Collective flow in event-by-event partonic transport plus hydrodynamics hybrid approach

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1 Introduction

Complete evolution of the strongly interacting matter formed in ultrarelativistic heavy-ion collisions is studied within a coupled Boltzmann transport and relativistic viscous hydrodynamics hybrid approach. The initial state includes event-by-event fluctuations of participating nucleons and produced partons with preequilibrium dynamics of partonic matter. The ensuing near-equilibrium evolution of matter is modeled within relativistic viscous hydrodynamics until freeze-out. We probe the role of parton dynamics in generating and maintaining the spatial anisotropy in the preequilibrium phase.

2 The Model

The preequilibrium phase is treated within AMPT model [1]. For the subsequent near-equilibrium evolution, (2+1)D viscous hydro code VISH2+1 [2] is used. At the switchover time $\tau_{\rm sw}$ from AMPT to VISH2+1, the energy density in the local rest frame is estimated from transverse positions of partons as [3]:

$$\epsilon(x,y) = \frac{N}{2\pi\sigma^2\tau_{\rm sw}} \sum_i E_i' \exp\left[-\frac{(x-x_i)^2+(y-y_i)^2}{2\sigma^2}\right],$$

where E_i' is the energy in the local rest frame, of the ith parton represented by a 2D Gaussian distribution of width $\sigma = 0.8$ fm. Hadrons are obtained by Cooper-Frye freezeout at $T_{\rm dec} = 120$ MeV.

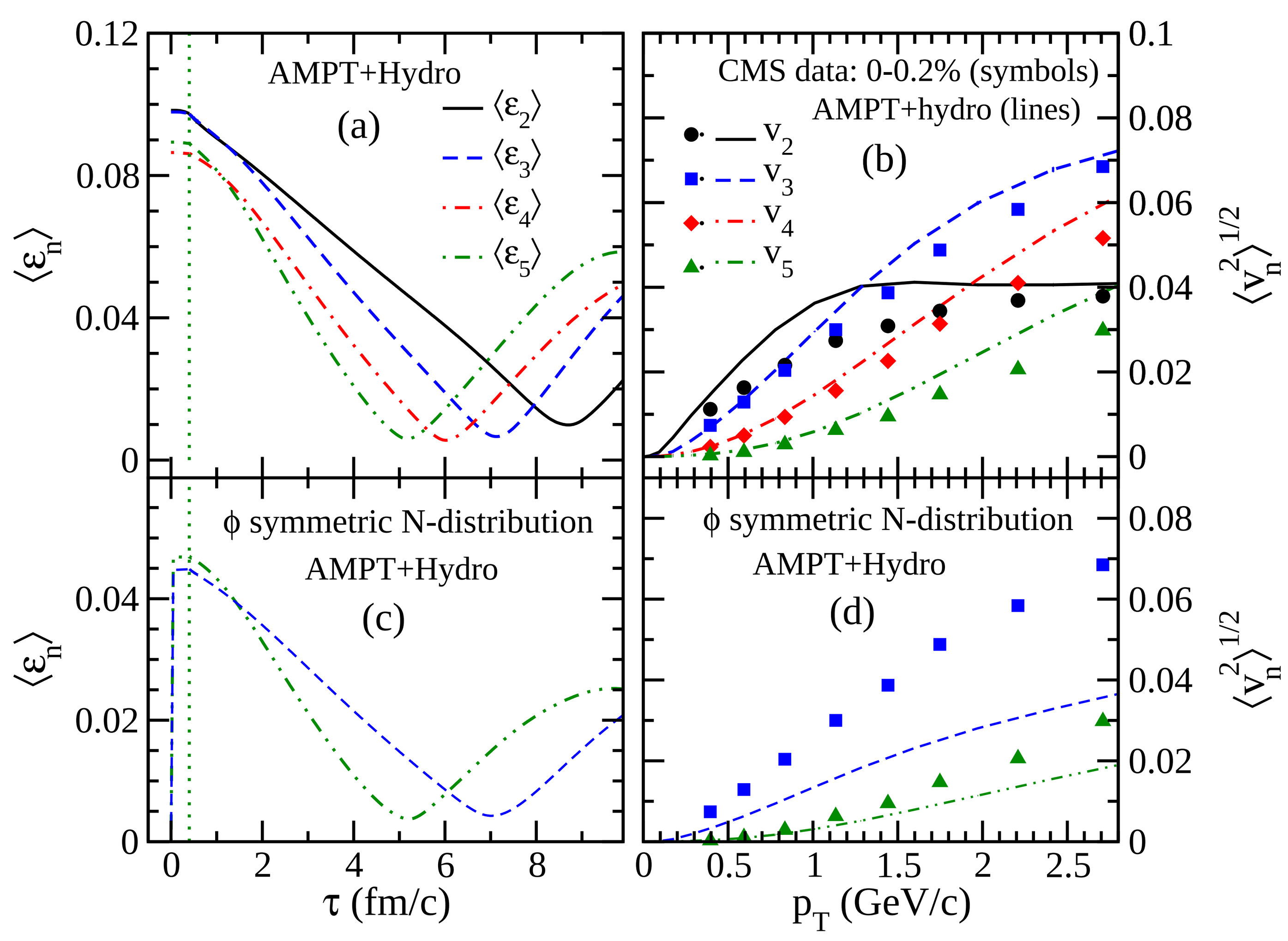
In the nonequilibrium phase-space distribution of particles $f = f_0 + \delta f$, we use the viscous correction as in Grad's 14-moment approximation [4] or Chapman-Enskog-like expansion [5]:

$$\delta f_{Grad} = \frac{f_0\tilde{f}_0}{2(\epsilon+P)T^2}\, p^\alpha p^\beta \pi_{\alpha\beta}, \qquad \delta f_{CE} = \frac{5 f_0\tilde{f}_0}{8PT(u\cdot p)}\, p^\alpha p^\beta \pi_{\alpha\beta},$$

where $\tilde{f}_0 \equiv 1 - r f_0$, with $r = 1, -1, 0$ for Fermi, Bose, and Boltzmann gases. Resonances of $m \leq 2$ GeV are used and results presented are after their decays.

3 Results and discussions

The results are for Pb+Pb collisions at $\sqrt{s} = 2.76$ TeV with a shear viscosity to entropy density ratio of $\eta/s = 0.12$ in VISH2+1 model.

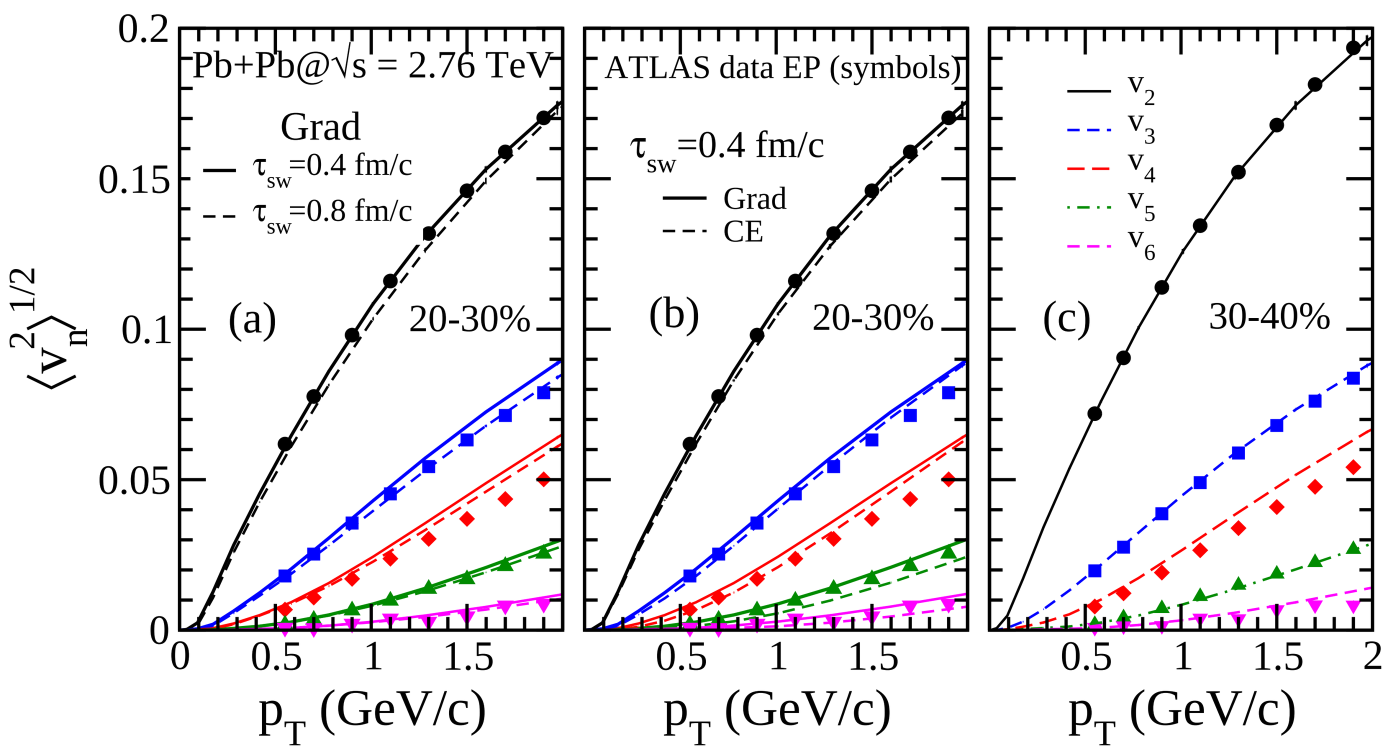


Time evolution of eccentricity $\langle\varepsilon_n\rangle$ and p_T dependence of flow coefficients, $v_n(p_T) = \langle\cos[n(\phi-\Psi_n)]\rangle$, of charged hadrons for head-on ($b=0$) collisions: (a)-(b) in the usual AMPT+Hydro and (c)-(d) with azimuthally symmetric nucleon distribution.

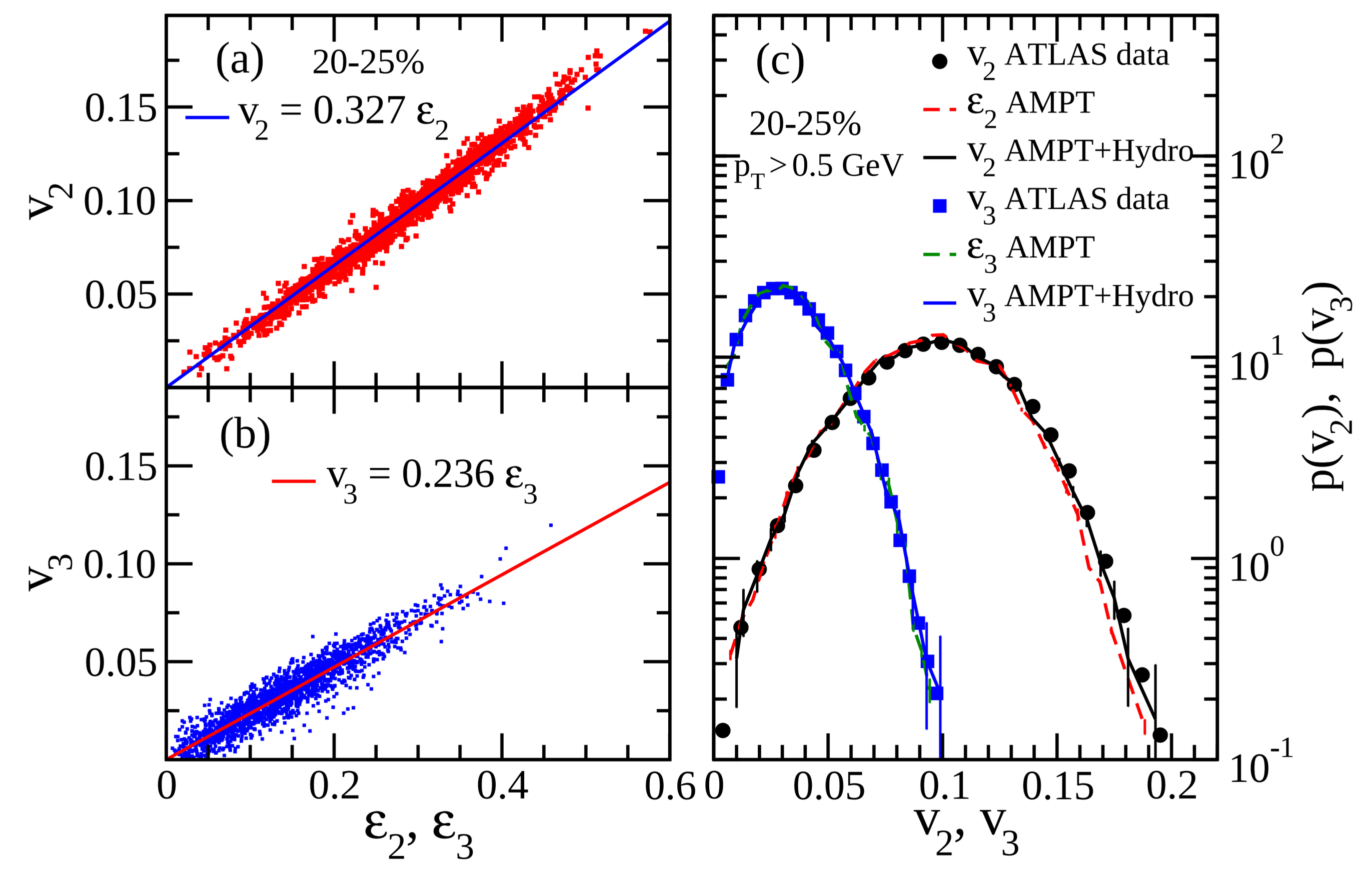
(b) In ultracentral collisions, $v_n(p_T)$ from AMPT+Hydro has the right trend as the CMS data; however, the model tends to overpredict v_2.

(c) Rapid generation of $\langle\varepsilon_3\rangle$ and $\langle\varepsilon_5\rangle$ occurs from parton formation.

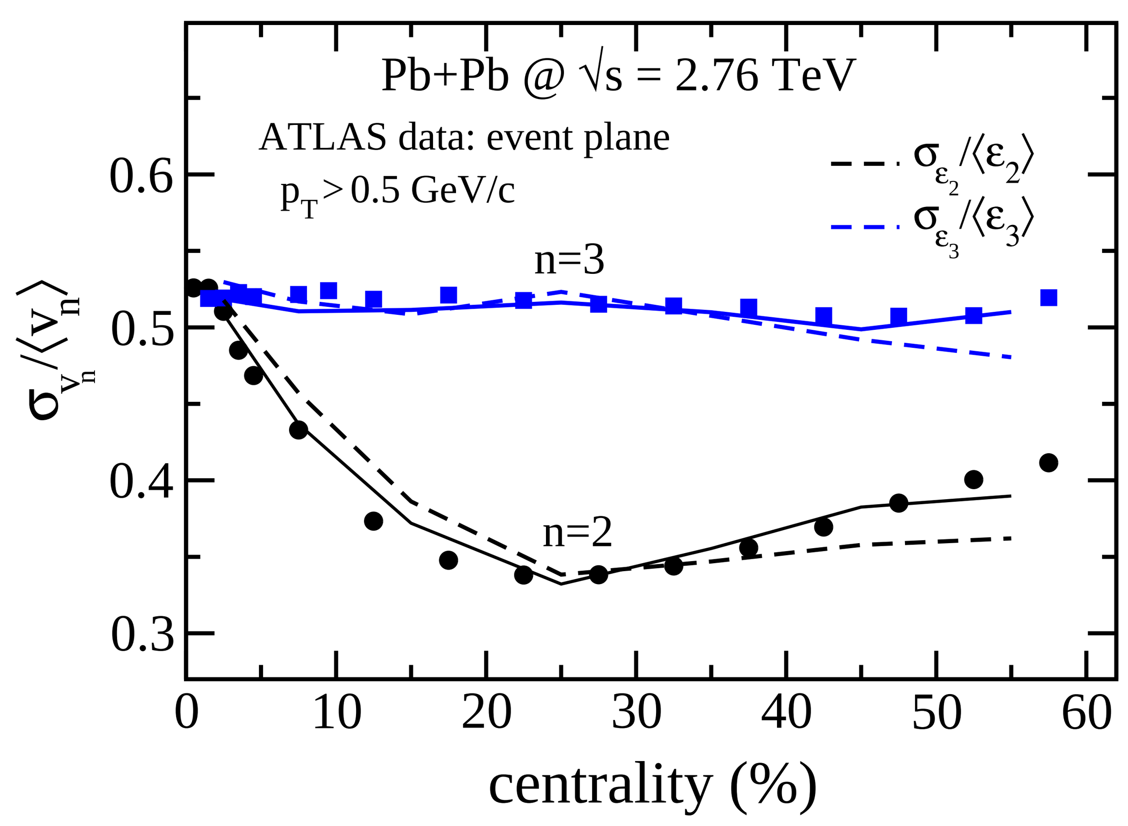
(d) This translates to $\sim 50\%$ of the total v_3 and v_5.



(a) varying switchover time within $[0.4, 0.8]$ fm/c does not affect v_n much.
(b) viscous corrections due to Grad and Chapman-Enskog give similar v_n.
(c) $\langle v_n^2(p_T)\rangle^{1/2}$ from AMPT+Hydro shows good overall agreement with ATLAS event-plane data for $30-40\%$ centrality. Good agreement (not shown) is also found for $10-20\%$, $20-30\%$, $40-50\%$, with a fixed $\eta/s = 0.12$ [3].



(a)-(b) Scatter plots for v_n versus ε_n ($n = 2, 3$) at $20-25\%$ centrality in AMPT+Hydro. The correlations can be described by $\langle v_n\rangle = k_n\varepsilon_n$.
(c) Probability density distribution $p(v_n)$ ($n = 2, 3$) from AMPT+Hydro agrees well with ATLAS data at $20-25\%$ centrality. Eccentricity scaled probability distributions $P(\varepsilon_n) \to P(v_n) = P(\varepsilon_n)/k_n$ are also in good agreement; except at large v_2, where enhanced k_2 (see panel (a)) causes $p(v_2)$ to drop faster.



Centrality dependence of relative fluctuations, $\sigma_{\varepsilon_n}/\langle\varepsilon_n\rangle$ and $\sigma_{v_n}/\langle v_n\rangle$, for $n = 2, 3$ in AMPT+Hydro as compared with the ATLAS data.

References

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