

# **Simple nuclear systems around $^{132}\text{Sn}$ studied via fast-timing measurements**

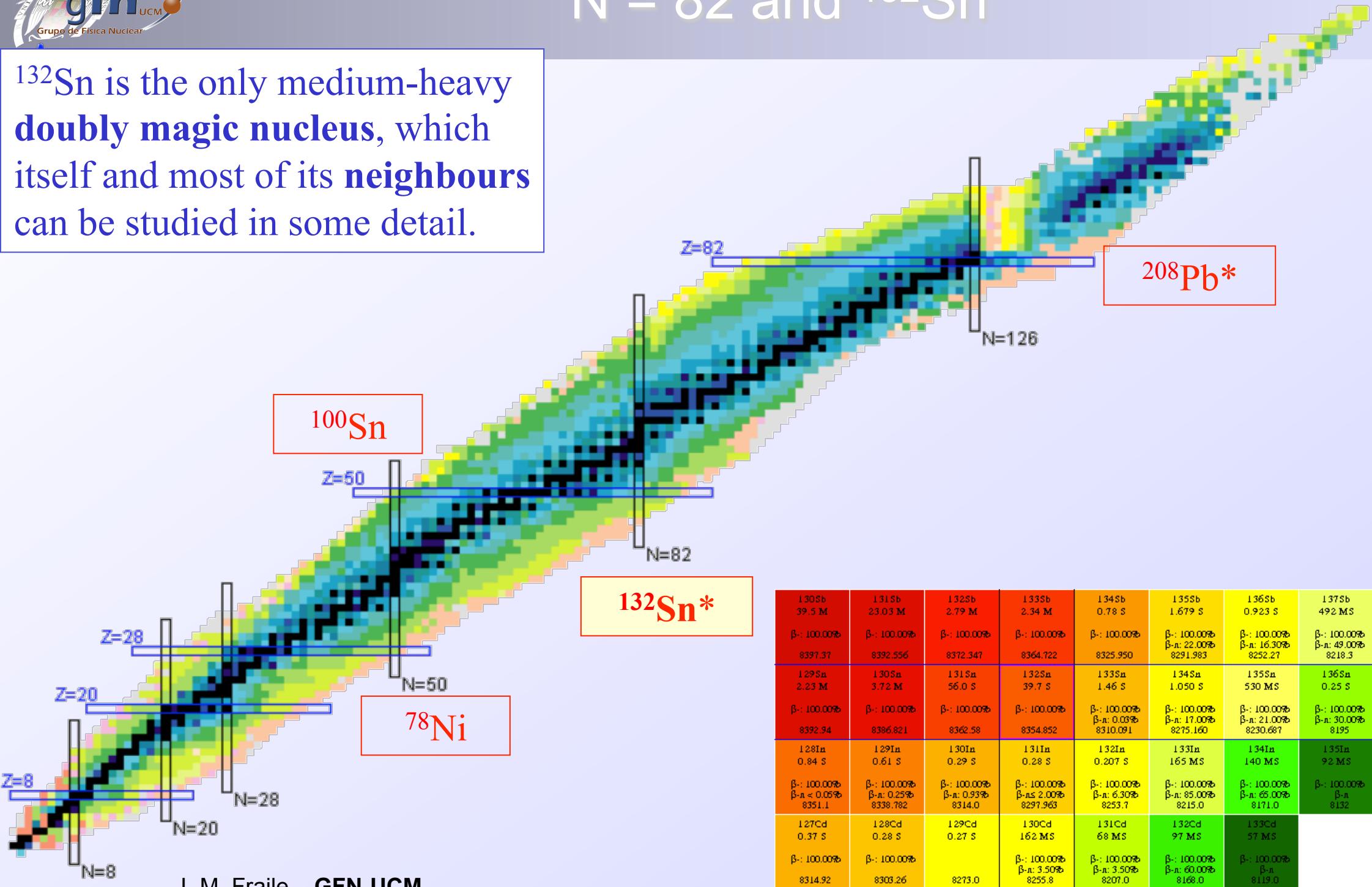
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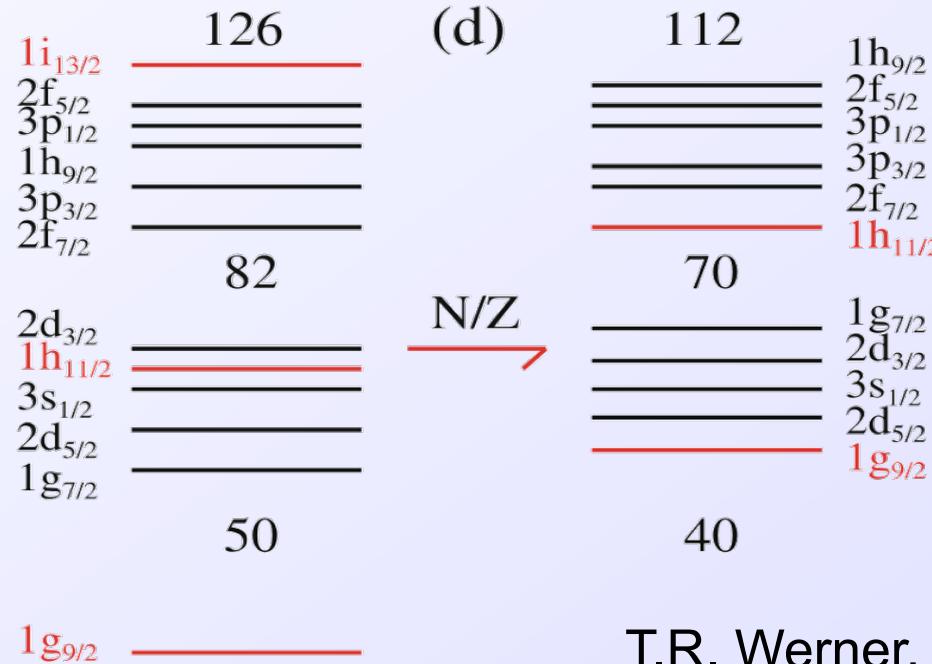
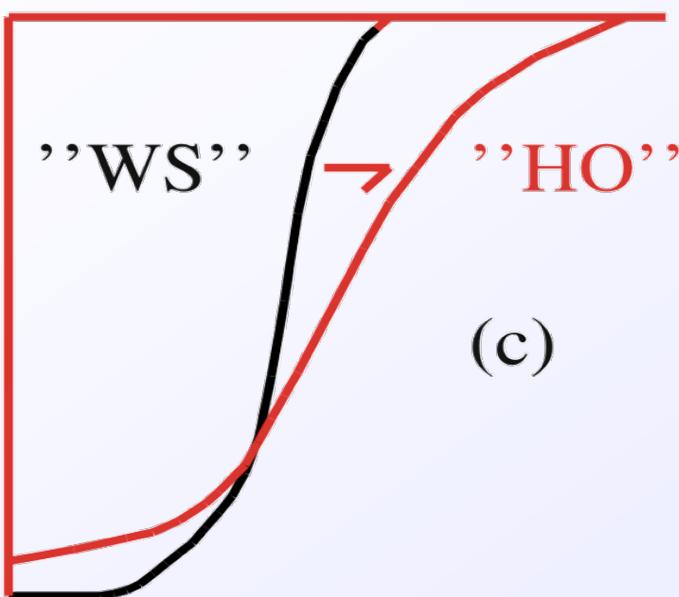


# $N = 82$ and $^{132}\text{Sn}$

$^{132}\text{Sn}$  is the only medium-heavy **doubly magic nucleus**, which itself and most of its **neighbours** can be studied in some detail.



# Soft potential leading to shell changes



## Possible signatures:

- reduction of spin-orbit splitting in n-rich nuclei
- increased neutron skin

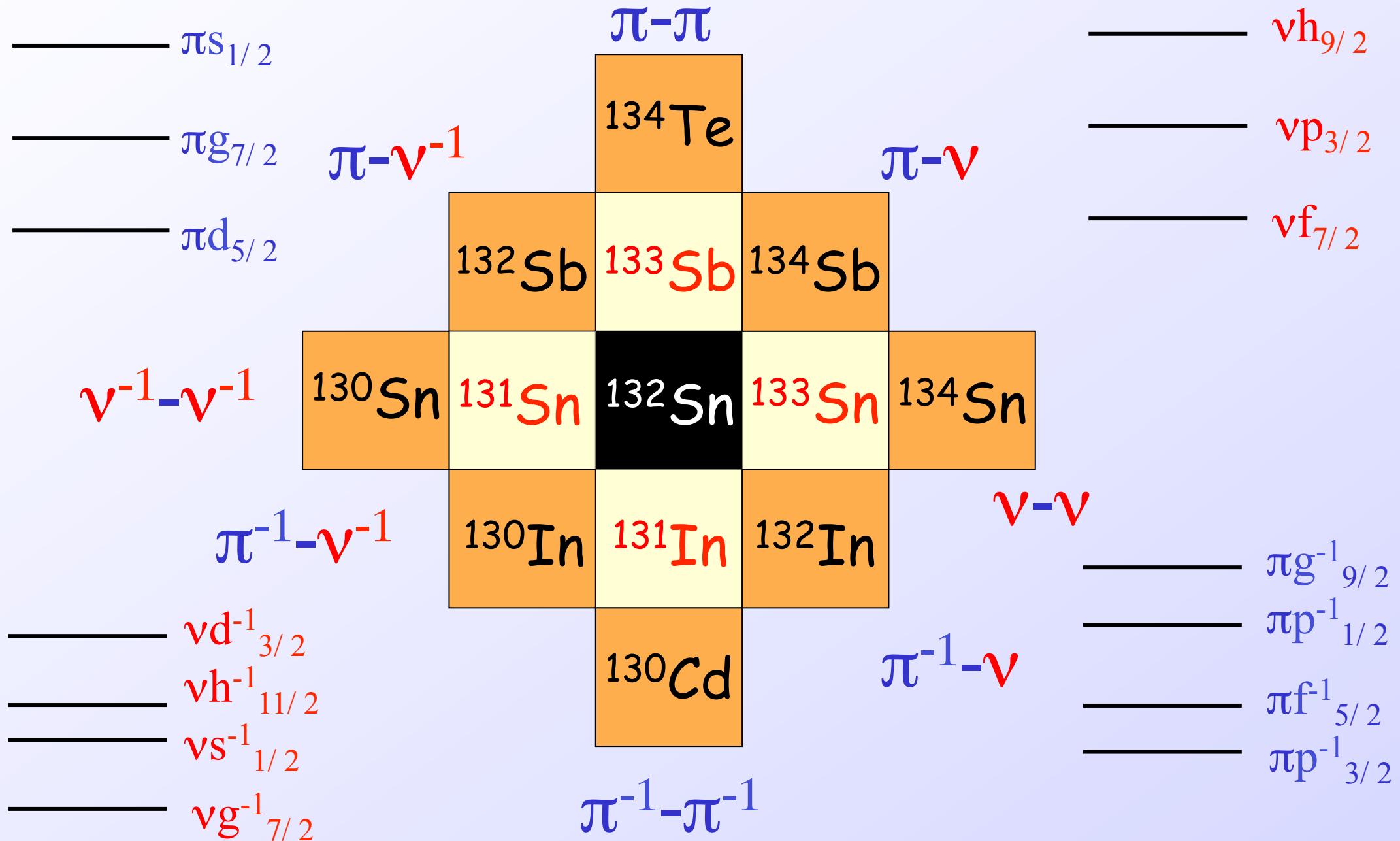
Test the shell-model effective Hamiltonian:

- single particle energies
- 2-body matrix elements of the residual interaction
- effective electromagnetic operators

T.R. Werner, J. Dobaczewski,  
W. Nazarewicz, Z. Phys.  
A358 (1997) 169

→ Transition rates required to constraint calculations  
 → Experimental information needed to better define the M1 operator

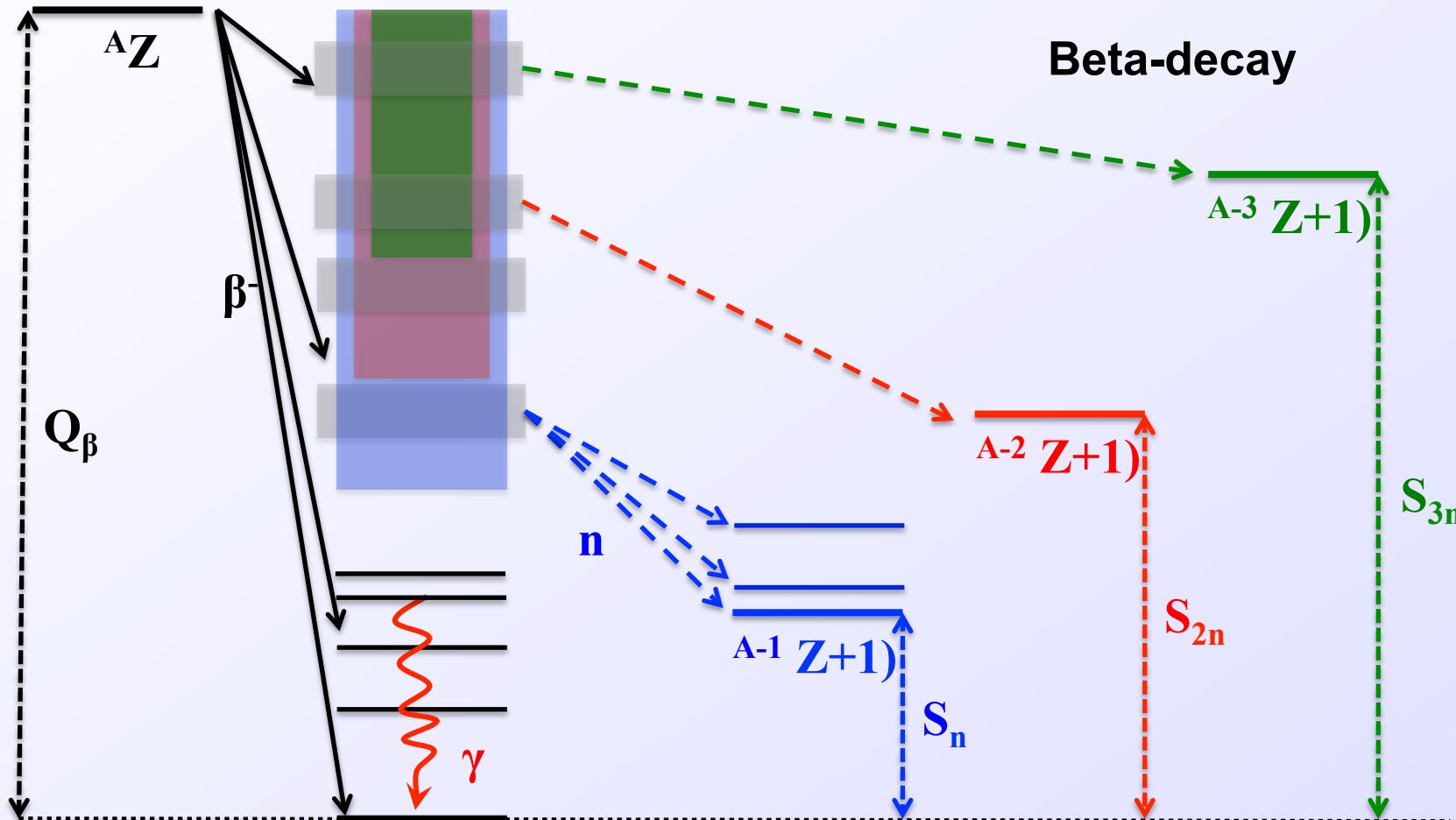
# Configurations



# 4<sup>+</sup> to 2<sup>+</sup> ratio

	130Te 23.0E+24 Y 34.08% $\beta^-$ : 100.00% 1.94	131Te 25.0 M $\beta^-$ : 100.00%	132Te 3.204 D $\beta^-$ : 100.00%	133Te 12.5 M $\beta^-$ : 100.00%	134Te 41.8 M $\beta^-$ : 100.00%	135Te 19.0 S $\beta^-$ : 100.00%	136Te 17.63 S $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 1.31% 1.69	137Te 2.49 S $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 2.99%	138Te 1.4 S $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 6.30% 2.04
51	129Sb 4.40 M $\beta^-$ : 100.00%	130Sb 39.5 M $\beta^-$ : 100.00%	131Sb 23.03 M $\beta^-$ : 100.00%	132Sb 2.79 M $\beta^-$ : 100.00%	133Sb 2.34 M $\beta^-$ : 100.00%	134Sb 0.78 S $\beta^-$ : 100.00%	135Sb 1.679 S $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 22.00%	136Sb 0.923 S $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 16.30%	137Sb 492 MS $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 49.00%
	128Sn 59.07 M $\beta^-$ : 100.00% 1.71	129Sn 2.23 M $\beta^-$ : 100.00%	130Sn 3.72 M $\beta^-$ : 100.00%	131Sn 56.0 S $\beta^-$ : 100.00%	132Sn 39.7 S $\beta^-$ : 100.00%	133Sn 1.46 S $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 0.03%	134Sn 1.050 S $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 17.00% 1.47	135Sn 530 MS $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 21.00%	136Sn 0.25 S $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 30.00% 1.56
49	127In 1.09 S $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 0.03%	128In 0.84 S $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : < 0.05%	129In 0.61 S $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 0.25%	130In 0.29 S $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 0.93%	131In 0.28 S $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 2.00%	132In 0.207 S $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 6.30%	133In 165 MS $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 85.00%	134In 140 MS $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 65.00%	135In 92 MS $\beta^-$ : 100.00% $\beta\text{-} \alpha$
	126Cd 0.515 S $\beta^-$ : 100.00% 2.25	127Cd 0.37 S $\beta^-$ : 100.00%	128Cd 0.28 S $\beta^-$ : 100.00%	129Cd 0.27 S $\beta^-$ : 100.00%	130Cd 162 MS $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 3.50% 1.40	131Cd 68 MS $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 3.50%	132Cd 97 MS $\beta^-$ : 100.00% $\beta\text{-} \alpha$ : 60.00%	133Cd 57 MS $\beta^-$ : 100.00% $\beta\text{-} \alpha$	
	78	79	80	81	82	83	84	85	N

# Transition rates – electronic timing



Beta-decay

States below  
isomers (i.e.  
Lohengrin work)

Fragmentation  
facilities

$S_{3n}$

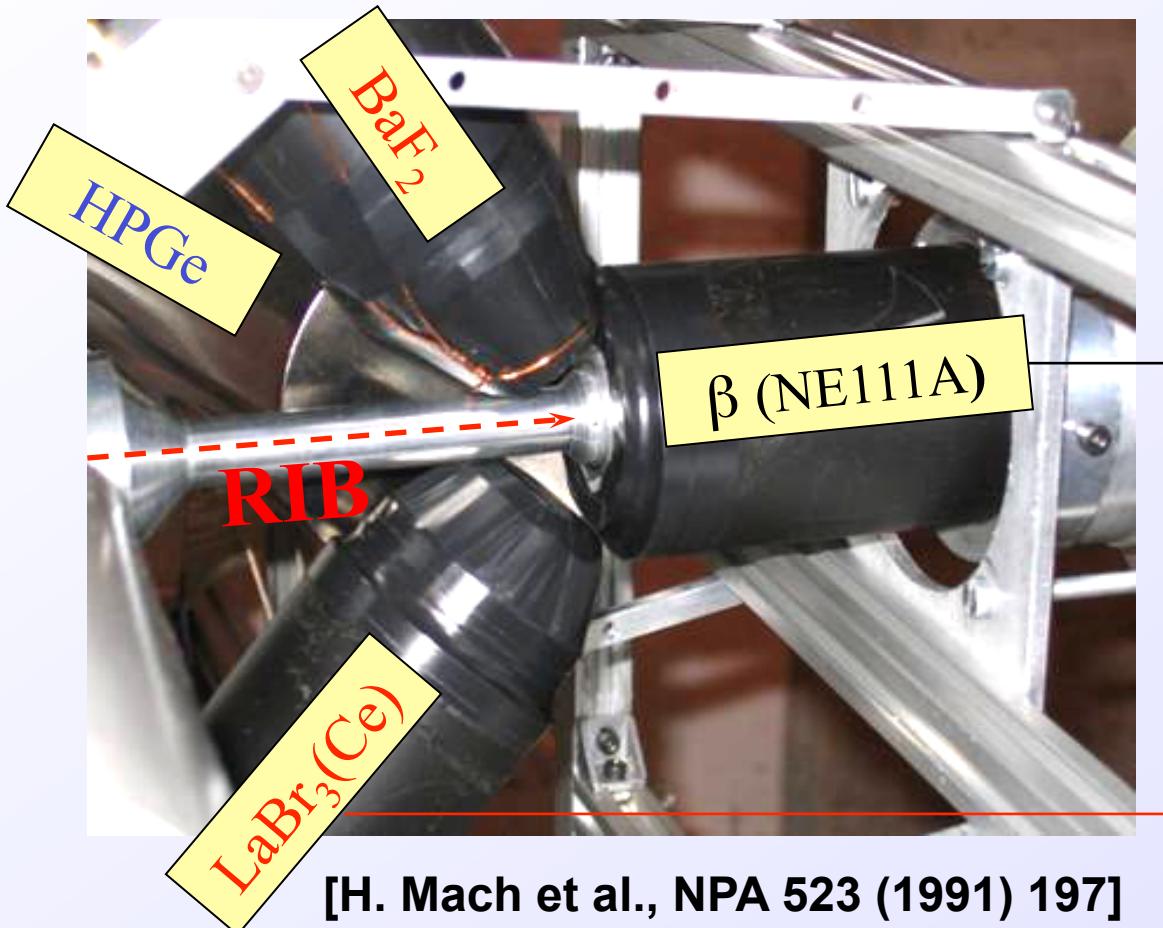
Fission

## Absolute transition rates

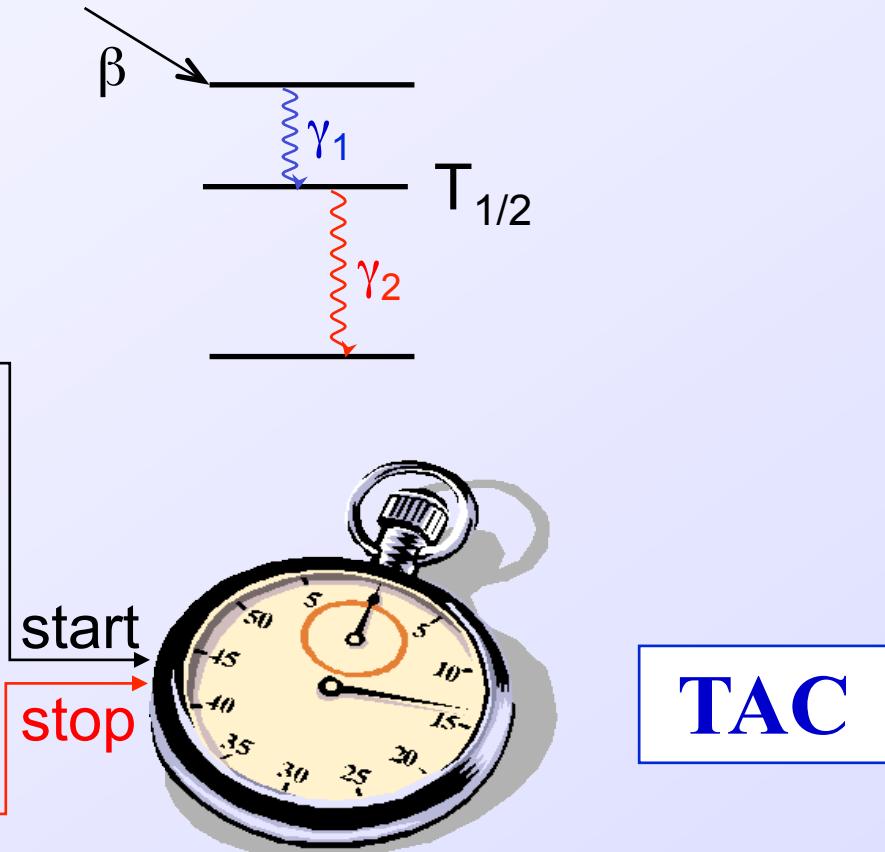
$$B(X\lambda; I_i \rightarrow I_f) = (2I_i + 1)^{-1} \left| \langle \psi_f | M(X\lambda) | \psi_i \rangle \right|^2$$

$$B(\frac{M}{E} \lambda; I_i \rightarrow I_f) = \frac{L[(2L+1)!!]^2 \hbar}{8\pi(L+1)} \left( \frac{\hbar c}{E_\gamma} \right)^{2L+1} P_\gamma(\frac{M}{E} \lambda; I_i \rightarrow I_f)$$

# The Advanced Time Delayed $\beta\gamma\gamma(t)$ method



[H. Mach et al., NPA 523 (1991) 197]



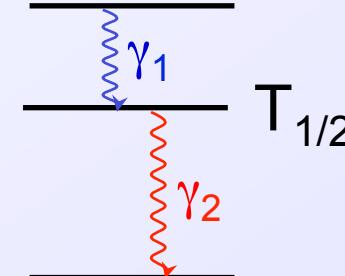
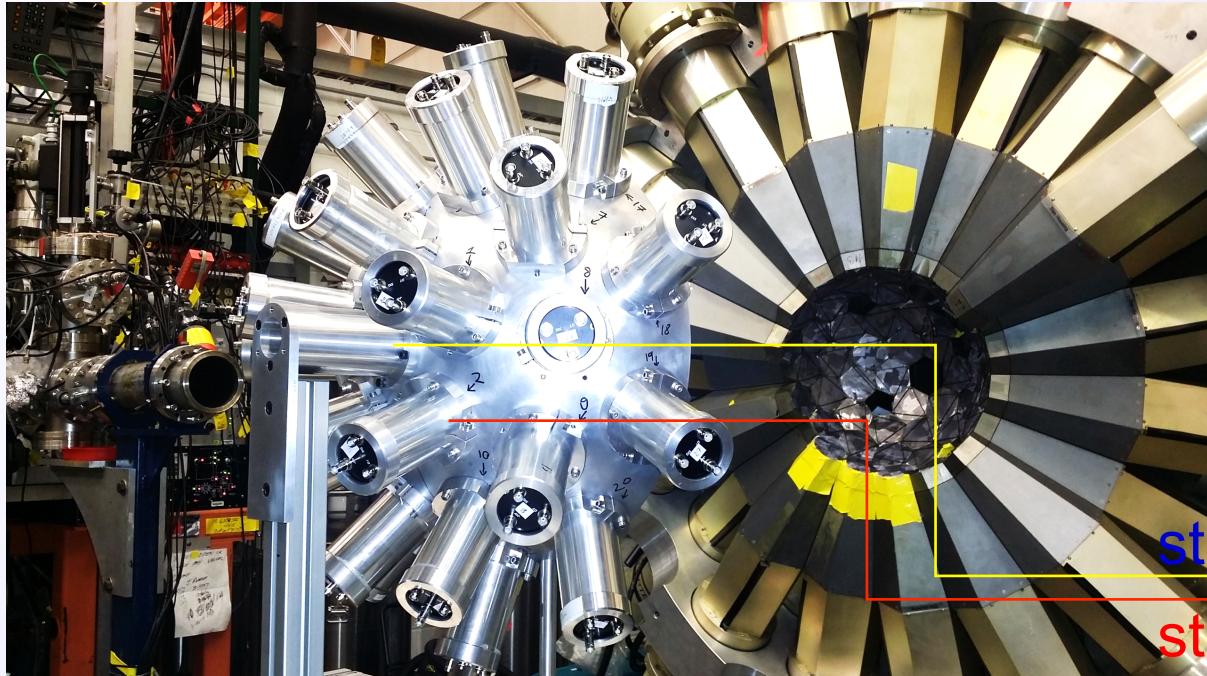
**HPGe:** BRANCH SELECTION  
 High energy resolution  
 Poor time response

**Plastic  $\beta$  scintillator:** TIMING  
 Fast response  
 Efficient start detector

**LaBr<sub>3</sub>(Ce)/BaF<sub>2</sub>:** TIMING  
 Fast response  $\gamma$ -detectors  
 Stop detectors

- Double coincidences:  $\beta\gamma$ : beta-Ge and beta-LaBr<sub>3</sub>
- Triple coincidences  $\beta\gamma\gamma$ : beta-Ge-Ge and beta-Ge-LaBr<sub>3</sub>

# Fast-timing $\gamma\gamma\gamma(t)$



**Time difference**

ROShpere IFIN-HH, EXILL-FATIMA ILL 2013, ANL

## HPGe: BRANCH SELECTION

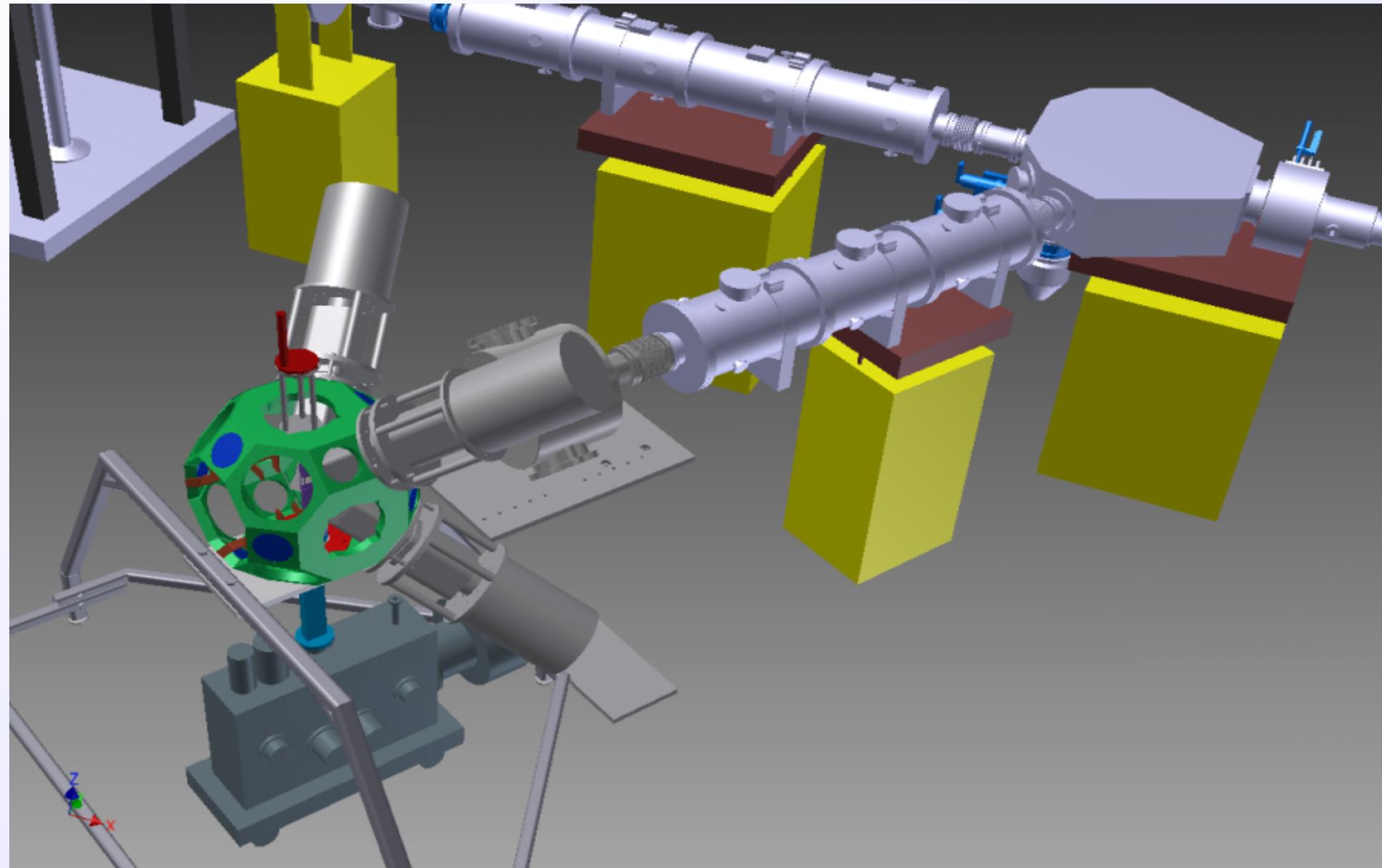
High energy resolution  
Poor time response

## LaBr<sub>3</sub>(Ce): TIMING

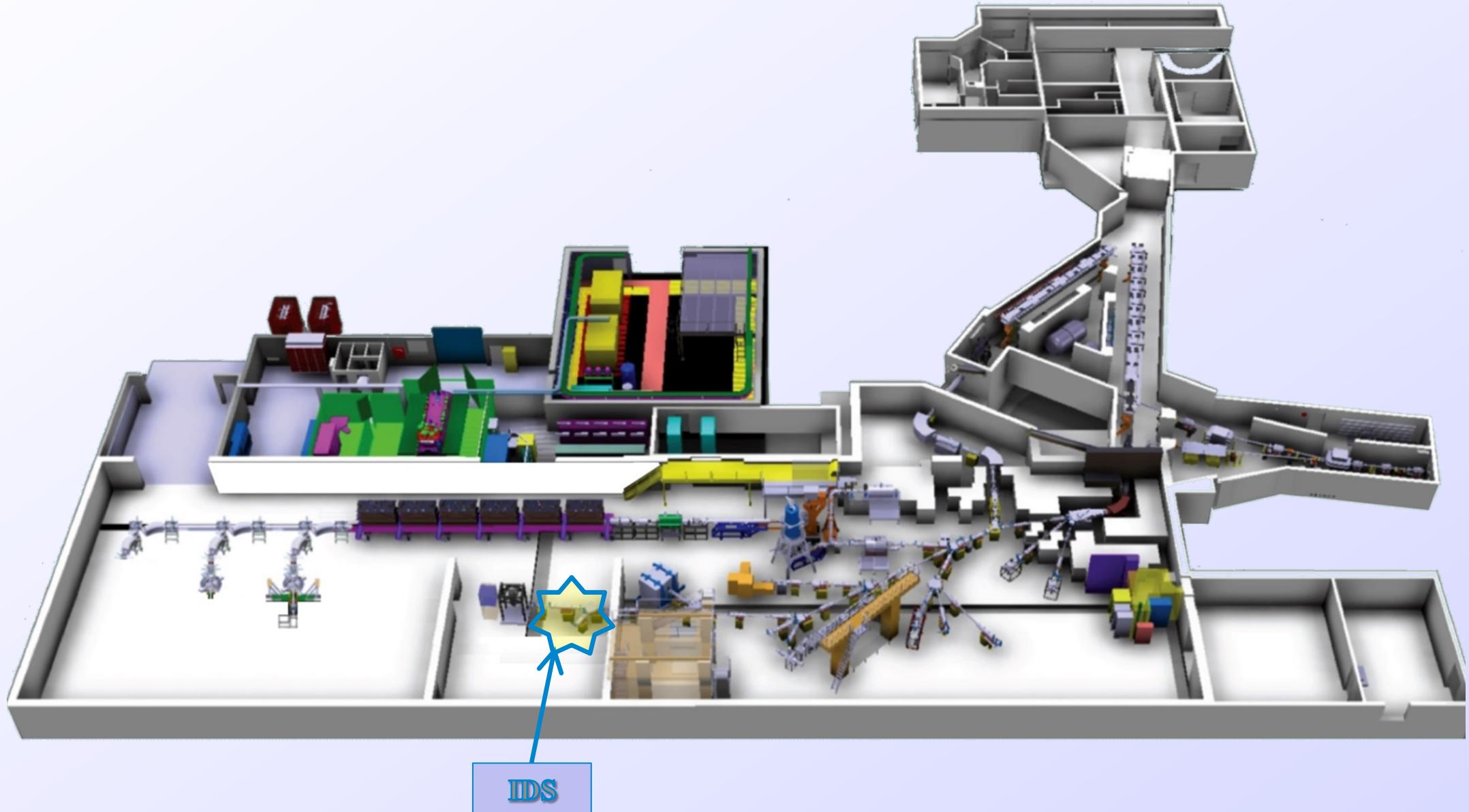
Fast response  $\gamma$ -detectors  
Start and stop detectors

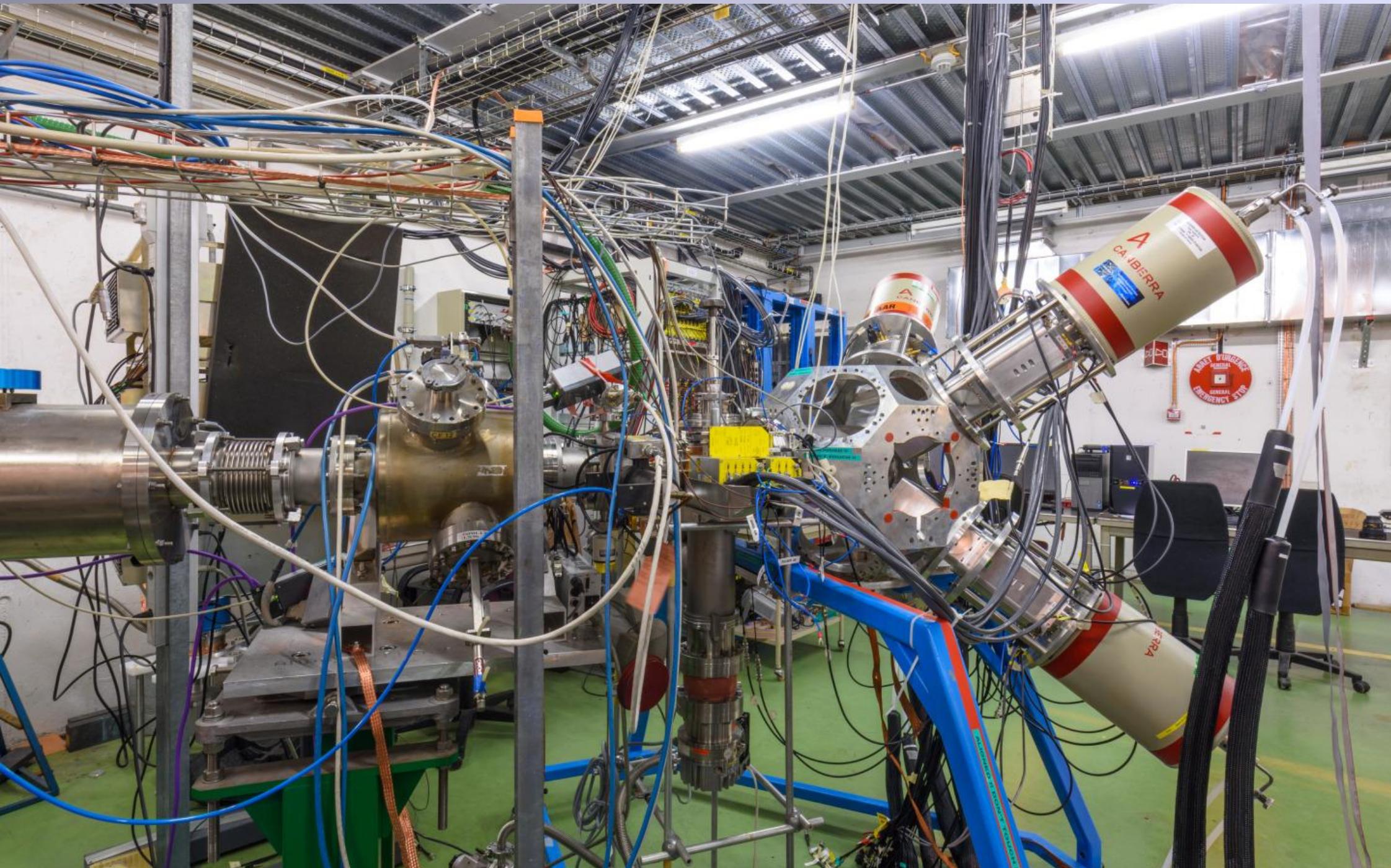
- Triple coincidences  $\gamma\gamma\gamma$ : Ge-Ge-Ge and Ge-LaBr<sub>3</sub>-LaBr<sub>3</sub>(t)
- 4-fold coincidences or fission selection

# IDS setup



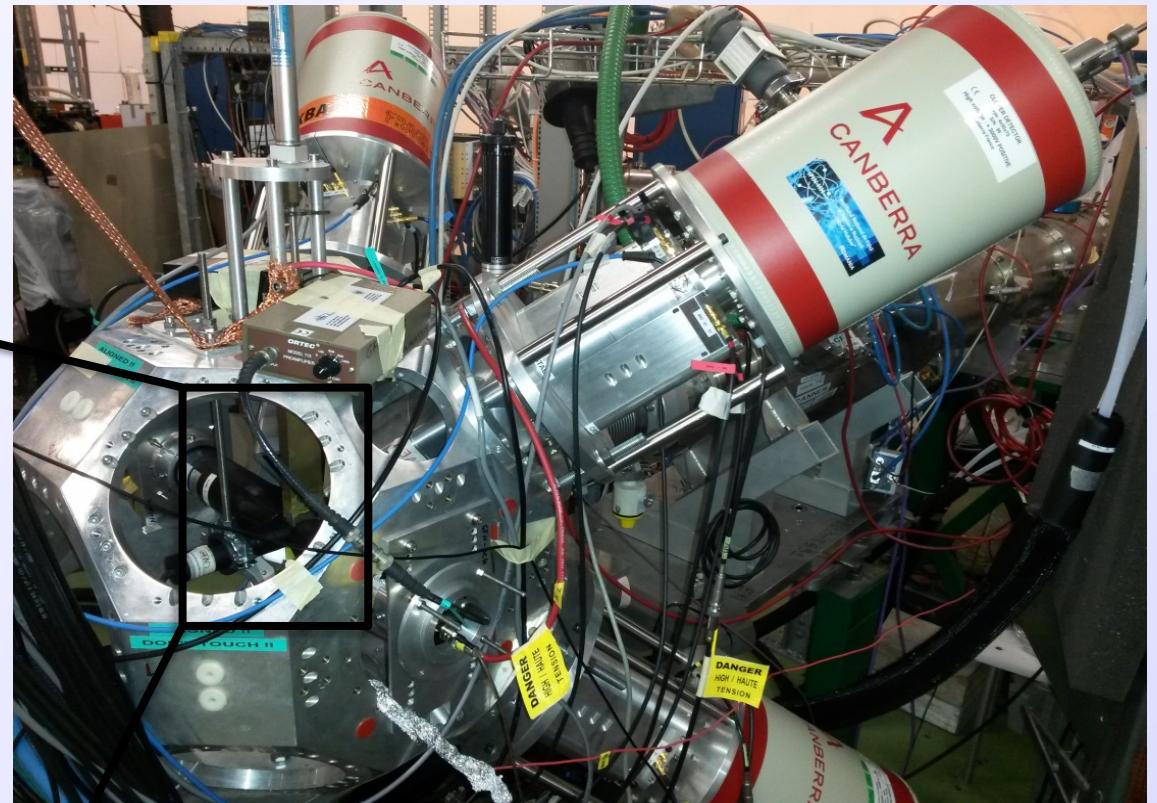
# IDS in the ISOLDE hall





# Transition rates: $\beta$ -decay setup at ISOLDE

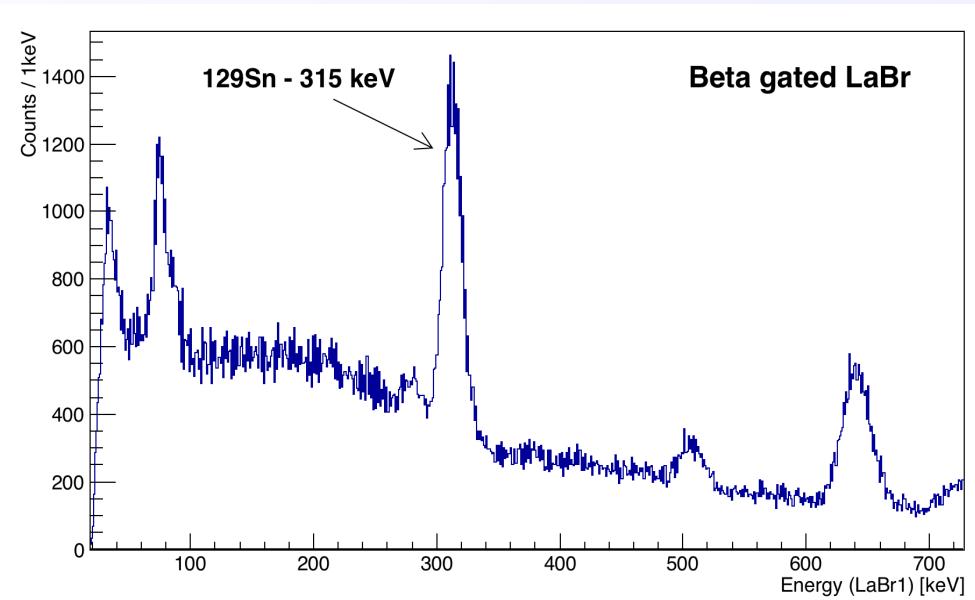
- 4 Clover HPGe ~ 3.7% eff. @600keV
- 2 LaBr<sub>3</sub>(Ce) ~ 4% (2% each)  
@600keV (or up to 6 detectors)
- 1 Plastic Scintillator ~ 20% eff.
- DAQ – Digital system
- Analog TACs



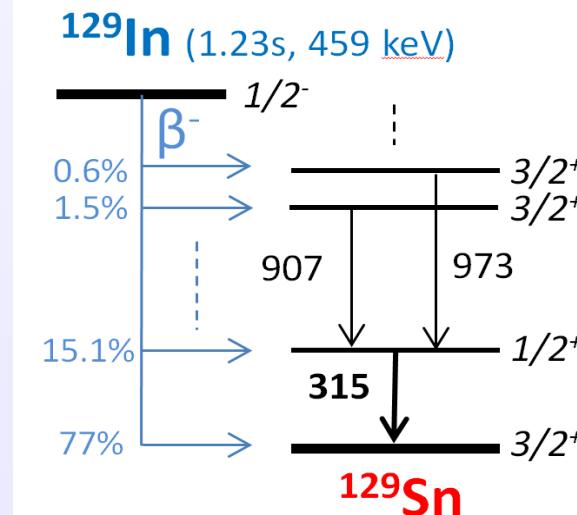
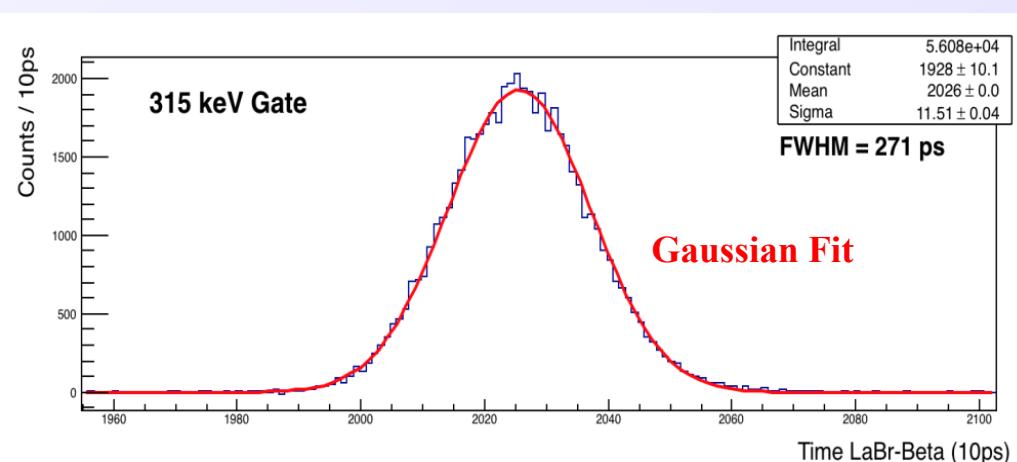
IDS

# $^{129}\text{In}$ decay at IDS

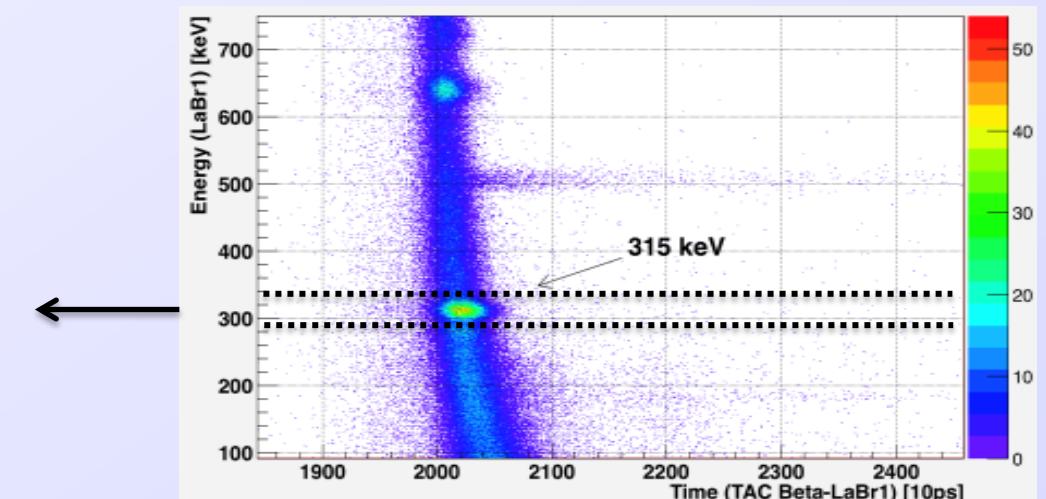
Fast timing measurement of the  $1/2^+$   
315-keV level in  $^{129}\text{Sn}$



Time distribution



H. Gausemel  
et. al, PRC  
69, 054307  
(2004)

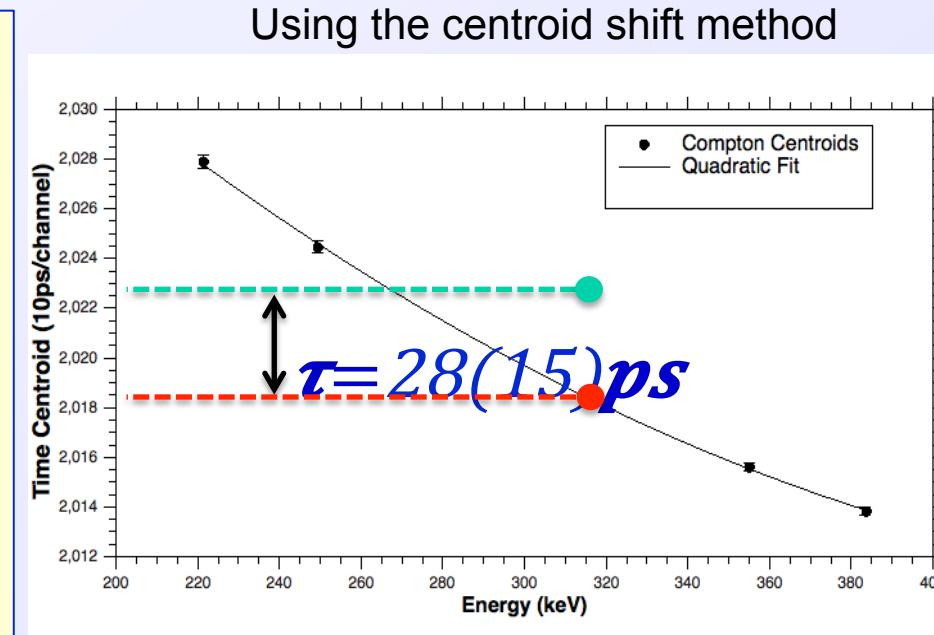


There is no indication of a long lived component in the beta-gated LaBr<sub>3</sub> timing spectrum

# $^{129}\text{In}$ decay at IDS

315-keV transition: Test for M1 effective operators  $3\text{s}_{1/2} \rightarrow 2\text{d}_{3/2}$  M1 1-forbidden  
 Predicting half-life using the effective charges and gyromagnetic factors from M. Danchev et. Al, PRC 84, 061306(R) (2011)  
 Unknown **M1 effective operator** for neutron holes:

$$T_{1/2}^{\text{theo}} (\langle d_{3/2} | M1 | s_{1/2} \rangle) \sim 4 \text{ ns}$$



[R. Liča, H. Mach et al.,  
 PRC 93, 044303 (2016) ]

$$T_{1/2}^{\text{exp}} (351-\text{keV}) = 19(10) \text{ ps}$$

Shell model calculations A. Gargano -  $^{132}\text{Sn}$  core  
 Single hole energies taken from  $^{131}\text{Sn}$   
 Effective interaction: CD-Bonn

A slightly different from zero **M1 effective operator** for neutron holes greatly improves the agreement without changing any other matrix elements

- ✓ Study of  $^{131}\text{In}$  at RIKEN
  - 1p hole in  $^{132}\text{Sn}$
  - $\pi p_{3/2}$  structure found
- ✓ SM: Evidence of the disappearance of the  $Z = 40$  proton subshell closures at  $N = 82$
- ✓ Changes in the shell structure in this region far off stability
- ✓ Reduction of the  $N=82$  gap for r-process

### $1p_{3/2}$ Proton-Hole State in $^{132}\text{Sn}$ and the Shell Structure Along $N = 82$

J. Taprogge,<sup>1,2,3</sup> A. Jungclaus,<sup>1,\*</sup> H. Grawe,<sup>4</sup> S. Nishimura,<sup>3</sup> P. Doornenbal,<sup>3</sup> G. Lorusso,<sup>3</sup> G. S. Simpson,<sup>5</sup> P.-A. Söderström,<sup>3</sup> T. Sumikama,<sup>6</sup> Z. Y. Xu,<sup>7</sup> H. Baba,<sup>3</sup> F. Browne,<sup>8,3</sup> N. Fukuda,<sup>3</sup> R. Gernhäuser,<sup>9</sup> G. Gey,<sup>5,10,3</sup> N. Inabe,<sup>3</sup> T. Isobe,<sup>3</sup> H. S. Jung,<sup>11,†</sup> D. Kameda,<sup>3</sup> G. D. Kim,<sup>12</sup> Y.-K. Kim,<sup>12,13</sup> I. Kojouharov,<sup>4</sup> T. Kubo,<sup>3</sup> N. Kurz,<sup>4</sup> Y. K. Kwon,<sup>12</sup> Z. Li,<sup>14</sup> H. Sakurai,<sup>3,7</sup> H. Schaffner,<sup>4</sup> K. Steiger,<sup>9</sup> H. Suzuki,<sup>3</sup> H. Takeda,<sup>3</sup> Zs. Vajta,<sup>15,3</sup> H. Watanabe,<sup>3</sup> J. Wu,<sup>14,3</sup> A. Yagi,<sup>16</sup> K. Yoshinaga,<sup>17</sup> G. Benzoni,<sup>18</sup> S. Bönig,<sup>19</sup> K. Y. Chae,<sup>20</sup> L. Coraggio,<sup>21</sup> A. Covello,<sup>21,22</sup> J.-M. Daugas,<sup>23</sup> F. Drouet,<sup>5</sup> A. Gadea,<sup>24</sup> A. Gargano,<sup>21</sup> S. Ilieva,<sup>19</sup> F. G. Kondev,<sup>25</sup> T. Kröll,<sup>19</sup> G. J. Lane,<sup>26</sup> A. Montaner-Pizá,<sup>24</sup> K. Moschner,<sup>27</sup> D. Mücher,<sup>9</sup> F. Naqvi,<sup>28</sup> M. Niikura,<sup>7</sup> H. Nishibata,<sup>16</sup> A. Odahara,<sup>16</sup> R. Orlando,<sup>29,30</sup> Z. Patel,<sup>31</sup> Zs. Podolyák,<sup>31</sup> and A. Wendt<sup>27</sup>

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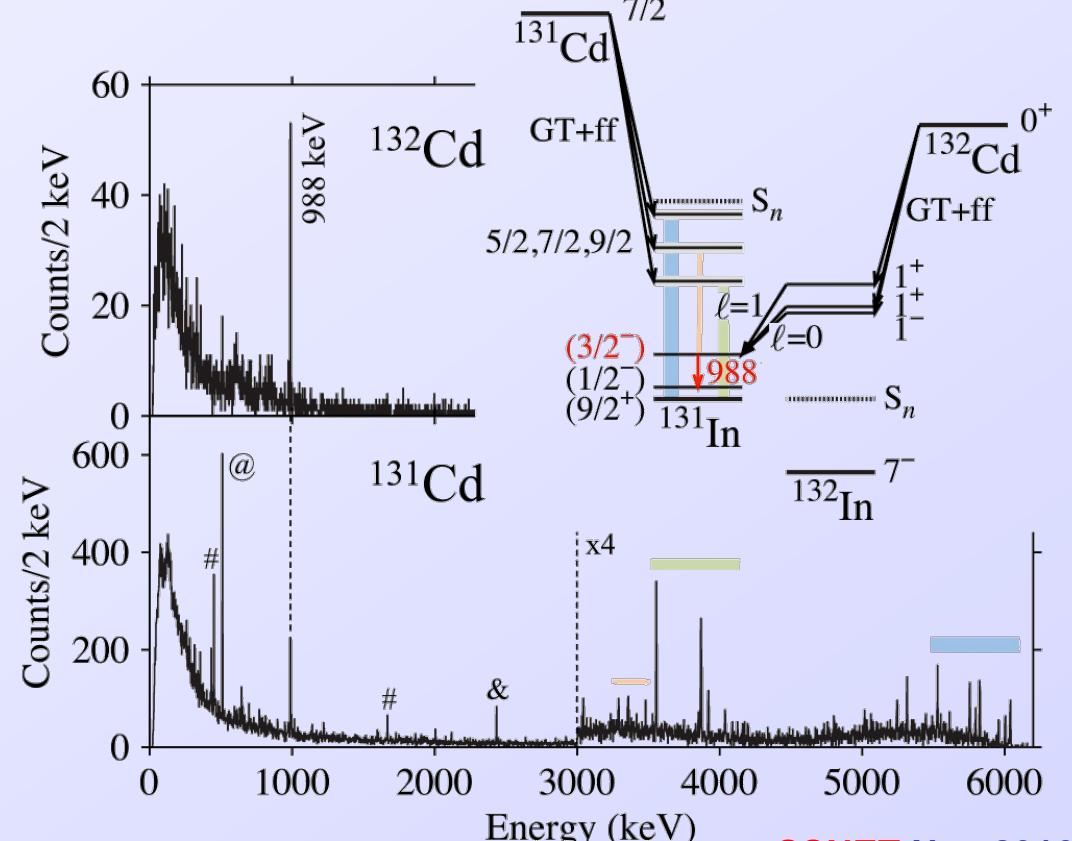
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<sup>10</sup>Institut Laue-Langevin, B.P. 156, F-38042 Grenoble Cedex 9, France

<sup>11</sup>Department of Physics, Chung-Ang University, Seoul 156-756, Republic of Korea

<sup>12</sup>Rare Isotope Science Project, Institute for Basic Science, Daejeon 305-811, Republic of Korea



# Odd mass Sn isotopes: $^{131}\text{Sn}$

✓ (Indirect) information on single-particle states

→ the  $\nu h_{11/2}$  (hole) at  $69 \pm 14$  keV

[B. Fogelberg PRC70 (2004)]

→ 65.1 keV measured without confirmation from coincidences...

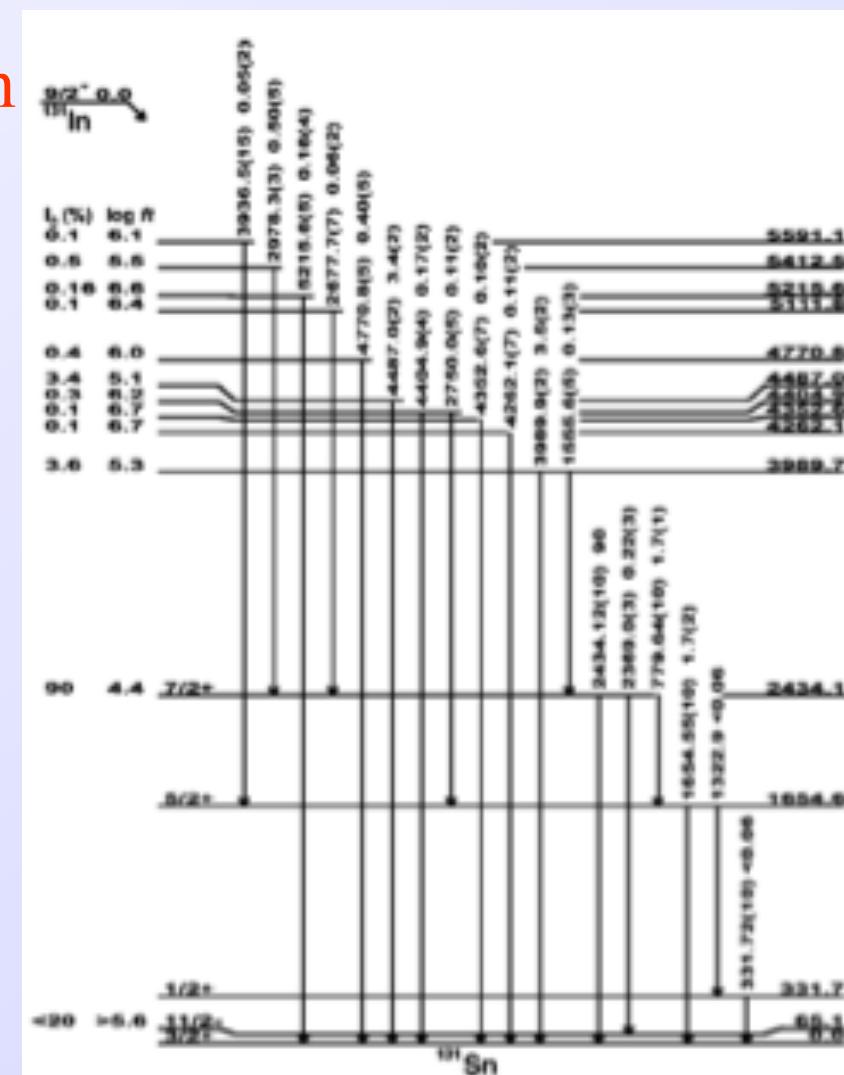
✓ Three beta-decaying isomers

→  $1/2^-$ ,  $T_{1/2} = 280(3)$  ms,  $P_n = 2\%$  (?)

→  $9/2^+$ ,  $T_{1/2} = 350(5)$  ms,  $P_n = 2\%$  (?)

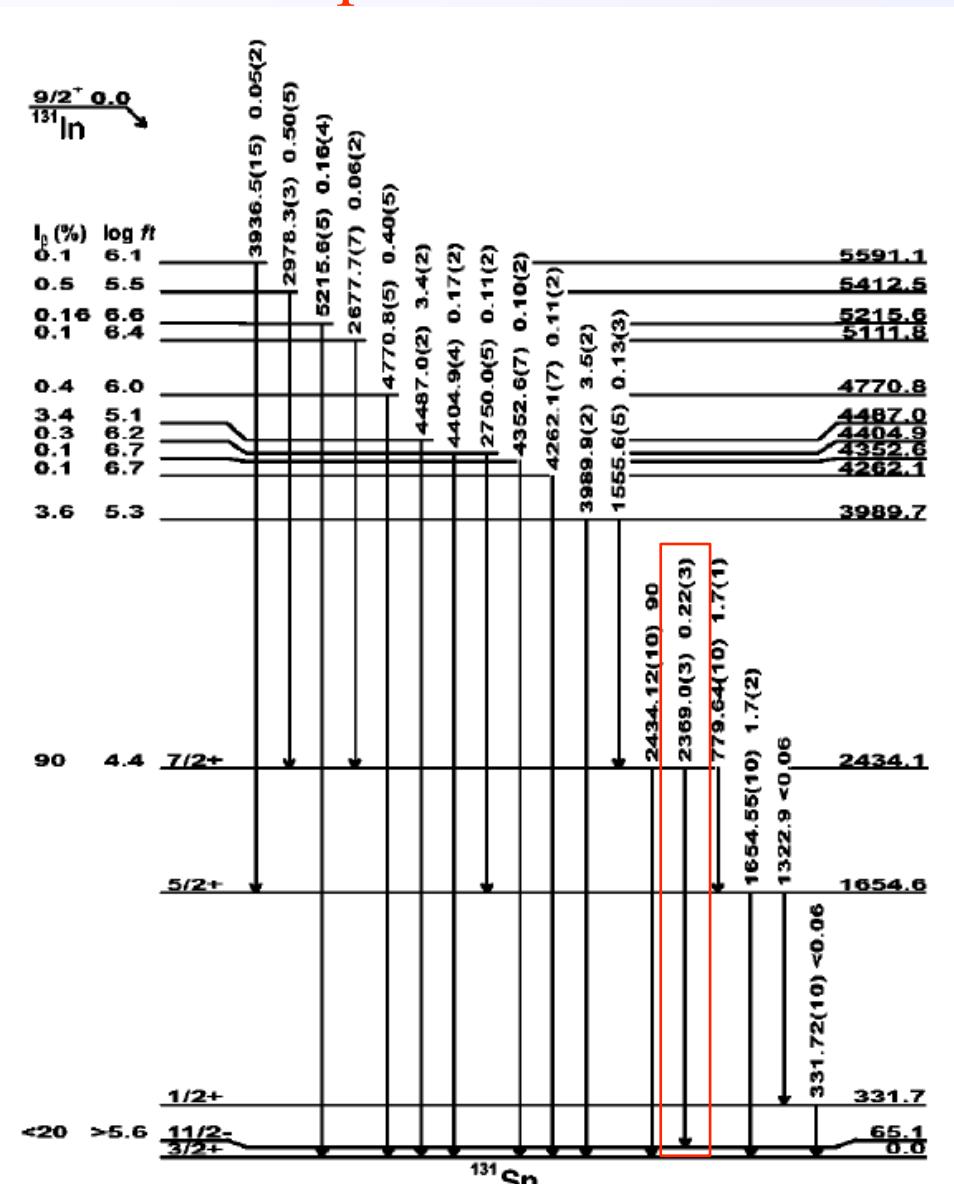
→  $21/2^+$ ,  $T_{1/2} = 350(5)$  ms

→  $Q_{\text{g.s.}} = 9177 (18)$  keV

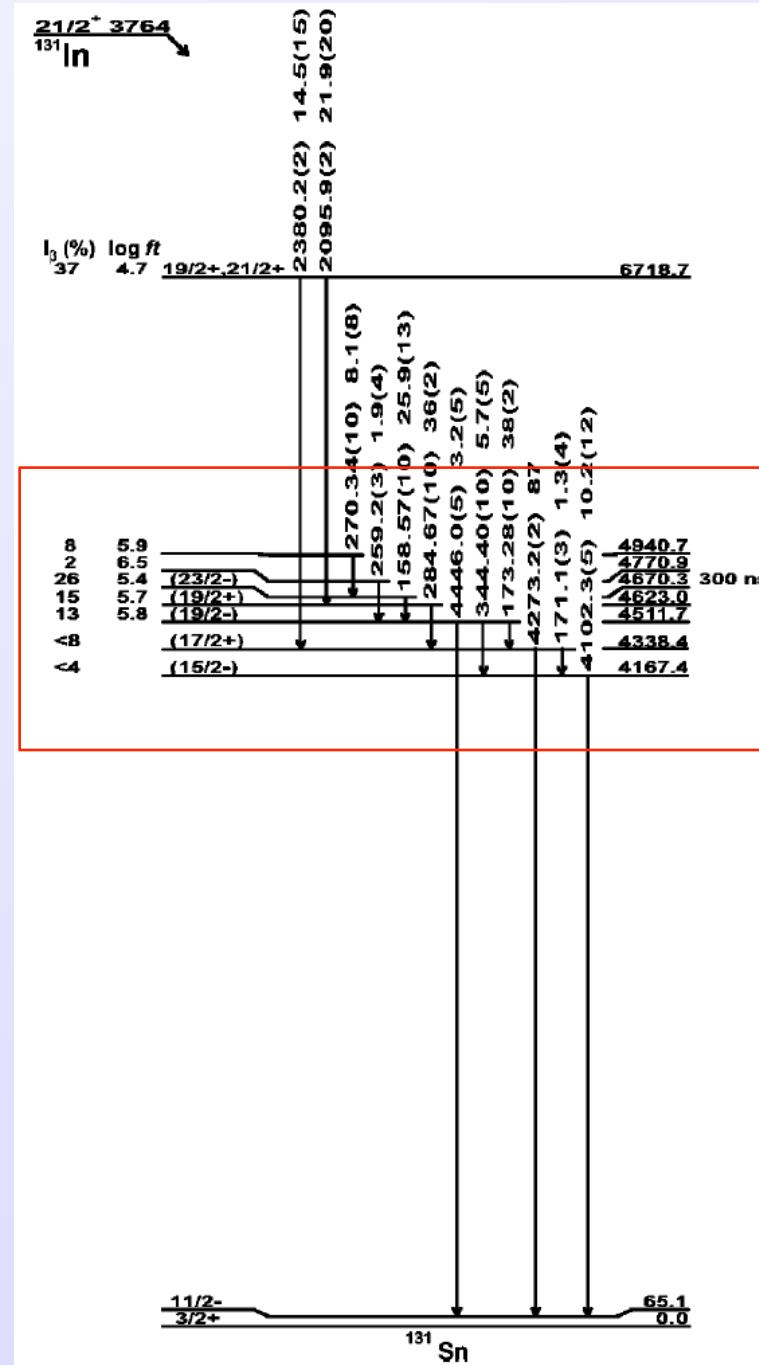


# $^{131}\text{Sn}$ measurement performed 2016

- ✓ M2 branch may point to measurable  $T_{1/2}$   
 $\rightarrow \sim 20 \text{ ps}$

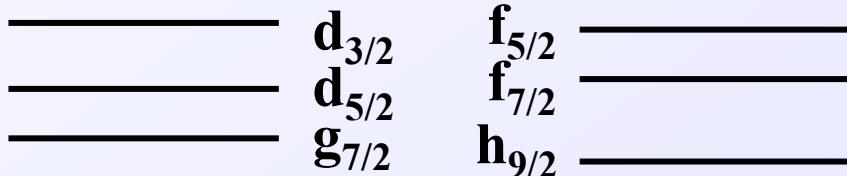


→ lifetimes

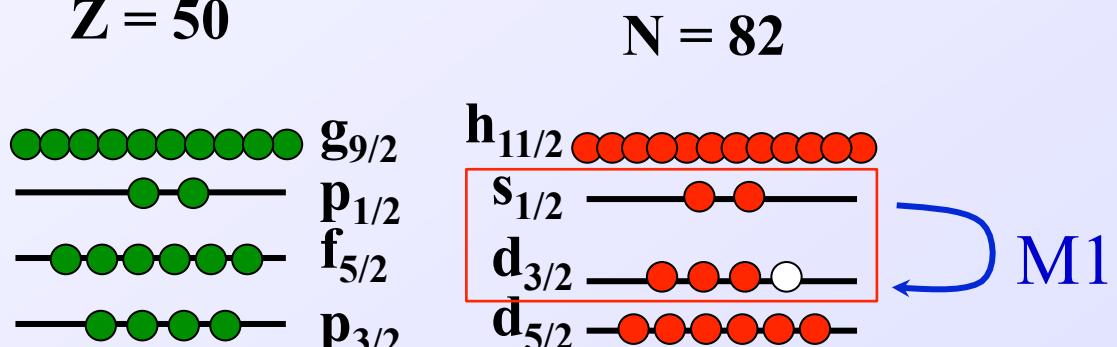


# $^{131}\text{Sn}$ measurement

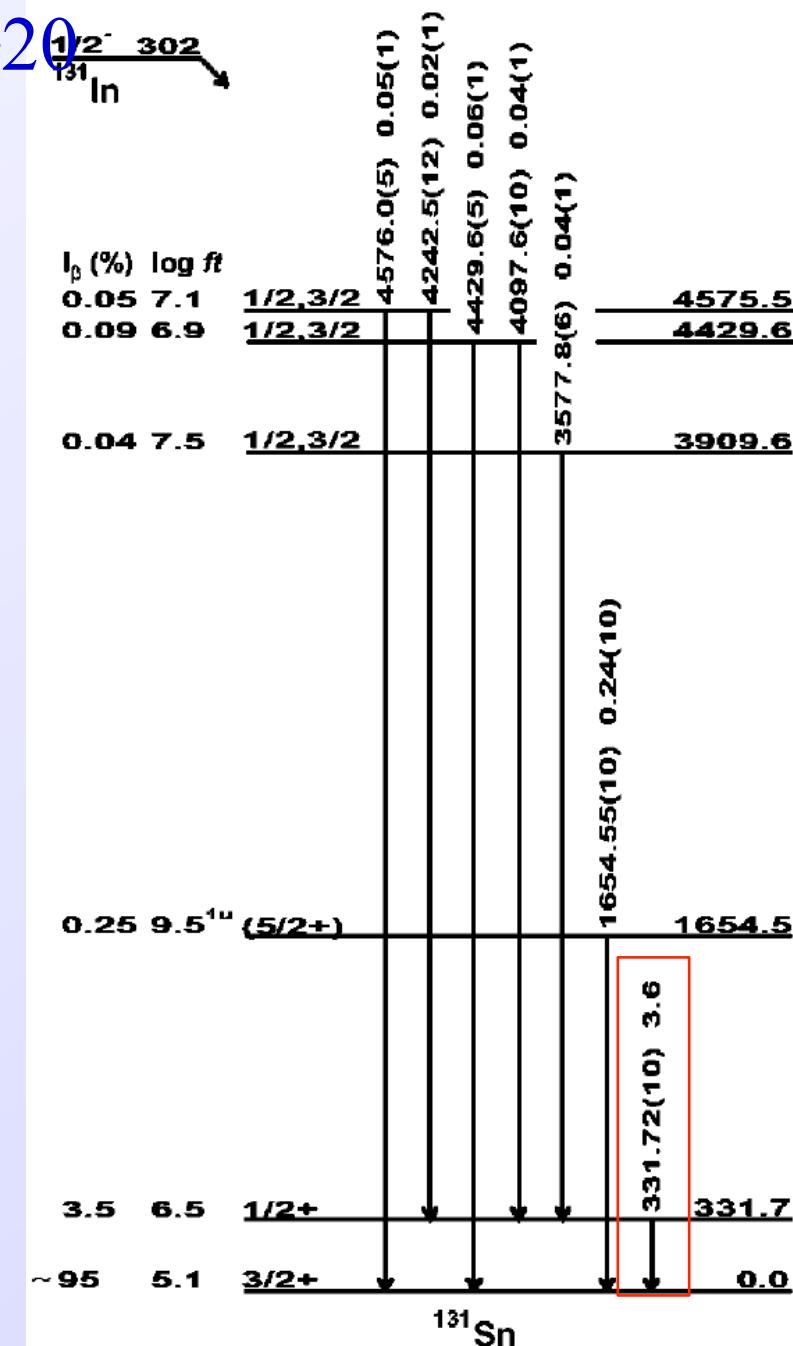
- ✓ Expected increased sensitivity by factor  $\sim 20$
- ✓ Isomer selectivity in In
  - disentangle decay schemes
- ✓ Lifetimes of high-lying levels
  - from  $21/2^+$  isomer, at  $\sim 4.5$  MeV
- ✓ Lifetimes 331-keV  $1/2^+$  level (& other)



$Z = 50$



→ forbiddenness of the transition, M1 operator  
→ similar to  $^{129}\text{Sn}$  measured at IDS



# Study of $^{133}\text{Sn}$

- ✓ Information about the M1 operator above  $^{132}\text{Sn}$
- ✓  $^{133}\text{Sn}$
- ✓  $2\text{p}_{1/2}$  single-particle candidate from  $^{132}\text{Sn}(\text{d},\text{p})$  was identified at 1.363 MeV

K.L. Jones et al., PRC84, 034601 (2011)

→ 300 keV lower than proposed value from  $\beta$ -decay

P. Hoff et al., Phys. Rev. Lett. 77, 1020 (1996)

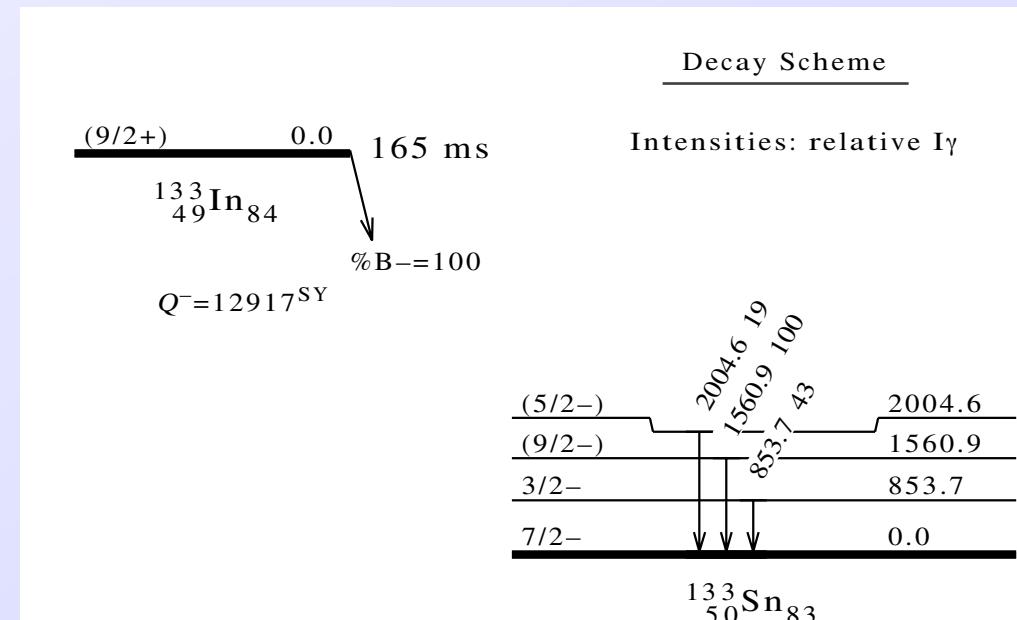
- ✓ No  $13/2^+$  observed to date

Isomer selective decay from  $^{133}\text{In}$  isomers

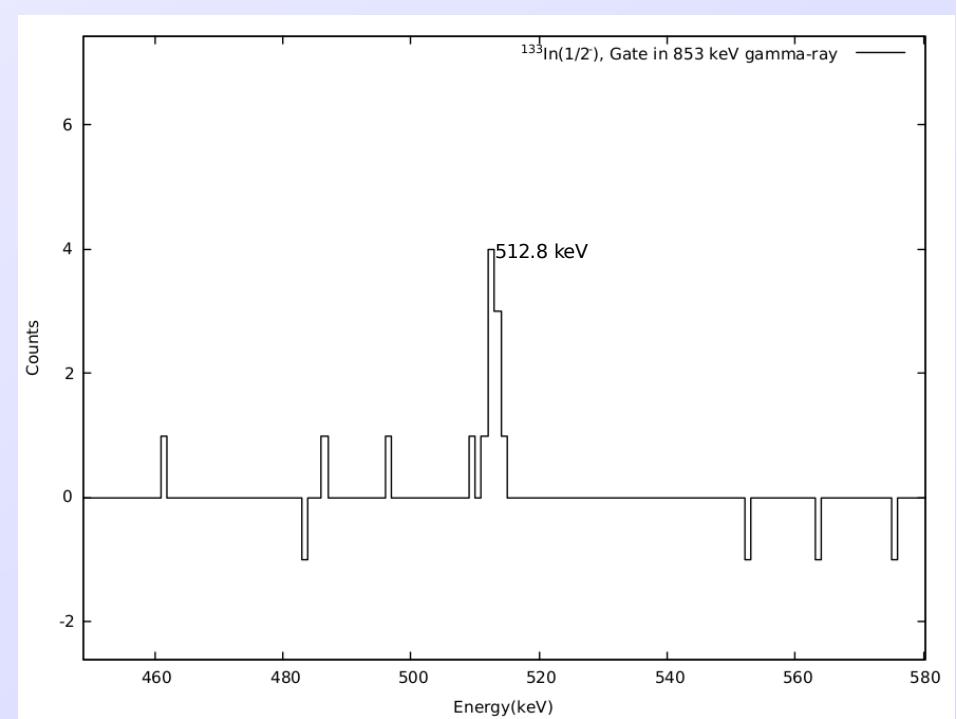
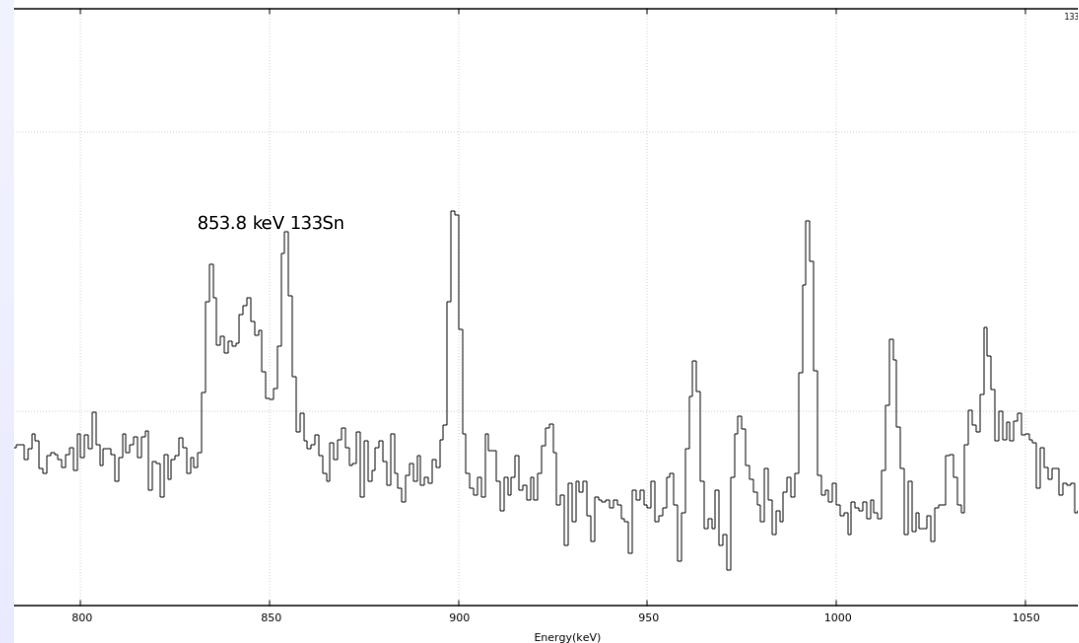
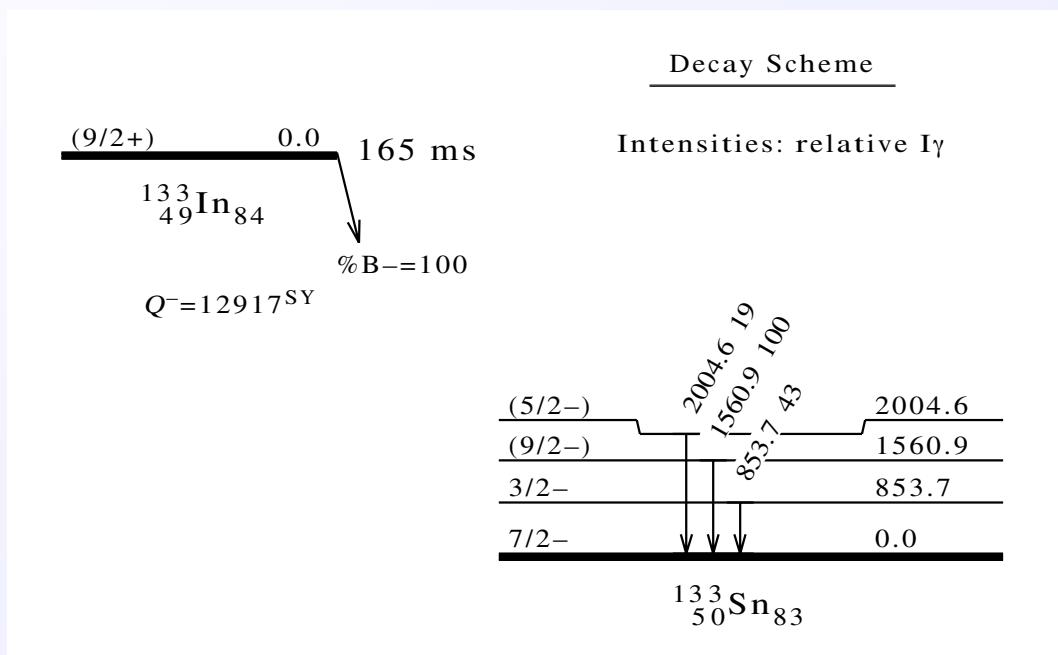
→  $(9/2^+)$  ground state and  $(1/2^-)$

$\beta$ -n branch from  $^{134}\text{In}$

Estimated ~20 higher statistics than 1996



# Preliminary analysis

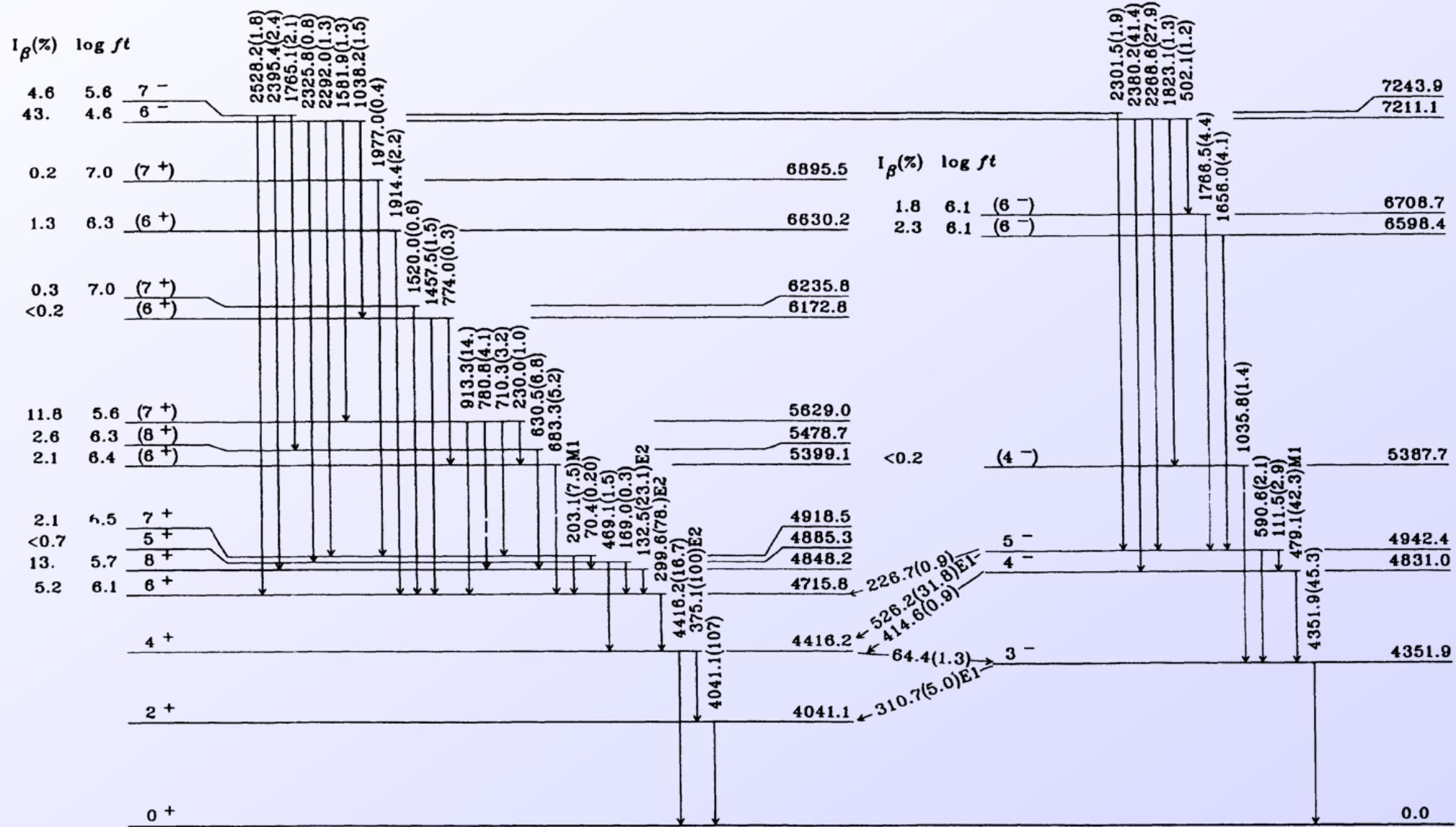


0.207 s

# 132Sn

$Q_\beta = 14.135$  MeV

B. Fogelberg et al., Phys.  
Rev. Lett. 73 (1994) 2413



# Available information on $^{132}\text{Sn}$

from Jan Blomqvist

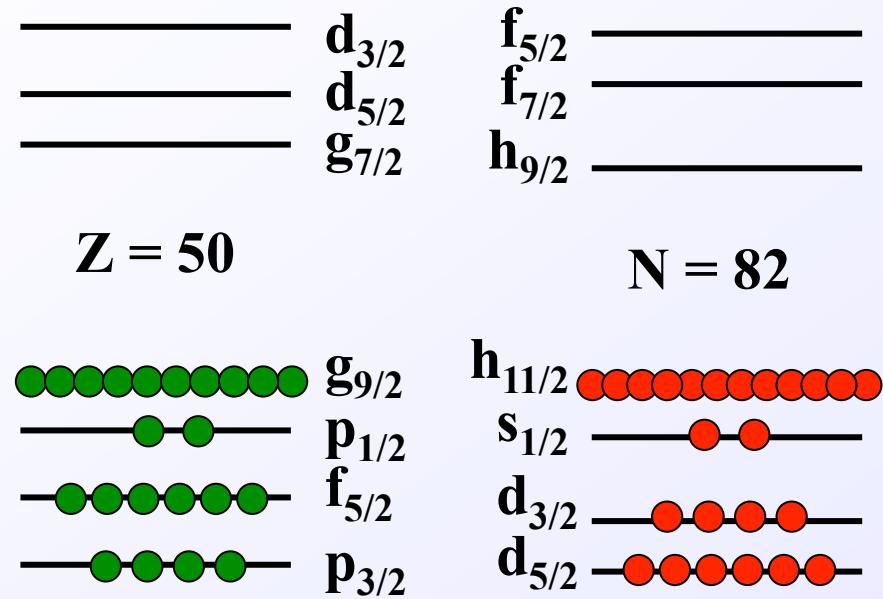
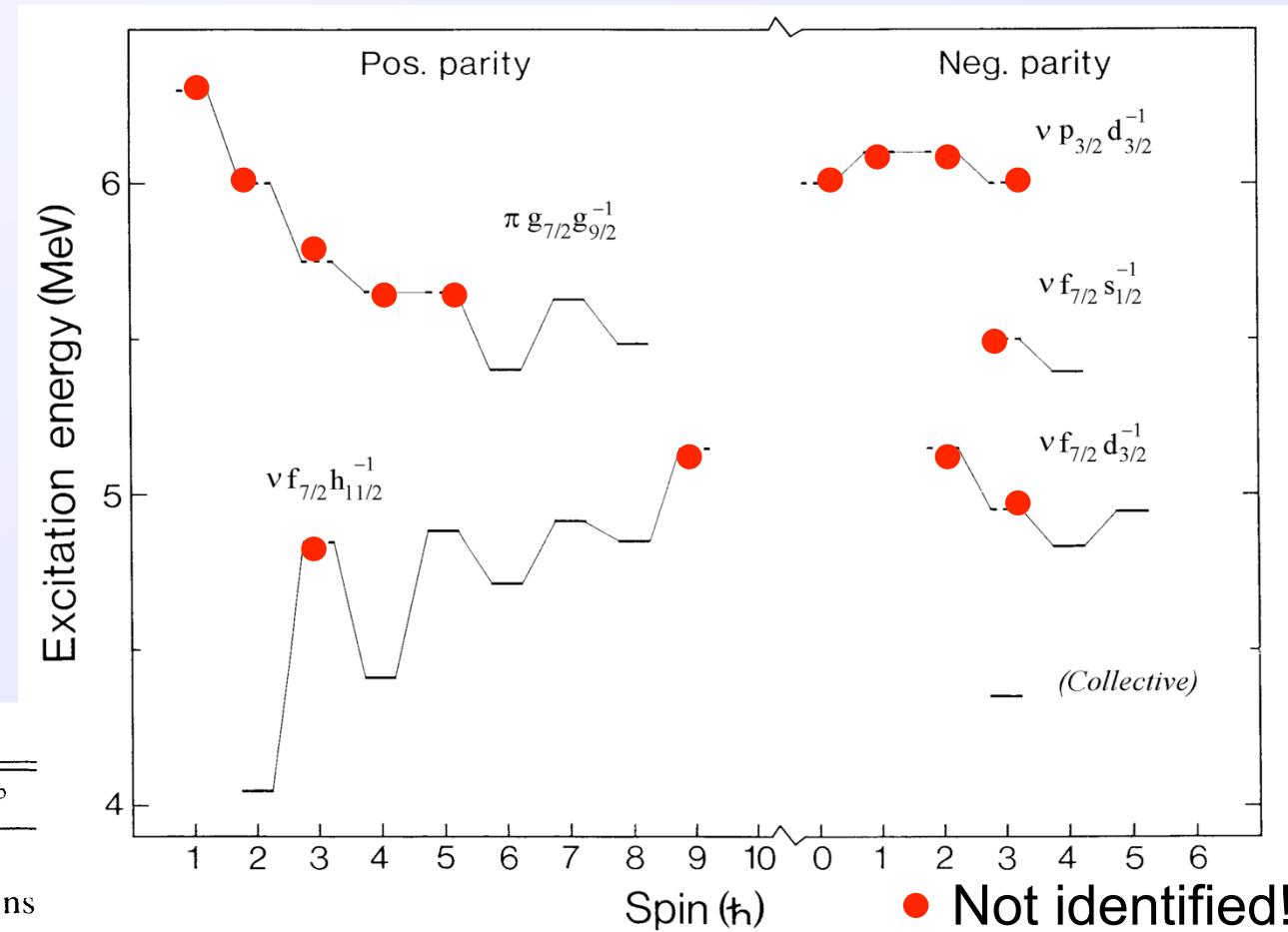


TABLE I. Half-lives of excited states in  $^{132}\text{Sn}$ .

Level (keV)	$J^\pi$	Half-life <sup>a,b</sup>
4351.9	$3^-$	<5.0 ps
4416.2	$4^+$	3.95(13) ns
4715.8	$6^+$	20.1(5) ns
4831.0	$4^-$	26.0(5) ps
4848.2	$8^+$	2.03(4) $\mu\text{s}$
4885.3	$5^+$	<40.0 ps
4918.5	$7^+$	62.0(7) ps
4942.4	$5^-$	17.0(5) ps
5629.0	$(7^+)$	13.0(ps)

<sup>a</sup>All data from the present work.

<sup>b</sup>Uncertainties are given in units of the last digit.



● Not identified!

H. Mach et al., Nuclear  
Physics A588 179c (1995)

# Identification of $^{132}\text{Sn}$ multiplets

**Multiplet**  $\nu f_{7/2} d_{3/2}^{-1}$  **from Henryk Mach after Jan Blomqvist**

$$B(M1; 5^- - 4^-) = (9/140\pi) [ \mu(f_{7/2}) - 7/3 \mu(d_{3/2}^{-1}) ]^2$$

$$\mu(f_{7/2}) \sim -1.0 \mu_N \quad \mu(d_{3/2}^{-1}) \sim +0.8 \mu_N$$

$$B(M1; 5^- - 4^-)_{\text{th}} = 0.168 \mu_N$$

$$B(M1; 5^- - 4^-)_{\text{exp}} = 0.127(36) \mu_N \quad \text{from experimental } T_{1/2} = 17(5) \text{ ps}$$

**Multiplet**  $\nu f_{7/2} h_{11/2}^{-1}$

$$B(M1; 7^+ - 8^+) = (27/98\pi) [ \mu(f_{7/2}) - 7/11 \mu(h_{11/2}^{-1}) ]^2$$

$$\mu(f_{7/2}) \sim -1.0 \mu_N \quad \mu(h_{11/2}^{-1}) \sim -1.0 \mu_N$$

$$B(M1; 7^+ - 8^+)_{\text{th}} = 0.012 \mu_N$$

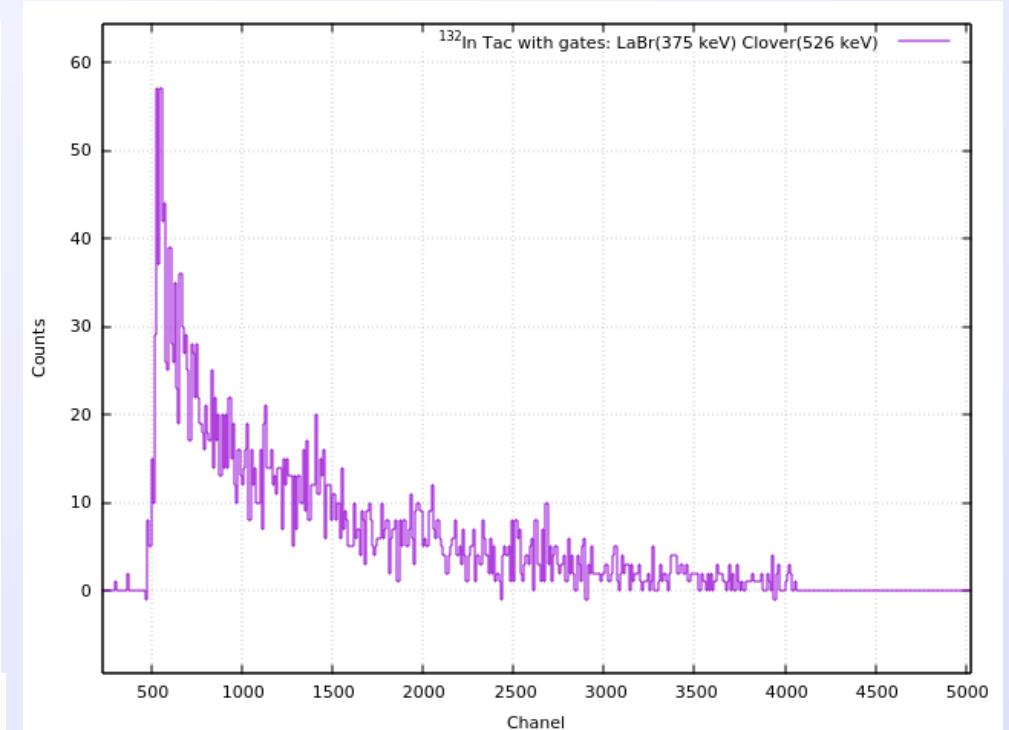
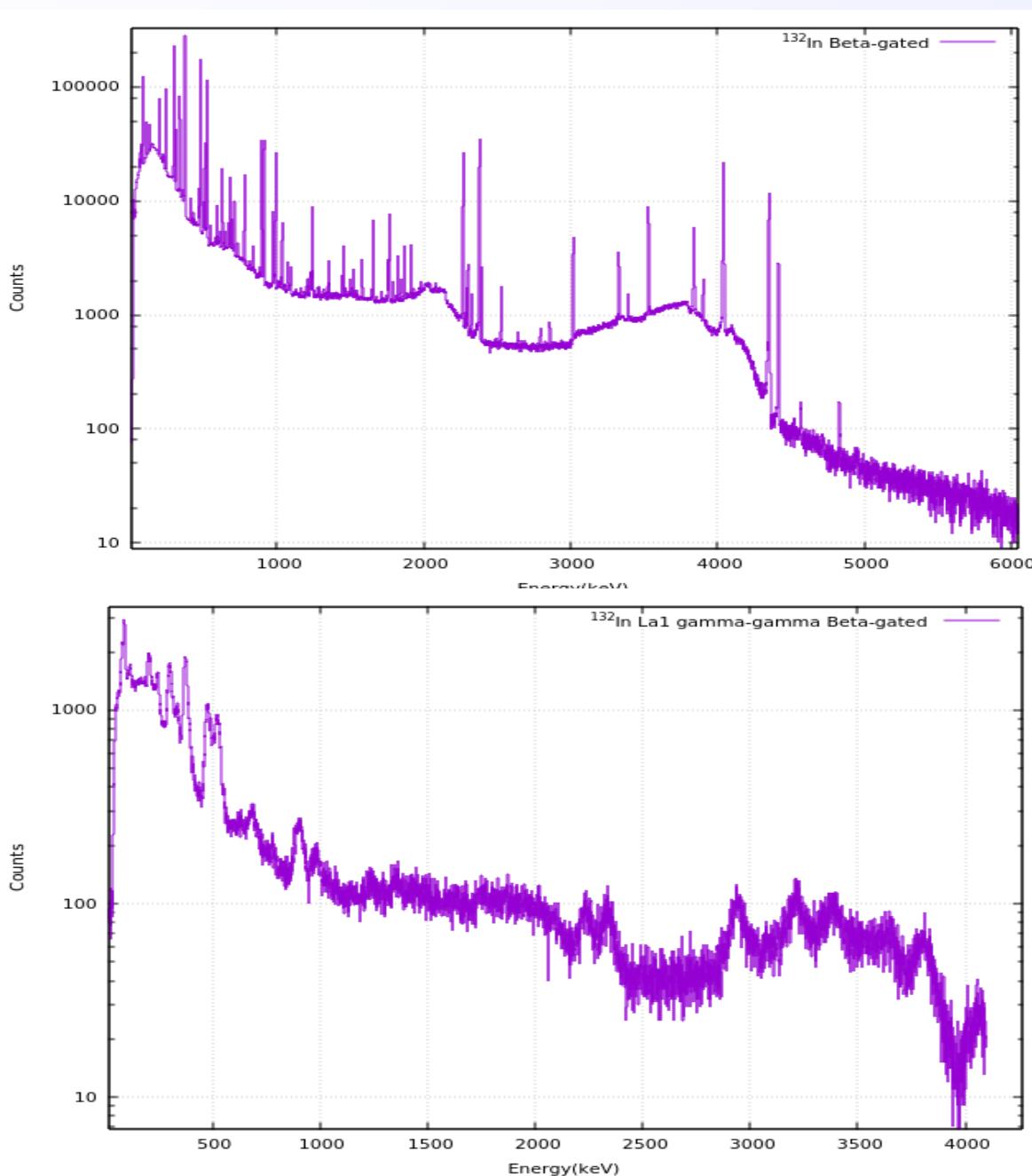
$$B(M1; 7^+ - 8^+)_{\text{exp}} = 0.042(6) \mu_N \quad \text{from exp. } T_{1/2} = 62(7) \text{ ps}$$

✓ Combination of **gamma** and **fast-timing** spectroscopy

# $^{132}\text{Sn}$ measurement

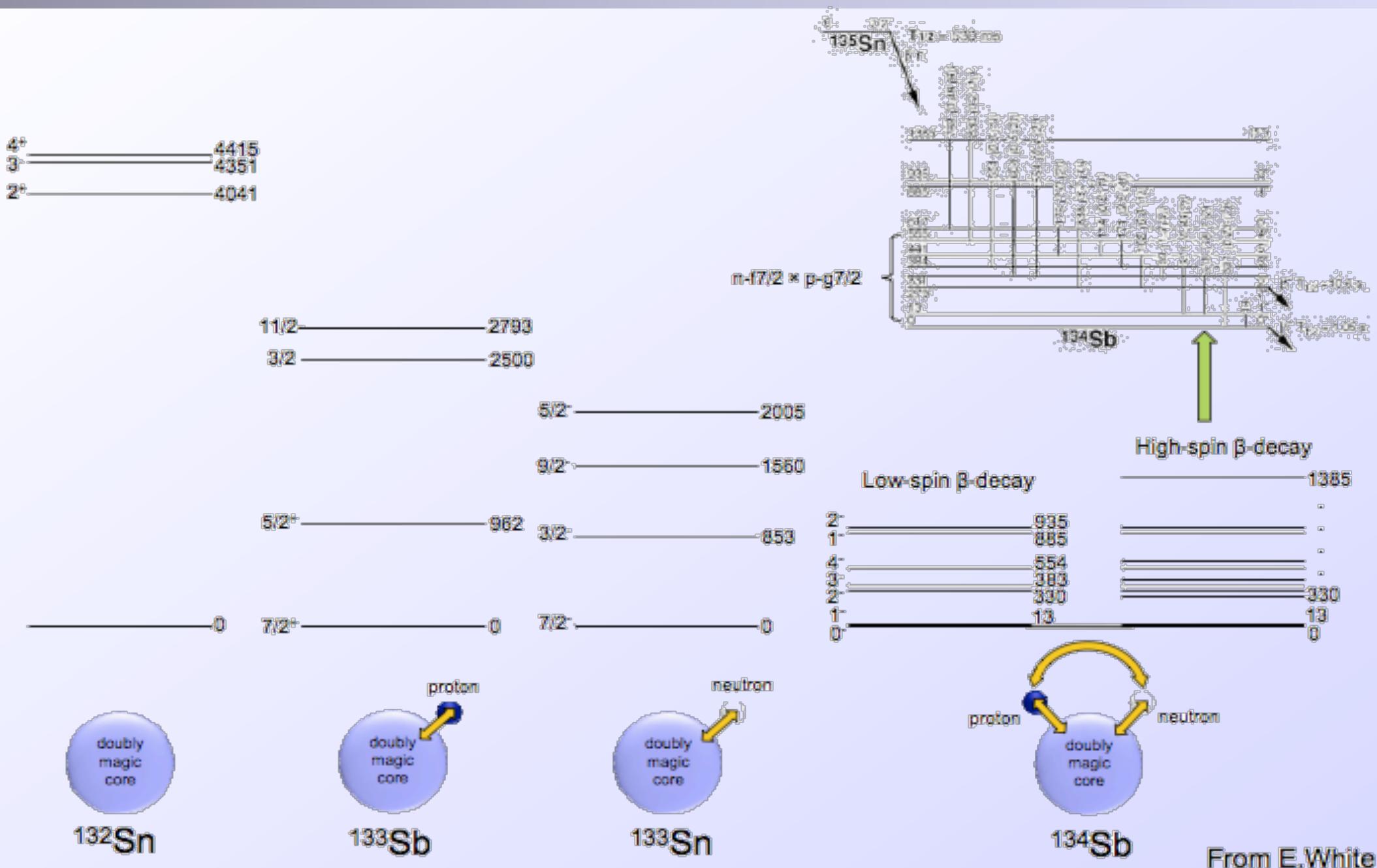
- ✓ Reach to several level lifetimes, including negative-parity states
  - transition rates
- ✓ Beta decay of  $^{132}\text{In}$ ; single beta-decaying isomer
  - spin/parity =  $7^-$
  - $T_{1/2} = 207 \text{ ms}$ ,  $Q = 14.1 \text{ MeV}$
  - $S_n = 7.3 \text{ MeV}$ ,  $P_n = 6.3(9)\%$
  - Daughter  $^{132}\text{Sn}$  to  $^{132}\text{Sb}$  ( $T_{1/2} = 39.7 \text{ s}$ )
- ✓ Beta decay of  $^{133}\text{In}$  via  $\beta$ -n branch; two beta-decaying isomer
  - spin/parity =  $(1/2^-)$ ,  $(9/2^+)$
  - $T_{1/2} = 165 \text{ ms}$ ,  $Q = 12.9 \text{ MeV}$
  - $S_n = 2.37 \text{ MeV}$ ,  $P_n = 85(10)\%$

# Preliminary $^{132}\text{Sn}$



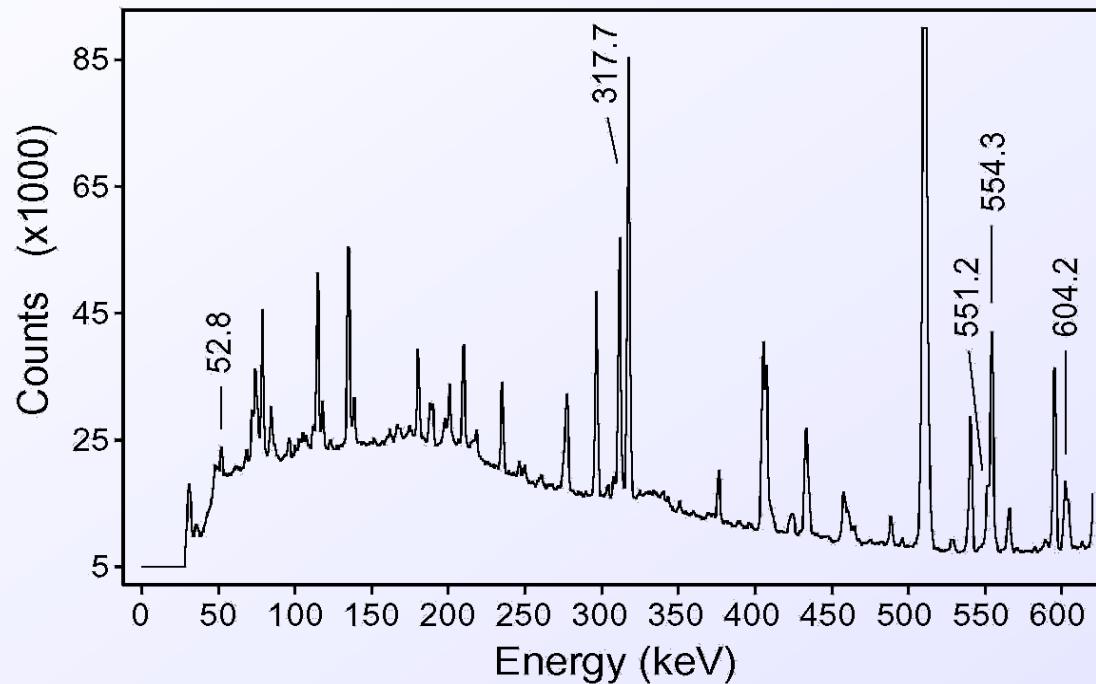
Check 4416-keV  $4^+$  state  
 $T_{1/2} \sim 3.7 \text{ ns}$

# “Simple” nuclei

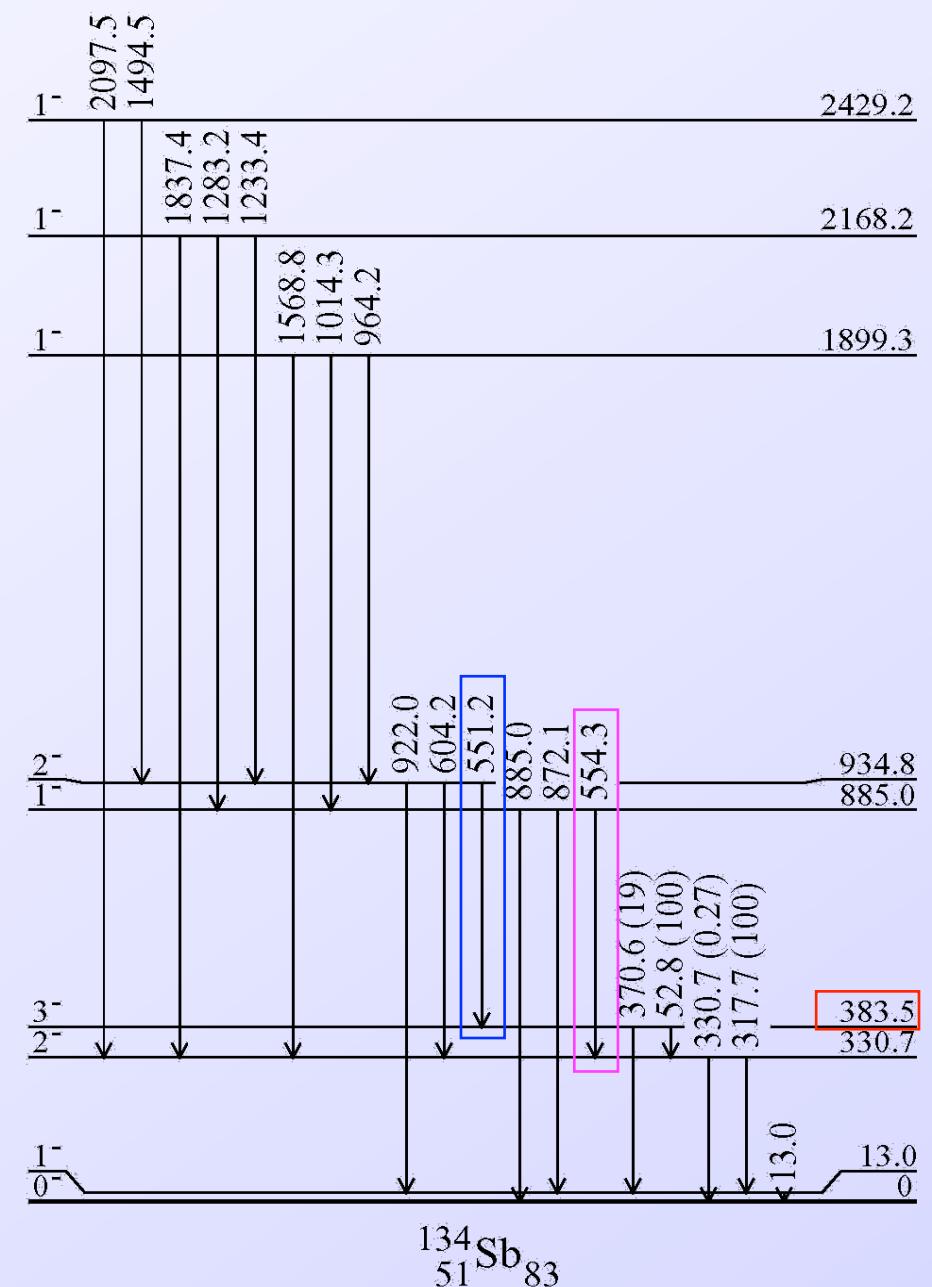


# $^{134}\text{Sb}$ ( $^{132}\text{Sn} + \text{p} + \text{n}$ ) beta-decay results

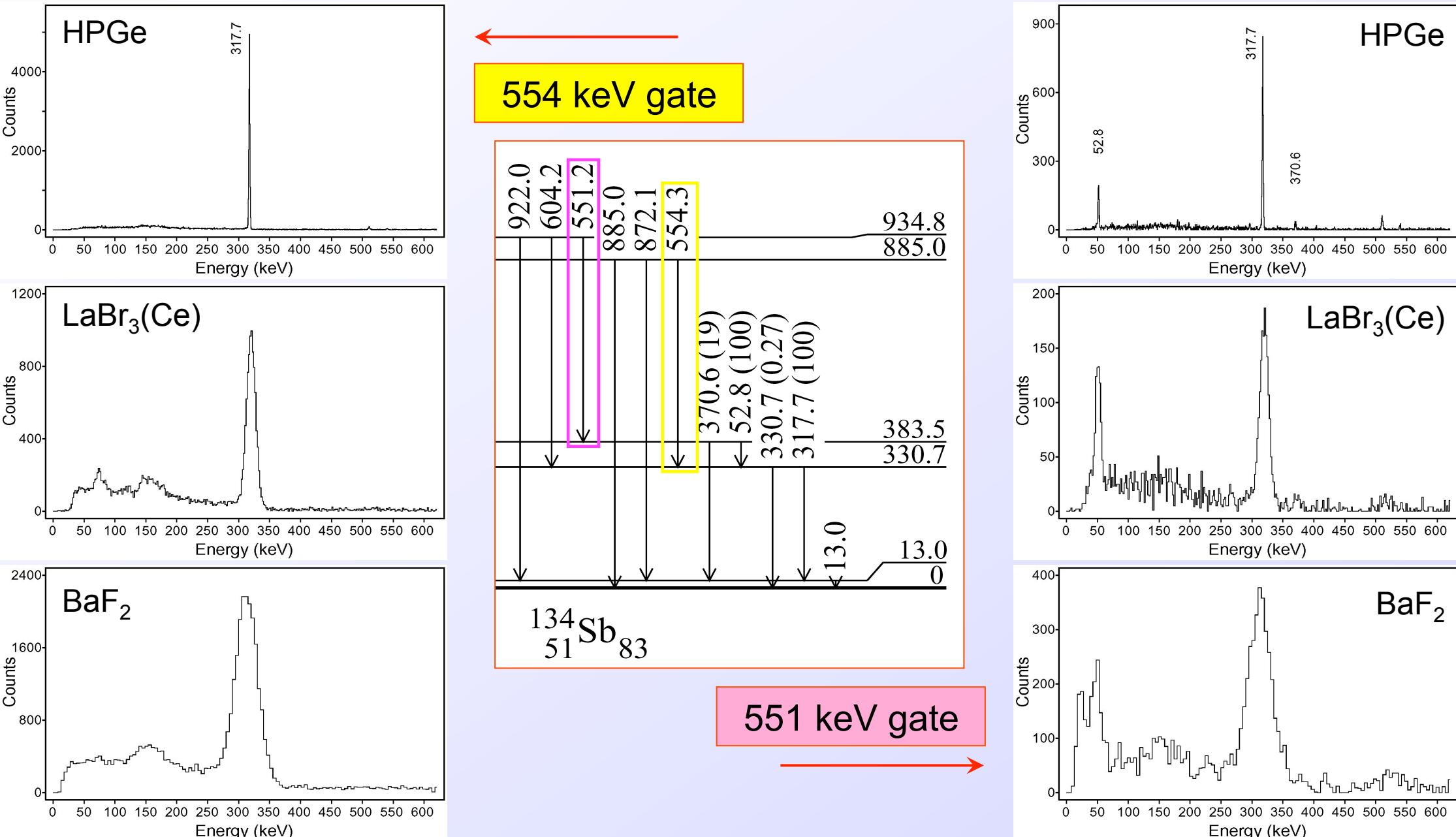
✓ Strong production of  $^{134}\text{Sn}$



- Clean spectra
- Weak branches
- Fast timing

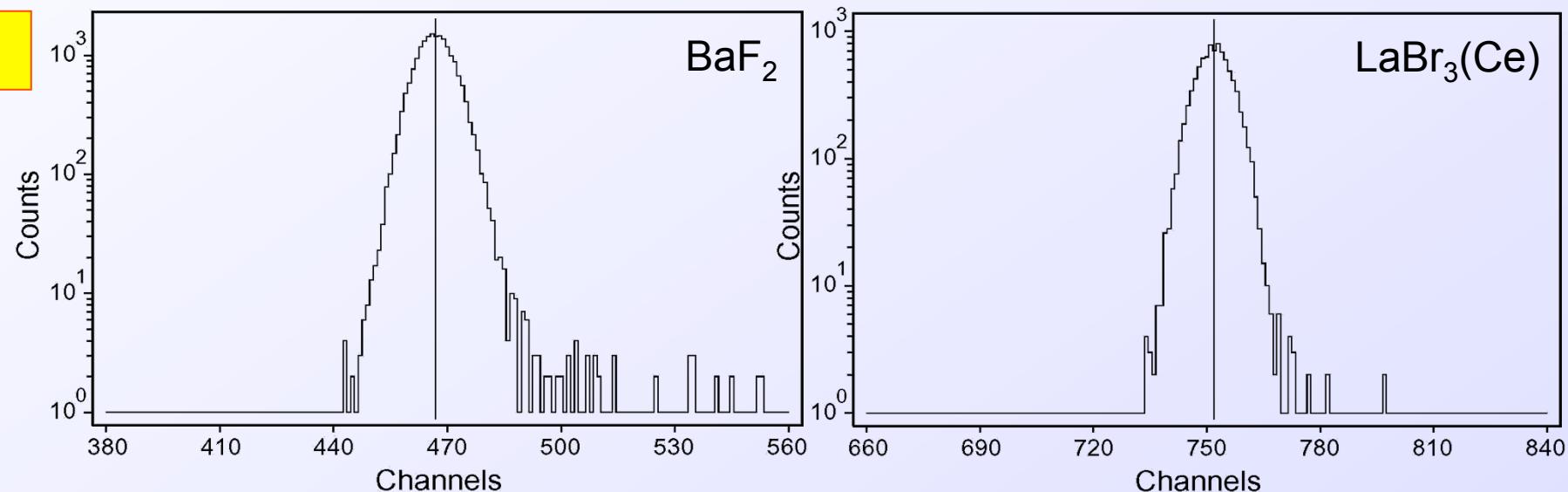


# $^{134}\text{Sb}$ results: lifetime of 383 keV level

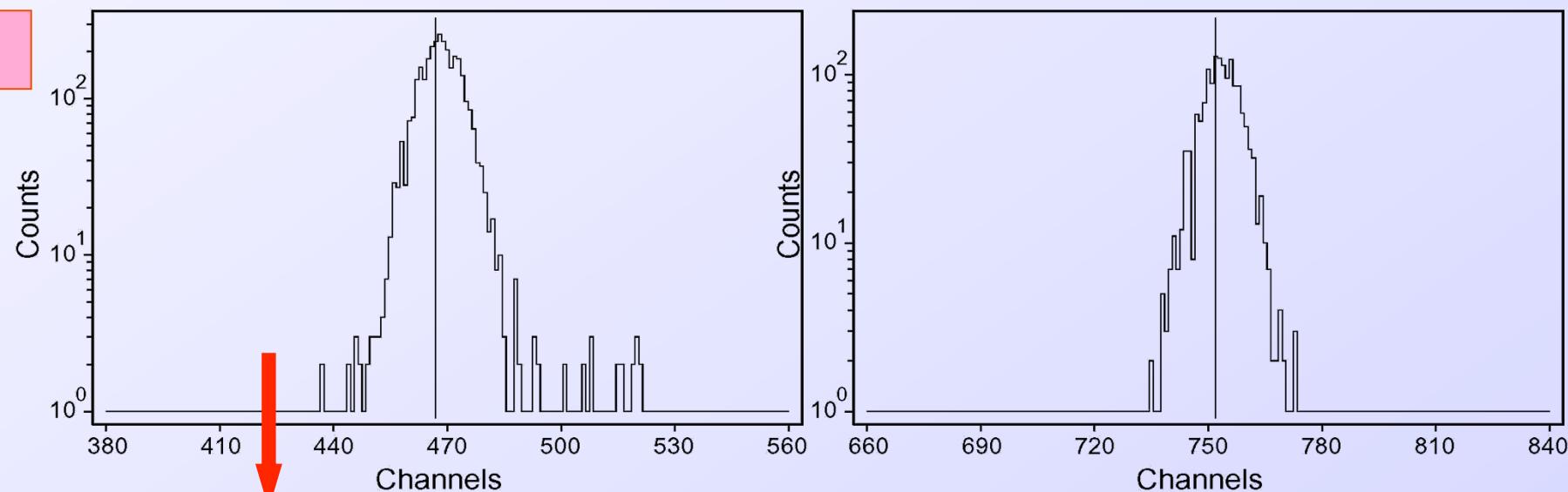


# $^{134}\text{Sb}$ results: lifetime of 383 keV level

554 keV gate



551 keV gate



$\text{Tau} = 40(8) \text{ ps}$

Calibrations need to be finalized

# $^{134}\text{Sb}$ results: comparison to shell model

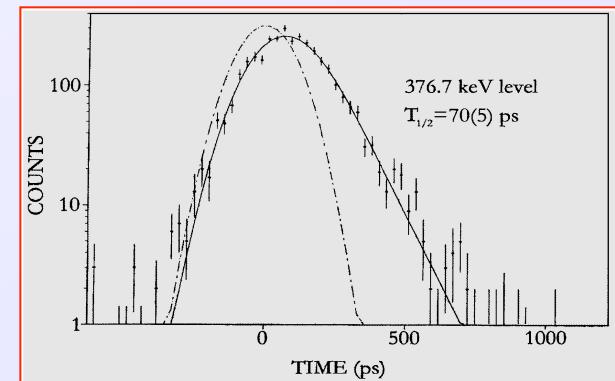
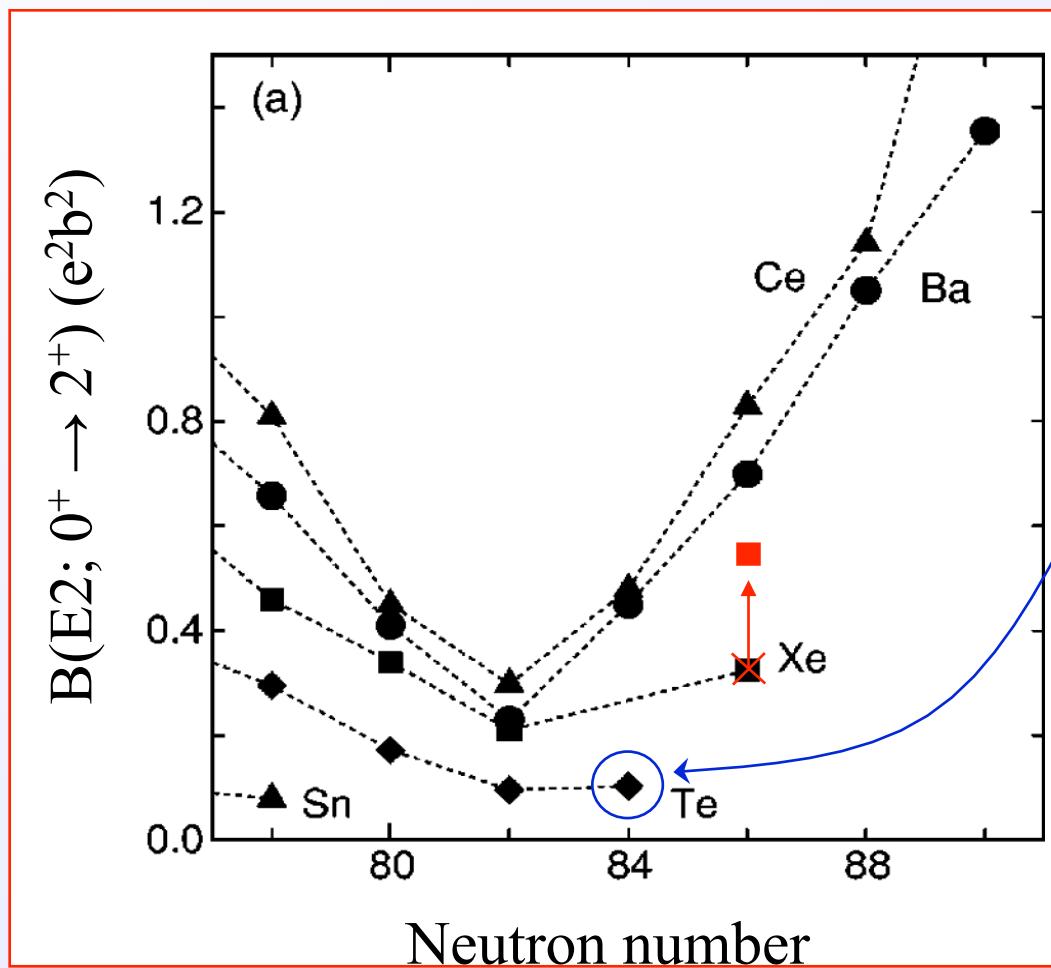
Levels $\pi g_{7/2} \nu f_{7/2}$	Exp (keV)	Brown (keV)	Covello & Gargano (keV)
0 <sup>-</sup>	0	0	0
1 <sup>-</sup>	13	333	52
2 <sup>-</sup>	331	404	385
3 <sup>-</sup>	383	587	429

Transition	Exp (keV)	Brown <sup>*</sup> (keV)	Covello Gargano (keV)
$3^- \rightarrow 2^-$	$B(M1) = 2.0(0.4) \mu_N^2$	1.60	1.39
$3^- \rightarrow 1^-$	$B(E2) = 118(26) e^2 fm^4$	84	115

$B(M1)$  is one of the fastest in all known nuclei at the excitation energy below 3 MeV

# $^{136}\text{Te}$ ( $^{132}\text{Sn} \oplus 2\text{p} \oplus 2\text{n}$ ) status

✓  $B(E2; 0^+ \rightarrow 2^+)$  rates in the region:



$^{140}\text{Xe}$ :  $T_{1/2} = 70(5)$  ps    **60% shorter**  
 [A. Lindroth et al., PRL 82 (1999) 4783]  
 + Th. Kröll et al., Xe CoulEx  
 [D. Radford et al., PRL 89 (2002) 222501]

TABLE II.  $B(E2; 0^+ \rightarrow 2^+)$  values ( $e^2 b^2$ ) measured in the present work, compared with shell-model calculations (SM) and adopted values from Ref. [8].

Nuclide	This Work	SM	Adopted [8]
$^{132}\text{Te}$	0.172(17)		
$^{134}\text{Te}$	0.096(12)	0.088	
$^{136}\text{Te}$	0.103(15)	0.25	
$^{128}\text{Te}$	0.346(26)		0.383(6)
$^{136}\text{Ba}$	0.46(4)		0.410(8)

This low  $B(E2)$  implies a mean life of **49(7) ps** for the  $2^+$  state in  $^{136}\text{Te}$

# $^{136}\text{Te}$ results: lifetime of the $2^+$ state

## ✓ Summary of results

$$B(E2; 2^+ \rightarrow 0^+) = 208(29) \text{ e}^2\text{fm}^4$$

$$B(E2; 2^+ \rightarrow 0^+) = 245(50) \text{ e}^2\text{fm}^4$$

$$B(E2; 2^+ \rightarrow 0^+) = 260?? \text{ e}^2\text{fm}^4$$

$$B(E2; 2^+ \rightarrow 0^+) = 303(20) \text{ e}^2\text{fm}^4$$

[D.Radford et al. PRL 88 (2002) 222501]

**ISOLDE work,  $\tau \sim 43(9)$  ps**

L.M Fraile et al., being prepared for publication

[A. Galindo-Uribarri, this workshop]

C. Baktash,  $B(E2\uparrow) = 0.15(1) \text{ e}^2\text{b}^2$   
 [Abstracts, Spring Seminar on NP 2007]

## Calculations:

$$B(E2; 2^+ \rightarrow 0^+) = 500 \text{ e}^2\text{fm}^4$$

$$B(E2; 2^+ \rightarrow 0^+) = 180 \text{ e}^2\text{fm}^4$$

$$B(E2; 2^+ \rightarrow 0^+) = 320 \text{ e}^2\text{fm}^4$$

$$B(E2; 2^+ \rightarrow 0^+) = 300 \text{ e}^2\text{fm}^4$$

$$B(E2; 2^+ \rightarrow 0^+) = 452 \text{ e}^2\text{fm}^4$$

$$B(E2; 2^+ \rightarrow 0^+) = 360 \text{ e}^2\text{fm}^4$$

A. Covello [D.Radford PRL 88 (2002) 222501]

J. Terasaki [PRC 66, 054313 (2002)]

A. Covello [D.Radford et al., Proc. World Sci. 2003]

N. Shimizu [PRC 70 054313 (2004)]

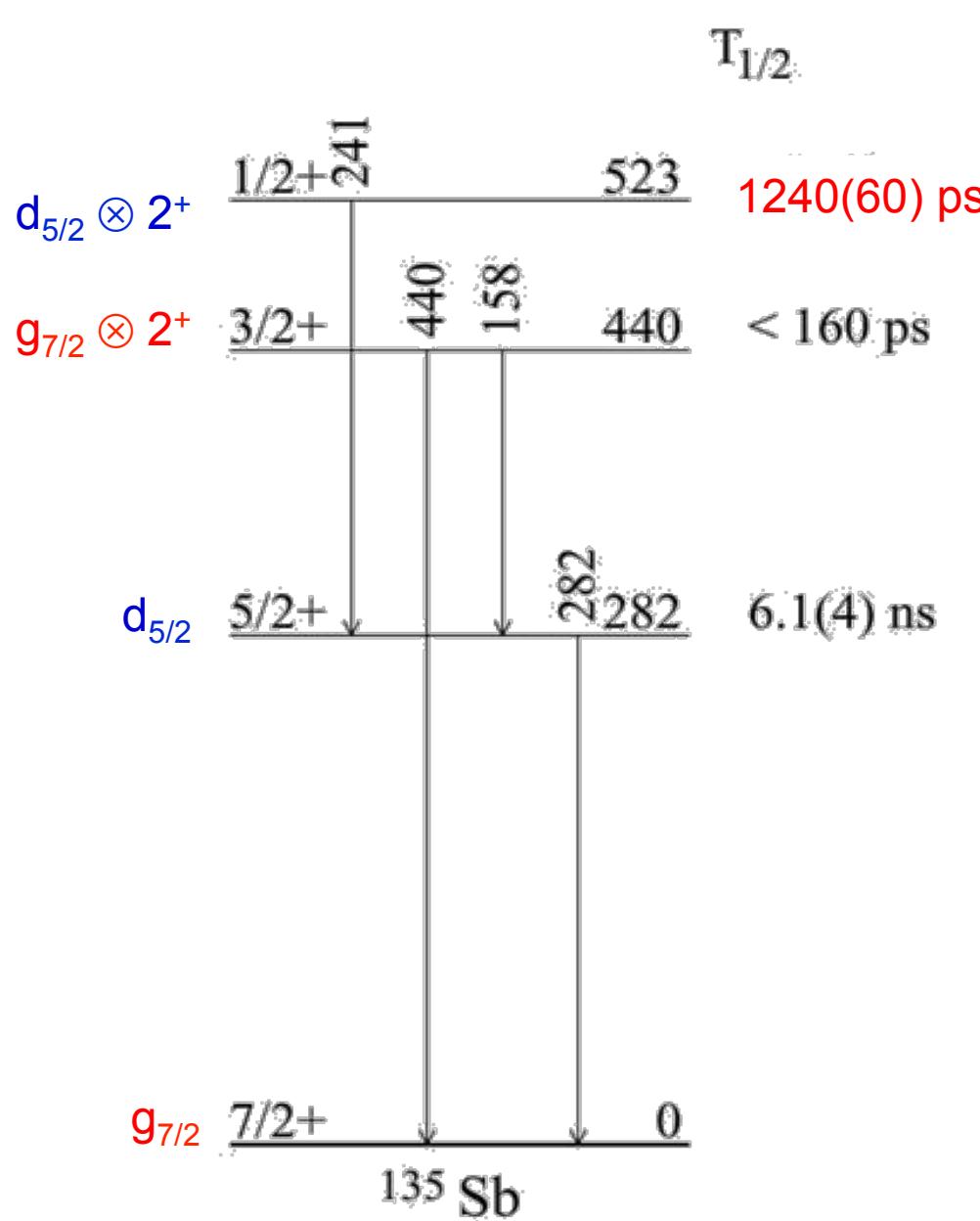
A. Brown

A. Covello and A. Gargano

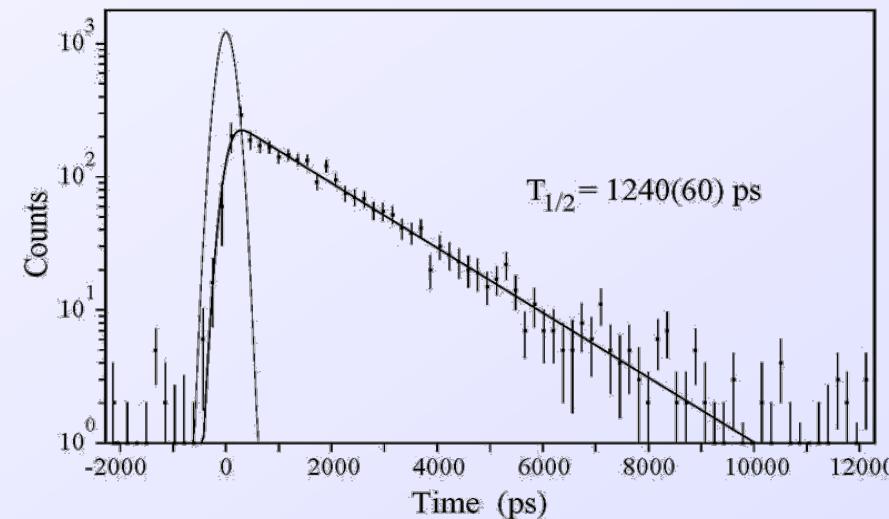
# Summary

- ✓ From the lifetime measurements we have identified
  - Extraordinary fast M1 transition connecting levels in the  $\pi g_{7/2}$ - $\nu f_{7/2}$  multiplet in  $^{134}\text{Sb}$ , with  $B(\text{M1}) = 2 \mu_N^2$
  - $\tau = 43(9)$  ps for  $2^+$  state in  $^{136}\text{Te} \Rightarrow$  faster  $B(\text{E2})$
  - $1/2^+$  state and very fast E2  $1/2^+ \rightarrow 5/2^+$  transition in  $^{135}\text{Sb}$ 
    - Reproduced by SM calculations
    - Collective, not compatible with a  $^{136}\text{Te}$  value...

# $^{135}\text{Sb}$ results: transition probabilities



241: **B(E2;  $1/2 \rightarrow 5/2$ ) = 12.7 (6) W.u.**



440: **B(E2;  $3/2 \rightarrow 7/2$ ) > 4.3 W.u.**

158: **B(M1;  $3/2 \rightarrow 5/2$ ) > 0.004 W.u.**

282: **B(E2;  $5/2 \rightarrow 7/2$ ) < 1.3 W.u.**

282: **B(M1;  $5/2 \rightarrow 7/2$ ) < 0.00017 W.u.**

Core excitation:

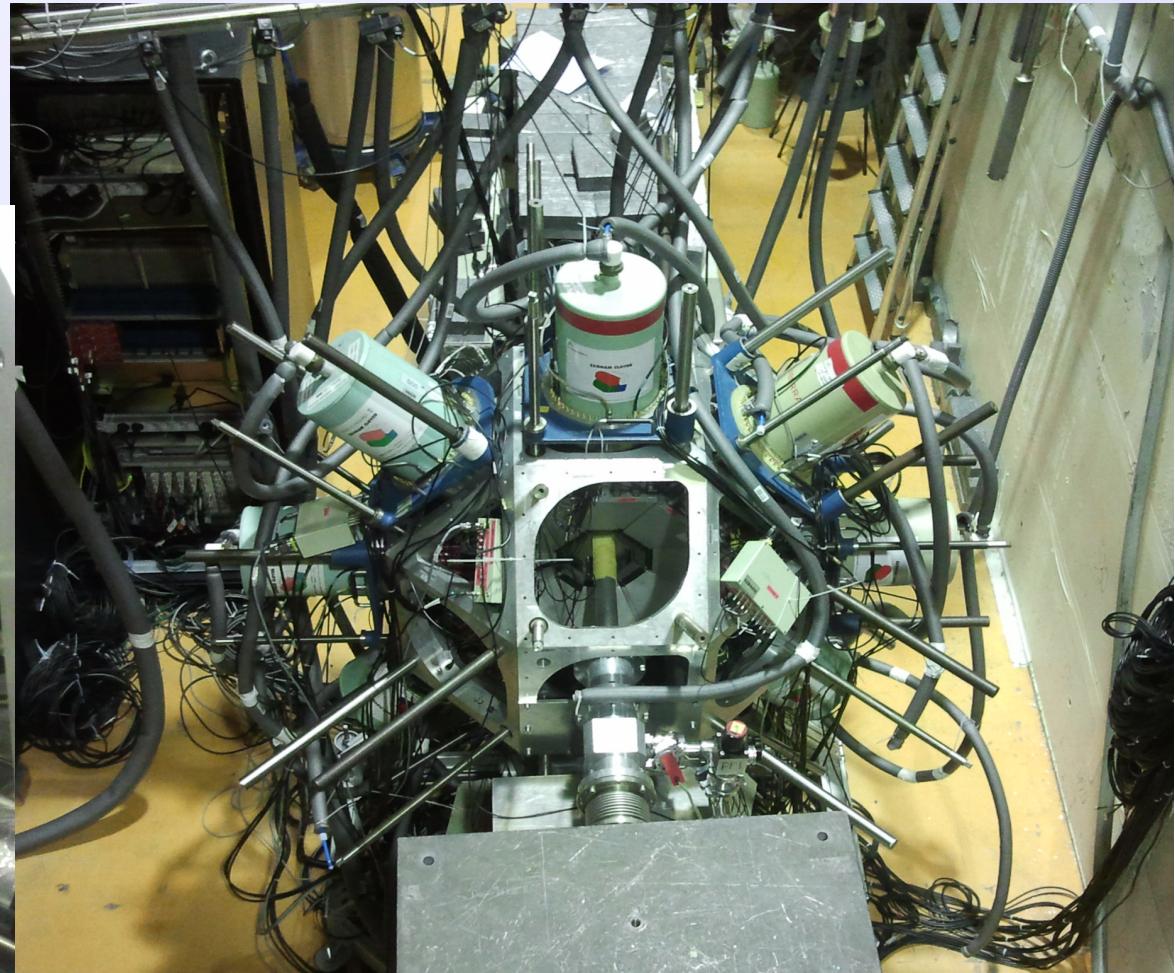
$^{134}\text{Sn}$  **B(E2;  $2 \rightarrow 0$ ) = 1.42 (24) W.u.**

( $^{136}\text{Te}$  **B(E2;  $2 \rightarrow 0$ ) = 5.0 (7) W.u.**)

# Rates in $^{136}\text{Te}$ EXILL-FATIMA, ILL Grenoble

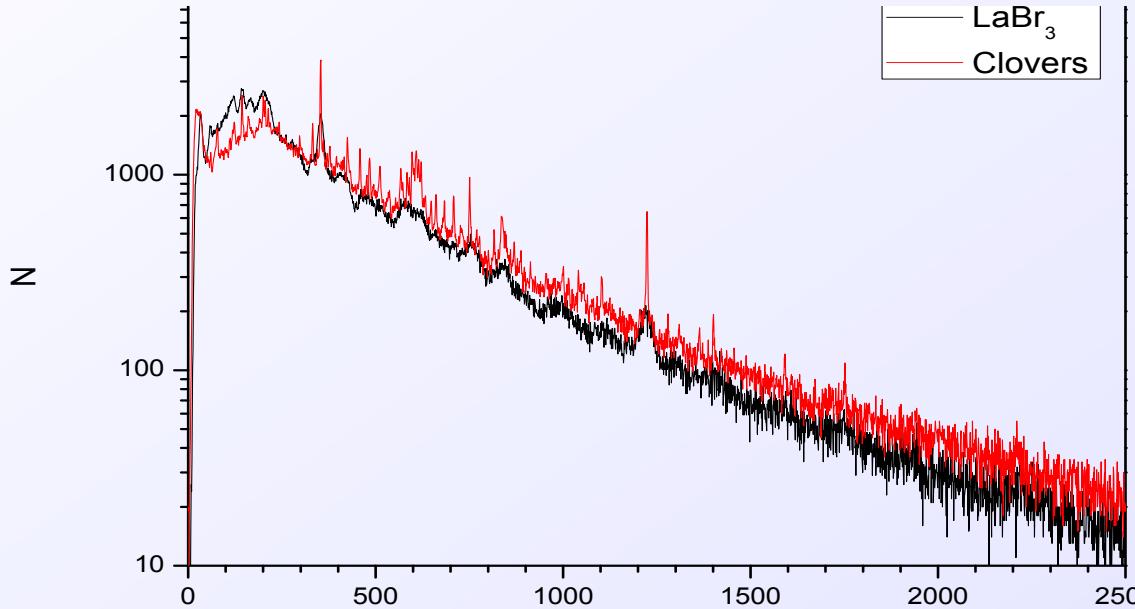
✓ EXOGAM + Fast timing LaBr<sub>3</sub> Ce) array

- Nuclear spectroscopy of prompt fission fragments in 2013
- Thermal neutron induced fission of  $^{235}\text{U}$ .
- EXOGAM + 16 LaBr<sub>3</sub> Ce)
- Digital DAQ for energy
- Analog TACs for timing

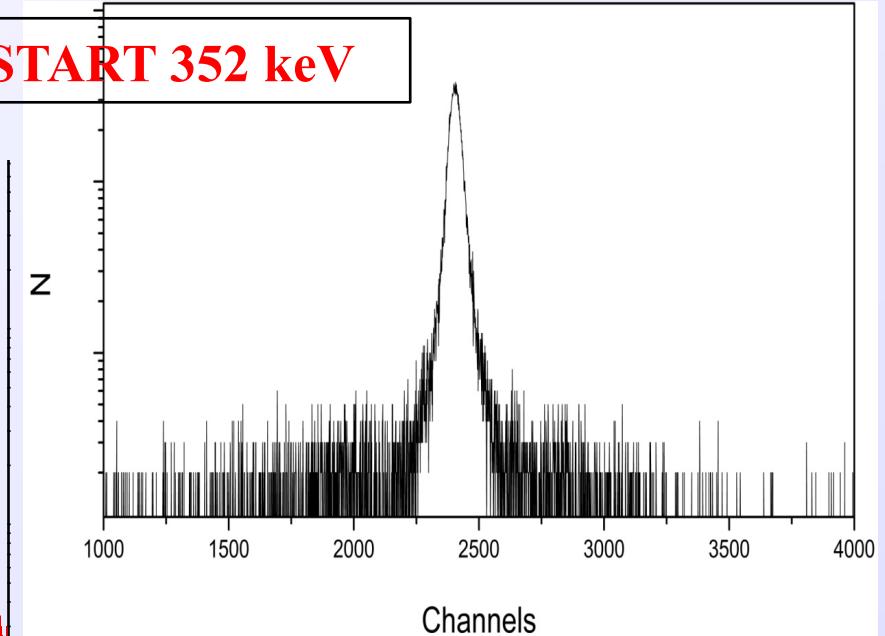


# Study of $^{136}\text{Te}$

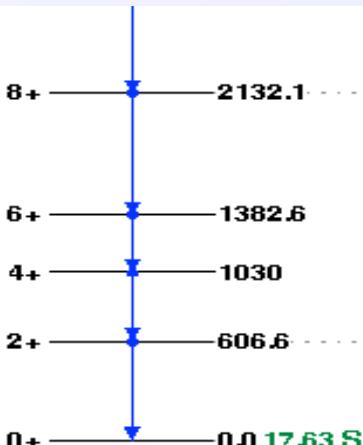
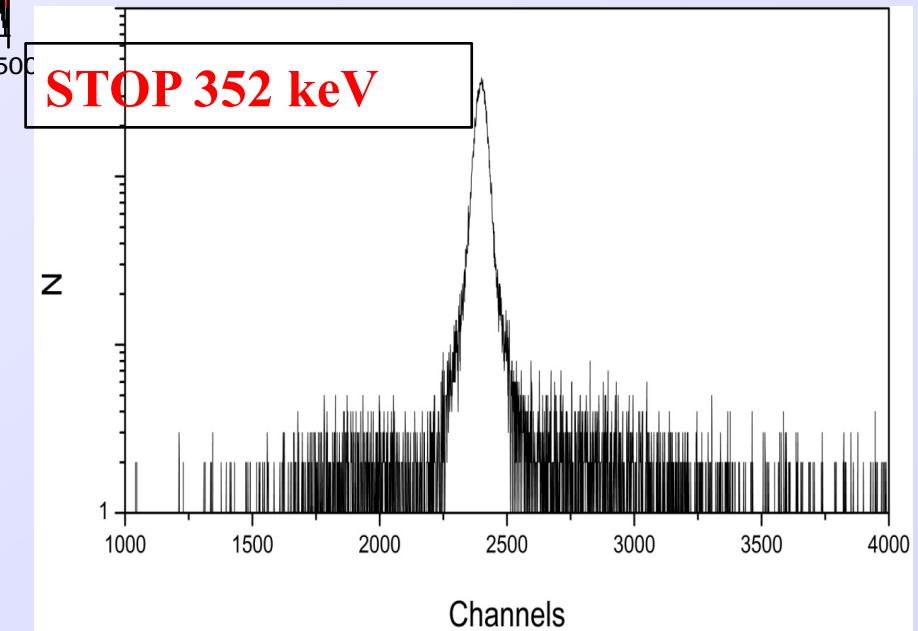
Ge 606 keV-La 423 keV



START 352 keV



STOP 352 keV



To be continued

V. Vedia et al.

# Conclusions

## ✓ Lifetime measurements

- Access to transition rates
- Systematics

## ✓ Combination

- Production techniques
- Experimental methods

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Thank you!