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QGP shear viscosity from combined analysis of elliptic and triangular flow

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The Quark-Gluon Plasma (QGP) created in heavy-ion collisions is well described by viscous hydrodynamic simulations. A key QGP transport coefficient, its specific shear viscosity η/s , can be extracted by comparing such simulations with experimental data. Previous extractions gave $(\eta/s)_{\text{QGP}} \sim (1-2.5)/(4\pi)$ where the $\sim 100\%$ uncertainty arises mainly from ambiguities in the initial fireball shape and density profile. To obtain $(\eta/s)_{\text{QGP}}$ with better precision, the ambiguities in the initial conditions must be addressed.

Published extractions of the specific shear viscosity have relied on elliptic flow measurements and the fact that η/s suppresses elliptic flow. It was recently realized that higher order harmonic flows are suppressed even more strongly with increasing η/s , and that the recently measured triangular flow allows to simultaneously constrain η/s and the initial conditions: viable initial conditions should describe the elliptic and triangular flows v_2 and v_3 simultaneously with the same η/s . We have performed such a simultaneous analysis of v_2 and v_3 [1]. We show that the normalized elliptic and triangular flow coefficients v_2/ecc_2 and v_3/ecc_3 (where ecc_n are the n -th order eccentricities of the initial state) can be obtained with 10-15% accuracy using single-shot hydrodynamical simulations where the initial conditions are averaged before hydrodynamical evolution, instead of the more realistic but costly event-by-event hydrodynamical approach where averaging is done only after separate evolution of each fluctuating initial condition.

For elliptic flow we find that, within 10-15%, $v_2/ecc_2 = v_2^2/ecc_2^2 = v_2^4/ecc_2^4$ where the expression on the left is obtained from single-shot hydrodynamics while the cumulant expressions on the right are extracted from event-by-event hydrodynamics. For triangular flow we find, at the same level of precision, that $v_3/ecc_3 = v_3^2/ecc_3^2 \neq v_3^4/ecc_3^4$. The ALICE data for charged hadron elliptic and triangular flow from Pb-Pb collisions at the LHC [2] are shown to obey these approximate (in-)equalities. Our hydrodynamic analysis [1] shows that the ALICE v_2 and v_3 data [2] can be explained simultaneously, at all collision centralities, if $(\eta/s)_{\text{QGP}} \approx 1/(4\pi)$. This requires MC-Glauber initial conditions which have smaller ecc_2 than CGC-motivated MC-KLN initial conditions. For MC-KLN initial conditions the v_2 data require larger $(\eta/s)_{\text{QGP}} \sim (2-2.5)/(4\pi)$ which, however, then underpredicts the measured triangular flow by 35-40%. We conclude that the large v_3 measured at the LHC requires either almost minimal QGP shear viscosity $(\eta/s)_{\text{QGP}} \approx 1/(4\pi)$, or a presently unknown mechanism for increasing the triangularity fluctuations in the initial state by $\sim 50\%$.

[1] Zhi Qiu, Chun Shen, and Ulrich Heinz, "Hydrodynamic elliptic and triangular flow in Pb-Pb collisions at $\sqrt{s}=2.76$ A TeV," Phys. Lett. B707, 151-155 (2012).

[2] K. Aamodt et al. (ALICE Coll.), "Higher harmonic anisotropic flow of charged particles in Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV," Phys. Rev. Lett. 107, 032301 (2011).

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