RESCATTERING EFFECTS AND TWO-STEP PROCESS IN KAON PHOTOPRODUCTION ON THE DEUTERON

A. SALAM\(^*\) AND K. MIYAGAWA

Simulation Science Center, Okayama University of Science, 1-1 Ridai-cho, Okayama 700-0005, Japan

H. ARENHÖVEL

Institut für Kernphysik, Universität Mainz, D-55099 Mainz, Germany

T. MART

Departemen Fisika, FMIPA, Universitas Indonesia, Depok 16424, Indonesia

C. BENNHOLD

Center for Nuclear Studies, Department of Physics, The George Washington University, Washington, D.C. 20052, USA

W. GLÖCKLE

Institut für Theoretische Physik II, Ruhr-Universität Bochum, D-44780 Bochum, Germany

Kaon photoproduction on the deuteron is investigated by considering \(YN\) and \(KN\) rescattering and the two-step process \(\gamma d \rightarrow \pi NN \rightarrow KYN\). A strong enhancement in the total cross section is found from the two-step process. \(YN\) rescattering has remarkable effects in the inclusive and exclusive cross section, while the effect of \(KN\) rescattering is much less important.

1. Introduction

Kaon photoproduction on the deuteron has been investigated by several people. Li et al.\(^1\) have extracted the elementary cross section from the deuteron target in the study of neutron channels. In a recent paper Yamashita et al.\(^2\) have investigated the process \(\gamma d \rightarrow \pi NN \rightarrow KYN\) using the isospin symmetry. The effect of \(KN\) rescattering in the inclusive cross section is found to be less important compared to \(YN\) rescattering. However, the two-step process \(\gamma d \rightarrow \pi NN \rightarrow KYN\) is found to be significant in the total cross section.

---

\(^*\)Permanent address: Departemen Fisika, FMIPA, Universitas Indonesia, Depok 16424, Indonesia.
mura et al.\textsuperscript{2} have calculated the $YN$ rescattering for the $K^+$ channels by using the Nijmegen $YN$ potential\textsuperscript{3}. They found sizeable effects in the inclusive cross sections from the $YN$ rescattering. This work is extended by considering the two-step process $\gamma d \rightarrow \pi NN \rightarrow KYN$ and the $KN$ rescattering\textsuperscript{4}. Other recent calculations also investigated the $YN$ rescattering\textsuperscript{5} and the pion mediated process in lowest order\textsuperscript{6}.

This paper presents the calculation of $K^+$ and $K^0$ photoproduction on the deuteron by considering $YN$ and $KN$ rescattering and the two-step process. The formulations are shown in Section 2, the results in Sect. 3, and the conclusions in Sect. 4.

2. Some Formulations

In the deuteron rest frame the exclusive cross section is given by

\[ \frac{d\sigma}{dp_K d\Omega_K d\hat{q}_Y} = \frac{m_{\gamma} m_N}{4(2\pi)^2 E_{\gamma} E_K W} \sum_{\mu_Y \mu_N \mu_d \lambda} \left[ \sqrt{2} \langle \Psi_{\mu_Y \mu_N} | t^{\gamma K}_\lambda | \Psi_{\mu_d} \rangle \right]^2 \]  \hspace{1cm} (1)

where $\mu_Y, \mu_N, \mu_d$, and $\lambda$ denote the spin projections of hyperon, nucleon, deuteron, and the photon polarization, respectively, $W^2 = (P_d + p_\gamma - p_K)^2$, and $\sqrt{2}$ comes from the proper antisymmetrization. The amplitude is approximated by the diagram in Figure 1.

Figure 1. Kaon photoproduction on the deuteron. Diagram (a) is impulse approximation (IA), (b) and (c) are $YN$ and $KN$ rescattering, respectively, and (d) is the two-step process ($\pi K$-process for short).

The impulse term and $YN$ rescattering (diagram (a) and (b), respectively) are calculated simultaneously as

\[ T_{IA+YN} = t^{tK} + t_{YN} G_{YN} t^{\gamma K}. \]  \hspace{1cm} (2)

By inserting the Lippmann-Schwinger equation for $t_{YN}$, we get

\[ T_{IA+YN} = (1 - V_{YN} G_{YN})^{-1} t^{tK}. \]  \hspace{1cm} (3)

After solving the last equation in the partial wave decomposition, one obtains the $YN$ rescattering amplitude by subtraction of the impulse term.
The $KN$ rescattering (diagram (c)) is evaluated directly as
\[ T_{KN} = t_{KN} G_{KN} t_{\gamma K}, \]
where we use a separable potential of rank-1 for $V_{KN}$. The $\pi K$-process (diagram (d)) is calculated in the same way as in the $KN$-rescattering.

3. Results

The results are calculated by using the elementary operator of Mart and Bennhold\cite{7} and the deuteron wave function of Bonn model\cite{8}. Fig. 2 shows the total cross section of $\gamma d \rightarrow KY N$ as function of $E_{\gamma}$. The $\pi K$-process (solid line) enhances the total cross section in all channels (dotted line). The next remarkable effect comes from $YN$ rescattering (short-dash line), while the effect of $KN$ rescattering (dash line) is negligible. Fig. 3 shows the differential cross section as function of $\theta_K$ calculated at different photon energies. $YN$ rescattering has remarkable effects at forward angles, while the $\pi K$-process at larger angles. The inclusive cross section as function of $p_K$ is shown in Fig. 4. $YN$ rescattering shows remarkable effects at the threshold and peak region, while the effect of $\pi K$-process appears at smaller kaon momenta. Some enhancement, whose origin is from the S-matrix pole of $V_{YN}$\cite{9}, is found at the $\Sigma$-threshold in the $\Lambda$-channels (indicated by arrows in the figure). Fig. 5 shows the exclusive cross section in the forward kaon
angle at photon energy 1.3 GeV as function of $\theta'_Y$ measured relative to the direction of momentum transfer $\vec{p}_\gamma - \vec{p}_K$ in the deuteron rest frame. The
Λ-channels are calculated at kaon momentum 870 MeV/c and Σ-channels at 810 MeV/c. $YN$ rescattering dominates the effect for all channels at larger $\theta'_Y$.

4. Conclusions

Kaon photoproduction on the deuteron is calculated by considering $YN$ and $KN$ rescattering and the two step process. A strong enhancement in the total cross section is found from the two-step process. $YN$ rescattering has remarkable effects in the inclusive and exclusive cross section, while the effect of $KN$ rescattering is negligible.

Acknowledgments

AS would like to thank the Simulation Science Center, Okayama University of Science, Okayama for financial support and very kind hospitality.

References

1. X. Li, L.E. Wright, and C. Bennhold, Phys. Rev. C45, 2011 (1992).
2. H. Yamamura et al., Phys. Rev. C61, 014001 (1999).
3. P.M.M. Maessen et al., Phys. Rev. C40, 2226 (1989).
4. A. Salam, Dissertation, Johannes Gutenberg Universität, Mainz, 2003.
5. B.O. Kerbikov, Phys. Atom. Nucl. 64, 1835 (2001).
6. O.V. Maxwell, *Phys. Rev.* **C69**, 034605 (2004).
7. T. Mart and C. Bennhold, *Phys. Rev.* **C61**, 012201 (2000).
8. R. Machleidt, K. Holinde, and Ch. Elster, *Phys. Rep.* **149**, 1 (1987).
9. K. Miyagawa and H. Yamamura, *Phys. Rev.* **C60**, 024003 (1999).