14th International Spring Seminar on Nuclear Physics

23rd May 2025

Approaching ^{100}Sn: Structural evolution in ^{98,100}Cd via lifetime measurements

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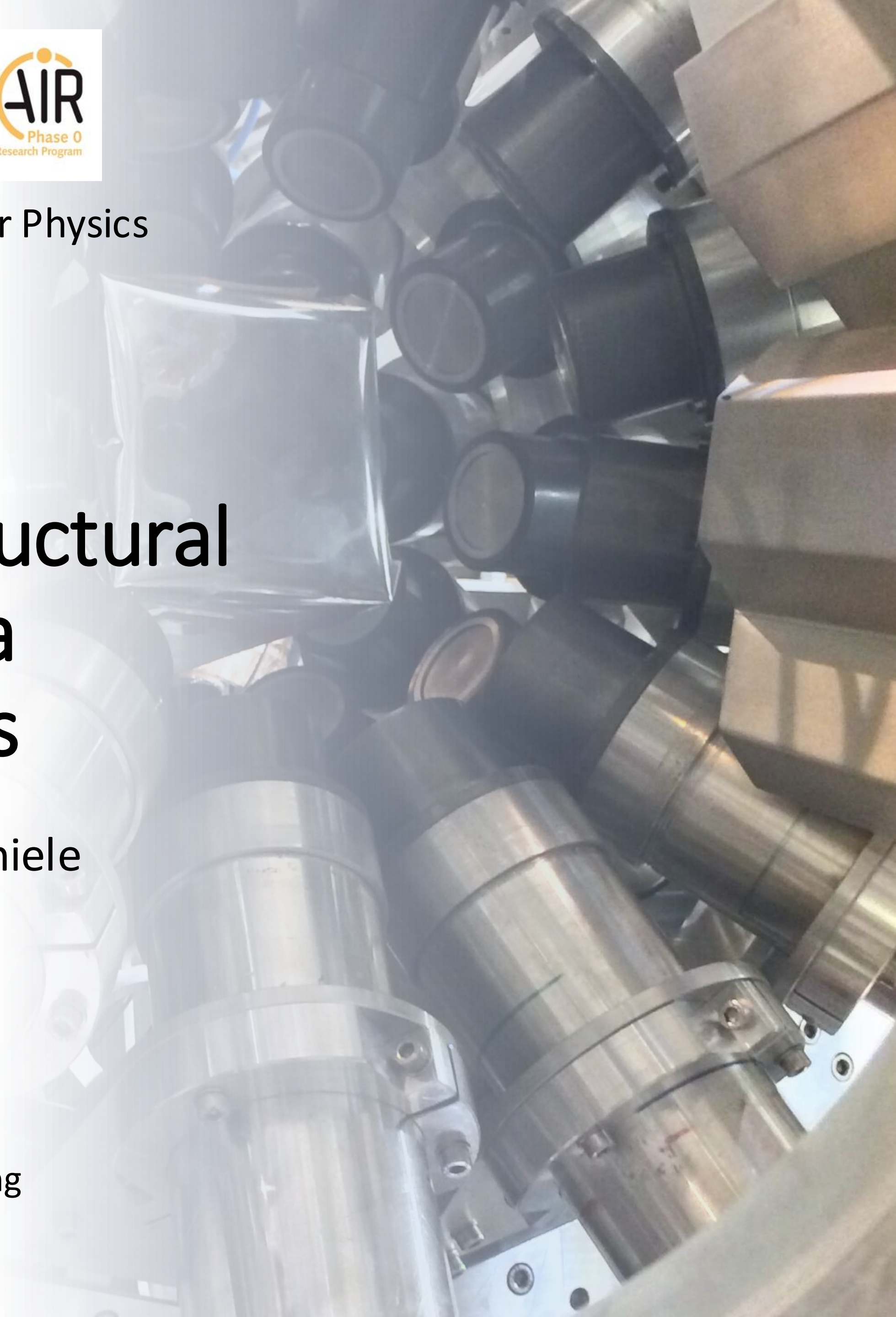
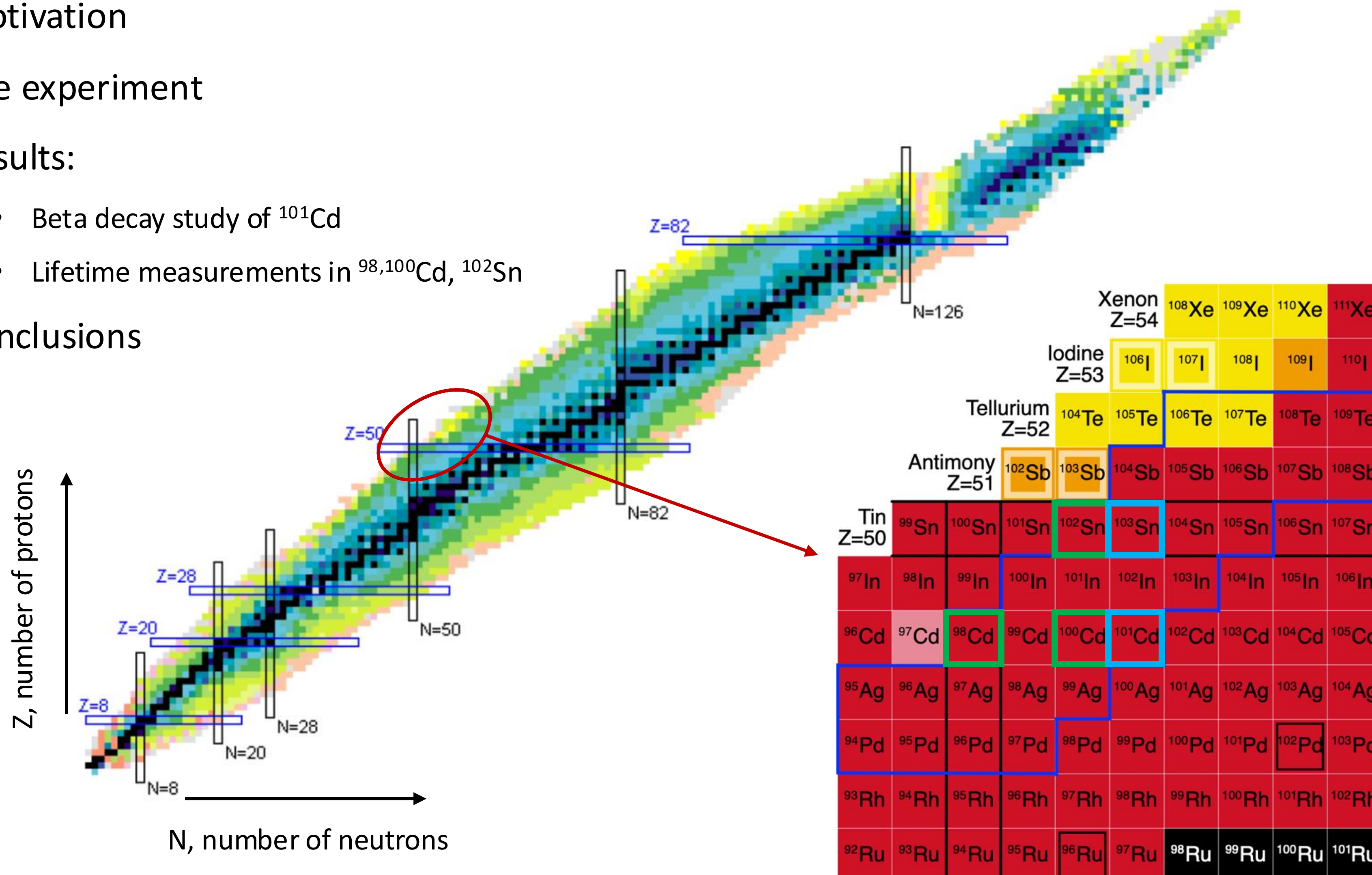


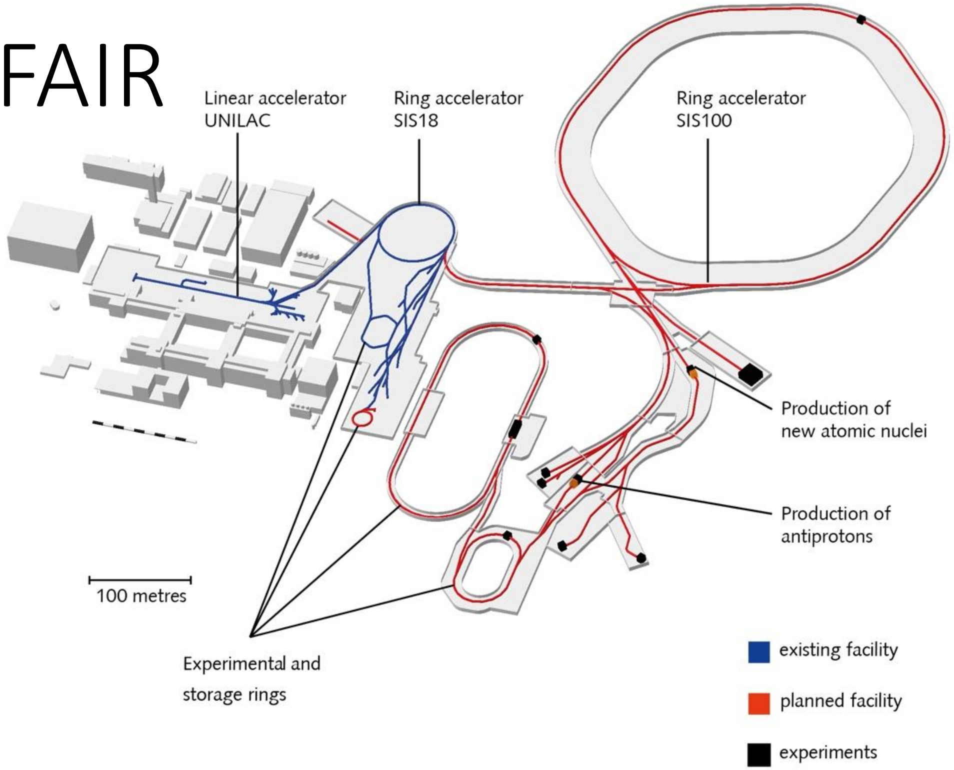
Outline

- Motivation
- The experiment
- Results:
  - Beta decay study of ^{101}Cd
  - Lifetime measurements in ^{98,100}Cd, ^{102}Sn
- Conclusions



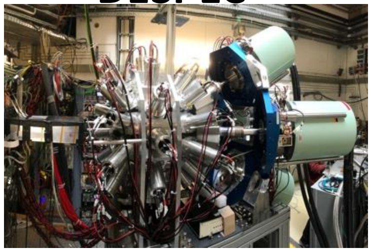
HISPEC-DESPEC at GSI-FAIR

Spectroscopic studies both **in-beam** (HISPEC) and with **stopped ions** (DESPEC).



AGATA

DESPEC



Strength of HISPEC/DESPEC:

- Complete spectroscopy with yields as low as **one ion per hour** (~nb)
- Sensitive to nuclear lifetimes spanning **13 orders of magnitud**e (10 ps – 100s)

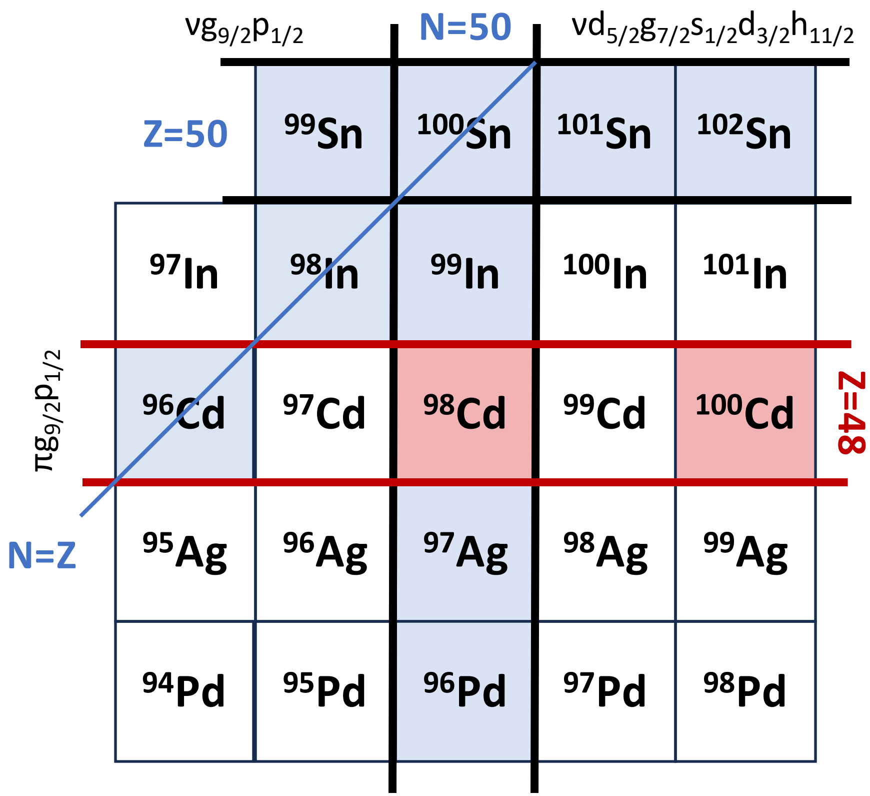
Key goals exploiting unique GSI-FAIR beams:

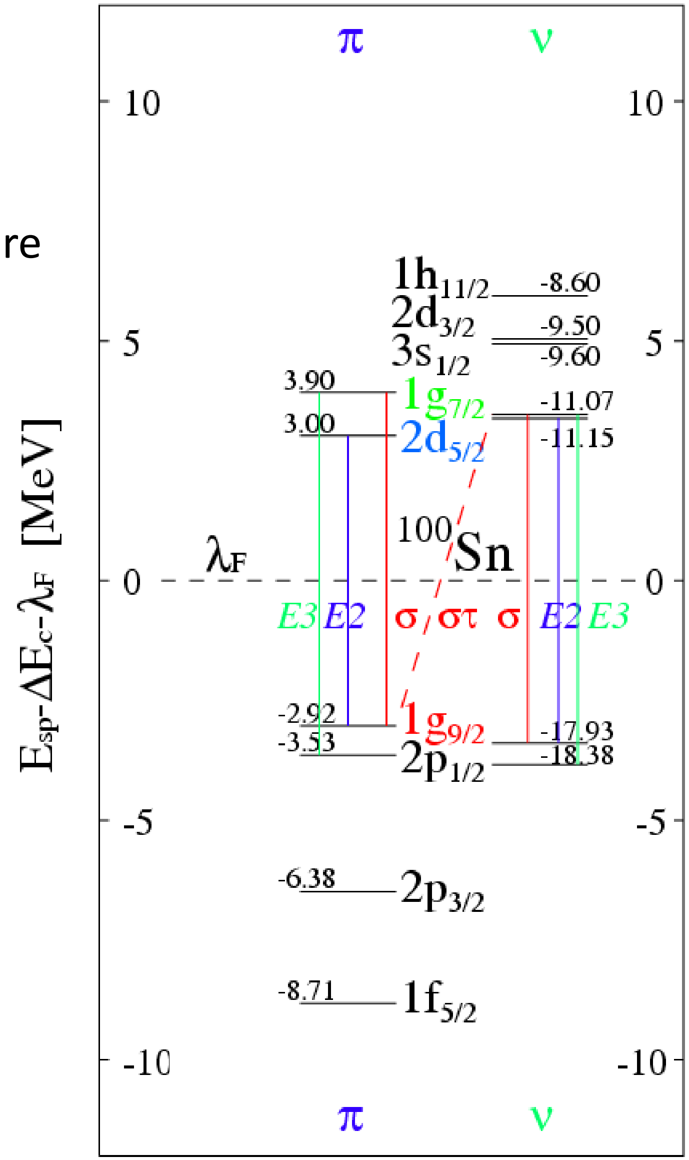
- Approach the r-process path along N=126: **nucleosynthesis of heavy nuclei**
- Nuclear structure of exotic nuclei (also around ^{100}**Sn**)

The ^{100}Sn region

^{100}Sn is the heaviest self-conjugate and doubly magic nucleus (N=Z=50)

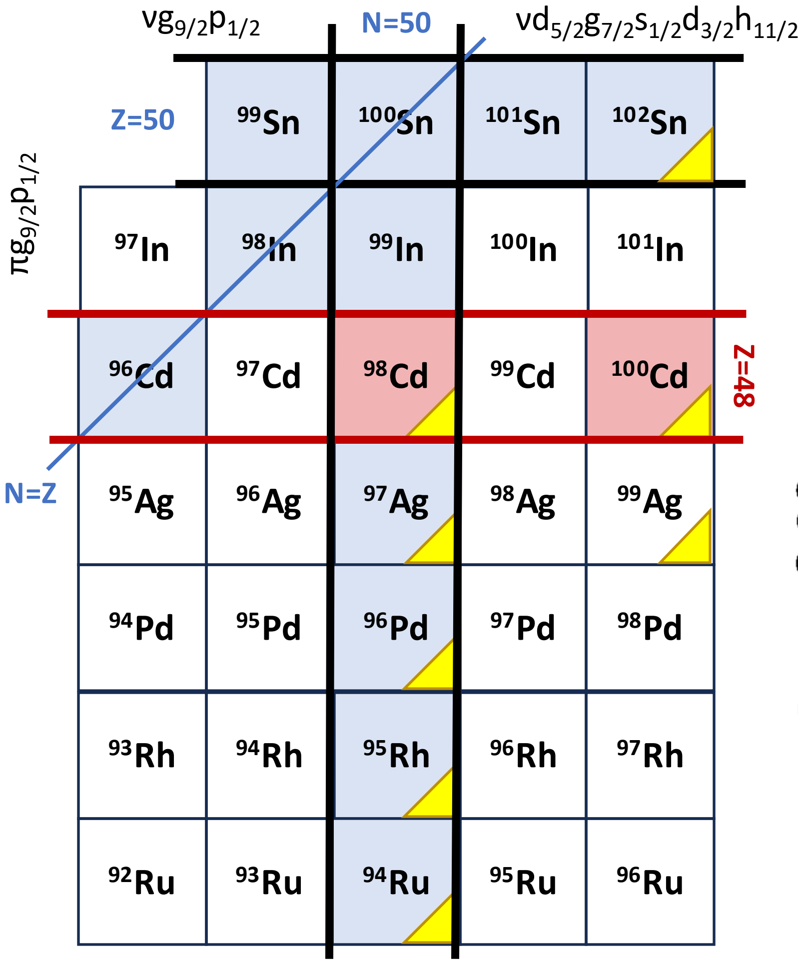
- coupling of **sp states** with respect to a doubly-magic core
- excellent probe to **proton-neutron correlations**



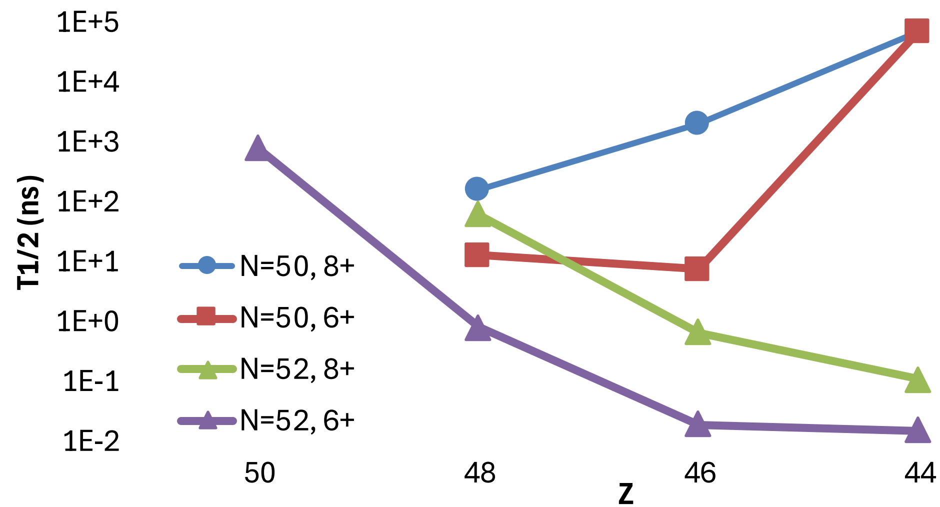


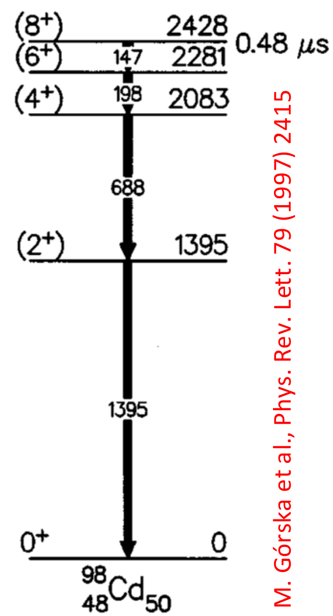
T. Faestermann, Prog.Part. Nucl. Phys. 69, 85 (2013)

Isomeric states in the ^{100}Sn region

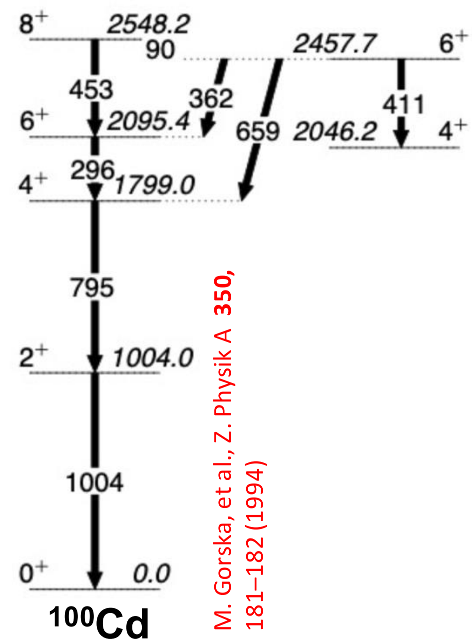



Isomeric states

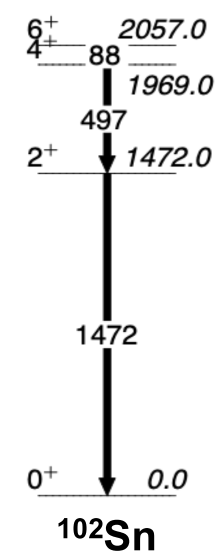




M. Górska et al., Phys. Rev. Lett. 79 (1997) 2415



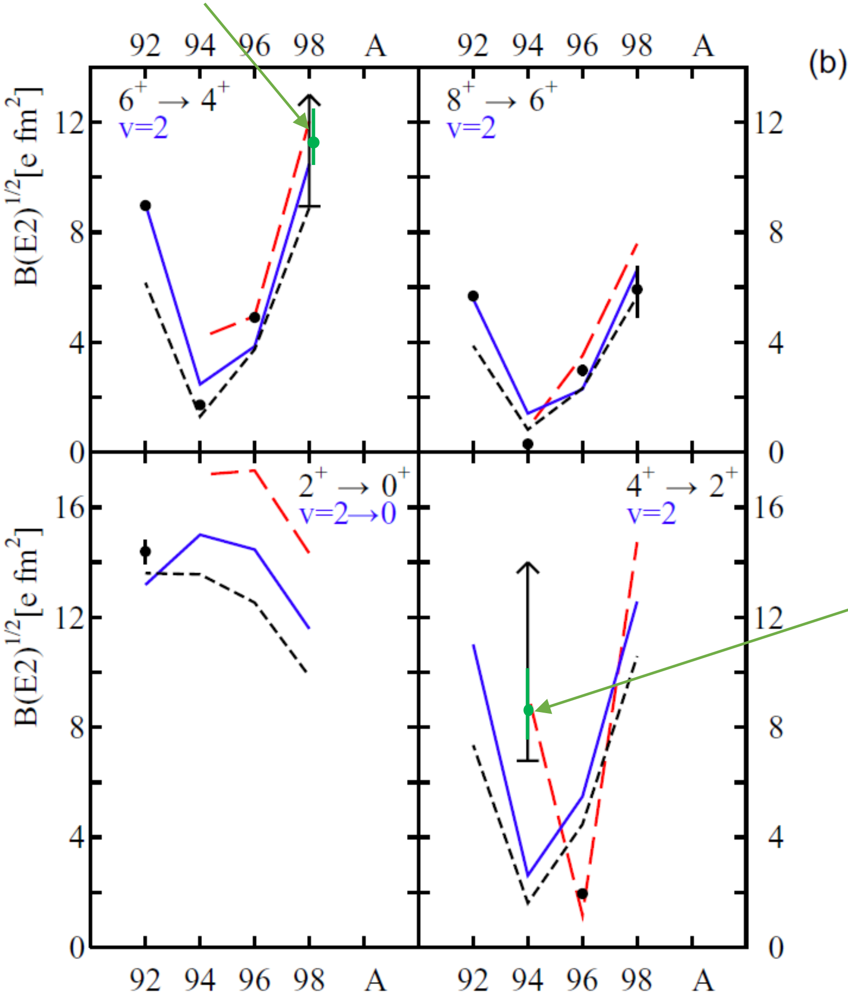
M. Gorska, et al., Z. Physik A **350**, 181–182 (1994)



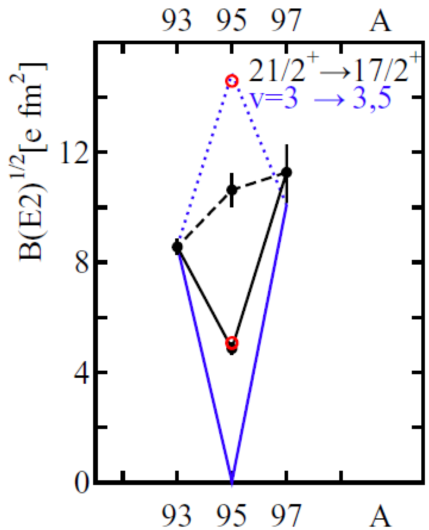
H.Grawe et al., Physics Letters B 820 (2021) 136591

Seniority mixing by core excitation in N=50

^{98}Cd 6^+ - J. Park et al., Phys. Rev. C 96, 044311 (2017)



H. Mach et al., Phys. Rev. C 95, 014313 (2017)



^{95}Rh - B. Das et al., Phys. Rev. Res. **6**, L022038 (2024)

^{94}Ru - B. Das et al., Phys. Rev. C **105**, L031304 (2022)

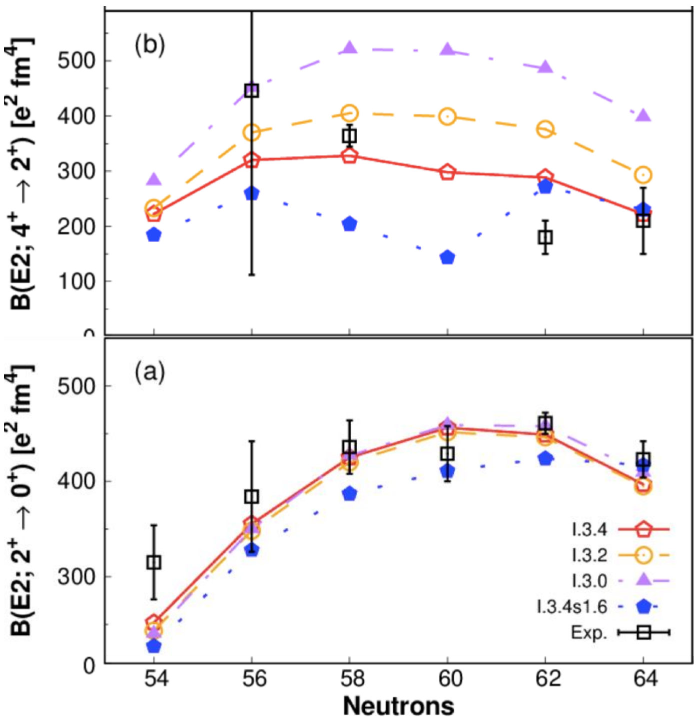
SDG: F. Nowacki

SMLB: A. F. Lisetskiy, B. A. Brown, M. Horoi, and H. Grawe, Phys.Rev. C 70, 044314 (2004).

SMCC: L. Coraggio, A. Covello, A. Gargano, and N. Itaco, Phys. Rev.C 70, 034310 (2004).

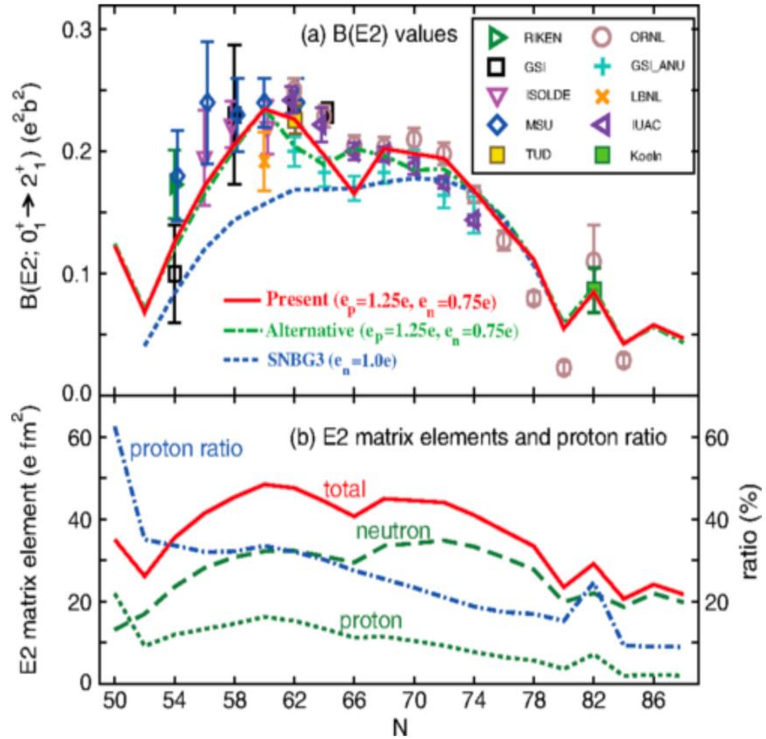
N>50: Sn isotopic chain

- LSSM explained the B(E2 : $0^+ \rightarrow 2^+$) trend by **activating protons and neutrons from the g9/2** orbital or by polarization mechanism
- Relative **proton contribution** larger towards ^{100}Sn
- 4^+ state influenced interplay of **pairing and quadrupole interactions** (A. P. Zuker)



A. P. Zuker et al., Phys. Rev. C 103, 024322 (2021)

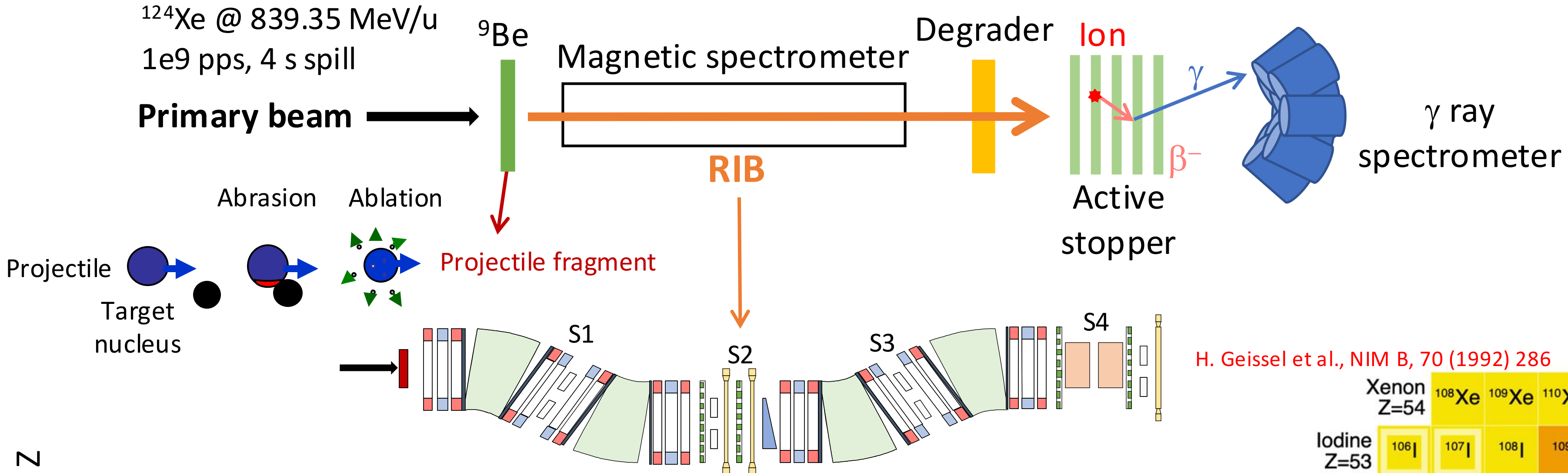
M. Siciliano et al., Phys. Lett. B 806, 135474 (2020)

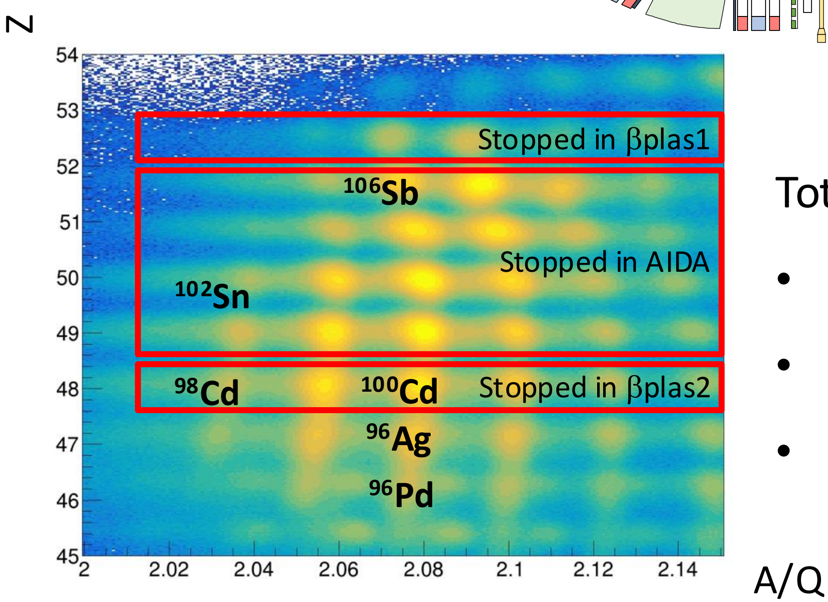


T. Togashi et al., Phys. Rev. Lett. 121 (2018) 062501

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

The FRS+DESPEC setup

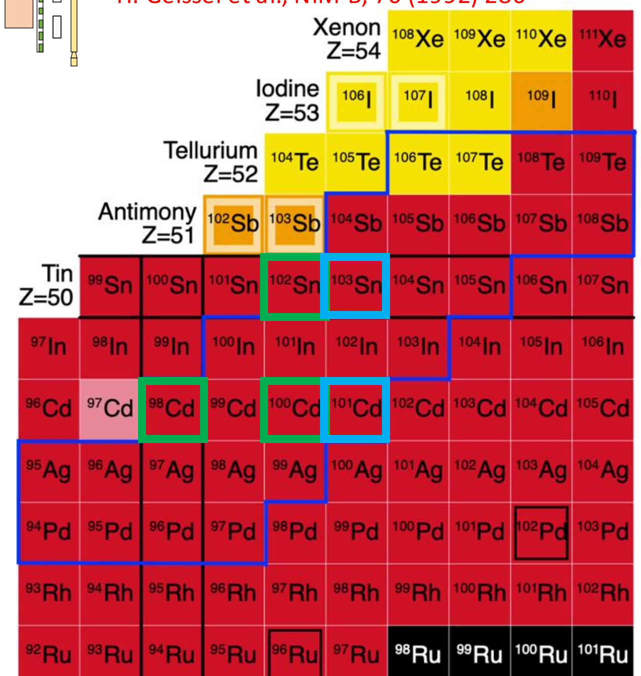




Total implanted ions:

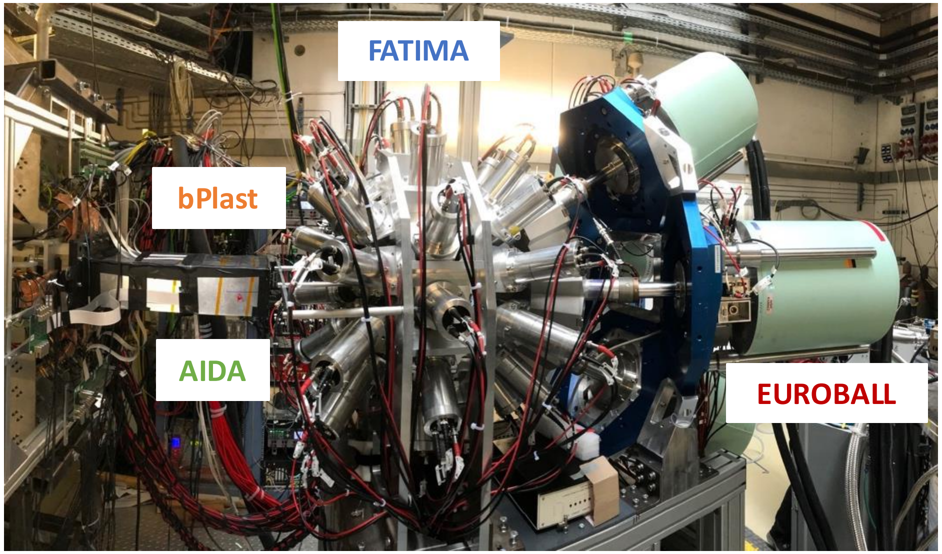
- ^{98}Cd: 1.097E6
- ^{100}Cd: 7.081E6
- ^{102}Sn: 3.62E5

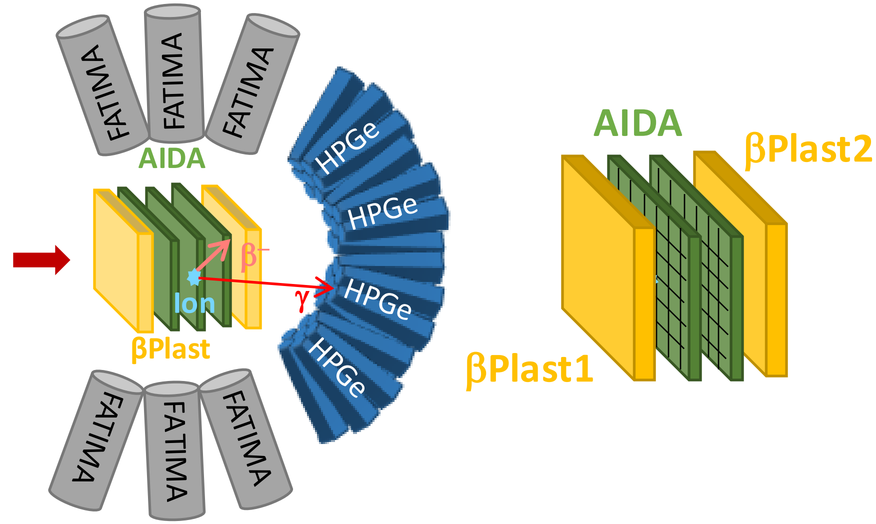
H. Geissel et al., NIM B, 70 (1992) 286



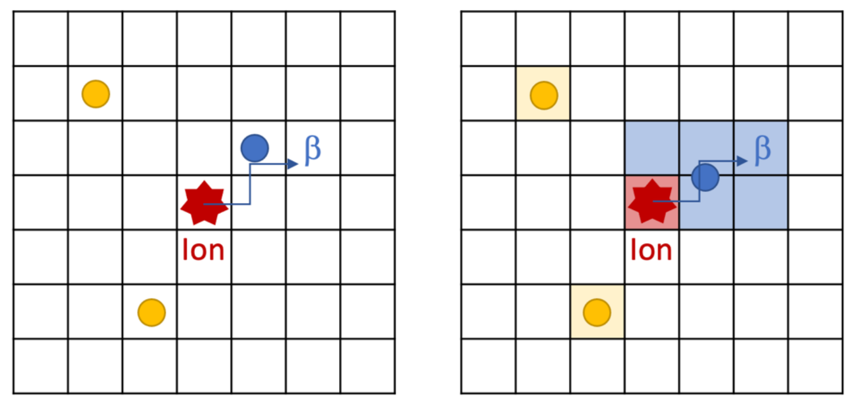
The DESPEC station

A. K. Mistry et al., NIM A 1033 (2022) 166662





- **AIDA:** 8x8 cm^2 DSSSD tiles, 16384 pixels
- **bPlast:** BC-400 plastic detector
- **EUROBALL:** four 7-fold HPGe clusters
- **FATIMA:** 36 $LaBr_3$(Ce) detectors



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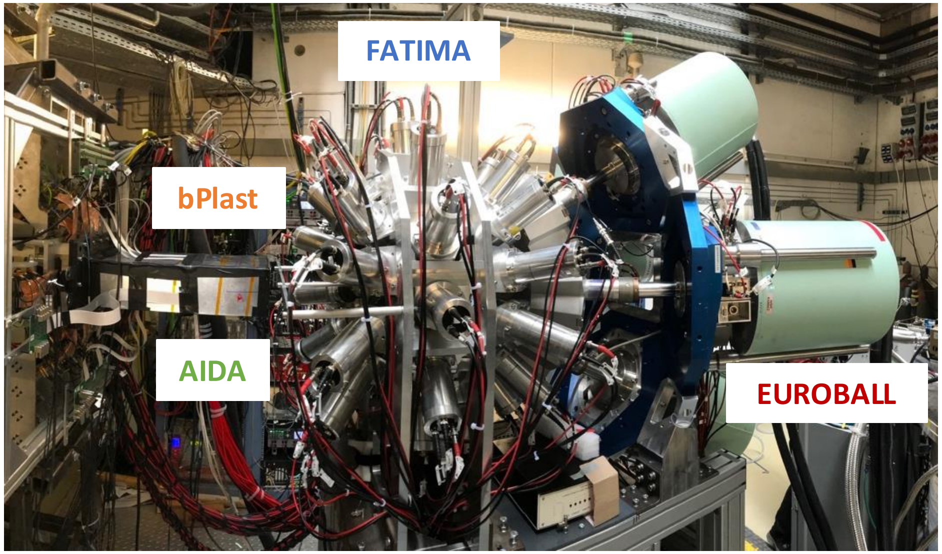
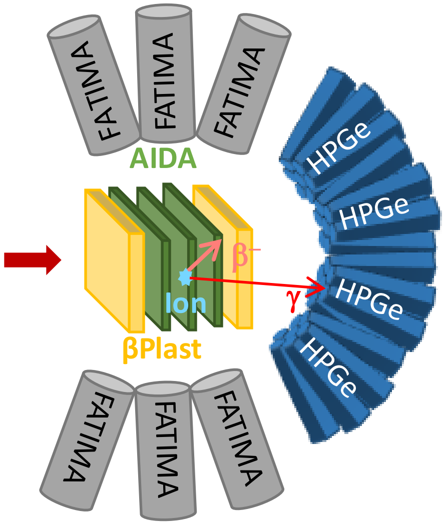
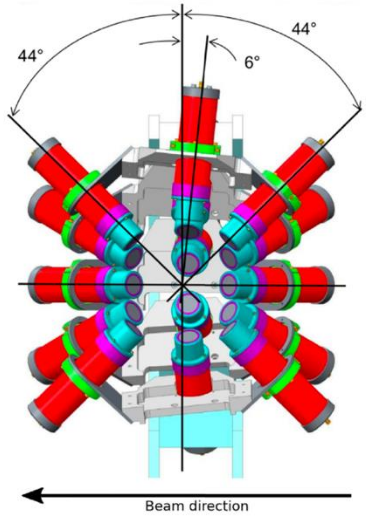
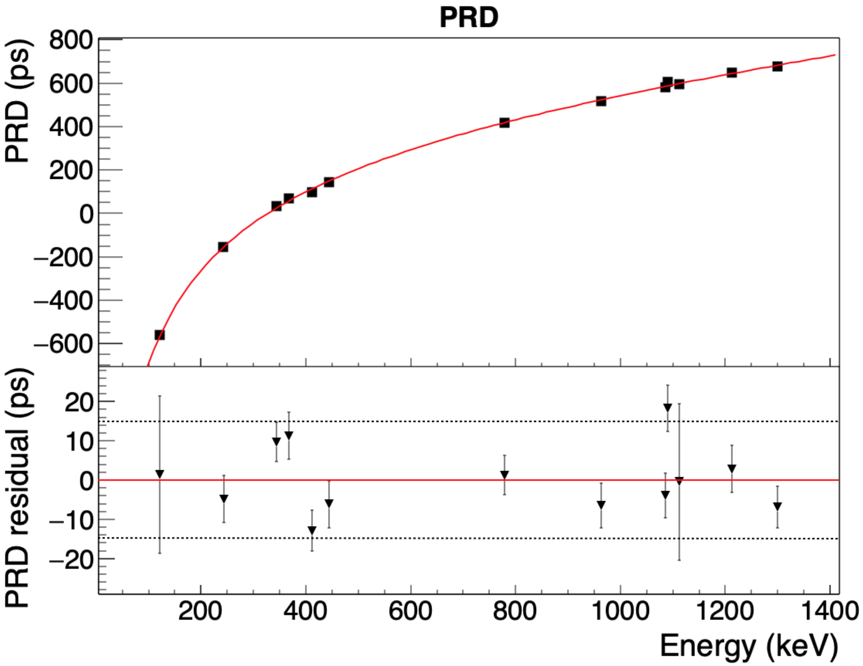
A. K. Mistry et al., NIM A 1033 (2022) 166662









- **AIDA:** 8x8 cm^2 DSSSD tiles, 16384 pixels
- **bPlast:** BC-400 plastic detector
- **EUROBALL:** four 7-fold HPGe clusters
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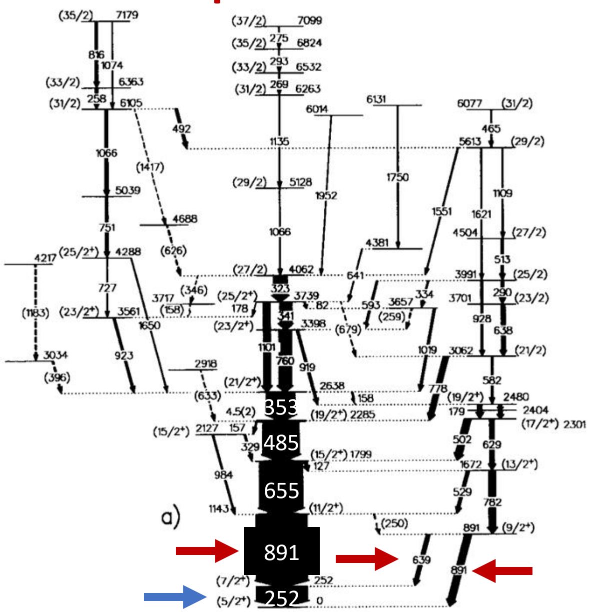
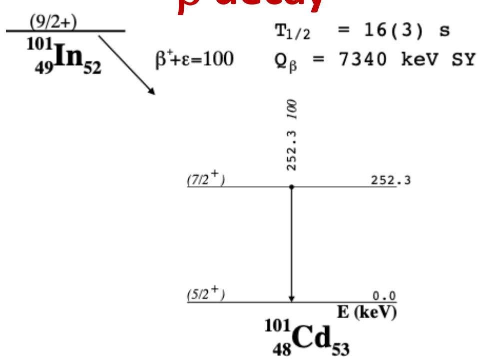
^{101}Cd: beta decay study

Fusion-evaporation reaction

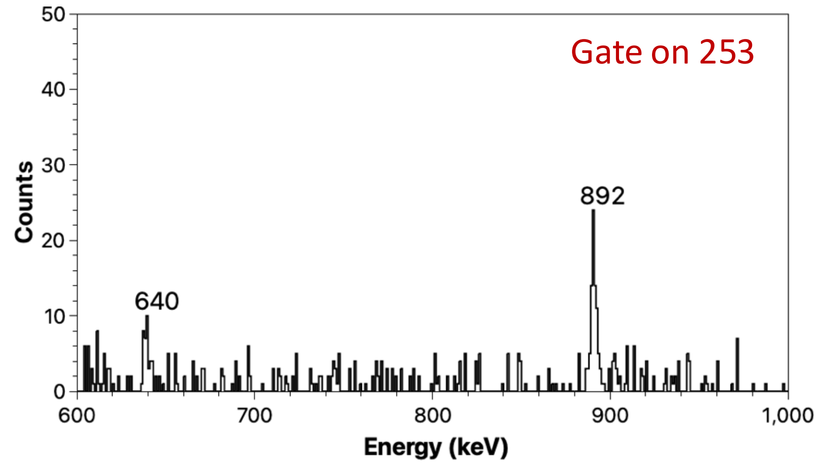


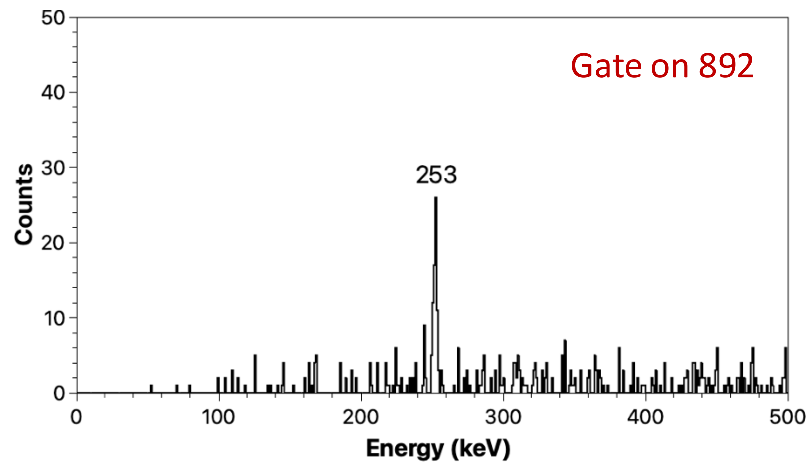
M. Palacz et al., Nucl. Phys. A 608 (1996) 227–242

β decay

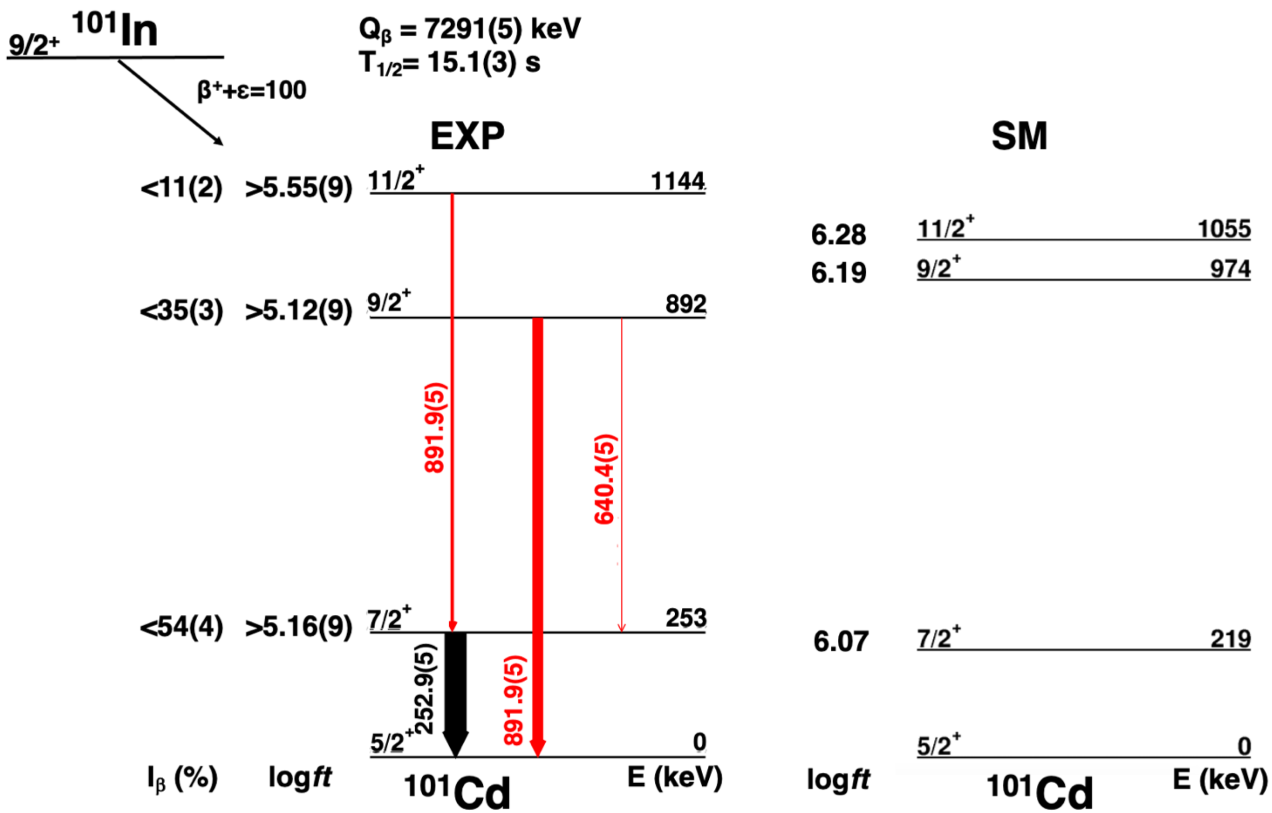


M. Huyse et al., Z. Phys. A 330 (1988) 121–122





^{101}Cd: beta decay study



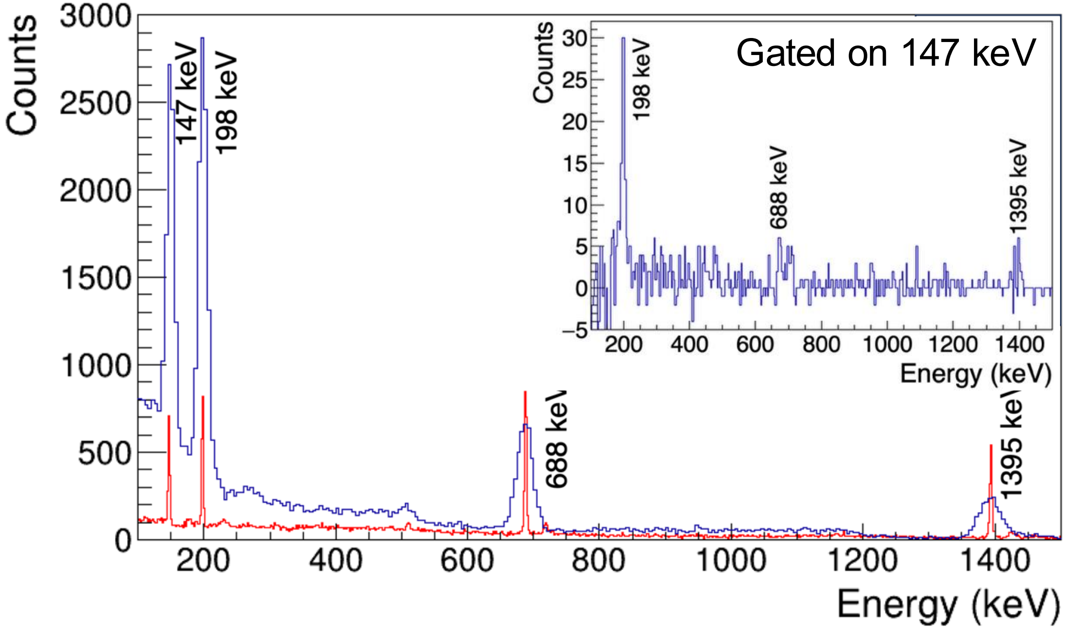
- Large-Scale Shell Model calculations based on a ^{90}Zr core
- A proton in the $0g_{9/2}$ shell is converted into a neutron placed in the $0g_{7/2}$ shell in the daughter nucleus

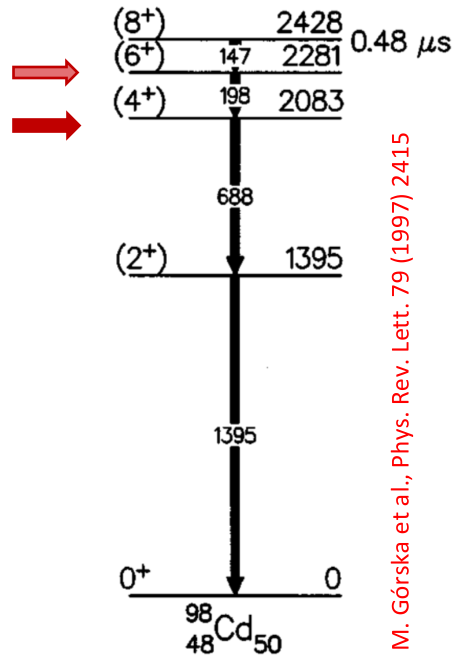
- Log*ft*s point at allowed β decay
- Previously suggested levels' spin and parity confirmed

Calculations performed by Y. Cenxi, Sun Yat-Sen University, China

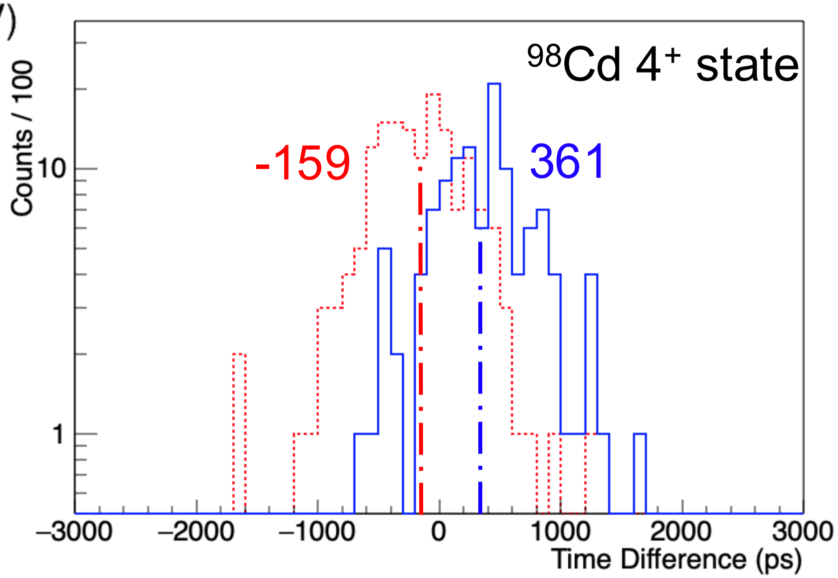
M. Polettini et al., EPJ Web Conf. 324 (2025) 00025

^{98}Cd levels' lifetimes





Isotope	I_i^π	τ
^{98}Cd	8_1^+	222(23)* ns
	6_1^+	21(1) ns
	4_1^+	58(27) ps
	2_1^+	–



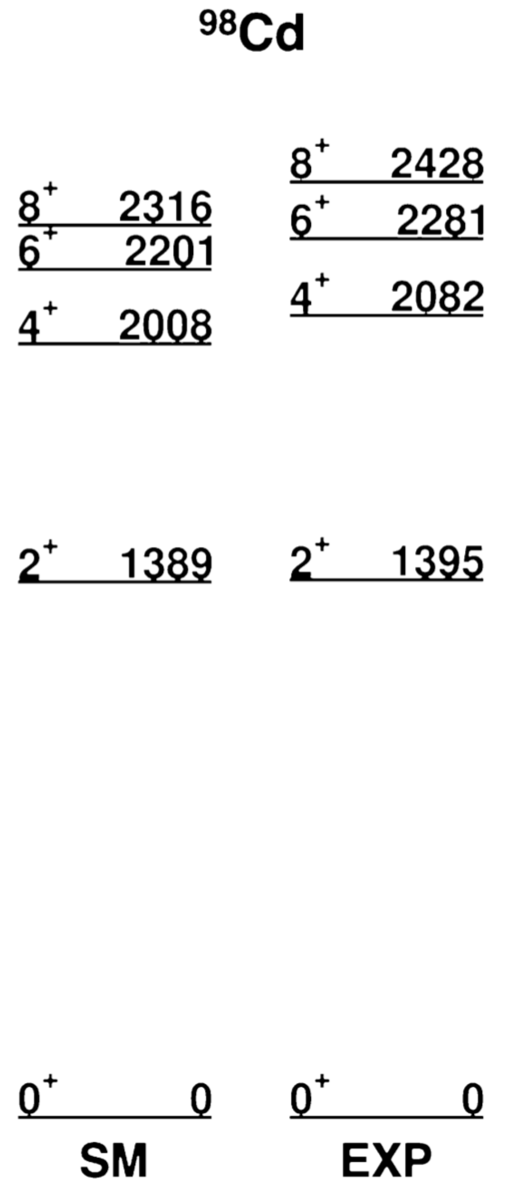
^{98}Cd: seniority description

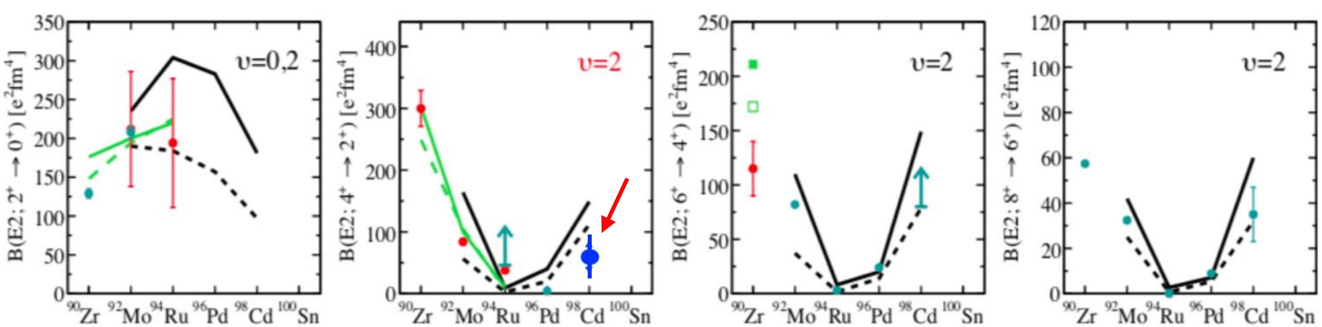
Isotope	$I_i^\pi \rightarrow I_f^\pi$	B(E2)$_{Exp}$	B(E2)$_{SM}$
^{98}Cd	$8^+ \rightarrow 6^+$	39(4)*	51
	$6^+ \rightarrow 4^+$	110(5)	126
	$4^+ \rightarrow 2^+$	98(50)	179
	$2^+ \rightarrow 0^+$	-	153

L. Coraggio et al., PRC 105, 034312 (2022), PRC 100, 014316 (2019), PRC 93, 064328 (2016)

- CD Bonn bare interaction, ^{56}Ni core
- proton effective charges: 1.2 to 1.6 e.

→ the system is well reproduced by including only the proton degree of freedom

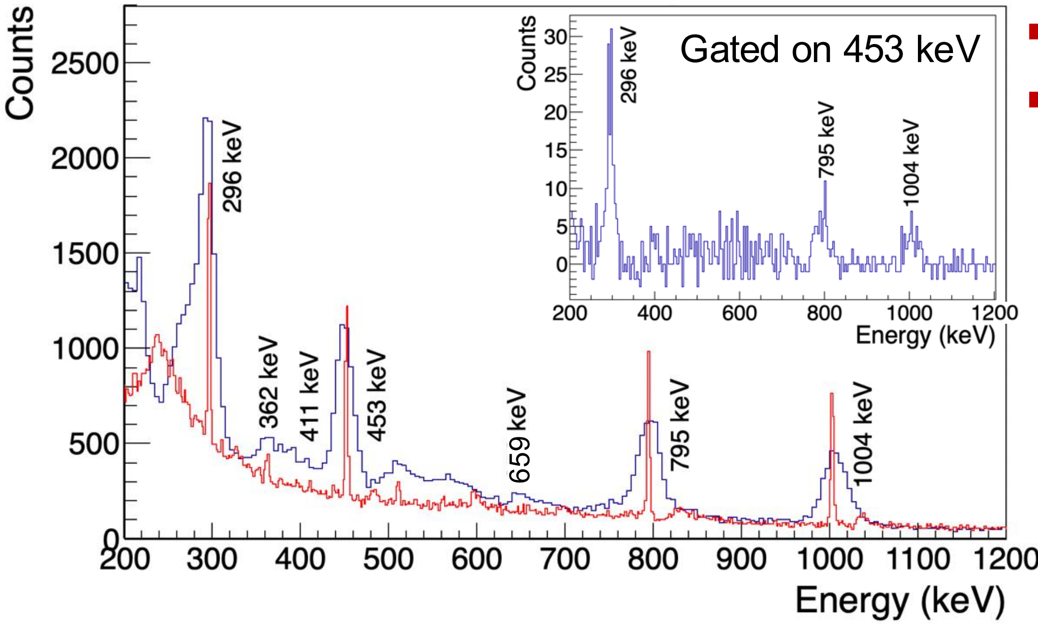


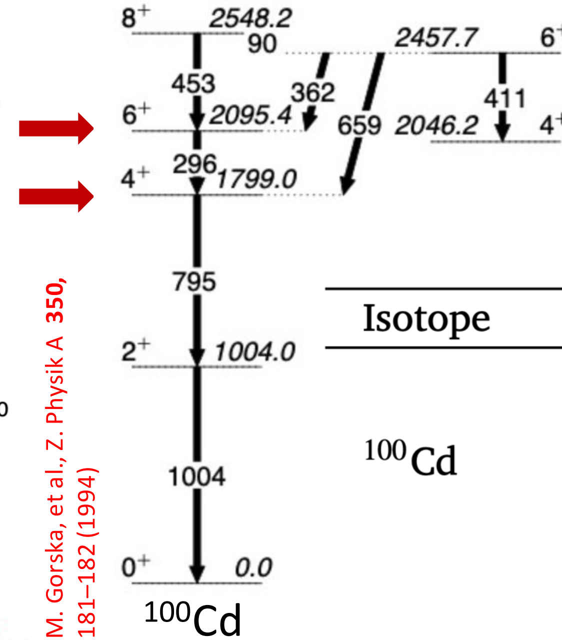


Adapted from R. M. Pérez-Vidal et al. Phys. Rev. Lett. 129 (2022) 112501

G. Zhang, M. Polettini et al., Phys. Lett. B 863 (2025) 139378

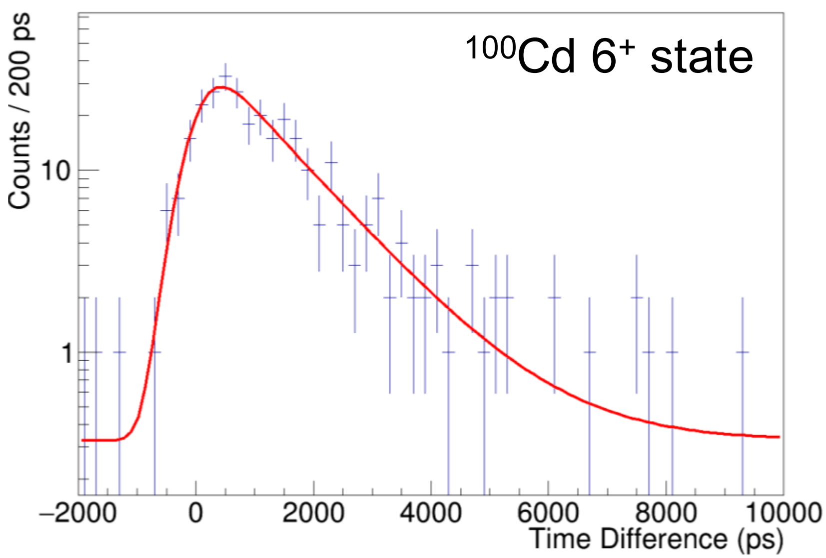
^{100}Cd levels' lifetimes

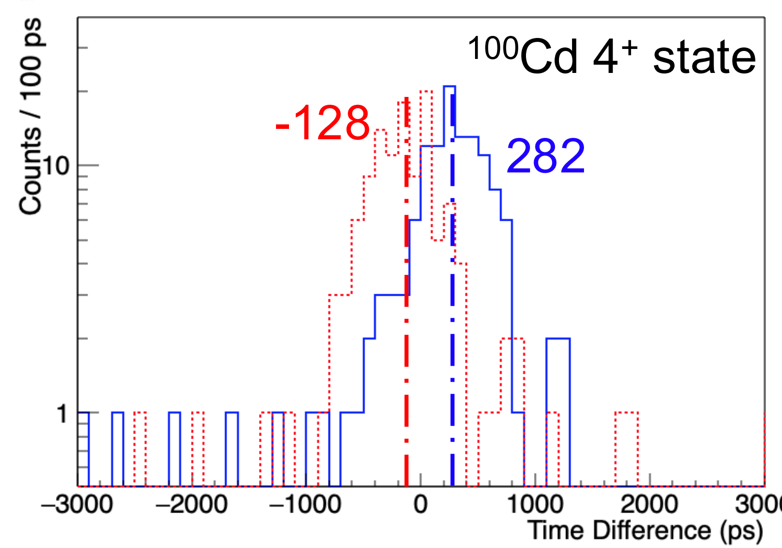




M. Gorska, et al., Z. Physik A **350**, 181–182 (1994)

Isotope	I_i^π	τ
^{100}Cd	8_1^+	91(5) ns
	6_1^+	1.2(1) ns
	4_1^+	36(25) ps
	2_1^+	-

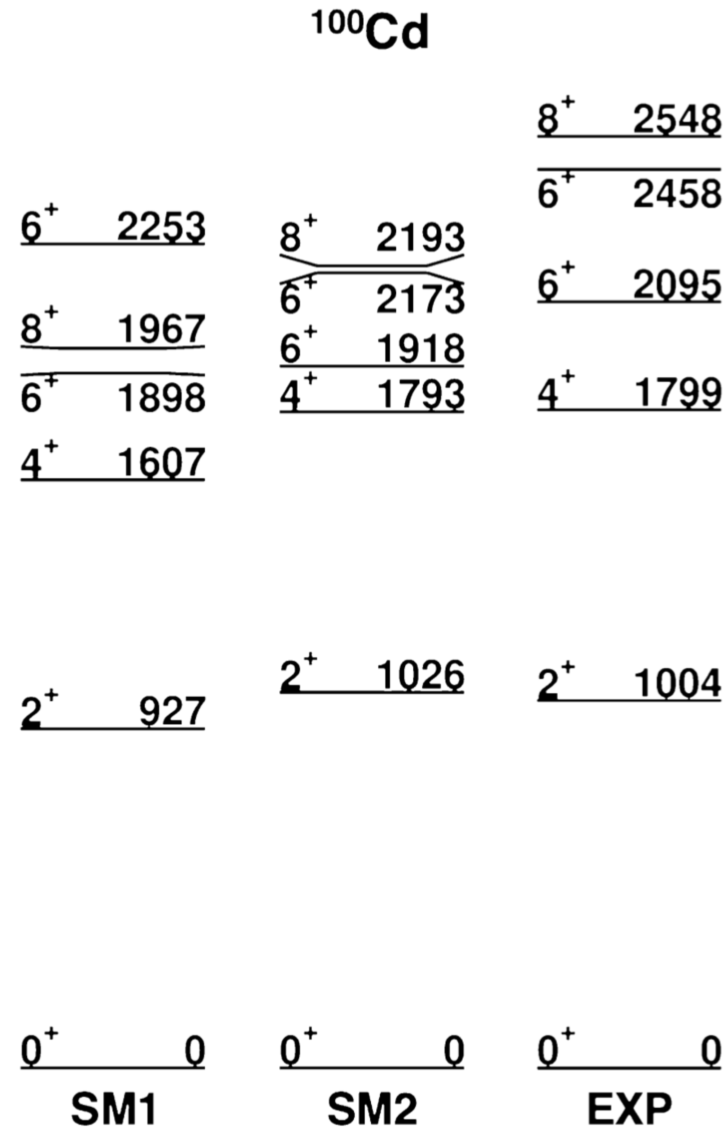




^{100}Cd: proton core breaking

Isotope	$I_i^\pi \rightarrow I_f^\pi$	$B(E2)_{Exp}$	SM1	SM2
^{100}Cd	$8^+ \rightarrow 6_2^+$	60(30)*	0.004	94
	$8^+ \rightarrow 6_1^+$	0.42(5)*	57	2
	$6_1^+ \rightarrow 4^+$	290(30)	170	107
	$4^+ \rightarrow 2^+$	71(40)	267	575
	$2^+ \rightarrow 0^+$	-	201	476

SM1 CD Bonn, ^{78}Ni core (e_n= 0.4-1 e, e_p= 1.2-1.7 e)
SM2 CD Bonn, ^{88}Sr core (e_n= 0.8-1 e, e_p= 1.6-1.8 e)
+ proton excitations from the $2p_{1/2}$ orbital



B(E2; $4^+ \rightarrow 2^+$) not well accounted for
→ **some degree of freedom still missing?**

Calculations performed by:
A. Gargano, G. De Gregorio, INFN Napoli

G. Zhang, M. Polettini et al., Phys. Lett. B 863 (2025) 139378

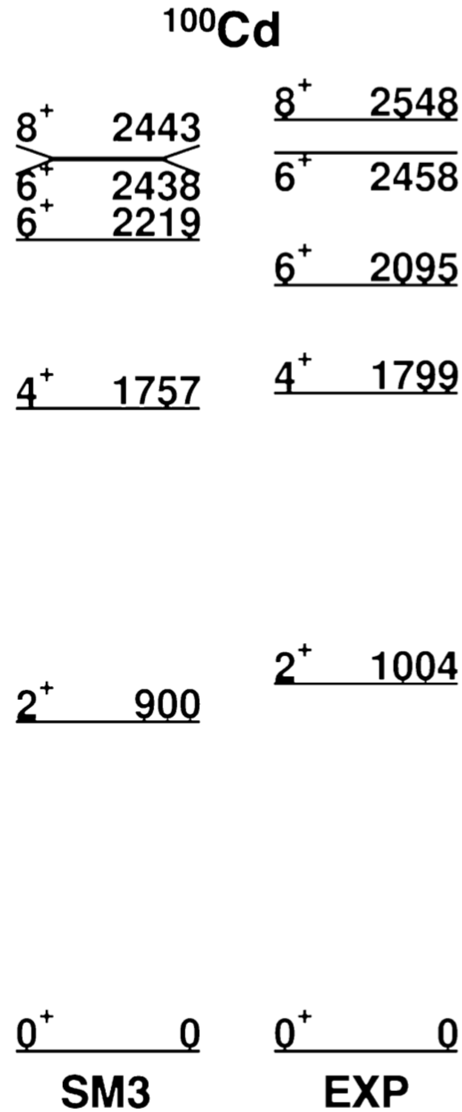
^{100}Cd: proton and neutron core breaking

Isotope	$I_i^\pi \rightarrow I_f^\pi$	B(E2)$_{Exp}$	SM1	SM2	SM3
^{100}Cd	$8^+ \rightarrow 6_2^+$	60(30)*	0.004	94	58
	$8^+ \rightarrow 6_1^+$	0.42(5)*	57	2	0.06
	$6_1^+ \rightarrow 4^+$	290(30)	170	107	283
	$4^+ \rightarrow 2^+$	71(40)	267	575	574
	$2^+ \rightarrow 0^+$	-	201	476	391

SM3 ^{80}Zr core and including $\pi\nu(0g1d2s)$ interaction

- π core breaking previously revealed essential to describe the physics in the region (^{98}Cd,^{104}Sn)
- $\pi(\nu)$ shell gap size: varied of +/- 1 MeV
- terms of p-p and n-n interactions have been excluded

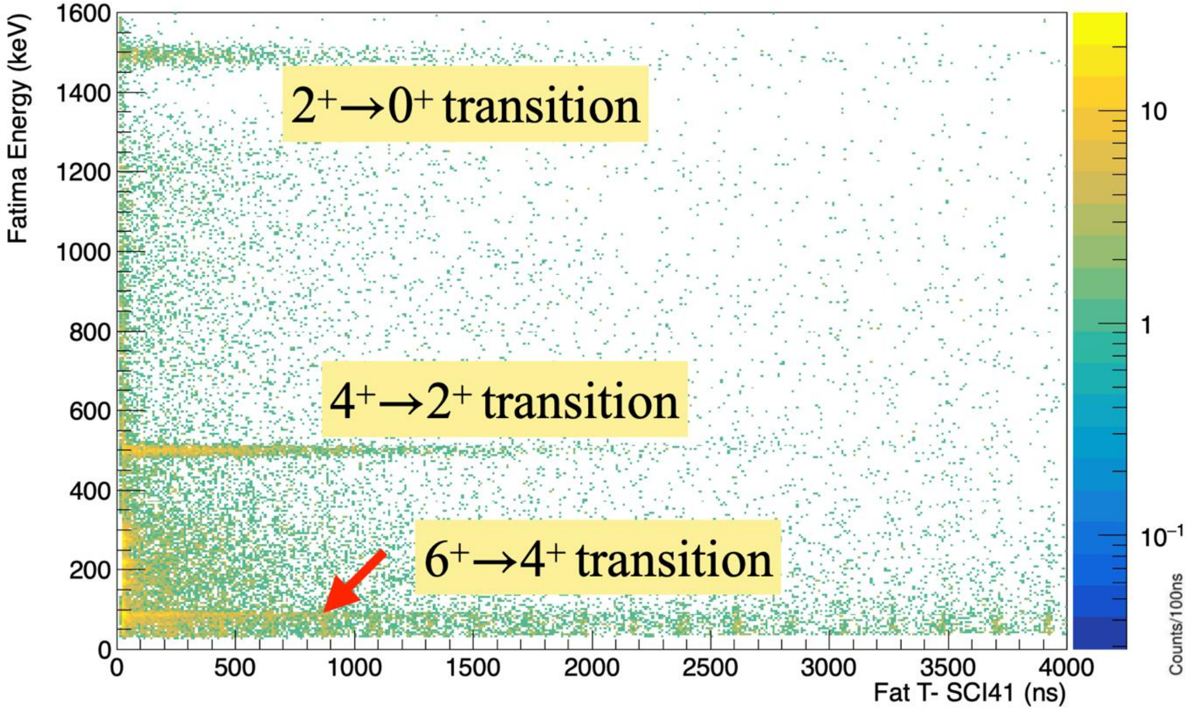
→ **Missing ingredients in the present form of the $\pi\nu$ interaction?**



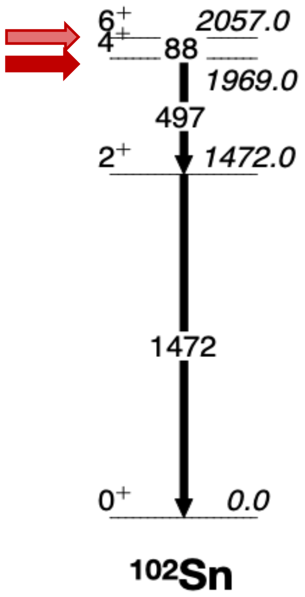
Calculations performed by:
A. Gargano, G. De Gregorio, INFN Napoli
F. Nowacki, IPHC Strasbourg

G. Zhang, M. Polettini et al., Phys. Lett. B 863 (2025) 139378

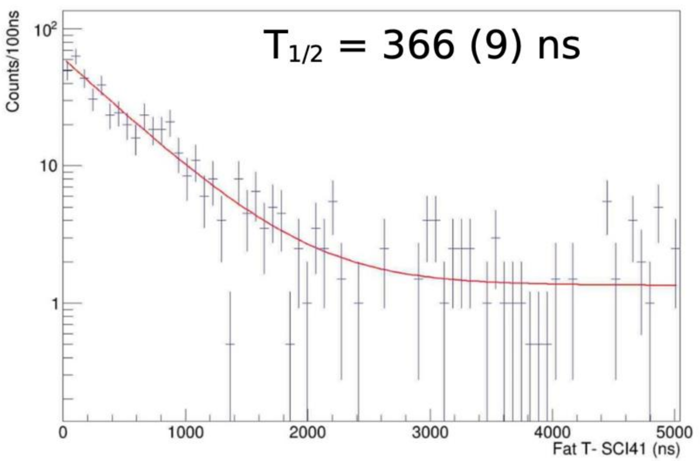
^{102}Sn: lifetime of the 4$^+$ state



$T_{1/2} = 367(11)$ ns



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



- Lifetime of the 6$^+$ isomer confirmed
- Lifetime of the 4$^+$ state measured for the first time

→ Letter in preparation

Conclusions

- Successful S496 run has been made by the local GSI group as well as a large remote group of participants during Covid-19 time
- Data analysis allowed to extract for the first time lifetime results by fast-timing measurement **6^+ and 4^+ states in ^{98,100}Cd**
- Assessment of **core breaking and relevance of proton-neutron interaction**, especially for the 4^+ state in ^{100}Cd.

Additional points:

- Study of low-lying states in **^{101}Cd via β–delayed spectroscopy**
- **^{102}Sn 4+ lifetime** being finalised
- Study of **^{103}Sn via α decay of ^{107}Te** will be performed

The DESPEC collaboration for the S496 experiment

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Thank you for your attention!