BLED WORKSHOPS
IN PHYSICS
VOL. 16, NO. 1
p. 81

Proceedings of the Mini-Workshop
Exploring Hadron Resonances
Bled, Slovenia, July 5 - 11, 2015

Eta and kaon production in a chiral quark model

B. Golli

Faculty of Education, University of Ljubljana, 1000 Ljubljana, Slovenia and Jožef Stefan Institute, 1000 Ljubljana, Slovenia

Abstract. We apply a coupled channel formalism incorporating quasi-bound quark-model states to calculate the pion- and photo-production amplitudes of η mesons and kaons. The meson-baryon and photon-baryon vertices are determined in the Cloudy Bag Model. Our model predicts sizable amplitudes in the P13, P33 and S11 partial waves in agreement with the recent partial-wave analyses of the MAID and the Bonn-Gatchina groups.

1 The model

This work is a continuation of a joint project on the description of baryon resonances by the Coimbra group (Manuel Fiolhais and Pedro Alberto) and the Ljubljana group (Simon Širca and B. G.) [1–8]. In the present work we extend our method which incorporates excited baryons represented as quasi-bound quark-model states into a coupled channel formalism using the K-matrix approach to calculate the scattering and photo-production amplitudes of strange mesons.

In our approach the T matrix for inelastic meson scattering is obtained by solving the Heitler's equation

$$T_{MB\,M'B'} = K_{MB\,M'B'} + i \sum_{M''B''} T_{MB\,M''B''} K_{M''B''\,M'B'} \,, \tag{1}$$

and similarly for the process $\gamma N \to MB$:

$$T_{MB\,\gamma N} = K_{MB\,\gamma N} + i \sum_{M'B'} T_{MB\,M'B'} K_{M'B'\,\gamma N} \,. \tag{2}$$

The K-matrix is split in the resonant and the background contribution

$$K_{M'B'\,MB} = -\sum_{\mathcal{R}} \frac{\mathcal{V}^{M}_{B\mathcal{R}} \mathcal{V}^{M'}_{B'\mathcal{R}}}{Z_{\mathcal{R}}(W)(W - W_{\mathcal{R}})} + K^{\mathrm{bkg}}_{M'B'\,MB} \,; \tag{3}$$

in the case of photoproduction, the meson-baryon vertex is replaced by the corresponding electro-magnetic vertex $\mathcal{V}^{\gamma}_{B\mathcal{R}}$.

The vertices are calculated in a version of the Cloudy Bag Model extended to the pseudo-scalar SU(3) meson octet [9] and the ρ meson:

$$H_{\mathrm{int}} = -\int d\mathbf{r} \left[\frac{i}{2f}\, \overline{q} \lambda_a (\gamma_5 \phi_a + \boldsymbol{\gamma} \cdot \mathbf{A}_a) q \; \delta_S + \frac{1}{4f^2}\, \overline{q} \lambda_a \gamma^{\mu} q (\phi \times \partial_{\mu} \phi)_a \theta_V \right] , \quad a = 1, 2, \ldots, 8 \,. \tag{4}$$

The model provides a consistent parameterization of the baryon-meson and baryon-photon coupling constants and form factors in terms of f (equivalent to f_π) and the bag radius $R_{\rm bag}$. We use the following values $R_{\rm bag} = 0.83$ fm and $f = 76$ MeV (consistent with the ground state calculations), while f for η and K can be increased in accordance with the phenomenological relations $f_K = 1.2\, f_\pi$, $f_\eta = 1.2\, f_\pi$. In addition, the bare masses of the resonances are also free parameters.

2 Pion scattering into the ηN, KΛ and KΣ channels

The ηN, KΛ and KΣ channels contribute significantly in the P11, P13 and S11 partial waves and less in the D13 partial wave; we have not included the latter partial wave in the present contribution. The KΣ channel is dominated by the S11, P13 and P33 partial waves; its contribution in the P31, S31 and D33 waves turns out to be less important.

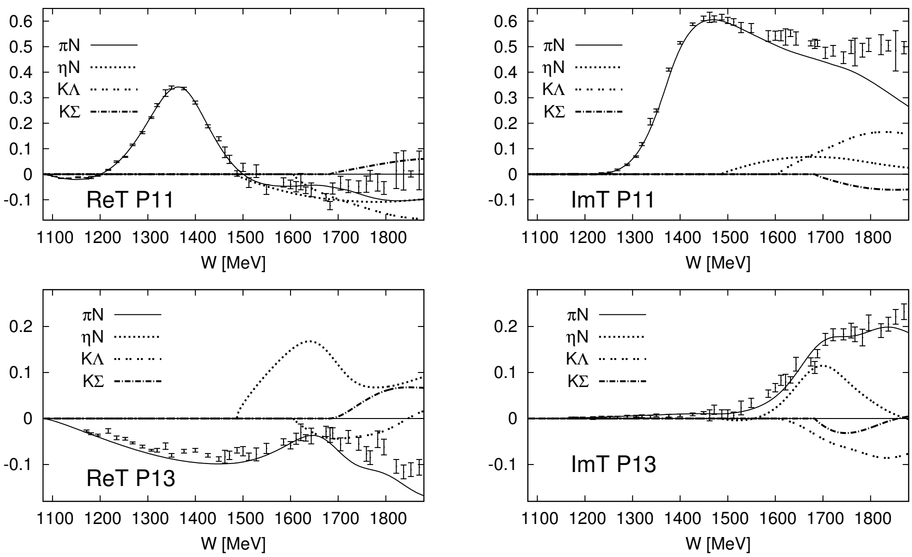

Fig. 1. The real and the imaginary part of the scattering T matrix for the elastic and the ηN, KΛ and KΣ channels. The data points are from the SAID partial-wave analysis [14].

Fig. 1 shows the results for positive parity $I = \frac{1}{2}$ partial waves. The P13 partial wave has not been considered in our previous calculations. In the present calculation we have included both resonances, the N(1720) and the N(1900), assuming one quark is excited to the d-state. The spin 1/2 (3/2) configuration turns out to dominate the lower (upper) resonance; the mixing angle of 10° provides the best agreement with experiment. Furthermore, in order to reproduce the experimental behaviour of ReT it has been necessary to include the second (volume) term in (4). Here a value of f closer to 93 MeV yields a better agreement with experiment. This term turns out to be important also in the P31 partial wave but is less significant in other partial waves discussed here.

In the P33 partial wave (see Fig. 2) η production in the ηΔ channel turns out to be almost negligible, but the KΣ channel yields rather important contribution which is also reflected in the photoproduction amplitudes, discussed in the following.

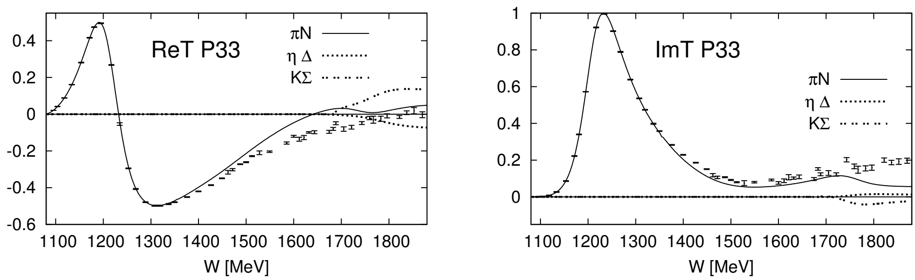

Fig. 2. The T matrix for the elastic and the ηΔ and KΣ P33 channels. Notation as in Fig. 1.

The important contribution of the ηN and KΛ channels in the S11 partial wave has already been discussed in our previous paper [7]. In the present approach we have not assumed a fixed mixing angle ($\vartheta \approx 30^\circ$) between the spin $\frac{1}{2}$ and $\frac{3}{2}$ three-quark configuration but have rather generated the configuration mixing through pion and kaon loops. This improves the behaviour of the T matrix at lower W but somewhat weakens the photoproduction amplitudes.

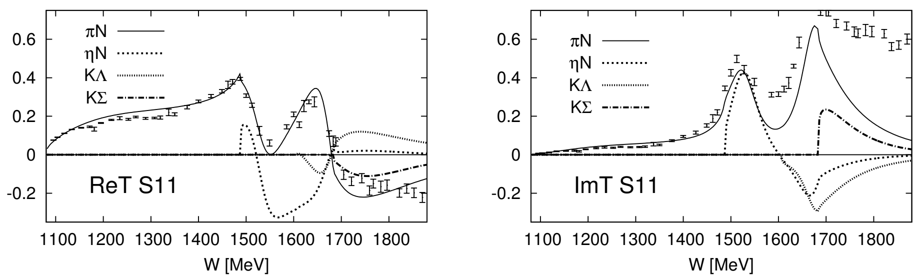

Fig. 3. The T matrix in the S11 partial wave. Notation as in Fig. 1.

3 Photoproduction of η mesons on the proton

Our model predicts that the N(1535) S11 resonance dominates η production, in accordance with the most recent MAID analysis [11] and the two analyses of the Bonn-Gatchina group [13] (disregarding the overall sign) (see Fig. 4).

In the P11 partial wave the η photoproduction amplitude is small; in addition, the contribution from the Roper resonance is almost negligible. On the other hand, the resonant contribution from the two resonances in the P13 partial wave dominates the M_{1+} and E_{1+} photoproduction amplitudes (see Fig. 5). While the

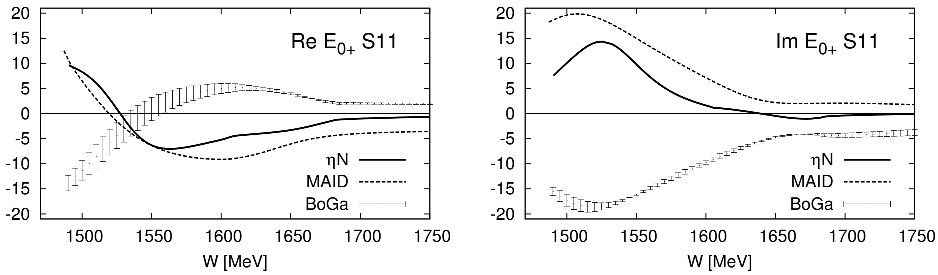

Fig. 4. The E_{0+} photoproduction amplitude (in units mfm^{-1}) compared to the recent MAID analysis [11] and the BG2014-01 and BG2014-02 solutions of the Bonn-Gatchina group [13].

M_{1+} amplitude remains close to the values obtained in the recent MAID and the Bonn-Gatchina analyses, the value of the E_{1+} multipole seems to give a too strong value in the region of the lower N(1720) resonance – but is in agreement with our result for the $\pi N \to \eta N$ channel.

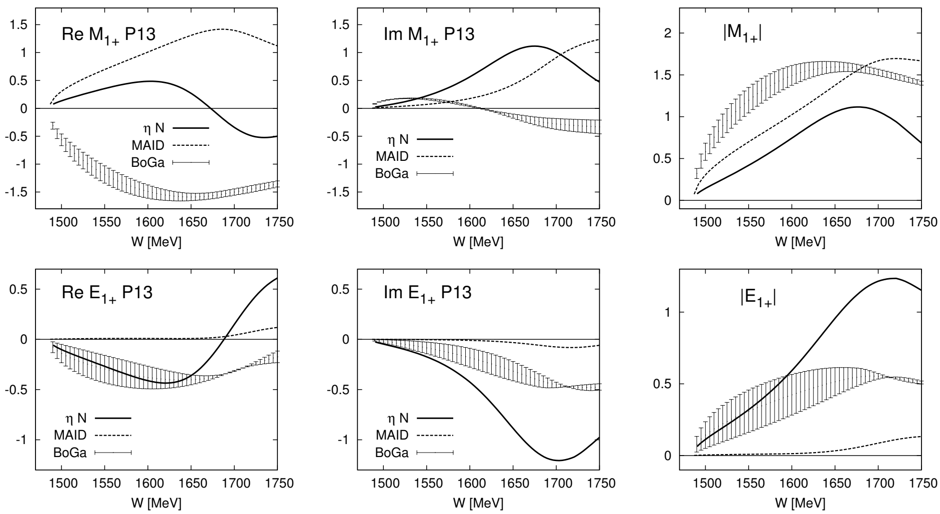

Fig. 5. As Fig. 4 for the M_{1+} and E_{1+} multipoles.

4 $K^+\Lambda$ photoproduction

The situation is similar to η production; the dominant contribution is the E_{0+} and arises through the excitation of the S11 resonances (see Fig. 6). The contribution of the P11 resonances is negligible. The strengths of the E_{1+} and M_{1+} multipoles in the P13 partial wave are almost equal, in agreement with the multipole analyses (see Fig. 7).

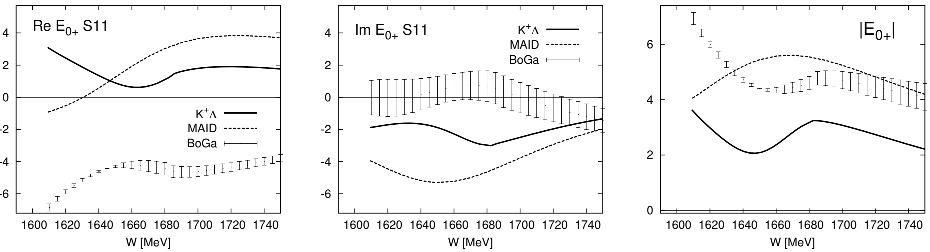

Fig. 6. The E_{0+} amplitude for the $K^+\Lambda$ channel. Notation as in Fig. 4; KAON-MAID taken from [12].

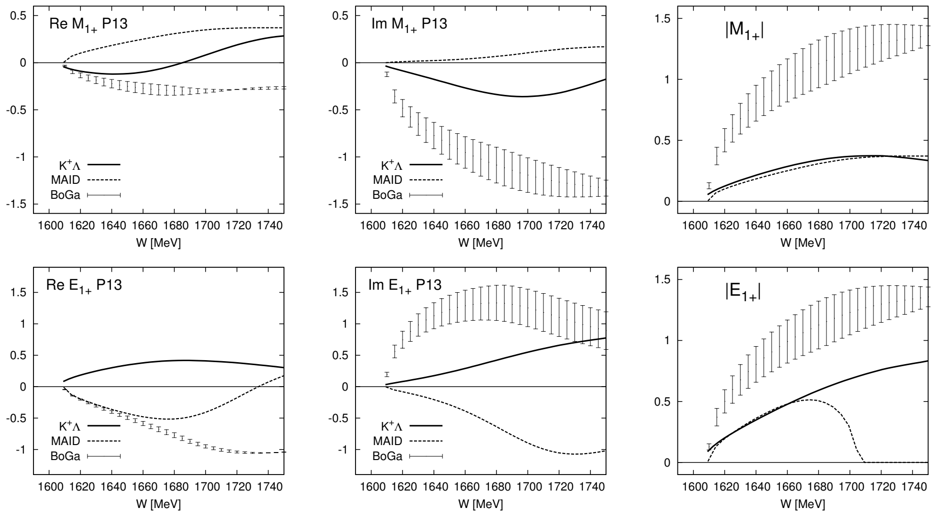

Fig. 7. As in Fig. 6 for the M_{1+} and E_{1+} multipoles.

5 $K\Sigma$ photoproduction

We present only the results for the $K^0\Sigma^+$ channel since the background contribution here is considerably smaller than in the $K^+\Sigma^-$ channel in which the behaviour close to the threshold is governed by the kaon pole term absent in the former channel. The $K^0\Sigma^+$ amplitudes consist of the isospin singlet and isospin triplet part, i.e. $A(\gamma + p \to K^0\Sigma^+) = \sqrt{2}\,A_p^{(1/2)} - \frac{1}{3}\,A^{(3/2)}$.

The E_{0+} multipole is dominated by the S11 resonances (see Fig. 8) while the contribution from the S31 resonance is negligible. The experimental situation here is rather unclear since even the two recent analyses of the Bonn-Gatchina group considerably differ from each other. Nontheless, the strength predicted by our model is in agreement with the multipole analysis.

The M_{1+} amplitude (see Fig. 9) is well described by the $\Delta(1600)$ resonance and the tail of the dominating $\Delta(1232)$ resonance. Let us notice that the same resonant mechanism governs the $K^+\Sigma^0$ channel (the P33 resonant contribution is a factor of -2 larger than the one shown in Fig. 9). The contribution from the P13 resonances is small. The situation is reversed in the case of the E_{1+} multipole;

there is no quark contribution in the P33 partial wave (similarly as in the πN channel), the main contribution arises from the quark s to d transition in the two P13 resonances.

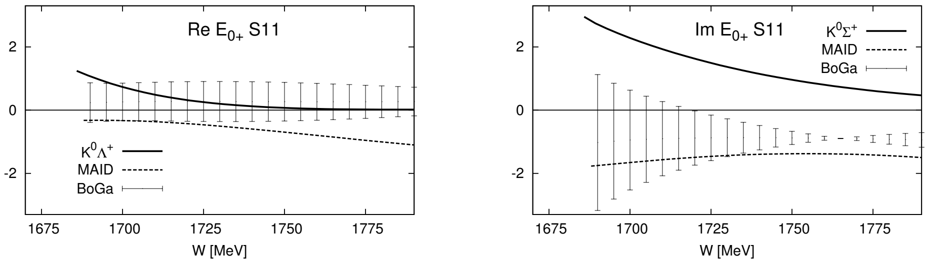

Fig. 8. The E_{0+} photoproduction amplitude for the $K^0\Sigma^+$ channel. Notation as in Fig. 6.

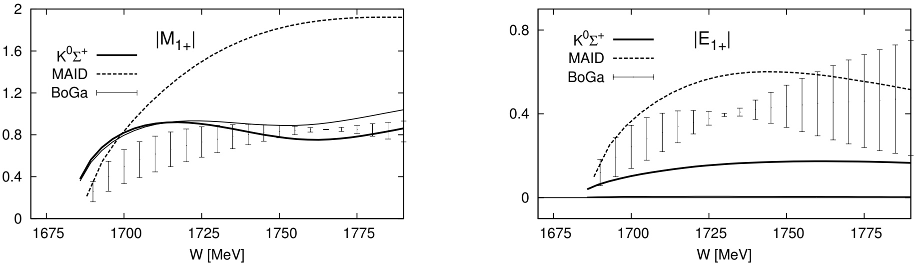

Fig. 9. The absolute values of the photoproduction amplitude for $\gamma N \to K^0\Sigma^+$. The thin solid line is the P33 contribution. Notation as in Fig. 6.

Acknowledgment. We would like to thank Lotar Tiator for sending us the preliminary results of the etaMAID analysis; see also the contribution of Jugoslav Stahov to these Proceedings.

References

1. M. Fiolhais, B. Golli, S. Širca, Phys. Lett. B **373**, 229 (1996).
2. P. Alberto, M. Fiolhais, B. Golli, and J. Marques, Phys. Lett. B **523**, 273 (2001).
3. B. Golli, S. Sirca, L. Amoreira, M. Fiolhais Phys.Lett. B553, 51-60 (2003).
4. P. Alberto, L. Amoreira, M. Fiolhais, B. Golli, and S. Širca, Eur. Phys. J. A **26**, 99 (2005).
5. B. Golli and S. Širca, Eur. Phys. J. A **38**, 271 (2008).
6. B. Golli, S. Širca, and M. Fiolhais, Eur. Phys. J. A **42**, 185 (2009).
7. B. Golli, S. Širca, Eur. Phys. J. A **47**, 61 (2011).
8. B. Golli, S. Širca, Eur. Phys. J. A **49**, 111 (2013).
9. E. A. Veit, B. K. Jennings, A. W. Thomas, R. C. Barret, Phys. Rev. D **31**, 1033 (1985).
10. D. Drechsel, S.S. Kamalov, L. Tiator, Eur. Phys. J. A **34**, 69 (2007).
11. J. Stahov et al., contribution to these Proceedings.
12. (Kaon MAID Partial Wave Analysis) http://www.kph.uni-mainz.de/MAID/kaon/
13. (Bonn Gatchina Partial Wave Analysis) http://pwa.hiskp.uni-bonn.de/
14. (SAID Partial Wave Analysis) http://gwdac.phys.gwu.edu/

Popolni eksperimenti pri fotoprodukciji psevdoskalarnih mezonov

Yannick Wunderlich

Helmholtz-Institut fuer Strahlen- und Kernphysik, Universitaet Bonn, Nussallee 14-16, 53115 Bonn, Germany

Predstavim problem, kako enolično izvrednotiti amplitude za fotoprodukcijo iz tako imenovanih popolnih eksperimentov. Pri tem smo lahko pozorni na določanje amplitude za celotno tvorbo ali pa na določanje multipolov. Na kratko obravnavam oba primera. Podrobneje opišem preliminarne rezultate prilagajanja multipolov kakor tudi določanja njihovih napak pri nedavnih meritvah polarizacije v področju resonance Δ.

Novi spektroskopski rezultati iz laboratorija Belle

Marko Bračko

Univerza v Mariboru, Smetanova ulica 17, SI-2000 Maribor, in Institut J. Stefan, Jamova cesta 39, SI-1000 Ljubljana

V prispevku predstavimo izbrane rezultate spektroskopskih meritev, opravljenih na izmerjenih podatkih, pridobljenih z detektorjem Belle, ki je stal ob trkalniku KEKB v laboratoriju KEK v Cukubi, na Japonskem. Trkalnik je obratoval med letoma 1999 in 2010, v tem času pa je s stabilnim delovanjem pri trkih elektronov in pozitronov različnih energij postal prava "tovarna" parov mezonov B, mezonov D in še leptonov tau. Ogromne količine kakovostnih podatkov so omogočile tudi številne spektroskopske meritve. Izbor tukaj predstavljenih rezultatov ustreza zanimanju in razpravam na delavnici.

Produkcija mezonov eta in kaonov v kiralnem kvarkovem modelu

Bojan Golli

Pedagoška fakulteta, Univerza v Ljubljani in Institut J. Stefan, Ljubljana, Slovenija

Formalizem sklopljenih kanalov, ki vključuje kvazi vezana večkvarkovska stanja, uporabimo za izračun sipalnih in fotoprodukcijskih amplitud mezonov eta in kaonov. Sklopitvene konstante in oblikovne faktorje določimo v modelu oblačne vreče. Model napove znatne amplitude v parcialnih valovih P13, P33 in S11, v skladu z najnovejšimi analizami parcialnih valov skupine iz Mainza in skupine iz Bonna in Peterburga.