On Narrow Nucleon Excitation $N^*(1685)$

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Abstract

We collected notes and simple estimates about putative narrow nucleon $N^*(1685)$– the candidate for the non-strange member of the exotic anti-decuplet of baryons. In particular, we consider the recent high precision data on $\eta$ photoproduction off free proton obtained by the Crystal Ball Collaboration at MAMI. We show that it is difficult to describe peculiarities of these new data in the invariant energy interval of $W \sim 1650 - 1750$ MeV in terms of known wide resonances. Using very simple estimates, we show that the data may indicate an existence of a narrow $N^*(1685)$ with small photocoupling to the proton.

Introduction to the neutron anomaly

The prediction of light and narrow anti-decuplet of baryons in the framework of the chiral quark soliton model ($\chi$QSM) [1] has a direct implication for the classical field of nucleon resonances spectroscopy: one should expect an existence of the nucleon state, which is much narrower than the usual nucleon excitations with analogous mass [1, 2, 3, 4].

An important observation was made in Ref. [5], it was demonstrated that the nucleon resonance from the anti-decuplet has a clear imprint of its exotic nature: the anti-decuplet nucleon is excited predominantly by the photon from the neutron, its photoexcitation from the proton target is strongly suppressed. Therefore the $\gamma n \rightarrow \eta n$ process has been suggested in Ref. [5] as a “golden channel” to search for the anti-decuplet nucleon. The modified partial wave analysis (PWA) of the elastic $\pi N$ scattering [3] showed that the existing data on $\pi N$ scattering can tolerate a narrow $P_{11}$ resonance if its $\pi N$ partial decay width is below 0.5 MeV and it has the mass around 1680 MeV.

Recently four groups - GRAAL [6, 7], CBELSA/TAPS [8], LNS [9], and Crystal Ball/TAPS [10] - reported an evidence for a narrow structure at $W \sim 1680$ MeV in the $\eta$ photoproduction on the neutron. The structure was observed as a bump in the quasi-free cross section (the neutron anomaly$^*$) and as a peak in the invariant-mass spectrum of the final-state $\eta$ and the neutron ($M(\eta n)$) [7, 8, 10]. The width of the bump in the quasi-free cross section is close to that expected due to the smearing of the target neutron bound.

$^*$The name “neutron anomaly” was introduced in Ref. [12] to denote the bump in the quasi-free $\gamma n \rightarrow \eta n$ cross section around $W \sim 1680$ MeV and its absence in the quasi-free $\gamma p \rightarrow \eta p$ cross section.
in a deuteron target by Fermi motion. The width of the peaks observed in the $M(\eta n)$ spectra is close to the instrumental resolution of the corresponding experiments [7, 8, 10].

Furthermore, a sharp resonant structure at $W \sim 1685$ MeV was found in the GRAAL data on the beam asymmetry for the $\eta$ photoproduction on the free proton [11, 12]. Such structure is not (or poorly) seen in the $\gamma p \rightarrow \eta p$ cross section [13, 14].

In Refs. [7, 11, 12, 15, 16, 17], the combination of the experimental findings was interpreted as a signal of a nucleon resonance with the mass near $\sim 1680$ MeV and unusual properties: the narrow width and the stronger photoexcitation on the neutron comparing to that on the proton. Alternatively, the authors of Refs. [19, 18] explained the neutron anomaly in terms of the interference of well-known resonances and in Ref. [20] due to effects of meson loops†.

In year 2010 more results on the neutron anomaly were obtained:

- In Ref. [21] the first study of quasi-free Compton scattering on the neutron in the energy range of $E_\gamma = 750 – 1500$ MeV was performed. The data reveal a narrow peak at $W \sim 1685$ MeV. Such peak is absent in the Compton scattering on the proton as well as in the reactions $\gamma n \rightarrow \pi^0 n$ and $\gamma p \rightarrow \pi^0 p$. The latter observation implies that the putative narrow resonance should have very small $\pi N$ partial width, that is in agreement with modified PWA of Ref. [3] and with theoretical expectations for the nucleons from the anti-decuplet [1, 2, 3, 4]. In other words, the neutron anomaly was also observed in the Compton scattering. For details of the corresponding analysis see Ref. [21].

We note that the explanations of the neutron anomaly in the $\eta$ photoproduction in terms of the interference of well-known resonances [19, 18] and due to effects of meson loops [20] obviously do not work in the case of the Compton scattering.

- Recently the data of the CBELSA/TAPS collaboration [8] on $\eta$ photoproduction off the neutron have been reanalysed by the same collaboration. Namely, the de-folding of the Fermi motion has been performed. The corresponding preliminary results were presented by B. Krusche at MESON10 workshop in Krakow [23]. One can use the results of this new analysis in order to extract the photocoupling of neutral component of $N^*(1685)$. The method is described in Ref. [15], following it one can easily obtain:

$$\sqrt{\text{Br}_{\eta N} A_{1/2}^n} \sim 15 \cdot 10^{-3} \text{ GeV}^{-1/2} \quad \text{(CBELSA/TAPS data)} \quad (1)$$

That value of the photocoupling is in a striking agreement with the value obtained in Ref. [15] from the analysis of the GRAAL data of Refs. [6, 7].

- The neutron anomaly is also seen in $\eta$ photoproduction on $^3$He, see preliminary data of the A2 collaboration in Master Theses of L. Witthauer [22]. The position of the bump in neutron quasi-free cross section is in agreement with the position of the

†It is worth noting here that the models of Refs. [19, 18, 20] do not predict the neutron anomaly, the observed peak in the neutron cross-section (and its apparent absence in the proton channel) has been used as an input for fitting of quite numerous model parameters.
corresponding bump obtained from the deuteron scattering in Refs. [6, 7, 8, 9, 10]. The width of the bump in $^3$He is larger than extracted from deuteron scattering, that is due to more wider Fermi momentum distribution in $^3$He nucleus.

Observation of the neutron anomaly in the scattering on new type of the nuclei ($^3$He) is important in order to exclude an appearance of the neutron anomaly due to nuclear and/or rescattering effects.

What about putative narrow $N^*(1685)$ in $\eta$ photoproduction off free proton?

It was predicted that the photoexcitation of the charge component of the anti-decuplet nucleon is strongly suppressed [5]. That makes its search more sophisticated. In Refs. [11, 12] a sharp resonant structure at $W \sim 1685$ MeV was found in the beam asymmetry data for the $\eta$ photoproduction on the free proton. Any resonance whose photoexcitation on the proton is suppressed may manifest itself in polarization observables due to interference effects. The results of Refs. [11, 12] for the beam asymmetry in the $\eta$ photoproduction on the free proton are shown in Fig. 1. One sees that around $W \sim 1685$ MeV (shown by the vertical dashed line) there is a narrow structure, which looks like a peak at forward angles and which develops into an oscillating structure at larger scattering angles. Such behaviour is typical for interference effects of a narrow resonance with smooth background.

Fits to the data provided an estimate of the photocoupling for the charge component of $N^*(1685)$ [11, 12]:

$$\sqrt{\text{Br}_{\eta N} A_{1/2}^p} \sim 1 \cdot 10^{-3} \text{ GeV}^{-1/2}. \quad (2)$$

One sees that the photocoupling of $N^*(1685)$ to the proton is much smaller than the coupling to the neutron (1).
Photocouplings (1) and (2) correspond to the following resonance cross section at its maximum‡ (at $W = M_R$):

$$\sigma_{\text{res}}(\gamma n \rightarrow \eta n)|_{W=M_R} \sim 8.5 \left( \frac{10 \text{ MeV}}{\Gamma_{\text{tot}}} \right) \mu b,$$

$$\sigma_{\text{res}}(\gamma p \rightarrow \eta p)|_{W=M_R} \sim 0.04 \left( \frac{10 \text{ MeV}}{\Gamma_{\text{tot}}} \right) \mu b.$$

Typical values of the non-resonant cross section at $W \sim 1680$ MeV is $\sigma_n \sim 5 - 6 \mu b$ for the neutron and $\sigma_p \sim 3 \mu b$ for the proton. One sees from that rough estimate that the resonance cross section on the proton is very small and even in a measurement with an ideal resolution it is almost impossible to see the corresponding resonance signal. The signal of weak resonance can be revealed through its quantum interference with the strong but smooth background amplitude, see e.g. [24, 25]. The interference enhancement of a weak signal was used in Refs. [11, 12] to reveal the signal of narrow $N^*(1685)$ in polarization observables. Note that in the case of interference a weak signal can appear not necessarily as a resonance bump but as a dip or a structure oscillating with energy.

In order to reveal a weak signal of $N^*(1685)$ in the cross section of $\gamma p \rightarrow \eta p$ processes one needs to perform detailed PWA. Here we just make a “back of an envelope” estimate. As we mentioned already a weak resonance should appear as a bump, dip or oscillating structure in the cross section. The \textit{maximally possible} magnitude of such structure can be estimated as:

$$\Delta \sigma_{\text{tot}} = 2\sqrt{\sigma_p \sigma_{\text{res}}(\gamma p \rightarrow \eta p)|_{W=M_R}} \sim 0.7 \mu b,$$

that number corresponds to $\sim 0.06 \mu b$/sr in the differential cross section. Note that the actual magnitude of the interference structure must be smaller than the above value, as the estimate (4) assumes that only one partial wave with quantum numbers of the putative resonance contributes to the cross section.

Recently the Crystal Ball Collaboration at MAMI published high precision data on $\eta$ photoproduction on free proton [26]. The cross section was measured with fine steps in the photon energy. The authors of Ref. [26] concluded that “... cross sections for the free proton show no evidence of enhancement in the region $W \sim 1680$ MeV, contrary to recent equivalent measurements on the quasifree neutron. However, this does not exclude the existence of an $N^*(1680)$ state...”. As we discussed above one should expect that the putative $N^*(1685)$ can be seen in the cross section only due to its interference with strong smooth background and the corresponding signal is not necessarily looks like a peak but rather as the structure oscillating with energy or as a dip.

Let us look more carefully at the energy behaviour of the total cross section in the energy region around $W \sim 1685$ MeV. The data of Ref. [26] for the total cross section of $\gamma p \rightarrow \eta p$ for $W$ in the interval 1650-1750 MeV are shown in Fig. 2. One sees clearly an oscillation structure with the distance between two extrema of $\Delta W \sim 40$ MeV (a

\footnote{We emphasize that the theoretical uncertainties in the estimates of the photocouplings (1) and (2) are rather large $\pm 40\%$. That can lead to $\pm 80\%$ uncertainties in the estimates of the resonance cross sections.}
minimum at $W \sim 1680$ MeV and a maximum at $W \sim 1720$ MeV). The amplitude of that oscillation structure (the difference between the values of the cross section at the extrema) is about $\sim 0.5 \, \mu b$ (cf. our “back of an envelope” estimate (4)). We see that in the invariant energy region 1680-1720 MeV the total cross section of $\gamma p \rightarrow \eta p$ reveals a narrow oscillation (or maybe dip) structure with the magnitude compatible with our expectations (4) for the interference pattern of the narrow $N^*(1685)$\textsuperscript{§}. The amplitude of the oscillation structure and its width are too close to the upper limits what one can expect for the putative narrow resonance $N^*(1685)$. It seems that several partial waves are in play. It might be that the wide resonances in the neighbourhood of $W \sim 1685$ MeV, such as $P_{11}(1710)$, $P_{13}(1720)$ and $D_{15}(1675)$ can contribute additionally to the enhancement of the observed oscillation. All these contributions can be disentangled by PWA.

Table 1: Interference of various partial waves in coefficients $A_i$ (5). The Legendre coefficient $A_1$ is highlighted because experimentally it clearly exhibits the rapid energy dependence at $W \sim 1650 − 1750$ MeV.

|       | $S_{11}$ | $P_{11}$ | $P_{13}$ | $D_{13}$ | $D_{15}$ |
|-------|---------|---------|---------|---------|---------|
| $S_{11}$ | $A_0$  | $A_1$  | $A_2$  | $A_2$  |         |
| $P_{11}$ | $A_1$  | $A_0$  | $A_2$  | $A_1$  | $A_3$  |
| $P_{13}$ | $A_1$  | $A_2$  | $A_0, A_2$ | $A_1, A_3$ | $A_1, A_3$ |
| $D_{13}$ | $A_2$  | $A_1$  | $A_1, A_3$ | $A_0, A_2$ | $A_2, A_4$ |
| $D_{15}$ | $A_2$  | $A_3$  | $A_1, A_3$ | $A_2, A_4$ | $A_0, A_2, A_4$ |

\textsuperscript{§}We note that this oscillation structure is also seen in the data of Ref. [13], however the authors attributed the structure to an instrumental effect
The differential cross section in the Legendre series:

\[ \frac{d\sigma}{d\Omega} = \frac{1}{4\pi} \sum_{i=0}^{\infty} A_i(W) P_i(\cos \theta), \]

where \( P_l \) are Legendre polynomials. Note that by definition the coefficient \( A_0(W) \) coincides with the total cross section. The coefficients \( A_i(W) \) receive contribution from interference of various partial waves. The partial waves (for \( l \leq 2 \)) which interfere in a given coefficient \( A_i(W) \) are listed in Table 1. As an entry in the table we show the coefficients \( A_i \) in which two chosen partial waves interfere.

In Fig. 3 we show the normalized Legendre coefficients (5) \( (A_i/A_0) \) extracted from the data of Ref. [26]. One sees that \( A_1 \) coefficient undergoes rapid change of its sign on the invariant energy interval of \( W \sim 1650 - 1730 \) MeV. Also \( A_3 \) changes its sign on that interval, whereas the coefficient \( A_2 \) shows little structure on that energy interval. We note that the rapid change of \( A_1 \) coefficient occurs exactly at invariant energy where the rapid change of photon beam asymmetry was observed in Refs. [11, 12]. To illustrate this we show in Fig. 1 the ratio of Legendre coefficient \( A_1/A_0 \) (5) extracted from data of Ref. [26] (low right insert) together with photon beam asymmetry of Refs. [11, 12].

It is clear from Table 1 that the rapid change of the sign of \( A_1 \) can be driven by the interference of various partial waves. Thus one definitely needs sizable values of \( P \) and/or \( D \) waves in the invariant energy interval of \( W \sim 1650 - 1750 \) MeV. That simple observation casts serious doubts on the model of Ref. [20], which predicts the dominance of \( S \)-wave in that energy interval.
In Fig. 4 we show normalized coefficients $A_i$ on the narrower energy interval of 1650-1750 MeV. The Legendre coefficient $A_1$ exhibits rapid change on this small energy interval\footnote{The coefficient $A_3$ also changes its sign in this energy region, but slower than $A_1$}. As we discussed above, the total cross section also shows the oscillation structure on the energy interval of 1650-1750 MeV (see Fig. 2). The width of the apparently seen structure in $A_1$ is wider than in $\sigma_{\text{tot}}$ ($\sim 80$ MeV versus $\sim 40$ MeV). Also the magnitude of the structure is larger than one can expect for the weak contribution of N$^\ast$(1685). It seems that other wide resonances contribute to the normalized $A_1$, that can be $P_{11}(1710)$, $P_{13}(1720)$, $D_{15}(1675)$. These resonances have masses around $W \sim 1685$ MeV and can also (in addition to putative N$^\ast$(1685)) lead to the change of the sign of $A_1$. To disentangle the contribution of these resonances one needs detailed PWA, which is beyond scope of these notes. Here we just make simple estimates to single out the “rapid” degrees of freedom from the data.

The main distinctive feature of putative N$^\ast$(1685) is its small width, one may try to single out its contribution to $A_1$ considering derivatives $dA_1/dW$. Indeed, looking at Fig. 4 one might see that the speed of $A_1$’s change with $W$ has probably a qualitatively different regime on narrow energy interval of $W \sim 1670 - 1700$ MeV. That observation invites us to study the “speed characteristic” of the normalized $A_1$:

$$S_1(W) \equiv W \frac{d}{dW} \left( \frac{A_1(W)}{A_0(W)} \right).$$

That quantity is dimensionless, it allows us to separate rapidly changing contributions from contributions of wide resonances and smooth background. It is difficult to extract $S_1(W)$ from the data because of statistical fluctuations in the data that induce large instabilities in the calculations of the derivative. We use the following procedure to compute $S_1(W)$: for each $i$th bin in $W$ we choose the energy interval $[W_i, W_{i+12}]$ (about 30 MeV wide) and fit the data by the 4th order polynomial (13 data points). After that, using resulting from
the fit polynomial, we compute $S_1(W)$ analytically for the 4 middle bins in the interval $[W_i, W_{i+1}]$. Obviously, the resulting value of $S_1(W)$ for a given $W$ depends on the initial bin in our procedure. The differences of values of $S_1(W)$ reflect the uncertainties in differentiation of the numerical data.

In Fig. 5 we plot $S_1(W)$ obtained by that procedure. We see that at $W$ around 1660 MeV and 1690 MeV the “speed characteristic” $S_1(W)$ (6) is very uncertain (one obtains very different values depending on the starting bin), whereas between these points the $S_1(W)$ is rather stable. That means that at points 1660 MeV and 1690 MeV the change of the regime of the $W$ dependence of the normalized $A_1$ happens. Also it is remarkable that $S_1(W)$ reaches its maximum at $W \sim 1680$ MeV (that is corresponds to the inflection point of the normalized $A_1$) which is close to zero of $A_1(W)$ at $W \sim 1685$ MeV. Such situation is typical for the case when $A_1$ appears as the result of interference of two partial waves: one is smooth (say $S$-wave) and another is dominated by a resonance (say $P$-wave). Note that the value of $S_1(W)$ at maximum at 1680 MeV is rather sizable: $S_{1 \text{max}} \sim 30$.

If one uses a simple model, which consist of smooth $S_{11}$ amplitude and a narrow $P_{11}$ resonance (mass $M_R$ and total width $\Gamma_R$) on the top of smooth $P_{11}$ background one can derive a simple expression for $S_{1 \text{max}}$:

$$S_{1 \text{max}} = 4 \frac{M_R}{\Gamma_R} \sqrt{\frac{\sigma_{\text{res}}}{\sigma_{\text{tot}}}} \sqrt{1 - r} \sqrt{1 - 2r},$$

where $r$ is the fraction of the $P_{11}$ partial wave in $\sigma_{\text{tot}}$ at $W = M_R$ and $\sigma_{\text{res}}$ is the resonance cross section. We note that this equation is derived under the assumptions that the
resonance is weak, i.e. \( \sigma_{\text{res}} \ll \sigma_{\text{tot}} \). We consider this limit because otherwise (for \( \sigma_{\text{res}} \sim \sigma_{\text{tot}} \)) the resonance should be seen in the total cross section as a clean cut peak.

From Eq. (7) one obtains that for the known wide resonances of width \( \Gamma_R \sim 100-200 \text{ MeV} \) \( S_{1}^{\text{max}} \leq (22-11) \) even for optimistically large cross section ratio of \( \sigma_{\text{res}}/\sigma_{\text{tot}} = 0.1 \). As an illustration, the contribution of \( P_{11}(1710) \) resonance to \( S_{1}(W) \) is shown by the dashed line in Fig. 5. For the calculations we used the central values\(^\dagger\) of the \( N(1710) \) parameters listed by the Particle Data Group \(^{27}\): \( M_R = 1710 \text{ MeV} \), \( \Gamma_R = 100 \text{ MeV} \) whereas for the photocoupling we took \( \sqrt{\text{Br}_{\eta N}A_{1/2}^{p}} \sim 8 \cdot 10^{-3} \text{ GeV}^{-1/2} \) which corresponds to the maximal value provided by PDG. The latter value corresponds to \( \sigma_{\text{res}}/\sigma_{\text{tot}} \sim 0.1 \), if one uses the central values of \( N(1710) \) parameters listed by PDG one obtains the contribution to \( S_{1}(W) \) which is about 10 times smaller than the one shown by the dashed line on Fig. 5.

We also tried to fit the data on the normalized Legendre coefficient \( A_{1}/A_{0} \) (see Fig. 4) on the energy interval \( W \sim 1650 - 1750 \text{ MeV} \) by smooth \( S_{11} \) partial wave plus \( N(1710) \) resonance. One can describe the data pretty well with \( M_R = 1685 \text{ MeV} \) and \( \Gamma_R = 100 \text{ MeV} \), however the photocoupling comes out very large \( \sqrt{\text{Br}_{\eta N}A_{1/2}^{p}} \sim 13 \cdot 10^{-3} \text{ GeV}^{-1/2} \). The latter value corresponds to the large resonance cross section of \( \sigma_{\text{res}} \sim 0.7 \mu \text{b} \), which could be easily seen (but actually not seen) in data on \( \sigma_{\text{tot}} \). Although the mass and width resulting from the fit are not in contradiction with the very uncertain values provided by the PDG \(^{27}\) for \( N(1710) \), the value of the photocoupling is far larger than that provided by the PDG. We note that the recent GWU PWA found no evidence for \( N(1710) \) \(^{28}\). Other PWA groups \(^{29, 30}\) definitely require this resonance, however with rather different masses and with width \( \geq 150 \text{ MeV} \).\(^{**}\)

The aim of above simple exercises was purely illustrative: it shows that it is very difficult to obtain the experimental value of \( S_{1}^{\text{max}} \sim 30 \) by contribution of known wide resonances if the corresponding resonance cross section is not large. For the case of the large resonance cross section the corresponding resonance should be visible as a peak in the differential cross section. According to Eq. (7), another possibility to obtain the large experimental value of \( S_{1}^{\text{max}} \sim 30 \) is due to the contribution of a narrow resonance with small photocoupling to the proton (small ratio of cross sections \( \sigma_{\text{res}}/\sigma_{\text{tot}} \)). From Eq. (7) we see that for each value of parameter \( r \) we can determine a relation between the resonance cross section \( \sigma_{\text{res}} \) and the resonance total width \( \Gamma_R \). Taking experimental values of \( \sigma_{\text{tot}} \sim 3 \mu \text{b} \) and \( S_{1}^{\text{max}} \sim 30 \) we plot in Fig. 6 the relation between the resonance cross section and the resonance width for several values of the parameter \( r \)\(^{††}\). Also we plot our estimation of the resonance cross section \(^{3}\) obtained from the analysis of the beam asymmetry in \( \eta \) photoproduction off free proton \(^{11, 12}\). More precisely, we plot the band corresponding to Eq. (3) \( \pm 80\% \) which reflects possible uncertainties in our estimates. For reader’s convenience we translated the Fig. 6 into the relation between the photocoupling \( \sqrt{\text{Br}_{\eta N}A_{1/2}^{p}} \) and the width of the putative resonance, see Fig. 7. Additionally, in Fig. 7 we show the solutions of Eq. (7) for the case of \( S_{1} \sim 20 \) by the dashed lines. That case\(^{†††}\)

\(^\dagger\)The case of \( M_R = 1700 \text{ MeV} \) is shown by dotted line.

\(^**\)Unfortunately, it is frequent that results of various PWA groups are in qualitative contradiction with each other. For a non-expert in PWA it is usually very difficult to figure out the physics reasons for that differences.

\(^{††}\)To fix this parameter from the experimental data one needs to perform PWA.
Figure 6: Lines show the relation between the resonance cross section $\sigma_{\text{res}}$ and the width of putative resonance $\Gamma_R$ obtained from Eq. (7) with the experimental input $S_1^{\text{max}} \sim 30$ and $\sigma_{\text{tot}} \sim 3 \, \mu$b. The lines correspond to values of the parameter $r = 0, 0.1, 0.2$ and $0.3$ (the larger $r$ the steeper the curve). Shaded area shows our estimate given by Eq. (3) $\pm 80\%$.

Figure 7: The same as Fig. 6, but translated to the relation between $\sqrt{\text{Br}_{\eta N} A_{1/2} P}$ and $\Gamma_R$. By dashed lines we show the solutions of Eq. (7) for the case of $S_1^{\text{max}} \sim 20$. 
takes into account possible contributions of wide resonances to $S_1(W)$, that resonances can contribute to some part of experimental value of $S_1 \sim 30$, see e.g. the dashed line in Fig. 5.

Given that our estimates are very rough, the agreement is rather impressive. We can conclude from the presented simple analysis that the observed in Ref. [26] oscillation of $\sigma_{\text{tot}}(\gamma p \to \eta p)$ and rapid change of the Legendre coefficient $A_1(W)$ around $W \sim 1685$ MeV may indicate an existence of new narrow $N^*(1685)$ resonance with $\Gamma_{\text{tot}} \leq 50$ MeV and small resonance photocoupling in the range of $\sqrt{\text{Br}_{\eta N} A_{1/2}^p} \sim (0.3 - 3) \cdot 10^{-3}$ GeV$^{-1/2}$.

Conclusions

Recent high precision measurements of the $\gamma p \to \eta p$ cross section [26] show the oscillation of $\sigma_{\text{tot}}(\gamma p \to \eta p)$ and rapid change of the Legendre coefficient $A_1(W)$ around $W \sim 1685$ MeV. These phenomena occurs at the same energy interval as previously observed in Refs. [11, 12] resonance behaviour of the photon beam asymmetry, see Fig. 1. We made very simple analysis of that phenomena using “speed characteristics” (6) in order to single out “rapid” contributions on the background of smooth contributions of known wide resonances. Our analysis showed that the data of [26] may indicate an existence of new narrow $N^*(1685)$ resonance with $\Gamma_{\text{tot}} \leq 50$ MeV and small resonance photocoupling in the range of $\sqrt{\text{Br}_{\eta N} A_{1/2}^p} \sim (0.3 - 3) \cdot 10^{-3}$ GeV$^{-1/2}$. These parameters are in agreement with the analysis of the photon beam asymmetry in $\gamma p \to \eta p$ process performed in Refs. [11, 12].

The estimates presented here provide us the feeling of the expected scales for the effect of putative $N^*(1685)$ in the cross section of $\gamma p \to \eta p$. The estimates also show that the effect of putative $N^*(1685)$ is interlaced with effects of neighbourhood wide resonances, such as $P_{11}(1710)$, $P_{13}(1720)$ and $D_{15}(1675)$. For example, the rapid change of the Legendre coefficient $A_1$ (but not oscillation structure in $\sigma_{\text{tot}}$) can be in principle described by the contribution of the 100 MeV wide $N(1710)$ resonance, however its photocoupling should be unrealistically large $\sqrt{\text{Br}_{\eta N} A_{1/2}^p} \sim 13 \cdot 10^{-3}$ GeV$^{-1/2}$. Surely, for more detailed separation of the putative narrow $N^*(1685)$ from other contributions one needs full PWA. We hope that our simple estimates were able to grasp main physics in observed phenomena and future PWA will be able to detail our observations.

It seems that all experimental facts discussed here strongly support the existence of new narrow nucleon excitation $N^*(1685)$ with properties\textsuperscript{‡‡} neatly coinciding with those predicted for the non-strange member of exotic anti-decuplet [1, 2, 3, 4, 5] (for the most recent analysis of the properties of anti-decuplet baryons see Ref. [31]).

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\textsuperscript{‡‡}The phenomenological properties of putative $N^*(1685)$ are summarized concisely in Ref. [12]
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