Fluctuating Hydro and Particleization

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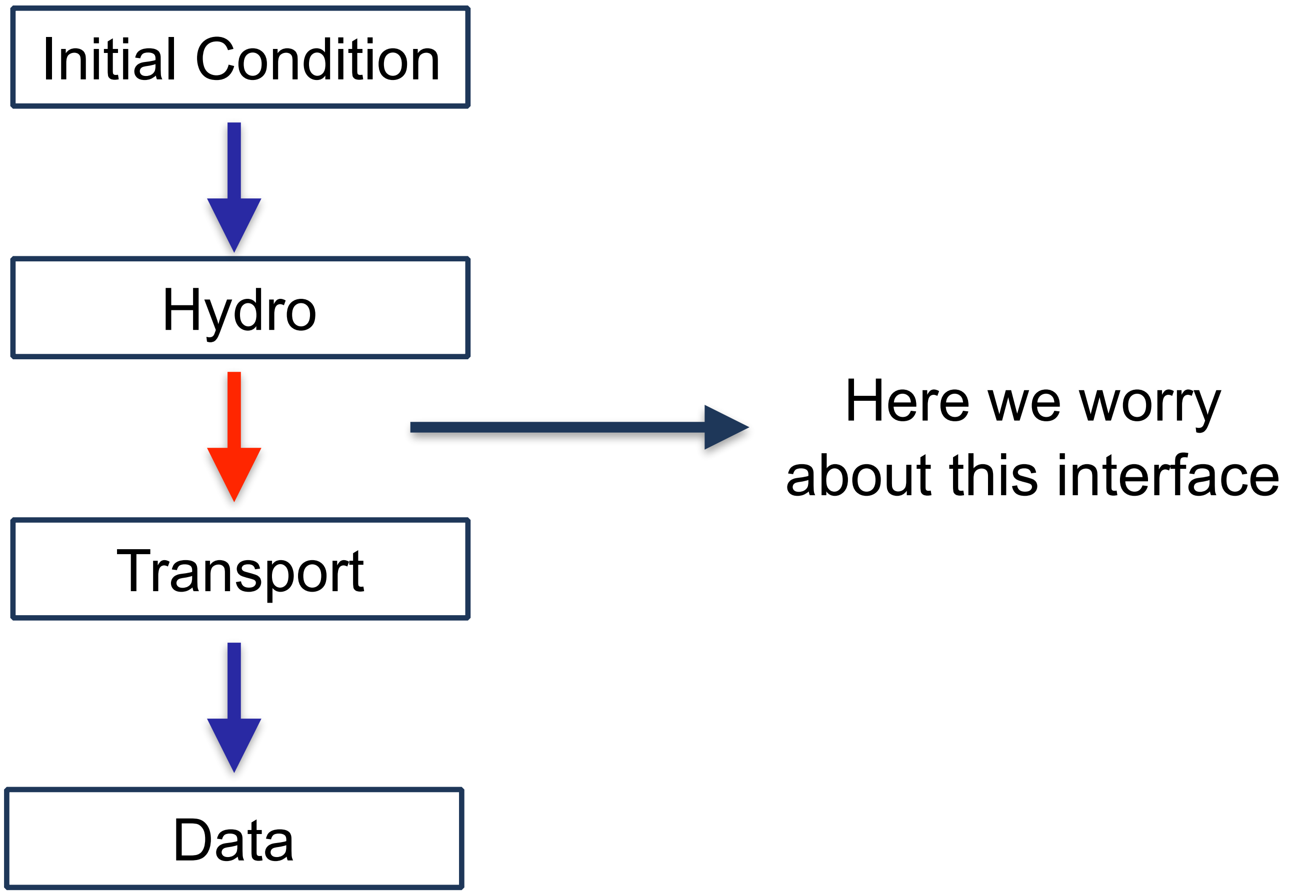
BEST COLLABORATION

BEST plan


Initial Condition
Hydro
Transport
Data
Here we worry
about this interface

Particleization

Typically done by use of the Cooper-Frye equation

$$E\frac{dN}{d^3p} = \int_\sigma f(x,p)p^\mu d\sigma_\mu \quad (1)$$

If all we need is the final state momentum distribution we are done!

However, then we miss:

- Re-scattering, resonance dynamics
- any other (mean field dynamics of the hadronic phase)
- etc…

Thus we need an interface between hydro and transport: Particleization

Particleization

Lets stay in co-ordinate space for the time being

Hyper-surface made out of m cells

B_i = Baryon number in cell "i" (ignore anti-baryon for the moment)

Fluctuating Hydro: Ensemble of hydro state $\{B_1, B_2, \ldots B_m\}$ which carry information of the correlations and fluctuations.

Thus fluctuating hydro provides a probability distribution for the B_i

$$P(B_1, B_2, \ldots, B_m)$$

Particleization

Baryon number conservation: $$\sum_{i=1}^{m} B_i = B_{tot} = const$$

We consider a subset: i= 1,2,…,n<m
And study the various cumulants, for example the (scaled) variance

For simplicity, look at just one cell: $$P_{hydro}(B) \equiv \sum_{B_2,\ldots,B_m} P(B_1, B_2, \ldots, B_m)$$

$$K_1 = \sum_B B\, P_{hydro}(B) = \langle B \rangle$$

$$K_2 = \sum_B B^2\, P_{hydro}(B) - \langle B \rangle^2$$

Fluctuating Hydro provides values for all cumulants!

For transport we need “particles”:

Common practice: Sample a Poisson (multinomial) distribution:

Again for one cell and a given value of B:

$$P(B_{CF}, B) = P_{Poisson}(B_{CF}; B)$$

Folding with the results from hydro we get

$$P(B_{CF}) = \sum_{B} P_{hydro}(B) P_{Poisson}(B_{CF}; B)$$

Cumulants

$$K_{1,CF} = \langle B \rangle = K_{1,hydro}$$
$$K_{2,CF} = K_{2,hydro} + K_{1,hydro}$$

There are extra contribution due to the Freeze out prescription

Same is true if global baryon number is concerned
by using multinomial instead of Poisson

Question:
Are these extra contributions real or spurious

Testparticles

Extra contribution can be suppressed by using test particles:

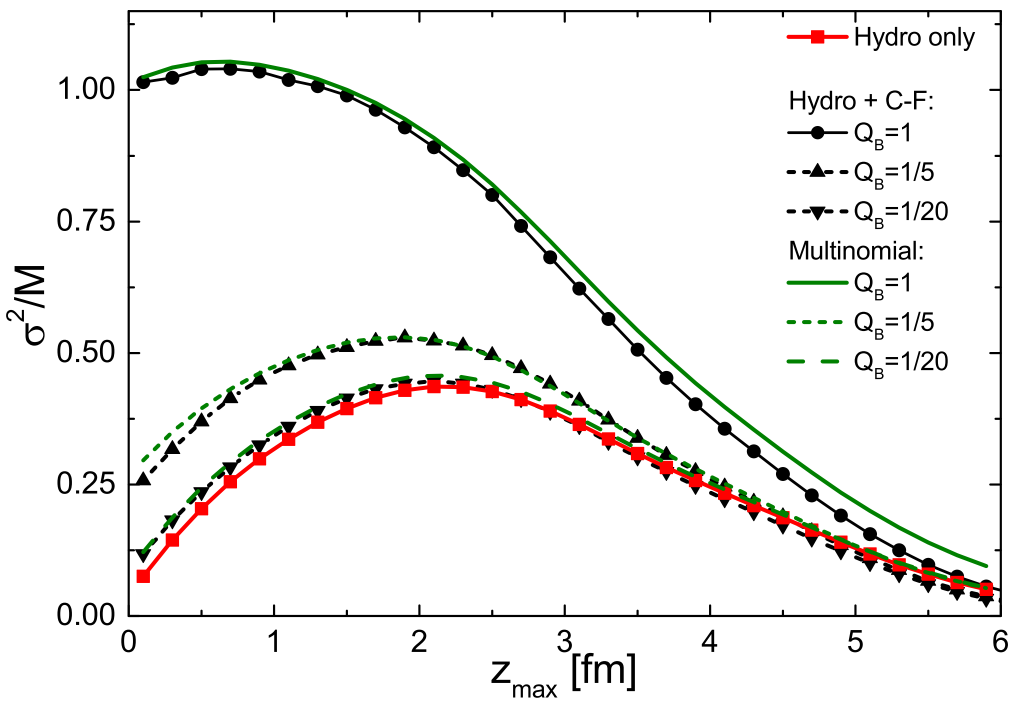
Each real particle is represented by N_T test particles:
Define $Q_B=1/N_T$ which is the baryon number of e.g. a test-proton

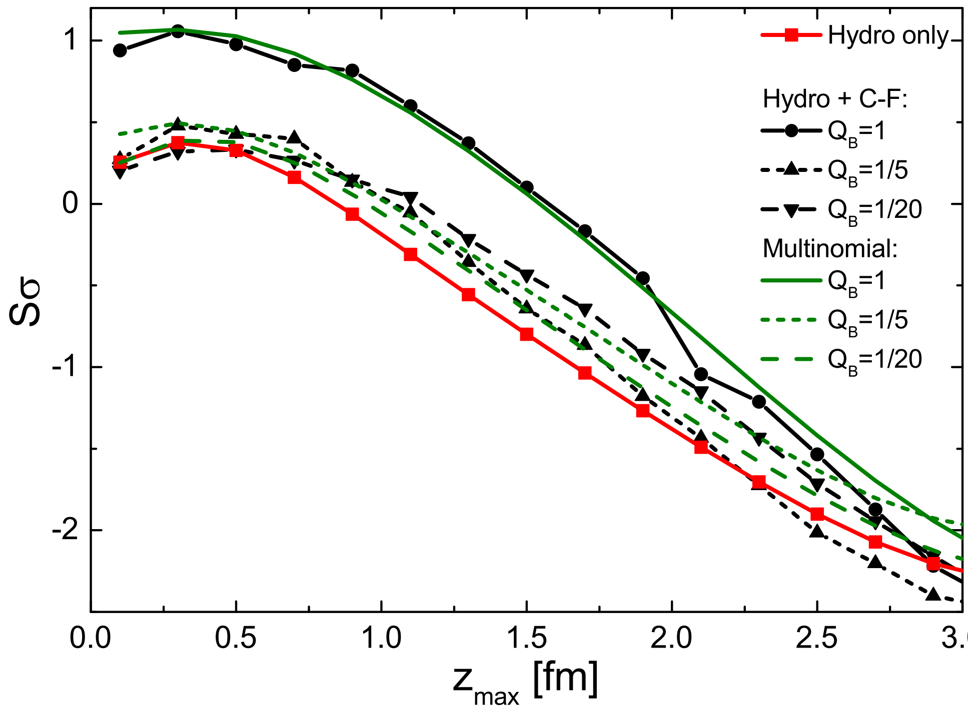
$$K_1^{B,CF} = \langle B \rangle = K_1^B$$
$$K_2^{B,CF} = K_2^B + Q_B K_1^B$$
$$K_3^{B,CF} = K_3^B + 3Q_B K_2^B + Q_B^2 K_1^B$$
$$K_4^{B,CF} = K_4^B + 6Q_B K_3^B + 7Q_B^2 K_2^B + Q_B^3 K_1^B$$

Alternative: Canonical sampling.

- Requires integer baryon number in cells
- Otherwise also test particles

Testparticles





Testparticles

- Computationally more intensive
- Lose correlations from resonance decay
- Will have to include these (and potentially other correlations) by propagating two particle distributions
  - Not done yet to my knowledge

Discussion

- For smooth, non-fluctuation hydro CF sampling is probably ok to simulate thermal noise
- Fluctuating initial conditions: Probably OK as well, not sure tough.
  - For lumps with large baryon number, CF "corrections" are sub leading anyway (N vs N^2)
- IF fluctuation hydro implies that thermal noise is "propagated" then CF sampling means double counting
  - Requires either testparticles, or coarse graining such that baryon number is integer in cell so that one can do canonical sampling
- CF sampling affects only "local" or delta-function piece of correlation functions.

Bottom Line

What is fluctuating hydro really?