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C. Bacci(x), R. Baldini-Celio, B. Esposito, C. Mencuccini, A. Reale, G. Sciacca, M. Spinetti and A. Zallo : ANGULAR DISTRIBUTIONS FOR SINGLE NEUTRAL PION PHOTOPRODUCTION FROM NEUTRON AT 450-800 MeV.

In this paper we report on an experiment performed at the Frascati 1.1 GeV electron synchrotron on the photoproduction of single neutral pions from neutrons in deuterium

(1) $$\gamma + d \longrightarrow \pi^o + n + (p_{sp}) .$$

The differential cross section for the process (1) has been measured for five c.m. angles θ_π^* ranging from 60^o to 135^o at energies of the incident photon 450 - 800 MeV.

The purpose of this measurement is to add experimental information on the photoproduction of single pions on nucleons in the energy region between the first (P_{33}, 1236 MeV) and the second (D_{13}, 1518 MeV) resonance of the πN state where the presence of other πN states is a well established fact. In this energy region the reaction (1) has been so far scarcely investigated(1).

A study of this reaction compared with the other single pion photoproduction channels on proton and neutron, leads to useful informations on the relative contributions of the isoscalar and isovector parts of the $I = 1/2$ pion photoproduction amplitudes.

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In particular this experiment contributes to the question if the P_{11}(1470 MeV) resonance is photoproduced on neutrons while experimentally it seems that it is not photoproduced on protons[2]. Indications that the P_{11} resonance is photoexcited on neutrons come from the other photoproduction channel $\gamma n \rightarrow \pi^- p$[3, 5].
Our results, which are in fair agreement with the measurement performed at the Tokyo synchrotron[1], show that in the energy region of the second resonance the differential cross section for the process (1) is nearly equal to the cross section for the photoproduction of single neutral pions on protons

(2) $$\gamma + p \rightarrow \pi^o + p \, .$$

On the contrary, in the energy region 450 - 650 MeV, the cross section for the process (1) show a clear trend to be larger than the cross section for the process (2).

A comparison of our results with a phenomenological analysis[5] gives support to the conclusion that the P_{11} is photoexcited on neutron.

The experimental apparatus has been described in a previous paper[6] where we reported our results on the reaction

(3) $$\gamma + d \rightarrow \pi^o + p + (n_{sp}) \, .$$

as compared to the reaction (2) we measured on H_2 target. The reactions (1) and (3) has been measured at the same time.

Briefly, the γ-ray beam was incident on a cylindrical deuterium target and monitored by a Wilson type quantameter.

The π^o was detected by a total absorption lead-glass Cerenkov counter with a veto counter in front, whose aim was to detect the forward emitted γ-ray from the $\pi^o \rightarrow \gamma\gamma$ decay and to measure its energy. The recoil nucleon from reactions (1) and (3) was detected by a thick cylindrical NE 102 A scintillation counter S (30 cm in diameter and 30 cm thickness). A thin scintillation counter in front of S

allowed to identify whether the recoil nucleon was a proton or a neutron.

The neutron detection efficiency of the counter S is shown in Fig. 1 as a function of the neutron kinetic energy, as discussed in ref. (7).

For each event we recorded, by using a PDP 8 computer on-line, the following informations: the pulse height of the Cerenkov counter, the time of flight of the nucleon over a basis of the order of 7 m, and the pulse heights of the scintillation counters of the nucleon telescope.

The detection efficiency of the apparatus for the reactions (1) and (3) has been calculated by the Monte Carlo method taking into account all the details of the experimental set-up. In this calculation the validity of the spectator model and the Hulthèn wave function for the momentum distribution of the nucleons in the target have been assumed.

The data reduction procedure has followed the same lines as in ref. (6).

The contamination from the multiple pion photoproduction experimentally comes out to be negligible.

The contamination from the Compton effect has been evaluated assuming equal cross sections for proton and neutron. A small $[(2-8)\%]$ energy dependent contribution has been found and properly subtracted.

The experimental data are presented as a function of $E^{*}_{\pi N}$, the total c. m. energy of the pion-nucleon final state system or as a function of E'_{γ} (E'_{γ} being the incident photon energy which gives on free nucleon a total c. m. energy equal to $E^{*}_{\pi N}$: $E'_{\gamma} = (E^{*2}_{\pi N} - M^{2}_{N})/(2M_{N})$). Because of the Fermi motion of the target nucleon, for a fixed energy of the outcoming nucleon, E'_{γ} was determined with a resolution of the order of $\pm$ 60 MeV. The angular resolution in the c. m. s. was about $\pm 7^{o}$.

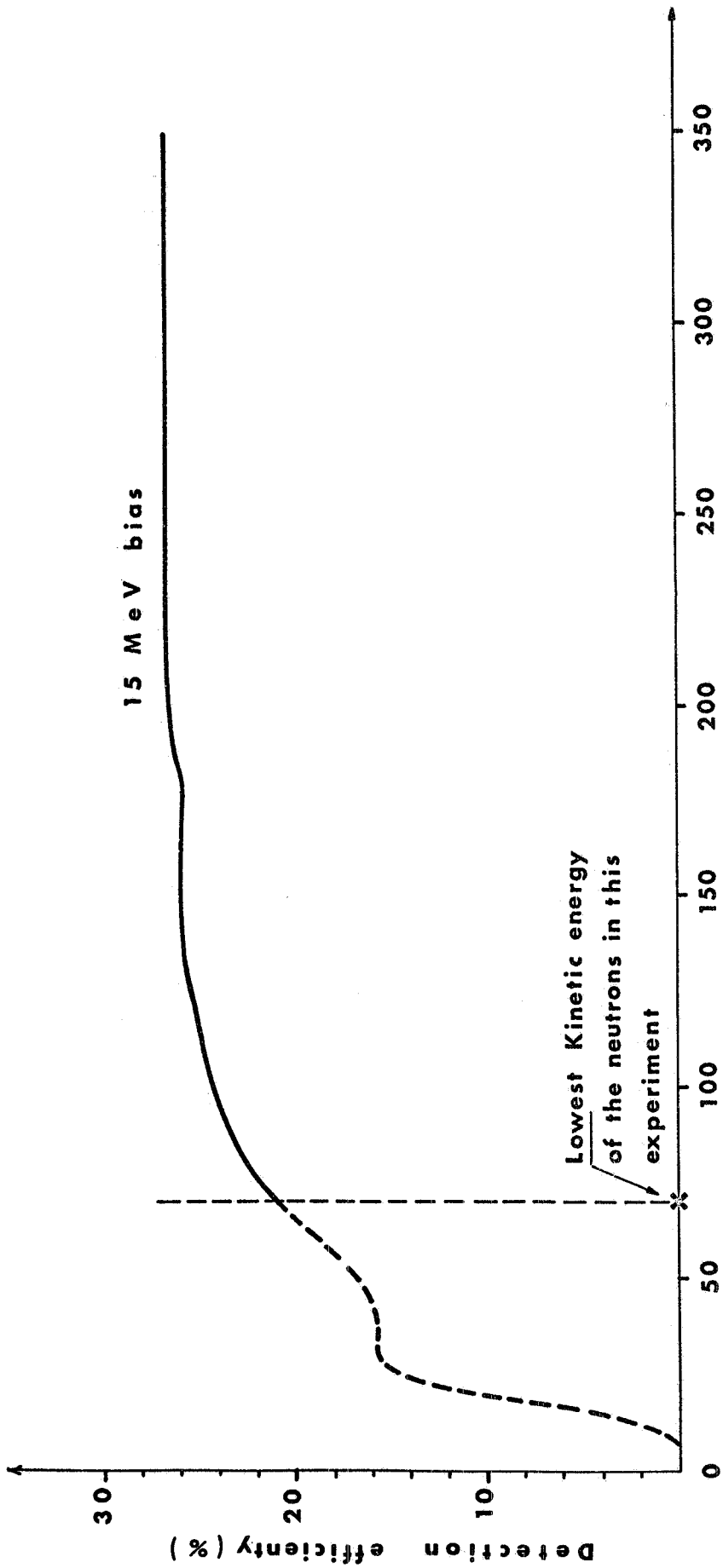

FIG. 1 - Detection efficiency of the neutron counter versus neutron kinetic energy[7] with a bias of 15 MeV equivalent proton energy.

We show in Fig. 2 and in Table I, for different angles and as a fucntion of the energies $E^*_{\pi N}$ and E'_γ, the ratio:

$$R = \frac{d\sigma}{d\Omega^*}\left[\gamma d \to \pi^o n(p_{sp})\right] \Big/ \frac{d\sigma}{d\Omega^*}\left[\gamma d \to \pi^o p(n_{sp})\right]$$

All the errors quoted are statistical only. By making the ratio between the cross sections, many systematic errors cancel each other, as well as corrections for final state effects. We evaluate ± 15 % the total systematic error on the cross sections (10% being the error on the detection efficiency we assume for the neutron detector).

In Fig. 3 the absolute values of:

$$\frac{d\sigma}{d\Omega^*}\left(\gamma n \to \pi^o n\right)$$

are reported as a function of the c.m. pion angle $\theta^*_{\pi^o}$, for five different energies E'_γ. We have extracted the free neutron cross sections by applying to the data from the neutron bound in deuterium the correction factor coming from our measurements of ref. (6), where final state interaction effects in deuterium were investigated.

As one can see from Fig. 2, the π^o photoproduction on neutron is larger than the π^o photoproduction on proton in the energy region 450 - 650 MeV. This indicates an appreciable contribution of the isoscalar part in the photoproduction amplitude.

We have reported in Fig. 3 theoretical predictions on the absolute value of the cross section, averaged on our energy resolution ($\pm$ 60 MeV). The curves a) and b), by Proia and Sebastiani[5,4], are predictions on reaction (1) starting from a multipoles analysis of π^o and π^+ photoproduction reaction on proton[8] and from the data on π^- photoproduction of references (3) and (10) respectively. The curve c) is a prediction starting from the amplitudes of Walker analysis[9]. The main difference of the two predictions is that curve a) implies a large contribution of the $P_{11}(1470)$ which is not present in curves b) and c).

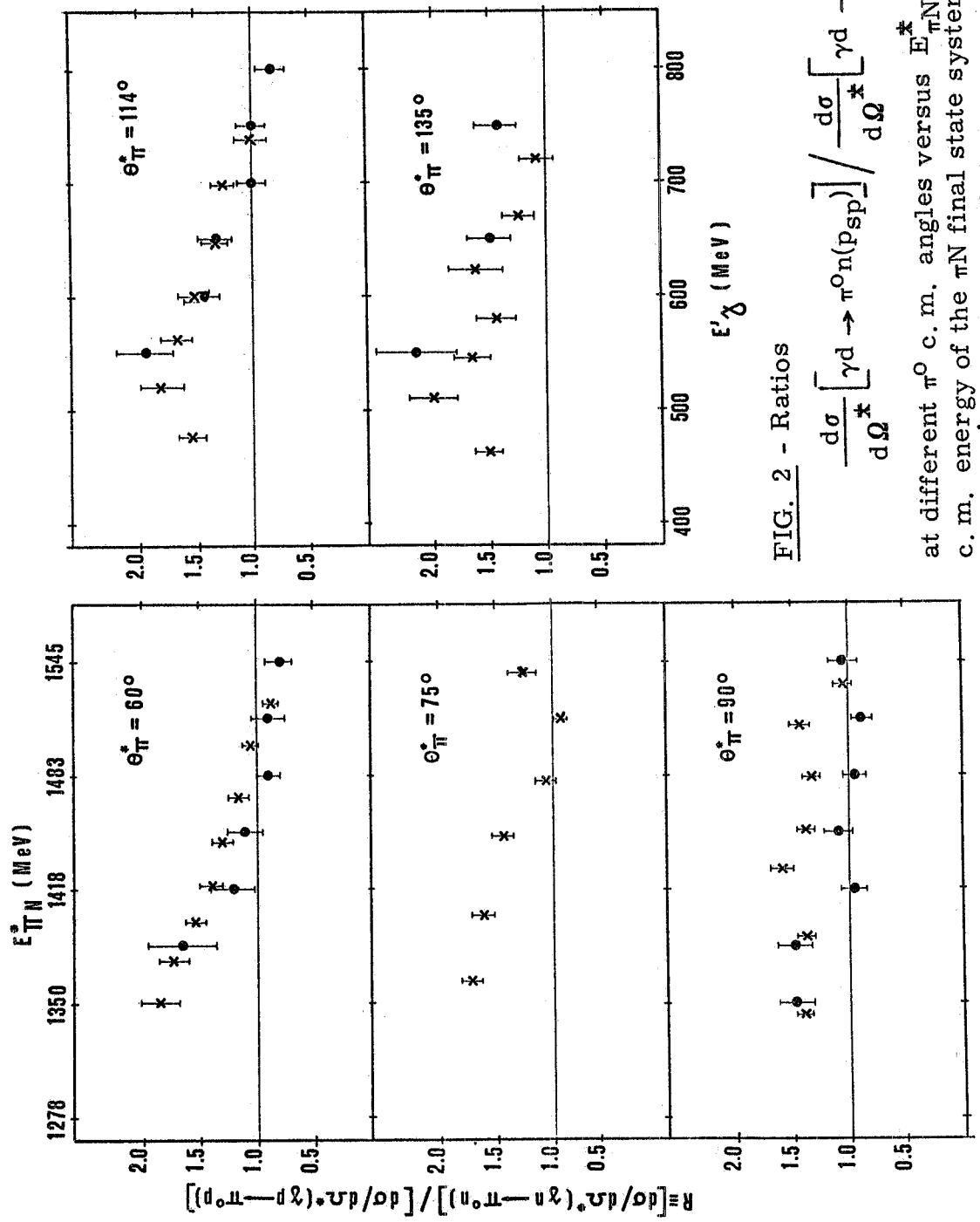

FIG. 2 - Ratios

$$\frac{d\sigma}{d\Omega^*}\left[\gamma d \rightarrow \pi^o n(p_{sp})\right] \Big/ \frac{d\sigma}{d\Omega^*}\left[\gamma d \rightarrow \pi^o p(n_{sp})\right]$$

at different π^o c. m. angles versus $E^*_{\pi N}$, the total c. m. energy of the πN final state system, and also versus E'_γ, the incident photon energy which gives on free nucleon a total c. m. energy $E^*_{\pi N}$.

‡ this experiment; ⧫ Ref. (1).

$\theta^*_{\pi^0}$ / E'_γ MeV	60°			75°			90°			114°			135°		
	1/r	dσ/dΩ* (μb/sr)	R	1/r	dσ/dΩ* (μb/sr)	R	1/r	dσ/dΩ* (μb/sr)	R	1/r	dσ/dΩ* (μb/sr)	R	1/r	dσ/dΩ* (μb/sr)	R
462													1.10	6.82 ±0.38	1.51 ±0.12
476										1.25	6.95 ±0.44	1.54 ±0.12			
495	1.27	8.10 ±0.57	1.85 ±0.17				1.27	8.99 ±0.35	1.40 ±0.07						
515				1.22	8.62 ±0.26	1.72 ±0.09				1.23	6.11 ±0.47	1.81 ±0.18	1.15	5.03 ±0.40	2.00 ±0.21
541	1.22	5.94 ±0.34	1.73 ±0.13										1.18	3.79 ±0.29	1.66 ±0.16
560							1.19	5.60 ±0.24	1.38 ±0.08	1.22	4.66 ±0.24	1.67 ±0.14			
576	1.19	4.46 ±0.19	1.54 ±0.09	1.15	5.30 ±0.16	1.62 ±0.10							1.19	2.98 ±0.30	1.44 ±0.17
601	1.16	3.67 ±0.20	1.40 ±0.10							1.19	3.75 ±0.29	1.52 ±0.15			
620							1.14	4.94 ±0.24	1.59 ±0.10				1.19	3.06 ±0.36	1.62 ±0.24
647	1.14	2.91 ±0.15	1.30 ±0.09	1.11	3.56 ±0.16	1.44 ±0.09	1.11	3.90 ±0.18	1.38 ±0.08	1.15	3.06 ±0.22	1.33 ±0.12			
676	1.12	2.54 ±0.13	1.16 ±0.09										1.18	2.67 ±0.24	1.20 ±0.14
697				1.09	2.85 ±0.17	1.06 ±0.09	1.08	3.95 ±0.17	1.33 ±0.08	1.12	3.12 ±0.20	1.26 ±0.10			
723	1.10	2.64 ±0.13	1.05 ±0.07										1.15	2.47 ±0.23	1.08 ±0.15
743				1.06	3.13 ±0.14	0.93 ±0.06	1.06	3.28 ±0.14	1.43 ±0.09	1.10	2.84 ±0.35	1.01 ±0.14			
763	1.09	2.32 ±0.13	0.87 ±0.07												
784				1.05	3.42 ±0.23	1.26 ±0.13	1.05	3.21 ±0.16	1.05 ±0.08						

TABLE I - Experimental values of the differential cross section of reaction (1), and of ratio R, versus E'_γ, for five π^0 c. m. angles. The absolute values of the cross sections have been multiplied by the factor 1/r listed above to take into account the deuterium corrections, as discussed in ref. (6).

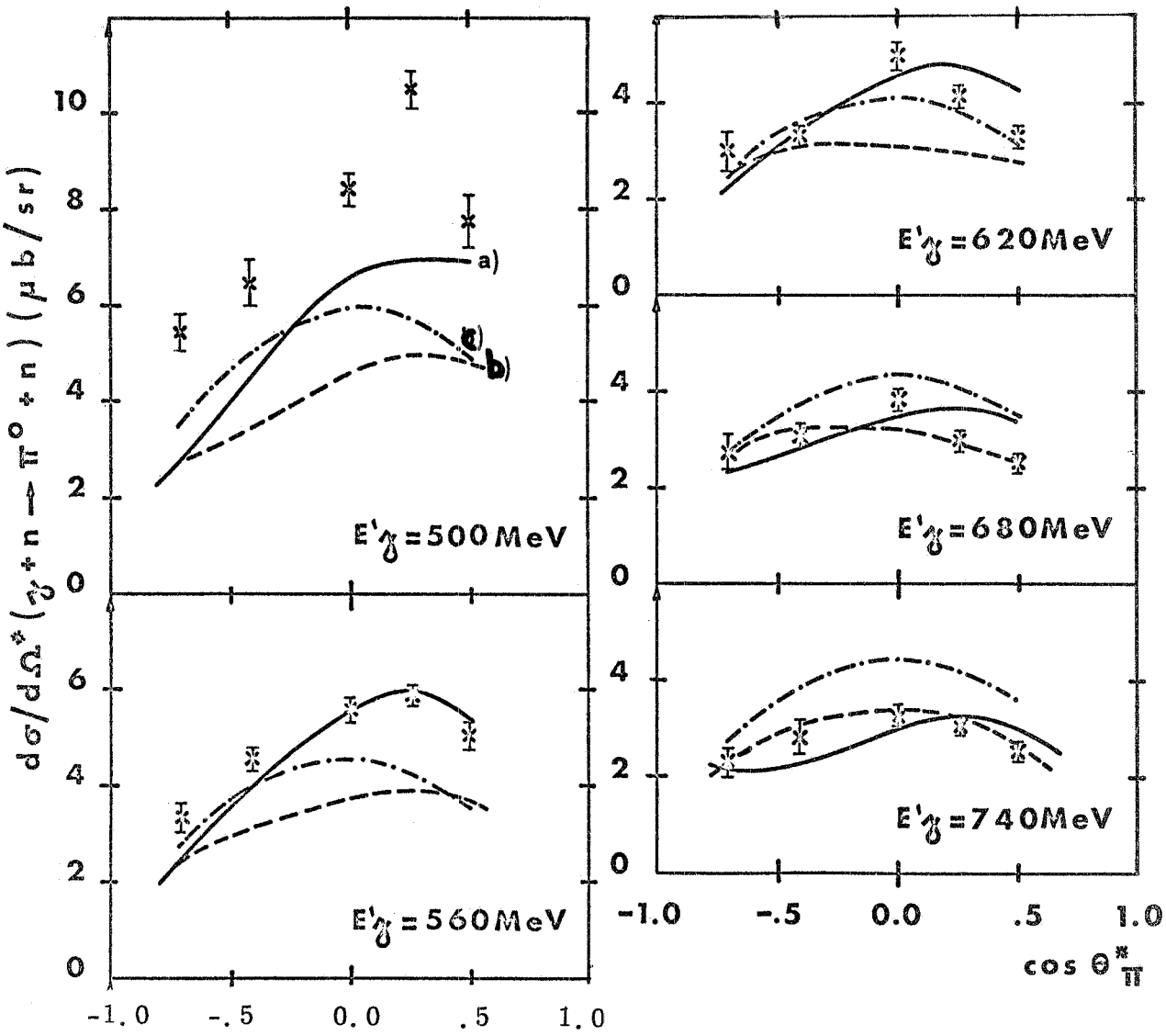

FIG. 3 - Differential cross-sections of the reaction $\gamma n \rightarrow \pi^{o} n$ for different values of E'_{γ}, versus $\cos \theta^{*}_{\pi}$.
The superimposed curves come:

a) from ref. (5) ;
b) from ref. (4) ;
c) from ref. (9) .

Our results, together with the π^- results[3] seem to favour the hypothesis of an appreciable presence of the $P_{11}(1470)$ in the neutron photoexcitation.

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