C. Bacci, R. Baldini-Celio, C. Mencuccini, A. Reale, M. Spinetti and A. Zallo : PHOTOPRODUCTION OF THE ETA MESON ON DEUTERIUM. -

LNF-69/9

C. Bacci[(x)], R. Baldini-Celio, C. Mencuccini, A. Reale, M. Spi-
netti and A. Zallo: PHOTOPRODUCTION OF THE ETA MESON ON
DEUTERIUM.

In this paper we report on an experiment performed at the Fra
scati 1.1 GeV electron synchrotron on the inelastic photoproduction
of the eta meson on deuterium

(1) $$\gamma + d \rightarrow \eta + (p, n).$$

The differential cross section for the process (1) has been mea
sured for different c. m. angles, at two photon energies around 850 MeV.
The overall energy resolution of the incident gamma beam was $\pm$ 35 MeV.

The purpose of the experiment is to make a direct comparison
of the eta photoproduction cross sections for deuterium and for hydro-
gen[1]. A study of these two reactions can lead to information on the re
lative properties of photoproduction from protons and neutrons from
which the relative contribution of the isoscalar and isovector parts of

(x) - Istituto Nazionale di Fisica Nucleare, Sezione di Roma, Roma
        (Italy).

the eta photoproduction amplitudes may be deduced.

Our results show that, within the accuracy of the measurements, the ratio of the cross section for the process (1) and the cross section for the photoproduction on free protons is about two and does not depend upon angle. This result indicates that the neutron and proton cross sections are quite similar and consistent with a center-of-mass angular distribution that is essentially isotropic.

The experimental set-up is shown schematically in Fig. 1. It is the same that we have used in a previous measurement on eta photoproduction in hydrogen[1].

The γ-ray beam was incident on a cylindrical deuterium target, 7 cm in diameter. The η's from reaction (1) were detected by measuring the angles and energies of both photons of the two photon decay mode.

Two pairs of photon detectors (each composed of a lead-glass total-absorption Cerenkov counter preceded by a veto scintillation counters) were used in order to increase the collection rate and to reduce possible sources of systematic errors.

The kinematical definition of the events from reaction (1) is given by the opening angle between the photon detectors and the energy maximum of the bremsstrahlung spectrum.

For each kinematical condition the detection efficiency of the apparatus was determined by a Monte Carlo calculation in which the measured energy resolution of the photon detectors and the Fermi motion of the target nucleons were properly taken into account.

The background, mainly due to multiple π^0 production, was measured by changing slightly the geometry of the apparatus in such a way to exclude the detection of η-events, but at the same time maintaining the same angle of each photon detector with respect to the γ-ray beam line. Since a strong correlation between the energies of the two detected photons is not expected for the background, we believe that this procedure can be used directly for a proper background subtraction. This method was successfully applied in our previous experiment on eta photoproduction in hydrogen[1].

Our results on the differential cross section for deuterium are shown in Fig. 2. In this same figure earlier results[1,2] on hydrogen at the same incident γ-rays energies are shown for comparison. The deuterium points refer to the γ-nucleon center-of-mass system.

The errors quoted are inclusive of the uncertainties in the background subtraction. In addition there are systematic errors due to un-
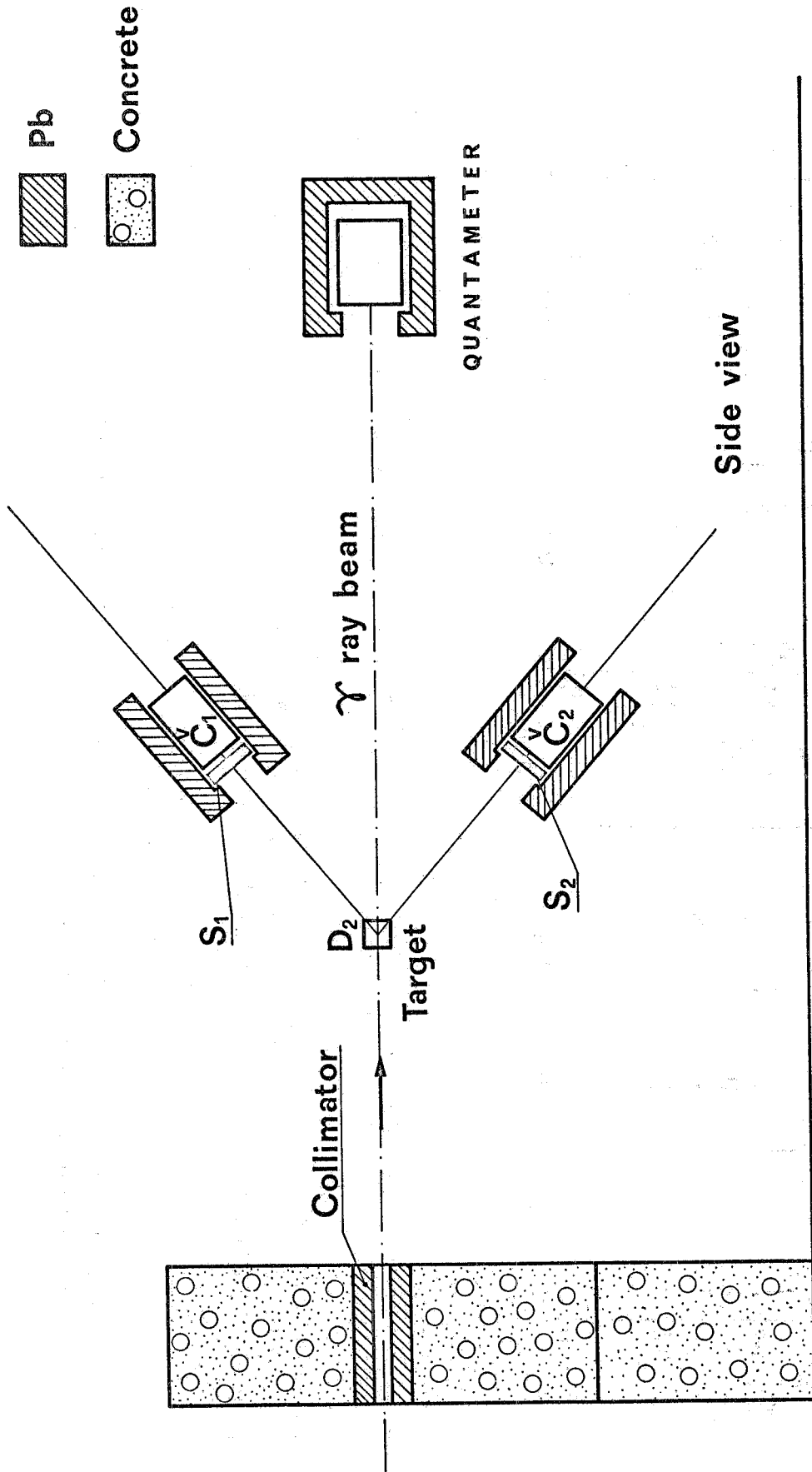
FIG. 1 - Schematic drawing of the experimental set-up; C_1 and C_2 are two lead glass Cerenkov counters; S_1 and S_2 veto scintillation counters. Each photon detector covers a typical laboratory solid angle of 12 msr. A Wilson type quantameter[8] was used.
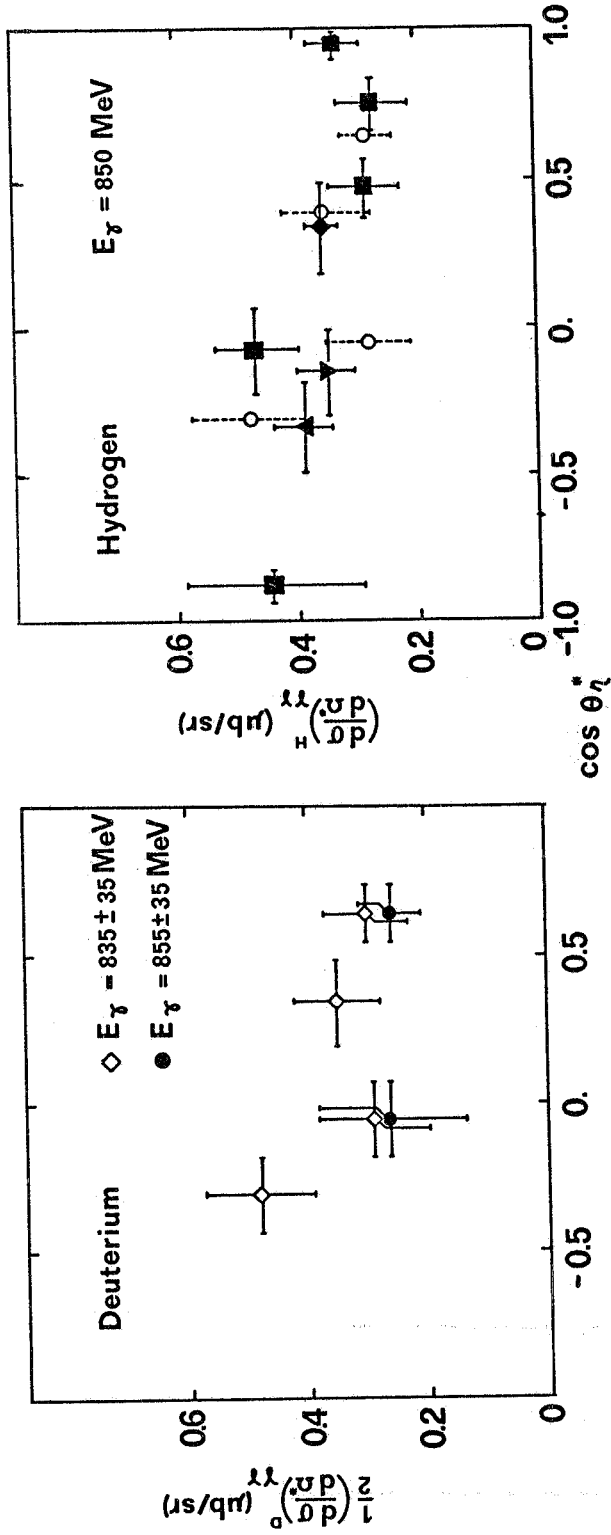
4.

FIG. 2 - Experimental results for $(d\sigma/d\Omega_\eta^*)$ $(\eta \longrightarrow \gamma\gamma)$ per nucleon in deuterium (upper points) and in hydrogen (lower points) as function of θ_η^* (η angle in the γ-nucleon c.m.s.) E_γ is the average energy of the incident photons. The points indicated with ■ are our results at $E_\gamma = 850 \pm 25$ MeV (A better determination of the efficiency has produced some difference in our results on hydrogen reported in ref. (1)). The points indicated with ▲ , ▼ and ◇ are from C. Bacci et al.; R. Pre post et al.; E. D. Bloom et al. respectively(2), for which we have assumed the latest world avera-ge(9) :

$$\frac{\Gamma\ (\eta \longrightarrow \text{all modes})}{\Gamma\ (\eta \longrightarrow \gamma\gamma)} = 0.26 \ .$$

For a comparison in the right part of the figure we have reported also an average of our experimental data on deuterium (open circle).

certainties in the quantameter calibration, shape of the bremsstrah-
lung spectrum near the maximum energy etc., which are not included.
This gives an overall systematic error of $\pm$ 10%. Note that a better de
termination of the efficiency has resulted in some difference in the
values reported for hydrogen in reference (1). The angular resolution
is shown by the horizontal error bars.

We observed from Fig. 2 that the differential cross sections
for hydrogen and for deuterium do not show a significant departure
from isotropy. Furthermore, the photoproduction rate per nucleon
for deuterium turns out to be equal to the rate for hydrogen.

The analysis of the experimental results has been carried out
by making use of the impulse approximation, which states, essential
ly, that the transition amplitudes for each of the two nucleons in the
deuteron target are linearly superposable[3].

In this approximation the differential cross section elastic plus
inelastic is given approximately by[3]:

$$(2) \qquad (\frac{d\sigma}{d\Omega^*})_D \varpropto A_p^2 + A_n^2 + 2\,\mathrm{Re}\,(A_p A_n^*)\,I\,(2\underline{\Delta})$$

where $A_p (A_n)$ is the amplitude for η production on free proton (neu-
tron) and $I(\underline{\Delta}) = \int \psi_D^2 \exp(2\,i\,\underline{\Delta}\cdot\underline{R})\,d^3\underline{R}$ is the deuteron form fac-
tor ($\underline{\Delta} = 1/2\,(\underline{k} - \underline{q})$ and where $\underline{k}$, $\underline{q}$ are the photon and η meson labo
ratory momenta, respectively). Due to the magnitude of the form fac
tor, the last term in (2) is small ($< 10\%$) for all of our kinematical
conditions. On the other hand the elastic part ($\gamma + d \to \eta + d$) of the
cross section is given by $(d\sigma/d\Omega^*)_{el} \varpropto |A_p + A_n|^2\,I^2\,(\underline{\Delta})$ and, as the
form factor is squared it turns out to be negligible at our values of
$\underline{\Delta}$. As a consequence, our measurement essentially determines the
inelastic part of $(d\sigma/d\Omega^*)_D$ in which the interference term is negligi
ble.

Now in order to interprete the observed cross section for deu
terium in terms of those for free nucleons one has to consider η re-
scattering and absorption effects. On the basis of a measurement on
inelastic η photoproduction on various nuclei that we have made using
the same apparatus[4], we are led to the conclusion that this correction
is small. Additional evidence for the assumption that rescattering and
absorption effects at our energy are negligible comes from a compari-
son of pion-nucleon scattering on hydrogen and deuterium[5]. Then:

$$(\frac{d\sigma}{d\Omega^*})_D \simeq A_p^2 + A_n^2 = (\frac{d\sigma}{d\Omega^*})_p^{free} + (\frac{d\sigma}{d\Omega^*})_n^{free}$$

In conclusion, our experimental result at $E_\gamma \simeq 850$ MeV/i. e. :

6.

$$\left(\frac{d\sigma}{d\Omega^{*}}\right)_{D} / \left(\frac{d\sigma}{d\Omega^{*}}\right)_{p}^{free} \simeq 2$$

which is approximately independent of angle therefore indicates that:

$$\left(\frac{d\sigma}{d\Omega^{*}}\right)_{p}^{free} \simeq \left(\frac{d\sigma}{d\Omega^{*}}\right)_{n}^{free} .$$

In terms of the isoscalar parts $T^{(o)}$ and $T^{(1/2)}$ of the $T = 1/2$ production amplitude $\langle \eta N | T | \gamma N \rangle$ this relation gives $| T^{(o)} + T^{(1/2)} |^2 \simeq$ $\simeq | T^{(o)} - T^{(1/2)} |^2$.

     Now if we assume, according to several experimental indications[6], that the η-nucleon system, just above threshold, goes through a $T = 1/2$, $J^P = 1/2^-$ resonance state at a center of mass energy of about 1520 MeV ($\Gamma \simeq 150$ MeV), then the principal multipole involved is the electric dipole E_{0+}. In this regard we are led to conclude that

$$(3) \qquad \left| E_{0+}^{(o)} + E_{0+}^{(1/2)} \right|^2 \simeq \left| E_{0+}^{(o)} - E_{0+}^{(1/2)} \right|^2$$

or that, $Re(E_{0+}^{(o)*} . E_{0+}^{(1/2)}) \simeq 0$.

     Assuming a resonant structure for both $E_{0+}^{(o)}$ and $E_{0+}^{(1/2)}$, it follows from (3) that either the isovector or the isoscalar part of the photoproduction amplitude is small.

     Supplementary information is necessary for a complete separation of the two isospin parts of the amplitude; for instance the isoscalar part of the amplitude could be isolated by elastic eta photoproduction on $T = 0$ nuclei[7].

REFERENCES -

(1) - C. Bacci, R. Baldini-Celio, C. Mencuccini, A. Reale, M. Spinetti and A. Zallo, Phys. Rev. Letters 20, 571 (1968).

(2) - C. Bacci, G. Penso, G. Salvini, C. Mencuccini and V. Silvestrini, Nuovo Cimento 45A, 983 (1966); R. Prepost, D. Lundquist and D. Quinn, Phys. Rev. Letters 18, 82 (1967); E. D. Bloom, C. A. Heusch, C. Y. Prescott and L. S. Rochester, Phys. Rev. Letters 21, 1100 (1968).

(3) - G. F. Chew and H. Lewis, Phys. Rev. 84, 779 (1951); G. F. Chew and M. L. Goldberger, Phys. Rev. 87, 778 (1952).

(4) - C. Bacci, R. Baldini-Celio, W. Eponeshnikov, C. Mencuccini, A. Reale, G. Salvini, M. Spinetti and A. Zallo, presented to the 1968 Vienna Conference on High Energy Physics (to be published).

(5) - E. Pauli, A. Muller, R. Barloutaud, J. Meyer, M. Beneventano, G. Gialanella and L. Paoluzi, Nuovo Cimento 34, 236 (1964).

(6) - A. T. Davies and R. G. Moorhouse, Nuovo Cimento 52A, 1112 (1967).

(7) - J. A. Alexandrov, A. V. Kutsenko, V. N. Hajkev and V. V. Pavlovskaja, Proc. of the Dubna Conference (1964).

(8) - R. R. Wilson, Nuclear Instr. and Meth. 1, 101 (1957).

(9) - Particle data group: Review of particle properties, UCRL 8030, pt. I, aug. 1968 (to be published in Rev. Mod. Phys.).