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Determining the $^{14}O(\alpha,p)^{17}F$ astrophysical rate from Measurements at *TwinSol*

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Abstract

The $^{14}O(\alpha,p)^{17}F$ reaction is an important trigger reaction to the α-p process in X-ray bursts. The most stringent experimental constraints on its astrophysical rate come from measurements of the time-inverse reaction, $^{17}F(p,\alpha)^{14}O$. Previous studies of this inverse reaction have sufficiently characterized the high-energy dependence of the cross section but there are still significant uncertainties at lower energies. A new measurement of the $^{17}F(p,\alpha)^{14}O$ cross section is underway at the Twin Solenoid (*TwinSol)* facility at the University of Notre Dame using an in-flight secondary ^{17}F beam. The initial results are promising but improvements are needed to complete the measurement. The initial data and plans for an improved measurement are presented in this manuscript.

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1. Introduction

Type I X-ray bursts are the most frequently observed thermonuclear explosions in nature (Cyburt et al. 2016). They occur in accreting binaries and emit X-rays with light curves lasting 10-100s and recurring with periods of hours to days. The peak of the burst is initiated with the α-p process [$^{14}O(\alpha,p)^{17}F(p,\gamma)^{18}Ne(\alpha,p)^{21}Na(p,\gamma)^{22}Mg$…], which eventually transitions to the rapid-proton (rp) capture process leading to heavy element production. Recent sensitivity studies have shown that a number of these (α,p) reactions along with a handful of others can have dramatic effects on the observed X-ray burst light curve (Cyburt et al. 2016, Parikh et al. 2008). Of particular importance is understanding the trigger reaction, $^{14}O(\alpha,p)^{17}F$, since its rate determines, in part, the astrophysical conditions under which the α-p process is initiated.

The astrophysical $^{14}O(\alpha,p)^{17}F$ rate is dominated by the contribution of resonances arising from ^{18}Ne levels above 6 MeV in excitation energy and a direct reaction component (Hahn et al. 1996). Studies (Harss et al. 1999, Blackmon et al. 2001) of the reaction have focused upon measurements of the time-inverse reaction, $^{17}F(p,\alpha)^{14}O$, since high-quality beams of ^{17}F have been available and targets of CH_2 are much easier to implement than the helium targets that are required to measure $^{14}O(\alpha,p)^{17}F$ directly. The data from these studies are plotted in Fig. 1. While these data seem adequate above ^{17}F beam energies of 55 MeV, below this energy the measurements are sparse and suffer from large uncertainties, making it difficult to assess any possible resonance structure. Particularly important is determining the properties of potential resonances near $E(^{17}F)$=40 MeV that could correspond to a known ^{18}Ne state at E=6.15 MeV (Hahn et al. 1996). A new study of the $^{17}F(p,\alpha)^{14}O$ reaction was recently initiated at the University of Notre Dame Nuclear Science Laboratory (NSL) to address these uncertainties.

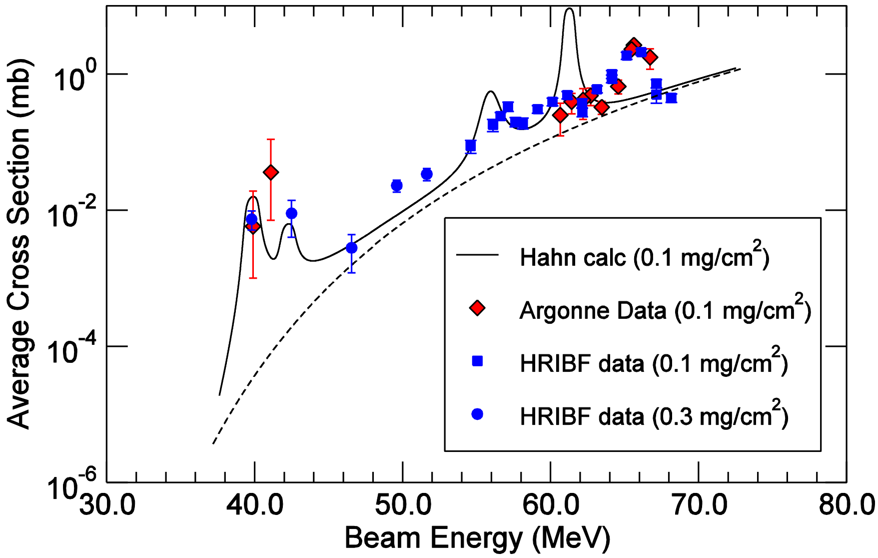

Figure 1: (color online) Previous $^{17}F(p,\alpha)^{14}O$ measurements. The HRIBF data are from Blackmon et al. 2001, and the Argonne data are from Harss et al. 1999. The target thickness is indicated in the legend. The solid curve is a prediction based upon resonance parameters from Hahn et al. 1996 averaged over the energy loss in the target.