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Investigations of short half-life states from SF of ^{252}Cf

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Abstract. By using different time-gated triple γ coincidence data, the half-lives ($T_{1/2}$) of several short lived states in neutron-rich nuclei have been studied. The first excited states in the ground state bands often decay by delayed γ emission. By creating triple γ coincidence spectra with time windows of 8, 16, 20, 28, and 48 ns, we have studied states with half-lives below 10 ns. The estimated half-lives of ^{102}Zr, ^{137}Xe, and ^{143}Ba are in reasonable agreement with previously reported values. We extract the first estimates of the half lives of the 2^+ states in ^{104}Zr and ^{152}Ce.

PACS. 21.10.Tg Lifetimes – 25.85.Ca Spontaneous fission – 27.60.+j $90 \leq A \leq 149$

1 Introduction

Half-lives of excited states provide important information on the deformation of nuclei. We have investigated whether a new technique of using triple γ coincidence data as a function of time applied to long-lived states [1] can be used for states with half-lives less than 10 ns. If so, then the technique may be used to determine deformations of other neutron-rich nuclei populated in spontaneous fission.

2 Technique

We estimated half-lives of excited states in neutron-rich nuclei populated in the spontaneous fission of ^{252}Cf by measuring the ratio of intensities for transitions populating and de-populating the state of interest. A schematic level scheme of the cascade in ^{98}Sr is shown in fig. 1 as an example. For this nucleus, we applied a double gate on the 565.1 and 289.0 keV transitions. Then we measured the ratio of intensities for the 144.3 and 433.0 keV transitions. The time resolution from constant fraction timing in our spectra is on the order of 10 ns. By varying the width of the coincidence time window, we can estimate the half-life of the level of interest, labeled as "L.O.I". As the time window is opened wider and wider, the intensity of the de-populating transition increases with respect to the intensity of the populating transitions. This relationship follows an exponential curve that can be fitted to estimate the half-life. Fitted curves are presented in fig. 2.

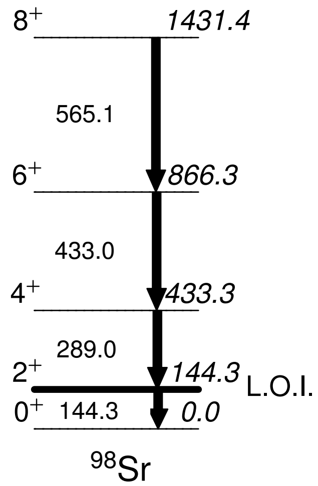

Fig. 1. ^{98}Sr Cascade.

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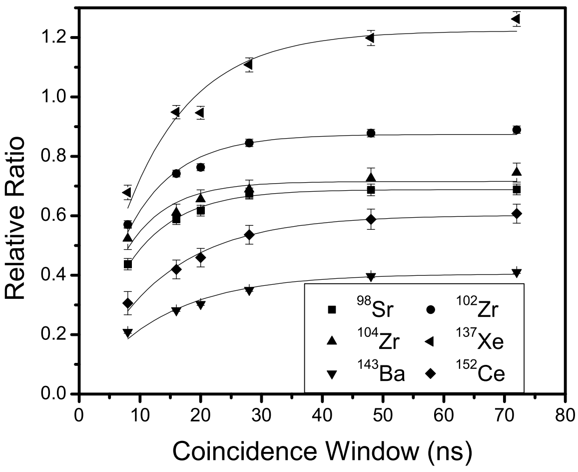

Fig. 2. Half-life curve fitting.

The technique gives good agreement with a previously known half-life below 10 ns for a transition of 314 keV in ^{137}Xe [2]. At energies of 80–200 keV, the measured half-lives are longer by a factor of 2–3 when compared to known results in this region. As a first estimate for transitions of 80–200 keV, a linear correction factor was applied and brought the measured values into good agreement with known values. Previously unknown half-lives for excited states in ^{104}Zr and ^{152}Ce were estimated with this technique.

3 Results

Our results are shown in table 1, along with values from the Evaluated Nuclear Structure Data Files (ENSDF) [3]. There is only one accurate value known for neutron-rich nuclei with a half-life less than 10 ns, the 2^+ state in ^{98}Sr. A systematic correction must be applied to our results because of time walk and other short-time corrections. This is a consequence of charge collection effects at the limits of our time resolution for these low-energy transitions. Thus, the correction depends on the energy of the de-populating transition. There is good agreement with previous results for the estimated half-life of the excited state in ^{137}Xe with a de-populating transition of 314.1 keV [2]. Thus we assume any time correction is small at these energies and higher. Also, good agreement is found with this measurement technique between our data and known values for longer-lived states [1]. Because of the lack of several precise measurements for half-lives under 10 ns as a function of energy, the exact nature of the correction is unknown.

We hypothesize as the simplest assumption that the ratio of true half-life to our measured half-life is given as a linear function of the energy of the transition de-exciting the state over the short range of 80–200 keV. The only precisely known result is for ^{98}Sr, where the ENSDF value is 2.78(8) ns and our estimated value is 5.6 ns. We fitted our correction to match this value and pass through the origin. The corrected estimate is derived from the uncorrected estimate by the following: ${T_{1/2}}^{\text{CE}} = {T_{1/2}}^{\text{UE}} \times E_\gamma/288.6$ keV. In table 1, the energy of the de-exciting transition is given, along with the uncorrected estimated (UE) and corrected estimated (CE) half-lives. The uncertainties in the uncorrected estimated values are statistical errors from the curve-fitting to the data. The uncertainties associated with the correction factor are unknown. Note that no corrected value is given for ^{137}Xe, as no correction is needed for that energy.

Table 1. Estimated half-lives ($T_{1/2}$ ns) of several states.

Nuclei	Energy	${T_{1/2}}^{\text{UE}}$	${T_{1/2}}^{\text{CE}}$	ENSDF
^{98}Sr	144.3 keV	5.6(2)	2.8[a]	2.78(8)
^{102}Zr	151.8 keV	5.7(4)	3.0	1.91(25)
^{104}Zr	140.3 keV	4.8(6)	2.3	N/A
^{137}Xe	314.1 keV	7.8(8)		8.1(4)
^{143}Ba	117.7 keV	9.0(8)	3.7	3.5(8)
^{152}Ce	81.7 keV	8.9(6)	2.5	N/A

([a]) The ^{98}Sr estimate was matched to the ENSDF value.

4 Discussion and summary

These new results provide the first estimates of the half-lives of the first excited state in ^{104}Zr and ^{152}Ce. These are in the range of several nanoseconds. However, a more complete understanding of the nature of the correction is necessary to reduce the uncertainty in our result. Our new triple γ coincidence method allows one to examine half-lives of many states populated in the SF of ^{252}Cf that have not been previously measured or have only imprecise measurements. We plan to investigate fully the timing problem and correction factor for low energy transitions to make this an accurate technique for half-lives below 10 ns.

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References

1. J.K. Hwang *et al.*, Phys. Rev. C **69**, 057301 (2004).
2. R.G. Clark, PhD Thesis, 1974.
3. Evaluated Nuclear Structure Data Files, National Nuclear Data Center, `http://www.nndc.bnl.gov/index.jsp`.