Phenomenological analysis of experimental data on \( \eta \)-photoproduction on protons*

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Abstract

The results of linear regression of differential cross sections, \( \Sigma \)- and \( T \)-asymmetries of \( \eta \)-photoproduction on protons in energy region from threshold up to 1 GeV are presented. Serious contradictions between angular distributions measured in different laboratories are revealed. The energy dependance of regression coefficients may be due to transition from energy region of \( S_{11}(1535) \) and \( D_{13}(1520) \) to energy region of \( D_{15}(1675) \) and \( F_{15}(1680) \) resonances.

During the past years \( \eta \)-photoproduction on protons has attracted increasingly high interest. This is due not only because this item is a new physical phenomenon different from photoproduction of pions but mainly because \( \eta \)-photoproduction should proceed through the small number of nucleon resonances. Even in energy region up to 1 GeV there will be not too many overlapping resonances that permits to extract reliable information on resonance parameters from experimental data.

Complete phenomenological analysis of experimental data on photoproduction, as a rule, encounters a number of problems, e.g. solving of nonlinear equations, removal of continuous and discrete theoretical ambiguities, elimination of experimental ambiguities, etc. Analysis of experimental data may be naturally divided in two stages \([1]\). The first is the linear regression which provides the information about the number of partial waves that contribute to the measured experimental characteristics of process and provides information on the resonances concerned. The linearity of the model used ensures that the estimates of regression coefficients are unbiased. The second is to determine the multipole amplitudes.

This paper is confined to the first stage of analysis. We have analysed all known experimental data on differential cross sections (angular distributions) of process \( \gamma p \to \eta p \) \([2, 4]\), and also the data on polarization observables, i.e. angular distributions of asymmetry \( \Sigma \), measured with linear polarized beam \([3]\) and angular distributions of asymmetry \( T \), measured on a polarized target \([4]\). The energy independent analysis consist in expanding angular distribution of the observables at definite energy using Legendre polinomials. To find how many terms in this expansion provide the best description of data standart statistical procedures including the Fisher criterion were used. Unlike the energy dependent

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analysis that is based on parametric models and, generally, gives biased estimates, energy
independent analysis relies on nonparametric model that provides unbiased estimates.
Expansion of the observables and corresponding statistics are:
\[
\frac{k}{q} \frac{d\sigma(\theta)}{d\Omega} = \sum a_n P_n(\cos \theta), \tag{1a}
\]
\[
\frac{k}{q} \frac{d\sigma}{d\Omega} \frac{1}{\sin^2 \theta} \Sigma = \sum b_n P_n(\cos \theta), \tag{1b}
\]
\[
\frac{k}{q} \frac{d\sigma}{d\Omega} \frac{1}{\sin \theta} T = \sum c_n P_n(\cos \theta). \tag{1c}
\]
Multipole decomposition of coefficients \(a_n\), \(b_n\), \(c_n\) up to terms \(E_3\) and \(M_3\) may be found in [7]. In all cases the best description of experimental data on \(d\sigma/d\Omega\), were obtained with three terms of the expansion. The dominance of s-wave, the coefficient \(a_0\), was already pointed out [2, 8]. However, the coefficients \(a_1\) and \(a_2\) connected, correspondingly, with the \(sp\)- and \(sd\)-interferences demonstrate the existence of serious contradictions between results in [2–4]. This is also displayed by Fig. 1. Since the observables \(d\sigma/d\Omega\), \(\Sigma\), \(T\) were measured at different energies and angles to form the statistics with \(\Sigma\) and \(T\) we used interpolated values of \(d\sigma/d\Omega\). The polarization statistics \(\Sigma\) and \(T\) were analysed with both \(d\sigma/d\Omega\) obtained in the same laboratory and \(d\sigma/d\Omega\) from another laboratories. To get the description of \(\Sigma(\theta)\) it was necessary to keep three terms in expansion. For the \(T(\theta)\) it was sufficient to keep two terms. The energy dependence of \(b_n\) and \(c_n\) is shown on Fig. 2 and 3.

Contradictions between angular distributions obtained in different laboratories are not reflected in the general behavior of the coefficients \(b_n\) and \(c_n\). In other words, these contradictions between \(d\sigma/d\Omega\) do not appear in polarizational observables.

Figure 1: Coefficients \(a_0\), \(a_1\), \(a_2\) in expansion (1a). Data are taken (a) from [2], (b) from [3], (c) from [4]; lines show the results of the fit.
Figure 2: Coefficients $b_0$, $b_1$, $b_2$ in expansion (1b). Data for $\Sigma$ are taken from [5]. (a) $d\sigma/d\Omega$ from [4], (b) $d\sigma/d\Omega$ from [3]. Square symbols: $d\sigma/d\Omega$ from [2].

Figure 3: Coefficients $c_0$, $c_1$ in expansion (1c). Data for $T$ are taken from [6]. (a) $d\sigma/d\Omega$ from [4], b) $d\sigma/d\Omega$ from [3]. Square symbols: $d\sigma/d\Omega$ from [2].

It seems to be instructive to consider the energy behaviour of coefficients $a_1$, $b_1$, $b_2$ and $c_0$, $c_1$. The change of energy dependence of this coefficients at 0.9 GeV might indicate the change of regime of the process. For instance, the decrease of $a_1$ from the threshold to 0.9 GeV may be due to the damping of $s$-wave and to weakening of $sp$-interference. The further rise of $a_1$ may be related with the contribution of higher partial waves. The decrease of $b_2$ at energies below 0.9 GeV may be related with resonance $D_{13}(1520)$; the growth of $b_2$ at energies 0.9–1.1 GeV may be due to influence of resonances $D_{15}(1675)$ and $F_{15}(1680)$. The interference of $d$- and $f$-waves should lead to the shift of angular distribution $\Sigma(\theta)$ to the smaller angles in the CM system as really seen in experiment [5]. The behaviour of $b_1$ at energies higher than 0.9 GeV can be attributed to $sf$-interference and so on.

Thus, energy dependance of regression coefficients found in our analysis may be due to the transition from energy region of $S_{11}(1535)$ and $D_{13}(1520)$ to energy region of $D_{15}(1675)$.
and $F_{15}(1680)$.

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