Net-Charge fluctuations in Pb-Pb collisions at $\sqrt{s}_{NN} = 2.76$ TeV using HYDJET++ model

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The study of event-by-event (ebe) fluctuations has attracted considerable interest of high energy physicists because of the idea that such fluctuations may reveal the degrees of freedom of the strongly interacting matter created in heavy-ion collisions. The observed fluctuations, in, general, are classified into two parts (i) The statistical fluctuations, which are resulted due to finite event multiplicity and (ii) The dynamical fluctuations, which may be divided into two subgroups; the one which do not change on ebe basis, e.g, due to B.E. statistics and/or decay of resonances, and the other which changes on ebe basis. Relevant example is charged to neutral particle ratio due to creation of DCC region or production of jets which contributes to high p_T tail in p_T distribution. The ebe net charge fluctuations in hh and AA collisions have drawn considerable attention because (i) a suppression in the net charge fluctuations has been theoretically predicted as a signature of the plasma state[1]. Such a decrease is expected as the charges are envisaged to be spread more evenly throughout the QGP volume than that in the hadronic gas, (ii) an enhanced charge fluctuations has been observed at RHIC and SPS energies[2], which might be due to anomalous proton number fluctuations at the critical point and (iii) in the absence of QGP, the deviation of such fluctuations from the statistical behaviour can be used to determine the abundance of ρ and ω mesons. The net-charge fluctuations are best studied by calculating the quantity ν_{dyn}[3], which is determined by the relative correlation strength of particle pairs.

$$\nu_{dyn} = \frac{< N_+(N_+ - 1) >}{< N_+ >^2} + \frac{< N_-(N_- - 1) >}{< N_- >^2} - 2\frac{< N_+ N_- >}{< N_+ >< N_- >}$$

where $\langle N_+ \rangle$ and $\langle N_- \rangle$ are the average number of positively and negatively charged particles within the phase space of interest. A negative value of ν_{dyn} signifies the dominant contribution from correlations between pairs of opposite charges. On the other hand, a positive value indicates the significance of the same charge pair correlations. The ν_{dyn} has been found to be robust against random efficiency losses[3].

An attempt is, therefore, made to study the net-charge fluctuations in Pb-Pb collisions at $\sqrt{s}_{NN} = 2.76$ TeV by analysing the data using the Monte Carlo generator HYDJET++. The number of events used in this analysis is 10^5 events with in the $\Delta\eta = 1.0$ and 1.6 and $0.2 < p_T < 5.0$ Gev/c phase space. The kinematics cuts are same as ALICE experimental measurement[4] of ν_{dyn} for the sake of comparison. MC model HYDJET++ has been used because it includes detailed treatment of soft hadron production as well as hard multiparton production. It takes into account parton rescattering and energy loss as well. HYDJET++ simulates relativistic heavy ion collisions as a superposition of the soft, hydro-type state and the hard state resulting from multiparton fragmentation.

Values of charged particle density, $dN_{ch}/d\eta$ predicted by the model and those reported earlier[5] are presented in Table 1. It is ob-

Centrality	$(dN_{ch}/d\eta)$	$(dN_{ch}/d\eta)^*$	Hydro(%)	Jet(%)
0 - 5	1460 ± 100	1601 ± 60	88.6	11.5
05 - 10	1212 ± 90	1294 ± 49	89.1	10.8
10 - 20	918 ± 111	966 ± 37	90.0	10.0
20 - 30	625 ± 83	649 ± 23	91.1	8.8
30 - 40	410 ± 62	426 ± 15	92.3	7.6
40 - 50	253 ± 45	261 ± 09	93.6	6.3
50 - 60	145 ± 31	149 ± 06	94.8	5.1
60 - 70	75 ± 19	76 ± 19	96.0	3.9

TABLE I: Values of $dN_{ch}/d\eta$ from HYDJET++ and ALICE data[5] as a function of centrality.

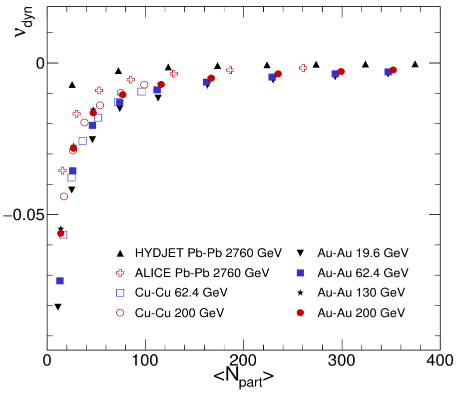

FIG. 1: Values of ν_{dyn} as a function of the collision centrality compared with other experiments measurements.

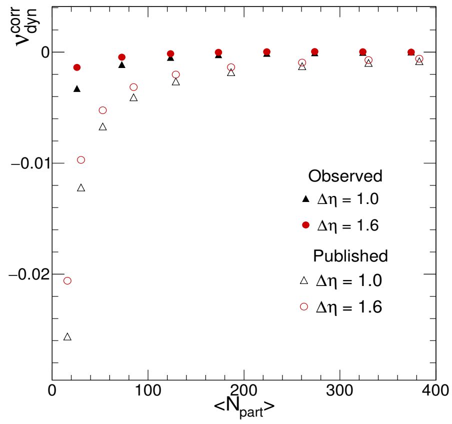

FIG. 2: Dependence of ν_{dyn}^{corr} with $\langle N_{part} \rangle$ for data and simulated events.

served that the contribution of hard processes is maximum in most central events (∼12%) and decrease significantly with increasing centrality (only ∼4% in peripheral collisions) while the contribution of soft processes is noticed to increase slightly with increasing centrality. It may be noticed that values of dN$_{ch}$/dη predicted by the model are somewhat smaller than the published values.

Variations of ν_{dyn} as a function of centrality, expresses in terms of the number of participating nucleons $\langle N_{part} \rangle$, for HYDJET++ Pb-Pb data at 2.76 TeV energy within pseudorapidity, $\Delta\eta = 1.0$ are displayed in Fig.1. Data points for published results at various energies (RHIC to LHC) are also displayed in same figure. The trend of variation of ν_{dyn} with $\langle N_{part} \rangle$ exhibited by the model and the data sets are nearly identical. Furthermore, negative values of ν_{dyn} indicate the dominance of correlation between pairs of opposite charges.

It is suggested that the values of ν_{dyn} are to be corrected for global charge conservation and finite detector acceptance[3]. The correction is incorporated by re-defining ν_{dyn} as $\nu_{dyn}^{corr} = \nu_{dyn} + \frac{4}{<N_{total}>}$, where $\langle N_{total} \rangle$ is the average total number of charged particles produced over a full phase space. Dependence of ν_{dyn}^{corr} with $\langle N_{part} \rangle$ for ALICE data and HYDJET++ are shown in Fig.2. The absolute values of ν_{dyn}^{corr} for HYDJET++ are smaller compared to data points. The differences are more pronounced for peripheral collisions than for central collisions while for most cemtral collisions the difference is very small. These findings, thus, indicate that the measurements of dynamic net-charge fluctuations in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV using the observable ν_{dyn} is well explained by the HYDJET++ model. The net-charge fluctuations are observed to be dominated by the correlations of oppositely charged particles. The energy dependence of the dynamical fluctuations shows a decrease in fluctuation going from RHIC to LHC energies. This trend of decrease of ν_{dyn} is nicely reproduced by the model.

References

[1] K. Adcox et al., *Phys. Rev. Lett.* **89** (2002) 082301.

[2] M. R. Atayan et al., *Phys. Rev.* **D71** (2005) 012002.

[3] C. Pruneau et al. *Phys. Rev.* **C66**, (2002) 044904.

[4] B. Abelev et al. *Phys. Rev. Lett.* **B110** (2013) 152301.

[5] K. Aamodt et al. *Phys. Rev. Lett.* **106** (2011) 032301.