BEAM REQUEST at Bucharest TANDEM

Experiment title: The low-lying level scheme of the odd-odd nucleus ${}^{130}_{57}La_{73}$

Experiment responsable:

Name: Manuela Ionescu-Bujor

E-mail address: bujor@nipne.ro **Phone:** 0214046148

Short presentation of the scientific project: 130La-proposal.pdf

Beam time request (unit=8 hours): 21 units

Desired period: February 2012

Desired beam properties:

Type: ${}^{12}C$ **Energy:** 50 MeV **Intensity:** 50 nA

Vacuum requests: Standard vacuum on the beam line nr.1

Special requirements for detectors, electronics: The array for γ spectroscopy: 5 HPGe, 4 planar Ge and 8 $LaBr_2$:Ce detectors

Minimal information needed for the radiological risk evaluation:

a) **Sources activity:** Calibration sources 1 - 10 μCi

b) **Use of open sources:** No

c) **Estimate of the residual activity as a result of irradiation:** ≤ 1 μCi

The low-lying level scheme of the odd-odd nucleus $^{130}_{57}\mathbf{La}_{73}$

M. Ionescu-Bujor, A. Iordachescu, D. Bucurescu, G. Cata-Danil, D. Deleanu, D. Filipescu, D.G. Ghita, T. Glodariu, N. Marginean, R. Marginean, C. Mihai, A. Negret, L. Stroe, T. Sava, N.V. Zamfir

National Institute for Physics and Nuclear Engineering, Bucharest, Romania

C.A. Ur

Physics Department, Padova University and INFN, Italy

I. SCIENTIFIC MOTIVATION

The structure of odd-odd nuclei with $A \approx 130$ exhibits a variety of interesting phenomena. The nuclei in this mass region are known to be γ-soft and their shapes are strongly influenced by the quasiparticles in the high-j orbitals. The bands built on the low-Ω $h_{11/2}$ proton and the high-Ω $h_{11/2}$ neutron orbitals having different shape-driving effects are of particular interest. One of the most striking features is the anomalous signature splitting and signature inversion. It was found that in several $\pi h_{11/2} \otimes \nu h_{11/2}$ bands at low spins the even-spin levels are favored energetically rather than the odd-spin members that are expected to be favored in the case of normal signature splitting. This phenomenon has been studied in the framework of the particle-triaxial-rotor model [1]. To decide whether signature inversion exists or not, it is important to know the exact spin values of the states in the band. Another interesting feature of odd-odd nuclei in this mass region is the occurrence of $\pi h_{11/2} \otimes \nu h_{11/2}$ doublet band structures interpreted as resulting from nuclear chirality. This phenomenon has been rather intensively investigated in the last decade, both experimentally [2–4] and theoretically [5–8]. Although existing information on relative spins and parities is sufficient to investigate the doubling of states, the knowledge of absolute spin and parity is important if detailed comparisons with theoretical calculations are to be made; thus reliable data on the decay properties near the bandhead is of importance. Such information, however, is often unavailable due to the well known difficulties encountered in the studies of odd- odd nuclei, resulting from the occurrence of isomeric decays or the existence of low-energy γ-ray transitions which are attenuated and are often below observation sensitivity thresholds for typical experiments.

The presently proposed experiment focuses on the odd-odd nucleus ^{130}La. The known high-spin level scheme in this nucleus is rather complex and includes several collective bands with a quadrupole deformation $\beta_2 \approx 0.2$ [9–11], a highly-deformed band with $\beta_2 \approx 0.4$ [12], as well as a side band of the $\pi h_{11/2} \otimes \nu h_{11/2}$ yrast band interpreted as resulting from chiral symmetry breaking [13]. However, based on the existing experimental data no firm spin-parity assignments could be made for the band-heads of the observed structures. The low-spin states were investigated in (EC+β^+) decay of ^{130}Ce [14]. An isomeric state with half-life of 17 ns and I^π=(1$^+$,2,3$^+$) was identified at an excitation energy of 110.4 keV, populating by a 110.4 keV transition the I^π=3$^{(+)}$ ground state. No link between the low-spin states and the high spin structures has been found. A spin-parity (9$^+$) for the $\pi h_{11/2} \otimes \nu h_{11/2}$ yrast band-head has been proposed in ref. [15] on the basis of excitation energy systematics of the band the doubly-odd $^{124-134}$La, by taking as reference the ^{128}La where the spin of the lowest observed state of the band was firmly assigned through experimental spectroscopy [16]. The adopted decay scheme of the yrast band in ^{130}La [17] is illustrated in the left part of Fig. 1.

In March 2009 we performed a 4 days experiment at the Bucharest Tandem accelerator aiming to investigate the low-lying levels in the decay of the yrast band of ^{130}La. The results of this study indicated a more complex level scheme compared to the adopted one, including two new isomeric states. A cascade of two low-energy γ-transitions has been found to link the high-spin structure to the ground state. The preliminary level scheme is illustrated in the right part of Fig. 1. On the basis of these preliminary results, we are proposing now a new experimental study of ^{130}La. The previous experiment is briefly presented in Section 2, while the experimental details of the new experiment are presented in Section 3.

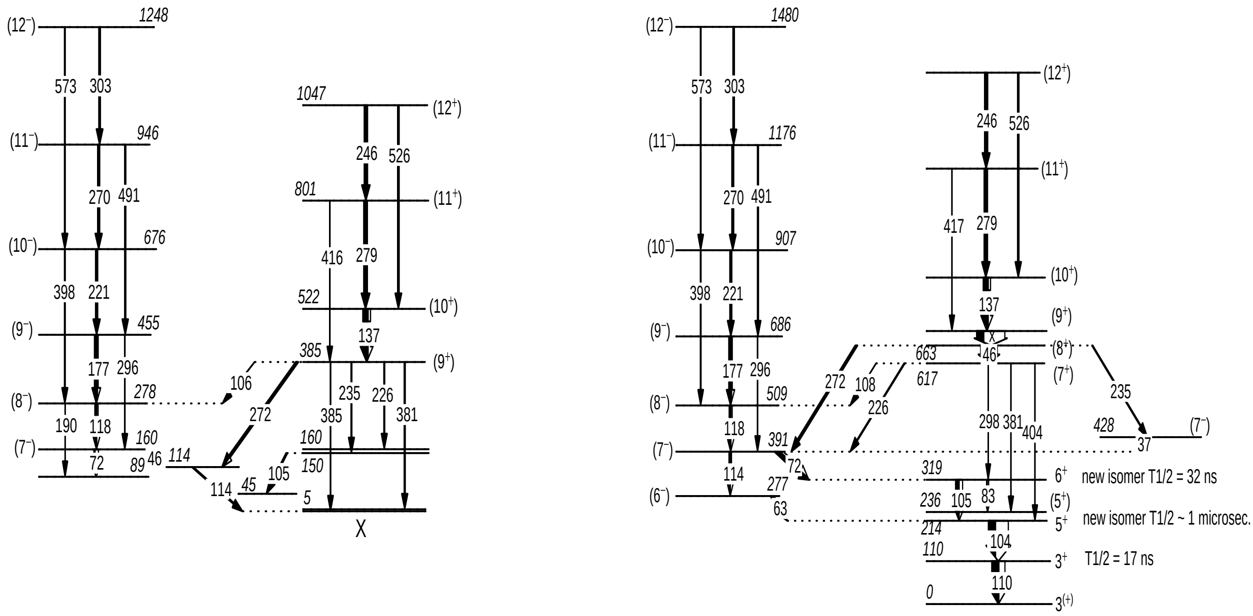

FIG. 1: Left: Partial level scheme of ^{130}La illustrating the decay out of the yrast band from ref. [17]. The energy of the lowest-lying state in not known. Right: The preliminary level scheme established on the basis of the experiment performed at the Bucharest Tandem accelerator in March 2009.

II. REPORT ON THE EXPERIMENT PERFORMED ON MARCH 2009

The excited states in ^{130}La were populated in the reaction ^{121}Sb(^{12}C,3n) at an energy of 49 MeV of the ^{12}C beam. The target consisted of 93 mg/cm^2 metallic Sb of natural enrichment. An array consisting of 7 HPGe detectors and a planar Ge detector was used for γ-rays detection. Coincidence data were sorted off-line into a symmetric E_γ-E_γ matrix using all detectors, and an asymmetric E_γ-E_γ matrix with the HPGe and planar detectors incremented on the x and y axis, respectively. One-dimensional planar spectra gated by the HPGe detectors were projected from the asymmetric matrix and were used to investigate the low energy γ transitions.

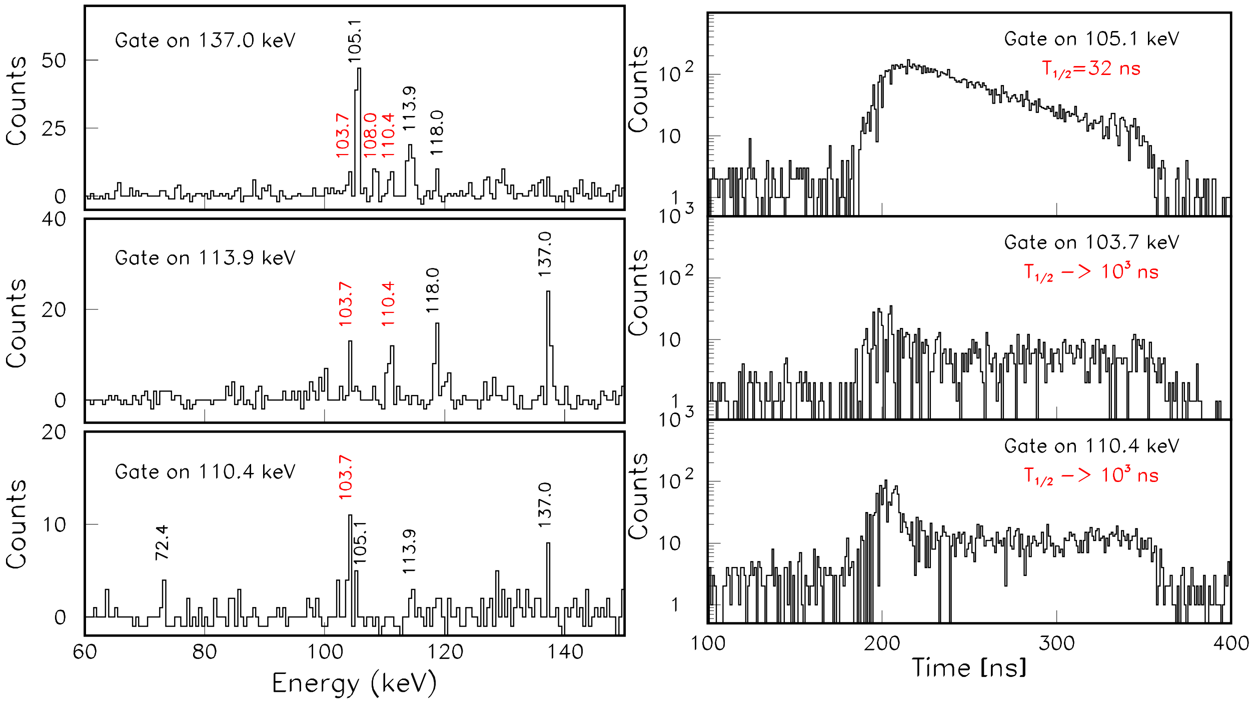

FIG. 2: Left: Energy spectra taken with the planar detector gated on the low-energy γ rays in ^{130}La. The new transitions are marked in red. Right: Time coincidence spectra for selected low energy transitions.

Illustrative coincidence spectra are shown in the left part of Fig. 2. In spite of the very low statistics, these spectra have clearly revealed the presence of a cascade of new γ lines, of 103.7 and 110.4 keV, which links the high-spin states to the ground state (see Fig. 1, right). The level deexcited by the 110.4 keV transition was identified as the first excited state known in ^{130}La [14, 17]. The time spectrum gated on the 105.1 keV γ ray indicated that it is isomeric, with a half-life of 32(3) ns. From the time spectra of the 103.7 and 110.4 keV a longer half-life, around 1 μs, was inferred for the level at 214 keV excitation energy. The proposed level scheme contains several low-energy transitions below 100 keV, namely the observed 72 and 83 keV γ rays, and the 37, 46 and 63 keV γ rays that could not be seen in the performed experiment. Note that a transition of unknown low energy was placed in the level scheme above the 663 keV state, to assure that the positive parity band is the yrast one.

III. DETAILS OF THE PRESENTLY PROPOSED EXPERIMENT

The present experiment aims to confirm and possibly complete the low-energy level scheme proposed in ^{130}La based on the results obtained in the previous experiment. It will be focused on the investigation of the very low γ-rays and on lifetime measurements for the longer-lived isomer.

The ^{130}La will be populated by the ^{121}Sb(^{12}C,3n) reaction at an energy of 50 MeV of the ^{12}C beam. The target will be made of enriched ^{121}Sb isotope, 30 mg/cm^2 thick, deposited on a Ta backing. An array consisting of 5 HPGe, 4 planar Ge and 8 $LaBr_2$:Ce detectors will be used. To allow the observation of very low-energy γ-rays a special target chamber made of quartz with walls of 2 mm thickness will be used. The lifetime of the new longer-lived isomer will be measured using the pulsed-beam system of the Tandem accelerator, with a pulsed width of several ns and a repetition period of 3.2 μs. If the pulsing system will be not available, the lifetime will be determined in a coincidence measurement, using the fast signal of the $LaBr_2$:Ce detectors to start the time to amplitude converter. By taking into account the results of the previous measurement and the planned improvements in the experimental conditions, in order to achieve the goals of the experiment we ask for 7 days of beam time.

---

[1] N. Tajima *et al.*, Nucl. Phys. A **572**, 365 (1994).
[2] T. Starosta *et al.*, Phys. Rev. Lett. **86**, 971 (2001).
[3] E. Grodner *et al.*, Phys. Rev. Lett. **97**, 72501 (2006).
[4] D. Tonev *et al.*, Phys. Rev. C **76**, 044313 (2007) and references therein.
[5] S. Frauendorf, Rev. Mod. Phys. **73**, 463 (2001).
[6] V.I. Dimitrov, S. Frauendorf S and F. Donau, Phys. Rev. Lett. **84** 5732, (2000).
[7] P. Olbratowski *et al.*, Phys. Rev. Lett. **93**, 052501 (2004).
[8] J. Meng *et al.*, Phys. Rev. C **73**, 037303 (2006).
[9] E.S. Paul *et al.*, Phys. Rev. C **36**, 1853 (1987).
[10] M.J. Godfrey *et al.*, J. Phys. G: Nucl. Part. Phys. **15**, 487 (1989).
[11] M.J. Godfrey *et al.*, J. Phys. G: Nucl. Part. Phys. **15**, 671 (1989).
[12] M.J. Godfrey *et al.*, J. Phys. G: Nucl. Part. Phys. **15**, L163 (1989).
[13] T. Koike *et al.*, Phys. Rev. C **63**, 061304(R) (2001).
[14] Xu Shuwei *et al.*, Z. Phys. A **356**, 35 (1996).
[15] Y. Liu *et al.*, Phys. Rev. C **54**, 719 (1996) and references therein.
[16] T. Hayakawa *et al.*, Z. Phys. **A 352**, 241 (1995).
[17] B. Singh, Nuclear Data Sheets **93** 33 (2001).