Axial-Vector Emitting
Weak Nonleptonic Decays of $\Omega_c^0$ Baryon

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Abstract
The axial-vector emitting weak hadronic decays of $\Omega_c^0$ baryon are investigated. After employing the pole model framework to predict their branching ratios, we derive the symmetry breaking effects on axial-vector-meson-baryon couplings and effects of flavor dependence on baryon-baryon weak transition amplitudes and, consequently, on their branching ratios.

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I. INTRODUCTION

The production of heavy baryons have always posed experimental challenges and hence, have generated much interest in their studies \cite{1-3}. Many interesting observations by CDF, D0, SELEX, FOCUS, Belle, BABAR, CMS, LHCb etc. \cite{5-14} in context of mass spectrum, lifetimes and decay rates have been made in recent years. Most recently, LHCb and CDF collaborations \cite{15-22} have announced more precise measurement of masses and lifetimes of $(\Xi^0_c, \Xi^+_c, \Lambda_b^0, \Xi_b^0, \Xi_b^-)$ baryons. Also, LHCb has now identified two new strange-beauty baryonic resonances, denoted by $\Xi_b^-$ and $\Xi_b^{-}\$\cite{23}, though many of doubly and triply heavy states are yet to be confirmed. In two body nonleptonic decay sector, first observation of $(\Omega^-_b \rightarrow \Omega^0_c \pi^-)$ decay process and measurement of CP-asymmetries for $\Lambda_b \rightarrow p\pi^-$ and $\Lambda_b \rightarrow pK^-$ are reported by CDF collaboration \cite{17,24}. On the other hand, LHCb has reported first observation of $\Lambda_b \rightarrow \Lambda^+_c D^-(s)$ and $\Lambda_b \rightarrow J/\psi p\pi^-$ decays and the measurement of the difference in CP-asymmetries between $\Lambda_b \rightarrow J/\psi p\pi^-$ and $\Lambda_b \rightarrow J/\psi pK^-$ and many other decays involving $b-$baryons \cite{25-29}. However, little progress has been made in observing decays of heavy charm meson. All these recent measurements have attracted, much needed, attention to heavy baryonic sector.

On the theoretical side, various attempts had been made to investigate weak decays of heavy baryons \cite{30-55}. A number of methods, mainly, current algebra (CA) approach, factorization scheme, pole model technique, relativistic quark model, framework based on next-to-leading order QCD improved Hamiltonian etc., have been employed. Recent experimental developments have prompted more theoretical efforts in $b-$baryon decays \cite{56-60}. In all these works, the focus has so far been on $s$-wave meson emitting decays of heavy baryons including $\Omega^0_c$ decays. Being heavy, charm and bottom baryons can also emit $p$-wave mesons. In past, the $p$-wave emitting decays of charm and bottom baryons have been studied using factorization and pole model approach \cite{61,66}. However, $p$-wave emitting decays of $\Omega^0_c$ baryon remain untouched. The fact, that $\Omega^0_c$ baryon is the heaviest and only doubly strange particle in charmed baryon sextet that is stable against strong and electromagnetic interactions, makes it an interesting candidate for the present analysis. Moreover, study of $s$-wave emitting decays of $\Omega^0_c$ baryon reveals that nonfactorizable W-exchange terms dominate as compared to factorizable contributions \cite{36}. This makes study of $\Omega^0_c$ decays even more important to understand the mechanism underlying W-exchange processes.

In our previous work \cite{66}, we have studied the scalar meson emitting decays of bottom baryons employing the pole model. We have shown that such decays can acquire significant pole (W-exchange) contributions to make their branching ratios comparable to $s$-wave meson emitting decays. In the present work, we analyze the axial-vector meson emitting exclusive nonleptonic decays of $\Omega^0_c$ baryon. We have already seen that for $\Omega^0_c$ decays the factorization contribution are small in comparison to the pole contributions in case of $s$-wave meson emitting decays. For the same reason, factorizable contributions to axial-vector meson emitting decays of $\Omega^0_c$ baryon are also expected to be suppressed. Therefore, we study weak nonleptonic decays of $\Omega^0_c$ emitting axial-vector mesons in the pole model approach. We employ the effects of symmetry breaking (SB) on strong couplings that may decide crucial pole diagram
contributions \[47, 67\]. We use the traditional non-relativistic approach \[68\] to evaluate weak matrix element to obtain flavor independent branching ratios (BRs) of $\Omega_c^0$ decays. Later, we employ the possible flavor dependence via variation of spatial baryon wave function overlap in weak decay amplitude. We find that BRs of all the decay modes are significantly enhanced on inclusion of flavor dependent effects.

The article is organized as follows: In sec. II, we give a general framework including spectroscopy of axial-vector mesons, decay kinematics and effective Hamiltonian. Sec. III deals with decay amplitude, weak transitions and axial-vector meson-baryon couplings. Numerical results are given in sec IV. We summarize our findings in last section.

II. GENERAL FRAMEWORK

A. Spectroscopy of Axial-Vector Mesons

The axial-vector meson spectroscopy has extensively been studied in literatures \[69–72\]. Here, we list the important facts. Spectroscopically, there are two types of axial-vector mesons: $3P_1 (J^{PC} = 1^{++})$ and $1P_1 (J^{PC} = 1^{-+})$. $3P_1$ and $1P_1$ states can either mix within themselves or can mix with one another. Experimentally observed non-strange and un-charmed axial-vector mesons exhibit first kind of mixing and can be identified as follows:

$3P_1$: meson 16-plet includes isovector $a_1(1.230)$ and four isoscalars, namely, $f_1(1.285)$, $f_1(1.420)/f_1'(1.512)$ and $\chi_c(3.511)$. The following mixing scheme has been used in isoscalar $(1^{++})$ mesons:

$$f_1(1.285) = \frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d}) \cos \phi_A + (s\bar{s}) \sin \phi_A,$$

$$f_1'(1.512) = \frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d}) \sin \phi_A - (s\bar{s}) \cos \phi_A. \quad (1)$$

$1P_1$: meson multiplet consists isovector $b_1(1.229)$ and three isoscalars $h_1(1.170)$, $h_1'(1.380)$ and $h_{c1}(3.526)$, where spin and parities of $h_{c1}(3.526)$ and $h_1'(1.380)$ states are yet to be confirmed, experimentally. These isoscalar $(1^{+-})$ mesons can mix in following manner:

$$h_1(1.170) = \frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d}) \cos \phi_{A'} + (s\bar{s}) \sin \phi_{A'},$$

$$h_1'(1.380) = \frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d}) \sin \phi_{A'} - (s\bar{s}) \cos \phi_{A'}. \quad (2)$$

The mixing angles are given by relation: $\phi_{A(A')} = \theta(\text{ideal}) - \theta_{A(A')}(\text{physical})$. The experimental observations predominantly favor the ideal mixing for these states i.e., $\phi_A = \phi_{A'} = 0^\circ$.

\[1\] here the quantities in brackets indicate their respective masses (in GeV).
The hidden-flavor diagonal states $a_1(1.230)$ and $b_1(1.229)$ cannot mix owing to C- and G-parity considerations. However, there are no such restrictions for the states involving strange partners namely, $K_{1A}$ and $K_{1A'}$ of $A(1^{+})$ and $A'(1^{-})$ mesons, respectively. They mix in the following convention to generate the physical states:

$$K_1(1.270) = K_{1A} \sin \theta_{K_1} + K_{1A'} \cos \theta_{K_1},$$
$$K_1(1.400) = K_{1A} \cos \theta_{K_1} - K_{1A'} \sin \theta_{K_1}.$$

(3)

Several phenomenological analyses based on the experimental information obtained twofold ambiguous solutions for $\theta_{K_1}$, i.e. $\pm 37^\circ$ and $\pm 58^\circ$. We wish to point out that the experimental measurement of the ratio of $K_1\gamma$ production in $B$ decays and the study of charm meson decays to $K_1(1.270)\pi/K_1(1.400)\pi$ favor negative angle solutions. Very recently, it has been shown that choice of mixing angle $\theta_{K_1}$ is intimately related to choice of angle for $f - f'$ and $h - h'$ mixing schemes. The mixing angle $\theta_{K_1} \sim 35^\circ$ is favored over $\sim 55^\circ$ for near ideal mixing for $f - f'$ and $h - h'$. Therefore, we use $\theta_{K_1} = -37^\circ$ for our calculation; however, we also give results on $-58^\circ$ for comparison.

B. Kinematics

The matrix element for the baryon decay process e.g. $B_i(\frac{1}{2}^+, p_i) \rightarrow B_f(\frac{1}{2}^+, p_f) + A_k(1^+, q)$ can be expressed as

$$\langle B_f(p_f)A_k(q)|H_W|B_i(p_i)\rangle = i\bar{u}_{B_f}(p_f)\varepsilon^{*\mu}(A_1\gamma_\mu\gamma_5 + A_2 p_f\mu\gamma_5 + B_1\gamma_\mu + B_2 p_f\mu)\bar{u}_{B_i}(p_i),$$

(4)

where $u_B$ are Dirac spinors for baryonic states $B_i$ and $B_f$. $\varepsilon^{*\mu}$ is the polarization vector of the axial-vector meson state $A_k$. $A_i$’s and $B_i$’s represent parity conserving (PC) and parity violating (PV) amplitudes, respectively. The decay width for the above process is given by

$$\Gamma = \frac{q_\mu}{8\pi E_f + m_f} \frac{E^2}{m_i^2}\left[2(|S|^2 + |P_2|^2) + \frac{E^2}{m_A^2}(|S + D|^2 + |P_1|^2)\right],$$

(5)

where $m_i$ and $m_f$ are the masses of the initial and final state baryons, and $q_\mu = (p_i - p_f)_\mu$ is the four-momentum of axial-vector meson

$$|q_\mu| = \frac{1}{2m_i}\sqrt{[m_i^2 - (m_f - m_A)^2][m_i^2 - (m_f + m_A)^2]},$$

where $m_A$ is the mass of emitted $p$-wave meson. The decay emplitude of the final state is now an admixture of $S$, $P$ and $D$ wave angular momentum states with

$$S = -B_1, \quad P_1 = -\frac{q_\mu}{E_A} \left(\frac{m_i + m_f}{E_f + m_f} A_1 + m_i A_2\right),$$
$$P_2 = \frac{q_\mu}{E_f + m_f} A_1, \quad D = -\frac{q_\mu^2}{E_A(E_f + m_f)} (B_1 - m_i B_2),$$

3
where $E_A$ and $E_f$ are the energies of the axial-vector meson and the daughter baryon, respectively. Furthermore, there are two independent $P$-wave amplitudes: one corresponds to the singlet spin combination of the parent and daughter baryon and the other corresponds to the triplet. The interference between the parity-violating $S$ and $D$ wave amplitudes and the parity-conserving $P$-wave amplitudes results in asymmetries for the daughter state with respect to the spin of the parent state. The corresponding asymmetry parameter is

$$\alpha = \frac{4m_A^2 \Re [S \ast P_2] + 2E_A^2 \Re [(S + D) \ast P_1]}{2m_A^2 (|S|^2 + |P_2|^2) + E_A^2 (|S + D|^2 + |P_1|^2)}. \quad (6)$$

Thus, to determine the decay rate and asymmetry parameters we require to estimate amplitudes, $A$ and $B$.

C. Hamiltonian

The QCD modified current $\otimes$ current effective weak Hamiltonian consisting Cabibbo-favored ($\Delta C = \Delta S = -1$), Cabibbo-suppressed ($\Delta C = -1, \Delta S = 0$) and Cabibo-doubly-suppressed ($\Delta C = -\Delta S = -1$) modes is given by

$$H_{\text{eff}}^{\text{W}} = \frac{G_F}{\sqrt{2}} \left\{ V_{ud} V_{cs}^* \left[ c_1 (\bar{u}d)(\bar{c}s) + c_2 (\bar{s}d)(\bar{u}c) \right]_{(\Delta C=\Delta S=-1)} + 
V_{ud} V_{cd}^* \left[ c_1 \left\{ (\bar{s}c)(\bar{u}s) - (\bar{d}c)(\bar{u}d) \right\} + c_2 \left\{ (\bar{u}c)(\bar{s}s) - (\bar{u}c)(\bar{d}d) \right\} \right]_{(\Delta C=-1, \Delta S=0)} - 
V_{us} V_{cd}^* \left[ c_1 (\bar{d}c)(\bar{u}s) + c_2 (\bar{u}c)(\bar{d}s) \right] \right\}_{(\Delta C=-\Delta S=-1)}; \quad (7)$$

where $V_{ij}$ and $(\bar{q}_i q_j) \equiv \bar{q}_i \gamma_\mu (1-\gamma_5) q_j$ denote the Cabibbo-Kobayashi-Maskawa (CKM) matrix elements and the weak $V-A$ current, respectively. We use the QCD coefficients $c_1(\mu) = 1.2$, $c_2(\mu) = -0.51$ at $\mu \approx m_c^2$. Furthermore, nonfactorizable effects may modify $c_1$ and $c_2$, thereby indicating that these may be treated as free parameters. The discrepancy between theory and experiment is greatly improved in the large $N_c$ limit. Interestingly, the charm conserving decays of $\Omega_c^0$ are also possible but they are kinematically forbidden in present analysis.

III. DECAY AMPLITUDES

In addition to the factorization contribution, the charmed baryon decay amplitudes acquire contributions from the pole diagrams involving the W-exchange process evaluated using the pole model framework [34]. Thus, the matrix element $\langle B_f A_k | H_W | B_i \rangle$ may be expressed as

$$\langle B_f A_k | H_W | B_i \rangle \equiv A_{\text{Pole}} + A_{\text{Fac}}; \quad (8)$$

where $A_{\text{Pole}}$ and $A_{\text{Fac}}$ represent pole (W-exchange) and factorization amplitudes, respectively. One may consider factorization as a correction to the pole model which includes the calculation of possible pole diagrams via $s-$, $u-$ and $t-$channels, where $t-$channel virtually
implicate tree-level diagrams \textit{i.e.} factorizable processes. The contribution of these terms can be summed up in terms of PC and PV amplitudes. The first term, \(A_{\text{pole}}\), involves the evaluation of the relevant matrix element

\[\langle B_f | H | B_i \rangle = \bar{u}_{B_i} (B + \gamma_5 A) u_{B_j}\]  

(9)

between two \(\frac{1}{2}^+\) baryon states. \(B\) and \(A\) are \(s\)-wave (PV) and \(p\)-wave (PC) decay amplitudes, receptively. \(A\) and \(B\) include the contributions of \(s\)- and \(u\)- channels for positive-parity intermediate baryon \((J^P = \frac{1}{2}^+)\) poles; henceforth, given by \(A_{\text{pole}}\) and \(B_{\text{pole}}\) as follows:

\[A_{\text{pole}} = -\sum_n \left[ \frac{g_{BfB_nA_k}a_{ni}}{m_i - m_n} + \frac{a_{fn}g_{B_nB_iA_k}}{m_f - m_n} \right],\]  

(10)

\[B_{\text{pole}} = \sum_n \left[ \frac{g_{BfB_nA_k}b_{ni}}{m_i + m_n} + \frac{b_{fn}g_{B_nB_iA_k}}{m_f + m_n} \right],\]  

(11)

where \(g_{ijk}\) are the strong axial-vector meson-baryon coupling constants; \(a_{ij}\) and \(b_{ij}\) are weak baryon-baryon matrix elements defined as

\[\langle B_i | H_W | B_j \rangle = \bar{u}_{B_i} (a_{ij} + \gamma_5 b_{ij}) u_{B_j} ,\]  

(12)

It is well known that the PV matrix element \(b_{ij}\) vanishes for the hyperons owing to \(\langle B_f A_k | H^\text{PV} | B_i \rangle = 0\) in the SU(3) limit. This also implies for non-leptonic charm meson decays that \(b_{ij} \ll a_{ij}\) suppressing \(s\)-wave contributions for \(\frac{1}{2}^+\) – poles. These contributions are further suppressed by presence of sum of the baryon masses in the denominator. Thus, only PC terms survive for non-leptonic decays of charm baryons. It has also been argued that the negative-parity intermediate baryon \((J^P = \frac{1}{2}^-)\) may also contribute to these processes. However, in the leading non relativistic limit one can ignore \(J^P = \frac{1}{2}^-\), \(\frac{3}{2}^-\), .... and higher resonances as they would require at least one power of momentum in \(H_W\) in order to connect them with the relevant ground state \([17]\). Moreover, evaluation of such terms require knowledge of the axial-vector meson strong coupling constants for these states which are currently unknown. Therefore, we have restricted our calculation to positive-parity intermediate baryon pole terms to estimate the pole contributions to the axial-vector meson emitting decays of charm baryons. The second term, \(A_{\text{Fac}}\), has also been ignored in present analysis owing to the fact that most of the decays come from W-exchange processes. Moreover, it has been shown in \([36]\) that non-factorizable W-exchange diagrams dominate over factorizable contributions for \(\Omega^0_c\) decay processes.

A. Weak Transitions

The flavor symmetric weak Hamiltonian \([40, 45]\) for quark level process \(q_i + q_j \rightarrow q_l + q_m\) can be expressed as,

\[H_W \cong V_{li}V^*_{jm} c_-(m_c)[B^{[i,j]}B_{[l,m]}H_{[i,j]}^{[l,m]}],\]  

(13)
where \( c_- = c_1 + c_2 \) and the brackets, \([ , ]\), represent the anti-symmetrization among the indices. The spurion transforms like \( H_{[1,3]}^{[2,4]} \). We obtain the weak baryon-baryon matrix elements \( a_{ij} \) for CKM favored and CKM suppressed modes from the following contraction:

\[
H_W \approx a_W [\overline{B}_{[i,j]}^k B_{[l,m]}^k H_{[i,j]}^{[l,m]}],
\]

where \( a_W \) is weak amplitude. It is worth remarking here that the enhancement due to hard gluon exchanges, coming through \( c_- \), will effect weak baryon-baryon matrix element. Also, we ignore the long-distance QCD effects reflected in the bound-state wave functions.

B. Axial-vector meson-baryon couplings

In SU(4), Hamiltonian representing the strong transitions is given by

\[
H_{strong} = \sqrt{2}(g_D + g_F)\left( \frac{1}{2} \overline{B}_{[a,b]}^d B_{[a,b]}^c A_d^c \right) + \sqrt{2}(g_D - g_F)(\overline{B}_{[a,b]}^d B_{[a,b]}^c A_d^c),
\]

where \( B_{[a,b]}^d, \overline{B}_{[a,b]}^d \) and \( A_d^c \) are the baryon, anti-baryon, and axial-vector meson tensors, respectively and \( g_D, g_F \) are conventional D-(F)-type strong coupling constants [30, 33, 37].

Experimentally, there are no measurements available for the axial-vector-meson-baryon coupling constants. However, using Goldberger-Treiman relation one can obtain \( g_{NNa_1} = \sqrt[7]{2} g_{NNa_1} = 8.36 \) for \( g_A = 1.28 \) given by \( \beta \) decay. QCD sum rules analysis [73] leads to

\[
g_D = 6.0 \quad \text{and} \quad g_F = 2.4,
\]

for \( \frac{g_D}{g_F} = 2.5 \). We wish to pointed out that the SU(4) symmetry is badly broken, hence it would not be wise to use SU(4) symmetry based strong coupling constants for charm baryon decays. Therefore, we consider the SU(4) breaking effects in strong coupling constants by using the Coleman-Glashow null result [74] from tadpole-type symmetry breaking that does not include any additional parameter. The symmetry broken (SB) baryon-meson strong couplings are calculated by

\[
g_A^{BB'} (SB) = \frac{M_B + M_B'}{2M_N} g_A^{BB'} (Sym),
\]

where \( g_A^{BB'} (Sym) \) is SU(4) symmetric couplings. The obtained values of SB strong axial-vector meson-baryon coupling constants relevant for our calculation have been given in table [1]. For heavy baryon decays, it has been observed [75] that mass independent strong couplings lead to smaller pole contributions. It is quite obvious that symmetry breaking will result in larger values for strong couplings as compared to symmetric ones due to mass dependence. Consequently, higher pole contributions would be expected. We also give the expressions for the \( g_A^{BB'} \) in terms of \( g_D \) and \( g_F \). However, we have given the absolute numerical values for the strong couplings where the actual sign would depend upon the conventions used and could be determined from their expressions in present case.
IV. NUMERICAL RESULTS AND DISCUSSIONS

In general, numerical evaluation of W-exchange terms (pole terms) involves weak matrix element of the form 
\[ \langle B_f | H^{PC}_W | B_i \rangle \]. In the non relativistic limit, Riazuddin and Fayyazuddin [68] has shown that the parity conserving weak Hamiltonian can be reduced to
\[ H^{PC}_W = \frac{G_F}{\sqrt{2}} V_{ud} V_{cs} \sum_{i \neq j} \alpha_i^+ \gamma_j^- (1 - \sigma_i \cdot \sigma_j) \delta^3(r), \] (18)
where operator \( \alpha_i^+ \) converts \( d \to u \) and \( \gamma_j^- \) converts \( c \to s \), following which, we can get a reasonable estimate of these terms. One can fix the scale by assuming the baryon overlap wave function to be flavor independent such that
\[ \langle \psi_f | \delta^3(r) | \psi_i \rangle_c \approx \langle \psi_f | \delta^3(r) | \psi_i \rangle_s, \] (19)
where \( \langle \psi_f | \delta^3(r) | \psi_i \rangle \) is baryon wave function overlap for corresponding flavor. Summing over all the ingredients, the pole contributions to different PC amplitudes has been calculated. The symmetry broken axial-vector meson-baryon couplings has been used to obtain the flavor independent branching ratios for possible Ωc baryon decays in CKM-favored, suppressed and doubly-suppressed modes as shown in column 2 of tables II-III, respectively. We wish to remark here that (19) leads to a well known SU(4) based relation that connects nonleptonic charmed baryon decays with hyperon decays. Since SU(4) is badly broken, a large mismatch between charm and strange baryon wave function overlaps would need a correction factor that has been practiced in many models based on different arguments [38, 43]. We wish to point out that we use \( \theta_{K_1} = -37^\circ \) as reference mixing angle, however, we also give results on mixing angle \(-58^\circ\) for comparison. We summarize our results as follows:

1. The branching ratios of all the decay channels range from \( 10^{-3} \) to \( 10^{-7} \). The branching ratios of dominant modes are \( O(10^{-3}) \sim O(10^{-4}) \).

2. The absence of weak PV transition amplitudes (\( b_{ij} \)'s) lead to zero decay asymmetries for all the decay modes.

3. Also, we observe that mass dependence of strong coupling coming through SB effects result in larger strong couplings and hence, higher BRs.

4. The only possible CKM favored (\( \Delta C = \Delta S = -1 \)) decay mode \( \Omega_c^0 \to \Xi^0 K_1^0 \) has branching ratio \( 2.10 \times 10^{-4} \) for \( \theta_{K_1} = -37^\circ \). The obtained branching ratio increases by a factor of \( \sim 2 \) for choice of mixing angle \( \theta_{K_1} = -58^\circ \). The \( \Omega_c^0 \to \Xi^0 K_1^0 \) decay may also acquire contribution from factorization term, however, the dominant contribution comes from non-factorizable W-exchange diagrams via \( u-pole \) only.

5. In CKM suppressed (\( \Delta C = -1, \Delta S = 0 \)) mode, the most dominant decay has \( \text{Br}(\Omega_c^0 \to \Xi^- a_1^+) = 1.44 \times 10^{-3} \). The next order dominant modes are \( \Omega_c^0 \to \Xi^0 a_1/\Xi^0 f_1/\Lambda \bar{K}^0/\Lambda \bar{K}^0 \). Here also, factorization terms may effect the decays involving \( a_1/f_1 \) though are further
suppressed due to color suppression and small CG coefficients. We wish to point out that the CKM suppression for $\Omega_c^0 \to \Xi^- a_1^-$ decay is compensated by QCD enhancement leading to the largest BR.

6. It may be noted that BRs of all the decays involving $K_1$ and $K_{1'}$ change with mixing angle. Overall trend shows an increase in BRs of decays involving $K_1$ nearly by a factor of two and decrease in BRs of decays with $K_{1'}$ in final state by 44% for $\theta_{K_1} = -58^\circ$.

7. As expected, the decay channels in Cabibbo doubly suppressed ($\Delta C = \Delta S = -1$) modes have relatively smaller BRs. Most of the decay channels have BRs $O(10^{-5})$. However, BRs of $\Omega_c^0 \to p \bar{K}_{1'}^0 / n \bar{K}_{1'}^0 / \Lambda f'_1$ decays may be approximated to $O(10^{-4})$.

8. All the decays involving non-strange meson in the final state have zero $u$-pole contributions except for $\Omega_c^0 \to \Lambda f'_1$ decay which acquire contributions from both $u$- and $s$- channels. The highly suppressed decay modes $\Omega_c^0 \to \Xi^0 K_1^0 / \Xi^- K_1^+$ have only $s$-pole contributions.

9. The decay modes consisting $b_1/h_1/h'_1$ mesons in the final states are forbidden in isospin limit.

Finally we give a few comments on flavor dependent effects. In literatures, several attempts have been made to establish the fact that lifetimes of semileptonic and nonleptonic decays of heavy flavor baryons show a strong dependence on square of the baryon wave function overlap at the origin, $|\psi(0)|^2$ \cite{42, 76, 78}. In order to lower the discrepancy in theory and experiment, one needs to take into account the variation of $|\psi(0)|^2$ (being a dimensional quantity). For example, in case nonleptonic decays, inclusion of flavor dependence of hadron wave function at the origin has resulted in good agreement between theory and experiment \cite{42, 79}. Following the analysis given in \cite{72}, we consider variation of $|\psi(0)|^2$ with flavor. It has been long advocated that a reliable estimate of wave function at origin of the ground state baryon can be obtained by experimental hyperfine splitting \cite{80}. A straightforward hyperfine splitting calculation, using constituent quark model, between $\Sigma_c$ and $\Lambda_c$ reveals

\[
m_{\Sigma_c} - m_{\Lambda_c} = \frac{16\pi}{9} \alpha_s(m_c) \frac{(m_c - m_u)}{m_c m_u^2} |\psi(0)|^2_{c}, \tag{20}\n\]

where we assume $|\psi(0)|^2_{\Sigma_c} = |\psi(0)|^2_{\Lambda_c}$. We obtain the flavor enhancement scale in strange and charm sectors from the following expression:

\[
\frac{m_{\Sigma_c} - m_{\Lambda_c}}{m_{\Sigma} - m_{\Lambda}} = \frac{\alpha_s(m_c) m_s(m_c - m_u)}{\alpha_s(m_s) m_c(m_s - m_u)} \frac{|\psi(0)|^2_{c}}{|\psi(0)|^2_{s}}, \tag{21}\n\]

which yields

\[
r \equiv \frac{|\psi(0)|^2_{c}}{|\psi(0)|^2_{s}} \approx 2.1, \tag{22}\n\]

for the choice $\alpha_s(m_c)/\alpha_s(m_s) \approx 0.53$ \cite{42, 63}. Finally, we discuss the effects of this scale enhancement due to variation of spatial baryon wave function overlap on branching ratios. The
flavor dependent BRs for CKM-favored, suppressed and doubly-suppressed modes evaluated using $|\psi(0)|^2$ variation are given in column 3 of tables III-IV respectively. We wish to point out that the implications of variation of spatial baryon wave function overlap lead to flavor enhancement scale ratio ($r$) to $\sim 2$. This may also be seen simply as a variation in $r$ from 1 to 2 for flavor dependent $|\psi(0)|^2$ owing to dimensionality arguments. In the absence of any experimental and theoretical information we compare our results with flavor independent BRs. We observe the following:

1. The variation of $|\psi(0)|^2$ has enhanced BRs of all the decays roughly by a factor of four as compared to flavor independent BRs. Consequently, number of decay modes with BRs of $\mathcal{O}(10^{-3})$ have become large.

2. The enhanced branching ratio of Cabibbo favored ($\Delta C = \Delta S = -1$) decay mode is $\text{Br}(\Omega_c^0 \to \Xi^0 K_1^0) = 9.20 \times 10^{-4}$ or roughly $\mathcal{O}(10^{-3})$. The BR may further increase to $1.83 \times 10^{-3}$ for $\theta_{K_1} = -58^\circ$ making it a viable candidate for experimental search.

3. The BRs of all decay channels in Cabibbo singly suppressed decay mode have enhanced to $\mathcal{O}(10^{-3})$ with second order BRs of $\mathcal{O}(10^{-4})$. The dominant decay modes with BRs of $\mathcal{O}(10^{-3})$ are $\Omega_c^0 \to \Xi^- a_1^+ / \Xi^0 a_1^0 / \Xi^0 f_1 / \Lambda f_1 / \Lambda K_1^0 / \Lambda K_1^0$ with highest $\text{Br}(\Omega_c^0 \to \Xi^- a_1^+) = 6.35 \times 10^{-3}$. However, the BRs may further increase or decrease with $\theta_{K_1} = -58^\circ$ for corresponding $K_1$ and $\bar{K}_1$ modes, respectively.

4. Also, for CKM doubly suppressed modes ($\Delta C = \Delta S = -1$), the BRs have increased by an order of magnitude. Many of the decay modes attain BRs of $\mathcal{O}(10^{-4})$, namely, $\Omega_c^0 \to p \tilde{K}_1^- / n \tilde{K}_1^0 / \Lambda f_1 / p \tilde{K}_1^- / n \tilde{K}_1^0 / \Sigma^+ a_1^- / \Sigma^- a_1^+ / \Sigma^- a_1^-$. All these decay channels have experimentally observable decay widths.

V. SUMMARY

We have analyzed axial-vector meson emitting exclusive two-body nonleptonic weak decays of $\Omega_c^0$ baryon for CKM-favored and suppressed modes in pole model approach. Considering the fact that W-exchange diagrams dominate $\Omega_c^0$ weak decays, we have ignored the possible factorizable contributions to some of the decay channels. The relevant baryon matrix elements of the weak Hamiltonian have been calculated which determine the pole term with short distance QCD corrections. Also, we have observed that mass dependence (SB effects) of strong couplings turns out to be crucial in deciding pole contributions to heavy baryon decays. These effects can be important specifically in the decays coming from the W-exchange process (pole diagram) only. Non-relativistic evaluation of weak matrix element involving PC weak Hamiltonian has been carried out for flavor independent and flavor dependent cases to predict BRs of $\Omega_c^0$ decays. For flavor independent case, the only dominant decay mode $\Omega_c^0 \to \Xi^- a_1^+$ has branching ratio of $\mathcal{O}(10^{-3})$. The next order dominant modes are $\Omega_c^0 \to \Xi^0 K_1^0 / \Xi^0 a_1^0 / \Xi^0 f_1 / \Lambda K_1^0 / \Lambda \bar{K}_1^0$. For flavor dependent case, we consider variation of spatial baryon wave function overlap at the origin i.e. $|\psi(0)|^2$ with flavor. We observe that the
introduction of flavor dependence has raised the BRs of all the decays roughly by a factor of four. A number of dominant modes $\Omega_c^0 \rightarrow \Xi^- a_1^+ / \Xi^0 K^0_1 / \Xi^0 a_0^0 / \Xi^0 f_1 / \Lambda K^0 / \Lambda \bar{K}^0$ now have BRs of $O(10^{-3})$. We wish to remark here that most of the decay channels in $\Omega_c^0$ decay through the W-exchange diagram; moreover, the W-exchange contributions dominate in rest of the process. Observation of such decays would shed some light on mechanism of W-exchange effects in these decay modes. A conventional concept expects the $p$-wave emitting decays to be kinematically suppressed; however, we find that BRs of axial-vector emitting decays of $\Omega_c^0$ are comparable to the experimentally observed two-body $s$-wave meson emitting decays of charm baryons. We hope this would generate ample interest in experimental search of these decay modes.

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TABLE I: Expressions of strong-coupling constants \( [SB = \text{Sym.} \times \frac{M_B + M'_B}{2M_N}] \) and their absolute numerical values at \( \theta_{K_1} = -37^\circ (-58^\circ) \).

| Strong Couplings | Absolute Values |
|-------------------|-----------------|
| \( g_A^{BB'} \times \frac{(M_B + M'_B)}{2M_N} \) | \( |g_A^{BB'}(SB)| \) |
| \( g_{K_1}^{Lp} \) | \( 3.47 \) | \( 6.113 \) |
| \( g_{K_1}^{\Sigma^0 p} \) | \( (-g_D + g_F) \) sin \( \theta_{K_1} \) | \( 2.46 \) (3.47) |
| \( g_{K_1}^{Lp} \) | \( \sqrt{3} g_D + \frac{g_F}{\sqrt{3}} \) cos \( \theta_{K_1} \) | \( 6.67 \) (4.42) |
| \( g_{K_1}^{\Sigma^0 p} \) | \( -g_D + g_F \) cos \( \theta_{K_1} \) | \( 3.27 \) (2.17) |
| \( g_{K_1}^{\Xi^-} \) | \( -\sqrt{3} g_D + \frac{g_F}{\sqrt{3}} \) sin \( \theta_{K_1} \) | \( 5.02 \) (7.08) |
| \( g_{K_1}^{\Xi^-} \) | \( -g_D + g_F \) sin \( \theta_{K_1} \) | \( 2.46 \) (3.47) |
| \( g_{K_1}^{\Xi^-} \) | \( -\sqrt{3} g_D + \frac{g_F}{\sqrt{3}} \) cos \( \theta_{K_1} \) | \( 6.67 \) (4.42) |
| \( g_{K_1}^{\Xi^-} \) | \( -g_D + g_F \) cos \( \theta_{K_1} \) | \( 3.27 \) (2.17) |
| \( g_{K_1}^{\Sigma^0 A} \) | \( -\sqrt{3} g_D + \frac{g_F}{\sqrt{3}} \) sin \( \theta_{K_1} \) | \( 0.54 \) (0.76) |
| \( g_{K_1}^{\Xi^-} \) | \( -\sqrt{3} g_D + \frac{g_F}{\sqrt{3}} \) sin \( \theta_{K_1} \) | \( 0.54 \) (0.76) |
| \( g_{K_1}^{\Xi^-} \) | \( -g_D + g_F \) sin \( \theta_{K_1} \) | \( 6.75 \) (9.52) |
| \( g_{K_1}^{\Xi^-} \) | \( -g_D + g_F \) cos \( \theta_{K_1} \) | \( 8.96 \) (5.95) |
| \( g_{K_1}^{\Xi^-} \) | \( -\sqrt{2}(g_D + g_F) \) sin \( \theta_{K_1} \) | \( 9.54 \) (13.44) |
| \( g_{K_1}^{\Xi^-} \) | \( -\sqrt{2}(g_D + g_F) \) cos \( \theta_{K_1} \) | \( 12.66 \) (8.40) |
| \( g_{K_1}^{\Xi^-} \) | \( -\frac{2g_F}{\sqrt{3}} \) sin \( \theta_{K_1} \) | \( 11.48 \) (16.17) |
| \( g_{K_1}^{\Xi^-} \) | \( 2g_D \) sin \( \theta_{K_1} \) | \( 8.12 \) (11.44) |
| \( g_{K_1}^{\Xi^-} \) | \( \frac{2g_F}{\sqrt{3}} \) cos \( \theta_{K_1} \) | \( 15.24 \) (10.11) |
| \( g_{K_1}^{\Xi^-} \) | \( 2g_D \) cos \( \theta_{K_1} \) | \( 10.77 \) (7.15) |
| \( g_{K_1}^{\Lambda} \) | \( 2(g_D - \frac{2g_F}{3}) \) | \( 7.40 \) |
| \( g_{K_1}^{\Lambda} \) | \( -\sqrt{3}(g_D + \frac{g_F}{\sqrt{3}}) \) | \( 7.40 \) |
| \( g_{f_1}^{L} \) | \( 0 \) | \( 0 \) |
| \( g_{f_1}^{L} \) | \( 0 \) | \( 0 \) |
| \( g_{f_1}^{L} \) | \( \frac{2g_F}{\sqrt{3}} \) | \( 8.51 \) |
| \( g_{f_1}^{L} \) | \( -\frac{2g_F}{\sqrt{3}} \) | \( 8.51 \) |
| \( g_{f_1}^{L} \) | \( 0 \) | \( 0 \) |
| \( g_{f_1}^{L} \) | \( 2g_D \) | \( 6.113 \) |
| \( g_{f_1}^{L} \) | \( g_D - g_F \) | \( 5.04 \) |
| \( g_{f_1}^{L} \) | \( \sqrt{2}(g_D - g_F) \) | \( 7.15 \) |
| \( g_{f_1}^{L} \) | \( -2\sqrt{2}g_D \) | \( 19.52 \) |
TABLE II: Branching ratios of $\Omega^0_c$ decays for CKM-favored ($\Delta C = \Delta S = -1$) and CKM-suppressed ($\Delta C = -1, \Delta S = 0$) modes at $\theta_{K_1} = -37^o(-58^o)$. Flavor dependent branching ratios include effects of $|\psi(0)|^2$ variation.

| Decays                  | $\Delta C = \Delta S = -1$ mode | $\Delta C = -1, \Delta S = 0$ mode |
|-------------------------|----------------------------------|----------------------------------|
| $\Omega^0_c \to \Xi^0 K^0$ | $2.10 \times 10^{-4} (4.16 \times 10^{-4})$ | $9.20 \times 10^{-4} (1.83 \times 10^{-3})$ |
| $\Omega^0_c \to \Lambda K^0$ | $3.72 \times 10^{-4} (7.39 \times 10^{-4})$ | $1.64 \times 10^{-3} (3.26 \times 10^{-3})$ |
| $\Omega^0_c \to \Lambda K^*$ | $4.53 \times 10^{-4} (2.00 \times 10^{-4})$ | $2.00 \times 10^{-3} (8.80 \times 10^{-4})$ |
| $\Omega^0_c \to \Sigma^+ K^0$ | $5.34 \times 10^{-5} (1.06 \times 10^{-4})$ | $2.36 \times 10^{-4} (4.68 \times 10^{-3})$ |
| $\Omega^0_c \to \Sigma^+ K^*$ | $5.77 \times 10^{-5} (2.54 \times 10^{-4})$ | $2.55 \times 10^{-4} (1.12 \times 10^{-4})$ |
| $\Omega^0_c \to \Sigma^0 K^0$ | $2.60 \times 10^{-5} (5.25 \times 10^{-5})$ | $1.17 \times 10^{-4} (2.32 \times 10^{-4})$ |
| $\Omega^0_c \to \Sigma^0 K^*$ | $2.83 \times 10^{-5} (1.25 \times 10^{-5})$ | $1.25 \times 10^{-4} (5.50 \times 10^{-5})$ |
| $\Omega^0_c \to \Xi^0 \eta^0$ | $7.30 \times 10^{-4}$ | $3.22 \times 10^{-3}$ |
| $\Omega^0_c \to \Xi^0 f_1$ | $5.74 \times 10^{-4}$ | $2.53 \times 10^{-3}$ |
| $\Omega^0_c \to \Xi^- a^*_1$ | $1.44 \times 10^{-3}$ | $6.35 \times 10^{-3}$ |

TABLE III: Branching ratios of $\Omega^0_c$ decays for CKM-doubly-suppressed ($\Delta C = -\Delta S = -1$) mode at $\theta_{K_1} = -37^o(-58^o)$. Flavor dependent branching ratios include effects of $|\psi(0)|^2$ variation.

| Decays                  | $\Delta C = -\Delta S = -1$ mode |
|-------------------------|----------------------------------|
| $\Omega^0_c \to p K^-$  | $7.41 \times 10^{-5} (1.46 \times 10^{-4})$ |
| $\Omega^0_c \to p K^*$  | $9.97 \times 10^{-5} (4.40 \times 10^{-5})$ |
| $\Omega^0_c \to n K^0$  | $7.40 \times 10^{-5} (1.47 \times 10^{-4})$ |
| $\Omega^0_c \to n K^*$  | $9.94 \times 10^{-5} (4.38 \times 10^{-5})$ |
| $\Omega^0_c \to \Xi^0 K^0$ | $1.83 \times 10^{-7} (3.64 \times 10^{-7})$ |
| $\Omega^0_c \to \Xi^- K^*_1$ | $1.79 \times 10^{-7} (3.55 \times 10^{-7})$ |
| $\Omega^0_c \to \Lambda f_1$ | $1.46 \times 10^{-5}$ |
| $\Omega^0_c \to \Lambda f'_1$ | $9.55 \times 10^{-5}$ |
| $\Omega^0_c \to \Sigma^+ a_1^*$ | $7.40 \times 10^{-5}$ |
| $\Omega^0_c \to \Sigma^0 a_1^*$ | $7.36 \times 10^{-5}$ |
| $\Omega^0_c \to \Sigma^- a_1^*$ | $7.33 \times 10^{-5}$ |