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Multiplicity fluctuation from hydrodynamic noise

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We discuss multiplicity fluctuation
caused by noises during hydrodynamic evolution of the quark-gluon fluid
created in high-energy nuclear collisions.
In this talk, we claim the following non-trivial consequences within a framework of relativistic fluctuating hydrodynamics [1]:

- Multiplicity (being approximately proportional to entropy) fluctuates from event to event due to hydrodynamic fluctuation of dissipative currents such as shear stress tensor and bulk pressure even if the initial state is the same in a macroscopic sense.
- *Event-averaged* entropy has to increase with time so that the system obeys the second law of thermodynamics as it should be. Entropy in a certain event can, however, *decrease* with time temporarily and locally due to the hydrodynamic fluctuations.
- The probability of decreasing entropy during hydrodynamic evolution is, of course, very small in general. Interestingly, the probability is quantified by the *fluctuation theorem* [2] as known in the non-equilibrium statistical mechanics.

We first discuss the fluctuation theorem in non-equilibrium statistical mechanics [2].
The fluctuation theorem has been a milestone in non-equilibrium statistical mechanics
since the linear response theory was established. Since the fluctuation theorem contains the Green-Kubo formula
at long-time limit, it is believed to capture some important properties of non-equilibrium processes
away from equilibrium.

We next solve the stochastic equation for dissipative currents
together with the temporal evolution equation for the energy density
in one-dimensionally expanding coordinate [3]
to demonstrate that the final entropy fluctuates from event to event for a given initial condition.
During the time evolution of the total entropy in a certain event,
reduction of the entropy occurs due to hydrodynamic fluctuation of
dissipative currents.
We show that the probability of decreasing entropy just obeys the above-mentioned fluctuation theorem.

We finally discuss the physics consequences of hydrodynamic fluctuations on final observables.
Fluctuation of the final entropy is taken over by the one of multiplicity.
Thus we discuss multiplicity distribution functions from a hydrodynamic fluctuation point of view.
We also discuss observables in small system
such as p+p or p/d+A collisions since the effect of fluctuations
are of particular importance in such smaller systems.

References

[1] K. Murase and T. Hirano, arXiv:1304.3243 [nucl-th].

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[3] J. D. Bjorken, Phys. Rev. D **27**, 140 (1983).

On behalf of collaboration:

None

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