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Title: Prompt Fission Neutron Detection and Neutron Scattering Measurements at WNR FP15L

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Prompt Fission Neutron Detection and Neutron Scattering Measurements at WNR FP15L

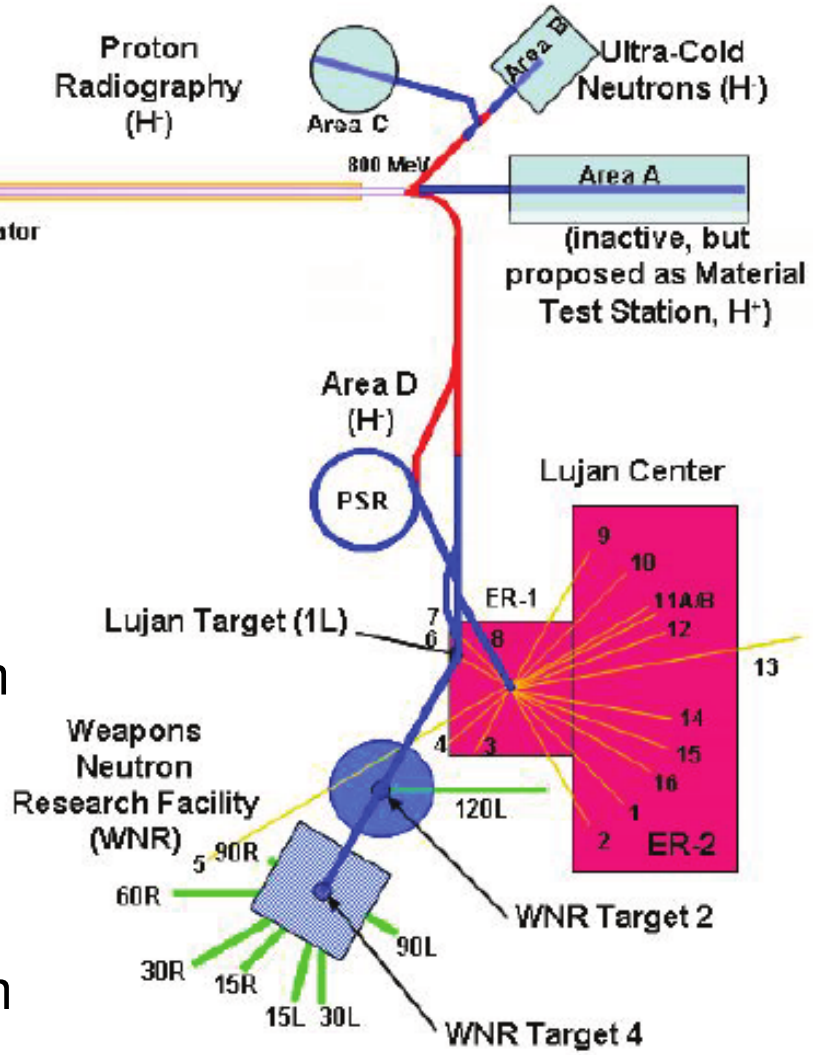
Nuclear Data Working Group

K. J. Kelly,
M. Devlin, J.M. O'Donnell, E.A. Bennett, *et al.*
on behalf of the Chi-Nu Collaboration

Outline

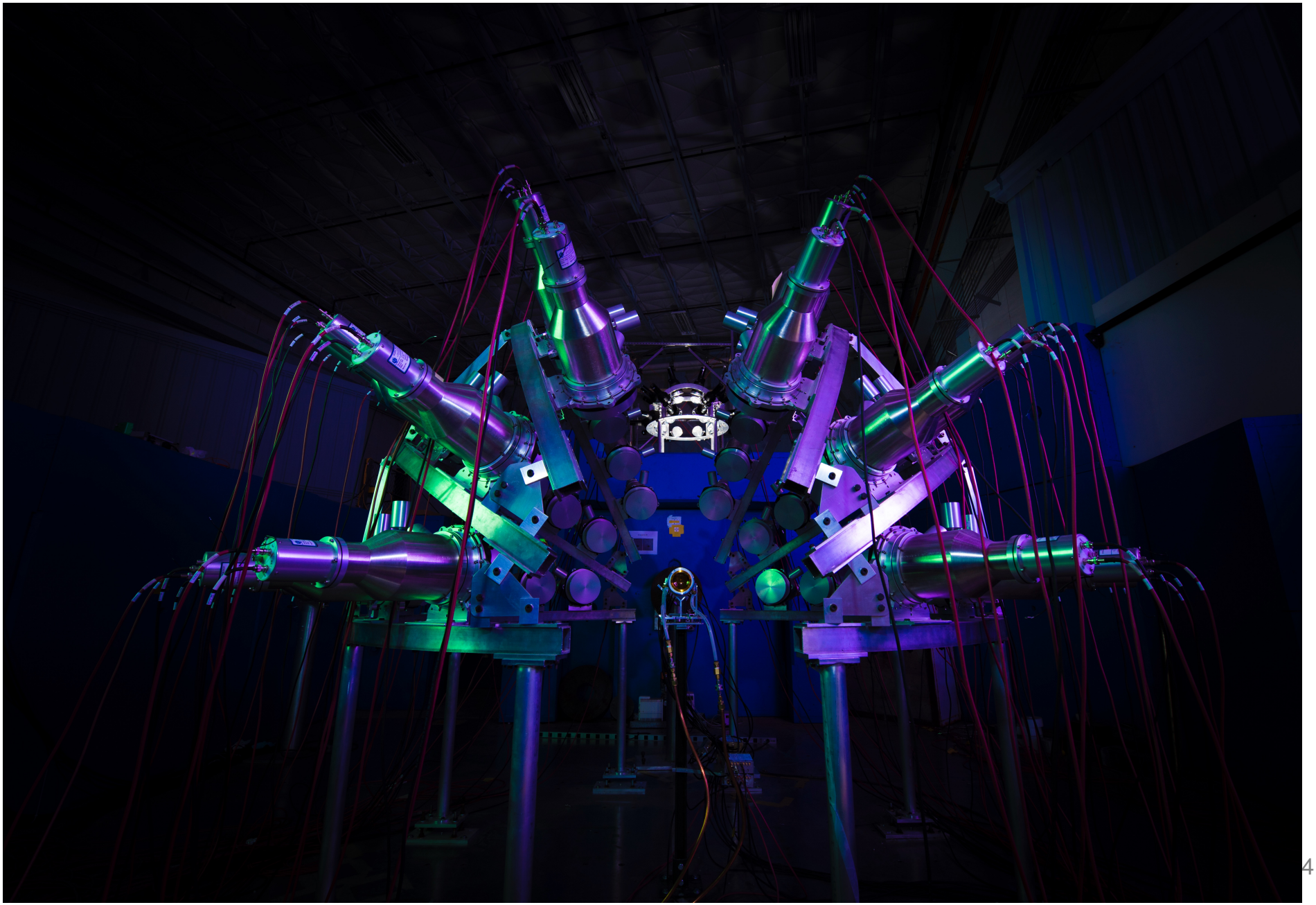
- LANSCE
- Chi-Nu Detectors and Measurements
- Neutron Scattering Measurements with Chi-Nu Detectors
- Future Neutron Scattering Measurements

The LANSCE Accelerator



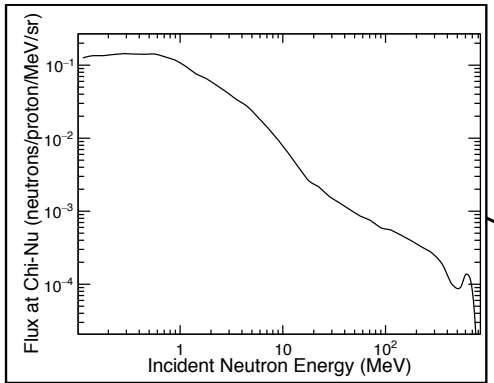
- Lujan Target
  - Moderated neutron target
  - Thermal – ≈MeV neutrons
  - Proton beam travels down
  - Flight paths perpendicular to p beam
- WNR Facility
  - Unmoderated tungsten target
  - Different flight path angles to p beam
  - Can obtain different flux shapes

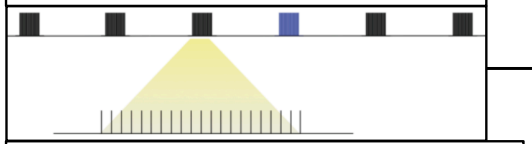
The Chi-Nu Arrays

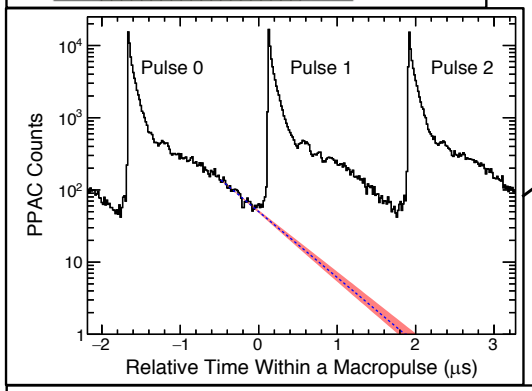


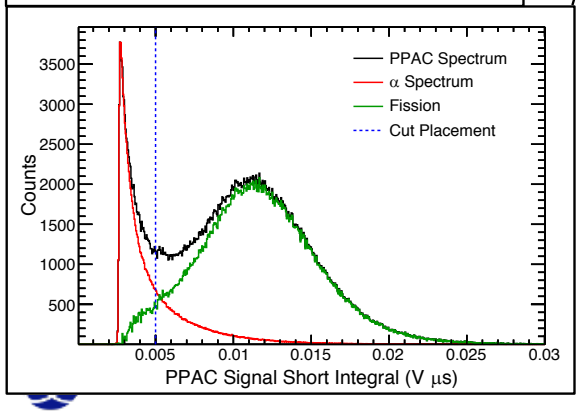
The Chi-Nu Experiment

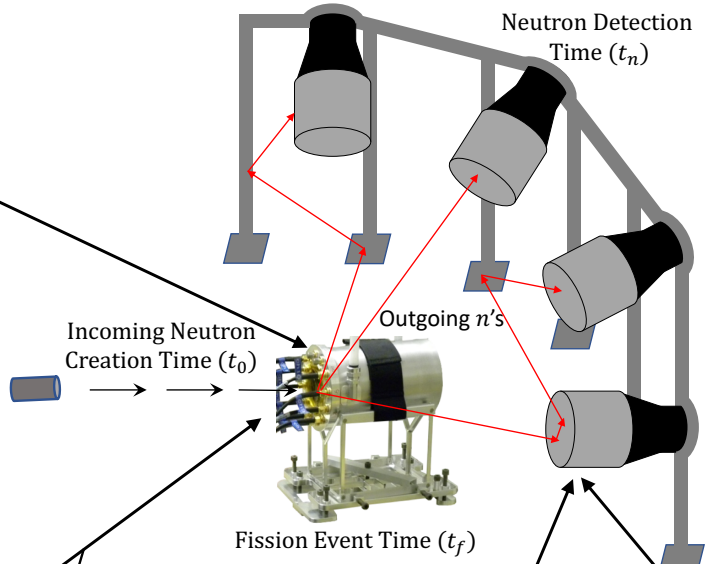
Haight *et al.* NDS **123** 130 (2015)
Devlin *et al.* NDS **148** 322 (2018)
Kelly *et al.* PRC **102** 034615 (2020)



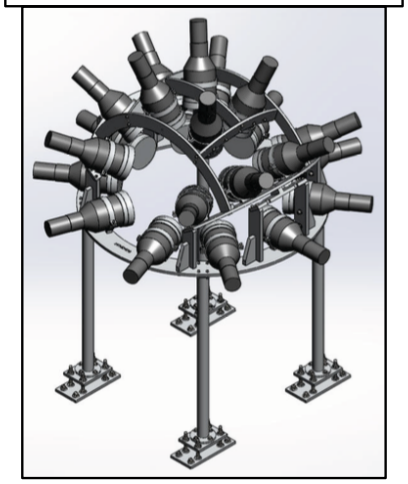




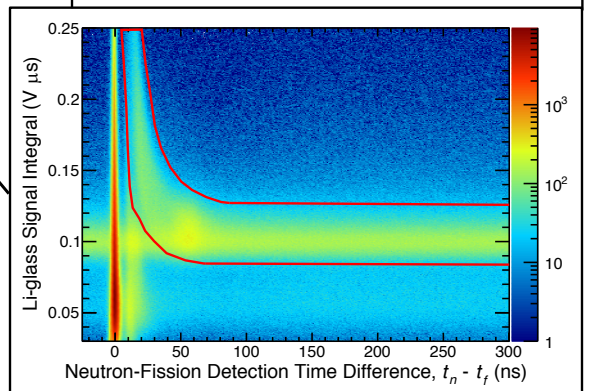


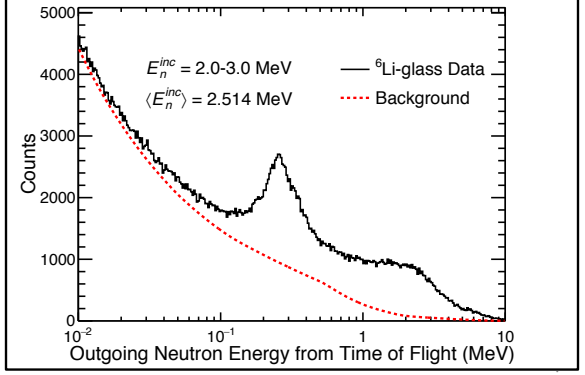


22 Li-glass Detectors
- ~0.4 m *n* flight path
- $E_n^{out} \approx$ 0.01-1.5 MeV



Chi-Nu is a double time-of-flight experiment
- $t_f - t_0 \rightarrow E_n^{inc}$
- $t_n - t_f \rightarrow E_n^{inc}$
- PPAC fission counter
- Two *n*-detector arrays used separately
- Combined to form single PFNS shape





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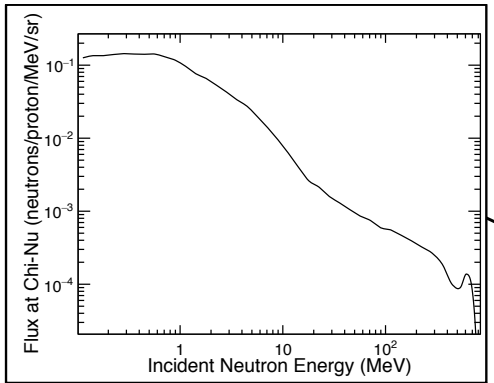
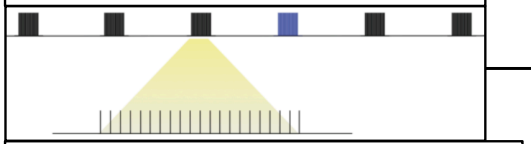
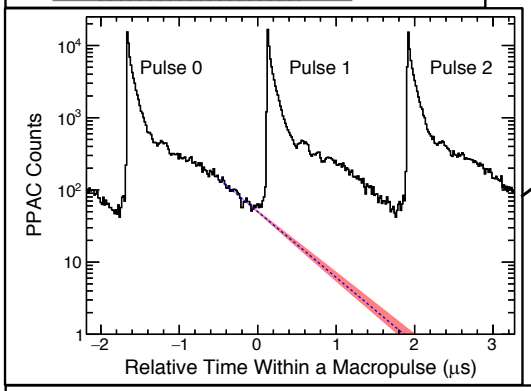
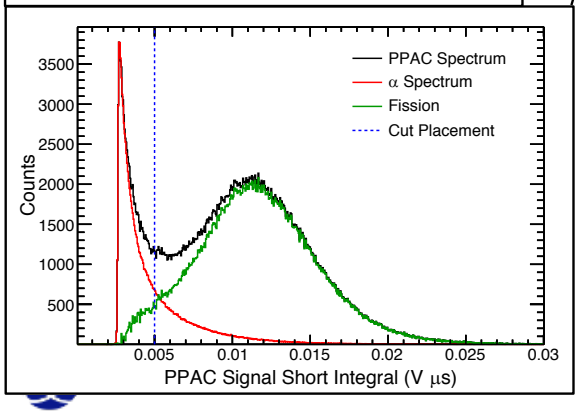
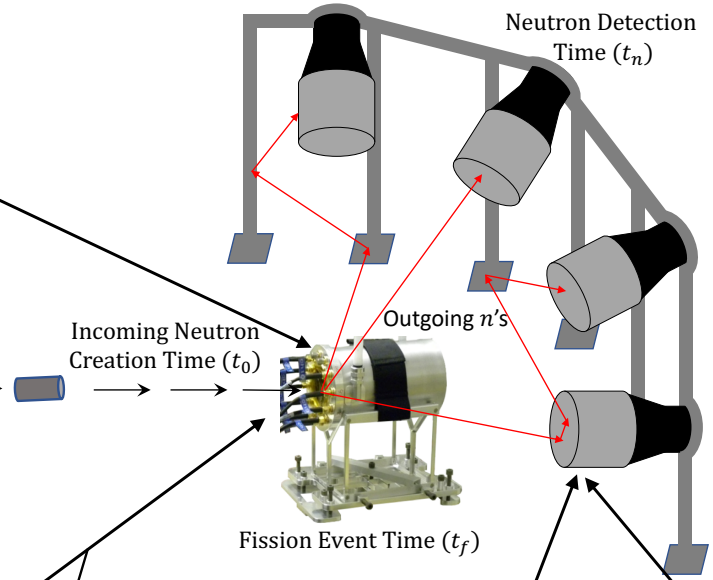


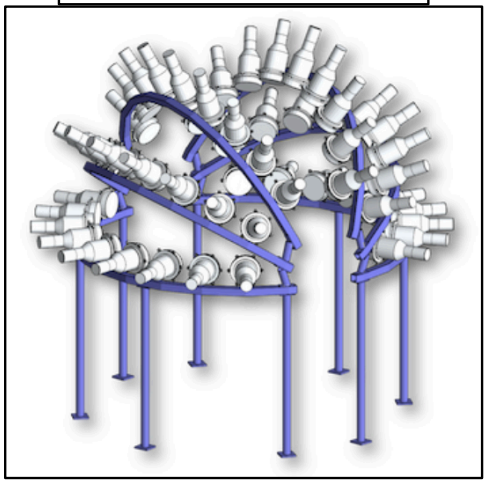








54 Liquid Scintillators
- ~1 m *n* flight path
- $E_n^{out} \approx$ 0.8-10 MeV



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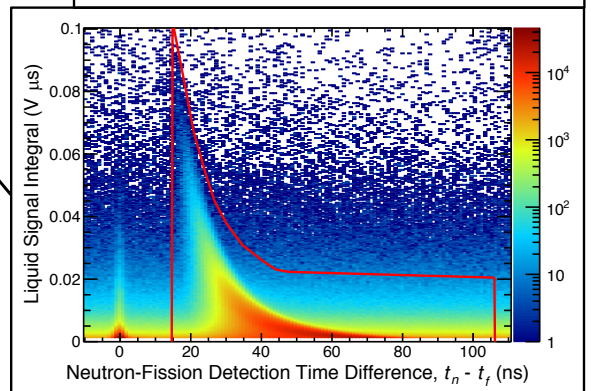
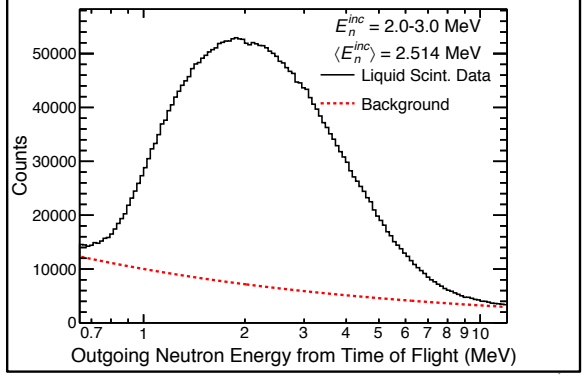
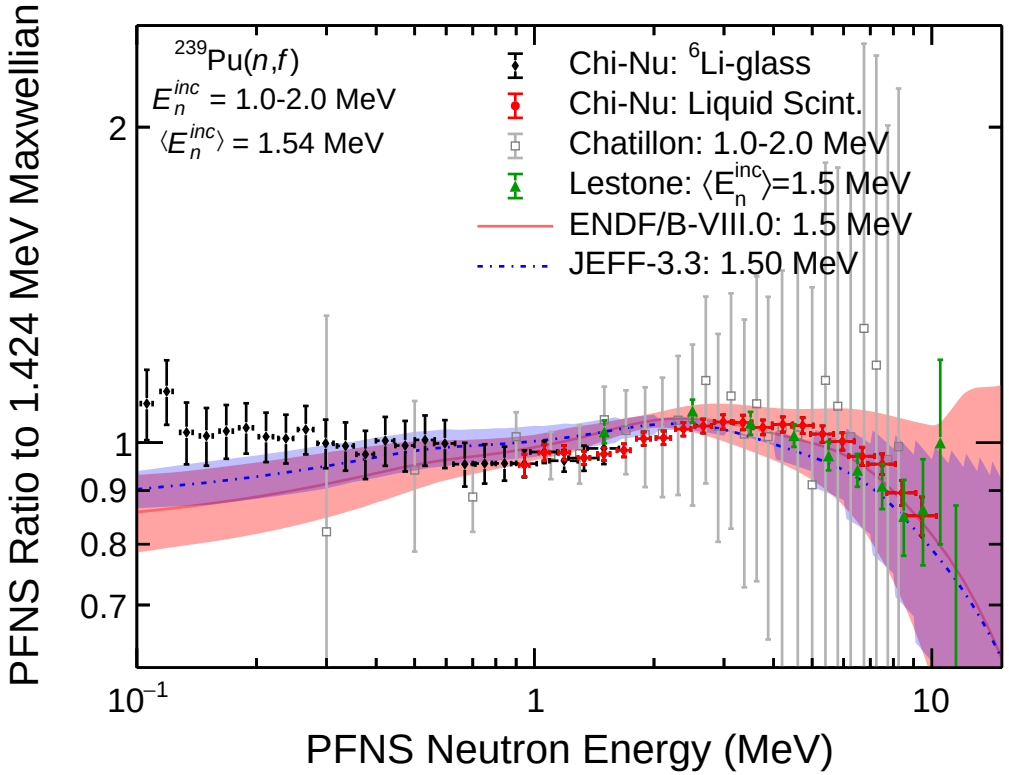
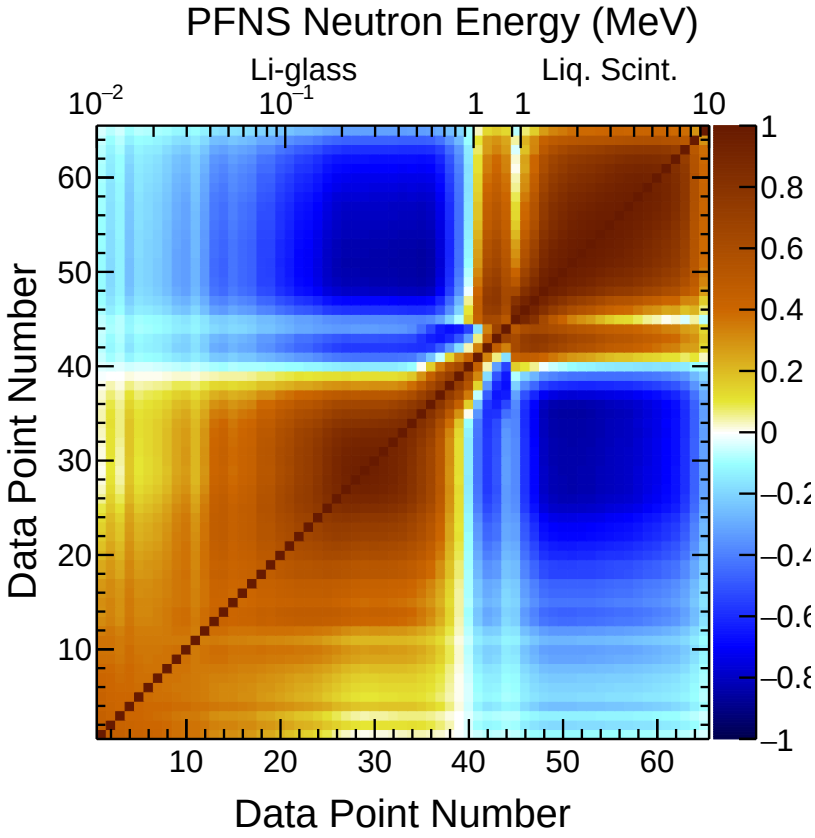




Combined PFNS Result from E_n^{out}=0.01–10 MeV





- Li-glass and LS measurements carefully combined
- Covariances preserve the combined shape of the PFNS
- Very similar analysis applied for all E_n^{inc} though...
  - Strong correlations exist between results at all E_n^{inc} values!

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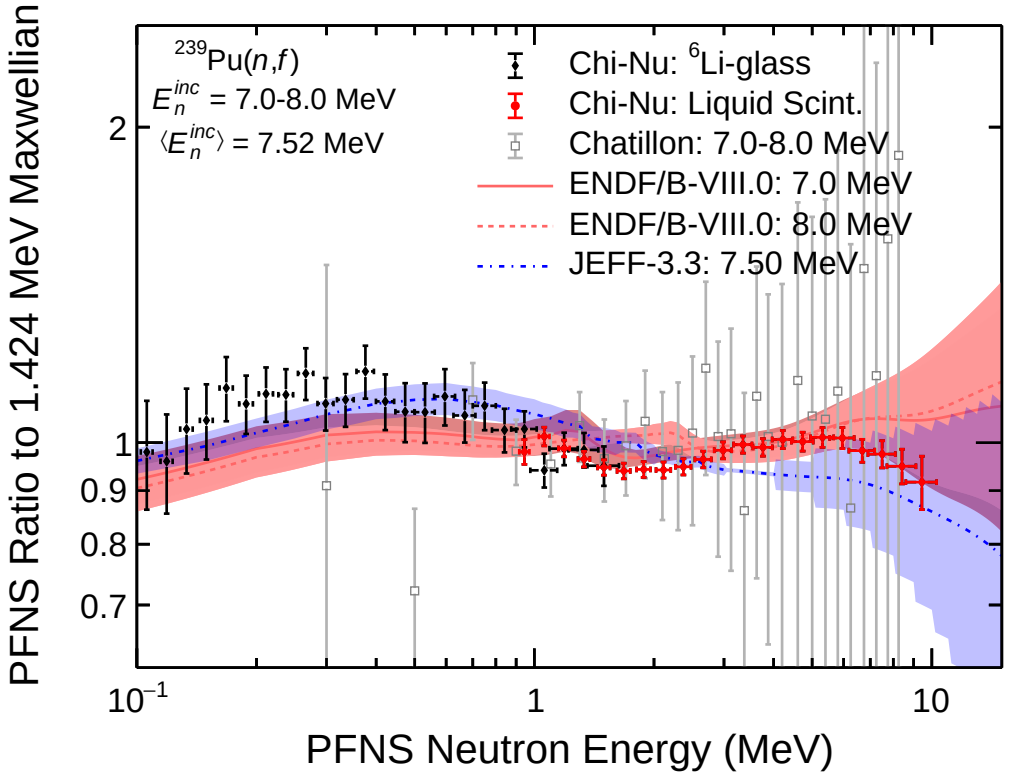

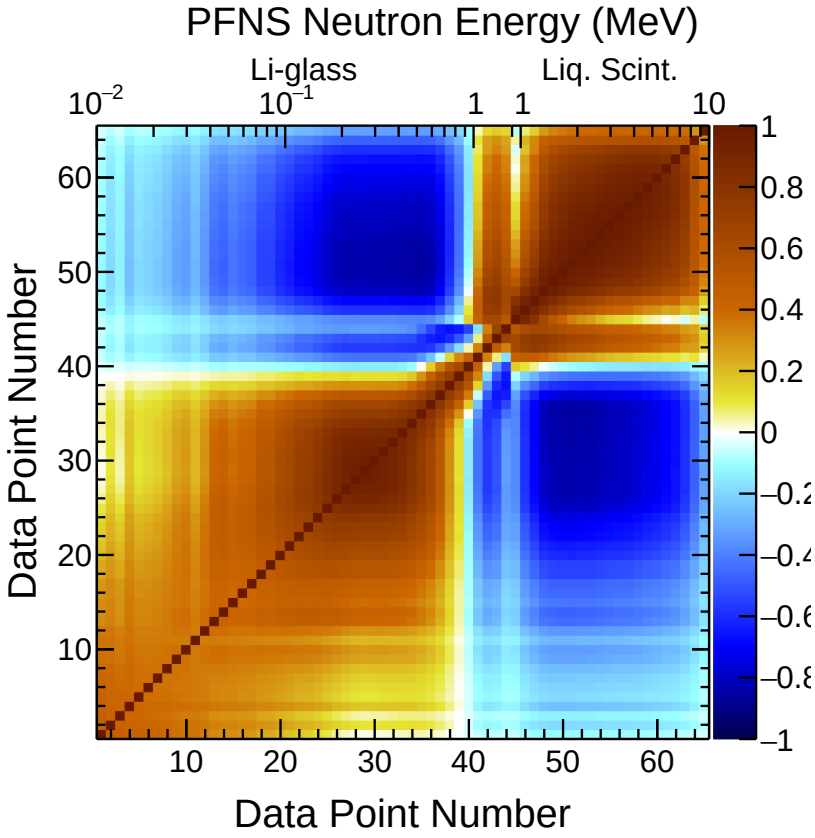

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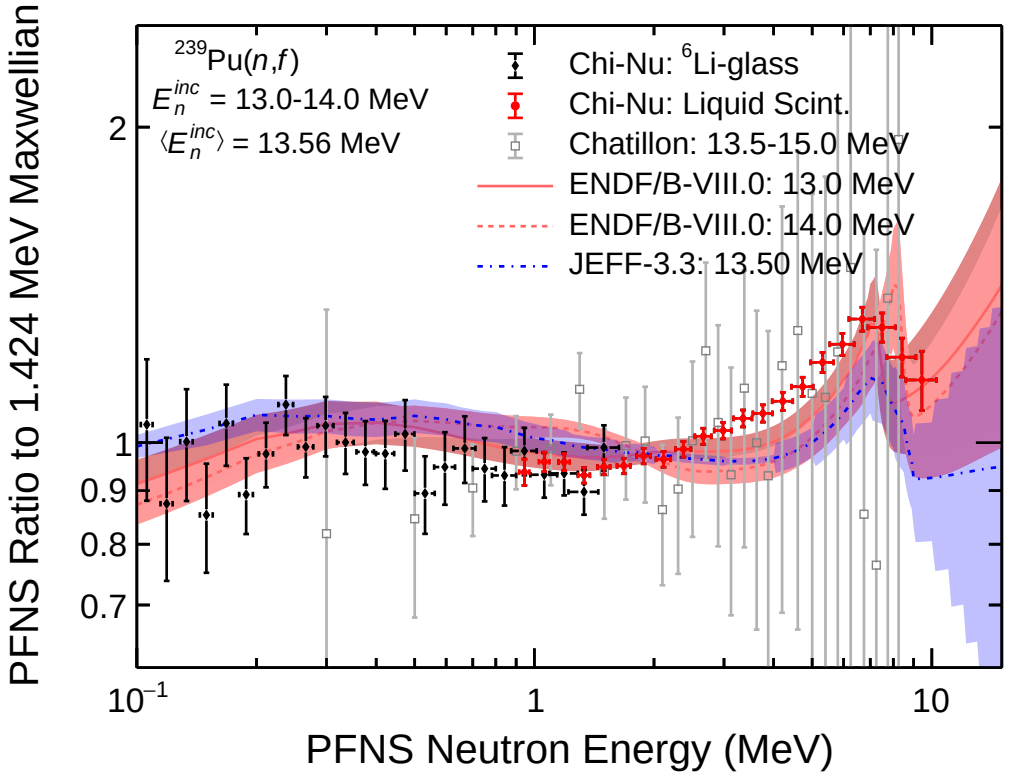

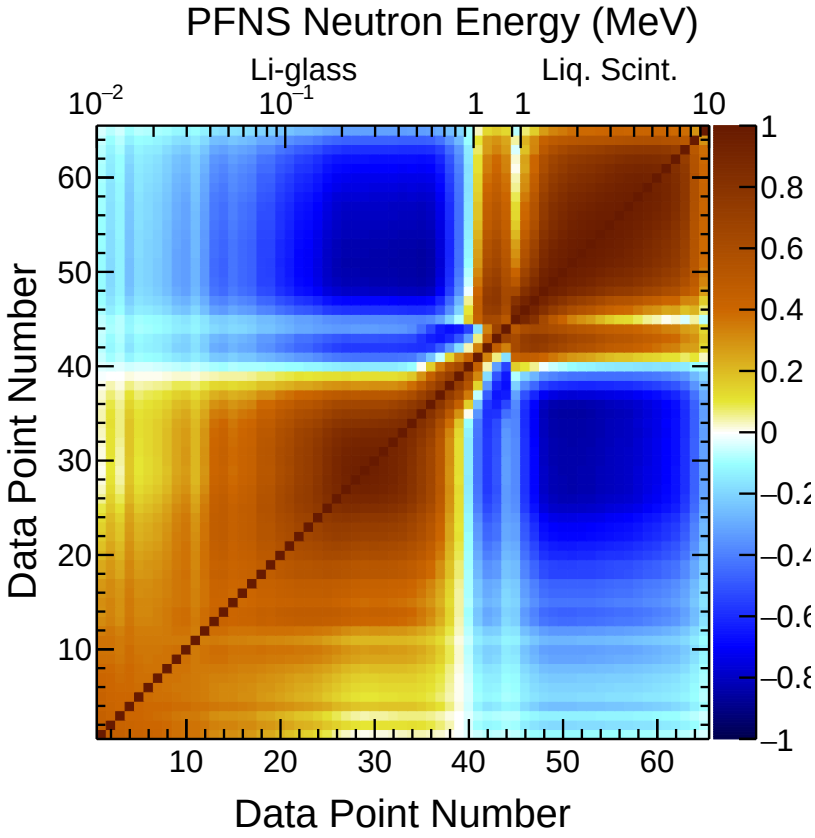

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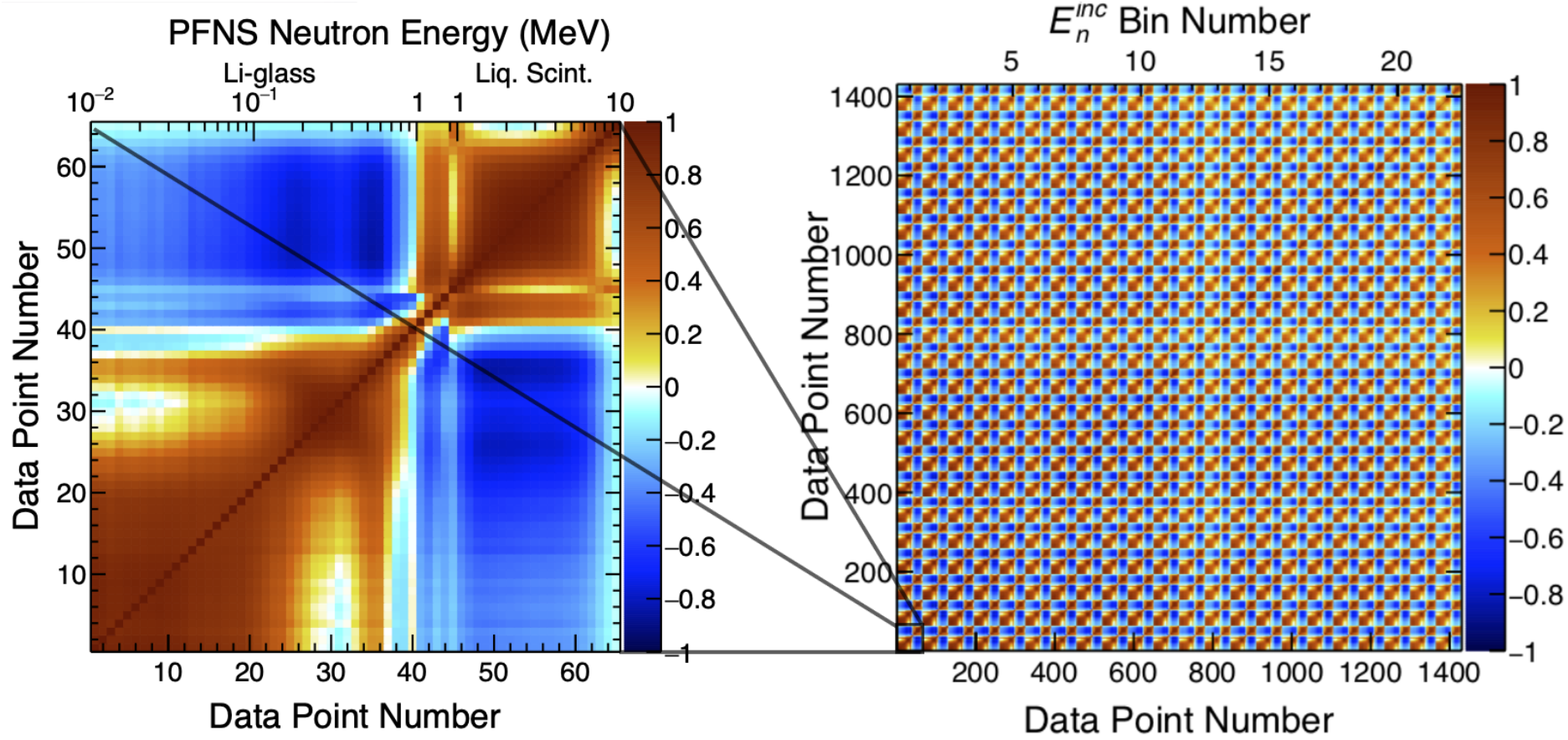
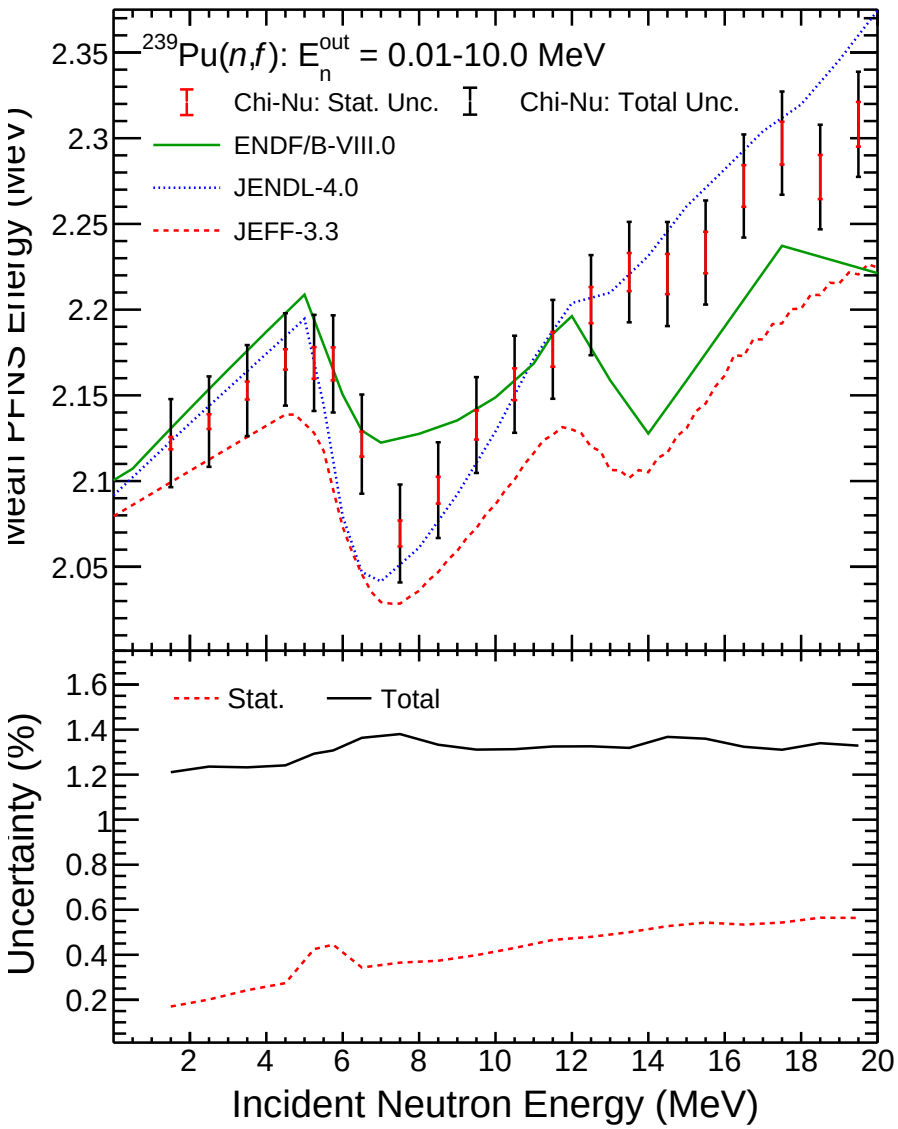
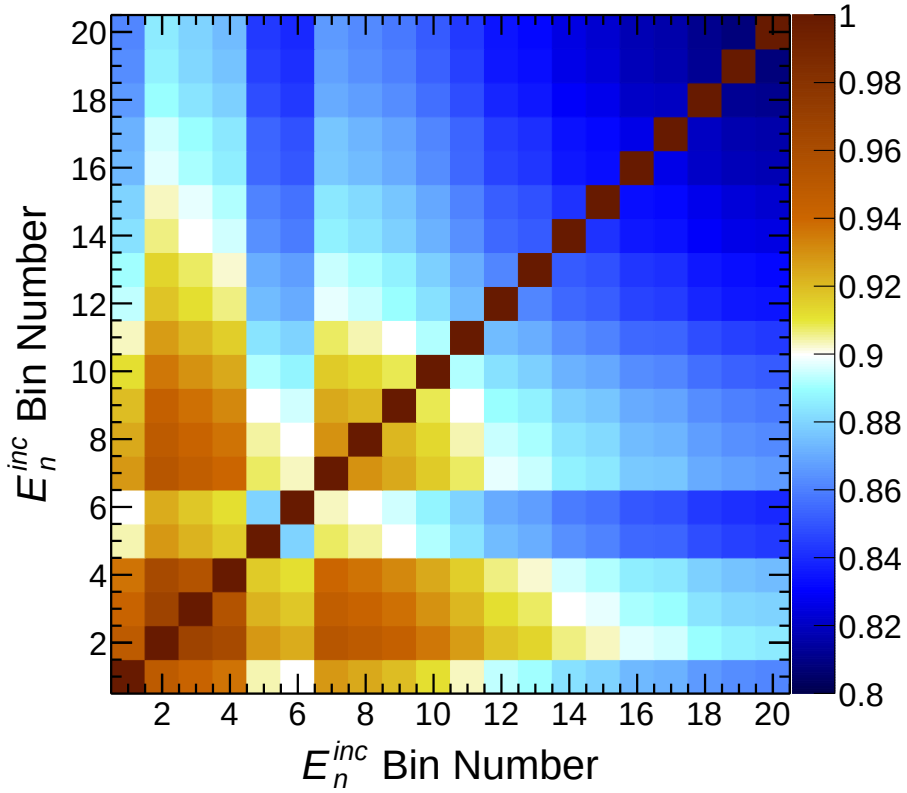
Single Covariance Matrix for Whole Data Set



- Any issue with a single E_n^{inc} leads to a change in all data points
- Necessary for accurately interpreting the collective results

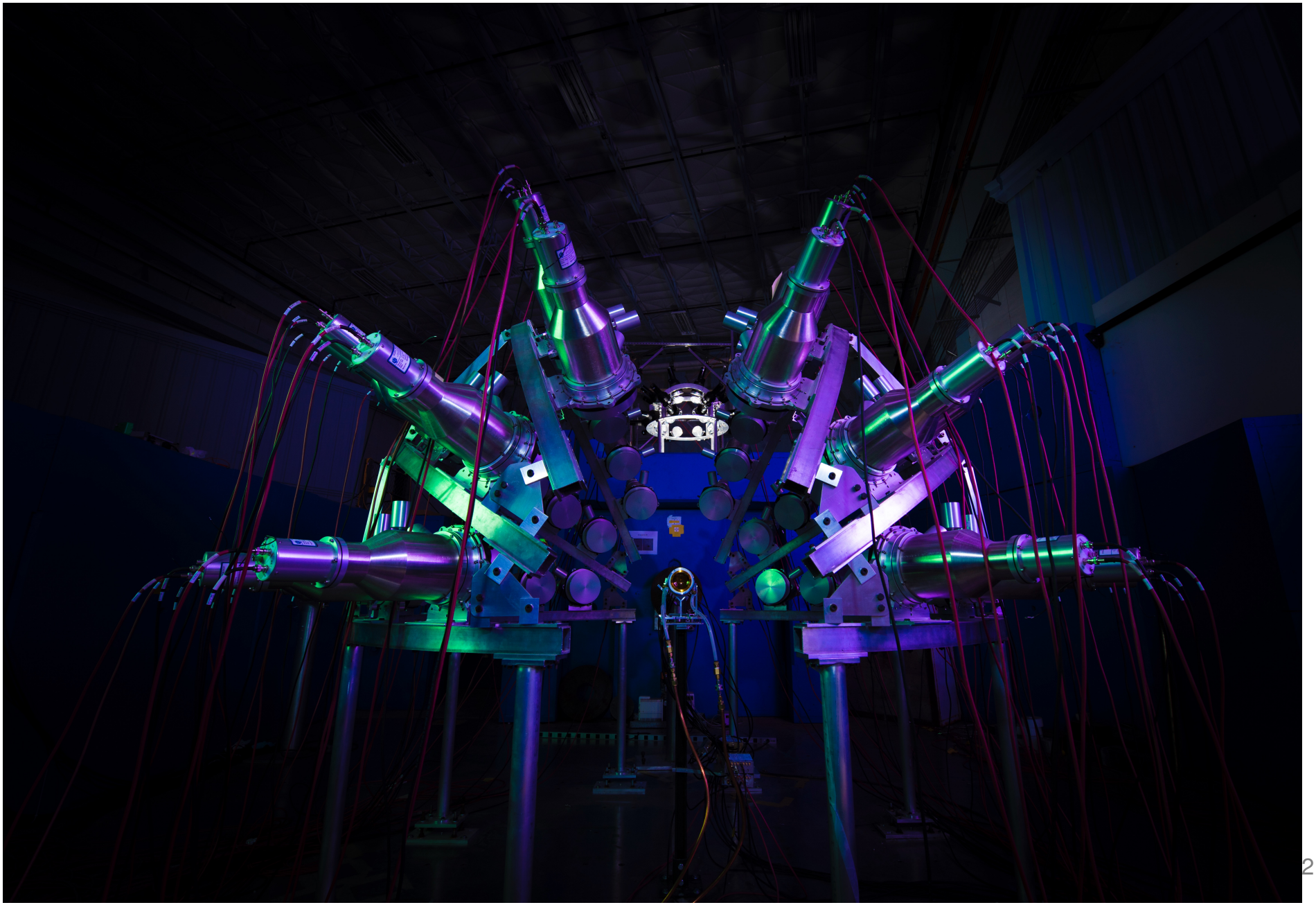
Correlations Across $E_n^{inc} \Rightarrow \langle E \rangle$ Correlations





- Had never been reported for an experiment before Chi-Nu
- $\langle E \rangle$ values are *highly correlated*

Liq. Scint. for Initial n Scattering Measurements



n-γ Coincidences Above Random Backgrounds

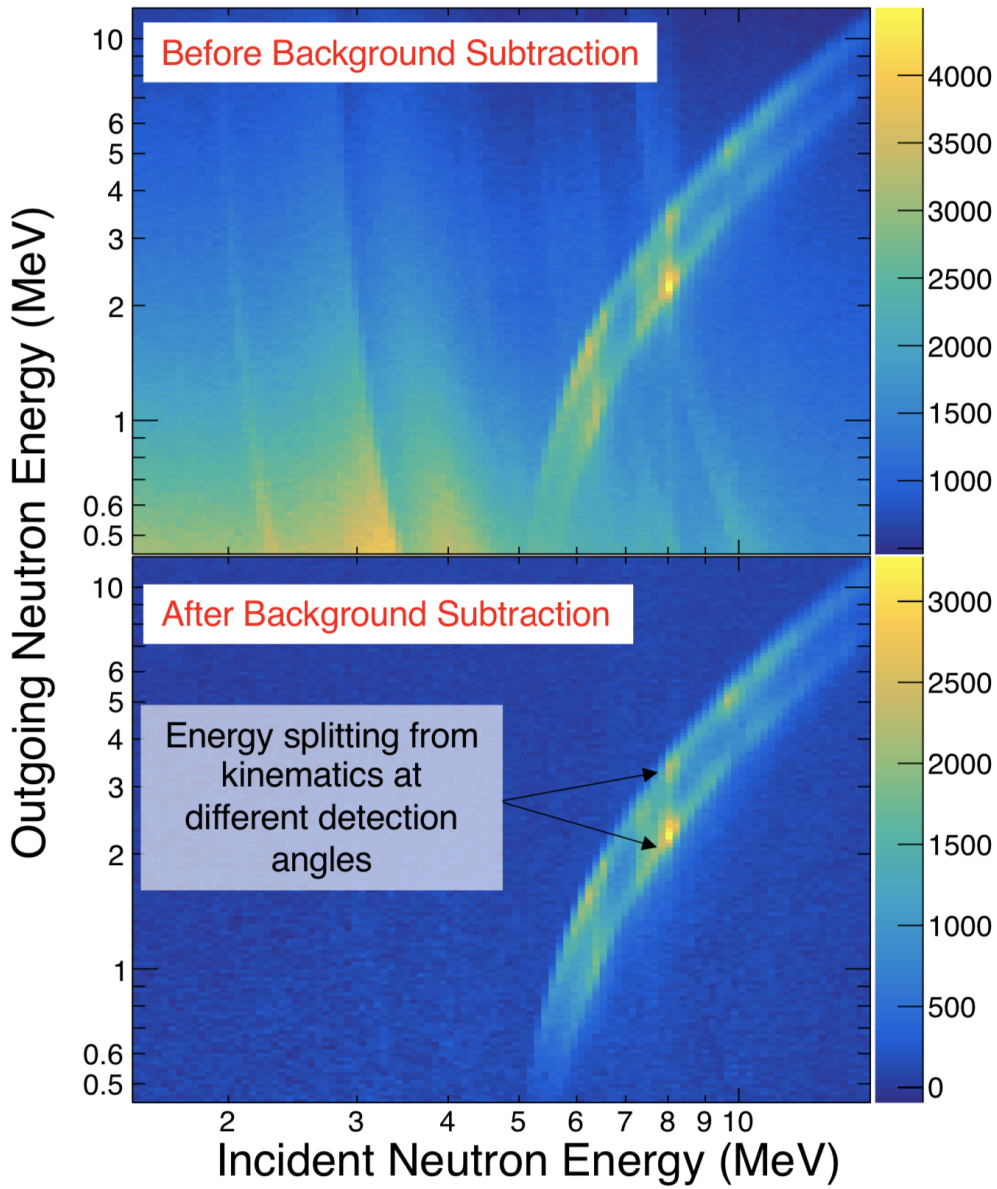
- Random coincidence rates derived form Poisson probabilities for *uncorrelated* detection rates †
  - true coincidence rate must be low
- Calculate the total probability for:
  1. Detecting a γ at time t_γ
  2. Not detecting n over coinc. time $t_n - t_\gamma$
  3. Detecting n at time t_n

$$\text{Coinc. Rate} = r_b = r_\gamma r_n \Delta_t$$

$$\Rightarrow \quad b = \frac{\gamma n}{N_{t_0}}$$

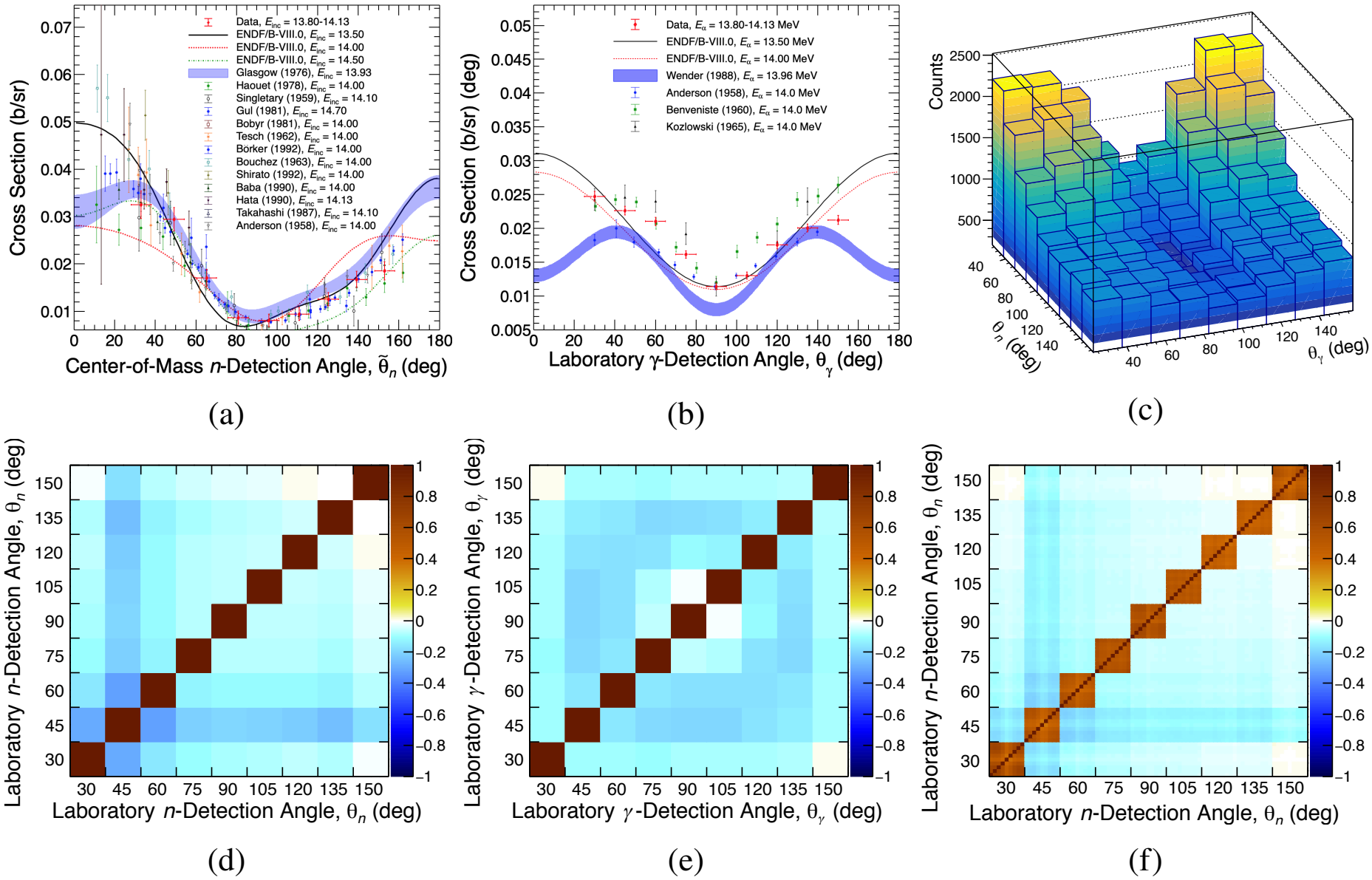
$$\text{with} \quad \gamma, n = \text{counts}$$

- Works remarkably well here, but what are the backgrounds?

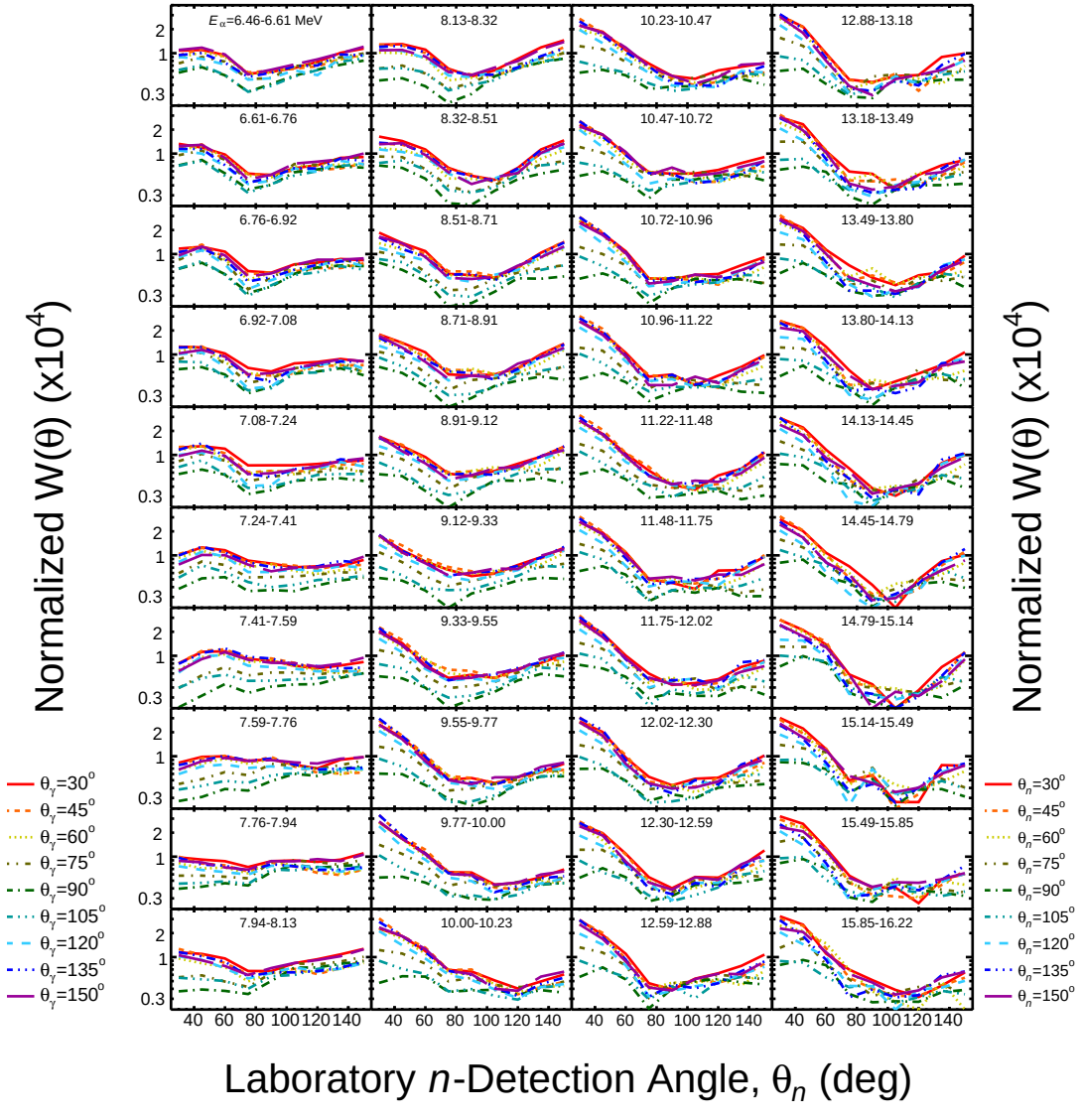


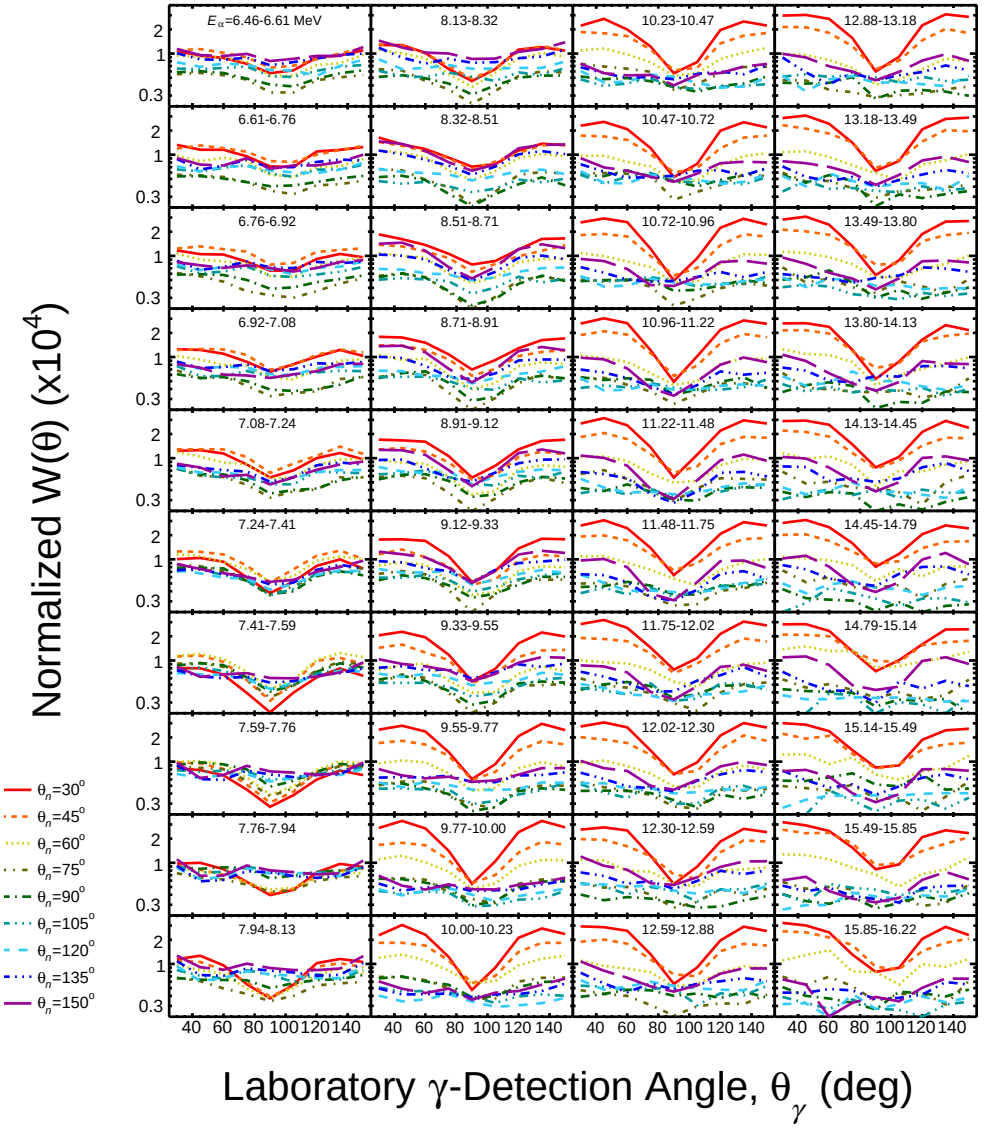
†O'Donnell, NIMA **805** (2016) 87

Extract n, γ, and Correlated n-γ Distributions

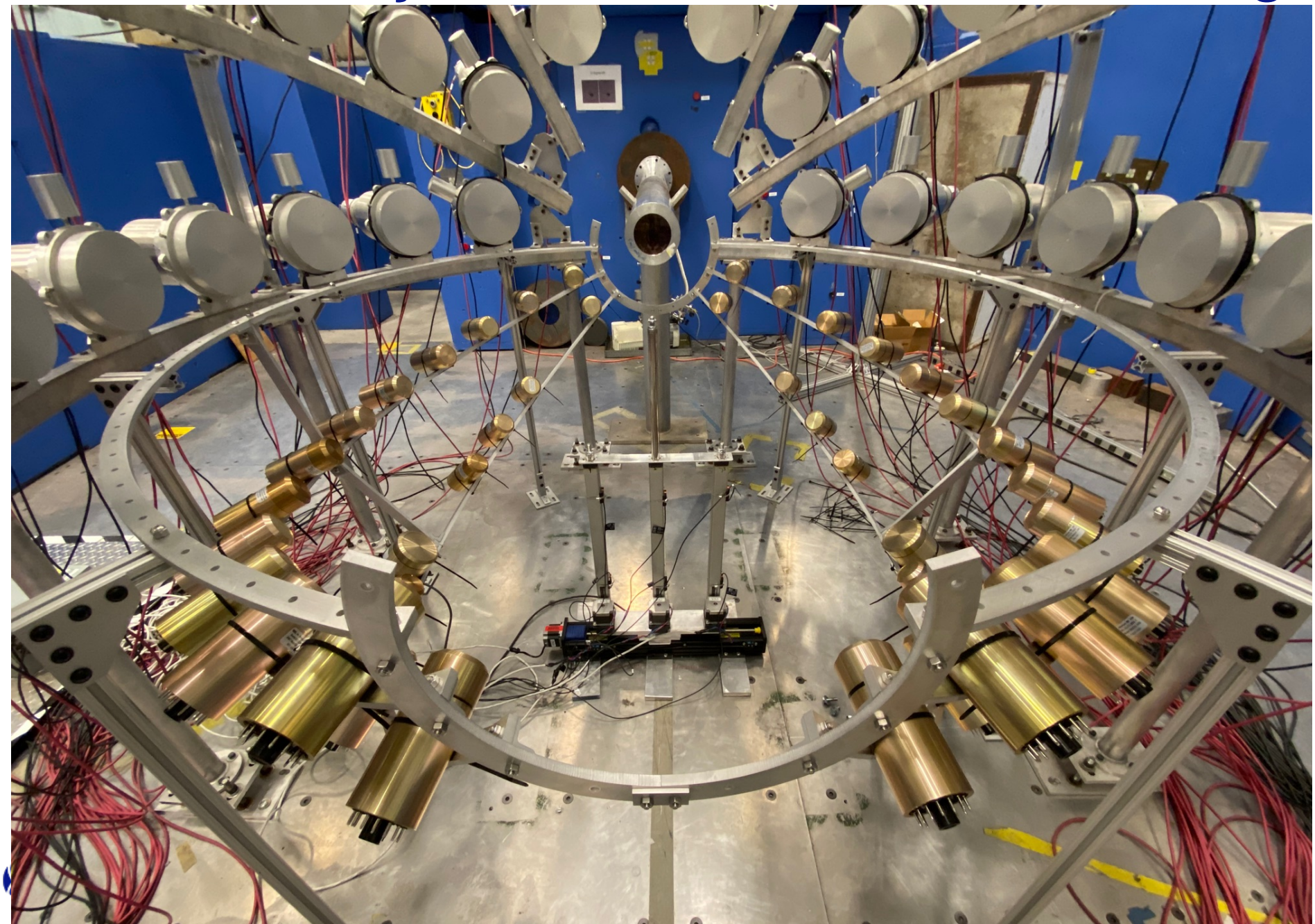


Corr. n-γ Distributions for Wide Range of E_n^{inc}





CoGNAC Array of CLYC Detectors for Scattering



Summary

- Chi-Nu: Mature capability to measure PFNS over a wide range of E_n^{inc} and E_n^{out} at WNR

- CoGNAC: Developing capability for precise measurements of neutron scattering cross sections and angular distributions using a highly-segmented CLYC detector array

- Complimentary analysis approaches and techniques

- Funded US DOE under Contract No. 89233218CNA000001
- Initial scattering work funded by LDRD Project 20190588ECR
- Meas. and Dev. funded by LDRD Project 20210329ER
- γ-production cross section measurements funded through Prop. ID 0000260569 submitted to DE-FOA-0002440