



INTRANS Workshop

22nd-25th January 2024

Core-breaking effects in the ^{100}Sn region: lifetime measurements in $^{98,100}\text{Cd}$

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Outline

- Case study:
 - Core-breaking effects in the ^{100}Sn region
 - Aims of the experiment
 - The FRS+DESPEC setup
- Analysis and results:
 - Ions' identification
 - Lifetime measurements in ^{102}Sn , $^{98,100}\text{Cd}$
 - Beta-decay study of ^{101}Cd

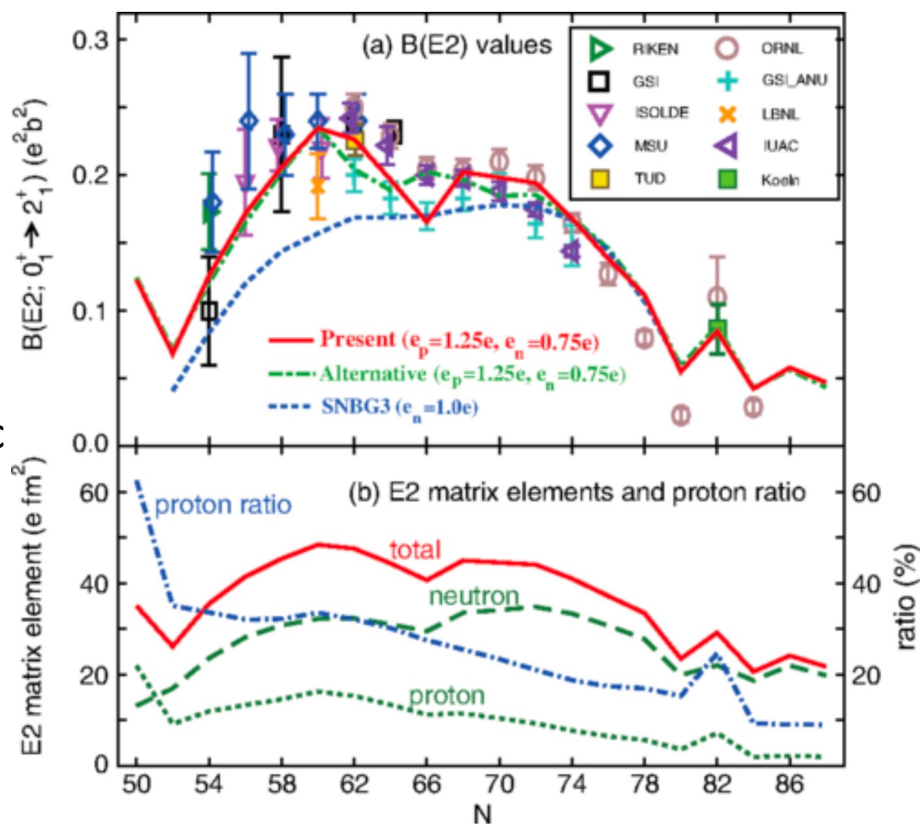
Motivation: the ^{100}Sn region

The ^{100}Sn region is subject of a multitude of experimental and theoretical studies to assess:

- the robustness of the $N = Z = 50$ **double shell closure**
- **core-breaking** effects
- the role of **p-n pairing** and **quadrupole** terms in shell model

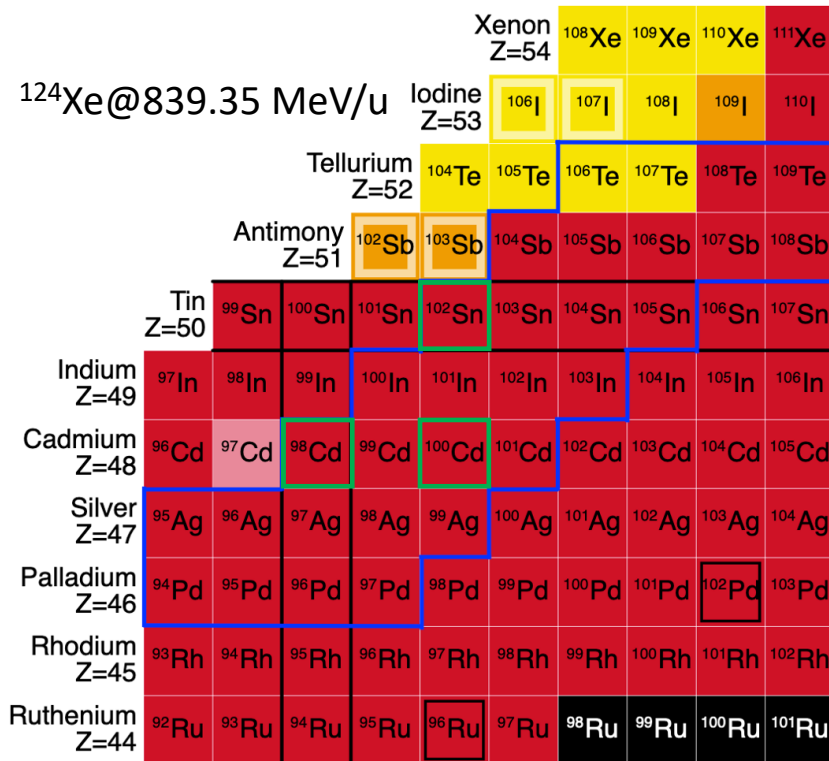
Known experimental information:

- ^{100}Sn studied with β decay \rightarrow doubly magic nature
- **E2** values in $^{102-130}\text{Sn}$ display the typical seniority scheme behavior



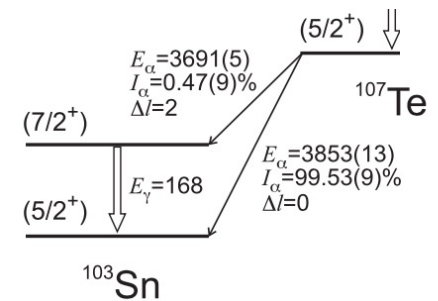
T. Togashi et al., Phys. Rev. Lett. 121 (2018) 062501

Aims of our experiment



Primary goals:

- Lifetime measurement of isomeric ($7/2^+$) state in ^{103}Sn , populated via the α -decay branch in ^{107}Te via α - γ timing



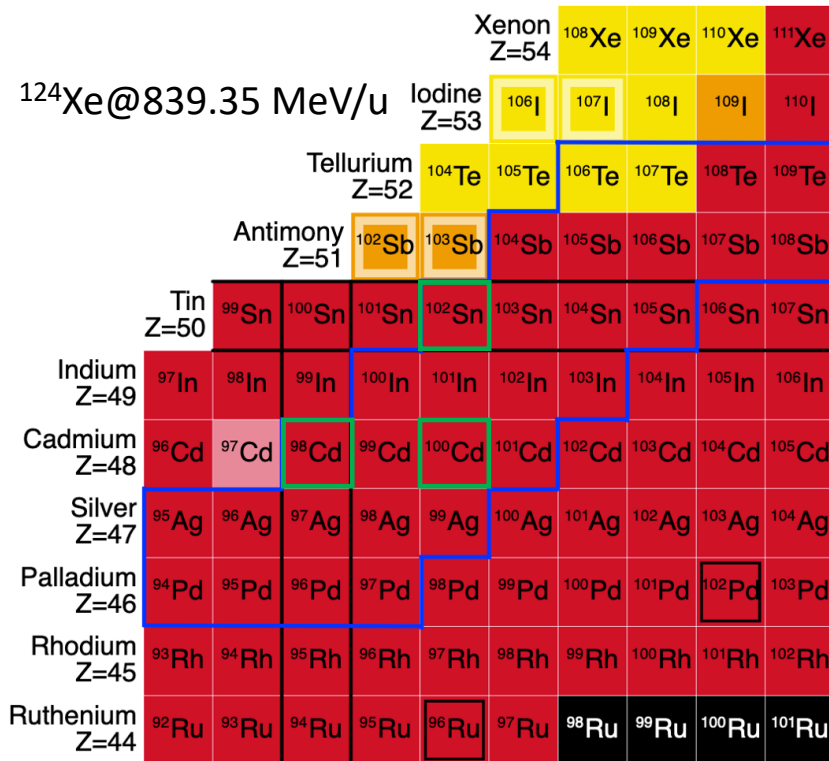
I. G. Darby PRL 105, 162502 (2010)

- Lifetime measurement of the 4^+ state in ^{102}Sn , via a direct measurement of time differences between 497- ($4^+ \rightarrow 2^+$) and 88-keV ($6^+ \rightarrow 4^+$) γ rays.



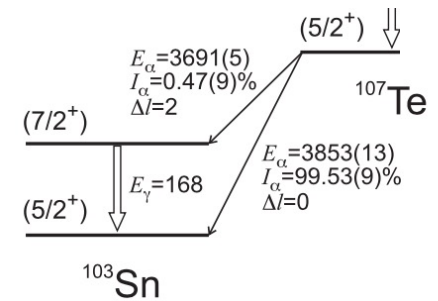
H. Grawe et al., Physics Letters B 820 (2021) 136591

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- Lifetime measurement of isomeric ($7/2^+$) state in ^{103}Sn , populated via the α -decay branch in ^{107}Te via α - γ timing



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- Lifetime measurement of the 4^+ state in ^{102}Sn , via a direct measurement of time differences between 497- ($4^+ \rightarrow 2^+$) and 88-keV ($6^+ \rightarrow 4^+$) γ rays.

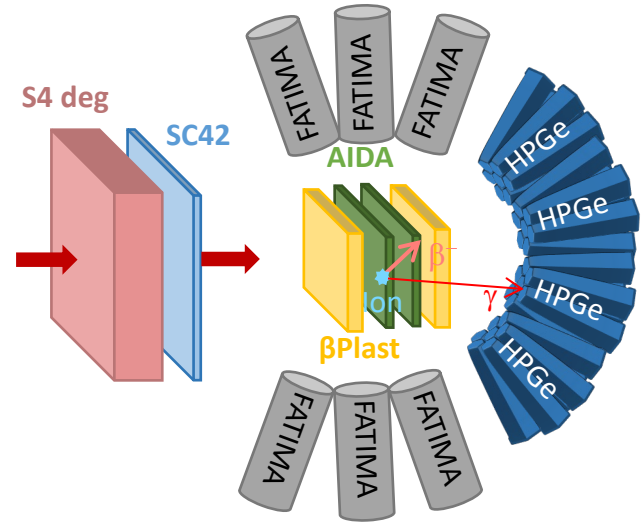
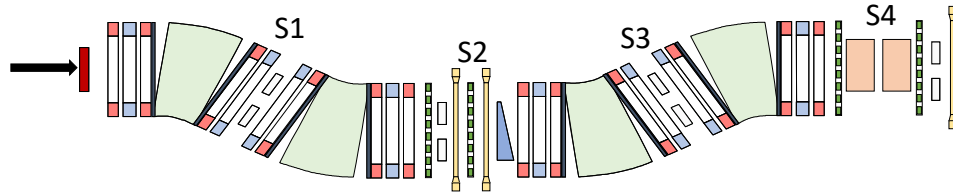


H. Grawe et al., Physics Letters B 820 (2021) 136591

^{48}Cd isotopic chain:
enhancement of collectivity induced by two proton holes in $g_{9/2}$ orbits.

The FRS+DESPEC setup at GSI

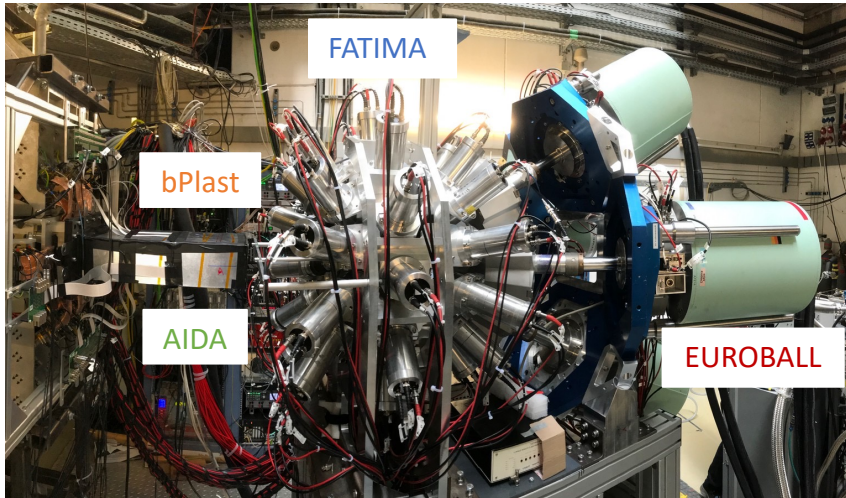
In-flight fragmentation: $^{124}\text{Xe}@839.35 \text{ MeV/u} + ^9\text{Be}$



Selection and identification:

$$B\rho - \Delta E - B\rho$$

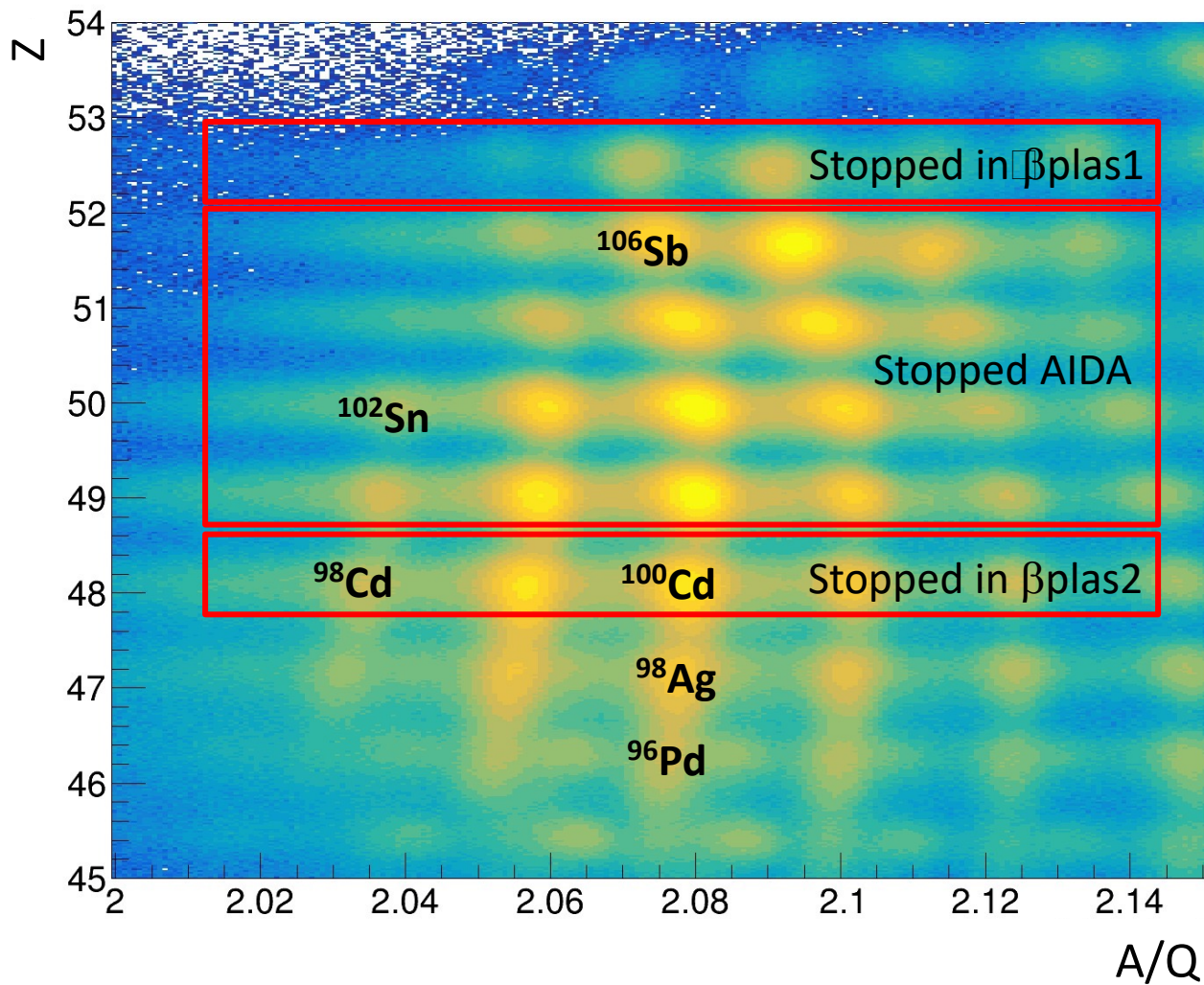
$$ToF - B\rho - \Delta E$$



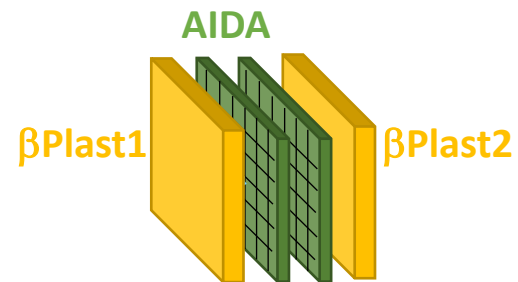
- **AIDA**: a stack of 2 DSSSD detectors
- **bPlast**: fast plastic detector
- **Euroball**: four 7-fold HPGe clusters
- **FATIMA**: 36 $\text{LaBr}_3(\text{Ce})$ detectors

A. K. Mistry et al., Nucl. Instrum. Methods Phys. Res. A 1033 (2022) 166662

Particle identification



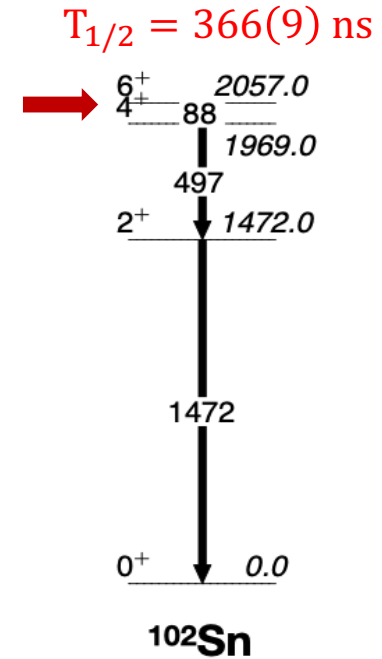
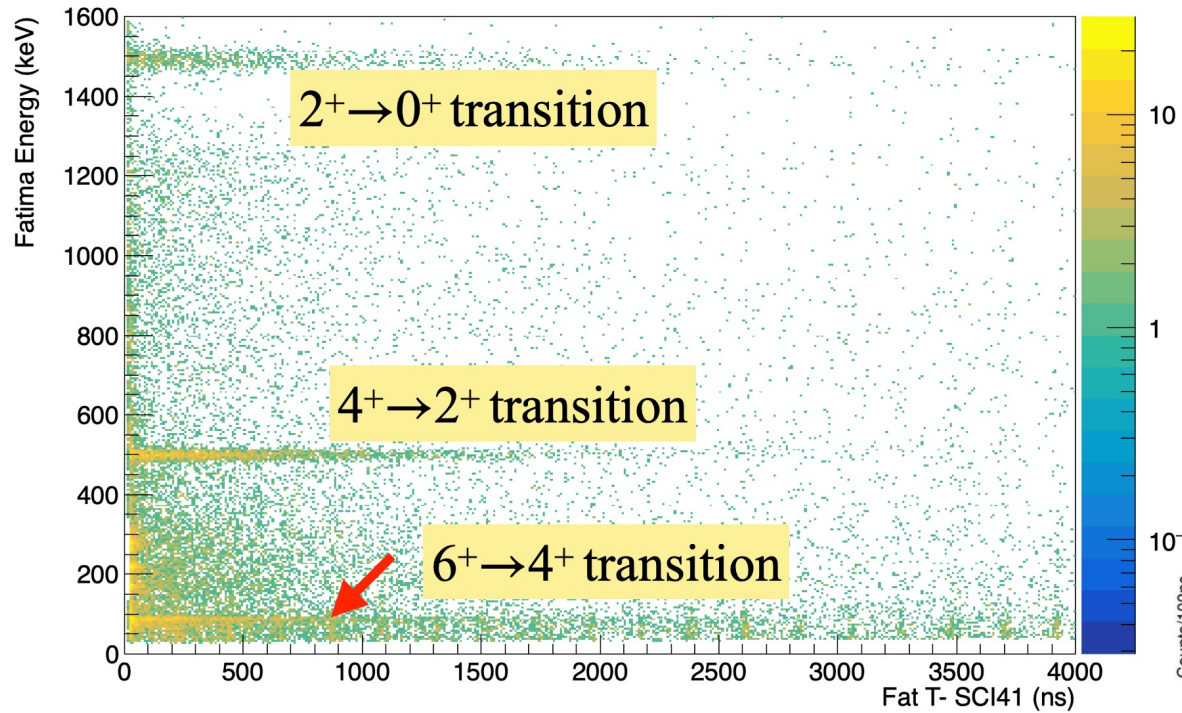
Ions with known isomers are labeled



Total implanted ions:

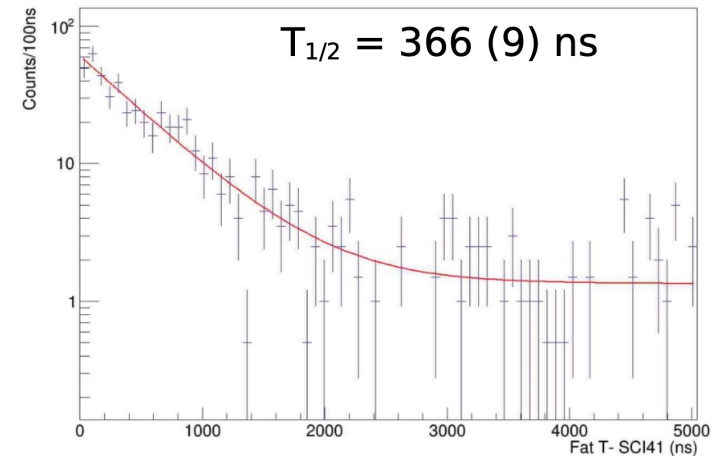
- ^{98}Cd : 1.097×10^6
- ^{100}Cd : 7.081×10^6
- ^{102}Sn : 3.62×10^5

^{102}Sn : isomer benchmark



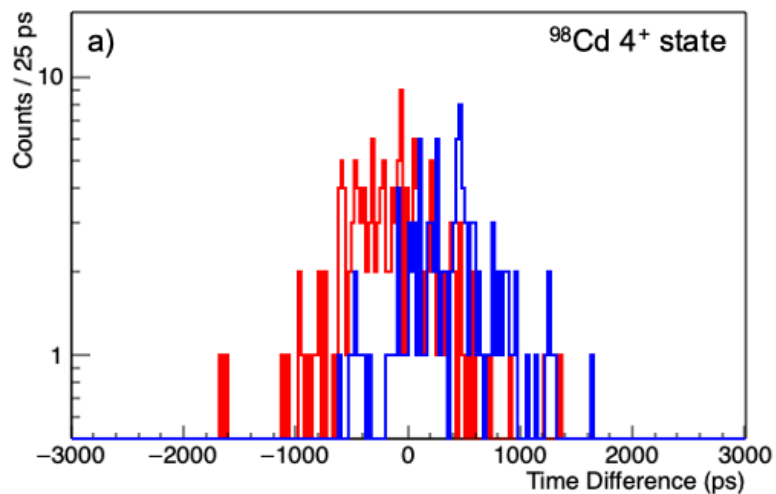
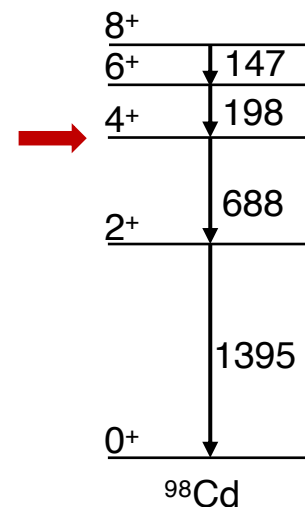
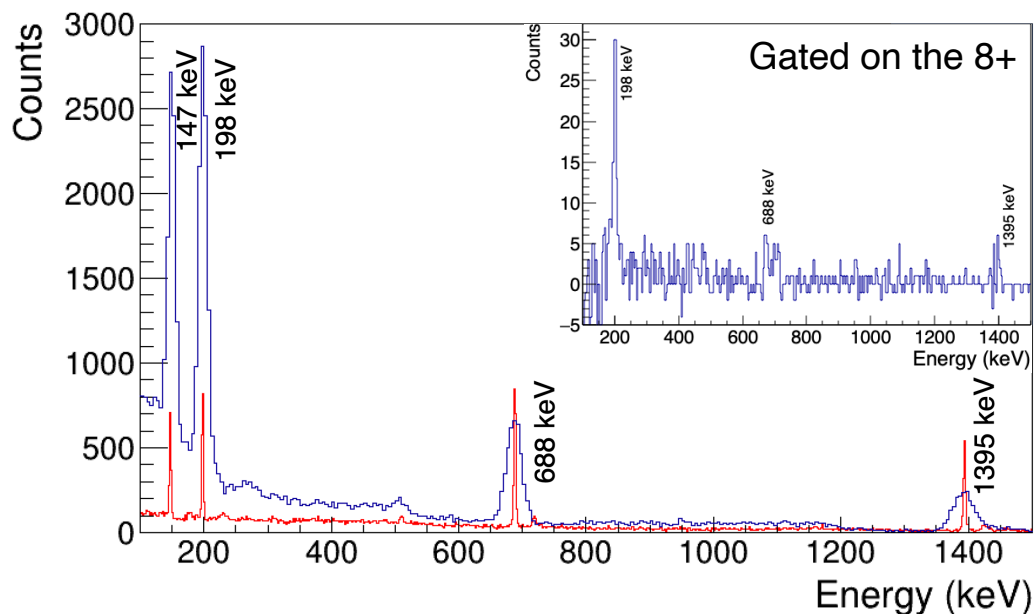
H. Grawe et al., Physics Letters B 820 (2021) 136591

- Lifetime measured by $\beta\text{-}\gamma\text{-}\gamma\text{-}\gamma\text{-}\alpha\text{-}\gamma$ time difference
- Ions produced in isomeric states
→ ion-implantation delayed time difference



S. Langelund, Master thesis (2021)

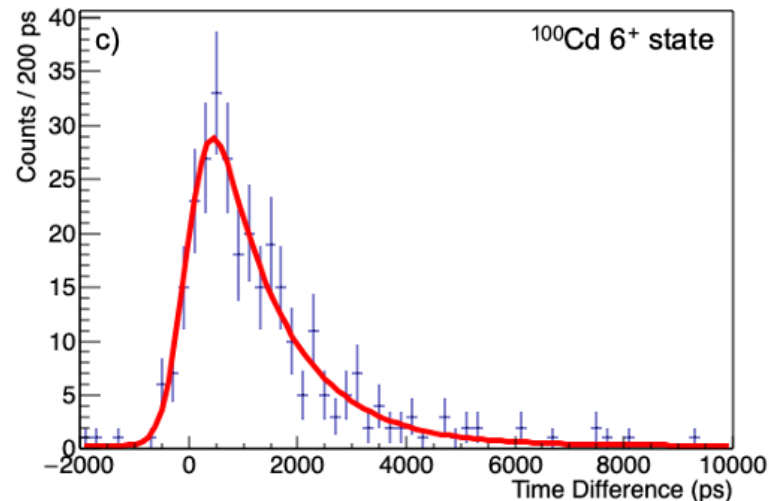
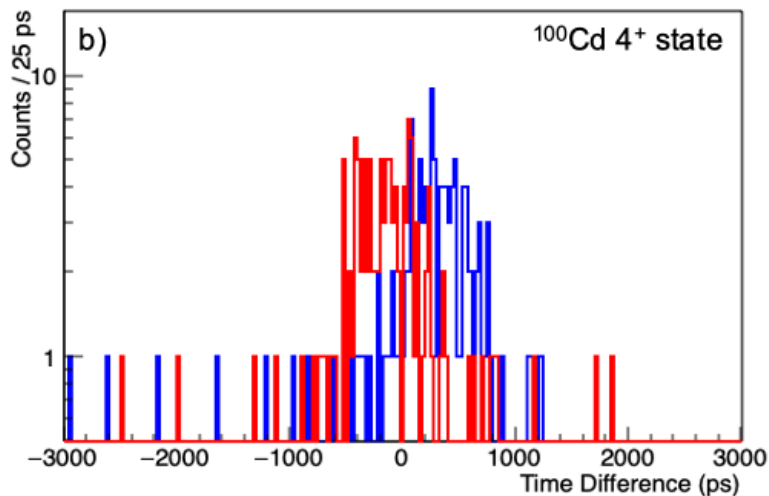
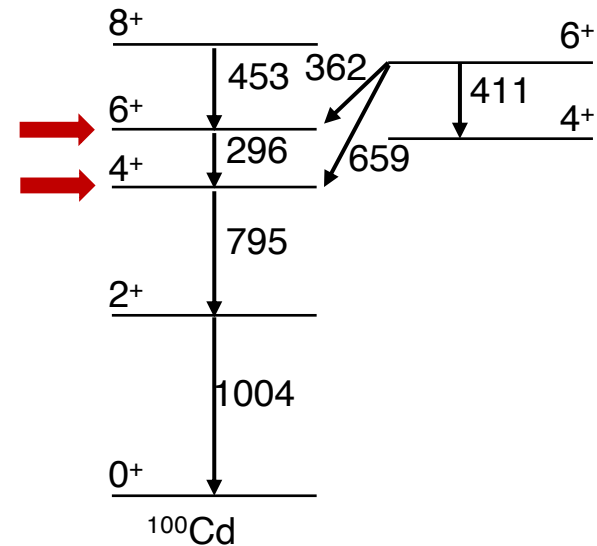
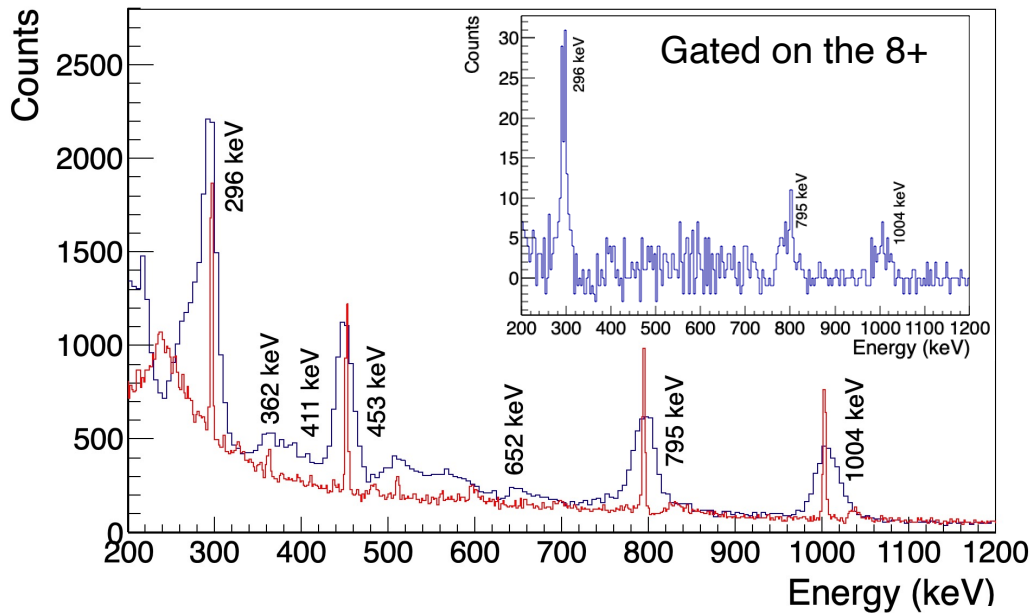
^{98}Cd : preliminary results



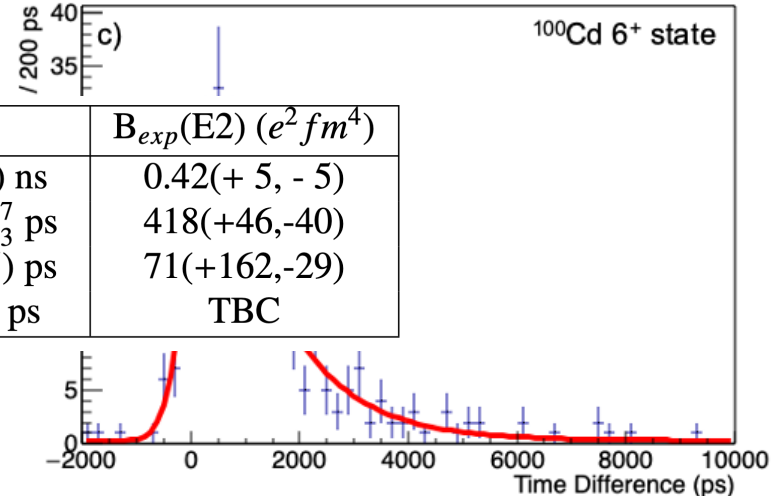
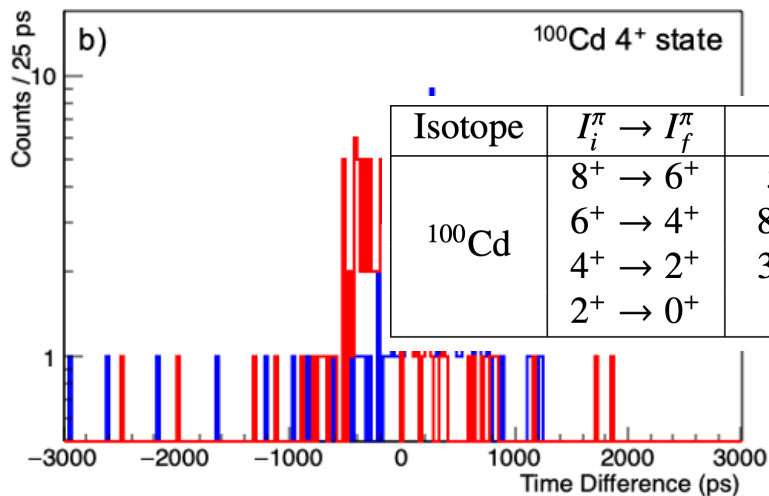
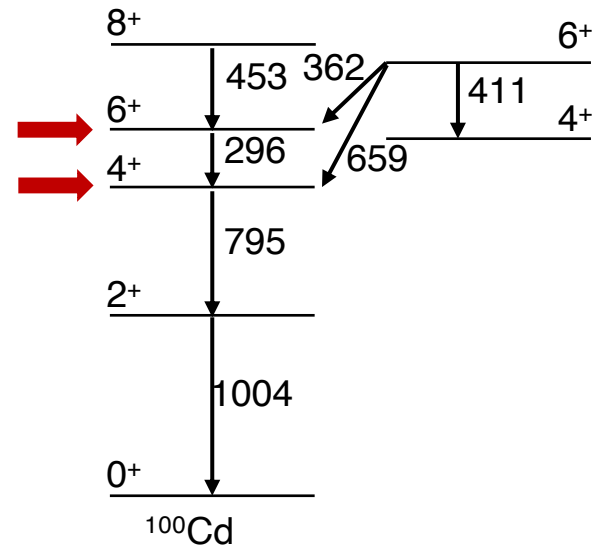
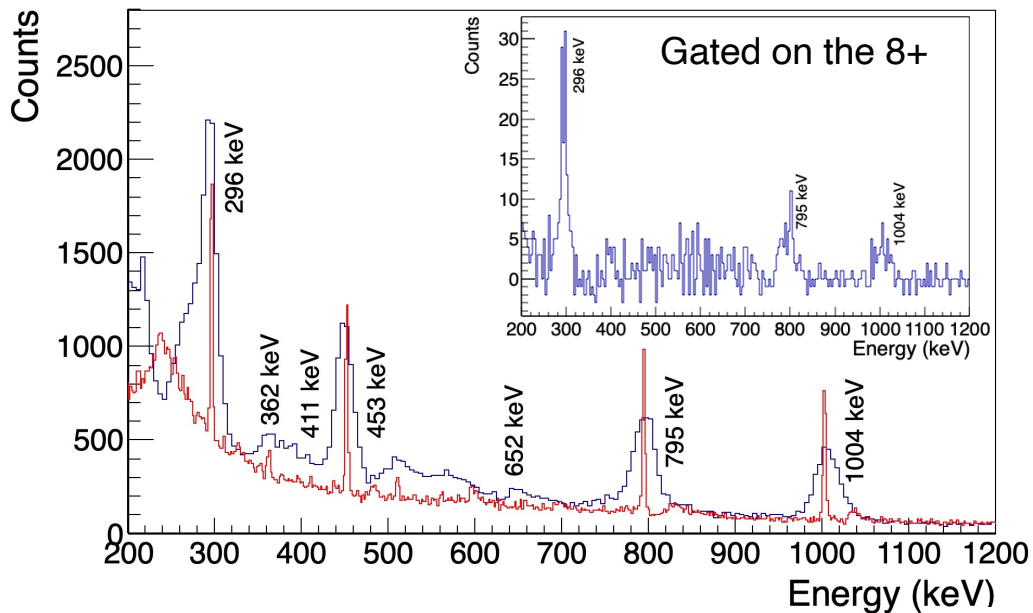
Isotope	$I_i^\pi \rightarrow I_f^\pi$	τ	$B_{exp}(E2) (e^2 fm^4)$
^{98}Cd	$8^+ \rightarrow 6^+$	221(14) ns	37(4)
	$6^+ \rightarrow 4^+$	11(1) ns*	122(18)
	$4^+ \rightarrow 2^+$	58(27)	98(+80,-29)
	$2^+ \rightarrow 0^+$	—	—

*Value taken from literature

^{100}Cd : preliminary results



^{100}Cd : preliminary results



Isotope	$I_i^\pi \rightarrow I_f^\pi$	τ	$B_{exp}(E2) (e^2 fm^4)$
^{100}Cd	$8^+ \rightarrow 6^+$	53(3) ns	0.42(+5, -5)
	$6^+ \rightarrow 4^+$	832^{+87}_{-83} ps	418(+46, -40)
	$4^+ \rightarrow 2^+$	36(25) ps	71(+162, -29)
	$2^+ \rightarrow 0^+$	$> 1^*$ ps	TBC

^{98}Cd : Comparison with SM

^{98}Cd

8^+ <u>2316</u>	8^+ <u>2428</u>
6^+ <u>2201</u>	6^+ <u>2281</u>
4^+ <u>2008</u>	4^+ <u>2082</u>
2^+ <u>1389</u>	2^+ <u>1395</u>

- Core: ^{56}Ni
- Valence space: $0f_{5/2}, 1p_{3/2}, 1p_{1/2}, 0g_{9/2}$
- Single particle energies: taken from the experimental spectrum of ^{57}Cu
- Two-body matrix elements: many-body perturbation starting from the CD-Bonn NN potential

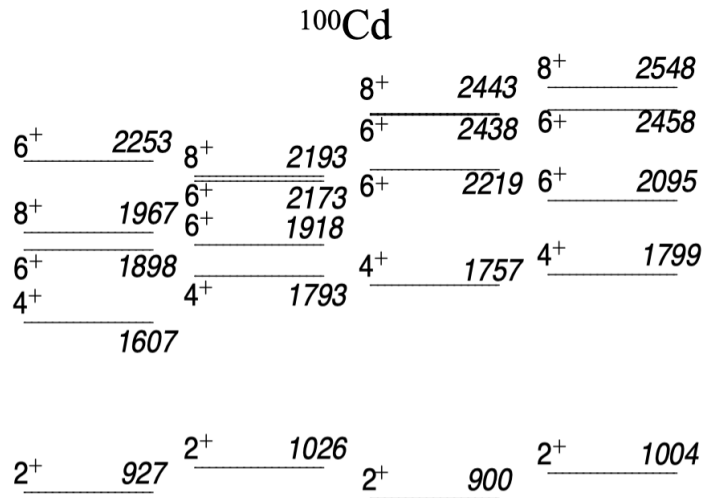
0^+ <u>0</u>	0^+ <u>0</u>
shell model	EXP

$B_{exp}(E2) (e^2 fm^4)$

$I_i^\pi \rightarrow I_f^\pi$	Exp	SM
$8^+ \rightarrow 6^+$	37(4)	50
$6^+ \rightarrow 4^+$	122(18)	125
$4^+ \rightarrow 2^+$	98(+80,-29)	178
$2^+ \rightarrow 0^+$	-	147

Good agreement with a seniority scheme description

^{100}Cd : Comparison with SM



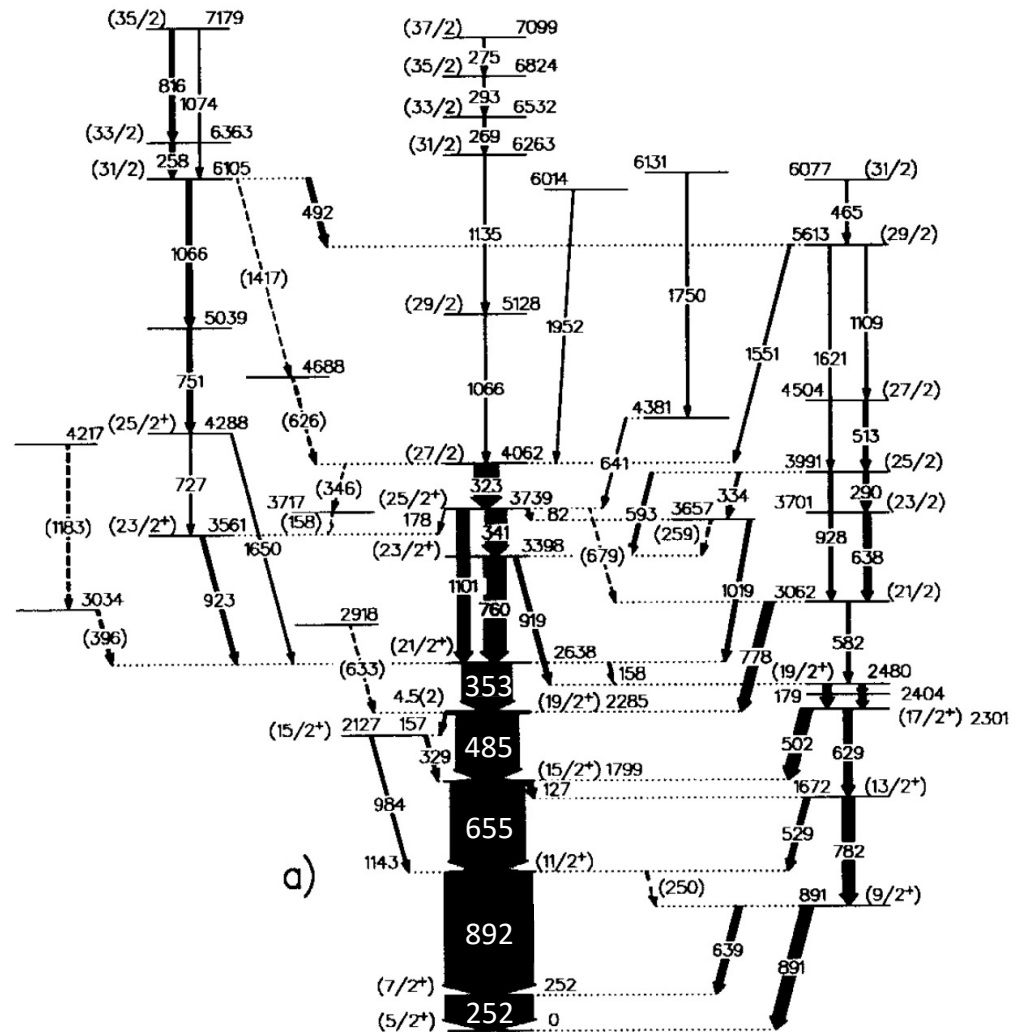
- Core**
- SM1** ^{78}Ni $0g_{7/2}, 1d_{5/2}, 1d_{3/2}, 2s_{1/2}, 0h_{11/2}$
[L. Coraggio et al., Phys. Rev. C 105 \(2022\) 034312](#)
- SM2** ^{88}Sr $\pi(1p_{1/2}0g1d_{5/2}), \nu(0g_{7/2}1d2s0h_{11/2})$
 proton cross-shell excitations
[L. Coraggio et al., Phys. Rev. C 91 \(2015\) 041301](#)
- SM3** ^{80}Zr $\pi\nu(0g1d2s)$
 proton and neutron cross-shell excitations
[B. S. Nara Singh et al., Phys. Rev. Lett. 107 \(2011\) 172502](#)

$B_{exp}(E2) (e^2 fm^4)$

$I_i^\pi \rightarrow I_f^\pi$	Expt	SM1	SM2	SM3
$8^+ \rightarrow 6_2^+$	60(+33, -27)	0.004	94	58
$8^+ \rightarrow 6_1^+$	0.42(5)	57	2	0.06
$6_1^+ \rightarrow 4^+$	418(+46, -40)	170	107	283
$4^+ \rightarrow 2^+$	71(+162, -29)	267	575	574
$2^+ \rightarrow 0^+$	-	201	476	391

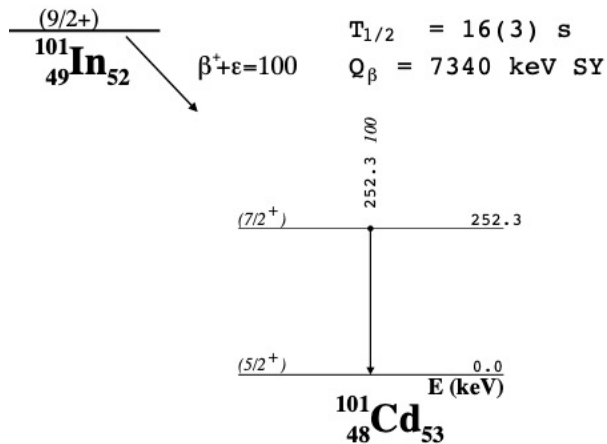
^{101}Cd : first measurement of I_β and $\log ft$

$^{58}\text{Ni}(^{50}\text{Cr}, 2p\alpha n)^{101}\text{Cd}$ reaction

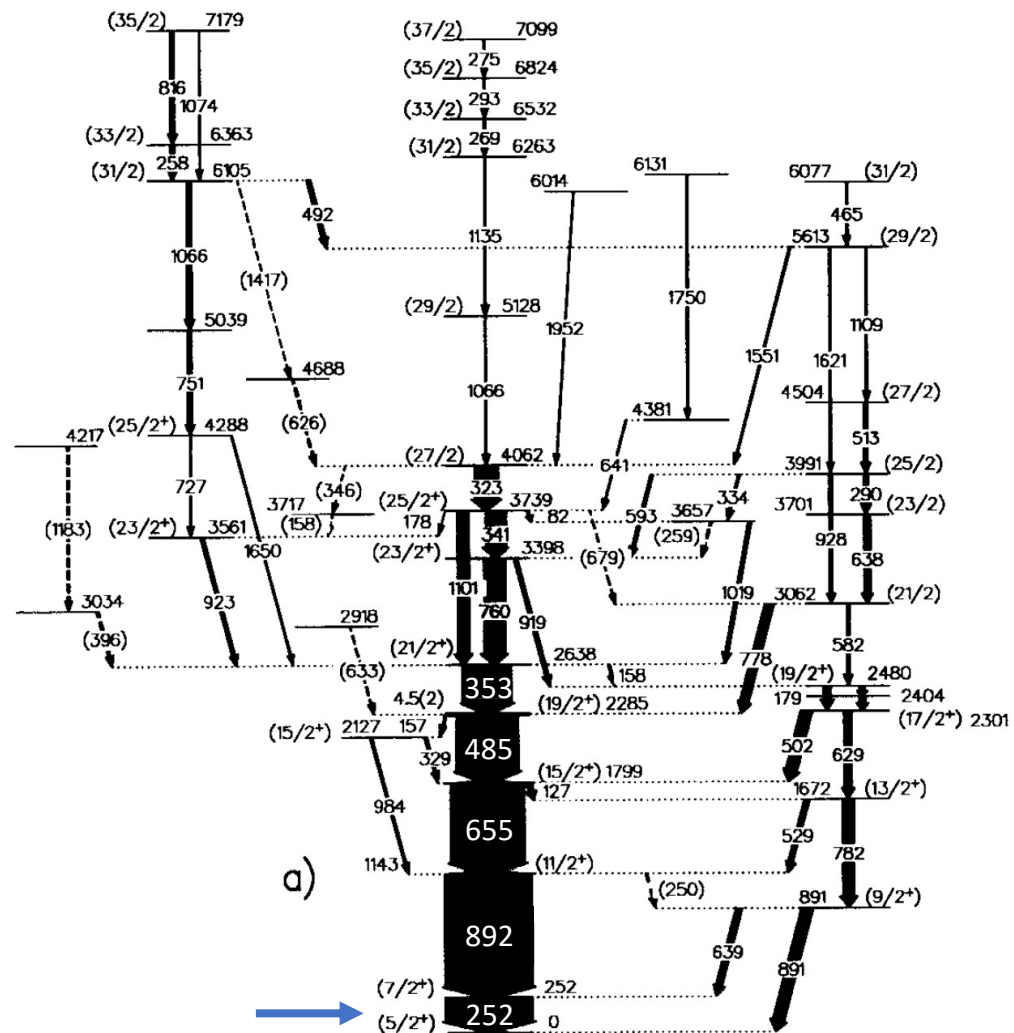


M. Palacz et al., Nucl. Phys. A 608 (1996) 227–242

^{101}Cd : first measurement of I_β and $\log ft$

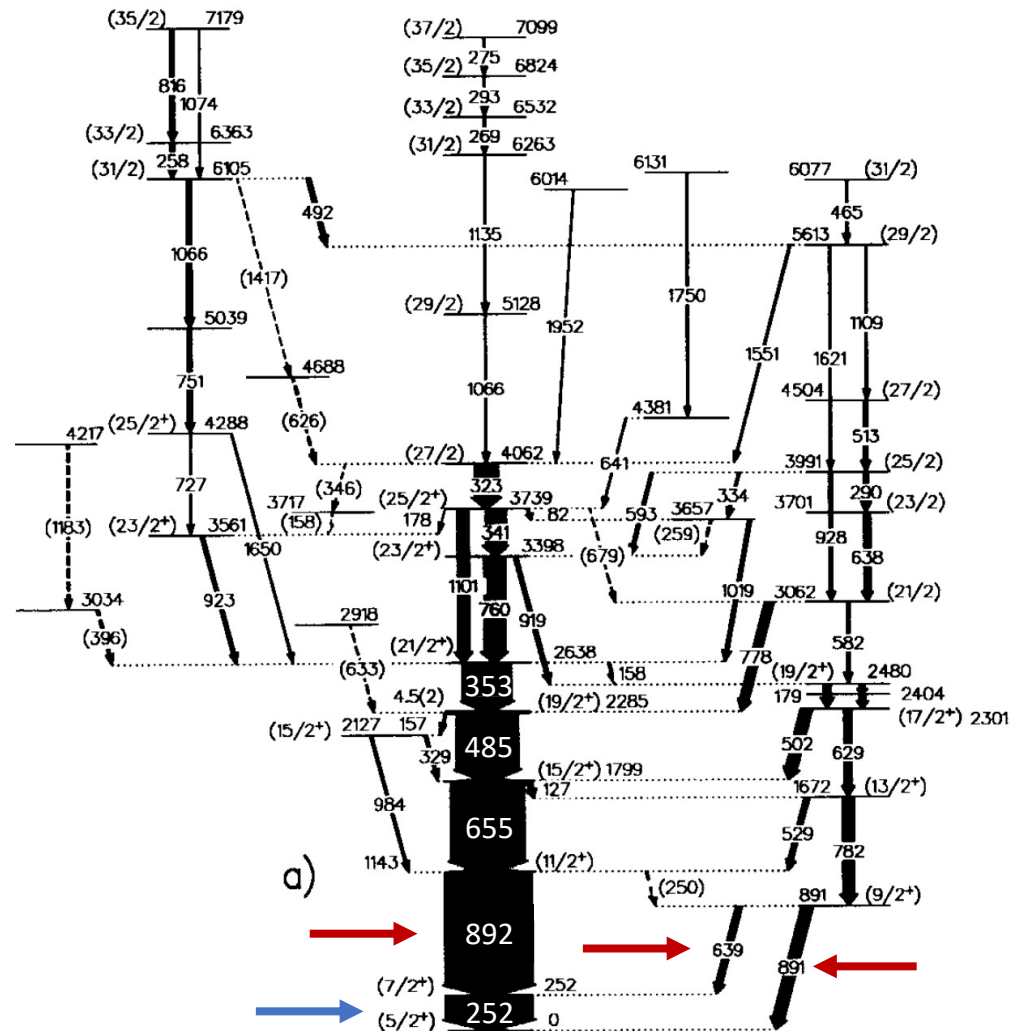
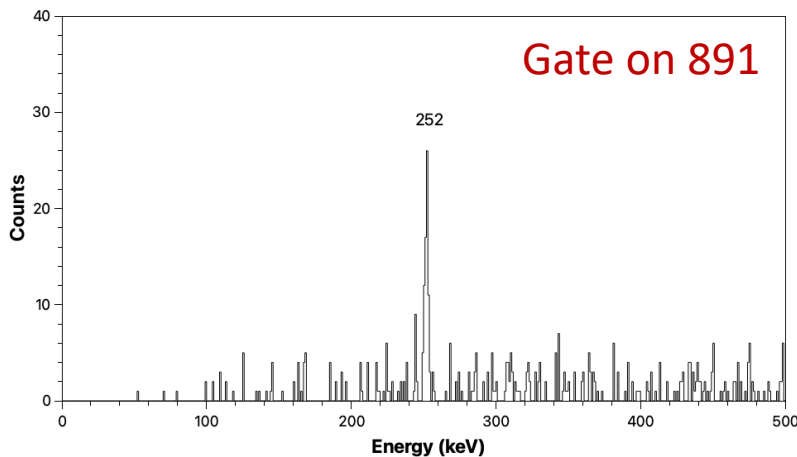
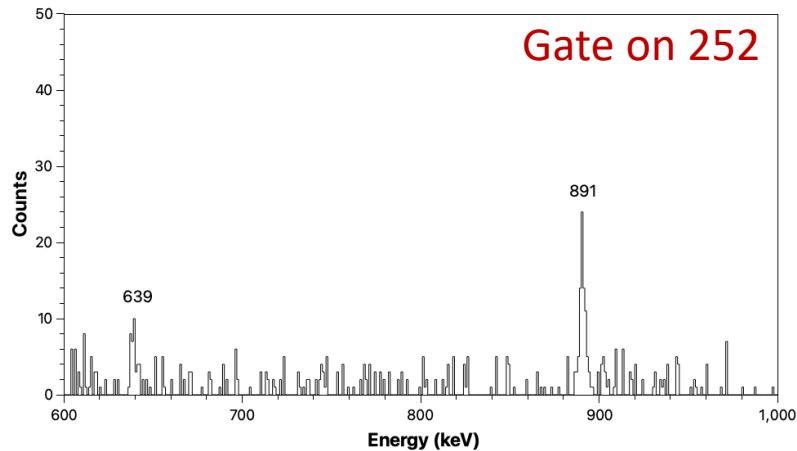


M. Huyse et al., Z. Phys. A 330 (1988) 121–122



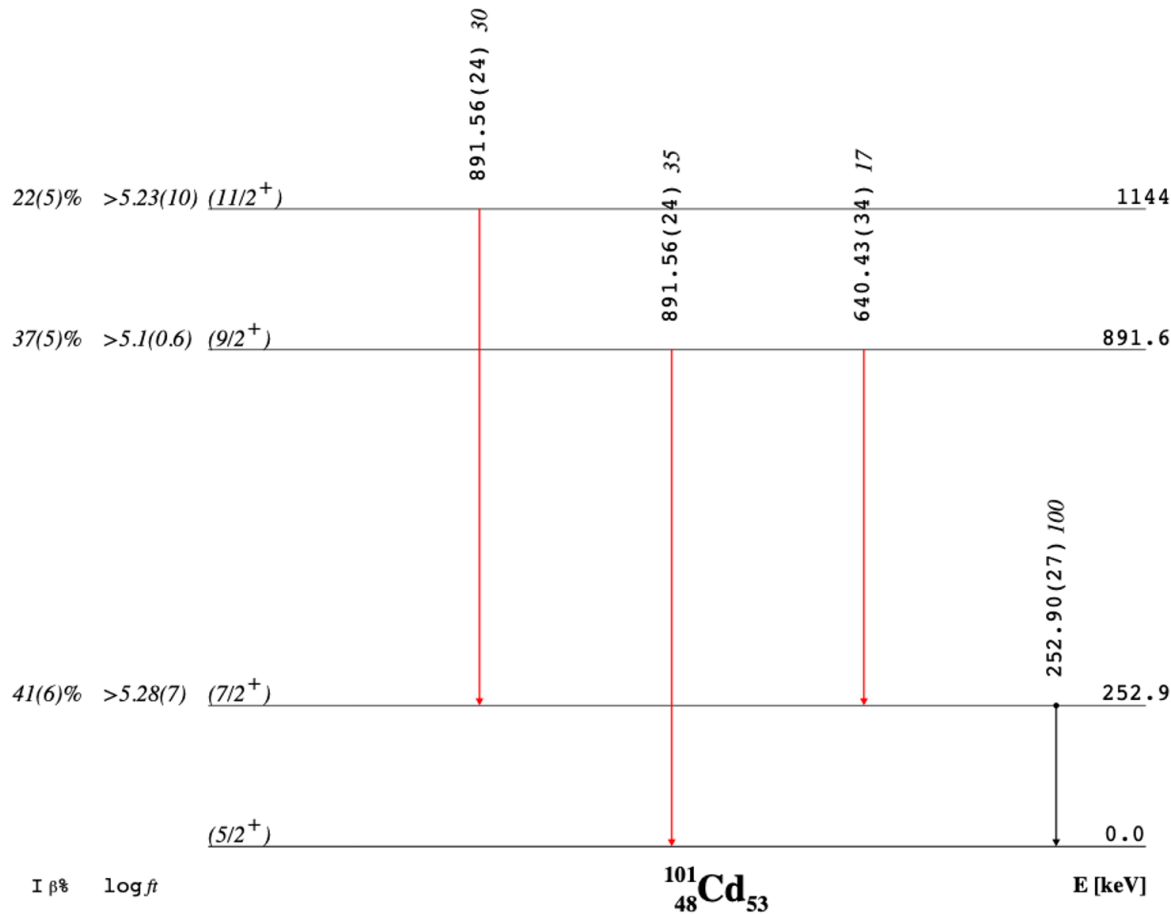
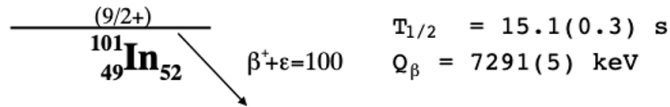
M. Palacz et al., Nucl. Phys. A 608 (1996) 227–242

^{101}Cd : first measurement of I_β and $\log ft$



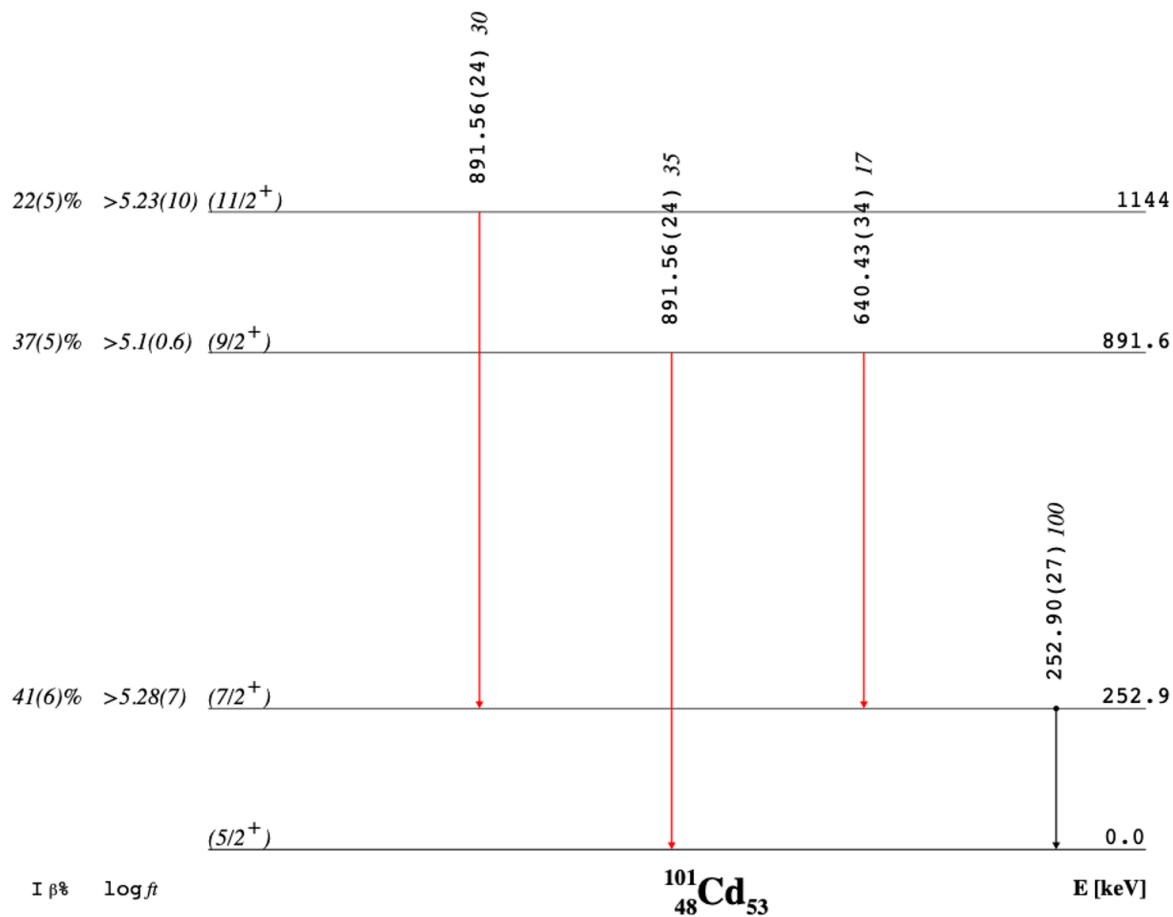
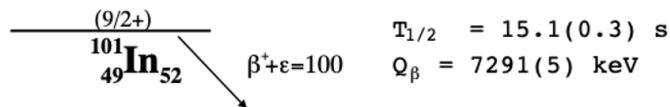
M. Palacz et al., Nucl. Phys. A 608 (1996) 227–242

^{101}Cd : comparison with theoretical calculations



- Levels' spin and parity confirmed
- **Allowed β decay**

^{101}Cd : comparison with theoretical calculations



6.28 ($11/2^+$) 1055

6.19 ($9/2^+$) 974.0

6.07 ($7/2^+$) 219.0

0.0 ($5/2^+$) 0.0

$\log ft$ E [keV]

Calculations performed by Yuan Cenxi (Sino-French Institute of Nuclear Engineering and Technology, Sun Yat-Sen University, Guangdong, China)

Conclusions and future perspectives

Our experimental study aimed at performing isomer and β decay studies in the ^{100}Sn region. The experiment was performed at GSI in April 2021 using the FRS+DESPEC setup.

First results:

- First lifetime results by fast-timing measurements in ^{102}Sn , $^{98,100}\text{Cd}$
- Beta-decay study of ^{101}Cd

Future developments:

- β decay studies in populated nuclei
- Study of ^{103}Sn via α -delayed γ -ray spectroscopy and related lifetime information
- Measurement of the 4+ state in ^{102}Sn

The DESPEC collaboration for the S496 experiment

G. Zhang, D. Mengoni, G. Pasqualato, D. Bazzacco, D. Brugnara, J. Ha, **Z.Huang**, S.M. Lenzi, M. Mazzocco, R. Menegazzo, A. Raggio, F. Recchia, F. Soramel, F.Galtarossa
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C. Appleton, T. Davidson, O. Hall, P. Woods, L. Sexton
University of Edinburgh

Thank you for
your attention!

