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# Observation of narrow $N^+(1685)$ and $N^0(1685)$ resonances in $\gamma N \to \eta\pi N$ reactions

V. Kuznetsov[+*1)], F. Mammoliti[*#], F. Tortorici[*#], V. Bellini[*#], V. Brio[*#], A. Gridnev[+], N. Kozlenko[+], G. Russo[*#], M. L. Sperduto[*#], V. Sumachev[+], C. Sutera[#]

[+]Petersburg Nuclear Physics Institute, 188300 Gatchina, Russia

[*]INFN – Sezione di Catania, I-95123 Catania, Italy

[#]Dipartimento di Fisica ed Astronomia, Università di Catania, I-95123 Catania, Italy

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The observation of a narrow structure at $W \sim \sim 1.68$ GeV in the $\gamma n \to \eta n$ excitation function at GRAAL, CBELSA/TAPS, LNS and A2@MAMI C [1–9] and in Compton scattering on the neutron $\gamma n \to \gamma n$ [10] (the so-called "neutron anomaly"), and two narrow structures at $W \sim 1.68$ GeV and $W \sim 1.72$ GeV in Compton scattering on the proton [11], in the precise data for the $\gamma n \to \eta n$ [12] and $\pi^- p \to \pi^- p$ [13] reactions may signal the existence of one ($N(1685)$) or two ($N(1685)$ and $N(1726)$) narrow nucleon resonances [14–19].

On the other hand, there are alternative interpretations of the "neutron anomaly" in terms of the specific interference of known wide resonances [20–24] or as the sub-threshold meson-nucleon production (cusp) [25, 26]. Although being questionable [27], the first assumption is widely discussed in literature.

The decisive identification of these experimental findings is a challenge for both theory and experiment. In the previous experiments the possible signal of $N(1685)$ was observed in so-called "formation" reactions in which the incoming particle interacts with the target nucleon and excites resonances. If $N(1685)$ does really exist, its signal should also be seen in multi-particle "production" reactions in which it would manifest itself as a peak in the invariant mass spectra of the final-state products. Possible reactions could be $\gamma N \to \pi\eta N$.

In this Letter, we report on the study of the $\gamma p \to \to \pi^0\eta p, \gamma p \to \pi^+\eta n, \gamma n \to \pi^0\eta n$, and $\gamma n \to \pi^-\eta p$ reactions using the data collected at the GRAAL facility [28].

Photons from $\eta \to 2\gamma$ and $\pi^0 \to 2\gamma$ decays and charged pions were detected in the BGO Ball. The recoil protons and neutrons emitted at forward angles $\theta_{\rm lab} \leq 25°$ were detected in the assembly of forward detectors. It consisted of two planar wire chambers, a thin scintillator hodoscope and a lead-scintillator wall.

At the first step of the data analysis $\eta$ and $\pi^0$ mesons were identified by means of the invariant masses of two properly chosen photons. Then the cuts on the proton and $\eta$ missing masses were applied.

At the second stage of the data analysis the cuts on the coplanarity and on the differences between the missing and invariant masses assuming two-body reactions with one real particle and one "effective" two-particle in the final state were imposed.

Given the goal of this work, only the events in the range of the energy of the incoming photon $E_\gamma = = 1.4 - 1.5$ GeV were selected for the further analysis. The lower limit of 1.4 GeV is close to the $\gamma N \to \pi N(1685)$ threshold. The upper value 1.5 GeV is the limit of the GRAAL beam and it also allows to avoid the contribution from higher-lying resonances. To eliminate the contamination of $\gamma N \to \eta\Delta$ events, the cuts on the invariant mass $1.12 \leq IM(\pi N) \leq 1.22$ GeV and the missing mass $MM(\gamma, \eta) \leq 1.22$ GeV were applied.

Fig. 1 shows the obtained $M(\eta N)$ spectrum (the sum of all reactions under study). There is a well pronounced peak at $\sim 1.68$ GeV. The Gaussian+3-order polynomial (signal-plus-background) fit results in the $\chi$-square of 23.9/23. The fit by 3-order polynomial (background) gives the $\chi$-square of 42.6/26. The log likelihood ratio of these two hypotheses ($\sqrt{2\ln(L_{B+S}/L_B)}$) corresponds to the confidence level of $4.6\sigma$.

The extracted peak position is $M = 1678 \pm 0.8_{\rm stat} \pm \pm 10_{\rm syst}$ MeV. The systematic uncertainty in the mass position originates from the uncertainties in the calibration of the GRAAL detector and tagger.

Our results support the existence of two narrow resonances, $N^+(1685)$ decaying, in particular, into $\eta p$ final state, and $N^0(1685)$ with one possible decay into $\eta n$ (i.e. the isospin-1/2 $N(1685)$ resonance). It is unclear

1)e-mail: Kuznetsov_va@pnpi.nrcki.ru

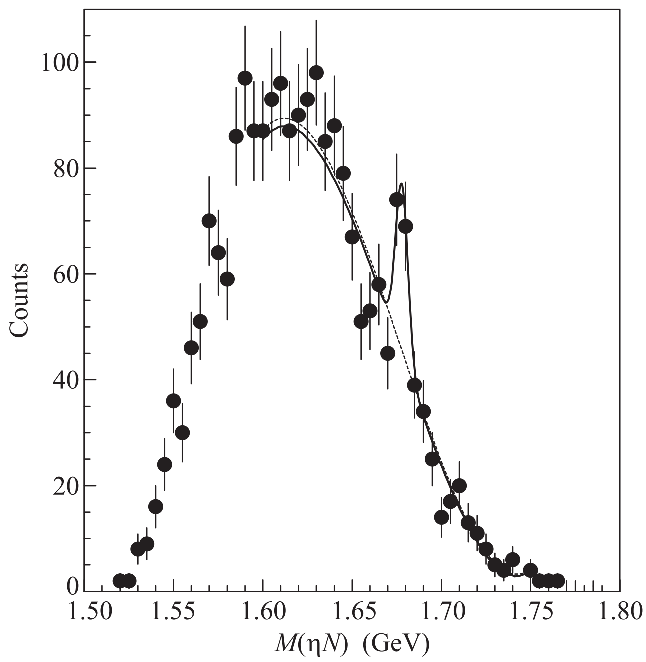


Fig. 1. Spectrum of extracted $M(\eta N)$ mass (sum of all channels) with corrections

if the interference of known wide resonances [20–24] or the cusp effect [25, 26] – two other hypotheses under discussion – could explain these results.

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