Quantum-State Selective Decay Spectroscopy of ^{213}Ra and ^{53}Co^{m}

Ch. Lorenz[1], L.G. Sarmiento[1], D. Rudolph[1], C. Fahlander[1], U. Forsberg[1], P. Golubev[1], R. Hoischen[1], N. Lalović[1,2], A. Kankainen[3], T. Eronen[3], L. Canete[3], D. Cox[3], J. Hakala[3], A. Jokinen[3], V. Kolhinen[3], J. Koponen[3], I. Moore[3], P. Papadakis[3], I. Pohjalainen[3], J. Reinikainen[3], S. Rinta-Antila[3], S. Stolze[3], A. Voss[3], M. Block[2,4,5], J. Gerl[2], D. Ackermann[2], M.L. Cortes[2], M. Dworschak[2], T. Habermann[2], F.P. Heßberger[2,4], J. Khuyagbaatar[2], I. Kojouharov[2], N. Kurz[2], D. Nesterenko[2], H. Schaffner[2], L.-L. Andersson[6], C. Droese[7], M. Eibach[5], J. Ketelaer[5]

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[2]GSI Helmholtzzentrum für Schwerionenforschung, D-64291 Darmstadt, Germany
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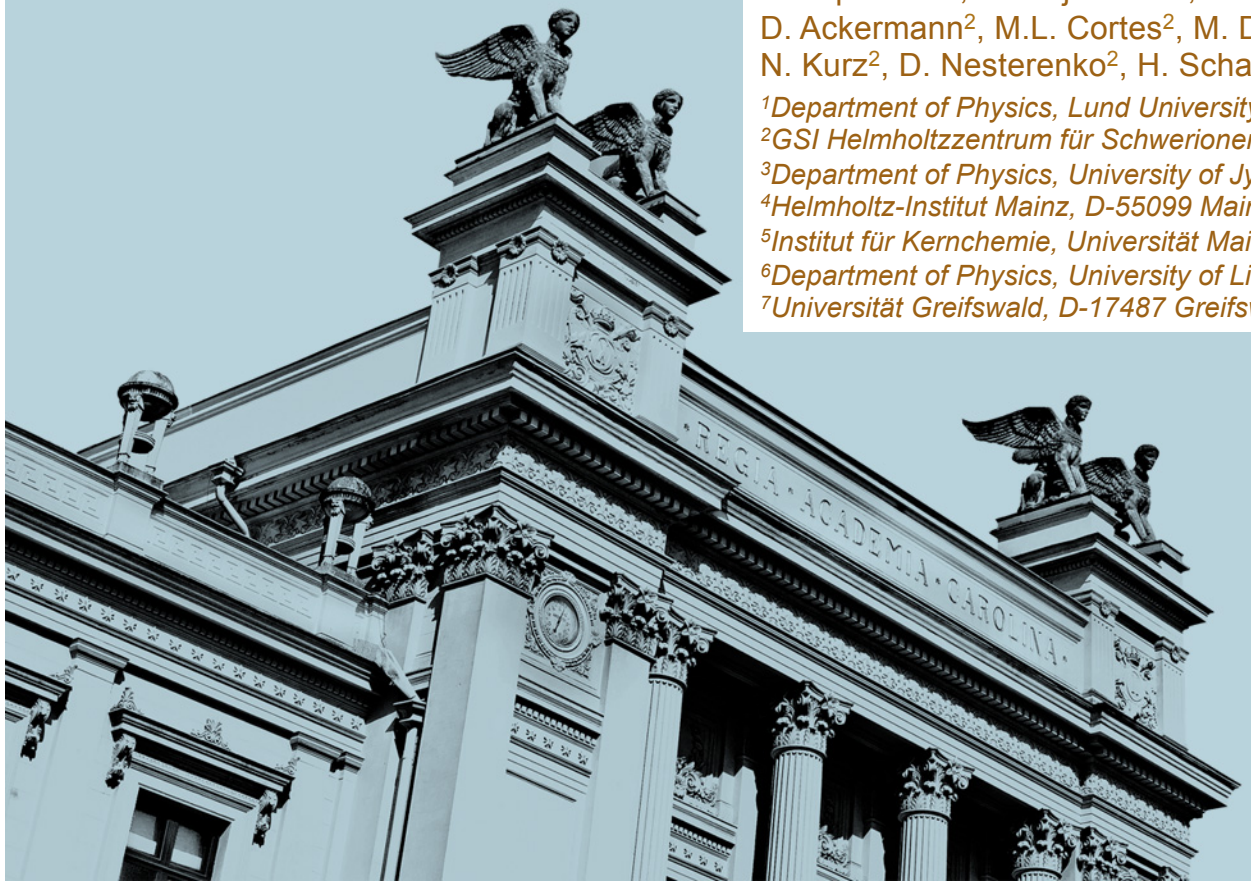
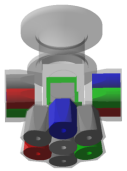
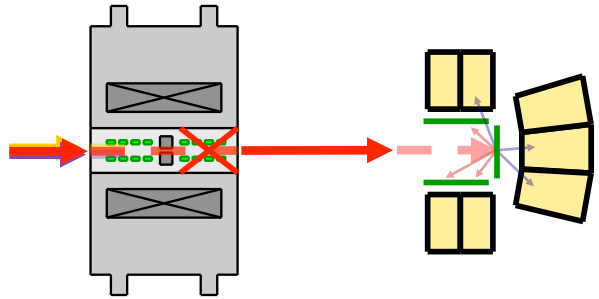
[4]Helmholtz-Institut Mainz, D-55099 Mainz, Germany
[5]Institut für Kernchemie, Universität Mainz, D-55128 Mainz, Germany
[6]Department of Physics, University of Liverpool, Liverpool, L69 7ZE, United Kingdom
[7]Universität Greifswald, D-17487 Greifswald, Germany



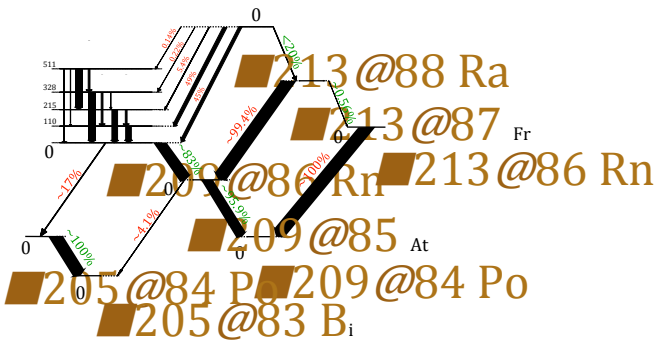
Outline

1. Geant4-aided Quantum-state Selective Decay Spectroscopy Setup and Simulation

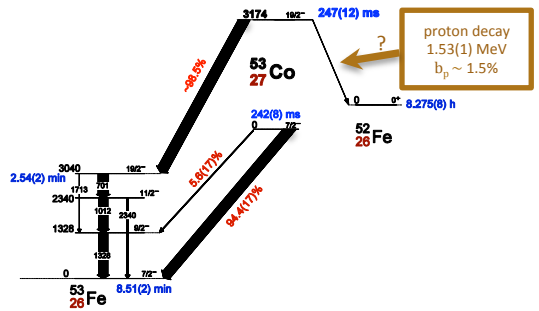




2. The Alpha Decay Branching in ^{213}Ra



3. The Proton Decay Branching in $^{53}Co^{m}$



4. Conclusion & Outlook

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Geant4-aided Quantum-state Selective Decay Spectroscopy

Setup and Simulation

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Incoming Beam
'Cocktail'

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Setup and Simulation

Penning Trap

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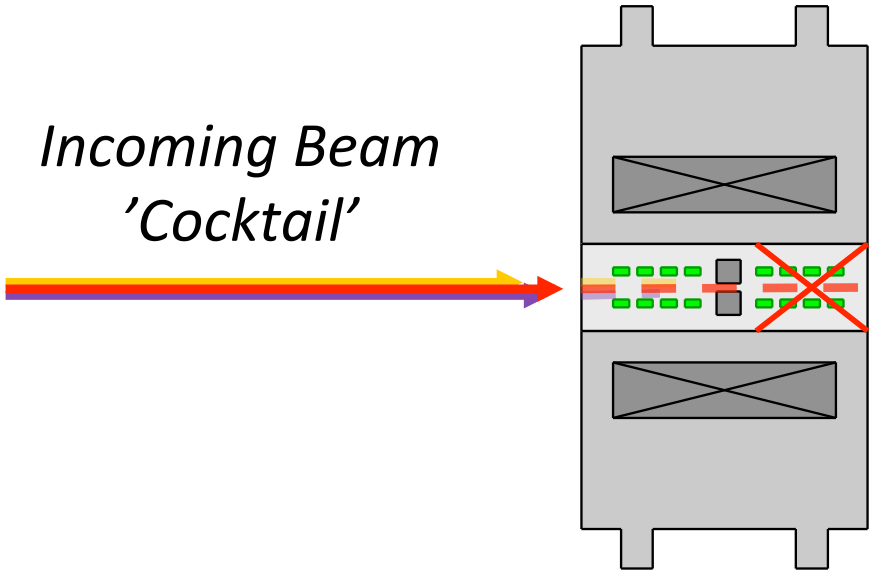

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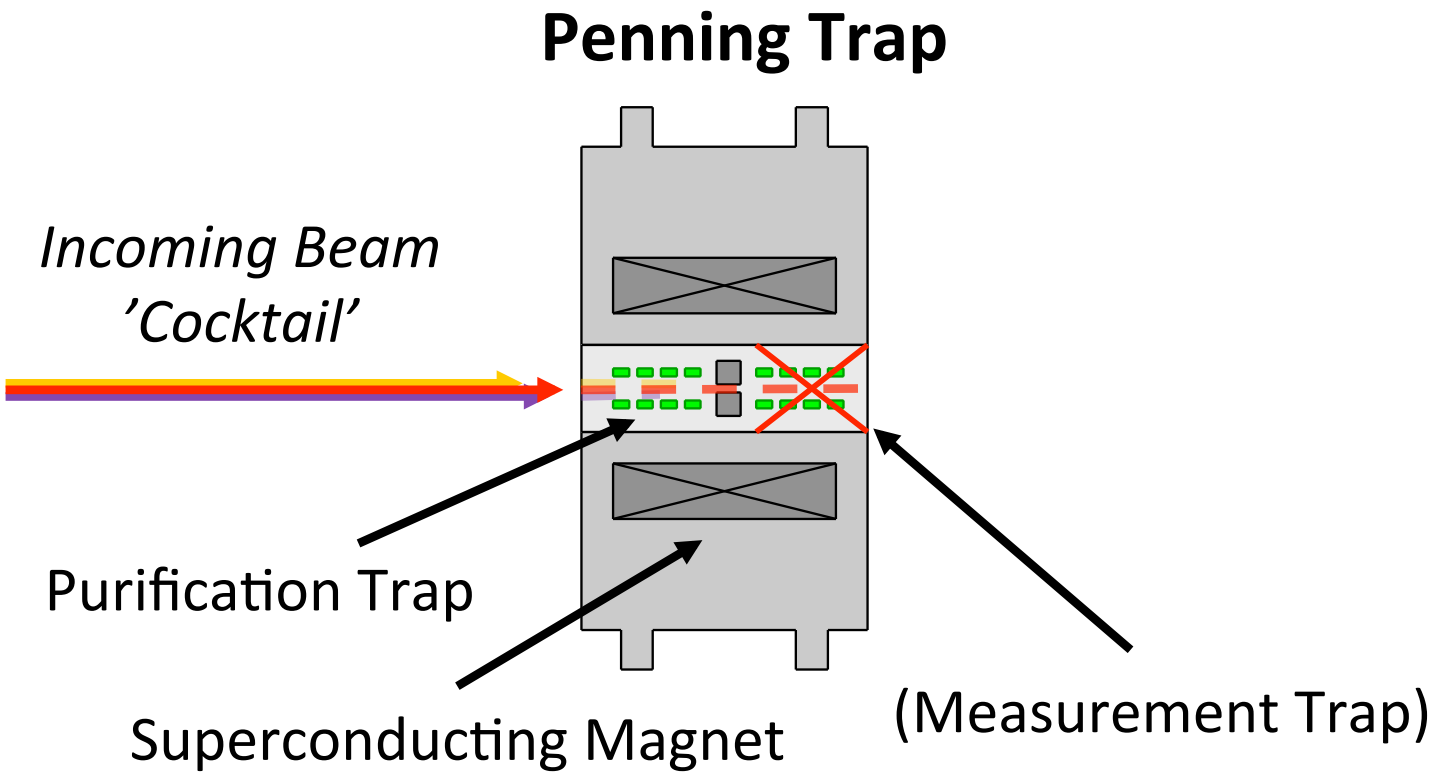

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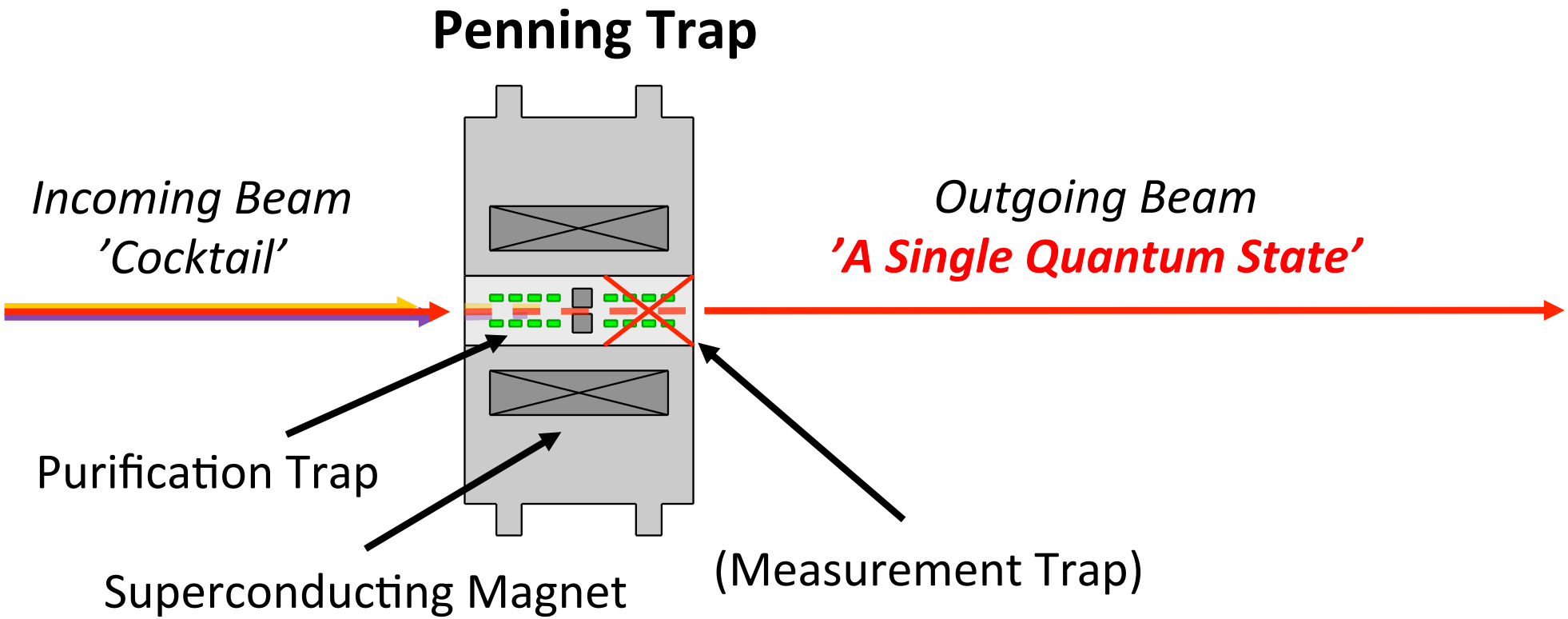

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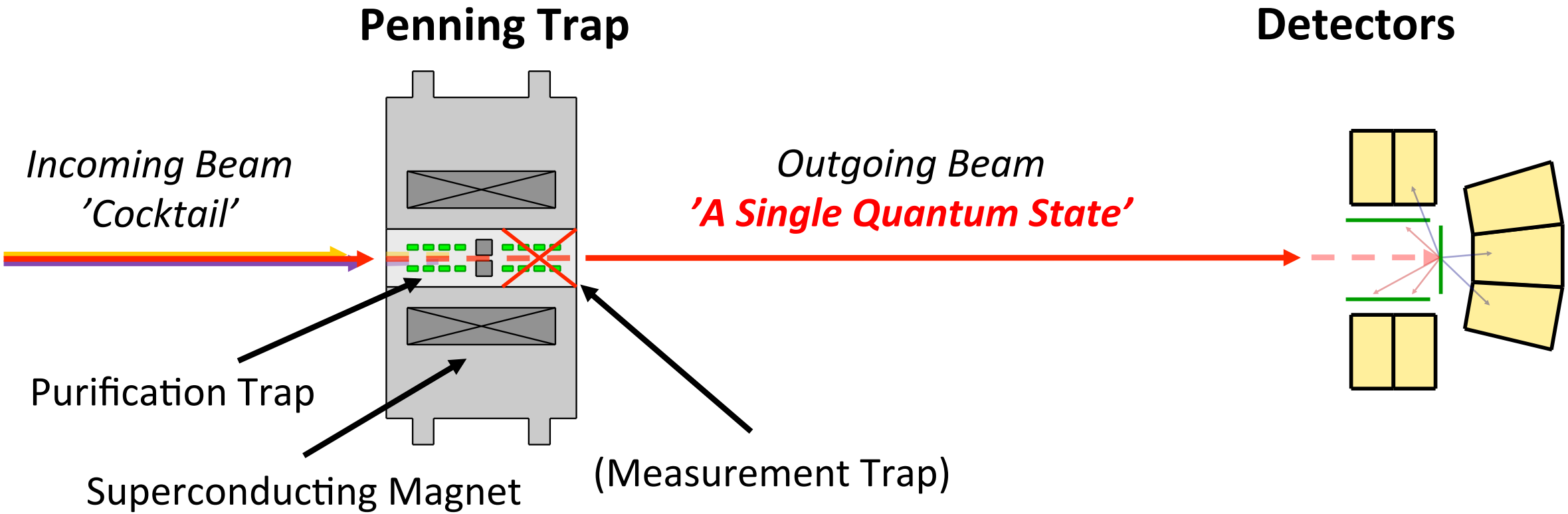

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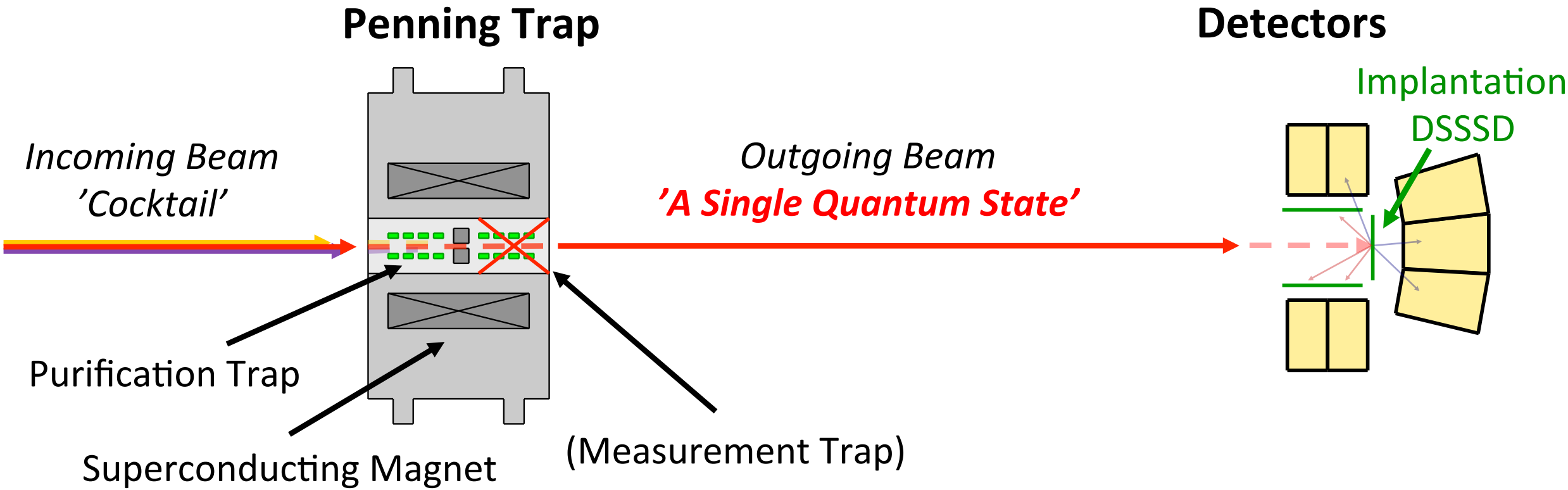

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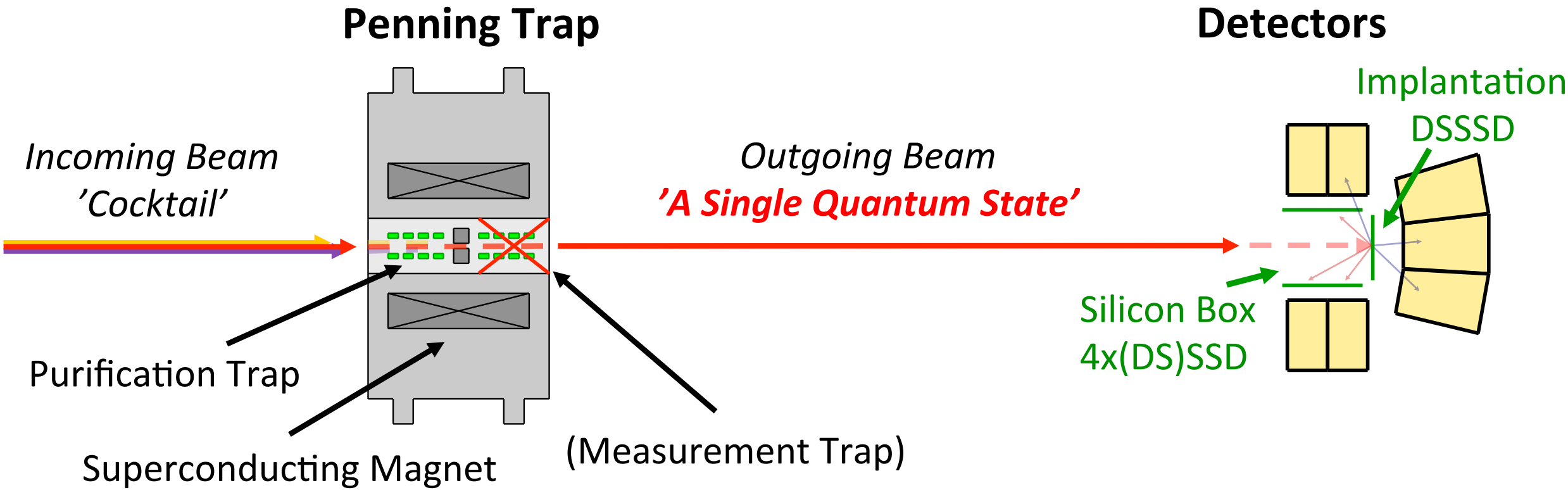

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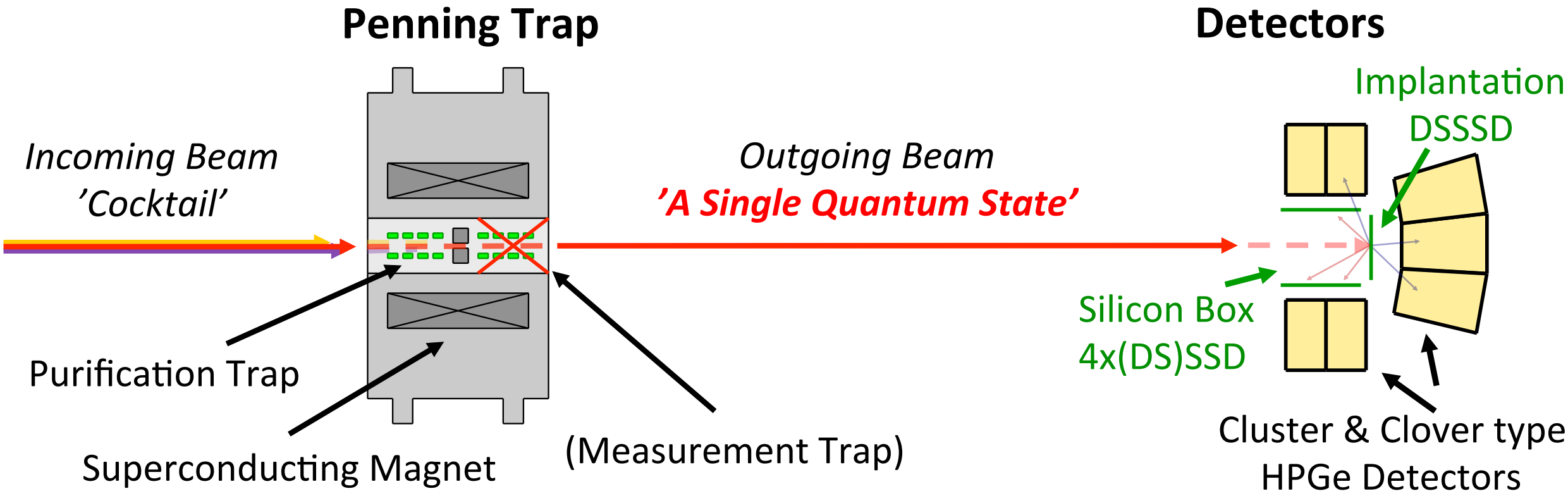

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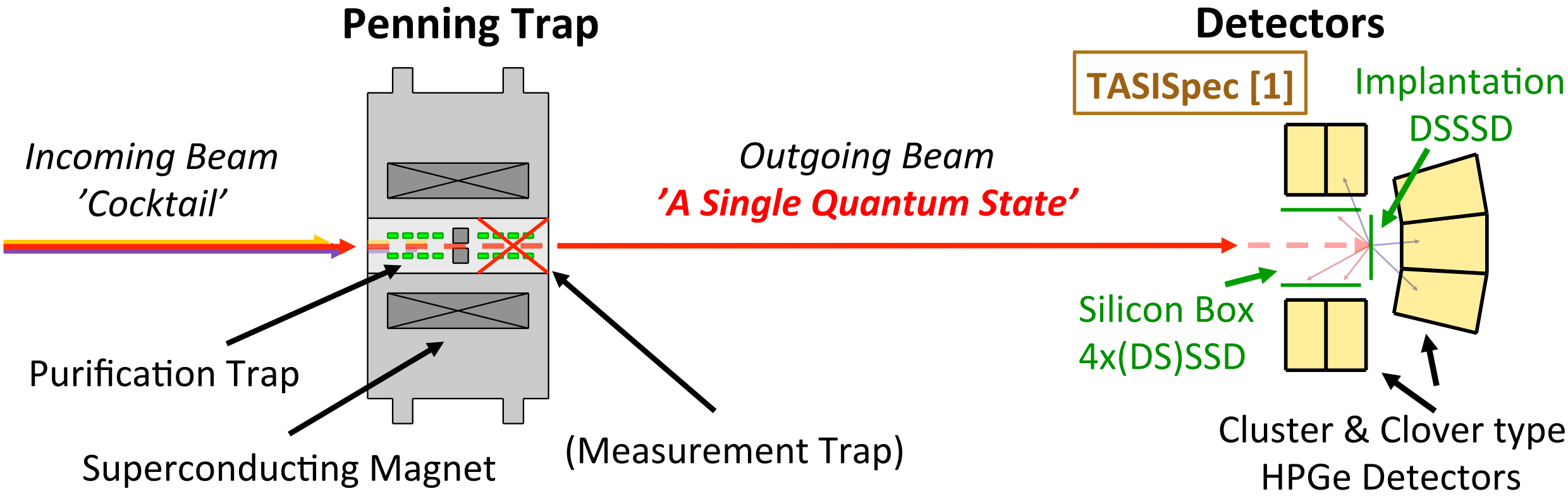

[1] L.-L. Andersson et al., Nucl. Instrum. Meth. A 622, 164 (2010).

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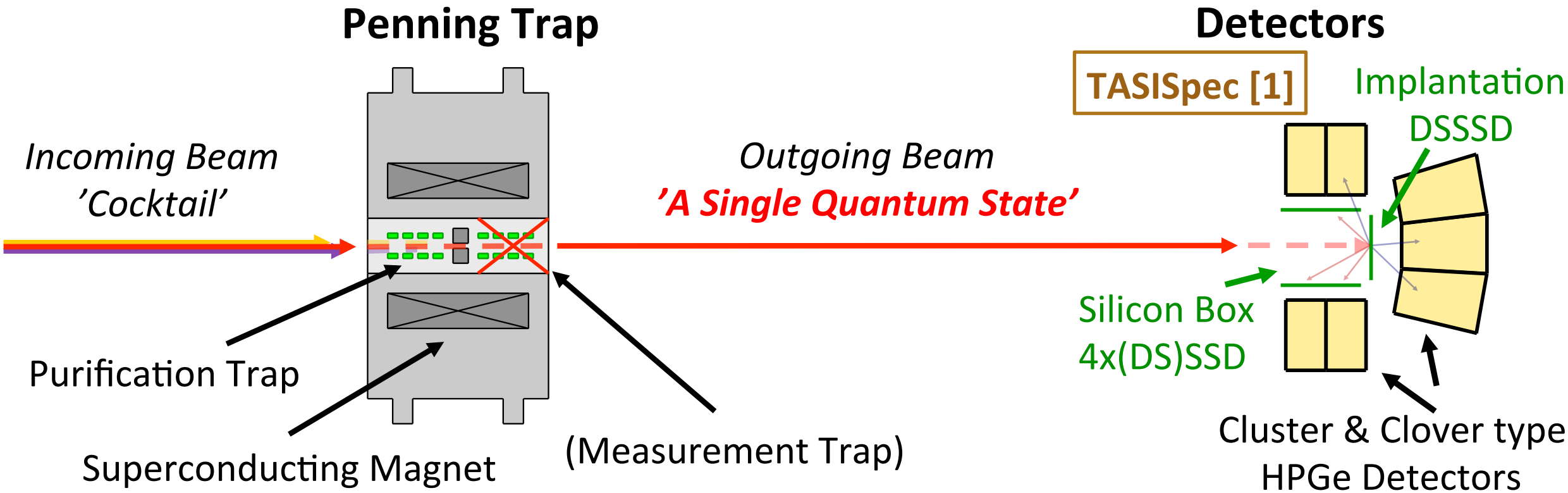

The whole detector setup is implemented in Geant4 [2]

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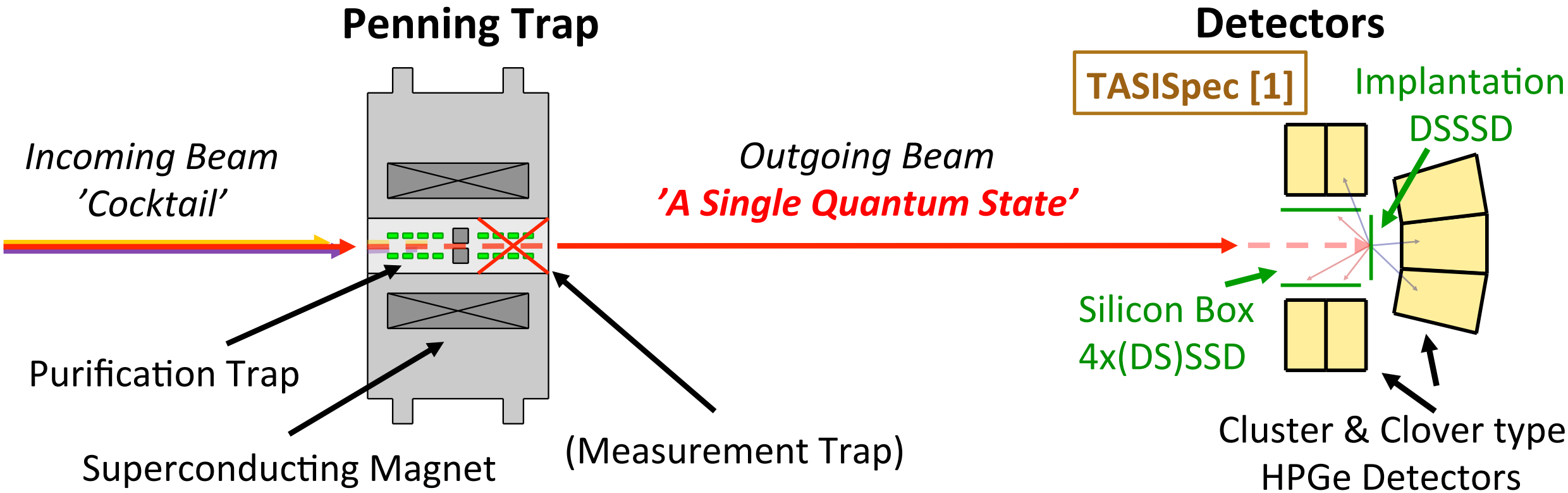

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Tune the parameters:

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→ …

→ Until it is self-consistent …

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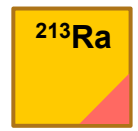
The Alpha Decay Branching in ^{213}Ra

The Alpha-Decay Branching in ^{213}Ra

0 $1/2^-$ 2.74(6) min

213@88 Ra



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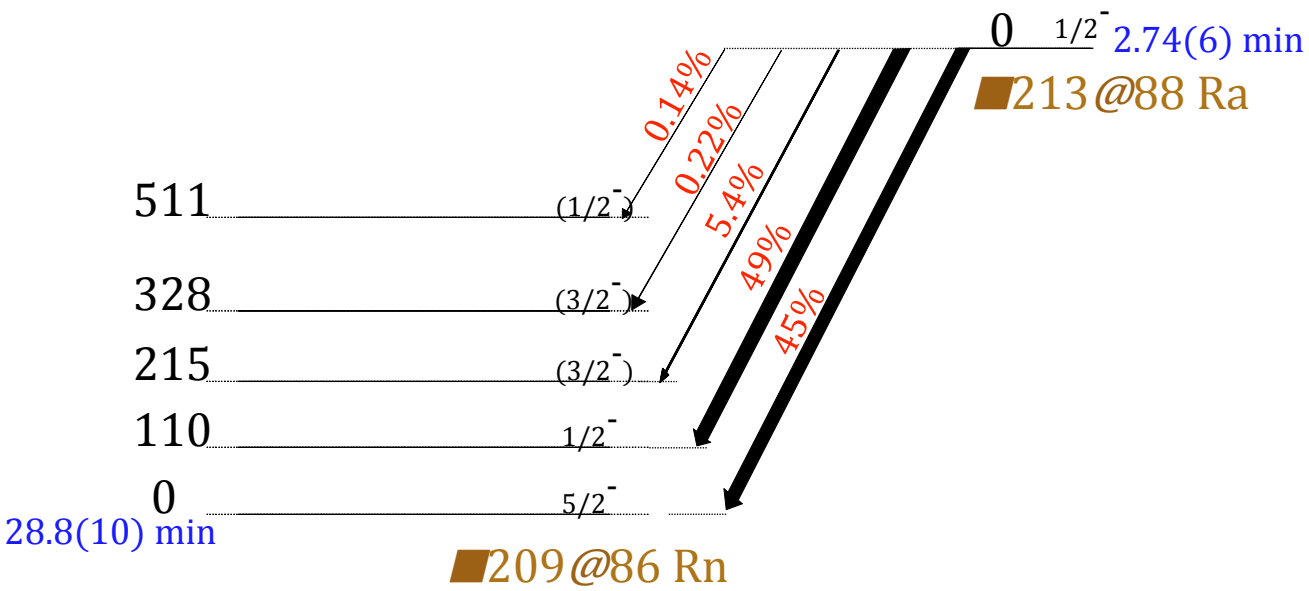

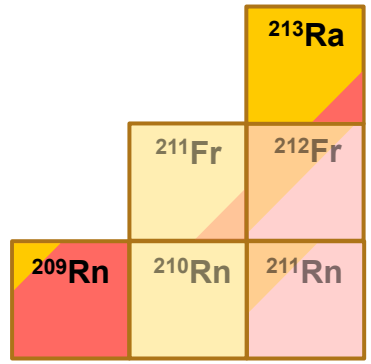

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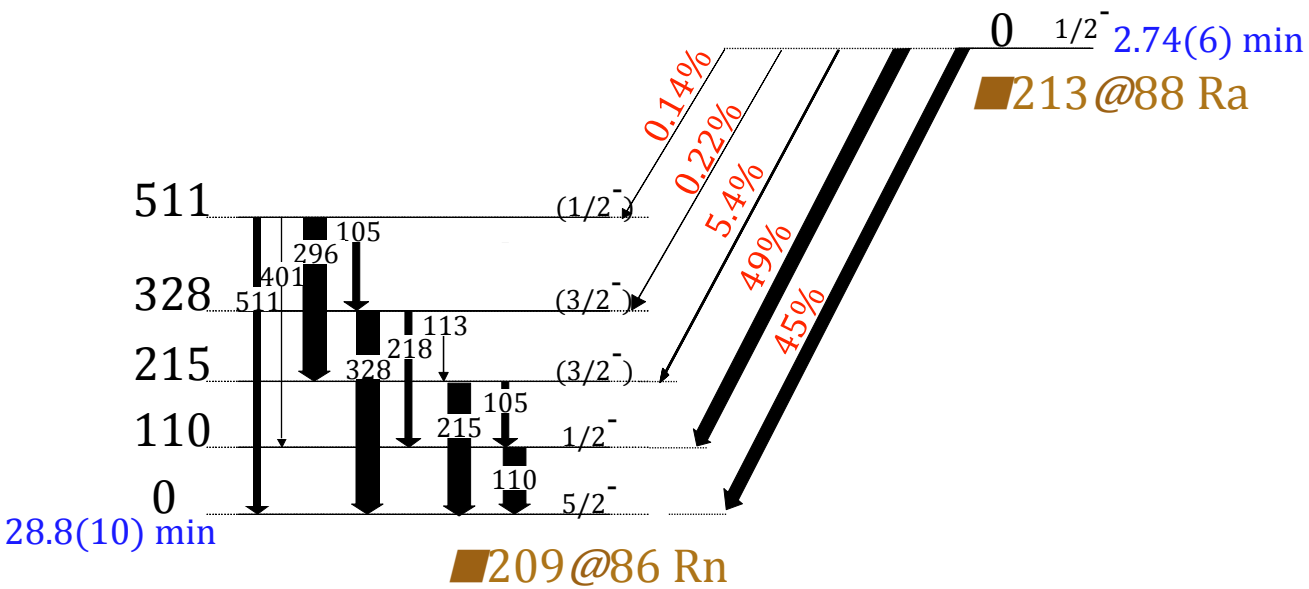

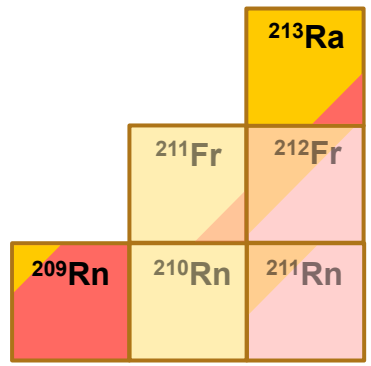

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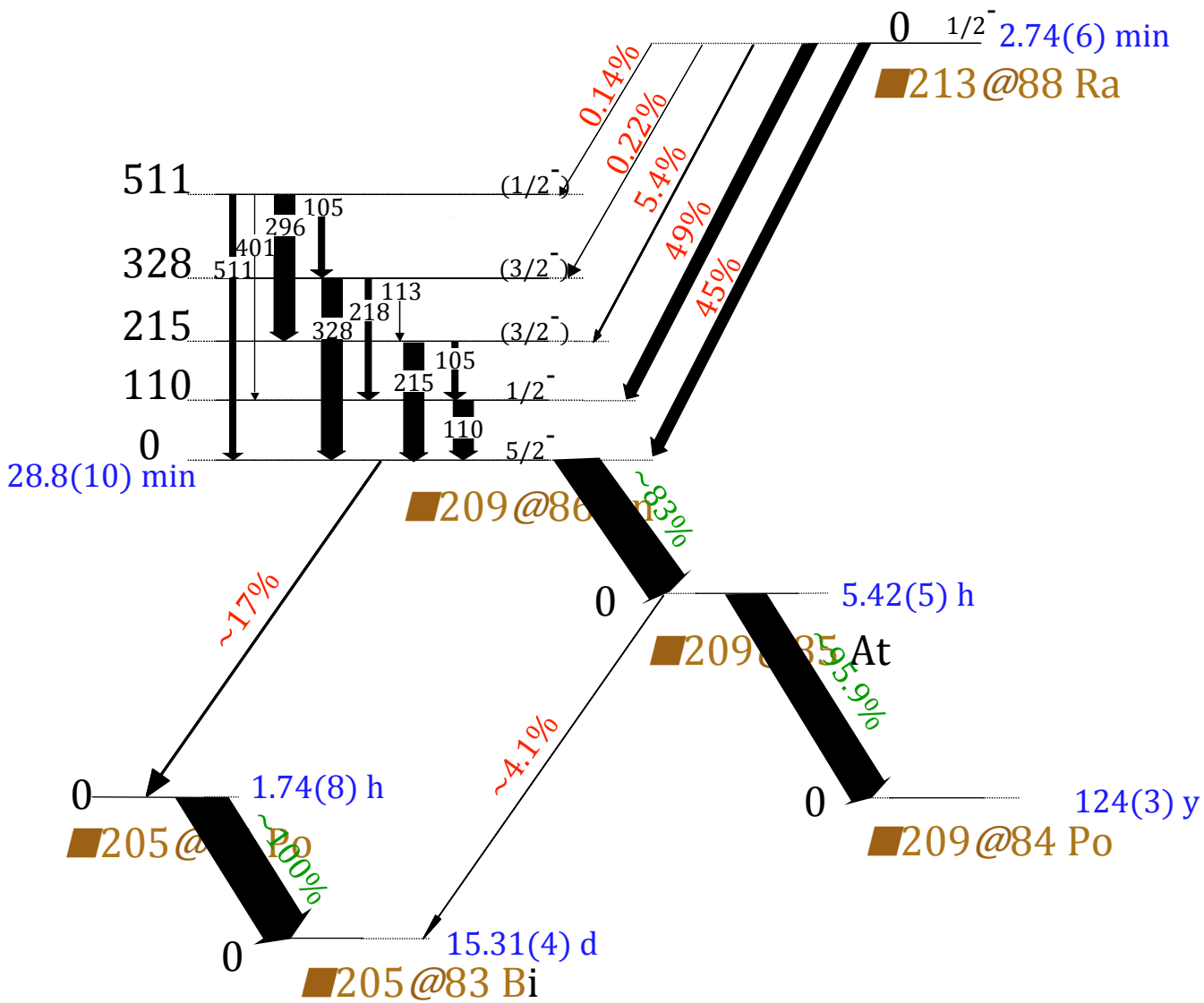

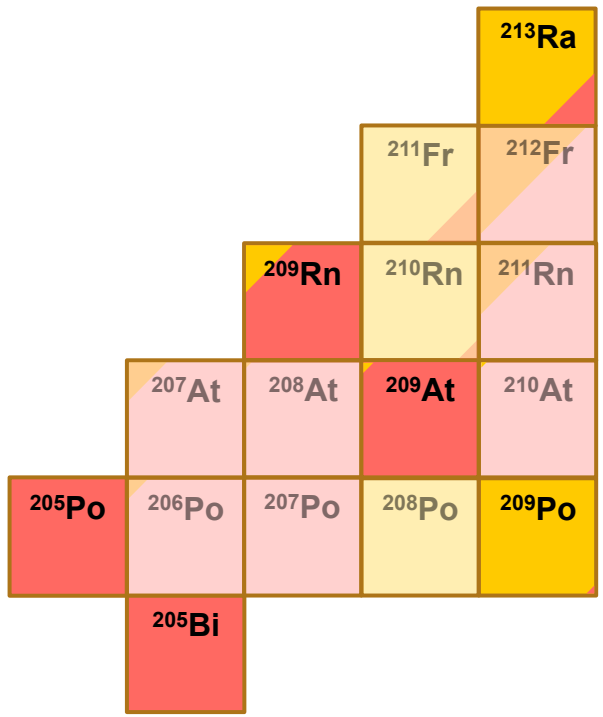

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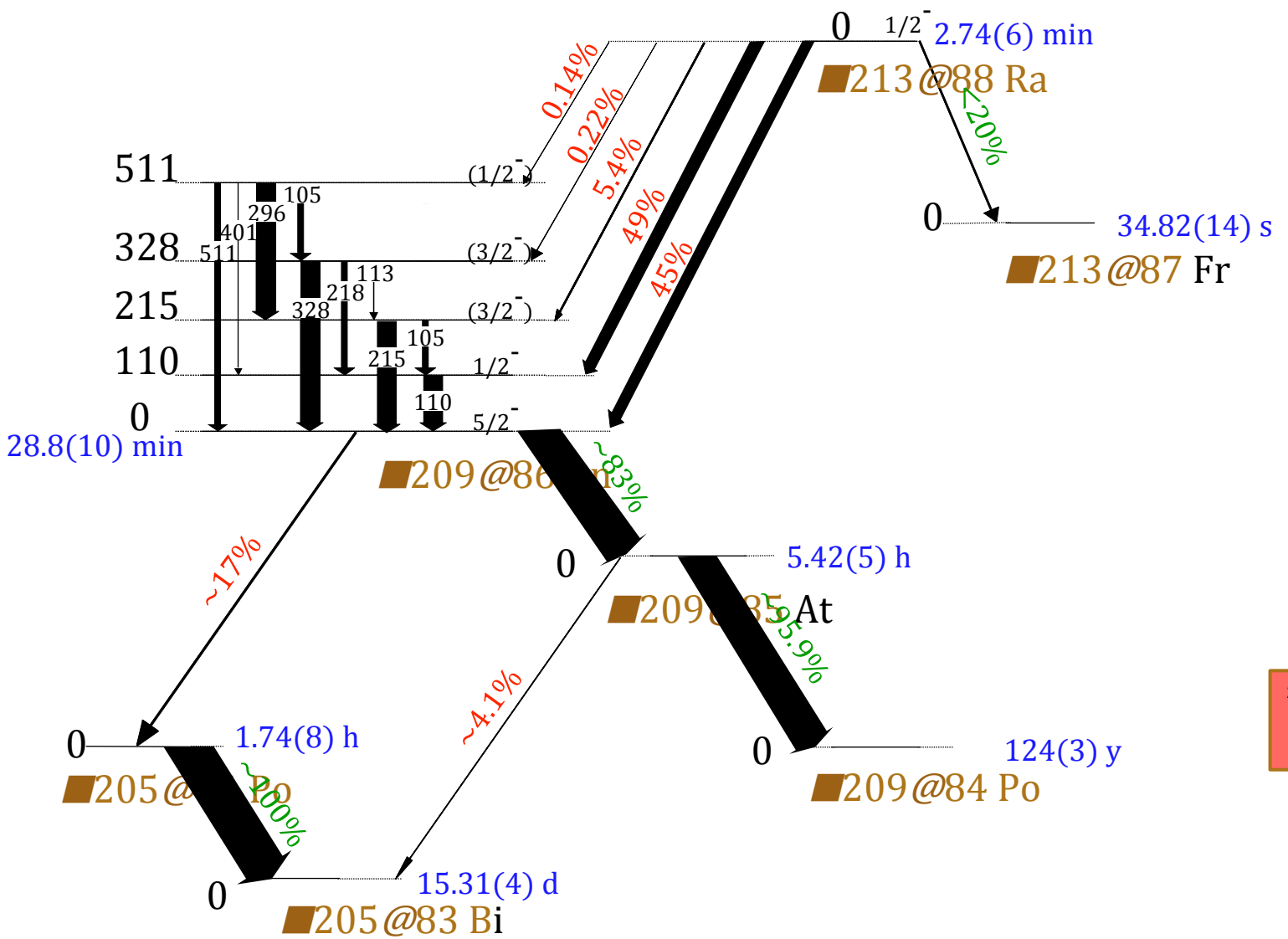

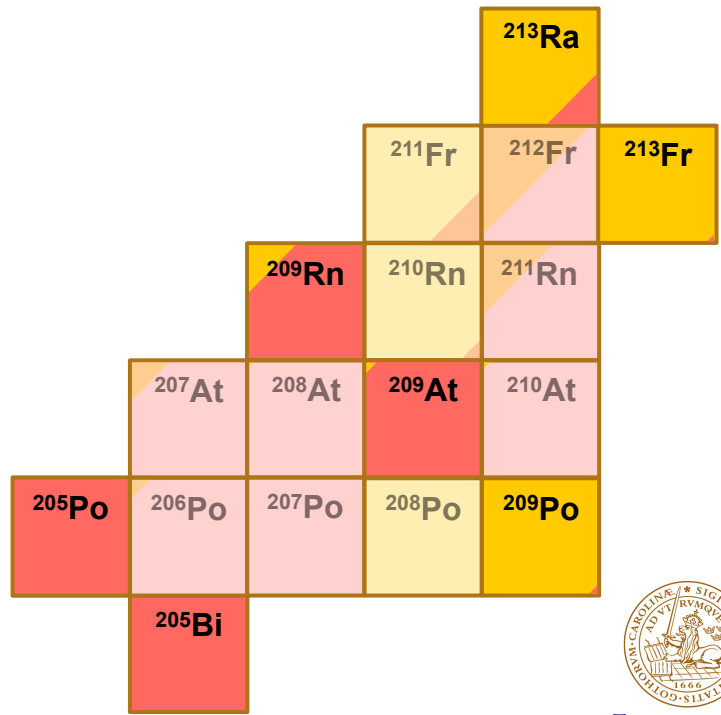

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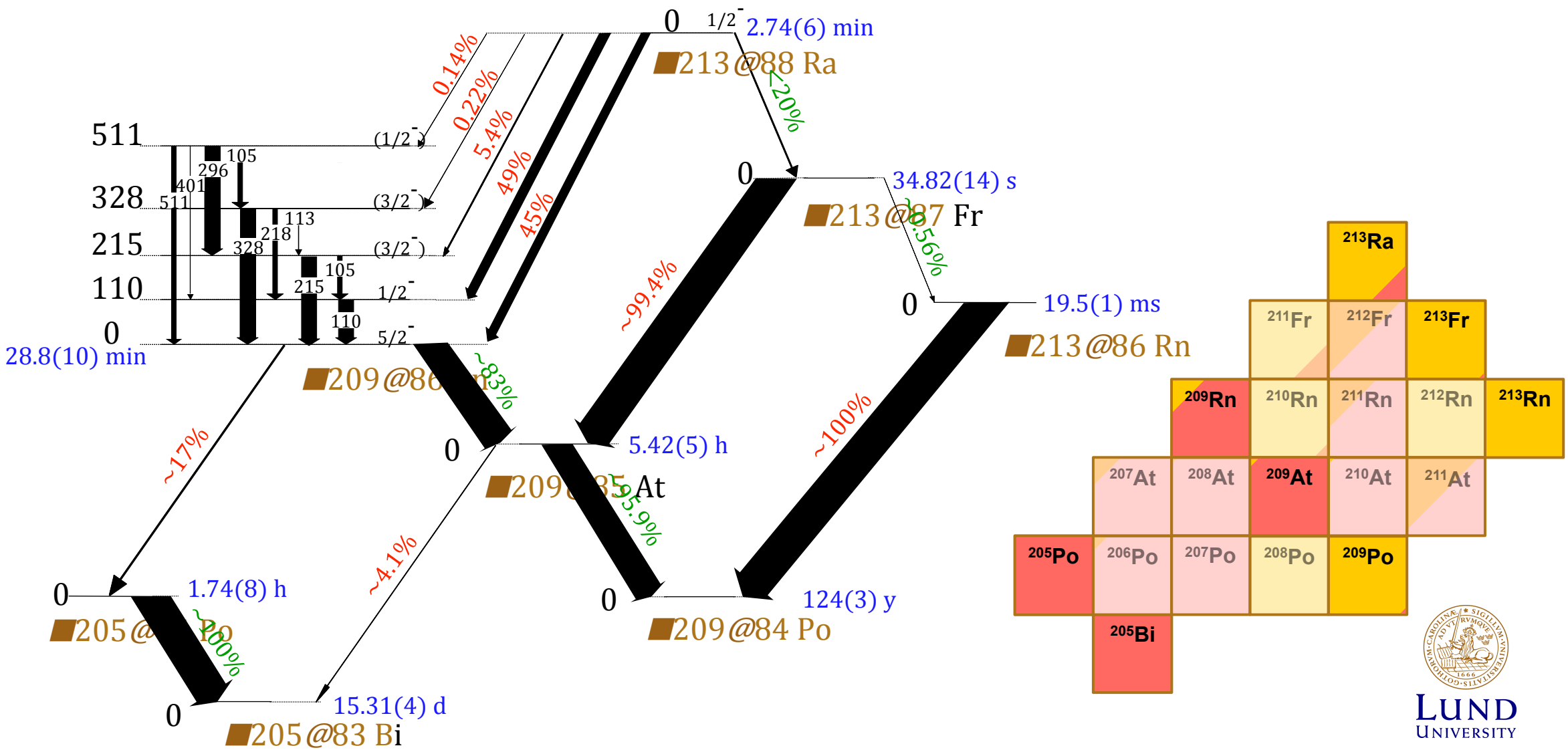

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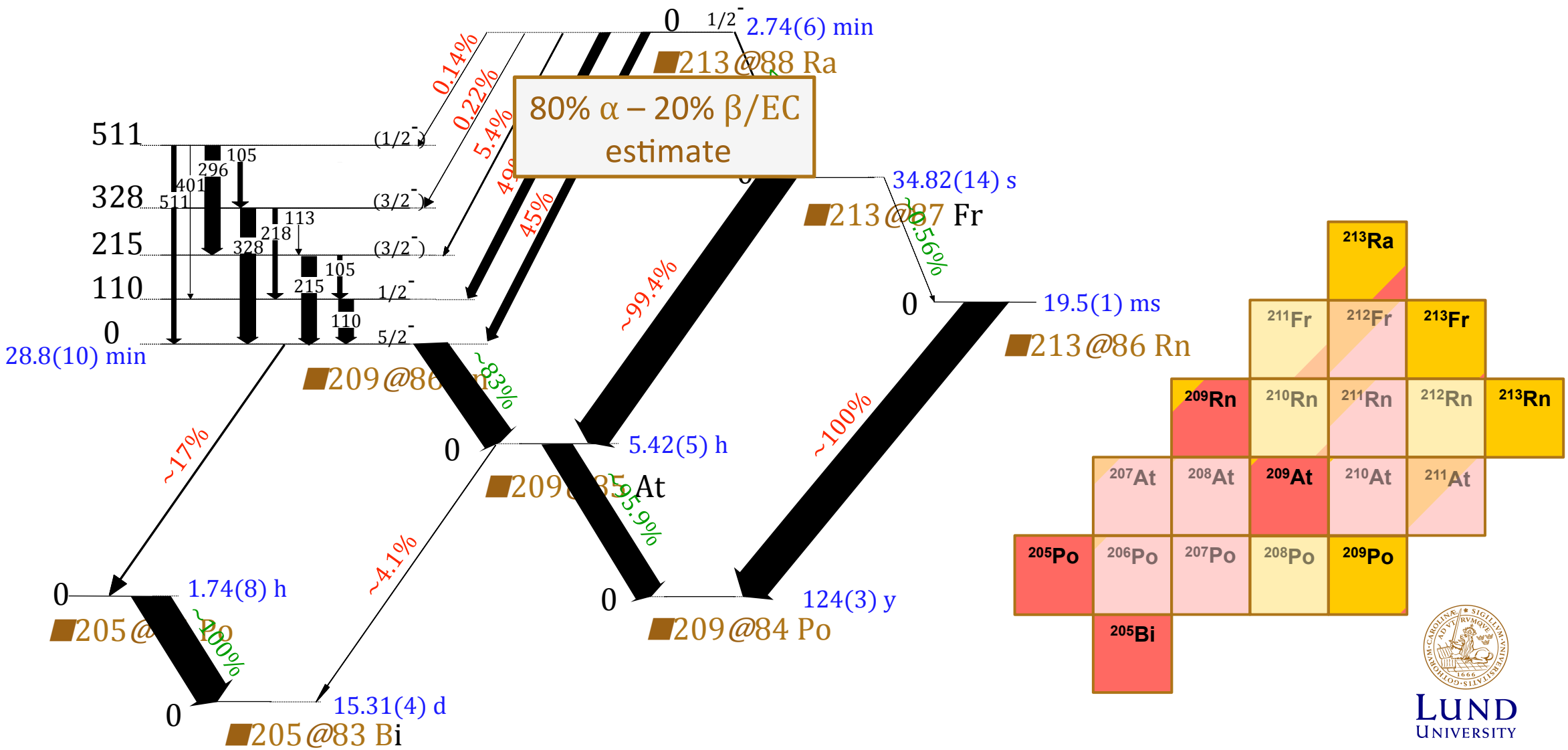

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The Alpha Decay Branching in ^{213}Ra

- Many quantities in the ^{213}Ra decay path date back to the first studies by K. Valli et al. in 1967/1968 [3]

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- Experiment @ GSI Darmstadt in 2009
- *Quantum-state selective* beam from SHIPTRAP (mass selection!) [6]: 100% pure beam of ^{213}Ra ground state

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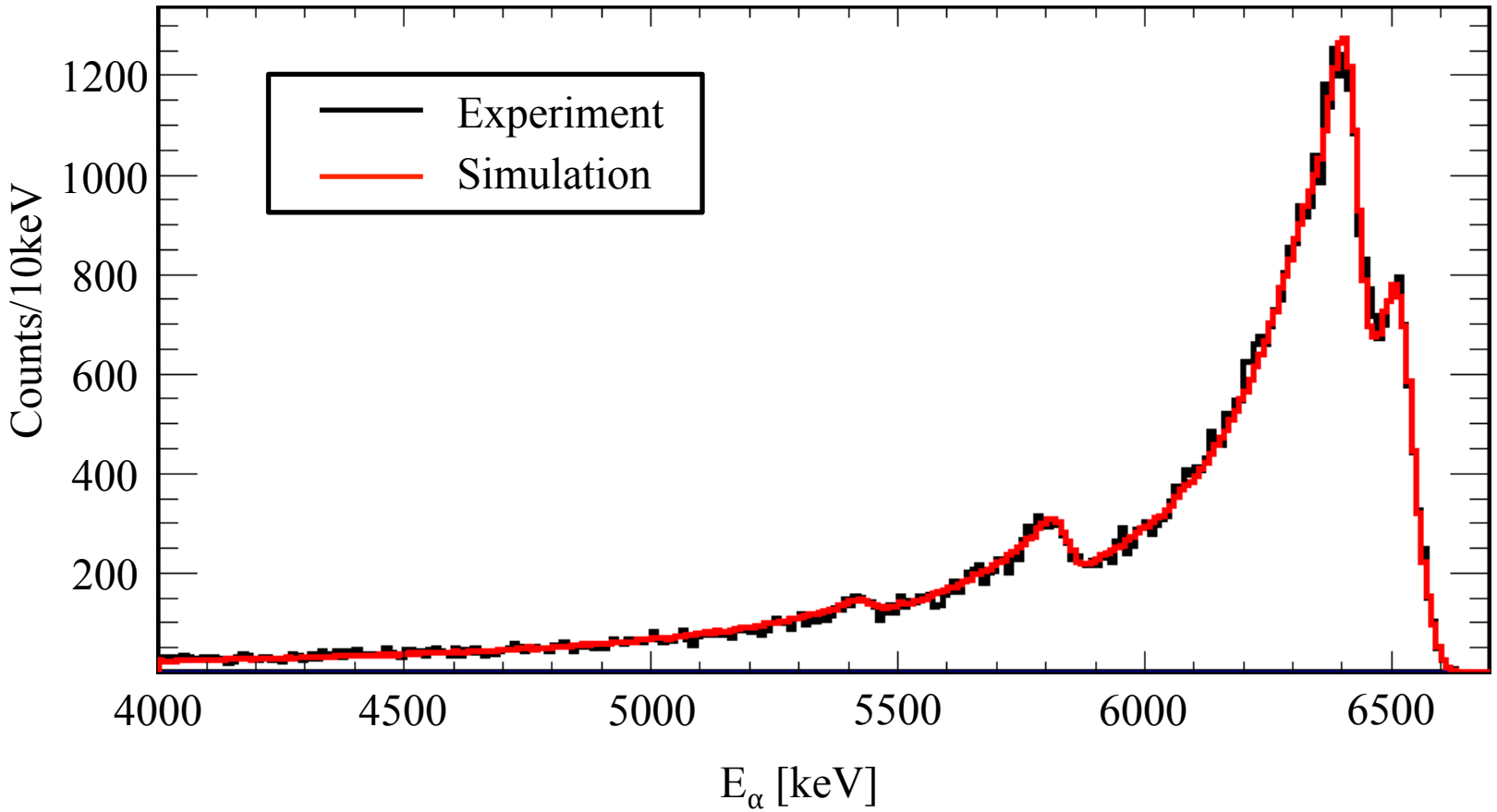
The Alpha Decay Branching in ^{213}Ra

→ Particle (α) spectrum



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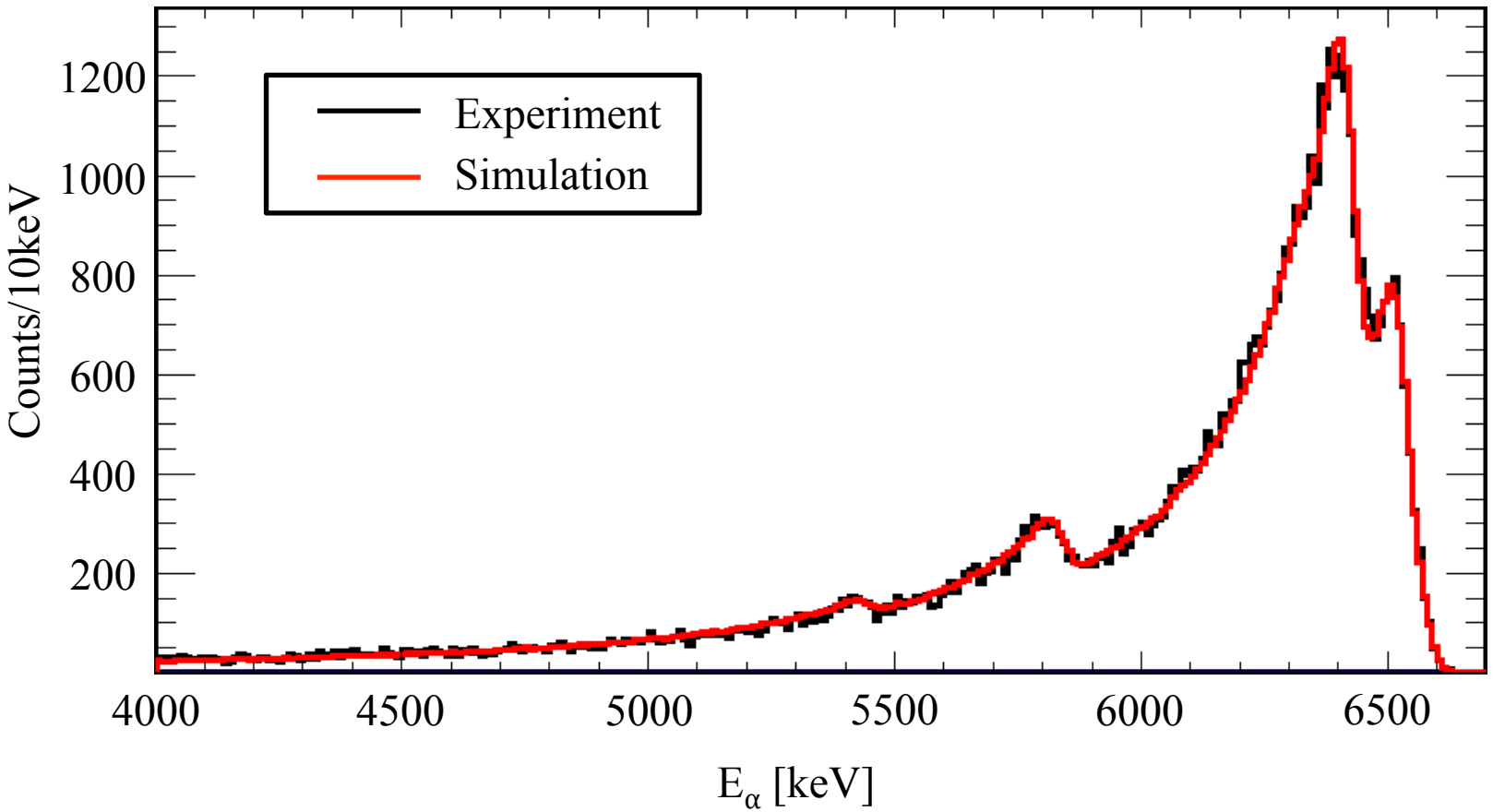

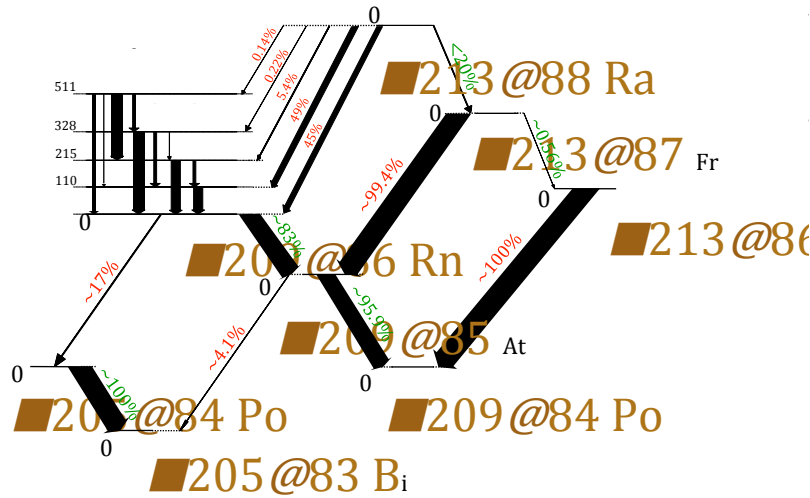

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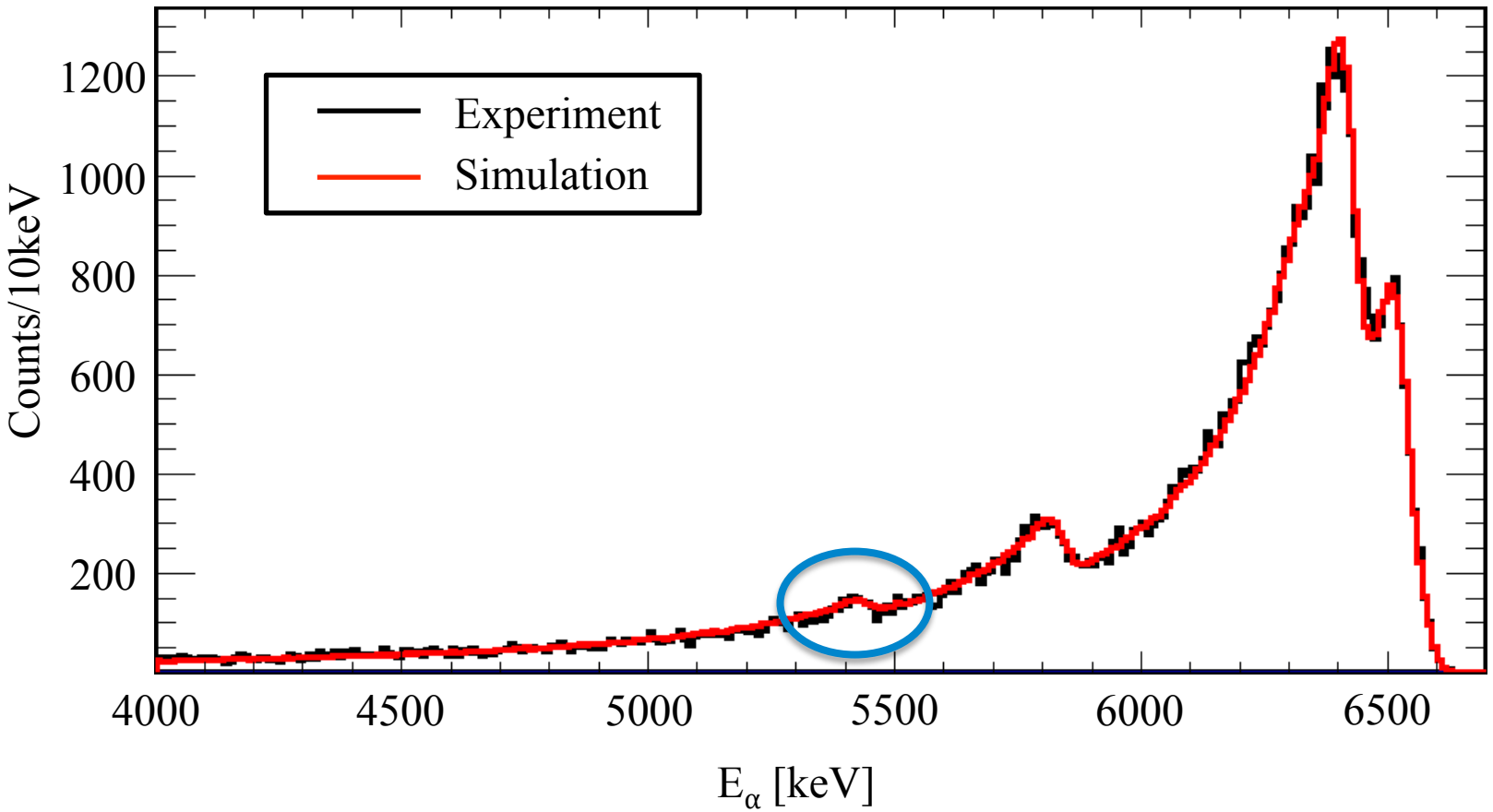

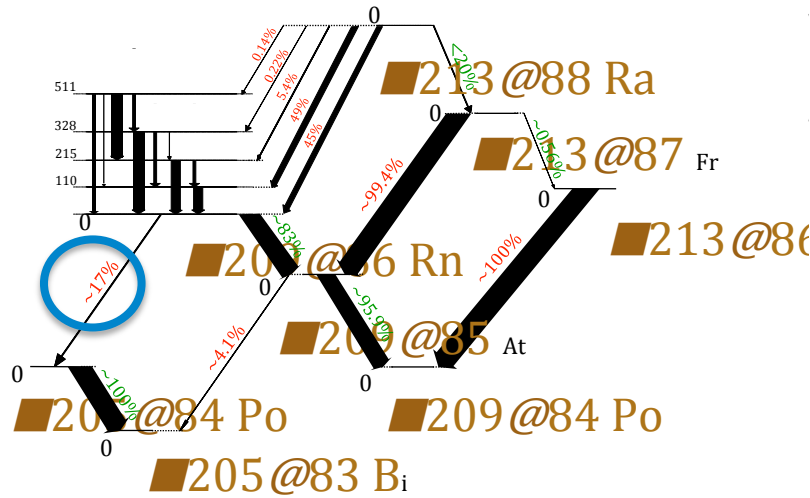

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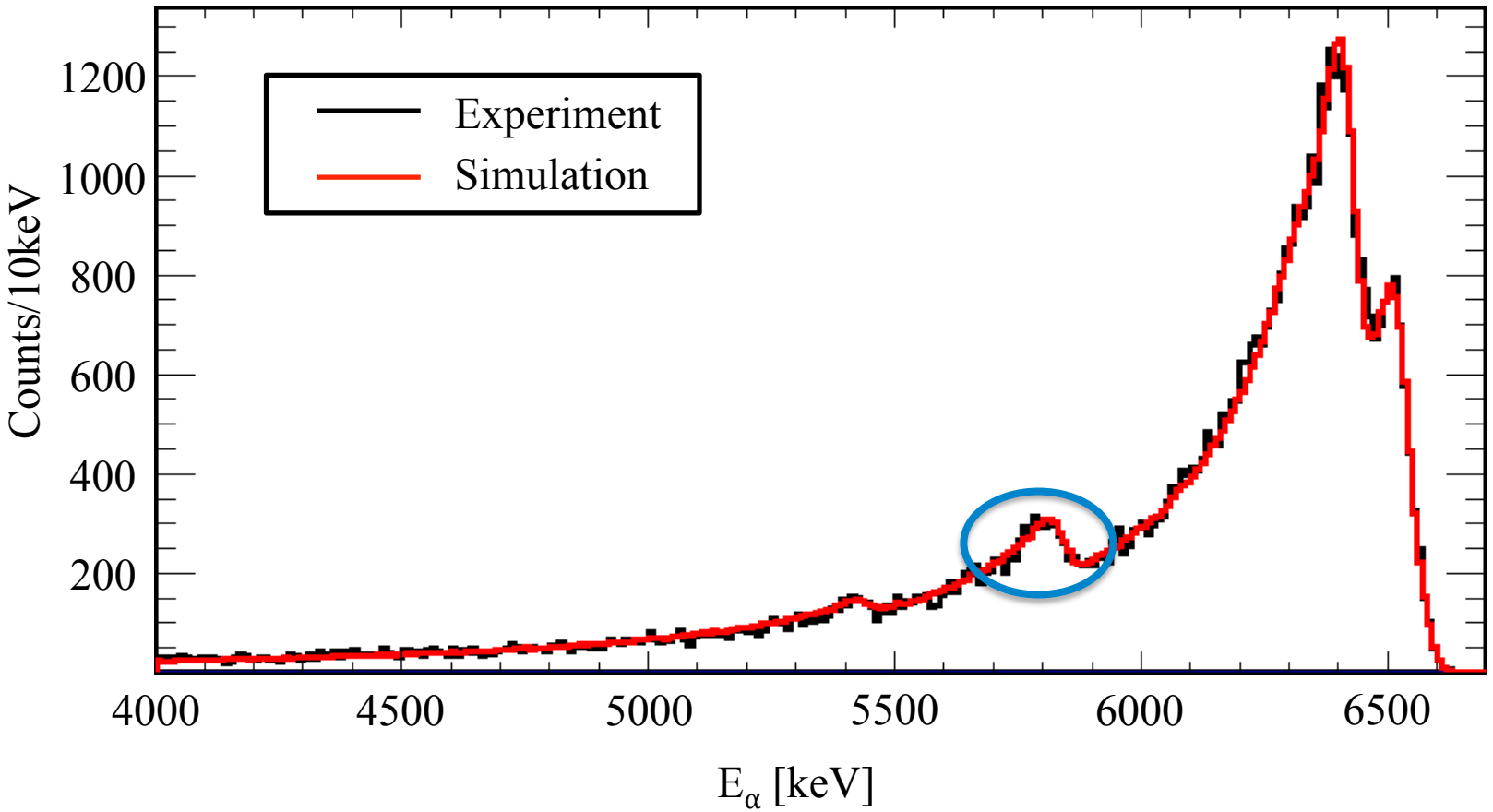

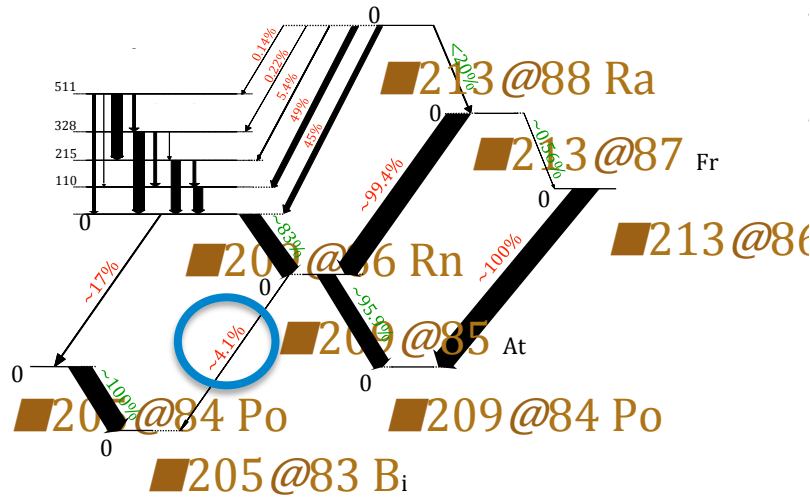

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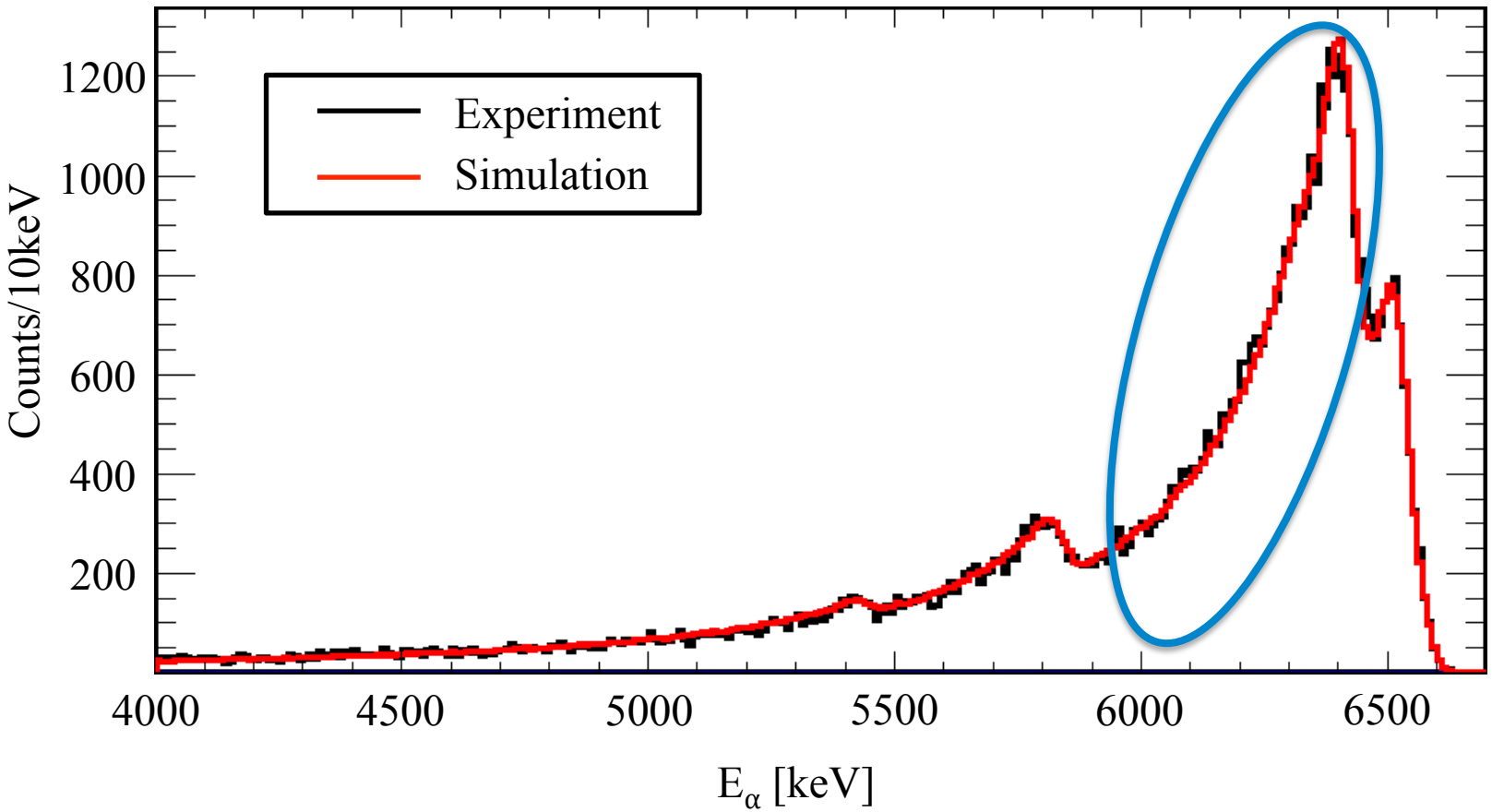

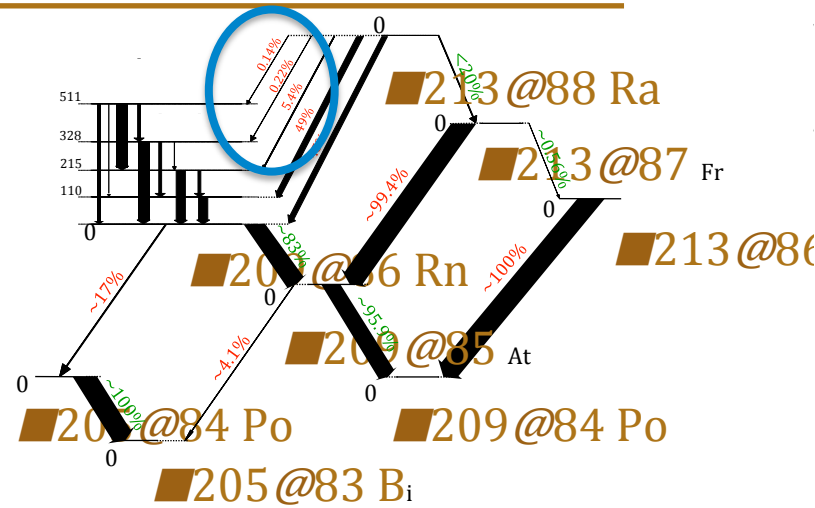

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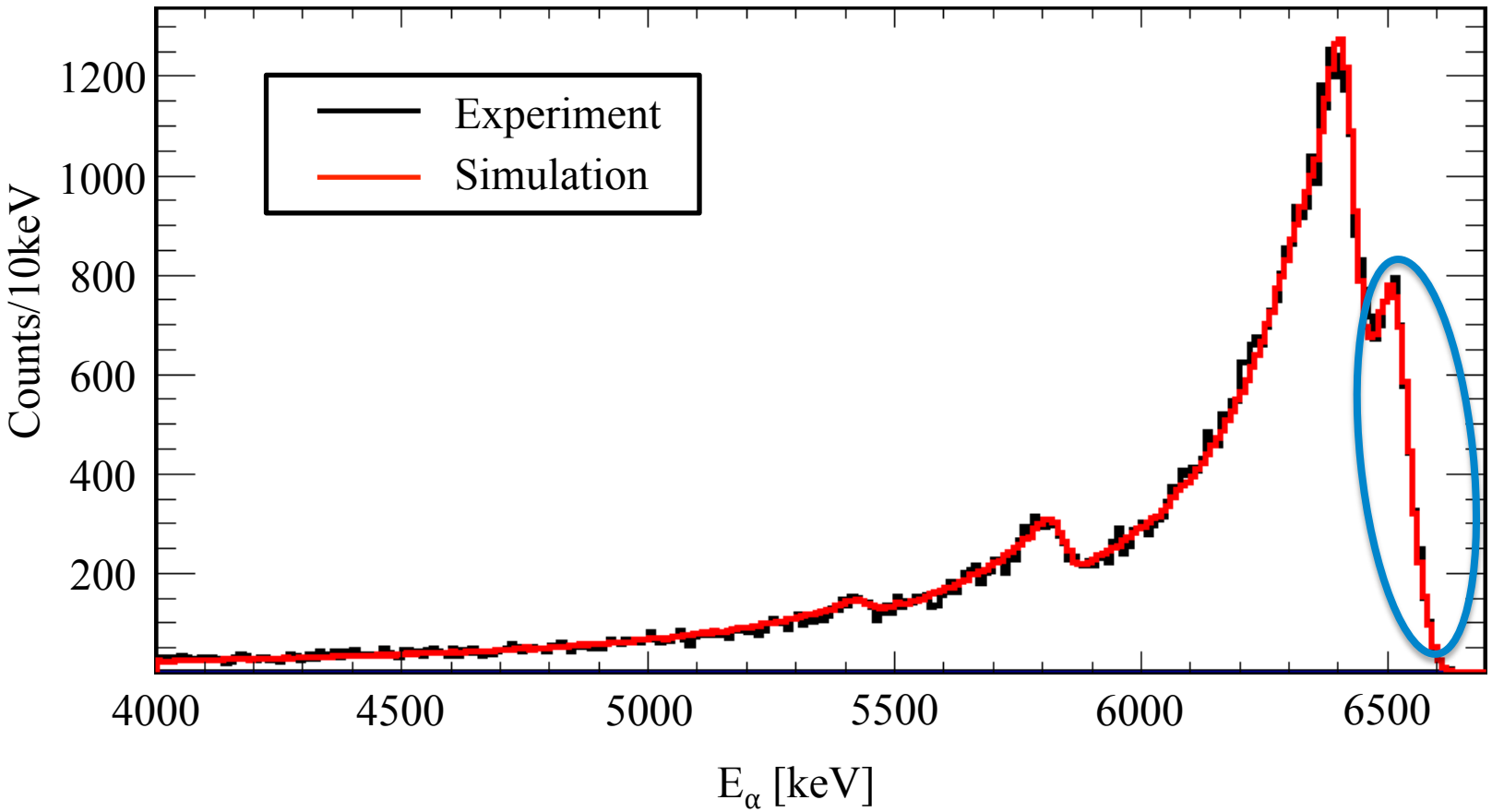

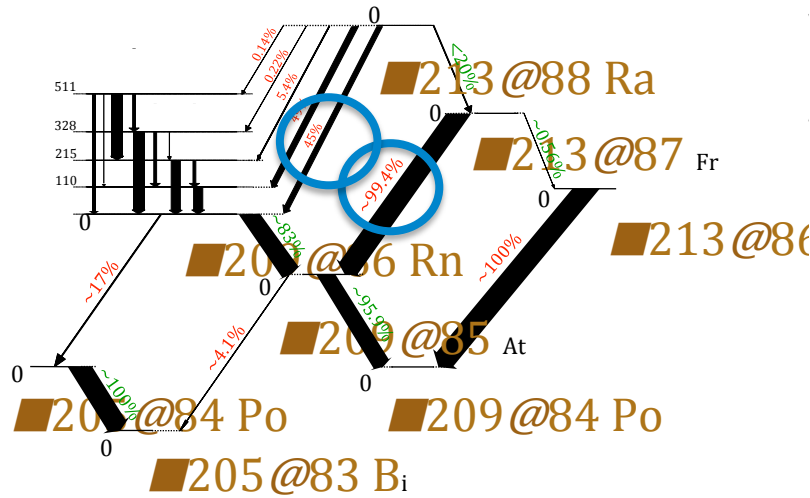

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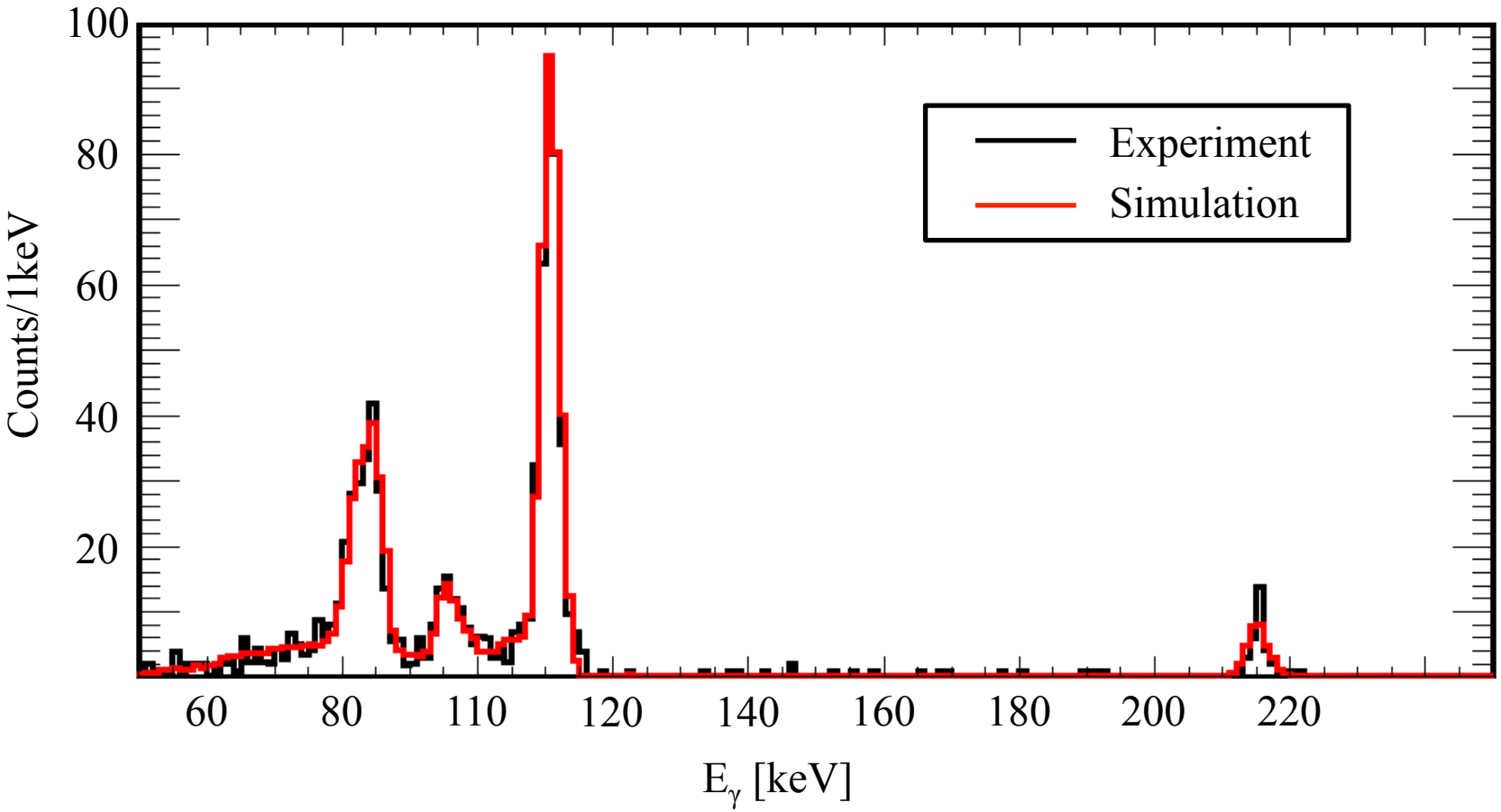

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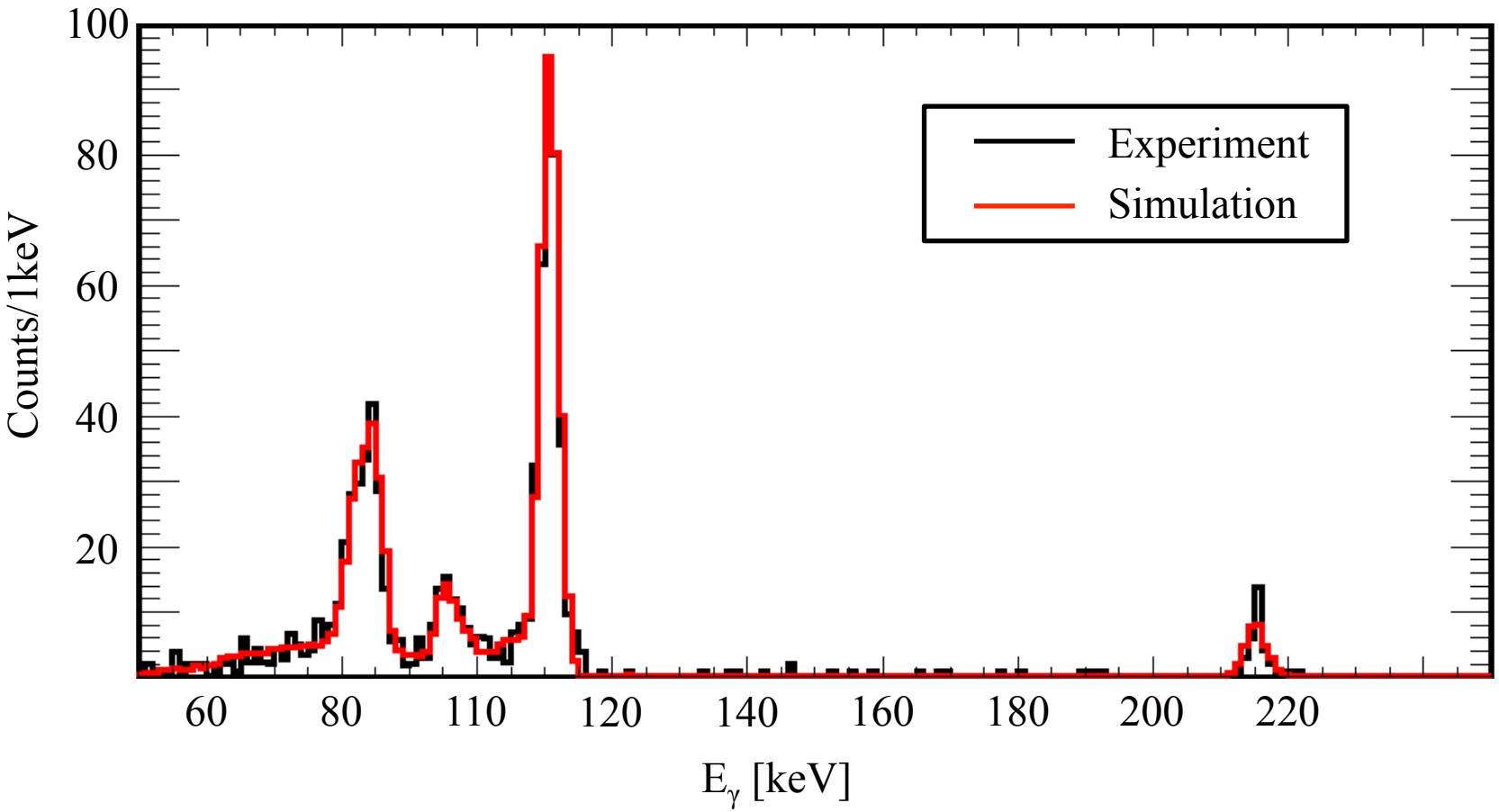

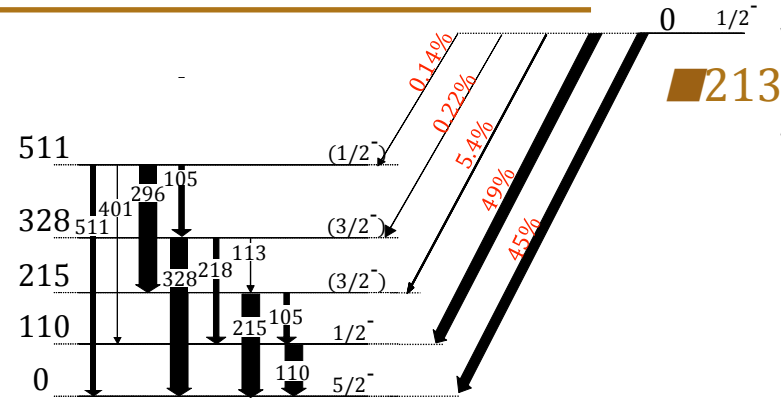

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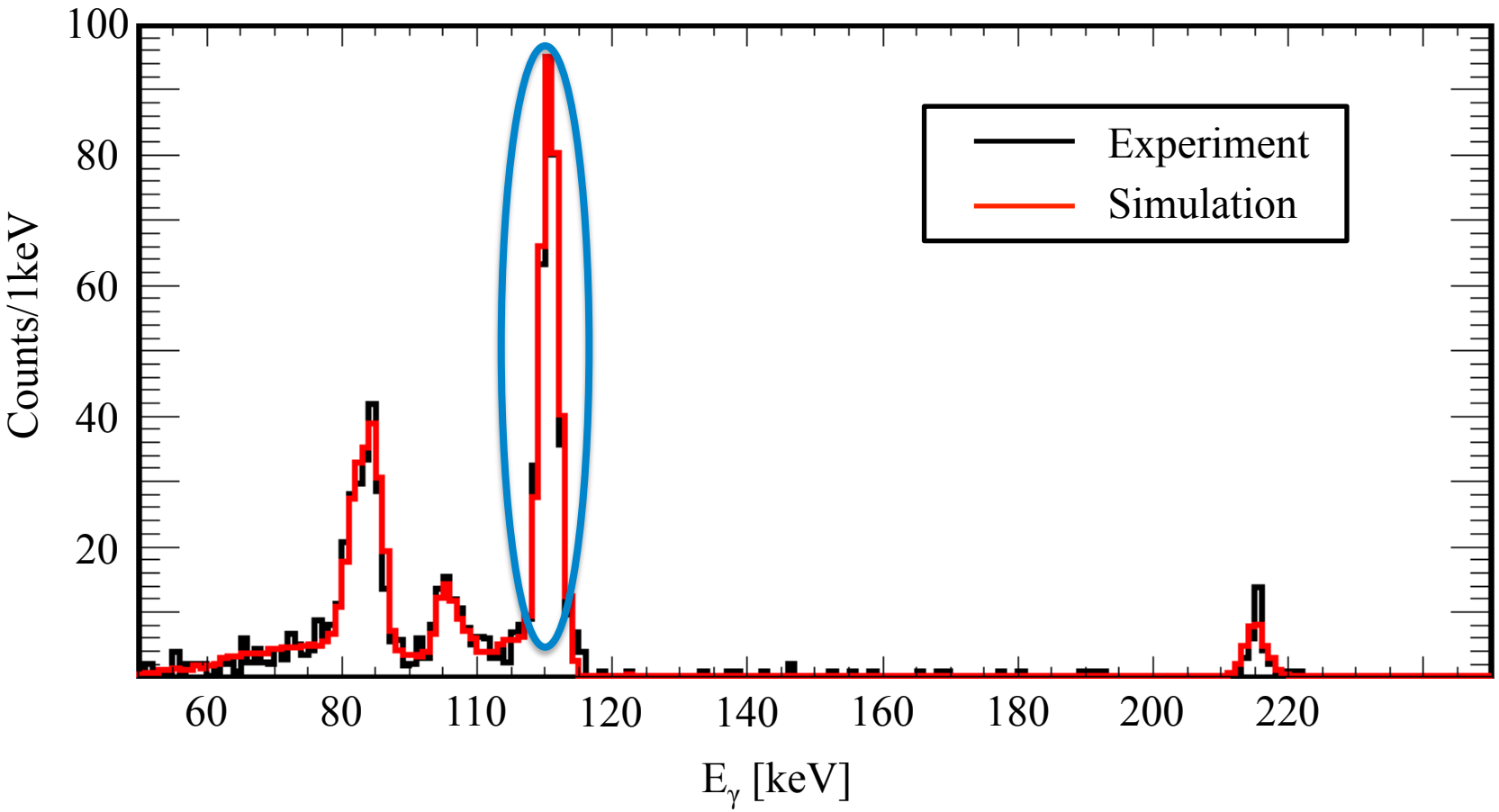
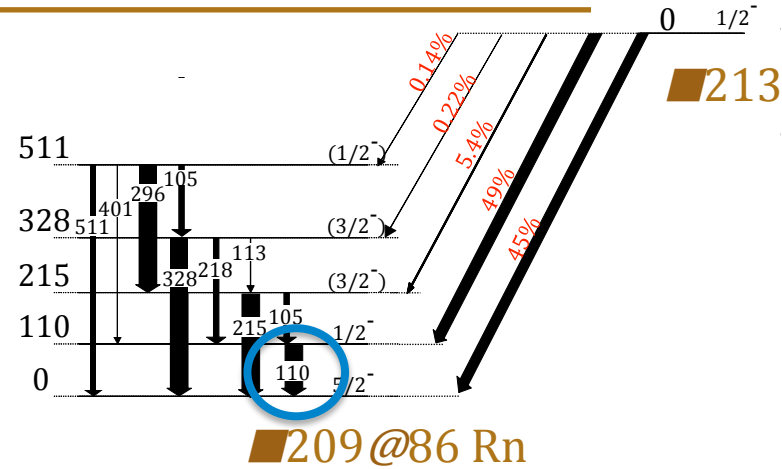
The Alpha Decay Branching in ^{213}Ra

→ Gamma spectrum





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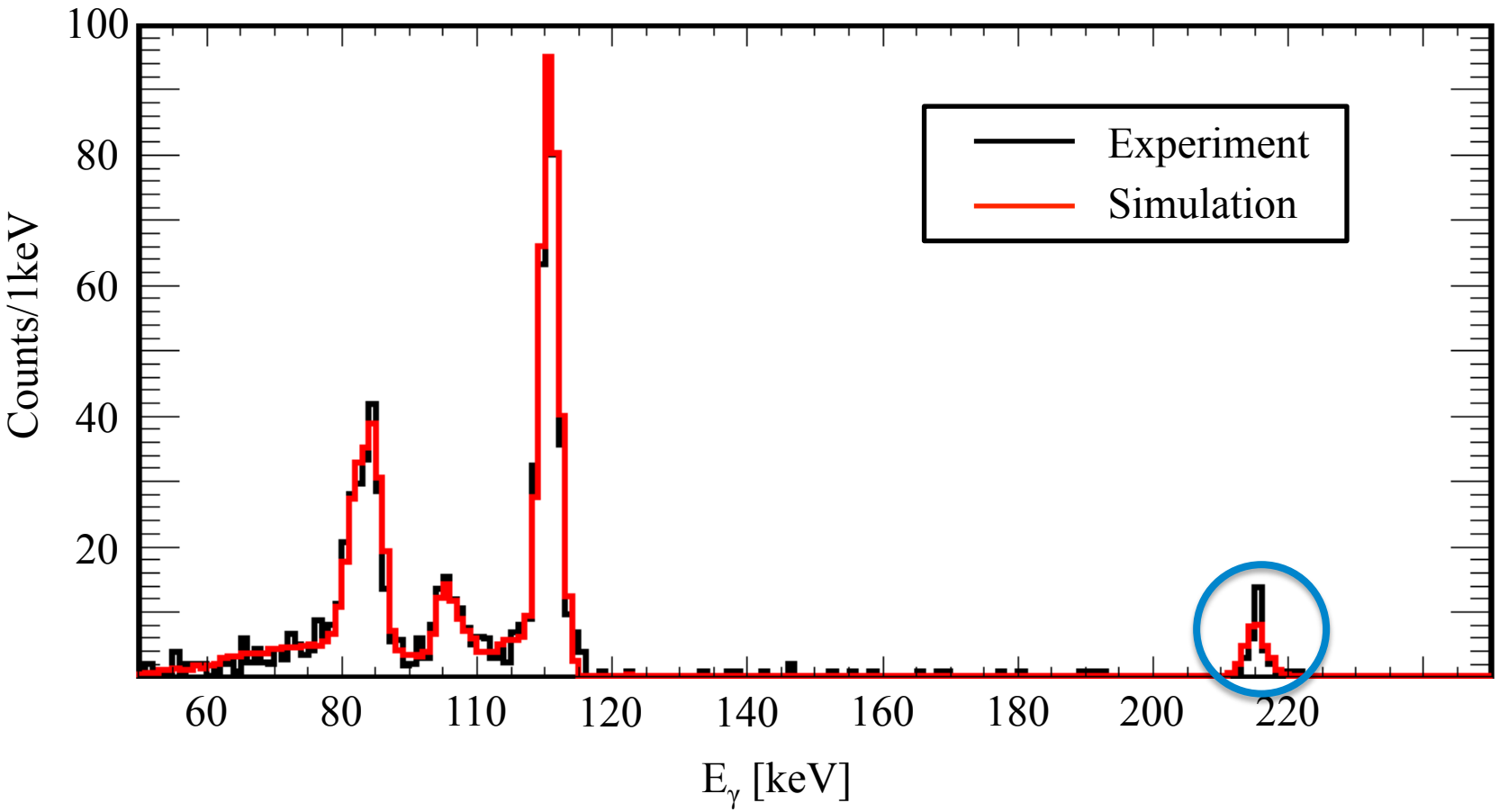

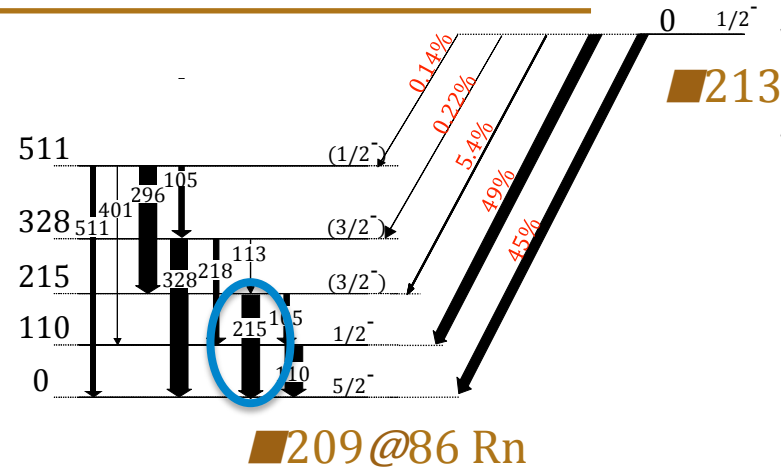

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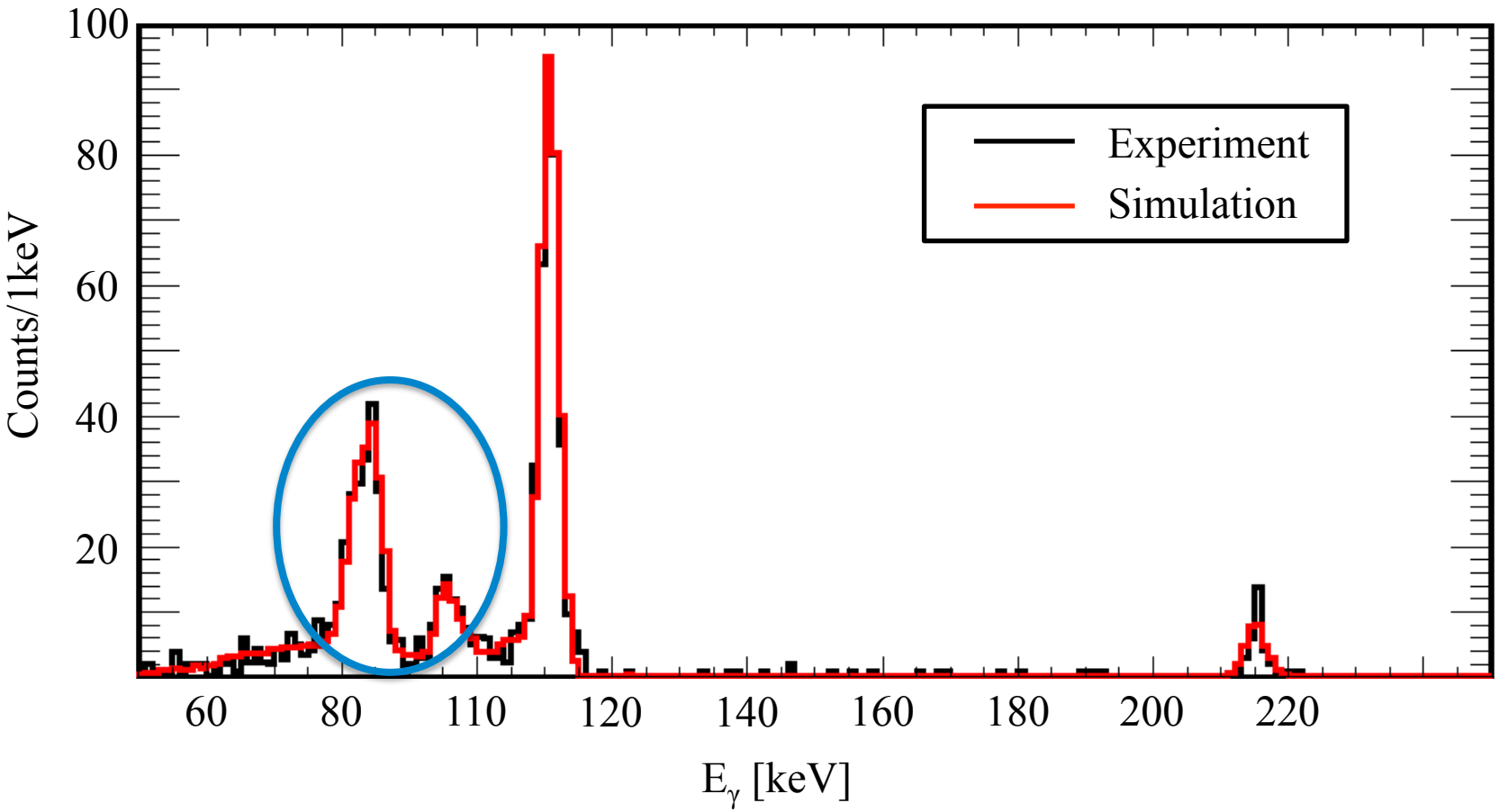

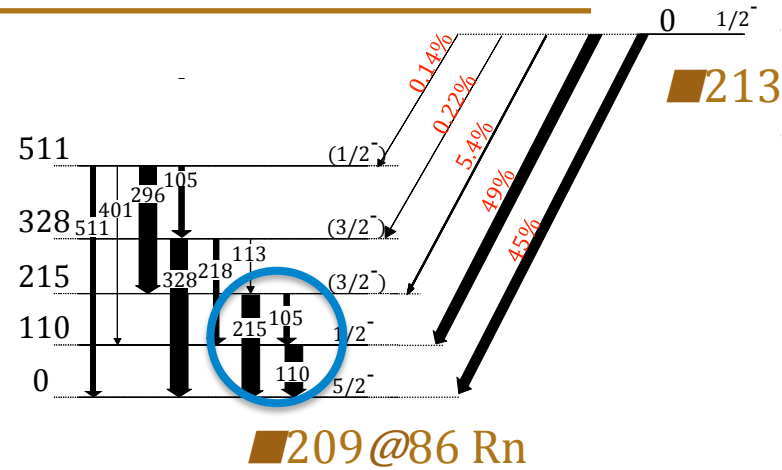

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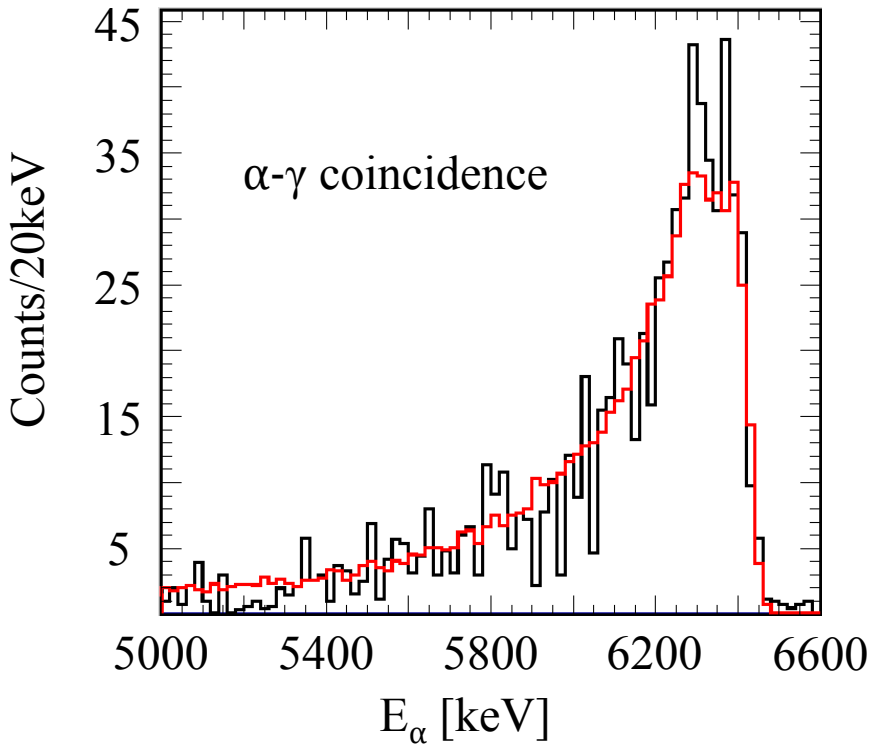
The Alpha Decay Branching in ^{213}Ra

→ Coincidence spectra



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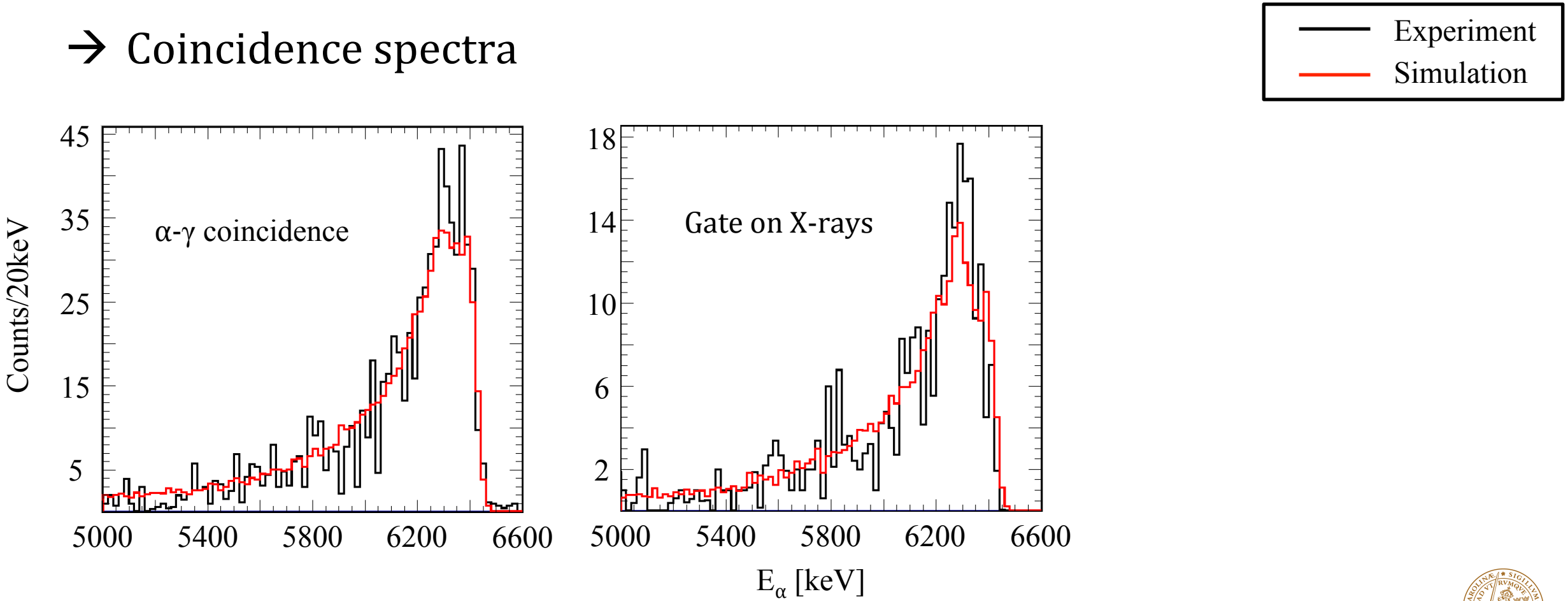

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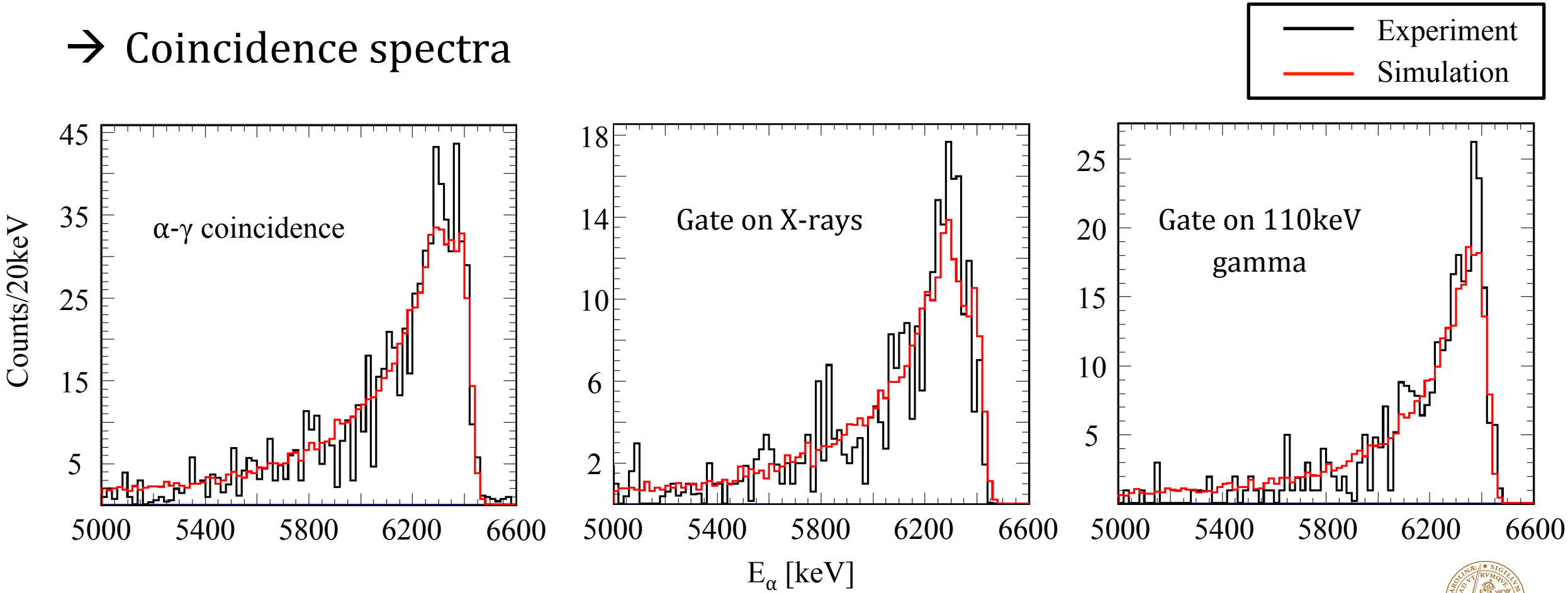

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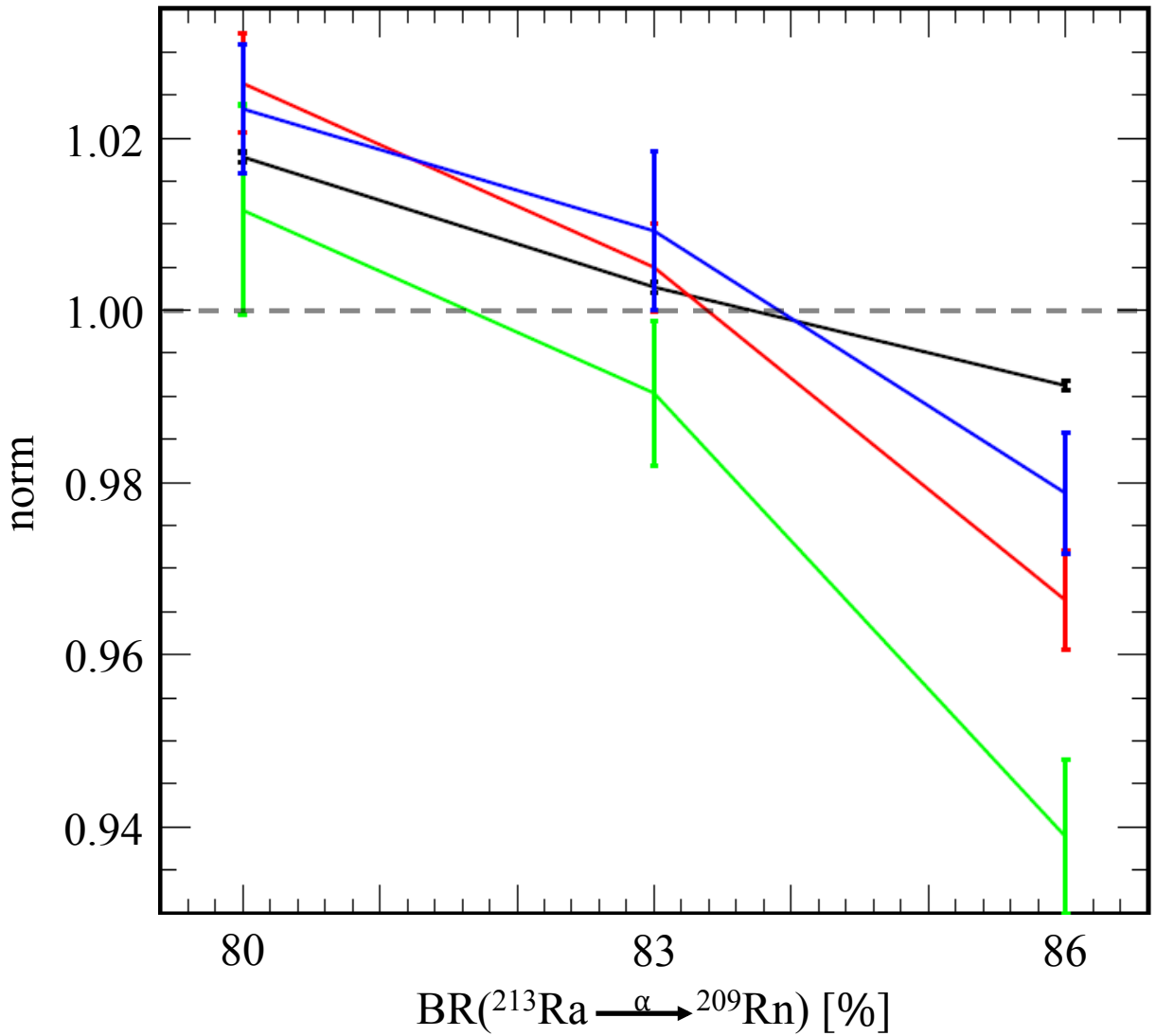
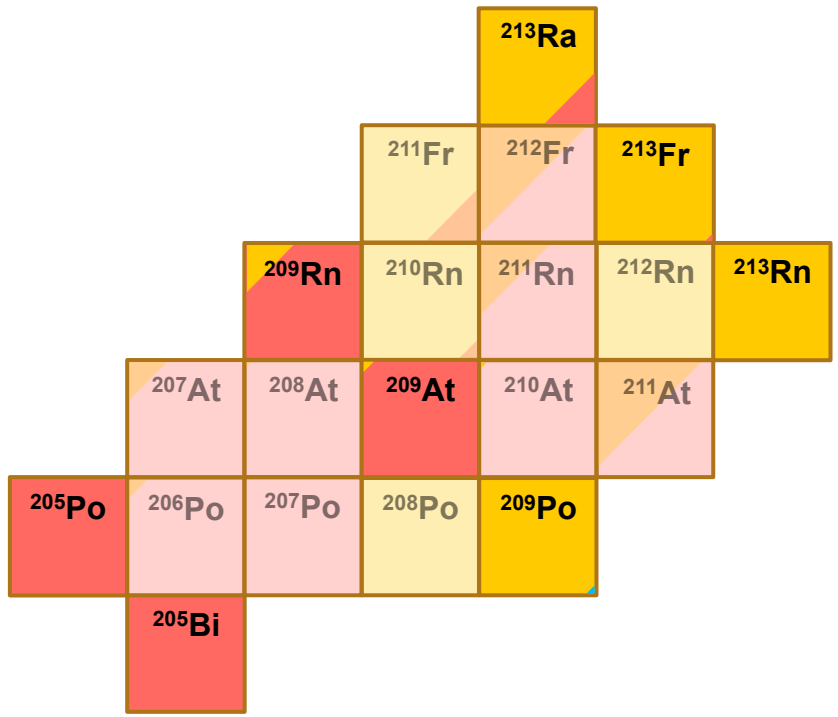


α spectrum
γ spectrum
α spectrum gated on X-rays
α spectrum gated on 110keV γ



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The Alpha Decay Branching in ^{213}Ra

What has changed?

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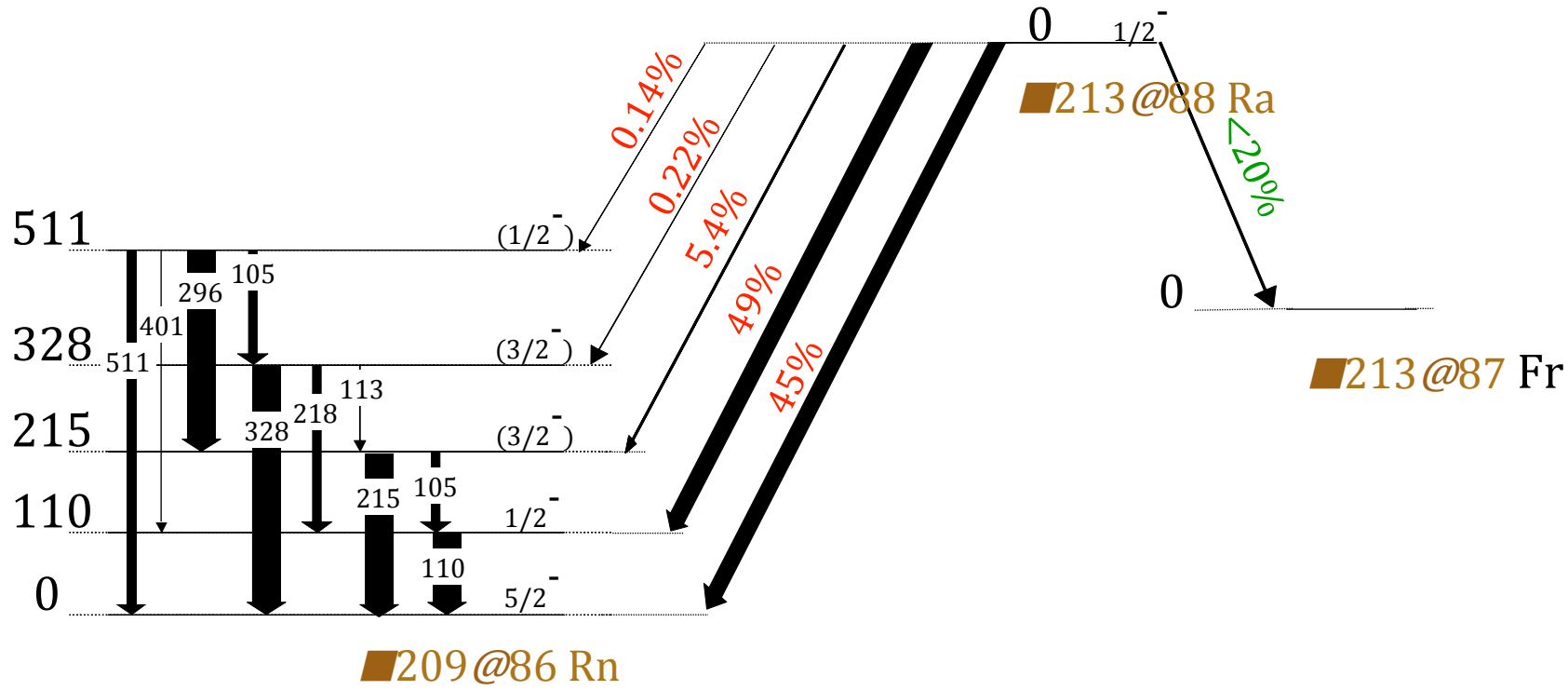

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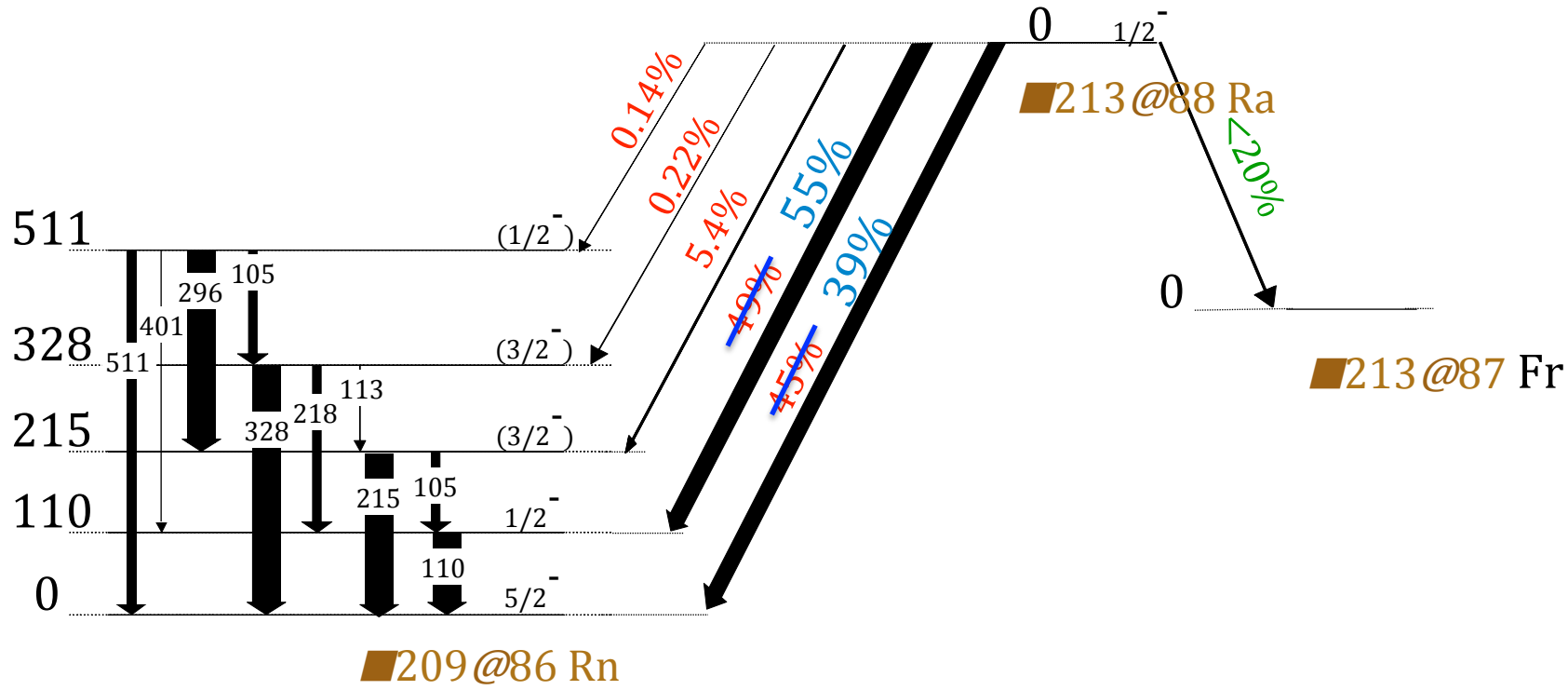

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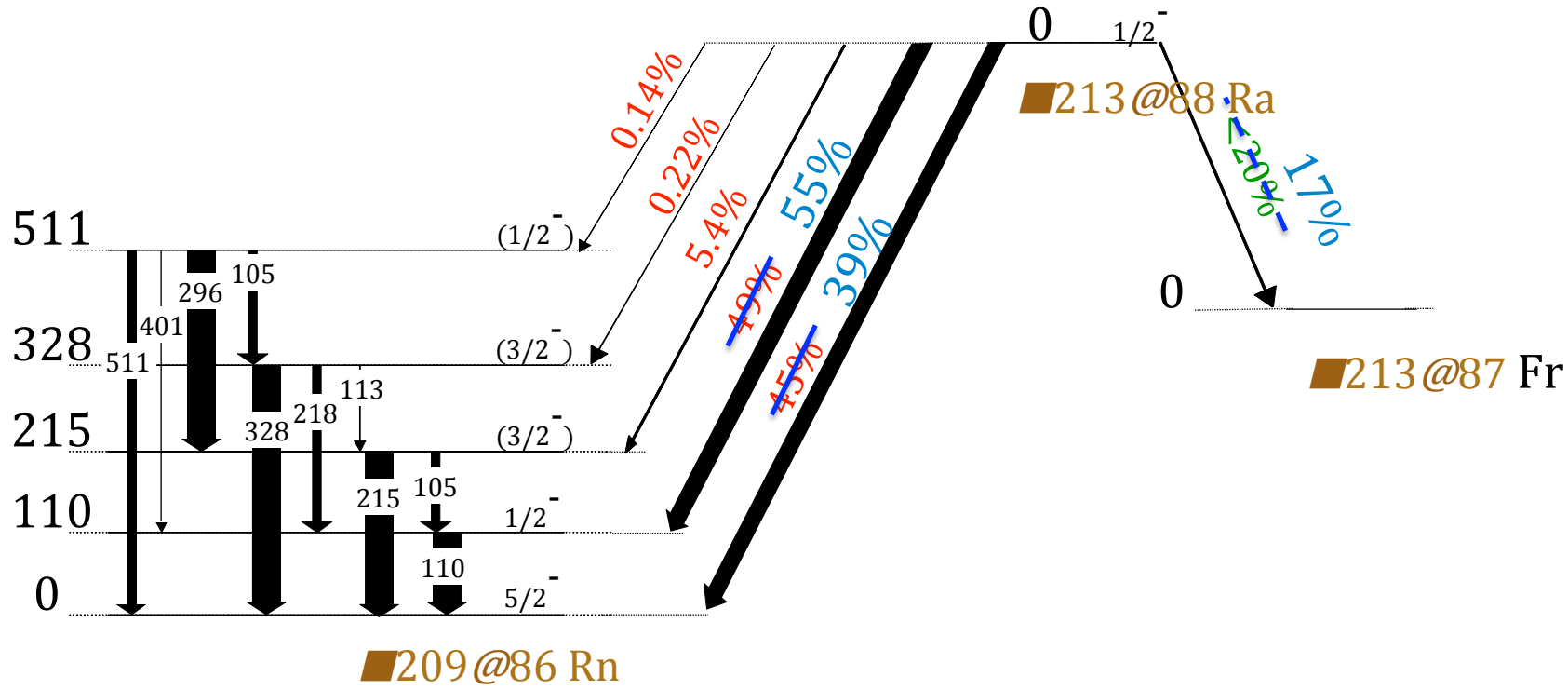

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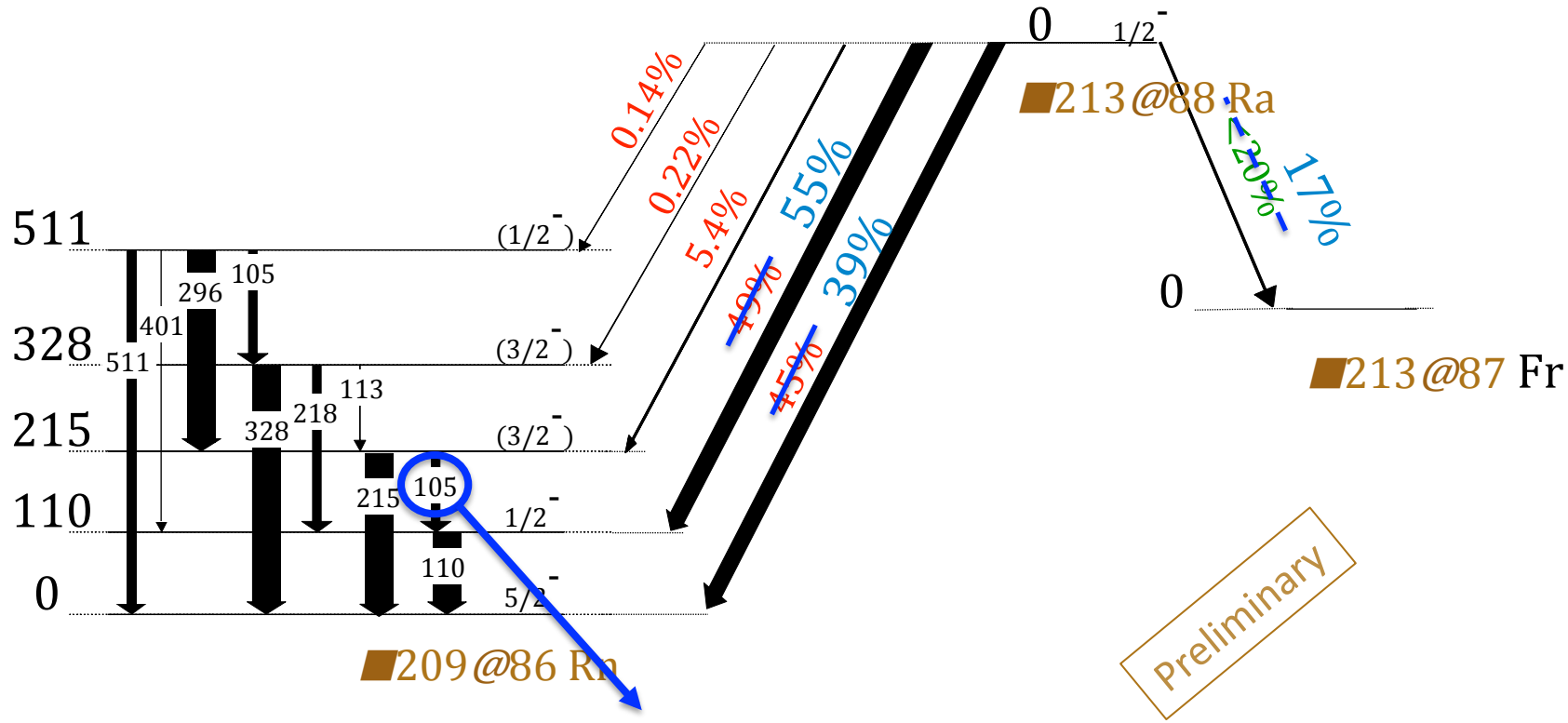

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The Proton Decay Branching in $^{53}Co^{m}$

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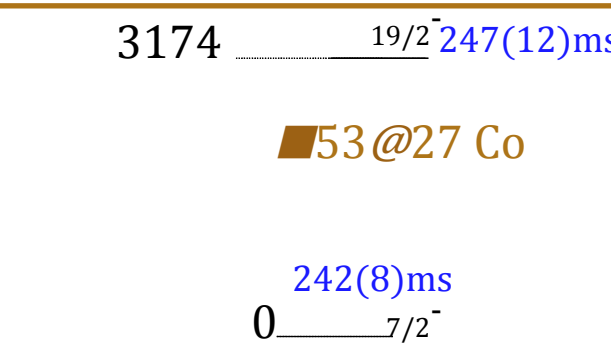

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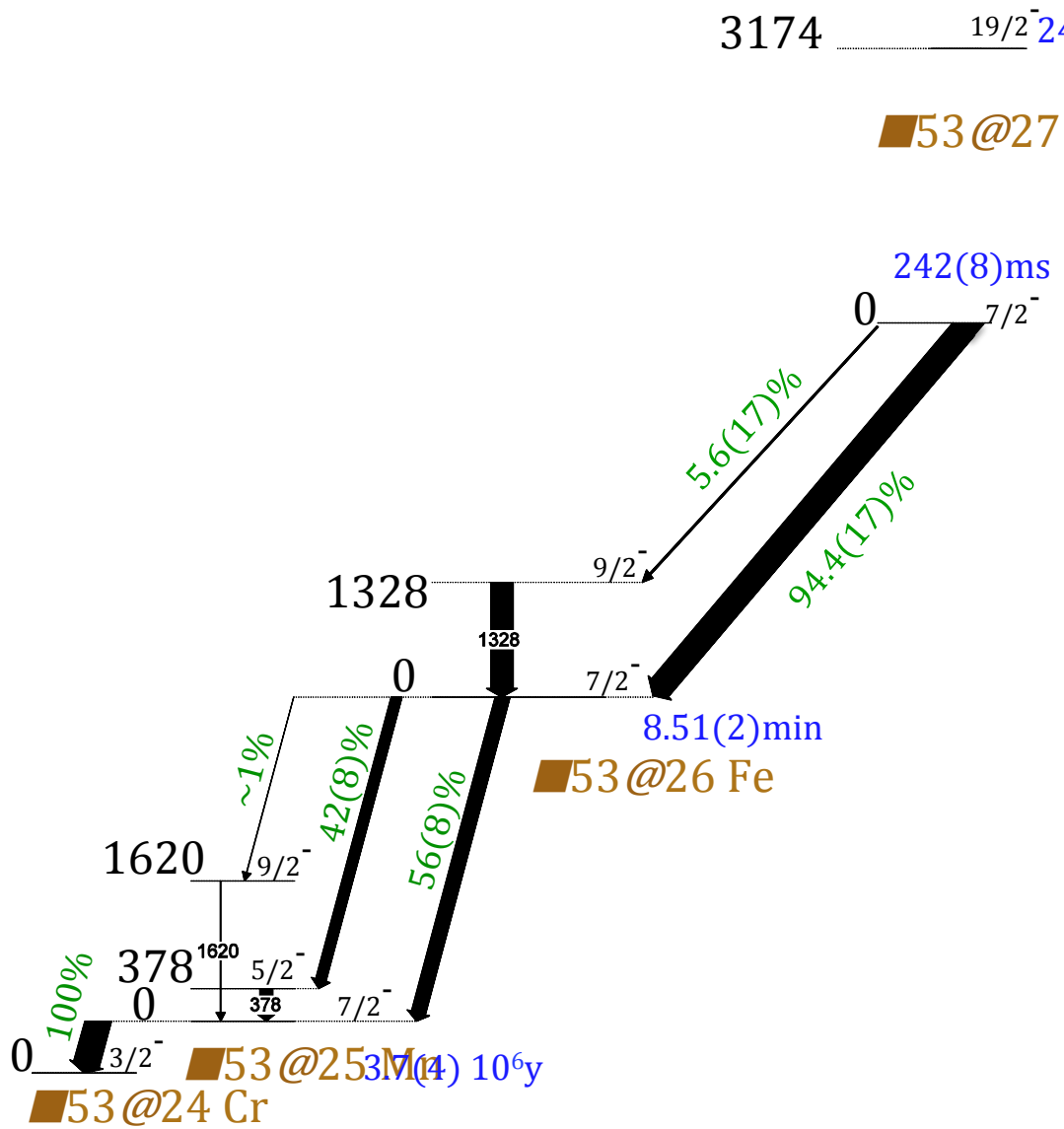

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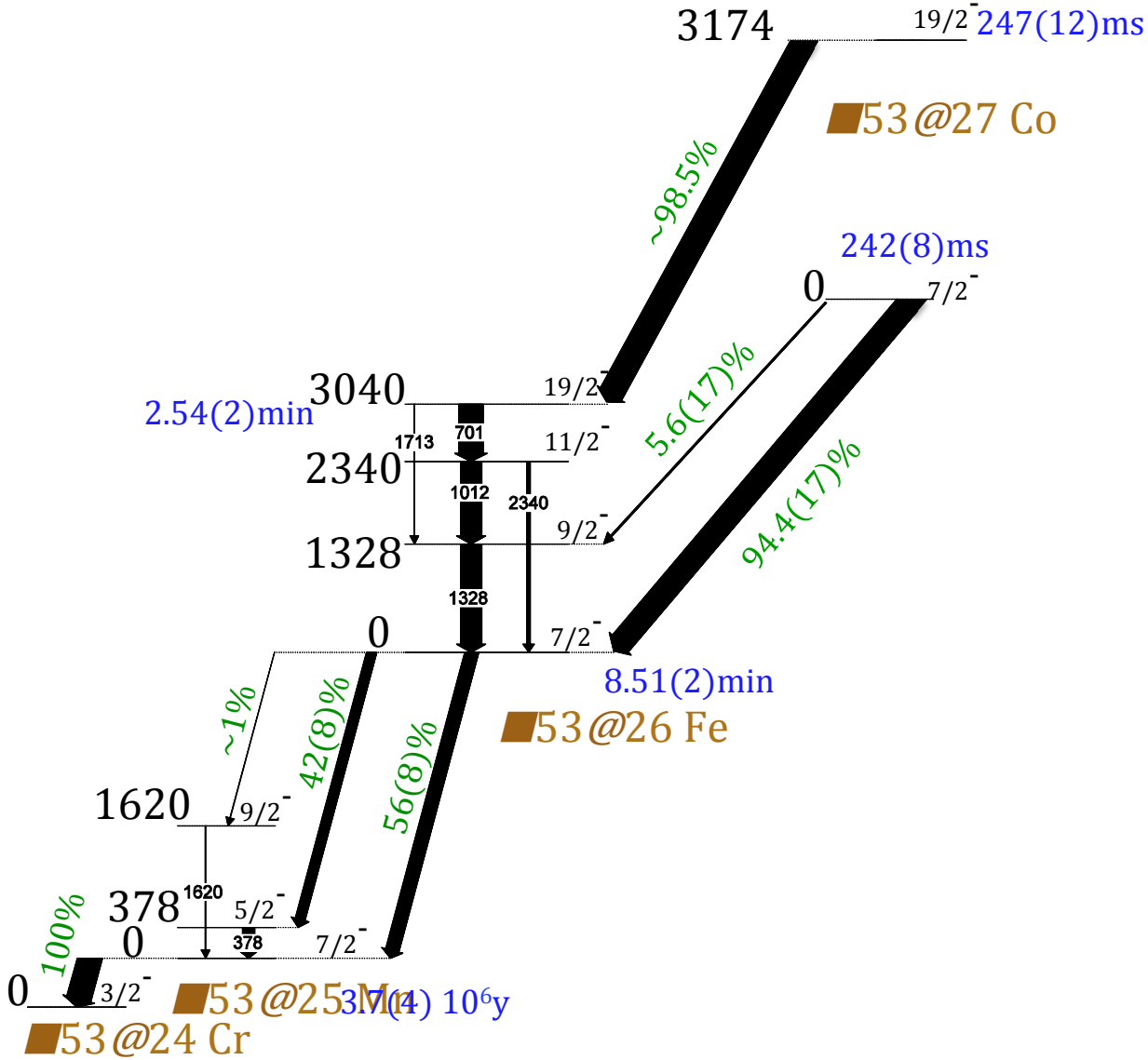

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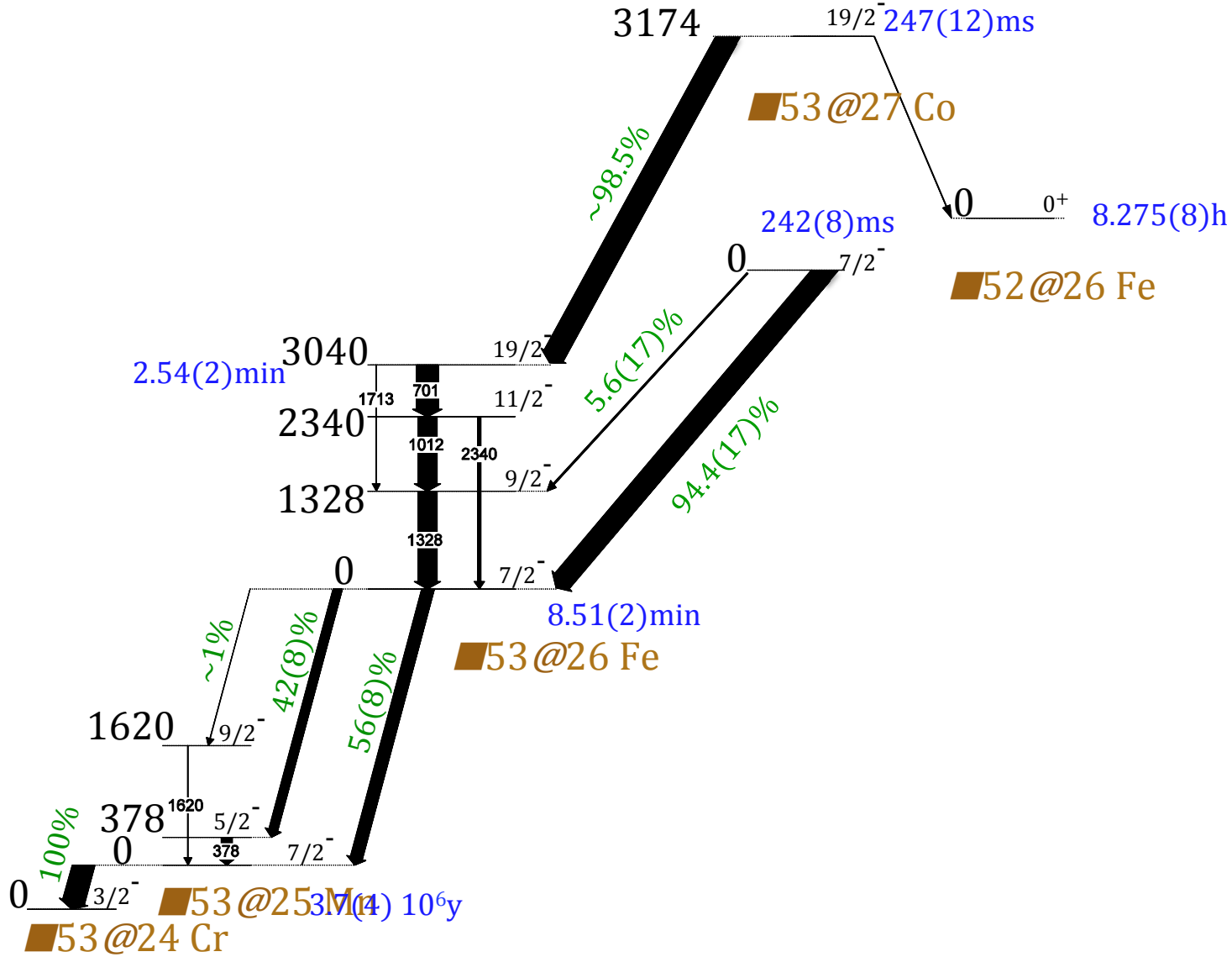

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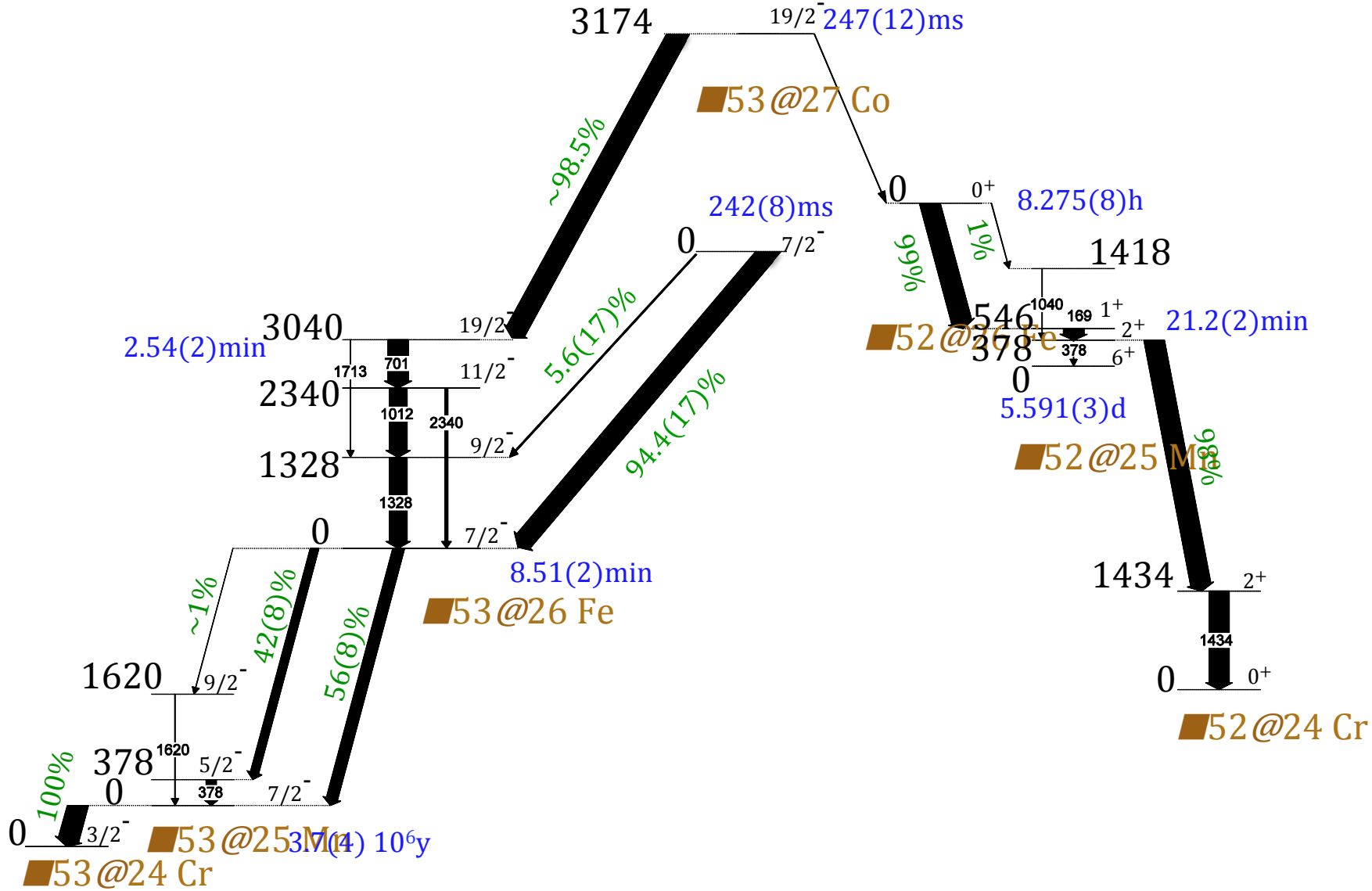

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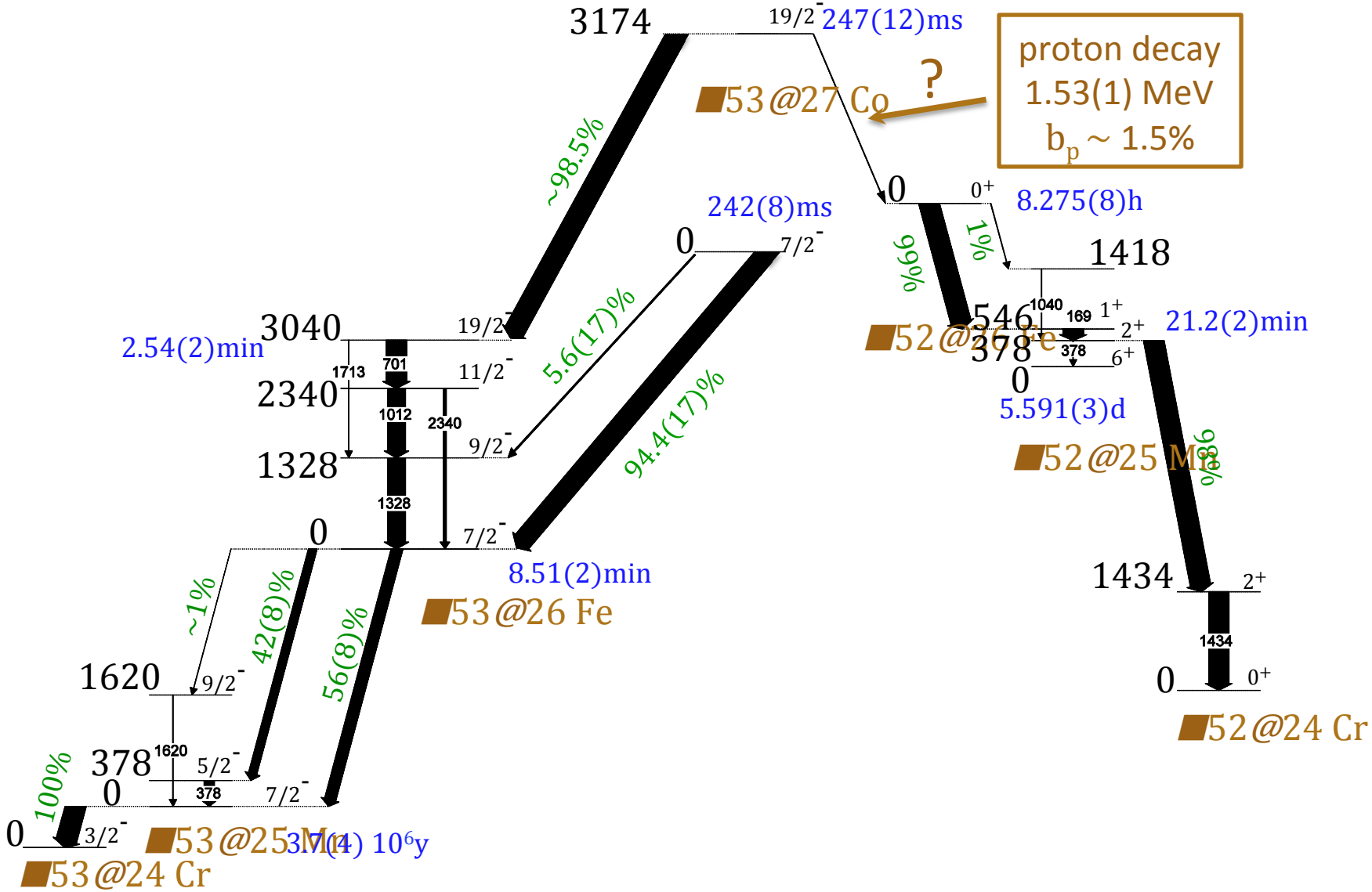

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- Experiment @ University of Jyväskylä (JYFL) in 2015
- *Quantum-state selective* beams from JYFLTRAP (mass selection!) [10]: 100% pure beams of ^{53}Co, $^{53}Co^{m}$, ^{52}Fe, $^{53}Fe^{m}$

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[10] V.S. Kolhinen et al., Nucl. Instrum. Meth. A 528, 776 (2004)

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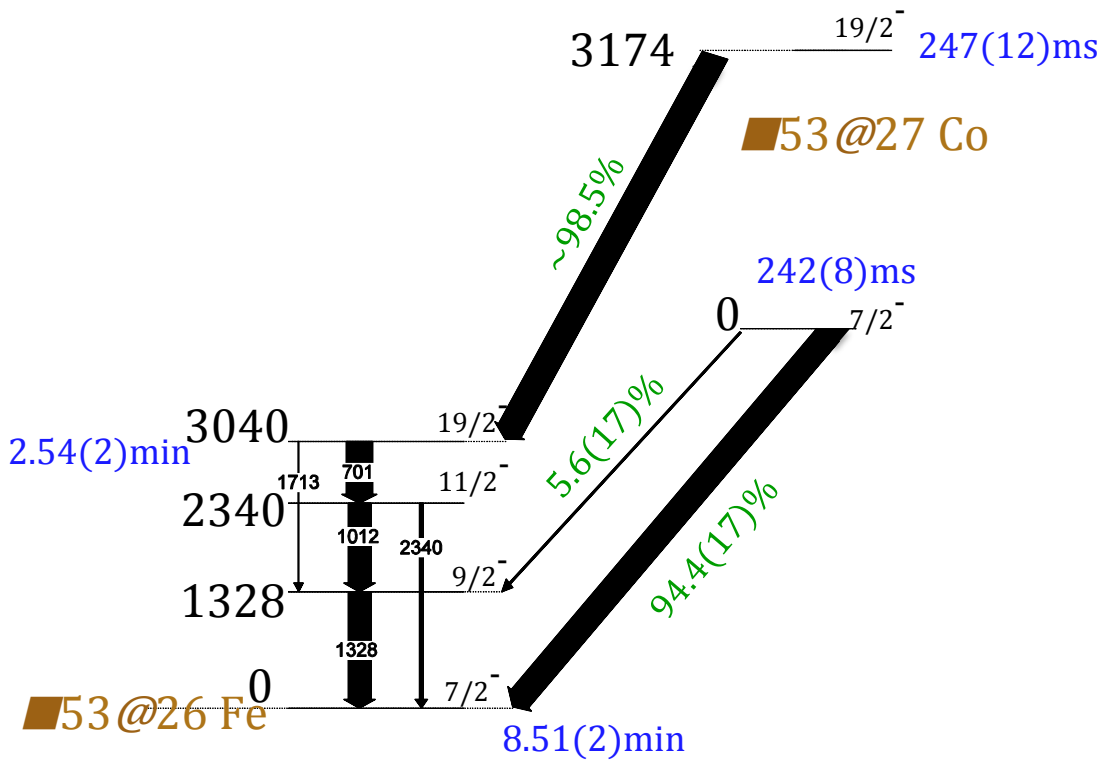

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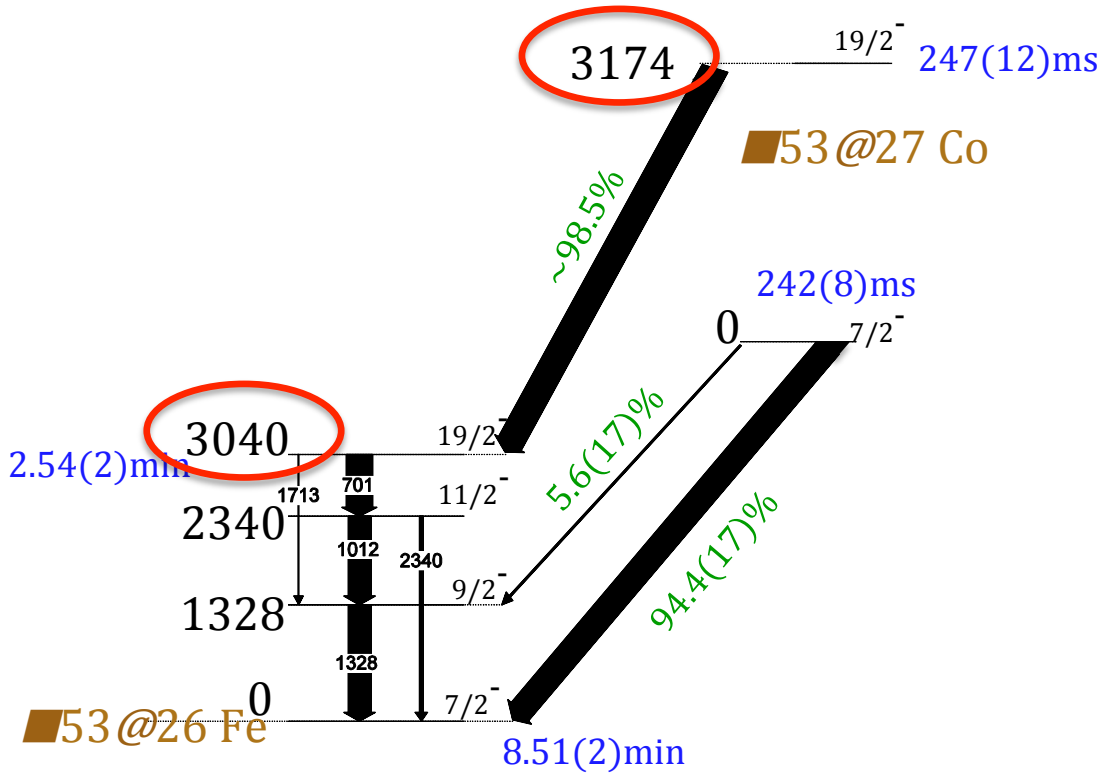

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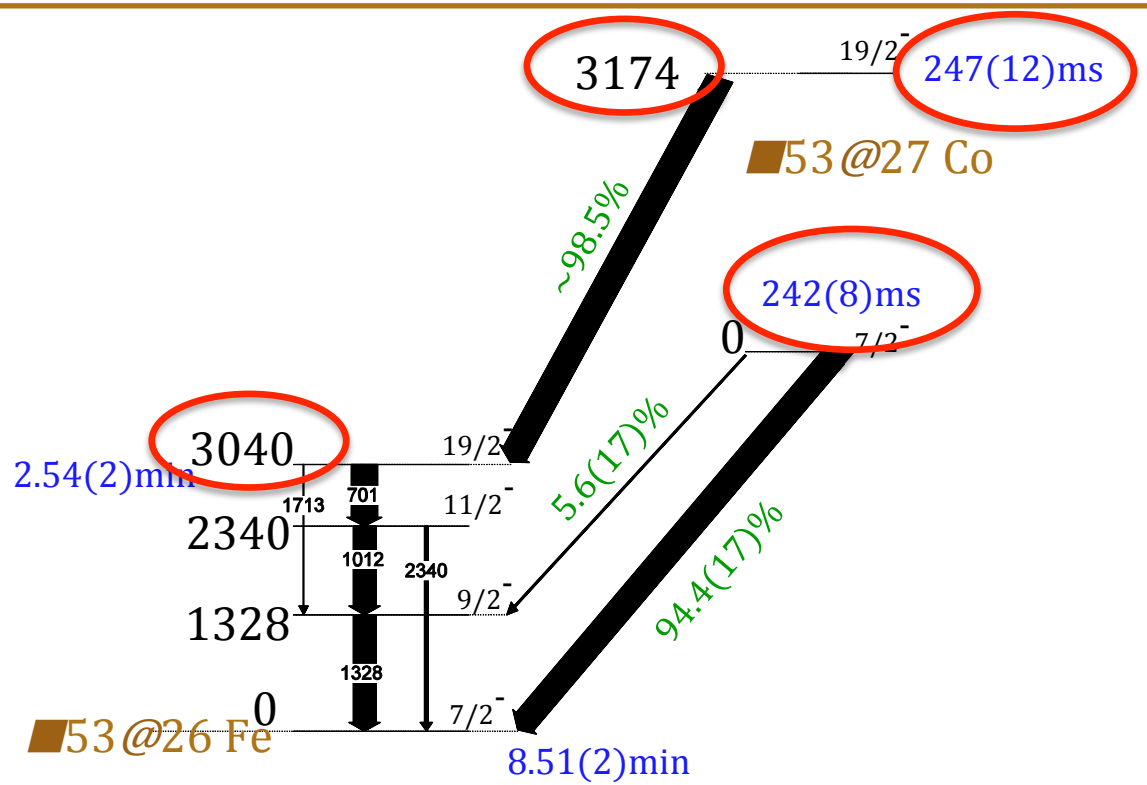

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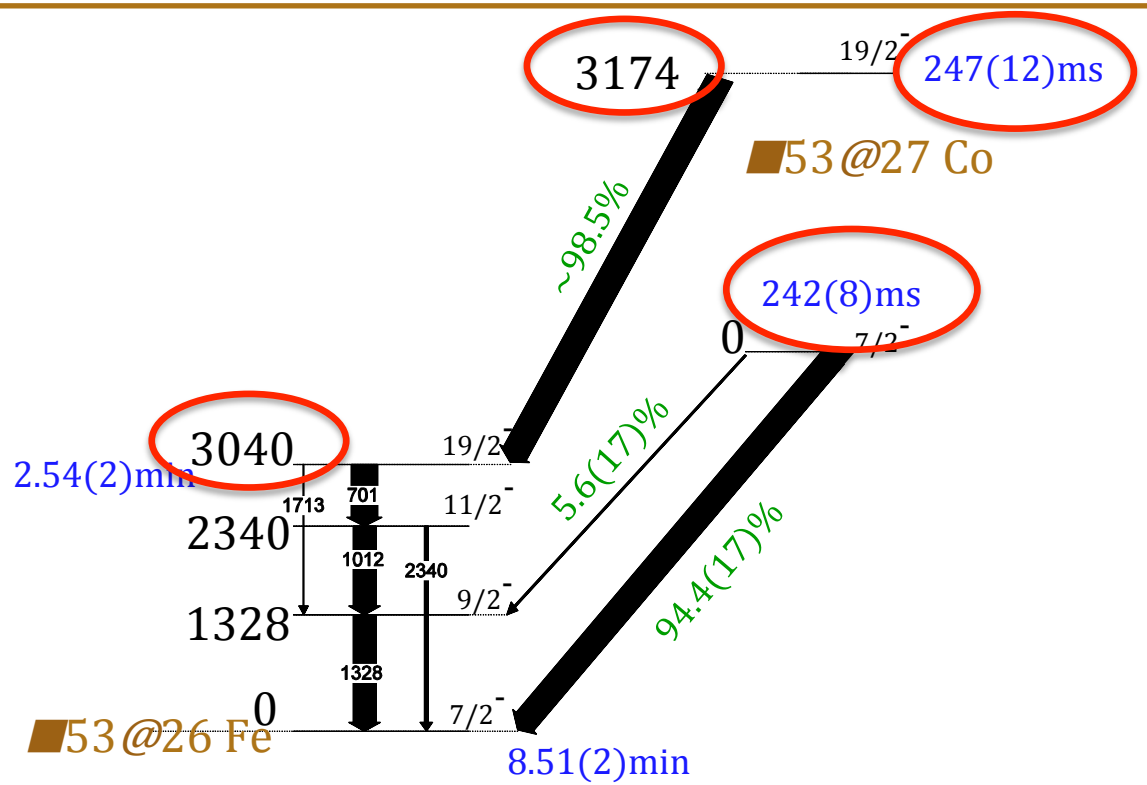

- Problem: the decay of the $7/2^-$ ground-state and the $19/2^-$ isomer of ^{53}Co to their isobaric analogue states (IAS) in ^{53}Fe are nearly identical!

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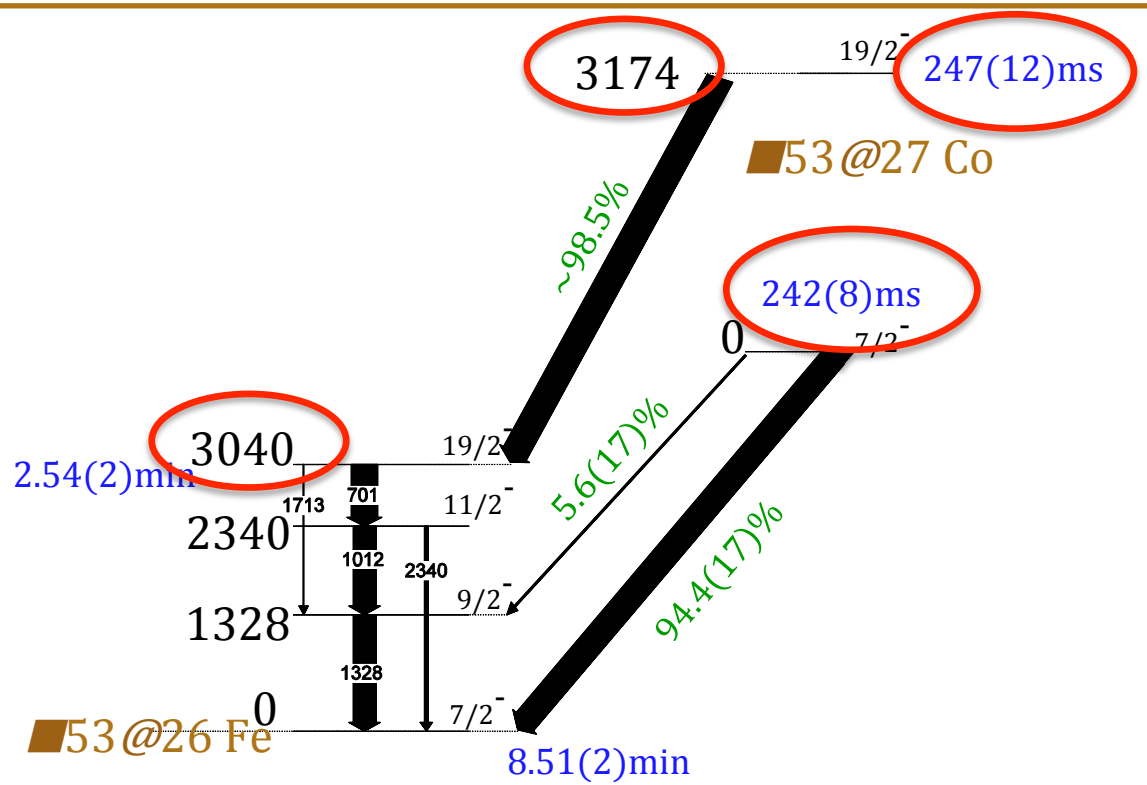
The Proton Decay Branching in $^{53}Co^{m}$



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→ *Quantum-state selective* radioactive beams needed

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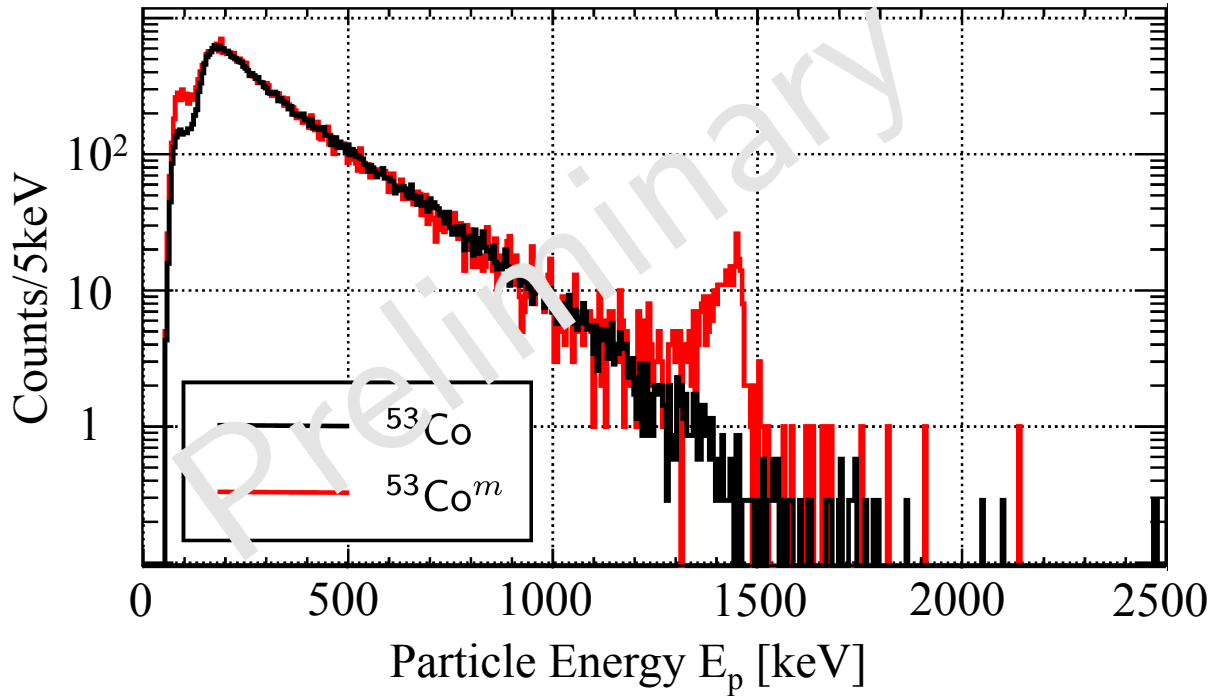
The Proton Decay Branching in $^{53}Co^{m}$

Experiment



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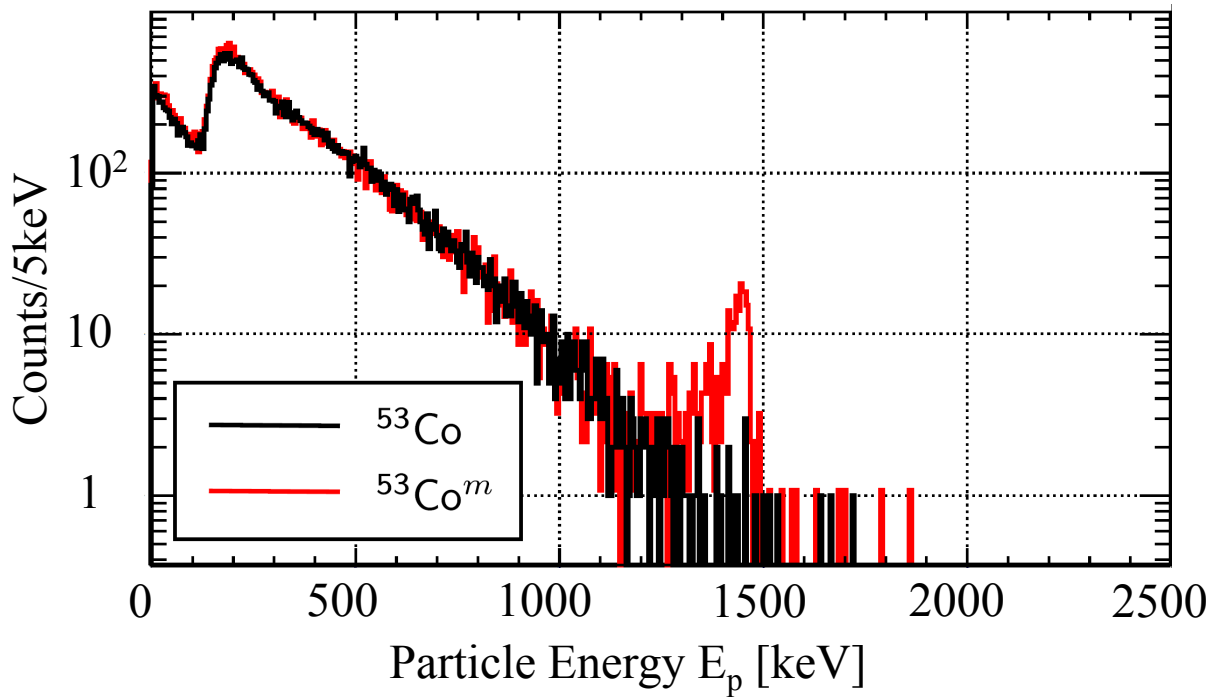
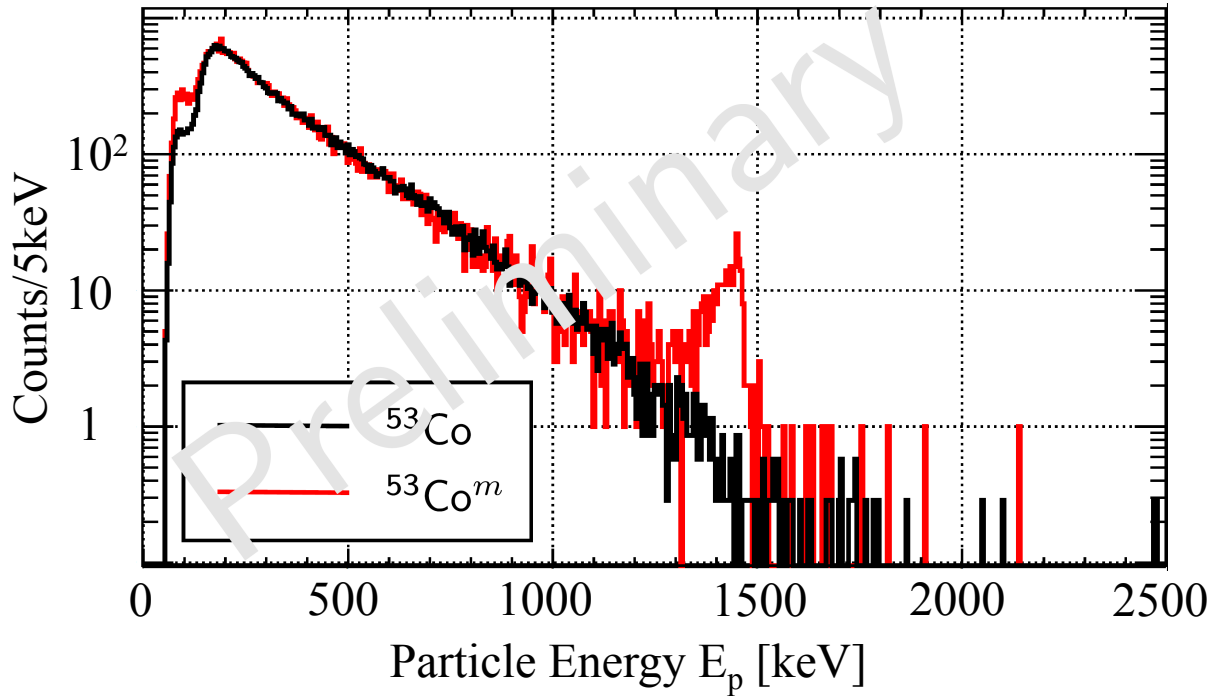
The Proton Decay Branching in $^{53}Co^{m}$

Experiment

Simulation





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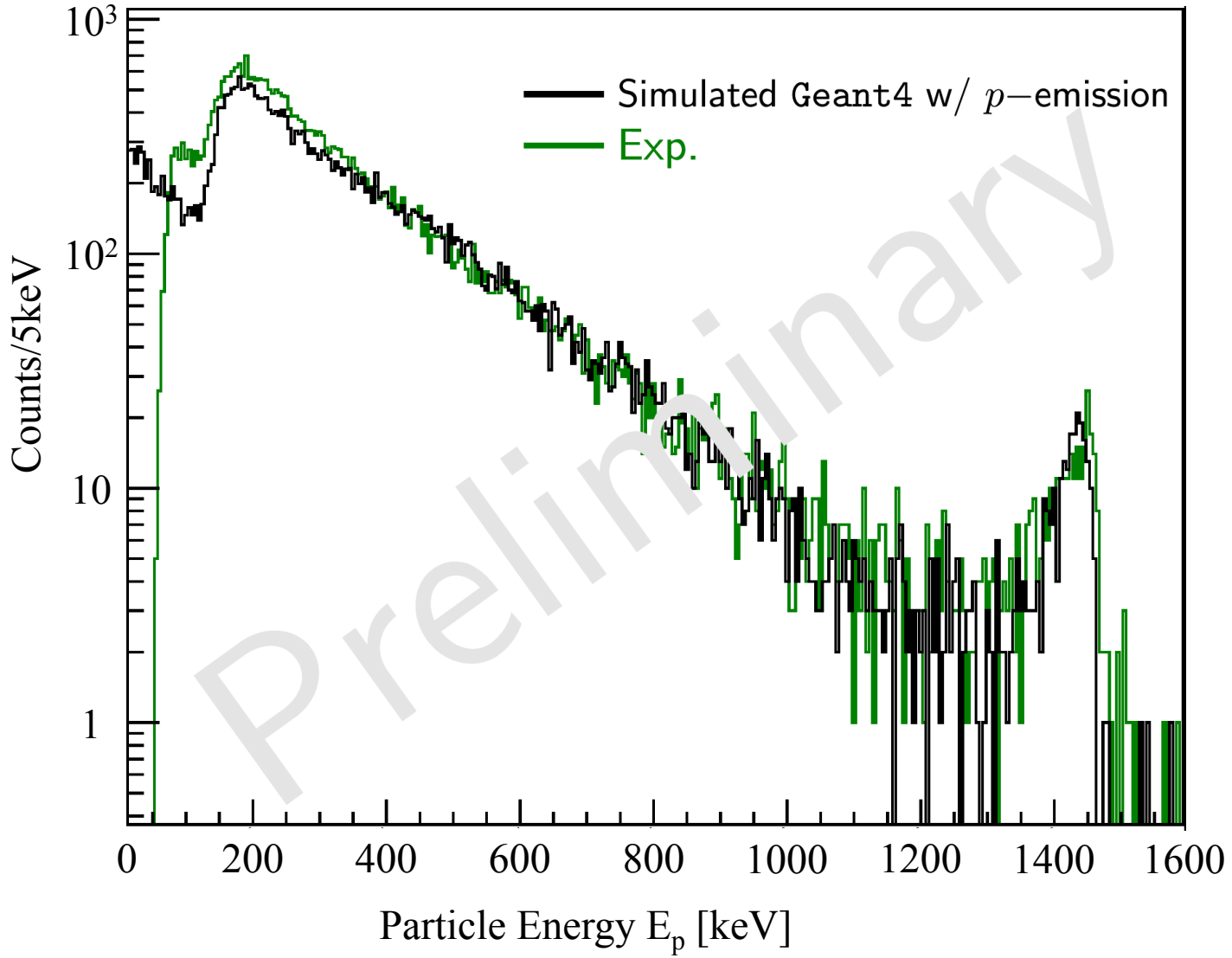

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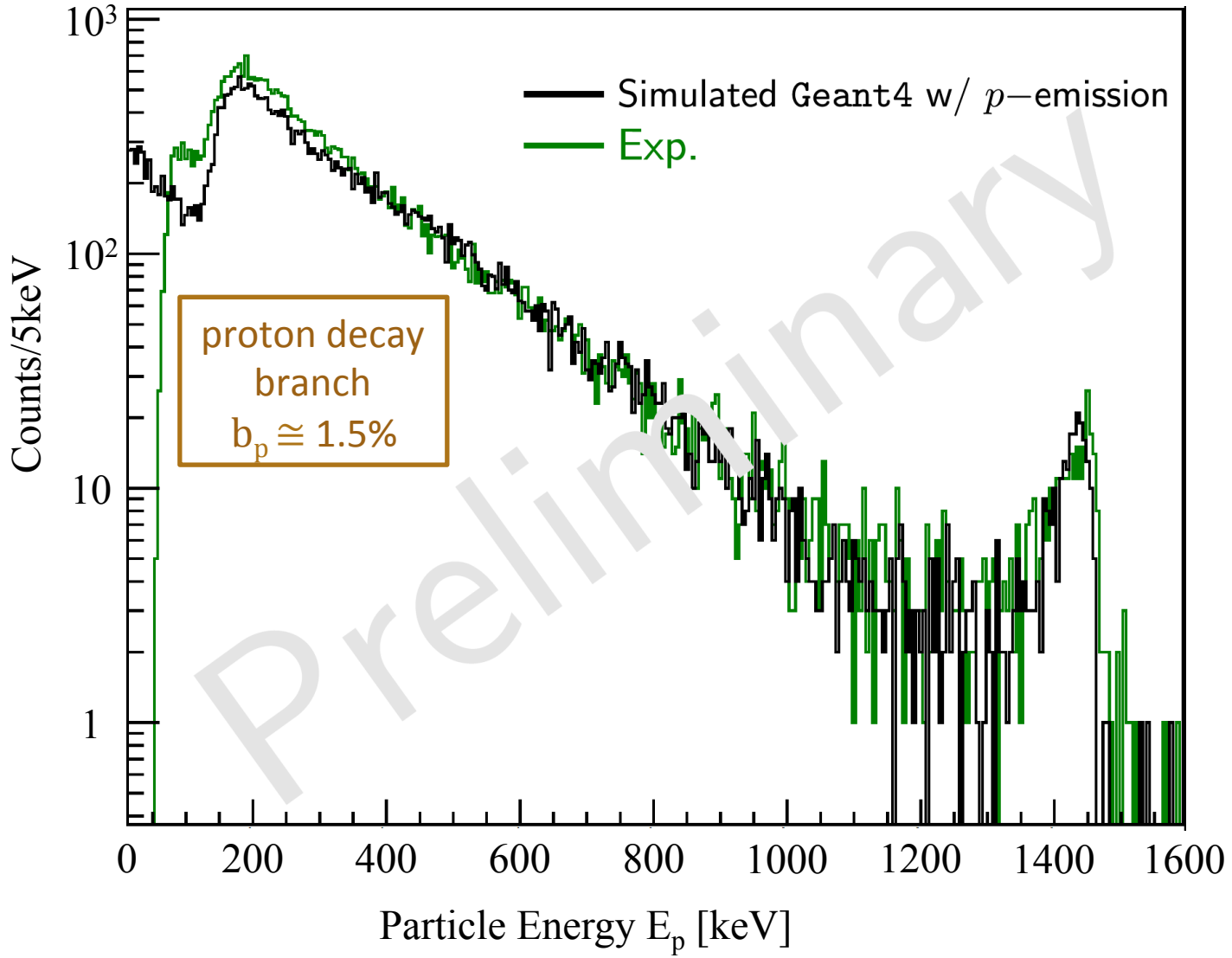

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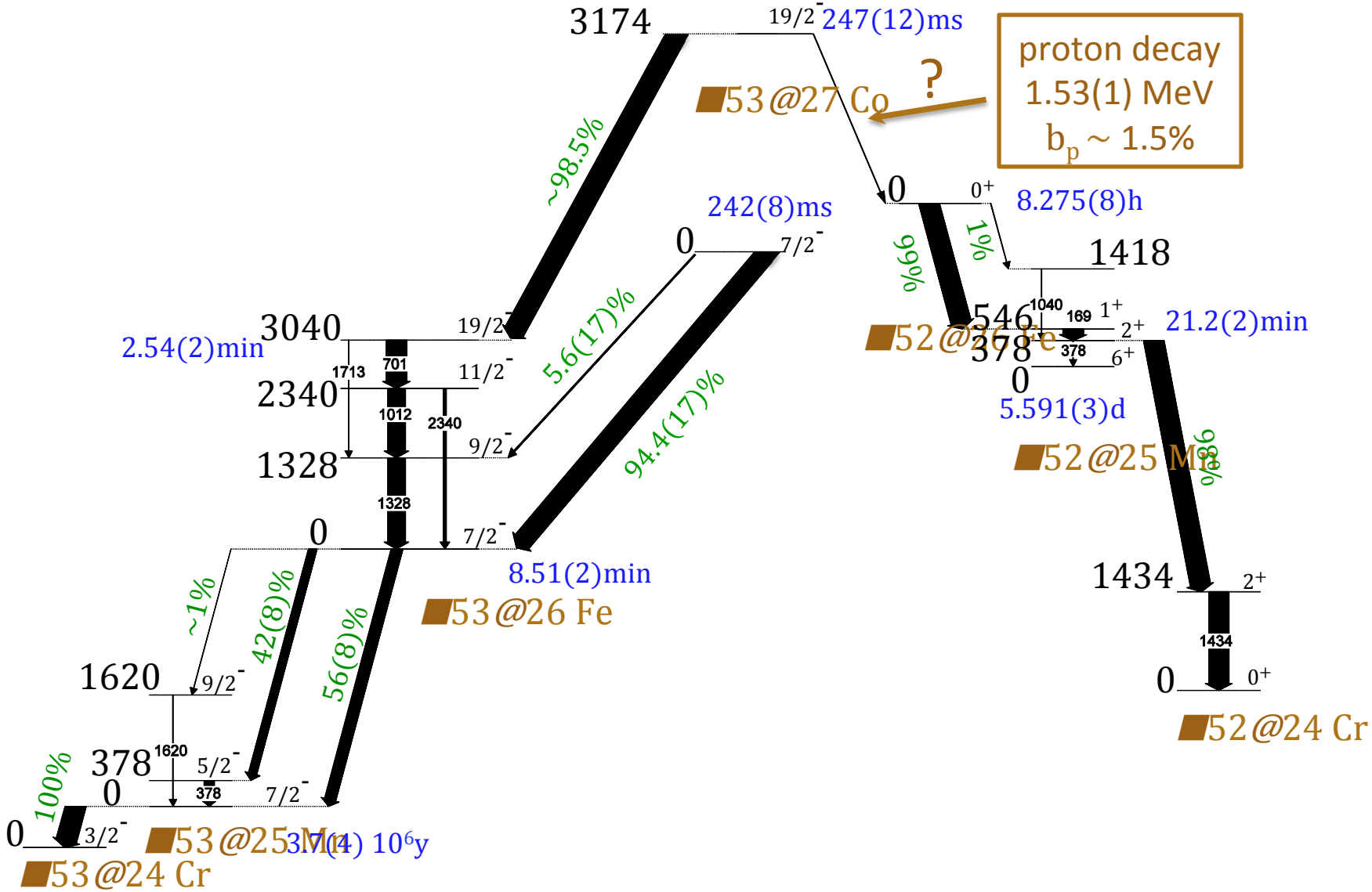

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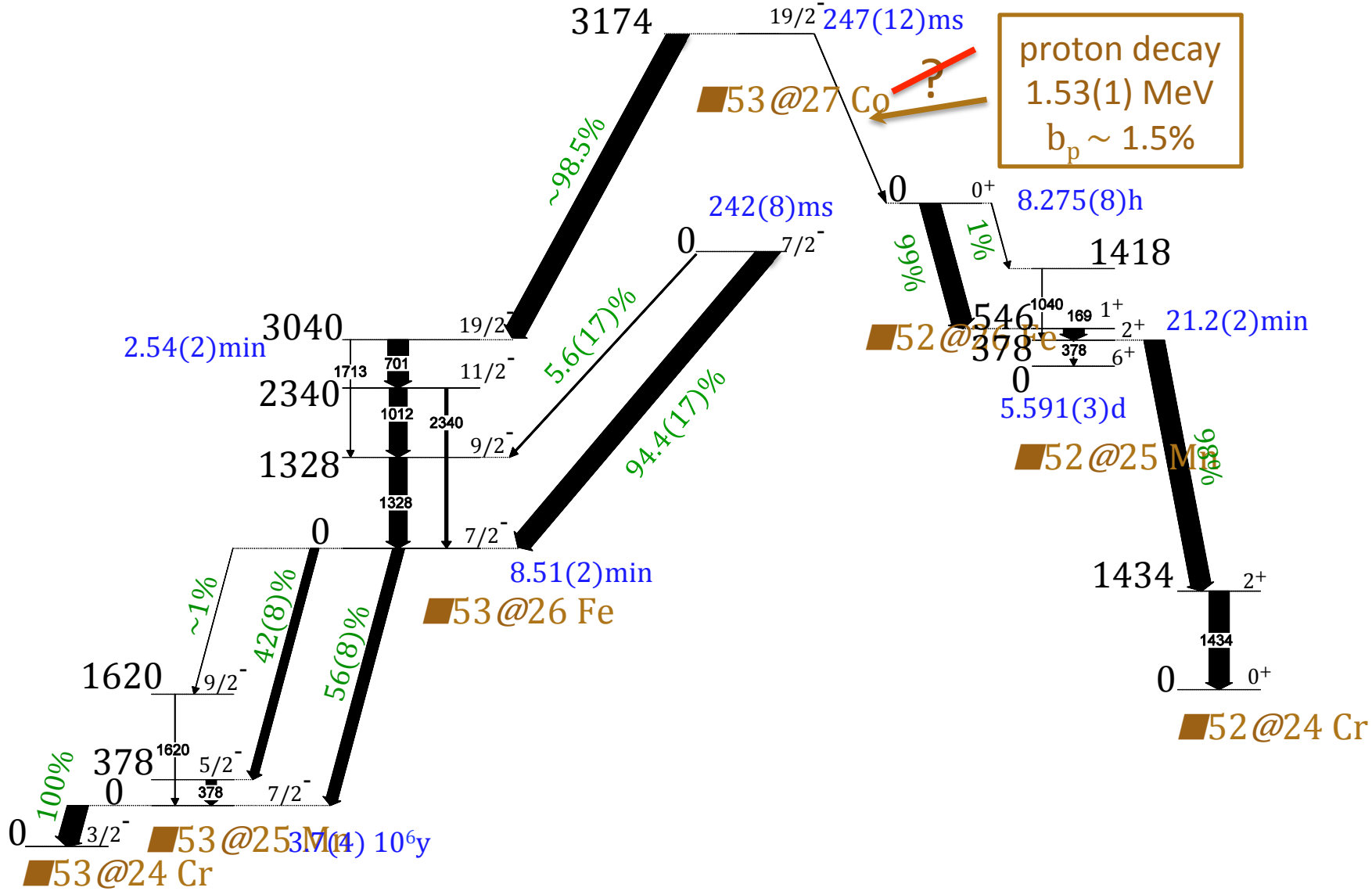

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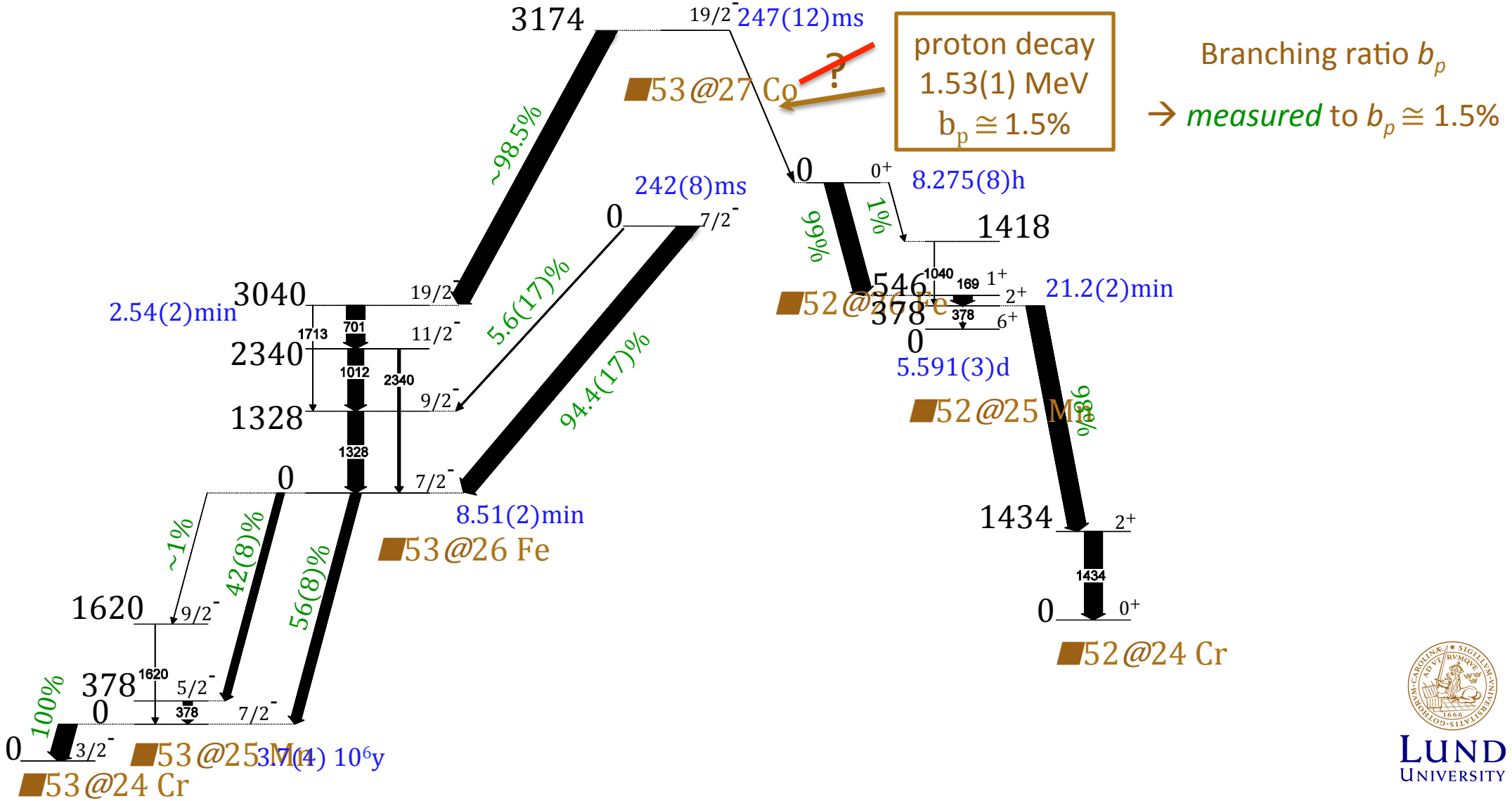

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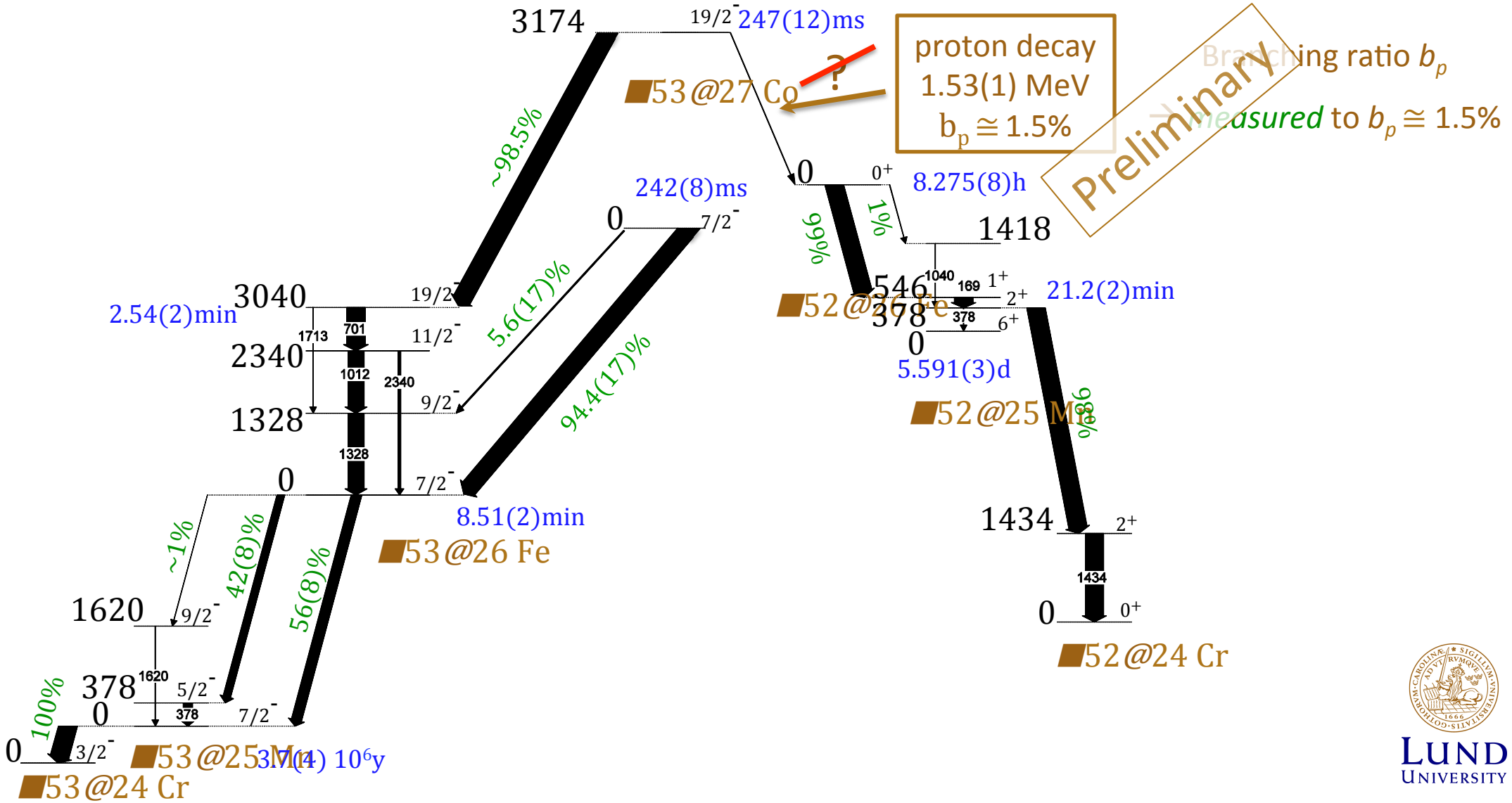

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Conclusion & Outlook

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- 100% pure beams + detectors system TASISpec + Geant4 Simulation

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Conclusion & Outlook

- 100% pure beams + detectors system TASISpec + Geant4 Simulation
  - New branching ratios in ^{213}Ra and ^{53}Co^{m}
  - New mixing ratios in ^{209}Rn

- Papers are in preparation for the two projects ^{213}Ra & ^{53}Co^{m}

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Conclusion & Outlook

- ***Simulation aided Quantum-State Selective Decay Spectroscopy***

  proofs to be a valuable technique to investigate cases where

  - decay patters are not unambiguous ($^{53}Co^{m}$)
  - but also for reviewing/remeasuring older decay data (^{213}Ra)

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Thank you for your Attention

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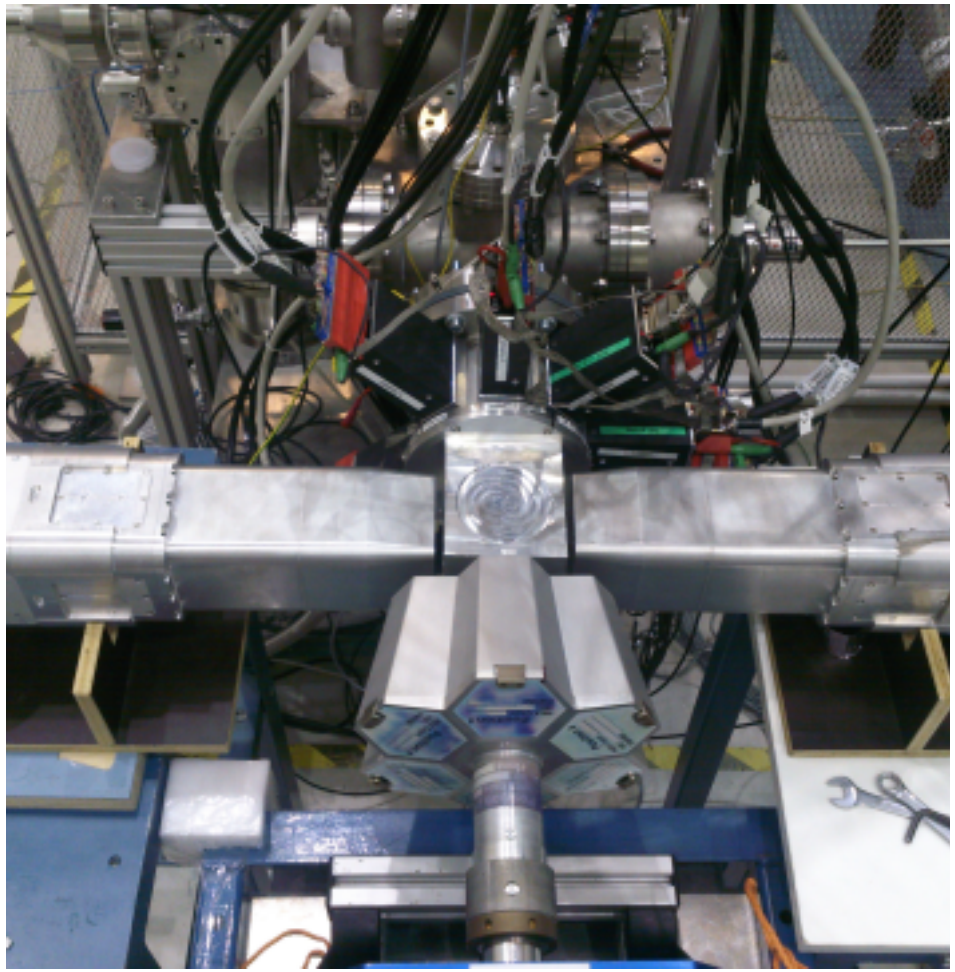
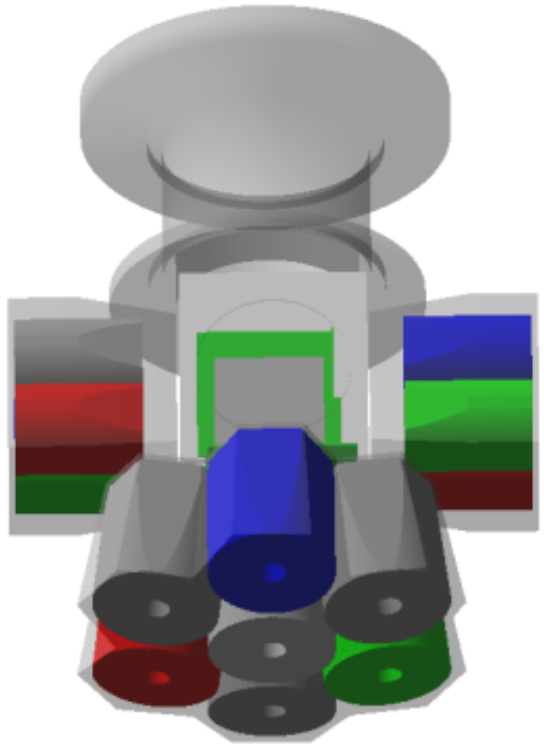
TASISpec in Jyväskylä





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