Improved decay data for the long-lived fission products ^{147}Nd, ^{111}Ag, and ^{156}Eu

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We have completed the successful campaign on improving the branching ratios following the decay of ^{147}Nd with the publication of our manuscript titled "Precise measurements of the γ-ray intensities following the β decay of ^{144}Ce and ^{147}Nd" in Phys Rev C [1]. Continuing the work in this collaboration, we have results on the decay of ^{156}Eu that report updated intensities with reduced uncertainties of most intense emissions by an order of magnitude or more. We expect to submit our manuscript to Phys Rev C with these results on ^{156}Eu in the upcoming weeks.

Significant progress has been made on the data analysis of the ^{111}Ag decay γ-ray intensities. A clean coincidence spectrum of ^{111}Ag was extracted from the β-γ experimental technique, giving high quality statistical data of the three most intense γ-ray emissions, 96, 245, and 342 keV. We found that our original measurement for the background of 0.663(10) cps is consistent with the data. Using this value for the background and correcting for the total amount of contamination in the sample (which we found was on the order of 0.1%), an exponential fit gives us a half-life of 7.42(1) days, which is in good agreement with the half-lives from current literature of 7.45(1) and 7.473(7) days [2,3]. Our measurement of the half-life gives us confidence in our characterization of the detector background. Figure 1 shows this overall half-life measurement, along with the fit as the solid red line.

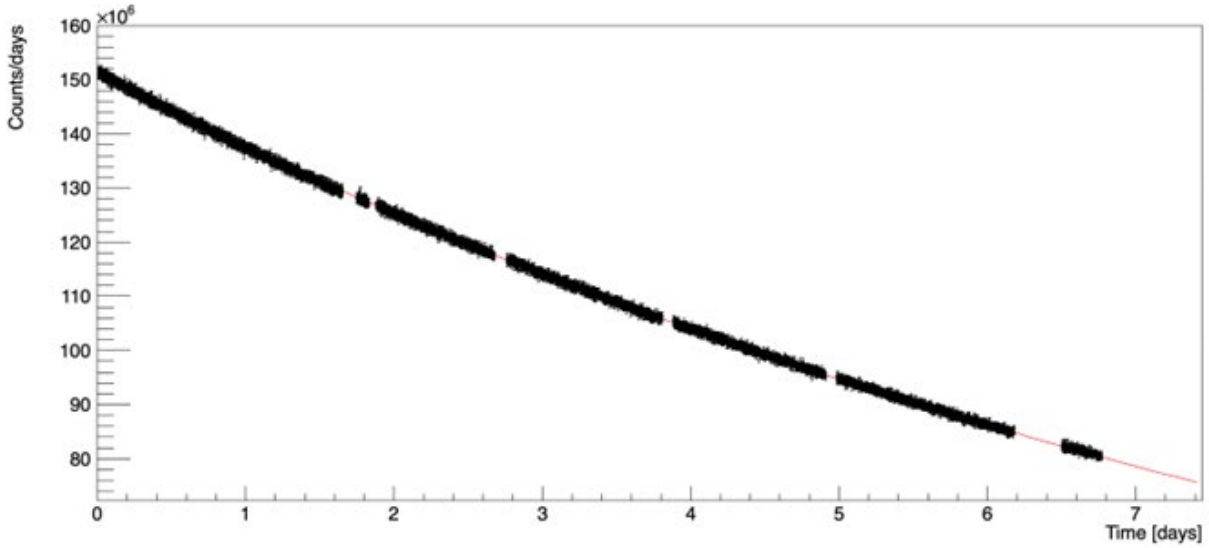

Fig. 1. A half-life curve for the measurement using the β-singles rate observed in the 4π gas counter. The solid red line shows a simple exponential fit to the data providing a half-life of 7.42(1) days.

The β-particle (ϵ_β) and β-γ ($\epsilon_{\beta\gamma}$) detection efficiencies are calculated using Geant4 simulations of the 4π gas counter, which were optimized over the past year to simulate the full decay of any isotope of interest. We have validated these simulated results of $\epsilon_{\beta\gamma}$ with experimental data by dividing the number

of β-γ coincidence events ($N_{\beta\gamma}$) by the total number of γ-rays of interest (N_γ) to produce experimentally measured β-γ detection efficiencies. For a clean determination of N_γ, a room background spectrum was collected for around the same amount of time as the experiment. The data acquisition system was configured in a way where the γ-ray singles events and β-γ coincidence events were processed by independent systems. Therefore, to calculate experimental efficiencies, a normalization factor was applied that includes detector dead-time contribution and accounts for the sample decaying over the periods of time where singles data was coincidence data were acquired. The measured $\epsilon_{\beta\gamma}$ for the 342 keV emission was calculated as 98.44(14)%, giving us an electronic threshold on our 4π gas counter during measurement of 0.65(11) keV, which is in excellent agreement to previous results using the same detector configuration and sample collection technique [1]. Using this same threshold, the 96 and 245 keV $\epsilon_{\beta\gamma}$ were 98.48(35)% and 98.45(26)%, respectively. The total β-particle detection efficiency given from Geant4 (independent of subsequent γ-ray emission), was determined to be 98.99(28)%.

The γ-ray detection efficiency calculations of TAMU's HPGe were performed by the Monte Carlo electron and photon transport code CYLTRAN. We executed the CYLTRAN simulation using the parameters and methods outlined by Texas A&M collaborators to calculate the γ-ray detection efficiencies for the 96, 245, and 342 keV photopeaks. The error of these simulated efficiencies for the HPGe detector are known to 0.4% for the 95 keV emission, and to 0.2% for the 245 and 342 keV emissions [4]. Our CYLTRAN γ-ray detection efficiencies for the 96, 245, and 342 keV photopeaks are 0.9887(20)%, 0.6674(13)%, and 0.5228(11)%, respectively.

We have preliminary results on the γ-ray intensities obtained from our measurement, shown in Table I. Updated values for the intensities of γ-ray emissions following the β decay of ^{111}Ag. with current evaluated data and the most recent literature results [2,5], and we have been able to achieve greater than 1% precision on the most intense emissions, 245 and 342 keV, emitted following the decay of ^{111}Ag.

[1] K. Kolos *et al.*, Phys. Rev. C **110**, 024307 (2024).

Table I. Updated values for the intensities of γ-ray emissions following the β decay of ^{111}Ag.

γ-ray energy [keV]	This work	ENSDF [1]	Collins *et al.* [5]
96.75	0.1026(35)%	0.1156(83)%	0.1018(14)%
245.4	1.077(9)%	1.236(90)%	1.113(14)%
342.13	6.62(3)%	6.68(33)%	6.68(7)%

[2] J. Blachot, Nucl. Data Sheets **110**, 1239 (2009).
[3] J. Dong *et al.*, Applied Radiation and Isotopes, 194 (2023).
[4] R.G. Helmer *et al.*, Nucl. Instrum. Methods Phys. Res. **A511**, 360 (2003).
[5] S. Collins *et al.*, Applied Radiation and Isotopes, **87** (2014).