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MEASUREMENTS OF π^o and η^o PHOTOPRODUCTION AT INCIDENT GAMMA-RAY ENERGIES OF 5.0-17.8 GeV*

by

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Measurements have been made on forward π^o photoproduction $\gamma + P \rightarrow \pi^o + P$ in the range of 2 - 5.5 GeV.[1] The results show a pronounced dip in the cross section at a value of the four momentum transfer squared $t = -0.5$ $(GeV/c)^2$. There has been considerable speculation on the energy dependence of this process at higher energies.[2] We have recently completed measurements at incident photon energies up to 17.8 GeV.

A collimated beam of bremsstrahlung photons from the SLAC linear accelerator irradiated the liquid hydrogen target, a 12" long by 2" diameter thin mylar cylinder. The yield of protons recoiling from the target was measured as a function of angle for a variety of proton momenta and primary energies.

The measurements were made with a 100" radius, 90^o bend second-order corrected spectrometer[3] which focussed momenta and production angles in a single focal plane normal to the impinging particles. The dispersion of this spectrometer was 1.66" per percent in momentum, and 0.32" per mr in production angle. Protons were identified and separated from pions on the basis of ionization loss in three trigger counters and by vetoing pions with a lucite Cerenkov counter. At all momenta, pion contamination was less than a few percent of the proton signal. The trigger counters were put in coincidence with eight hodoscope counters 10" by 3/4" by 1/4" thick located at the focal plane. The whole counter assembly was rotatable so that the axes of the hodoscope counters could be aligned with kinematic "missing mass lines" in the focal plane. The resolution of the apparatus was limited by the multipole coulomb scattering of particles in the liquid hydrogen target.

The beam intensity was continuously monitored with both a Cerenkov monitor, and secondary emission quantameter. The secondary emission quantameter was periodically calibrated against a silver calorimeter to obtain an absolute calibration. Typical beam intensities were of the order of 10^{11} equivalent quanta per second, and counting ranged from 5×10^2 counts per second to 50 counts per second.

π^o and η^o cross sections were determined by measuring the proton yield as a function of angle above and below their kinematic thresholds. Figure 1 shows a typical yield curve obtained with a peak bremsstrahlung energy of 11.5 GeV, and a recoiling proton momentum corresponding to $t = -0.7 (\mathrm{GeV/c})^2$. The protons in the negative missing-mass-squared region are kinematically forbidden for single processes and are attributable to double processes within the target (these "ghost protons" are frequently observed in π^o photoproduction experiments). The background was phenomenologically fitted with a polynomial (Fig. 1 shows this fit). Under the conditions of our experiment compton scattered protons were not resolved from those associated with π^o production. η^o production was not well resolved from ρ^o production at higher energies and results are given only for 6 GeV incident photons.

Yields were translated into cross sections taking into account the spectrometer acceptance, the trigger counter efficiencies and the bremsstrahlung beam calibration. Conservative errors on the yields and cross sections were applied to allow for uncertainties in the background subtractions. Figure 2 shows the cross sections $d\sigma/dt$ obtained for π^o production at photon energies of 6, 11, and 16 GeV. These cross sections have been corrected for compton scattering using the vector dominance model to estimate the compton cross section: $d\sigma/dt$ (compton) $\approx 0.3e^{-8|t|}\mu b / (\mathrm{GeV/c})^2$.[4] Agreement of our 6 GeV photoproduction results with the DESY photoproduction results at 5.8 GeV is excellent.

Photoproduction of π^o mesons at forward angles can proceed via the exchange of ω^o or B^o mesons in the t channel. In the framework of the Regge theory it had previously been hypothesized that B^o meson exchange would become less important at high energies and that the process would be dominated by ω^o exchange (the one-ω-exchange model). It was therefore predicted[2] that the π^o photoproduction cross section would behave like the $\pi^- + P \rightarrow \pi^o + N$ charge exchange cross section, where only ρ-exchange is permitted, i.e., that $d\sigma/dt$ would show both a shrinking of the forward peak with increasing energy and a sharp dip at $t \approx -.5(\mathrm{GeV}/c)^2$. In fact, our results show that the dip at $t = -.5(\mathrm{GeV}/c)^2$ becomes less deep at high energies and that the shrinkage is less strong than would be predicted from Reggeized ω^o exchange. For instance at $t = -.9(\mathrm{GeV}/c)^2$ the effective α in $d\sigma/dt \sim s^{2\alpha-2}$ is $.05 \pm .06$, whereas one would expect from the ω^o trajectory a value of α equal to $-.4$.

If we interpret our results in the conventional Regge framework with only poles, we would infer that the B^o meson Regge trajectory is rather flat and dominates the behaviour at moderate t values and high energies.

Figure 3 shows the η^o cross section $d\sigma/dt$ as a function of t at 6 GeV primary photon energy. For comparison the dotted line shows the π^o cross section. The η^o cross section falls monotonically as a function of t and shows no dip at $t \approx -.5(\mathrm{GeV}/c)^2$. We therefore would conclude that photoproduction of η^o mesons at moderate t values does not proceed predominately via Reggeized ρ^o meson exchange.[5] In summary, while other explanations are not ruled out, we would conclude in the framework of conventional Regge theory that both ω^o and B^o Regge-exchange are important for π^o photoproduction and that, contrary to expectation, the B^o trajectory dominates at moderate t values and high energies. For η^o photoproduction we would conclude that the Reggeized ρ^o exchange does not play a dominant role.

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2. A summary of theoretical work is given by H. Harari, 1967 Stanford Linear Accelerator Center Electron Photon Symposium, p. 337. See also A. Dar and V. Weisskopf, (to be published in Phys. Rev. Letters).

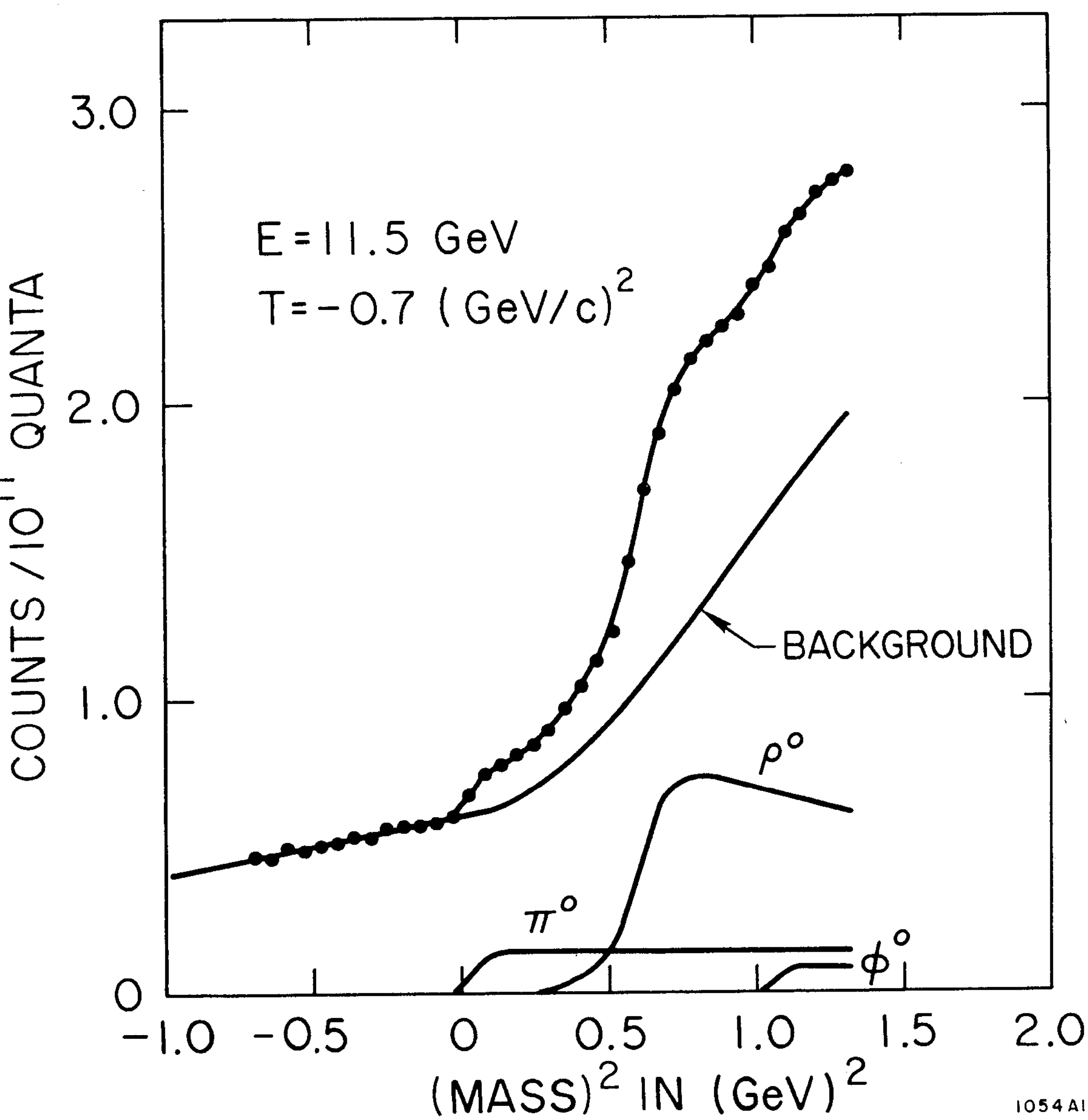
3. The SLAC 1.6 GeV/c spectrometer is described in the SLAC Users Handbook Section E.

4. We assumed from the vector dominance model that $d\sigma/dt(\gamma + P \rightarrow \gamma + P) = \kappa\, d\sigma/dt(\gamma + P \rightarrow \rho + P)$ and chose $\kappa \approx 3.6 \times 10^{-3}$. The cross section $d\sigma/dt(\gamma + P \rightarrow \rho + P)$ was approximated from our own experimental data (to be published).

5. A. Dar and V. Weisskopf, Phys. Rev. Letters 20, 726 (1968), calculated η^o photoproduction from a comparison with $\pi^- + P \rightarrow \omega^o + N$. Our results do indeed follow their predictions within a factor 1.5. However, their calculations are based on the implicit assumption that ρ^o photoproduction and $\pi^- + P \rightarrow \omega^o + N$ are both dominated by ρ-exchange.

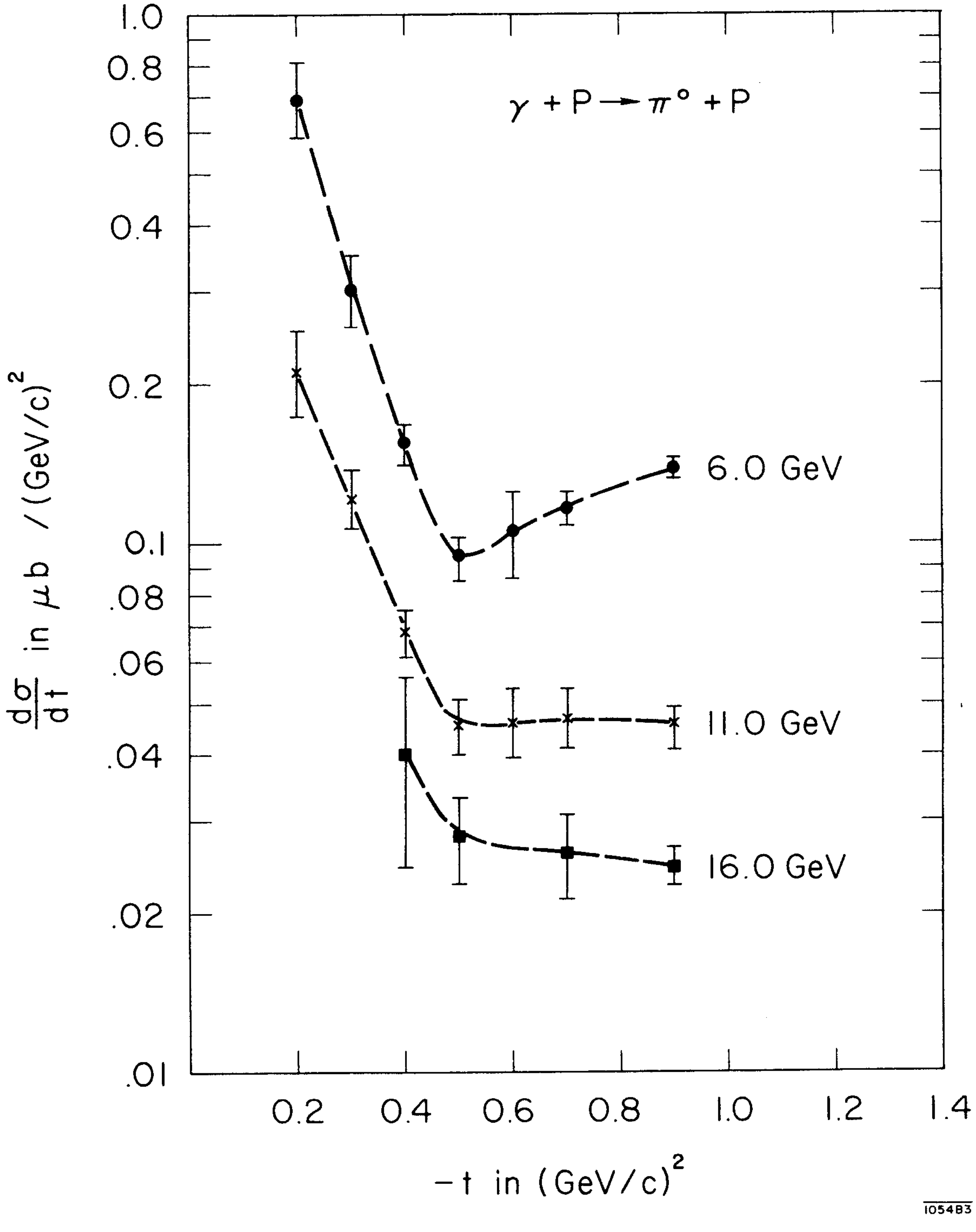
FIGURE CAPTIONS

1. A typical yield curve taken at a peak bremsstrahlung energy of 11.5 GeV and $t = -.7\,(\mathrm{GeV}/c)^2$ yield in counts per hodoscope counter per 10'' equivalent quanta are plotted as a function of "missing mass squared." The fitted contributions of the background and the π^o, ρ^o, and ϕ^o yields are shown.
2. $d\sigma/dt$ for π^o photoproduction in $\mu b/(\mathrm{GeV}/c)^2$ versus $-t$ in $(\mathrm{GeV}/c)^2$ for 6 GeV, 11 GeV, and 16 GeV primary photon energies. Dotted lines have been drawn through the points to guide the eye.
3. $d\sigma/dt$ for η^o photoproduction in $\mu b/(\mathrm{GeV}/c)^2$ versus $-t$ in $(\mathrm{GeV}/c)^2$ at a primary energy of 6 GeV. The dotted line, taken from Fig. 2, shows π^o production for comparison.



3.0
2.0
1.0
0
COUNTS / 10^11 QUANTA
E = 11.5 GeV
T = −0.7 (GeV/c)^2
BACKGROUND
ρ°
π°
φ°
−1.0
−0.5
0
0.5
1.0
1.5
2.0
(MASS)^2 IN (GeV)^2
1054A1

Fig. 1



$\gamma + P \rightarrow \pi^{\circ} + P$
6.0 GeV
11.0 GeV
16.0 GeV
$\frac{d\sigma}{dt}$ in μb /(GeV/c)^2
$-t$ in (GeV/c)^2
1.0
0.8
0.6
0.4
0.2
0.1
.08
.06
.04
.02
.01
0.2
0.4
0.6
0.8
1.0
1.2
1.4
105483

Fig. 2

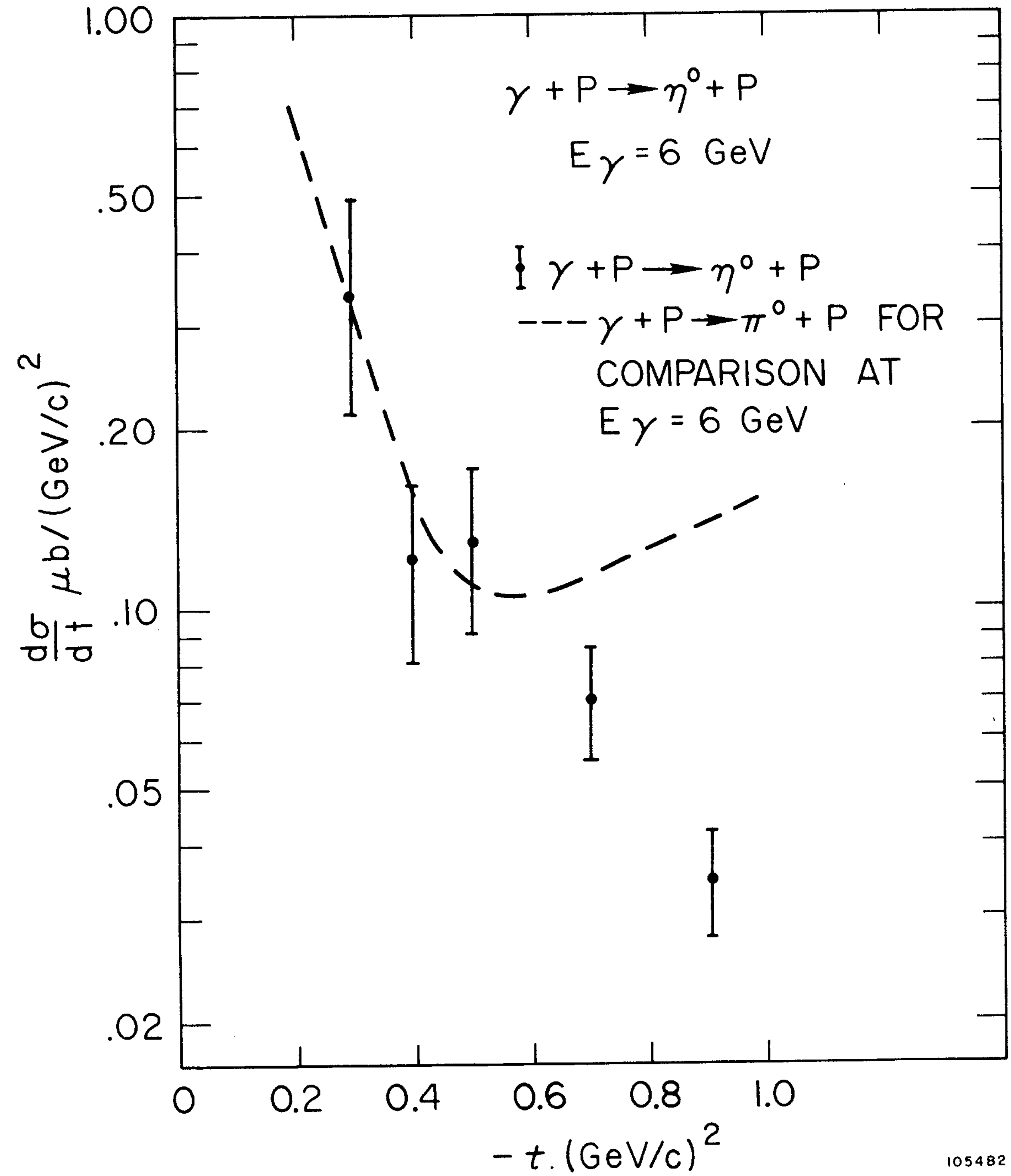

1.00
.50
.20
.10
.05
.02
$\frac{d\sigma}{dt}$ μb/(GeV/c)^2
$\gamma + P \rightarrow \eta^0 + P$
$E_\gamma = 6$ GeV
$\gamma + P \rightarrow \eta^0 + P$
$\gamma + P \rightarrow \pi^0 + P$ FOR COMPARISON AT $E_\gamma = 6$ GeV
0
0.2
0.4
0.6
0.8
1.0
$-t$, (GeV/c)^2
105482

Fig. 3