EMISSION OF ENERGETIC PROTONS INTO THE BACKWARD HEMISPHERE IN THE 64, 129, 200, 270 MeV $^{3}He + ^{238}U$ REACTION

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Spectra of protons emitted into the backward hemisphere in coincidence with two fission fragments were measured in the 64, 129, 200, 270 MeV $^{3}He + ^{238}U$ reaction. The angular correlation between two fission fragments was used tc calculate momentum deposition in the residual nucleus. The experimental setup has been described previously.[1] A low pressure, x-y position-sensitive wire chamber was used to detect one fission fragment, while the second fragment was detected in a position-sensitive surface-barrier detector. Protons were detected in the telescope consisting of a 400μm surface-barrier silicon detector ΔE element and a Na-I E detector. The telescope was positioned in the range of angles 140°-160° (LAB).

At all four energies substantial yields of energetic protons were found (Fig. 1) which cannot be explained by evaporation from fully equilibrated compound nuclei. The origin of these energetic emissions remains unknown. Based on the proton energy and direction, and on the measured momentum deposition in the target residue, a momentum balance factor R was calculated

$$R = \frac{\langle p_{\parallel}\rangle_{ejectile} + \langle p_{\parallel}\rangle_{recoil}}{p_o}$$

Here p_o denotes the incident beam momentum, $\langle p_{\parallel}\rangle_{ejectile}$ the projection of the ejectile momentum on the beam axis, and $\langle p_{\parallel}\rangle_{recoil}$ is the projection of the recoil momentum of the beam direction. Figure 1 shows the evolution of the value of R with increasing energy. A value of R = 1 indicates that the observed protons come predominantly from complete fusion events. Values of R < 1 indicate that some non-equilibrium emission has occurred prior to fission, in addition to the proton one observes. The value of R=1 at E/A = 22MeV shows, that central collisions are the main source of observed proton yields at this energy. The decrease of R with

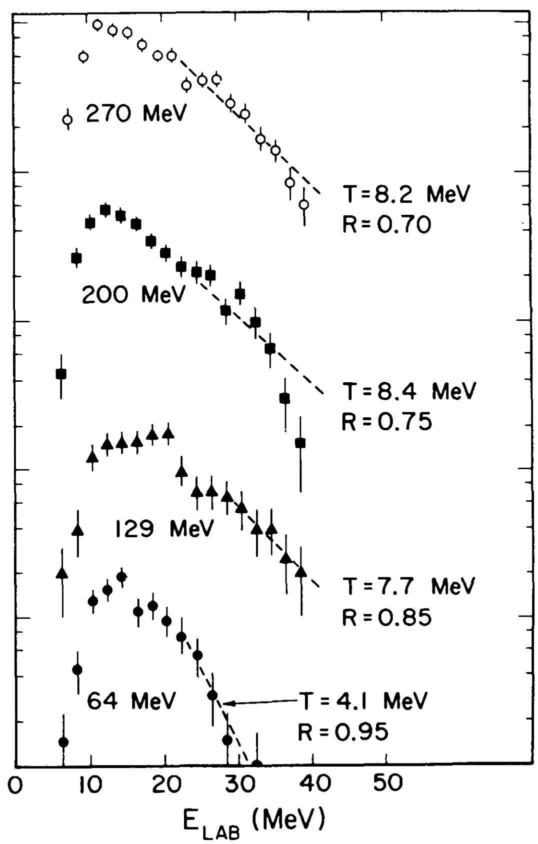

Figure 1. Energy spectra of protons emitted at 150°LAB coincidence with two fission fragments.

increasing bombarding energy (Fig. 1) suggests, that some fraction of the cross section for central collisions does not lead to the full momentum and energy deposition when bombarding energy increases. It has been previously observed[2] that in the reaction of 150 MeV ^{6}Li with a ^{238}U target, energetic protons in the backward hemisphere are associated with the complete momentum deposition in the composite system. Comparing 150-MeV ^{6}Li + ^{238}U reaction with 130 MeV ^{3}He + ^{238}U one can conclude that the incident energy per nucleon seems to be the most relevant variable with which one can describe energy and momentum loss in central collisions.

Finally, "apparent temperatures" were calculated for all proton spectra, using a Maxwellian distribution

$$N(E) \propto \sqrt{E}\, \exp(-E/T)$$

Figure 1 shows the temperature values that were obtained. It is interesting to notice that the "apparent temperature" saturates when the bombarding energy increases past 40 MeV/u. This is consistent with the observed saturation and subsequent decrease in momentum and energy deposition in the target nucleus near this energy.

In summary, the evolution in the average momentum and energy deposition in central collisions was investigated. It is suggested, that for the incident energy $E > 40$ MeV/u the probability of complete fusion in central collisions decreases with increasing bombarding energy. Since the incident energy per nucleon, rather than the total incident energy, seems to be the relevant variable in describing the limit to fusion in central collisions, one can expect important limitations on temperatures (or total excitation energies) attainable in collisions induced by complex nuclei around 40 MeV/nucleon.

1) M. Fatyga et al., IUCF Scientific and Technical Report, 147 (1983); K. Hicks et al., IUCF Scientific and Technical Report, 145 (1983).

2) M. Fatyga et al., IUCF Scientific and Technical Report, 109 (1984); to be published.