Energy dependence of elliptic flow from heavy-ion collision models

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Introduction

Elliptic flow (v_2) measured in heavy-ion collisions are believed to arise because of the pressure gradient developed when two nuclei collides at non-zero impact parameters followed by subsequent interactions among the constituents. Measurements in the experiments at the Relativistic Heavy Ion Collider (RHIC) have revealed a large value of v_2 [1] for most of the produced hadrons. The transverse momentum (p_T) dependence has revealed a novel mechanism of hadron production and evidence for contributions from partonic phase. RHIC has undertaken a low energy beam scan program to identify the turn-off beam energy where NCQ scaling/partonic contribution disappears. Further it has been shown that the pseudorapidity (η) dependence of v_2 for charged hadrons show a longitudinal scaling as observed for the multiplicity distributions in these collisions [2, 3].

The anisotropic elliptic flow parameter is defined as the 2$^{\rm nd}$ Fourier coefficient v_2 of the particle distributions in emission azimuthal angle (ϕ) with respect to the reaction plane angle (Ψ), and can be written as

$$\frac{dN}{d\phi} \propto 1 + 2v_2 \cos(2(\phi - \Psi)). \qquad (1)$$

For a given rapidity window the second coefficient is

$$v_2 = \langle \cos(2(\phi - \Psi)) \rangle = \langle \frac{p_x^2 - p_y^2}{p_x^2 + p_y^2} \rangle, \qquad (2)$$

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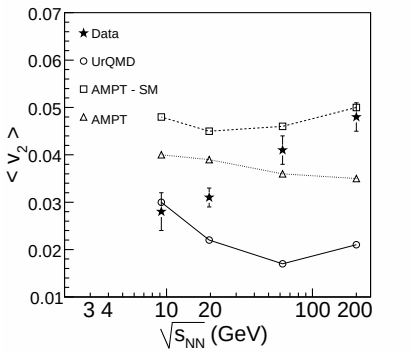

FIG. 1: $\langle v_2 \rangle$ for charged particles at midrapidity for minimum bias collisions at $\sqrt{s_{\rm NN}}$ = 9.2, 19.6, 62.4 and 200 GeV [4, 5] compared to corresponding results from AMPT and UrQMD model calculations.

where p_x and p_y are the x and y component of the particle momenta. In this paper, we compare the experimentally measured v_2 values for charged hadrons to models based on transport approach (UrQMD [6] and AMPT [7]) and that which incorporates the partonic coalescence mechanism (AMPT-SM) for the various beam energies. Detailed comparison of p_T and η dependent v_2 from data and various models will be presented.

Data and Models

Figure 1 shows the $\langle v_2 \rangle$ for charged particles at midrapidity for various $\sqrt{s_{\rm NN}}$ for minimum bias (0-80%) collisions [5]. The results for $\sqrt{s_{\rm NN}}$ = 9.2 GeV are for minimum bias 0-60% collisions [4]. The $\langle v_2 \rangle$ value increases linearly from about 3% at 9.2 GeV to about

5% at 200 GeV. The experimental data are compared to $\langle v_2 \rangle$ calculated from UrQMD, AMPT and AMPT-SM with default settings. The centrality selection is same for data and the models. In contrast to observations from the data, the model $\langle v_2 \rangle$ values either remain constant or decreases slightly with increasing $\sqrt{s_{\rm NN}}$. The $\langle v_2 \rangle$ value from UrQMD at 9.2 GeV and those from AMPT-SM at 200 GeV are in good agreement with the data. The $\langle v_2 \rangle$ values from AMPT lies intermediate to those from UrQMD and AMPT-SM. If we assume the $\langle v_2 \rangle$ values from UrQMD to be the contribution from hadronic phase, then this contribution (v_2^{UrQMD}/v_2^{data}) varies from 100% to about 40% of the measured $\langle v_2 \rangle$ as beam energy increases from 9.2 GeV to 200 GeV. The higher values of $\langle v_2 \rangle$ in data indicates the possible contribution that can come in such transport models due to inclusion of initial/final state scattering effects and/or due to partonic interactions. Comparison with AMPT-SM reflects that at 62.4 and 200 GeV, the $\langle v_2 \rangle$ has contributions from partonic interactions and at lower $\sqrt{s_{\rm NN}}$ this contribution reduces significantly as observed in data and not in the model.

Summary

In summary, we have presented a compilation of the available data for elliptic flow parameter, v_2, of charged particles at RHIC as a function $\sqrt{s_{\rm NN}}$. These results are compared to corresponding model calculations from UrQMD and AMPT (default and string melting versions). The $\langle v_2 \rangle$ values at midrapidity increases with increase in $\sqrt{s_{\rm NN}}$. The AMPT-SM model agrees quite well with the $\langle v_2 \rangle$ data at 200 GeV and gives higher values of $\langle v_2 \rangle$ compared to data for the other beam energies studied. The results from UrQMD matches with the $\langle v_2 \rangle$ data at 9.2 GeV and gives lower values of $\langle v_2 \rangle$ compared to data for the other beam energies studied. Comparison with AMPT shows the growing importance of initial and final state scattering to $\langle v_2 \rangle$ with increase in $\sqrt{s_{\rm NN}}$. Considering the $\langle v_2 \rangle$ values from UrQMD to be the contribution from hadronic matter, the higher values from the AMPT-SM model reflects additional contribution due to partonic interactions. The difference between UrQMD and data $\langle v_2 \rangle$ values at midrapidity is about 60% at 200 GeV. This together with agreement of the experimental measurements with AMPT-SM results at 200 GeV clearly indicates substantial contribution of the $\langle v_2 \rangle$ measured at RHIC from partonic contributions. Whereas the agreement of measured $\langle v_2 \rangle$ values with those from UrQMD at midrapidity for 9.2 GeV suggests that the experimental results can be understood within the frame work of a hadronic model.

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