Event-by-event correlations of anisotropic flow generation in a hybrid approach

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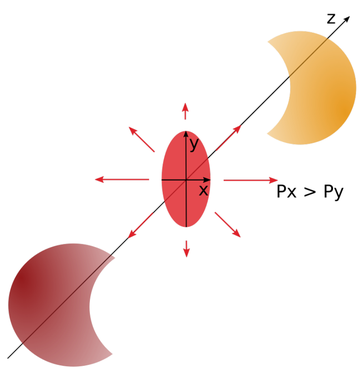
Initial state and anisotropic flow

- Off-central collision: eccentricity of the fireball → anisotropic flow in the final state
- Both the initial state eccentricities as well as the viscosity affect the flow measured in the final state
- In order to determine the transport coefficients, the initial state has to be under control
- Due to the lack of easy-accessible observables, there is significant theoretical uncertainty



SMASH-vHLLE-hybrid

- Open-source, modular, charge conserving hybrid approach for the description of intermediate/ high energy heavy-ion collisions [1,2]
- Freezeout at hypersurface of constant energy density ϵ_{switch}. Use shear viscosity with results independent of this technical parameter [3]
- Particles are sampled according to Cooper-Frye formula and evolved in hadronic transport

SMASH
- Hadronic transport approach
- Initial conditions

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vHLLE
- 3+1D viscous hydrodynamics
- CORNELIUS routine to determine freezeout surface

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smash-hadron-sampler
- Cooper-Frye sampler
- Particlization of fluid elements

+

SMASH
- Hadronic transport approach
- Evolution of the late hadronic rescattering stage

Initial condition models

SMASH IC
- Particles propagate and interact till hypersurface of constant proper time (=passing time)
- Particles are smeared out
- Full 3D space and momentum information

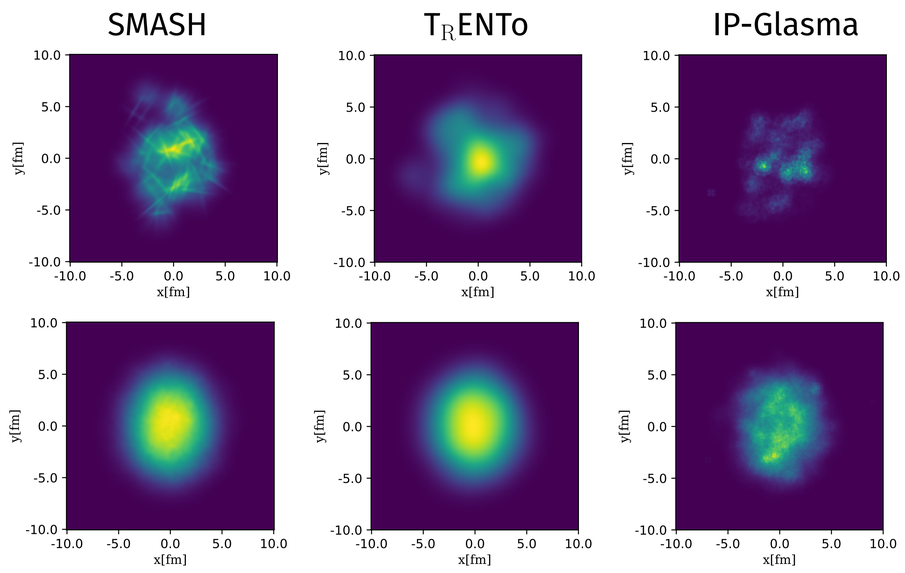
T$_R$ENTo
- Generalized, effective parametric ansatz for reduced thickness function in the transverse plane [4]
- $\left(\frac{T_A^p+T_B^p}{2}\right)^{1/p}$
- Fluctuations, but no momentum space information

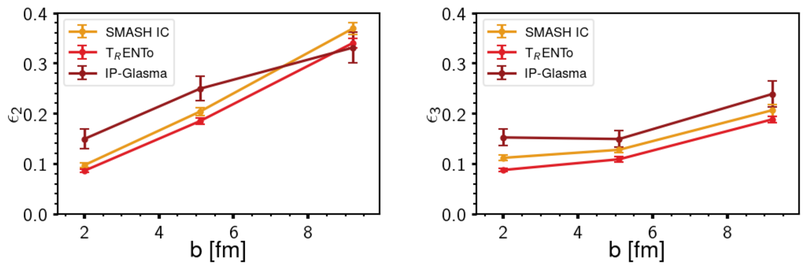
IP-Glasma
- Yang-Mills initial state model within CGC framework with impact parameter dependent saturation [5]
- Describes both fluctuations of nucleon positions and color charges
- Provides radial flow and momentum anisotropy

Averaged properties

Single event transverse energy profile

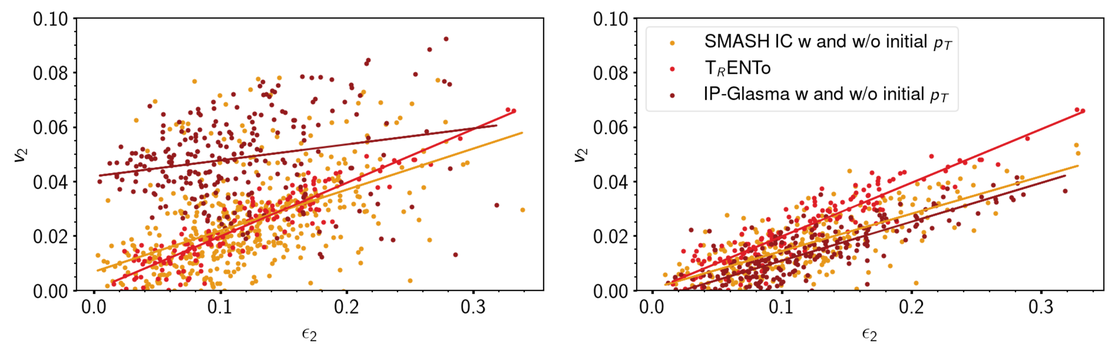
Average transverse energy profile





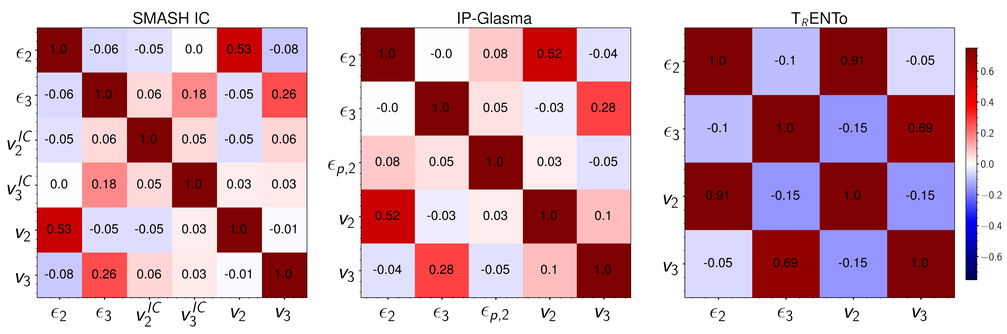
Averaged quantities at $\sqrt{s_{NN}} = 200$ GeV are very similiar → differences only visible on event-by-event basis!

Event-by-event response



Comparison with radial flow (left) and with all radial flow in longitudinal direction (right). Initial condition models with initial transverse momentum information reduce linear correlation between eccentricity and flow due to varying magnitude of radial flow.

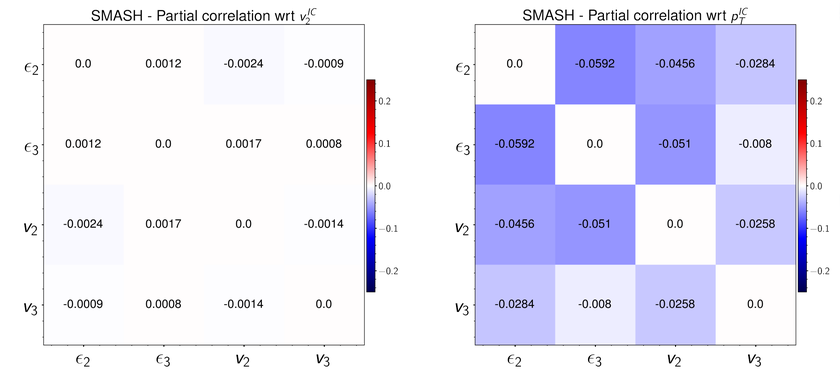
Correlations



For $\sqrt{s_{NN}} = 200$ GeV, 20-30 %, 500 IC events, correlations are only relevant between eccentricities and corresponding final flows. Anti-correlations between ϵ_2 and ϵ_3 for T$_R$ENTo result in anti-correlations between final flow modes. For other models, this effect is negligible.

Effect of radial flow

- Using partial correlation, one can study the effect of a control variable on two other variables.
- With this, one can study the impact of initial flows on ϵ_n-v_n correlations.



- All differences between partial and total correlation are small when calculating with respect to v_2^{IC} → no effect of anisotropic radial flow
- Partial correlation with respect to $\langle p_T \rangle$ is reduced → presence of radial flow reduces correlation between eccentricities and final flow

Conclusions & Outlook

- Radial flow has significant impact on generation of momentum anisotropy. Depending on its magnitude, flow generation is reduced
- Anisotropic radial flow has for different centralities and energies no effect on flow generation
- Future work: Study impact of pre-equilibrium evolution, study systematic differences in ϵ_2/ϵ_3 distribution, $\rho(p_T, v_2)$

References

[1] Anna Schäfer, *et al.* (2022). Eur. J. A 58 (11), 230. [2122.08724]

[2] `https://github.com/smash-transport/smash-vhlle-hybrid`

[3] Niklas Götz, Hannah Elfner (2022). Phys. Rev. C 106, 054904 [2207.05778]

[4] J. Scott Moreland, *et al.* (2015). Phys. Rev. C 92, 011901. [1412.4708]

[5] Björn Schenke. *et al.* (2012). Phys. Rev. Lett. 108, 252301 [1202.6646]