Measurement of Low-lying E1 transition Strength in $^{136}Ce_{78}$

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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 ($LaBr_3$:Ce-HPGe) detectors in Bucharest. ^{136}Ce will be populated through fusion-evaporation reaction ^{128}Te(^{12}C,4n)^{136}Ce at energy of 55 MeV. We expect the halflife 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∼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^{π}=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^{π}=2^+ at energy of 552 keV. Negative parity states with I^{π}=5^- and 7^- have also been reported

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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^π=5^- state in the N=78 nucleus ^{136}Ce, using the advanced fast-timing coincidence technique described in Ref. [9]. The I^π=5^- state decays (see figure 3) by a pure stretched E1 decay of energy 664 keV to the I^π=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.

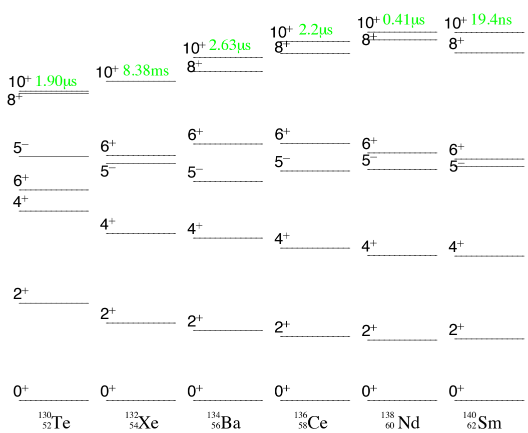

Figure 1: Systematics of low-lying positive-parity and 5^- states in N=78 isotones.

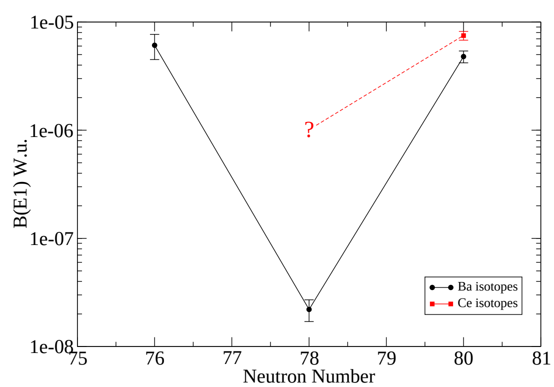

Figure 2: Systematics of $B(E1; 5^- \rightarrow 4^+)$ in Ba isotopes.

2. Experimental Details

The nuclei of interest will be populated through fusion-evaporation reaction ^{128}Te(^{12}C,4n)^{136}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}C+^{128}Te re-

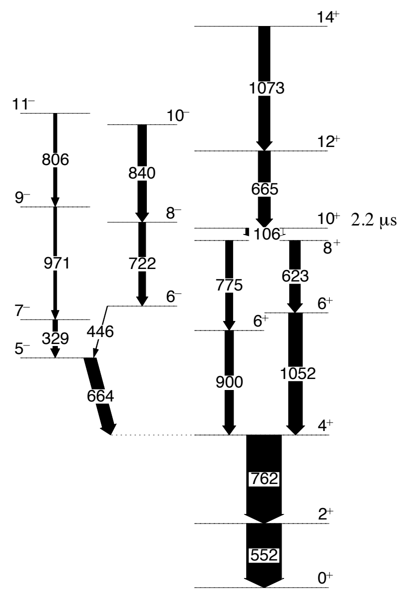

Figure 3: Partial level schemes of ^{136}Ce taken from [14].

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

We aim to measure the halflife 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 halflife is measured from the relative shift between the centroids of the forward and backward time spectra, made by slicing a LaBr$_3$-LaBr$_3$-ΔT cube.

Figure 5 (a) shows the time spectra associated with the decay of the yrast for 5^- in ^{138}Ce. An extracted experimental halflife 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 LaBr$_3$(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 halflife for the 5^- state of ^{136}Ce of $\sim$90 ps, however, if the hindrance is similar to that observed in the N=78 isotone ^{134}Ba, a halflife of close to 9 ns would be observed.

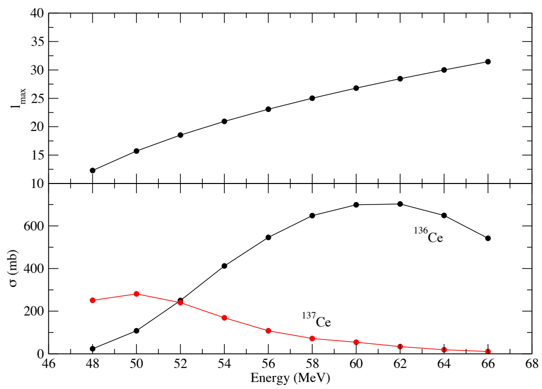

Figure 4: PACE4 cross-section calculations for the xn channels of the ^{12}C+^{128}Te reaction.

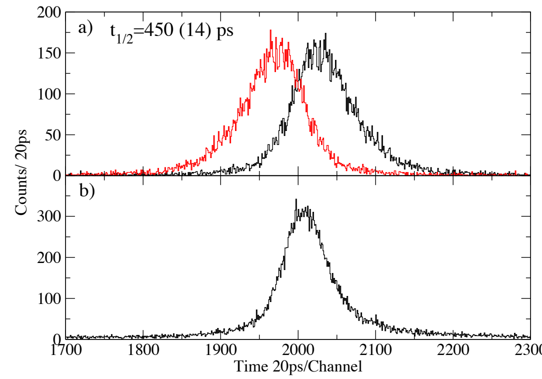

Figure 5: Time spectra obtained for the decay of the 5^- state in ^{138}Ce. (a) Time distributions, plotted with black line, are gated on (77-, 390-keV), while the red line shows the symmetric time distribution gated on (390- , 77-keV).

3. Rate Estimated and Beam-Time Request

Assuming a 1mg/cm^2 ^{128}Te target, a 10 pnA ^{12}C beam and production cross-section of 550 mb, we will produce 1.5x10^5 ^{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 halflife of the 5^- state and 1 day for calibrations.

The Bucharest array is expected to have the addition of three 1.5" × 1.5" $LaBr_3$:Ce detectors provided by the DESPEC collaboration. This will bring the total number of $LaBr_3$: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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