Decay experiments at RIKEN: neutron-rich Sm & Gd isotopes

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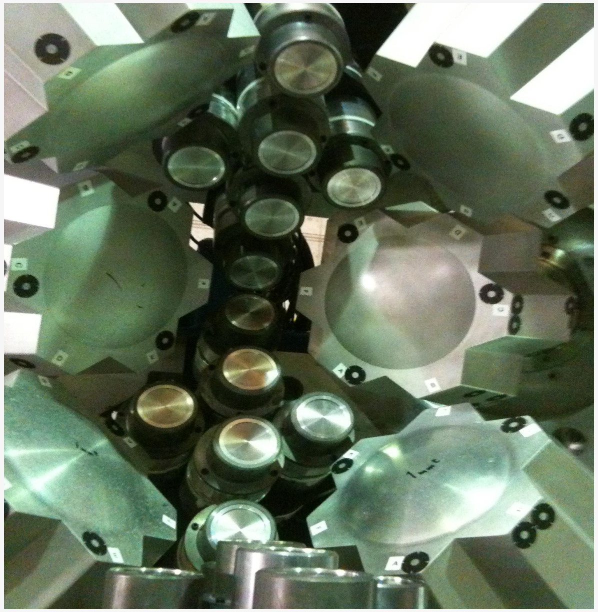
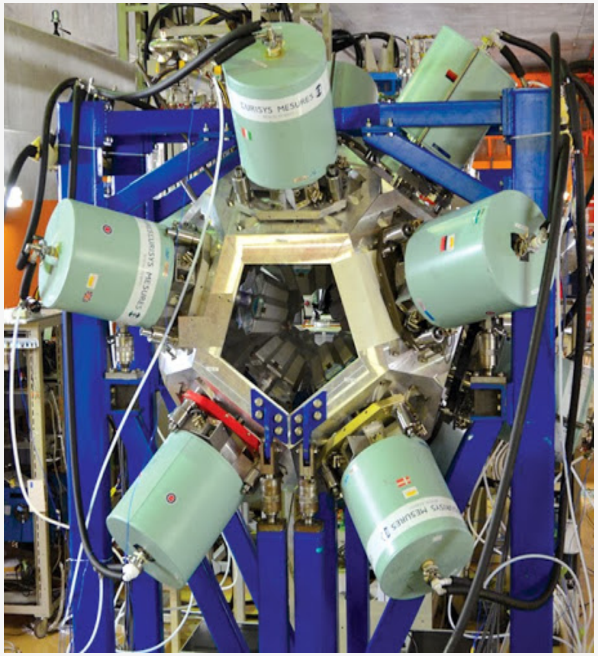
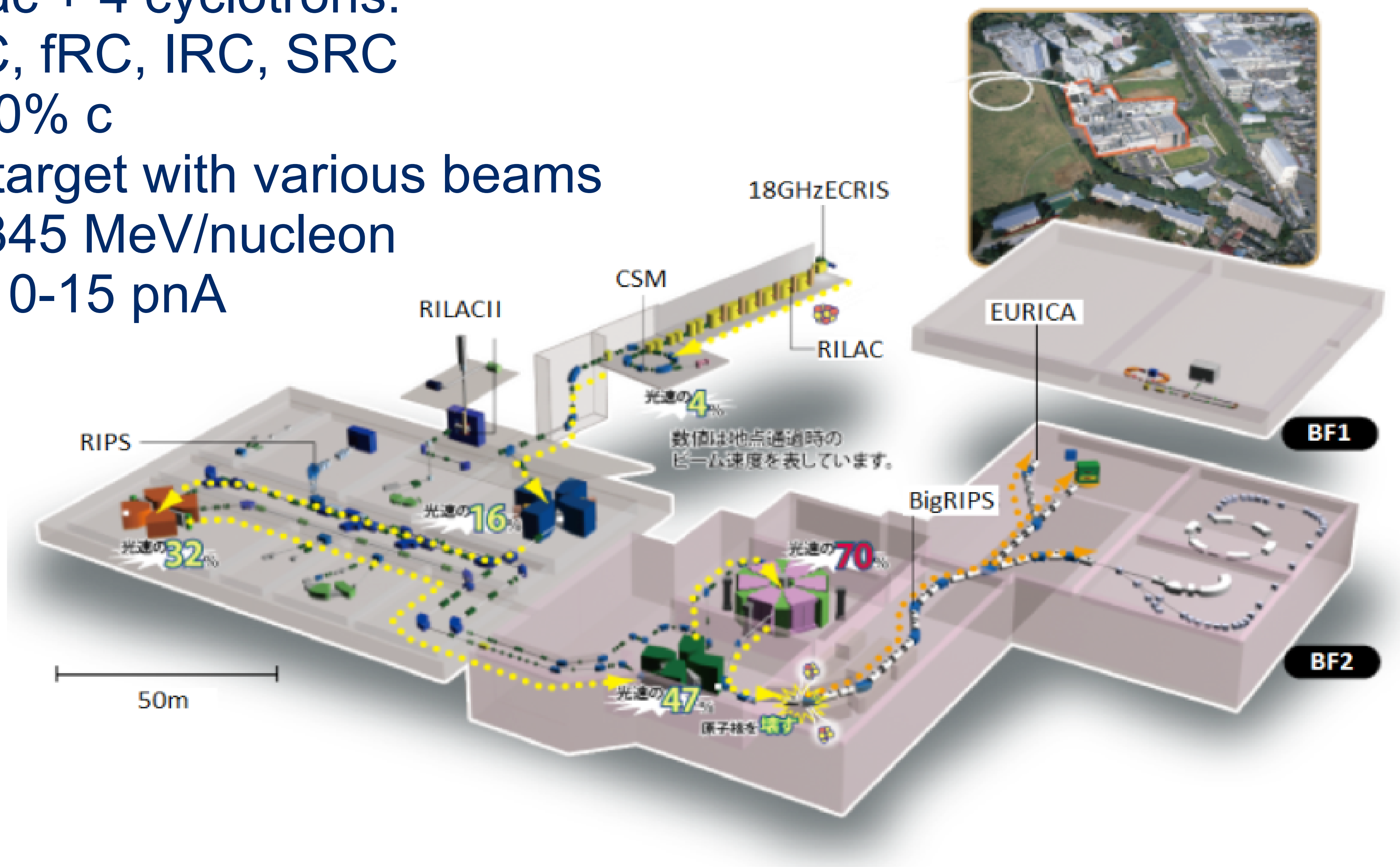




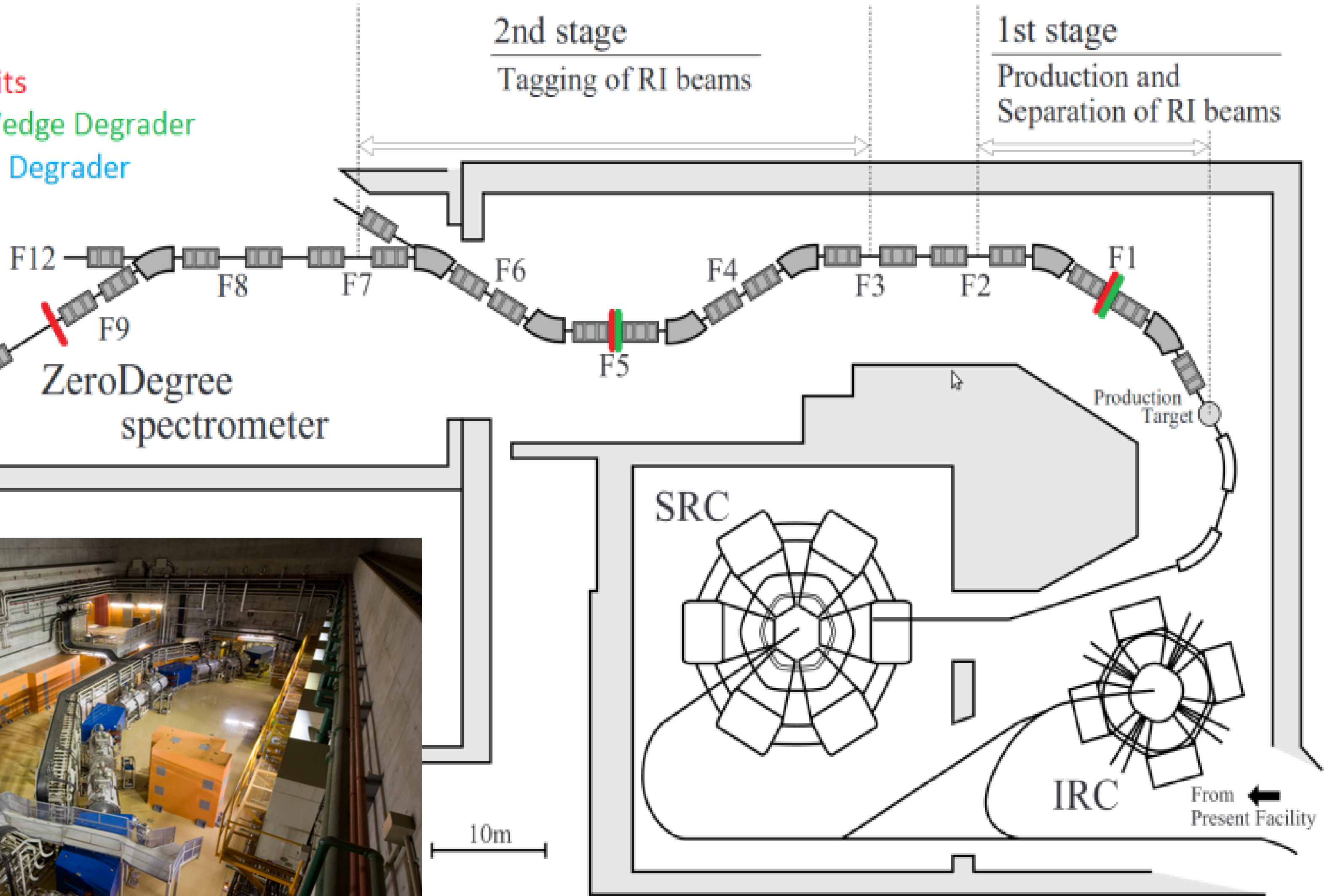
Radioactive Isotope Beam Factory: RIBF

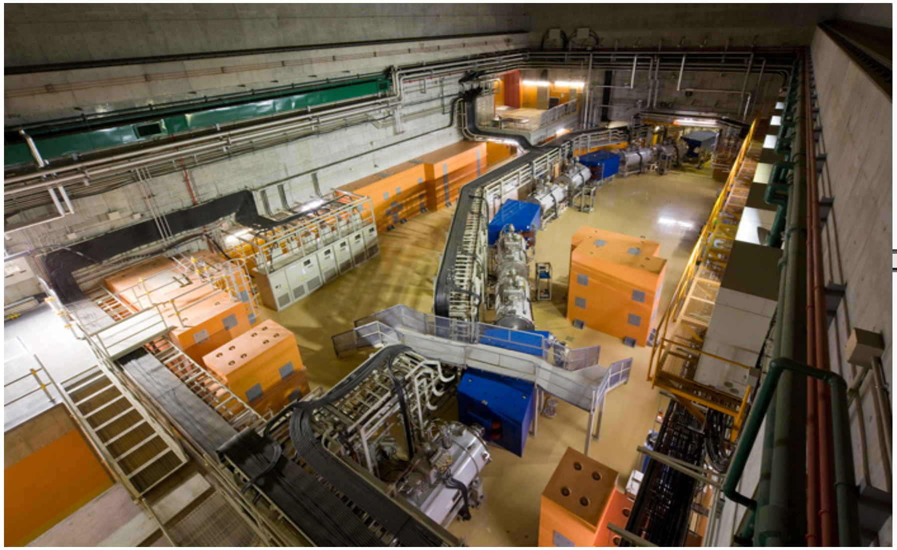
- Linac + 4 cyclotrons: RRC, fRC, IRC, SRC → 70% c
- Be target with various beams
- U: 345 MeV/nucleon
- U: 10-15 pnA



BigRIPS & ZeroDegrees

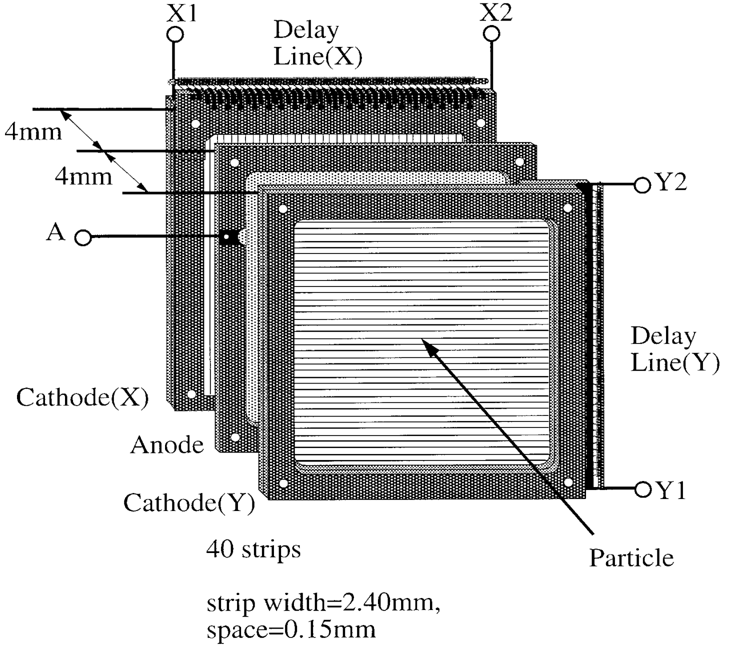
= Slits
= Wedge Degrader
= Al Degrader

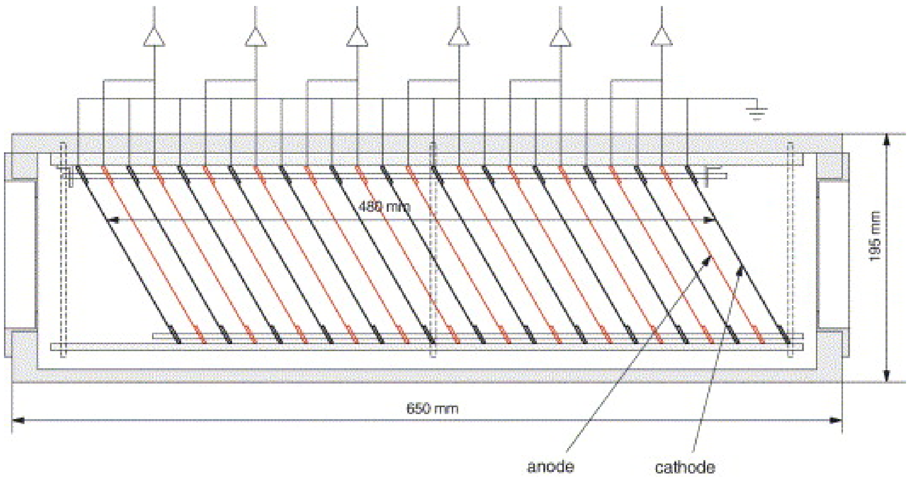




BigRIPS detectors

PPAC: Parallel Plate Avalanche Counter
→ trajectory of particle





TEGIC: Tilted Electrode Gas Ionisation Chamber
→ energy loss of particle

$$\frac{A}{q} = \frac{B\rho}{\beta\gamma uc}$$

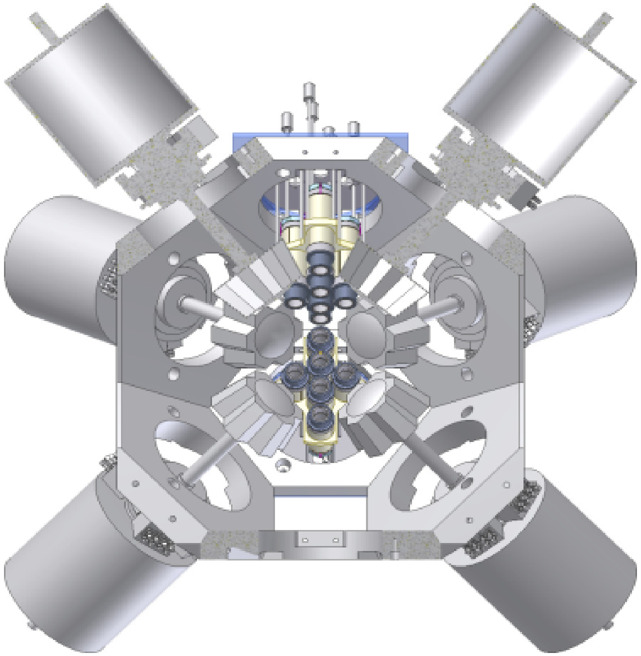
Plastic detectors
→ TOF of particle

$$\Delta E = \frac{4\pi e^4 Z^2}{m_0 v^2} N z \left[ln\frac{2m_0v^2}{I} - ln(1-\beta^2) - \beta^2 \right]$$

WAS3ABI & EURICA

WAS3ABI: Wide-range Active Silicon-Strip Stopper Array for Beta and Ion detection

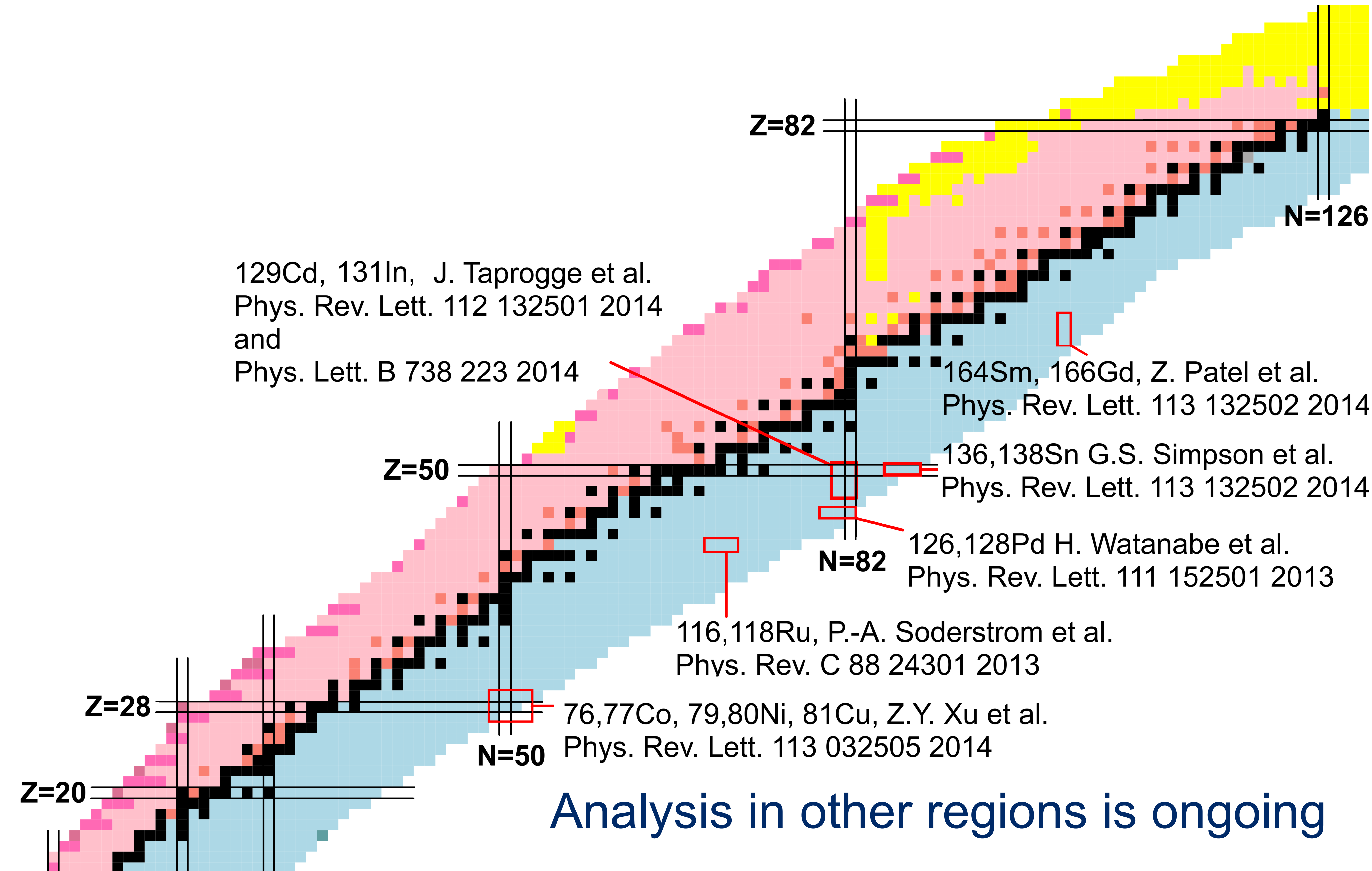
- Upto 5 DSSDs
- 60x40 1mm strips



EURICA: Euroball RIKEN Cluster Array

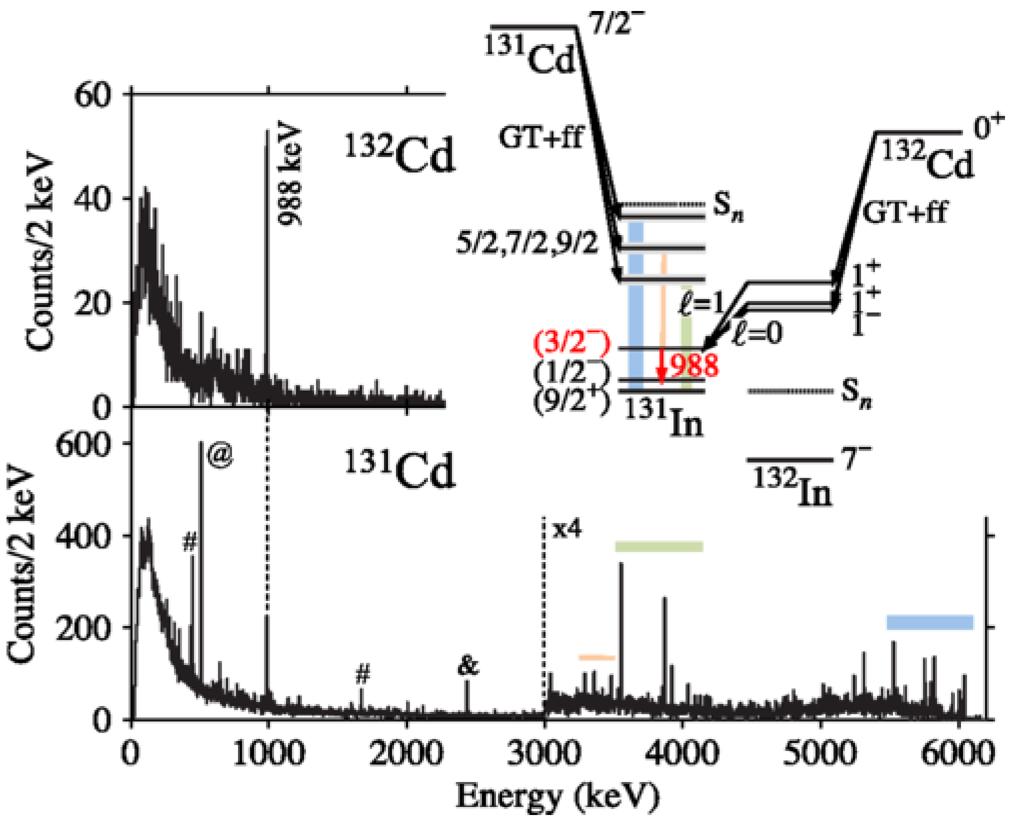
- 84 HPGe crystals in 12x7 clusters from the RISING array
- Analogue & digital branches for energy & timing
- $LaBr_3(Ce)$ (Surrey & Brighton) and plastics

The nuclear landscape



Analysis in other regions is ongoing

Published results: 131In



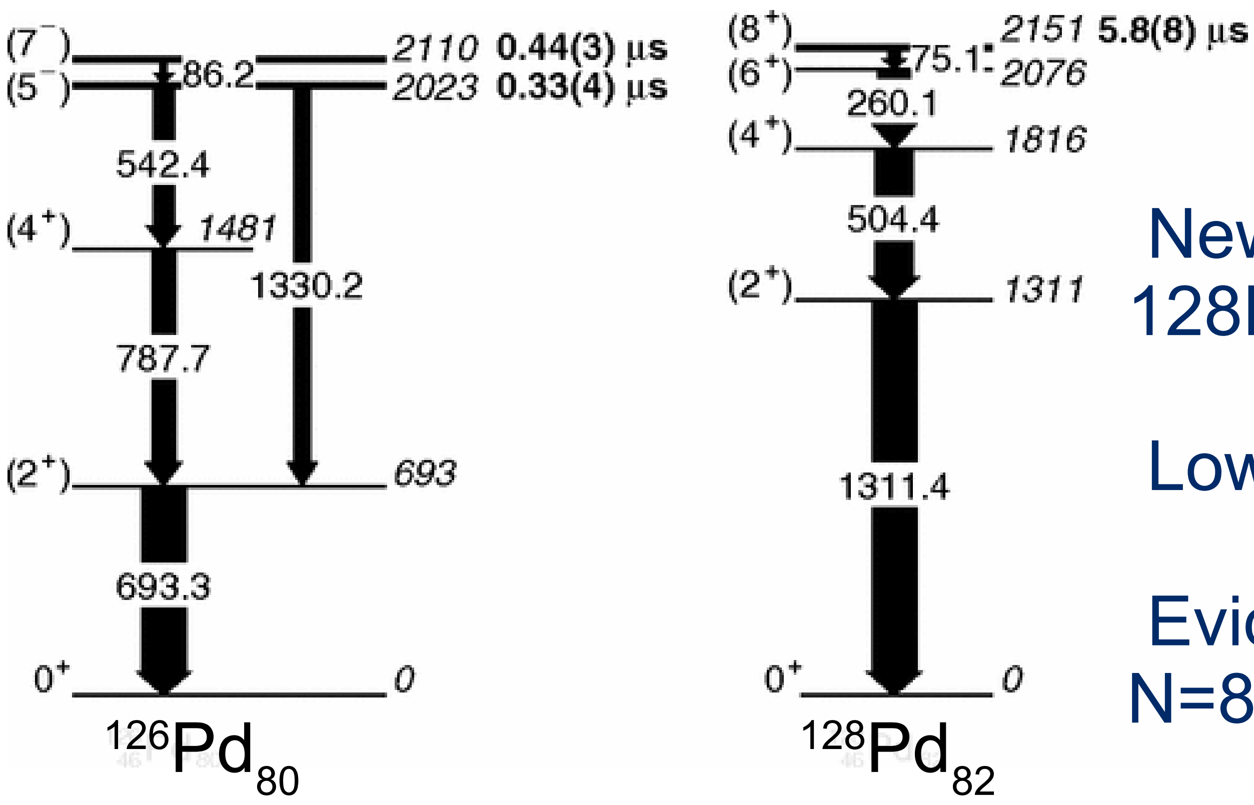
131In = 1 proton hole nucleus w.r.t. 132Sn

New single-particle state (red) in 131In used for shell model calculations below N=82

No evidence for a Z=40 subshell closure at N=82

J. Taprogge et. al. Phys. Rev. Lett. **112,** 132501 (2014)

Published results: 126,128Pd



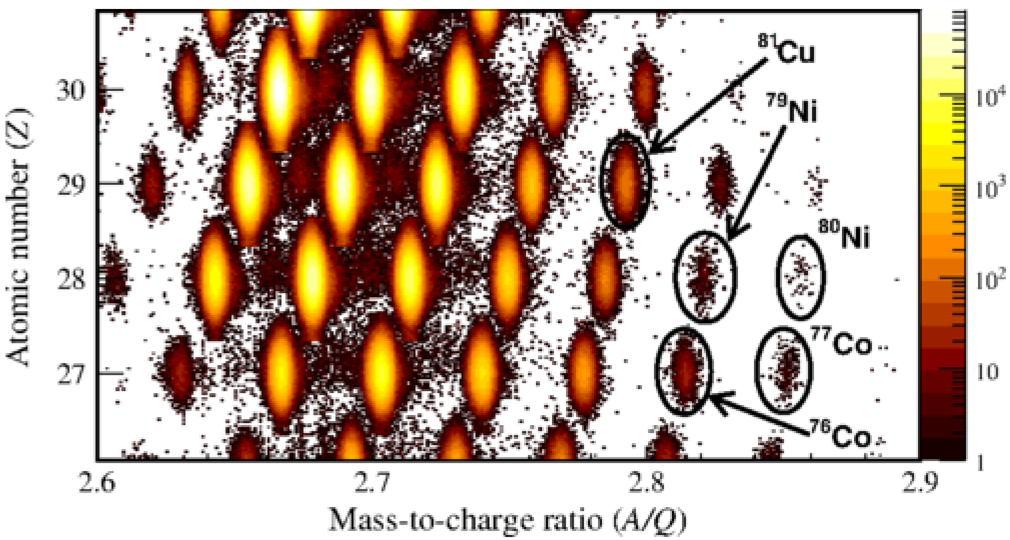
New isomers in 126Pd & 128Pd

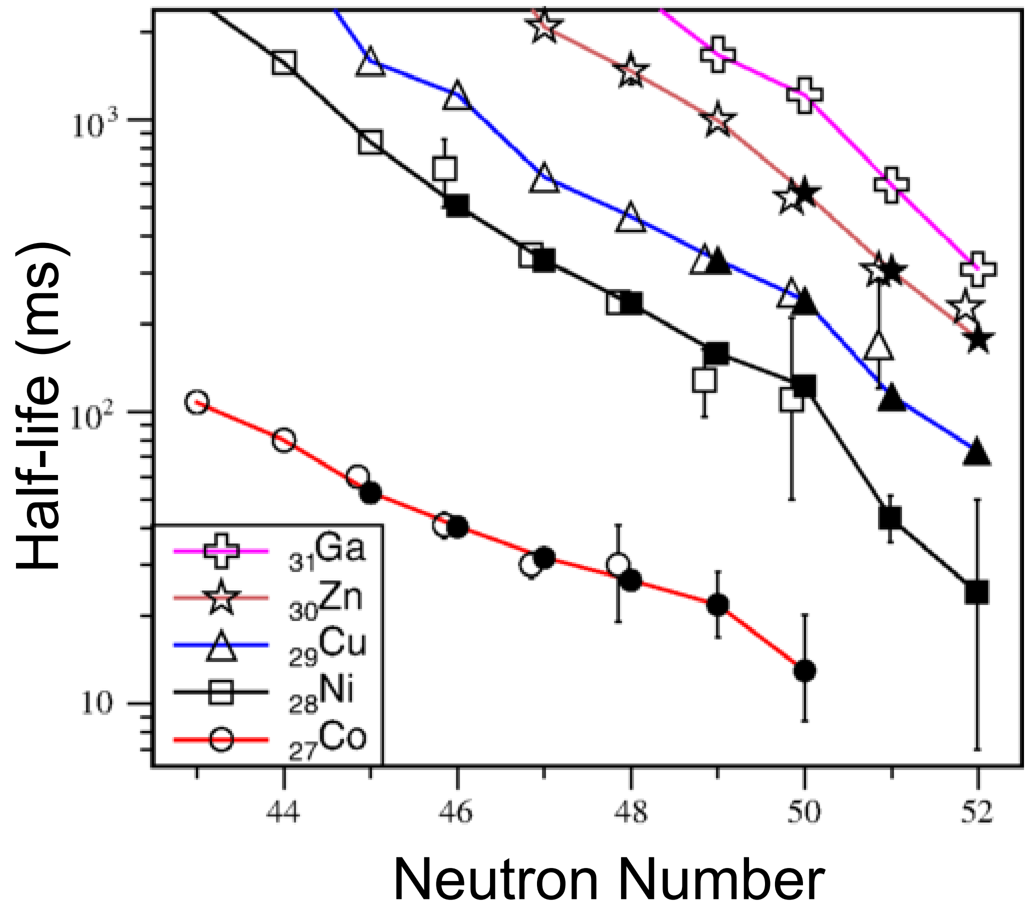
Lowest Z for N=82

Evidence for a robust N=82 shell closure

H. Watanabe et. al. Phys. Rev. Lett. **111,** 152501 (2013)

Published results: β decay around 78Ni

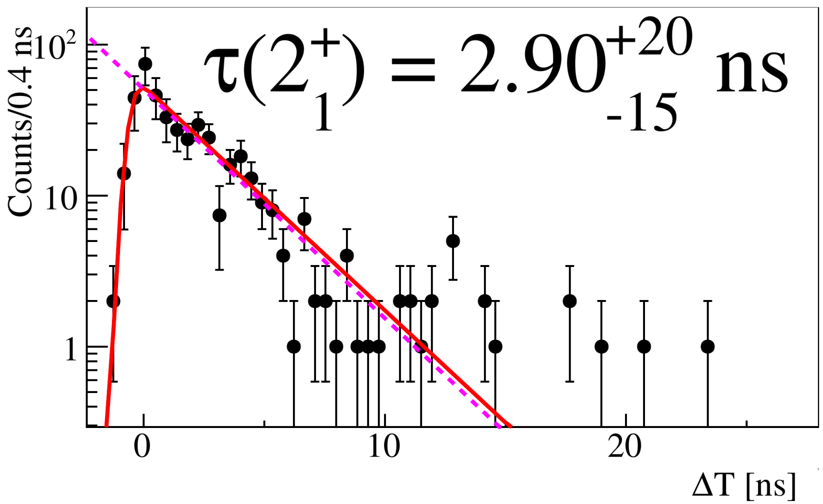


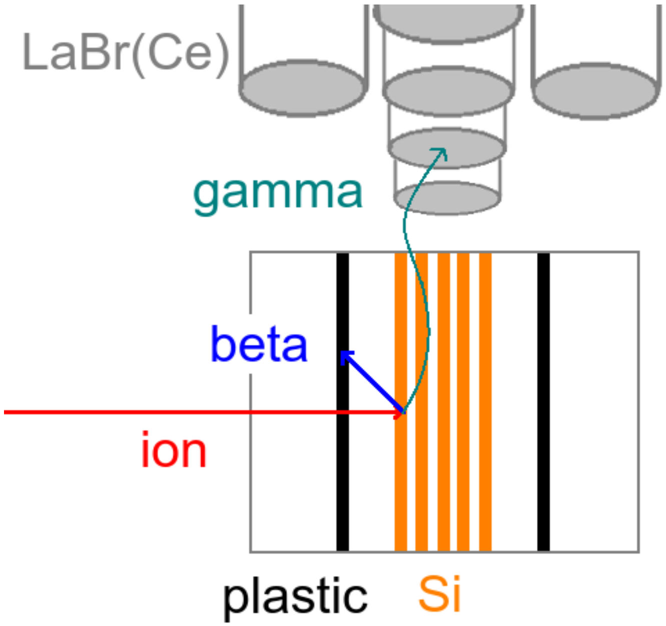


- 5 new β $t_{1/2}$s measured
- Half-lives show magicity of Z=28 & N=50

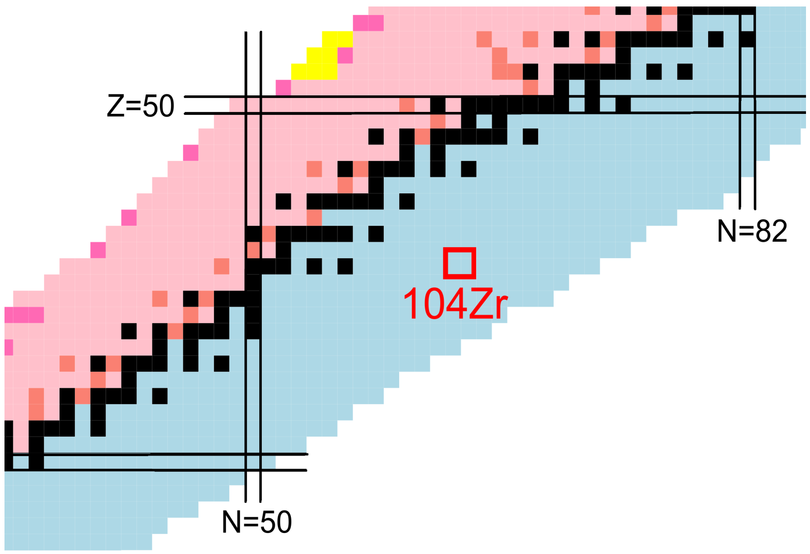
Z. Y. Xu et. al. Phys. Rev. Lett. **113,** 032505 (2014)

Fast timing data: 104Zr





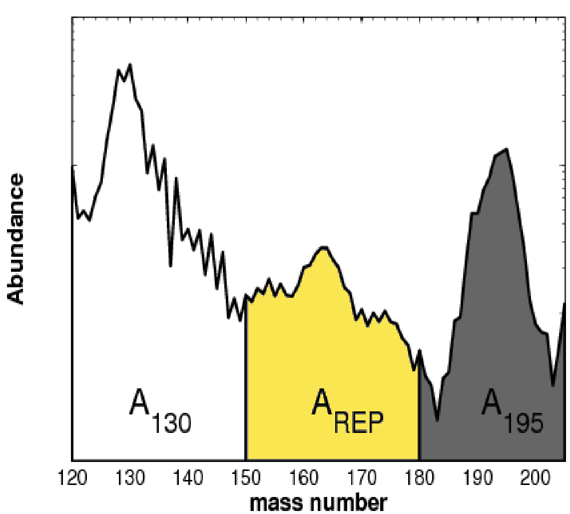
Previously measured as:
τ(2+) = 2.9(4) ns

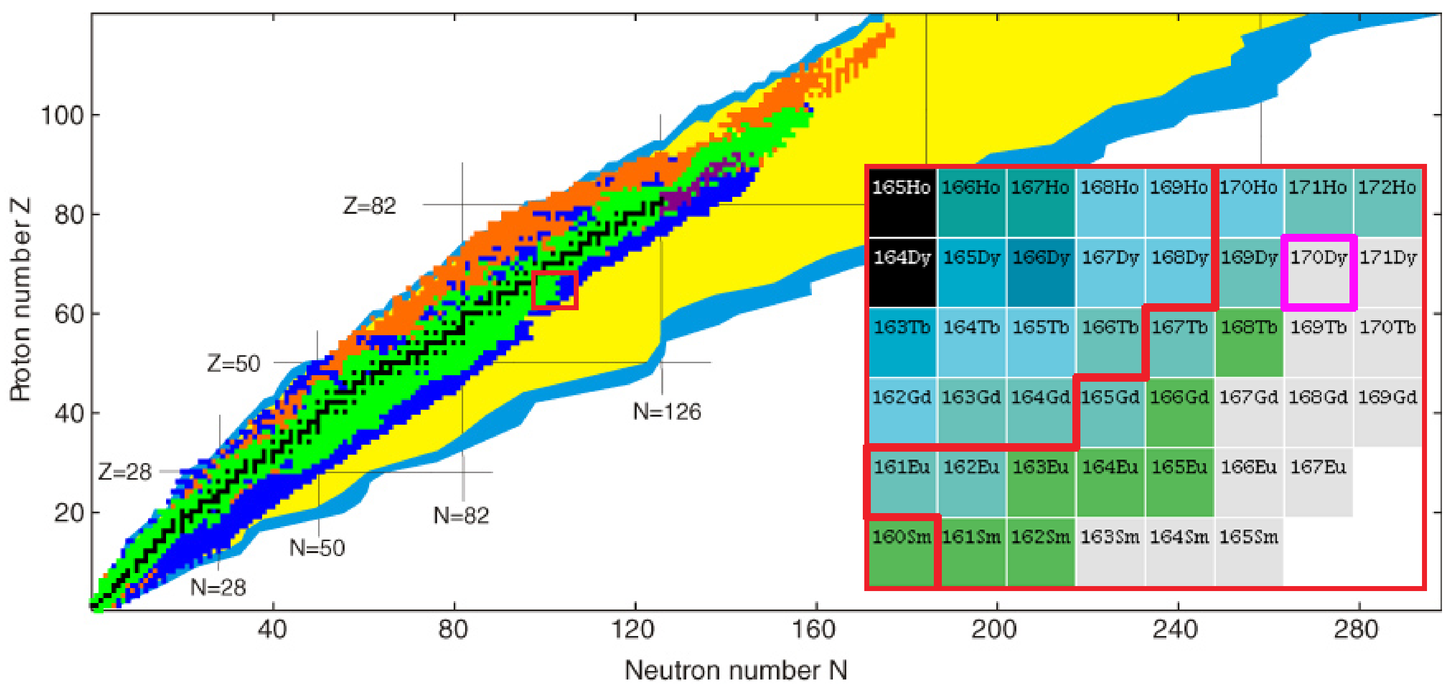


F. Browne,
University of Brighton

Mid-shell region

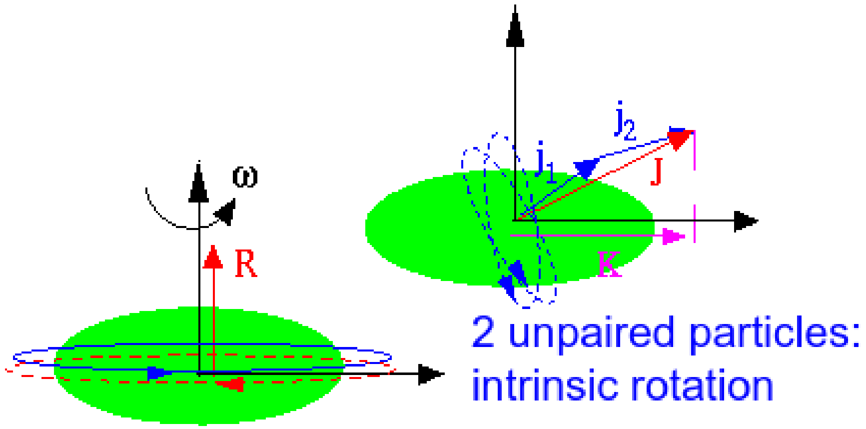
- Maximum deformation expected at doubly mid-shell region
- Closed-shell nuclei → "waiting points" of the r process
- REP → mid-shell nuclear deformation



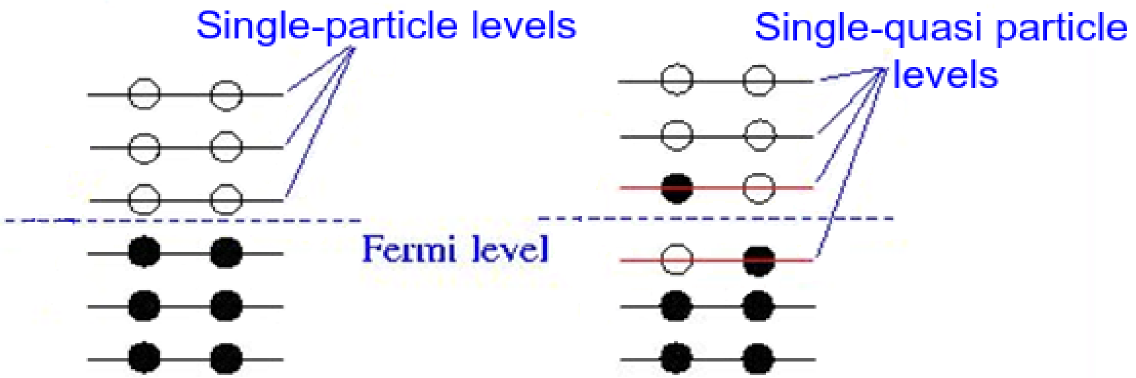


K isomers

- Nuclear deformation → K isomers
- Quasiparticle configuration → spin projections, K, on symmetry axis
- Transitions can be forbidden by ΔK≤λ
- K-forbiddenness → long-lived states: K isomers
- Use to probe low-lying excited states



Fully paired: collective rotation



Ground state configuration 2-quasiparticle configuration

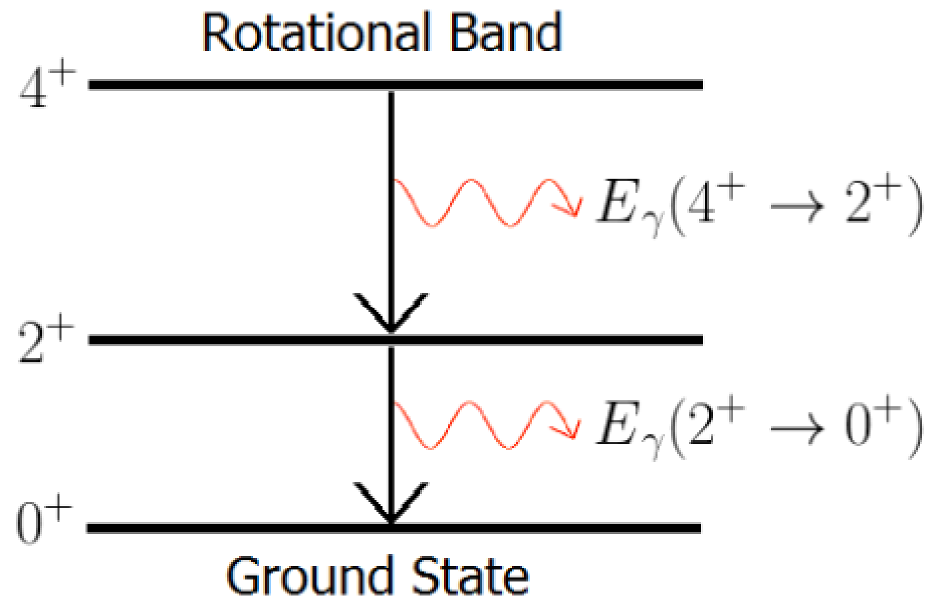
Collectivity

Measures of collectivity:

$$E_{rot}(J) = \frac{\hbar^2}{2I} J(J+1)$$

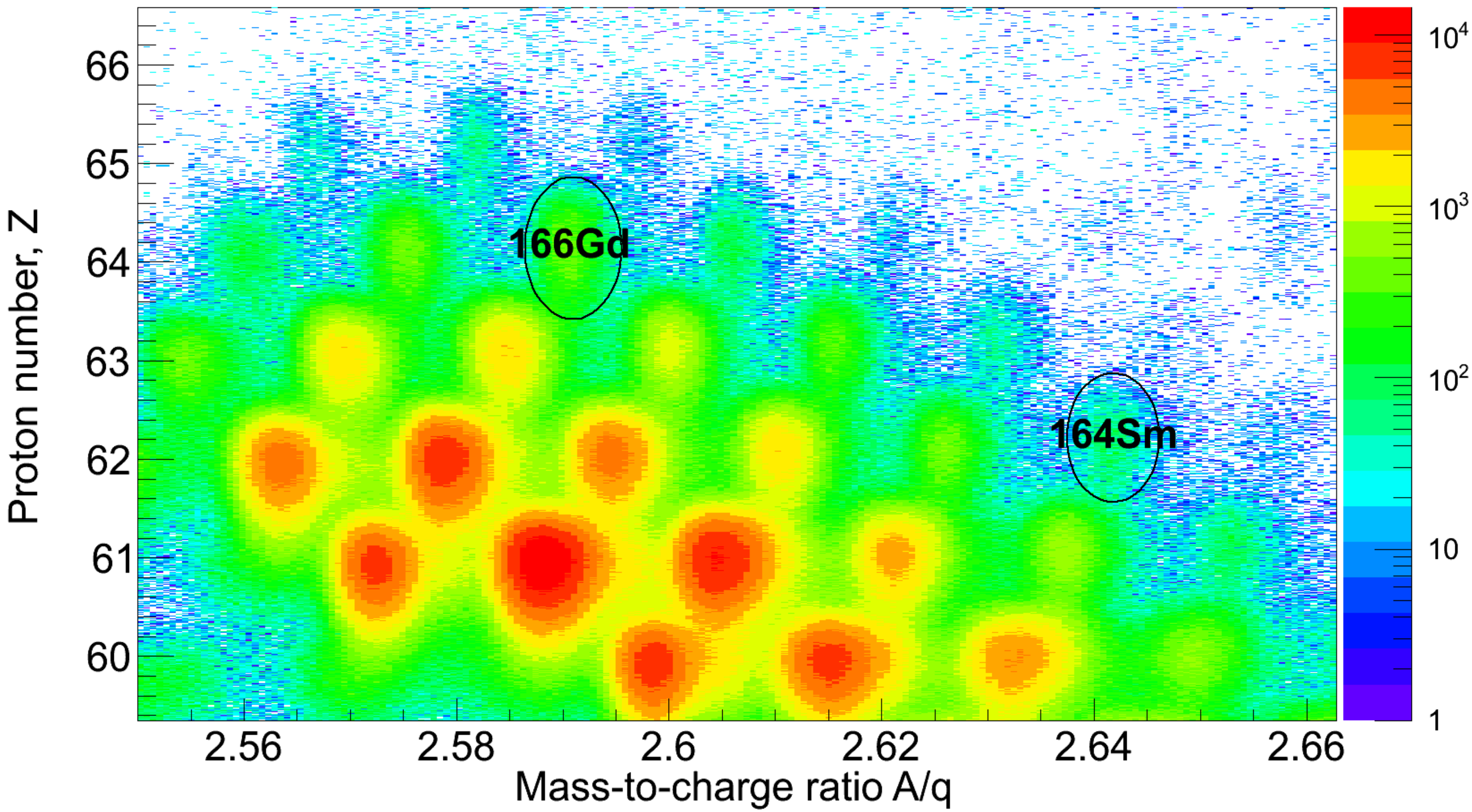
$$R(4^+/2^+) = \frac{E_{rot}(4^+)}{E_{rot}(2^+)}$$

$$B(E2) \propto \frac{1}{\tau}$$



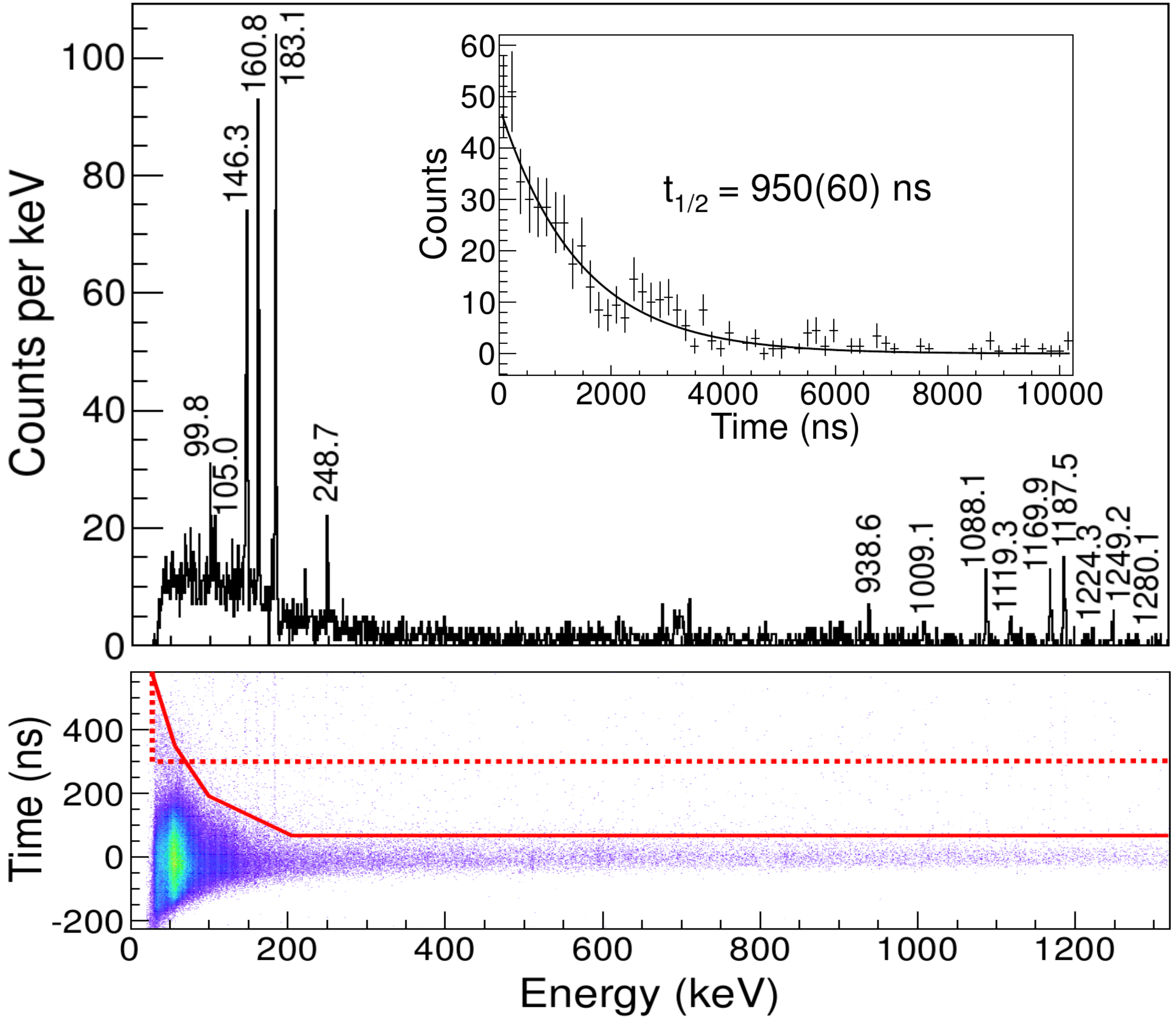
B(E2) = transition strength
I = moment of inertia, proportional to deformation
J= spin of state

In-beam PID



≈ 40,000 implanted 166Gd nuclei
≈ 8,000 implanted 164Sm nuclei

166Gd: γ spectroscopy



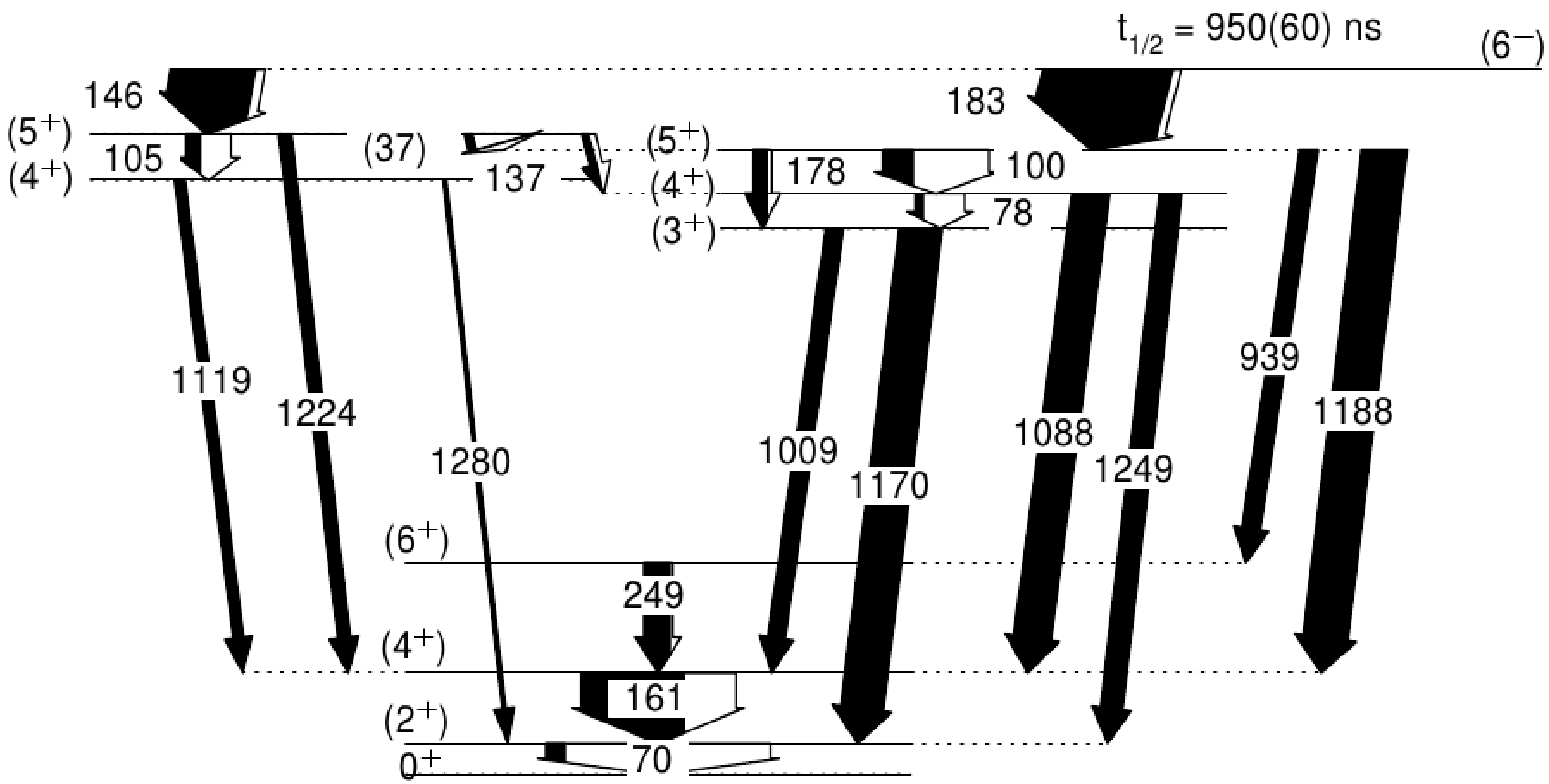
Prompt flash removed to reduce background in spectrum

Fixed time cut for γ intensities

Half-life found from strong γs

Z. Patel et. al. Phys. Rev. Lett. **113,** 262502 (2014)

166Gd level scheme



- Level scheme based on γ-γ coincidences
- Transition multipolarities from intensity balance
- Fragment of 2-qp band → 4+ bandhead

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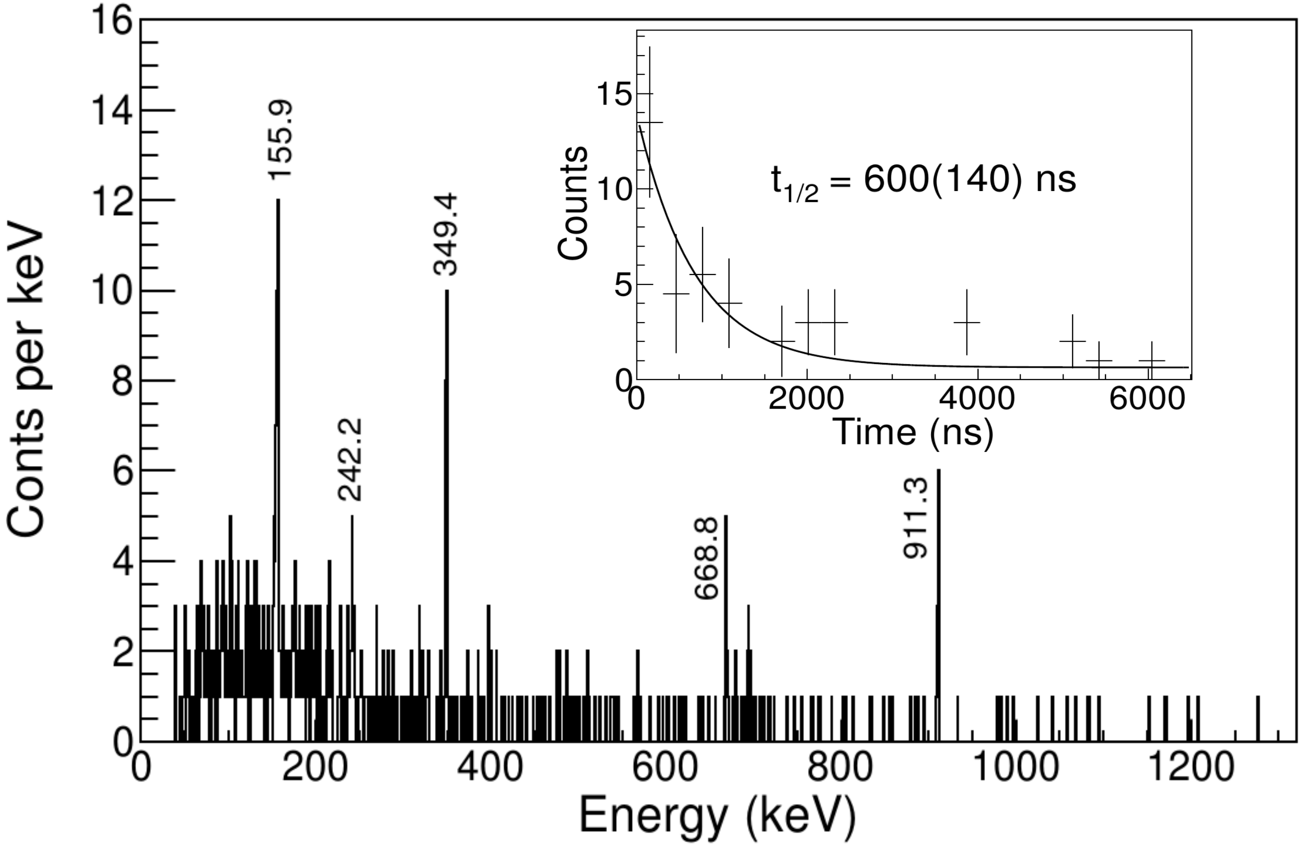
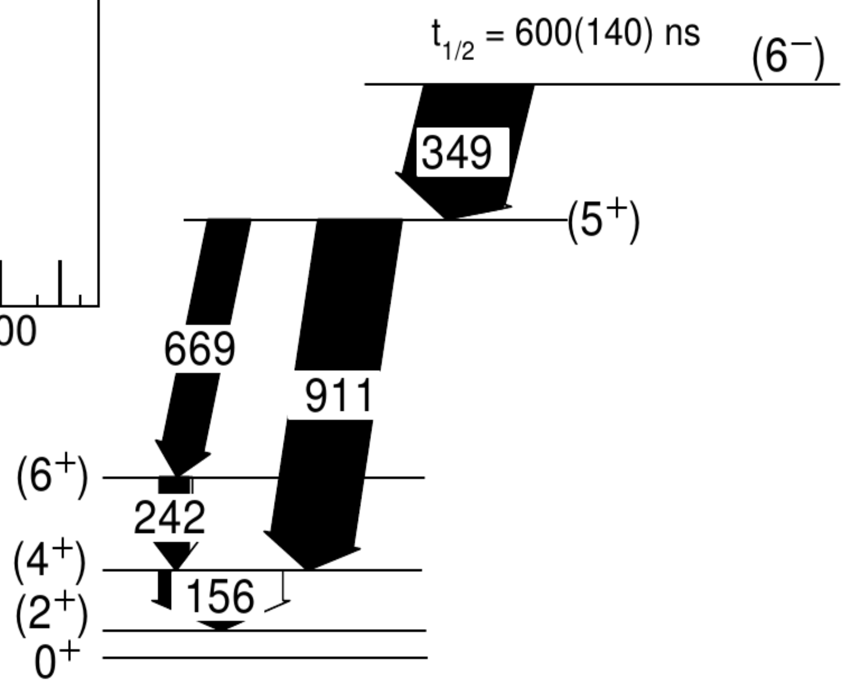
164Sm: γ spectroscopy



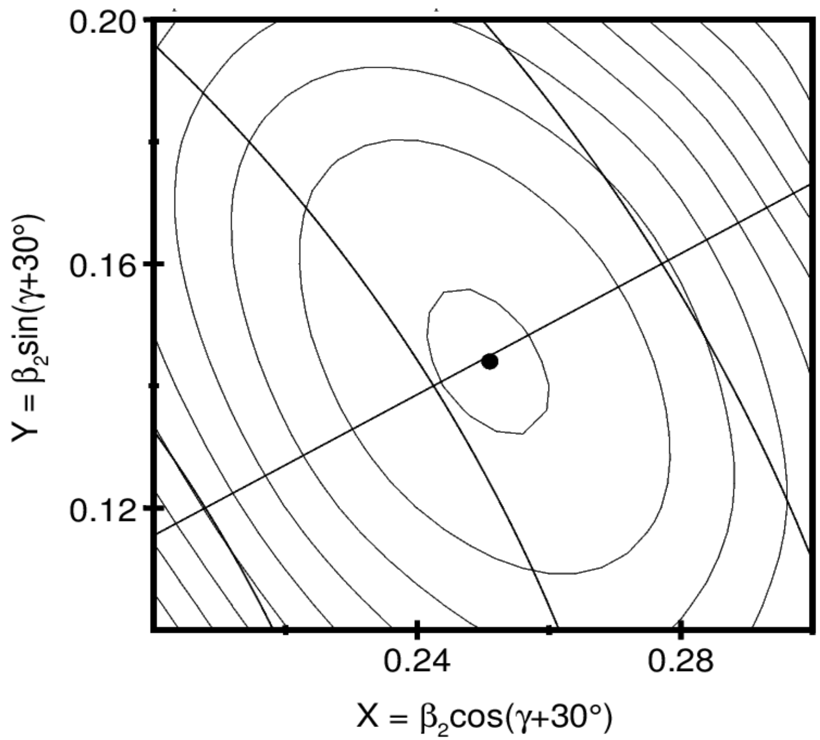


Statistics too low to see the $2^+ \rightarrow 0^+$

Z. Patel et. al. Phys. Rev. Lett. **113,** 262502 (2014)

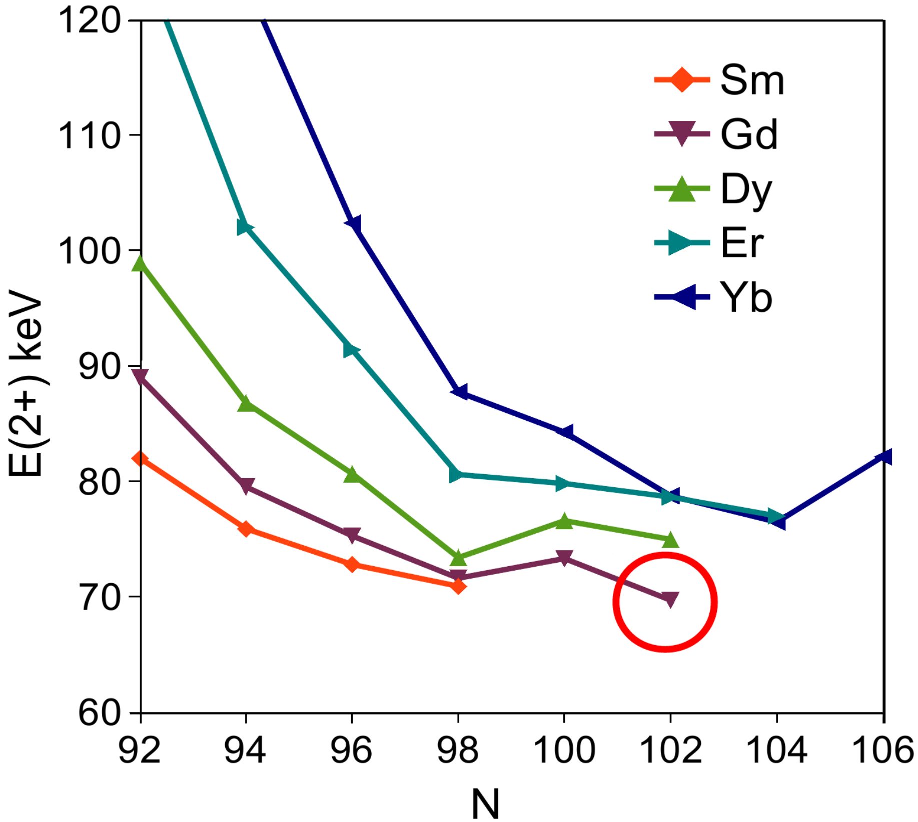
PES calculations

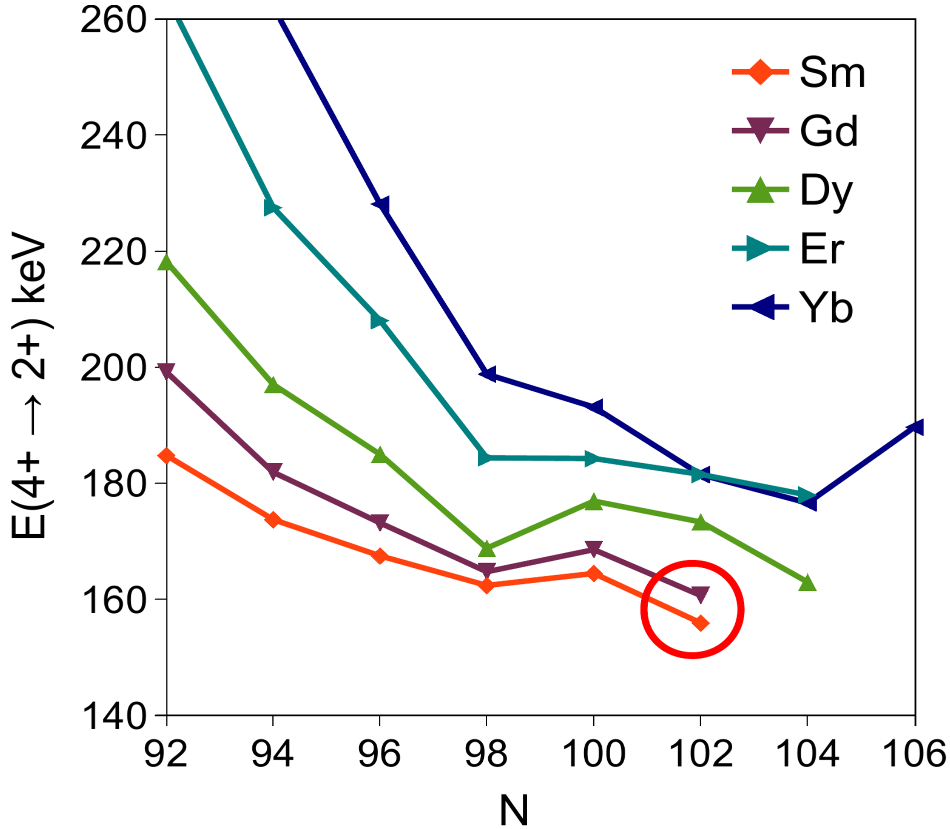
Potential energy surface calculations minimised in β_2, β_4, β_6 deformation space with γ=0



Nucleus	K	config.	E_x (MeV)	E_x (MeV) exp.
166Gd	6-	$\nu5/2^-[512] \times \nu7/2^+[633]$	1.288	1.601
166Gd	4+	$\pi3/2+[411] \times \pi5/2+[413]$	1.300	1.350
164Sm	6-	$\nu5/2^-[512] \times \nu7/2^+[633]$	1.301	1.416+E(2^+)

Energy systematics

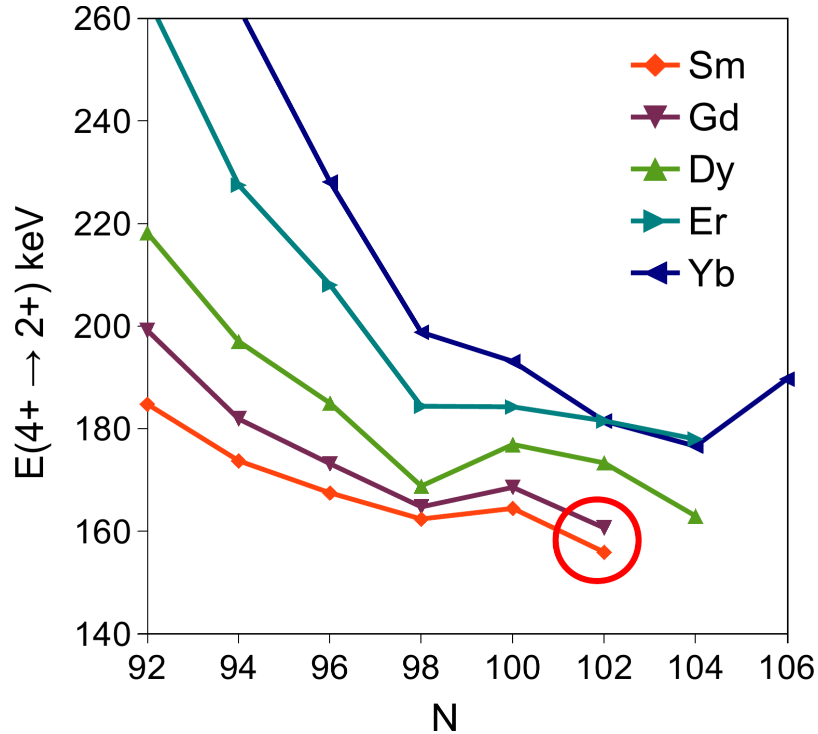


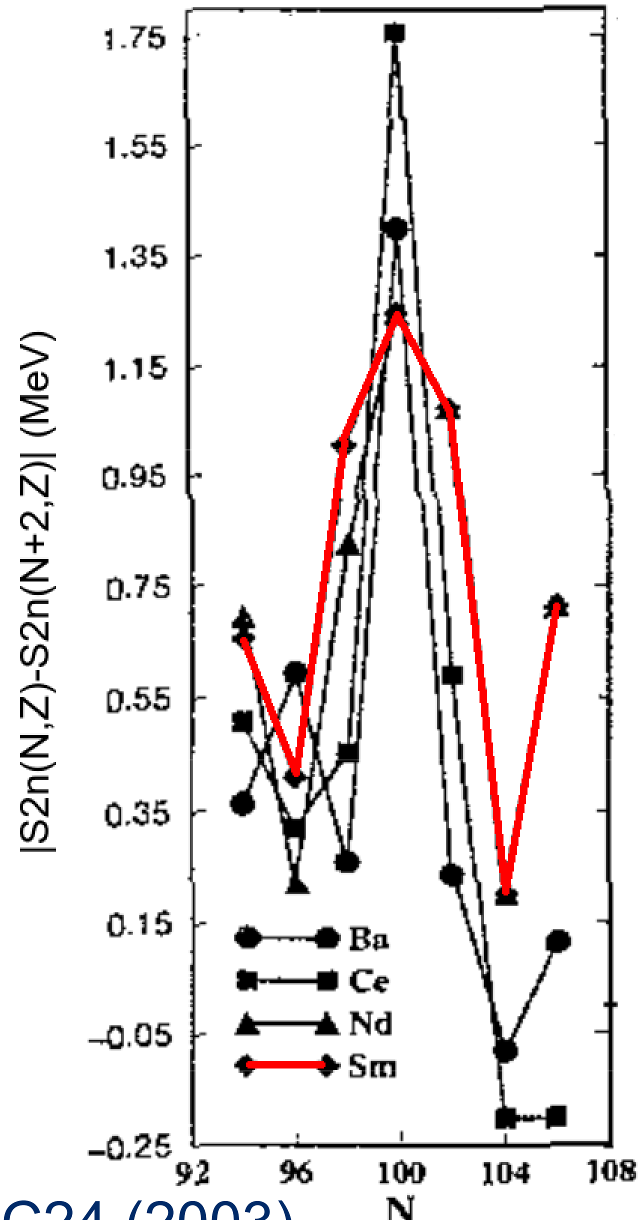


- Most deformed N=102 nuclei to date
- Highlights an increase at N=100: deformation minimum or shell gap
- Most calculations → maximum deformation at N=104
- PES calculations → maximum deformation at N=100, 102

Deformed shell gap

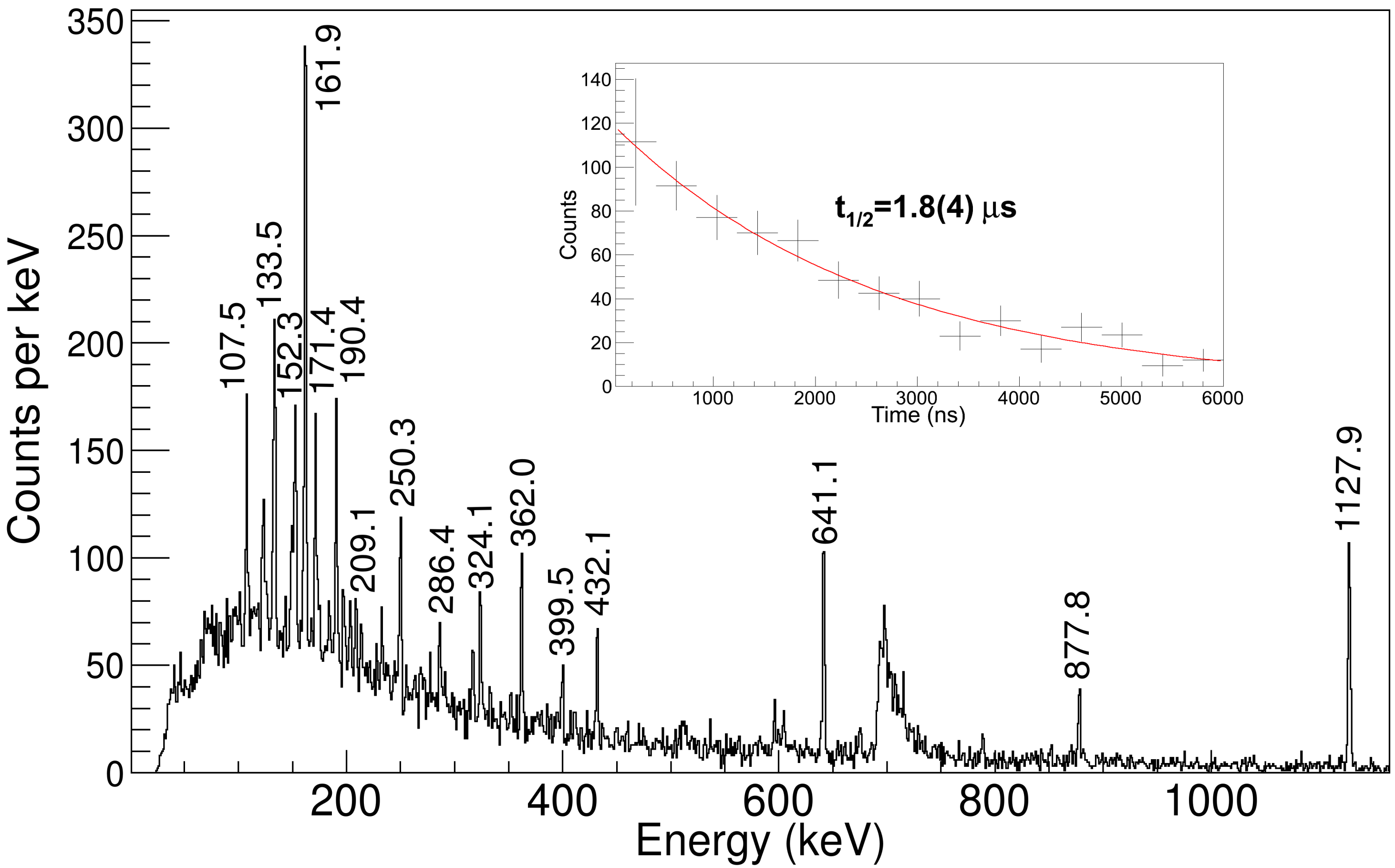
- L. Satpathy & S. K. Patra predict a deformed shell gap at N=100 from S_{2n}
- Our systematics support a deformed shell gap
- This will influence r-process calculations

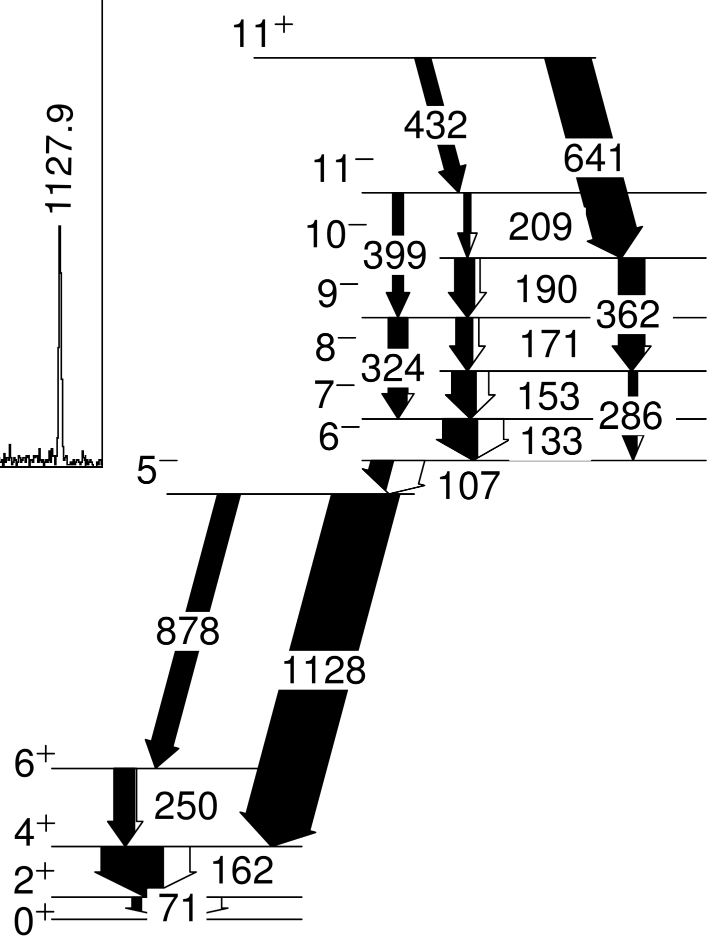




L. Satpathy and S.K. Patra Nucl. Phys. **A722,** C24 (2003)

160Sm





- New 4qp state in 160Sm
- Lightest nucleus with a 4qp state to date

Summary

Data from 164Sm & 166Gd → first evidence of a deformed shell gap at N=100

Using the RIBF we can probe further away from stability into neutron-rich regions

We can get information on excited states for nuclei with a very small yield

Questions?

Thank you for your attention.

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