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Gamma-ray Production Cross Sections for Active Neutron Interrogation with GENESIS

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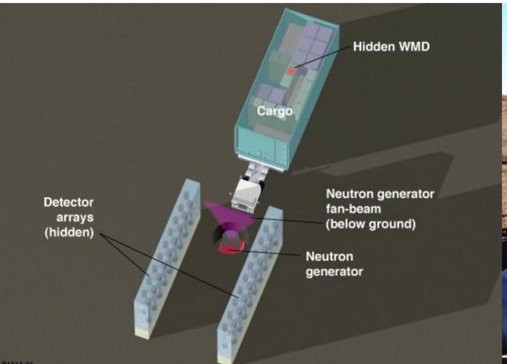
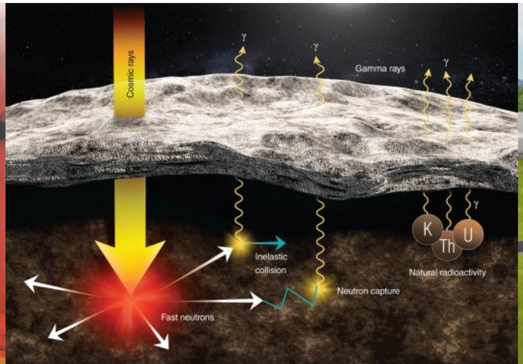
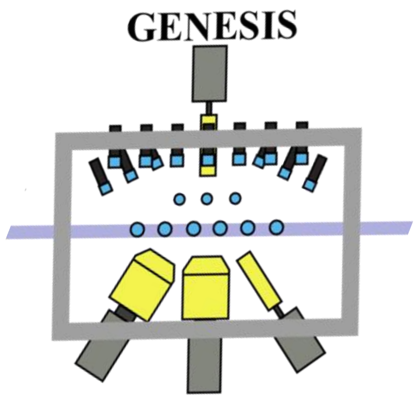






Nuclear Data Needs for Active Neutron Interrogation



Goal: Provide partial γ-ray cross sections for high priority nuclides for neutron active interrogation applications

Priority	Elements
First	C, N, O, Na, Al, Si, Fe, Cu, Pb, W, U, Pu
Follow-up	He, Li, Be, B, Cl, Cr, Mn, Ni, Ge, Br, Cd, I, Cs, La
Remaining	F, Mg, P, S, Ar, K, Ca, Ti, As, Kr, Mo, Sn, Sb, Xe, Gd, Bi, Np, Am, Tm, Nb

S. McConchie, et al., Technical Report No. ORNL/TM-2021/1900, 2021.

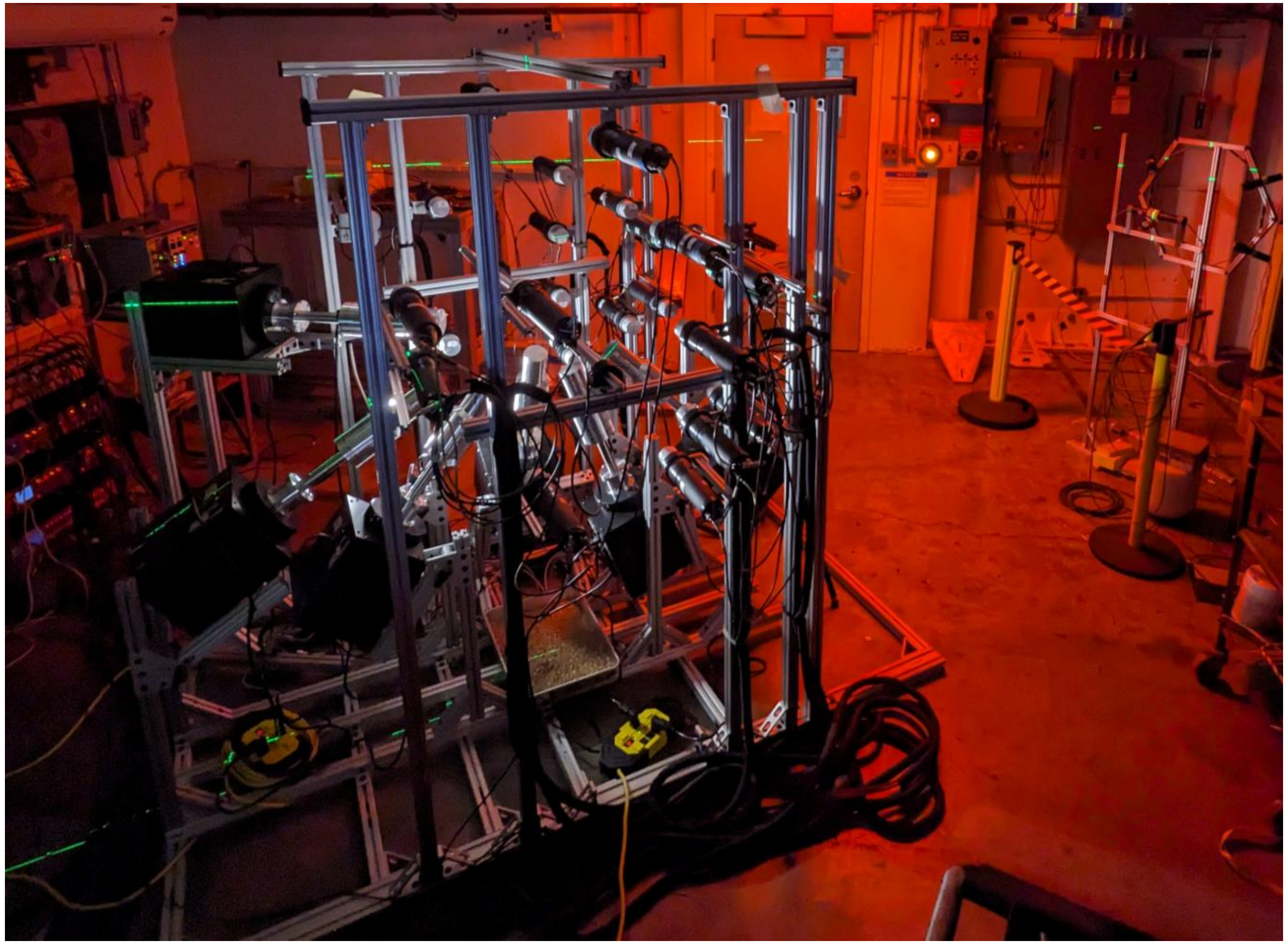
GENESIS Activities

- (green) Published/Submitted for publication
- (yellow) Datasets that have been produced and are under investigation
- (red circle) Focus of this project

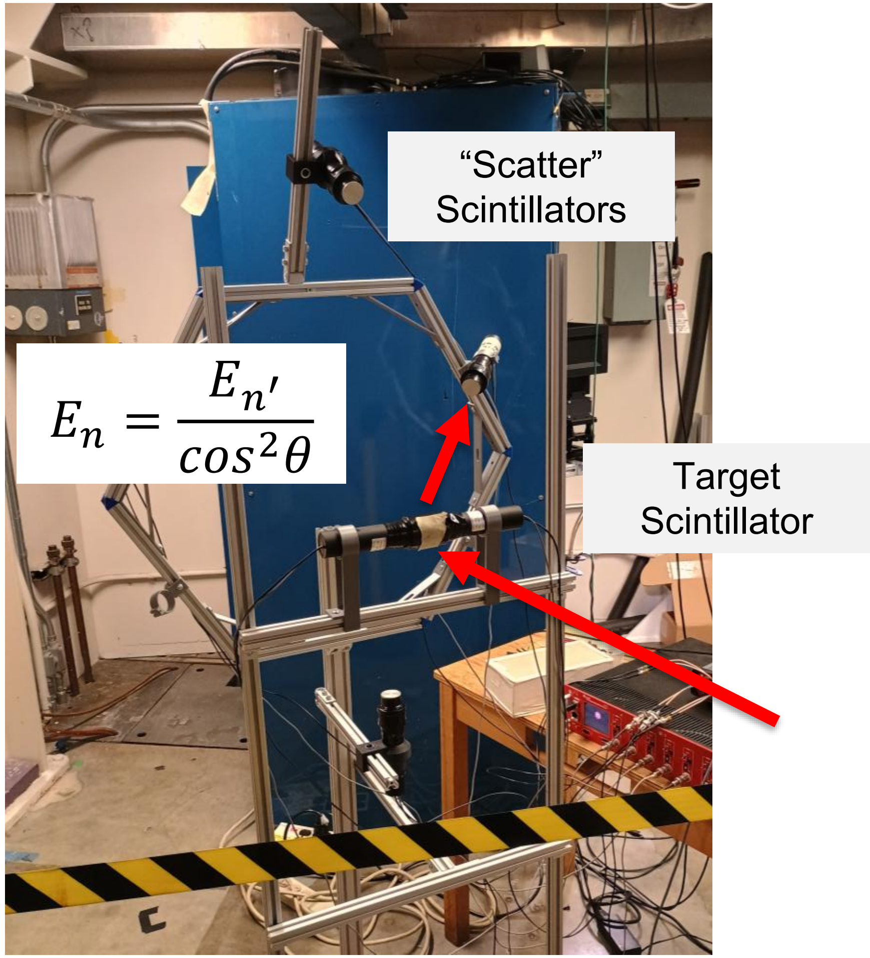
Collaboration/Strategic Partnerships

- Stockpile Stewardship Academic Alliance (Bernstein)
- Physics-informed machine learning for nuclear data (Matters)
- NA-113 at LLNL (Bleuel)
- LANL (Kelly)
- BNL (Brown, Chimanski)

The GENESIS Array



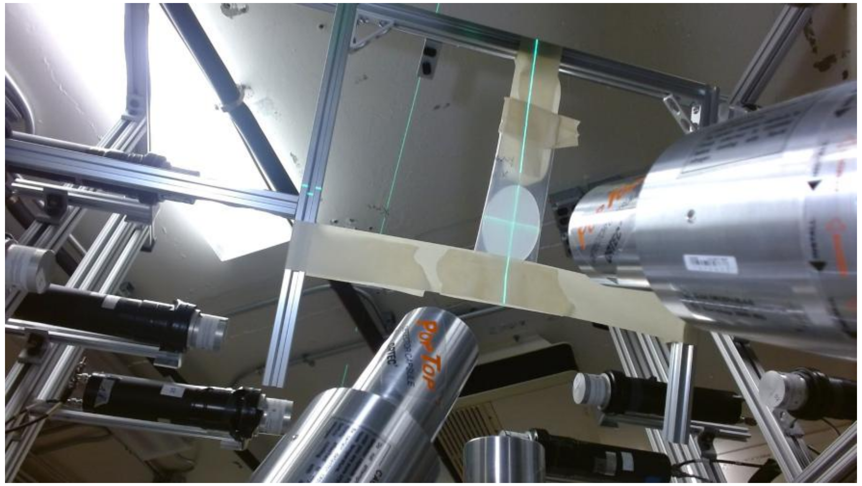
7 mechanically-cooled HPGe detectors
26 PSD-capable liquid scintillators

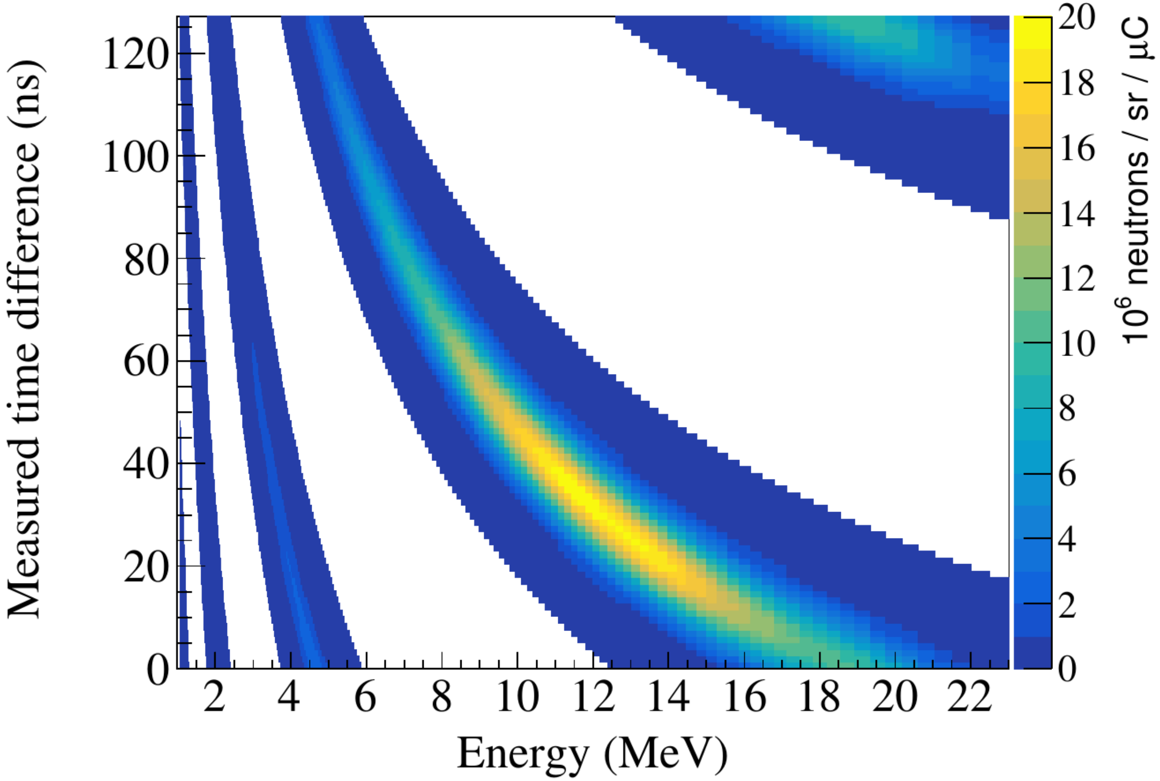


Liquid scintillator-based neutron spectrometer (sTOF)

GENESIS Experiment on ^{23}Na metallic target

- 10.5 g ^{23}Na metal target encapsulated in epoxy
- ~8 uA, 25 MeV $^{2}H^{+}$ on carbon breakup target
- Integration of 6 new HPGes (45-160°)
- 26 organic liquid scintillators in groups of 4 (20°, 40°, 66°, 90°, 110°, and 145°)
- 115 h on ^{23}Na, 75 h on epoxy blank



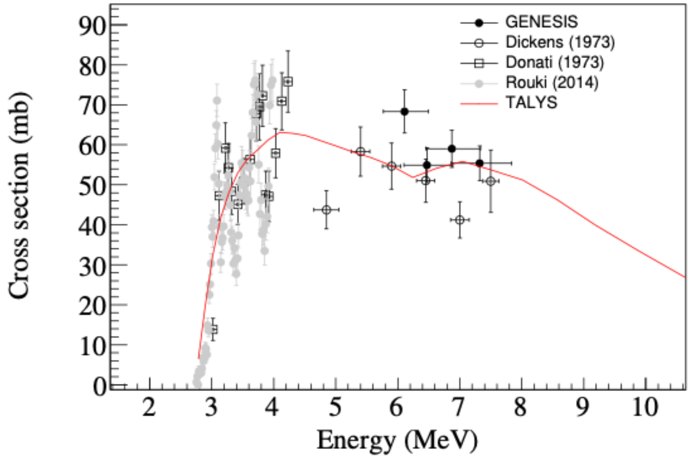


Complications:
- many γ-rays showing significant Doppler broadening
- cyclotron beam pulse frame overlap

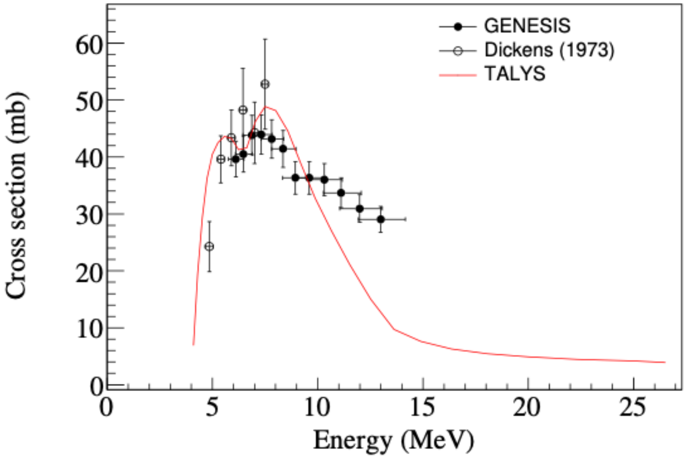
Measured γ rays from fast neutrons on ^{23}Na

Reaction	γ-ray Energy (keV)	Neutron Energy Range (MeV)
$(n, n'\gamma)$	2390.6	6.11
	1950.6	6.11
	2639.8	6.11 – 7.32
	2263.3	6.11 – 7.32
	627.4	6.11 – 7.32
	2981.7	6.11 – 8.94
	2541.3	6.11 – 8.94
	3237.2	6.11 – 12.99
	1772	6.11 – 12.99
(n, α)	656.0	6.11 – 18.41
	822.7	6.11 – 18.65
(n, np)	1274.5	8.35 – 19.51
$(n, 2n)$	890.9	14.09 – 19.51
(n, p)	1016.9	6.11 – 18.41

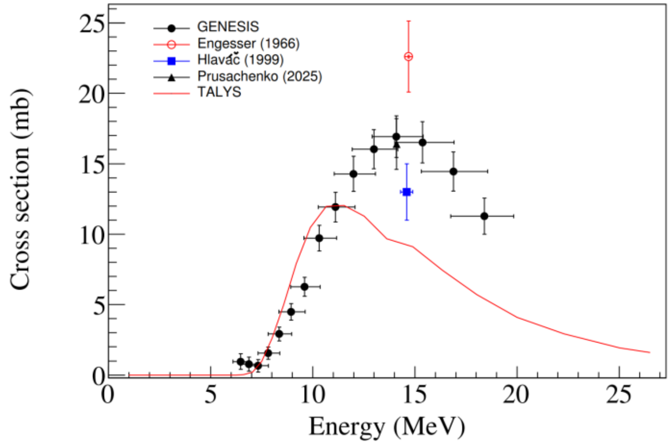
J. Gordon, B.L. Goldblum, et al., "Gamma rays from fast neutron interactions with ^{23}Na," (to be submitted by end of quarter).



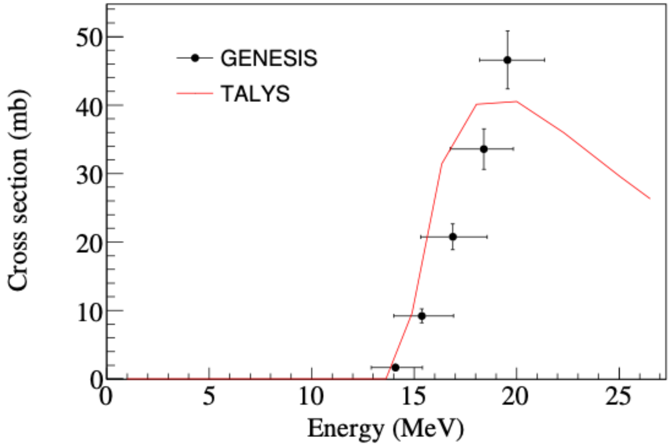
E_γ = 2639.8 keV via ^{23}Na(n,n'γ)



E_γ = 1772 keV via ^{23}Na(n,n'γ)



E_γ = 822.7 keV via ^{23}Na(n,αγ)



E_γ = 890.9 keV via ^{23}Na(n,2nγ)

Angular information

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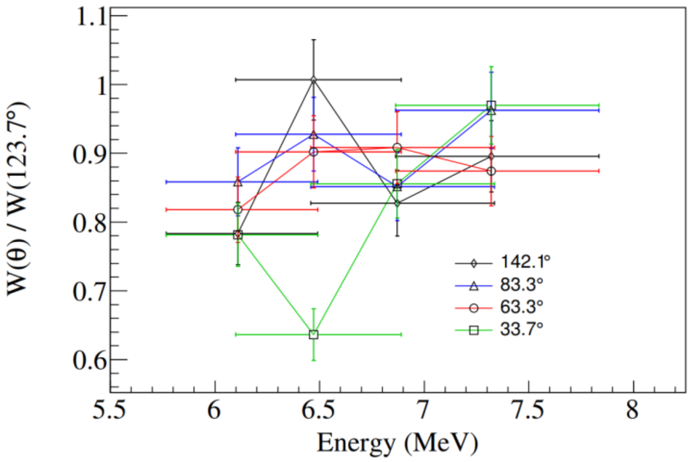

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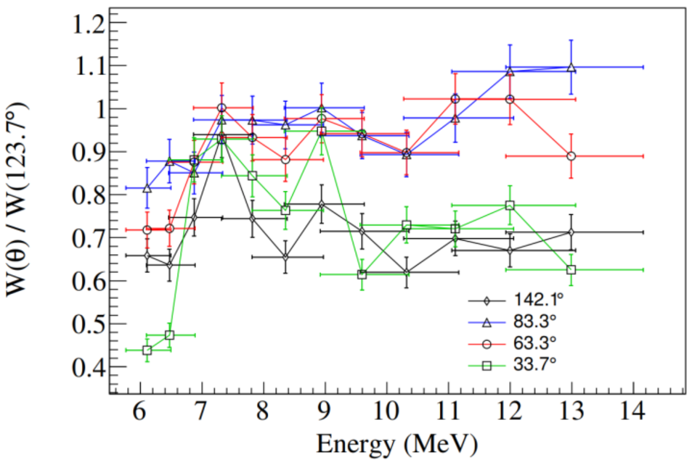

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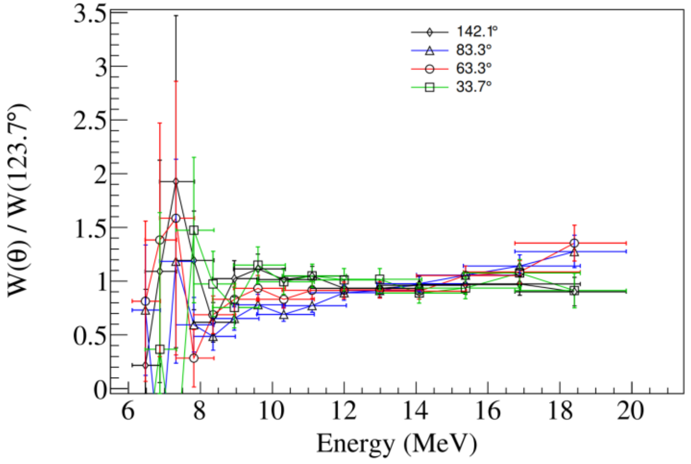

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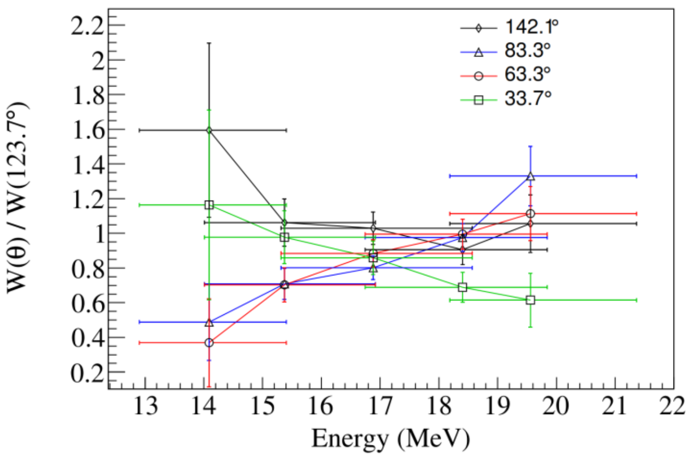


E_γ = 890.9 keV via ^{23}Na(n,2nγ)

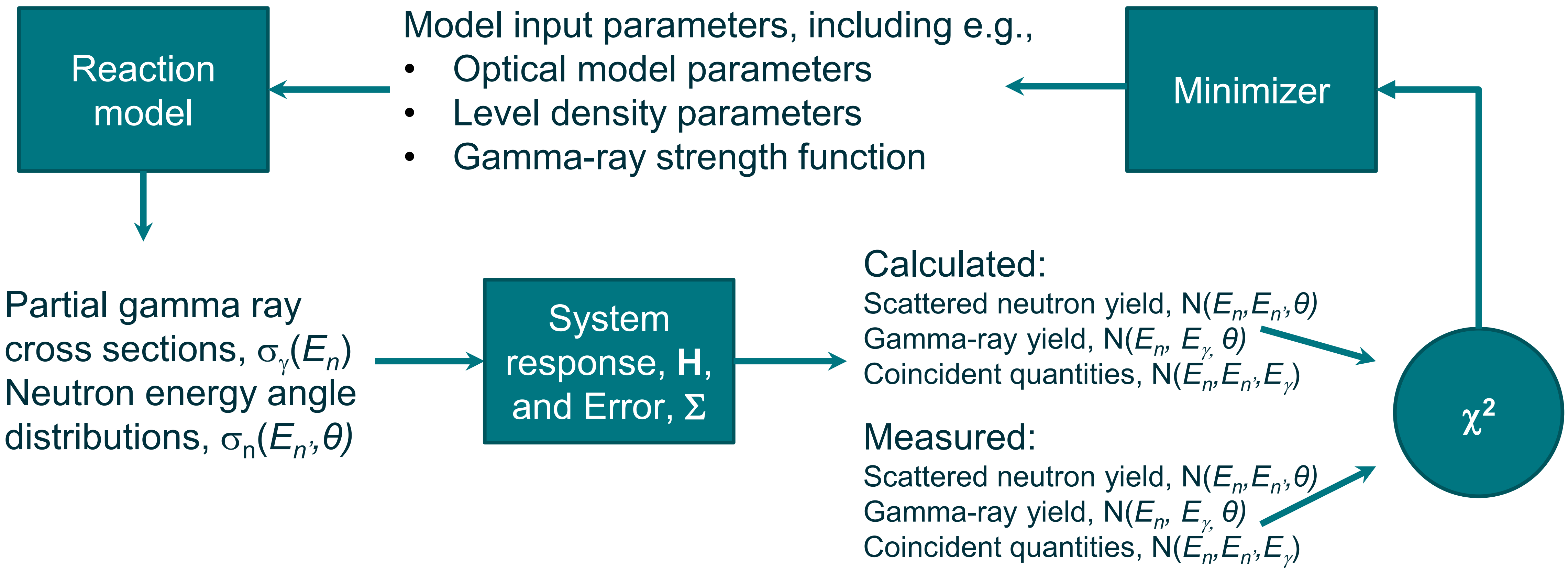
A more direct link between the nuclear data and reaction theory

The traditional approach:

$$\sigma(E_n, \theta) = \frac{Y_{obs}(E_n, \theta) - Y_{bkg}(E_n, \theta)}{\varepsilon(E', \theta)\phi(E_n)N_T}$$

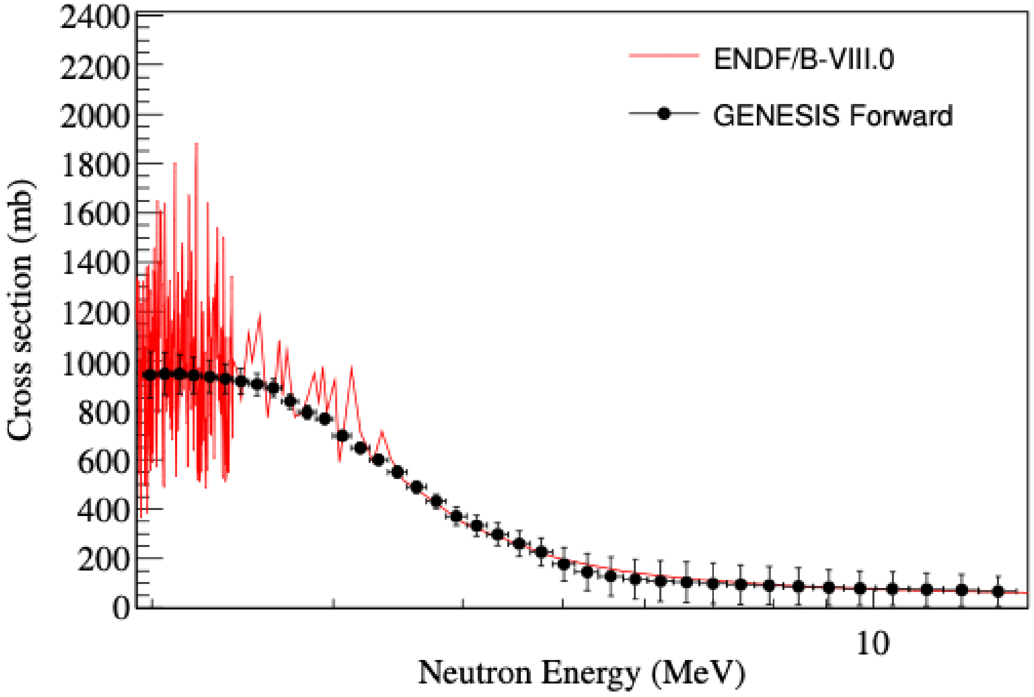
J. Gordon, B.L. Goldblum, et al., "Forward modeling approach to nuclear reaction cross sections: Applications in neutron inelastic scattering," (accepted in Phys. Rev. C, https://doi.org/10.1103/wdzh-ybzf).

Forward modeling method with GENESIS Observables

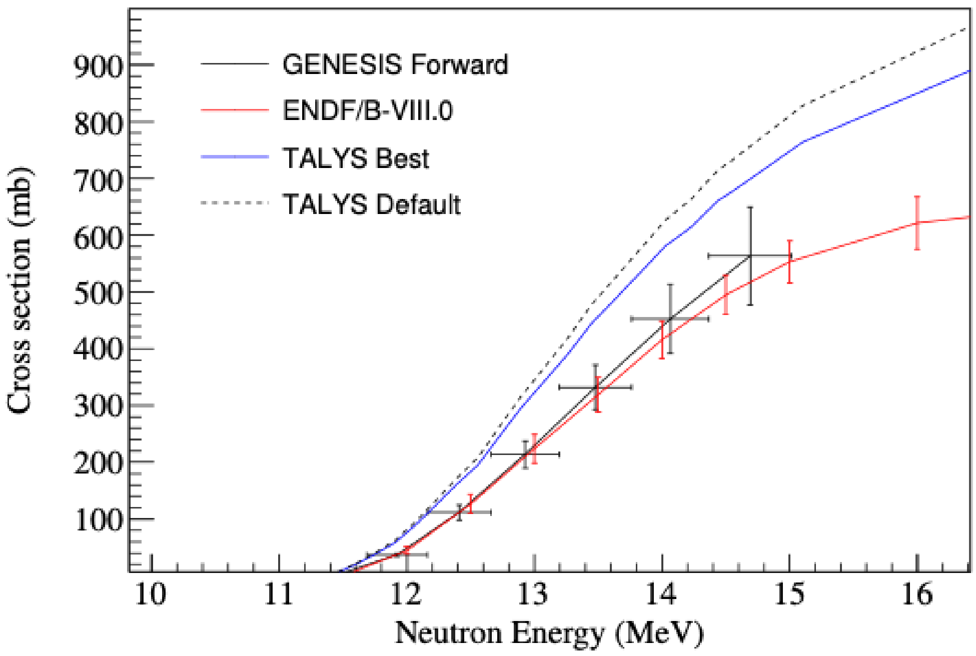


J. Gordon, B.L. Goldblum, et al., "Forward modeling approach to nuclear reaction cross sections: Applications in neutron inelastic scattering," (accepted in Phys. Rev. C, https://doi.org/10.1103/wdzh-ybzf).

Successes of forward modeling in ^{56}Fe(n,x) data



^{56}Fe(n,n$_1$’) neutron inelastic scattering cross section to the first excited state in ^{56}Fe ($E = 846.8$ keV)

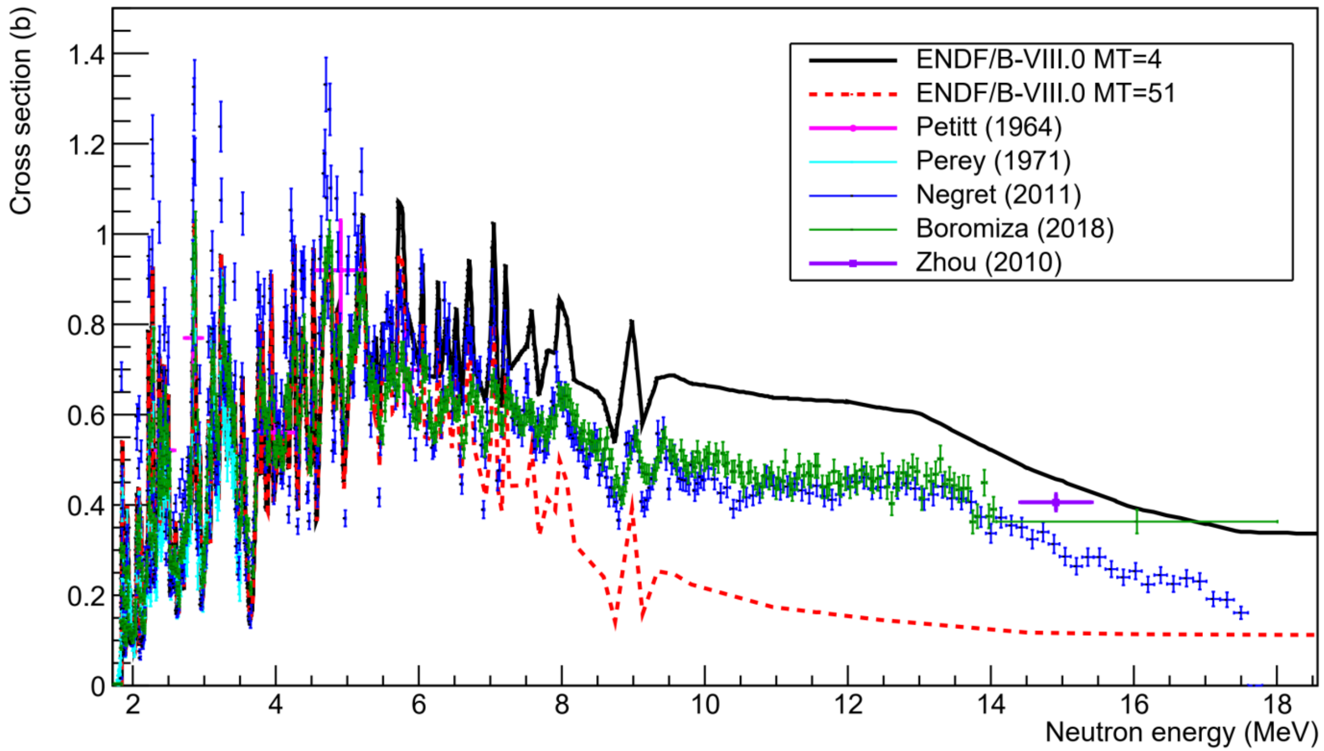


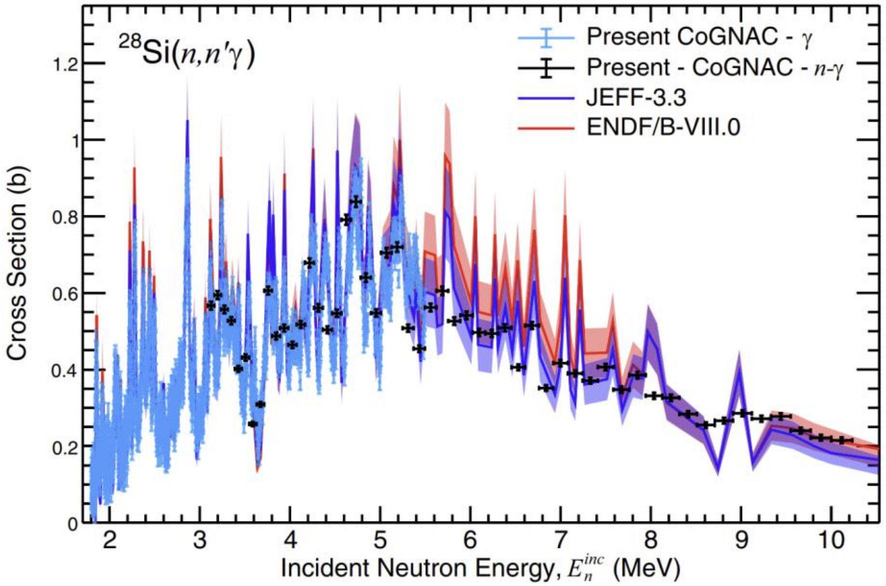
^{56}Fe(n,2n) cross section calculated using the forward model compared w/ TALYS, TALYS best, and ENDF (Gordon, UC Berkeley)

J. Gordon, B.L. Goldblum, et al., “Forward modeling approach to nuclear reaction cross sections: Applications in neutron inelastic scattering,” (accepted in Phys. Rev. C, https://doi.org/10.1103/wdzh-ybzf).

Looking forward: ^{28}Si(n,n'): Beam in March 2026

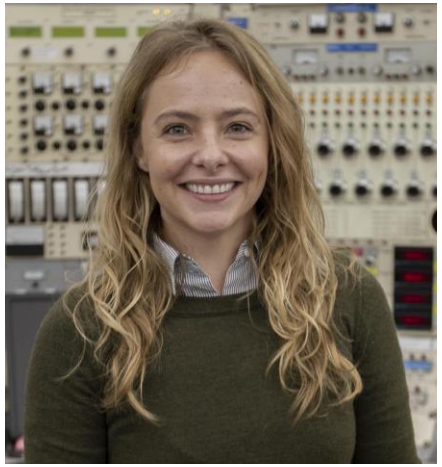
- Isotopically pure target on loan from Kelly (LANL) used in recent publication
  K. Kelly et al., PRC 112 (2025)
- Targeted energy range: 1.5 - 15 MeV
- ENDF: inelastic scattering on first few levels taken from ENDF/B-V





MT=51
K. Kelly et al. PRC 112 (2025)

Acknowledgments



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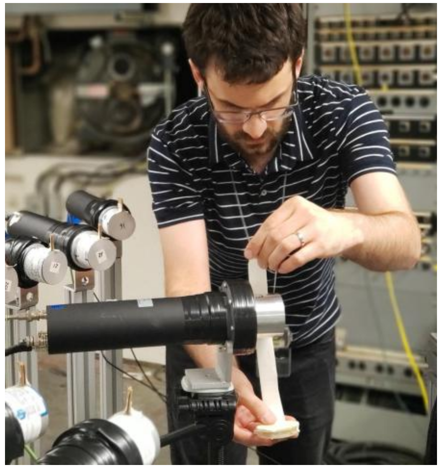

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