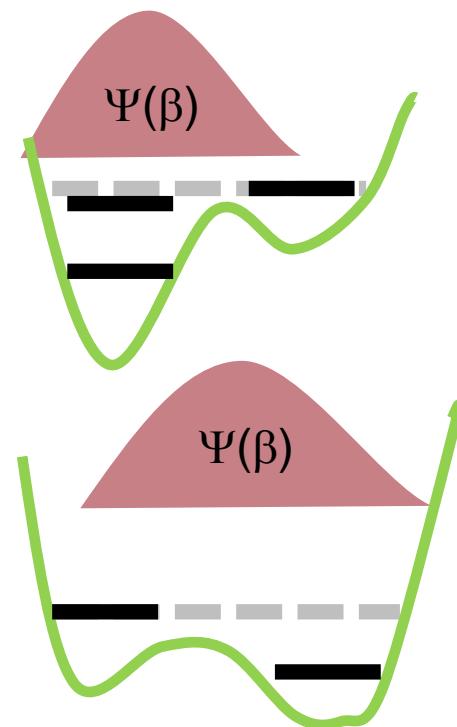


Quest for common semantics: A few remarks to ‘*shape coexistence*’, ‘*beta-vibration*’, and ‘*phase transition*’

Norbert Pietralla, Institut für Kernphysik, TU Darmstadt

- **Shape Coexistence**
- **β -vibration**
- **Phase Transition**

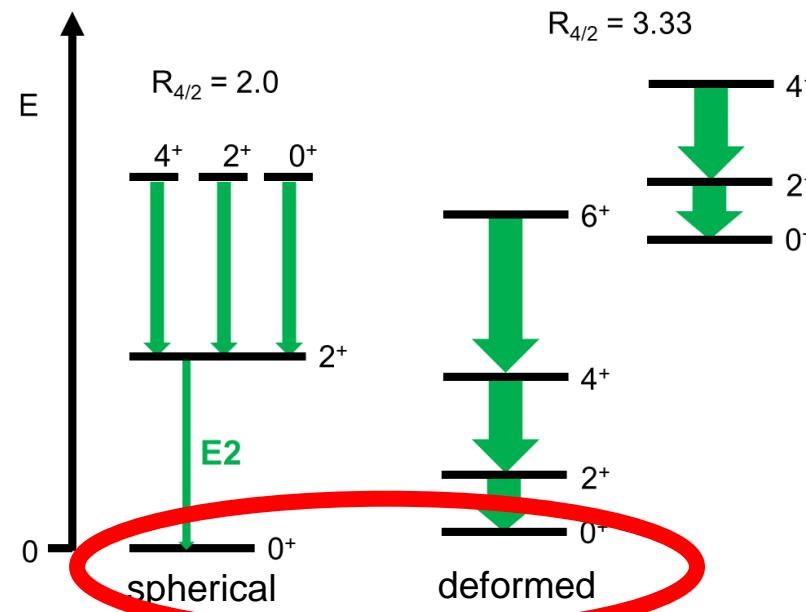


Shape Coexistence



- **Coexistence** = simultaneous occurrence of the different
- Heyde & Wood (RMP, 2012): „....nuclear eigenstates with different shapes...“

Extreme example
of Shape Coexistence



Occasional Misunderstanding



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Truth 1: „Shape Coexistence requires 2 distinct potential minima.“

Truth 2: „Occurrence of strong E0 transitions require wave functions of initial and final states with contributions of considerably different shapes, each.“

Common Misunderstanding: „Strong E0 transitions is empirical proof for Shape Coexistence with 2 different potential minima and strong mixing.“

Shape Coexistence vs Fluctuations

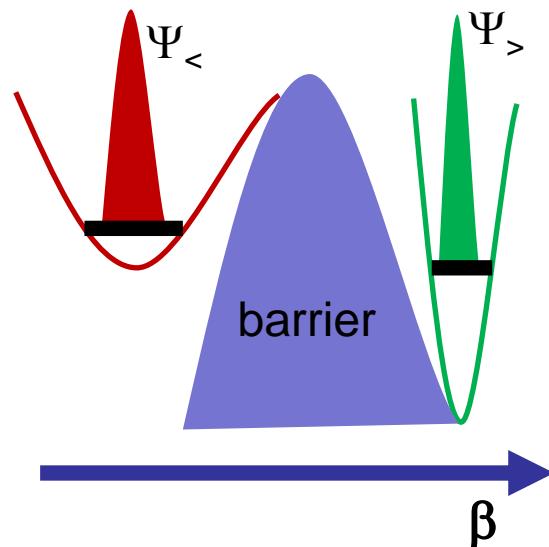


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Shape Coexistence

„thick“ barrier \leftrightarrow little mixing

„rigid“ potential minima

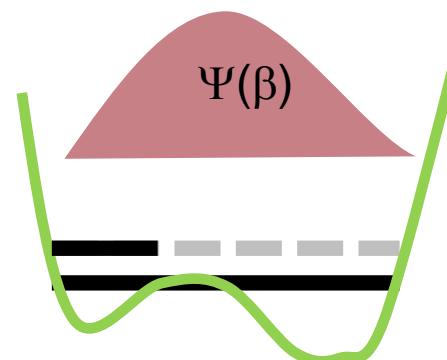


Different states have different shapes

Shape Fluctuations

„thin“ barrier \leftrightarrow strong mixing

soft potential / soft shape



All states share contributions with different shapes

Shape Coexistence vs Fluctuations

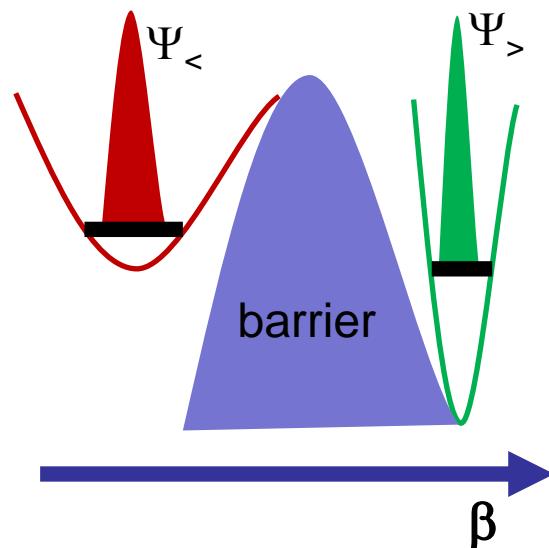


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Shape Coexistence

„thick“ barrier \leftrightarrow little mixing

„rigid“ potential minima

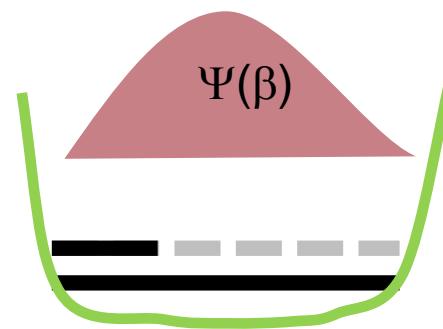


Different states have different shapes

Shape Fluctuations

soft potential

no barrier \leftrightarrow strong mixing



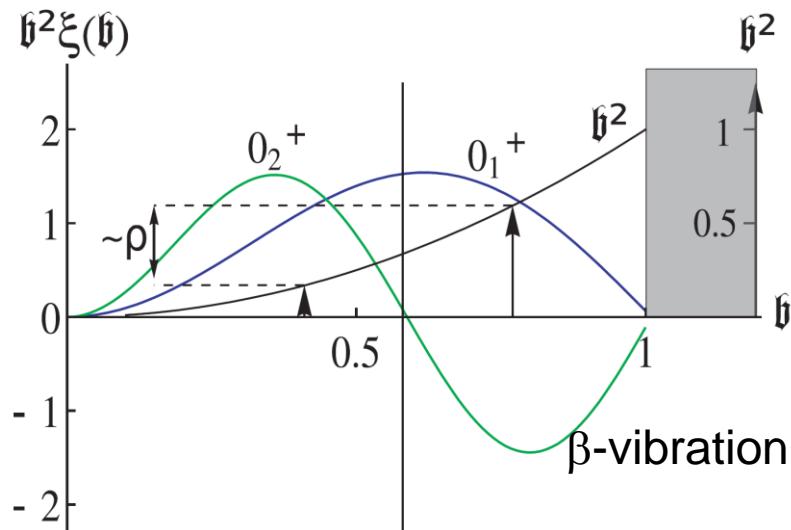
All states share contributions with different shapes

E0 transitions in Soft Potentials



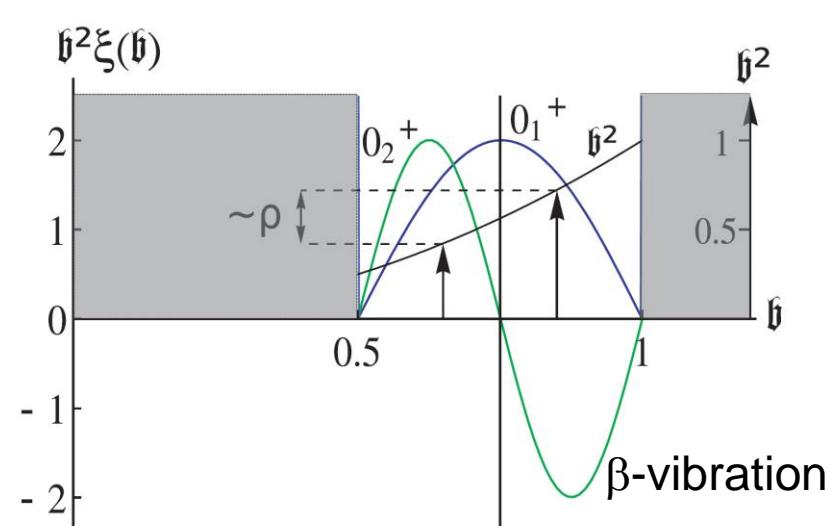
Very soft potential \rightarrow strong E0 transitions

Example: X(5) / CBS($r_\beta=0$)



Stiffer potential \rightarrow weaker E0 transitions

Example: CBS($r_\beta=0.5$)



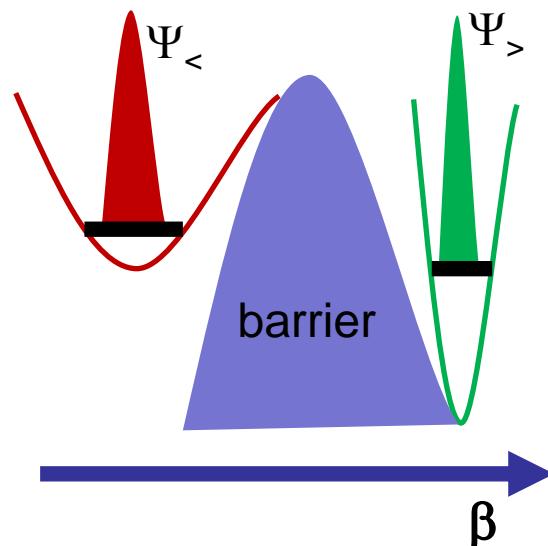
J.Bonnet, A.Krugmann, J.Beller, NP, R.V.Jolos, Phys. Rev. C 79, 034307 (2009).

Empirical Aspect of E0 Transitions



„thick“ barrier \leftrightarrow little mixing

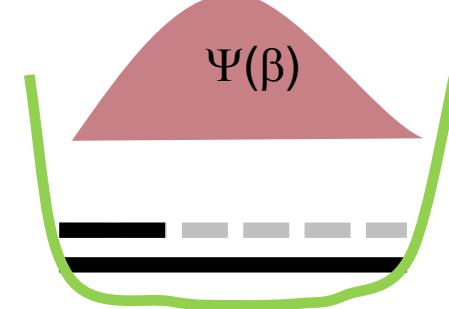
Shape Coexistence



wide potential, no/small barrier

Shape Fluctuations

Strong E0 transitions occur



Conclusion: „Shape Coexistence with strong mixing“ is a contradiction in itself.

Strong E0 transitions are evidence for a soft and wide potential in β instead of Shape Coexistence (in its strict sense)!

„ β -Vibration“



= **excitation in the β -degree of freedom** (per definition)

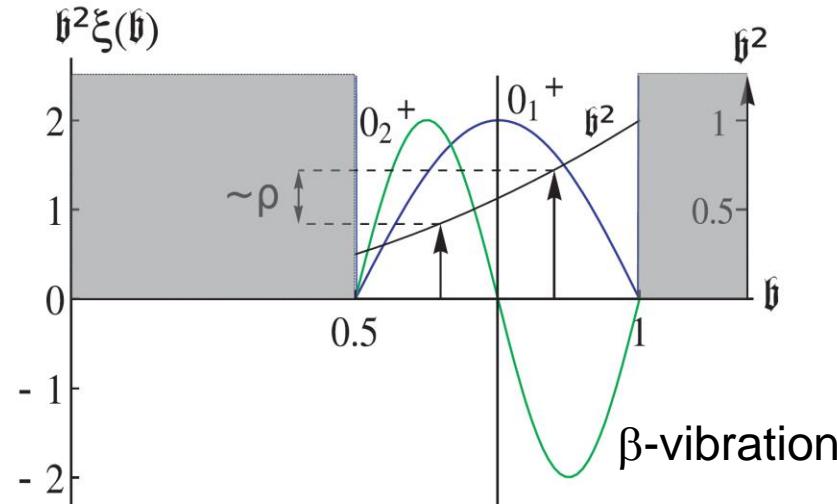
ideally:

$$\Psi \approx \psi(\beta) \eta(\gamma) D(\Omega)$$

ground state: ψ_0

β -vibration: ψ^*

Example: CBS

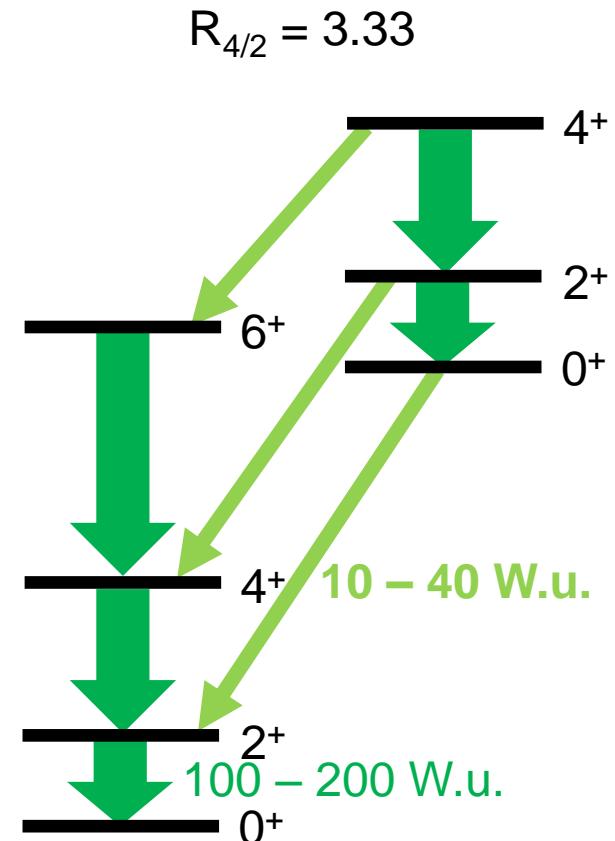


Common Misconception



The **β -band** is ...

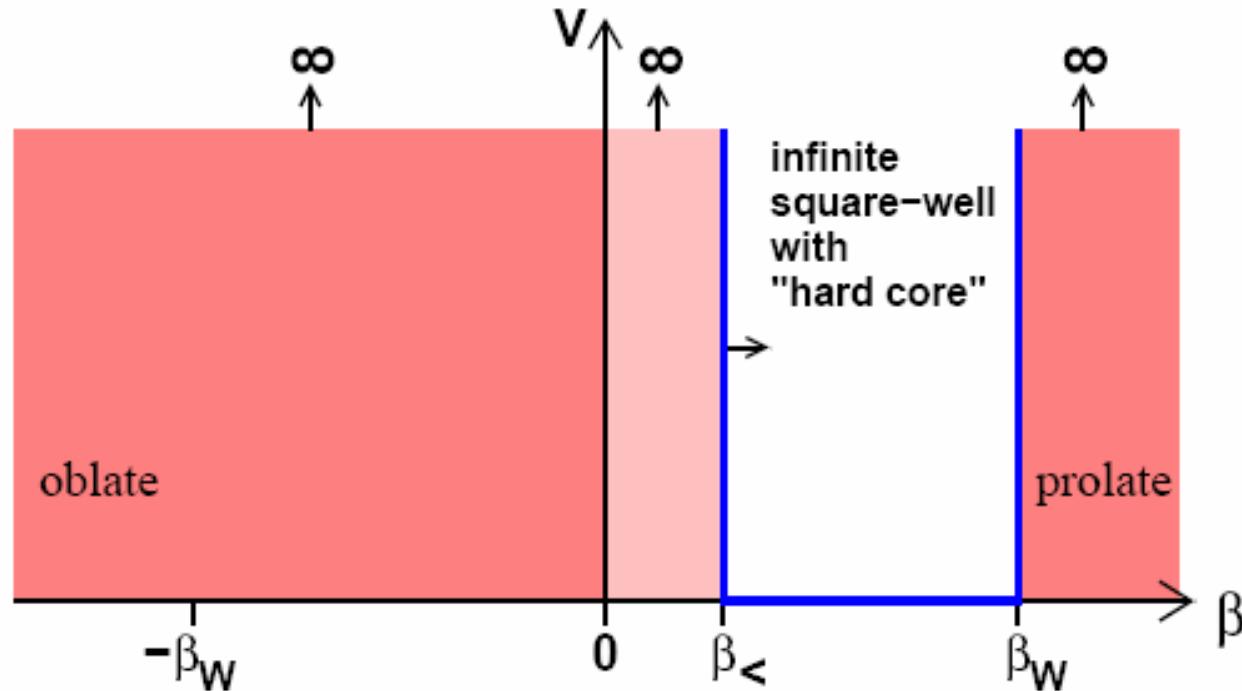
- a **low-lying** $K^\pi=0^+$ band in rigidly deformed nuclei
- best developed in deformed nuclei with **$R_{4/2} \approx 3.33$**
- decaying collectively to the ground band with E2 strengths of **dozens of W.u.**



Confined beta-Soft Rotor (CBS)



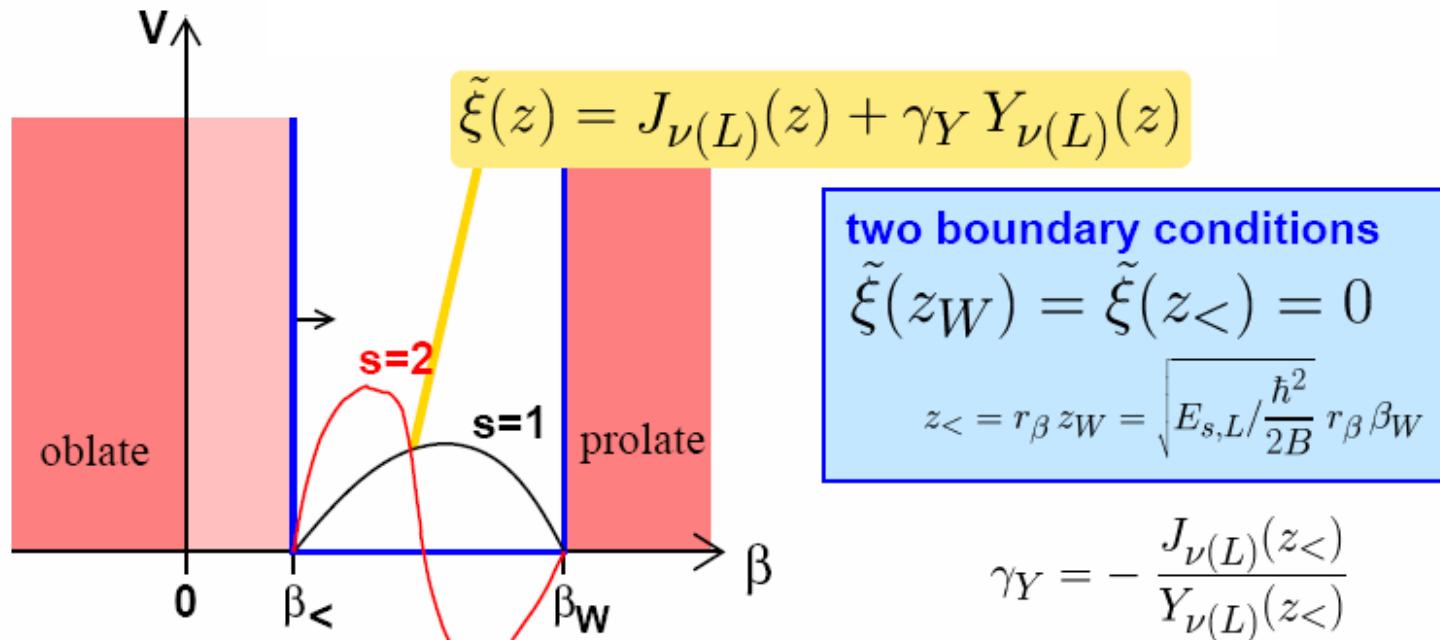
N.Pietralla, O.Gorbachenko (2004)



$$r_\beta = \beta_</\beta_W \in [0, 1[$$

X(5) Rigid Rotor

Solution of the Confined beta-Soft Rotor

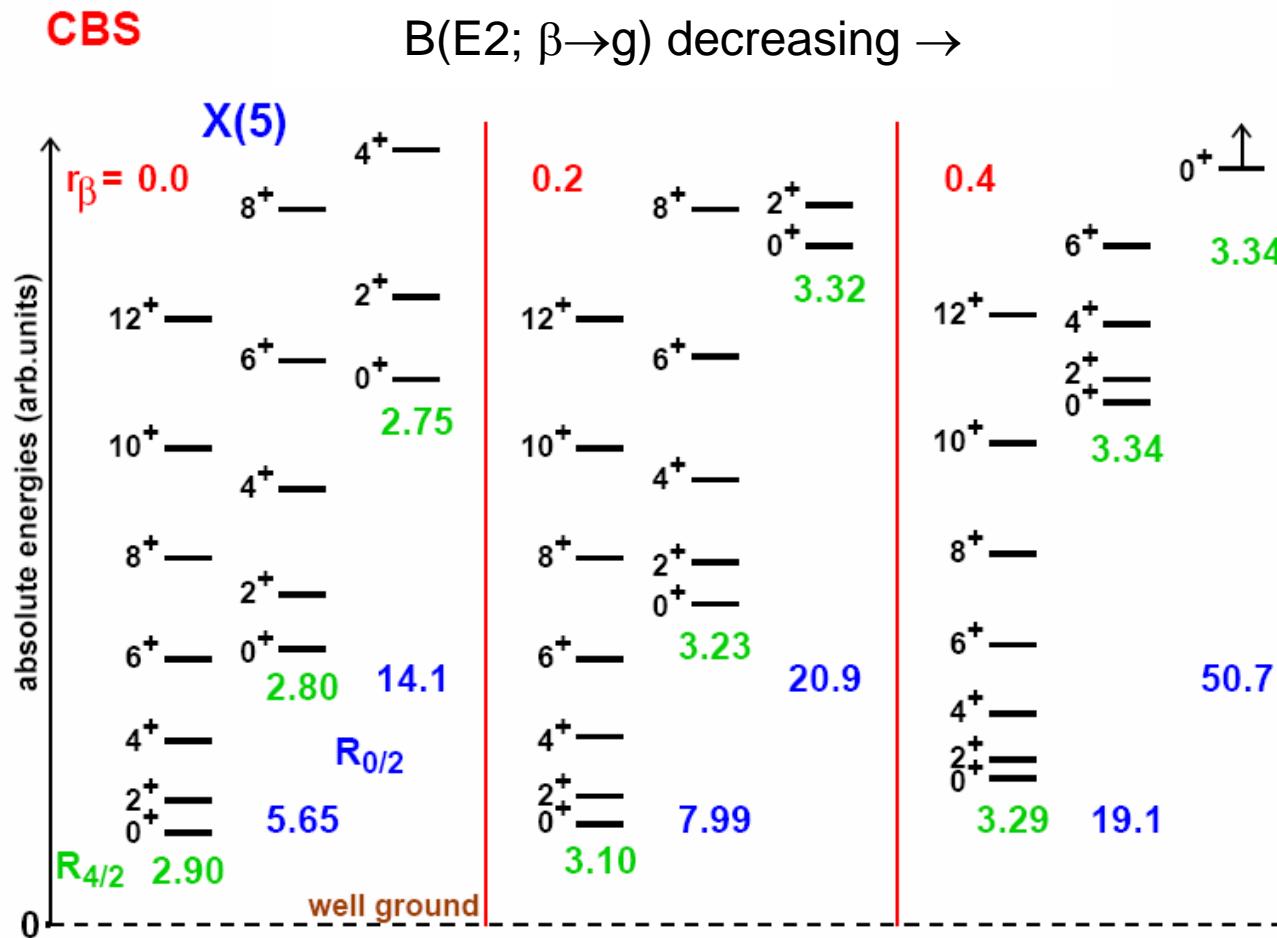


quantization $D_L^{r_\beta}(z_W) = J_{\nu}(z_W) Y_{\nu}(r_\beta z_W) - J_{\nu}(r_\beta z_W) Y_{\nu}(z_W) = 0$

$z_{s,L} = \sqrt{E_{s,L}/\frac{\hbar^2}{2B}} \beta_W$ **s-th zero of D**

$$E_{s,L} = \frac{\hbar^2}{2B \beta_W^2} z_{s,L}^2$$

Energy Spectry as a Function of r_β

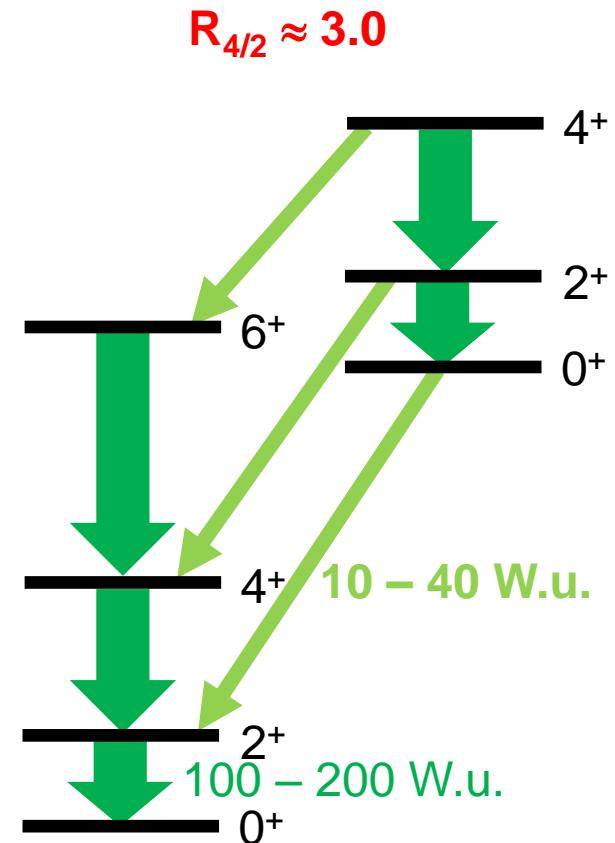


In fact,



the **β -band** is ...

- a **high-lying** $K^\pi=0^+$ band in **rigidly deformed** nuclei
- decaying **very weakly** to the ground band of **rigidly deformed** nuclei
- best accessible in **softly deformed** nuclei with $R_{4/2} \approx 3.0$



Phase Transition



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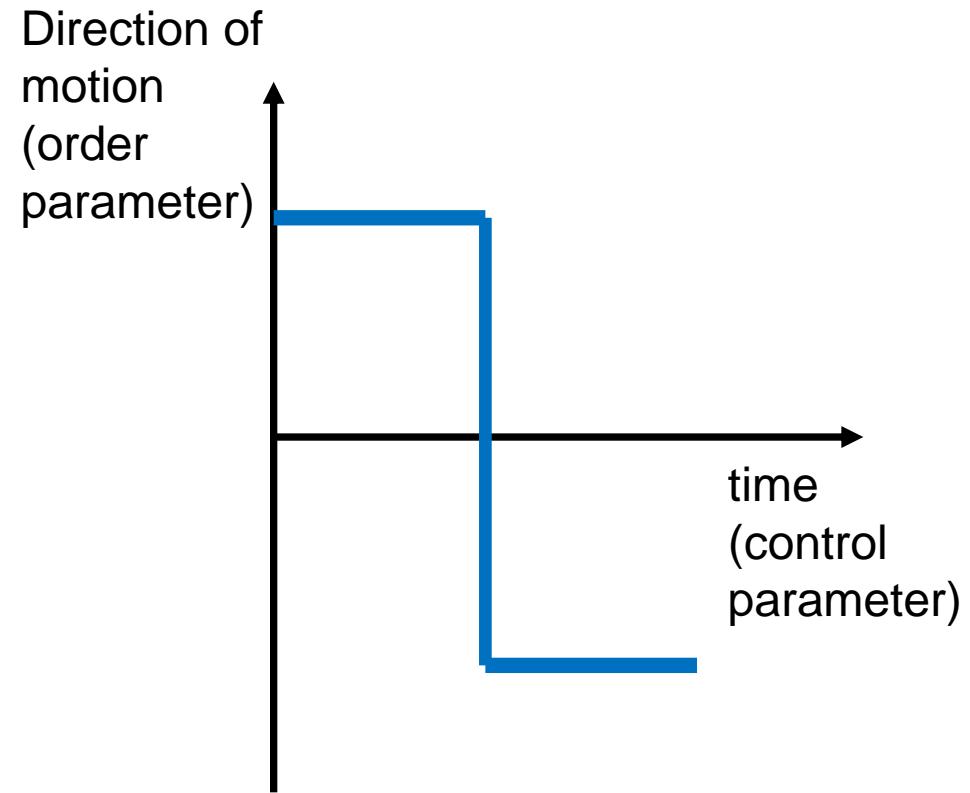
Ehrenfest classification: Order of phase transition = order of the derivative of the Free Energy for which a discontinuity occurs.

Landau / Lifshitz: Second Order Phase Transition requires difference in symmetry.

Not everything is a phase transition...

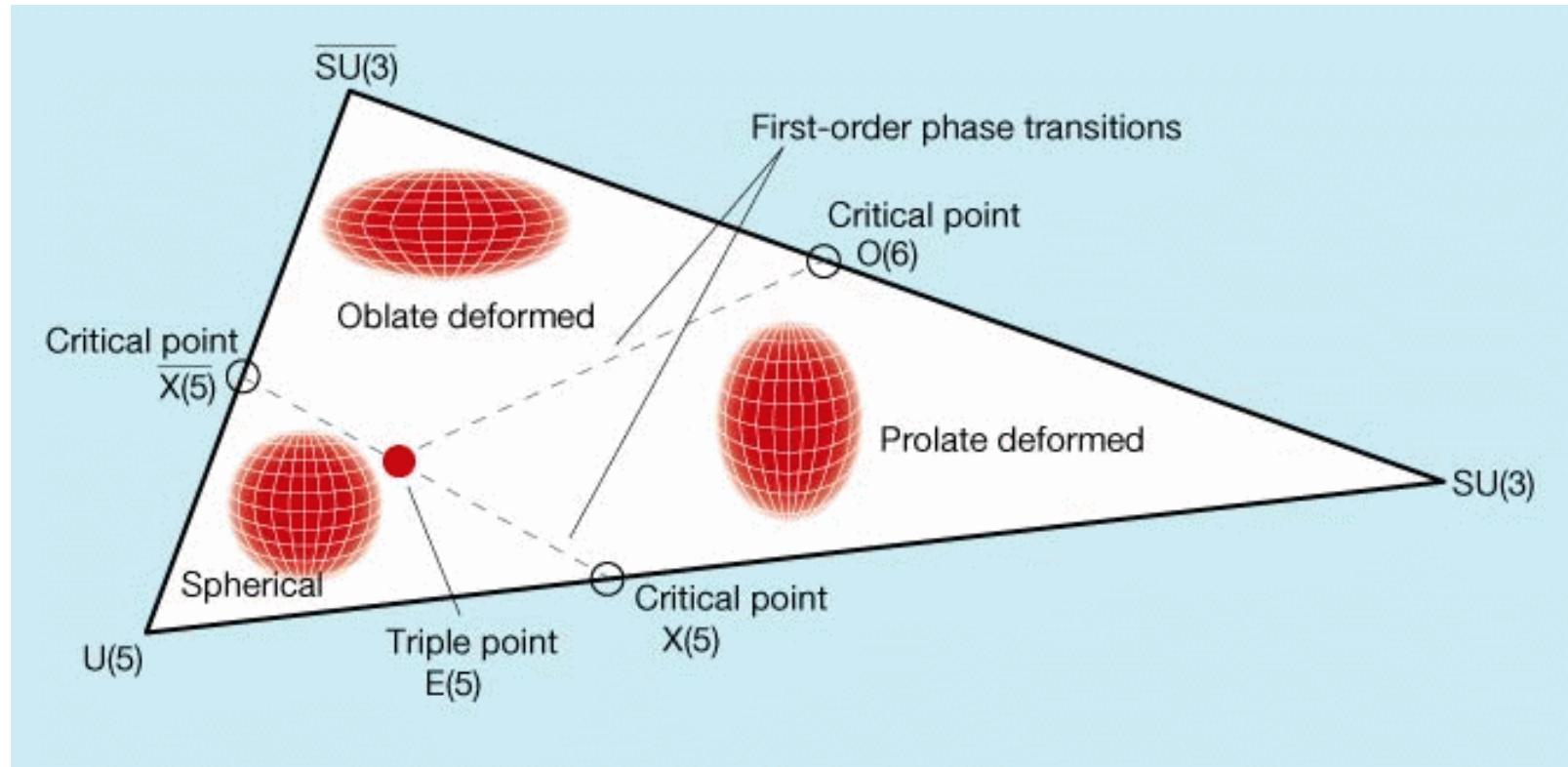


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Proposal: If a symmetry transformation links the two situations, then they are not two distinct phases.

Phases in the extended Casten Triangle



The *d-parity transformation* ($s \rightarrow s$, $d \rightarrow -d$) transforms the prolate to the oblate side of the Casten triangle. Is $O(6)$ a *Critical Point*?

Summary



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- Shape Coexistence vs Shape Softness
- Definition of β -vibration
- Is it appropriate to call the prolate and the oblate side of the Casten triangle different shape phases?

Let's discuss it!

Thank you very much!

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Volker Werner



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