Search for ^{14}F via the reaction ^{13}O + p

V. Z. Goldberg, G. G. Chubarian, B. T. Roeder, A. Banu, M. McCleskey, E. Simmons, G. Tabacaru, L. Trache, R. E. Tribble, G. V. Rogachev,[1] E. Johnson,[1] M. A. Coronado,[1] J. Mitchell,[1] and C. Fu[2]

[1]*Department of Physics, Florida State University, Tallahassee, Florida 32306, USA*

[2]*National Institute of Standards and Technology (NIST), Gaithersburg, MD, USA*

Beams of exotic (radioactive) nuclei are mainly used to obtain new data on exotic nuclei in nuclear reactions. These beams are most easily produced at high energies (> 30 MeV/u) via projectile fragmentation or fusion-evaporation reactions in inverse kinematics due to the high negative Q-value for these reactions. Therefore, the beam ions produced in the reactions also have relatively high energy. However, various experimental and theoretical considerations often require lower energy beams (< 10 MeV/u). In these cases, the ISOL method of exotic beam production is preferable, where available. Unfortunately, as one approaches the limits of particle stability and the time delay between the beam production in the ISOL target and re-acceleration increases, the final yield for the most exotic nuclei is greatly reduced. Taking into account the low cross section for the initial production of the most exotic nuclei, slowing down the beam in a medium and then re-accelerating could result in a non-negligible loss in intensity.

In a recent experiment at the Texas A&M University (TAMU) Cyclotron Institute, a search for the resonance states in ^{14}F was conducted. There exist no experimental data on this exotic odd-odd nucleus. ^{14}F has three neutrons less than the lightest known particle-bound Fluorine isotope (^{17}F) and is also expected to be unstable to proton decay [1]. To study ^{14}F, the reaction ^{13}O+p resonant scattering employing the thick target inverse kinematics method (TTIK) [2] was used. The most effective reaction to produce ^{13}O ($T_{1/2}$=8.6ms) at TAMU was found to be ^{1}H(^{14}N, ^{13}O)2n (Q-value = =-29.1 MeV) with E(^{14}N) ≥ 31.2 MeV/u. However, the TTIK requires that the beam energy should be relatively low (~10 MeV/u) [3].

Since the ISOL method mentioned above is unavailable at TAMU and difficult or impossible to use at other facilities for ^{13}O, we used a different approach for the experiment. The ^{13}O secondary beam was produced with a ^{14}N primary beam at 38 MeV/u impinging on a hydrogen gas target, cooled by liquid nitrogen, with a pressure of 3 atm. The 31 MeV/u ^{13}O beam resulting from the fusion-evaporation reaction was then separated and delivered to the target chamber with the conventional MARS [4] approach. The intensity of the ^{13}O secondary beam was ≈5x10^{3} p/s for a ^{14}N beam intensity of ≈100 pnA. A thick polypropylene foil of (≈1.5 mm) was placed in the middle of the MARS scattering chamber to degrade the beam energy of the ^{13}O (see Fig. 1). This energy degrader was necessary in order to reduce the ^{13}O beam to the energies required for the TTIK method. Next, the beam passed through a 0.1 mm Bicron-400 plastic scintillator placed 100 mm downstream from the polypropylene foil. Two PMTs around the scintillator provided the start time signal and a measurement of the intensity of the beam. The sum of the PMT signals was also used to analyze the specific energy loss in the scintillator. The 10% energy resolution provided for complete separation of ^{13}O events from ^{10}C events (≈12% contamination in the beam) (Fig. 2). Following the scintillator (10mm distance), the beam enters the TTIK scattering

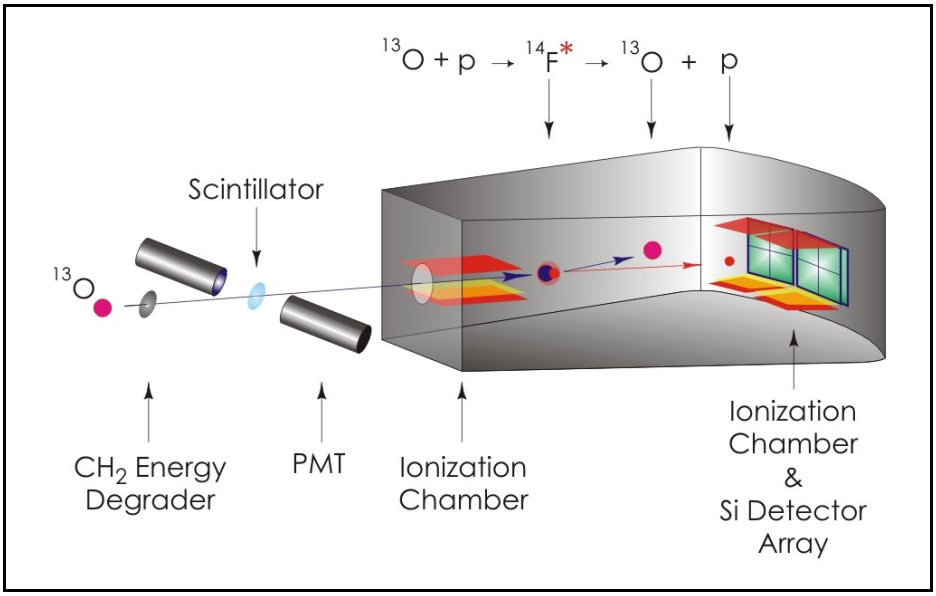

FIG. 1. Diagram showing the TTIK chamber and the detector setup

chamber [3] (see Fig. 1) through a thin Havar window (3μm). The TTIK chamber was filled with methane gas (CH_4) to provide the target to study the ^{13}O+p resonant interaction. At the entrance of the TTIK

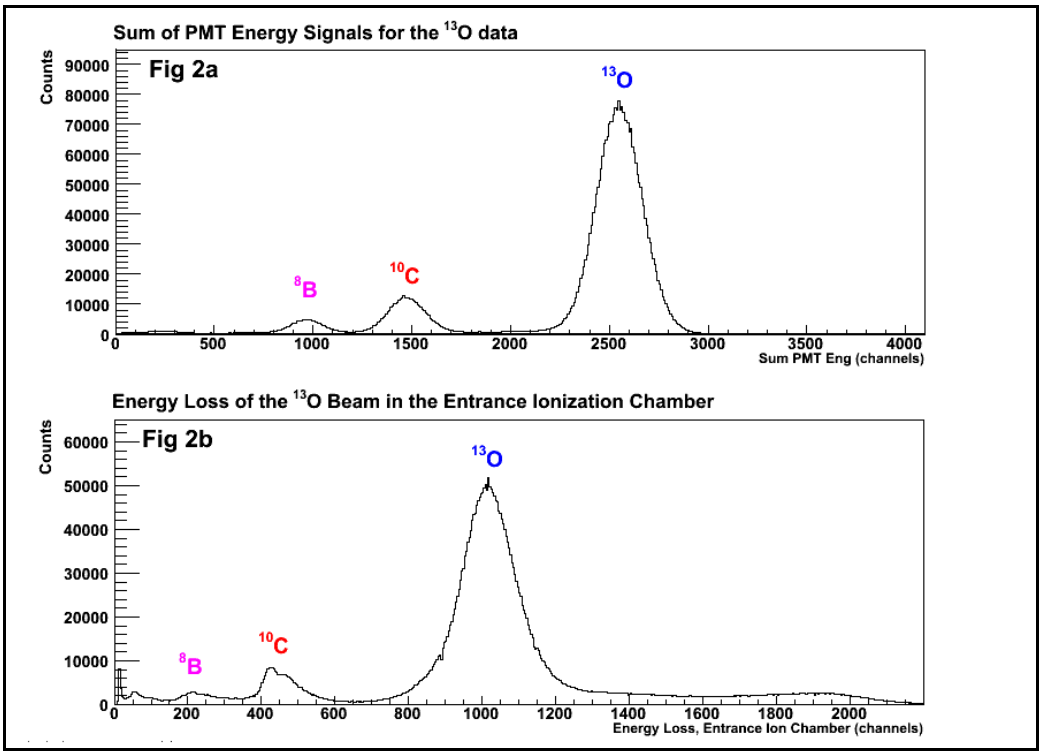

FIG. 2. Energy spectra obtained from the sum of the PMT signals (2a) and the energy loss in the Entrance Ionization Chamber (2b). The ^{13}O events are well separated from the contaminants in the beam in both cases.

chamber, there was a windowless ionization chamber working with the gas in the scattering chamber. At the entrance of the TTIK scattering chamber, the energy of ^{13}O was ≈11MeV/u, but due to energy straggling in foils and the scintillator, the beam energy spread was ≈16 MeV, and the angular divergence was about 2 degrees. However, the loss of intensity due to slowing down the energy was less than 10% according to events in the entrance ionization chamber. One of the advantages of the TTIK method is that, despite this poor beam quality, it is still possible to study resonance reactions with an expected final energy resolution better than 100 keV. The energy resolution of the entrance ionization chamber is better than the width of the beam and this can be used to further improve the final resolution during the offline data analysis.

The pressure of the gas in the chamber was adjusted to stop the ^{13}O ions before the Si detector telescopes placed near the wall of the scattering chamber. Before the detector telescopes, there were two small ionization chambers. This detection system provides for the clear identification of the protons from the reactions in the scattering chamber. The ^{13}O measurements were made with methane gas in the chamber and with a gas mixture of Ne+CO_2 (background measurements). In addition, measurements were made with the ^{14}O beam (instead of ^{13}O) to compare results with published data for previous measurements of resonances in ^{15}F [5]. The analysis of this data is ongoing and we expect to have some results within a few months.

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