The Joint Institute for Nuclear Astrophysics

Study of the ^{69}Br rp-Process Waiting Point

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Motivation

The ability to perform experiments with ***radioactive beams*** *has opened the doorway through which the advanced exploration of the cosmos as well as the fundamental properties of the nucleus can proceed. In particular, by probing the structure of nuclei along the dripline important waiting point data and capture cross-sections are obtained relating to,*

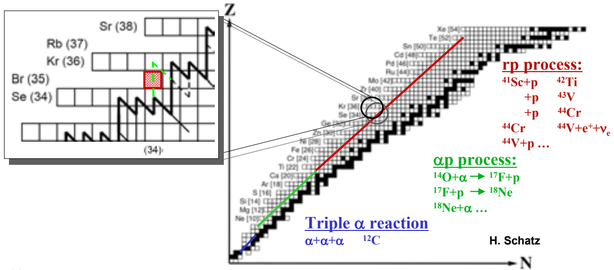
- **Understanding Nucleosynthesis Through the rp-Process**
- **Exploring the Unknown Nuclear Landscape**
  - **Probing the limits of stability**
- **Exploring Astrophysical Objects and Phenomenon**
  - **Novae, Neutron Stars, X-ray Bursts, etc.**

Waiting Points of the rp-Process

- **The rp-process (rapid proton capture) takes place near the proton-rich dripline and is thought to account for the production of various proton rich nuclei especially for A>60.**
- **The movement to larger A is dictated by the proton capture and β-decay rates along the path. It is therefore important to have accurate knowledge of the nuclear structure for the nuclei along the path, in particular proton separation energies.**

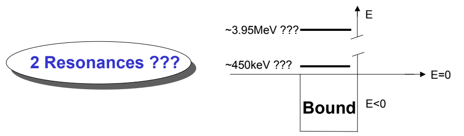
$$\langle\sigma\nu\rangle=\sqrt{\frac{8}{\pi\mu}}\,\frac{1}{(kT)^{3/2}}\int_0^\infty \sigma(E)\,E\,e^{-\frac{E}{kT}}\,dE$$

- **Waiting Points: Nuclei with low S_p, long β-decay half-lives, or low capture cross-sections may result in a build up of nuclei in these waiting point regions.**



H. Schatz

- **^{69}Br is proton unbound by at least 450 keV. Determination of the proton separation energy is critical to processing through the waiting point.**



Progression to larger A nuclei may be enhanced through 2p capture through the E>0 resonance in ^{69}Br. Additional data on nuclei in the vicinity of this waiting point is also to be obtained in experiment 02023 which will improve the understanding of the rp-process.

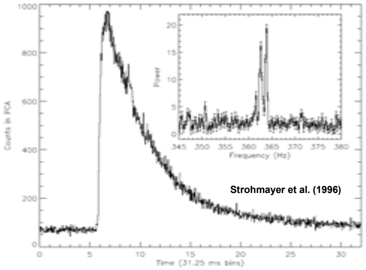
HiRA is a collaboration between the following institutions

Credits: ESA. Illustration by Martin Kornmesser, ESA/ECF

One possible site for the rp-process is in accreting binary systems. This artists conception is an illustration of Cygnus X-1, a blackhole which is accreting matter for its companion supergiant HDE 226868. The same concept is true for system with an accreting neutron star or white dwarf where the companion has filled its Roche lobe and can thereby transfer matter to the surface of the star where conditions may exist for thermonuclear runaway and explosive burning.

X-Ray Bursts

One possible scenario in which the rp-process may occur is in accreting binary systems where explosive hydrogen burning takes place on the surface of a neutron star. Here the environment provides the necessary conditions for movement through the rp-process path. Below is a figure showing the light curve of a typical burst event.



Strohmayer et al. (1996)

Information obtained through the study of ^{69}Br and surrounding nuclei will result in better constraints on calculations relating to such light curves and similar observations.

Setup for Experiment 02023

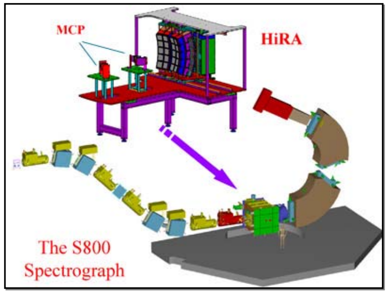
- **Experiment 02023 was proposed to measure the ^{69}Br(p,γ) Q-value and make a precise determination of the proton separation energy.**
- Analysis for experiment 02023 is currently underway.
- Calibration of the various experimental devices is continuing with preliminary results expected over summer 2006.

Experimental Setup & Method

❑ **The Q-value measurement of ^{69}Br(p,γ) is made via an analysis of correlations in the proton breakup spectrum in the following,**

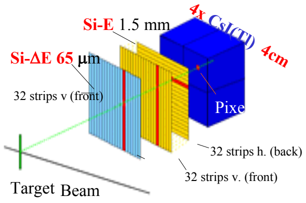
$$^{69}\mathrm{Br}^{*}\rightarrow{}^{68}\mathrm{Se}+\mathrm{p}$$

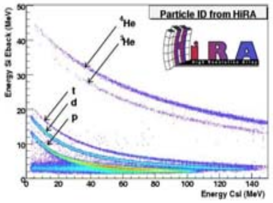
❑ **In order to produce the unstable ^{69}Br a secondary beam is produced using the CCF at the NSCL in conjunction with the A1900 fragment separator. Multiple beams consisting primarily of ^{71}Br exit the focal plane of the separator and are guided into the experimental vault. For experiment 02023 an Al target was used with a beam energy of 65 MeV/A.**



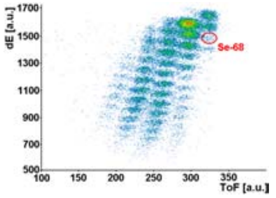
❑ **The ^{68}Se is detected in the focal plane of the S800 spectrometer where it can be distinguished from other breakup products and the unreacted beam. The measurements from the S800 yield information on the energy and angle of the ^{68}Se residue.**

❑ **HiRA (High Resolution Array) is used for the identification of light charged particles in this case the breakup proton. The ability to effectively separate different nuclei is clearly demonstrated in the figure on the right.**





The array consists of 16 telescopes containing a thin (ΔE), single-sided Si strip detector and a thick (E) double-sided Si strip detector. CsI(Tl) crystals make up the 4 quadrants behind the silicon. The small pitch of the strips results in the high angular resolution necessary for such precise measurements.



❑ **Detection of ^{68}Se events in the focal plane of the S800 allows for the kinematical reconstruction of the decay.**

❑ **The figure on the left shows the identification of ^{68}Se heavy residue.**

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