Charge balance function in pp collision at $\sqrt{s} = 200$ GeV

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The study of charge and charge-momentum correlations are important issues related to multiparticle production in high-energy interactions, as they may provide information on the hadronization time. The balance function (BF) proposed by [1], measures the correlation between oppositely charged particles produced in an interaction, and the width of its distribution can be related to the hadronization time. Experimental data on $\pi^+/K^+ + p$ interaction [2] and the PYTHIA generated data on $p+p$ interaction [3], both at $\sqrt{s} \sim 22$ GeV show that the BFs depend on the charged particle multiplicity. Here we report a preliminary study on the BF for 50,000 $p+p$ events at $\sqrt{s} = 200$ GeV using the AMPT, a multiphase transport model [4] and compare it with the STAR data. We find that the model prediction of the BFs are neither hadronization-like nor multiplicity dependent.

The BF, though originally defined in terms of a combination of four different types of charge-related conditional densities projected to the rapidity variable, reads [1]

$$B(\delta y) = \frac{1}{2}\left[\frac{\langle n_{+-}(\delta y)\rangle - \langle n_{++}(\delta y)\rangle}{\langle n_{+}\rangle} + \frac{\langle n_{-+}(\delta y)\rangle - \langle n_{--}(\delta y)\rangle}{\langle n_{-}\rangle}\right]. \quad (1)$$

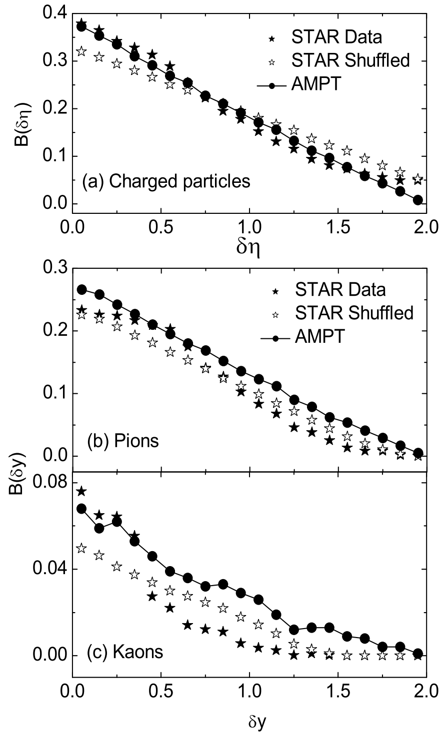

FIG. 1: The balance function for $p+p$ collisions at $\sqrt{s} = 200$ GeV. The STAR data [5] is compared with the AMPT (default) prediction.

Here n_{+-} and $n_{++}(n_{--})$ are the numbers of pairs of opposite and like-sign charged particle densities, n_+ (n_-) are the number of positive (negative) charged particles and each number corresponds to a given rapidity range δy. The quantities are averaged over all events. In FIG. 1 the AMPT prediction of the BFs in $p+p$ interaction at $\sqrt{s} = 200$ GeV along with the RHIC-STAR data [5] are graphically plotted against δy. Following the particle selection criteria of [5], we take the following transverse momentum (p_t) intervals: for all charged particles $0.2 < p_t < 2.0$ GeV/c, for identified charged species $0.2 < p_t < 0.6$ GeV/c. Notice that in either case *i.e.*, for all charged particle pairs or for the identified pairs (pions and kaons), the AMPT prediction neither completely matches with the STAR data, nor does the variation coincide with that of the charged shuffled STAR data. Each shuffled event has all the momentum correlations present in it as the correlation is in an actual event, but the charge-momentum correlations are wiped out. We also verify whether the BFs are boost invariant over the entire rapidity interval or not. We find that they depend on the size of

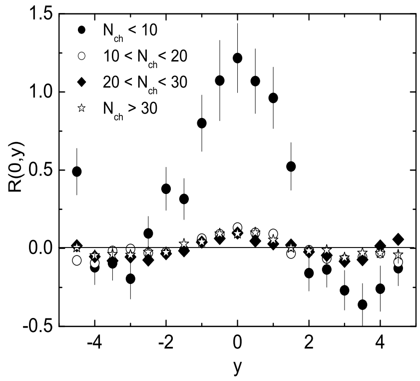

FIG. 2: Two-particle correlation function for $y_2 = 0$ and $y_1 = y$ for different multiplicity intervals in $p + p$ collision at $\sqrt{s} = 200$ GeV.

the rapidity window. Moreover, the relation between the balance function in a particular rapidity window (Y_w), $B(\delta y|Y_w)$, and in the full rapidity range $B(\delta y|Y = \infty)$,

$$B(\delta y|Y_w) = B(\delta y|\infty)(1 - \delta y/Y_w), \qquad (2)$$

as proposed in [6] is approximately satisfied.

The most important parameter of a balance function analysis is the width of the BF, given as

$$\langle \delta y \rangle = \sum B(\delta y_i)\delta y_i / \sum B(\delta y_i). \qquad (3)$$

The width parameter measures the hadronization time in quark-hadron phase transition, if there is any. Such transition may take place in relativistic nuclear collisions. While an early stage of hadronization is expected to result in a broad BF, late hadronization leads to a narrower distribution [1]. In case of $p + p$ collisions at $\sqrt{s} = 200$ GeV, usually we do not expect a partonic phase and the hadronization is almost instantaneous. So the BF is expected to be wider than that of the nucleus-nucleus collision at that energy scale. We obtain $\langle \delta y \rangle \sim 1.2$, and the parameter is almost independent of the charged particle multiplicity. Thus the narrowing of the BF with increasing multiplicity as it is observed in the PYTHIA simulated $p+p$ events [3], is not observed here.

The results on the charged BF analysis is supplemented by the (reduced) two-particle correlation function of oppositely charged particles:

$$R_2^{+-}(y_1, y_2) = \frac{1}{2}\left[\frac{\rho_2^{+-}(y_1, y_2)}{\rho_1^{+}(y_1)\rho_1^{-}(y_2)} + \frac{\rho_2^{-+}(y_1, y_2)}{\rho_1^{-}(y_1)\rho_1^{+}(y_2)}\right] - 1, \qquad (4)$$

where $\rho(y)$ is the inclusive particle density in y. For $y_1 = 0$ and $y_2 = y$ the $R^{+-}(0, y)$-function is calculated for four multiplicity bins. The plots of R-functions in FIG. 2 show a significantly higher correlation in the low multiplicity events ($n_{ch} < 10$), otherwise the multiplicity dependence of the R-function is not so prominent for other multiplicity cuts. An opposite observation was made from the PYTHIA model [3] analysis. So the string fragmentation mechanism of the PYTHIA nicely reproduces all the charge correlation properties in heavy-ion interactions and in $p + p$ collision while the AMPT (default) produces only the charge-momentum correlation but no charge correlation in the $p+p$ collision. The effectiveness of AMPT has to tested for nucleus-nucleus collisions and also using the string melting mode.

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