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ANALYSIS OF TRANSVERSE MOMENTUM DISTRIBUTIONS FOR pp INTERACTIONS AT 360 GeV/c IN THE FRAMEWORK OF A QUARK-DIQUARK FRAGMENTATION MODEL

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ABSTRACT

Using a quark-diquark fragmentation model, in which either the Field-Feynman or the Lund model is coupled with a quark-diquark distribution function, we study transverse momentum distributions, p_T, for the inclusive reactions pp → hadron + anything at 360 GeV/c. We find that a primordial mean transverse momentum $\langle k_T \rangle \simeq 0.4$ GeV/c can well reproduce the p_T^2 distributions of charged hadrons, π^o, K_s^o, Λ^o, K^* and Σ^* and the Feynman x-p_T correlations. We confirm that a diquark in a proton plays an important rôle in reproducing the x-p_T correlation of Λ^o.

1. INTRODUCTION

Recently we have constructed a quark-diquark fragmentation model to investigate the reaction mechanisms of soft hadronic processes [1]. This model consists of two parts, i.e. quark-diquark distributions in a nucleon and hadronization mechanisms of quarks and diquarks. For the latter we adopt two familiar models, i.e. the Field-Feynman independent fragmentation model (Field-Feynman) [2] and the Lund string model (Lund) [3]. By comparing model predictions with Feynman x distributions for proton-proton collisions at 360 GeV/c, we found in Ref. 1 that the diquark system in a proton plays an important rôle especially in reproducing the x distribution of Λ^o which extends to large values of x. S. Ekelin et al. [4] have also pointed out experimental evidence for diquark systems from phenomenological analyses of hard processes. The importance of the diquark in the high p_T region has been pointed out by the ABCDHW collaboration [5].

It is interesting to investigate the rôle of the diquark for the p_T distribution of soft hadronic processes. In the present paper, transverse momentum (p_T) distributions in the reaction pp → hadron + anything at 360 GeV/c are studied in the framework of our quark-diquark fragmentation model. All parameters entering in the two hadronization models have been fixed by using data on e^+e^- → hadrons in which hadronization mechanisms manifest themselves most cleanly. We can thus extract reliable information about the quark-diquark distributions in a nucleon. We are primarily concerned with a primordial transverse momentum of quarks and diquarks in the nucleon.

Data reduction is described in Section 2. Since details of the quark-diquark fragmentation model have been presented in Ref. 1, we briefly describe the framework of our model in Section 3. We present in Section 4 p_T distributions and x-p_T correlations for various hadrons together with the model predictions. Section 5 presents a brief discussion of our results and gives our conclusions.

2. DATA REDUCTION

Detailed descriptions of the set-up of the European Hybrid Spectrometer (EHS) and the data reduction have been published in Refs. [6] to [9]. We therefore briefly describe the selection criteria of the data used in the present analysis. The 80 cm Rapid Cycling Bubble Chamber (RCBC) was exposed to a beam of 360 GeV/c protons. A major part of the exposure of 160K pictures was scanned and measured for inelastic interactions with at least one associated V^o or γ seen in the bubble chamber. The sample corresponds to a sensitivity of 1.6 events/μb. We selected events with good measurement quality by applying the following criteria: the fitted probability of strange particle hypotheses is larger than 2% and $\Delta p/p$ is less than 20%, Δp and p being the error of momentum measurement and the magnitude of momentum, respectively, for charged particles. We assumed that all charged particles are $\pi^{\pm}$, except for slow protons identified by ionization in RCBC. We have checked that the residual π/p/K ambiguity does not significantly affect the results. It should be noted that the charged particle $h^{\pm}$ distributions are single particle distributions with V^o observed in the bubble chamber.

3. THE QUARK-DIQUARK FRAGMENTATION MODEL

For the construction of the model, we assume a reaction mechanism of soft hadronic processes which is a two step process; first a quark or a diquark is extracted from the projectile or target protons and then hadronizes. The model is therefore factorized into two parts describing quark or diquark distributions in a proton and subsequent hadronization processes of these quarks or diquarks as illustrated in Fig. 1. For the quark structure of the proton, we adopt two viewpoints; a proton consists of a quark-diquark or of three independent quarks. With the help of the dual Regge model [10,11], we parametrize the quark distribution functions according to these two views, being denoted as QD and IQ, respectively:

$$G_{QD}(x) = \frac{1}{B(\alpha_q+1,\alpha_{qq}+1)} x^{\alpha_q}(1-x)^{\alpha_{qq}} \qquad 1)$$

$$G_{IQ}(x) = \frac{1}{B(\alpha_q+1,2\alpha_q+2)} x^{\alpha_q}(1-x)^{2\alpha_q+1} \qquad 2)$$

where $-\alpha_a$ and $-\alpha_{qq}$ correspond to the intercepts of meson ($q\bar{q}$) and baryonium ($qq\bar{q}\bar{q}$) trajectories, respectively [12,13] and $B(\alpha,\beta)$ denotes the beta function.

The hadronization model, Field-Feynman or Lund, is combined with the distribution function (1) or (2). The parameters in the two hadronization models have been determined by using data on $e^+e^- \rightarrow$ hadrons [1]. The mean transverse momenta arising from the hadronization process were found to be about 0.4 GeV/c for both the Field-Feynman and the Lund models.

Transverse momenta of hadrons produced in pp collisions could arise not only from the hadronization of quarks but also from the primordial motion of quarks in a proton, which we did not take into account in our original model [1]. We thus introduce the primordial transverse momentum k_T of quarks in a proton according to a function

$$\exp\ (-k_T^2/2\langle k_T\rangle^2)\ ,$$

where $\langle k_T\rangle$ is the mean transverse momentum. All formulations described above are incorporated into the Monte Carlo program EPOCS [14].

4. COMPARISON OF DATA WITH MODEL PREDICTIONS

4.1 p_T^2 distributions

Figures 2a-e show the p_T^2 distributions of $h^\pm$, π^o, K_s^o and Λ^o, where we can see at least two components of slopes if the spectra are decomposed into exponential forms. Average p_T values are tabulated in Table 1.

We examine the model predictions derived from the Field-Feynman and Lund models with the quark-diquark distribution function (1), for which we also assume a primordial mean transverse momentum $\langle k_T\rangle$ of 0.0, 0.4 or 0.8 (GeV/c). The normalization is performed in such a way that the model prediction in the quark-diquark configuration for each value of $\langle k_T\rangle$ reproduces the inclusive cross-section of h^- in a similar manner as was done in Ref. 1 in which we have shown that our model can predict fairly well relative production rates of h^+, π^o, K_s^o and Λ^o.

Since we found that the Lund model with the diquark could also reproduce global features of all data as well as Field-Feynman, we present here only the predictions of the Field-Feynman model. Furthermore, we also attempted to check one of the latest versions of the LUND model (FRITIOF version 0.0) [15] called LUND M.C. in this paper. As seen in Figs. 2a-e, the LUND M.C. also provides a consistent representation of the data.

It is well-known that sharp slopes in the small p_T^2 region are due to resonance production. We therefore incorporate into the Field-Feynman not only pseudoscalar (PS) mesons and octet (8) baryons but also vector (V) and decuplet (10) resonances with an equal weight, namely (PS)/(V) = 1 and (8)/(10) = 1. It is shown in Figs. 3a-e that the Field-Feynman model coupled with the distribution function (1) and $\langle k_T \rangle$ = 0.4 GeV/c explains the structure of transverse spectra; hadrons arising from resonance decay contribute dominantly to the small p_T^2 regions while directly produced hadrons contribute to larger p_T^2 regions.

The p_T^2 distributions of $K^{*\pm}(892)$ and $\Sigma^{*\pm}(1385)$ [16] are shown in Figs. 4a-d, together with the model predictions for $\langle k_T \rangle$ = 0.4 GeV/c. It is seen that the model predicts well the shape of the p_T^2 distributions for the K^* and Σ^* resonances.

4.2 <u>x-$\langle p_T \rangle$ correlations</u>

It is known that the average values of the transverse momentum $\langle p_T \rangle$ are a function of the Feynman variable x, the so-called "seagull effect". Incorporating the quark-diquark distribution function (1) together with a primordial mean transverse momentum $\langle k_T \rangle$ = 0.4 GeV/c into the Field-Feynman and Lund models, we attempt to calculate the x-p_T correlations as shown in Figs. 5a-e.

We have pointed out in Ref. 1 the importance of the diquark system (ud) with spin 0 in target or projectile protons. It is thus interesting to check if the diquark is really necessary to reproduce the x-p_T correlations. We also consider the Field-Feynman model with the distribution function (2) for three independent quarks. The primordial mean transverse momentum $\langle k_T \rangle$ = 0.4 GeV/c is also taken into account. The p_T^2 distributions obtained from the Field-Feynman model without diquark are found to be quite similar to those predicted from the same model with diquarks.

For the x-$<p_T>$ correlations for h^+ and Λ^o we find that the diquark plays a significant rôle as shown in Figs. 5b and e, respectively. We observe that for h^+ the Field-Feynman model without the diquark gives higher $<p_T>$ than data for $x > 0.1$ GeV/c. Furthermore, for Λ^o, this model cannot reproduce the rather flat distribution of $<p_T>$ and predicts no events for $x > 0.6$. As seen in Fig. 5e, the $<p_T>$ grows quickly with x: the reason for this is that the configuration without the diquark gives an extremely small contribution in this x region and consequently momentum conservation makes the p_T large. Both of these defects cannot be improved even if different values of $<k_T>$ are used. In our model, Λ^o is mainly created from the valence ud diquark combined with an s quark of the sea. The diquark having large momentum therefore plays an essential rôle for producing Λ^o with large x. Here we also show the predictions of the LUND M.C. which also predicts well the shape of x-p_T correlations.

5. DISCUSSION AND CONCLUSIONS

Using the quark-diquark fragmentation model, we have successfully described the transverse spectra of various hadrons produced in pp collisions at 360 GeV/c. Important ingredients of our model are the hadronization mechanisms, i.e. the Field-Feynman or the Lund model coupled with the quark-diquark distribution function. As expected from a previous analysis of the Feynman x distributions [1], the model with a diquark in the proton can reproduce fairly well the transverse distributions $d\sigma/dp_T^2$ and the x-p_T correlations.

In the present analysis we have clarified another important feature, namely that quarks or diquarks in a nucleon have to retain the primordial mean transverse momentum $<k_T> \simeq 0.4$ GeV/c which is almost equal to the transverse momentum introduced in hadronization processes. This is, after all, a natural observation since the transverse momenta of the quarks in the nucleon and those created in the hadronization process have a common origin, quark confinement.

Acknowledgement

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REFERENCES

[1] J.L. Bailly et al., Zeit. Phys. C31 367 (1986).

[2] R.D. Field, R.P. Feynman and G.C. Fox, Nucl. Phys. B128 1 (1977)-

[3] T. Sjöstrand, Computer Phys. Comm. 28 229 (1983).

[4] S. Ekelin, S. Fredriksson, M. Jandel and T.I. Larsson, Phys. Rev. D28 257 (1983).

[5] A. Breakstone et al., Zeit. Phys. C28 335 (1985).

[6] M. Aguilar-Benitez et al., Nucl. Instrum. Methods 205 79 (1983).

[7] J.L. Bailly et al., Zeit. Phys. C22 119 (1984).

[8] J.L. Bailly et al., Zeit. Phys. C23 205 (1984).

[9] M. Asai et al., Zeit. Phys. C27 11 (1985).

[10] A. Capella et al., Phys. Lett. 81B 68 (1979)
G. Cohen-Tannovdji et al., Phys. Rev. D19 3397 (1979).

[11] A.V. Batunin, A.K. Kikhoded and A.N. Tolstenkov, preprint of IHEP, Serpukhov, 1984-131.
V.V. Anisovich, M.N. Kobrinsky and J. Nyiri, preprint of IHEP, Leningrad, 1984-982.

[12] K. Kinoshita, H. Noda and T. Tashiro, Prog. Theor. Phys. 68 1699, 2086 (1982).

[13] H. Minakata, Phys. Rev. D20 1656 (1979).

[14] K. Kato and T. Munehisa, KEK report 84-18 e^+e^- event generator EPOCS (in Japanese).

[15] B. Andersson, G. Gustafson and B. Nilsson-Almqvist, LU-TP 86-3 Feb. (1985).

[16] T. Aziz et al., Zeit. Phys. C30 381 (1986).

Table 1

Average values of p_T

	$\langle p_T \rangle$ (GeV/c)
h^+	0.372 ± 0.002
h^-	0.334 ± 0.003
π^o	0.341 ± 0.028
K^o_s	0.442 ± 0.013
Λ^o	0.479 ± 0.026

Figure captions

Fig. 1 : Parton diagram for quark and diquark hadronization in proton-proton interaction.

Fig. 2 : p_T^2 distributions: a) h^-, b) h^+, c) π^o, d) K_s^o and e) Λ^o. Predictions of the Field-Feynman model including diquarks are also presented. The mean transverse momentum $<k_T>$ is taken to be 0.0 (dotted curve), 0.4 (solid curve) and 0.8 (dashed curve) GeV/c. Predictions of the LUND M.C. are also presented (dash-dotted curve).

Fig. 3 : Contributions from direct production (solid curve) and resonance decay (dashed curve) predicted from the Field-Feynman model with diquarks and $<k_T>$ = 0.4 GeV/c: a) h^-, b) h^+, c) π^o, d) K_s^o and e) Λ^o.

Fig. 4 : p_T^2 distributions for a) $K^{*+}(892)$, b) $K^{*-}(892)$, c) $\Sigma^{*+}(1382)$ and d) $\Sigma^{*-}(1382)$. The solid curve shows the predictions of the Field-Feynman model with diquark and $<k_T>$ = 0.4 GeV/c.

Fig. 5 : Feynman x average p_T correlations for a) h^-, b) h^+, c) π^o, d) K_s^o and e) Λ^o. Solid curves: the Field-Feynman model with diquarks. Dotted curves: the Field-Feynman model with three independent quarks. The primordial mean transverse momentum $<k_T>$ is assumed to be 0.4 GeV/c for each prediction. Dashed curves: the LUND M.C.

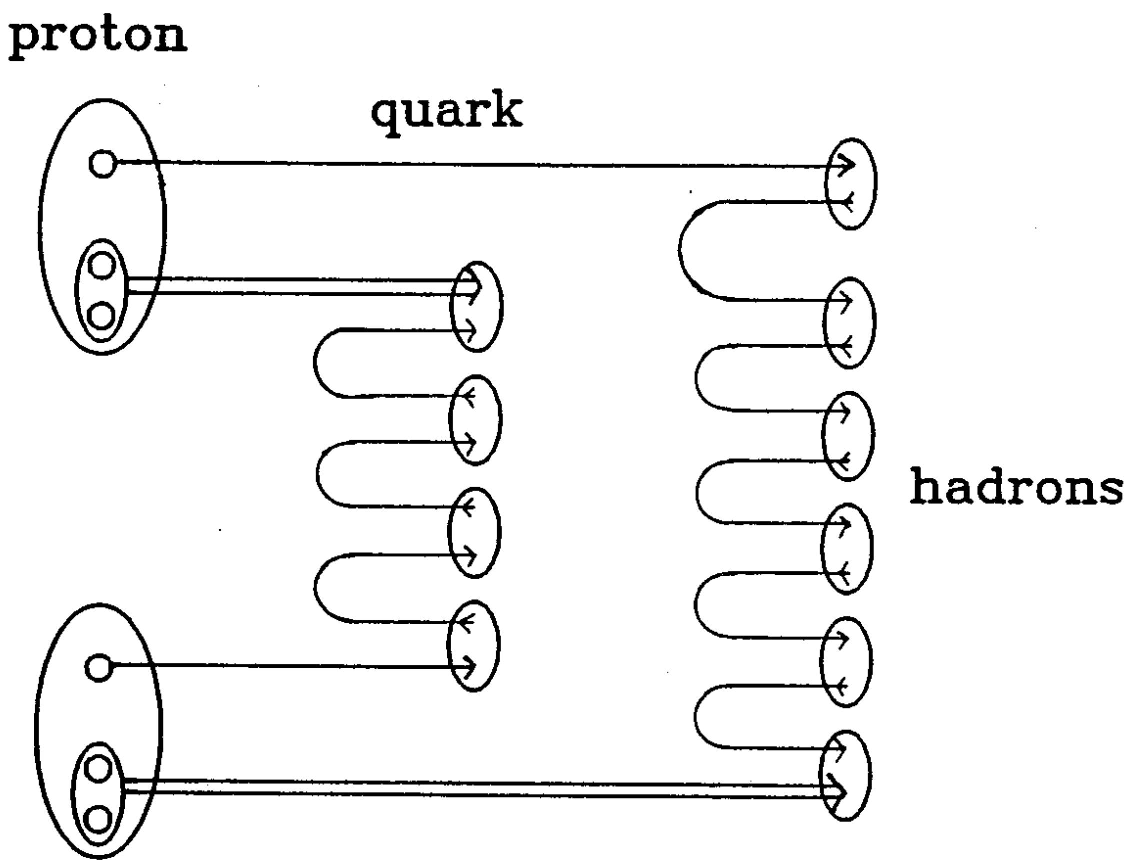

FIG.1

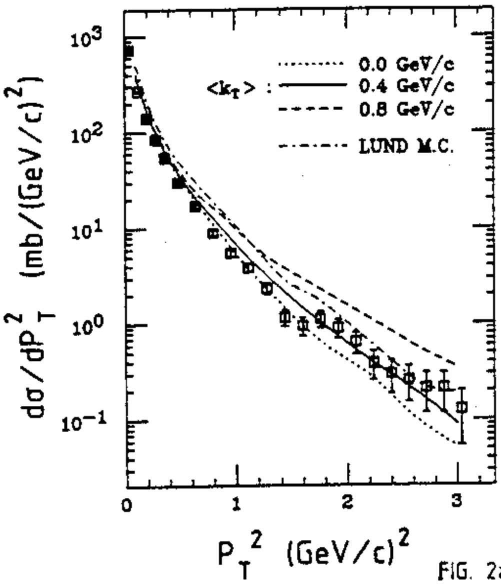

FIG. 2a

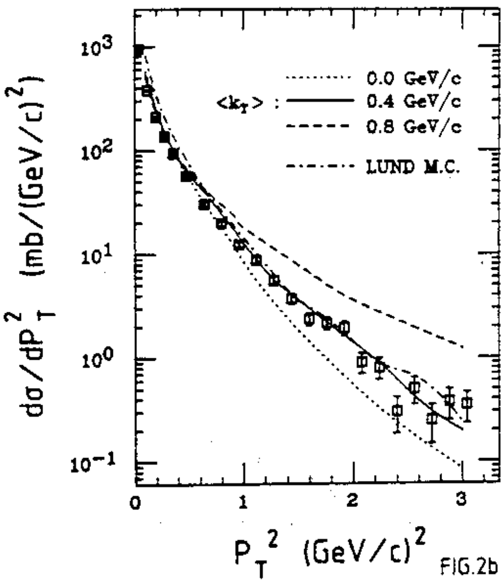

FIG.2b

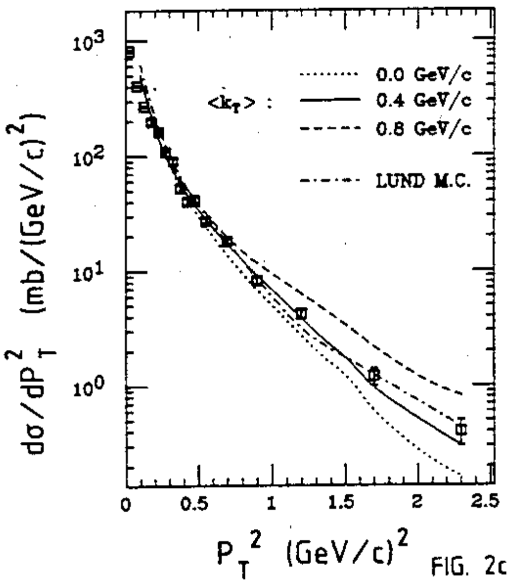

FIG. 2c

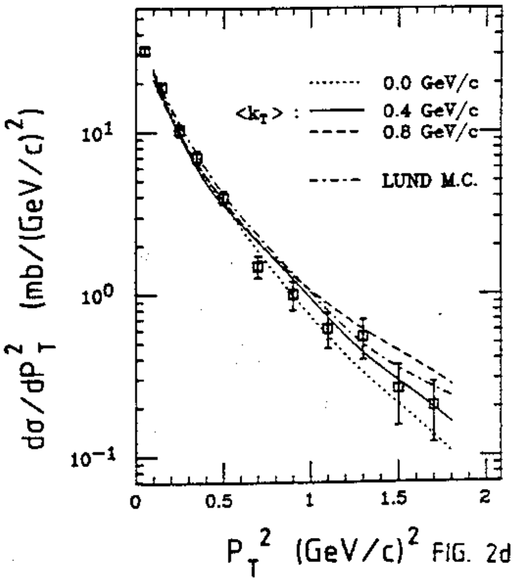

FIG. 2d

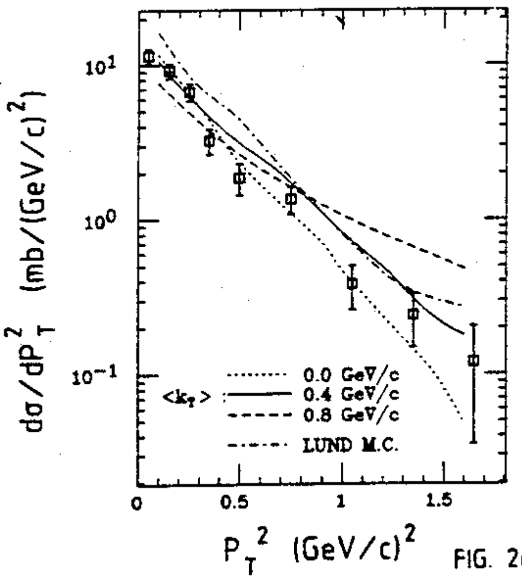

FIG. 2e

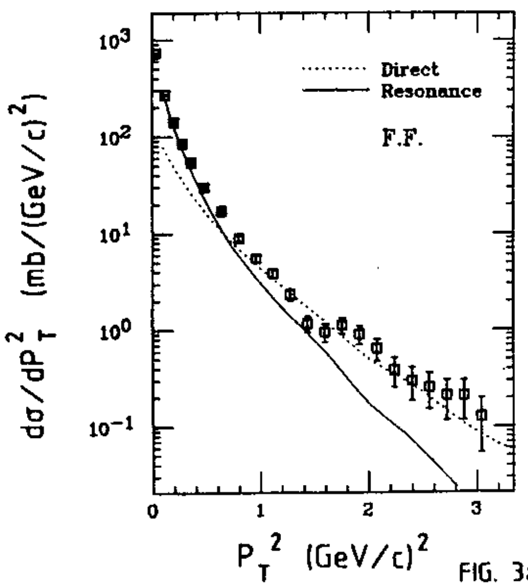

FIG. 3a

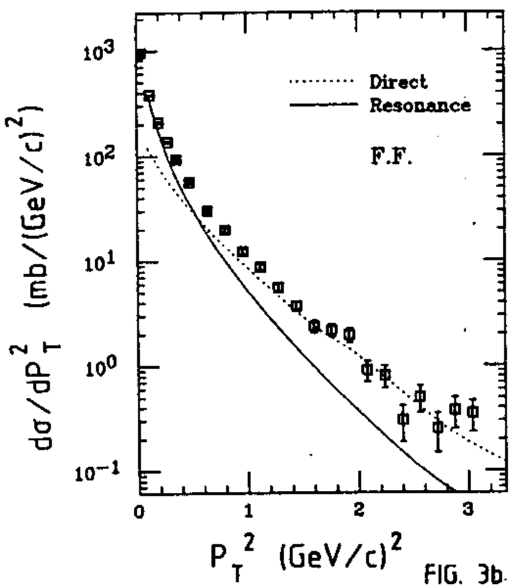

FIG. 3b

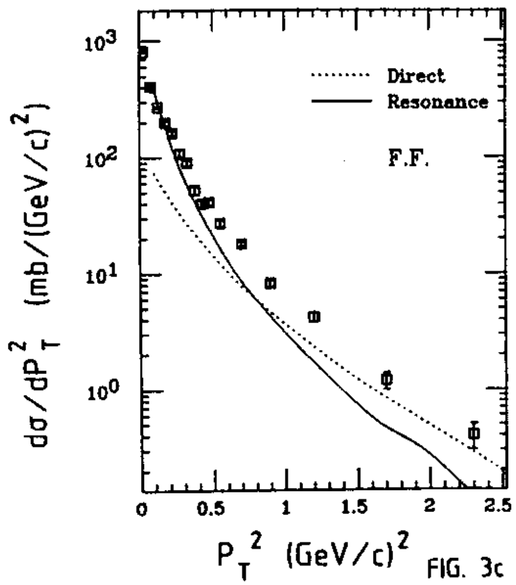

FIG. 3c

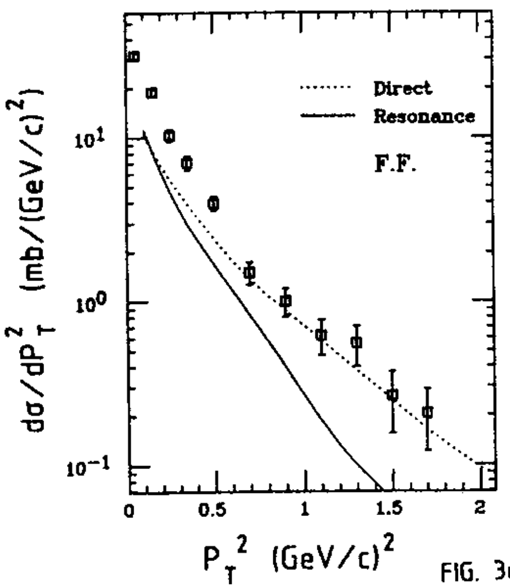

FIG. 3d

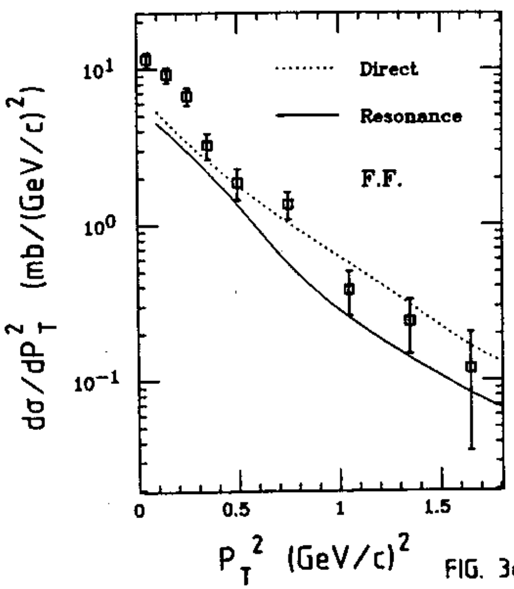

FIG. 3e

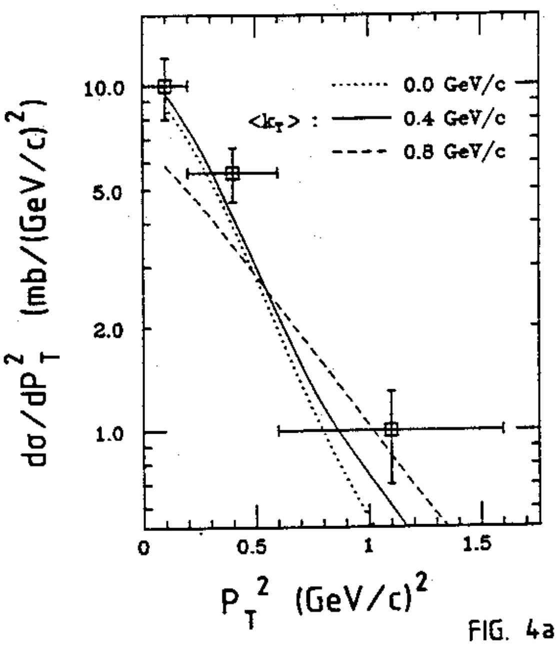

FIG. 4a

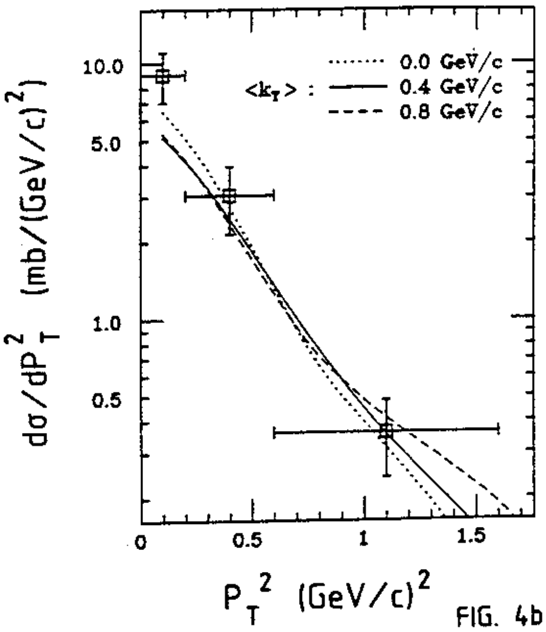

FIG. 4b

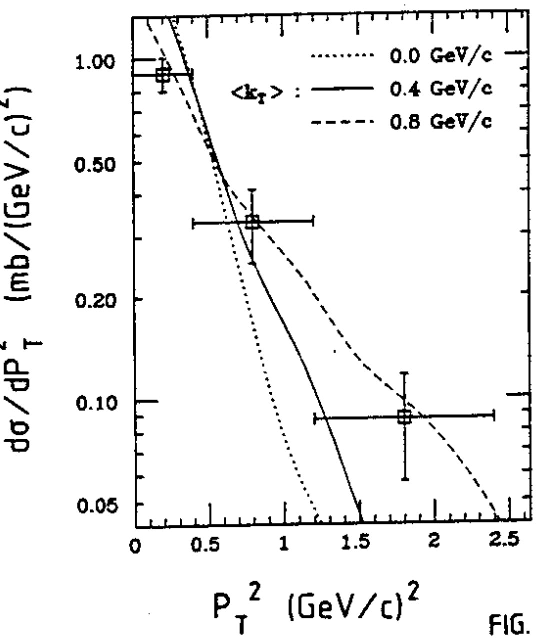

FIG. 4c

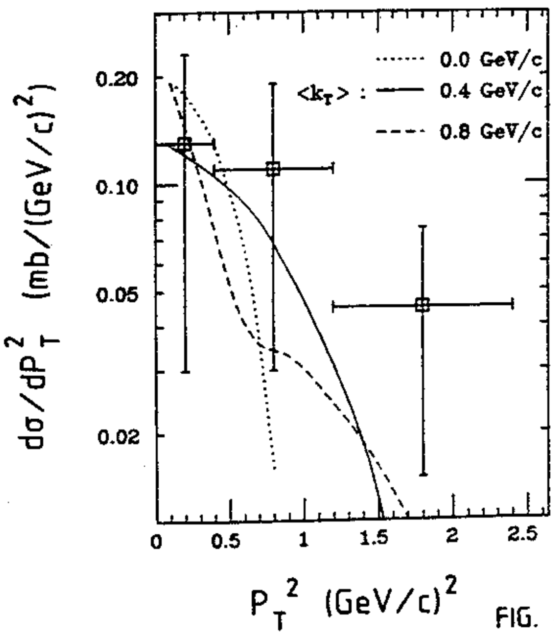

FIG. 4d

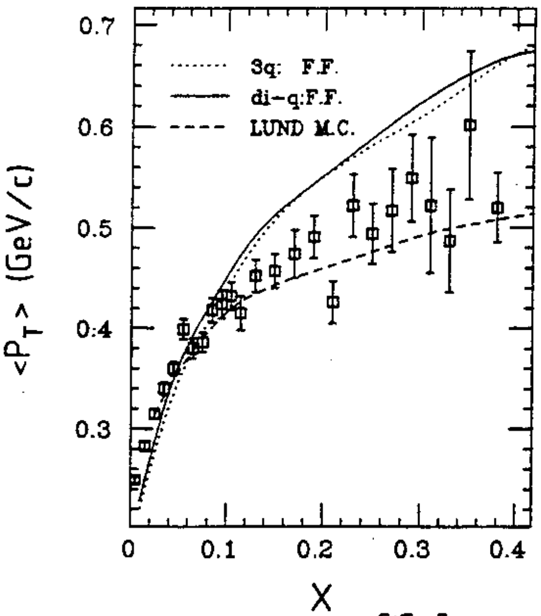

FIG. 5a

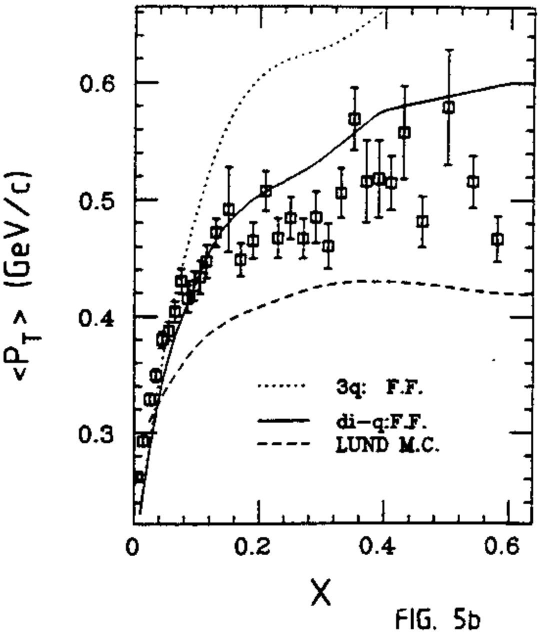

FIG. 5b

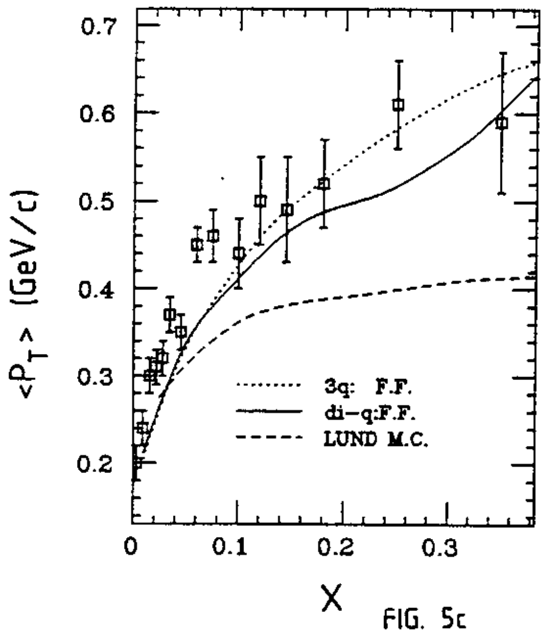

FIG. 5c

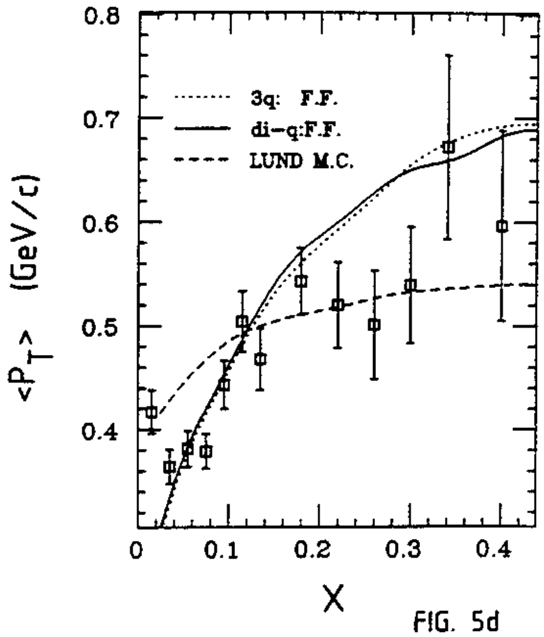

FIG. 5d

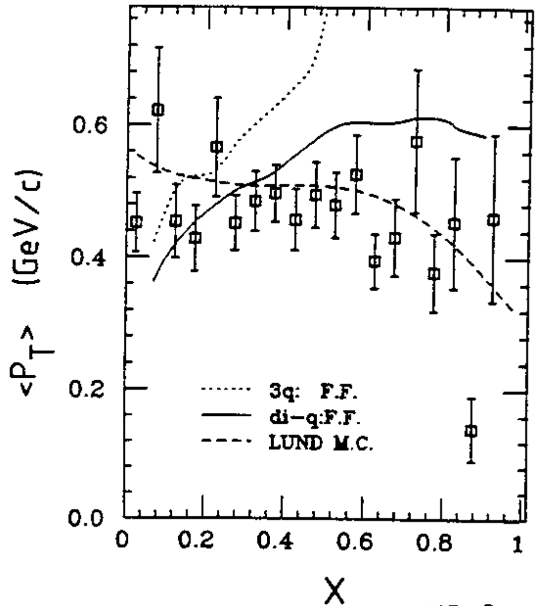

FIG. 5e