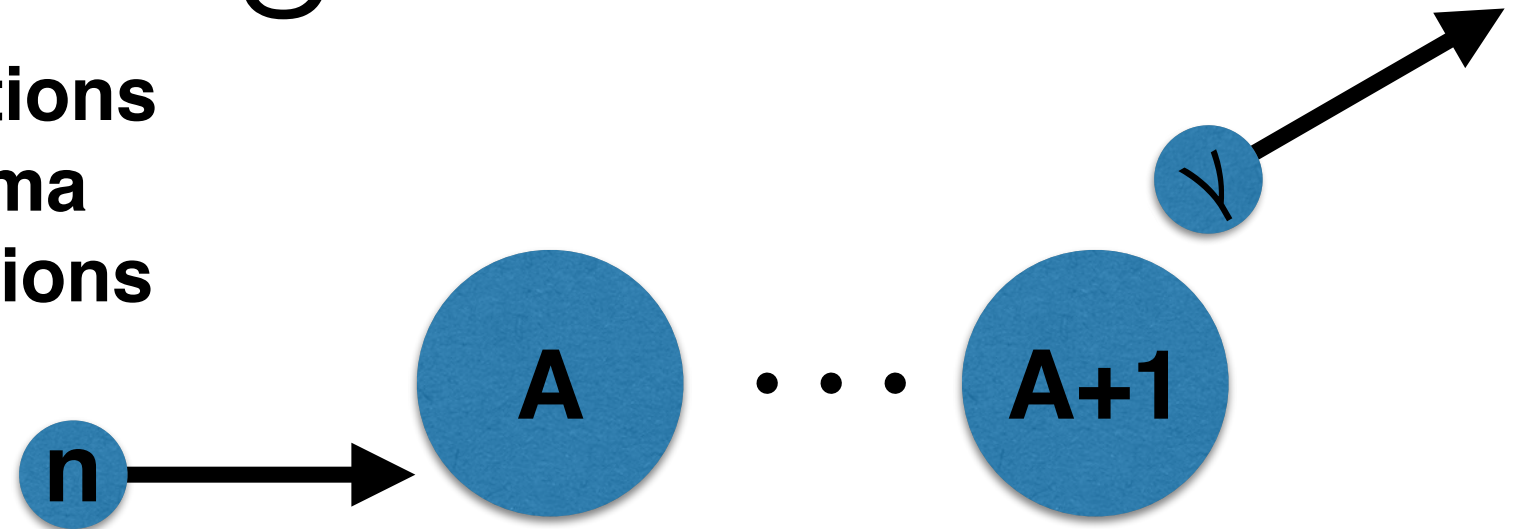


Apollo and Gamma Ray Measurements with Helios at Argonne

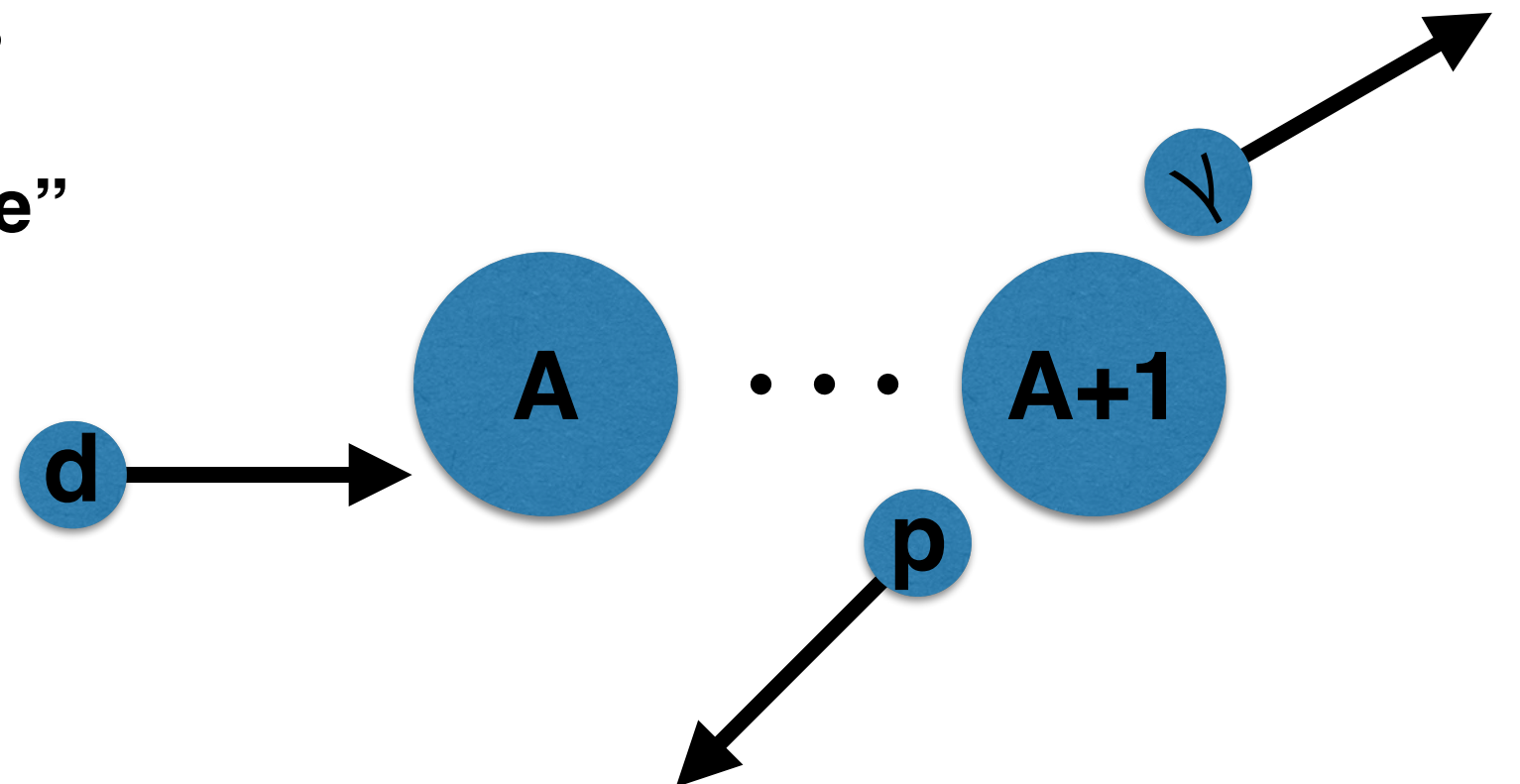
Jack Winkelbauer
Los Alamos National Laboratory

Neutron Capture and the Photon Strength Function

- Reasonable (n,γ) predictions require reasonable gamma ray de-excitation predictions



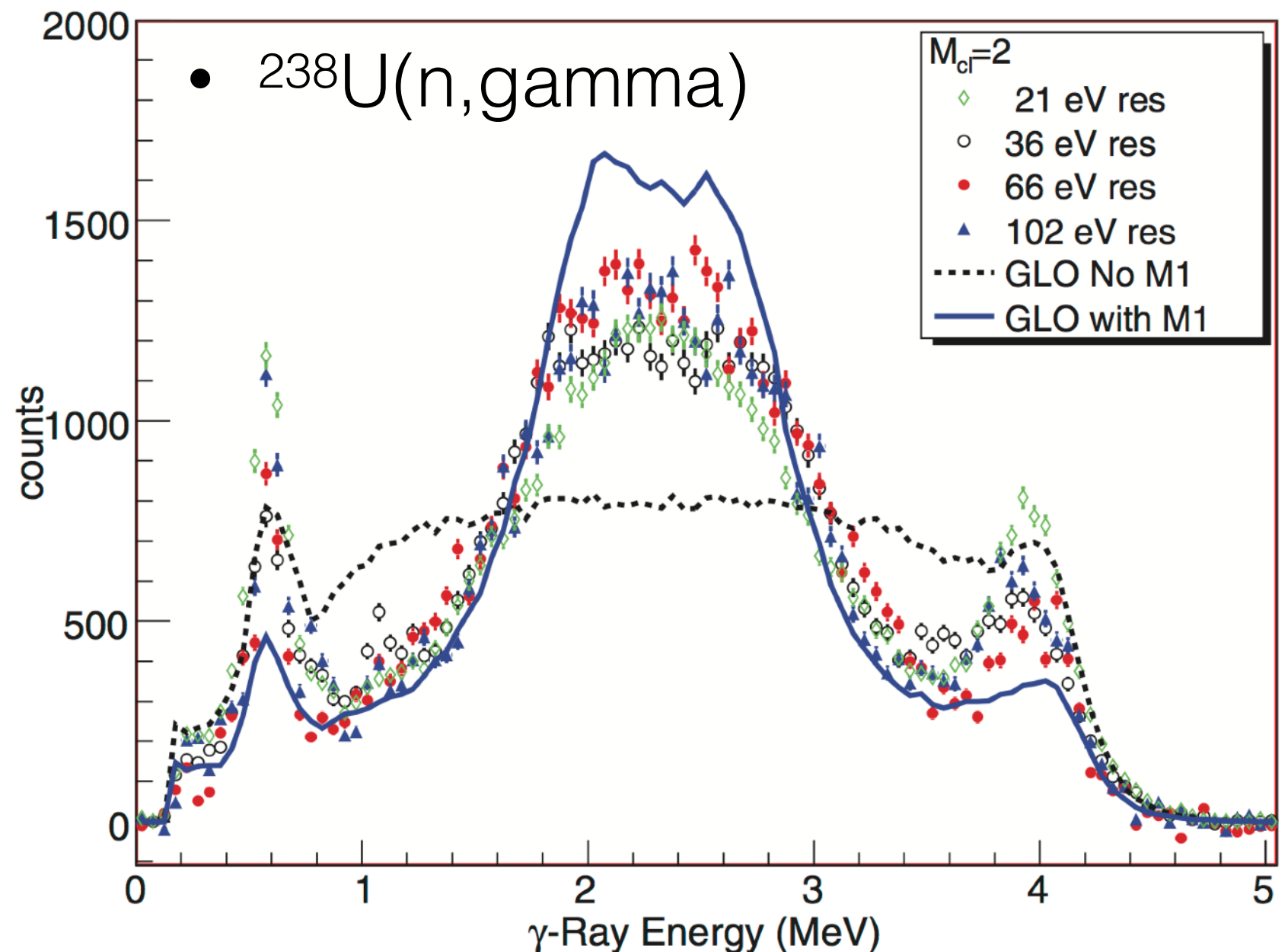
- If direct measurement is impossible, (n,γ) can be studied using “surrogate” reactions



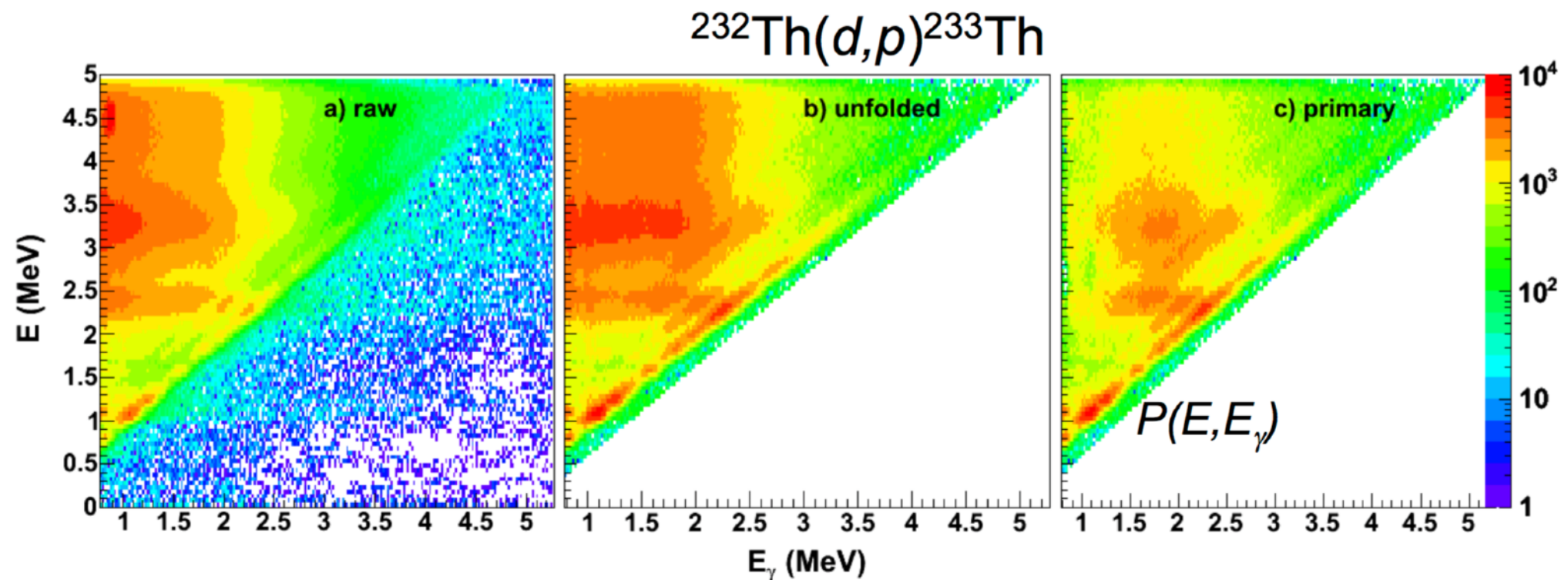
- Observed γ -spectrum $\approx (\text{PSF}) \times (\text{Level Density})$

“Spectrum Fitting” Method

- “Forward Analysis” using Geant4 simulation
- Direct (n, γ) measurements at LANSCE
- Demonstrated with heavy, medium mass nuclei.
- Can also be applied to indirect reaction studies



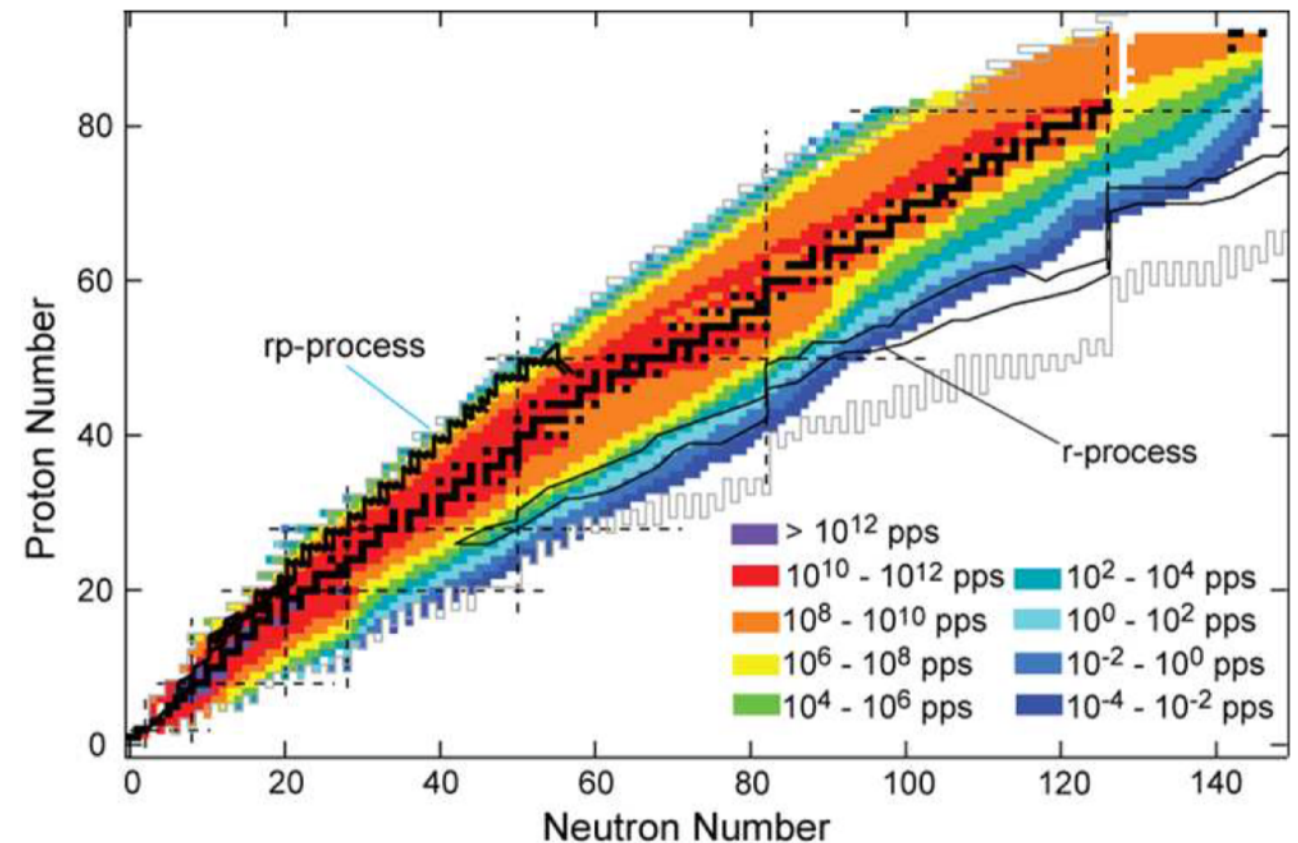
The “Oslo” Method



- **Transfer and Inelastic Scattering reactions (normal kinematics), Beta-Oslo at MSU**
- **Brink-Axel Hypothesis**
- **“Low energy enhancement”**
- **Extract PSF and NLD “simultaneously”**

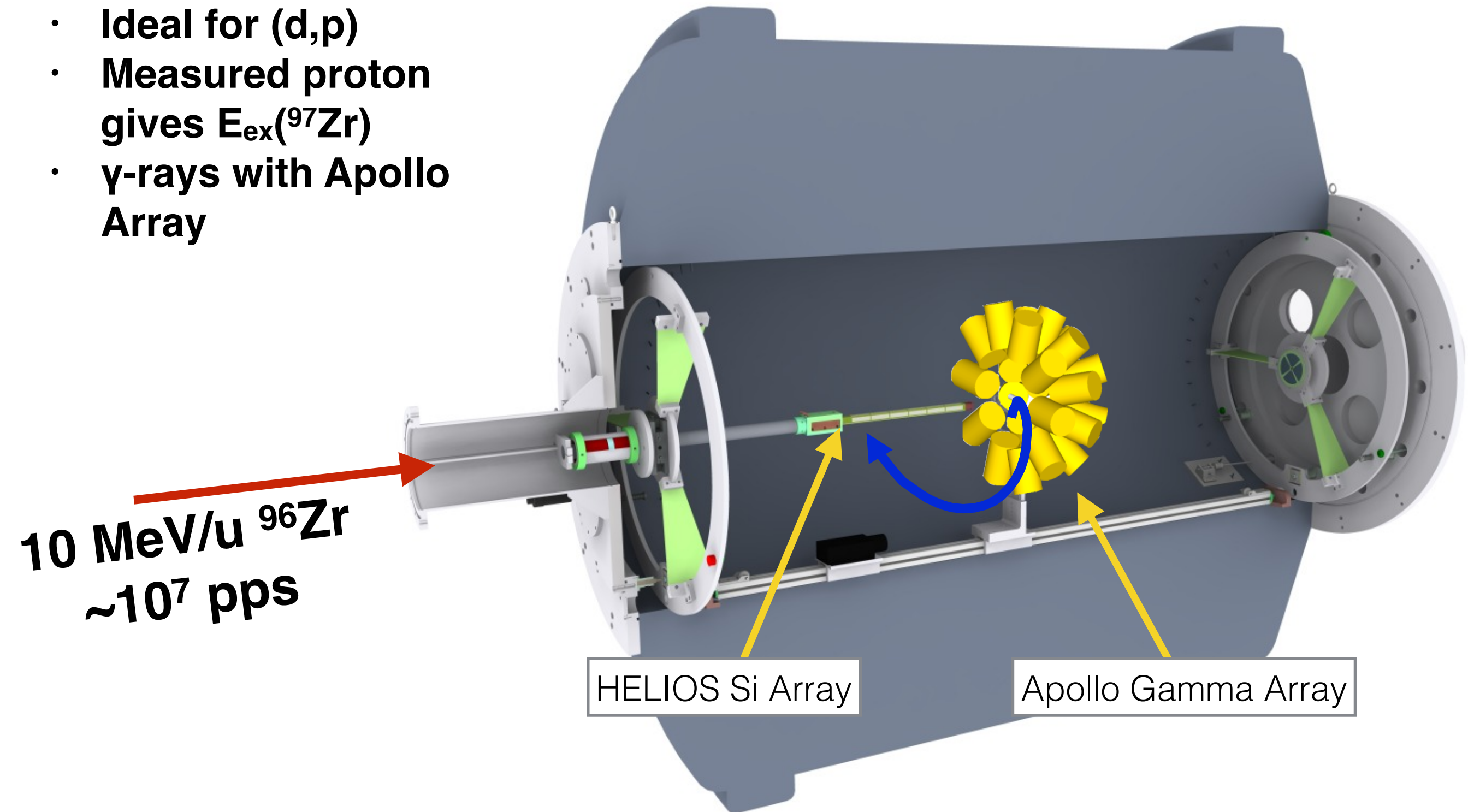
Objectives

- Does PSF from (d,p) look like PSF from (n, γ)?
- Does “Oslo” get it right?
- How to connect statistical model to discrete nuclear structure?
- Long term: Constrain (n, γ) for unstable nuclei at ATLAS and then FRIB



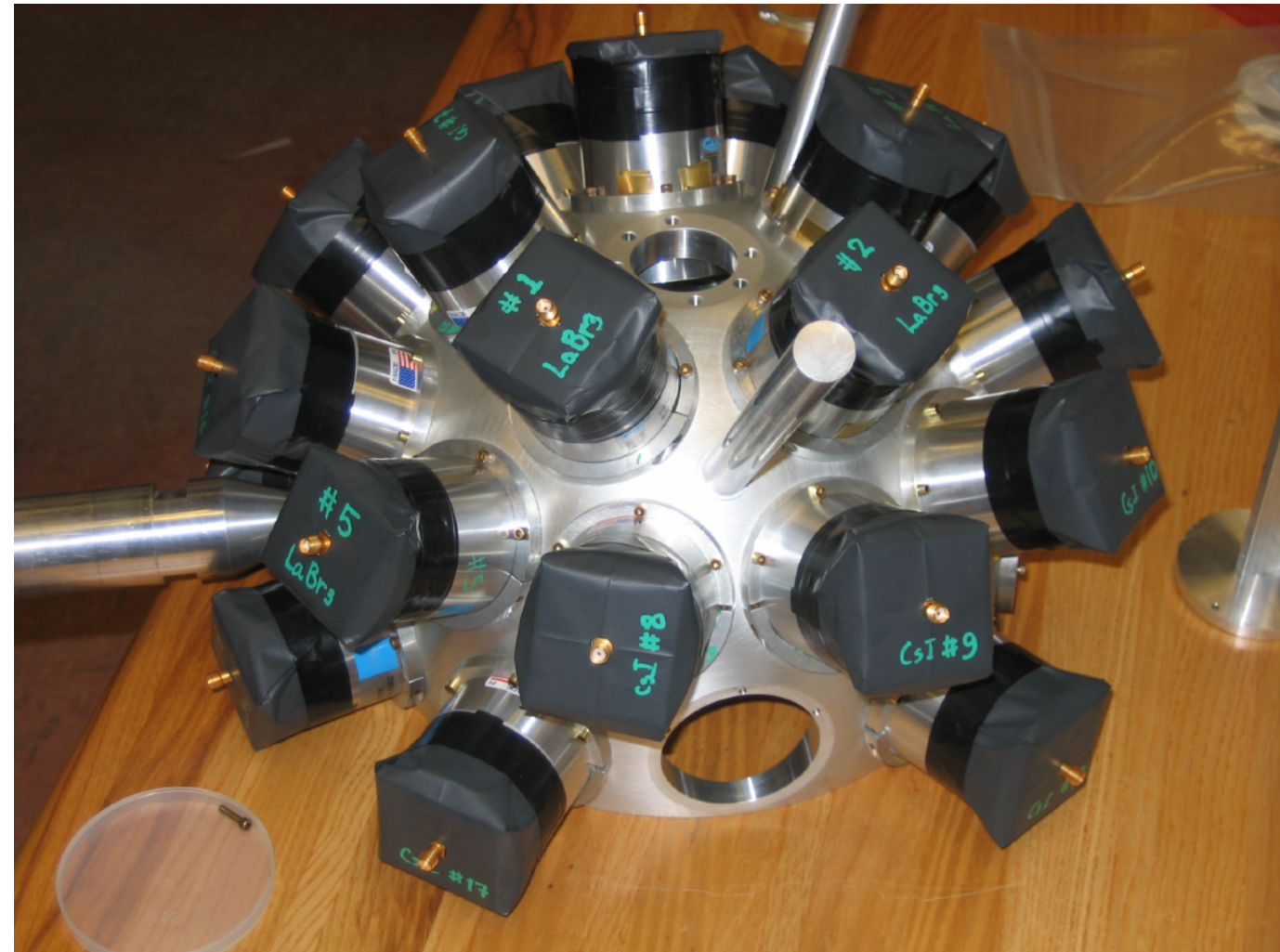
Apollo+Helios at ATLAS

- Ideal for (d,p)
- Measured proton gives $E_{\text{ex}}(^{97}\text{Zr})$
- γ -rays with Apollo Array



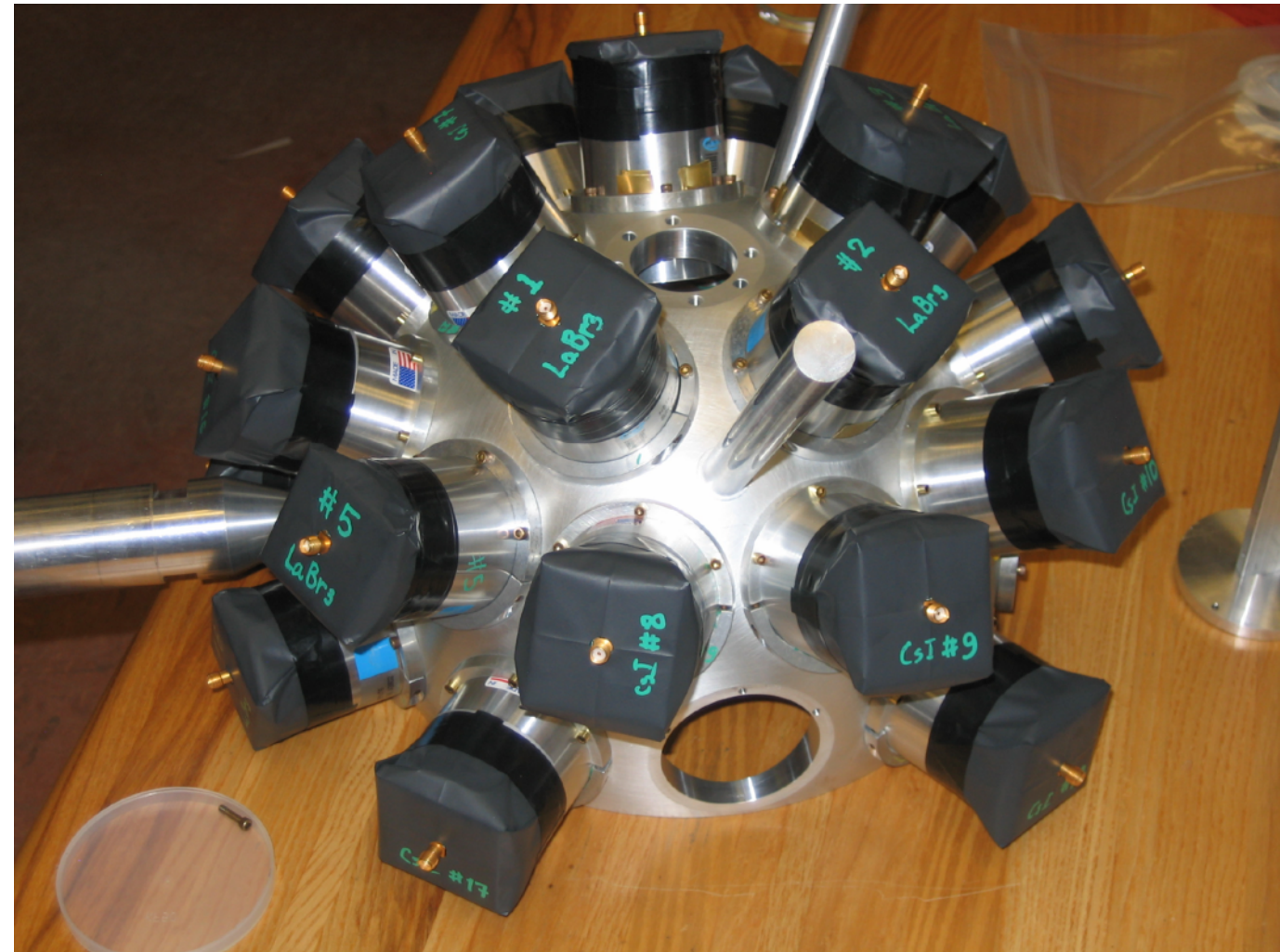
Apollo Array

- Designed and built at LANL 2011-2012
- Moved to ANL 2013
- Tested with beam inside Helios - June 2014
- First physics run $^{96}\text{Zr}(d,p)$ - April 2016
- $^{57}\text{Fe}(d,p)$ - Aug. 2016
- Isomeric $^{18}\text{F}(d,p)$ - Oct. 2016 (D. Santiago)



Apollo Array

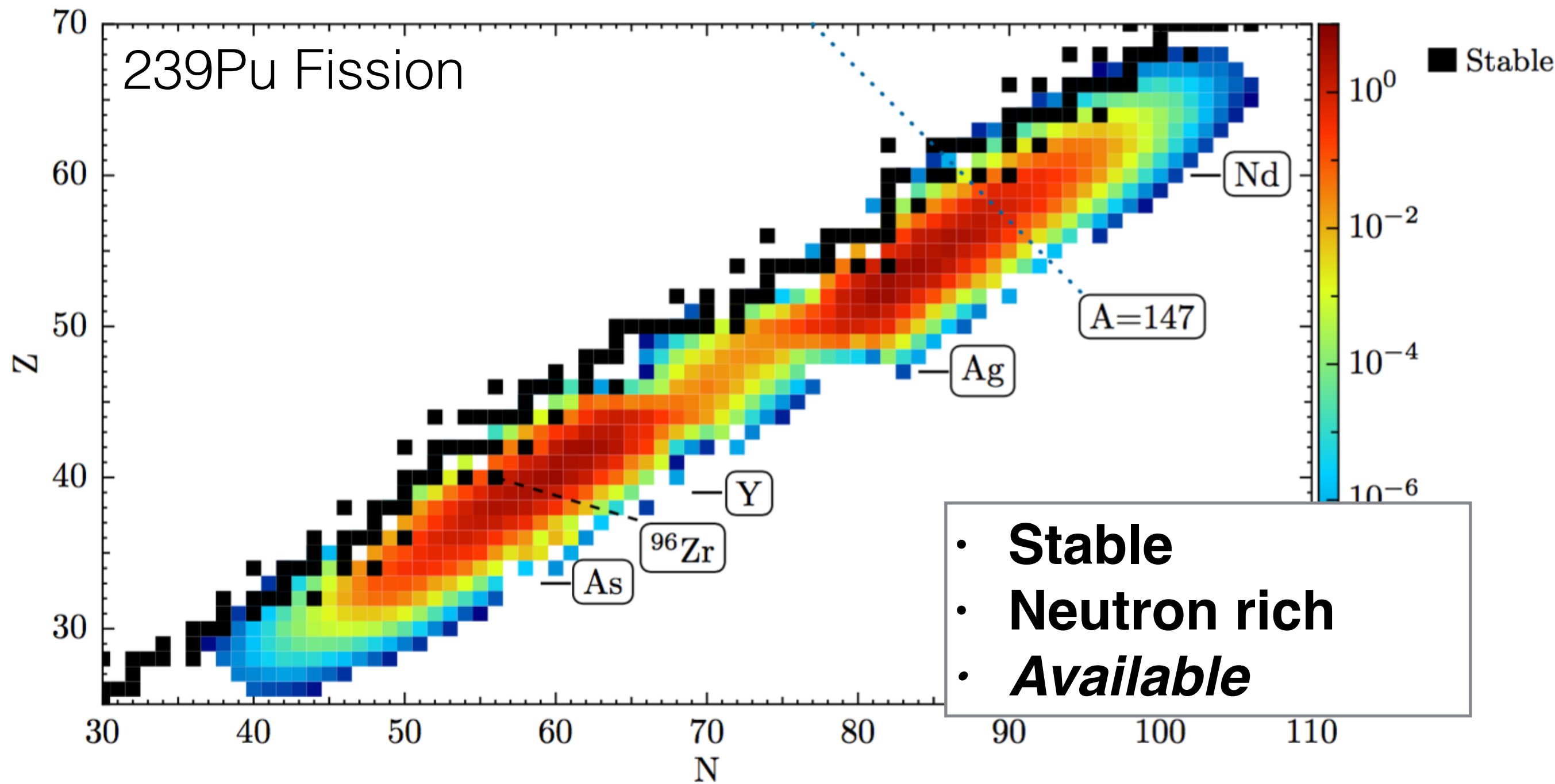
- **21 Detectors (6 LaBr, 15 CsI)**
- **2" x 3" crystals, light readout with Silicon Photomultipliers**
- **Compact, portable**
- **Unaffected by magnetic field**



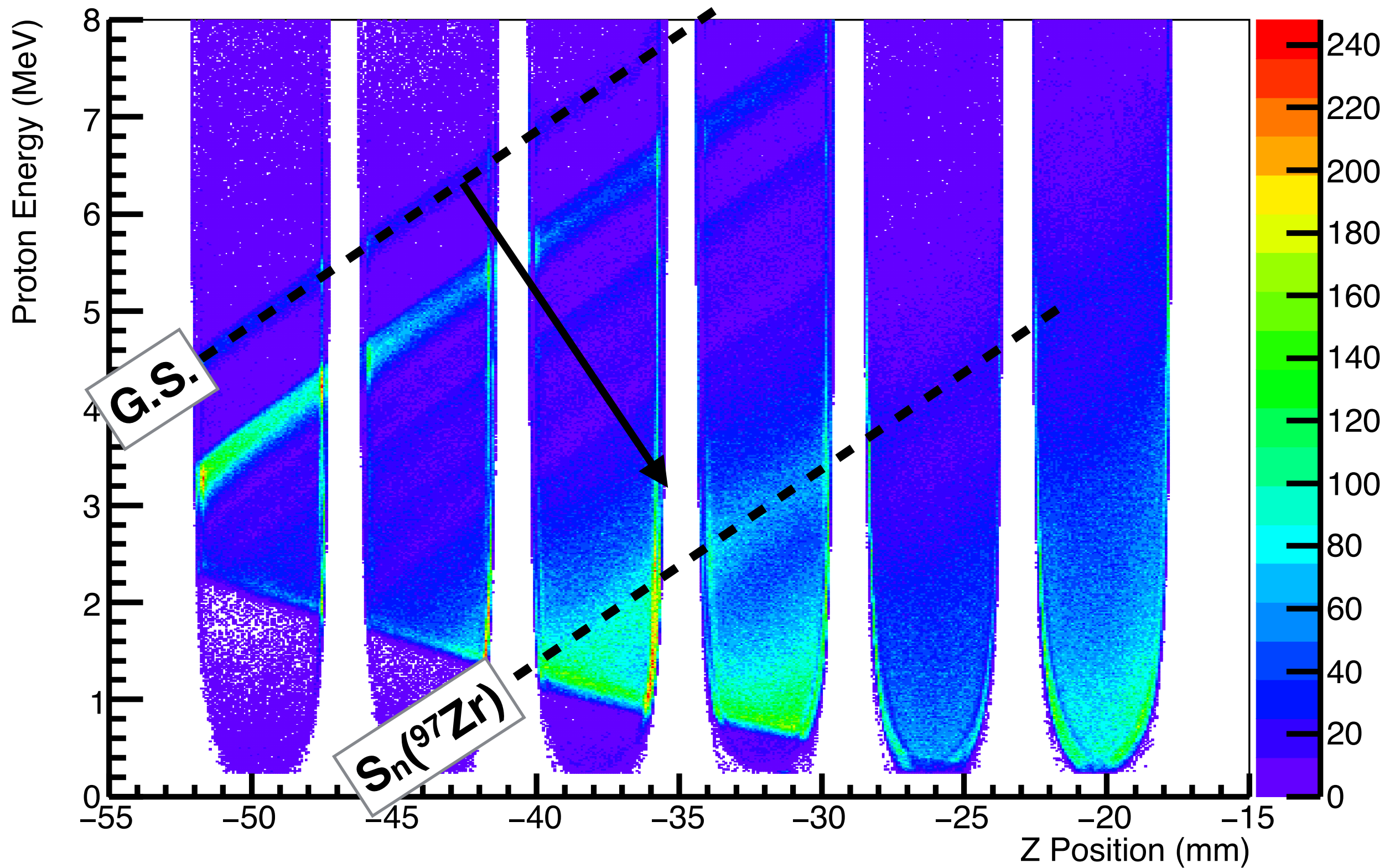
Apollo + Helios



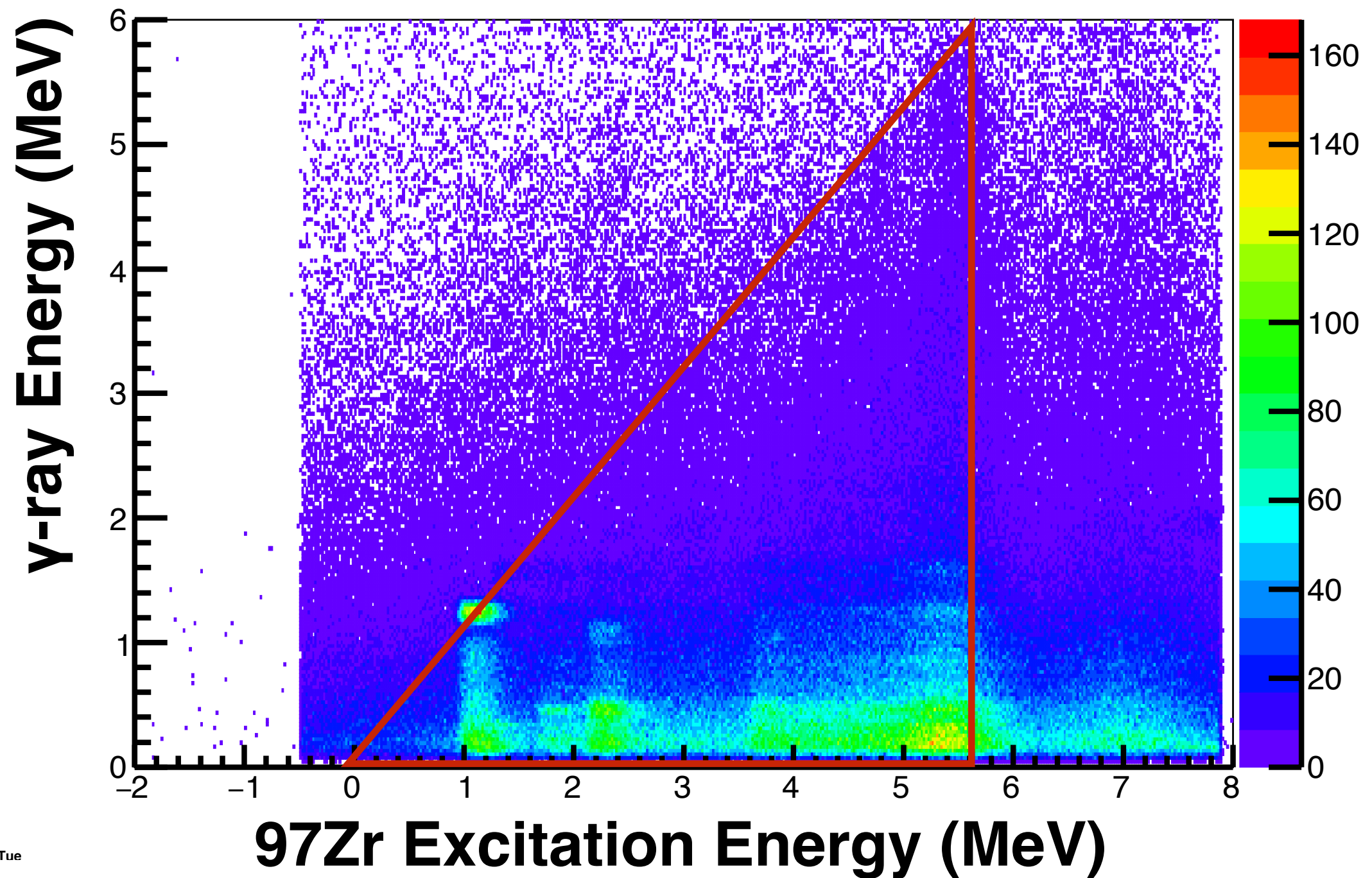
^{96}Zr - A Test Case



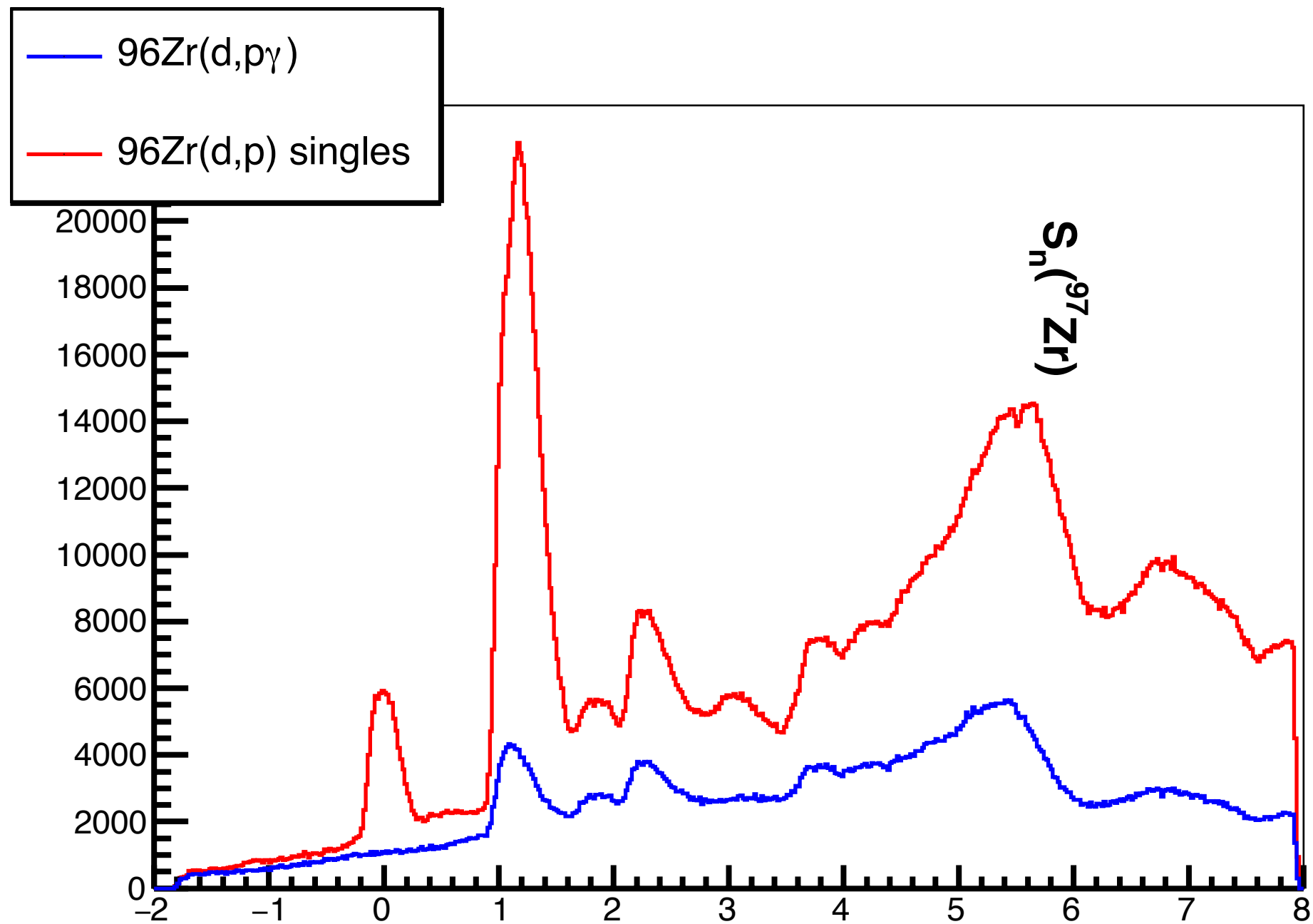
$^{96}\text{Zr}(\text{d},\text{p})$



$^{96}\text{Zr}(d,p\gamma)$



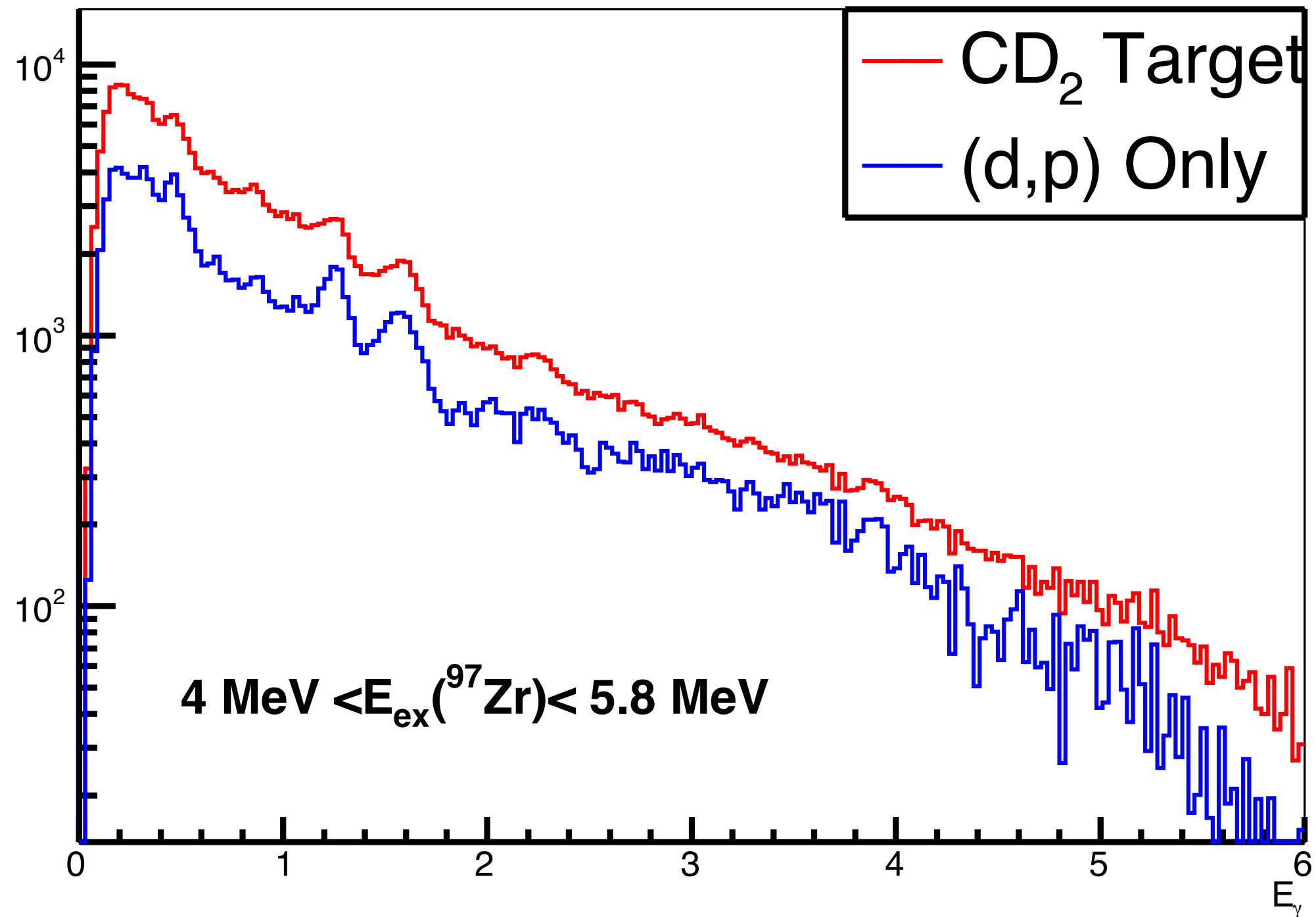
$^{96}\text{Zr}(d,p\gamma)$



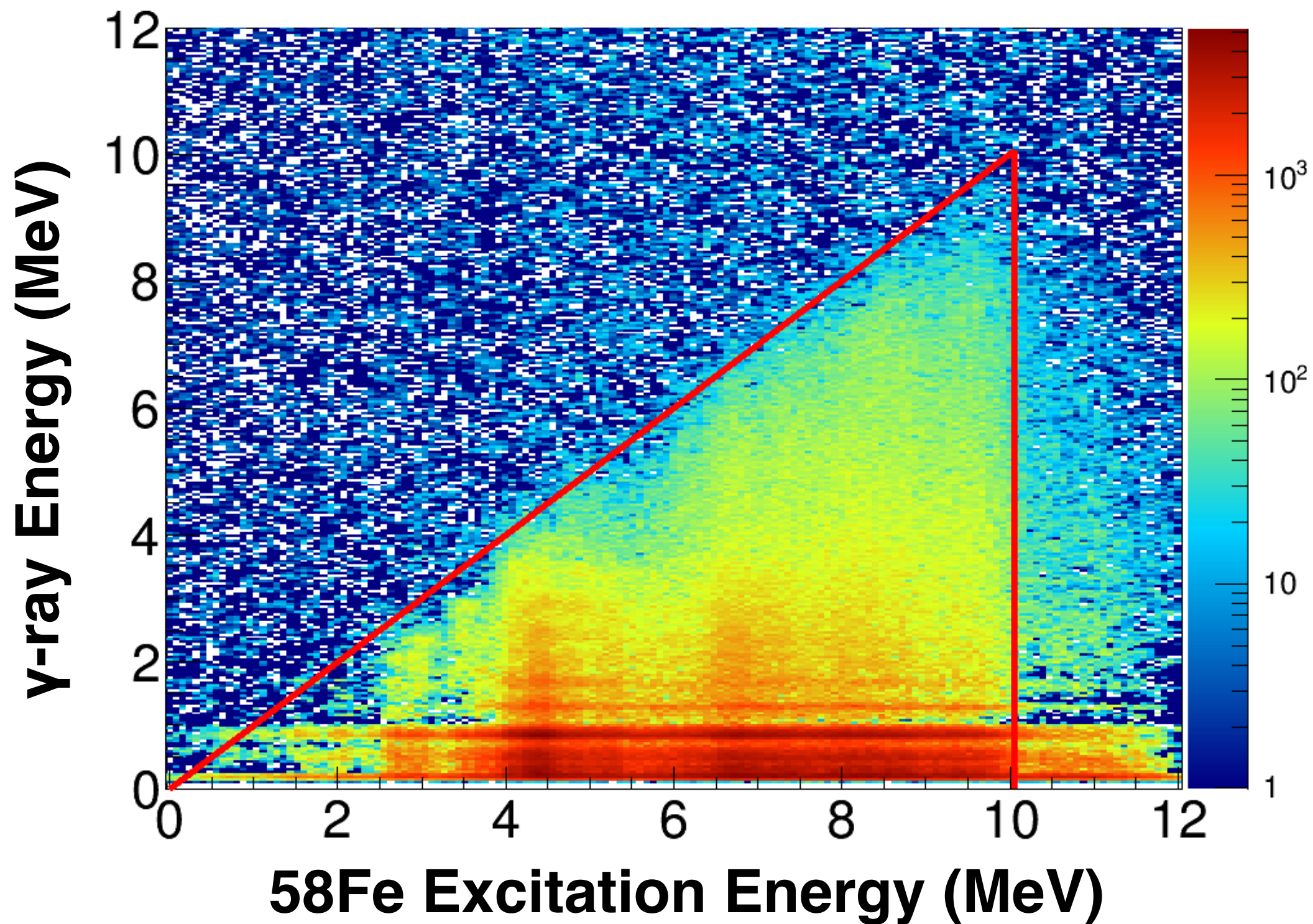
Fri Mar 24 01:07:18 2017

^{97}Zr Excitation Energy (MeV)

γ -ray Spectrum



$^{57}\text{Fe}(\text{d},\text{p}\gamma)$



C. Prokop, LANL Postdoc

Acknowledgements

J. Winkelbauer¹, S. Mosby¹, A. Couture¹, H. Y. Lee¹, S. Kuvvin³, C.R. Hoffman², J. Ullmann¹, A. Spyrou⁴, S.N. Liddick⁴, A.C. Larsen⁵, B.B. Back², M.L. Avila², B.V. Kheswa⁵, T. Renstroem⁵, G. Tveten⁵, R. Talwar², D. Santiago-Gonzales⁶

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