^{3}He INDUCED PION PRODUCTION

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We have made a preliminary measurement of the pion spectrum from the $^{12}C(^3He,\pi^+)^{15}N^*$ reaction at 268 MeV bombarding energy and at a laboratory angle of 35° to search for the extremely rare "pionic fusion" process, in which the final nucleus is formed in a low-lying bound state and most of the kinetic energy of relative motion in the entrance channel is converted into a single fast pion.

Two theoretical models have been proposed recently to describe such a process. Klingenbeck, Dillig and Huber[1] (KDH) have developed a microscopic model in which the two-nucleon process $NN \rightarrow NN\pi$ is embedded in a many-body mechanism that leads naturally to a coupling of the initial relative motion to the final pion field. In this model, a meson exchanged between a nucleon in the projectile and a nucleon in the target nucleus excites one of the nucleons into a Δ-resonance, thereby avoiding thermalization and storing the kinetic energy of the entrance channel in an internal or quark excitation of a bound nucleon. This configuration propagates coherently through the nucleus and then decays into the final nuclear state by emitting a pion. Germond and Wilkin[2] have developed a model for the inverse reaction (pion induced fission) in which the pion is absorbed on a ^{4}He constituent of the target nucleus. They do not attempt to calculate this process microscopically, but establish a relationship between, for example, the $^6Li(\pi^+,^3He)^3He$ reaction and the $^4He(\pi^+,p)^3He$ subprocess. Their calculations are in partial agreement with the data for the inverse reaction.[3]

In the first $A(^3He,\pi^+)A+3$ experiments done in the near threshold region at Orsay,[3] a surprisingly large cross section (~20 nb/sr) was observed for the exclusive $^3He(^3He,\pi^+)^6Li$ and $^4He(^3He,\pi^+)^7Li$ reactions at $T(^3He) = 283$ MeV (94 MeV/nucleon). This is quite a large cross section at such a low energy (~30 MeV above threshold) and transferred momentum (~3 fm^{-1}). The cross section for the $^6Li(^3He,\pi^+)^9Be$ reaction at 270 MeV bombarding energy was found to be about 100 pb/sr, which is more than two orders of magnitude smaller than that for ^{3}He and ^{4}He targets. The transferred momentum in this case is about 3.6 fm^{-1}.

In the KDH model, one expects strong selection rules reflecting the structure of the specific state in which the final nucleus is left. Strongly excited states should be those whose cluster structure matches the entrance channel fragmentation. We therefore chose the $^{12}C(^3He,\pi^+)^{15}N$ reaction for our initial experiment to look for enhanced transitions to the 10.7 MeV ($9/2^+$) and 15.4 MeV ($13/2^+$) states in ^{15}N, which are believed to have a 3-nucleon cluster structure.[4]

Fig. 1 shows the $^{12}C(^3He,\pi^+)^{15}N$ spectrum obtained during a ~2 hr run with an average beam current of about 300 enA. We saw no evidence above background (~50 pb/sr) for transitions to bound final states, but a substantial yield was observed to the continuum. Checks were made to demonstrate that the counts in the continuum were due to pions and not positrons. The reaction mechanism for continuum production may be different from that responsible for transitions to bound final states, where a very large momentum transfer (~850 MeV/c) must be absorbed by the nucleus.

These results do not contradict the KDH model, since this model predicts a very rapid decrease in cross section with increasing target mass, largely due

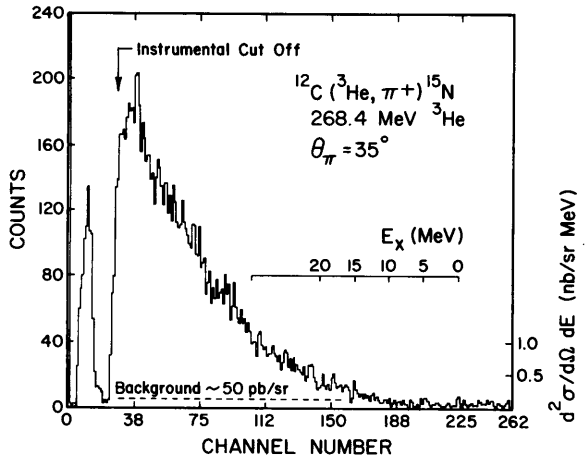

Figure 1. Pion spectrum from the reaction $^{12}C(^3He,\pi^+)^{15}N$ at T(^{3}He) = 268.4 MeV and θ_π = 35°.

to the increase in momentum transfer. The background level in Fig. 2 is about equal to the cross section observed at Orsay for the $^6Li(^3He,\pi^+)^9Be$ (E_x=0-3.0 MeV) reaction and hence is a good deal larger than that expected for $^{12}C(^3He,\pi^+)^{15}N$. The background could be reduced in future runs by optimizing the scintillator thicknesses in the focal plane detector array.

Fig. 2 shows the momentum transfers for the ^{3}He, ^{6}Li and $^{12}C(^3He,\pi^+)$ reactions, and the $^{16}O(p,\pi^+)^{17}O$ reaction for comparison. According to the KDH model,[1] the cross section for the coherent "pionic fusion" process should increase as the bombarding energy, and hence the momentum transfer, is decreased — until the point is reached (~30 MeV above threshold) where phase space dominates. Measurements of the energy dependence

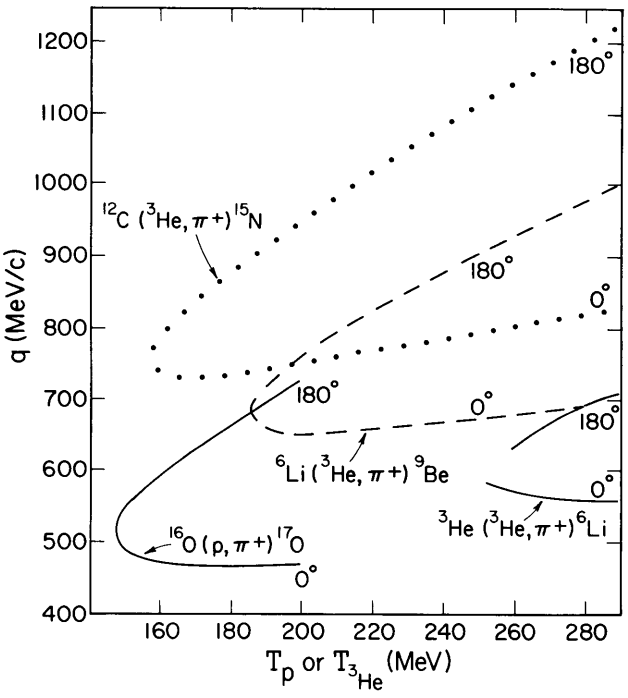

Figure 2. Momentum transfer vs. bombarding energy at θ_π = 0 and 180° for several (^{3}He,π^+) reactions and a typical (p,π^+) reaction.

of the (^{3}He,π) reaction would shed light on the nature of the multi-nucleon pion production process and provide guidance for further theoretical developments.

1) K. Klingenbeck, M. Dillig and M.G. Huber, Phys. Rev. Lett. 47, 1654 (1981); M.G. Huber and K. Klingenbeck in Pion Production and Absorption in Nuclei - 1981, ed. R.D. Bent (AIP Proceedings No. 79, 1982) p 89; M. Dillig, private communication (1982).

2) J.F. Germond and C. Wilkin, Phys. Lett. 106B, 449 (1981), and in Pion Production and Absorption in Nuclei - 1981 ed. R.D. Bent, (AIP Proceedings No. 79, 1982) p. 411.

3) Y. Le Bornec and N. Willis, ibid p. 155.

4) H.B. Bingham et al., Phys. Rev. C 11, 1913 (1975).