EXPERIMENT PROPOSAL

Mapping the U(5)-O(6) shape/phase transition: Lifetime measurements in ^{132}Ba

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Abstract

We propose to measure lifetimes in the ground state band of ^{132}Ba, populated in the ^{124}Sn(^{12}C, 4n) reaction through the Recoil Distance Doppler Shift (RDDS) method using the ROSPHERE spectrometer and the Bucharest plunger device. The ROSPHERE spectrometer, in its mixed configuration consisting of 14 HPGe detectors and 11 $LaBr_3$(Ce) fast scintillators, allows also sub-nanosecond lifetime measurements through the in-beam fast timing method, thus enabling combined lifetime measurements in the range from several picoseconds to several nanoseconds.

1. Scientific motivation

The Ba mass region is known as a transitional region, the nuclear structure evolving from quasi-rotational bands characteristic of lighter isotopes through an O(6) region (^{128}Ba [1,5], ^{130}Ba[4,7]) towards a spherical shape. The evolution from γ-soft to spherical shape goes through a shape transition, the critical point being described by the E(5) symmetry [2], the best empirical example of this symmetry being the ^{134}Ba nucleus [3]. The Ba isotopic chain offers an unique possibility in the study of the evolution of nuclear collectivity from the O(6) symmetry to the U(5) symmetry and of the phase/shape transition associated with this evolution.

Recent IBM calculations in the region [6] have shown, based on electromagnetic and hadronic data, that the structure of Ba nuclei in this region is transitional between U(5) and O(6) dynamic symmetries. Understanding the nature of the critical point symmetry and of the neighboring nuclei requires a detailed knowledge on the lifetimes of the first excited states in the ground state band. Such detailed information is lacking for ^{132}Ba, even for the lowest members of the ground state band.

Recently, the structure of ^{132}Ba was studied in the (p,t) reaction [6], in the ^{124}Sn(^{13}C, 5n) [8], in the β decay of ^{132}La [9], while the lifetime information comes from a Coulex experiment [10] (only for the 2_1^+ and the 2_2^+ states) and from the electronic timing method in the ^{122}Sn(^{13}C, 3n) reaction [11] (for the 5^- state and a limit for the 7^- state). There is no other lifetime information for the yrast band (besides the long 10^+ isomer). We propose an experiment aimed at measuring lifetimes for excited states in ^{132}Ba through the RDDS method [12] using the ROSPHERE array and the Bucharest plunger device. We expect also that some levels will have lifetimes in the range of the in-beam fast-timing method [13].

2. Experiment Proposal

We propose to use the ^{124}Sn(^{12}C, 4n) reaction at a beam energy of 58 MeV to populate the ground state band in ^{132}Ba. A cross-section calculation, performed with the statistical model code CASCADE, shows an increasing cross-section for the 4n channel from the Coulomb barrier (~42MeV) up to 60 MeV where the 5n channel opens. At 58 MeV, Cascade estimates a 760 mb cross-section out of 815 mb total reaction cross-section. Alternatively, the ^{122}Sn(^{13}C, 3n) reaction can be used, with similar high cross-section for the population of ^{132}Ba, but at a lower beam energy.

Given the high cross-section, we estimate that a 2 pnA beam of $^{12}C^{6+}$, delivered by the Bucharest 9 MV Tandem accelerator, bombarding a target of 0.5 mg/cm^2 ^{124}Sn on 4 mg/cm^2 Au backing will be enough to generate a counting rate of 3-4 kHz per HPGe detector. The beam intensity will be tuned further to assure a stable target-stopper distance, especially at short distances.

The γ-rays will be detected in the ROSPHERE array, in its mixed configuration, comprising 14 HPGe detectors placed in the 37, 90 and 143 degrees rings and 11 $LaBr_3$(Ce) scintillators placed in the remaining positions. By using the ROSPHERE array in the mixed configuration, we will be able to measure longer lifetimes through the in-beam fast-timing method. The 7^- state has an upper limit for the lifetime of 0.2 ns [11], thus being a candidate for the fast-timing method. Also, the halftime of the 5^- state, measured in [11] has a relative error larger than 50%, which could be improved in this experiment.

Fig.1 shows a partial level scheme as published in Ref. [8]. In this mass region the occurrence of the yrast 10^+ isomer ($T_{1/2}$=8.9(1) ns for ^{132}Ba) is a challenge in performing RDDS measurements, but based on the our previous experience with the ^{120}Te, ^{134}Ce, ^{138}Nd experiments, the states below the isomer are populated through other states, bypassing the isomer, with enough intensity to perform the Differential Decay Curve Method (DDCM) [14] coincidence analysis.

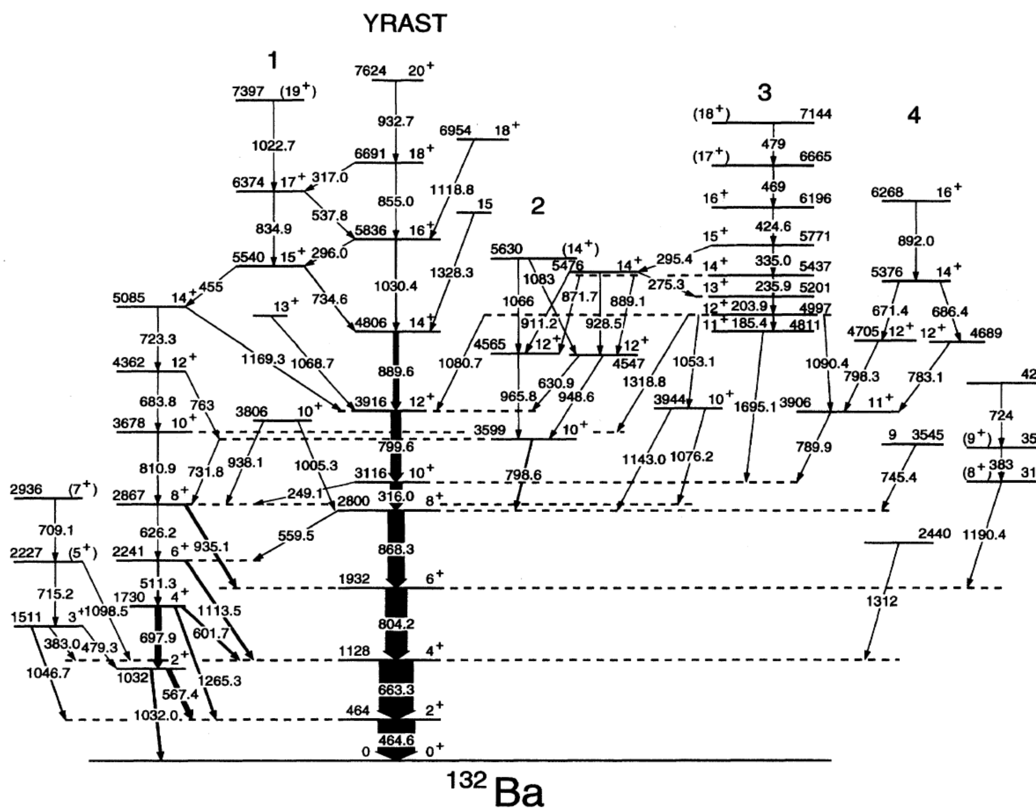

Fig 1 Partial level scheme of ^{132}Ba, studied in the ^{124}Sn(^{13}C, 5n). Figure from [8].

The lifetime of the 2^+ was estimated in the Coulex experiment [10] to be 21.8(11) ps. In a previous experiment, lifetimes in the ground state band of the isotone nucleus ^{134}Ce were measured with the same setup proposed to be used here. Because the ground state sequence $6^+ \rightarrow 4^+ \rightarrow 2^+$ in ^{132}Ba is similar in regard to the transition energies to the corresponding sequence in the ^{134}Ce nucleus (814 keV, 639 keV, 409 keV, respectively), we estimate that the lifetime of the 2^+ state is actually longer, in the range 25-35 ps. Based on the same argument, we estimate the lifetime of the 4^+ state to be in the range 3-4 ps, while the lifetime of 6^+ should be shorter than 2 ps.

We estimate that we will need to measure at 10 target-stopper distances in order to be able to measure lifetimes in the range 1-40 ps. On average, we need a day of beam time for each distance to achieve the high statistics needed for the coincidence DDCM analysis and an extra day for the target-stopper alignment, pumping and beam tuning.

3. Summary

Requested beam, energy and intensity: $^{12}C^{6+}$, 58 MeV, 2pnA
Requested beam-line: ROSPHERE + plunger
Requested beam-time: 11 days

4. References

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