Search for tetrahedral states and X(5) symmetry in Yb nuclei with N~90 through Coulomb excitation using HIE-ISOLDE and Miniball

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- Strasbourg, France
- Darmstadt, Germany
- Köln, Germany
- Athens, Greece
- Kolkata, India

ISOLDE RILIS Yields of Yb nuclei

6. Ytterbium

Yb was the first element tested off- and on-line at the ISOLDE RILIS [1]. Neutron-deficient Yb isotopes down to ^{153}Yb were ionized and used for in-source atomic spectroscopy with the RILIS of the IRIS facility in Gatchina [24]. Here we report the yields obtained at ISOLDE with a standard Ta foil target and W ionizer. [5] With the RILIS the Yb yields were enhanced by a factor of about 20 against surface ionization. The now measured on-line efficiency was probably below the off-line measured 15% [1]. Note that the W ionizer is

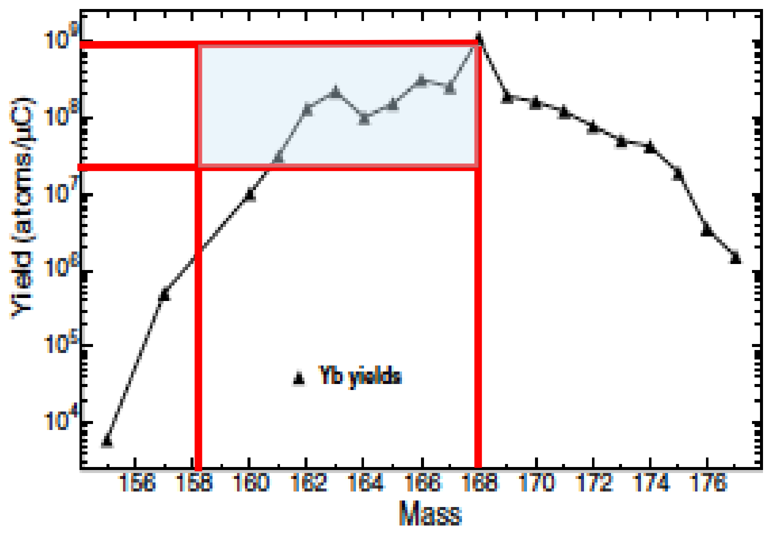
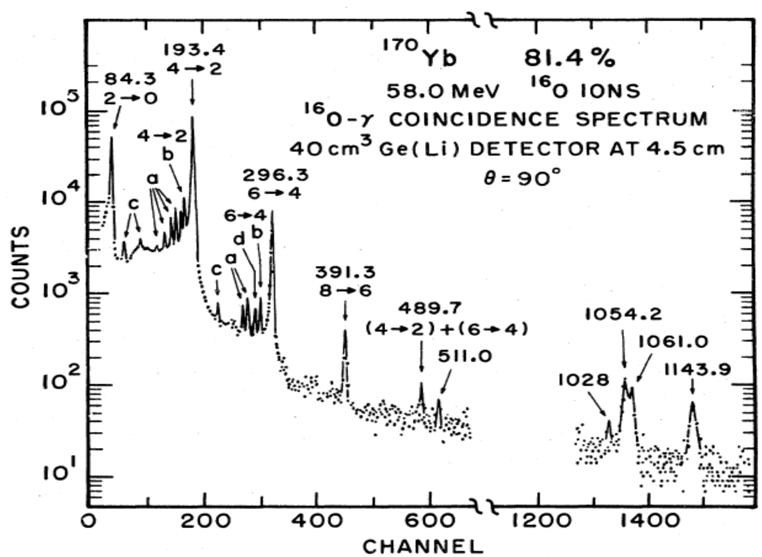
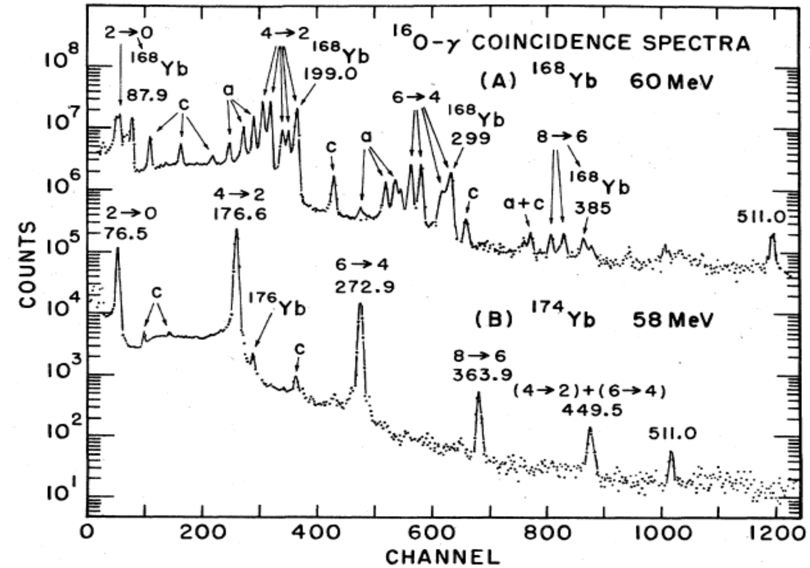


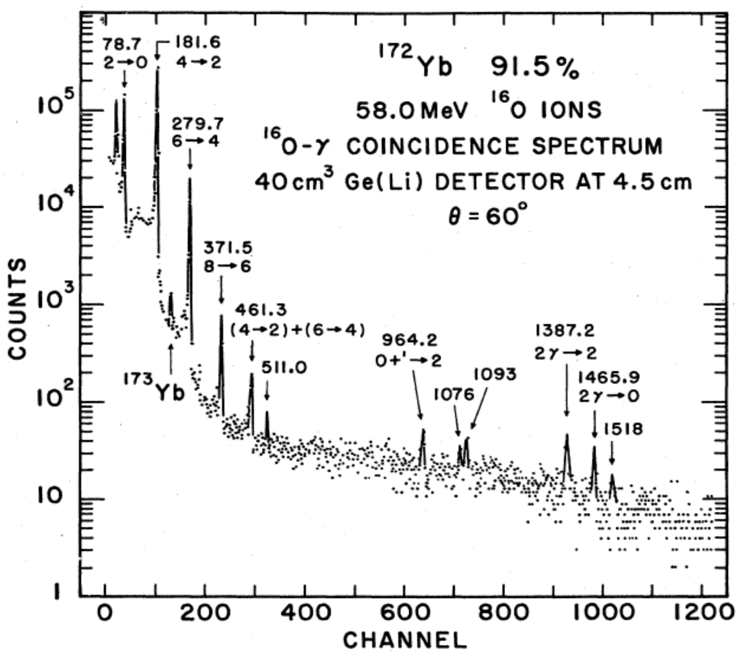
Fig. 3. Ion yields of ytterbium isotopes from a Ta foil target.

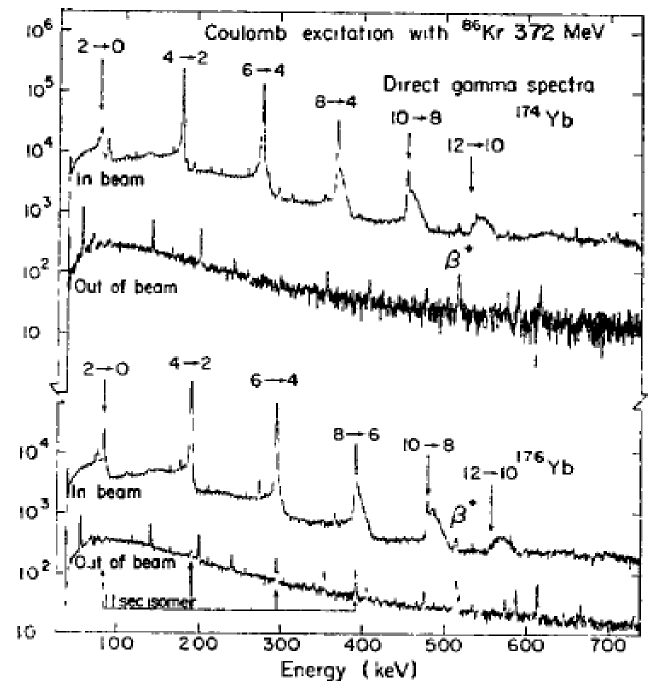
Coulex of stable ^{168}Yb - ^{176}Yb

L. L. RIEDINGER *et al.*









Octahedral and thetrahedral shapes

$$\mathcal{R}(\vartheta,\varphi;\hat{\alpha}) = R_0\, c(\hat{\alpha}) \left[1 + \sum_{\lambda=2}^{\lambda_{\max}} \sum_{\mu=-\lambda}^{\lambda} \alpha_{\lambda,\mu}\, Y_{\lambda,\mu}(\vartheta,\varphi)\right]$$

$$\hat{\alpha} \equiv \{\alpha_{\lambda,\mu};\ \lambda = 2, 3,\ \ldots \lambda_{\max};\ \mu = -\lambda,\ -\lambda+1, \ldots\ +\lambda\}$$

$\alpha_{40} \equiv +o_1;\quad \alpha_{4,\pm4} \equiv +\sqrt{\frac{5}{14}}\, o_1\qquad \alpha_{60} \equiv +o_2;\quad \alpha_{6,\pm4} \equiv -\sqrt{\frac{7}{2}}\, o_2$

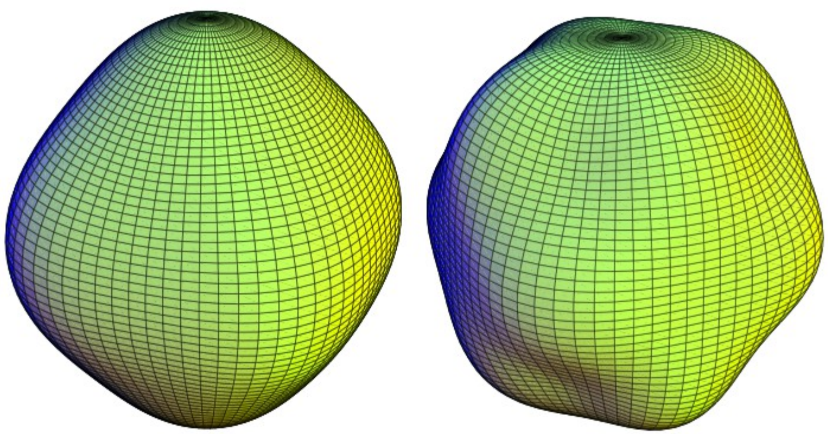


Fig. 1. Comparison of two octahedrally deformed nuclei. Left: octahedral deformation of the first order, $o_1 = 0.10$; right: octahedral deformation of the second order, $o_2 = 0.04$.

$\alpha_{3,\pm2} \equiv t_1\qquad \alpha_{7,\pm2} \equiv t_2\,;\quad \alpha_{7,\pm6} \equiv -\sqrt{\frac{11}{13}}\, t_2$

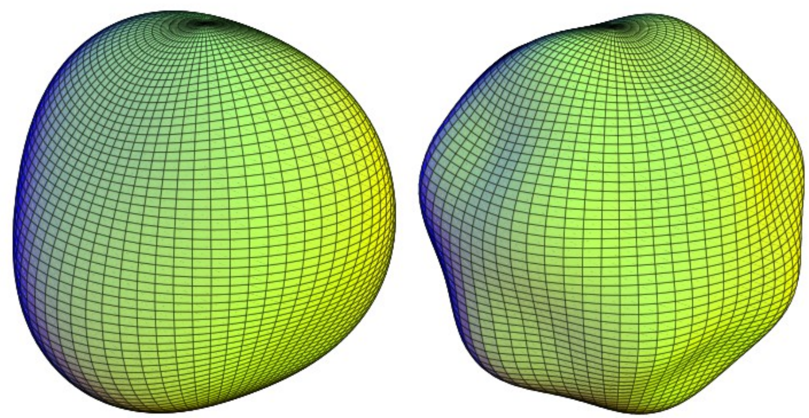
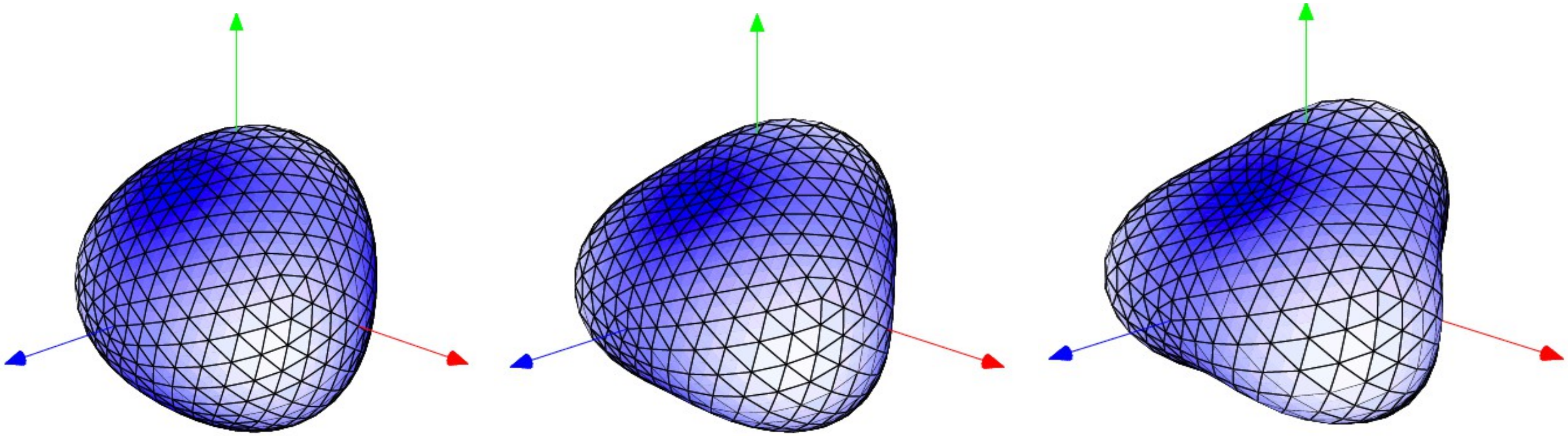


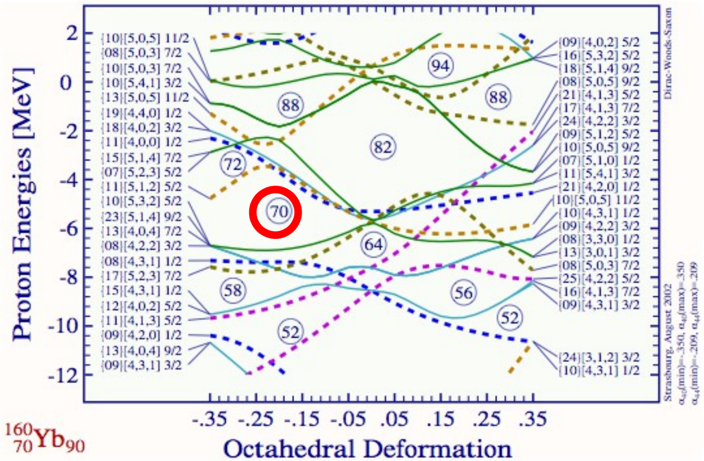
Fig. 2. Comparison of two tetrahedrally deformed nuclei. Left: tetrahedral deformation of the first order, $t_1 = 0.15$; right: tetrahedral deformation of the second order, $t_2 = 0.05$.

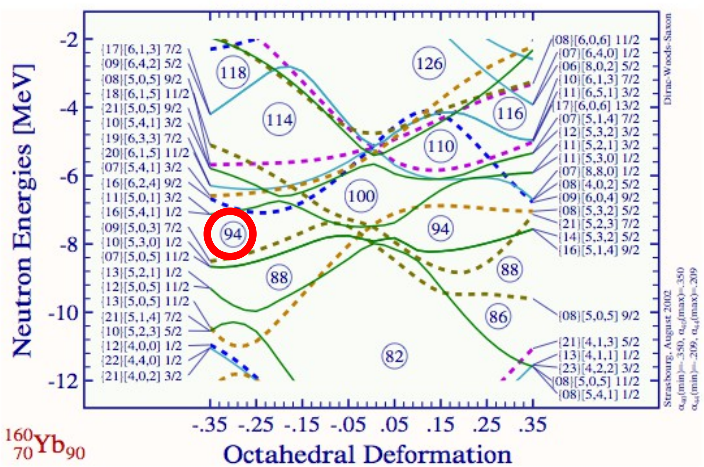
Tetrahedral symmetric surfaces at increasing values of rank λ deformations α_{32} = 0.1, 0.2, 0.3



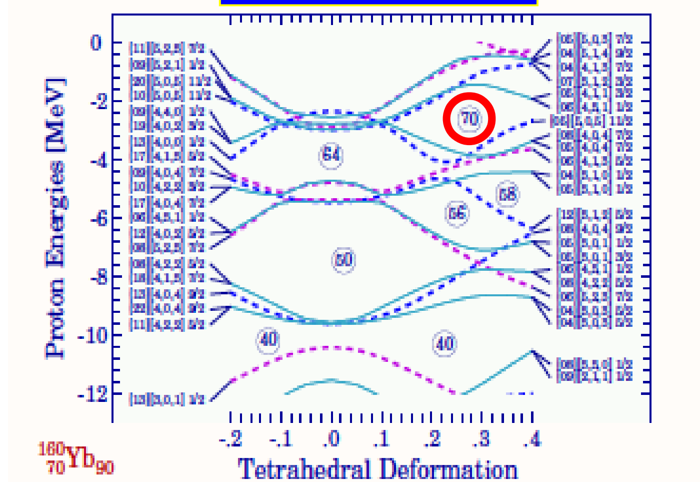
Octahedral and thetrahedral spectra

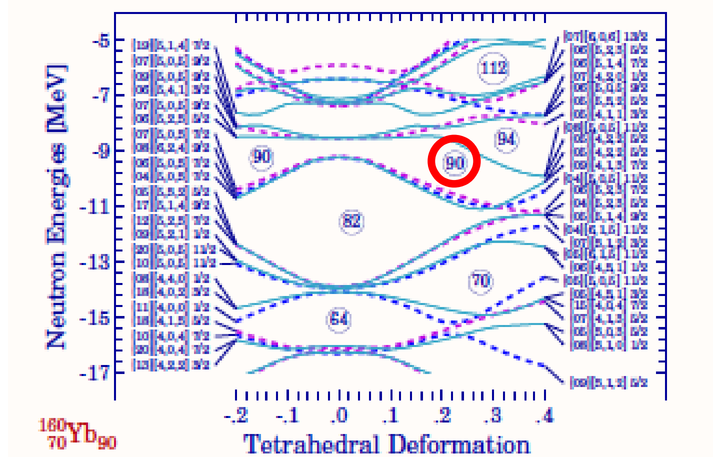
Octahedral





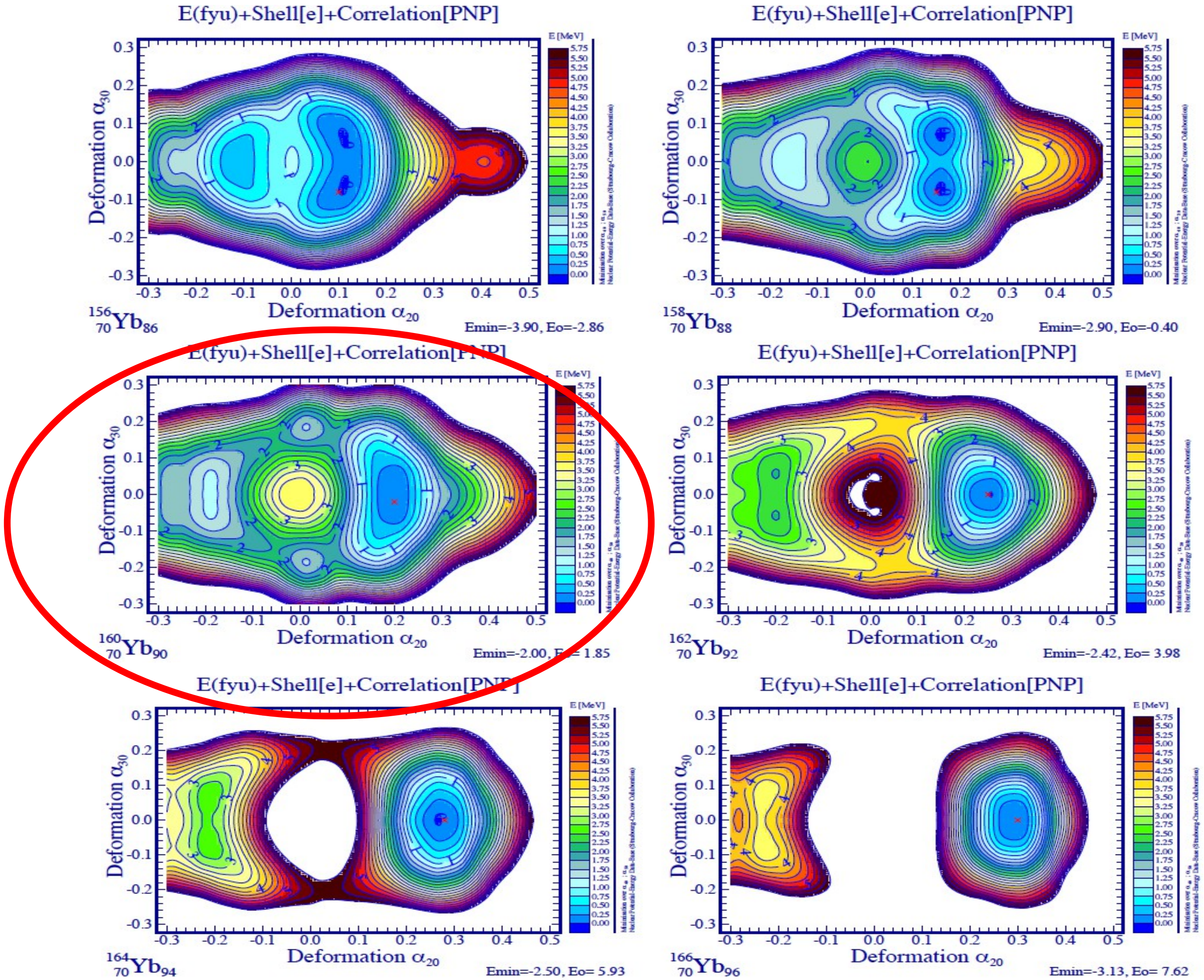
Tetrahedral





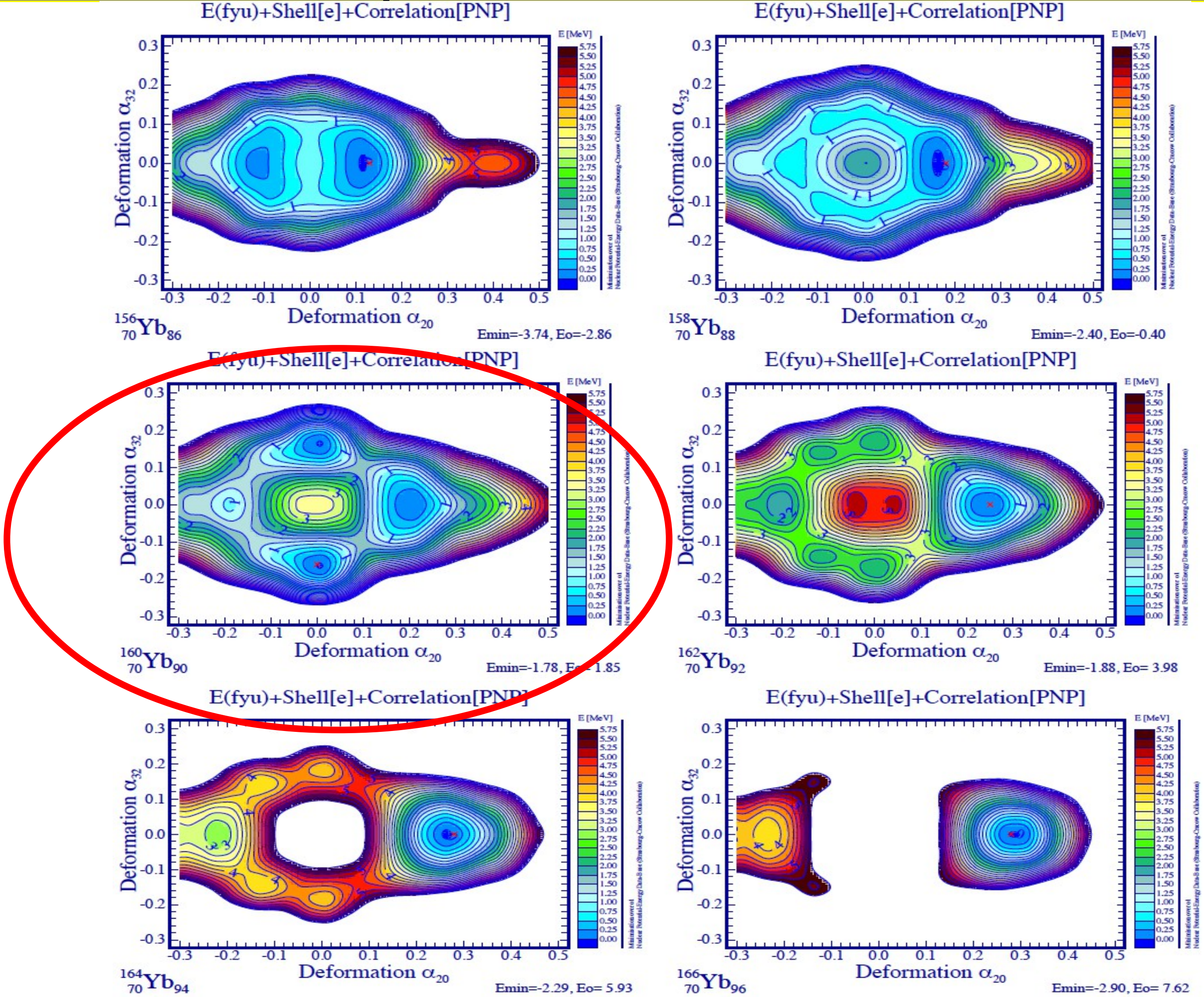
4-fold degeneracies => new large (magic) gaps

Disapperarance of the α_{30} pear-shape octupole effects in the Yb isotopes



J. Dudek

Tetrahedral symmetry competition (the effect of α_{32}) and octupole effects in the Yb isotopes



J. Dudek

Desexcitation patterns

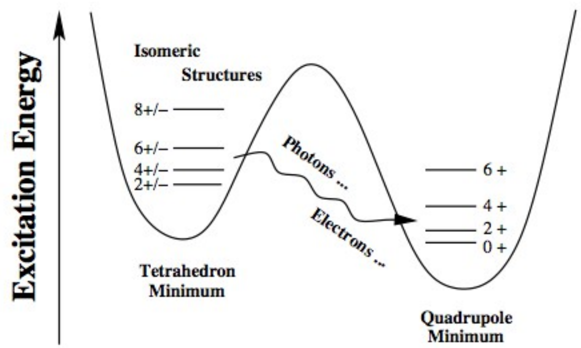
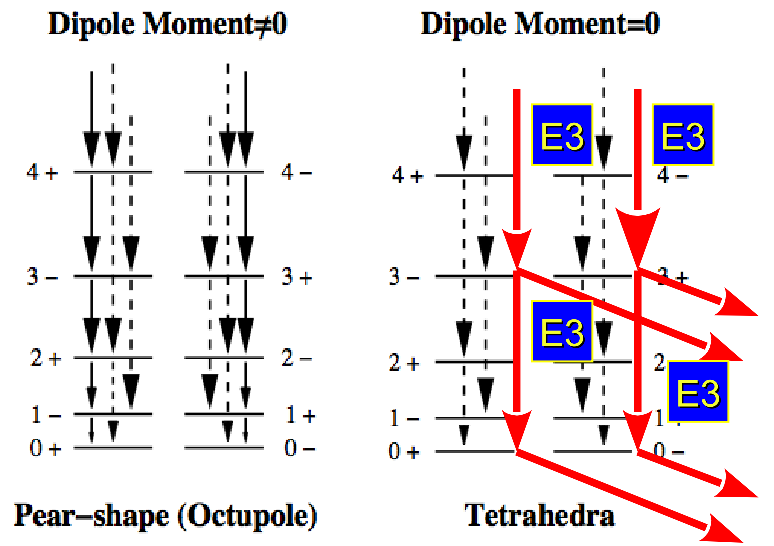
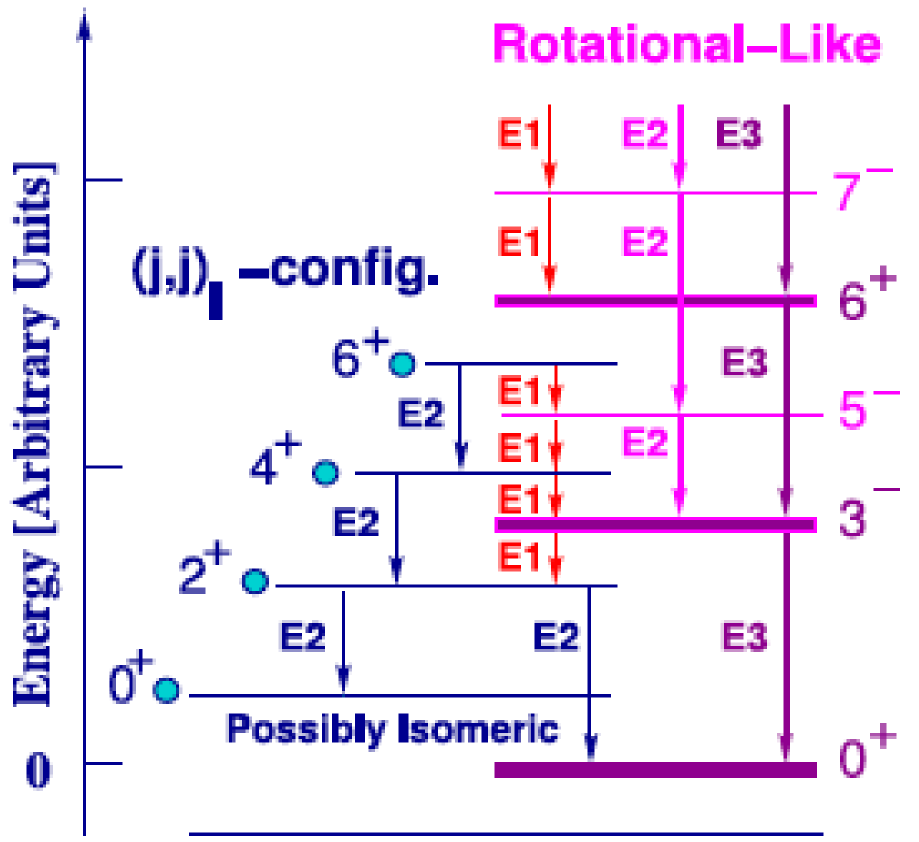


Fig. 7. Schematic illustration: structure and possibilities of the decay out of a tetrahedral minimum. Since the lowest-order tetrahedral deformation has the same geometrical features as the octupole deformation α_{32}, the concerned nuclei may generate parity-doublet rotational bands known from the studies of the octupole shapes. Establishing the structure of the bands (parity doublets?), the nature of the inter- and intra-band transitions (dipole? quadrupole? octupole?), the properties of the side-feeding and the decay branching ratios all that will greatly help identifying the symmetry through experiments.



Desexcitation patterns



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Nonzero Quadrupole Moments of Candidate Tetrahedral Bands

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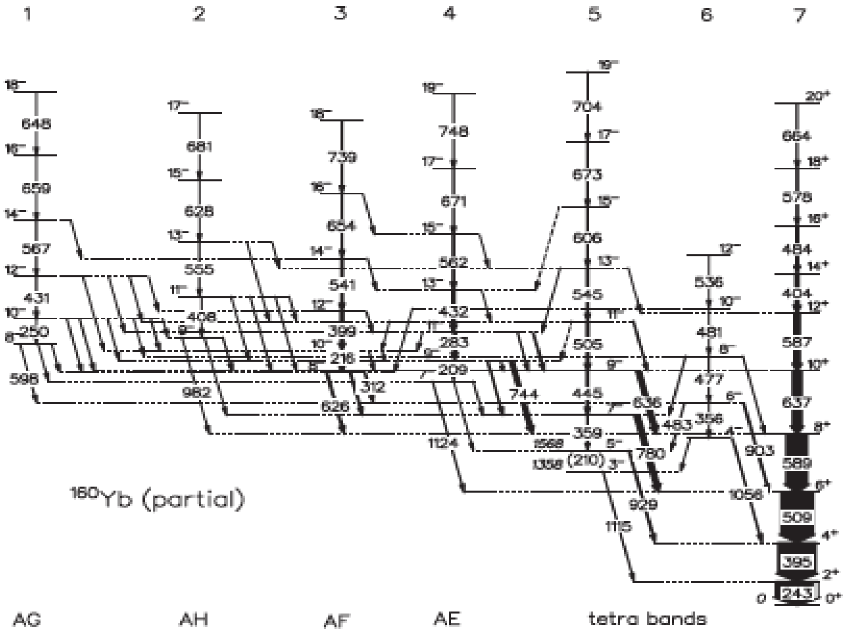
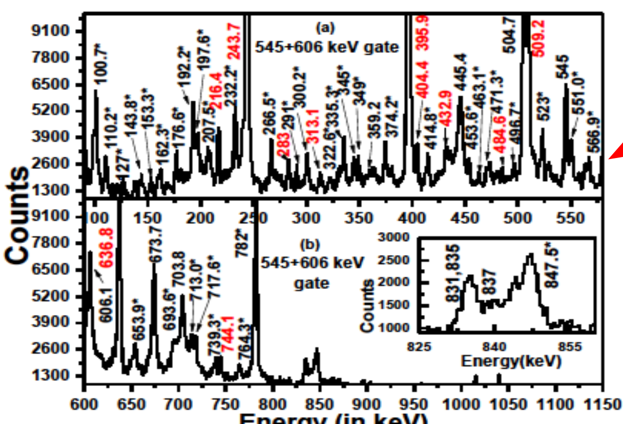
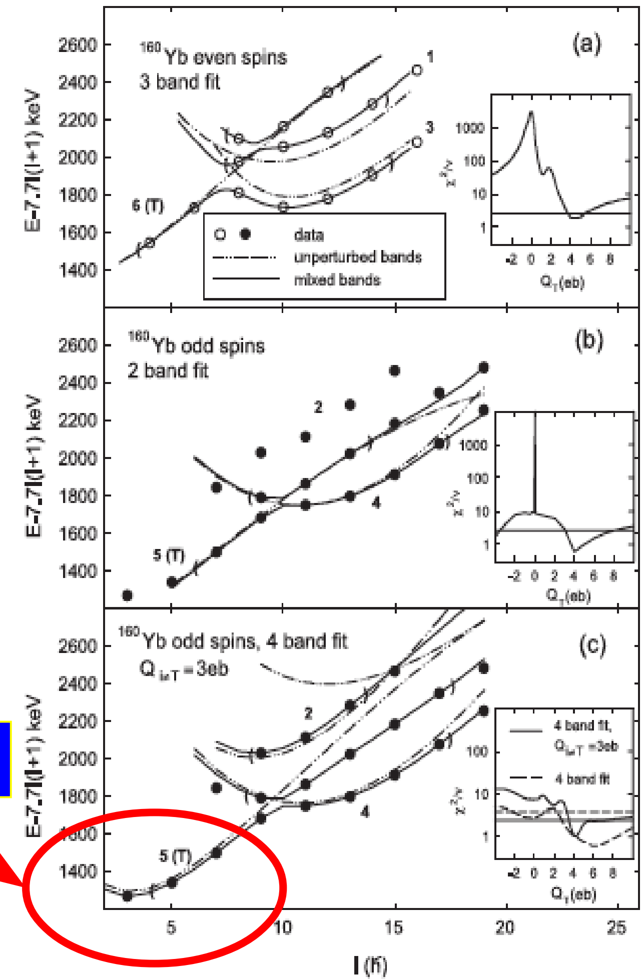




Fusion

Coulex



The ^{160}Yb case

- The ^{160}Yb nucleus (Z=70 and N=90) is double-magic with respect to the predicted tetrahedral symmetry.
- The properties of the low-spin states, crucial to establish the symmetry, are not yet well known.
- The spin and parity assignments to a low-lying 1255 keV state are contradicting: 3^- or 4^+ ?
- The identification of the first 3^-, 5^-, 6^+, 7^- states and their decay in-band and towards the ground-state band or other unobserved bands is crucial for the discovery of the tetrahedral bands.

The ^{160}Yb case

- To check if the populated negative-parity states are members of the tetrahedral band, one should measure with good accuracy the de-excitation transition probabilities B(E3)↓, B(E2)↓ and B(E1)↓ knowing that the B(E2)/B(E1) branching ratios corresponding to the in-band to out-of-band are predicted 1÷2 orders of magnitude smaller than in the standard octupole states.

Critical point X(5) symmetry in N~90 nuclei

- The nuclei with N~90 (^{160}Yb, ^{162}Yb, ^{164}Yb) are the candidates in which the critical point symmetry X(5) is expected to be best realized.

- The branching ratios of transitions from non-yrast states will constitute a more stringent test of the model predictions.

Shape phase diagram in IBM

Level scheme in X(5)

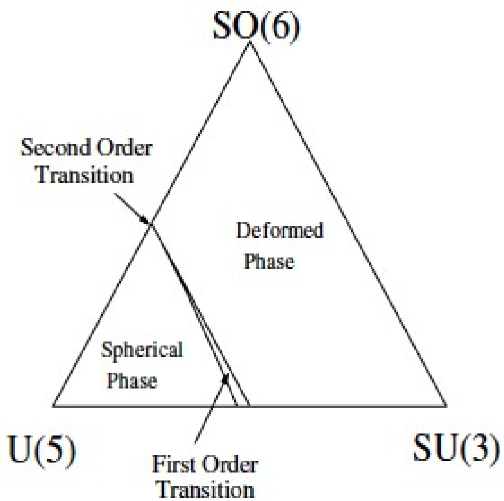


FIG. 2. Phase diagram of nuclei in the interacting boson model.

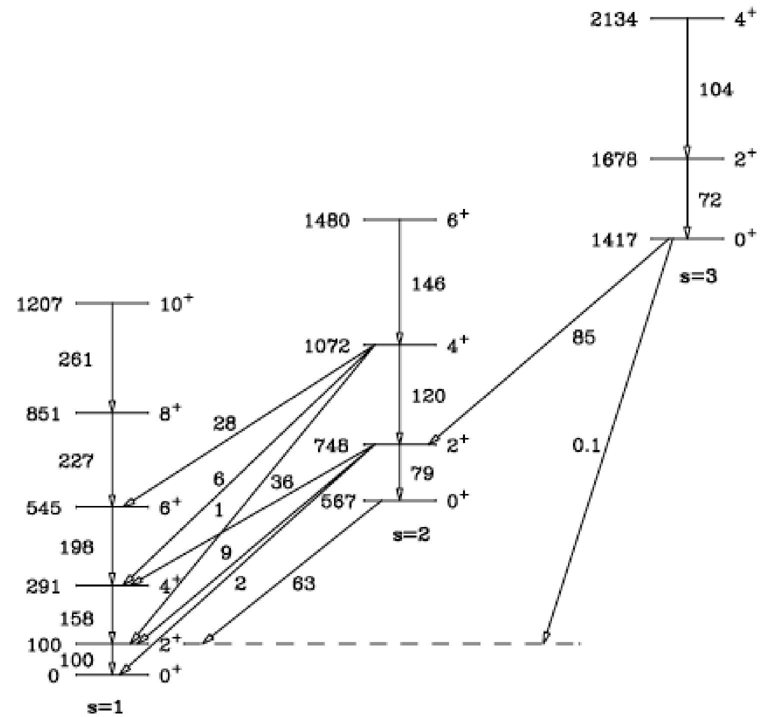
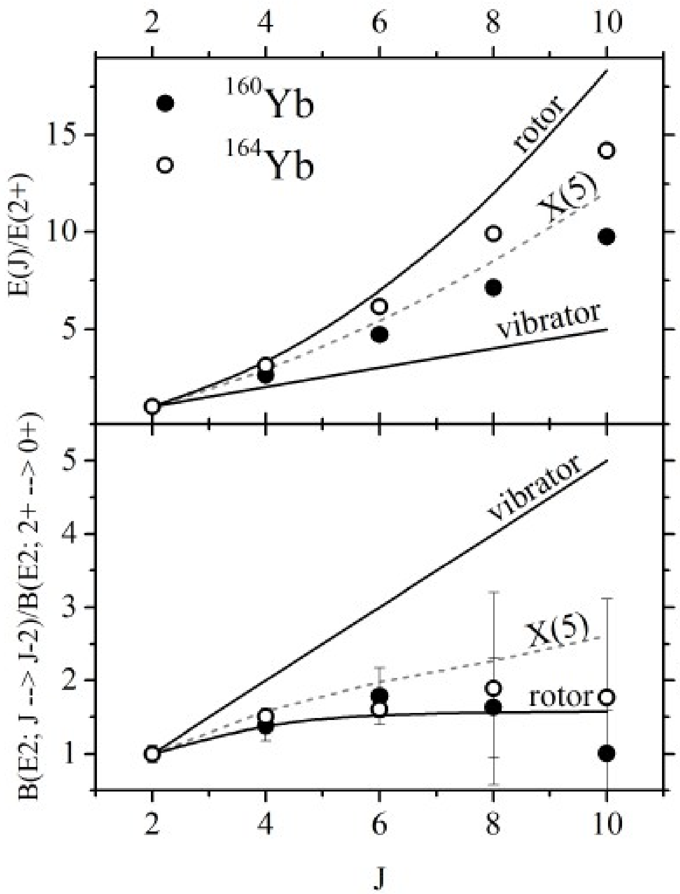


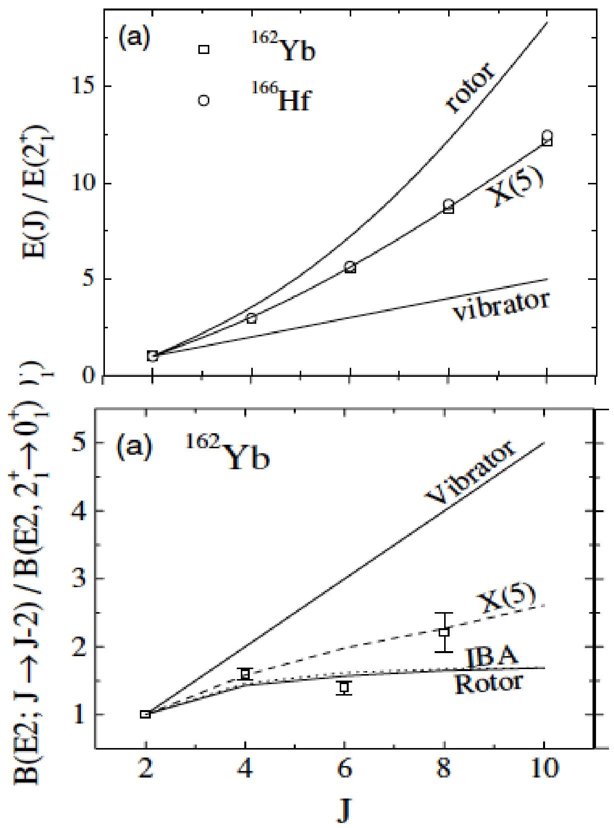
FIG. 2. Schematic representation of the lowest portion of the spectrum of X(5) symmetry. Only states with $n_\gamma = 0$ are shown. Energies are in units of the energy of the first excited state, $E_{2_1} - E_{0_1} = 100$. B(E2) values are in units of $B(E2; 2_1 \rightarrow 0_1) = 100$.

Iachello, PRL 94 (2004)

Iachello, PRL 87 (2001)

^{160}Yb, ^{162}Yb, ^{164}Yb nuclei





Transition between X(5) and rigid rotor

Deformation dependent models with different potentials: confined β-soft (CBS)

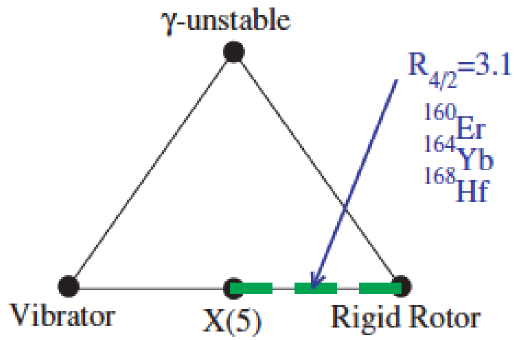
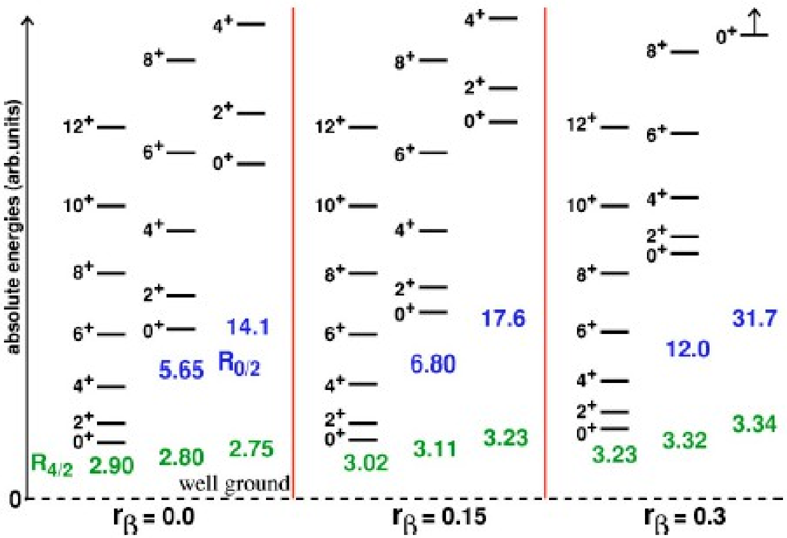


FIG. 1. (Color online) Schematic structural triangle for the nuclear collective model [9] where the vertices represent idealized limits of structure and the legs transition regions. The CBS model describes the transition region from X(5) to the symmetric rigid rotor (dashed line). Nuclides with $R_{4/2} = 3.1$ (e.g., ^{164}Yb, ^{168}Hf, and ^{160}Er, on which this paper focuses) might be intermediate between X(5) and the rigid rotor.

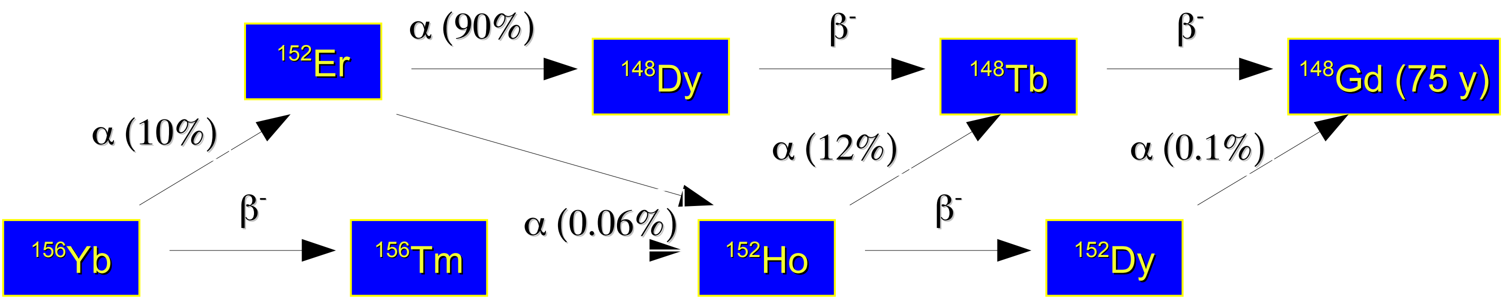


Pietralla, PRC 70 (2004); K. Dusling, PRC 73 (2006)

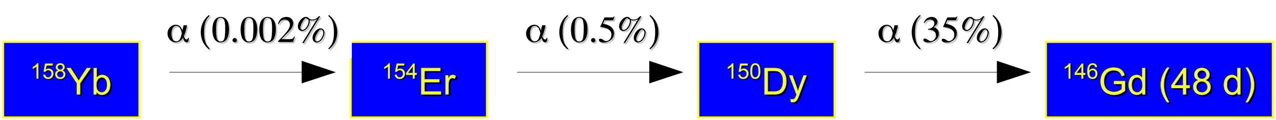
Contaminants

- ^{156}Yb (1x10^4, 26 s) : Dy - 4x10^9 (stable), Er - 6x10^8 (19 min),
  Eu - 1.3x10^6 (15 d)
- ^{158}Yb (1x10^6,1.5 min) : Dy - 2x10^9 (stable), Ho - 1x10^{10} (10 min),
  Er - 6x10^8 (2 h), Tm - 1x10^9 (4 m)
- ^{160}Yb (1x10^7, 4.8 min) : Lu - 5x10^6 (36 s), Tm - 1x10^8 (9 min),
  Er - 4 x10^8 (28 h), Ho - 3x10^{10} (25 m)
- ^{162}Yb (1x10^8, 19 min) : Lu - 2x10^7 (1.4 min), Tm - 3x10^8 (24 s)
- ^{164}Yb (1x10^{10}, 76 min) : Lu - 3x10^7 (3 min), Tm - 4x10^7 (5 min)
- ^{166}Yb (3x10^8, 57 h) : Hf - 6x10^5 (7 min), Lu - 3x10^7 (2 min)
- ^{168}Yb (1x10^9, stable) : Hf - 6x10^5 (26 min), Lu - 3x10^7 (1.4 min)

Radiation

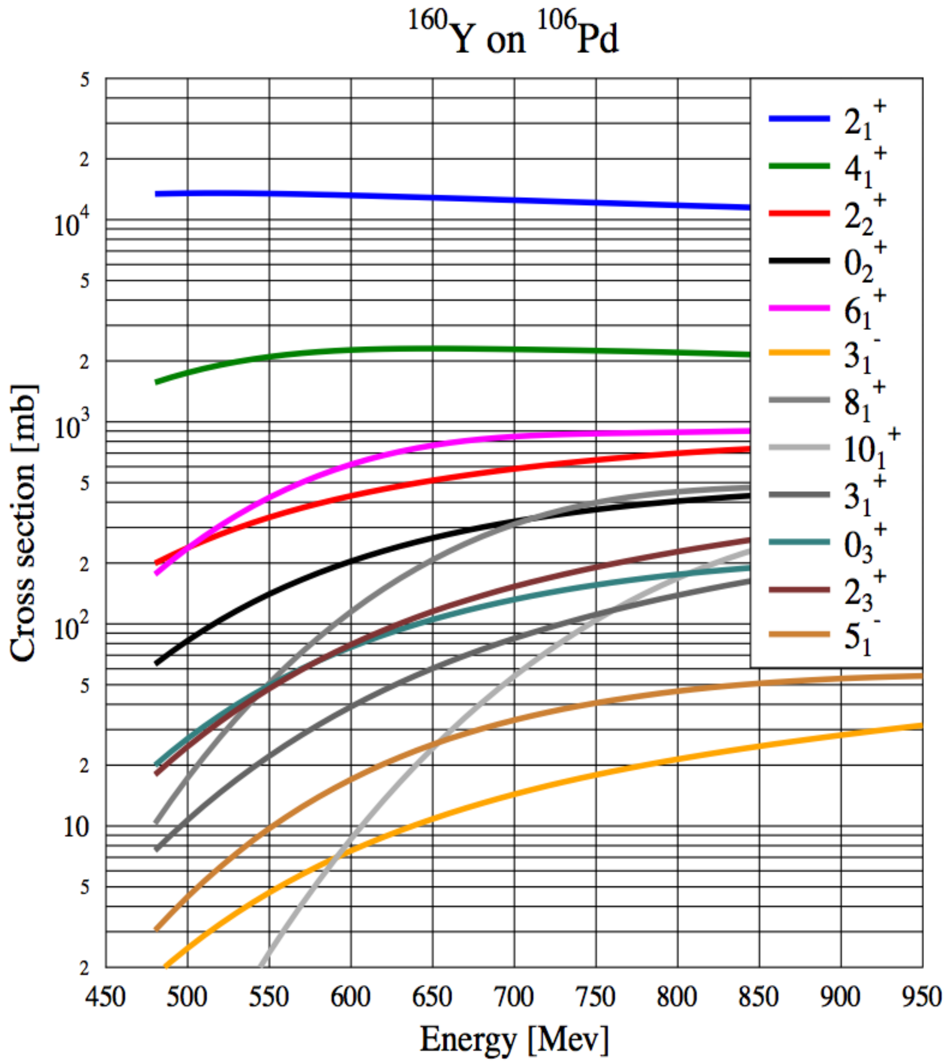


Long livetime → negligible (~3x10^{-4})



Weak branch → negligible (~10^{-5})

GOSIA calculations for ^{160}Yb on ^{106}Pd



T. Konstantinopoulos

Summary of requested shifts:

Bea m	Intensity	Target	Ion source	Shifts	Laser ON	Laser OFF	Beam purity	Counts ($2^+ \to 0^+$)	Counts ($3^- \to 0^+$)
^{156}Yb	$1x10^3$	Pd	Ta	-	-	-	-		
^{158}Yb	$1x10^5$	Pd	Ta	4	3	1	90%	900	-
^{160}Yb	$1x10^6$	Pd	Ta	10	9	1	90%	32000	30
^{162}Yb	$1x10^7$	Pd	Ta	4	3	1	90%	130000	130
^{164}Yb	$1x10^9$	Pd	Ta	3	2	1	50%	1300000	1300
^{166}Yb	$3x10^7$	Pd	Ta	4	3	1	50%	130000	130
^{168}Yb	$1x10^9$	Pd	Ta	3	2	1	50%	1300000	1300

28 shifts beam on target
3 shifts beam preparation
4 shifts beam change

Thank you for your attention !