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# Elliptic flow and fluctuation in Au+Au collisions at the STAR-BES energies in the AMPT model.

We study the elliptic flow parameter ($v_2$) and its event-by-event (e-by-e) fluctuation for the charged hadrons produced in $^{197}$Au+$^{197}$Au collisions at the nucleon-nucleon center of momentum energy $\sqrt{s_{\rm NN}} = 7.7$, 11.5, 19.6, 27.0, 39.0 and 62.4 GeV of the STAR Beam Energy Scan (BES) program. We use A Multiphase Transport (AMPT) model in its string melting (SM) configuration, apply the same kinematic cuts to the simulation as in the experiment, and compare the experiment with the simulation wherever the experimental results are available. The objective is to see to what extent the experiment can be reproduced by the AMPT simulation, and set thereby a reference baseline for the same. We adopt different methods to determine the $v_2$-parameter, like the participant-plane method $v_2\{P\}$, the event-plane method $v_2\{EP\}$, the two-particle cumulant $v_2\{2\}$ and four-particle cumulant $v_2\{4\}$ methods. Dependence of the $v_2$ parameter on collision centrality, transverse momentum ($p_T$), pseudorapidity ($\eta$) and $\sqrt{s_{\rm NN}}$ are examined. The auto-correlation effect has been taken care of while determining the centrality of a collision. The issue of non-flow effects arising out of inter-particle correlations is also addressed in the centrality dependence of $v_2\{2\}$ and the same of its e-by-e fluctuation. In the experiment the centrality dependence of the $v_2\{2\}$-parameter based upon two-particle cumulants, is well reproduced by the AMPT-SM at each $\sqrt{s_{\rm NN}}$ considered. In the framework of AMPT-SM, the contribution of non-flow effects is found to be quite small in this regard. However, AMPT-SM can predict the $p_T$-dependence of $v_2$ only for very soft hadrons. Beyond $p_T \sim 1$ GeV/c the simulation grossly under predicts the experiment. The simulation also significantly under predicts the $\eta$-distribution of $v_2$ obtained from the event-plane method. We see that the experimental $v_2$-values marginally increase with increasing $\sqrt{s_{\rm NN}}$, which again is not reflected in the simulation. We also study the centrality dependence of the e-by-e fluctuation of $v_2$, that of the eccentricity parameter $\varepsilon_2$, and the $\sqrt{s_{\rm NN}}$-dependence of the said fluctuations and their relative fluctuations. Fluctuation in $v_2$ almost linearly rises with decreasing centrality with a very small gradient. The simulations in this regard reasonably match with the experiment. Non-flow effects do not influence the results significantly. The $\varepsilon_2$-parameter, obtained from the Monte-Carlo Glauber model and using different methods, almost linearly increase with decreasing centrality. It is interesting to note that the $v_2$-fluctuation linearly scales with the $\varepsilon_2$-fluctuation. Both the $v_2$-fluctuation and its relative fluctuation non-monotonically depend upon $\sqrt{s_{NN}}$ in the experiment as well as in the simulation. A flattening around $\sqrt{s_{\rm NN}} = 19.6$ and 27.0 GeV indicates some kind of suppression in the $v_2$-fluctuation, which is another interesting observation. We finally conclude that, while the AMPT-SM can satisfactorily reproduce some of the STAR-BES results on $v_2$ and its fluctuation, it under estimates the experiment on some other counts. The model therefore requires some fine tuning. It however remains an open question whether the suppression observed in the $\sqrt{s_{NN}}$-dependence of the $v_2$-fluctuation can be attributed to some critical phenomenon or not.

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