The specific shear viscosity of a hot hadron gas

R.J. Fries and Zhidong Yang

More than a decade ago data from experiments at the Relativistic Heavy Ion Collider (RHIC) first seemed to indicate that quark gluon plasma (QGP) at temperatures close to the crossover to a hadron gas behaves like a strongly coupled liquid with a specific shear viscosity η/s close to the conjectured lower quantum bound of $1/4\pi$ [1]. In the years since, rapid developments in viscous relativistic fluid dynamics have helped us quantify η/s in QGP close to the crossover temperature. However, modern estimates rely on hadronic transport models to describe the hadronic phase of nuclear collisions. This leads to a puzzle. Calculations of η/s from various hadronic transport models offer to a wide range of differing predictions. Some popular transport models predict η/s to be almost 10 times the value extracted for QGP around the crossover temperature. No sharp features in η/s as a function of temperature are expected at the crossover.

To improve this situation we attempt an extraction of the hadronic specific shear viscosity directly from data. We use the fact that shear viscosity is not only changing the time evolution of the nuclear collision, but that the presence of shear stress distorts thermal particle distributions away from their equilibrium form, $f \rightarrow f + \delta f$. This can be detected in final freeze-out spectra. The shear stress itself can be expressed through derivatives of the flow field and the specific shear viscosity in the Navier Stokes approximation [2,3].

To this end we have developed a blastwave model including viscous corrections in the Navier Stokes approximation. The blastwave parameterizes the final flow field of the expanding hadron gas. The temperature at freeze out as well as the flow field and η/s appear as fit parameters [2,3]. We have used a Bayesian analysis method to extract the freeze out parameters for various centralities in Au+Au collisions

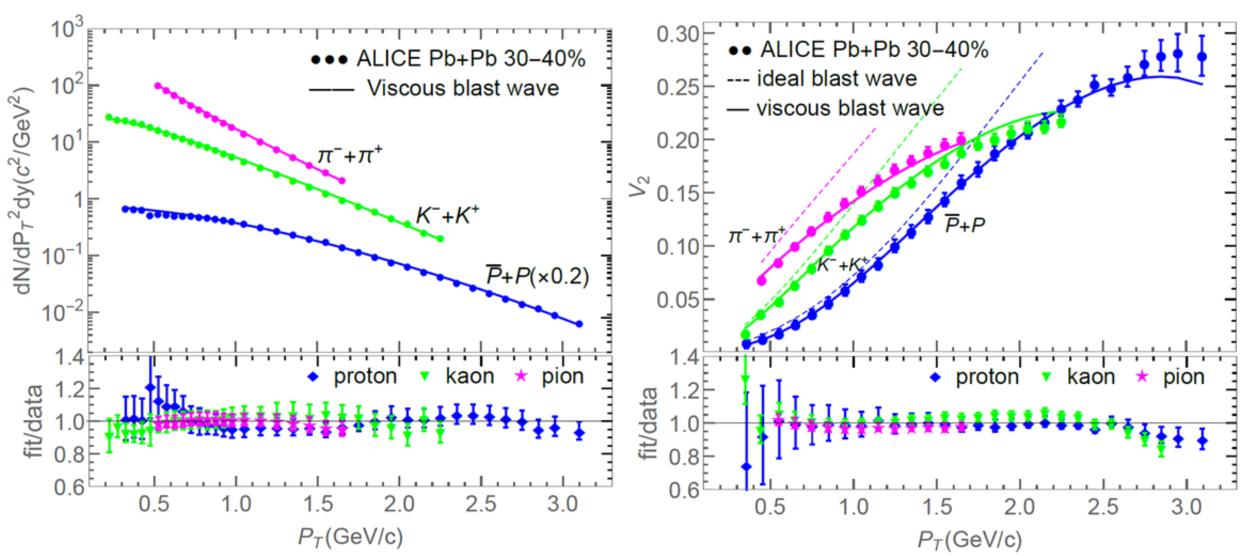

FIG. 1. Results from our blastwave fit for 30-40% centrality data from ALICE [4]. Left: Spectra of pions, kaons and protons. Right: Elliptic flow for the same particles. The ratios of fits over data is shown at the bottom of each plot.

at RHIC and Pb+Pb collisions at the Large Hadron Collider (LHC). We have utilized transverse momentum spectra and elliptic flow data of pions, kaons and protons in our analysis, see Fig. 1 for an example. We also conduct a careful analysis of systematic uncertainties in our extraction of η/s.

We find that the specific shear viscosity drops rather rapidly between 110 and 140 MeV, reaching values close to the quantum bound at the upper temperature reach of our analysis, see Fig. 2. Values extracted from RHIC and LHC are consistent with each other. Note that with changing temperature there is a change in chemical potentials of stable hadrons which needs to be accounted for when interpreting our result.

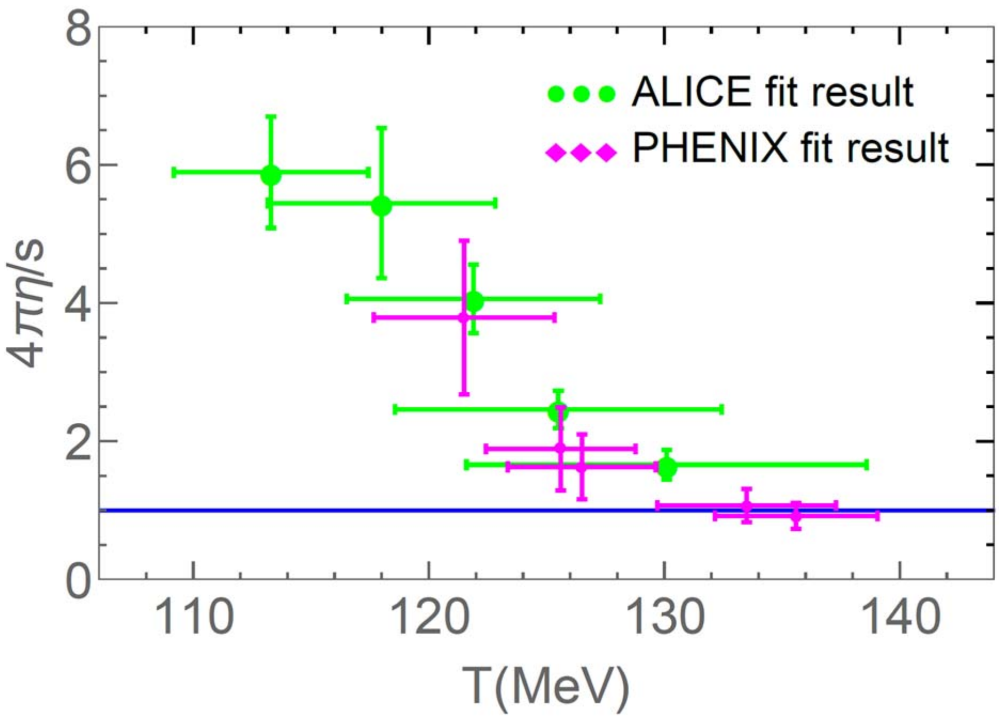

FIG. 2. The specific shear viscosity $\boldsymbol{\eta/s}$ for various temperatures in the hadronic phase extracted from freeze-out data.

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[3] Z. Yang and R.J. Fries, J. Phys. Conf. Ser. **832**, 012056 (2017).
[4] B. Abelev *et al.* [ALICE Collaboration], Phys. Rev. C **93**, 034913 (2016).
[5] B. Abelev *et al.* [ALICE Collaboration] JHEP **06**, 190 (2015).