COMPLEX FRAGMENT EMISSION IN COINCIDENCE WITH ANGLE-CORRELATED FISSION FRAGMENTS IN THE 270 MeV ^{3}He + ^{232}Th SYSTEM

D.E. Fields, K. Kwiatkowski, K.B. Morley, E. Renshaw,
J.L. Wile[a], S.J. Yennello[b], and V.E. Viola
Indiana University Cyclotron Facility, Bloomington, Indiana 47408

R.G. Korteling
Simon Fraser University, Burnaby, BC, V5A 1S6 CANADA

A description of the sources of complex fragments formed in nuclear reactions well above the Fermi energy is critical for understanding the decay of hot nuclear matter. Earlier experiments[1–4] with ^{3}He and ^{14}N projectiles from E/A = 20 MeV/A to 100 MeV/A on heavy target nuclei have shown that the sources of intermediate mass fragment (IMF = $3 \leq Z \leq 15$) production can be classified into three distinct categories: (1) a projectile-like source whose angular distribution peaks strongly at forward angles and whose energy spectra peak near the beam velocity; (2) emission from an equilibrated compound-nucleus-like source resulting in an isotropic angular distribution and steeply sloping Maxwellian energy spectra; and (3) non-equilibrated fast emission from a target-like source with a forward peaked angular distribution and Maxwellian energy spectra that have flatter slopes than for equilibrated emission. In order to classify IMFs according to their production mechanism, exclusive experiments have been conducted both at IUCF and elsewhere.[4] These experiments have confirmed the existence of two target-like mechanisms and indicate that the non-equilibrium mechanism becomes more important at higher bombarding energies. Missing from these experiments, however, was a complete picture of the reaction dynamics including excitation energy in the emitting system.

In order to fill this gap in the experimental data, an experiment has been performed at the Indiana University Cyclotron Facility in which detected IMFs have been tagged with linear momentum and excitation energy transfer to the target. Beams of 270 MeV ^{3}He were used to bombard a self-supporting 678 g/cm^2 ^{232}Th target in the IUCF 162-cm scattering chamber. IMF detectors consisting of gas ion chambers followed by silicon detectors and CsI (or BgO) crystals were placed at eight angles around the target (see Fig. 1) and delivered excellent charge resolution up to Z = 15 and good mass resolution for isotopes up to mass 12. In the same plane with the IMF detectors were two arrays, each consisting of four silicon strip detectors placed on either side of the beam. The two arrays were used to detect energy, position, and time-of-flight of coincident fission fragments. This information can give us the direction and velocity of the recoiling heavy residue in coincidence with an emitted IMF. Also, since the total missing mass can be related to the number of emitted neutrons, the excitation energy deposited in the system can be determined given a reasonable mass resolution of the fission fragment detection system.

Figure 2 shows both the geometry of the fission fragment detector and a diagram of the resistive network for position detection and subsequent electronics. Signals proportional to (L−X)/L are extracted from the front surface of the detector through the resistive chain. The entire back of the detector is covered with an aluminized layer, and the energy and

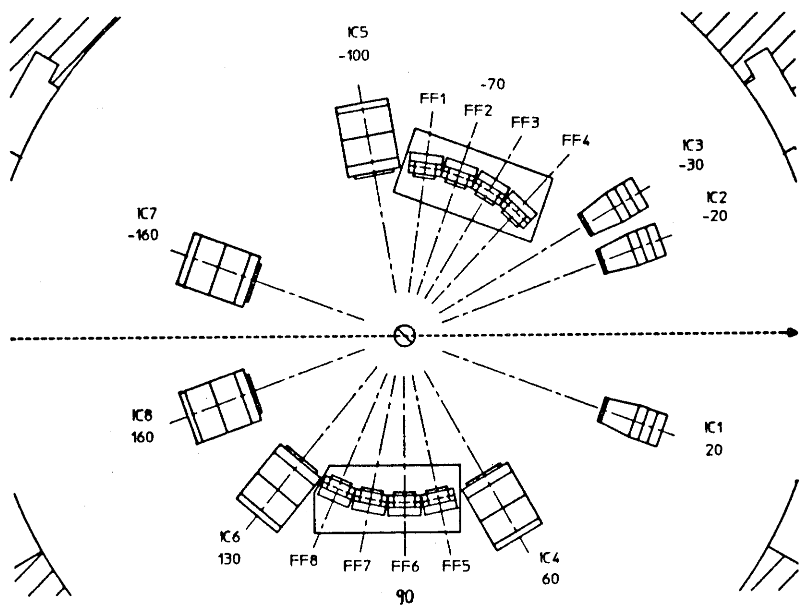

Figure 1. Setup for experiment E304.

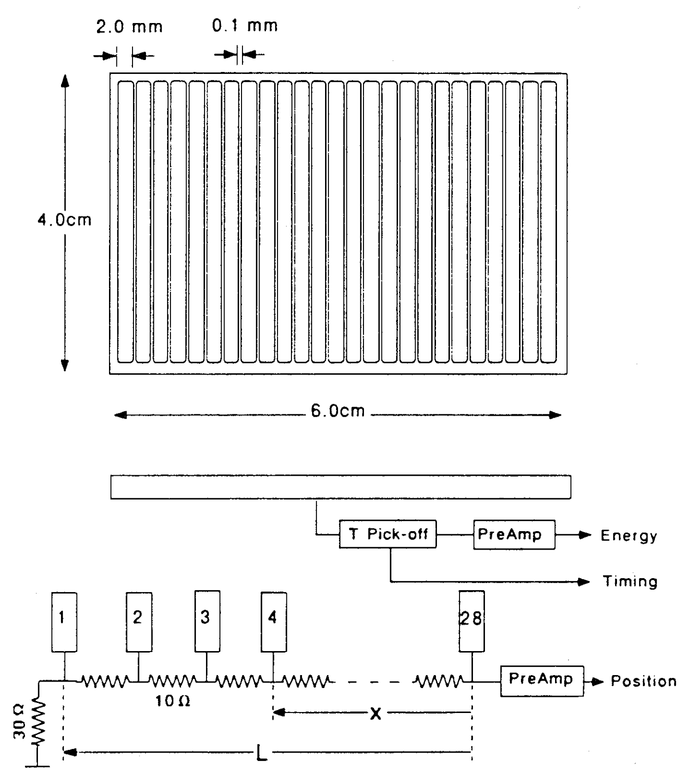

Figure 2. Geometry and electronics diagram of the fission fragment detector.

time signals are taken from there. Figure 3 shows strip position as a function of fragment energy. The top portion of the figure shows the curvature of the position lines due to offsets in the electronics whereas in the bottom portion the function

$$Position = \frac{P \cdot E}{E}$$

has been replaced by

$$Position = \frac{P \cdot E - P_0}{E - E_0}$$

thereby straightening the position lines and making analysis easier.

A check on the accuracy of the angular calibrations of the fission fragment detectors was performed by using data from a thin ^{252}Cf fission source taken immediately after the production run. The folding angle between coincident fission fragments from the source

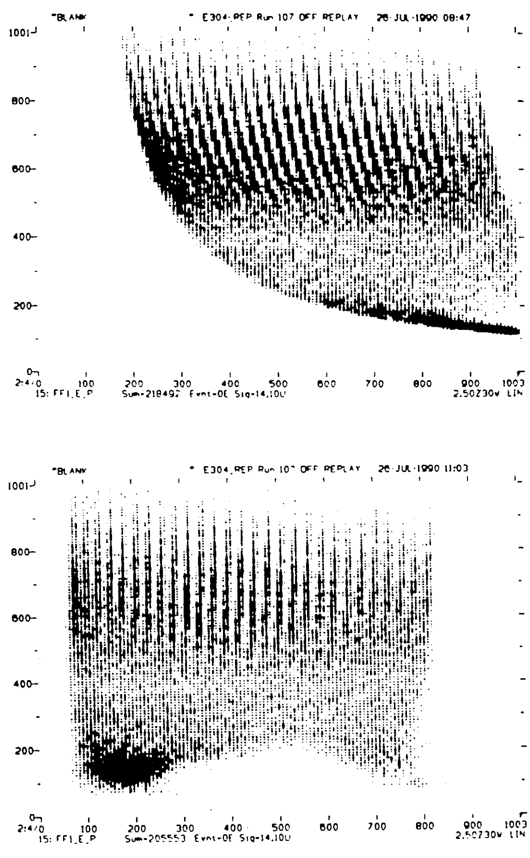

Figure 3. Top: Position = (P · E)/E, Bottom: Position = ((P · E) − P_0)/(E−E_0).

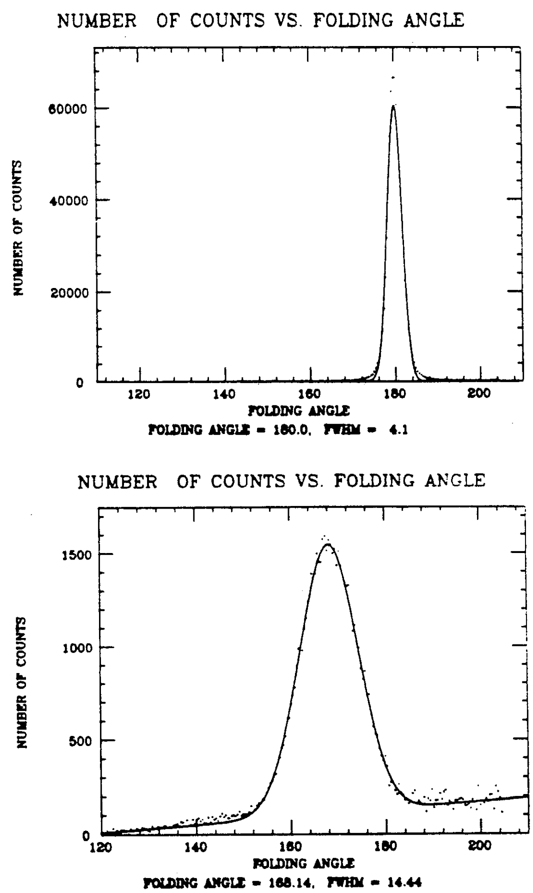

Figure 4. Folding angle distributions for (top) ^{252}Cf source and (bottom) fission fragments from the 270 MeV ^{3}He + ^{232}Th reaction in coincidence with IMFs at 120°.

should be 180° with a width dominated by neutron emission of approximately 4°. This was checked and found to be correct to within 0.05° as seen in the top portion of Fig. 4. In addition, the method of momentum transfer determination was checked by gating fission fragment folding angles from the ^{232}Th target on coincident IMFs at a particular angle and noting the corresponding shift in the centroid of the folding angle distribution. The lower portion of Fig. 4 shows a folding angle distribution for fission fragments in coincidence with IMFs at 120°. The data has a centroid shifted and spread in agreement with Monte Carlo simulations of the kinematics involved.

In addition to position and folding angle calibrations for the fission fragments, all charge and mass gating for all IMF telescopes were performed and compressed data was written to tape in the first pass through the data. As a result, singles cross-sections for all isotopes were derived; preliminary inclusive IMF angular distributions are presented in Fig. 5.

[a] Present address: Indiana Academy, Ball Sate University, Muncie, IN
[b] Present address: Michigan State University, East Lansing, MI

1. K. Kwiatkowski, *et al.*, Phys. Lett. **B171**, 41 (1986).
2. M. Fatyga, *et al.*, Phys. Lett. **B185**, 321 (1987).
3. D.E. Fields, *et al.*, Phys. Lett. **B220**, 356 (1989).
4. M. Fatyga, Phys. Rev. Lett. **58**, 2527 (1987).

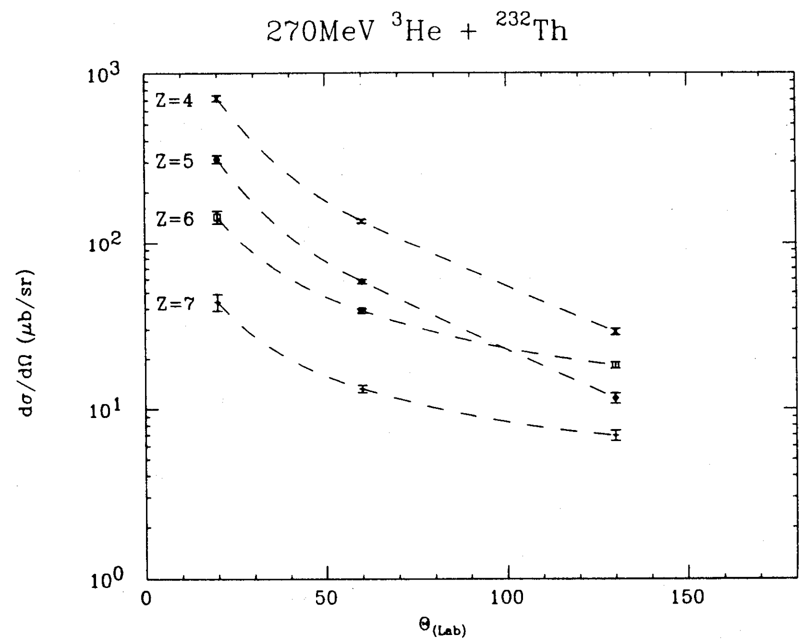

Figure 5. Preliminary inclusive angular distribution for Z = 4–7 for the 270 MeV ^{3}He + ^{232}Th reaction.