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# Linking Fluctuations and Correlations in Relativistic Heavy Ion Collisions *

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We investigate the connection between previously unassociated multiplicity, transverse momentum, and flow correlation and fluctuation observables in relativistic heavy ion collisions [1, 2, 3]. Multiplicity fluctuations can provide a means to test theories of the initial production of partons, while transverse momentum fluctuations are used to study the degree of equilibration of the matter in the following system. Flow studies generally focus on relating a deterministic transverse expansion of that matter to the initial geometrical shape of the partonic distribution with the expectation that event-by-event fluctuations in this shape explain fluctuations in flow measurements. In all cases the measured observables rely on two or more particle correlation methods. We show that these three observables probe the same correlation function and therefore require a common explanation. We further argue that the common correlation is the result of an inhomogeneous initial parton density in conjunction with anisotropic transverse expansion. Finally, we take the origin of the initial state inhomogeneities to be the result of particle production from Color Glass Condensate (CGC)-Glasma flux tube sources and calculate the collision centrality and beam energy dependence of these observables in a common framework.

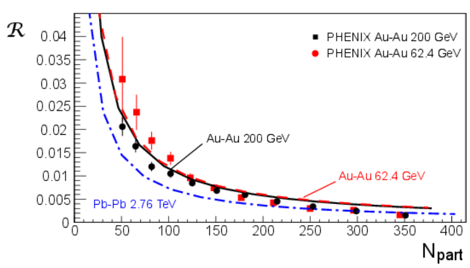


Figure 1: Multiplicity fluctuations $\mathcal{R}$. PHENIX data [4].

Multiplicity fluctuations $\mathcal{R}$ quantify the deviation of the pair momentum distribution of hadrons from that of the singles squared. In the absence of correlations, the pair distribution factorizes and $\mathcal{R}$ vanishes. We calculate $\mathcal{R}$ in a CGC-Glasma framework where coherent flux tube parton sources are randomly distributed at distances determined by the gluon saturation scale $Q_s$ with multiplicities proportional to $\alpha_s^{-1}(Q_s)$. Figure 1 shows our comparison to PHENIX data for RHIC energies with a prediction for Pb-Pb collisions at 2.76 TeV.

We take correlated particles to be those emerging from the same source. Anisotropic flow modifies these correlations such that the final transverse momenta of partons depends on their initial location and partons with common origins are modified in the same way. From this, we calculate transverse momentum fluctuations in Fig. 2 and elliptic flow fluctuations in Fig. 3 noting the change in collision energy is due primarily to $Q_s$. Importantly, if global equilibrium of the medium is achieved or flow fluctuations arose solely from fluctuations in geometrical shape then transverse momentum fluctuations should vanish. Our results and positive values of momentum fluctuations suggest that flow fluctuations (as they are measured) probe the two-particle correlation function rather than the fluctuation in geometrical shape of the collision volume.

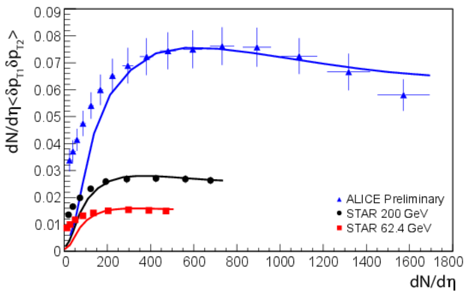


Figure 2: Transverse momentum fluctuations. Data: [5, 6].

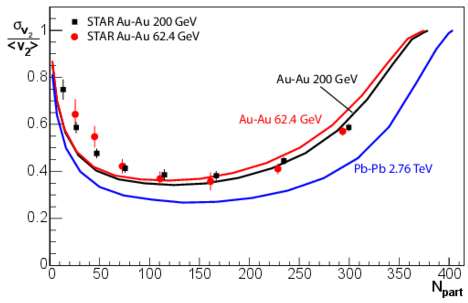


Figure 3: Elliptic flow fluctuations. STAR data [7].

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