EXPERIMENT PROPOSAL

RDDS lifetime measurements in ^{120}Ba

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We propose an experiment to measure lifetimes in the ground state band of ^{120}Ba, populated in the ^{106}Cd(^{16}O,2n) reaction, through the Recoil Distance Doppler Shift (RDDS) method using the ROSPHERE spectrometer and the Bucharest plunger device [1]. The ROSPHERE spectrometer, in its mixed configuration, consisting of 15 HPGe detectors and 10 $LaBr_3$(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.

I. SCIENTIFIC MOTIVATION

The Ba mass region is well known as a transitional region, the nuclear structure evolves from quasi-rotational bands characteristic of lighter isotopes (^{122}Ba [2–4]) through an O(6) region (^{128}Ba [5, 6], ^{130}Ba [7, 8]) towards a spherical shape. This is visualised in the insert from Fig. 1 using the E_{4^+}/E_{2^+} ratio as a first estimate of the nuclear shape.

In Fig. 1 a plot of the B(E2) for the $2^+ \to 0^+$ for the Ba isotopes against the neutron number N is presented. This shows the evolution of the collectivity across the neutron shell, which shows a normal behaviour one would expect, *e.g.* an increase in collectivity towards the midshell region and a decrease after this point. This image is possible in

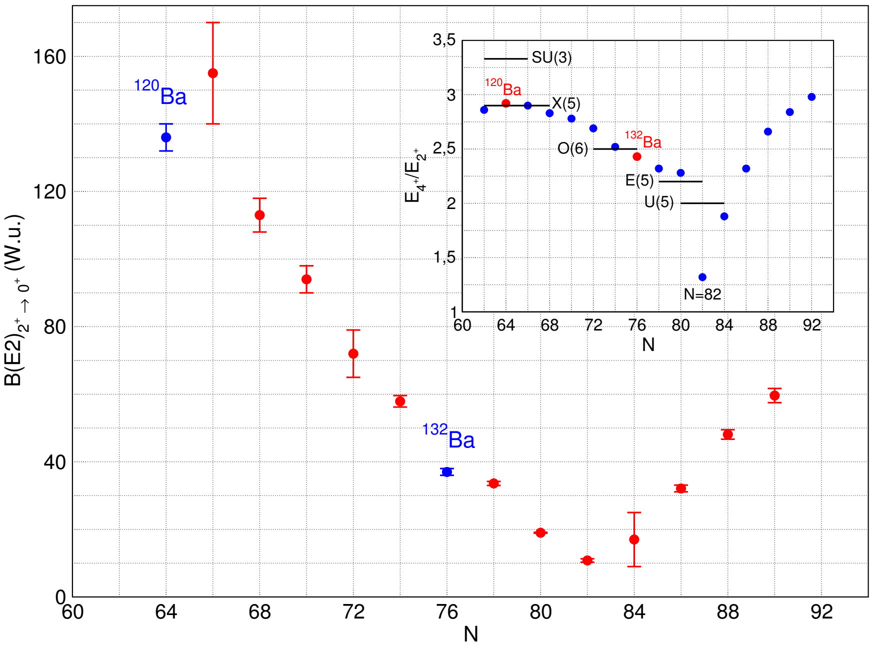

FIG. 1: Ba isotopes systematics. The insert shows the evolution of the E_{4+}/E_{2+} ratio which is a rough indicator of the shape of the nucleus, while the main graph shows the evolution of the B(E2)$_{2^+\to 0^+}$ values through the Ba isotopic chain. The B(E2) values in ^{120}Ba and ^{132}Ba are preliminary results measured by our group. The rest of the data are taken from [9].

part to the recently measured B(E2) ^{120}Ba which adds to the information on the Ba isotopic chain. This measurement was achieved due to a test performed at the Bucharest 9MV Tandem accelerator to assess the feasibility of producing ^{120}Ba through the ^{106}Cd(^{16}O,2n) reaction.

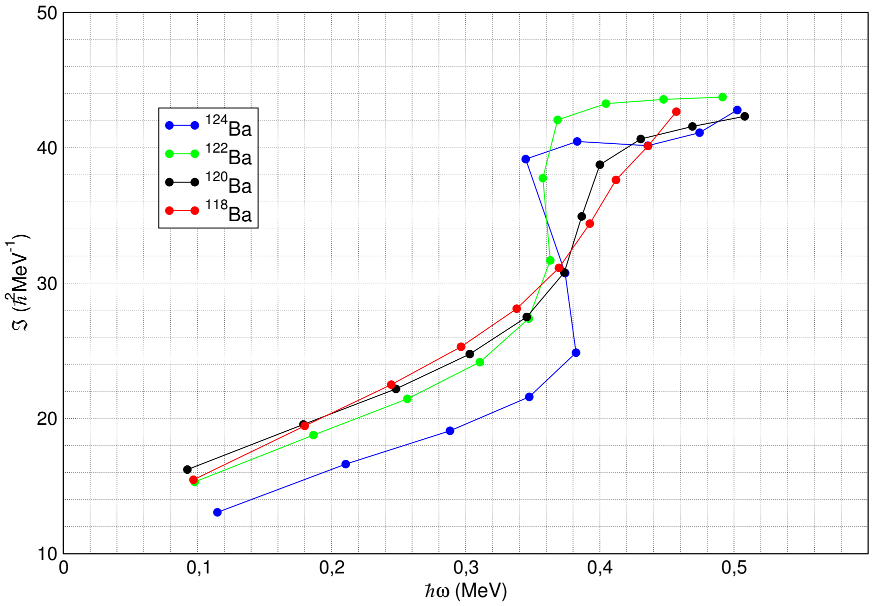

FIG. 2: Moment of inertia plotted against rotational frequency for the yrast states in ^{118}Ba, ^{120}Ba, ^{122}Ba and ^{124}Ba. The data are taken from [9].

In Fig. 2 a plot is shown of the moment of inertia $\Im = \hbar\,(2J-1)\,/\,(E_J - E_{J-2})$ against the rotational frecvency $\hbar\omega = (E_J - E_{J-2})\,/2$. For the ^{118,120}Ba an upbend of the moment of inertia can be observed in constrast with the backbend exibited for the ^{122,124}Ba. The data also shows that the moment of inertia for the lighter nuclei has a higher value, as previous observed in Ref. [2]. Considering that the moment of inertia scales with the mass of the nucleus as $\Im \approx A^{5/3}$, the $\approx 10\%$ difference between the moment of inertia of ^{120}Ba and ^{122}Ba may arise form a bigger deformation of the former.

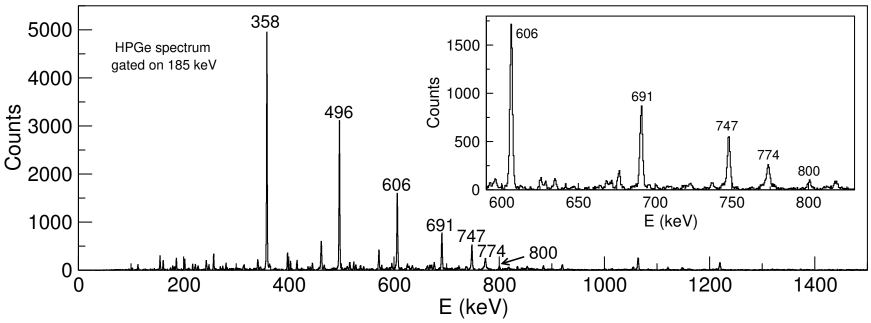

FIG. 3: HPGe spectra of ^{120}Ba measured during our test run. The spectra are gated on the 185 keV depopulating the first 2^+ state. The insert shows there are no line shapes present up to the 691 keV transition that depopulates the first 10^+ state.

Further understanding the structure of the ^{120}Ba nucleus requires the knowledge of the lifetimes of the first excited states in the ground state band. Such information is lacking, even for the lowest members of the ground state band. We propose an experiment to measure lifetimes of the excited states in ^{120}Ba through the RDDS method [10] using the ROSPHERE spectrometer and the Bucharest plunger device.

II. EXPERIMENT PROPOSAL

In Fig. 3 are presented the HPGe spectra we measured during the test performed at the Bucharest 9MV Tandem accelerator. A beam of ^{16}O bombarded a $\approx$ 2 mg/cm^2 self supporting ^{106}Cd target with a beam energy of 66 MeV and an intensity of $\approx$ 2 pnA. The test showed that the we can produce ^{120}Ba and that the states up to spin 16 $\hbar$ are populated.

The insert in Fig. 3 shows that the lifetimes of the levels bellow the first 10^+ state, which decays through the 691 keV transition, are above the sensitivity range of the Dopper Shift Attenuation method (DSAM), *e.g.* the energy peaks corresponding to the transitions depopulating this levels do not exibit line shapes. In Fig. 4 is a partial level scheme from Ref. [12] is shown.

We propose an experiment to measure lifetimes in ground state band of ^{120}Ba populated through the ^{106}Cd(^{16}O,2n) reaction . The experiment in Ref. [2, 3] measured for this reaction the cross section at 64.5 MeV for the 2n exiting channel to be (7 ± 3)% of the compound nucleus cross section, value corroborated by the data obtained from our test. The cross section calculation performed with the statistical model code `CASCADE` shows similar cross section of $\approx$10 mb at an incident energy between 61 and 66 MeV, while the fusion cross section more than doubles in this energy range.

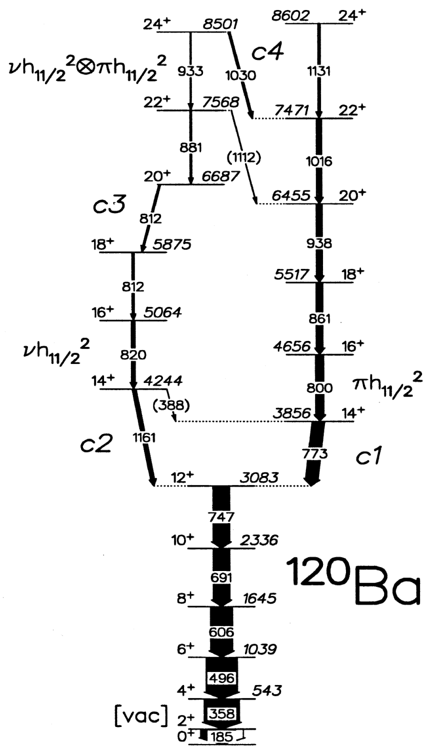

FIG. 4: Part of the level scheme of ^{120}Ba reported in [12].

For this experiment we request a $\approx$ 0.5 mg/cm^2 enriched ^{106}Cd target on a $\approx$ 2.5 mg/cm^2 Ta backing. The beam energy will be reduced from 71 MeV to about 66 MeV as it reaches the ^{106}Cd target.

Given the low cross section a longer than usual measurement time for each target to stopper is required in order to gather the statistics needed to performe the Differential Decay Curve Method (DDCM) [11] coincidence analysis. The beam intensity needs to be tuned in order to obtain a good compromise between the counting rate, the target stability with respect to the stopper at the shortest distances and to prevent damage by overheating the target.

The γ-rays will be detected with the ROSPHERE spectrometer, a detector array containing 15 Compton-suppressed HPGe detectors placed in 3 rings at 37, 90 and 143 degrees and 10 LaBr$_3$(Ce) scintillators placed in the remaining 2 rings at 70 and 110 degrees. In this mixed configuration we are also able to measure longer lifetimes using the in-beam fast-timing method and allow us to lower the uncertainty of the lifetime of the first 2^+ state through the in-beam fast timing method.

We estimate that we need to measure at 8 target to stopper distances to be able to measure lifetimes in the range 1-20 ps while at the same time we will be measuring the lifetime of the first 2^+ state. An average of one and a half day per distance is required to get the high statistics needed for the DDCM analysis and an extra day for the target-stopper alignment and beam tuning.

III. BEAMTIME REQUEST

Considering the following conditions:

- ≈ 0.5 mg/cm^2 ^{106}Cd target on a ≈ 2.5 mg/cm^2 Ta backing;
- 71 MeV incident energy of the ^{16}O beam, which corresponds to $\approx$ 64.7-66 MeV energy integration in the target;
- an average ^{120}Ba production cross section of 10 mb inside the ^{106}Cd layer, representing $\approx 4\%$ from the total reaction cross section and an average of 10 gamma rays emitted by any fusion-evaporation product;

we plan to use an intensity of ≈ 5 pnA, which correspond roughly to ≈ 850 ^{120}Ba nuclei per second and ≈ 5 kHz/HPGe crystal.

Taking into account:

- a similar lifetime for the first 10^+ state as that measured for ^{122}Ba in Ref. [4];
- a $\gamma-\gamma$ coincidence absolute photo-peak efficiency at 747 keV of $\approx 4.5\times10^{-4}$ for the sum of the HPGe detectors in ROSPHERE, as measured from the test data;

we get a ≈ 200 counts/day for the 691 keV transition depopulating of the first 8^+, gated on the shifted component of 747 keV feeder transition, in the Fw-Bw coincidence matrix at the smallest target-stopper distance. We ask therefore for 13 days of beam time to measure lifetimes in the ground state band of ^{120}Ba and one extra day for the target-stopper alignment, pumping and beam tuning.

IV. SUMMARY

Requested beam, energy and intensity: ^{16}O @ 71 MeV, 5 pnA
Requested beam-line: Experimental line 1 - ROSPHERE + plunger
Requested beam-time: 14 days

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