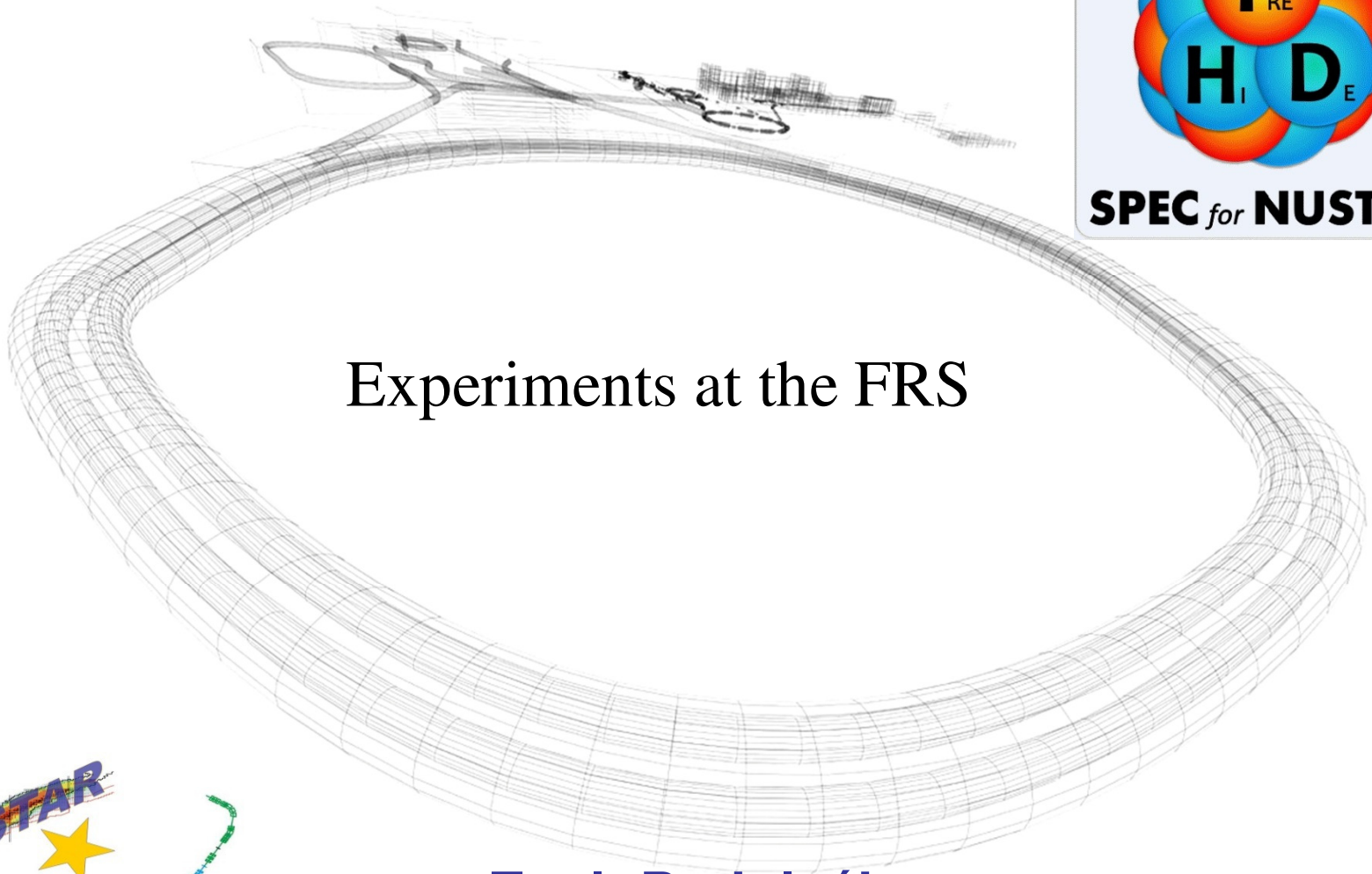
# The DESPEC physics case for FAIR-0

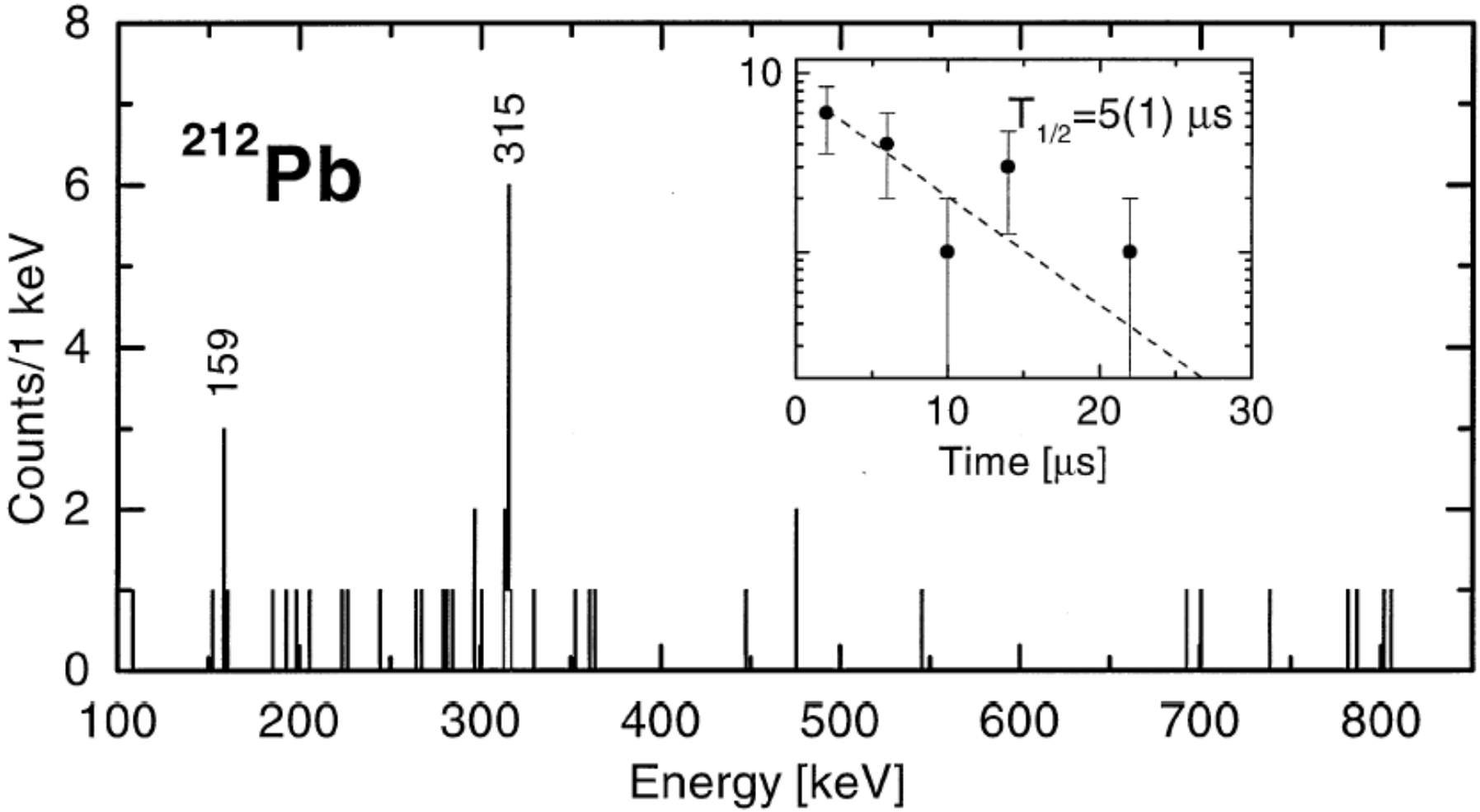


Experiments at the FRS

Zsolt Podolyák

# DESPEC: very sensitive!

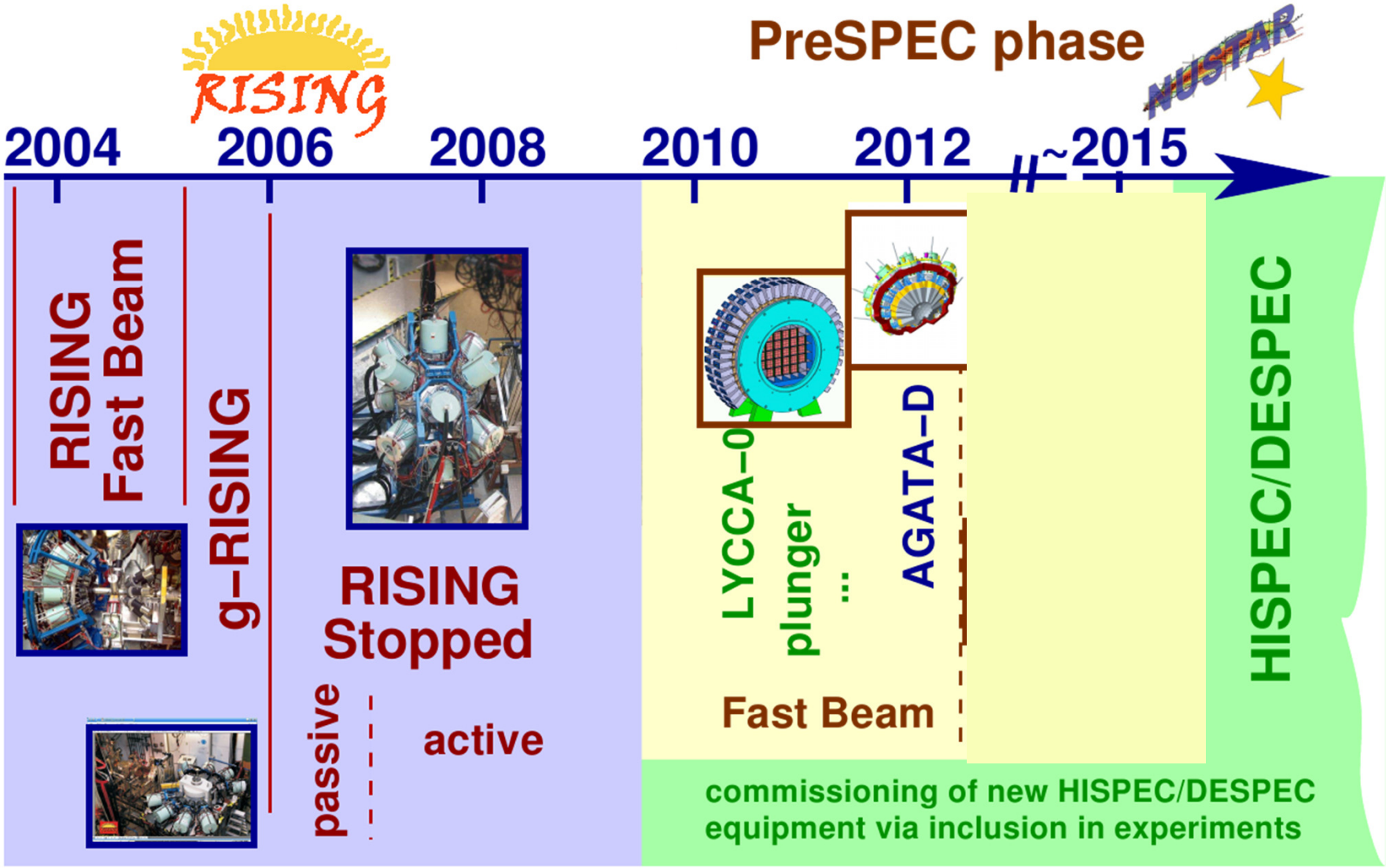
370 implanted $^{212}$Pb ions!




decay of the $\nu g_{9/2}^2$ $8^+$ isomer

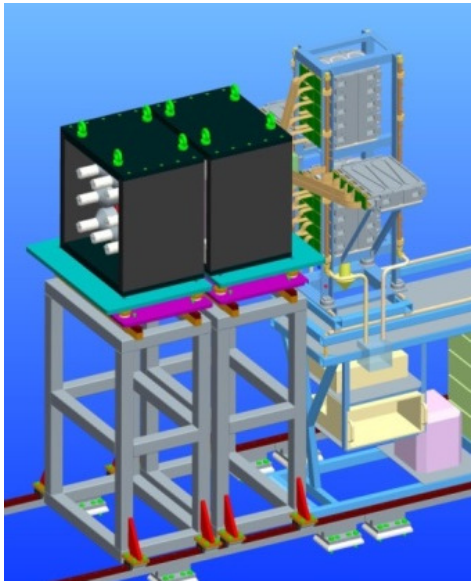
M. Pfützner et al., Phys. Lett. B 444 (1998) 32.

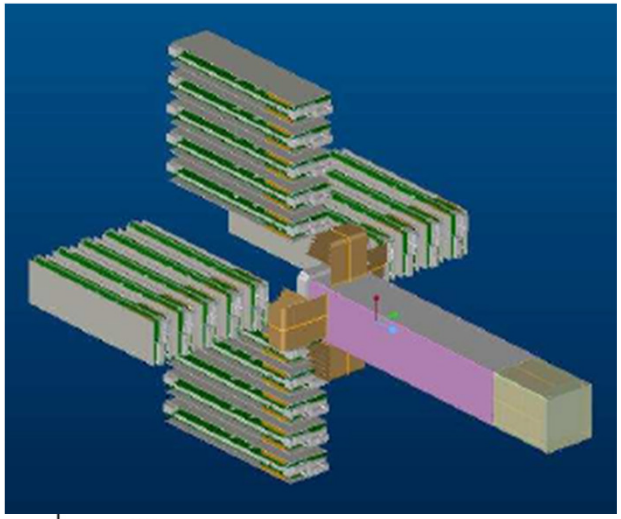
# γ-ray spectroscopy at GSI (and FRS)



# Developed equipment

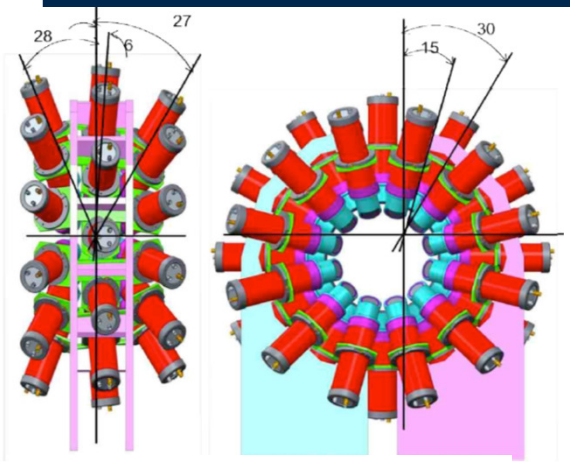
AIDA implantation and decay detector

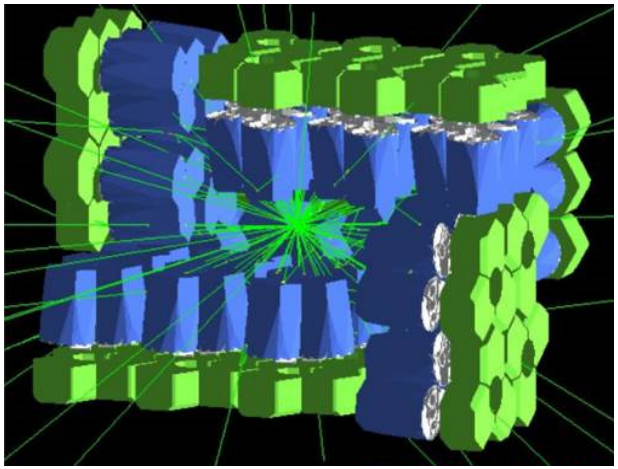




DTAS for β-strength distribution

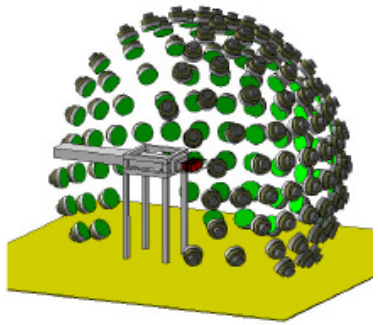
FATIMA to measure ps-ns lifetimes



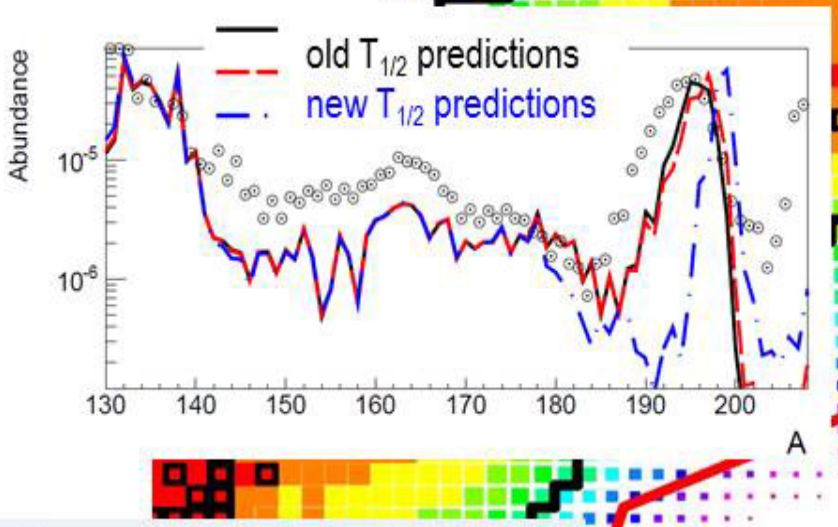
DEGAS for high-resolution spectroscopy

MONSTER for neutron spectroscopy



# DESPEC (phase 0)

Physics workshop held in September 2016
Focus on heavy neutron-rich nuclei
$^{208}$Pb and $^{238}$U beams
Several detector systems ready:
DTAS, FATIMA, AIDA,
DEGAS, BELEN

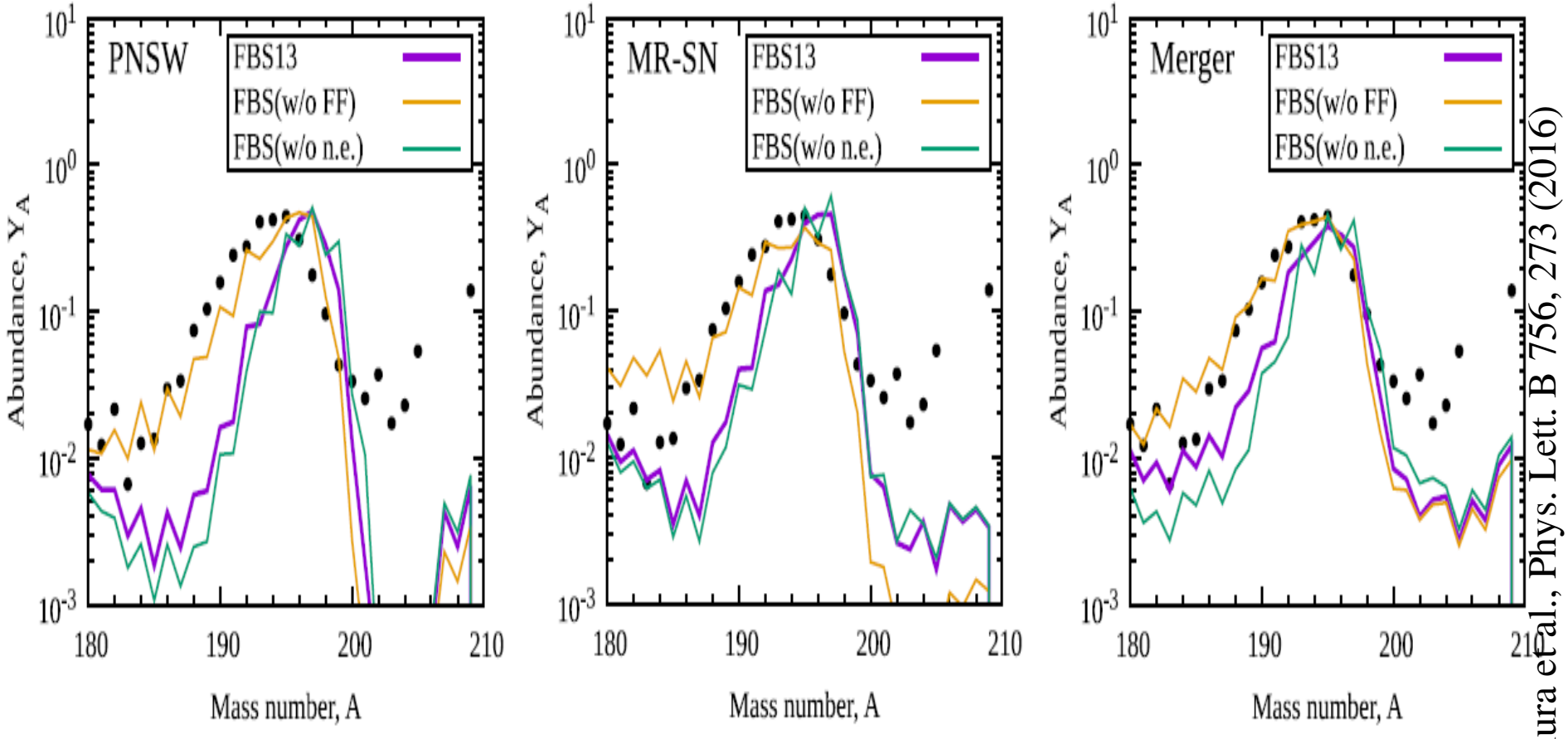



Mass abundances depend on the detailed structureof N=126 nuclei around the 3rd r-process waiting point




DESPEC will measure
-β-lifetimes
-neutron-branchings
-strength distributions
-level structure

# r-process abundances = f (*nuclear properties*; astro.site)




neutron richness →

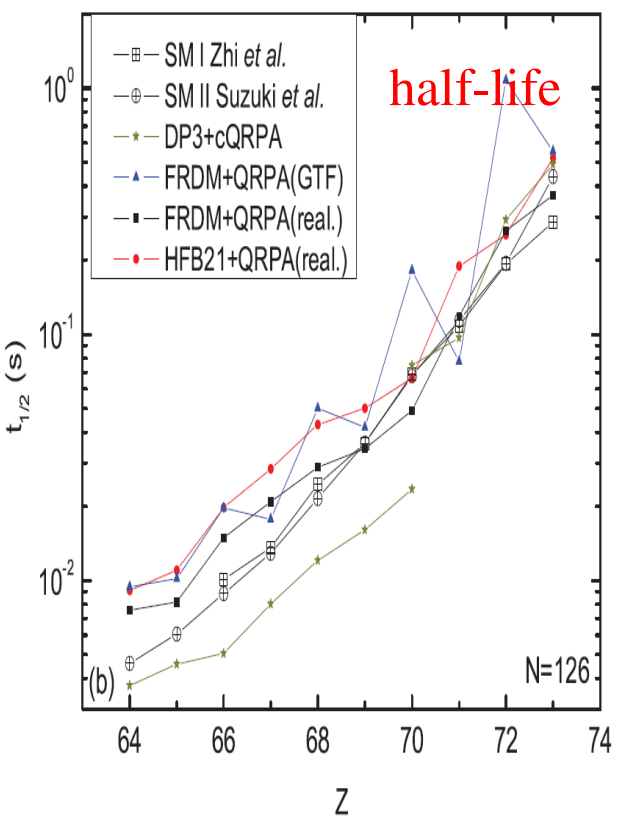
entropy ←

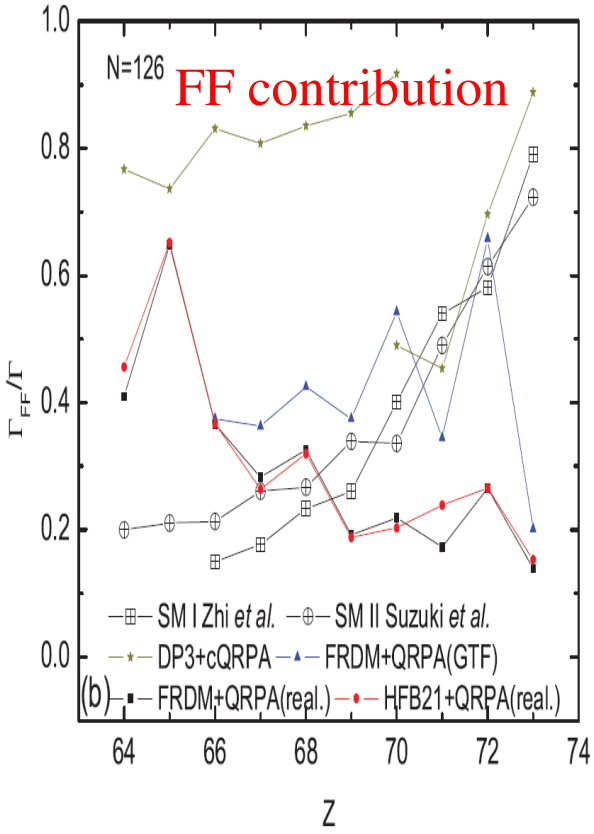
Proto-neutron star wind Magneto-rotational supernovae Neutron-star merger

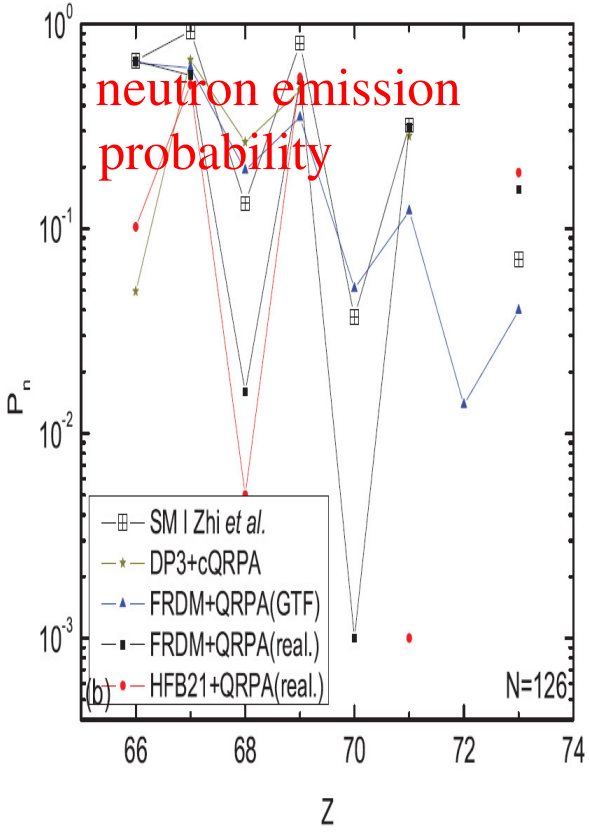
Without First-Forbidden β decay; Without β-delayed neutron evaporation

N. Nishimura et al., Phys. Lett. B 756, 273 (2016)

# N~126 r-process path nuclei



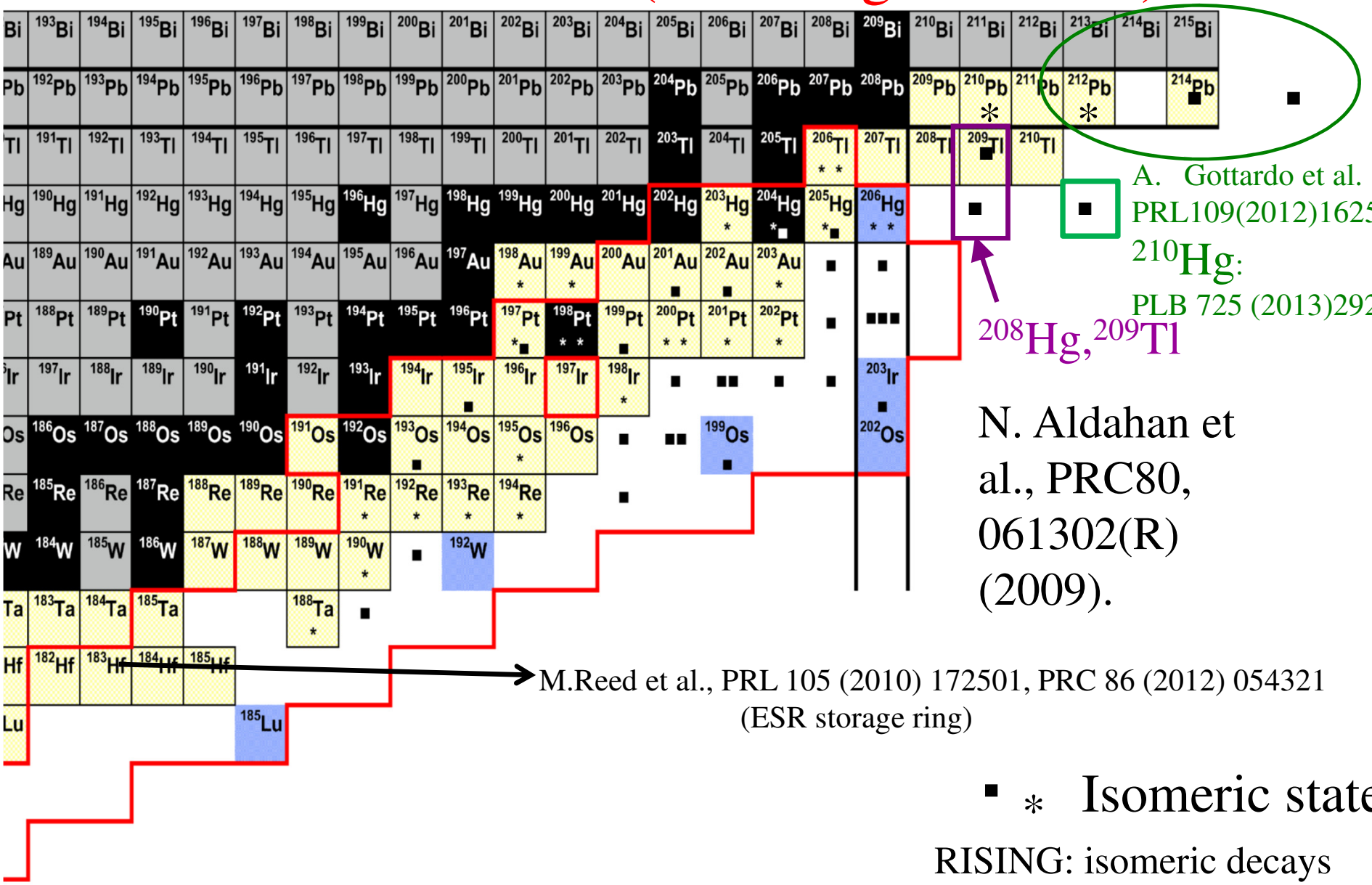




$T_{1/2}(\beta)$: competition *FF* $\nu 1i_{13/2} \rightarrow \pi 1h_{11/2}$ and allowed $\nu 1h_{9/2} \rightarrow \pi 1h_{11/2}$

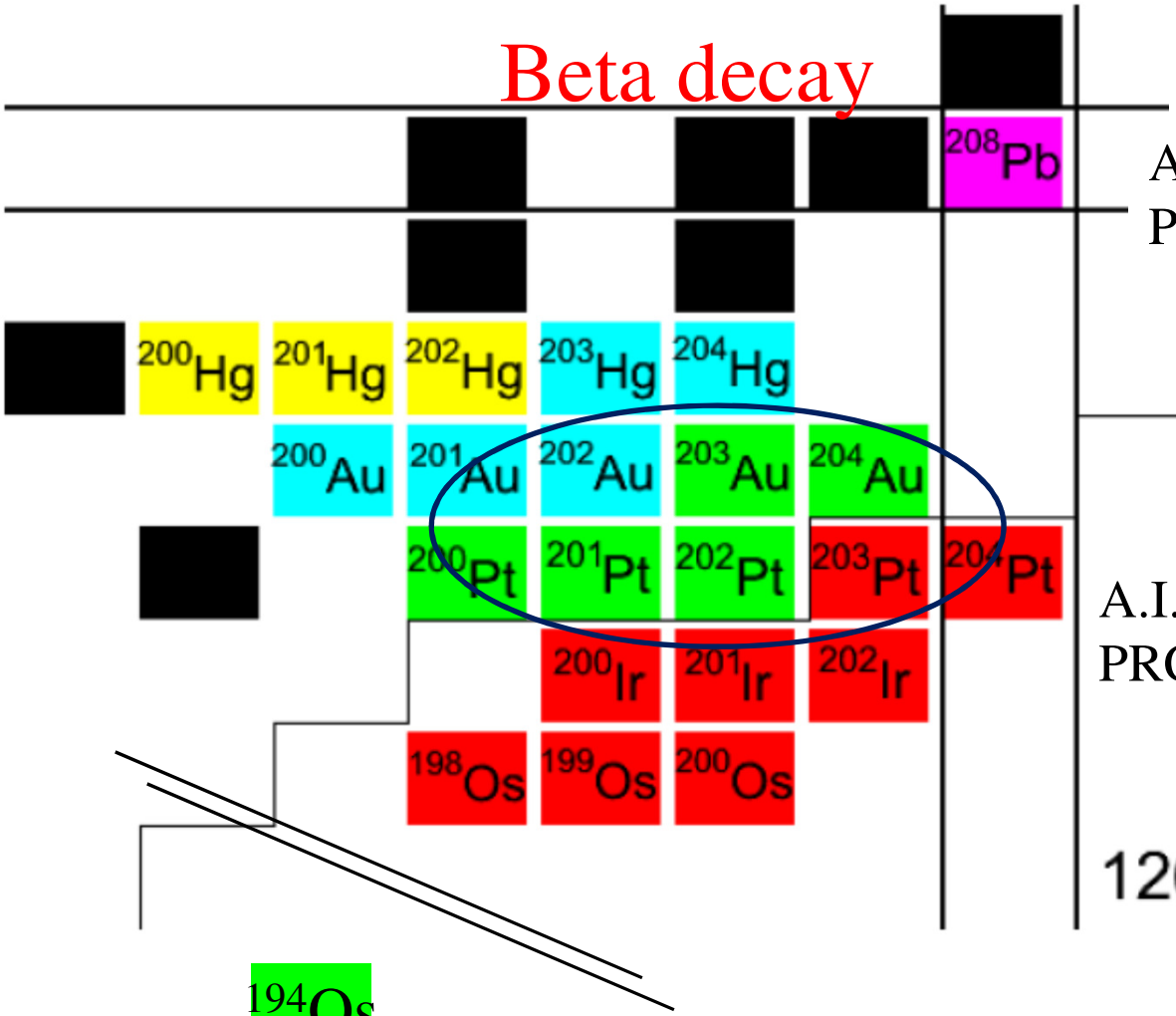
D.-L. Fang, B.A. Brown, T. Suzuki, Phys. Rev. C 88, 034304 (2013)

# Isomeric states (from fragmentation)




S. Steer et al., Phys. Rev. C 84 (2011) 044313

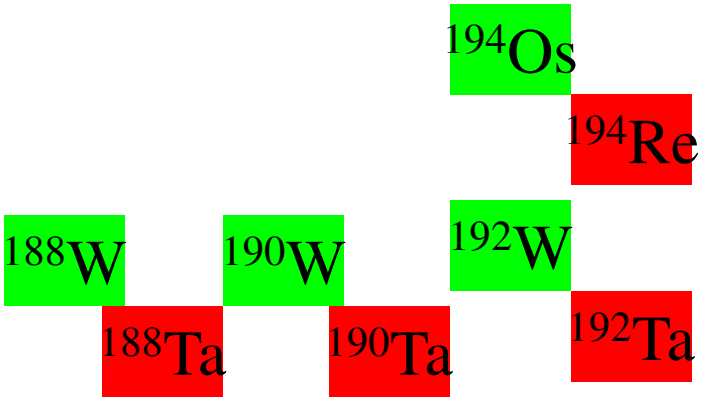
# Beta decay




T1/2: G.Benzoni et al., PLB 715 (2012) 293

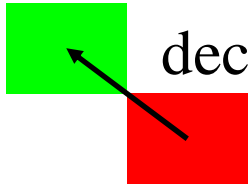
A.I. Morales et al., PRC 89 (2014) 014324

A.I. Morales et al., PRC 88 (2013) 014319




N. Al-Dahan et al., PRC85 (2012) 034301

N. Alkhomashi et al., PRC80 (2009) 064308



decay into

implanted

# Lifetime measurements

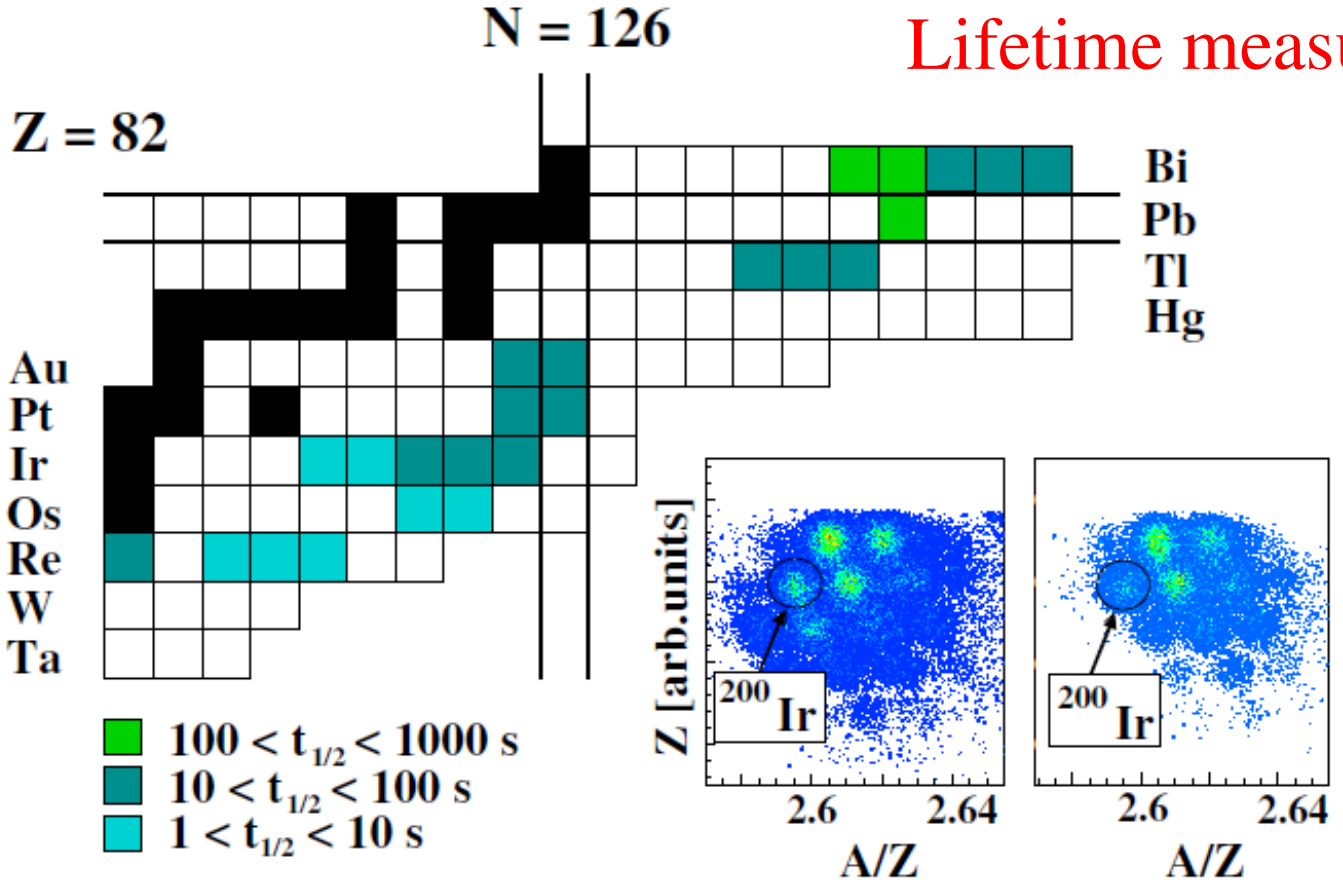
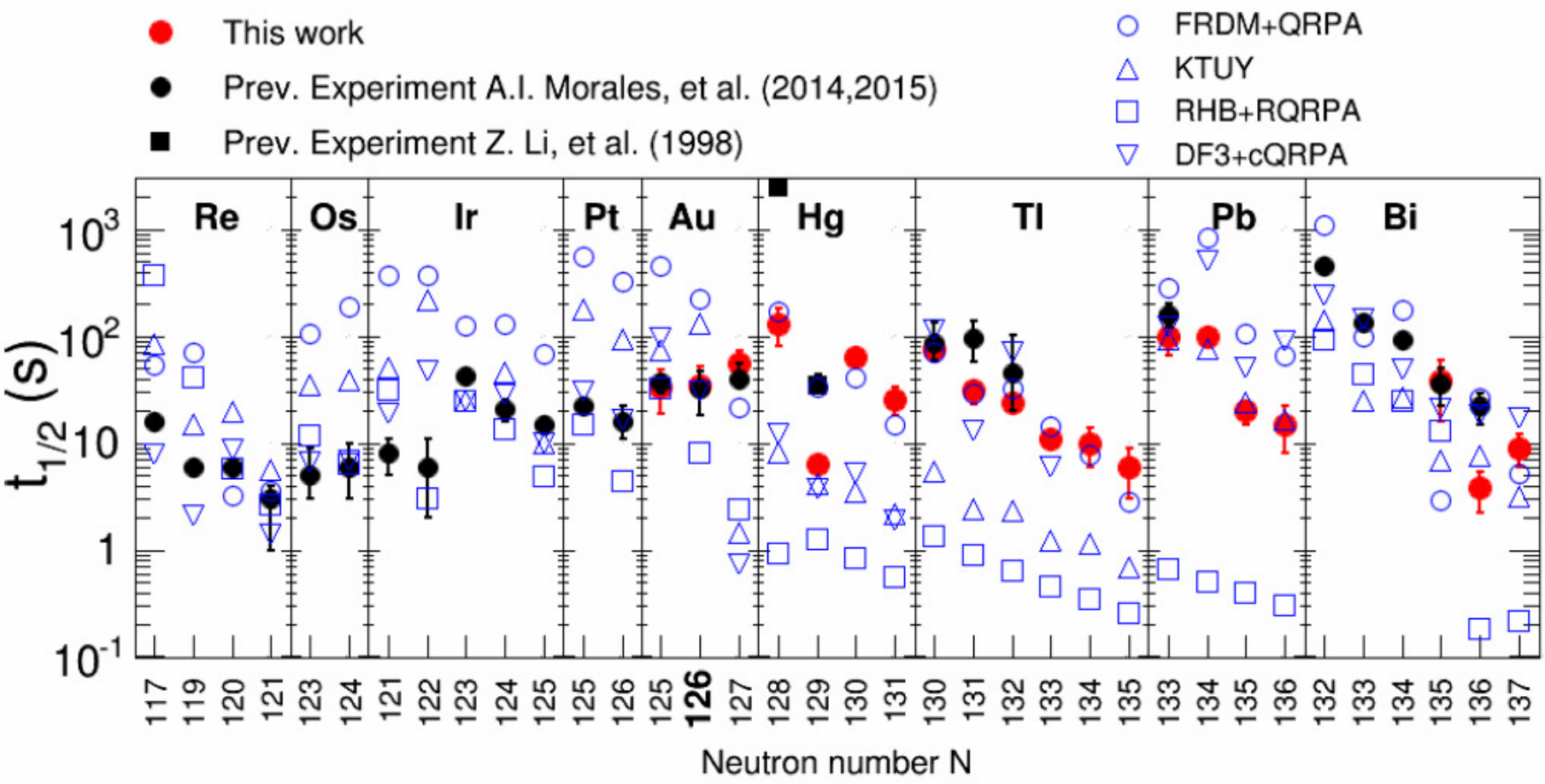



FIG. 1 (color online). Neutron-rich $N \sim 126$ region analyzed during the stopped beam RISING campaign. Measured half-lives are shown in color scale. Inset: Identification plots for $Z$ as a function of $A/Z$ at the final focal plane of the separator (left) and in the active stopper (right).

A.I. Morales et al., Phys. Rev. Lett. 113, 022702 (2014)

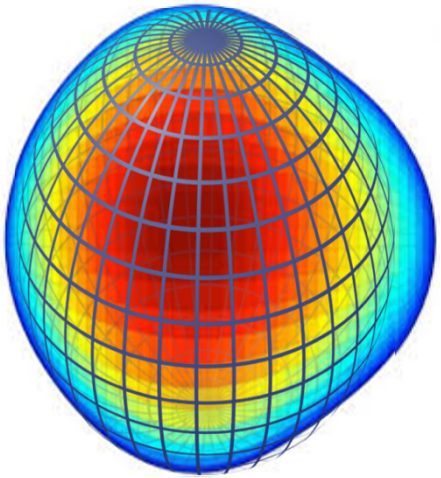
# Lifetime measurements

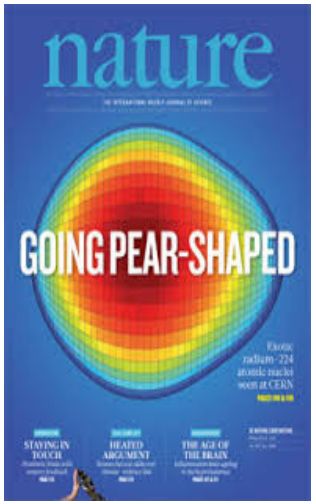



⇒ The most neutron-rich N=126 for which lifetime was measured is $^{204}$Pt

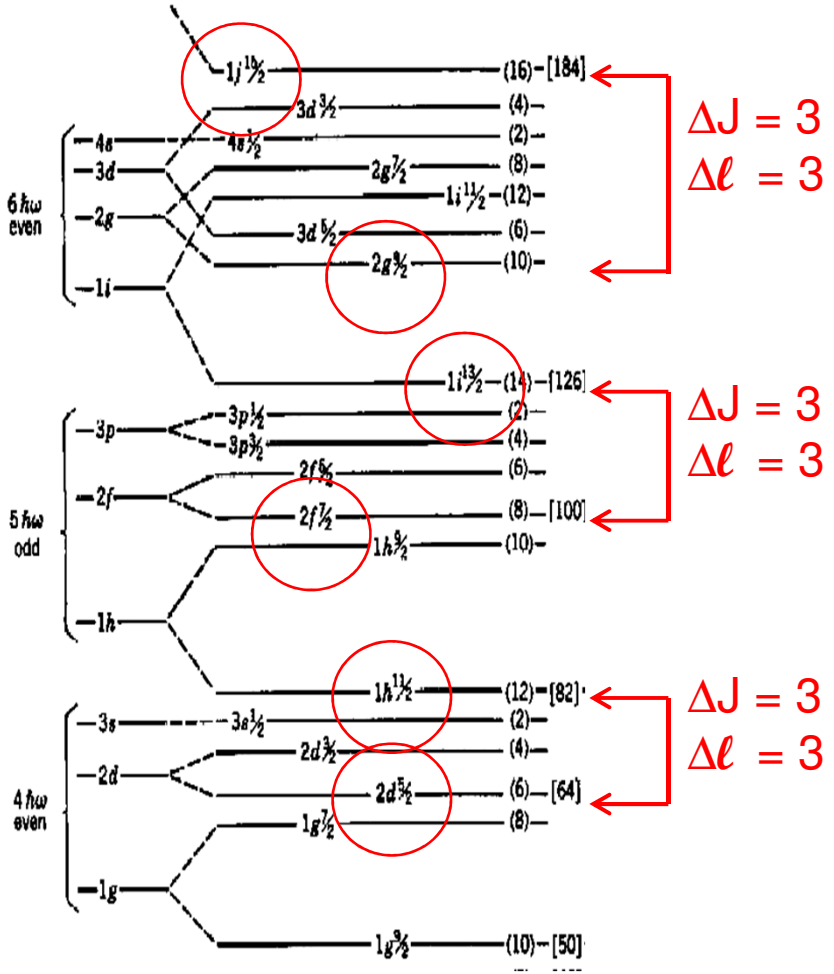
R. Caballero-Folch et al., PRL17, 012501 (2016)

# Octupole Correlations





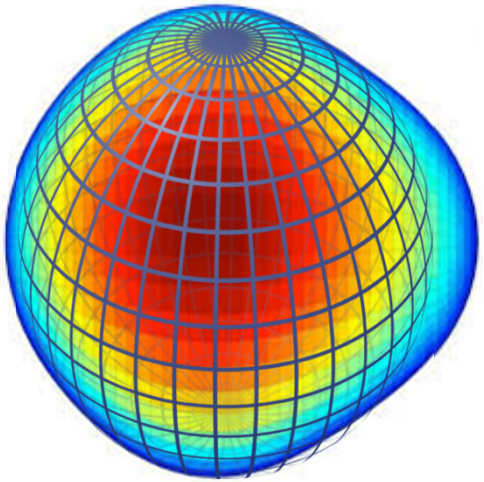

- The strongest octupole correlations are expected around n-rich A~150 and **A~225**

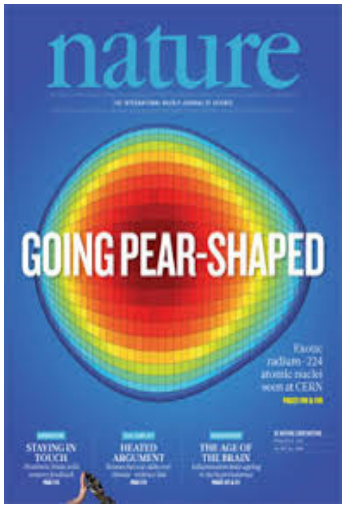



Pending questions:

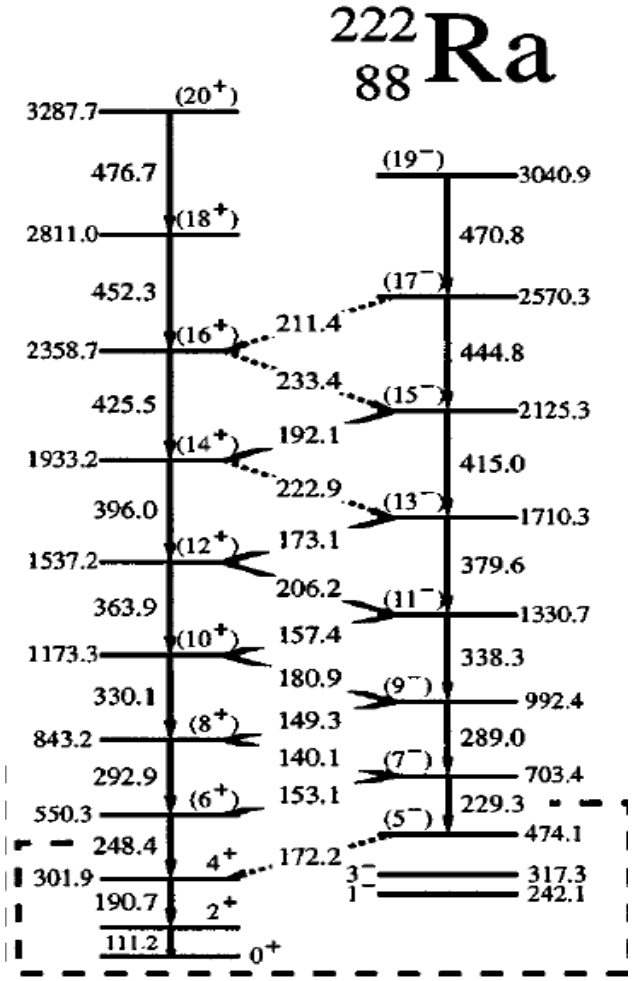
- Maximum of octupole deformation
- Static or dynamic deformation
- Role of quadrupole-octupole coupling

# Octupole Correlations






- Octupole-deformed (pear-like) shapes appear under particular conditions:




Cocks et al., PRL 78 (1997) 2920

Particular features:

- Large B(E1) transition probabilities
- Large B(E3) strengths → difficult to measure
- Interleaved positive- and negative-parity states

- **FATIMA** = **FA**st **TIM**ing **A**rray = State of the art gamma-ray detection array for precision measurements of nuclear structure in the most exotic and rare nuclei.
  - Energy resolution better than 3% at 1 MeV.
  - FEP detection efficiency better than 5% at 1 MeV.
  - Excellent timing qualities (approaching 100 picoseconds).

Nuclear Instruments and Methods in Physics Research A 748 (2014) 91–95

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Technical Notes

## A $LaBr_3$: Ce fast-timing array for DESPEC at FAIR

Oliver J. Roberts [a,*], Alison M. Bruce [a], Patrick H. Regan [b,e], Zsolt Podolyák [b], Christopher M. Townsley [b], John F. Smith [c], Kieran F. Mulholland [c], Andrew Smith [d]

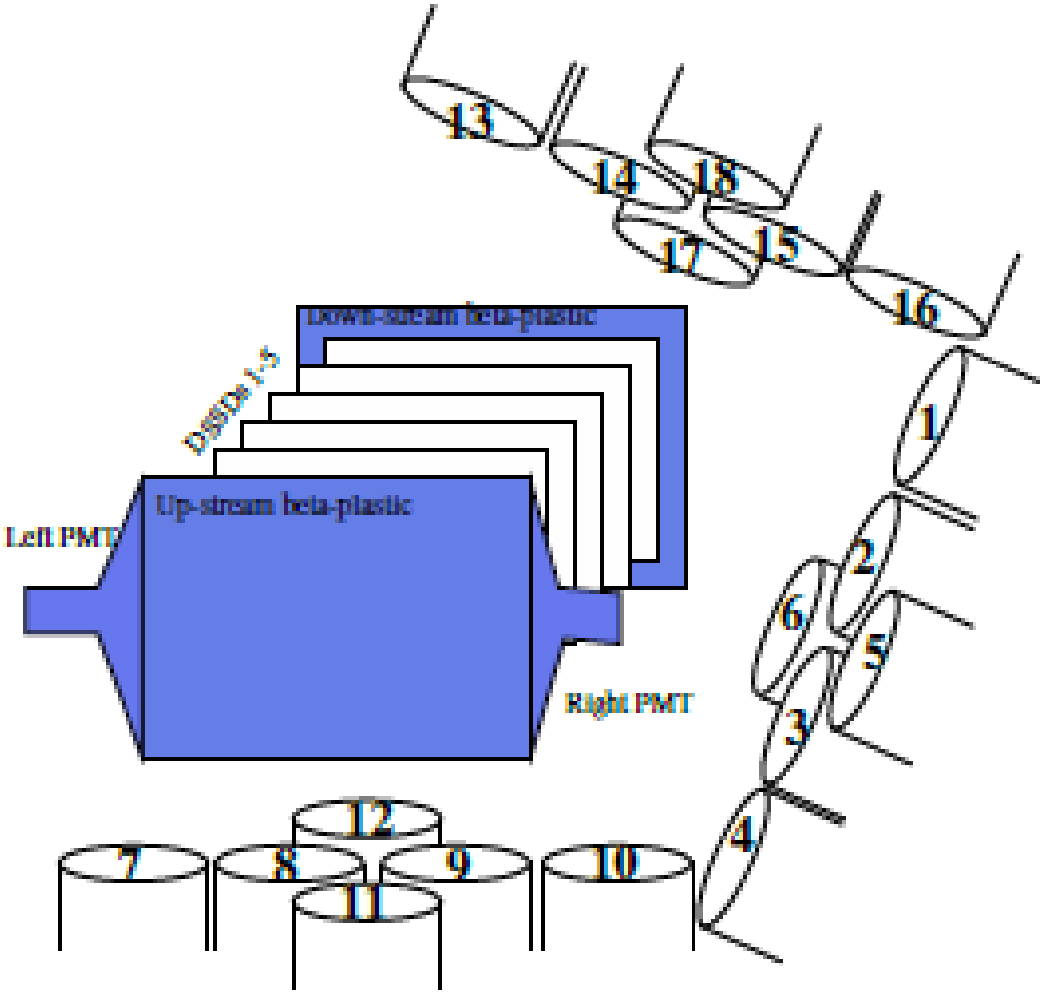
[a] School of Computing, Engineering and Mathematics, University of Brighton, Brighton BN2 4GJ, UK
[b] Department of Physics, University of Surrey, Guildford GU2 7XH, UK
[c] School of Engineering, The University of the West of Scotland, Paisley PA1 2BE, UK
[d] The University of Manchester, Oxford Road, Manchester, M13 9PL, UK
[e] National Physics Laboratory, Teddington, TW11 0LW, UK

# Fast-timing following fragmentation (in-flight fission)

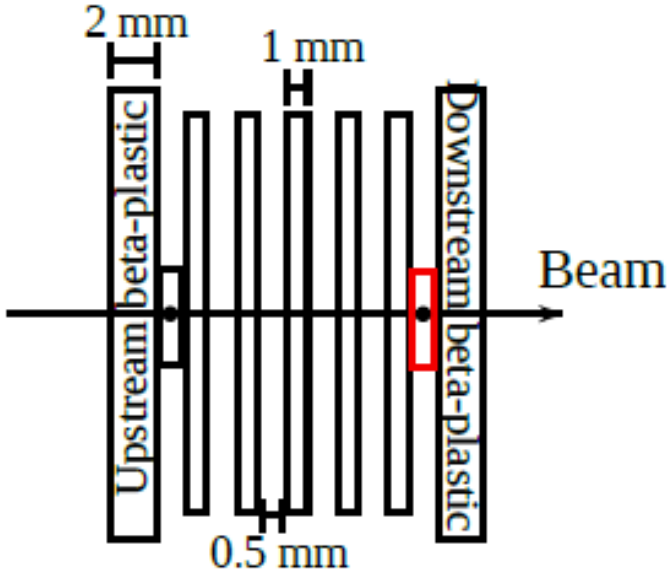
12 Ge clusters + 18 LaBr3(Ce)

EURICA+
LaBr3(Ce)

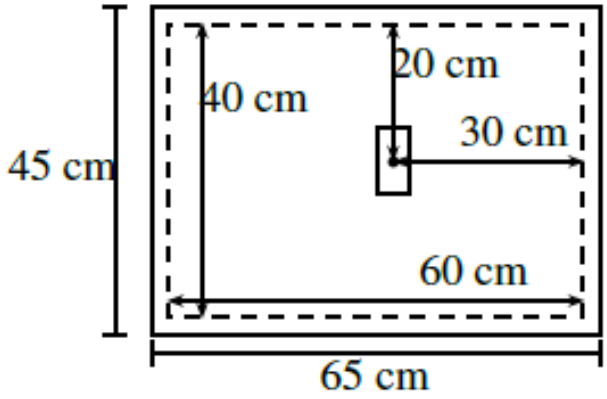
# Beta-gamma timing




F. Browne, PhD thesis, University of Brighton (2016)




(b) Profile view of the stopper array, where the beam axis is labelled. The source capsule positions are represented by a black and red rectangle, with the dot inside representing the position of the source pellet.




(a) The stopper array as viewed from downstream. The dashed lines represent WAS3ABi behind the upstream $\beta$-plastic, which is shown by the solid line. The beam axis and source position are denoted by the central black dot.

# Fast-timing results

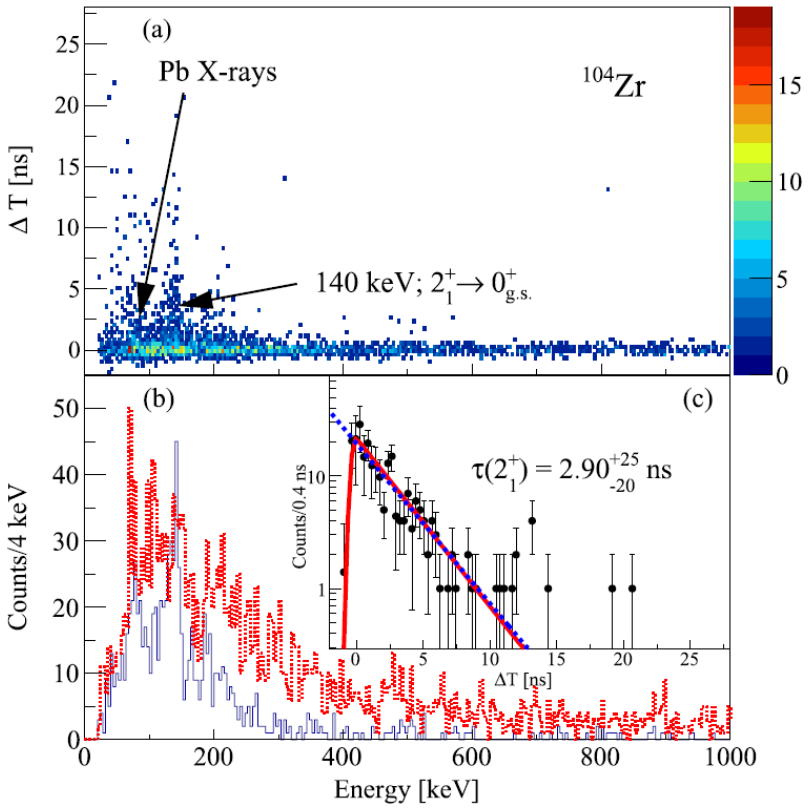



**Fig. 1.** (Colour online.) (a) Energy–time-difference matrix observed in coincidence with $\beta$-electrons detected within 1 s of an $^{104}$Y implantation. (b) The $\gamma$-ray energy spectrum of the delayed (solid blue) and prompt (dashed red) components of the matrix. (c) Background subtracted time difference spectrum for the $2_1^+ \rightarrow 0^+_{g.s.}$ transition. (See text for details of the fits.)

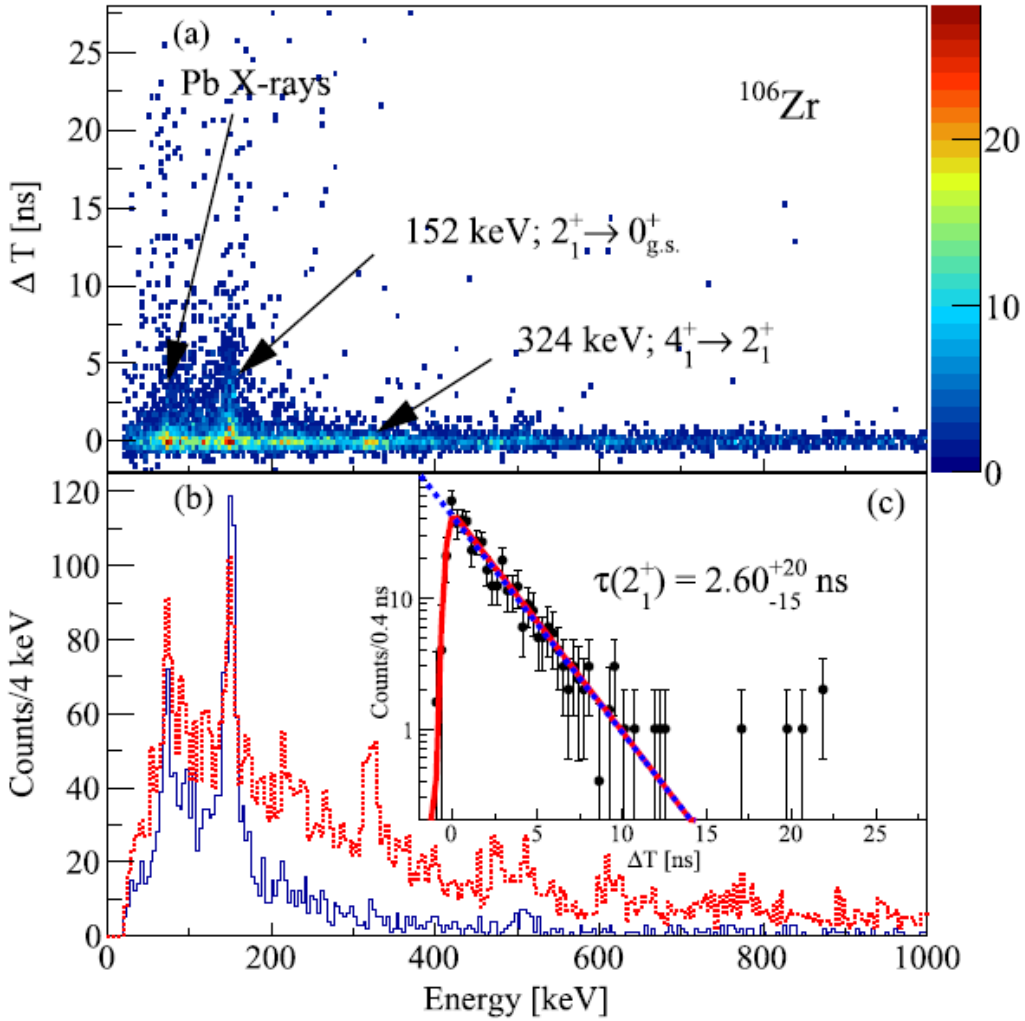



**Fig. 2.** (Colour online.) (a) Energy–time-difference matrix observed in coincidence with $\beta^-$ detected within 0.3 s of an $^{106}$Y implantation. (b) The $\gamma$-ray energy spectrum of the delayed (solid blue) and prompt (dashed red) components of the matrix. (c) Background subtracted time difference spectrum for the $2_1^+ \rightarrow 0^+_{g.s.}$ transition. (See text for details of the fits.)

$4 \times 10^5$ $^{104}$Y

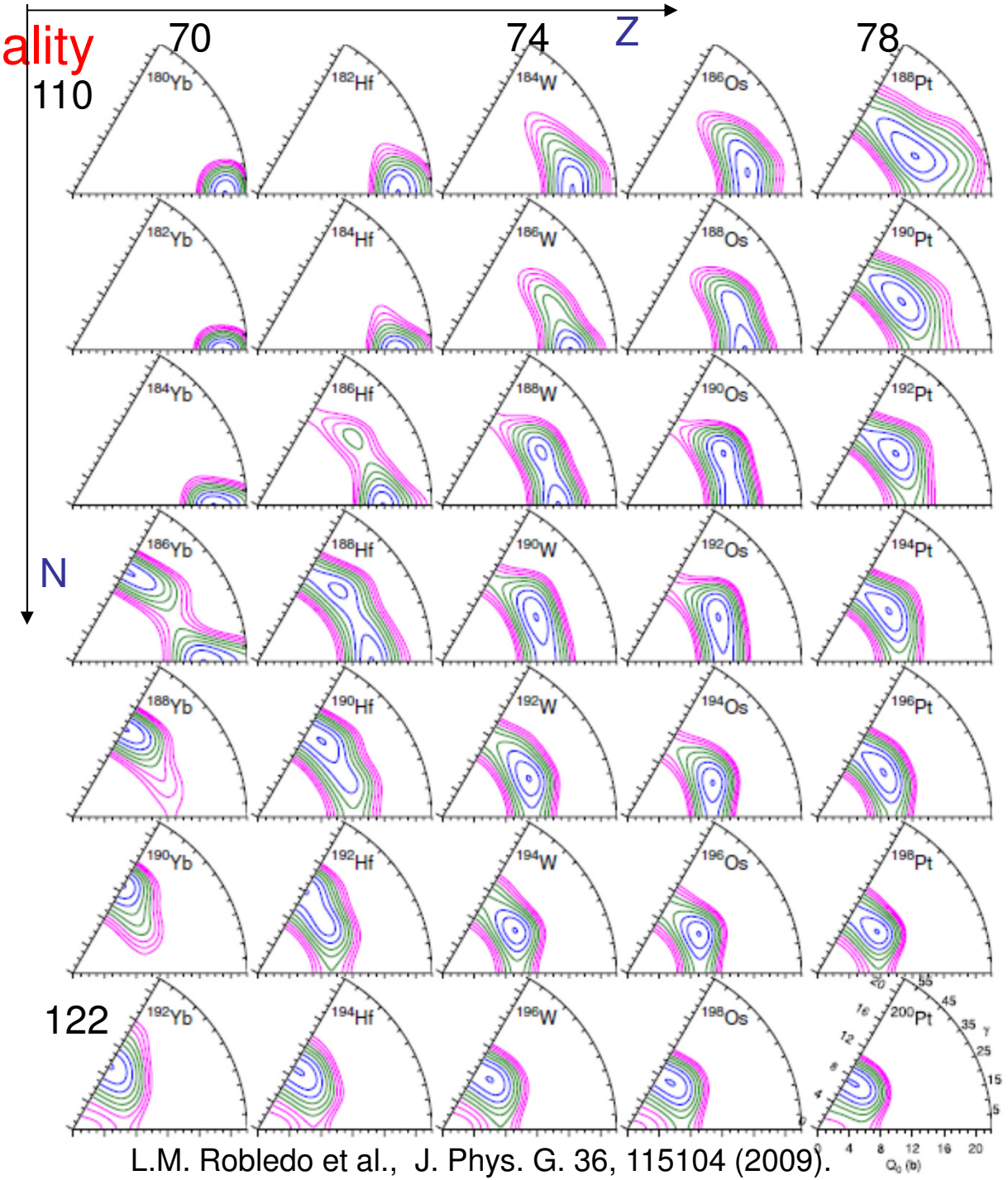
$6 \times 10^5$ $^{106}$Y

F. Browne et al., Phys. Lett. B 750 (2015) 448

# Shape transition, triaxiality
# Neutron-rich A~190

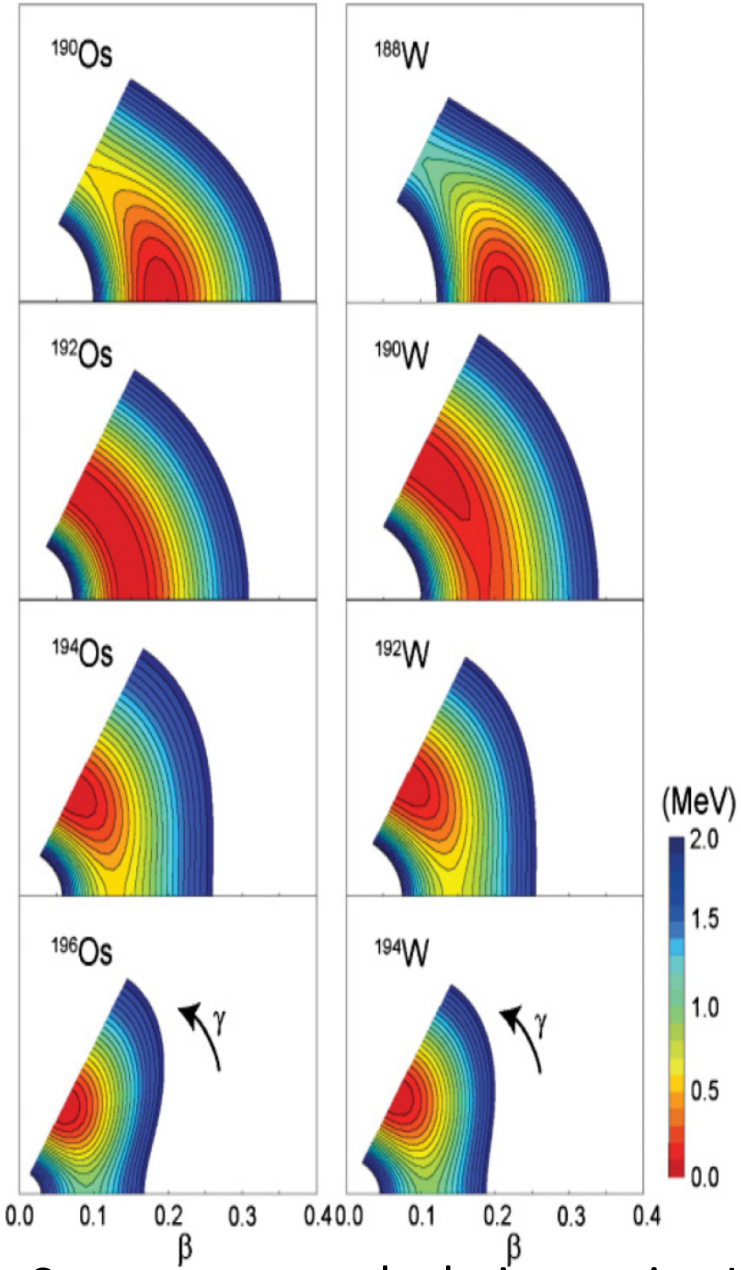
Stringent test of theories/models

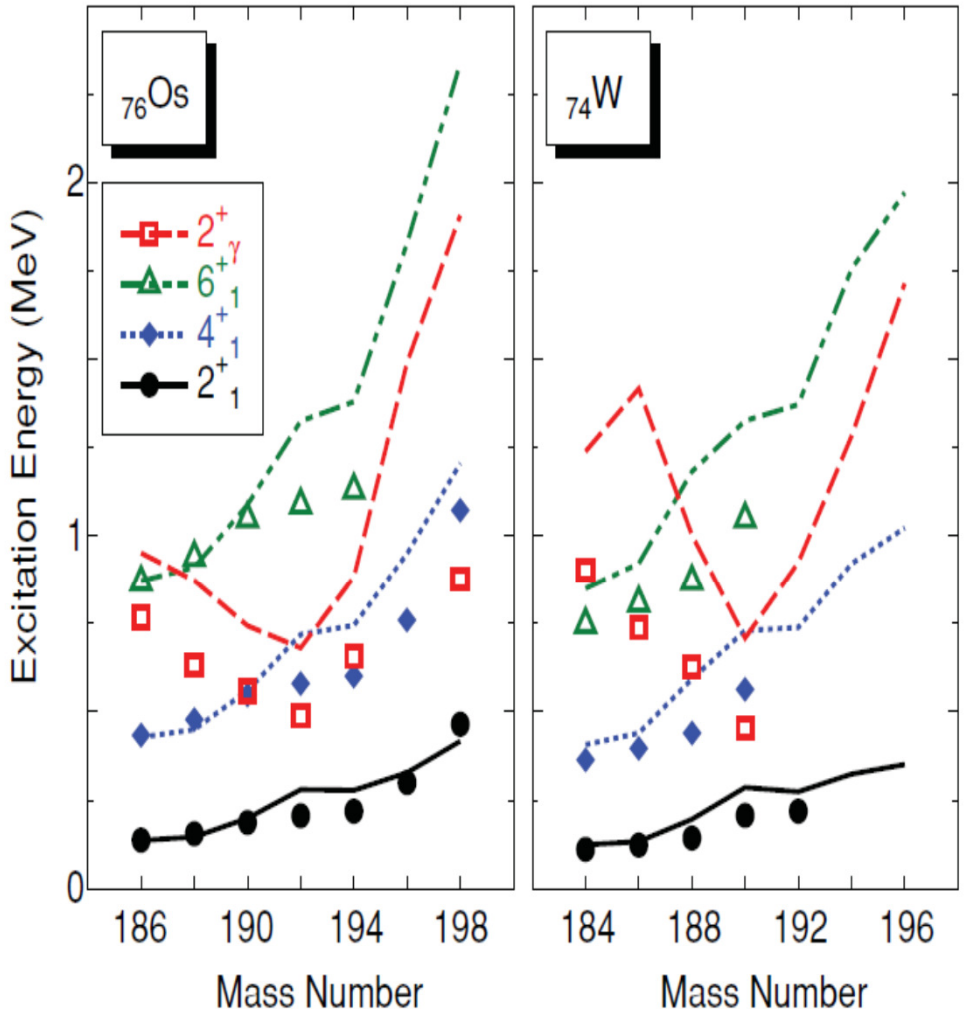
(SLy4 Skyrme interaction)




L.M. Robledo et al., J. Phys. G. 36, 115104 (2009).

# Beta-gated (fast-timing) W-Pt region at GSI/FAIR



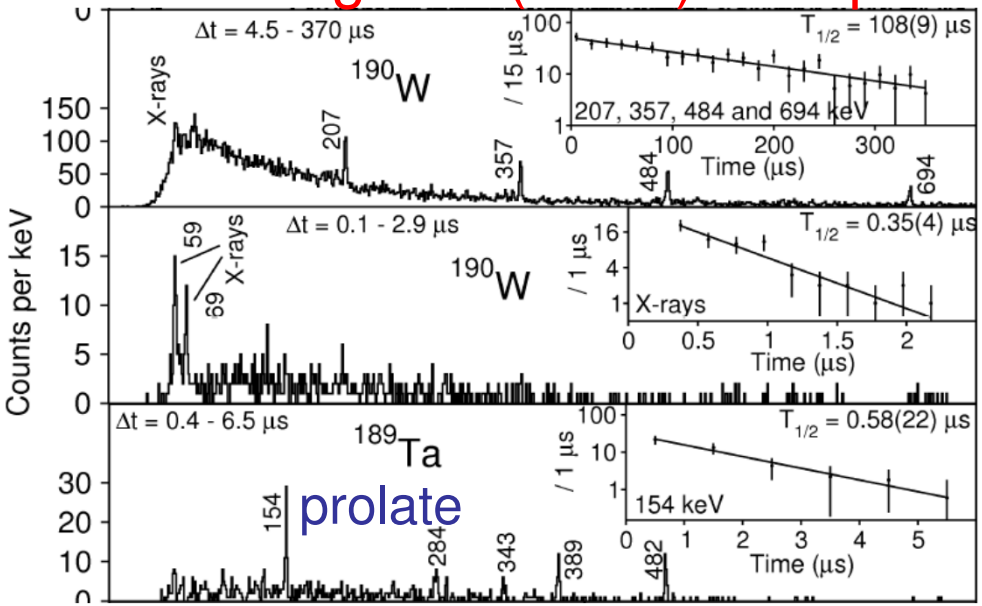



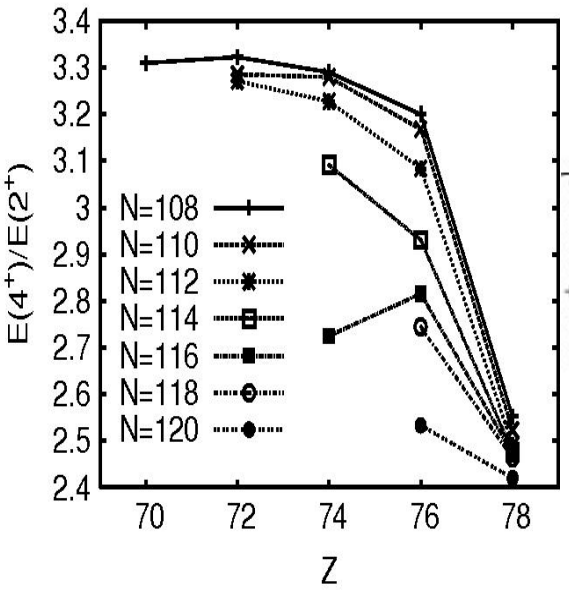

**Spectroscopic calculations of the low-lying structure in exotic Os and W isotopes**

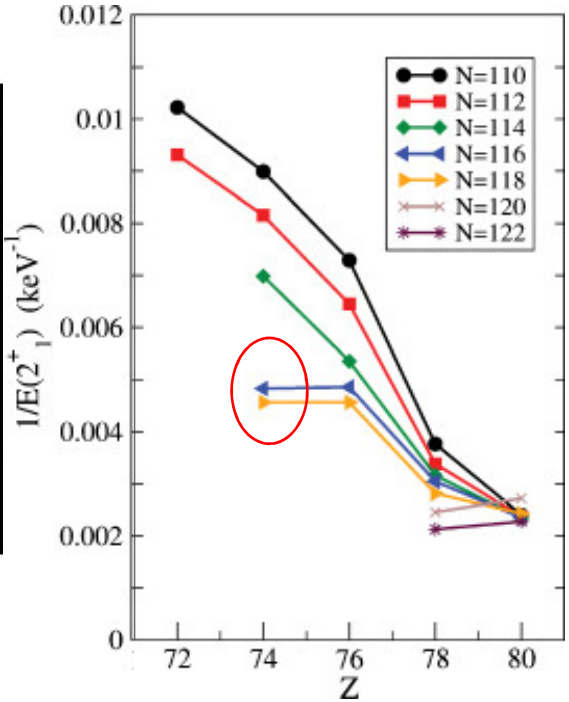
K. Nomura,[1] T. Otsuka,[1,2,3] R. Rodríguez-Guzmán,[4] L. M. Robledo,[5] P. Sarriguren,[4] P. H. Regan,[6] P. D. Stevenson,[6] and Zs. Podolyák[6]

Spectroscopy calculations using IBM projections from Gogny D1S EDF

# Tungsten (Z=74) isotopes

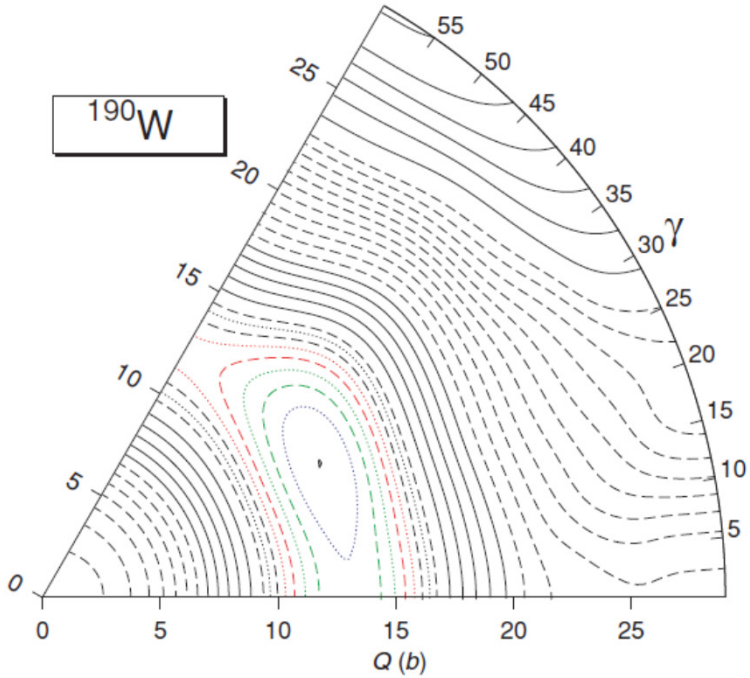



## 190W prolate? (K isomers)

G.J. Lane et al., PRC82, 051304 (2010)

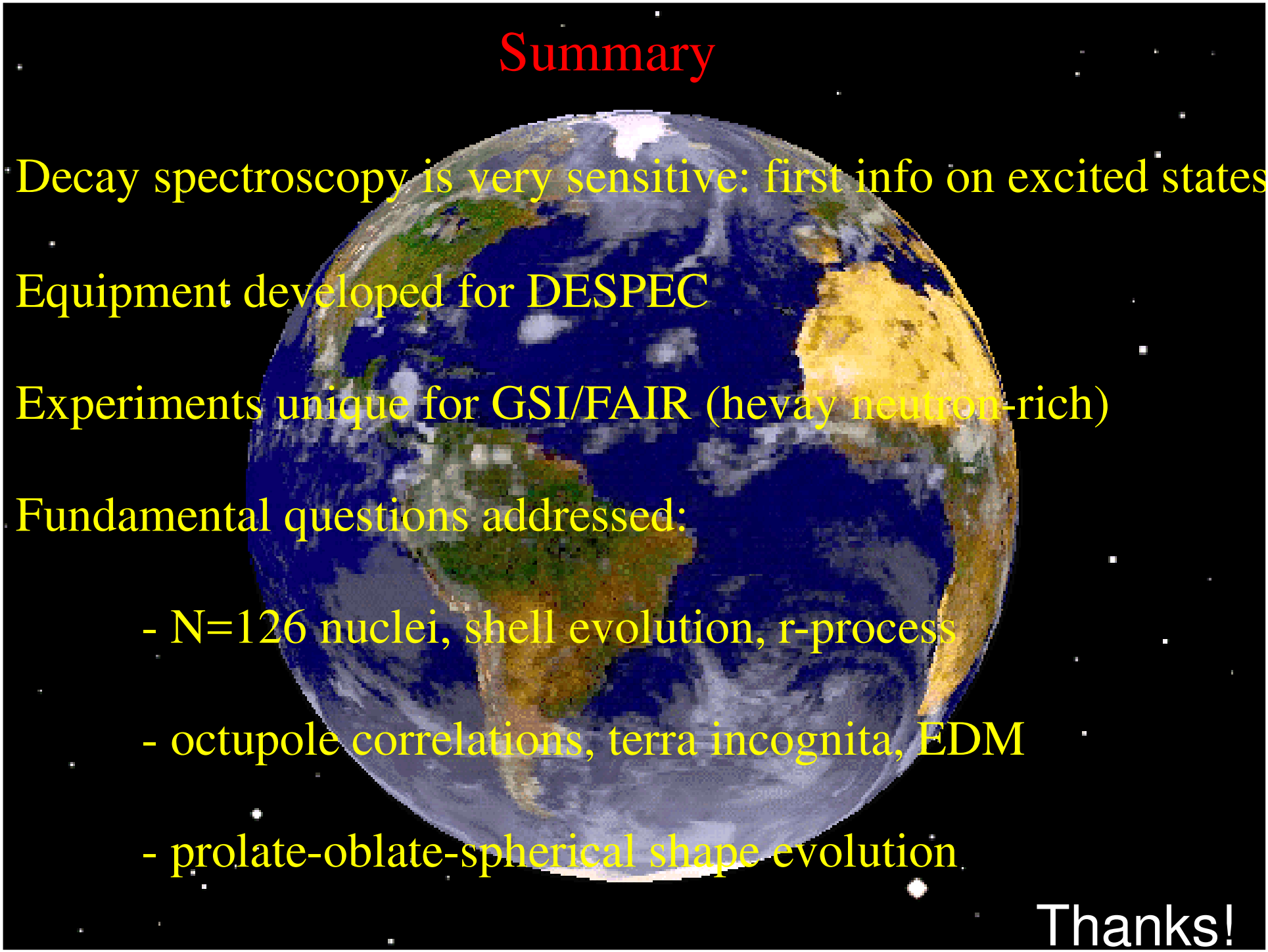



P. Sarriguren, R. Rodriguez-Guzman,
L.M. Robledo,
PRC 77, 064322 (2008)

## 192W shape?

192W: N. Alkhomashi, P.M. Regan et al., PRC80, 064308 (2009)

# Summary



Decay spectroscopy is very sensitive: first info on excited states

Equipment developed for DESPEC

Experiments unique for GSI/FAIR (hevay neutron-rich)

Fundamental questions addressed:

- N=126 nuclei, shell evolution, r-process
- octupole correlations, terra incognita, EDM
- prolate-oblate-spherical shape evolution

Thanks!