Triaxiality and Wobbling with AGATA

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Triaxiality and Wobbling with AGATA

- Triaxiality and Wobbling
- “Best experimental case” ^{163}Lu
- Other nuclei in the Lu/Hf region
- The role of AGATA

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Triaxiality and Wobbling

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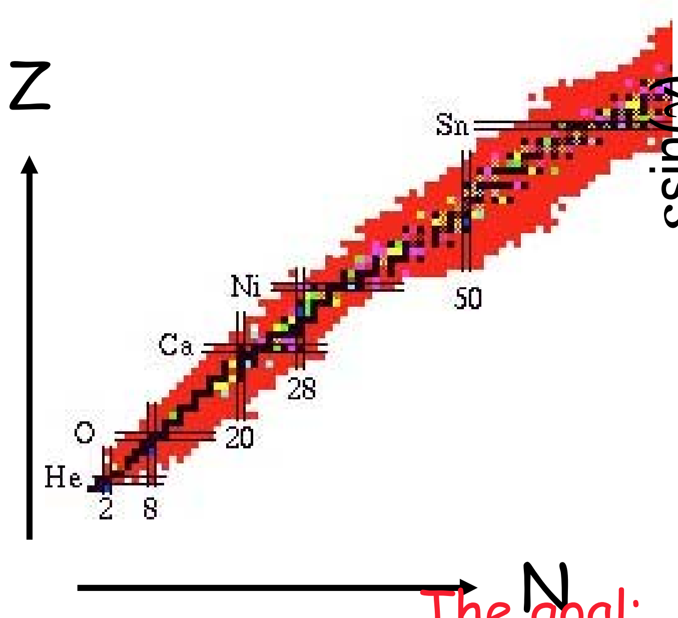
The A~165 mass region

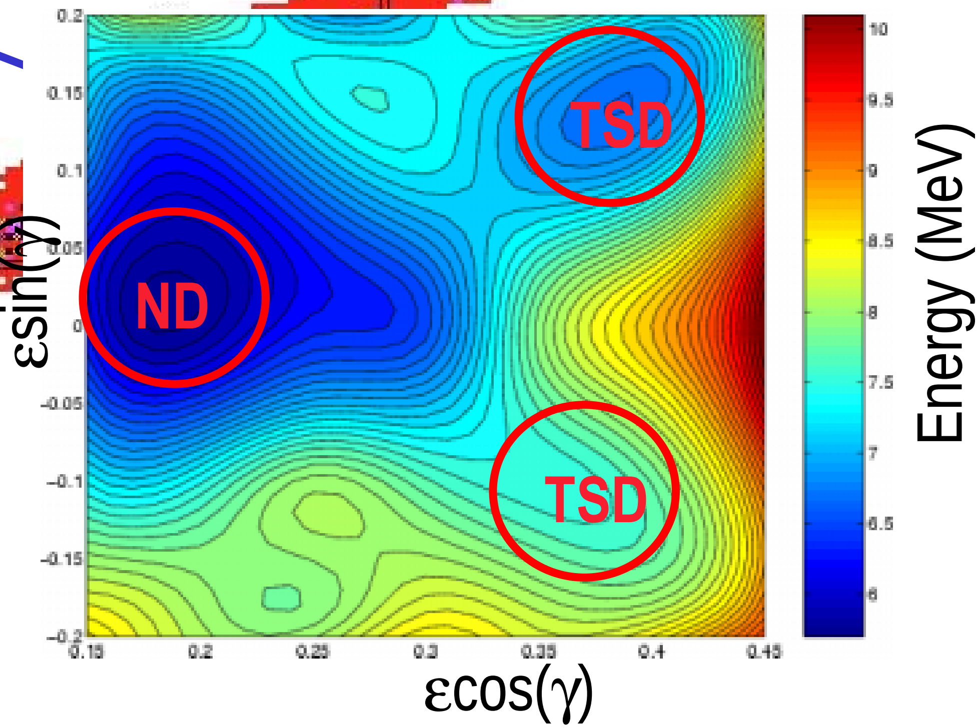
N~94

Z~71



Total energy surface for ^{163}Lu

I=57/2, $(\pi;\alpha)$=(+,+1/2)



The goal:

To find experimental evidence for the triaxial deformation

Signatures of triaxiality

Quasiparticle excitation energy
Relation between signature partner bands
Electromagnetic decay strength between bands

These effects can be caused by other phenomena

Breaking of chiral symmetry
Wobbling excitations

These phenomena are directly related to the triaxiality of the nucleus

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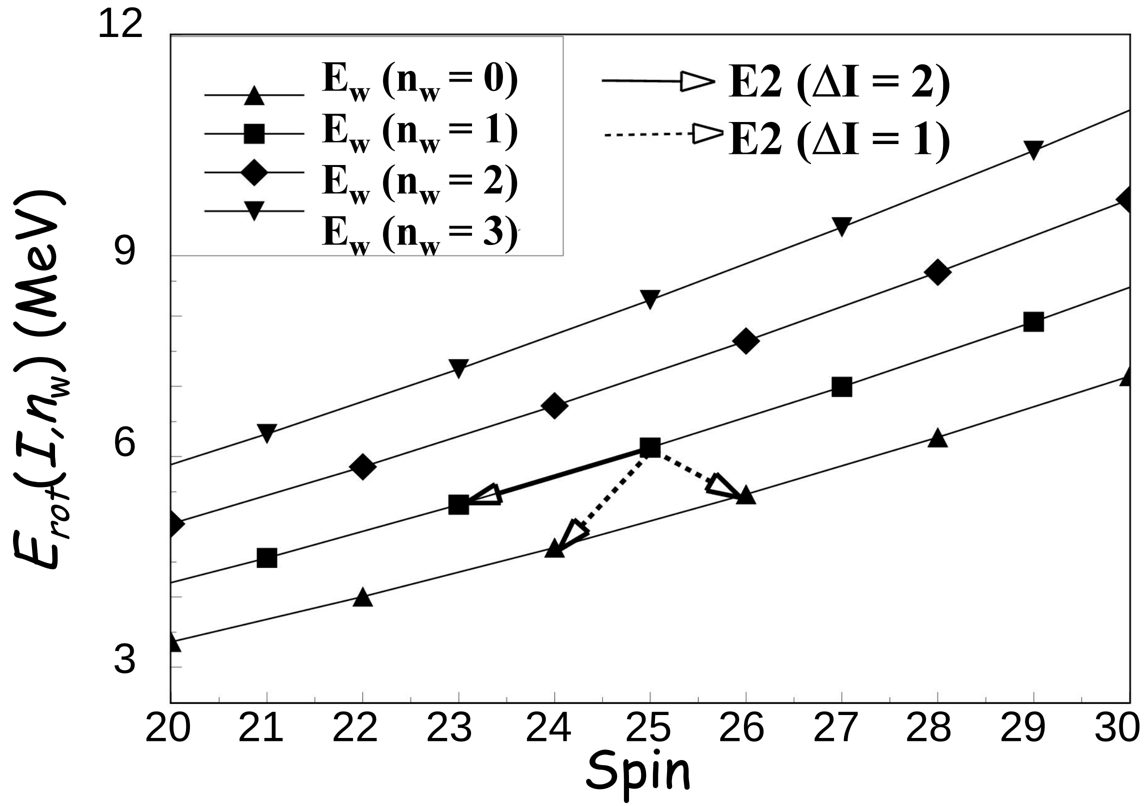
Wobbling in the Odd-even triaxial system



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I. H

I. H 3), 014319

J_k

$$E_{rot}(I,n_w) = A_1 I(I+1) + (n_w + \tfrac{1}{2})\,\hbar\omega_w$$

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Wobbling in the Odd-even triaxial system

Particle rotor with:
One **aligned** particle and a **wobbling core**

$$H_{pr} = H_{int} + \sum_{k=1,2,3} A_k R_k^2 \quad ,\text{where } \vec{R}_k = (\vec{I} - \vec{j})$$

Assuming $j_1 \approx j$

$$H = A_1 (I_1 - j_1)^2 + A_2 I_2^2 + A_3 I_3^2$$

$$E_{rot}(I, n_w) = A_1 I (I+1) + (n_w + \tfrac{1}{2}) \hbar\omega_w - 2A_1 I_1 j_1 + A_1 j_1^2$$

I. Hamamoto, Phys. Rev. C **65** (2002), 044305

I. Hamamoto & G. Hagemann, Phys. Rev. C **67** (2003), 014319

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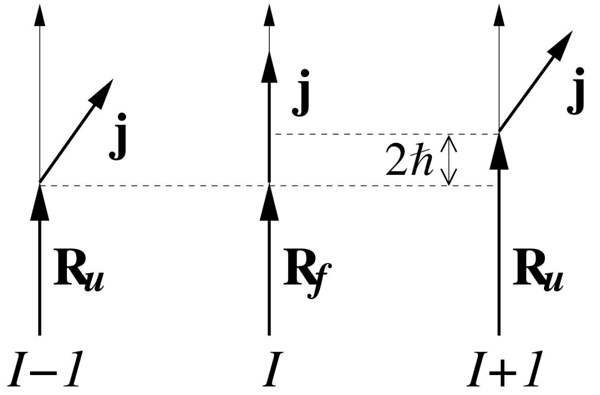
Two different ways to couple the particle and core spin

"Crankinglike"



I. Hamamoto, Phys. Rev. C **65** (2002), 044305

I. Hamamoto & G. Hagemann, Phys. Rev. C **67** (2003), 014319

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The signatures of wobbling

Family of rotational bands with similar intrinsic structure and increasing excitation energy.

Observables $J^{(2)}$, i_x, Q_t, ΔE^*

Characteristic decay pattern between bands, with $\Delta n_w=1$ transitions competing with $\Delta n_w=0$ in-band transitions

Phonon rule:

$B(E2, n_w=2 \rightarrow n_w=1) \approx 2 * B(E2, n_w=1 \rightarrow n_w=0)$

$B(E2, n_w=2 \rightarrow n_w=0) \approx 0$

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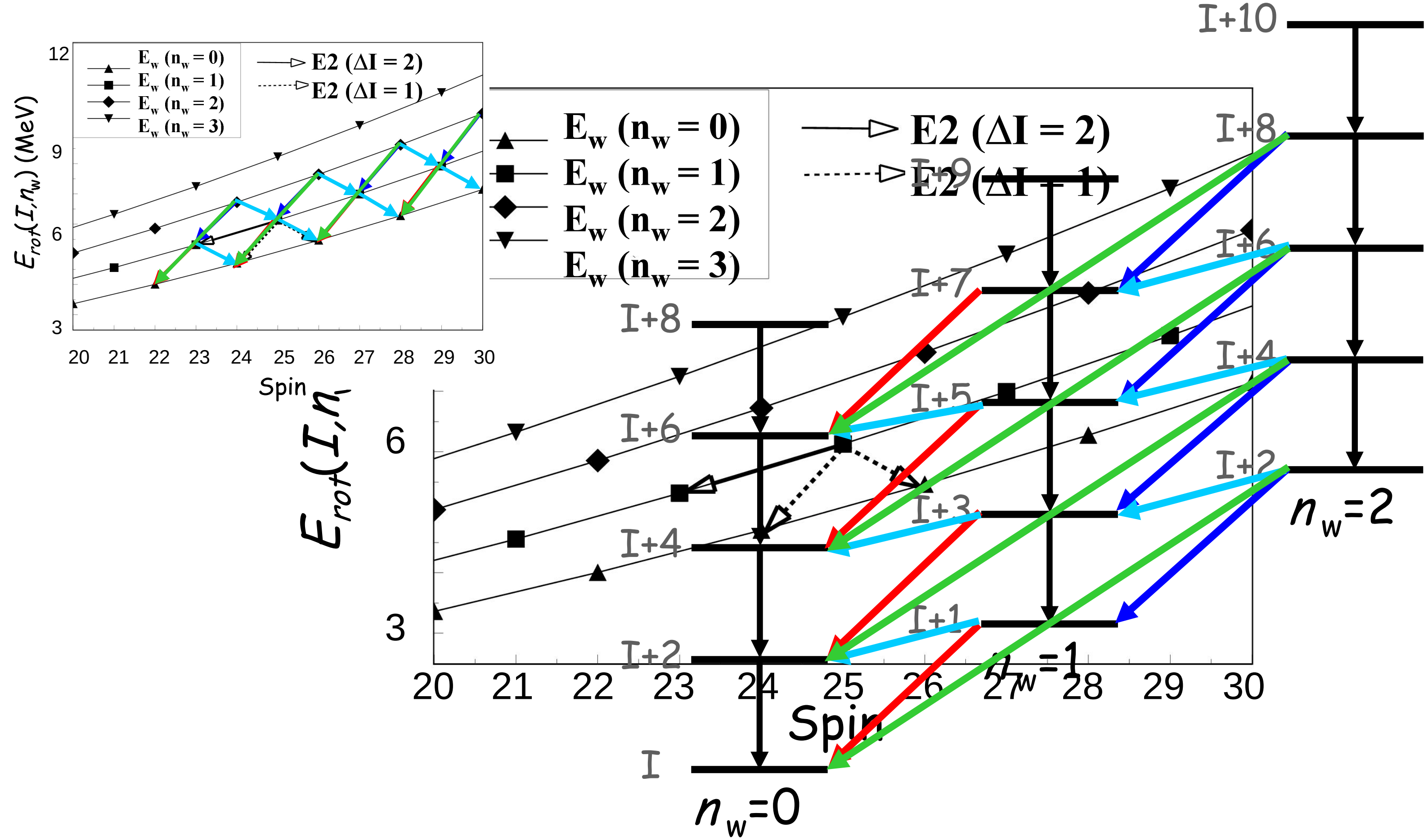
The signatures of wobbling



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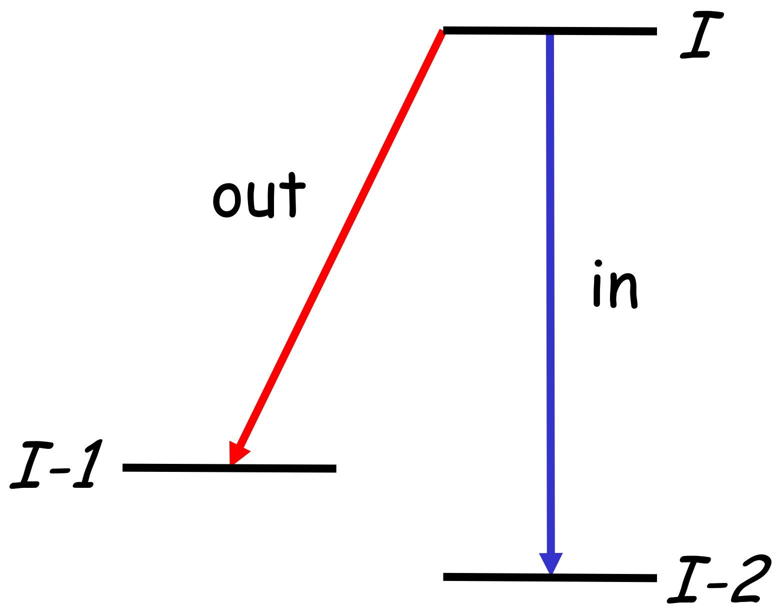
Information from the connecting transitions

Angular distributions
DCO measurements
Linear Polarisation

→ Spin and parity
Mixing ratio of E2/M1

↓

Ratios of reduced electromagnetic moments



$B(E2)_{out}/B(E2)_{in}$

and

$B(M1)/B(E2)_{in}$

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Best case: ^{163}Lu

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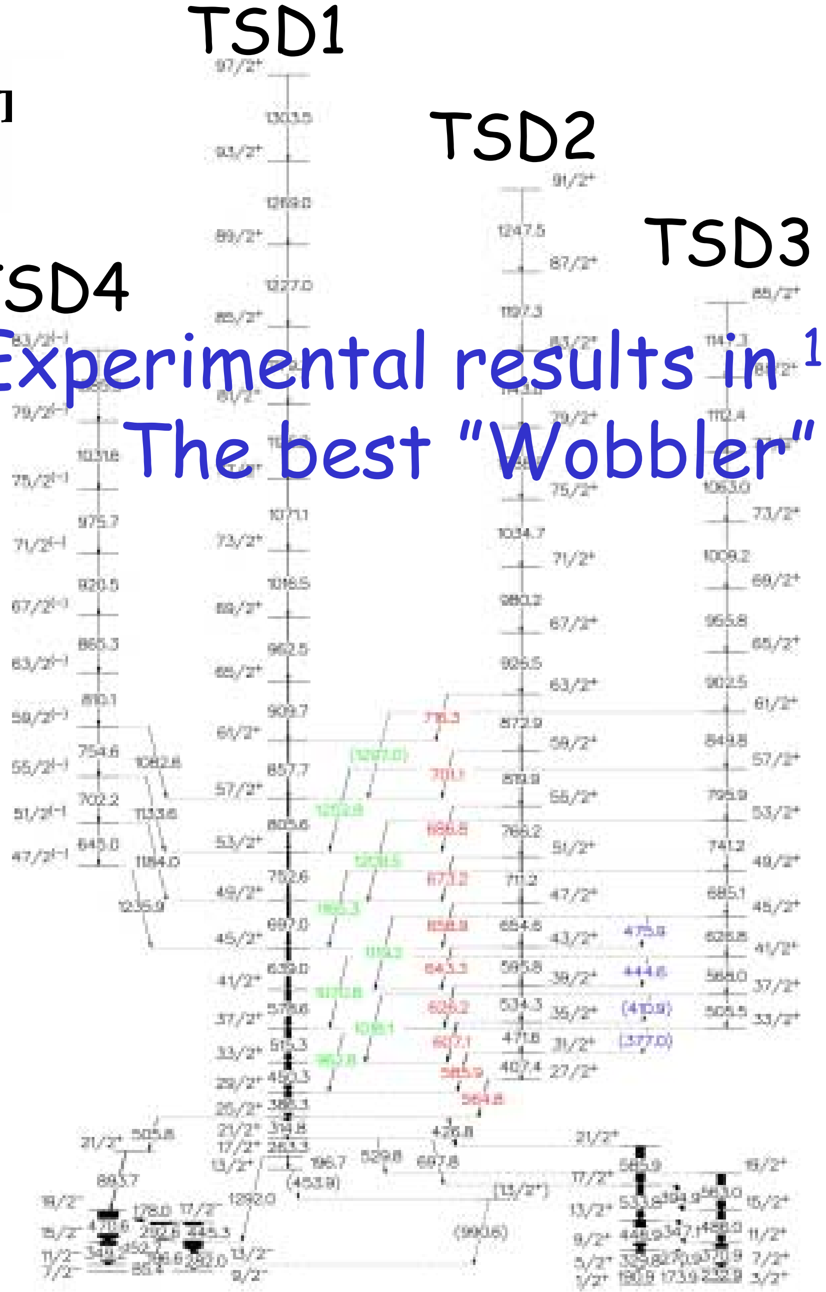
Experimental results in ^{163}Lu
The best "Wobbler"



Relative population

TSD1: 10%

TSD2: 3%

TSD3: 1.2%

TSD4: 0.9%

D.R. Jensen et al., Phys. Rev. Lett. **89** (2002), 142503.

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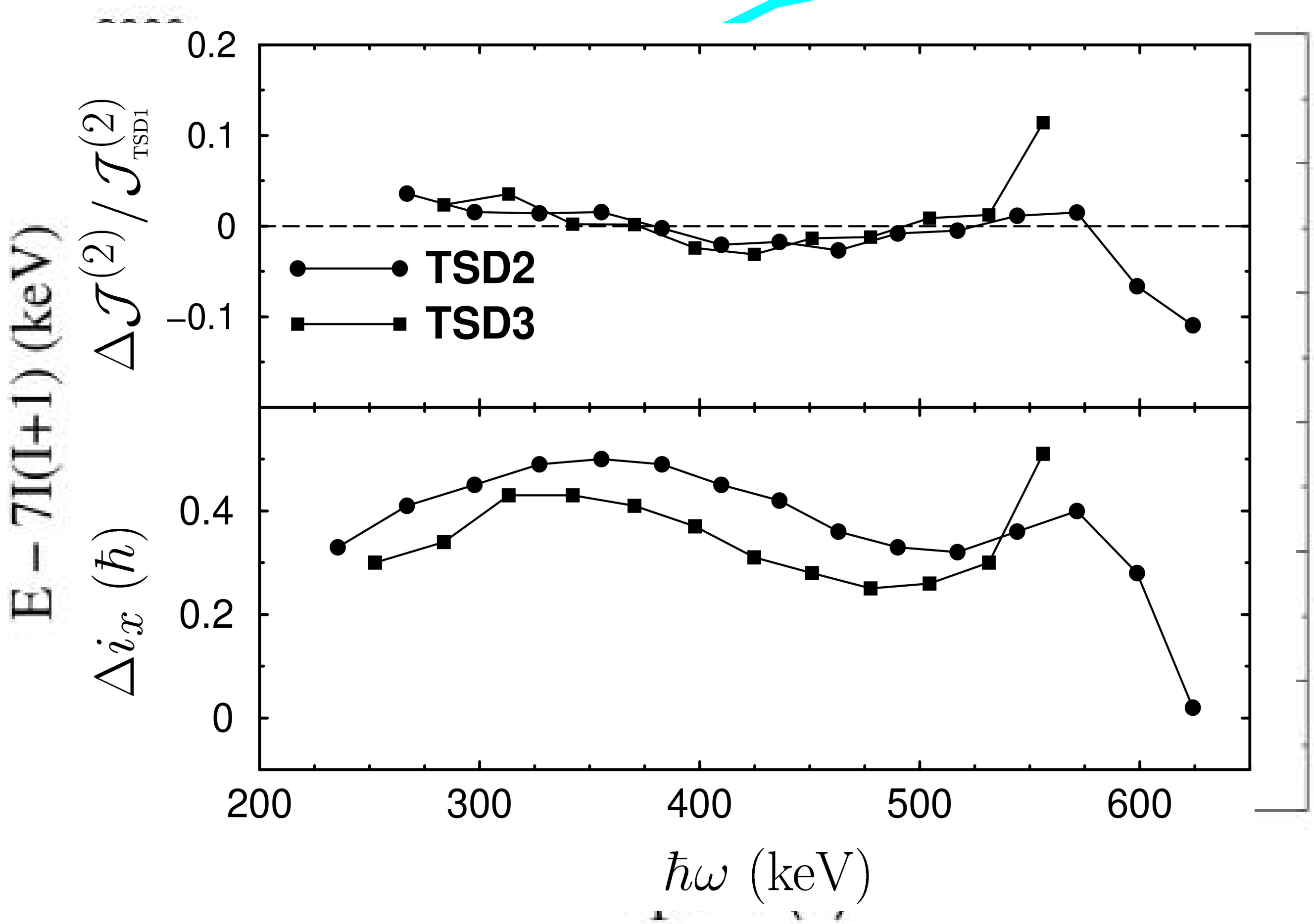
The family of wobbling bands

Theory: close to rigid moment of inertia D3 relative to TSD1



D.R. Jensen et al., Phys. Rev. Lett. **89** (2002), 142503.

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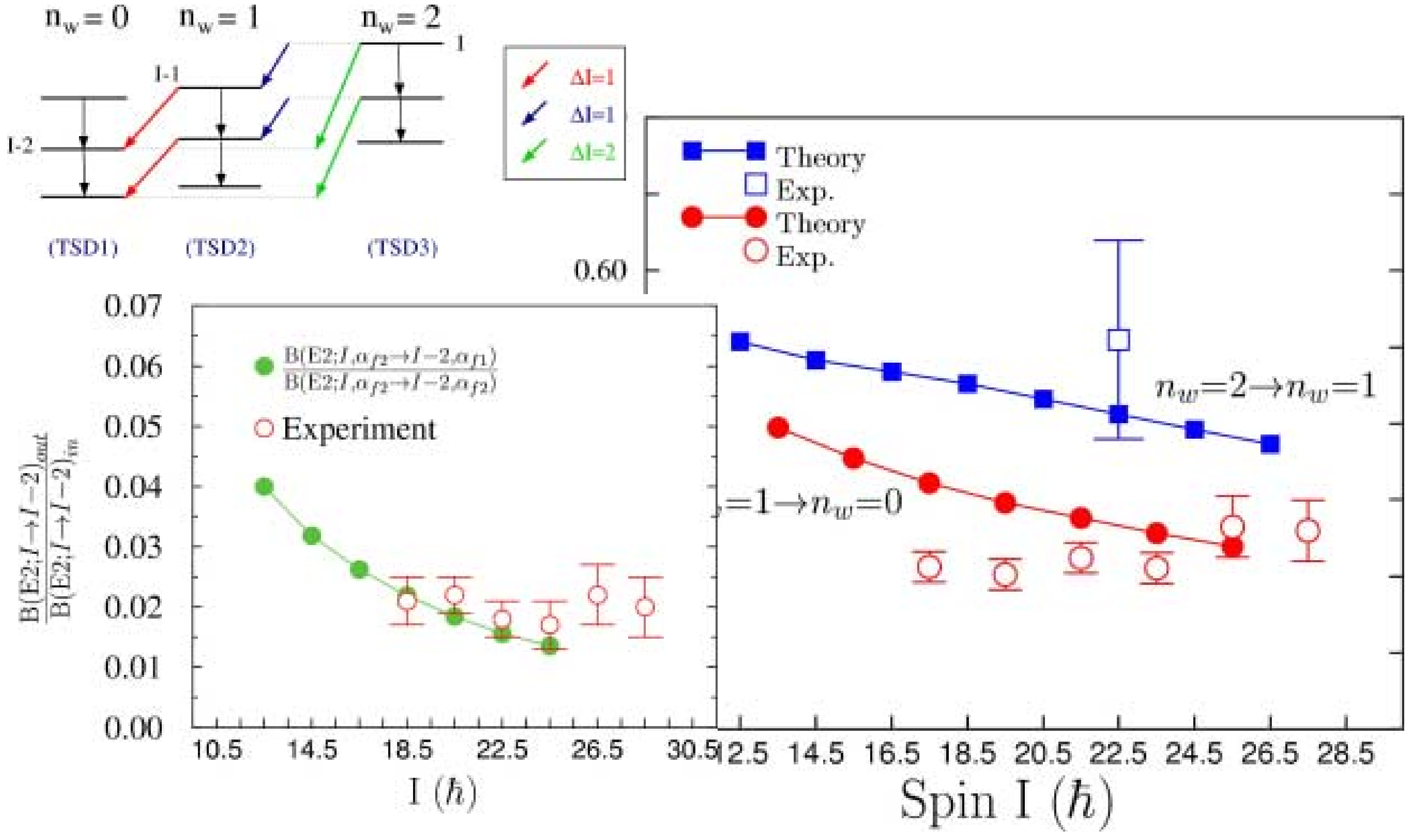
Experiment compared to theory



D.R. Jensen et al., Phys. Rev. Lett. **89** (2002), 142503.

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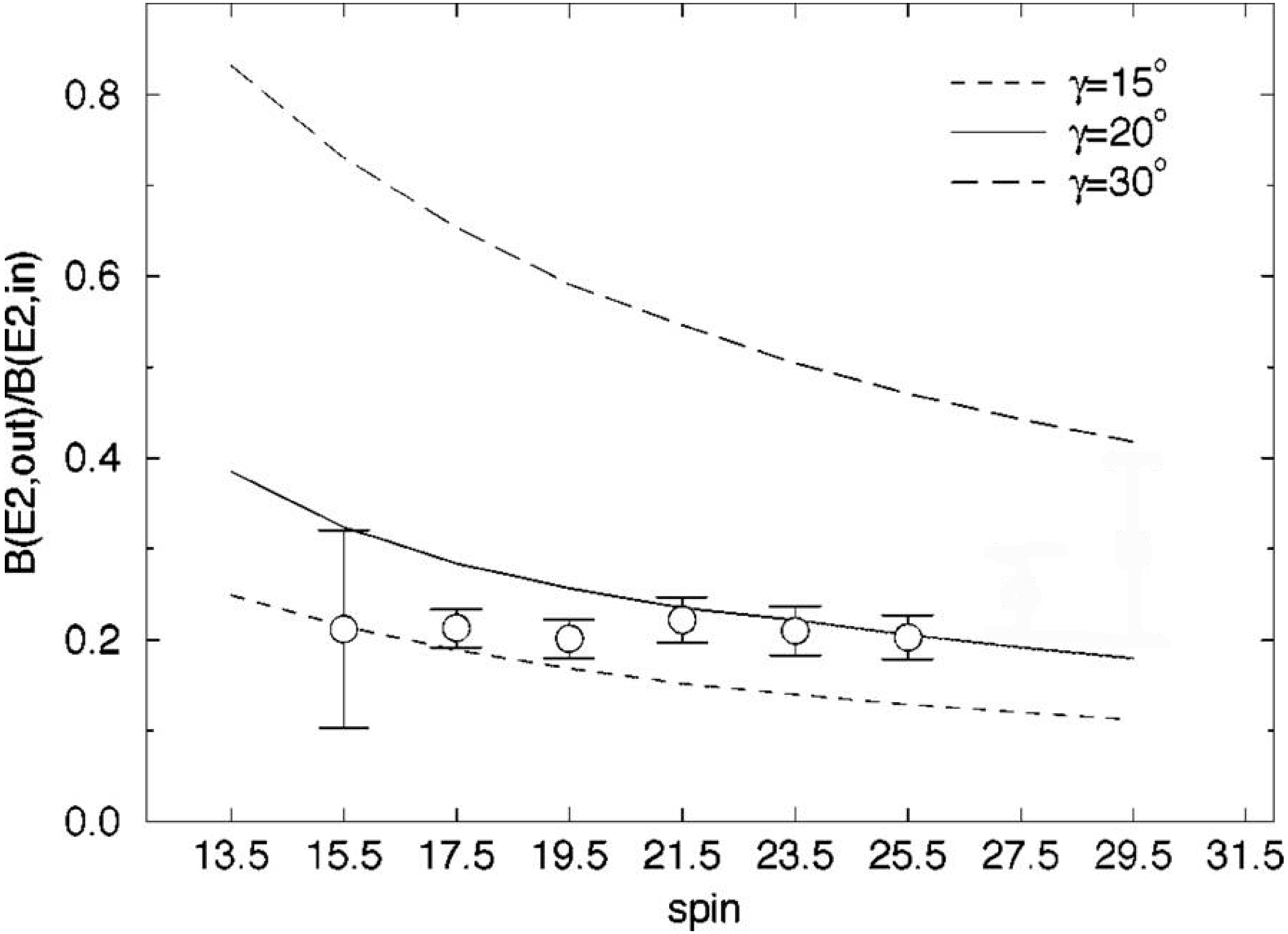
Dependence on γ



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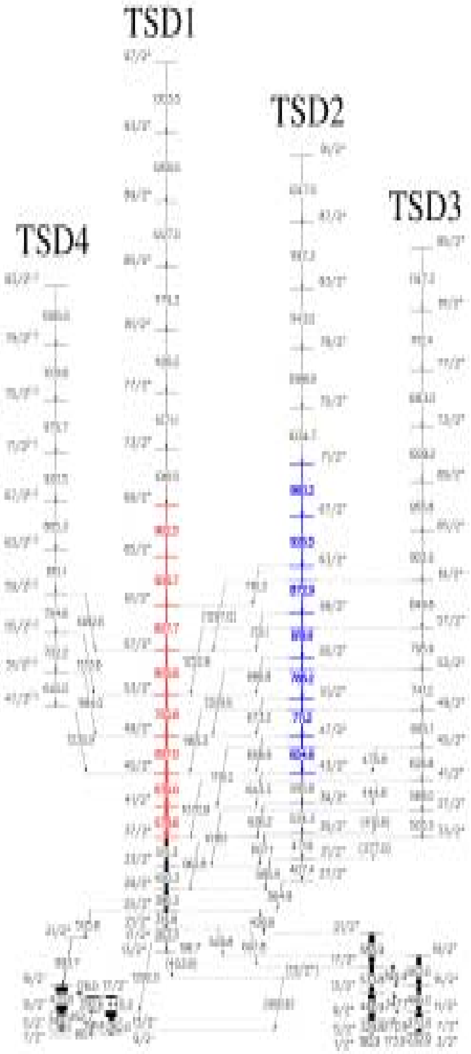
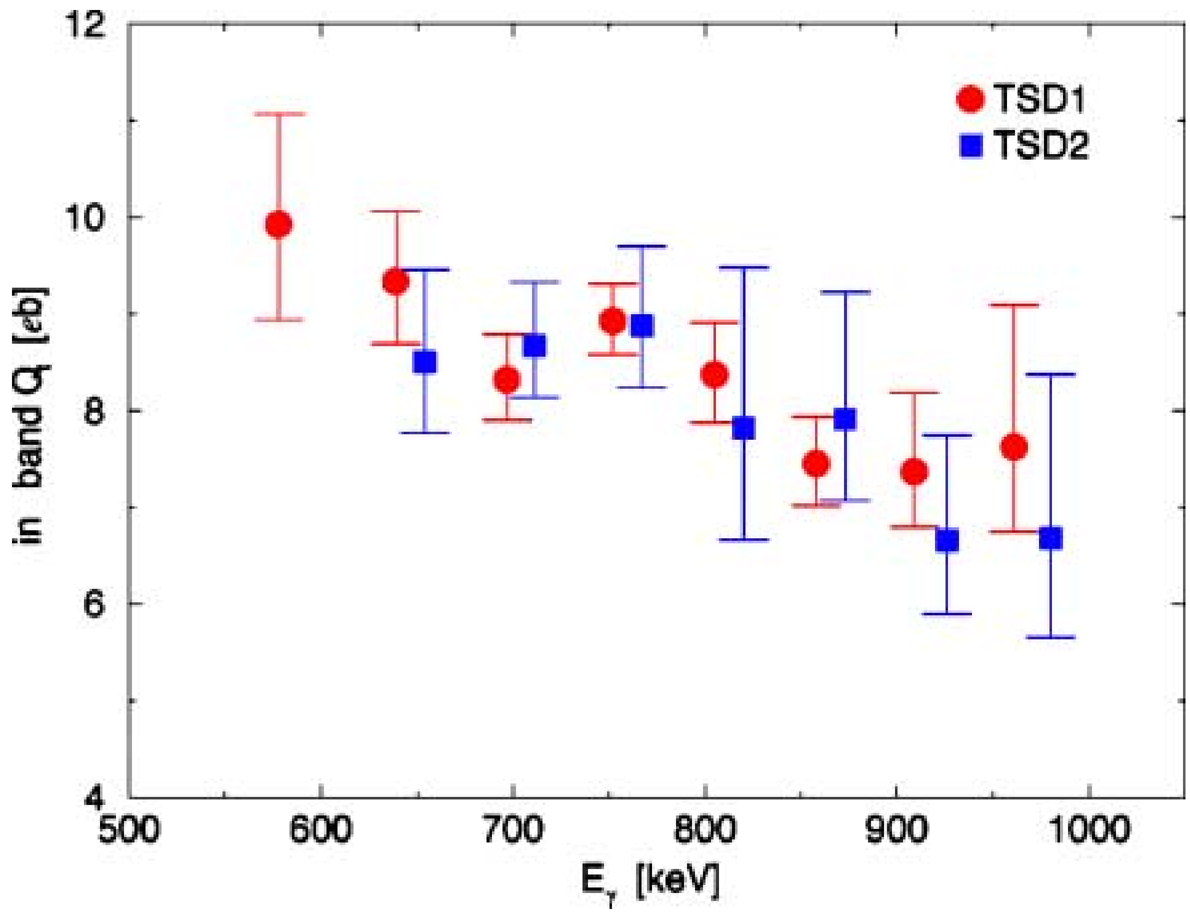
Transition quadrupole moments

A. Görgen et al., Phys. Rev. C **69** (2004), 031301R





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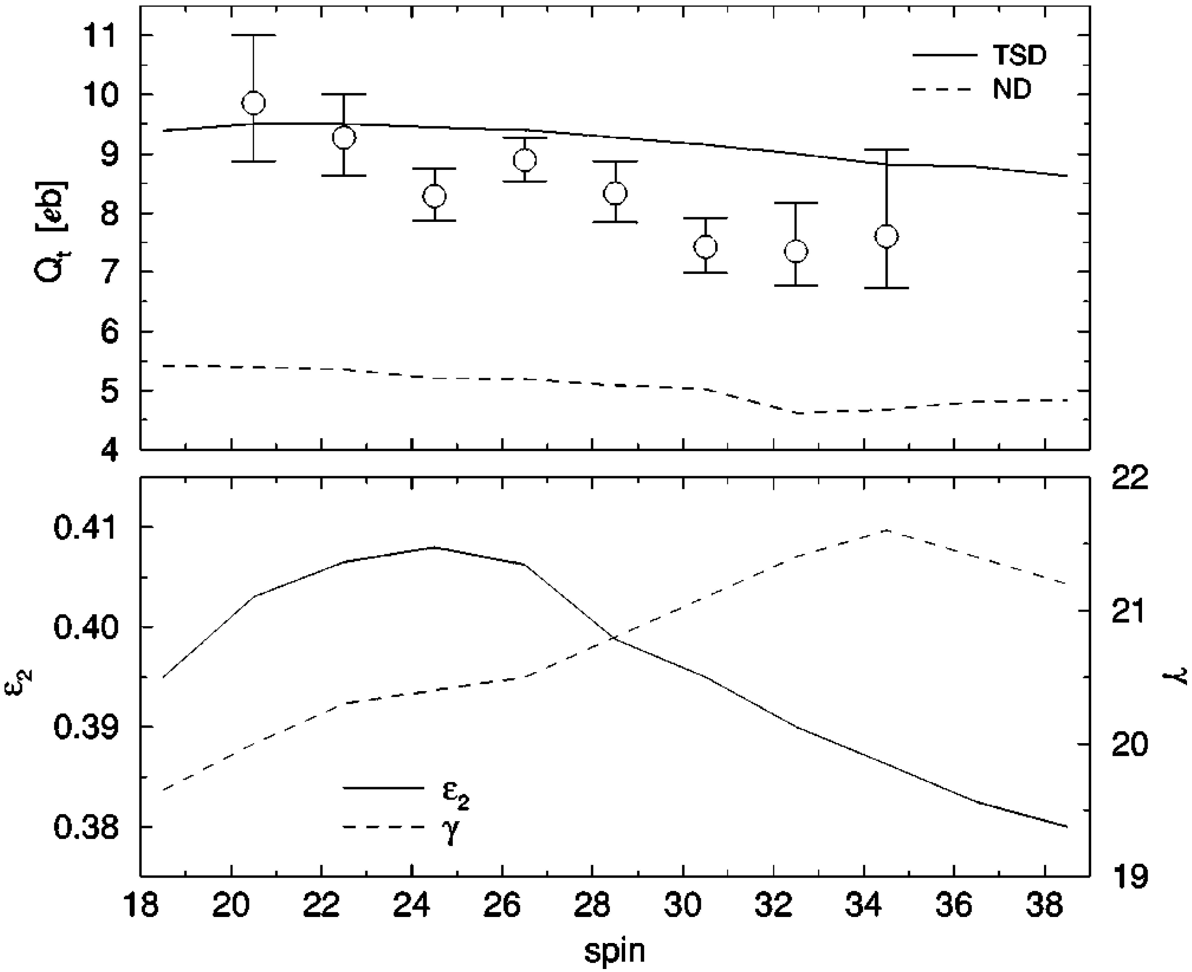
Dependence on γ



A. Görgen et al., Phys. Rev. C **69** (2004), 031301R

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Wobbling summary

Characteristic large $B(E2)_{out}/B(E2)_{in}$ values which approximately fulfill the phonon rule

Good agreement with PR calculations

The wobbling frequency, $\hbar\omega_w$, can be reproduced on average for $n_w=1$, but not the spin dependence.

The observed anharmonicity $\hbar\omega_w$ ($n_w=2$) < $\hbar\omega_w$ ($n_w=1$) can not be explained by PR calculations which only includes the $\pi i_{13/2}$ subshell coupled to the triaxial rotor

Speculation: The I dependence of in-band Q_t's together with constant $B(E2)_{out}/B(E2)_{in}$ for $n_w=1$ to $n_w=0$ as opposed to the expected 1/I dependence may be caused by a moderate increase in γ over the observed spin range.

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Neighbouring nuclei

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Triaxial bands in Lu/Hf nuclei

^{162}Hf	^{163}Hf	^{164}Hf	^{165}Hf	^{166}Hf	^{167}Hf	3 (0) 10^{-3} ^{168}Hf L	^{169}Hf	1 (0) 10^{-2} ^{170}Hf
2 (0) ^{161}Lu W?	3 (0) ^{162}Lu	6 (4) 10^{-1} ^{163}Lu W W L	8 (2) 10^{-1} ^{164}Lu L	5 (2) 10^{-2} ^{165}Lu W (W) L	^{166}Lu	5 (3) 10^{-2} ^{167}Lu W	1? (1) 10^{-2} ^{168}Lu	^{169}Lu

7 (0) ^{174}Hf L	1?(1) ^{175}Hf

6 (4) 10^{-1} ^{163}Lu W W L

- Number of TSD bands observed
- Number of TSD bands connected to ND
- Order of strength relative to yrast
- Wobbling phonon excitations
- Lifetimes measured

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Wobbling excitations in the region

[165]Lu: Euroball, 2002

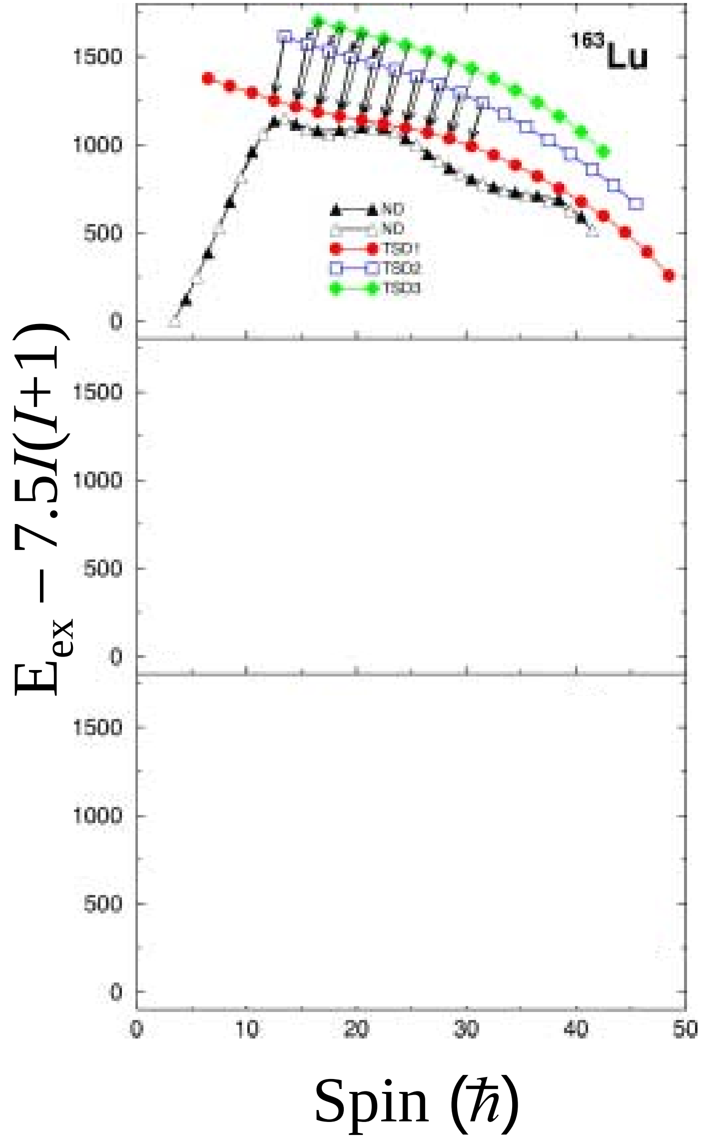
A one-phonon wobbling excitation has been firmly established, and presumably also a second-phonon band.

G. Schönwasser et al., Phys. Lett. B **552** (2003), 9.

[167]Lu: Gammasphere, 2000

A one-phonon wobbling excitation has been firmly established.

H. Amro et al., Phys. Lett. B **553** (2003), 197.



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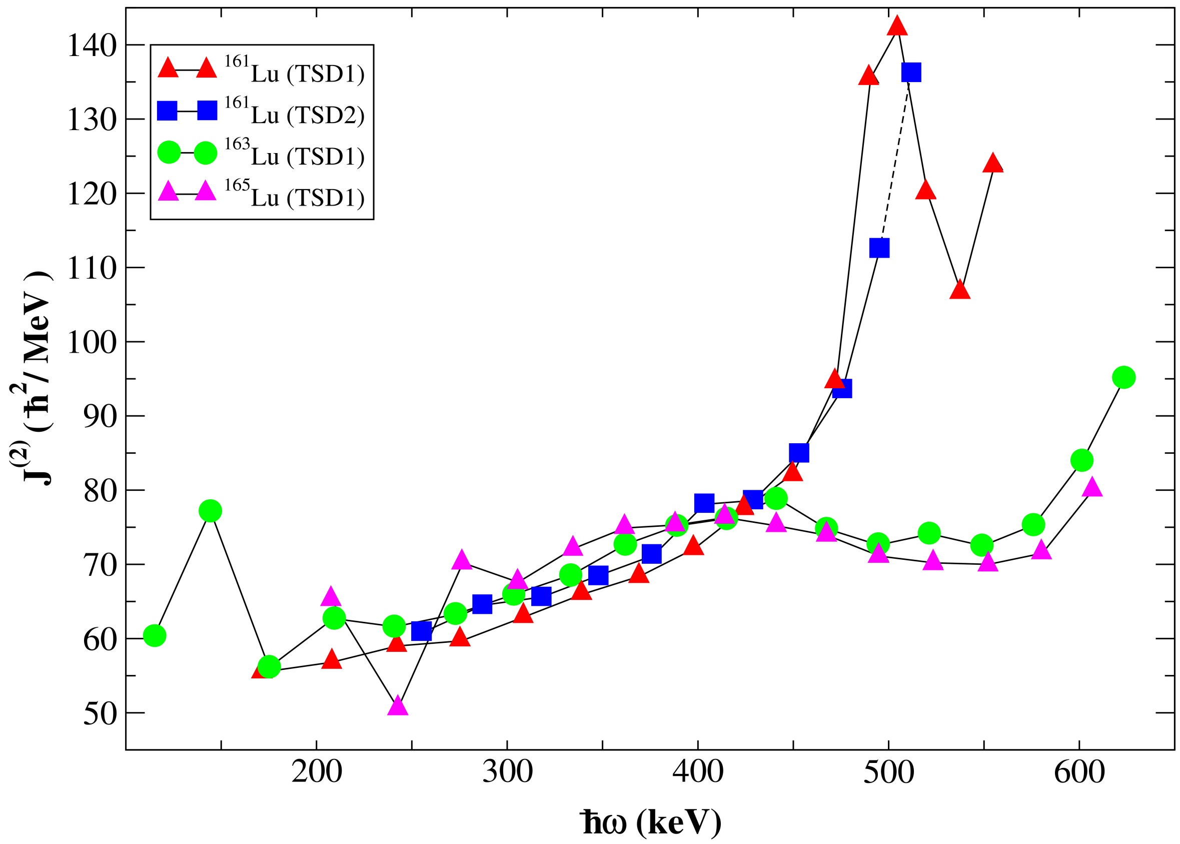
TSD in ^{161}Lu



P. Bringel et al., Eur.Phys. J. A **16** (2003), 155. (*GASP data*)
P. Bringel et al., to be published. (EUB data)

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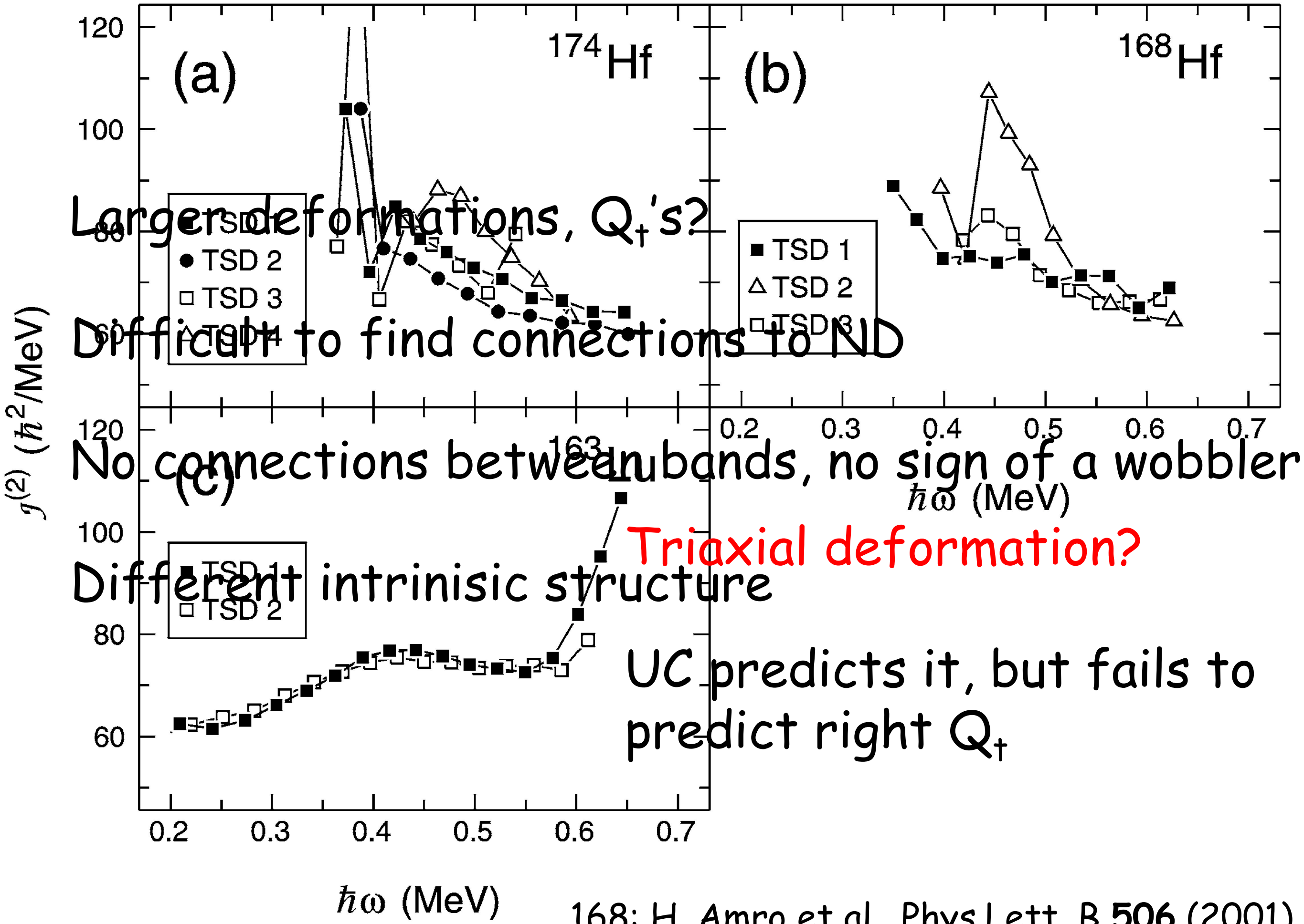
TSD in Hafnium?



Larger deformations, Q_t's?

Difficult to find connections to ND

No connections between bands, no sign of a wobbler

Triaxial deformation?

Different intrinisic structure

UC predicts it, but fails to predict right Q_t

168: H. Amro et al., Phys.Lett. B **506** (2001) 39.
174: M. Djongolov et al., Phys.Lett. B **560** (2003) 24.

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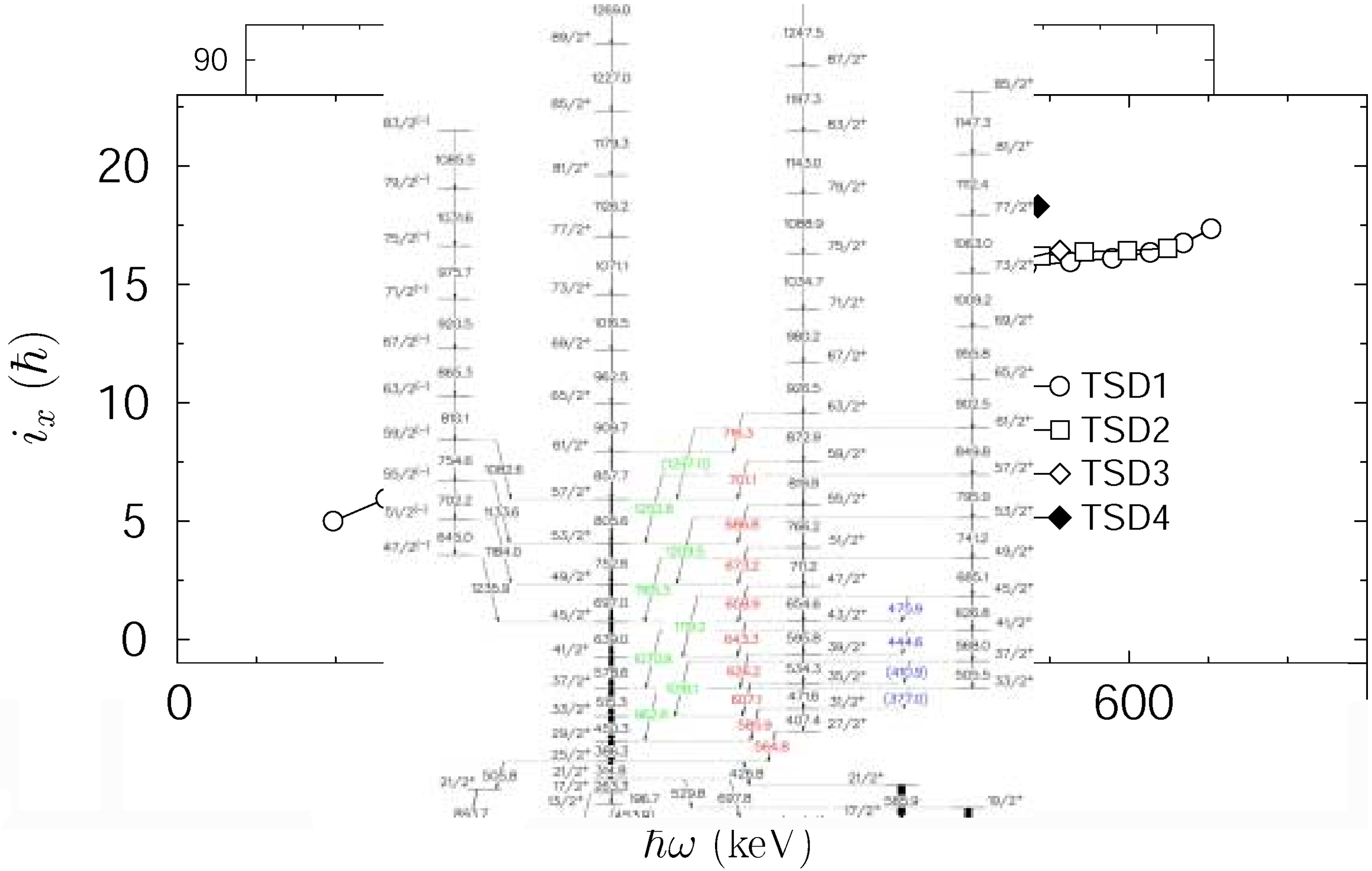
Other configurations and signature partners

^{163}Lu: TSD 4 is not a member of the wobbling family of bands.



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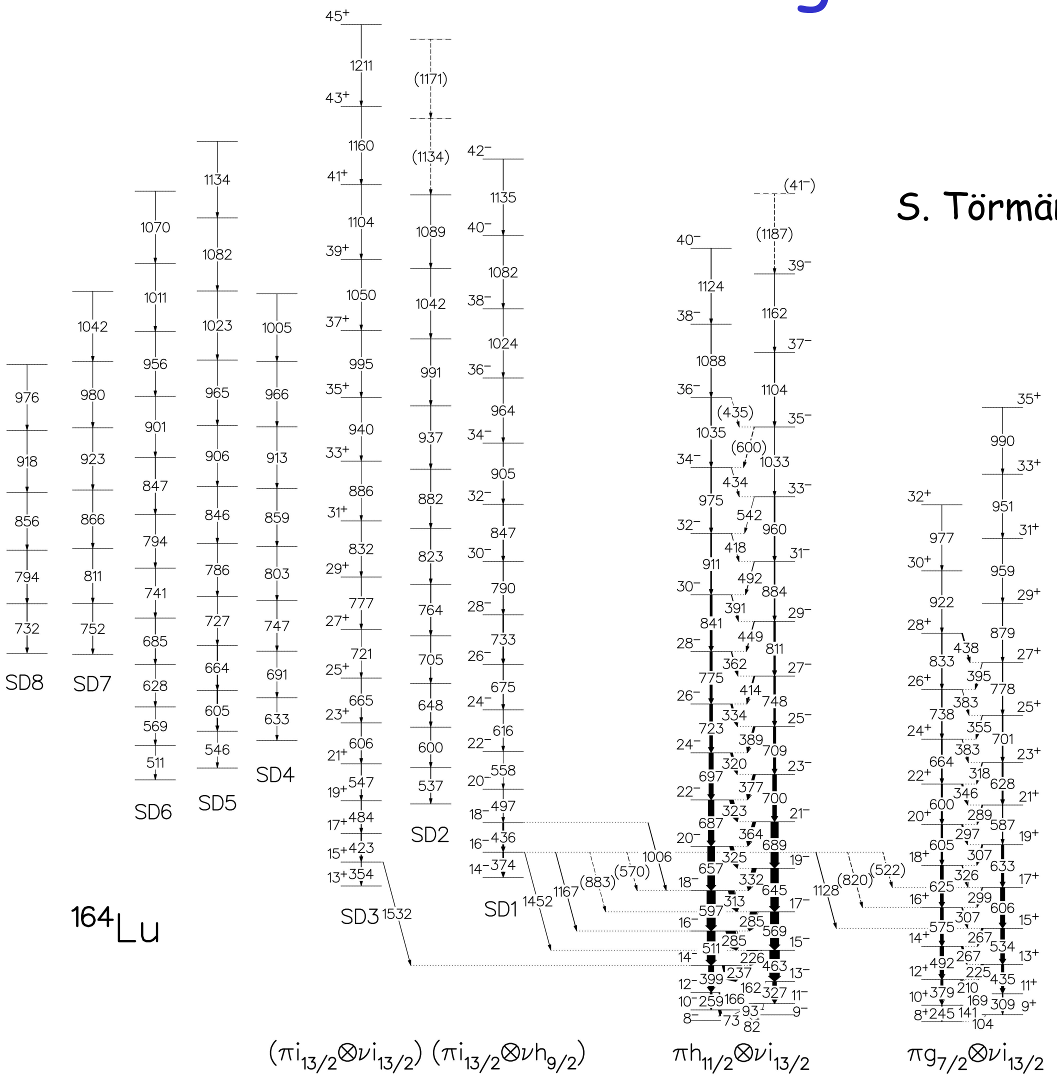
Other configurations and signature partners



S. Törmänen et al., Phys.Lett. B **454** (1999) 8.

^{164}Lu:

Only two of the eight bands have an assignment. Possible signature partners and wobbling bands.

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Studying the quasi continuum

The number of two step paths along the TSD ridge (number of TSD bands) in 163Lu gated on TSD (red) and ND (blue) transitions.

Performed an analysis of the fluctuation of counts

in

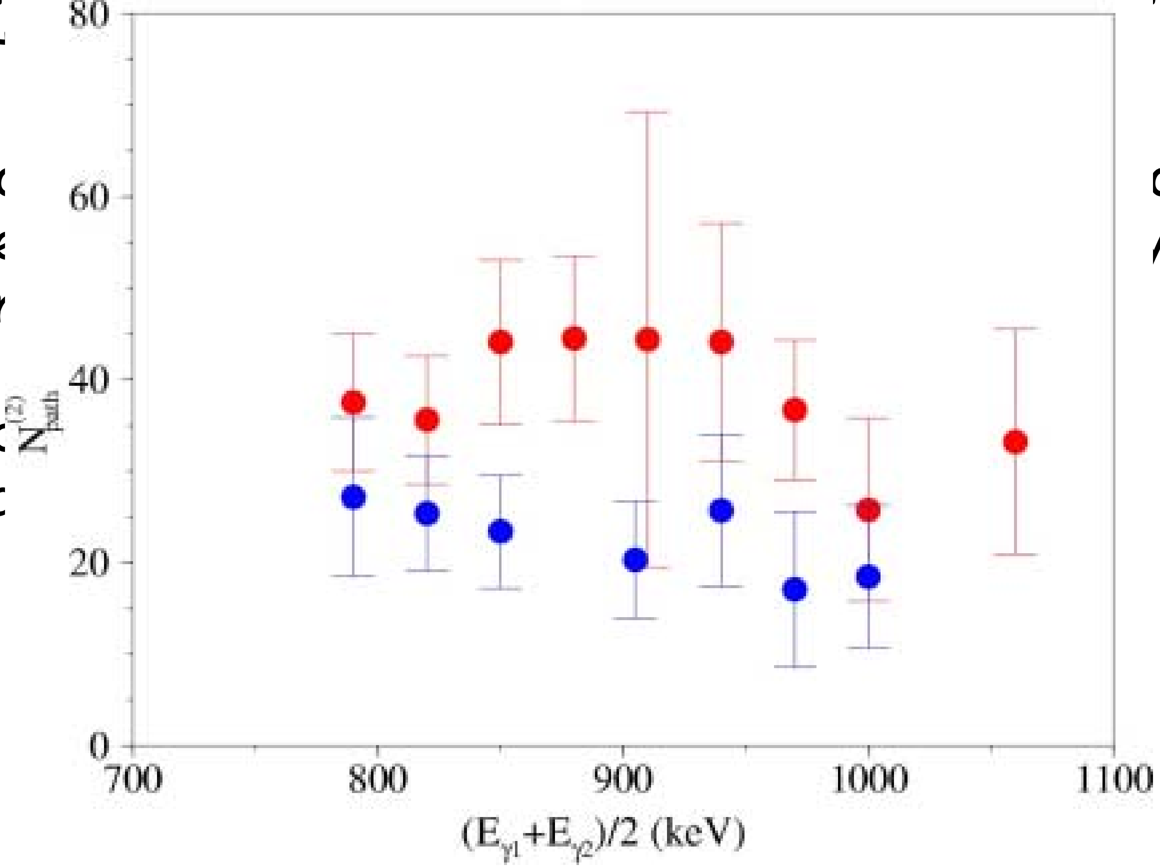
Loc ... on

the ... y

cor

Dic

trc



S.W. Ødegård et al., Eur. Phys. J. A **14** (2002) 309.

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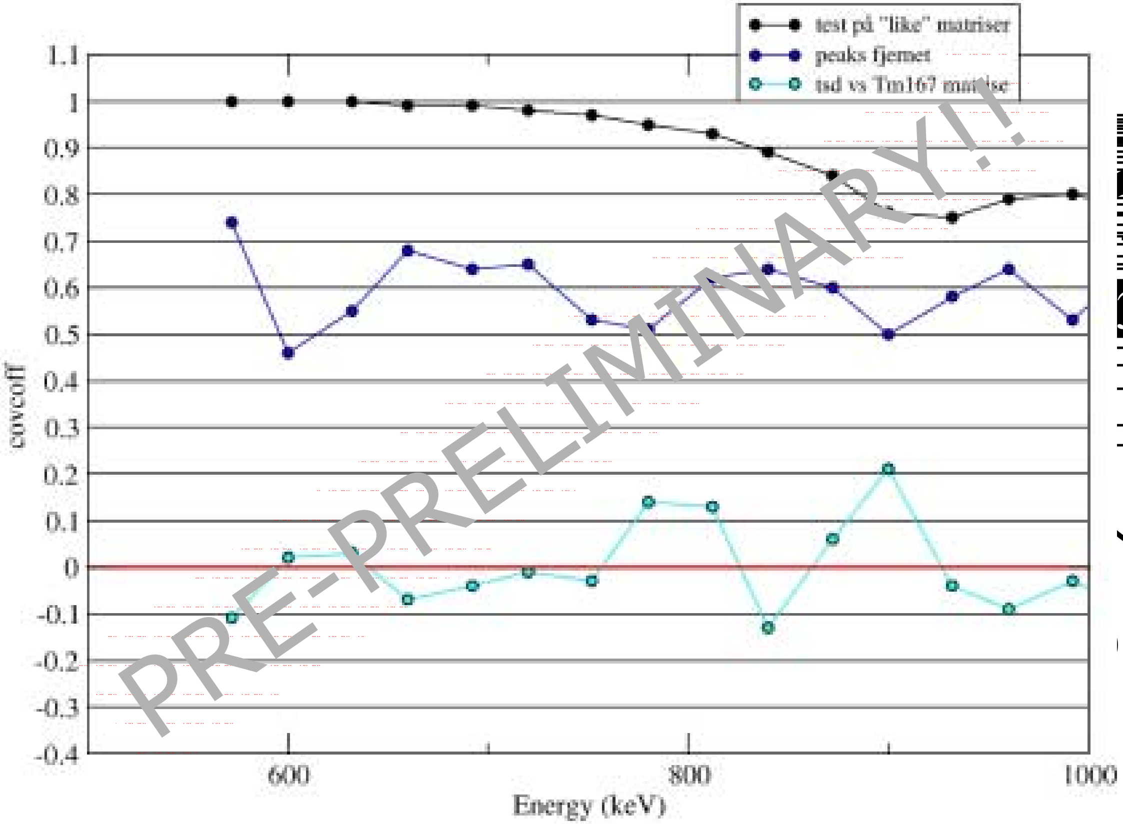
Studying the quasi continuum

The Covariance analysis measures the "similarity" of the two gated matrices

Result: Approx. 40 TSD bands feed the TSD yrast while approx. 20 TSD bands feed the ND states.



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The role of AGATA

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AGATA

- The necessary information to understand triaxiality and its effects is found in the details.
- Need energy, presice angle and interaction points for each γ detected.
- Need to pick out the correct γ's of interest (which are very weak within the reaction channel)
- Need to find and understand linking transitions
- To explore the boundaries of this mass region and to find stable triaxiality in other mass regions.
- AGATA does have a mission, even with stable beams

Triaxiality and Wobbling with AGATA

The bottom line

- The Lu-Hf region is rich in strongly deformed triaxial band structures coexisting with normal deformed structures
- The triaxiality is proven by the observation of the one- (and two-phonon wobbling excitation) in several nuclei
- New experimental results lead to new questions. There is still a lot to learn and understand
- Agata is a tool with the sensitivity needed to further probe and reveal the nature of triaxiality in nuclei

Collaborating institutions

NBI, Univ. of Copenhagen
Univ. Of Oslo
Univ. of Lund
Univ. of Bonn
Univ. of Milano
Univ. of Padova
INFN, Legnaro
Univ. of Camerino
Inst. of Nucl. Phys, Krakow

Univ. of Liverpool
Univ. of Paisley
Argonne Natl. Lab
Mississippi State Univ.
Univ. of Tennessee
LBL Berkeley
IReS Strasbourg
Yale Univ.