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Photoproduction of the Θ^+ pentaquark in Feynman and Regge theories

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Photoproduction of the Θ^+ pentaquark on the proton is analyzed by using isobar and Regge models. The difference in the calculated total cross section is found to be more than two orders of magnitude for a hadronic form-factor cutoff $\Lambda > 1$ GeV. Comparable results would be obtained for $0.6 \leqslant \Lambda \leqslant 0.8$ GeV. The contribution of the Θ^+ photoproduction to the GDH integral is also calculated. By comparing with the current phenomenological calculation, it is found that the GDH sum rule favors the result obtained from the Regge approach and isobar model with small Λ.

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The observation of a narrow baryon state from the missing mass spectrum of K^+n and K^+p with extracted mass $M = 1540$ MeV [1–5] has led to great excitement in the hadronic and particle physics communities. This state is identified as the Θ^+ pentaquark that has been previously predicted in the chiral soliton model [6]. Since then numerous investigations on Θ^+ production have been carried out. In general, these efforts can be divided into two categories: investigations using hadronic processes and those using electromagnetic processes. Electromagnetic production (also known as photon-induced production) is, however, well known as a “cleaner” process, since the electromagnetic interaction can be easily controlled. However, the photoproduction process provides an easier way to “see” the Θ^+, which contains an antiquark, since all required constituents are already present in the initial state [7]. Other processes, such as e^+e^- and $\bar{p}p$ annihilation, would produce the strangeness-antistrangeness (and baryon-antibaryon in the case of e^+e^-) from gluons, a consequence of the suppressed cross section [8].

Several Θ^+ photoproduction studies have been performed by using isobar models with the Born approximation [9–16], with resulting cross sections ranging from several nanobarns to almost one micro barn, depending on the Θ^+ width, parity, hadronic form-factor cutoff, and the exchanged particles used in the process. Those parameters are unfortunately still uncertain at present. Furthermore, the lack of information on coupling constants has severely restricted the number of exchanged particles used in the process, and additional information is needed on a number of resonances that have been shown to play important roles at W around 2 GeV and to determine the shape of cross sections of $K\Lambda$ and $K\Sigma$ photoproduction [17].

Therefore, it is important to constrain the proliferation of models by using all available information to achieve a reliable cross-section prediction, which is urgently required by present experiments. For this purpose the isobar and Regge models are exploited using all available coupling constant information. The use of the Regge model has a great advantage since the number of uncertain parameters is much less than those of the isobar model. From the experience in $K\Lambda$ and $K\Sigma$ photoproduction, the Regge model works quite well at high energies, despite its small number of parameters, and the discrepancy with experimental data at the resonance region is found to be less than 50% [18,19]. Given the high threshold energy of this process ($W \approx 2$ GeV) it is naturally imperative to consider the Regge mechanism in the calculation. As an example, a reggeized isobar model has been shown to be quite successful in explaining experimental data of η and η' photoproduction up to the photon lab energy $E_\gamma^{\rm lab} = 2$ GeV [20].

In this paper I compare the cross sections obtained from both models and investigate the effect of hadronic form-factor cutoff (Λ) variation in the isobar model. To this end, I will consider the positive parity of Θ^+, since previous calculations have found the cross section to be one tenth as large if one used the negative parity state, and so concern with overprediction of cross sections by isobar models is warranted. The primary motivation is to investigate the effect of Λ variation and compare the varied cross sections with that of the Regge model. To further support the findings, the contribution of the Θ^+ photoproduction to the Gerasimov-Drell-Hearn (GDH) integral from both models will be calculated. Since only the proton GDH integral is relatively well understood [21], only photoproduction on the proton,

$$\gamma(k) + p(p) \longrightarrow \bar{K}^0(q) + \Theta^+(p'),$$

will be calculated. In the isobar model the amplitudes are obtained from a series of tree-level Feynman diagrams, as shown in Fig. 1. They contain the p, Θ^+, K^*, and K_1 intermediate states. The neutral kaon K^0 cannot contribute to this process since a real photon cannot interact with a neutral meson. The K^* and K_1 intermediate states are considered here, since previous studies on $K\Lambda$ and $K\Sigma$ photoproduction have proven their significant roles. The transition matrix for both reactions can be decomposed into

$$M_{\rm fi} = \bar{u}(\boldsymbol{p}') \sum_{i=1}^{4} A_i M_i u(\boldsymbol{p}), \tag{1}$$

where the gauge- and Lorentz-invariant matrices M_i are given in, for example, Ref. [22]. In terms of the Mandelstam variables s, u, and t, the functions A_i are given by

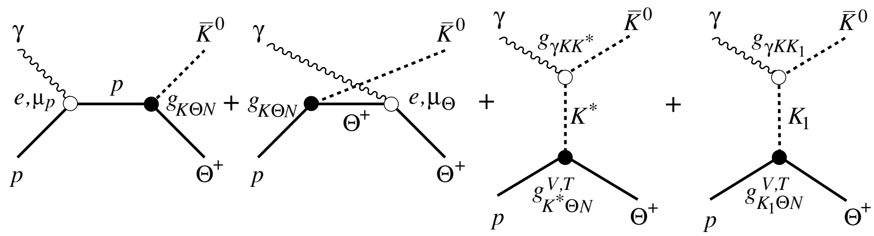

FIG. 1. Feynman diagrams for Θ^+ photoproduction on the proton: $\gamma + p \longrightarrow \bar{K}^0 + \Theta^+$.

$$A_1 = -\frac{eg_{K\Theta N}F_1(s)}{s-m_p^2}\left(1+\kappa_p\frac{m_p-m_\Theta}{2m_p}\right) - \frac{eg_{K\Theta N}F_2(u)}{u-m_\Theta^2+im_\Theta\Gamma_\Theta}\left[1+\frac{\kappa_\Theta\left(m_\Theta-m_p-\frac{i}{2}\Gamma_\Theta\right)}{2m_\Theta}\right] - \frac{G^T F_3(t)}{M\left(t-m_{K^*}^2+im_{K^*}\Gamma_{K^*}\right)(m_\Theta+m_p)}, \tag{2}$$

$$A_2 = \frac{2eg_{K\Theta N}}{t-m_K^2}\left(\frac{1}{s-m_p^2}+\frac{1}{u-m_\Theta^2}\right)\widetilde{F}(s,u,t) + \frac{G^T_{K^*}F_3(t)}{M\left(t-m_{K^*}^2+im_{K^*}\Gamma_{K^*}\right)(m_\Theta+m_p)} - \frac{G^T_{K_1}F_3(t)}{M\left(t-m_{K_1}^2+im_{K_1}\Gamma_{K_1}\right)(m_\Theta+m_p)}, \tag{3}$$

$$A_3 = \frac{eg_{K\Theta N}}{s-m_p^2}\frac{\kappa_p F_1(s)}{2m_p} - \frac{eg_{K\Theta N}}{u-m_\Theta^2}\frac{\kappa_\Theta F_2(u)}{2m_\Theta} - \frac{G^T_{K^*}F_3(t)}{M\left(t-m_{K^*}^2+im_{K^*}\Gamma_{K^*}\right)}\frac{m_\Theta-m_p}{m_\Theta+m_p} + \frac{(m_\Theta+m_p)G^V_{K_1}+(m_\Theta-m_p)G^T_{K_1}}{M\left(t-m_{K_1}^2+im_{K_1}\Gamma_{K_1}\right)}\frac{F_3(t)}{m_\Theta+m_p}, \tag{4}$$

$$A_4 = \frac{eg_{K\Theta N}}{s-m_p^2}\frac{\kappa_p F_1(s)}{2m_p} + \frac{eg_{K\Theta N}}{u-m_\Theta^2}\frac{\kappa_\Theta F_2(u)}{2m_\Theta} + \frac{G^V_{K^*}F_3(t)}{M\left(t-m_{K^*}^2+im_{K^*}\Gamma_{K^*}\right)}, \tag{5}$$

where κ_p and κ_Θ indicate the anomalous magnetic moments of the proton and Θ, respectively, and M is taken to be 1 GeV to make the coupling constants

$$G^{V,T}_{K^*(K_1)\Theta N} = g^{V,T}_{K^*(K_1)\Theta N}\, g_{K^*K\gamma} \tag{6}$$

dimensionless.

The inclusion of hadronic form factors at hadronic vertices is performed by utilizing the Haberzettl prescription [23]. The form factors in this calculation are taken as

$$F_i(q^2) = \frac{\Lambda^4}{\Lambda^4+\left(q^2-m_i^2\right)^2} \tag{7}$$

with $q^2 = s, u, t$, and where $i = p, \Theta, \bar{K}$, with Λ the corresponding cutoff. The form factor for non-gauge-invariant terms $\widetilde{F}(s,u,t)$ in Eq. (3) is chosen to satisfy crossing symmetry and to avoid a pole in the amplitude [24].

The coupling constant $g_{K\Theta N}$ is calculated from the decay width of the $\Theta^+ \to K^+n$ by using

$$\Gamma = \frac{g^2_{K^-\Theta^+n}}{4\pi}\frac{E_n-m_n}{m_\Theta}\,p, \tag{8}$$

with

$$p = \frac{\left[\left\{m_\Theta^2-(m_K+m_n)^2\right\}\left\{m_\Theta^2-(m_n-m_K)^2\right\}\right]^{1/2}}{2m_\Theta}. \tag{9}$$

The precise measurement of the decay width is still lacking because of the experimental resolution. The reported width is in the range of 6–25 MeV [1–5,25,26]. Theoretical analyses of K^+N data result in $\Gamma \leqslant 1$ MeV [27], whereas the Particle Data Group [28,29] finds $\Gamma = 0.9 \pm 0.3$ MeV. Based on this information, a width of 1 MeV is used in the calculations that follow. The isobar model is found to become insensitive to the value of $g_{K\Theta N}$ coupling constant, once the K^* and K_1 exchanges are included. Explicitly,

$$\frac{g_{K\Theta N}}{\sqrt{4\pi}} = 0.39. \tag{10}$$

The magnetic moment of Θ^+ is also not well known. A recent chiral soliton calculation [30] yields a value of $\mu_\Theta = 0.82\mu_N$, from which we obtain $\kappa_\Theta = 0.35$. As with the $g_{K\Theta N}$ coupling constant, the calculation is also insensitive to the numerical value of the Θ^+ magnetic moment, so that it is safe to use this value. Note that the Regge model does not depend on this coupling constant nor on the Θ^+ magnetic moment.

The transition moment is related to the radiative decay width by

$$\Gamma_{K^*\to K\gamma} = \frac{\alpha}{24}\left(\frac{g_{K^*K\gamma}}{M}\right)^2\left[m_{K^*}\left(1-\frac{m_K^2}{m_{K^*}^2}\right)\right]^3. \tag{11}$$

The decay width for $K^{*0}(892)$ is well known, that is [28],

$$\Gamma_{K^{*0}\to K^0\gamma} = 116 \pm 10\,\text{keV}. \tag{12}$$

Thus, we obtain $g_{K^{*0}K^0\gamma} = -1.27$, where we have used the quark model prediction of Singer and Miller [31] to constrain the relative sign.

The coupling constants $g^V_{K^*\Theta N}$ and $g^T_{K^*\Theta N}$ are also not well known. Therefore, following Refs. [14,15] one can use $g^V_{K^*\Theta N} = 1.32$ and neglect $g^T_{K^*\Theta N}$ owing to lack of information on this coupling. Combining the electromagnetic and hadronic coupling constants gives

$$\frac{G^V_{K^*\Theta N}}{4\pi} = 8.72 \times 10^{-2}. \tag{13}$$

Most previous calculations excluded the K_1 exchange, mainly because of the lack of information on the corresponding coupling constants. Reference [15] used the vector dominance relation $g_{K_1K\gamma} = eg_{K_1K\rho}/f_\rho$ to determine the electromagnetic coupling $g_{K_1K\gamma}$, where $f_\rho^2/4\pi = 2.9$ and $g_{K_1K\rho} = 12$ is taken from the effective Lagrangian calculation of Ref. [32]. As in the case of K^*, the K_1 hadronic tensor coupling will be neglected in this calculation for the same reason. Following Ref. [15], the K_1 axial vector coupling $g^V_{K_1\Theta N}$ is estimated from an isobar model for $K^+\Lambda$ photoproduction by using the extracted $G^V_{K^*\Lambda N}/G^V_{K_1\Lambda N}$ ratio. However, instead of using the result of the WJC model [33], the extracted ratio found in Ref. [17] can be exploited. There are two models given in Ref. [17], that is, a model with and a model without the missing resonance $D_{13}(1895)$, which give a ratio of -0.24 and -8.25, respectively. Incidentally, Ref. [33] gives a ratio of -8.26, that is, similar to the model without missing resonance. The calculation here will use this ratio and exclude the result from the model with missing resonance, since the latter leads to a divergence contribution to the GDH sum rule, as will be described later. In summary, the calculation uses

$$\frac{G^V_{K_1\Theta N}}{4\pi} = -7.64 \times 10^{-3}. \tag{14}$$

The cross section can be easily calculated from the functions A_i given by Eqs. (2)–(5) [34].

For the Regge model one should only use the last two diagrams in Fig. 1. Hence, the result from the Regge model will not depend on the value of $g_{K\Theta N}$ or on the Θ^+ magnetic moment. The procedure is adopted from Ref. [18]; that is, one replaces the Feynman propagator with the Regge propagator

$$P_{\rm Regge} = \frac{s^{\alpha_{K^i}(t)-1}}{\sin[\pi\alpha_{K^i}(t)]} e^{-i\pi\alpha_{K^i}(t)} \frac{\pi\alpha'_{K^i}}{\Gamma[\pi\alpha_{K^i}(t)]}, \tag{15}$$

where K^i refers to K^* and K_1, and $\alpha_{K^i}(t) = \alpha_0 + \alpha'\, t$ denotes the corresponding trajectory [18]. Note that Ref. [18] used form factors for extending the model to larger momentum transfer ("hard" process region). Here these form factors are not used since the corresponding cross sections at this region are already quite small and, therefore, will not strongly influence the result of our calculation. We also note that systematic analyses of experimental data on ρ, ω, and J/Ψ photoproduction explicitly require hadronic form factors [35].

In both models, however, one can also calculate the spin-dependent total cross sections

$$\sigma_{\rm T} = \frac{\sigma_{3/2} + \sigma_{1/2}}{2} \quad \text{and} \quad \sigma_{\rm TT'} = \frac{\sigma_{3/2} - \sigma_{1/2}}{2}, \tag{16}$$

where the latter is of special interest since it can be related to the proton anomalous magnetic moment κ_p using the GDH sum rule

$$-\frac{2\pi^2\alpha\kappa_p^2}{m_p^2} = \int_0^\infty \frac{d\nu}{\nu}[\sigma_{1/2}(\nu) - \sigma_{3/2}(\nu)] \equiv I_{\rm GDH}, \tag{17}$$

with $\nu = E_\gamma^{\rm lab}$ and where $\sigma_{1/2}$ ($\sigma_{3/2}$) represents the cross section for possible proton and photon spin combinations with a total spin of 1/2 (3/2). Thus, one can calculate the contribution of the Θ^+ photoproduction to the GDH integral

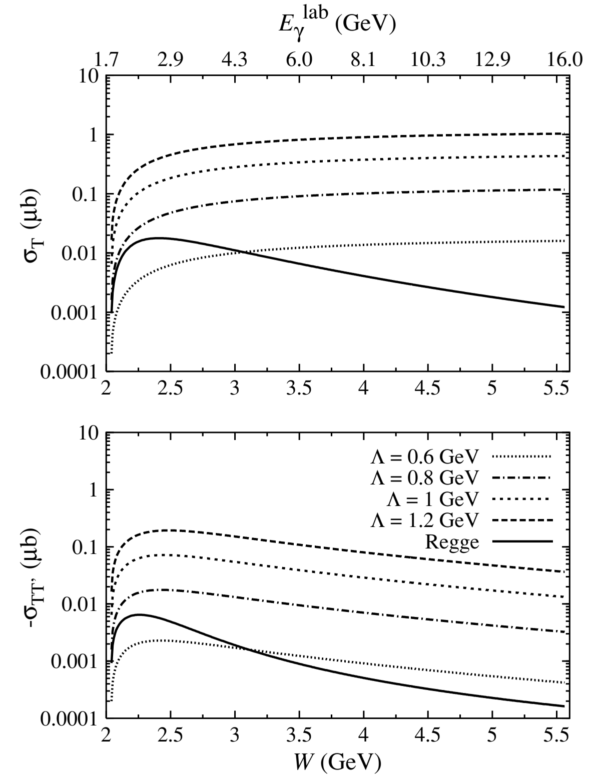

FIG. 2. Total cross sections $\sigma_{\rm T}$ and $-\sigma_{\rm TT'}$ of the isobar and Regge models. In the isobar model, variation of the total cross section for different hadronic form-factor cutoffs is shown.

$I_{\rm GDH}$ defined by Eq. (17). Note that in deriving Eq. (17) it has been assumed that the scattering amplitude goes to zero in the limit of $|\nu| \to \infty$ [36].

The result of this calculation is depicted in Fig. 2, where the total cross section obtained from the isobar model with different hadronic cutoffs and that from the Regge model are compared. Obviously, the hadronic cutoff strongly controls the magnitude of the cross section in the isobar model. By varying Λ from 0.6 to 1.2, both total cross sections increase by two orders of magnitude, whereas their shapes remain stable and tend to saturate at high energies. In the Regge model, both $\sigma_{\rm T}$ and $-\sigma_{\rm TT'}$ steeply rise to maximum at W around 2.2 GeV and monotonically decrease after that. Regge cross sections are clearly more convergent than isobar ones. From threshold up to $W = 3$ GeV, the cross-section magnitude of the Regge model falls between the results obtained from the isobar model with $\Lambda = 0.6$ and 0.8 GeV. Starting from $W = 3$ GeV, the magnitude becomes smaller than the result from the isobar model with $\Lambda = 0.6$ GeV. Thus, future calculation should consider the hadronic cutoff in the range of 0.6–0.8 GeV.

The contribution from the pentaquark photoproduction to the GDH integral is shown in Fig. 3, where the result from isobar and Regge models is compared as in Fig. 2. Clearly, the contribution is positive and small [note that direct calculation of the left-hand side of Eq. (17) gives -205μb]. Nevertheless, the positive contribution to $I_{\rm GDH}$ invites an interesting discussion if we consider the current knowledge of the GDH individual contribution on the proton. By summing up contributions from $\pi, \eta, \pi\pi$, and K photoproduction,

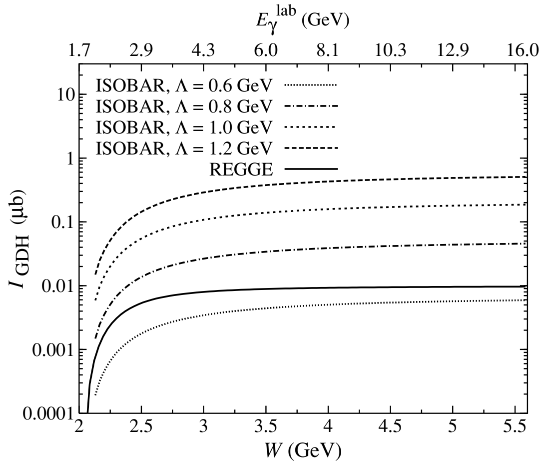

FIG. 3. Contribution of the Θ^+ photoproduction to the GDH integral of the proton for isobar (with different hadronic form-factor cutoffs) and Regge models.

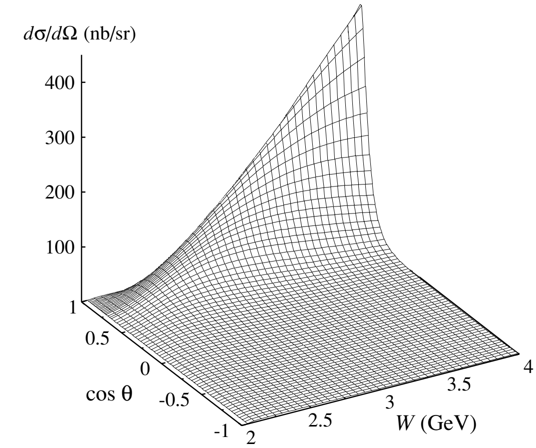

FIG. 4. Differential cross section for Θ^+ photoproduction on the proton as functions of $\cos\theta$ and W from the isobar model obtained with $\Lambda = 1$ GeV. The same pattern, but with a magnitude 20 times smaller, would be obtained if one used $\Lambda = 0.6$ GeV.

including the contribution from the higher energy part, Ref. [21] found $I_{\rm GDH} = -202\,\mu$b. Recent calculations of vector meson (ω, ρ^0, and ρ^+) contributions [16] indicate that their total contribution is also small ($+0.26\,\mu$b). From this point of view, a negative (or positive but small) contribution is more likely. In other words, the prediction from the Regge model is more desired than those of the isobar model with $\Lambda \geqslant 0.8$ GeV.

As previously mentioned, the isobar model that includes the missing resonance [17] yields a ratio of $G^V_{K^*\Lambda N}/G^V_{K_1\Lambda N} = -0.24$. Using this ratio, the predicted $-\sigma_{\rm TT'}$ flips to negative values at W around 3 GeV and starts to diverge from that point. This behavior merely emphasizes that certain mechanisms (such as resonance exchange) are missing in the process. Therefore, the calculation here does not use this ratio.

A recent isobar calculation for $K^+\Lambda$ photoproduction [37] claimed that a soft hadronic form factor (small Λ) is not desired by field theory. A harder form factor is achieved by including some u-channel resonances in the model. However, the authors do not build an explicit relation of this statement with the field theory. At tree level the extracted coupling constants are assumed to effectively absorb some important ingredients in the process, such as rescattering terms and higher order corrections, which are clearly beyond the scope of an isobar model. Therefore, the constants cannot be separated from the form factors. Together, they define the effective coupling constants. Hence, it is hard to say whether at tree level an isobar model should simultaneously produce SU(3) coupling constants and large cutoffs, that is, weak suppression on the divergent Born terms. A careful examination of the u-channel resonance coupling constants reveals relatively large corresponding error bars, which indicates that the inclusion of these resonances is trivial [38].

The predicted differential cross sections are shown in Figs. 4 and 5. The result shown in Fig. 4 is obtained by using $\Lambda = 1$ GeV. By varying the Λ value, only the magnitude of the cross section changes, whereas its shape with respect to W and $\cos\theta$ remains stable. Thus, the difference between isobar and Regge models is quite apparent in these figures. The isobar model limits measurements only at $0 \leqslant \cos\theta \leqslant 0.5$, whereas the Regge model allows for a complete angular distribution of differential cross section at energies between threshold and 2.5 GeV. At smaller $\cos\theta$ the cross section increases with W and becomes constant for $W > 3.5$ GeV, in contrast to the prediction from the isobar model, in which the cross section sharply increases as a function of W. Future experimental measurements at JLab, SPRING-8, or ELSA will certainly be able to settle this problem.

In conclusion, Θ^+ photoproduction has been simultaneously investigated by using isobar and Regge models. A comparable result is achieved if one uses a hadronic cutoff between 0.6 and 0.8 GeV. This result indicates that previous calculations that used a harder hadronic form factor are probably overestimates. By calculating the contribution to the GDH integral it is found that the Regge model and isobar model with $\Lambda \leqslant 0.6$ GeV are favorable.

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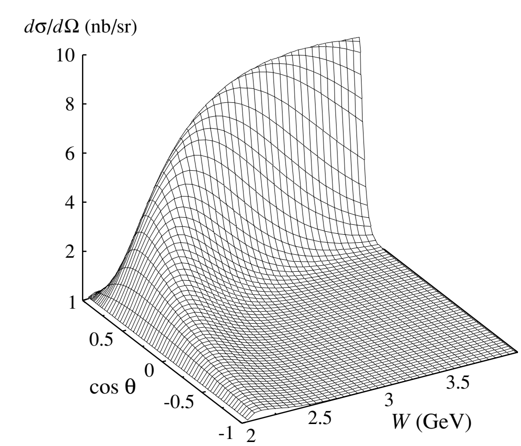

FIG. 5. Differential cross section for Θ^+ photoproduction on the proton as functions of $\cos\theta$ and W from the Regge model.

[1] T. Nakano *et al*., Phys. Rev. Lett. **91**, 012002 (2003).
[2] J. Barth *et al*., Phys. Lett. **B572**, 127 (2003).
[3] S. Stepanyan *et al*., Phys. Rev. Lett. **91**, 252001 (2003); V. Kubarovsky *et al*., *ibid*. **92**, 032001 (2004).
[4] V. V. Barmin *et al*., Phys. At. Nucl. **66**, 1715 (2003).
[5] A. Airapetian *et al*., Phys. Lett. **B585**, 213 (2004).
[6] D. Diakonov, V. Petrov, and M. Polyakov, Z. Phys. A **359**, 305 (1997).
[7] M. Karliner and H. J. Lipkin, Phys. Lett. **B597**, 309 (2004).
[8] A. I. Titov, A. Hosaka, S. Date, and Y. Ohashi, Phys. Rev. C **70**, 042202(R) (2004).
[9] Y. Oh, H. C. Kim, and S. H. Lee, Phys. Rev. D **69**, 014009 (2004).
[10] S. I. Nam, A. Hosaka, and H.-Ch. Kim, Phys. Lett. **B579**, 43 (2004).
[11] Y. R. Liu, P. Z. Huang, W. Z. Deng, X. L. Chen, and S. L. Zhu, Phys. Rev. C **69**, 035205 (2004).
[12] W. W. Li *et al*., High Energy Phys. Nucl. Phys. **28**, 918 (2004).
[13] P. Ko, J. Lee, T. Lee, and J. H. Park, hep-ph/0312147.
[14] W. Liu, C. M. Ko, and V. Kubarovsky, Phys. Rev. C **69**, 025202 (2004).
[15] B. G. Yu, T. K. Choi, and C.-R. Ji, Phys. Rev. C **70**, 045205 (2004).
[16] Qiang Zhao, J. S. Al-Khalili, and C. Bennhold, Phys. Rev. C **65**, 032201(R) (2002).
[17] T. Mart and C. Bennhold, Phys. Rev. C **61**, 012201(R) (2000); Kaon-Maid, http://www.kph.uni-mainz.de/MAID/kaon/kaonmaid.html.
[18] M. Guidal, J. M. Laget, and M. Vanderhaeghen, Nucl. Phys. **A627**, 645 (1997).
[19] T. Mart and T. Wijaya, Acta Phys. Pol. B **34**, 2651 (2003).
[20] W. T. Chiang, S. N. Yang, L. Tiator, M. Vanderhaeghen, and D. Drechsel, Phys. Rev. C **68**, 045202 (2003).
[21] D. Drechsel, S. S. Kamalov, and L. Tiator, Phys. Rev. D **63**, 114010 (2001).
[22] F. X. Lee, T. Mart, C. Bennhold, and L. E. Wright, Nucl. Phys. **A695**, 237 (2001).
[23] H. Haberzettl, C. Bennhold, T. Mart, and T. Feuster, Phys. Rev. C **58**, R40 (1998).
[24] R. M. Davidson and R. Workman, Phys. Rev. C **63**, 025210 (2001).
[25] A. Aleev *et al*., hep-ex/0401024.
[26] S. Nussinov, hep-ph/0307357.
[27] R. A. Arndt, I. I. Strakovsky, and R. L. Workman, nucl-th/0311030; W. R. Gibbs, Phys. Rev. C **70**, 045208 (2004); A. Sibirtsev, J. Haidenbauer, S. Krewald, and U.-G. Meissner, Phys. Lett. **B599**, 230 (2004).
[28] Particle Data Group: S. Eidelman *et al*., Phys. Lett. **B592**, 1 (2004).
[29] R. N. Cahn and G. H. Trilling, Phys. Rev. D **69**, 011501 (2004).
[30] H.-C. Kim, Phys. Lett. **B585**, 99 (2004).
[31] P. Singer and G. A. Miller, Phys. Rev. D **33**, 141 (1986).
[32] K. Haglin, Phys. Rev. C **50**, 1688 (1994).
[33] R. A. Williams, C.-R. Ji, and S. R. Cotanch, Phys. Rev. C **46**, 1617 (1992).
[34] B. B. Deo and A. K. Bisoi, Phys. Rev. D **9**, 288 (1974); G. Knöchlein, D. Drechsel, and L. Tiator, Z. Phys. A **352**, 327 (1995).
[35] A. Donnachie and P. V. Landshoff, Phys. Lett. **B478**, 146 (2000); A. Sibirtsev, K. Tsushima, and S. Krewald, Phys. Rev. C **67**, 055201 (2003); A. Sibirtsev, S. Krewald, and A. W. Thomas, J. Phys. G **30**, 1427 (2004).
[36] S. D. Bass, Z. Phys. A **355**, 77 (1996).
[37] S. Janssen, J. Ryckebusch, D. Debruyne, and T. Van Cauteren, Phys. Rev. C **65**, 015201 (2002).
[38] P. Bydzovsky (private communication).