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 $\gamma$ 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-ps 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 RIPS 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 $\beta$-$\gamma$ spectroscopy. The parent nuclei were produced by the in-flight fission of a 345 MeV/A $^{238}$U beam on a 555 mg/cm$^2$ 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 ($\beta$-plastics). To correlate a $\beta$-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 $\beta$-decay time to reduce contamination from granddaughter decays.

The level lifetime was obtained by measuring the time difference between the $\beta$-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 $4^+_1 \rightarrow 2^+_1$ transitions. Figure 1 shows preliminary results of the background subtracted time difference spectra gated on the $2^+_1 \rightarrow 0^+_0$ 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 $E_\gamma$ 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.](image-url)

Table 1.: Comparison between $\tau$ values derived in this work and adopted values$^3$.

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>E($2^+_1$) [keV]</th>
<th>$\tau$ [ns]</th>
<th>ENSDF $\tau$ [ns]</th>
</tr>
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<tbody>
<tr>
<td>$^{102}$Zr</td>
<td>151.8(1)</td>
<td>2.7(3)</td>
<td>2.6(6)</td>
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<tr>
<td>$^{104}$Zr</td>
<td>139.3(3)</td>
<td>3.2(3)</td>
<td>2.9(4)</td>
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</table>

References
2) Z. Patel et al.: In this report.