Breaking SU(3) spectral degeneracies in heavy deformed nuclei

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Dynamical symmetries in nuclear physics

- A Hamiltonian H of a nuclear model that commutes with every element x $([H, x] = 0)$ of a Lie Algebra g is said to have symmetry g (invariant under g).
- In this case H can be written as a function of Casimir operators $C(g), C(g'), C(g'')$ ... of a chain of subalgebras $g \supset g' \supset g''$ ... of g
- Since symmetry implies degeneracy,different irreducible representations of g classify different sets of eigenstates of the system

Proxy-SU(3)

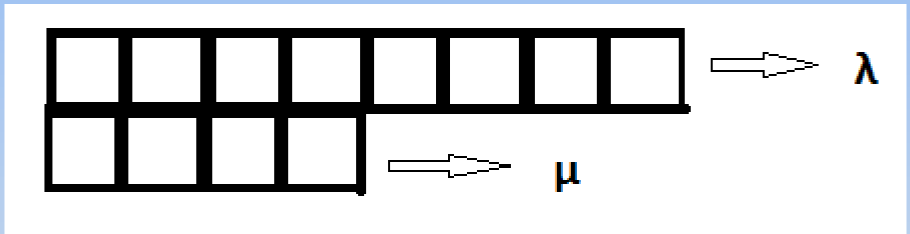
- It has been found that Nilsson orbitals that differ by $\Delta K[\Delta N\ \Delta n_z\ \Delta\Lambda] = 0[110]$ have large spatial overlaps
- Substitution of the intruder parity orbitals of each nuclear shell with their $0[110]$ partner orbitals from the next lower shell creates a shell which restores the symmetry of the harmonic oscillator i.e. SU(3)

50-82 p	50-82 p	sdg p	sdg p
3s1/2	1/2[400]	3s1/2	1/2[400]
2d3/2	1/2[411]	2d3/2	1/2[411]
	3/2[402]		3/2[402]
2d5/2	1/2[420]	2d5/2	1/2[420]
	3/2[411]		3/2[411]
	5/2[402]		5/2[402]
1g7/2	1/2[431]	1g7/2	1/2[431]
	3/2[422]		3/2[422]
	5/2[413]		5/2[413]
	7/2[404]		7/2[404]
1h11/2	1/2[550]	1g9/2	1/2[440]
	3/2[541]		3/2[431]
	5/2[532]		5/2[422]
	7/2[523]		7/2[413]
	9/2[514]		9/2[404]
	11/2[505]		

Nuclear shell	Harmonic oscillator shell	Symmetry
28-50	pf	U(10)
50-82	sdg	U(15)
82-126	pfh	U(21)
126-184	sdgi	U(28)

Irrep selection in the proxy-SU(3) scheme

- The eigenvalues of the Casimir operators are functions of the irreps that characterize the system
- The irreps of SU(3) are characterized by the pair (λ, μ) and can be expressed by the corresponding Young tableux



- In proxy-SU(3) the highest weight irrep is chosen because it gives the most symmetric configuration of the total wave function

Proxy-SU(3) Hamiltonian

Including only one body and two body terms leads to a Hamiltonian with eigenvalues

$$H = \alpha L^2 + \beta I_2$$

Eigenvalues of the invariant operators	$\langle L^2 \rangle = l(l+1)$
	$\langle I_2 \rangle = \frac{1}{9}(\lambda^2 + \mu^2 + 3\lambda + 3\mu + \lambda\mu)$

In this scheme bands belonging to the same irrep are degenarate

- Casimir invariants do not break the degeneracy within an irrep
- O(3) scalars break the degeneracy

Bosonic models

- Ground state stands alone
- γ_1 and β_1 bands are in the next irrep

Fermionic models

- Ground state band, γ_1 band and first $K = 4$ band are in the first irrep
- β_1, γ_2 and second $K = 4$ band are in the next irrep

Including up to three body terms leads to a Hamiltonian

$$H = \alpha L^2 + \beta I_2 + \Gamma\omega$$

where $\Omega = \mathrm{LQL}$

Omega operator matrix elements

$$\Omega_{KK} = \sqrt{6}(2\lambda + \mu + 3)[l(l+1) - 3K^2],$$

$$\Omega_{K\pm 2K} = -3[3(\mu \mp K)(\mu \pm K + 2)(l \pm K + 2) \times (l \pm K + 1)(l \mp K)(l \mp K - 1)/2]^{1/2}.$$

Including up to four body terms leads to a Hamiltonian

$$H = \alpha L^2 + \beta I_2 + \delta\Lambda$$

where $\Lambda = \mathrm{LQQL}$

Lambda operator matrix elements

$$\begin{aligned}
\Lambda_{KK} &= 2(2\lambda + \mu + 3)^2[l(l+1) - 3K^2] \\
&\quad - 18K^4 + 6K^2[5l(l+1) - 3] \\
&\quad - 12l^2(l+1)^2 - 72l(l+1) \\
&\quad - 3(\mu - K)(\mu + K + 2)[l(l+1) - 3K^2] \\
&\quad - 3(\mu + K)(\mu - K + 2)[l(l+1) - 3K^2], \\
\Lambda_{K\pm 2K} &= 6[(\mu \mp K)(\mu \pm K + 2)(l \pm K + 2)(l \pm K + 1) \\
&\quad \times (l \mp K)(l \mp K - 1)]^{1/2}(2\lambda + \mu \mp 3K)
\end{aligned}$$

Parameter independent quantities in proxy-SU(3)

Splitting of the ground state and γ_1 bands

$$\frac{E\left(L_\gamma\right)-E\left(L_g\right)}{E\left(2_\gamma\right)-E\left(2_g\right)}$$

Splitting of the ground state and $K=4$ bands

$$\frac{E\left(L_{\mathrm{K}}\right)-E\left(L_g\right)}{E\left(4_{\mathrm{K}}\right)-E\left(4_g\right)}$$

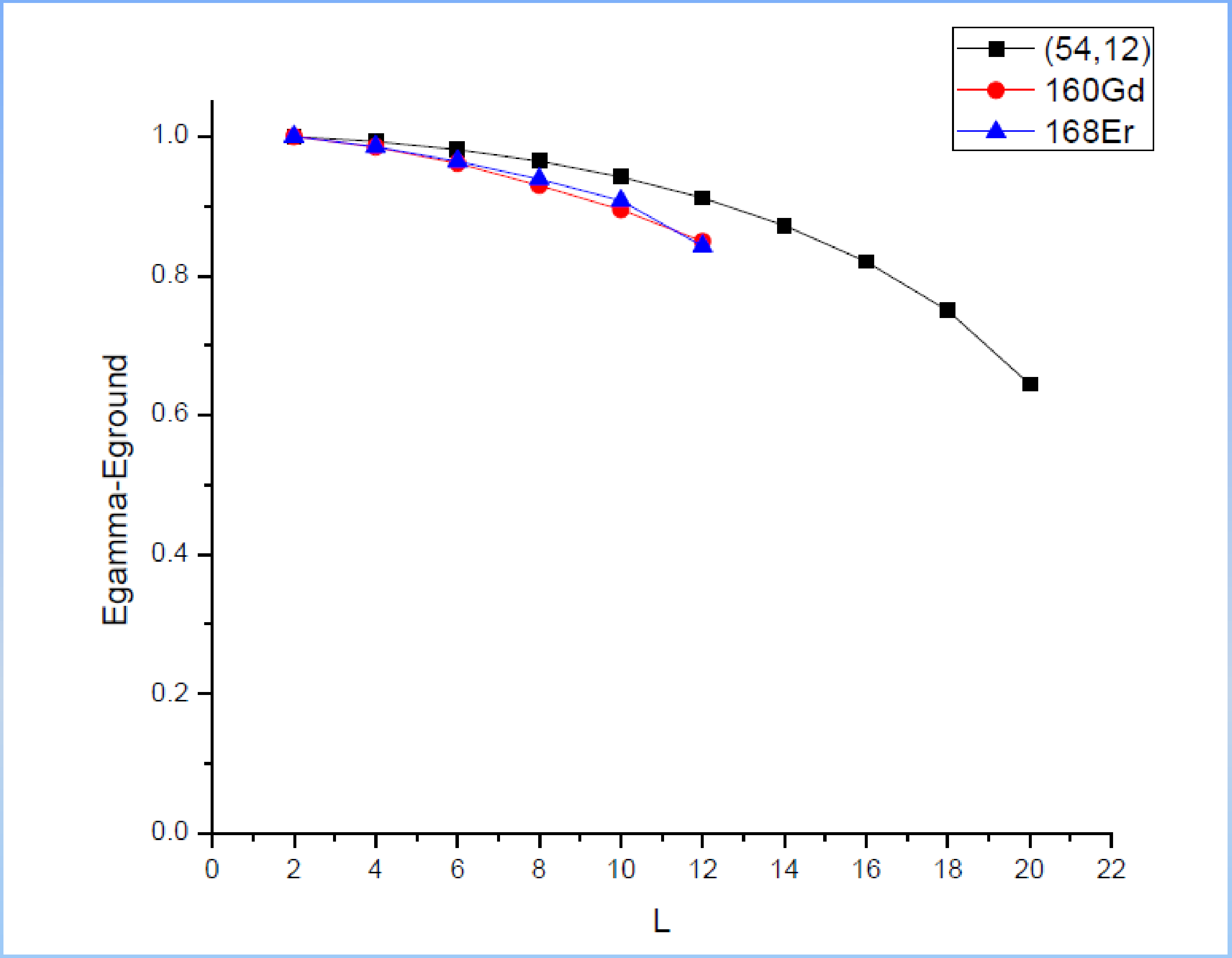
Higher 0^+ bandheads

$$\frac{E\left(0_n\right)-E\left(0_1\right)}{E\left(0_2\right)-E\left(0_1\right)}$$

Odd even staggering within γ bands

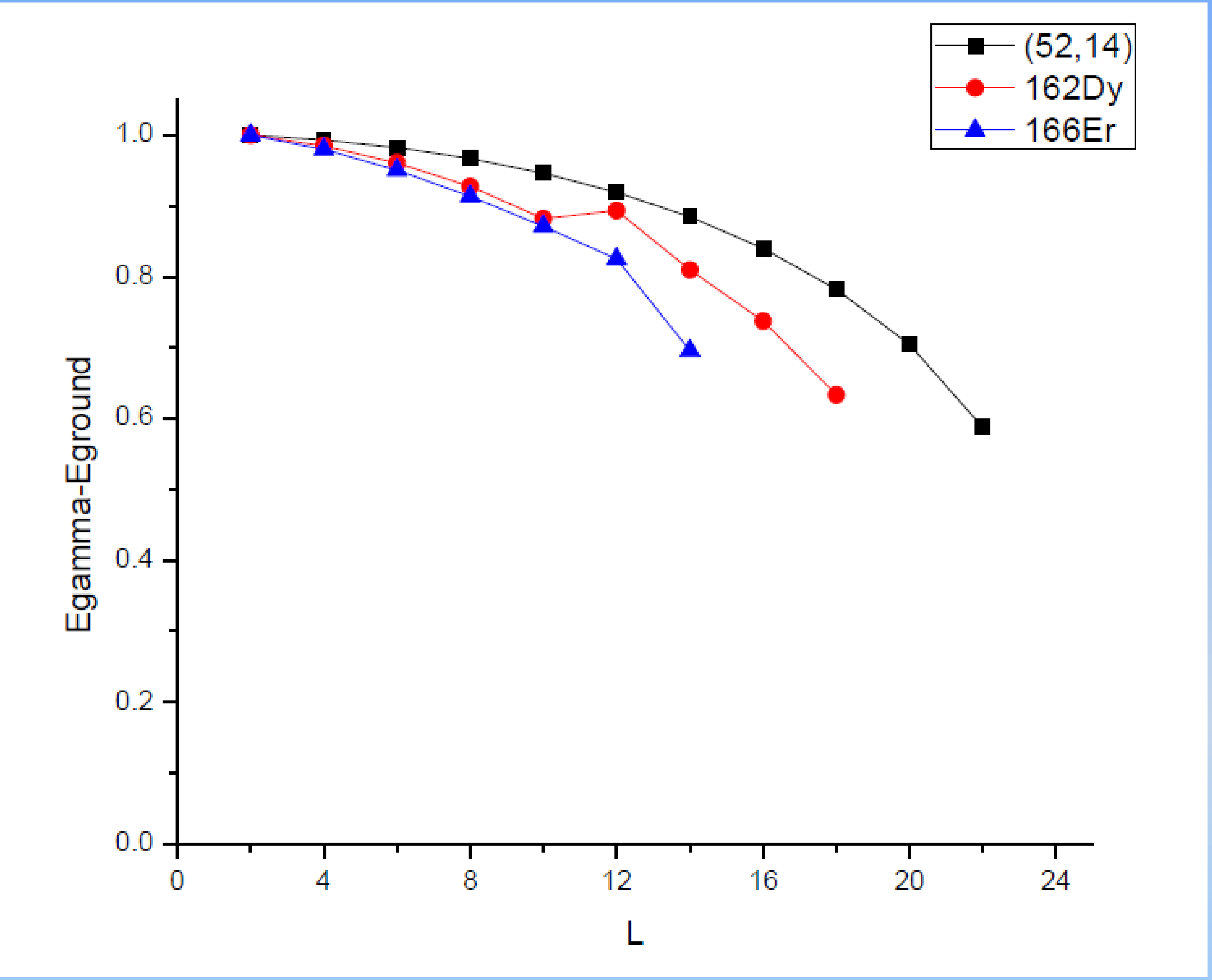
$$\frac{\Delta E(L)}{\Delta \mathrm{E}(3)}$$

Splitting of the ground state and γ_1 bands



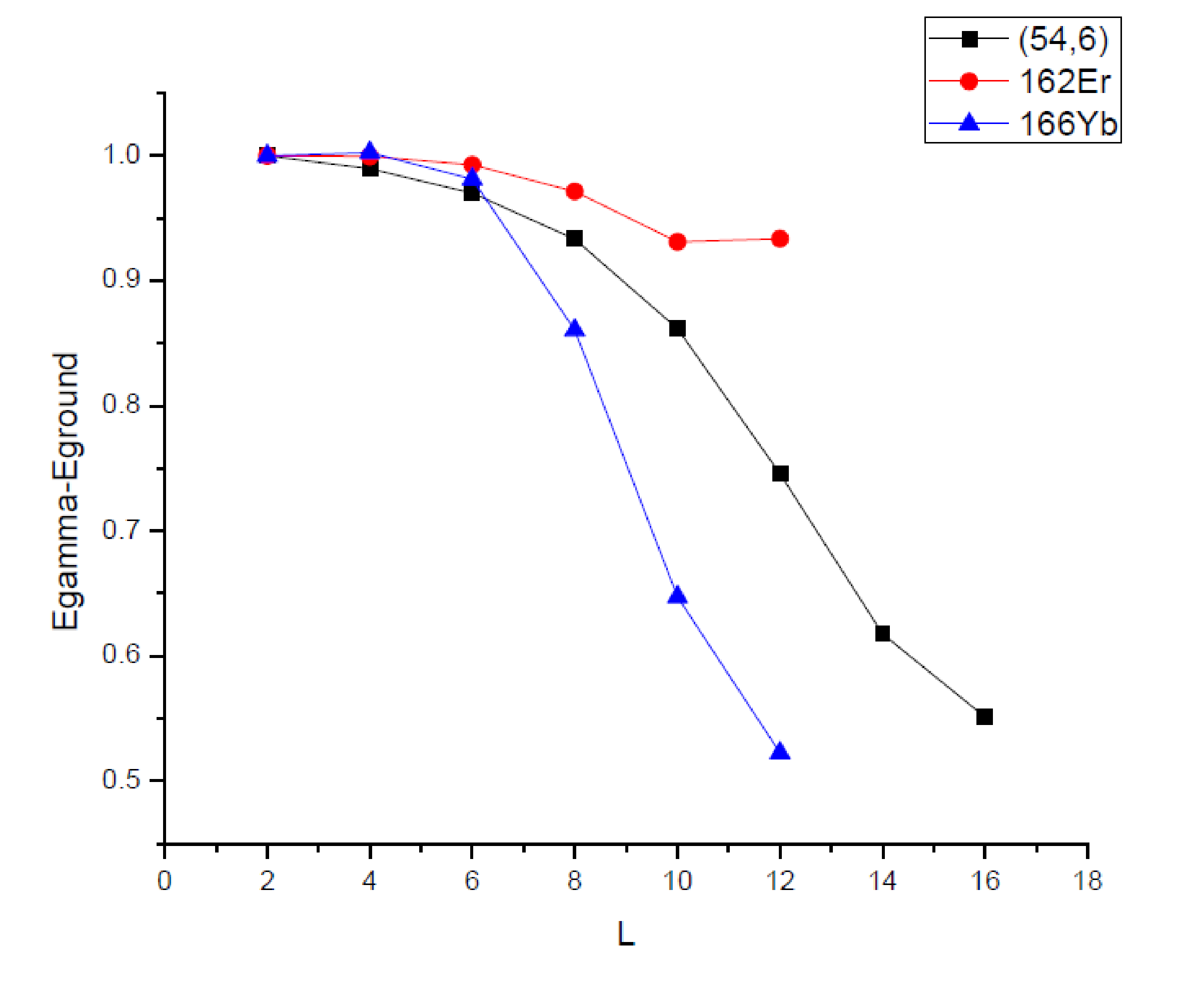
The ground state and γ_1 bands of both ^{160}Gd and ^{168}Er are characterized by the $(54,12)$ irrep in proxy-SU(3).

Splitting of the ground state and γ_1 bands



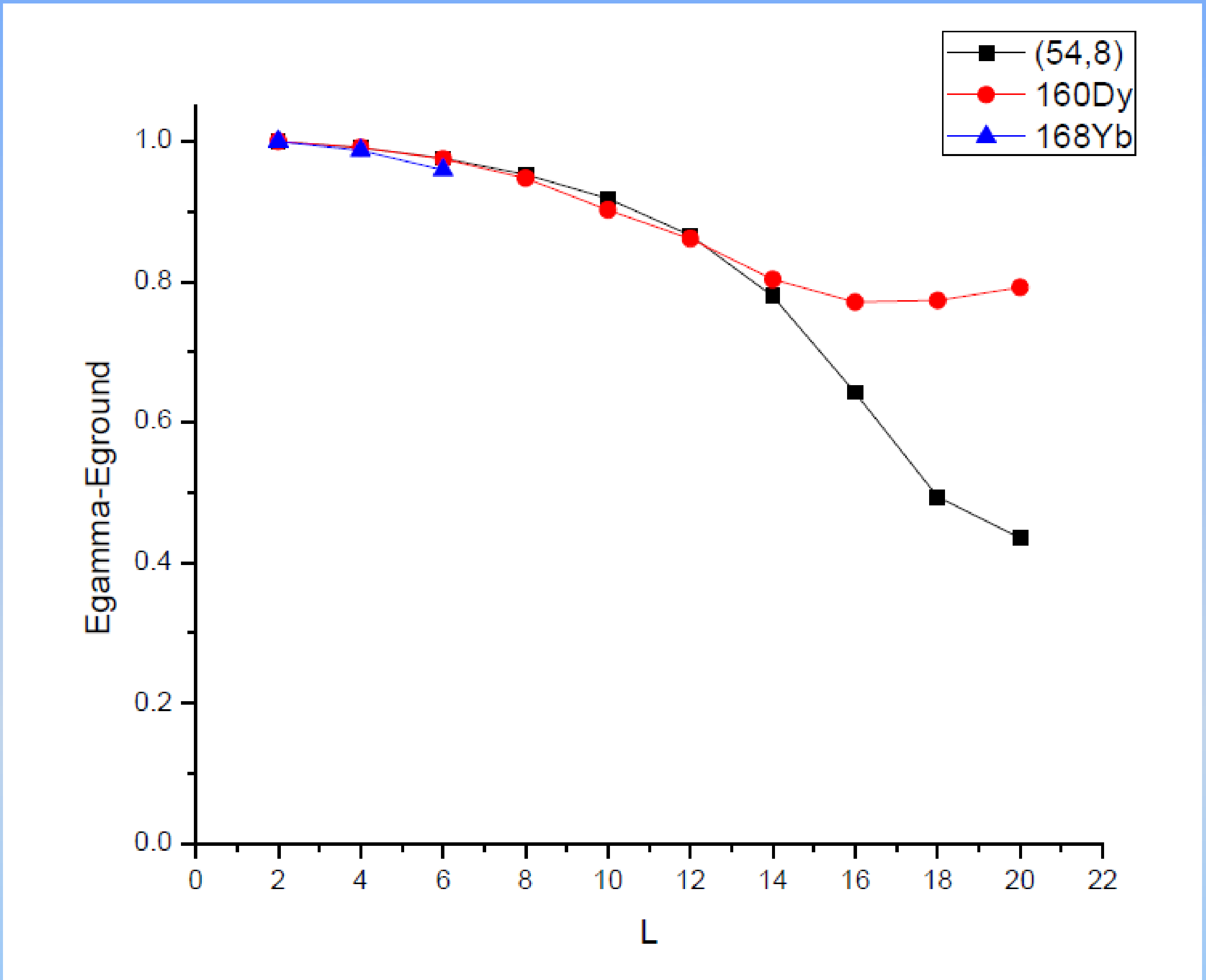
The ground state and γ_1 band of both ^{162}Dy and ^{166}Er are characterized by the $(52,14)$ irrep in proxy-SU(3).

Splitting of the ground state and γ_1 bands



The ground state and γ_1 band of both ^{162}Er and ^{166}Yb are characterized by the $(54,6)$ irrep in proxy-SU(3).

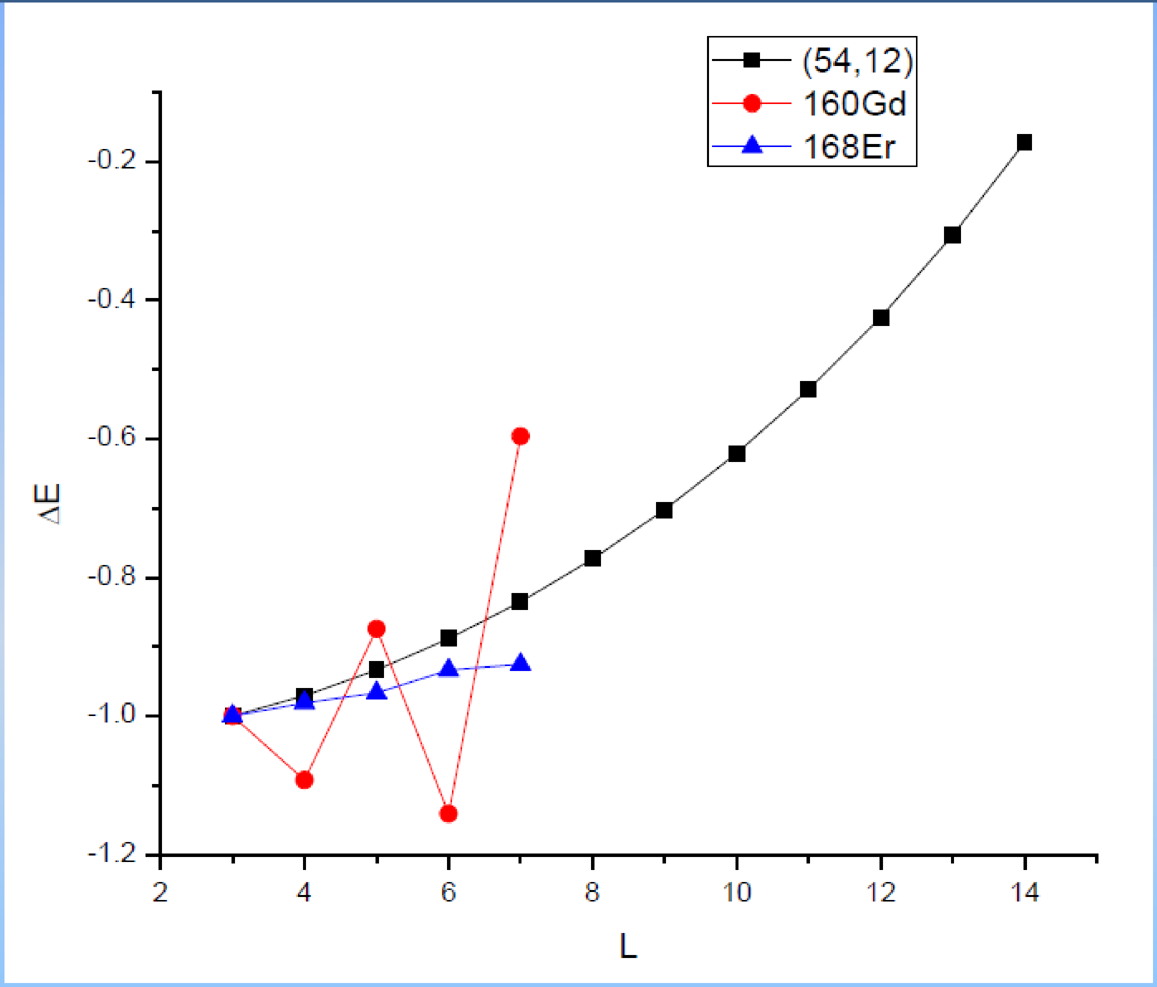
Splitting of the ground state and γ_1 bands



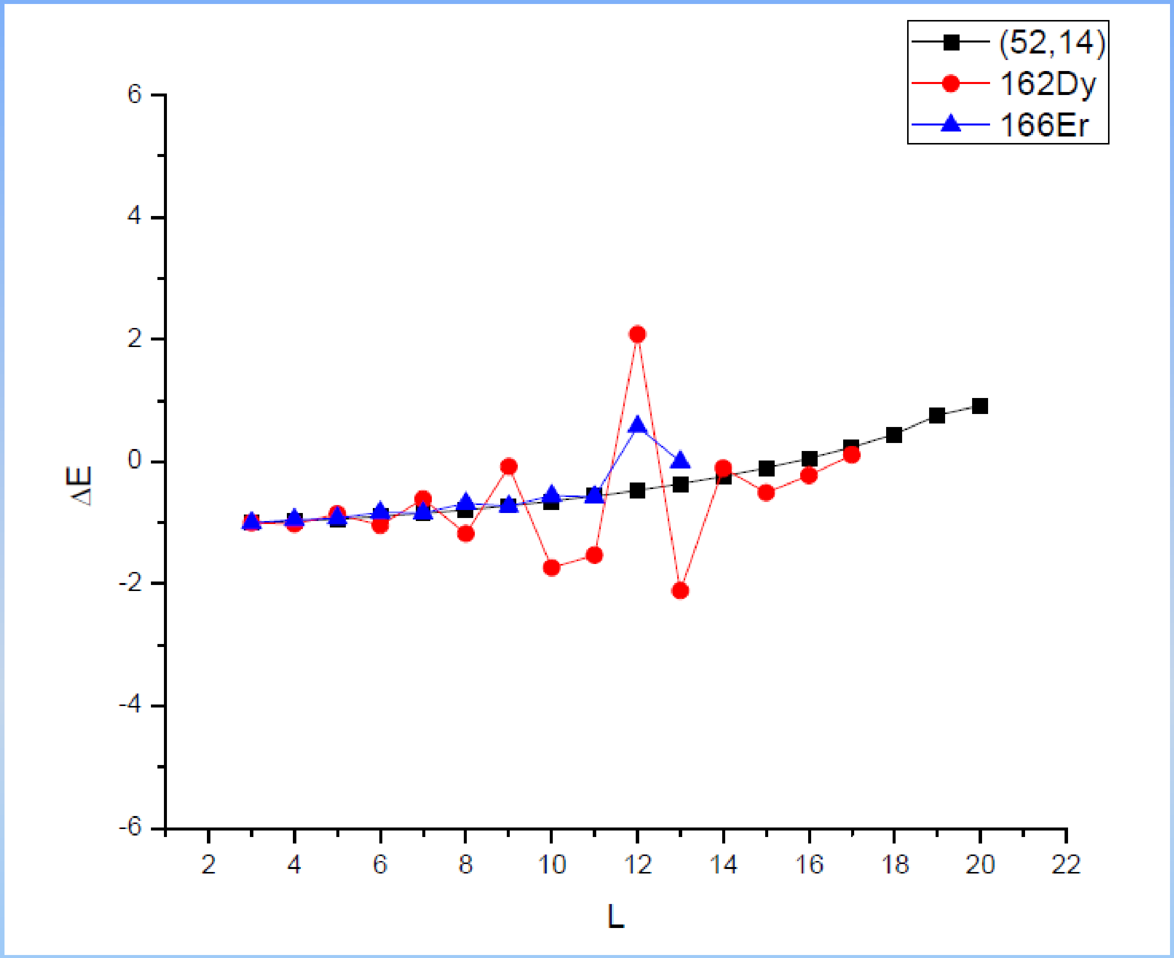
The ground state and γ_1 band of both ^{160}Dy and ^{168}Yb are characterized by the $(54,8)$ irrep in proxy-SU(3).

Odd even staggering within γ bands

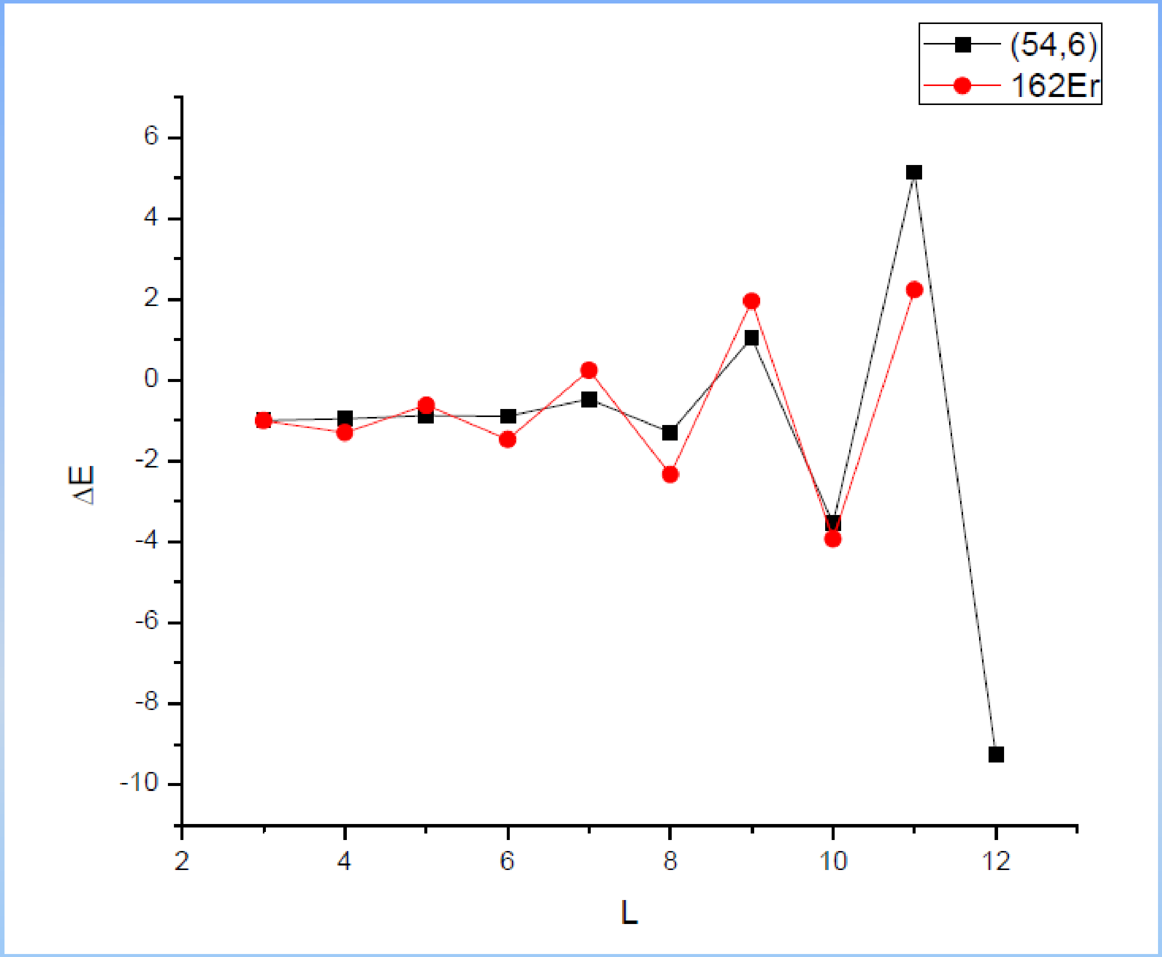
$$\frac{\Delta E(L)}{\Delta \mathrm{E}(3)}\ \mathrm{where}\Delta(\mathrm{L}) = \mathrm{E}(\mathrm{L}) - \frac{(L+1)E(L-1)+LE(L+1)}{2L+1}$$



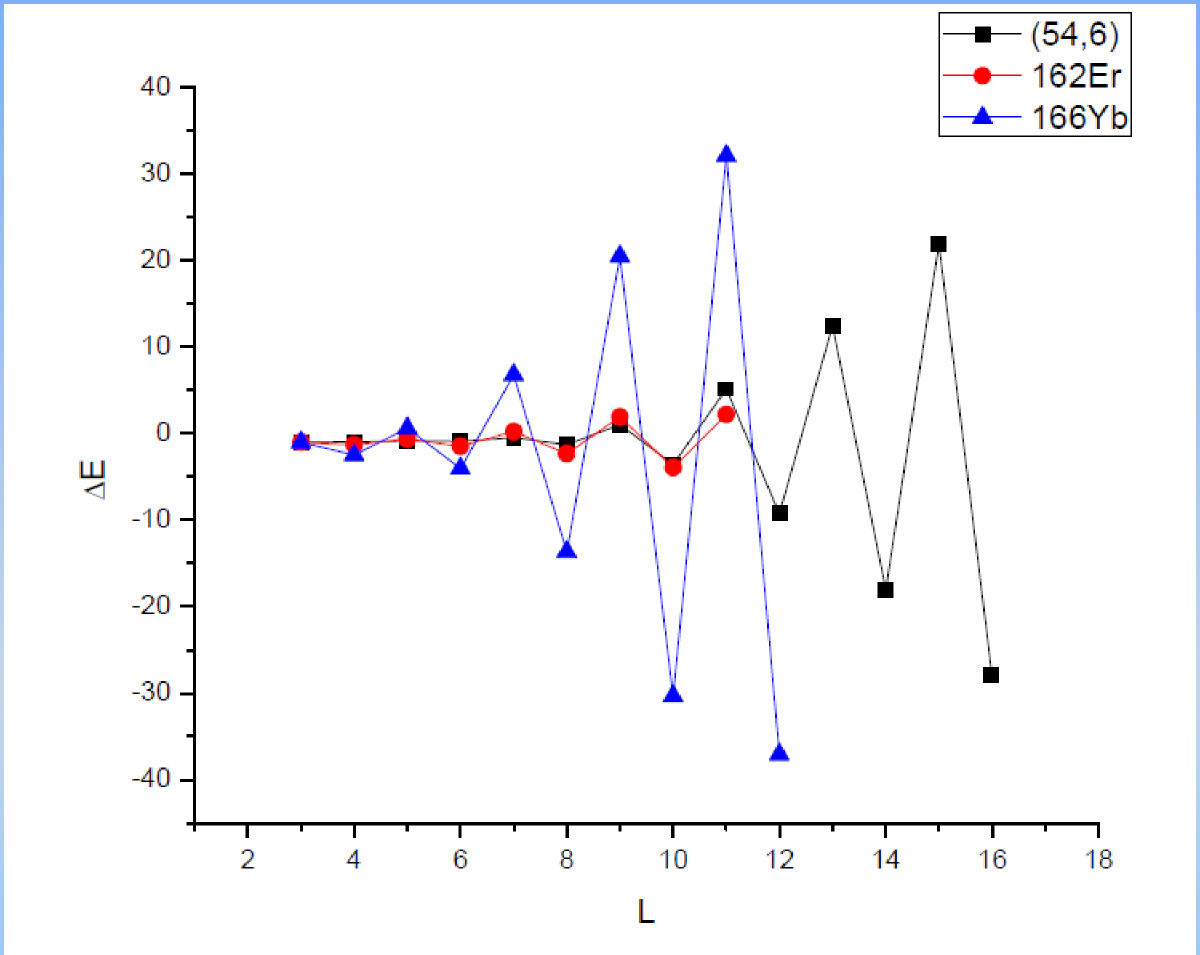
Odd even staggering within γ bands



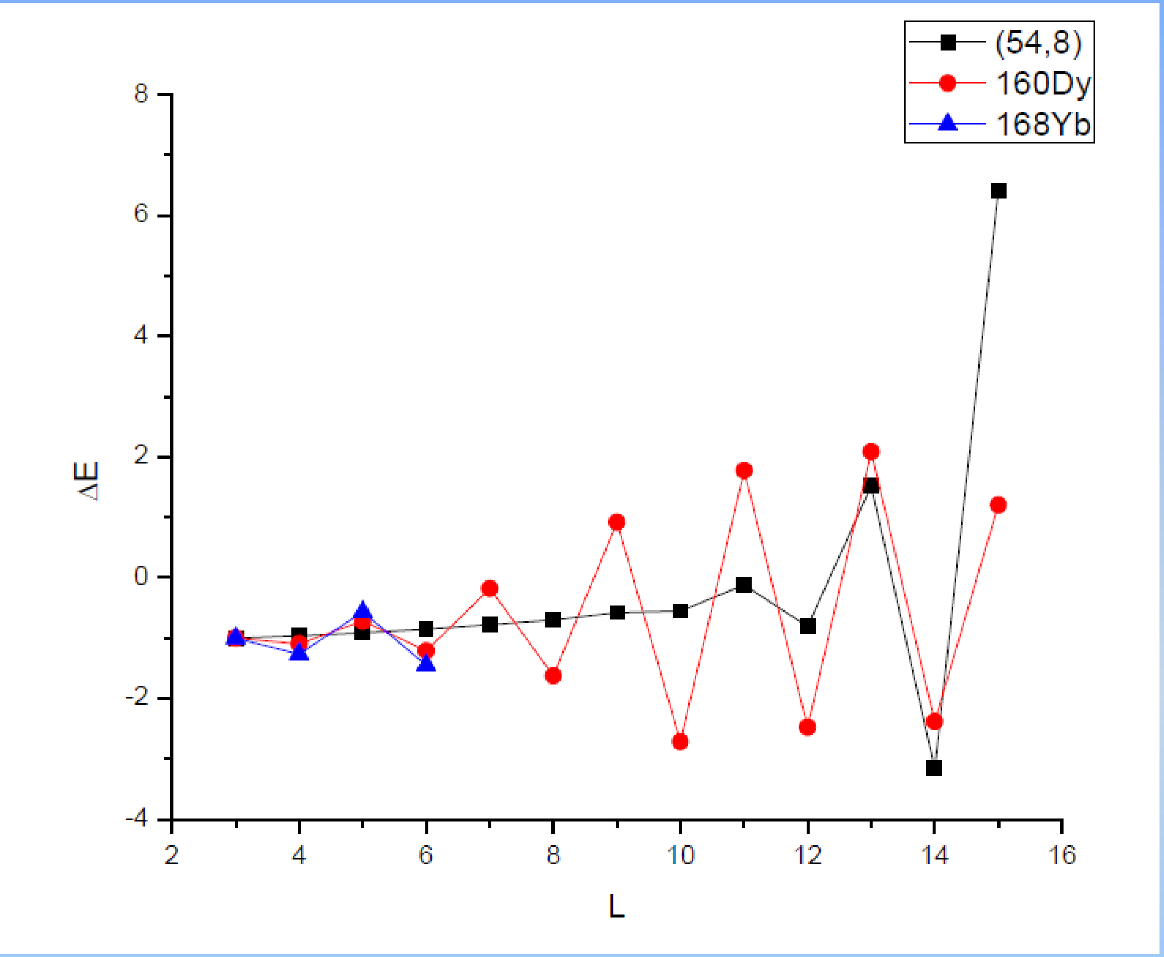
Odd even staggering within γ bands



Odd even staggering within γ bands



Odd even staggering within γ bands



Thank you for your time!!