The Joint Institute for Nuclear Astrophysics

Neutron Rich Ge-Br Isotopes

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Introduction

The astrophysical r-process is responsible for synthesis of roughly half of the elements heavier than iron. In spite of this significance, there are many uncertainties regarding the site of the r-process and the neutron-rich nuclei involved. Studying these nuclei presents a challenge, as they lie far from the valley of stability.

Neutron rich nuclei play an important role in both nuclear astrophysics and nuclear structure. Central to the study of nuclear structure are the shape of a nucleus and how that shape changes from spherical to deformed. In some regions there is a smooth change in deformation as nucleons are either added or subtracted, and yet in other regions this transition is very rapid.

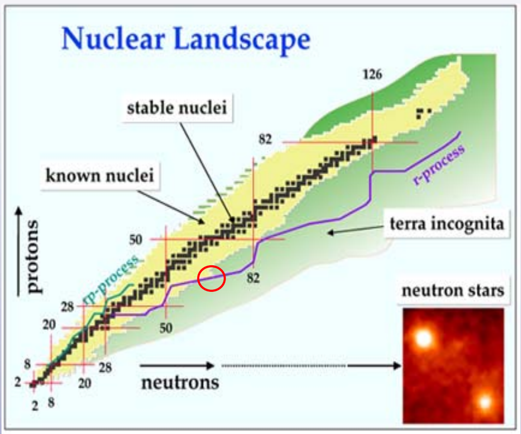
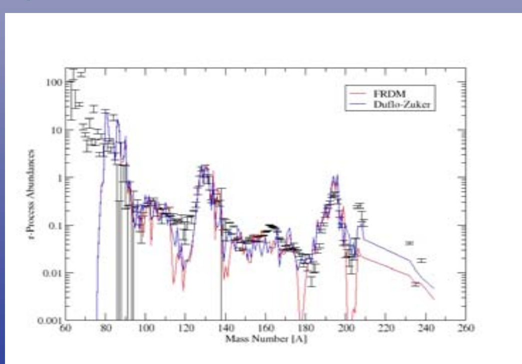


Chart of the nuclides showing regions of known and unknown nuclear properties (nuclear masses, β decay half-lives, P_n values, etc.). The region of interest for the present work in circled. Note that most of the r-process path lies in the region of unknown nuclear properties.

r-process



Solar system r-process abundances (data points), compared to simulations using two different nuclear mass models. Large differences are seen in predictions for around A=130, A=190 mass peaks, and for A > 200.

Objective

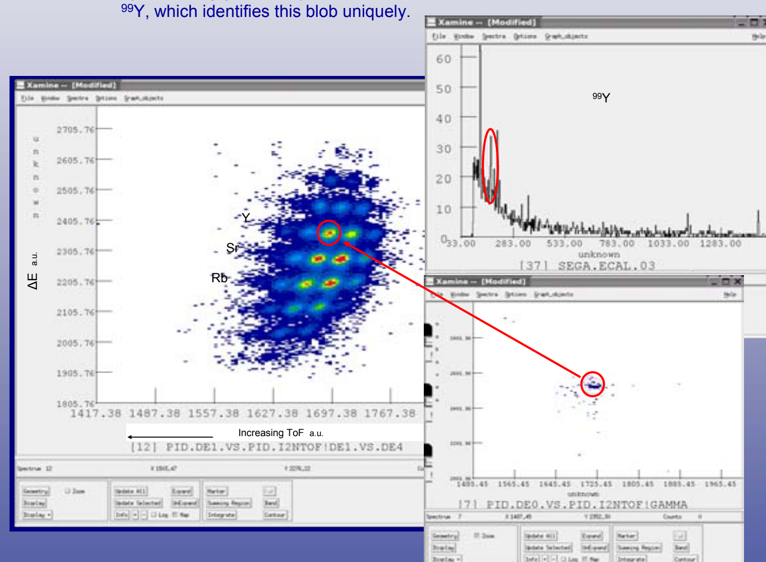
Modeling can set constraints on astrophysical scenarios in which the r-process is thought to occur. Nuclear properties such as masses, β decay half-lives, and β delayed neutron emission probabilities are direct inputs for such r-process models.

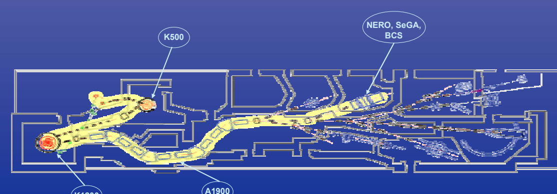
In addition, the nuclear structure properties of neutron rich nuclei can vary greatly from nuclei that are closer to stability. The region of interest lies between the N=56 sub-shell closure and the N=60 onset of deformation just below the Sr-Zr region, for which the most pronounced transition from spherical to deformed ground-state shapes have been observed.

A recent experiment has measured the masses, β decay half-lives, β delayed neutron emission probabilities, and ground state deformation of several neutron Ge-Br isotopes. These measurements provide additional data for r-process models, as well as clarify the onset of deformation just below a region of strongly deformed nuclei.

Particle ID

ΔE – time of flight spectrum for region of interest. TOF is determined by time between a thin scintillator in the A1900 focal plane and a thin scintillator just before the beta end station detector system. Identification is done by observing gamma rays from an isomeric state in ^{99}Y, which identifies this blob uniquely.





Experimental Setup

Neutron rich Ge-Br isotopes have been studied at the NSCL at Michigan State University. Production is by fragmentation of a 120 MeV/u ^{136}Xe beam on a Be target. The A1900 fragment separator filters out unwanted species produced in this reaction. The transmitted nuclei are implanted in a dual-sided silicon detector, which is part of the Beta Counting System detector. Implanted nuclei are identified by the ΔE-time of flight method. Beta decays are then be detected by a single-sided silicon detector, which is also part of the Beta Counting System. Beta-delayed neutrons are detected by the NERO neutron counter, which surrounds the Beta Counting System. This provides measurements of the β decay half-lives and β-delayed neutron emission probabilities.

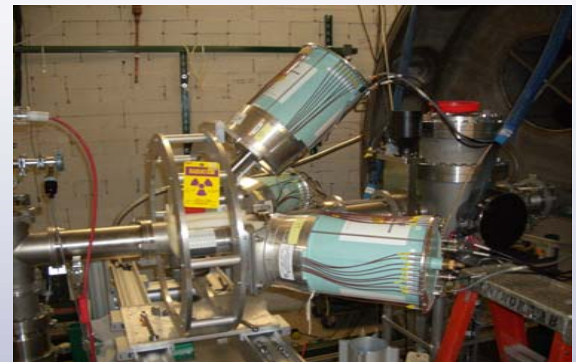
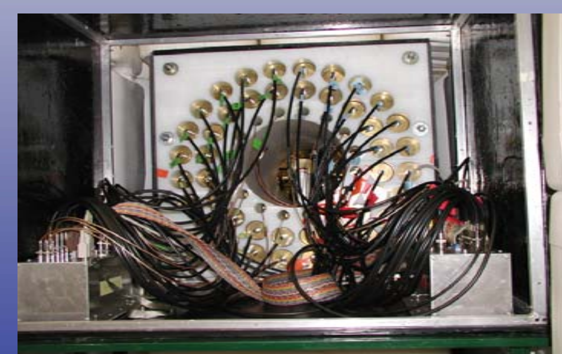


Photo of SeGA (Segmented Germanium Array) surrounding the Beta Counting System. SeGA is made up of twelve 75% relative efficiency HPGe detectors. Total efficiency is 5.3%, with a typical energy resolution of 3.5keV at gamma energies of 1.3MeV.



End view of NERO (Neutron Emission Ratio Observer) detector. A polyethylene moderator holds an inner ring of sixteen ^{3}He detectors and two outer rings of BF_3 detectors. The moderator is surrounded by a Boron Carbide shell to minimize neutron background. The Beta Counting System sits inside the center cavity. NERO measures the number of neutrons emitted after a beta decay in the Beta Counting System.

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