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Low Density Clustering in Near Fermi-Energy Collisions

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The nucleon collisions and thermal shock which occurs during near Fermi-Energy heavy ion collisions leads naturally to the production of nucleonic matter at sub-normal densities. Experiments suggest that average nuclear densities as low as ∼0.4 times normal density are reached. However there are large density fluctuations throughout the collision. In the early stages of the reaction the fluctuations are dynamically induced and lead to a decoupling of the momentum sphere of the initial participant matter from that of the remaining nucleons. This important feature of the dynamically evolving system manifests itself as kinematic differences between the early emitted light (gas) ejectiles and the remaining (liquid) matter. As the system relaxes toward equilibrium the two momentum spheres become more and more similar. Eventually the distinction is lost. The original kinematic differences can be exploited to probe the size and properties of the initial interaction zone, Such analyses reveal a large degree of alpha particle clustering at low densities. For densities near 0.025 normal density, temperature and density dependent symmetry energy coefficients have been derived from isoscaling analyses of the yields of nuclei with A # 4 produced in the collisions of 35A MeV ^{64}Zn + ^{92}Mo and ^{197}Au. The symmetry energies are much larger than those obtained in mean field calculations. They are in much better agreement with results of a recently proposed Virial Equation of State calculation.