



Updates and Results from Recent LANL PFNS and Neutron Scattering Measurements

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On behalf of the Chi-Nu and CoGNAC Teams

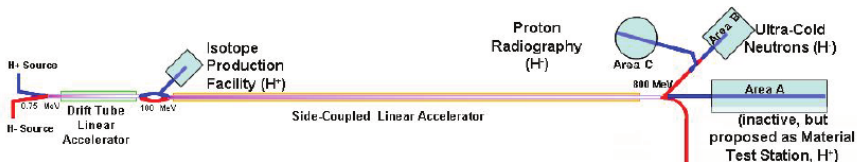
2022 CSEWG Meeting

Outline

- LANSCE Overview
- Chi-Nu PFNS Updates
 - Final ^{235}U Results
 - Preliminary ^{238}U Results
 - Very preliminary ^{240}Pu Results
 - PFNS Ratios
- CoGNAC Neutron Scattering Approach
 - Prelim. Results for $^{12}\text{C}(n,n'_1)$ Cross Section
 - Prelim. Results for Inelastic Scattering on ^{27}Al
 - Prelim. Results for Inelastic Scattering on ^{56}Fe
- Future Work



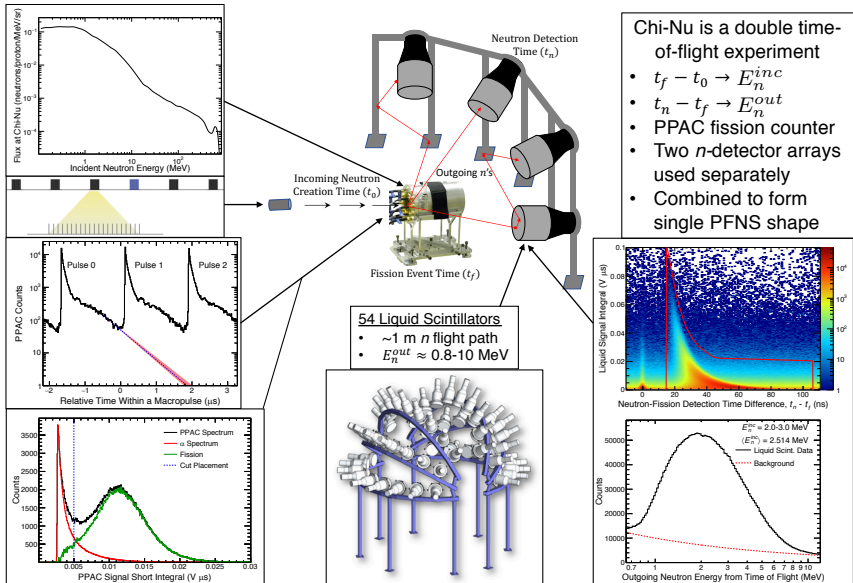
The LANSCE Accelerator



- Lujan Target
 - Moderated neutron target
 - Thermal – \approx 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

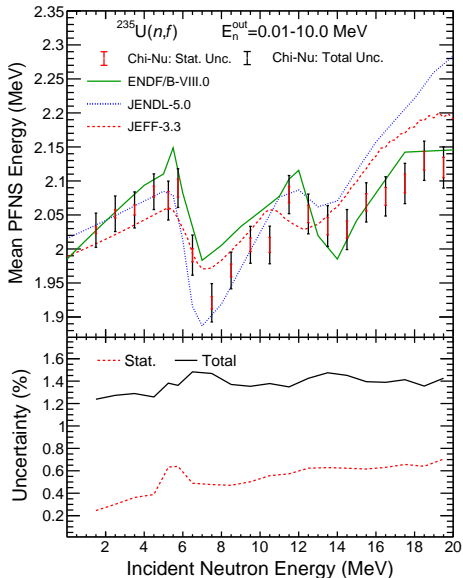
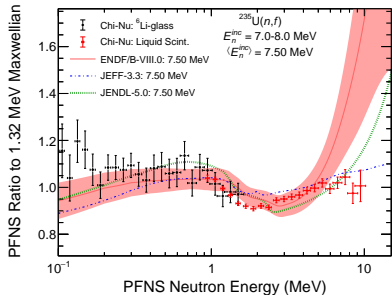
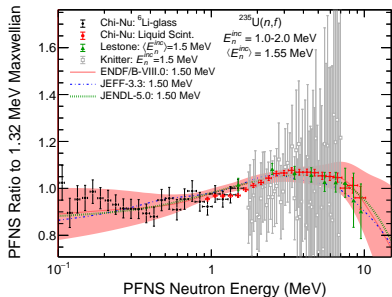


Chi-Nu Experiment Overview

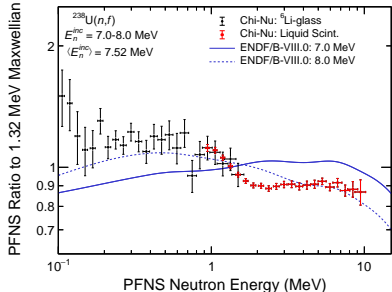
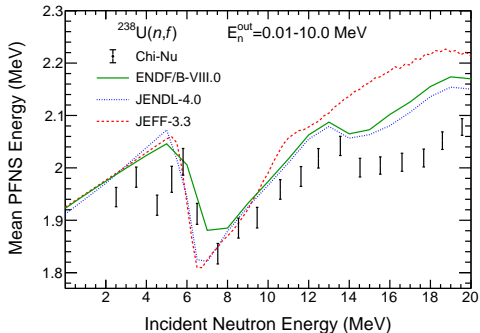
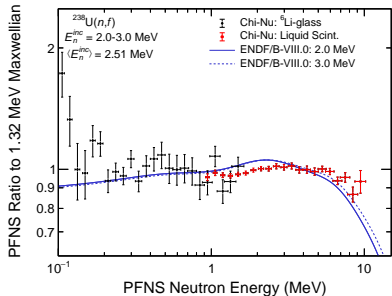


^{235}U Final PFNS Results

Kelly *et al.* PRC **105**, 044615 (2022)

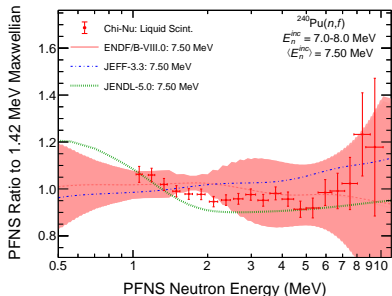
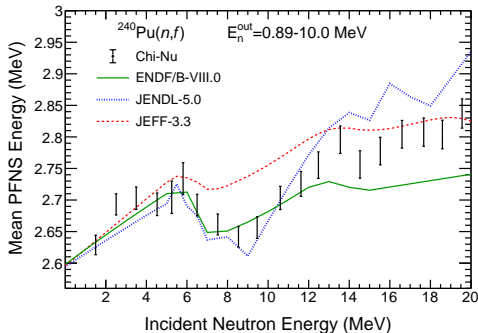
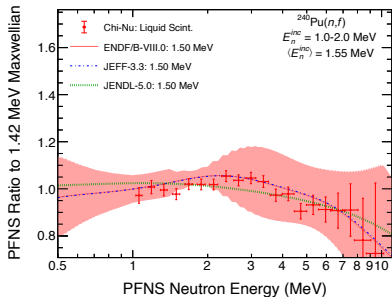


^{238}U Preliminary PFNS Results



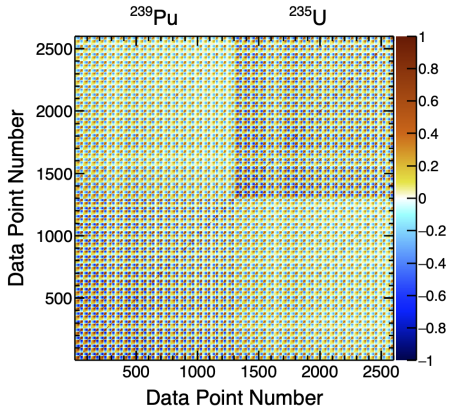
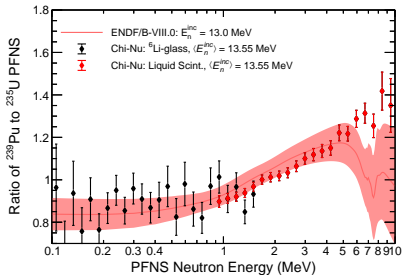
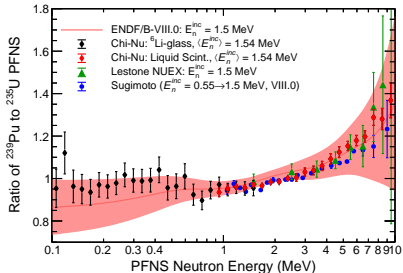
- Largest remaining tasks
 - Fine tune MCNP at edges of liquid scintillator data
 - Fission fragment angular anisotropy impact
- Finalized within ≈ 1 month

^{240}Pu Very Preliminary PFNS Results



- Run with dual-gain liquid scintillators
 - No Li-glass in beam
- s.f measured with Li-glass for extension of liquid scintillators to lower energies
- Still lots to do!

PFNS Ratios

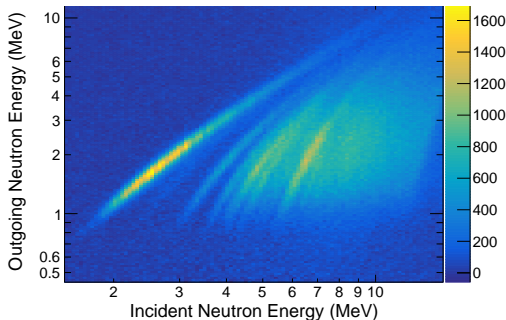
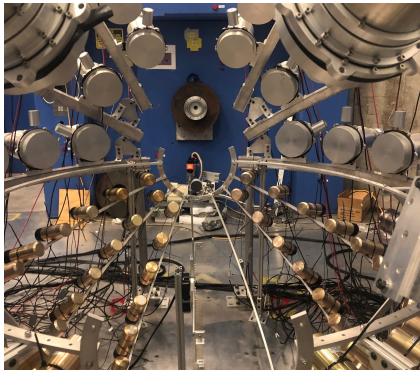


- Single correlation matrix describing relationship between all data points of each target
- Ratios of ^{239}Pu , ^{235}U , ^{238}U , and ^{240}Pu to each other will be available soon



CoGNAC n - γ Approach to Scattering

- PSD n - γ separation \Rightarrow treat each detector as both n and γ detector
 - Incident Neutron Energy, E_n^{inc} , from t_0 - t_γ time difference
 - Outgoing Neutron Energy, E_n^{out} , from t_γ - t_n time difference
- Chi-Nu liquid scintillator array and in-development CLYC detector array



Iterative Unfolding of Neutron Spectra

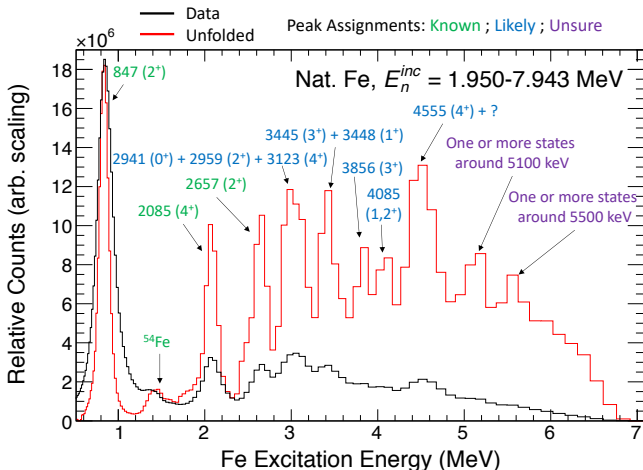
$$m_{\alpha/\beta}^{(n+1)}(E) = \frac{m_{\alpha/\beta}^{(n)}(E)c_{\alpha}(E)}{\sum_{i=1}^N \mathcal{R}(E, E_i)m_{\alpha/\beta}^{(n)}(E_i)}$$

Kelly *et al.*, NIMA **1010** (2021) 165552

Kelly *et al.*, NIMA **866** (2017) 182

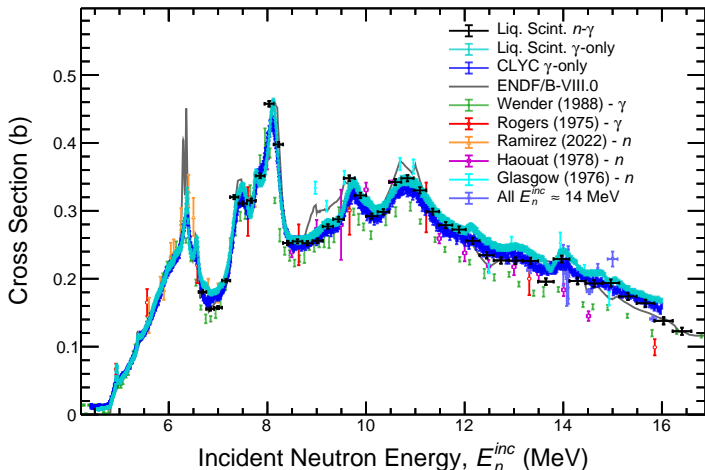
Gold, Report ANL-6984 (1964)

- Improves resolution of state excitations
- Corrects for environmental n scattering effects
- Extract full strength of each excited state
 - Demonstrated with continuous PFNS in MCNP

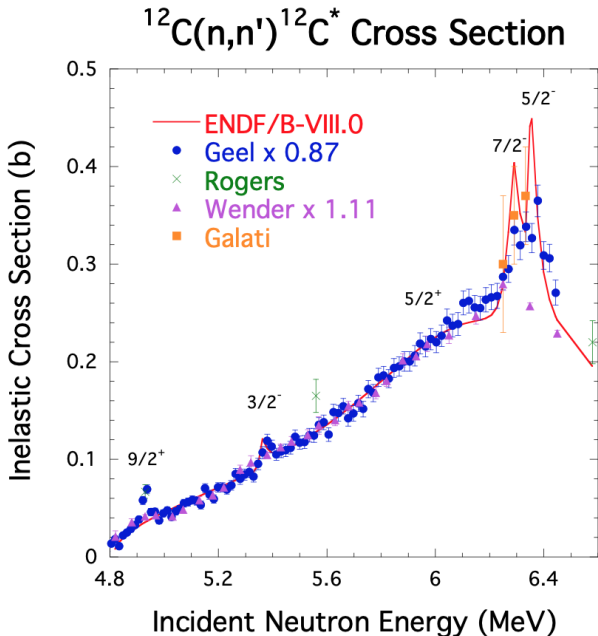


Preliminary $^{12}\text{C}(n,n'\gamma)$ Cross Section

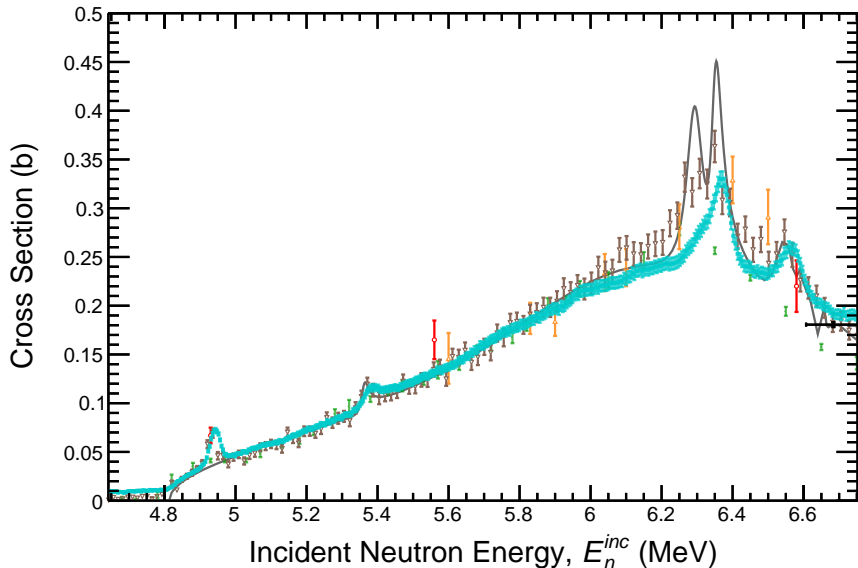
- Correlated $n\text{-}\gamma$ Distributions: Kelly *et al.*, PRC **104** (2021) 064614
- Note: All data sets are shape data (not absolute)
- Measured cross section 3 ways: Liqd. $n\text{-}\gamma$, Liqd. γ , and CLYC γ



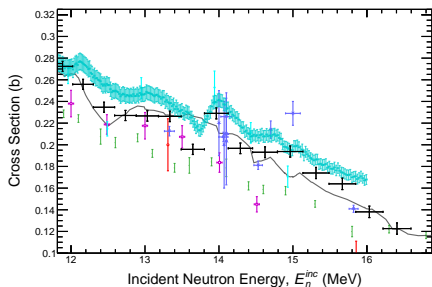
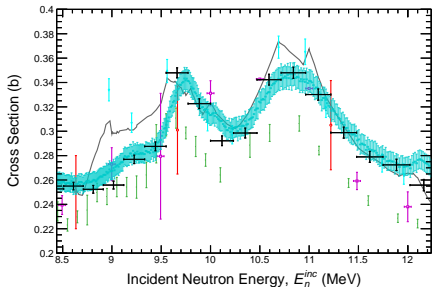
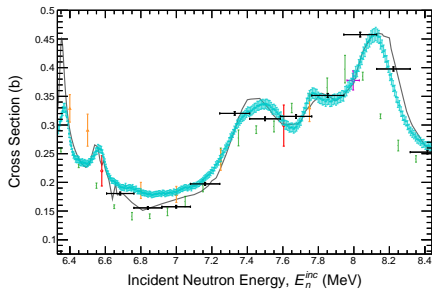
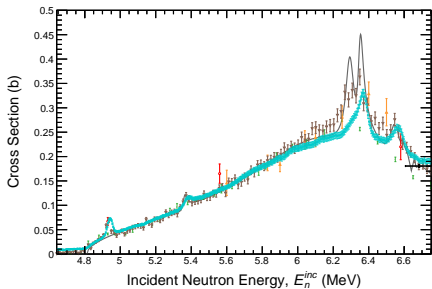
Prelim. $^{12}\text{C}(n,n'\gamma)$ Cross Section: Liq. Scint. γ



Prelim. $^{12}\text{C}(n,n'\gamma)$ Cross Section: Liq. Scint. γ

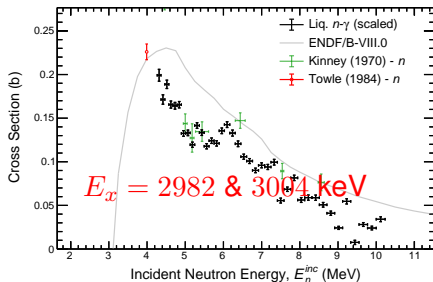
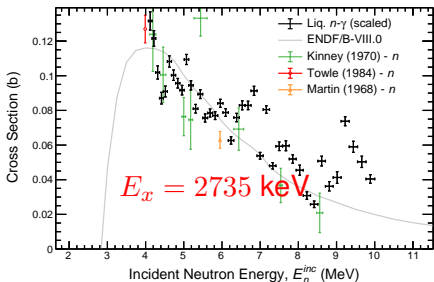
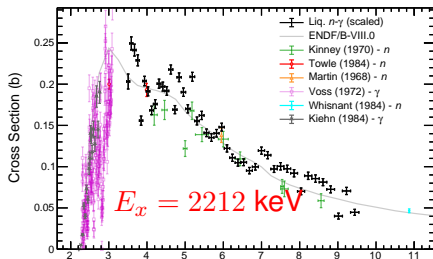
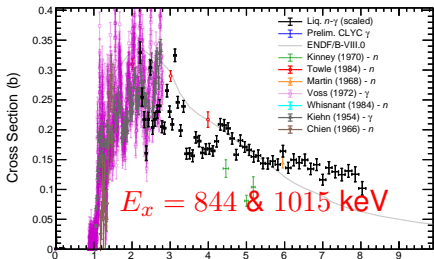


Prelim. $^{12}\text{C}(n,n'\gamma)$ Cross Section: Liq. Scint. γ

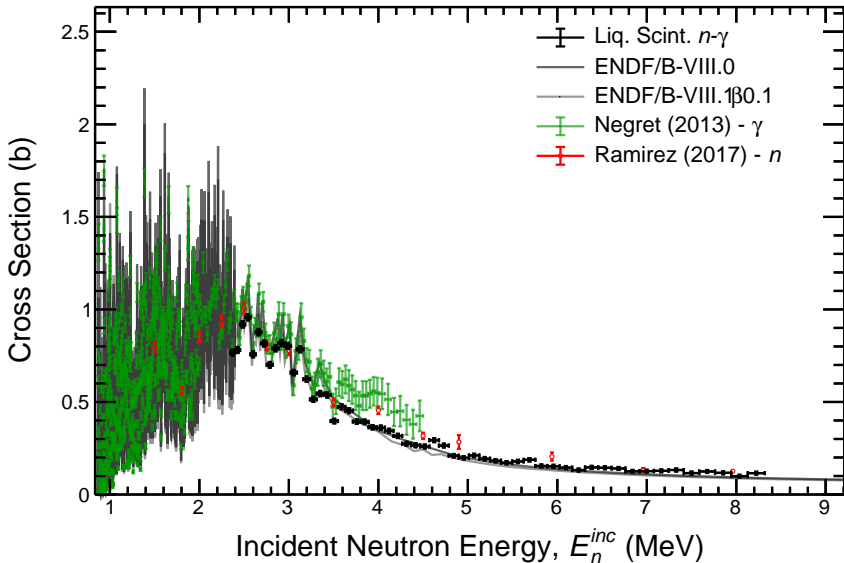


Preliminary Results for $^{27}\text{Al}(n,n'\gamma)$

- All data normalized to 4.0 MeV data point at $E_x = 2212$ keV

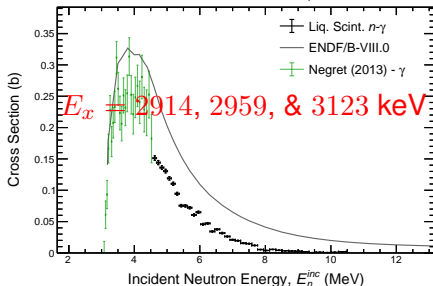
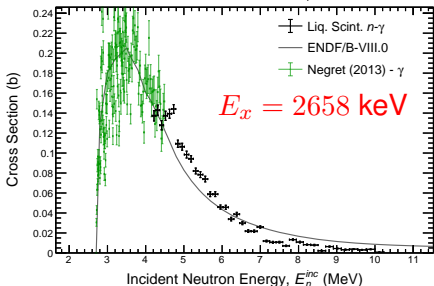
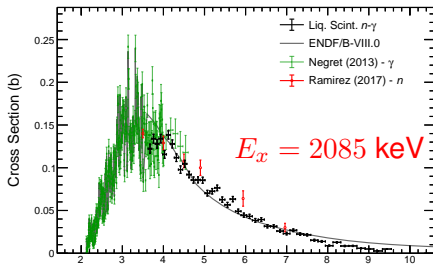
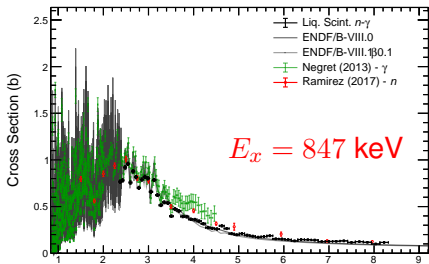


Preliminary Results for $^{56}\text{Fe}(n,n'\gamma) - 847 \text{ keV } 2^+$



Preliminary Results for $^{56}\text{Fe}(n,n'\gamma)$

- All data normalized to 4.0 MeV data point at $E_x = 2085$ keV



Summary

- OES-funded Chi-Nu PFNS Measurements Nearing Completion
 - ^{235}U PFNS finalized, published, included in ENDF/B-VIII.1 β eval.
 - ^{238}U PFNS nearly complete, submitted for evaluation soon
 - NCSP-funded ^{240}Pu measurement completed, analysis underway
 - n - γ analysis technique works well for inelastic cross sections
 - γ -only promising as well for select isotopes and E ranges
 - Multiple scattering results in line for publication next year
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→Initial work funded by LDRD Project 20190588ECR

→Exp. and analysis funded by LDRD Project 20210329ER

→ γ -production cross section measurements funded by NA-22 via
Proposal ID 0000260569 submitted to DOE-FOA-0002440

→Fe data acquisition and, in part, analysis funded by Proposal ID
0000017653 submitted to DOE-FOA-17-1763

→ ^{240}Pu PFNS work funded by NCSP

