TIMESCALE PHENOMENA IN FRAGMENTATION PROCESSES

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The space-time evolution of heavy ion reaction trajectories - starting from the ordered projectile - target motion in the entrance channel and finally leading to a rather disordered multiparticle system - is one of the principal motivations for the study of high energy nucleus-nucleus collisions. Fortunately, there are several observables related to the evolution of the system. For example the isotopic yield ratios reflect the N/Z composition of the emitting system [1]. Yield ratios of boron fragments emitted in ^{12}C and ^{18}O induced reactions at E/A = 84 MeV are shown in Fig. 1 as a function of the neutron-to-proton ratio of the composite system of target and projectile [1]. For these "midrapidity" fragments ($\theta = 40^o$) the yield ratio is independent of the projectile and is obviously closely related to the N/Z ratio of the composite system or the target nucleus. (Because of the light projectile, both N/Z ratios are very similar.) As expected, yield ratios of boron fragments resulting from decays of projectile-like fragments show no sensitivity to the target nucleus. (The crosses and stars in Fig. 1 indicate the results of measurements for ^{12}C induced reactions at E/A = 86 MeV [2].) On the other hand, isotopic yield ratios of midrapidity light particles (see upper part of Fig. 1) are sensitive to the N/Z composition of both, the target nucleus *and* the projectile nucleus indicating emission from a source where projectile and target nucleons equally contribute. Such a 1:1 mixing ratio [1] is consistent with emission from a nuclear fireball in the early stages of the reaction. Intermediate mass fragments emitted at more backward angles seem to be made of target-like nuclear matter, i.e. the emission takes place after global equilibration of the N/Z ratio.

Because of their sensitivity to quantum statistics and final-state interactions, two-particle correlation functions contain *more quantitative* information about the space-time characteristics of the emitting system. For a thermalized system contained in a volume V the correlation function of two non-identical particles of spins s_1 and s_2 can be approximated [3] as

$$R(q) = \frac{2\pi}{(2s_1+1)(2s_2+1)\cdot V\cdot q^2}\cdot\sum_{J,\ell}(2J+1)\cdot\frac{\partial\delta_{J,\ell}}{\partial q}. \qquad (1)$$

Here, $\delta_{J,\ell}$ is the scattering phase shift for channel spin ℓ and total angular momentum J. Qualitatively, the inclusion of the temporal evolution of the emitting system is expected to reduce the calculated two-particle correlations. Therefore, source radii extracted under the assumption of negligible lifetime represent upper limits for the spatial extent of the emitting system [5].

Intuitively one expects a stronger localization for more energetic particles, which may be emitted in an earlier stage of the reaction. Fig. 2 shows two-proton correlation functions measured for ^{14}N induced reactions on ^{197}Au at E/A = 35 MeV and an average laboratory angle $\theta_{av} = 35^o$. In order to explore the dependence of R(q) on the energy of the outgoing particles, the correlation functions were evaluated for different constraints on the sum energy, $E_1 + E_2$, of the two coincident protons. The maximum at q ≈ 20 MeV/c becomes more pronounced with increasing total kinetic energy of the coincident

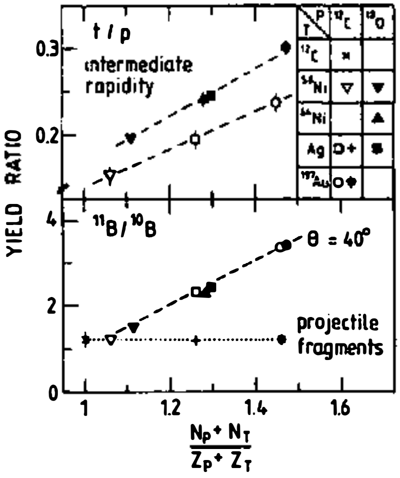

Figure 1:
Ratios of isotopic yields of boron (lower part) and hydrogen (upper part) plotted as a function of the N/Z ratio of the composite system of projectile and target [1,2].

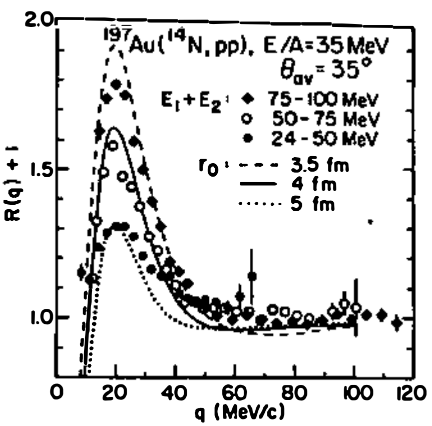

Figure 2:
Two-proton correlation function for ^{14}N induced reactions on ^{197}Au at E/A=35 MeV.

particles, i.e. more energetic particles are emitted from sources which are more localized in space-time. This may indicate emission from a spatially expanding source[6]. It may, however, also reflect different time scales associated with particle emission.

In order to give a rough estimate of the time-scale involved, we assumed for simplicity a constant spatial dimension of $r_0 = 3$ fm corresponding to a nuclear system consisting of about 50 nucleons. The correlations observed in the three summed-energy ranges 24-50, 50-75 and 75-100 MeV correspond then in Koonins formulation [4] to $v' \cdot \tau$ values of about 12, 6 and 4 fm, respectively. Assuming emission from a source which moves with half beam velocity, emission times of 90, 33 and 18 fm/c are extracted. Qualitatively, this energy dependence of the emission time is consistent with recent numerical simulations of the particle emission process [5]. In particular preequilibrium light particles seem to be emitted after only a few nucleon-nucleon collisions.

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