Density determinations in heavy ion collisions

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Heavy ion collisions (HIC) are often used as a tool to investigate the properties of excited nuclear matter. Measured yields of different ejectiles as well as their energy spectra and their correlations in momentum space can be used to infer the properties of the emitting source. Despite the fact that a great deal of experimental data has been accumulated from HIC during the last few decades, reconstruction of the properties of the hot expanding nuclear system remains a difficult task. Two major problems are the complications inherent in incorporating nonequilibrium effects and in the treatment of strong correlations that are already present in equilibrated nuclear matter.

An often employed simple approach to handling these effects is the freeze-out approximation. Starting from hot dense matter produced in HIC, this approach assumes the attainment of local thermodynamic equilibrium after a short relaxation time. Chemical equilibrium may also be established in the expanding fireball as long as the reaction rates in the expanding hot and dense nuclear system are above a critical value. While more microscopic approaches employing transport models that describe the dynamical evolution of the many particle system are being pursued, a freeze-out approach provides a very efficient means to get a general overview of the reaction. Such approaches have been applied in heavy-ion reactions, to analyze the equation of state of nuclear matter but also in high-energy experiments (RHIC, LHC) to describe the abundances of emitted elementary particles. Much information on the symmetry energy, on phase instability, etc., has been obtained using this concept.

The main objective of our work is to determine the values of the temperature, T, matter density, n_B and asymmetry coefficient $\delta=(N-Z)/A$ characterizing the freeze-out state, from the five experimental yields, Yp, Yd, Yt, Yh and Yα of the light charged Z = 1, 2 species. This problem is easily solved within the nuclear statistical equilibrium (NSE), applicable in the region of low density and moderate temperature where medium effects can be neglected. Within the quantum statistical approach (QS) to nuclear matter, correlations and bound state formation are treated using Green's functions to derive in-medium few-body wave equations. In Figure 1 we compare the results obtained for T and n_B, deduced from experimental data on yield of particles with Z=1 and 2, using the NSE (Albergo's) approach, the QS approach, the Mekjian coalescence model and the quantum fluctuation analysis method (see Ref. [1] for details).

It is seen from the figure that the density values derived by both the coalescence and fluctuation methods are in rather good agreement with QS results that include medium effects, but in disagreement with the values derived from NSE. The NSE is applicable only at very low densities. The discrepancies with NSE are substantially reduced if medium effects, such as Pauli blocking, are taken into account.

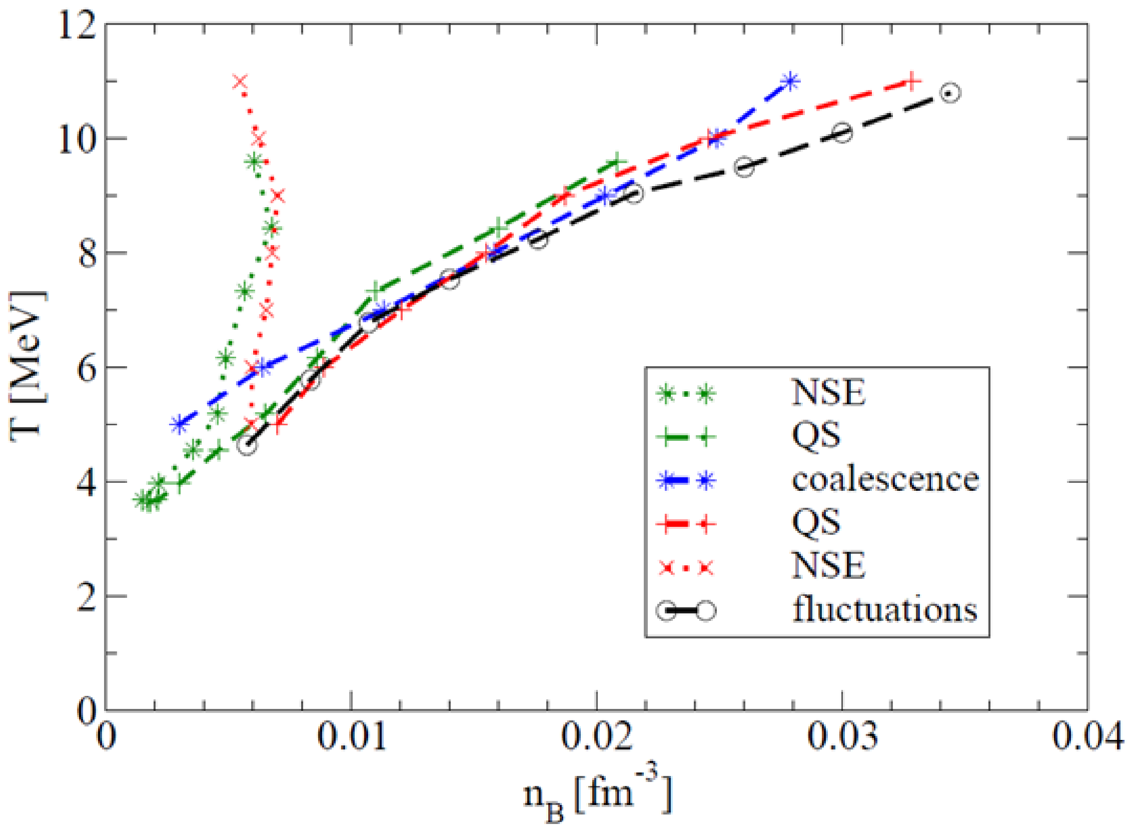

FIG. 1. (Color online) Baryon density derived from experimental data for yields of light elements.

[1] G. Roepke *et al*., Phys. Rev. Lett. (submitted).