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Nuclear Resonance Fluorescence states in 239Pu

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Disclaimer

Lawrence Livermore National Laboratory

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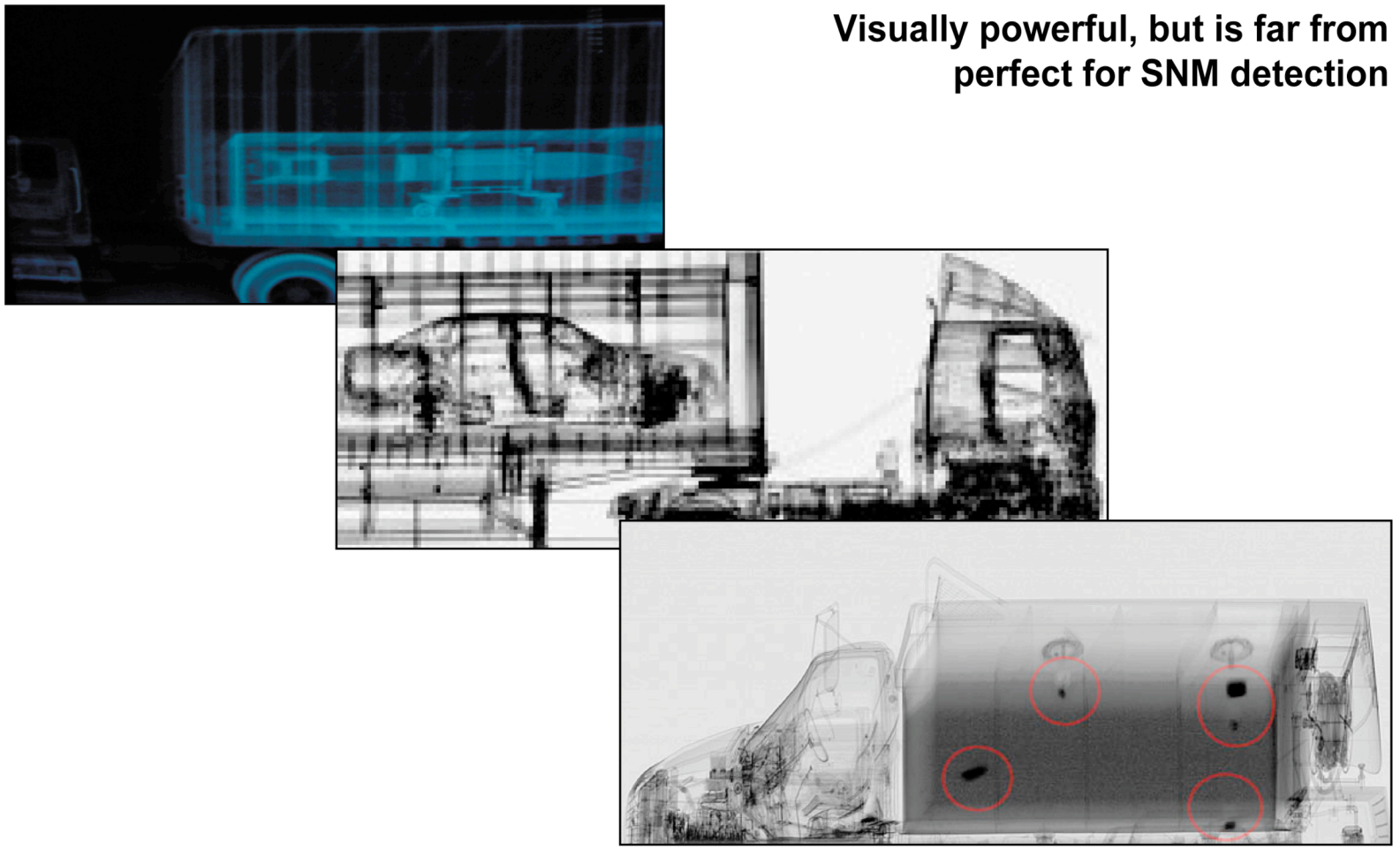
Outline

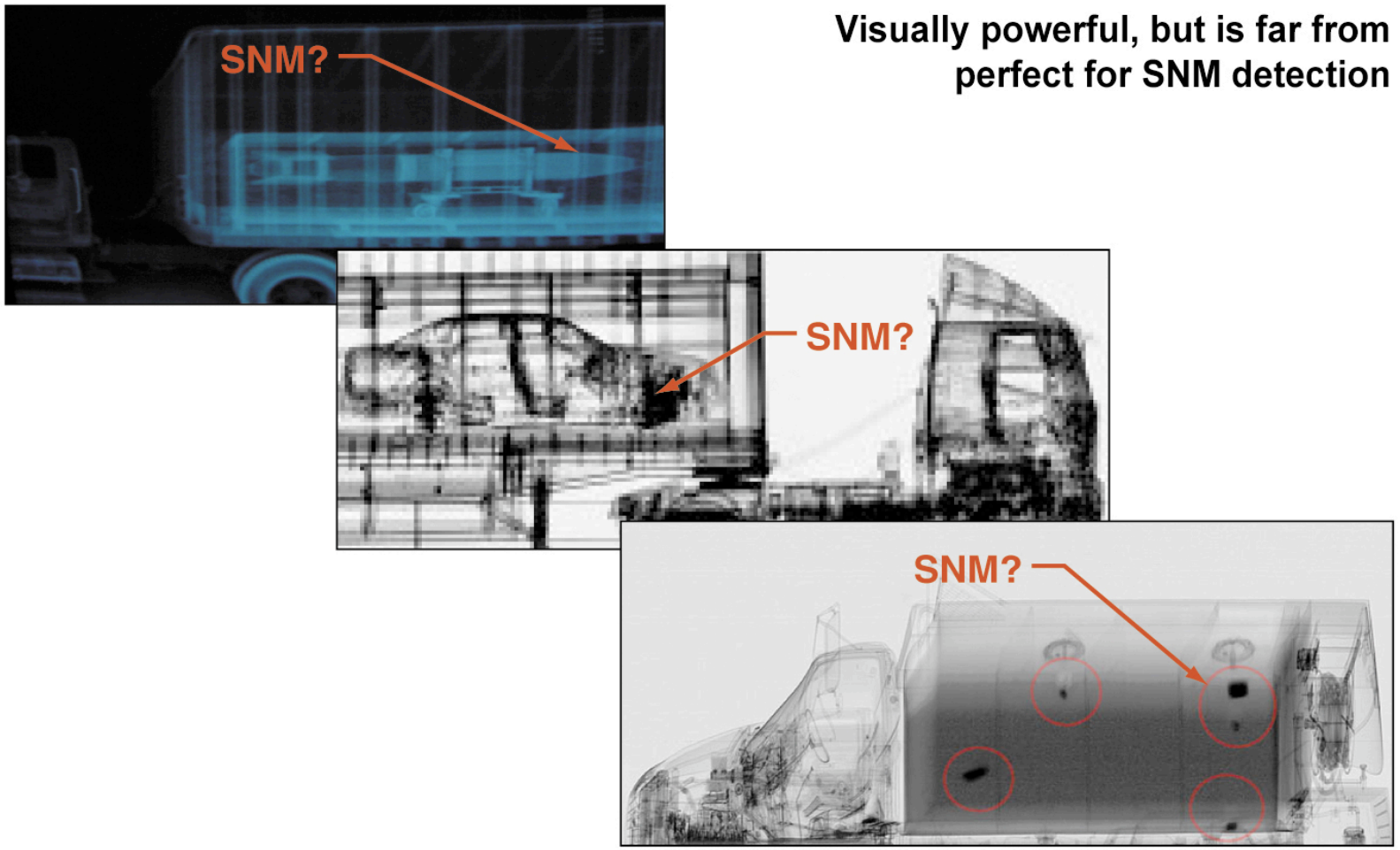
- Motivation and Background
- NRF measurements on Pu
  - MIT
  - UCSB
- Summary

Current systems: radiography



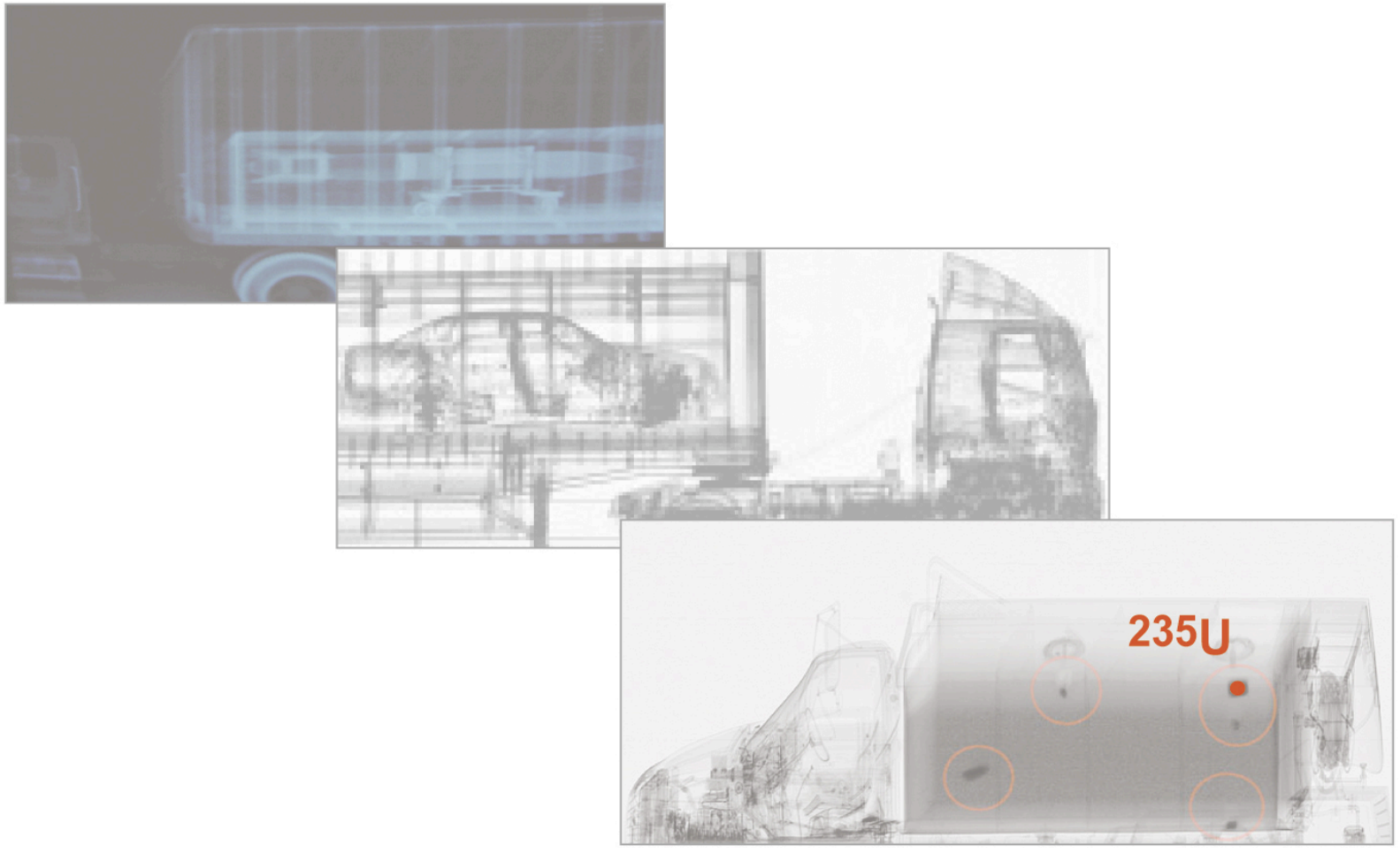
Visually powerful, but is far from perfect for SNM detection

Limitation: density silhouette



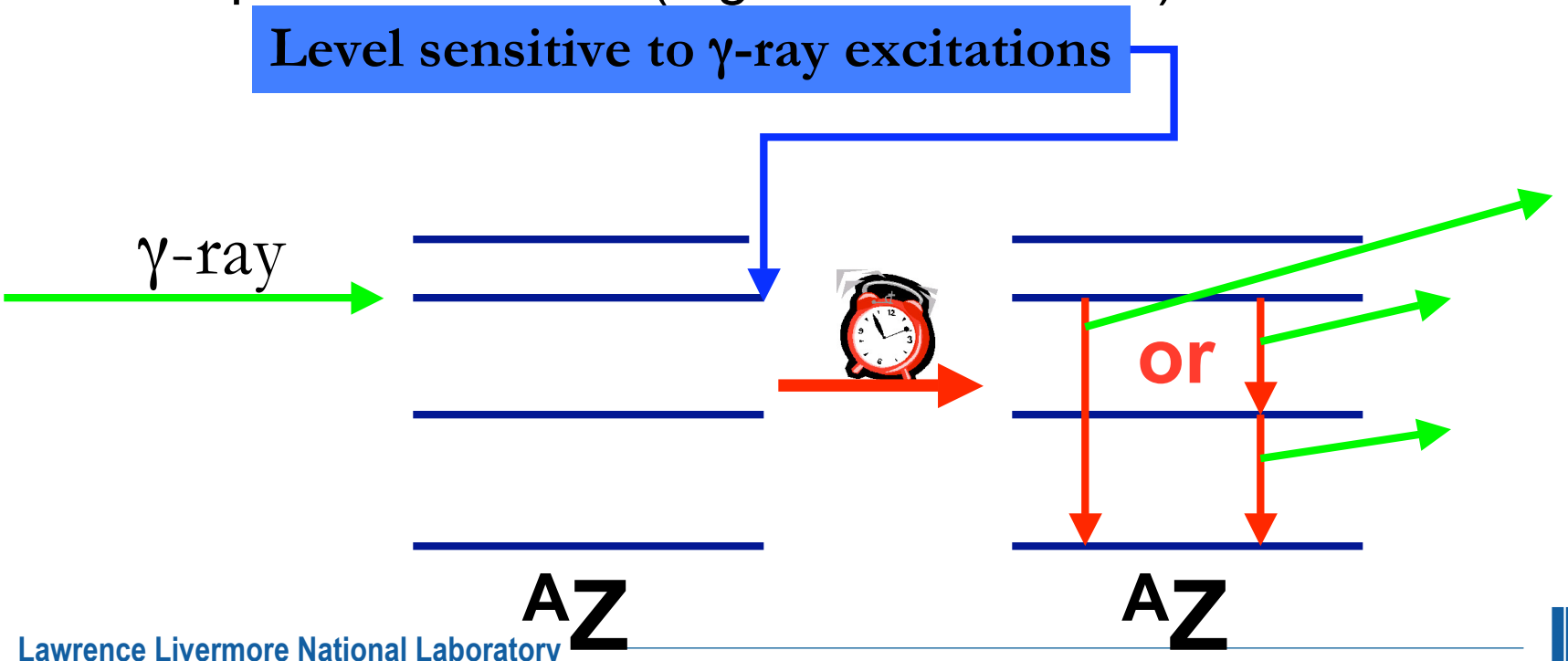
Visually powerful, but is far from perfect for SNM detection

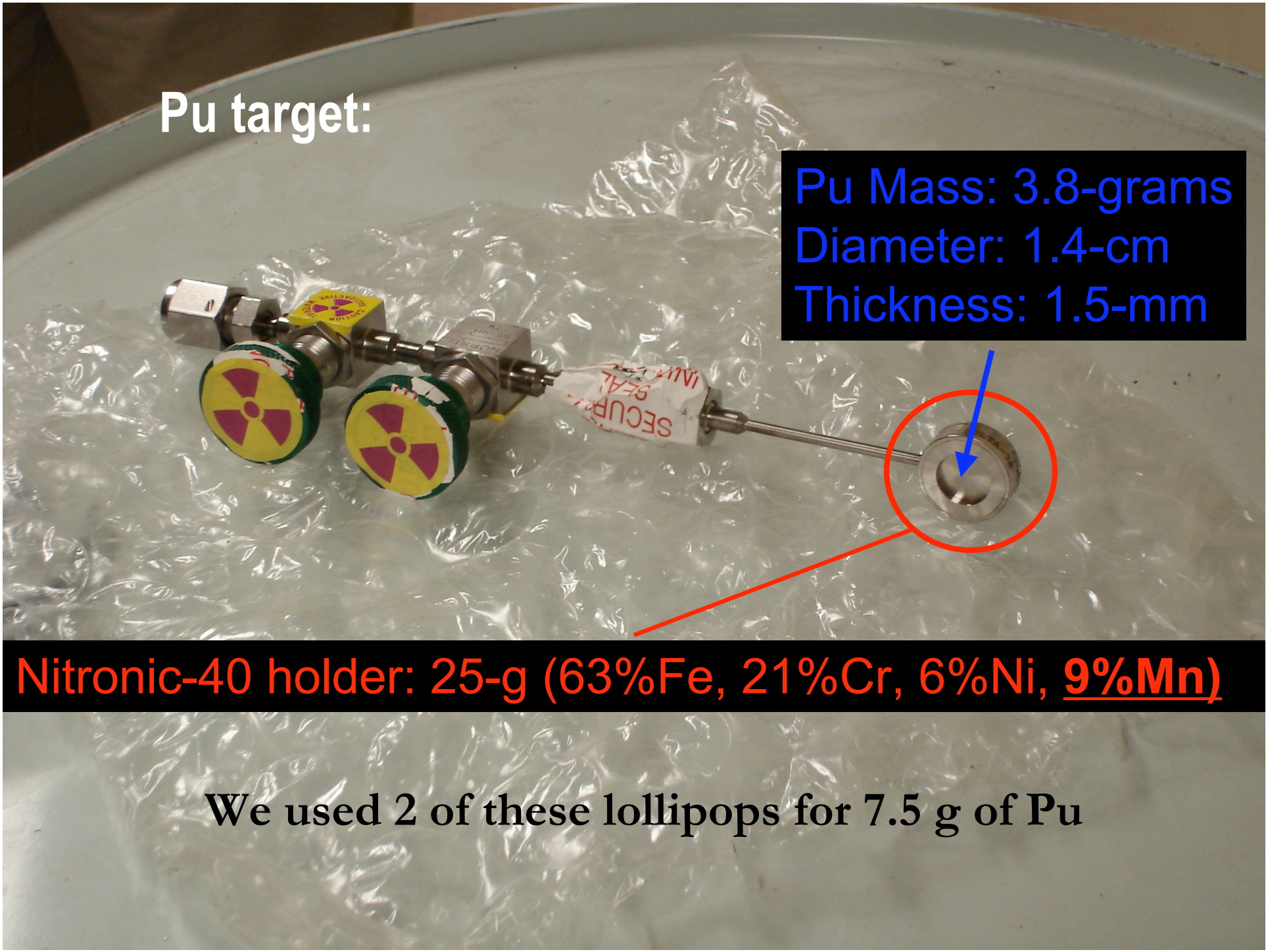
NRF ⇒ isotopic sensitivity



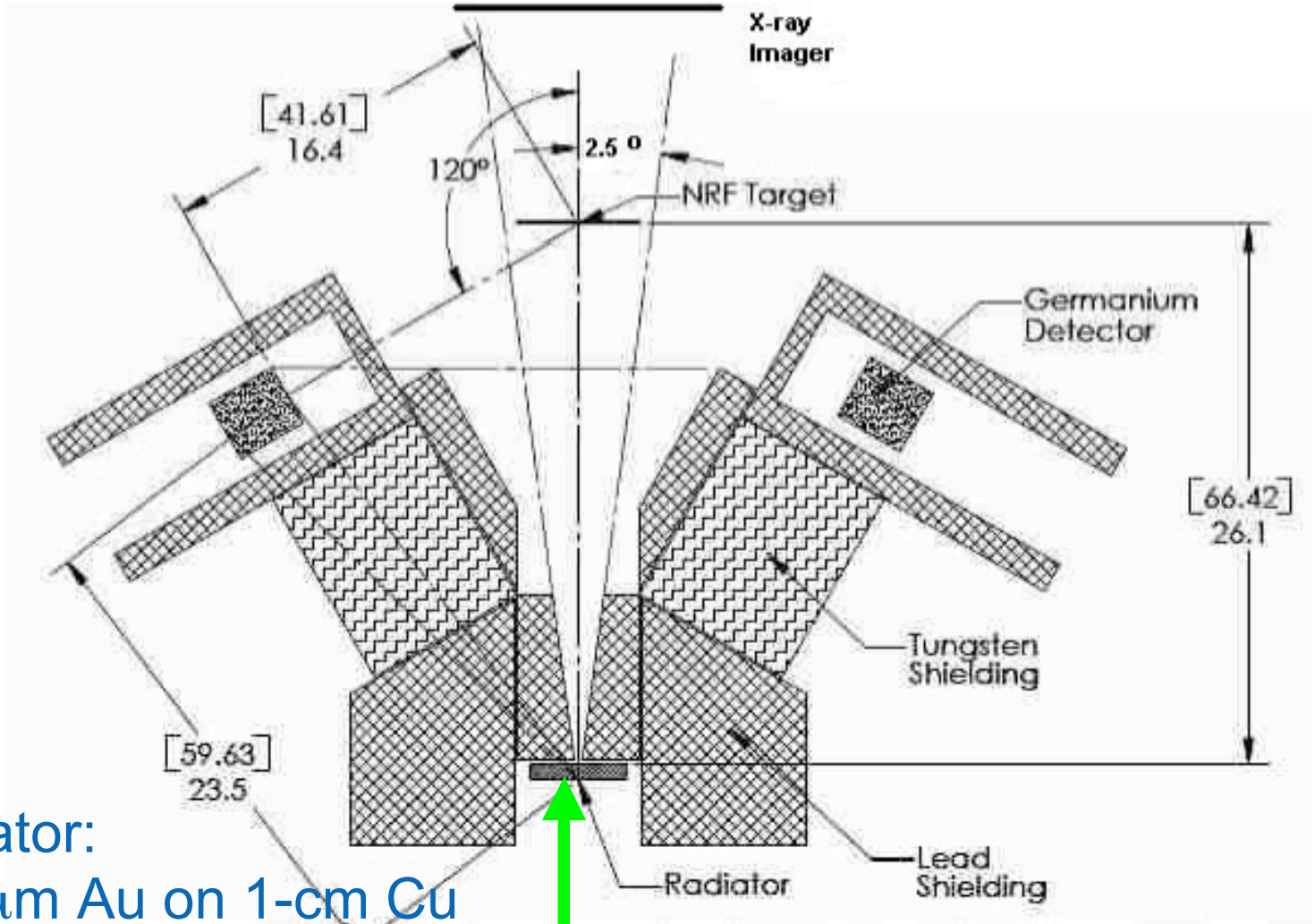
Nuclear Resonance Fluorescence (NRF)

- An energetic photon (γ-ray) at a resonant energy of a particular isotope can excite that isotope.
- The excited nucleus then will decay by emitting a set of γ-rays
- Dipole excitations (e.g. scissors mode)



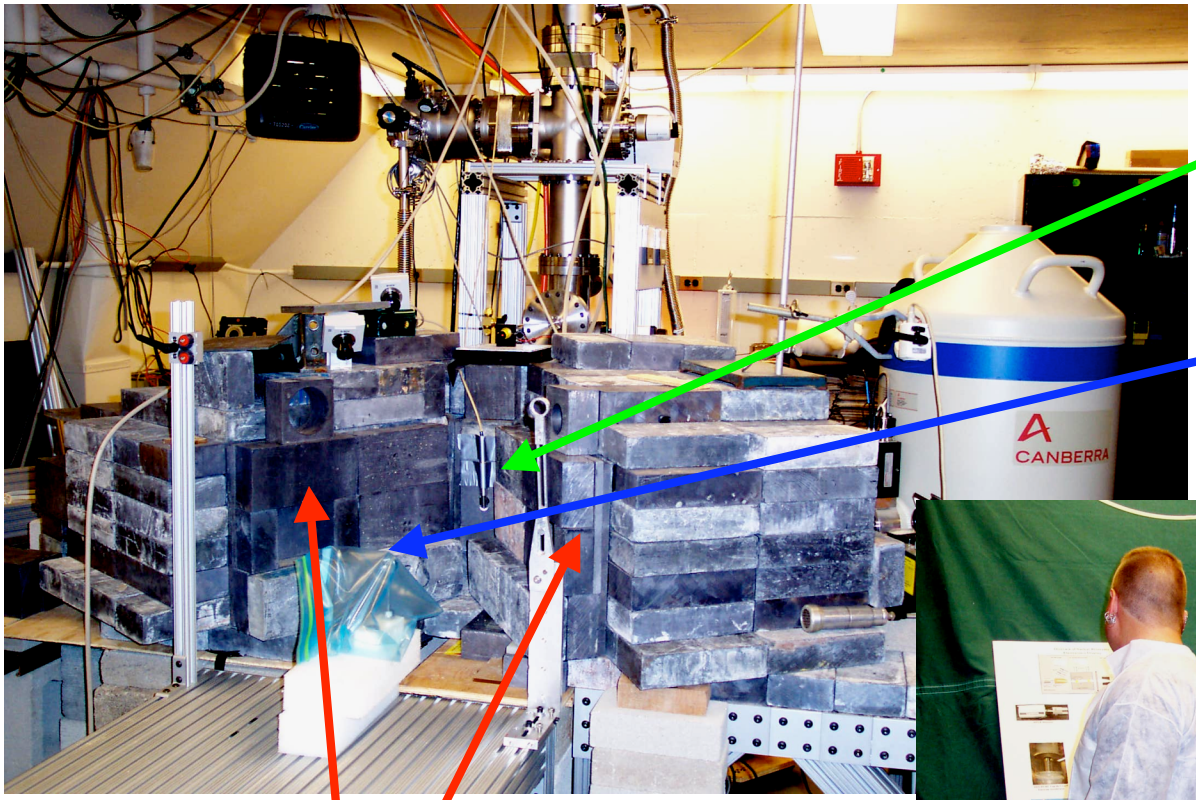

Pu target:
Pu Mass: 3.8-grams
Diameter: 1.4-cm
Thickness: 1.5-mm
Nitronic-40 holder: 25-g (63%Fe, 21%Cr, 6%Ni, 9%Mn)
We used 2 of these lollipops for 7.5 g of Pu

Experimental Setup: (*Passport*)



Radiator:
102-μm Au on 1-cm Cu
(cooling and e⁻ cleanup)

Experimental End Station

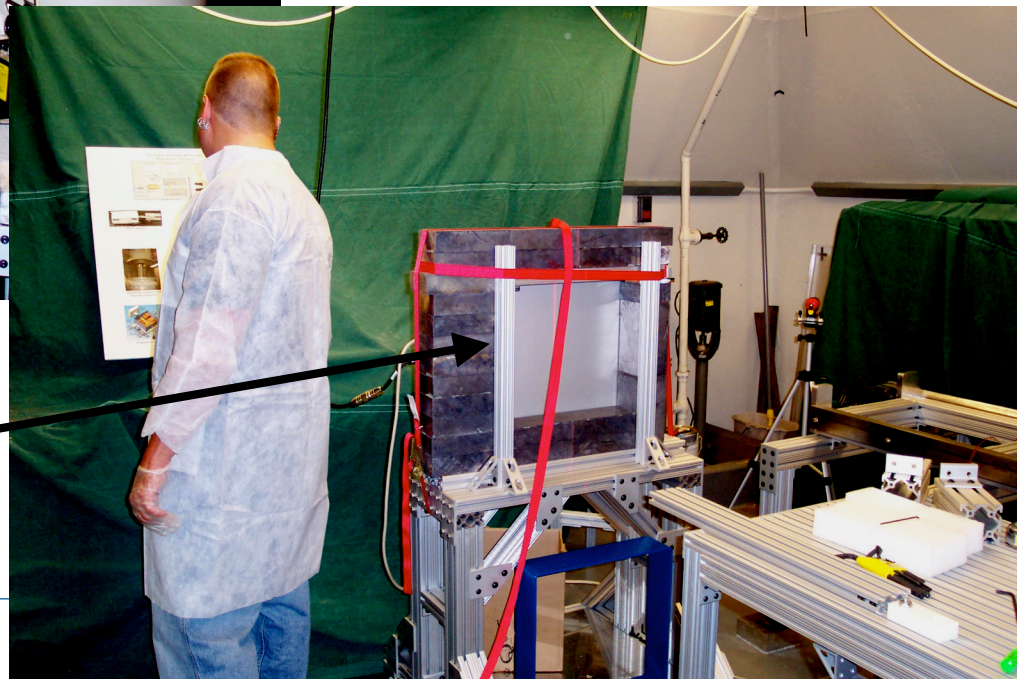


Collimator/Radiator

NRF target

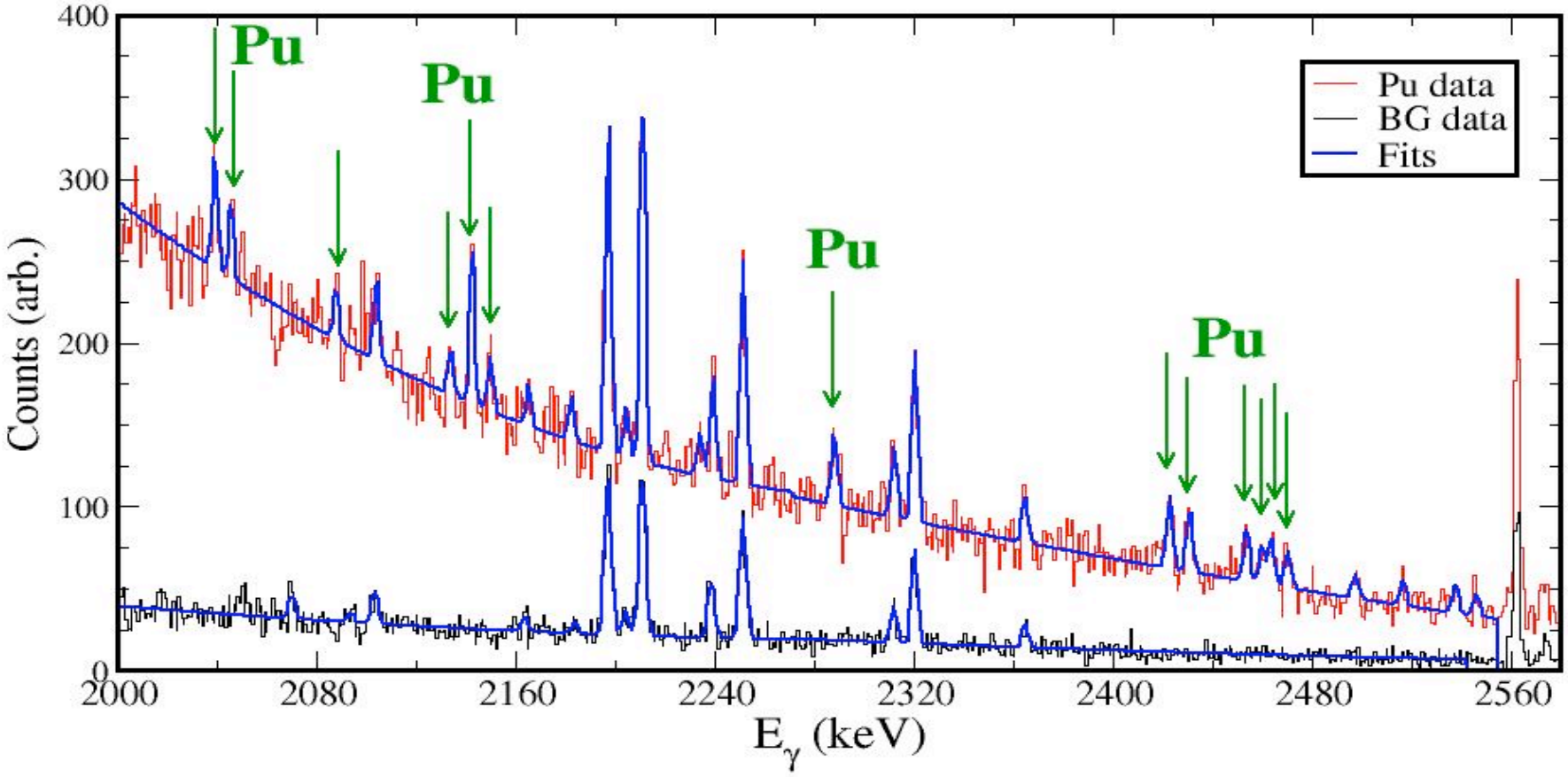
HPGe

X-ray Imager



NRF measurements (2.8 MeV e.p.)

NRF measurement on Pu at MIT with bremsstrahlung source



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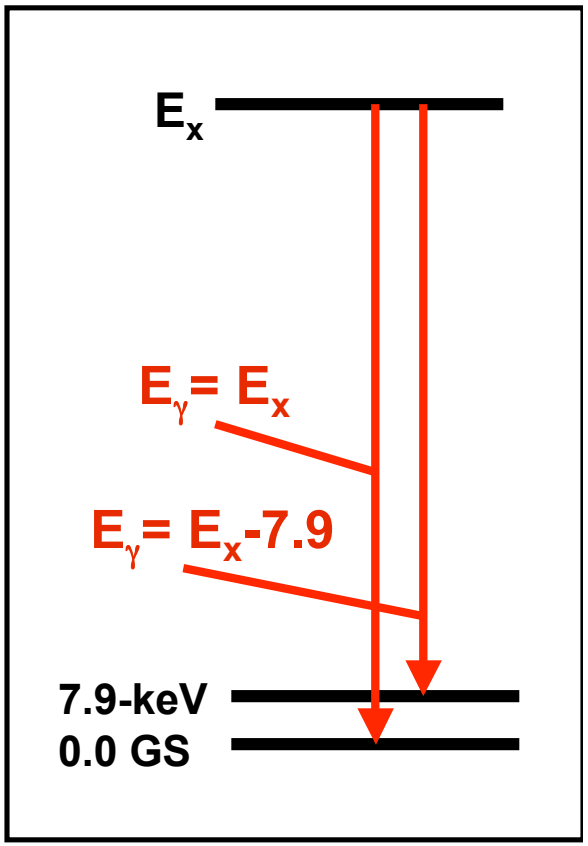
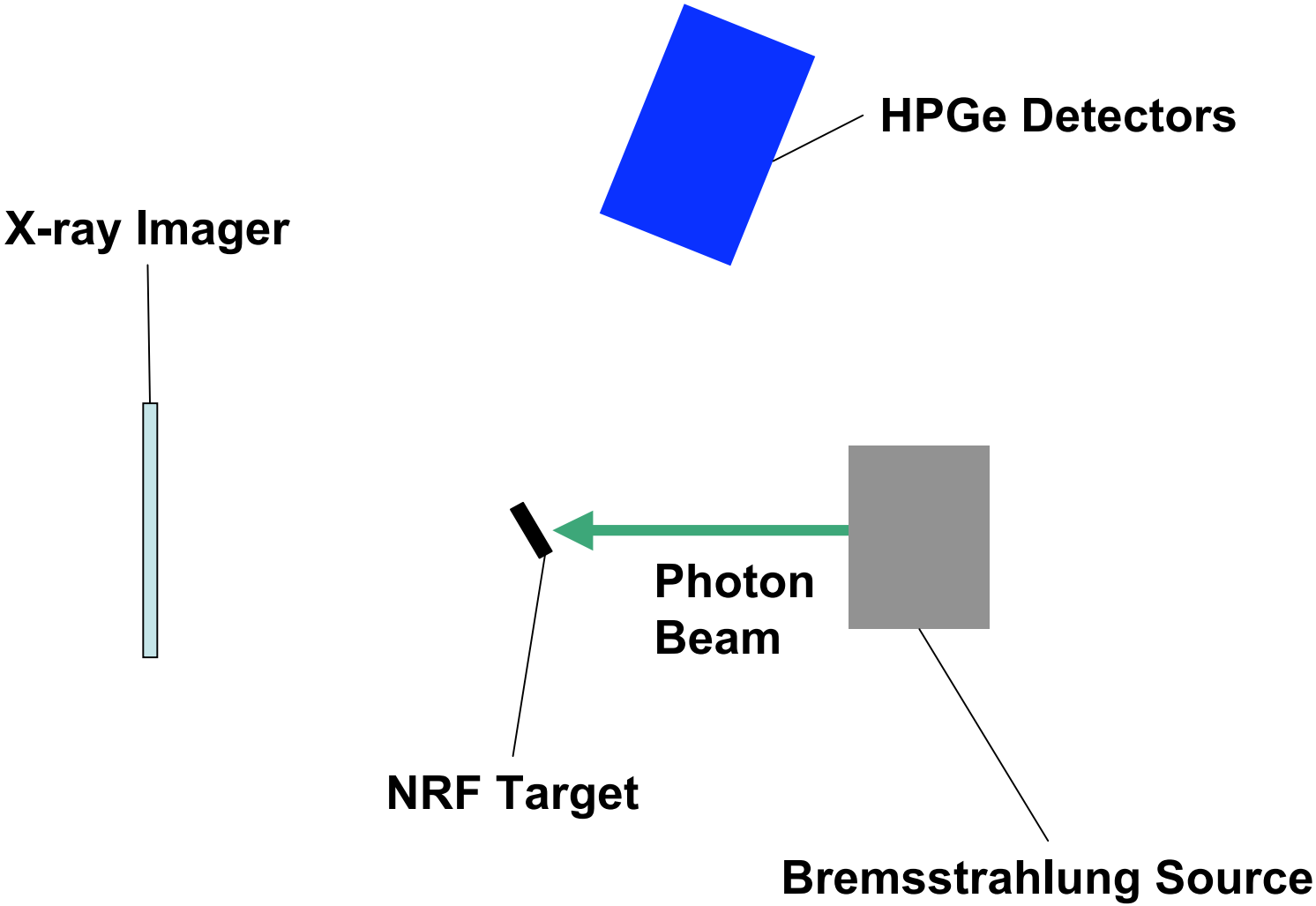
NRF results for ^{239}Pu

Transition Energy	Sigma	Cross-section (eV barns)
2040.25(33)	5.8	8(2)
2046.89(33)	4.2	5(2)
2089.14(34)	3.7	4(2)
2135.00(34)*	3.5	4(2)
2143.56(34)*	9.7	13(2)
2150.98(34)*	4.2	5(2)
2289.02(34)	6.2	8(2)
2423.48(35)**	7.2	10(2)
2431.66(35)**	6.3	9(3)
2454.37(35)	6.2	9(3)
2460.46(35)	4.7	6(4)
2464.60(35)	5.7	8(4)
2471.07(35)	4.6	6(2)

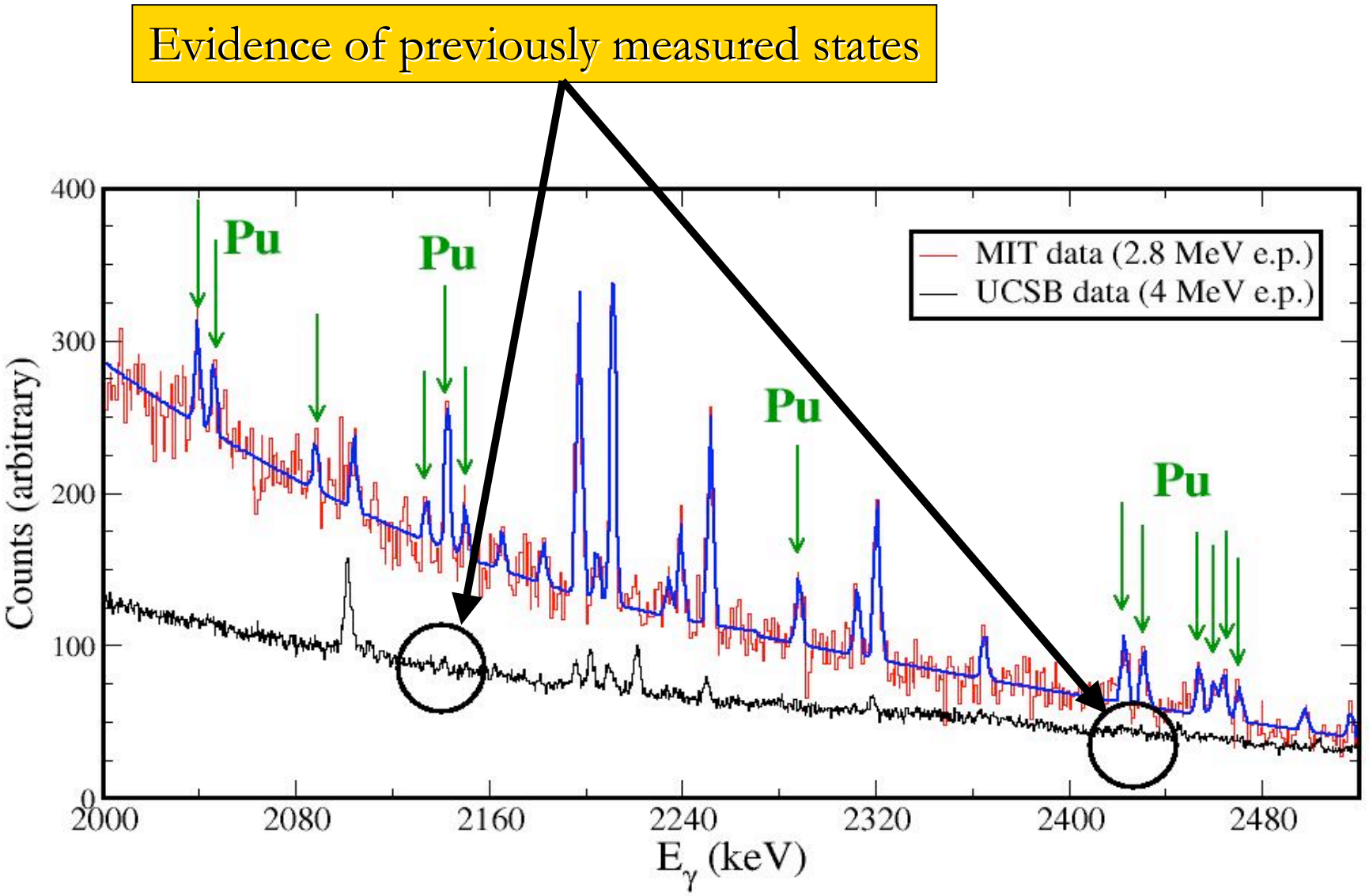


Systematics imply these resonances are magnetic dipole

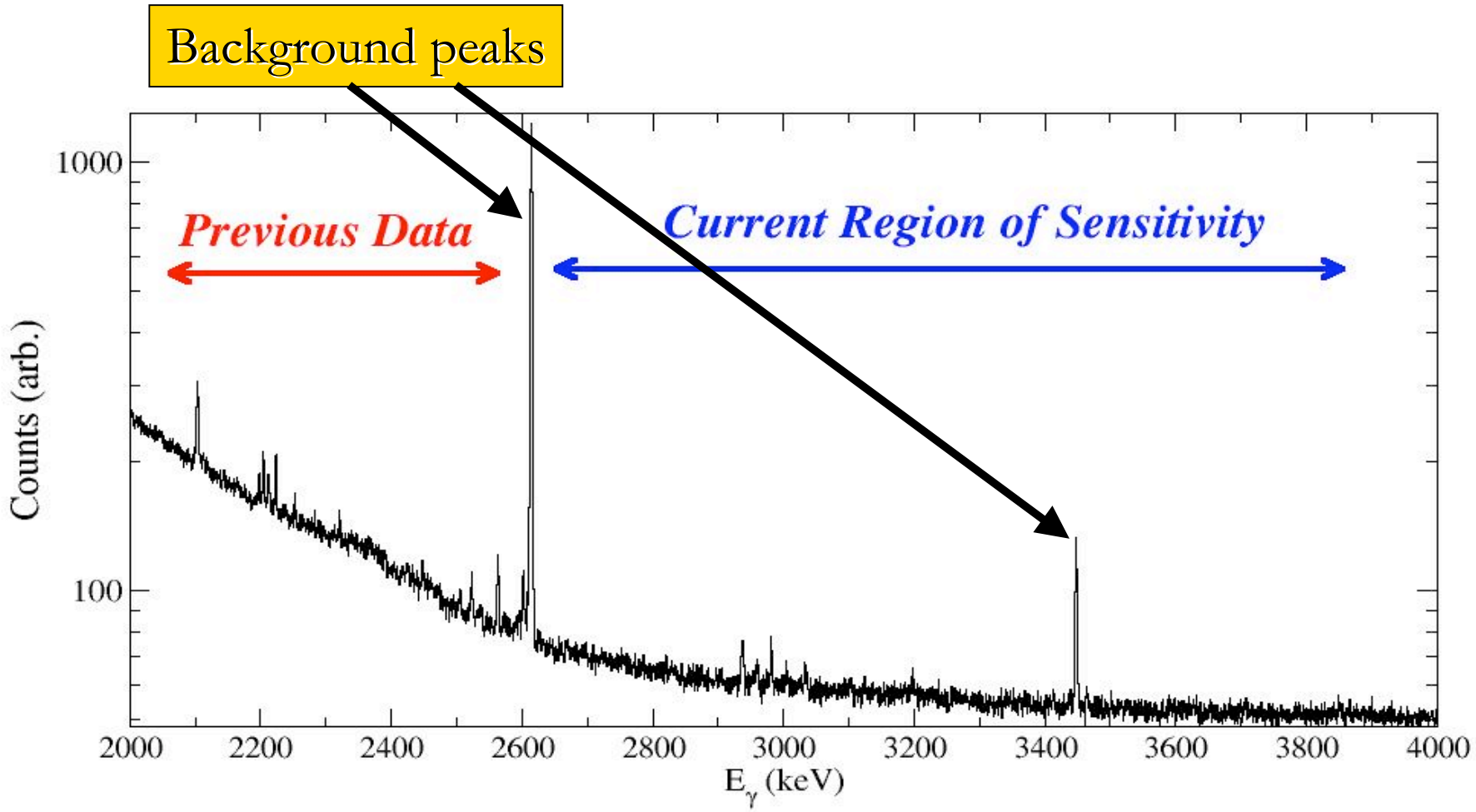
UCSB setup


HPGe Detectors
X-ray Imager
Photon
Beam
NRF Target
Bremsstrahlung Source

Best data collected at 4.0 MeV

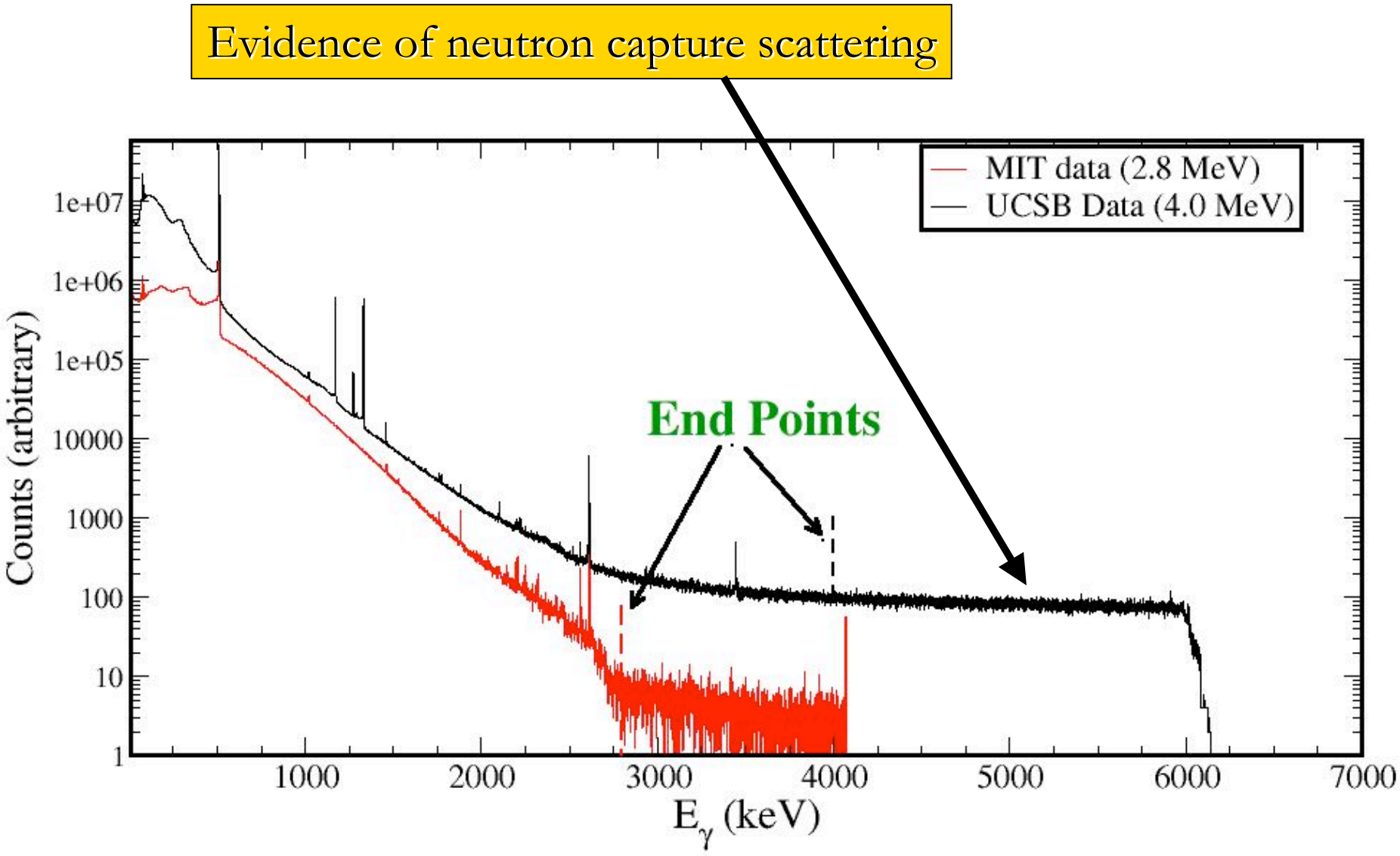


Region of best sensitivity (analysis is ongoing)



NRF peaks expected to be small

Background Issues



Summary

- NRF measurements have been performed on ^{239}Pu < 2.5 MeV
  - PRC/RC is in publication (Phys. Rev. C **78** 041601 (2008))
- NRF measurements have been performed on ^{239}Pu > 2.5 MeV
- Backgrounds indicate unexpected neutron capture scattering
  - Return to UCSB and perform background runs at 4.0 MeV
  - Need about 48 hours worth of data to match the data statistics
- Analysis is just beginning
  - Spectra are corrected for deadtime, efficiency, and summed.
    - Waiting for background spectrum.
  - Detailed analysis will be performed by UC Berkeley graduate student, James McFarland.
    - Peer-reviewed article to follow

Collaboration

- M.S. Johnson, D.P. McNabb, C.A. Hagmann, E.B. Norman, *LLNL*
- W. Bertozzi, S.E. Korbly, R.J. Ledoux, W.H. Park, *Passport Systems Inc.*
- UC Berkeley, graduate students and postdocs: Bethany Lyles, Erik Swanberg, Kayla Evans, Ragnar Stroberg, James McFarland (analyzing data)
- *Facilities at UCSB and HVRL/MIT*