Search for isomeric states in ^{132,134}Cd and ^{136,138}Sn and the study of their β-decays

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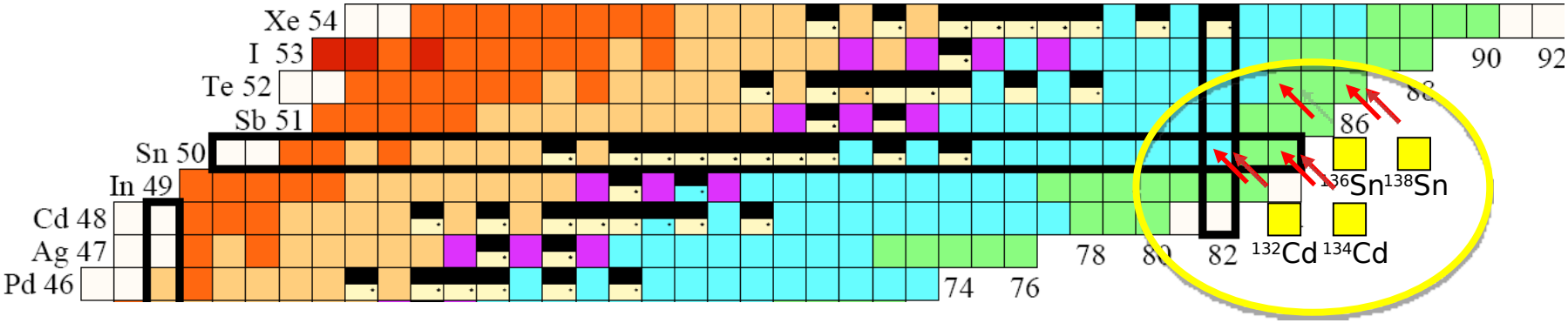
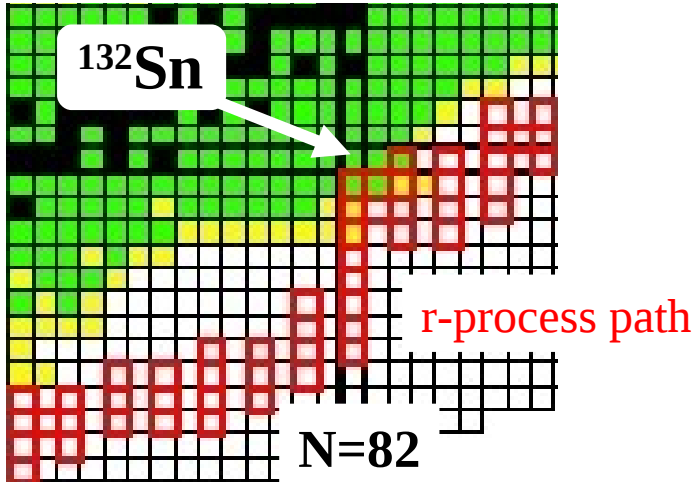
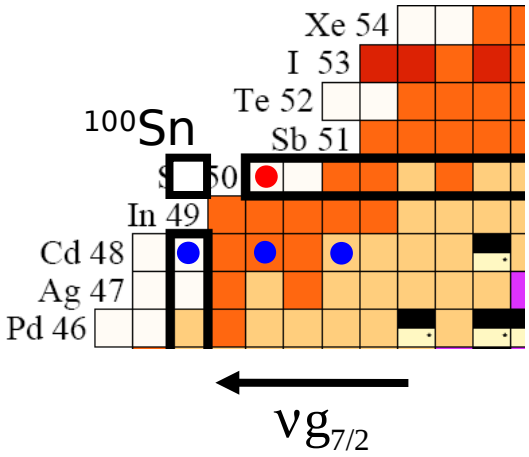
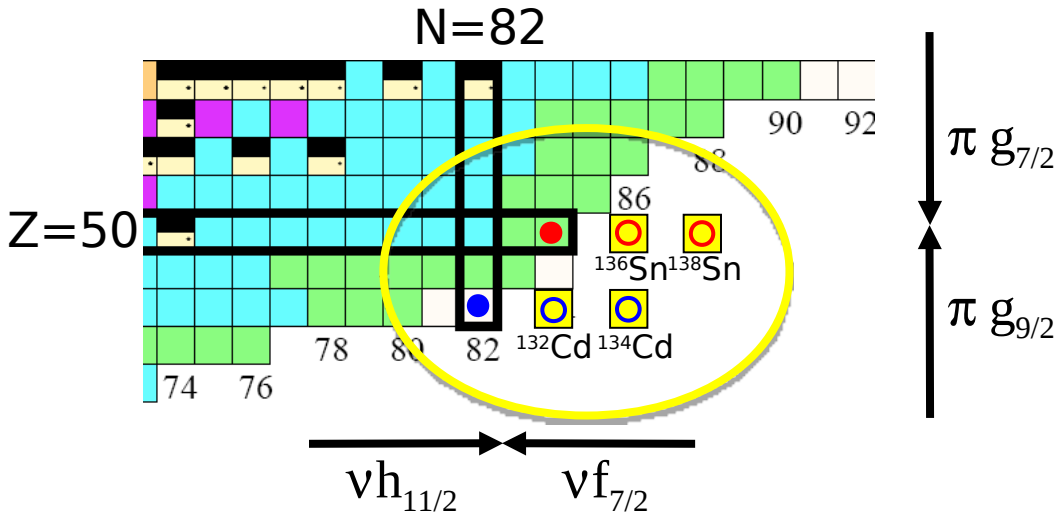


- nuclear structure interest (shell model)
- nuclear astrophysics interest (all considered nuclei are r-process waiting points)



The search for $\nu(f_{7/2})^2$ 6^+ and $\pi\,(g_{9/2})^2$ 8^+ seniority isomers in ^{132,134}Cd and ^{136,138}Sn





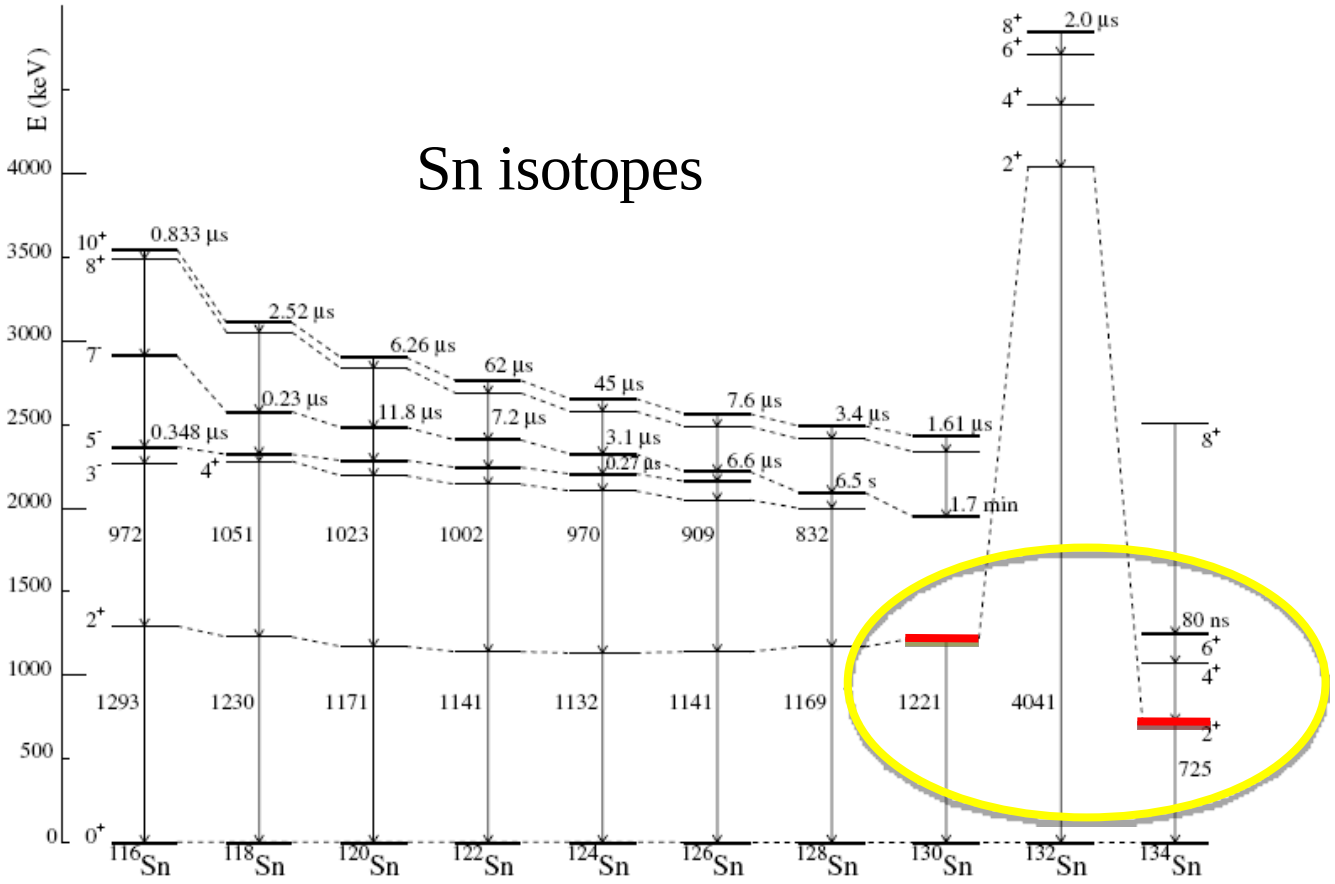
● known 6^+ isomer: $\nu(g_{7/2})^2$

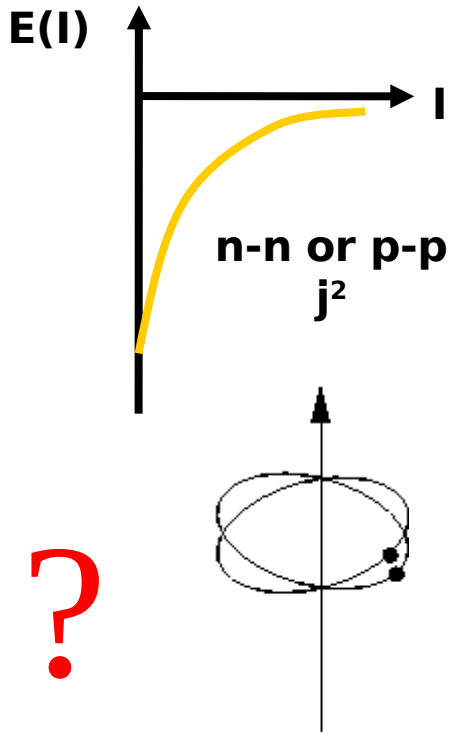
Persistence of 8^+ isomers in ^{100,102}Cd !

● ○ known/expected 6^+ isomer: $\nu(f_{7/2})^2$

● ○ known/expected 8^+ isomers: $\pi\,(g_{9/2})^2$

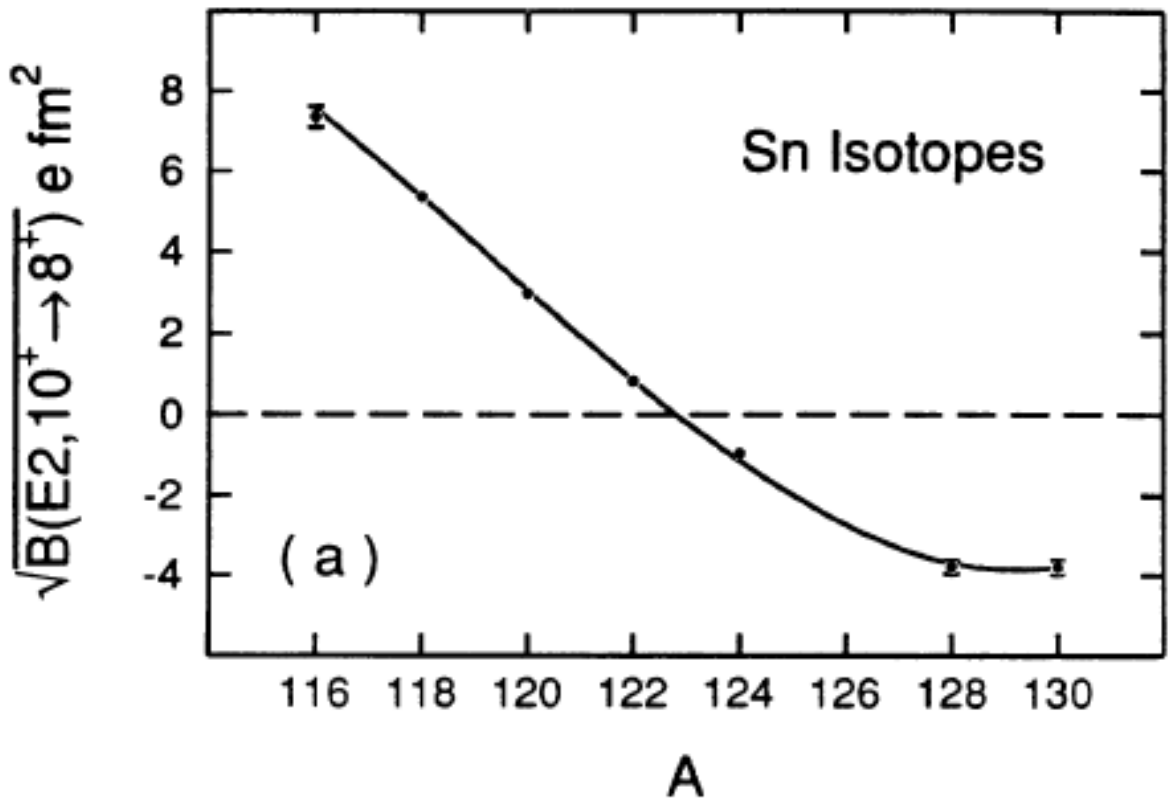
Low 2^+ excitation energy in ^{134}Sn: How does the systematics continue in ^{136,138}Sn ?





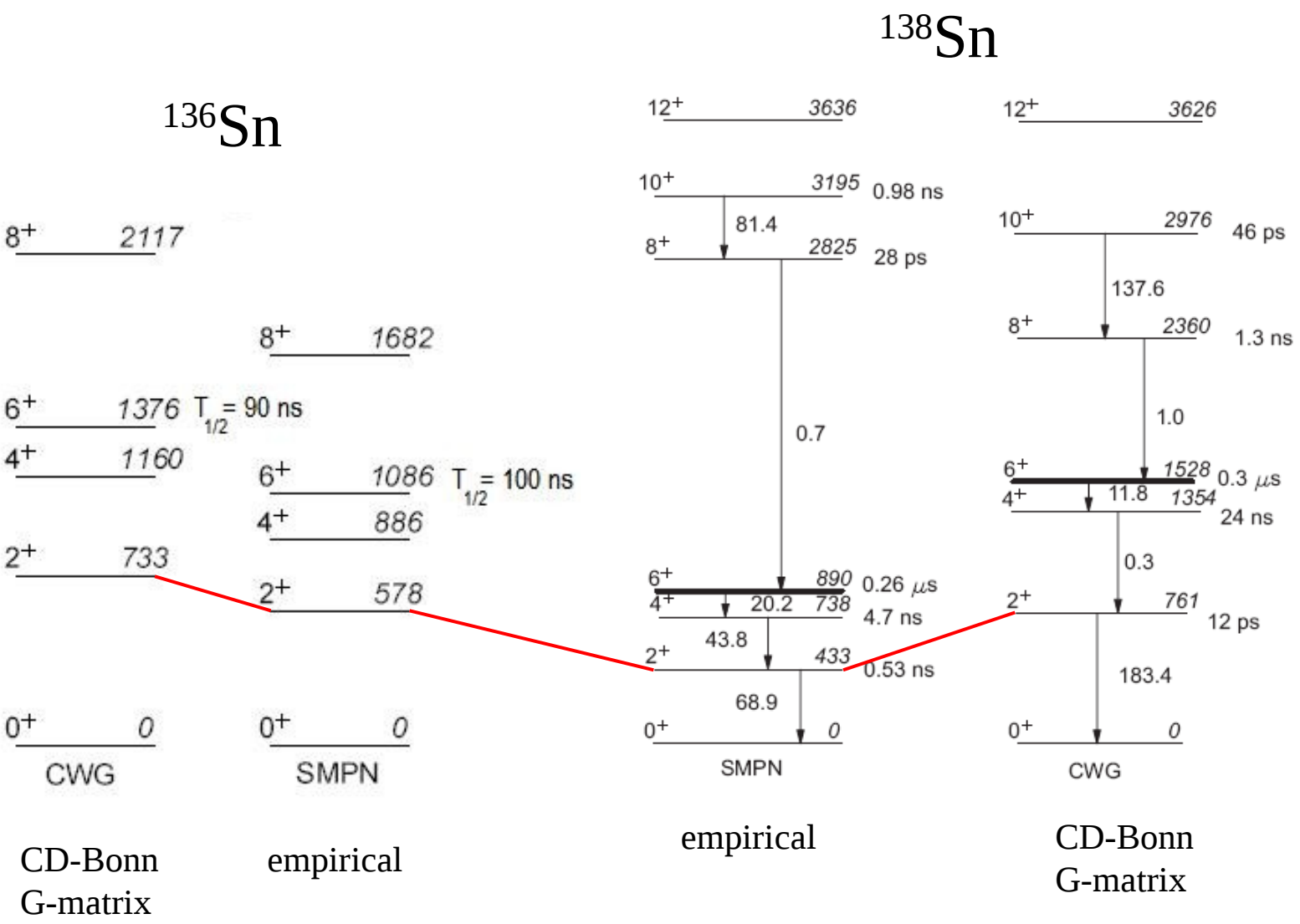
J.A. Pinston *et al.*, J. Phys. G 30 (2004) R57

Isomeric half-lives longest mid-shell



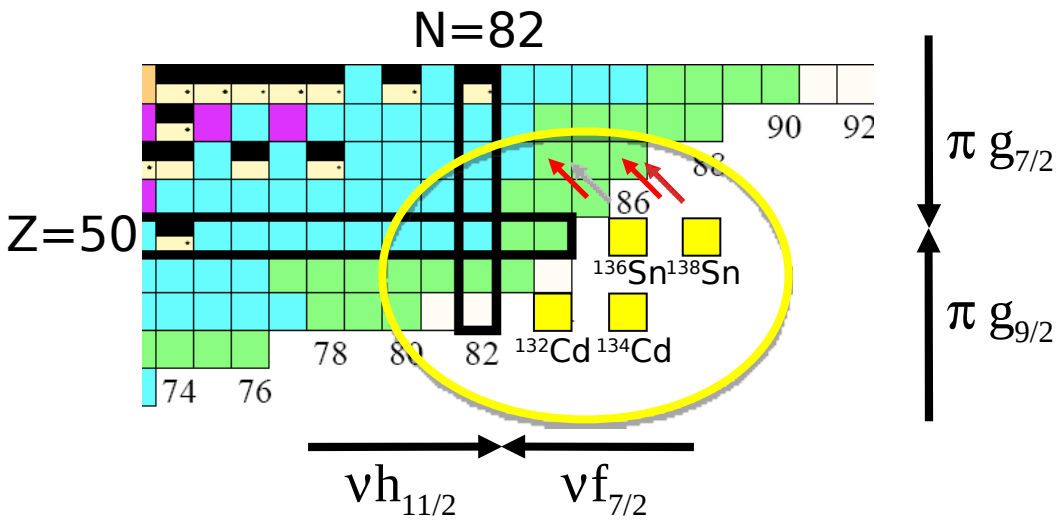
R. Broda, *et al*. Phys. Rev. Lett. 68 (1992) 1671

Different shell model predictions for ^{136,138}Sn



Predictions of 2^+ energies differ beyond ^{134}Sn – important to measure !

The β-decays ^{136}Sn → ^{136}Sb and ^{138}Sn → ^{138}Sb

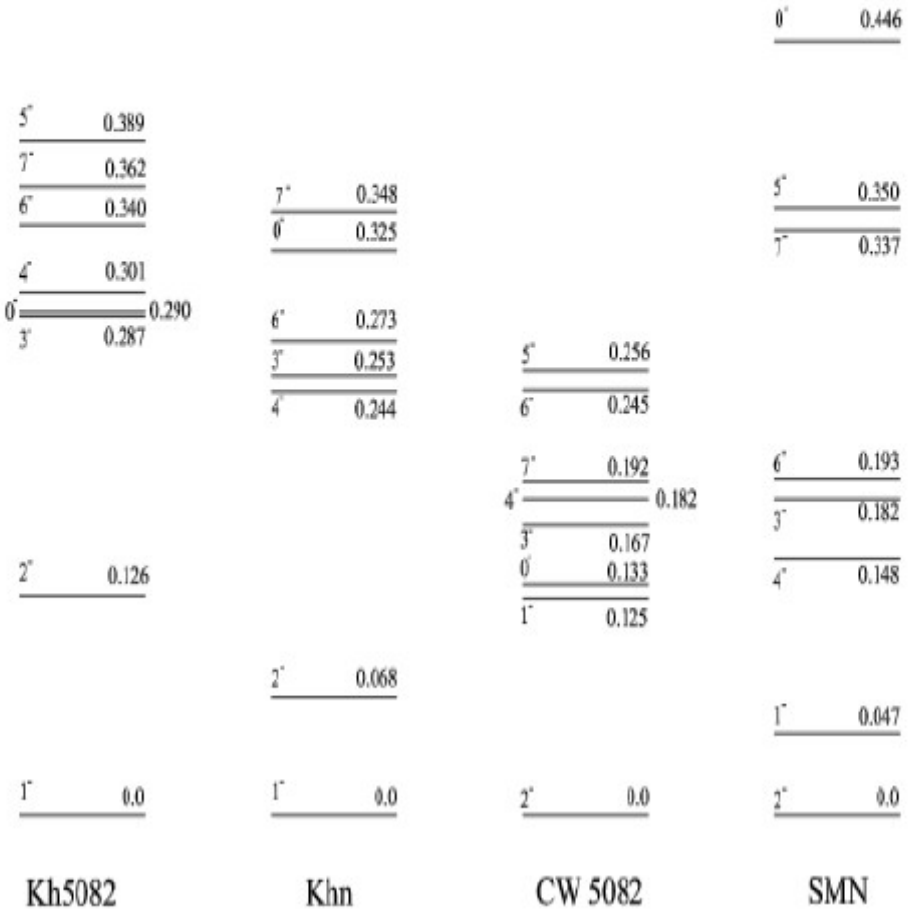


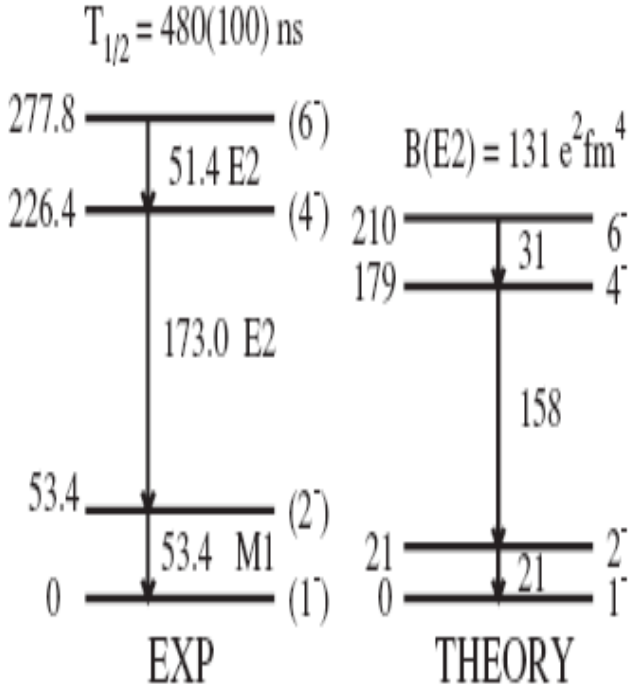
Only a few excited states known in ^{136}Sb and none in ^{138}Sb !

Will provide an excellent test of shell-model interactions (allow the tensor part of the interaction to be tested which is the most difficult part to reproduce).

Theoretical predictions vary, more experimental data required !

Comparison between experiment and theory for ^{136}Sb

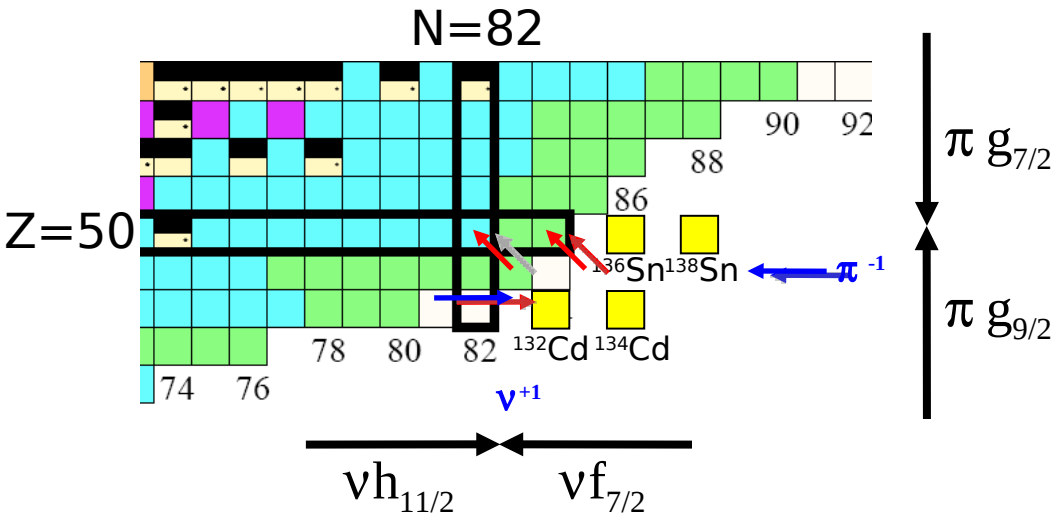




Theoretical calculations vary !

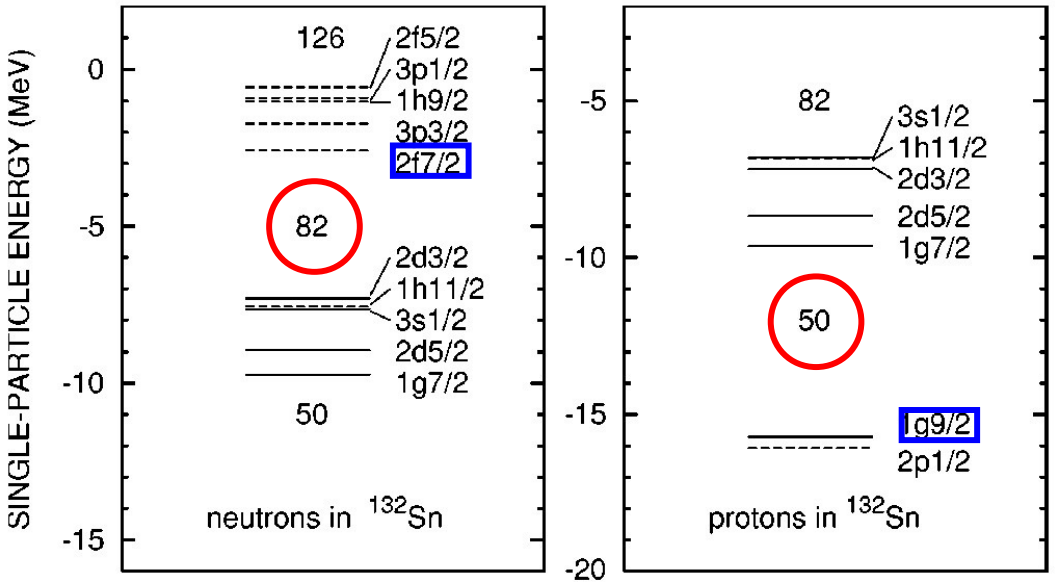
G. Simpson *et al.*, Phys. Rev. C76 (2007) 041303

The β-decays ^{132}Cd → ^{132}In and ^{134}Cd → ^{134}In

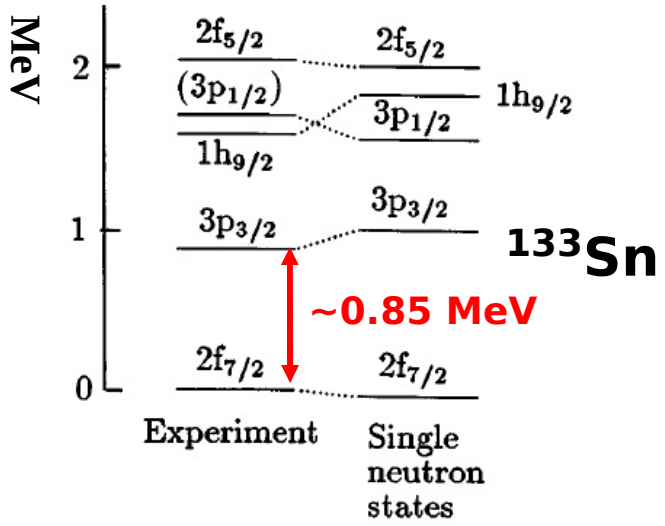


- The basic **νπ** $^{-1}$ structure information is required for shell model calculations.
- The N=83 isotones are the best candidates to observe the shell evolution at large isospin, i.e. the evolution of the monopole interaction (tensor interaction between π $g_{9/2}$ and ν$f_{7/2}$).

The shell structure in ^{132}Cd and ^{132}In



J.Terasaki et al, PRC66 (02), V.I.Isakov at al, nucl-th/0202044



Low excitation energy $\nu p_{3/2}$

P.Hoff et al, PRL77 (96)

^{132}Cd is the $\pi^{-2}\ \nu^{+2}$ valence nucleus
g.s. configuration:
$(\pi\ g_{9/2}^{-2}\ \nu f_{7/2}^{2})_{0^+}$

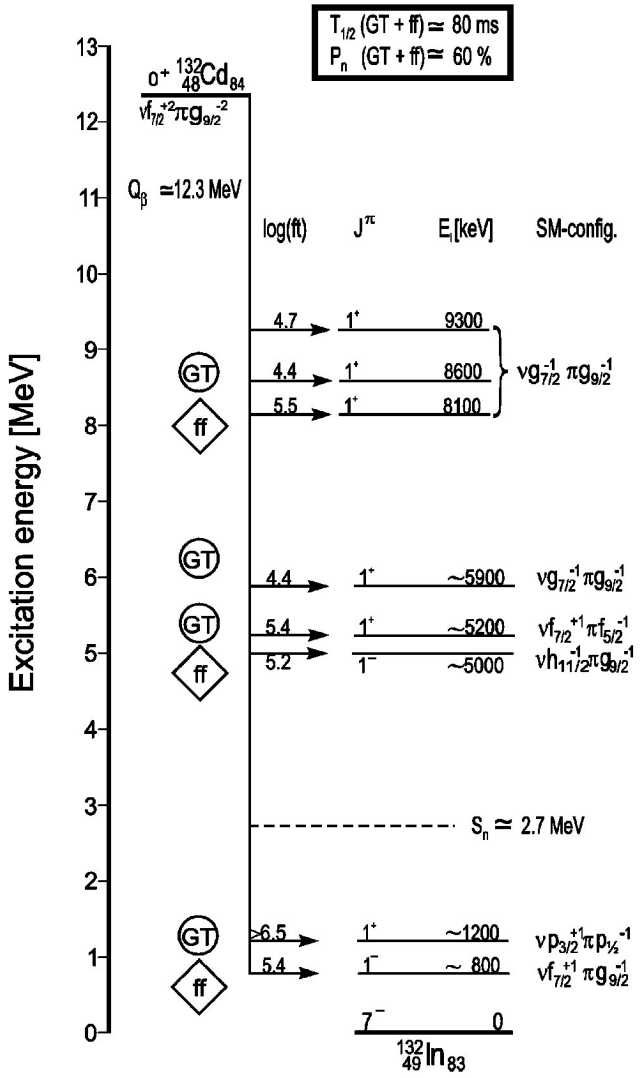
^{132}In is the $\pi^{-1}\ \nu^{+1}$ valence nucleus
g.s. configuration: $(\pi\ g_{9/2}^{-1}\ \nu f_{7/2})_{7^-}$

Allowed GT decays $\nu g_{7/2} \rightarrow \pi\ g_{9/2}$ (goes to 4QP states)

$\nu f_{7/2} \rightarrow \pi\ f_{5/2}$ (goes to high energy states)

First forbidden decays $\nu f_{7/2} \rightarrow \pi\ g_{9/2}$ (goes to the low lying 1^- state)

Available information on ^{132}In



M.Hannawald et al., PRC 62 (2000) 054301

Measurement performed at ISOLDE with:

- the RILIS ion-source
- the Mainz neutron longcounter
- ΔE plastic β-detector

Gross β-decay properties:

$T_{1/2}$ = 97(10) ms P_n ~ 60%

Q_β ~ 12.3 $MeV_{EST.}$ ~11.7$_5$ $MeV_{SYS.}$

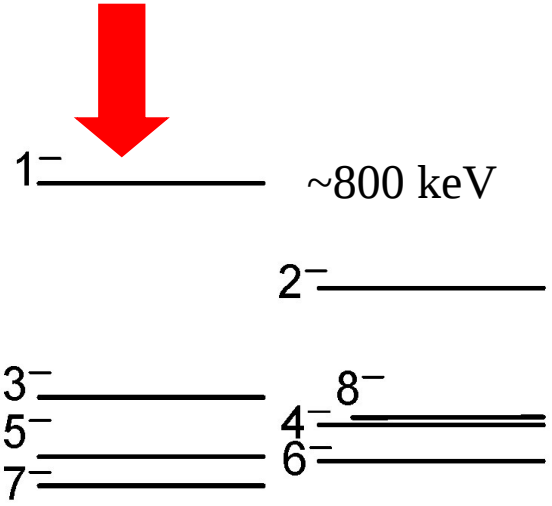
Excitation energy of the populated levels estimated from the β- distribution

The β-decay proceeds (100-P_n) ~ 40% populating states below S_n - mostly one state at ~800 keV

Predictions for the $\nu f_{7/2}\,\pi\, g_{9/2}^{-1}$ multiplet in ^{132}In

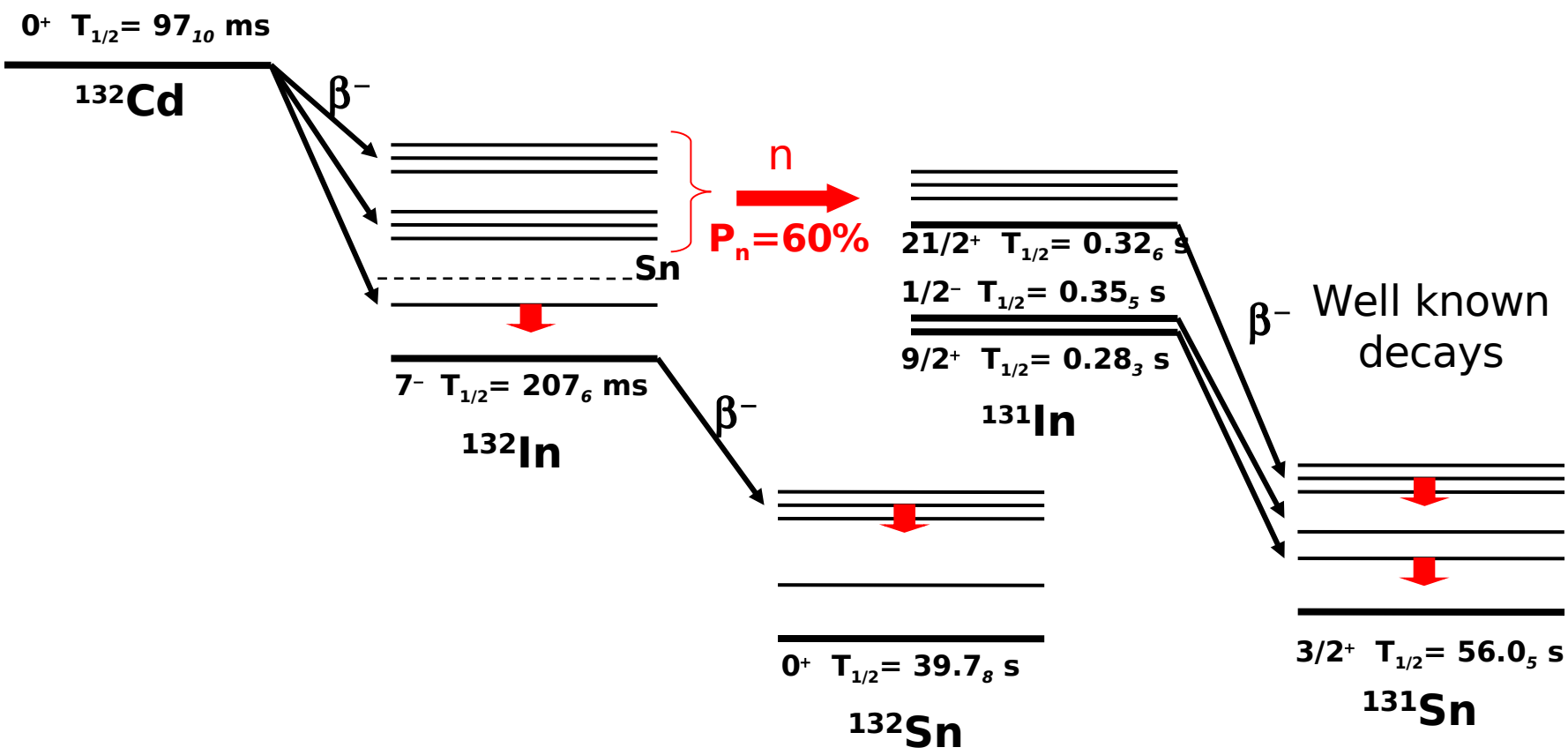
- no residual interaction available
  A. Covello et al. Working on CD-Bonn realistic interaction
- multiplet "shape" estimate, using the interaction TBME $f_{7/2}\, g_{9/2}^{-1}$ from the ^{208}Pb region.
  Good agreement on the multiplet "amplitude", 800 keV from 7^- to 1^-.
- The expected transition energy ranges from ~600 keV (E2 character) to ~70 keV (M1 character).
- α_{tot}~1.6 for 70 keV M1 transition

40% feeding by FF transition to the low lying 1^- state



SM estimate of the $f_{7/2}\, g_{9/2}^{-1}$ multiplet

Decay sequence of ^{132}Cd

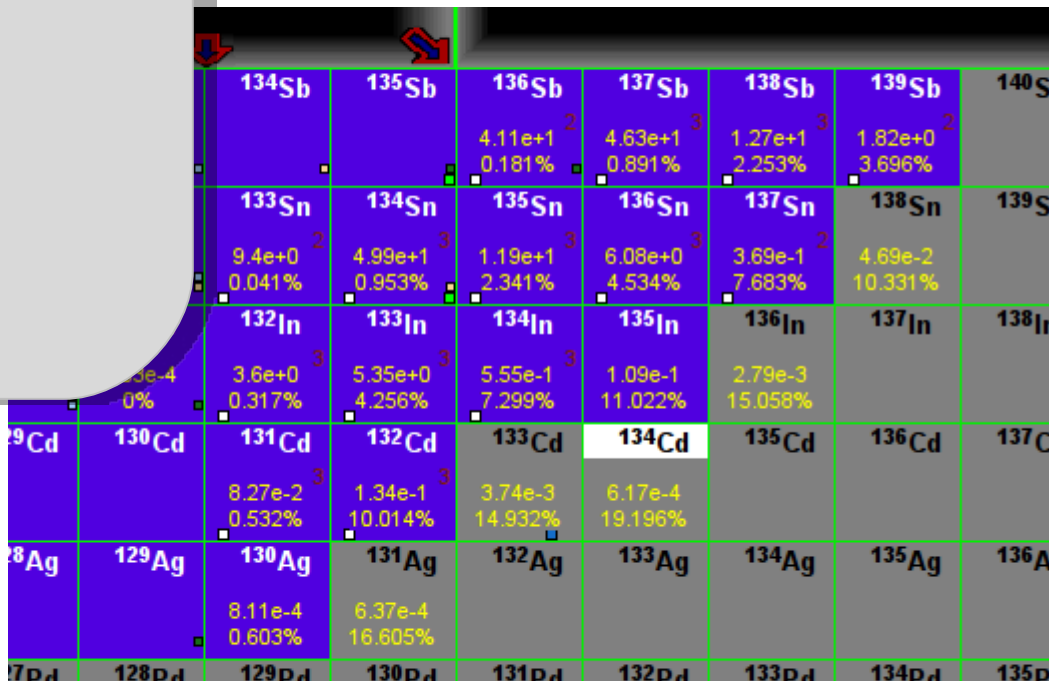


- γ-transitions in ^{131}In following the β-delayed n-emission from ^{132}Cd can be identified.
- β-delayed γ-transitions in ^{131}Sn will also be measured.
- The measurement provides information on the wave function components.

M.Hannabald et al., PRC 62 (00)
B.Fogelberg et al., PRC 70 (04)
Yu.Khazov et al., NDS 107(06)

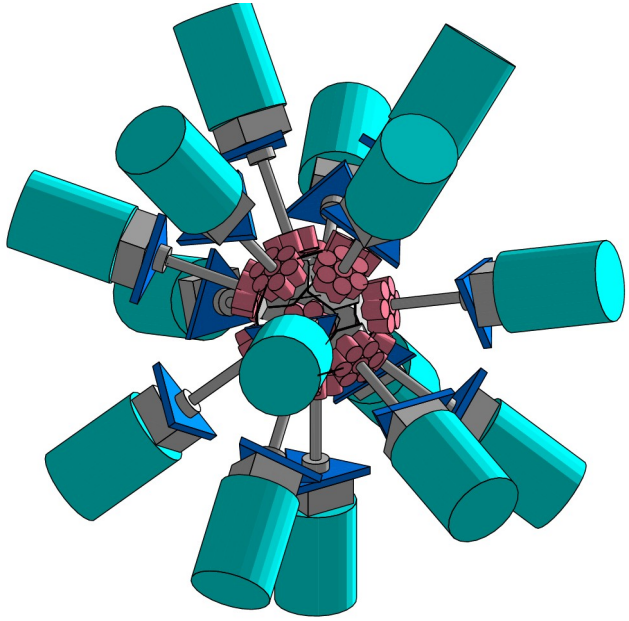
Secondary beam rate estimations

- 5 pnA ^{238}U primary beam
- Same target and degrader thicknesses as for new isotopes:
  - 1 mm Pb target + 0.3 mm Al stripper
  - 5 mm Al F1 wedge
  - 1.8 mm Al F5 wedge
- Setting on ^{134}Cd, $B\rho_{max}$ + 3 %
- All nuclei of interest in one setting
- Low rate @ F11: below 200 pps



Isomeric gamma-ray yield estimation

- Particle yield/day using calculated cross-sections:
  - ^{132}Cd: 1.1x10^{4}
  - ^{134}Cd: 5.3x10^{1}
  - ^{136}Sn: 5.2x10^{5}
  - ^{138}Sn: 4.1x10^{3}
- 15 % gamma-ray efficiency
- 10 % isomeric ratio (expected from data of known isomers)
- Gamma-ray yield/day:
  - ^{132}Cd: 1.7x10^{2}
  - ^{134}Cd: 8.0x10^{-1}
  - ^{136}Sn: 7.8x10^{3}
  - ^{138}Sn: 6.1x10^{1}
- Decay in flight not included



- All nuclei in one single setting → maybe switch to two settings
- Low rate at F11 → beta-gamma spectroscopy at the same time
- ^{134}Cd challenging → yet undiscovered, other new isotopes?

Install EXOGAM at PF1B neutron guide end 2012 – mid 2013

^{241}Pu, ^{235}U(n_{th},F) reactions to produce n-rich FFs

Analysis with γ–γ–γ coincidences

Can add other detectors ($LaBr_3$, LEPS, STEFF)