Experimental study of astrophysically important $^{22}Ne(\alpha,n)^{25}Mg$ reaction via $^{22}Ne(^{6}Li,d)^{26}Mg$ reaction performed at sub-Coulomb energies

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The $^{22}Ne(\alpha,n)^{25}Mg$ reaction is a very important reaction for nuclear astrophysics as a source of neutrons for the *s*-process that is responsible for the formation of about half the elements heavier than Iron [1]. The weak component of the s-process occurs in massive stars ($M>10M_o$), where the $^{22}Ne(\alpha,n)^{25}Mg$ reaction is the dominant neutron source during the helium burning and the carbon-shell burning phases [2].

The direct measurement of the $^{22}Ne(\alpha,n)^{25}Mg$ reaction at energies that cover Gamow window energy range cannot be done at present because the cross section is prohibitively small. Hence, we conducted series of experiments that allowed us to develop a technique to constrain the $^{22}Ne(\alpha,n)^{25}Mg$ reaction and other astrophysically relevant α-capture reactions using low energy beams from K150 cyclotron and MDM spectrometer.

First, we investigated the well-studied reaction $^{12}C(^{6}Li,t)^{15}O$ [3]. This was the test run to verify detection of Z=1 ions in the MDM focal plane detector (Oxford) and determine energy resolution. This reaction was carried out using a beam of 72 MeV ^{6}Li ions and a self-supporting ^{12}C target with a thickness of 45 μg/cm^2. The reaction products were separated using the MDM spectrometer placed at 4.95^0 from the beam axis, and the tritons, populating the known states of ^{15}O (namely 12.84 MeV and 15.05 MeV), were observed by the focal plane detector (Oxford). The spectrum of tritons is shown Fig. 1. It is very similar to that measured in [3] and it was found that the energy resolution was better than 80 keV.

After the completion of this experiment, the Ni-Cr proportional counter wires inside the Oxford Detector were replaced with the new set of slightly thinner wires made out of stablohm-675, which resulted in better position resolution for the particle trajectories.

In order to constrain the $^{22}Ne(\alpha,n)^{25}Mg$ reaction, the α-capture reaction of $^{22}Ne(^{6}Li,d)^{26}Mg$ was carried out at sub-Coulomb energies. We used a 1.0 MeV/u beam of ^{22}Ne ions and a ^{6}LiF target of thickness 30 μg/cm^2 made on a 10 μg/cm^2 ^{12}C backing. The MDM spectrometer was set at 5^0 relative to the beam axis. The magnetic field settings of the spectrometer were set to cover the deuteron energies populating the 10.6 MeV – 11.5 MeV excitation energy range of the ^{26}Mg nucleus. For the recoil deuterons, the focal plane of the MDM spectrometer was positioned very close to the 3rd proportional counter wire of the Oxford detector. The raw position spectrum of this wire (Fig. 2) depicts the various states of ^{26}Mg that were observed in this experiment. It is clear from Fig. 2 that while statistics was not sufficient for conclusive results, the states in ^{26}Mg have been populated. In particular, we observed about 50 events that correspond to the known 11.3 MeV state in ^{26}Mg [4] (raw position 0.3 in Fig. 2) that plays

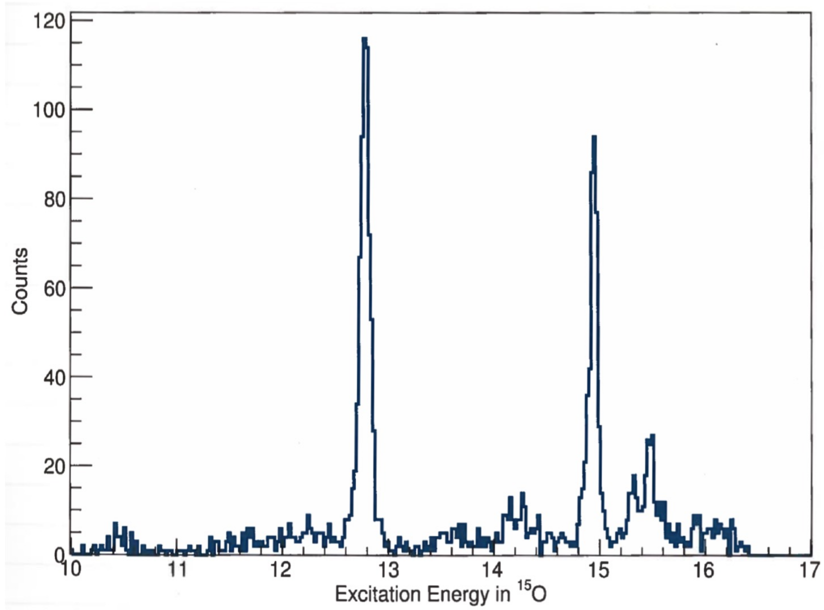

FIG. 1. The spectrum of tritons from the $^{12}C(^{6}Li,t)^{15}O$ reaction measuredby the MDM spectrometer and Oxford detector. The two strongest peaks are the known 12.84 MeV and 15.05 MeV states in ^{15}O.

an important role in the $^{22}Ne(\alpha,n)^{25}Mg$ reaction at astrophysical energies. Hints of the lower lying states (raw position >0.3 in Fig. 2), that may be even more important, have been observed. Better statistics has to be accumulated however. At the time of this writing, an experiment that featured a factor of 10 better

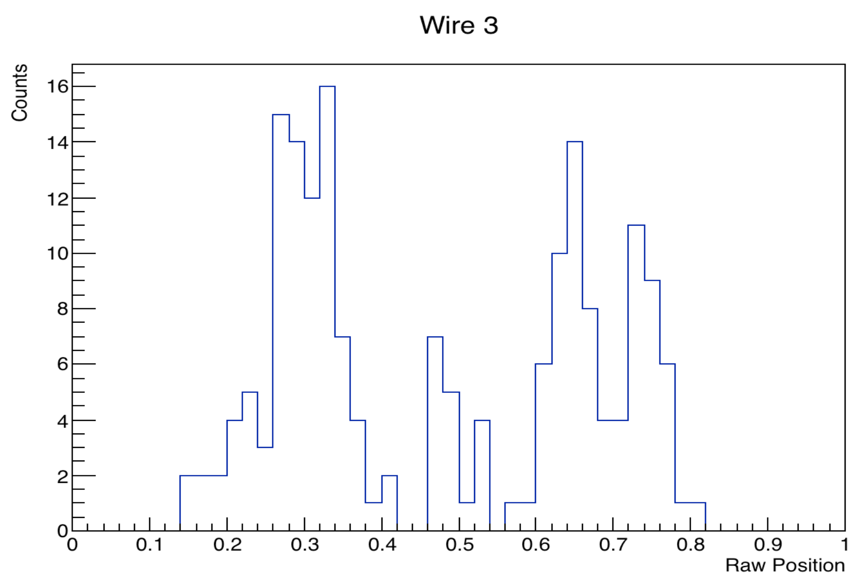

FIG. 2. 3rd wire raw position of deuterons from the $^{6}Li(^{22}Ne,d)^{26}Mg$ reactions. The strong leftmost peak is a known 11.3 MeV states in ^{26}Mg [4].

statistics has been performed in April. The analysis is currently underway. We believe that we will be able to dramatically reduce the uncertainties for the $^{22}Ne(\alpha,n)^{25}Mg$ reaction cross section at low energies when the analysis is complete.

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