Plain Language Summary

Temperature and net baryochemical potential dependence of η/s in a hybrid approach

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Heavy-ion collisions at intermediate to high collision energies can be successfully described theoretically by using so called hybrid approaches. For the cool and dilute late stages of the evolution, they use a transport model, which describes the evolution of individual particles which move, scatter and decay. In the hot and dense early stage of the evolution, a so called quark-gluon plasma is formed. No individual particles exist anymore due to the strong interactions of the subnuclear matter. This state can be described by hydrodynamics, the same theory which is also used to describe liquids.

An important observation in experiments is that the speed of outgoing particles in off-central collisions shows a characteristic behaviour, as it is not equally distributed. In an off-central collision, the collision zone is not round but almond shaped. Due to he smaller extent in one direction and the collective behaviour of the liquid, as opposed to single particles, this means that there is a different pressure in the different directions of the collision zone. This in turn results into a a different expansion speed of the medium and also into a different speed of the emitted particles, depending on the direction of their movement. This different speed is referred to as flow.

How much the speed of the emitted particles is modified by the shape of the collision zone depends on a property of the quark-gluon plasma: its shear viscosity, which is the property of a medium to reduce gradients of speed. It is currently not possible to completely determine the shear viscosity from first principles, but multiple predictions exist, which are commonly used as an input to hybrid approaches. However, most of them assume a constant or temperature dependent shear viscosity, whereas it can be in general also dependent on the net baryochemical potential.

Using the hybrid approach SMASH-vHLLE-hybrid, we insert a temperature and net-baryochemical potential dependent shear viscosity into the hydrodynamic model. As hydrodynamics calculates the time evolution in terms of the energy-density and net-baryon density, we parameterise the shear viscosity in these quantities as well. The parameters are chosen in such a way as to match theoretical predictions. We compare different dependencies on the net-baryon density as well as to other common choices for the shear viscosity. The aim is to get a qualitative understanding of the importance of the density dependence. In order to achieve this, we performed extensive simulations of thousand of collision events using high performance computing (HPC) tools in order to get statistics comparable to collider events.

The main results of this paper include the small impact of the net-baryon density dependence on the observed flow. However, this does not mean that in general the net baryochemical potential does not matter, as it contributes to the energy density. This becomes clear when changing the point at which the description is switched between hydrodynamics and transport.

Here it could be shown that the parameterisztion in the energy density is the only one which preserves flow for different transitions. As the flow strongly depends on the shear viscosity, this means that the parameterization in the energy density approximates the shear viscosity in the hadronic description, which is currently hard to extract for collision setups.