INT-16-3

Mo, 9/19/16: Origins of fluctuations in heavy ion collisions:
(U. Heinz)

1) Initial state after impact:

colored quantum fields that fluctuate from event to event

- The initial impact deposits energy and/or baryon number at midrapidity that is taken away by color interactions from incoming nucleons that move at beam rapidity.
- The probability for this happening at a given position in the transverse plane depends on the location of color charge at the time of impact. Initially color charge is confined inside nucleons, so stopped energy "measures" the transverse position of nucleons at impact. Also, on a shorter length scale, the transverse position of net color charge inside a nucleon.

$\longrightarrow$ spatial fluctuations of the initially "stopped" energy and net baryon number. $\xrightarrow{\text{hydro}}$ anisotropic flow

- The scattering process of projectile glue with target glue is a process with stochastic outcome in momentum space $\xrightarrow{\text{hydro}}$ fluctuating viscous stresses, and fluctuating initial flow velocities.

$\longrightarrow$ phase-space fluctuations

- Initial-state two particle momentum correlations; anisotropic spatial constraints of overlap region or of color patches within the overlap region $\rightarrow$ anisotropic initial momentum correlations scaled by $Q_s(\vec{x}_\perp)$.

(U. Heinz) Mo, 9/19/2016

Evolution until hydrodynamization:

- anisotropic flow (through the creation of x-p correlations)
- decorrelation of initial-state momentum correlation via interactions? How to model/compute this?

Hydrodynamic stage:

- matching to hydro immediately replaces (by construction)

$$f(x,p) \longrightarrow f_{eq}\left(x, \frac{p\cdot u(x)}{T(x)}\right) + \delta f^{shear}\left(x, \frac{\pi^{\mu\nu}(x) p_\mu p_\nu}{(\varepsilon+P)(x)\, T^2(x)}\right) + \delta f^{bulk} + \delta f^{diffusion}$$

$\longrightarrow$ all pQCD power-law tails are lost and can never be recovered!

- thermal momentum and particle number correlations $\longleftrightarrow$ viscous corrections to these??

- thermal fluctuations are non-negligible if viscous effects are non-negligible
  - importance of viscous effects:
    figure of merit: $Kn = \frac{\eta\,\theta}{s\,T} = \frac{\tau_{scatt}}{\tau_{exp}}$
  - importance of thermal fluctuation (Yan + Grönqvist)
    figure of merit $\frac{\theta^4}{\varepsilon+P} = \frac{\text{Hubble 4-volume}}{\text{enthalpy density}}$

Both depend on the dynamical state of the medium

Particlization of the medium:

- guess momentum distribution from macroscopic information by the amount of information available ($T^{\mu\nu}$, j^{ν} = 14 moments of f, not more!)

  → never guess power law tails (if want to know whether some initial-state pQCD power law tails survive until hadronization, cannot use hydro, must use kinetic theory)

- finite number statistics: sample some underlying continuous phase-space probability distribution with a finite number of hadrons

  → number and momentum fluctuations and 2 particle correlations

  ? → to get 2-particle correlations, should I sample 2-particle distribution? How do I get this from hydro?

- Does UrQMD correctly evolve the total of all fluctuations and correlations in its initial state? How do I test this, given that the initial state is not a continuous distribution, but only a sampling of the multiparticle distribution that embodies them