PROCEEDINGS OF SCIENCE

Hadronic description for Omega baryon photoproduction

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In the present work, we investigate subsequential production of three kaons and Ω^- baryon based on an effective Lagrangian approach. We only consider the intermediate states with the light mass baryon to suggest the minimum of the total cross section. Coupling constants for verteces of meson-octet baryons are fixed from the empirical data and/or quark models together with SU(3) symmetry considerations and these for meson-decouplet are predicted not only quark model but also Chiral-quark soliton model calculation. Gauge invariance of the resulting amplitude is maintained by introducing the contact currents by extending the gauge-invariant approach of Haberzettl for one-meson photoproduction to two-meson photoproduction.

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1. Introduction

Ω^- baryon (sss) was predicted by the quark model in 1962 and its existance was proved experimentally in 1964 [1]. However, since the laste 1980's, few significant progress has been made in Oemga spectroscopy because of the closing of the then existing kaon factories. In 2006, the spin property of the omega baryon was shown [2]. Recently, the CLAS Collaboration at the Thomas Jefferson National Accelerator Facility (JLab) initiated a cascade physics program; the Collaboration has established, in particular, the feasibility to do omega baryon spectroscopy via photoproduction reactions such as $\gamma p \to K^+K^+K^0\Omega^-$ [3]. A dedicated experiment for this reaction is currently underway. In the present work, we would like to suggest the extimation of the toall cross section of the omega baryon production.

2. Formalism

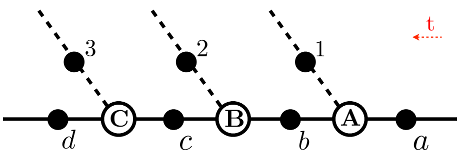

Figure 1: Sequential hadronic photoproduction mechanism of three kaons off an initial baryon.

The meson-baryon diagram we considered in the present work is shown in Figure 1. Sequential hadronic photoproduction mechanism of three kaons off an initial baryon $B_a \to M_1 + M_2 + M_3 + B_d$. Indices $x = a,b,c,d$ label the baryons B_z depicted as solid lines and $y = 1,2,3$ label the K mesons M_y shown as dashed lines. The three meson-baryon-baryon vertices F_Z are labeled by $Z = A,B,C$; the vertex F_A, for example, describes the transition $B_a \to M_1 + M_b$. Acorrding to the position of the nuetural kaon, there can be three type of diagram such that (M_1,M_2,M_3) can be (K^+,K^+,K^0), (K^+,K^0,K^+) and (K^0,K^+,K^+). Denoting the four single-baryon currents by Γ^μ_x (where $x = x,b,c,d$), the three single-meson currents by J^μ_y (where $y = 1,2,3$), and the three contact-type interaction cuttrents by M^μ_Z (where $Z = A,B,C$), the total three-meson production current resulting from this procedure has ten topologically distinct contributions,

$$\begin{aligned} M^\mu = & \underbrace{F_C t_c F_B t_b F_A t_a \Gamma^\mu_a + F_C t_c F_B t_b \Gamma^\mu_b t_b F_A + F_C t_c \Gamma^\mu_c t_c F_B t_b F_A + \Gamma^\mu_d t_d F_C t_c F_B t_b F_A}_{\text{baryon currents}} \\ & + \underbrace{F_C t_c F_B t_b J^\mu_1 \Delta_1 F_A + F_C t_c J^\mu_2 \Delta_2 F_B t_b F_A + J^\mu_3 \Delta_3 F_C t_c F_B t_b F_A}_{\text{meson currents}} \\ & + \underbrace{F_C t_c F_B t_b M^\mu_A + F_C t_c M^\mu_B t_b F_A + M^\mu_C t_c F_B t_b F_A}_{\text{interaction currents}} \end{aligned} \tag{2.1}$$

where t_x $(x = a,b,c,d)$ and Δ_x $(y = 1,2,3)$ are the baryon and meson propagators, respectively.

In addition to this meson-baryon diagram, the photon can couple to 8 positions except the neutral kaon line. Therefore we consider 24 diagrams. To suggest the minimum of the total cross section, we only consider the lighest hyperon states.

As an one example, let us consider one baryon current in the case of $(M_1, M_2, M_3) = (K^+, K^+, K^0)$. The vertex functions in this case are given by

$$F_\Xi = g_\Xi p_{3\lambda} f_\Xi(p_3^2; p_4^2, q_2^2), \tag{2.2}$$

$$t_\Xi = \frac{\not{q}_2 + m_\Xi}{q_2^2 - m_\xi^2}, \tag{2.3}$$

$$F_\Lambda = g_\Lambda \gamma_5 \not{p}_2 f_\Lambda(p_2^2; q_2^2, q_1^2), \tag{2.4}$$

$$t_\Lambda = \frac{\not{q}_2 + m_\Xi}{q_1^2 - m_\Lambda^2}, \tag{2.5}$$

$$F_p = g_p \gamma_5 \not{p}_1 f_p(p_1^2; q_1^2, q_3^2), \tag{2.6}$$

$$t_p = \frac{\not{q}_3 + m_p}{q_3^2 - m_p^2}, \tag{2.7}$$

$$\Gamma_p = \left[I + \frac{\kappa_p}{2m_p} \not{k}_1 \right] \not{\epsilon}_\gamma \tag{2.8}$$

where k_1 and k_2 are momentum of incoming photon and proton, respectively. Momenta p_1, p_2, p_3 and p_4 are the outgoing three kaons and omega baryon, respectively, while other momentum q_i and ε_γ are momentum of the intermediate hyperon and the polarization vector of the photon. In above case, the photon couples to the incoming proton.

3. Numerical result

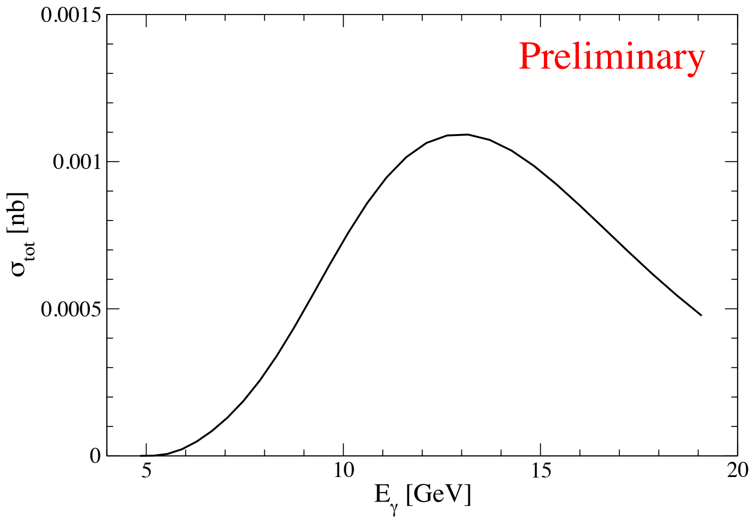

Figure 2: Total cross section as a function of the photon energy.

In Figure 2, we show the total cross section up to 20 GeV to see when the cross section starts to decrease even though effective Lagrangian approach is ambiguous at such a high energy region.

Parameters in this work are taken from Ref. [4] for baryons octet and Ref. [5] and [6] for baryon decuplet.

4. Summary and outlook

In the present talk, we reviewed a recent study of Ω baryon photoproduction off the nucleon target, i.e., $\gamma p \to K^+K^+K^0\Omega^-$. Since there is no data of the cross section for Ω^- baryon, we suggest the minimum only considering the lightest mass hyperon intermediate states. In the future, we would like to include the role of high-spin hyperon resonances cotribution in this scattering process.

References

[1] V. E. Barnes, P. L. Connolly, D. J. Crennell, B. B. Culwick, W. C. Delaney, W. B. Fowler, P. E. Hagerty and E. L. Hart *et al.*, Phys. Rev. Lett. **12**, 204 (1964).

[2] B. Aubert *et al.* [BaBar Collaboration], Phys. Rev. Lett. **97**, 112001 (2006) [hep-ex/0606039].

[3] *Photoproduction of the very strangest baryons on the proton target in CLAS12*, Spokespersons: M. Dugger, J. Goetz, L. Guo, E. Pasyuk, I.I. Strakovsky, D.P. Watts, and V. Ziegler (The Very Strange Collaboration), JLab Proposal E12–11–005a, Newport News, VA, USA, 2013.

[4] K. Nakayama, Y. Oh and H. Haberzettl, Phys. Rev. C **74**, 035205 (2006) [hep-ph/0605169].

[5] G. -S. Yang and H. -C. Kim, Few Body Syst. **54**, 325 (2013).

[6] H. C. Kim (private communication).