Shape-changes and Isomers in neutron-rich Zr-Mo-Ru nuclei

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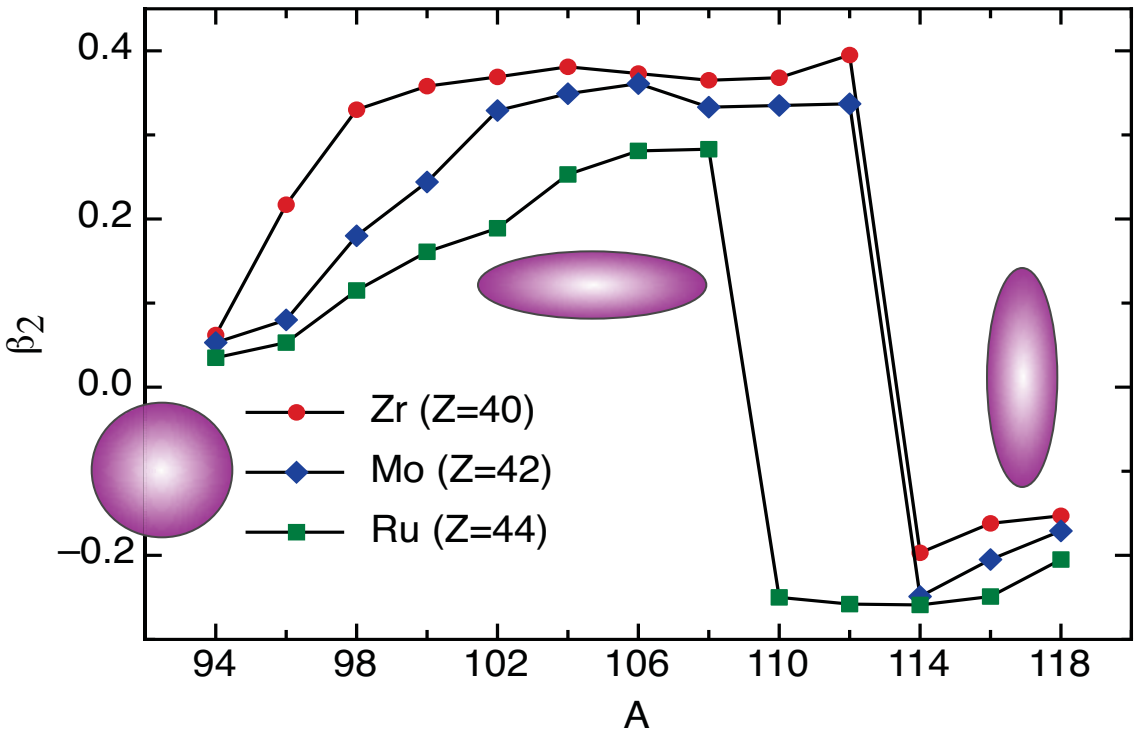
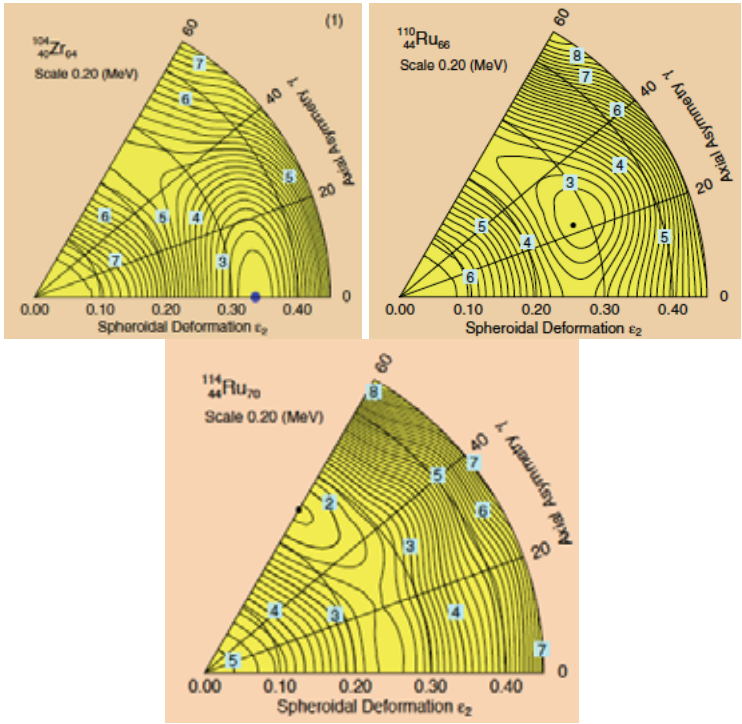
Introduction & Motivation



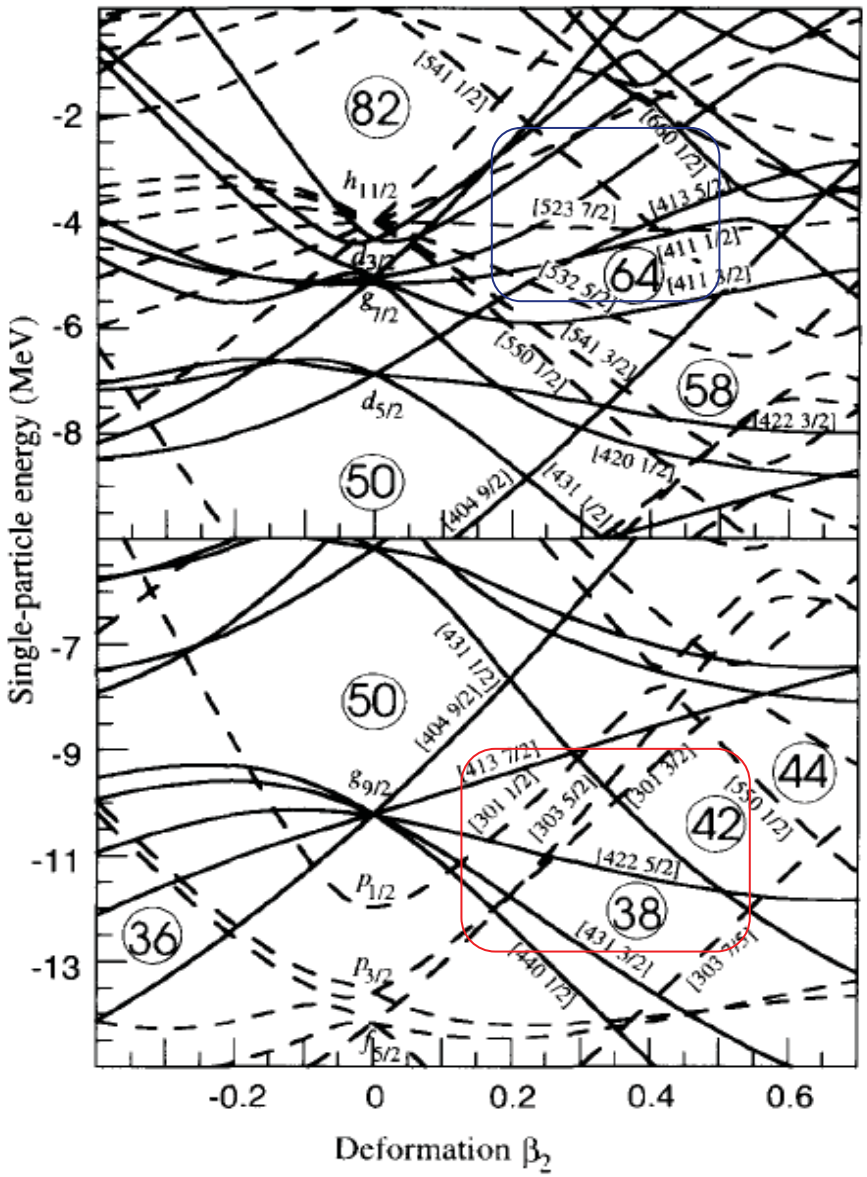
P. Moller et al., ADNDT 59 (1995) 185



P. Moller et al., ADNDT 94 (2008) 758

- what is the size of deformation and how it changes with A and Z?
- which are the single-particle orbitals near the Fermi level and what role do they play in building deformation, e.g. identification of the “intruder” orbitals?

K-Isomers



- deformed with axially symmetric shape
- high-Ω orbitals near the proton and neutron Fermi surfaces

protons

(prolate): 5/2[422] ($g_{9/2}$) & 5/2[303] ($f_{5/2}$)
(oblate): 7/2[413] ($g_{9/2}$) & 5/2[413] ($g_{7/2}$)

neutrons

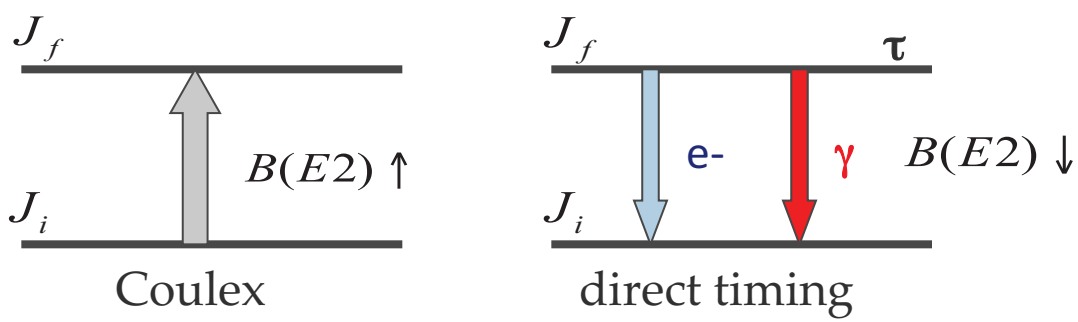
(prolate): 5/2[532] ($h_{11/2}$) & 5/2[413] ($g_{7/2}$)
(oblate): 7/2[523] ($h_{11/2}$) & 5/2[512] ($h_{9/2}$)

- existence of K-Isomers (with K=5 and 6)
- ✓ information about the pairing and residual spin-dependent interactions in deformed neutron-rich nuclei

Size of deformation with 10^4 ions/sec beam

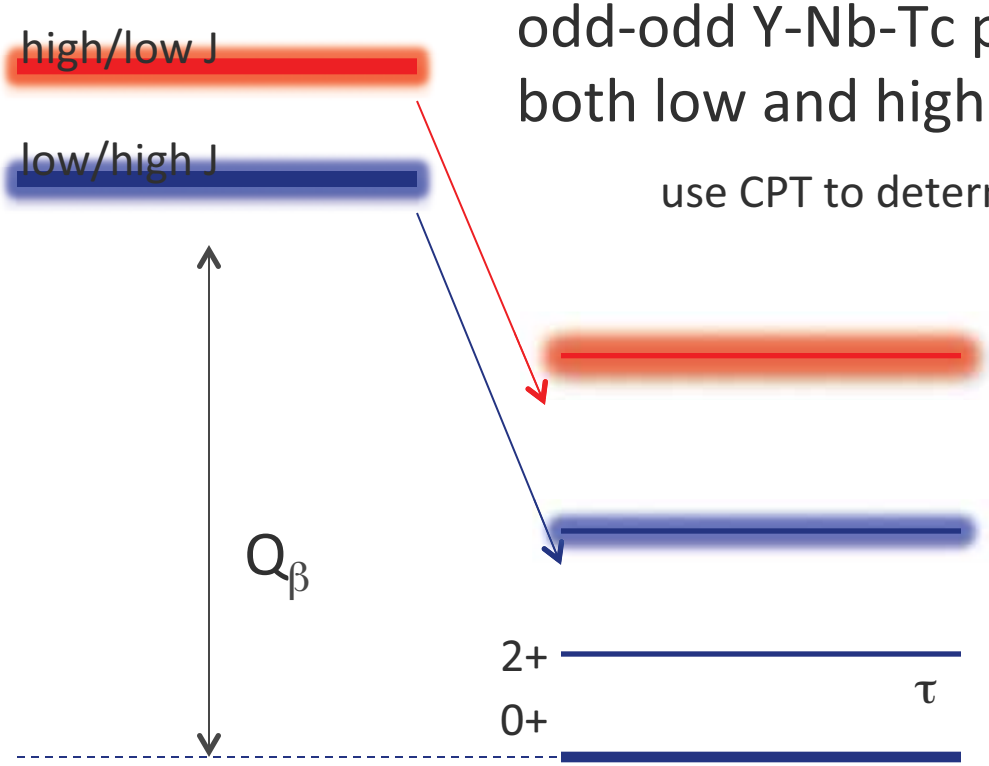
→ **reactions:** Coulex, DSAM & plunger –> usually rates are lower than the room background!

→ **radioactive decay:** a blazing source for decay spectroscopy -> the issue is if the state of interest is populated, depends on the properties of the parent



direct (electronic) timing – well developed in the past, e.g. βγ(t), **plastic scintillators** for β – good!, but for gammas **Ge** (down to ~1 ns) or BaF2 (good timing, but compromised energy resolution) -> **need for efficient detectors with good energy and time resolutions -> e.g. LaBr(Ce) approaching limits down to ~ 40 ps!**

Populating states of interest in β− decay



odd-odd Y-Nb-Tc parent nuclei - > existence of both low and high spin β− decaying states

use CPT to determine the excitation energy

access to variety of states, both intrinsic and collective

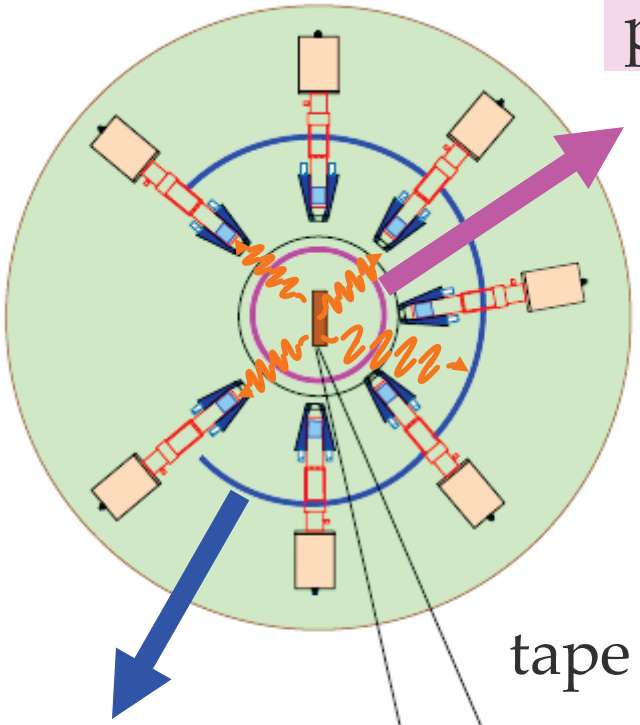
- ✓ gamma-ray spectroscopy with X-array would be a powerful tool, including βγ coin
- ✓ using $LaBr_3$(Ce) detectors in conjunction with X-array to measure fast (ps) lifetimes

what CARIBU can offer?

Tc (Z=43): 112 (610^4), 114 (100), 116 (0.012)
Nb(Z=41): 108 (310^4), 110 (~100)
Y(Z=39): 102 (210^5), 104 (410^3), 106 (~100)

β− counting station with GS

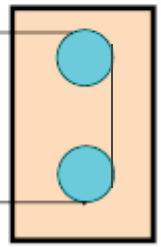
GAMMASPHERE



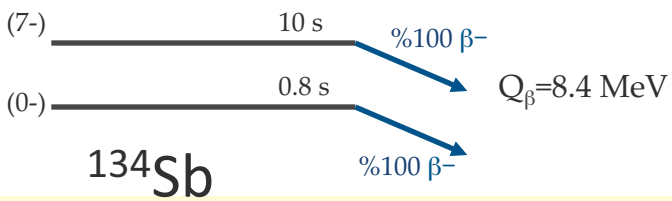
plastic scint. (β−)

heavy scintillator filling holes

tape system



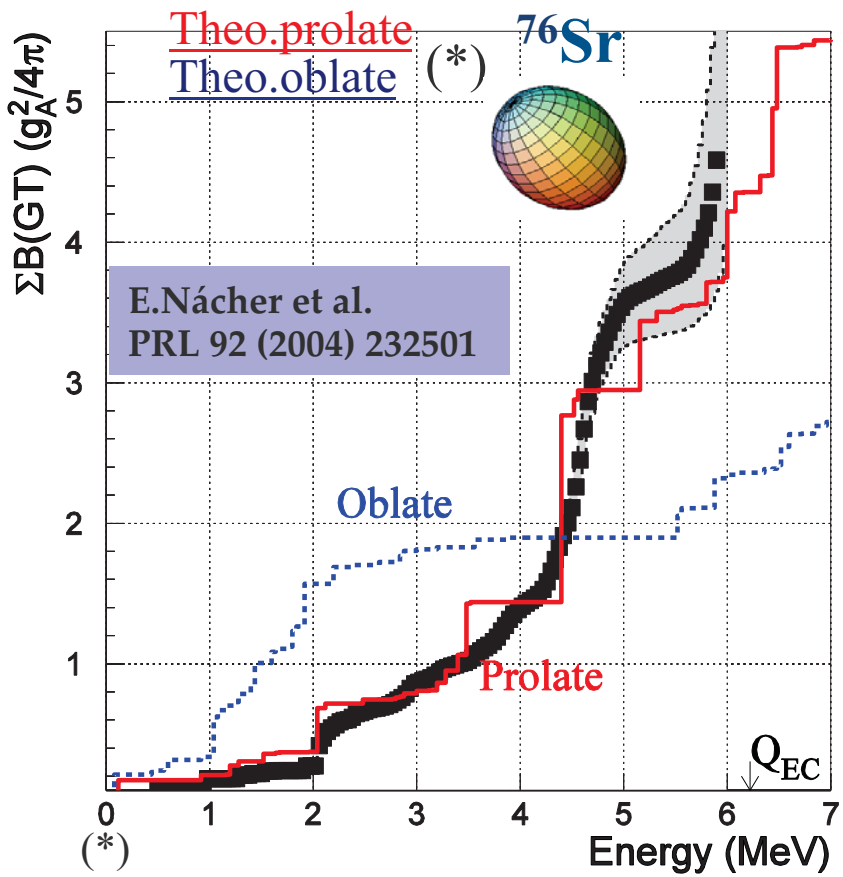
- high resolution & sensitivity
- powerful β−γ−γ coin – resolving weak cascades & isomers!

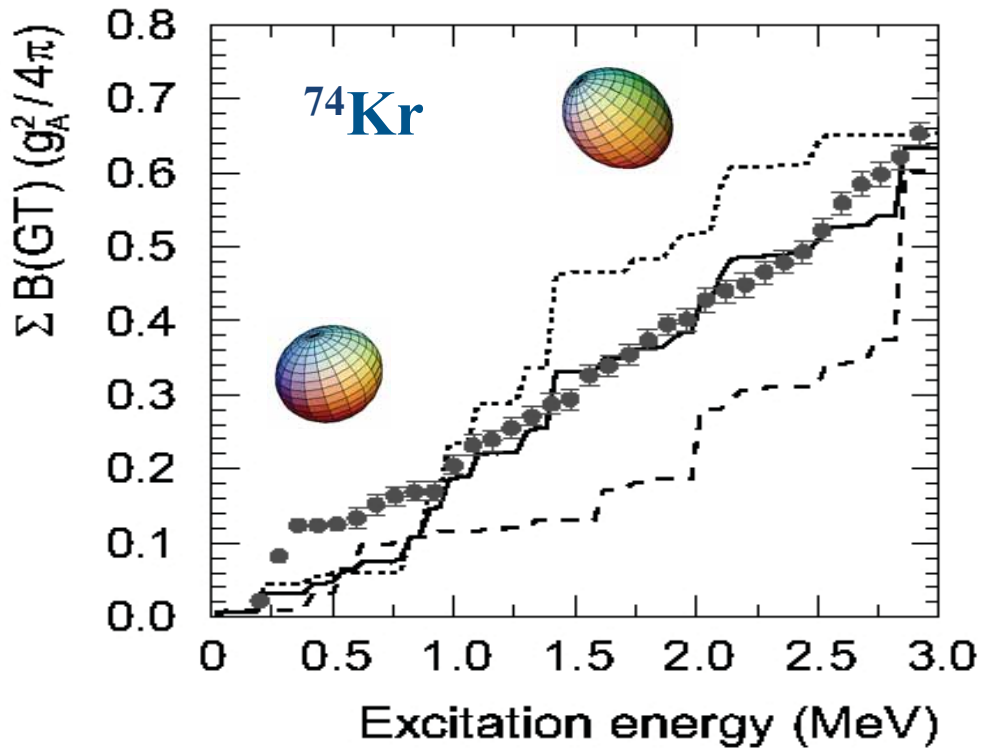


GS as a calorimeter

- P. Reiter et al. Phys. Rev. Lett. 84, 3542 (2000)
- with a modest upgrade – suitable for β− decay studies – HRGS & TAGS

Shape measurements using TAGS





E. Poirier *et al.* PRC 69 (2004) 034307

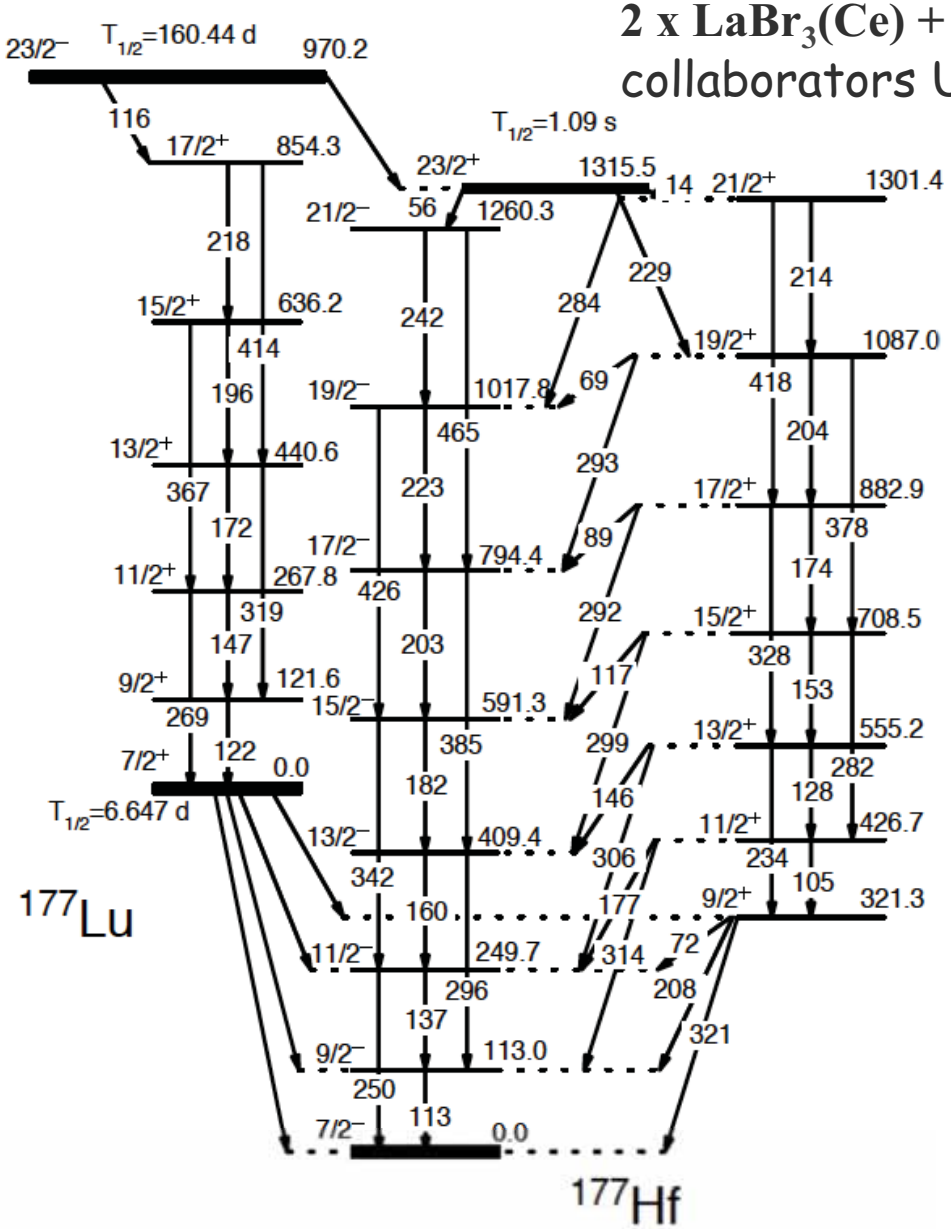
Ground state of ^{76}Sr prolate (β_2~0.4) as indicated by in-beam studies by Lister et al., PRC 42 (1990) R1191

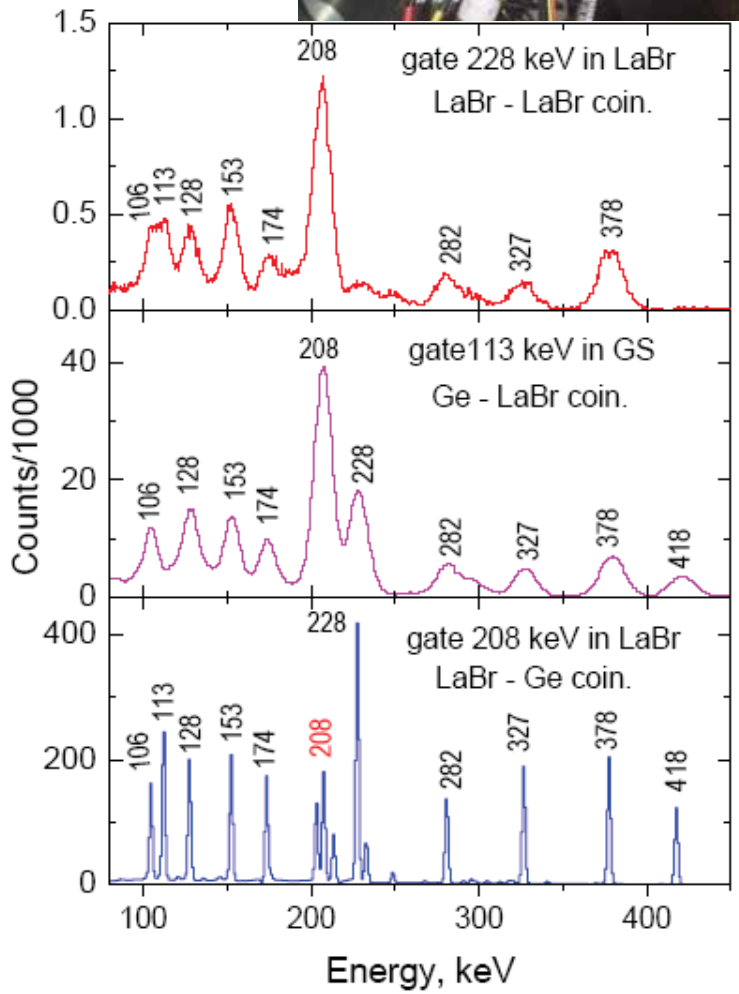
Ground state of ^{74}Kr:(60±8)% oblate, in agreement with other exp results and with theoretical calculations (A. Petrovici *et al.*)

GS-$LaBr_3$(Ce) coincidences

2 x $LaBr_3$(Ce) + GS

collaborators Univ. Sofia

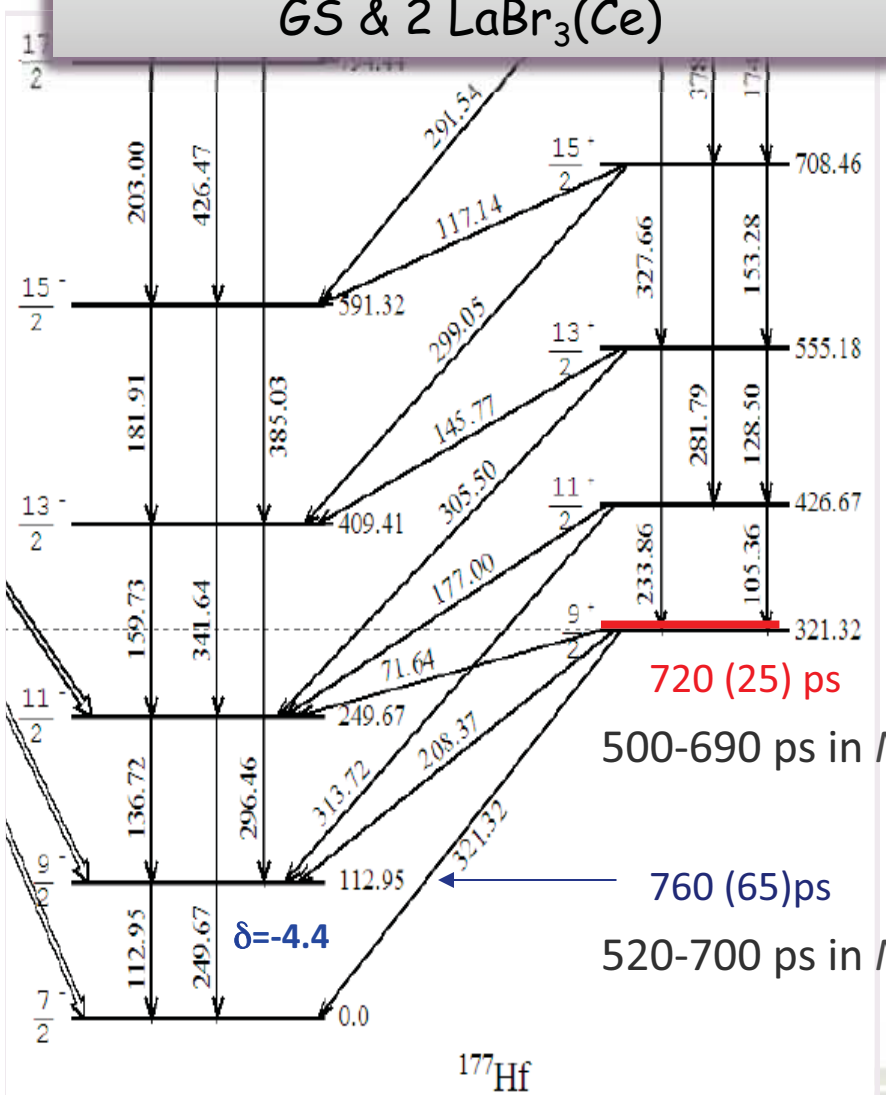




Fast (ps) timing measurements

Direct (electronic) timing – γ-γγ(Δt)

GS & 2 $LaBr_3$(Ce)

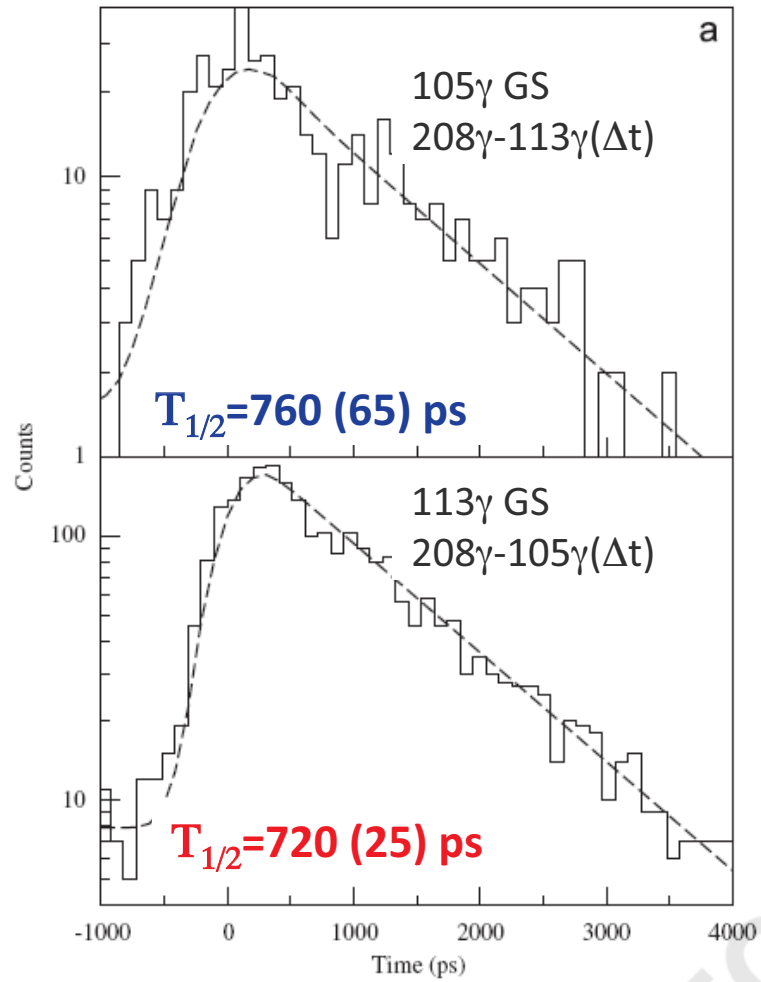


720 (25) ps

500-690 ps in *NDS*

760 (65)ps

520-700 ps in *NDS*



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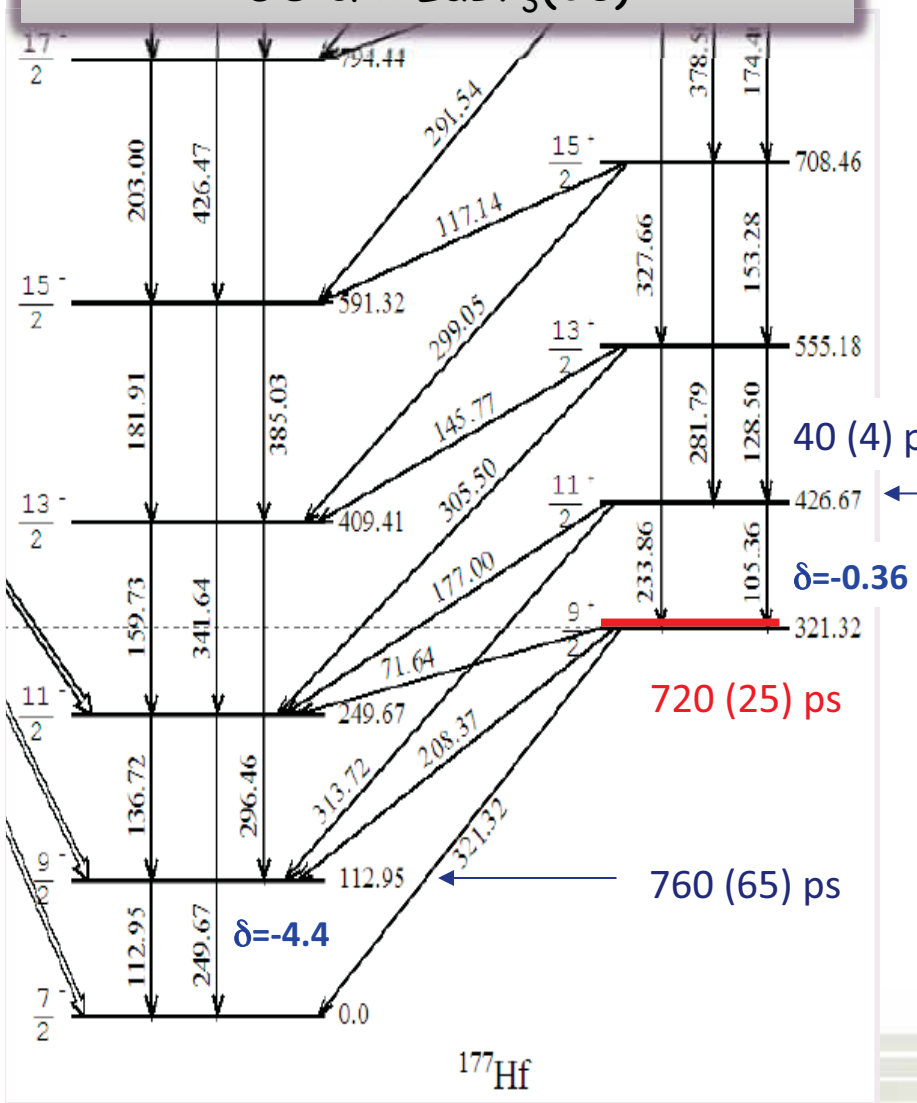

40 (4) ps

δ=-0.36

720 (25) ps

760 (65) ps

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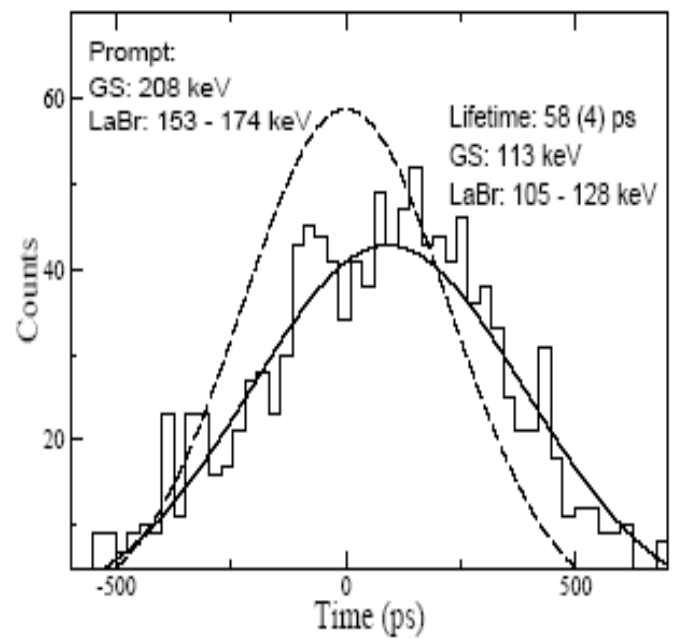
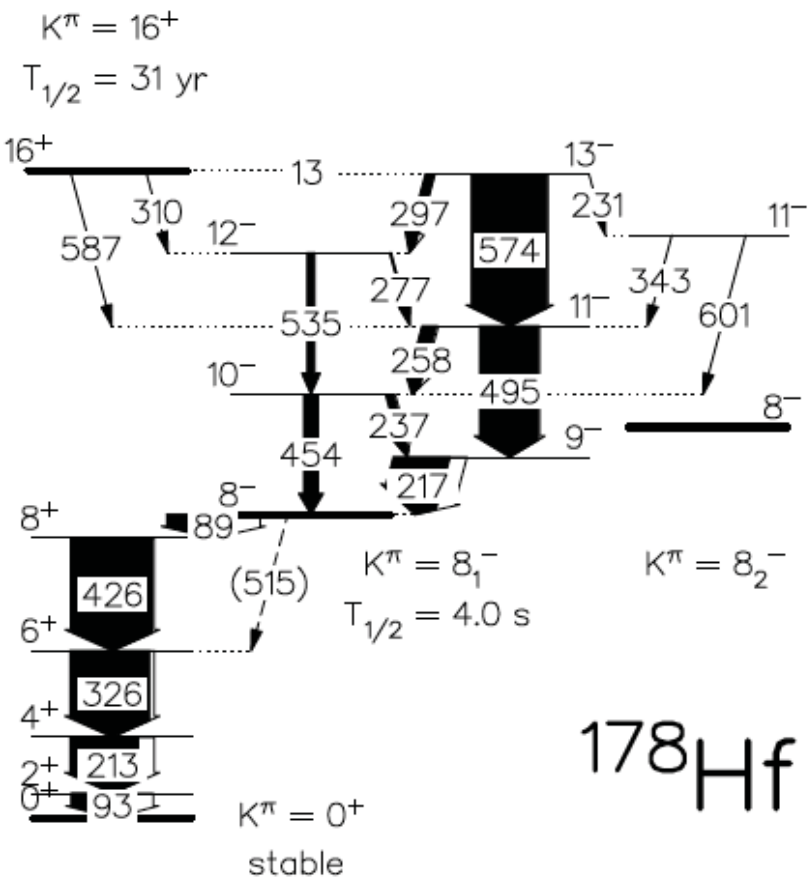
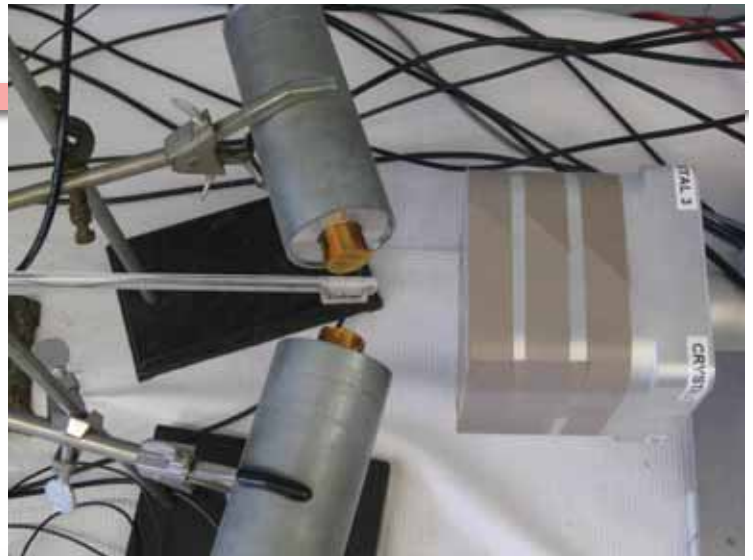
γ–ray coincidence and fast-timing measurements using $LaBr_3$(Ce) detectors and gammasphere ☆

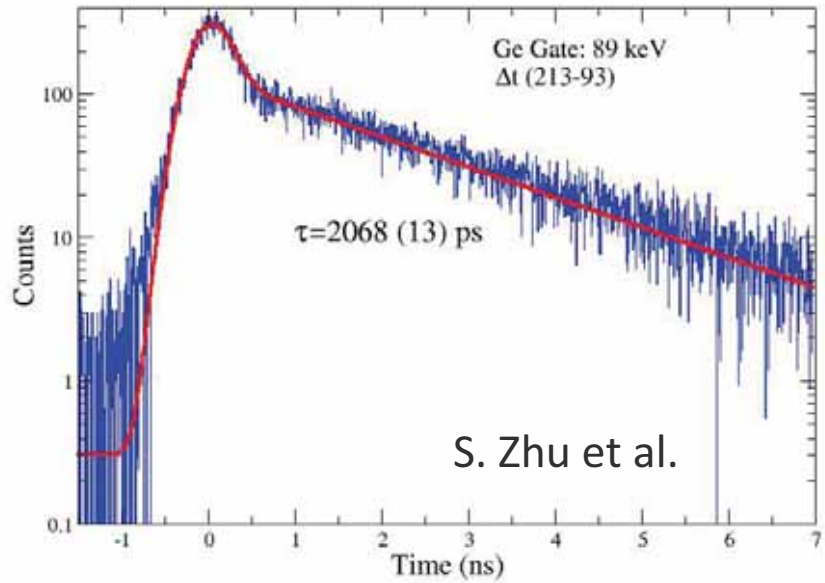
S. Zhu [a,*], F.G. Kondev [a], M.P. Carpenter [a], I. Ahmad [a], C.J. Chiara [a,b], J.P. Greene [a], G. Gurdal [a], R.V.F. Janssens [a], S. Lalkovski [c], T. Lauritsen [a], D. Seweryniak [a]



Precise lifetime measurements







τ(2+)=2155 (33) ps - *NDS*

Conclusions

- **Fast-timing capabilities - a valuable addition to the CARIBU decay station**
  - ✓ **good physics** and a **simple concept**: $LaBr_3$(Ce) scintillator array in conjunction with Ge hi-res detectors (X-array)
- **Shape changes and quantification of deformation in neutron-rich Zr-Mo-Ru nuclei**
  - ✓ combination between TAGS and HRGS would be very powerful tool
- **Identification of single-particle structures and K-Isomers**
- **Utilizing the high sensitivity and calorimetric capabilities of Gammasphere in decay of neutron-rich nuclei**