LANSCE Experimental Updates II: Neutron Scattering at WNR

Keegan J. Kelly,*
Matt Devlin, John O'Donnell, Eames Bennett

Nuclear Data Week 2020 (CSEWG)

Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of the U.S. Department of Energy (Contract No. 89233218CNA000001). This work was also funded by LDRD awards 20190588ECR and 20210329ER.

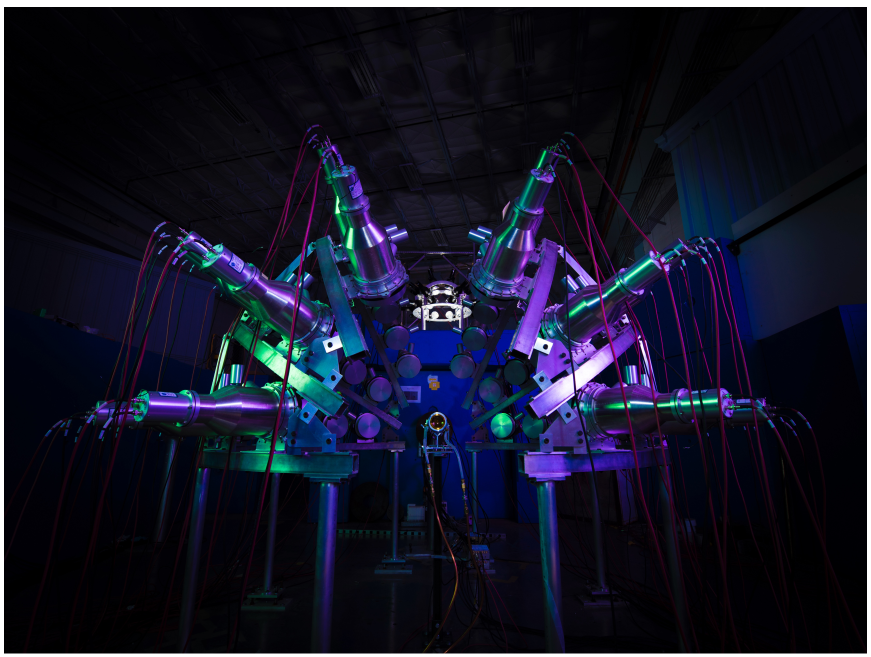
11/30/2020

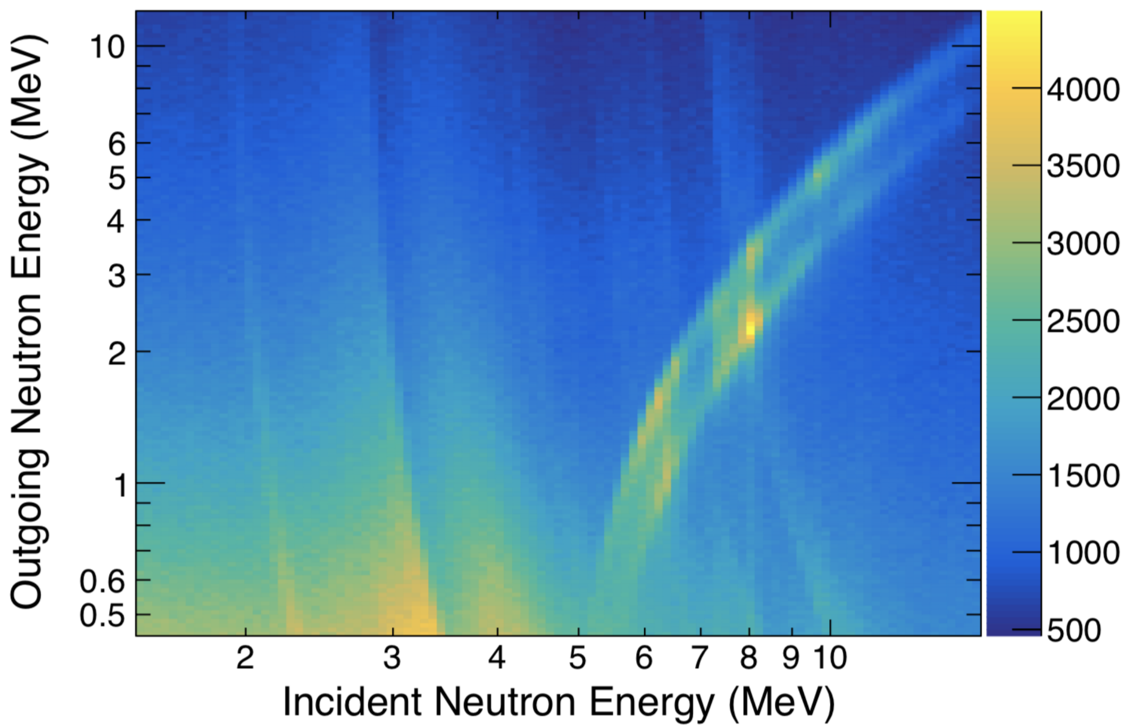
LA-UR-20-XXXXX

Scattering Analysis with the Chi-Nu Liquid Scintillators

- Liquid scintillators have poor decent PSD and timing, but γ energy resolution
- Can still learn about a more ideal n-γ using this array
- Start with easy case: natural carbon
  - Note: utilized the RPI sample changer for these measurements

<u>Begin by simply looking for n-γ coincidence in post-processing analysis</u>



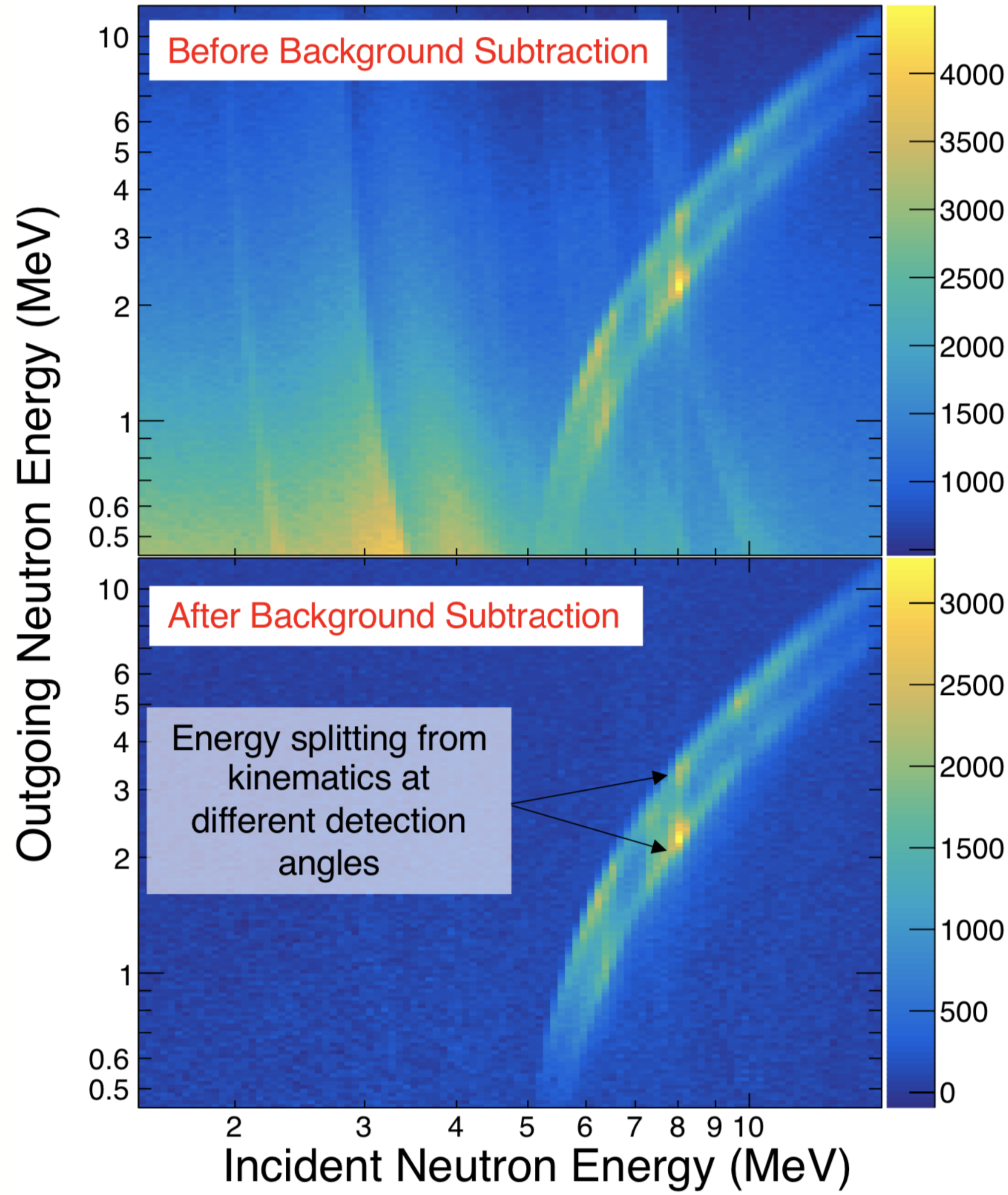


Random-Coincidence Background Technique Works

- Random coincidence rates derived form Poisson probabilities for *uncorrelated* detection rates [†]
  - true coincidence rate must be low
- Calculate the total probability for:
  1. Detecting a γ at time t_γ
  2. Not detecting n over coinc. time $t_n - t_\gamma$
  3. Detecting n at time t_n

$$\text{Coinc. Rate} = r_b = r_\gamma r_n \Delta_t$$
$$\Rightarrow b = \frac{\gamma n}{N_{t_0}}$$
$$\text{with } \gamma, n = \text{counts}$$

- Works remarkably well here

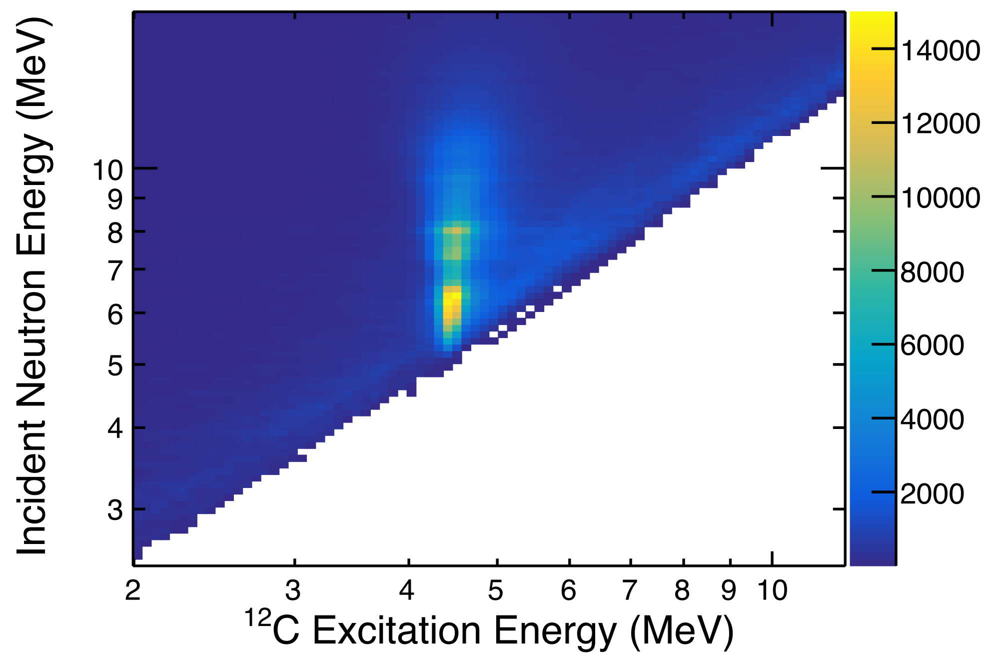


[†] O'Donnell, NIMA **805** (2016) 87

Random-Coincidence Background Technique Works

- Random coincidence rates derived form Poisson probabilities for *uncorrelated* detection rates †
  - true coincidence rate must be low
- Calculate the total probability for:
  1. Detecting a γ at time t_γ
  2. Not detecting n over coinc. time $t_n - t_\gamma$
  3. Detecting n at time t_n

$$\text{Coinc. Rate} = r_b = r_\gamma r_n \Delta_t$$
$$\Rightarrow b = \frac{\gamma n}{N_{t_0}}$$
$$\text{with } \gamma, n = \text{counts}$$



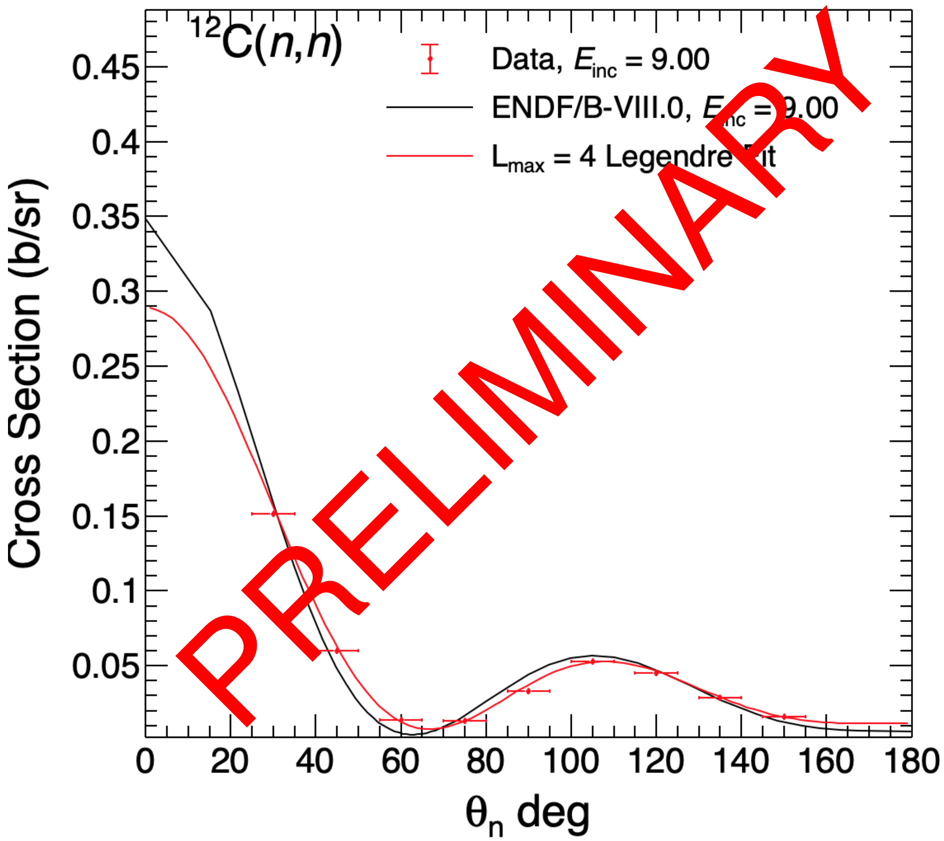
- Works remarkably well here

† O'Donnell, NIMA **805** (2016) 87

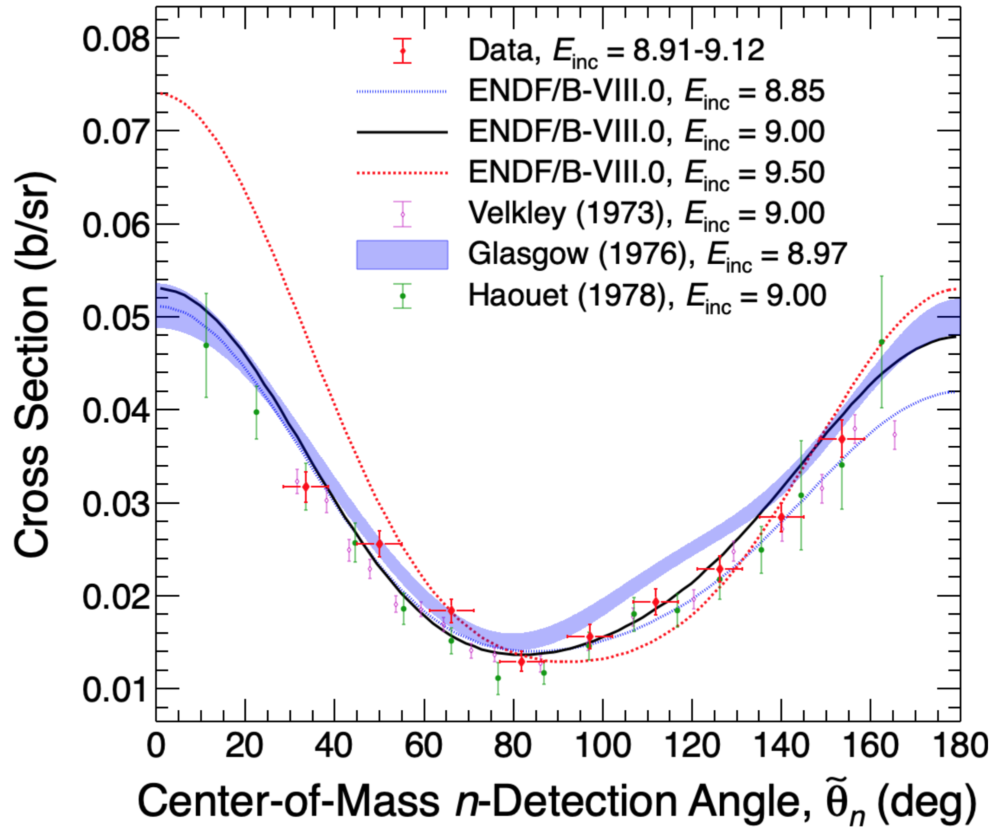
Able to Extract Carbon n Angular Distributions

Extract n angular distributions from elastic scattering and correlated n-γ distributions from inelastic scattering

Elastic Scattering



Inelastic Scattering

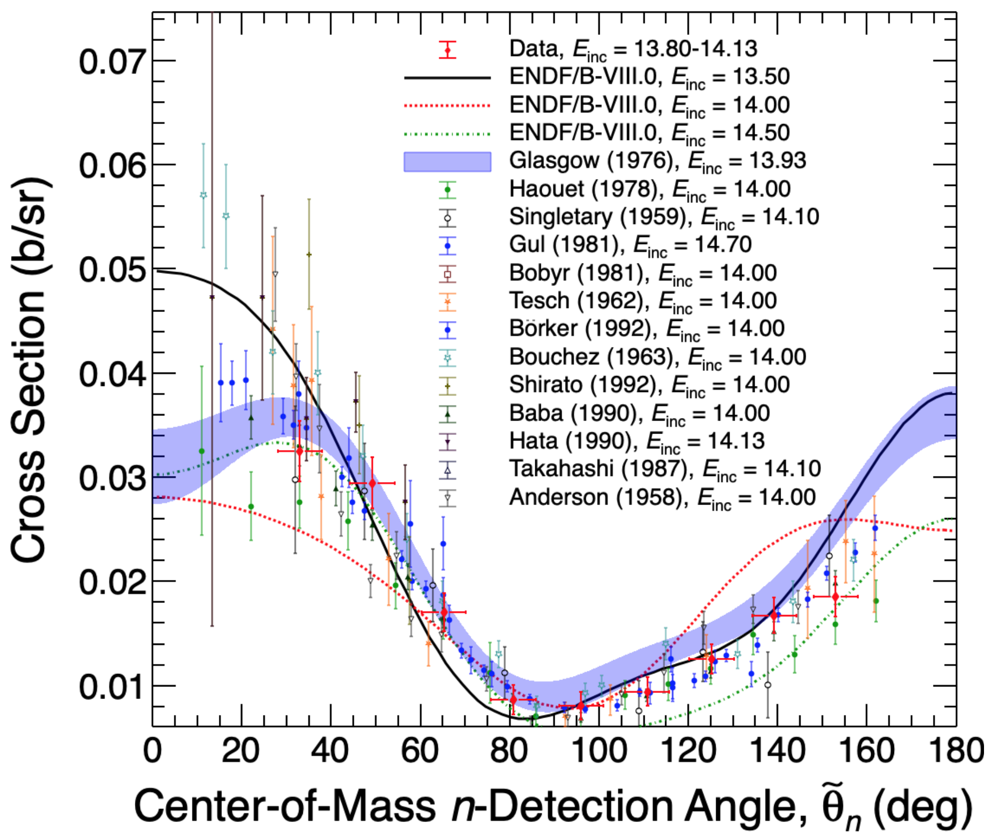


$\rightarrow$ n distributions have been measured many times in the past

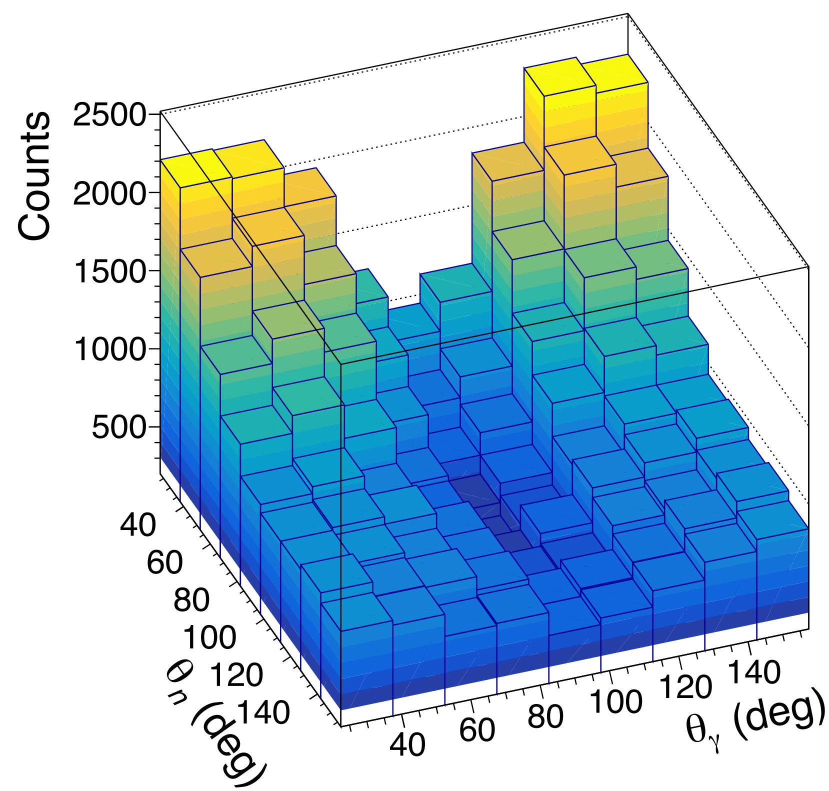
Correlated n-γ Distributions Collected as Well

Extract n angular distributions from elastic scattering and correlated n-γ distributions from inelastic scattering

Inelastic n Distributions (13.80–14.13 MeV)



Correlated n-γ Distributions (6.17–6.31 MeV)



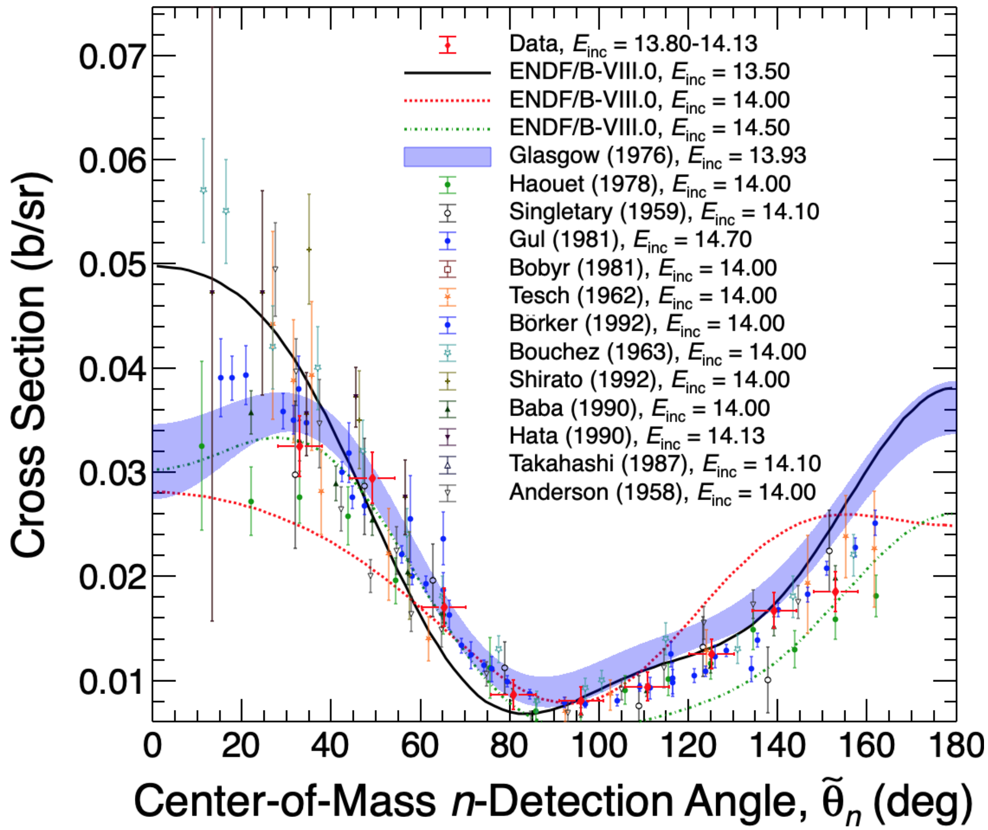
Very few experiments have measured n-γ distributions

→ Measured at limited energies and angles

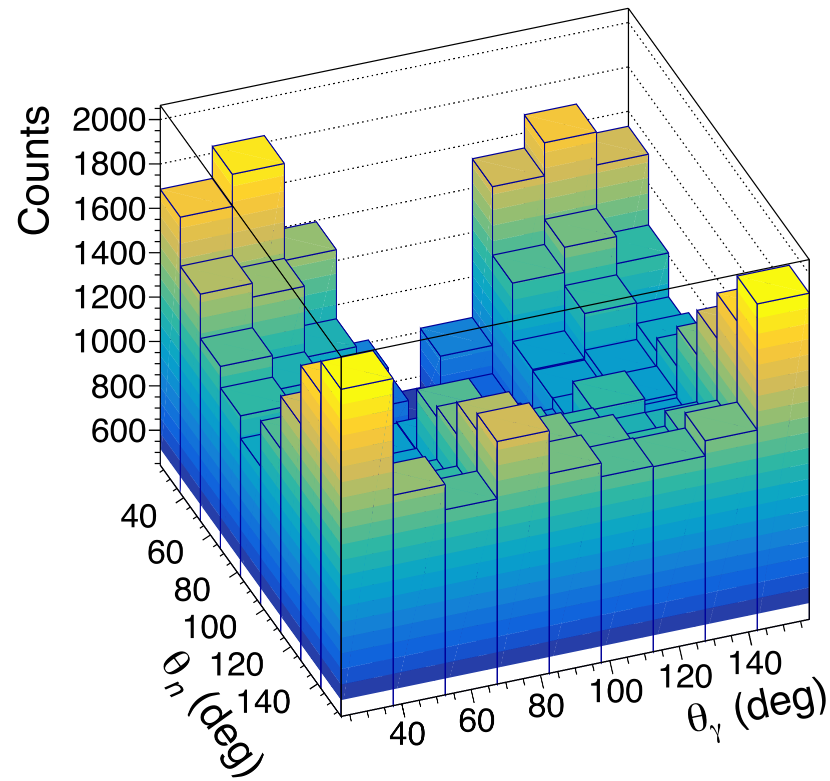
Even Simple Angular Dists. Can Be Complicated!

Extract n angular distributions from elastic scattering and correlated n-γ distributions from inelastic scattering

Inelastic n Distributions (13.80–14.13 MeV)



Correlated n-γ Distributions (7.94–8.13 MeV)



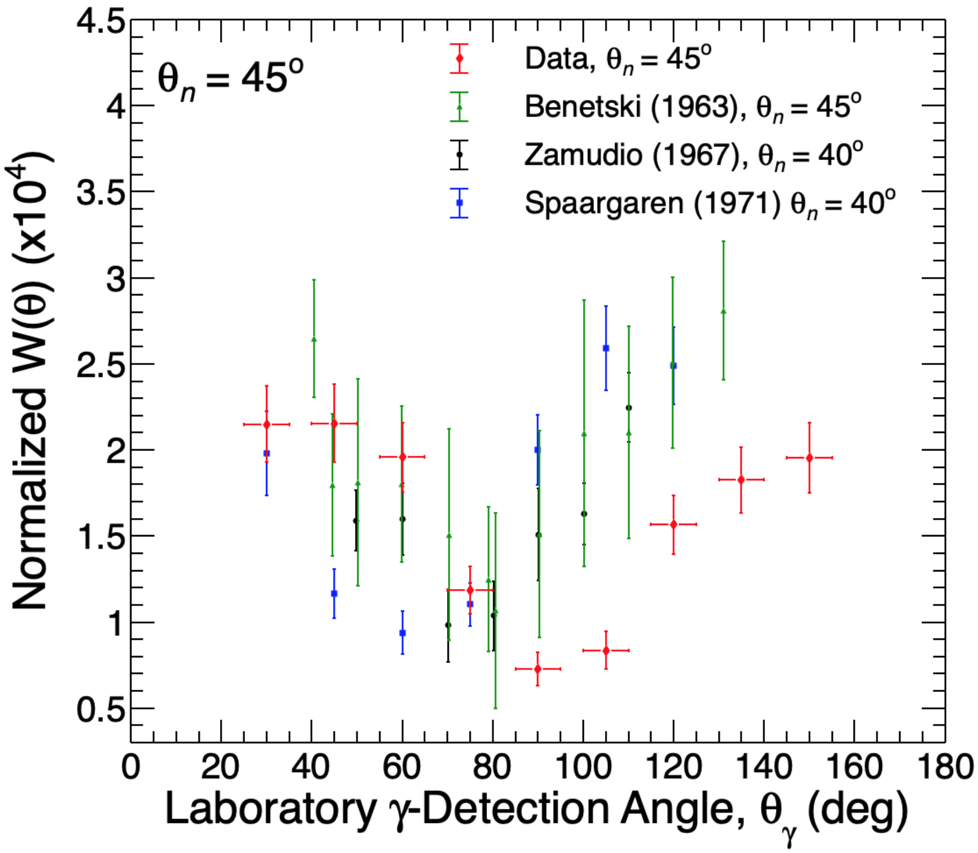
Distributions can change rapidly with incident energy

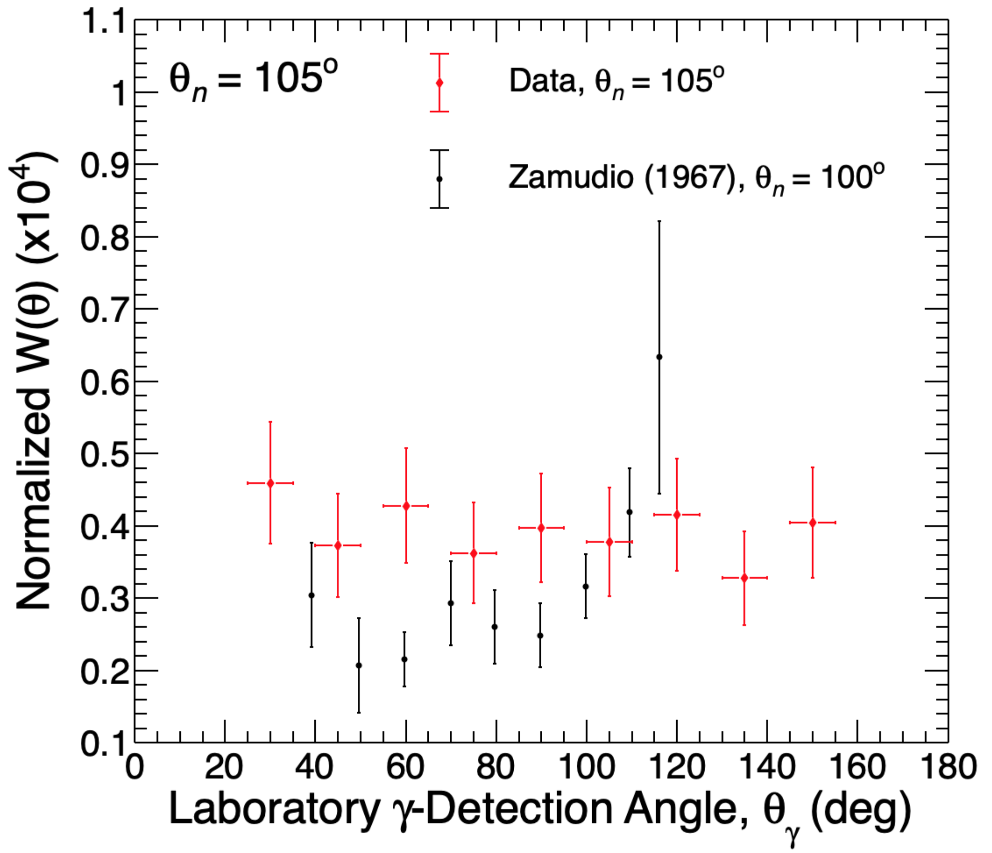
$\Rightarrow$ Need to measure the entire distribution

Lit. Data on Correlated n-γ Dists. Limited to 14 MeV

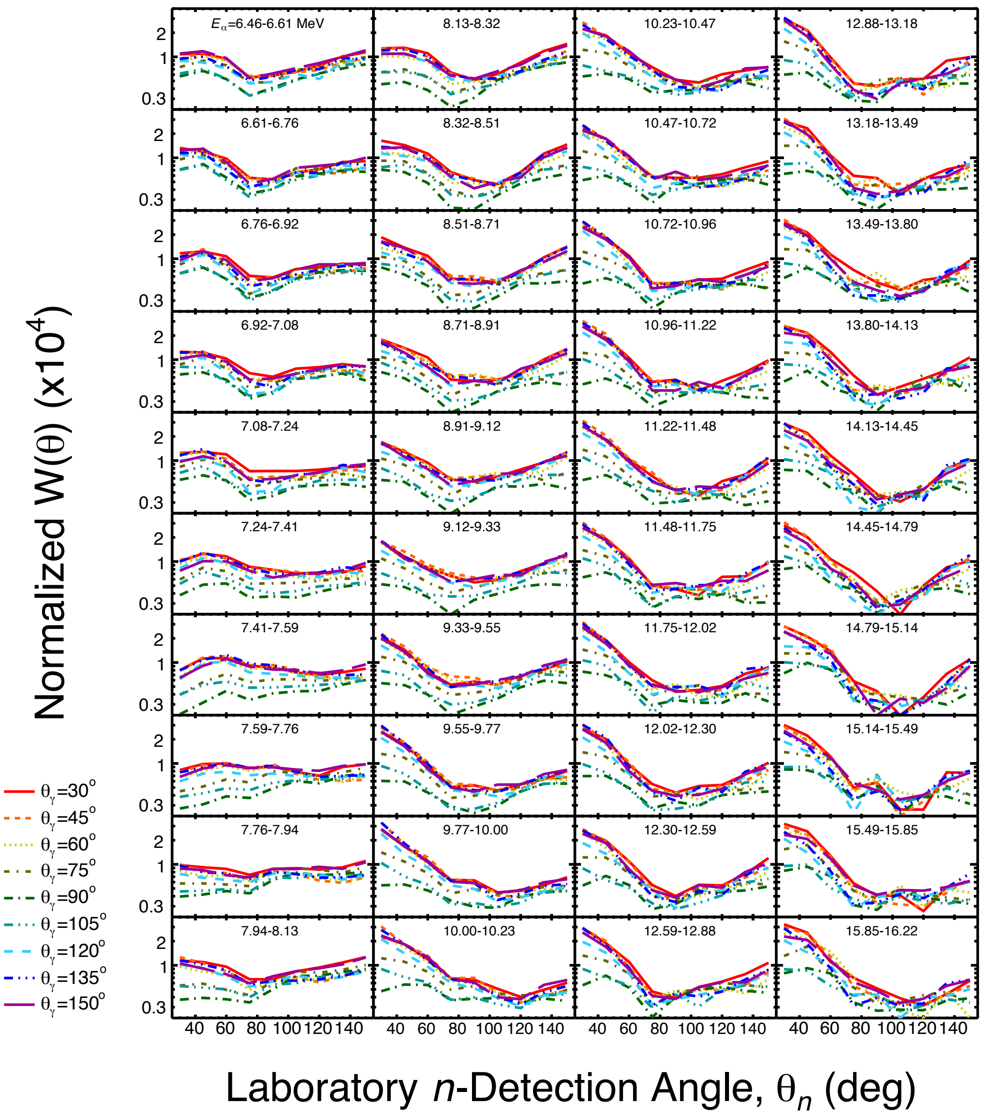
Correlated n-γ distributions from literature are poorly-known.

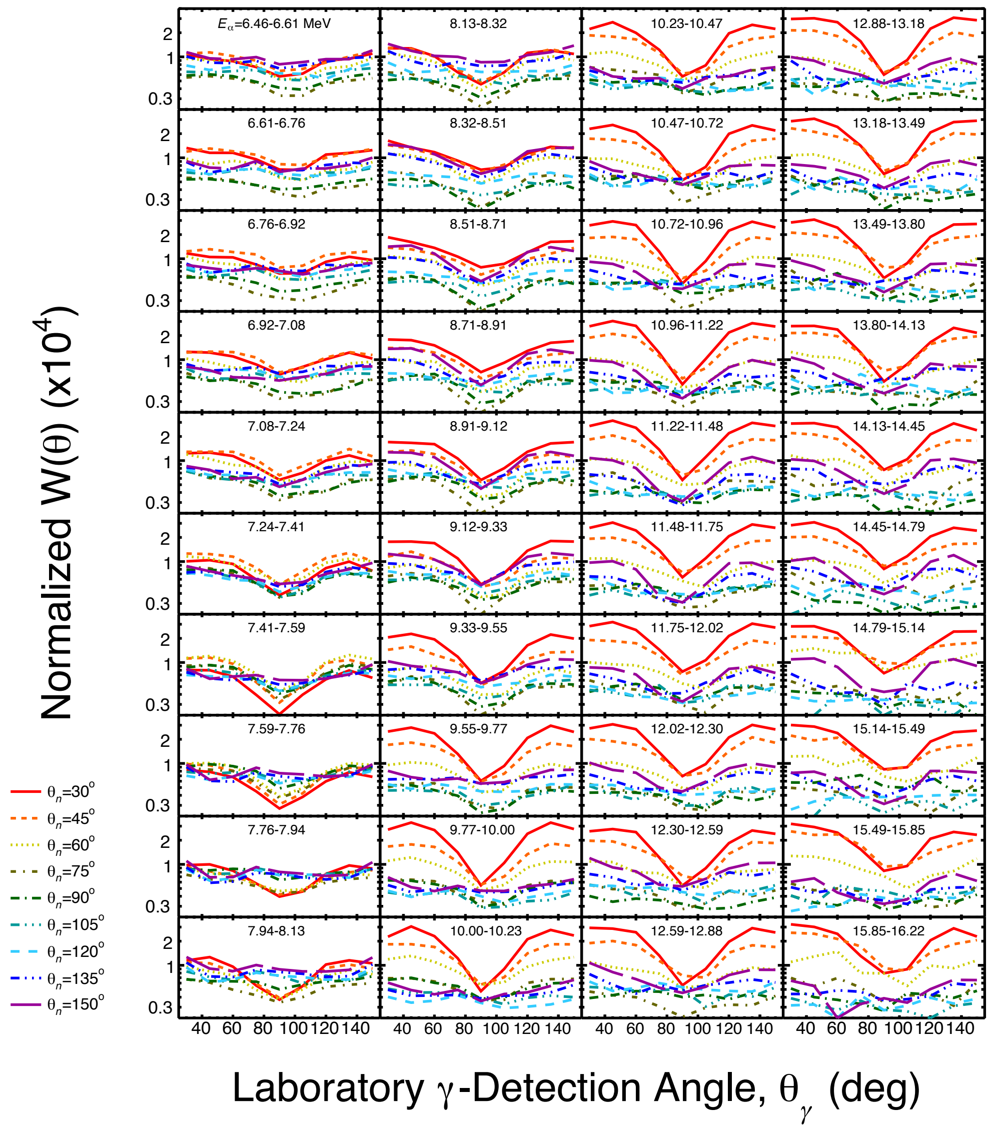
All measurements at other incident neutron energies are new





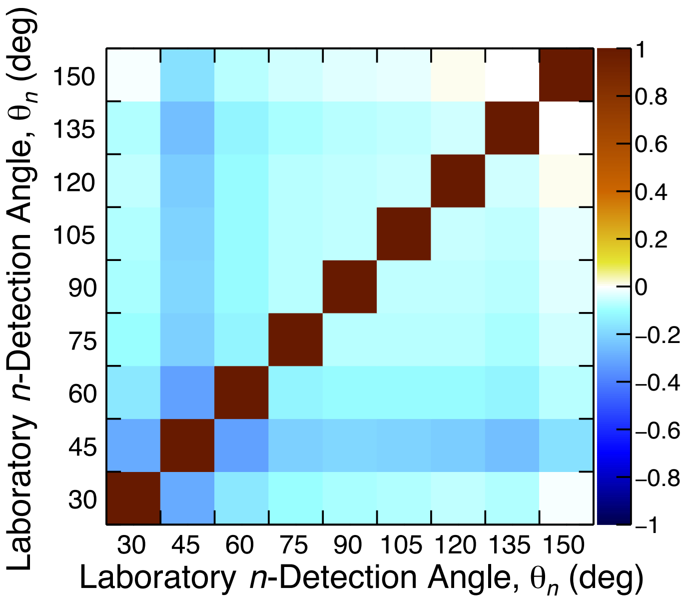
Can View Data as n-Dists at each θ_γ, or Vice Versa



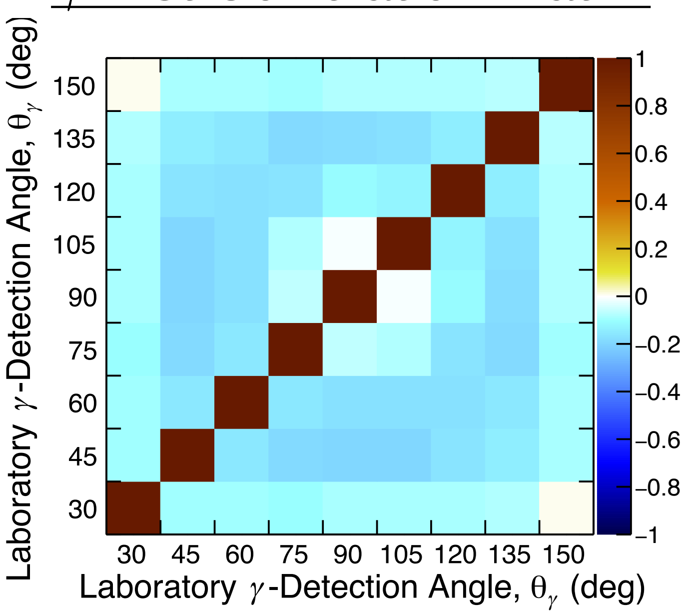


Results Complete with Detailed Covariances

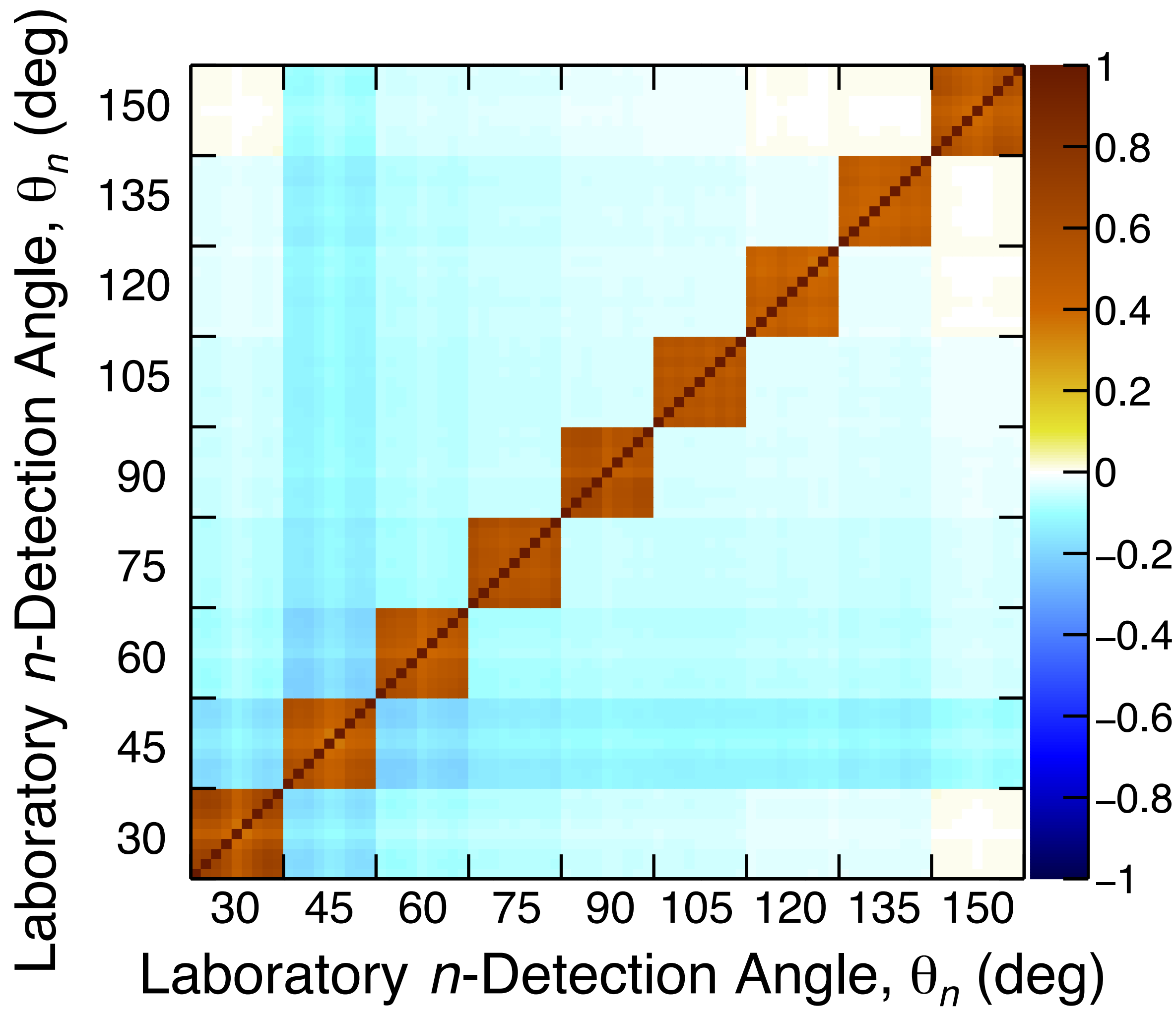
n Dist Correlation Matrix



γ Dist Correlation Matrix



n-γ Dist Correlation Matrix



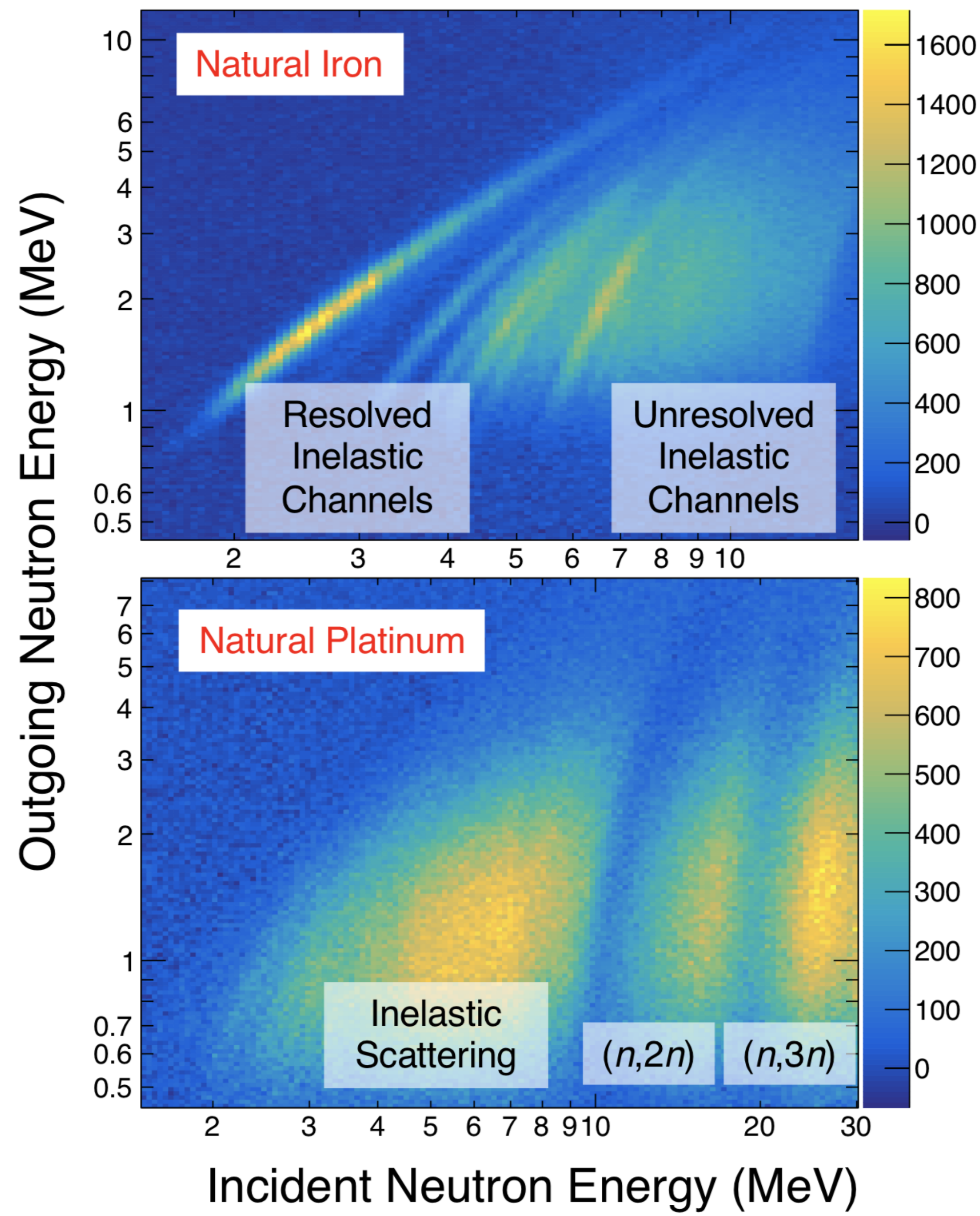
Measurements of Fe and Pt Show Capabilities

Natural Fe

- Separation of low-lying states is possible
- Extensions to lower energies could separate more states
- Shows separation limitations based on level density

Natural Pt

- Six naturally-occurring Pt isotopes
- Continuously high net level density
- Clearly observe onset of $(n,2n)$ and $(n,3n)$ channels
  - Separable from inelastic scattering



Summary and Future Work

- Liquid scintillators can be useful as dual n-γ detectors
  - Carbon inelastic scattering PRC in prep
- Clear limitations from liquid scintillators, and from the employed detector geometry
  - PSD not valid for all observed n and γ energies
  - n energy range restricted to higher energies
  - Very poor γ energy resolution
  - Wide angular coverage per detector
- Points towards a more ideal detector identity and geometry
  - More on that next year...