Neutron-transfer and elastic scattering with ^{26}Mg

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The one neutron transfer and elastic scattering of ^{26}Mg was studied using a 12 MeV/nucleon beam and the MDM spectrometer. The motivation is two fold. First, we use the transfer ^{13}C(^{26}Mg,^{27}Mg)^{12}C to obtain the ANC of ^{27}Mg and from it that of ^{27}P through mirror symmetry, which will allow the direct component of the radiative proton capture on ^{26}Si at stellar energies to be estimated. The second is to add to the systematics of elastic scattering data with *sd*-shell projectiles in this energy region.

^{26}Al, through its β-decay to the 2+ excited state ^{26}Mg and the subsequent decay into the ground state (0+) via a 1.809 MeV γ-ray, is an important observable for many astrophysical events, and many efforts have been put forth to map the Galaxy by means of this γ-ray [1]. It is therefore of great interest to understand the nucleosynthesis of ^{26}Al within the various astrophysical environments in which it is produced, including supernovae, novae, Wolf-Rayet stars and red giants. The nucleosynthesis of ^{26}Al is complicated by the presence of a low-lying (228.3 keV) 0+ isomeric state. This isomeric state is very strongly inhibited from decaying by γ-ray emission to the ground state (5+) of ^{26}Al due to the large spin difference. Its lifetime is much shorter (6.345 sec) and it β-decays directly to the ground state of ^{26}Mg through a super-allowed 0+ to 0+ transition, thus avoiding the observable 1.809 MeV γ-ray of interest. However, at high temperatures (T_9= 0.4 [2]) equilibrium is reached between ^{26gs}Al and ^{26m}Al which is relevant to some high temperature astrophysical events such as novae. The rate of the ^{26}Si(p,γ)^{27}P reaction is important because it depletes ^{26}Si that would otherwise be available to β^+ decay into the isomeric state of ^{26}Al.

Because of its short lifetime it is not possible to make a target of ^{26}Si that could then be bombarded by protons. Even if such a target could be made, the experiment could not be reasonably done in a terrestrial laboratory at astrophysical energies due to the Coulomb repulsion and the very small cross sections that result. The reaction in inverse kinematics would also be difficult due to the proton target, the radioactive ^{26}Si beam and the problem with the Coulomb repulsion. These difficulties indicate an indirect approach to the experimental problem. The ^{26}Si(p,γ)^{27}P reaction has been suggested [3] as a candidate to be studied by means of the relevant mirror nucleus, ^{27}Mg. The astrophysical reaction rate for the ^{26}Si(p,γ)^{27}P reaction can be determined from the ANC of ^{27}P which in turn can be determined by first finding the ANC of the mirror nucleus ^{27}Mg and then using charge symmetry considerations to extract that of ^{27}P (see [4]).

To find the ANC for ^{27}Mg, a ^{26}Mg beam was used on a thin (100 μg/cm^2) ^{13}C target and both elastic scattering and ^{13}C(^{26}Mg,^{27}Mg)^{12}C single neutron transfer were measured. The 12 MeV/nucleon ^{26}Mg beam was accelerated by the K500 superconducting cyclotron at Texas A&M University, and was delivered through the Beam Analysis System (BAS) and onto the ^{13}C target. Reaction products were separated using the Multipole-Dipole-Multipole (MDM) spectrometer and were observed by means of the Oxford detector. The Oxford detector consists of an ionization chamber filled with isobutene, with

two anode plates to measure energy loss in the gas, four position-sensitive avalanche counters (ACs) to measure the position and angle in the detector, and a plastic scintillator in which the reaction products stop and their residual energy is measured by means of two phototubes.

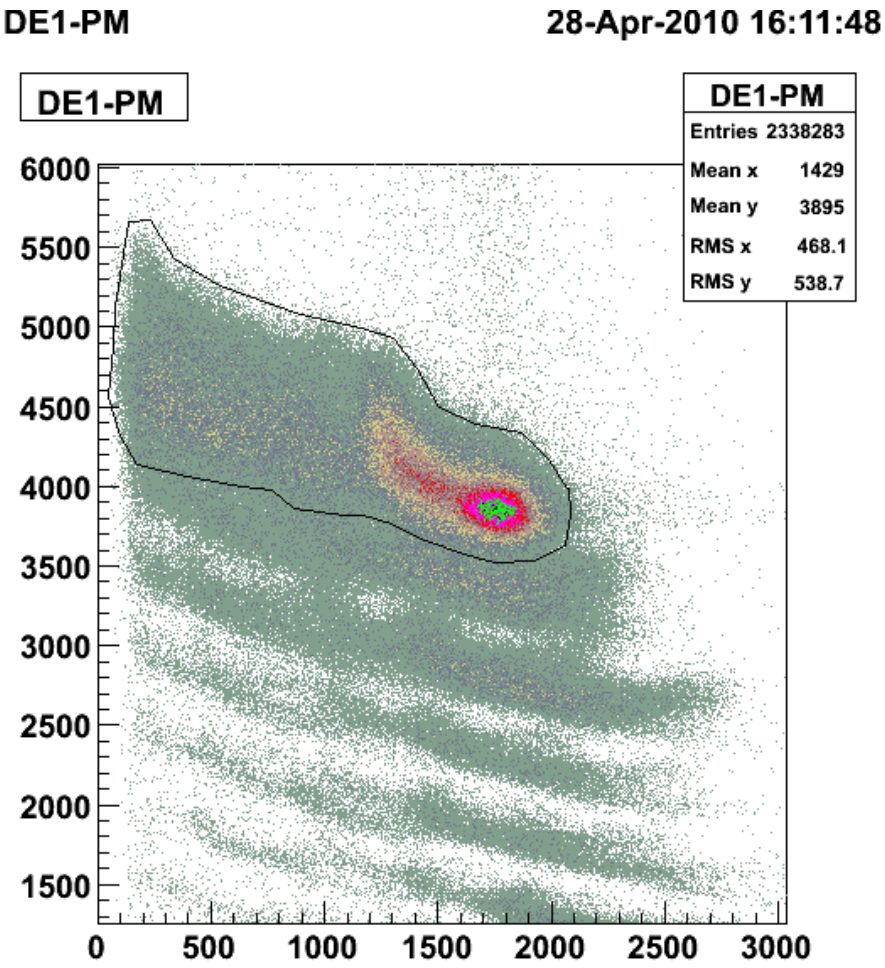

FIG. 1. $\Delta E\text{-}E_{res}$ measured with the MDM spectrometer centered at 6 deg.

As we go to increasingly higher masses, isotope identification with the detector becomes more difficult. In an attempt to reduce noise, this experiment was performed using a new electronics setup with all signal processing and recording electronics in the cave, utilizing CAEN 16ch shaper-amplifier modules and Mesytec VME ADCs. Particle identification was made in two steps. First, as Z separation is still good, Mg was selected using a polygon condition applied to a $\Delta E\text{-}E_{res}$ histogram [Fig. 1]. Next the isotopes of Mg (^{26}Mg and ^{27}Mg for the elastics and transfer respectively) were found to be well separated in a plot of their position in the focal plane vs. their residual energy [Fig. 2]. The focal plane position of the individual isotopes was then plotted as a function of the reconstructed target angle from which the angular distributions were obtained. Angular distributions for the ground state and first excited state for

^{26}Mg were measured from 2 to 14° in the laboratory frame, while distributions for the single neutron transfer to the ground state and first excited states of ^{27}Mg were measured from 2° to 11° lab.

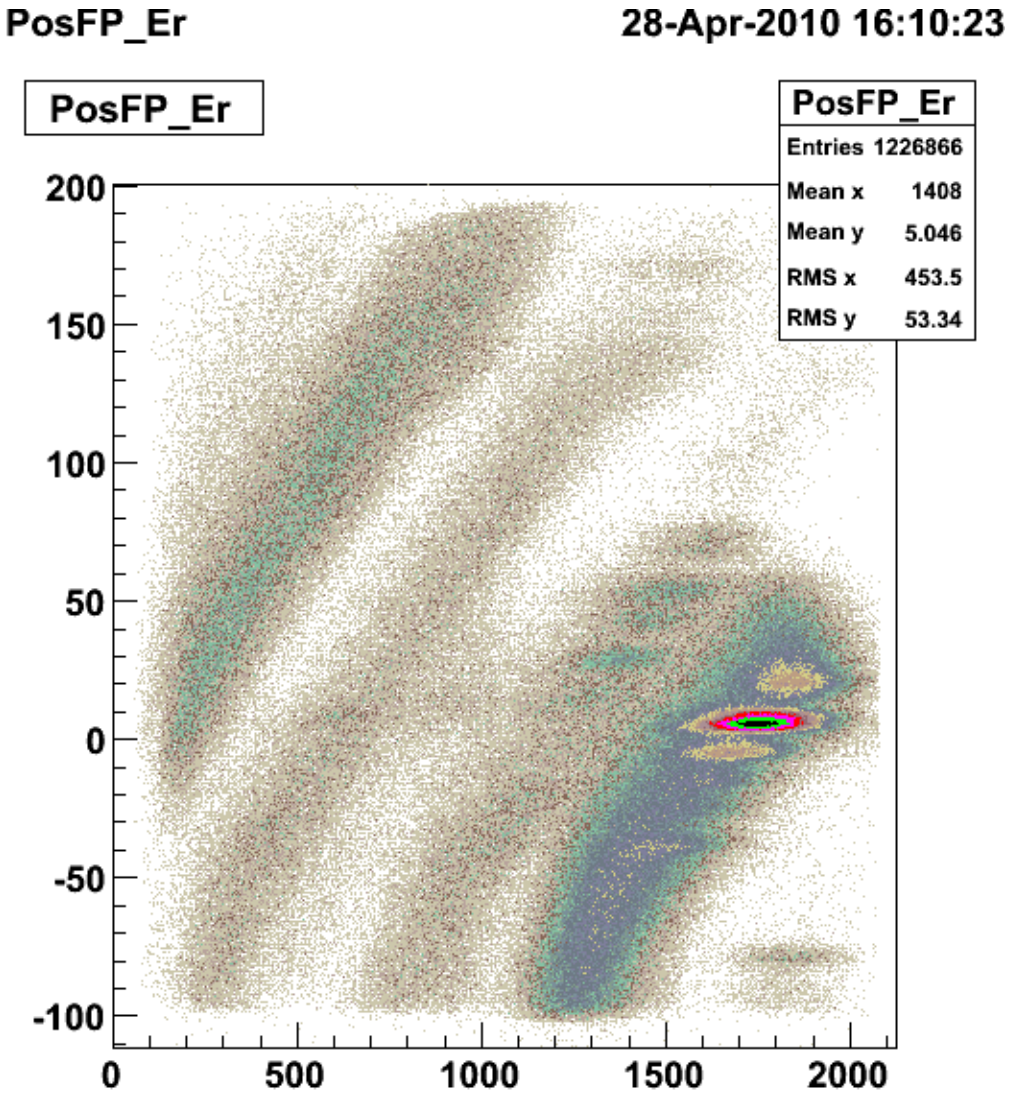

FIG. 2. Separation of Mg isotopes in a focal plane position vs. E_{res} histogram.

Work is currently underway to fit the elastic angular distribution starting from optical model potentials obtained by the double folding procedure of Ref. [5]. The optical model parameters found for the elastic scattering will be applied to the entrance and exit channels in DWBA calculations of the one neutron transfer. Preliminary angular distributions are shown in Fig. 3.

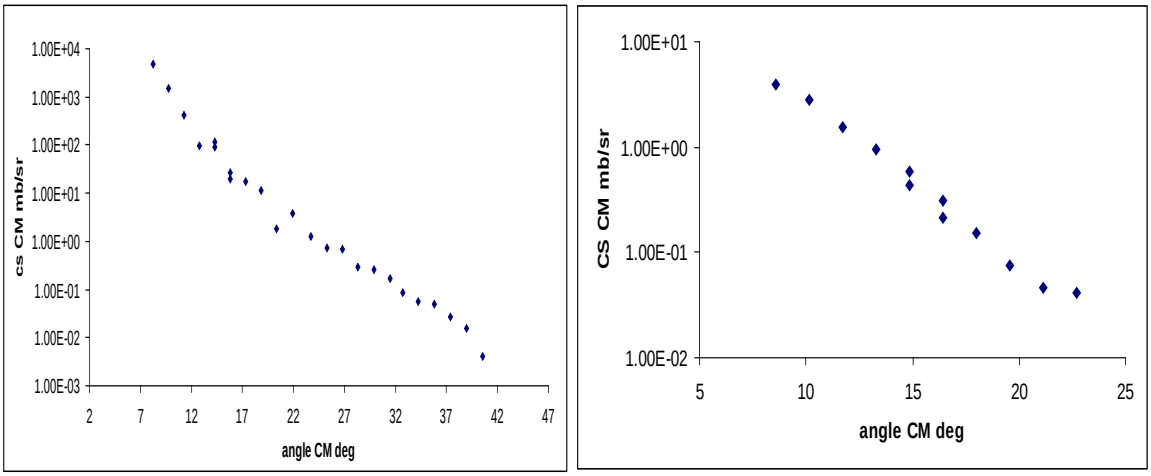

FIG. 3. On the left is the measured angular distribution for the elastic scattering of ^{26}Mg on ^{13}C. On the right is the angular distribution for the transfer reaction ^{13}C(^{26}Mg, ^{27}Mg) ^{12}C.

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[2] A. Coc, M.-G. Porquet, and F. Nowacki, Phys. Rev. C **61**, 015801 (1999).

[3] R.E. Tribble, private communication.

[4] N.K. Timofeyuk, *Deducing Stellar Reaction Rates from Mirror Nuclear Decays*, Nuclear Physics News, Vol. **19**, No. 2

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