THE PRODUCTION OF ETA ZERO MESONS IN $\pi - p$ COLLISIONS *

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The production process for η^0 mesons in πP collisions is studied in some detail in an energy interval from below threshold up to 1100 MeV. Specifically, the reaction is $\pi^- + p \to \eta^0 + N$ and the incident pion kinetic energies are 545, 588, 619, 659, 755, 827, 878, 916, 1003 and 1151 MeV. The cross-section and the angular distribution of the η^0 are measured at each energy above threshold.

The two gamma ray decay mode of the η^0 is detected by the electron shower conversion of the gamma rays in an array of iron plate spark chambers suitably triggered by an electronic logic which is activated by the disappearance of an incident π^- [1]. Events are identified by the unique kinematics of a particle decaying into two gamma rays. The kinematics are such that the opening angle between the two gammas in the πP barycentric system have a minimum θ_η which depends upon the velocity of the parent particle and in addition the maximum number of events occur there. This characteristic distribution enables one to cleanly separate the $\eta^0 \to 2\gamma$ from the $\pi^0 \to 2\gamma$ and to reduce multiple π^0 comtamination which arises because of less than 100% gamma ray detection efficiency. The final state velocities of the η^0 and π^0 are quite different at any given incident π^- energy; for example at 900 MeV incident π^- energy, the minimum opening angle for the π^0, θ_π is 28° and that of the η_0, θ_η is 100°. These general features are illustrated in Fig. 1. At the highest

(cos η^0 coefficients)

T, MeV	588	619	659	755	827	878	916	1003	1151
σ, mb	0.39± ±0.05	0.92± ±0.08	0.98± ±0.09	0.88± ±0.11	0.60± ±0.10	0.30± ±0.14	0.52± ±0.09	0.45± ±0.07	0.38± ±0,07
A_0, mb/sr	0.031± ±0.002	.075± —0.005	.078± ±.005	.070± ±.006	.048± ±.003	.024± ±.014	.041± ±.003	.037± ±.004	.030± ±.003
A_1, mb/sr								.043± ±.009	.030± ±.006

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energy (1151 MeV) it is possible to have reactions $\pi^- + p \rightarrow \omega^0 + N$ and $\pi^- + p \rightarrow \varrho^0 + N$. These may subsequently decay via modes involving only gamma rays in the final state (e. g. $\omega^0 \rightarrow \pi^0 + \gamma$, $\varrho^0 \rightarrow \pi^0 + \gamma$). Decays of this type, when studied in an opening angle distribution, give a distribution exhibiting two maxima with one of the maxima very nearly at the ninimum opening angle for the two gammas from the η^0. The amount of these modes which may be present in the sample at this energy is under investigation.

The cross-section at each energy is determined from the electronic rate, the scanning of the pictures and the gamma ray efficiencies calculated by Monte Carlo techniques. The resulting cross-sections (for the mode $\eta^0 \rightarrow 2\gamma$ only) are shown in Fig. 2. and are tabulated in the second column of Table. The first energy point, which is below η^0 production threshold, has a cross-section which is consistent with zero. The cross-section then exhibits a very rapid rise, reaching a maximum of $0.98 \pm \pm 0.09$ mb at 659 MeV, and then decreases slowly at higher energies. Contributions of < 0.2 mb from $\pi^- + p \rightarrow \Lambda^0 + K^0$ have been subtracted out at the four highest energies. In the region of the very steep rise there

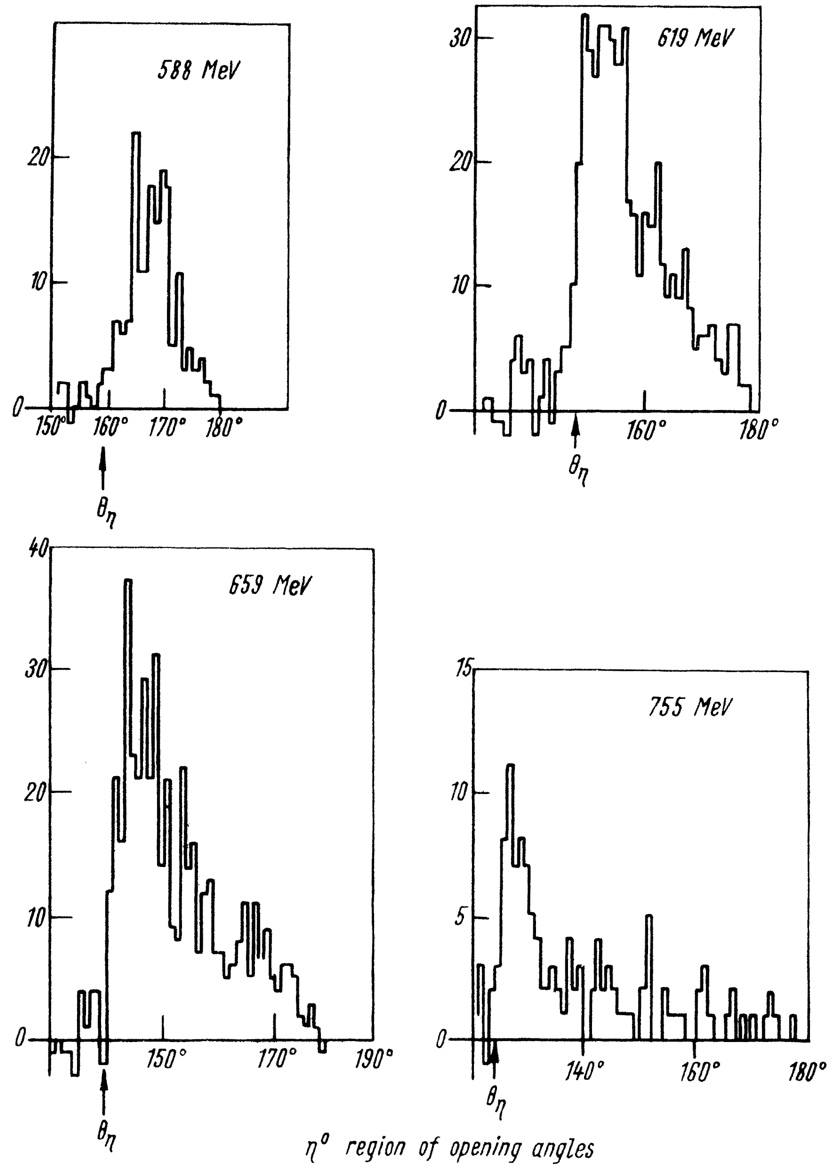

Fig. 1.

are three experimental points. The first two of these points correspond to 92 ± 5 MeV/c and 159 ± 5 MeV/c momentum for the η^0 in the πP barycentric system, and the respective cross-sections are 0.39 ± 0.05 mb and 0.92 ± ± 0.08 mb. The η^0 barycentric momentum

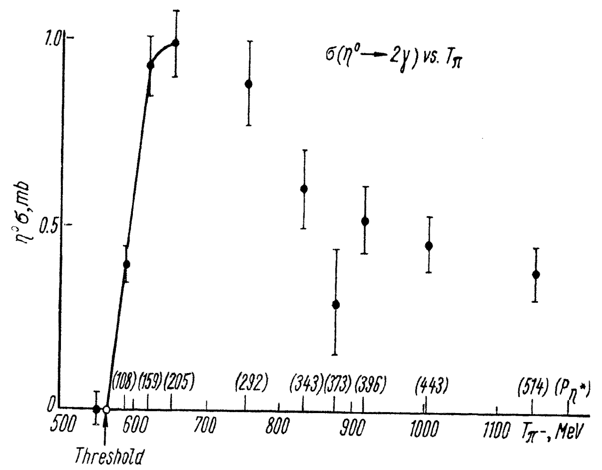

Fig. 2.

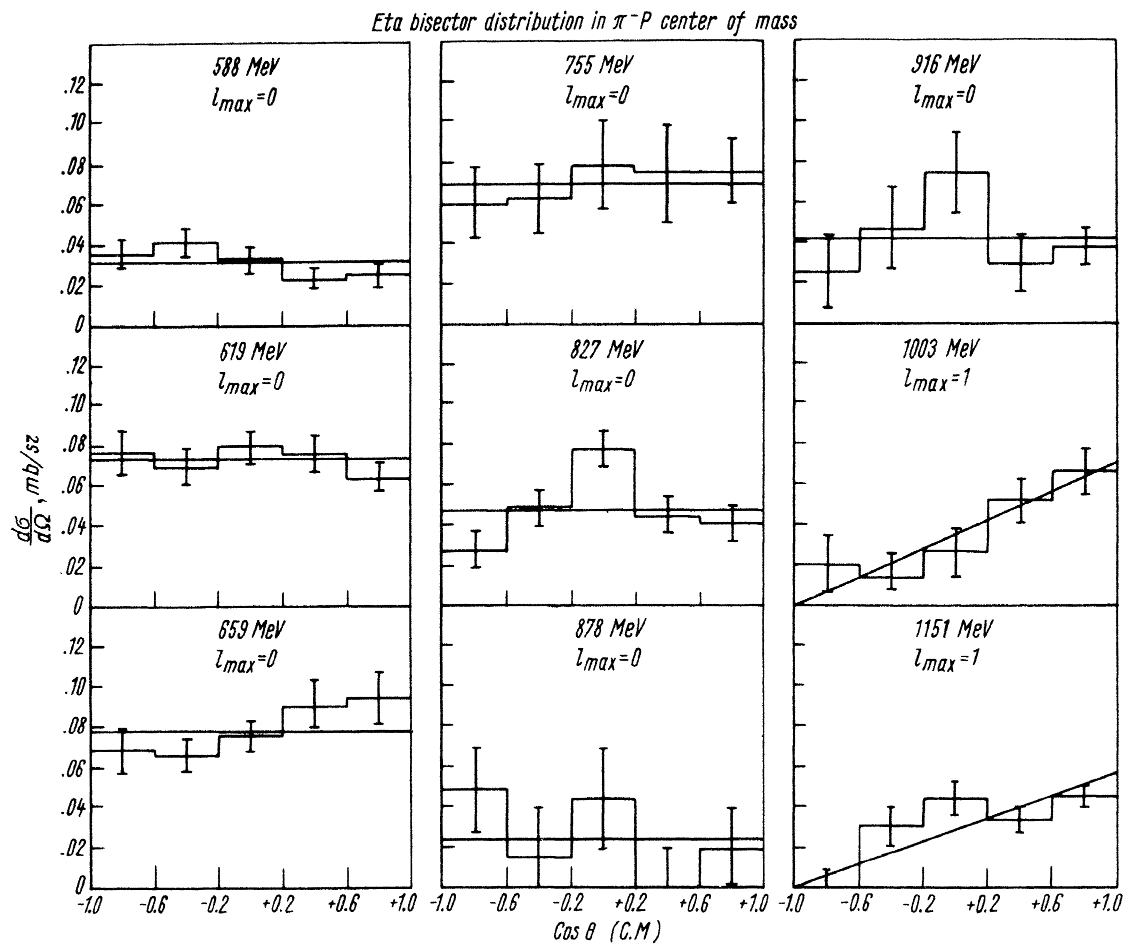

Fig. 3.

is determined by using the observed minimum opening angle which is very sensitive in this region. The θ_{min} indicated in Fig. 1 are those predicted from wire orbit measurements. These yield a momentum ratio of 1.73 ± 0.11 and a cross-section ratio of 2.36 ± 0.30. Assuming a barycentric momentum dependence of the cross-sections near threshold of the form $\sigma \propto \varrho^{2l+1}$ this appears to be consistent with either S or P-wave productions; D-wave appears to be excluded. More detailed information relevant to this point is contained in the angular distributions.

In order to find the angular distribution of the η^0 one first finds experimentally the angular distribution of the bisectors of the two gamma rays resulting from the η^0 decay. A cosine series expansion is fit to the bisector distribution and the coefficients for the η^0 distribution are unambiguously deduced. The l_{max} (i. e. the highest power of cos θ chosen for the fit at each energy was that for which the χ^2 probability exceeded 4% and for which the highest term was statistically significant. The average number of events in each angular distribution is of the order of 300. The distributions are shown in Fig. 3. This procedure resulted in fits which were isotropic for all energies from threshold up to 1003 MeV. The 1003 and 1151 MeV distributions require a cos θ^* term but no higher terms. This behaviour favors $S_{1/2}$ or $P_{1/2}$ production at threshold with some higher states entering at higher energies.

It is inconsistent with pure $P_{3/2}$ or $D_{3/2}$ throughout the entire energy region. These results would seem to indicate that the reaction $\pi^- + p \rightarrow \eta^0 + N$ does not play a large role in any $D_{3/2}$ $T = 1/2$ resonance at 600 MeV.