Nuclear structure study for the neutron-rich nuclei beyond ^{132}Sn

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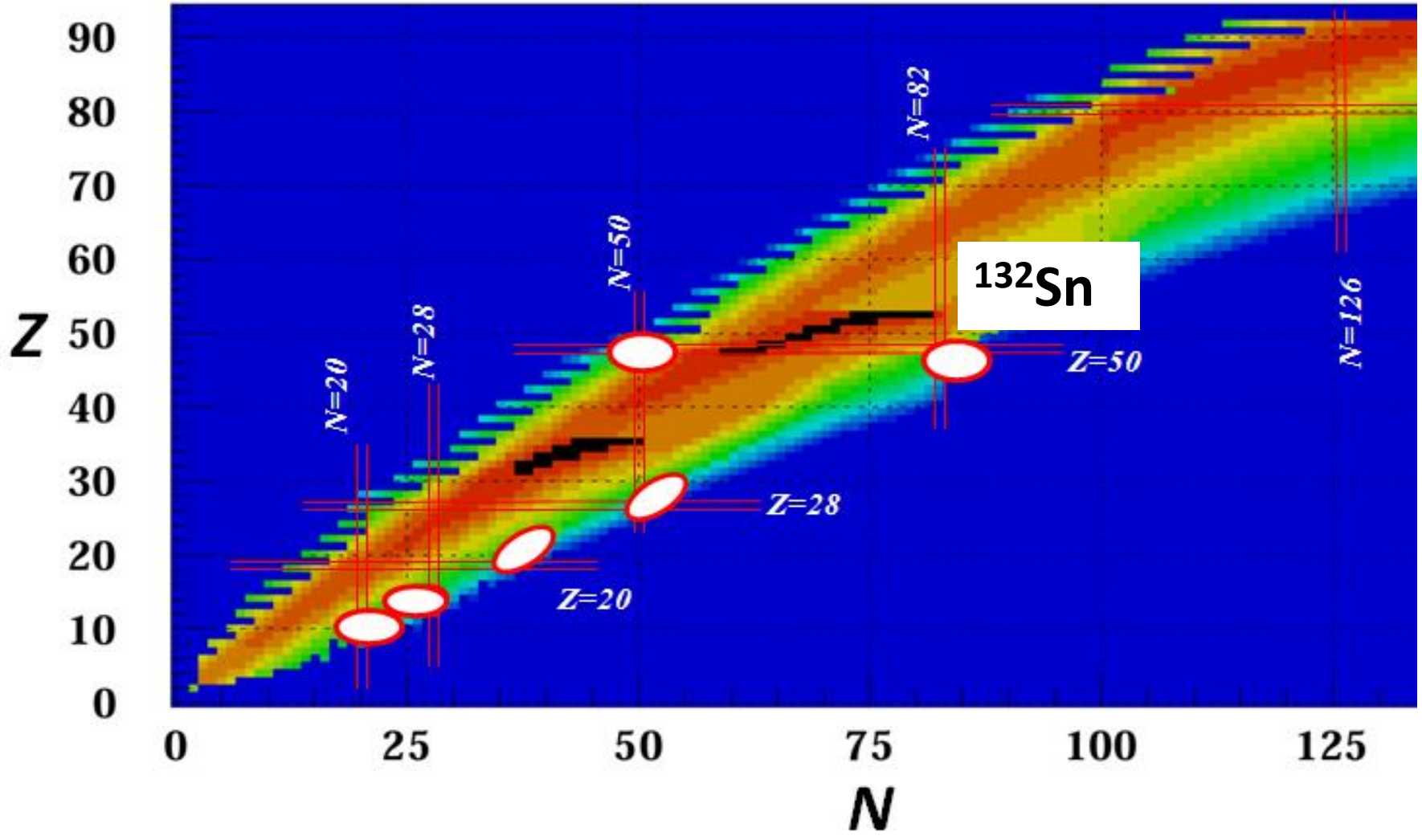
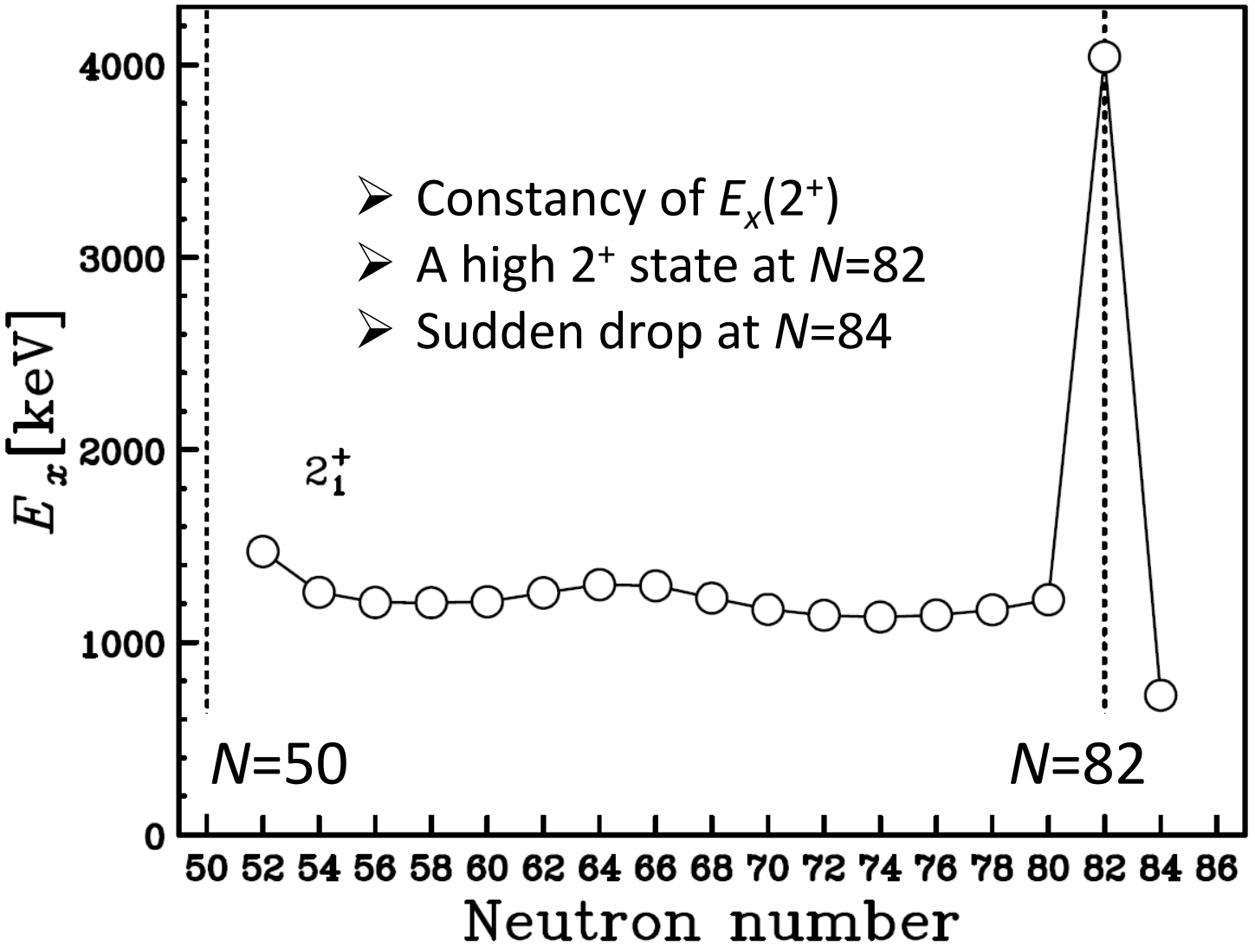
- Experiment
- Results on the first 2^+ states in ^{136}Sn and ^{132}Cd
- Summary

Motivation I

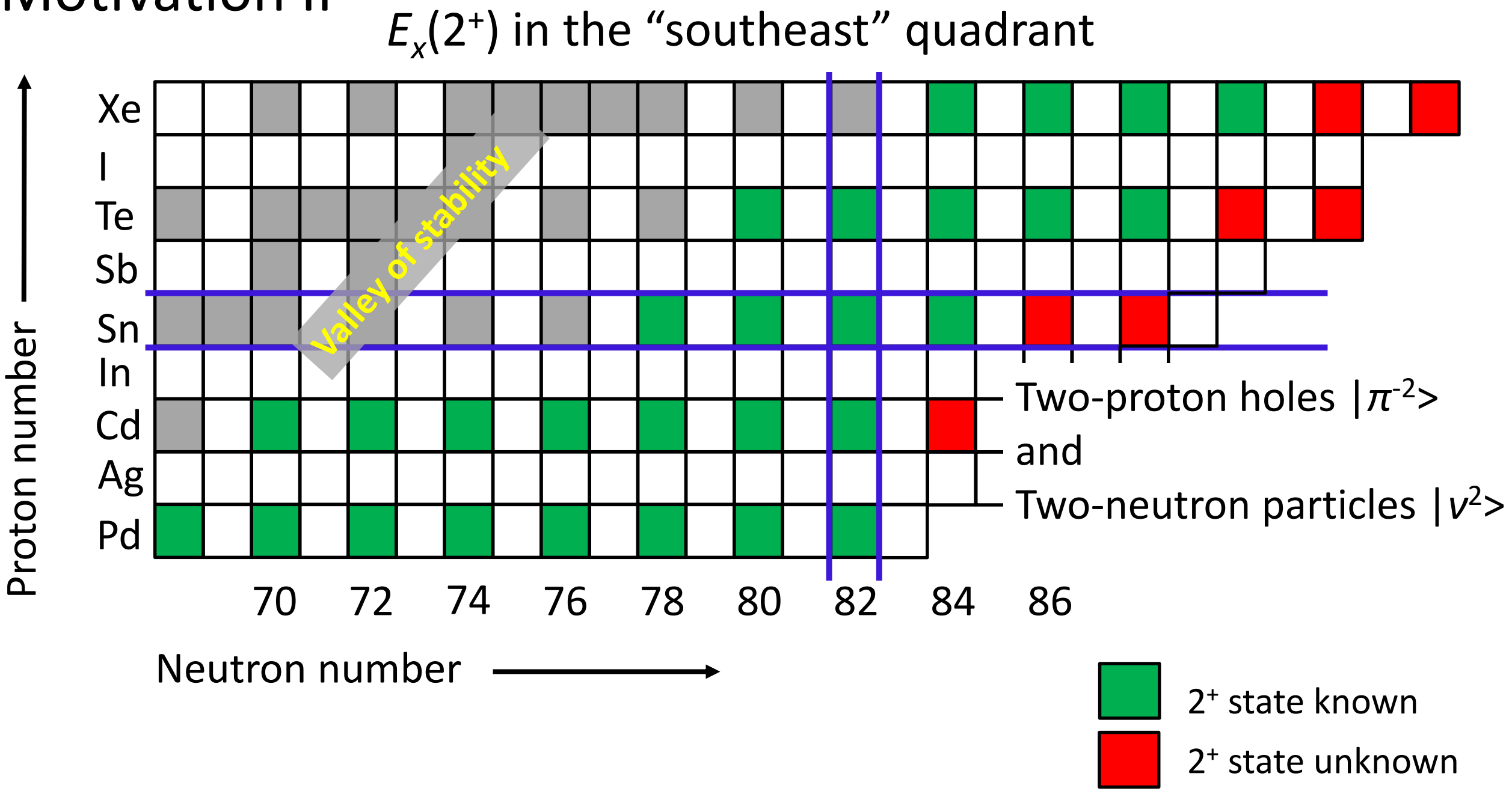


Motivation I

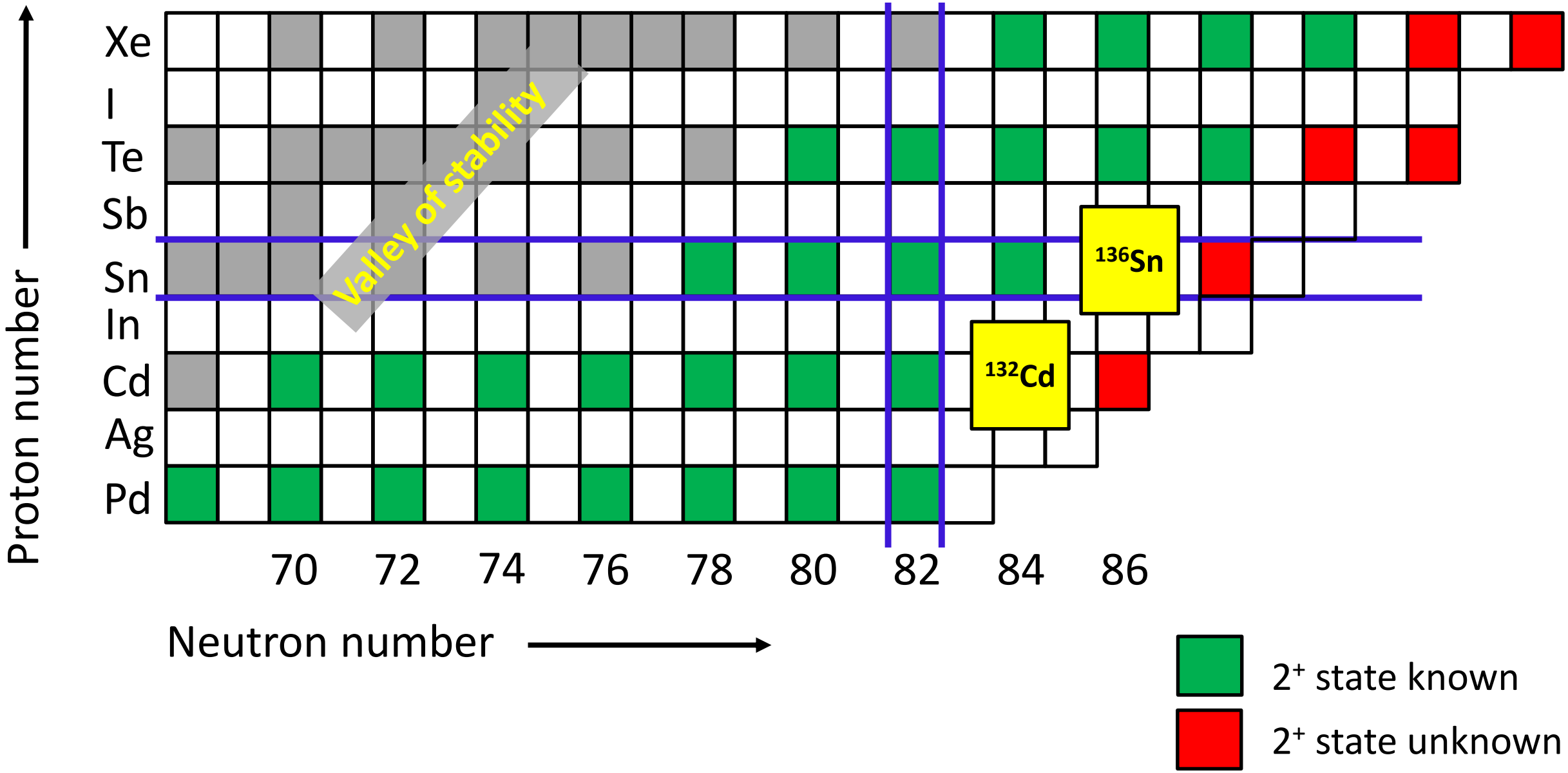
Interesting phenomena in $E_x(2^+)$



Motivation II



Studying region



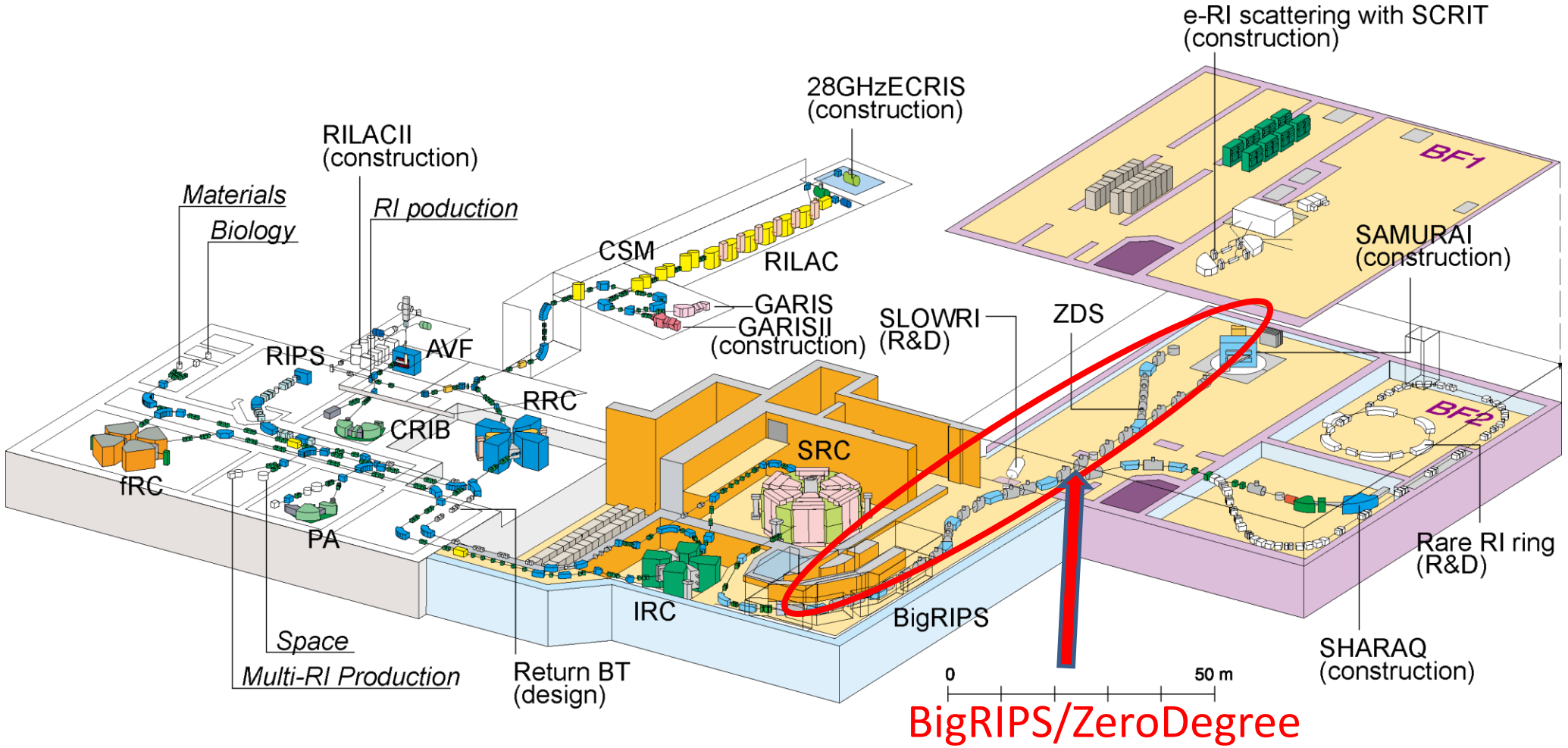
Experimental method

- One- and two-proton removal reactions following fission of U
  -- to access the exotic neutron-rich nuclei

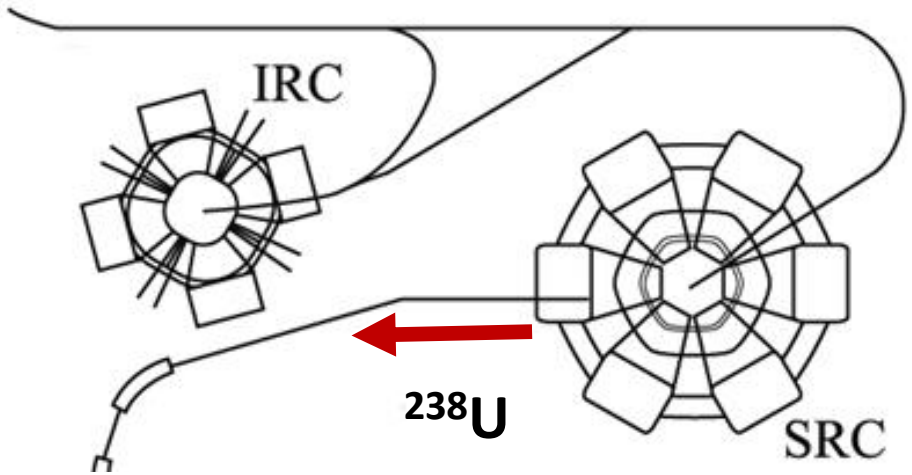
- In-beam gamma-ray spectroscopy
  -- to identify the low-lying excited states

Experiment

Radioactive Isotope Beam Factory : BigRIPS and ZeroDegree

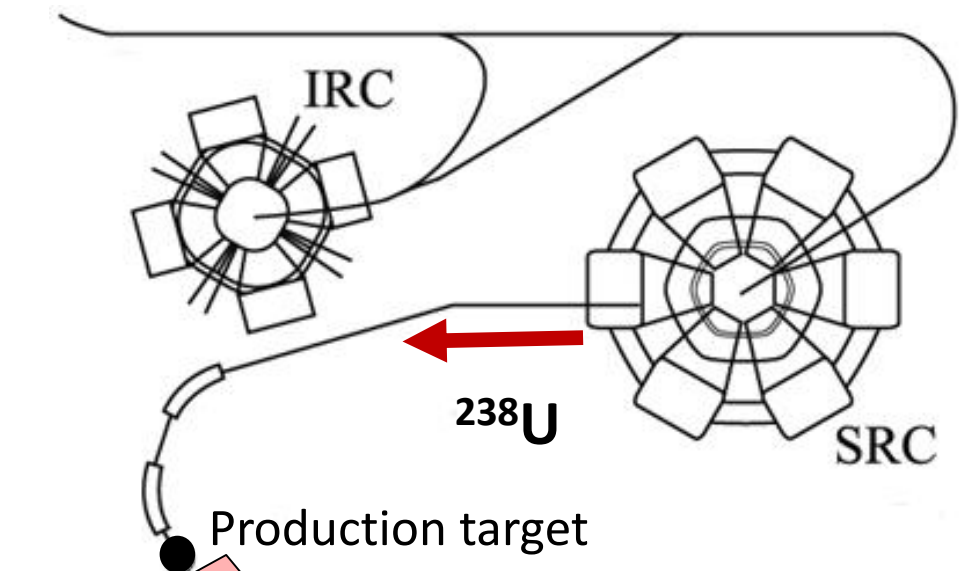


Experimental setup

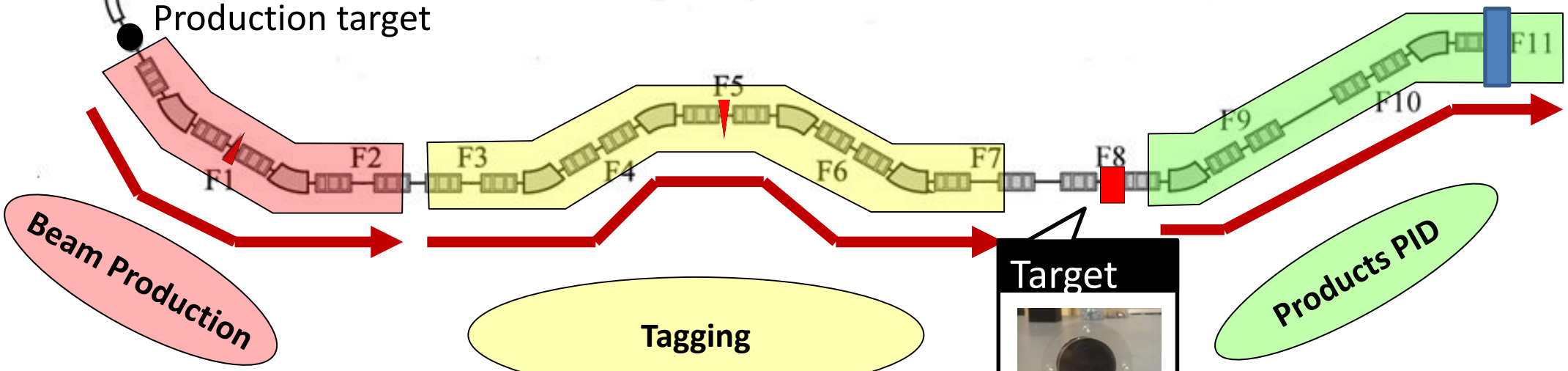


Superconducting Ring Cyclotron (SRC)

Experimental setup



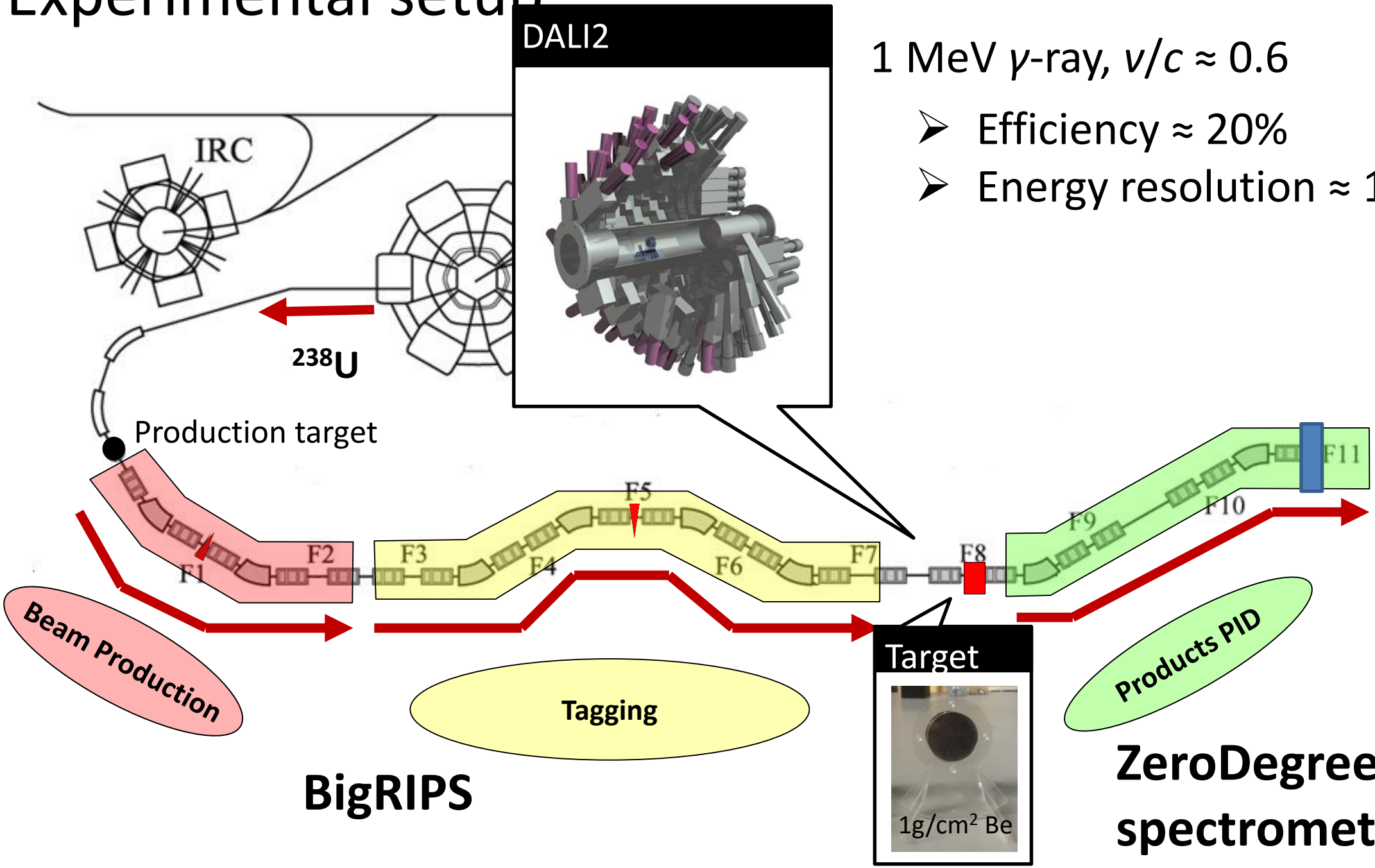
- Identification for secondary beams
  Bρ-Δ*E*-TOF
- Identification for reaction residues
  Bρ-Δ*E*-TOF-Total kinetic energy
- Reaction energy: ~240 MeV/*u*



BigRIPS

ZeroDegree spectrometer

Experimental setup



1 MeV γ-ray, $v/c \approx 0.6$

- Efficiency ≈ 20%
- Energy resolution ≈ 15% (FWHM)

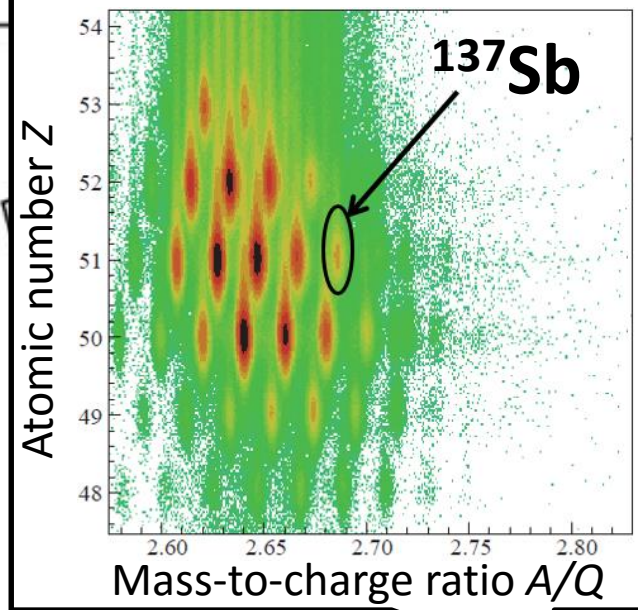
DALI2 array

186 NaI(Tl) detectors

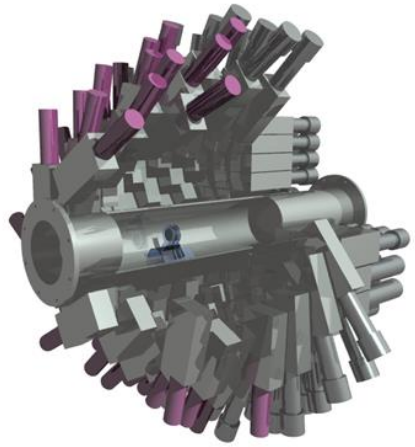
Inside

$^{137}Sb \rightarrow {}^{136}Sn$

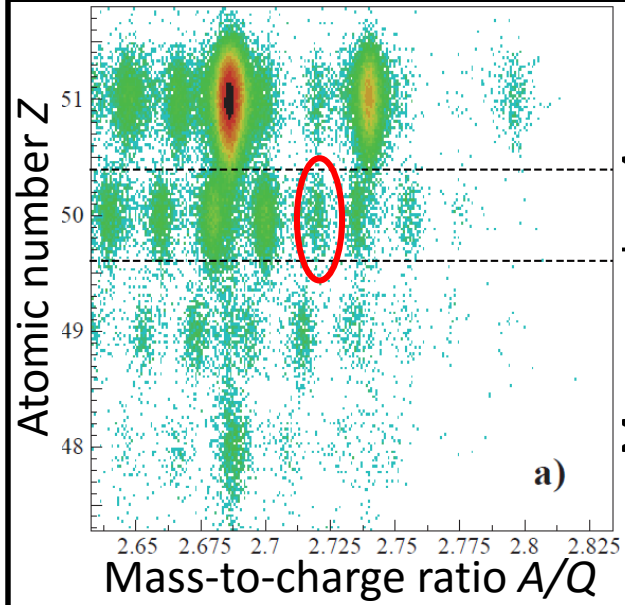
Projectile PID@BigRIPS



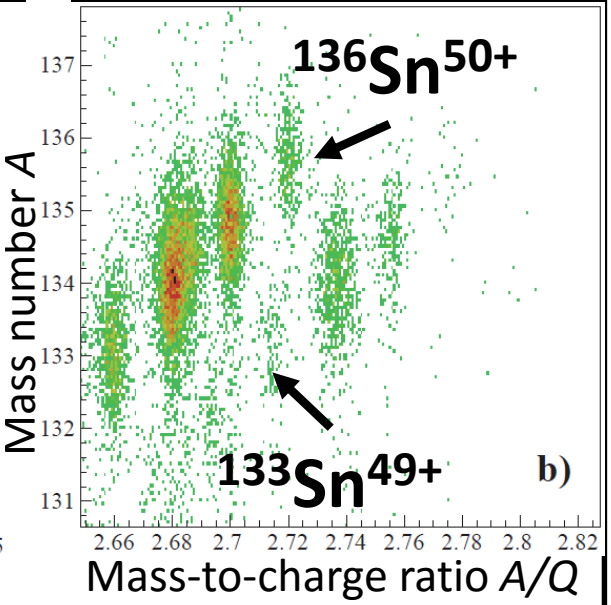
DALI2

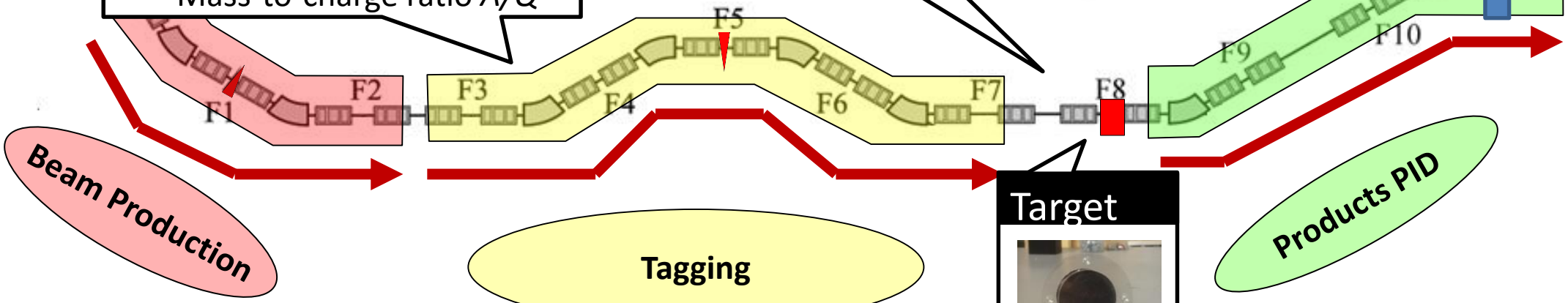


Ejectile PID@ZeroDegree

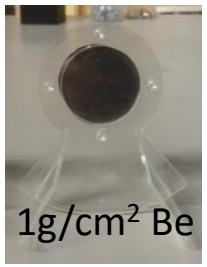


Charge-state ID





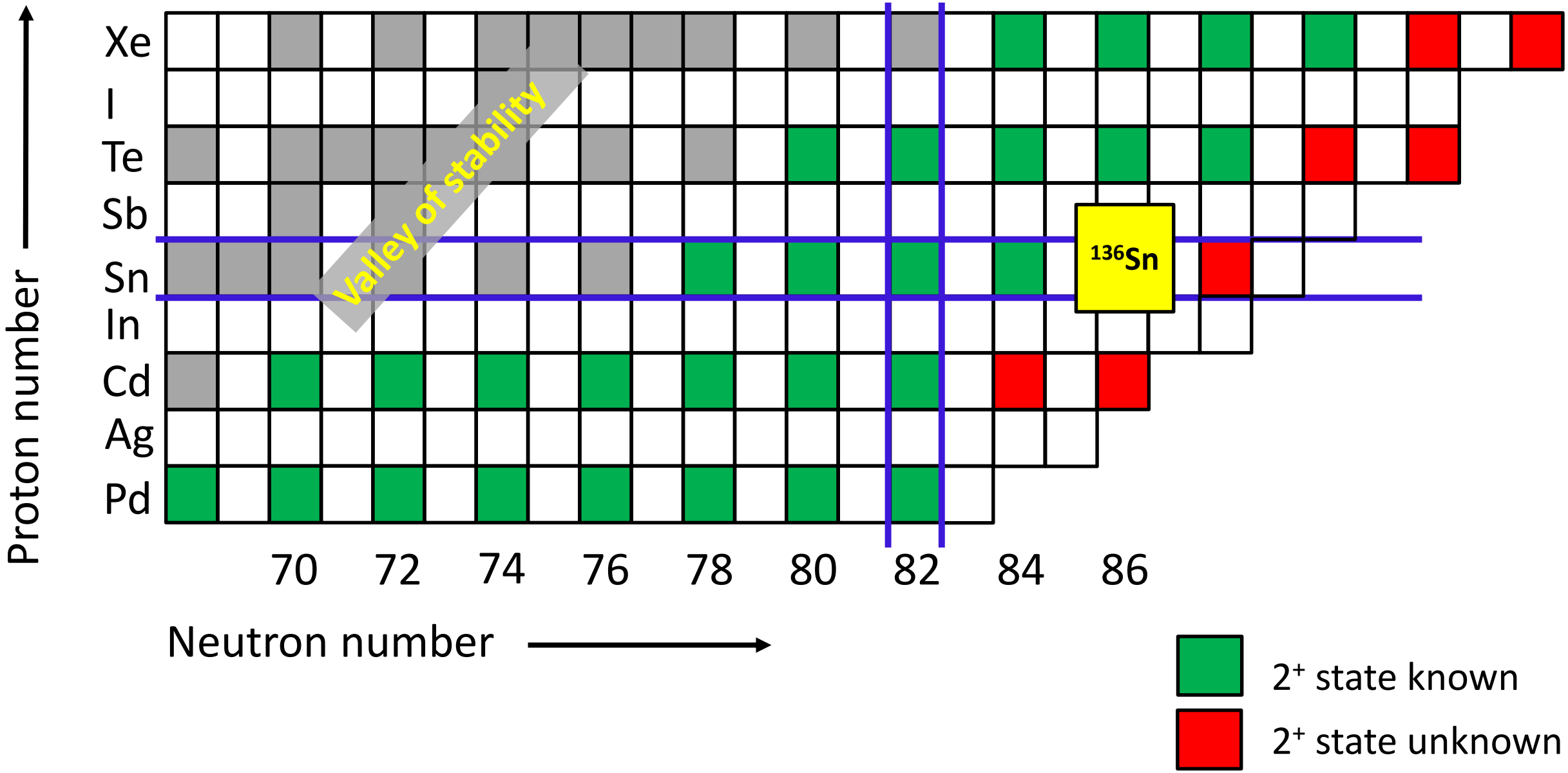
Target



BigRIPS

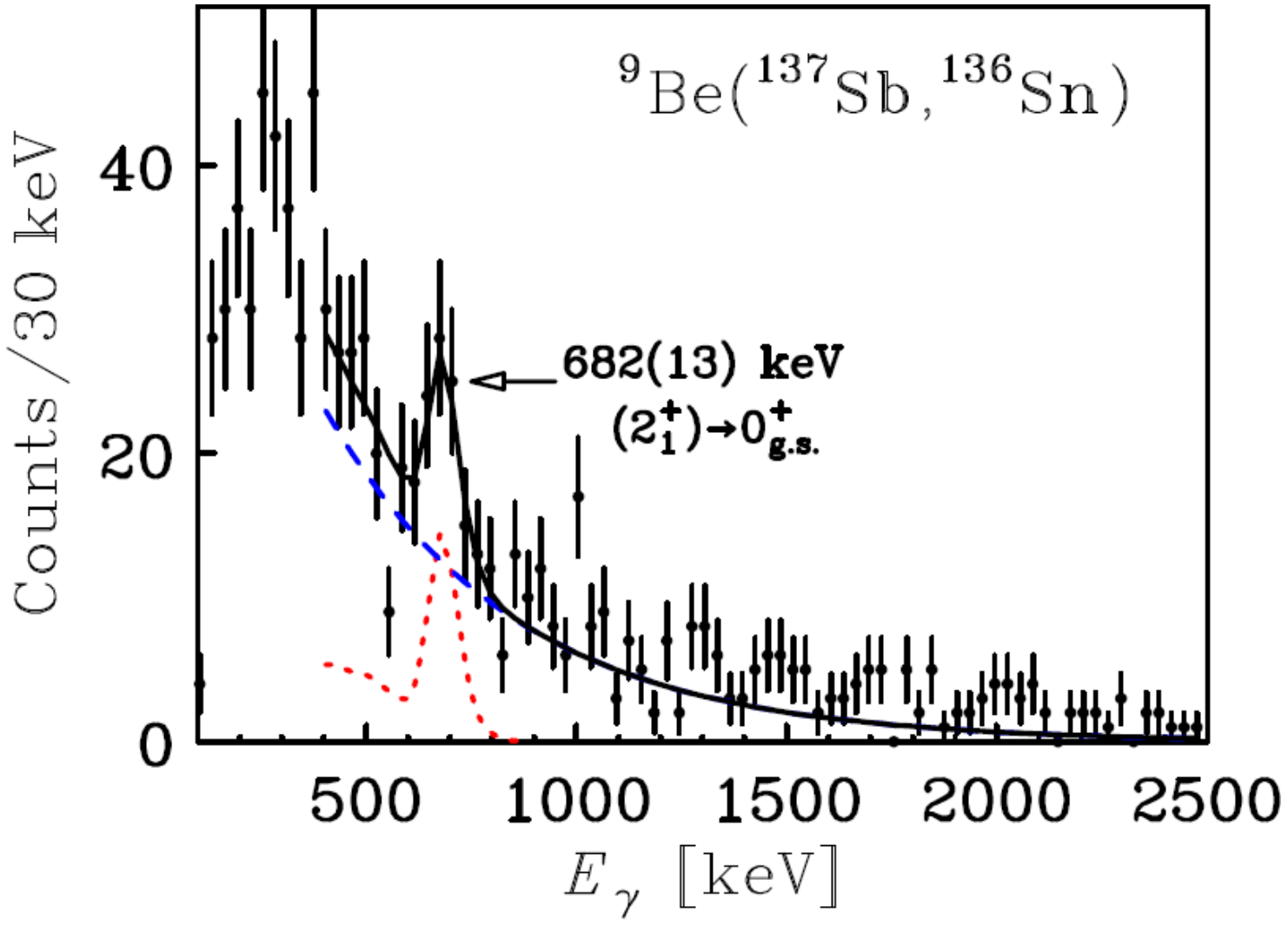
ZeroDegree spectrometer

Results


Xe
I
Te
Sb
Sn
In
Cd
Ag
Pd
Valley of stability
^{136}Sn
70
72
74
76
78
80
82
84
86
Proton number
Neutron number
2⁺ state known
2⁺ state unknown

The first 2^+ state in ^{136}Sn

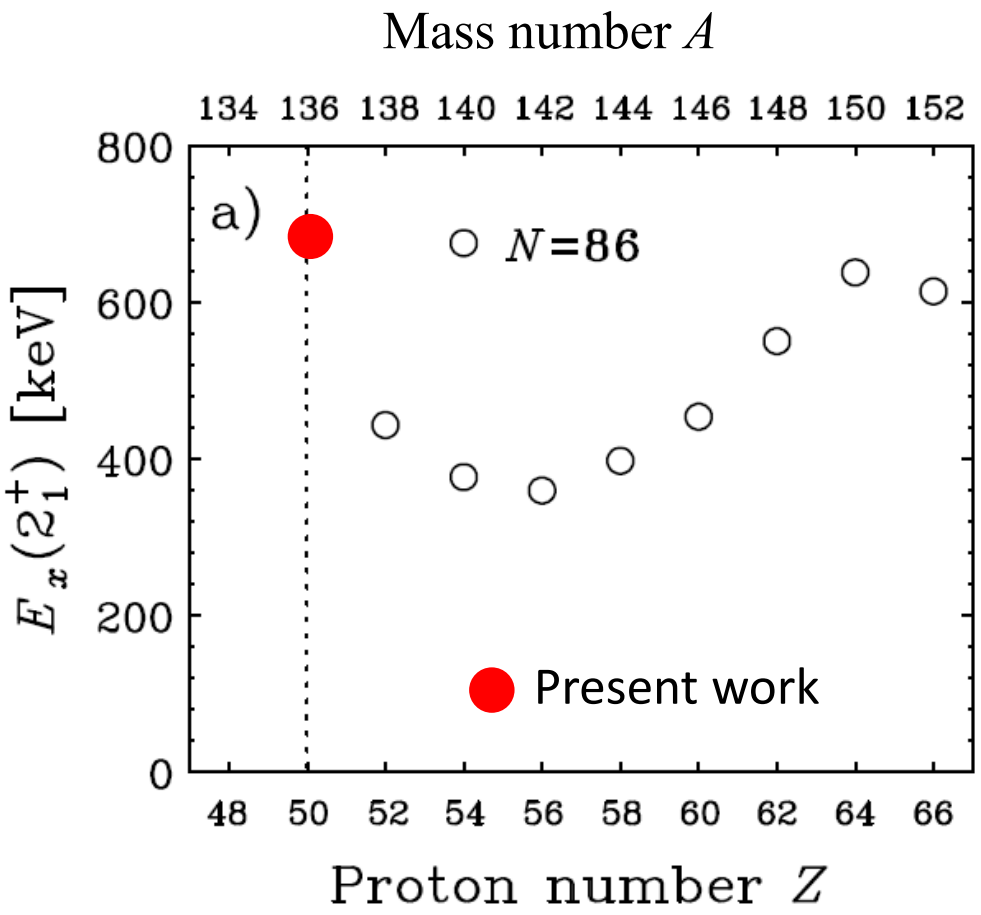
One-proton removal reaction



HW, N. Aoi et al., Prog. Theor. Exp. Phys. 2014, 023D02(2014)

Systematics of $E_x(2^+)$

- Z = 50 magicity in N = 86 isotones
- Constant $E_x(2^+)$ beyond N = 82 → Seniority scheme
- Asymmetric $E_x(2^+)$ pattern around N = 82



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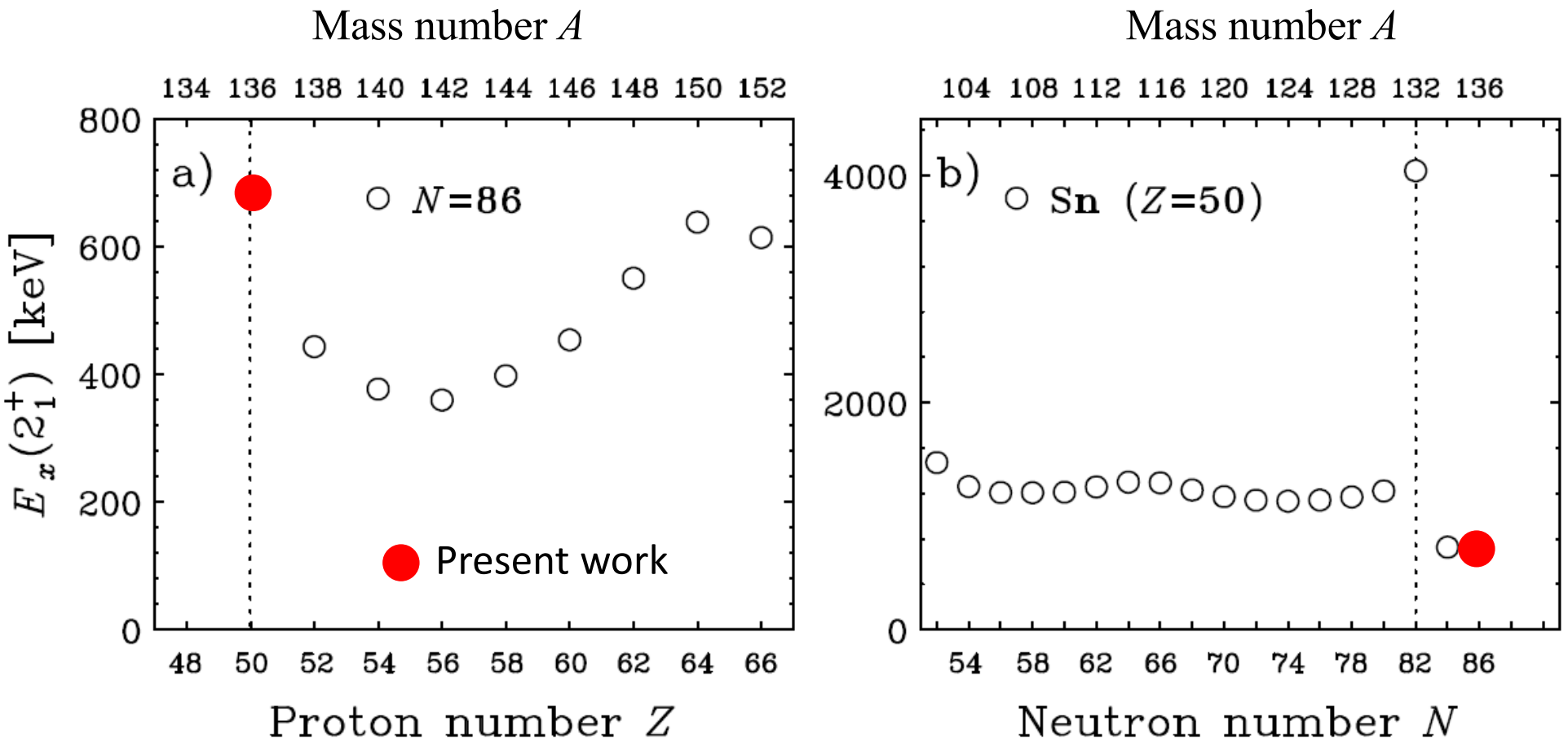

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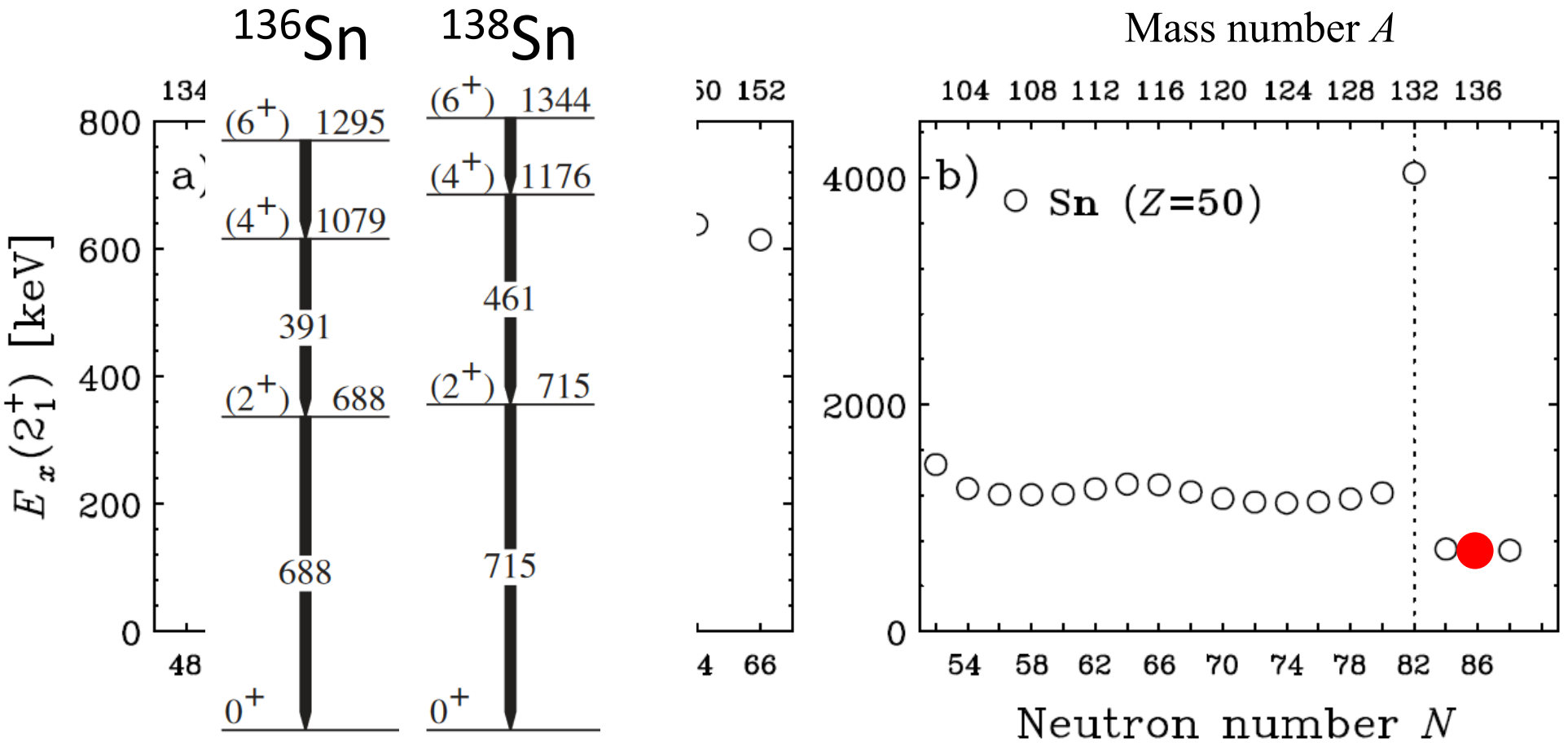

G. Simpson et al., Phys. Rev. Lett.113, 132502 (2014)

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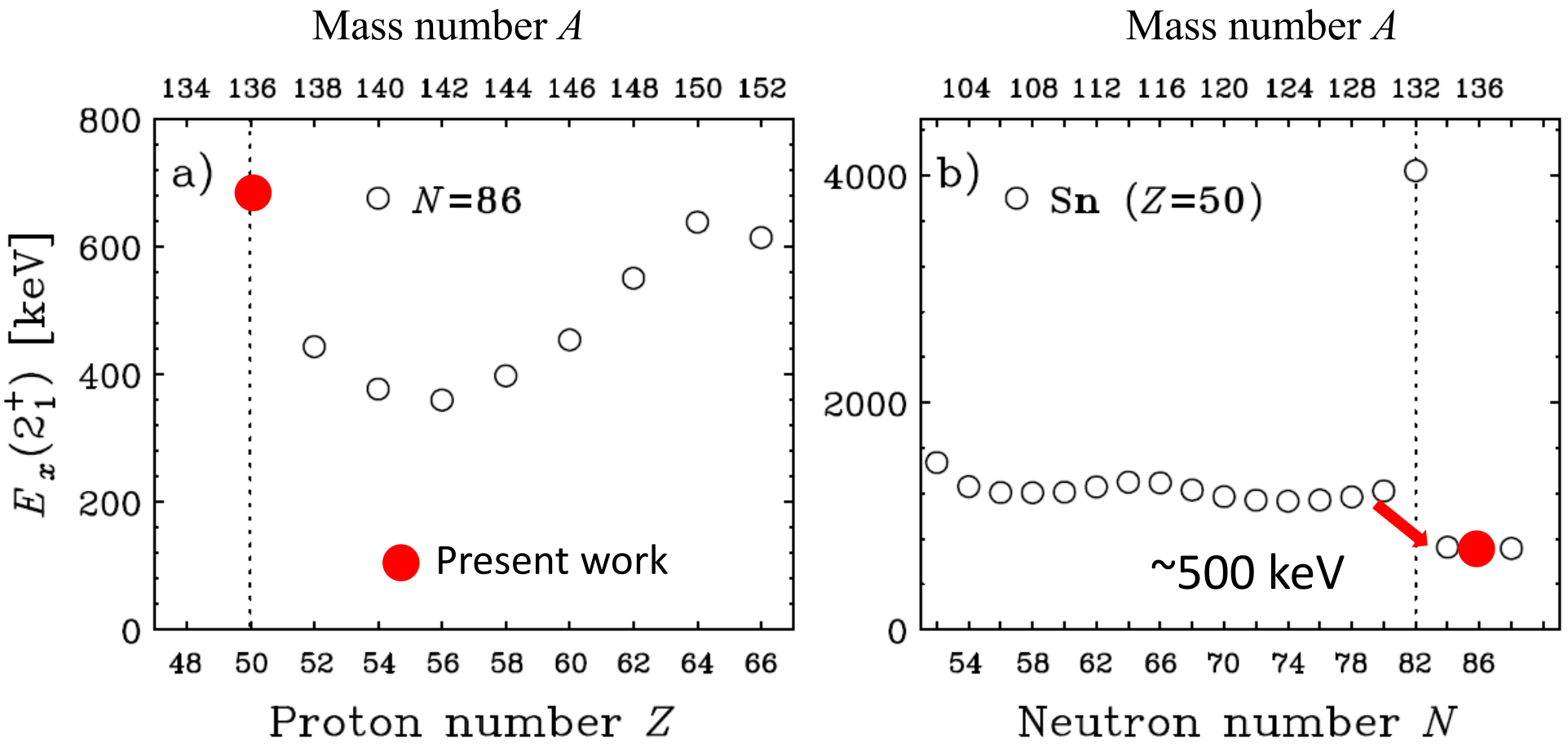
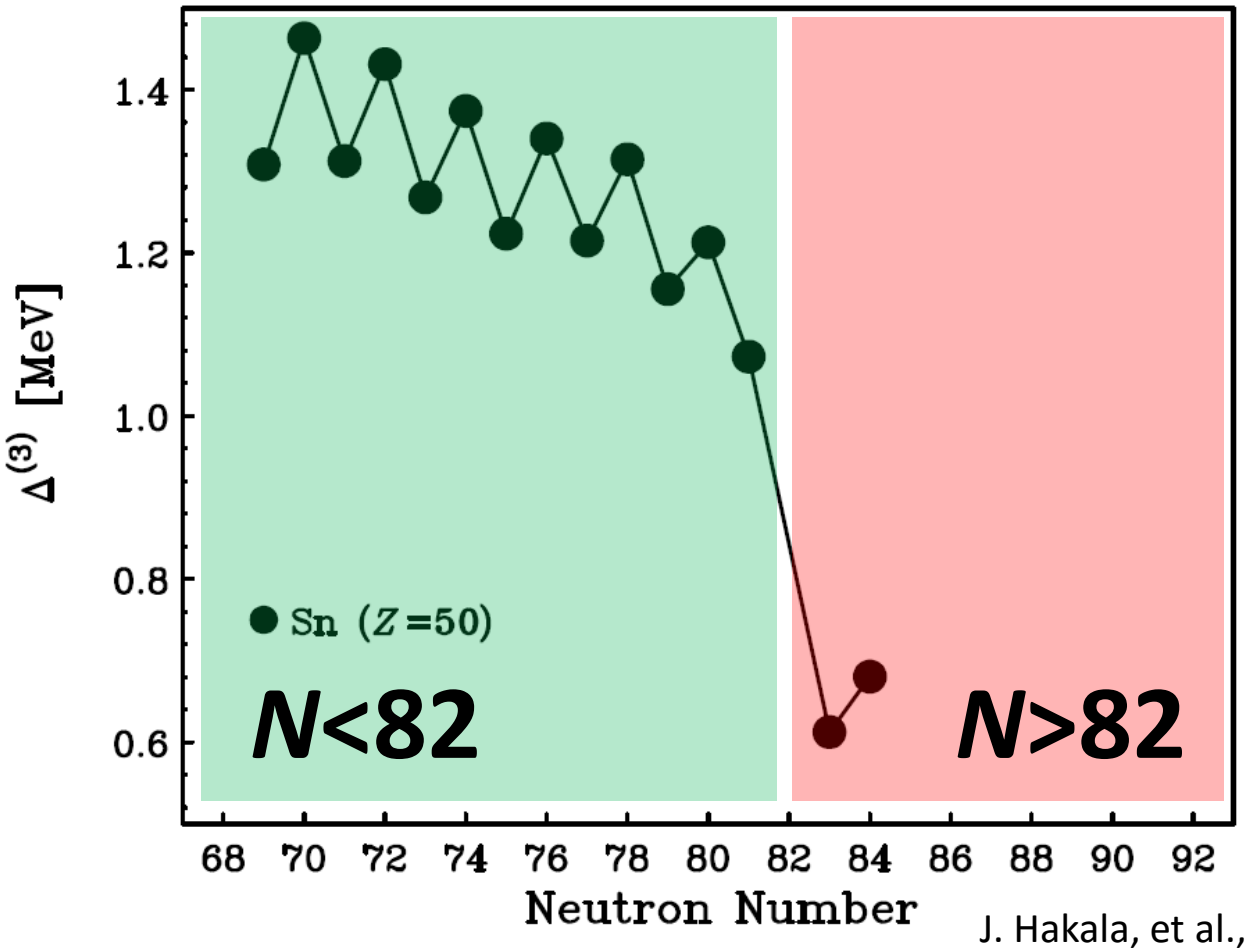


Possible reason

Reduction of pairing?

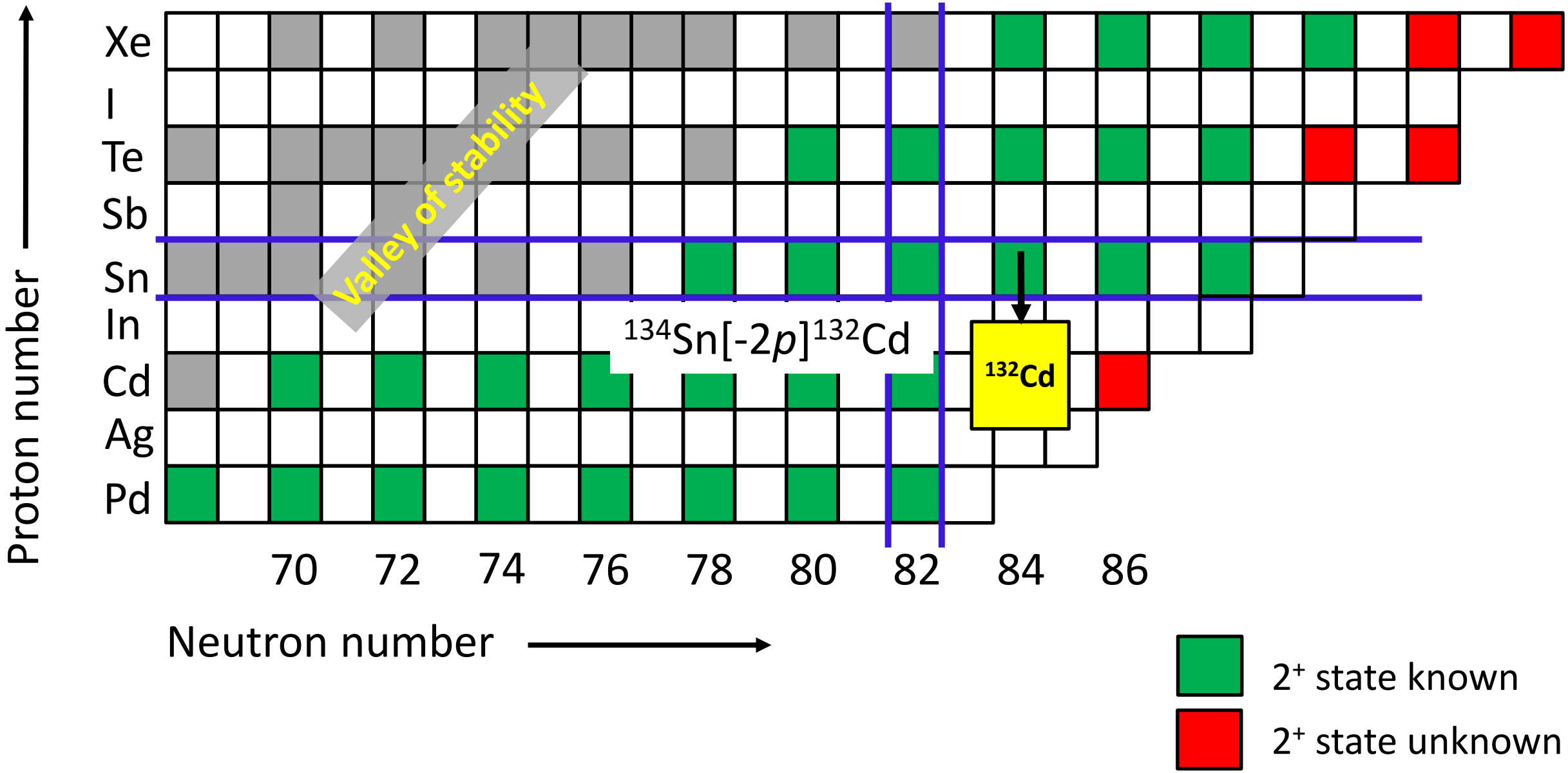
<--$E_x(2^+)$ is determined by the strength of pairing

$$\Delta^{(3)}(N) = (-1)^N[B(N\text{-}1) + B(N\text{+}1) - 2B(N)]/2$$



J. Hakala, et al., Phys. Rev. Lett. 109, 032501(2012).

Results


Xe
I
Te
Sb
Sn
In
Cd
Ag
Pd
Valley of stability
^{134}Sn[-2p]^{132}Cd
^{132}Cd
70
72
74
76
78
80
82
84
86
Proton number
Neutron number
2$^+$ state known
2$^+$ state unknown

Summary

- Nuclear structure study for the nuclei beyond ^{132}Sn
  One- and two-proton removal
  In-beam gamma-ray spectroscopy

- First 2^+ state in ^{136}Sn
  Seniority scheme holds beyond $N = 82$ and asymmetric $E_x(2^+)$ pattern

- First 2^+ state in ^{132}Cd

- Neutron pairing reduction beyond $N = 82$

- Future experimental study in this region
  Mass measurement, $B(E2)$

Collaborators

HW, N. Aoi, H. Baba, P. Doonerbal, Zs. Dombradi, Y. Kondo, J. Lee, H. Liu, M. Matsushita, T. Motobayashi, D. Nishimura, H. Otsu, H. Sakurai, D. Sohler, D. Steppenbeck, Y. Sun, S. Takeuchi, Z. Tian, Zs. Vajta, T. Yamamoto, Z. Yang, Y. Ye, R. Yokoyama, and K. Yoneda

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Univ. of Hongkong, *Rikkyo Univ.*, *TiTech*, *Univ. of Tokyo*, *Tokyo Univ. of Science*