(solid curve) radiations are searched to minimize χ^2. The inclusion of one E3 partial wave lowers χ^2 from 19.8 to 1.6 and is strongly influenced by the data near to 0° and 180°. At 39 MeV excitation the E3 multipole contributes only about 0.5% of the total cross section.

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NEW EFFECTS IN ^{3}He-CAPTURE REACTIONS AT IUCF ENERGIES

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Although they have been somewhat neglected in recent years, studies of radiative capture reactions utilizing light composite projectiles such as deuterons and ^{3}He-particles have yielded valuable nuclear structure information in the low-energy domain.[1] States excited as resonances in these reactions,[2] as well as those strongly populated as final states, are presumably ones with sizable cluster configuration amplitudes. As we have shown in our earlier work, especially on the cluster capture reaction ^{3}H(^{3}He,γ)^{6}Li,[3] the direct capture mechanism is at least as important in cluster captures as it is in proton capture, at high enough γ-ray energies. Since this process, as well as initial-state semi-direct capture,[4] populates preferentially those final states with wave functions having a large overlap with bound states of target plus projectile, we expect deuteron capture to select states with strong 2-particle configurations, ^{3}He (or ^{3}H) capture to select 3-particle states, etc. We have therefore initiated a series of experiments aimed at exploring the same sorts of phenomena we have observed in (p,γ) capture,[5] but this time employing a ^{3}He projectile.

First, we decided to look at $^{9}\mathrm{Be}(^{3}\mathrm{He},\gamma)^{12}\mathrm{C}$, to see whether the same final states seen in $^{11}\mathrm{B}(\mathrm{p},\gamma)^{12}\mathrm{C}$ would be populated, and whether the relative populations would be similar or different. As expected from the simple direct-capture argument outlined above, the $^{12}\mathrm{C}$ final states are populated quite differently. For example, the 0^{+} second excited state is relatively more important in the $(^{3}\mathrm{He},\gamma)$ spectrum than in the (p,γ) spectrum, while the ground state transition is relatively less important.[6] Capture to several final states near 19 MeV excitation in $^{12}\mathrm{C}$ shows up strongly in both spectra, indicating that 3-particle, 3-hole configurations may be more important in the 1-particle, 1-hole region of $^{12}\mathrm{C}$ than is usually believed. Calculations by Wang and Shakin,[7] performed fifteen years ago, had suggested this possibility, but analyses of experiments looking at this region of excitation in recent years largely ignored the 3-p,3-h contributions.

Guided by the interesting relationships we found between captures into closed-subshell nuclei and their one-nucleon-added neighbors,[8] we examined $^{12}\mathrm{C}(^{3}\mathrm{He},\gamma)$, populating states of $^{15}\mathrm{O}$, to see whether there would be related 3-nucleon cluster-capture transitions into $^{12}\mathrm{C}$ and $^{15}\mathrm{O}$. While that question is still open, since we have not yet had the opportunity to return for a more detailed look at $^{9}\mathrm{Be}(^{3}\mathrm{He},\gamma)$, the initial results are very promising. The spectra we obtained[6] for the $^{12}\mathrm{C}(^{3}\mathrm{He},\gamma)^{15}\mathrm{O}$ reaction, leading to a nucleus in which a number of final states are energetically available, indicate that only a few are in fact populated. Those states, expected in the direct-capture picture to be of primarily 3-p,3-h character, are the same states which have been identified (with essentially the same relative strength) in the demonstrably direct[9] $^{3}\mathrm{He}$-transfer reaction $^{12}\mathrm{C}(^{6}\mathrm{Li},^{3}\mathrm{H})^{15}\mathrm{O}$. Figure 1 shows a comparison between our $^{12}\mathrm{C}(^{3}\mathrm{He},\gamma)$ results and those observed in the $^{3}\mathrm{He}$ transfer reaction. The cross sections for populating the $^{15}\mathrm{O}$ states seen in Ref. 9 have been turned into a simulated gamma-ray spectrum by a Monte Carlo program utilizing our gamma detector's monoenergetic gamma-ray response function.

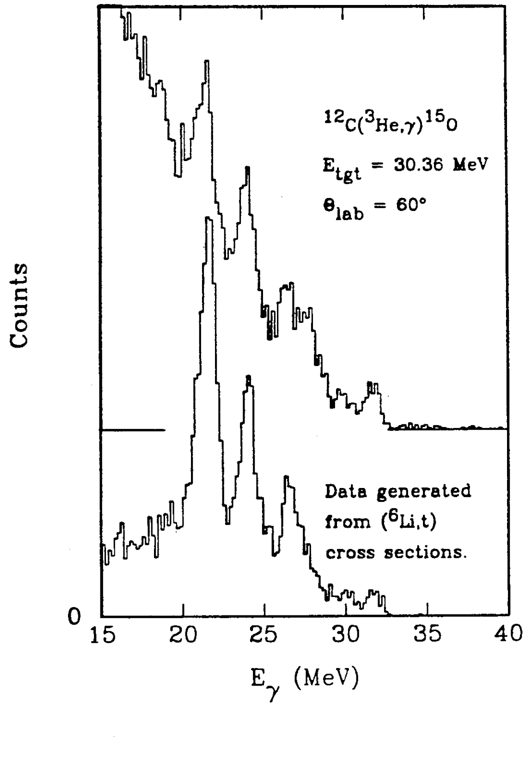

Figure 1. Comparison of $^{3}\mathrm{He}$ capture to $^{3}\mathrm{He}$ transfer. The upper histogram shows the γ-ray spectrum resulting from $^{3}\mathrm{He}$ capture into $^{15}\mathrm{O}$. The lower histogram was generated using cross sections for the $(^{6}\mathrm{Li},\mathrm{t})$ transfer reaction reported in Ref. 9.

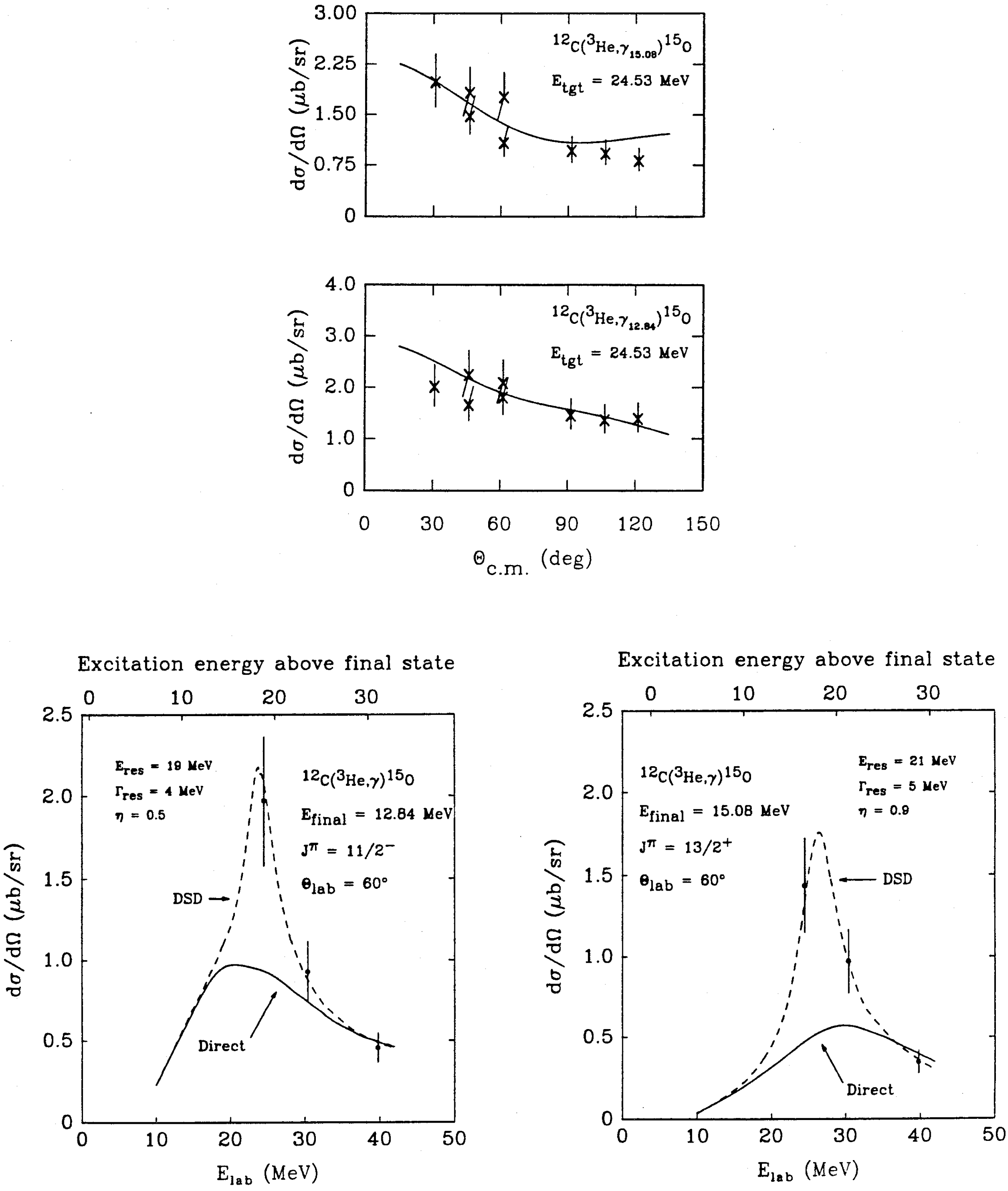

Figure 2. Differential cross section angular distributions and energy dependences for the 12.84 MeV and 15.08 MeV states in ^{15}O.

With this result in hand, we began making more detailed measurements of the $^{12}C(^3He,\gamma)$ reaction, looking at both angular distributions and energy dependences (to the limited extent allowed by the small cross sections and the constraints on cyclotron energy changes). Figure 2 shows the results of these new measurements. For the transitions to the two highest-lying states populated, this figure shows angular distributions, fit with calculations using the same direct-semidirect capture program utilized earlier in our analyses of proton capture data. The model does a good job of reproducing the ^3He capture measurements. The energy dependences are, unfortunately, only suggestive of what would be a previously unreported effect if it holds up after further experiments are performed. The direct term alone cannot reasonably account for either the magnitude or for the shape of the energy-dependent cross sections, while the addition of a semi-direct term (at exactly where the giant dipole resonance for these final states would be expected) goes nicely through the data points. Unfortunately, the sparse amount of data does not allow us to make unambiguous statements about the nature of the capture mechanism. In order to measure the more closely-spaced energy-dependent spectra needed to resolve this question, we have arranged a run at TUNL, where excitation functions can more easily be measured, for mid-1988. We eagerly await the results of that run.

The data we already have available on ^3He capture indicate that cluster capture reactions will be an extremely rewarding technique to explore more thoroughly in this energy range. In addition to the specific run described above, we hope to look at ^3He capture in other light nuclei, and to study (D,γ), $(^4He,\gamma)$, and other few-nucleon cluster capture reactions as complementary channels to more fully understand the magnitude and importance of n-particle, n-hole configurations.

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