E0 transition strength from X(5) to the rigid rotor

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- Motivation
- Introduction to CBS rotor model
- Relative $E0$ transition strength
- Evolution of absolute $E0$ transition strength
- $E2 - E0$ correlation observables
- Summary

J. Bonnet, A. Krugmann, J. Beller, N. Pietralla, and R. V. Jolos
Phys. Rev. C **79**, 034307 (2009)

SFB 634

LOEWE – Landes-Offensive zur Entwicklung Wissenschaftlich-ökonomischer Exzellenz

Motivation

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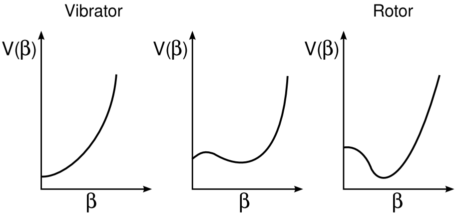
- With increasing A, heavy nuclei can undergo rapid quantum phase transitions



Motivation

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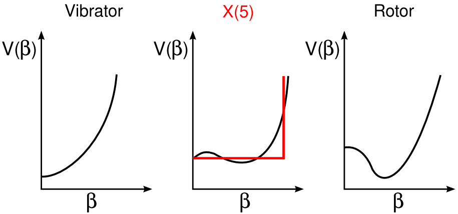

- Geometrical collective solution of the Bohr Hamiltonian:

$$H = -\frac{\hbar^2}{2B}\left[\frac{1}{\beta^4}\frac{\partial}{\partial\beta}\beta^4\frac{\partial}{\partial\beta} + \frac{1}{\beta^2 \sin 3\gamma}\frac{\partial}{\partial\gamma}\sin 3\gamma\frac{\partial}{\partial\gamma} - \frac{1}{4\beta^2}\sum_k \frac{Q_k^2}{\sin^2(\gamma - \frac{2}{3}\pi k)}\right] + V(\beta,\gamma)$$

- Parameter free square well potential
- Analytical wave functions (Bessel functions)

Motivation

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- Calculate level scheme for X(5) solution

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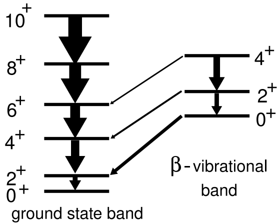
- Calculate level scheme for X(5) solution

$$R_{4/2} = \frac{E(4_1^+)}{E(2_1^+)} = 2.90$$



Motivation

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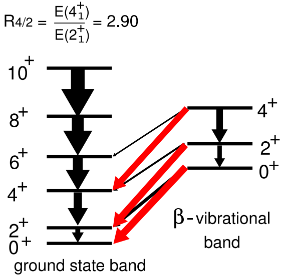
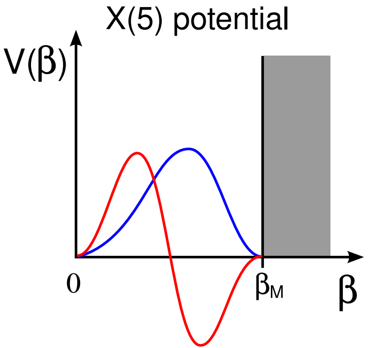
- Calculate level scheme for X(5) solution



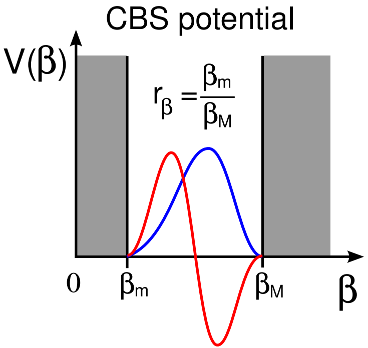
- High $E0$ (electric monopole) transition strengths in case of shape change

Confined β-soft (CBS) rotor model



F. Iachello,
Phys. Rev. Lett. **87**, 052502 (2001)

Confined β-soft (CBS) rotor model



N.Pietralla and O.M.Gorbachenko,
Phys.Rev. C **70**, 011304 (2004)

Confined β-soft (CBS) rotor model

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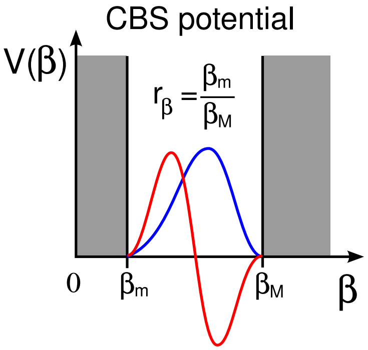

N.Pietralla and O.M.Gorbachenko, Phys.Rev. C **70**, 011304 (2004)

- Wave functions are **confined** in a β-**soft** potential
- Potential stiffness is defined as
  $r_\beta = \frac{\beta_m}{\beta_M}$
  $r_\beta = 0 \rightarrow X(5)$
  $r_\beta = 1 \rightarrow$ rigid rotor
  Typical values between 0.1 (^{150}Nd) and 0.5 (well deformed nuclei)
- Study $E0$ transition strengths on the path from X(5) to the well deformed nuclei

$E0$ operator and $E0$ transition strength

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- $E0$ operator for axially symmetric quadrupole deformation:

$$T(E0) = \frac{3}{4\pi} ZeR^2\beta^2$$

- $E0$ transition strength:

$$\rho^2(E0) = \left(\frac{3Z}{4\pi}\right)^2 |\langle\psi_f|\beta^2|\psi_i\rangle|^2$$

- $\rho^2(E0)$ is a dimensionless quantity
- The largest values are around $100 \cdot 10^{-3} = 0.1$

Angular momentum dependence of relative $E0$ transition strength

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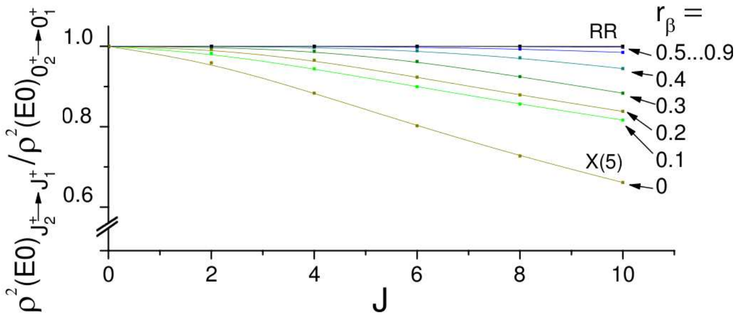

- For increasing angular momentum the model predicts a decreasing $E0$ transition strength.
- Rising potential stiffness $\rightarrow$ $E0$ strength approach a constant value.

Evolution of absolute $E0$ transition strength

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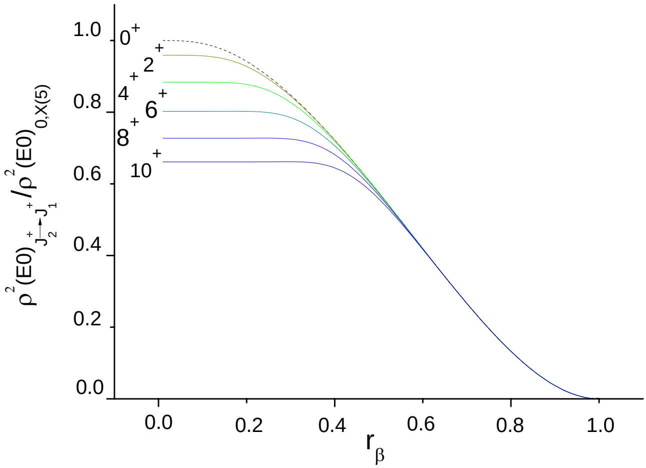

$E2 - E0$ correlation observables

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- Rasmussen introduced the Z-independent quantity

$$X_{Rasm} = \frac{\rho^2(E0; 0_2^+ \to 0_1^+) e^2 R^4}{B(E2; 0_2^+ \to 2_1^+)}$$

- In the rigid rotor limit he obtained: $X_{Rasm} = 4\beta^2$
- In the CBS model we get the expression:

$$X_{CBS} = \frac{\langle \Psi_{0_1^+} |\, T(E0)\, | \Psi_{0_2^+} \rangle^2 \, \beta_M^2}{\langle \Psi_{2_1^+} |\, T(E2)\, | \Psi_{0_2^+} \rangle^2}$$

- With the CBS model, we can trace the evolution of X as a function of nuclear stiffness!
- But still dependence of scaling factor β_M

New scaling-factor independent quantity Y

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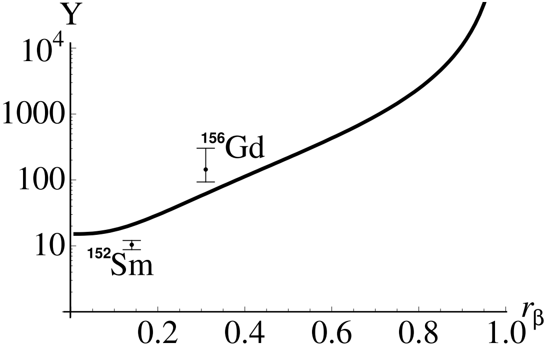
$$
\begin{aligned}
Y &= \frac{\rho^2(0_2^+ \rightarrow 0_1^+)\,(e^2 R^4 Z)^2\,(\frac{3}{4\pi})^2}{B(E2, 0_2^+ \rightarrow 2_1^+)^2} \\
&= \frac{\langle \Psi_{0_1^+} |\, T(E0)\, | \Psi_{0_2^+} \rangle^2}{\langle \Psi_{2_1^+} |\, T(E2)\, | \Psi_{0_2^+} \rangle^4}
\end{aligned}
$$

- Y theoretically depends **only** on the stiffness parameter r_β.

Ratio Y as a function of r_β



- Y increases monotonically with the stiffness parameter r_β...

Ratio Y as a function of the $R_{4/2}$ ratio

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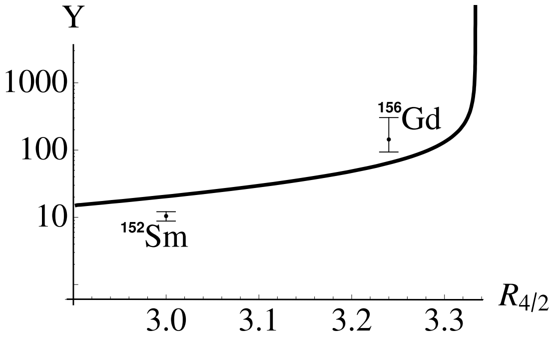

- … and increases with the $R_{4/2}$ ratio too.

Summary

- Successful investigation of E0 transition strength in the CBS model
- Relative $E0$ strength (for a given r_β) decrease with angular momentum.
- Absolute $E0$ transition strength decrease with increasing potential stiffness r_β.
- A new observable $Y \propto \rho^2(E0; 0_2^+ \rightarrow 0_1^+)/B(E2; 0_2^+ \rightarrow 2_1^+)^2$ has been proposed
  - is independent of the absolute nuclear deformation
  - solely depends on the nuclear stiffness.
- The few available data are in reasonable agreement with the CBS model.

Summary

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- Successful investigation of E0 transition strength in the CBS model
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- **Outlook:** More data needed!
  Measure E0 matrix elements with inelastic electron scattering at S-DALINAC

Thank you for your attention!

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SFB 634

HIC for FAIR

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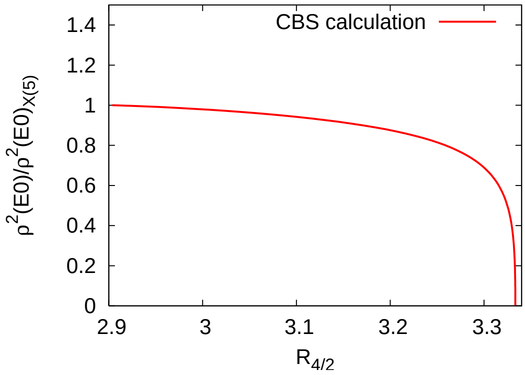
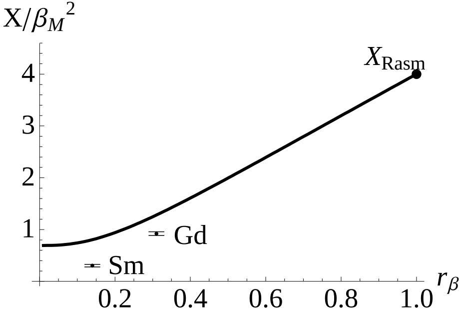
ökonomischer Exzellenz

Additional content

Absolute E0 strength as a function of $R_{4/2}$



Evolution of X as a function of nuclear stiffness



- Verification of Rasmussens prediction in the rigid rotor limit: $X_{Rasm} = 4\beta^2$
- But still dependence of scaling factor β_M

Stiffness dependence of relative $E0$ strength

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