

Recent Advancements and Updated PFNS Results from the Chi-Nu Experiment

November 7th, 2018: CSEWG 2018, BNL

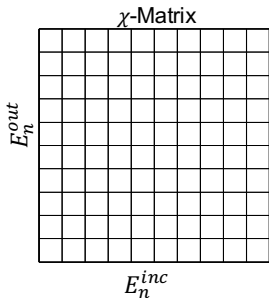
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Work performed under the auspices of
U.S. DOE by LANL under contract DE-AC52-06NA25396
and LLNS, LLC under contract DE- AC52-07NA27344

Chi-Nu Goals, Method, and Challenges

Goals

- Measure the neutron χ -matrix
- ^{252}Cf , ^{235}U , ^{239}Pu
- PFNS for ranges of E_n^{inc}

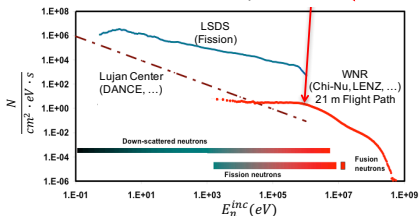
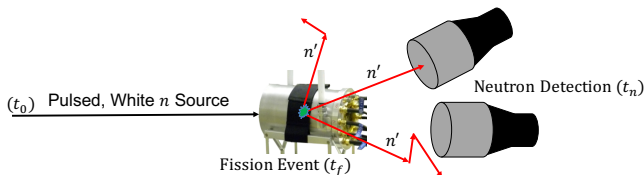


Method

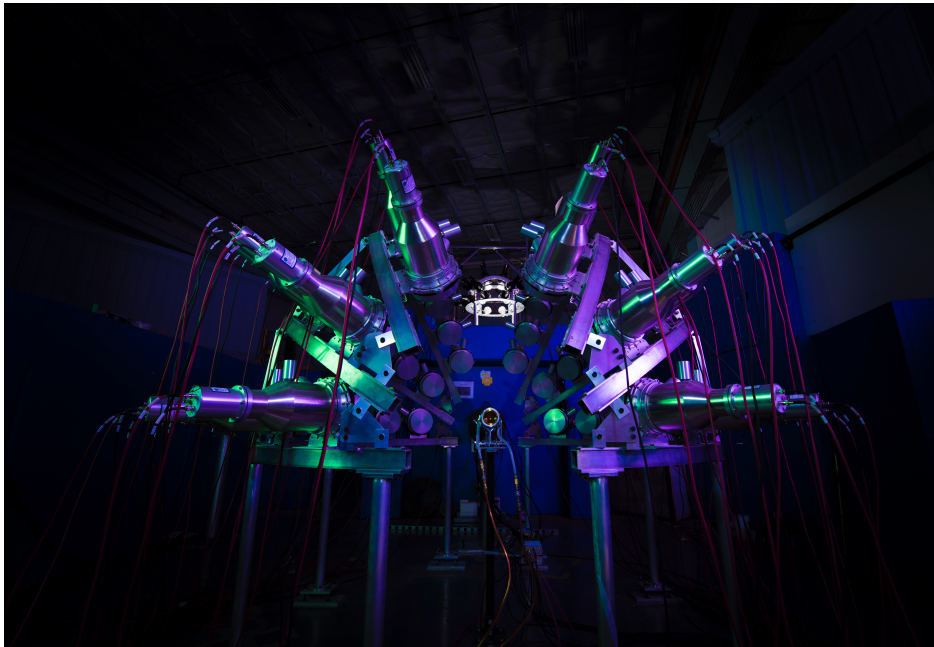
- Double TOF
- PPAC target
- $E_n^{out} < 2 \text{ MeV}$
 - 22 ^6Li -glass
- $E_n^{out} > 800 \text{ keV}$
 - 54 Liquid Scint.

Challenges

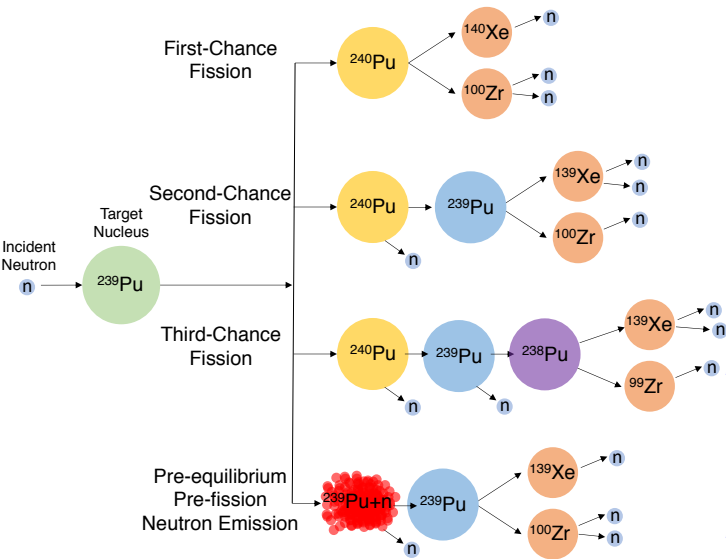
- $E_n^{inc} \geq 0.7 \text{ MeV}$
 - $\leq 20 \text{ MeV}$
- $E_n^{out} \geq 0.01 \text{ MeV}$
 - $\leq 10 \text{ MeV}$
- Detailed Uncertainties



The Chi-Nu Arrays



Varieties of Fission



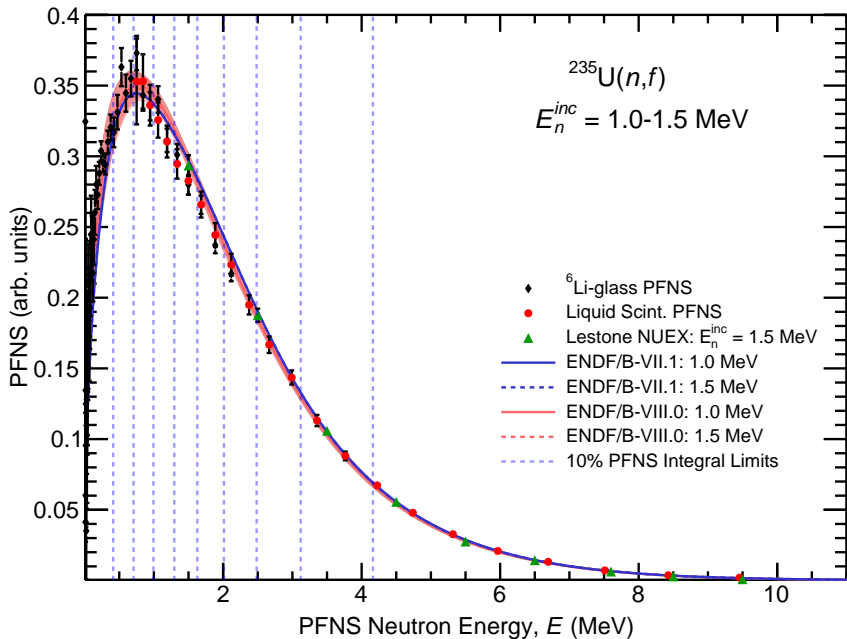
Observable for All Incident Energies

Observable for $E_n^{inc} \gtrsim 6\text{MeV}$
Not Previously Observed for ^{235}U

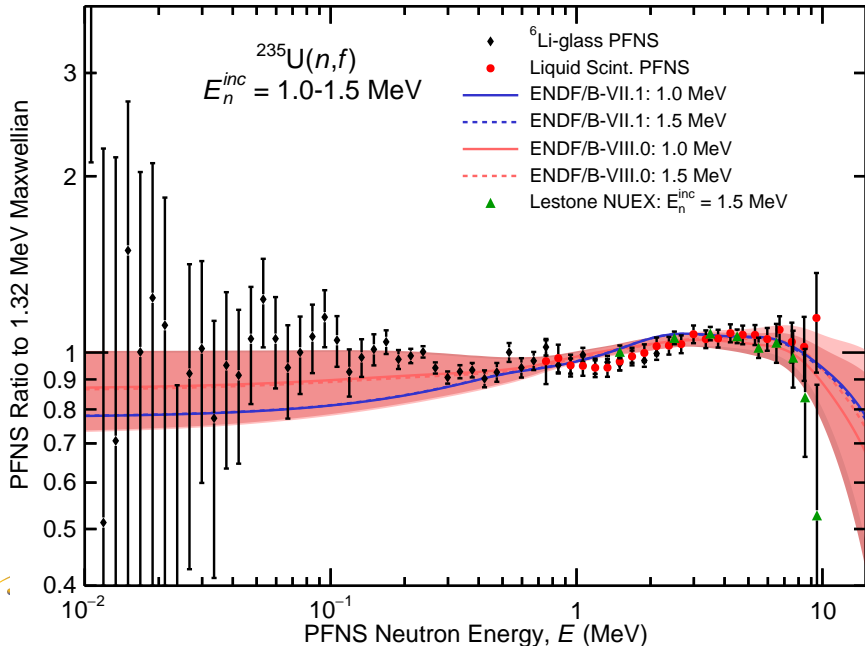
Observable for $E_n^{inc} \gtrsim 12\text{MeV}$
Not Prev. Observed for ^{235}U or ^{239}Pu

Observable for $E_n^{inc} \gtrsim 12\text{MeV}$
Not Prev. Observed for ^{235}U or ^{239}Pu

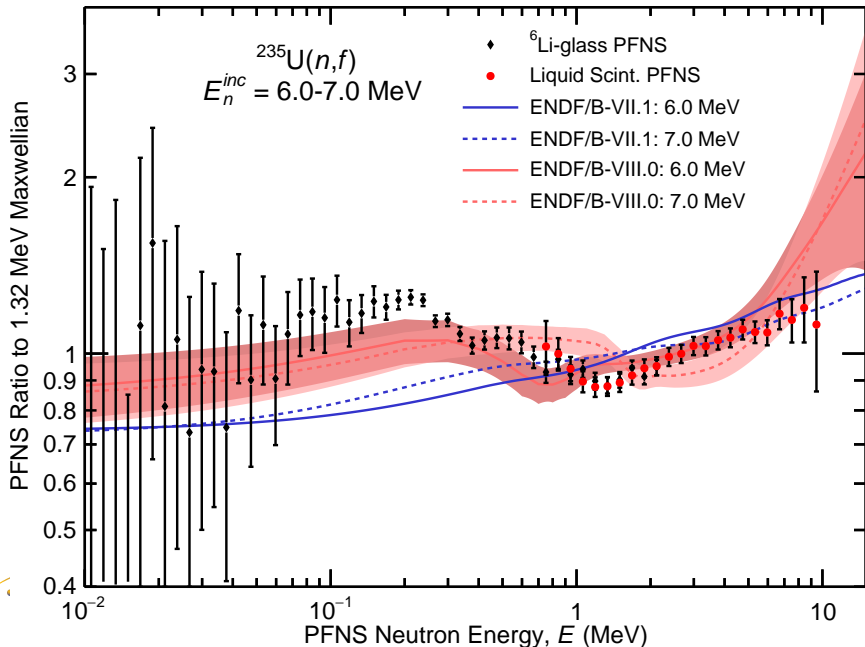
Example PFNS Not as a Ratio



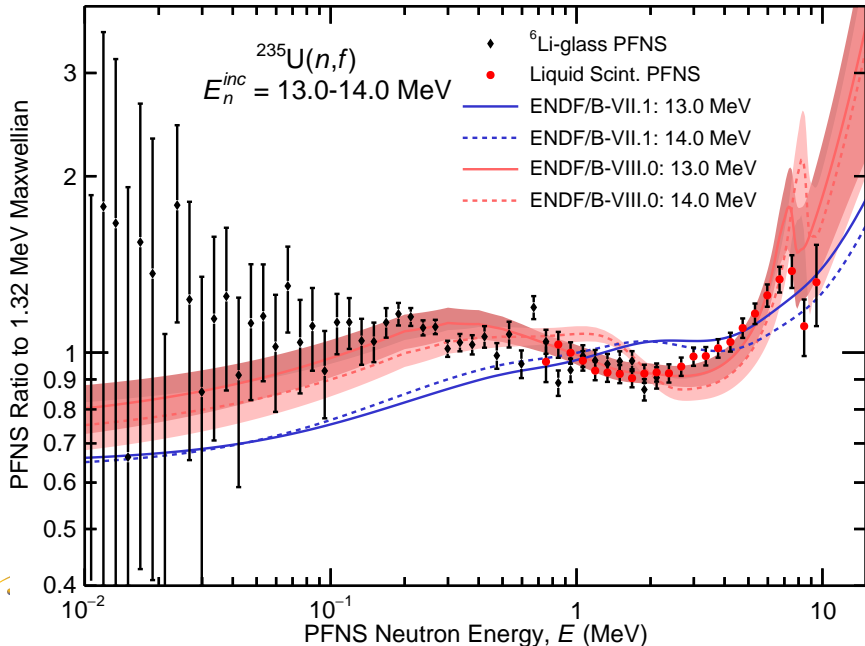
Preliminary ^{235}U : First-Chance Fission



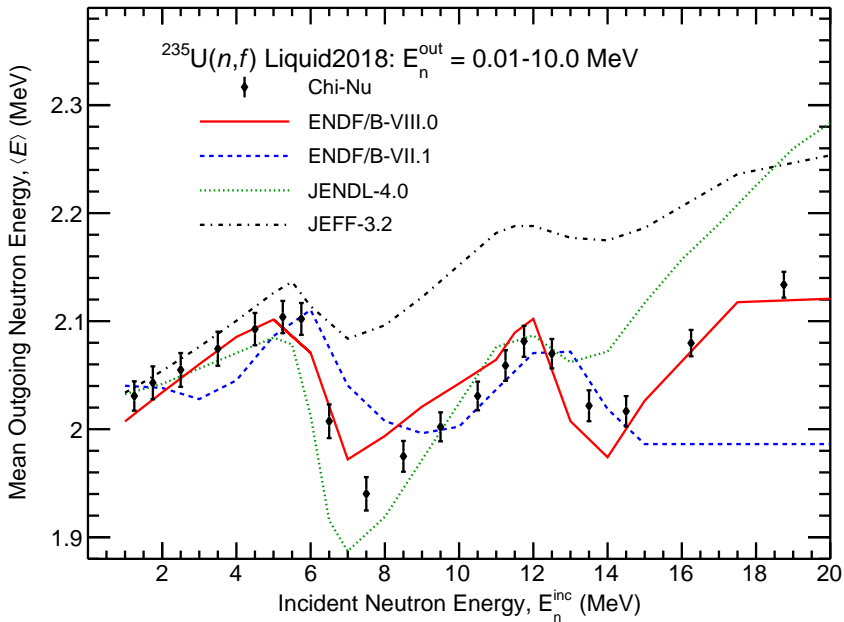
Preliminary ^{235}U : Second-Chance Fission



Preliminary ^{235}U : Third-Chance Fission and Pre-eq.



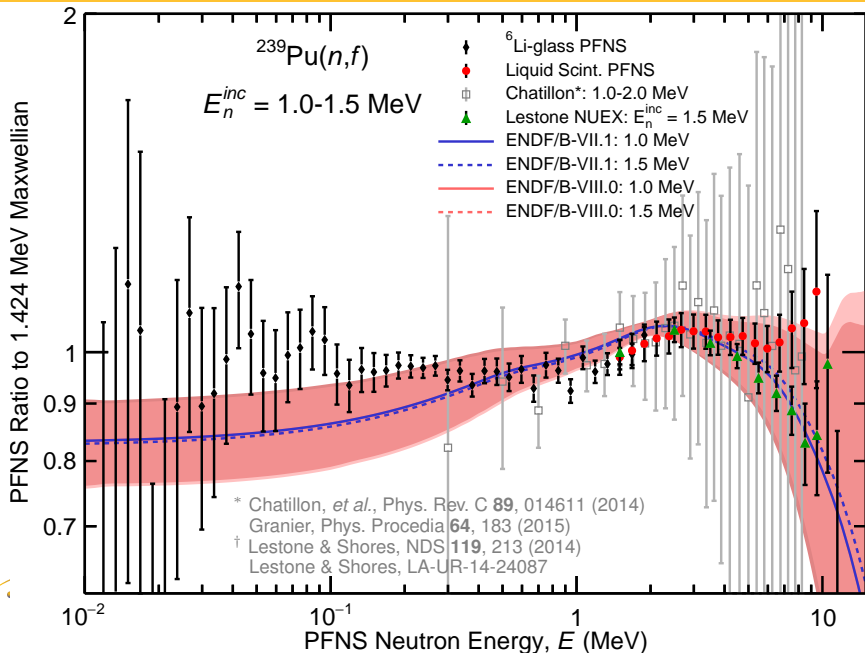
Preliminary ^{235}U Mean PFNS Energies



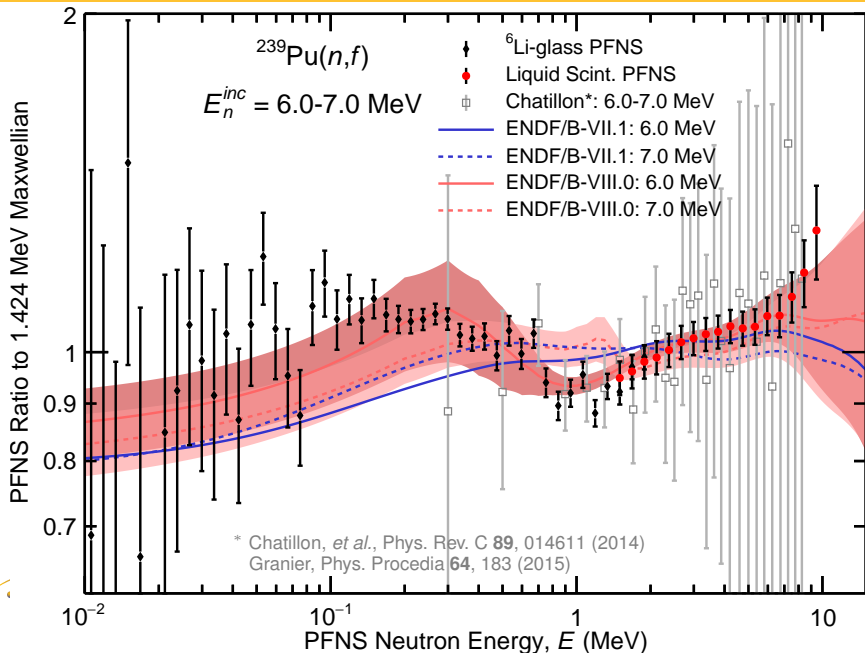
Chi-Nu ^{235}U PFNS Conclusions

- Unambiguously observe the onset of second-chance fission in PFNS
 - **First Observation!**
- Chi-Nu data confirm existence of pre-equilibrium pre-fission contribution
 - **First Continuous Double-Differential Observation!**
 - Though the effect may be smaller than indicated in ENDF/B-VIII.0.
- Observe third-chance fission trends in the PFNS and Mean Energies
 - **First Observation!**
- In general, good agreement between Chi-Nu and ENDF/B-VIII.0
- Mean energies trending higher as a result of including Chi-Nu data
 - Note: ENDF/B-VIII.0 changed as a result of evaluation technique, physical models, *and* Chi-Nu Data
 - The ENDF/B-VIII.0 PFNS *both with and without* Chi-Nu data reproduce Chi-Nu data better than ENDF/B-VII.1

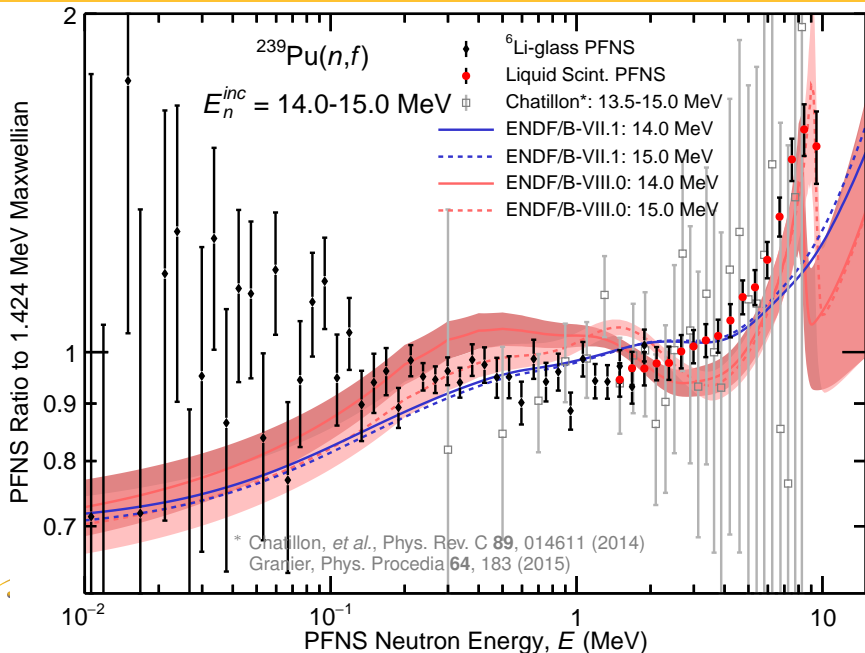
Preliminary ^{239}Pu : First-Chance Fission



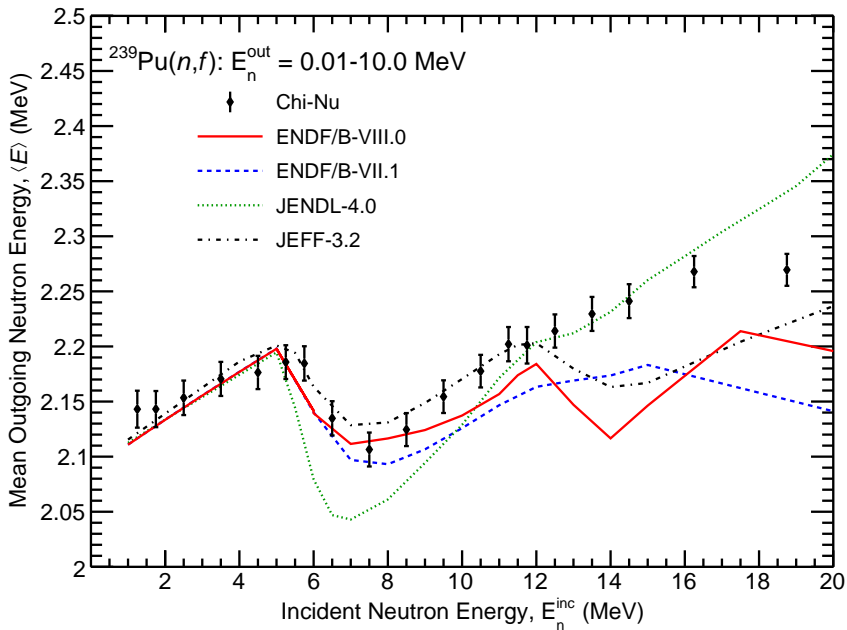
Preliminary ^{239}Pu : Second-Chance Fission



Preliminary ^{239}Pu : Third-Chance Fission and Pre-eq.



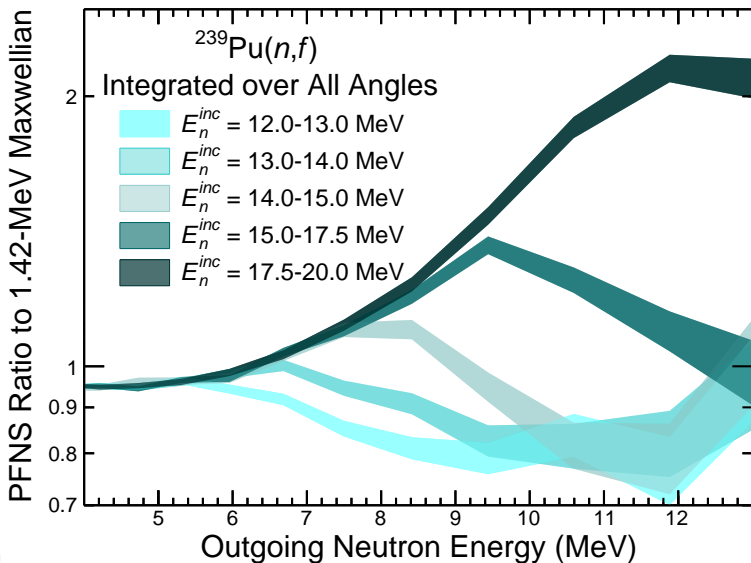
^{239}Pu Mean PFNS Energies



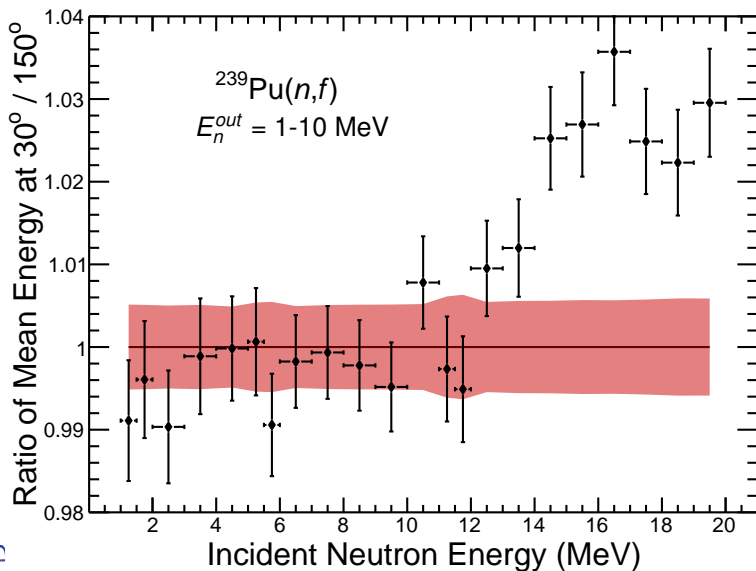
Chi-Nu ^{239}Pu PFNS Conclusions

- Unambiguously observe second-chance features *in the PFNS*
 - **First Observation!**
- Third-chance fission features are not as drastic in the Chi-Nu data
 - Mean energy does not show a strong dip at third-chance fission...
 - **First Definitive Non-Observation!**
 - Third-chance fission more prominent at backward angles?
- Pre-equilibrium component of PFNS is clearly observed at multiple incident energies
 - **First Observation!**
 - Chatillon *et al.* claim to be independent of pre-equilibrium neutrons...
- In general, good agreement is obtained between Chi-Nu and ENDF/B-VIII.0
 - Changes from ENDF/B-VII.1 to VIII.0 driven by evaluation technique and PFNS model physics
- Prelim. Evaluation with Chi-Nu ^{239}Pu data shows potential impact on ENDF/B library

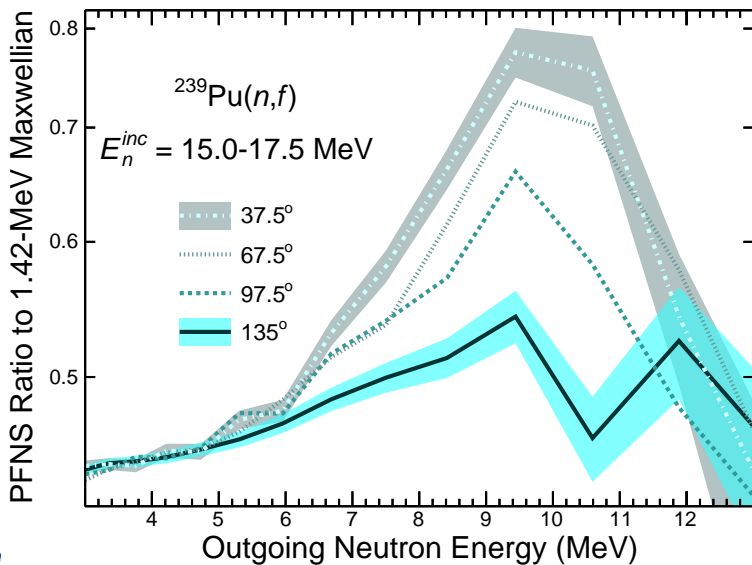
$^{239}\text{Pu}(n,f)$ Pre-Fission Pre-Equilibrium Neutron Trends



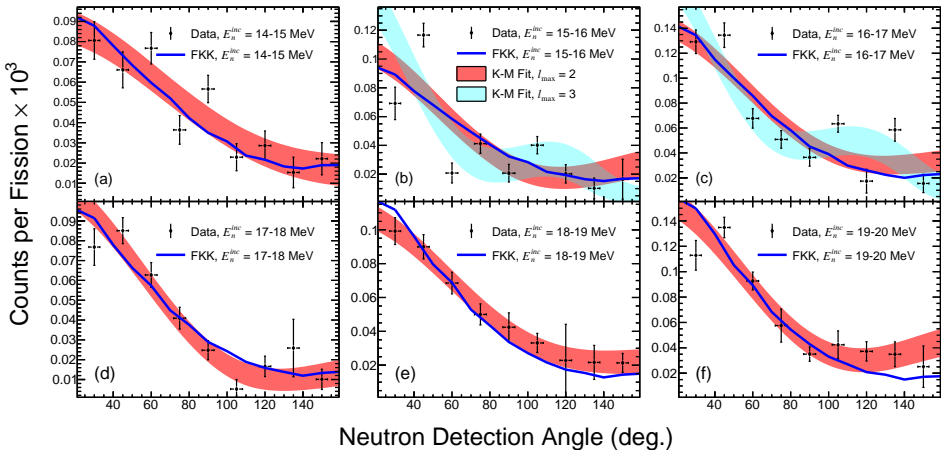
$^{239}\text{Pu}(n,f)$ Pre-Fission Pre-Equilibrium Neutron Trends



$^{239}\text{Pu}(n,f)$ Pre-Fission Pre-Equilibrium Neutron Trends



$^{239}\text{Pu}(n,f)$ Pre-Fission Pre-Equilibrium Neutron Trends



Pre-Eq. Conclusions and Chi-Nu Outlook

- First fission-tagged continuous double-differential observations of the pre-equilibrium pre-fission component of fission neutron spectrum
- The exciton model is widely used in PFNS models
 - *No Angular Distribution Predictions from Exciton Model*
- Data suggest no pre-eq. correlation with fission axis orientation
 - Has been assumed, but not demonstrated
- Clear differences in PFNS as a function of angle just from pre-eq.
- Future Data and Analyses at Chi-Nu
 - Pre-eq. analysis for ^{235}U
 - Angular distributions of entire PFNS
 - n - n , n - γ , and γ - γ correlations
 - ^{238}U PFNS measurement
 - ^{252}Cf PFNS measurement