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COMMENT ON THE ISR π^0-π^0 AZIMUTHAL CORRELATION DATA

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Abstract

The π^0-π^0 azimuthal angle distributions measured at ISR are described in terms of standard large $p_\perp$ 2 jet and 3 jet contributions in combination with a background obtained by superimposing two uncorrelated π^0 spectra (one at high $p_\perp$ the other at low $p_\perp$). The main characteristics of the data can be fitted suprisingly well by a simple analytic expression. We emphasize the importance of having azimuthal angle correlation data at higher values of the transverse momentum cut.

The azimuthal angle distributions of large transverse momentum pions produced in hadron-hadron collisions are expected to receive contributions from the production of both two and three large $p_\perp$ jets. In particular, at very high transverse momenta these processes must give the dominant contributions. Obviously it is important to define quantitatively the kinematical regions where possible background effects are efficiently suppressed.

The π^0-π^0 azimuthal correlation data from the ISR[1] are analyzed with a transverse momentum cutoff such that both the π^0's have $p_\perp > 1.2$ GeV/c ; the data are plotted for various transverse energy bins from $E_\perp = 6$ GeV up to $E_\perp = 20$ GeV. The transverse energy in this experiment has been defined as

$$E_\perp = |\vec{p}_{1\perp}| + |\vec{p}_{2\perp}| + |\vec{p}_{1\perp} + \vec{p}_{2\perp}| \qquad (1)$$

where $\vec{p}_{1\perp}$, $\vec{p}_{2\perp}$ denote the transverse momenta of the π^0's. The results (Fig. 1) are characterized by a "same side" ($\Delta\phi \approx 20^\circ$) and an "opposite side" ($\Delta\phi \approx 180^\circ$) enhancement. Increasing the transverse energy causes the broad "same side" peak to gradually disappear, while the "opposite side" peak becomes more pronounced.

It has been pointed out [2] that the "same side" peak in the ϕ distribution cannot be interpreted by the contribution of QCD 2 jet and 3 jet production, even if $p_\perp$ smearing and jet broadening are taken into account. Typically the data near the region $\phi = 180^\circ$ (or acoplanarity angle $\psi \equiv \pi - \phi = 0^\circ$) are nicely described by two jet processes ; as ψ increases these 2 jet contributions are suppressed leaving only the 3 jet processes ; but these jet contributions lie below the data near $\psi = 90^\circ$

by factors of 5 - 20 and exhibit no significant enhancement in the region $\psi = 100^{\circ} - 160^{\circ}$. However, the transverse momentum cut used for the pions is dangerously small ($p_{\perp} > 1.2$ GeV/c). Therefore large contributions might still be present due to π^{0}'s belonging to the background of the beam fragments.

In this short comment we point out that indeed the data can be described suprisingly well by adding a third component in which the $\pi^{0}(\pi^{0}_{2})$ with lower $p_{\perp}$ comes from the background due to the beam and target fragments while the higher $p_{\perp}$ $\pi^{0}(\pi^{0}_{1})$ is produced according to the usual single particle high $p_{\perp}$ spectrum. This choice **is motivated by the fact that the** beam and target fragmention background is expected to decrease exponentially while the large $p_{\perp}$ pion spectrum drops according to a power law.

Fixing the transverse energy defined by Eq. (1), a kinematical correlation is introduced. At a given transverse energy $E_{\perp}$ and transverse momentum of one of the pions ($p_{2\perp}$) the transverse momentum of the other pion ($p_{1\perp}$) is determined by the relation

$$p_{1\perp} = \frac{E_{\perp}^{'2} - p_{2\perp}^{2}}{2(E_{\perp}' + p_{2\perp}\cos\phi)} \quad , \quad E_{\perp}' = E_{\perp} - p_{2\perp} \tag{2}$$

where ϕ is the azimuthal angle between π_{1}^{0} and π_{2}^{0}. We fix $p_{2\perp}$ at the value of the transverse momentum cut $p_{2\perp} = 1.2$ GeV/c and $p_{1\perp}$ varies with ϕ as in (2).When the transverse energy is not too large the ϕ dependence given by Eq. (2) is sizeable. For example at $E_{\perp} = 8$ GeV and $p_{2\perp} = 1.2$ GeV/c we obtain for the parallel and antiparallel configuration the values $p_{1\perp} = 2.8$ GeV/c and 4.0 GeV/c respectively. Since in this transverse momentum region the one particle inclusive cross section falls approximately as $p_\perp^{-8.5}$, the "same side" ($\phi = 0^\circ$) configuration is strongly enhanced with respect to the "opposite side" ($\phi = 180^\circ$) configuration. This effect, however, becomes less significant at higher values of the transverse energy.

To be more precise we require a fit to the single π° spectrum. According to the same group [3] , the π° inclusive cross section can be described by the formula

$$E\,\frac{d^3\sigma}{d^3p} = C\,\frac{(1-x_\perp)^{9.5}}{p_\perp^{\,n_{eff}(x_\perp)}} \qquad (3a)$$

where $x_\perp = 2p_\perp/\sqrt{s}$. In the region $x_\perp = 0.1 \div 0.3$, $n_{eff}(x_\perp)$ can be fitted approximately by

$$n_{eff}(x_\perp) = a - b\,x_\perp \qquad (3b)$$

with $a = 9.3 \pm 0.4$, $b = 4.8 \pm 0.5$. Using equations (1) and (2) and assuming that both the low $p_\perp$ (π°_2) and high $p_\perp$ (π°_1) spectra depend negligibly on rapidity we can derive from Eq. (3a) the formula

$$\frac{d^2\sigma}{dE_\perp d\phi} \propto \frac{C'(1-x_{1\perp})^{9.5}}{p_{1\perp}(\phi)^{n_{eff}(x_{1\perp})}} \cdot \left(\frac{dE_\perp}{dp_{1\perp}}\right)^{-1}\Bigg|_{p_{2\perp}\ \text{fixed}} \qquad (4)$$

where $x_{1\perp} = 2p_{1\perp}/\sqrt{s}$. At fixed $E_\perp$ the ϕ dependence is completely given via $p_{1\perp}(\phi)$ (see Eq. (2)).

In Figure 1 we plot the ϕ distribution determined by this expression at transverse energies $E_\perp = 8, 12, 18$ GeV, with $p_\perp = 1.2$ GeV/c and $\sqrt{s} = 52$ GeV. For $n_{eff}(x_\perp)$ we use the values $a = 9.3$ and $b = 5.0$. The parameter C' was fixed by fitting the distribution to the "same side" enhancement of the data at $E_\perp = 8$ GeV. The agreement with the measured distributions, both in shape and normalization is remarkably good. In the same Figure we also plot the smeared 2 jet and 3 jet contributions calculated in Ref. 2.

It is clear that the background is too large to try to draw any conclusion concerning the importance of the 3 jet contributions.

We have checked the validity of the analytic approximation (4) by a Monte Carlo program, in which the kinematical conditions of the data are taken into account precisely. Assuming a Gaussian distribution with $\langle \vec{q}_\perp^{\,2} \rangle \approx$ $\approx (0.7 - 0.8 \text{ GeV/c})^2$ for the background contributions we found azimuthal angle correlations in agreement with the dotted curves of Fig.1 determined by Eq. (4).

The background considered here can be easily suppressed by increasing the value of the transverse momentum cut above 1.2 GeV/c: for example if we require $p_\perp > 2.5$ GeV/c and use an even larger Gaussian width, $\langle \vec{q}_\perp^{\,2} \rangle \approx$ $\approx (1. \text{ GeV/c})^2$, the background would be suppressed by a factor of 5-10 with respect to the more interesting and fundamental 3 jet contributions. Thus it would be extremely intresting to have data with larger $p_\perp$ cuts ($p_\perp > 2.0$, 2.5 GeV/c e.g.), so that it would be possible to study the gradual suppression of the kinematical background correlation discussed here and the emergence of the 3 jet contribution.

Finally we remark that the p_{out} distributions with $p_{\perp} > 5$ GeV and $x_e > 0.4$ + published by the same group [1)] are free from this kinematical background.

Acknowledgement

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\+ Here $p_{\perp}$ denotes the transverse momentum of the trigger pion and x_e defined as $x_e = -(\vec{p}_{1\perp} \cdot \vec{p}_{2\perp}) / (|\vec{p}_{1\perp}| \cdot |\vec{p}_{2\perp}|)$.

References

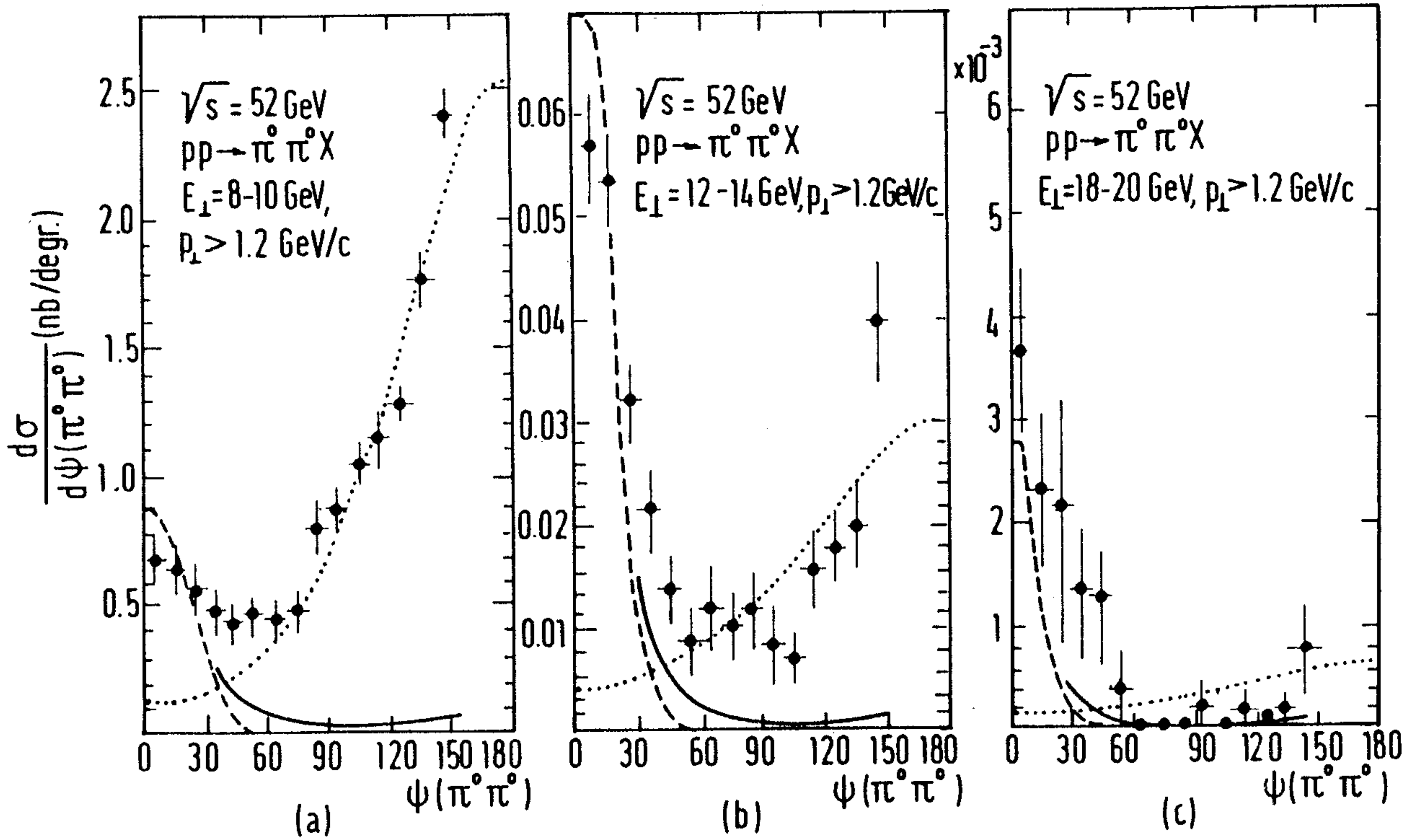
1) J.H. Cobb et.al. Phys. Rev. Lett. 40 (1978) 1420;
C. Kourkoumelis et. al. CERN report, CERN - EP/79 -36 (1979).

2) Z. Kunszt and E. Pietarinen, DESY 79/33 (1979) to be published.

3) C. Kourkoumelis et. al., Inclusive π^0 production at very large at the ISR, CERN report (1979) and D. Lissauer, private communication.

Figure Captions

Fig. 1 a, b, c) Kinematical background (dotted lines), smeared 3 jet (solid lines) contributions to the $\pi^0 - \pi^0$ acoplanarity angle distributions $(\psi = \pi - \phi)$ measured in proton-proton collisions at $\sqrt{s}$ = 52 GeV. The unnormalized data are scaled to the smeared two jet distribution predicted near $\psi = 0^\circ$ at $E_\perp$ = 12 - 14 GeV, see Fig. 1b. The kinematical background curves are then normalized to the data points in the region $\psi = 120^\circ - 160^\circ$ at $E_\perp$ = 8 - 10 GeV.



$\frac{d\sigma}{d\psi(\pi^\circ\pi^\circ)}$ (nb/degr.)
$\sqrt{s}$ = 52 GeV
$pp \to \pi^\circ \pi^\circ X$
$E_\perp$=8-10 GeV,
$p_\perp$ > 1.2 GeV/c
$\psi(\pi^\circ\pi^\circ)$
(a)
$\sqrt{s}$ = 52 GeV
$pp \to \pi^\circ \pi^\circ X$
$E_\perp$ = 12-14 GeV, $p_\perp$ > 1.2 GeV/c
$\psi(\pi^\circ\pi^\circ)$
(b)
x10^{-3}
$\sqrt{s}$ = 52 GeV
$pp \to \pi^\circ \pi^\circ X$
$E_\perp$=18-20 GeV, $p_\perp$ > 1.2 GeV/c
$\psi(\pi^\circ\pi^\circ)$
(c)

Fig.1