Hope College
Hope College Digital Commons

18th Annual Celebration of Undergraduate Research and Creative Activity (2019)

Celebration of Undergraduate Research and Creative Activity

4-12-2019

Determining the β Decay Strength Function of 91Rb

William von Seeger
Hope College

Jason Gombas
Hope College

Follow this and additional works at: https://digitalcommons.hope.edu/curca_18

Part of the Physics Commons

Recommended Citation

Repository citation: von Seeger, William and Gombas, Jason, "Determining the β Decay Strength Function of 91Rb" (2019). *18th Annual Celebration of Undergraduate Research and Creative Activity (2019).* Paper 32.
https://digitalcommons.hope.edu/curca_18/32
April 12, 2019. Copyright © 2019 Hope College, Holland, Michigan.

This Poster is brought to you for free and open access by the Celebration of Undergraduate Research and Creative Activity at Hope College Digital Commons. It has been accepted for inclusion in 18th Annual Celebration of Undergraduate Research and Creative Activity (2019) by an authorized administrator of Hope College Digital Commons. For more information, please contact digitalcommons@hope.edu.

Determining the β Decay Strength Function of ^{91}Rb

W. von Seeger, P.A. DeYoung, A. Spyrou, J. Gombas,
The SuN Group at the National Superconducting Cyclotron Laboratory, Hope College

Abstract

The r-process predicts the formation of elements heavier than iron and occurs in neutron star mergers and supernovae. The β decay strength function reveals nuclear structure properties necessary to improve r-process models. Measurements of the ^{91}Rb strength function, a nucleus involved in the r process, were made at the National Superconducting Cyclotron Laboratory (NSCL) this past July (2018). The ^{91}Rb were made with the A1900 fragment recoil separator, then stopped in a long gas cell, and finally implanted in a mylar tape. Spectra and multiplicity of γ rays from the daughter, ^{91}Sr, coincident with β particles from the decay of implanted ^{91}Rb give one the information needed to determine the β decay strength function. Electrons produced by the β decay were measured in a plastic detector constructed at Hope College and γ rays were detected in the Summing NaI (SuN) detector. Coincidences between electrons and γ rays were needed to identify the energy level in the ^{91}Sr daughter nucleus to which the parent ^{91}Rb decayed and to quantify the probability of that decay path. β particles from the decay of ^{91}Rb are difficult to distinguish from background events due to the buildup of long-lived daughter particles that subsequently also β decay. A tape system extending into the beam pipe through SuN is needed to move radioactive daughter particles away from the detector. Thus, a conventional Si surface barrier β detector could not be employed because of minimal space inside the beam pipe. The needed β detector was fabricated to fit inside the small beam pipe and around the tape system. The 20 cm long, barrel-shaped detector was constructed out of scintillating plastic with wave-shifting fiber optic cables on the exterior leading to photomultiplier tubes outside the SuN detector. Preliminary results are shown.

r process

Nuclear fusion does not occur for nuclei heavier than iron. Roughly half of the elements heavier than iron are formed through the *r* process. Nuclei undergo rapid neutron capture and β decay toward the valley of nuclear stability. The *r* process requires a large number of free neutrons, extreme temperature, and pressure. The *r* process is theorized to occur in supernovae and neutron star mergers.

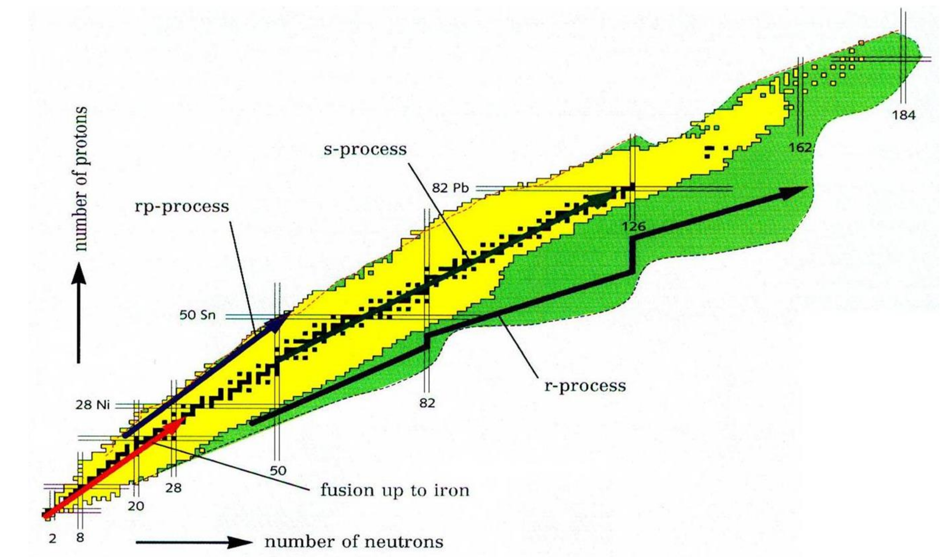

Figure 1: Path of the r-process
From: http://www.phys.utk.edu/expnuclear/nucastro.html

Experimental Set Up

A secondary beam of ^{91}Rb, produced from a primary beam of ^{96}Zr at 120 MeV/u, was delivered to the gas stopping cell at the NSCL. The 70 keV ^{91}Rb beam was then delivered to the SuN detector and implanted on the mylar tape as part of the Tape System for Active Nuclei (SuNTAN). SuNTAN extends into SuN and is surrounded by the β detector known as the Scintillating Plastic with Optical Transport (SuNSPOT). The fiber optic cables on SuNSPOT lead out of SuN to 2 photomultiplier tubes (PMT).

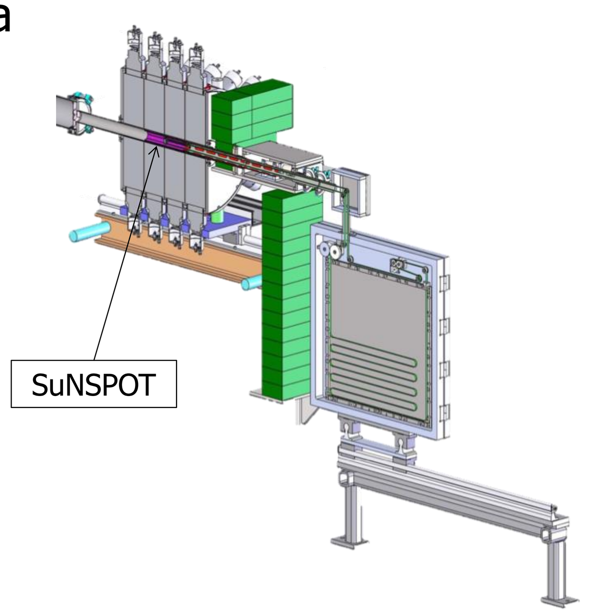

Figure 2: Diagram of SuN, SuNTAN, and SuNSPOT together

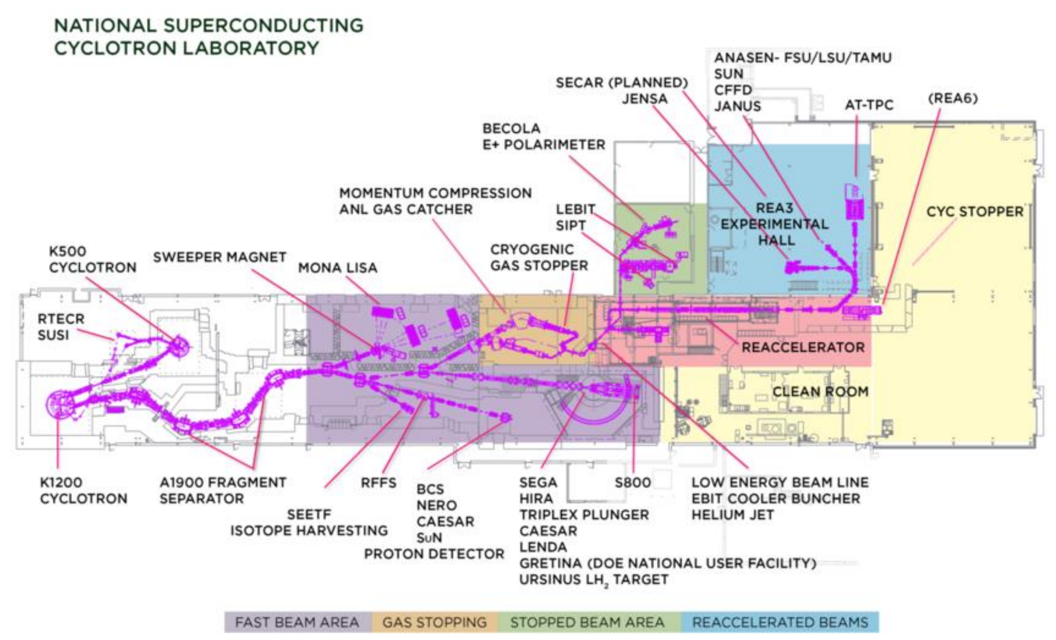

Figure 3: Layout of the NSCL

Detector Fabrication

The β detector was fabricated from 8 slats of BC-408 organic scintillating plastic with 4 trenches on the outside face. The inside face of each slat was painted with a water and titanium dioxide reflective paint. The 8 slats were then glued together with epoxy in an octagonal tube. BCF-91A wave-shifting fiber optic cables were then glued into the trenches on each slat with EJ-500 optical cement. The entire outside of the detector, as well as the edge faces of both openings, were painted with the titanium dioxide reflective paint.

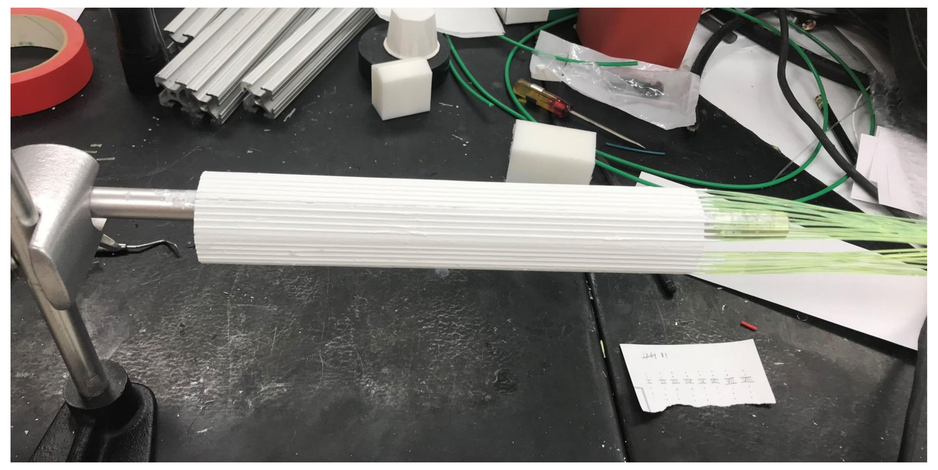

Figure 4: Image of completed β detector

Detector Properties

BC-408 has an attenuation length almost 20 times greater than the length of the detector, thus a minimal amount of light from a detection will be lost. The scintillating plastic produces light with a range of wavelengths with a maximum of 425 nm. The fibers shift the range of wavelengths to a maximum of 494 nm, a wavelength still of sufficiently high energy for the PMTs to detect with good resolution. The wave-shifting fibers lower the energy of the photons delivered to the PMTs, but the fibers direct the light down the length of the fibers toward the PMTs, whereas clear fibers do not and thus lose large amount of light making the event difficult to detect.

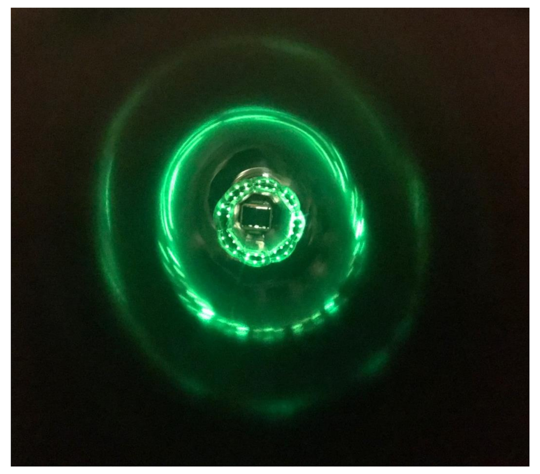

Figure 5: Image of ends of fibers illuminated in beam pipe

Detector Operation

β particles of low energy must be detected. Low energy β particles are difficult to detect because PMTs typically detect a large amount of background noise, which is produced by thermal excitation of the Bi-alkali layer. When the 2 PMTs are in coincidence β particles can be accurately detected at lower energies because the probability that background signals happen in coincidence is low.

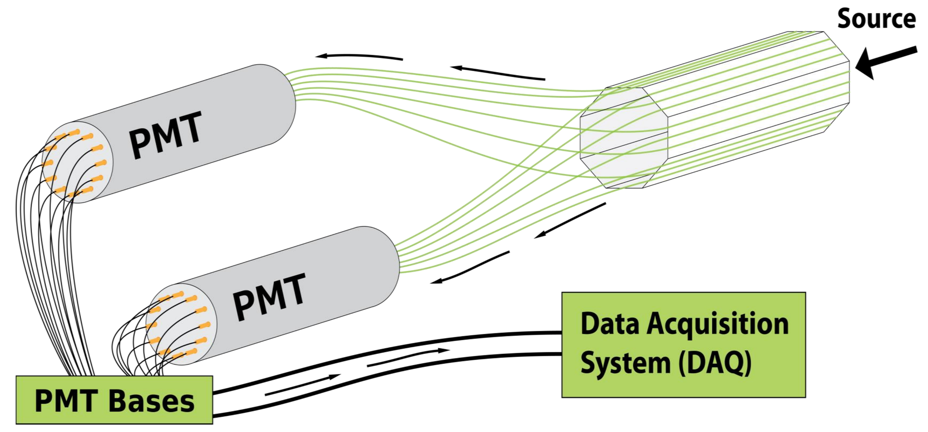

Figure 6: Diagram of SuNSPOT connected to the 2 PMTs

Preliminary Results

The β decay strength function is needed to determine the decay path in the *r* process. Simulations of the Total Absorption Spectra (TAS), Sum of Segments Spectra, and multiplicity spectra produced with GEANT4 to reproduce experimental data. A preliminary β decay strength function was extracted from this data and compared to previous measurements.

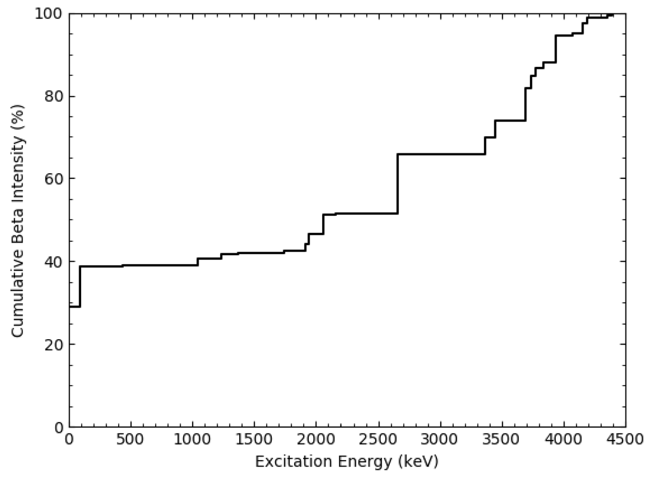

Figure 7: Preliminary β decay strength function for ^{91}Rb

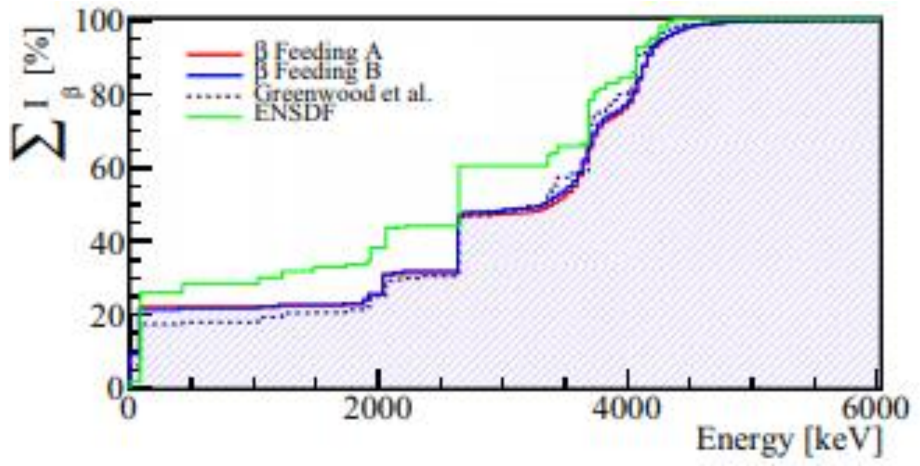

Figure 8: β decay strength function found in the literature
S. Rice *et al.*, Phys. Rev. C 96, 014320 (2017)

Future Work

SuNSPOT and SuNTAN again will be employed with SuN in an upcoming experiment at the NSCL in October (2018). One of the goals of the experiment will be to determine the β decay strength function of another isotope having a long-lived daughter to further improve r-process models.

Acknowledgments

This material is based upon work supported by the National Science Foundation under grant No. PHY-1613188.

Background from an article on www.newscientist.com by Leah Crane