4-12-2024

β-decay Strength Function of 53Ni and 52Co

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Abstract

The p process is believed to be responsible for the formation of heavy proton-rich nuclei in the universe. Because p nuclei are short-lived, the specific properties of their reaction and decay paths are difficult to measure. This work deals with the decays of two nuclei, ^{53}Ni and ^{52}Co. β^+ decays for each isotope were recorded with the Summing NaI(Tl) detector at the National Superconducting Cyclotron Laboratory. A preliminary β-decay Intensity Function was derived with Total Absorption Spectroscopy. Total energy spectra, β-particle spectra, individual γ-energy spectra, and multiplicity spectra for decays to levels in the child nucleus were modeled with GEANT4 based on information from the National Nuclear Data Center. The measured spectra, when fit with the simulated spectra, give the probability that a particular child level is populated during decay. Refined results, when compared to theory, will provide insight into the formation of p-nuclei elements.

Method

All of the data for this experiment were collected at the National Superconducting Cyclotron Laboratory (NSCL) with the Summing NaI(Tl) (SuN) detector and a Double-Sided Silicon Strip Detector (DSSD). The segmented SuN detector recorded the individual γ rays of the decays. Total absorption spectroscopy sums all γ rays released in the decay to find the energy levels in the child fed during decay. The DSSD detector, placed in the center of SuN, recorded the implant and β^+ decay time and energy.

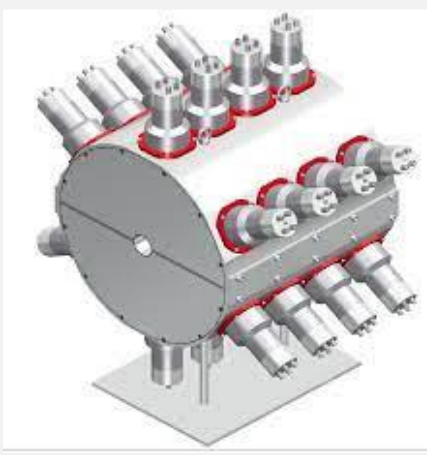

Figure 1: Image of the Summing NaI(Tl) detector

Half Life

The half-lives of the isotopes can also inform nuclear models. Due to the DSSD having very precise time information, half-lives could also be extracted. The graphs below are decay curves recorded by measuring the time between the implant and the decay with the DSSD. By performing an exponential fit, half-lives can be determined. The accepted half-lives of these isotopes in the NNDC database are 55(7) ms and 104(7) ms for ^{53}Ni and ^{52}Co respectively. Experimental results from this analysis were 68(1.8) ms and 110(1.3) ms again respectively for ^{53}Ni and ^{52}Co.

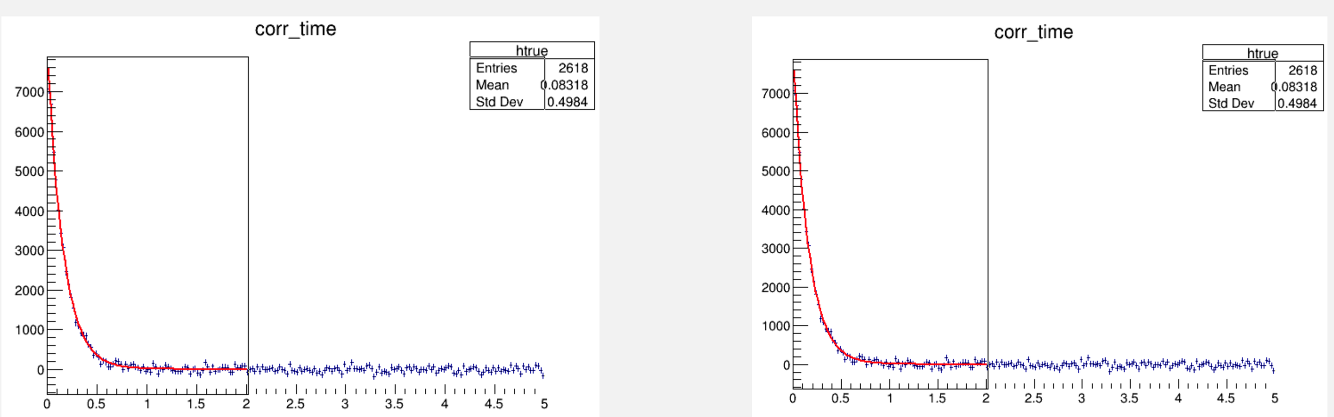

Figure 4: These spectra show the decay curve fits
Right: ^{53}Ni, Left: ^{52}Co

Data Analysis

Particle Identification: The beam for this experiment consisted of a cocktail of three dominant isotopes (^{53}Ni, ^{52}Co, and ^{48}V). Implanted isotopes of interest were identified on an event-by-event basis from energy loss in an upstream thin detector and the DSSD energy.

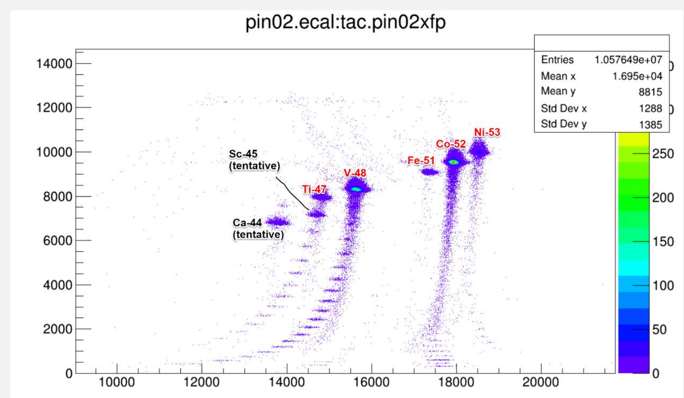

Figure 2: Image of particle identification of energy loss and DSSD energy

Correlation: The decays occur with an exponential time distribution (see half-life) after implantation. The specific implantation events need to be correlated with particular decay events. To achieve this, each decay was correlated with the most recent implant preceding the decay. Due to the random nature of decay and implant, some events were improperly correlated. So, to account for this, another purposely incorrect correlation was made by taking each decay and going forward in time to the next implant. Then the real and random correlations were subtracted.

Proton-Unbound Level

A unique feature of this analysis is information can be extracted on the decay strength to proton unbound levels (unlike on the neutron rich side) because the DSSD registers the energy of the emitted protons.

Purpose

The aim of this experiment is to extract the β-decay Intensity Function, $I_{\beta+}$ and the Gamow-Teller Transition Strength Function (BGT), for heavy isotopes on the proton-rich side of the valley of stability. The isotopes in this study are important in the understanding of the nucleosynthesis of proton-rich elements (p process). The aim then for obtaining these functions for ^{53}Ni and ^{52}Co is to provide experimental data for theorists so that current nuclear models describing the structure of p-nuclei can be improved.

χ^2 Minimization

The $I_{\beta+}$ can be extracted from the data by using a multidimensional χ^2 minimization procedure. GEANT4 creates theoretical spectra of Total energy spectra, β-particle spectra, individual γ-energy spectra, and multiplicity spectra each individual populated level based on branching ratio probabilities and Q value. Basis states created with GEANT4 are fit to the experimental spectra. The feeding intensity can be calculated from the renormalized fit coefficients for each basis state.

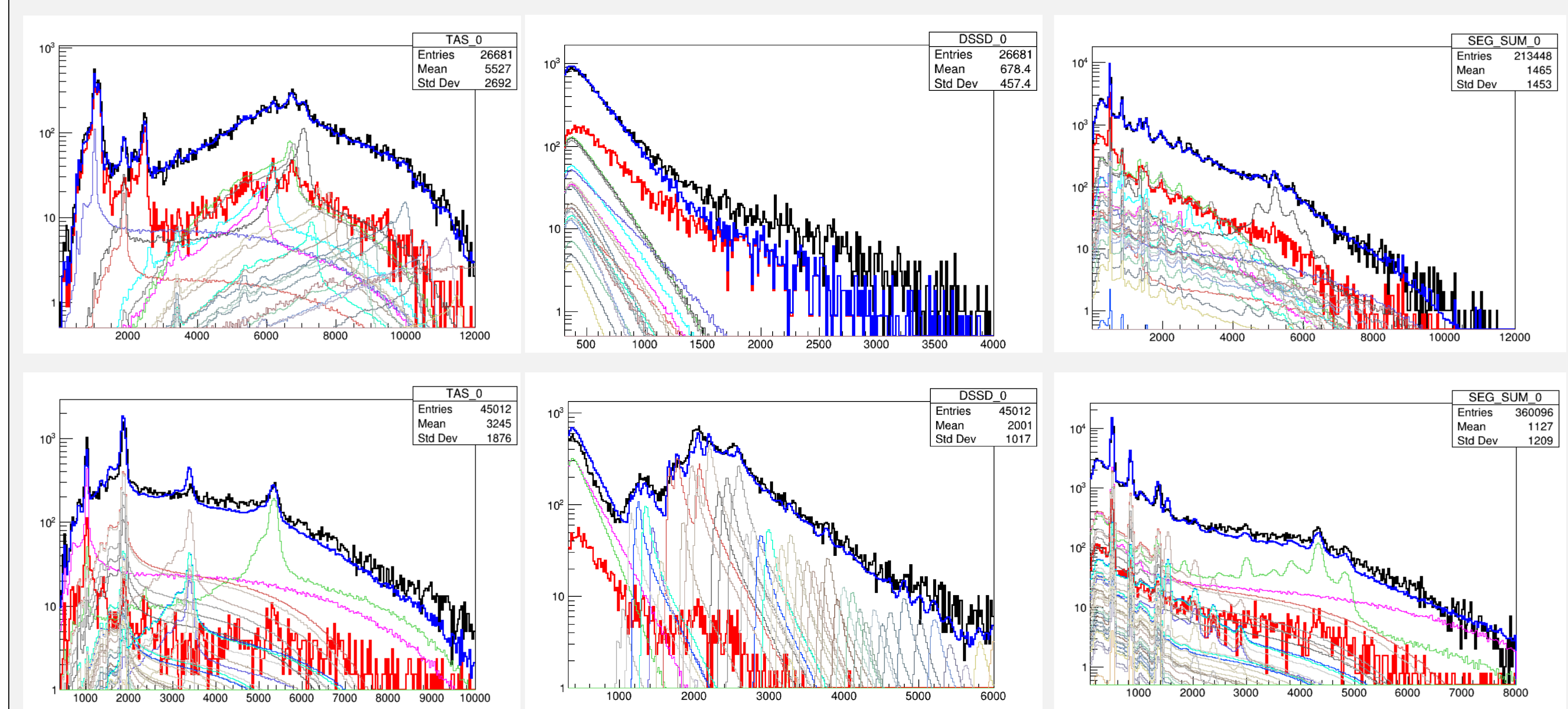

Figure 4: Top shows 52Co and bottom shows 53Ni. Then moving left to right spectra are Total energy spectra, β-particle spectra, individual γ-energy spectra

Future Work

The analysis is ongoing. Currently fits are being refined for each experimental spectra. Once fits are concluded $I_{\beta+}$ and BGT will be extracted and compared with theoretical models.

Acknowledgements

A special thanks to the Carol Guess endowed research fund, the NSCL SuN group at MSU, the NSF, and MSGC for providing funding and other support throughout the course of this experiment.

NSF: 192384 MSCG: 80NSSC20M0124