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Short note

Search for hyperdeformed structures populated in the ^{37}Cl+^{120}Sn reaction by using EUROBALL III

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Abstract. The ridge structure with $\Delta E_\gamma = \pm$ 30 keV, observed in the past in coincidence with protons emitted in the reaction 187 MeV ^{37}Cl + ^{120}Sn and attributed to an hyperdeformed nuclear shape in ^{152}Dy, has been studied in a new experiment performed with the EUROBALL III array. The ridge is now observed in coincidence with transitions in the yrast superdeformed band of ^{152}Dy but no discrete rotational bands have been identified.

PACS. 27.70.+q Properties of specific nuclei 150≤A≤189 – 21.10.Re Properties of nuclei: collective levels

The search for hyperdeformed (HD) structures in nuclei is at the forefront of the nuclear physics research. Indications for the population of HD shapes were evidenced in the past in the fission of actinide nuclei [1]. Furthermore, the population of hyperdeformed rotational bands have also been investigated by using in-beam γ-ray techniques in the mass region of A=150-160, where they have been predicted [2,3] to occur at very high angular momenta (J≥70 $\hbar$). The experiments performed so far in the Dy [4–6] region have produced possible indication of hyperdeformed shapes in the form of a ridge structure. In the Gd [7,8] region no evidence for hyperdeformed shapes was found.

A ridge structure with $\Delta E_\gamma = \pm$ 30 keV was observed in an earlier Chalk River experiment [4] in coincidence with the protons emitted in the reaction 187 MeV ^{37}Cl + ^{120}Sn. The moment of inertia expected for a rotor based on a HD shape is $\mathcal{J}^{(2)} \approx 130\ \hbar^2$ MeV^{-1}, which corresponds to a difference of ≈30 keV between the energies of two consecutive transitions in the rotational band. Consequently, evidence of such HD structures should be revealed by a ridge at $\Delta E_\gamma \sim 30$ keV when cuts perpendicular to the diagonal of a E_γ-E_γ matrix are performed.

Two successive experiments with the GASP spectrometer [5,6] confirmed the presence of this ridge structure in the ^{152}Dy nucleus. A detailed analysis of the ridge revealed that two different sequences of diagonal cuts located at energies $(E_{\gamma 1}+E_{\gamma 2})/2 = 1308+(n\times 30)$ keV (R1) and $(E_{\gamma 1}+E_{\gamma 2})/2 = 1349+(n\times 30)$ keV (n=0,1,..,8) (R2), contribute to the $\Delta E_\gamma = \pm$ 30 keV structure. The statistics collected in the two GASP experiments were not sufficient to extract discrete transitions and to establish firmly the nature of the states that produce the ridge. Additional experiments were also done by using the EUROGAM II array [9,10].

Therefore, to shed more light on this phenomenon, a new experiment has been performed with the EUROBALL III array. A beam of 187 MeV ^{37}Cl (intensity ∼3-4 pnA) from the Tandem XTU+ALPI Linac accelerator complex of the Laboratori Nazionali di Legnaro was focused

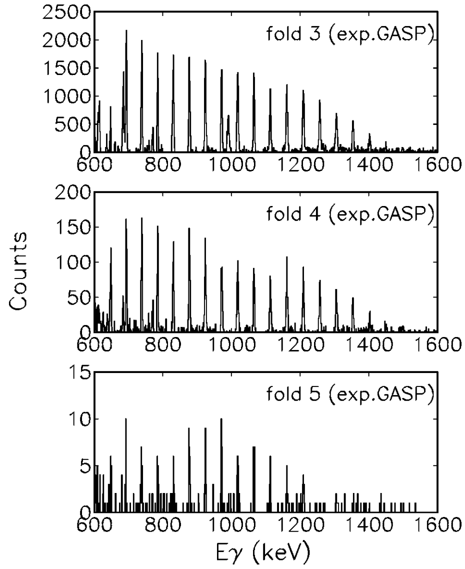

Fig. 1. Spectra of the yrast SD band in ^{152}Dy as obtained by setting multiple gates in the γ^n events in coincidence with protons and with conditions on sum energy H>14 MeV and fold k>10 measured in the GASP inner ball

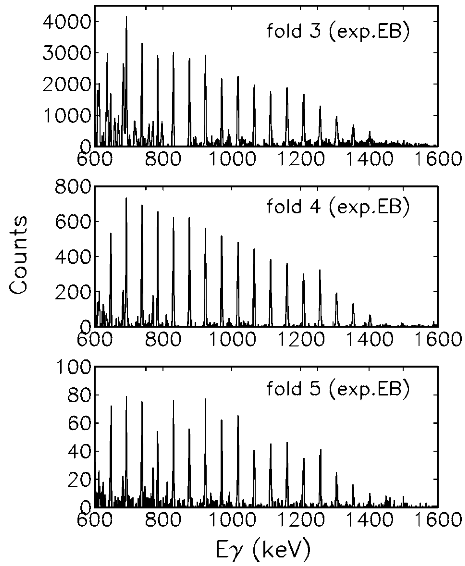

Fig. 2. Spectra of the yrast SD band in ^{152}Dy as obtained in the present EUROBALL experiment by setting multiple gates in the γ^n events in coincidence with protons

onto a stack target composed by two foils of ^{120}Sn with a thickness of 400 μg/cm^2 each. Gamma-rays were detected with the EUROBALL III array which consisted of 15 cluster germanium detectors placed in the backward hemisphere, 26 clover germanium detectors located in two rings at around θ=90^o and 30 tapered single-crystal germanium detectors located at forward angles. All detectors were Compton-suppressed by individual BGO shields. The EUROBALL III spectrometer housed a reaction chamber where the 4π charged particles detector array ISIS, composed of 40 ΔE-E Si-telescopes (130 μm and 1000 μm thickness), was installed [11].

In 8 days run we collected about 6×10^9 events with a trigger condition of at least 5 γ-rays , before the Compton suppression of single detectors, in coincidence with charged particles or at least 7 γ-rays (unsuppressed) without the coincidence with charged particles. Cluster and clover elements were incorporated in the trigger as individual detectors.

In the data presort, 900×10^6 triples or higher γ-ray fold Compton suppressed events in coicidence with protons were obtained. The comparison between the present statistics and that collected in previous GASP experiment [6] was performed by looking at the ^{152}Dy yrast superdeformed band. For consistency, the data from the GASP experiment were reanalyzed with the same " spike-free" [12] programs used here for the higher γ-ray fold EUROBALL data.

The spectra of the ^{152}Dy yrast superdeformed band, obtained in the two experiments using GASP and EUROBALL III, are shown in Figs. 1 and 2, respectively. As expected, the gain factor between the two cases depends on the γ-ray fold considered. This is shown in a more quantitative way in Fig. 3 where the ratio between the counts

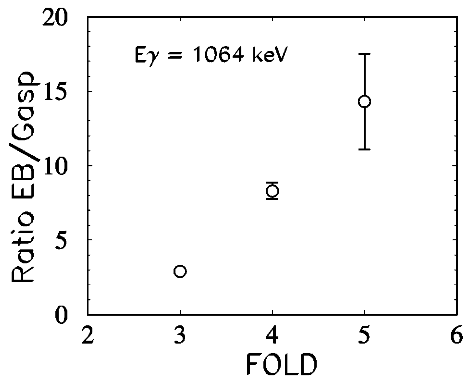

Fig. 3. Ratio between the counts of the peak at E$_\gamma$=1064 keV of the yrast SD band obtained in the EUROBALL and GASP experiments as a function of the γ-ray fold

obtained for the SD band transition at E$_\gamma$=1064 keV in the two experiments is reported as a function of the γ-ray fold.

From Fig. 3 it is evident that the statistics is increased by one order of magnitude in the EUROBALL data set, when 4-fold events are considered, altough the running time of the latter experiment was a factor of two shorter than in the GASP case.

Despite the higher collected statistics, the two ridge structures correlated with the sequences of diagonal cuts suggested in the earlier works are barely seen in the present data set. This is understood as due to the higher background from low γ-ray fold events. Low γ-ray fold events were indeed suppressed in previous experiments [4-6] by conditions on the sum energy (H>14 MeV) and γ-ray fold (k>10) measured in the inner ball of the 8π and GASP spectrometers.

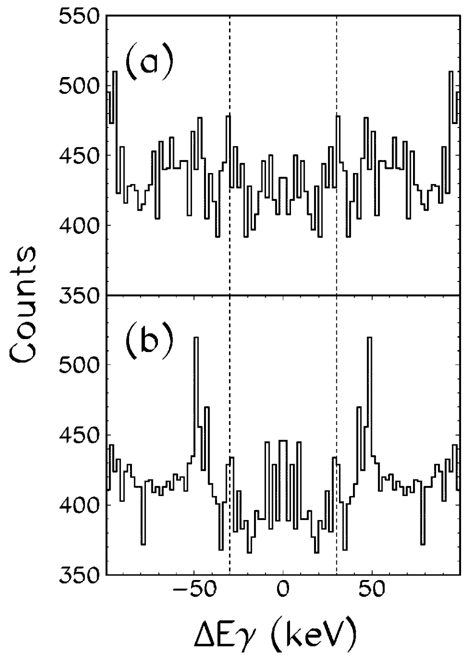

Fig. 4. Spectra showing energy differences $\Delta E_\gamma = E_{\gamma 1} - E_{\gamma 2}$ corresponding to diagonal cuts in the E_γ-E_γ matrix taken in coincidence with protons and with double gates on the ^{152}Dy yrast superdeformed band. The spectra are obtained by summing 10 diagonal cuts at the energies $(E_{\gamma 1}+E_{\gamma 2})/2 = 1308+(n\times 30)$ keV (n=0,..,9) (a) or at the energies $(E_{\gamma 1}+E_{\gamma 2})/2 = 1349+(n\times 31)$ keV (n=0,..,9) (b)

To select only the γ-ray emission associated to the higher angular momentum states, γ-γ matrices were built from γ^4 and γ^5 events after setting gates on transitions in the ^{152}Dy yrast SD band. Despite a drastic reduction in statistics, ridges at $\Delta E_\gamma \sim 30$ keV are clearly seen in the matrix derived from the γ^4 data, as shown in Fig. 4, when diagonal cuts are performed at the energies suggested in previous works for the so called R1 ridge (Fig. 4a) and R2 ridge (Fig. 4b). Such ridge structures are evidenced only in coincidence with the ^{152}Dy SD band. They are not seen, indeed, in the matrices built with the selection of other low spin structures in ^{152}Dy (e.g. the prolate band) or in the ^{153}Dy.

Whether or not this ridge is associated with the exotic HD shape, that cannot be directly demonstrated from the present experiment. The statistics obtained in this EUROBALL III experiment is, indeed, not sufficient to look for discrete transitions associated with the ridge structures.

Nevertheless, the fact that this structure is seen only in coincidence with the yrast SD band in the ^{152}Dy nucleus seems to confirm its high spin nature and that it originates from ^{152}Dy.

The coincidence with the SD band is consistent with the assumed HD origin, since a decay is expected from HD to SD shapes. In principle, the coincidence with the SD band can be also explained by assuming that the $\Delta E_\gamma \sim 30$ keV ridge is associated with the decay-out from the SD band. This possibility seems to be unlikely, however, since only few consecutive transitions are expected to connect the SD bands to the underlying normally deformed structures.

If the HD nature is assumed, it is possible that the decay out from the HD structure would populate not only the yrast but also the excited SD bands, as predicted in [13] for nuclei in this mass region. The branches towards excited SD bands would be probably too weak to be detected in coincidence.

In conclusion, we stress that the increase in statistics obtained with the new generation of γ-ray spectrometers seems to be not sufficient to solve the problem of the existence or not of discrete HD bands in nuclei, because of the reduction in the signal-to-noise ratio due to the background from low γ-ray fold events which are not suppressed as in the previous cases.

Future experiments in this field would certainly benefit from the new possibilities open by the inner-ball of the EUROBALL IV array which should be able to enhance the sensitivity of the instrument to signals from the highest spin states.

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