The energy dependence of directed and elliptic flow

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Abstract

The energy excitation functions of $v_1$ and $v_2$ from $\sqrt{s} = 90$ MeV to $\sqrt{s} = 200$ GeV are explored within the UrQMD transport approach. It is discussed in the context of the available data. It is found that, in the energy regime below $\sqrt{s} = 40$ GeV, the inclusion of nuclear potentials is necessary to describe the data. Above 40 GeV beam energy, the UrQMD model starts to underestimate the elliptic flow. Around the same energy the slope of the rapidity spectra of the proton directed flow develops negative values. This effect is known as the third flow component ("antiflow") and cannot be reproduced by the transport model. These differences can possibly be explained by assuming a phase transition from hadron gas to quark gluon plasma at about 40 GeV. This poster is based on the following publications [1, 2, 3].

The UrQMD model

For our investigation, the Ultra-relativistic Quantum Molecular Dynamics model (UrQMD v2.2) [4, 5] is applied to heavy ion reactions from different energy regimes. It simulates multiple interactions of in-going and newly produced particles, the excitation and fragmentation of colour strings and the formation and decay of hadronic resonances. A phase transition to a quark-gluon state is not incorporated explicitly into the model dynamics. The UrQMD transport model is successful in describing the yields and the $p_T$ spectra of different particles in $p+p$ and $AA$ collisions [6].

Time evolution

Let us now explore the time evolution of the pressure gradients in connection with the elliptic flow development. The transverse pressure gradients have been calculated for the first 10 fm at $E_{lab} = 40$ GeV (see Figure 1(top)).

Directed flow

To characterize the amount and the direction of the directed flow of protons over the energy range from $2 - 100$ GeV one can extract the slope around midrapidity from the normalized rapidity distributions usually referred to as the $F$ parameter [7].

In Figure 2 one observes that at lower energies the inclusion of a nuclear potential is needed to reproduce the data. The fraction $v_2$ starts at zero for low energies and then rises fast to almost 100% at high energies. Note that this fraction reaches 90% already at 40 GeV beam energy, similar to the energy regime where a phase transition is expected. As shown in Figure 3, the energy density of the formed hadrons is much smaller than the total volume, therefore the effective pressure of the formed hadrons alone in the model seems to be too small to generate enough $v_2$. Thus, this finding supports the interpretation of the need for initial pressure from "pre-QGP" matter already at low SPS energies.

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References