ODD TRANSITIONAL NUCLEI BELOW N = 82

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The level schemes of all neutron deficient odd mass nuclei with $50 < (Z,N) < 82$ show characteristic low lying $11/2^-$-isomers which can be interpreted as $1h_{11/2}$-shell model states. As the $1h_{11/2}$-shell is the only one of negative parity in this mass region, levels based on this isomeric state will have no admixture from neighbouring shells. Therefore they seem to be well suited for the investigation of the collective behaviour of these nuclei.

The even-even nuclei of this mass region show a systematic trend from harmonic vibrator behaviour which we find near to closed shells, to soft asymmetric rotators and to more rigid rotators |1|. This transition from spherical to deformed nuclei is obvious also from the level schemes of the odd mass nuclei. Fig. 1 shows that in nuclei with N=81 and 80 we have the well-known one-phonon multiplet based on the $11/2^-$-level as predicted by a weak coupling model. Odd nuclei with $N < 80$ show the so-called decoupled bands |2| above the $11/2^-$ isomeric levels, except the odd neutron nuclei with N = 77, which show more rotational bands with $\Delta I = 1$. These collective bands of odd mass nuclei can be described in the framework of a particle plus rotor model worked out by Nakai and Stephens |2| which takes into account the Coriolis interaction. It predicts typical level sequences which depend on the sign of the deformation. From the splitting of the $h_{11/2}$-state within a Nilsson model calculation (fig. 1) we expect $K = 1/2$ bands for prolate odd proton nuclei with Z near 50, and $K = 11/2$ bands for oblate deformation. In odd neutron nuclei of this region

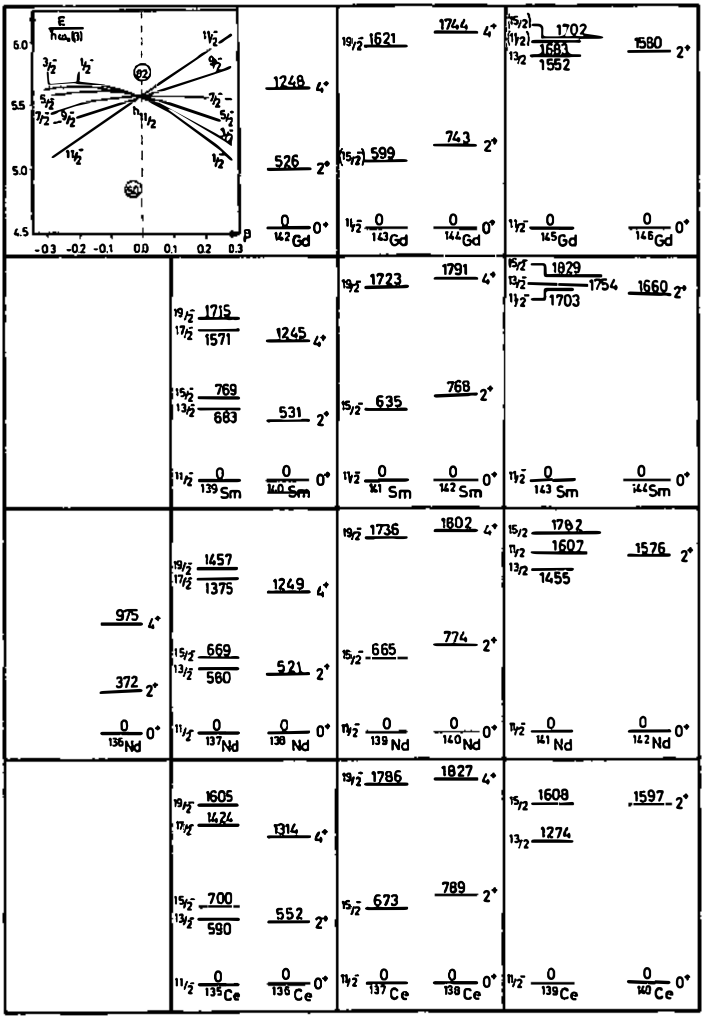
ε / ħω0(1)
6.0
5.5
5.0
4.5
-0.3 -0.2 -0.1 0.0 0.1 0.2 0.3
β
82
50
3/2-
1/2-
5/2-
7/2-
9/2-
11/2-
h11/2
11/2-
9/2-
7/2-
5/2-
3/2-
1/2-
1248 4+
526 2+
0 0+
142Gd
19/2- 1621
(15/2-) 599
11/2- 0
143Gd
1744 4+
743 2+
0 0+
144Gd
(15/2) 1702
(11/2) 1683
13/2 1552
11/2- 0
145Gd
1580 2+
0 0+
146Gd
19/2- 1715
17/2- 1571
15/2- 769
13/2- 683
11/2- 0
139Sm
1245 4+
531 2+
0 0+
140Sm
19/2- 1723
15/2- 635
11/2- 0
141Sm
1791 4+
768 2+
0 0+
142Sm
15/2- 1829
13/2- 1754
11/2- 1703
11/2- 0
143Sm
1660 2+
0 0+
144Sm
975 4+
372 2+
0 0+
136Nd
19/2- 1457
17/2- 1375
15/2- 669
13/2- 560
11/2- 0
137Nd
1249 4+
521 2+
0 0+
138Nd
19/2- 1736
15/2- 665
11/2- 0
139Nd
1802 4+
774 2+
0 0+
140Nd
15/2 1782
11/2 1607
13/2 1455
11/2- 0
141Nd
1576 2+
0 0+
142Nd
19/2- 1605
17/2- 1424
15/2- 700
13/2- 590
11/2- 0
135Ce
1314 4+
552 2+
0 0+
136Ce
19/2- 1786
15/2- 673
11/2- 0
137Ce
1827 4+
789 2+
0 0+
138Ce
15/2 1608
13/2 1274
11/2- 0
139Ce
1597 2+
0 0+
140Ce

Fig. 1a

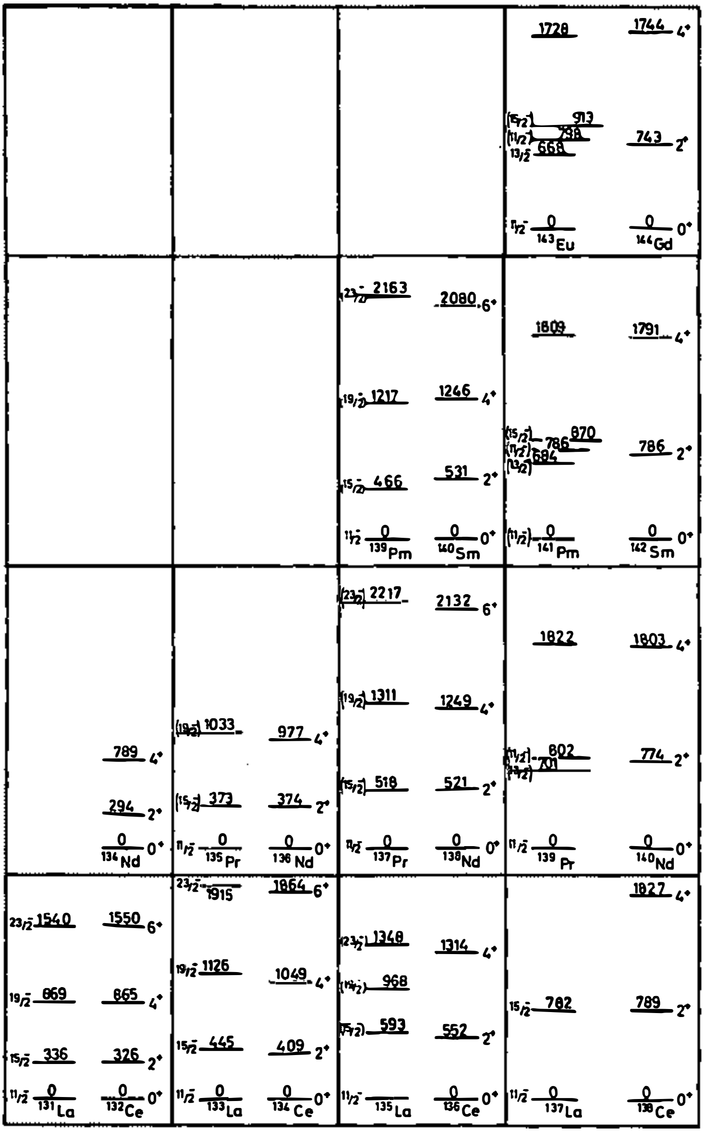
1728
1744 4+
(15/2-) 913
(11/2-) 798
13/2- 668
743 2+
11/2- 0
143Eu
0 0+
144Gd
(23/2-) 2163
2080 6+
(19/2-) 1217
1246 4+
(15/2-) 466
531 2+
11/2- 0
139Pm
0 0+
140Sm
1809
1791 4+
(15/2-) 870
(11/2-) 786
(13/2-) 684
786 2+
(11/2-) 0
141Pm
0 0+
142Sm
789 4+
294 2+
0 0+
134Nd
(19/2-) 1033
977 4+
(15/2-) 373
374 2+
11/2- 0
135Pr
0 0+
136Nd
(23/2-) 2217
2132 6+
(19/2-) 1311
1249 4+
(15/2-) 518
521 2+
11/2- 0
137Pr
0 0+
138Nd
1822
1803 4+
(11/2-) 802
(13/2-) 701
774 2+
11/2- 0
139Pr
0 0+
140Nd
23/2- 1540
1550 6+
19/2- 869
865 4+
15/2- 336
326 2+
11/2- 0
131La
0 0+
132Ce
23/2- 1915
1864 6+
19/2- 1126
1049 4+
15/2- 445
409 2+
11/2- 0
133La
0 0+
134Ce
(23/2-) 1348
1314 4+
(19/2-) 968
(15/2-) 593
552 2+
11/2-
135La
0 0+
136Ce
1827 4+
15/2- 782
789 2+
11/2- 0
137La
0 0+
138Ce

Fig. 1b

Fig.1. High spin bands of odd neutron (a) and odd proton (b) nuclei and ground-state bands of the neighbouring even-even nuclei. The inset shows the splitting of the $1h_{11/2}$-state calculated in the framework of the Nilsson model.

with N near 82 we have just the opposite situation, that is, we expect $K = 1/2$ bands for oblate deformation and $K = 11/2$ bands for prolate nuclear shape. The difference in level sequence for these two types of collective bands calculated on the basis of the Stephens model is shown in |2| , where the sign of the deformation parameter β is chosen for the case of odd neutron nuclei. From the rotation aligned bands, that is for $K = 1/2$, we will see that in in-beam experiments levels with the spin sequence 23/2 - 19/2 - 15/2 - 11/2 are strongly populated due to the dominance of the yrast cascade, whereas for $K = 11/2$ levels with the spin sequence 19/2 - 17/2 - 15/2 - 13/2 - 11/2 of the deformation aligned band will be strongly populated. But besides these yrast levels there are levels of lower spin and negative parity belonging to this collective bands, which are not observed by in-beam studies, but which perhaps will be populated in beta decay. The observation of such low spin levels in addition to the yrast cascade will be a good test of the calculations in the framework of the Stephens model and perhaps will give some hints to details, such as to an asymmetry or the softness of the core.

I will discuss such experimental results of the odd proton nucleus ^{135}Pr, where from the β-decay of the $9/2^-$ ground state of ^{135}Nd we find a population of levels with negative parity, and the odd neutron nucleus ^{137}Nd. From our experiments it is evident that a $11/2^-$ level of ^{137}Pm decays by β^+ + EC.

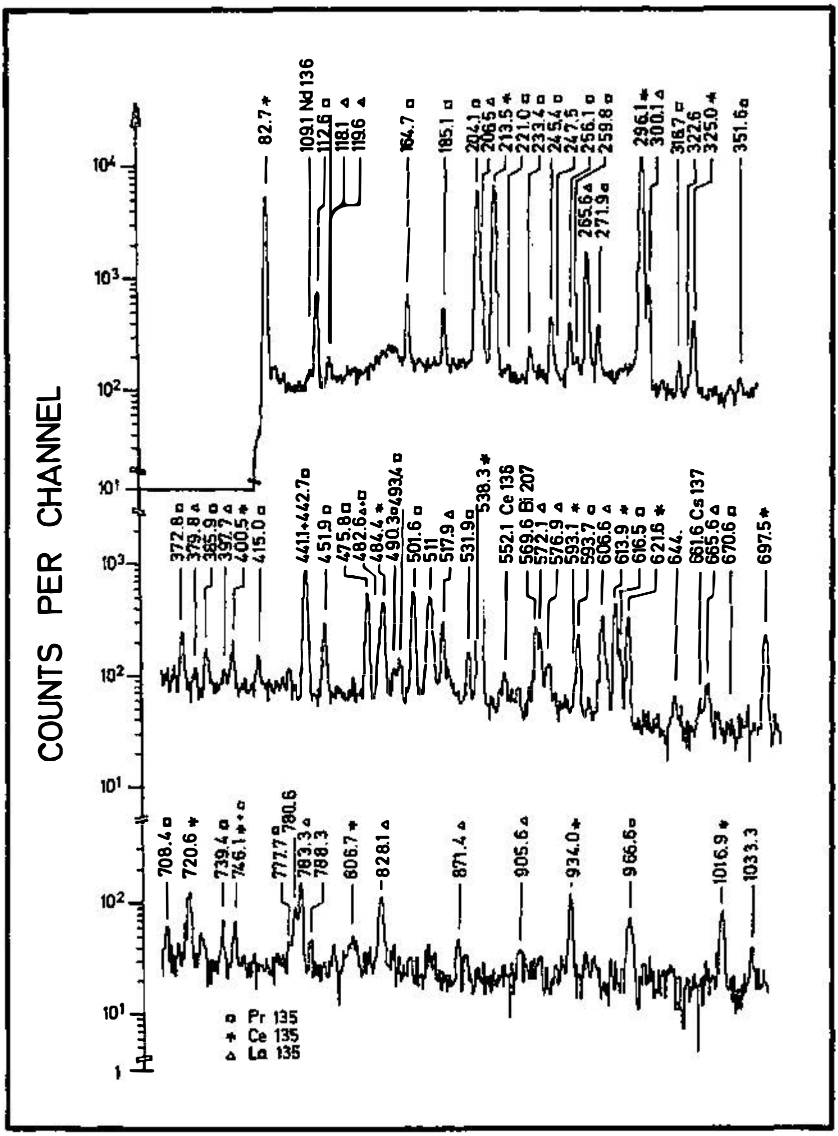
COUNTS PER CHANNEL
10⁴
10³
10²
10¹
1
82.7 *
109.1 Nd 136
112.6 ▫
118.1 ▵
119.6 ▵
164.7 ▫
185.1 ▫
204.1 ▫
206.5 ▵
213.5 *
221.0 ▫
233.4 ▫
245.4 ▫
247.5
256.1 ▫
259.8 ▫
265.6 ▵
271.9 ▫
296.1 *
300.1 ▵
316.7 ▫
322.6
325.0 *
351.6 ▫
372.8 ▫
379.8 ▵
385.9 ▫
397.7 ▵
400.5 *
415.0 ▫
441.1+442.7 ▫
451.9 ▫
475.8 ▫
482.6 ▵+▫
484.4 *
490.3 ▫
493.4 ▫
501.6 ▫
511
517.9 ▵
531.9 ▫
538.3 *
552.1 Ce 136
569.6 Bi 207
572.1 ▵
576.9 ▵
593.1 *
593.7 ▫
606.6 ▵
613.9 *
616.5 ▫
621.6 *
644.
661.6 Cs 137
665.6 ▵
670.6 ▫
697.5 *
708.4 ▫
720.6 *
739.4 ▫
746.1 *+▫
777.7 ▫
780.6
783.3 ▫
788.3
806.7 *
828.1 ▵
871.4 ▵
905.6 ▵
934.0 *
966.6 ▫
1016.9 *
1033.3
▫ Pr 135
* Ce 135
▵ La 135

Fig. 2a

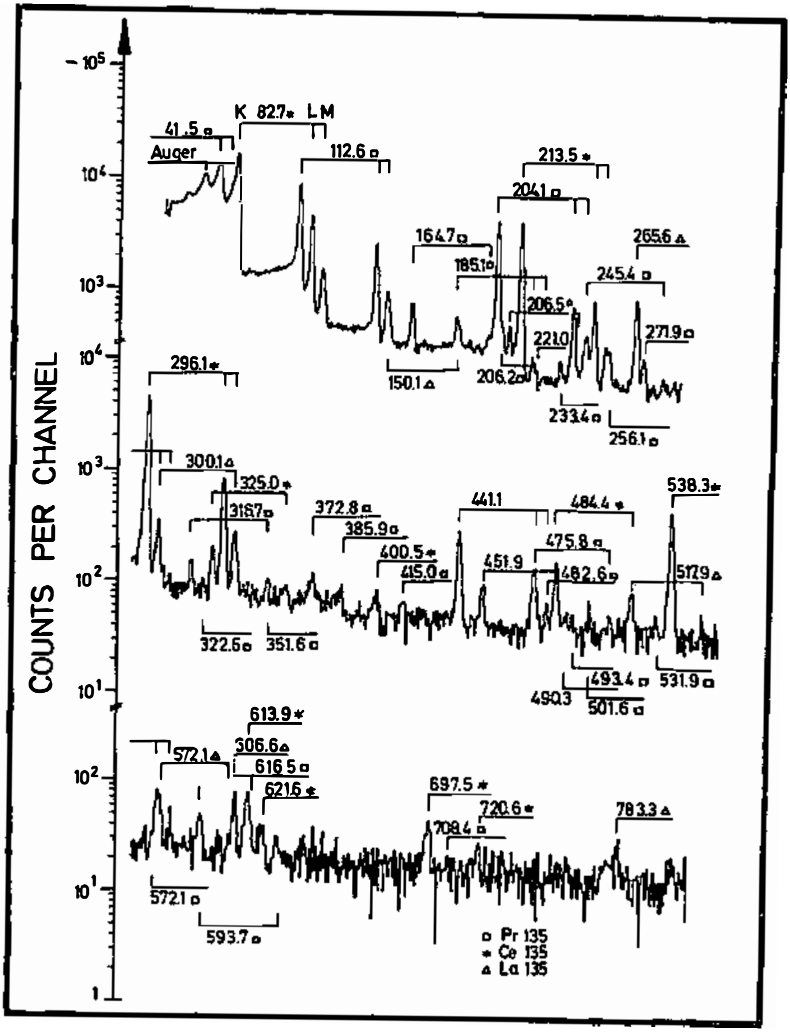

Fig. 2b

Fig.2. (a) γ- and (b) conversion electron spectrum of the decay of ^{135}Nd.

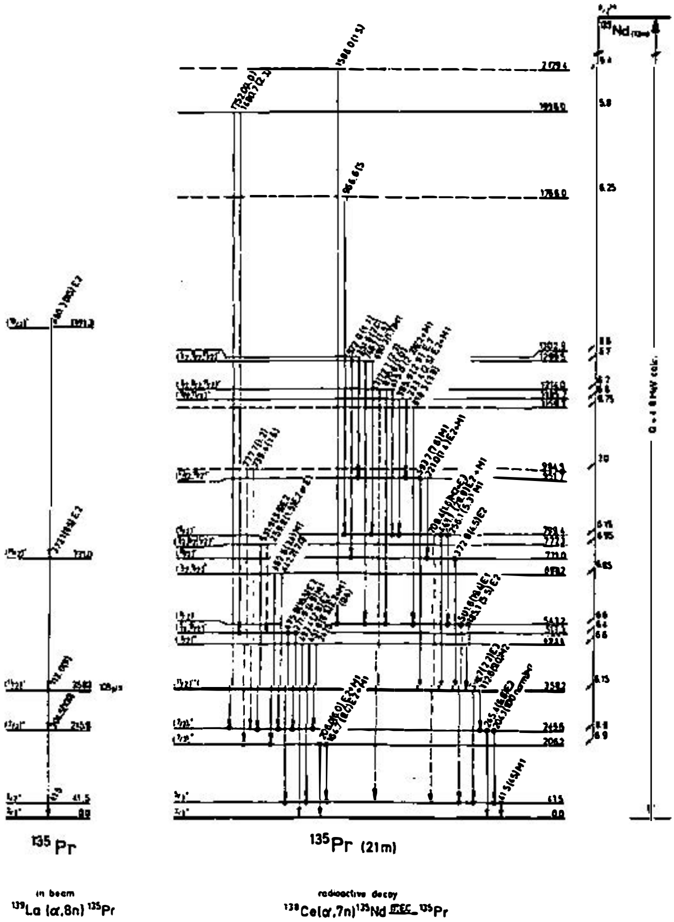

Fig.3. Partial decay scheme of ^{135}Pr.

We produced the neutron deficient nuclei by (α,xn) reactions using the external α-beam of the Karlsruhe Isochronous Cyclotron. We studied the electromagnetic transitions of the nuclei by measuring γ-single spectra γγ-coincidences and conversion electron spectra "in beam" as well as "off beam". The off beam measurements were done using mass separated sources. A γ- and e^--spectrum of the decay of ^{135}Nd are shown in fig. 2. Fig. 3 shows partial

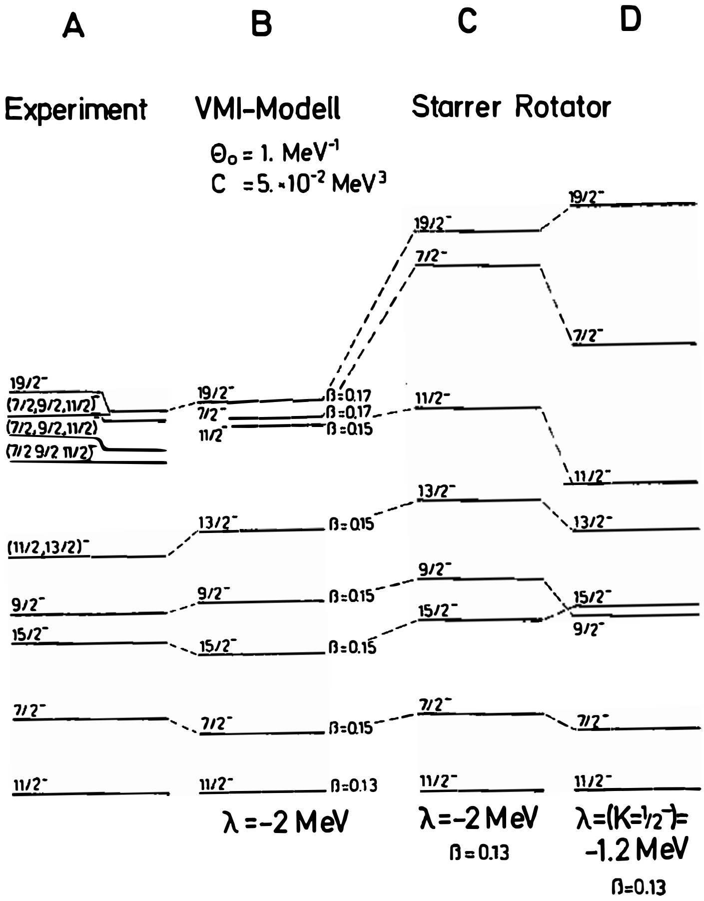

Fig.4. Comparison of calculated and experimentally found levels of ^{135}Pr.

decay schemes of ^{135}Pr constructed from "in beam" and "off beam" observed electromagnetic transitions. Levels of negative parity found in our experiments are compared with those calculated in the Stephens model in fig. 4 (row A and C). As there is no good agreement, we tried to take into account the softness of the core, which we could expect from the neighbouring even-even nuclei. In order to introduce a soft core, we added to the Hamiltonian of ref. |2| a term $C(\theta-\theta_o)^2/2$, which is well known from the VMI-model of even-even nuclei. The

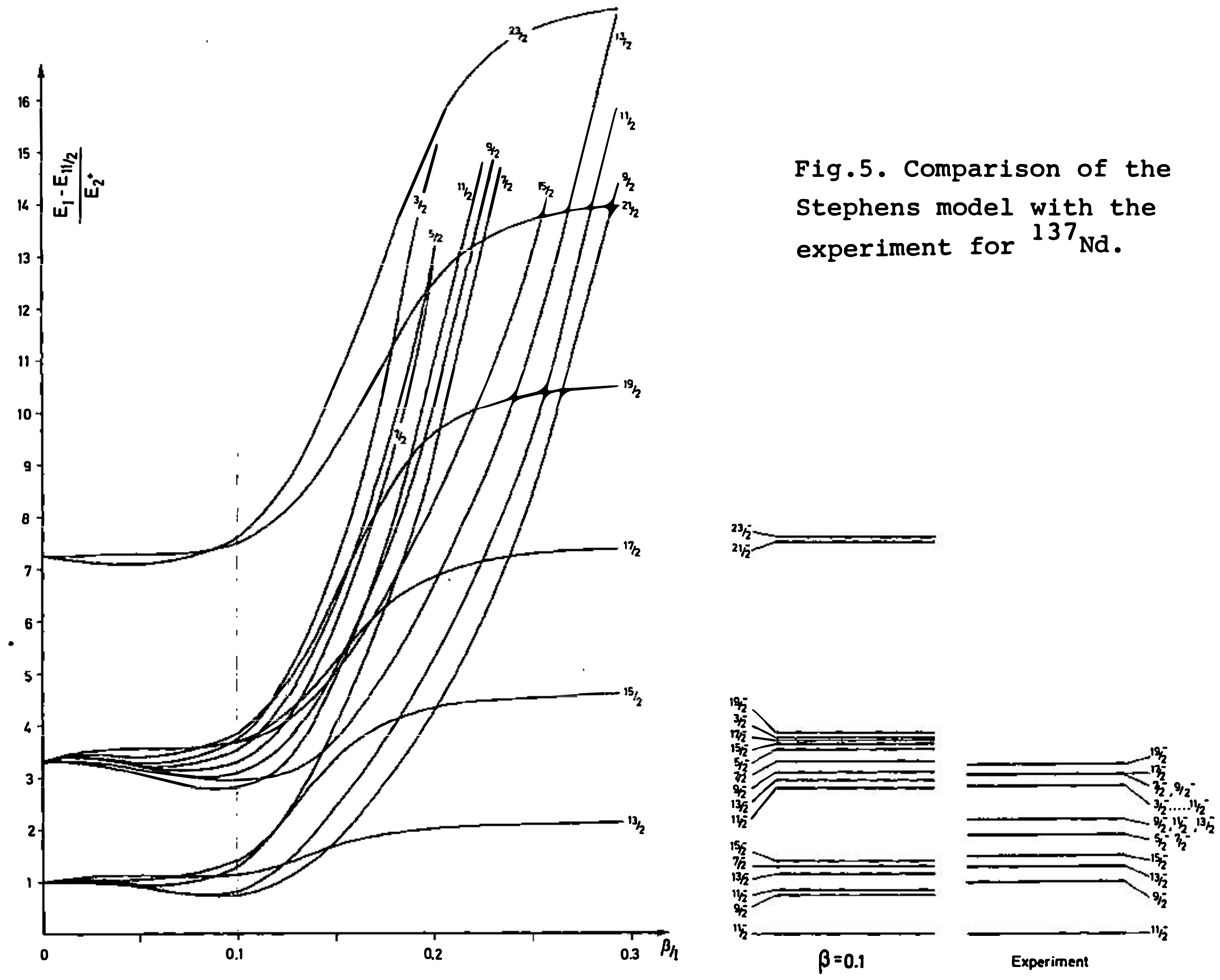

Fig.5. Comparison of the Stephens model with the experiment for ^{137}Nd.

level energies were calculated from the condition $\partial E_I(\theta)/\partial\theta = 0$. The result of such a calculation is shown in row B of fig. 4. The ground-state moment of inertia θ_0 and the stiffness parameter C show in comparison with those of the neighbouring even-even nuclei (about 5 MeV^{-1} and $1\cdot 10^{-2}$) that the core of the odd nucleus is more spherical and less soft than the neighbouring even-even nucleus. The comparison of experimentally determined levels with negative parities of the odd neutron nucleus ^{137}Nd with the calculations is shown in fig. 5. The model predicts the distance between the multiplets a little too large, whereas the level distances within a multiplet agree with experimental results. Taking into account a variable moment of inertia, we obtained no better fit to our experimental level scheme. Calculations of J. Meyer ter Vehn |3| for a particle coupled to an asymmetric core fit our data within a limit of ±50 keV, when using an asymmetry parameter $\gamma = 26^\circ$ for the core.

REFERENCES

|1| D. Habs et al., Z. Physik 267 (1974) 149.

|2| F.S. Stephens et al., LBL-Report 652 (1972);
F.S. Stephens, Proc. Int. Conf. on Nuclear Physics, München 1973, Vol. II, p. 372.

|3| J. Meyer ter Vehn, private communication.