ABSTRACT ID #52

Constraining the ^{69}Zn Neutron Capture Cross-Section via the β-Oslo Method

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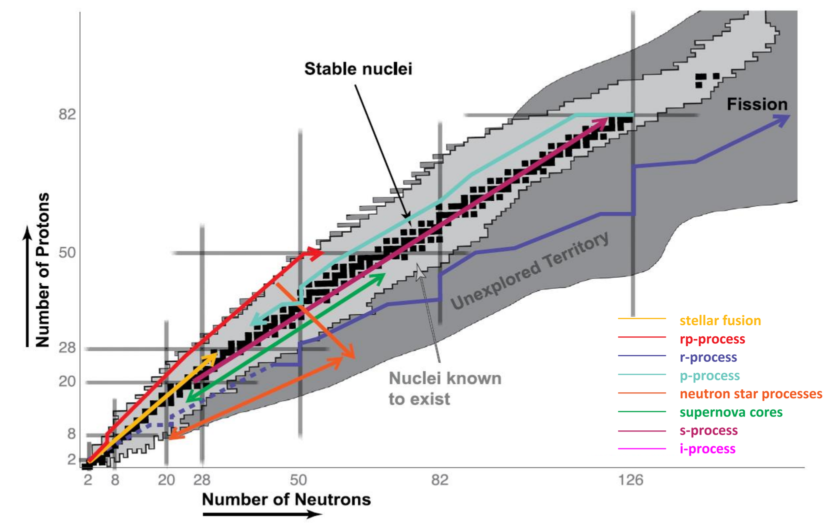
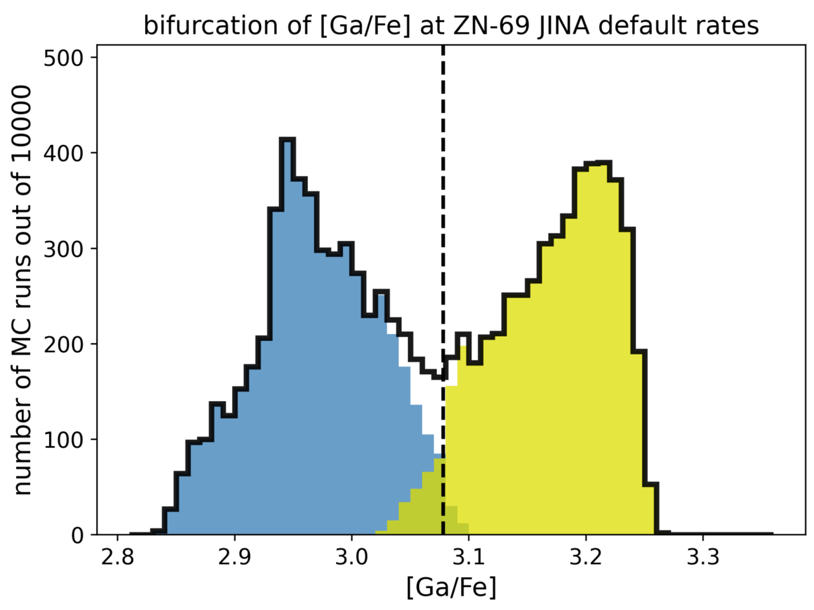
i-Process Nucleosynthesis



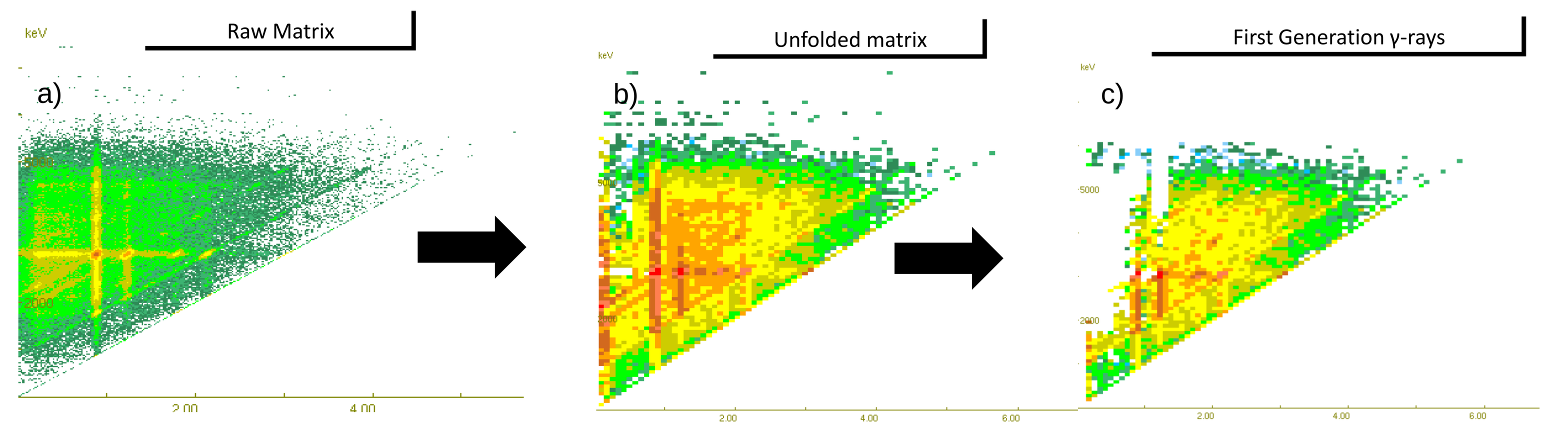
The astrophysical intermediate neutron capture process (i-process) occurs ≤ 8 nucleons away from stability. For *i*-process nucleosynthesis, theoretical models rely significantly on neutron capture (n,γ) reactions; in order to constrain these models we need experimental information about these neutron capture reactions [1].

The ^{69}Zn(n,γ)^{70}Zn reaction has high impact for the production of Ga [2]. A bifurcation in the predicted abundance distribution for [Ga/Fe] is shown to the right, where the default neutron-capture rates are shown with the vertical dashed line in the plot, and the black histograms are the total abundance distributions predicted by the sensitivity study. The blue and yellow histograms show sub-samples in which the reaction rates of the specific reaction were multiplied by factors >1 and <1 respectively.



Oslo Method Steps

Unfolding of E_x vs E_γ spectrum → Isolation of primary γ-ray spectrum → Extraction of NLD and GSF → Normalization of GSF and NLD

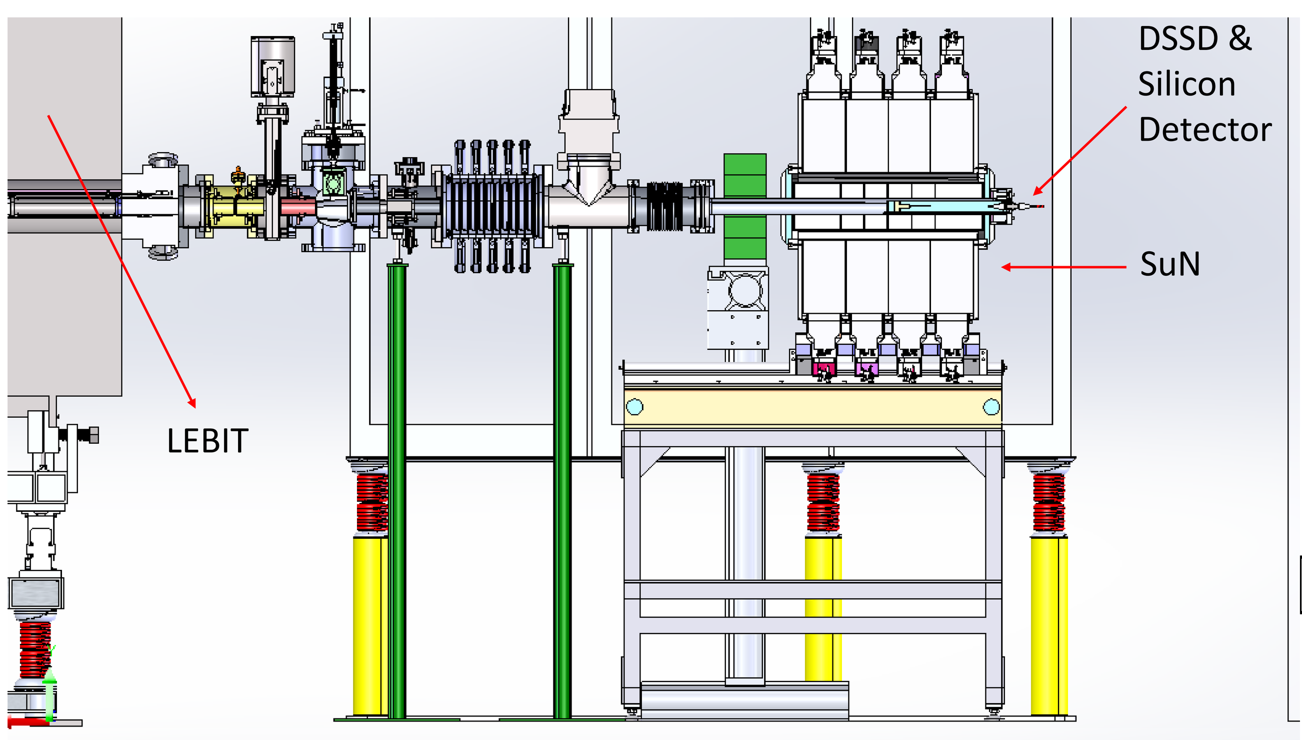


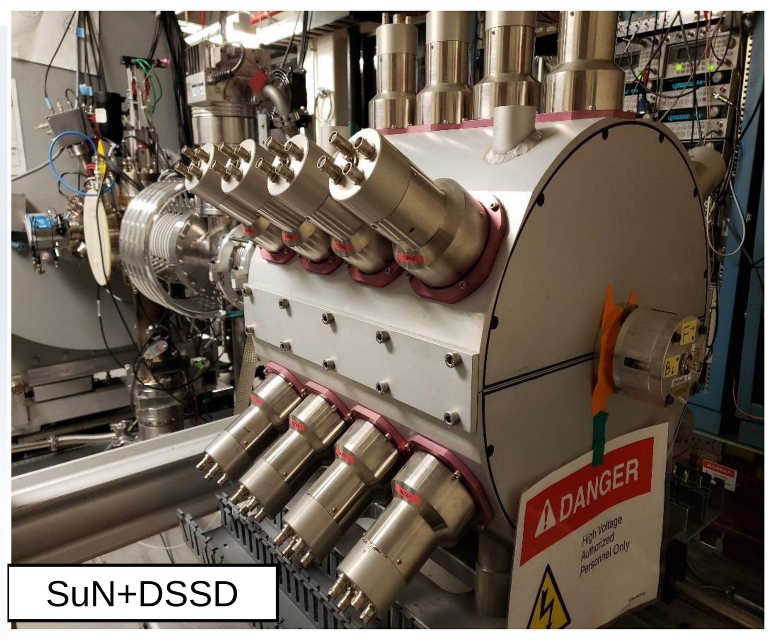
Steps in the β-Oslo method: a) shows the raw experimental matrix from SuN, b) shows the unfolded matrix after accounting for detector response, and c) shows the results from the iterative subtraction procedure, where the first-generation γ-rays were isolated. The NLD and GSF were extracted from the first-generation γ-ray spectra and normalized.

We can use β-Oslo method to experimentally determine the GSF and NLD for ^{70}Zn, and constrain the ^{69}Zn(n,γ)^{70}Zn reaction.

Experimental Details

Total Absorption Spectroscopy (TAS) with SuN + LEBIT

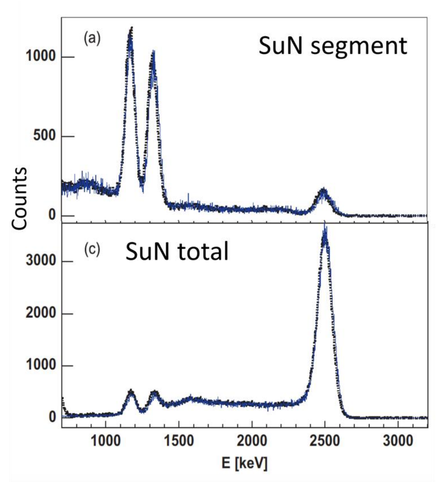


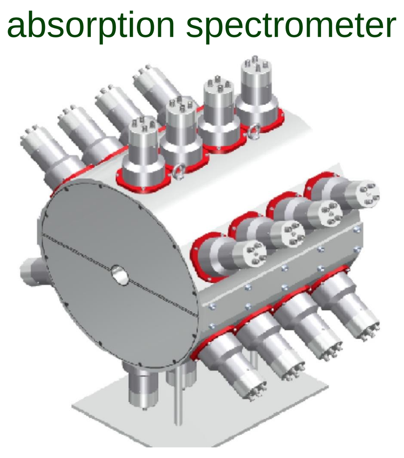


Experimental setup for the β-decay experiment at the NSCL using LEBIT and the SuN detector. ^{70}Cu ions were thermalized in the gas cell and passed through LEBIT. The β-decay implantation Si detector is placed the the center of SuN.

Summing NaI(Tl) (SuN) total absorption spectrometer

^{60}Co Decay in SuN





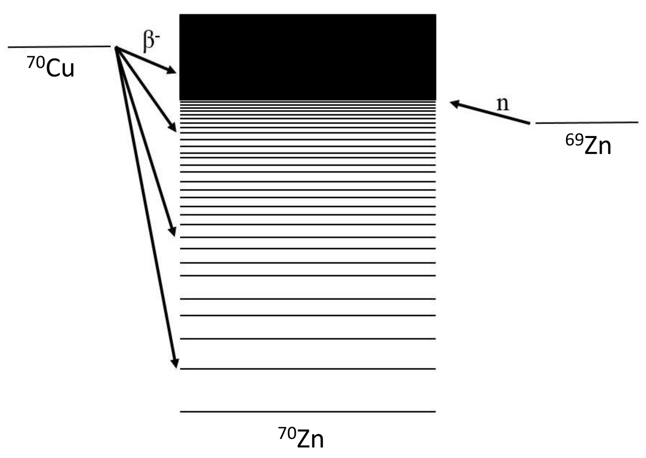
8 segments, 24 PMTs
- 16 in. diameter
- 16 in. long
- 1.8 in. bore hole

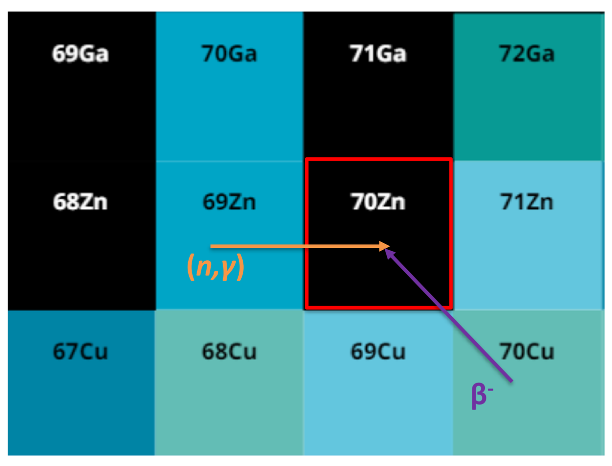
- 8 Segments give information about individual γ-rays
- Summing γ-rays from all segments gives information about excitation energies

- ^{70}Cu produced from a ^{76}Ge beam at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University
- ^{70}Cu ions sent through the Gas Stopping Facility [3] and then to the Low Energy Beam and Ion Trap (LEBIT) [4].
- LEBIT measured the percentage of each spin parity state of ^{70}Cu in the ion beam and then sent them to the Summing NaI (SuN) detector [4].
- B-decay electrons detected with a double sided silicon strip detector (DSSD) at the center of SuN

β-Oslo Method

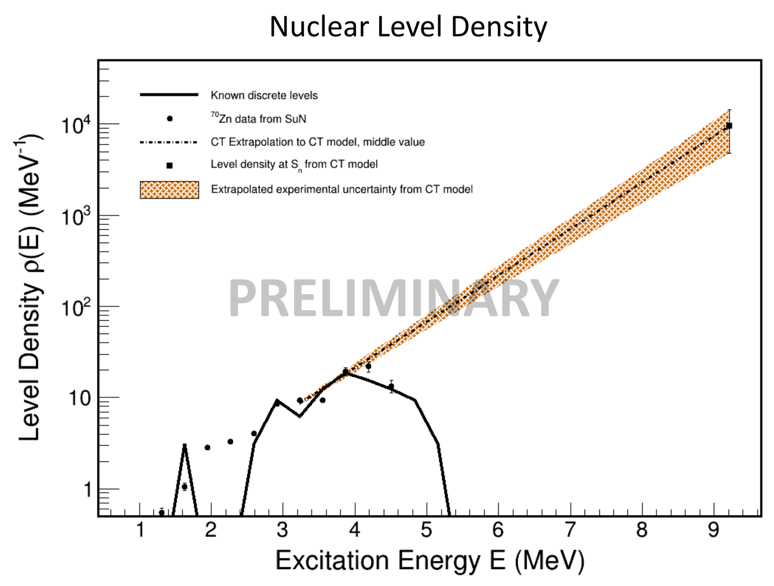
Direct measurements of (n,γ) reactions on radioactive targets are often not possible so we rely on indirect measurements and theory to predict cross-sections. The Hauser Feschbach statistical model relies on the optical model potential (OMP), nuclear level density (NLD), and γ-ray strength function (GSF).

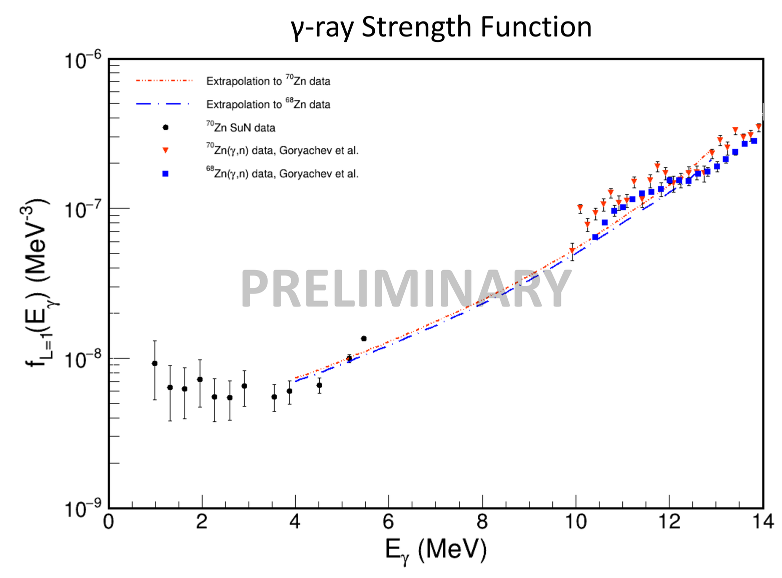




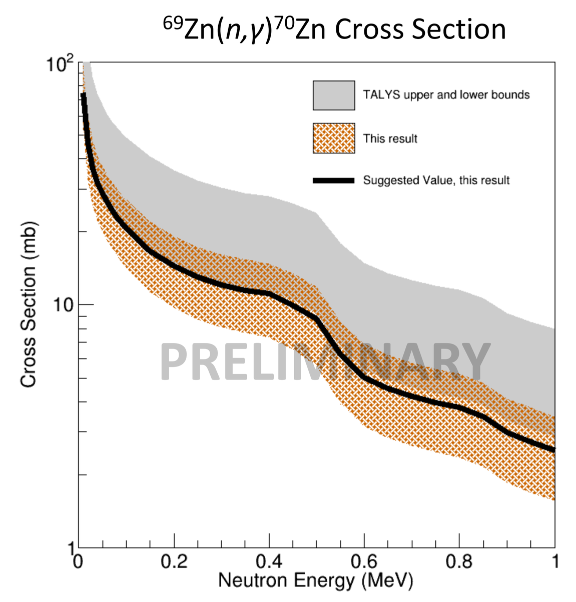
We populate the ^{70}Zn compound nucleus via β-decay instead of neutron-capture and use the procedure outlined from the standard Oslo method [5] to extract NLD and GSF information from excitation energy-tagged γ-ray experimental spectra.

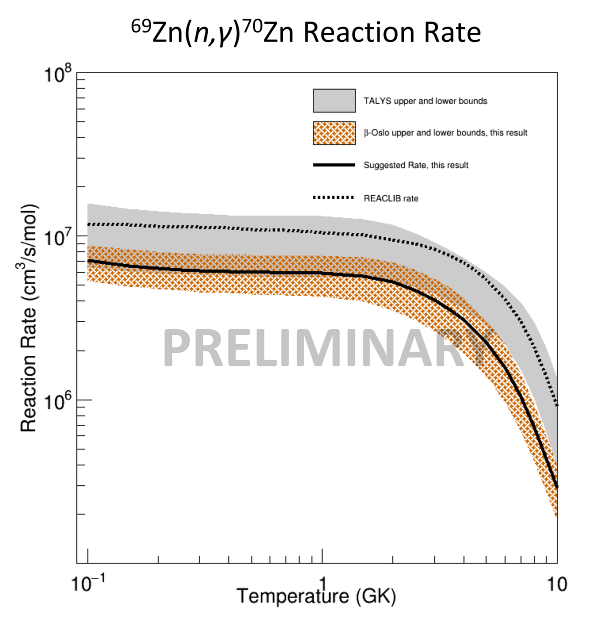
Results and Future Work



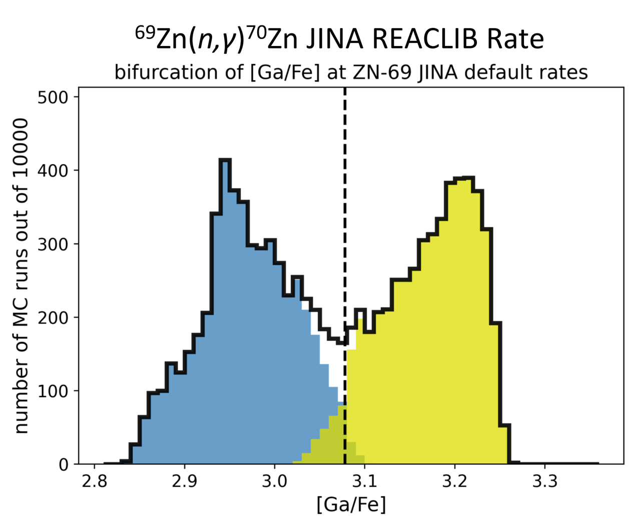


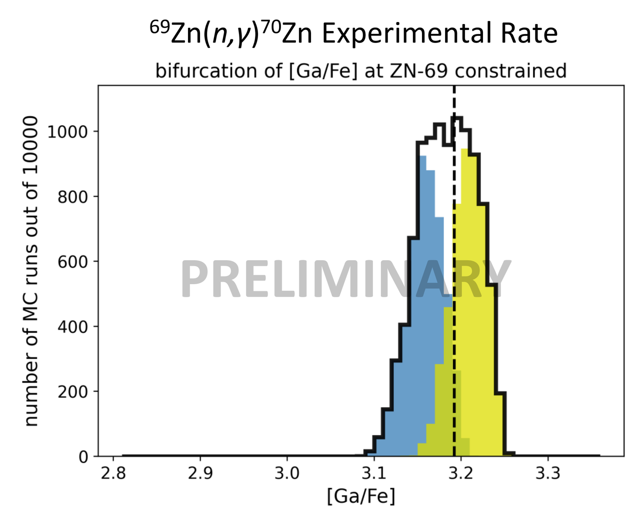
Preliminary experimental NLD and GSF from this work. The NLD was normalized to known levels and extrapolated out to S_n using a CT fit. The GSF is normalized to ^{70}Zn(γ,n) and ^{68}Zn(γ,n) data





Preliminary experimental cross-sections and reaction rates from this work. The orange bands represent the experimental constraint, and the grey bands represent the uncertainty in cross-section and reaction rates from TALYS

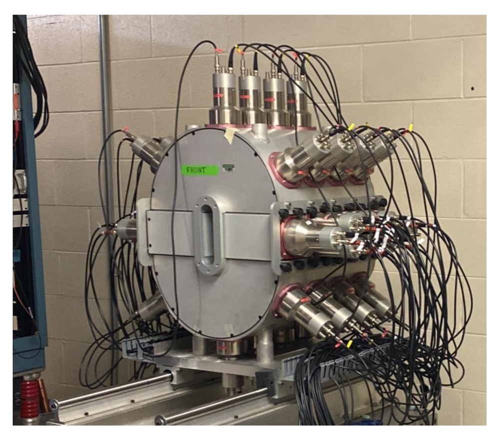




The preliminary constraint of the bifurcation plot of [Ga/Fe] i-process abundances [2]. The experimental constraint compresses the bifurcation in the predicted abundances quite significantly.

Future Work

- Compare to results from FRIB experiment using SuN++ ran in 2024
- Investigate using the Shape Method [6] as a model-independent way to extract the shape of the GSF and remove model dependency of the β-Oslo method



SuN was upgraded to SuN++
12 NaI and 8 $CeBr_3$ detectors added

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