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Probing lifetimes of short-lived nuclear resonances of astrophysical interest

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Classical novae and Type I X-ray bursts (XRBs) are among the most frequent thermonuclear stellar explosions in the Galaxy. The 30P(p,γ)31S reaction acts as a nucleosynthesis bottleneck in the flow of material to heavier masses, affecting several nova observables. The dominant source of uncertainty in the current recommended reaction rate is the theoretical γ decay width of the 3/2+, 260-keV resonance in 31S. We have observed evidence for γ rays originating from the resonance using the Doppler Shift Lifetimes (DSL) facility at TRIUMF, which was designed for lifetime measurements in the 10^−15 - 10^-12 s range [1]. We have upgraded DSL to DSL2 and successfully commissioned it during the first run of the experiment to determine the lifetime of the key 22Na(p, γ)23Mg resonance in novae [2]. The data analysis is currently in progress, and a second run has been scheduled for October 2024. Our proposal to measure the lifetime of the key 31S resonance using DSL2 has also been approved, aiming to put the 30P(p, γ)31S reaction rate on a fully experimental footing and to eliminate the nuclear uncertainties in simulations of nova observables.

Under XRB conditions, the strength of the NiCu cycle is predicted to have significant impacts on the modeling of X-ray burst light curves and the composition of the burst ashes. Currently, experimental information on the 59Cu(p,γ)60Zn and 59Cu(p,α)56Ni reactions is scarce. We have developed a detection system that utilizes a particle-X-ray coincidence technique (PXCT) to measure lifetimes in the 10^-17 - 10^-15 s range. The performance of the PXCT system has been thoroughly tested and is ready for the 60Ga decay measurement in the stopped-beam area of FRIB. This work will provide the life times and decay branching ratios of discrete 60Zn resonances, thereby constraining the competition between the 59Cu(p,γ)60Zn and 59Cu(p, α)56Ni reactions and the strength of the NiCu cycle [3].

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[3] L. J. Sun, J. Dopfer, A. Adams et al., In preparation.

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