The observation of anisotropic collective flow in the small systems produced by proton-proton and proton-nucleus collisions at the Relativistic Heavy-Ion Collider and the Large Hadron Collider has lead theorists to the radical hypothesis that hydrodynamics can occur without thermal equilibration. Viscous hydrodynamic flow has the effect of smoothing out fluctuations in particle momenta, but conversely particle “jets” have the effect of simultaneously increasing particle number and transverse momentum while inducing fluctuations. We study an observable that indicates the covariance of multiplicity and momentum of particles produced in nuclear collisions to discover if it can distinguish jet versus hydrodynamic dynamics. We use simulated events of proton-proton and nucleus-nucleus collisions to compare the behavior of our observable for collision events with high and low multiplicities.

Motivation and Observable

Expectation: proton-proton collisions display positive correlation with particle number and momentum

\[ \langle p_T^2 \rangle = \langle p_T^2 \rangle - \langle p_T \rangle^2 \]

PYTHIA

- events without jets indicate positive correlation with multiplicity.
- events with jets indicate negative correlation with multiplicity.

\[ \langle p_T \rangle = \langle \sum_i p_{T,i} \rangle \]

Covariance Particle Variance

\[ \langle p_T \rangle = \langle p_T \rangle / \langle N \rangle \]

Out of Equilibrium Correlations

\[ D = D_{\text{eq}} + D_{\text{jet}} (1 - S) \]

Initial value Equilibrium value

Survival Probability \( S \): Indicates the system's level of equilibration.

\[ S = 1 \rightarrow \text{no interaction} \]
\[ S = 0 \rightarrow \text{local equilibrium} \]

Consequential Behaviors

- \( D = 1 \langle N \rangle / \langle N \rangle \) in equilibrium
- \( (N)D \) follows the behaviors of \( S \) where \( (N)D \) travels from the initial condition to the equilibrium condition

Error Estimates: Sub-group method

- 30 groups of 1M events.
- Observables calculated in each group.
- Values are averaged over subgroups.
- Error bars are subgroup standard deviations.

\[ R = \frac{(N(N-1)) - \langle N \rangle^2}{\langle N \rangle^2} \]

Binning and particle sample space effects multiplicity fluctuations.

See poster 311 by Mary Cody.