Capability of the Califa Endcap for lifetime measurements of excited nuclear states*

S. Heil[1], M. Bayram[1], M. Petri[1], and the R3B collaboration[2]
[1]TU Darmstadt, Darmstadt, Germany; [2]GSI, Darmstadt, Germany

Transitional electromagnetic matrix elements offer deep insights into the structure of nuclear wave functions, since the electromagnetic interaction is well known. Providing such key experimental observables is thus very important for refining and testing modern state-of-the-art nuclear structure theories. The most direct, model independent way of determining transitional matrix elements is by measuring the lifetime of excited nuclear states. This type of experiments has been carried out successfully for nuclei at or near the valley of stability, providing a wealth of nuclear structure information. For very exotic nuclei such studies become more challenging, due to the low intensity of the radioactive ion beams. Thus, utilizing a setup with high efficiency and large acceptance, like R^3B, could open a new window of opportunity for this type of measurements.

In this report we investigate the feasibility of performing lifetime measurements of excited nuclear states using the CALIFA Endcap of the R^3B setup [1]. For lifetime measurements using the Doppler effect of a decelerating nucleus, i.e. the Recoil Distance Method, a γ-ray detector with excellent energy resolution is needed. HPGe detectors provide the highest intrinsic energy resolution for γ-ray detection compared to any other detector currently available. However, when dealing with fast beams, other effects dominate the in-beam energy resolution of this detector, resulting in a total energy resolution comparable with other γ-ray detectors, such as $LaBr_3$. The Endcap of CALIFA includes four rings of $LaBr_3$ detectors at the most forward direction (c. f. Fig. 1) and therefore provides a unique opportunity to perform such experiments at the R^3B setup. We have carried out extensive simulations to test the feasibility of lifetime measurements at the R^3B setup using the CALIFA Endcap at a range of beam energies, from 100 MeV/u up to 800 MeV/u, and for different mass regions.

Figure 2 shows the simulated γ-ray spectrum from the innermost $LaBr_3$ detector ring of the CALIFA Endcap when a neutron-rich ^{62}Fe beam at an energy of 97.8 MeV/u gets Coulomb excited in a 300 μm Au foil and further decelerated by a 300 μm Nb foil, with a target degrader separation of 1.2 mm. The first 2^+ state of ^{62}Fe with an excitation energy of 877 keV has a lifetime of 8 ps [2]. The resulting γ-ray spectrum includes the Coulomb excitation contribution of 30% from the degrader [2]. Experimentally this can be disentangled by performing a measurement with a very large target degrader separation. If such a measurement is not possible, e. g. due to beam time constraints, the degrader contribution can be disentangled by cross section considerations. The simulated γ-ray spectra from the $LaBr_3$ detectors of the CALIFA Endcap (c. f. Fig. 2) are very similar to the one obtained with HPGe detectors (c. f. Fig. 1 in [2]) confirming that such experiments are now feasible at the R^3B setup. This expands the R^3B experimental program to a complete new field of experiments. Currently we are developing a compelling experimental program to measure lifetimes of excited states in exotic nuclei using the CALIFA Endcap.

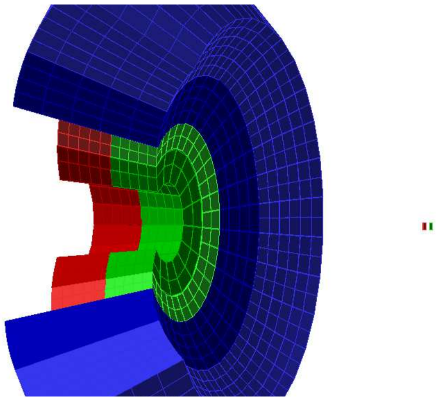

Figure 1: Illustration of the simulated Califa Endcap.

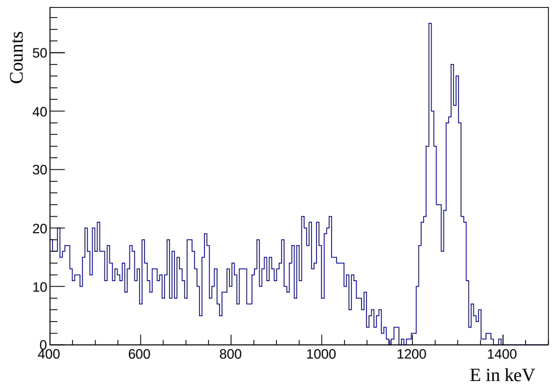

Figure 2: Simulated energy spectrum for the CALIFA Endcap detector ring at 9.9° (LaBr).

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References

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