MEASUREMENT NEAR THRESHOLD OF THE (^{3}He, π) REACTION BY RECOIL DETECTION

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The (^{3}He, π) process leading to a bound final system (sometimes referred to as "pionic fusion") has been observed for several targets in the projectile lab energy range of 50-100 MeV/amu. While the cross-section is of order 10^{-32} cm^2/sterad for He targets, a much smaller yield appears to be typical of heavier targets such as Li and B.[1] The drop in yield is more than would be anticipated from the higher momentum transfer alone. More cases need to be studied before a proper understanding can be expected. A more efficient detection technique would make possible a systematic exploration of the pionic fusion process.

In the fall of 1982, we mounted an ion chamber of the Erskine[2] type in the focal plane of the IUCF QQSP spectrometer and an attempt was made to observe the ^{9}Be(^{3}He, π) process by measuring the mass-12 recoil longitudinal and transverse momentum distributions. The two-body pionic fusion process would be expected to produce a kinematic locus centered on the beam momentum with the position of the recoil event along the locus giving the missing pion momentum and thus the angle of emission.

The broad range and large solid angle of the QQSP makes possible in principle the concurrent detection with very high efficiency near threshold of ions of charge 5, 6, and 7, corresponding to the π^+, π^0, and π^- triplet.

While we succeeded in operating the QQSP for the first time at 0°, and were able to identify and measure the momentum distributions of many recoil species, and were able to demonstrate detection sensitivities of the order of 10^{-33} cm^2 for ^{12}B and ^{12}C ions, this first short run showed a number of difficulties which made it difficult to extract publishable cross-sections.

The heavy ion detector depth, in combination with the large spread in exit angles of the QQSP, limited the recoil ranges to a narrow band which could be centered on only one Z value per run. To pass the beam through the 0° exit port of the QQSP required running the magnetic field at a value which moved the higher energy ^{12}B events off the detector. A high flux of proton and alpha particles from the target appeared as noise on the baseline of the slow chamber pulses which gave tails on the mass identification spectra, and limited the useable beam currents to about 40 nA. The spallation background from carbon buildup on the target was found to be at the expected level. This limiting background would be much smaller for slightly heavier targets, but a detector with a lower mass in the ion path would be needed.

The November 1982 run showed that the recoil method was feasible but that a focal plane detector with better rate-handling properties was needed. During 1983 a new detector array was assembled by the Munich

participants and a short development run was made in October to test the improved setup. The detector array consisted of two PPAC low-mass chambers covering about half the width of the focal plane and separated by about 10 cm to give horizontal and vertical position and angle for each ion, along with a precise arrival time measurement to give the ion velocity (in combination with the cyclotron rf). The PPAC were followed by a thin-windowed proportional chamber for dE/dx information.
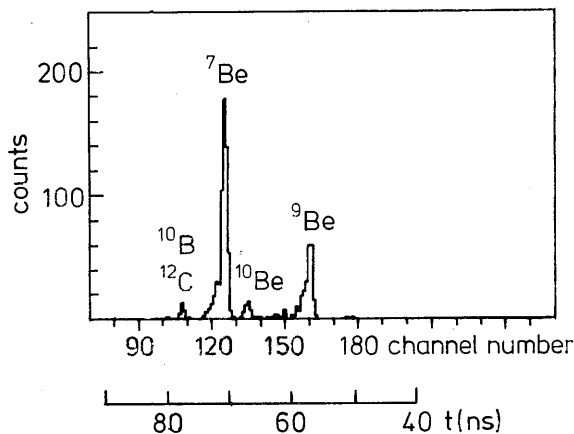
The array measured horizontal and vertical recoil emission angles at the target to a precision of 0.1^o and 1° respectively, the difference being due to the respective magnifications of the QQSP optics. The flight time could be measured to better than 0.7 ns. Velocity and magnetic rigidity are combined to give a precise ion charge-to-mass ratio, with the proportional chamber pulse height used to remove ambiguities such as ^{10}B and ^{12}C.

Analysis of the data tapes is just beginning. A representative mass spectrum is shown in Fig. 1. The foldover from the rf frequency can be removed by the second, short-path velocity measured between the two PPAC detectors.

While it is still too early to quote any definitive performance data from the most recent test run, it appears that the new detector setup is very well-behaved under demanding running conditions and that it may now be possible to apply the method to pionic fusion measurements.

Figure 1. Time-of-flight spectrum measured with a 0.5 mg/cm^2 Be target and an incident ^{3}He beam of 180 MeV. The faster ^{7}Be arrived one rf period earlier than the ions of masses 9 through 12.

1) Y. LeBornec et al., Phys. Rev. Letters 47, 1870 (1981).

2) J.R. Erskine, Nucl. Instrum & Methods 135, 67 (1976).