Superdeformed band in the ^{143}Eu nucleus: Study of the decay out

A.Atac[a], M.Piiparinen[a], B.Herskind[a], J.Nyberg[a], G.Sletten[a], G.de Angelis[b], S.Forbes[c],N.Gjørup[a], G.Hagemann[a], F.Ingebretsen[d], H.Jensen[a], D.Jerrestam[a], H.Kusakari[f], R.Lieder[a], G.M.Marti[f], S.Mullins[c], D. Santonocito[a], H.Schnare[f], K.Strähle[f], M.Sugawara[a], P.O.Tjøm[d], A.Virtaten[a] and R.Wadsworth[g]

[a] The Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark
[b] Laboratori Nazionali di Legnaro, Legnaro, Italy
[c] Oliver Lodge Laboratory, University of Liverpool, Liverpool, U.K.
[d] Department of Physics, University of Oslo, Oslo, Norway
[e] The Studsvik Science Laboratory, Nykobing, Sweden
[f] Institut für Kernphysik, Jülich, Germany
[g] Department of Physics, University of York, York, U.K.

Nuclear superdeformation was observed for the first time in 1985-1986 in the ^{152}Dy nucleus [1] by Twin et al. using a thechnique pionered by the Niels Bohr Institut where rotational structures at high spin show up as ridges in $E\gamma$-$E\gamma$ coincidence correlation plots. 19 γ-rays were observed with a very constant spacing of 47(1) keV giving a dinamic moment of inertia j^2=87 $\hbar^2$MeV^{-1} corresponding to a 2:1 major to minor axis ratio. A measurement [2] of the half-life of the superdeformed levels suggested that the average shape was associated with a quadrupole moment of Q_0=18(3) eb confirming the 2 to 1 axis ratio.

Such discovery was characterized by many unusual properties [3]:
a) Unusual feeding pattern: deformed nuclei show an increasing population intensity when spin decreases due to the side-feeding, superdeformed nuclei show a characteristic plateau.
b) Unusual depopulation pattern: intensity of superdeformed bands drop to zero within $\approx$2 transitions.
c) Unobservation of connecting γ-rays.
Concerning the last topic only in one case [4] it has been possible to observe the decay connecting the superdeformed band to the Yrast states. Thus superdeformed excitation energies and spin assignments are usually not known. Spin assignments can be guessed either knowing the mean spin at which the Yrast line is populated and estimating the angular momentum lost by the nucleus in the connecting transitions or fitting the level spacings under the assumption of a definite, constant, moment of inertia. Basing on such guesses one obtains the I^π assignments from 22 to 60 for the superdeformed band of the ^{152}Dy nucleus. From the intensity pattern of the superdeformed band one can deduce that the band is fed mostly above spin 50 $\hbar$ suggesting that here is where the superdeformed band become Yrast. Extrapolating from the normally deformed states up to spin 50 $\hbar$ it can be estimate that the spin 60 $\hbar$ level is about at 30 MeV of excitation energy.

In 1988 a second superdeformed band was found in ^{149}Gd by B.Haas et al. using the 8π spectrometer in Chalk River and untill now more than 20 have been identified in the A$\approx$150 mass region and as many in the Mercury region A$\approx$190. In all these cases the connection between the superdeformed and the normal deformed states has not been found. Due to the high level density of normal deformed states in the deexcitation region the number of possible deexcitation paths is very large, preventing or making very difficult the observation of the direct decay. Since the differents paths connect two definite levels, the direct decay, as it was suggested by B.Herskind et al., can be reconstructed on the basis of the sum energy released. Under the assumption of decay paths of only two transitions, the sum of the two consecutive γ-ray energies has a well definite value. Therefore a sum spectrum can be produced in triple (or higher-fold) coincidence events setting a gate on one (or more) γ-ray transition of the superdeformed band and summing up the other two γ-ray energies. Discrete peaks observed in that spectrum can therefore be related to the deexcitation of the superdeformed band.

Two different experiments have been performed using the Nordball detector at NBI with 19 Compton suppressed Ge detectors and a BaF_2 inner ball and the Ga.Sp. detector with 30 Compton suppressed Ge detectors and a BGO multiplicity filter fig.1. In both cases the reaction used to populate the superdeformed states in the ^{143}Eu nucleus was ^{110}Pd(^{37}Cl,4n) at 160 MeV. In the first experiment the event rate was $\approx$600 Hz and a total of 10^9 events were collected. In the second the event rate was $\approx$6000 Hz with and a total of 3^*10^9 events were collected. Since the analysis of these data is still in progress all the results shown concern the first experiment.

The sum spectrum of two γ-ray energies in coincidence with one of the superdeformed transition is shown in fig.2. All relevant peaks in the 1.8 to 3.0 MeV energy region are sum of two transitions of the superdeformed band. Above 3.0 MeV 6 peaks are interpreted as the sum of two linking transitions. Such identification is made requiring that the energy differences between such peaks has to match the energy differences of known levels in the Yrast structure. On this basis one determine the energy of the initial superdeformed state as 8582(4) keV. Spins of superdeformed levels can be assigned assuming that the two linking transitions are most likely stretched or unstretched E1 taking away 0 or 1 unit of angular momentum each. Endeed an assigment of 37/2 and 41/2 for the first two states cannot be excluded.

The insert of fig.3 shows the energy-spin diagram for the superdeformed and normal deformed states of ^{143}Eu. The superdeformed band ends at spin I=35/2 $\hbar$ 3634 keV above the Yrast line and extends up to I=123/2 $\hbar$ at an excitation energy of 33174 keV becaming Yrast at spin 40 $\hbar$.

References:

1) Twin, P.J. et al.: Phys. Rev. Lett. 55 (1985) 1380

2) Bently, M.A. et al.: Phys. Rev. Lett. 59 (1987) 2141

3) Dudek,J.: Prog. Part. Nucl. Phys. 28 131-185 (1982)

4) Lunardi. S.: These proceedings

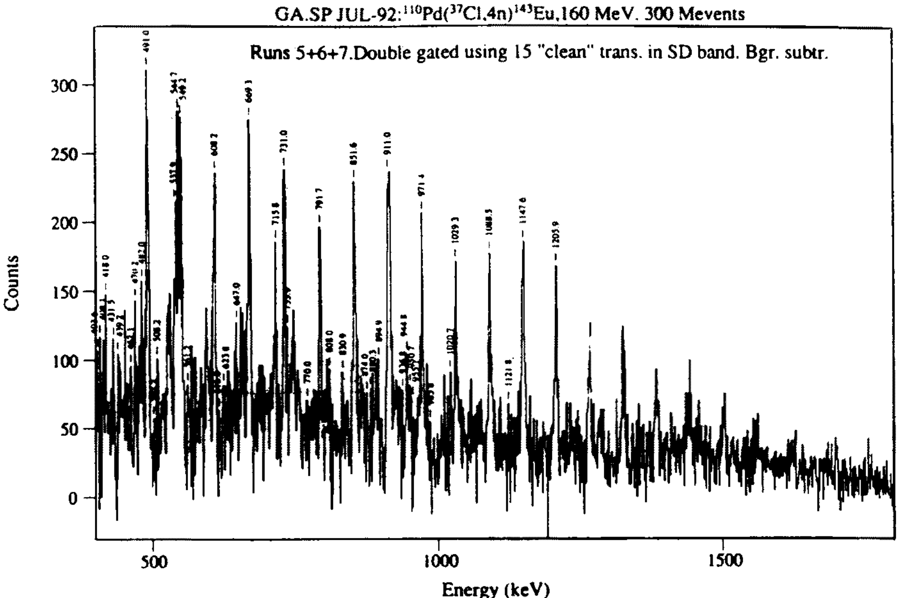
GA.SP JUL-92:110Pd(37Cl,4n)143Eu,160 MeV. 300 Mevents
Runs 5+6+7.Double gated using 15 "clean" trans. in SD band. Bgr. subtr.
Counts
Energy (keV)
0
50
100
150
200
250
300
500
1000
1500

Fig. 1

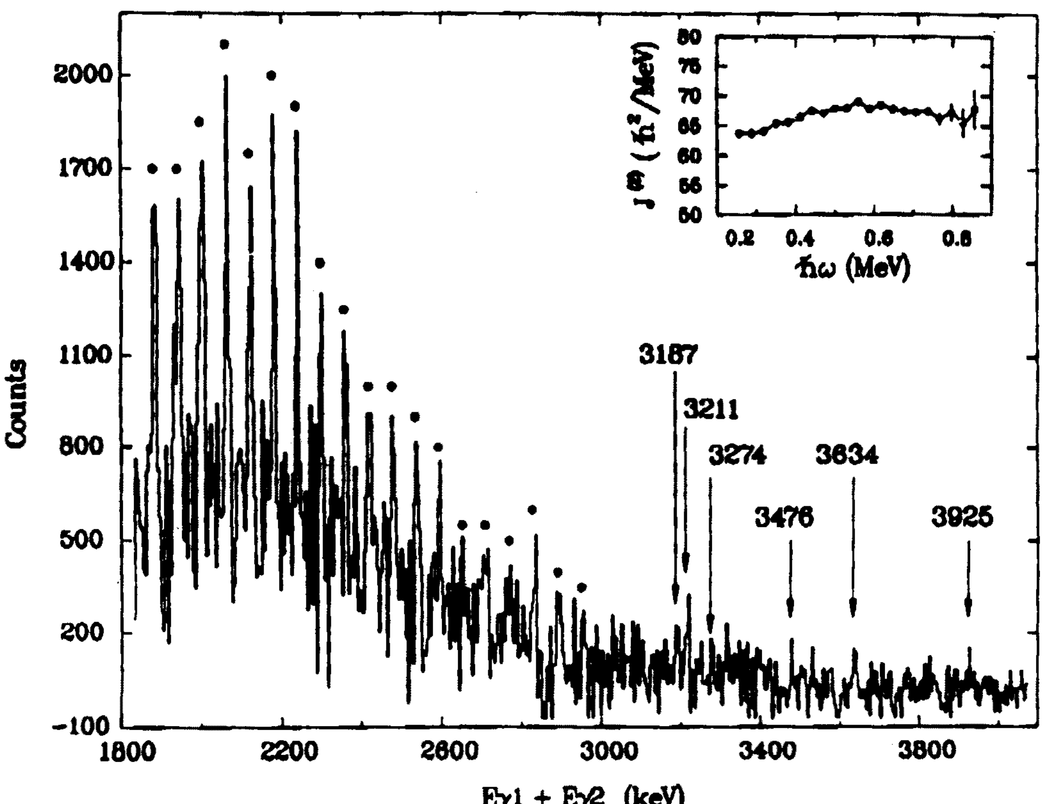
Counts
Eγ1 + Eγ2 (keV)
3187
3211
3274
3476
3634
3925
ħω (MeV)
-100
200
500
800
1100
1400
1700
2000
1800
2200
2600
3000
3400
3800

Fig. 2

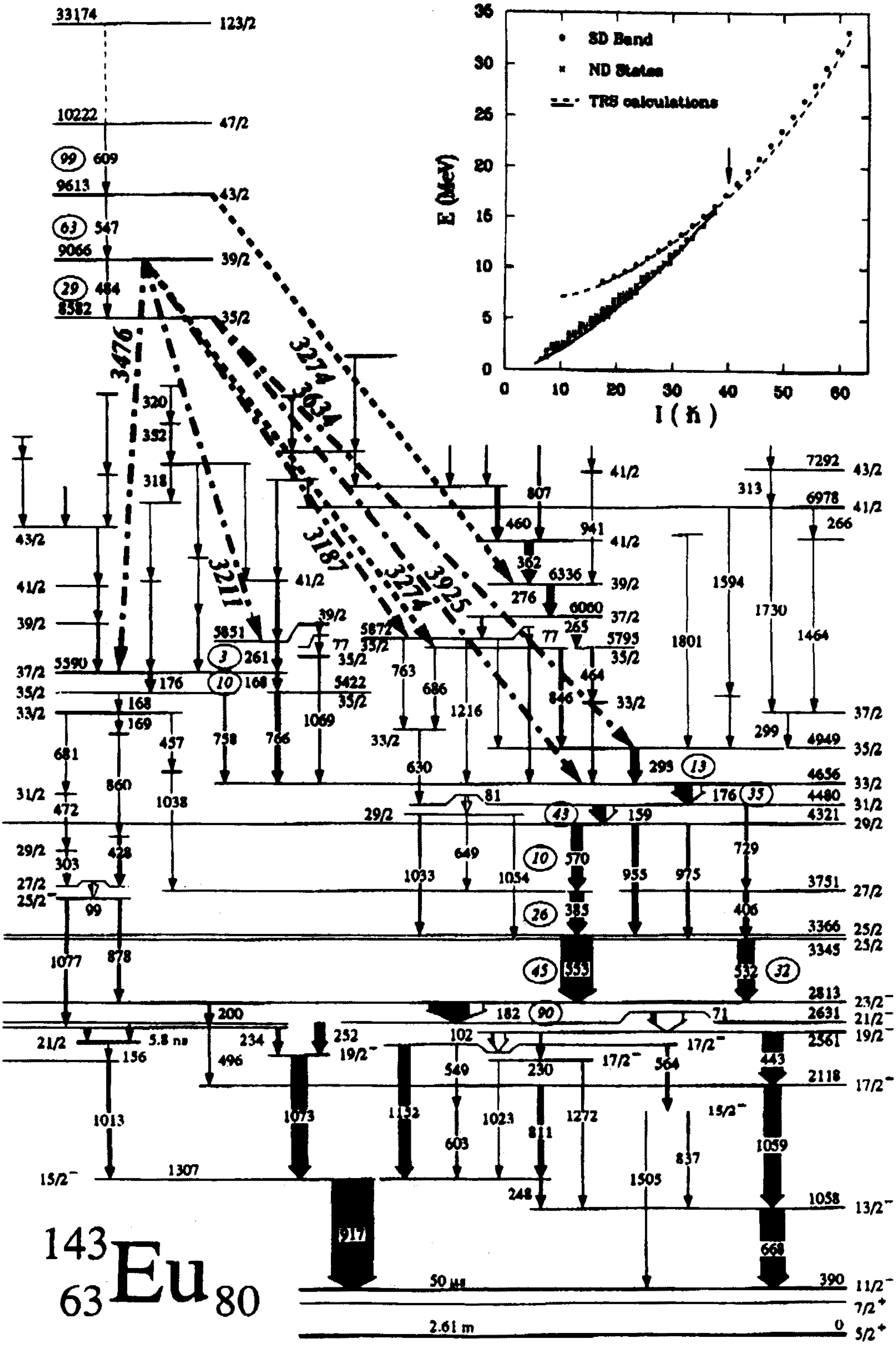

Fig. 3.