The Shape-Transitional ^{98}Zr: Measurement of the B(E2) value with GRETINA/CHICO2

TECHNISCHE UNIVERSITÄT DARMSTADT

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Overview

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- Shape (Phase) Transitions ...
- … and Coexistence
- Spherical and Deformed Shape in Zr Isotopes
    - G.S. Collectivity in the transitional ^{98}Zr
    - Experiment: GRETINA & CHICO2 @ ATLAS / CARIBU
    - New, more stringent Limits on B(E2)

Shape (Phase) Transitions

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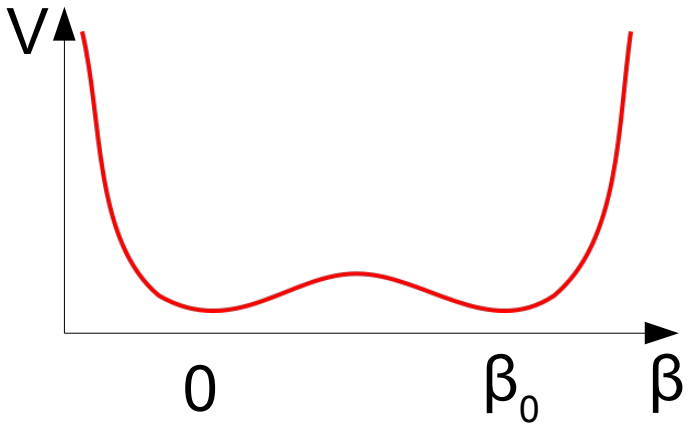
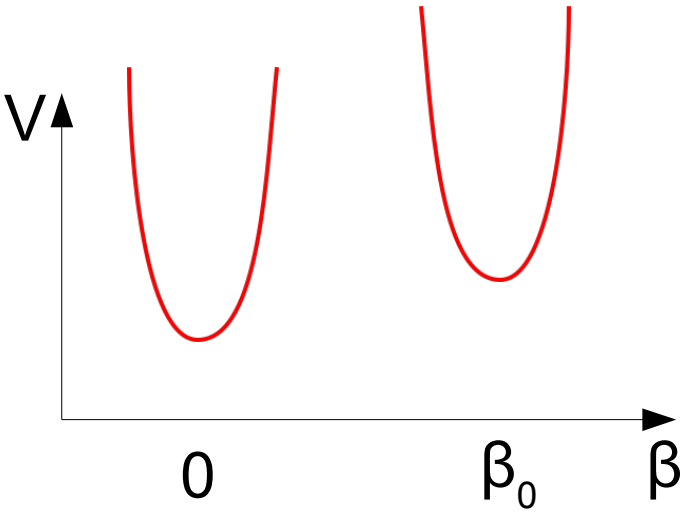
Shape Transition with Strong Mixing / Low Barrier



- Within one valence space
- X(5) / E(5) / CBS

F. Iachello, PRL 85/87 (2000/2001)
N. Pietralla, PRC 70 (2004)

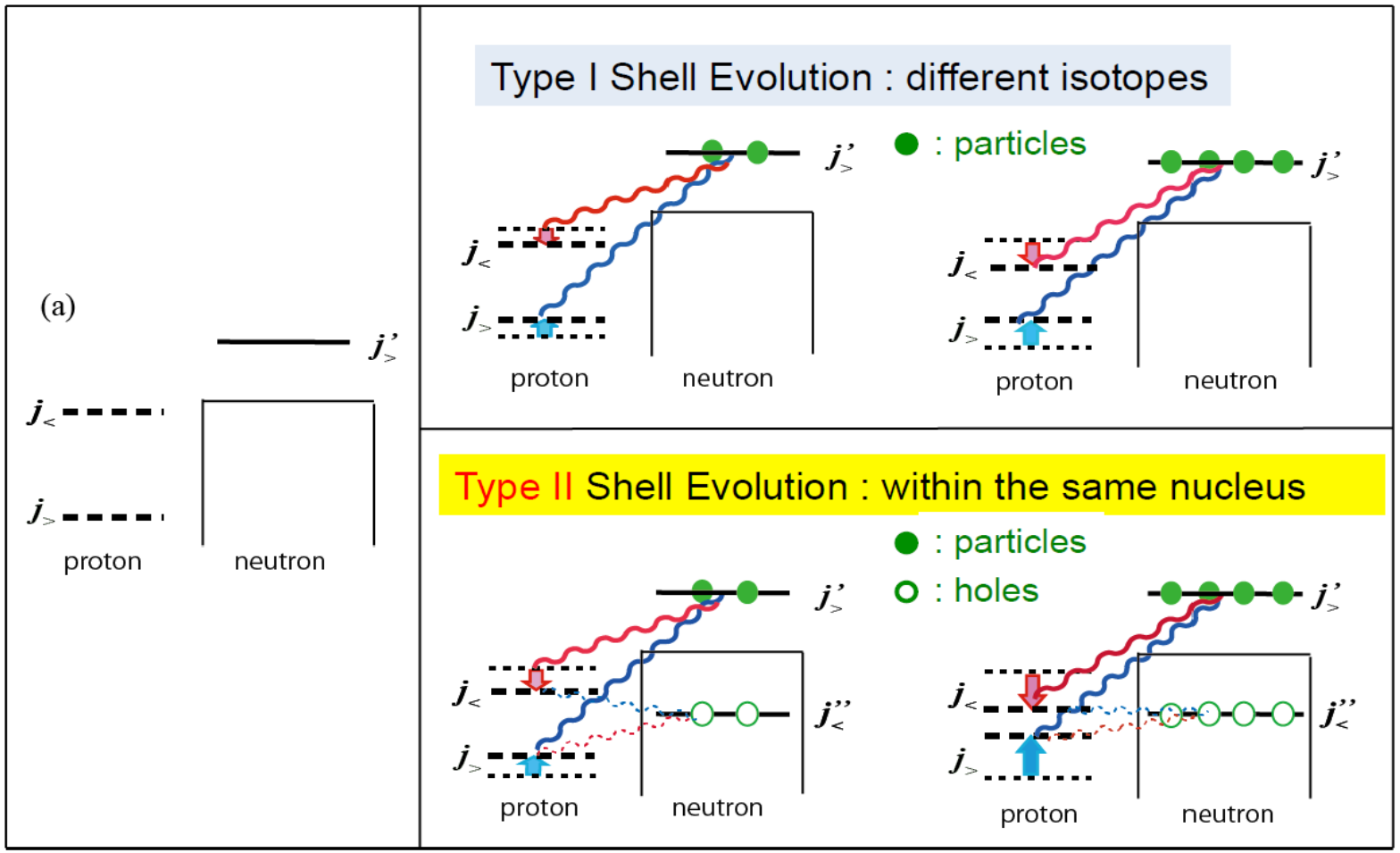
Shape Transition with Weak Mixing / High Barrier



- Two valence spaces (normal + intruder)
- **High-Barrier case**

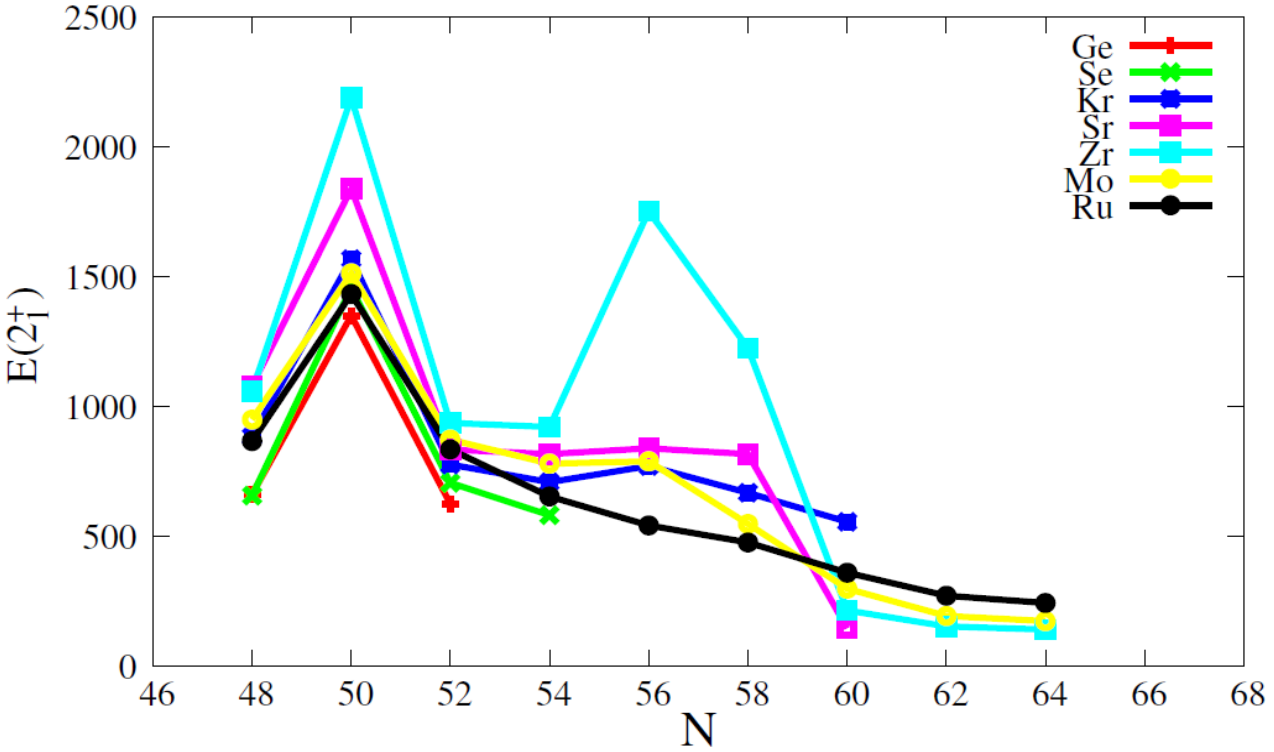
A. Leviathan, PRC 74 (2006)

Type II Shell Evolution



Togashi et al., Phys. Rev. Lett. 117, 172502 (2016)

$E(2_1^+)$ Systematics at N=56-60



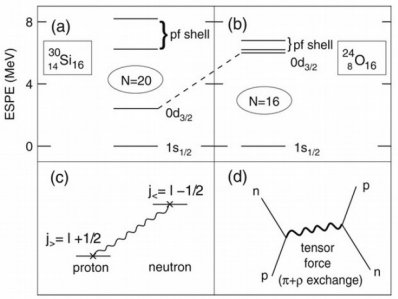
Ru: smooth drop

Mo: small peak at 56, moderate drop

Zr: clear peak at N=56,*58* in Zr

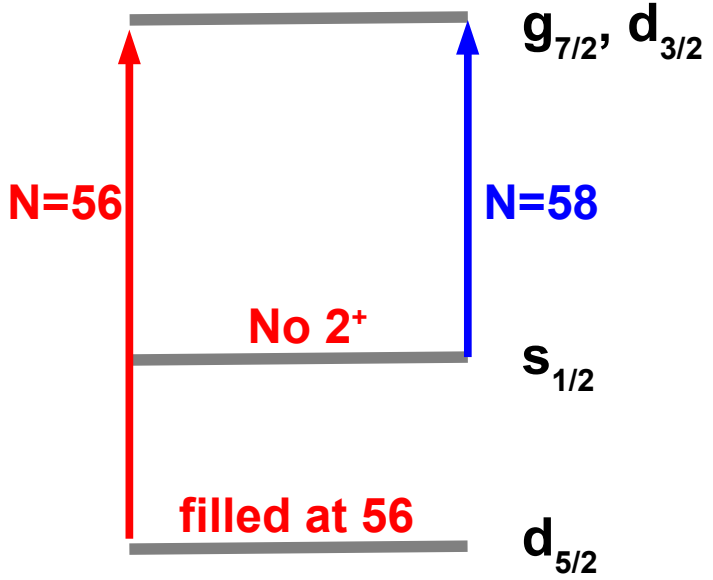
Sr: „peak" N=56, drop past *58*

Kr: small peak at 56, smooth after



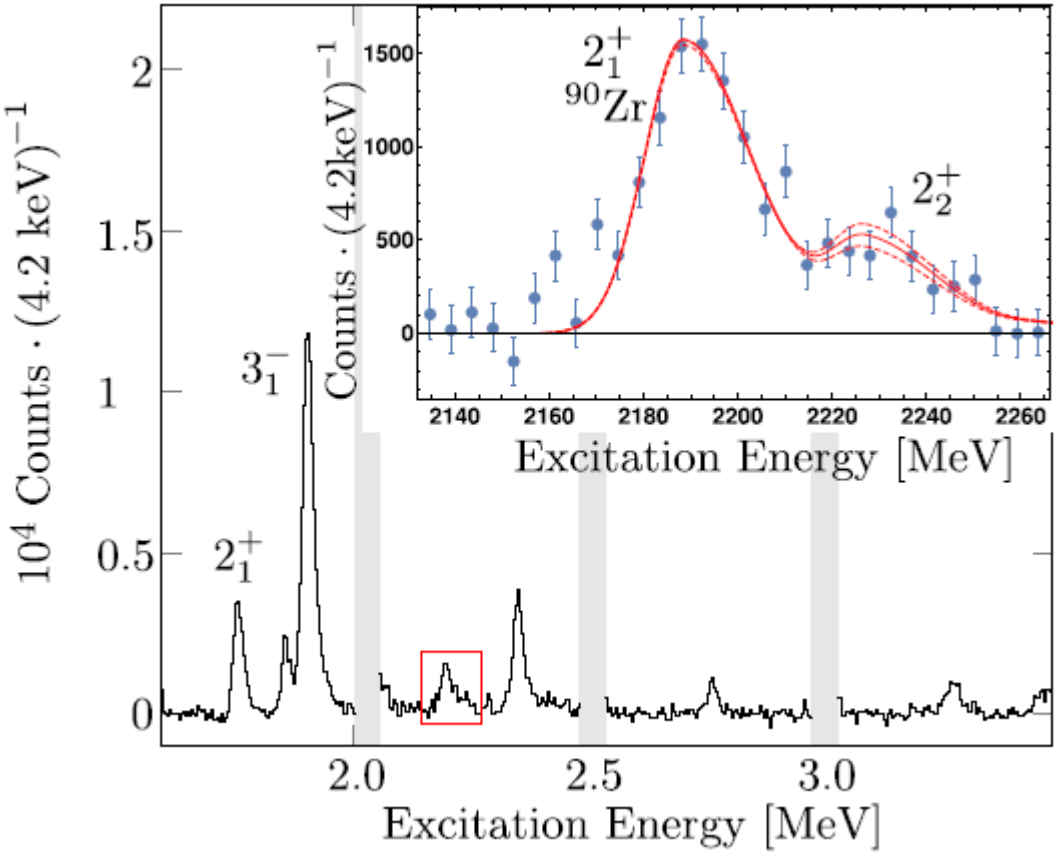
Weak coupling (p-n) was shown for Z~40, N<56 in prev. works

Assume it here -> $E(2_1^+)$ depends mainly on SPEs



For Z>40 $\nu g_{7/2}$ fills and is lowered because of $\pi g_{9/2}$ -> gaps disappear

^{96}Zr – Type II Shell Evolution



Electron Scattering at the S-DALINAC

C. Kremer, PRL 117, 172503 (2016)

^{96}Zr – Type II Shell Evolution

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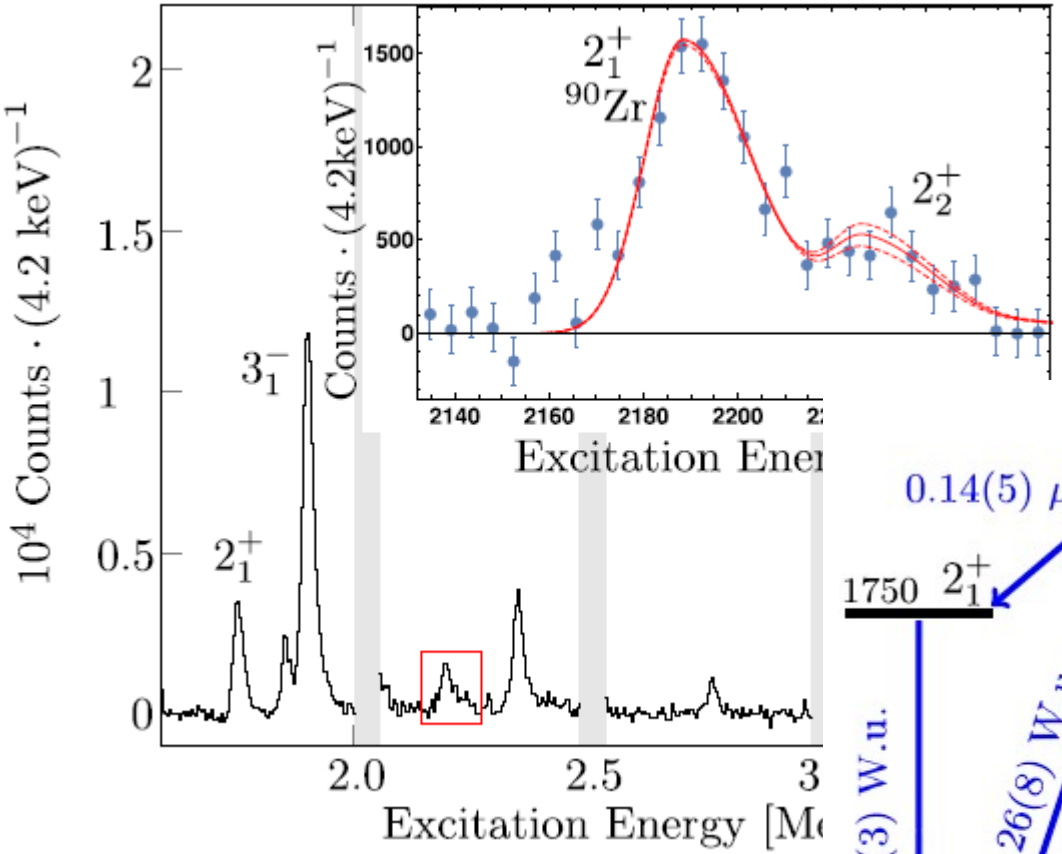
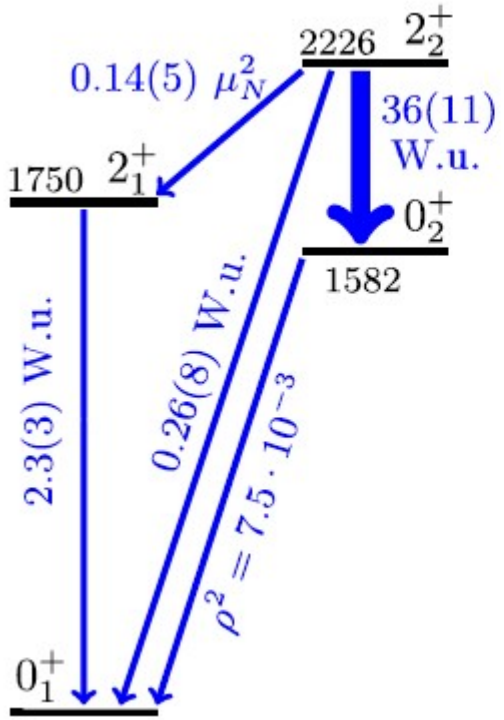
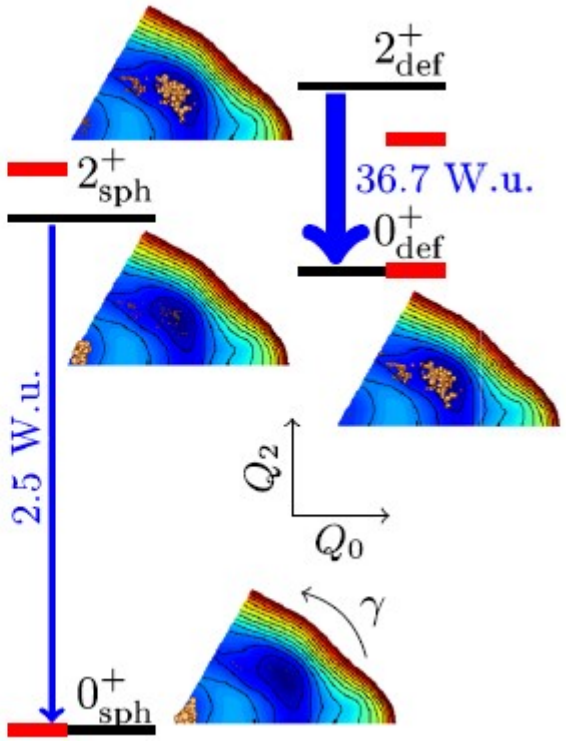


Electron Scattering at the S-DALINAC

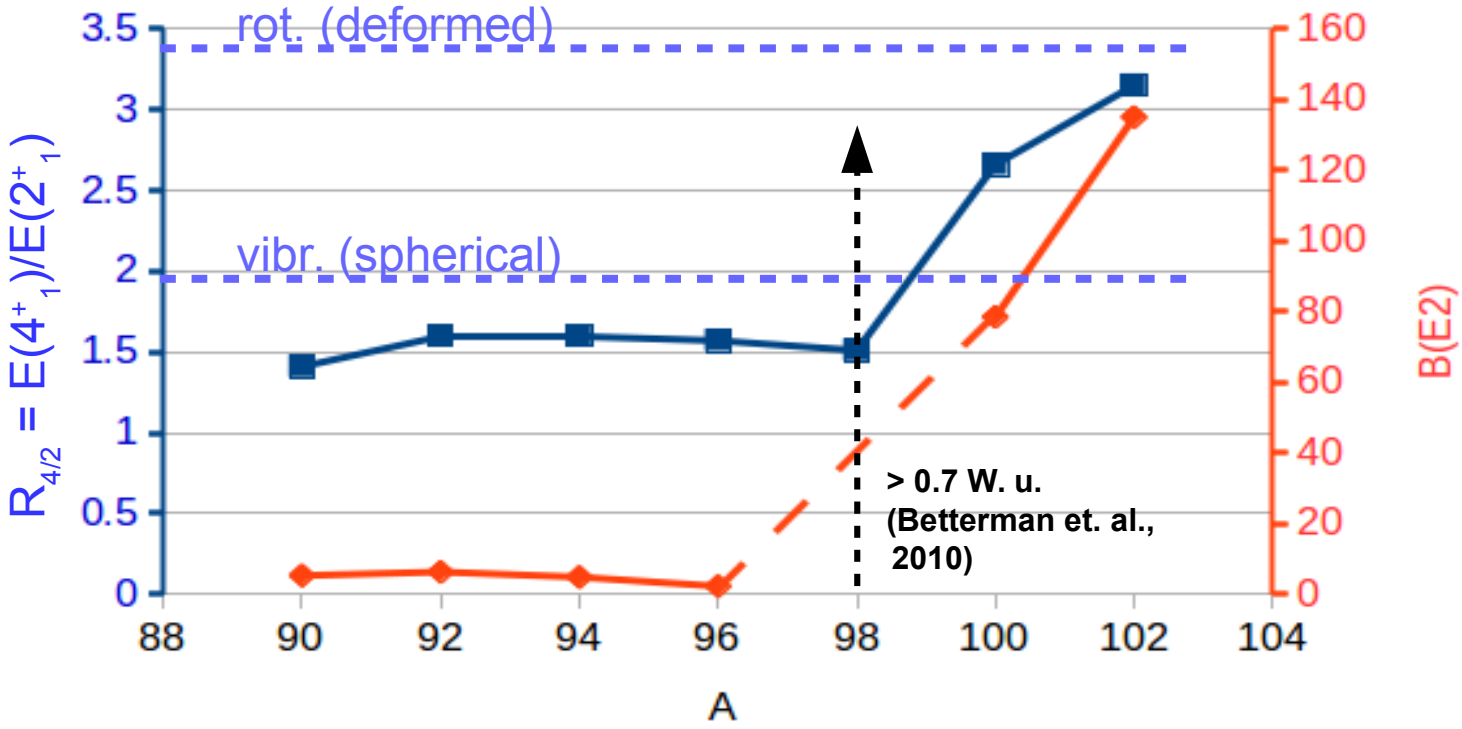
C. Kremer, PRL 117, 172503 (2016)





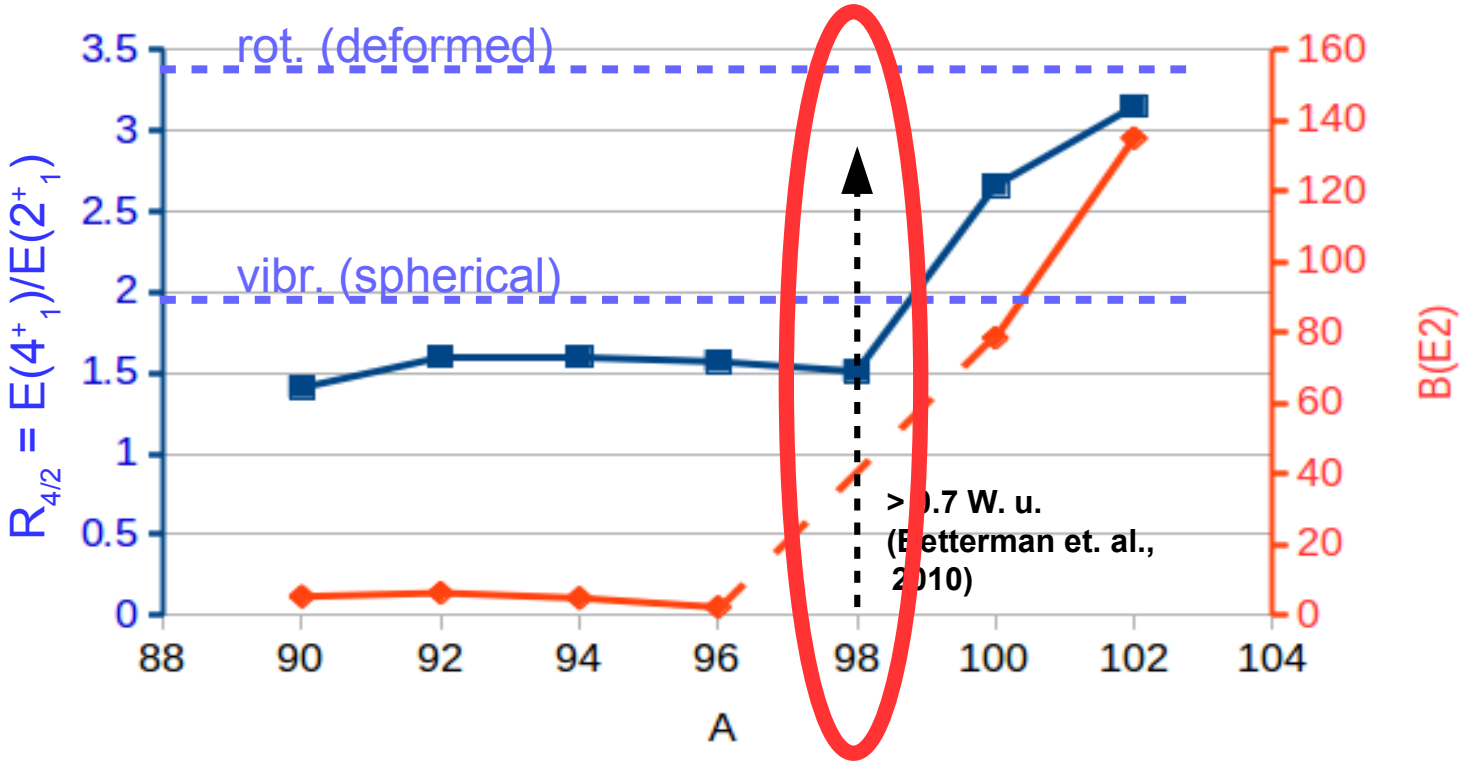
Well-separated spherical and Deformed minima
=> weakly mixing structures

Shape Transition in Zr Isotopes



- **Closed $d_{5/2}$-shell in ^{96}Zr → Spherical ground state**
- **Deformation in ^{100}Zr → Deformed ground state**

Shape Transition in Zr Isotopes



- **Closed $d_{5/2}$-shell in ^{96}Zr → Spherical ground state**
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Coulex Experiment

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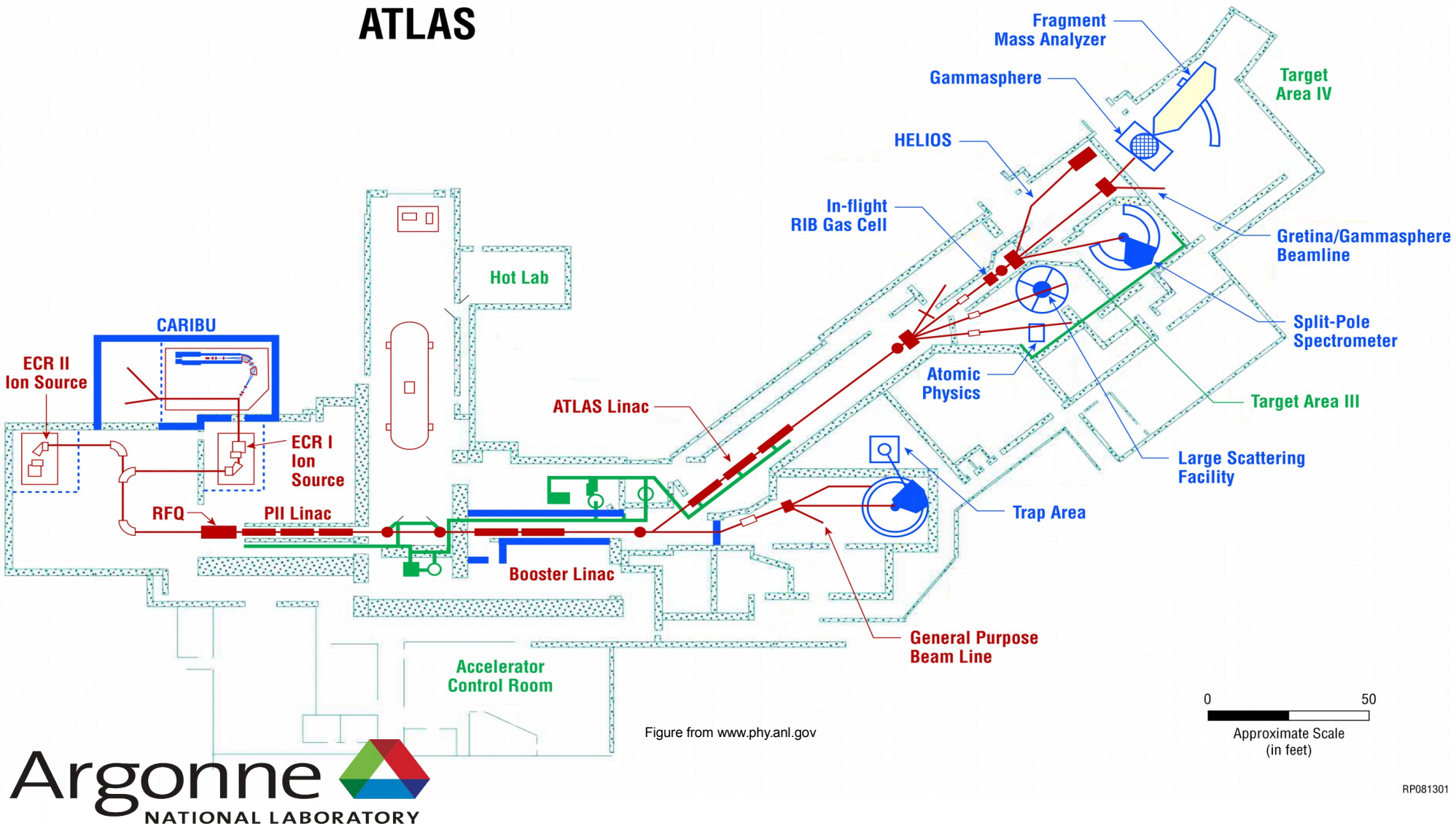
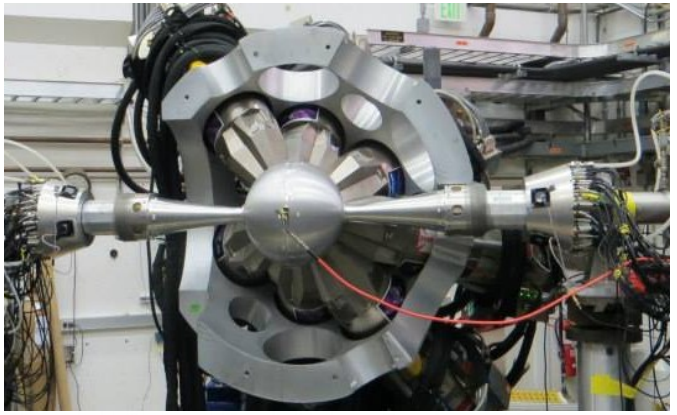


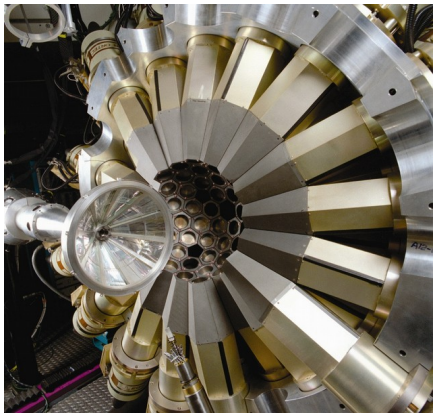
Figure from www.phy.anl.gov

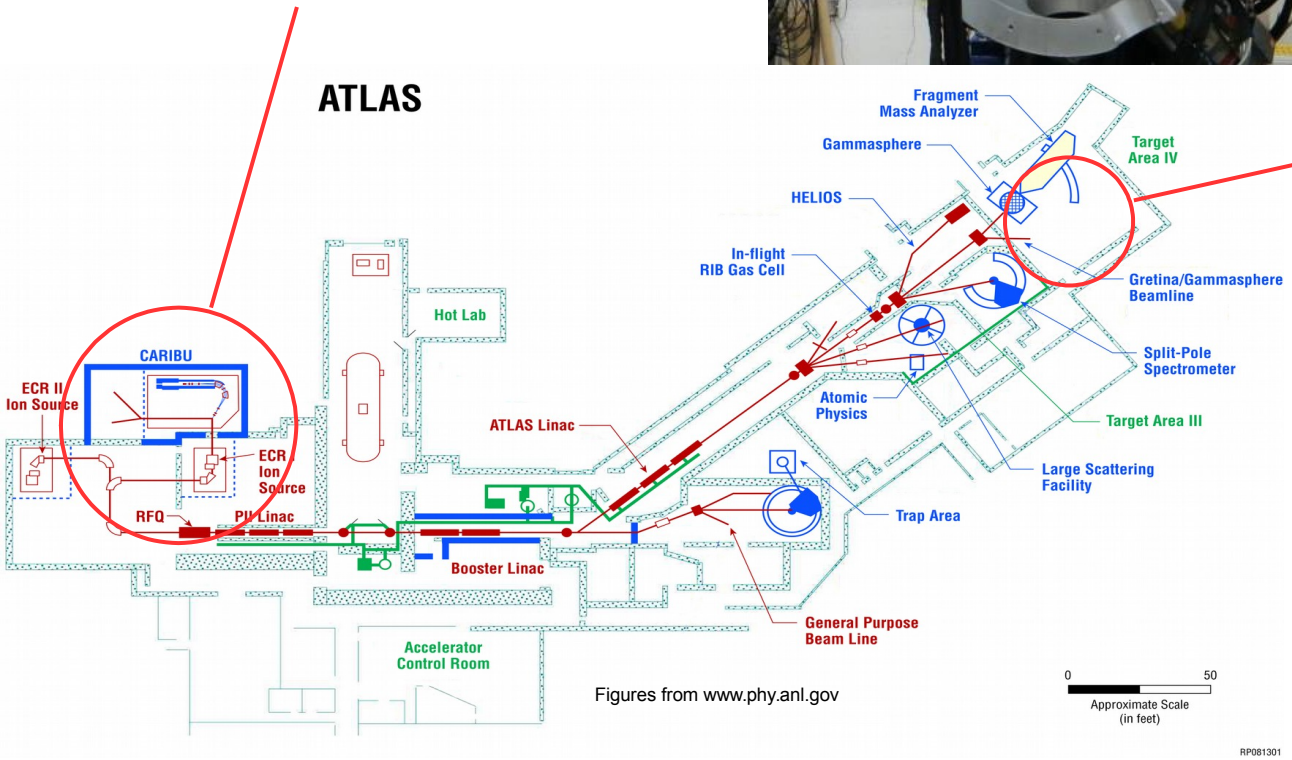
Argonne NATIONAL LABORATORY

Coulex Experiment

- ^{252}Cf fission source
- Gas catcher
- ECR charge breeder

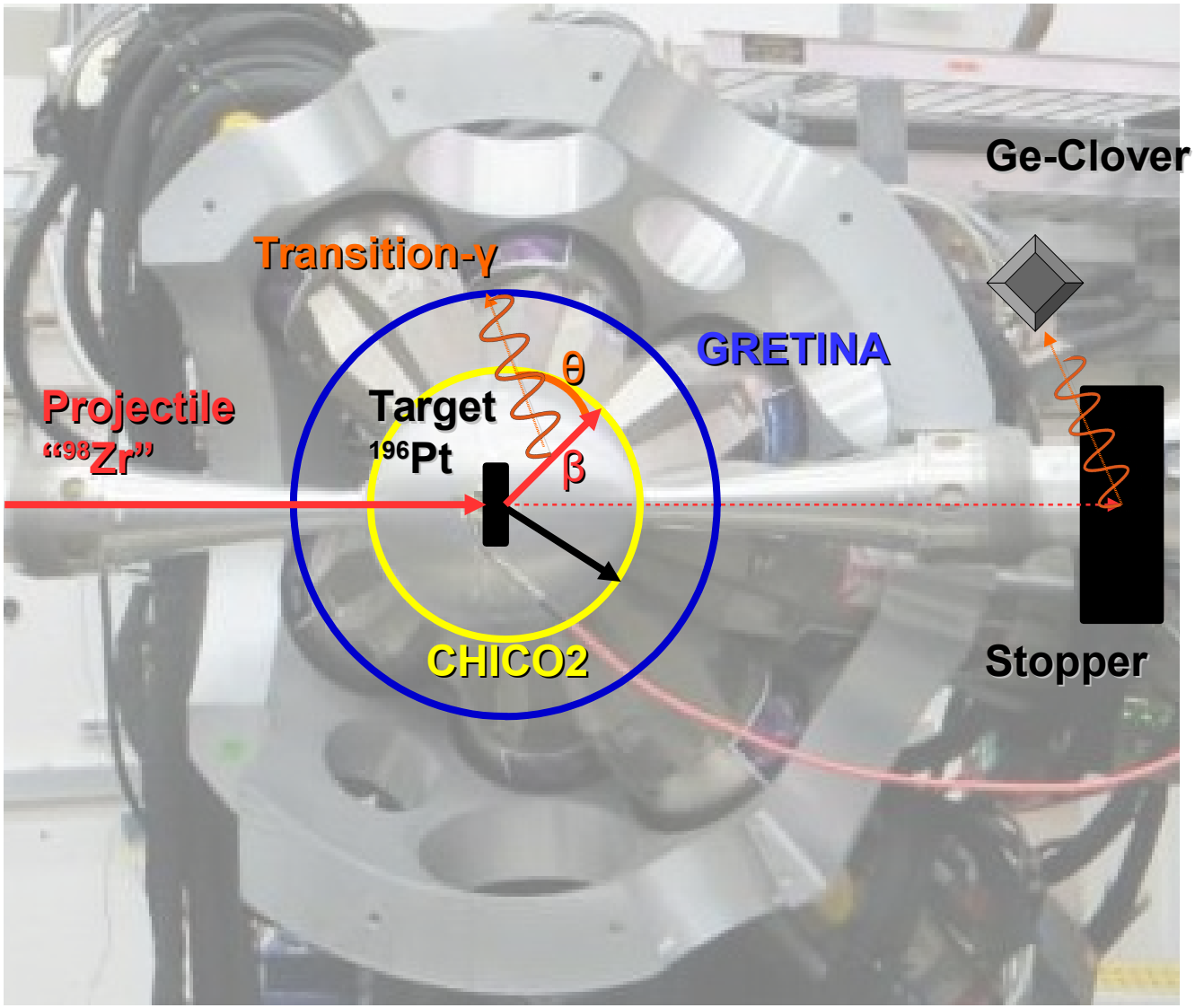






GRETINA & CHICO2
(ε_γ = 6.5%, ΔE/E ~ 1%, Δθ ~ 1°)

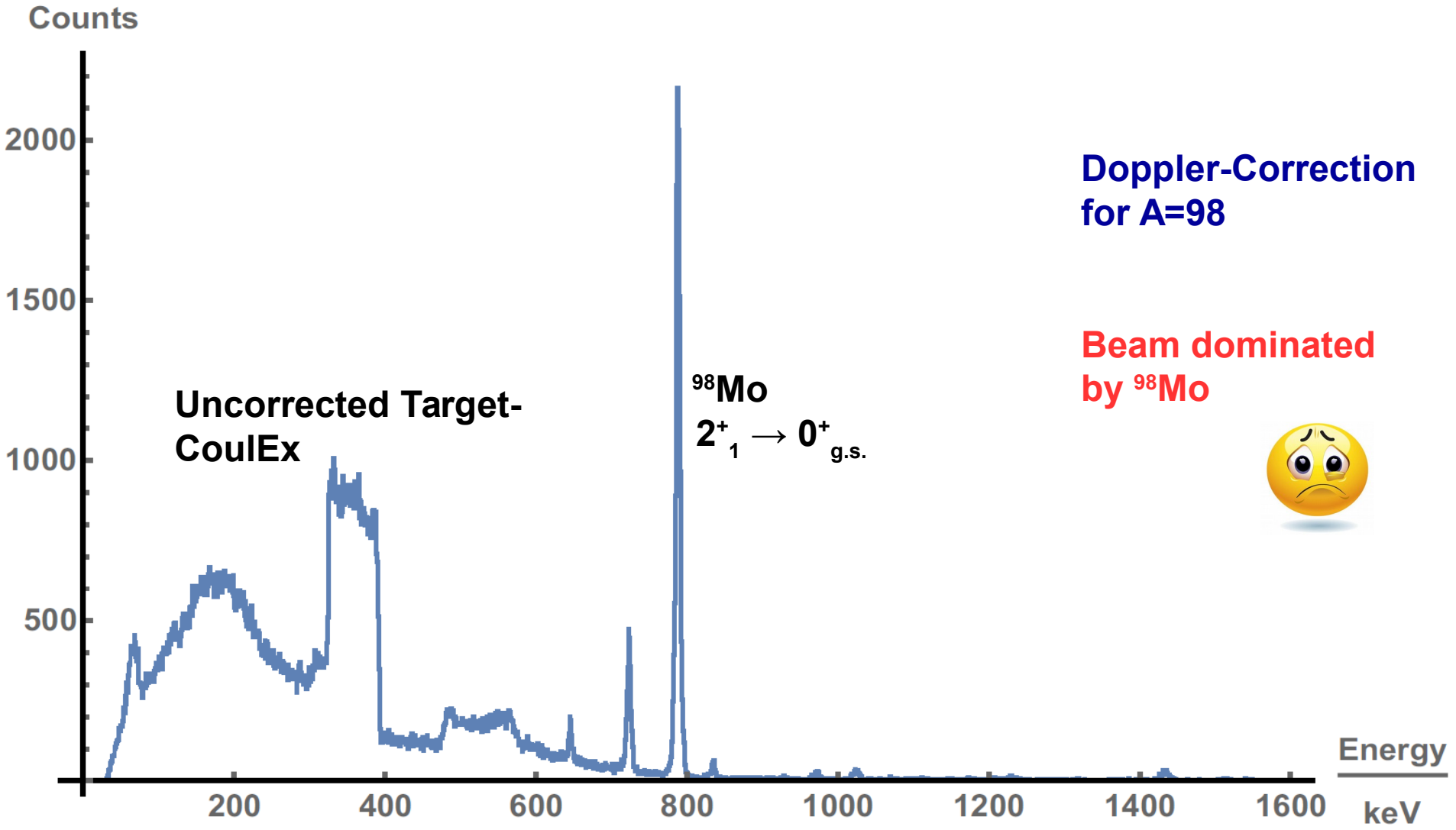
Kinematics Reconstruction



- CoulEx of P/T
- Detection of Ejectiles (P/T) with CHICO2
- Calculate γ-angle θ & velocity β
- Correct for Doppler-shift in energy: $E' \approx E\,(1 + \beta)\cos(\theta)$

→ use of CHICO2 for Doppler-correction & safe CoulEx

Spectra



Doppler-Correction for A=98

Beam dominated by ^{98}Mo

Analysis → no ^{98}Zr in-beam

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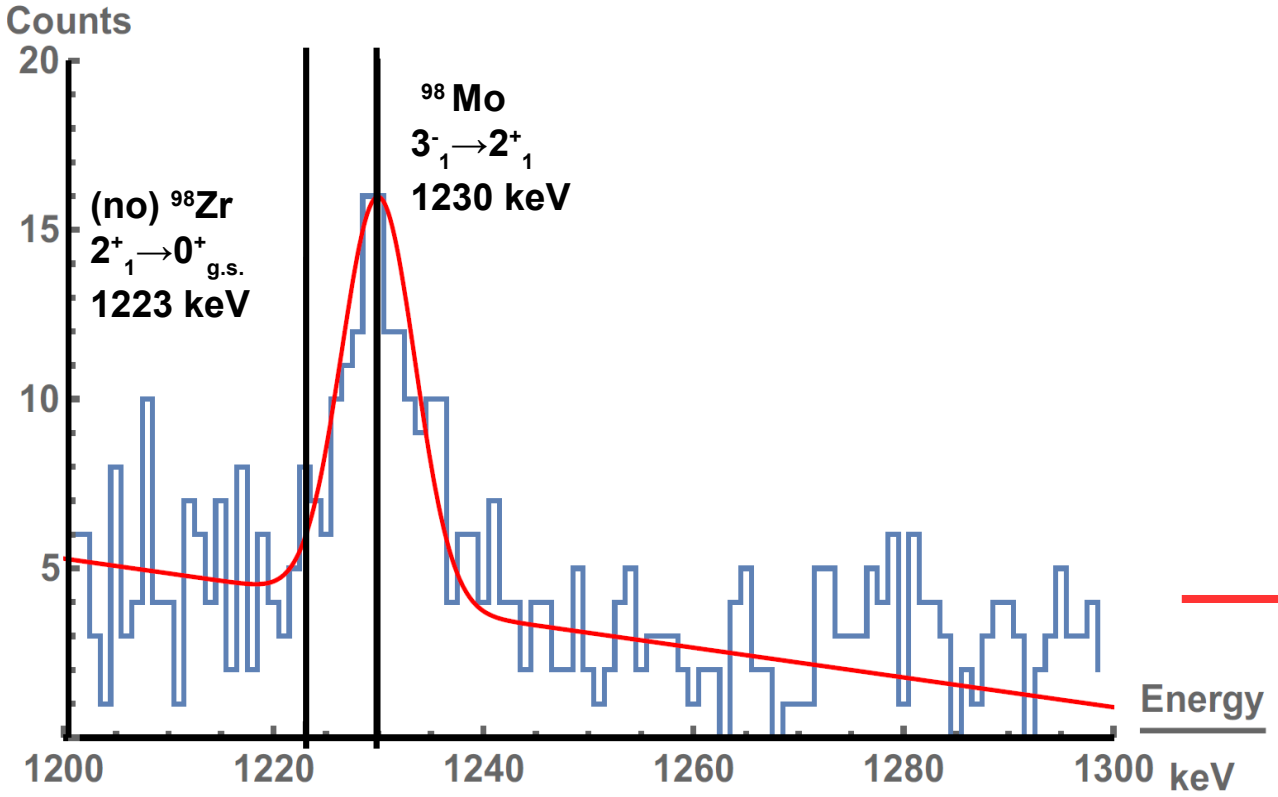
- Beam composition analysis
- Calibration with standard sources
- Reaction partner selection
- Doppler-correction using CHICO2



No

^{98}Zr $2^+_1 \rightarrow 0^+_{g.s.}$ – transition observed

Analysis → no ^{98}Zr in-beam

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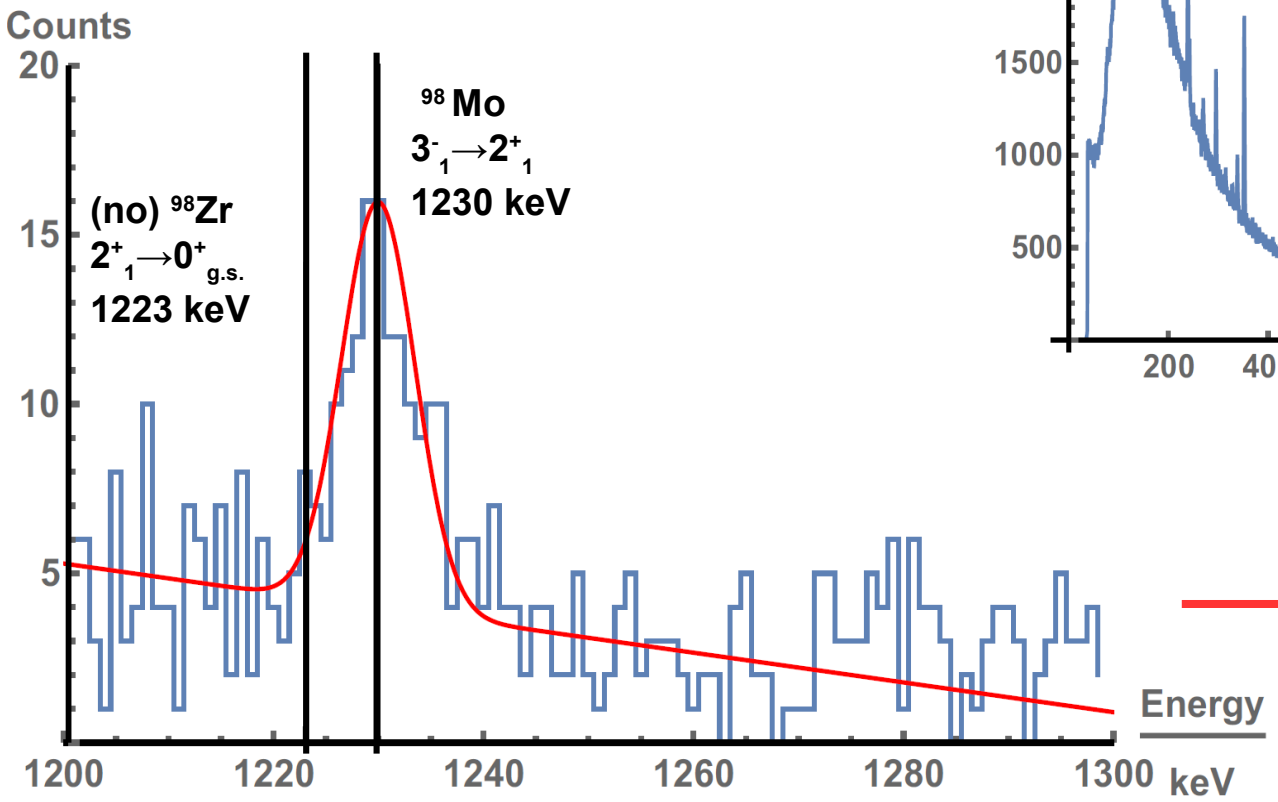
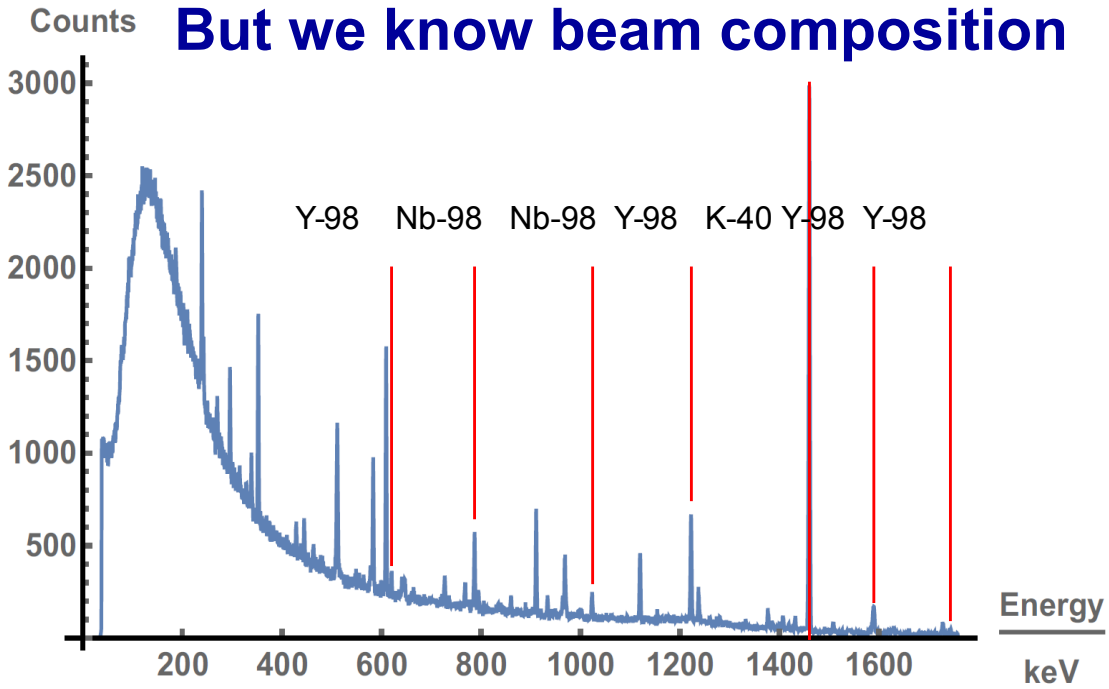


But we know beam composition

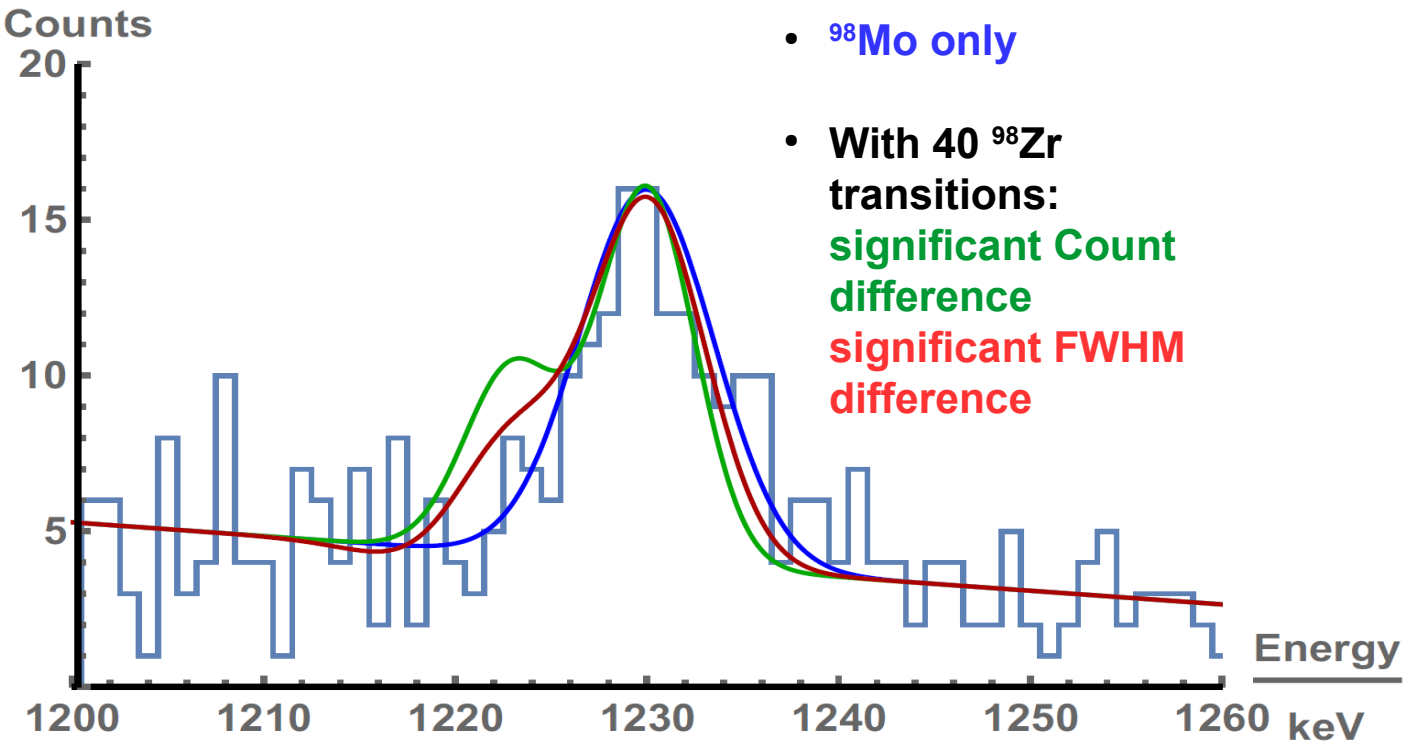


No

^{98}Zr $2^+_1 \rightarrow 0^+_{g.s.}$ – transition observed

New Stringent B(E2) Limits

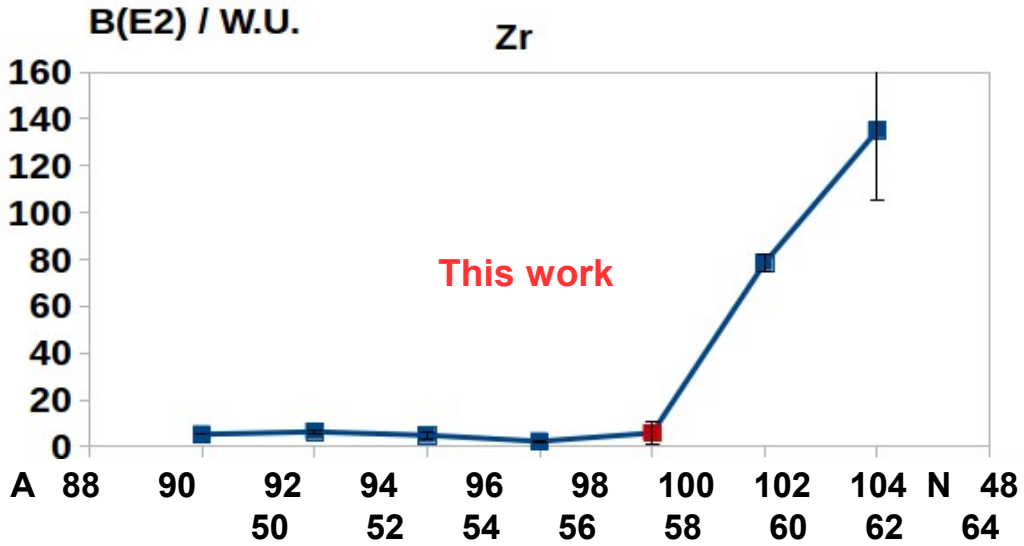
- Stopped Beam Analysis →152(64) pps ^{98}Zr in beam
- Transition would have been observed with >40 transtition counts
- GOSIA: Expected ~460 counts with B(E2) = 10 W.u. and 2400 pps



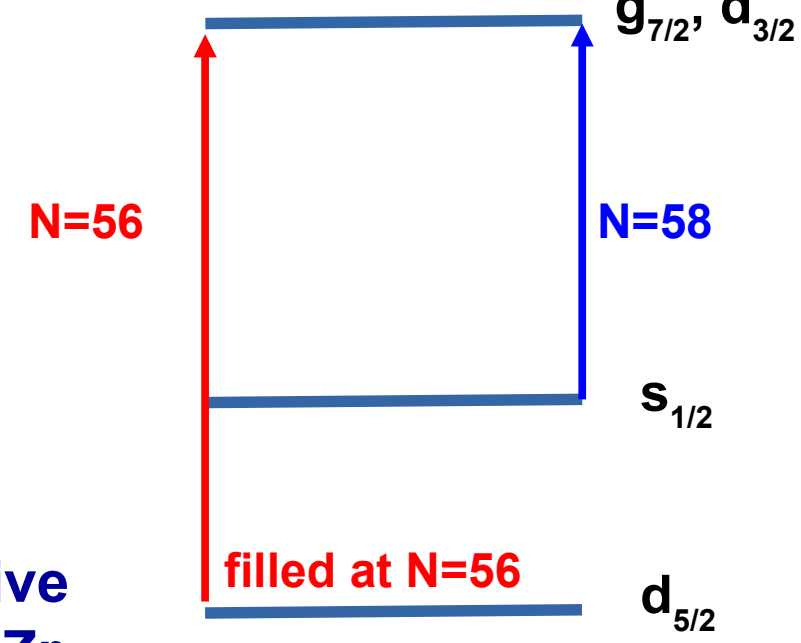
- ^{98}Mo only
- With 40 ^{98}Zr transitions:
  significant Count difference
  significant FWHM difference

→ B(E2) < 17 W.u.

^{98}Zr Spherical

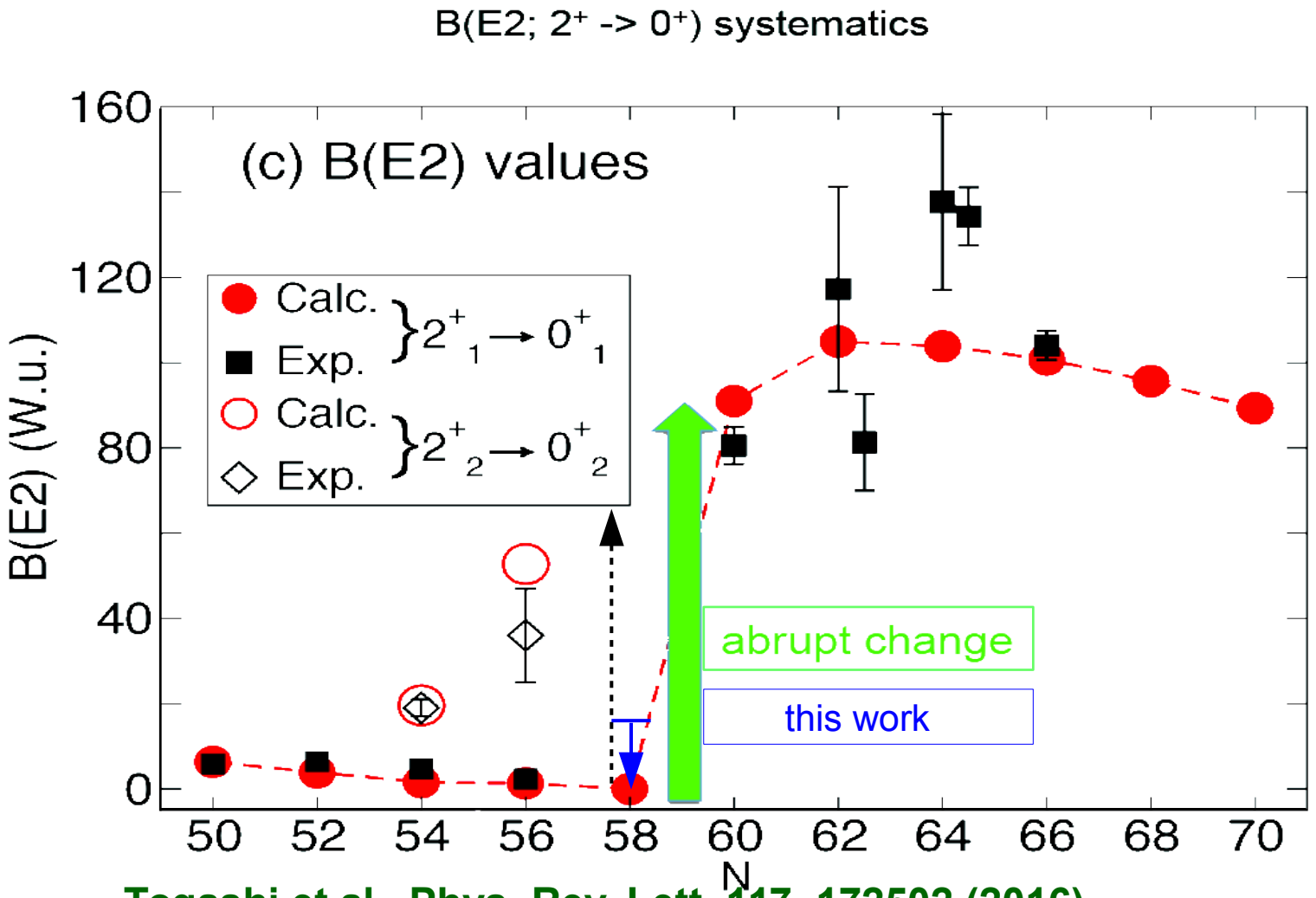


- $s_{1/2}$ likely low
- p-n interaction relatively weak
- Little n scattering from $s_{1/2} \rightarrow d_{3/2}$ / $g_{7/2}$



→ **^{98}Zr is spherical, weakly collective QPT to deformed occurs past ^{98}Zr (between N=58 and N=60)**

Comparison to Shell Model



Togashi et al., Phys. Rev. Lett. 117, 172502 (2016)
T. Otsuka et al., J. Phys. G: Nucl. Part. Phys. 43, 024009 (2016)

Summary

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- **Investigated shape transition in Zr**
- **Determined 17 W.u. > $B_{Zr\text{-}98}(E2; 2^+_1 \rightarrow 0^+_{g.s.})$ > 0.7 W.u.**
- **Phase transition after N=58**
- **Good agreement with theory**

- **Precision & higher-lying transitions missing to proof shape coexistence in ^{98}Zr**

Thank you !

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