Comment on "Charged Particle Ratio Fluctuation as a Signal for Quark-Gluon Plasma" and "Fluctuation Probes of Quark Deconfinement"

Charge fluctuations studied on event-by-event basis have been suggested by two groups [1,2] (see also [3]) to provide a signal of the quark-gluon plasma (QGP) produced in heavy-ion collisions at high energies. Specifically, Jeon and Koch [1] and Asakawa, Heinz and Müller [2] proposed to study the fluctuation measure

$$\frac{V(Q)}{\langle N_{\rm ch}\rangle} = \frac{\langle (Q-\langle Q\rangle)^2\rangle}{\langle N_{\rm ch}\rangle} \;, \qquad (1)$$

where Q is the charge (electric or baryon) and $N_{\rm ch}$ is the number of electrically charged particles both measured in a given rapidity interval; $\langle ...\rangle$ denotes averaging over events. The measure (1) equals approximately unity for the equilibrium hadron gas and it is 2 to 3 times smaller [1,2] when the charge fluctuations are generated in QGP and the entropy, which controls the final state particle multiplicity, is conserved. Since various phenomena which occur in the hadron phase rather increase than decrease the fluctuations created in QGP the smallness of (1), if measured, seems to be an unambiguous signal of the plasma production.

Jeon and Koch [1] and Asakawa *et al.* [2] assume that the final state charge fluctuations are created when QGP produced at the collision early stage achieves local thermodynamic equilibrium. They argue that the fluctuations are not increased to the level characteristic for the hadron phase due to the rapid system expansion. However, it seems a legitimate assumption that the fluctuations are determined even earlier i.e. at the initial stage of heavy-ion collision when the energy of the participating nucleons is released and nonequilibrium parton system emerges. The longitudinal collective motion, which counteracts the relaxation of the fluctuations, develops just at this stage. Thus, we assume that the final state charge fluctuations observed in a rapidity window Δy_f are fully determined by the initial stage charge fluctuations in the rapidity window Δy_i, which corresponds to Δy_f. Such a scenario does not exclude formation of the equilibrium QGP. It only demands that the processes of thermalization, hadronization, etc. redistribute the charges at the scale smaller than Δy. Then, the charge within the window is conserved during the temporal evolution.

The number of charge carriers dramatically increases at the collision early stage. If the charge fluctuations are indeed created initially the numerator of the measure (1) is determined by the much smaller number of carriers than the denominator. Therefore, the measure is expected to be *small*. One gets a rough estimate of (1) assuming that the initial fluctuations of the electric charge in Δy_i are due to the variation of the number of protons occurring in Δy_i. For the central collisions and Δy_i being nuch smaller than the full rapidity interval, these fluctuations are expected to be poissonian. Therefore, the measure (1) reads

$$\frac{V(Q)}{\langle N_{\rm ch}\rangle} = \frac{\langle Z\rangle}{\langle N_{\rm ch}\rangle} \;, \qquad (2)$$

where Z is number of participating protons. In the case of baryon charge fluctuations one replaces Z by the number of participating nucleons. In order to remove a possible contribution of the geometrical fluctuations it was proposed in [1] to use

$$\frac{1}{4}\langle N_{\rm ch}\rangle V(N^+/N^-) \;, \qquad (3)$$

instead of (1) in experimental studies of the electric charge fluctuations. The measure (3) approximately equals (1) for sufficiently small multiplicity fluctuations. If the charge fluctuations are indeed governed by the initial ones the use of (3) instead of (1) will reduce the measured fluctuations even in the central collisions because the charge fluctuations which are proportional to the produced entropy do not contribute to (3).

Since the charge particle multiplicity per participating proton is about 8 at CERN SPS energy [4] and it is even larger at BNL RHIC, the value given by eq. (2) is significantly smaller than unity. One notes that our estimate remains similar if the valence quarks instead of protons are the charge carriers at the collision early stage. Thus, the smallness of charge fluctuations, if measured, can be interpreted either as a result of the equilibrium QGP or due to the initial charge variation. Rapid expansion of the matter produced in nucleus-nucleus collisions can freeze both types of fluctuations or the superposition of them. If the mechanism of freezing is not efficient enough the fluctuations characteristic for the hadronic final state will be observed.

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