Quadrupole Moments of Wobbling Excitations in ^{163}Lu

Andreas Görgen et al.

talk by

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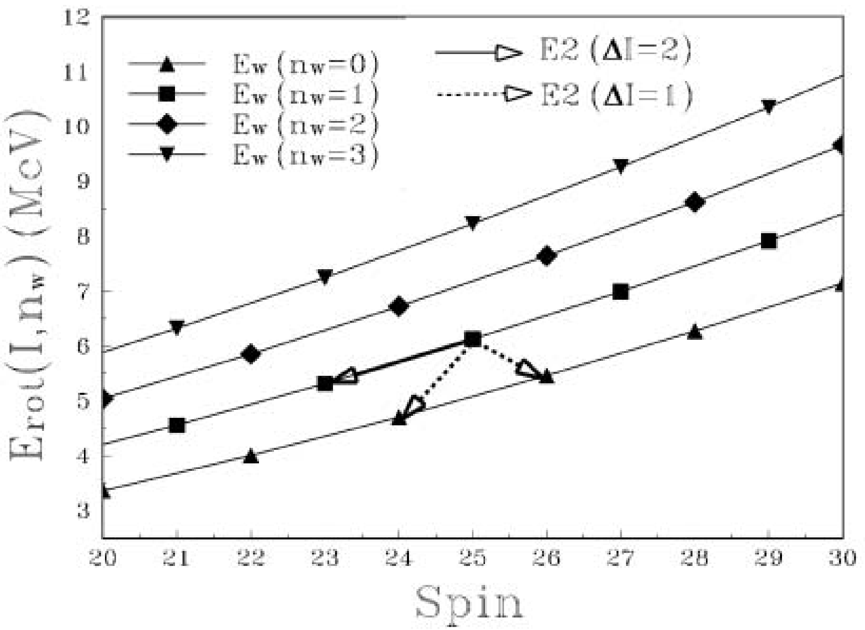
Wobbling:

Bohr and Mottelson:

triaxiality: $\mathcal{J}_X > \mathcal{J}_Y > \mathcal{J}_Z$

high spin: $I \approx I_X >> 1$

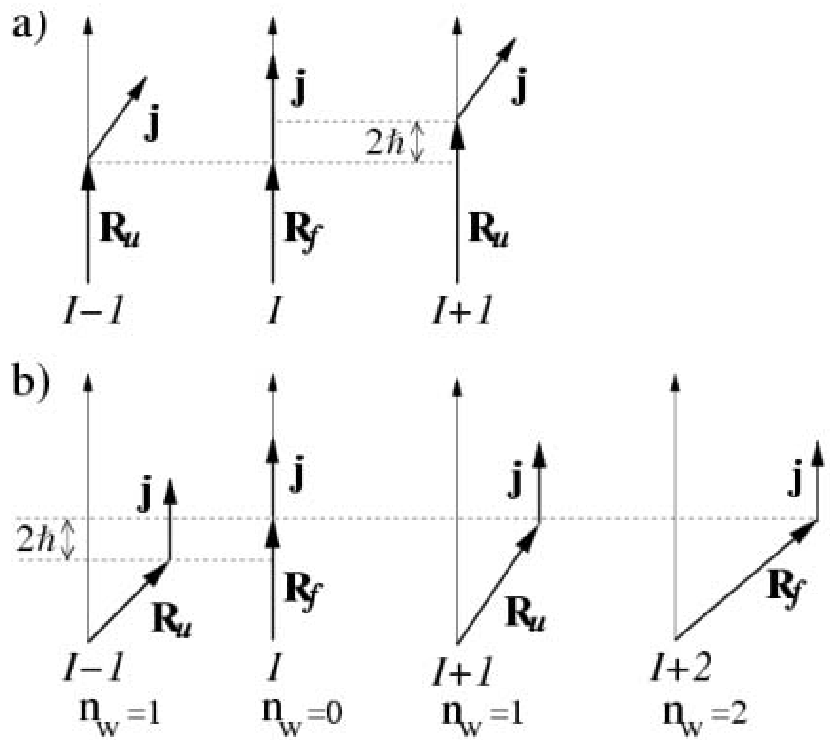


$$E_R(I,n_w) = \frac{I(I+1)}{2\mathcal{J}_X} + h\omega_w(n_w + 1/2)$$

$$\hbar\omega_w = \frac{I}{\mathcal{J}_x}\sqrt{\frac{(\mathcal{J}_x - \mathcal{J}_y)(\mathcal{J}_x - \mathcal{J}_z)}{\mathcal{J}_y \mathcal{J}_z}}$$

Wobbling with high-j aligned particles:

"cranking scenario"

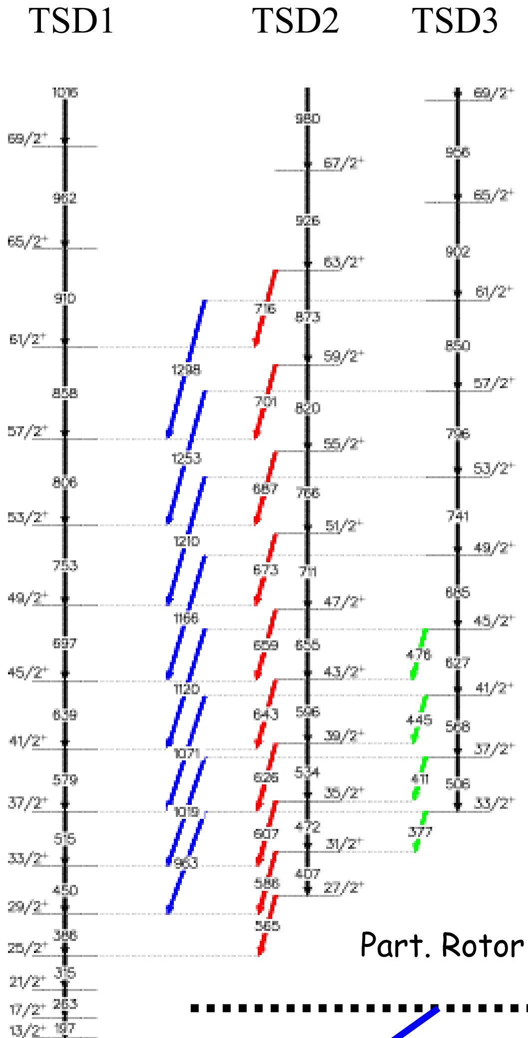


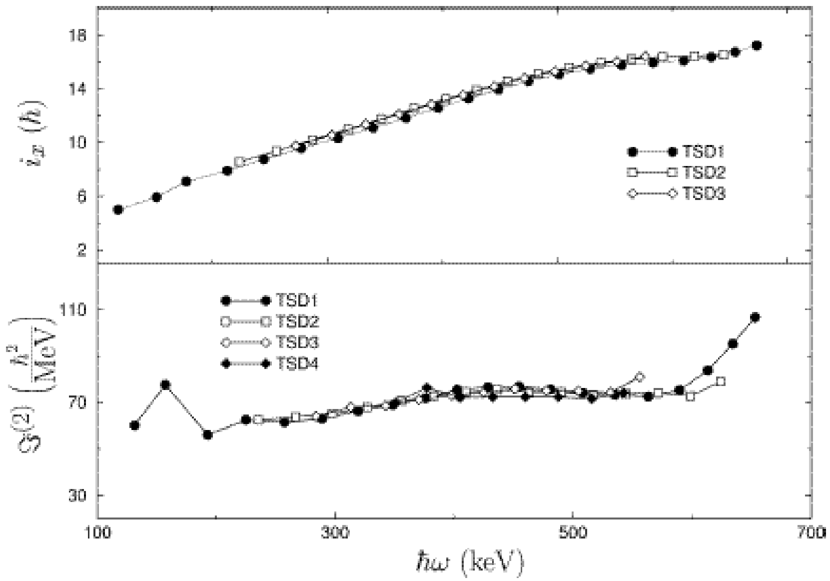
"wobbling scenario"

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

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

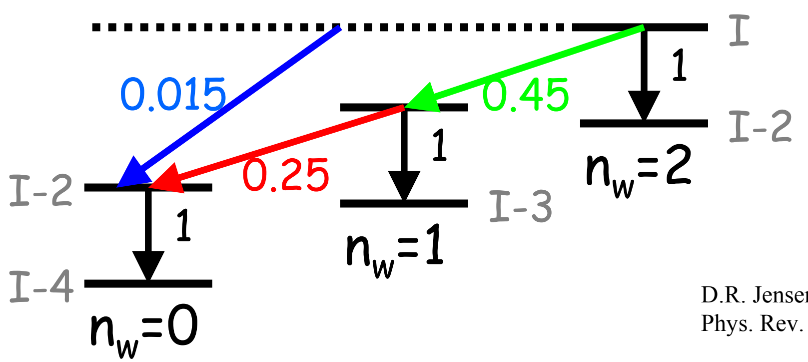
Evidence for the wobbling mode in ^{163}Lu

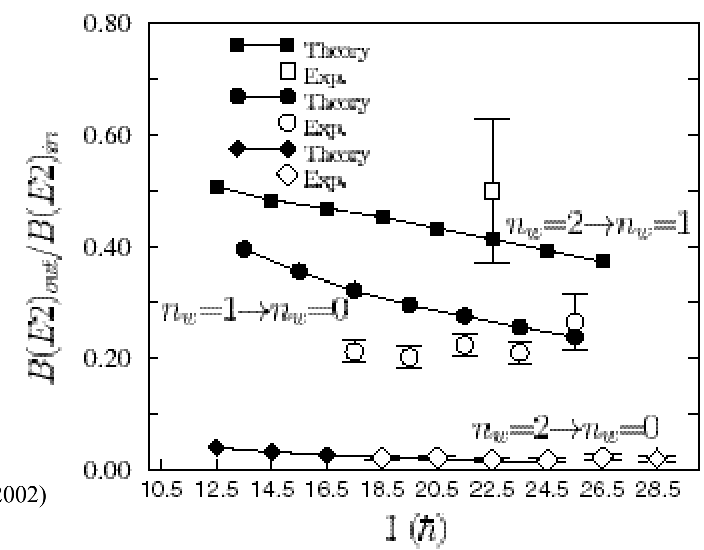




$B(E2;n_w,I \rightarrow n_w-1,I-1) \propto n_w/I$

Part. Rotor calc., B(E2)'s





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

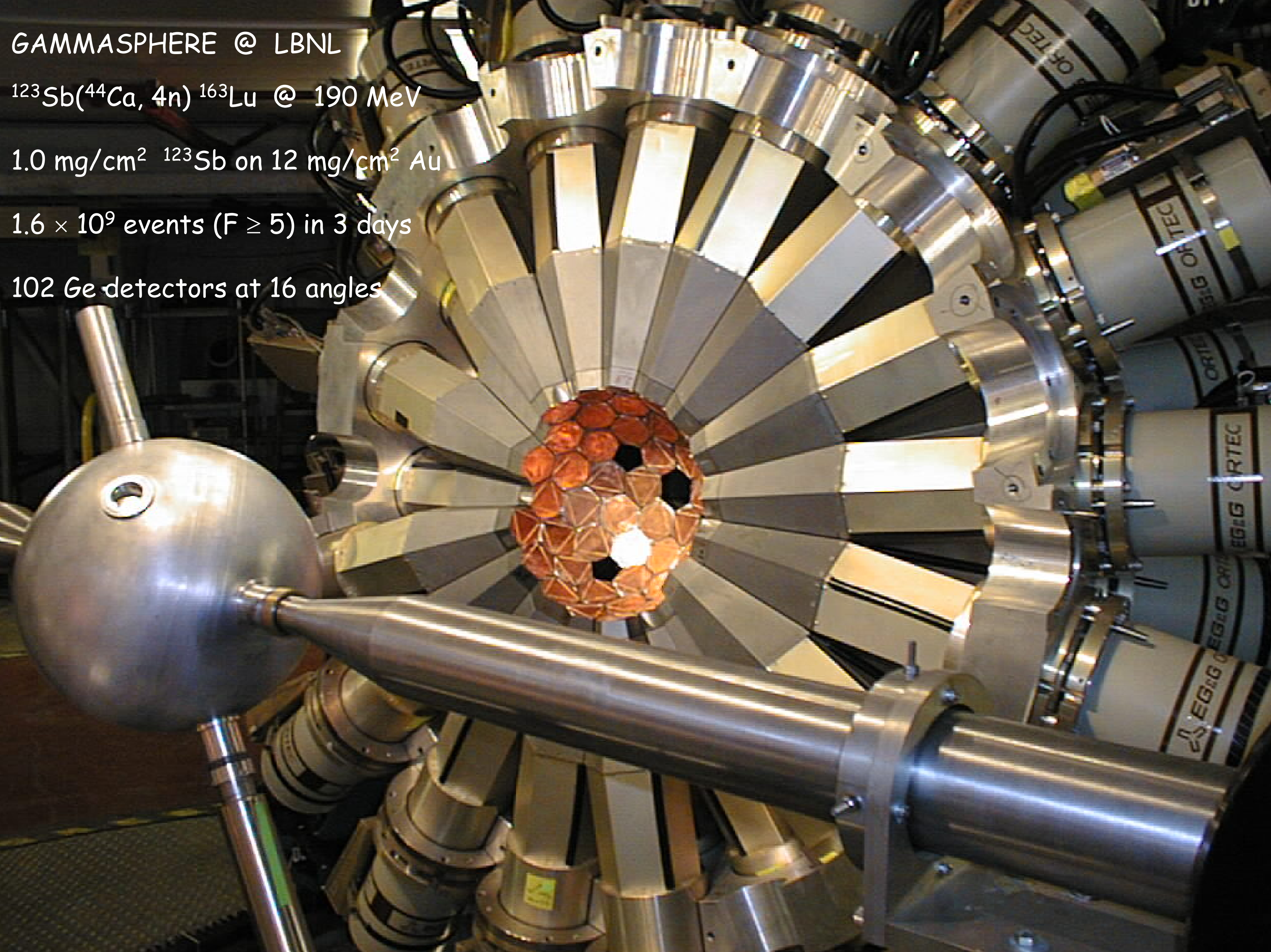
GAMMASPHERE @ LBNL

^{123}Sb(^{44}Ca, 4n) ^{163}Lu @ 190 MeV

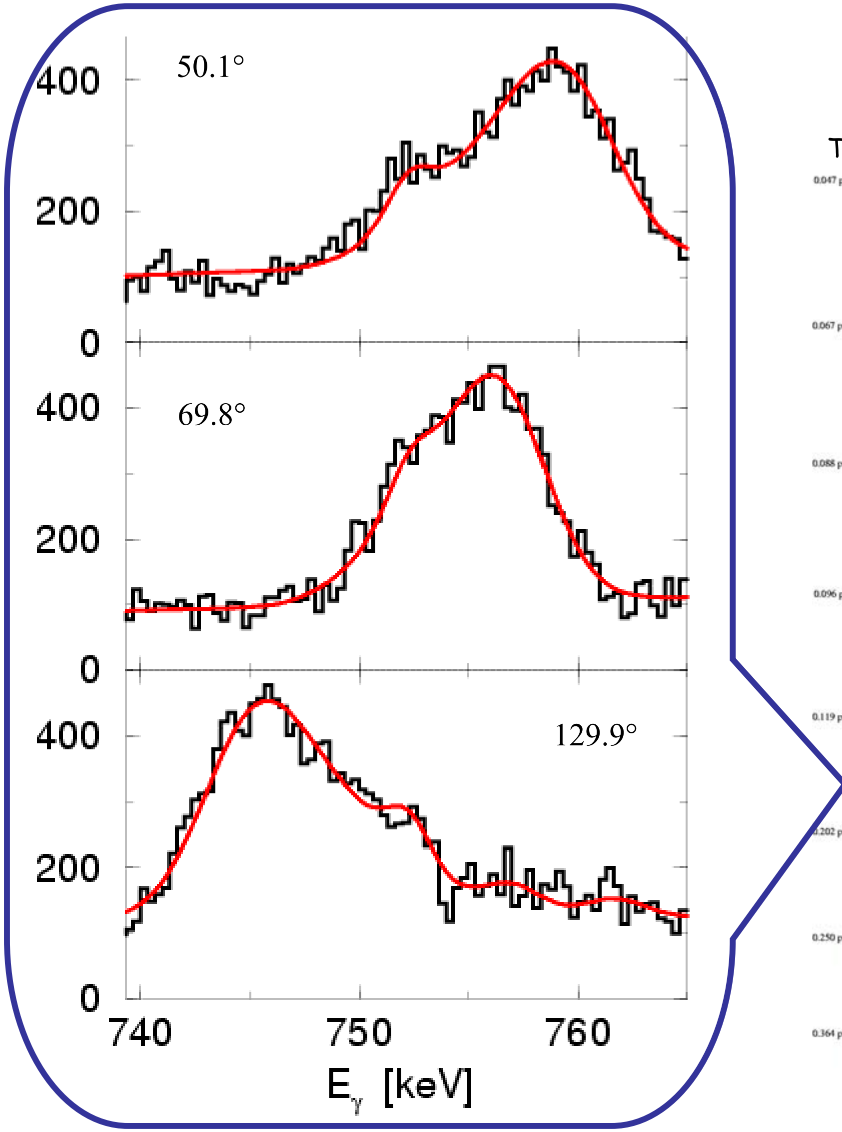
1.0 mg/cm^2 ^{123}Sb on 12 mg/cm^2 Au

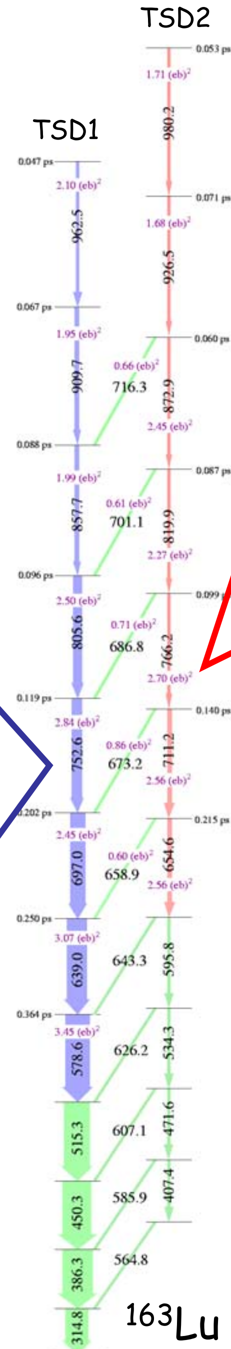
1.6 $\times$ 10^9 events (F $\geq$ 5) in 3 days

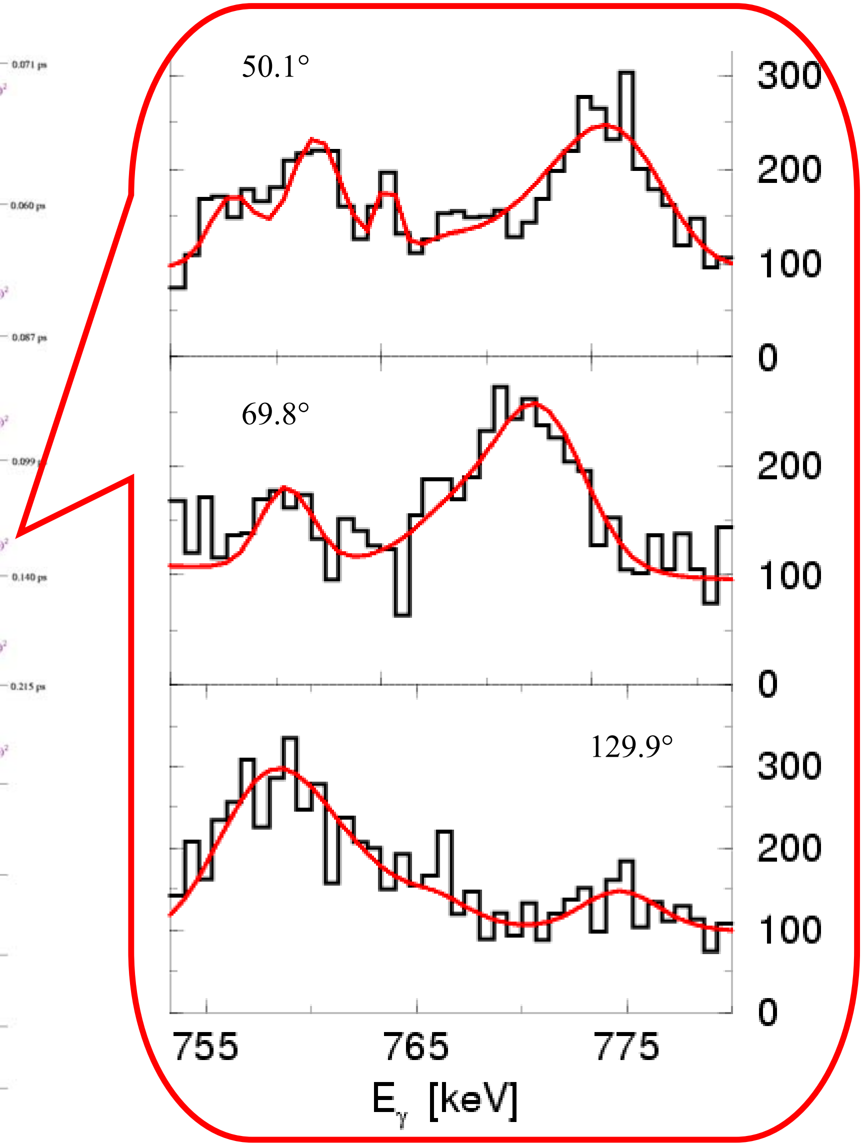
102 Ge detectors at 16 angles



DSAM lineshape analysis

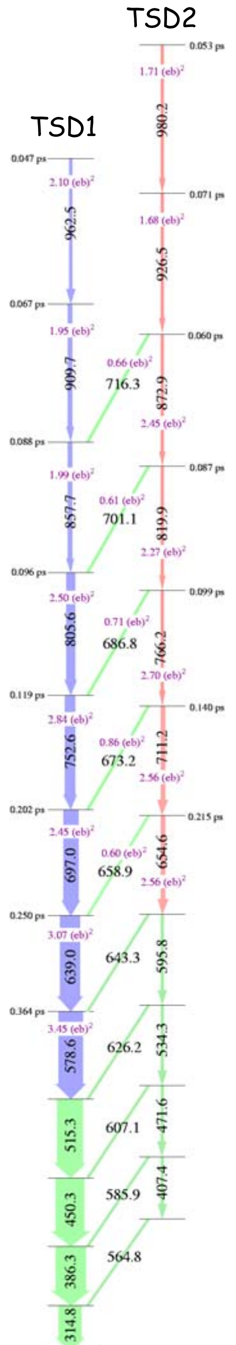






Lifetimes measured for

- 8 states in TSD1
- 7 states in TSD2



We know:

This measurement:

- total transition probabilities $\lambda_{tot}=1/\tau$
- for TSD1: $B(E2;in) = B(E2;\, n_w=0, I \rightarrow n_w=0, I\text{-}2)$

Thin target experiments at Euroball:

- branching ratios $\lambda_{out}/\lambda_{in}$

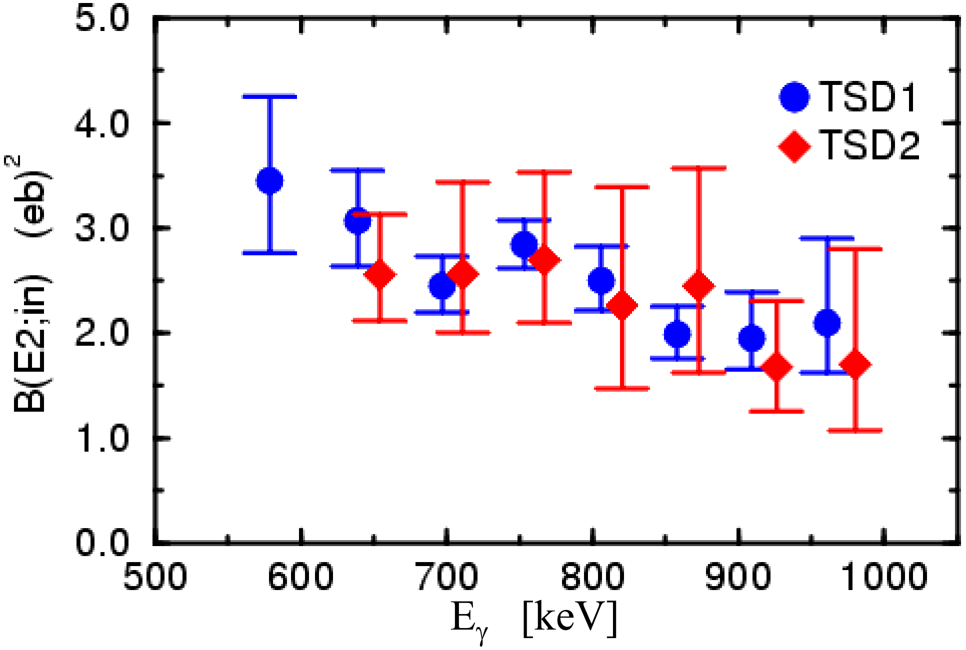
  $\Rightarrow$ for TSD2: $B(E2;in) = B(E2;\, n_w=1, I \rightarrow n_w=1, I\text{-}2)$
- mixing ratio δ (from DCO/lin. polarization)

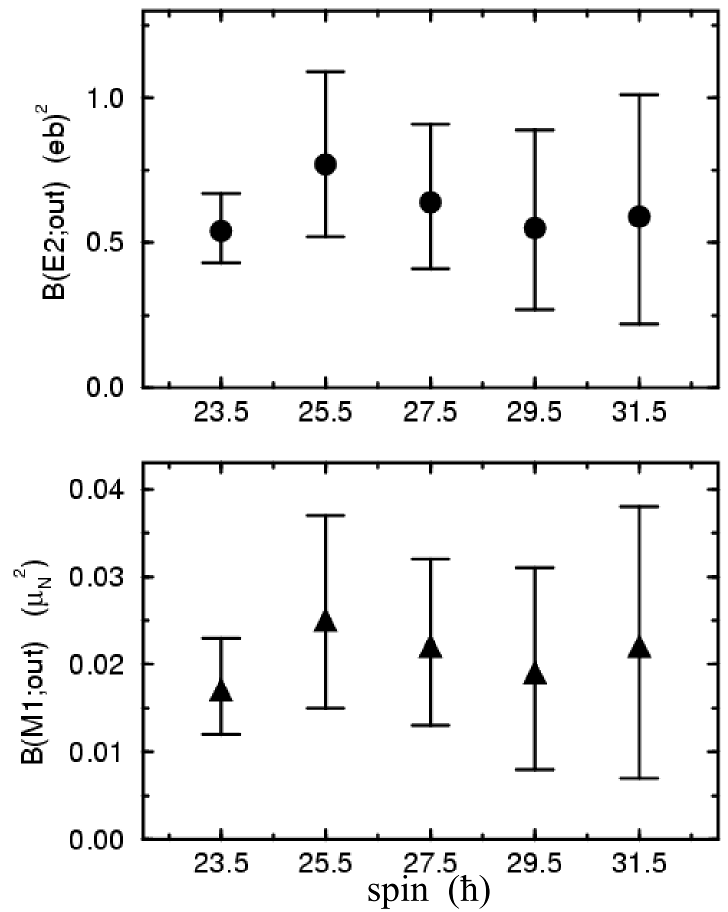
  $\delta = -3.10^{+0.36}_{-0.44}$ $\Rightarrow$ 90% E2 and 10% M1

  $\Rightarrow$ $B(E2;out) = B(E2;\, n_w=1, I \rightarrow n_w=0, I\text{-}1)$

  $\Rightarrow$ $B(M1;out) = B(M1;\, n_w=1, I \rightarrow n_w=0, I\text{-}1)$

transition strengths





in-band transitions:

- B(E2)'s very similar for TSD1 and TSD2
- both show a decrease

inter-band transitions:

- B(E2)'s and B(M1)'s are ~constant (with large errors)

What can we learn ?

How to extract a quadrupole moment from a B(E2)

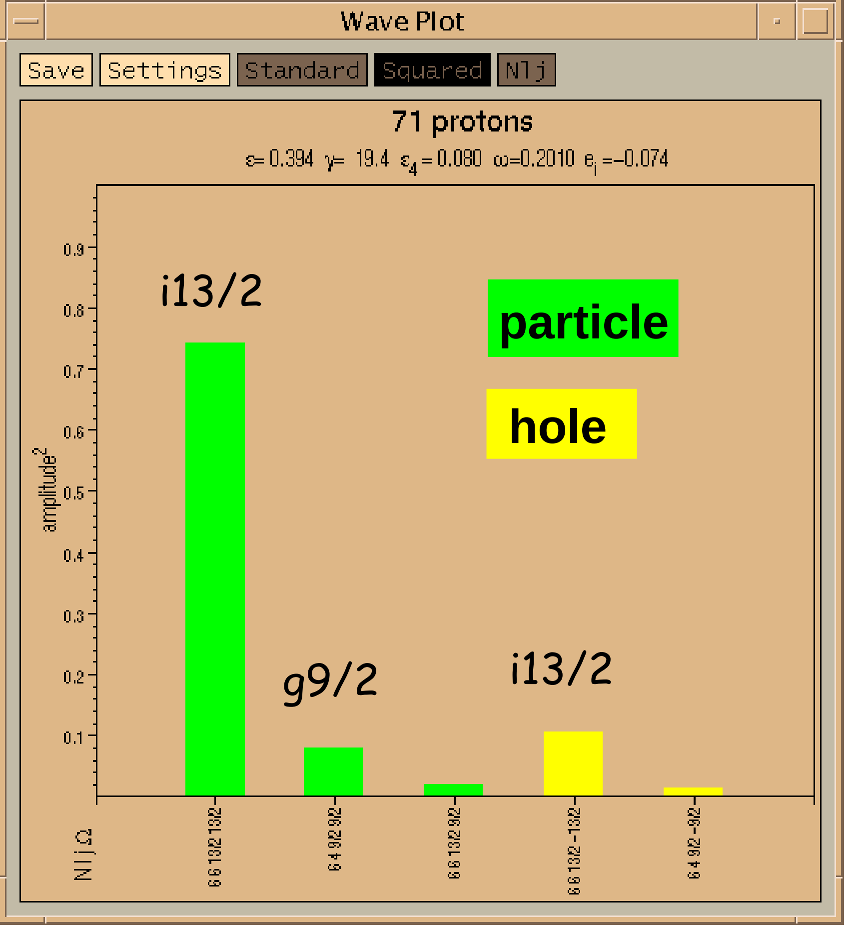
axial symmetric nuclei: $B(E2) = \frac{5}{16\,\pi}\,(eQ)^2\,\langle\, I_i\, K\, 2\, 0\, |\, I_f\, K\,\rangle^2$

K is not a good quantum number in a triaxial nucleus

we have to use a distribution of different K values:

$$B(E2) = \frac{5}{16\,\pi}\,(eQ)^2 \sum_K C^2_K\,\langle\, I_i\, K\, 2\, 0\, |\, I_f\, K\,\rangle^2$$

How do we get the coefficients C^2_K ?



Ultimate Cranker:

"pure" $i_{13/2}$ configuration

aligned with rotational axis

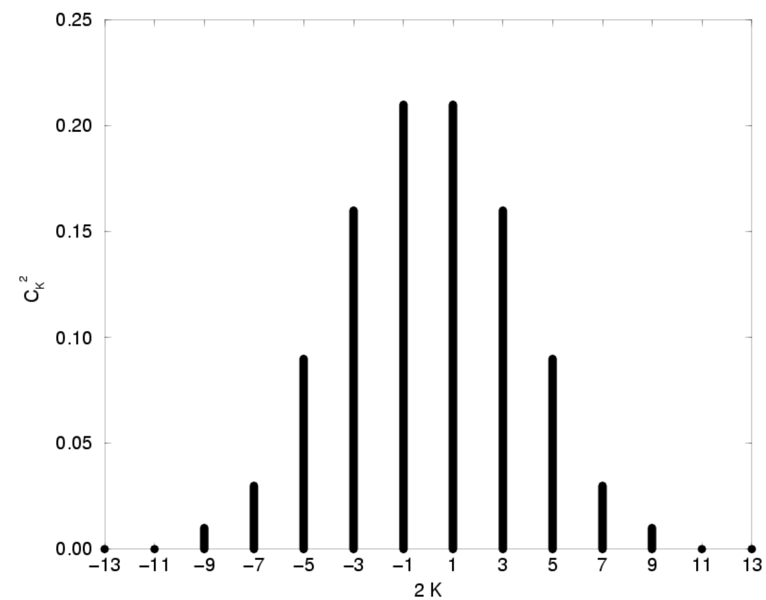
$\Downarrow$

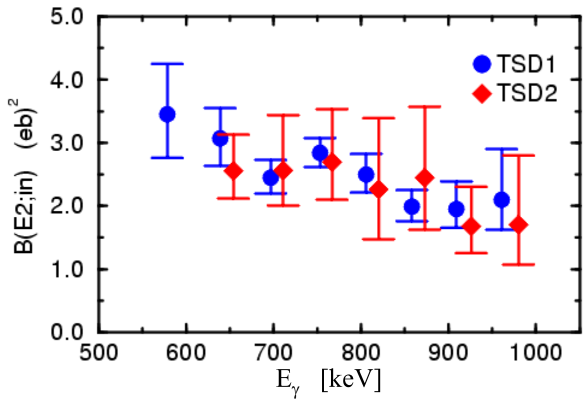
geometric problem

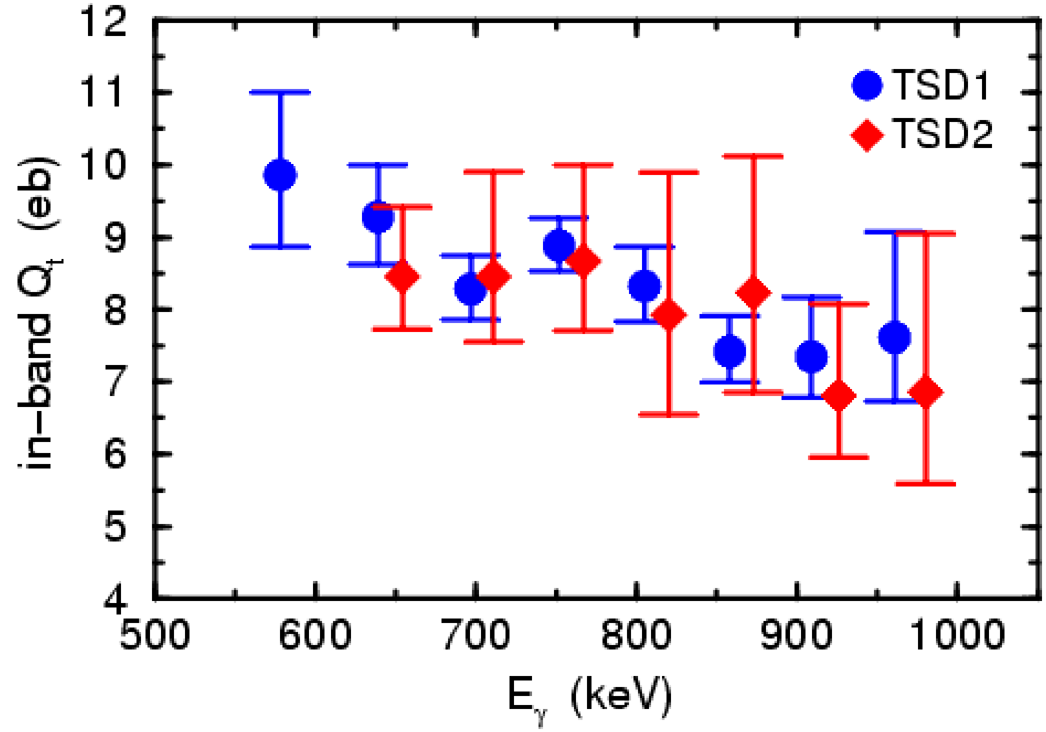
$\Rightarrow$ C^2_K from Wigner's D-functions

$D^j_{jK}\,(\,0,\,\pi/2,\,0\,)$ with $j = 13/2$

$$B(E2) = \frac{5}{16\,\pi}\,(eQ)^2 \sum_K C^2_K\,\langle\, I_i\,K\,2\,0\,|\,I_f\,K\,\rangle^2$$







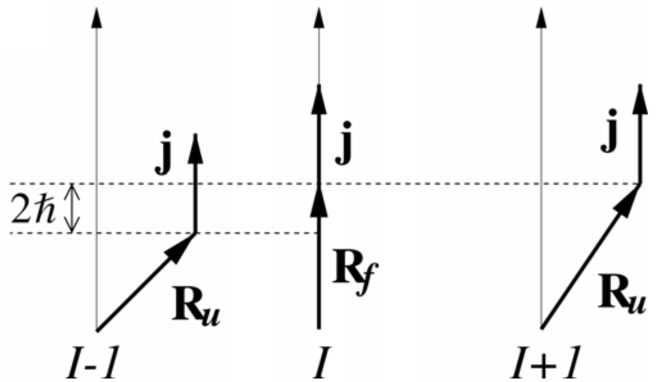
almost identical quadrupole moments

$\Rightarrow$ similar intrinsic structure

we need to understand the decrease

Should the quadrupole moments for TSD1 and TSD2 be the same?

different vector coupling



TSD1	TSD2
K = I	K = I-1

(with rotational axis as quantization axis)

relevant Clebsch-Gordan: $\langle I \;\; K \;\; 2 \;\; -2 \mid I-2 \;\; K-2 \rangle$

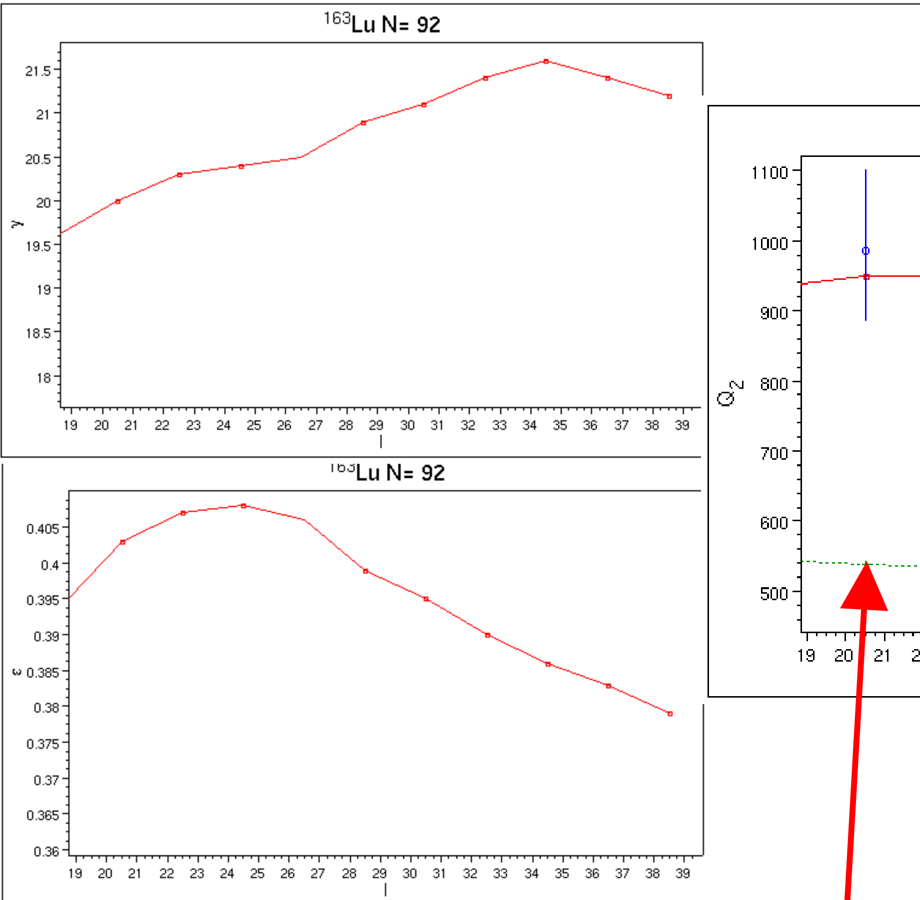
examples:

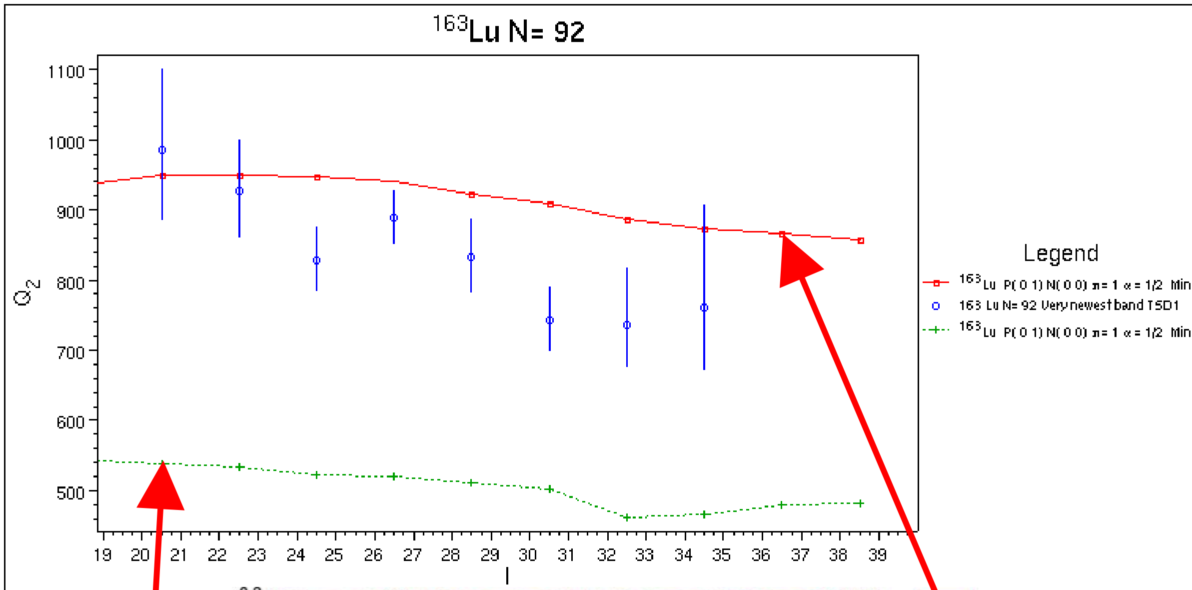
$\langle 55/2 \;\; 55/2 \;\; 2 \;\; -2 \mid 51/2 \;\; 51/2 \rangle = 0.964$

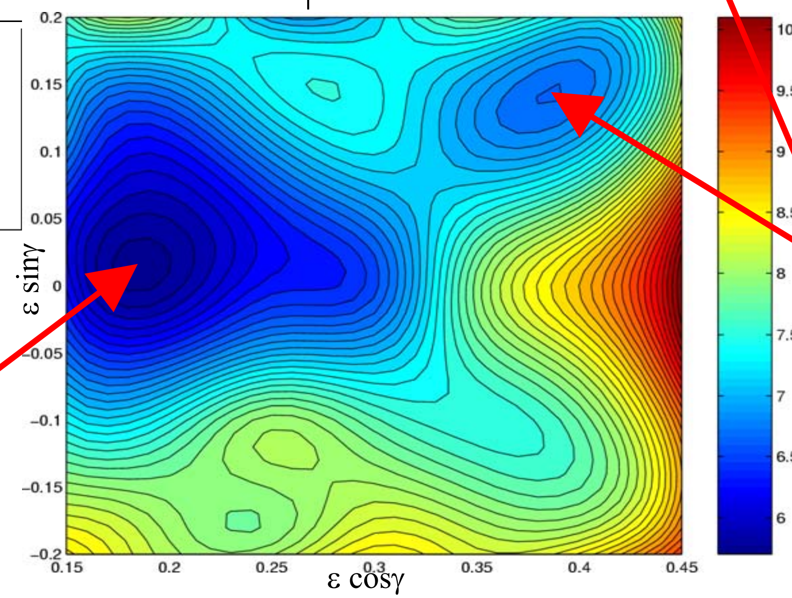
$\langle 55/2 \;\; 53/2 \;\; 2 \;\; -2 \mid 51/2 \;\; 49/2 \rangle = 0.928$

$\Longrightarrow$ ~ 4 % difference between 0-phonon and 1-phonon bands

Cranking calculations for TDS1 (ultimate cranker)







$\varepsilon = 0.40$
$\gamma = 21°$

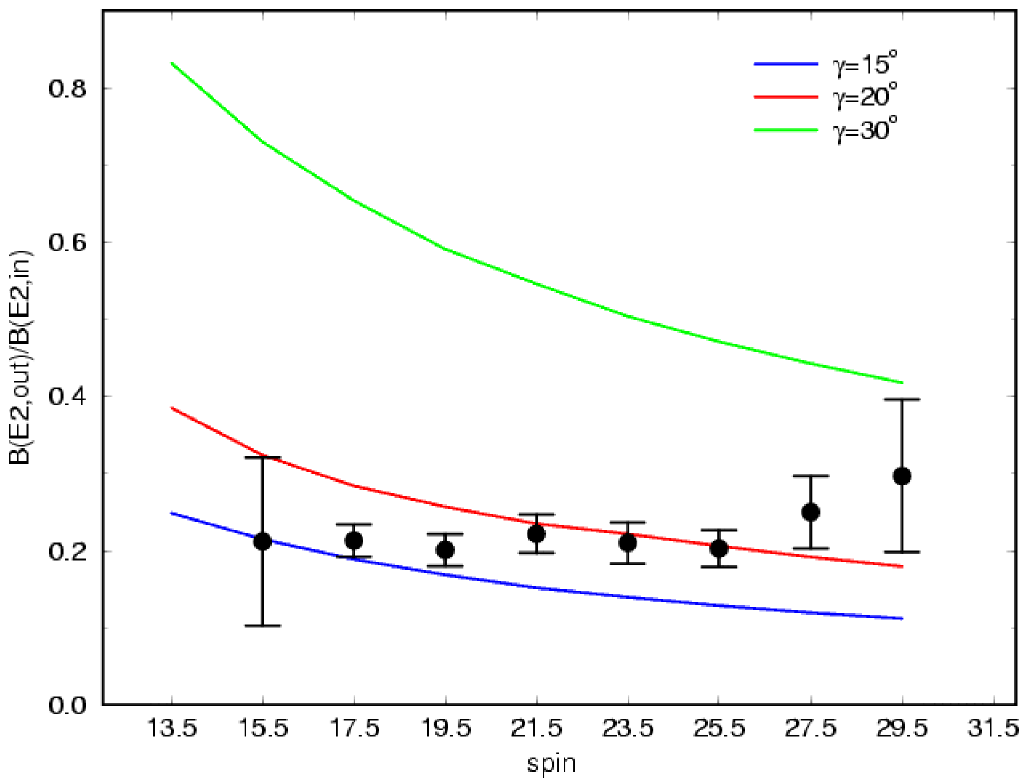
$\varepsilon = 0.18$
$\gamma = 3°$

R. Bengtsson, private communication

The ratio B(E2;out)/B(E2;in) is very sensitive to γ, but independent of ε

$$B(E2;n_w,I \rightarrow n_w\text{-}1,\ I-1) \propto \frac{n_w}{I}\sin^2(\gamma+30^\circ)$$

$$B(E2;n_w,I \rightarrow n_w,I-2) \propto \cos^2(\gamma+30^\circ)$$



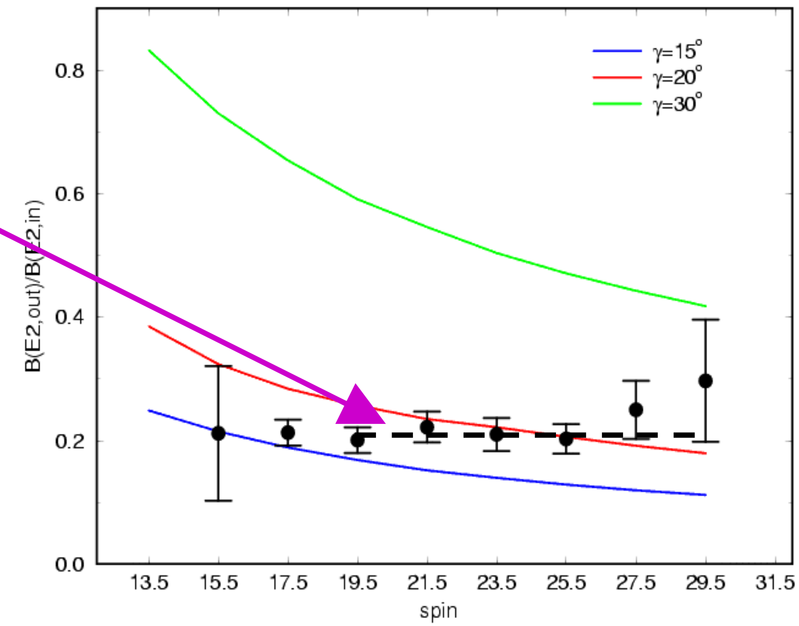
Particle-rotor calculation from:

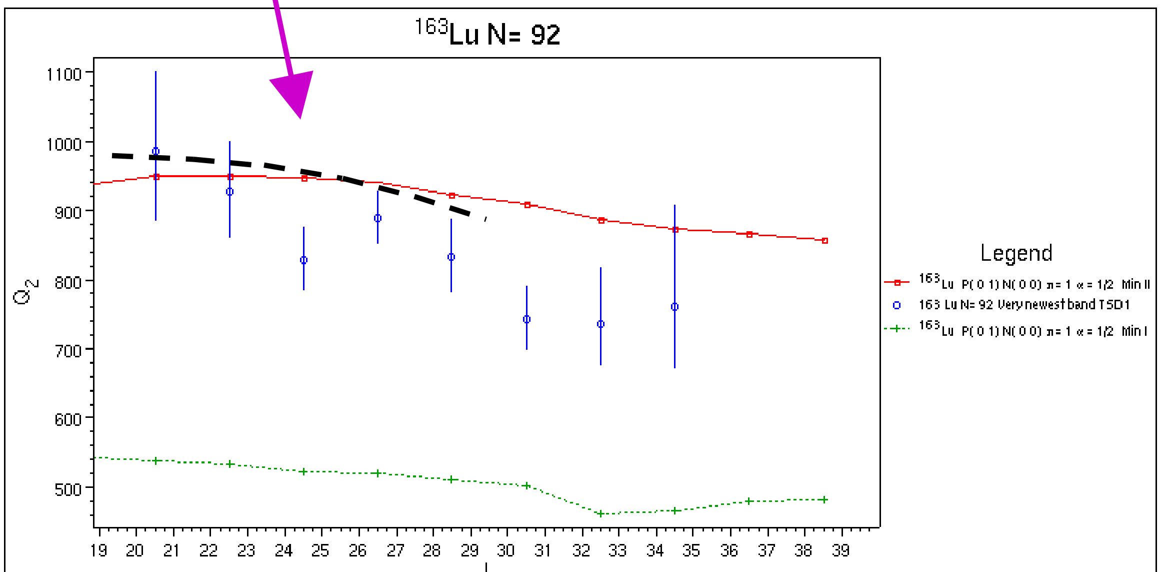
I. Hamamoto and G.B. Hagemann, Phys. Rev. C **67**, 014319 (2003)

Constant B(E2) ratio can be explained by increase in γ from ~16°…22°

Constant B(E2) ratio can be explained by increase in γ from ~16°…22°

Explains stronger decrease of Q at the same time.





Summary:

- strong evidence for wobbling phonon excitations in odd-mass Lu isotopes based on characteristic E2 inter-band transitions

- lifetime measurements in ^{163}Lu find very similar Q_t's for TSD1 and TSD2
  $\Rightarrow$ strong indication for similar intrinsic structure of the wobbling bands

- in-band Q_t's show decrease with angular momentum,
  trend is reproduced by cranking calculations: increase in γ and decrease in ε

- constant B(E2)'s of the inter-band transitions can be understood by increase in γ, thus restoring the 1/I dependence inherent in the wobbling mode

$\Rightarrow$ new results support the wobbling picture and give a handle on triaxiality for the first time

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