Shape change in the A~100 region - new experimental data

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@ Eurogam, Gammasphere, Lohengrin, EXILL , FIPPS and JYFLTRAP

SSNET 2017, Gif-sur-Yvette

Shape change at A~100 (a long story ...)

discovery — Chiefetz, et al., Phys. Rev. Lett. 25, 38 (1970)

early interpretation – two minima — Sheline, et al., Phys. Lett. B 41, 115 (1972)

spin-orbit-partner (SOP) - strong attraction between $\nu g_{7/2}$ and $\pi g_{9/2}$

- II order shape transition, Federman and Pittel, Phys. Lett. B 69, 385 (1977)

two minima, promotion from $\pi p_{1/2}$ to $\pi g_{9/2}$, (4-q.p, SOP + ***self-reinforcement***)

Meyer, Henry, Mann and Heyde, Phys.Lett. B 177, 271 (1986)

Heyde, Van Isacker, Waroquier, Wood, Meyer, Phys. Rep. 102, 291 (1983)

Heyde, Jolie, et al., Phys. Rev. C 69, 054304 (2004)

population of deformation-driving $\nu h_{11/2}$ Kumar and Guyne, Phys. Rev. V 32, 2116 (1985)

Skalski, Heenen, Bonche, Nucl. Phys. A 559, 221 (1993)

Z=40 and N=56 subshell closures

Werner, Dobaczewski, Guidry, Nazarewicz, Sheikh, Nucl. Phys. A 559, 221 (1993)

Unanswered questions:

population of $\nu h_{11/2}$ vs. $\nu g_{7/2}$ - where is $\nu h_{11/2}$ in ^{95}Sr , ^{97}Zr ?

strongly deformed bands at N=59 based on $\nu g_{7/2}$ and $h_{11/2}$ **- not present** !

Lhersonneau, et al., Phys. Rev. C 49, 1379 (1994)

^{92}Sr, ^{94}Sr, ^{96}Sr - $\nu(h_{11/2}\, g_{7/2})_9^-$ T. Rzaca-Urban , et al., Phys. Rev. C 79, 024319 (2009)

difference between the deformation onset in Sr and Ru isotopes

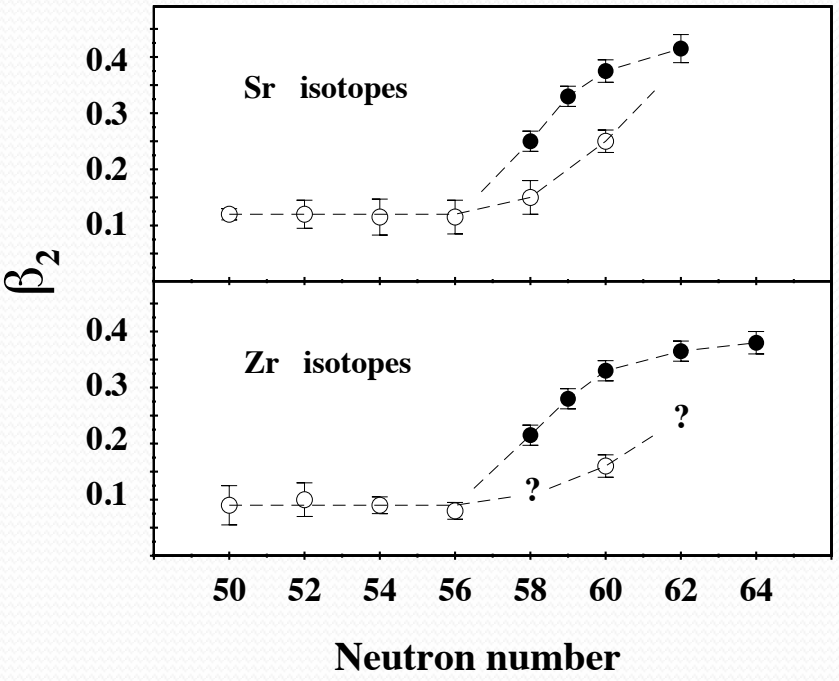
A~100 revisited experimentally (I)

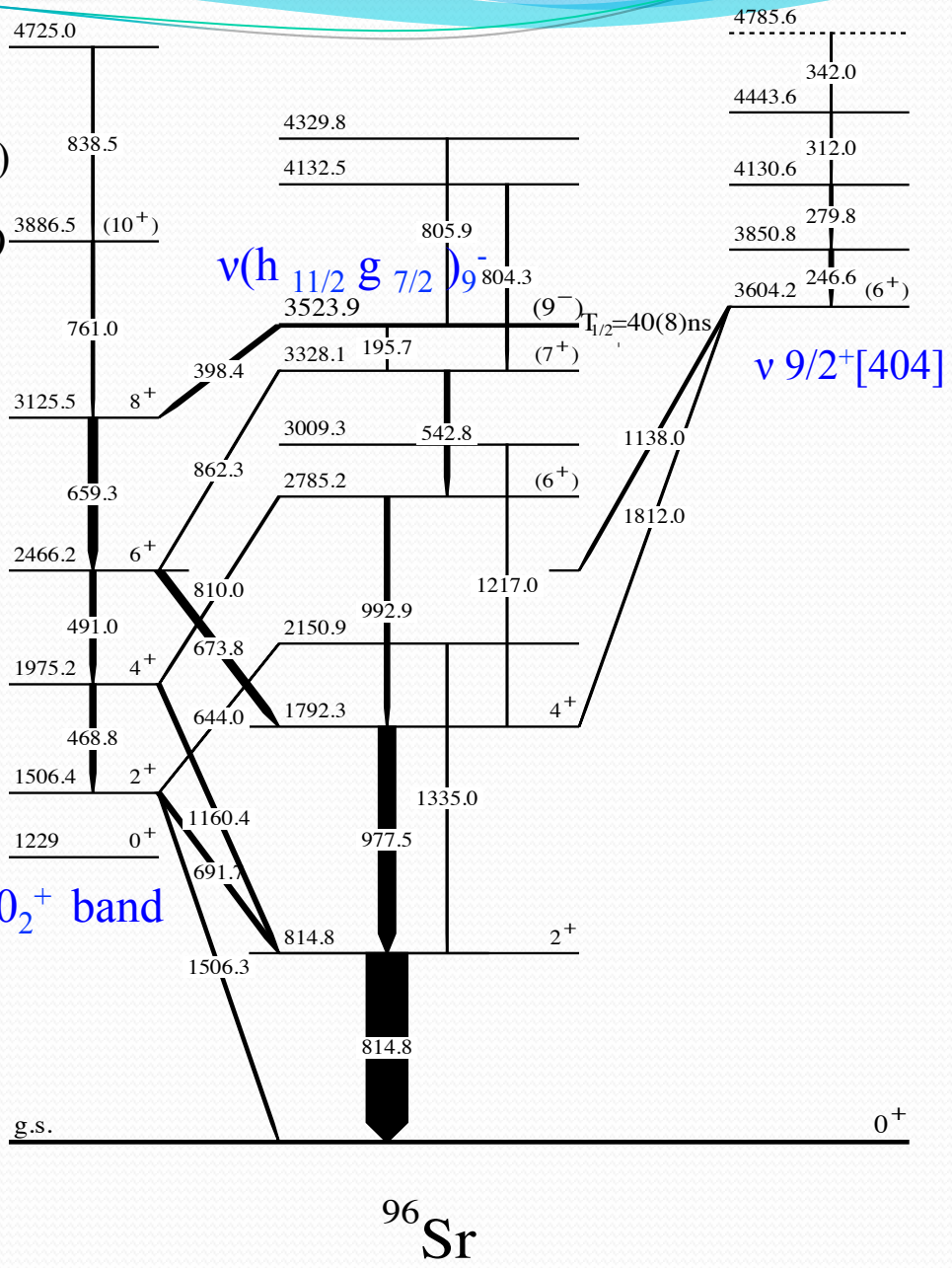
Measured: ^{96}Sr, ^{97}Sr, ^{98}Zr , ^{99}Zr
WU, et al., Nucl. Phys. A 689, 605 (2001)

- no strongly deformed $\nu h_{11/2}$ bands at N=59

- weakly-deformed 0_2^+ bands at N=58

- unusual 2-q.p. deformed bands at N=58

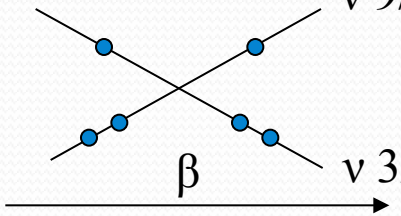




The $g_{9/2}$ neutron 'extruder' in the A~100 region

- proposed in ^{99}Y : $(\pi 5/2^+[413]\ \nu\ 3/2^+[411]\ \nu 9/2^+[404])_{11/2+,17/2+}$, G-M doublet
  Meyer, et al., Nucl. Phys A 439, 510 (1985)
- observed directly in ^{99}Zr and ^{101}Zr - WU, et al., Eur. Phys. J. A 22, 241 (2004)

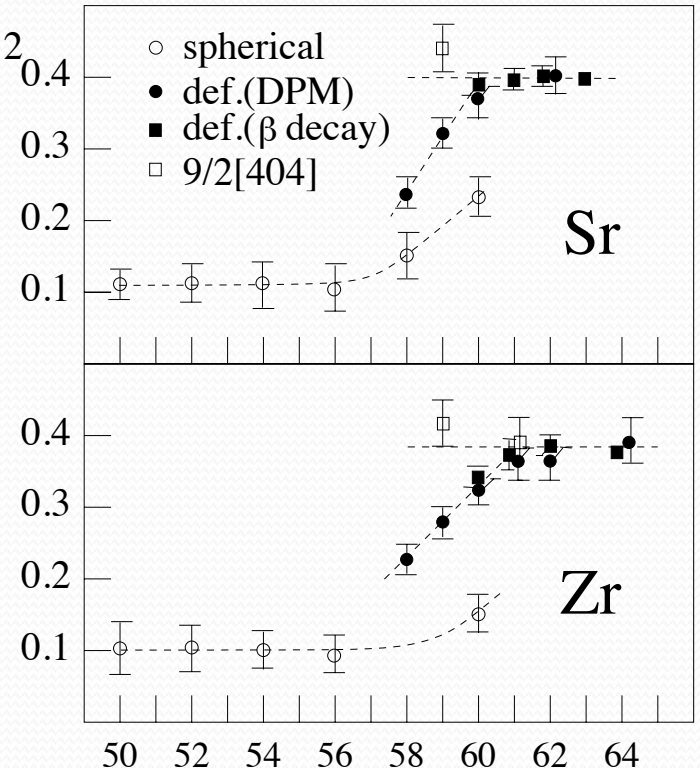
'deformation-driving mechanism' :
Kleinheinz et al. Phys. Rev. Lett. 32, 68 (1977)
A ~ 150 region, $\nu\ 11/2^-[505]$ - $h_{11/2}$ 'extruder'



- spectroscopy of the $\nu 9/2^+[404]$ orbital:
  odd-N nuclei : ^{97}Sr, ^{99}Zr, ^{101}Zr

  even-even nuclei : 2 q.p. G-M doublets with $\nu 9/2^+[404]$
  strongly deformed bands in ^{96}Sr ,^{98}Sr, ^{98}Zr, ^{100}Zr and ^{102}Zr
  J.L. Durell et al., Eur. Phys. J A 20, 97 (2004)

  odd-odd nuclei: in ^{98}Y
  ($\pi 5/2^+[413]\ \nu 9/2^+[404]$) $_{2+,7+}$ G-M expected
  (1+), strongly-deformed band suggested
  strongly-deformed, 2s isomer - mass and spin ?



New data on ^{98}Y and ^{98}Zr
WU, et al., Phys. Rev. C 96, 044333 (2017)

1. No strongly deformed, 1^+ band in ^{98}Y

2. ($\pi 5/2^+[413]$ $\nu 9/2^+[404]$) $_{2+,7+}$, G-M doublet in ^{98}Y :

new 180 ns isomer - structure ?

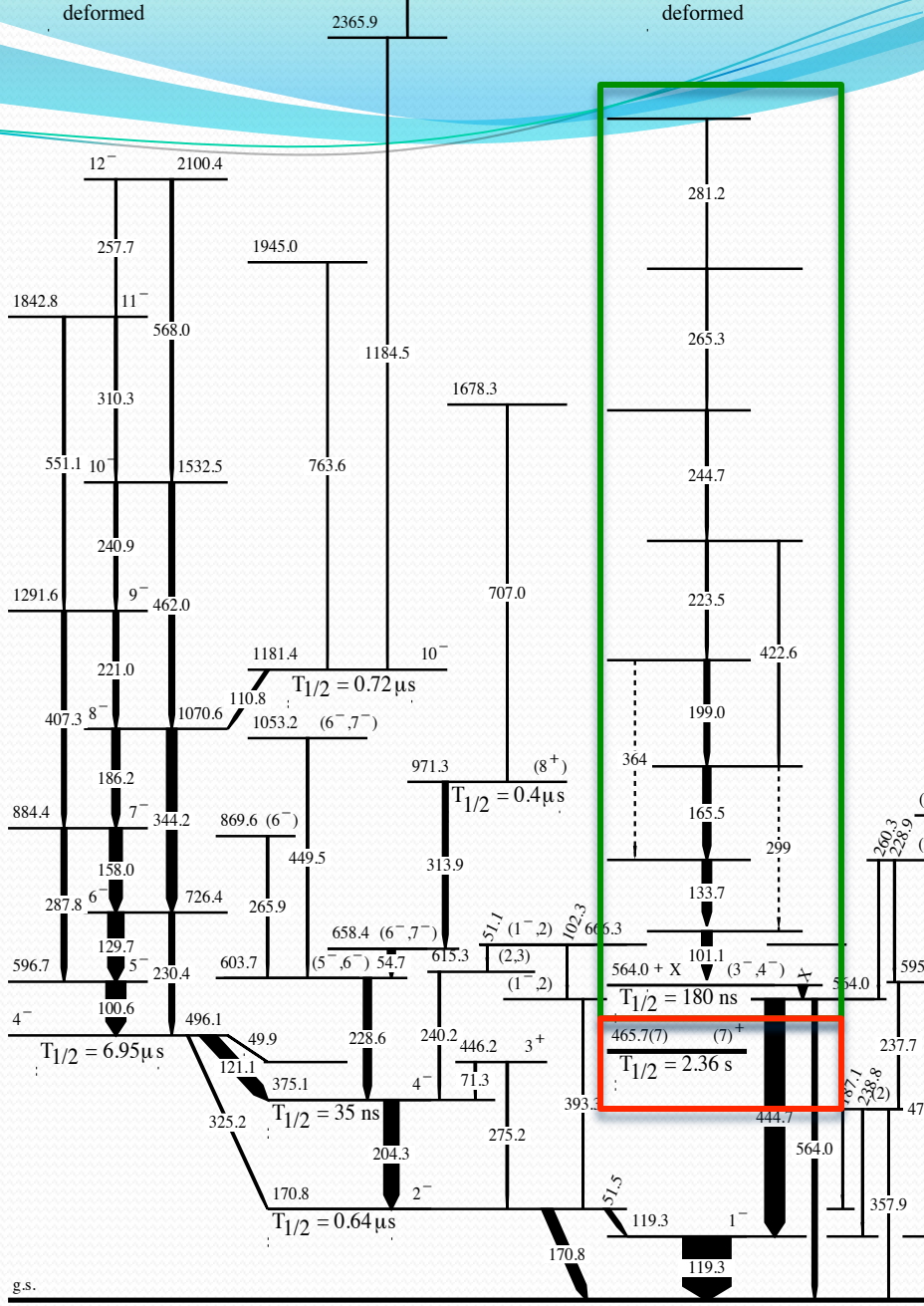
Gammasphere, ^{252}Cf fission
Eurogam 2, ^{248}Cm fission

- excitation (564.0 +X) keV, X < 30 keV
- weak in-band E2, strong deformation
- spin I = (3^-, 4^-)

2s isomer - ($\pi 5/2^+[413]$ $\nu 9/2^+[404]$) $_{7+}$

JYFL Penning trap - excitation 465.7(7) keV

Eurogam + Gammasphere
- no deformed band on top of 2s isomer !
- spin I = (6^+,7^+) Not (4,5) reported previously



Phys. Rev. C 96, 044333 (2017) ^{98}Y

β-decay of 2s isomer populates deformed 2-q.p. band based on 6^+ level. *log ft* =4.9

$\nu\, g_{7/2} \longrightarrow \pi\, g_{9/2}$

GT

$\{\pi 5/2^+[413]\ \nu 9/2^+[404]\ (\nu 3/2^+[411])^2\}_{7+}$

$\longrightarrow \{\nu 9/2^+[404]\ \nu 3/2^+[411]\}_{6+}$

B. Cheal et al. / Physics Letters B 645 (2007) 133

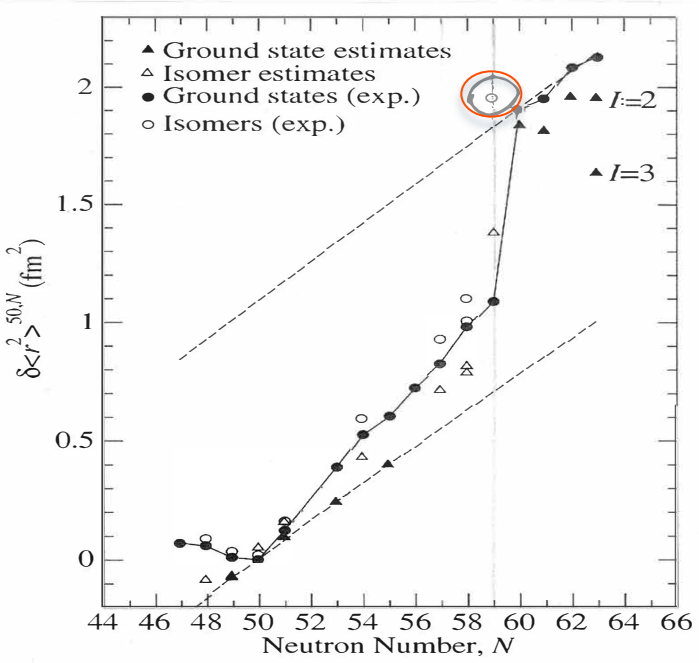


Fig. 3. Experimental charge radii compared to estimates with contributions from static $\beta 2$ deformation al one.

$$\beta^2_{\mathrm{rms}} = \langle\beta_2\rangle^2 + \left(\langle\beta_2^2\rangle - \langle\beta_2\rangle^2\right) = \beta^2_{\mathrm{static}} + \beta^2_{\mathrm{dyn.}}$$

^{98}Y, g.s. 0^-

AME2012:

Q = 8992 keV

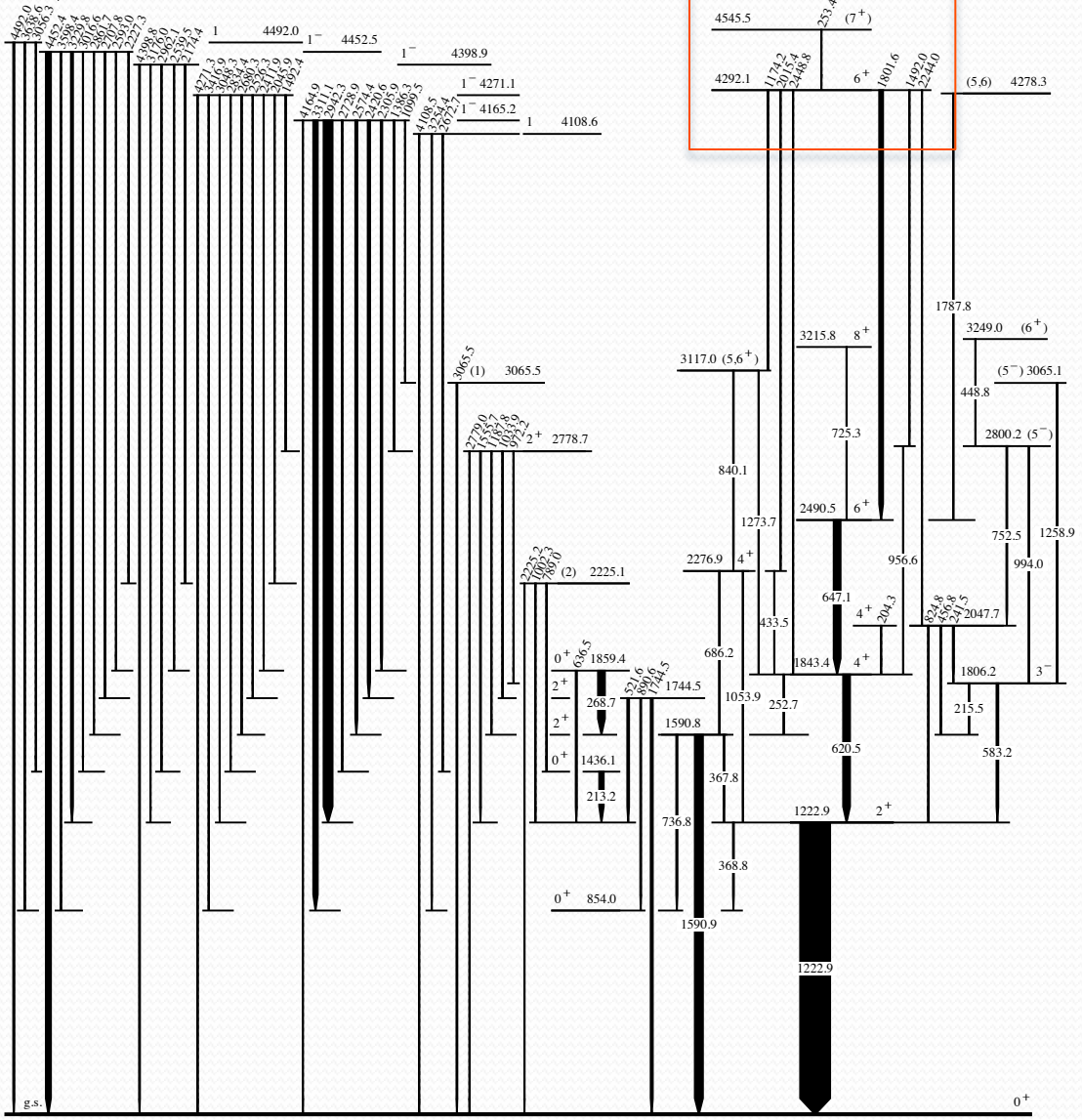
$T_{1/2}$ = 0.548 s

β^- decay

^{98}Y, 465.7 $(6,7)^+$

β^- decay $T_{1/2}$ = 2.36 s

$\nu 9/2^+[404]$

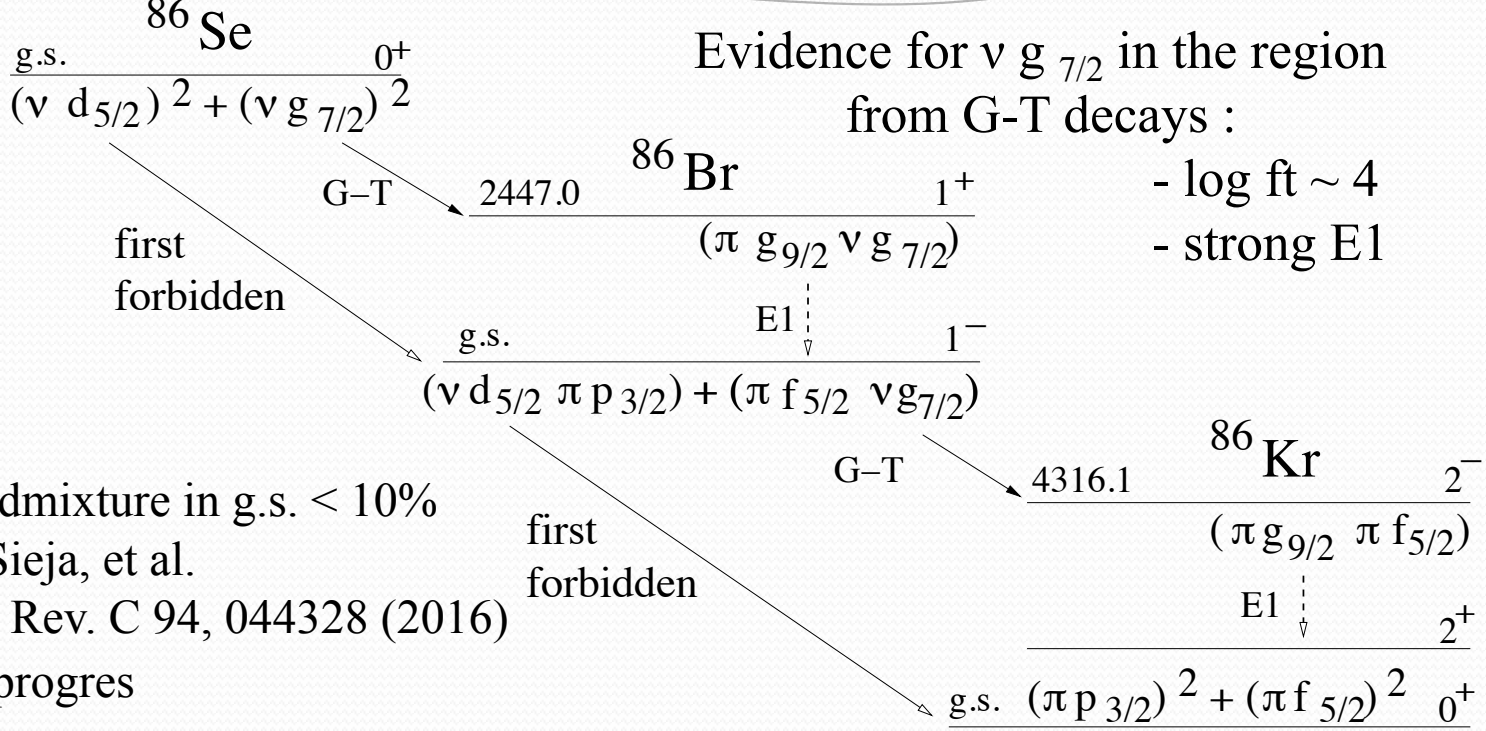


^{98}Zr

Phys. Rev. C 96, 044333 (2017)

Summary and perspectives

1. $\nu\, g_{7/2}$



Evidence for $\nu\, g_{7/2}$ in the region from G-T decays :

- log ft ~ 4
- strong E1

A= 86 - $(\nu\, g_{7/2})^2$ admixture in g.s. < 10%

WU , K. Sieja, et al.
Phys. Rev. C 94, 044328 (2016)

A= 88 - work in progres

similar conclusions for N=51

F. Didierjean, et al. Phys Rev. C 96, 044320 (2017)

2. $\nu\, h_{11/2}$ at N=57

- spin of the 2264 keV level in ^{97}Zr is not 11/2 ?
- structure of the 142ms, high-spin isomer in ^{97}Y ?
- work in progres

3. Shell model and the collectivity in the region.

- collectivity at N=53

j-1 anomaly

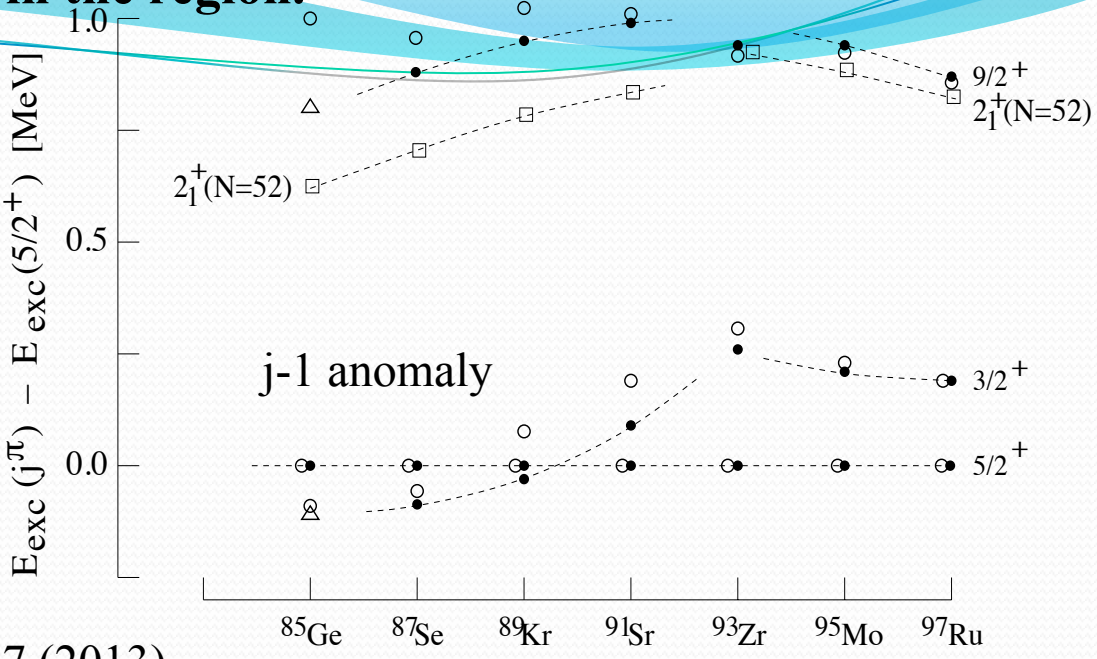
T. Rząca-Urban, K. Sieja, WU, et al.,
Phys. Rev. C 88, 034302 (2013)

M.Czerwiński, T.Rzaca-Urban,WU et al.,
Phys. Rev. C 92, 014328(2015)

- the effect reproduced well by SM

→ B(E2) up to 30 W.u.
deduced β2 ~ 0.2

K. Sieja , et al., Phys. Rev. C 88, 034327 (2013)

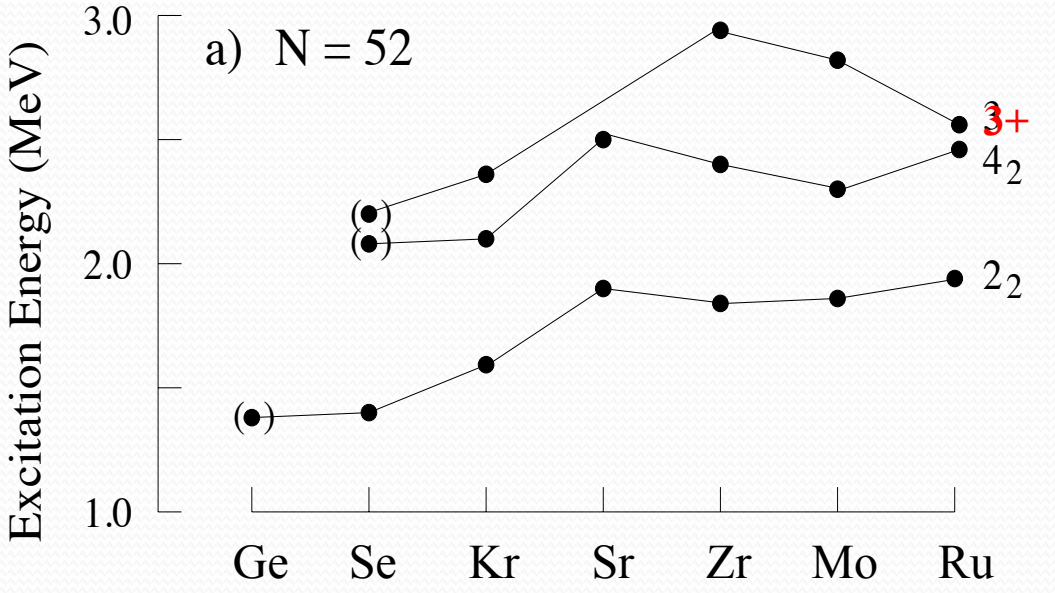


- γ collectivity - present in the
28 < Z < 50 range

T. Materna, WU, K. Sieja, et al.,
Phys. Rev. C 92, 034305 (2015)

T. Rząca-Urban, K. Sieja, WU, et al.,
Phys. Rev. C 95, 064302 (2017)

The role of γ collectivity ?



4. Shell model vs. deformed potential

MCSM description of shape change in Zr isotopes

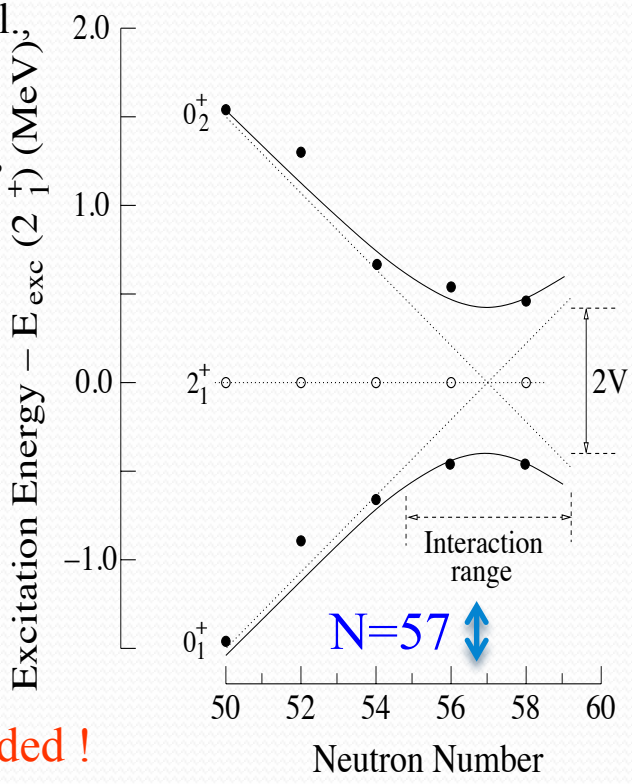
T.Togashi,Y.Tsunoda,T.Otsuka, and N.Shimizu, Phys. Rev. Lett. 117, 172502 (2016)

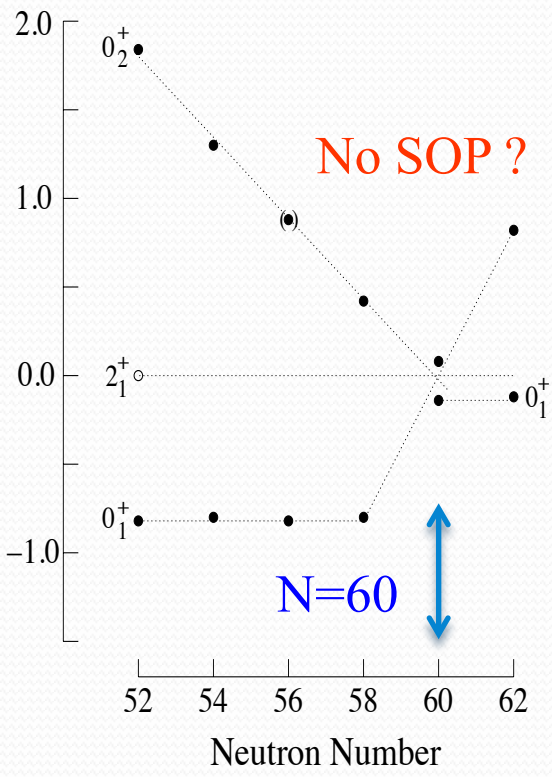
- high population of $\pi g_{9/2}$, type-II shell evolution (self-reinforcing effect)
- II order (quantum) phase transition - B(E2) increase from 5 W.u. at N=58 to 100 W.u. N=60
- ν g 9/2 not present (deep in the core) - how to get ν 9/2[404] to the Fermi surface ?

5. Evolution of deformation: Ru vs. Sr

- in Ru V ~ 400 keV (constant)
  W.U., M. Jentschel, R.F. Casten, et al., Phys. Rev. C 031304(R), (2013)
- in Sr V ~ 80 keV ? [H.T. Fortune, Nucl. Phys. A 957, 184 (2017)]
- SOP in Ru but not in Sr ?
- what mechanism in Sr ?
- N=56 gap: ν 9/2[404] between ν d $_{5/2}$ and ν g $_{7/2}$?
- ν 9/2[404] in even-even nuclei
  work in progress

Theoretical help on ν 9/2[404] needed !



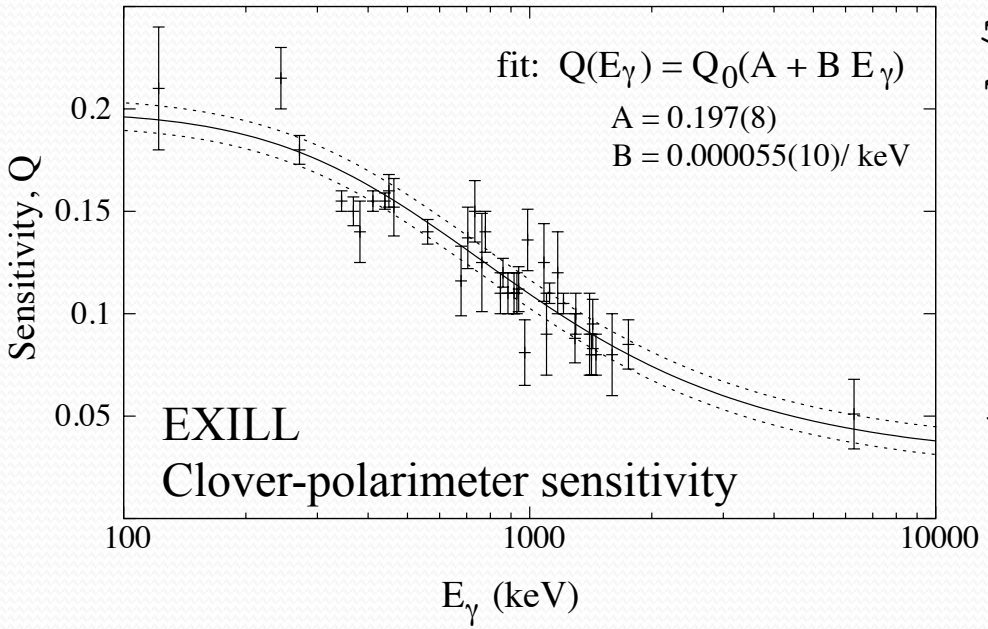


6. Experimental progress - spins and parities of nuclear levels (EXILL, FIPPS)

Example: 2926.3 keV level in ^{86}Kr
- previous assignment $I^{\pi} = 2^{+}$
- new assignment $I^{\pi} = 1^{+}$

Linear polarization – parities
Pexp = -0.58(15)

$I^{\pi} = 1+$: Pth = -0.48(5)
$I^{\pi} = 3+$: Pth = -0.99(8)



Angular correlations - spins