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Alpha energy distribution as a probe for the feeding of ND and SD bands in ^{151,152}Dy nuclei

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Abstract. The study of the α-particle energy distributions associated with ND and SD states in ^{151,152}Dy has been carried out. The Dy isotopes were produced in the reaction ^{37}Cl+^{123}Sb at 191 MeV via the (α5n) and (α4n) channels, respectively. In ^{151}Dy the α-particle energy distributions associated to ND and SD are very different from each other, both at the low and high energy sides inducing a difference of 3 MeV in the α-particle mean energy. In ^{152}Dy the situation is different; the α-particle spectral shapes are similar and a difference in the α-particle mean energy of only 0.7 MeV is deduced. A description in terms of energy localization of entry states is given.

PACS. 21.10.Re Collective levels – 21.10.G Nuclear deformations – 25.60.Pj Fusion reactions – 27.70.+q $150 \leq A \leq 180$

1 Introduction

Evidence for a large number of superdeformed (SD) rotational bands has been gathered for the last ten years in several mass regions of the nuclear chart. The feeding and deexcitation of these bands have been mainly studied in the mass 150 and 190. Concerning the feeding of the SD bands in these mass regions, the limits of the entry region in the E,J plane, which is likely to populate SD structures, have not been so extensively studied as the γ-decay spectroscopy. This problem has been addressed using a large array of Compton-suppressed Ge detectors associated with an array of BGO to measure the sum energy and the multiplicity of the γ-rays emitted in the reaction [1–4]. The comparison between the measured entry distributions leading to the population of normal and SD states and the intensity of the SD branch in ^{191}Hg, ^{192}Hg and ^{152}Dy by the Argonne group [2] gives strong support to a feeding of SD bands governed essentially by level densities and by the potential barrier separating SD and ND states; the decision of trapping within the SD well is not made until the γ cascade, emitted from the entry point into the residual nucleus, is under the barrier separating the ND and SD states [3–5].

Additional detectors for light charged particles have also been used when charged reaction products, protons or α-particles are involved. In the latter cases, the emphasis was on special characteristics of the particle energy distributions which could be related to the population of the SD rotational bands [6–8] as compared to the population of the normal deformed (ND) bands. In the reaction ^{37}Cl + ^{120}Sn at 187 MeV, leading to ^{152}Dy via a (p5n) channel, the analysis by Viesti et al [7] of the energy distributions of the protons emitted in coincidence with the SD bands are found to be identical to the energy distributions of the protons emitted in coincidence with ND bands. This result confirms a previous study of Galindo-Uribarri et al. [6] in ^{133}Nd.

In a recent study of the reaction ^{37}Cl on ^{120}Sn at 187 MeV, Viesti et al [8] measured the energy distribution of α-particles emitted at 34^0 with respect to the beam and populating the yrast SD band in ^{150}Tb. They found that, in the laboratory system, the energy of these particles, in coincidence with the SD transitions, was 2 MeV lower than that of the α-particles in coincidence with the yrast ND structures. Using a BGO inner ball, they also reported a strong correlation between the α-particle energy distributions and the spin of the ND entry states in ^{150}Tb: larger being the spin, lower being the mean energy of the α emitted and narrower being the energy distribution. Therefore, in this reaction it appears possible to enhance the relative population of the SD structures by setting proper conditions on the energy of the α-particles. If confirmed as a general behaviour, this filtering of highly deformed structures could help in the search of hyperdeformed (HD) shapes of the nuclei. Tentative evidence for such shapes has been presented in this mass region [7,9].

In view of this summary, the role played by charged particles in the population of the highly deformed structures appears rather contrasted. The proton energy seems to be unaffected by the states populated in the residual nucleus while the α-particle appears to be a sensitive probe. In order to further investigate on the role of α-particles in populating the ND and SD bands, we have analyzed the energy distributions of α-particles emitted in the reaction ^{37}Cl + ^{123}Sb at 191 MeV. At this energy, the yrast SD bands in ^{151}Dy and ^{152}Dy nuclei are both populated, via the (α5n) and (α4n) channels respectively.

2 Experimental set-up

The experiment was performed at the VIVITRON accelerator in Strasbourg. A ^{37}Cl beam, with 2 particle nA intensity, impinged on a 0.5 mg/cm^2 ^{123}Sb target deposited on a 0.6 mg/cm^2 carbon backing. The EUROGAM II [10] array of Compton-suppressed Ge detectors was used to detect the γ-rays. The protons and α-particles emitted in the reaction were detected in the DIAMANT array of CsI detectors [11] inserted into the Ge array. These particles were identified by the pulse shape analysis method. The data acquisition system allowed the coding of γ and particle energies, particle identification and particle-γ time delays. We required, to trigger the data acquisition system, that at least five Ge detectors fire in the same event, before Compton suppression ($F_\gamma^{raw} \geq 5$) . We will discuss here solely the events where *only one* α-particle was detected.

The α-particle energies in the laboratory system were transformed to the center of mass (CM) reference frame, neglecting the recoil effect of neutron evaporation. The results of α-particle energy distributions are presented for the events with only one α-particle detected at laboratory angles $\leq 70^0$. In this angular range the energy of all the particles was always higher than the energy thresholds for particle identification. Under this condition no bias, due to a low energy threshold, is introduced into the α-particle energy distributions. The γ-ray spectra were gain-matched and the energies were corrected for Doppler shifts, event by event, taking into account the energy and the direction of the emitted α-particle [12]. From this set of data we obtained 84.7 10^6 events with one α-particle and at least three γ-rays after Compton-suppression. Figure 1 shows the total γ-ray energy projection of these events for a Compton suppressed γ-fold $F_\gamma \geq 3$. The dominant lines in the spectra are associated with ^{150}Dy, ^{151}Dy, ^{152}Dy and ^{153}Dy residual nuclei. The observed intensities

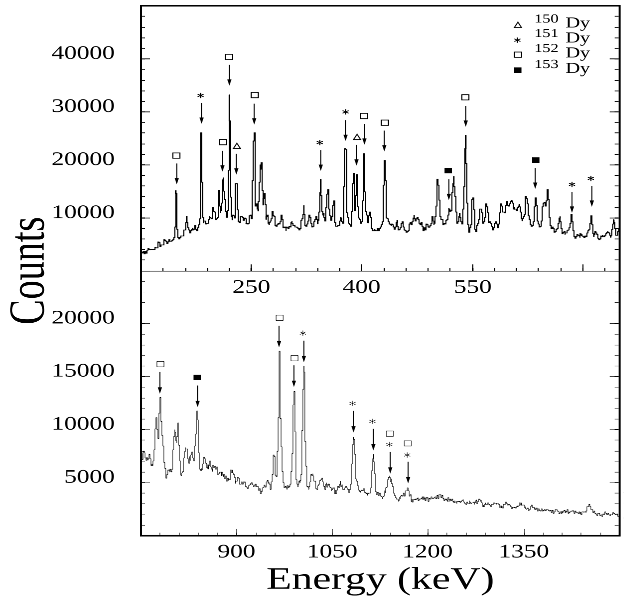

Fig. 1. γ-ray spectrum gated by only one α-particle detected in DIAMANT. Strong yrast transitions in Dy nuclei are shown: ^{150}Dy (△), ^{151}Dy (⋆), ^{152}Dy (square), ^{153}Dy (black square).

of the (2αxn), (αpxn) and (pxn) channels leading respectively to Gd, Tb and Ho isotopes have been reduced by the one α-particle selection to $\simeq$50%, 20% and less than 1% from their respective yields. The analysis of these data has been carried out using the NDIM [13] and Radware [14] software packages to construct two or three dimensional matrices.

3 Results

3.1 α-particle energy distributions in coincidence with ND states

Events corresponding to the population of Dy residual nuclei have been extracted from the α-particle coincidences by double gating on known yrast transitions at low spin belonging to each isotope. The following transitions have been used to select the different Dy isotopes: 230, 803 and 808 keV for ^{150}Dy, 182, 378 and 1005 keV for ^{151}Dy, 220, 254 and 990 keV for ^{152}Dy and the double ($\frac{11}{2}^- \rightarrow \frac{7}{2}^-$), ($\frac{15}{2}^- \rightarrow \frac{11}{2}^-$) 636 keV for ^{153}Dy.

Figure 2 shows the CM α-particle energy distributions related to the four different isotopes of Dy and corresponding to events with a Compton suppressed γ-ray fold $F_\gamma \geq 3$. The absolute energy values are systematically affected by an uncertainty of 1 MeV which includes the energy spread ($\pm$0.75 MeV), due to the opening angle of the CsI detectors in the angular range between 11^0 and 70^0 and the energy uncertainty due to energy calibration ($\leq \pm 0.25$ MeV) over the whole range of α-particle energies. The change in shape of the distributions with the number of evaporated neutrons (from 3 to 6) is evident. In going from ^{150}Dy to ^{153}Dy, the mean α-particle energy varies

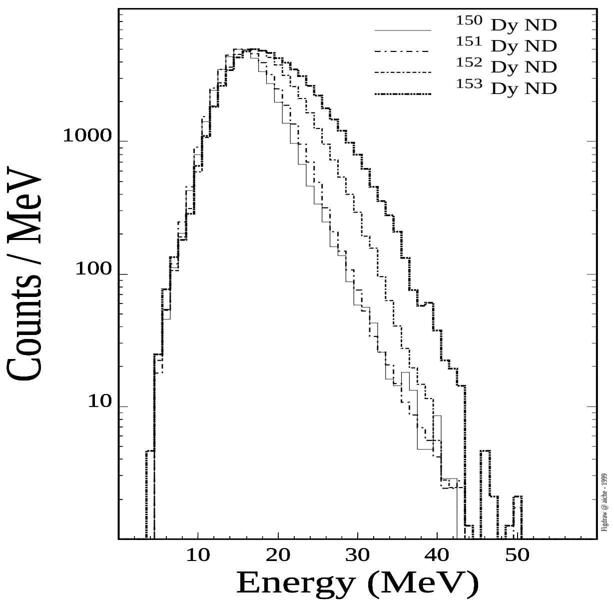

Fig. 2. CM energy distributions of α-particles in γ-γ coincidences with yrast transitions in ^{150}Dy (thin solid line), ^{151}Dy (dashed), ^{152}Dy (dot-dashed) and ^{153}Dy (thick dashed). The distributions are normalized to the maximum number of counts in the ^{153}Dy distribution.

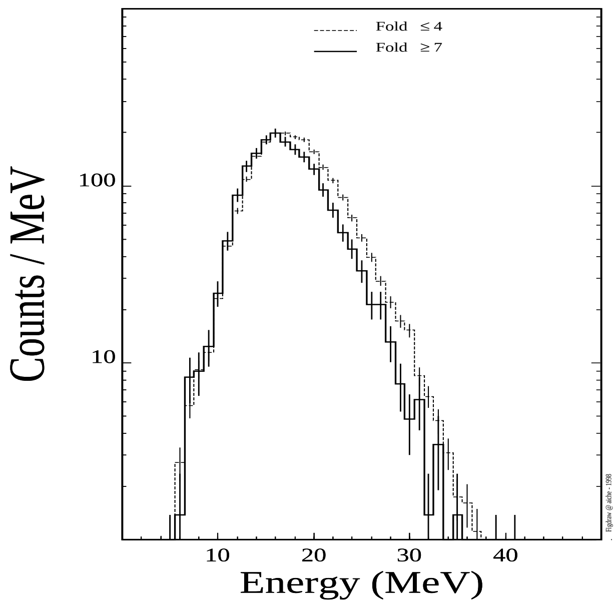

Fig. 3. CM energy distribution of α-particles in γ-γ coincidences with yrast transitions in ^{152}Dy, associated to a γ-ray fold $F_\gamma \leq 4$ (dashed line) and $F_\gamma \geq 7$ (solid line). Spectra are normalized at the maximum of the $F_\gamma \geq 7$ spectrum.

from 16.7±0.1 MeV to 20.0±0.1 MeV and the full width at half maximum (FWHM) of the distributions varies from 7.8 MeV to 11.2 MeV (Table 1). The energy uncertainties quoted represent only the statistical ones. These results are in agreement with previous findings [6,8], as well as with the predictions given by the statistical model evaporation code PACE2 [15]. However, the relative intensity for the production of the different isotopes is not correctly reproduced by the code. The change in the distributions reflects the variation of the excitation energy corresponding to the entry region populating the different isotopes. Alpha-particles with higher energies feed preferentially the heavier isotopes. The α-particle energy distributions associated to ^{150}Dy and ^{151}Dy are very similar. This is certainly due to the limitation of the available phase-space in the α-particle emission. Nevertheless, because of the large difference in the Q-values for the two reaction channels, the entry regions in the two nuclei are very different explaining the large difference in the intensities for the two channels (Fig. 1).

For each double gated Dy isotope we have constructed a matrix E_α^{CM} versus F_γ, the number of Compton suppressed Ge detectors which fired. Each event is only contributing to one point in this matrix. The large thresholds set on both F_γ^{raw} and F_γ imply that only high γ-ray multiplicity events are stored in the matrix (see further). Then, the projection of the matrix on the E_α^{CM} axis was built for different values of F_γ. We show on Fig. 3 the α-particle energy distribution feeding ^{152}Dy for the selected folds $F_\gamma \leq 4$ and $F_\gamma \geq 7$. The variation of the distribution is clearly seen. For $F_\gamma \geq 7$, the high energy part of the distribution ($E_\alpha >$20MeV) is strongly reduced.

A comparison between Fig. 2 and 3 shows that the α-particle energy distribution evolves qualitatively in the same way if one goes from ^{152}Dy to ^{151}Dy or from $F_\gamma \leq 4$ to $F_\gamma \geq 7$ in the only ^{152}Dy nucleus. On the one hand (^{152}Dy to ^{151}Dy evolution), the high energy particles are suppressed because the thermal energy available in the decay is decreased by the emission of one additional neutron, on the other hand (^{152}Dy , fold selection) the available energy in the decay is suppressed by the requirement of a large γ-ray multiplicity put by the condition $F_\gamma \geq 7$ which corresponds to a large amount of energy required in the γ-decay. These results are in agreement with the findings of [8] in ^{150}Tb for the dependence of the α distribution on bins taken in the γ K-fold measured with the GASP inner ball.

At first thinking, it might appear surprising to obtain some multiplicity selection by using the fold distribution measured with EUROGAM II, due to the small efficiency of the Ge detectors and also because they are Compton suppressed. In fact the mean value of the F_γ distribution shows only a small variation when one goes from ^{152}Dy to ^{151}Dy. Nevertheless, the relative contribution of different multiplicities to one particular fold is very different as shown on Fig. 4. The fold response of EUROGAM II, in the conditions of the experiment with $F_\gamma^{raw} \geq 5$ and including the effect of the Compton suppression, has been simulated for events of γ-multiplicity M_γ increasing from 10 and 45. The details of the simulation are given elsewhere [16]. The γ-ray energy was set to 900 keV. The same number of events (250000) for each M_γ value (from

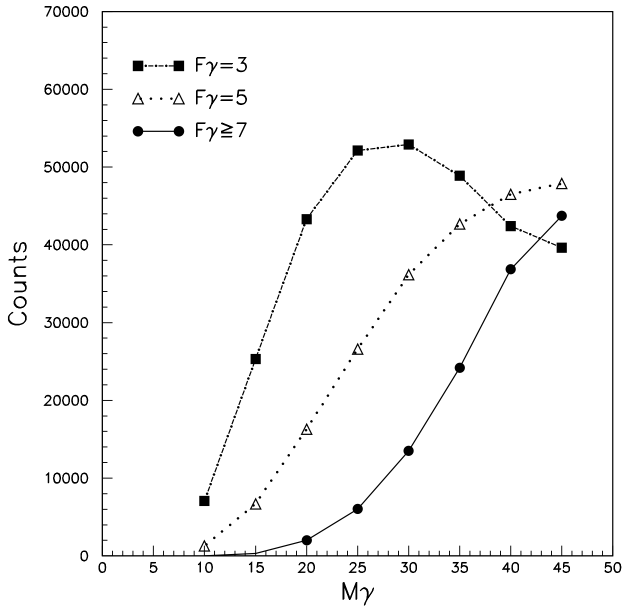

Fig. 4. Relative contribution of multiplicity M_γ to the fold response F_γ (Compton suppressed γ-ray fold). The gamma energy is equal to 900 keV.

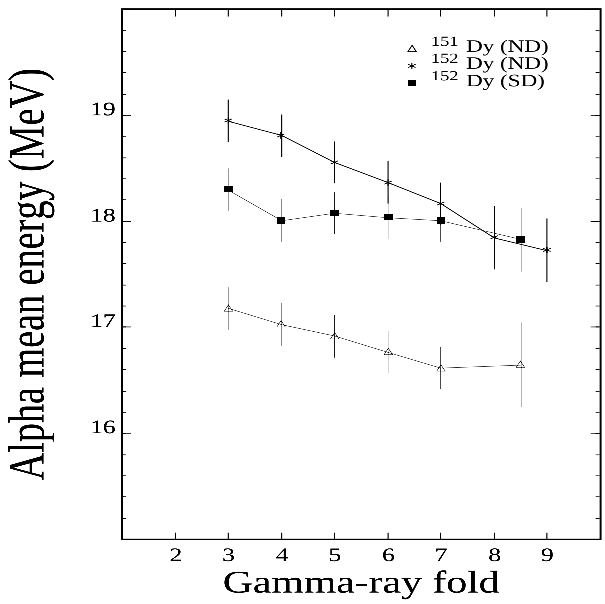

Fig. 5. Mean energy of α-particles versus γ-ray Compton suppressed fold F_γ. α-particles have been recorded in γ-γ coincidence with yrast ND and SD γ-transitions in ^{152}Dy (respectively stars and black squares) and ND yrast γ-rays in ^{151}Dy (triangles). The last point in the mean α-particle energy for SD ^{152}Dy and ND ^{151}Dy is a summation on fold ≥ 8 associated with a mean fold 8.5. Uncertainties are only statistical.

10 to 45) has been used to obtain the evolution of the multiplicity contribution to each fold. The results are given in Fig. 4. This figure clearly shows that the selection of a high fold condition, $F_\gamma \geq 7$, favours high multiplicity events compared to $F_\gamma=3$.

The dependence of the mean energy of the α-particles on the γ-ray fold F_γ is shown in Fig. 5 for the ND states of ^{151}Dy and ND states of ^{152}Dy evaporation residues. In both nuclei, the mean energy decreases as the γ-ray fold increases. For ^{152}Dy the energy variation is 1.2 MeV going from fold 3 to 9. This energy variation is of the same order as the mean energy change when passing from ^{152}Dy to ^{151}Dy (Table 1). It is reasonable to relate the observed energy dependence on the fold to a dependence on the γ-ray multiplicity and then to a dependence on the spins of the entry states populating the residual nucleus.

3.2 α-particle energy distributions in coincidence with SD states

3.2.1 ^{152}Dy

The γ-ray spectrum of the yrast SD band in ^{152}Dy was extracted by double gating on all combinations of SD transitions [22] , with the exception of the 602, 648, 970, 1113, 1161 and 1450 keV polluted transitions. Figure 6 shows such a spectrum. In order to extract the α-particle energy distribution associated with the SD band, we have constructed a cube having as dimensions the γ-ray fold, the α-particle energy, and the γ-ray energy from the events having at least two γ-ray energies within two pre-defined sets of gates. The set of gates corresponding to the energies of the SD transitions is called G-G. The other set of gates, called F-F, corresponds to γ-ray energies close to the SD energies of gates G-G; they are chosen in the structureless part of the total projection γ-ray spectrum. The width of each background gate is the same as its relative SD gate.

The energy distribution of the α-particles in coincidence with the SD transitions has been obtained by subtracting the spectrum corresponding to the F-F set of gates from the α energy distribution corresponding to the G-G set of gates. Such a spectrum is shown in Fig. 7. Except for the intensity, the α-particle spectrum is independent of the G-G set of gates used in the analysis. The γ-γ-γ-α energy distribution has also been constructed and gives the same results with less statistics.

The mean energy of the α-particles is 18.0$\pm$0.1 MeV and the FWHM of the distribution is 8.6 MeV. These values have to be compared (Table 1) to the mean energy 18.7$\pm$0.1 MeV and FWHM 9.6 MeV of the distribution obtained for the ND states in ^{152}Dy. The mean energy for the SD states is slightly smaller than the mean energy of the ND states. The mean energy value is the same as that for the mean α-particle energy associated with the ND states with the largest γ-ray fold ($F_\gamma \geq 7$) (see Fig. 5). Furthermore, the α-particle energy is weakly dependent on the fold compared to the variation observed for the ND states. This can be understood on the assumption of a rather localized region of entry states for the SD band implying a high and well-defined value of the multiplicity. In this case, the measured γ-ray fold distribution only re-

Table 1. Mean values and FWHM of α-particle energy distributions for Dy residual nuclei selected with gates on ND or SD γ-transitions. Uncertainties are statistical ones, absolute mean energy uncertainties are 1MeV.

	^{150}Dy (ND)	^{151}Dy (ND)	^{151}Dy (SD)	^{152}Dy (ND)	^{152}Dy (SD)	^{153}Dy (ND)
$< E_\alpha >$ (MeV)	16.7(1)	17.0(1)	14.1(5)	18.7(1)	18.0(1)	20.0(1)
FWHM (MeV)	7.8	8.3	6.7	9.6	8.6	11.2

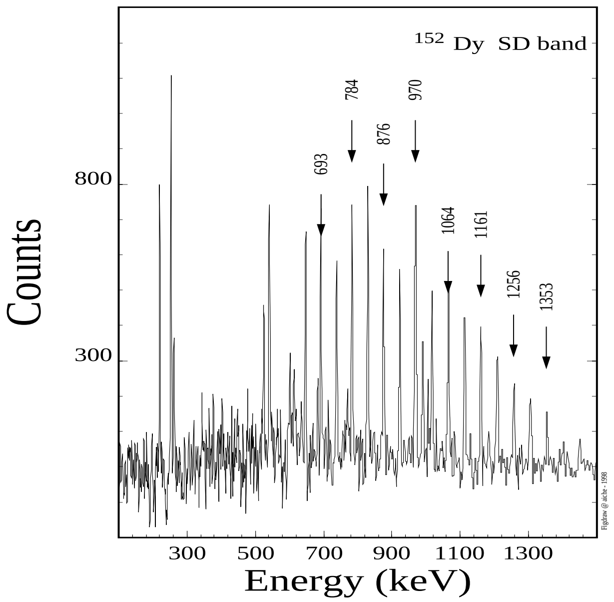

Fig. 6. Double gated γ-ray spectrum (background subtracted) of the SD yrast band in ^{152}Dy requiring at least two γ-ray transitions among the 693, 737, 784, 829, 876, 923, 1017, 1065, 1209, 1256, 1305, 1353 and 1401 keV members of the SD band together with the presence of only one α-particle in the event.

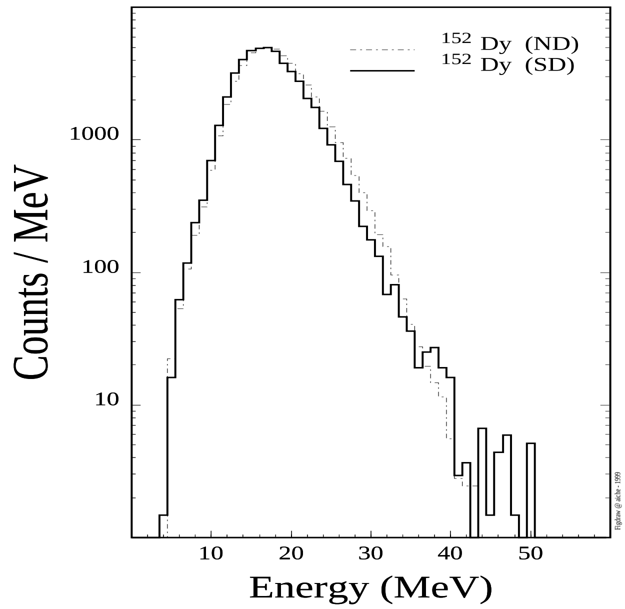

Fig. 7. Energy distribution of the α-particles in coincidence with the SD transitions of the SD yrast band in ^{152}Dy (solid line). This spectrum was obtained by summing over all the double γ-ray gated α-particle spectra after backgroud subtraction. The α-particle energy distribution double gated on yrast transitions (dashed line) in ^{152}Dy is shown for comparison. The ND distribution is normalized at the maximum of the SD distribution.

flects the response function of the gamma array to high multiplicity events.

From the measured mean α-particle energies we can estimate the mean excitation energies of the entry states feeding the ^{152}Dy SD and ND states. The Q-value has been obtained from the table of Audi et al. [18]. For the neutron energy we have used the mean kinetic energy E_n=2.6 MeV given by the PACE2 evaporation code. Furthermore, we have assumed E_n to be the same for neutrons feeding ND and SD states. Starting from a compound nucleus excitation energy equal to 91.4 MeV, we find mean excitation energies E(ND)=31.5±1.5 MeV and E(SD)=32.2 ±1.5 MeV. The E(SD) value is in very good agreement with the value reported by Khoo et al. [2] (E(SD)=35±4 MeV) in the reaction ^{120}Sn+^{36}Si at 170 MeV populating the ^{152}Dy yrast SD band via the 4n channel. In addition, a similar value of the entry state energy (E(SD)=33.3±0.6 MeV) has been found by Taras et al. [1] in the reaction ^{124}Sn+^{30}Si at 160 MeV populating the ^{149}Gd yrast SD band in the 5n channel. In these experiments, E(SD) was deduced from measurement of the sum energy of the γ-rays emitted in coincidence with SD transitions.

Within our assumptions, the difference in the mean energy of α-particles populating the SD and ND states (Table 1) is the same as the difference between the excitation energies E(SD) and E(ND). The resulting difference is smaller than the variation of the energy of the entry states populating the ND states in ^{152}Dy versus the γ-ray fold. The entry region for the SD states appears restricted to only a part of the region populating statistically the ND states. This is also supported by the narrower width of the distribution of the α-particle in coincidence with SD transitions due to a reduction of the number of high energy alphas.

The low energy part of the α-particle distribution in coincidence with SD transitions is not noticeably different from the distribution associated with the ND states. If the α-particles emitted in coincidence with the SD transitions had been emitted from especially deformed ellipsoidal shapes of the nuclei, the lowering of the Coulomb barrier for the emission of α-particles along the axis should have been reflected by an enhancement of the low energy part of the α distribution when compared to the distribution associated to ND states. Then we conclude, in ^{152}Dy, that there is no direct relation between the shape of the cold SD residual nucleus formed after neutron and statistical γ-ray evaporation and the shape of the "hot" nucleus in high spin states which have populated the SD states. This result is in agreement with previous observations of proton distributions feeding the ^{152}Dy yrast SD states [7]and the ^{133}Nd strongly deformed states [6].

These results, together with the observation that the mean SD α-particle energy corresponds to a high fold value for ND states (Fig. 5), strongly support the conclusion that the observed variation in the mean energies between SD and ND states is mainly an angular momentum effect. The population of the SD band originates from states located at a mean energy of 7.2 MeV above the crossing energy of the ND and SD yrast lines taken at 25 MeV [19]. The SD band appears to be fed directly in the highest spin states in a statistical manner since we do not observe any significant variation in the relative intensity of the SD transitions by conditioning the γ-ray spectrum on the lower or higher regions of the α-particle energy distribution. The observed intensity of the SD band relative to the channel intensity appears to be about 1%, i.e. of the same order than the previously reported SD band intensities populated in the pure (xn) channels [19,23].

3.2.2 ^{151}Dy

The spectrum of the yrast SD band of the ^{151}Dy nucleus obtained by double gating on the known SD transitions in ^{151}Dy at 682, 786, 838, 891, 941, 1043, 1094 keV [20] and on one α-particle is shown in Fig. 8. In order to get the maximum statistic for the highest transitions of this γ-spectrum, all the identified α-particles, without restriction in the angular range, have been used. The SD transitions with energies below 1144 keV are clearly seen but with lower intensities than in the case of ^{152}Dy. The highest energy transitions in the SD band do not rise above background.

The α-particle energy distribution (with angular range $\leq 70^0$) associated with the SD band in ^{151}Dy is obtained by double gating on the SD transitions, corresponding to the spectrum in Fig. 8, plus the additional requirement that a third energy γ-ray in the event be one of the clean 734, 891, 941 keV transitions. This triple γ-coincidence requirement was necessary to eliminate the effect of the background. As already mentioned in the ^{152}Dy case, such a procedure do not change the spectral shape but only leads to a lower statistic than a γ-γ-α coincidences spectrum (Fig. 7). The α-particle spectrum, in the ^{151}Dy case, is shown in Fig.9, where the α distribution populating the ND states is given for reference. The two figures 7 and 9

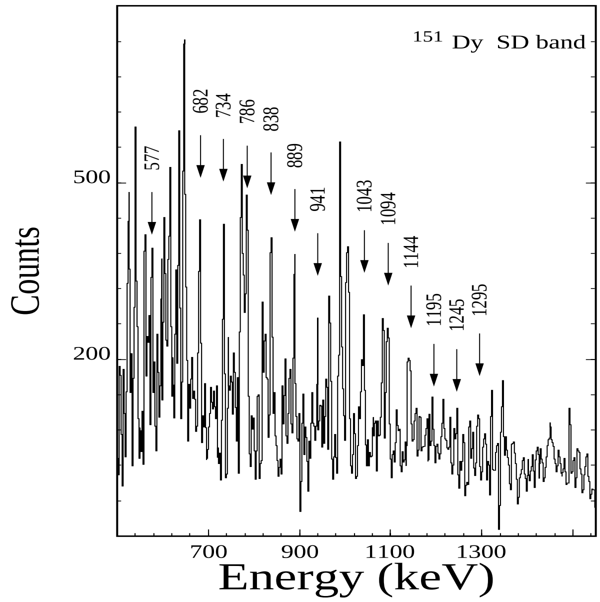

Fig. 8. γ-ray spectrum (background subtracted) of the SD yrast band in ^{151}Dy following a triple γ coincidence analysis requiring at least two γ-ray transitions among the 682, 734, 786, 838, 889, 941, 1043, 1094 and 1195 keV members of the band together with the presence of only one α-particle in the event.

allow a comparison between the α-particle energy distributions feeding the ND and SD bands in the two nuclei.

In contrast to the case of ^{152}Dy, the particle distributions corresponding to the population of ND and SD states of ^{151}Dy are significantly different. The mean energy of the α-particle feeding SD states (Fig. 9) is 14.1±0.5 MeV and the FWHM distribution is 6.7 MeV. These values are to be compared with a mean α-particle energy of 17.0±0.1 MeV and a FWHM of 8.3 MeV measured for the ND states (Table 1). The difference between the two distributions concerns mainly the high energy part of the spectrum. The most energetic α-particles do not populate the SD band. This can be clearly seen in Fig. 10 which shows the double gated γ-spectra obtained when gates are set on α-particles having an energy greater than 16.5 MeV (Fig.10 bottom) and smaller than 16.5 MeV (Fig. 10 top).

With the same assumption of constant neutron kinetic energy we can evaluate the mean energies of the states populating the SD and ND bands in ^{151}Dy. We find that E(ND)=21.1±1.5 MeV and E(SD)=24.0±2MeV. In this case, the mean entry energy of the states feeding the SD yrast band is close to the energy of 25 MeV [21] at which the yrast lines for ND states and SD states cross at spin 115/2 $\hbar$. The last SD transition clearly seen, at the energy of 1142 keV, corresponds to the deexcitation of this spin state.

The results obtained for ^{151}Dy can be compared with the results of [8] for the ^{150}Tb populated in the (α,3n) channel. In these two cases, and in contrast with what we found for ^{152}Dy, the mean energy for the α-particles in

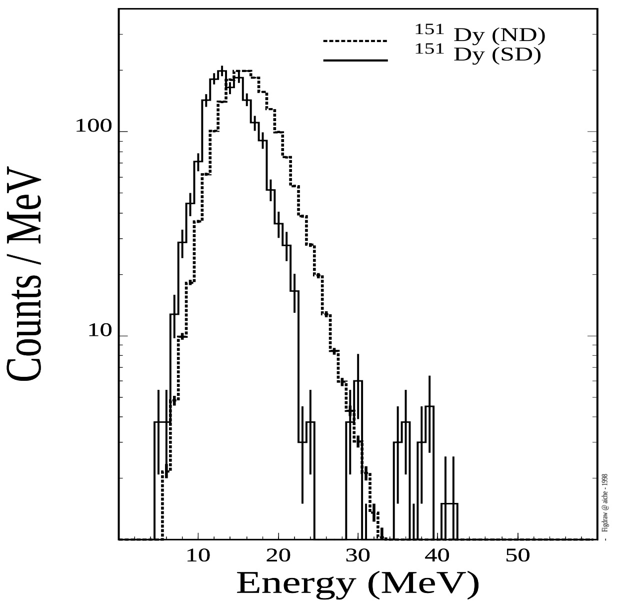

Fig. 9. Energy distribution of the α-particles in coincidence with the SD (solid line) transitions of the yrast band in ^{151}Dy. The spectrum was obtained by summing individual distributions from $\gamma\gamma\gamma$ coincidences. The first two γ-ray transitions are part of the list given in the caption of Fig. 6. The third γ-ray transition is one of the 734 keV, 891 keV, 941 keV transition. The energy distribution of α particle double gated on yrast ND transition (dashed line) in ^{151}Dy is recalled. The ND distribution is normalized at the maximum of the SD distribution.

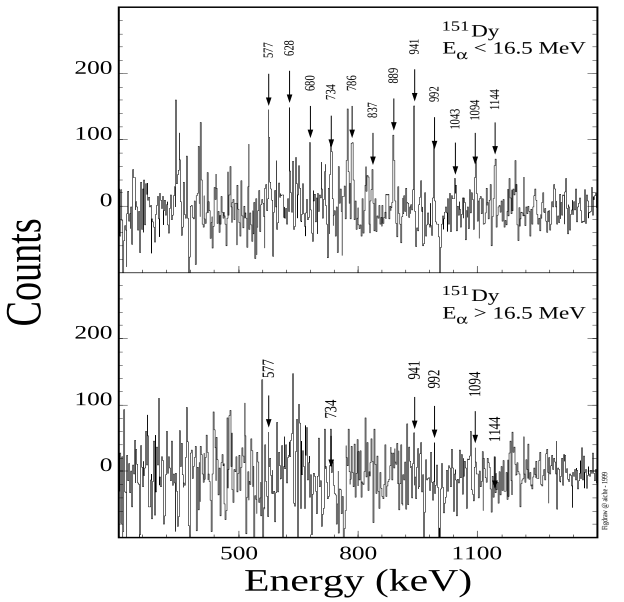

Fig. 10. Spectra of SD transitions in ^{151}Dy in coincidence with α-particles with energies ranging between 0 and 16.5 MeV (part A) and energies larger than 16.5 MeV (part B).

coincidence with SD states is lower than the mean energy of the α-particles in coincidence with ND states. Also the distributions are narrower. In ^{150}Tb, the energy difference between the two distributions is of the order of 2 MeV for α-particles measured in the laboratory at 34^0 which corresponds to 1.3 MeV in the CM, which is the same as the energy difference when one goes from ^{150}Tb to ^{149}Tb [8].

In the present experiment, the mean α-particle energy difference in ^{151}Dy between the ND and SD cases is 2.9 ± 0.6 MeV; the effect of the feeding of the SD states on the α-particle distribution appears to be larger in ^{151}Dy than in ^{150}Tb. In fact in the reaction $(\alpha 5n)^{151}$Dy the α-particle energy required to populate the SD states is much more constrained (E(ND)=21.1 MeV) than in the $(\alpha 3n)^{150}$Tb reaction (E(ND)$\simeq$40MeV), assuming a neutron energy of 2.6 MeV and a crossing energy for the ND and SD yrats lines located around 25 MeV.

In addition to the clear difference between the high energy part of the ND and SD distributions, the two spectra in Fig. 9 exhibit a difference on the low energy side. This difference might be a signature of a lowering of the Coulomb barrier for the α-particle emission and of a large deformation of the nuclei populating the SD states in ^{151}Dy. Calculations performed with the Monte-Carlo computer code GANES [24], using Cassini parametrisation of the nuclear shapes, show that in the system ^{37}Cl on ^{123}Sb the average α-particle emission barrier varies from 16.8 MeV for a spherical nucleus to 16.0 MeV for a deformed ellipsoid with an axis ratio equal to 2. This barrier effect together with the increase of the moment of inertia results in the reduction of the α-spectrum mean energy of about 2 MeV. Because of the high selectivity required in this particular channel to populate entry states located above the crossing point between ND and SD yrast lines, only α-particles emitted from highly deformed shapes could meet these conditions.

3.3 Hyperdeformation

We have extracted from the γ-ray cube the triple coincidence events associated with a list of gates corresponding to the energies of the discrete transitions of the so-called HD band in ^{152}Dy given by Galindo-Uribarri et al. [9]. The spectrum obtained is displayed in Fig. 11. The similarity with the spectrum published by the Canadian group is striking at least for the first six transitions at 1266, 1300, 1326, 1354, 1380 and 1408 keV. This band was associated initially with the population of an HD structure on the basis of ridges with an energy separation of ± 30 keV appearing in the proton-gated γ-γ coincidence events when a constraint was set on the sum of the energies of the two γ-rays $1375 \leq E_{\gamma 1} + E_{\gamma 2} \leq 1500$keV. These ridges were confirmed later on by Viesti et al. [7], in the same reaction at the same energy, but with larger statistics. However the discrete transitions were not confirmed. From the ridge spacing, a moment of inertia J=130 MeV^{-1} was inferred, corresponding to an HD shape, β=0.9, populated at spin larger than $60\hbar$. It

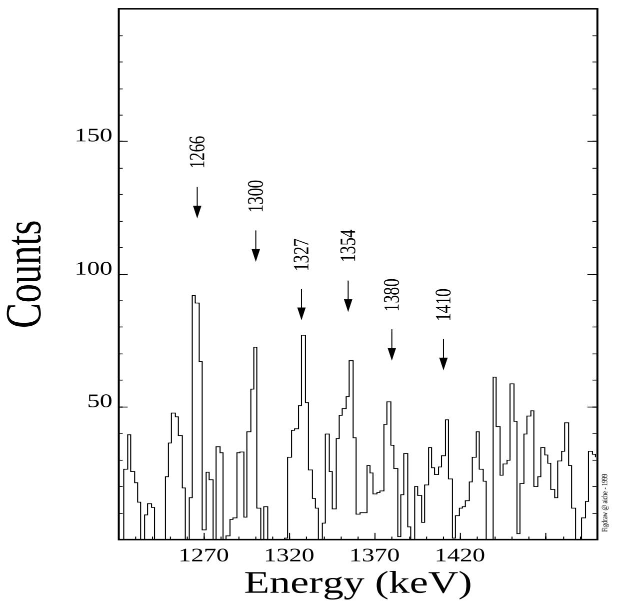

Fig. 11. Spectrum (background substracted) following a triple γ coincidence analysis requiring at least two γ-rays within the set of 1266, 1299, 1327, 1355, 1380, 1410 and 1440 keV γ-ray transitions in ^{152}Dy. The presence of an α-particle is also required.

was suggested that such a shape could only be populated in charged-particle channels due to the decrease of the fissility parameter to explain the survival of the residual nuclei against the fission process.

We merely point out that the observation of a set of discrete transitions with an average spacing of about 30 keV in some Dy isotopes is reproducible in a channel which also involves a charged particle. We could not determine in which Dy isotope these transitions occur. The statistics of the discrete transitions were also too low to determine the energy distribution of the α-particles or even the γ-fold distribution associated with this structure.

Furthermore, considering that the data do not show evidence for excited SD bands in ^{152}Dy, the intensity of which is estimated to be a few % of the yrast band intensity, the observation of an HD structure would be rather surprising unless the emission of the α-particle, thereby cooling the compound nucleus, competes strongly with fission.

4 Conclusion

We have studied the distribution of α-particles populating the ND and SD structures of ^{151}Dy and ^{152}Dy formed simultaneously in the reaction ^{37}Cl+^{123}Sb. In the case of ^{152}Dy, the comparison between spectral shapes of α-particles from ND and SD bands shows relatively small differences. In this residual nucleus the mean energy of the α-particles populating the SD band is only slightly lower than that of α-particles leading to ND states. The population of the ^{152}Dy SD band in the (α4n) channel is similar to the previously reported population in pure (xn) channels, indicating that the emission of an α-particle in this reaction channel does not play a significant role as long as the entry energy is high enough above the crossing point of the SD and ND yrast lines.

In the case of ^{151}Dy, the spectral shapes of α-particles are different for ND and SD states. The lowering of the mean energy of the α-particles measured in the case of the SD of ^{151}Dy is of the same order than the one already found in the population of the ^{150}Tb SD states by Viesti et al [8]. This is explained first by a channel effect and second by the localization of the energy at which the SD yrast line crosses the ND yrast line. The narrow width of the α-particle distribution indicates a narrow entry region in energy for the SD band. An estimate on the basis of the statistical model locates the entry energy close to the energy crossing point between the ND and SD yrast lines. The differences observed on the low energy side of the distributions between the α-particle associated to SD and ND states might be an indication of the emitter deformation. However, the effect is difficult to quantify.

The energy distributions of the evaporated α-particles populating ND and SD states confirm the previous observations in the ^{152}Dy nucleus populated via the (p5n) channel [7] and in the ^{150}Tb nucleus populated via the (α3n) channel [8]. We conclude that the energy distributions of the evaporated particles populating ND and SD states is not specificaly dependent on the kind of evaporated particle. These observations reflect essentially the location of the entry region and the phase space available regarding the yrast line itself either ND or SD.

Finally we have observed, in coincidence with the α-particles, six transitions with an energy spacing of 30 keV and energies identical to the ones previously attributed to the decay of a hyperdeformed structure at high spin in ^{152}Dy.

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