Event-by-Event Fluctuations in 40, 80, and 158 AGeV/c Pb+Au Collisions

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Abstract. Event-by-event fluctuations of mean p_T and net charge in 40, 80, and 158 AGeV/c Pb+Au collisions are presented. Observed dynamical mean p_T fluctuations in central events are about 1 %, which are very similar to RHIC data. Centrality dependence of mean p_T fluctuations at 158 AGeV/c shows a peculiar non-monotonic pattern with respect to the extrapolation from the fluctuations measured in p+p collisions. Dynamical net charge fluctuations smaller than the charge conservation limit are observed. The fluctuations corrected for the charge conservation in central events are comparable to RHIC results.

1. Introduction

Event-by-event fluctuations of mean p_T have been proposed as a possible probe to search for the phase transition, especially the QCD critical point via their non-monotonic variation with control parameters such as beam energy and centrality [1]. On the other hand, the fluctuations can be used to evaluate the extent of thermal equilibrium by comparison with the extrapolated fluctuations in nucleon-nucleon collisions. Net charge fluctuations have been proposed as a probe to search for the phase transition via suppression due to smaller charge units of (anti-)quarks than those of hadrons [2, 3]. Comparisons with cascade models may clarify whether the observed fluctuations are described by resonance gas models.

Detailed description of CERES experiment is found elsewhere [4, 5]. For the present analysis, charged particles are reconstructed with the following subset of detectors. Two silicon drift detectors (SDD's) measure the primary vertex position, and a cylindrical Time Projection Chamber reconstructs trajectories and measures momenta of charged particles. The centrality is defined with the charged particle multiplicities measured by the SDD's and a scintillation Multiplicity Counter. The acceptance in the azimuthal angle is full 2π at 80 and 158 AGeV/c while it is limited to $\sim 1.3\pi$ at 40 AGeV/c. Pseudo-rapidity coverage is $2.0 < \eta < 2.9$ which covers mid-rapidity.

‡ For the full CERES/NA45 Collaboration author list and acknowledgments see the contibution by A. Marín (D. Adamovà *et al*) in this volume.

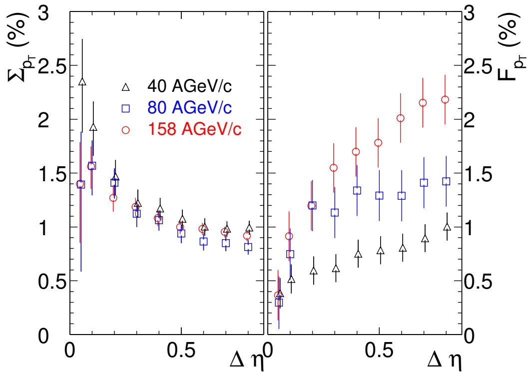

Figure 1: Σ_{p_T} (left) and F_{p_T} (right) as a function of $\Delta\eta$ at $0.1 < p_T < 1.5$ GeV/c in 6.5 % central events.

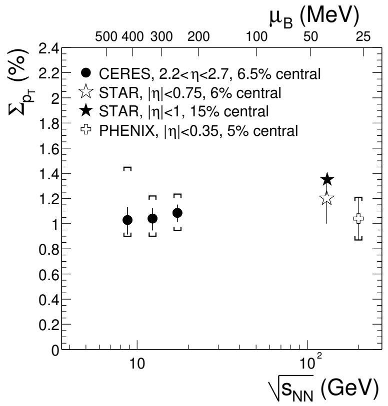

Figure 2: Σ_{p_T} as a function of $\sqrt{s_{NN}}$ in central events.

2. Mean p_T Fluctuations

The following two measures are used to evaluate mean p_T fluctuations. The normalized dynamical fluctuation Σ_{p_T} [5] is proportional to mean covariance of all charged particle pairs per event [6]. The second measure F_{p_T} [8] is proportional to $\langle N\rangle\Sigma^2_{p_T}$, where $\langle N\rangle$ is the mean charged particle multiplicity within the acceptance. In Fig. 1, Σ_{p_T} decreases only by 40% as the pseudo-rapidity interval ($\Delta\eta$) increases, whereas F_{p_T} increases by a factor of $3 \sim 5$. At a given $\Delta\eta$, F_{p_T} differs significantly among the three beam energies, while the difference in Σ_{p_T} is slight. Therefore the robust measure Σ_{p_T} is used to investigate collision energy dependence.

Fig. 2 shows Σ_{p_T} as a function of nucleon-nucleon center of mass energy ($\sqrt{s_{NN}}$) in $2.2 < \eta < 2.7$ and $0.1 < p_T < 2$ GeV/c in 6.5 % central events, compared to RHIC data at $\sqrt{s_{NN}} = 130$ GeV [9, 10], and 200 GeV [8]. The observed fluctuations at SPS and at RHIC are similarly about 1 %. No indication for non-monotonic variation or enhanced fluctuations is observed. Note that a predicted fluctuation at the critical point is $\sim 2\%$ [1], far above the measured values.

Fig. 3 shows fluctuations corrected for short range momentum correlations at 158 AGeV/c as a function of the number of participants (N_{part}). The fluctuations between the minimum-bias data set and the central data set are consistent. As a baseline (dashed lines) reflecting the superposition of individual nucleon-nucleon collisions, we employ the formula $\Sigma^{AA}_{p_T} = 12\% \cdot (\langle N_{part}\rangle/2)^{-1/2}$, where the 12 % is a measured fluctuation in p+p collisions at ISR [7], which corresponds to $F_{p_T} \simeq 1.4$ %. Significant deviations from the baseline are observed in semi-central events, whereas in peripheral events (centrality $\geq 66\%$) and in central events (centrality $\leq 20\%$), the fluctuations are consistent with the baseline. The maximum of F_{p_T} is about 2.8 % at $N_{part} = 50 \sim 100$, corresponding to $25 - 50$ % central events. The observed centrality dependence as well as the increase of F_{p_T} with the upper p_T cut is similar to the observations by PHENIX [8].

In Fig. 4, F_{p_T} of RQMD and UrQMD without the rescattering is consistent with

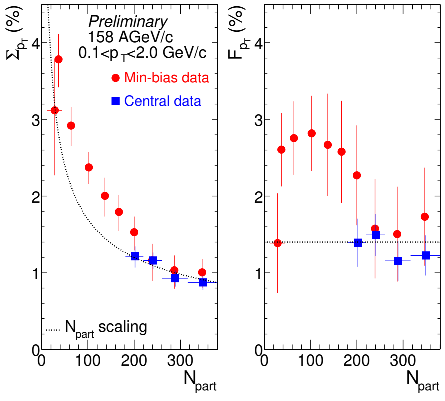

Figure 3: Σ_{p_T} (left) and F_{p_T} (right) as a function of N_{part} at 158 AGeV/c.

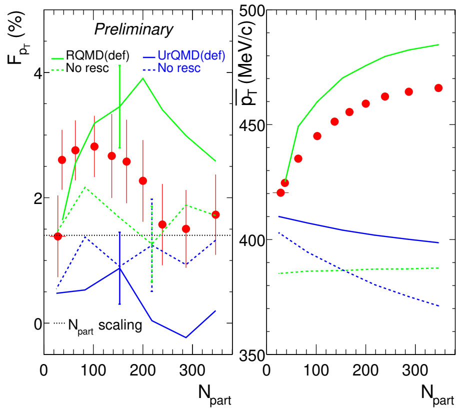

Figure 4: F_{p_T} (left) and $\overline{p_T}$ (right) as a function of N_{part} compared to RQMD and UrQMD at 158 AGeV/c.

the baseline as expected. With the rescattering, RQMD reproduces qualitatively both the increasing tendency of mean p_T and the non-monotonic dependence of fluctuations, while UrQMD underestimates the both observables.

3. Net charge fluctuations

As a measure of net charge fluctuations, we use ν_{dyn} [11], representing dynamical fluctuations of the difference between normalized multiplicity of positive particles and that of negative particles. The measure is advantageous since the correction for the global charge conservation is constant and additive, and no efficiency correction is necessary.

Fig. 5 shows ν_{dyn} multiplied with mean charged particle multiplicity as a function of N_{part} at the three beam energies. The dashed lines show the charge conservation limit assuming a shape of the rapidity distribution is unchanged with centrality. The total multiplicities are estimated based on the NA49 measurements [12]. The observed fluctuations are lower than the charge conservation limit. Since the fluctuations are much above the QGP model predictions of ~ -3.5 [2, 3], no indication for the phase transition is observed. Decreasing tendencies of $\langle N \rangle \nu_{dyn}$ with $\langle N_{part} \rangle$ are observed at the three beam energies. Whether this is due to a deviation of the charge conservation limit due to the change of the rapidity width, or due to a real deviation of the fluctuations from the multiplicity scaling, is under investigation.

Fig. 6 shows ν_{dyn} corrected for the charge conservation ($\tilde{\nu}_{dyn} \equiv \nu_{dyn} + 4/\langle N \rangle_{4\pi}$, where $\langle N \rangle_{4\pi}$ is the total charged particle multiplicity) as a function of $\sqrt{s_{NN}}$ with CERES, STAR [13, 14], and PHENIX data [15]. A decrease of $\tilde{\nu}_{dyn}$ is observed at SPS energies, whereas the decrease is tiny from SPS top energy to RHIC energies. Both RQMD and UrQMD are in reasonable agreement with the data at SPS.

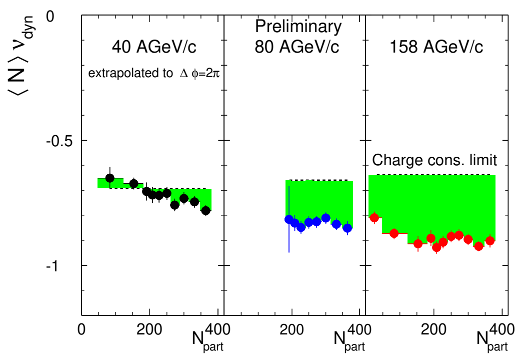

Figure 5: $\langle N \rangle \nu_{dyn}$ as a function of N_{part} at $2.05 < \eta < 2.85$ and $0.1 < p_T < 2.5$ GeV/c.

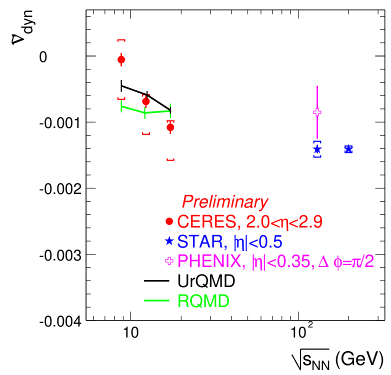

Figure 6: $\tilde{\nu}_{dyn}$ as a function of $\sqrt{s_{NN}}$ in central events.

4. Conclusions

Dynamical mean p_T fluctuations of ~ 1 % in central events are observed, which are similar to the fluctuations measured at RHIC. F_{p_T} shows non-monotonic centrality dependence with a maximum of ~ 2.8 % in semi-central events, which is about a factor of 2 enhanced over the p+p extrapolation. A similar tendency is observed also at PHENIX. RQMD qualitatively reproduces both enhancement of fluctuations in semi-central events and increase of mean p_T as a function of centrality.

Dynamical net-charge fluctuations are smaller than the charge conservation limit. The $\langle N \rangle \nu_{dyn}$ slightly decreases from peripheral to central events. The $\tilde{\nu}_{dyn}$ decreases at SPS energies but varies little from the SPS top energy to RHIC energies. UrQMD and RQMD reproduce the observed fluctuations at SPS.

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