Spectroscopy of neutron-rich nuclei around ^{110}Zr

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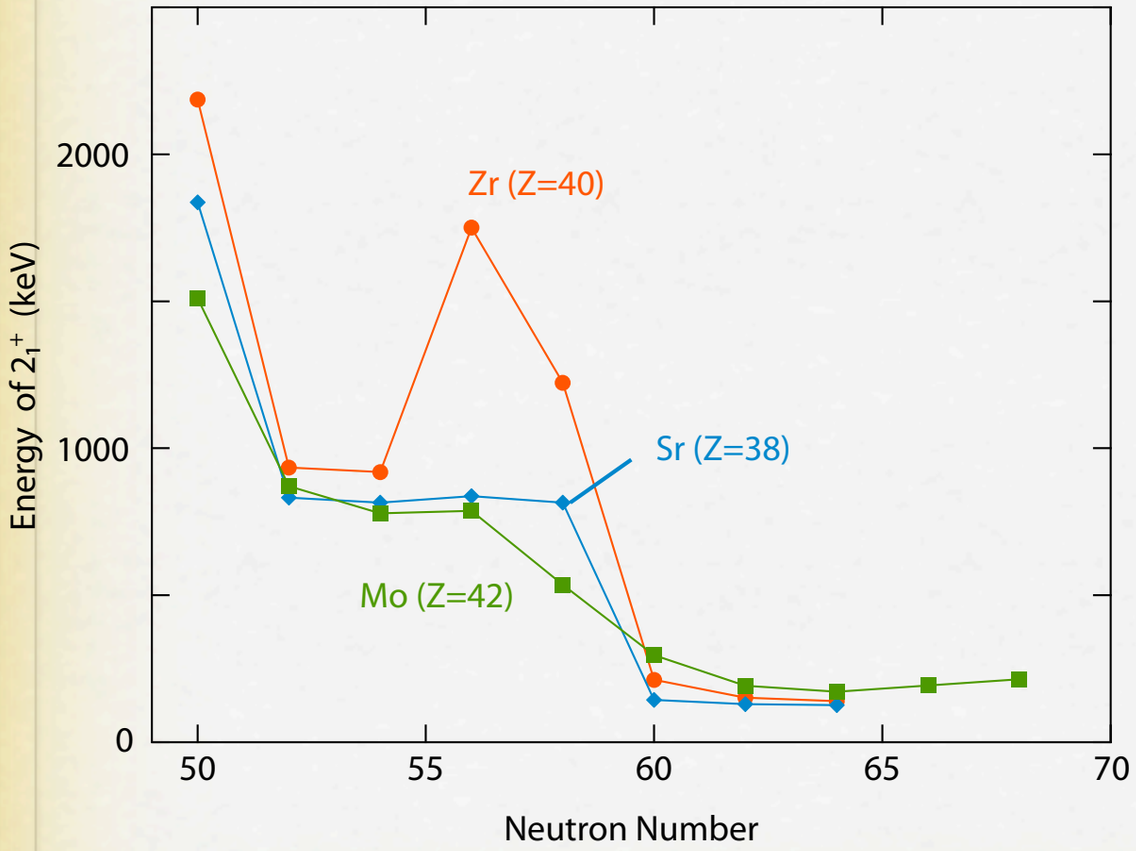
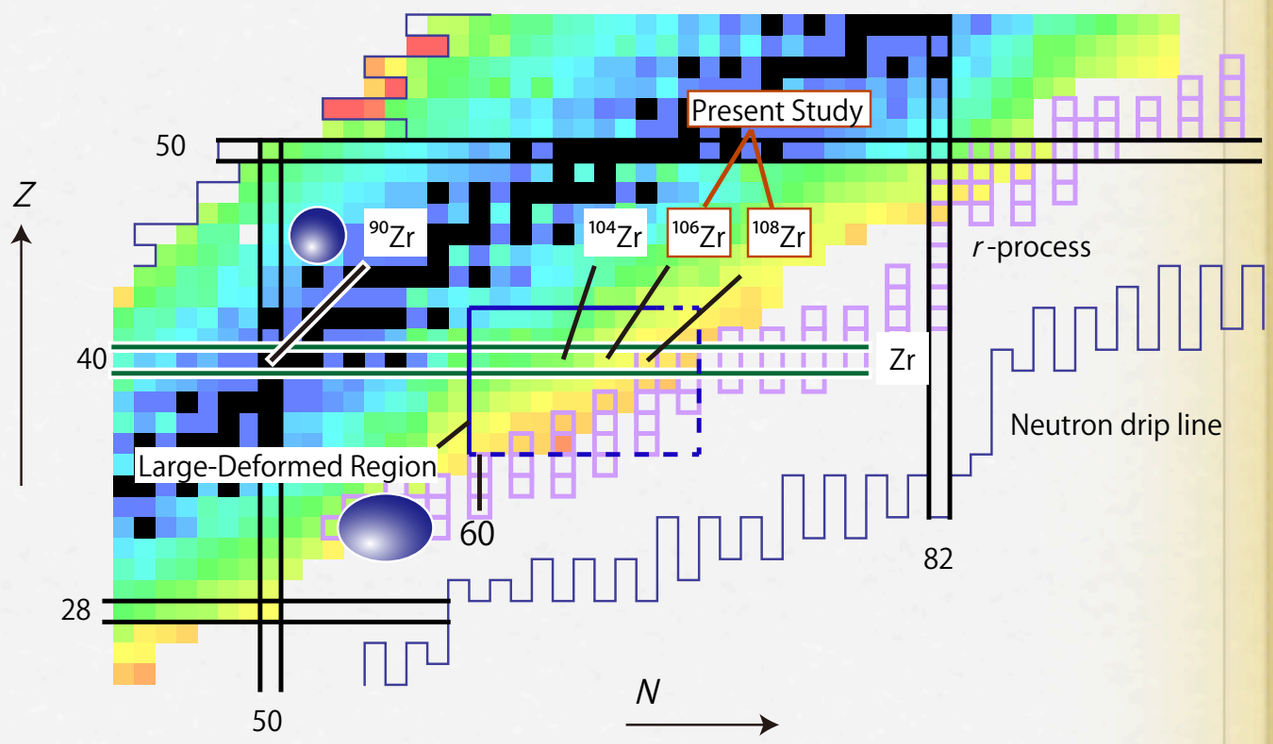
- Introduction: Structural evolution of Zr isotopes
- Decay spectroscopy for ^{106,108}Zr performed at RIBF
- Decay spectroscopy of neutron-rich nuclei around ^{110}Zr with E(U)RICA
- Summary

Large deformed Region

- Sudden onset of large deformation at N=60
- Deformation evolution

  Related to deformed shell gap for neutron?



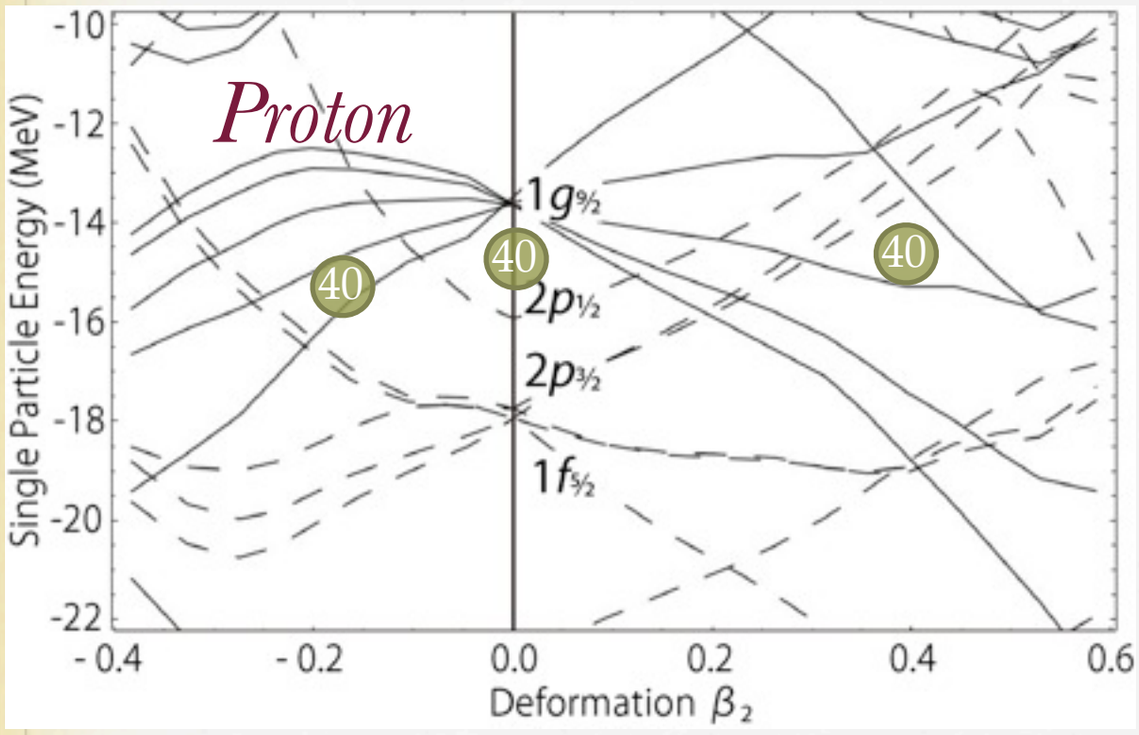


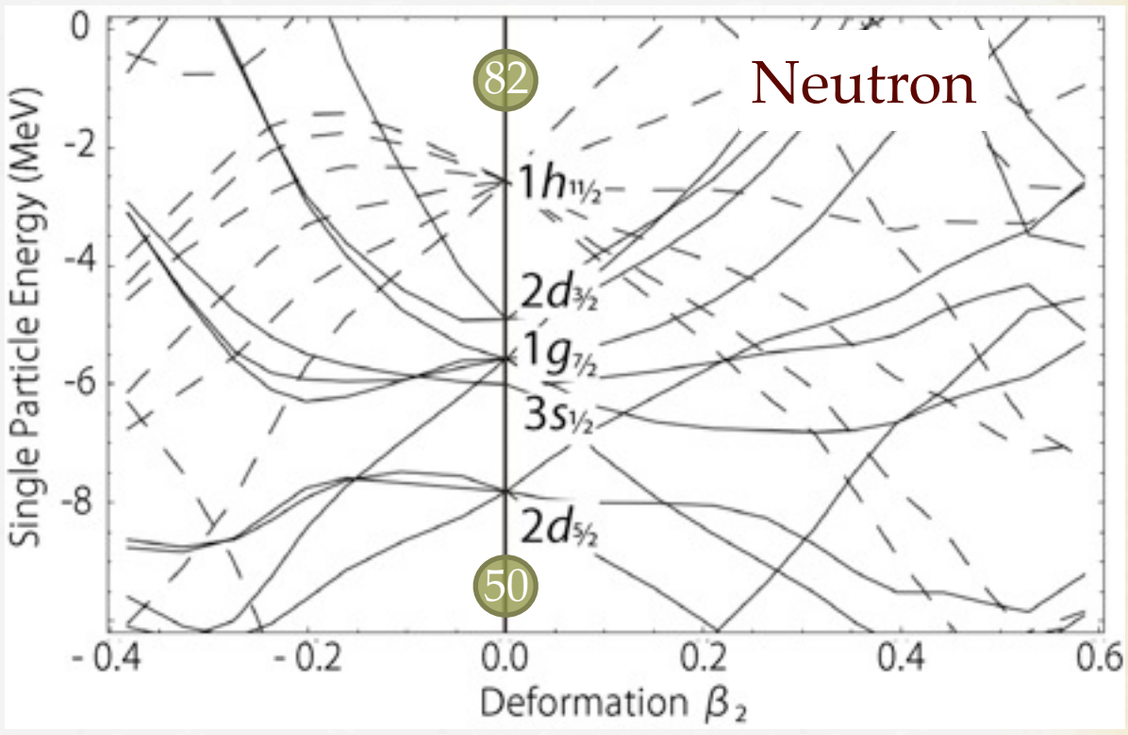
Nilsson Diagram

- Zr isotopes (Z=40)

  Gap for spherical, prolate and oblate shapes

  Enhancement of deformation evolution as a function of neutron number





HFB Calculation for ^{108}Zr using SLy4 by Yoshida-san

Decay Spectroscopy for ^{106,108}Zr performed at RIBF

T. Sumikama *et al.*, Phys. Rev. Lett. **106**, 202501 (2011)

Collaborators

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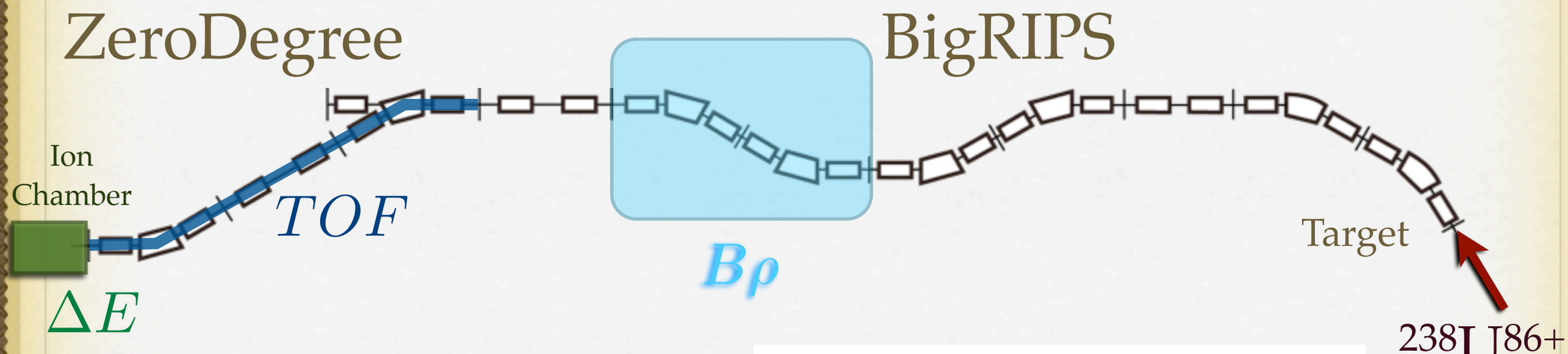
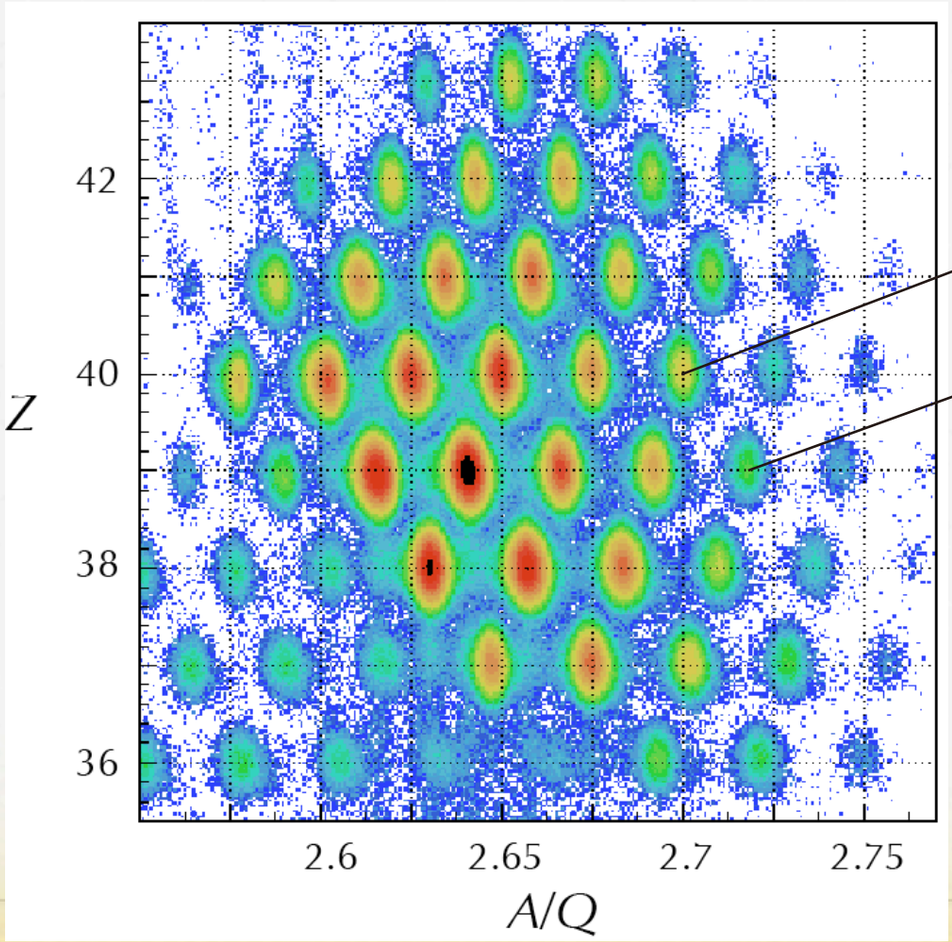
Università di Milano, INFN	A. Bracco, F. Camera
University of Surrey	Zs. Podolyák, P.M. Walker
University of York	D.G. Jenkins

Secondary Beam Production



- $B\rho$ @ BigRIPS
- TOF @ ZeroDegree (ZD)
- ΔE ion chamber



Gamma-ray from ^{106}Zr

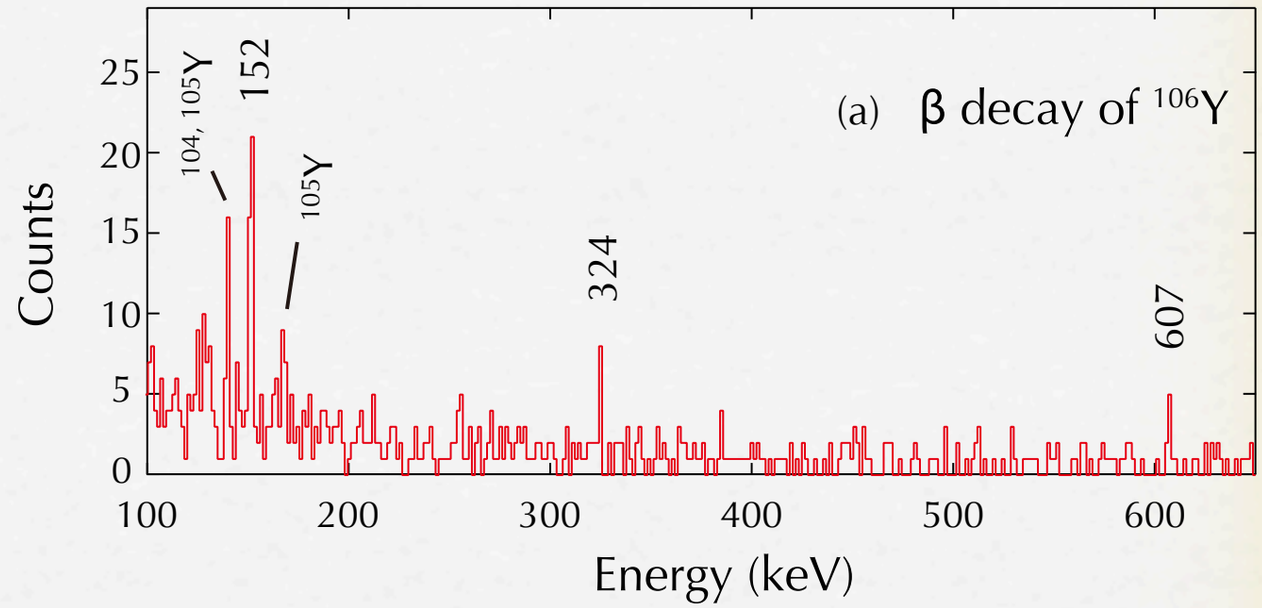
- β-delayed γ-ray from ^{106}Zr (β decay of ^{106}Y)

- Spin assignment

  Most intense peak

  152 keV

  $2_1^+ \longrightarrow 0_1^+$



- Other peaks

  324 keV: $4_1^+ \longrightarrow 2_1^+$

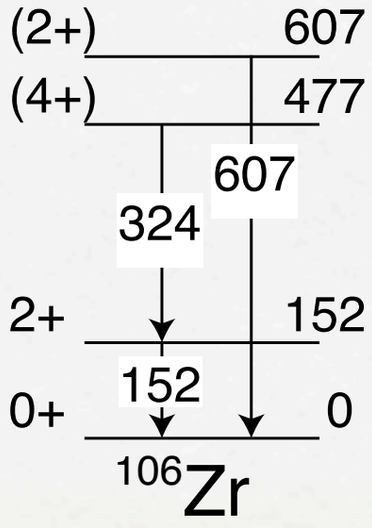
  607 keV: $2_2^+ \longrightarrow 0_1^+$

- Prediction (IBM)

  $E(4_1^+) = 455$ keV

  $E(2_2^+) = 618$ keV

S. Lalkovski and P. Vanlsacker, PRC 79, 044307 (2009).



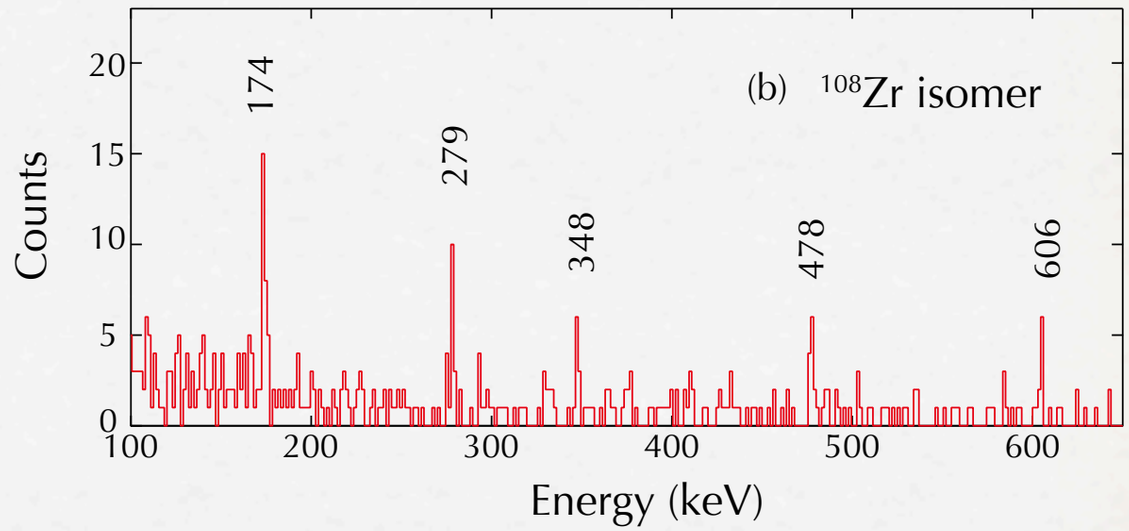
Isomeric state in ^{108}Zr

- Isomer was discovered. (620±150 ns)

- Possible ground-state structure of ^{108}Zr

  Deformed as lighter Zr isotopes

  Spherical due to possible N=70 subshell gap



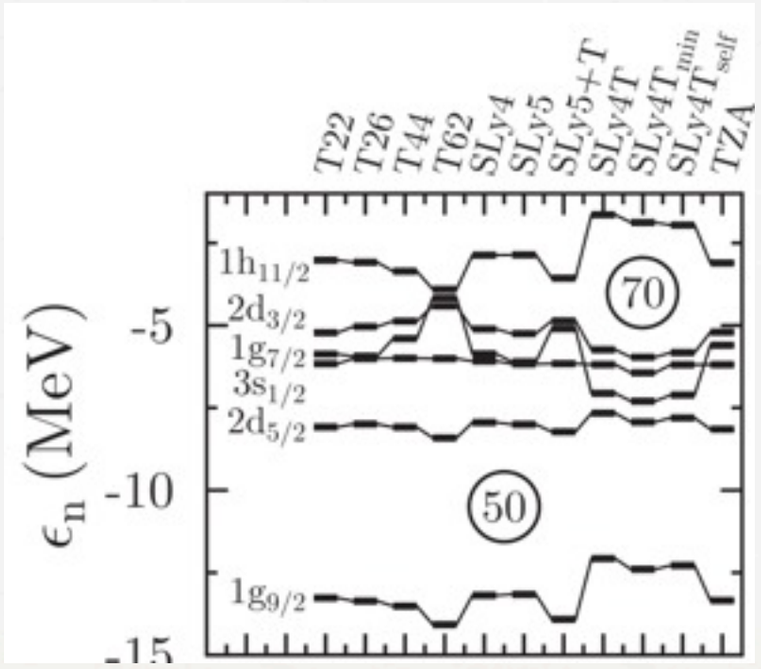
Spherical Shape around ^{110}Zr

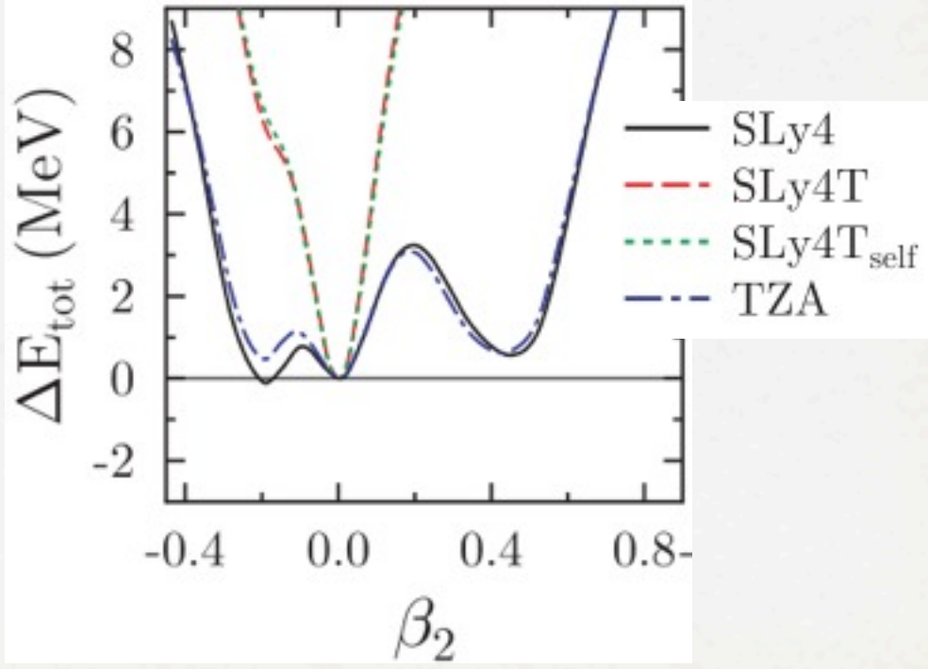
- Shell gap at N=70
- Spherical shape

  Skyrme EDF with a tensor force + a reduced spin-orbit term

  M. Bender et al., PRC 80, 064302 ('09).

For Neutron





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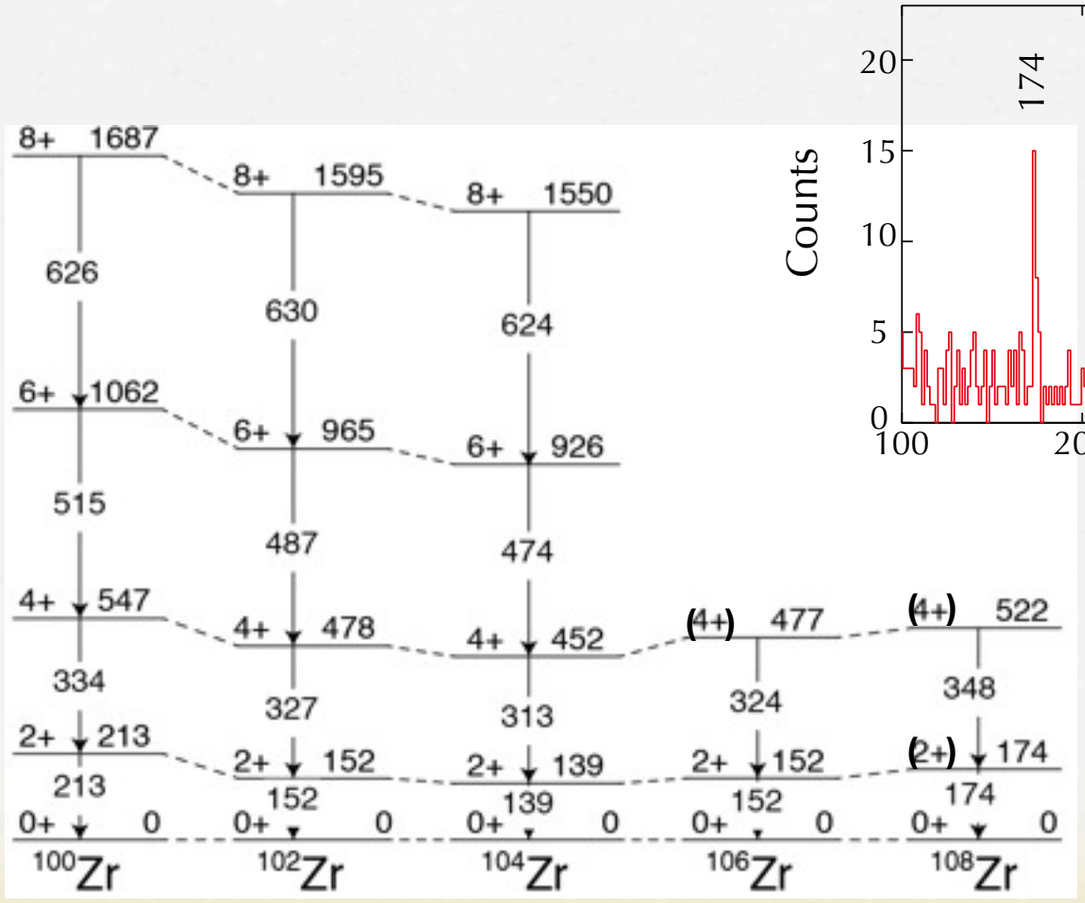
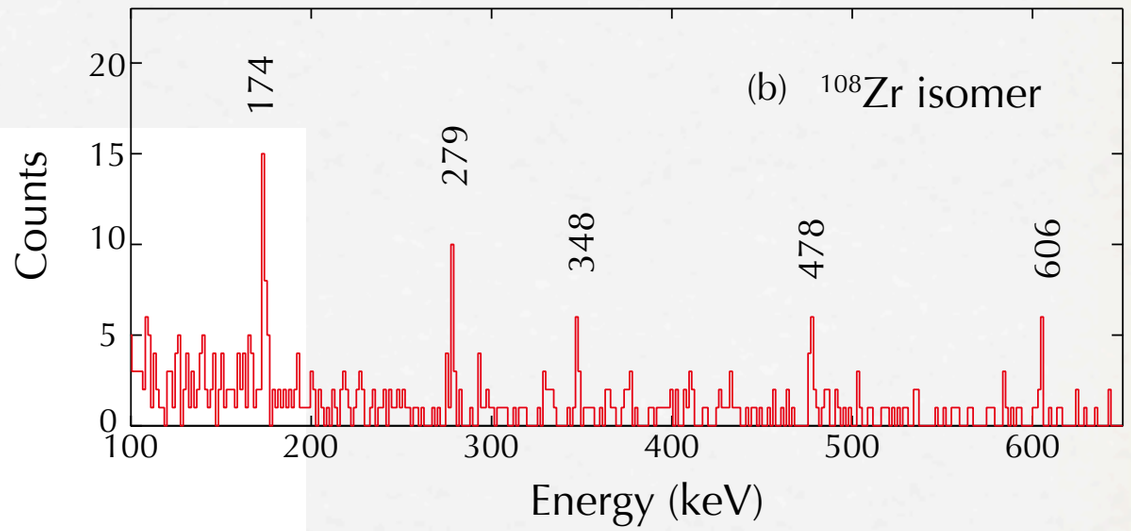
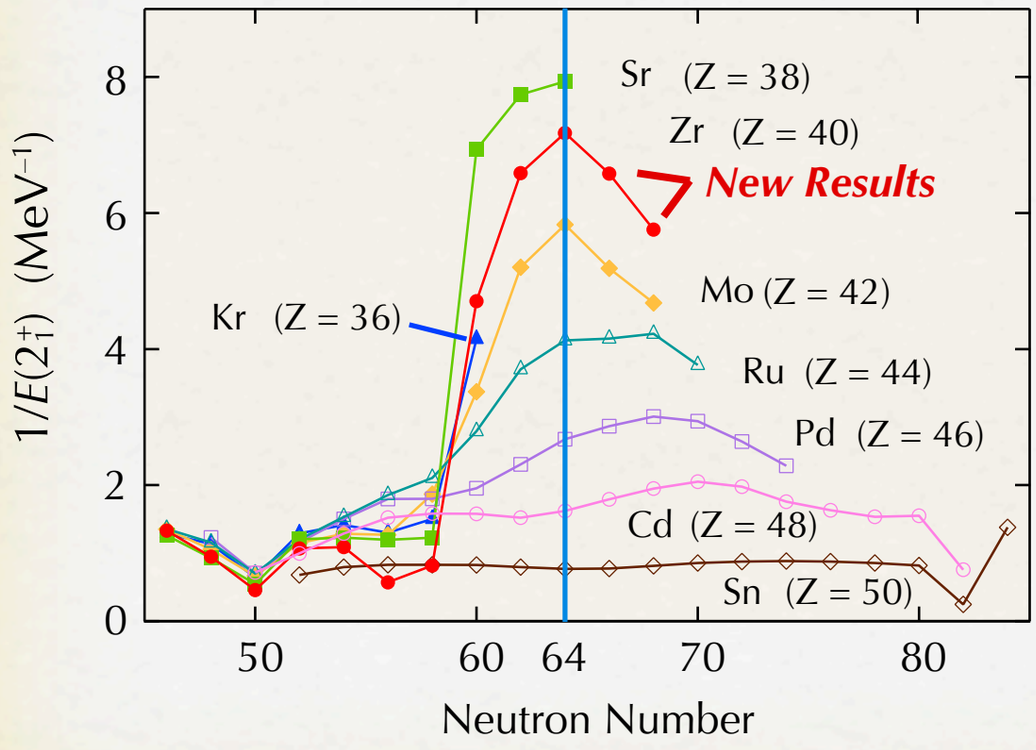




Systematics of even-even nucleus

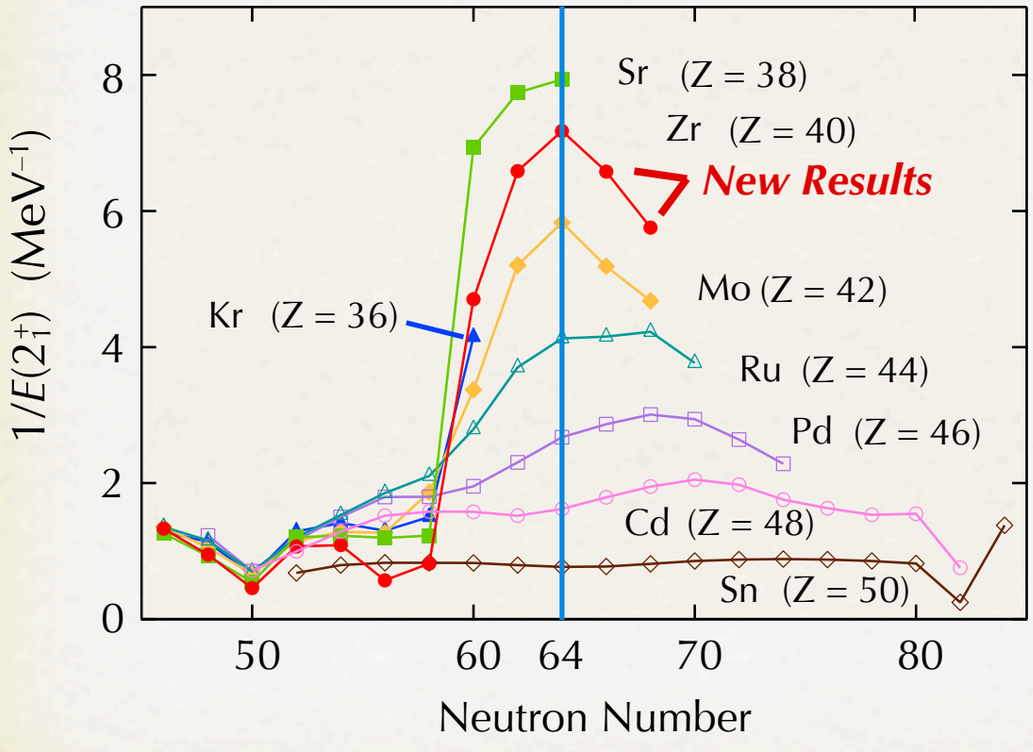
- $1/E(2_1^+)$
  - Maximum @ N=64 for Mo and Zr isotopes

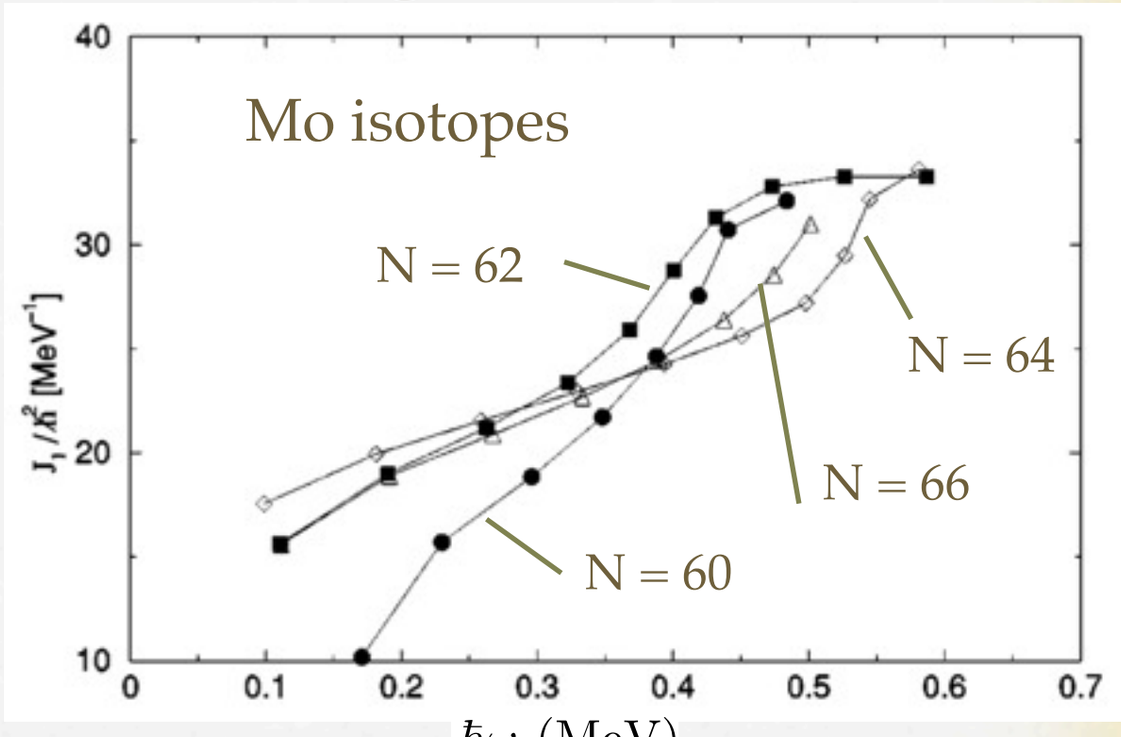


Systematics of even-even nucleus

- $1/E(2_1^+)$
  - Maximum @ N=64 for Mo and Zr isotopes

- Band crossing due to rotation alignment of $h_{11/2}$ neutron pair
  - Stability @ N=64
    - **Deformed sub-shell closure @ N=64**

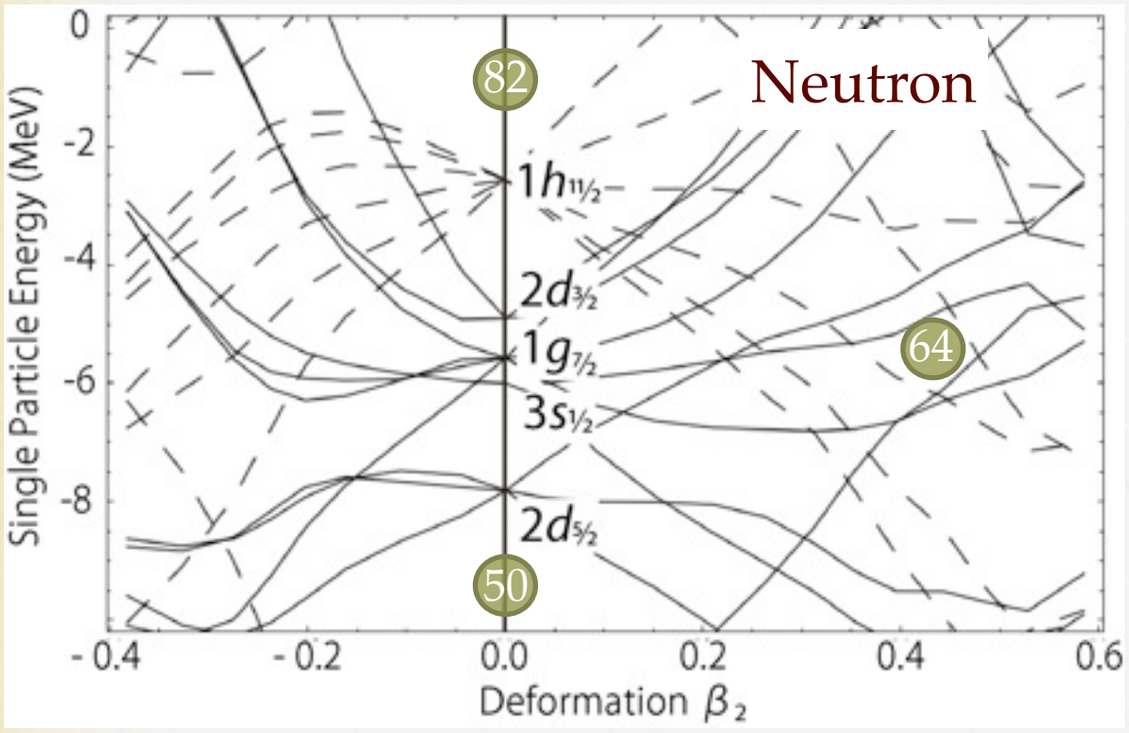




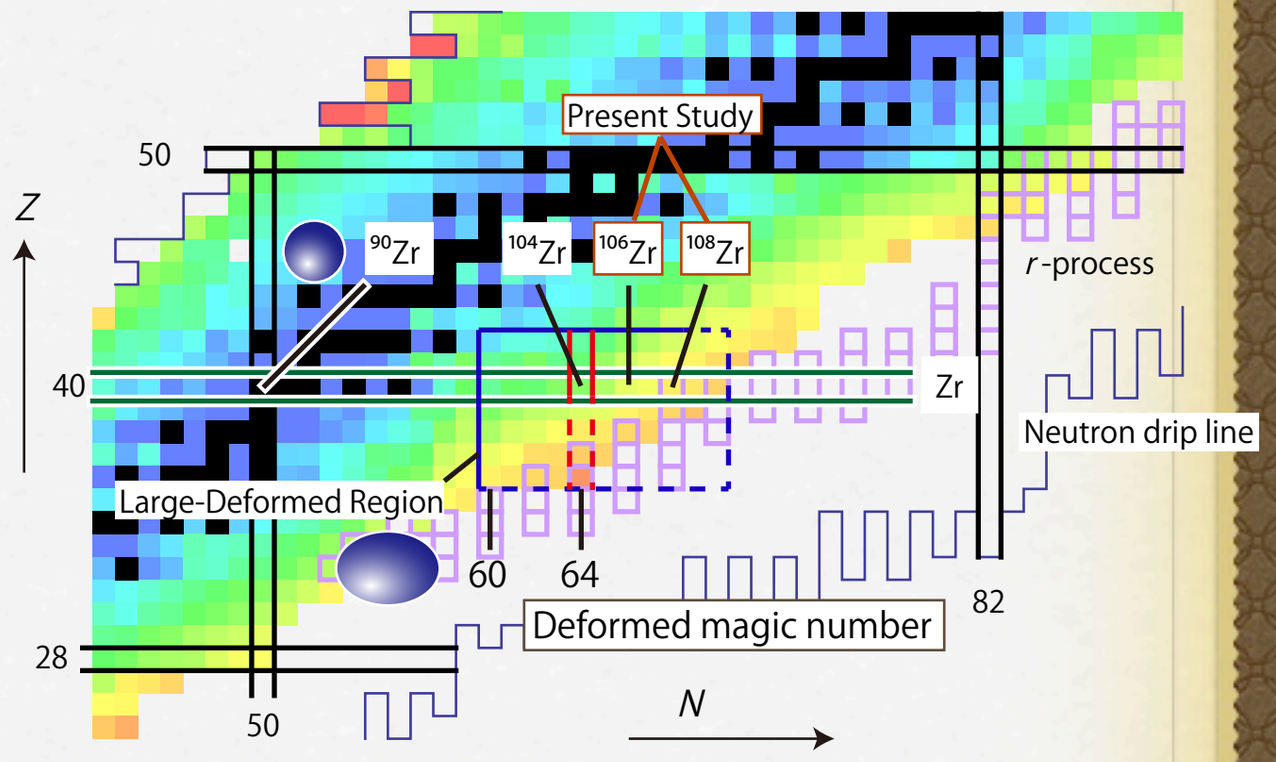
Hua et al., PRC 69, 014317 (2004)

Systematics of even-even nucleus

- $1/E(2_1^+)$
  - Maximum @ N=64 for Mo and Zr isotopes
- Deformed magic number @ N=64

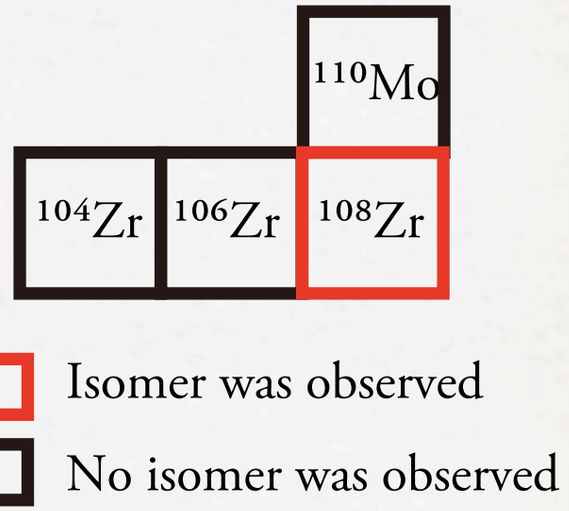


HFB with SLy4 for ^{108}Zr by Yoshida-san



Possible Structure of Isomeric state in ^{108}Zr

- Long-lived isomer in even-even nucleus (620±150 ns)

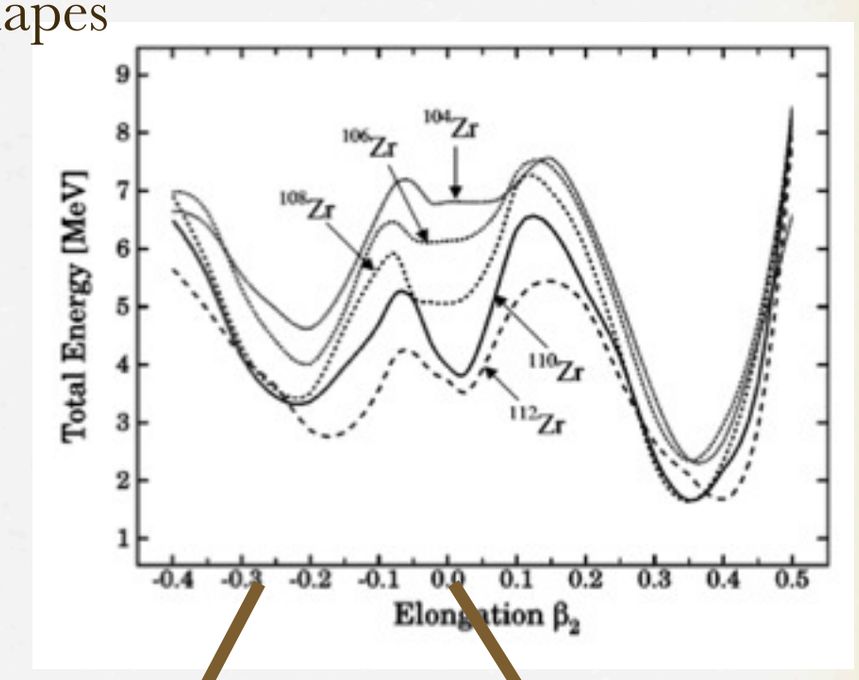


1. Tetrahedral shape isomer

Shell effect for spherical should be small.

Energy barrier between oblate and tetrahedral shapes

N. Schunck et al., PRC 69, 061305(R) (‘04).



2. High *K*-isomer

Two quasineutron states

Known for N=62 isotones; ^{102}Zr, ^{100}Sr

Predictions for prolate (Z=40) and oblate (N=66)

F. R. Xu et al., PRC 65, 021303(R) (’02).

Decay Spectroscopy around ^{110}Zr with E(U)RICA

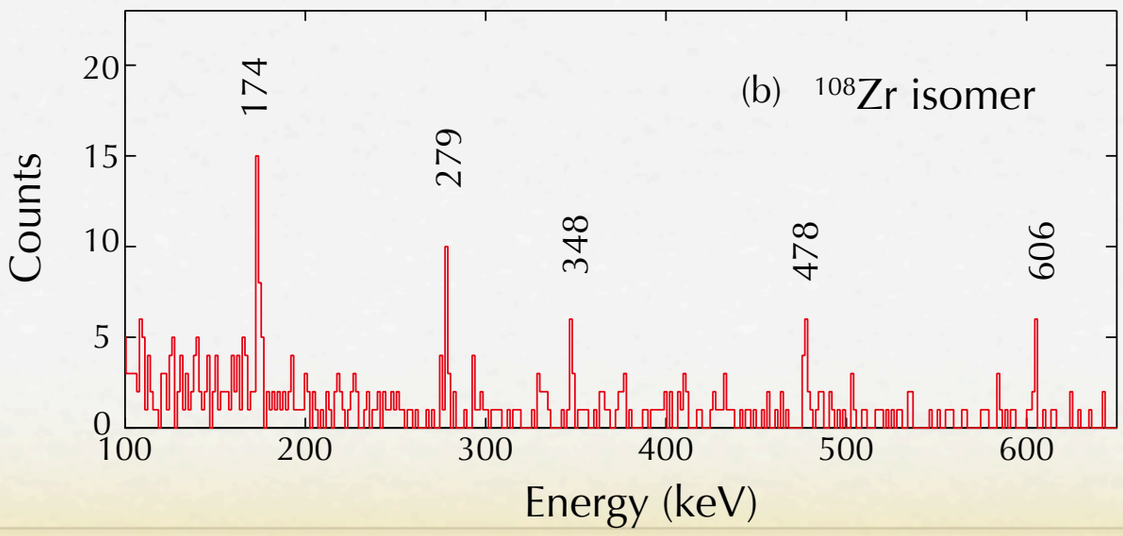
Zr, & Mo Isotopes

^{108}Zr Isomer

- Previous experiment
  - Half-life: 620±150 ns
  - Identified 5 peaks

Passive stopper exp. @ RIBF
Identified 9 peaks
T. Nakao, Doctor thesis (2010)

- Next step
  - Detection of missing γ-ray peaks
  - Energy of isomeric state: Level scheme
  - Search for isomer in even-even nuclei



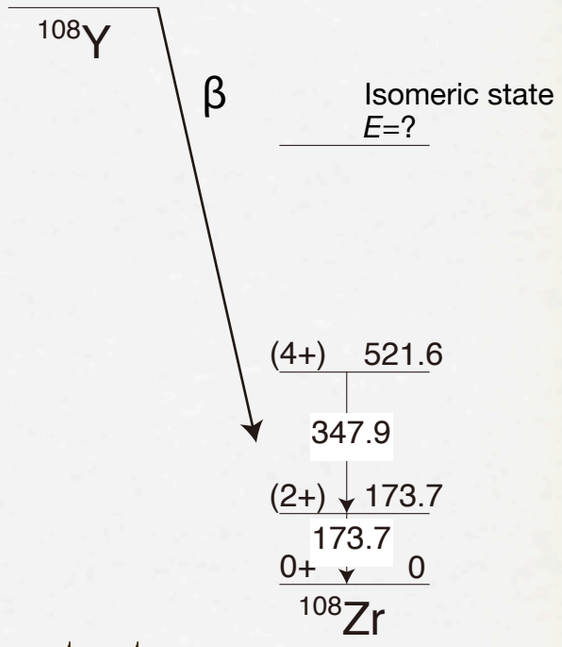
Decay Spectroscopy of ^{108}Zr

- Spectroscopy of ^{108}Zr isomer with high statistics

  Search for missing γ-ray peaks

  γ-γ coincidence

- Beta decay of ^{108}Y to ^{108}Zr



- Level scheme

  Common peaks correspond to low-lying states.

- Structure from E and $t_{1/2}$
  - Tetrahedral shape?
  - High-K isomer?

Isomer Search In Even-even Nuclei

- N=68: ^{110}Mo with high statistics
- N=70: ^{110}Zr and ^{112}Mo

- 1. Tetrahedral shape isomer in ^{108}Zr

  a. Tetrahedral shape isomer in ^{110}Zr

  b. Ground state of ^{110}Zr is predicted to be tetrahedral shape.

  N. Schunk et al., PRC **69**, 061305(R) (2004).

  Prolate shape may become an isomer??

- 2. Isomer of ^{108}Zr is the high K isomer

  Two quasineutron states around ^{108}Zr

  F. R. Xu et al., PRC **65**, 021303(R) (2002).

Ground-State Structure of ^{110}Zr

- Low-lying states
  - Isomer in ^{110}Zr
  - β-decay of ^{110}Y
    - No chance using ~ 3 pnA ^{238}U beam
- Test of predicted transition to spherical shape at N=70

^{106}Zr & ^{112}Mo

- β-decay of ^{106}Y to ^{106}Zr
- Confirmation of 2_2^+ state

  Detection of γ-ray from 2_2^+ to 2_1^+ states

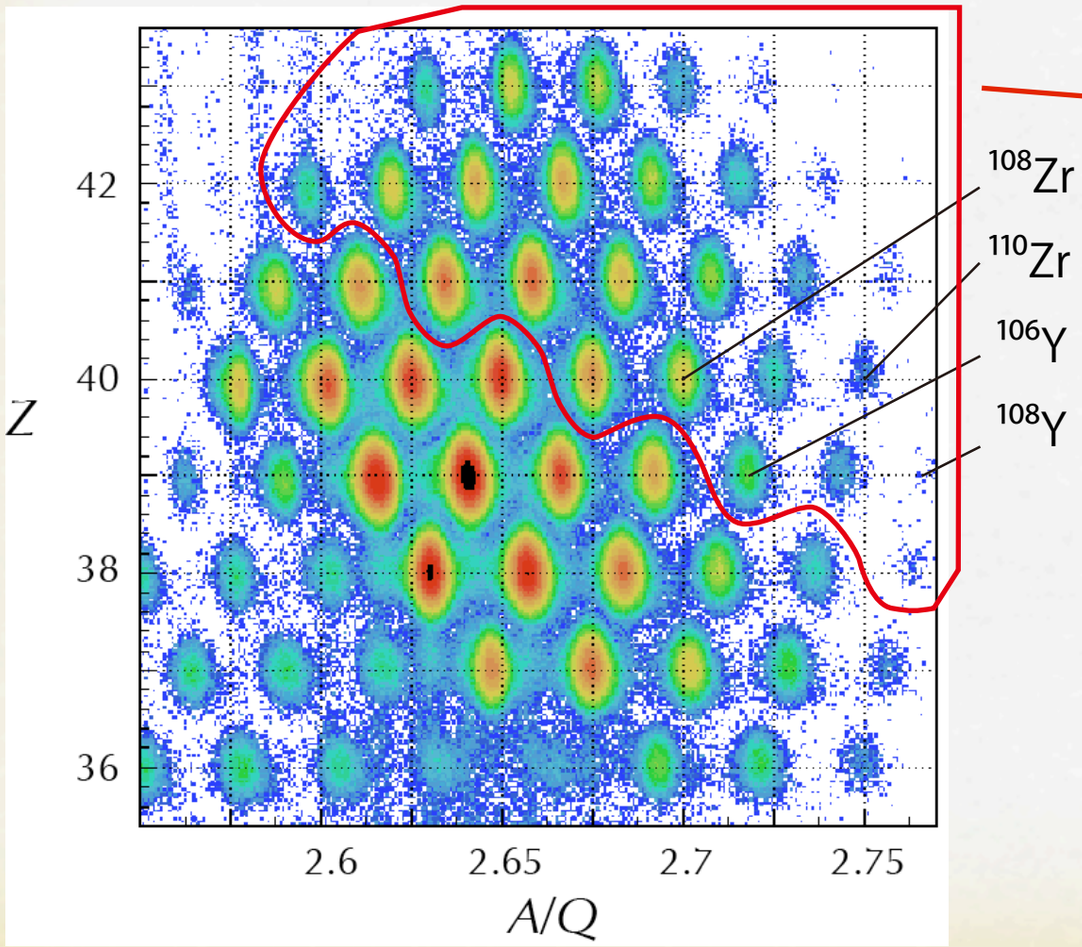
- β-decay of ^{112}Nb to ^{112}Mo
- Energy of 2_1^+

Beam Time Estimation

Use of High Intensity Beam

- High intensity beam
  from ~ 0.3 pnA to 5 pnA (avg. 3 pnA)
- Keep Total Yield to ~ 100 cps

- Separation @ BigRIPS



- Ratio: (N≧67)/(All)=0.13

Decay Spectroscopy with EURICA

- Improvement of γ-ray counts from previous exp.
  - γ-ray efficiency: 4 clovers to EURICA
    x 7
  - High intensity beam
    from ~ 0.3 pnA to 5 pnA (avg. 3 pnA)
    x 10
  - Beam time (8 days)
    x 4
  - Total
    x 280

Previous Exp.		*New Exp.*
Isomer: up to ^{108}Zr	→	Isomer: up to ^{110}Zr
β-γ: up to ^{106}Zr		β-γ: up to ^{108}Zr

Beam Time Estimation

- β-γ & Isomer spectroscopy around ^{110}Zr (N=67 - 72)
  - 8 days
- Beam tuning/Circuit & Detector check
  - 2 days
- Total
  - 10 days

Thank you for your attention