Lifetime Measurement in ^{103,104}Rh with RDDS Method in Inverse Kinematics: A Test for Nuclear Chirality

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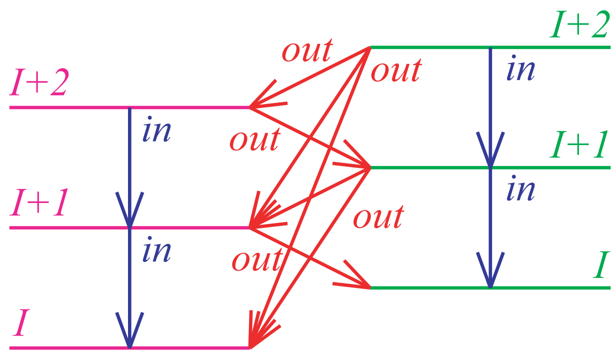
Introduction

- Criteria for Nuclear Chirality
  - Nearly degenerate $\Delta I = 1$ twin bands with the same parity
  - $B(E2 : I \rightarrow I-2)_{\text{in,out}}$ and $B(M1 : I \rightarrow I-1)_{\text{in,out}}$ values are the same or similar between both bands.



From C.M. Petrache et. al. Phys. Rev. Lett. 96 (2006) 112502

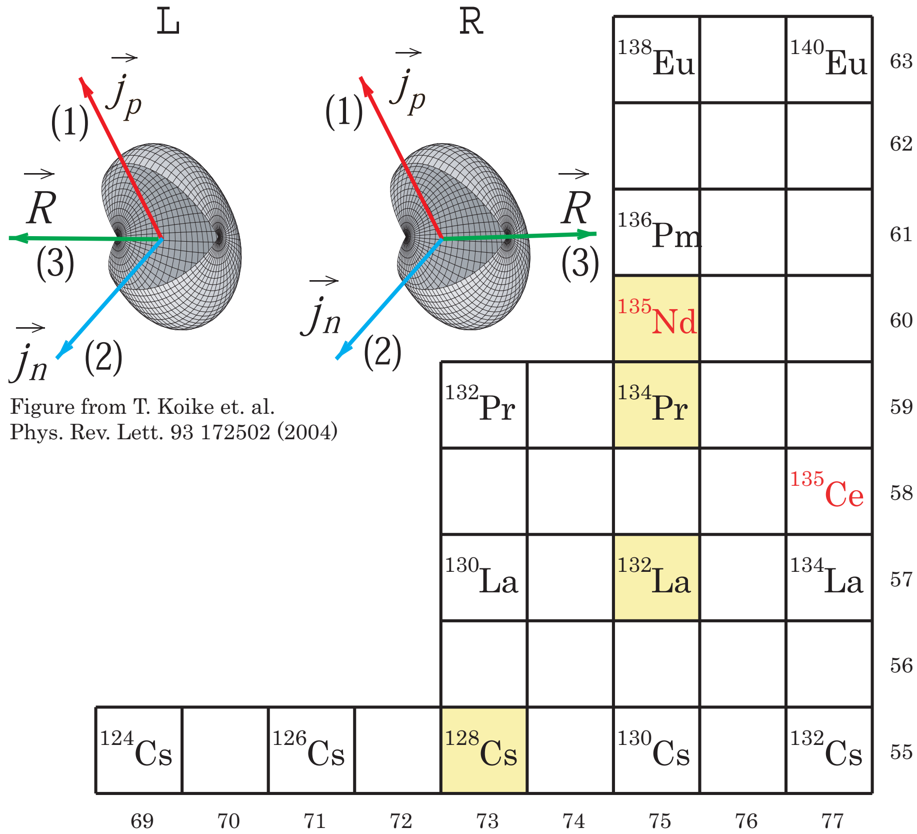
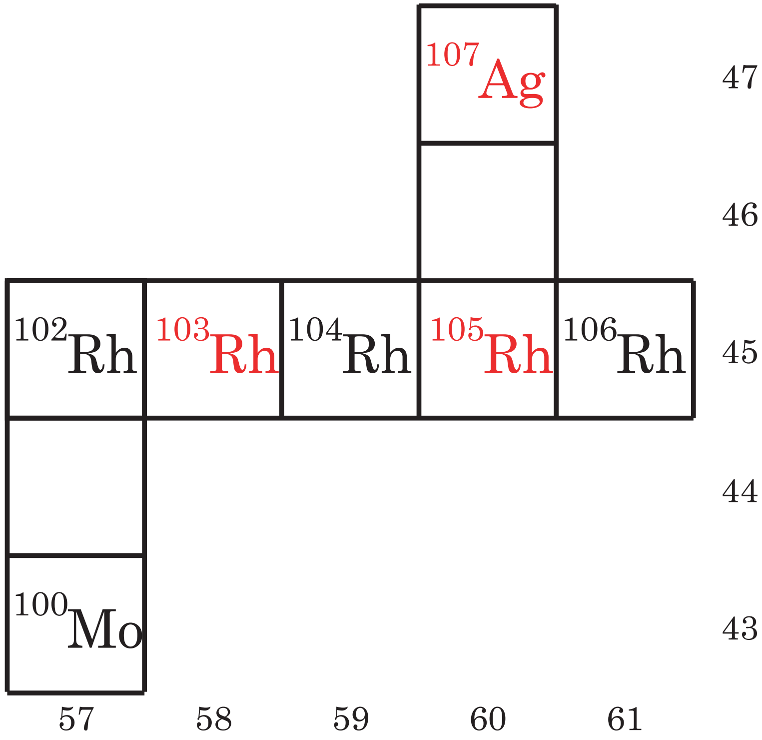
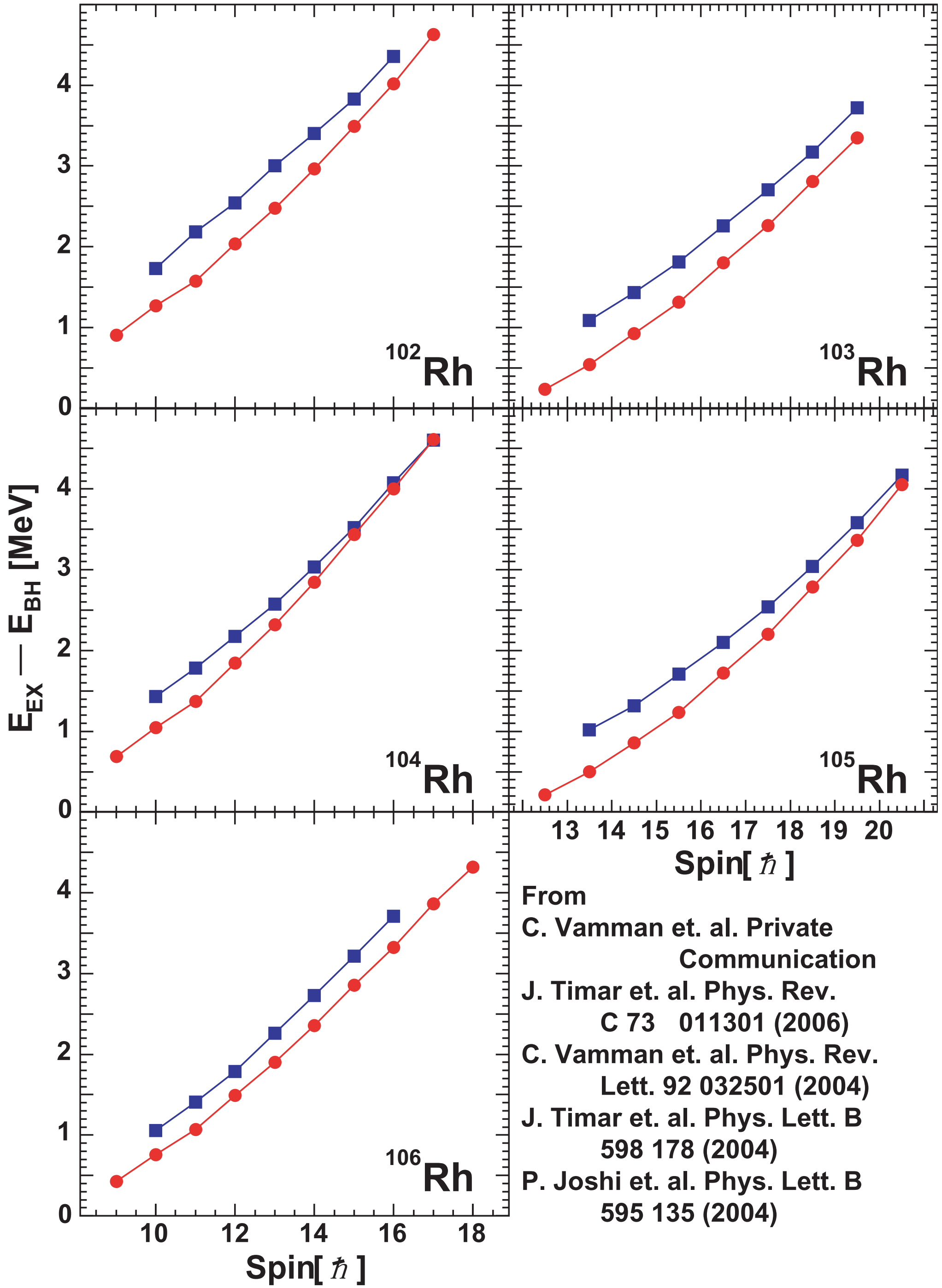


Figure from T. Koike et. al.
Phys. Rev. Lett. 93 172502 (2004)

- The Best Configuration for mass 100 region $\cdots\ \pi g_{9/2}^{-1} \otimes \nu h_{11/2}$
  1. shortest axis of the triaxial shape
     j_n; neutron-particle in a high-j_n shell
  2. longest axis of the triaxial shape
     j_p; proton-holl in a high-j_n shell
  3. intermidiate axis of the triaxial shape
     R; core rotation

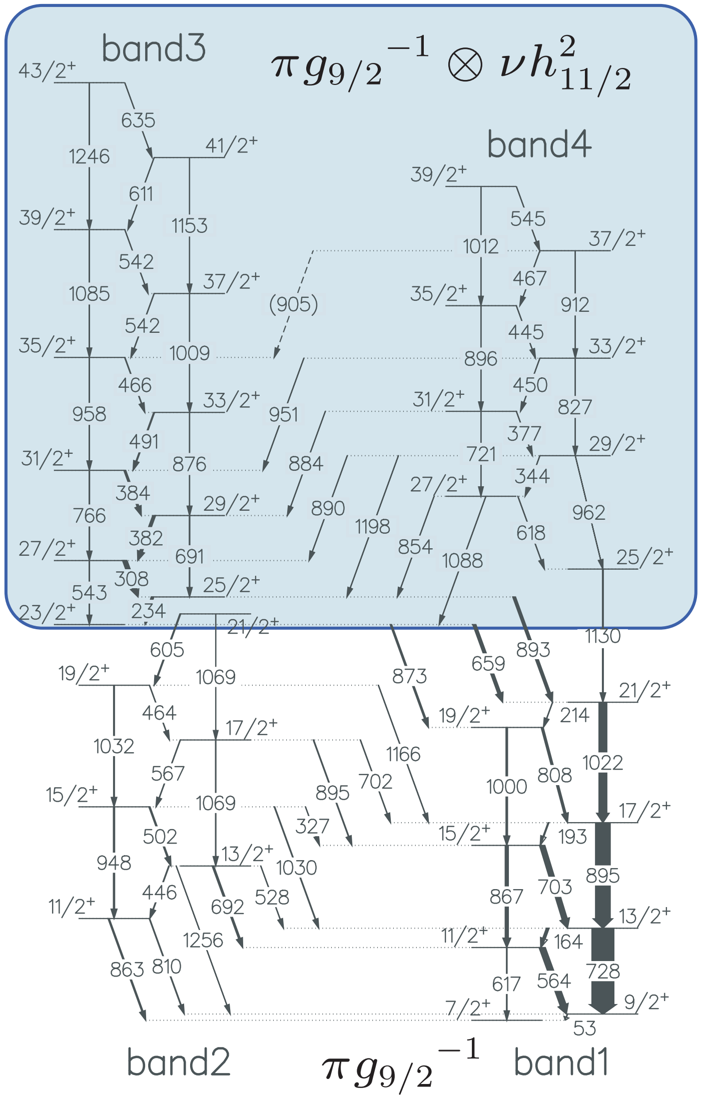
Chiral candidates in the mass 100 region

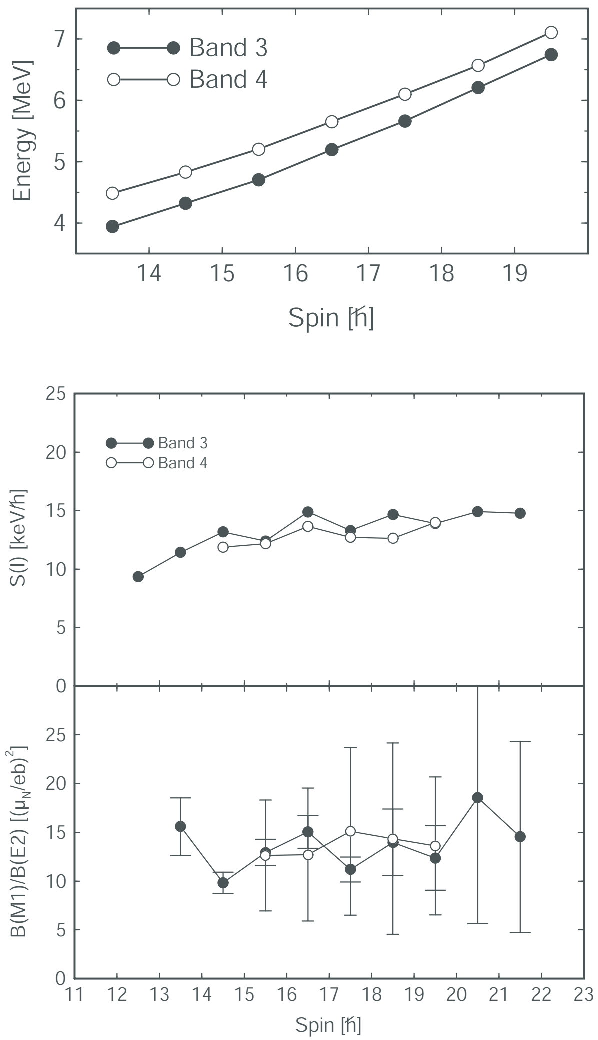


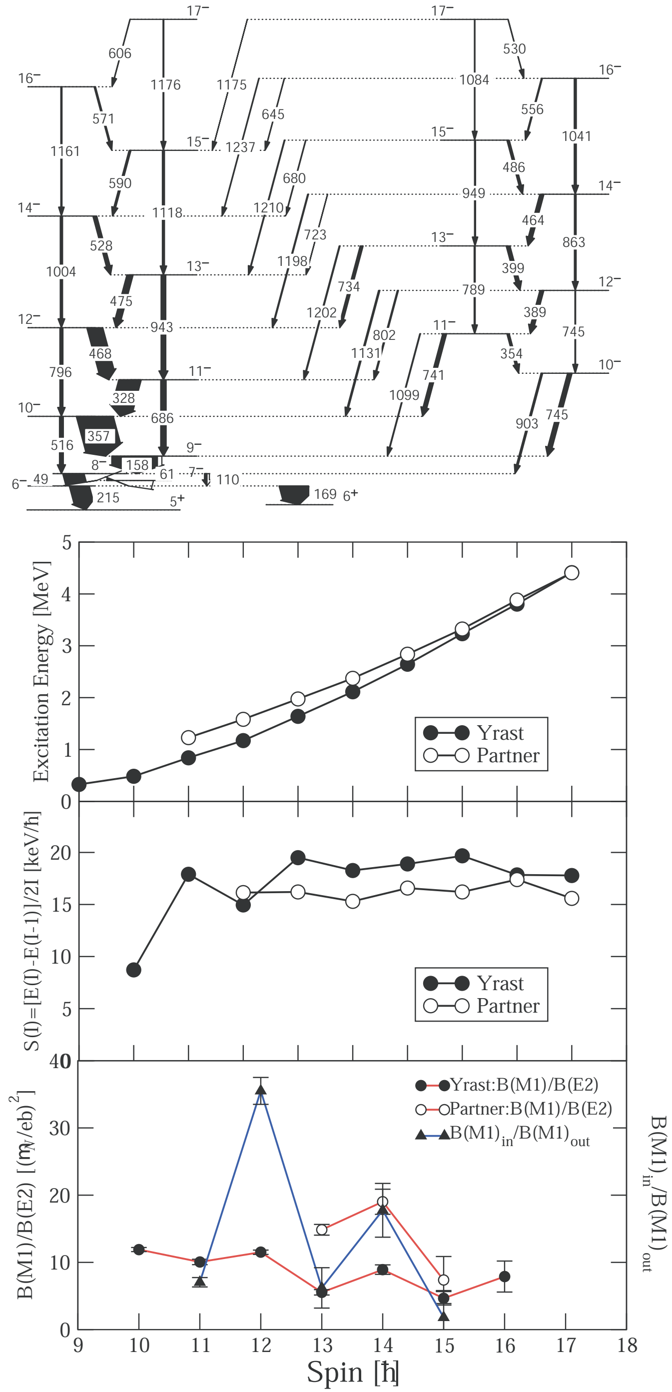


- The doublet bands are built on
  - $\pi g_{9/2}{}^{-1} \otimes \nu h_{11/2}$ configuration for odd-odd nuclei
  - $\pi g_{9/2}{}^{-1} \otimes \nu h_{11/2}{}^{2}$ configuration for odd-A nuclei (broken pair of neutron)
- The energy degeneracy gets better from ^{102}Rh to ^{104}Rh and then gets less to ^{106}Rh.
  - The degeneracy is only 2-keV at the best in ^{104}Rh.

Chiral candidates in ^{103,104}Rh

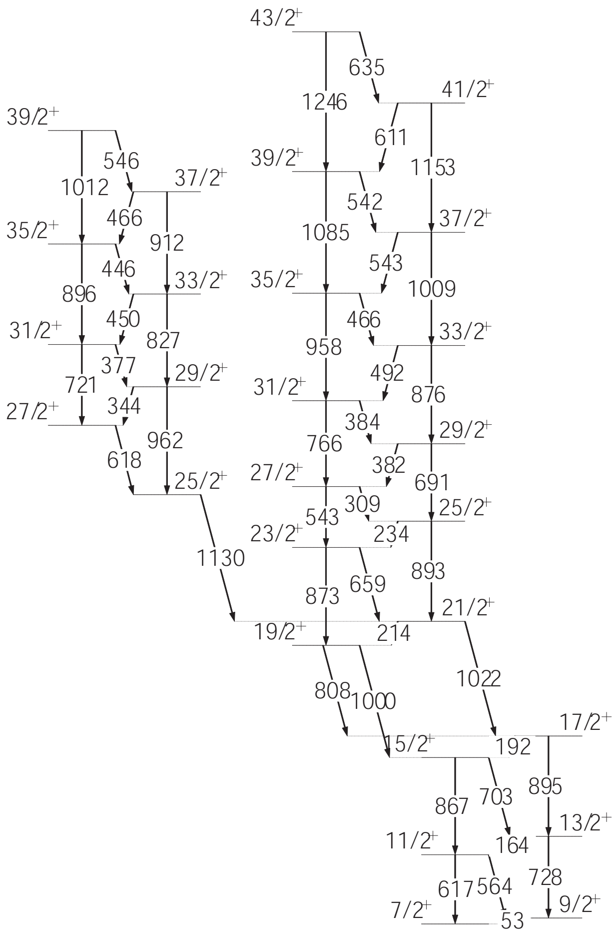




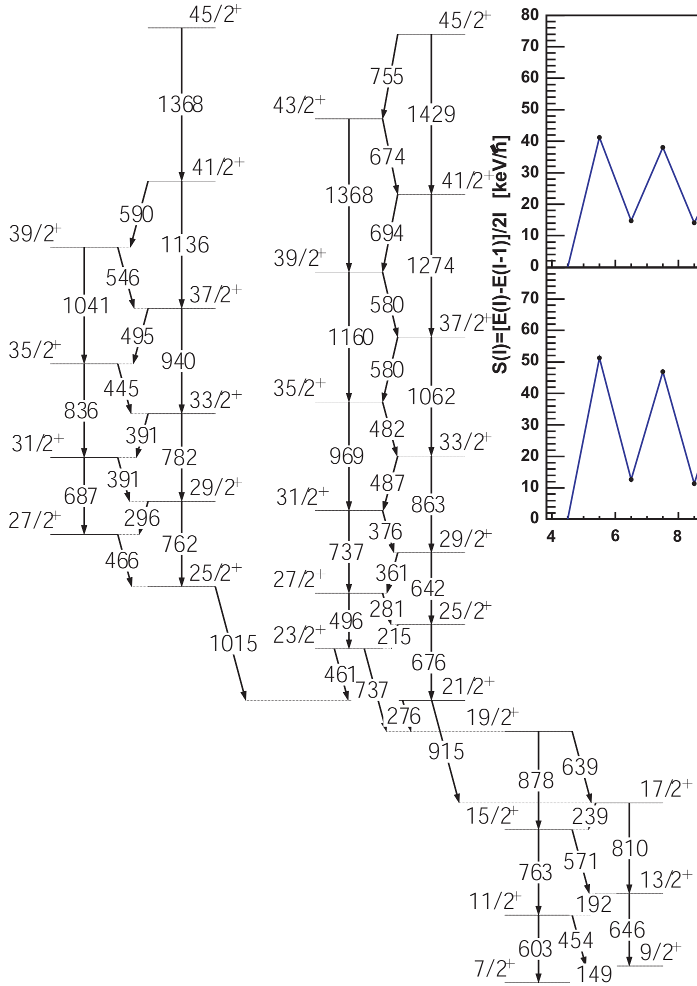


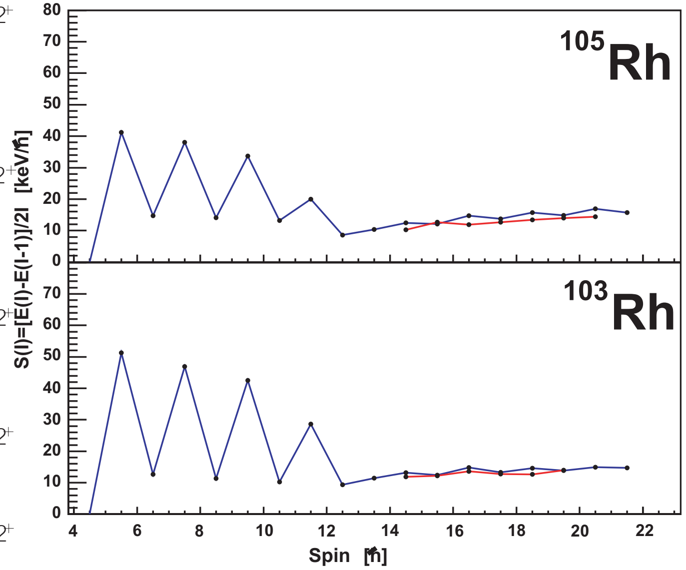
From J. Timar et. al. Phys. Rev. C 73 (2006) 011301.
C. Vaman et. al. Phys. Rev. Lett. 92 (2004) 032501.

^{103}Rh and ^{105}Rh



^{103}Rh



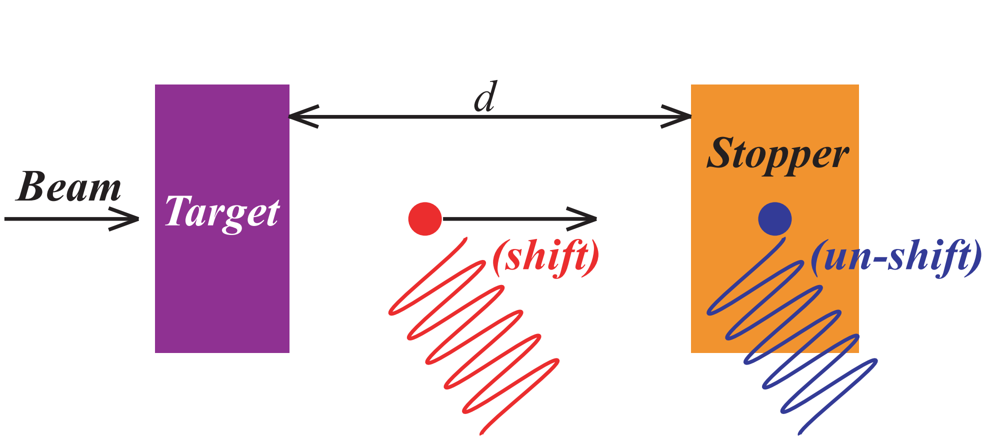


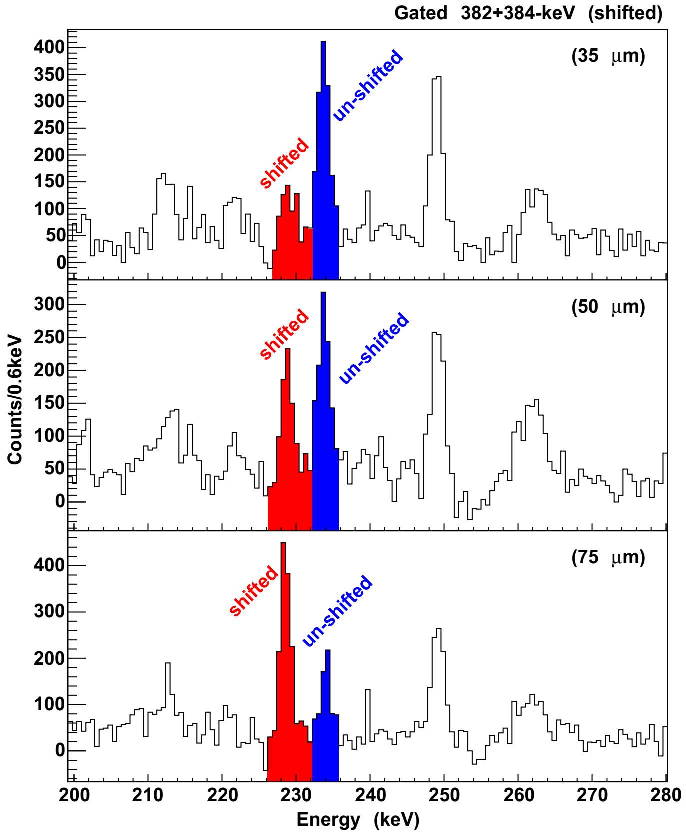
^{105}Rh

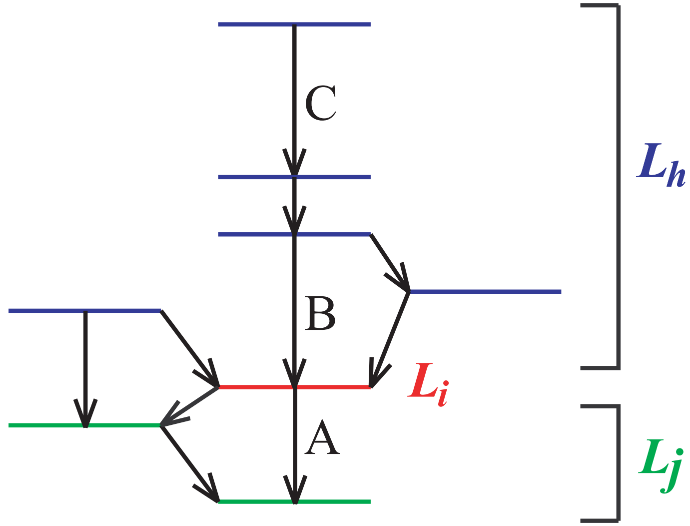
- ^{105}Rh was reported TAC calcuration

J. Timar et. al. Phys. Lett. B 598 (2004) 178

Coincidence Recoil Distance Doppler Shift Method (RDDS)







$$\frac{dn_i}{dt} = -\lambda_i n_i(t) + \sum_h \lambda_h n_h(t) b_{hi}$$

$$\tau_i = \frac{-N_{ij}(t) + b_{ij}\sum_h N_{hi}(t)}{\frac{dN_{ij}(t)}{dt}}$$

$$\tau_i = \frac{I^{\mathrm{BA}}_{\mathrm{s,u}}(x)}{I^{\mathrm{BA}}_{\mathrm{s,s}}(x+\Delta x) - I^{\mathrm{BA}}_{\mathrm{s,s}}(x-\Delta x)}\frac{2\Delta x}{v}$$

$$\tau_i = \frac{I^{\mathrm{CA}}_{\mathrm{s,u}}(x) - \alpha I^{\mathrm{CB}}_{\mathrm{s,u}}(x)}{I^{\mathrm{CA}}_{\mathrm{s,s}}(x+\Delta x) - I^{\mathrm{CA}}_{\mathrm{s,s}}(x-\Delta x)}\frac{2\Delta x}{v}, \alpha = \frac{I^{\mathrm{CA}}}{I^{\mathrm{CB}}}$$

From A. Dewald et. al. Z. Phys. A 334 (1989) 163;

G. Böhm et. al. Nucl. Inst. Meth. Phys. Res. A 329 (1993) 248

GAMMASPHERE GSFMA169

Lifetime measurement of candidate chiral members in the $A \sim 100$ region

- Recoil Distance Doppler Shift Method (RDDS)
  - GAMMASPHERE Ge detectors array
  - Cologne universiry plunger device
- Inverse Kinematics Reaction (Large recoil velocity $\beta \sim 0.05$)

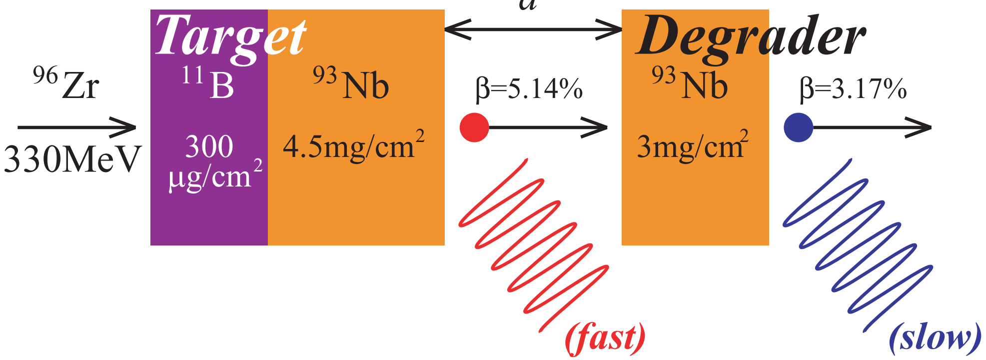
  Reaction ^{11}B(^{96}Zr,xn)^{104,103}Rh (x=3,4)

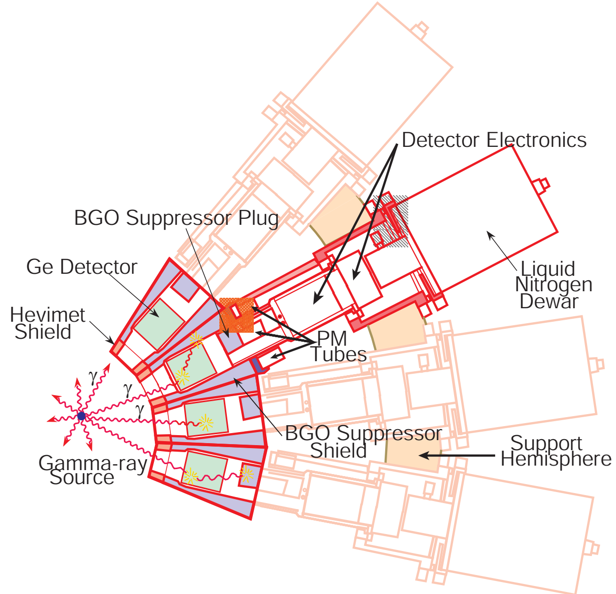
  Beam E(^{96}Zr) = 330MeV

  (from ATLAS accelerator at ANL)

  Trigger γ-γ

  7 distances (8,15,23,35,50,75,100 μm)

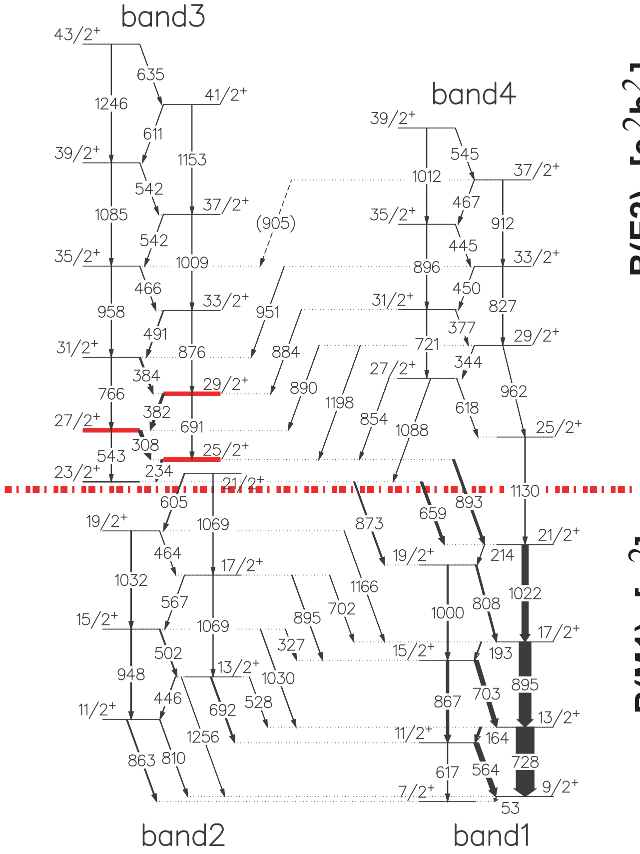




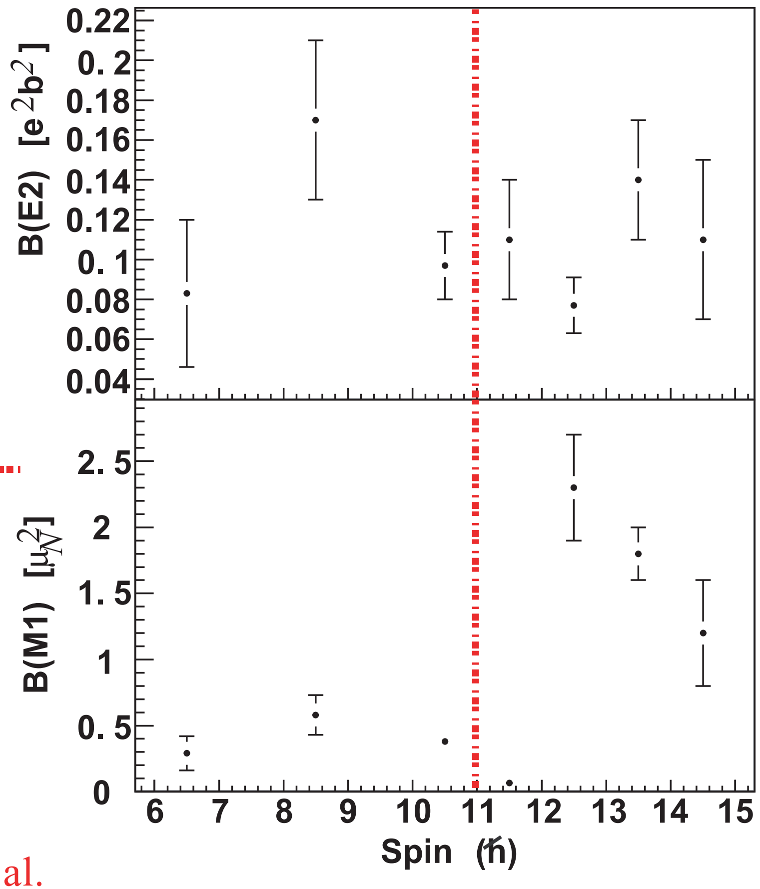
Front ring angle	Front ring N_{det}	Back ring angle	Back ring N_{det}
		121.72°	5
35.26°	8	129.93°	10
50.07°	10	145.45°	10
58.28°	5	162.73°	5

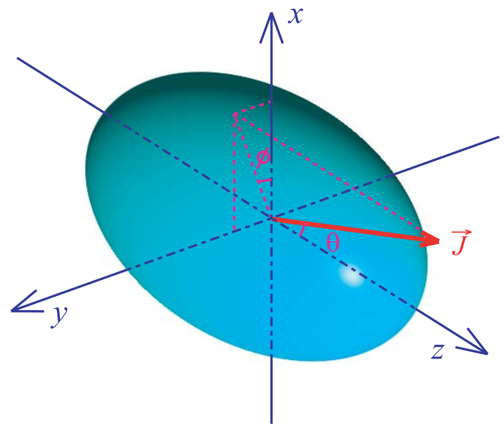
84 γ-γ matrices are created ring by ring for each distances.

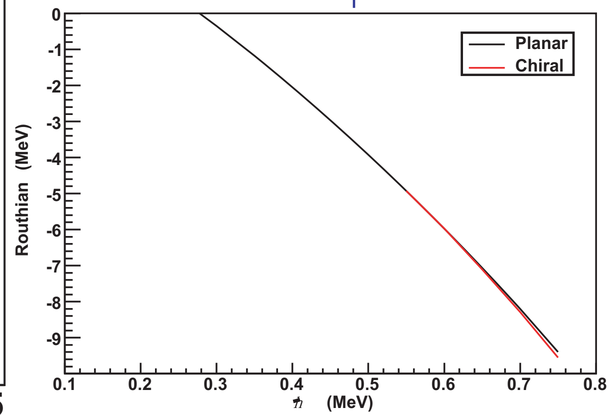
Experiment result of ^{103}Rh and calculated values of ^{105}Rh



Level scheme From J. Timar et. al.
Phys. Rev. C 73 (2006) 011301





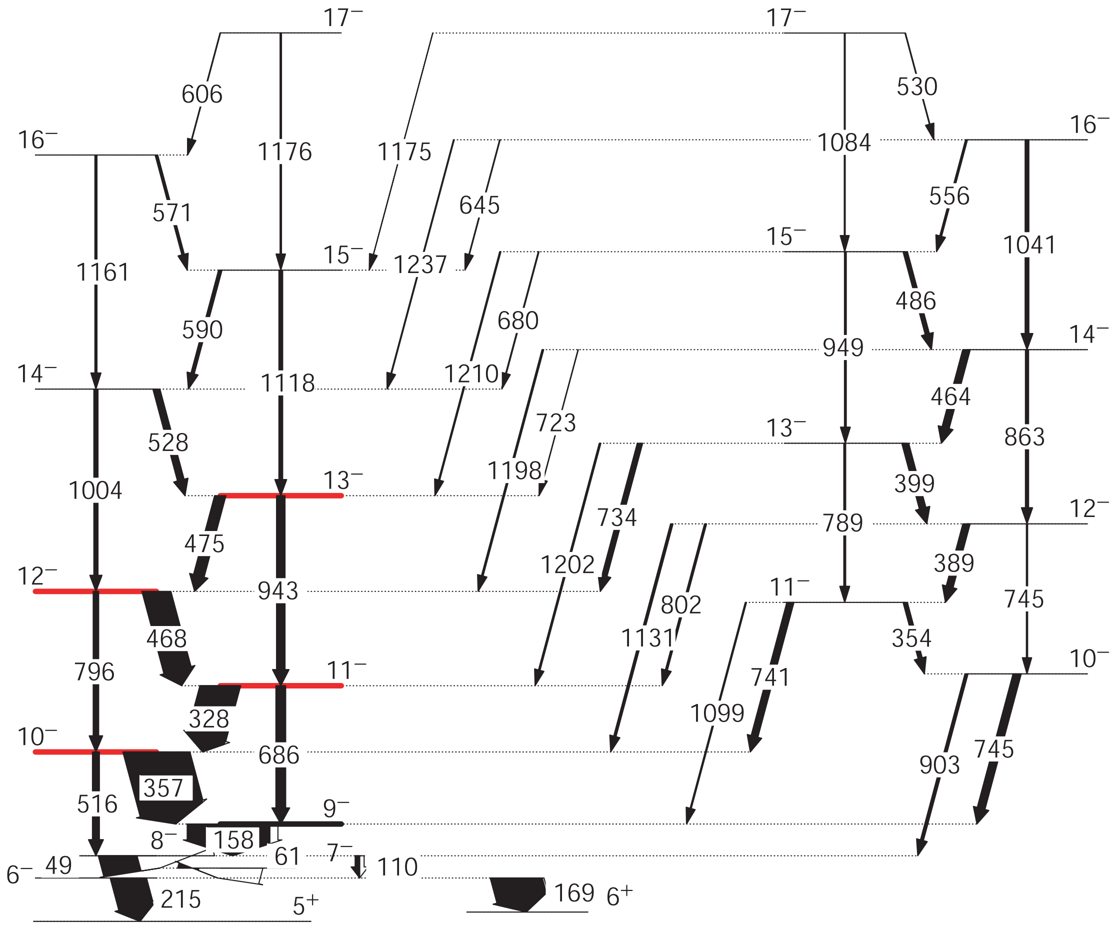


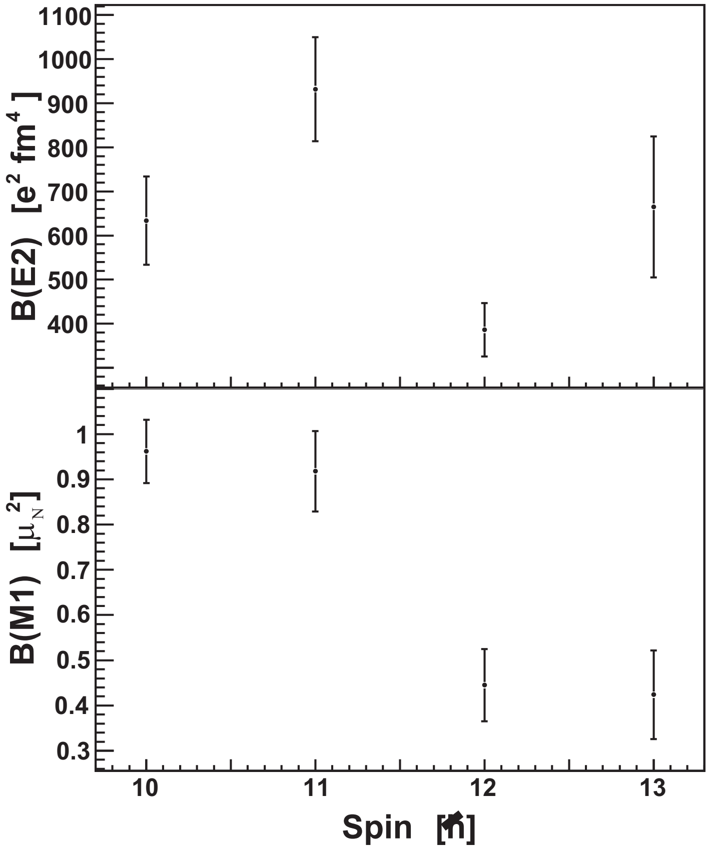
TAC Calc from J. Timar et. al.
Phys. Lett. B 598 (2004) 178

Level			TAC for ^{105}Rh		Exp. for ^{103}Rh	
Energy (keV)	Spin (J^π)	ω	B(E2) (e^2b^2)	B(M1) ($\mu_N{}^2$)	B(E2) (e^2b^2)	B(M1) ($\mu_N{}^2$)
3631	$25/2^+$	0.25	0.09	2.28	0.077(14)	2.3(4)
3940	$27/2^+$	0.30	0.09	2.16	0.14(3)	1.8(2)
4322	$29/2^+$	0.35	0.09	2.03	0.11(4)	1.2(4)

ω	planar	aplanar
0.55	−4.297	−4.297
0.60	−5.971	−5.976
0.65	−7.064	−7.102
0.70	−8.206	−8.295
0.75	−9.397	−9.552

Result for ^{104}Rh





- The $B(M1)/B(E2)$ staggering has been observed in the previous experiment.
  - This is suspected for chiral selection rule if the staggering is caused by $B(M1)$ values. C. Vamman et. al. Phys. Rev. Lett. 92 (2004) 032501.
  - However, the staggering is caused by $B(E2)$ staggering.
  - The behavior of $B(E2)$ staggering is cannot be understood and needs theoretical interpretations.

Summary

- The lifetime of chiral candidates member in the ^{103,104}Rh isotopes are measured.
  - RDDS、GAMMASPHERE
- ^{103}Rh
  - Three lifetimes related to chiral doublets are extracted.
  - The experimental results are compared to TAC calculations for ^{105}Rh.
  - TAC calculation indicates chiral doublet in the $\omega \geq 0.55$ region
  - Three levels $(0.25 \geq \omega \geq 0.35)$ were consisted with TAC calculations for ^{105}Rh.
- ^{104}Rh
  - Four lifetimes are extracted.
  - The reported $B(M1)/B(E2)$ seems staggering from $B(E2)$.
  - In $B(E2)$ needs theoretical explanation.