Thermodynamic Properties of Nuclear Matter ◇

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One motivation for investigating heavy ion collisions is to determine the thermodynamic properties of nuclear matter, i.e. the behaviour for high densities, pressures, temperatures, and possibly information about phase transitions. All these quantities refer to a system in thermodynamical equilibration while a heavy ion collision is a rather extreme non-equilibrium process. The question is how to gain information on these quantities under such circumstances.

In this work we approach this question within the local phase space configuration approximation (LCA) (see [1,2] and contributions in this volume). From relativistic BUU calculations [3] we see that during a large part of the collision the local momentum space distribution still retains the memory of the two incident nuclei. We therefore parametrisize the momentum space distribution by two covariant Fermi distributions of finite temperature taking also into account the Pauli-principle in the overlap region. As an example Fig. 1 shows the BUU momentum distribution and the fitted 2-Fermi sphere distribution for a central collision in the origin of the cm-system. One can see that there is a good correspondence between both pictures and therefore the parametrisation of the LCA is reasonable.

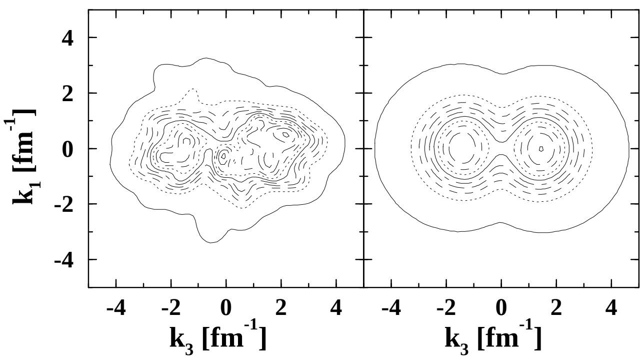

Fig. 1: Local momentum distribution of the BUU (left) and fit (right) for a central 400 MeV·A Ca + Ca reaction after a timestep of 20 fm/c.

To solve the relativistic BUU equation we use the relativistic Landau-Vlasov method (RLV) [3] with covariant gaussian test particles in coordinate and momentum space. We are therefore able to calculate all thermodynamic properties locally. Thus we determine density, collective velocity, the energy-momentum tensor, and pressure directly from the RLV calculation taking the anisotropy of the local momentum space into account. From the fitting procedure shown in Fig. 1 we also obtain local temperatures, which should be interpreted as subsystem temperatures. We are therefore also able to discuss questions of instabilities.

As an example we show the application of this procedure to the spectator matter in semiperipheral Au+Au and Ca+Ca reactions at 400 MeV·A. In Fig.2 we show the path of the spectator in a P-ρ diagramm. The prominent observation is a negative slope, i.e. negative compressibility, in the later stages of the process. This indicates that the system has entered the spinodal region and will become unstable. Thus we can fix the onset of the fragmentation process in a mean field approach. It is remarkable that the spinodal is entered at a relatively early time of the reaction around 45 fm/c. For the corresponding spectator temperature a value of around 8.7 MeV is extracted which is in the region of the values determined by the ALADIN collaboration for the liquid-gas phase transition [4].

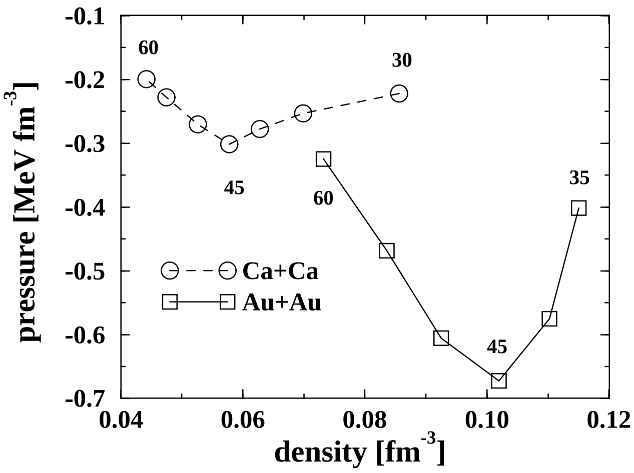

Fig. 2: The evolution of pressure density in 400 MeV·A Ca + Ca and Au + Au collisions as a function of time (denoted in fm/c on the points).

References

[1] L. Sehn, H. Wolter, Nucl. Phys. **A** (n press)
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[3] C. Fuchs, H. Wolter, Nucl. Phys. **A589** (1995) 732
[4] J. Pochodzalla et al., Phys. Rev. Lett. **75** (1995) 1040

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