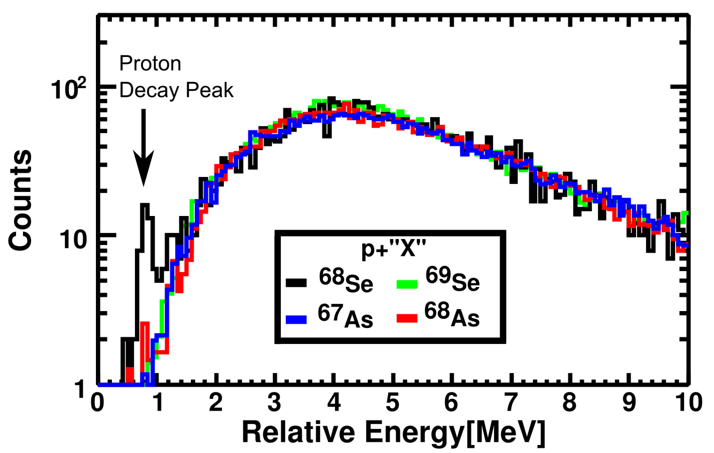
Direct Measurement of ^{69}Br Ground State Proton Emission and Implications for the rp-Process



Comparison of the reconstructed relative energy spectra for proton emission from various nuclei produced during the experiment. Proton emission at high relative energies will be similar for all of the nuclei shown. At low relative energies, γ-decay is the dominant decay mode and therfore no proton decays are observed. For the ^{69}Br ground state, however, proton decay is the only available decay mode since ^{69}Br is known to be proton unbound and has no states into which it can γ-decay. Consequently, a decay peak is observed at 785 keV.

Intense thermonuclear explosions, know as *X-ray bursts*, can occur in the atmosphere of neutron stars which accrete matter from their nearby binary companion stars. These bursts are observed to last for about 10-100 seconds and can reoccur with a typical frequency of hours to days. Fusion reactions involving the accreted hydrogen and helium synthesize heavy elements as well as release energy that powers the burst.

During the burst, sequential fast proton captures on heavy seed nuclei followed by slower β-decays produce the heaviest nuclei in the rapid proton capture, or *rp-process*. The nuclear physics of isotopes along the rp-process path determines many of the properties of longer duration X-ray bursts. Certain nuclei involved in the rp-process, however, are inhibited from capturing protons and also have long β-decay half-lives. These are known as *waiting-point* nuclei since the process must "wait" for the long β-decay in order to continue the proton capture process and produce even heavier masses beyond the waiting-point. The ^{68}Se waiting-point is an example of such a nucleus. In this case, however, the waiting-point may be bypassed through the sequential capture of two protons. This depends sensitively on the proton separation energy of ^{69}Br which is poorly known and has been experimentally sought after for more than 20 years.

JINA scientists and other collaborators have performed the first direct measurement of the proton separation energy of ^{69}Br at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University. A rare isotope beam composed of ^{70}Se was used to produce highly unstable ($t_{1/2}$<24 ns) ^{69}Br nuclei which decay through proton emission, ^{69}Br→p+^{68}Se. The decay protons were identified and their kinematic properties measured using silicon strip detectors known as the High Resolution Array (HiRA). The heavy ^{68}Se decay products were detected using the S800 magnetic spectrograph. In the figure above, the black spectrum shows the reconstructed relative energy for ^{69}Br decay. The peak at low relative energies is due to protons that are emitted from the ground as well as the lowest excited states. This is not observed for other nuclei produced in the experiment since γ-decay is their dominant decay mode while proton decay is strongly inhibited.

From the relative energy spectrum a proton separation energy of S_p = -785 keV for ^{69}Br was extracted. Using an X-ray burst model from Schatz et al. together with recent data from the JINA REACLIB Database we found that the waiting-point will not be significantly bypassed during an X-ray burst. Therefore, for these systems, ^{68}Se will remain a waiting-point in the rp-process.

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