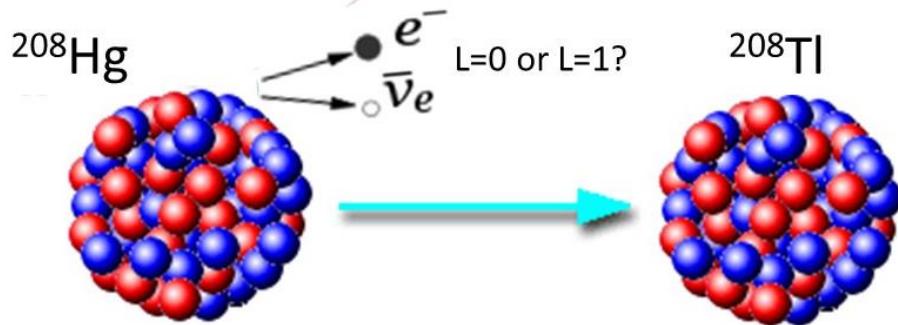
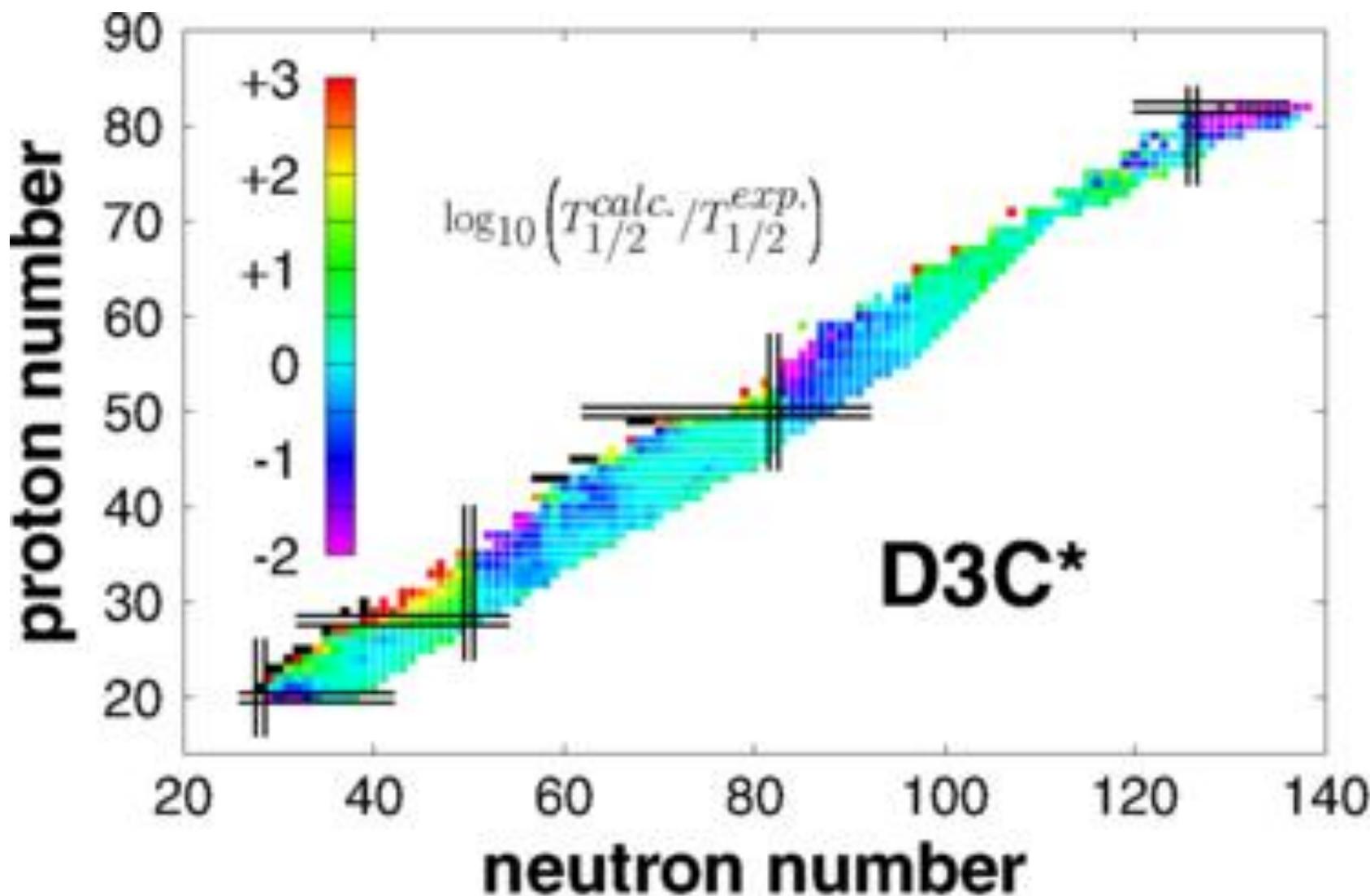


## Competition between Allowed and First-Forbidden $\beta$ Decay: The Case of $^{208}\text{Hg} \rightarrow ^{208}\text{Tl}$

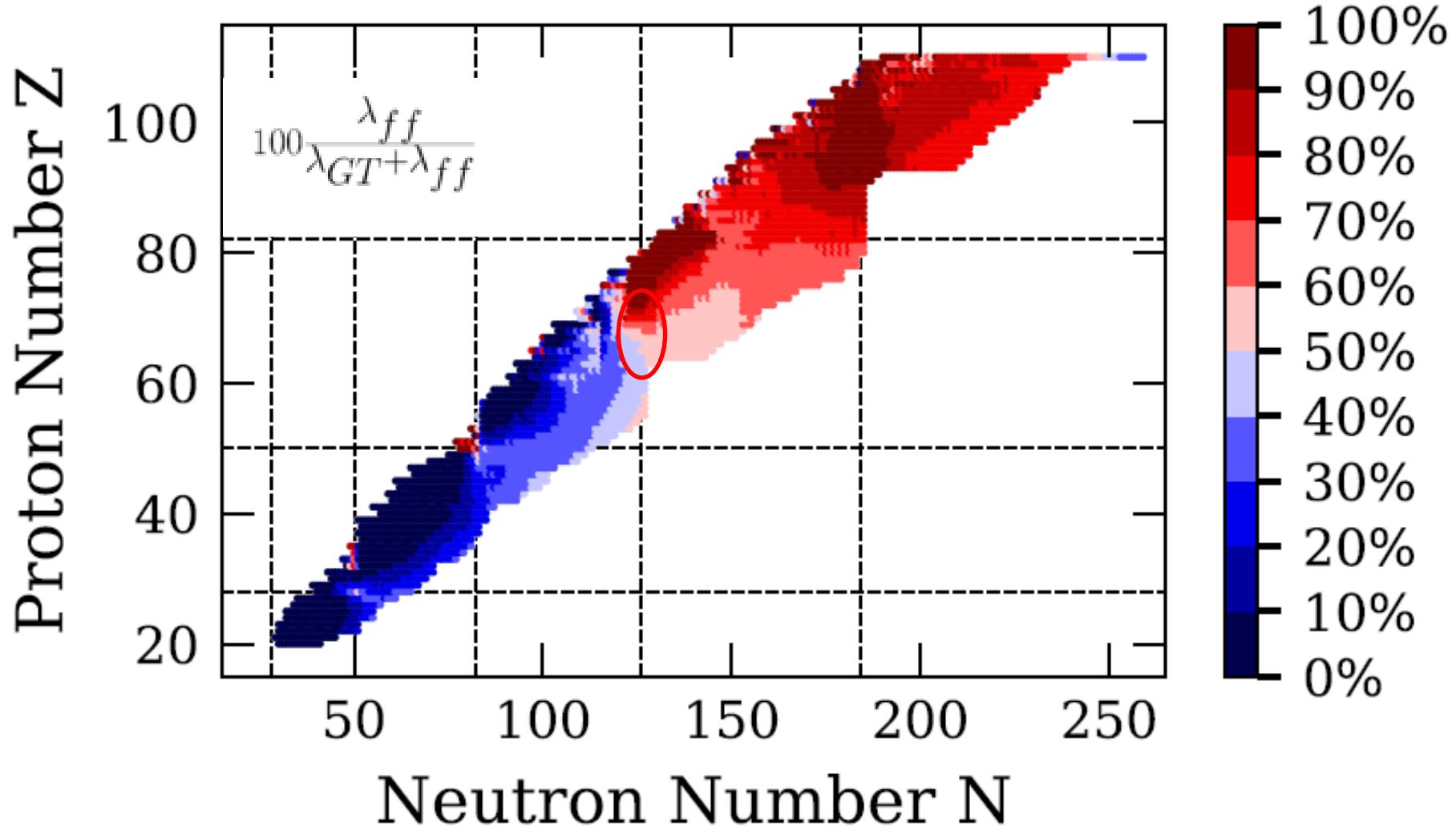
R. J. Carroll,<sup>1</sup> Zs. Podolyák,<sup>1,2</sup> T. Berry,<sup>1</sup> H. Grawe,<sup>3</sup> T. Alexander,<sup>1</sup> A. N. Andreyev,<sup>4,22</sup> S. Ansari,<sup>5</sup> M. J. G. Borge,<sup>6</sup> M. Brunet,<sup>1</sup> J. R. Creswell,<sup>7</sup> L. M. Fraile,<sup>8</sup> C. Fahlander,<sup>9</sup> H. O. U. Fynbo,<sup>10</sup> E. R. Gamba,<sup>11</sup> W. Gelletly,<sup>1</sup> R.-B. Gerst,<sup>5</sup> M. Górska,<sup>3</sup> A. Gredley,<sup>7</sup> P. T. Greenlees,<sup>12,13</sup> L. J. Harkness-Brennan,<sup>7</sup> M. Huyse,<sup>14</sup> S. M. Judge,<sup>15</sup> D. S. Judson,<sup>7</sup> J. Konki,<sup>12,13</sup> J. Kurcewicz,<sup>6</sup> I. Kuti,<sup>16</sup> S. Lalkovski,<sup>1</sup> I. H. Lazarus,<sup>17</sup> R. Lică,<sup>6,18</sup> M. Lund,<sup>10</sup> M. Madurga,<sup>6,23</sup> N. Marginean,<sup>18</sup> R. Marginean,<sup>18</sup> I. Marroquin,<sup>19</sup> C. Mihai,<sup>18</sup> R. E. Mihai,<sup>18</sup> E. Nácher,<sup>19</sup> A. Negret,<sup>18</sup> C. Nita,<sup>18,11</sup> S. Pascu,<sup>18</sup> R. D. Page,<sup>7</sup> Z. Patel,<sup>1</sup> A. Pereea,<sup>19</sup> J. Phrompao,<sup>20</sup> M. Piersa,<sup>21</sup> V. Pucknell,<sup>17</sup> P. Rahkila,<sup>12,13</sup> E. Rapisarda,<sup>6</sup> P. H. Regan,<sup>1,15</sup> F. Rotaru,<sup>18</sup> M. Rudigier,<sup>1</sup> C. M. Shand,<sup>1</sup> R. Shearman,<sup>1,15</sup> S. Stegemann,<sup>5</sup> T. Stora,<sup>6</sup> Ch. Sotty,<sup>14,18</sup> O. Tengblad,<sup>19</sup> P. Van Duppen,<sup>14</sup> V. Vedia,<sup>8</sup> R. Wadsworth,<sup>4</sup> P. M. Walker,<sup>1</sup> N. Warr,<sup>5</sup> F. Wearing,<sup>7</sup> and H. De Witte<sup>14</sup>



## Calculated vs experimental beta-decay half-lives



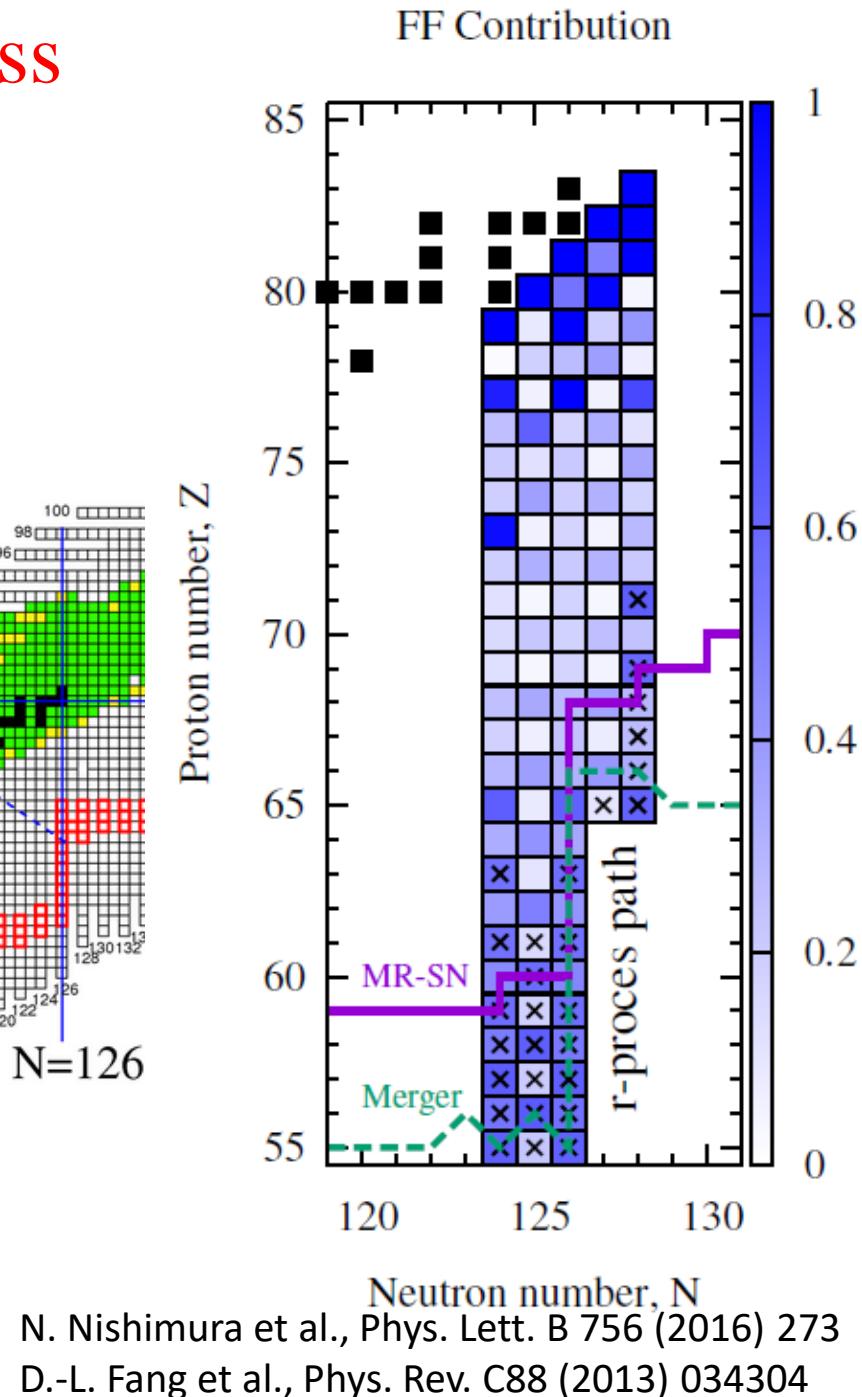
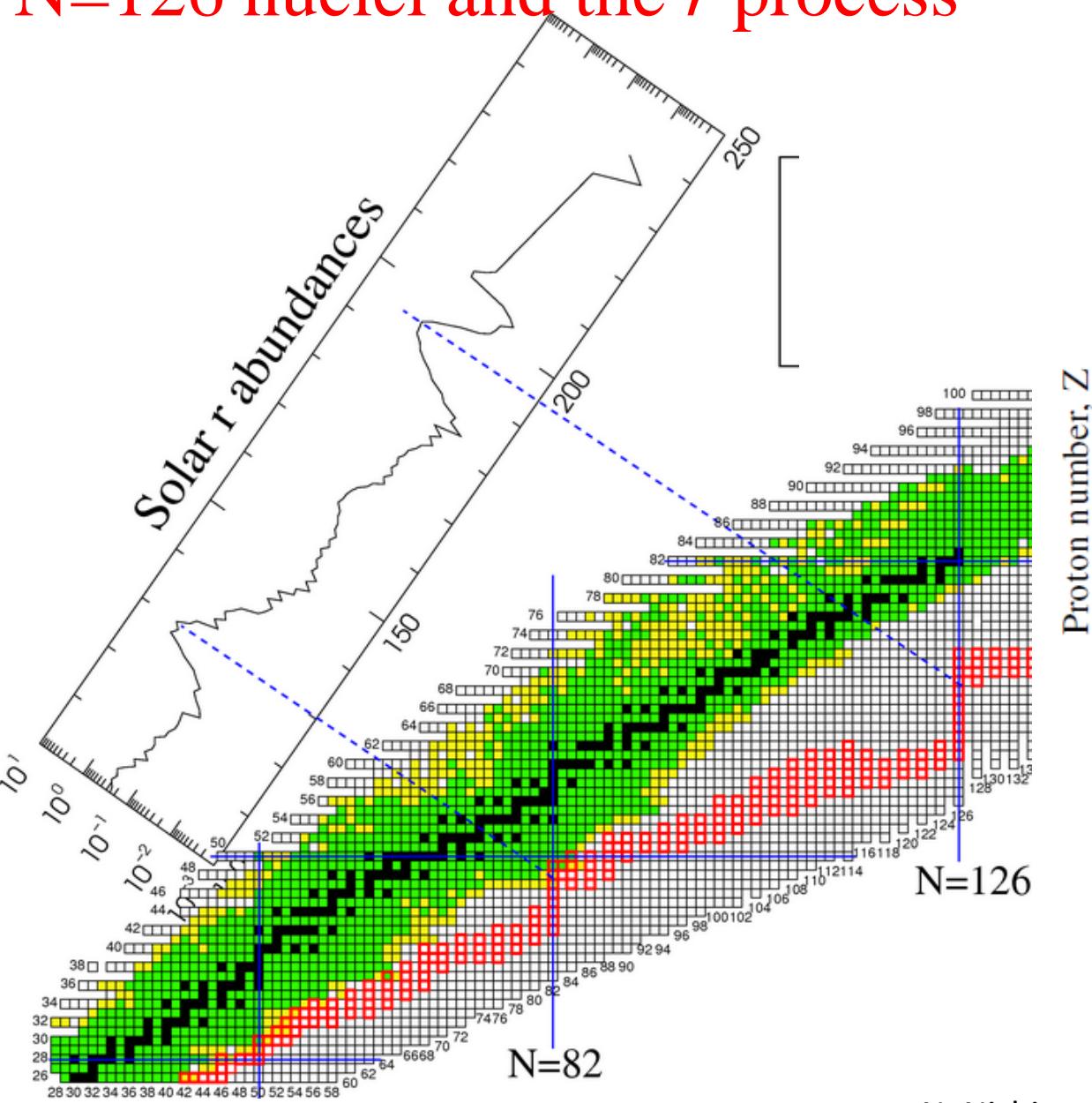
# First-forbidden beta decay



E.M. Ney, J. Engel, T.Li. N. Schunck, PRC102,034326 (2020)

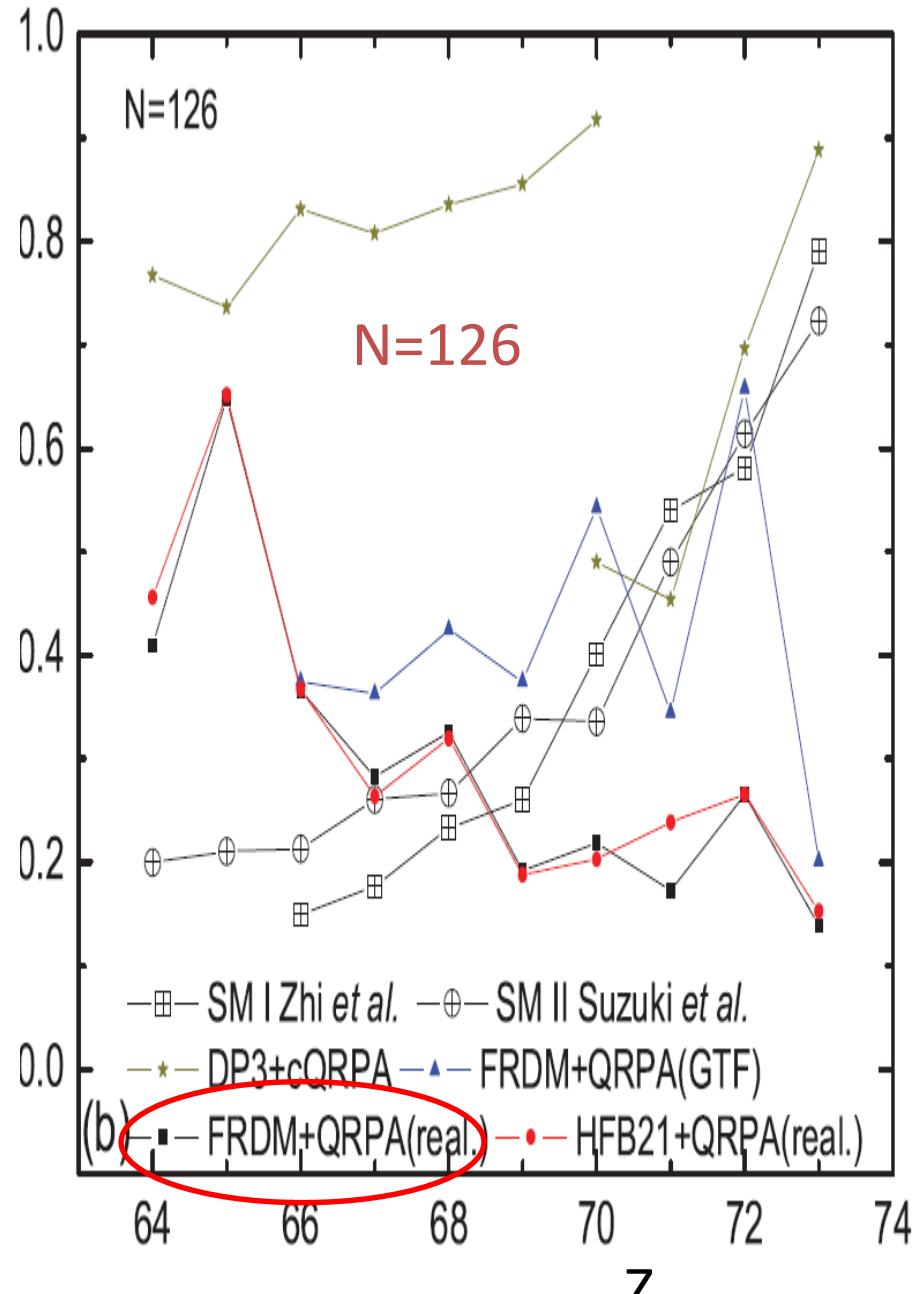
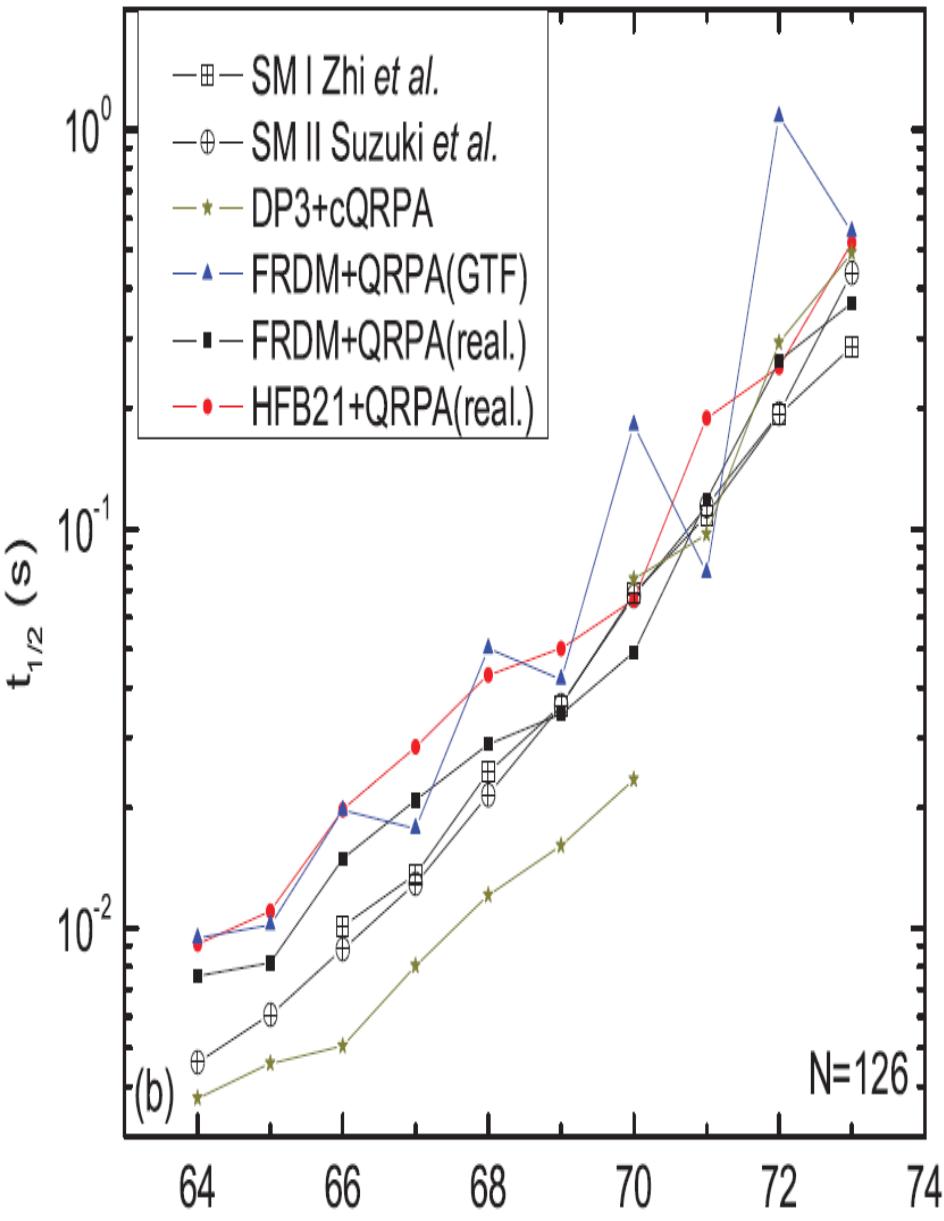
FIG. 5. First-forbidden contribution to the rates. Dashed lines

# N=126 nuclei and the *r* process



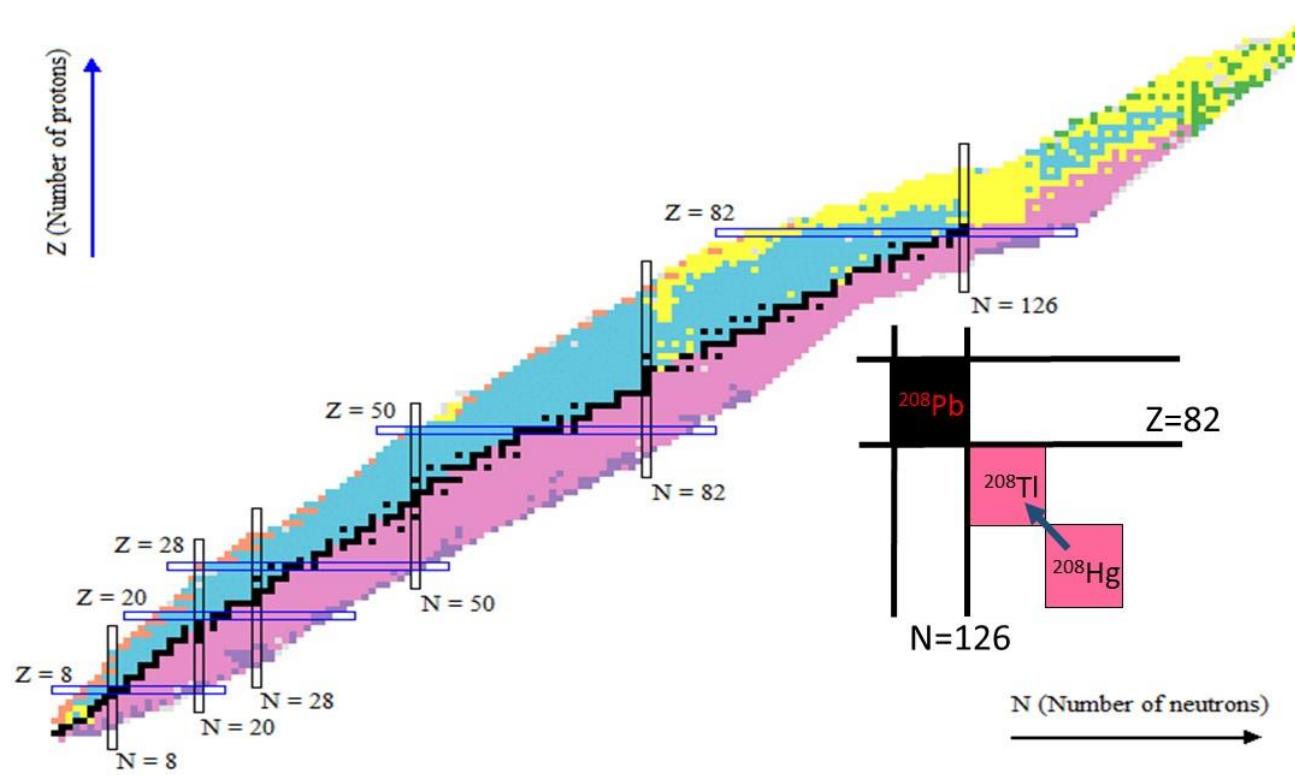
N. Nishimura et al., Phys. Lett. B 756 (2016) 273  
D.-L. Fang et al., Phys. Rev. C88 (2013) 034304

# First-forbidden $\beta$ decay

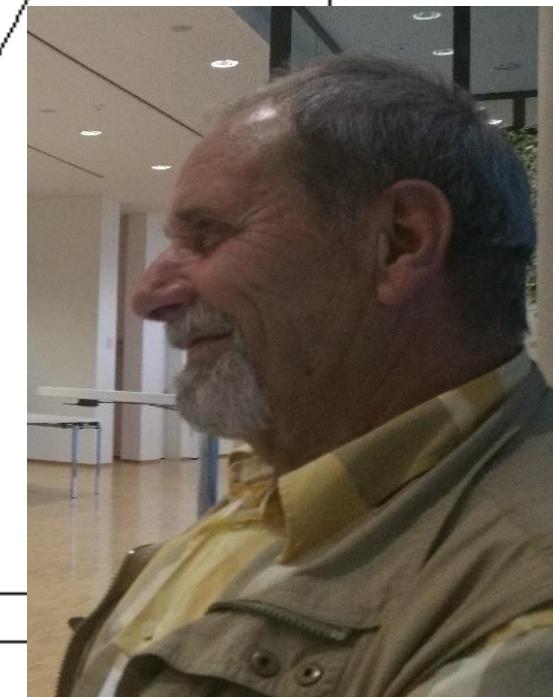
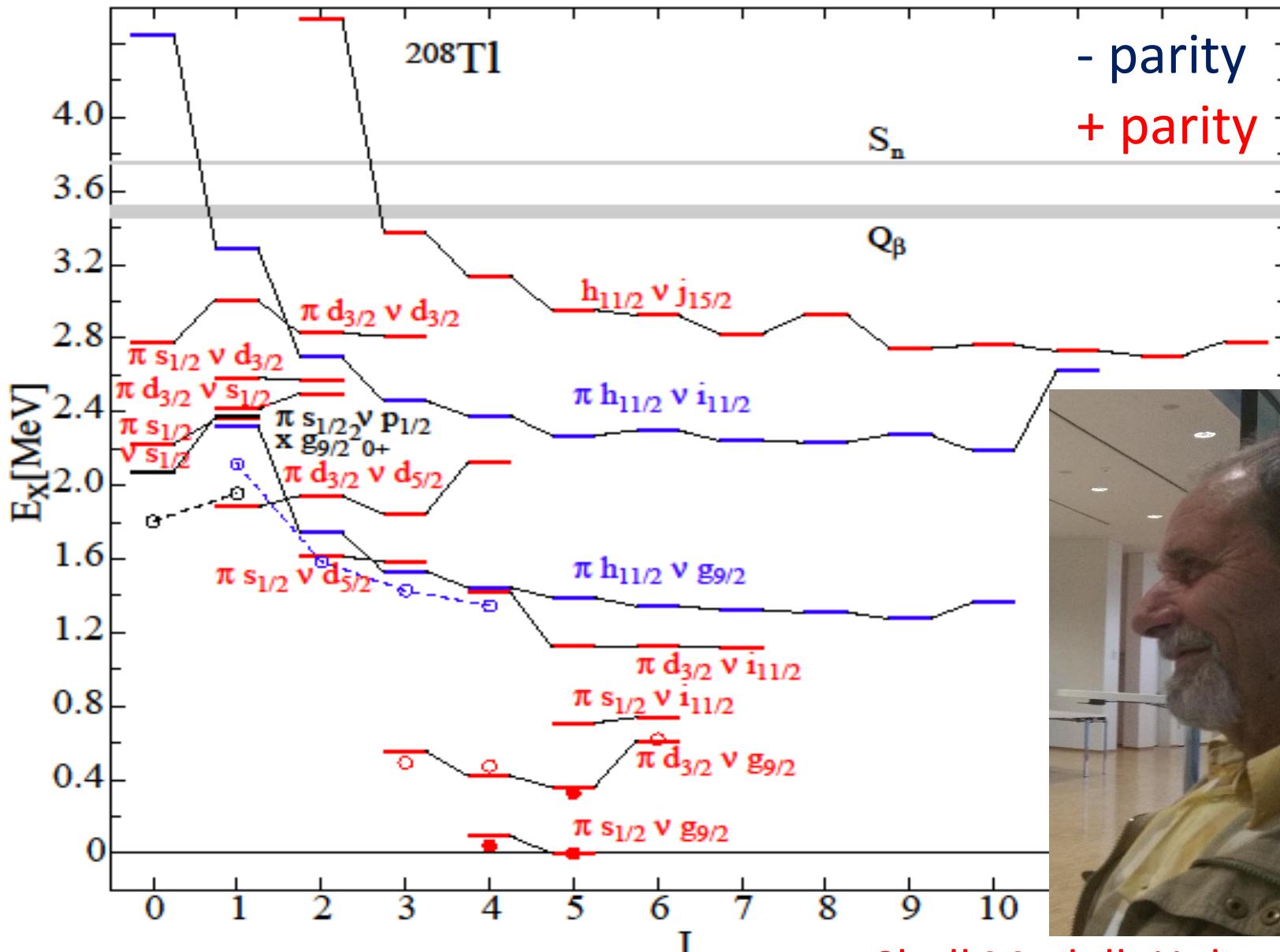


# Ideal nucleus to study first-forbidden vs allowed beta decay?

- well understood wave functions => close to doubly magic nuclei
- low  $Q_{\beta}$  value (few states to be populated) => close to stability
- both negative and positive parity spin 0 and 1 states with  $E_x < Q_{\beta}$

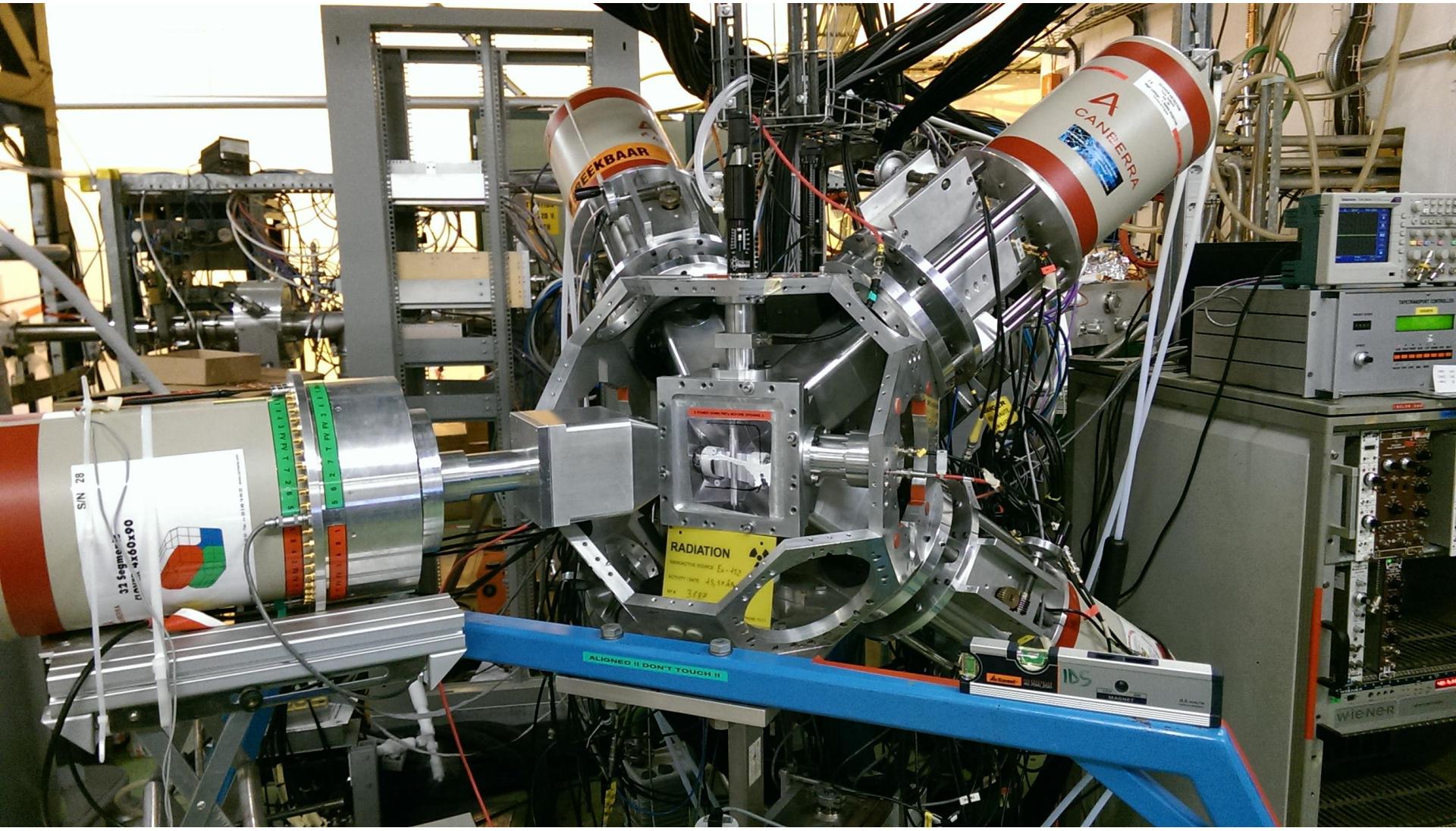


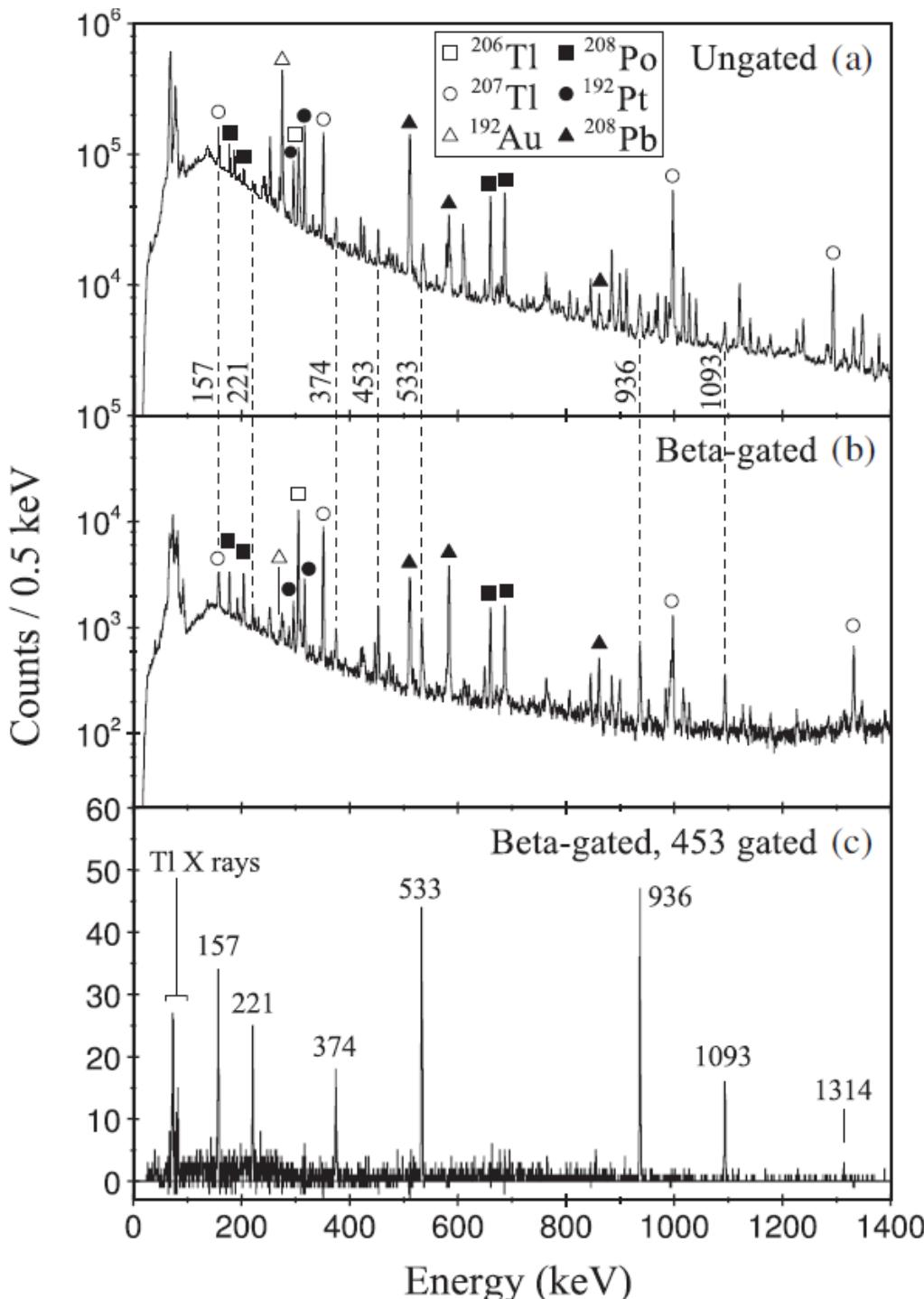
# Ideal nucleus to study first-forbidden vs allowed beta decay?



Shell Modell: Hubert Grawe

# ISOLDE decay station





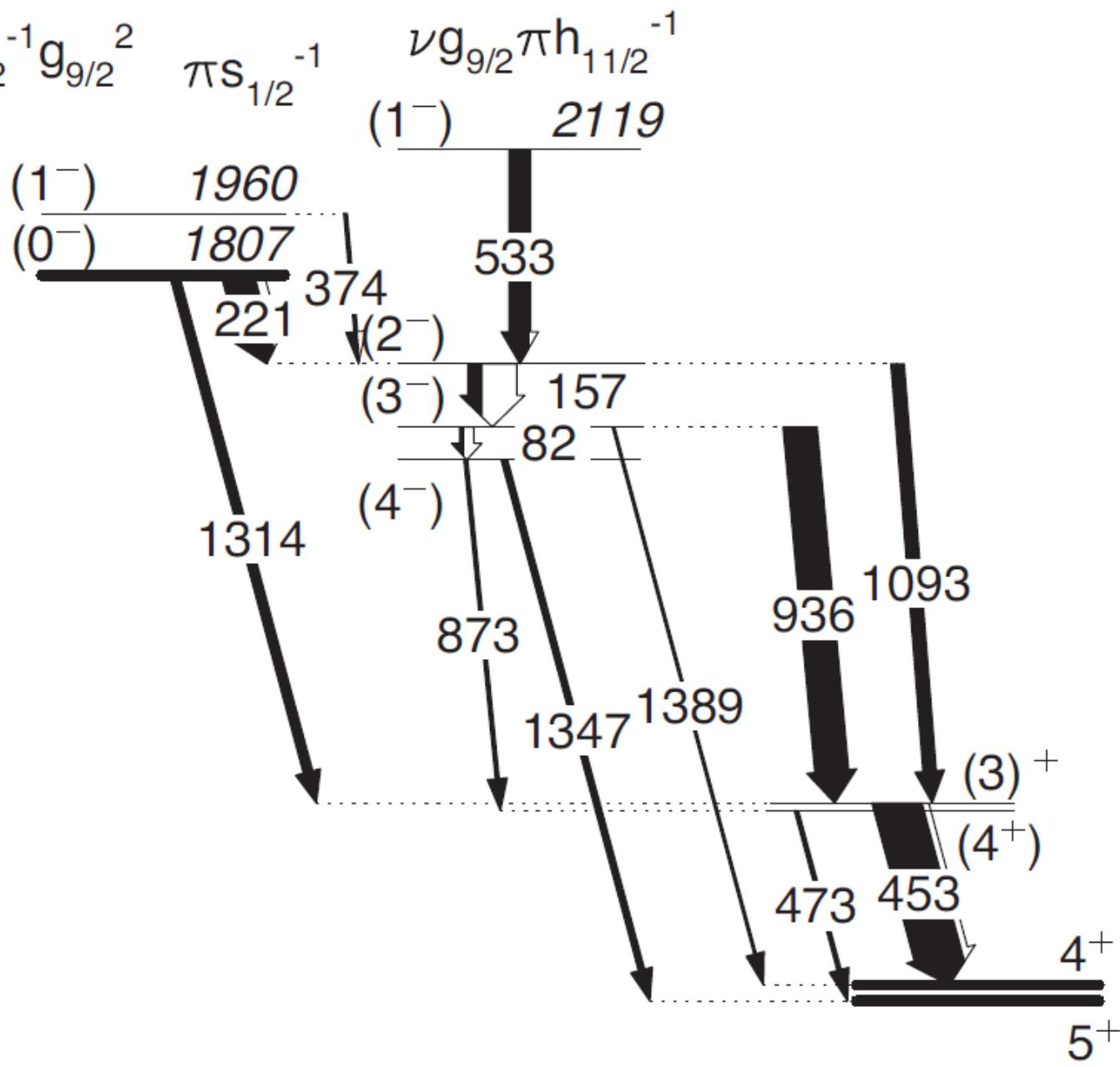
$p$  (1.4 GeV)+Pb

$^{208}\text{Hg}$  rates:

~ 5 pps (2014)  
~25 pps (2016)

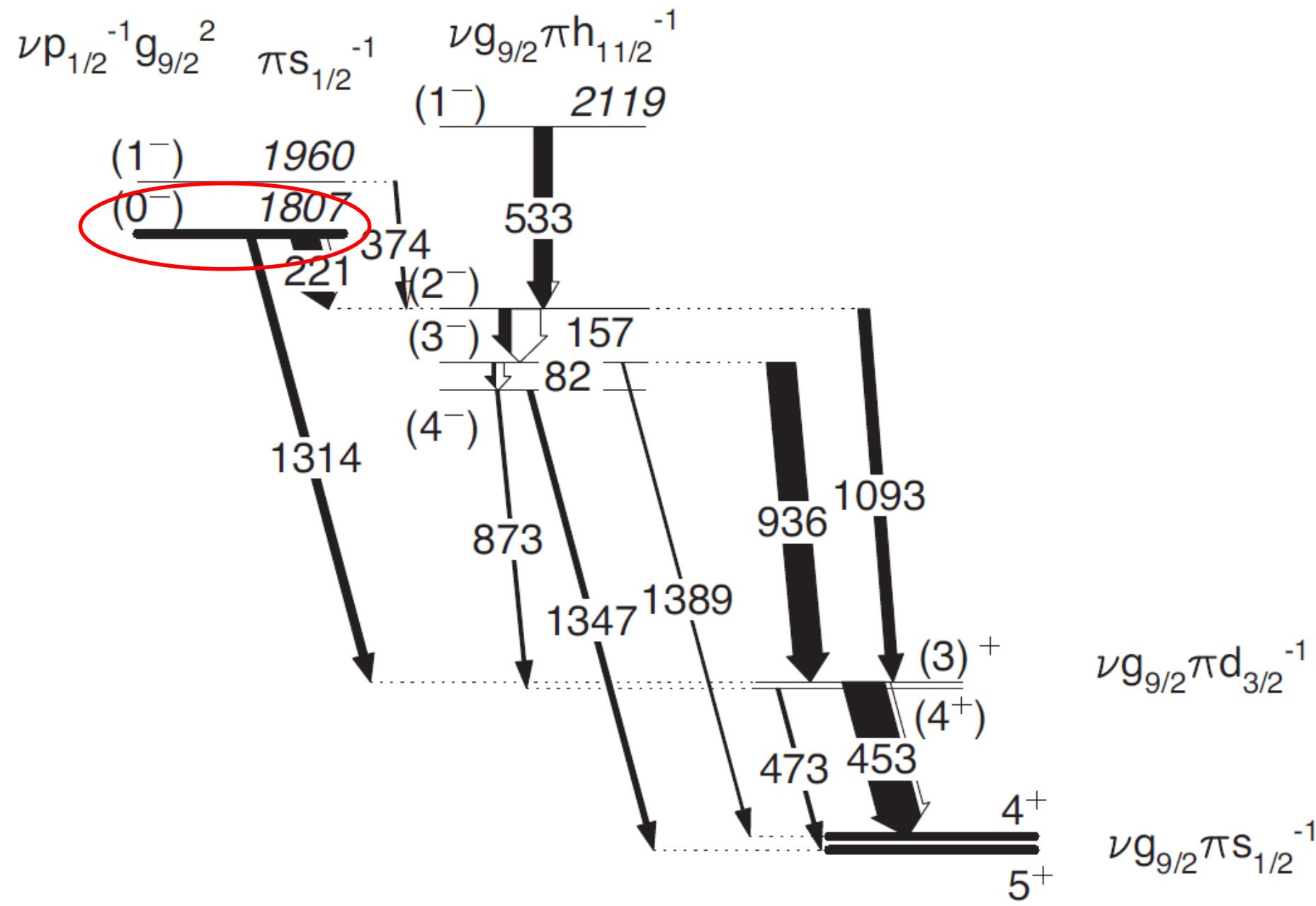
Also molecules:  
 $^{206}\text{Hg}^1\text{H}_2$  and  $^{192}\text{Au}^{16}\text{O}$

**208Tl**



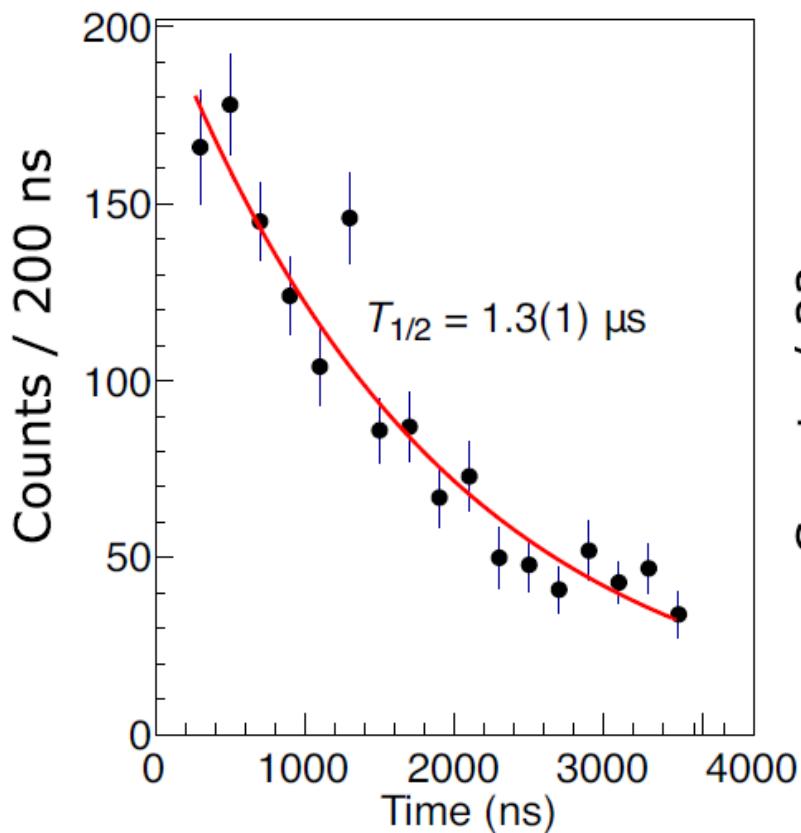
$\nu g_{9/2} \pi d_{3/2}^{-1}$

$\nu g_{9/2} \pi s_{1/2}^{-1}$

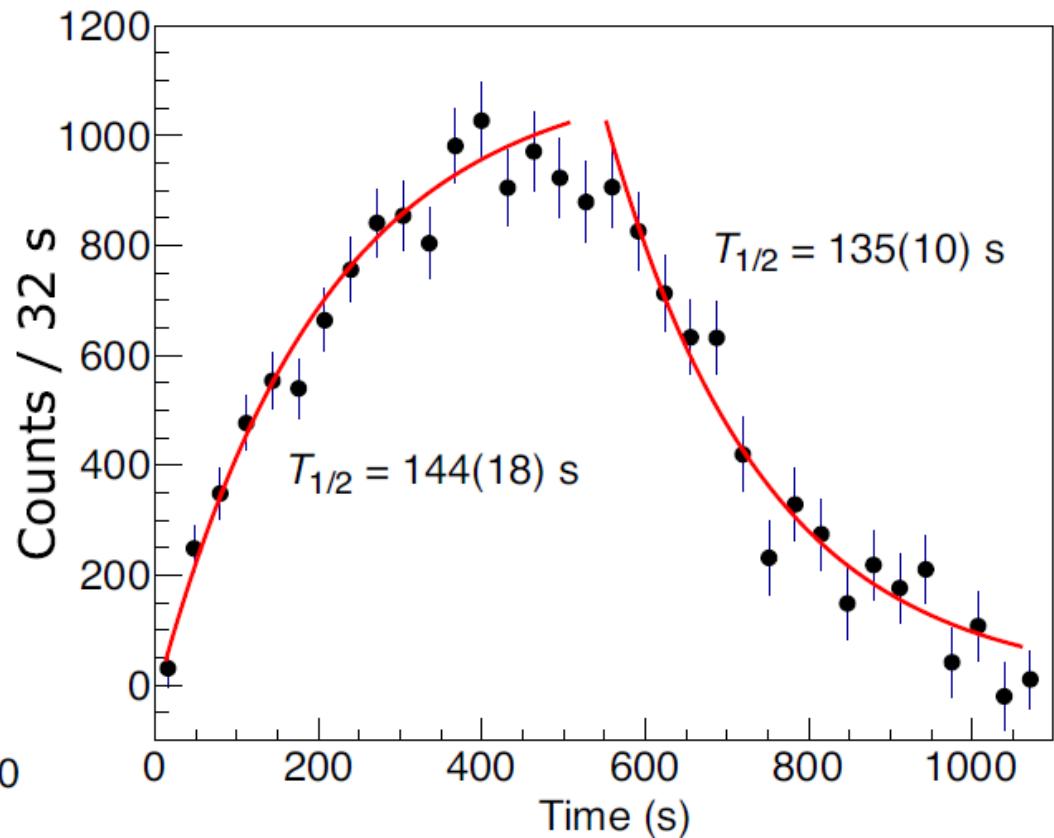


# Lifetime measurements

Isomer



Ground state



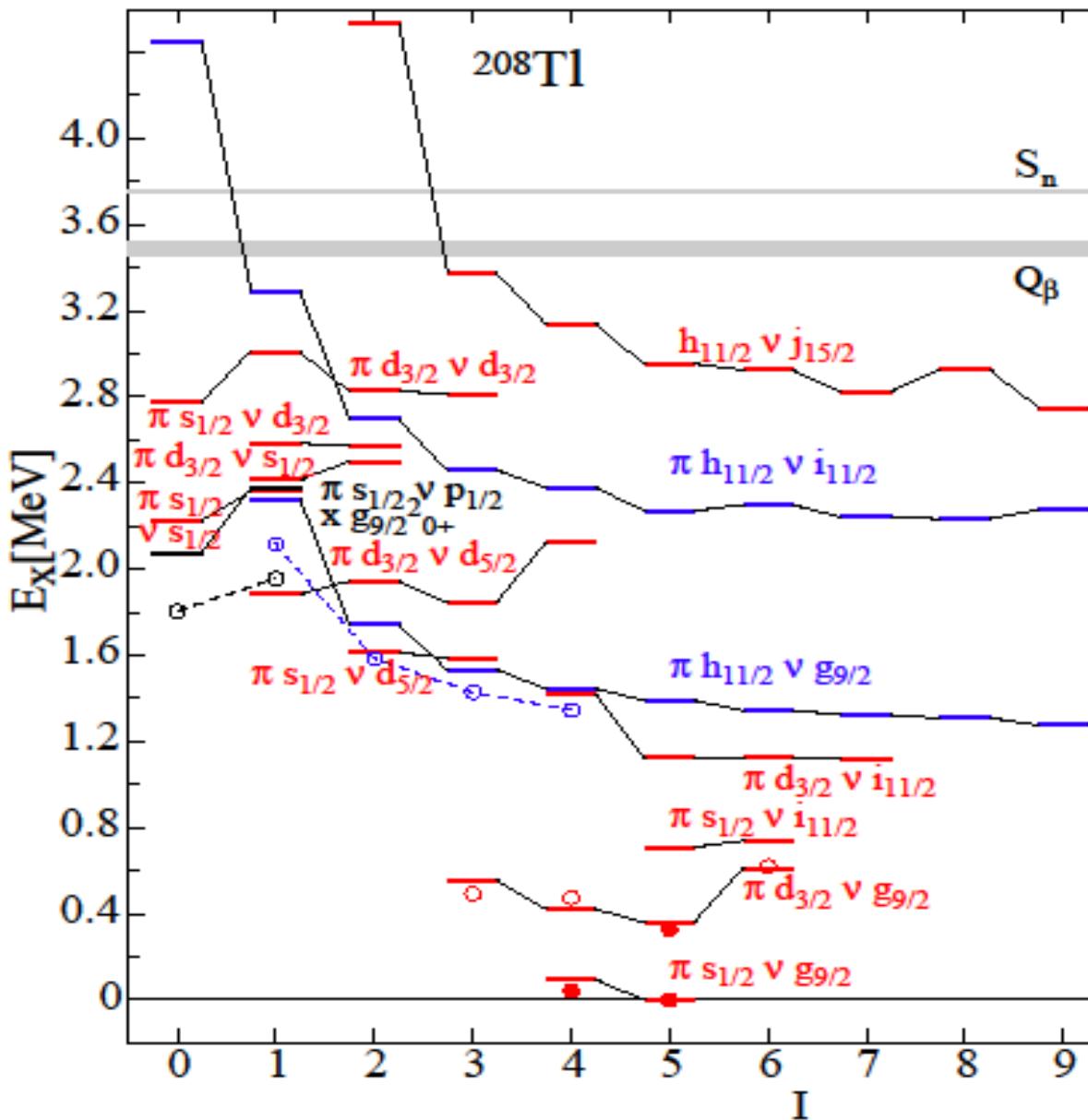
Previous values:

41(5) min L. Zhang et al., PRC 49, R592 (1994).

132(50) s R. Caballero-Folch et al., PRL117, 012501 (2016)

PRC 95, 064322 (2017).

# First-forbidden vs allowed beta decay



Beta decay via FF:

$\nu g_{9/2} \rightarrow \pi h_{11/2}$

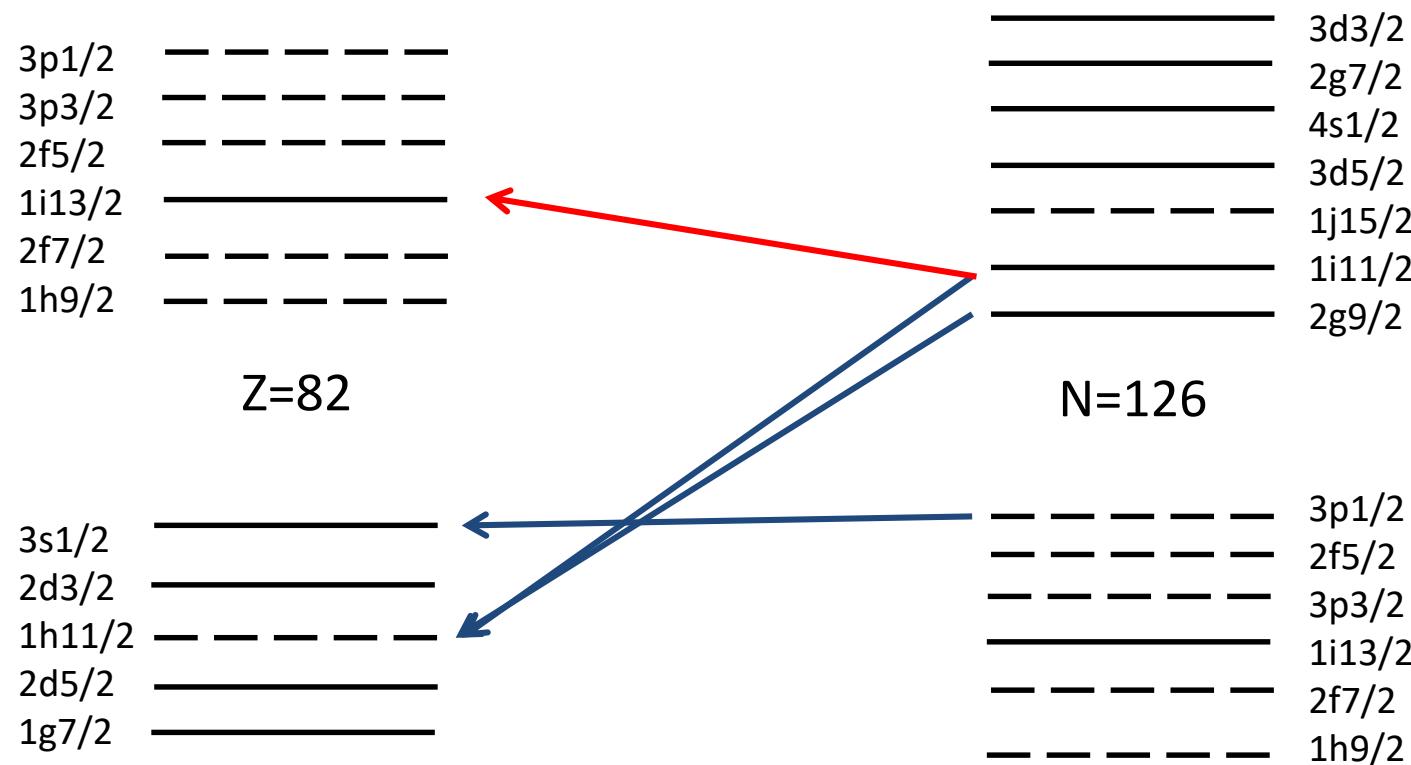
$\nu i_{11/2} \rightarrow \pi h_{11/2}$

OR

Allowed transitions  
( $\nu 1g_{9/2} \rightarrow \pi 0g_{7/2}$ )

~~Allowed  $\nu i_{11/2} \rightarrow \pi i_{13/2}$ :~~  
Via ***small mixing*** of  
 $\pi^2 \pi i_{13/2} \nu i_{11/2}$  into  
the low-lying  $1^+$  states

# Competition between first-forbidden and allowed beta decay



Decays resulting in 2p2h not shown;  $1g_{9/2} \rightarrow 0g_{7/2}$  etc forbidden by  $\Delta n=0$  selection rule

# Conclusions

First-forbidden – allowed  $\beta$ -decay competition in  $^{208}\text{Hg} \rightarrow ^{208}\text{Tl}$

First-forbidden won (three negative parity states directly fed)

First observation of  $0^+ \rightarrow 0^- \beta$  decay when daughter state core excited (important for mesonic corrections of effective operators)

$^{208}\text{Tl}$  validates/tests the proton-neutron interaction (H7B)