C. Bacci, R. Baldini-Celio, C. Mencuccini, A. Reale, M. Spinetti and A. Zallo : ANGULAR DISTRIBUTION FOR THE ETA MESON PHOTOPRODUCTION FROM HYDROGEN AT 775-850 MeV. -

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C. Bacci[(x)], R. Baldini-Celio, C. Mencuccini, A. Reale, M. Spinetti and
A. Zallo: ANGULAR DISTRIBUTION FOR THE ETA MESON PHOTOPRO_
DUCTION FROM HYDROGEN AT 775-850 MeV. -

(Submitted for publication to Physical Review Letters)

        In this paper we report an experiment performed at the Frascati
1.1 GeV Electronsynchrotron on the photoproduction of the eta meson
from hydrogen

(1) $\gamma + p \to \eta + p$

The forward differential cross section has been measured at the three
energies K = 775, 800, 850 MeV of the incident photons for different
eta center-of-mass angles θ^x. The energy resolution ΔK was typi-
cally ± 25 MeV. The purpose of this experiment was to investigate not
far from the threshold energy on the presence in photoproduction of
higher partial waves besides the dominant η-nucleon (η-N)S wave
resonance[1].

        Our results are given in Fig. 3a, 3b, 3c. They show that in the
reaction $\gamma + p \to \eta + p$ up to K = 850 MeV (corresponding to a c.m. total
energy $E^x = 1573$ MeV) the differential cross section is not increasing

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at forward angles in a sensible way. At backward angles a departure from isotropy could start between K = 800 MeV and K = 850 MeV. At the corresponding c.m. total energies the angular distributions for the reaction $\pi^- + p \rightarrow \eta + n$ [2,3] are clearly not isotropic.

The experimental set up is shown in Fig. 1. The γ-ray beam hit on a cylindrical liquid-hydrogen target 7 cm in diameter and was monitored by a Wilson type quantameter [4].

The η from the reaction (1) were detected by measuring both the angles and energies of their two decay photons. Each photon detector was a lead-glass total absorption Cerenkov counter with a veto scintillation counter in front, covering a typical laboratory solid angle of 12 mster.

Two pairs of photon detectors were permanently used, in order to increase the collection rate and to reduce possible sources of systematic instrumental errors.

For each pair of photon detectors, events giving a coincidence (C1C2 S1S2 or C3C4 S3S4) were recorded and the corresponding pulse heights from the Cerenkov registered and analyzed using a PDP8 computer on line. Systematic calibrations with monochromatic electrons from a pair spectrometer were made. The gain stability in the pulse height analysis was automatically controlled [5] during the measurement. The energy resolution of our photon detectors was about ±16% at 500 MeV, changing roughly as $1/\sqrt{E}$ with the photon energy. The kinematical definition of the events from reaction (1) depends on the opening angle 2β between the photon detectors and the maximum energy of the bremsstrahlung spectrum. In fact, the $\eta \rightarrow \gamma\gamma$ kinematics gives a minimum angle between the two γ's which increases as the η energy decreases so that the minimum energy for detectable η's is determined by the maximum angle covered by the photon detectors. On the other end the maximum η energy is fixed essentially by the maximum energy of the bremsstrahlung spectrum. For each of the kinematical situations considered, the events are represented by points in a two dimensional logaritmic plot whose coordinates are the energies of the two detected photons (see Fig. 2a, b). The η events from reaction (1) are expected to occupy in this plot a well defined region which has been determined by a Monte Carlo calculation taking properly into account the measured energy resolution of the Cerenkov and the geometrical situation.

Concerning the background, the single π^0 photoproduction process is completely ruled out for kinematical reasons since a bias of $E_\gamma \simeq 100$ MeV in the photon energy is set in each Cerenkov.

The background of $\gamma\gamma$ events showing up out of the η region

Side View

Top View

Pb
CONCRETE
PLEXIGLASS
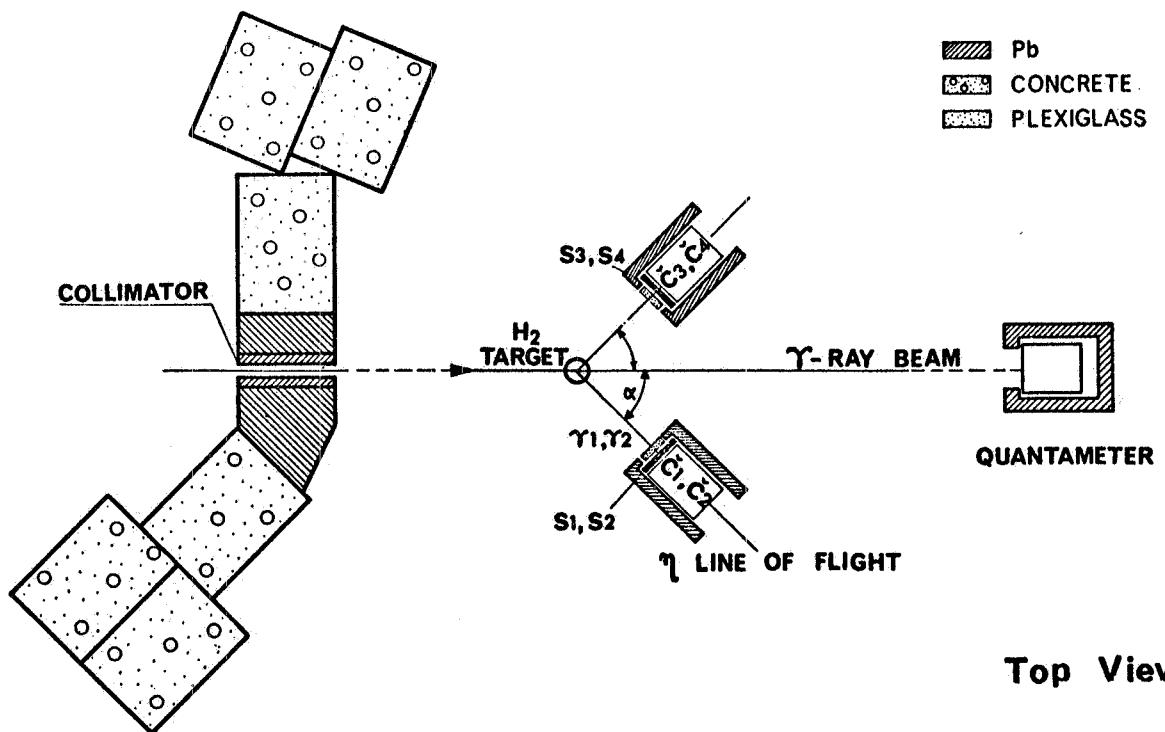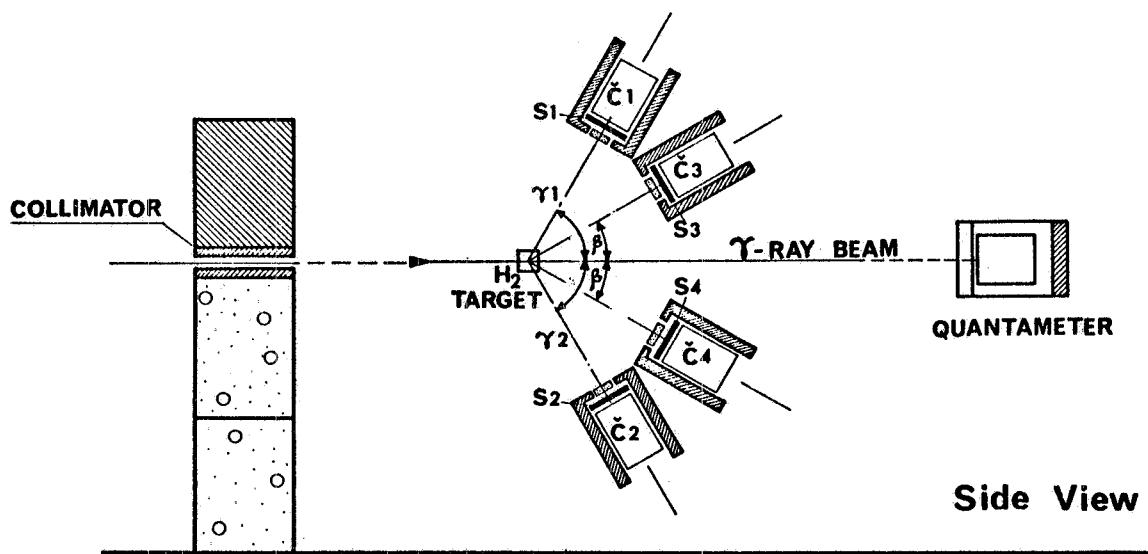
FIG. 1 - Experimental set up for the two pairs of photon detectors. The angle α is the laboratory emission angle of the η, while 2β represents the opening angle of the two detected γ's from the $\eta \to \gamma\gamma$ decay. C_1, C_2 and C_3, C_4 are lead-glass Cerenkov counters, S1, S2 and S3, S4 veto scintillation counters.

4.
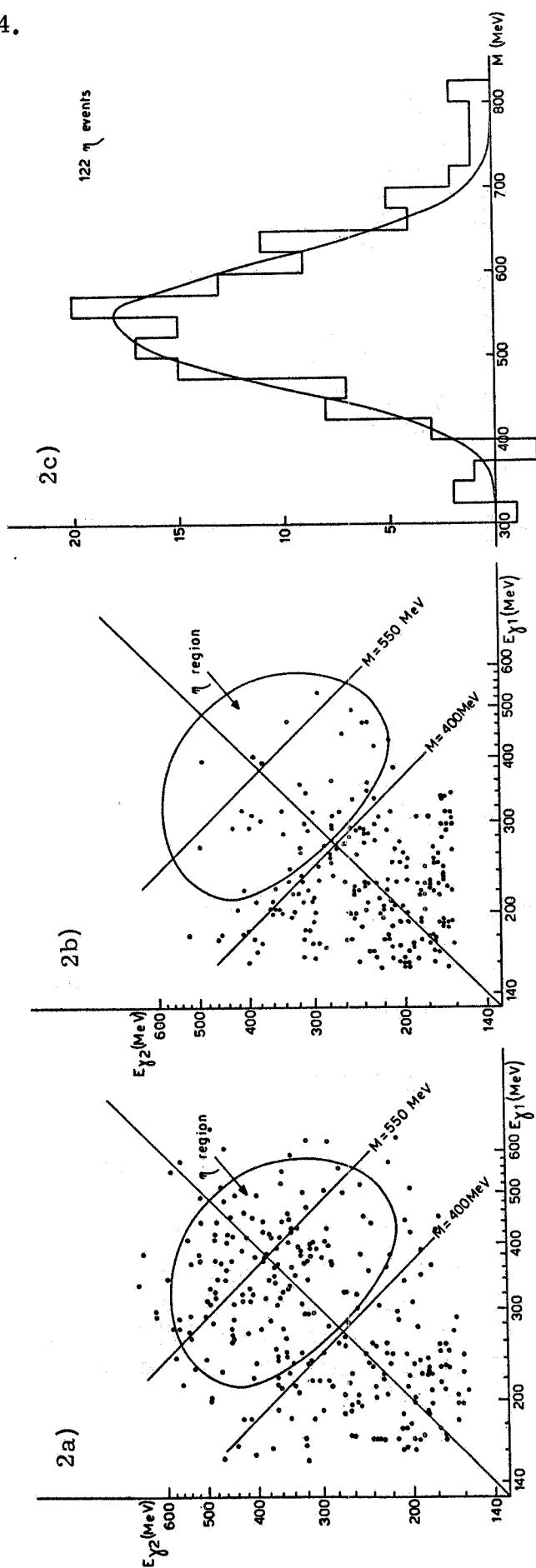
FIG. 2 - (a) Typical $E\gamma_1$, $E\gamma_2$ plot when the η detection is allowed by the geometrical arrangement of the Cerenkov's; the dotted line which defines the η region is calculated by a Monte Carlo program. The full lines M = const represent the loci of $\gamma\gamma$ events from 2γ decays of particles of masses M in case of point counters.

(b) The same than (a) but with the η not detectable due to the opening angle of the photon detectors.

(c) Mass hystogram as obtained by projecting the $\eta \to \gamma\gamma$ events of Fig. 2(a) on the bisector of the coordinates after having subtracted the background. The full line gives the η peak shape as predicted by a Monte Carlo calculation.

(in Fig. 2a) is mainly due to multiple π^0 production and other η decays.

For this background strong correlation between the energies of the two detected photons is not expected. Thus, to measure this conta mination, the geometry was slightly changed in order to exclude the η events detection, but keeping constant at same time the angle of each Cerenkov with respect to the γ-ray beam line. With this procedure we have found that the background counting rate outside the η region did not change. A typical background spectrum is shown in Fig. 2b.

By projecting the η events of the E γ_1, E γ_2 plot on the bisector of the coordinates, after having subtracted the background, a mass hystogram is derived which is shown in Fig. 2c. The solid line represents the mass distribution for the $\eta \to \gamma\gamma$ decays as predicted by a Monte Carlo calculation.

Our results on the differential cross section for η photoproduction in hydrogen are shown in Fig. 3.

The measured c.m. cross sections $(d\sigma/d\Omega^{x})_{\gamma\gamma}$ for the reaction (1) when the η decays by the $\eta \to \gamma\gamma$ mode are reported on the ordinates on the left of Fig. 3. The differential cross sections $(d\sigma/d\Omega^{x})_{\text{all modes}}$ for all the decay modes of the produced η are repor ted on the ordinates on the right in Fig. 3 as calculated from $(d\sigma/d\Omega^{x})_{\gamma\gamma}$ by using the last world average[6] for $\Gamma(\eta \to \text{all modes})/$ $\Gamma(\eta \to \gamma\gamma) = 1/0.43 = 2.32$.

The errors we quote in Fig. 3 are inclusive of the uncertainties on the background subtraction. In addition, there are systematic errors due to the uncertainties on the quantameter calibration, target thickness, shape of the bremsstrahlung spectrum near the maximum energy and efficiency calculation which we estimate to yield an overall systematic error of $\simeq \pm 10\%$ (not included in Fig. 3). Our experimental points in Fig. 3 show as horizontal flags the angular interval over which the cross section is averaged.

In Fig. 3 previous experimental results[7,8] on η photoproduction are also reported.

The data we report suggest the following remarks:

a) - The data points at 775 and 800 MeV show an angular distri bution essentially isotropic. At K = 850 MeV the forward angular distri bution is still consistent with isotropy, while the point we have measu red at θ_{η}^{x} = 150°, could show a tendency to an increase of the cross section at backward angles. On this respect an extension of this mea surement in the backward region could be interesting. At K = 850 MeV a best fit to the experimental points with a $\cos\theta^{x}$ polinomial form

6.
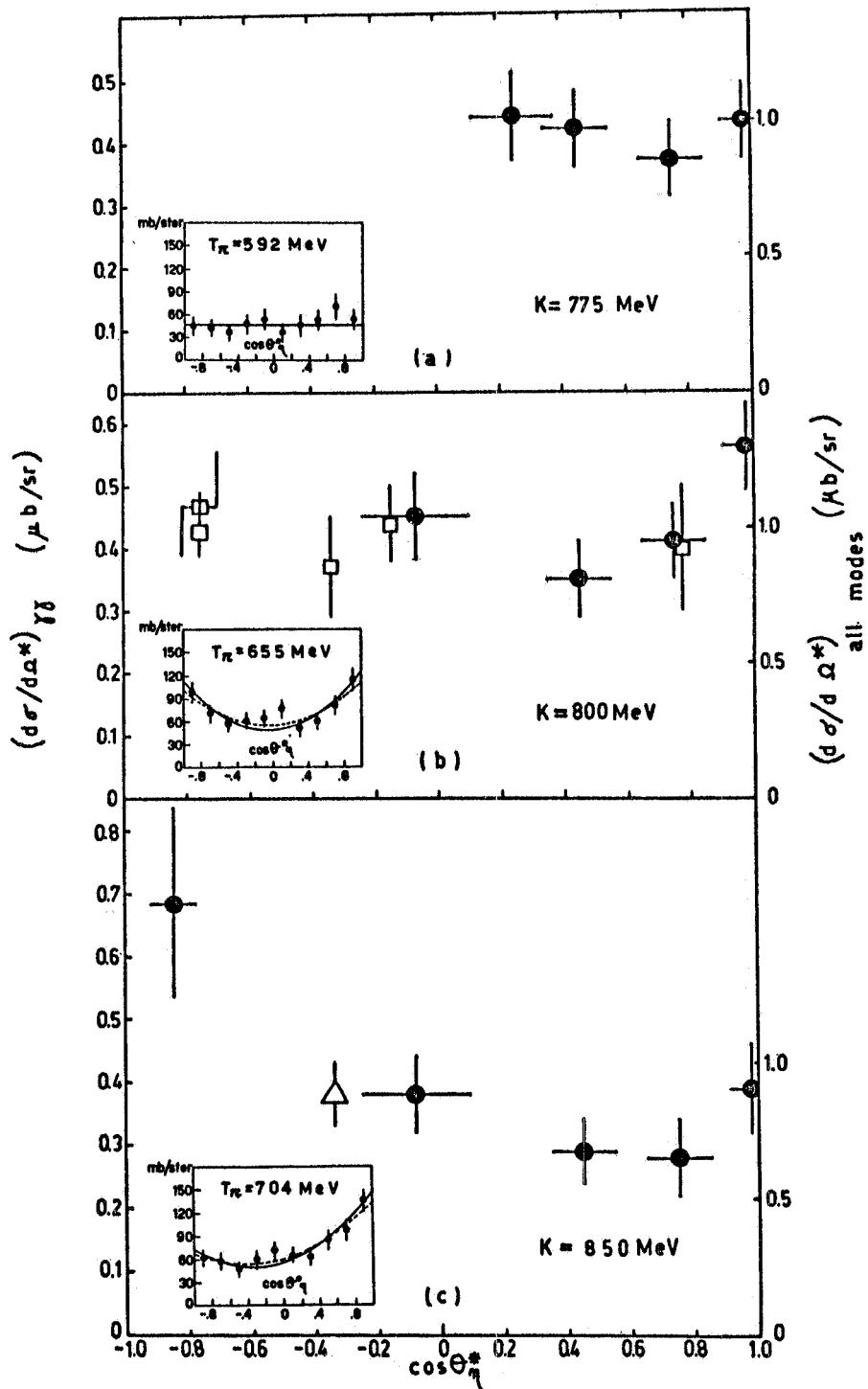
FIG. 3 - Experimental results $(d\sigma/d\Omega^x)_{(\eta \to \gamma\gamma)}$ (ordinates on the left) and $(d\sigma/d\Omega^x)_{(\eta \to all\ modes)}$ (ordinates on the right) as a function of θ_η^x (c. m. angle of the η) at the three different energies K of the incident photon. The points indicated with open squares in Fig. 3b are from ref. 7. The point indicated with open triangle in Fig. 3c is from ref. 8. The angular distribution results for the $\pi^- + p \to \eta + n^{(2)}$ reaction at approximately the same c. m. total energy are reported in the small frames.

$(d\sigma/d\Omega^x)_{\eta} = \sum\limits_{l=0}^{N} c_l (\cos\theta^x_{\eta})^l$ gives $\chi^2/n = 2.06$ if we put $N = 0$ (n is the number of data points minus the number of varied parameters), while we get $\chi^2/n = 0.31$ if we let l go up to $N = 2$ (in this latter case the following values in $\mu b/sr$, for the coefficients are found: $C_o = 0.33 \pm \pm 0.03$, $C_1 = -0.23 \pm 0.05$ and $C_2 = 0.25 \pm 0.06$).

b) - The angular distributions for the $\pi^- + p \rightarrow \eta + n$ [2] reaction at the same c.m. total energy are also reported in the small frames of Fig. 3. A comparison with our results on reaction (1) shows a rather different behaviour of these two reactions. In the $\pi^- + p \rightarrow \eta + n$ angular distributions, terms through $\cos^2\theta^x_{\eta}$ become important already at $T_{\pi} = 655$ MeV. This energy corresponds to $K = 800$ MeV for the photoproduction reaction where the distribution is still isotropic. Therefore, in photoproduction on protons, at least up to this energy, no evidence is found of the contributions of P_{11}, D_{13} or P_{13} partial waves which can explain the $\pi^- + p \rightarrow \eta + n$ angular distribution data.

c) - A possible explanation for the different angular behaviour between the $\pi^- + p \rightarrow \eta + n$ and $\gamma + p \rightarrow \eta + p$ reactions might be found considering that the photoproduction on protons of pure $T = 1/2$ isospin states proceeds via a combination of both an isoscalar $T^{(0)}$ and an isovector $T^{(1/2)}$ parts in the production amplitude: $\langle \eta p/T/\gamma p \rangle \propto T^{(0)} - T^{(1/2)}$. It might happen that the two contributions are of the same order of magnitude so that a cancellation is effective and the contribution of some higher partial wave is depressed. If this is the case, the effect of partial waves higher than S_{11} could show itself when the photoproduction occurs on neutron since now the contributions of the isoscalar and isovector parts add together: $\langle \eta n/T/\gamma n \rangle \propto T^{(0)} + T^{(1/2)}$. In this respect a study of the reaction $\gamma + n \rightarrow \eta + n$ on deuterium would be of interest.

8.

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