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Cite as: AIP Conference Proceedings **2160**, 070010 (2019); https://doi.org/10.1063/1.5127733
Published Online: 02 October 2019

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Proton Spectroscopic Strengths of ^{18}Ne

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Abstract: Much effort has been made to understand the origins of ^{18}F in novae. Due to its relatively long half-life (~2 hours), ^{18}F can survive until the nova envelope is transparent, and therefore can provide a sensitive diagnostic of nova nucleosynthesis. It is likely produced through the beta decay of ^{18}Ne, which is itself produced (primarily) through the ^{17}F(p,γ) reaction. Understanding the direct capture contribution to the ^{17}F(p,γ) reaction is important to accurately calculate it. As such, the proton spectroscopic strengths of low-lying states in ^{18}Ne are needed. At the University of Notre Dame a measurement of the ^{17}F(d,n) reaction has been performed using a beam produced by the *TwinSol l*ow energy radioactive beam facility. Preliminary data analysis is presented.

Introduction

Classical novae occur in binary star systems when a white dwarf accumulates enough material to trigger an explosive release of energy. During this time many unstable isotopes are created via the hot CNO cycle and material subsequently ejected into the interstellar medium. This ejected material forms an envelope which is initially opaque to gamma rays. As the envelope expands and cools, the decay signature of some radioactive nuclei, predominately 511 keV gamma rays, becomes observable by satellites such as INTEGRAL. [1] These 511 keV gamma rays are emitted from electron-positron annihilation following the β^+ decay of the neutron-deficient radioactive material. Due to its relatively long half-life ($T_{1/2} \approx 110$m) and high abundance, ^{18}F is a likely candidate for the source of observable gamma rays. As such it is critical to attain a proper understanding of the amount of ^{18}F remaining after the explosive burst.

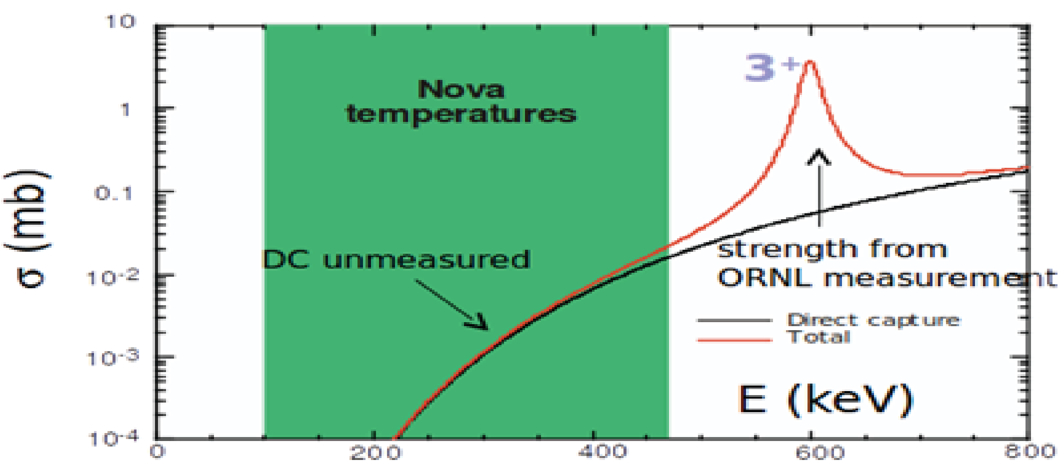

Figure 1: Cross section of the ^{17}F(p,γ) reaction demonstrating how direct capture dominates at the astrophysically relevant energies.

25th International Conference on the Application of Accelerators in Research and Industry
AIP Conf. Proc. 2160, 070010-1–070010-4; https://doi.org/10.1063/1.5127733
Published by AIP Publishing. 978-0-7354-1905-6/$30.00

^{18}F is primarily created from the reaction sequence $^{16}O(p,\gamma)^{17}F(p,\gamma)^{18}Ne(\beta^+)^{18}F$. From this it is clear that a detailed understanding of the $^{17}F(p, \gamma)$ reaction rate is essential to predict the amount of ^{18}F that will be available to decay. At novae temperatures the reaction cross section is dominated by the unmeasured direct capture rate, though there is a significant contribution by a strong 3^+ resonance at 599.8-keV, above the proton threshold (See Figure 1). [2] The current intensities of beams of ^{17}F readily available are insufficient to measure the direct capture cross section directly. As such, indirect means are necessary to determine the spectroscopic strengths of the bound states of ^{18}Ne which then constrain the direct capture contribution.

Experimental Description

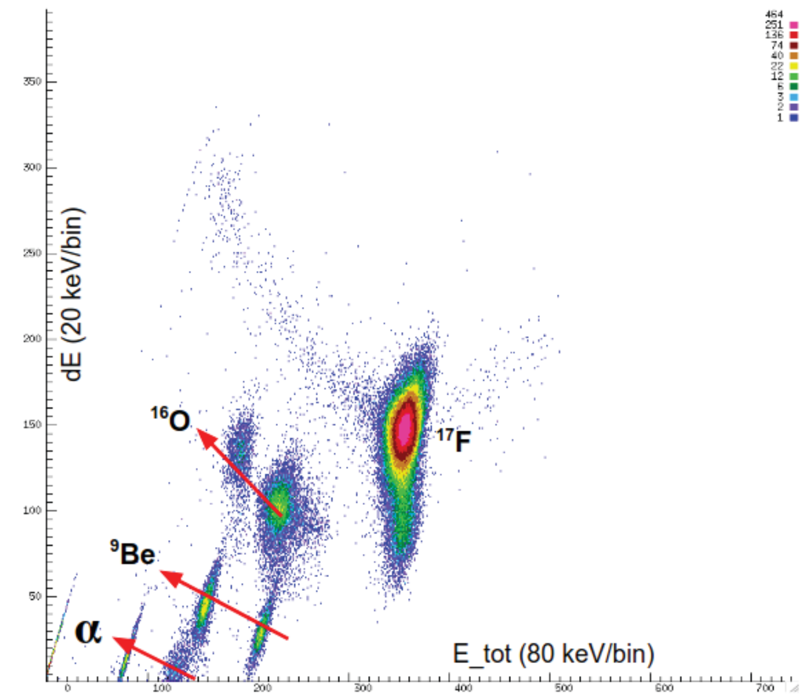

Figure 2: Particle ID plot taken with a silicon telescope placed at the target location.

At the University of Notre Dame (UND), a study of the $^{17}F(d,n)$ reaction was performed in inverse kinematics utilizing the *TwinSol* device to create a beam of radioactive ^{17}F where *TwinSol* is a coupled pair of superconducting solenoids used to created radioactive ion beams by impinging a gas cell production target. The reactants are then collected, purified, and focused by the coupled solenoids. A more detailed description can be found in [3]. The resultant 57.2 MeV beam of ^{17}F was bombarded onto a 510 μg/cm^2 CD_2 target at a rate of roughly 2 x 10^5 pps. The beam was 87% pure with the primary contaminants being ^{16}O and ^{9}Be (See Figure 2). Beam optimization was done using a calibrated silicon telescope, a 20-μm silicon detector backed by a 1000-μm detector, mounted at the CD_2 target location.

Figure 3 shows the experimental setup. The outgoing neutrons were detected in a combination of the two arrays: VANDLE and UMDSA [4,5]. The University of Michigan Deuterated Scintillator Array (UMDSA) covering laboratory angles in the range 18º to 120º (28º to 151º in the center-of-mass frame). The Versatile Array of Neutron Detectors (VANDLE) is an array of plastic scintillators covering in the angular range 40º to 170º (8º to 117º in the center-of-mass frame). [6] The recoils were detected downstream in a plastic scintillator which provided a reference times so that the time-of-flight of the neutrons could be determined.

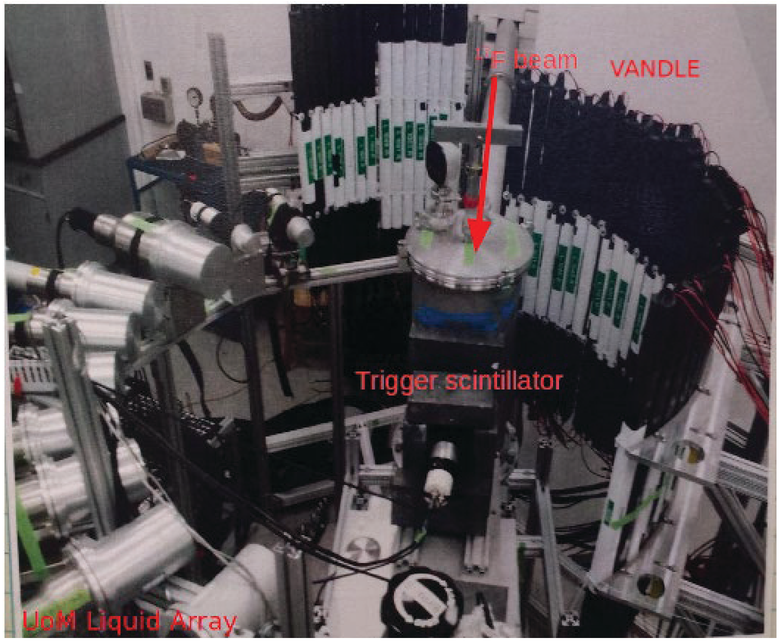

Figure 3: Experimental setup comprised of UMDSA (left), VANDLE (right), and the trigger scintillator (center)

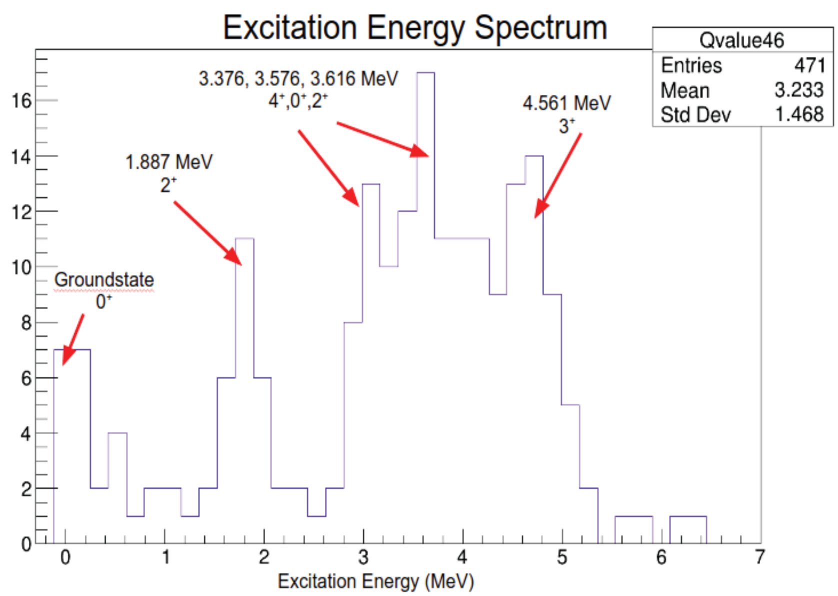

Figure 4: Summed excitation energy spectrum.

Data Discussion

Unfortunately, the VANDLE bars did not have the capability to do pulse shape discrimination (PSD) so the data was swamped by room background gamma rays. PSD in UMDSA rendered these data almost entirely free of gamma background. Figure 4 shows an excitation energy spectrum extracted from UMDSA. We see clear population of the ground-state and several of the bound states. In addition we see significant population of the 3+ unbound state. The spectroscopic strength of this state has been measured multiple times, and the data will be normalized to this state [7,8]. The intrinsic efficiencies of these detectors has been well studied via the ^{7}Li(p,n) reaction. Currently, angular distributions are being extracted and spectroscopic strengths will be determined.

In conclusion the ^{17}F(d,n) reaction was measured in order to determine the spectroscopic strengths of low-lying states in ^{18}Ne. An excitation energy spectrum is shown and currently angular distributions are being extracted in order to determine the spectroscopic strengths of these states. These spectroscopic factors will allow a more precise calculation of the ^{17}F(p,γ) reaction rate.

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