

# Probing lifetimes of short-lived nuclear resonances of astrophysical interest

Monday, July 22, 2024 4:55 PM (20 minutes)

Classical novae and Type I X-ray bursts (XRBs) are among the most frequent thermonuclear stellar explosions in the Galaxy. The  $^{30}\text{P}(p,\gamma)^{31}\text{S}$  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  $\gamma$  decay width of the  $3/2^+$ , 260-keV resonance in  $^{31}\text{S}$ . We have observed evidence for  $\gamma$  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  $^{22}\text{Na}(p,\gamma)^{23}\text{Mg}$  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  $^{31}\text{S}$  resonance using DSL2 has also been approved, aiming to put the  $^{30}\text{P}(p,\gamma)^{31}\text{S}$  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  $^{59}\text{Cu}(p,\gamma)^{60}\text{Zn}$  and  $^{59}\text{Cu}(p,\alpha)^{56}\text{Ni}$  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  $^{60}\text{Ga}$  decay measurement in the stopped-beam area of FRIB. This work will provide the life times and decay branching ratios of discrete  $^{60}\text{Zn}$  resonances, thereby constraining the competition between the  $^{59}\text{Cu}(p,\gamma)^{60}\text{Zn}$  and  $^{59}\text{Cu}(p,\alpha)^{56}\text{Ni}$  reactions and the strength of the NiCu cycle [3].

This work is supported by the U.S. National Science Foundation under Grant Nos. PHY-1102511, PHY-1565546, PHY-1913554, PHY-2110365, and PHY-2209429, the U.S. Department of Energy under Award Nos. DE-SC0016052 and DE-SC0024587, the Natural Sciences and Engineering Research Council of Canada, and the National Research Council of Canada.

[1] L. J. Sun, C. Fry, B. Davids et al., Phys. Lett. B 839, 137801 (2023). [2] B. Davids, C. Wrede et al., TRIUMF EEC S2193.

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

**Presenter:** SUN, Lijie (Facility for Rare Isotope Beams)

**Session Classification:** Reaction & Structure Related to Nuclear Astrophysics