LETTERS TO THE EDITOR

JETS AND MULTIPLICITY DISTRIBUTIONS ASSOCIATED WITH LARGE $p_{\perp}$ PARTICLE

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It is pointed out that multiplicity distributions associated with a large $p_{\perp}$ trigger can provide useful information on the underlying jet structure. In particular, in the presently investigated s and $p_{\perp}$ range, the $\bar{n}/D$ ratio is expected to be markedly larger than Wróblewski's value (~ 1.9). Study of the $p_{\perp}$ and s dependence of this ratio can discriminate between Poisson-like versus KNO-like behaviour of the multiplicity distribution in the jet itself and separately in the remaining low $p_{\perp}$ background.

It is an exciting possibility that the production of hadrons with large transverse momenta in hadron-hadron collisions is due to hard scattering of hadron constituents [1]. If the scattered partons fragment into hadrons essentially independently of the rest of environment (low $p_{\perp}$ background) we expect to see in the final state two large $p_{\perp}$ jets of hadrons balancing each other in transverse momentum. This picture already gets some support from the ISR experiments but the direct observation of jets is difficult since the jet balancing a large $p_{\perp}$ trigger is expected to consist dominantly of medium or even low p particles.

In this note we point out that the multiplicity distributions associated with a large $p_{\perp}$ trigger can provide us with useful information about the underlying dynamics at high transverse momenta. As a simple consequence of the jet picture we predict in particular that in the presently investigated s and $p_{\perp}$ range the value of the $\bar{n}/D$ ratio is substantially larger than Wróblewski's value ($\sim$ 1.9). Study of the s and $p_{\perp}$ dependence of this ratio can

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provide direct information on the $\bar{n}/D$ ratio separately for the jet itself and for the background and can discriminate between Poisson-like and KNO-like[1] behaviour of both multiplicity distributions.

The argument is based on the expected absence of (or at most weak) correlation between the parton fragmentation and the low $p_\perp$ background (otherwise why jets?). In this case we can write for the multiplicity distribution associated with a large $p_\perp$ trigger the following form:

$$P_n = \sum_{k=0}^{n} p_k^{\mathrm{B}} p_{n-k}^{\mathrm{J}}, \tag{1}$$

where p_k^{B} and p_{n-k}^{J} are the multiplicity distributions in the low $p_\perp$ background and the jet[2], respectively (also in the following the subscripts "B" (J) will be used for the background (jet), respectively).

Form (1) is a convolution of two independent multiplicity distributions of the background and the jet fragmentation, respectively, and has several interesting features which we shall illustrate by studying in detail the $\bar{n}/D$ ratio associated with a large $p_\perp$ trigger.

It follows form (1) that:

$$D^2 = D_{\mathrm{B}}^2 + D_{\mathrm{J}}^2 \tag{2}$$

and, therefore,

$$\frac{\bar{n}}{D} = \frac{\bar{n}_{\mathrm{B}} + \bar{n}_{\mathrm{J}}}{\sqrt{D_{\mathrm{B}}^2 + D_{\mathrm{J}}^2}}\,. \tag{3}$$

We see that:

(a) expression (3) is symmetric in subscript "B" and "J";

(b) for fixed $\bar{n}_{\mathrm{B(J)}}$ and $D_{\mathrm{B(J)}}$ and growing $\bar{n}_{\mathrm{J(B)}}$ and $D_{\mathrm{J(B)}}$ the ratio $\bar{n}/D$ approaches the ratio $\bar{n}_{\mathrm{J(B)}}/D_{\mathrm{J(B)}}$ for the jet itself or for the background, respectively;

(c) for not too different values of $\bar{n}_{\mathrm{B}}$ and $\bar{n}_{\mathrm{J}}$, and D_{B} and D_{J}, respectively, the ratio $\bar{n}/D$ is larger than the ratios $\bar{n}_{\mathrm{B(J)}}/D_{\mathrm{B(J)}}$.

We expect that for $p_\perp$ large enough ($\gtrsim$2–3 GeV/c, say), to a good approximation, the multiplicity distributions in the background and the jet depend only on the variable $\sqrt{s}-2p_\perp$ and $p_\perp$, respectively ($\sqrt{s}$ denotes the cms energy of the collision and $p_\perp$ is the trigger transverse momentum). Thus the requirement of a constant average multiplicity $\bar{n}_{\mathrm{B(J)}}$ and dispersion $D_{\mathrm{B(J)}}$ in the background or the jet corresponds to keeping $\sqrt{s}-2p_\perp$ = const or $p_\perp$ = const, respectively.

The expected behaviour of the ratio $\bar{n}/D$ is illustrated in a more quantitative way in Fig. 1. We plot there the $\bar{n}/D$ ratio (calculated from formula (3)) as a function of the jet (background) average multiplicity $\bar{n}_{\mathrm{J(B)}}$ for fixed background (jet) average multiplicity:

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[1] By KNO-like multiplicity distribution we mean that $\bar{n}/D \approx$ const.

[2] Since the multplicity of the jet on the trigger side is always close to one (trigger itself) it is irrelevant whether the two jets fragment independently or not.

$\bar{n}_{B(J)} = 5$, $\bar{n}_{B(J)} = 10$ and $\bar{n}_{B(J)} = 15$ (Figs 1a, b, c, respectively). For each value of the $\bar{n}_{B(J)}$ we consider three different cases for the ratio $\bar{n}_{J(B)}/D_{J(B)}$:

$\bar{n}_{J(B)}/D_{J(B)} = 1.9$ (KNO-like bahaviour),
$\bar{n}_{J(B)}/D_{J(B)} = \bar{n}_{J(B)}$ (Poisson distribution in single particles), and
$\bar{n}_{J(B)}/D_{J(B)} = \bar{n}_{J(B)}/2$ (Poisson distribution in pairs of particles).

For the multiplicity which is kept fixed the value $\bar{n}_{B(J)}/D_{B(J)} = 1.9$ (Wróblewski's value) is always taken for definitness. This is not an unreasonable choice for not too large values of the $\bar{n}_{B(J)}$[3] and in any case the sensitivity of our discussion to a particular value of the $\bar{n}_{B(J)}/D_{B(J)}$ (within reasonable limits) is weak even at the quantitative level.

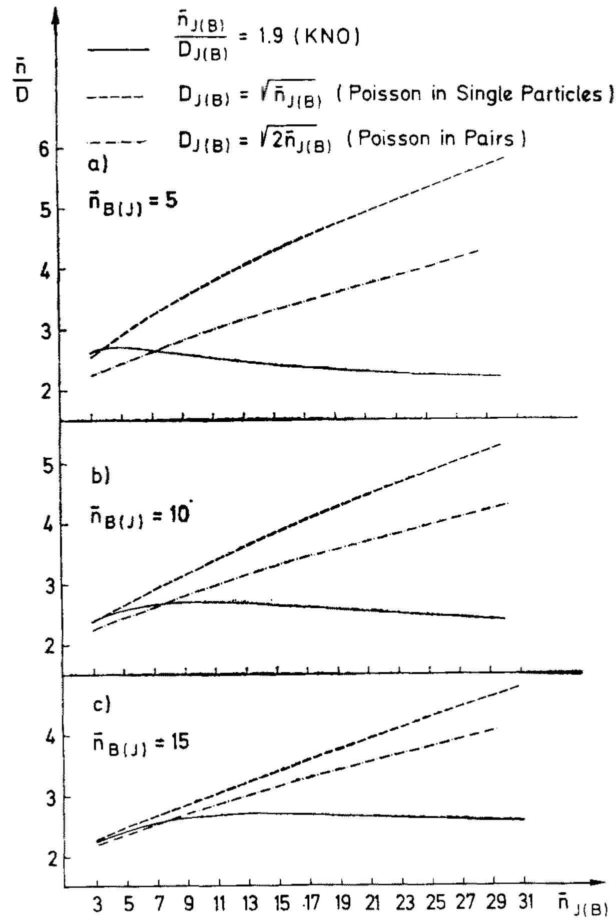

Fig. 1. The ratio $\bar{n}/D$ associated with a large $p_\perp$ trigger plotted as a function of the jet (background) average multiplicity $\bar{n}_{J(B)}$ for fixed values of the background (jet) multiplicity $\bar{n}_{B(J)}$: a) $\bar{n}_{B(J)} = 5$; b) $\bar{n}_{B(J)} = 10$; c) $\bar{n}_{B(J)} = 15$, and the value $\bar{n}_{B(J)}/D_{B(J)} = 1.9$. In each case three different possibilities for the behaviour of the ratio $\bar{n}_{J(B)}/D_{J(B)}$ are considered (see the text)

[3] We shall come back in the following to the question of the ratio $\bar{n}_B/D_B$ for the background. The value 1.9 should be considered as the lower limit for this ratio.

From Figs 1a, 1b, 1c (taken for fixed $\bar{n}_B$ and varying $\bar{n}_J$) we observe that for the $\bar{n}_J \leqslant 5$ the calculated $\bar{n}/D$ is similar for the different assumptions on the behaviour of the $\bar{n}_J/D_J$ and has the value sizably larger than Wróblewski's value used for the background. For $\bar{n}_B = 10$ and $\bar{n}_J \approx 5-6$ (which correspond to $\sqrt{s} \sim 20$ GeV and $p_\perp \sim 2-3$ GeV/c) we get $\bar{n}/D \approx 2.5-2.7$. Preliminary data are in good quantitative agreement with this expectation [3]. For larger values of the $\bar{n}_J$ (at a fixed $\bar{n}_B$) the ratio $\bar{n}/D$ becomes sensitive to the behaviour of the ratio $\bar{n}_J/D_J$ and from Fig. 1 we can expect that measurements of the $\bar{n}/D$ ratio up to the value $\bar{n}_J = 10-12$ can discriminate between the KNO- versus Poisson-like behaviour for the jet itself.

The study of the background multiplicity distribution is even more straightforward. Measurements of the ratio $\bar{n}/D$ over the ISR energy range (the $\bar{n}_B$ varying from 10 to 15, say) for a value of the $\bar{n}_J$ fixed e.g. between 5 and 10 can indeed choose between different types of the dependence on the $\bar{n}_B$ of the ratio $\bar{n}_B/D_B$. It is usually expected that the background associated with a large $p_\perp$ trigger is in many respects similar to the minimum bias sample at the energy $(\sqrt{s}-2p_\perp)$. In view of the observed universal dependence on the available energy of the average multiplicity in different hadronic reactions the relation $\bar{n}_B(\sqrt{s}, p_\perp) = \bar{n}(\sqrt{s}-2p_\perp)$ is presumably approximately correct ($\bar{n}$ is the average multiplicity in the unbiased sample). However, the relation $\bar{n}_B/D_B \approx$ const is less certain since it is conceivable that the long range effects disappear in the background associated with a large $p_\perp$ trigger (e.g. if they are due only to the existence of the diffraction dissociation).

In conclusion we argue for measurements of the $\bar{n}/D$ ratio in the multiplicity distributions associated with a large $p_\perp$ trigger at different energies and trigger transverse momenta. Similar study for the deep inelastic lepton-hadron reactions would also be interesting.

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REFERENCES

[1] S. Berman, J. Bjorken, J. Kogut, *Phys. Rev.* **D4**, 3388 (1971).

[2] See e.g. M. Jacob, Summaries of the Consecutive ISR Discussion Meetings on Large $p_\perp$ Phenomena.

[3] I. Derado, private communication from the Aachen–CERN–Heidelberg–München Streamer Chamber Collaboration.