INCLUSIVE PHOTOPRODUCTION AND THE TRIPLE REGGE FORMULA

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Abstract : We report a study of the inclusive reactions $\gamma p \to \pi^{\pm}$ + anything and $\gamma n \to \pi^{-}$ + anything at the photon energy of 7.5 GeV. The high π^{+}/π^{-} ratio observed in the target fragmentation region is explained by applying the triple regge formalism. We also investigate the inclusive photoproduction of the Δ^{++} and ρ° resonances.

Résumé : Etude des réactions $\gamma p \to \pi^{\pm}$ + x et $\gamma n \to \pi^{\pm}$ + x pour des photons d'énergie 7.5 GeV. La valeur élevée du rapport π^{+}/π^{-} observée dans la région de fragmentation de la cible est expliquée à l'aide du formalisme de Regge triple. Nous avons aussi étudié la production inclusive des résonances Δ^{++} et ρ°.

A - INTRODUCTION :

This analysis is based on 170 000 pictures taken in the 82" SLAC deuterium-filled bubble chamber exposed to a nearly monochromatic linearly polarized photon beam of 7.5 GeV.

In analyzing the data we have neglected the contribution of the coherent events. Positive tracks with momentum less than 1.3 GeV/c were taken to be either protons or pions according to their observed ionization. All negative tracks and positive tracks with a momentum greater than 1.3 GeV/c were assumed to be pions. The presence of $K^{\pm}$ mesons, estimated to constitute $\sim$ 3% of the charged tracks has thus been neglected. All other experimental details concerning this experiment can be found in reference 1.

In graph 1, we observe the momentum distribution of the identified protons and it exhibits two well defined regions, the first one which extends up to 250 MeV/c can be readily identified as the spectator proton distribution, while the higher momentum distribution corresponds to the recoil proton. Therefore by introducing a cut of 250 MeV/c we can separate γp from γn reactions in the inclusive case and we are able to investigate the four sets of reactions :

$$(\gamma p, \pi^{\pm}) \equiv \gamma p \to \pi^{\pm} + \text{anything}$$

$$(\gamma n, \pi^{\pm}) \equiv \gamma n \to \pi^{\pm} + \text{anything}$$

B - REACTIONS $(\gamma p,\pi^{\pm})$ and $(\gamma n,\pi^{\pm})$:

First we have determined the π^+ and π^- total inclusive cross sections ratio and the result is :

$$\frac{\sigma(\gamma p,\pi^+)}{\sigma(\gamma p,\pi^-)} = \frac{\sigma(\gamma n,\pi^-)}{\sigma(\gamma n,\pi^+)} = 1.2 \pm .1$$

A very interesting behaviour of these ratios as a function of q^2 has been recently reported in an electroproduction experiment [2].

We analyze our data in terms of the inclusive structure functions $F(x)$, $F(P_{\parallel})$ and $F(P_{\perp}^2)$ [1] and we will discuss the most prominent features of these distributions.

The $F(x)$ distribution (plotted in Fig.2) shows all four sets of data exhibiting similar characteristics : a rapid rise as x increases from -1 to 0, followed by a gradual decrease up to x = 0.6 where a rapid drop off

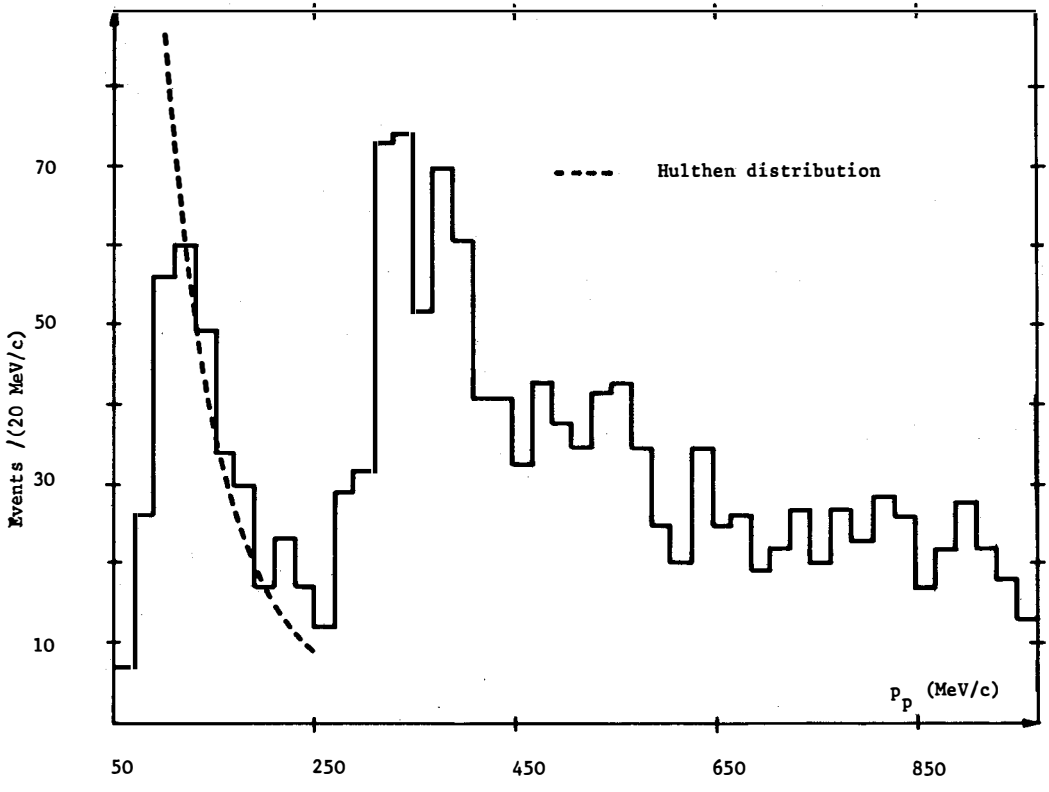


Fig.1 : Momentum distribution of the positive outgoing tracks identified as protons

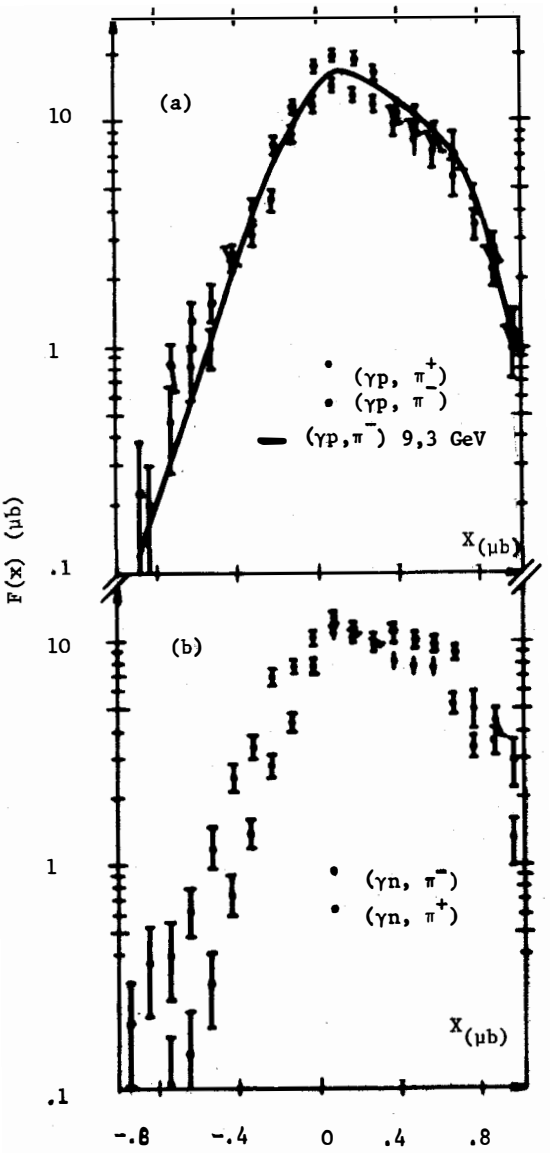


Fig. 2 : The structure function F(x) as a function of x for :

a) the reaction $(\gamma p, \pi^{\pm})$ and
b) the reaction $(\gamma n, \pi^{\pm})$

The solid line represents the SBT collaboration $(\gamma p, \pi^-)$ data at 9.3 GeV.

is observed. In the target fragmentation region ($-1 < x < -.5$) the F(x) distributions of $(\gamma p,\pi^+)$ and $(\gamma n,\pi^-)$ are larger than the $(\gamma p,\pi^-)$ and $(\gamma n,\pi^+)$ respectively. All four distributions are approaching each other at $x = 0$ and in the beam fragmentation region ($x > 0.5$) they essentially fall off together.

The $F(P_{\parallel})$ distribution has been compared in the target fragmentation region with predictions [3] via factorization from hadron induced reactions. As we can see from Fig-3 a better agreement is obtained for the $(\gamma p,\pi^-)$ data than for the $(\gamma p,\pi^+)$. The structure function $F(P_\perp^2)$ exhibits an exponential behaviour with a slope of $\sim (6\pm1)$ GeV^{-2} for the four distributions. A possible break in the $P_\perp^2$ distributions at $P_\perp^2 \simeq 0.3$ is indicated in the four reactions.

C - THE π^+/π^- RATIO AND THE TRIPLE REGGE FORMULA :

We have observed that in the target fragmentation region the $(\gamma p,\pi^+)$ and $(\gamma n,\pi^-)$ F(x) distributions are larger than the $(\gamma p,\pi^-)$ and $(\gamma n,\pi^+)$ respectively ; and the corresponding ratio increases as we approach the limit $x = -1$. For a statistically more significant study of this π^+/π^- ratio we have compared [4] our data with the high statistics experiment $(\gamma p,\pi^-)$ of SLAC at the nearby energy of 9.3 GeV [5]. The calculated ratio is shown in Fig. 4 and we observe a strong backward peack, reaching a value of 10 for $-1 < x < -.8$, followed by a sharp drop off at $x = -.5$ and reaching a value of 1 in the pionization region ($x \simeq 0$). The data available for $\pi^+ p$ [6] and pp [7] experiments seem to support the presence of this backward peak.

If we consider the reactions $(\gamma p,\pi^\pm)$ in the target fragmentation region they can be described [8] according to the triple regge diagrams shown in Fig.5 (where $\mathbb{P}$ stands for Pomeron and $\alpha(t)$ are the exchanged regge trajectories). For π^+ production we can exchange either the neutron (n) or the Δ° trajectories. For π^- production only the Δ^{++} trajectory is allowed. If we write now the formulas corresponding to these diagrams, we obtain for the different exchanged trajectories :

$$\frac{d\sigma}{dtdx}\Big|_n = \gamma_{\mathbb{P}\gamma\gamma}(o)\ \gamma_{ppnn}(t)\ |\ \beta_n(t)\ |^2\ (1-|x|)^{1-2\alpha_n(t)}$$

$$\frac{d\sigma}{dtdx}\Big|_\Delta = \gamma_{\mathbb{P}\gamma\gamma}(o)\ \gamma_{pp\Delta\Delta}(t)\ |\ \beta_\Delta(t)\ |^2\ (1-|x|)^{1-2\alpha_\Delta(t)}$$

where the γ's are the corresponding couplings, the $\beta(t)$'s the regge residues and :

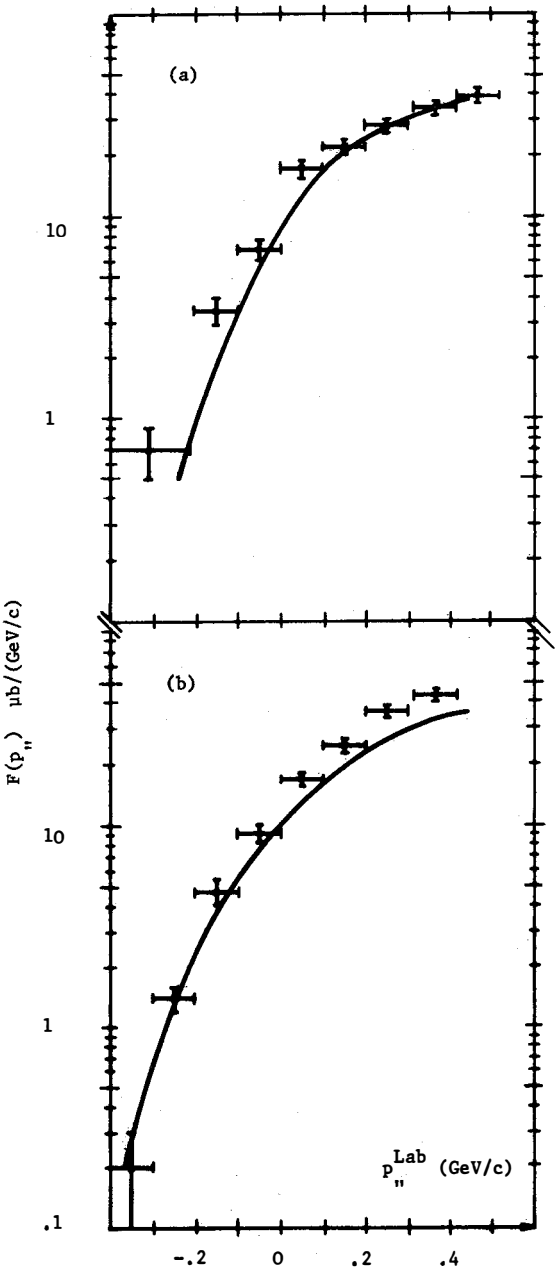


Fig. 3 : The structure function $F(p_{\pi})$ in the target fragmentation region : a) reaction $\pi(\gamma p, \pi)$ and b) reaction $(\gamma p, \pi^{+})$. The solid lines are the predictions of CHAN et al.

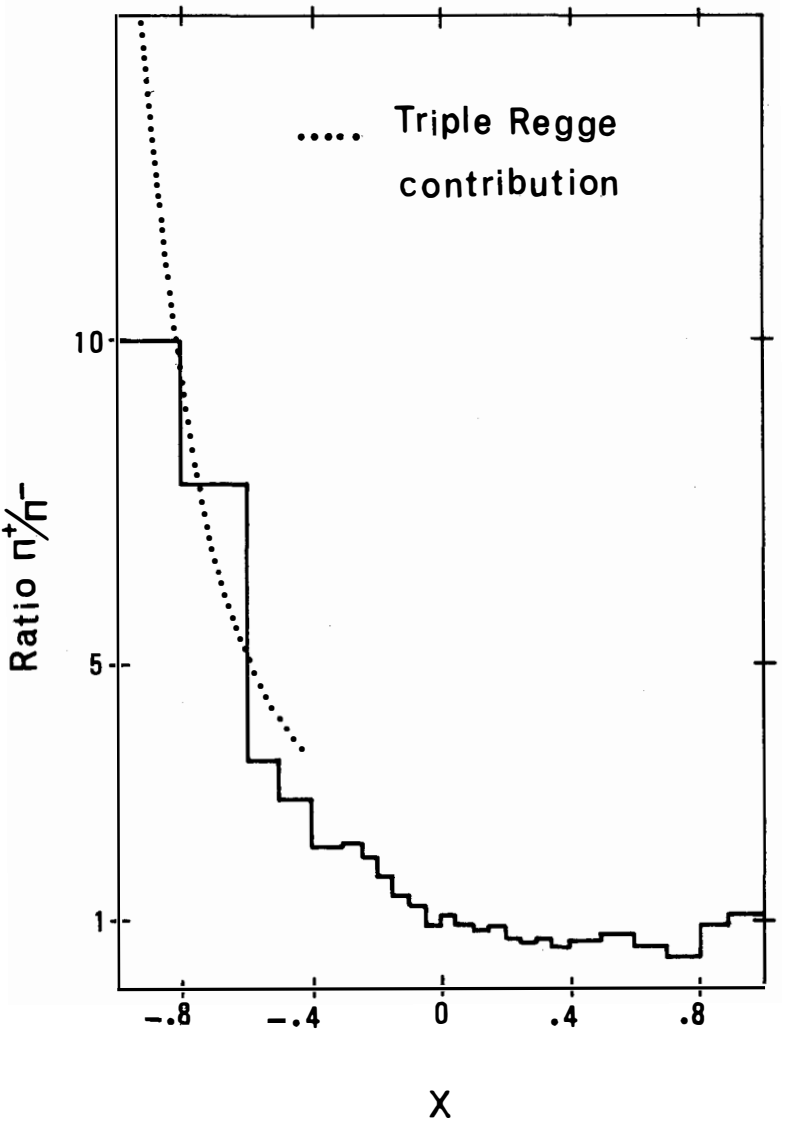
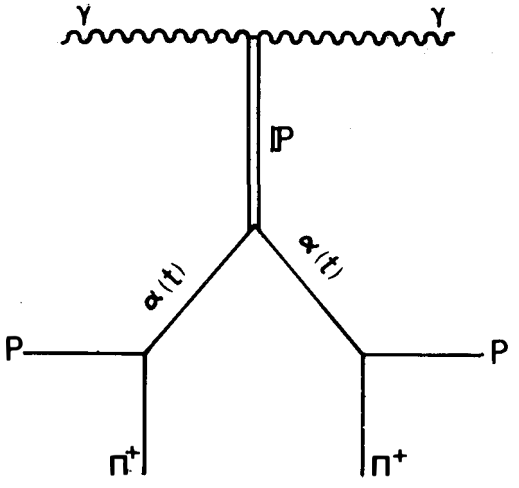
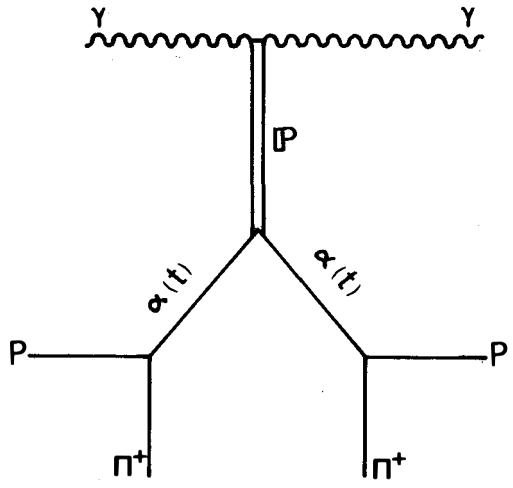


Fig.4 : RATIO of π^+ to π^- PRODUCTION in γp INTERACTIONS



1a

$\alpha(t) = \alpha_N(t), \alpha_{\Delta^0}(t)$



1b

$\alpha(t) = \alpha_{\Delta^{++}}(t)$

Fig.5 : TRIPLE REGGE DIAGRAMS

$$t = m^2(1-|x|) + \mu^2 - (P^2 + \mu^2) / |x|$$

with m = mass of proton and μ = mass of pion

The coupling $\gamma_{\mathbb{P}\gamma\gamma}(o)$ cancels out in the ratio, therefore, we expect our result to be independent of the beam. The couplings $\gamma_{\mathbb{P}nn}$ and $\gamma_{\mathbb{P}\Delta\Delta}$ can be related using SU(6) and the corresponding coefficients :

$$\gamma_{\mathbb{P}nn} = 1.2\ \gamma_{\mathbb{P}\Delta\Delta}$$

If we introduce now the effective trajectories $\alpha(t)$ and residues $\beta(t)$ calculated by C. Risk [9] from an analysis of pp inclusive collisions we obtain the triple regge contribution [10] to the ratio represented by the dotted line in Fig. 4. It is important to notice that the baryon trajectories obtained from inclusive studies, have intercept one or two units lower than those obtained from two body reactions [11]. In Fig. 6 we compare the triple regge calculation with the compilation of the ratio π^+/π^- for π^+p reactions as given by Morrison [12]. As we can see, the triple regge contributes with a backward peak in agreement with the experimental results. For the photoproduction case if we would apply the same formalism in the fragmentation region of the beam, using vector dominance it is easy to see that the same trajectory would be exchanged for π^+ and π^- production. Thus, we predict a value of one for the π^+/π^- ratio in the photon fragmentation region, as it is verified experimentally (Fig.4). It is interesting to note that the comparison of triple regge predictions is being made with an experiment where there is not enough beam energy to be strictly in the triple regge limit (S large and S/M^2 large) ; but as it was pointed out by W.S. Lam et al [13] according to duality one can extend the validity of the triple regge formula to lower energies and larger region in x and in that case it should describe the average behaviour.

D - INCLUSIVE PHOTOPRODUCTION OF RESONANCES :

1- The reaction $\gamma p \to \Delta^{++}$ + anything

A very strong signal Δ^{++} is observed in the $p\pi^+$ invariant mass distribution for all identified γp reactions. For the purpose of this analysis we have defined the Δ^{++} events through the mass cut $1.12 < M(p\pi^+) < 1.32$ GeV. In Fig. 7 we plot the F(x) distribution which exhibits a rapid rise from $x = -1$ reaching a maximum value in the interval $-.85 < x < -.75$, consistent with a backward leading particle behaviour. Several authors [14] have

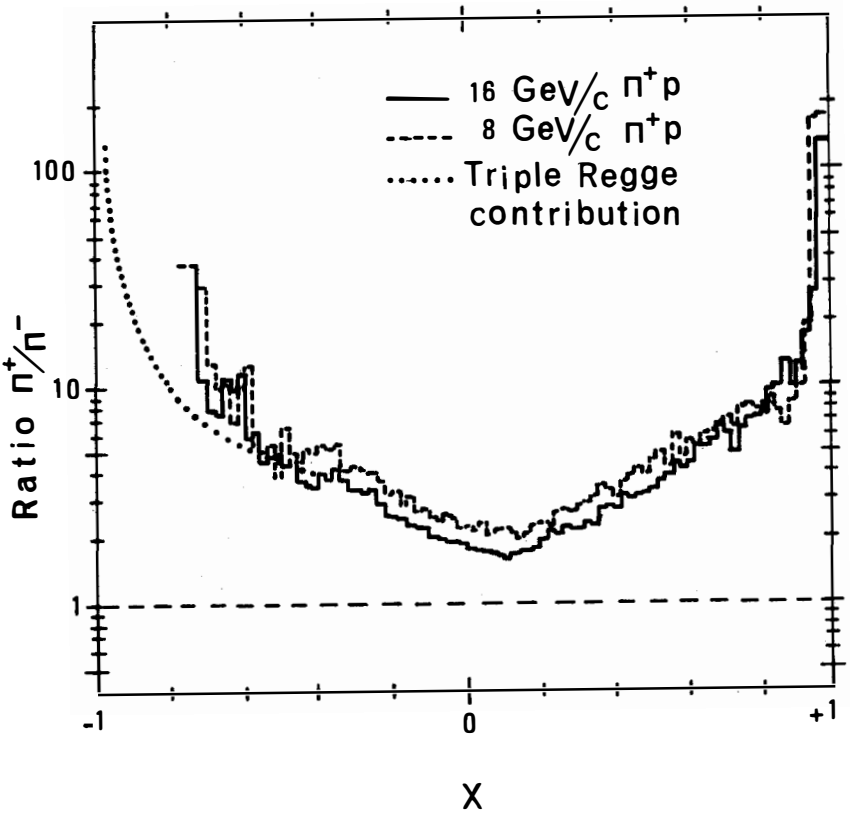


Fig.6 : RATIO of π^+ to π^- PRODUCTION in π^+p INTERACTIONS

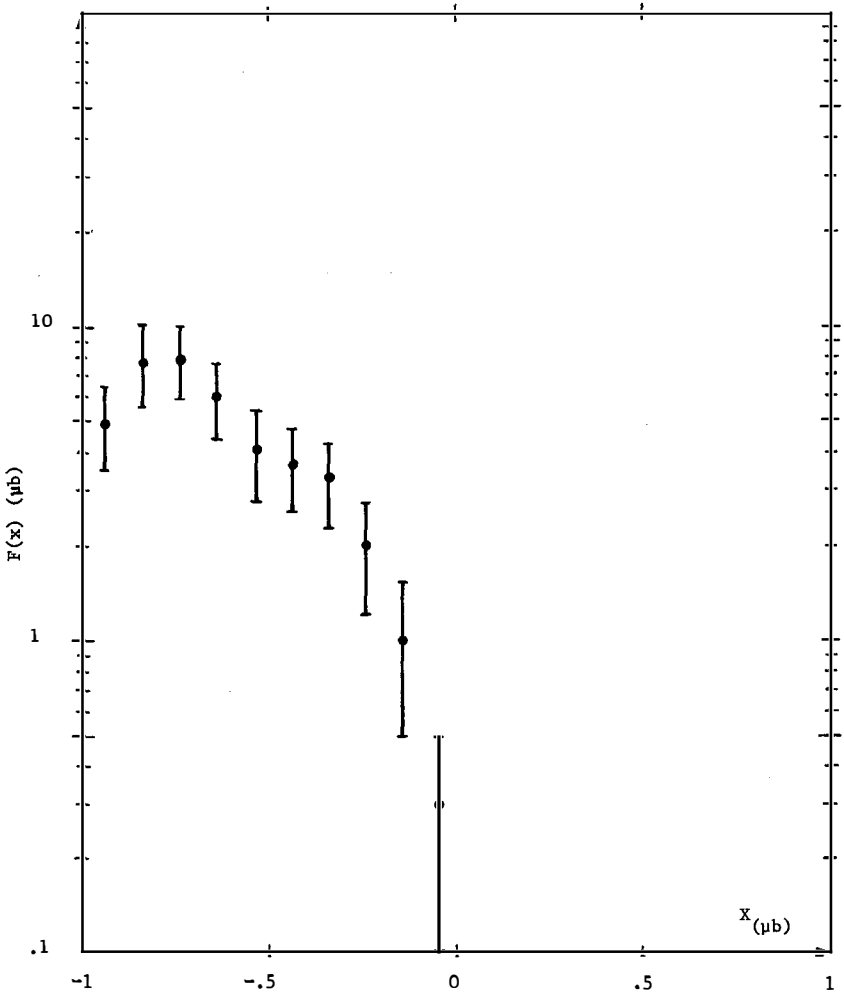


Fig. 7 : The structure function F(x) as a function of x for the reaction (γp, Δ^{++})

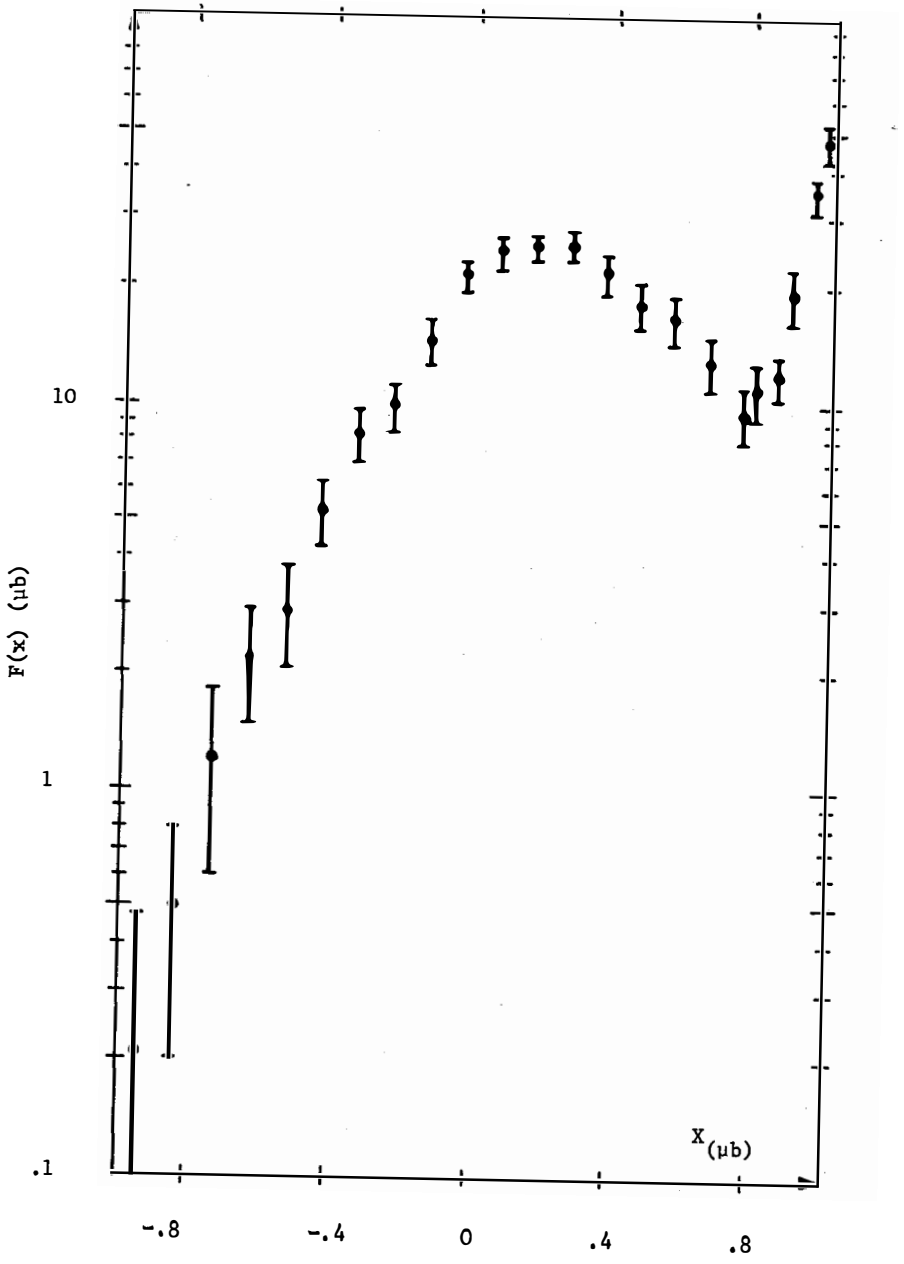


Fig. 8 : The structure function F(x) as a function of x for the reaction (γn, ρ°)

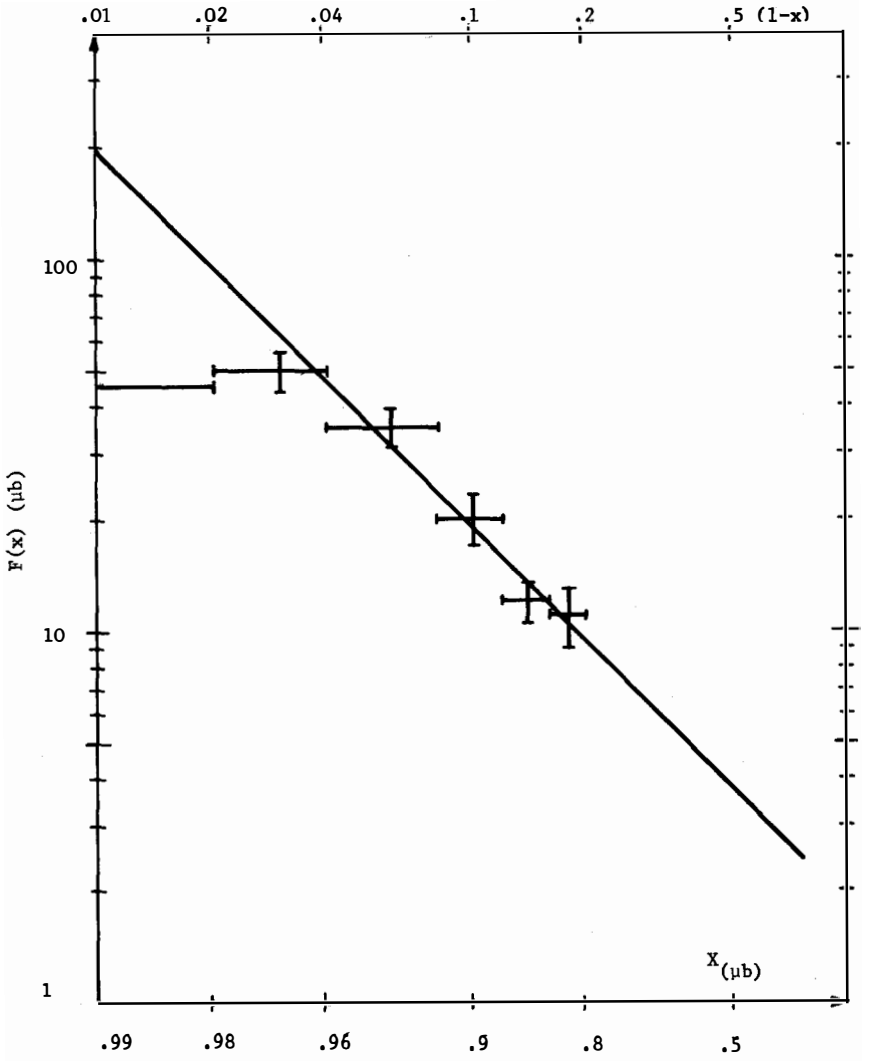


Fig. 9 : The logarithm of F(x) for the reaction ($\gamma n, \rho^{\circ}$) as a function of $\ell n(1-x)$ in the interval $x>0.8$. The straight line corresponds to the expression : const. $(1-x)^{-1}$.

examined the contribution of the one pion exchange mechanism to inclusive reactions and these studies have shown that a peak in the F(x) distribution is expected in the neighbourhood of $x \simeq -.85$ consistent with our findings.

2- The reaction $\gamma n \to \rho^\circ$ + anything

The $\pi^+ \pi^-$ invariant mass distribution for all $\pi^+ \pi^-$ combinations shows a ρ° mass signal and we have selected the ρ° events by introducing the mass cut $.6 < M(\pi^+ \pi^-) < .85$ GeV. The corresponding F(x) distribution (Fig.8) exhibits for $x > .7$ (instead of the sharp drop off observed in pion production) a strong- leading particle effect as we approach the limit $x=1$.

If we apply now the triple regge formula in the fragmentation region of the beam for the reaction $\gamma n \to \rho^\circ$ + anything (where n stands for nucleon) we obtain :

$$F(x,t) \simeq (1-|x|)^{1-2\alpha(t)}$$

and in the case of a triple Pomeron term :

$$F(x) = \frac{C}{1-|x|}$$

In Fig. 9 we plot $\ln F(x)$ versus $\ln(1-x)$ for our ρ° inclusive data in the region $.8 < x < 1$. The data is well described [15] by a straight line in the region $.8 < x < .96$. The fall off in the very forward direction ($x>.96$) was found to be a result of the loss of two prong events with zero opening angle (mistaken as e^+e^- pairs). A fit to the data in the interval $.8 < x < .96$ yields a value of $1-2\alpha(t) = 0.9 \pm 0.2$ consistent with a Pomeron exchange mechanism.

E - CONCLUSION :

In the present γd experiment at 7.5 GeV it has been found that it is possible to separate γp from γn reactions in the inclusive case. Charge symmetric reactions $(\gamma p, \pi^\pm)$ and $(\gamma n, \pi^\mp)$ are found to be similar. The ratio of the total inclusive π^+ / π^- (π^-/π^+) cross sections for γp (γn) reactions was estimated to be $1.2 \pm .1$.

The prediction for the target fragmentation region obtained from hadron induced reactions via factorization of the Pomeron and other possible regge exchanges are in good agreement with our $(\gamma p, \pi^-)$ data. For the $(\gamma p, \pi^+)$ data a deviation is observed at the higher P_L values.

We investigate the ratio π^+/π^- as a function of x and found a strong backward peak which can be explained within the framework of the triple regge formalism.

The Δ^{++} inclusive data exhibits a leading particle behaviour in the backward direction and it is consistent with a one pion exchange mechanism. The ρ° inclusive production shows a strong- leading particle effect in the forward direction (as expected from the vector dominance model) and this effect is well described by a triple Pomeron term.

ACKNOWLEDGEMENTS

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15 - Altough the ρ° signal sits on a high background in the interval $.8 < x < 1$ the contribution of the pions that constitute the background is small.