Energy and Centrality Dependence of Rapidity Densities at RHIC *

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Signals of the formation of a quark-gluon plasma in high-energy heavy-ion collisions are sensitive to the initial condition of the dense matter created in the early stage of the collisions. Global bulk observables at the Relativistic Heavy-ion Collider (RHIC) such as the rapidity density of multiplicity and transverse energy provide important constraints on those initial conditions. We focus here on how the systematics (energy and centrality dependence) of this observable can be used to differentiate between competing entropy production mechanisms.

Theoretical estimates of the initial condition at RHIC vary over a wide range because of the (as yet) unknown interplay between soft and hard mechanisms of multiparticle production in nuclear collisions. Phenomenological models ranging from soft string models, perturbative QCD (pQCD) models, and classical Yang-Mills approaches have been proposed to predict the produced entropy. In these models there are basic physical parameters, such as the nuclear size dependence of the scale, $p_0(\sqrt{s},A)$, separating perturbative QCD and nonperturbative components, that control the magnitude of entropy production. In multiple mini-jet pQCD-inspired models, such as HIJING, the unknown nuclear gluon shadowing and parton energy loss due to final state interactions also lead to a factor of ~ 2 variation in the predictions for the final charged hadron rapidity density in the central region. With the first measurements of the $dN_{ch}/d\eta$ from the PHOBOS experiment and the other experiments at the Relativistic Heavy-ion Collider (RHIC), the theoretical uncertainties can soon be considerably reduced.

The aim of this letter is to emphasize that the centrality or impact parameter dependence of the charged particle rapidity density provides a key observable that, combined with other differential measurements, can significantly narrow the current band of uncertainty of the initial conditions produced at RHIC and search for evidence of novel gluon saturation phenomena or dynamical screening effects at high density.

The energy dependence of the charged hadron multiplicity has been shown by PHOBOS to be enhanced relative to pp reactions and is consistent with the onset of pQCD dynamics driven by the binary nature of semi-hard (mini-jet) processes. Though similar energy dependence is predicted by very different pQCD based models, the centrality dependence can differentiate between them. In principle, parton saturation is expected to occur at asymptotic high-energy in collisions of very heavy nuclei. The interesting question is where this occurs in practice. We proposed that the centrality or A dependence of the hadron multiplicity at RHIC and higher energies may help to answer this question.

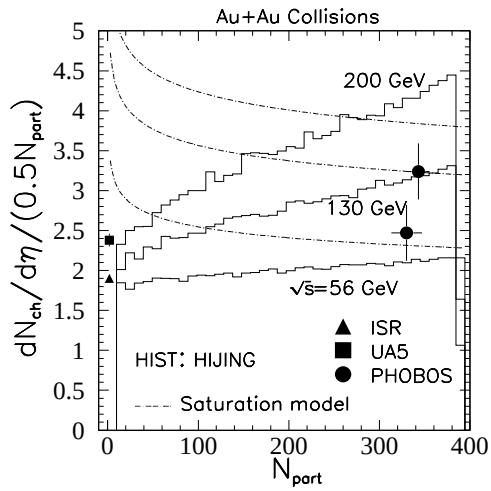

Figure 1: The charged particle (psuedo) rapidity density *per participating baryon pair* is shown as functions of the number of participant baryons for central $Au+Au(b<3\text{fm})$ collisions at $\sqrt{s}=56$, 130 and 200 AGeV. Results of HIJING1.35 (solid histograms) are compared to $pp(\bar{p}$ and PHOBOS data and to EKRT predictions (dot-dashed).

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