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Viscous QCD matter at RHIC and LHC energies. Insights from viscous hydrodynamics + hadron cascade hybrid approach

We present recent results from the newly developed hybrid code
VISHNU [1] which couples viscous hydrodynamics for the quark-gluon plasma (QGP) with a hadron cascade model for the late hadronic stage. By describing the hadronic rescattering and freeze-out stage microscopically, we improve on earlier purely hydrodynamic models which required additional adjustable parameters to describe the transport and freeze-out characteristics of the hadron phase. By describing the QGP phase as a viscous rather than ideal fluid (as done in previous macroscopic + macroscopic hybrid codes), we account for the non-zero viscosity of the quark-gluon plasma which we can now determine empirically, without contamination from an incomplete treatment of the late hadronic dynamics, by comparing VISHNU results with experimental elliptic flow data.

Using the Monte-Carlo-Glauber or Monte-Carlo-KLN models to
generate event by event fluctuating initial entropy density profiles and averaging these profiles either in the reaction-plane (i.e. directly) or in the participant-plane (i.e. after recentering and rotating each event so that the main axes of its entropy density align), we generate smooth average initial conditions for viscous hydrodynamics which account in different ways for the event by event fluctuations in shape and orientation of the initial state of the collision fireball [2]. We find that the eccentricity scaled elliptic flow v_2/ϵ is a universal function of charged multiplicity per unit overlap area $(1/S)(dN_{ch}/dy)$ that depends only on the QGP viscosity but not on the initialization models [3]. Comparing these universal curves with experimental measurements we find that the specific QGP viscosity $(\eta/s)_{QGP}$ is constrained to fall in the range $1 < 4\pi(\eta/s)_{QGP} < 2.5$ where the width of this range is entirely dominated by model uncertainties for the initial eccentricities [3]. Compared to analysis based on pure viscous hydrodynamics this reduces the previously quoted robust upper limit for $(\eta/s)_{QGP}$ by a factor 2.5. The same $(\eta/s)_{QGP}$ values extracted in [3] from the centrality dependence of the p_T-integrated elliptic flow of all charged hadrons also provide, for the first time, a consistently good simultaneous description of the p_T spectra and differential elliptic flow $v_2(p_T)$ for charged hadrons as well as identified pions and protons over the entire range of collision centralities in 200 A GeV Au+Au collisions [4].

[1] H. Song, S. Bass and U. Heinz, Phys. Rev. C, in press [arXiv:1012.0555].

[2] T. Hirano and Y. Nara, Phys. Rev. C79, 064904,(2009).

[3] H. Song, S. Bass, U. Heinz, T. Hirano and C. Shen, arXiv:1011.2783 [nucl-th].

[4] H. Song, S. Bass, U. Heinz, T. Hirano and C. Shen, arXiv:1101.4638 [nucl-th].

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