$e^{\pm}$ induced single kaon production off the neucleon

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Introduction

We study single kaon production off the nucleon induced by electron (positron) i.e. $e^-(e^+) + N \rightarrow \nu_e(\bar{\nu}_e) + \bar{K}(K) + N'$ in the intermediate energy range. This study has been done keeping the electron accelerator facility at JLab, Mainz Mikrotron, etc. into account. The availability of continuous wave electron accelerators at Mainz and Thomas Jefferson National Accelerator Facility(JLab) with 100% duty cycle in the energy range of few GeV with very high luminosity has given opportunity to study associated particle production. However, in the sub-GeV region ($\sim$ 1.5 GeV) it is basically the single kaon production which is dominant due to the availability of large phase space. These reactions may help to check the sensitivity of D and F couplings because $g_A(= D + F)$ is very well known, but not much information is available for the other combinations. Also one may study the Q^2 dependence of the weak form factors. We have obtained the total cross section σ and using the results for σ, the single kaon production rates are obtained corresponding to the KAOS experiment [1, 2] which is being performed at the Institut für Kernphysik in Mainz, Germany.

Formalism and discussions

The processes considered here are the charged lepton induced weak $|\Delta S| = 1$ process. The possible single kaon processes induced by electron are

$$\begin{aligned} e^- + n &\rightarrow \nu_e + K^- + n \\ e^- + p &\rightarrow \nu_e + \bar{K^0} + n \\ e^- + p &\rightarrow \nu_e + K^- + p, \end{aligned} \qquad (1)$$

and the corresponding positron induced processes are:

$$\begin{aligned} e^+ + n &\rightarrow \bar{\nu}_e + K^+ + n \\ e^+ + n &\rightarrow \bar{\nu}_e + K^0 + p \\ e^+ + p &\rightarrow \bar{\nu}_e + K^+ + p, \end{aligned} \qquad (2)$$

The expression for the differential cross section in the laboratory frame for the above processes is given by

$$\begin{aligned} d^9\sigma &= \frac{1}{4ME_e(2\pi)^5}\frac{d\vec{k}'}{(2E_\nu)}\frac{d\vec{p}\,'}{(2E'_p)}\frac{d\vec{p}_k}{(2E_k)} \\ &\times\ \delta^4(\Sigma_i p_i - \Sigma_f p_f)\bar{\Sigma}\Sigma|\mathcal{M}|^2, \end{aligned} \qquad (3)$$

where $k(k')$ is the momentum of the incoming(outgoing) lepton with energy $E(E')$, $p(p')$ is the momentum of the incoming(outgoing) nucleon with mass M. The kaon 3-momentum is $\vec{p}_k$ having energy E_k, $\bar{\Sigma}\Sigma|\mathcal{M}|^2$ is the square of the transition amplitude averaged(summed) over the spins of the initial(final) state. The transition amplitude may be written as

$$\mathcal{M} = \frac{G_F}{\sqrt{2}}\, j_\mu J^\mu = \frac{g}{2\sqrt{2}} j_\mu \frac{1}{M_W^2}\frac{g}{2\sqrt{2}} J^\mu, \qquad (4)$$

where j_μ and J^μ are the leptonic and hadronic currents respectively. The hadronic current, shown in Fig.1, are obtained from a systematic manner using the SU(3) chiral Lagrangian. We also included the lowest lying resonance Σ^* in our calculations. The details of which can be found in the Refs. [3, 4]. The cross

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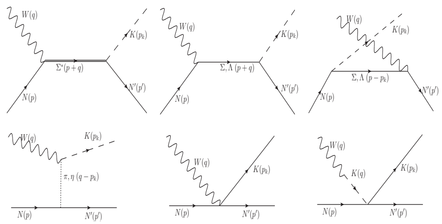

FIG. 1: Feynman diagrams for the process $e^- N \to \nu_e N' \bar{K}$ and $e^+ N \to \bar{\nu}_e N' K$.

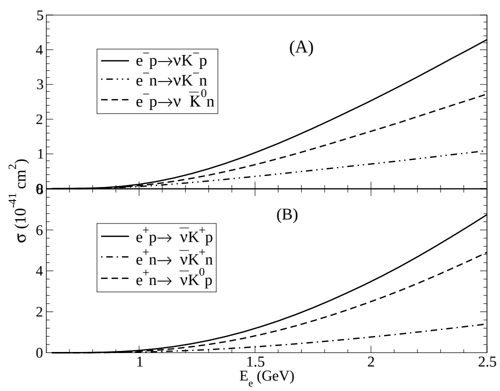

FIG. 2: Cross section σ vs Electron(Positron) energy E_e for the $\bar{K}$(K) production

section obtained after integrating over kinematic variables of Eq.3 are given in the Fig.2. We also investigated the individual terms appeared in the Fig.1. We find that the σ for the positron induced process is more than the corresponding electron induced process. This is due to the s-channel process present in the electron induced process. We also checked the individual terms appeared in the Fig.1 and found that the contact term is most dominant in both the cases. The other dominant term is the Λ propagator (in both s and u channel), the dominance of which is easily understood from the Clebsch-Gordan coefficients involved. However, the individual contribution from the resonance is not strong and contribute to the total σ only $\sim 5\%$, but the interference terms are destructive and lowers the σ.

To see in terms of the number of events for the single kaon production, we have obtained event rates for the electron induced processes. These calculations are done for the KAOS experiment [1, 2]. The events per day are presented over here for 1 gm of fiducial volume. The electron current is taken as 0.1mA. To get the event rates we first obtained the averaged cross-section on convoluting flux with the total cross-section $\bar{\sigma} = \int_{E_{\rm th}}^{E_{\rm high}} dE\ \phi(E)\ \sigma(E)$, where $\phi(E)= 0.625 \times 10^{15}$ electrons/sec corresponding to 1mA of current, $E_{\rm th}$ is the threshold energy of the reaction, $E_{\rm high}$ is the maximum energy of the electron. We have performed these calculations by taking various average electron energies which would correspond to the maximum electron energy $E_{\rm high}$ in the context of the present calculation for the event rates, $\sigma(E)$ is the total scattering cross section. For example for the process $e^- p \to K^- p \nu_e$ at 1 GeV the expected kaon events will be $\sim$ 40. However, the numbers will be reduced if we apply the cuts for the KAOS detector.

In summary, we have developed a microscopical model for single kaon production off nucleons induced by electrons/positrons. This is based on the SU(3) chiral Lagrangian. The calculations are performed upto an electron/positron energy of 2.5GeV upto which this model should be quite reliable.Using the expression of the cross section, we have obtained the events corresponding to the KAOS experiment. We think that the events are large enough to be measured at KAOS.

References

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