CHARGED PARTICLE RATIO FLUCTUATIONS AND CHARGE TRANSFER FLUCTUATIONS FROM A RECOMBINATION APPROACH* **

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We analyse charged particle ratio fluctuations and charge transfer fluctuations within samples of central Au+Au events at $\sqrt{s_{NN}} = 200$ GeV simulated using a dynamical recombination approach including an explicit transition from quark to hadronic matter (quark Molecular Dynamics, qMD). In previous papers, we argued that the recombination-hadronization procedure implemented in the qMD model is responsible for the vanishing of the initial QGP fluctuations for both observables. In this investigation, the rapidity window size dependence (critical in fluctuation analyses) of charged particle ratio fluctuations within qMD is calculated and found to be compatible with the hadronic values. Charge transfer fluctuations are studied as a function of rapidity for a fixed rapidity window. This observable turns out to be insensitive to the quark stage of the qMD model, even in the midrapidity region. These results might indicate a drastic effect of (recombination-)hadronization on fluctuation observables and might explain the compatibility of the available experimental results on charged particle ratio fluctuations with hadronic expectations.

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Charged particle ratio fluctuations [1, 2] and charge transfer fluctuations [3, 4] have been proposed to pin down the existence of the quark–gluon plasma state created in central heavy ion reaction at the highest energy available at RHIC–BNL. In previous analyses [5–7] performed with the dynamical recombination model quark Molecular Dynamics (qMD) [8, 9], we already argued that (recombination-)hadronization [10–12] might blur the expected QGP signals and bring them to their hadronic expectation values, in line with the work from Ref. [13]. We study further charged particle ratio fluctuations and charge transfer fluctuations within the framework of the qMD model with a sample of central Au+Au events at $\sqrt{s_{NN}} = 200\,A$GeV.

Charged particle ratio fluctuations are quantified by the measure $\tilde{D}$ defined as [14]:

$$\tilde{D} = \frac{1}{C_\mu C_y} \langle N_{\rm ch} \rangle \langle \delta R^2 \rangle_{\Delta y}\,, \tag{1}$$

where $N_{\rm ch}$ stands for the number of charged particles, $R = (1+F)/(1-F)$ with $F = Q/N_{\rm ch}$, Q being the electric charge. Following [15], these fluctuations are corrected by the factors C_μ and C_y. It was argued that depending on the nature of the initial system, $\tilde{D}$ yields distinctly different results: $\tilde{D} = 1$ for a QGP, $\tilde{D} = 2.8$ for a resonance gas and $\tilde{D} = 4$ for an uncorrelated pion gas.

Charged particle ratio fluctuations have been measured at RHIC–BNL [16–19] and CERN–SPS [20, 21] energies. All experimental analyses yield results compatible with the hadronic expectations. We already showed in [5–7] within the framework of the dynamical recombination procedure used in the qMD model that charged particle ratio fluctuations increase together with hadronization up to $\tilde{D} \approx 3.5$ in the final state, even though the signal is initially compatible with the QGP expectation $\tilde{D} \approx 1$.

Fig. 1 (left) depicts the rapidity window size dependence of the $\tilde{D}$ measure. The size of the rapidity window Δy used is crucial for the fluctuations of conserved charges: On the one hand, the rapidity slice used should not be too small in order to avoid purely statistical fluctuations and the transport of charges through hadronic rescattering. On the other hand, Δy should neither be too large to avoid global charge conservation which would lead to a vanishing signal. $\tilde{D}$ goes to 4 when the rapidity window Δy is decreased to very small values. It is to be expected because within very small rapidity slices, only one resonance decay product can be observed (*e.g.* from $\rho^0 \to \pi^+ + \pi^-$) so that the system appears uncorrelated. With increasing Δy, $\tilde{D} \approx 3.5$ in agreement with the resonance gas result and stays constant until $\Delta y \approx 3$. The further increase with even larger Δy is shown for completeness and arises from the term c_y correcting for global charge conservation, going to $c_y = 0$ when almost all particles are taken into account.

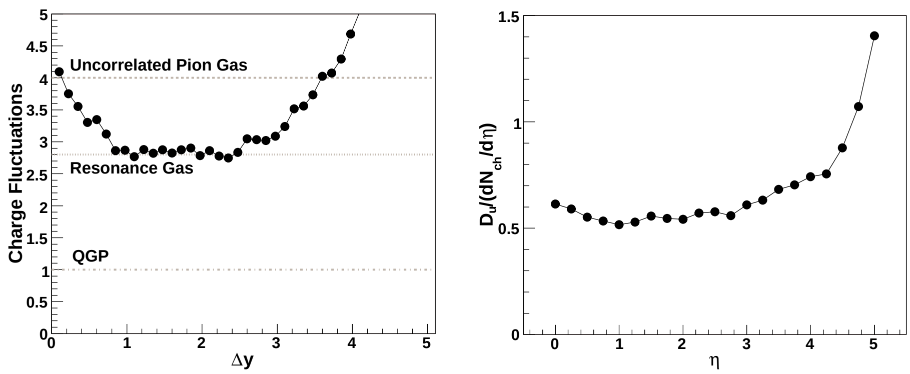

Fig. 1. Left: Charged particle ratio fluctuations $\tilde{D}$ (full symbols) as a function of the width of the rapidity window Δy. Also shown are the values for an uncorrelated pion gas, a resonance gas and a QGP. Right: Charge transfer fluctuations $D_u/(dN_{\rm ch}/d\eta)$ as a function of the pseudo-rapidity η calculated with $\Delta\eta = \pm 0.5$.

We now turn to charge transfer fluctuations, which should be sensitive to the extent of the QGP fraction in rapidity space and defined as [3]:

$$D_u(\eta) = \langle u(\eta)^2 \rangle - \langle u(\eta) \rangle^2 \,, \tag{2}$$

with the charge transfer $u(\eta)$ being the forward–backward charge difference:

$$u(\eta) = [Q_{\rm F}(\eta) - Q_{\rm B}(\eta)]/2 \,, \tag{3}$$

where $Q_{\rm F}$ and $Q_{\rm B}$ are the charges in the forward and backward hemisphere of the region separated at $\eta = 0$. $D_u/(dN_{\rm ch}/d\eta)$ is proportional to the local charge correlation length, smaller in a QGP than in a hadronic phase. One expects to observe the lowest value of the charge transfer fluctuations at midrapidity, where the energy density is the highest and where the plasma is located. The rapidity dependence of $D_u/(dN_{\rm ch}/d\eta)$ should thus exhibit a dip in the central region. Experimental data on this observable are not available.

Similar to the $\tilde{D}$ measure discussed above, charge transfer fluctuations increase with time up to their hadronic value of $D_u/(dN_{\rm ch}/dy) \approx 0.5$ with hadronization [5–7]. The result obtained is in line with the hadronic expectation [3, 4, 22], even though the qMD result is initially compatible with a QGP, $D_u/(dN_{\rm ch}/dy) \approx 0.1$.

The results from the present calculations for $D_u/(dN_{\rm ch}/dy)$ are shown in Fig. 1 (right) as a function of rapidity. qMD calculations are essentially flat with $D_u/(dN_{\rm ch}/dy) \approx 0.6$. In particular, no deep at midrapidity appears even though a quark stage is explicitly included.

In conclusion, we have studied charged particle ratio fluctuations and charge transfer fluctuations within the framework of the dynamical recombination procedure of the qMD model, in which a quark stage is explicitly included. As a function of the rapidity window size, $\tilde{D}$ is essentially flat and compatible with the hadronic expectations. For charge transfer fluctuations, the centrality dependence exhibits no deep at central rapidities. These results confirm calculations performed earlier with the qMD model and indicate that hadronization itself might destroy the QGP fluctuations.

REFERENCES

[1] S. Jeon, V. Koch, *Phys. Rev. Lett.* **85**, 2076 (2000).

[2] M. Asakawa, U.W. Heinz, B. Muller, *Phys. Rev. Lett.* **85**, 2072 (2000).

[3] S. Jeon, L. Shi, M. Bleicher, *Phys. Rev.* **C73**, 014905 (2006).

[4] L.J. Shi, S. Jeon, *Phys. Rev.* **C72**, 034904 (2005).

[5] S. Haussler, S. Scherer, M. Bleicher, `arXiv:hep-ph/0702188`.

[6] S. Haussler, M. Bleicher, S. Scherer, SQM 2007.

[7] S. Haussler, M. Bleicher, S. Scherer, International Workshop on Critical Point and Onset of Deconfinement, 2007.

[8] S. Scherer, M. Hofmann, M. Bleicher, L. Neise, H. Stoecker, W. Greiner, *New J. Phys.* **3**, 8 (2001).

[9] M. Hofmann, M. Bleicher, S. Scherer, L. Neise, H. Stoecker, W. Greiner, *Phys. Lett.* **B478**, 161 (2000).

[10] D. Molnar, S.A. Voloshin, *Phys. Rev. Lett.* **91**, 092301 (2003).

[11] R.J. Fries, B. Muller, C. Nonaka, S.A. Bass, *Phys. Rev. Lett.* **90**, 202303 (2003).

[12] V. Greco, C.M. Ko, P. Levai, *Phys. Rev. Lett.* **90**, 202302 (2003).

[13] C. Nonaka, B. Muller, S.A. Bass, M. Asakawa, *Phys. Rev.* **C71**, 051901 (2005).

[14] S. Jeon, V. Koch, *Phys. Rev. Lett.* **85**, 2076 (2000).

[15] M. Bleicher, S. Jeon, V. Koch, *Phys. Rev.* **C62**, 061902 (2000).

[16] C.A. Pruneau *et al.* [STAR Collaboration], *Heavy Ion Phys.* **21**, 261 (2004).

[17] G.D. Westfall *et al.* [STAR collaboration], *J. Phys. G* **30**, S1389 (2004).

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

[19] J. Nystrand *et al.* [PHENIX Collaboration], *Nucl. Phys.* **A715**, 603 (2003).

[20] H. Sako,H. Appelshaeuser *et al.* [CERES/NA45 Collaboration], *J. Phys. G* **30**, S1371 (2004).

[21] C. Alt *et al.* [NA49 Collaboration], *Phys. Rev.* **C70**, 064903 (2004).

[22] S. Jeon, L. Shi, M. Bleicher, *J. Phys. Conf. Ser.* **27**, 194 (2005).