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ANGULAR DISTRIBUTIONS FOR SINGLE NEUTRAL PION PHOTOPRODUCTION FROM NEUTRONS AT 450-800 MeV

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Differential cross sections for single photoproduction of neutral pion on neutron have been measured at different c.m. angles for photon energies, between 450 - 800 MeV.
The results are compared with the existing theories and seem to favour the hypothesis of an appreciable presence of the P_{11} (1470) in the neutron photoexcitation.

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

$$\gamma + d \rightarrow \pi^0 + n + (p_{sp}). \quad (1)$$

The differential cross section for the process (1) has been measured for five c.m. angles θ_π^* ranging from 60° to 135° 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 so far scarcely been investigated [1].

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

In particular this experiment contributes to the question whether 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 synchroton [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

$$\gamma + p \rightarrow \pi^0 + p. \quad (2)$$

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 neutrons.

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

$$\gamma + d \rightarrow \pi^0 + p + (n_{sp}). \quad (3)$$

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^0 was detected by a total absorption lead-glass Čerenkov counter with a veto counter in front, whose aim was to detect the forward emitted γ-ray from the $\pi^0 \rightarrow \gamma\gamma$ 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 us to identify whether the recoil nucleon was a proton or a neutron.

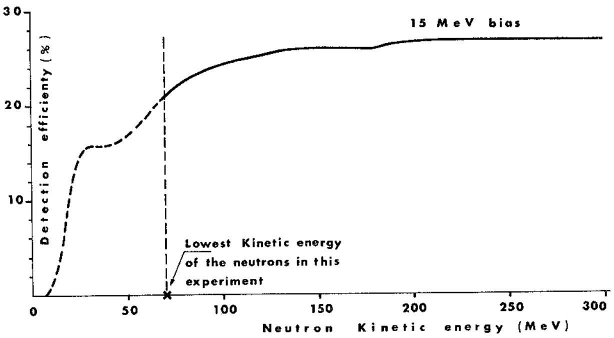

Fig. 1. Detection efficiency of the neutron counter versus neutron kinetic energy [7] with a bias of 15 MeV equivalent proton energy.

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 information: the pulse height of the Čerenkov counter, the time of flight of the nucleon over a base 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 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 a 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 outgoing nucleon E'_γ was determined with a resolution of the order of ± 60 MeV. The angular resolution in the c.m.s. was about ±7°.

We show in fig. 2 and in table 1, for different angles and as a function of the energies $E^*_{\pi N}$ and E'_γ, the ratio :

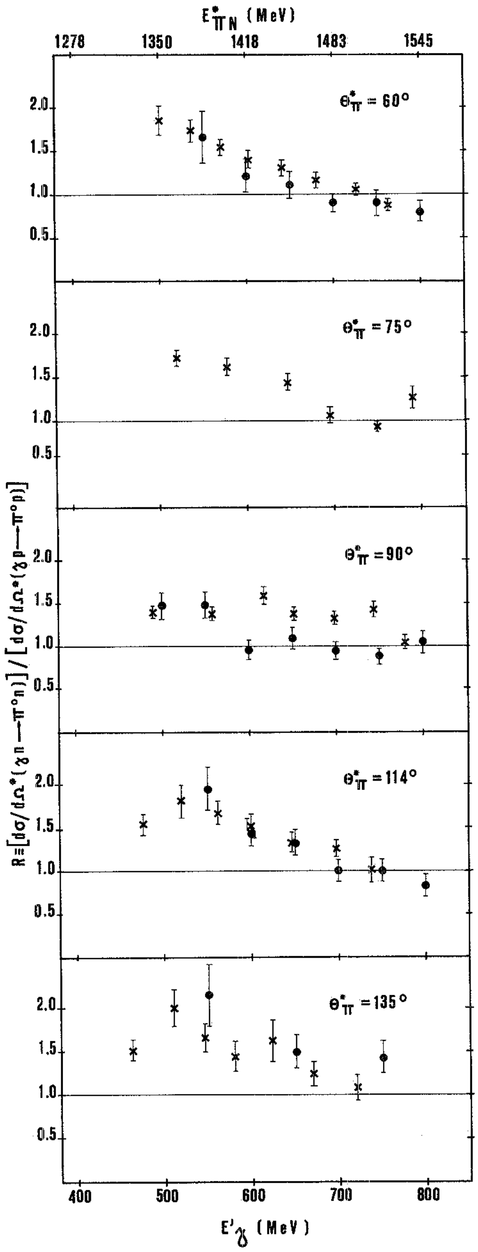

Fig. 2. Ratios $R = d\sigma/d\Omega^* [\gamma d \to \pi^0 n(p_{sp})] / d\sigma/d\Omega^* [\gamma d \to \pi^0 p(n_{sp})]$ at different π^0 c.m. angles versus $E^*_{\pi N}$, the total c.m. energy of the πN final state system, and also versus E'_γ, the incident photon energy which gives on free nucleon a total c.m. energy $E^*_{\pi N}$. ⫱ this experiment; ⧲ ref. [1].

$$R = \frac{d\sigma}{d\Omega^*}[\gamma d \to \pi^0 n(p_{sp})] \Big/ \frac{d\sigma}{d\Omega^*}[\gamma d \to \pi^0 p(n_{sp})].$$

All the errors quoted are statistical only. By

Table 1

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 $1/r$ to take into account the deuterium corrections, as discussed in ref. [6].

$\theta^*_{\pi^0}$	60°			75°			90°			114°			135°		
E'_γ MeV	$1/r$	$d\sigma/d\Omega^*$ (μb/sr)	R	$1/r$	$d\sigma/d\Omega^*$ (μb/sr)	R	$1/r$	$d\sigma/d\Omega^*$ (μb/sr)	R	$1/r$	$d\sigma/d\Omega^*$ (μb/sr)	R	$1/r$	$d\sigma/d\Omega^*$ (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						

taking the ratio between the cross sections, many systematic errors cancel each other, as well as corrections for final state effects. We estimate ± 15% for the total systematic error on the cross sections (10% being the error in the detection efficiency we assumed for the neutron detector).

In fig. 3 the absolute values of: $d\sigma/d\Omega^*$ ($\gamma n \rightarrow \pi^0 n$) are shown as a function of the c.m. pion angle $\theta^*_{\pi^0}$, 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^0 photoproduction on neutrons is larger than the π^0 photoproduction on protons in the energy region 450 - 650 MeV. This indicates an appreciable contribution of the isoscalar part in the photoproduction amplitude.

We have shown in fig. 3 theoretical predictions on the absolute value of the cross section, averaged on our energy resolution (± 60 MeV). The curves a) and b), by Proia and Sebastiani [5,4], are predictions on reaction (1) starting from a multipole analysis of π^0 and π^+ photoproduction reactions on protons [8] and from the data on π^- photoproduction of refs. [3] and [10], respectively. The curve c) is a prediction starting from the amplitudes of Walker's analysis [9]. The main difference between the two predictions is that curve a) implies a large contribution of the

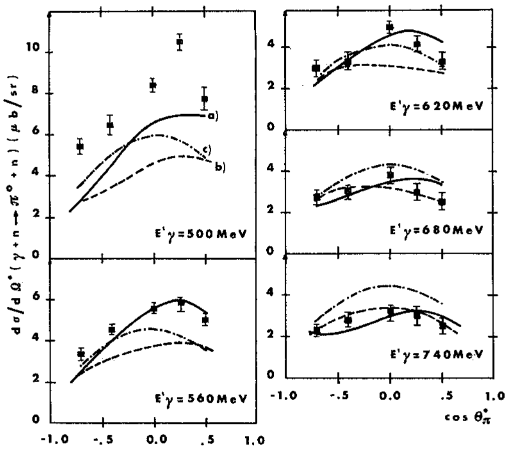

Fig. 3. Differential cross-sections of the reaction $\gamma n \rightarrow \pi^0 n$ for different values of E'_γ, versus cos θ^*_π. The superimposed curves come : a) from ref. [5]; b) from ref. [4] ; c) from ref. [9].

P_{11}(1470) which is not present in curves b) and c).

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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