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SUGGESTION FOR TESTING THE HYPOTHESIS OF LOCAL COMPENSATION
OF TRANSVERSE MOMENTUM

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Suggestion for Testing the Hypothesis of Local Compensation
of Transverse Momentum*

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Abstract

We describe an experimental test of the hypothesis of local compensation of transverse momentum in multiparticle production.

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In the present note, which is intended as an addendum to Ref. [1], we will suggest an experimental test of the hypothesis of local compensation of transverse momentum which does not require observation of the transverse momenta of neutral particles. For a discussion of local compensation of transverse momentum and a derivation of results which follow from this assumption the reader is referred to [1-5]. Throughout the following discussion we will assume from convenience that all hadrons have the same mass, m , and that all charges are either 1,0 or -1.

Consider a scattering event involving a collection of hadrons $\{h_i\}$:

$$h_1 + h_2 \rightarrow h_3 + \dots \quad (1)$$

Let $\sqrt{s}$ be the total c.m.s. energy, y_i be the c.m.s. rapidity of h_i , k_{ij} and k_{i2} be the two components of c.m.s. transverse momentum of h_i , and q_i be the charge of h_i . We assume $y_1 < y_2$ so that $y_1 = -Y/2$ and $y_2 = Y/2$, where

$$Y = \ln\left(\frac{s}{m^2}\right) + 2 \ln\left(\frac{1}{2} + \sqrt{\frac{1}{4} - \frac{m^2}{s}}\right).$$

In addition, of course, $k_{ij} = 0$, for $i, j=1,2$.

Define the transverse momentum carried by particles of charge q with rapidity between a and b to be given by

$$K_j(a, b, q) = \sum_{\substack{i \\ a \leq y_i < b \\ q_i = q}} k_{ij} \quad (2)$$

Then the transverse momentum zone graph $Z_j(y)$ defined in [1] is given by

$$Z_j(y) = \sum_q K_j(-Y/2, y, q) \quad (3)$$

Let $\langle \dots \rangle$ represent the operation of averaging over all final states

which might appear in (1). Rotational invariance implies

$$\langle Z_j(y) \rangle = 0 ,$$

and requires that the correlation function $C_{ij}(y, y')$

$$C_{ij}(y, y') = \langle Z_i(y) Z_j(y') \rangle$$

must have the form

$$C_{ij}(y, y') = \frac{1}{2} \delta_{ij} C(y, y') .$$

The simplest test of local compensation of transverse momentum can be gotten by measuring $C(y, y')$. The hypothesis of local compensation of transverse momentum requires, in part, that (A) as s becomes large $C(y, y')$ must approach an energy independent limit and (B) if $|y - y'|$ is made larger than a certain energy independent correlation length λ , $C(y, y')$ must rapidly approach 0. Unfortunately, the most reliable measurement of $C(y, y')$ would require an apparatus capable of determining the rapidities and transverse momenta of all charged particles and all neutral particles in any final state. Such a detector does not exist at present and is not likely to be constructed in the near future. A less reliable measurement of $C(y, y')$ could be made by expressing $C(y, y')$ as an integral of second order density correlations [1], then measuring these quantities. But even this would depend on an apparatus capable of simultaneously determining the rapidities and momenta of any pair of particles for all possible combinations of charge, which once again does not seem feasible at present.

Another alternative can be gotten by recognizing that conservation of transverse momentum in process (1) can be written in the form

$$\sum_q K_j(-Y/2, y, q) = - \sum_q K_j(y, Y/2, q),$$

which implies $C(y, y')$ is given by

$$C(y, y') = - \sum_{j, q, q'} \langle K_j(-Y/2, y, q) K_j(y', Y/2, q') \rangle. \quad (4)$$

If the summation in (4) is now restricted to include only charged particles we obtain a correlation function $C'(y, y')$ which can be measured at present:

$$C'(y, y') = - \sum_{\substack{j \\ q, q' \neq 0}} \langle K_j(-Y/2, y, q) K_j(y', Y/2, q') \rangle. \quad (5)$$

Moreover, if $C(y, y')$ fulfills (A) and (B), then as we will show, $C'(y, y')$ would also be expected to fulfill these conditions. Thus the test of local compensation of transverse momentum which we propose is simply to determine whether $C'(y, y')$ obeys (A) and (B).

An argument which suggests that if $C(y, y')$ does obey (A) and (B) then $C'(y, y')$ will also fulfill these conditions goes as follows. If $C(y, y')$ falls rapidly once $|y - y'|$ is greater than a certain λ , then by using (4) to calculate the difference between $C(a, d)$ and $C(b, c)$ we find that

$$\sum_{j, q, q'} \langle K_j(a, b, q) K_j(c, d, q') \rangle \quad (6)$$

must fall rapidly if $a < b < c < d$ and $c - b$ is made greater than λ . Thus the total transverse momenta in two widely separated regions must be uncorrelated. One would therefore expect that if we remove the summation

over q and q' in (6) the result

$$\sum_j \langle K_j(a,b,q) K_j(c,d,q') \rangle \quad (7)$$

will also fall rapidly if $a < b < c < d$ and $c-b$ is made greater than λ .

It would be quite surprising if total transverse momenta in widely separated intervals were uncorrelated but the transverse momenta carried by particular types of charge within these intervals were correlated nonetheless. Actually by using the full set of assumptions of local compensation of quantum numbers [1] it can be proved that (7) must also become small once $c-b > \lambda$. The proof will not be given here, however.

In any case, if we now sum (7) with the restriction $q, q' \neq 0$, we find that $C'(y,y')$ must fall rapidly if $y'-y$ becomes greater than λ . Similarly, if (4) approaches an energy independent limit as s becomes large, then (6) must, and therefore we would expect (7) to approach an energy independent limit. Thus $C'(y,y')$ should also approach an energy independent limit as s becomes large.

For comparison, if the matrix element for process (1) were given by an uncorrelated transverse momentum cutoff of the form

$$f(k_{31}, k_{32}) f(k_{41}, k_{42}) \dots,$$

where $f(k_1, k_2)$ is a fixed energy independent function, then as s becomes large for y and y' far from the ends of rapidity space and $y' \gg y$ $C'(y,y')$ would approach the form

$$C'(y,y') = \frac{2}{3} \left(\frac{1}{2} + \frac{y}{Y} \right) \left(\frac{1}{2} - \frac{y'}{Y} \right) \langle N_c \rangle \langle (k_1^2 + k_2^2) \rangle. \quad (8)$$

The quantity $\langle N_c \rangle$ in (8) is the mean charge multiplicity, which would grow linearly with Y , and $\langle (k_1^2 + k_2^2) \rangle$ is the mean squared transverse momentum for a single particle, which would approach an energy independent limit.

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