C. Bacci, R. Baldini-Celio, B. Esposito, C. Mencuccini, A. Reale, G. Sciacca, M. Spinetti and A. Zallo : NEUTRAL PION PHOTOPRODUCTION ON PROTON FROM DEUTERIUM IN THE ENERGY RANGE 400-800 MeV.

C. Bacci[x], R. Baldini-Celio, B. Esposito, C. Mencuccini, A. Reale, G. Sciacca, M. Spinetti and A. Zallo: NEUTRAL PION PHOTOPRODUCTION ON PROTON FROM DEUTERIUM IN THE ENERGY RANGE 400÷800 MeV. -

In this paper we report an experiment performed at Frascati 1,1 GeV electronsynchrotron on the photoproduction of π^0 mesons on proton from hydrogen and deuterium

$$(1) \qquad \gamma + p \rightarrow \pi^0 + p$$

$$(2) \qquad \gamma + d \rightarrow \pi^0 + p + (n_s)$$
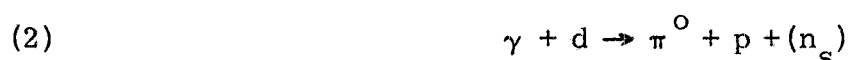
The differential cross section for reaction (1) has been measured by detecting both the proton and the forward emitted photon from the π^0 decay, in the energy range of the incident photon $E_\gamma = 400 \div 800$ MeV, at three different angles in the center of mass system (c.m.s.) $\theta_\pi^x = 60^0$, 90^0 and 135^0. As far as reaction (2) is concerned we have mantained the same experimental conditions chosen for the reaction (1) only refilling the same target with deuterium instead of hydrogen.

In this case the spectator neutron (n_{sp}) was not detected.

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The main purpose of this experiment is to compare the cross section for process (2) with the cross section for a free proton i.e. process (1). This comparison is essentially a test on the validity of the "impulse approximation" by which people generally analyze the photoproduction on deuterium.

Actually the experimental situation on the impulse approximation is not completely clear due to the lack of experimental data, expecially for the π^{o} photoproduction[1]. For the π^{+} photoproduction the experimental data show a deviation from the impulse approximation predictions of the order of $(5 \div 10)\%$[2]. Our results show that, sticking to the spectator model, sensible discrepancies appear in the π^{o} photoproduction on bound proton in deuterium.
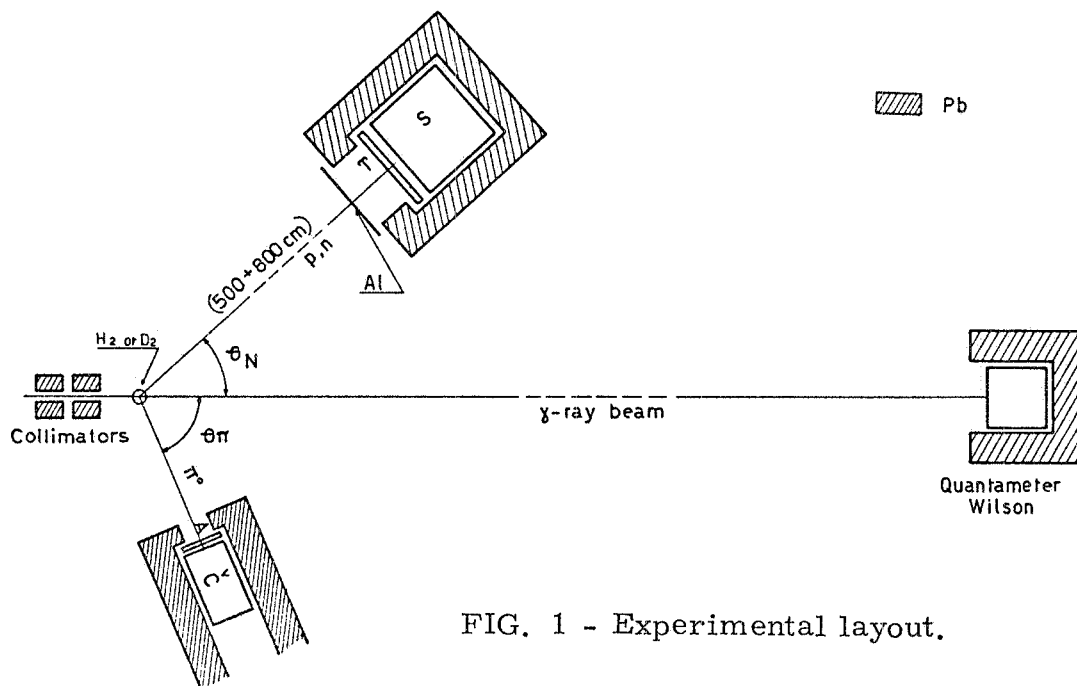
The experimental set up is shown in Fig. 1.

FIG. 1 - Experimental layout.

The γ ray beam was incident on a cylindrical liquid hydrogen or deuterium target, 7 cm in diameter, and was monitored by a Wilson type quantameter[3].

The recoil protons from reactions (1) and (2) were detected by a proton telescope consisting in a thin (1 cm thickness) scintillation counter T, followed by a thick cylindrical (30 cm thickness, 30 cm in diameter), scintillator, S.

The π^{o} was detected by a cylindrical total absorption lead glass Cerenkov counter C (15 cm in diameter, 25 cm thickness) detecting the forward emitted γ ray. In front of it a veto scintillation counter A was used to reject charged particles.

For each event we recorded, using a PDP8 computer on-line, the pulse heights in the T, S and C counters and the time-of-flight of the proton on a 5÷8 meters basis. The time-of-flight resolution was ∼1 ns F.W.H.M.

The photon energy resolution of our Cerenkov was about 16% at 500 MeV.

The bidimensional spectra of the S and T pulse heights allowed to eliminate completely the pion background in the proton telescope.

In order to know the correct number of protons in the angular region covered by the telescope and their right kinetic energy, corrections have been made for the nuclear interactions, the multiple scattering and the energy loss of the protons along their path. A small correction in the time of flight due to different pulse heights in the S counter has been also made.

In order to evaluate the differential cross sections from the yield, the detection efficiency of the apparatus has been calculated by the Monte Carlo method.

As far as reaction (2) is concerned we have assumed the validity of the spectator model[4] and a momentum distribution of the target nucleons following the Hulthen wave function.

In our conditions the detection efficiency drops down rapidly for momenta of the target nucleons greater than 150 MeV/c. It is worth while noting, that, within the accuracy of our measurement, the efficiency does not depend on the various deuterium wave functions usually considered (Hulthen, Gaussian, Hulthen-Gartenhaus).

The contamination due to multiple pion photoproduction comes out to be negligible. This was checked moving the upper end of the bremsstrahlung spectrum. For each angle the experimental cross sections for process (1) were compared with the already published results[6].

The agreement we obtained made us confident that no serious systematic error was present in our measurement.

When comparing processes (1) and (2) we have fixed the same c.m. energy $E^x_{\pi p}$ of the pion-proton final state[5] system. Because of the Fermi motion, for a fixed energy of the outcoming proton, $E^x_{\pi p}$ was determined, around its average value, with a resolution of the order ±60 MeV. When using hydrogen as a target the energy resolution was of the order of ±15 MeV.

In order to get the cross section for the process (1) and (2) we have subtracted the contamination (∼5%) due to the Compton effect which was undistinguishable in our apparatus.

4.

We report in Table I and Figure 2 for different angles and as a function of $E^x{}_{\pi p}$ and E'_γ the ratio

$$r = (\frac{d\sigma}{d\Omega^x})(\ \gamma D \rightarrow \pi^\circ pn_s)/(\frac{d\sigma}{d\Omega^x})(\ \gamma p \rightarrow \pi^\circ p)$$

The measurements on hydrogen have been averaged on the same energy intervals as for deuterium, to take into account the different energy re solutions in the two cases.

TABLE I

$\theta_\pi^x = 60^\circ$		$\theta_\pi^x = 90^\circ$		$\theta_\pi^x = 135^\circ$	
E'_γ	r	E'_γ	r	E'_γ	r
505	0.78 ± 0.07	430	0.82 ± 0.03	471	0.93 ± 0.06
559	0.84 ± 0.07	476	0.84 ± 0.03	520	0.87 ± 0.07
606	0.85 ± 0.05	508	0.77 ± 0.03	556	0.81 ± 0.06
658	0.79 ± 0.05	547	0.85 ± 0.03	596	0.82 ± 0.07
701	0.83 ± 0.05	591	0.84 ± 0.04	644	0.77 ± 0.08
733	0.98 ± 0.06	623	0.77 ± 0.04	683	0.90 ± 0.08
773	1.08 ± 0.11	667	0.91 ± 0.05	736	0.81 ± 0.09
		710	0.86 ± 0.05		
		738	0.90 ± 0.07		

The errors quoted are statistical only. We are confident that by making the ratio of the cross sections, many of the possible systematic errors cancel each other.

A deviation from 1 for the ratio r is evident in our data.

The curves which have been drawn in Fig. 2 are a theoretical evaluation which has been made[7] of this ratio by taking into account
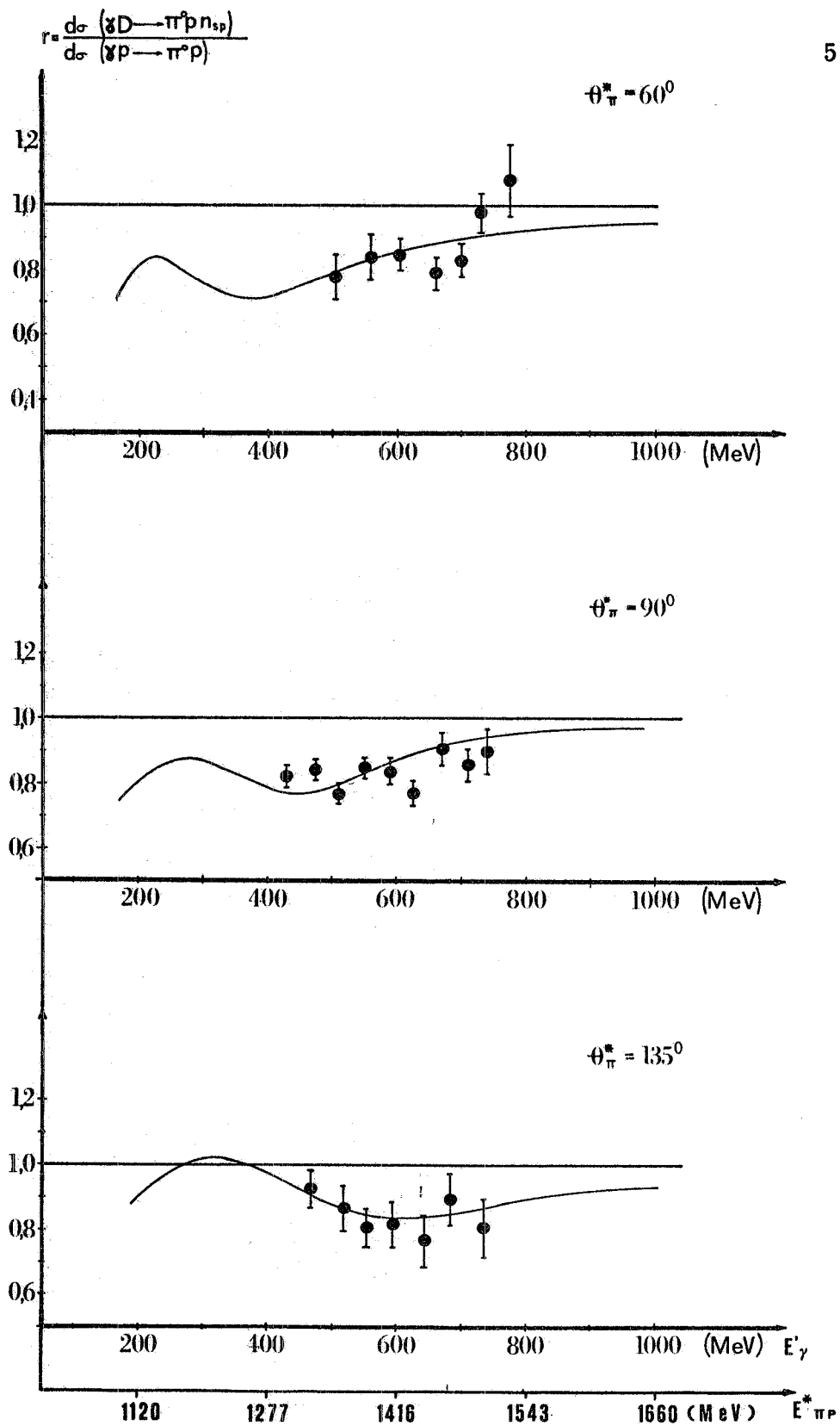
FIG. 2 - Ratio $r \equiv \dfrac{d\sigma}{d\Omega^x}(\gamma\, D \rightarrow \pi^{0}p(n_{sp}))/\dfrac{d\sigma}{d\Omega^x}(\gamma\, p \rightarrow \pi^{0}p)$ at different π^{0} c.m. angles versus $E^x_{\pi p}$, the total c.m. energy of the $\pi^{0}p$ final state system and also versus E'_{γ}, the incident photon ener gy which gives on free proton a total c.m. energy $E^x_{\pi p}$.

the scattering of the outcoming pion and proton with the neutron, and the contribution to the π^o photoproduction by charge exchange effects.

These curves are in a good agreement with our data so that one could conclude that the deviation from 1 of the ratio could be interpreted as a final state interaction effect.

The observed deviations for the π^o photoproduction are not un consistent at our energies with the π^+ case if isotopic spin arguments for the interactions of the outcoming pion, and the Pauli principle for the nucleons interactions are properly taken into account.

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