DEFORMED STRUCTURES AND SHAPE COEXISTENCE IN ^{98}ZR

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Overview

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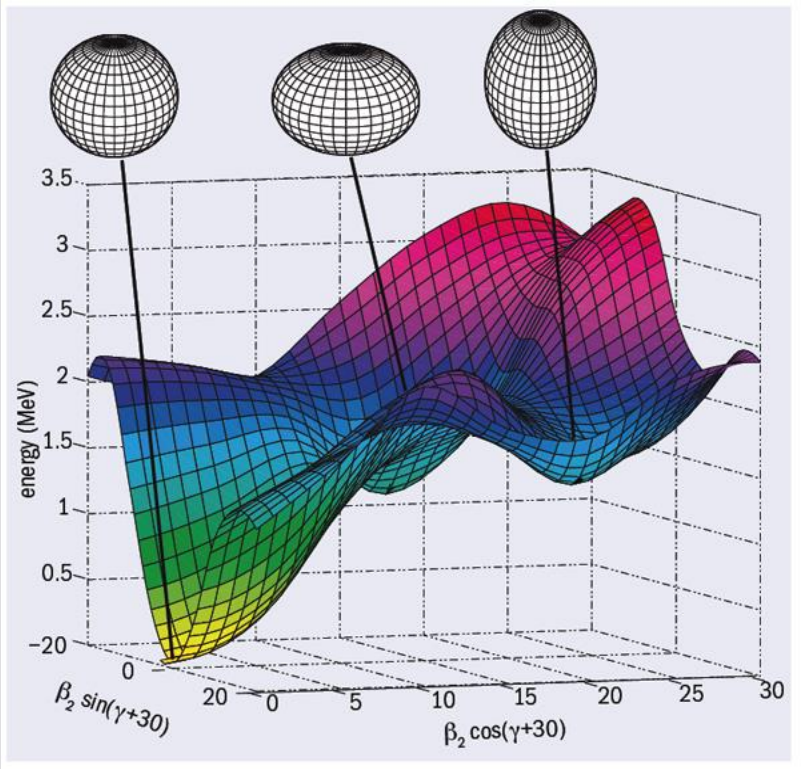
- Shape coexistence in Zr isotopes
- High-statistics experiment of the decay of ^{98}Y to ^{98}Zr
- Experiment run with 8pi@TRIUMF
- Expanded level scheme
- Re-measured conversion electrons
- Precise measurement key branching ratios
- Propose new band structure

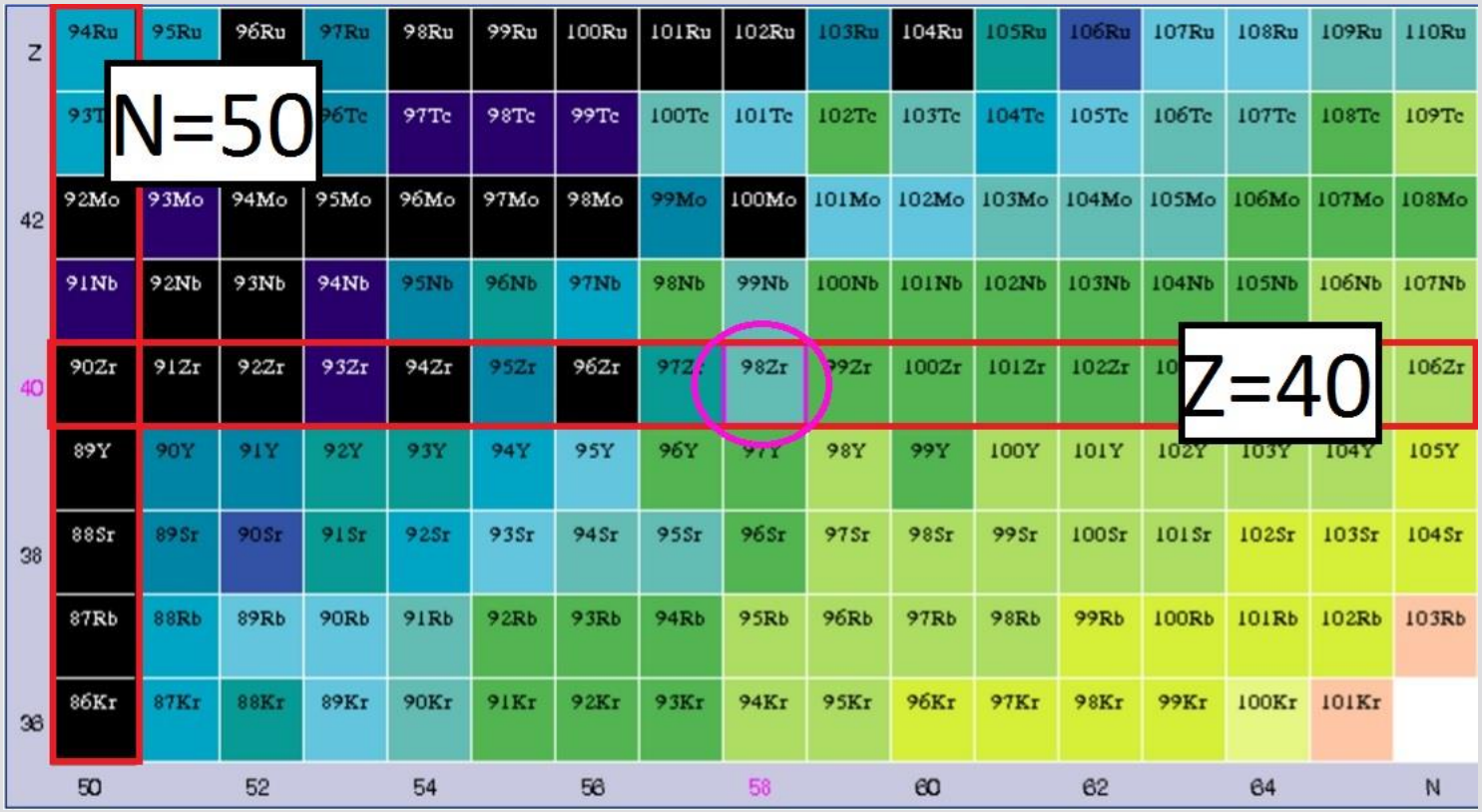
NUCLEAR SHAPE COEXISTENCE

- Shape coexistence is denoted by a near degeneracy of different shapes
- States at similar excitation energy exhibit different intrinsic deformation
- It is believed to happen in all but the lightest nuclei



Potential energy surface for ^{186}Pb with a spherical, oblate and prolate minima (Andreyev et al. Nature 2000).

SHAPE COEXISTENCE IN THE A~100 REGION



^{98}Zr

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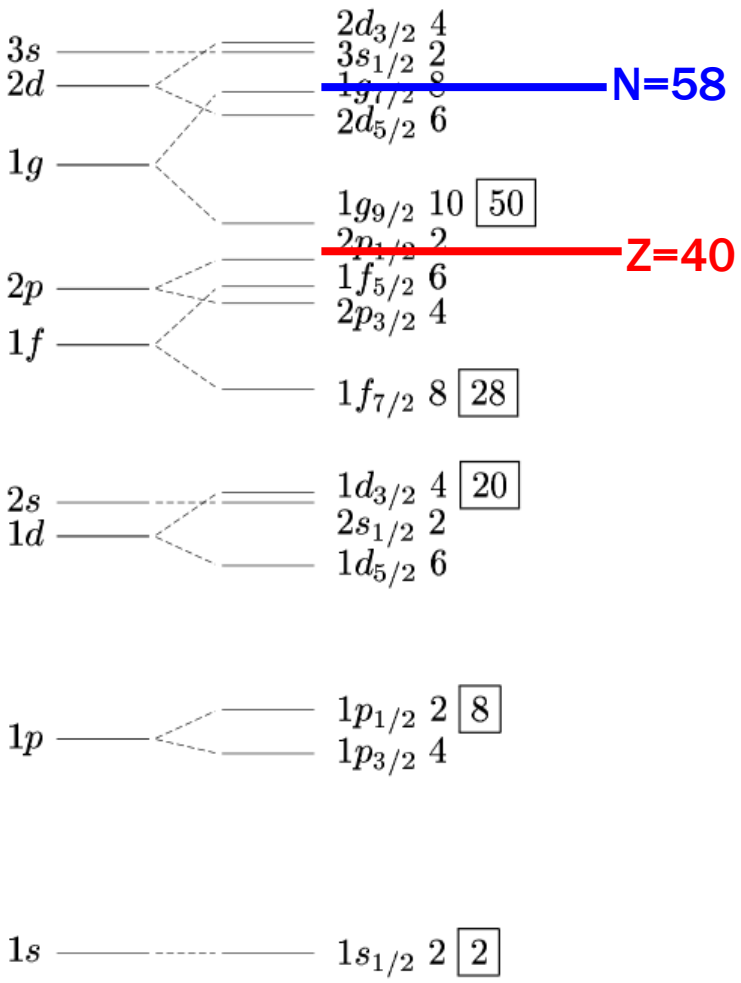
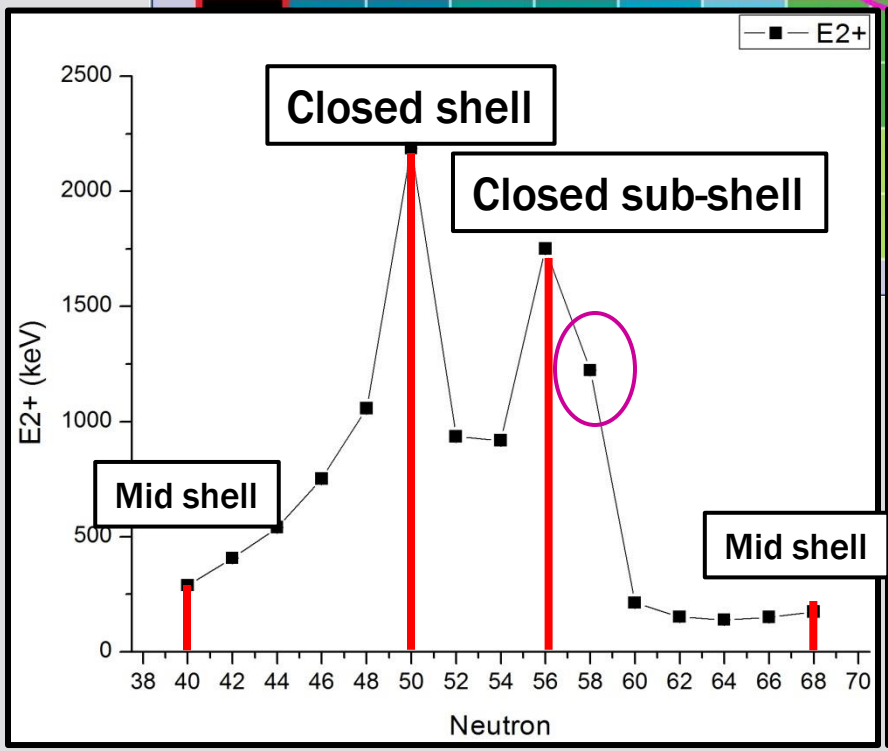
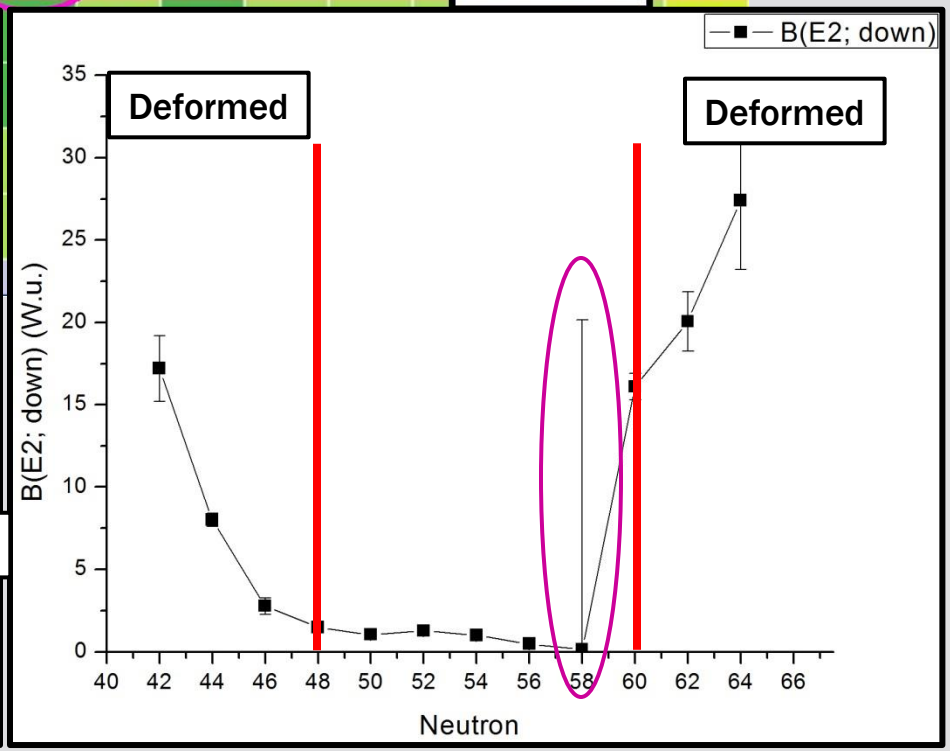


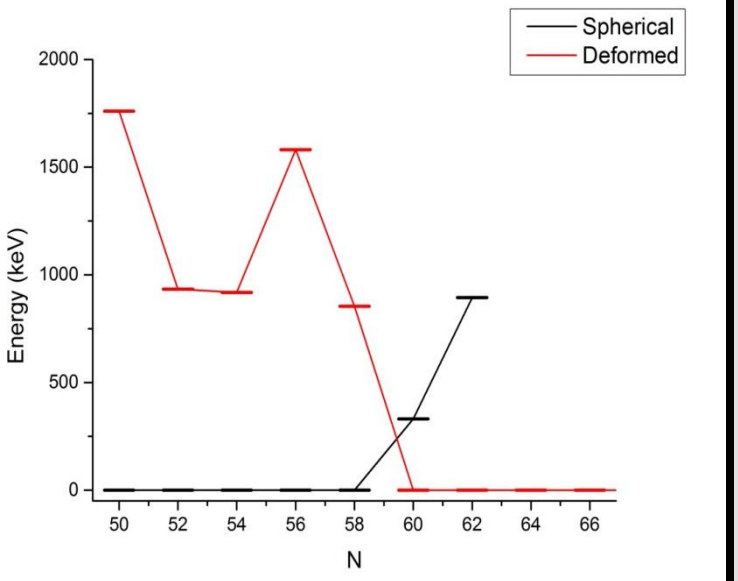
SHAPE COEXISTENCE IN THE A~100 REGION





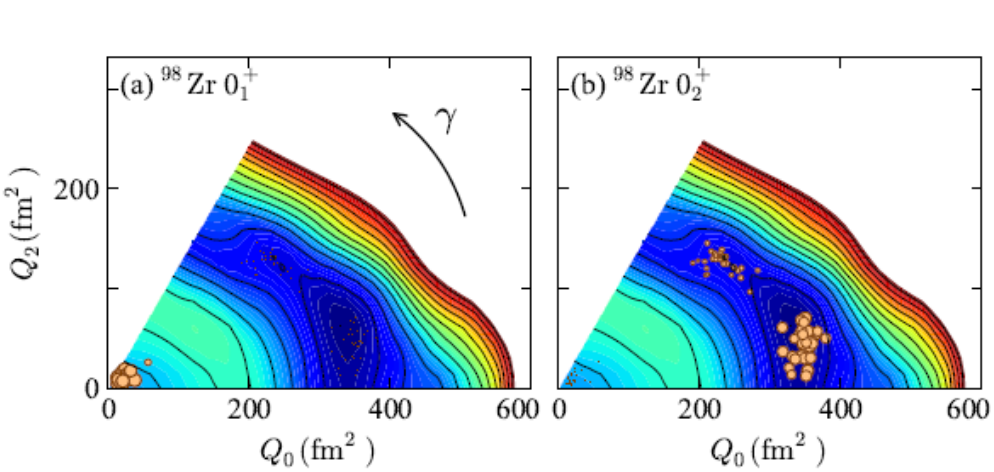
HYPOTHETICAL CONFIGURATION INVERSION

Previous shell model calculations suggest that this sudden increase of deformation is caused by an inversion of the band structure



R.k. Sheline PLB41 (115)

Very recent calculations suggest that is a quantum phase transition based on the $g_{9/2}$ occupation



Quantum Phase Transition in the Shape of Zr isotopes, Togashi *et al. arXiv:1606.09056v2*

ISAC@TRIUMF

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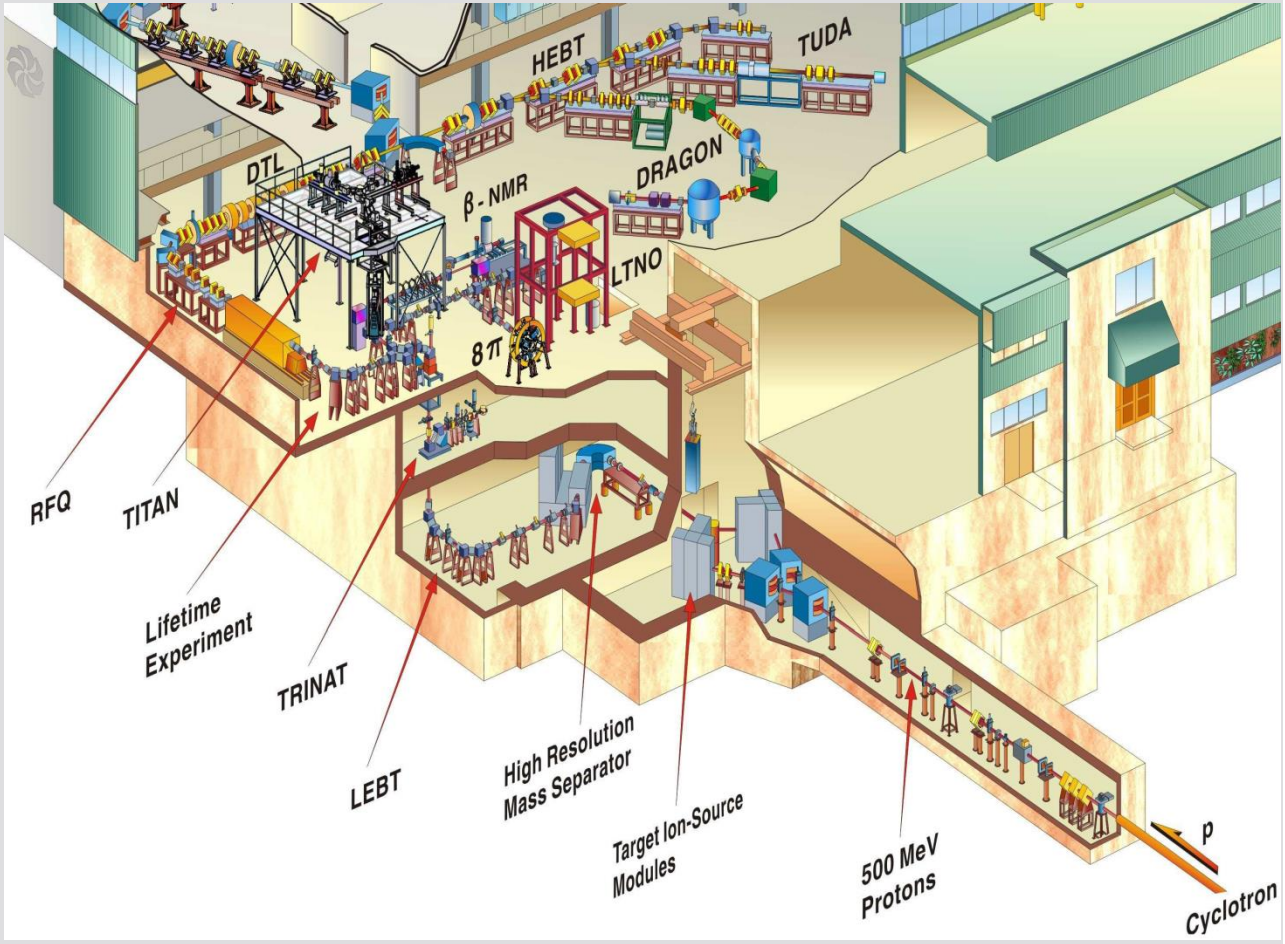
- 500-MeV protons impacting on an UC_x target
- Isotopes are surface (Re) ionized
- A=98 mass is selected by the mass separator
- Ions are implanted in an aluminized mylar tape



BETA DECAY OF ^{98}Y

- ^{98}Rb ($T_{1/2}$=114 ms) and ^{98}Sr ($T_{1/2}$=653 ms) ion beam
- Production yield of the order of ~10^6 ions/sec
- No significant amount of ^{98}Y ($T_{1/2}$=548 ms, $J^{\pi}=(0)^-$) or ^{98m}Y ($T_{1/2}$=2.0 s, $J^{\pi}=(4,5)$) was observed on the beam

8π SPECTROMETER AT TRIUMF

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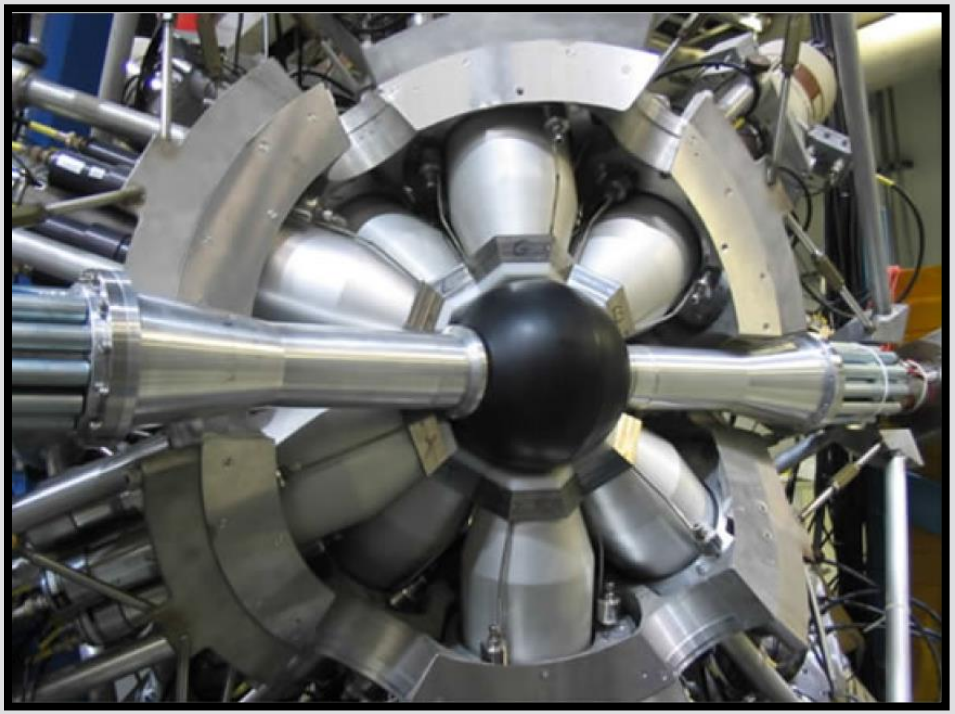
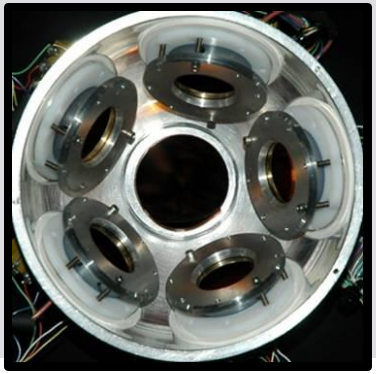


8pi array:

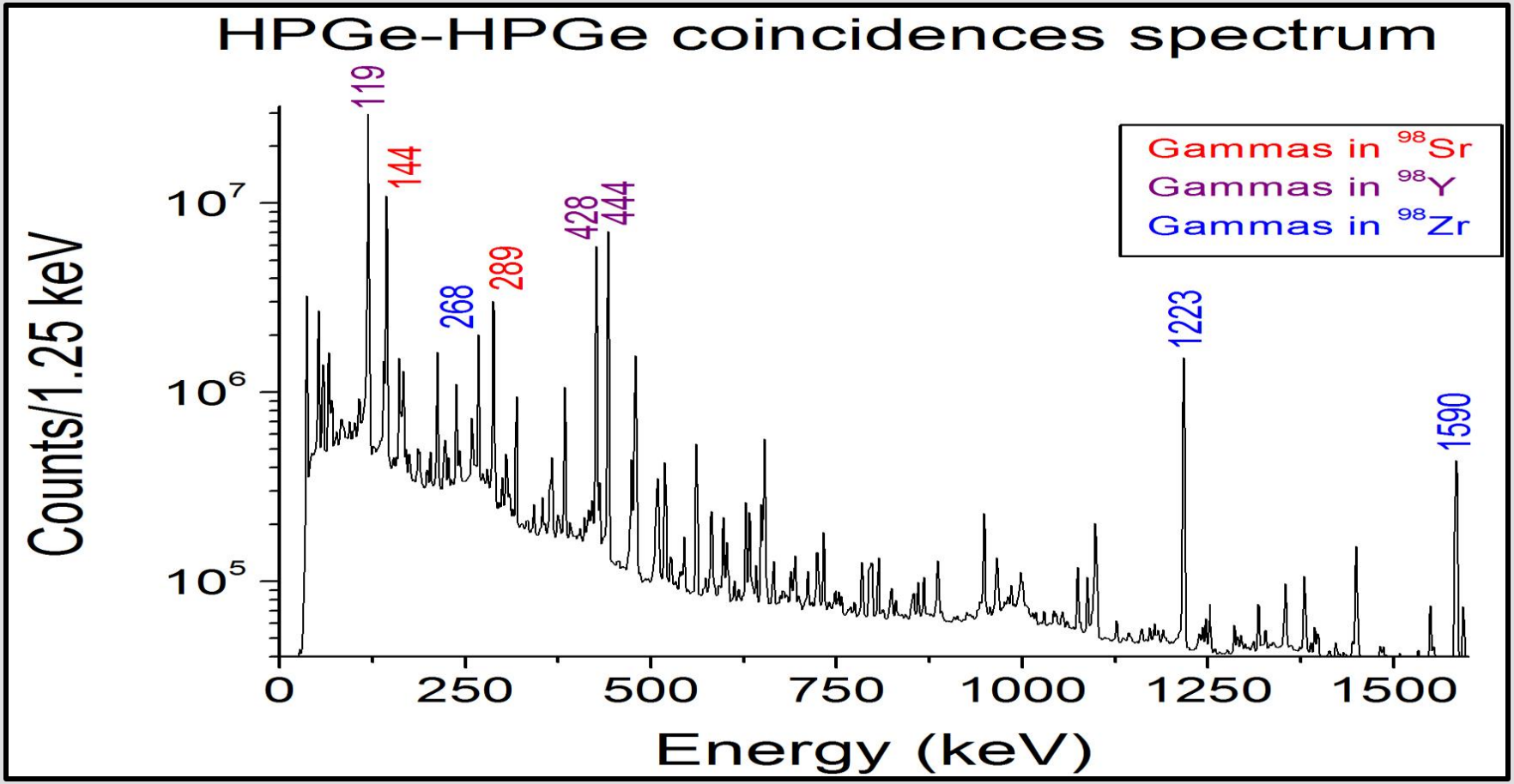
- 20 HPGe γ-ray detectors
- BGO Compton suppression shields
- ~2% absolute efficiency @1.3MeV



PACES array: 5 Si(Li) LN_2 cooled conversion electron detectors

COINCIDENCE ANALYSIS

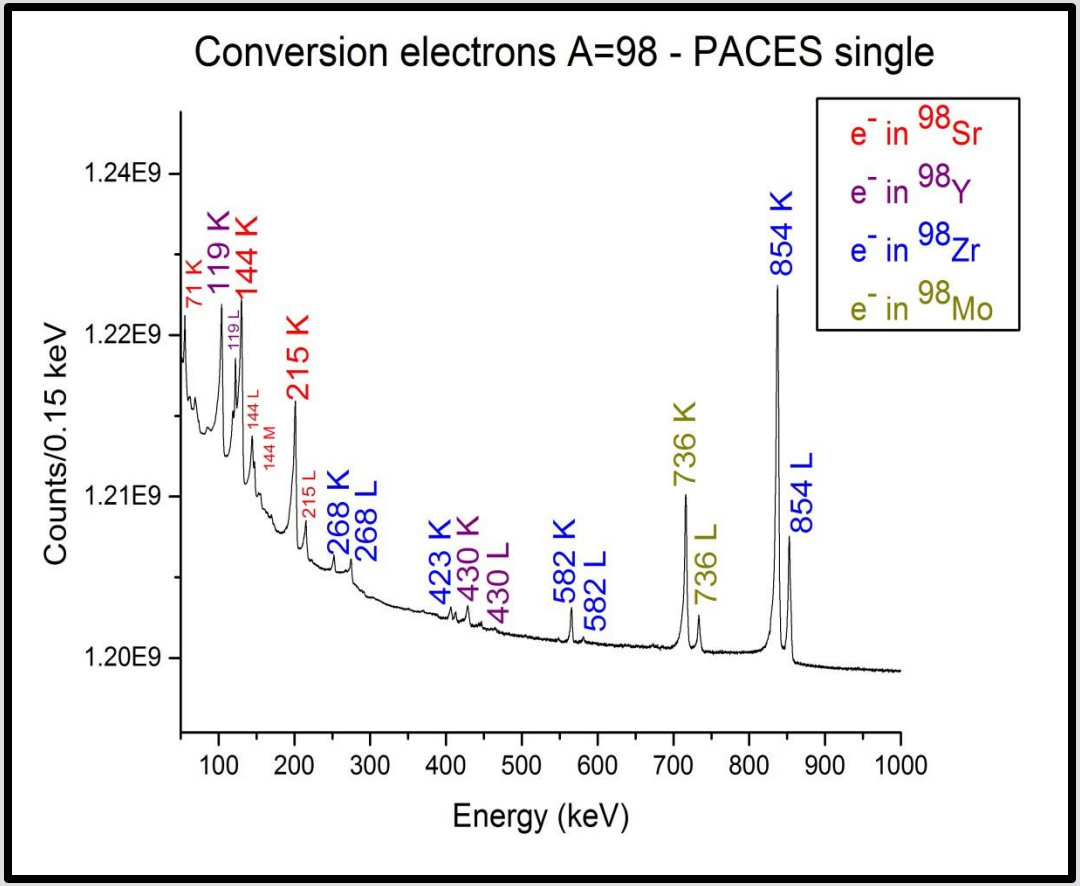
Time-random-background subtracted β-γ-γ coincidence matrix contains ~3.5 10^8 events

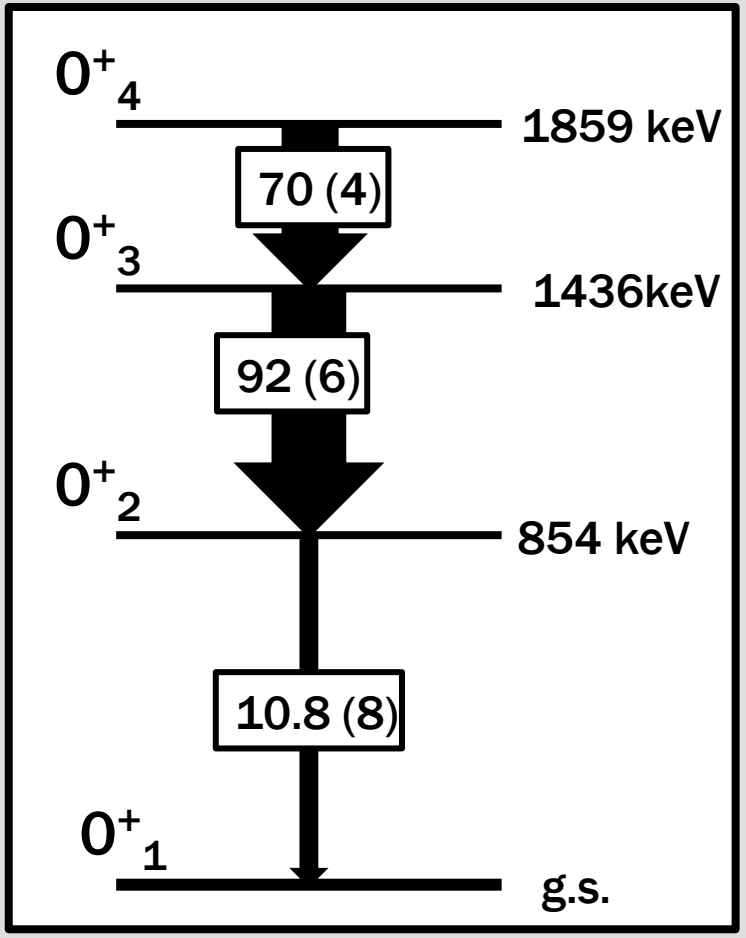


No isomeric decay has been observed

CONVERSION ELECTRONS

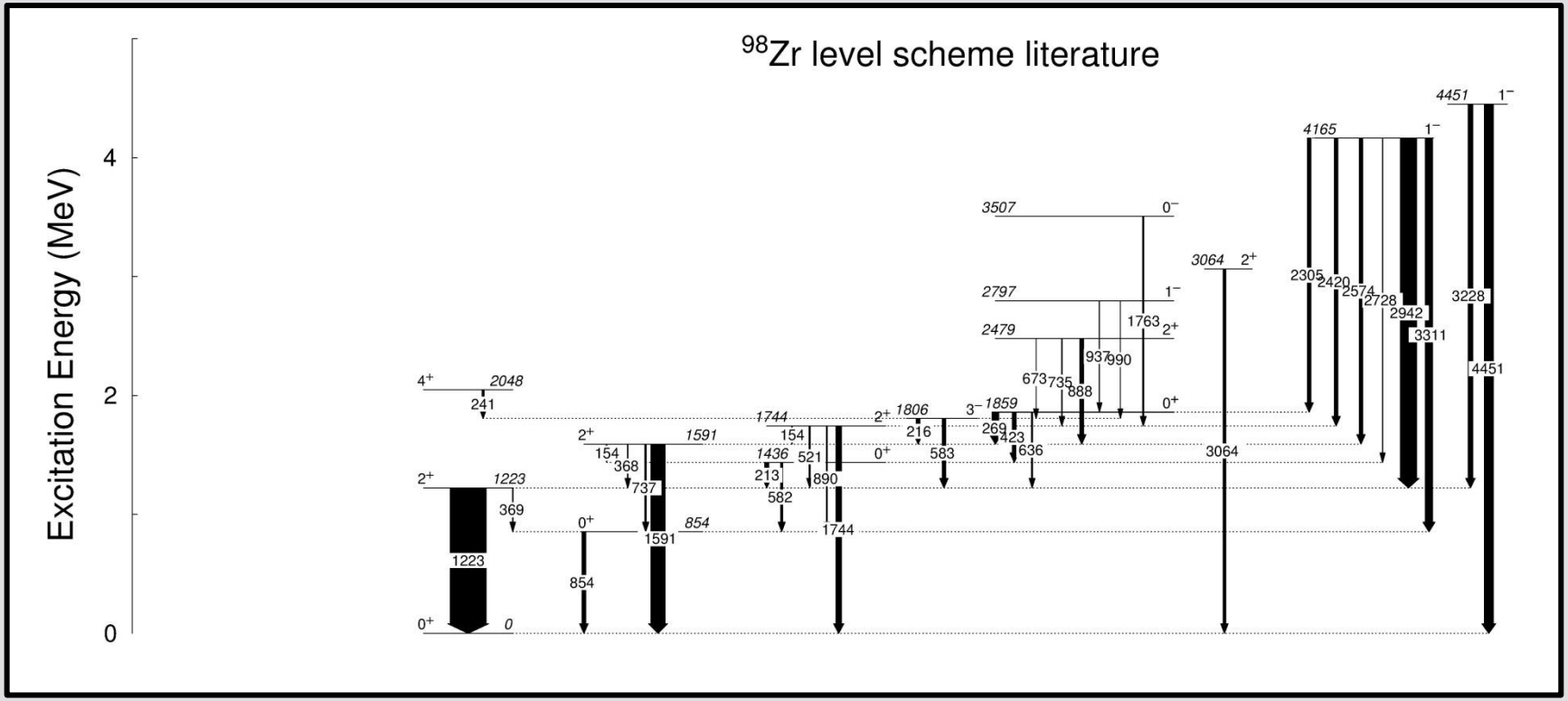
Conversion electron energy spectra detects in single PACES events



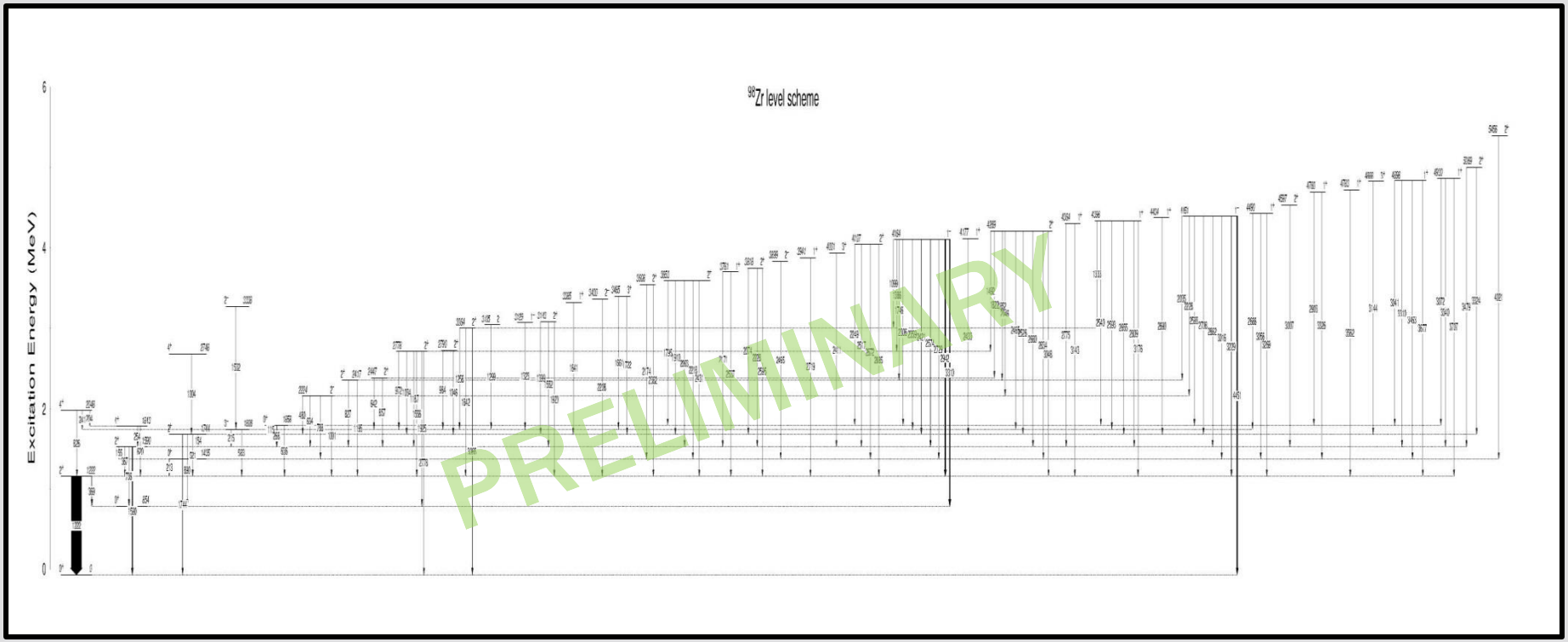


Previous level scheme

Previous level scheme of ^{98}Zr populated in the β$^-$ decay of ^{98}Y ($T_{1/2}$=548 ms, J^π=(0)$^-$)



Preliminary new level scheme



- Scheme extended up to ~5.5 MeV
- ~50 levels, ~20 not previously seen in β decay and another ~20 completely new
- Three levels removed from the level scheme
- ~120 transitions placed, ~70 of them new

Relative intensities

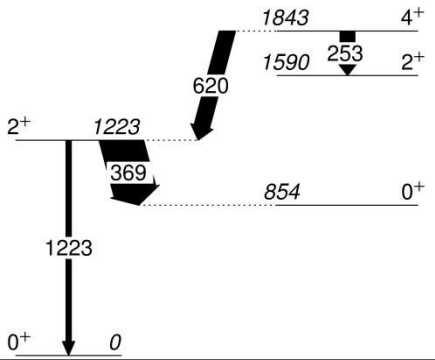
Transition	E_γ (keV)	Relative intensity C.Y. Wu	*W. Urban*	This work
		^{98}Zr		
$4_1^+ \rightarrow 2_1^+$	620.7	1.00	1.00	1.00
$4_1^+ \rightarrow 2_2^+$	252.7	0.014(2)	0.052(18)	0.010(1)
$2_1^+ \rightarrow 0_1^+$	1222.7	1.00	1.00	1.00
$2_1^+ \rightarrow 0_2^+$	370.0	0.021(2)	0.009(3)	0.0205(2)

PRELIMINARY

C.Y. Wu et al. PHYSICAL REVIEW C **70**, 064312 (2004)

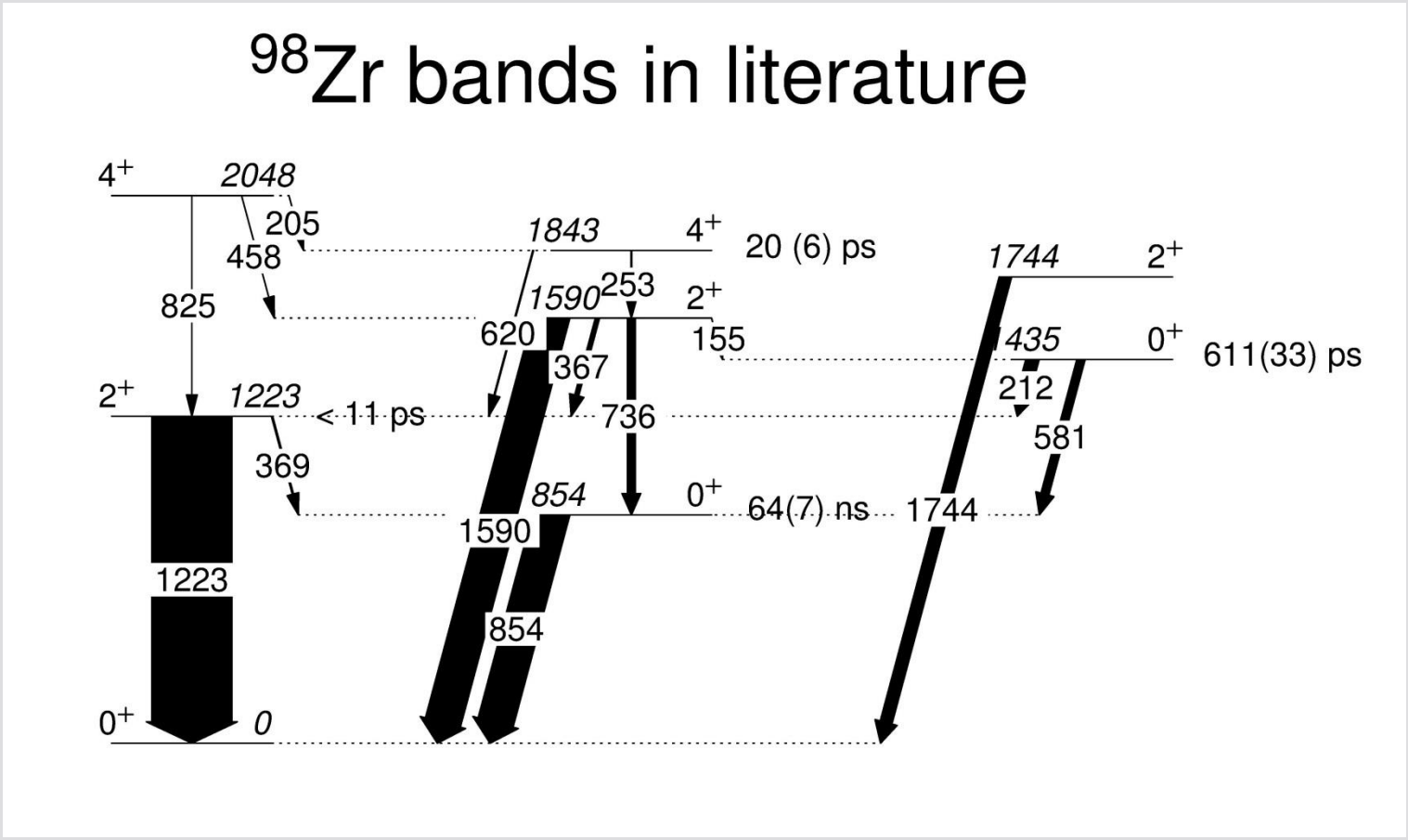
W. Urban et al. / Nuclear Physics A 689 (2001) 605–630

Relative B(E2)



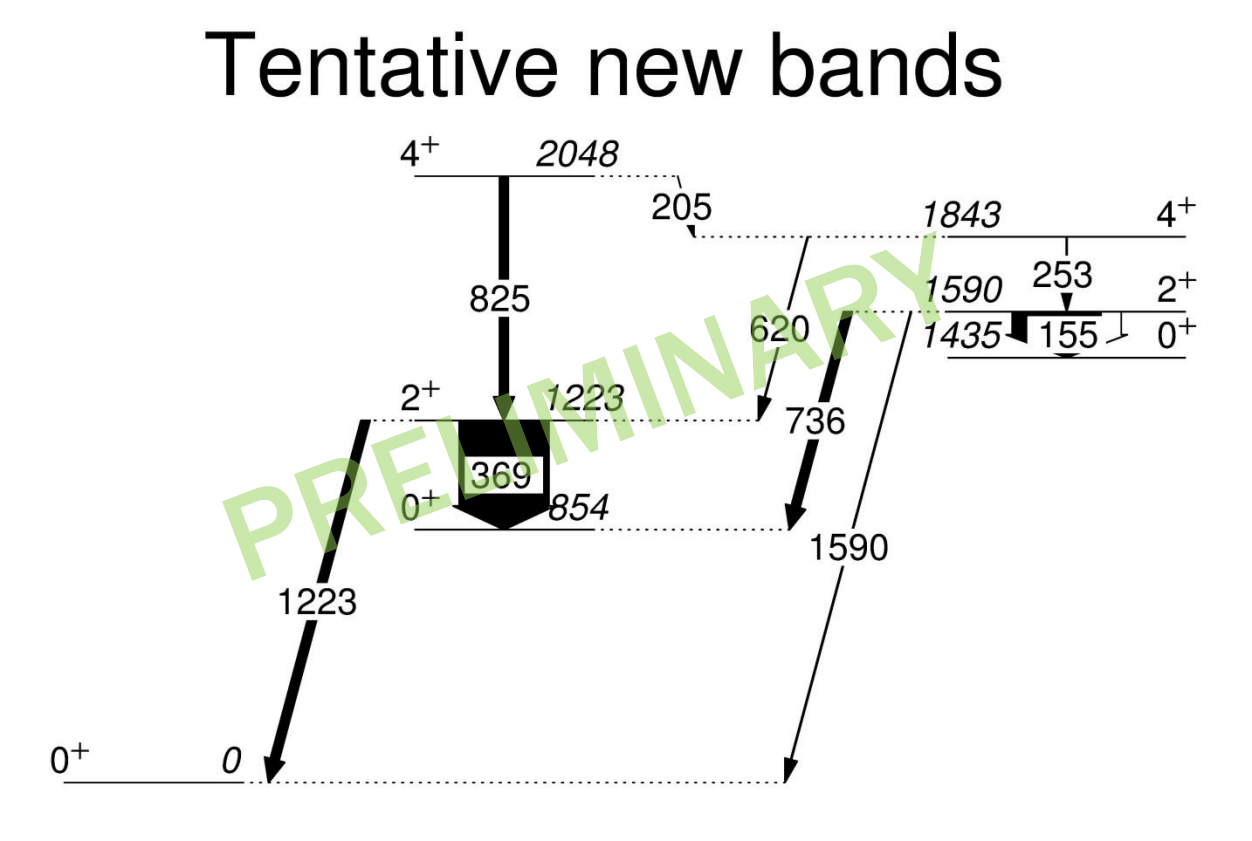
$$B(E2) = 9.52 \cdot 10^6 \cdot A^{-\frac{4}{3}} \cdot E^{-5} \cdot BR/\tau$$

^{98}Zr bands in literature



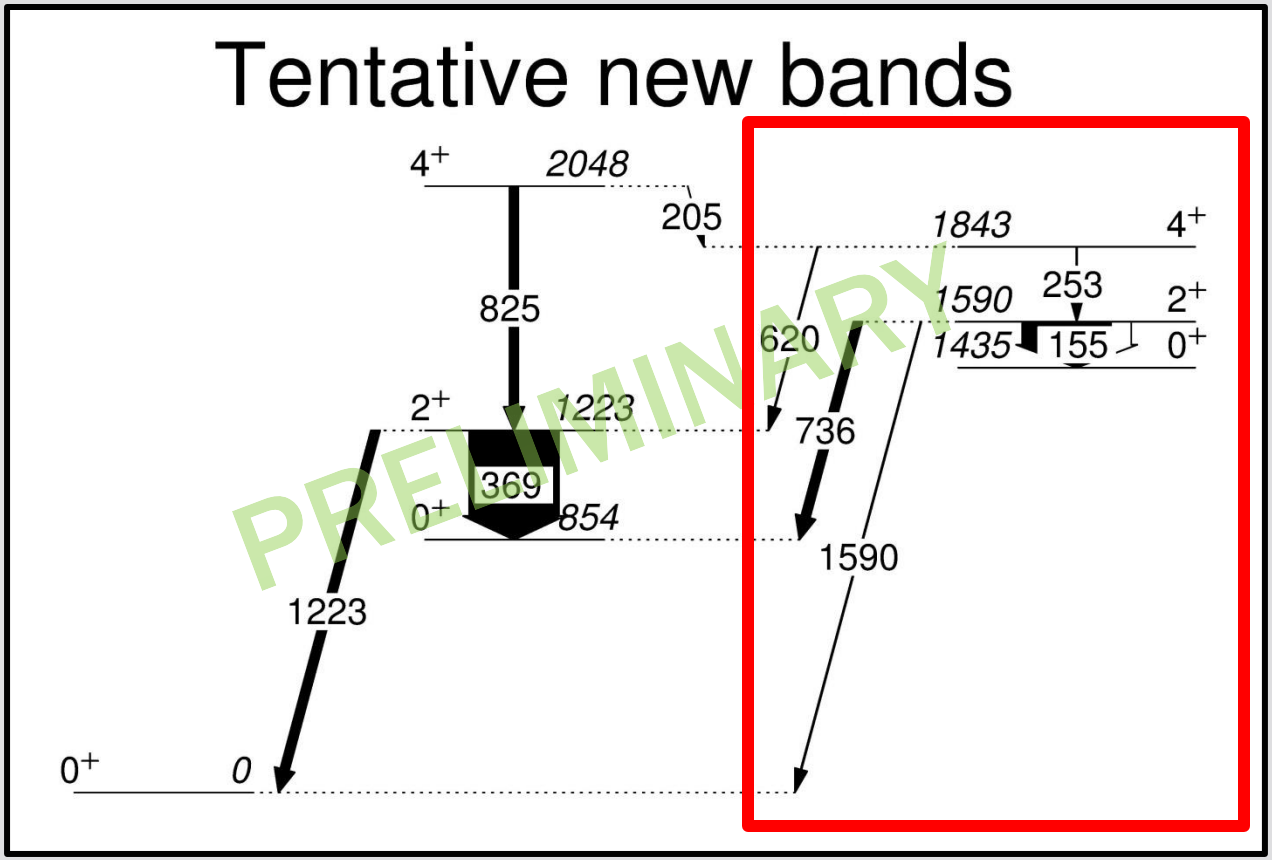
Bands, energies and intensities are from NNDC

Preliminary ^{98}Zr bands



Relative B(E2) from this work

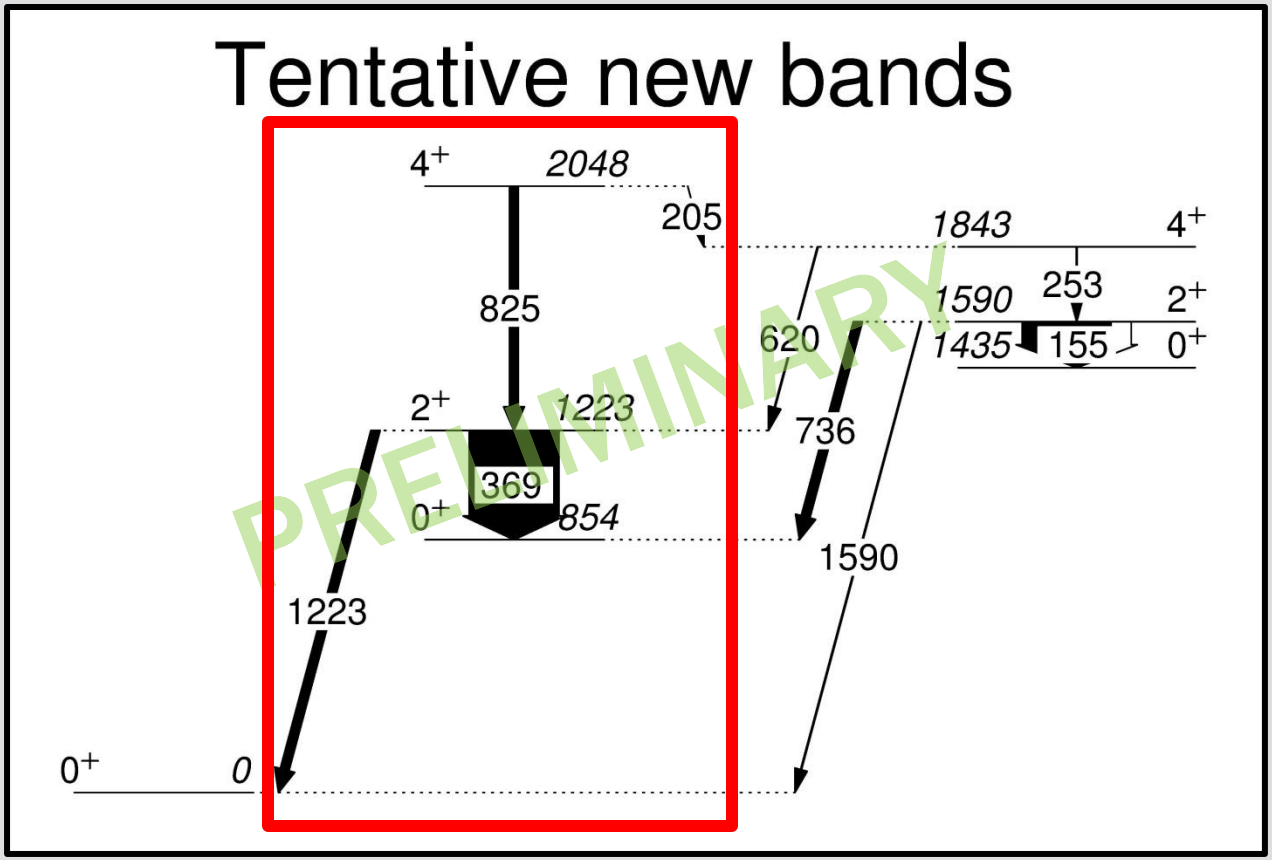
Preliminary ^{98}Zr bands



Quasi-rotational band (up to J~20$^+$) with β_2=0.22(2)

W. Urban et al., Nucl. Phys. A **689**, 605 (2001)

Preliminary ^{98}Zr bands



Rotational band E4/E2~3.2

Conclusions

- Preliminary high-statistics study of the ^{98}Y β^- decay
- Expanded the ^{98}Zr level scheme
  - ~20 new levels
  - ~70 new transitions
- Re-measured conversion electrons
- Branching ratios in key transitions
- Proposed a tentative new deformed band
- Ongoing work:
  - More relative B(E2) to be calculated
  - Construct a band on the 0^+_4
  - Search for negative parity states

ACKNOWLEDGEMENTS

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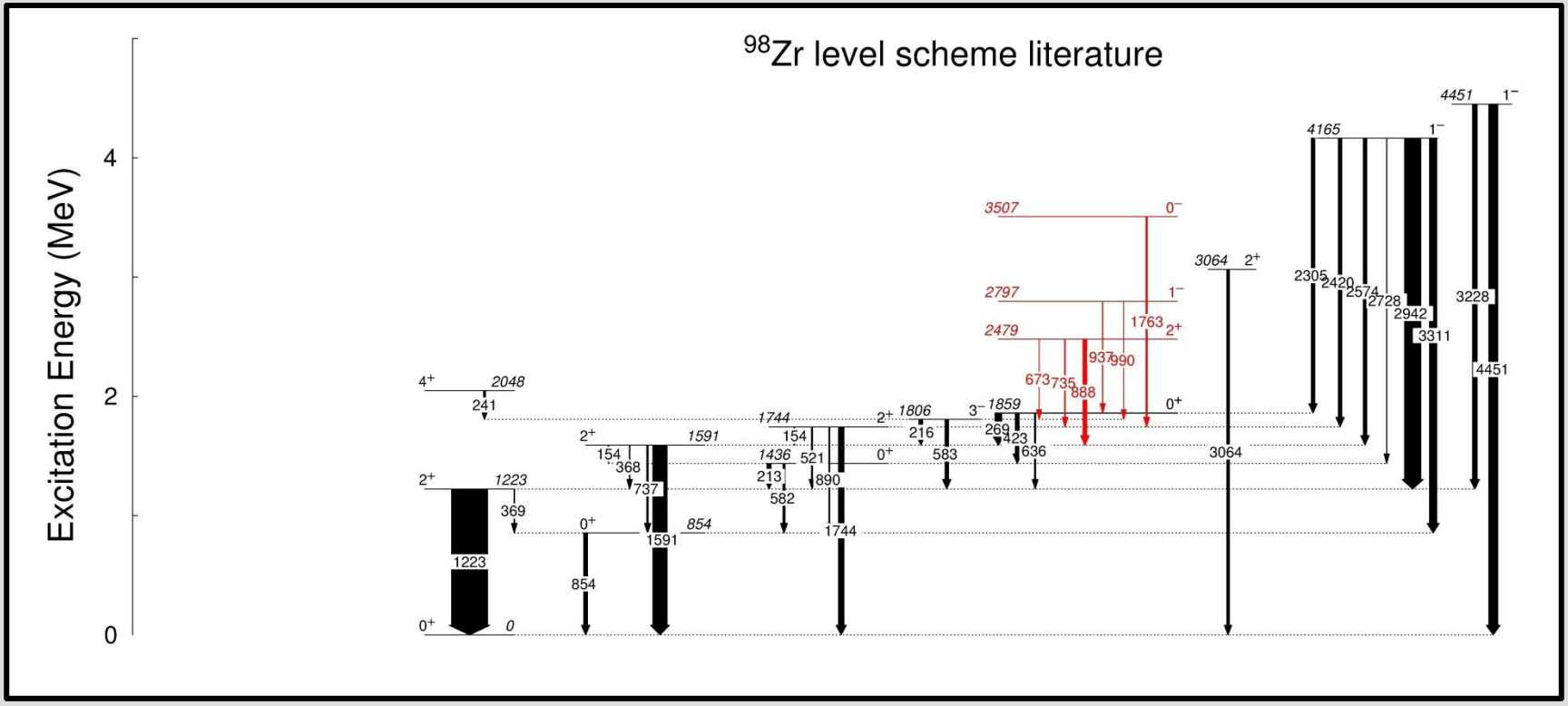
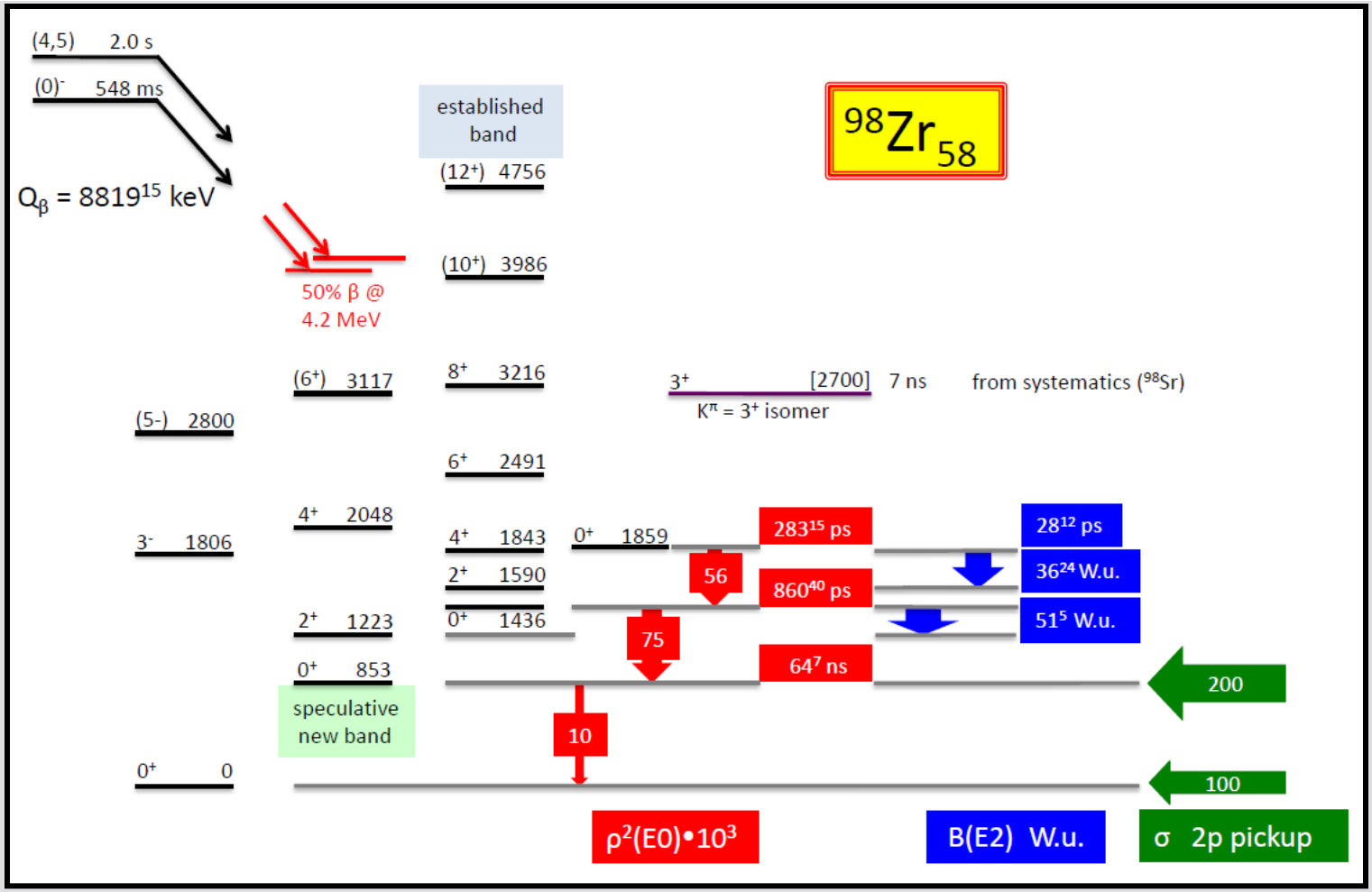
Previous level scheme

Most of the previous level scheme has been confirmed, but these three states were not observed



6^+ candidates



Rotational band E4/E2~3.2, E6/E4~1.9

- This new branching ratio for the $2^+_1 \rightarrow 0^+_2$ transition, yields B(E2)> 5 W.u.
- Assuming B(E2; $2^+_1 \rightarrow 0^+_1$)~ 1 W.u., a B(E2)~10 W.u. can be expected
- Calculations predict a $T_{1/2}(2^+_1)$ = 3-5 ps (shell model), 0.6 ps (IBM), 0.2 ps (VAMPIR)
- This would imply B(E2; $2^+_1 \rightarrow 0^+_2$)= 12-300 W,u. and a high collectivity

(Shell model) Sieja *et al.* PHYSICAL REVIEW C **79**, 064310 (2009)
(IBM) Betterman *et al.* PHYSICAL REVIEW C **82**, 044310 (2010)
(VAMPIR) Petrovici PHYSICAL REVIEW C 85, 034337 (2012)

Nuclear shell modl

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- Nucleons occupy orbitals within the atomic nucleus, similar to atomic electrons
- Unlike electrons, there are two different type of fermions in the nucleus
- Each occupy independent orbitals
- Closed shells push the nuclei toward spherical shapes
- Open shells push the nuclei toward deformed shapes