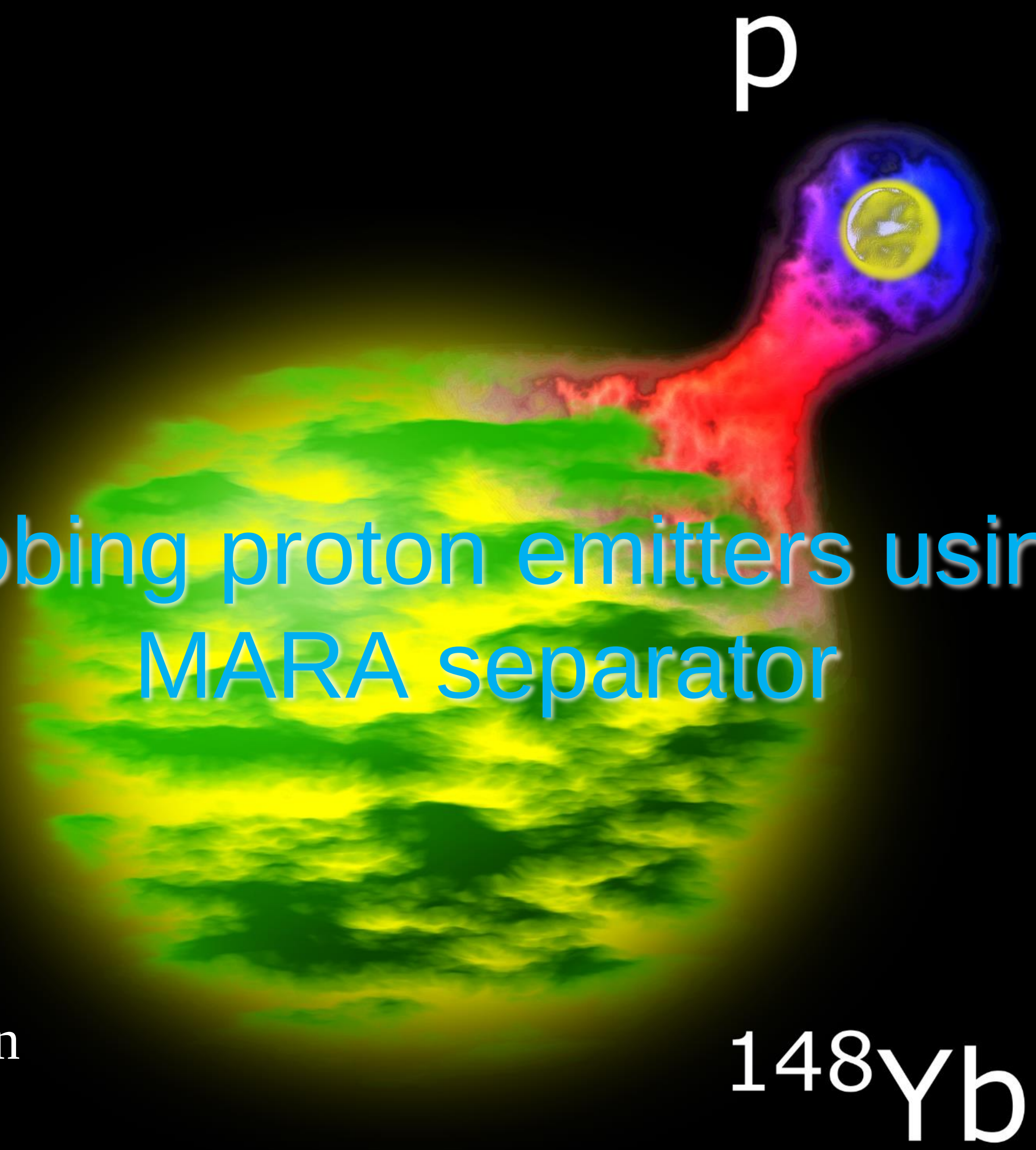
Probing proton emitters using MARA separator



Kalle Auranen

TASCA22

11.05.2022

Probing proton emitters using MARA separator

1) New proton-emitting isotope ^{149}Lu
2) In-beam γ-ray spectroscopy of ^{147}Tm (preliminary)

Proton emission

- A rare type of radioactivity where a proton is ejected from a nucleus
  - First evidence in 1970's: 19^- isomeric state in ^{53}Co
    [J. Cerny et al. Phys. Lett., B33 (1970), p. 284]
    [K. P. Jackson et al. Phys. Lett., B33 (1970), p. 281]
  - First ground-state proton emitter: ^{151}Lu
    [S. Hofmann et al. Z. Phys., A305 (1982), p. 111]
  - Approximately 30 ground-state proton emitters are known
    [B. Blank, M.J.G. Borge, Prog. in Part. and Nucl. Phys. 60 (2008) 403–483] (+2)

Why study Lutetium?

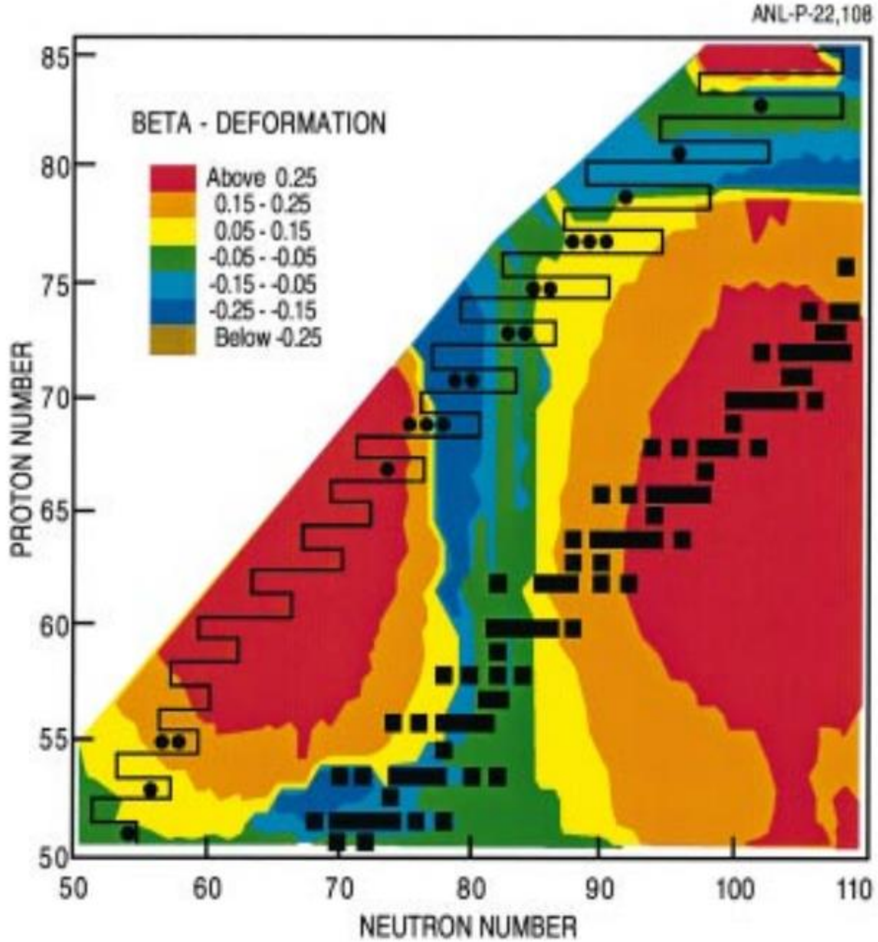


Figure 5 Contour plot of the quadrupole deformation parameter b2 taken from (89), showing the general trend of the deformations. Filled circles are the known proton emitters, and the predicted proton drip-line also taken from (90) is shown as a solid line, modified where experimental evidence is available.

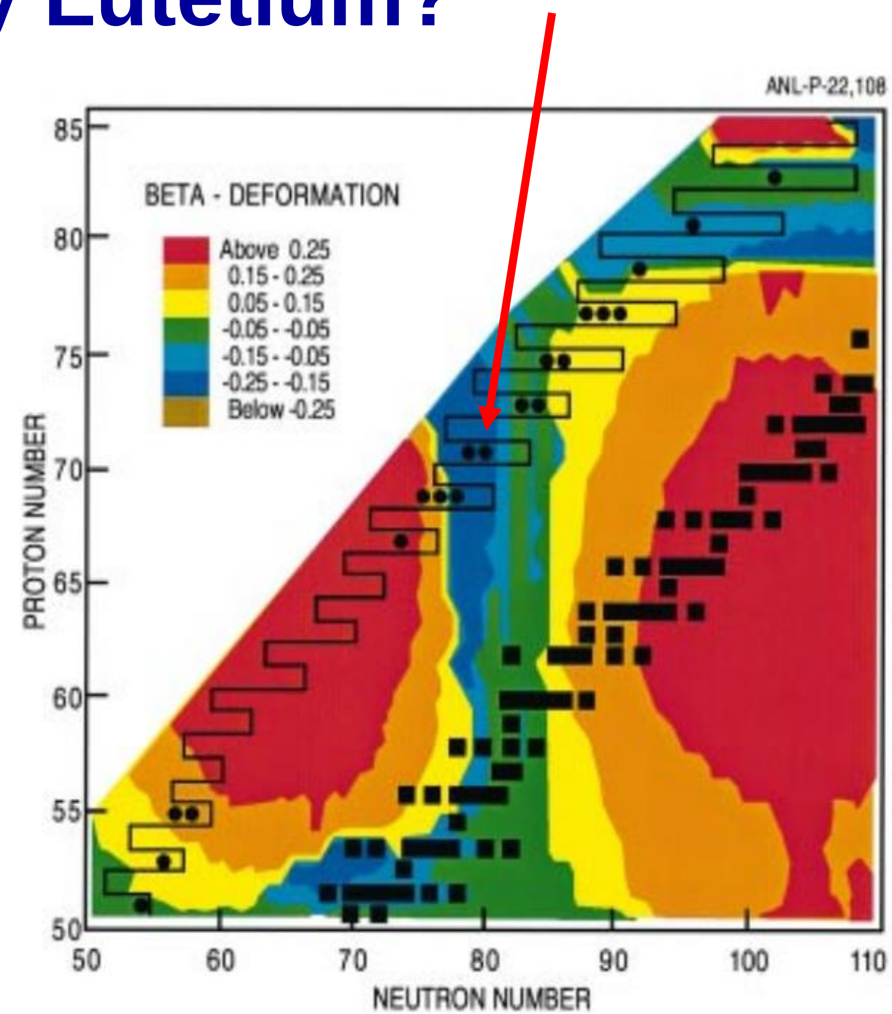
[P.J. Woods, C.N. Davids, Annu. Rev. Nucl. Part. Sci. 47 541 (1997)]

JYFL

Why study Lutetium?

- Very few oblate deformed proton emitters are known

^{151}Lu



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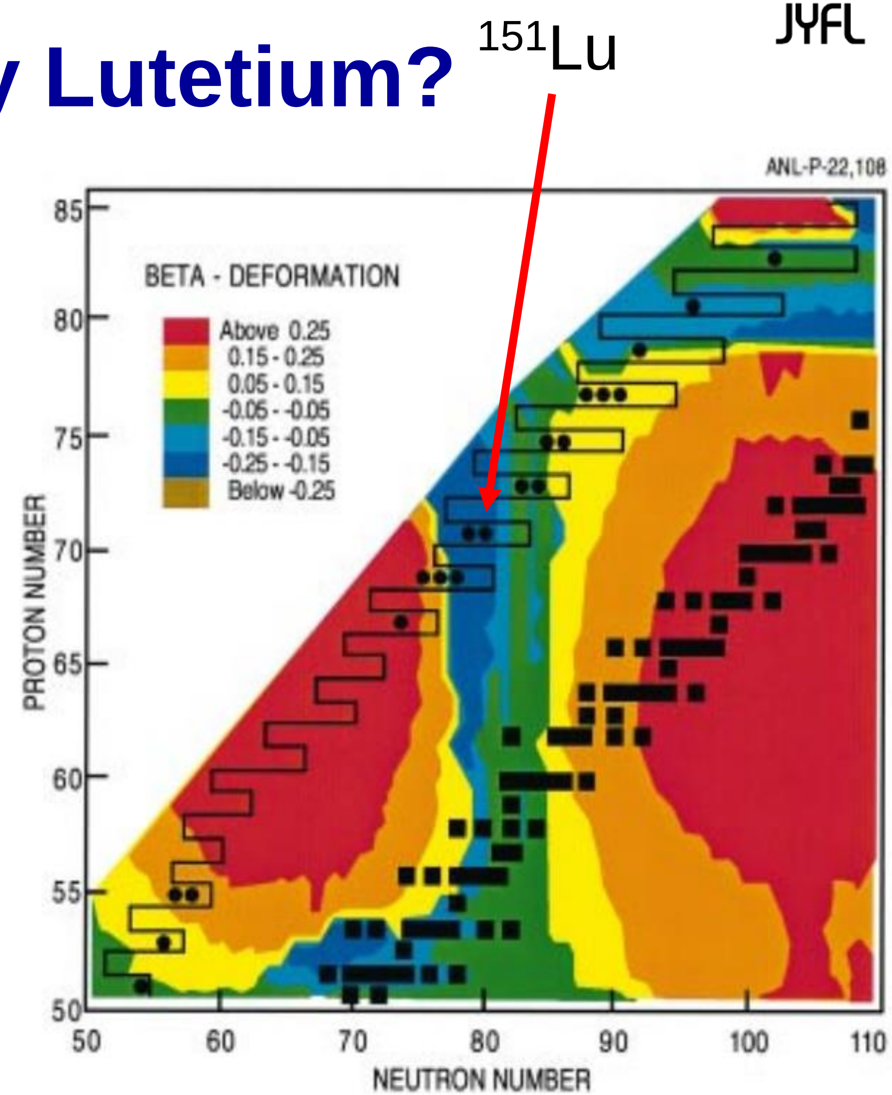
Why study Lutetium?

- Very few oblate deformed proton emitters are known
- ^{151}Lu
  - $\beta_2 = -0.11$ ($11/2^-$ g.s.)
    [Procter et al. PLB 725 79 (2013)]
  - $\beta_2 = -0.12$ ($3/2^+$ m)
    [Taylor et al. PRC 91 044322 (2015)]



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Why study Lutetium?

TABLE I. Theoretical predictions for the one proton separation energy ($S_p = -Q_p$) and ground-state deformation β_2 of ^{149}Lu.

Model	S_p(MeV)	β_2
RHB [29]	-1.77	-0.158
FRDM [30, 31]	-1.52	-0.187
RMF [32]	-1.946	-0.166

– β_2 = -0.11 ($11/2^-$ g.s.)

[Procter et al. PLB 725 79 (2013)]

– β_2 = -0.12 ($3/2^+$ m)

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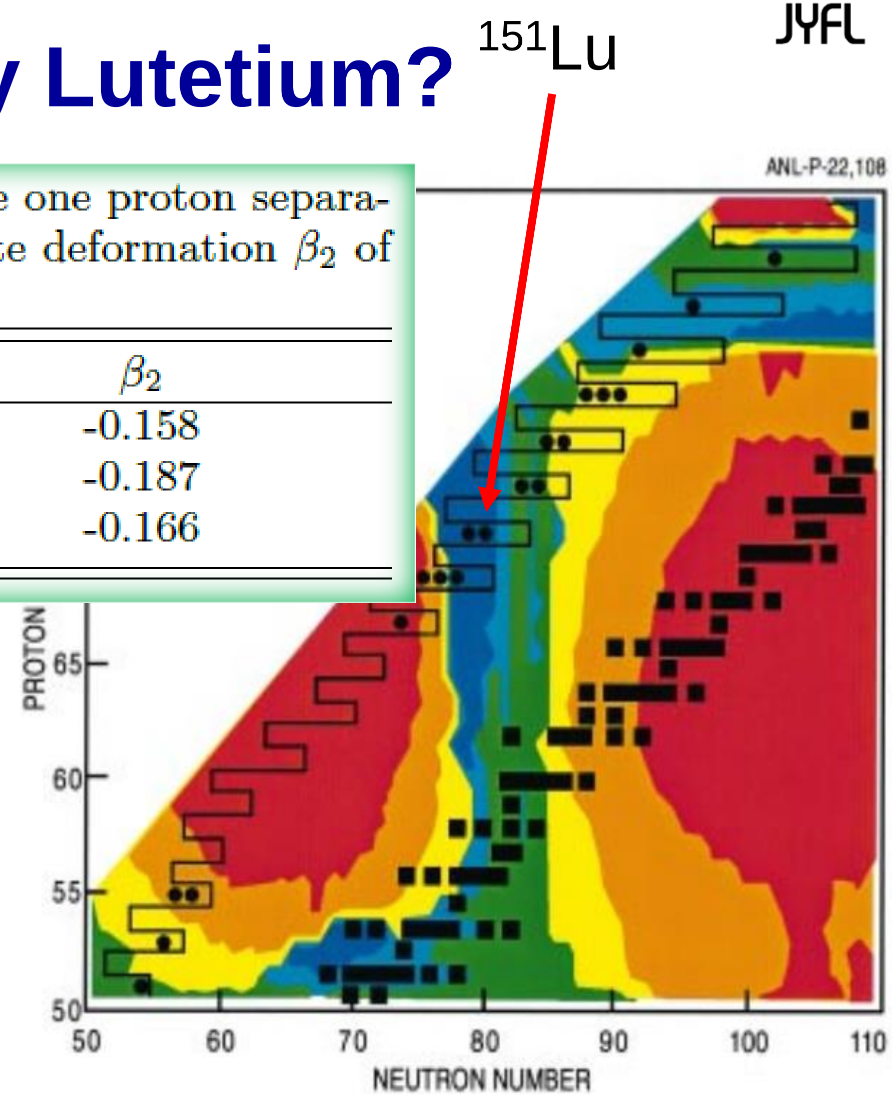

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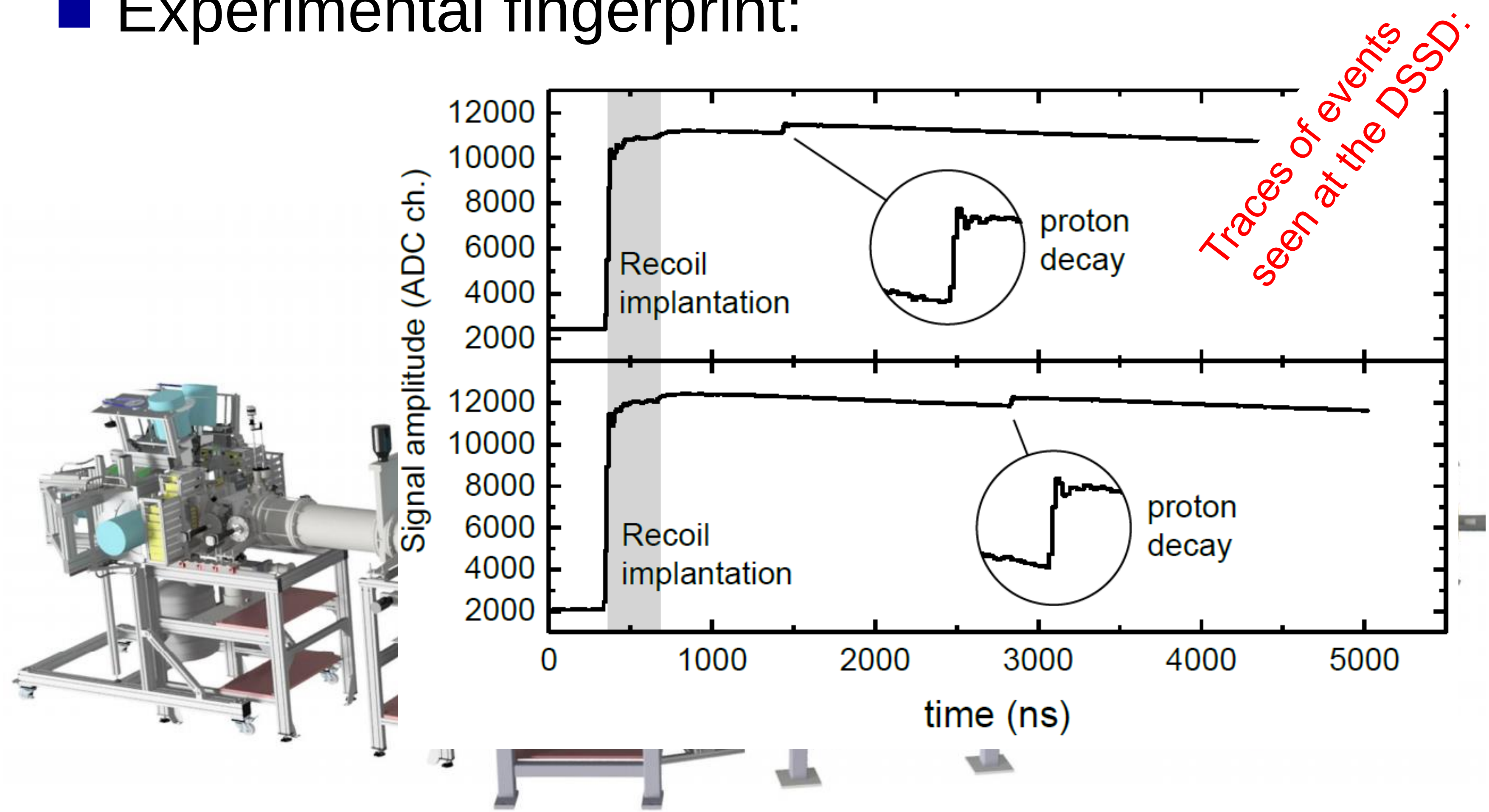
Experiment

- ^{96}Ru(^{58}Ni,*p4n*) ^{149}Lu fusion-evaporation reaction
- MARA
  - A/q identification
- DSSD (159 μm thick, 192 x 72 pixels with 670 μm pitch)
  - Traces with 10 ns sample rate
- JYTube + JUROGAM3 γ-ray spectrometer

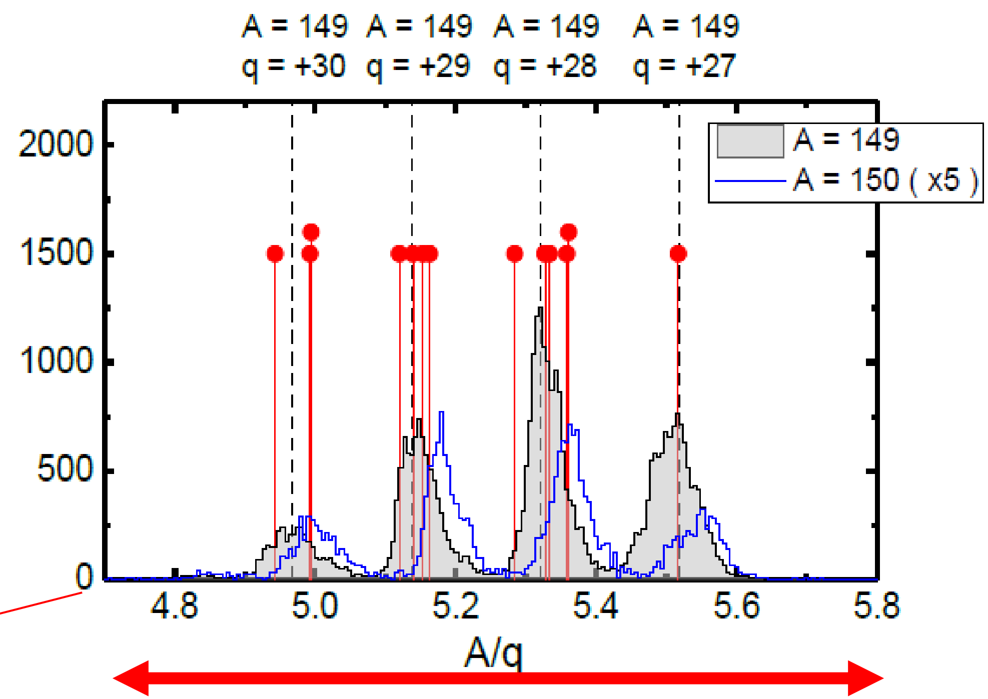
Results

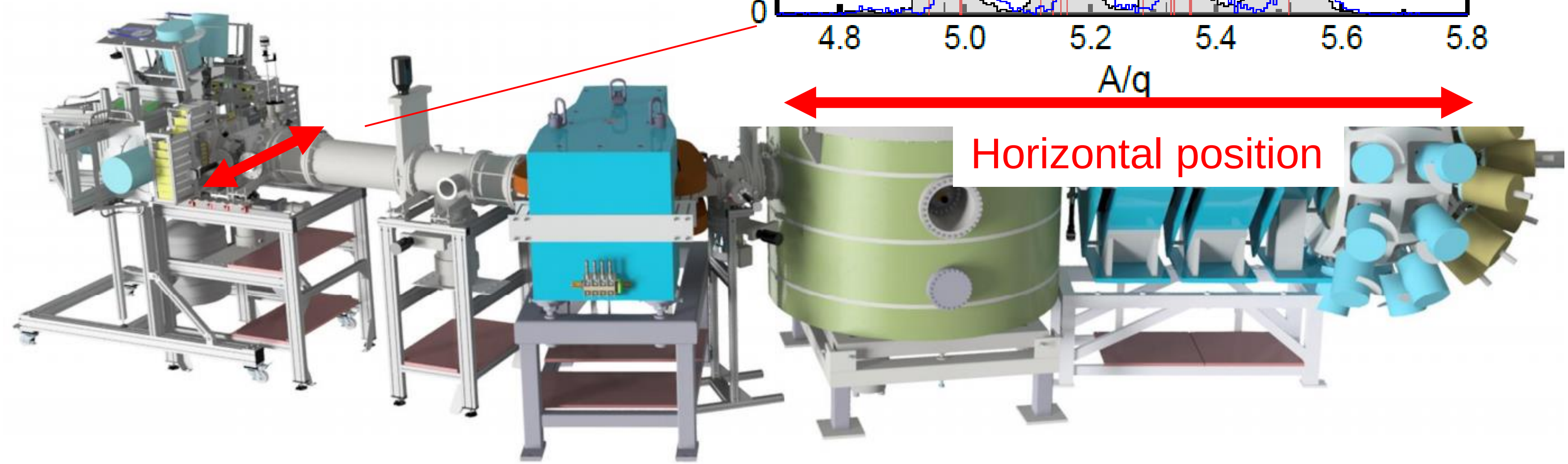
- 14 candidates for fast proton emission
- Experimental fingerprint:



Results

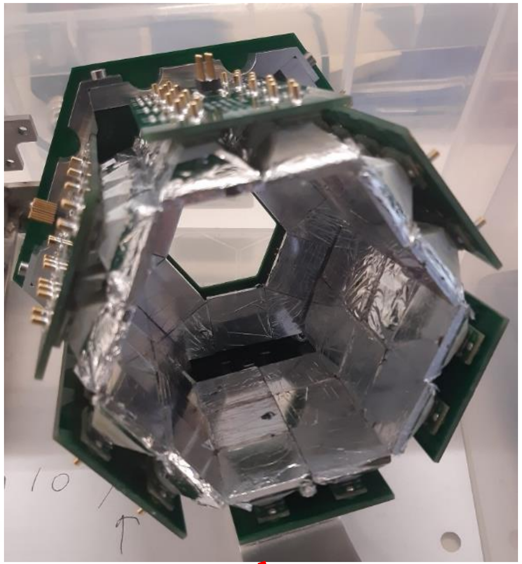
- A/q identification
  - Most likely A = 149
- Reference spectra gated with $^{149,150}Er$ isomers

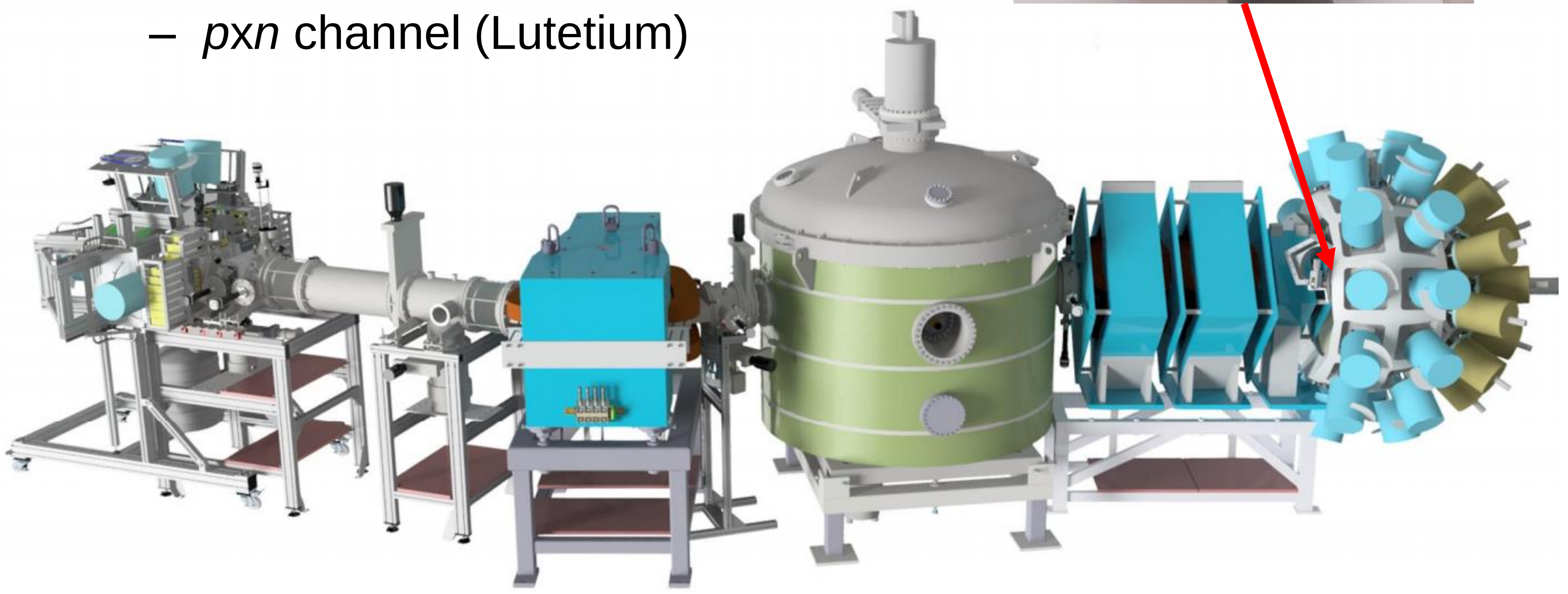




Results

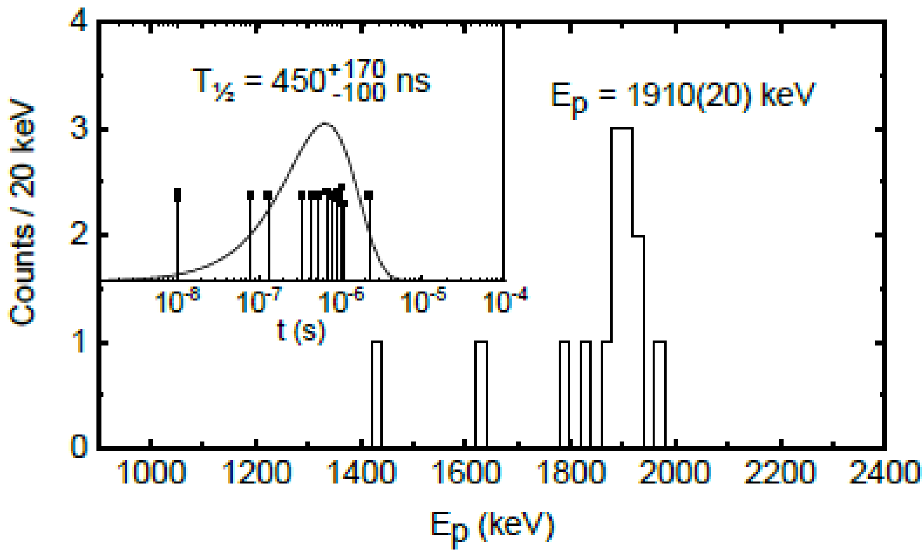
- Element assignment per JYTube data
- Candidates correlate with 0 or 1 evaporated charged particles
  - *pxn* channel (Lutetium)





Results

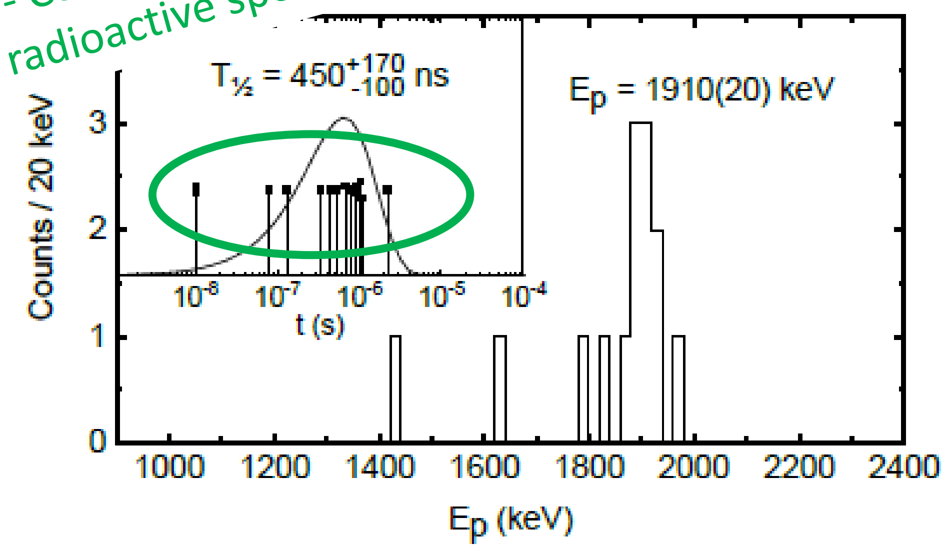
- E_p = 1910(20) keV
  - Highest measured for a g.s. proton emitter



Results

- E_p = 1910(20) keV
  - Highest measured for a g.s. proton emitter
- $T_{1/2} = 450(^{+170}_{-100})$ ns
  - Shortest *directly* measured for a g.s. proton emitter

Passes the 90% probability test**
- Consistent with the decay of a single radioactive species



**K. H. Schmidt, EPJA 8, 141 (2000).

JYFL

Results

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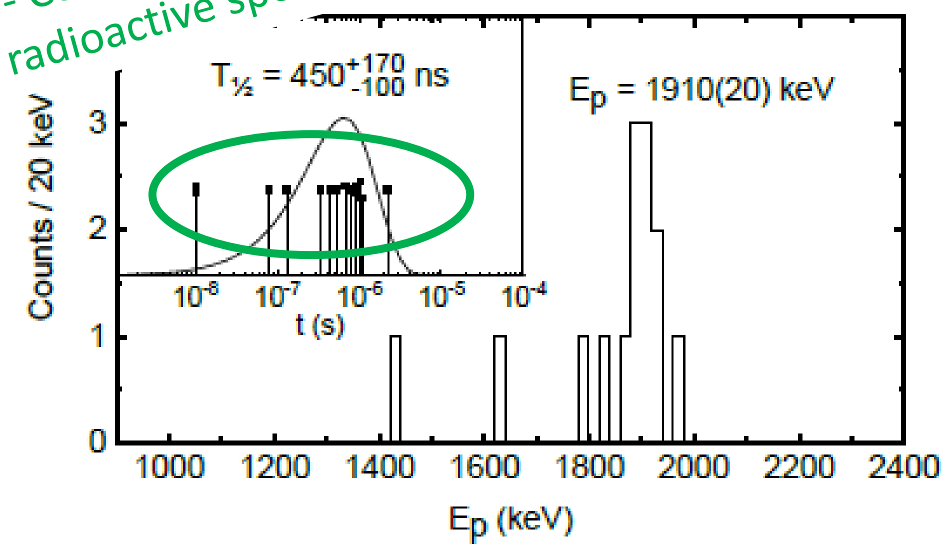
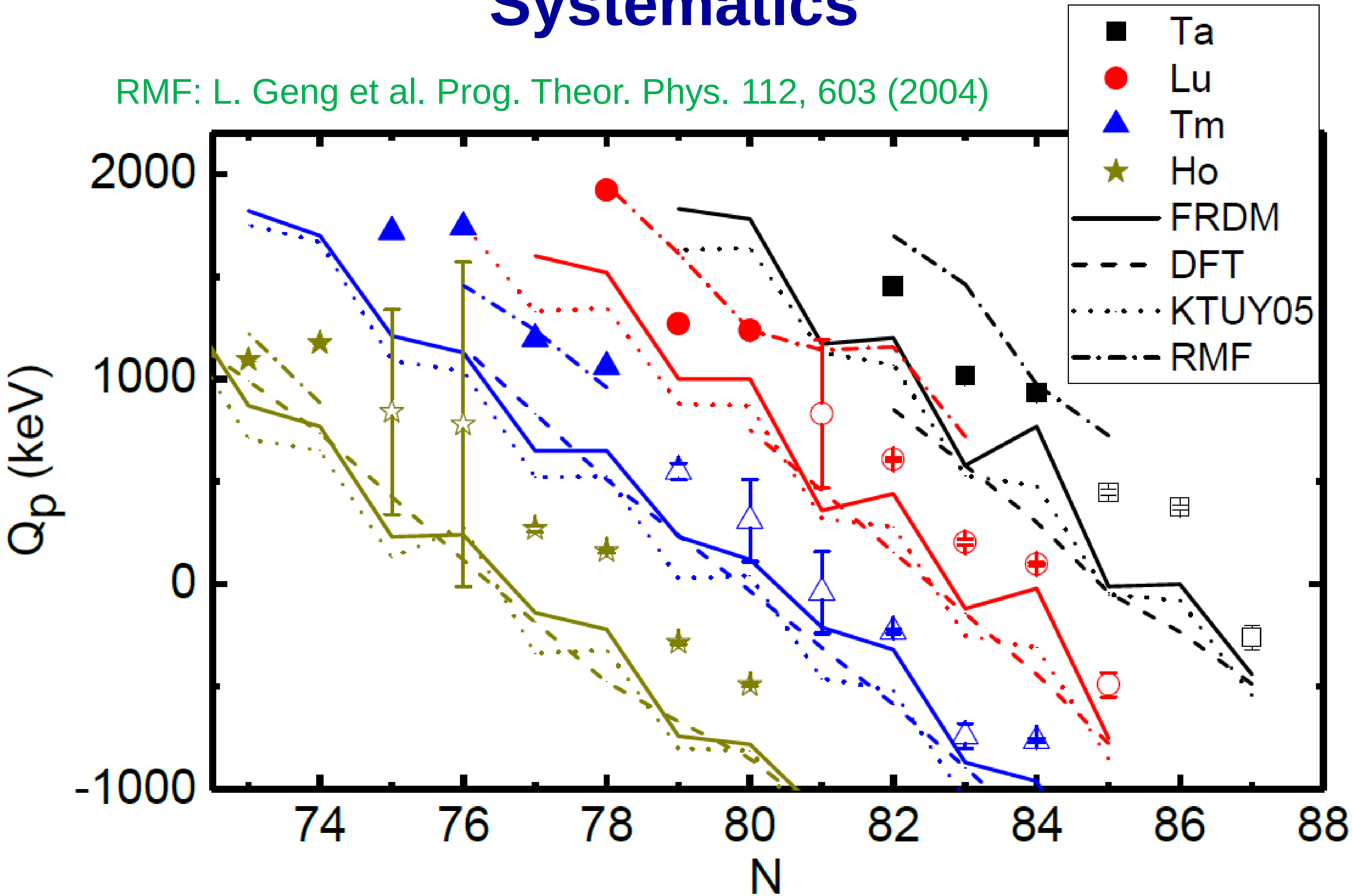


- E_p = 1910(20) keV
  - Highest measured for a g.s. proton emitter
- $T_{1/2} = 450(^{+170}_{-100})$ ns
  - Shortest *directly* measured for a g.s. proton emitter
- Geiger-Nuttall law
  [Chen EPJA 55, 214 (2019)]
  - 956 ns ($l_p = 5$; within 1σ)
  - $\pi(h_{11/2})$

**K. H. Schmidt, EPJA 8, 141 (2000).

Systematics

RMF: L. Geng et al. Prog. Theor. Phys. 112, 603 (2004)



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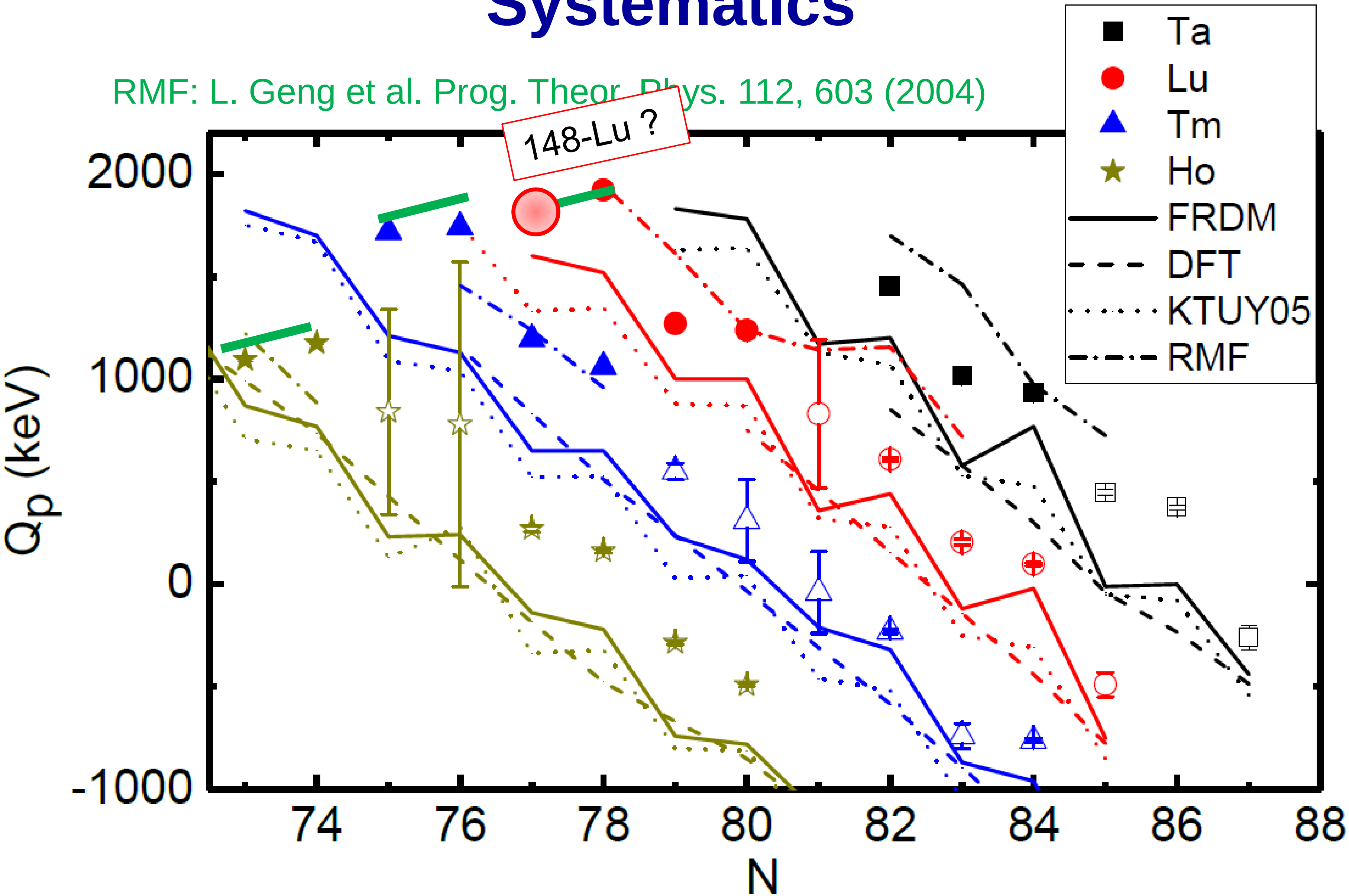
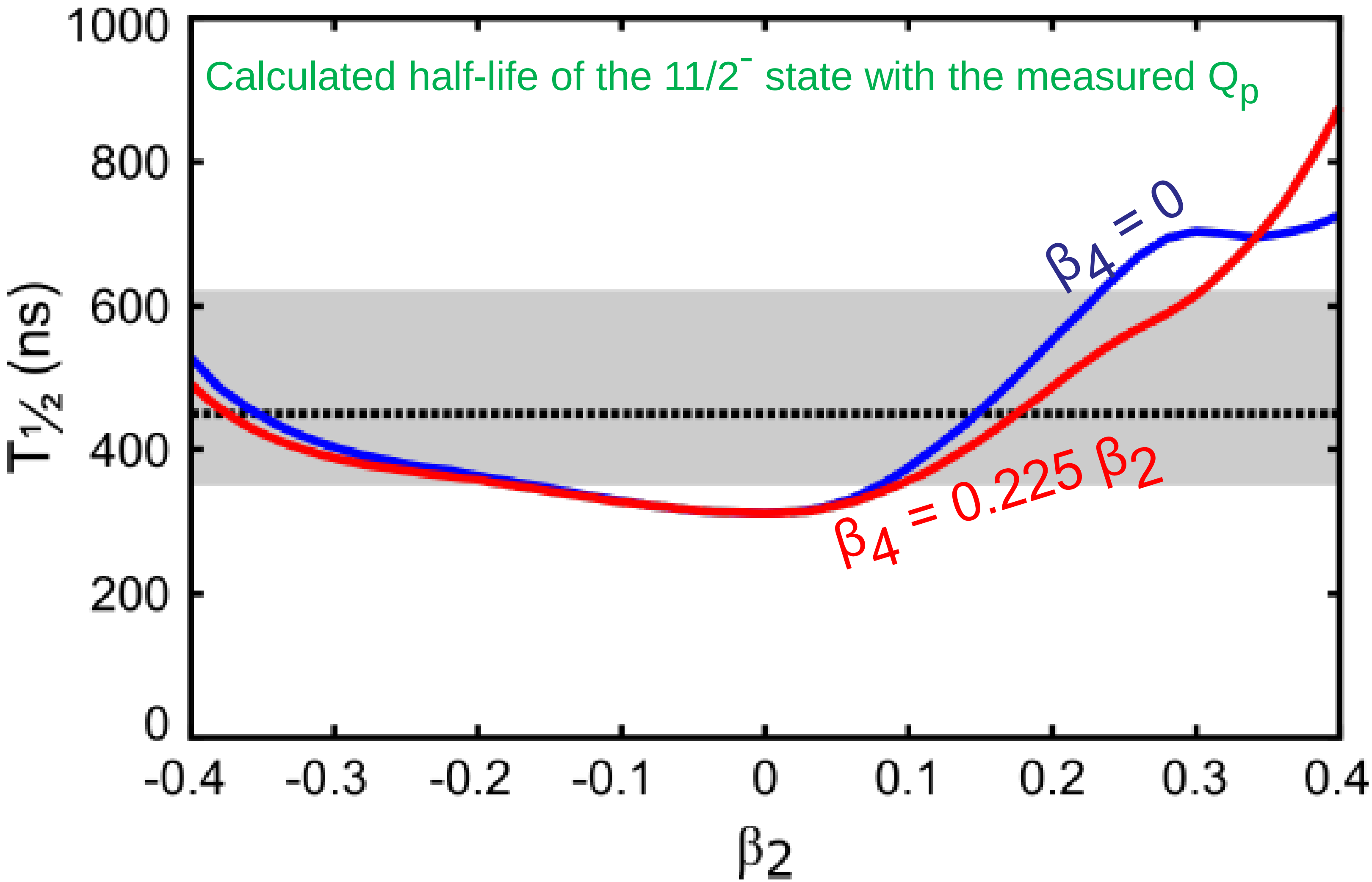


Non-adiabatic quasiparticle model

(L.S. Ferreira, E. Maglione)



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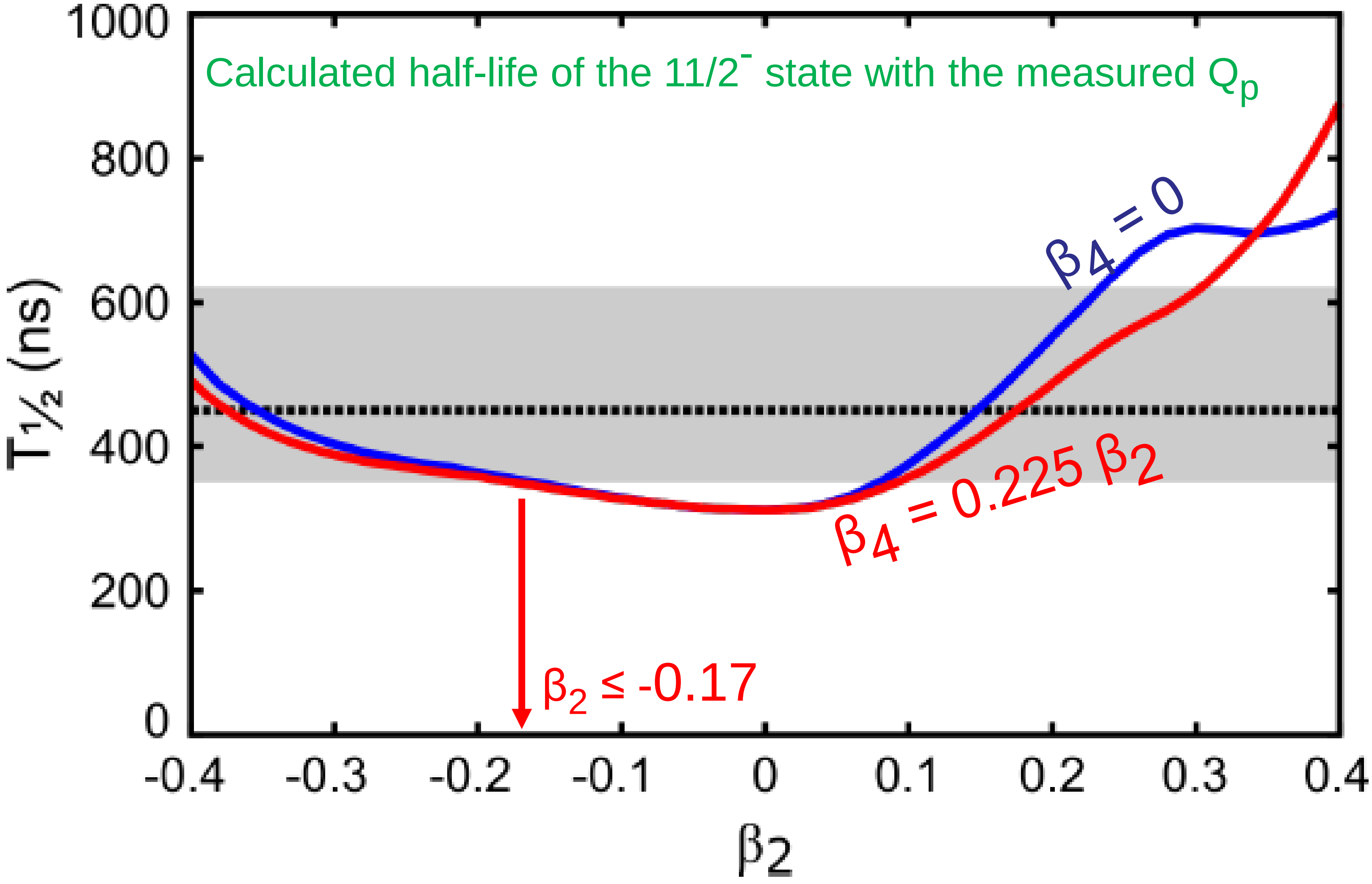
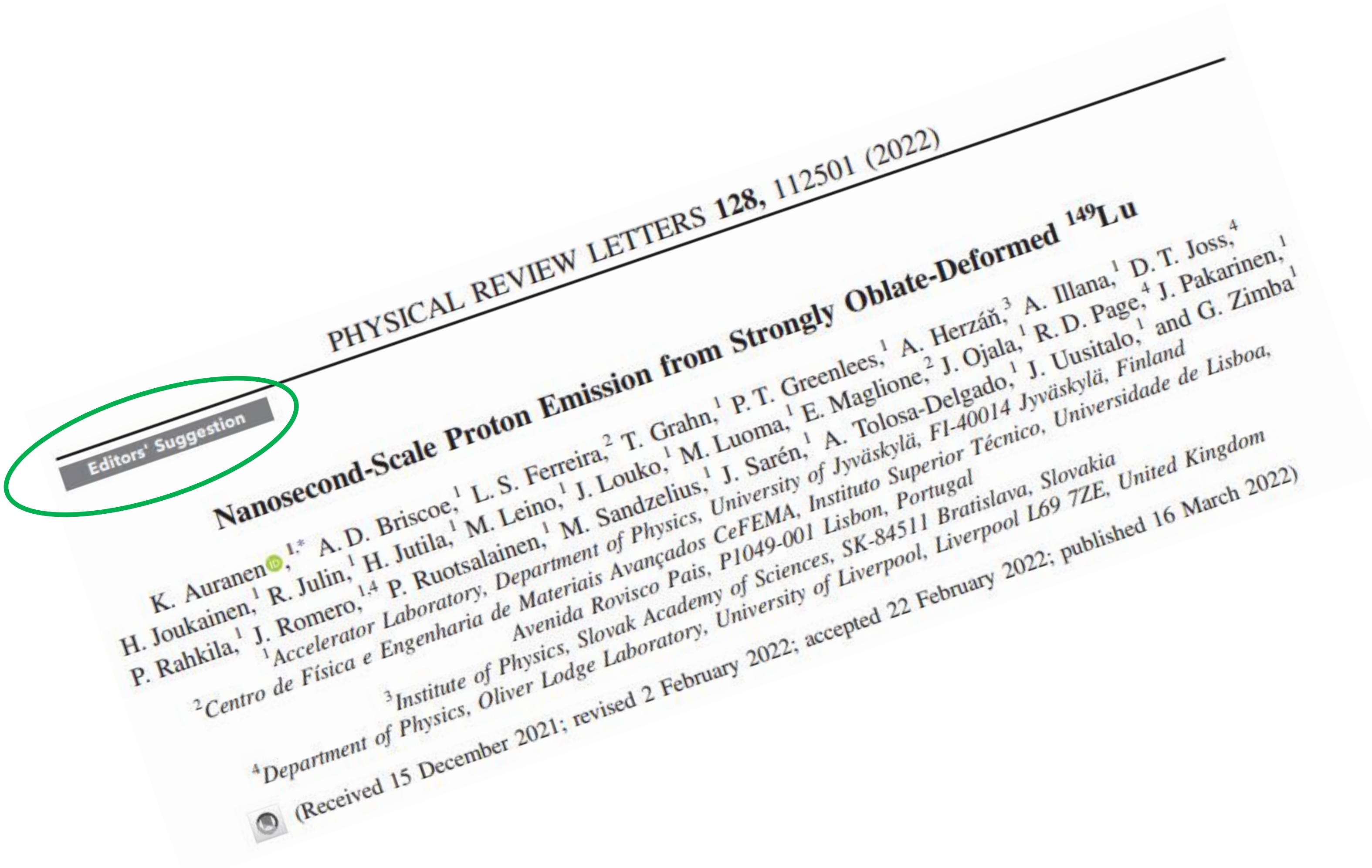


Publication



Editors' Suggestion

PHYSICAL REVIEW LETTERS **128**, 112501 (2022)

Nanosecond-Scale Proton Emission from Strongly Oblate-Deformed ^{149}Lu

K. Auranen,[1,*] A. D. Briscoe,[1] L. S. Ferreira,[2] T. Grahn,[1] P. T. Greenlees,[1] A. Herzáň,[3] A. Illana,[1] D. T. Joss,[4] H. Joukainen,[1] R. Julin,[1] H. Jutila,[1] M. Leino,[1] J. Louko,[1] M. Luoma,[1] E. Maglione,[2] J. Ojala,[1] R. D. Page,[4] J. Pakarinen,[1] P. Rahkila,[1] J. Romero,[1,4] P. Ruotsalainen,[1] M. Sandzelius,[1] J. Sarén,[1] A. Tolosa-Delgado,[1] J. Uusitalo,[1] and G. Zimba[1]

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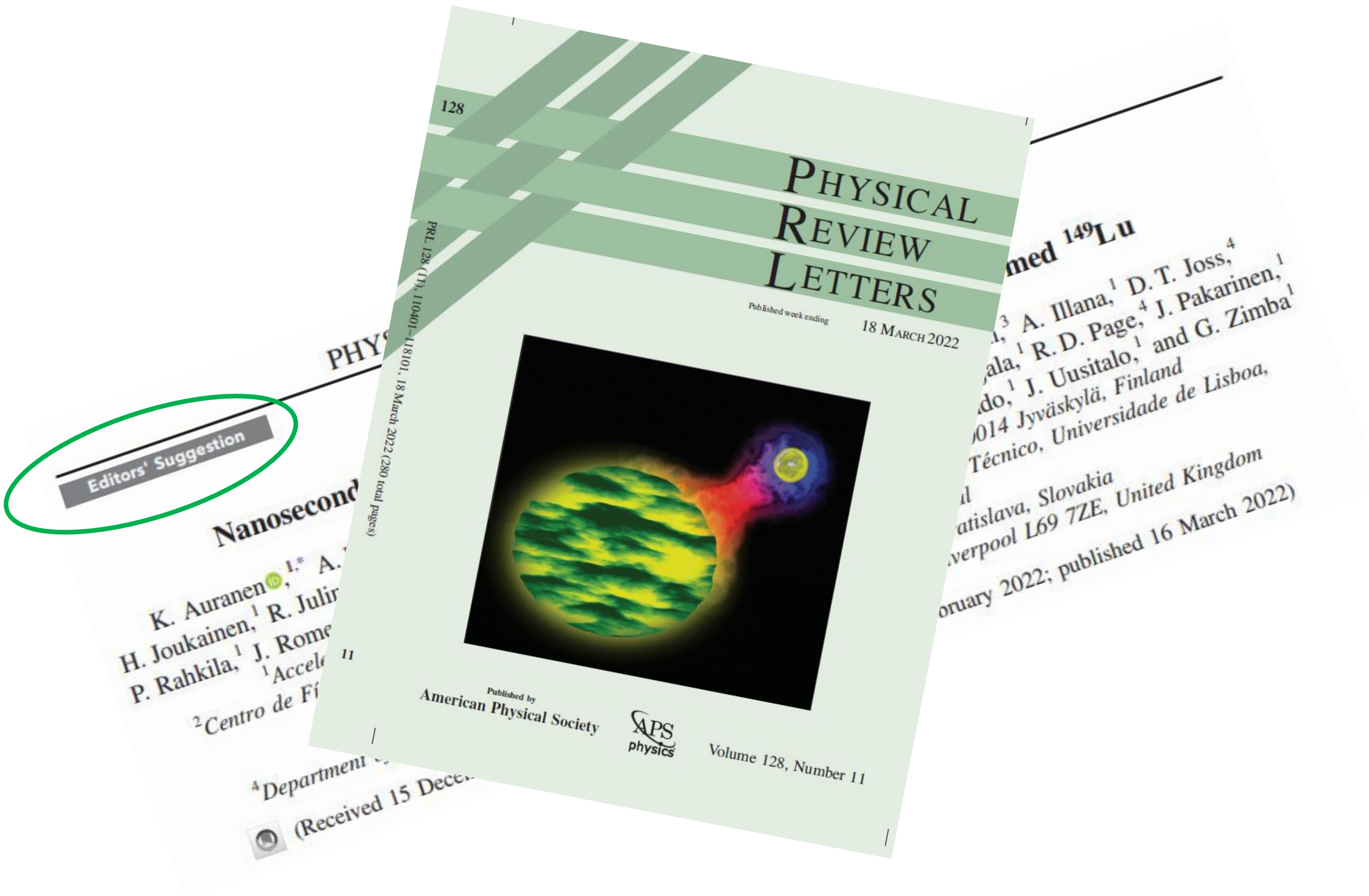
Publication



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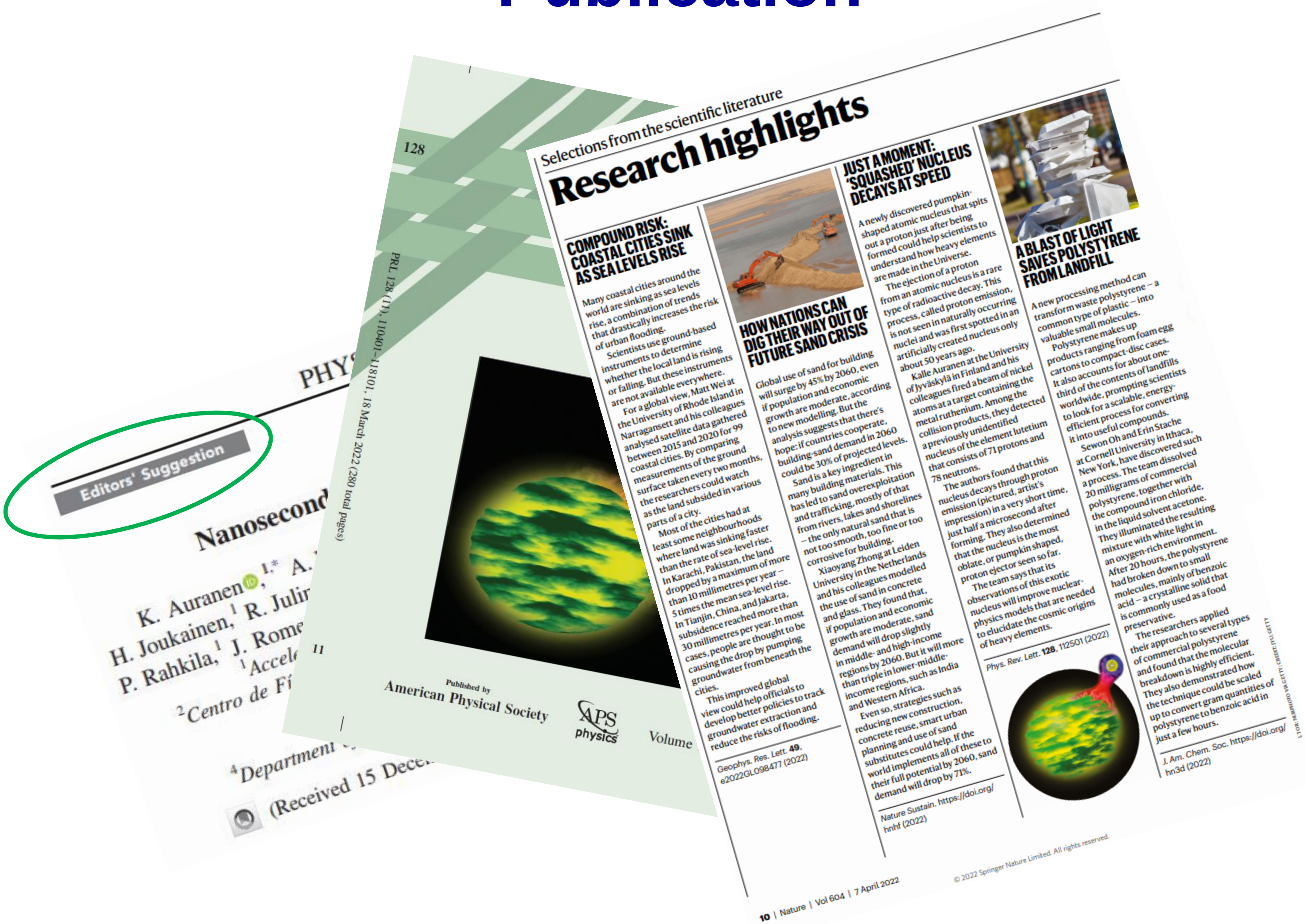
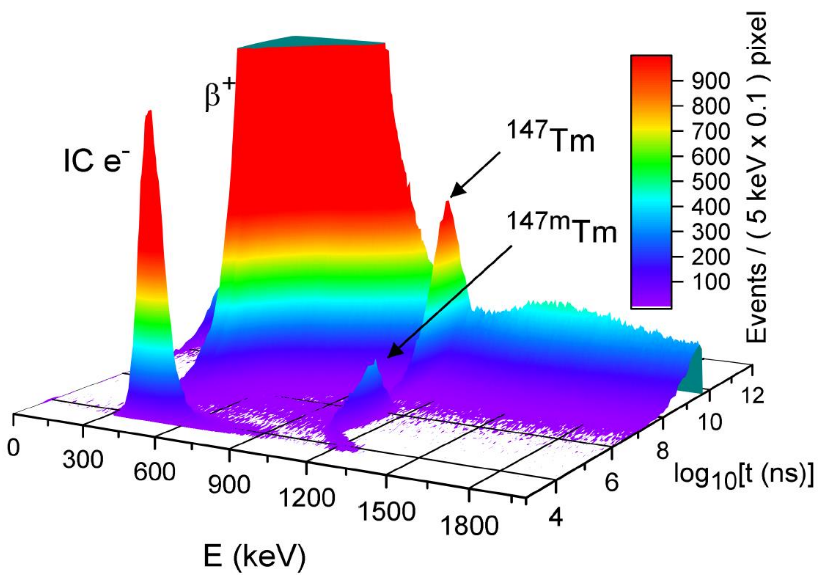


2) In-beam γ-ray spectroscopy of ^{147}Tm

^{92}Mo(^{58}Ni,*p2n*) ^{147}Tm



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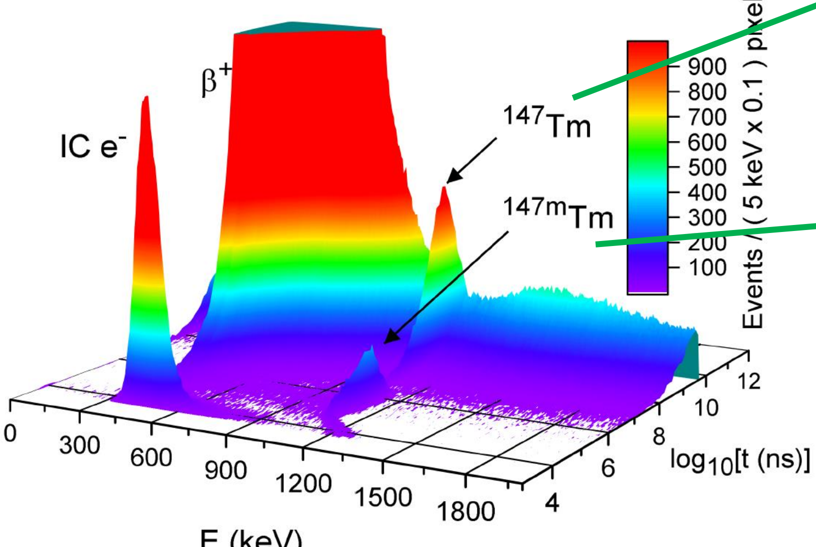
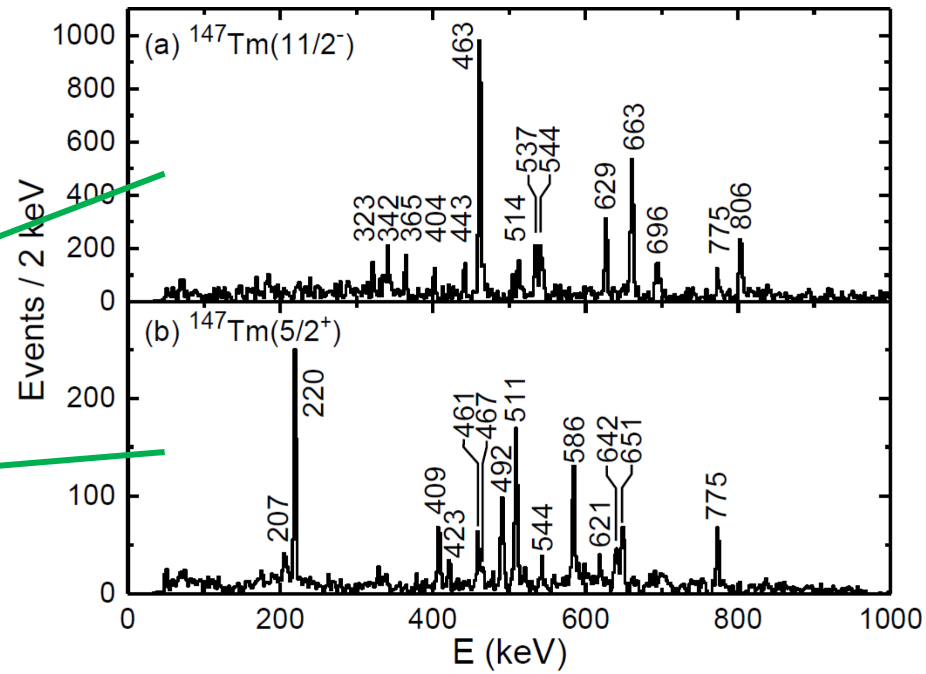
147-Tm tagged singles





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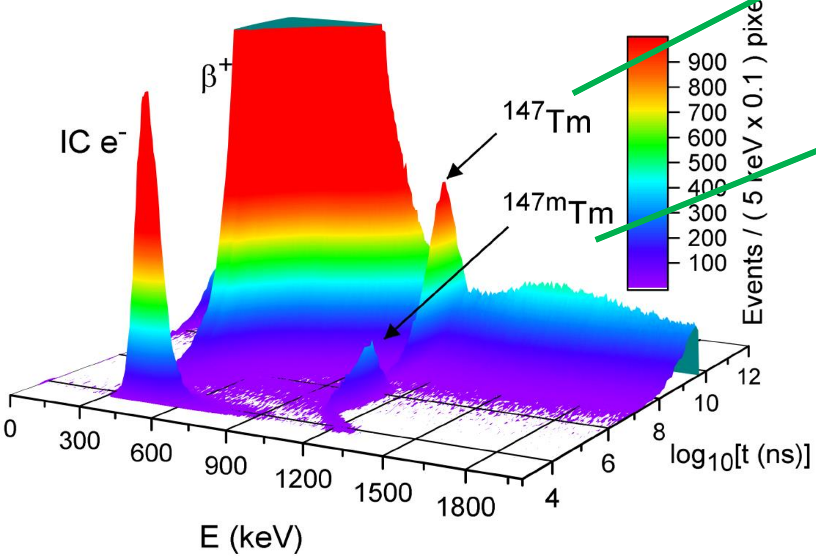
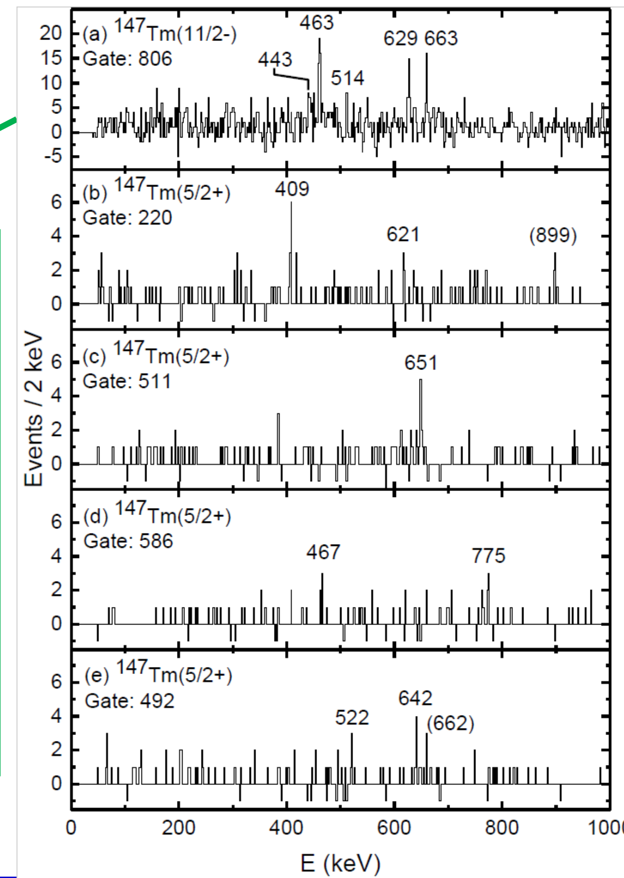
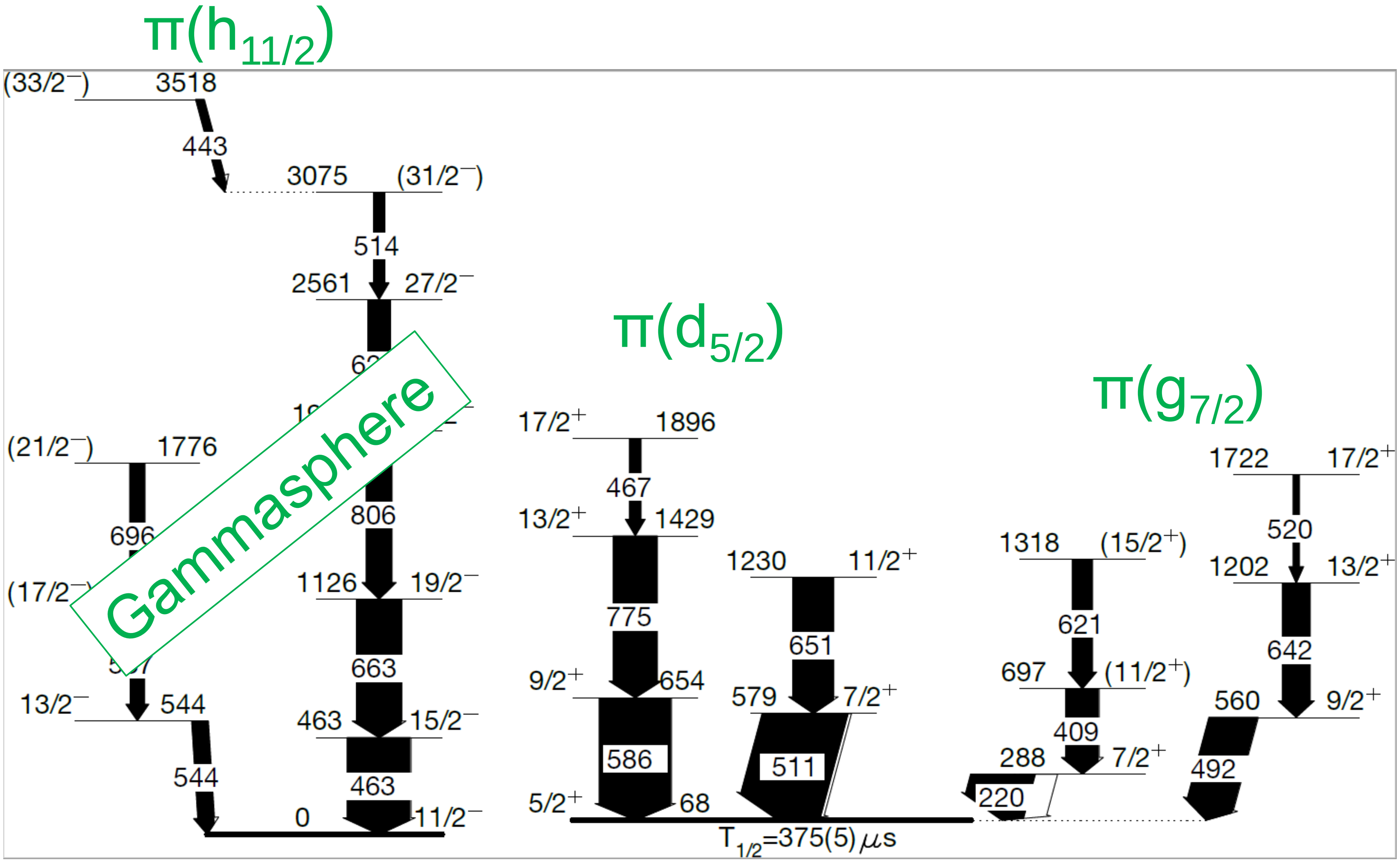


147-Tm tagged γ-γ coincidences



^{147}Tm level scheme



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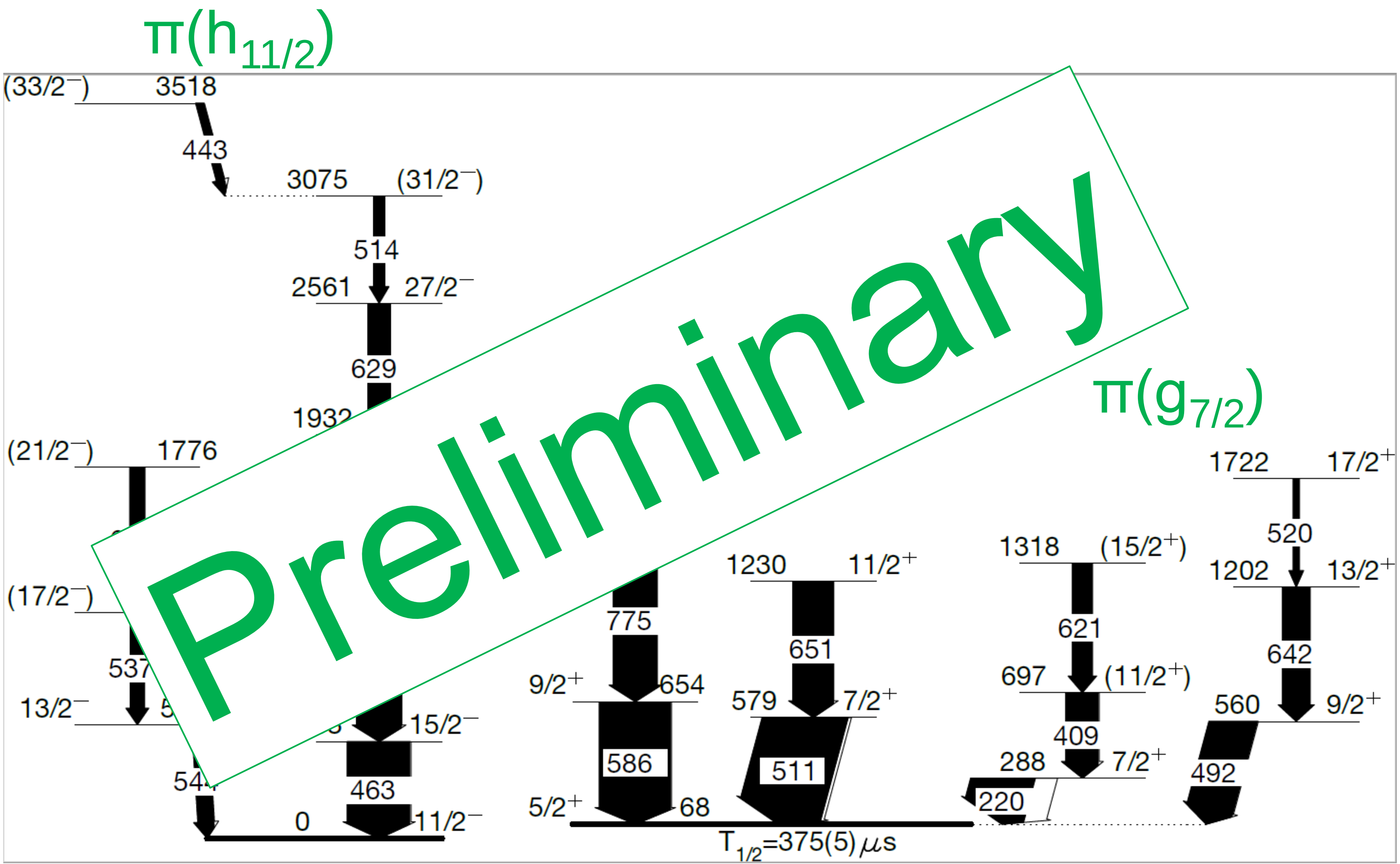

Thank You!