DECAY OF HIGHLY EXCITED NUCLEI

ISOTOPE RATIOS FOR COMPLEX FRAGMENTS EMITTED IN THE 200 MeV $\vec{p} + {}^{nat}Ag$ REACTION*

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The emission of complex fragments from reactions induced by intermediate-energy protons below about 1 GeV has been shown to proceed via both statistical decay and fast, nonequilibrium mechanisms. Nonequilibrium emission, which dominates the forward-angle spectra, remains poorly understood. These ejectiles are characterized by rapidly-rising cross sections near 0°, suggesting formation on a very short time scale.

Here we examine the properties of intermediate mass fragments (IMFs) emitted at very forward angles in the 200 MeV $\vec{p} + {}^{nat}Ag$ reaction. The studies were conducted at IUCF with a 200 MeV polarized proton beam of average intensity 15–30 nA and spot size ≤ 2 mm in diameter. High purity silver targets of thicknesses 1.22 and 1.62 mg/cm^2 were bombarded in the 162 cm dia. scattering chamber and were alternated during the experiment to minimize any effects of carbon buildup.

Measurements for He ejectiles and IMFs (IMF: $3 \leq Z \lesssim 12$) were performed with a pair of particle-identification/time-of-flight telescopes, each consisting of an axial-field gas-ionization chamber operated at 20 Torr of CF_4 gas, followed by two silicon surface-barrier detectors of thicknesses 90 μm and 1 mm, respectively, and a 5 mm lithium-drifted-silicon detector. Time-of-flight was measured with respect to the beam rf, which provided a timing resolution of $\sim$ 300 ps. The two telescopes were placed symmetrically at $\pm 9°$ with respect to the beam axis in one experiment and $\pm 15°$ in another.

The coalescence model[1] has been applied to the energy spectra at 15°. Experimental proton spectra have been used as input for both the proton and neutron distributions; the fits are shown in Fig. 1 as solid lines. The coalescence momentum, P_0, which parameterizes this model was determined with a chi-squared minimization routine to provide a best fit to the data. From the value of P_0, the interaction zone radius was calculated as in Ref. 1. The coalescence momentum ($\sim$ 240–280 MeV/c) is found to increase systematically with ejectile mass, while the reverse trend is observed for the interaction zone radius ($\sim$ 1.95–1.70 fm). The calculation fits the tails of the IMF spectra rather well, yielding interaction zone radii of about 2 fm, much smaller than the radius of the composite systems. In the framework of this model, the results for the source radii are consistent with a mechanism in which the incident proton interacts with only a localized region of the target nuclear matter density before emission of complex fragments occurs.

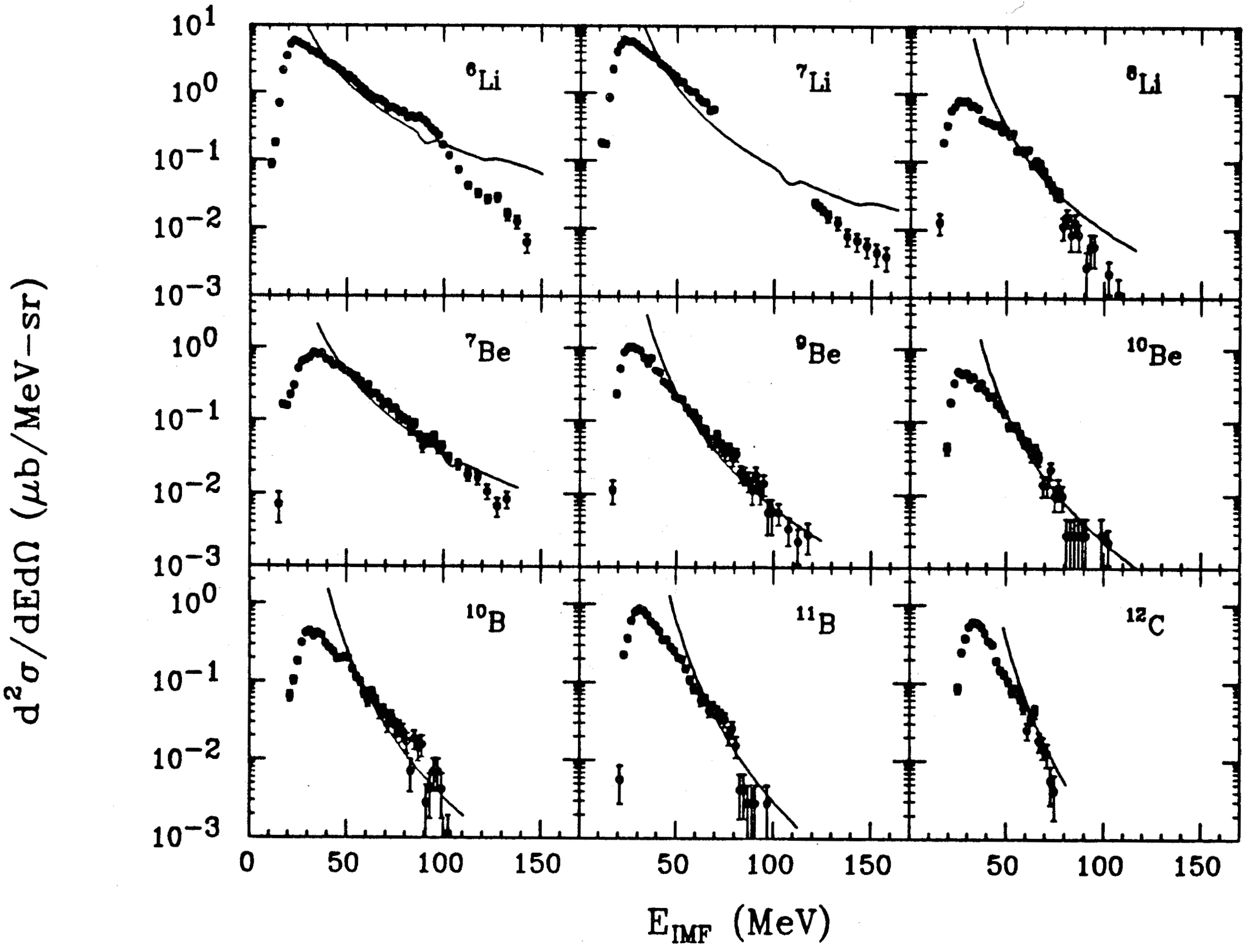

Figure 1. Kinetic energy spectra of IMFs, as indicated on figure, for the 200 MeV $\vec{p}$+ ^{nat}Ag reaction at an emission angle of 15°. Solid line is the result of a coalescence fit to experimental proton spectra.

The isotopic composition of the elemental IMF yields may also possess important information concerning the reaction mechanism.[2] An equilibrated system should preferentially emit fragments which reflect both the N/Z ratio of the composite system and the most energetically favored pathway for decay. On the other hand, nonequilibrium IMF formation may be more strongly influenced by the projectile composition, leading to species with N/Z closer to unity. Thus, to first order, one would expect neutron excess isotopes to reflect longer interaction time, or a more equilibrated source.

Isotope ratios, defined as the yield of a given isotope to the total elemental yield, are presented as a function of IMF kinetic energy in Fig. 2. For fragment energies near the Coulomb peak, beta-stable and neutron-excess isotopes are the most abundant species, consistent with a picture in which at least partial equilibration has been achieved prior to IMF emission. As the fragment energy increases, the probability for emitting isotopes

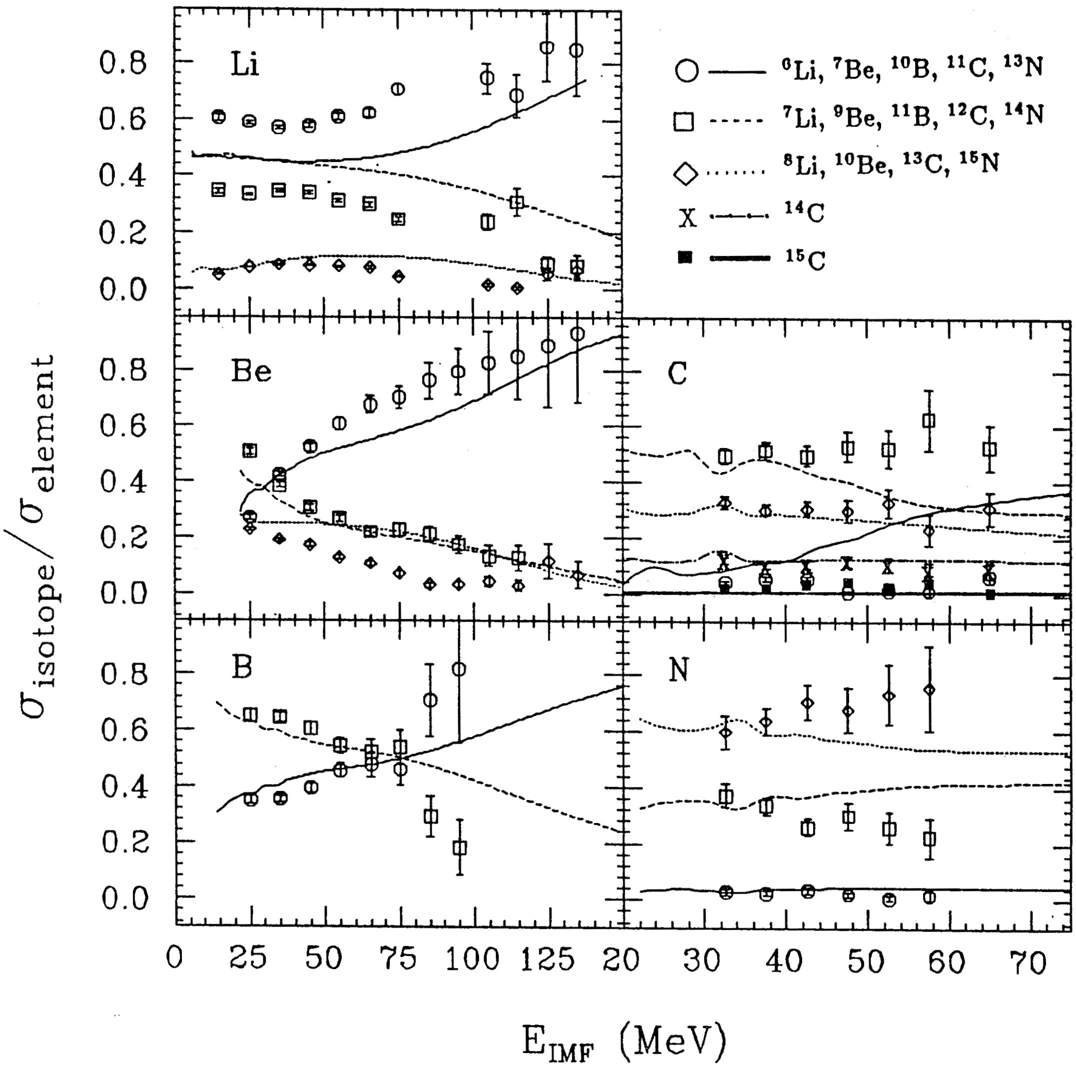

Figure 2. Ratio of individual isotopic yields to total element yield for Li, Be, B, C and N fragments observed at 15° as a function of IMF energy. Lines are the result of an accreting source calculations[3,4] as identified in the figure. Nuclides are identified by key at upper right.

with $N/Z \leq 1$ grows in importance, especially for Z = 3-to-5 fragments. Thus, the most neutron-deficient isotopes of a given element appear to be selectively identified with the nonequilibrium component of the fragment yields. In Fig. 2 the observed isotopic ratios are compared with the predictions of an accreting source model.[3,4] The parameters of the models, accretion rate, Fermi energy and source size, were fixed by requiring a fit to the elemental differential cross section distribution at the angle of observation. These values were an accretion rate of 2.0 nucleons/fm/c, a Fermi energy of 22 MeV and an initial source size of eight nucleons.

As observed in Fig. 2, the model qualitatively reproduces the trends observed in the data for Z = 3–5 fragments. For heavier fragments the preference for the growth of neutron-deficient ejectiles in the high-energy tails of the spectra is much less pronounced. This may in part be due to the fact that with increasing atomic number the ratio of equilibrated to nonequilibrated IMFs increases,[3] thus favoring $N \geq Z$ fragments.

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LIGHT PARTICLE CORRELATION FUNCTIONS FOR THE ^{3}He + Ag REACTION AT 200 MeV

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For collisions at non-relativistic energies, particle-particle correlation functions,[1] gated on the energy of the detected particles, indicate that the space-time extent of the initial source which produces the most energetic particles generally increases with the size of the projectile.[2] The most dramatic sensitivity to the space-time evolution of such reactions might, therefore, be expected for light-ion-induced reactions on heavy targets, reflecting the evolution from an initial configuration involving the projectile and a few target nucleons to the equilibrated target-like residue. Here we present measurements of light-ion-induced reactions that illustrate effects which influence the correlation functions of very energetic particles emitted during these early stages——effects which are averaged away in energy averaged correlation function data.