What can highly-charged thallium tell us about how our Sun was born?

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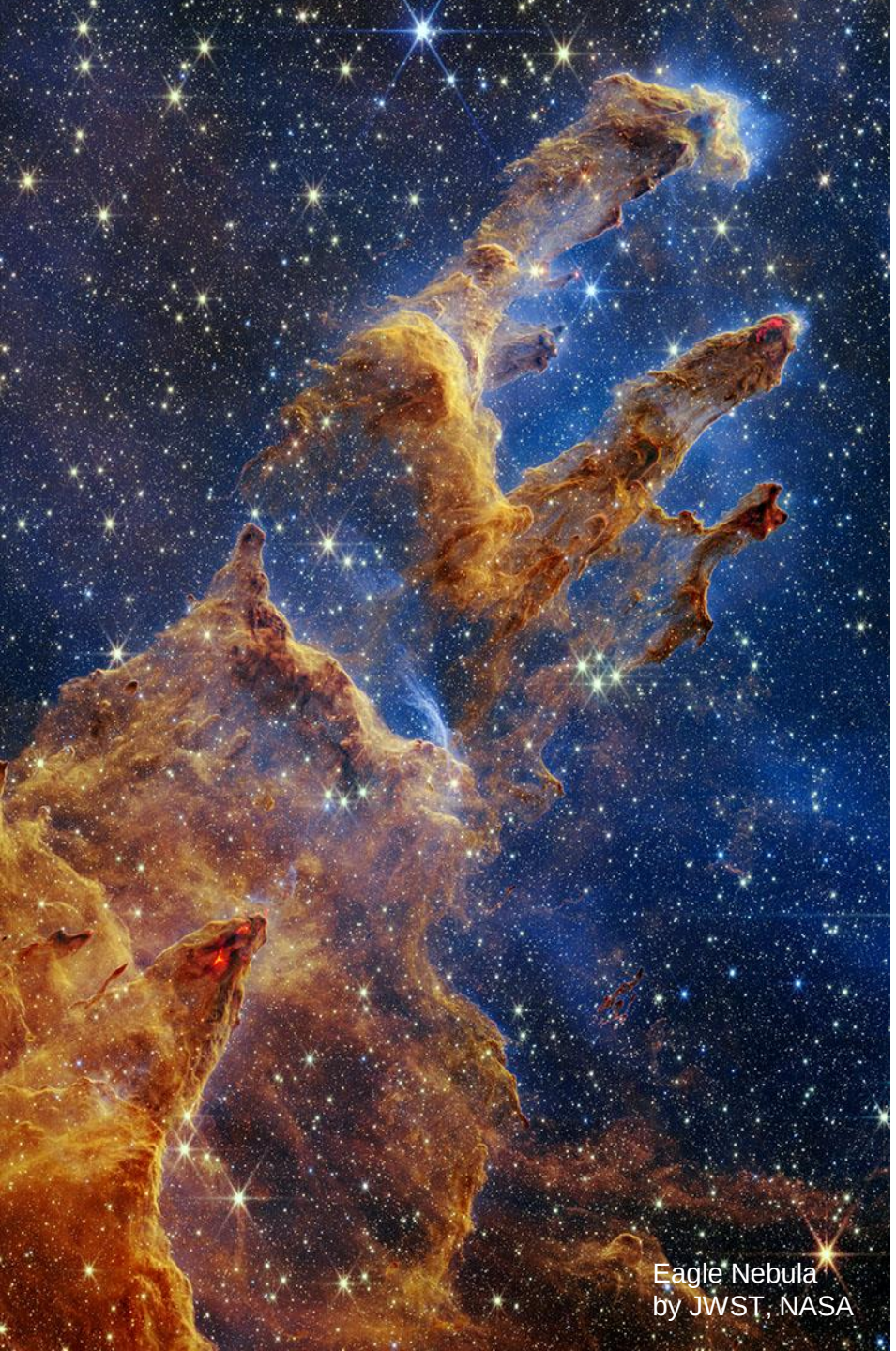
FAIR-GSI PhD Prize – December 2025

Danielle Adams
for TRIUMF

2025-12-18

Discovery, accelerated

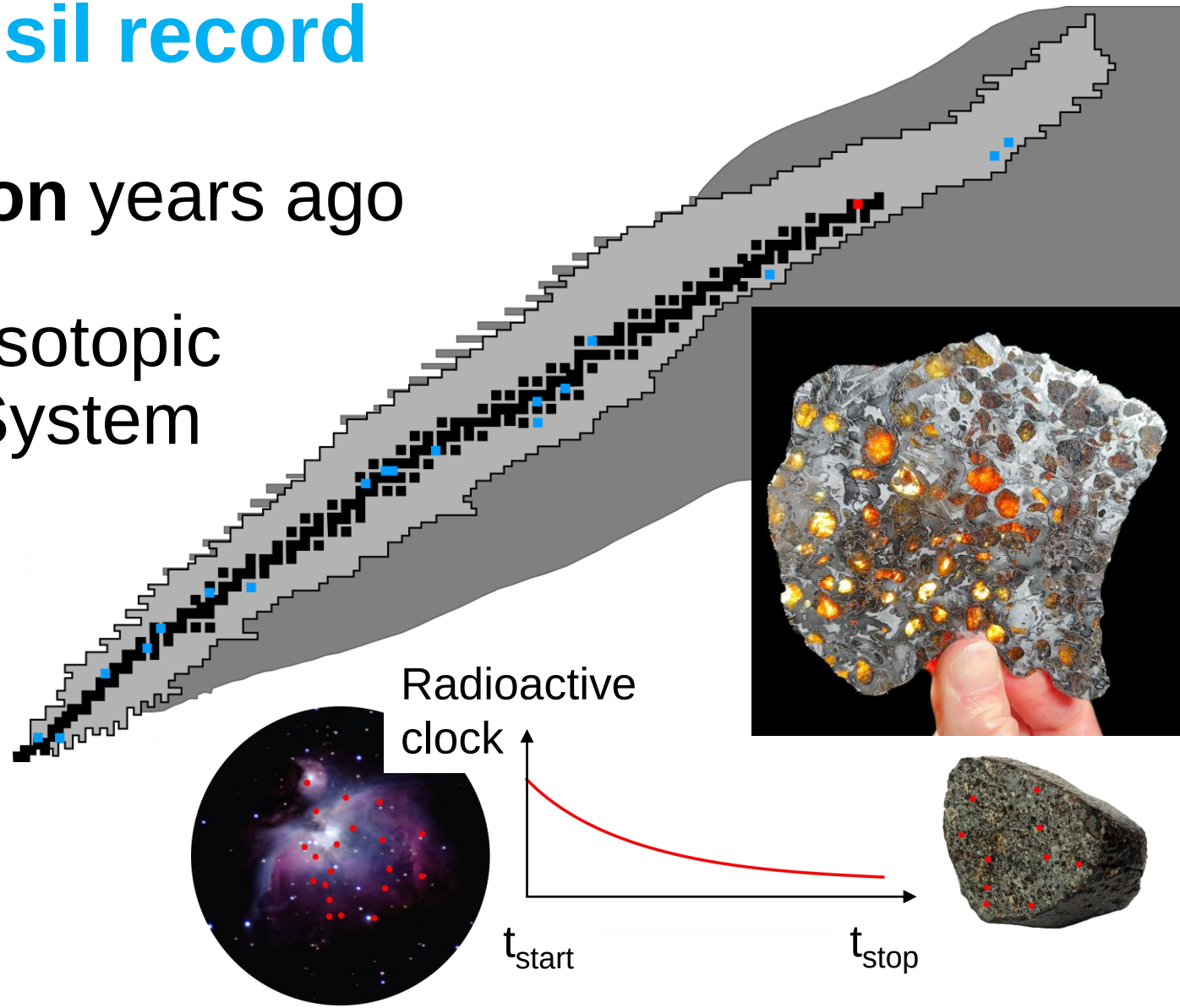

Eagle Nebula
by JWST, NASA

How (we think) our Sun formed

- Sun formed in the filaments of a giant molecular cloud
- Cloud is very cold → isolated from chemical enrichment
- Molecular clouds typically live 20-30 Myr

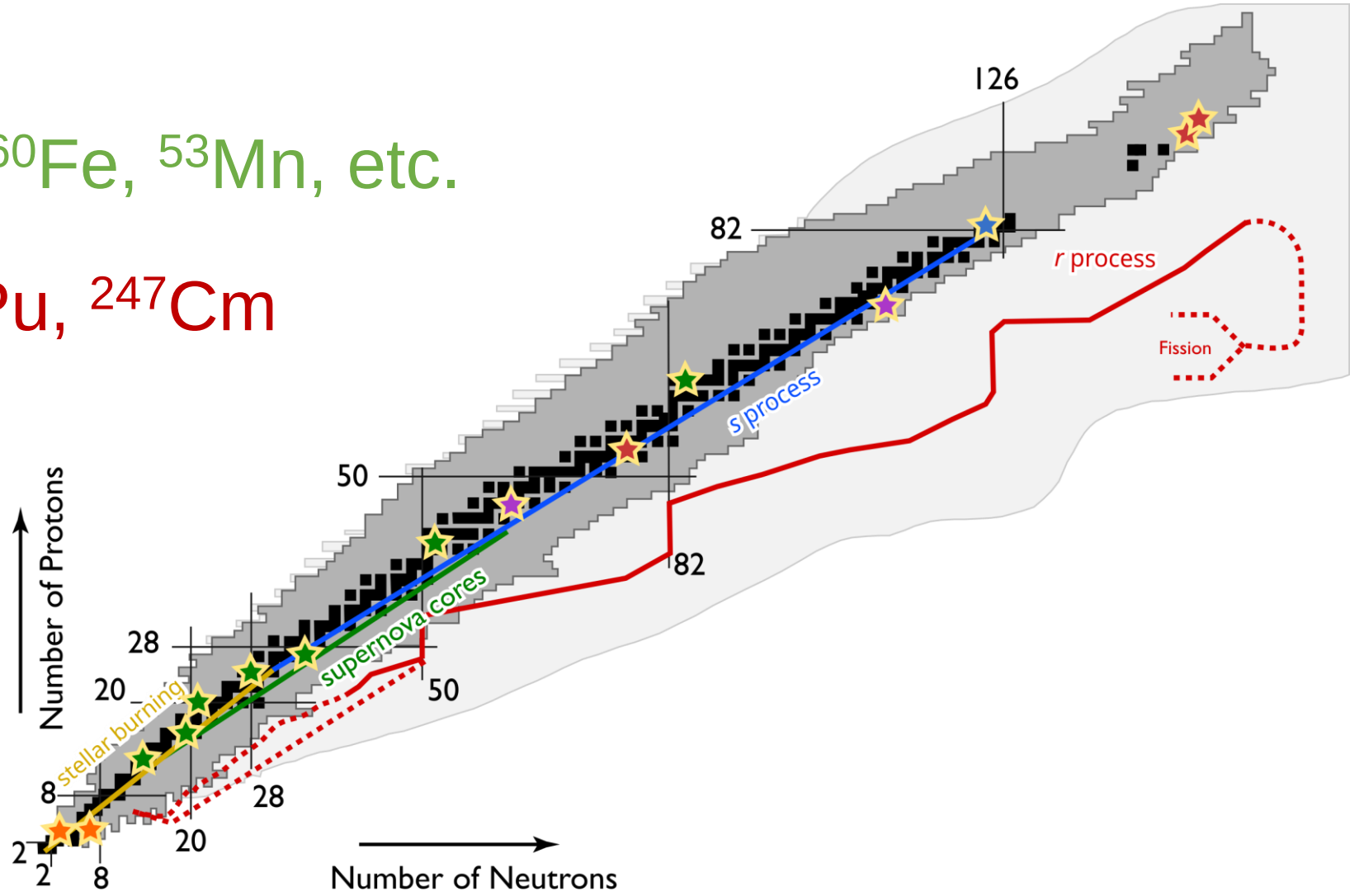
Meteorites leave a fossil record

- The Sun formed **4.5 billion** years ago
- Meteorites preserve the isotopic ratios of the early Solar System
- 19 nuclei can be used as **radioactive clocks**
  - Half-lives ~ 10 Myr



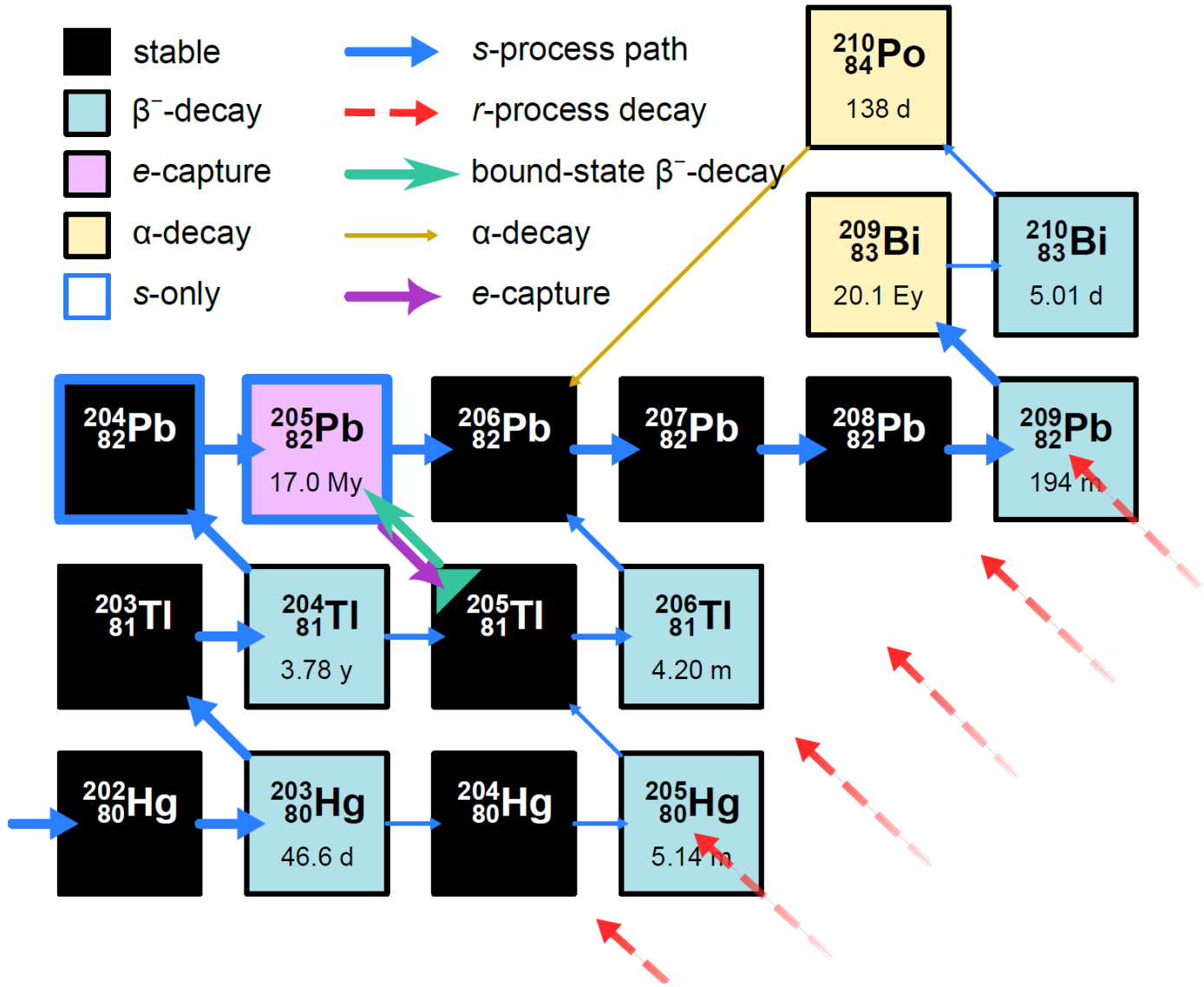
Different sources give us different information

- Supernovae: ^{26}Al, ^{60}Fe, ^{53}Mn, etc.
- *r* Process: ^{129}I, ^{244}Pu, ^{247}Cm
- *s* Process: ^{205}Pb
- *s* + *r*: ^{107}Pd, ^{182}Hf
- Blake *et al.* (1973) Nature 242:98-100

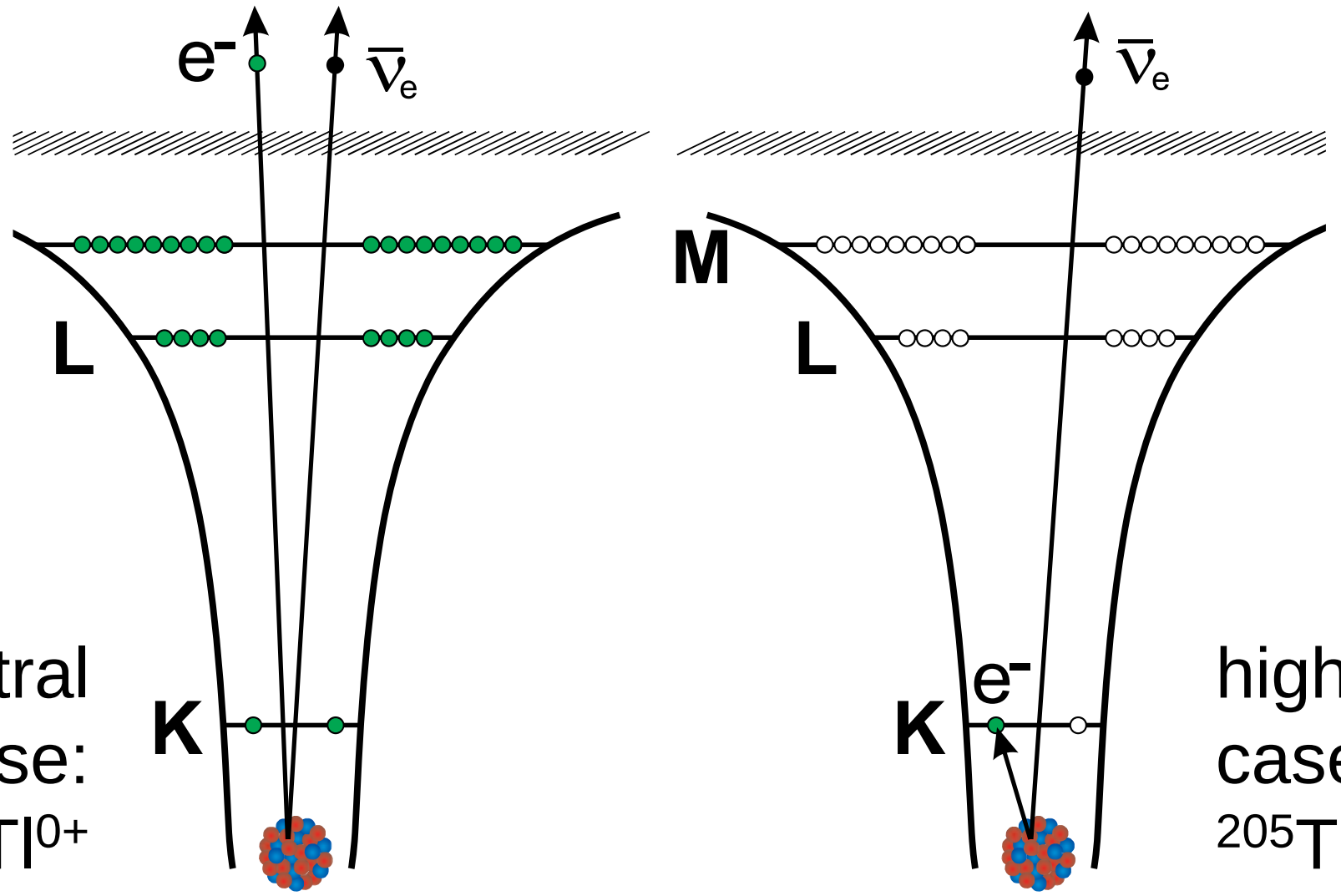


^{205}Pb is the unique s-only SLR

- Both ^{205}Pb & ^{204}Pb are **s-only isotopes**



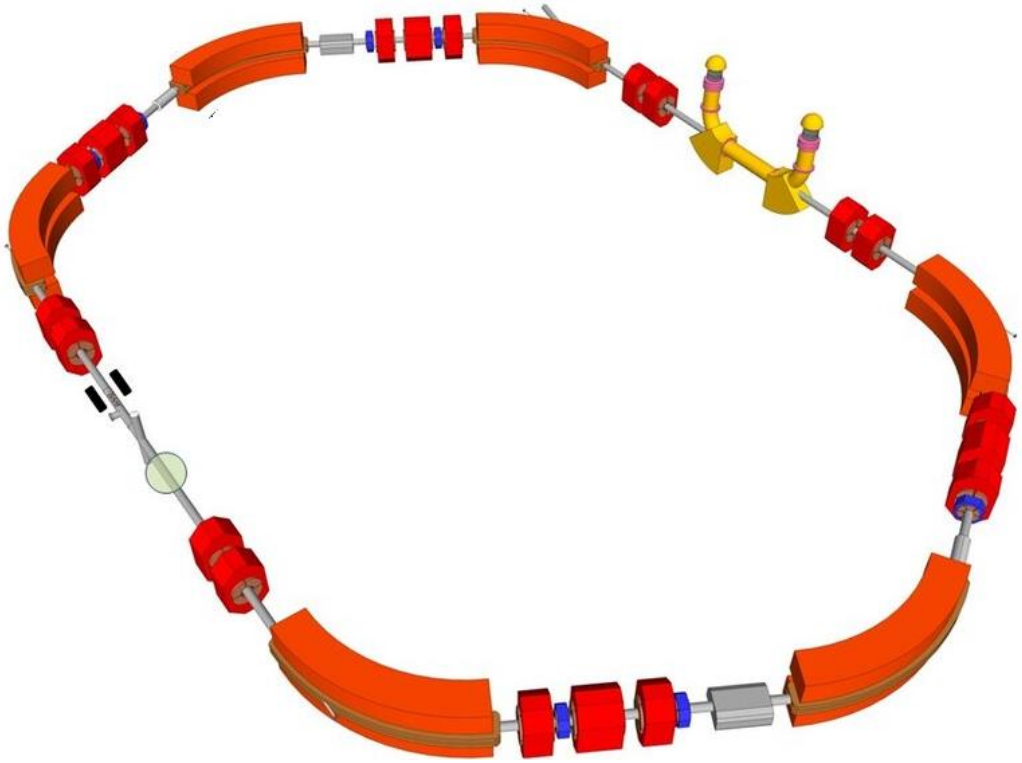
What is bound-state β decay?



neutral case: $^{205}Tl^{0+}$

highly-charged case: $^{205}Tl^{81+}$

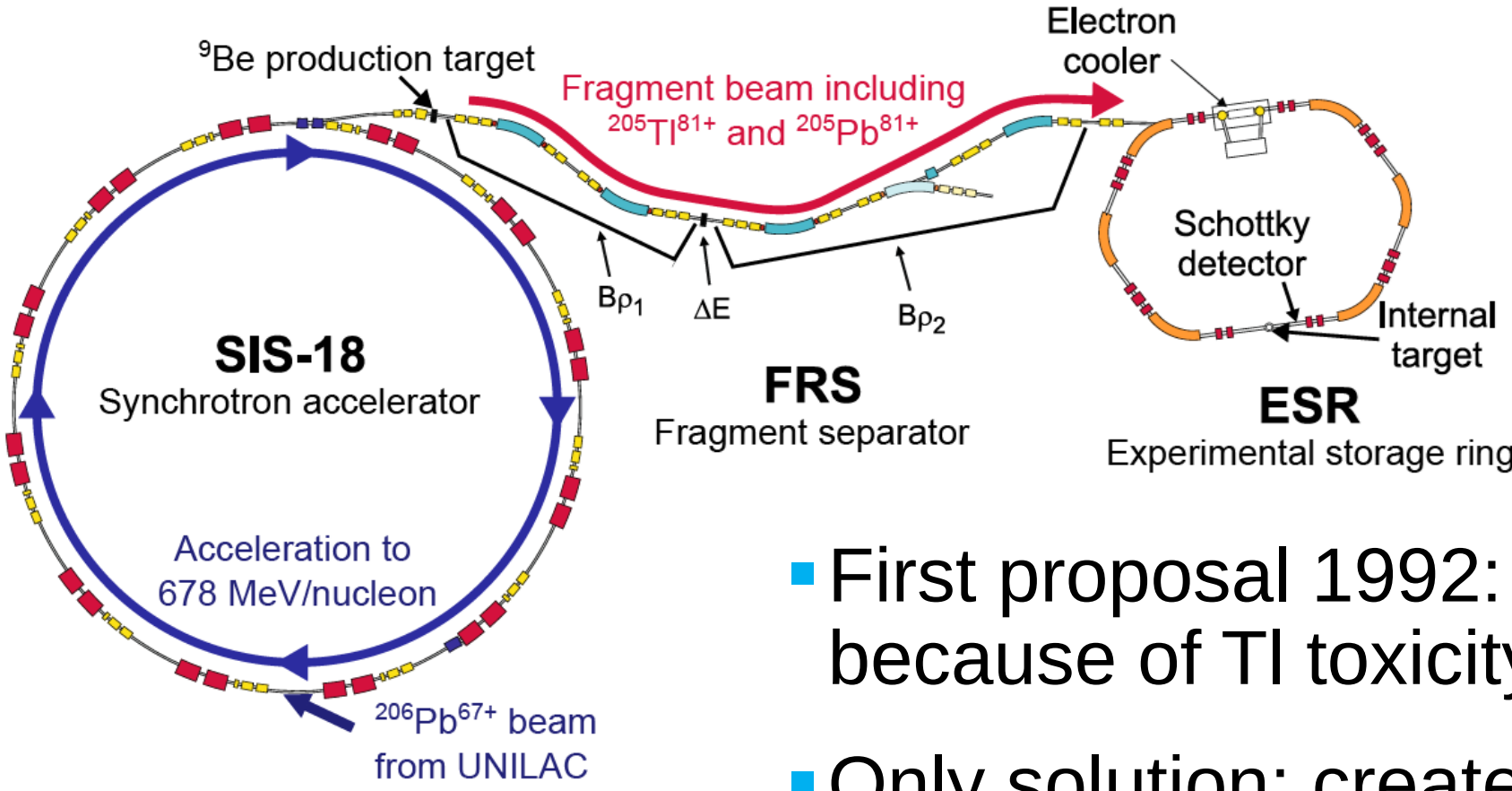
Experimentally measured only at ESR!



- $^{163}Dy^{66+}$ - 1992
- $^{187}Re^{75+}$ - 1996
- $^{207}Tl^{81+}$ - 2005

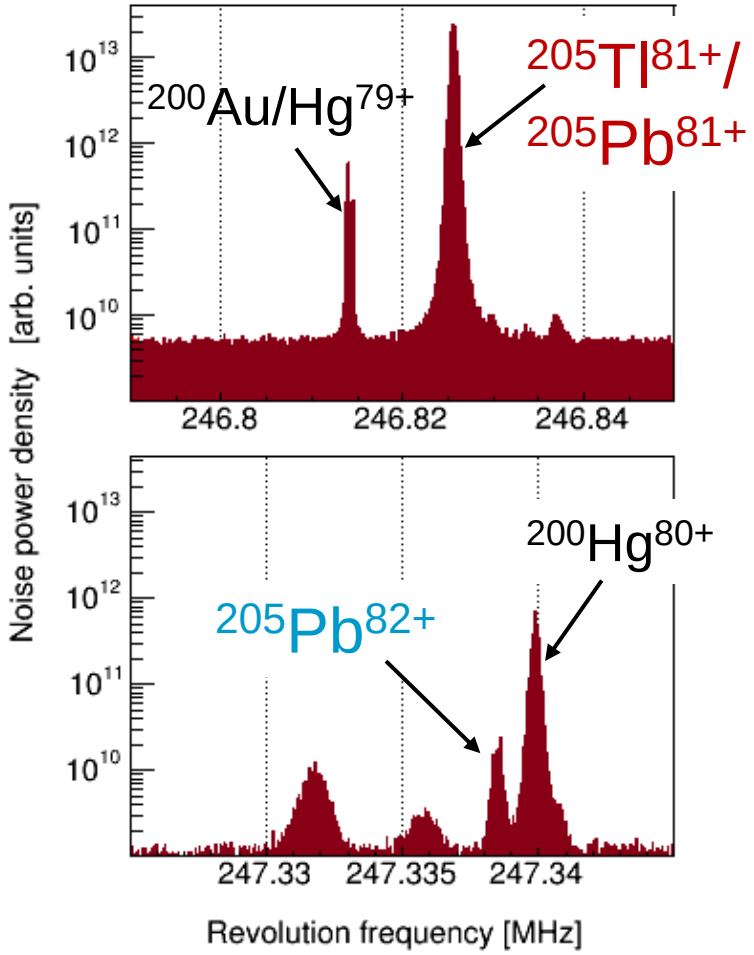
- Requirements:
  - fully stripped ions
  - hours lifetimes
  - millions of ions

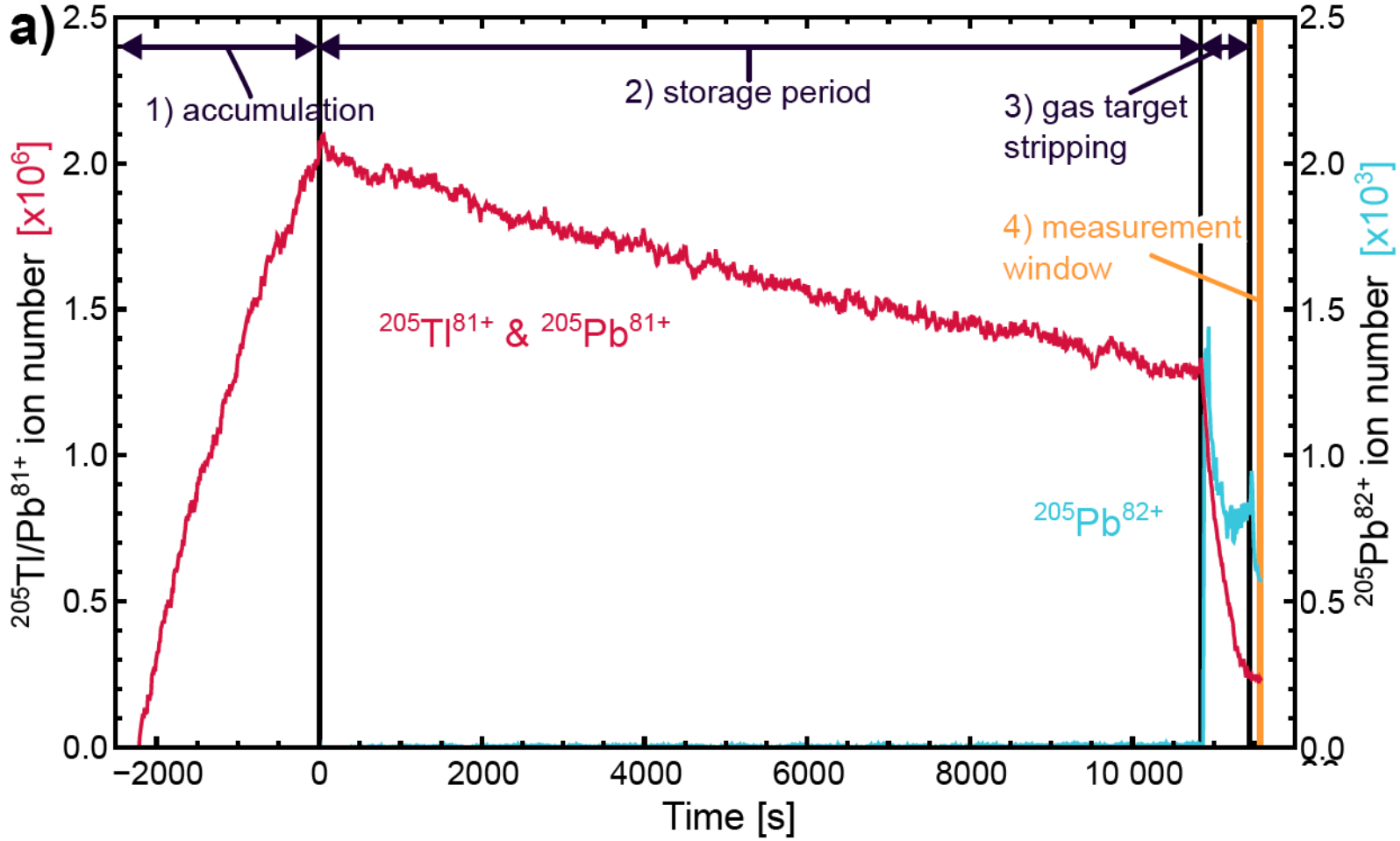
Bound-state beta-decay of $^{205}Tl^{81+}$ at GSI



- First proposal 1992: not possible because of Tl toxicity
- Only solution: create $^{205}Tl^{81+}$ by projectile fragmentation

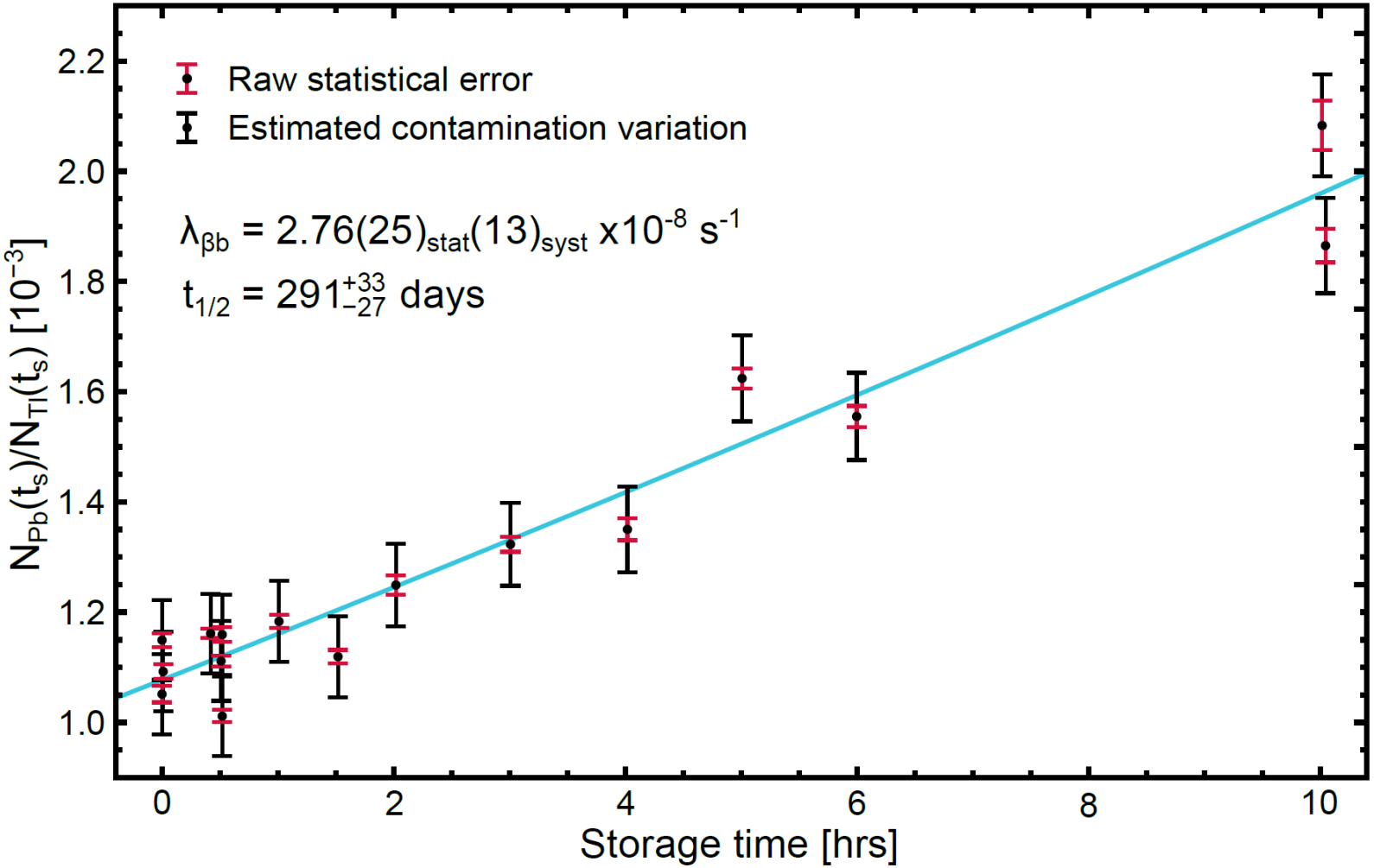
Storing $^{205}Tl^{81+}$ creates $^{205}Pb^{81+}$ daughters



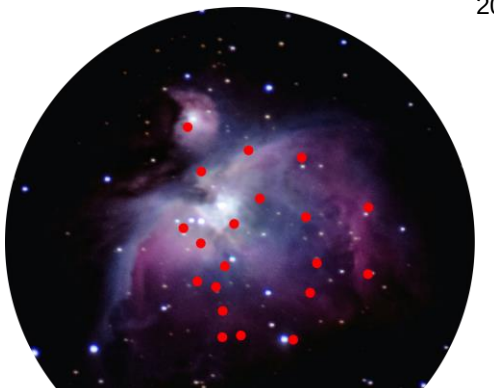


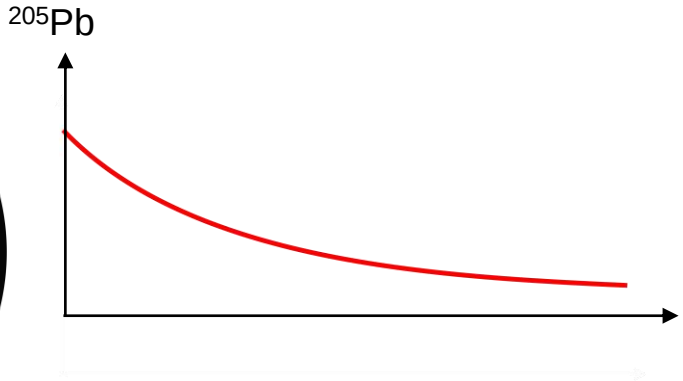
Linear fit gives half-life

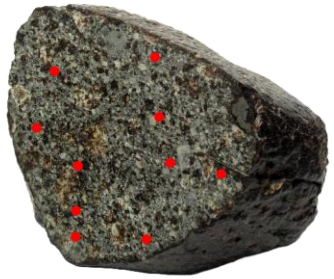
- Half-life result:
  $t_{1/2} = 291^{+33}_{-27}$ d

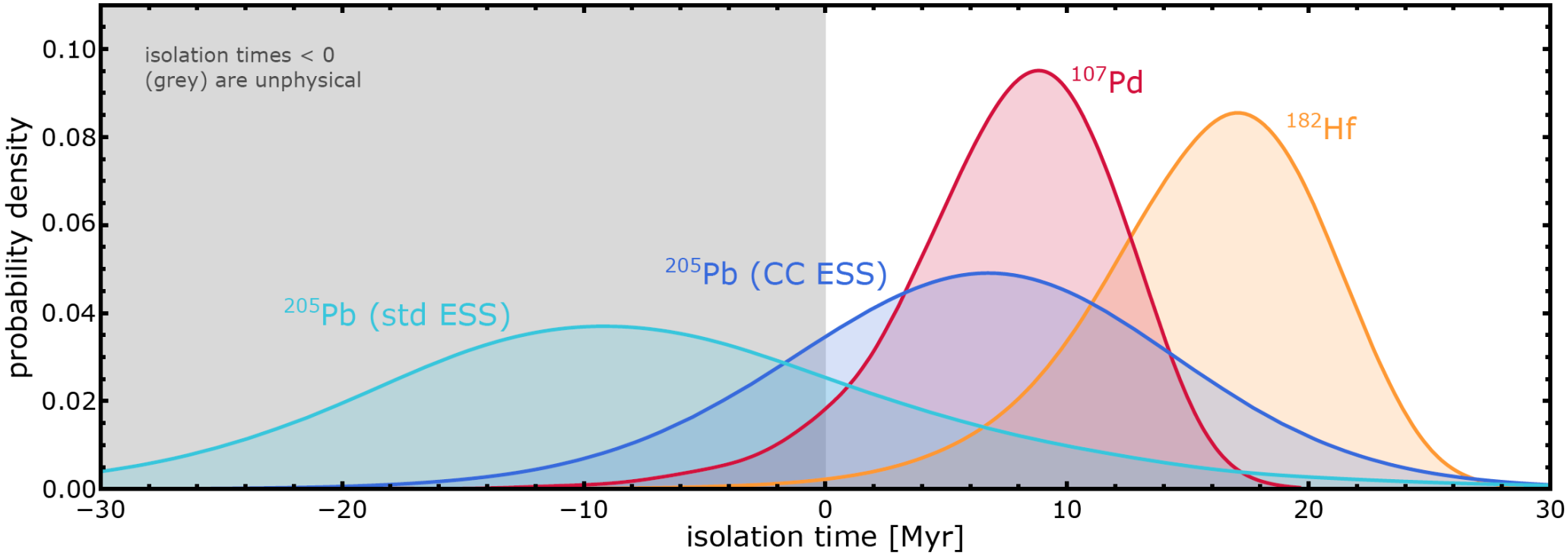


Isolation time of solar material









Thank you
Merci

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Prof. Fritz Bosch* (1940-2016)


Prof. Paul Kienle* (1931-2013)


Prof. Hans Geissel* (1950-2024)

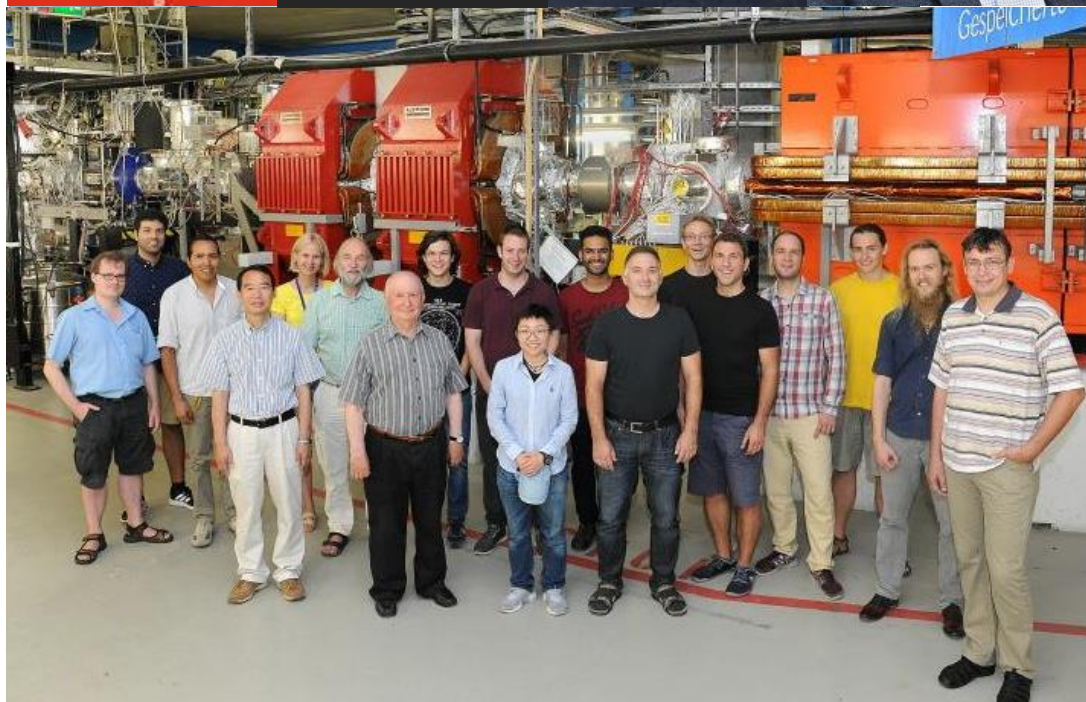

Dr. Markus Steck* (1959-2025)


Dr Ragandeep Singh Sidhu


Dr Rui Jiu Chen


Dr Riccardo Mancino


Prof Yury Litvinov



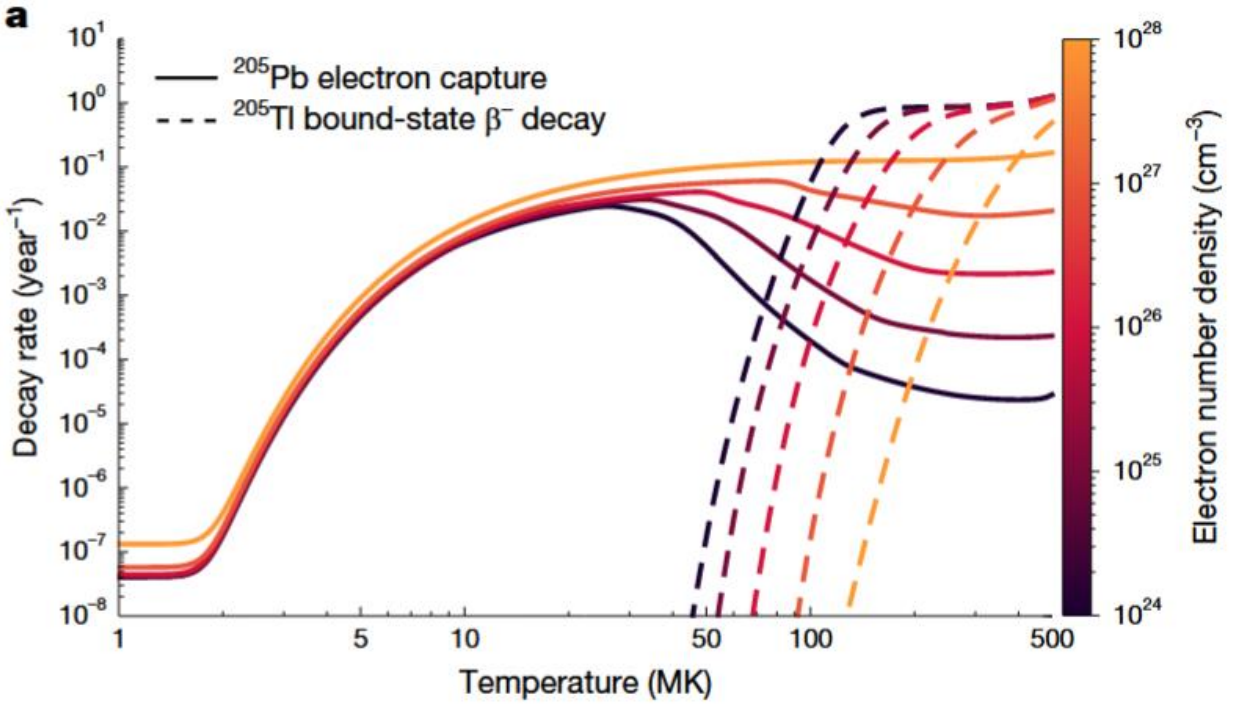
Stellar weak decay rates

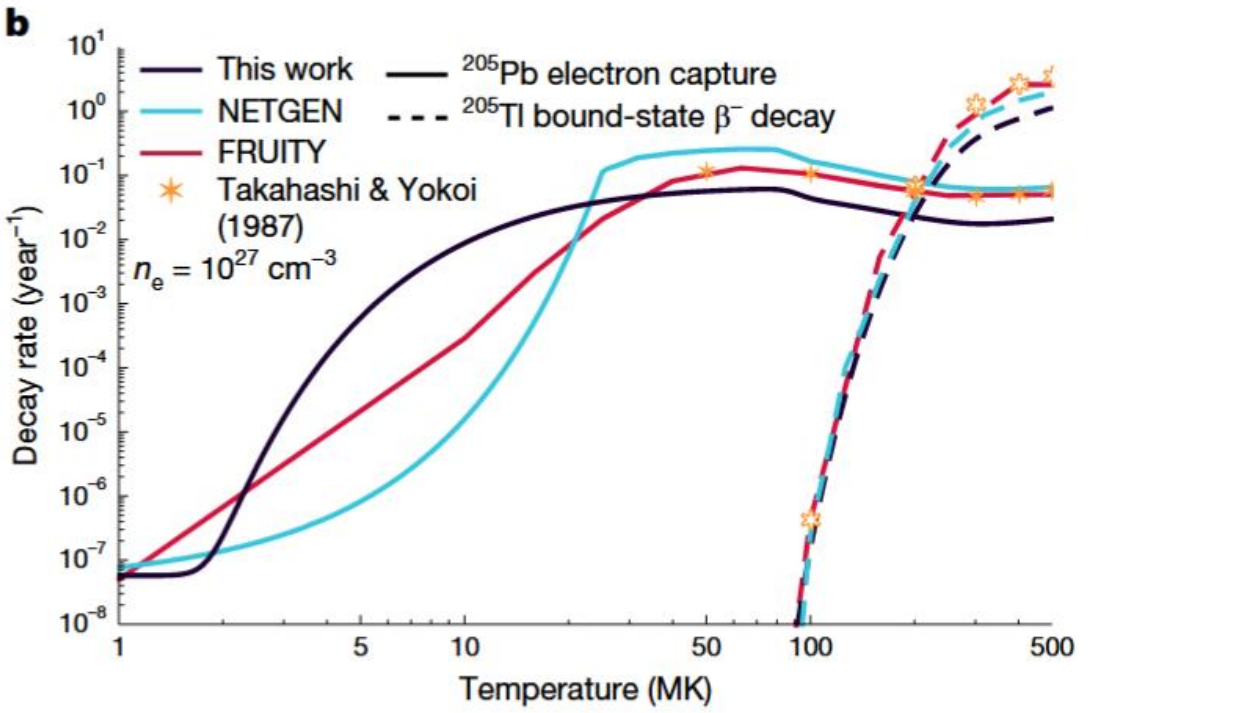
- Riccardo Mancino calculated new T- & ρ_e-dependent rates
- Followed the prescription by Takahashi & Yokoi (1983)
  - Slight fix to their plasma corrections


Dr Riccardo Mancino


Prof. Dr. Gabriel Martinez-Pinedo

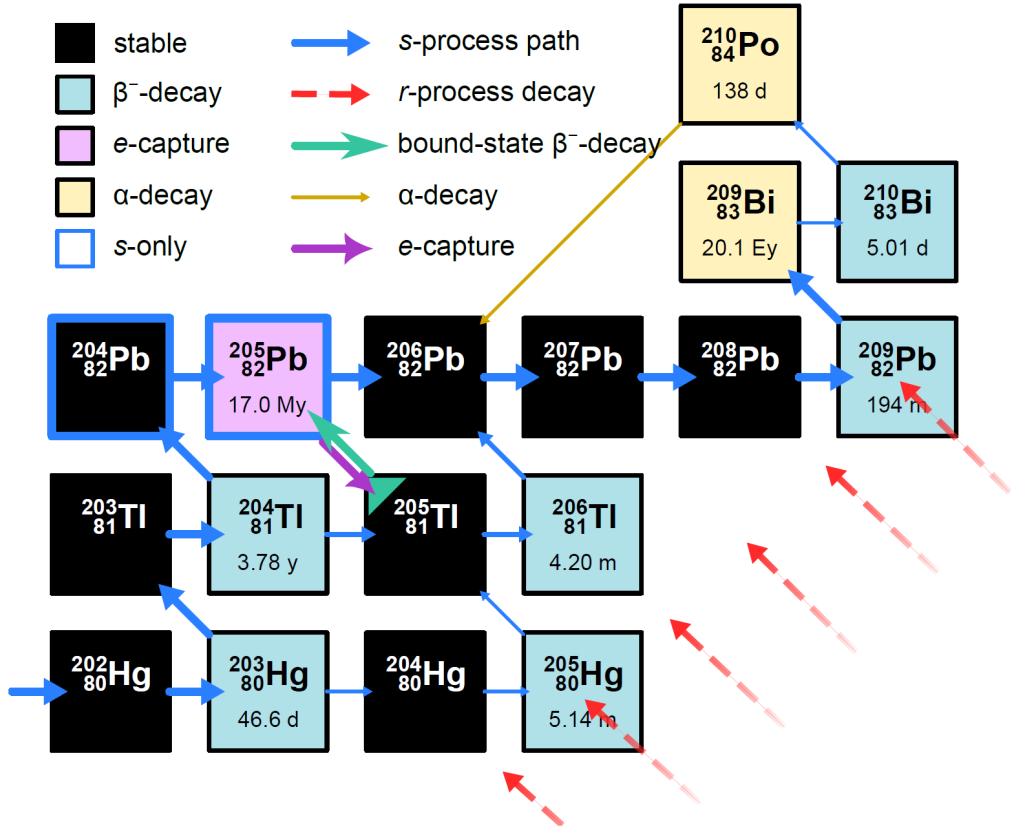

Dr Thomas Neff

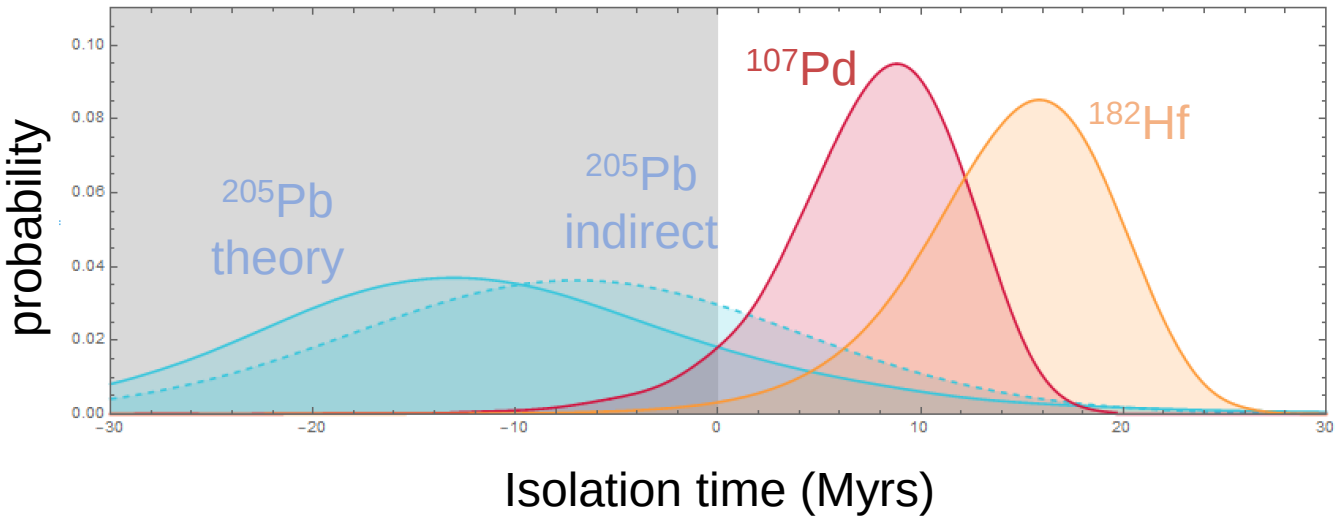




Future work: $^{205}Pb(n,\gamma)$ via surrogate reactions

- ^{205}Pb cross section:
  - Theory evaluation: 213(34) mbarn (value used in Nature paper)
  - Indirect $(\vec{\gamma},\gamma')$ method: 130(25) mbarn
- Halving cross section
  → 23% ^{205}Pb AGB yield increase
  → +5 Myrs isolation time
- Whilst meteorite uncertainties are still dominant, ^{205}Pb cross section has significant impact





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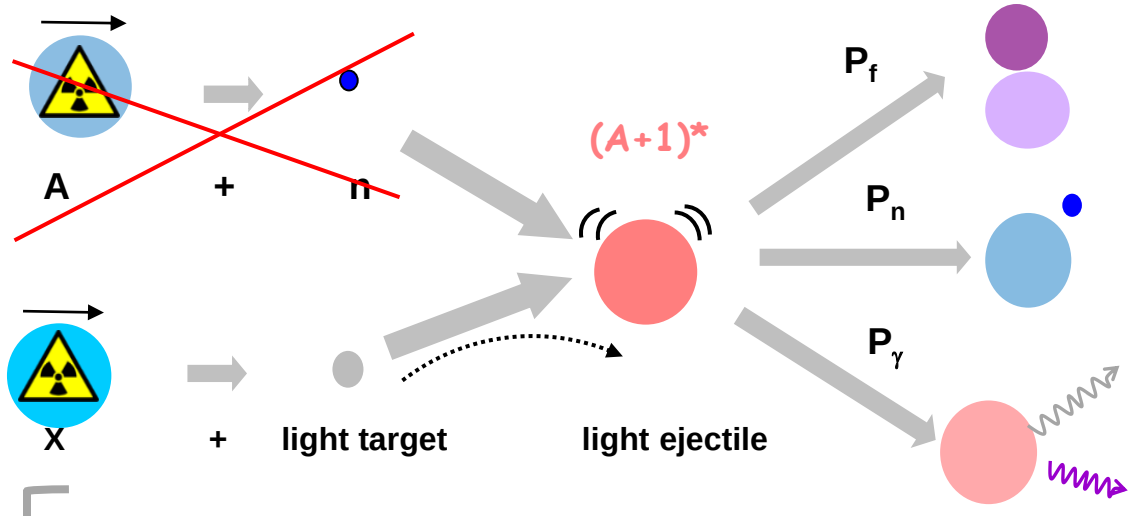

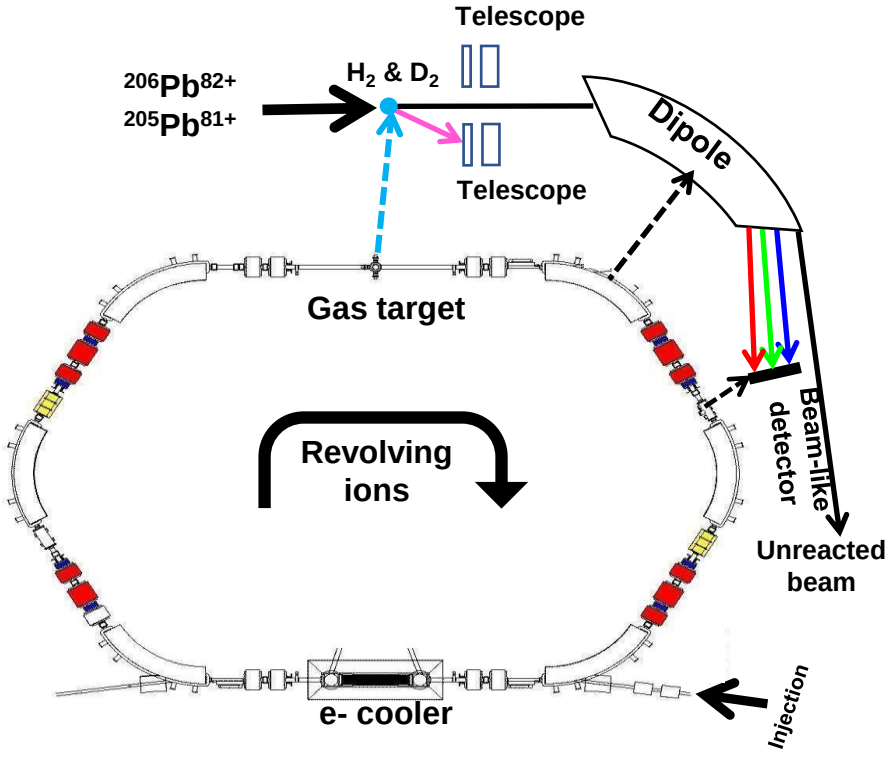

$P_i(E^*)$

Used to constrain models and provide much more accurate predictions for neutron-induced cross-sections of nuclei far from stability.

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