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Superdeformed nuclear matter in nuclei with Z $\geq$ 82: Magnetic properties and neutron shell gap

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Abstract. We report the results of an experiment, realized with the EUROBALL IV spectrometer, in which superdeformed (SD) states have been populated in ^{197,198}Pb nuclei. Crosstalk transitions between two signature partner SD bands in ^{197}Pb have been observed with an established $M1$ character, giving access to the magnetic properties of the $\nu[752]5/2$ intruder orbital. Six new SD bands have been identified in ^{197,198}Pb. The results are interpreted in the framework of cranked Hartree-Fock calculations. A mixing between quasi-particle excitations and an octupole vibration is suggested in the two SD isotopes.

PACS. 21.10.Re Collective levels – 21.60.Ev Collective models – 23.20.Lv γ transitions and level energies – 27.80.+w $190 \leq A \leq 219$

1 Introduction

The superdeformed matter properties in the $A \sim 190$ mass region remain an open question in particular for the nuclei with $Z \geq 82$. Interests of exploring superdeformed (SD) nuclei in this region are the possibilities to determine the effective gyromagnetic spin factor and to have access to intrinsic orbitals which will not be reached until the spectroscopy of superheavy elements is realized. The magnetic properties of the nuclear superdeformed matter can be deduced experimentally from the observation of the $M1$ transitions (crosstalk) linking two signature partner superdeformed bands.

We report here the results of an experiment in which SD states have been populated in ^{197,198}Pb nuclei. Crosstalk transitions between two signature partner SD bands in ^{197}Pb, based upon the $\nu[752]5/2$ neutron intruder orbital, have been found with an established $M1$ character, giving access to the magnetic properties of this orbital [1]. Six new SD bands, which probably represent three pairs of signature partners, have been found in this work. Two pairs have been assigned to the ^{197}Pb nucleus, the third one to the ^{198}Pb nucleus [2]. The results are discussed in the framework of cranked Hartree-Fock (HF) calculations.

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2 Experiment

Excited high-spin states in ^{197,198}Pb were populated by the ^{186}W(^{18}O,7n) reaction. The target, consisting of two self-supported ^{186}W foils of about 200 μg/cm^2 thickness each, were bombarded by 117 MeV ^{18}O beam delivered by the VIVITRON accelerator in Strasbourg. The γ-rays were detected with the EUROBALL IV array [3] comprising an inner ball of 210 BGO crystals and 71 Compton-suppressed Ge detectors which represent 239 individual crystals. A condition of four unsuppressed Ge detectors firing in coincidence combined with an inner ball multiplicity of 8 was required to start the acquisition. After presorting the raw data (prompt time window, add-back of clover and cluster composite detectors, Compton rejection), a total of 10^9 four- and higher-fold events have finally been analyzed. Directional Correlations from Oriented states (DCO) measurements have been done [1].

3 Results and discussion

3.1 Magnetic properties

Firstly, the two SD bands initially discovered by Hibbert *et al.* in ^{197}Pb [4] have been extended to lower frequencies

and we have observed eight crosstalk transitions (96, 108, 116, 129, 135, 152, 153 and 175 keV) between these two signature partner SD bands [1]. The energy sum rules between the SD transitions and these new crosstalk transitions are fulfilled with a maximum deviation of 0.5 keV. DCO measurements confirm the $\Delta I = 1$ assignment. Under the assumption that the two bands are signature partners, the only possibility is that the crosstalk transitions have $M1$ multipolarity.

$B(M1)/B(E2)$ branching ratios have been determined for several states of the two SD bands. The average value $B(M1)/B(E2) = 0.046 \pm 0.010\ {\mu_N}^2/(\mathrm{eb})^2$ has been obtained for the two SD bands. These ratios leads to a good agreement with the theoretical value obtained by microscopic HF + BCS calculations [5], interpreting the two bands as built on the two signatures of the $\nu j_{15/2}$ [752]5/2 neutron intruder orbital. The effective spin gyromagnetic factor g_s^{eff} derived in this work appears to be equal to the theoretical g_s^{free} value. This surprising lack of quenching is now the third evidence obtained for neutron SD orbitals, contrary to the results obtained for proton SD orbitals ($\alpha = g_s^{\mathrm{eff}}/g_s^{\mathrm{free}} \sim 0.6$). More precise data of the $B(M1)/B(E2)$ branching ratios are needed, for odd-N and odd-Z nuclei, covering a wider range of nuclei and configurations in order to systematically investigate the quenching of the g-factors and the applicability of the model.

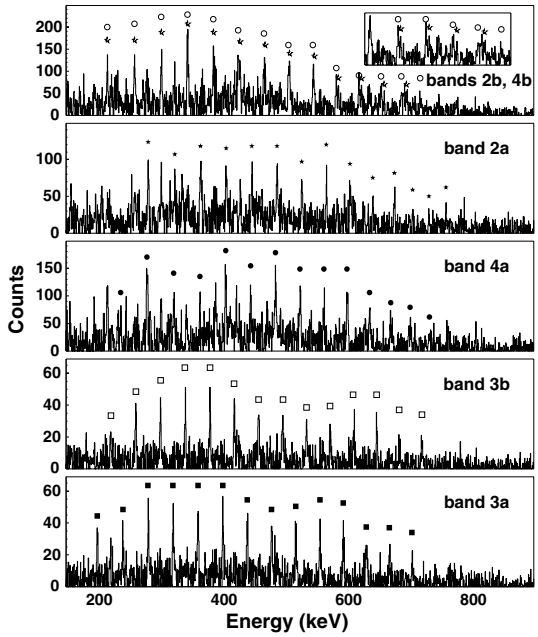

Fig. 1. Fourfold gated spectra of the new SD bands 3a and 3b, and threefold spectra of the new SD bands 2a, 2b, 4a and 4b. Bands 3a, 3b, 4a, 4b are assigned to ^{197}Pb and bands 2a, 2b to ^{198}Pb. The insert of the upper figure enlarging the high-energy range shows the separation between bands 2b and 4b.

3.2 New excited superdeformed bands

In this work, six new SD structures labeled bands 2a, 2b, 3a, 3b, 4a and 4b [2] have been identified in ^{197,198}Pb nuclei as shown in fig. 1. It should be noticed that band 2a and band 2b have very close γ-ray energies to band 4a and band 4b, respectively. The transition energies of bands 2a, 3a and 4a lie at the mid-point of the transition energies of band 2b, 3b and 4b, respectively, suggesting that they are three pairs of signature partners. The proposed spins for the band heads of bands 2a, 2b, 3a, 3b, 4a and 4b are 10, 8, 17/2, 19/2, 19/2 and 17/2, respectively. The two strongest cascades, labeled band 3a and band 3b, belong most likely to the ^{197}Pb nucleus. The four remaining new bands have been tentatively assigned to ^{197}Pb (band 4a and band 4b) and ^{198}Pb nucleus (band 2a and band 2b). These assignments are based on the properties of the new bands with respect to theoretical calculations and comparisons with known configurations of the neighbouring nuclei.

The yrast SD band in ^{197}Pb (^{198}Pb) represents only 0.2% (0.5%) of the corresponding reaction channel, which is weaker than in lighter SD lead nuclei. The intensities of the new bands, normalized to 1.0 for the corresponding yrast SD band, are 0.17(2) for bands 2a and 2b, 0.27(2) for bands 3a and 3b and 0.09(2) for bands 4a and 4b.

The single-particle Routhians have been obtained for ^{196}Pb in self-consistent cranked Hartree-Fock-Bogoliubov calculations [6] and the only neutron valence SD orbitals are the [512]5/2, [624]9/2 and [752]5/2 orbitals. Two bands (band 4a and band 4b) have the properties (behaviour of the moment of inertia $\Im^{(2)}$ and incremental alignment) required for a configuration based on the ν[512]5/2 orbital. However, the quasi-particle excitation scheme can explain neither the two other excited SD bands (band 3a and 3b) in ^{197}Pb nor the two bands (band 2a and 2b) in ^{198}Pb which have a too large intensity relative to the yrast SD band. We suggest that the $\nu[512]5/2 \otimes \nu[624]9/2$ excitation might be lowered by a coupling with a residual octupole Y_{32} interaction.

The experimental data underline also the importance of pairing in the Pb isotopes. All microscopic calculations have difficulties to reproduce the $\Im^{(2)}$ when dealing with the heaviest nuclei, ^{198}Pb being therefore a stringent test for further theoretical investigations.

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