The study of $^{27}Si(p, \gamma)^{28}P$ reaction using its mirror $^{27}Al(n, \gamma)^{28}Al$

A. Spiridon, R. Chyzh, M. Dag, B.T. Roeder, A. Saastamoinen, and R.E. Tribble

X-ray bursts are the most frequent thermonuclear explosion occurring in the universe and represent one type of phenomena responsible for heavier element nucleosynthesis. For this reason and others, a number of powerful X-ray observatories have been used to take large amounts of data on these bursts. The interpretation of these observations, however, is problematic due to the lack of a complete understanding of the nuclear physics at the base of these phenomena [1]. Among the various processes occurring in X-ray bursts, the most important is the rp-process. It is dominated by (p, γ), (α, p) reactions and β-decays. Critical nuclear data is needed related to these processes such as: nuclear masses, β-decay rates and reaction rates. There have been major strides made for the first two parameters. However, as most of the nuclei participating in the rp-process do not exist as stable nuclei, most of the reaction rates, so far, have only been estimated based on theory [2].

As with any nuclear reaction network, some reactions are more important than others. Several have been suggested for X-Ray bursts following different model calculations. One such reaction that we chose to research is the radiative proton-capture reaction $^{27}Si(p, \gamma)^{28}P$. We studied this indirectly using the mirror reaction $^{27}Al(n, \gamma)^{28}Al$ with the purpose of using the properties of the mirror nuclei ^{27}Al and ^{28}Al in the estimation of the reaction rate.

A series of 4 experiments were done for this with the purpose of obtaining (1) the elastic cross-section distribution for optical model potential parameters and (2) the neutron transfer cross-section distribution for the DWBA analysis and the determination of the asymptotic normalization coefficients.

The first pair of experiments was done in direct kinematics with a beam of ^{13}C at 12 MeV/n on targets of ^{27}Al of different thicknesses (100 $\mu g/cm^2$, 270 $\mu g/cm^2$ and 800 $\mu g/cm^2$). The second pair was done in inverse kinematics with a beam of ^{27}Al at 12 MeV/n on a target of ^{13}C (100 $\mu g/cm^2$). All four studies were done at Texas A&M University using beams accelerated by the K150 cyclotron. The reaction products were separated using the Multipole-Dipole-Multipole (MDM) spectrometer and the nuclei of interest were observed with the Oxford focal plane detector.

Preliminary results can be seen in the Fig. 1. Pictures (top left) and (top right) show the angular distributions of the elastic and transfer cross-sections in C.M. for direct kinematics. Similarly, pictures (bottom left) and (bottom right) show the angular distributions of the elastic and transfer cross-sections in C.M. for inverse kinematics. Fig. 2 shows various attempts at optical potential fits with the Wood-Saxon model for the data in Fig. 1, (top left) and (bottom left). However, there are discrepancies in the data that we suspect are related to normalization factors (possibly related to the Faraday Cup measurements or the target thickness determination) or analysis errors and this has lead to the decision to reanalyze everything.

Currently, there is no preliminary estimation of the $^{27}Si(p, \gamma)^{28}P$ reaction rate yet as that is the final step in the analysis.

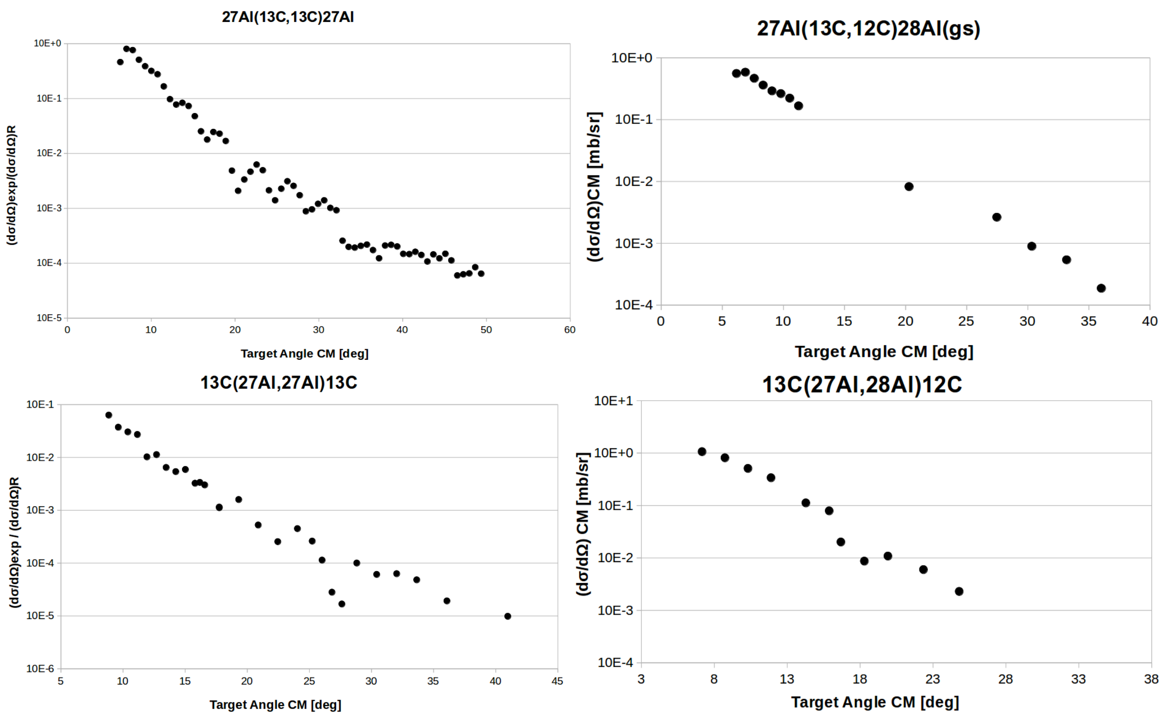

FIG. 1. Measured angular distributions of the cross sections for (top left) ^{27}Al(^{13}C,^{13}C)^{27}Al, (top right) ^{27}Al(^{13}C,^{12}C)^{28}Al, (bottom left) ^{13}C(^{27}Al,^{27}Al)^{13}C, and (bottom right) ^{13}C(^{27}Al,^{28}Al)^{12}C.

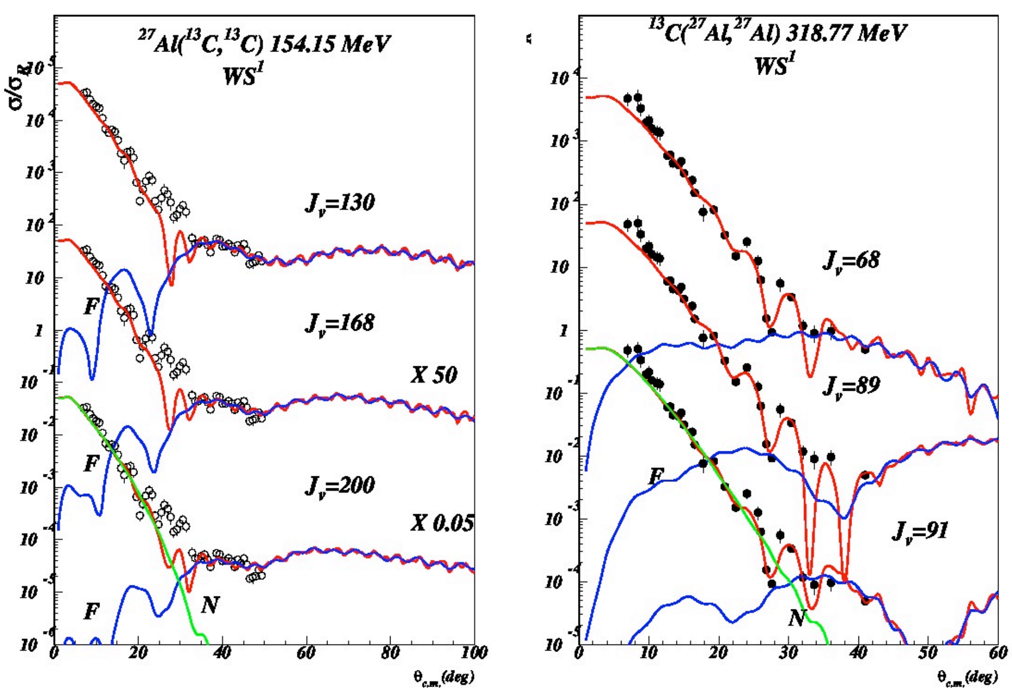

FIG. 2. Optical model fits for the elastic cross-section distributions obtained from the reactions, (left) ^{27}Al(^{13}C,^{13}C)^{27}Al, and (right) ^{13}C(^{27}Al,^{27}Al)^{13}C.

[1] H. Schatz, Prog. Part. Nucl. Phys. **66**, 277 (2011).
[2] H. Schatz and K. Rehm, Nucl. Phys. **A777**, 601 (2006).