

# Droplet formation in an expanding nucleon gas

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In energetic central heavy ion collisions it is generally assumed that, after going thru an early stage of hot and compressed nuclear matter, the system, before freezing out, will undergo a substantial expansion causing local cooling. At energies around or above 10A GeV the current picture is that the hot system while cooling passes from a phase involving at least partially deconfined quarks and gluons into a purely confined hadronic phase. At energies below 1A GeV the hot phase is still predominantly a nucleonic gas which, however, in the expansion phase can partially 'liquefy' i.e. clusterize in analogy to, but less controlled than, the processes used in clusterization devices for atomic physics. In both energy regimes one hopes to be able to determine basic parameters, such as the critical temperature  $T_c$  or the latent heat of the (first order) phase transition. Due to the finite size of the nuclear systems available in accelerator physics and the complexity of the dynamics of heavy ion reactions, convincing progress on this frontier has proven to be a difficult task. Concerning the liquid-to-gas transition onsets of plateau's in caloric curves [1] have been interpreted [2] in ways that relate only indirectly to first order transitions. 'Unambiguous' signatures such as negative heat capacities [3] have been subjected to critical reviewing [4]. Claims to the determination of  $T_c$  [5, 6] vary substantially in the proposed values. Obviously more experiment based constraints on the problem would be useful for reducing the model dependence of quantitative conclusions.

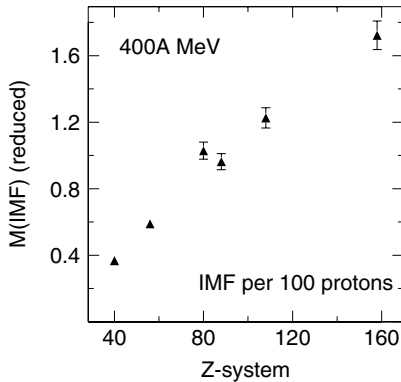


Fig. 1. Rise of cluster (IMF) multiplicity with system size in central collisions at 400A MeV. The data are normalized to 100 protons.

Such data, obtained with the FOPI apparatus in central symmetric heavy ion collisions with beams of 400A MeV, are presented in the two figures. In order to better understand the finite-size problem we have varied the system size from Ca+Ca ( $Z_{sys} = 40$ ) all the way to Au+Au ( $Z_{sys} = 158$ ), investigating five systems of different size (indicated in the figures). We find that the multiplicity of clusters with charge  $\geq 3$  (intermediate-mass fragments IMF), when reduced to the same number of available charges, grows with system size, Fig.1. We therefore

can conclude that the increased flow characterizing heavier systems indeed leads to a cooling process favouring gradual 'liquefaction'. This is a non-trivial finding as theoretical predictions [7] have tended to predict that strong flow gradients would prevent coagulation: as in two-particle correlations the effective radii of homogeneity should be diminished by flow.

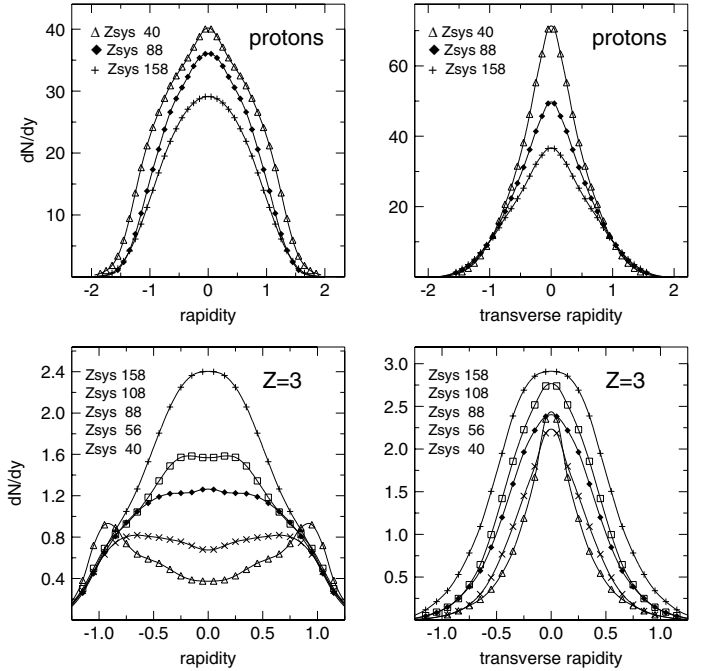


Fig. 2. Scaled longitudinal (left) and transverse rapidity distributions of single nucleons (top) and Li clusters (bottom). Note that the data are normalized to the heaviest system (Au+Au,  $Z_{sys} = 158$ ). The system size is varied as indicated in the panels.

More details of the mechanism at work are seen in Fig.2 which compares the evolution of the longitudinal and the transverse rapidity distributions with system size for the 'gas' (protons) which is prevalent for the light (surface-dominated) systems, and the 'droplets' which appear in increasing numbers at *mid-rapidity* as the system-size increases, accompanied by a broadening of the transverse velocities. We suggest that this broadening is associated with radial flow initiating the local cooling.

## References

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