PROCEEDINGS OF SCIENCE

PoS(Hadron2017)058

η and η' photoproduction with ηMAID

V. L. Kashevarov[*], **L. Tiator and M. Ostrick**
Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, Germany
E-mail: `kashevar@uni-mainz.de`, `tiator@uni-mainz.de`,
`ostrick@uni-mainz.de`

A phenomenological analysis of η and η' photoproduction on the protons and the neutrons with EtaMAID model is presented. The model includes 23 nucleon resonances parameterized by Breit-Wigner functions with energy dependent widths. At high energies, $W > 3$ GeV, Regge cut phenomenology was applied with vector and axial-vector meson exchanges in the t channel. In the resonance region, low partial waves with L up to 4 were subtracted from the t-channel contribution. Parameters of the resonances were obtained from a fit to available experimental data. The nature of the most interesting observations in the data is discussed.

XVII International Conference on Hadron Spectroscopy and Structure - Hadron2017
25-29 September, 2017
University of Salamanca, Salamanca, Spain

---

[*] Speaker.

Photoproduction of η and η' mesons is a selective probe to study the nucleon resonances. Several single- and double-spin observables and also differential cross sections with high statistical accuracy have recently been measured for η and η' photoproduction on both protons and neutrons. We present results of the phenomenological analysis of the experimental data with EtaMAID model.

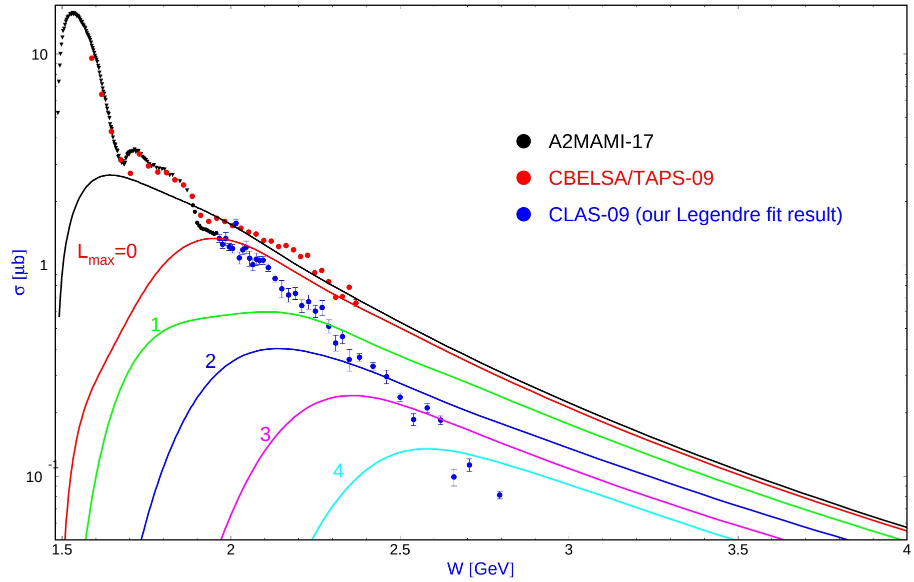

Figure 1: The total cross section for $\gamma p \to \eta p$ reaction. Data: A2MAMI-17 [6], CBELSA/TAPS-09 [8]. CLAS-09 data were obtained with Legendre fit to differential cross sections from Ref. [9]. The black line is the full Regge contribution. The red, green, blue, magenta, and cyan lines are results of the subtraction from the full Regge contribution of the partial waves with L_{max} = 0, 1, 2, 3, and 4 consequently.

The isobar model EtaMAID [1, 2] was developed in 2002 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, 5, 6] to describe the new data for η and η' photoproduction on the proton. The new updated EtaMAID version includes also η and η' photoproduction on the neutron.

At high energies, $W > 3$ GeV, Regge cut phenomenology was applied. The model includes exchanges of vector (ρ and ω) and axial vector (b_1 and h_1) mesons in the t-channel 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].

EtaMAID is a Regge-plus-Resonance model and has a disadvantage of double counting in the overlapping region, energies below $W = 2.5$ GeV, where both s-channel resonance contributions and t-channel Regge background are of similar order. To avoid this double counting, low partial waves with L up to 4 were subtracted from the t-channel contribution in the resonance region. The result of a such subtraction is illustrated in Fig. 1. The Regge contribution to the total cross section for $\gamma p \to \eta p$ reaction is shown by the black line. The red, green, blue, and magenta lines correspond to the subtraction of the partial waves with L_{max} = 0, 1, 2, and 3 consequently. Finally, the Regge background after the subtraction with L_{max} = 4 is shown by the cyan line. All resonances with L up to 4 and PDG **??** overall status of two stars and more were included in the fit.

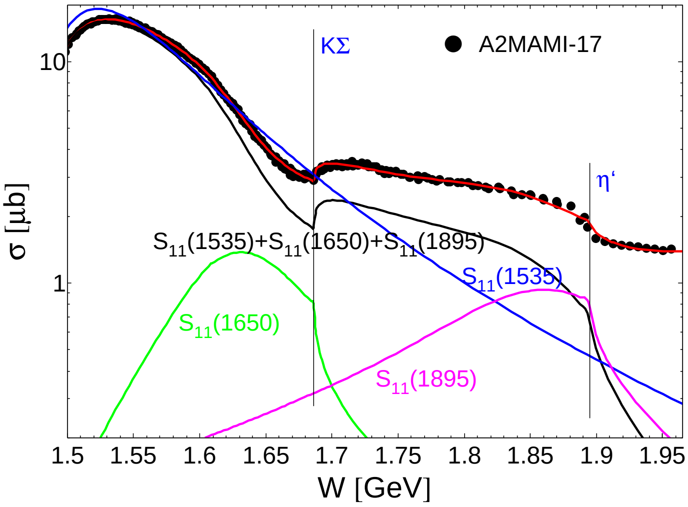

Figure 2: Total cross section of the $\gamma p \to \eta p$ reaction with partial contributions of the main nucleon resonances. Red line: New EtaMAID solution. Vertical lines correspond to thresholds of $K\Sigma$ and $\eta' N$ photoproduction. Data: A2MAMI-17 [6].

The most interesting fit results are presented in Figs. 2-6 together with corresponding experimental data.

In Fig. 2, the total $\gamma p \to \eta p$ cross section is shown. A key role in the description of the investigated reactions is played by three s-wave resonances N(1535)$1/2^-$, N(1650)$1/2^-$, and N(1895)$1/2^-$, see partial contributions of these resonances in Fig. 2. 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 KΣ 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. 2) and provides a fast increase of the total cross section in the $\gamma p \to \eta' p$ reaction near threshold (see black line in Fig. 3). A good agreement with the experimental data was obtained for the cross sections of the $\gamma p \to \eta' p$ reaction, Fig. 3. The main contributions to this reaction come from $N(1895)1/2^-$, $N(1900)3/2^+$, and $N(2130)3/2^-$ resonances.

Very interesting results were obtained during the last few years for the $\gamma n \to \eta n$ reaction. The excitation function for this reaction shows an unexpected narrow structure at $W \sim 1.68$ GeV,

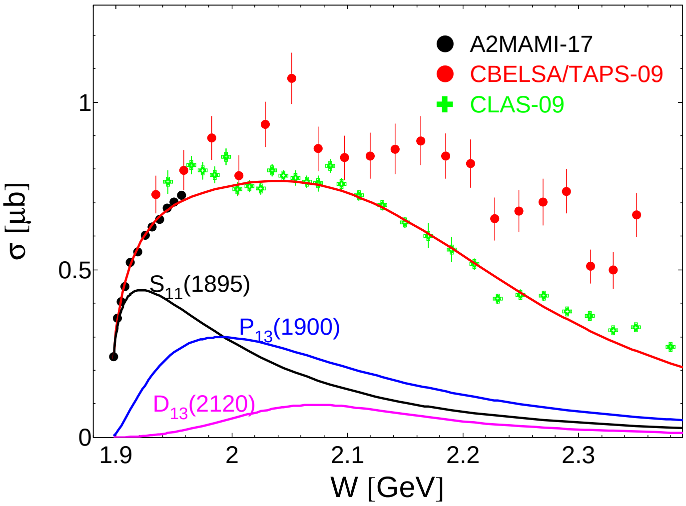

Figure 3: Total cross section of the $\gamma p \to \eta' p$ reaction with partial contributions of the main nucleon resonances. Red line: new EtaMAID solution. Data: A2MAMI-17 [6], CBELSA/TAPS-09 [8], and CLAS-09 [9].

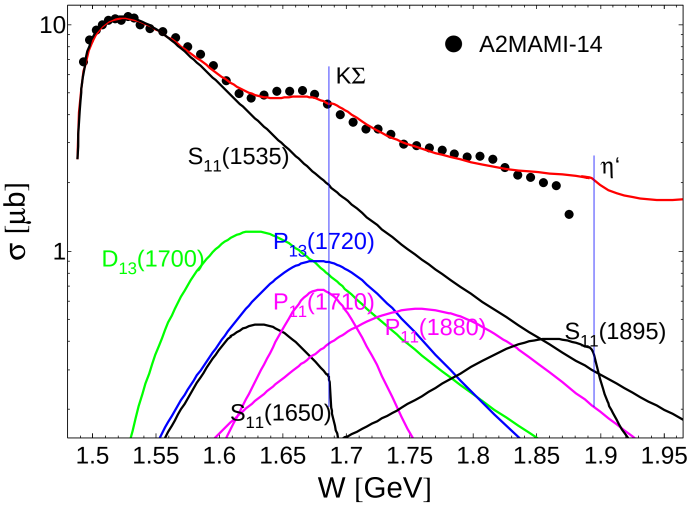

Figure 4: Total cross section of the $\gamma n \to \eta n$ reaction with partial contributions of the main nucleon resonances. Red line: new EtaMAID solution. Data: A2MAMI-14 [11].

which is not observed in $\gamma p \to \eta p$. As an example, the total cross section measured with highest statistics in Mainz [11] is shown in Fig. 4. 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 analysis, the narrow structure is explained as the interference of s, p, and d waves, see partial contributions of the resonances in Fig. 4. Our full solution, red line in Fig. 4, 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. 3 for the

$\gamma p \to \eta p$ reaction. However, the data demonstrate a cusp-like effect at the energy of ~ 50 MeV below. This remains an open question for our analysis as well as for the final state effects in the data analysis.

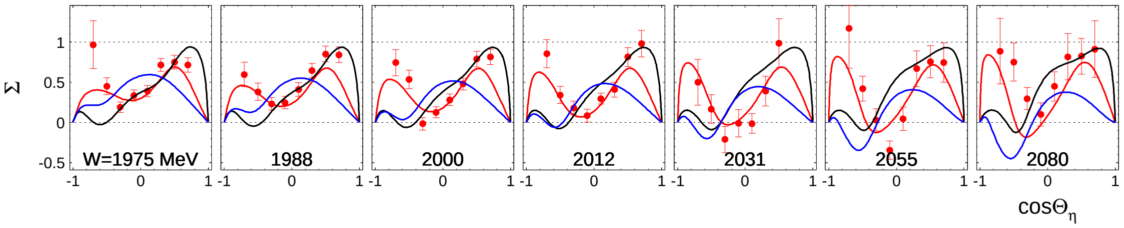

Figure 5: Beam asymmetry Σ for the $\gamma p \to \eta p$ reaction. Red line: new EtaMAID solution. Results of the refit to the data without $N(2120)3/2^-$ are shown by the black lines and without $N(2060)5/2^-$ - blue lines. Data: CLAS-17 [13],

Recently, the CLAS collaboration reported a measurement of the beam asymmetry Σ for both $\gamma p \to \eta p$ and $\gamma p \to \eta' p$ reactions [13]. At high energies, $W > 2$ GeV, the $\gamma p \to \eta p$ data have maximal Σ asymmetry at forward and backward directions, see Fig. 5. 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.

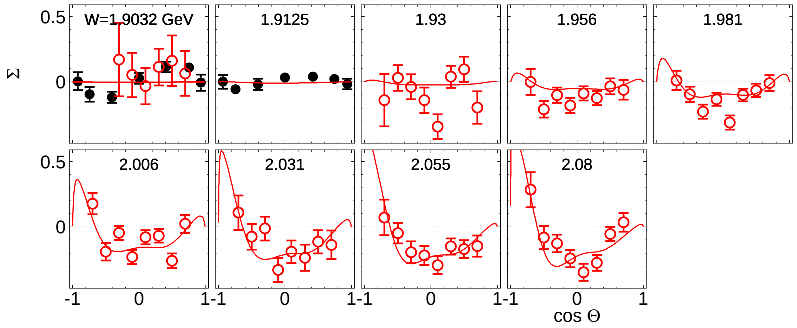

Figure 6: Beam asymmetry Σ for the $\gamma p \to \eta' p$ reaction. Red line: new EtaMAID solution. Data: GRAAL-15 [14] (black), CLAS-17 [13] (red).

The beam asymmetry Σ for $\gamma p \to \eta' p$ reaction is presented in Fig. 6 with the GRAAL data [14] having a nodal structure near threshold. Such a shape of the angular 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 at near threshold region. Our new solution describes the Σ data well at $W > 1.95$ GeV.

In summary, we have presented results of the phenomenological analysis of η and η' photoproduction on the protons and the neutrons with updated version of EtaMAID model. The model describes well all currently available data. The cusp in the ηp total cross section, in connection with the steep rise of the $\eta' p$ 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 ηn and the dip in ηp 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 KΣ decay channel of the $N(1650)1/2^-$ resonance. The angular dependence of Σ for $\gamma p \to \eta p$ 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 $\gamma p \to \eta' p$, 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.

This work was supported by the Deutsche Forschungsgemeinschaft (SFB 1044).

References

[1] W. -T. Chiang, S. N. Yang, L. Tiator, and D. Drechsel, Nucl. Phys. **A700**, 429 (2002).

[2] W.-T. Chiang, S. N. Yang, L. Tiator, M. Vanderhaeghen, and D. Drechsel, Phys. Rev. C **68**, 045202 (2003).

[3] J. Akondi *et al.* (A2 Collaboration at MAMI), Phys. Rev. Lett. **113**, 102001 (2014).

[4] V. L. Kashevarov, M. Ostrick, L. Tiator, Bled Workshops in Physics, Vol.**16**, No.1, 9 (2015).

[5] V. L. Kashevarov, M. Ostrick, L. Tiator, JPS Conf. Proc. **13**, 020029, (2017).

[6] V. L. Kashevarov *et al.* (A2 Collaboration at MAMI), Phys. Rev. Lett. **118**, 212001 (2017).

[7] V. L. Kashevarov, M. Ostrick, L. Tiator, Phys. Rev. C **96** 035207 (2017).

[8] V. Crede *et al.* (CBELSA/TAPS Collaboration), Phys. Rev. C **80**, 055202 (2009).

[9] M. Williams *et al.* (CLAS Collaboration), Phys. Rev. C **80**, 045213 (2009).

[10] C. Patrignani *et al.* (Particle Data Group), Chin. Phys. C **40**, 100001 (2016).

[11] (A2 Collaboration at MAMI), D. Werthmüller *et al.* , Phys. Rev. C **90**, 015205 (2014).

[12] (A2 Collaboration at MAMI), L. Witthauer *et al.* , Phys. Rev. C **95**, 055201 (2017).

[13] P. Collins *et al.*, (CLAS Collaboration), Phys. Lett. B **771** , 213 (2017).

[14] P. Levi Sandri *et al.* (GRAAL Collaboration), Eur. Phys. J. A **51** , 77 (2015).