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JOHANNES GUTENBERG
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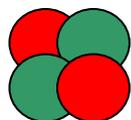
UNIVERSIDAD
NACIONAL
DE COLOMBIA



Spectroscopy of Element 115 Decay Chains at TASCA



LUND
UNIVERSITY



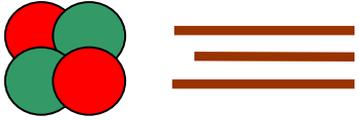
Ulrika Forsberg

on behalf of the TASIpec@TASCA collaboration

October 15, 2014

Science and Technology for FAIR, Worms

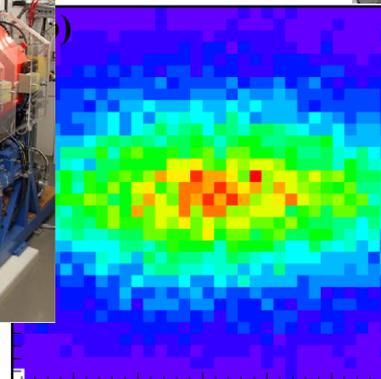
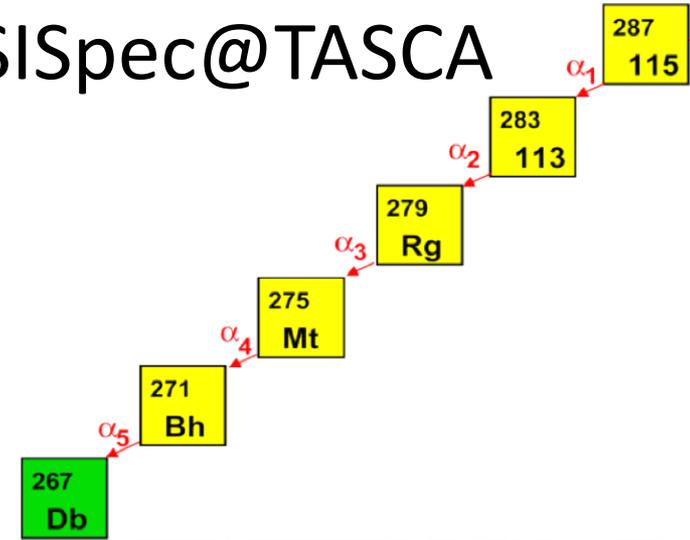


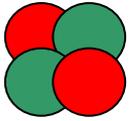


Outline



- Superheavy elements (SHE)
- Overview + results: E115@TASISpec@TASCA
- Two interesting physics cases
- Plans for the future

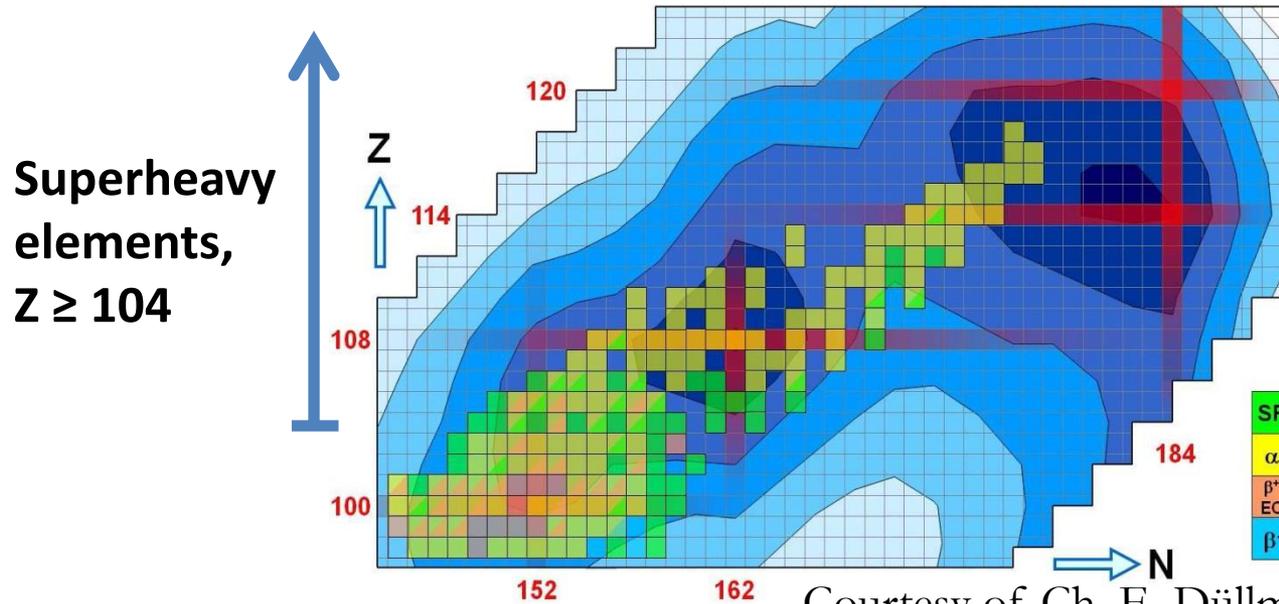


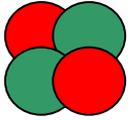


≡≡≡ Super Heavy Elements



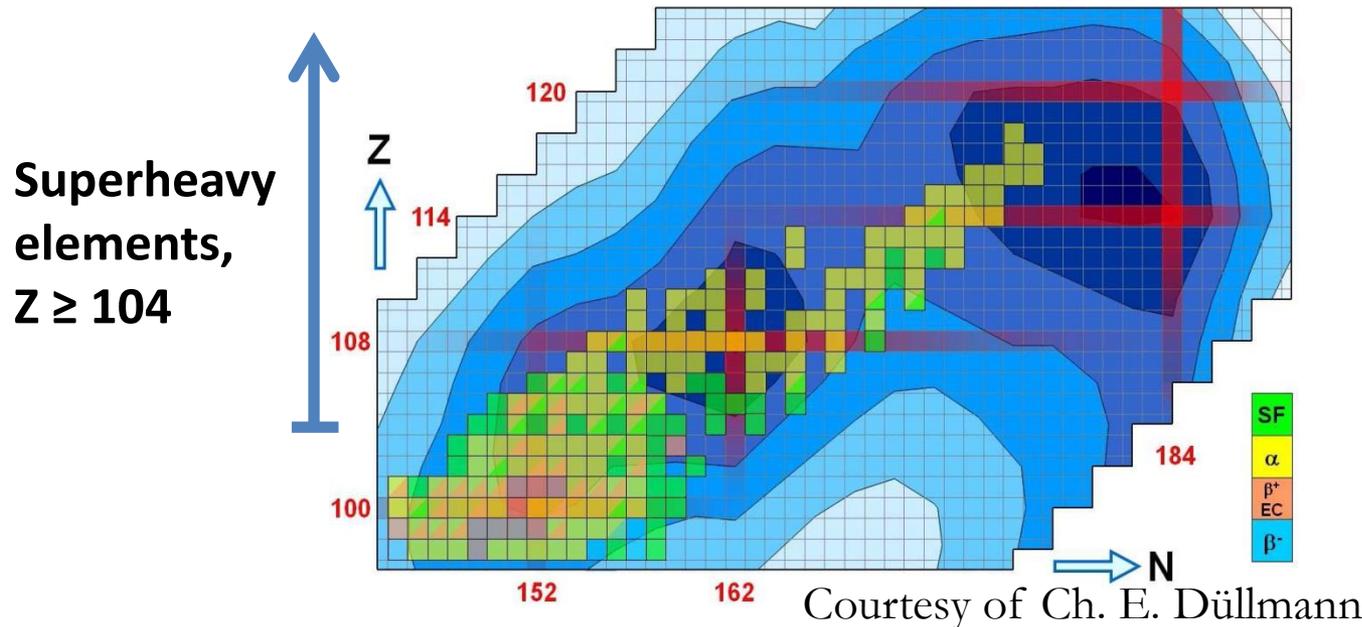
- Definition: $Z \geq 104$
- $Z = 107-112$ (Bh-Cn) discovered at GSI
- $Z = 113$ reported from FLNR (Dubna, Russia) and RIKEN (Japan)
- $Z = 114-118$ reported from FLNR (Dubna, Russia).
Some confirmed at GSI and LBNL (US). **Accepted:** ${}_{114}\text{Fl}$, ${}_{116}\text{Lv}$
- $Z = 119-120$ searched for at GSI

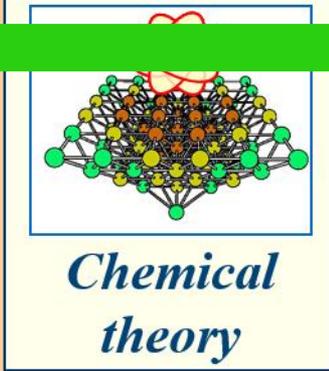
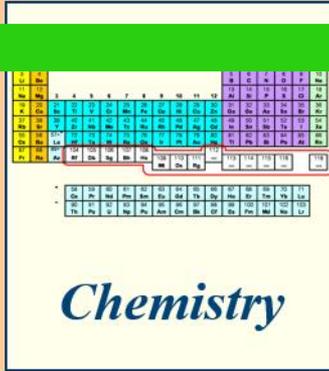
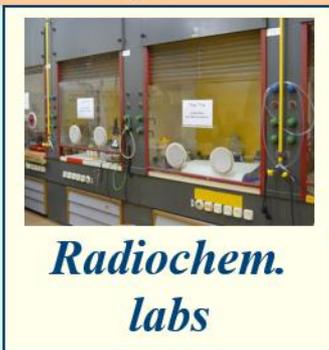
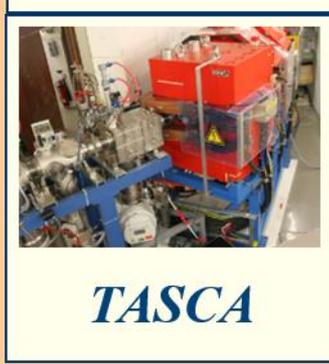
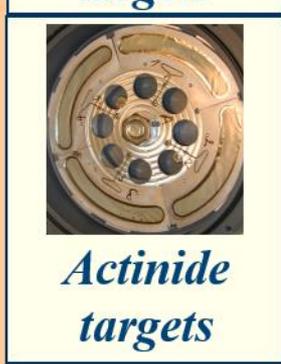
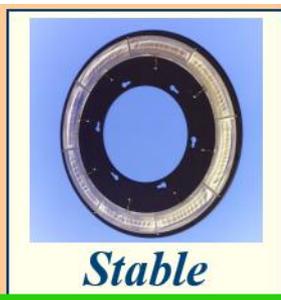
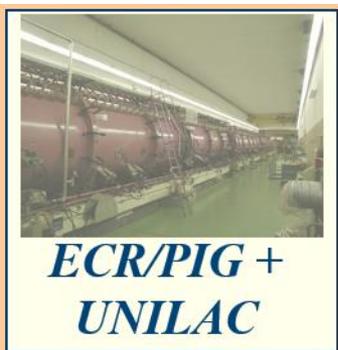


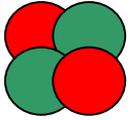


≡ Detailed SHE studies at GSI

- Nuclear structure
- Reaction studies
- Precise mass measurements
- Chemical properties
- X-ray fingerprinting



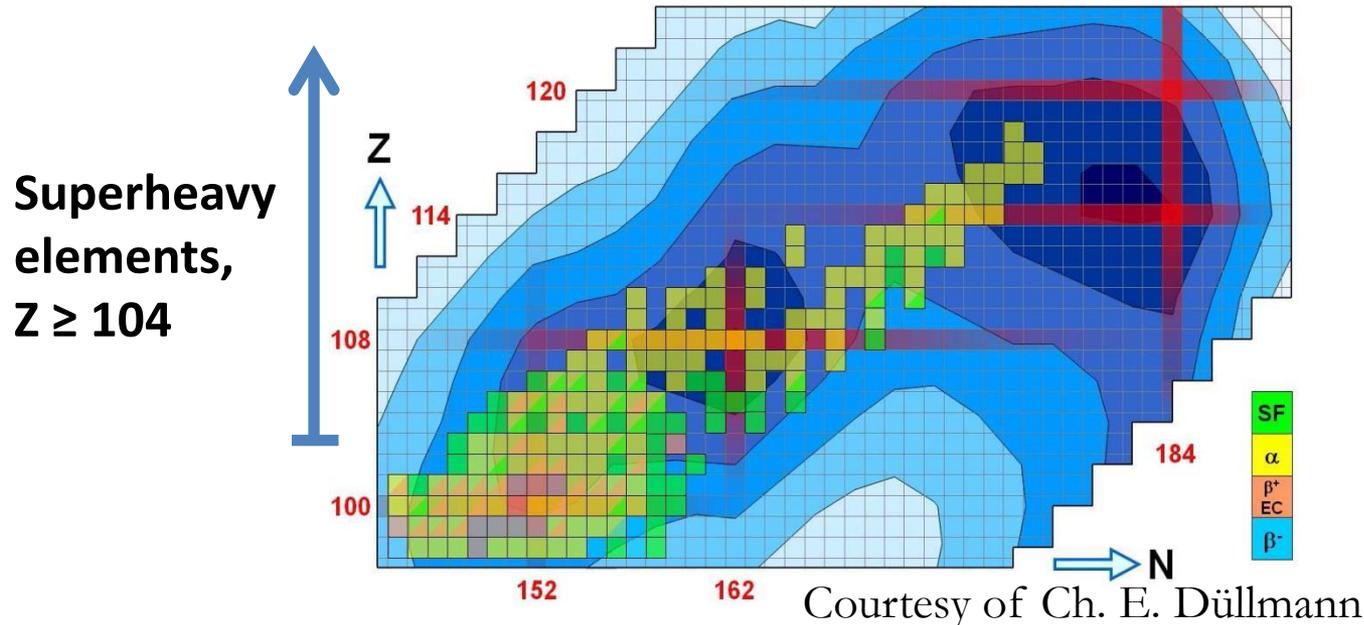


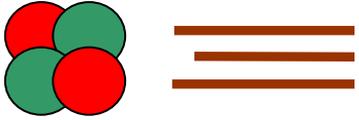


Element $Z = 115$



X-ray Fingerprinting & Nuclear Structure



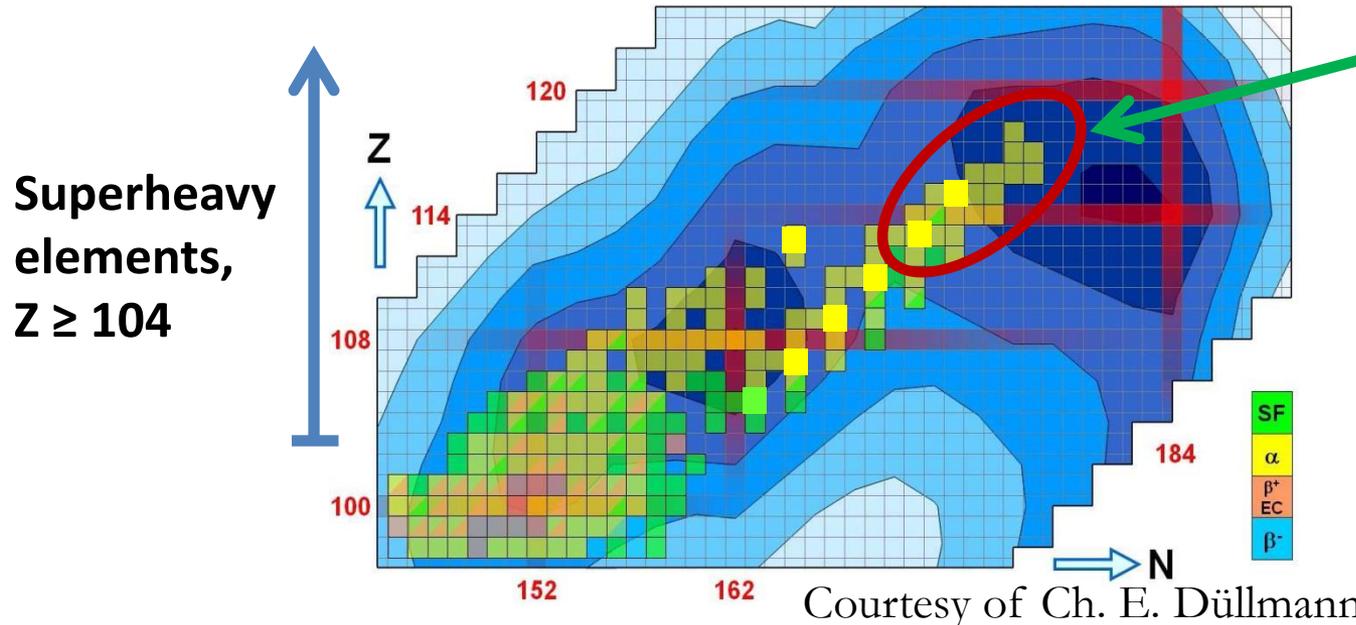


Background

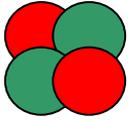


Elements $Z = 113-118$ reported at FLNR (Dubna, Russia):

- observed/claimed in ^{48}Ca -induced reactions on actinide targets
(Yu.Ts.Oganessian, J. Phys.G34, R165 (2007) etc.)
- chains end by spontaneous fission



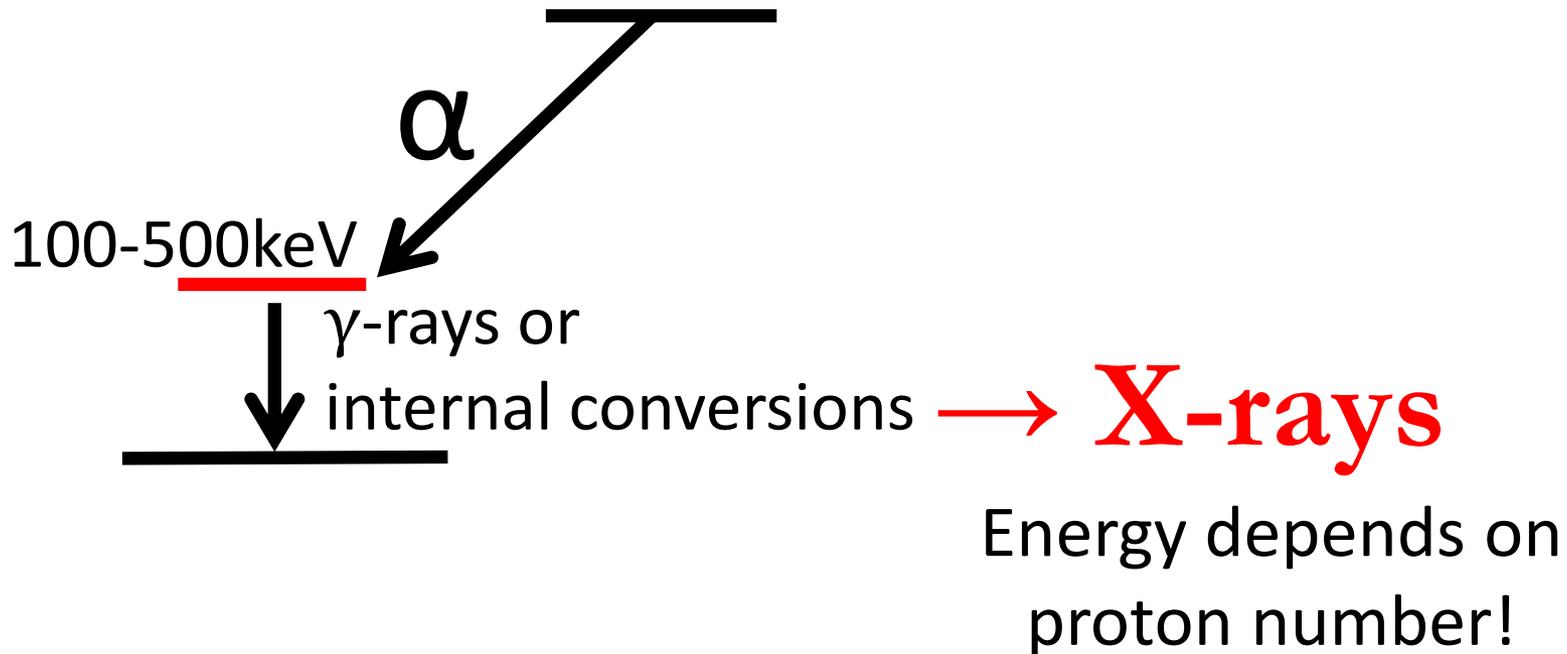
Need direct measurement of atomic numbers!



X-ray Fingerprinting



Look for **characteristic X-rays** emitted in coincidence with α decays!



TASISpec@TASCA collaboration

... among the Top Ten **APS Physics Newsmakers of 2013!**

PHYSICAL REVIEW LETTERS **111, 112502 (2013)**



Spectroscopy of Element 115 Decay Chains

D. Rudolph,^{1,*} U. Forsberg,¹
 Ch. E. Düllmann,^{2,3,4} J. M. Gates,⁵
 J. V. Kratz,⁴ K. Rykaczewski,⁶ M.
 D. Cox,⁷ X. Derkx,^{3,4} K. Ebner,
 I. Kojouharov,² N. Kurz,² B.
 I. Ragnarsson,¹ J. Runke,²

N. Trautmann

²GSI Helmholtzzentrum für Schwerionenforschung GmbH

⁴Johannes Gutenberg Universität Mainz

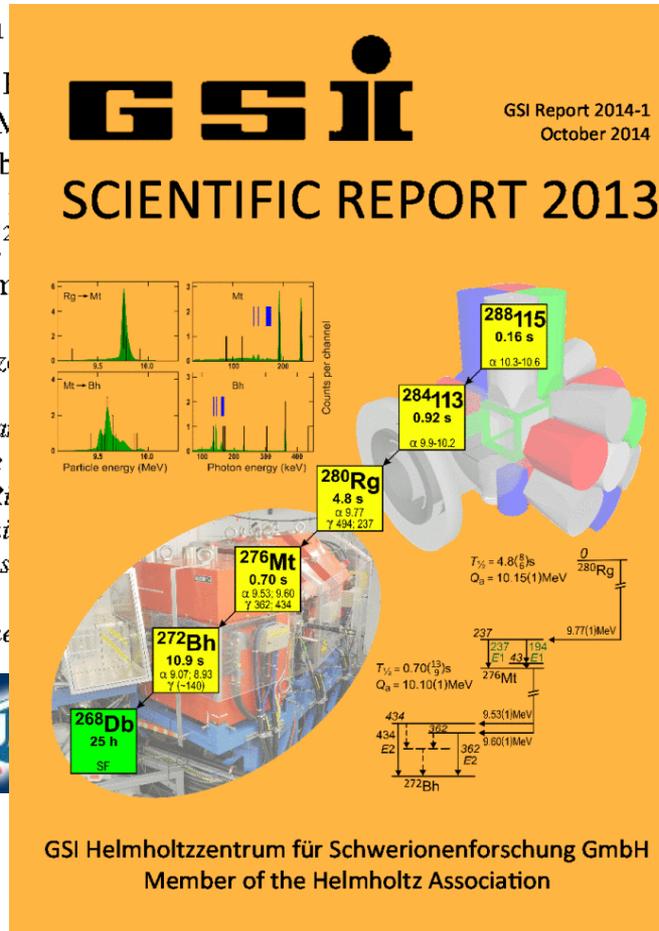
⁵Lawrence Livermore National Laboratory

⁶Oak Ridge National Laboratory

⁷University of Jyväskylä

⁸Advanced Science Research Center, Brookhaven National Laboratory

¹⁰Paul Scherrer Institut



L. Andersson,³ A. Di Nitto,⁴
 R.-D. Herzberg,⁷ J. Khuyagbaatar,³
 M. Kikuchi,² H. Brand,² B. G. Carlsson,¹
 M. G. G. Geisler,² B. Kindler,² J. Krier,²
 P. Omtvedt,⁹ P. Papadakis,⁷
 M. P. P. Torres,² T. Traut,⁴
 M. Wiehl,^{3,4}



Physikalisches Institut, Universität Mainz, Germany

University of Jyväskylä, Finland

Lawrence Livermore National Laboratory, USA

Oak Ridge National Laboratory, USA

University of Jyväskylä, Finland

Department of Applied Physics, University of Jyväskylä, Finland

Physikalisches Institut, Universität Mainz, Germany

Physikalisches Institut, Universität Mainz, Germany



LUNDS UNIVERSITET



UNIVERSITY OF LIVERPOOL



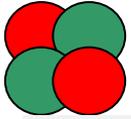
Special thanks to ...

UNILAC



ENSAR





E115 is everywhere...



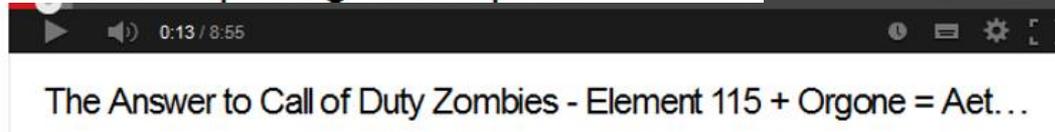
element 115 bob lazar



Upload



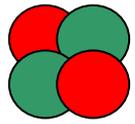
The summer of Bob Lazar - Spacing Out! Ep 58



The Answer to Call of Duty Zombies - Element 115 + Orgone = Aet...



Let's Play Tomb Raider III - Part 42 - Element 115

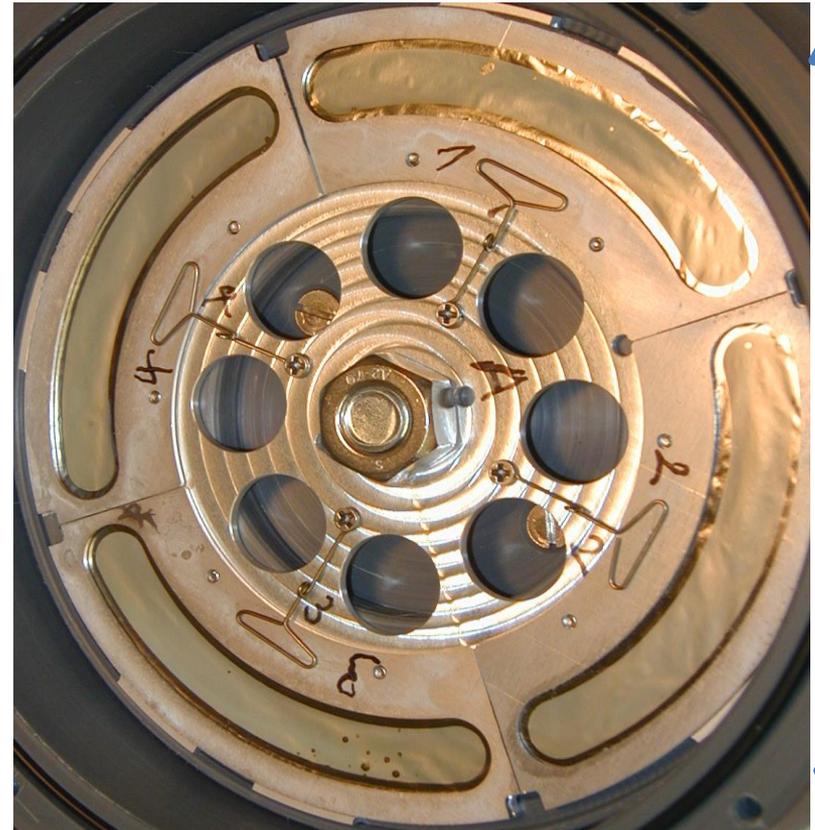
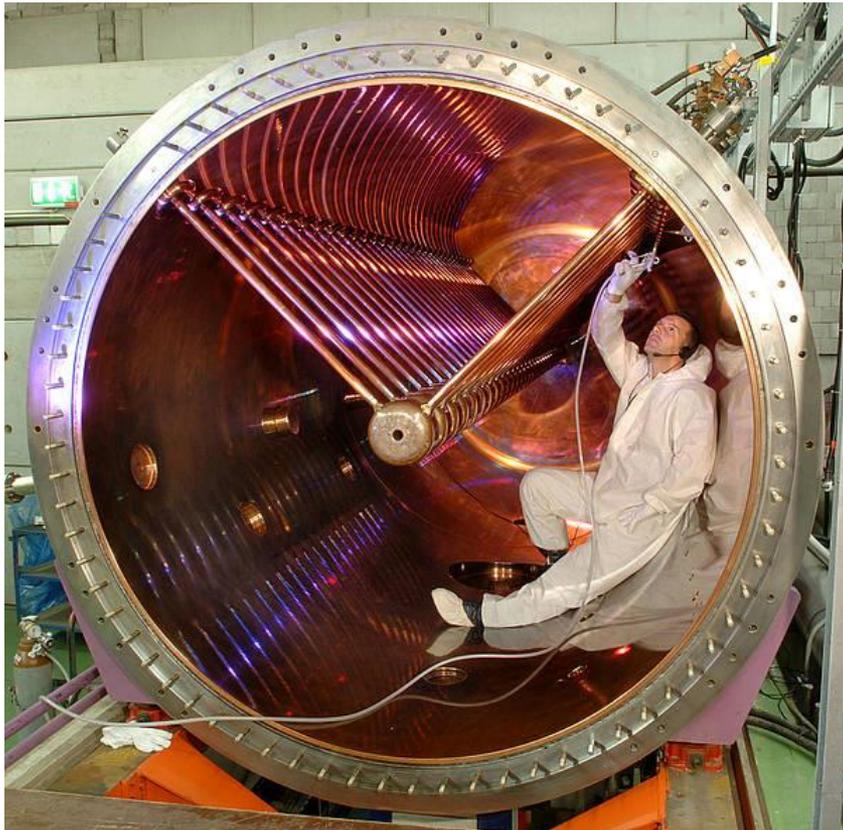


Production of E115 at GSI



Beam: ${}^{48}\text{Ca}$ ions, $\sim 1 \mu\text{A}$ DC, pulsed (5 ms on/15 ms off)

Target: 0.83 mg/cm^2 ${}^{243}\text{Am}_2\text{O}_3$ on $2 \mu\text{m}$ Ti backing



Production and Separation of E115

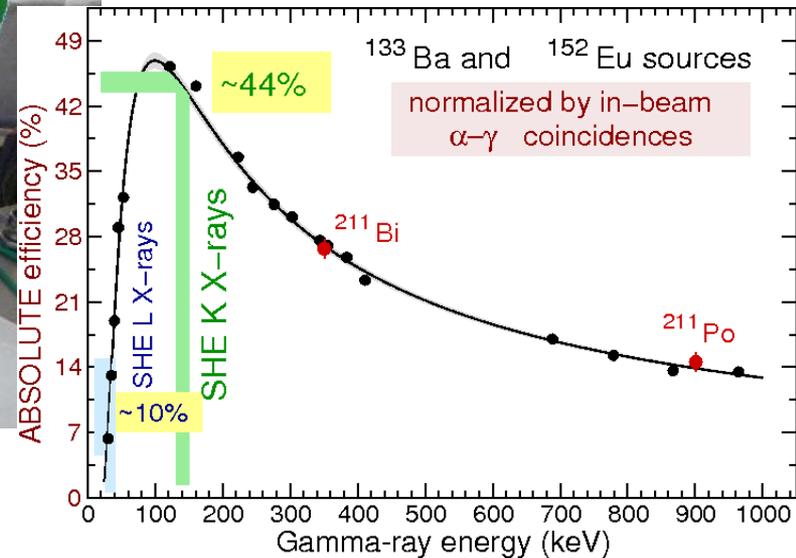
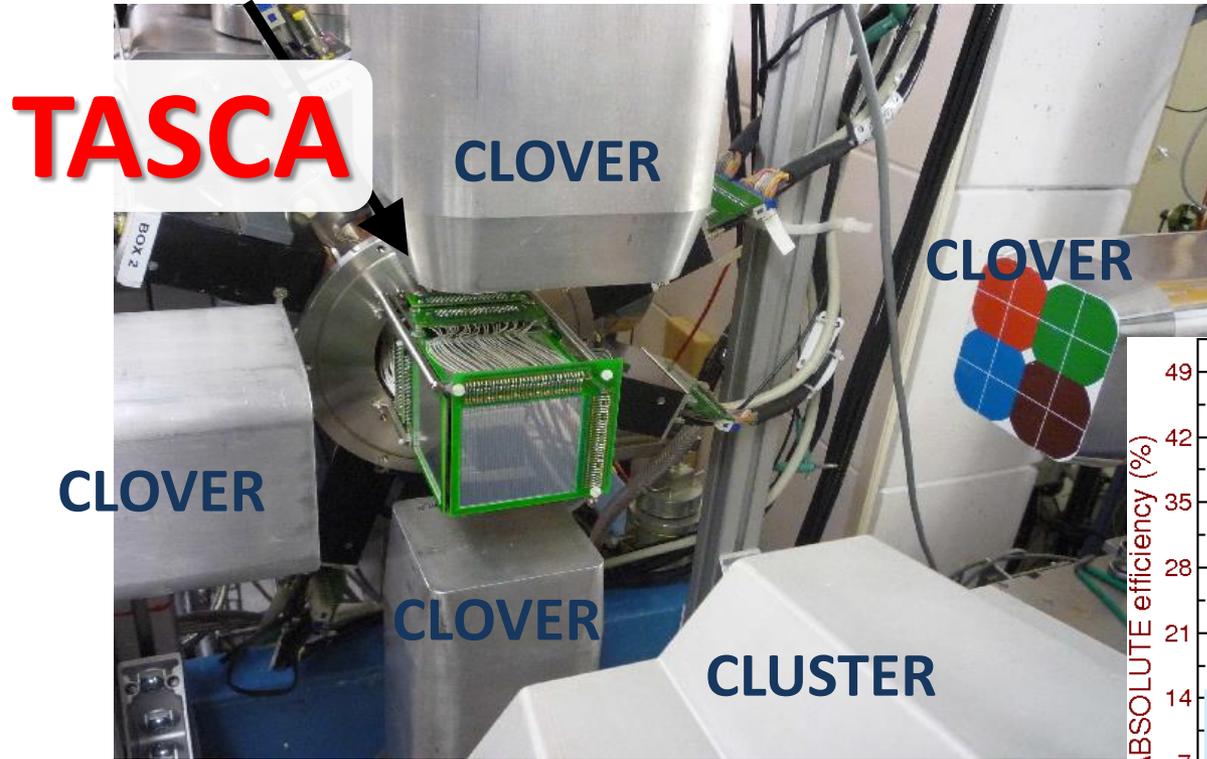


^{48}Ca ions: $6 \cdot 10^{12}/\text{s}$

Trigger rate: $\sim 100/\text{s}$

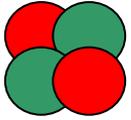


TASiSpec



1 Implantation DSSSD (1024 pixels)
4 box-DSSSDs (1024 pixels)
=> ~80% α -detection efficiency

4 Ge Clover (4*4 crystals)
1 Ge Cluster (7 crystals)
=> ~40% γ -detection eff. at 150 keV

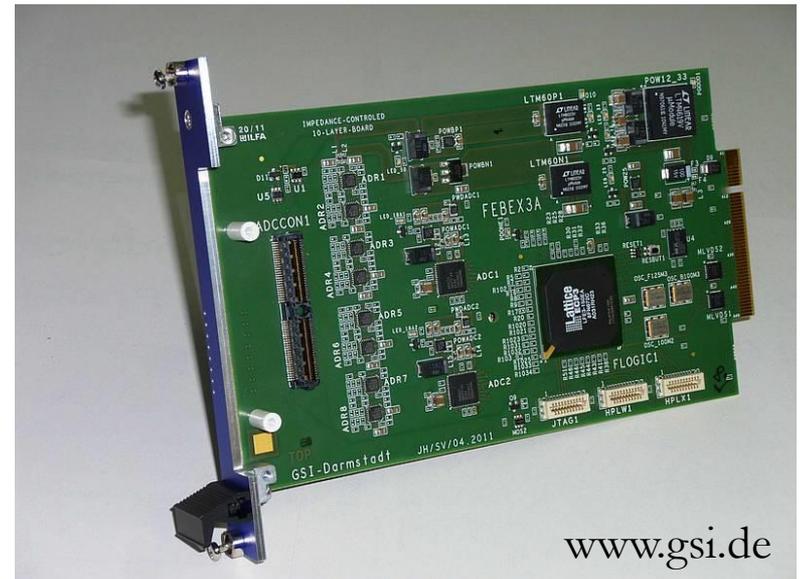


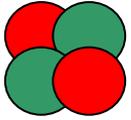
Electronics



- 25 Ge-crystals: SIS 3302 digital electronics
- 96 DSSSD n-sides: analogue electronics
- 96 DSSSD p-sides: **FEBEX** digital electronics

- Developed at **GSI-EE**
- **60 MHz** dead-time free ADC sampling
- Offline **resolution** optimisation
- Large **dynamic range**
- Reduce **background** from summing





Electronics

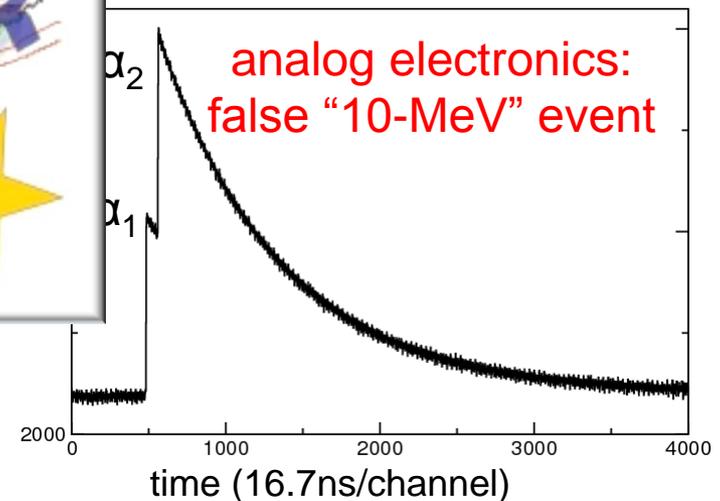


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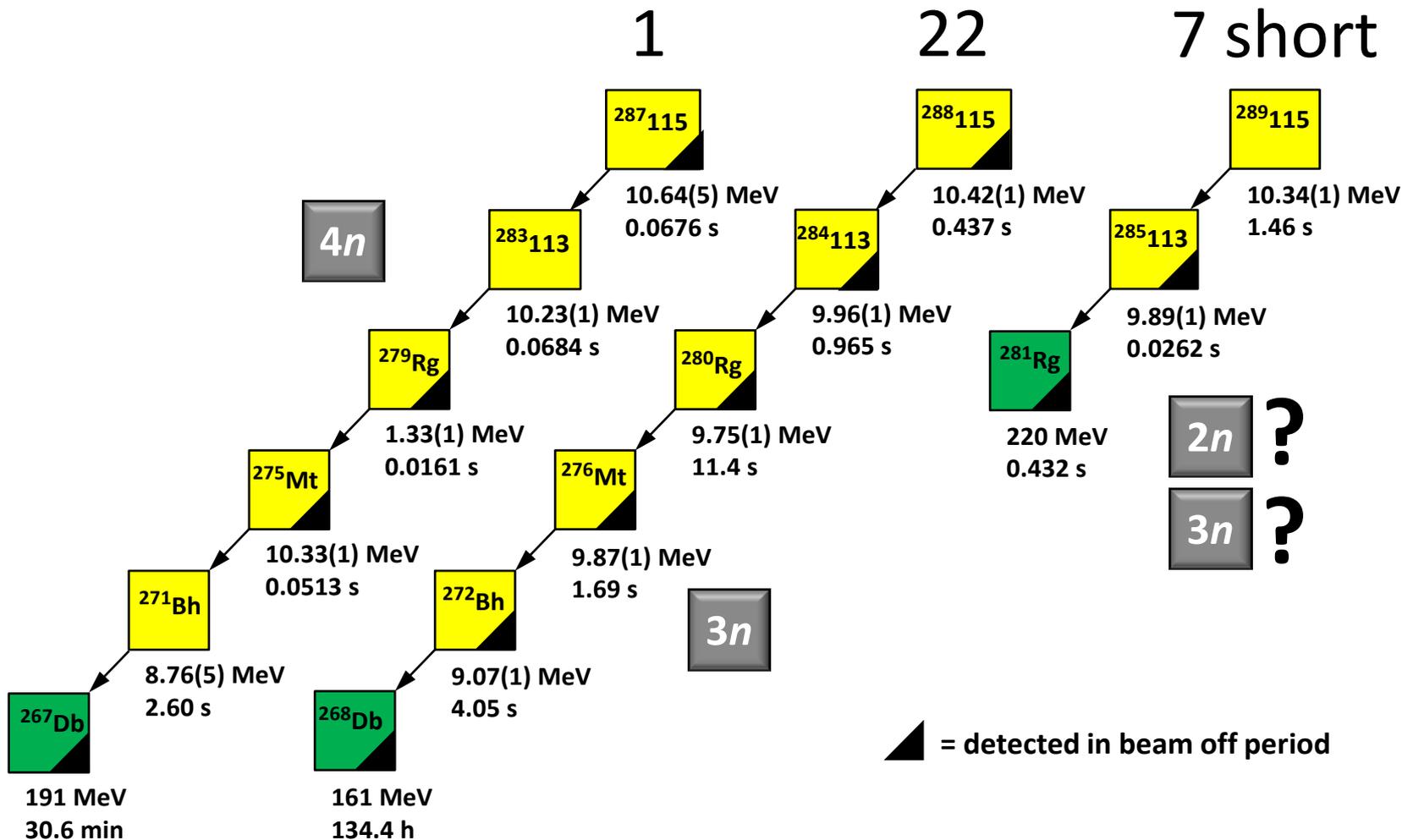


Signal

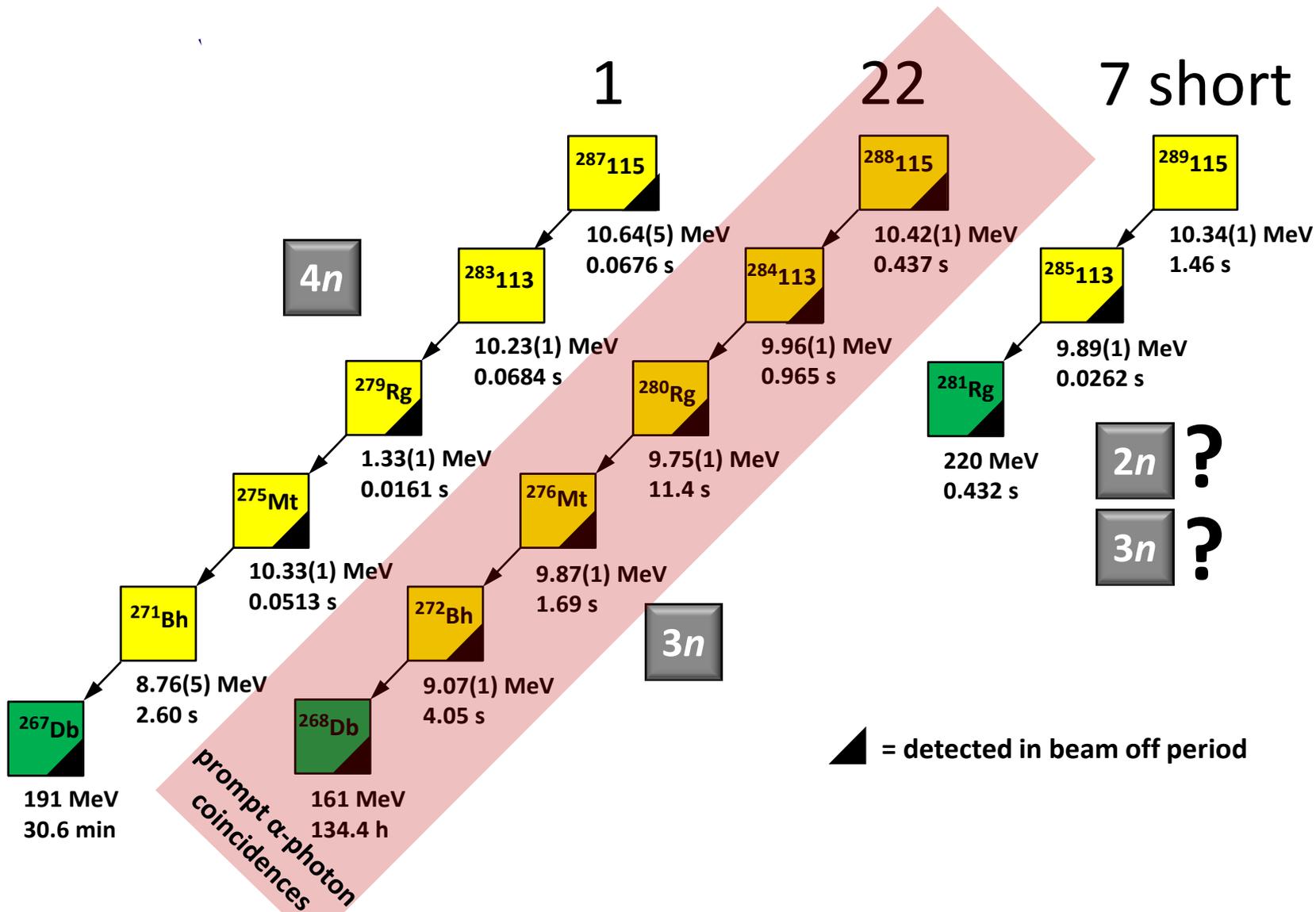


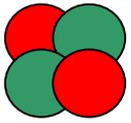


≡ 30 chains detected in 18 days



 \equiv 30 chains detected in 18 days

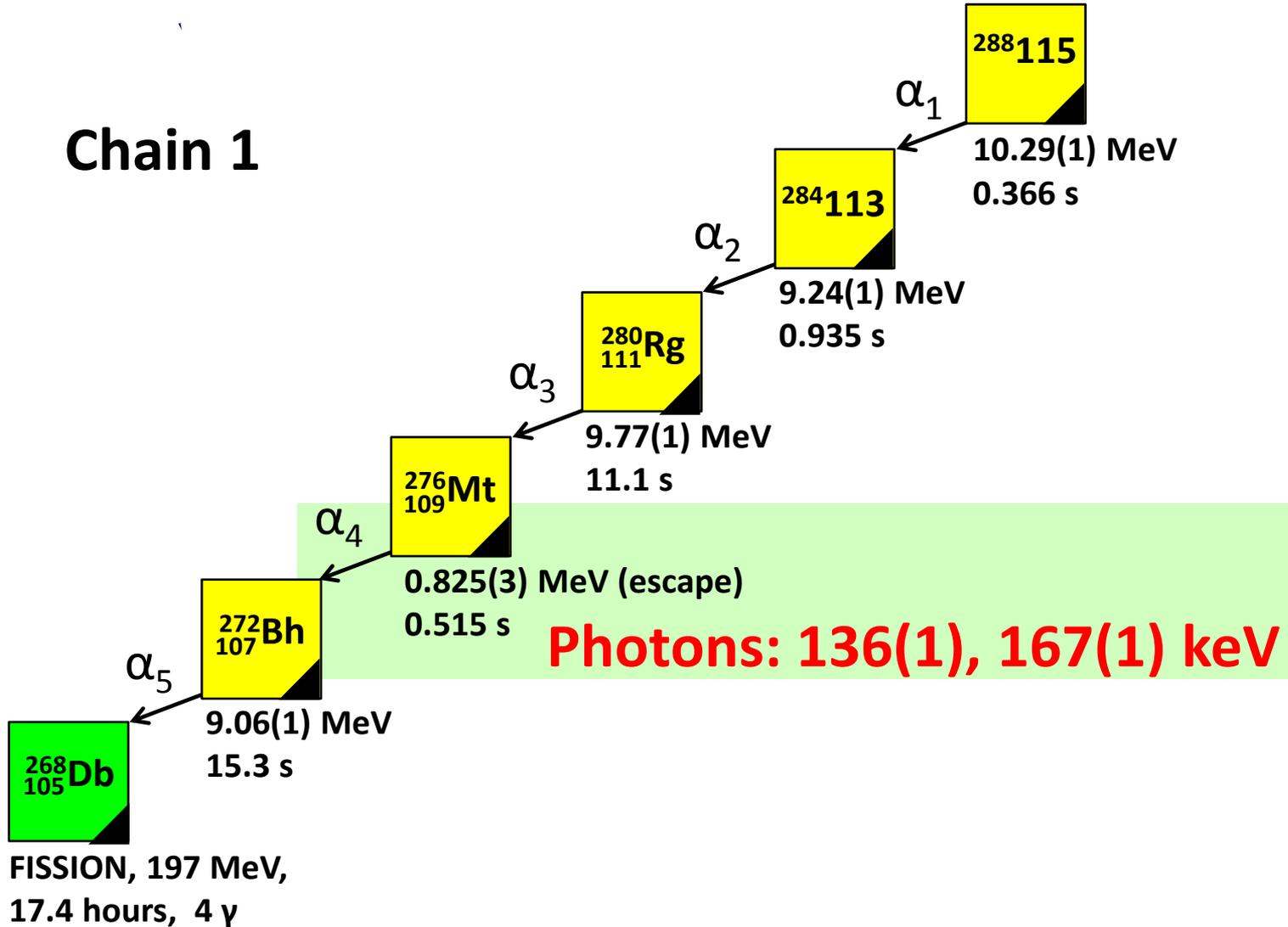


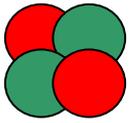


Case 1: Potential X-rays



Chain 1

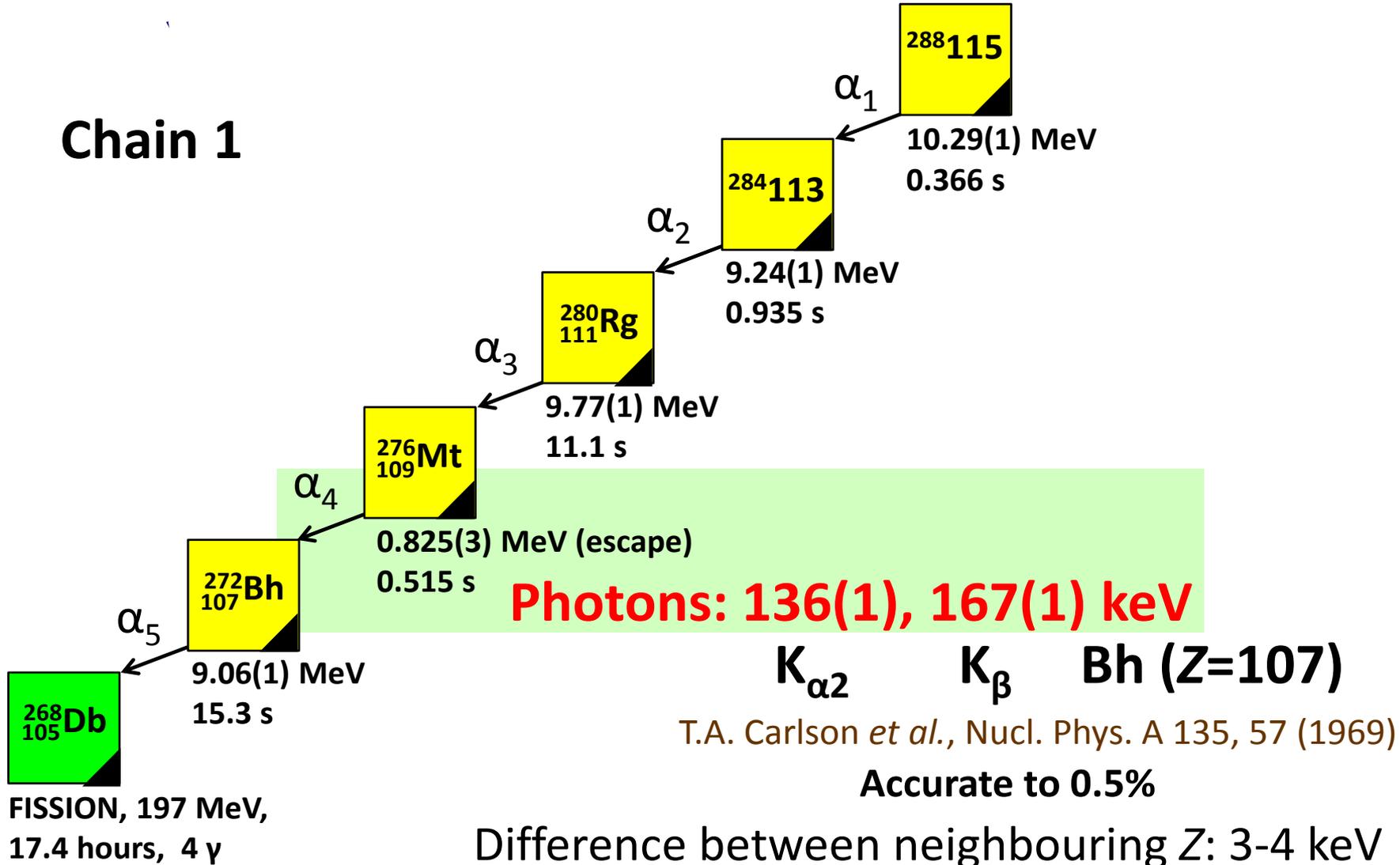




Case 1: Potential X-rays

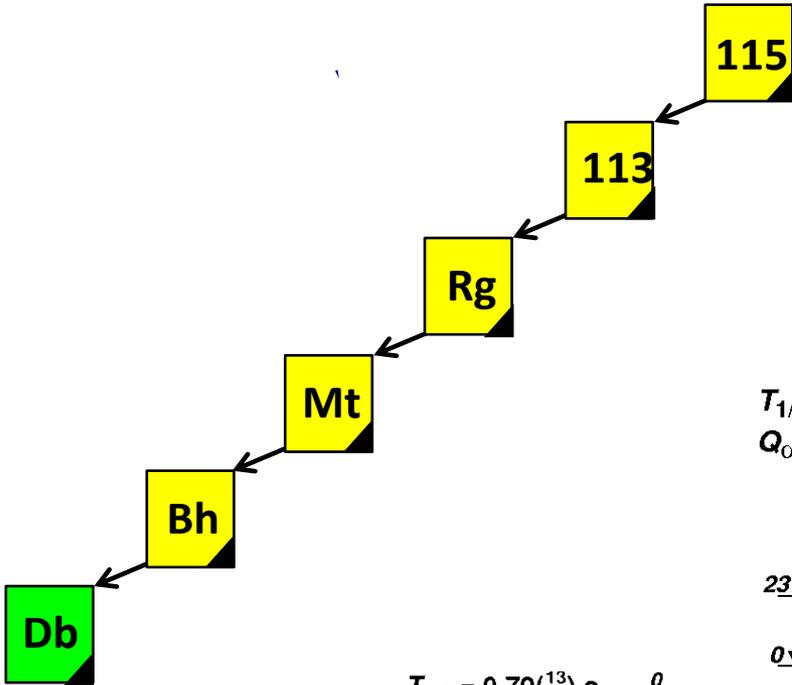


Chain 1

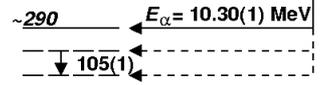




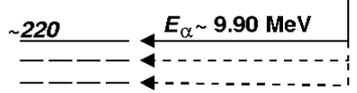
Level schemes



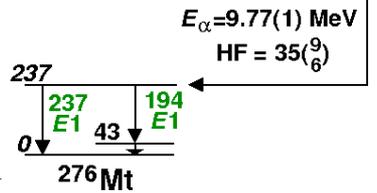
$T_{1/2} = 0.16^{(3)}_2$ s
 $Q_\alpha \sim 10.7$ MeV



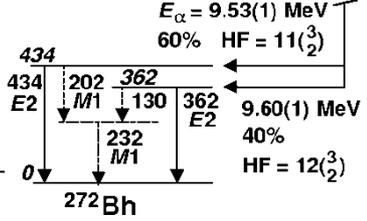
$T_{1/2} = 0.94^{(16)}_{12}$ s
 $Q_\alpha \sim 10.3$ MeV



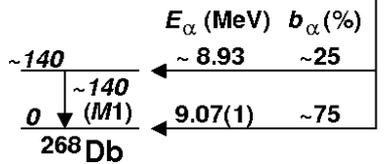
$T_{1/2} = 4.8^{(8)}_6$ s
 $Q_\alpha = 10.15(1)$ MeV

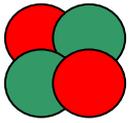


$T_{1/2} = 0.70^{(13)}_9$ s
 $Q_\alpha = 10.10(1)$ MeV

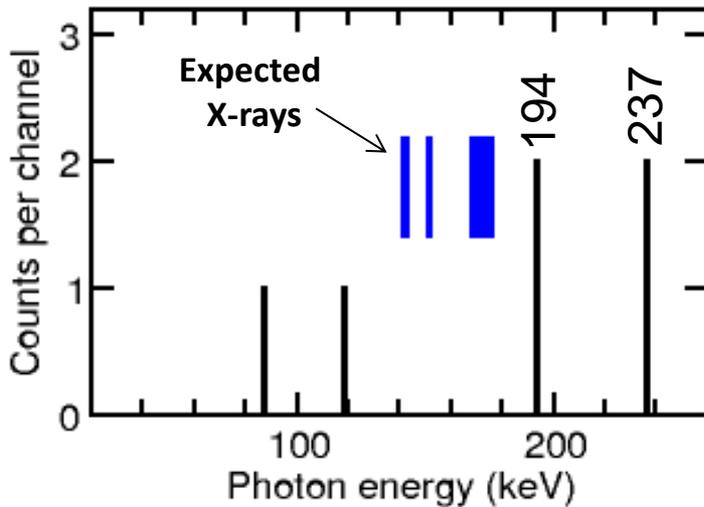
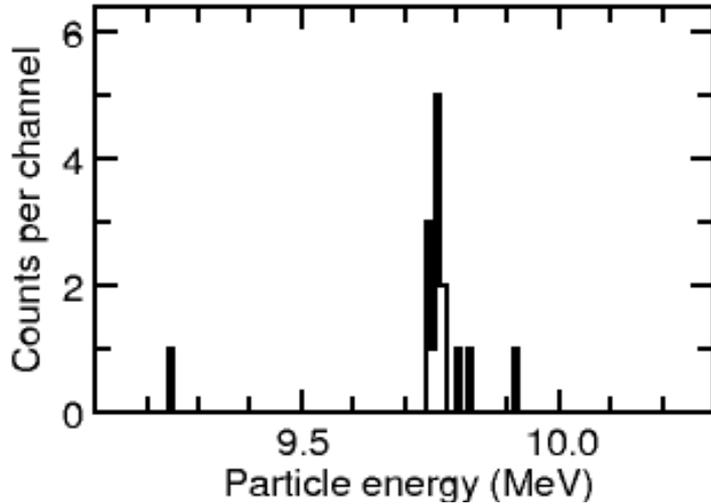


$T_{1/2} = 10.9^{(21)}_{15}$ s
 $Q_\alpha = 9.21(1)$ MeV

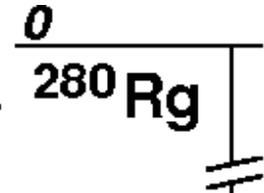




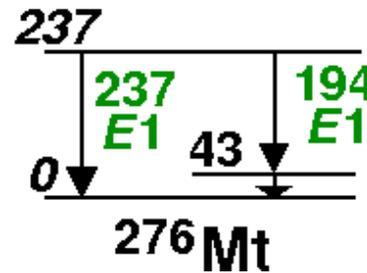
≡ Rg → Mt level scheme

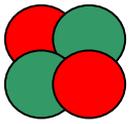


$$T_{1/2} = 4.8^{(8)}_6 \text{ s}$$
$$Q_{\alpha} = 10.15(1) \text{ MeV}$$



$$E_{\alpha} = 9.77(1) \text{ MeV}$$
$$\text{HF} = 35^{(9)}_6$$





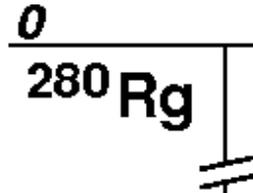
GEANT4 simulations



IF a level scheme looks like this...

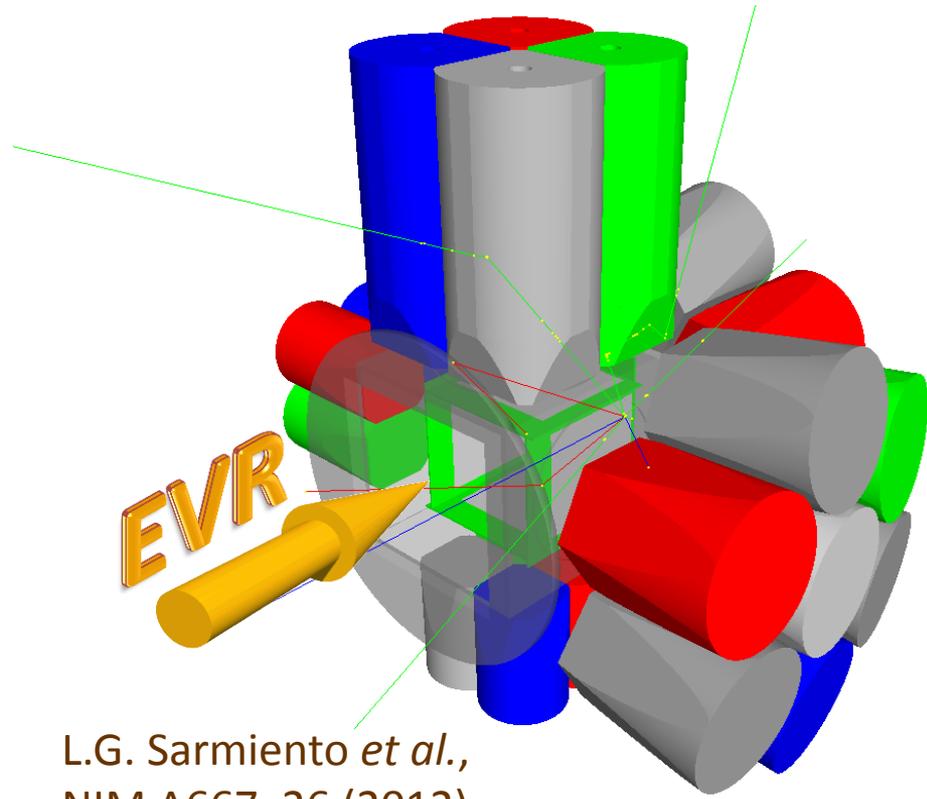
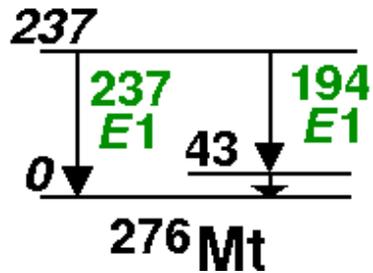
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$$Q_\alpha = 10.15(1) \text{ MeV}$$



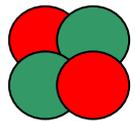
$$E_\alpha = 9.77(1) \text{ MeV}$$

$$\text{HF} = 35^{(9)}_6$$



L.G. Sarmiento *et al.*,
NIM A667, 26 (2012)

what is the response of TASIpec?
(α , γ , e^\pm , X-rays...)

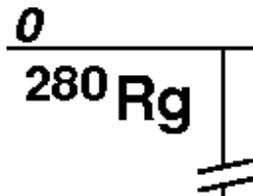


Rg \rightarrow Mt simulations

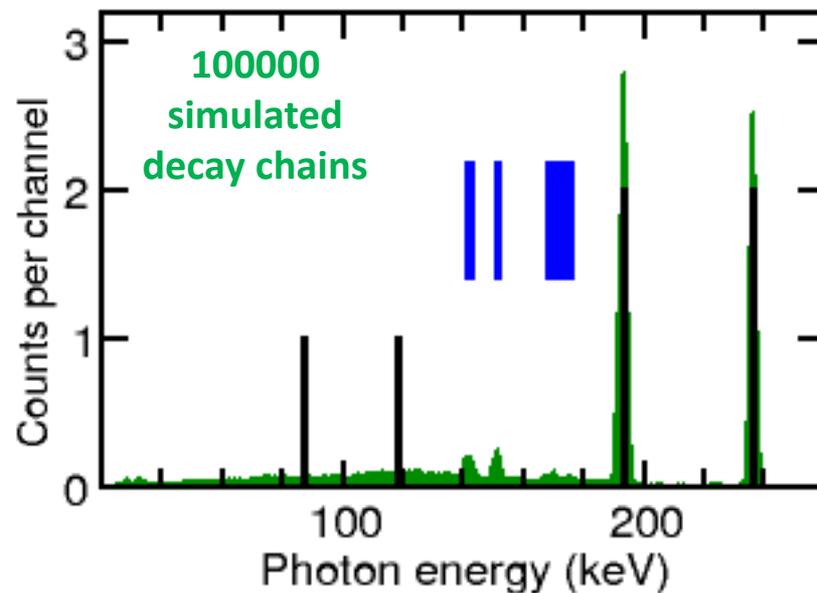
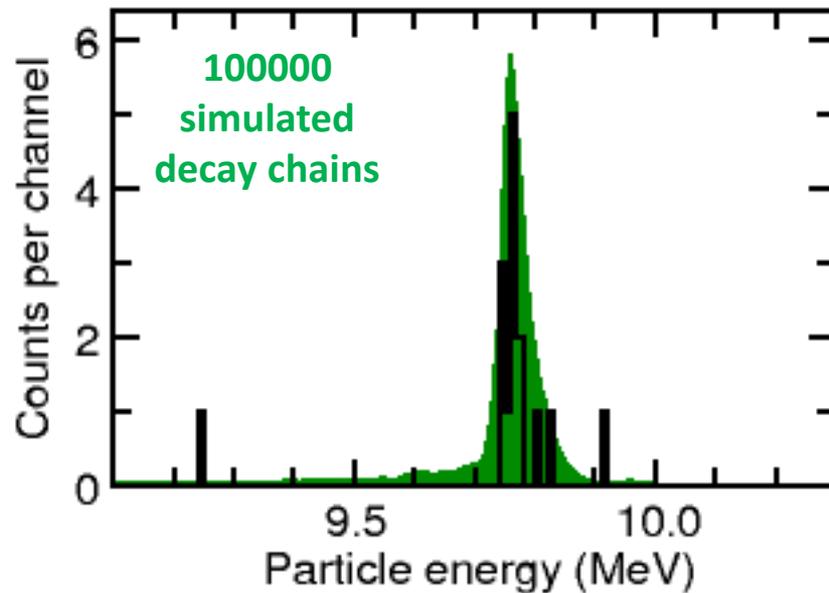
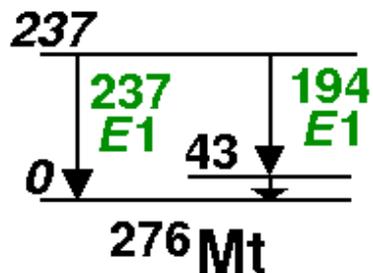


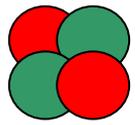
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$$Q_{\alpha} = 10.15(1) \text{ MeV}$$



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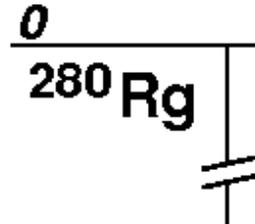


Rg \rightarrow Mt simulations

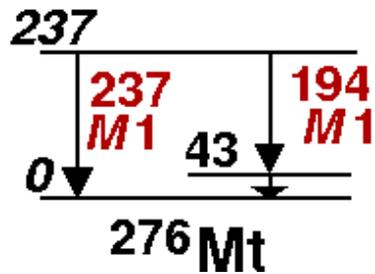


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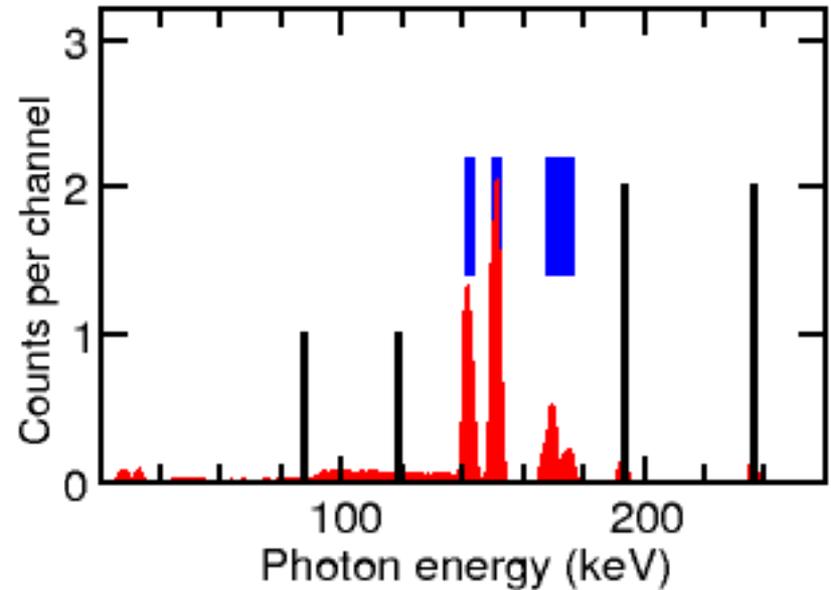
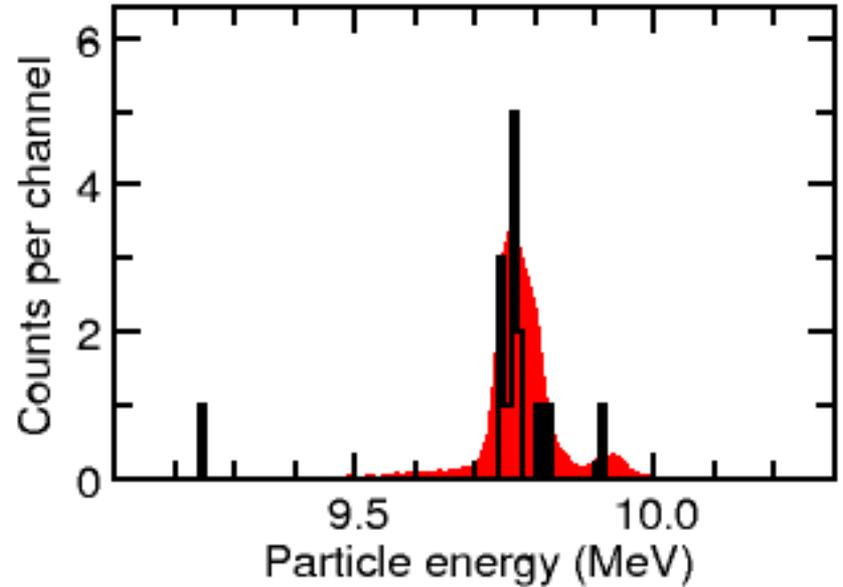
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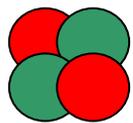


$$E_\alpha = 9.77(1) \text{ MeV}$$
$$\text{HF} = 35^{(9)}_6$$



Would have been the perfect fingerprinting case!



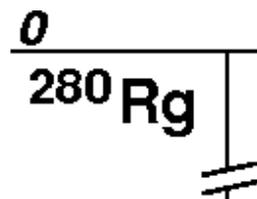


Case 2: E1-transitions

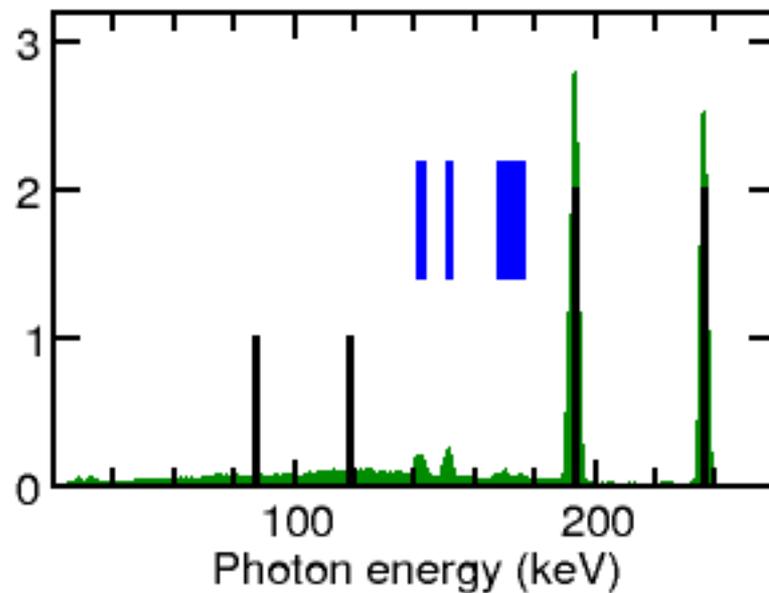
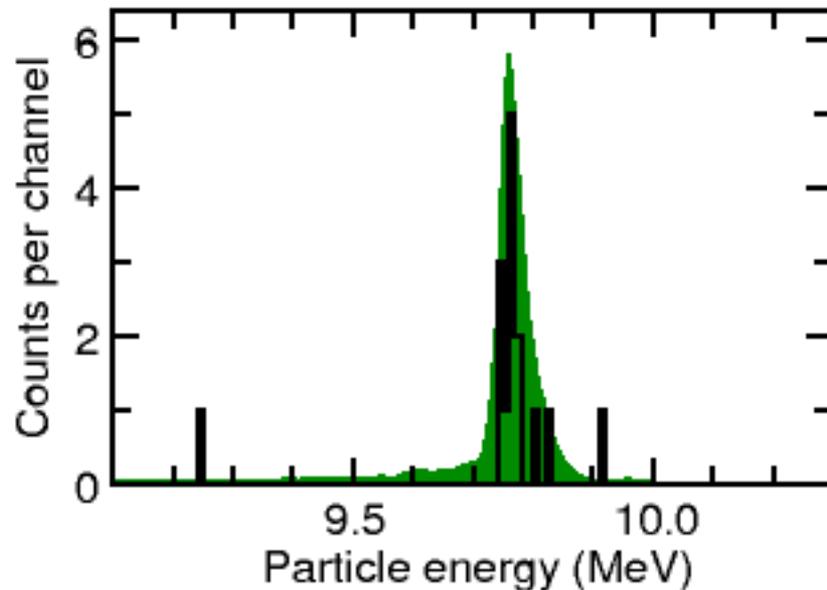
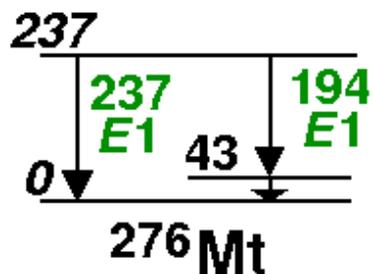


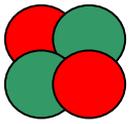
$$T_{1/2} = 4.8^{(8)}_6 \text{ s}$$

$$Q_\alpha = 10.15(1) \text{ MeV}$$



$$E_\alpha = 9.77(1) \text{ MeV}$$
$$\text{HF} = 35^{(9)}_6$$

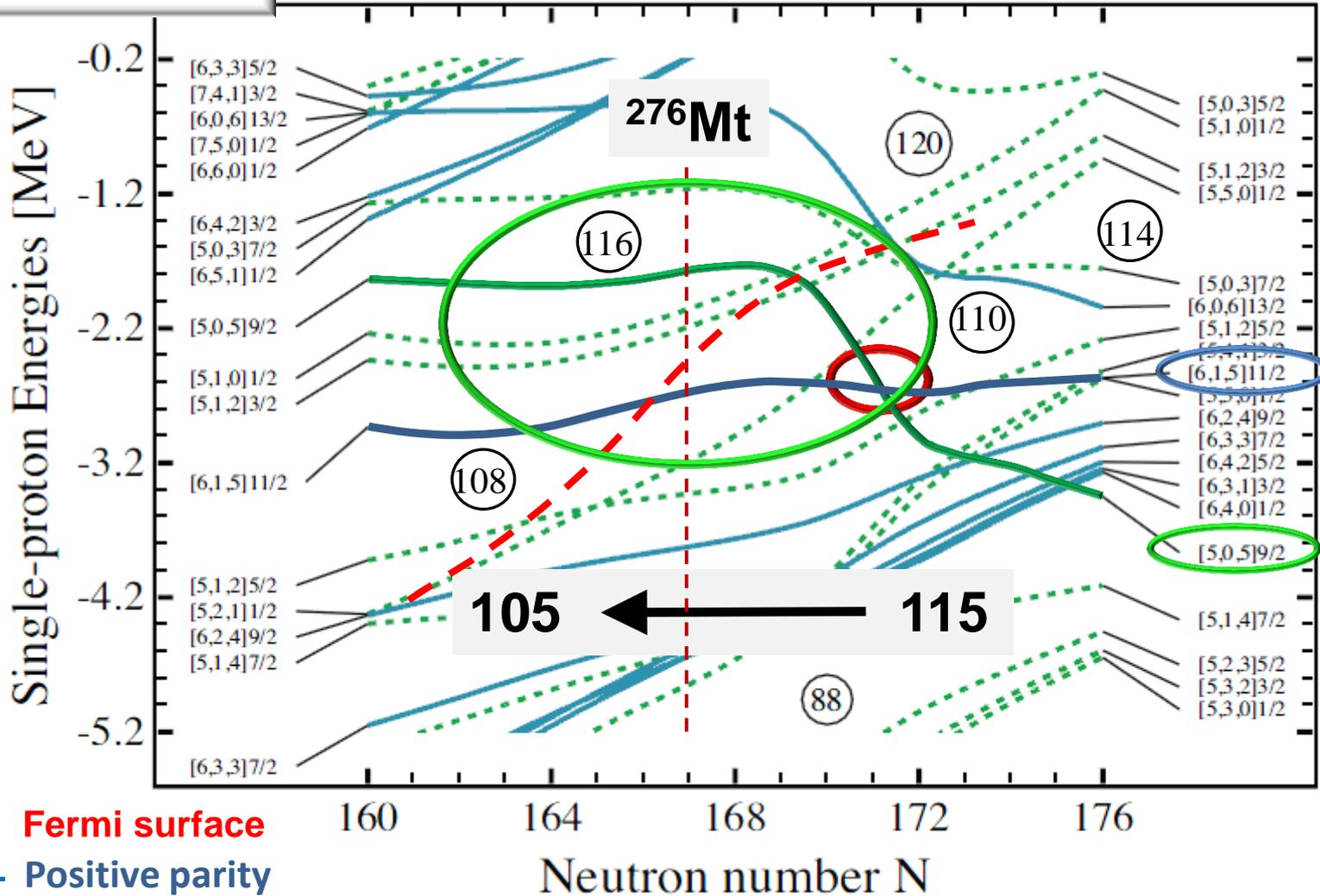


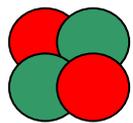


≡ Nilsson orbitals, protons



UNEDF1^{SO}





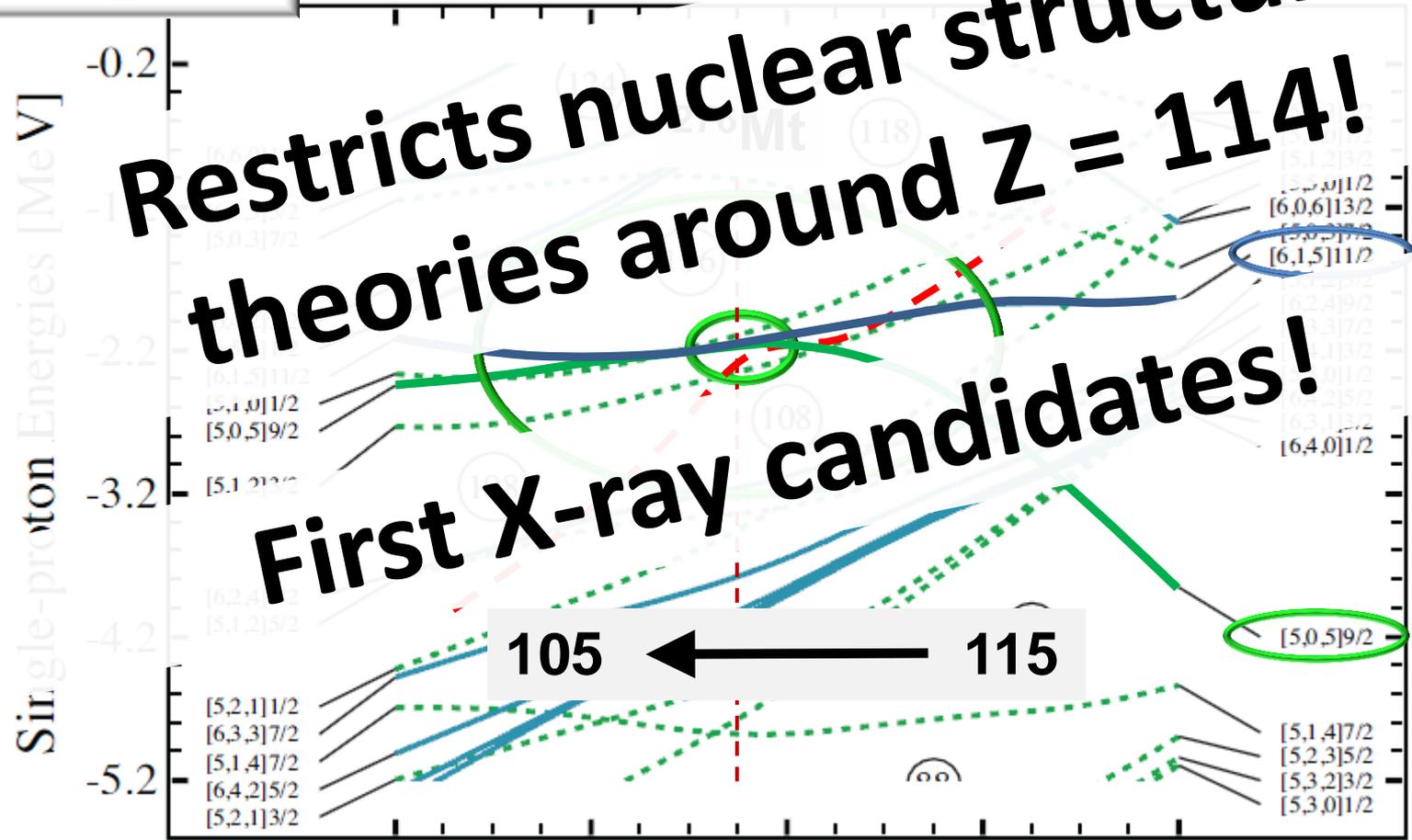
≡ Nilsson orbitals, protons

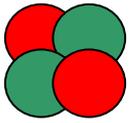


UNEDF1_L

Restricts nuclear structure theories around Z = 114!

First X-ray candidates!





Outlook

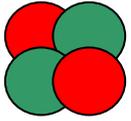


SHE - new sub-collaboration in **NUSTAR@FAIR**

- Nuclear structure
- Fingerprinting
- Mass measurements
- Search for new elements
- Chemical properties
- Laser spectroscopy
- Fusion reactions
- Transfer reactions

complements...

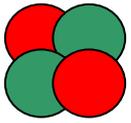




Outlook



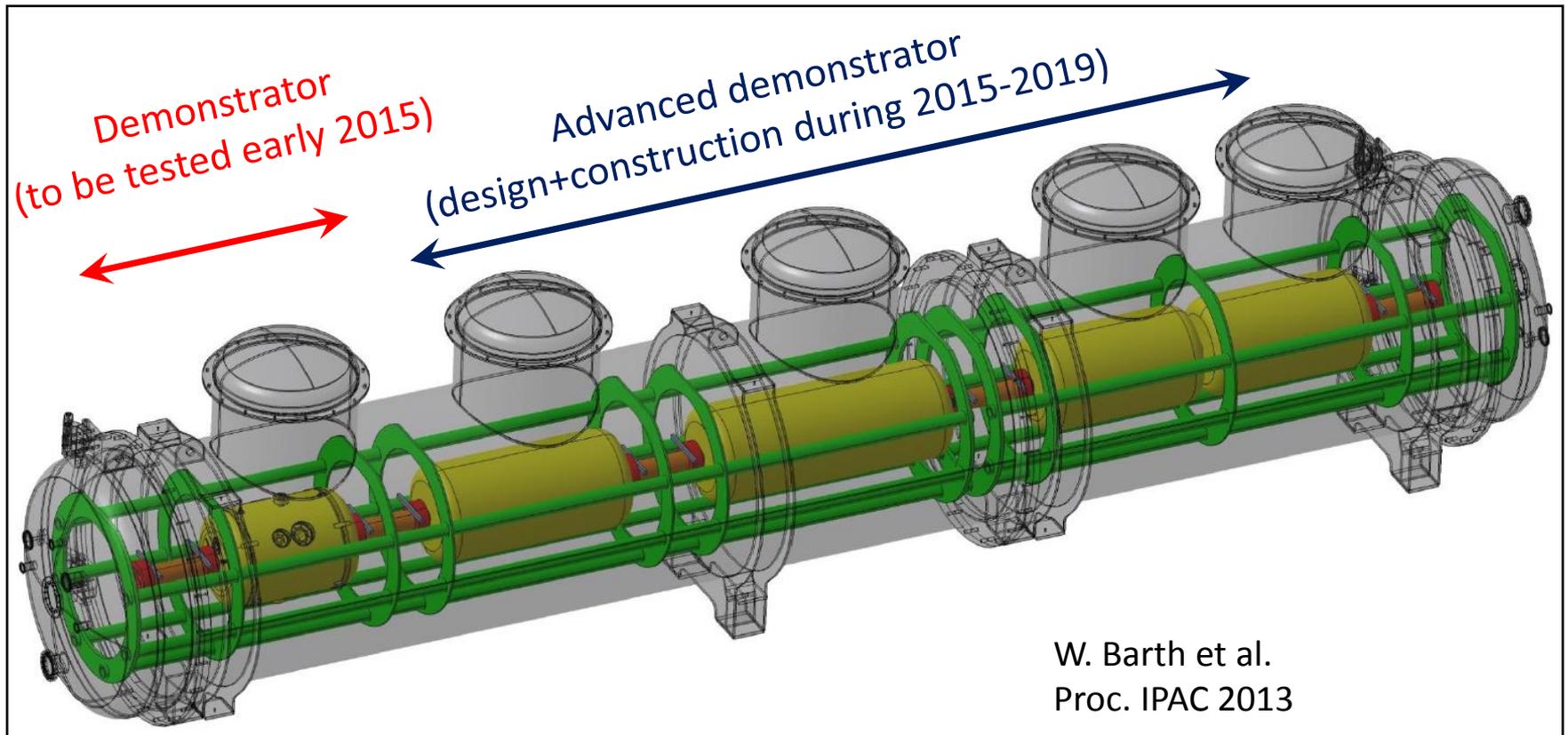
Since UNILAC is not suited for simultaneous acceleration of beams for SIS100 and SHE research...

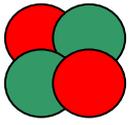


Outlook

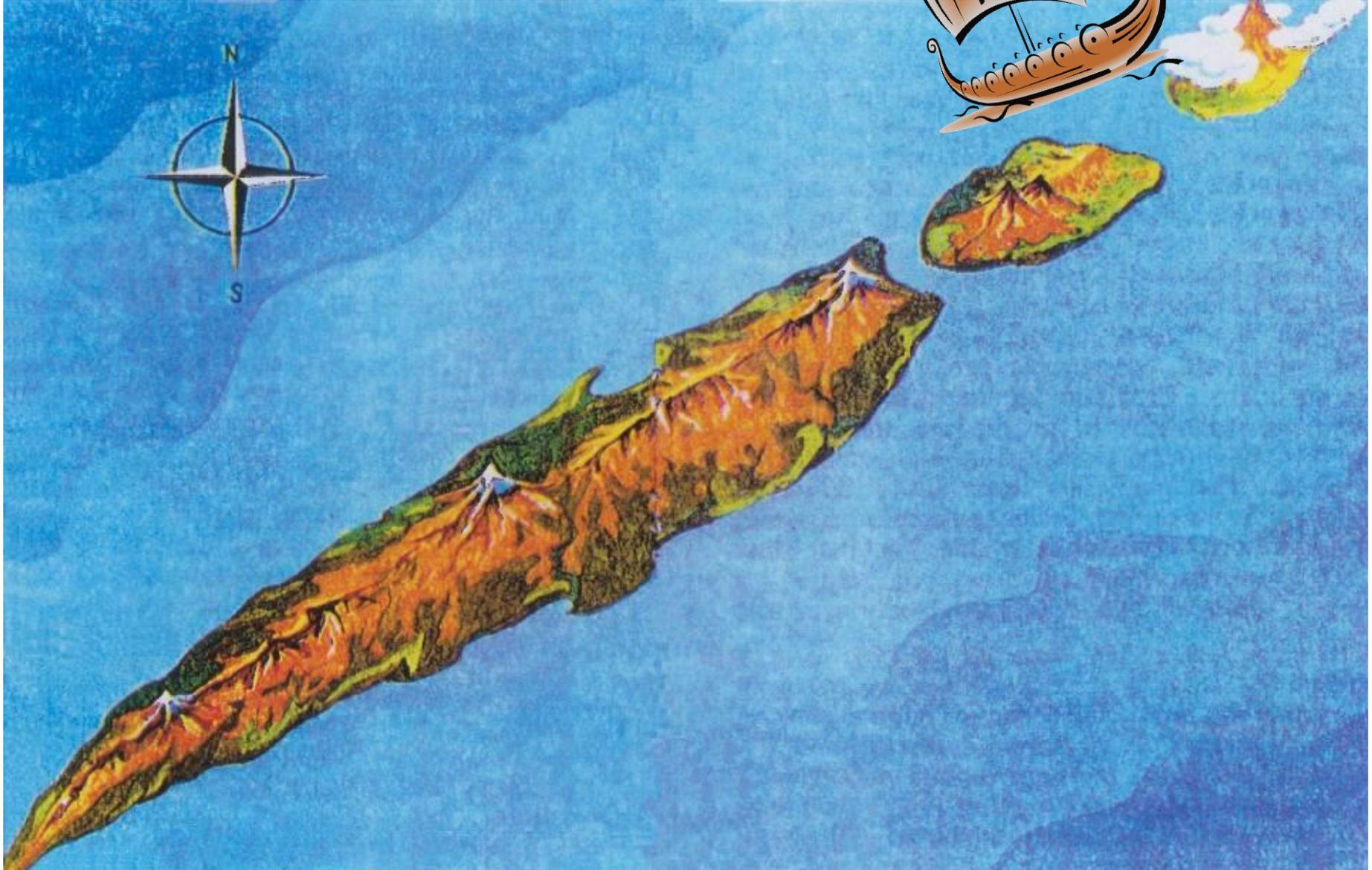
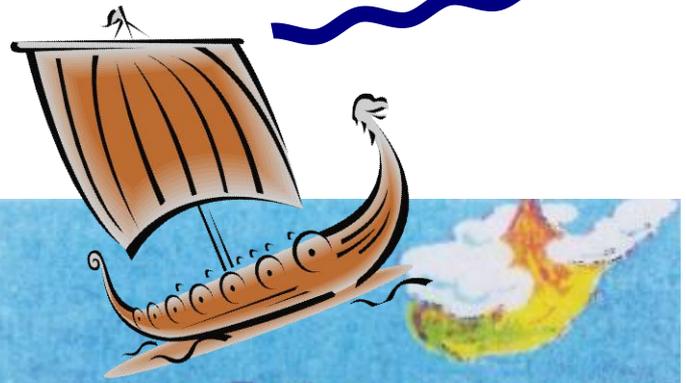


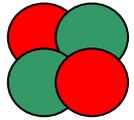
New **dedicated** sc cw LINAC is being built!





Summary





Thank you for
your attention!

