Φ-measure of electric charge in Pb+Pb interactions

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The event-by-event (e-by-e) fluctuation of conserved quantities like the electric charge, baryon number, strangeness etc., can be used to detect the dynamics of high-energy nucleus-nucleus (AB) collisions [1]. It is expected that a nucleus-nucleus (AB) collision system should exhibit critical behavior near the end point of the QGP to hadron phase boundary of the QCD phase diagram. Therefore, e-by-e fluctuations can distinguish AB events associated with the QGP formation [2]. It is speculated that in a QGP the fluctuation of electric charge should be suppressed [3]. However, the NA49 [4], PHENIX [5] and STAR [6] experiments do not confirm such a prediction. We study the e-by-e fluctuation by using the Φ-measure, defined as [7]

$$\Phi_q = \sqrt{\frac{\langle Z^2 \rangle}{\langle N \rangle}} - \sqrt{\bar{z^2}}, \quad \text{where} \quad z = q - \bar{q} \quad (1)$$

Here q denotes the charge of a single hadron, $\bar{q}$ is the average of the corresponding distribution, the event variable $Z = \sum_{i=1}^{N}(q_i - \bar{q})$ is determined by summing over all charged hadrons (N in number) belonging to an event, and $\langle\ \rangle$ represents averaging over all events. If particles are correlated only by the global charge conservation (GCC) then,

$$\Phi_{q,GCC} = \sqrt{1-P} - 1, \qquad P = \frac{\langle N_{ch} \rangle}{\langle N_{ch} \rangle_{tot}} \quad (2)$$

where $\langle N_{ch} \rangle$ and $\langle N_{ch} \rangle_{tot}$ are, respectively the mean charged hadron multiplicity within the detector acceptance and in the full phase space [8]. The effect of GCC is removed in the measure $\Delta\Phi_q = \Phi_q - \Phi_{q,GCC}$. If correlations (anticorrelations) beyond GCC are present then $\Delta\Phi_q < 0$ ($\Delta\Phi_q > 0$) [8].

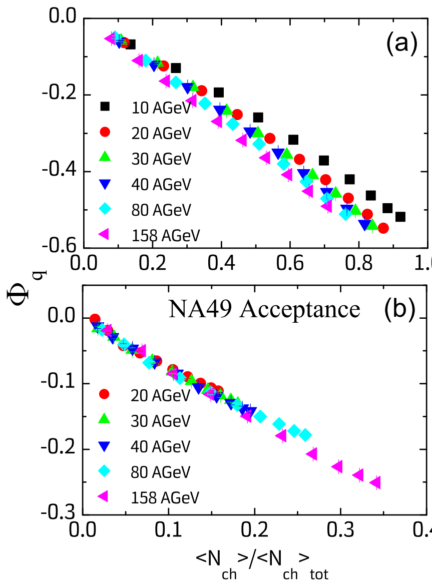

FIG. 1: Φ_q with the fraction of accepted particles.

We present some results on the Φ_q-measure in central Pb+Pb collisions at incident beam energies $E_{\text{lab}} = 10A$, $20A$, $30A$, $40A$, $80A$ and $158A$ GeV, simulated by the ultra-relativistic quantum molecular dynamics (UrQMD) [9]. The energy values correspond to the NA49 experiment [10]. The selected centrality bins are, 0–10% at $158A$ GeV and 0–7% for the other energies. Charged hadrons with $p_T < 0.2$ GeV/c are considered for analysis. We compute Φ_q and $\Delta\Phi_q$ within rapidity intervals $\Delta y = 0.3 - 3.0$ increasing in steps of 0.3. Equivalently the fraction of accepted particles $\langle N_{ch} \rangle / \langle N_{ch} \rangle_{tot}$ is determined. Figure 1(a) shows Φ_q plotted against $\langle N_{ch} \rangle / \langle N_{ch} \rangle_{tot}$. In Fig. 1(b) we present the same plot for the

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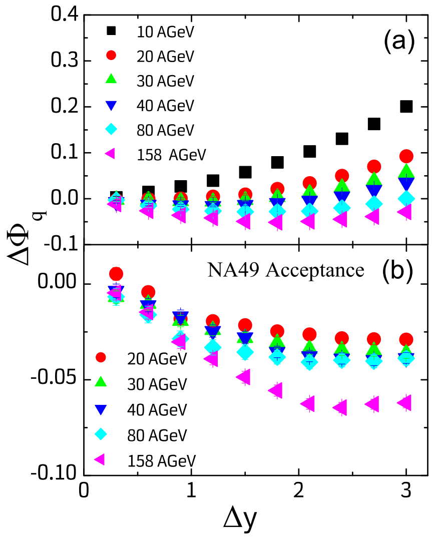

FIG. 2: $\Delta\Phi_q$ as a function of Δy.

kinematic acceptance of the NA49 experiment [10]. In both cases Φ_q monotonically decreases with increasing Δy. The results indicate that GCC is a major source of particle correlation. The acceptance of NA49 experiment makes the results almost independent of E_{lab}. We plot $\Delta\Phi_q$ against Δy in Fig.2. In absence of any kinematic cut $\Delta\Phi_q$ increases with Δy at lower E_{lab}, while at higher E_{lab} it remains almost uniformly distributed against Δy. On the other hand, with the NA49 acceptance $\Delta\Phi_q$ is negative valued and its magnitude reduces with increasing Δy. The results indicate presence of correlation (anti-correlation) between oppositely charged particles beyond GCC. However, in both cases the $\Delta\Phi_q$ values are larger than the expectation from a QGP system ($-0.5 < \Delta\Phi_q < -0.15$). The beam energy dependence of $\Delta\Phi_q$ is shown in Fig. 3 for $\Delta y = 1.2$ and 3.0. In absence of any kinematic cut we find that $\Delta\Phi_q$ monotonically decreases with increasing $\sqrt{S_{\text{NN}}}$. However, using the NA49 acceptance the $\Delta\Phi_q$ values, particularly at lower energies, have been significantly reduced and an energy independence of $\Delta\Phi_q$ is observed. Corresponding UrQMD simulation nicely matches with the experiment.

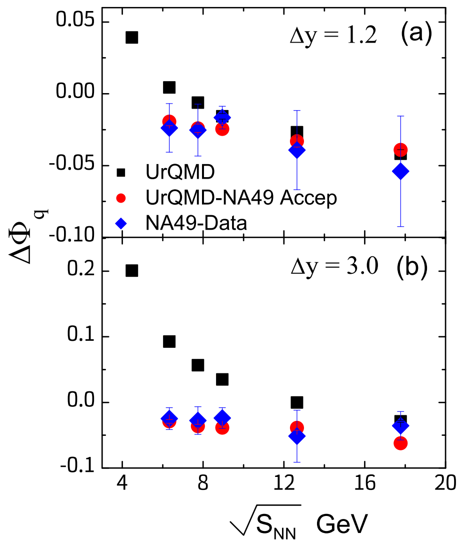

FIG. 3: $\Delta\Phi_q$ against E_{lab} at two different Δy.

References

[1] E. V. Shuryak, Phys. Rep. 61, 71 (1980).
[2] M. Luzum and H. Petersen, J. Phys. G 41, 063102 (2014).
[3] S. Jeon and V. Koch, Phys. Rev. Lett. 85, 2076 (2000); M. Asakawa *et al.* Phys. Rev. Lett. 85, 2072 (2000).
[4] C. Blume *et al.*, Nucl. Phys. A 715, 55 (2003).
[5] K. Adcox *et al.*, Phys. Rev. Lett. 89, 082301 (2002).
[6] J. Adams *et al.*, Phys. Rev. C 68, 044905 (2003).
[7] M. Gaździcki and S. Mrówczyński, Z. Phys. C 54, 127 (1992).
[8] J. Zaranek, Phys. Rev. C 66, 024905 (2002).
[9] S. A. Bass *et al.*, Prog. Nucl. Part. Phys., 41, 255 (1998).
[10] C. Alt *et al.*, Phys. Rev. C 70, 064903 (2004).