Los Alamos NATIONAL LABORATORY

LANSCE CoGNAC and Chi-Nu Experimental Updates

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On behalf of the LANL/LLNL Chi-Nu PFNS Team and the CoGNAC Experiment Team

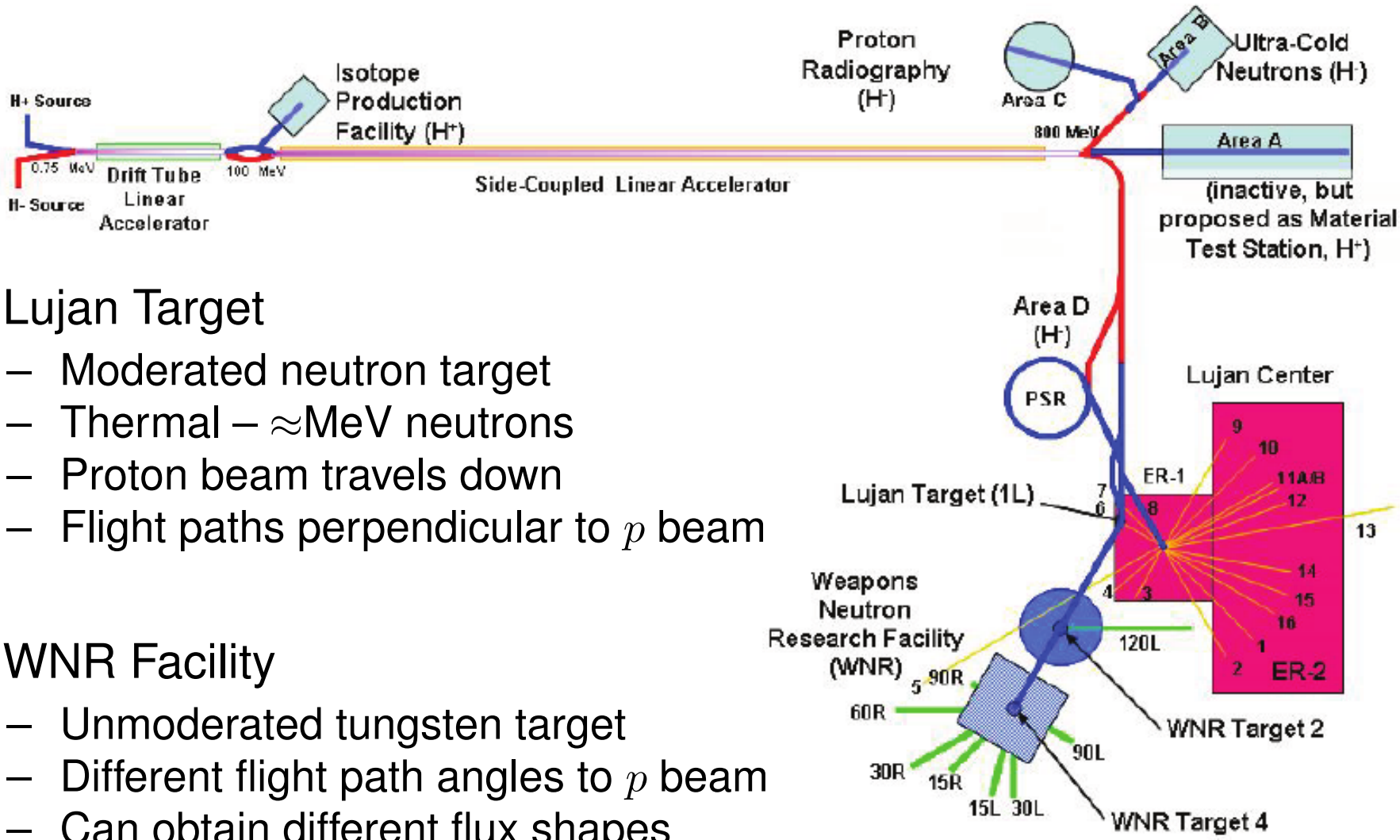
2023 CSEWG Meeting

NNSA National Nuclear Security Administration
LA-UR-23-33042
11/17/2023

Outline

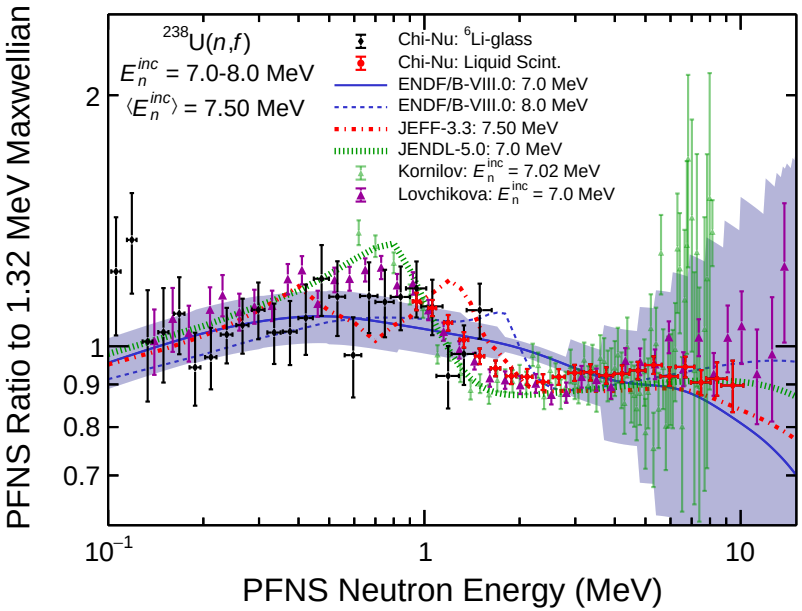
- LANSCE Overview
- Chi-Nu PFNS Updates (Joint LANL / LLNL Effort)
  - ^{238}U(n,f) PFNS Results
    - Published in PRC over this last year
  - ^{240}Pu Results Delivered to Evaluations
    - Publication in internal review stage
- CoGNAC Neutron Scattering Approach
  - Results for ^{12}C(n,$n'\gamma$) Cross Section
    - Published in PRC over this last year
  - Results for ^{56}Fe(n,$n'\gamma$)
    - Publication nearing internal review stage
  - Preliminary Results for ^{16}O(n,$n'\gamma$) - publication in early stages
  - Preliminary Results for ^{28}Si(n,$n'\gamma$) - very preliminary
  - Preliminary Analysis for ^{12}C(n,n) is In Progress
  - CLYC Data Forthcoming

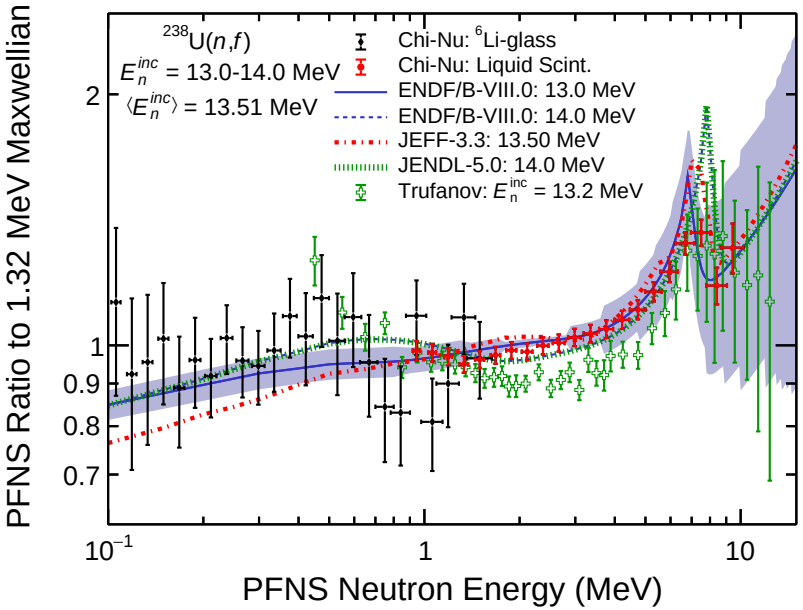
The LANSCE Accelerator

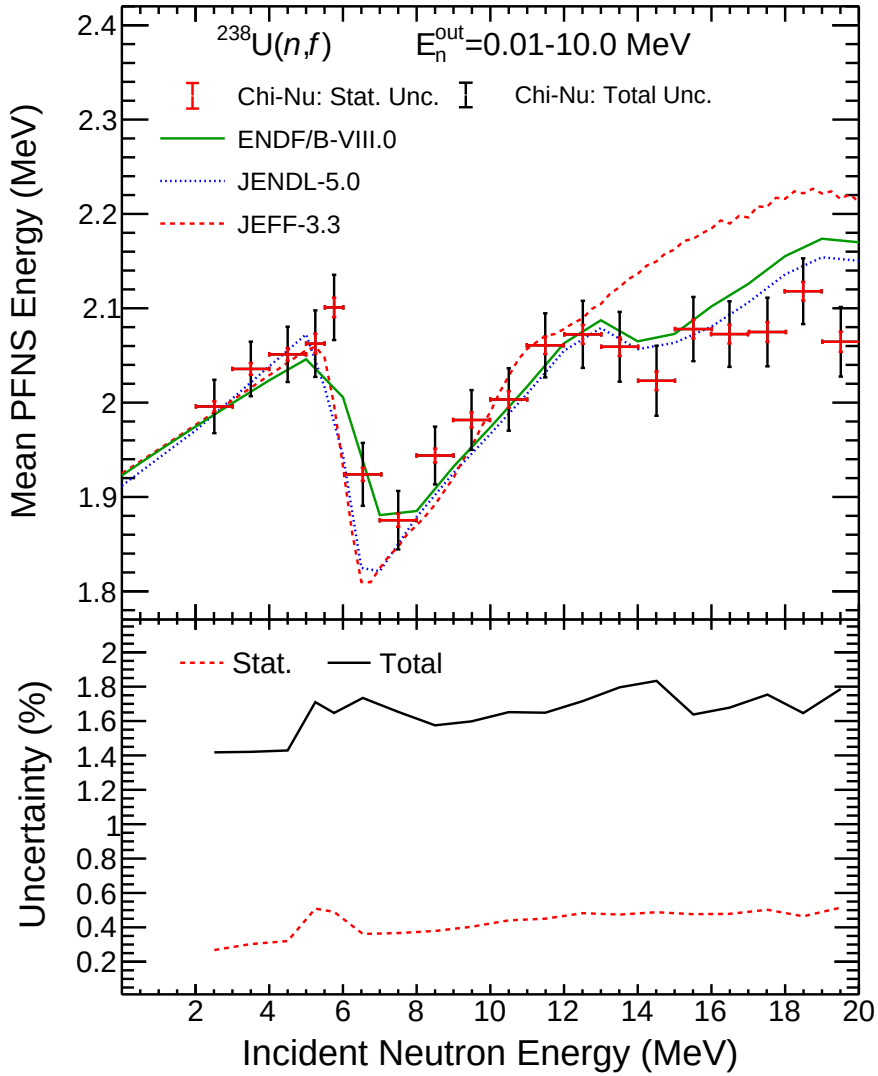


- Lujan Target
  - Moderated neutron target
  - Thermal – ≈MeV neutrons
  - Proton beam travels down
  - Flight paths perpendicular to p beam
- WNR Facility
  - Unmoderated tungsten target
  - Different flight path angles to p beam
  - Can obtain different flux shapes

^{238}U(n,f) PFNS Results

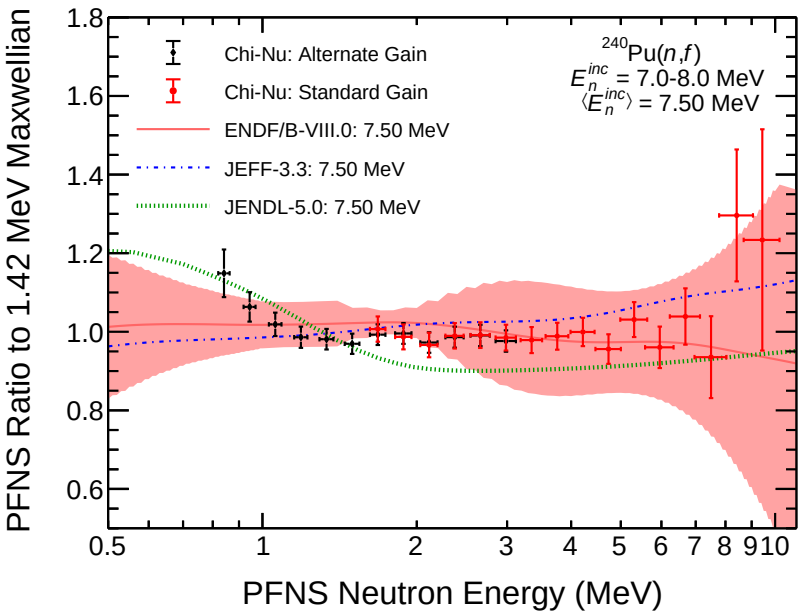


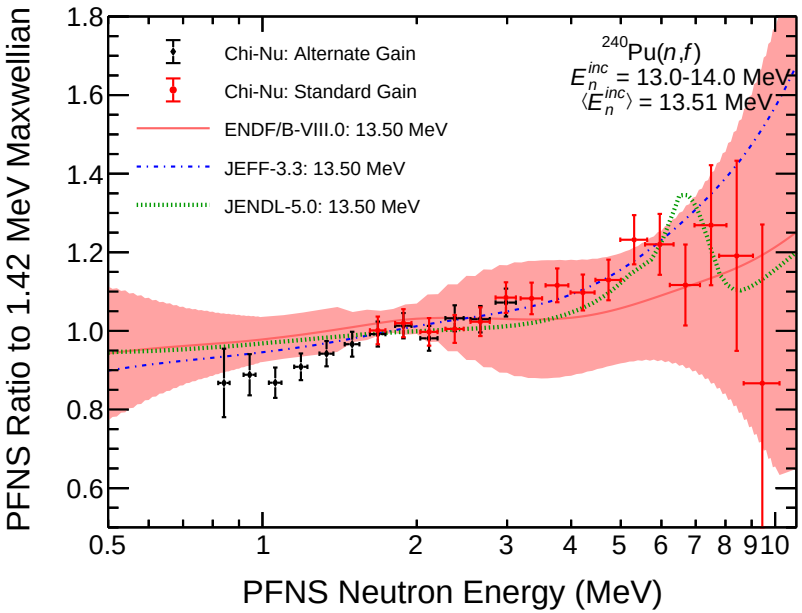


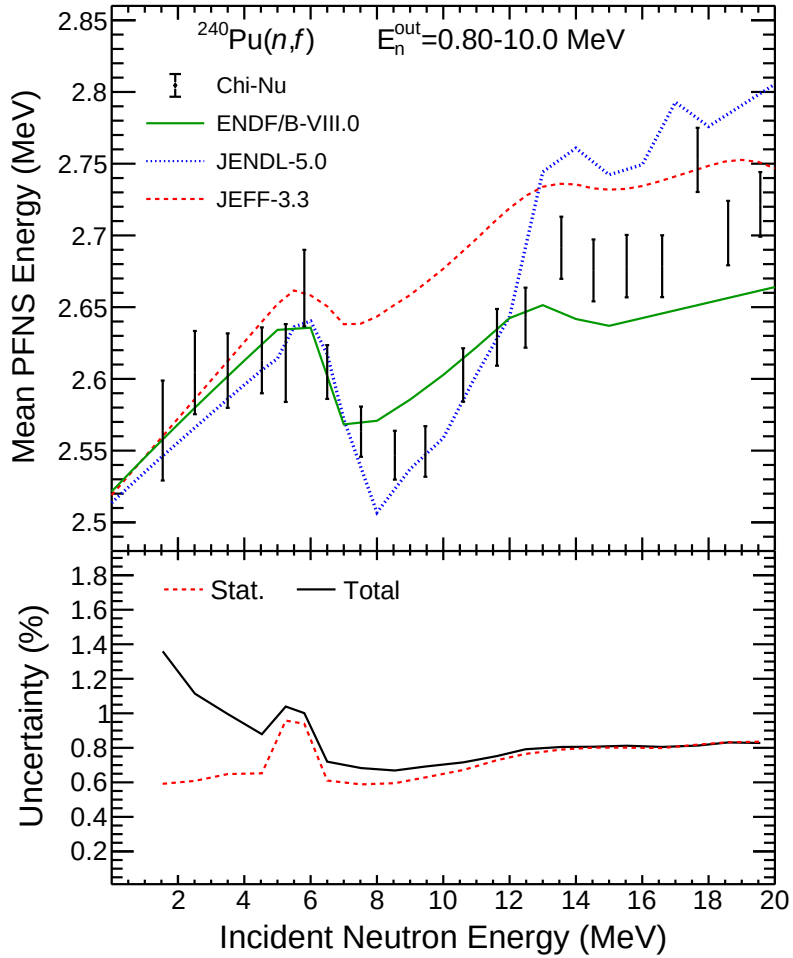


- Data delivered to D. Neudecker
  - K.J. Kelly, *et al.*, PRC **108** (2023) 024603

^{240}Pu(n,f) PFNS Results



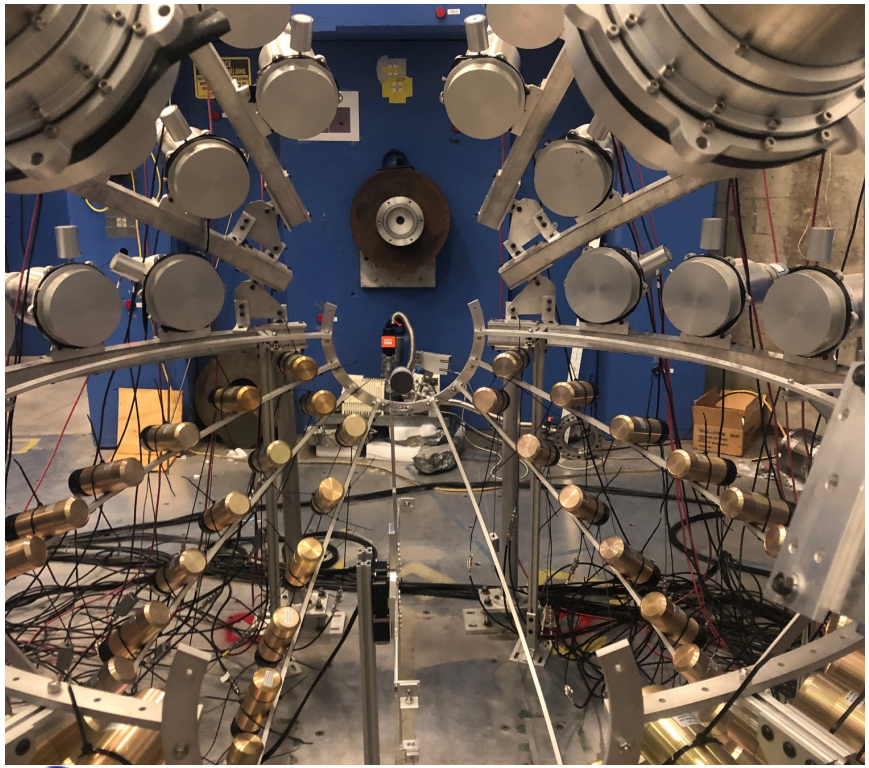


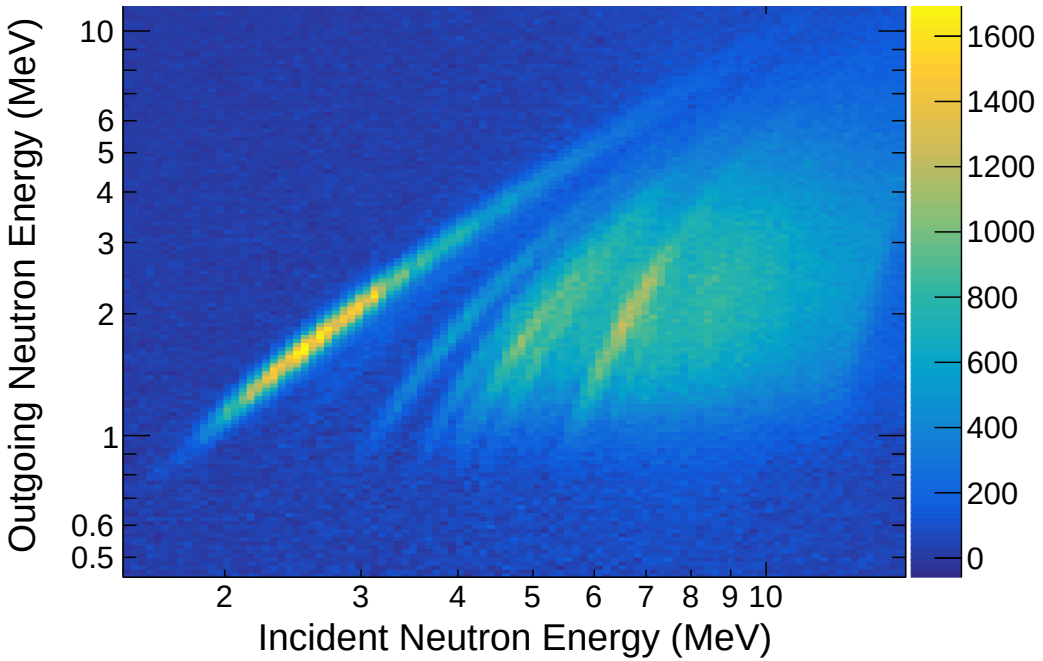


- Data delivered to D. Neudecker and A.E. Lovell
  - Iterative process of including data into evaluation

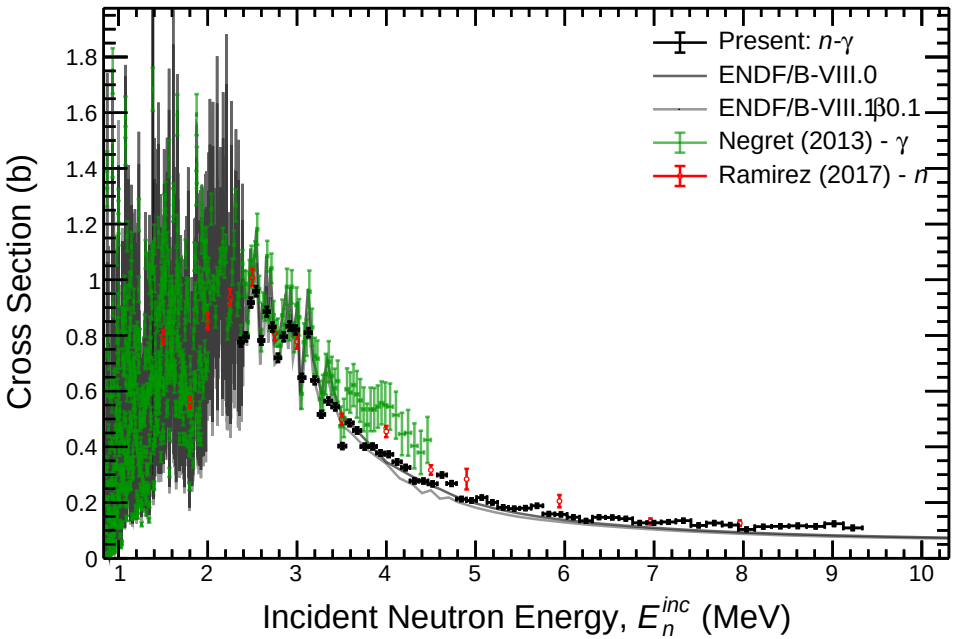
CoGNAC n-γ Approach to Scattering

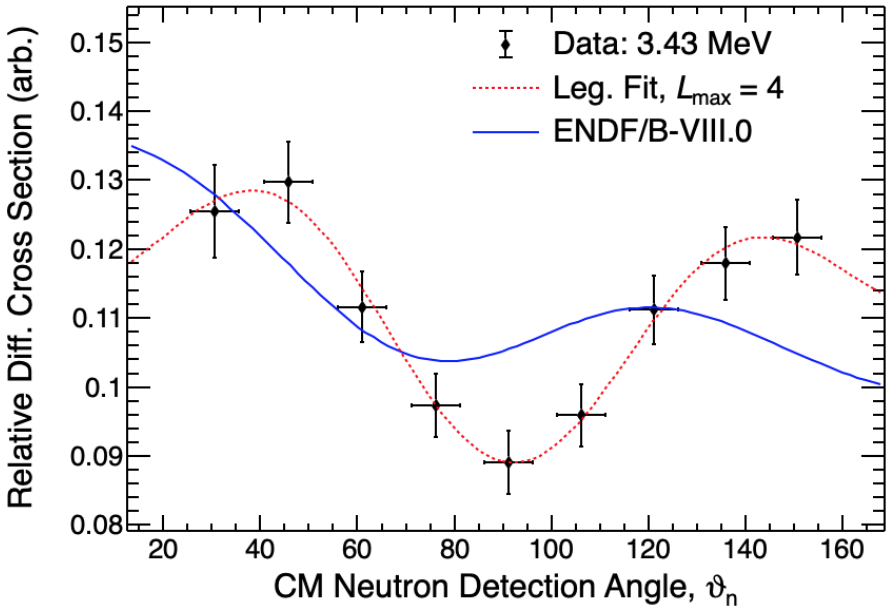
- PSD n-γ separation $\Rightarrow$ treat each detector as both n and γ detector
  - E_n^{inc} from t_0-t_γ; E_n^{out} from t_γ-t_n
  - γ-only or n-only analysis; n-γ 2D Response-based spectrum unfolding
  - 54 EJ-309 detectors from Chi-Nu, with 72 CLYC-6 detectors
- See Kelly *et al.* PRC **108** (2023) 014603 and Kelly *et al.* PRC **104** (2021) 064614 for details

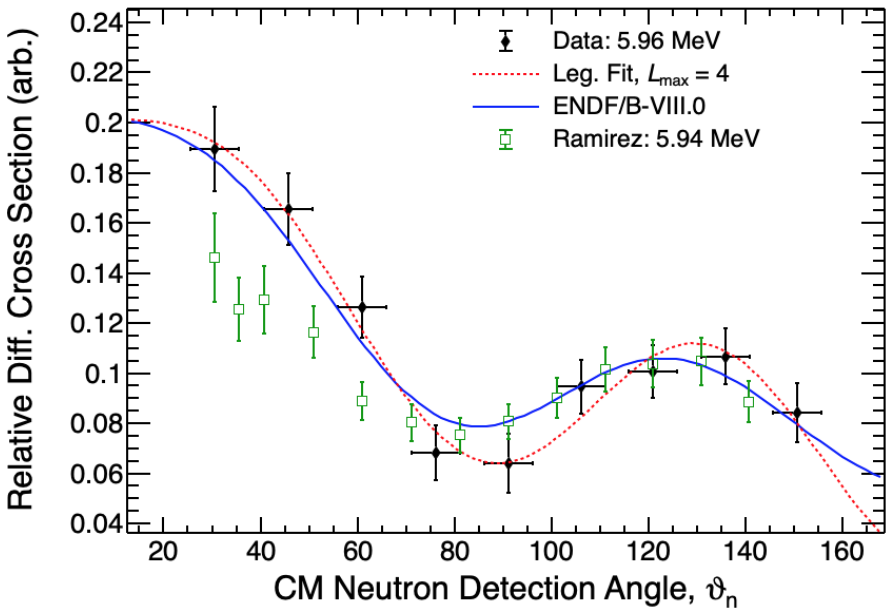




^{56}Fe$(n,n'_1\gamma)$ - 0.847 MeV

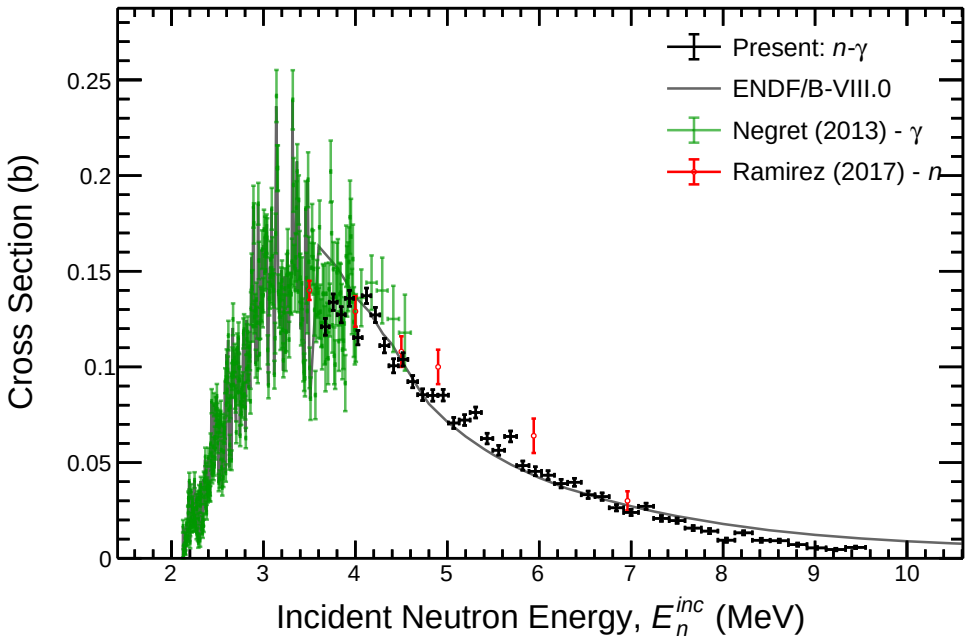


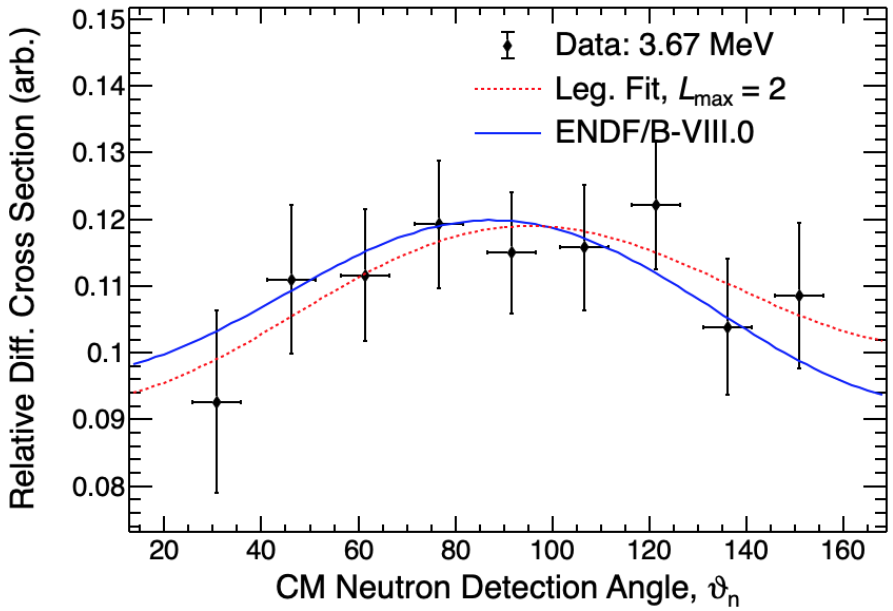


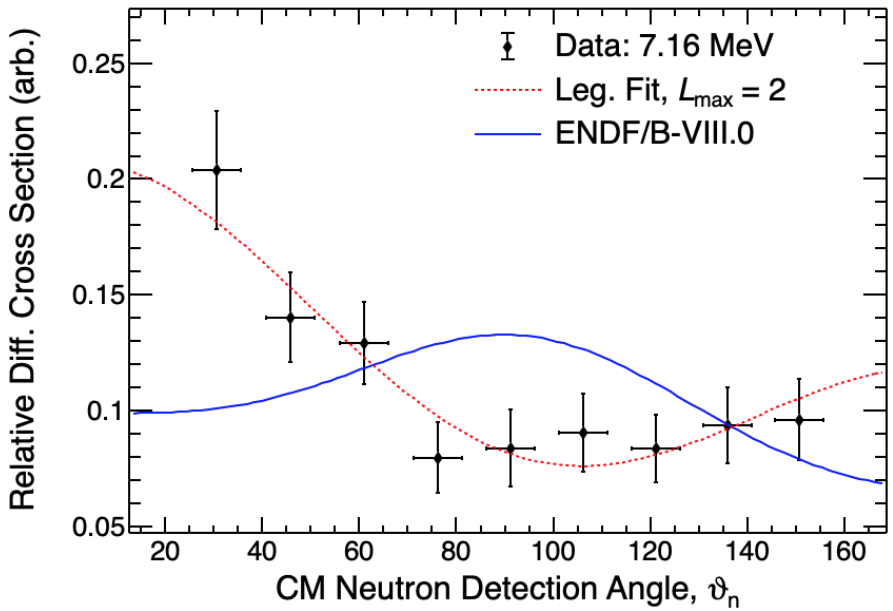


- ^{56}Fe data also include correction fo natural target isotopic composition
  - Sys. unc. from this correction not yet included
- Resonances impact measured angular distributions
- Evaluations use average params

^{56}Fe$(n,n'_2\gamma)$ - 2.058 MeV







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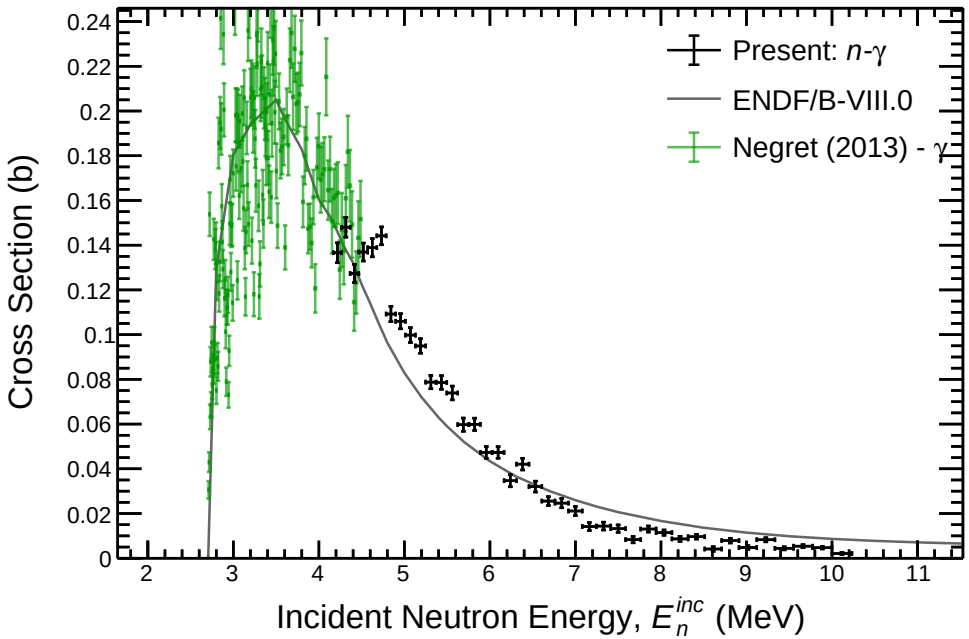
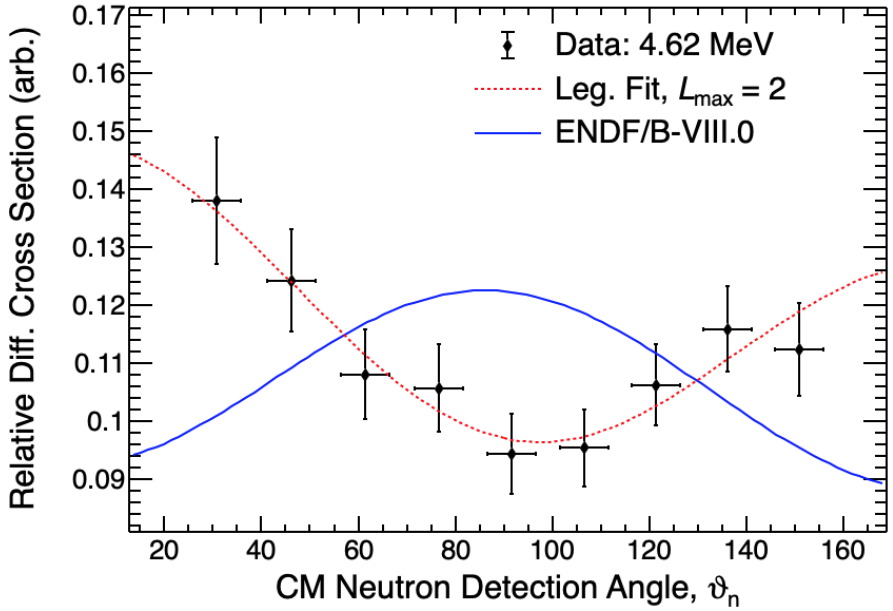
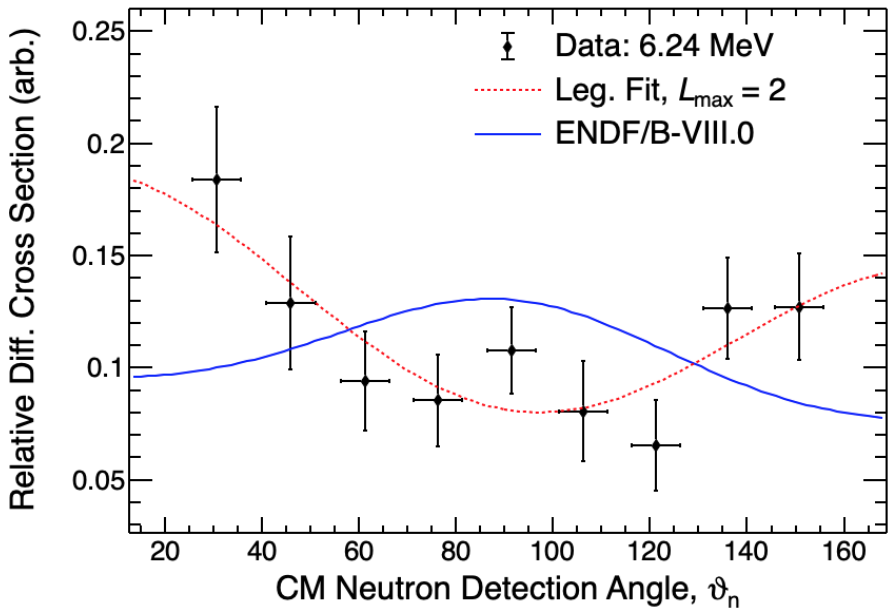
^{56}Fe$(n,n'_3\gamma)$ - 2.658 MeV







- ^{56}Fe data also include correction fo natural target isotopic composition
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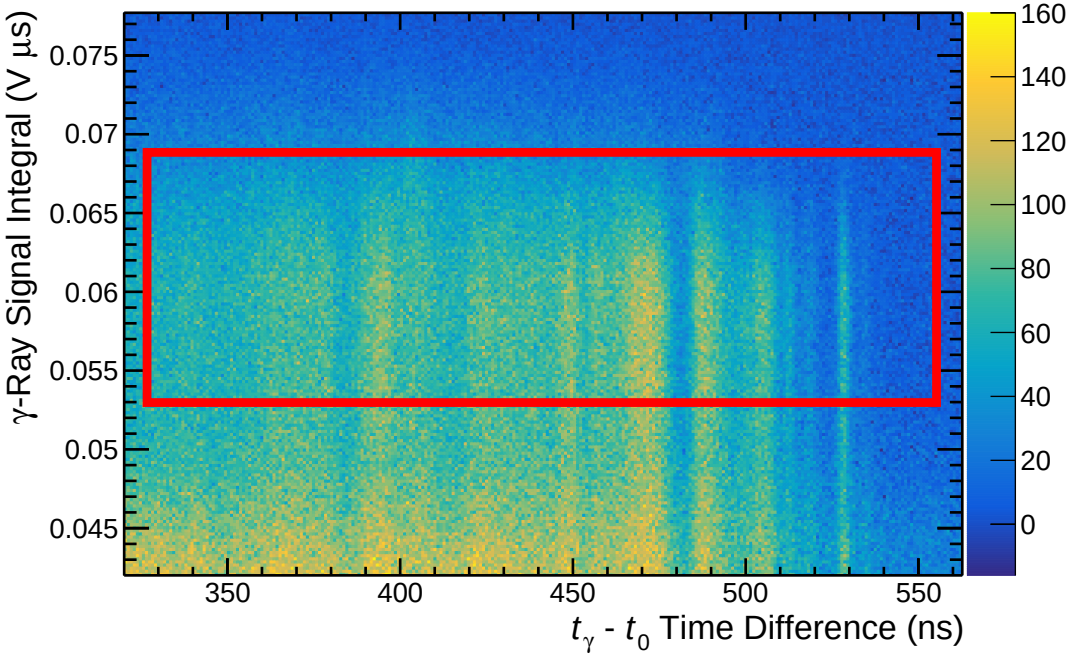
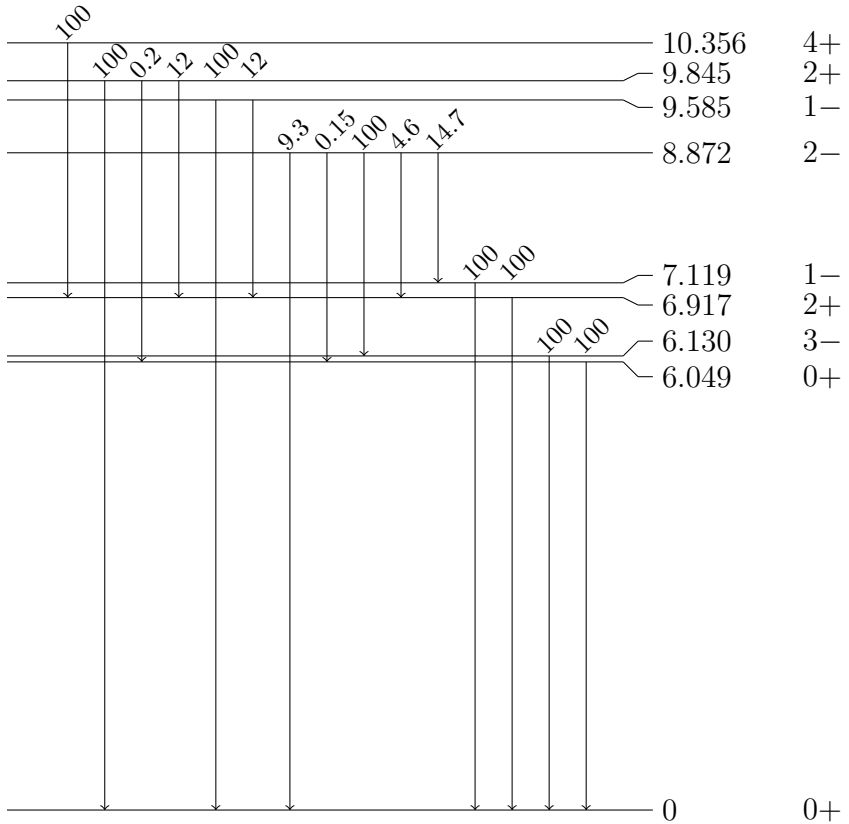
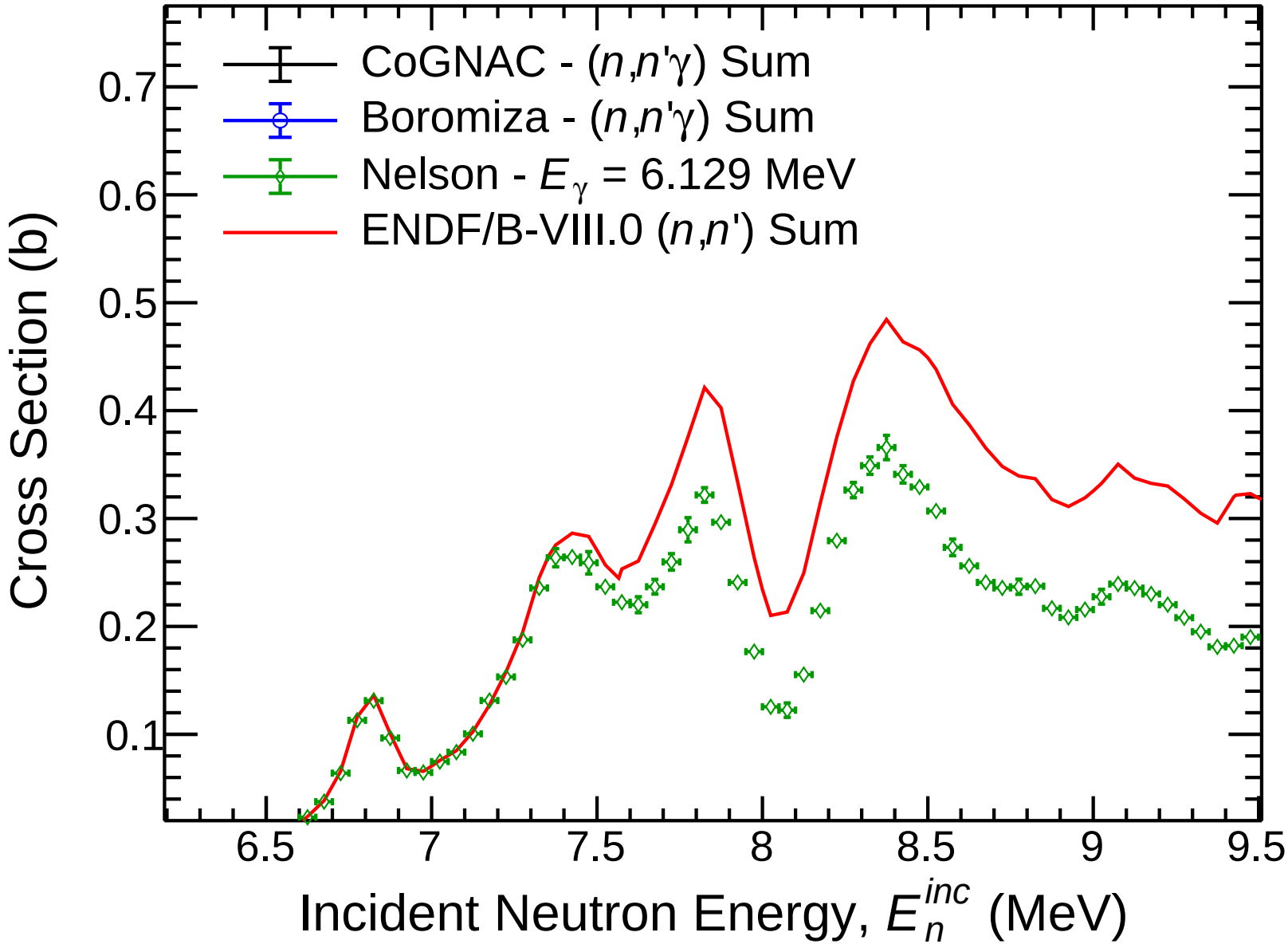
γ-only Analysis of ^{16}O(n,$n'\gamma$)





- Lowest 4 states in ^{16}O decay entirely to the ground state
  - only ≈3% difference in γ efficiency from E_γ = 6.1–7.1 MeV
- 8.872 keV 5th state decays 99.3% through first 4 states
- 6th, 7th decay to ground, higher decay through first 4 states
  - Charged particle emission takes over above E_n^{inc} = 10–12 MeV

Preliminary Results for $^{16}O(n,n'\gamma)$



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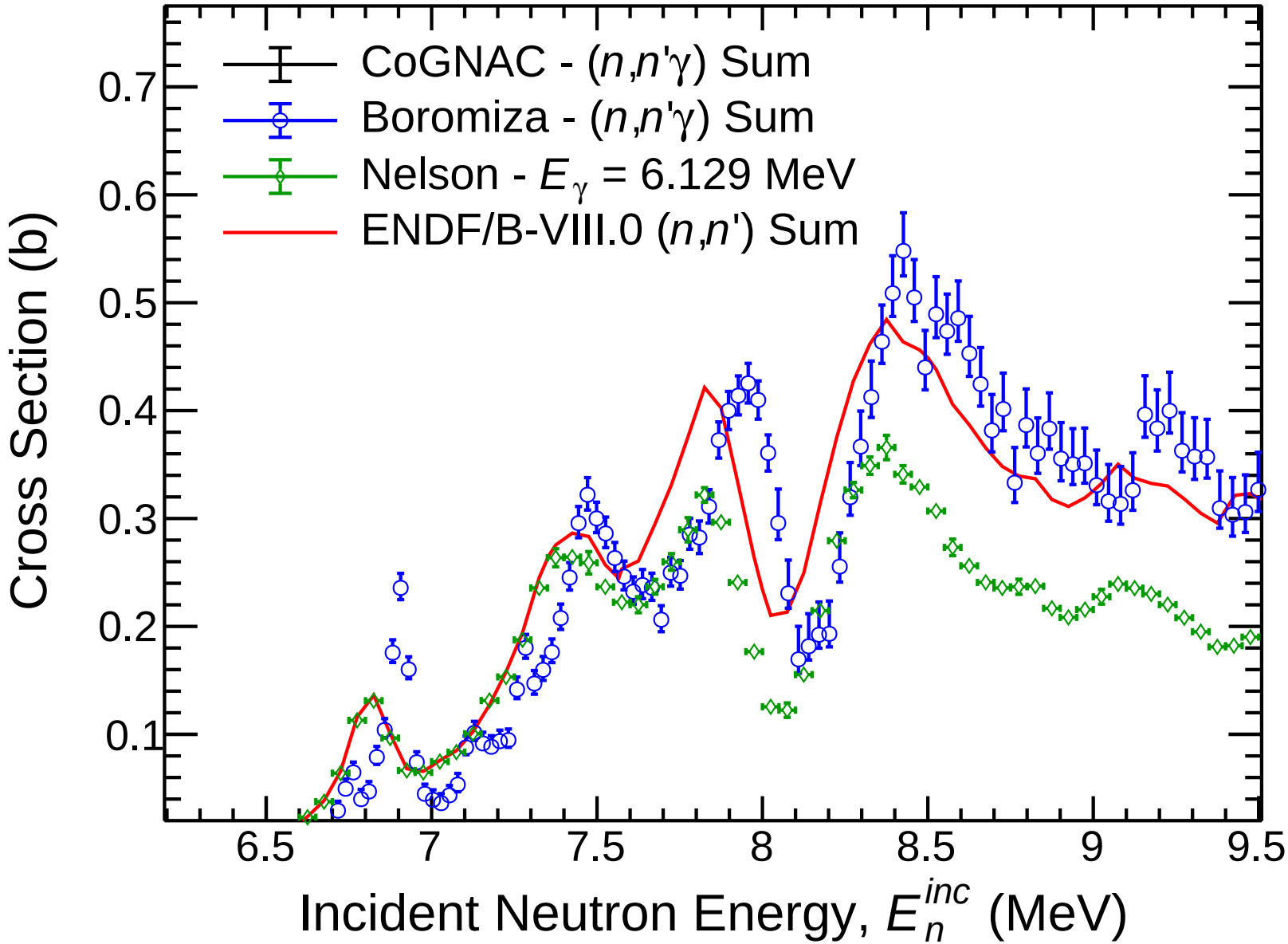
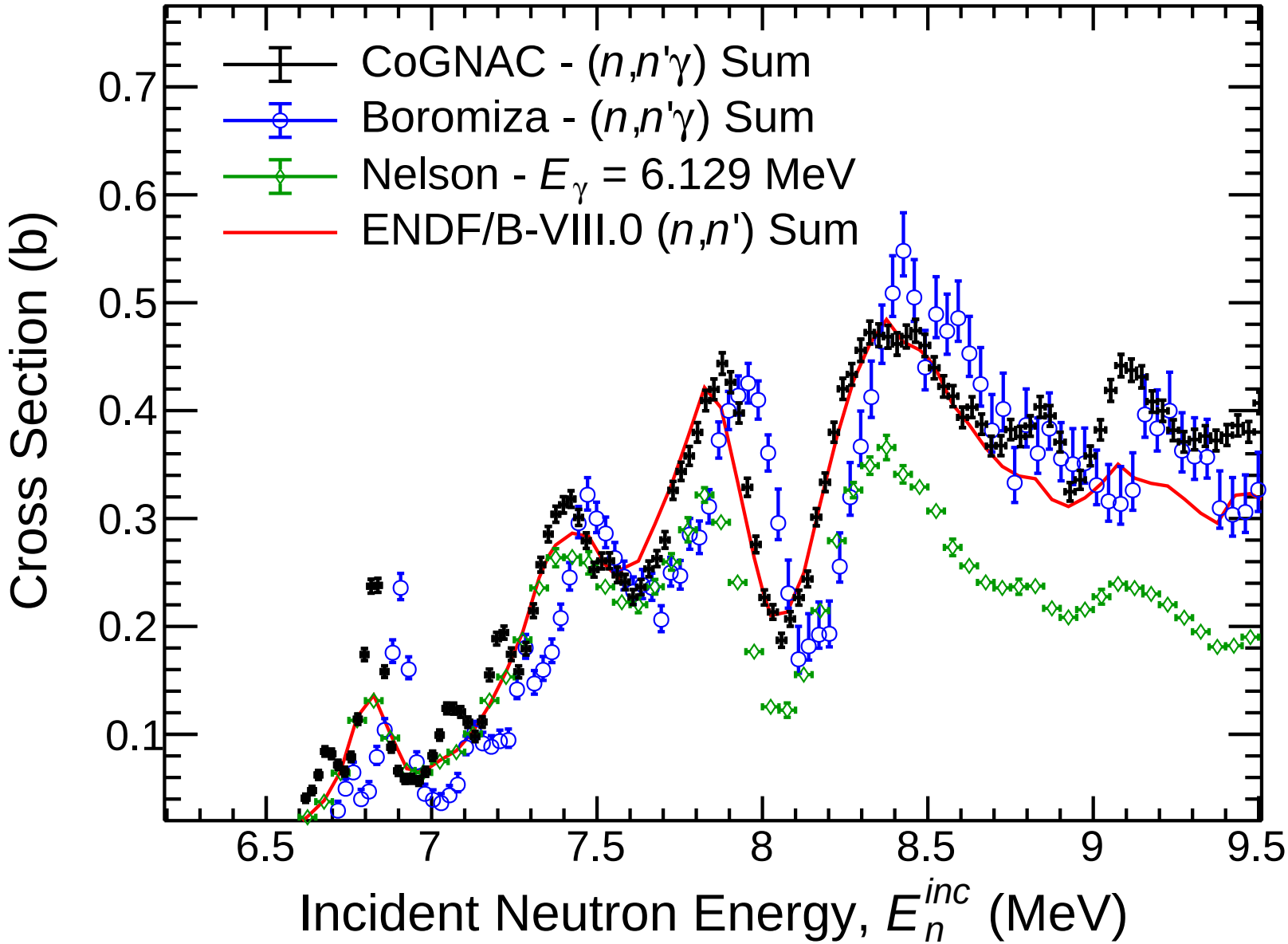
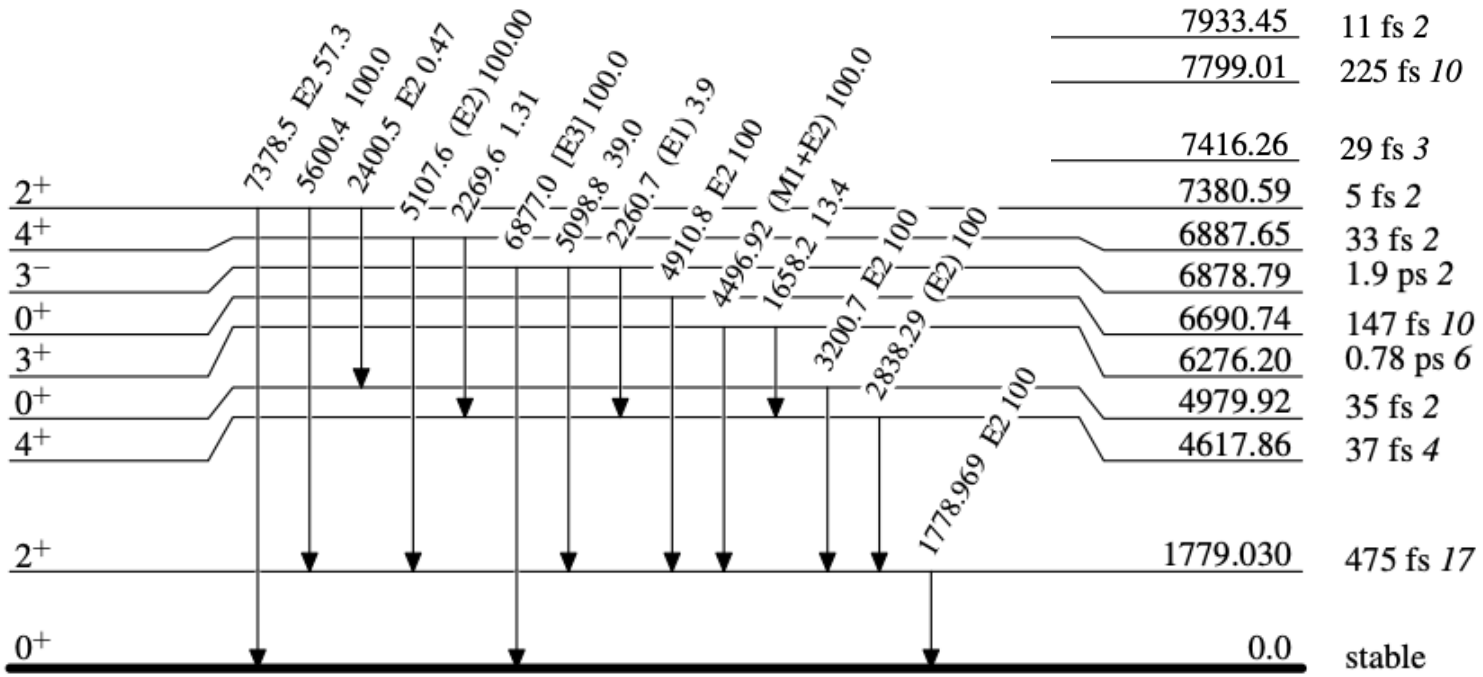


Preliminary Results for $^{16}O(n,n'\gamma)$

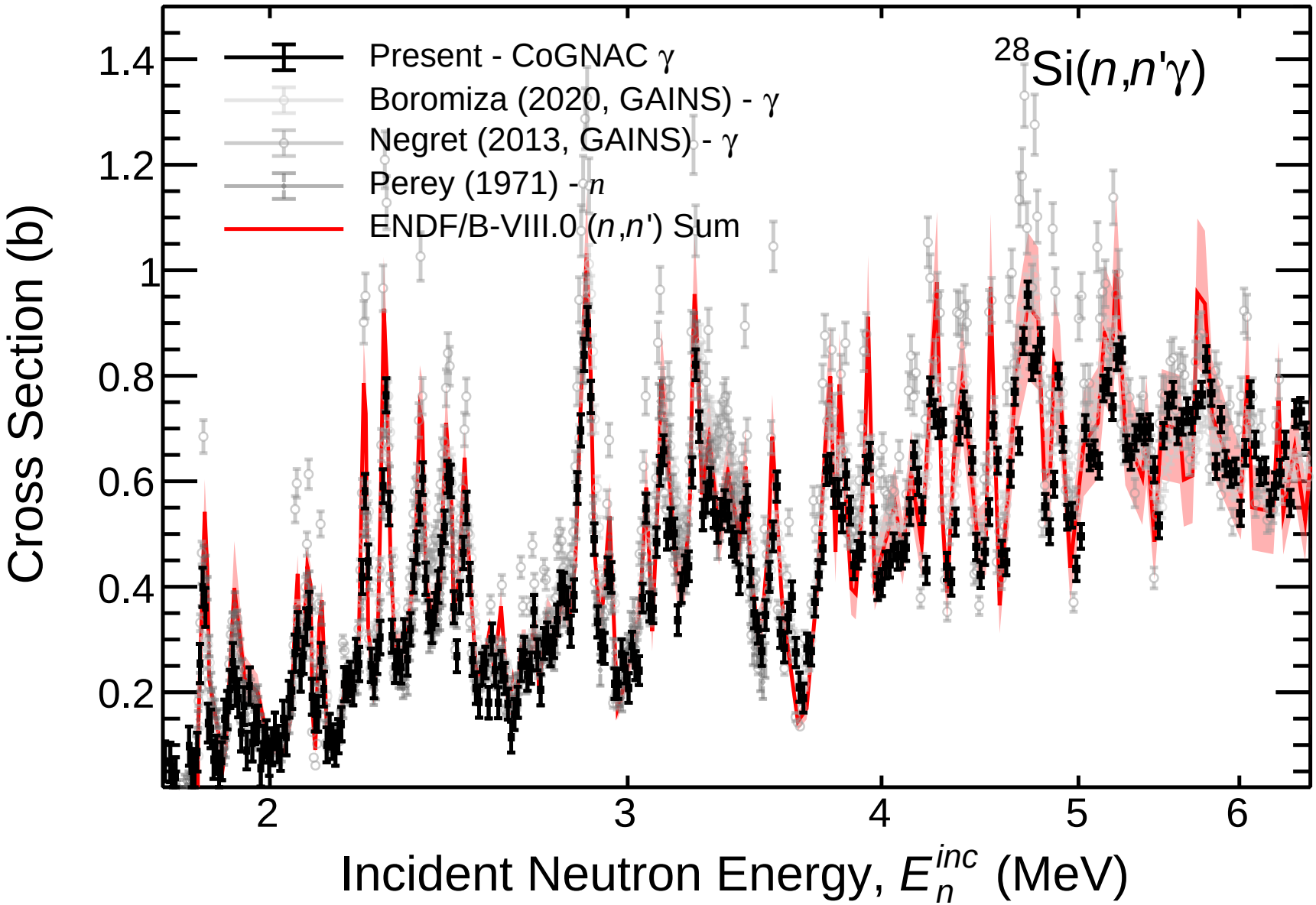


^{28}Si Data Analysis Paths - γ and n-γ



- 1st state easily accessible in n-γ, and γ-only for ≈3 MeV
- 2nd & 3rd states likely separable after unfolding
  - Both decay entirely to the 1st state with 4th, thus γ-only should capture full $(n,n'\gamma)$
- 4th separable after unfolding; 5th state may overlap with 6th & 7th
- Combined results for 8th & 9th, and 10th & 11th could be possible

Prelim. Res.: ^{28}Si γ-only XS for 1.779 MeV γ



Summary

- OES-funded LANL/LLNL PFNS Measurements Completed
  - NCSP-funded ^{240}Pu data delivered to ENDF Evaluators
  - ^{233}U PPAC fabrication at LLNL in progress this year
- n-γ analysis technique works well for inelastic cross sections
  - ^{56}Fe, ^{12}C, ^{28}Si; ^{16}O was more difficult
- Liquid scintillator γ-only promising as well for select isotopes and E ranges
  - ^{12}C, ^{16}O, ^{28}Si, and more
  - More possibilities open with CLYC γ rays
- Multiple scattering results in line for publication next year

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$\rightarrow$Initial work funded by LDRD Project 20190588ECR

$\rightarrow$Exp. and analysis funded in part by LDRD Project 20210329ER

$\rightarrow\gamma$-production cross section measurements funded by NA-22 via Proposal ID 0000260569 submitted to DOE-FOA-0002440

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

$\rightarrow^{240}$Pu and ^{233}U PFNS work funded by NCSP

$\rightarrow^{12}$C(n,n) exploration funded by LANL OES/SAT