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β-decay Strength function of 99,100 Y

Nathaniel Jobson
Hope College

A. Spyrou

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N. Jobson, P.A. DeYoung, A. Spyrou
Hope College, The SuN Group at NSCL

Abstract

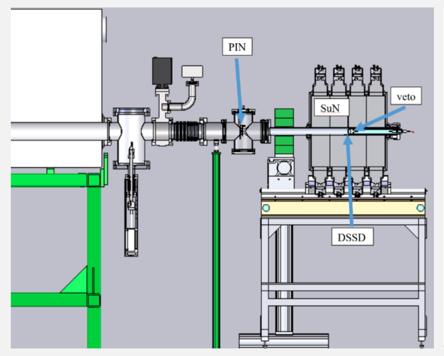
The rapid neutron capture process (r process) is responsible for the formation of numerous heavy nuclei in the universe. To obtain better models for heavier nuclei that are part of the r process, the decay paths of ^{99,100}Y were analyzed. This work was done using the Summing NaI(Tl) detector at the National Superconducting Cyclotron Laboratory. The $I_\beta(E)$ and the Beta Gamow-Teller function (BGT) were extracted from the measured Total Absorption Spectra (TAS), Sum of Segments (SEG), and Multiplicity spectrum. The $I_\beta(E)$ and the Beta Gamow-Teller function (BGT) were extracted from the measured spectra and then compared to the Quasi-Random Phase Approximation theory.

Purpose

The goal of this research is to find the $I_\beta(E)$ function, from which the Beta Gamow-Teller function can be calculated. These can be compared the theoretical predictions of the decay of ^{99,100}Y to improve theory. The theory must be refined as multiple elements that are crucial for understanding the r process that are inaccessible in a laboratory setting. These elements must be modeled with theories like Quasi-Random Phase Approximation (QRPA) and Shell Model. These theories can be applied to astrophysics and are important for the creation of next generation nuclear reactors.

Method

The data from this experiment was collected at the National Cyclotron Laboratory using the **Su**mming **N**aI(Ti) detector (SuN). The detector is highly efficient (85% for ^{137}Cs) to reduce the number of γ rays that are not measured. This increases the accuracy of TAS and SEG, for more information see the TAS, SEG and Multiplicity section. The experimental equipment also includes multiple PIN detectors which collect the time of flight of a particle and a Double Sided Strip Detector (DSSD) which collects the Location and energy of a Particle implantation to aid in Particle Identification.



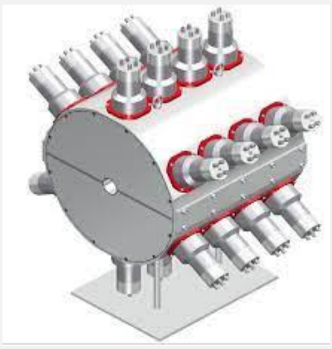


Figure 2 and 3: Images of the Summing NaI(Ti) detector

TAS, SEG, and Multiplicity

This experiment was conducted with analysis of Total Absorption Spectra (TAS) and Sum of Segments Spectra (SEG) from the decay of radioactive parent nuclei. The TAS curve shows the total absorption spectrum, which adds the total deposited energy in all the segments. This indicates the energy level that gets populated in the daughter particle. The SEG spectra shows the energy recorded by an individual segment. The information collected with the SEG spectra gives information about the specific decay path in the child nucleus. Multiplicity shows the number of individual segments in the detector, of the possible 8, that registered energy.

Particle Identification

The beam in this experiment was a cocktail beam, meaning that there are multiple different nuclei within the beam. To analyze a specific particle, the particles need to be identified on an event by event basis. This is done by using a combination of the time of flight and implantation energy which leads to the different groups seen in Figure 4. The associated events within a specific area of the plot are cut out to be analyzed. The TAS and SEG spectra are then compared to the level schemes from the Evaluated Nuclear Structure Data File (ENSDF) to confirm their identity. Another way their identity is verified is by determining the half-life of the particle and comparing it to values from the National Nuclear Data Center (NNDC).

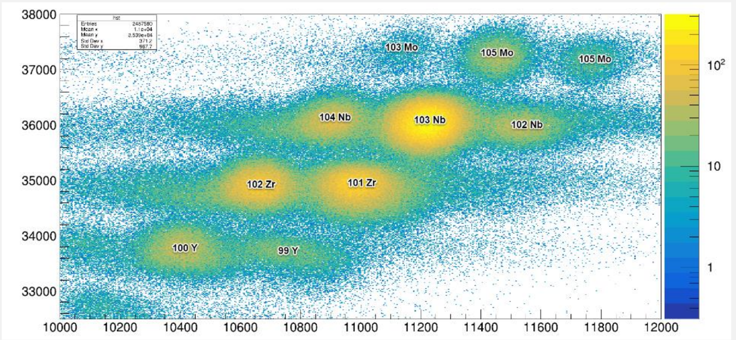
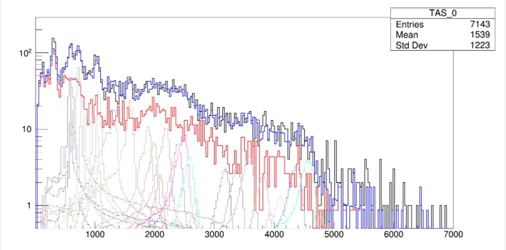


Figure 4: Image of Particle Identification plot

Fitting

The $I_\beta(E)$ function is found with a multidimensional χ^2 minimization fit. For each possible decay path, GEANT4 simulated 2,000,000 events. The simulation takes into account the atomic mass, atomic number, Q value, and the probability of the parent nucleus to follow a given decay path. The resulting histograms, where the scale factors are adjusted, for each decay path are summed together to minimize the multidimensional χ^2 value.



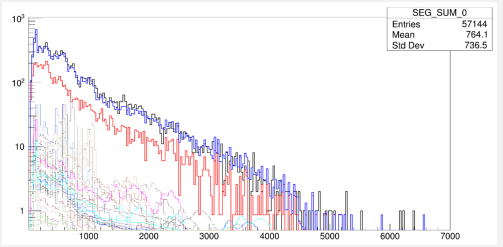


Figure 5: Left sows TAS and Right shows SEG

Results

The agreement between the theoretical model and the experimental data is poor. The discrepancy is a result of QRPA being meant to model a large region of nuclei in general instead of accurately modeling a specific nuclei. To allow for improved agreement, the data from this experiment will be used to further refine the QRPA model and develop the next generation improved of models.

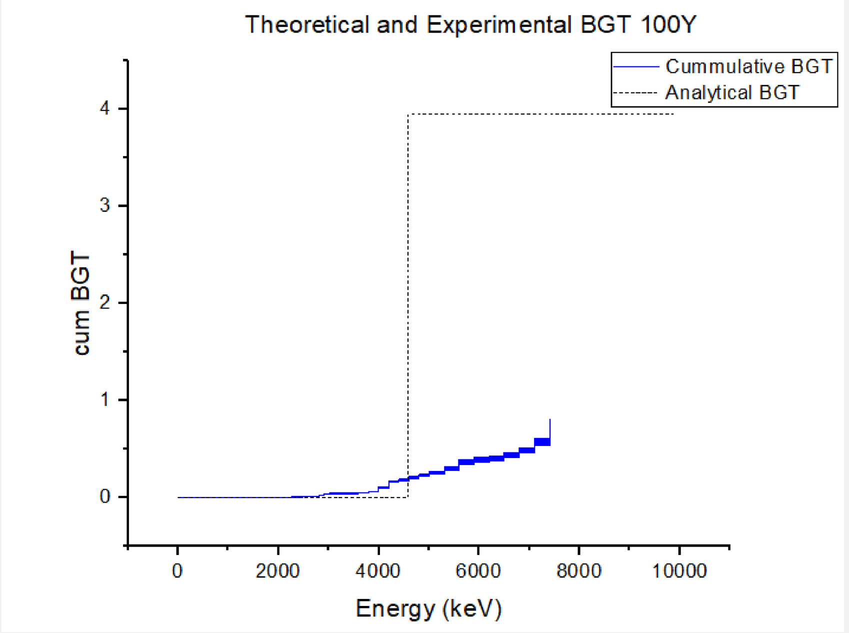


Figure 5: Image of BGT plot

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