

Measurement of Low-lying E1 transition Strength in $^{136}\text{Ce}_{78}$

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Abstract

We propose to measure the E1 decay probability from the yrast 5^- state in ^{136}Ce , using a mixed array of hyperpure germanium and lanthanum tribromide ($\text{LaBr}_3:\text{Ce-HPGe}$) detectors in Bucharest. ^{136}Ce will be populated through fusion-evaporation reaction $^{128}\text{Te}(^{12}\text{C},4n)^{136}\text{Ce}$ at energy of 55 MeV. We expect the half-life of the 5^- state in ^{136}Ce to be ~ 90 ps. This will be compared with the systematics of the region which appear to show an increased E1 hindrance at neutron number $N=78$.

1. Motivation

The nuclei of mass $A\sim 135$ and near the $N=82$ shell closure are known to demonstrate a variety of interesting phenomena. One such nucleus is ^{136}Ce which has 8 protons outside the $Z=50$ shell closure and 4 neutron holes prior to the $N=82$ shell closure. Even- Z , $N=78$ isotones all exhibit yrast $I^\pi=10^+$ isomeric states from ^{128}Sn to ^{140}Sm , based on $(\nu h_{11/2})^{-2}$ configurations. Figure 1 shows the systematics of the $N=78$ isotones with $52 \geq Z \leq 62$ [1-6].

The level structure of ^{136}Ce has been investigated earlier in a number of studies [5, 4, 7, 8]. These studies identified the yrast $I^\pi=2^+$ at energy of 552 keV. Negative parity states with $I^\pi=5^-$ and 7^- have also been reported

by [4] at $E_x = 1978$ - and 2307 -keV respectively. Muller-Veggian et al. [5] suggested $\nu[h_{11/2} \otimes s_{1/2}/d_{3/2}]$ a two-neutron configuration as the underlying single-particle structure for these states. Similar negative parity states have been reported in other $N=78$ isotones.

This proposal seeks to measure the electromagnetic decay rate of the $I^\pi=5^-$ state in the $N=78$ nucleus ^{136}Ce , using the advanced fast-timing coincidence technique described in Ref. [9]. The $I^\pi=5^-$ state decays (see figure 3) by a pure stretched E1 decay of energy 664 keV to the $I^\pi=4^+$ state at 1314 keV. It is well known that E1 transitions are forbidden in the restricted valence shell model space. Figure 2 shows the systematics of $B(E1; 5^- \rightarrow 4^+)$ in Ba isotopes [10, 11, 12]. It can be seen that the in ^{134}Ba E1 transition is hindered by a factor of about 100 compared to apparently similar decays in the neighbouring $N=76$ and $N=80$ isotopes. This proposal aims to measure the E1 transition rate for the $5^- \rightarrow 4^+$ yrast decay in ^{136}Ce to see if a similar excess hindrance compared to its $N=80$ and 76 neighbours is also observed.

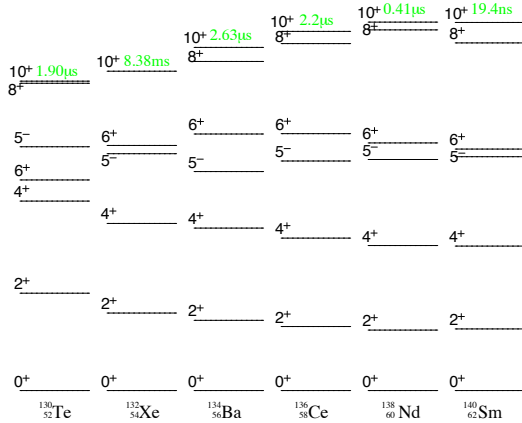


Figure 1: Systematics of low-lying positive-parity and 5^- states in $N=78$ isotones.

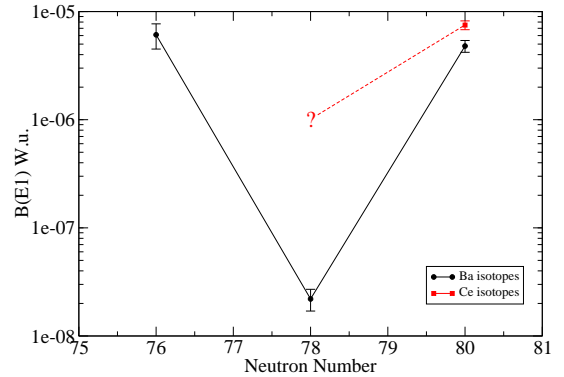


Figure 2: Systematics of $B(E1; 5^- \rightarrow 4^+)$ in Ba isotopes.

2. Experimental Details

The nuclei of interest will be populated through fusion-evaporation reaction $^{128}\text{Te}(^{12}\text{C}, 4n)^{136}\text{Ce}$ at energy of 55 MeV. The cross-section for production calculated with the PACE4 code [13] for this reaction is 550 mb. Figure 4 shows the predicted xn reaction channel cross-sections and l_{max} for the $^{12}\text{C}+^{128}\text{Te}$ re-

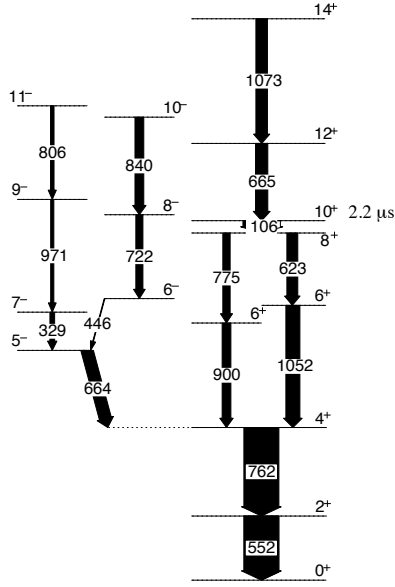


Figure 3: Partial level schemes of ^{136}Ce taken from [14].

action. The target will have a thick Pb backing to stop the reaction products in the target chamber.

We aim to measure the half-life of the 5^- state in ^{136}Ce by taking the time difference between the $7^- \rightarrow 5^-$ (329 keV) and the $5^- \rightarrow 4^+$ (664 keV) transitions as described in Ref [9]. Using this method, the half-life is measured from the relative shift between the centroids of the forward and backward time spectra, made by slicing a LaBr₃-LaBr₃- ΔT cube.

Figure 5 (a) shows the time spectra associated with the decay of the yrast for 5^- in ^{138}Ce . An extracted experimental half-life of $t_{1/2}=450(14)$ ps [15] was obtained from the centroid shift of the time difference spectra gated on 77- and 390-keV transitions in the LaBr₃(Ce) detectors. Figure 5 (b) shows the time distribution of a the background gate used. Assuming a similar $B(E1)$ strength for the $5^- \rightarrow 4^+$ decays between ^{136}Ce and ^{138}Ce , an estimate of the expected $E1$ transition probability can be inferred from the E_γ^3 transition rate dependence. Using this we can estimate a half-life for the 5^- state of ^{136}Ce of ~ 90 ps, however, if the hindrance is similar to that observed in the N=78 isotope ^{134}Ba , a half-life of close to 9 ns would be observed.

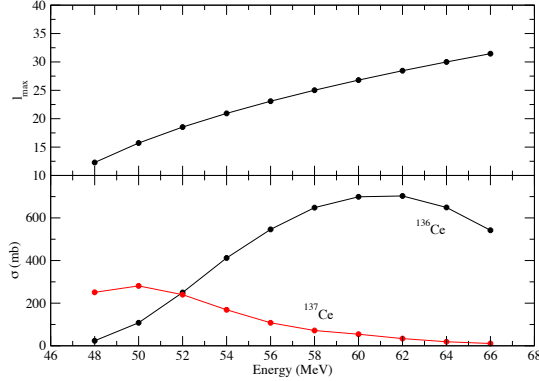


Figure 4: PACE4 cross-section calculations for the xn channels of the $^{12}\text{C}+^{128}\text{Te}$ reaction.

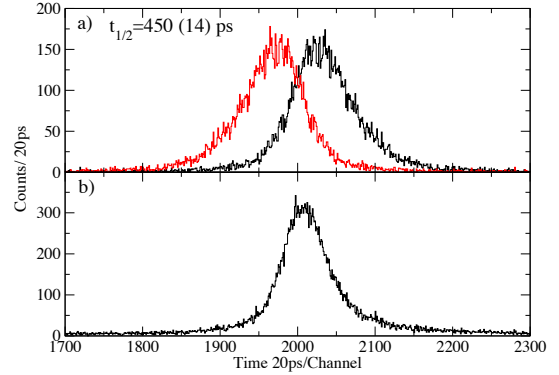


Figure 5: Time spectra obtained for the decay of the 5^- state in ^{138}Ce . (a) Time distributions, plotted with black line, are gated on (77-, 390-keV), while the red line shows the symmetric time distribution gated on (390-, 77-keV).

3. Rate Estimated and Beam-Time Request

Assuming a $1\text{mg}/\text{cm}^2$ ^{128}Te target, a 10 pA ^{12}C beam and production cross-section of 550 mb , we will produce 1.5×10^5 ^{136}Ce pps. Using an estimated 10% population of the 5^- state, 2% Ge efficiency and an average LaBr_3 efficiency of 0.5%, we can expect 27 useful Ge- LaBr_3 - LaBr_3 coincidences per hour or 600 per day. 4 day's beam time will be sufficient to measure the half-life of the 5^- state and 1 day for calibrations.

The Bucharest array is expected to have the addition of three $1.5'' \times 1.5''$ $\text{LaBr}_3:\text{Ce}$ detectors provided by the DESPEC collaboration. This will bring the total number of $\text{LaBr}_3:\text{Ce}$ detectors to be used in the final set-up to 11 and will increase the efficiency for the combined LaBr_3 detectors to 1.9% at 662 keV.

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