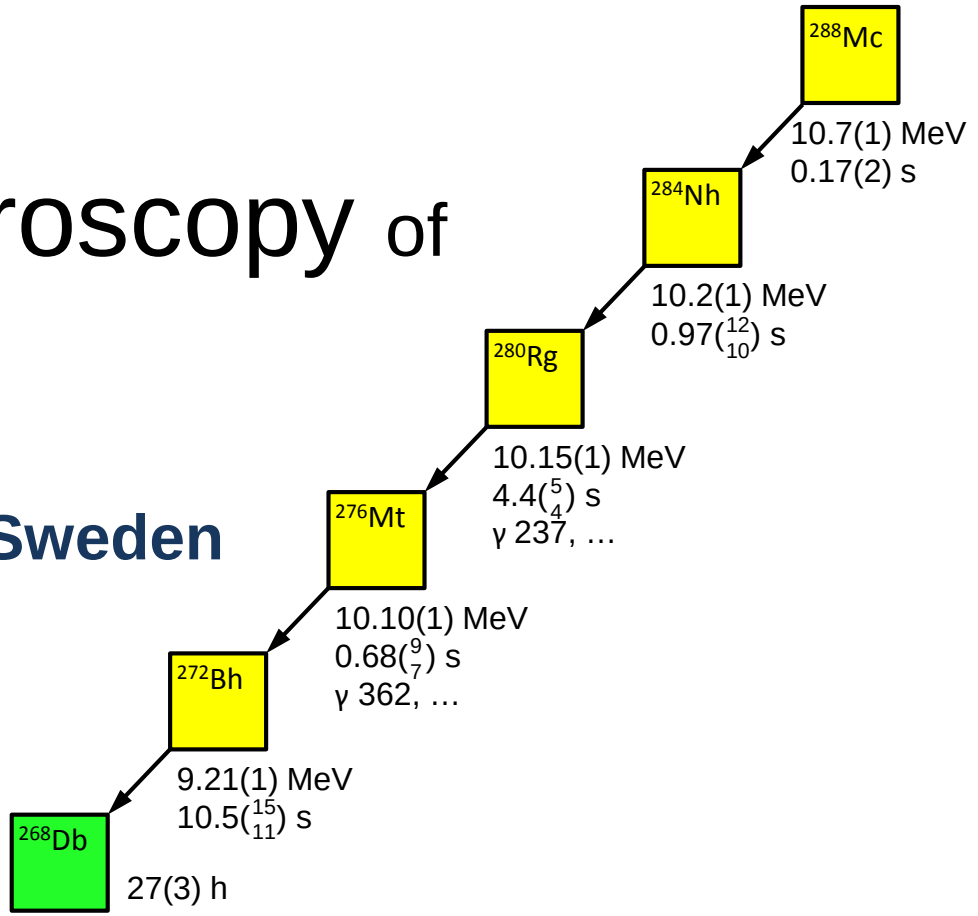
Alpha-Photon Coincidence Spectroscopy of Superheavy Nuclei

D. Rudolph, Lund University, Sweden

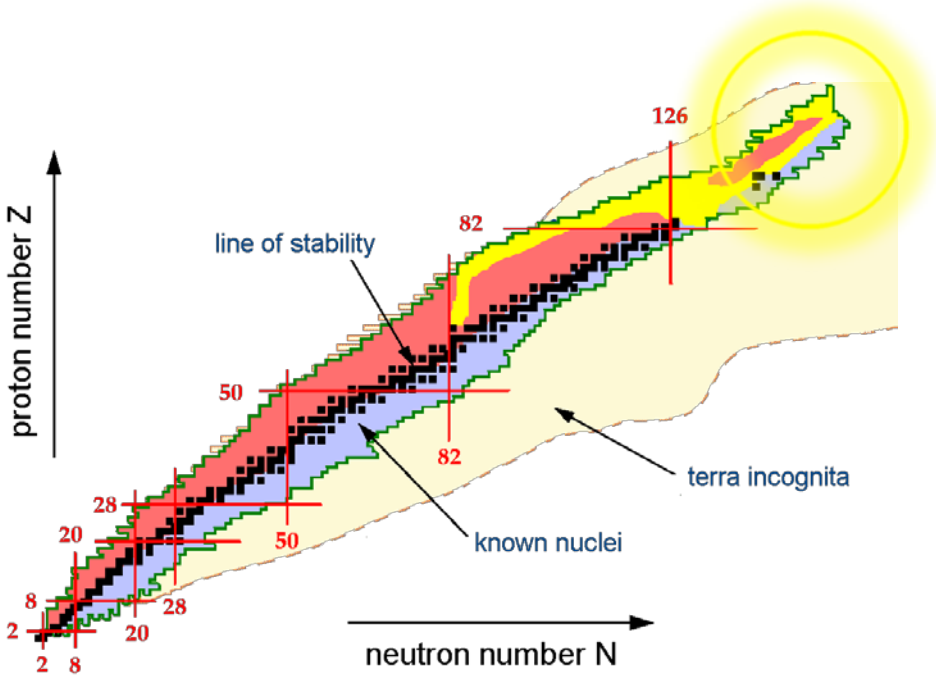


LUNDS UNIVERSITET

20th Colloque GANIL, October 2017, Amboise, France

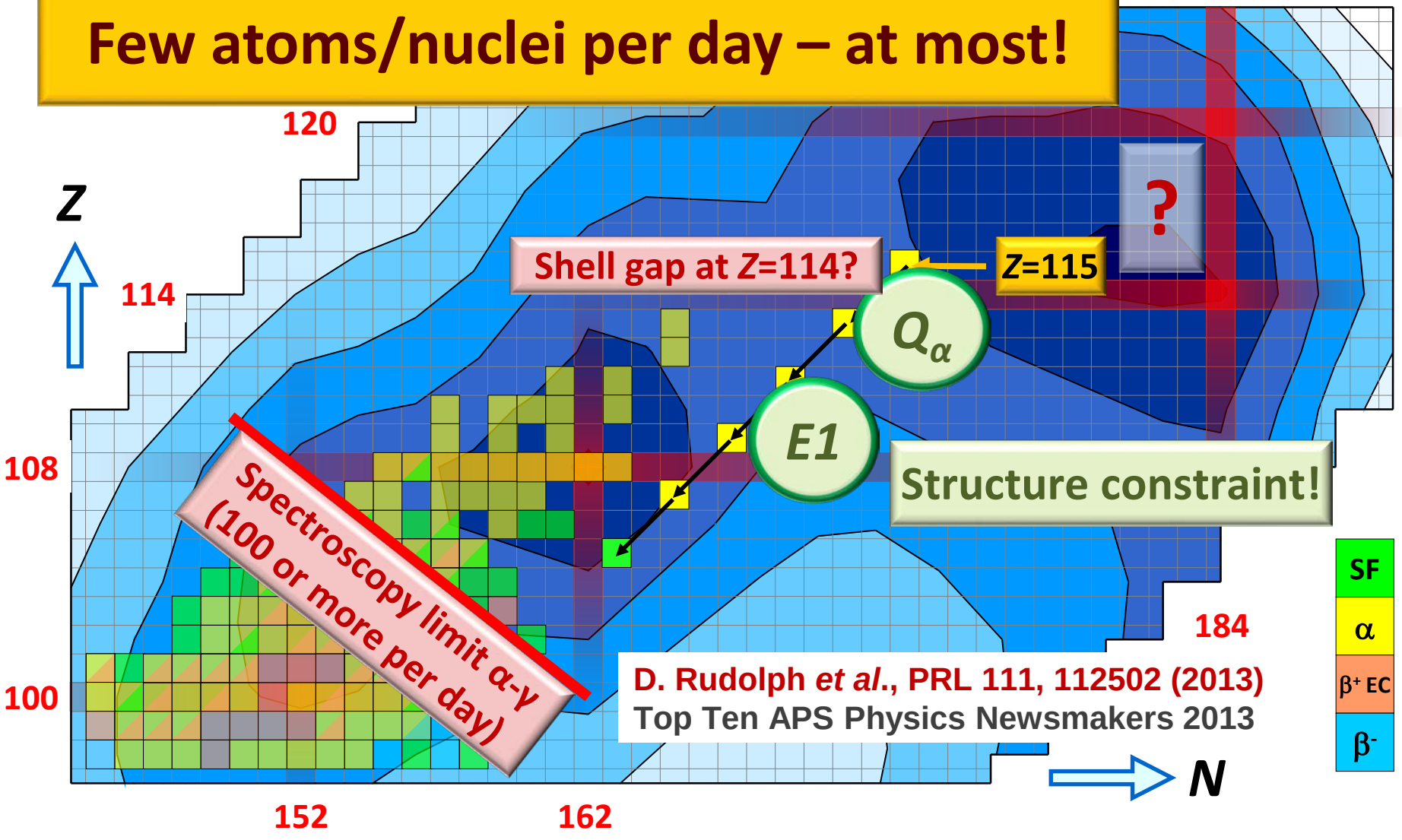
Outline

- Introduction
- Nuclear Structure Issues
- Spectroscopy Tools
- Future Efforts
- Summary



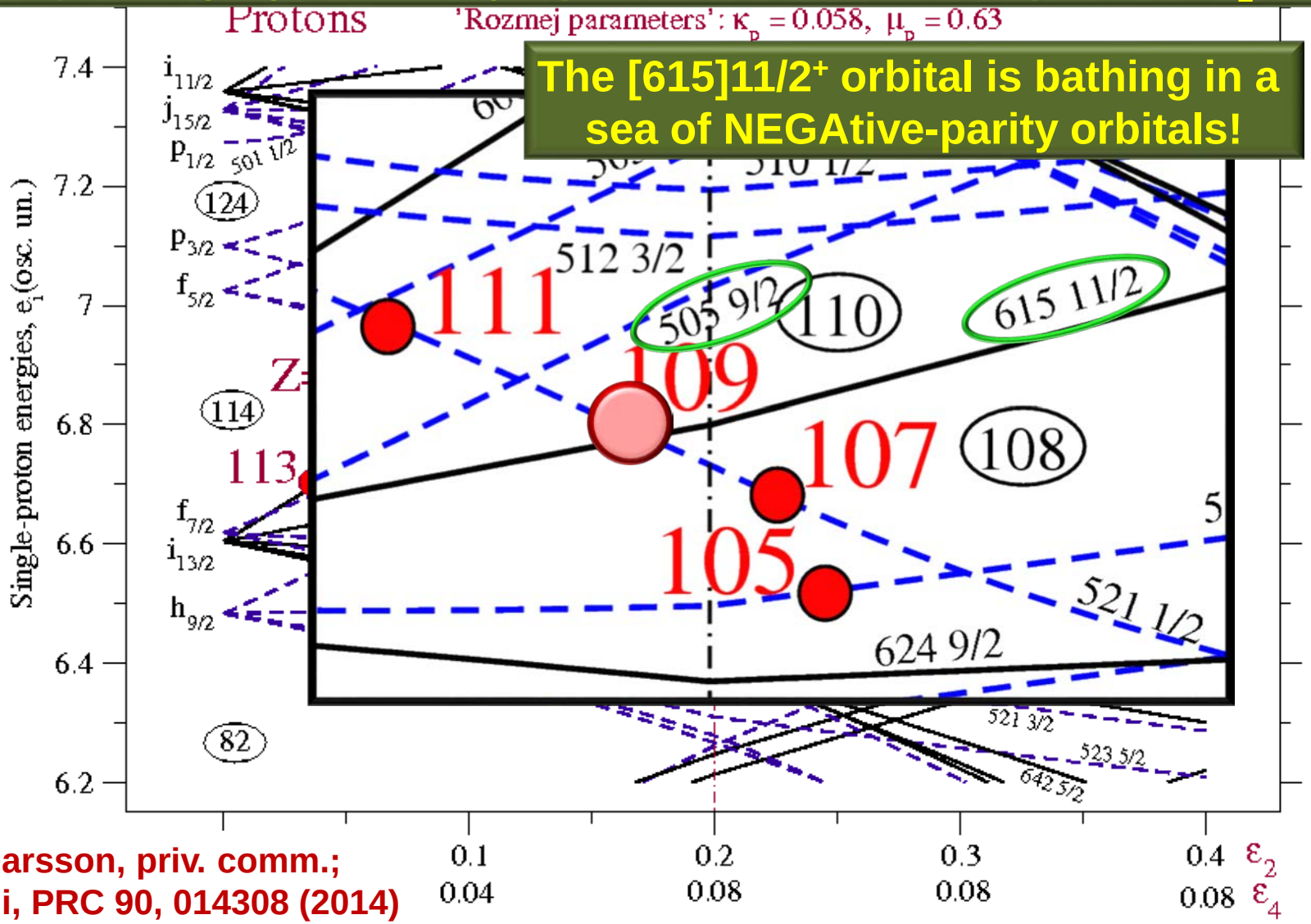
Where is the Island of Stability? Does it Exist in the First Place?

Few atoms/nuclei per day – at most!



Probe & Guide Nuclear Structure Theory

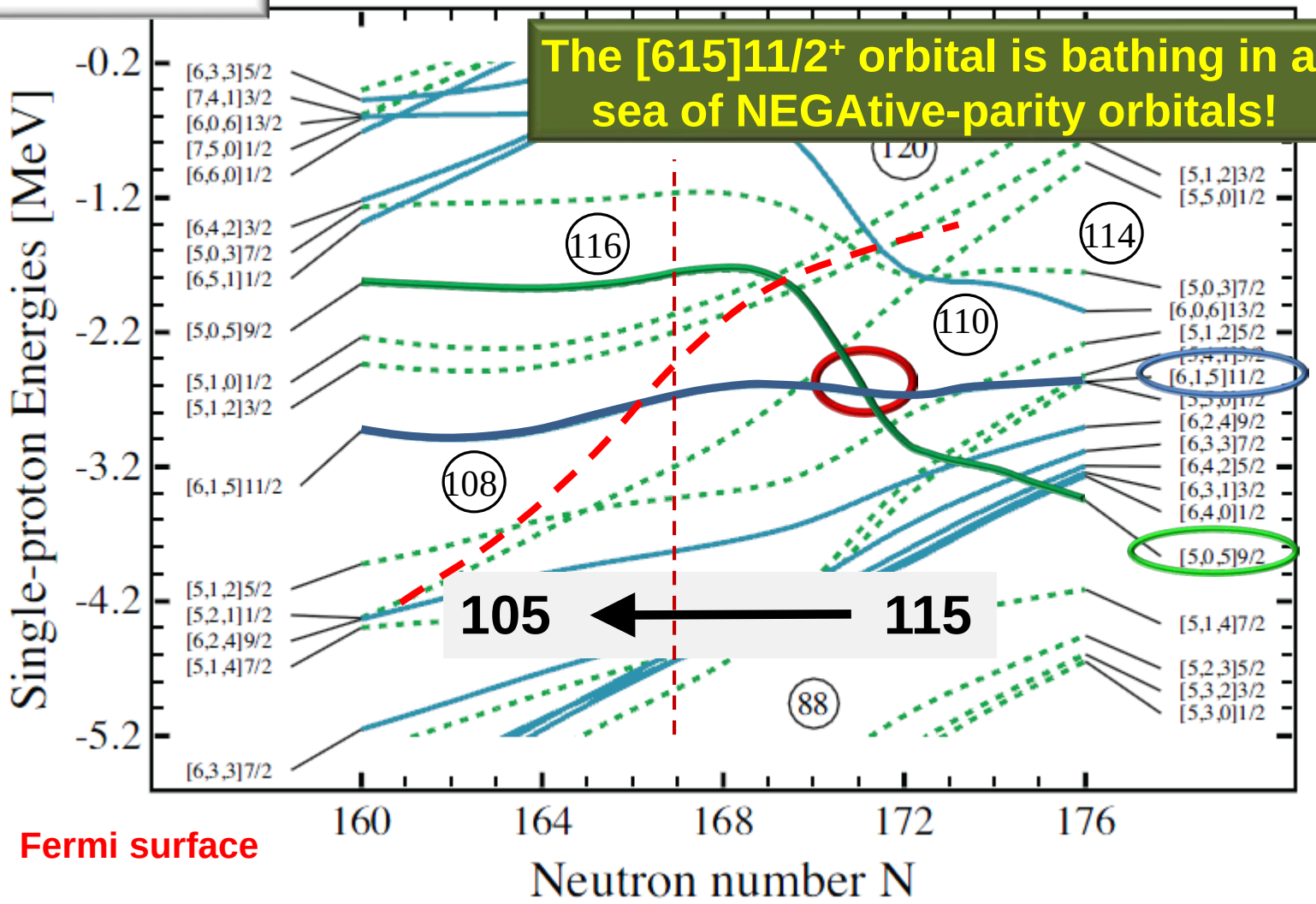
Parity-changing Δl =1 single-particle orbitals are required at β_2~0.2!



I. Ragnarsson, priv. comm.;
Yue Shi, PRC 90, 014308 (2014)

EDF Single-particle Diagrams

UNEDF1$^{SO}_{L}$



Yue Shi *et al.*, PRC 90, 014308 (2014)

EDF Single-particle Diagrams

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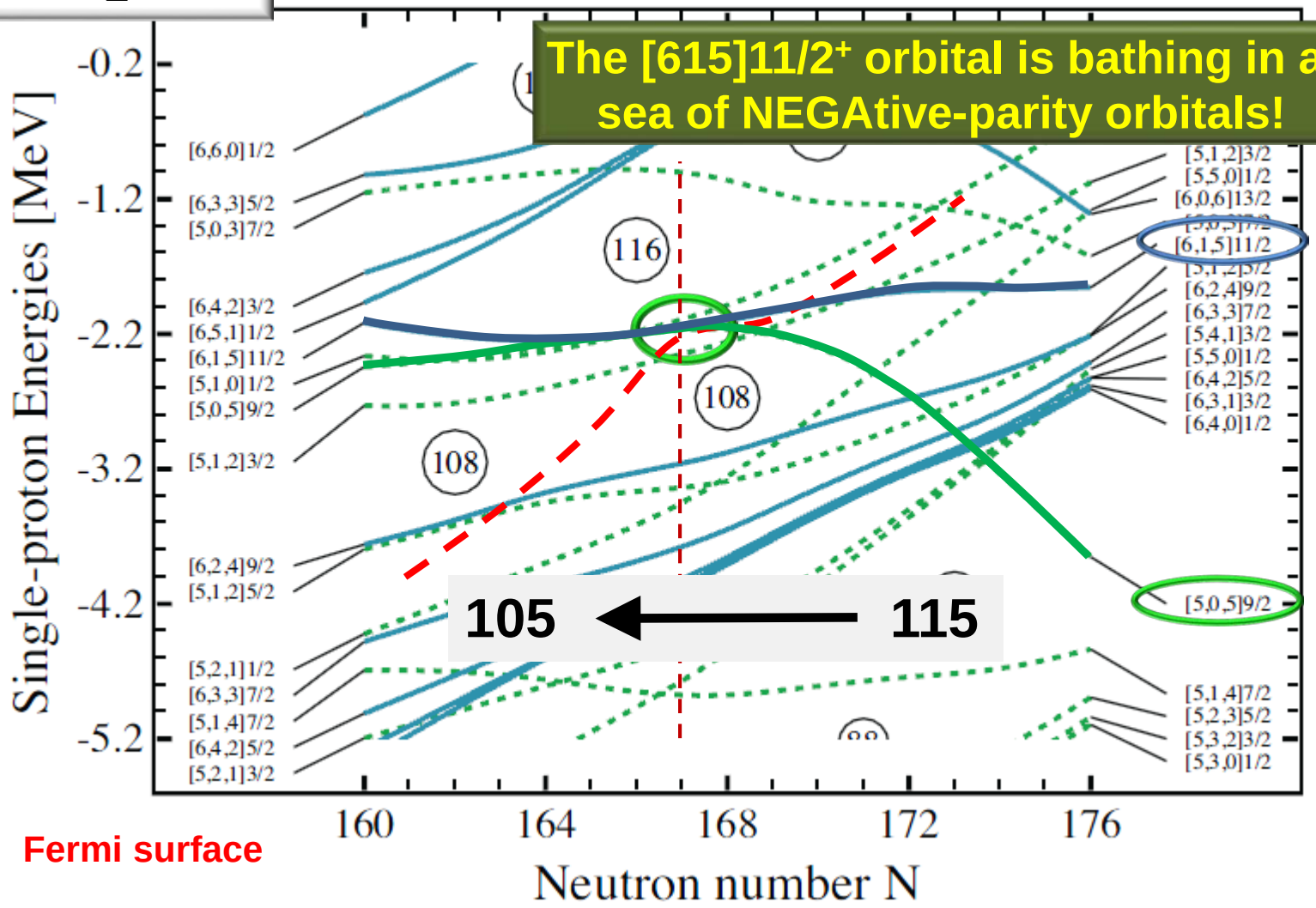
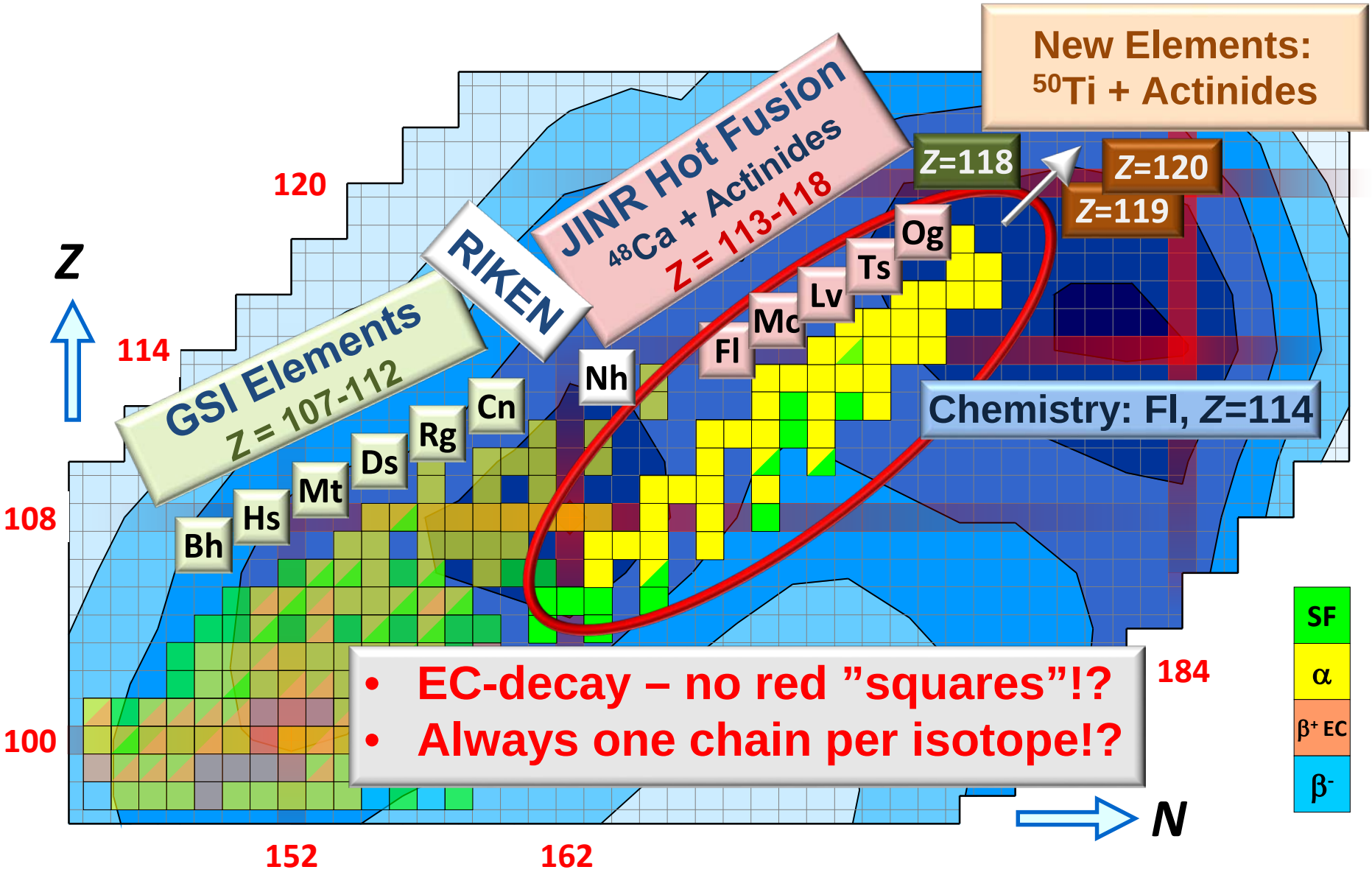


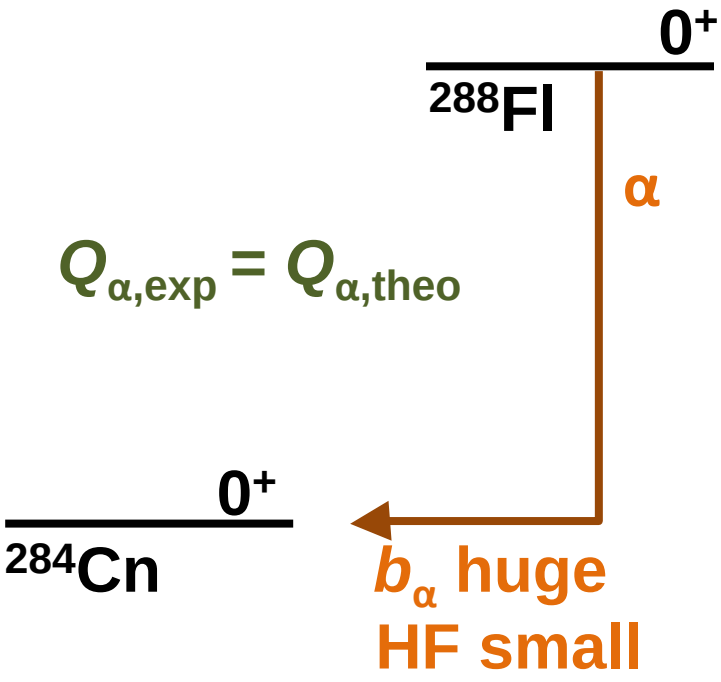
Yue Shi *et al.*, PRC 90, 014308 (2014)

(Reasonably) Current Status



Alpha-decay Reminder

Even-even nuclei …



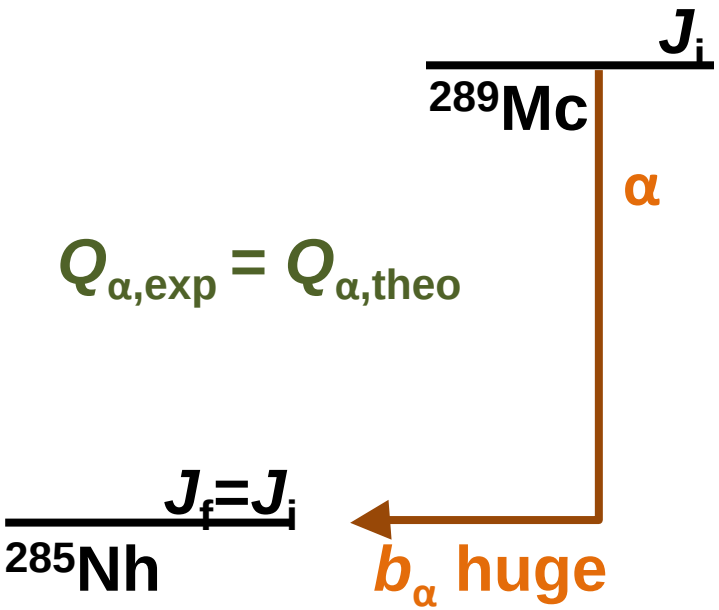
Fl 288
0.64 s
α 9.93(3)

Cn 284
0.10 s
sf 100%

Note: some experimental results somewhat simplified.

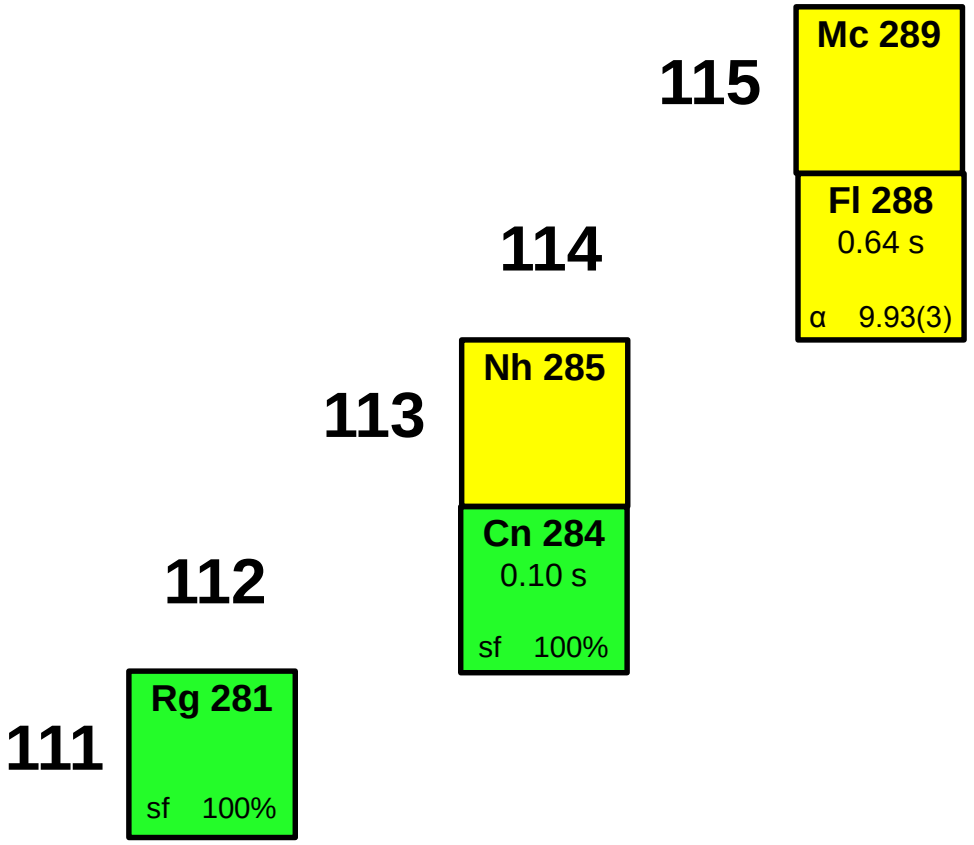
Alpha-decay Reminder

Odd-even nuclei …



$Q_{\alpha,exp} = Q_{\alpha,theo}$

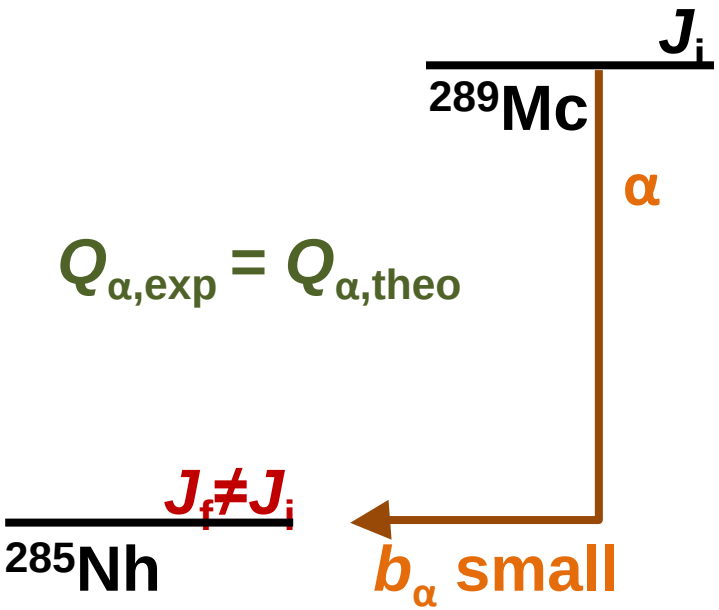
b_α huge
HF small



Note: some experimental results somewhat simplified.

Alpha-decay Reminder

Odd-even nuclei …



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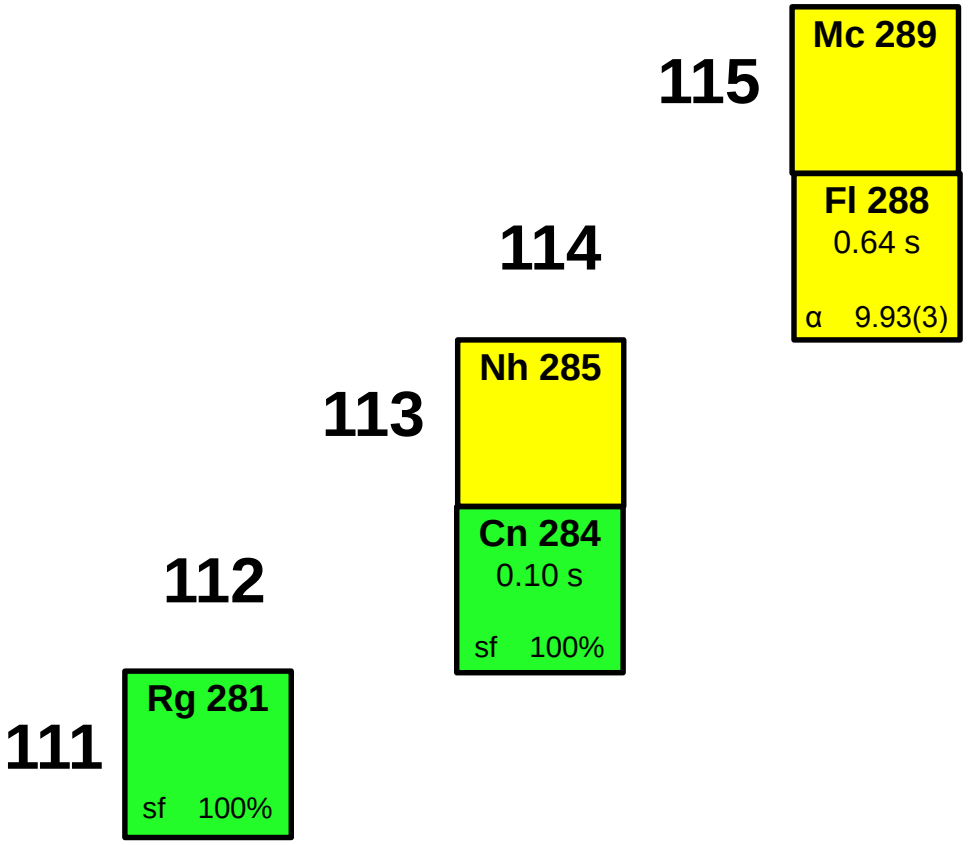

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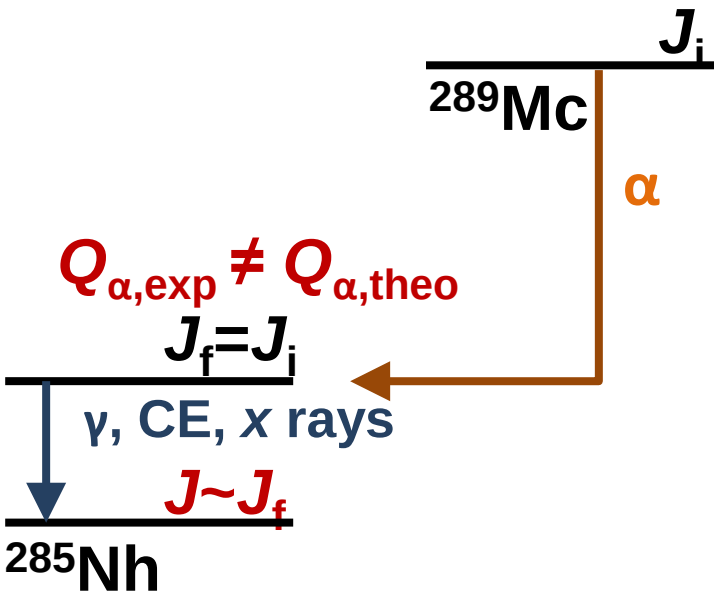
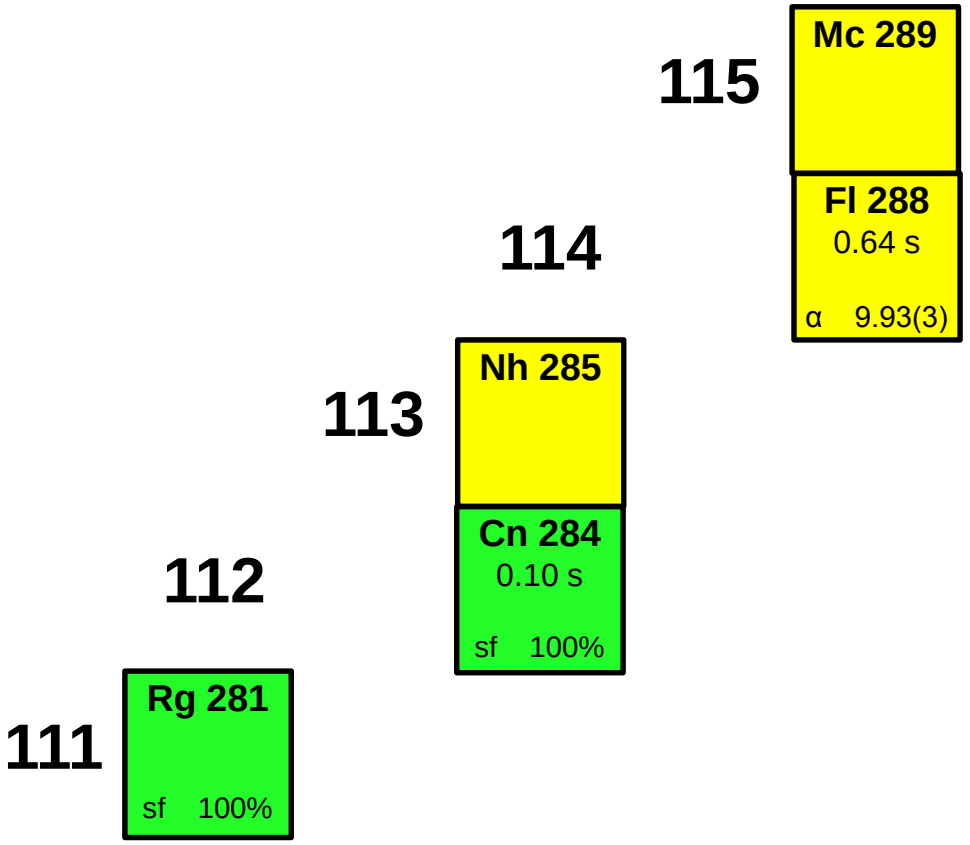
Alpha-decay Reminder

Odd-even nuclei …



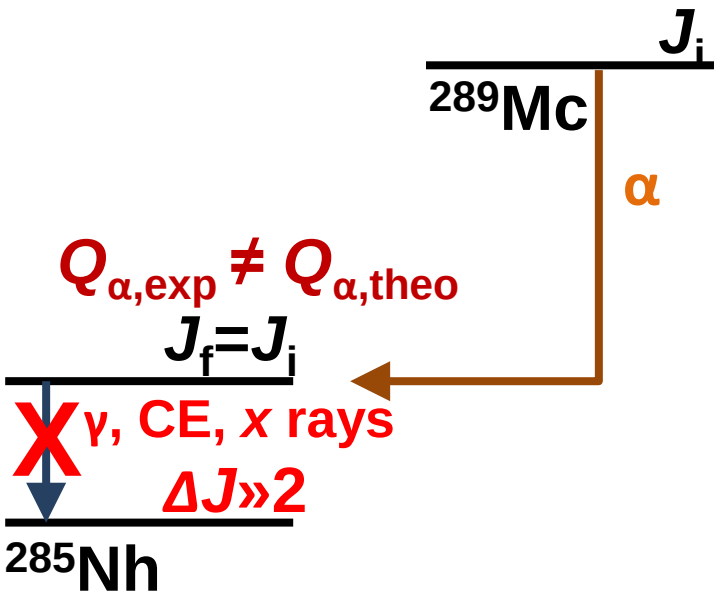


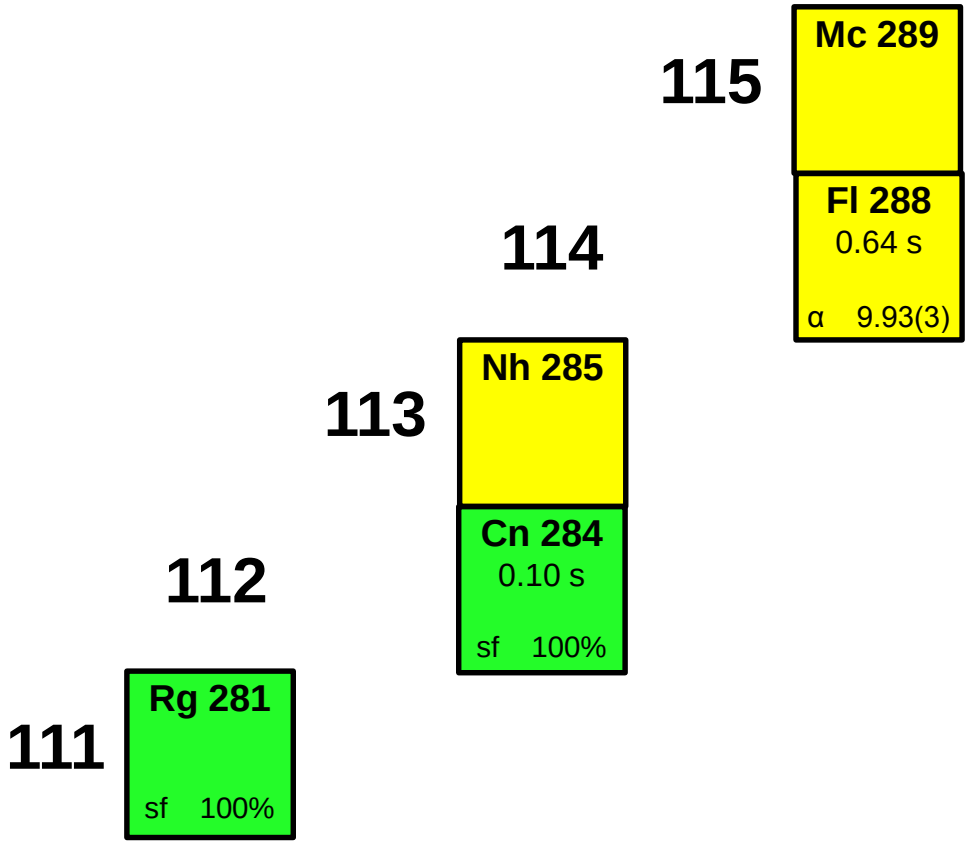
Alpha-photon coincidences!

Note: some experimental results somewhat simplified.

Alpha-decay Reminder

Odd-even nuclei …





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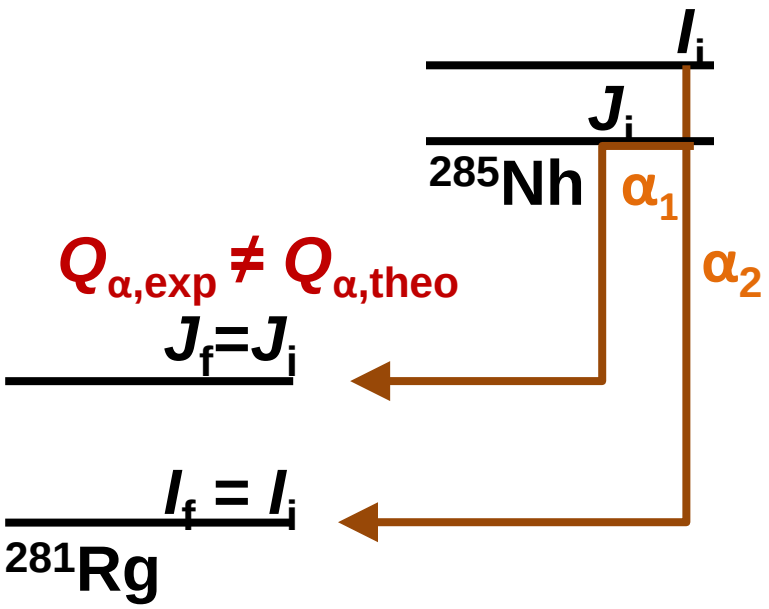
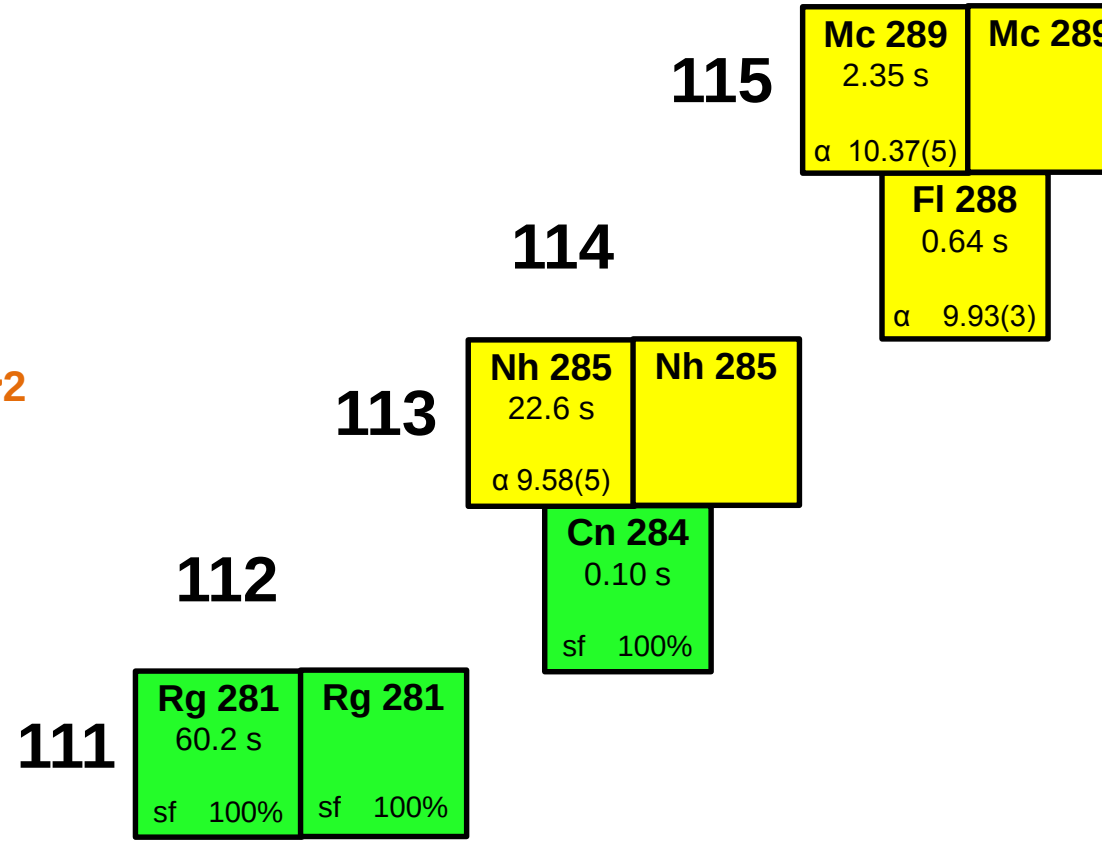
Alpha-decay Reminder

Odd-even nuclei …





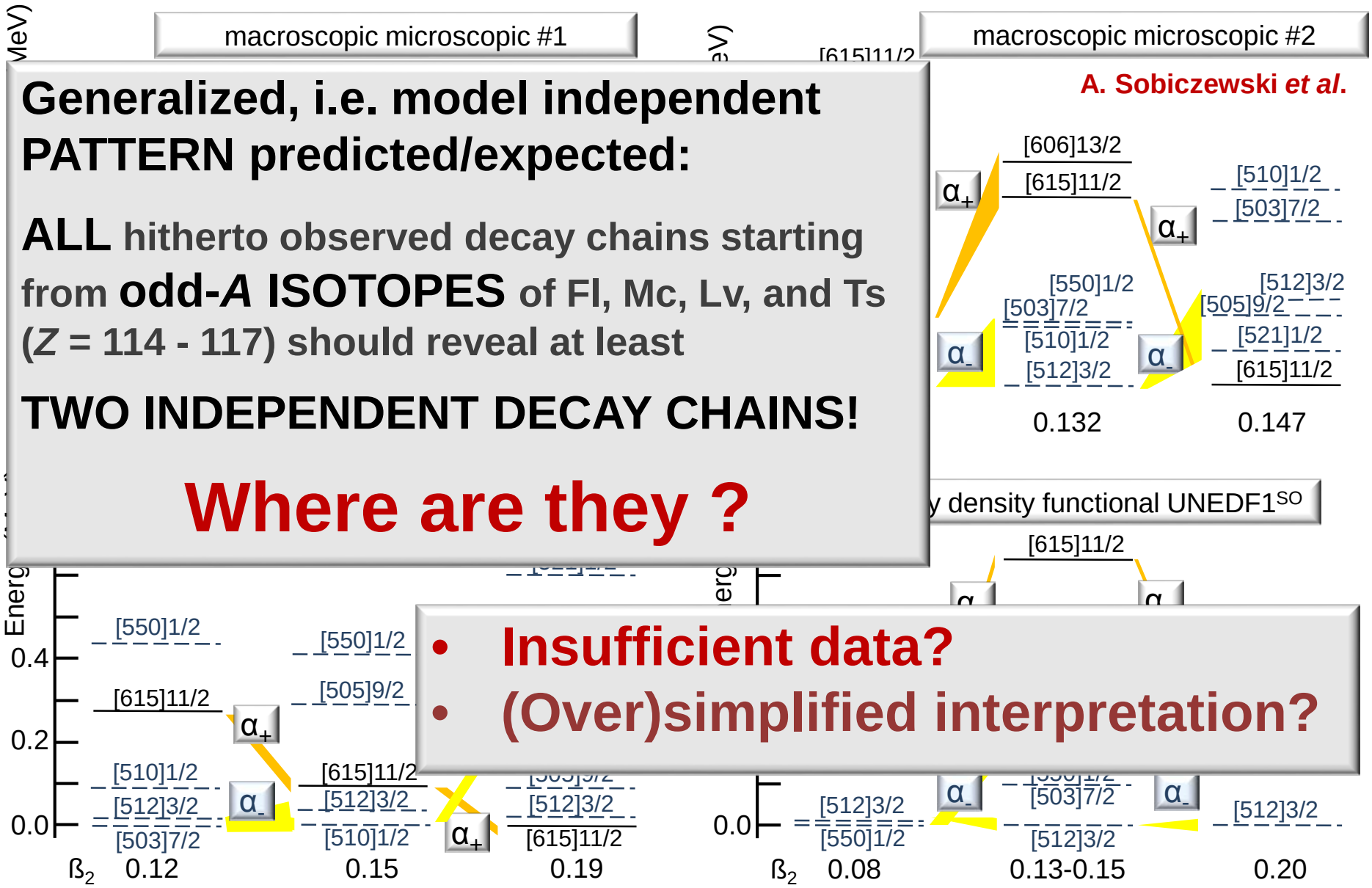
***J* ≠ *I*:**

Two parallel α-decay branches!

COMMON ACROSS the nuclidic CHART!

U. Forsberg *et al*., NPA 953, 117 (2016); PLB 760, 293 (2016); PhD thesis, Lund University

Nuclear Structure Theory ^{289}Mc-^{285}Nh-^{281}Rg



Generalized, i.e. model independent PATTERN predicted/expected:

ALL hitherto observed decay chains starting from **odd-*A* ISOTOPES** of Fl, Mc, Lv, and Ts (*Z* = 114 - 117) should reveal at least

TWO INDEPENDENT DECAY CHAINS!

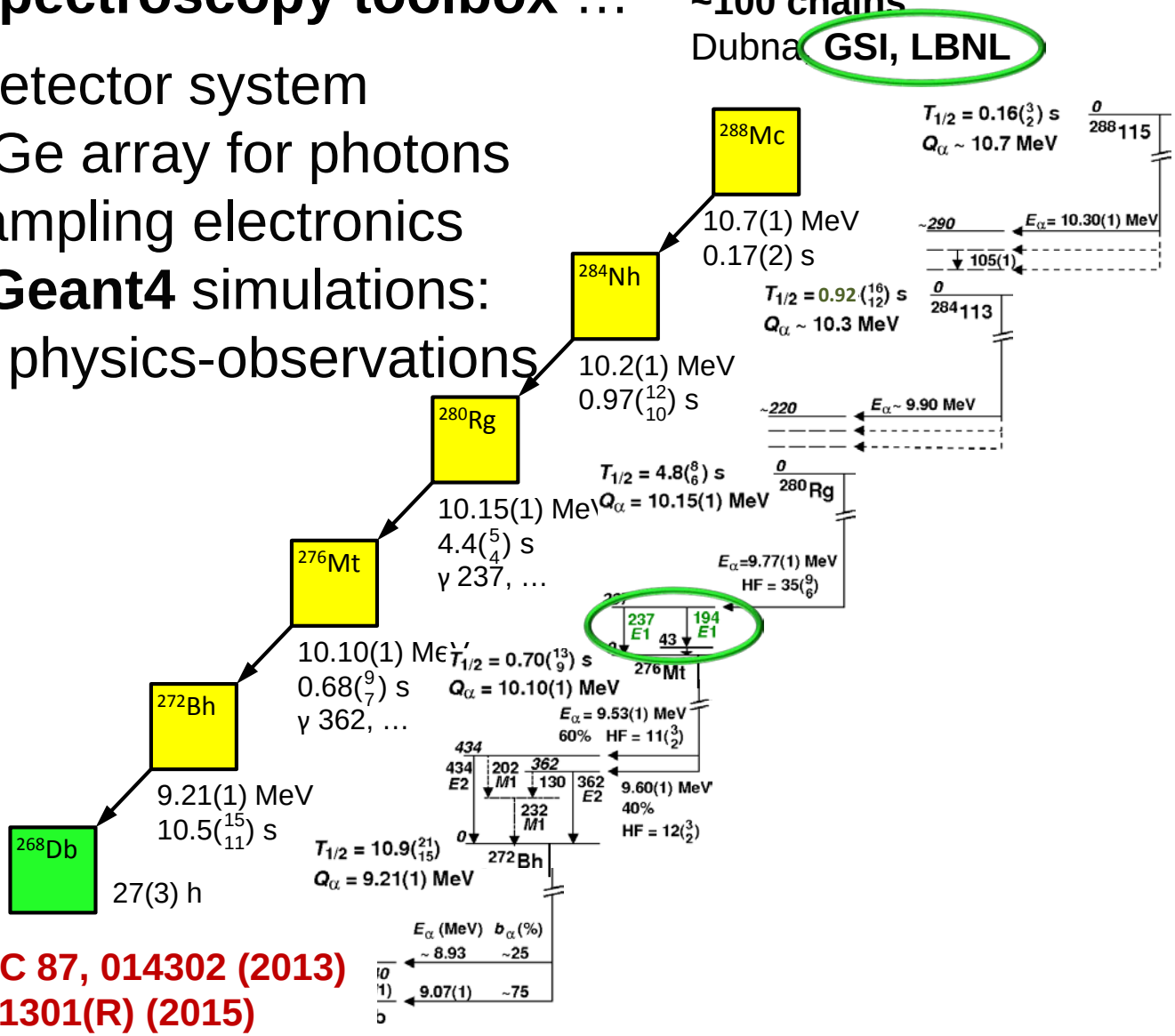
Where are they ?

- **Insufficient data?**
- **(Over)simplified interpretation?**

E115 – “Summary & Conclusions”

Open the **modern spectroscopy toolbox** …

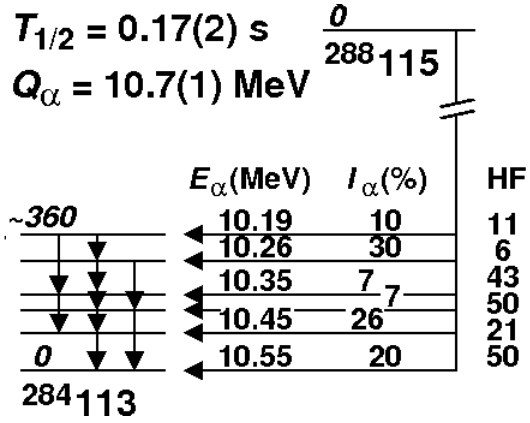
- fully pixelized Si detector system
- complement with Ge array for photons
- employ “digital” sampling electronics
- cross-check with **Geant4** simulations: **self-consistency** physics-observations

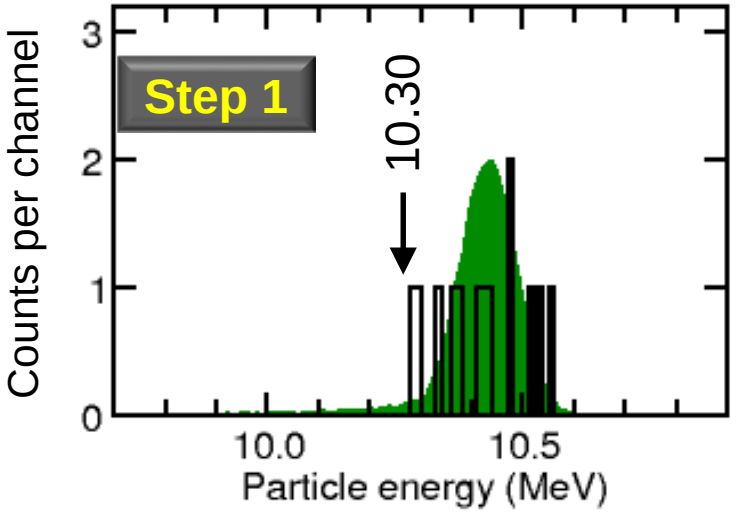


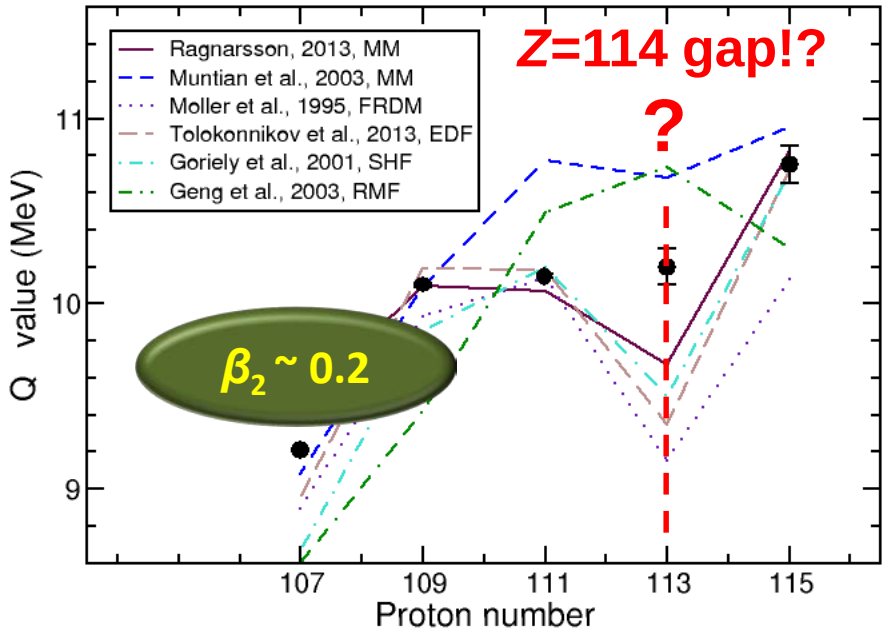
Yu.Ts. Oganessian et al., PRC 87, 014302 (2013)
J.M. Gates et al., PRC 92, 021301(R) (2015)

Results Decay Step 1: ^{288}Mc→ ^{284}Nh

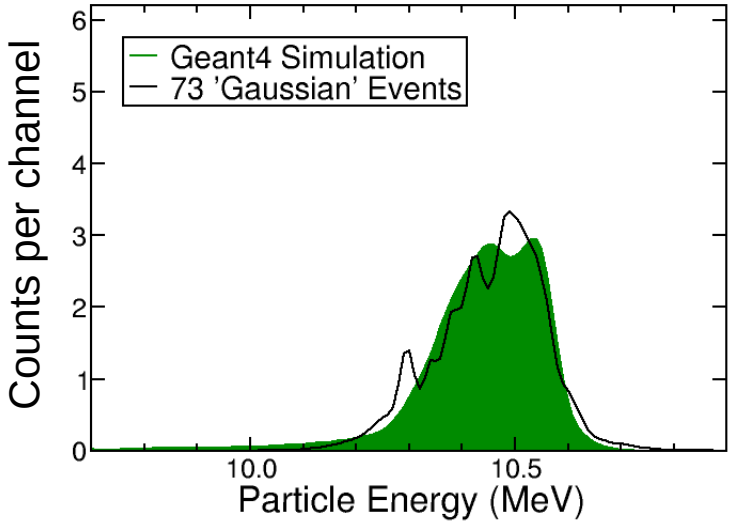
Step 1







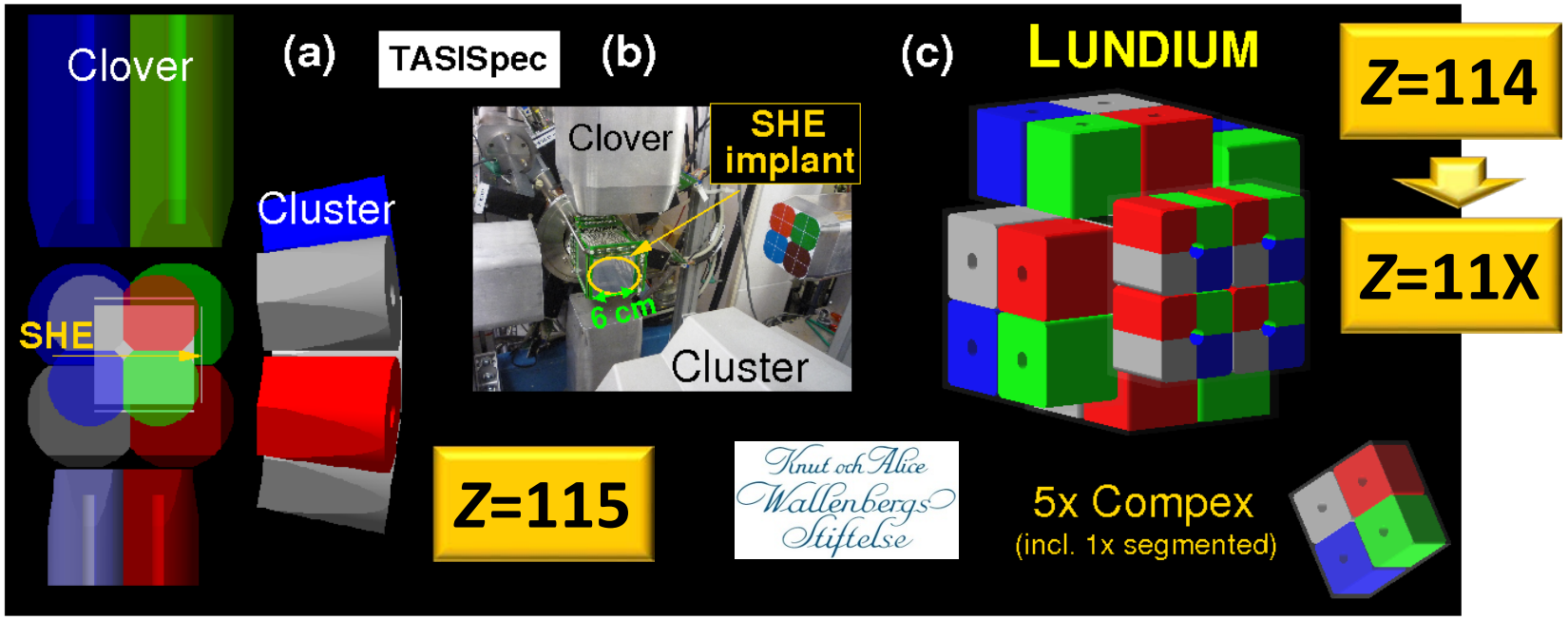
GEANT4 simulations: 100000 decays, normalized to number of α's



Future: "LUNDIUM" Chamber

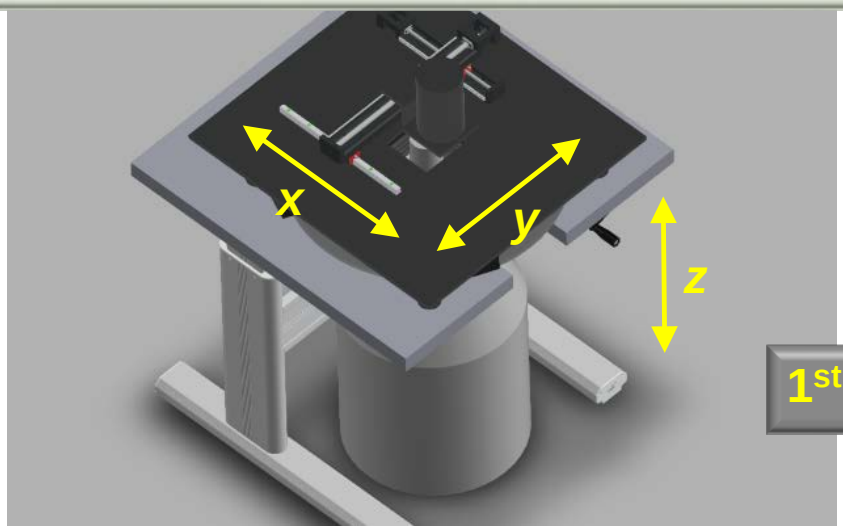
- Optimize (new, 1.5 M€!) Ge solid-angle coverage x 1.4
- Move into nominal TASCA focal plane x 1.4
- Increase segmentation of the implantation DSSSD
- Add & optimize active (ACS!) and passive shielding
- (Increase primary beam intensity – cw-LINAC x ~5)

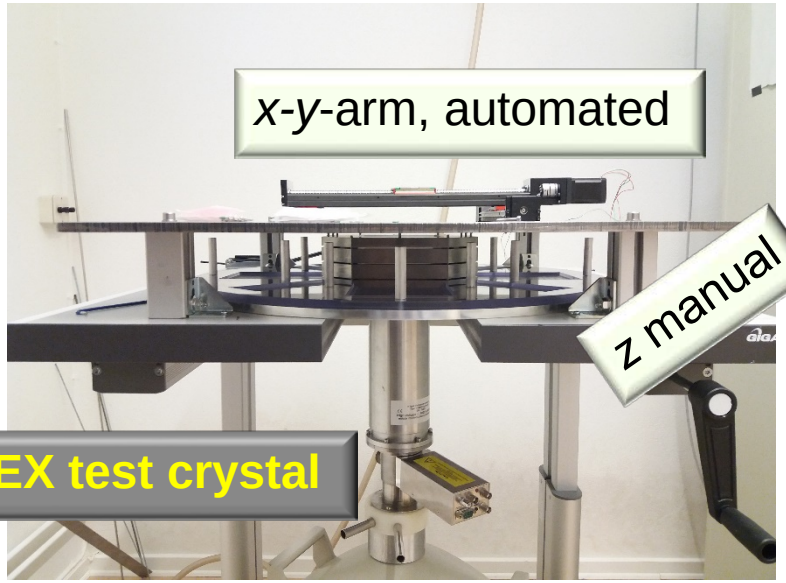
order of magnitude in sensitivity!
nuclear spectroscopy on 1 pb level!



Infrastructure: COMPEX Scanning Table

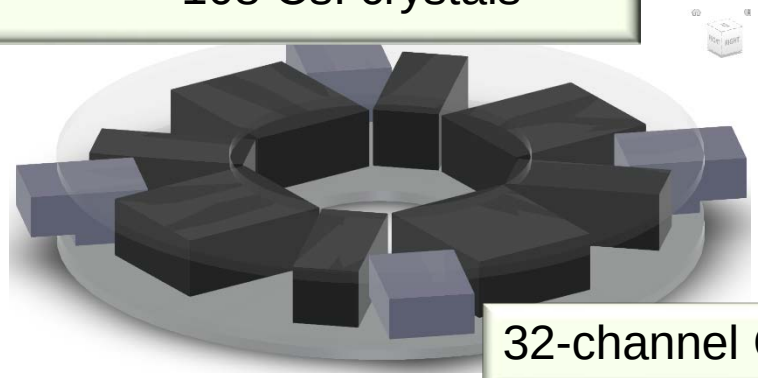
Heavimet source canister (~1 GBq)
Collimator: 100mm long, 1mm diameter

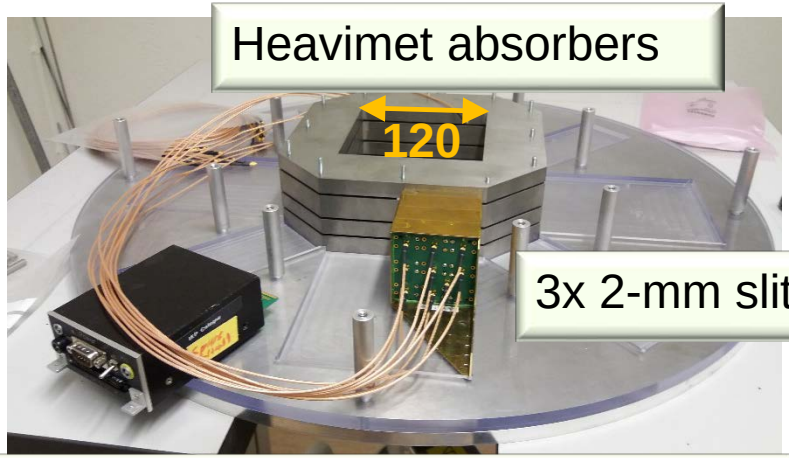




1st COMPEX test crystal

90º scatter – 12 LYCCA modules
108 CsI crystals





32-channel Cologne preamplifiers + FEBEX3 read-out

Summary & Outlook

LUNDIUM Chamber & COMPEX Germaniums:

- start: Q3 2016; test crystal: 1/2017; design fixed 9/2017; 1st test capsule: 11/2017; 1st COMPEX: 1/2018; segm. COMPEX: 11/2018
- construction of vacuum chamber and DSSSD upgrade: < 9/2018
- first experiment behind TASCA at GSI: 2019 (with some ACS)

Alpha-photon (γ rays and/or *x* rays) **coincidence spectroscopy** in the superheavy element regime itself **is decisive for** any nuclear-structure based **understanding** of the shell structure **of the heaviest elements**.

Some problems:

- Sensitivity for electron conversion (**EC**) decays**?**
- **Isotopic assignments** / multiple chains from the same isotope: **Conclusive** mass, ***A***, (in progress) **and** proton number, ***Z*** , (feasible) measurements highly desirable!