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## Quark-gluon plasma shear viscosity at RHIC and the LHC: results from the hybrid model VISHNU

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Viscous hydrodynamic calculations have shown that the quark-gluon plasma (QGP) shear viscosity can be extracted from elliptic and triangular flow data [1]. However, strong non-equilibrium effects, both in the chemical composition and the kinetic evolution, during the hadronic stage influence the development and distribution of flow anisotropy and must be correctly accounted for when extracting the QGP viscosity. For an improved description of the hadronic evolution, we developed the hybrid model VISHNU which couples viscous hydrodynamic expansion of a QGP fluid to a microscopic description of hadronic rescattering and chemical and thermal freeze-out using the UrQMD cascade [2]. In this talk, we will summarize a number of key results obtained with VISHNU:

- a) We present a robust method for extracting the QGP viscosity from the collision centrality dependence of the eccentricity-scaled charged hadron elliptic flow [3].
- b) We extract the QGP shear viscosity at RHIC energies from elliptic flow data, giving quantitative estimates for initial pre-equilibrium flow and from model ambiguities of the initial fireball eccentricity. We discuss the prospects for reducing the main uncertainties from initial conditions through a combined analysis of elliptic, triangular and higher-order harmonic flow coefficients using event-by-event VISHNU simulations.
- c) We show that, with the QGP viscosity extracted in [3], VISHNU yields an excellent description of all soft-hadron data from Au+Au collisions at top RHIC energy [4].
- d) Extrapolating to Pb+Pb collisions at the LHC, and comparing with recent experimental results from the ALICE Collaboration, we show that the LHC data are again well described by VISHNU, with approximately the same constant QGP viscosity as at RHIC energies [5], including the proton elliptic flow in the most central collisions which cannot be correctly reproduced in a purely hydrodynamic approach [6].
- e) Using an improved implementation of baryon-antibaryon annihilation in UrQMD, VISHNU is shown to resolve the “proton puzzle” at the LHC [7].

### References

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