Lifetime measurements of excited states in $^{102,\,104}$Zr with a $LaBr_3$(Ce) array

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Developments of novel scintillator materials have offered a step-change in performance characteristics of scintillation detectors for γ ray measurements. In particular, cerium-doped lanthanum tri-bromide ($LaBr_3$(Ce)) has proven to be a promising candidate for measuring lifetimes of low-lying excited nuclear states in the ps-to-ns range. Such information is a powerful tool in extracting, for example, nuclear deformations.

An array of 18 $LaBr_3$(Ce) detectors was installed at the F11 focal plane of the BigRIPS spectrometer, augmenting the existing EURICA array[1)2)]. In order to examine the performance of the $LaBr_3$(Ce) array, the known lifetimes of the 2_1^+ states in $^{102,\,104}$Zr were measured by means of β-γ spectroscopy. The parent nuclei were produced by the in-flight fission of a 345 MeV/A ^{238}U beam on a 555 mg/cm^3 thick ^{9}Be target. The fission fragments were transported through BigRIPS and the ZeroDegree spectrometer before being implanted into the WAS3ABi active stopper (5 highly segmented DSSSDs), which lies between two plastic scintillators (β-plastics). To correlate a β-decay event with an implanted ion, a signal in the same DSSSD pixel to the implant was required. A time condition was placed on the ion implantation to β-decay time to reduce contamination from granddaughter decays.

The level lifetime was obtained by measuring the time difference between the β-plastic, and a signal in the $LaBr_3$(Ce) array. A systematic uncertainty of 10% was added to the measured 2_1^+lifetimes to account for the lifetimes of higher-lying levels. This was estimated from the time difference spectra for the $4_1^+ \to 2_1^+$ transitions. Figure 1 shows preliminary results of the background subtracted time difference spectra gated on the $2_1^+ \to 0_{g.s.}^+$ transitions, the energies of which are given in Tab. 1 along with the mean lifetime of the levels, which are in good agreement with literature values[3)].

The energy systematics indicate increased collectivity as N increases, however, the dependence of the transition probability on E_γ results in a longer lifetime for the 2_1^+state in ^{104}Zr than for ^{102}Zr. Future work will concentrate on a more complete characterisation of the low-energy background, the prompt-response function and the contribution of systematic uncertainties. The lifetimes of the 2_1^+states of more exotic Zr isotopes will also be measured.

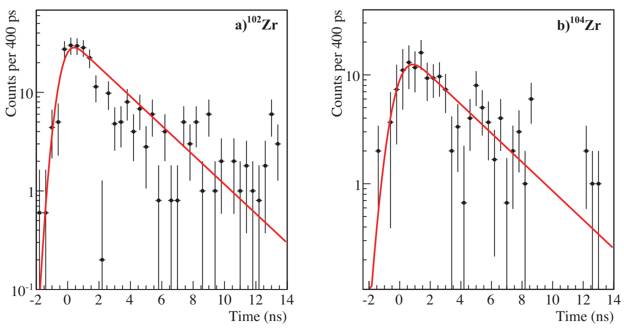

Fig. 1.: Preliminary, background subtracted time difference spectra for, a) ^{102}Zr and b) ^{104}Zr. The extracted mean lifetimes of the 2_1^+states are listed below.

Table 1.: Comparison between τ values derived in this work and adopted values[3)].

Nuclide	E(2_1^+) [keV]	τ [ns]	ENSDF τ [ns]
^{102}Zr	151.8(1)	2.7(3)	2.6(6)
^{104}Zr	139.3(3)	3.2(3)	2.9(4)

References
1) P.-A. Söderström *et al.*, Nucl. Instr. and Meth. **B317**, 649 (2013).
2) Z. Patel *et al.*: In this report.
3) Evaluated Nuclear Structure Data File, http://www.nndc.bnl.gov/ensdf

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