
$\Xi_{c1}^0 \to \Delta^0 K^- \pi^+$	$\frac{1}{3}\lvert 2B_f' - C_f' + E_f' - 2I_f' + C_s' - E_s' + 2G_s' \rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*0} K^- K^+$	$\frac{1}{6}\lvert -2B_f' - C_f' - E_f' - 2I_f' + C_s' + E_s' + 2G_s' \rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*0} \pi^- \pi^+$	$\frac{1}{6}\lvert -2B_f' - C_f' - E_f' - 2I_f' + C_s' + E_s' + 2G_s' \rvert^2$
$\Xi_{c1}^0 \to \Delta^- \overline{K}{}^0 \pi^+$	$\lvert -C_f' + E_f' - F_f' + C_s' - E_s' + F_s' + 2G_s' \rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*-} \overline{K}{}^0 K^+$	$\frac{1}{3}\lvert -C_f' - E_f' - F_f' + C_s' + E_s' + F_s' + 2G_s' \rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*-} \pi^+ \eta^0$	$\frac{1}{18}\lvert C_f' - 3E_f' - F_f' - C_s' + 3E_s' + F_s' - 2G_s' \rvert^2$
$\Xi_{c1}^0 \to \Sigma^{*-} \pi^0 \pi^+$	$\frac{1}{6}\lvert C_f' + E_f' - F_f' - C_s' - E_s' + F_s' - 2G_s' \rvert^2$
$\Xi_{c1}^0 \to \Xi^{*0} K^+ \pi^-$	$\frac{1}{3}\lvert 2B_f' - C_f' + E_f' - 2I_f' + C_s' - E_s' + 2G_s' \rvert^2$
$\Xi_{c1}^0 \to \Xi^{*0} K^0 \pi^0$	$\frac{1}{6}\lvert -2B_f' + C_f' - E_f' + 2I_f' - C_s' - E_s' - 2F_s' - 2G_s' \rvert^2$
$\Xi_{c1}^0 \to \Xi^{*-} K^+ \pi^0$	$\frac{1}{6}\lvert C_f' - E_f' - F_f' - C_s' + E_s' + F_s' - 2G_s' \rvert^2$
$\Xi_{c1}^0 \to \Xi^{*-} K^0 \pi^+$	$\frac{1}{3}\lvert -C_f' - E_f' - F_f' + C_s' + E_s' + F_s' + 2G_s' \rvert^2$

Also, there is a large number of relations between Cabibbo-allowed and -suppressed squared matrix elements. The relations between matrix elements when the mesons are either in a relatively even or odd angular momentum state are

$$|M(\Lambda_c^+ \to \Delta^{++}\pi^-\pi^0)_{(L=0,2,\ldots)}|^2 = \tfrac{3}{2}s_1^2 |M(\Lambda_c^+ \to \Delta^0 \overline{K}{}^0 \pi^+)_{(L=0,2,\ldots)}|^2 \,, \tag{36a}$$

$$|M(\Xi_{c1}^0 \to \Xi^{*0} K^0 \pi^0)_{(L=0,2,\ldots)}|^2 = 2s_1^2 |M(\Xi_{c1}^0 \to \Sigma^{*0} \overline{K}{}^0 \pi^0)_{(L=0,2,\ldots)}|^2 \,, \tag{36b}$$

$$|M(\Xi_{c1}^0 \to \Delta^{++} K^- \pi^-)_{(L=0,2,\ldots)}|^2 = s_1^2 |M(\Xi_{c1}^0 \to \Delta^{++} K^- K^-)_{(L=0,2,\ldots)}|^2 \,. \tag{36c}$$

There are also a few relations that are independent of the relative angular momentum between the mesons; they are

$$|M(\Lambda_c^+ \to \Delta^- \pi^+ \pi^+)|^2 \le 12 s_1^2 |M(\Lambda_c^+ \to \Sigma^{*0} \pi^0 \pi^+)|^2 \,, \tag{36d}$$

$$|M(\Xi_{c1}^0 \to \Delta^- \overline{K}{}^0 \pi^+)|^2 = 3 s_1^2 |M(\Xi_{c1}^0 \to \Sigma^{*-} \pi^+ \overline{K}{}^0)|^2 \,, \tag{36e}$$

$$|M(\Xi_{c1}^0 \to \Delta^0 K^- \pi^+)|^2 = 2 s_1^2 |M(\Xi_{c1}^0 \to \Sigma^{*0} \pi^+ K^-)|^2 \,. \tag{36f}$$

Through a cancellation within each operator comprising the Hamiltonian we find that the Cabibbo-suppressed decay $\Xi_{c1}^0 \to \Sigma^{*0}\eta^0\pi^0$ proceeds entirely through even angular momentum channels.

There are 16 reduced matrix elements contributing to the process $S \to h^* MM$, 10 are from $\mathcal{O}_{\overline{15}}$, and the remaining six are from $\mathcal{O}_6$. We find that there is only one relation between matrix elements and it is between Cabibbo-allowed decays with the mesons in an even angular momentum state

$$|M(\Omega_c^0 \to \Sigma^{*+} \overline{K}{}^0 K^-)|^2 = 2 |M(\Omega_c^0 \to \Sigma^{*0} \overline{K}{}^0 \overline{K}{}^0)|^2 \,.$$

There are no relations between decays with the mesons in a relatively odd angular momentum state. Consequently the only relation is

$$|M(\Omega_c^0 \to \Sigma^{*+} \overline{K}{}^0 K^-)|^2 \ge 2 |M(\Omega_c^0 \to \Sigma^{*0} \overline{K}{}^0 \overline{K}{}^0)|^2 \tag{37}$$

and this is due to isospin. The matrix elements for these decays are not tabulated.

II. SEMILEPTONIC DECAYS

The operator responsible for the semileptonic decay of charmed baryons is $(c\overline{s})(\overline{l}\,^+\overline{\nu}_l)$ for Cabibbo-allowed decays and $s_1(c\overline{d})(\overline{l}\,^+\overline{\nu}_l)$ for Cabibbo-suppressed decays where l denotes e or μ (τ is too massive to participate) and ν_l its associated neutrino. The operator transforms as a $\overline{3}$ under flavor SU(3) and the Hamiltonian has nonzero elements $H_3(\overline{3})=1$ for Cabibbo-allowed decays and $H_2(\overline{3})=s_1$ for Cabibbo-suppressed decays.

A. Three-body final states

For the process $T \to Bl^+\nu_l$ there is only one SU(3) singlet possible from $3\otimes\overline{3}\otimes 8$ and consequently only one reduced matrix element. Thus, the effective Hamiltonian for semileptonic decay can be written

$$H_{\text{eff}} = \alpha H_a(\overline{3}) T^b \overline{B}\,{}^a_b \overline{l}\,^+ \overline{\nu}_l \,. \tag{38}$$

All the matrix elements are related and we find that

$$\begin{aligned}|M(\Xi_{c1}^{0}\to\Xi^{-}l^{+}\nu_l)|^2=|M(\Xi_{c1}^{+}\to\Xi^{0}l^{+}\nu_l)|^2&=\tfrac{3}{2}|M(\Lambda_c^{+}\to\Lambda^{0}l^{+}\nu_l)|^2\\&=\frac{1}{s_1^2}|M(\Xi_{c1}^{0}\to\Sigma^{-}l^{+}\nu_l)|^2\\&=\frac{6}{s_1^2}|M(\Xi_{c1}^{+}\to\Lambda^{0}l^{+}\nu_l)|^2\\&=\frac{2}{s_1^2}|M(\Xi_{c1}^{+}\to\Sigma^{0}l^{+}\nu_l)|^2=\frac{1}{s_1^2}|M(\Lambda_c^{+}\to nl^{+}\nu_l)|^2\ .\end{aligned}\tag{39}$$

Experimentally, only a few inclusive branching ratios have been measured;[17] they are

$$B(\Lambda_c^{+}\to\Lambda^{0}e^{+}X)=(1.1\pm0.8)\times10^{-2}\ ,\tag{40a}$$

$$B(\Lambda_c^{+}\to pe^{+}X)=(1.8\pm0.9)\times10^{-2}\ ,\tag{40b}$$

$$B(\Lambda_c^{+}\to e^{+}X)=(4.5\pm1.7)\times10^{-2}\ ,\tag{40c}$$

where X denotes unidentified hadrons and ν_e.

The only SU(3) singlets that can be constructed for the process $T\to h^{*}l^{+}\nu_l$ are

$$\epsilon_{bcd}H_a(\bar{3})T^{d}\bar{h}^{*abc}\ \text{and}\ \epsilon_{abc}\bar{h}^{*abc}H_d(\bar{3})T^{d}\ ,\tag{41}$$

both of which vanish since h^{*} is totally symmetric on its three indices. Hence we would not expect to see any lone decuplet resonances produced in the semileptonic decay of the charmed baryons in the $\bar{3}$ representation.

Turning now to the **6** representation and the process $S\to Bl^{+}\nu_l$,we see that only one nonzero SU(3) singlet can be formed from the available tensors, giving the effective Hamiltonian

$$H_{\text{eff}}=\beta\epsilon^{abf}H_f(\bar{3})S_{ac}\bar{B}\,^{c}_{b}\bar{l}^{+}\bar{\nu}_l\ .\tag{42}$$

It is obvious from the flavor wave function of the Ω_c^{0} that it cannot Cabibbo-allowed decay to a member of the baryon octet and that it will only decay via a Cabibbo-suppressed mode to $\Xi^{-}l^{+}\nu_l$; consequently there are no relations possible. This, however, is not the case for the process $S\to h^{*}l^{+}\nu_l$ where both Cabibbo-allowed and -suppressed decays are possible. The effective Hamiltonian for the process is

$$H_{\text{eff}}=\gamma H_a(\bar{3})S_{bc}h^{*abc}\bar{l}^{+}\bar{\nu}_l\ ,\tag{43}$$

from which we find that

$$|M(\Omega_c^{0}\to\Omega^{-}l^{+}\nu_l)|^2=\frac{3}{s_1^2}|M(\Omega_c^{0}\to\Xi^{*-}l^{+}\nu_l)|^2\ .\tag{44}$$

B. Four-body final states

Returning to the $\bar{3}$ representation of charmed baryons and looking at the decays $T\to BMl^{+}\nu_l$, we find that there are three reduced matrix elements that can contribute to the decay process. The effective Hamiltonian for such decays is

$$\begin{aligned}H_{\text{eff}}=a\,[T^{a}H_a(\bar{3})](\bar{B}\,^{c}_{d}M^{d}_{c})\bar{l}^{+}\bar{\nu}_l+bT^{a}\bar{B}\,^{b}_{a}M^{c}_{b}H_c(\bar{3})\bar{l}^{+}\bar{\nu}_l\\+cT^{a}M^{b}_{a}\bar{B}\,^{c}_{b}H_c(\bar{3})\bar{l}^{+}\bar{\nu}_l\ .\end{aligned}\tag{45}$$

There are many relations between the squared matrix elements for various decay modes, as shown in Table XIII for Cabibbo-allowed decays and in Table XIV for Cabibbo-suppressed decays. Many are due to isospin, for instance,

$$\begin{aligned}|M(\Lambda_c^{+}\to\Sigma^{0}\pi^{0}l^{+}\nu_l)|^2&=|M(\Lambda_c^{+}\to\Sigma^{+}\pi^{-}l^{+}\nu_l)|^2\\&=|M(\Lambda_c^{+}\to\Sigma^{-}\pi^{+}l^{+}\nu_l)|^2\ ,\end{aligned}\tag{46}$$

but some are due to the full SU(3) symmetry, for example,

$$|M(\Xi_{c1}^{0}\to\Lambda^{0}\pi^{-}l^{+}\nu_l)|^2=|M(\Xi_{c1}^{0}\to\Sigma^{-}\eta^{0}l^{+}\nu_l)|^2\ .\tag{47}$$

There is only one nonzero matrix element that can be constructed for the decays $T\to h^{*}Ml^{+}\nu_l$, and so the matrix elements for all the decay modes are related. The effective Hamiltonian is

$$H_{\text{eff}}=\alpha\epsilon_{abc}\bar{h}^{*ade}T^{b}M^{c}_{d}H_e(\bar{3})\bar{l}^{+}\bar{\nu}_l\ ,\tag{48}$$

where α is the unknown reduced matrix element. The relative squared matrix elements for Cabibbo-allowed (-suppressed) decays can be found in Table XV (Table XVI). Phase-space-correction factors must be applied as in the previous cases. By coincidence, the Cabibbo-allowed processes with the largest matrix elements are those that will be modified the most by these corrections.

Turning now to the **6** representation and the decay process $S\to BMl^{+}\nu_l$ we find that there are three reduced matrix elements that can contribute and so the effective Hamiltonian for the process is

$$\begin{aligned}H_{\text{eff}}=&\alpha\epsilon^{acf}S_{ab}H_f(\bar{3})\bar{B}\,^{b}_{d}M^{d}_{c}\bar{l}^{+}\bar{\nu}_l\\&+\beta\epsilon^{acf}S_{ab}H_f(\bar{3})M^{b}_{d}\bar{B}\,^{d}_{c}\bar{l}^{+}\bar{\nu}_l\\&+\gamma\epsilon^{cdf}S_{ab}H_f(\bar{3})\bar{B}\,^{a}_{c}M^{b}_{d}\bar{l}^{+}\bar{\nu}_l\ .\end{aligned}\tag{49}$$

The results of which are shown in Table XVII, from which we see that the only relations between matrix elements are those due to isospin, such that

$$|M(\Omega_c^{0}\to\Xi^{-}\bar{K}^{0}l^{+}\nu_l)|^2=|M(\Omega_c^{0}\to\Xi^{0}K^{-}l^{+}\nu_l)|^2\ ,\tag{50a}$$

$$2|M(\Omega_c^{0}\to\Xi^{-}\pi^{0}l^{+}\nu_l)|^2=|M(\Omega_c^{0}\to\Xi^{0}\pi^{-}l^{+}\nu_l)|^2\ ,\tag{50b}$$

$$2|M(\Omega_c^{0}\to\Sigma^{0}K^{-}l^{+}\nu_l)|^2=|M(\Omega_c^{0}\to\Sigma^{-}\bar{K}^{0}l^{+}\nu_l)|^2\ .\tag{50c}$$

TABLE XIII. Squared matrix elements for the Cabibbo-allowed decays $T\to BMl^+\nu_l$ in terms of the reduced matrix elements a, b, and c.

Process	Squared matrix element
$\Lambda_c^+\to\Lambda^0\eta^0 l^+\nu_l$	$\frac{1}{9}\|3a+2b+2c\|^2$
$\Lambda_c^+\to\Sigma^0\pi^0 l^+\nu_l$	$\|a\|^2$
$\Lambda_c^+\to\Sigma^+\pi^- l^+\nu_l$	$\|a\|^2$
$\Lambda_c^+\to\Sigma^-\pi^+ l^+\nu_l$	$\|a\|^2$
$\Lambda_c^+\to pK^- l^+\nu_l$	$\|a+b\|^2$
$\Lambda_c^+\to n\bar{K}^0 l^+\nu_l$	$\|a+b\|^2$
$\Lambda_c^+\to\Xi^-K^+ l^+\nu_l$	$\|a+c\|^2$
$\Lambda_c^+\to\Xi^0K^0 l^+\nu_l$	$\|a+c\|^2$
$\Xi_{c1}^+\to\Sigma^+K^- l^+\nu_l$	$\|b\|^2$
$\Xi_{c1}^+\to\Lambda^0\bar{K}^0 l^+\nu_l$	$\frac{1}{6}\|b-2c\|^2$
$\Xi_{c1}^+\to\Sigma^0\bar{K}^0 l^+\nu_l$	$\frac{1}{2}\|b\|^2$
$\Xi_{c1}^+\to\Xi^0\eta^0 l^+\nu_l$	$\frac{1}{6}\|2b-c\|^2$
$\Xi_{c1}^+\to\Xi^-\pi^+ l^+\nu_l$	$\|c\|^2$
$\Xi_{c1}^+\to\Xi^0\pi^0 l^+\nu_l$	$\frac{1}{2}\|c\|^2$
$\Xi_{c1}^0\to\Lambda^0K^- l^+\nu_l$	$\frac{1}{6}\|b-2c\|^2$
$\Xi_{c1}^0\to\Sigma^0K^- l^+\nu_l$	$\frac{1}{2}\|b\|^2$
$\Xi_{c1}^0\to\Sigma^-\bar{K}^0 l^+\nu_l$	$\|b\|^2$
$\Xi_{c1}^0\to\Xi^-\eta^0 l^+\nu_l$	$\frac{1}{6}\|2b-c\|^2$
$\Xi_{c1}^0\to\Xi^-\pi^0 l^+\nu_l$	$\frac{1}{2}\|c\|^2$
$\Xi_{c1}^0\to\Xi^0\pi^- l^+\nu_l$	$\|c\|^2$

Two reduced matrix elements contribute to the process $S\to h^* l^+\nu_l$ for which the effective Hamiltonian is

$$H_{\rm eff}=\delta\bar{h}^{*abc}S_{ab}M_c^dH_d(\bar{3})\bar{l}^+\bar{\nu}_l+\zeta\bar{h}^{*abc}S_{ad}H_b(\bar{3})M_c^d\bar{l}^+\bar{\nu}_l\ , \tag{51}$$

TABLE XIV. Squared matrix elements for the Cabibbo-suppressed decays $T\to BMl^+\nu_l$ in terms of the reduced matrix elements a, b, and c.

Process	Squared matrix element (mod s_1^2)
$\Lambda_c^+\to p\pi^- l^+\nu_l$	$\|b\|^2$
$\Lambda_c^+\to n\eta^0 l^+\nu_l$	$\frac{1}{6}\|b-2c\|^2$
$\Lambda_c^+\to n\pi^0 l^+\nu_l$	$\frac{1}{2}\|b\|^2$
$\Lambda_c^+\to\Lambda^0K^0 l^+\nu_l$	$\frac{1}{6}\|2b-c\|^2$
$\Lambda_c^+\to\Sigma^-K^+ l^+\nu_l$	$\|c\|^2$
$\Lambda_c^+\to\Sigma^0K^0 l^+\nu_l$	$\frac{1}{2}\|c\|^2$
$\Xi_{c1}^+\to\Lambda^0\eta^0 l^+\nu_l$	$\frac{1}{36}\|6a+b+c\|^2$
$\Xi_{c1}^+\to\Sigma^0\pi^0 l^+\nu_l$	$\frac{1}{4}\|2a+b+c\|^2$
$\Xi_{c1}^+\to\Sigma^+\pi^- l^+\nu_l$	$\|a+b\|^2$
$\Xi_{c1}^+\to\Sigma^-\pi^+ l^+\nu_l$	$\|a+c\|^2$
$\Xi_{c1}^+\to pK^- l^+\nu_l$	$\|a\|^2$
$\Xi_{c1}^+\to n\bar{K}^0 l^+\nu_l$	$\|a+c\|^2$
$\Xi_{c1}^+\to\Xi^-K^+ l^+\nu_l$	$\|a\|^2$
$\Xi_{c1}^+\to\Xi^0K^0 l^+\nu_l$	$\|a+b\|^2$
$\Xi_{c1}^+\to\Sigma^0\eta^0 l^+\nu_l$	$\frac{1}{12}\|b+c\|^2$
$\Xi_{c1}^+\to\Lambda^0\pi^0 l^+\nu_l$	$\frac{1}{12}\|b+c\|^2$
$\Xi_{c1}^0\to\Lambda^0\pi^- l^+\nu_l$	$\frac{1}{6}\|b+c\|^2$
$\Xi_{c1}^0\to\Sigma^0\pi^- l^+\nu_l$	$\frac{1}{2}\|b-c\|^2$
$\Xi_{c1}^0\to\Sigma^-\eta^0 l^+\nu_l$	$\frac{1}{6}\|b+c\|^2$
$\Xi_{c1}^0\to\Sigma^-\pi^0 l^+\nu_l$	$\frac{1}{2}\|b-c\|^2$
$\Xi_{c1}^0\to\Xi^-K^0 l^+\nu_l$	$\|b\|^2$
$\Xi_{c1}^0\to nK^- l^+\nu_l$	$\|c\|^2$

TABLE XV. Squared matrix elements for the Cabibbo-allowed decays $T\to h^*Ml^+\nu_l$ normalized with respect to the process $\Xi_{c1}^0\to\Sigma^{*0}K^- l^+\nu_l$.

Process	Squared matrix element
$\Lambda_c^+\to\Sigma^{*0}\pi^0 l^+\nu_l$	2
$\Lambda_c^+\to\Sigma^{*-}\pi^+ l^+\nu_l$	2
$\Lambda_c^+\to\Xi^{*-}K^+ l^+\nu_l$	2
$\Lambda_c^+\to\Sigma^{*+}\pi^- l^+\nu_l$	2
$\Lambda_c^+\to\Xi^{*0}K^0 l^+\nu_l$	2
$\Xi_{c1}^+\to\Sigma^{*+}K^- l^+\nu_l$	2
$\Xi_{c1}^+\to\Sigma^{*0}\bar{K}^0 l^+\nu_l$	1
$\Xi_{c1}^+\to\Xi^{*0}\eta^0 l^+\nu_l$	3
$\Xi_{c1}^+\to\Xi^{*0}\pi^0 l^+\nu_l$	1
$\Xi_{c1}^+\to\Xi^{*-}\pi^+ l^+\nu_l$	2
$\Xi_{c1}^+\to\Omega^-K^+ l^+\nu_l$	6
$\Xi_{c1}^0\to\Xi^{*0}\pi^- l^+\nu_l$	2
$\Xi_{c1}^0\to\Xi^{*-}\pi^0 l^+\nu_l$	1
$\Xi_{c1}^0\to\Xi^{*-}\eta^0 l^+\nu_l$	3
$\Xi_{c1}^0\to\Omega^-K^0 l^+\nu_l$	6
$\Xi_{c1}^0\to\Sigma^{*0}K^- l^+\nu_l$	1
$\Xi_{c1}^0\to\Sigma^{*-}\bar{K}^0 l^+\nu_l$	2

the matrix elements of which are shown in Table XVIII. We see that there are relations not only due to isospin but some due to the full SU(3) symmetry. We find that

$$2|M(\Omega_c^0\to\Xi^{*0}K^-l^+\nu_l)|^2=2|M(\Omega_c^0\to\Xi^{*-}\bar{K}^0l^+\nu_l)|^2=|M(\Omega_c^0\to\Omega^-\eta^0l^+\nu_l)|^2\ , \tag{52a}$$

$$3|M(\Omega_c^0\to\Xi^{*0}\pi^-l^+\nu_l)|^2=6|M(\Omega_c^0\to\Xi^{*-}\pi^0l^+\nu_l)|^2=|M(\Omega_c^0\to\Omega^-K^0l^+\nu_l)|^2\ , \tag{52b}$$

TABLE XVI. Squared matrix elements for the Cabibbo-suppressed decays $T\to h^*Ml^+\nu_l$ normalized with respect to the process $\Xi_{c1}^0\to\Sigma^{*-}\pi^0 l^+\nu_l$.

Process	Squared matrix element (mod s_1^2)
$\Lambda_c^+\to\Delta^+\pi^- l^+\nu_l$	2
$\Lambda_c^+\to\Delta^0\pi^0 l^+\nu_l$	4
$\Lambda_c^+\to\Sigma^{*0}K^0 l^+\nu_l$	1
$\Lambda_c^+\to\Delta^-\pi^+ l^+\nu_l$	6
$\Lambda_c^+\to\Sigma^{*-}K^+ l^+\nu_l$	2
$\Xi_{c1}^+\to\Delta^+K^- l^+\nu_l$	2
$\Xi_{c1}^+\to\Delta^0\bar{K}^0 l^+\nu_l$	2
$\Xi_{c1}^+\to\Sigma^{*0}\eta^0 l^+\nu_l$	3
$\Xi_{c1}^+\to\Sigma^{*0}\pi^0 l^+\nu_l$	$\frac{1}{2}$
$\Xi_{c1}^+\to\Sigma^{*-}\pi^+ l^+\nu_l$	2
$\Xi_{c1}^+\to\Xi^{*-}K^+ l^+\nu_l$	2
$\Xi_{c1}^0\to\Delta^0K^- l^+\nu_l$	2
$\Xi_{c1}^0\to\Delta^-\bar{K}^0 l^+\nu_l$	6
$\Xi_{c1}^0\to\Sigma^{*-}\pi^0 l^+\nu_l$	1
$\Xi_{c1}^0\to\Sigma^{*-}\eta^0 l^+\nu_l$	3
$\Xi_{c1}^0\to\Sigma^{*0}\pi^- l^+\nu_l$	1
$\Xi_{c1}^0\to\Xi^{*-}K^0 l^+\nu_l$	2

TABLE XVII. Squared matrix elements for the decays $S \to BMl^+\nu_l$ in terms of the reduced matrix elements α, β, and γ.

Process	Squared matrix element
$\Omega_c^0 \to \Xi^- \bar{K}^0 l^+ \nu_l$	$\lvert\gamma\rvert^2$
$\Omega_c^0 \to \Xi^0 K^- l^+ \nu_l$	$\lvert\gamma\rvert^2$
$\Omega_c^0 \to \Xi^- \pi^0 l^+ \nu_l$	$s_1^2 \frac{1}{2} \lvert\alpha\rvert^2$
$\Omega_c^0 \to \Xi^- \eta^0 l^+ \nu_l$	$s_1^2 \frac{1}{6} \lvert\alpha - 2\beta + 2\gamma\rvert^2$
$\Omega_c^0 \to \Xi^0 \pi^- l^+ \nu_l$	$s_1^2 \lvert\alpha\rvert^2$
$\Omega_c^0 \to \Lambda^0 K^- l^+ \nu_l$	$s_1^2 \frac{1}{6} \lvert -2\alpha + \beta - 2\gamma\rvert^2$
$\Omega_c^0 \to \Sigma^0 K^- l^+ \nu_l$	$s_1^2 \frac{1}{2} \lvert\beta\rvert^2$
$\Omega_c^0 \to \Sigma^- \bar{K}^0 l^+ \nu_l$	$s_1^2 \lvert\beta\rvert^2$

TABLE XVIII. Squared matrix elements for the decays $S \to h^* Ml^+\nu_l$ in terms of the reduced matrix elements δ and ζ.

Process	Squared matrix element
$\Omega_c^0 \to \Xi^{*0} K^- l^+ \nu_l$	$\frac{1}{3} \lvert\delta + \zeta\rvert^2$
$\Omega_c^0 \to \Xi^{*-} \bar{K}^0 l^+ \nu_l$	$\frac{1}{3} \lvert\delta + \zeta\rvert^2$
$\Omega_c^0 \to \Omega^- \eta^0 l^+ \nu_l$	$\frac{2}{3} \lvert\delta + \zeta\rvert^2$
$\Omega_c^0 \to \Xi^{*0} \pi^- l^+ \nu_l$	$s_1^2 \frac{1}{3} \lvert\delta\rvert^2$
$\Omega_c^0 \to \Xi^{*-} \eta^0 l^+ \nu_l$	$s_1^2 \frac{1}{18} \lvert\delta - 2\zeta\rvert^2$
$\Omega_c^0 \to \Xi^{*-} \pi^0 l^+ \nu_l$	$s_1^2 \frac{1}{6} \lvert\delta\rvert^2$
$\Omega_c^0 \to \Omega^- K^0 l^+ \nu_l$	$s_1^2 \lvert\delta\rvert^2$
$\Omega_c^0 \to \Sigma^{*0} K^- l^+ \nu_l$	$s_1^2 \frac{1}{6} \lvert\zeta\rvert^2$
$\Omega_c^0 \to \Sigma^{*-} \bar{K}^0 l^+ \nu_l$	$s_1^2 \frac{1}{3} \lvert\zeta\rvert^2$

and also one purely isospin relation

$$2\lvert M(\Omega_c^0 \to \Sigma^{*0} K^- l^+ \nu_l)\rvert^2 = \lvert M(\Omega_c^0 \to \Sigma^{*-} \bar{K}^0 l^+ \nu_l)\rvert^2 . \tag{52c}$$

CONCLUSIONS

We have examined the predictions of flavor SU(3) for the weak nonleptonic and semileptonic decay of charmed baryons in both the $\bar{3}$ and **6** representations of SU(3). The matrix elements for Cabibbo-allowed, -suppressed, and doubly Cabibbo-suppressed decay modes were parametrized in terms of reduced matrix elements which have been tabulated explicitly. At the present time only a few decay modes (Cabibbo-allowed) have been experimentally observed; in the future when a larger event sample has been collected the relations derived in this work can be tested and/or used to reveal some of the underlying dynamics responsible for charmed-baryon decay.

The predictive power of SU(3) invariance is, in some cases, somewhat limited due to phase-space-correction factors that must be included. However, these uncertainties can be eliminated by experimentally determining the relative contributions from different angular momentum channels.

The role of final-state interactions in charmed-baryon decay is not known. Their importance depends upon the spectroscopy of hadrons near the mass of the Λ_c^+. The existence of many resonances may cause deviations from the SU(3) predicted amplitude for an observed final state. It is not a test of SU(3) at the weak vertex to compare these predictions with experiment before removing the FSI and phase-space corrections. In the future there could be sufficient experimental data on the decay of charmed baryons to allow the FSI to be removed and hence allow the SU(3) predictions to be tested.[18]

If the sextet component of the Hamiltonian dominates nonleptonic decay processes, as hinted at by perturbative QCD, then this will be directly observable by the absence of $I=1$ final states in the doubly Cabibbo-suppressed decay of the Ω_c^0. Sextet dominance will also give rise to new relations between decay rates. These new relations between two-body decay modes have been considered previously in Refs. 4, 19, and 20 and can be derived from this work for all nonleptonic processes by neglecting the contribution from $\mathcal{O}_{\overline{15}}$.

An interesting prediction of SU(3) is that the $\bar{3}$ cannot semileptonically decay to an $h^* l^+ \nu_l$ final state because a nonzero SU(3) invariant cannot be constructed. Also, all the matrix elements for the semileptonic decay of the $\bar{3}$ to $Bl^+\nu_l$ final states are related. This is also true for the decays of the $\bar{3}$ to $h^* Ml^+\nu_l$ final states.

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