On the Net Charge Fluctuations at Mid-Rapidity at SPS, RHIC and LHC.

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1. Introduction

There are several theoretical as well as experimental studies on even-by-event fluctuation of global observables at SPS, RHIC and LHC energies. One of the observales, net charge fluctuation, has been termed to be very promising signal of such studies [1, 2]. Several experiments have studied net charge fluctuation at SPS, RHIC and LHC energies [4−−7]. In this note, we have tried to understand the results of net charge fluctuation measured in different experiments and tried to explain the nature of the measured fluctuation strength.

2. Measures

On the basis of the thermal model calculations, Variable D was proposed to measure [1] net charge fluctuation strength defined as :

$$D = \langle N_{ch}\rangle\langle \delta R^2\rangle = 4\frac{\langle \delta Q^2\rangle}{\langle N_{ch}\rangle} \tag{1}$$

where, $\langle \delta R^2\rangle = \langle R^2\rangle - \langle R\rangle^2$, R being the ratio of positive to negative charged particles($\frac{N_+}{N_-}$), $Q = N_+ - N_-$ and $N_{ch} = N_+ + N_-$ and $\langle ....\rangle$ denotes average over event enssemble. For a pion gas, $D \approx 4$ where as for a QGP state $D \approx 1$ consisting of u , d quarks and gluons. This calculations is based on the assumption that the entropy of the system in hadronic and QGP state is conserved, all particles involved in the calculations are massless, they are in thermal equilibrium and non-interacting. However several correction factors are needed to take care for the finite net charge within acceptance due to baryon stopping, finite bin size width in rapidity and global net charge conservation. The Corrected prediction for D is [2]

$$\tilde{D} = \begin{cases} 1 & \text{quark gluon plasma} \\ 2.8 & \text{resonance gas} \\ 4 & \text{uncorrelated pion gas} \end{cases} \tag{2}$$

Lattice calculation has predicted $D \approx 4.0$ for uncorrelated pion gas and $D \approx 3.0$ after consideration of resonance decay and for a QGP $D \approx 1.0 - 1.5$ [3]. The CERES Collaboration [4] and STAR collaboration [5, 6] used a measure called, ν_{dyn} to measure the net charge dynamical (dyn) fluctuation strength defined as;

$$\nu_{dyn}(M) = \frac{\langle N_+(N_+-1)\rangle_M}{\langle N_+\rangle^2_M} + \frac{\langle N_-(N_--1)\rangle_M}{\langle N_-\rangle^2_M} - 2\frac{\langle N_+N_-\rangle_M}{\langle N_+\rangle_M\langle N_-\rangle_M} \tag{3}$$

By construction $\nu_{dyn} = 0$ in the absence of any correlations. The measure ν_{dyn} is related to measure D by the relation[3]:

$$\nu_{dyn} \times \langle N_{ch}\rangle \approx D - 4 \tag{4}$$

For any measure, two important factors namely, the dependence on detector inefficiency and volume fluctuation can affect the results to a great extent. Very recently it has been proposed to use strongly intensive measures to study event-by-event fluctuations which are independent of volume fluctuation [8]. The variable ν_{dyn} is independent of single particle detector inefficiency and volume fluctuation however it decreases inversely propotional to event multiplicity. The scaled ν_{dyn} is an intensive measure. All the variables mentioned above have inherent multiplicity dependence either in one form or the other. It is

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therefore essential to avoid this multiplicity dependence to understand the results of one experiment while comparing with the results of another experiment.

3. Results and Discussion

In this section of the the note, our main focus will be on the experimental studies carried out at mid-rapidity only. We have chosen CERES results as SPS measurement since CERES measurement was carried out near mid-rapidity region($2.2\langle\eta\rangle 2.7$) at CERN-SPS. The observed fluctuation strength measured in ALICE experiment in terms of ν_{dyn} in p+p collisons at 2.76 TeV is $-0.2412 \pm 0.0074(stat) \pm 0.0108(sys)$ within the psedurapidity interval of $\Delta\eta = 1.0$. and $-0.2141 \pm 0.0057(stat) \pm 0.0103(sys)$ for the pseudorapidity interval $\Delta\eta = 1.6$ [7]. After correcting for global charge conservation and other effects the reported signal strengths are $D = 3.388 \pm 0.005(stat) \pm 0.154(sys)$ for psedudorapidity $\Delta\eta = 1.0$ and $D = 3.206 \pm 0.008(stat) \pm 0.103(sys)$. It is essential to estimate the dilution of correlation strength in pp collisons under the influence of high multiplicity environment, one can scale the fluctuation strength with average charge mulplicity used in pp collisions and pb+Pb collisions. The expected value of D after dilution in Pb+Pb collisions at 2.76 TeV within pseudorapidity window $\delta\eta = 1.0$ and within pseudorapidity window $\delta\eta = 1.6$ has been shown in figure1. It is observed from figure1 that the expected dilution of fluctuation strength in p+p collisions at 2.76 TeV give rise to the similar value of D variable to the measured value of D from ν_{dyn} after correction for global charge conservation, finite acceptance correction as reported in [7]. Therefore the observed dynamical net charge fluctuation in Pb+Pb collisons at 2.76 TeV in ALICE experiment is similar as in p+p collisions and the lower fluctuation strength in Pb+Pb collisons at 2.76 TeV can be fully explained by the the dilution of fluctuation strength under higher multiplicity environment in Pb+Pb collisions. Thus the measured fluctuation strength in LHC in Pb+Pb collisions at 2.76 TeV are closer to the theoretical prediction of hadronic gas.

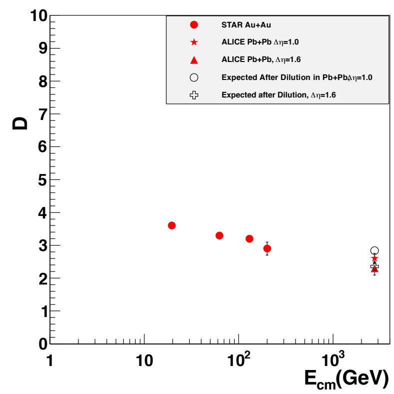

FIG. 1: D as function of $\sqrt{s}$. The solid filled circles are from STAR Collaboration Measurement. The filled stars correspnds AICE measurement at $\Delta\eta = 1.0$. The filled triangle corresponds to ALICE results at $\Delta\eta = 1.6$. The open circle and cross symbol correspnds to expected value of D in Pb+Pb collisions in at 2.76 TeV after the dilution of fluctuation strength in p+p collisions at 2.76 TeV

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