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Probing proton emitters using MARA separator

Kalle Auranen

TASCA22

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^{148}Yb

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?

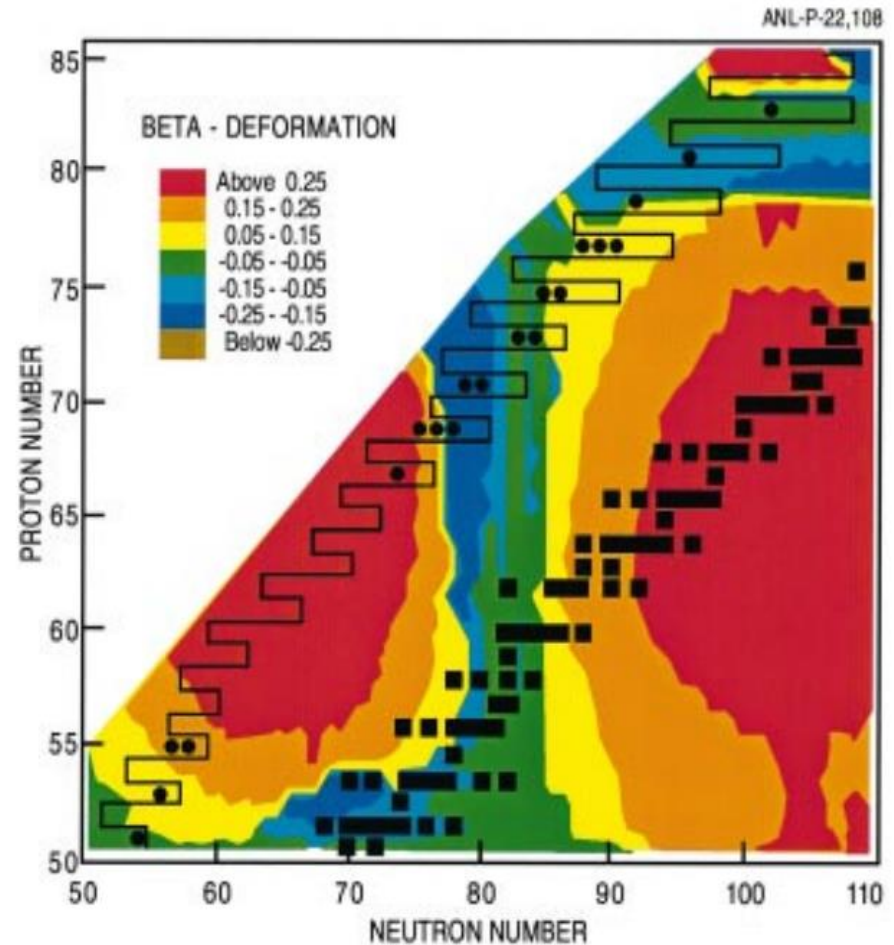


Figure 5 Contour plot of the quadrupole deformation parameter b_2 taken from (89), showing the general trend of the deformations. Filled circles are the known proton emitters, and the predicted proton drip-line also taken from (90) is shown as a solid line, modified where experimental evidence is available.

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

Why study Lutetium? ¹⁵¹Lu

- Very few oblate deformed proton emitters are known

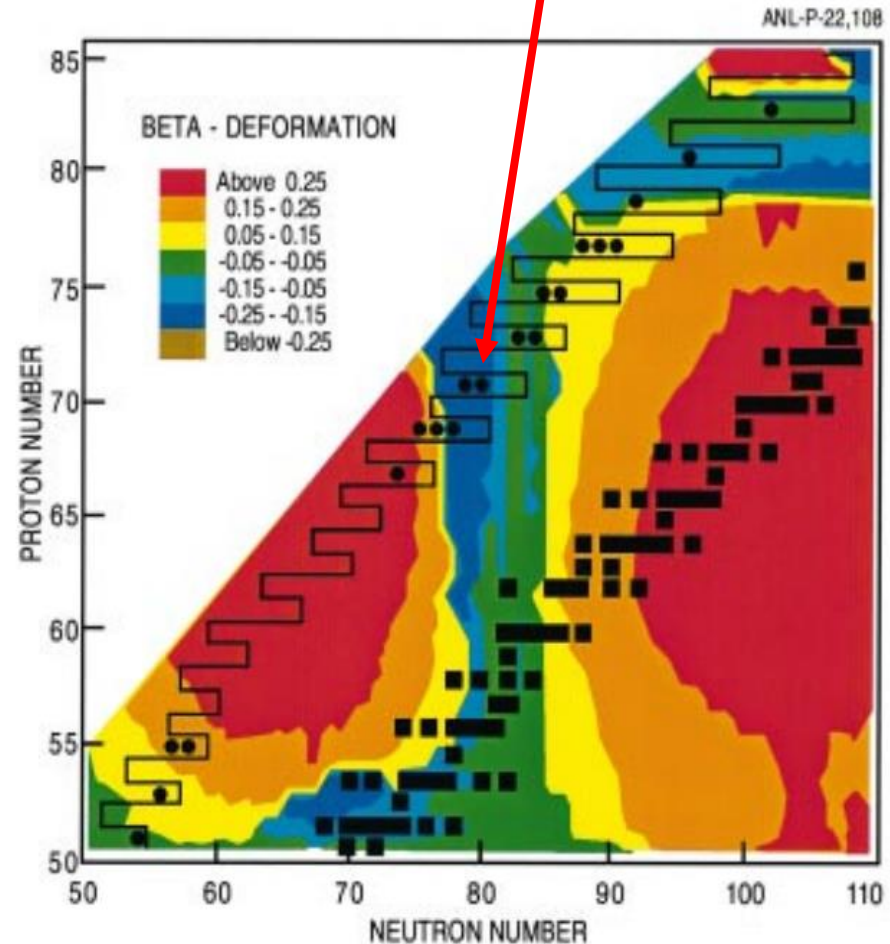


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Why study Lutetium?

- 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)]

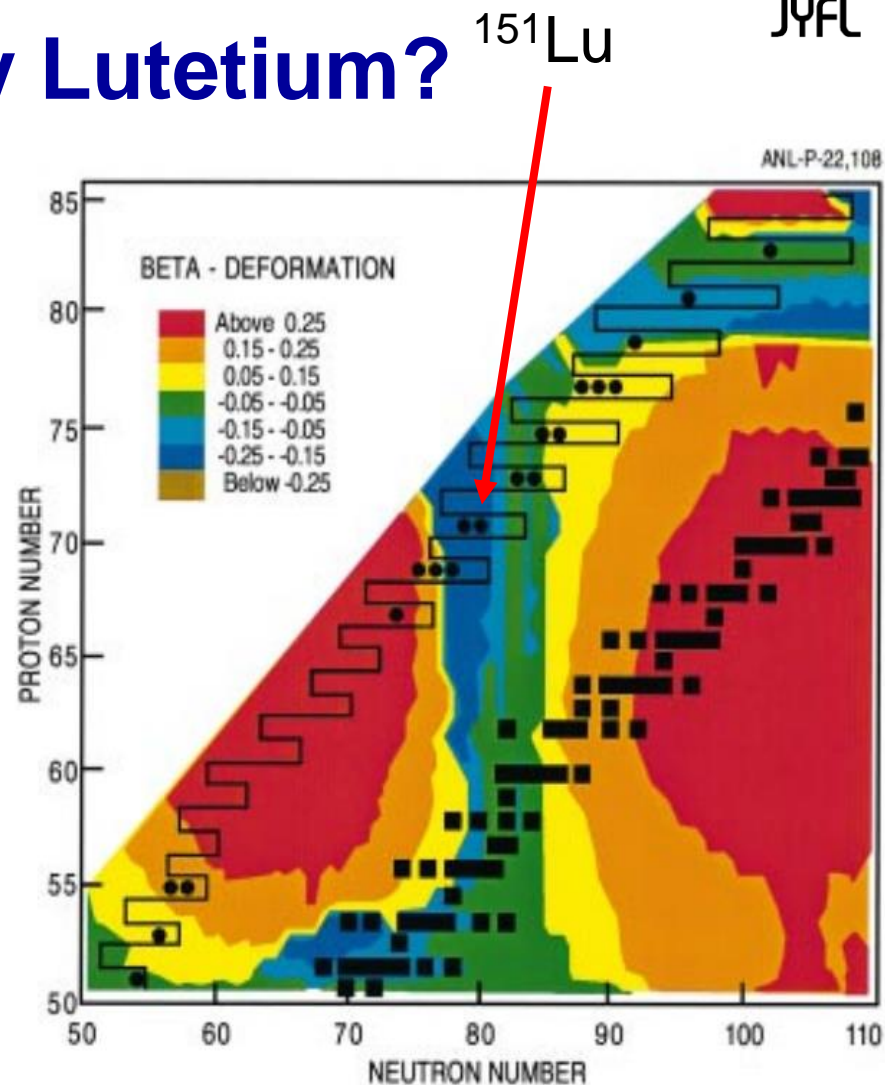


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Why study Lutetium?

¹⁵¹Lu

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

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

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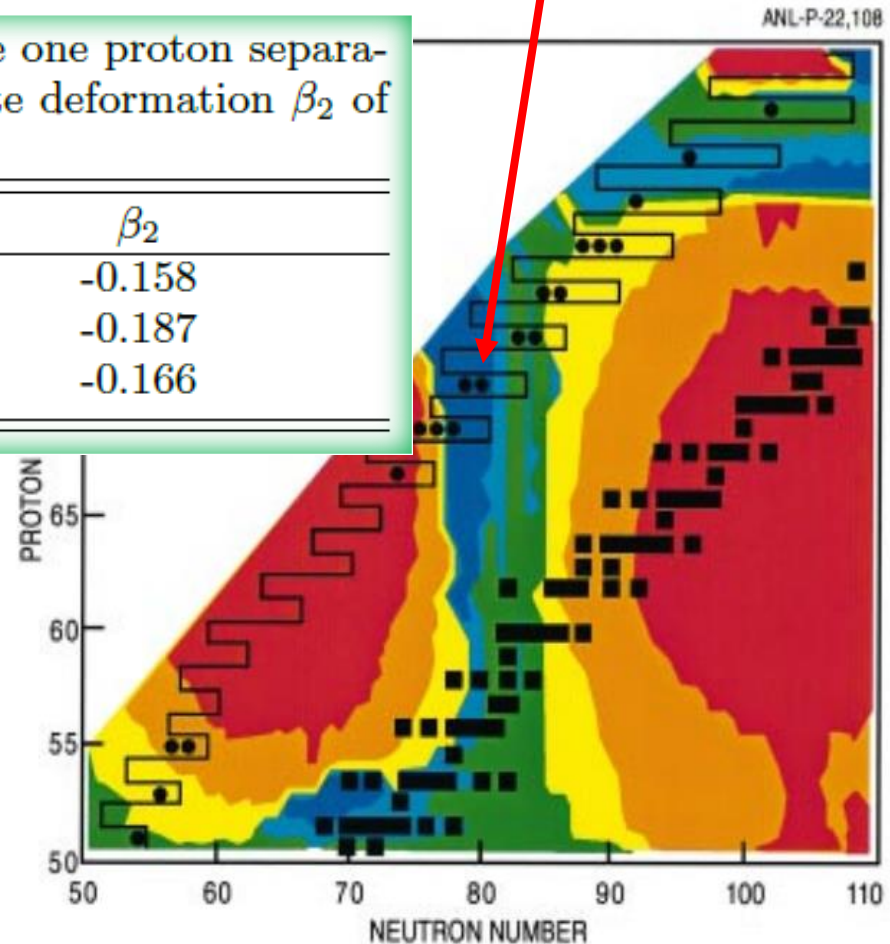


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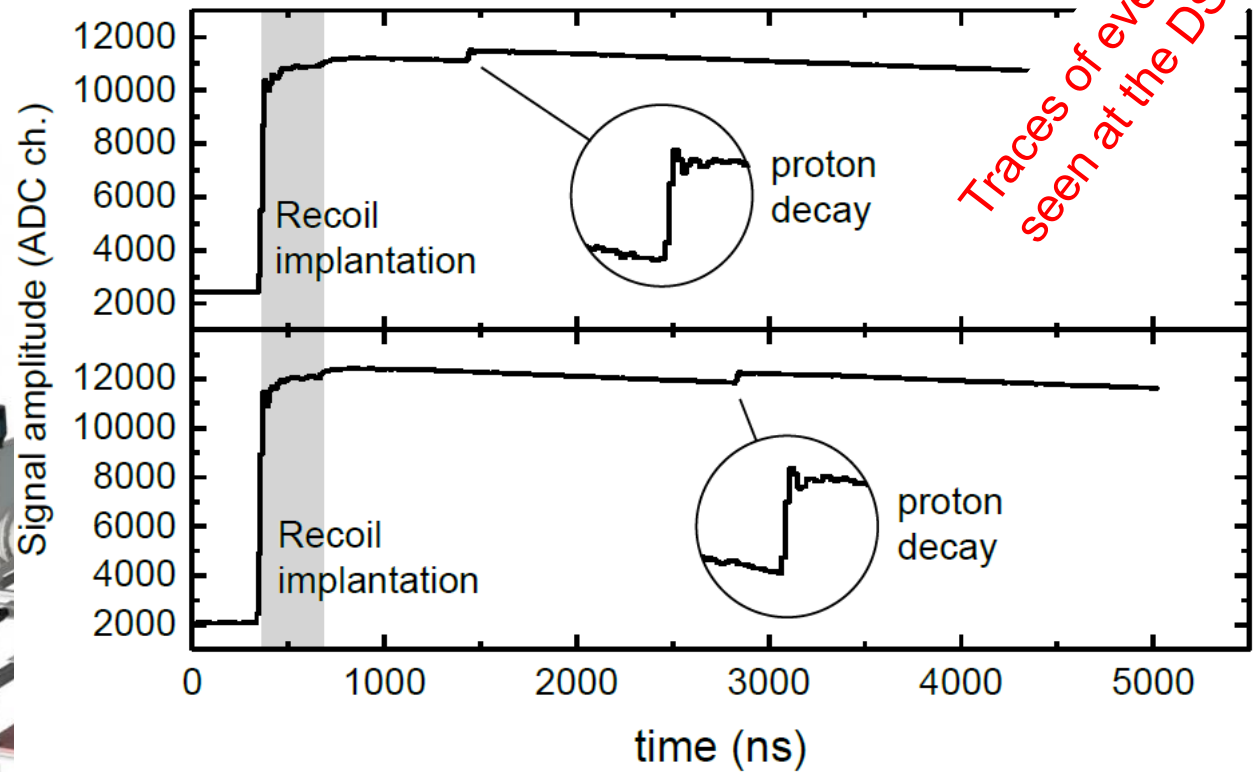
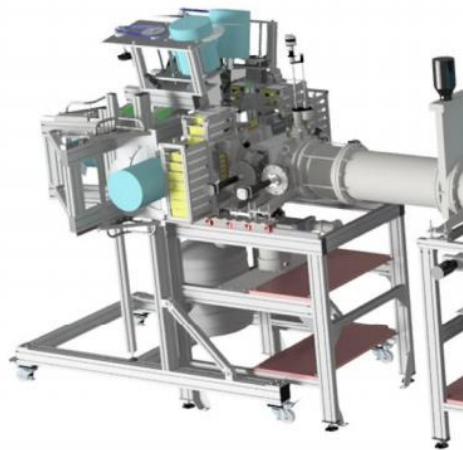
Experiment

- $^{96}\text{Ru}(^{58}\text{Ni}, p4n) ^{149}\text{Lu}$ 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



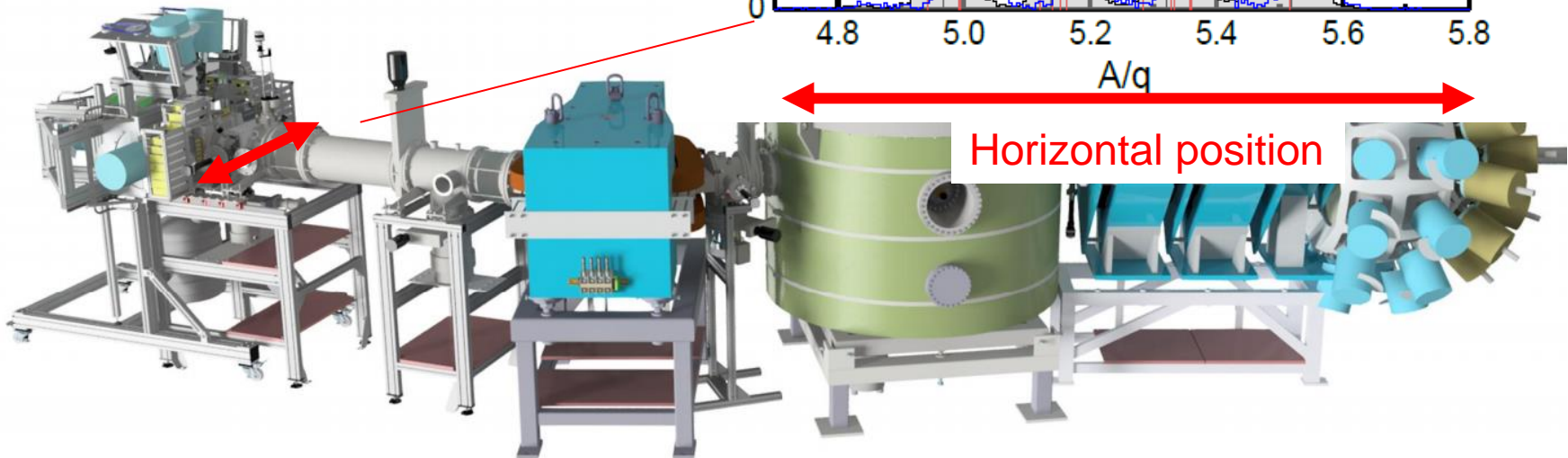
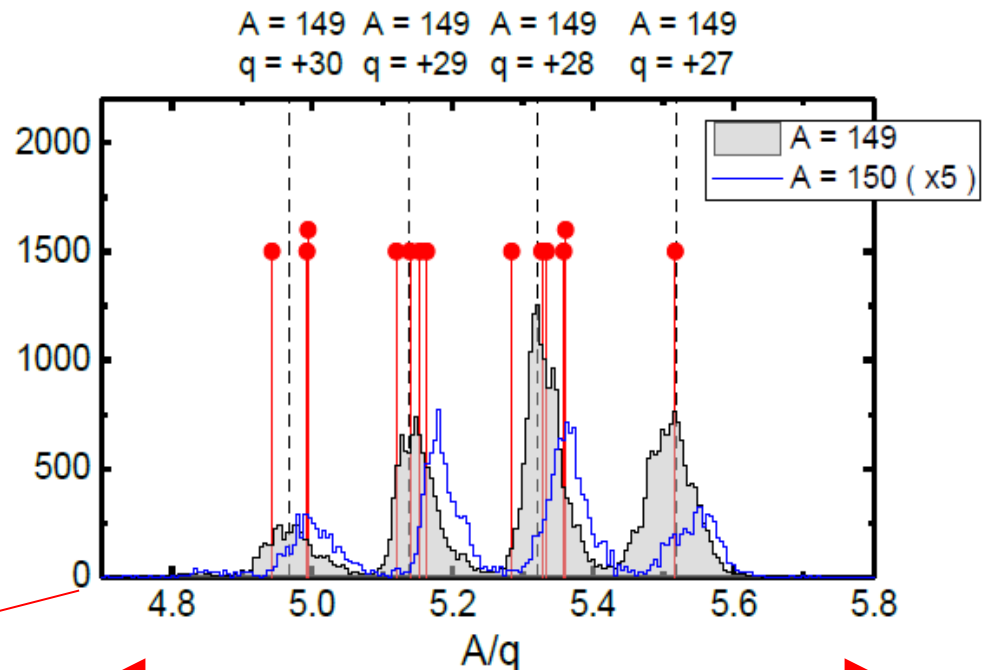
Results

- 14 candidates for fast proton emission
- Experimental fingerprint:



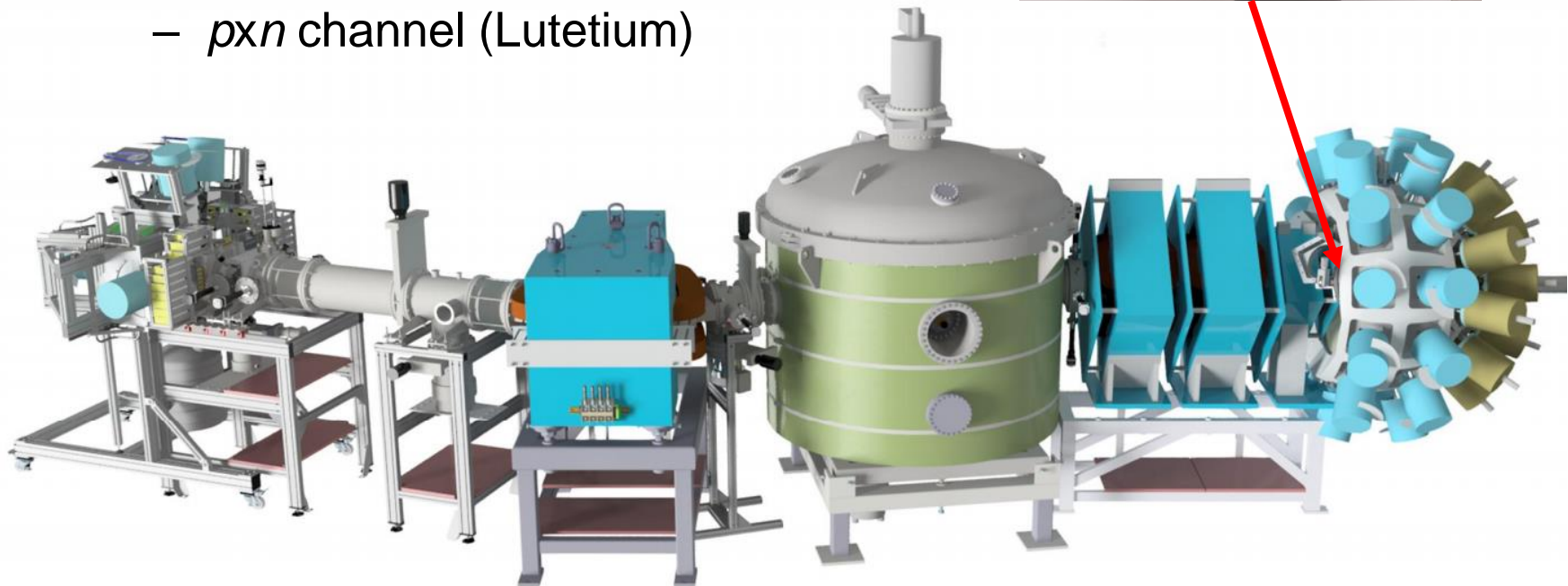
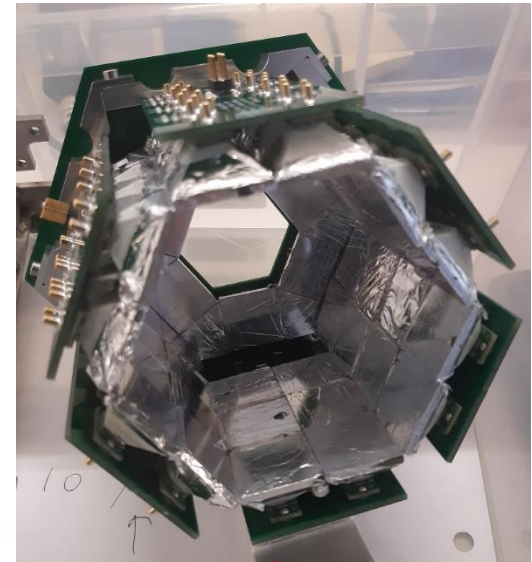
Results

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



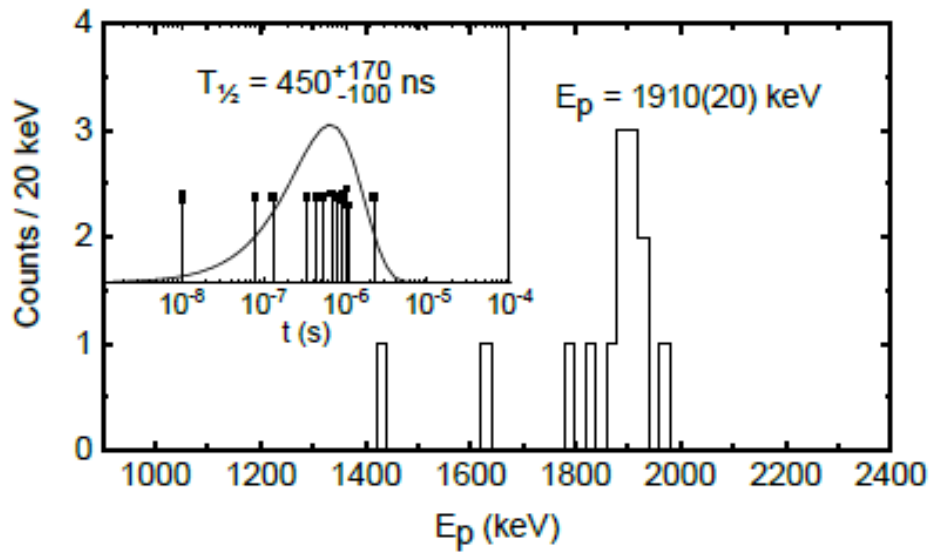
Results

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



Results

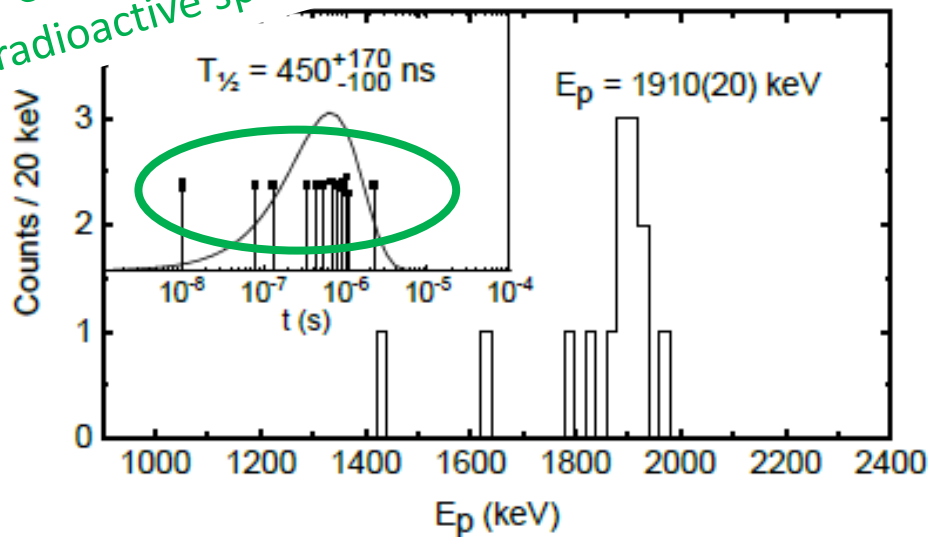
- $E_p = 1910(20)$ keV
 - Highest measured for a g.s. proton emitter



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

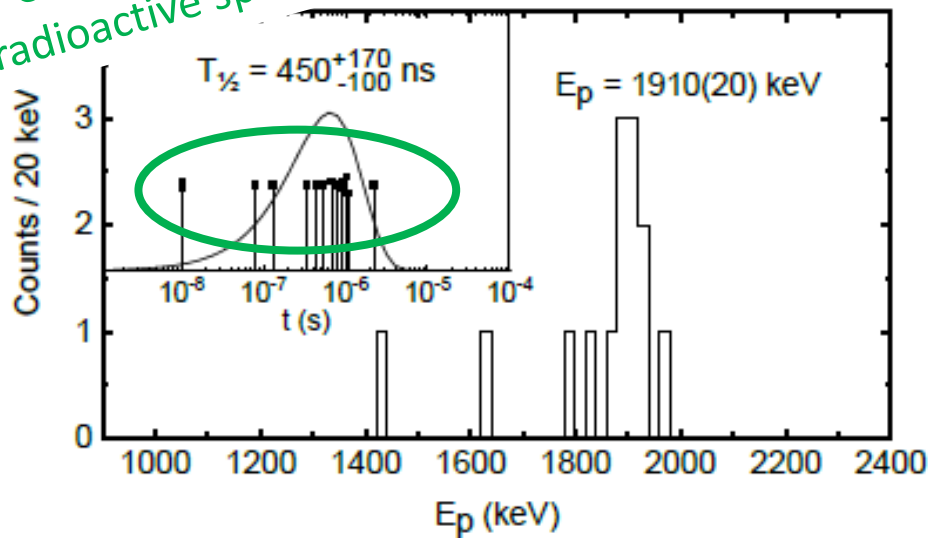
Passes the 90% probability test**
 - Consistent with the decay of a single radioactive species



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

Results

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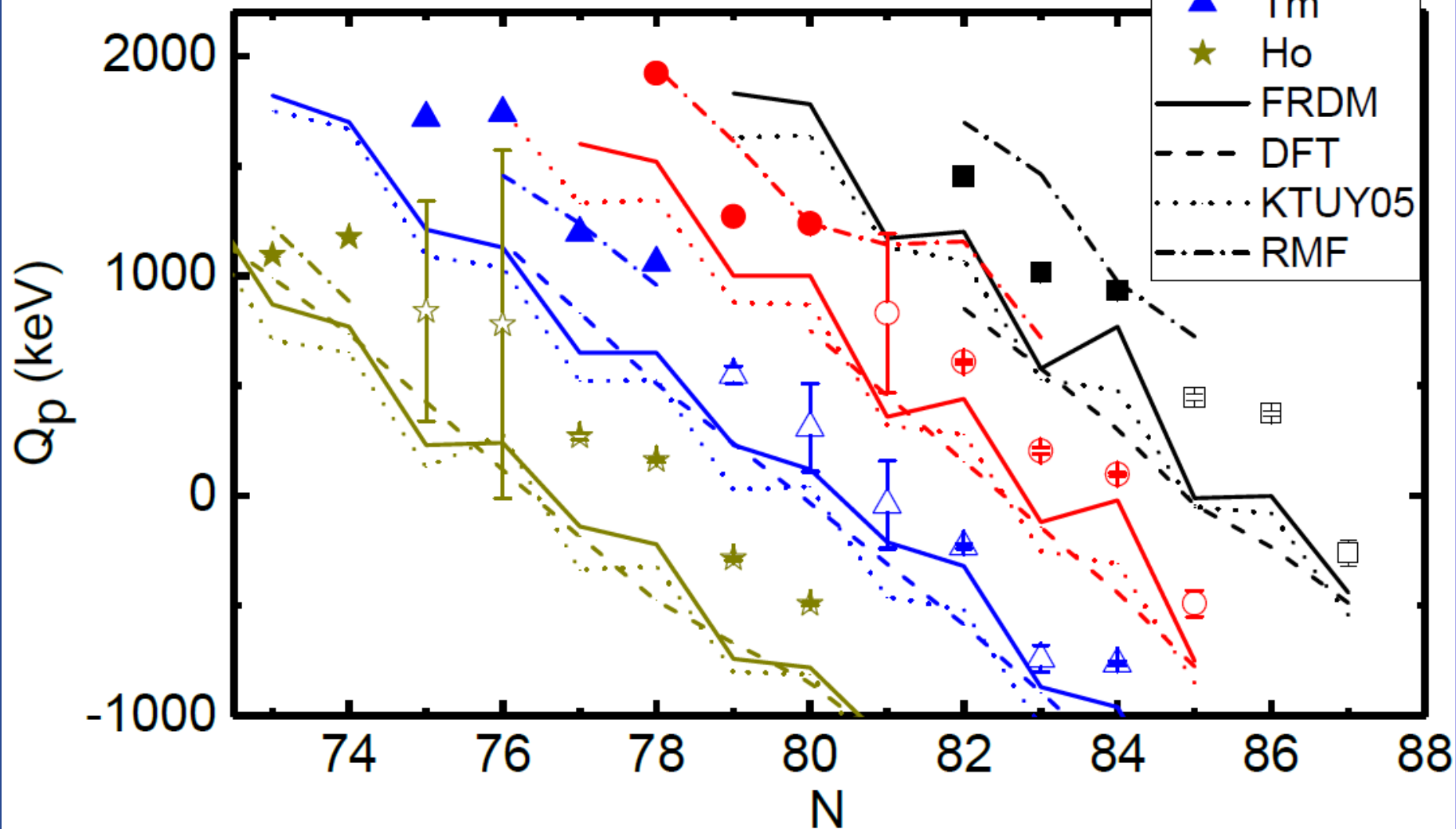


- $E_p = 1910(20)$ keV
 - Highest measured for a g.s. proton emitter
- $T_{1/2} = 450(^{+170}_{-100})$ ns
 - Shortest *directly* measured for a g.s. proton emitter
- Geiger-Nuttall law
 [Chen EPJA 55, 214 (2019)]
 - 956 ns ($I_p = 5$; within 1σ)
 - $\pi(h_{11/2})$

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

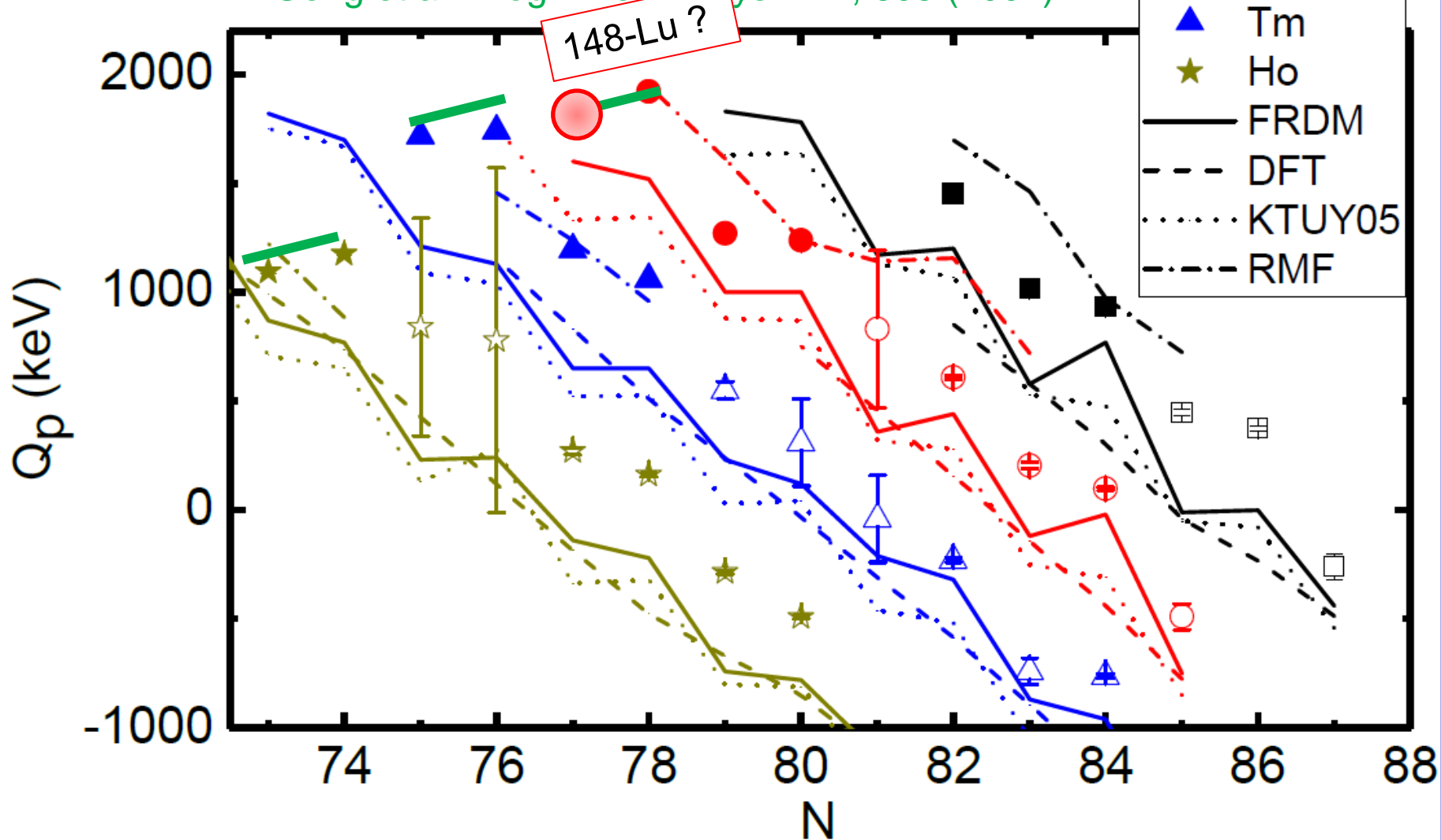
Systematics

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



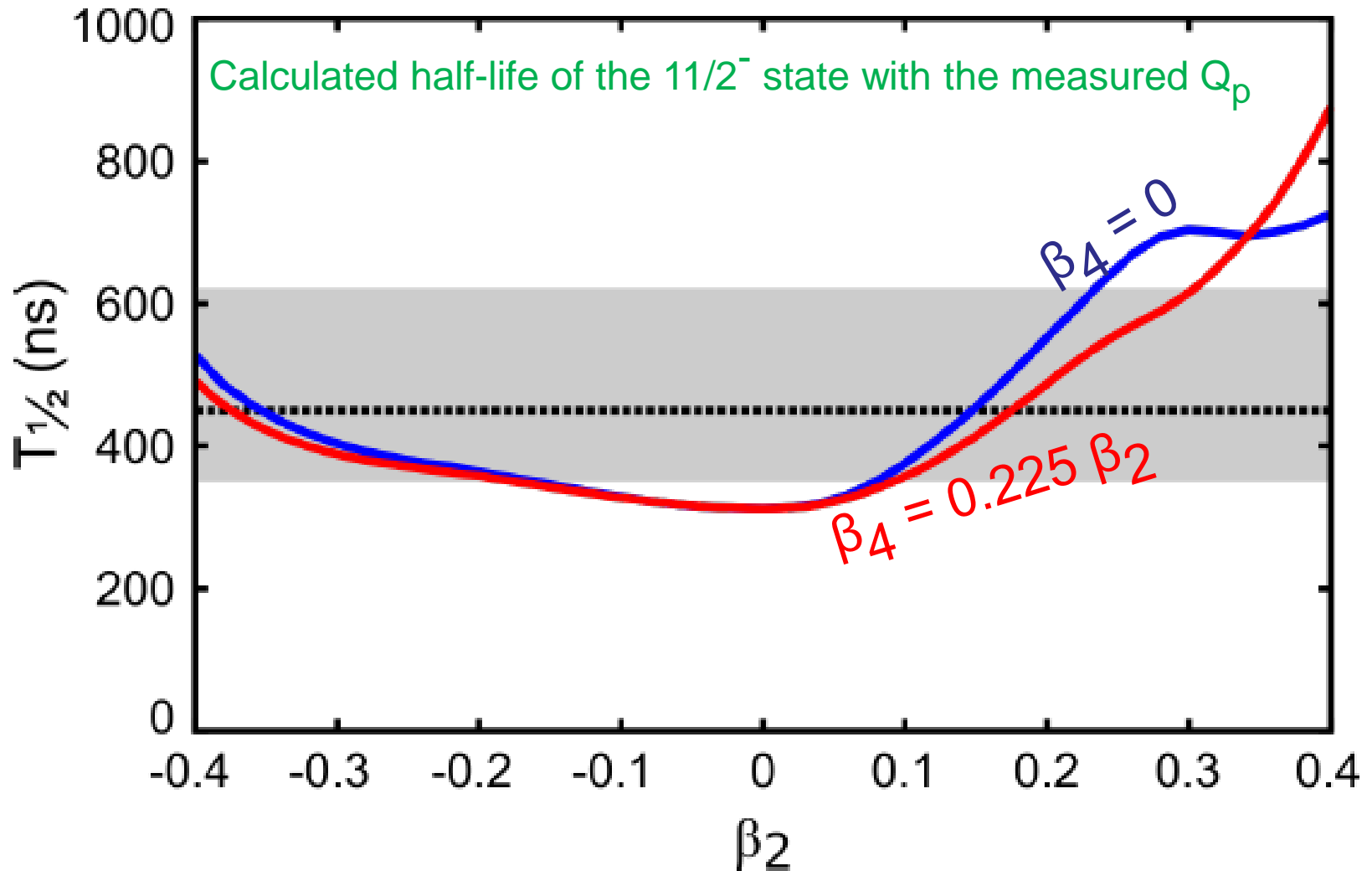
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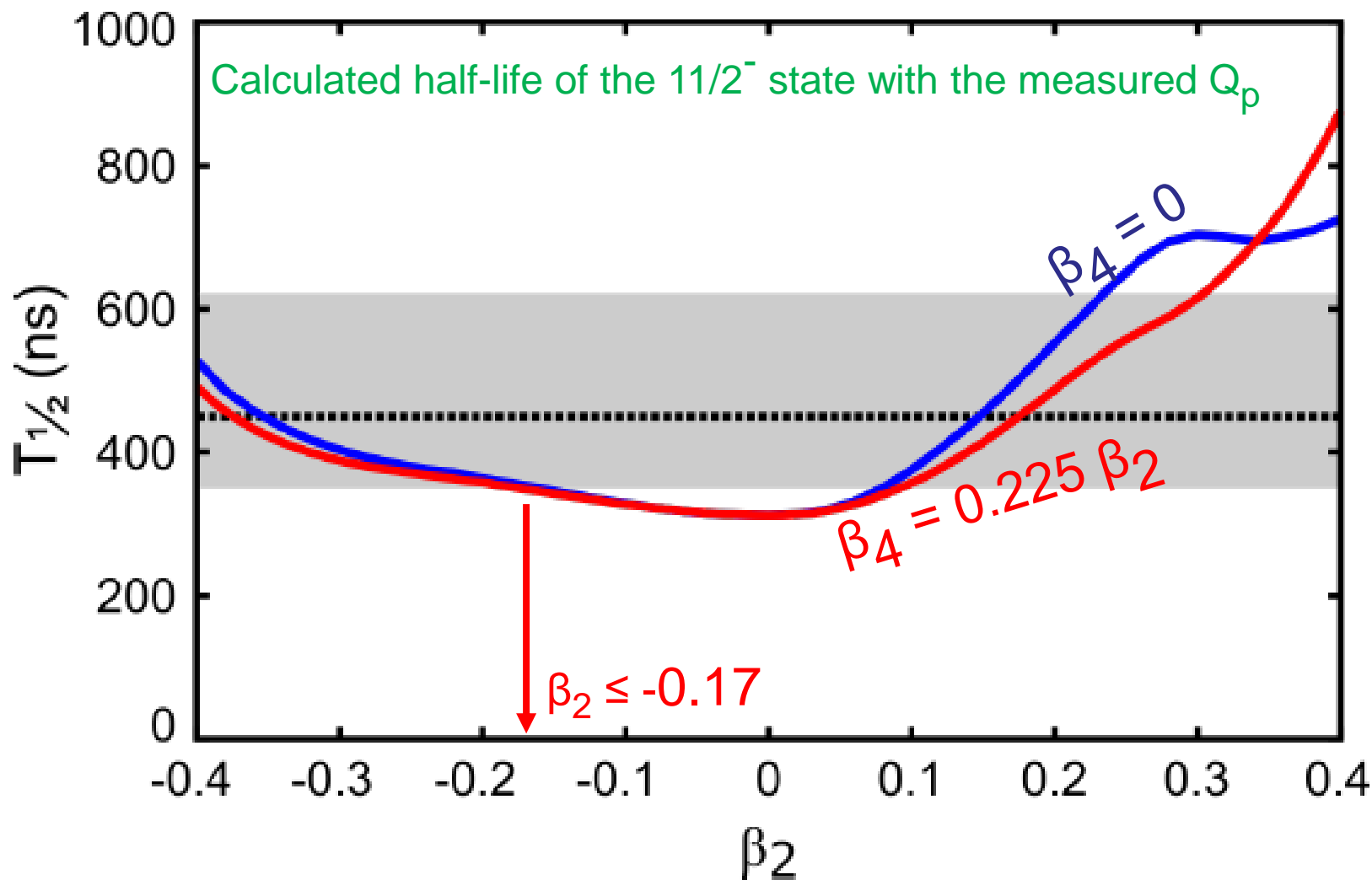
Non-adiabatic quasiparticle model

(L.S. Ferreira, E. Maglione)



Non-adiabatic quasiparticle model

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Publication

Editors' Suggestion

PHYSICAL REVIEW LETTERS 128, 112501 (2022)

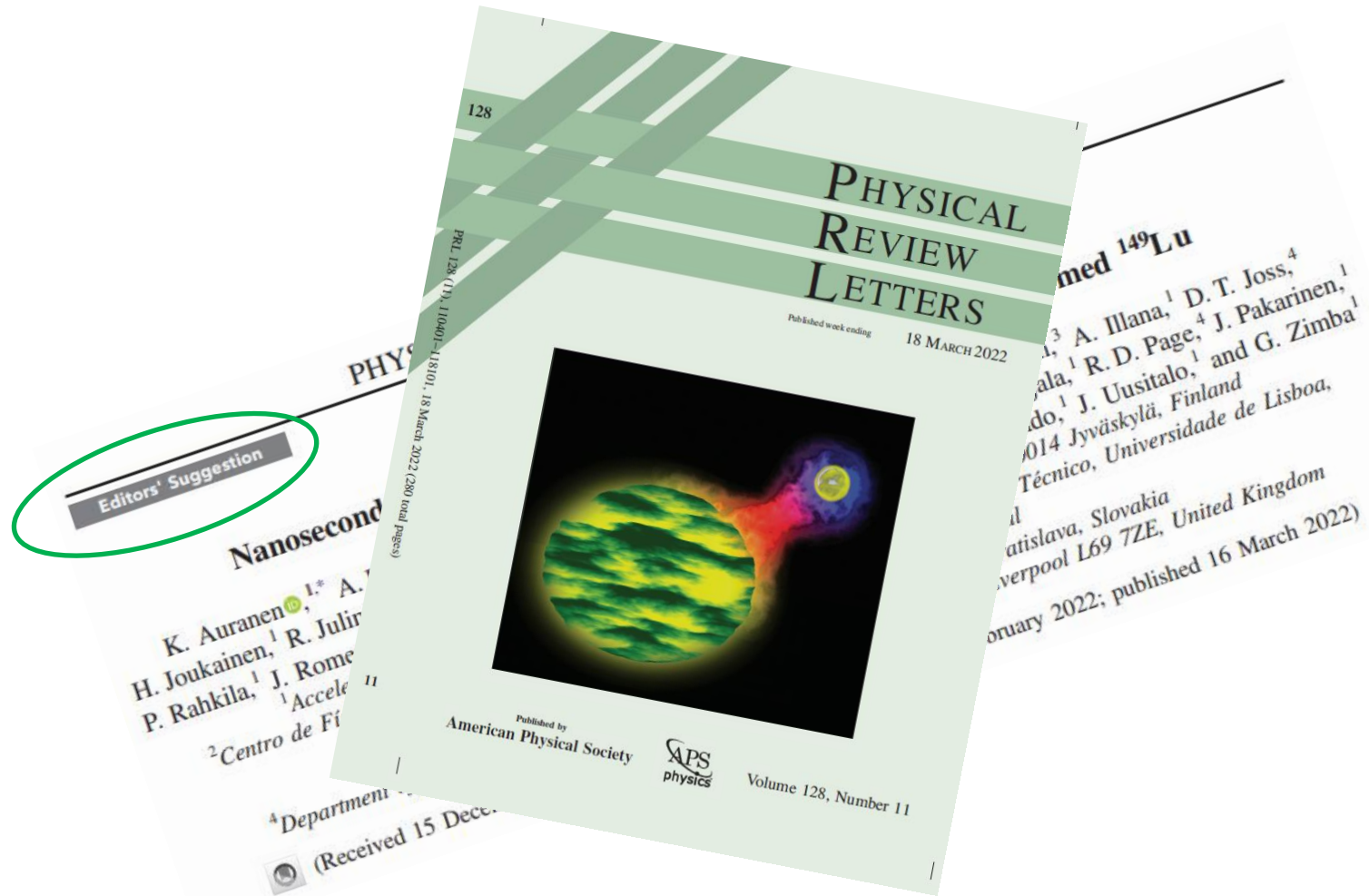
Nanosecond-Scale Proton Emission from Strongly Oblate-Deformed ¹⁴⁹Lu

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H. Joukainen¹, R. Julin¹, H. Jutila¹, M. Leino¹, J. Louko¹, M. Luoma¹, E. Maglione², J. Ojala¹, R. D. Page⁴, J. Pakarinen¹,
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18 March 2022 (280 total pages)

Editors' Suggestion

Nanosecond

K. Auranen^{1,*}, A. ...
 H. Joukainen,¹ R. Julin ...
 P. Rahkila,¹ J. Rome ...
¹Centro de Fi ...
²Department ...
 (Received 15 Dec ...)

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J. Am. Chem. Soc. <https://doi.org/10.1021/acs.jchemsoc.2c01111>

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Selections from the scientific literature

Research highlights

COMPOUND RISK: COASTAL CITIES SINK AS SEA LEVELS RISE

Many coastal cities around the world are sinking as sea levels rise, a combination of trends that drastically increases the risk of urban flooding. Scientists use ground-based instruments to determine whether the local land is rising or falling. But these instruments are not available everywhere. For a global view, Matt Wei at the University of Rhode Island and his colleagues Narrağaness and his colleagues analysed satellite data gathered between 2015 and 2020 for 99 coastal cities. By comparing measurements of the ground surface taken every two months, the researchers could watch as the land subsided in various parts of a city. Most of the cities had at least some neighbourhoods where land was sinking faster than the rate of sea-level rise. In Karachi, Pakistan, the land dropped by a maximum of more than 10 millimetres per year – 5 times the mean sea-level rise. In Tianjin, China, and Jakarta, Indonesia, subsidence reached more than 30 millimetres per year. In most cases, people are thought to be causing the drop by pumping groundwater from beneath the cities. This improved global view could help officials to develop better policies to track and reduce groundwater extraction and groundwater extraction and reduce the risks of flooding.

Geophys. Res. Lett. **49**, e2022GL098477 (2022)

HOW NATIONS CAN DIG THEIR WAY OUT OF FUTURE SAND CRISIS

Global use of sand for building will surge by 45% by 2060, even if population and economic growth are moderate, according to new modelling. But the analysis suggests that there's hope: if countries cooperate, building-sand demand in 2060 could be 30% of projected levels. Sand is a key ingredient in many building materials. This has led to sand overexploitation and trafficking, mostly of that from rivers, lakes and shorelines – the only natural sand that is not too smooth, too fine or too corrosive for building. Xiaoyang Zhong at Leiden University in the Netherlands and his colleagues modelled the use of sand in concrete and glass. They found that, if population and economic growth are moderate, sand demand will drop slightly in middle- and high-income regions by 2060. But it will more than triple in lower-middle-income regions, such as India and Western Africa. Even so, strategies such as reducing new construction, concrete reuse, smart urban planning and use of sand substitutes could help. If the world implements all of these to their full potential by 2060, sand demand will drop by 71%.

Nature Sustain. <https://doi.org/10.1038/s41891-022-00111-1>

JUST A MOMENT: 'SQUASHED' NUCLEUS DECAYS AT SPEED

A newly discovered pumpkin-shaped atomic nucleus that spits out a proton just after being formed could help scientists to understand how heavy elements are made in the Universe. The ejection of a proton from an atomic nucleus is a rare type of radioactive decay. This process, called proton emission, is not seen in naturally occurring nuclei and was first spotted in an artificially created nucleus only about 50 years ago. Kalle Auranen at the University of Jyväskylä in Finland and his colleagues fired a beam of nickel atoms at a target containing the metal ruthenium. Among the collision products, they detected a previously unidentified nucleus of the element lutetium that consists of 71 protons and 78 neutrons. The authors found that this nucleus decays through proton emission (pictured, artist's impression) in a very short time, just half a microsecond after forming. They also determined that the nucleus is the most oblate, or pumpkin shaped, proton ejector seen so far. The team says that its observations of this exotic nucleus will improve nuclear-physics models that are needed to elucidate the cosmic origins of heavy elements.

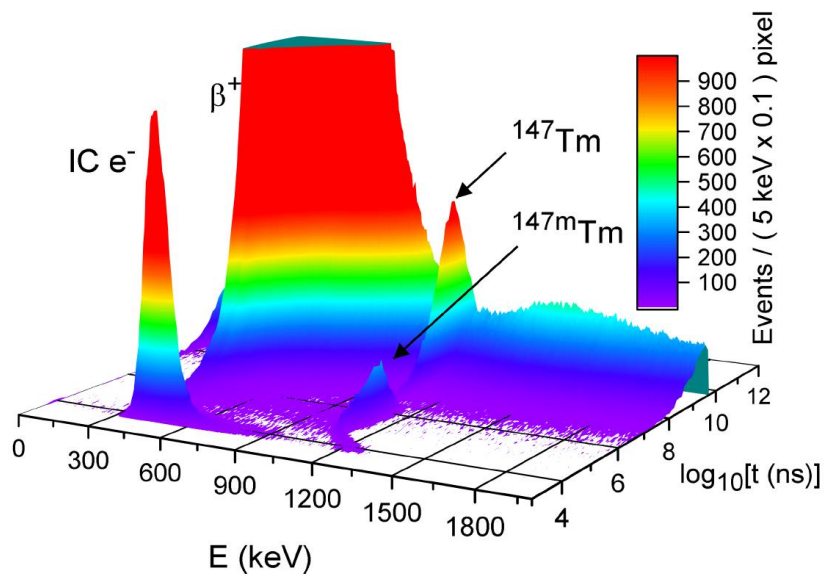
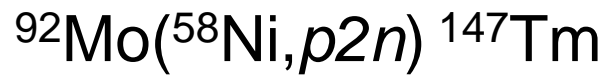
Phys. Rev. Lett. **128**, 110201 (2022)

A BLAST OF LIGHT SAVES POLYSTYRENE FROM LANDFILL

A new processing method can transform waste polystyrene – a common type of plastic – into valuable small molecules. Polystyrene makes up products ranging from foam egg cartons to compact-disc cases. It also accounts for about one-third of the contents of landfills worldwide, prompting scientists to look for a scalable, energy-efficient process for converting it into useful compounds. Sewon Oh and Erin Stache at Cornell University in Ithaca, New York, have discovered such a process. The team dissolved 20 milligrams of commercial polystyrene, together with the compound solvent acetone, in the liquid solvent acetone. They illuminated the resulting mixture with white light in an oxygen-rich environment. After 20 hours, the polystyrene had broken down to small molecules, mainly of benzoic acid – a crystalline solid that is commonly used as a food preservative. The researchers applied their approach to several types of commercial polystyrene and found that the molecular breakdown is highly efficient. They also demonstrated how the technique could be scaled up to convert gram quantities of polystyrene to benzoic acid in just a few hours.

J. Am. Chem. Soc. <https://doi.org/10.1021/acs.jchemsoc.2c01111>

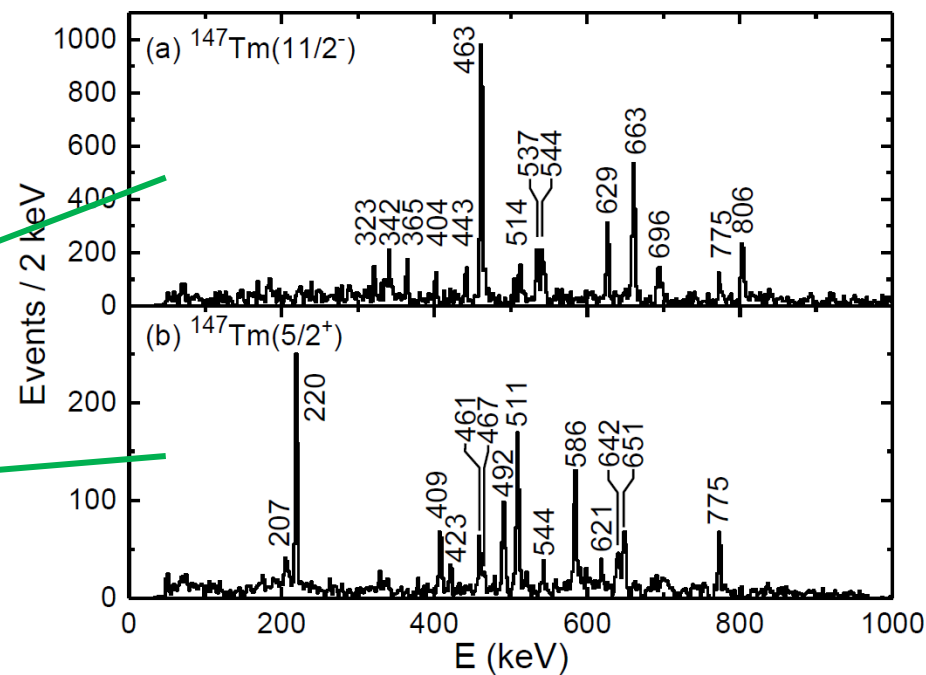
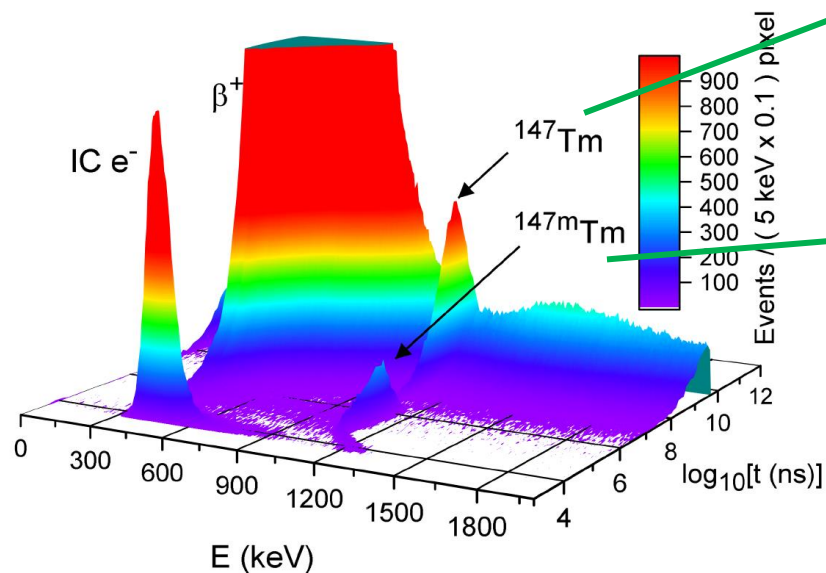
2) In-beam γ -ray spectroscopy of ^{147}Tm



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$^{92}\text{Mo}(^{58}\text{Ni}, p2n) ^{147}\text{Tm}$

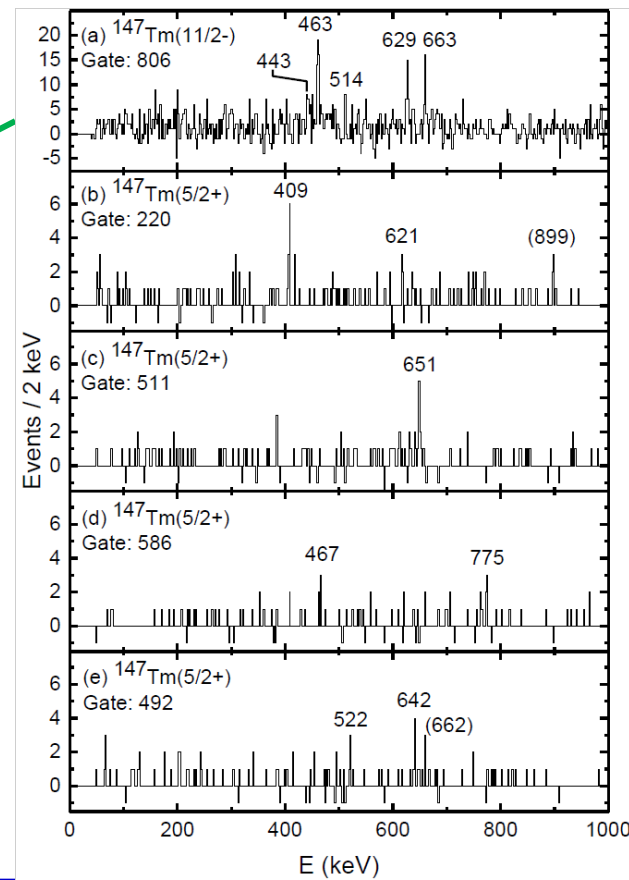
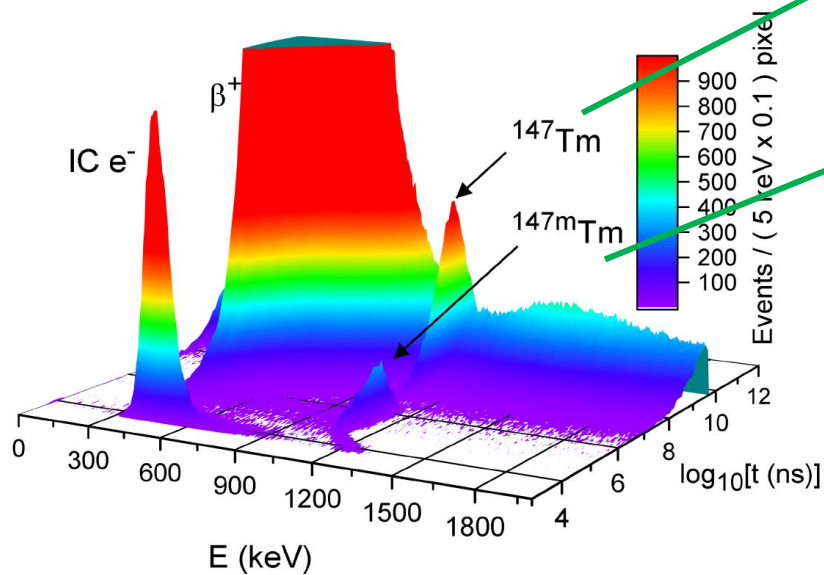
^{147}Tm tagged singles



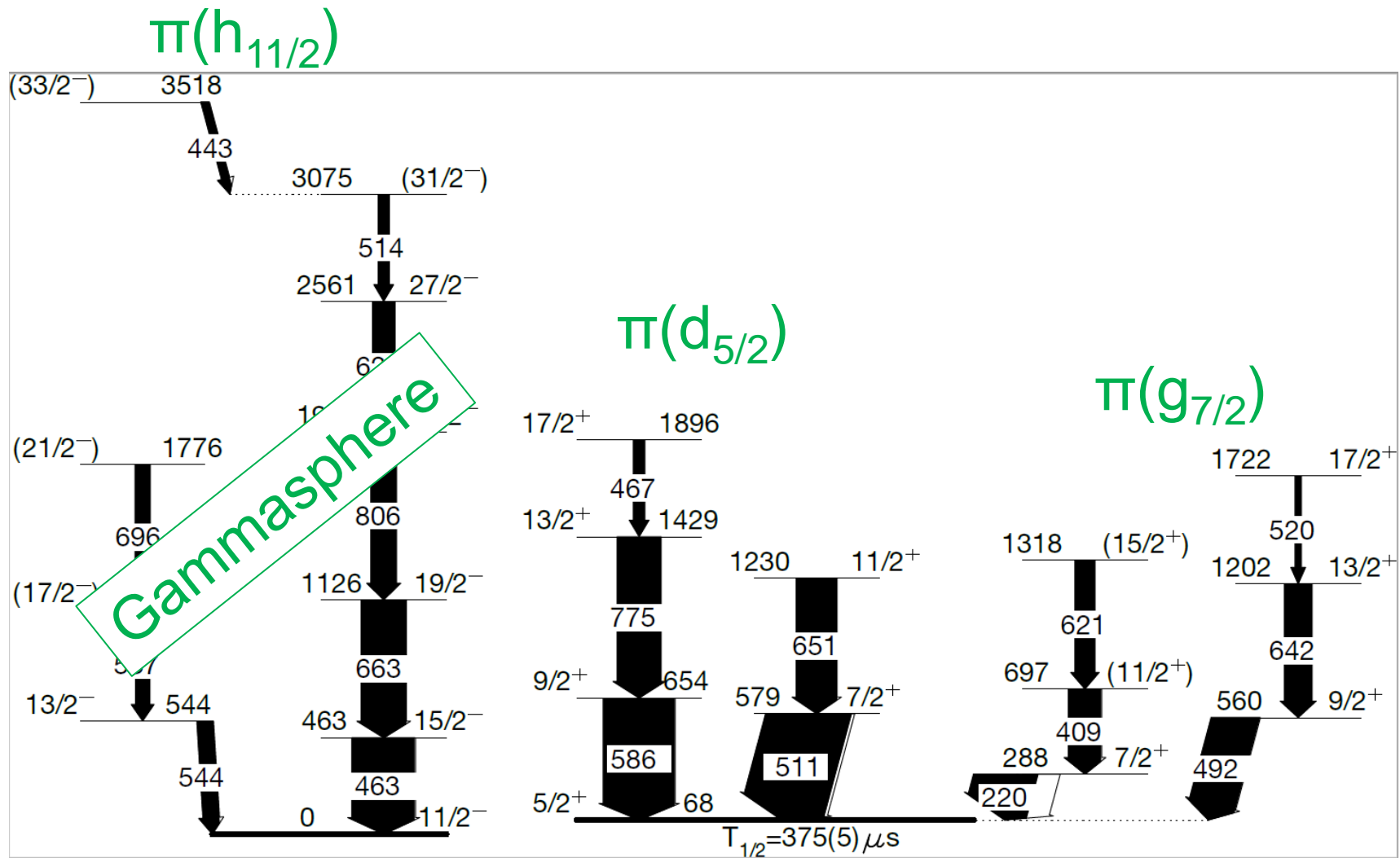
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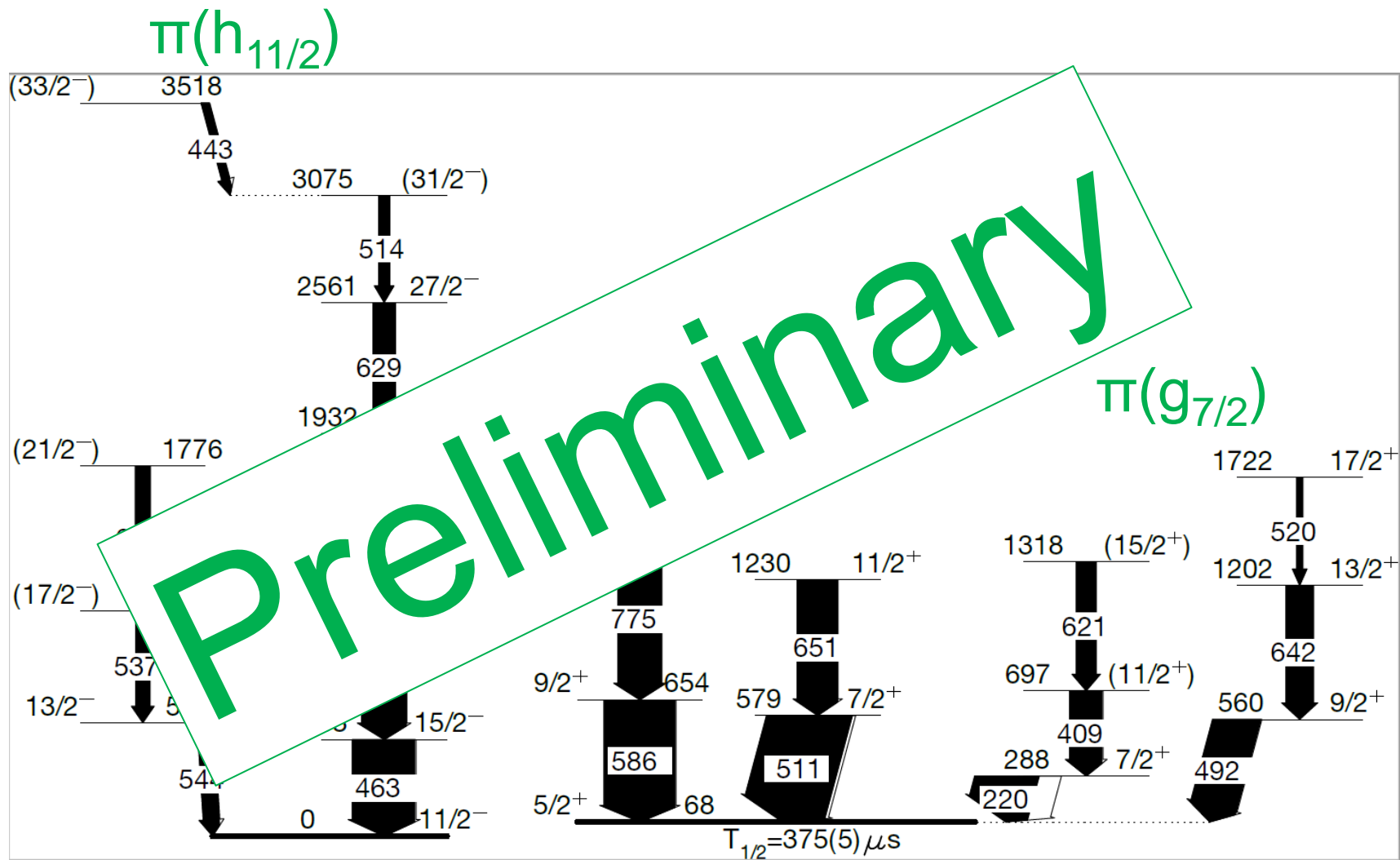
^{147}Tm tagged γ - γ coincidences



^{147}Tm level scheme



^{147}Tm level scheme



Thank You!

