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Constraining the 15O(α,γ) 19Ne reaction rate using the GADGET II TPC

The 15O(α,γ)19Ne breakout reaction from the hot CNO cycles is significant to the thermonuclear runaway that causes type I X-ray bursts on accreting neutron stars. At breakout temperatures (≈0.5GK), this reaction is strongly dominated by a single resonance with center of mass energy 506 Kev corresponding to a 19Ne state having excitation energy of 4.03 MeV. An experimental upper limit has been placed on its strength, but the lower limit on the resonance strength and therefore the astrophysical reaction rate is unconstrained experimentally. Since the lifetime of the state is well known, only a finite experimental value for the alpha-particle branching ratio is needed to determine the rate. With this strong motivation, we have proposed an experiment to measure a finite value for the branching ratio and hence the reaction rate at FRIB using an upgraded version of the Gaseous Detector with Germanium Tagging (GADGET) and this proposal has been accepted by the FRIB's first Program Advisory Committee (PAC). These measurements will proceed via the 20Mg(βpα)15O decay sequence using the β decay of 20Mg followed by a proton emission to the 4.03 MeV 19Ne state. These decay events yield a characteristic signature: the emission of a proton and alpha particle. To achieve the high granularity necessary for the identification of this characteristic signature, we have upgraded the GADGET's Proton Detector into a time projection chamber (TPC). A MICROMEGAS board with 1024 (2.2×2.2 mm2) pads and high-density GET electronics has been installed to accommodate the large number of electronics channels. In order to test the functionality as a TPC, a 228Th source is placed inside the gas handling system of the detector which allows us to bleed 220Rn α inside the TPC. The α tracks from the 220Rn decay have been successfully seen, demonstrating the system's functionality. This upgraded version is known as GADGET II and has three distinct elements: the Segmented Germanium Array (SeGA) for γ - detection, a beam-pipe cross that houses a beam energy degrader and diagnostics, and the new TPC. The TPC has been simulated using the ATTPCROOTv2 data analysis framework based on the FairRoot package for 20Mg and 220Rn decay events. Based on these simulations, a machine learning algorithm is being developed that will be integrated with the ATTPCROOTv2 analysis framework to identify candidates in the data. Transfer learning will be used to refine the machine-learned models after the experiment using real in − situ data on 20Mg(βp)19Ne events for single protons and 20Na(βα)16O daughter-decay events for single alphas. These simulations will be useful in selecting events of interest based on their unique signature to provide background free measurements.
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