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Hypernuclear decay of strangeness -2 hypernuclei: Weak and strong baryon-baryon-meson vertices

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Since the discovery in 1952 of the first strange fragment in emulsion chamber experiments, much effort has been put into our knowledge of the nuclear chart to the SU(3) sector. Worldwide, the study of the interactions among nucleons and hyperons has been a priority in the research plan of many experimental facilities. After more than sixty years of Λ-hypernuclear studies, some attention has been placed in the production of ΛΛ-hypernuclei and more recently, proposals have been made to study Ξ-hypernuclear spectroscopy.
Our main objective is to calculate the weak decay rate for ΛΛ-hypernuclei, including all the intermediate baryonic channels allowed by the strong interaction. In this contribution we focus on the analysis of the decay induced by two-body transitions starting with a ΛΛ pair. We present the weak and strong coupling constants required to perform such calculations using a meson-exchange model, built upon the exchange of mesons belonging to the ground state of pseudoscalar and vector octets. The tree-level values for the baryon-baryon-meson coupling constants are derived using SU(3) symmetry for pseudoscalar mesons and the Hidden Local Symmetry for vector mesons.

The 8th International Workshop on Chiral Dynamics 2015
Pisa, Italy June 29 – July 03, 2015

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The study of the decay of hypernuclear systems gives us a very valuable information on the strong and weak interaction between hyperons and nucleons. These exotic systems decay mainly through two-body mechanisms, involving one or two hyperons (ΛN or $\Lambda\Lambda$) in the initial state and none or one hyperon (Y) in the final state (NN or YN). One-meson-exchange models can give us a theoretical description of the elementary reaction, requiring the knowledge of strong and weak baryon-baryon-meson (BBM) couplings. While the vertices for the $\Lambda N \to NN$ were already derived a few years ago [1, 2] in the context of the decay of single-Λ hypernuclei, the ones involving an initial $\Lambda\Lambda$ pair were only derived for the direct $\Lambda\Lambda \to YN$ weak transition [3, 4, 5, 6], participating in the decay of strangeness -2 systems. The consideration of the strong interaction between the baryons in the initial pair ($\Lambda\Lambda - \Xi N - \Sigma\Sigma$) leads to additional weak two-body transitions, starting from either a ΞN pair or a $\Sigma\Sigma$ one, and therefore requires the explicit calculation of new strong and weak vertices. The main objective of this work is to present the relevant vertices for the $\Lambda\Lambda - \Xi N \to YN$ amplitude, namely, $\Lambda\Lambda - \Xi^- p(\Xi^0 n) \to \Lambda n$, $\Lambda\Lambda - \Xi^- p(\Xi^0 n) \to \Sigma^- p$ and $\Lambda\Lambda - \Xi^- p(\Xi^0 n) \to \Sigma^0 n$.

In a meson exchange picture, every $\Lambda\Lambda \to YN$ transition can be understood in terms of the exchange of mesons between the interacting baryons, with masses related to the inverse of the interaction range and with quantum numbers allowed by the symmetries governing the underlying dynamics. Within this model, a reaction can be understood as a product of two contributions: a strong vertex and a weak one, where the strangeness variation occurs, connected through the meson propagator. While the calculation for the exchange of pseudoscalar mesons other than the pion requires the use of $\mathrm{SU}(3)_f$ symmetry, the inclusion of vector mesons in the formalism requires the use of $\mathrm{SU}(6) = \mathrm{SU}(2)_s \times \mathrm{SU}(3)_f$ spin-flavour symmetry ($\mathrm{SU}(6)_W$ for the weak vertices), as will be explained further below.

1. Baryon-baryon-meson vertices

The description of the interaction between two baryons of the $(1/2)^+$ octet through the exchange of either a pseudoscalar or a vector meson, needs the knowledge of the interaction Lagrangian connecting two baryons and a meson for each of the vertices involved in the corresponding diagram. The formalism for the construction of such Lagrangians was developed by Callan, Coleman, Wes and Zumino in 1968 [7, 8]. In these types of realizations whenever functions of the Goldstone bosons appear, they are always accompanied by at least one space-time derivative. Since the interaction with Goldstone bosons must vanish at zero momentum in the chiral limit the expansion of the Lagrangian at low energies is in powers of derivatives and pion masses.

1.1 Pseudoscalar mesons

1.1.1 Strong baryon-baryon-meson coupling

The strong Lagrangian corresponding to the exchange of a pseudoscalar meson has the following form [9, 10, 11],

$$\mathscr{L}^S = \mathrm{Tr}\left[\overline{B}\left(i\gamma^\mu \nabla_\mu\right) B\right] - M_B \,\mathrm{Tr}\left[\overline{B}B\right] + D\,\mathrm{Tr}\left[\overline{B}\gamma^\mu\gamma_5\left\{u_\mu, B\right\}\right] + F\,\mathrm{Tr}\left[\overline{B}\gamma^\mu\gamma_5\left[u_\mu, B\right]\right], \qquad (1.1)$$

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where F and D are the octet baryon to meson couplings, B ($\overline{B^i_j} = (B^j_i)^\dagger \gamma_4$) is the matrix representing the inbound (outbound) baryons

$$B = \begin{pmatrix} \frac{1}{\sqrt{2}}\Sigma^0 + \frac{1}{\sqrt{6}}\Lambda & \Sigma^+ & p \\ \Sigma^- & -\frac{1}{\sqrt{2}}\Sigma^0 + \frac{1}{\sqrt{6}}\Lambda & n \\ \Xi^- & \Xi^0 & -\frac{2}{\sqrt{6}}\Lambda \end{pmatrix}, \tag{1.2}$$

and $\nabla_\mu B = \partial_\mu B + \left[\Gamma_\mu, B\right]$ the covariant derivative introduced to account for gauge invariance. Writing explicitly this derivative, one obtains:

$$\begin{aligned}\mathscr{L}_{\phi B} =& i\gamma^\mu \operatorname{Tr}\left[\overline{B}\partial_\mu B\right] - M_B \operatorname{Tr}\left[\overline{B}B\right] + i\gamma^\mu \operatorname{Tr}\left[\overline{B}[\Gamma_\mu, B]\right] + D\gamma^\mu\gamma_5 \operatorname{Tr}\left[\overline{B}\left\{u_\mu, B\right\}\right] \\ &+ F\gamma^\mu\gamma_5 \operatorname{Tr}\left[\overline{B}[u_\mu, B]\right].\end{aligned} \tag{1.3}$$

The two first contributions correspond to the kinetic and mass terms for the baryons, while the dependence on the meson fields is contained in the Γ_μ and u_μ operators:

$$\Gamma_\mu = \frac{1}{2}\left(u^\dagger\partial_\mu u + u\partial_\mu u^\dagger\right) \quad u_\mu = \frac{i}{2}\left(u\partial_\mu u^\dagger - u^\dagger\partial_\mu u\right), \tag{1.4}$$

where u is defined as $u = \mathrm{e}^{i\frac{\phi}{\sqrt{2}f}} \simeq 1 + i\frac{1}{\sqrt{2}f}\phi$, with f the meson decay constant, and ϕ the selfadjoint matrix of inbound pseudoscalar mesons, thus fulfilling the condition $\phi = \phi^\dagger$,

$$\phi = \begin{pmatrix} \frac{1}{\sqrt{2}}\pi^0 + \frac{1}{\sqrt{6}}\eta & \pi^+ & K^+ \\ \pi^- & -\frac{1}{\sqrt{2}}\pi^0 + \frac{1}{\sqrt{6}}\eta & K^0 \\ K^- & \overline{K^0} & -\frac{2}{\sqrt{6}}\eta \end{pmatrix}. \tag{1.5}$$

1.1.2 Weak baryon-baryon-meson vertices

The starting point to derive the weak vertices is the heavy baryon chiral perturbation Hamiltonian introduced by Jenkins and Manohar [12, 13] to account for strangeness changing amplitudes, all the while neglecting those terms in which the decuplet baryon matrices appear. Using a lowest-order chiral analysis one can only generate parity violating amplitudes, since the weak chiral Lagrangian describing parity-conserving transitions has the wrong transformation property under the combined action of the charge and parity operators [14]. The effective Lagrangian:

$$\mathscr{L} = G_F m_\pi^2 \sqrt{2} f_\pi \left(h_D \operatorname{Tr}\left[\overline{B}\left\{\xi^\dagger h\xi, B\right\}\right] + h_F \operatorname{Tr}\left[\overline{B}\left[\xi^\dagger h\xi, B\right]\right]\right), \tag{1.6}$$

is written in terms of the dimensionless constants h_D and h_F, which can be fit to reproduce known meson decay amplitudes and the s-wave nonleptonic weak decays of the baryon octet members. The h operator is a 3x3 matrix with a single non-zero element, $h_{23} = 1$, which accounts for strangeness variations of $|\Delta S| = 1$. The operator ξ plays a role equivalent to the one of the u operator in the strong Lagrangian defined in the previous section.

As stated above, the use of the weak effective Hamiltonian at lowest order allows us to obtain only the parity violating amplitudes. The standard method to compute the parity conserving amplitudes is based in the pole model[15], according to which the weak transition is shifted from the

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meson vertex to the baryonic (and mesonic) line. The starting point is to consider the transition amplitude for the nonleptonic emission of a meson, $\langle B' M_i(q)|H_W|B\rangle$,

$$\sum_n \left[\delta(\vec{p}_n-\vec{p}_{B'}-\vec{q})\frac{\langle B'|A_i^\mu(0)|n\rangle\langle n|H_W(0)|B\rangle}{p_B^0-p_n^0}\right]+\sum_{n'}\left[\delta(\vec{p}_B-\vec{p}_{n'}-\vec{q})\frac{\langle B'|A_i^\mu(0)|n'\rangle\langle n'|H_W(0)|B\rangle}{p_B^0-q^0-p_{n'}^0}\right], \quad (1.7)$$

where the use of a complete set of states $\sum_n |n\rangle\langle n|$ leads to a series of contributions dominated by the baryon $(1/2)^+$ pole terms, as shown in Fig. 1, that become singular in the SU(3) soft-meson limit and represent the leading contribution to the parity-conserving amplitudes [16]:

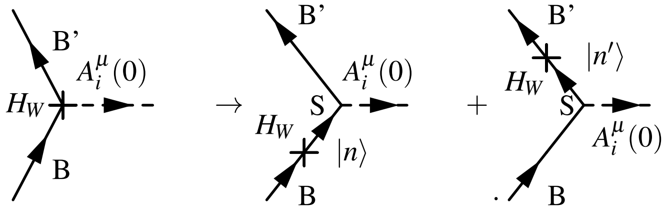

Figure 1: Schematic representation of Eq. (1.7), with S and H_W denoting strong and weak vertices.

For the calculation of the weak pole vertices it is necessary to express the physical states in terms of the baryon octet fields $|B_i\rangle$, as well as the meson states in terms of $|M_i\rangle$ [17]. Furthermore, the mesonless weak transition between baryons, $\langle B|H_W(0)|B'\rangle$, can be computed using low-energy theorems for mesons. These theorems express the matrix element for the emission of a meson of zero (or small) four-momentum in terms of the corresponding matrix element in the absence of the soft meson and some equal-time commutators of currents [18]. They are based on the existence of certain symmetry in a given physical process, which give rise to degenerate multiplets (a state containing an arbitrary number of Goldstone bosons) with couplings related by the symmetry. Therefore, we will be able to relate the strong scattering amplitudes to the weak vertices [17],

$$\lim_{q\to 0}\langle B \xrightarrow{PV} B' M_i\rangle = \lim_{q\to 0}\langle B' M_i|H_{PV}|B\rangle = -\frac{i}{F_\pi}\langle B'|[F_i,H_6]|B\rangle. \quad (1.8)$$

where, following Cabibbo's theory, we have assumed that the weak hamiltonian transforms like the sixth component of an octet, H_6, according to the CP invariance of $H_W^{\Delta S=1}$, and F_i are the corresponding $SU(3)$ generators.

1.2 Vector mesons

The interaction between baryons and vector mesons has not been as extensively studied as the ones involving pseudoscalar mesons, but there are theories, as the one based in hidden local symmetry (HLS) [19], which can accommodate vector mesons consistently with chiral symmetry. In order to incorporate these mesons in our formalism, the following Lagrangian is used:

$$\begin{aligned}\mathscr{L}_{VBB} = &-g\{\langle \overline{B}\gamma_\mu[V_8^\mu,B]\rangle+\langle\overline{B}\gamma_\mu B\rangle\langle V_8^\mu\rangle+\frac{1}{4M}\big(F\langle\overline{B}\sigma_{\mu\nu}[\partial^\mu V_8^\nu-\partial^\nu V_8^\mu,B]\rangle \\ &+D\langle\overline{B}\sigma_{\mu\nu}\{\partial^\mu V_8^\nu-\partial^\nu V_8^\mu,B\}\rangle\big)+\langle\overline{B}\gamma_\mu B\rangle\langle V_0^\mu\rangle+\frac{C_0}{4M}\langle\overline{B}\sigma_{\mu\nu}V_0^{\mu\nu}B\rangle\}, \quad (1.9)\end{aligned}$$

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which may be obtained from the generalization of the HLS formalism in SU(2) to the SU(3) sector. There, V_8 and V_0 are the octet and singlet terms in the vector meson matrix respectively,

$$V_\mu = \frac{1}{2}\begin{pmatrix} \rho^0+\omega & \sqrt{2}\rho^+ & \sqrt{2}K^{*+} \\ \sqrt{2}\rho^- & -\rho^0+\omega & \sqrt{2}K^{*0} \\ \sqrt{2}K^{*-} & \sqrt{2}\overline{K^{*0}} & \sqrt{2}\phi \end{pmatrix}_\mu , \tag{1.10}$$

where the constant C_0 is chosen to be $3F-D$, such that the ϕNN vertex is null (according to naive expectations based in the Okubo Zweig Iizuka, *OZI*, rule) and the anomalous magnetic coupling of the ωNN vertex gives $\kappa_\omega \simeq 3F-D$ [20]. The baryon mass is represented by M, while g equals $g=\frac{m}{\sqrt{2}f_\pi}$ where m is the mass of the exchanged meson and f_π is the π decay constant.

For the weak vertices the introduction of the SU(6)$_W$ group is necessary. This group describes the product of the SU(3) flavour group with the SU(2)$_W$ spin group, which is the proper group to consider when dealing with particles in motion, as the ones involved in weak decay processes [21]. For the parity-conserving interactions the pole model and the soft-meson reduction theorem introduced in Subsection 1.1.2 should be used again, decomposing the weak PC vertex into a strong and weak PV contributions, analogously to the previous calculation.

2. Results

We present in Tables 1 through 4 our results for the strong, weak PV and weak PC coupling constants. Charge and isospin conservation (violation) at the strong (weak) vertices, put restrictions on the allowed mesons, as listed in the tables. In order to give the numerical estimates of the coupling constants, we use the results of analyses that included the decuplet (out of the scope of the present paper) and the octet baryons, which lead to the following values $D=1.18$ MeV, $F=0.7$ MeV, $h_D=-0.5$ MeV, $h_F=0.91$ MeV and $f_\pi \simeq 93$ MeV[13]. For vector mesons $D=2.4$, $F=0.82$, $b_V=-8.36\times10^{-7}$, $b_T=8.36\times10^{-7}$ and $c_V=7.08\times10^{-7}$.

Pseudoscalar			Vector					
Coupling	**Analytic value**	**N. value**	**Coupling**	**Analytic value**	**N. value**	**Coupling**	**Analytic value**	**N. value**
$p\pi^-\overline{n}$	$D+F$	1.88	$\Xi^-K^{*+}\overline{\Lambda}_T$	$-\frac{g(D-3F)}{8\sqrt{3}M}$	-0.004	$p\omega_8\overline{p}_T$	$\frac{g(D+F)}{8\sqrt{3}M}$	-0.232
$\Xi^-K^+\overline{\Lambda}$	$-\frac{1}{\sqrt{2}}\left(\frac{D}{\sqrt{3}}-\sqrt{3}F\right)$	0.37	$\Xi^-K^{*+}\overline{\Lambda}_V$	$-\frac{g\sqrt{3}}{2}$	0.866	$p\omega_8\overline{p}_V$	$-\frac{g\sqrt{3}}{2}$	0.866
$\Xi^-K^+\overline{\Sigma^0}$	$\frac{1}{\sqrt{2}}(D+F)$	1.33	$p\rho^-\overline{n}_T$	$\frac{g(D+F)}{4\sqrt{2}M}$	-0.569	$n\omega_8\overline{n}_T$	$\frac{g(D+F)}{8\sqrt{3}M}$	-0.232
$p\pi^0\overline{p}$	$\frac{1}{\sqrt{2}}(D+F)$	1.33	$p\rho^-\overline{n}_V$	$-\frac{g}{\sqrt{2}}$	0.707	$n\omega_8\overline{n}_V$	$-\frac{g\sqrt{3}}{2}$	0.866
$p\eta\overline{p}$	$-\frac{1}{\sqrt{2}}\left(\frac{D}{\sqrt{3}}-\sqrt{3}F\right)$	0.38	$\Xi^-K^{*+}\overline{\Sigma^0}_T$	$\frac{g(D+F)}{8M}$	-0.403	$\Xi^0K^{*0}\overline{\Lambda}_T$	$-\frac{g(D-3F)}{8\sqrt{3}M}$	-0.004
$\Xi^-K^0\overline{\Sigma^-}$	$D+F$	1.88	$\Xi^-K^{*+}\overline{\Sigma^0}_V$	$-\frac{g}{2}$	0.5	$\Xi^0K^{*0}\overline{\Lambda}_V$	$-\frac{g}{2}$	0.5
$n\pi^0\overline{n}$	$-\frac{1}{\sqrt{2}}(D+F)$	-1.33	$\Xi^-K^{*0}\overline{\Sigma^-}_T$	$\frac{g(D+F)}{4\sqrt{2}M}$	-0.569	$\Xi^0K^{*0}\overline{\Sigma^0}_T$	$-\frac{g(D+F)}{8M}$	0.403
$n\eta\overline{n}$	$-\frac{1}{\sqrt{2}}\left(\frac{D}{\sqrt{3}}-\sqrt{3}F\right)$	-1.34	$\Xi^-K^{*0}\overline{\Sigma^-}_V$	$-\frac{g}{\sqrt{2}}$	0.707	$\Xi^0K^{*0}\overline{\Sigma^0}_V$	$-\frac{g}{6}$	0.167
$\Xi^0K^0\overline{\Lambda}$	$\frac{1}{\sqrt{2}}\left(\frac{D}{\sqrt{3}}+\sqrt{3}F\right)$	-0.376	$p\rho^0\overline{p}_T$	$\frac{g(D+F)}{8M}$	-0.403	$n\rho^+\overline{p}_T$	$\frac{g(D+F)}{4\sqrt{2}M}$	-0.569
$\Xi^0K^0\overline{\Sigma^0}$	$-\frac{1}{\sqrt{2}}(D+F)$	-1.33	$p\rho^0\overline{p}_V$	$-\frac{g}{2}$	0.5	$n\rho^+\overline{p}_V$	$-\frac{g}{\sqrt{2}}$	0.707
			$n\rho^0\overline{n}_T$	$-\frac{g(D+F)}{8M}$	0.403	$nK^{*-}\overline{\Sigma^-}_T$	$\frac{g(D-F)}{4\sqrt{2}M}$	-0.279
			$n\rho^0\overline{n}_V$	$\frac{g}{2}$	-0.5	$nK^{*-}\overline{\Sigma^-}_V$	$\frac{g}{\sqrt{2}}$	-0.707

Table 1: Strong baryon-baryon-meson couplings (in units of $\frac{1}{\sqrt{2}f}$ for the pseudoscalar, $-\frac{g}{M}$ for the tensor (T) and $-g$ for the vector (V) components)

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Pseudoscalar			Vector		
Coupling	**Analytic value**	**N. value**	**Coupling**	**Analytic value**	**N. value**
$pK^-\overline{n}$	$\sqrt{2}(h_D+h_F)$	0.58	$pK^{*-}\overline{n}$	$\frac{1}{6\sqrt{2}}(b_T-b_V)+\frac{5}{9\sqrt{2}}c_V$	-3.05
$\Xi^-\pi^+\overline{\Lambda}$	$\left(\frac{h_D}{\sqrt{3}}-\sqrt{3}h_F\right)$	-1.86	$\Xi^-\rho^+\overline{\Lambda}$	$\frac{1}{6\sqrt{3}}\left(-\frac{1}{2}b_T+\frac{1}{2}b_V+c_V\right)$	0.08
$\Xi^-\pi^+\overline{\Sigma^0}$	$-(h_D+h_F)$	-0.41	$\Xi^-\rho^+\overline{\Sigma^0}$	$\frac{1}{36}(-3b_T-3b_V+10c_V)$	-1.26
$\Xi^-\pi^0\overline{\Sigma^-}$	h_D+h_F	0.41	$p\overline{K^{*0}}\overline{p}$	$\frac{\sqrt{2}}{6}\left(\frac{1}{2}b_V-\frac{1}{3}c_V\right)$	0.99
$\Xi^-\eta\overline{\Sigma^-}$	$-\sqrt{3}(h_D+h_F)$	-0.71	$\Xi^-\rho^0\overline{\Sigma^-}$	$-\frac{5}{18}c_V$	1.26
$p\overline{K^0}\overline{p}$	$\sqrt{2}(h_D-h_F)$	-1.99	$\Xi^-\omega_8\overline{\Sigma^-}$	$\frac{5}{6\sqrt{3}}c_V$	-2.19
$n\overline{K^0}\overline{n}$	$2\sqrt{2}h_F$	2.57	$n\overline{K^{*0}}\overline{n}$	$\frac{\sqrt{2}}{3}\left(-\frac{1}{4}b_V+\frac{2}{3}c_V\right)$	-2.06
$\Xi^0\pi^0\overline{\Lambda}$	$\frac{1}{\sqrt{6}}(h_D-h_F)$	-0.576	$\Xi^0\omega_8\overline{\Sigma^0}$	$\frac{1}{4\sqrt{6}}(-b_T-b_V)+\frac{5}{6\sqrt{6}}c_V$	-1.55
$\Xi^0\pi^0\overline{\Sigma^0}$	$\frac{1}{\sqrt{2}}(h_D+h_F)$	0.290	$\Xi^0\rho^0\overline{\Sigma^0}$	$-\frac{1}{4\sqrt{2}}b_T+\frac{1}{12\sqrt{2}}b_V-\frac{5}{18\sqrt{2}}c_V$	-0.37
$\Xi^0\eta\overline{\Lambda}$	$-\frac{1}{\sqrt{2}}(h_D-h_F)$	0.997	$\Xi^0\omega_8\overline{\Lambda}$	$\frac{1}{12\sqrt{2}}(-b_T+b_V-2c_V)$	-0.097
$\Xi^0\eta\overline{\Sigma^0}$	$\frac{3}{\sqrt{6}}(h_D+h_F)$	0.502	$\Xi^0\rho^0\overline{\Lambda}$	$\frac{1}{12\sqrt{6}}(-3b_T-b_V+2c_V)$	-1.04
			$\Xi^0K^{*+}\overline{p}$	$\frac{1}{6\sqrt{2}}(-b_T+b_V)$	-1.27
			$\Xi^0\rho^+\overline{\Sigma^-}$	$\frac{1}{6\sqrt{2}}(-b_T+b_V)$	-1.27

Table 2: Weak parity-violating baryon-baryon meson couplings (in terms of $-\frac{G_F f_\pi m_\pi^2}{\sqrt{2}f}$).

Coupling	Analytic value	Numeric value
$pK^-\overline{n}$	$-\frac{1}{2}\left(\sqrt{3}F+\frac{D}{\sqrt{3}}\right)\frac{\sqrt{3}-1}{m_n-m_\Lambda}\frac{2fA_{\Lambda p}}{\sqrt{2}}-\frac{1}{2}(F-D)\frac{\sqrt{3}-1}{m_n-m_{\Sigma 0}}\frac{2fA_{\Sigma^+p}}{\sqrt{2}}$	1.23
$\Xi^-\pi^+\overline{\Lambda}$	$\frac{D}{\sqrt{3}}\frac{\sqrt{3}-1}{m_{\Xi^-}-m_{\Sigma^-}}2fA_{\Sigma^+p}+\frac{2f}{\sqrt{2}}(D-F)\frac{\sqrt{3}+1}{m_\Lambda-m_{\Xi 0}}\frac{1}{2\sqrt{2}}\left(A_{\Lambda p}-\sqrt{3}A_{\Sigma^+p}\right)$	−0.34
$\Xi^-\pi^+\overline{\Sigma^0}$	$F\frac{\sqrt{3}-1}{m_{\Xi^-}-m_{\Sigma^-}}2fA_{\Sigma^+p}+\frac{1}{\sqrt{2}}(D-F)\frac{\sqrt{3}-1}{m_{\Sigma 0}-m_{\Xi 0}}\frac{2f}{2\sqrt{2}}\left(A_{\Lambda p}+\sqrt{3}A_{\Sigma^+p}\right)$	−1.36
$\Xi^-\pi^0\overline{\Sigma^-}$	$-\frac{1}{2}(F-D)\frac{\sqrt{3}-1}{m_{\Sigma^-}-m_{\Xi^-}}2fA_{\Sigma^+p}-F\frac{\sqrt{3}-1}{m_{\Xi^-}-m_{\Sigma^-}}2fA_{\Sigma^+p}$	2.09
$\Xi^-\eta\overline{\Sigma^-}$	$-\frac{1}{2}\left(\frac{D}{\sqrt{3}}+\sqrt{3}F\right)\frac{\sqrt{3}-1}{m_{\Sigma^-}-m_{\Xi^-}}2fA_{\Sigma^+p}+\frac{D}{\sqrt{3}}\frac{\sqrt{3}-1}{m_{\Xi^-}-m_{\Sigma^-}}2fA_{\Sigma^+p}$	−3.62
$p\overline{K^0}\overline{p}$	$-\frac{1}{\sqrt{2}}(F-D)\frac{1-\sqrt{3}}{m_p-m_{\Sigma^+}}2fA_{\Sigma^+p}$	−0.37
$n\overline{K^0}\overline{n}$	$-\frac{1}{2}\left(\frac{D}{\sqrt{3}}+\sqrt{3}F\right)\frac{\sqrt{3}-1}{m_n-m_\Lambda}\frac{2fA_{\Lambda p}}{\sqrt{2}}-\frac{1}{2}(D-F)\frac{\sqrt{3}-1}{m_n-m_{\Sigma 0}}\frac{2fA_{\Sigma^+p}}{\sqrt{2}}$	0.86
$\Xi^0\pi^0\overline{\Sigma^0}$	$-\frac{1}{2}(D-F)\frac{1}{m_{\Sigma 0}-m_{\Xi 0}}\frac{-f}{\sqrt{2}}\left(A_{\Lambda p}+\sqrt{3}A_{\Sigma^+p}\right)-\frac{D}{\sqrt{3}}\frac{1}{m_{\Xi 0}-m_\Lambda}\frac{f}{\sqrt{2}}\left(A_{\Lambda p}-\sqrt{3}A_{\Sigma^+p}\right)$	0.77
$\Xi^0\eta\overline{\Sigma^0}$	$\left(-\frac{1}{6}(D+3F)\frac{1}{m_{\Sigma 0}-m_{\Xi 0}}+\frac{D}{\sqrt{3}}\frac{1}{m_{\Xi 0}-m_\Lambda}\right)\frac{-f}{\sqrt{2}}\left(A_{\Lambda p}+\sqrt{3}A_{\Sigma^+p}\right)$	−0.57
$\Xi^0\pi^0\overline{\Lambda}$	$-\frac{1}{2}(D-F)\frac{1}{m_\Lambda-m_{\Xi 0}}\frac{f}{\sqrt{2}}\left(A_{\Lambda p}-\sqrt{3}A_{\Sigma^+p}\right)-\frac{D}{\sqrt{3}}\frac{1}{m_{\Xi 0}-m_{\Sigma 0}}\frac{-f}{\sqrt{2}}\left(A_{\Lambda p}+\sqrt{3}A_{\Sigma^+p}\right)$	0.08
$\Xi^0\eta\overline{\Lambda}$	$\left(-\frac{1}{6}(D+3F)\frac{1}{m_\Lambda-m_{\Xi 0}}-\frac{D}{\sqrt{3}}\frac{1}{m_{\Xi 0}-m_\Lambda}\right)\frac{f}{\sqrt{2}}\left(A_{\Lambda p}-\sqrt{3}A_{\Sigma^+p}\right)$	0.18

Table 3: Weak baryon-baryon-pseudoscalar meson parity-conserving couplings. Numeric values in terms of $-G_F m_\pi^2$. The reduced matrix elements used to calculate the weak transition between baryon fields can be determined by a fit to experimental data for specific PV transitions, for which we choose $\Sigma^+\to p+\pi^0$ (A_{Σ^+p}) and $\Lambda\to p+\pi^-$ ($A_{\Lambda p}$), taking the values $A_{\Sigma^+p}=-3.27\times 10^{-7}$ and $A_{\Lambda p}=3.25\times 10^{-7}$ [16].

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Coupling	Analytic value	Numeric value
$pK^{*-}\overline{n}_T$	$-\frac{(D-3F)}{8\sqrt{3}}\frac{\sqrt{3}-1}{m_n-m_\Lambda}\frac{2fA_{\Lambda p}}{\sqrt{2}}+\frac{(D-F)}{8}\frac{\sqrt{3}-1}{m_n-m_{\Sigma^0}}\frac{2fA_{\Sigma^+p}}{\sqrt{2}}$	0.54
$pK^{*-}\overline{n}_V$	$\frac{\sqrt{3}}{2}\frac{\sqrt{3}-1}{m_n-m_\Lambda}\frac{2fA_{\Lambda p}}{\sqrt{2}}+\frac{1}{2}\frac{\sqrt{3}-1}{m_n-m_{\Sigma^0}}\frac{2fA_{\Sigma^+p}}{\sqrt{2}}$	−0.57
$\Xi^-\rho^+\overline{\Lambda}_T$	$\frac{D}{4\sqrt{3}}\frac{\sqrt{3}-1}{m_{\Xi^-}-m_{\Sigma^-}}2fA_{\Sigma^+p}-\frac{(D-F)}{4\sqrt{2}}\frac{\sqrt{3}+1}{m_\Lambda-m_{\Xi^0}}\frac{2f}{2\sqrt{2}}\left(A_{\Lambda p}-\sqrt{3}A_{\Sigma^+p}\right)$	0.20
$\Xi^-\rho^+\overline{\Lambda}_V$	$-\frac{1}{\sqrt{2}}\frac{\sqrt{3}+1}{m_\Lambda-m_{\Xi^0}}\frac{2f}{2\sqrt{2}}\left(A_{\Lambda p}-\sqrt{3}A_{\Sigma^+p}\right)$	2.45
$\Xi^-\rho^+\overline{\Sigma^0}_T$	$-\frac{F}{4}\frac{\sqrt{3}-1}{m_{\Xi^-}-m_{\Sigma^-}}2fA_{\Sigma^+p}+\frac{(D-F)}{4\sqrt{2}}\frac{\sqrt{3}-1}{m_{\Sigma^0}-m_{\Xi^0}}\frac{2f}{2\sqrt{2}}\left(A_{\Lambda p}+\sqrt{3}A_{\Sigma^+p}\right)$	0.62
$\Xi^-\rho^+\overline{\Sigma^0}_V$	$-\frac{\sqrt{3}-1}{m_{\Xi^-}-m_{\Sigma^-}}2fA_{\Sigma^+p}-\frac{1}{\sqrt{2}}\frac{\sqrt{3}-1}{m_{\Sigma^0}-m_{\Xi^0}}\frac{2f}{2\sqrt{2}}\left(A_{\Lambda p}+\sqrt{3}A_{\Sigma^+p}\right)$	2.64
$\Xi^-\rho^0\overline{\Sigma^-}_T$	$\frac{(D-F)}{8}\frac{\sqrt{3}-1}{m_{\Sigma^-}-m_{\Xi^-}}2fA_{\Sigma^+p}+\frac{F}{4}\frac{\sqrt{3}-1}{m_{\Xi^-}-m_{\Sigma^-}}2fA_{\Sigma^+p}$	−0.90
$\Xi^-\rho^0\overline{\Sigma^-}_V$	$\frac{1}{2}\frac{\sqrt{3}-1}{m_{\Sigma^-}-m_{\Xi^-}}2fA_{\Sigma^+p}+\frac{\sqrt{3}-1}{m_{\Xi^-}-m_{\Sigma^-}}2fA_{\Sigma^+p}$	1.11
$\Xi^-\omega\overline{\Sigma^-}_T$	$\frac{(D-F)}{8\sqrt{3}}\frac{\sqrt{3}-1}{m_{\Sigma^-}-m_{\Xi^-}}2fA_{\Sigma^+p}+\frac{D}{4\sqrt{3}}\frac{\sqrt{3}-1}{m_{\Xi^-}-m_{\Sigma^-}}2fA_{\Sigma^+p}$	−0.51
$\Xi^-\omega\overline{\Sigma^-}_V$	$-\frac{1}{2\sqrt{3}}\frac{\sqrt{3}-1}{m_{\Sigma^-}-m_{\Xi^-}}2fA_{\Sigma^+p}-\frac{1}{\sqrt{3}}\frac{\sqrt{3}-1}{m_{\Xi^-}-m_{\Sigma^-}}2fA_{\Sigma^+p}$	0.64
$p\overline{K^{*0}}\overline{p}_T$	$\frac{(D-F)}{4\sqrt{2}}\frac{1-\sqrt{3}}{m_p-m_{\Sigma^+}}2fA_{\Sigma^+p}$	−0.31
$p\overline{K^{*0}}\overline{p}_V$	$\frac{1}{\sqrt{2}}\frac{1-\sqrt{3}}{m_p-m_{\Sigma^+}}2fA_{\Sigma^+p}$	−0.78
$n\overline{K^{*0}}\overline{n}_T$	$-\frac{(D+3F)}{8\sqrt{3}}\frac{\sqrt{3}-1}{m_n-m_\Lambda}\frac{2fA_{\Lambda p}}{\sqrt{2}}-\frac{(D-F)}{8}\frac{\sqrt{3}-1}{m_n-m_{\Sigma^0}}\frac{2fA_{\Sigma^+p}}{\sqrt{2}}$	0.23
$n\overline{K^{*0}}\overline{n}_V$	$\frac{\sqrt{3}}{2}\frac{\sqrt{3}-1}{m_n-m_\Lambda}\frac{2fA_{\Lambda p}}{\sqrt{2}}-\frac{1}{2}\frac{\sqrt{3}-1}{m_n-m_{\Sigma^0}}\frac{2fA_{\Sigma^+p}}{\sqrt{2}}$	−1.34
$\Xi^0K^{*+}\overline{p}_T$	$\frac{F-D}{4}\frac{1}{m_{\Xi^0}-m_{\Sigma^0}}\frac{-f}{\sqrt{2}}\left(A_{\Sigma^+p}+\sqrt{3}A_{\Lambda p}\right)+\frac{-(D+F)}{4\sqrt{2}}\frac{1}{m_p-m_{\Sigma^+}}A_{\Sigma^+p}+\frac{D+3F}{8\sqrt{3}}\frac{1}{m_{\Xi^0}-m_\Lambda}\frac{f}{\sqrt{2}}\left(A_{\Lambda p}-\sqrt{3}A_{\Sigma^+p}\right)$	0.693
$\Xi^0K^{*+}\overline{p}_V$	$-\frac{1}{2}\frac{1}{m_{\Xi^0}-m_{\Sigma^0}}\frac{-f}{\sqrt{2}}\left(A_{\Sigma^+p}+\sqrt{3}A_{\Lambda p}\right)+\frac{1}{\sqrt{2}}\frac{1}{m_p-m_{\Sigma^+}}A_{\Sigma^+p}-\frac{\sqrt{3}}{2}\frac{1}{m_{\Xi^0}-m_\Lambda}\frac{f}{\sqrt{2}}\left(A_{\Lambda p}-\sqrt{3}A_{\Sigma^+p}\right)$	−0.866
$\Xi^0\rho^-\overline{\Sigma^-}_T$	$-\frac{F}{4}\frac{1}{m_{\Xi^0}-m_{\Sigma^0}}\frac{-f}{\sqrt{2}}\left(A_{\Sigma^+p}+\sqrt{3}A_{\Lambda p}\right)+\frac{D-F}{4\sqrt{2}}\frac{1}{m_{\Sigma^-}-m_{\Xi^-}}2fA_{\Sigma^+p}-\frac{D}{4\sqrt{3}}\frac{1}{m_{\Xi^0}-m_\Lambda}\frac{f}{\sqrt{2}}\left(A_{\Lambda p}-\sqrt{3}A_{\Sigma^+p}\right)$	0.276
$\Xi^0\rho^-\overline{\Sigma^-}_V$	$-\frac{1}{2}\frac{1}{m_{\Xi^0}-m_{\Sigma^0}}\frac{-f}{\sqrt{2}}\left(A_{\Sigma^+p}+\sqrt{3}A_{\Lambda p}\right)+\frac{1}{\sqrt{2}}\frac{1}{m_{\Sigma^-}-m_{\Xi^-}}2fA_{\Sigma^+p}$	1.28
$\Xi^0\omega\overline{\Sigma^0}_T$	$\left(\frac{F-D}{8}\frac{1}{m_{\Sigma^0}-m_{\Xi^0}}+\frac{D}{4}\frac{1}{m_{\Xi^0}-m_{\Sigma^0}}\right)\frac{f}{\sqrt{2}}\left(A_{\Sigma^+p}+\sqrt{3}A_{\Lambda p}\right)$	0.46
$\Xi^0\omega\overline{\Sigma^0}_V$	$\left(-\frac{1}{2}\frac{1}{m_{\Sigma^0}-m_{\Xi^0}}+\frac{1}{2}\frac{1}{m_{\Xi^0}-m_{\Sigma^0}}\right)\frac{-f}{\sqrt{2}}\left(A_{\Sigma^+p}+\sqrt{3}A_{\Lambda p}\right)$	-0.58
$\Xi^0\rho^0\overline{\Sigma^0}_T$	$\frac{D-F}{8}\frac{1}{m_{\Sigma^0}-m\Xi^0}\frac{f}{\sqrt{2}}\left(A_{\Sigma^+p}+\sqrt{3}A_{\Lambda p}\right)-\frac{D}{4\sqrt{3}}\frac{1}{m_{\Xi^0}-m_\Lambda}\frac{f}{\sqrt{2}}\left(A_{\Lambda p}-\sqrt{3}A_{\Sigma^+p}\right)$	-0.58
$\Xi^0\rho^0\overline{\Sigma^0}_V$	$\frac{1}{2}\frac{1}{m_{\Sigma^0}-m\Xi^0}\frac{f}{\sqrt{2}}\left(A_{\Sigma^+p}+\sqrt{3}A_{\Lambda p}\right)$	-0.29
$\Xi^0\omega\overline{\Lambda}_T$	$\left(\frac{D-F}{8}\frac{1}{m_\Lambda-m_{\Xi^0}}-\frac{D}{12}\frac{1}{m_{\Xi^0}-m_\Lambda}\right)\frac{f}{\sqrt{2}}\left(A_{\Lambda p}-\sqrt{3}A_{\Sigma^+p}\right)$	-0.53
$\Xi^0\omega\overline{\Lambda}_V$	$\left(-\frac{1}{2}\frac{1}{m_\Lambda-m_{\Xi^0}}+\frac{1}{m_{\Xi^0}-m_\Lambda}\right)\frac{f}{\sqrt{2}}\left(A_{\Lambda p}-\sqrt{3}A_{\Sigma^+p}\right)$	2.00
$\Xi^0\rho^0\overline{\Lambda}_T$	$\frac{F-D}{8}\frac{1}{m_\Lambda-m_{\Xi^0}}\frac{f}{\sqrt{2}}\left(A_{\Lambda p}-\sqrt{3}A_{\Sigma^+p}\right)+\frac{-D}{4\sqrt{3}}\frac{1}{m_{\Xi^0}-m_{\Sigma^0}}\frac{-f}{\sqrt{2}}\left(A_{\Sigma^+p}+\sqrt{3}A_{\Lambda p}\right)$	0.46
$\Xi^0\rho^0\overline{\Lambda}_V$	$-\frac{1}{2}\frac{1}{m_\Lambda-m_{\Xi^0}}\frac{f}{\sqrt{2}}\left(A_{\Lambda p}-\sqrt{3}A_{\Sigma^+p}\right)$	0.67

Table 4: Weak baryon-baryon-vector meson parity-conserving couplings in terms of $-\frac{g}{M}$ and $-g$ for the tensor (T) and vector (V) components respectively

3. Summary

In the present work the focus has been placed on the calculation of the baryon-baryon-meson coupling structures required to evaluate the $\Lambda\Lambda-\Xi N\to YN$ weak transition, appearing when the strong interaction is accounted for in the decay of $\Lambda\Lambda$-hypernuclei.

Within a meson-exchange model, the strong baryon-baryon-meson constants have been derived with the use of the lowest-order effective strong Lagrangian representing the interaction of the ground state (g.s.) $(1/2)^+$ baryon octet and the g.s. pseudoscalar meson $(0)^-$ octet, while the inclusion of the $(1)^-$ vector meson interaction has been done using the hidden local symmetry formalism. Regarding the weak vertices, we have discussed that a lowest-order chiral analysis can only provide us with PV coupling constants, but not with the PC ones. In order to account for the existence of weak parity-conserving amplitudes, the well-tested pole model has been used, according to which the weak transitions are moved from the vertex to the baryon line. These pole

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terms, being singular in the SU(3) soft-meson limit, represent the leading contribution to the PC amplitudes, and can be computed via current algebra.

The quantities that have been derived here are being used in the evaluation of the decay of $^{6}_{\Lambda\Lambda}$He, where a complete description of the weak decay mechanism, including all possible effects of the strong interaction, is being performed [22].

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