LONG-RANGE (FORWARD-BACKWARD) RAPIDITY CORRELATIONS AT LHC

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Although hadronic forces have short-range in rapidity space, one expects long-range dynamical correlations induced by unitarity (multiple-scattering) [1]. In order to illustrate this mechanism let us consider a simple case where the average multiplicity of charged particles $< N_0 >$ in each inelastic collisions is independent of the average number $< n >$ of inelastic collisions. (In a realistic case, energy-momentum conservation introduces a dependence of $< N_0 >$ on $< n >$). The average charged multiplicity in a pp collision is then

$$< N > = < n > < N_0 > \quad . \tag{1}$$

Here

$$< n > = \sum_{n=1}^{\infty} n \ \sigma_n \Bigg/ \sum_{n=1}^{\infty} \sigma_n \tag{2}$$

where σ_n is the probability to have n inelastic collisions.

Let us now consider the correlation between particles produced in the forward and backward hemispheres. One has

$$\begin{aligned} < N_F N_B > - < N_F >< N_B > &= < n > (< N_{0F} N_{0B} > - < N_{0F} >< N_{0B} >) \\ &+ \left[\left(< n^2 > - < n >^2 \right) \right] < N_{0F} >< N_{0B} > \quad . \end{aligned} \tag{3}$$

The first term of (3) is the correlation between particles produced in the same inelastic collision. Assuming these correlations to have short-range in rapidity this term is very small - and, actually, vanishes if one takes a rapidity gap of 1.5 to 2 units between the forward and backward rapidity intervals. By doing so, possible correlations between particles produced in different inelastic collisions also vanish - because these particles are far away in rapidity.

In this way, one is left with the last term in (3). We see that there is a long-range correlation between particles which are far away in rapidity. This correlation is due to the fluctuation in the number of inelastic collisions, controlled by unitarity. If the number of inelastic collisions is fixed, then $< n^2 > - < n >^2 = 0$ and the long-range correlation vanishes. Thus, if one takes an event sample of fixed multiplicity, the long-range correlation goes away.

A full calculation of the forward-backward correlation [2] including predictions for LHC energies [3] has been performed in the framework of the dual parton model (DPM) [4]. In this model particle production occurs via string fragmentation. There are two strings per inelastic collision. The first collision involves two strings of type diquark-quark. The other collisions involve two strings of type $\bar{q}$-q. Eqs. (1)-(3) are then replaced by

$$< N >= \sum_{n=1}^{\infty} \sigma_n \left(2 < N^{qq-q} > +(2n-2) < N^{q-\bar{q}} >\right) \Big/ \sum_{n=1}^{\infty} \sigma_n \tag{4}$$

where $< N^{qq-q} >$ and $< N^{q-\bar{q}} >$ are the average multiplicities of the qq-q and q-$\bar{q}$ strings, respectively. Neglecting the small contribution due to the short-range correlations within individual strings, one then has

$$< N_F N_B > - < N_F >< N_B >= 4 \left[< n^2 > - < n >^2\right] < N^{q-\bar{q}} >_F < N^{q-\bar{q}} >_B \quad . \tag{5}$$

Note that taking for F and B rapidity intervals of one unit length, i.e. :

$$F\{y_1, y_1 + 1\} \quad ; \quad B(-y_1 - 1, -y_1) \tag{6}$$

and varying y_1 one can determine experimentally the rapidity distribution of the q-$\bar{q}$ strings. At moderate enrgies, these strings are relatively short, spanning the central rapidity region. Therefore, one predicts a sharp decrease of the F-B correlation when y_1 increases. This decrease has been found experimentally [5] and is in good agreement with the model results [2] [3]. At LHC the rapidity distribution of a q-$\bar{q}$ string is flatter than at lower energies and, thus, the decrease of the F-B correlation with increasing y_1 is predicted to be less sharp. As for the strength of the F-B correlation it is predicted to increase steadily with increasing energy [2] [3]. At LHC the correlation slope in pp is of 82 % for F and B intervals defined as $0 \leq |y| \leq 4$, and of 72 % for $0 \leq |y| \leq 1$ [3].

In the numerical calculations, energy-momentum conservation has been taken into account exactly. Moreover, we have also taken into account another source of correlation, namely the fluctuation of the string ends - controlled by momentum distribution functions. However, at high-energies, the dominant efffect is the one due to the fluctuation in the number of strings and eq. (5) is a good approximation to the exact formula. In (5) the values of $< n^2 >$ and $< n >$ are computed within the perturbative reggeon calculus. This is a generalized eikonal model which in particular, includes as intermediate states, high mass diffractive excitation described by triple Pomeron graphs. The latter are quite important at LHC energies.

The mechanism described above is also responsible in DPM for the broadening with increasing energy of the KNO multiplicity distribution [6].

What is the interest of measuring the LRC at LHC ? Since the average number of strings increases with energy it could happen that the simple string mechanism of multiparticle production described above, becomes invalid. Indeed, overlapping strings could merge into "ropes" leading to F-B correlations very different from the ones predicted in independent string models. This phenomenon is even more probable in the case of central nucleus-nucleus collisions. Of course, if such is the case, the way in which the F-B correlation is affected depends on the especific model of string fusion, i.e. on whether or not long-range correlations are present in the rope. When the strings fuse, merging their momenta as well as their quantum number, without producing long-range correlations, one predicts [6] a substantial decrease of the F-B correlation as compared to the predictions above.

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