



η and η' photoproduction with EtaMAID including Regge phenomenology*

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Abstract. We present a new version of the EtaMAID model for η and η' photoproduction on nucleons. The model includes 23 nucleon resonances parameterized with Breit-Wigner shapes. The background is described by vector and axial-vector meson exchanges in the t channel using the Regge cut phenomenology. Parameters of the resonances were obtained from a fit to available experimental data for η and η' photoproduction on protons and neutrons. The nature of the most interesting observations in the data is discussed.

EtaMAID is an isobar model [1, 2] for η and η' photo- and electroproduction on nucleons. The model includes a non-resonant background, which consists of nucleon Born terms in the s and u channels and the vector meson exchange in the t channel, and s -channel resonance excitations, parameterized by Breit-Wigner functions with energy dependent widths. The EtaMAID-2003 version describes the experimental data available in 2002 reasonably well, but fails to reproduce the newer polarization data obtained in Mainz [3]. During the last two years the EtaMAID model was updated [4–6] to describe the new data for η and η' photoproduction on the proton. The presented EtaMAID version includes also η and η' photoproduction on the neutron.

At high energies, $W > 3$ GeV, Regge cut phenomenology was applied. The models include t -channel exchanges of vector (ρ and ω) and axial vector (b_1 and h_1) mesons as Regge trajectories. In addition to the Regge trajectories, also Regge cuts from rescattering $\rho\mathbb{P}$, ρf_2 and $\omega\mathbb{P}$, ωf_2 were added, where \mathbb{P} is the Pomeron with quantum numbers of the vacuum $0^+(0^{++})$ and f_2 is a tensor meson with quantum numbers $0^+(2^{++})$. The obtained solution describes the data up to $E_\gamma = 8$ GeV very well. For more details see Ref. [7]. Energies below $W = 2.5$ GeV are dominated by nucleon resonances in the s channel. All known resonances with an overall rating of two stars and more were included in the fit. To avoid double counting from s and t channels in the resonance region, low partial waves with L up to 4 were subtracted from the t -channel Regge contribution.

The most interesting fit results are presented in Figs. 1-5 together with corresponding experimental data.

In Fig. 1, the total $\gamma p \rightarrow \eta p$ cross section is shown. A key role in the description of the investigated reactions is played by three s -wave resonances $N(1535)1/2^-$,

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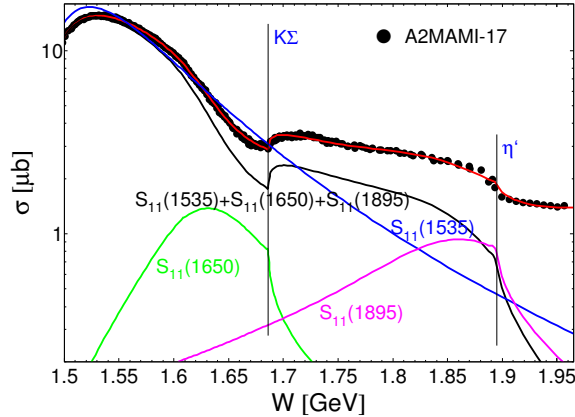


Fig. 1. (Color online) Total cross section of the $\gamma p \rightarrow \eta p$ reaction with partial contributions of the main nucleon resonances. Red line: New EtaMAID solution. Vertical lines correspond to thresholds of $K\Sigma$ and $\eta' N$ photoproduction. Data: A2MAMI-17 [6].

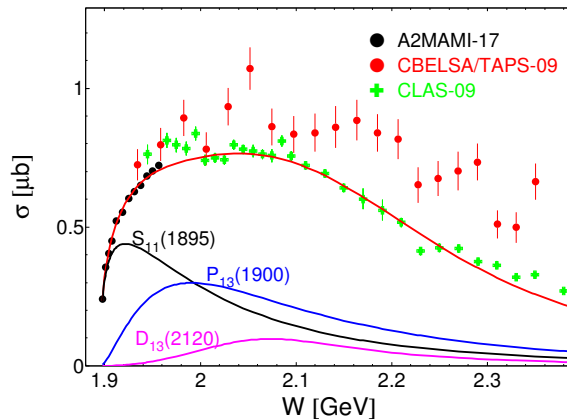


Fig. 2. (Color online) Total cross section of the $\gamma p \rightarrow \eta' p$ reaction with partial contributions of the main nucleon resonances. Red line: New EtaMAID solution. Data: A2MAMI-17 [6], CBELSA/TAPS-09 [9], and CLAS-09 [10].

$N(1650)1/2^-$, and $N(1895)1/2^-$, see partial contributions of these resonances in Fig. 1. The first two give the main contribution to the total cross section and are known very well. An interference of these two resonances is mainly responsible for the dip at $W = 1.68$ GeV. However, the narrowness of this dip we explain as a threshold effect due to the opening of the $K\Sigma$ decay channel of the $N(1650)1/2^-$ resonance. The third one, $N(1895)1/2^-$, has only a 2-star overall status according to the PDG review [10]. But we have found that namely this resonance is responsible for the cusp effect at $W = 1.96$ GeV (see magenta line in Fig. 1) and provides a fast increase of the total cross section in the $\gamma p \rightarrow \eta' p$ reaction near threshold (see black line in Fig. 2). A good agreement with the experimental data was

obtained for the cross sections of the $\gamma p \rightarrow \eta' p$ reaction, Fig. 2. The main contributions to this reaction come from $N(1895)1/2^-$, $N(1900)3/2^+$, and $N(2130)3/2^-$ resonances.

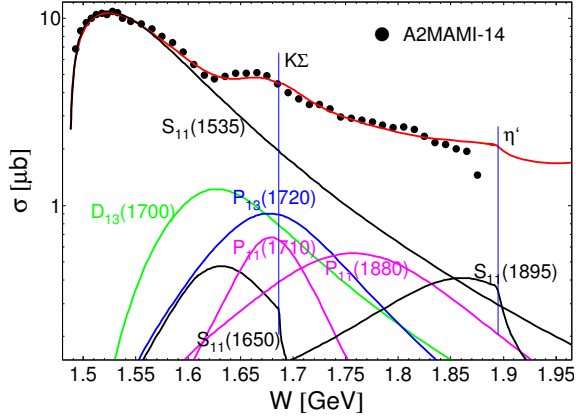


Fig. 3. (Color online) Total cross section of the $\gamma n \rightarrow \eta n$ reaction with partial contributions of the main nucleon resonances. Red line: New EtaMAID solution. Data: A2MAMI-14 [11].

Very interesting results were obtained during the last few years for the $\gamma n \rightarrow \eta n$ reaction. The excitation function for this reaction shows an unexpected narrow structure at $W \sim 1.68$ GeV, which is not observed in $\gamma p \rightarrow \eta p$. As an example, the total cross section measured with highest statistics in Mainz [11] is shown in Fig. 3. The nature of the narrow structure has been explained by different authors as a new exotic nucleon resonance, or a contribution of intermediate strangeness loops, or interference effects of known nucleon resonances, see Ref. [12]. In our analyses, the narrow structure is explained as the interference of s , p , and d waves, see partial contributions of the resonances in Fig. 3. Our full solution, red line in Fig. 3, describes the data up to $W \sim 1.85$ GeV reasonably well and shows a cusp-like structure at $W = 1.896$ GeV similar as in Fig. 2 for the $\gamma p \rightarrow \eta p$ reaction. However, the data demonstrate a cusp-like effect at the energy of ~ 50 MeV below. This remains an open question for our analyses as well as for the final state effects in the data analysis.

Recently, the CLAS collaboration reported a measurement of the beam asymmetry Σ for both $\gamma p \rightarrow \eta p$ and $\gamma p \rightarrow \eta' p$ reactions [13]. At high energies, $W > 2$ GeV, the $\gamma p \rightarrow \eta p$ data have maximal Σ asymmetry at forward and backward directions, see Fig. 4. We have found that an interference of $N(2120)3/2^-$ and $N(2060)5/2^-$ resonances is responsible for such an angular dependence. The data was refitted excluding the resonances with mass around 2 GeV. The most significant effect we have found by refitting without $N(2120)3/2^-$ (black line) and $N(2060)5/2^-$ (blue line). The red line is our full solution.

The beam asymmetry Σ for $\gamma p \rightarrow \eta' p$ reaction is presented in Fig. 5 with the GRAAL data [14] having a nodal structure near threshold. Such a shape of the an-

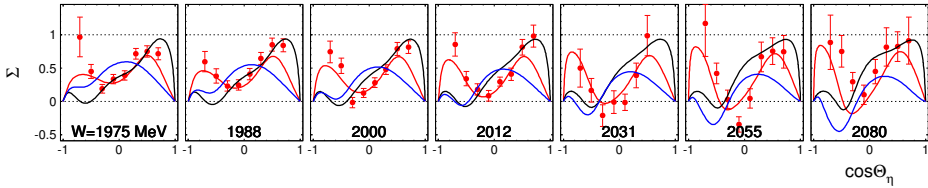


Fig. 4. (Color online) Beam asymmetry Σ for the $\gamma p \rightarrow \eta p$ reaction. Red line: New EtaMAID solution. Results of the refit to the data without $N(2120)3/2^-$ are shown by the black lines and without $N(2060)5/2^-$ - blue lines. Data: CLAS-17 [13],

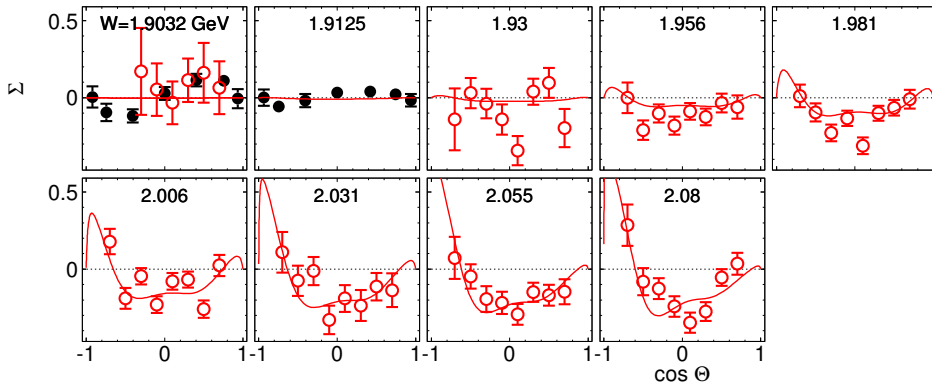


Fig. 5. Beam asymmetry Σ for the $\gamma p \rightarrow \eta' p$ reaction. Red line: New EtaMAID solution. Data: GRAAL-15 [14] (black), CLAS-17 [13] (red).

gular dependence could be explained by interference of s and f or p and d waves. However, the energy dependence is inverted in all models. The EtaMAID-2016 solution [5] describes the shape of the GRAAL data for Σ , but not the magnitude. The new CLAS data [13] can not solve this problem because of poor statistics new threshold. Our new solution describes the Σ data well at $W > 1.95$ GeV.

In summary, we have presented a new version η MAID-2017n updated with new resonances and new experimental data. The model describes the data currently available for both η and η' photoproduction on protons and neutrons. The cusp in the η total cross section, in connection with the steep rise of the η' total cross section from its threshold, is explained by a strong coupling of the $N(1895)1/2^-$ to both channels. The narrow bump in $\eta\eta$ and the dip in $\eta\eta'$ channels have a different origin: the first is a result of an interference of a few resonances, and the second is a threshold effect due to the opening of the $K\Sigma$ decay channel of the $N(1650)1/2^-$ resonance. The angular dependence of Σ for $\gamma p \rightarrow \eta p$ at $W > 2$ GeV is explained by an interference of $N(2120)3/2^-$ and $N(2060)5/2^-$ resonances. The near threshold behavior of Σ for $\gamma p \rightarrow \eta' p$, as seen in the GRAAL data, is still an open question. A further improvement of our analysis will be possible with additional polarization observables which soon should come from the A2MAMI, CBELSA/TAPS, and CLAS collaborations.

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