AMD and inverse spallation reaction with $^{12}C+^{1}H$ at 95 A MeV

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The inverse spallation reaction of $^{12}C+^{1}H$ at 95 A MeV from Ref.1 has been used to examine different elements of the stochastic processes in the anti-symmetrized molecular dynamics (AMD)[2-6], focusing on the diffusion process and cluster correlation. The standard AMD code has a quantum blanching process, which is called "diffusion process' to reproduce the multi-fragmentation events from intermediate heavy ion collisions. However in this energy region, excited intermediate mass fragments are copiously generated in general and they cool down by sequential decay process before they are observed in the experiments. Therefore the primary products from AMD are significantly overlayed with those products from the secondary decays. In another words, the experimental products are closely related to both processes, primary dynamics of AMD and secondary decay process of an afterburner and often it is difficult to separate these two processes.

Spallation reactions use light ions, mostly protons, as the incident ions, bombarded on a heavier mass target in the energy range from 100 A MeV to above A GeV. Since the projectile is small, most products are produced from the target. However in the normal kinematics, many products are generated in wider angular and energy ranges. In order to observe all products in flight, reverse kinematic is often used, since all products are produced at the beam direction with similar velocity as the projectile. However this is not true for protons. Protons are generated at all angles with wider energy distribution in the center of mass frame. Therefore in the inverse kinematic reactions, the protons emitted at the

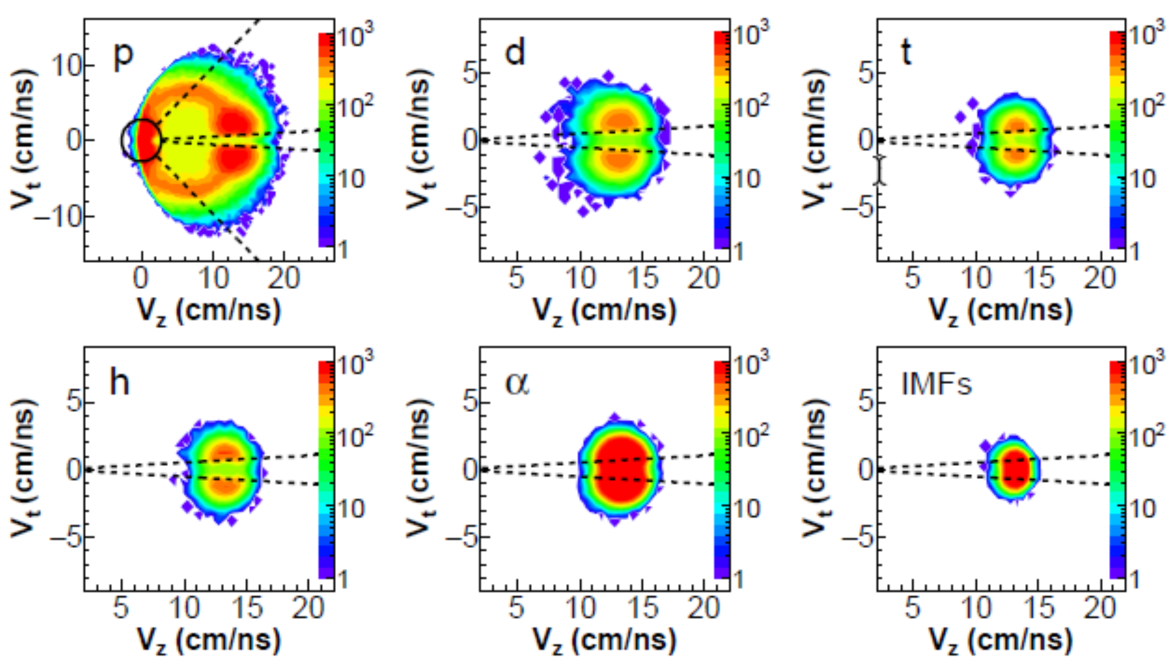

Fig. 1. 2D velocity plots for $^{12}C+^{1}H$ at 95 A MeV from AMD+Gemini simulations for particles indicated in each figure. Same Z scale is used for all.

backward hemisphere may provide a test bench in which only the primary dynamics is dominated with no sequential decay disturbance. These protons may provide a sensitive probe to verify different elements of the stochastic processes incorporated in AMD.

Along the above scenario, $^{12}C+^{1}H$ at 95 A MeV data set from [1] is examined. In Fig.1, two dimensional velocity plots, $d^2\sigma/dVtdVz$, of p, d, t, h, α and IMFs are shown from AMD+Gemini.

The ring and dashed lines indicate the experimental detection limits. Protons show a rather wide distribution with clear three distinct sources, a projectile-like (PLF) source centered near the beam velocity, an intermediate velocity (IV) source with about a half beam velocity and a target-like (TLF) source near the origin and inside the circle, indicating most of them are not observed experimentally. All other clusters show essentially a PLF source alone. The PLF protons, therefore, are produced from two processes, the dynamical process of AMD at early stage and the sequential decay additions of Gemini from heavier clusters at later stages. On the other hand, the IV protons are mainly produced by the AMD dynamics alone, since no excited IV cluster source exists. The IV protons form a ring, which indicate that these protons are produced by quasi-elastic scattering between one nucleon in the target and the projectile proton. These overviews of the velocity distributions confirm the isolated production mechanism of the IV protons, that is, they are produced mainly from the early stage of the dynamics of AMD and therefore detailed study of these protons may provide a sensitive probe for the AMD modeling. Now further detailed study is underway, comparing the AMD predictions with the experimental data.

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