PRE-EQUILIBRIUM CALCULATIONS OF BACKWARD-ANGLE PROTON SPECTRA

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The emission of supra-thermal protons at extreme backward angles with spectra slopes two-three times greater than for an equilibrated compound nucleus has been observed for several reactions between complex nuclei and ^{238}U.[1-4] By tagging these events with angle-correlated fission fragments, it has been shown that they originate in collisions which involve large linear momentum transfers from the projectile to target. In Table I, the properties of these spectra are summarized. Here, the quantity R represents the sum of the momenta of the proton and fissioning nucleus relative to the beam momentum.

These data are compared with the pre-equilibrium excition model of Machner[5] in Fig. 1. The solid lines that represent spectral slopes, or apparent temeratures T_s, from Table 1; the dashed lines are the sum of decay plus pre-equlibrium calculations and the dotted lines indicate the pre-equilibrium component. In all cases the best fits were obtained with one-hole and N+1 particle states for the exciton number, where N is the number of projectile nucleons. Relative to the CLUST code, the probability for energetic proton emission is significantly enhanced in these calculations, although they still underpredict the data. As seen from the energy dependence of the ^{3}He data, the quality of the fits is observed to improve with increasing energy. For projectiles of roughly the same energy/nucleon, the calculations predict an increase in pre-equilibrium emission with increasing projectile mass. However, this leads to an overprediction for the high-energy tail of the ^{16}O-induced reaction. In addition, the pre-equilibrium exciton model calculations

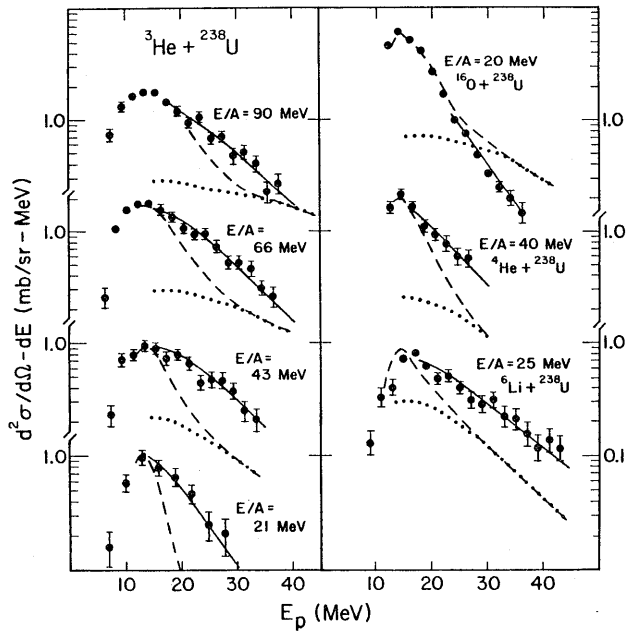

Figure 1. Spectra of protons emitted at at backward angles in complex-nucleus-induced reactions with ^{238}U, as identified on figure. Solid line represents slope temperature, T_s; dotted line is pre-equilibrium calculation of Ref. 5, and dashed line is sum of equlibrium plus non-equilibrium components.

Table I

Parameters of backward-angle proton spectra ($\theta \geq 140°$)
in coincidence with angle-correlated fission fragments

Projectile	Energy (MeV/Nucleon)	$d\sigma/d\Omega$ (mb/sr)	R	T_s(MeV)	T_{CN}(MeV)
^{3}He (Ref.4)	21.3	12	0.95 ± 0.03	3.9	1.55
	43.0	17	0.85 ± 0.03	3.9	1.55
	66.7	30	0.75 ± 0.03	6.2	2.62
	90.0	32	0.70 ± 0.03	6.9	3.03
^{4}He(Ref.1)	20.0	- -	1.00 ± 0.03	3.6*	1.57
	40.0	20	0.95 ± 0.05	5.2*	2.26
^{6}Li (Ref.2)	25.0	13	0.95 ± 0.05	7.0	2.20
^{16}O (Ref.3)	20.0	28	1.00 ± 0.05	4.6	2.84

*Apparent temperatures for non-equilibrium source derived from two-source fit to these data; ^{4}He data taken with higher resolution, thereby permitting decompositions.

for back-angle deuteron emission (not shown here) yielded better agreement with the data than for protons at a given energy. While the pre-equilibrium calculations underpredict the data, they represent a significant improvement relative to intranuclear cascade calculations, for which the cross sections are an order of magnitude too low.

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