Finding α-clustering in Ultra-relativistic $^{16}O^{16}O$ collisions

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Setup

In this work, we explore possible signatures of the phenomenon of α-clustering in $^{16}O^{16}O$ collisions at both RHIC and LHC energies [1–3].

We model the $^{16}O^{16}O$ initial state with Trento [4] using three different models of the ^{16}O nucleus:

- Smooth Woods-Saxon profile, without constituent quarks
- Smooth Woods-Saxon profile, with constituent quarks
- Nuclear lattice effective field theory profiles containing α-clustering [5]

Hydrodynamic modeling is performed using the iEBE-VISHNU package [6]. Transport coefficients are parameterized as in [7, 8]. Fig. 1 shows initial energy densities alongside maximum Knudsen and inverse Reynolds numbers for shear and bulk viscous stresses, using [9]:

$$\mathrm{Kn}_\pi = \tau_\pi \sqrt{\sigma_{\mu\nu}\sigma^{\mu\nu}},\ \mathrm{Kn}_\Pi = \tau_\Pi\theta,\ \mathrm{Re}_\pi^{-1} = \sqrt{\pi_{\mu\nu}\pi^{\mu\nu}}/P,\ \mathrm{Re}_\Pi^{-1} = |\Pi|/P$$

In general, $^{16}O^{16}O$ collisions yield large Knudsen and inverse Reynolds numbers, implying that the hydrodynamic description in $^{16}O^{16}O$ is pressed to its limits.

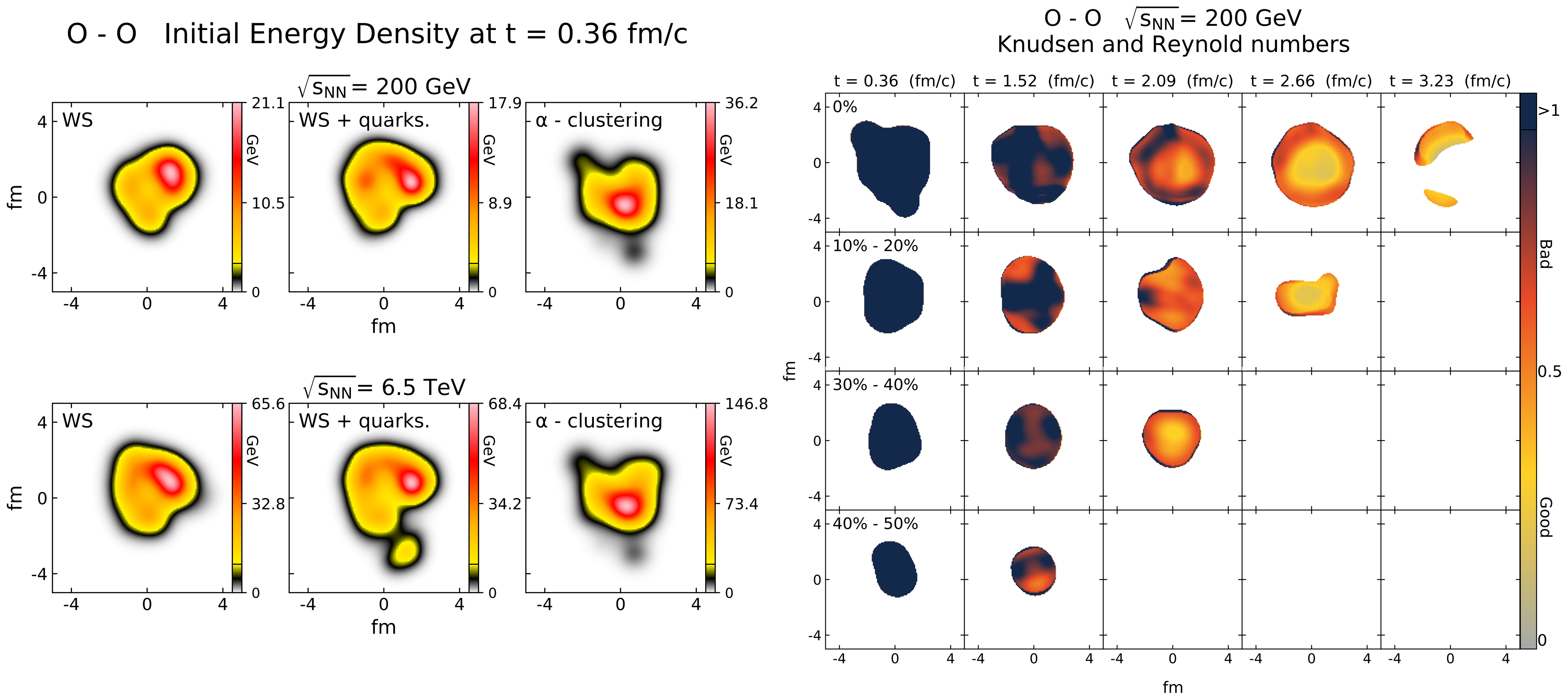

Figure 1: Left: Initial energy densities for three different initial-state models at RHIC (top) and LHC (bottom) energies. The same random seed is used in each panel. **Right**: Centrality class and time dependence of maximum Knudsen or inverse Reynolds number distributions in the transverse plane. The hydrodynamic evolution is clearly pushed to its limits at early times.

Results

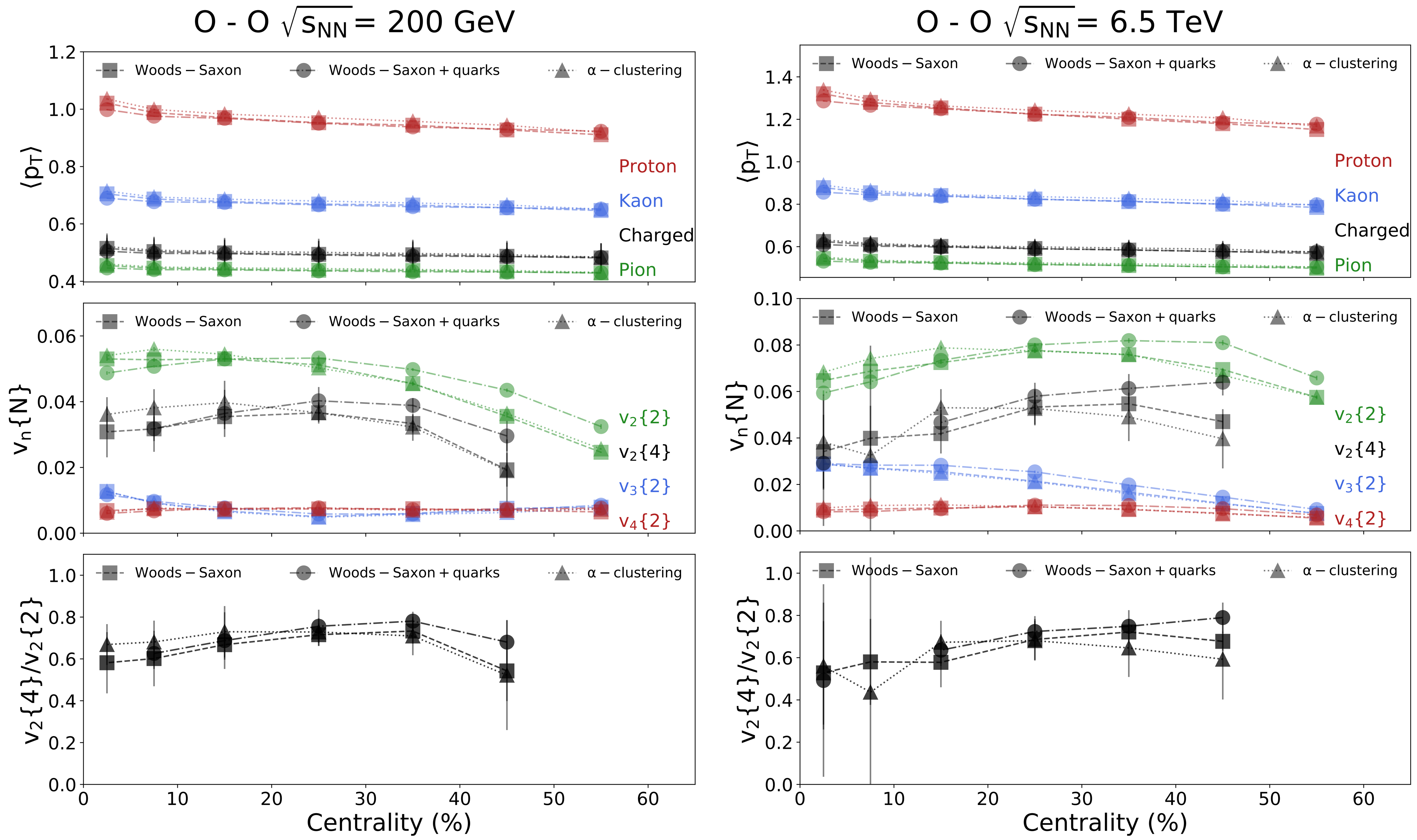

Figure 2: Left: Average transverse momentum $\langle p_T \rangle$, flow coefficients $v_n\{N\}$, and the ratio $v_2\{4\}/v_2\{2\}$, for all three initial-state models at RHIC energies. A total of 10^4 events were generated and all quantities are plotted as functions of centrality. **Right**: Same as the lefthand side, but at LHC energies.

We find that the effects of α-clustering are rather weak in $\langle p_T \rangle$, but detectable in flow observables, particularly in $v_2\{k\}$. The inclusion of subnucleonic degrees of freedom in the initial state leads to an enhancement of v_2 at centralities about $\sim 15\%$, while the effects α-clustering are of a similar order of magnitude and are confined to centralities below $\sim 20\%$. The effects on the ratio $v_2\{4\}/v_2\{2\}$ behave similarly, but the three initial state models considered here appear to be consistent with one another within statistical errors.

Conclusions

α-clustering in $^{16}O^{16}O$ collisions quantitatively affect the centrality dependence of the $v_n\{k\}$ at the same order of magnitude as the inclusion of constituent quarks within individual nucleons. The hydrodynamic modeling of $^{16}O^{16}O$ collisions exhibits large gradients and viscous stresses, as parameterized by the Knudsen and inverse Reynolds numbers. Obtaining a qualitatively clean signature of α-clustering will likely require more sensitive techniques, such as the use of a flow-based principal component analyses [10].

References and Acknowledgement

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