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MULTIPLICITY DEPENDENCE OF THE AVERAGE TRANSVERSE MOMENTUM IN π^+p, K^+p AND pp COLLISIONS AT 250 GeV/c

EHS/NA22 Collaboration

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ABSTRACT

The average transverse momentum $\langle p_T \rangle$ has been studied as a function of the charge multiplicity n in π^+p, K^+p and pp collisions at 250 GeV/c ($\sqrt{s} \approx 22$ GeV) and compared to that at other energies. The effect of cuts in rapidity and p_T is demonstrated. A comparison to currently used low-p_T models shows that the two-chain Dual Parton Model underestimates the experimentally observed correlation at large p_T. The new version of the two-chain LUND-FRITIOF Model is better than the first version of this model, but still overestimates the correlation.

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After a first indication in a cosmic ray experiment [1], the UA1 experiment [2] has established an *increase* of the mean transverse momentum $\langle p_T \rangle$ with increasing charged particle density $\Delta n/\Delta y$ in rapidity. A similar increase has recently been observed in a second cosmic ray experiment [3] and at the Tevatron [4]. Though much weaker at ISR energies, an increase is now also seen there [5,6]. Besides the growth of the effect between ISR and Collider, the correlation between $\langle p_T \rangle$ and $\Delta n/\Delta y$ becomes stronger when low p_T tracks are excluded and when the analysis is restricted to the central region. Explanations have been proposed in terms of possible evidence for hadronic phase transition in a thermodynamical model [7], small impact parameter scattering in a geometrical model [8] or the production of mini-jets from semi-hard scattering [9,10,11].

At lower energies [12], on the other hand, a *decrease* of $\langle p_T \rangle$ with n had been observed. This decrease is mainly visible at the high n tail of the distribution and is generally interpreted as a phase space effect.

Further analysis is needed at different energies and in different phase space regions.

The experiment (NA22) has been performed at CERN in the European Hybrid Spectrometer (EHS), equipped with the Rapid Cycling Bubble Chamber (RCBC) and exposed to a 250 GeV/c ($\sqrt{s}$=22 GeV) positive meson enriched, tagged beam. The experimental set-up is described in [13] and references given therein.

The data have been taken with a minimum bias interaction trigger. Charged particle tracks are reconstructed from hits in the wire- and drift-chambers of the two lever-arm magnetic spectrometer and from measurements in the bubble chamber. The momentum resolution $\langle \Delta p/p \rangle$ varies from a maximum of 2.5% at 30 GeV/c to around 1.5% above 100 GeV/c.

Events are accepted when measured and reconstructed charge multiplicity n are consistent, charge balance is satisfied, no electron is detected among the secondary tracks, the number of rejected tracks ($\Delta p/p > 0.25$) is at most 0,1,1,2 and 3 for events with charge multiplicity 2,4,6,8 and >8, respectively.

After these cuts, our present inelastic sample consists of 81 000 π^+p, 35 000 K^+p and 5 800 pp events. For momenta $p_{LAB} < 0.7$ GeV/c, the range in the bubble chamber and/or the change of track curvature is used for proton identification. In addition, a visual ionization scan has been used for $p_{LAB} < 1.2$ GeV/c on the full K^+p and pp and part of the π^+p sample. Particles with momenta $p_{LAB} > 1.2$ GeV/c are not identified in the present analysis and are treated as pions. For the reported analysis the three samples have been combined since no beam-dependence is observed.

The distribution in the charge multiplicity n has already been reported in [13], that in the transverse momentum p_T in [14].

In this paper we want to show that the growth of the slope of $\langle p_T \rangle$ vs. n from a negative value below ISR to a positive value is a smooth one. It becomes positive sooner for the central rapidity region and for large p_T than for the outer regions and low p_T.

Comparing in Fig.1a the highest available energy data to some intermediate and low energy data, we see that $\langle p_T \rangle$ is surprisingly energy independent for low multiplicities. The slope of $\langle p_T \rangle$ vs. n, on the other hand, is negative for low energies and becomes positive at ISR. This leads to a fast increase of $\langle p_T \rangle$ with energy for high multiplicities. However, the distributions compared here have been obtained with different cuts applied to the corresponding data.

- The Tevatron data ($\sqrt{s}$=1800 GeV) are for negative particles with p_T <3 GeV/c and pseudo-rapidity $|\eta|$ <3.25 and are corrected for a p_T >150 MeV/c selection [4],
- the UA1 data (900 and 546 GeV) have pseudo-rapidity $|\eta| < 2.5$ and are corrected for a $p_T > 150$ MeV/c selection [2b,c],
- the ISR data (63 GeV) have rapidity $|y| < 2.0$ and are biased at low p_T [6a],
- the NA22 data (22 GeV) are shown for $|y| < 2.0$,
- the NA5 data (19 GeV) have rapidity $|y| < 1.5$ [12c]
- the 5.6 GeV data have no cuts [12a].

To see the variation of the slope in phase-space, the effect of a p_T cut on our data is shown in Fig.2 for the rapidity window $|y| < 0.5$, in Fig.3 for $|y| < 2.0$. Tracks not fulfilling the cut condition neither contribute to $\langle p_T \rangle$ nor to n. In the narrow $|y|$ window no difference is observed when excluding diffractive events. In the wide window exclusion of diffractive events enhances $\langle p_T \rangle$ at low n.

The conclusions to be drawn from Figs. 2 and 3 for our energy region are:

1. The higher the cut on p_T at given window size in y, the more positive becomes the slope of $\langle p_T \rangle$ vs. n.
2. For the larger p_T-cuts, the slope is more positive in the narrow window (Fig.2) than in the wide one (Fig.3). Note, however, that the difference is more than compensated, if density $\Delta n/\Delta y$ is used instead of n (change of scale in Fig.3 by a factor 4).

In any case, starting from a decrease of $\langle p_T \rangle$ vs. n (or $\Delta n/\Delta y$) in our data when averaged over all p_T, an increase becomes visible already at $\sqrt{s} \approx 22$ GeV when low p_T tracks are excluded. The effect becomes almost independent of the rapidity window if particle density is used rather than multiplicity. Mechanisms proposed to explain the UA1 and Tevatron data may already be needed to describe data as low as $\sqrt{s} = 22$ GeV.

Alternatively, in Fig.2 and 3, our data are compared to two currently used low p_T models. These are a two-chain version of the Dual Parton Model [15, 14] (solid lines) and the two-chain LUND-FRITIOF Model [16], the latter in its version 1.6 [16a] (dashed) and 2.0 [16b] (dot-dashed). Both models are run in the standard LUND Monte Carlo framework [17]. Clearly, without additional ingredients, like hard scattering as introduced in [11] for collider energies, DPM cannot reproduce the behaviour at large p_T, while it does well at low p_T. On the other hand, our dashed lines show that in FRITIOF 1.6 the correlation was largely overestimated. This was due to single (hard) gluon radiation in this early version of the model. In version 2.0, single gluon radiation has been replaced by a branching process [16b] and hard parton scattering has been introduced. The FRITIOF2.0 (dot-dashed) lines are far from perfect, but come now closer to the data, in particular at larger p_T.

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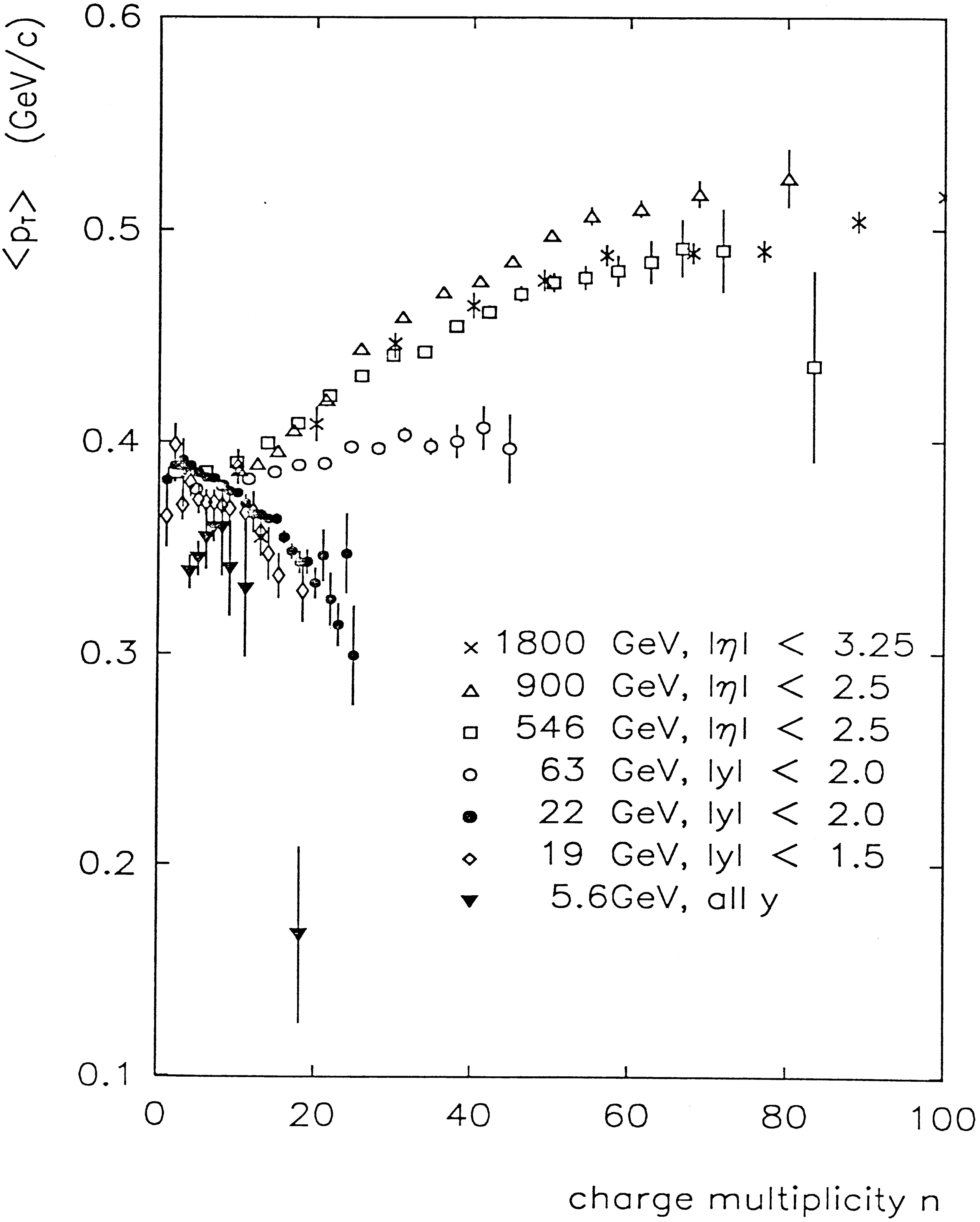
FIGURE CAPTIONS

Fig.1 The average transverse momentum $\langle p_T \rangle$ as a function of charge multiplicity n for $\pi^- p$ at $p_{LAB} = 16$ GeV/c [12a], pp at 200 GeV/c [12c], K^+p, π^+p and pp combined at 250 GeV (this experiment), pp at $\sqrt{s} = 63$ GeV [6a], $p\bar{p}$ at 546 GeV [2b] and 900 GeV [2c] and pp at 1.8 TeV [3]. Cuts are different for different experiments and are indicated.

Fig.2 The average transverse momentum $\langle p_T \rangle$ as a function of charge multiplicity n for $\pi^+/K^+/pp$ collisions at 250 GeV/c, in the rapidity window $|y| < 0.5$, for the four p_T cuts indicated. The solid lines correspond to a two-chain version of DPM [15, 14], the dashed ones to FRITIOF1.6 [16a] and the dot-dashed ones to FRITIOF2.0 [16b].

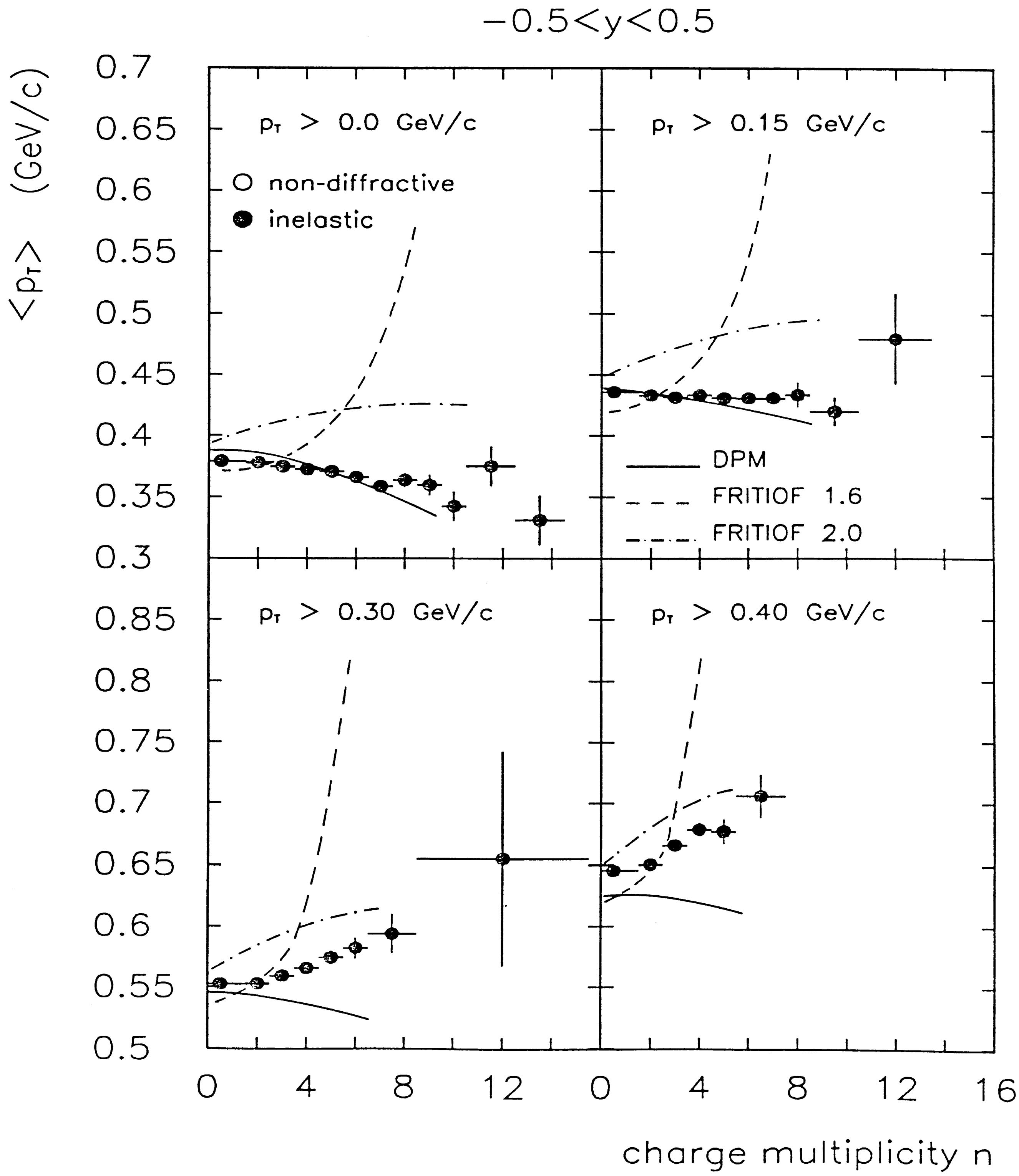
Fig.3 Same as Fig.2, but for the rapidity window $|y| < 2$.

Figure 1



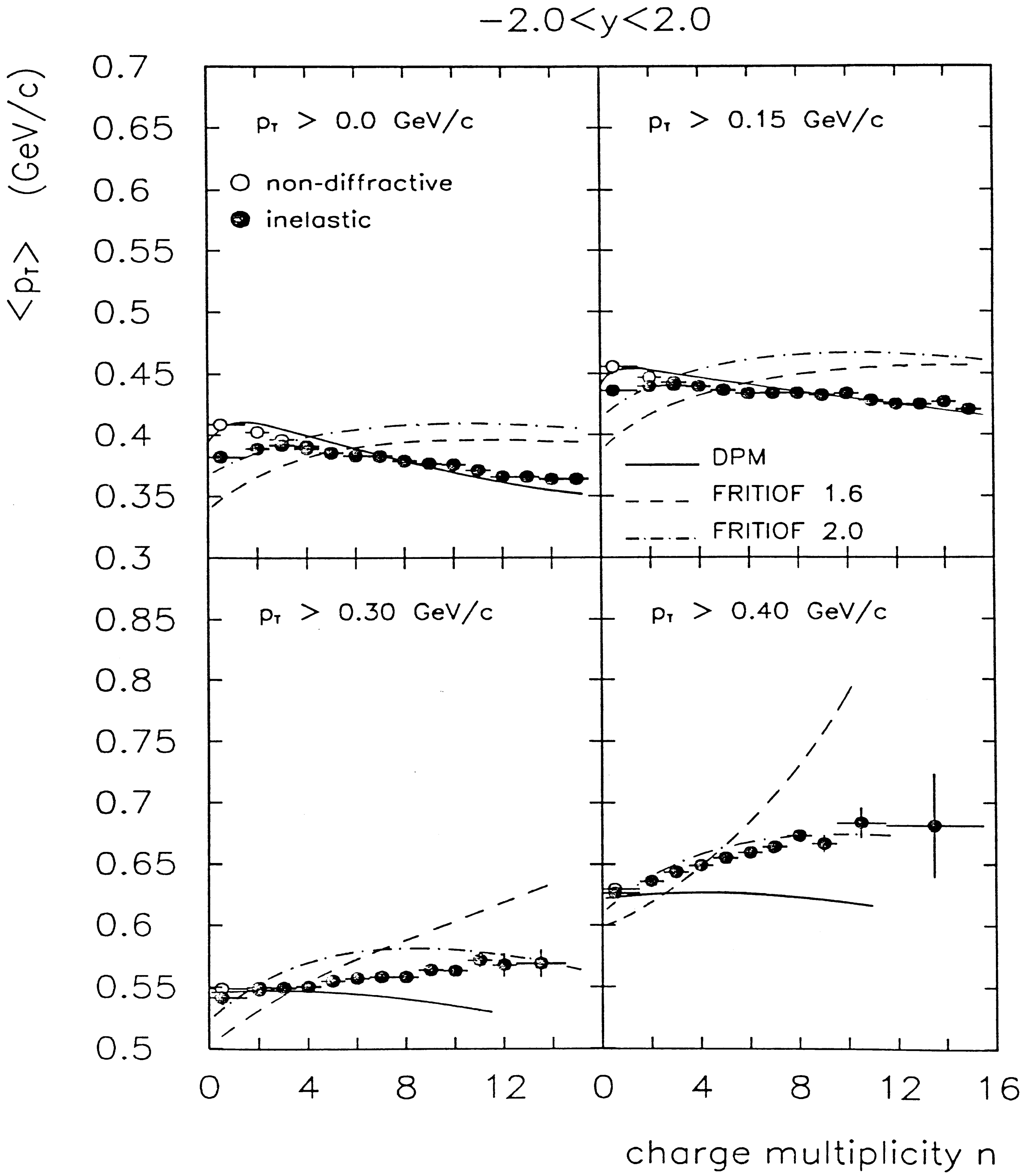
<pT> (GeV/c)
0.6
0.5
0.4
0.3
0.2
0.1
0
20
40
60
80
100
charge multiplicity n
× 1800 GeV, |η| < 3.25
△ 900 GeV, |η| < 2.5
□ 546 GeV, |η| < 2.5
○ 63 GeV, |y| < 2.0
● 22 GeV, |y| < 2.0
◇ 19 GeV, |y| < 1.5
▼ 5.6GeV, all y

Figure 2



−0.5<y<0.5
<pT> (GeV/c)
pT > 0.0 GeV/c
O non-diffractive
inelastic
pT > 0.15 GeV/c
DPM
FRITIOF 1.6
FRITIOF 2.0
pT > 0.30 GeV/c
pT > 0.40 GeV/c
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0
4
8
12
0
4
8
12
16
charge multiplicity n

Figure 3



−2.0<y<2.0
$\langle p_T \rangle$ (GeV/c)
p_T > 0.0 GeV/c
O non-diffractive
● inelastic
p_T > 0.15 GeV/c
DPM
FRITIOF 1.6
FRITIOF 2.0
p_T > 0.30 GeV/c
p_T > 0.40 GeV/c
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0
4
8
12
0
4
8
12
16
charge multiplicity n