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THE NUCLEAR STRUCTURE OF DEFORMED ODD-ODD NUCLEI: EXPERIMENTAL AND THEORETICAL INVESTIGATIONS

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ABSTRACT: Previous surveys [1,2] of experimental level structure in deformed odd-odd nuclei have been updated with recent results for the lanthanide and actinide regions. The relative strengths of the effective neutron-proton interaction derived from these data are compared. The predictive power of a semi-empirical model for level structure in deformed odd-odd nuclei is demonstrated. Comparison is made with recent Hartree-Fock calculations [3] of selected nuclei.

CONCLUSIONS:

1. Experimental Gallagher-Moszkowski (G-M) matrix elements can be correlated with zero-range force calculations assuming a single value for the force parameter, for nuclei in both the rare-earth and actinide regions (Figure 1, Tables 1 and 2).

2. In assessing 27 G-M matrix elements in the rare -earth region, Boisson et al. [1] developed a parameterization of a modified central force , the so-called CPTL form, that produced a root-mean-square (RMS) deviation of 17 keV compared with experiment (Figure 2). This result was markedly better than for calculations where either a zero-range or a simple central force was employed. For 5 newly measured matrix elements, the CPTL potential shows predictive power no better than that of a zero-range force calculation (Table 3).

3. The predictive power of models for structure in deformed odd-odd nuclei is shown in Figure 3 and Table 4. The experimental data for ^{238}Np are compared with the following model calculations:

A) Standard model + quasiparticle excitations from harmonic-oscillator calculations,

B) Standard model + quasiparticle excitations from empirical data,

C) Standard model + empirical data + Wigner term in calculated E(GM) [4],

D) Hartree-Fock approximation + BCS pairing calculation [3].

The lowest RMS deviation is found for model B (see Figure 3).

[1] J.P. Boisson et al., Phys. Rpts. 26, 99(1976); [2] R.W. Hoff et al., Gamma-Ray Spectroscopy and Related Topics-1984, ed. S. Raman (Amer. Inst. Phys., 1985); [3] L. Bennour et al., Nucl. Phys. A465, 35(1987); [4] P.C. Sood & R.N. Singh, Nucl. Phys. A373, 519(1982).

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Table 1. Gallagher-Moszkowski Matrix Elements for Actinide Nuclei.

Proton	Neutron	Nucleus	Experimental E(GM) (keV)	Calculated Z-RForce Piepenbr Boisson	Calculated HrtreeFck Bennour Quentin
1/2+400+	1/2+631-	238Np	88.0	31.7	8
1/2-530+	7/2-743+	234Pa	78.9	116.6	84
	1/2+631-	238Np	9	109.6	52
5/2+642+	1/2+631-	238Np	82.4	69.8	51
	5/2+622+	238Np, 242Am	36.2	39.7	70
5/2-523-	1/2-501-	240Am, 242Am	45.4	43.8	40
	1/2+631-	238Np, 240-2Am	55.0	60.3	71
		244Am	70.0		69
	1/2+620+	242Am	21.9		22
	5/2+622+	238Np, 240Am 242Am, 244Am	6.1	95.2	12
	7/2+624-	244Am	200.2	207.7	341
3/2-521+	9/2-734+	248Bk	186.5	134.4	116
	7/2+613+	250Bk	66.4	60.0	105
	1/2+620+	250Bk	110.3	114.9	139
7/2+633+	9/2-734+	248Bk	122.0	188.6	344
	7/2+613+	250Bk	135.0	46.6	72
	1/2+620+	250Bk	83.6	60.4	57
	3/2+622-	250Bk	91.2	68.8	37
	1/2-761-	250Bk	38.0		41
			RMS deviation:	37	71

Table 2. Newby Terms for K=0 Bands in Actinde Nuclei.

Proton	Neutron	Nucleus	Experimental E(N) (keV)	Calculated E(N) values: Z-RForce Piepenbr Boisson	HrtreeFck Bennour Quentin	Frisk [a]
1/2+400+	1/2+631-	238Np	-3.1			-17
1/2-530+	1/2+631-	234Pa	-42.5	-44.2	12.5	27
		236Pa	-45.9	-44.2	16.4	26
		238Np	-44.2	-43.1	17.0	25
5/2+642+	5/2+622+	238Np	-49.3	-59.1	-73.0	-29
		242Am	-59.4	-59.1	-73.0	-29
5/2-523-	5/2+622+	238Np	23.3	-15.2	13.0	27
		240Am	28.0	-14.7	13.2	27
		242Am	27.3	-14.6	13.4	27
		244Am	25.7	-14.5	13.0	27
7/2+633+	7/2+624-	244Am	33.1		14.9	63
	7/2+613+	250Bk	-25.0	-58	-63.2	-19
			Mean deviation:	4.3	10.7	15.7
			RMS deviation:	18	48	45

[a] H.Frisk, "Systematics of Rotational Bands with K=0 in Odd-Odd Nuclei", Lund Inst. of Tech. Report, Lund-MPh-88/5, March 1988.

Table 3. G-M Matrix Elements, Rare Earth Region, Boisson et al. [1]
Predicted values for newly measured cases

Proton	Neutron	Nucleus	Experimental E(GM)	Calculated Values ZRF	CF	CPTL
3/2+411+	7/2+633+	166Ho	191.2	87	94	146
1/2+411-	1/2-521-	168Tm	192.5	130	130	94
1/2+411-	7/2-514-	176Lu	122.9	180	171	321
9/2-514+	7/2-514-	176Lu	-68.2	-260	-239	-141
5/2+402+	5/2-512+	174Lu	129.0	150	145	169
Data listed above		RSM deviations:		105	95	108
		# entries:		5	5	5
Data set A (B-P)		RSM deviations:		43	40	17
		# entries:		27	27	27

Table 4. Odd-Odd Nuclei in Actinide and Rare Earth Regions: Comparison of bandhead energies and rotational parameters from experiment and semi-empirical model calculations.

Nucleus	Number of bands	Energy range (keV)	Bandhead mean dev. (exp-calc) (keV)	Rot parameter mean dev. (exp-calc) (%)
238Np	13	0 - 460	32	3.0
240Am	7	0 - 1020	42	3.7
242Am	13	0 - 1020	56	4.4
244Am	16	0 - 680	19	7.4
250Bk	14	0 - 570	17	4.7
160Tb	8	0 - 380	41	8.1
166Ho	10	0 - 560	47	8.7
170Tm	5	0 - 450	63	5.2
176Lu	12	0 - 840	58	9.2
182Ta	7	0 - 270	24	3.9

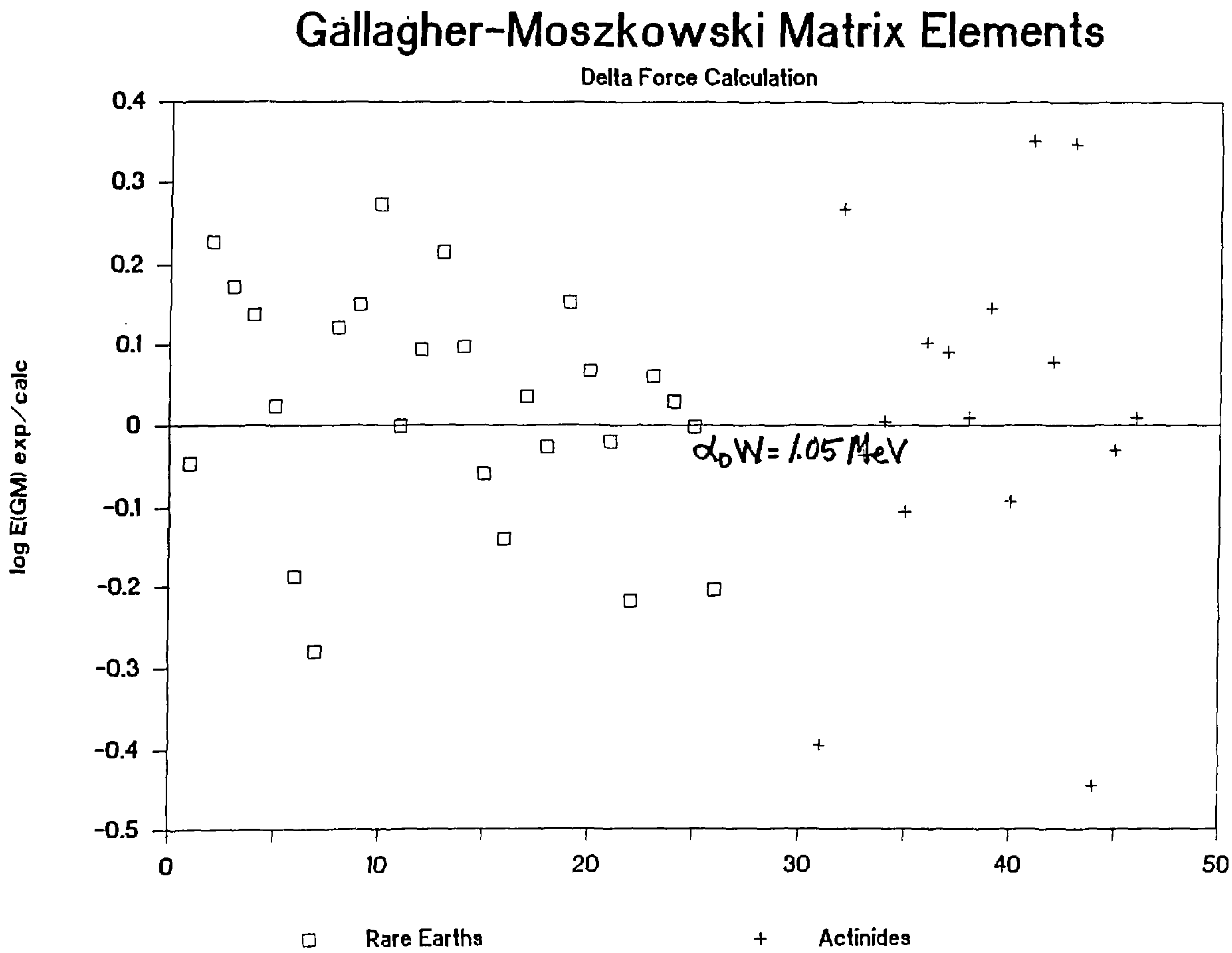
Gallagher-Moszkowski Matrix Elements
Delta Force Calculation
log E(GM) exp/calc
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
10
20
30
40
50
$\alpha_0 W = 1.05$ MeV
Rare Earths
Actinides

Figure 1.

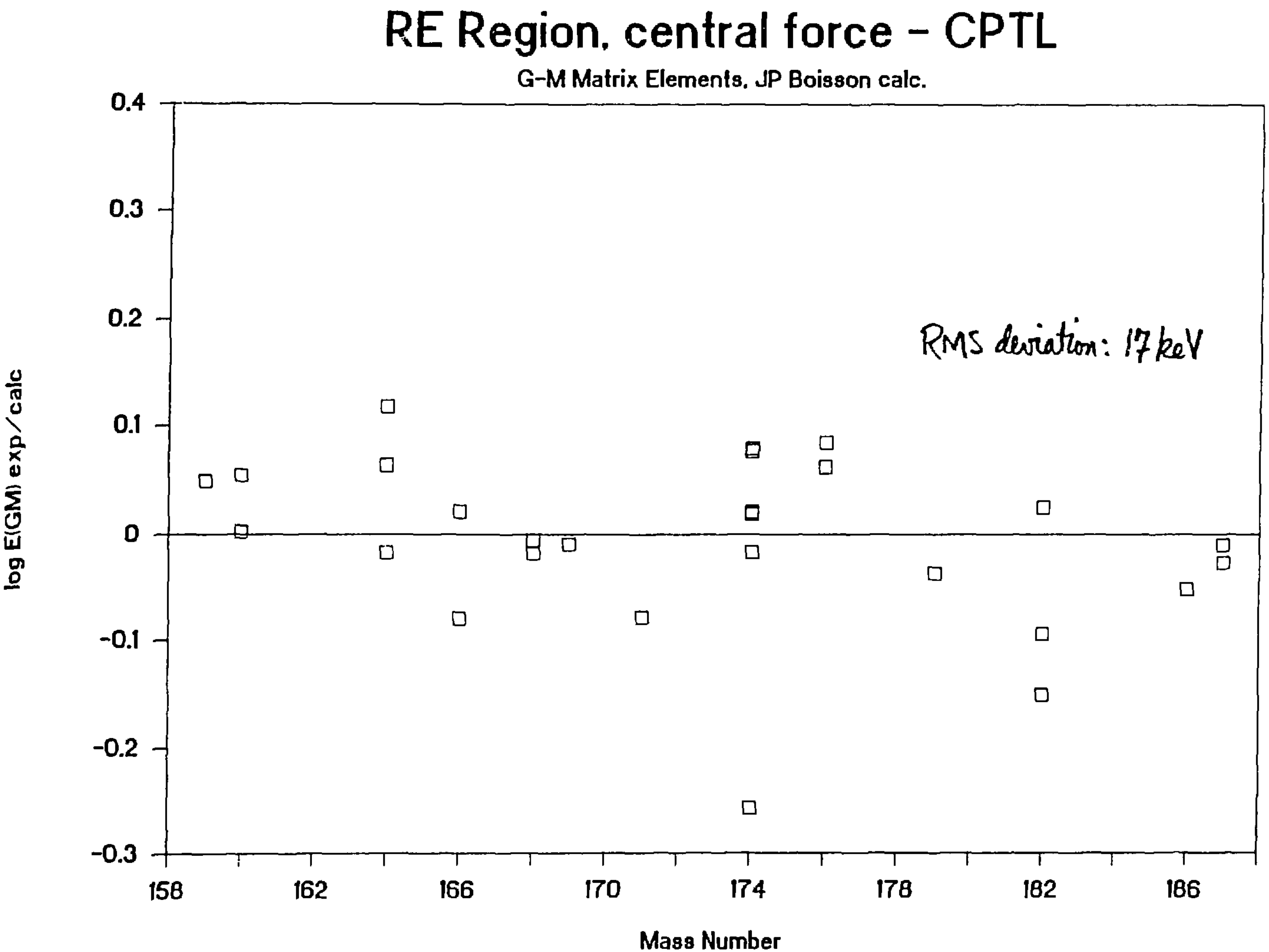
RE Region, central force - CPTL
G-M Matrix Elements, JP Boisson calc.
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
log E(GM) exp/calc
RMS deviation: 17 keV
158
162
166
170
174
178
182
186
Mass Number

Figure 2.

^{238}Np Bandhead Energies – Calculated and Experimental

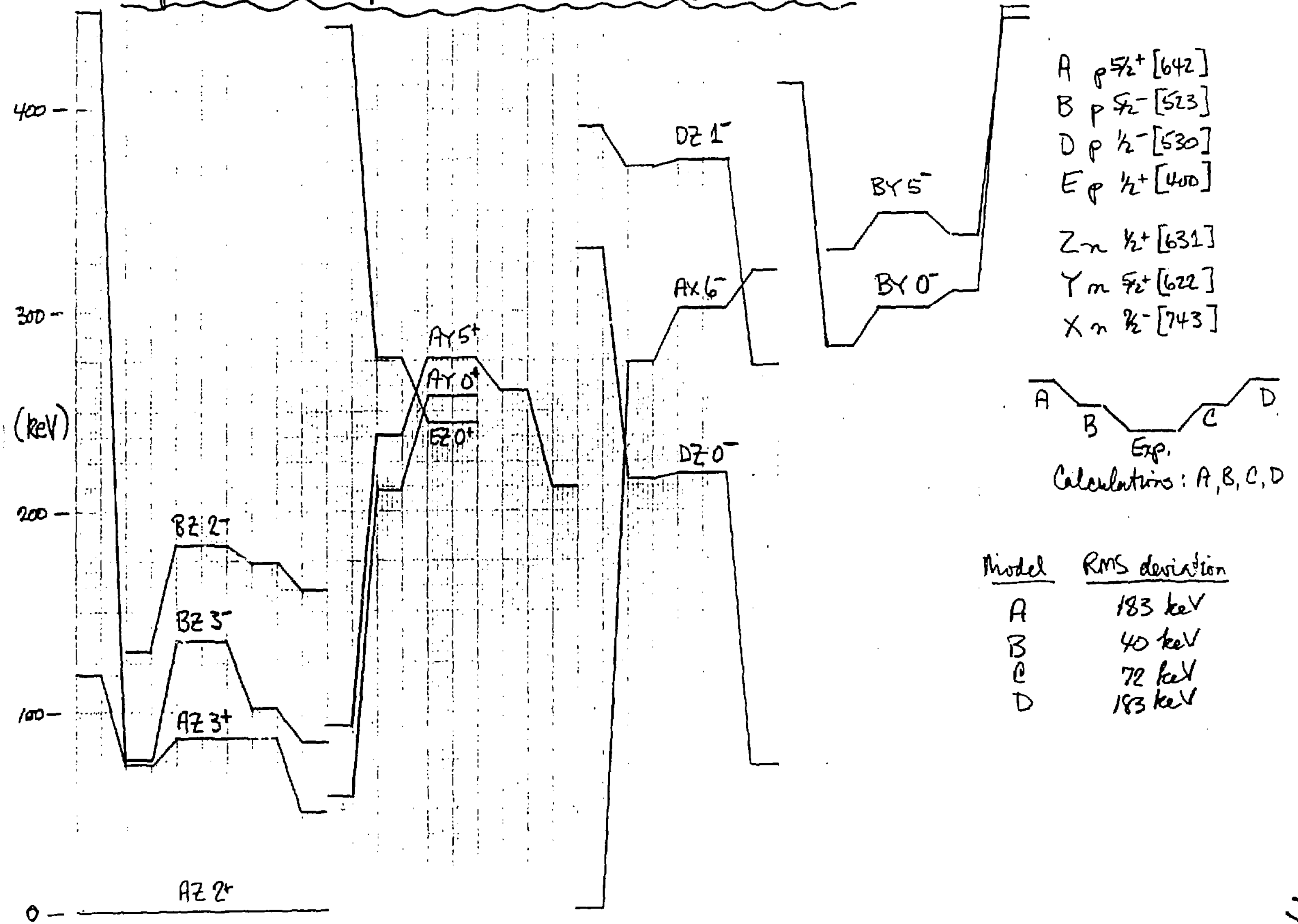

Figure 3.

Modeling Scheme for Odd-Odd Deformed Nuclei

EMPIRICAL DATA:
NEIGHBORING ODD-MASS NUCLEI

Single particle excitation energies	Incremental additions to moment of inertia

THEORETICAL CALCULATION:
P-n RESIDUAL INTERACTION

Gallagher-Moszkowski splitting (E_{GM}) Newby shift (E_N)

$$E_I = E^P_{\Omega} + E^N_{\Omega'} + \frac{\hbar^2}{2\mathcal{J}_{0\text{-}0}}\left[I(I+1) - K^2\right] \pm \frac{E_{GM}}{2} - \delta_{K,0}(-1)^{I} E_N$$

⇓

Modeled level structure of odd-odd nucleus

T. von Egidy, et al, Phys. Rev. C 29 (1984) 1243.