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STUDY OF JET STRUCTURE IN PROTON-PROTON COLLISIONS WITH LARGE TRANSVERSE MOMENTUM SECONDARIES

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ABSTRACT

In pp collisions with large transverse momentum secondaries an increased multiplicity is observed when compared to normal pp collisions. We show that this excess of secondaries stems from the correlated emission of particles in a narrow rapidity interval.

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One of the characteristic features of proton-proton collisions with a high transverse momentum secondary is the increase of the number of particles produced when compared to average collisions [1]. The aim of the present paper is to study the behaviour of these additionally produced particles. The experimental data consist of 63 000 events of proton-proton collisions recorded with the Split Field Magnet detector installed at the CERN Intersecting Storage Rings. The energy of the colliding protons was 26 on 26 GeV. A trigger selected high transverse momentum particles $p_\perp > 2$ GeV/c) of either charge at about 45° cm angle. For experimental details see ref. [2].

Triggering on a large $p_\perp$ particle one can look for a jet structure either in the vicinity of the trigger or in the region of azimuthal angle 180° away from the trigger. In the first case the triggering particle is thought to be part of the jet while in the second case a jet would compensate the large $p_\perp$ of the trigger. We start discussing the first case.

One region of the phase space where an excess of particles is observed is the region around the large $p_\perp$ particle. This is illustrated in fig. 1, where the rapidity distribution is given for secondaries in an azimuthal angle region near the trigger. If we compare this rapidity distribution with the one for normal events, also shown in fig. 1, we observe that the excess of secondaries occurs only near the triggering particle in rapidity. This group of additional secondaries taken together with the triggering particle is often referred to as a "jet".

In fig. 2 we present the transverse momentum distribution of the particles in the jet with respect to the jet axis, $p_\perp^J$. The jet axis is defined by the vector sum of the momenta of all particles in the group, whose transverse momenta with respect to the large $p_\perp$ particle are smaller than 0.4 GeV/c.

In order to obtain a well defined jet only secondaries contributing at least 30% of the total jet momentum were included.

To correct for a possible remaining background of particles not belonging to the jet, the triggering particles in each event was artificially defined to have opposite rapidity (i.e. flipped in θ^* from 45°

to -45^{o}) and the jet defining procedure repeated. This procedure yielded background distributions.

In fig. 2 we show the $(p_{\perp}^{J})^{2}$ distribution of the secondaries in a jet, the background having been subtracted in the manner described above. The exponential slope of the distribution is ~ -6 (GeV/c^{2})$^{-2}$, i.e. of the same magnitude as in high energy hadron-hadron collisions. The increase of the slope at low values of $(p_{\perp}^{J})^{2}$ is possibly due to the fact that we define the jet axis by the charged particles only.

The second region in phase space where a clear increase of secondaries in large $p_{\perp}$ proton-proton collisions is observed, is the region of azimuthal angles opposite to the triggering large $p_{\perp}$ particle. This excess is illustrated in fig. 3, where the rapidity distribution for these secondaries is given. One observes that the multiplicity in the phase space region considered increases by a factor 2-3 in large $p_{\perp}$ collisions as compared to normal events.

Secondaries emitted in azimuthal angle opposite to a large $p_{\perp}$ particle (being denoted here as the "away" region) show a significant two-particle short range correlation. In fig. 4(a) the distribution of the rapidity differences between two particles of opposite charge with transverse momenta of at least 0.6 GeV/c is shown. In comparison we also give the distribution obtained by combining secondaries from different events. The ratio of the two distributions is also shown in fig. 4(c). The relative strength of the two-particle correlations increases with the transverse momentum of the particles as can be observed by comparing figs 4(c), 5(a) and 5(b).

Short range correlations are also present in pairs of the same charge as demonstrated in figs 4(b) and 4(d). In this case the correlation is weaker, however, than for pairs of opposite charge.

These correlated pairs of particles are not restricted to a limited region in rapidity, but cover the full rapidity interval. This can be seen in fig. 6, where contour lines for the correlation function $C(y_1, y_2)$ are given. If we denote the one and two-particle density function as $\rho^{I}(y_1, y_2)$ and $\rho^{II}(y_1, y_2)$ respectively, then

$$C(y_1, y_2) = \rho^{II}(y_1, y_2) - \rho^{I}(y_1)\, \rho^{I}(y_2) \quad .$$

The fact that we observe strong short range two-particle correlations in the azimuthal angle region away from the trigger is consistent with the assumption that the excess of particles in high $p_\perp$ collisions stems from the production of groups of particles.

REFERENCES

[1] P. Darriulat, "Hadronic Collisions with a Large Transverse Momentum Product", rapporteurs talk at the International Conference on High Energy Physics, Palermo (Italy), 23-28 June 1975.

[2] CERN-Collège de France-Heidelberg-Karlsruhe Collaboration, "General Characteristics of Large $p_\perp$ Events, paper submitted to the XVIII International Conference on High Energy Physics, Tbilisi 1976.

FIGURE CAPTIONS

Fig. 1 The rapidity distribution of negative secondaries produced in events triggered on a large $p_\perp$ particle of positive charge with $\theta \sim 45^\circ$ and $p_\perp > 2.0$ GeV/c. Only secondaries are entered in the histogram being near in azimuth to the triggering particle, $\Delta\phi = \pm 25^\circ$, and having a transverse momenta $0.5 < p_\perp < 1.0$ GeV/c. The full line represents the equivalent distribution for normal events.

Fig. 2 The transverse momentum squared distribution with respect to the jet axis of particles forming a jet, containing the triggering large $p_\perp$ particle.

Fig. 3 Same as fig. 1, but for secondaries in the azimuthal angle region away from the trigger, $140^\circ < \phi < 220^\circ$.

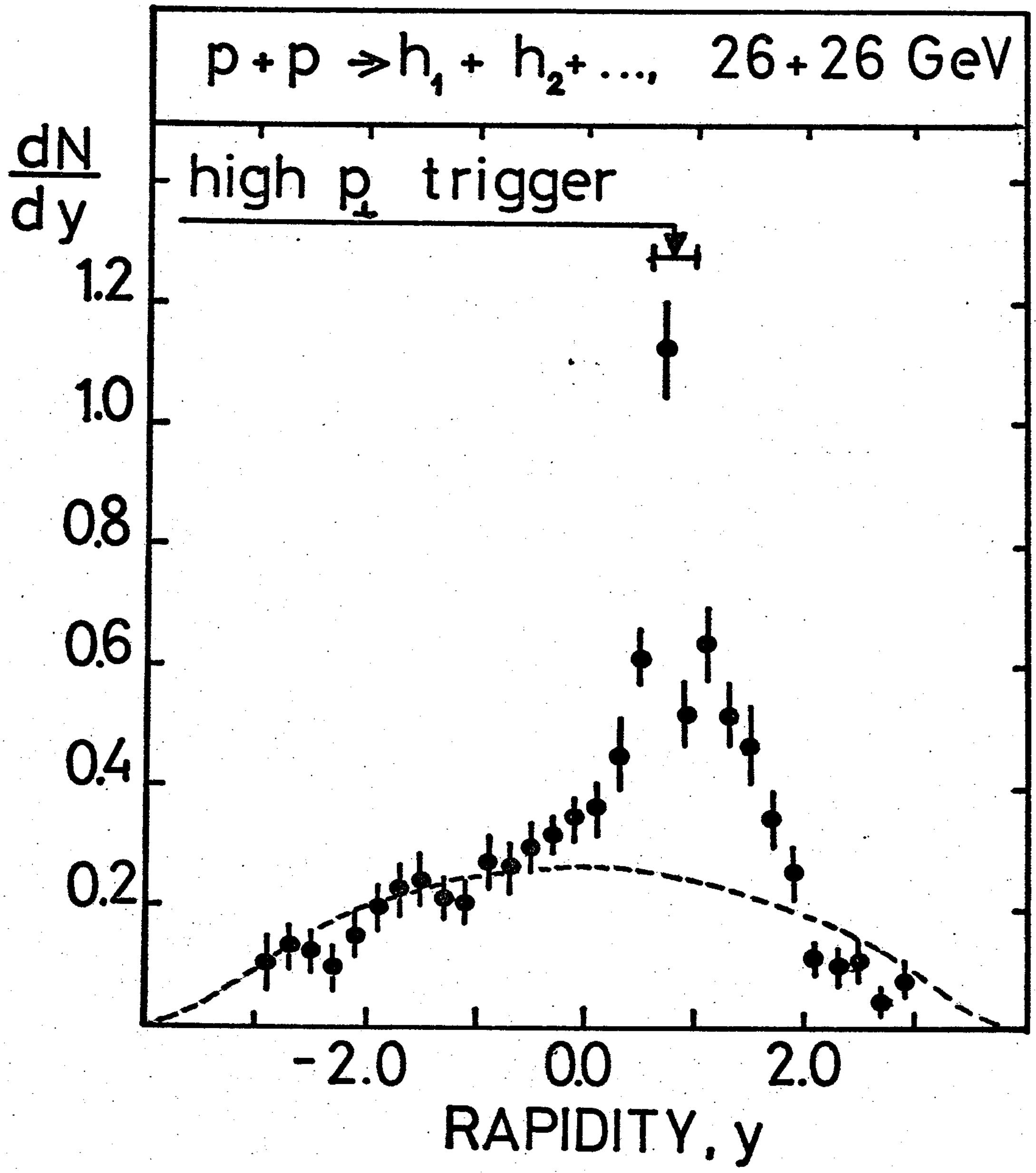
Fig. 4 The distribution of the rapidity difference of pairs of particles with opposite charge (fig. 4(a)) and with same charge (fig. 4(b)) produced in large $p_\perp$ events in the azimuthal angle region away from the trigger (full line). Also shown is the equivalent distribution for uncorrelated pairs obtained by combining secondaries from different events. In both cases only secondaries with $p_\perp > 0.6$ GeV/c were entered.

Fig. 4(b) and (d) show a normalized rapidity difference distribution obtained by taking the ratio of the distributions of figs 4(a) and 4(b) respectively, to the background distributions of these figures.

Fig. 5 Normalized rapidity difference for secondaries of opposite charge with $p_\perp > 0.3$ GeV/c (fig. 5(a)) and $p_\perp > 0.9$ GeV/c (fig. 5(b)).

FIGURE CAPTIONS (Cont'd)

Fig. 6 Contour lines for the correlation function $C(y_1, y_2)$ for particle pairs of opposite charge produced in the azimuthal angle region opposite to the trigger.



p + p → h₁ + h₂ + ..., 26 + 26 GeV
dN/dy
high p⊥ trigger
1.2
1.0
0.8
0.6
0.4
0.2
-2.0
0.0
2.0
RAPIDITY, y

Fig. 1

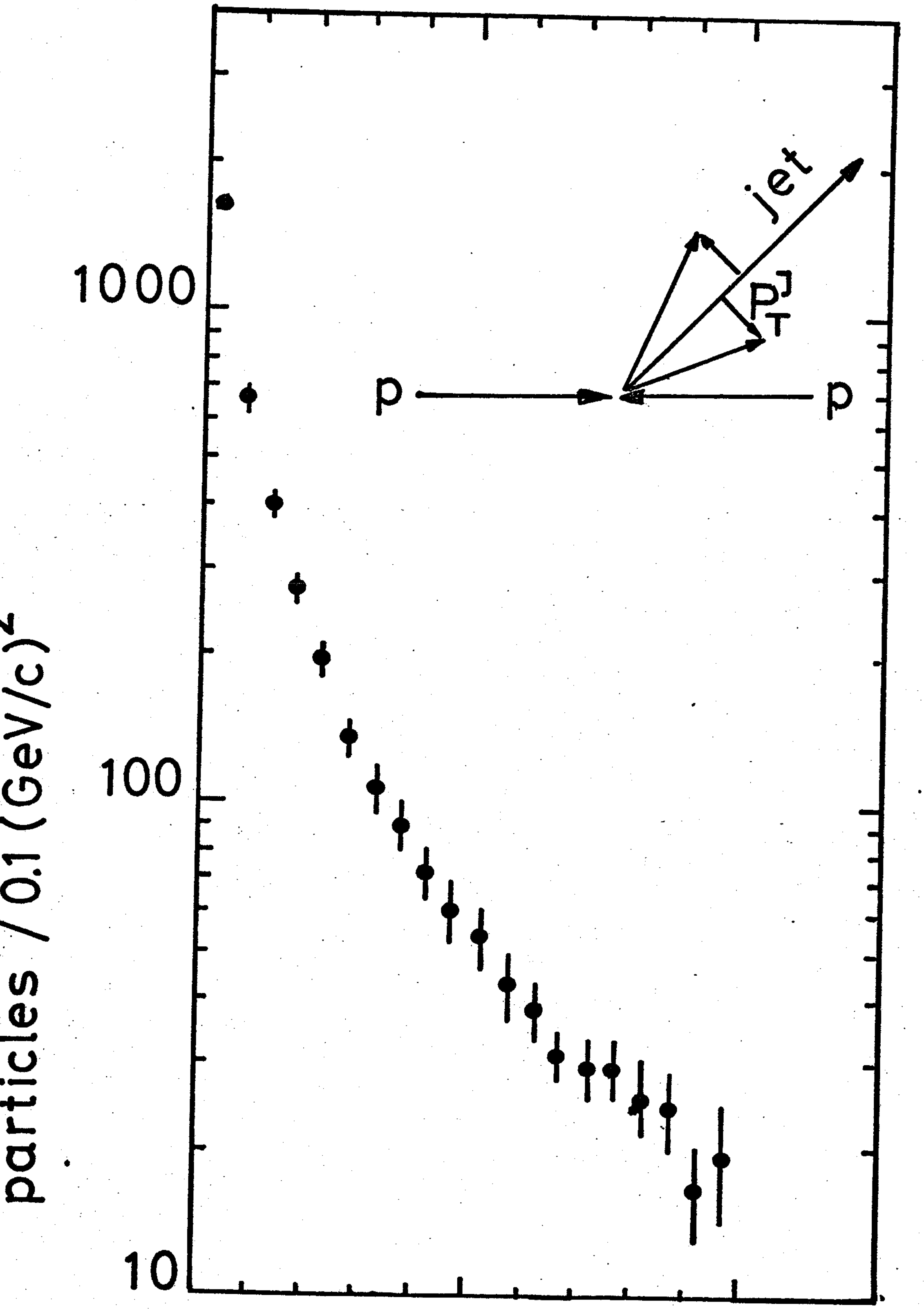


Fig. 2

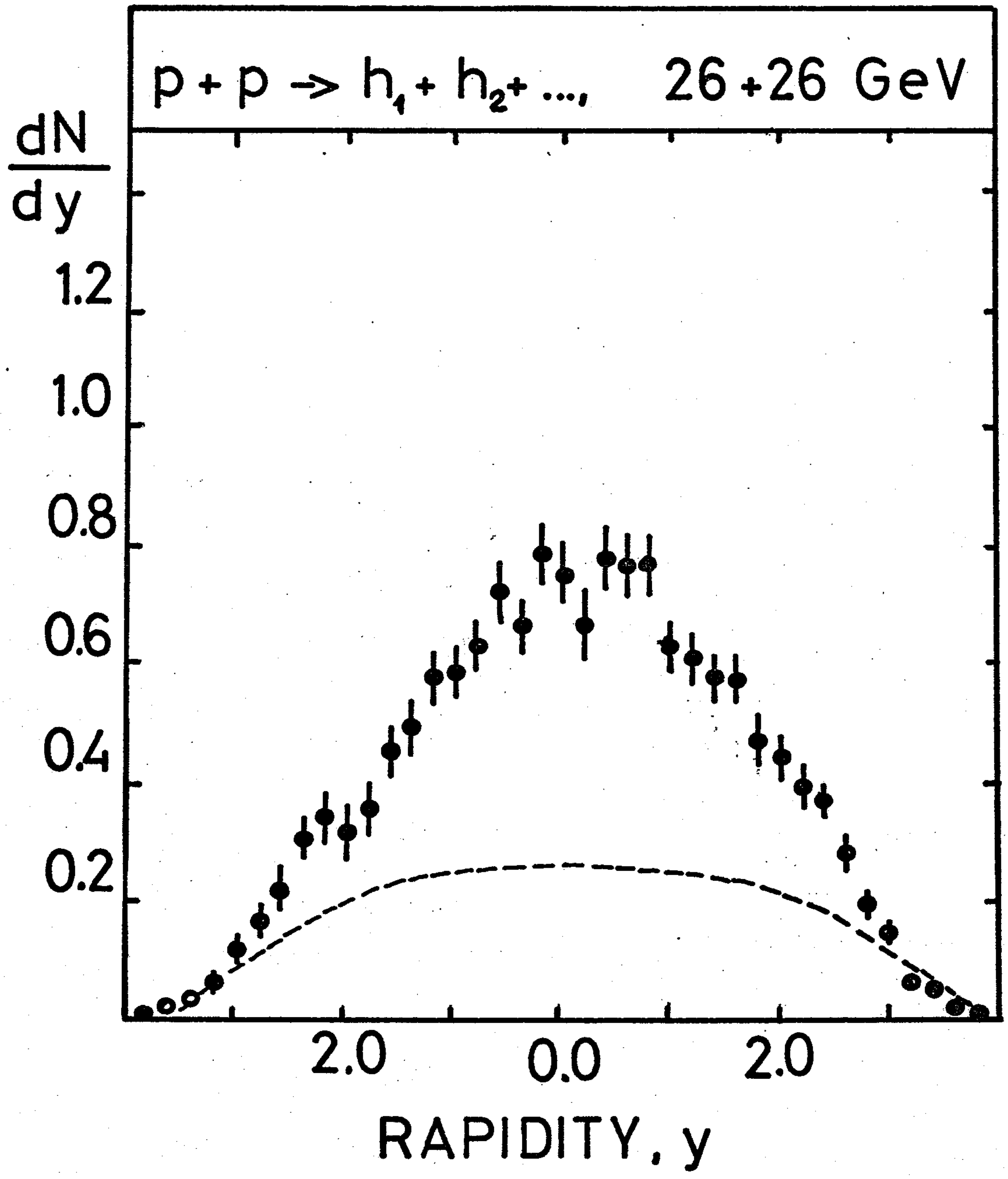


Fig. 3

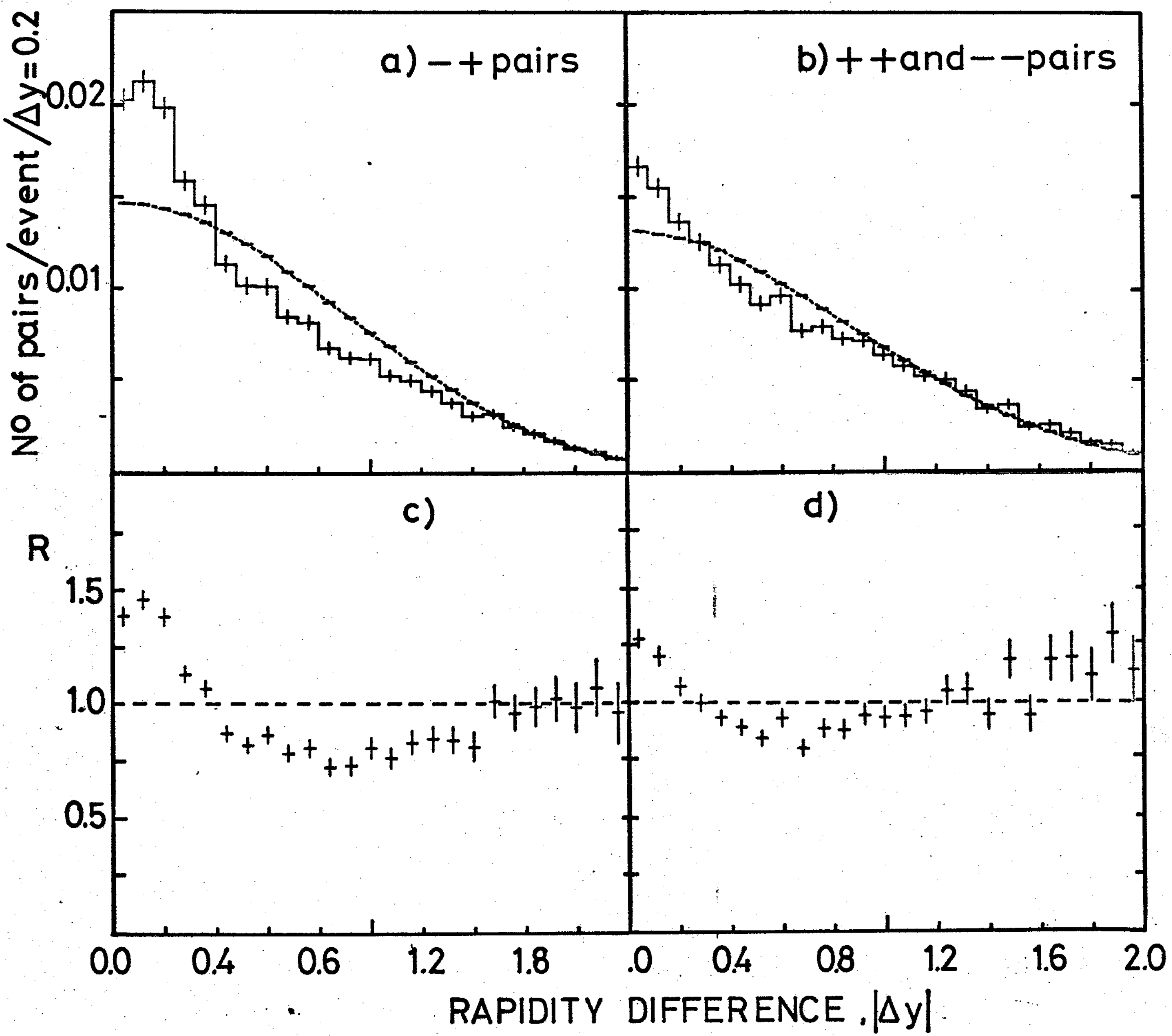

No of pairs/event/Δy=0.2
0.02
0.01
a) −+ pairs
b) ++ and −− pairs
c)
d)
R
1.5
1.0
0.5
0.0
0.4
0.6
1.2
1.8
.0
0.4
0.8
1.2
1.6
2.0
RAPIDITY DIFFERENCE, |Δy|

Fig. 4

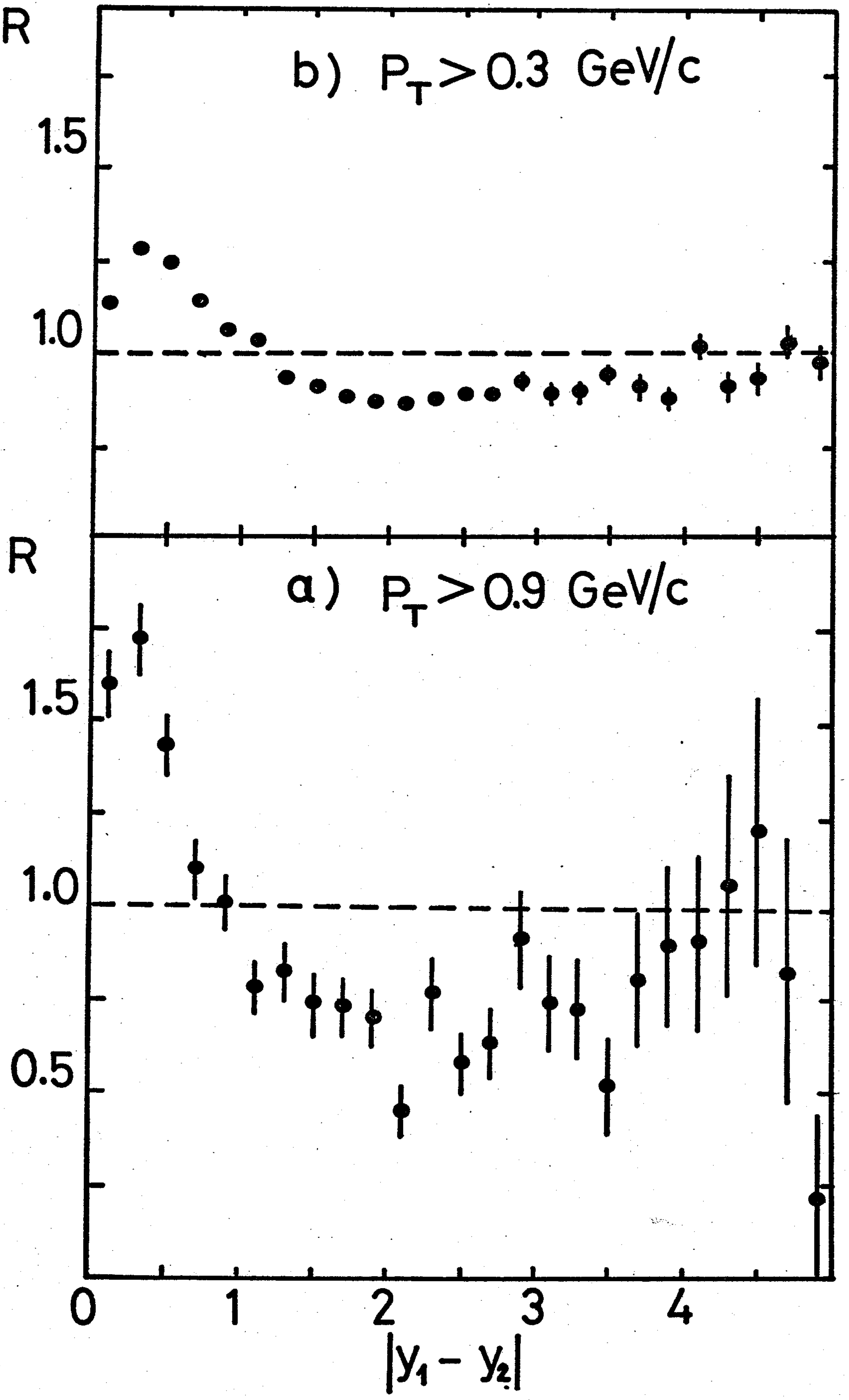


Fig. 5

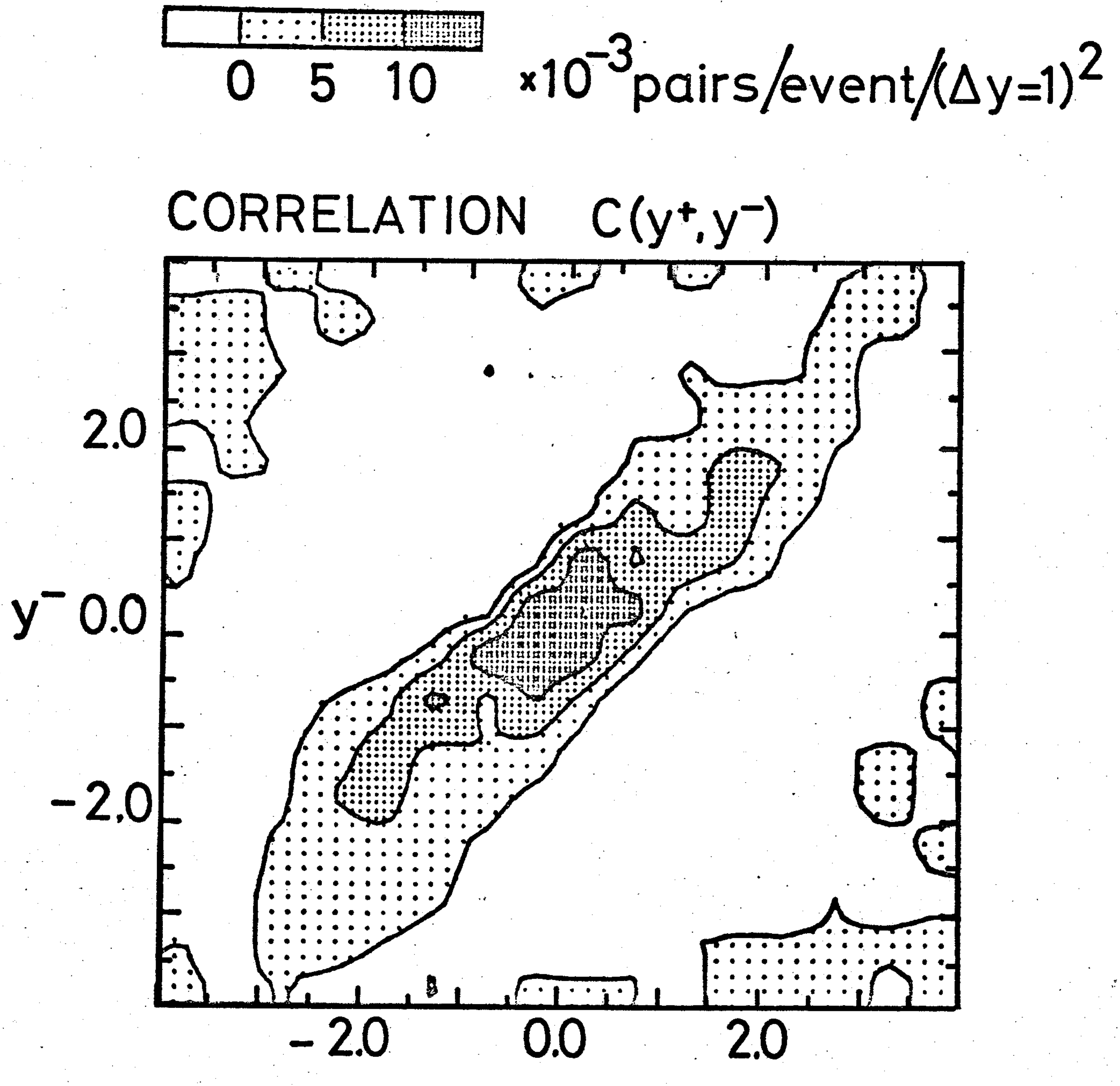

0 5 10
$\times 10^{-3}$ pairs/event/$(\Delta y{=}1)^2$
CORRELATION $C(y^+, y^-)$
2.0
y^- 0.0
-2.0
-2.0
0.0
2.0
y^+

Fig. 6