$\bar{\nu}$-induced kaon production

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The importance of the study of strange particle production has been recently emphasized in literature as it would help to have a well understood Monte Carlo generator for predicting the neutrino event rates in the various neutrino oscillation experiments as well as in the understanding of the standard model. In this work, we have studied the charged current single kaon production induced by antineutrinos with free nucleons close to their threshold energies. The contributions of different terms have been obtained using a microscopical model based on the SU(3) chiral Lagrangian. The basic parameters of the model are f_π, the pion decay constant, Cabibbo's angle, the proton and neutron magnetic moments and the axial vector coupling constants for the baryons octet, D and F, which are obtained from the analysis of the semileptonic decays of neutron and hyperon. The basic reaction for the neutrino induced charged current kaon production is

$$\bar{\nu}_l(k) + N(p) \rightarrow l^+(k') + N'(p') + K(p_k), \quad (1)$$

where $l = e, \mu$, N&N'=n,p, K=K$^-$&$\bar{\mathrm{K}}^0$ and $\bar{\Sigma}\Sigma|\mathcal{M}|^2$ is the square of the transition amplitude averaged(summed) over the spins of the initial(final) state and amplitude $\mathcal{M}$ is given by,

$$\mathcal{M} = \frac{G_F}{\sqrt{2}} j_\mu^{(L)} J^{\mu\,(H)} \quad (2)$$

where $j_\mu^{(L)}$ and $J^{\mu\,(H)}$ are the leptonic and hadronic currents respectively, G_F is the Fermi coupling constant. Feynman diagrams contributing to the amplitude are given in Fig.1. The structure of the hadronic current and details of the formalism are given in Ref.[1]. The expression for the differential cross section in the lab frame for the above process is given by,

$$d^9\sigma = \frac{1}{4ME(2\pi)^5}\frac{d\vec{k}'}{(2E_l)}\frac{d\vec{p}'}{(2E_p')}\frac{d\vec{p}_k}{(2E_K)} \times \delta^4(k + p - k' - p' - p_k)\bar{\Sigma}\Sigma|\mathcal{M}|^2, \quad (3)$$

where $\vec{k}$ and $\vec{k'}$ are the 3-momenta of incoming and outgoing leptons with energy E and E' respectively. The kaon 3-momentum is $\vec{p}_k$ having energy E_K and M is the nucleon mass.

In Fig.2, we have presented the results of the cross section for $\nu_\mu p \rightarrow \mu^+ K^- p$ channel. We consider Σ^* resonance having decay width of about 40 MeV. Following the convention used in the Ref.[2] we write the lowest order SU(3) chiral Lagrangian to incorporate Σ^* resonance. We fit the free parameter used in the Lagrangian with Δ decay width $\Gamma_\Delta \sim 120$ MeV. The spin 3/2 propagator for the resonance is,

$$G^{\mu\nu}(P) = \frac{P_{RS}^{\mu\nu}(P)}{P^2 - M_{\Sigma^*}^2 + iM_{\Sigma^*}\Gamma_{\Sigma^*}}, \quad (4)$$

where P(=p+q) is the momentum carried by the Σ^*, having mass M_{Σ^*} and width Γ_{Σ^*}. $P_{RS}^{\mu\nu}$ is Rarita-Schwinger projection operator. For Σ^* width (Γ_{Σ^*}) we used the Lagrangian to get the total width,

$$\Gamma_{\Sigma^*}(W) = \Gamma_{\Sigma^* \rightarrow \Lambda\pi}(W) + \Gamma_{\Sigma^* \rightarrow \Sigma\pi}(W), \quad (5)$$

$$\Gamma_{\Sigma^* \rightarrow Y\pi} = \frac{C_Y}{192\pi}\left(\frac{\mathcal{C}}{f_\pi}\right)^2 \frac{\left((W + M_Y)^2 - m_\pi^2\right)}{W^5} \lambda^{3/2}(W^2, M_Y^2, m_\pi^2)\,\Theta(W - M_Y - m_\pi). \quad (6)$$

where, M_Y is the mass of the hyperon Y(=

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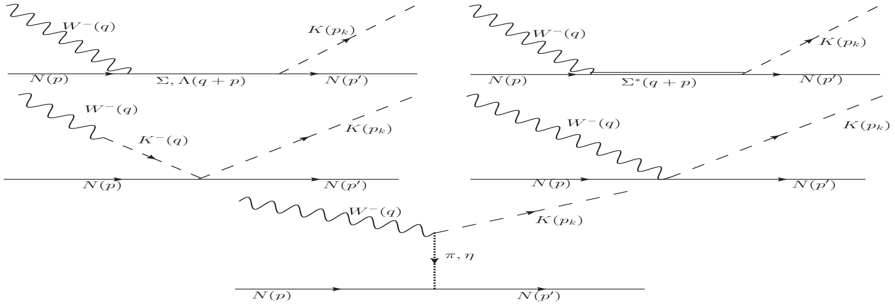

FIG. 1: Feynman diagrams for the process $\bar{\nu}N \to lN'\bar{K}$. First row from left to right: s-channel Σ, Λ propagator (labeled SC in the text),s-channel Σ^* Resonance (SCR), second row: kaon pole term (KP); Contact term (CT) and last row: Pion(Eta) in flight (πP, (ηP)).

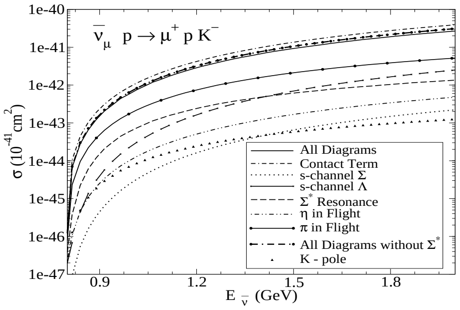

FIG. 2: Contribution of the different terms to the total cross section for the $\nu_\mu p \to \mu K^+ p$ reaction.

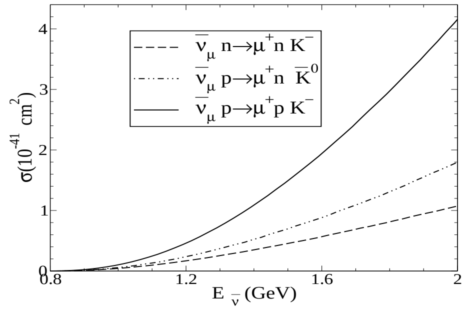

FIG. 3: Total cross section for $\bar{\nu}_\mu$-induced kaon production.

Λ and Σ). λ is the Callen lambda function, Θ is the step function and W is the center of mass energy. The factor C_Y is 1 for Λ and $\frac{2}{3}$ for Σ and $\mathcal{C}$ is a parameter used in the SU(3) Lagrangian which is fitted to obtain Δ decay width. In the present calculation we have assumed C_5^A dominance. In Fig.2, we present the contribution of various Feynman diagrams shown in Fig.1 to the total cross section for the reaction $\bar{\nu}p \to \mu^+ pK^-$. In Fig.3 we show the cross sections for the processes $\bar{\nu}p \to \mu^+ pK^-$, $\bar{\nu}p \to \mu^+ n\bar{K}^0$ and $\bar{\nu}n \to \mu^+ nK^-$. These calculations are useful for ~ 1 GeV anti-neutrino experiments being performed at MiniBooNE, atmospheric neutrino experiments as well as future experiments like NOVA, T2K phase-II and beta beam experiments. We find that the cross sections for anti-neutrino induced kaon production is about 2 orders of magnitude smaller than the corresponding reactions for one pion production. However, they are sufficient for studying at Minerνa experiment. The details of the results will be presented in the symposium.

References

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