Notes on New Narrow N*

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We briefly discuss the most recent evidences for narrow nucleon excitation (N*) with mass around 1680 MeV. The data show that the N* should have much stronger photocoupling to the neutron than to the proton. That makes it a good candidate for the anti-decuplet member.

Theoretical predictions for anti-decuplet N*

In this short contribution we discuss fresh evidences for the nucleon from the anti-decuplet [1]. A detailed account for predictions and evidences for new narrow nucleon can be found in Ref. [2]. Main properties of N* from the anti-deculpet which were predicted theoretically in years 1997-2004 are the following:

- Quantum numbers are P_{11} ($J^P = \frac{1}{2}^+$, isospin=$\frac{1}{2}$) [1].
- Narrow width of $\Gamma \leqslant 40$ MeV [1,3,5].
- Mass of $M \sim 1650 - 1720$ MeV [4,5].
- Strong suppression of the proton photocopling relative to the neutron one [6]. This prediction was based on SU(3) flavour symmetry only. Therefore it can be used as a clear benchmark for a nucleon member of the anti-decuplet.
- The πN coupling is suppressed, N* prefers to decay into ηN, $K\Lambda$ and $\pi\Delta$ [1,3,5].

N* in γn collisions

In the γn collisions (with non-suppressed exit channels such as ηn, γn, $K_S\Lambda$, etc.) the signal of the anti-decuplet nucleon should be seen as a prominent narrow peak in the cross section [6]. However, the neutron is bound in a nucleus, hence the narrow resonance signal is hidden by nuclear effects (by the Fermi motion at the first place[1]). Four groups - GRAAL [9,10], CBELSA/TAPS [11], LNS [12], and Crystal Ball/TAPS [13] - managed to overcome this difficulty and reported evidence for a narrow structure at $W \sim 1680$ MeV in the η photoproduction on the neutron (neutron anomaly[2]).

In year 2011 more results on the neutron anomaly were obtained. In Ref. [14] the neutron anomaly was also observed in the Compton scattering – the study of quasi-free Compton scattering on the neutron revealed a narrow ($\Gamma = 28 \pm 12$ MeV) peak at ~ 1685 MeV with significance of $\sim 4.6\sigma$. Such peak is absent in the proton Compton scattering.

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[1] Observation of the neutron anomaly in the η photoproduction off ^{3}He [7] excludes other nuclear effects.

[2] The name "neutron anomaly" was introduced in Ref. [8] to denote the bump in the quasi-free $\gamma n \to \eta n$ cross section around $W \sim 1680$ MeV and its apparent absence in the quasi-free $\gamma p \to \eta p$ cross section.

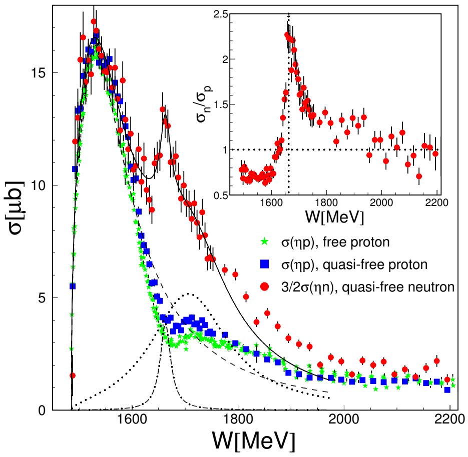

Figure 1: Figure from Ref. [15]. Total cross sections as function of final state invariant mass W with cut on spectator momentum $p_s \leqslant 100$ MeV. (Red) dots: quasi-free neutron, (blue) squares: quasi-free proton, (green) stars: free proton data. Insert: ratio of quasi-free neutron - proton data.

In Ref. [15] the de-folding of the Fermi motion in quasi-free η photoproduction off neutron has been performed. As a result the data exhibit pronounced narrow ($\Gamma = 25 \pm 12$ MeV) peak at $W \sim 1670$ MeV in the total cross section of $\gamma n \to \eta n$ shown in Fig. 1.

Looking at this figure, the first natural hypothesis is that the peak is due to contribution of a narrow nucleon resonance. However, due to the very negative attitude of the community to narrow pentaquarks (see e.g. [16]) one tries to find another explanation for the neutron anomaly first. Detailed discussion of the "conventional explanations" can be found in Ref. [2]. Some of them are refuted already by recent experimental data of Refs. [14,15]. Here we touch presently popular results of Ref. [17] only. Ref. [17] attributes the peak in the neutron channel (see e.g. Fig. 1) to the KY threshold cusp effects.

A dedicated experimental search of the KY threshold cusp effects was performed in Ref. [18]. A very small effect was found. Our studies (in preparation) showed that if the peak in Fig. 1 is due to the cusp effects it would imply that $S_{11}(1650)$ resonance must have extraordinarily large coupling to KY channels, in acute disagreement with flavour SU(3). Moreover several questions to cusp effects of Ref. [17] remain unanswered: 1) Why the neutron anomaly is absent in the pion photoproduction? 2) What is the physics reason for very fine cancelation (fine tuning) of the KY threshold cusp effects in the proton channel?

N* in γp collisions

The first search of the putative anti-decuplet nucleon in $\gamma p \to \eta p$ process was performed in Refs. [2,8]. It was found that the beam asymmetry Σ exhibits a sharp structure around $W \sim 1685$ MeV. That structure looks like a peak at forward angles which develops into an oscillating structure at larger scattering angles. Such a behaviour may occur by interference

observable	extracted value	refs. (neutron data)	refs. (proton data)
mass (MeV)	1680 ± 15	[9–15] [3]$^{\star)}$	[2,8,20,22] [3]$^{\star)}$
$\Gamma_{\rm tot}$ (MeV)	$\leqslant 40$	[9–15] [3]$^{\star)}$	[2,8,20,22] [3]$^{\star)}$
$\Gamma_{\pi N}$ (MeV)	$\leqslant 0.5$	[3]$^{\star)}$	[3]$^{\star)}$
$\sqrt{{\rm Br}_{\eta N}}A^n_{1/2}$ (10^{-3} GeV$^{-1/2}$)	12-18	[15,21]	
$\sqrt{{\rm Br}_{\eta N}}A^p_{1/2}$ (10^{-3} GeV$^{-1/2}$)	1-3		[2,8,20,22]

Table 1: *Our estimate* of properties of the putative narrow N* extracted from the data. $^{\star)}$In Ref. [3] the elastic πN scattering data were analyzed and the tolerance limits for N* parameters were obtained. The preferable quantum numbers in this analysis are P_{11}.

of a narrow resonance with a smooth background. The observed structure was identified in Refs. [2,8] with the contribution of a resonance with mass $M \sim 1685$ MeV, narrow width of $\Gamma \leqslant 25$ MeV, and small photo-coupling of $\sqrt{{\rm Br}_{\eta N}}A^p_{1/2} \sim (1-2)\cdot 10^{-3}$ GeV$^{-1/2}$.

About an year ago the Crystal Ball Collaboration at MAMI published high precision data on η photoproduction on the free proton [19]. The cross section was measured in fine steps in photon energy. The measured cross section exhibits an oscillating with energy structure around 1690 MeV. The best fit to the data was achieved with a new version of SAID (GE09) [19]. However, inspection of this fit reveals a systematic deviation of data from the fit curves in the $1650-1730$ MeV region. In [20] this deviation was interpreted as indication for a nucleon resonance with mass of $M \sim 1685$ MeV, a narrow width of $\Gamma \leqslant 50$ MeV, and a small resonance photo-coupling in the range of $\sqrt{{\rm Br}_{\eta N}}A^p_{1/2} \sim (0.3-3)\cdot 10^{-3}$ GeV$^{-1/2}$. In this case no PWA of the data was performed as needed to decide whether or not a resonance occurs in a certain partial wave.

Such PWA was performed in Ref. [22]. A fit using only known broad resonances and standard background amplitudes can not describe the relatively narrow oscillating structure in the cross section in the mass region of 1660-1750 MeV. An improved description of the data can be reached by either assuming the existence of a narrow resonance at a mass of about 1700 MeV with small photo-coupling or by a threshold effect. In the latter case the observed structure is explained by a strong (resonant or non-resonant) $\gamma p \to \omega p$ coupling in the S_{11} partial wave. When the beam asymmetry data of Refs. [2,8] are included in the fit, the solution with a narrow P_{11} state is preferred. In that fit, mass and width of the putative resonance converge to $M \sim$1694 MeV and $\Gamma \sim 40$ MeV, respectively, and the photo-coupling to $\sqrt{{\rm Br}_{\eta N}}A^p_{1/2} \sim 2.6\cdot 10^{-3}$ GeV$^{-1/2}$.

In Table 1 we summarize *our estimates* of the properties of the narrow N* which can be extracted from the present data. The obtained values fit neatly to the predicted properties of the anti-decuplet N*. Future experiments, especially on double polarization neutron observables, will show whether an analogous Table will appear in PDG.

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