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LARGE ANGLE HIGH ENERGY PHOTOPRODUCTION OF SINGLE π^+ MESONS FROM LIQUID HYDROGEN

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ABSTRACT

We have measured angular distributions for single photoproduced π^+ mesons at 4.0, 5.0, and 7.5 GeV incident photons energies and at lab angles from 11° to 66° with the S.L.A.C. 8 GeV spectrometer. Combined with previous S.L.A.C. results, this gives complete angular coverages for this range of energies. The data show the usual "t" and "u" diffraction peaks and a "central plateau" region dropping as $S^{-7.3}$.

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Previous experiments on the photoproduction of single charged pion production from hydrogen via $\gamma + P \rightarrow \pi^+ + N$ have been made over the range of $|t|$ values from 0 to $3.0(\text{GeV}/c)^2$ and $|u|$ values from 0 to $1.7(\text{GeV}/c)^2$.[1,2] The cross sections in $d\sigma/dt$ can be approximated by the formulae $d\sigma/dt \propto S^{-2}e^{-3.3|t|}$ for $1 < |t| < 3(\text{GeV}/c)^2$ and $d\sigma/dt \propto S^{-3}e^{-|u|}$ for $.5 < |u| < 1.5(\text{GeV}/c)^2$. It seemed of interest to obtain complete angular distributions over several energies, which could be compared with the elastic πP scattering distributions[3].

The experiment was a standard single arm "missing mass" identification of the process using an analysis of the kinematic step to provide cross section measurements[1,2]. The SLAC 8 GeV Spectrometer[4] was used to analyze pions (and protons) produced by the SLAC bremsstrahlung beam passing through a liquid hydrogen target. The beam layout is shown in Fig. 1. The bremsstrahlung beam could be prepared either with a radiator 52 meters upstream from the liquid hydrogen target (distant-targeting) which was then followed by a sweep magnet to remove the main electron beam, or in order to obtain maximum photon beam intensities could be prepared by placing a radiator 2 meters in front of the hydrogen target and allowing both the photons and electrons to proceed through the target. The pure photon beam obtained with the distant targeting could be monitored with a secondary emission quantameter. The close up targeting was monitored with the standard SLAC toroids to give the number of electrons in the beam and effective photon fluxes were calculated from the amount of radiator in the beam line. These calculations were cross checked by changing the amount of radiator in the beam line, and by comparing the observed rates with the standard bremsstrahlung beam. The rates used for these cross comparisons were measured with the 1.6 GeV spectrometer set to detect low energy pi plus mesons (500 MeV/c) produced at 90° in the lab. The two methods of comparison gave agreement to a few percent.

The counting system is shown in Fig. 1. The trigger system contained a threshold gas Cerenkov counter employing Freon 12 with high efficiency for pions (~ 99%) above 1.75 GeV/c, a lucite threshold Cerenkov counter which rejected protons with momenta less than 1.5 GeV/c, and two trigger scintillators. Pions above 1.8 GeV/c were recorded by a coincidence between the scintillator trigger counters, the threshold gas Cerenkov counter and the Lucite counter. At momenta below 1.7 GeV/c a coincidence was made with only the trigger scintillator and the threshold lucite counter. Protons and Kaons were monitored by observing the trigger rates with the scintillators, the Cerenkov gas counter in anti-coincidence, and the lucite Cerenkov counter in coincidence for momenta above the threshold in the Lucite counter. The trigger pulses were used to strobe the momentum (p) and angle defining (theta) hodoscopes and the pulses were sorted into missing mass bins. A cut was made with an "X" hodoscope to reject non-target associated backgrounds. The "X" hodoscope was placed two meters in front of the focal plane and consisted of 21 counters that divided the horizontal plane (or production angle) into twenty-one pieces. This information when combined with the knowledge of the horizontal production angle obtained with the theta hodoscope permitted a rough reconstruction of the horizontal point of origin of the particle at the target. A loose cut was made on this position (98% efficient as determined from electron scattering) that provided a rejection against non-target associated room backgrounds of about twenty to one. Singles rates were kept below a few per pulse at all times, and dead-time corrections typically ran at 10% or less.

For data taking conditions the spectrometer was set to a fixed angle and the momentum was varied in order to obtain the curves for yield versus the "missing mass squared" from which the kinematic step at the appropriate threshold could be obtained. The spectrometer was operated so that the acceptance was constant within a few per cent over the fiducial region set by the p and theta hodoscopes. The azimuthal acceptance was determined by adjustable front slits. The solid angle and efficiency of the spectrometer could be obtained from the known geometrical and magnetic parameters of the system, or by calibration with the proton peak associated with elastic electron proton scattering. The two methods agreed within a few per cent. The main uncertainty in determining absolute cross sections came from the uncertainties in the knowledge of the absorption and knock-on electron corrections in the counter telescope. These corrections were of the order of 22% with an estimated systematic uncertainty of 5%. Our estimated systematic uncertainty on the absolute cross sections is 10%.

Fig. 2 shows our final measured cross sections. The error bars contain statistical errors and systematic errors for the measured dead-time corrections and the extrapolated background subtractions underneath the kinematic step.

For $|t|$ values up to about $3(\mathrm{GeV}/c)^2$ the data show the typical exponential ($e^{-3.3\cdot|t|}$) fall off of the cross section observed by Boyarski <u>et al</u>.[1] The data for the u-channel show a slower fall off with $|u|$ ($\sim e^{-1.3\cdot|u|}$) which is in reasonable agreement with the results of Anderson <u>et al</u>.[2] The central plateau region is distinct from either of these regions and has only a small dependence on the $|t|$ or $|u|$ values, but a very strong S dependence. There is a sharp breakway from the $|t|$

and $|u|$ channel regions and therefore this central region seems to have a phase such that it adds incoherently or mildly destructively with the $|t|$ and $|u|$ channel contributions. The S dependence of $d\sigma/dt$ measured at 90° C.M. goes as $S^{-7.3 \pm .4}$. If the 90° C.M. data are extrapolated into the low energy region, the cross sections agree with those observed for low energy "resonance averaged" photoproduction of single pions in the 1-3 GeV region[5].

Fig. 3 shows a comparison of the five GeV data of the present experiment multiplied by a scale factor, and the corresponding π^+ and π^- elastic scattering data and $\pi^0 p$ charge exchange[(3)]. The πp data show the same qualitative features of forward and backward peaks and a central plateau region dropping with a high S dependence. As can be seen from Fig. 3 the backward peak and plateau region can be approximately represented by the form:

$$\frac{d\sigma}{dt}(\gamma P \rightarrow \pi^+ P) \simeq \frac{1}{2}\left[\frac{d\sigma}{dt}(\pi^+ P \rightarrow \pi^+ P) + \frac{d\sigma}{dt}(\pi^- P \rightarrow \pi^- P)\right] \frac{1}{217}$$

The $\frac{1}{217}$ scale factor is the ratio of the γP total cross section to the average of the π^+P and π^-P total cross sections. This factor scales the $\gamma P \rightarrow \pi^+ N$ and πp elastic differential cross sections very well, thus showing the close correspondence between large angle photoproduction and hadronic processes. The marked dip of the pion data at the junction of the central plateau with the forward and backward peaks seems to be absent in out data. The S dependence observed for the 90° C.M. pion data is also very close to that observed in this experiment. In view of the fact that the 90° C.M. cross section extrapolates to the observed 1.5 GeV low energy resonance cross sections it would seem plausible to regard the cross sections observed by us at high energies to be the residue of the resonance or S channel cross sections.

An interesting interpretation of the pion results has been obtained in a quark or parton interchange model by Gunion et al.[6] This model assumes that the incoming and central target particle scatter by interchanging constituents and involves a hadronic form factor for both vertices. This model leads to a central plateau region dropping as $\sim S^{-13/2}$ when applied to photoproduction.

In summary there is a "central plateau" in the angular distribution of single photoproduced pions falling as $S^{-7.3}$. Our photoproduction results clearly parallel those observed for hadronic scattering and demand a common explanation.

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References

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3 A. N. Diddens, "Total Cross Sections and Elastic Scattering at High Energies", 4th International Conference on High Energy Collisions, Oxford, England, p. 127, (1972).

4 The S.L.A.C. Users Handbook provides a description of the 8 GeV/c Spectrometer.

5 L. S. Osborne, Proceedings of the International Symposium on Electron and Photon Interactions at High Energies, p. 91, (1965).

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Figure Captions

1) Experimental Layout. The counters of the 8 GeV spectrometer are shown in the insert.

2) Results of the experiment. Results for small $|t|$ and $|u|$ values are indicated (Ref. 1,2).

3) Comparison of our 5 GeV data with the 5 GeV π^+ and π^- elastic scattering, and $\pi^- p$ charge exchange.

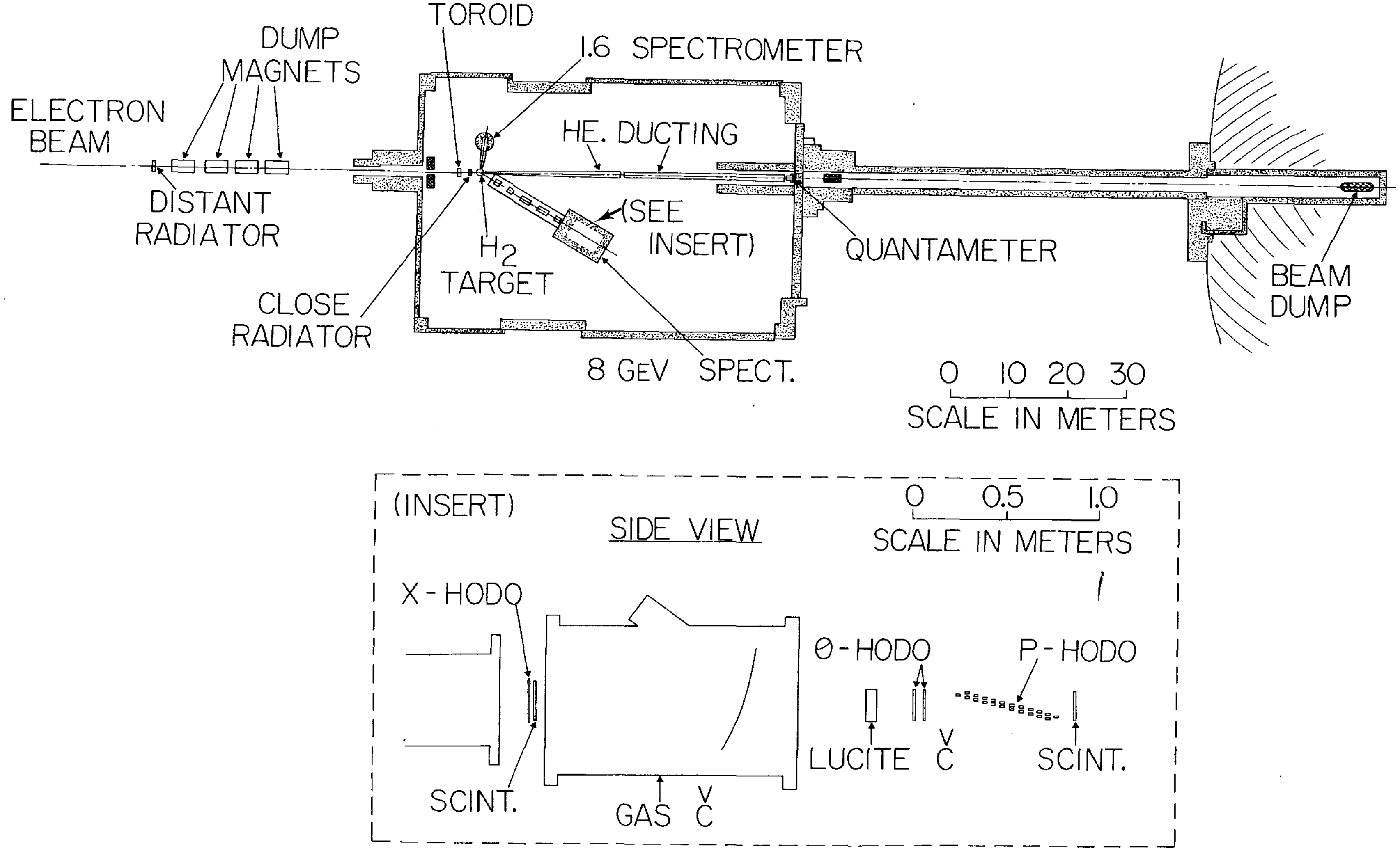
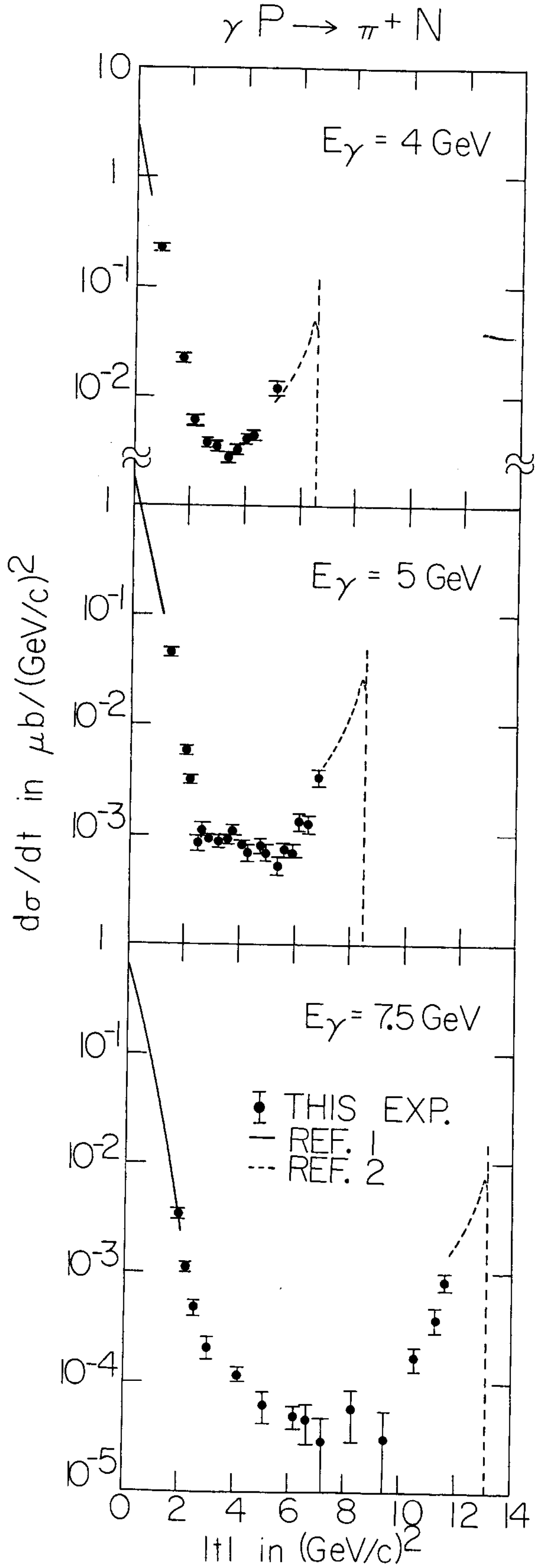
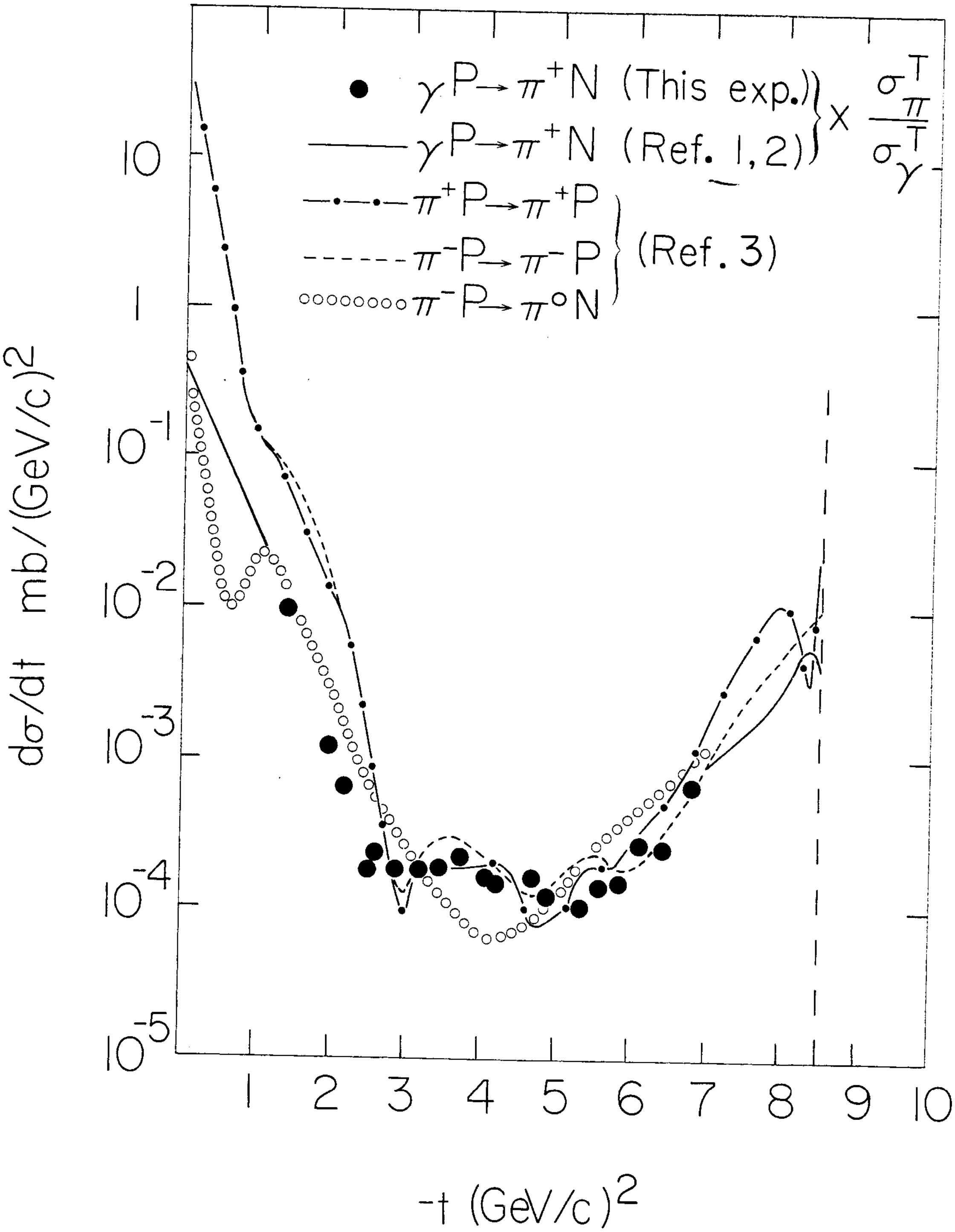

TOROID
DUMP MAGNETS
1.6 SPECTROMETER
ELECTRON BEAM
HE. DUCTING
DISTANT RADIATOR
(SEE INSERT)
H2 TARGET
QUANTAMETER
CLOSE RADIATOR
BEAM DUMP
8 GeV SPECT.
0 10 20 30
SCALE IN METERS
(INSERT)
SIDE VIEW
0 0.5 1.0
SCALE IN METERS
X-HODO
Θ-HODO
P-HODO
LUCITE
Č
SCINT.
SCINT.
GAS Č

Fig. 1



γ P ⟶ π⁺ N
Eγ = 4 GeV
Eγ = 5 GeV
Eγ = 7.5 GeV
THIS EXP.
REF. 1
REF. 2
dσ/dt in μb/(GeV/c)²
|t| in (GeV/c)²

Fig. 2



γP→π+N (This exp.)
γP→π+N (Ref. 1,2)
× σπT/σγT
π+P→π+P
π−P→π−P
π−P→π°N
(Ref. 3)
dσ/dt mb/(GeV/c)2
10
1
10-1
10-2
10-3
10-4
10-5
1 2 3 4 5 6 7 8 9 10
-t (GeV/c)2

Fig. 3