Improving the ^{238}U(n,n') cross section using neutron-gamma coincidences

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BLUF (Bottom Line Up Front)

LBNL

- Built and benchmarked the *Gamma Energy Neutron Energy Spectrometer for Inelastic Scattering* (GENESIS).
- Performed ***^{56}Fe(n,xnγ)*** and ^{238}U(n,xγ) production runs in 2021.
- Analysis underway

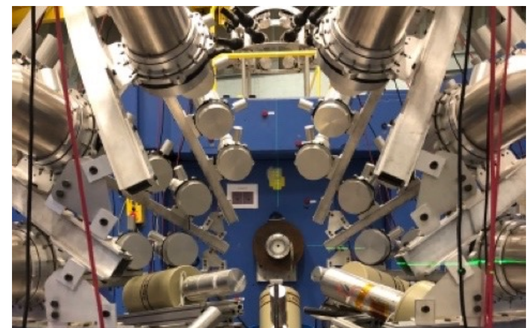
Josh Brown

Joey Gordon

GENESIS ^{238}U and ^{56}Fe Data being analyzed and interpreted

LANL

- Took first Chi-Nu + HPGe data 9/19
- ^{56}Fe+n data (performed under separate funding) provides a path forward for ^{238}U

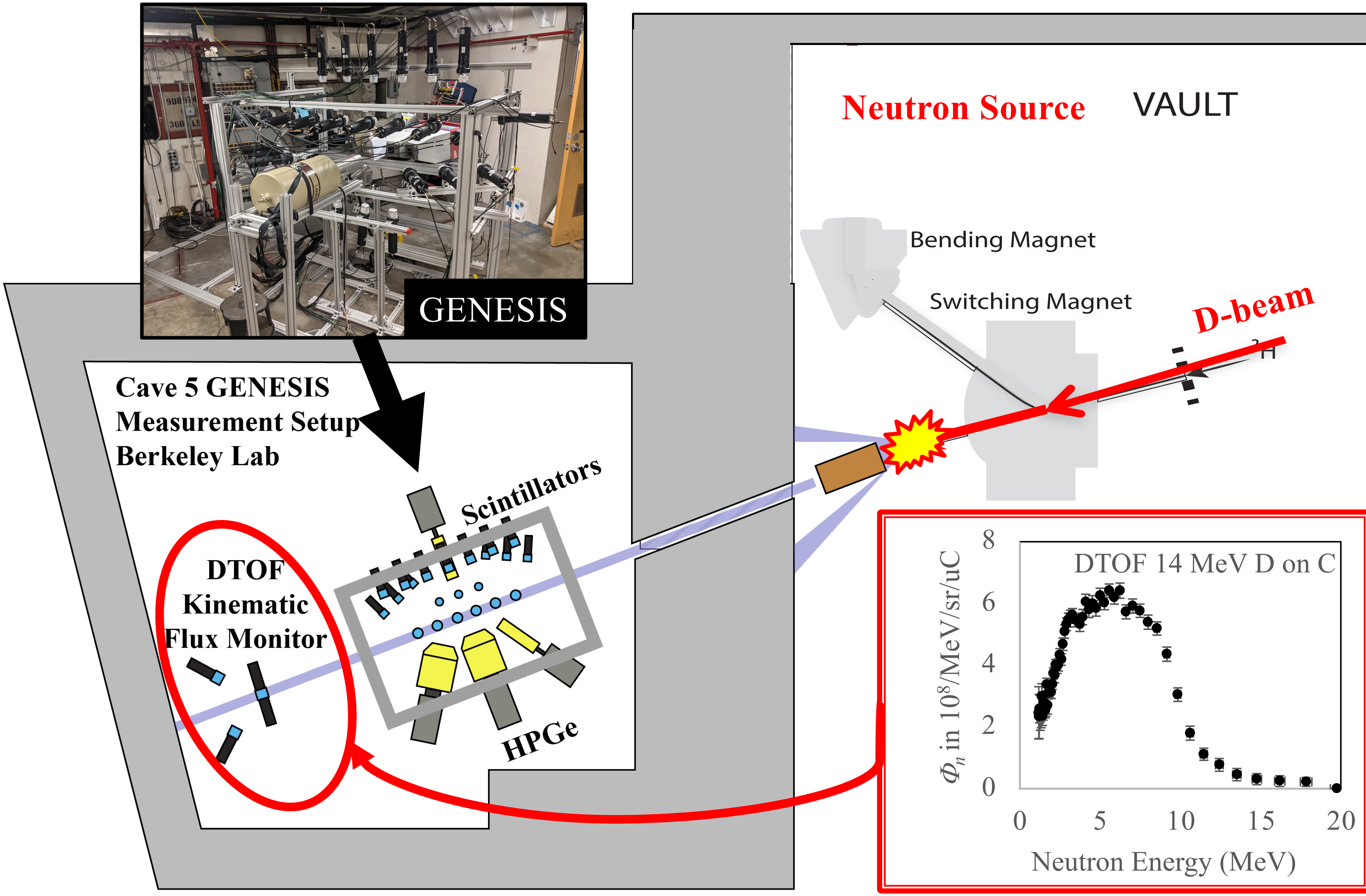


Chi-Nu + HPGe

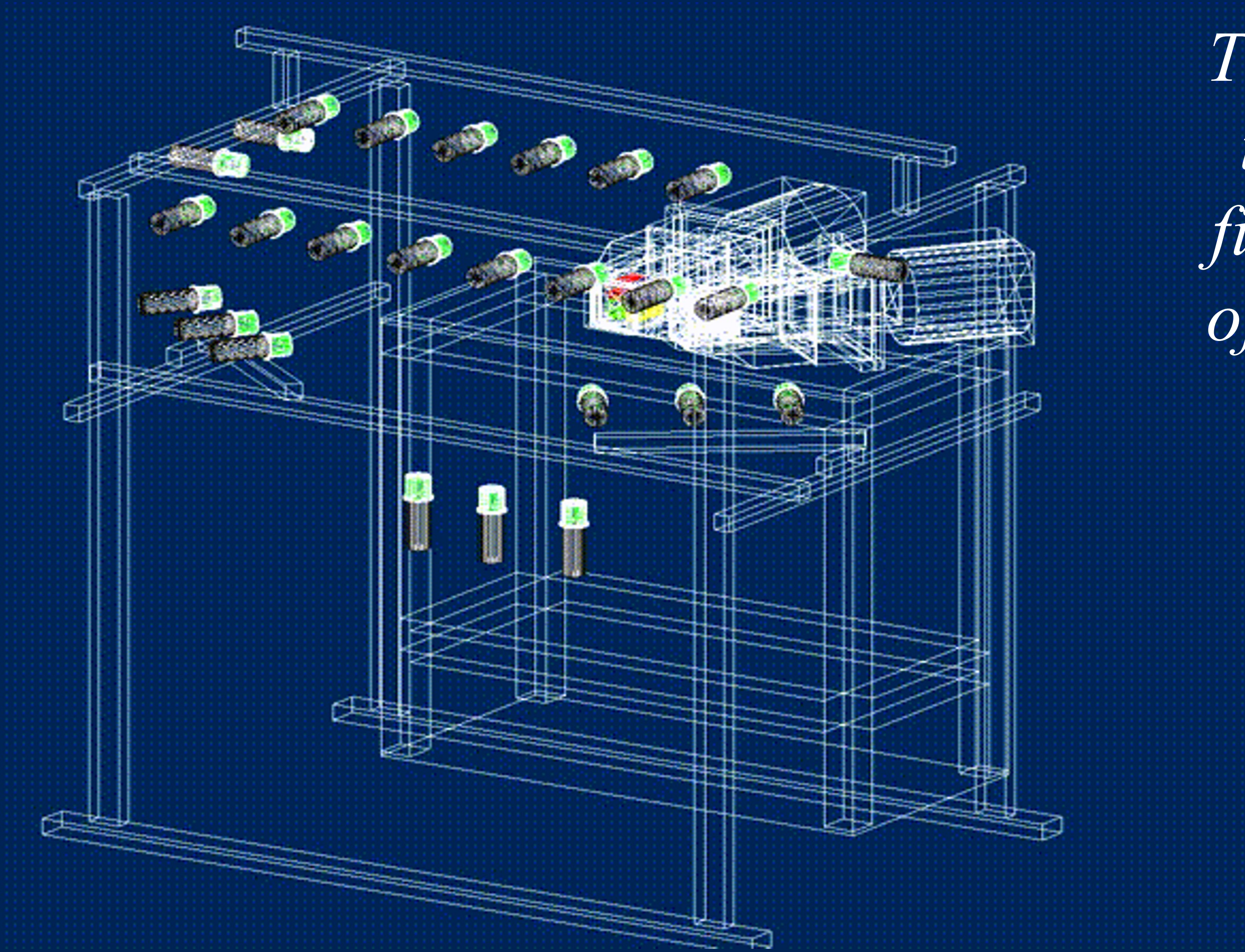
BNL/NNDC

- Preparing for evaluation using other data set (^{86}Kr)
- Working with LBNL to develop an event generator that will allow for a forward fit comparison to the evaluation.

GENESIS at the 88-Inch cyclotron



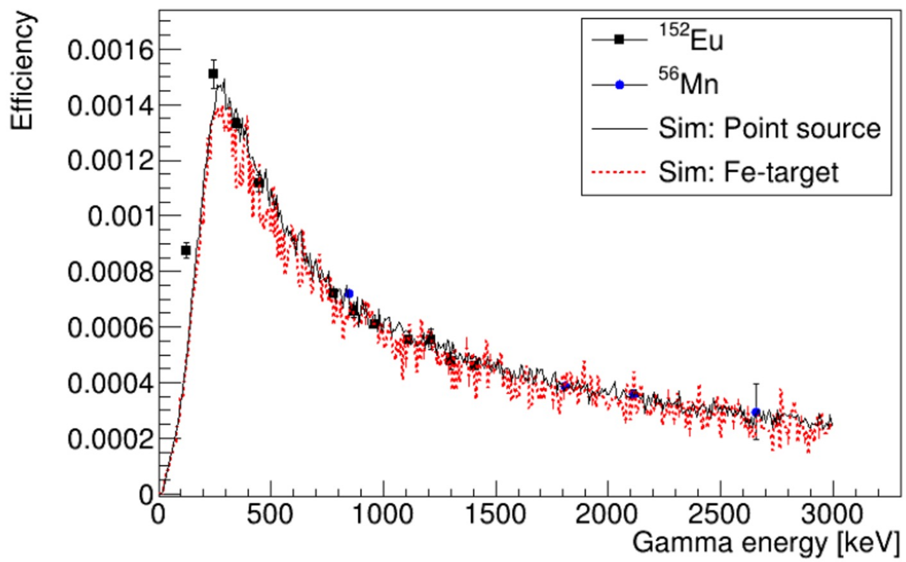
GENESIS has been fully modeled in GEANT and benchmarked using ^{252}Cf and multiple γ-ray sources



This benchmarking together with the finite energy range of our beam allows for multiple simultaneous measurements

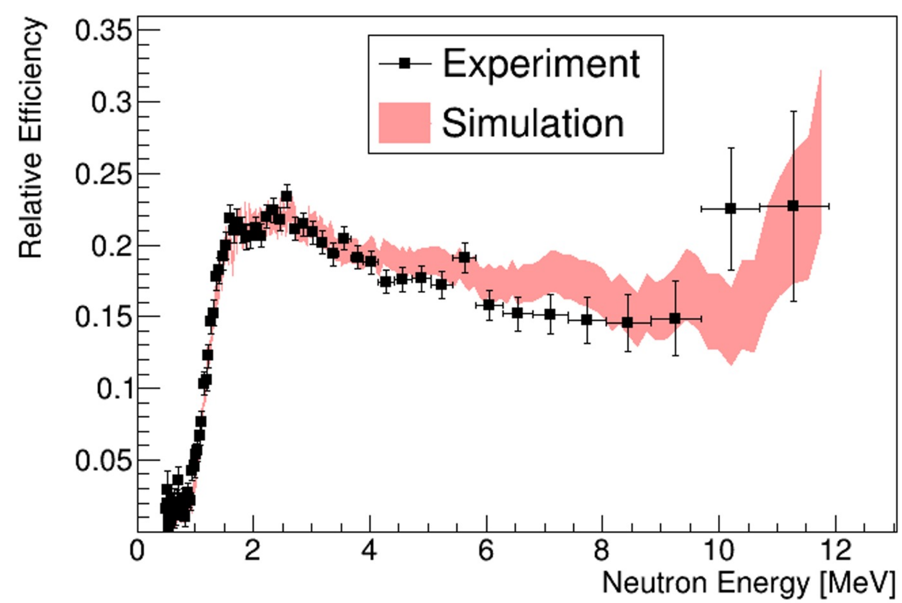
Josh Brown

Our goal of propagating modeled observables through a detector response function requires ***accurate*** simulation of GENESIS

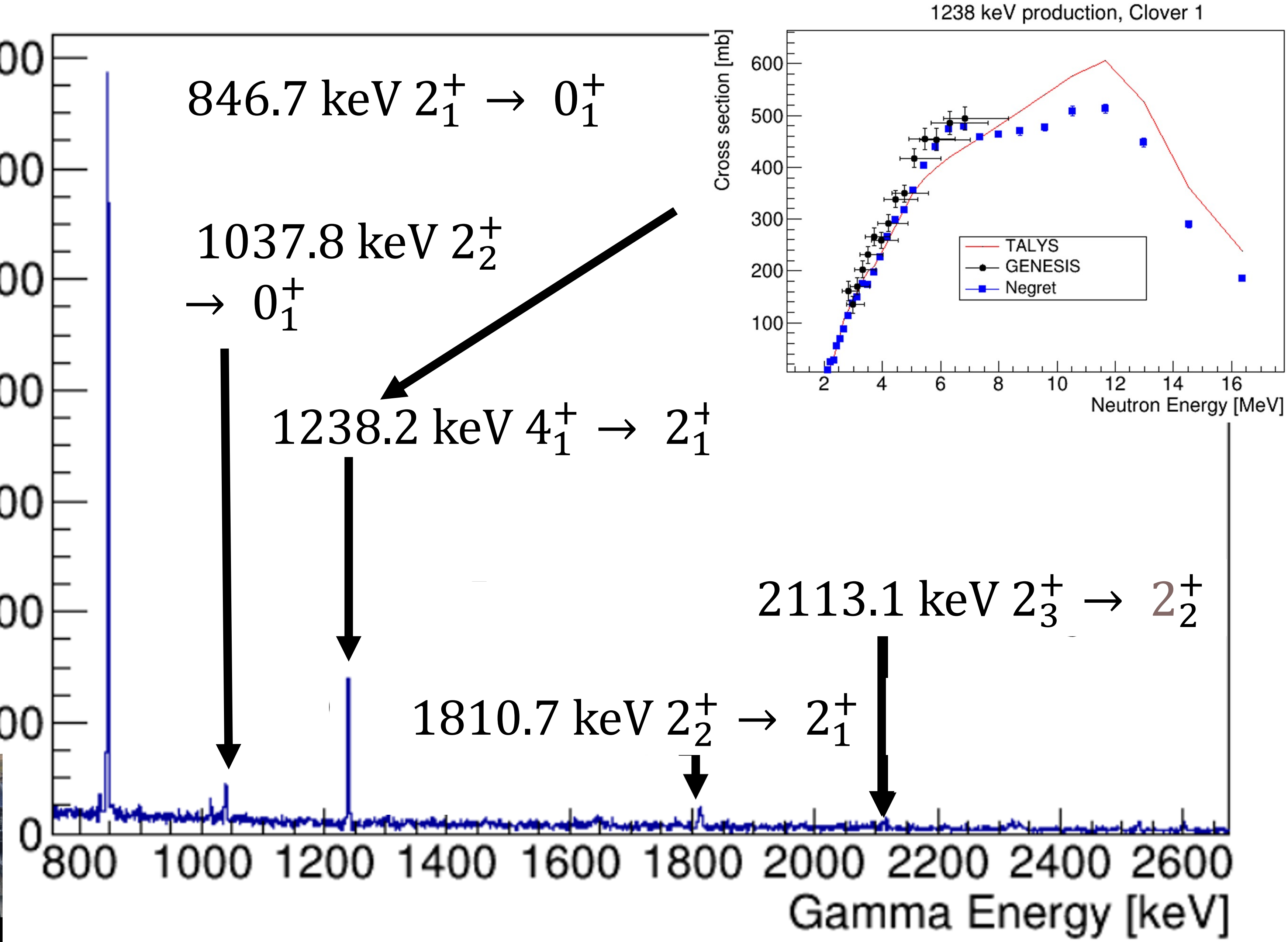


Percent level agreement in measured and simulated gamma response with isotropic and extended sources

Cf-252 source used to benchmark integral and differential neutron detection efficiency



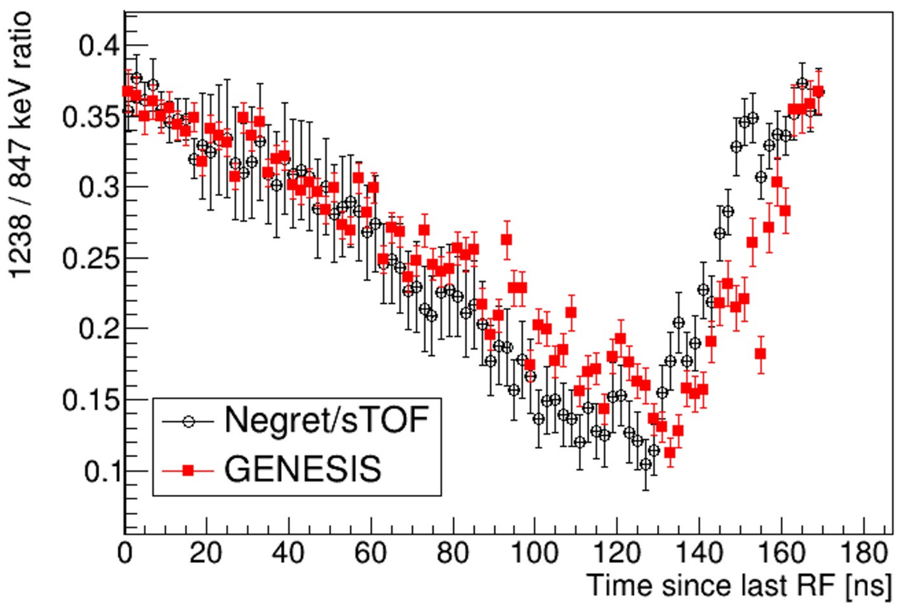
^{56}Fe neutron-gated γ spectrum



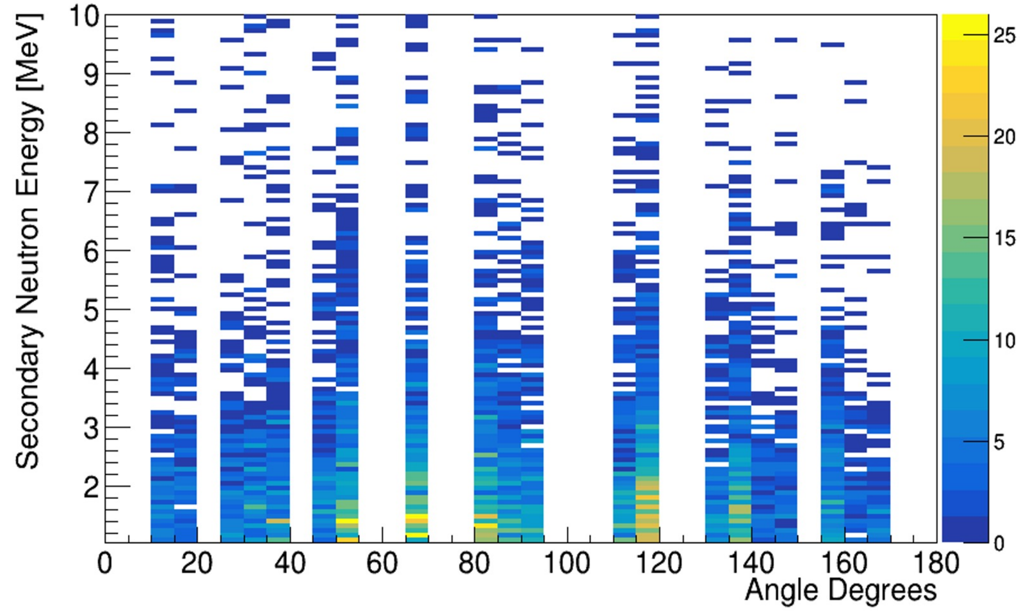
J.M. Gordon

Yrast $4^+ \rightarrow 2^+$ (1238 keV) to $2^+ \rightarrow 0^+$ (847 keV) ratio

$$\frac{4_1^+ \rightarrow 2_1^+ \ (E_x = 2085 \text{ keV})}{2_1^+ \rightarrow 0_1^+ \ (E_x = 847 \ keV)}$$

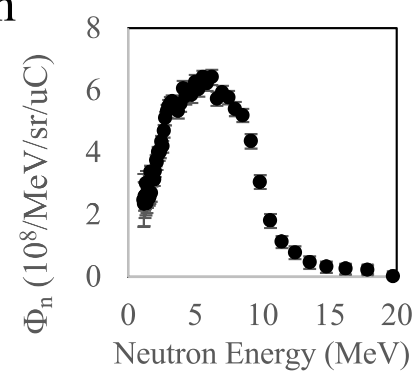


$N_n(E_n, \theta_n)$
gated on the $2_1^+ \rightarrow 0_1^+$



Significant differences seen 140-160 ns after RF, e.g.:

- ~~1.2-1.3 MeV~~
- 2.9-3.2 MeV
- ~~11.7-13.3 MeV~~



Majority of yield coming in below 4 MeV is consistent with significant compound emission

What about (n,elastic)?

J.M. Gordon

*A. Negret *et al.*, PRC 90, 034602 (2014)

J.M. Gordon

Yrast $4^+ \to 2^+$ (1238 keV) to $2^+ \to 0^+$ (847 keV) ratio

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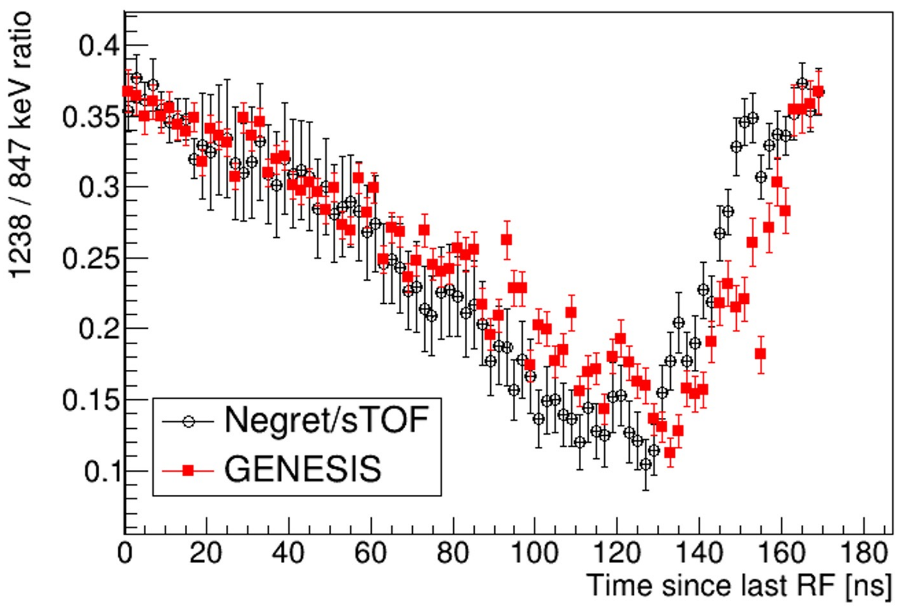

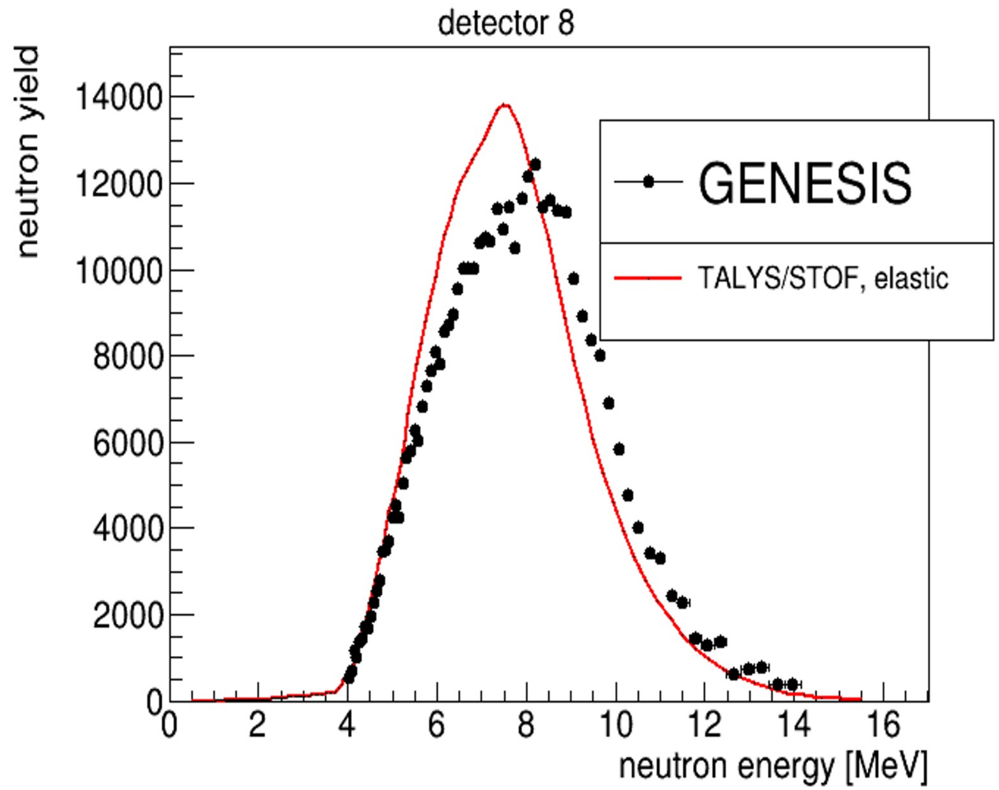

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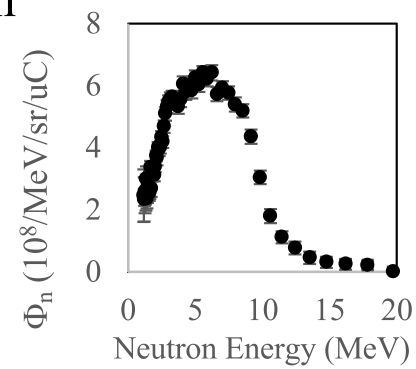
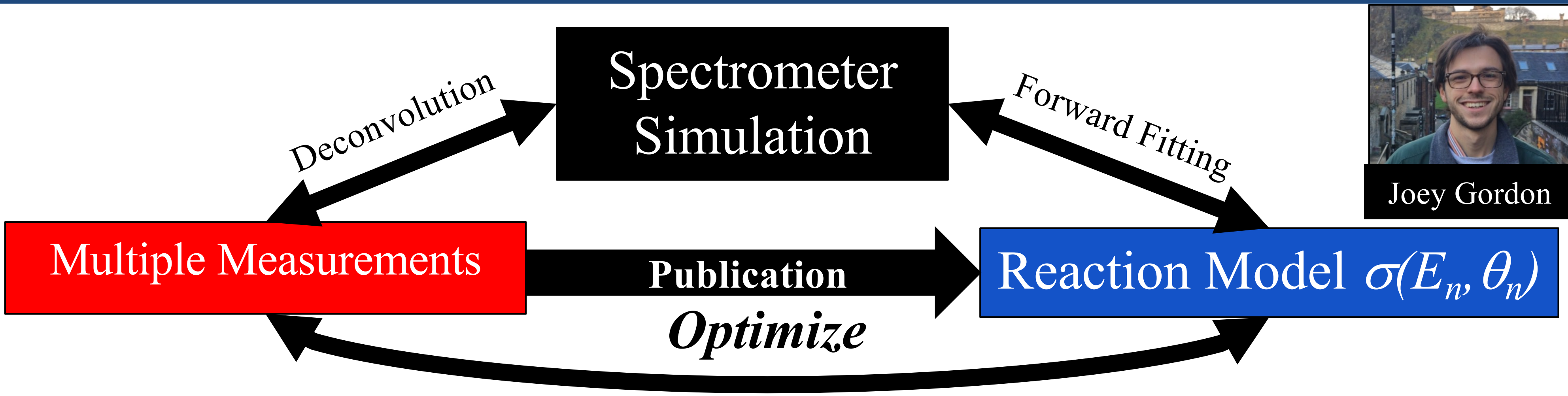


A blank-subtracted neutron spectrum shows elastically-scattered neutrons at forward angles

Analysis to be completed in CY23

J.M. Gordon

We are developing a forward fit process to determine optimal neutron reaction modeling parameters using Talys

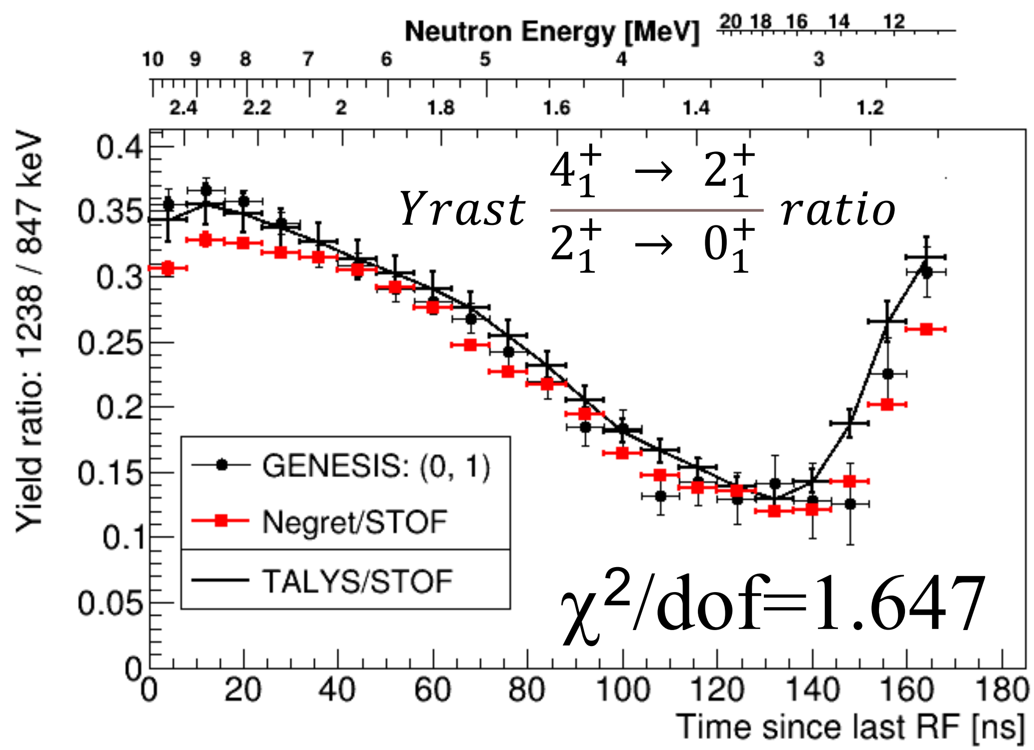


Joey Gordon

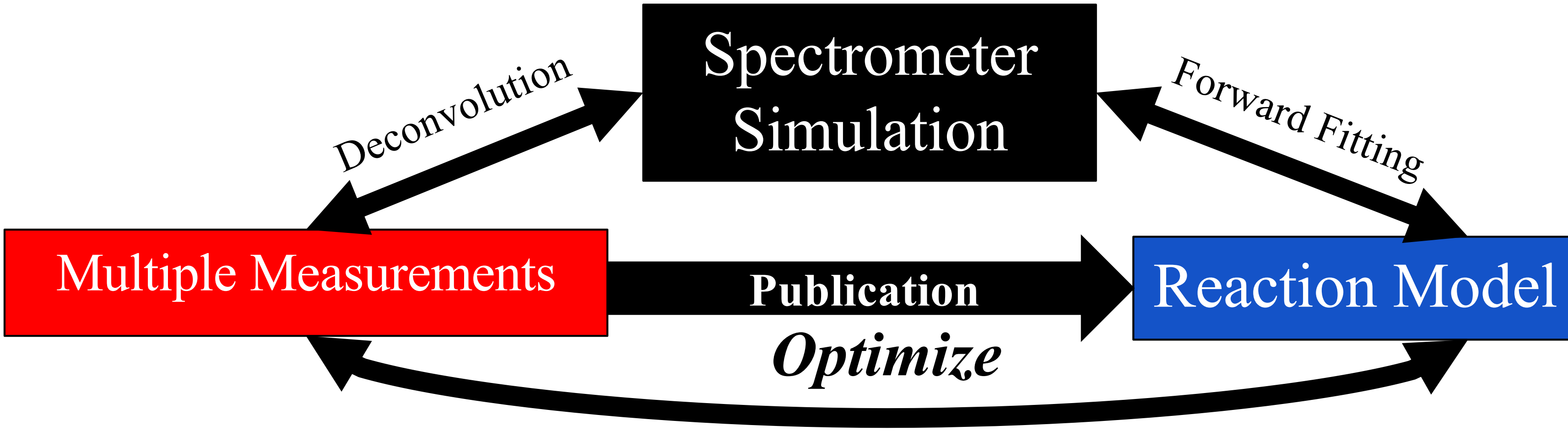
20 input parameters, including

- Level density parameters
- Gamma-ray strength function
- Optical model parameters
- Branching ratios

Wait for it Jo…



We are developing a forward fit process to determine optimal neutron reaction modeling parameters using YAHFC

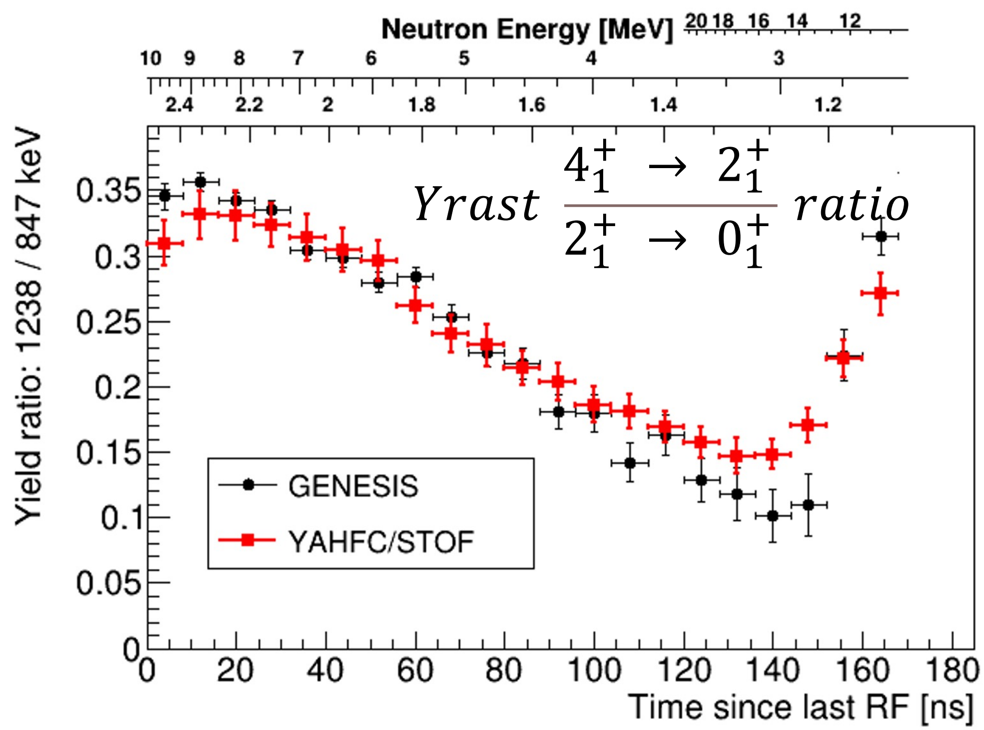


Joey Gordon

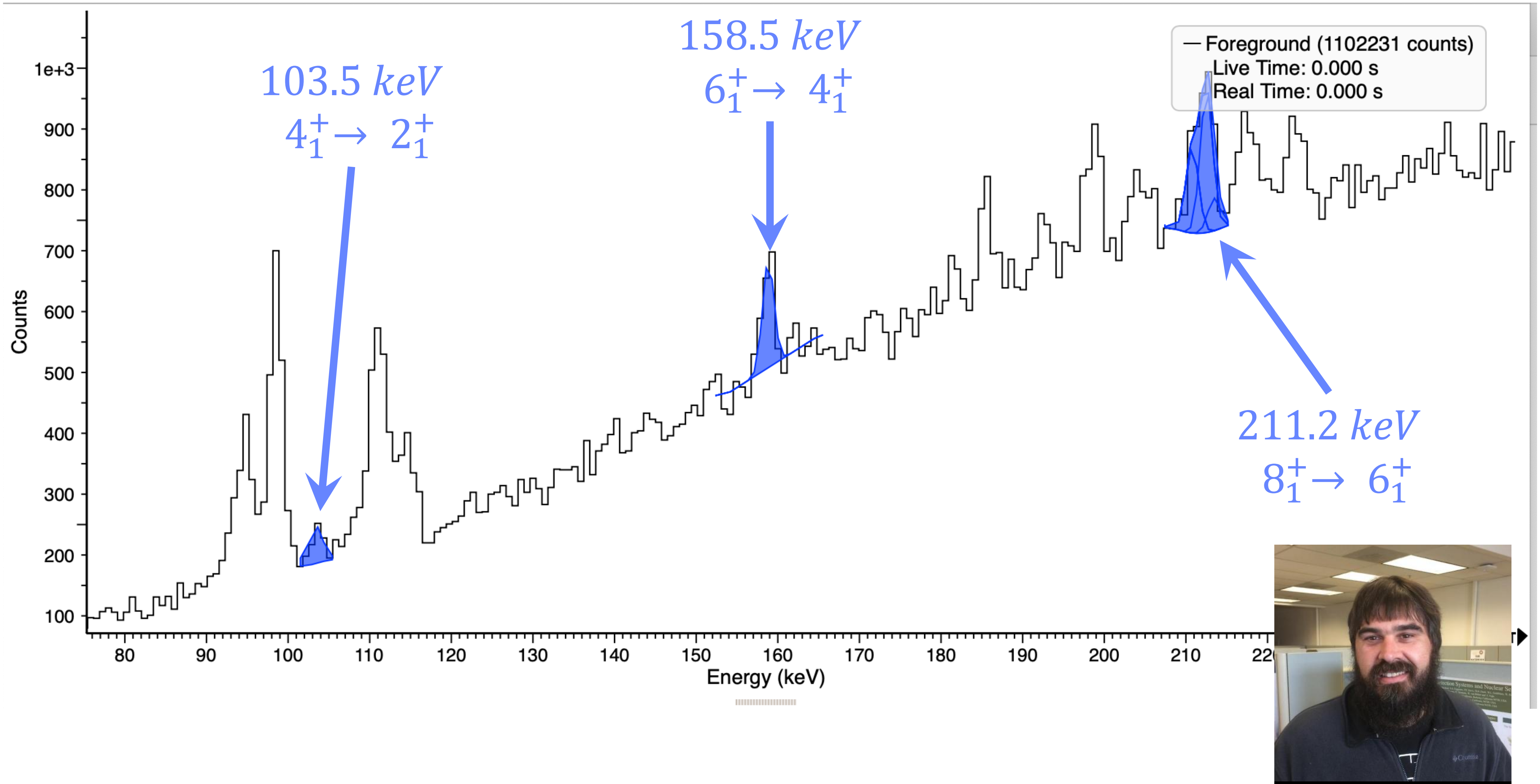
20 input parameters, including

- Level density parameters
- Gamma-ray strength function
- Optical model parameters
- Branching ratios

Monte Carlo codes provide a simpler approach to error propagation

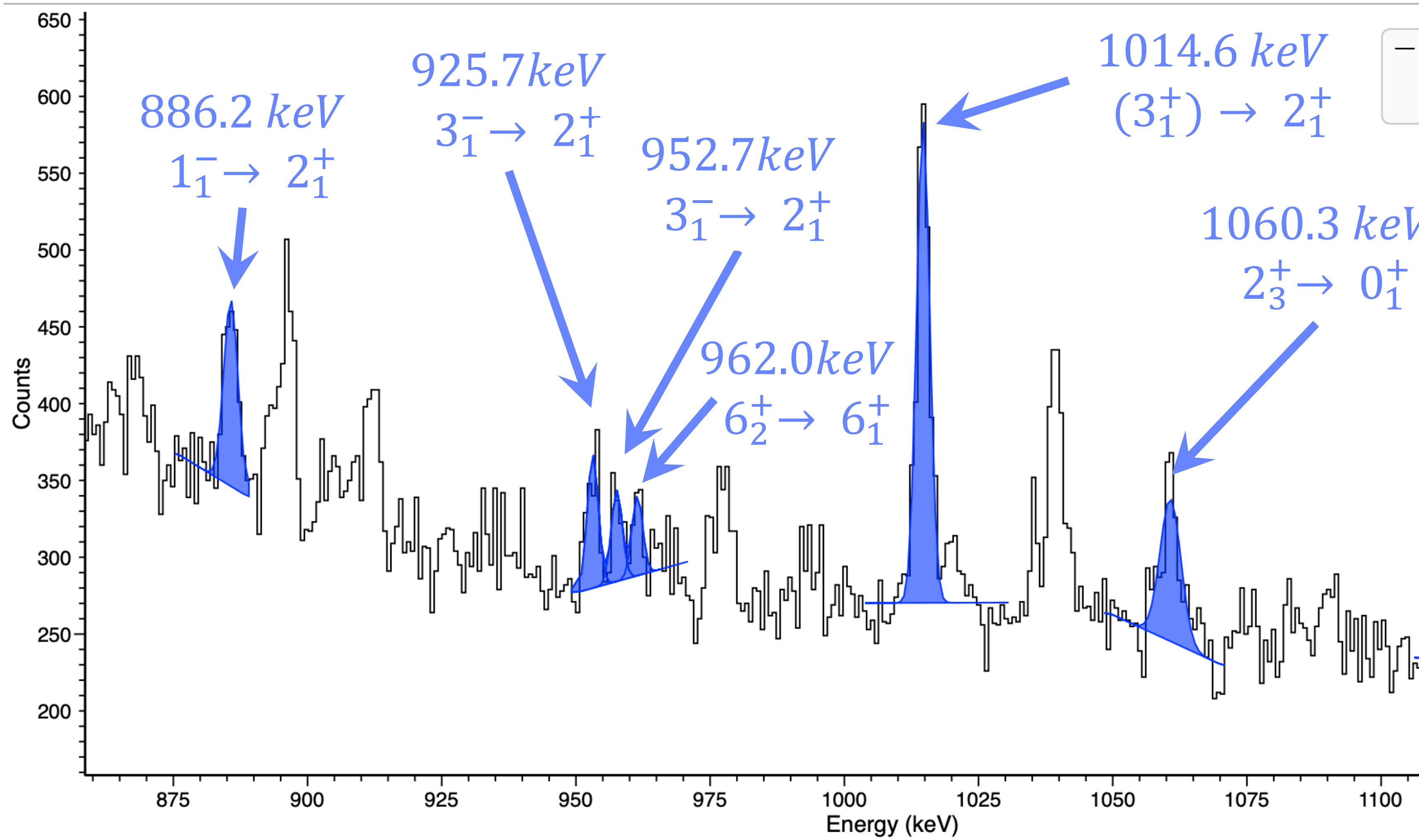


Neutron-gated ^{238}U Yrast Cascade

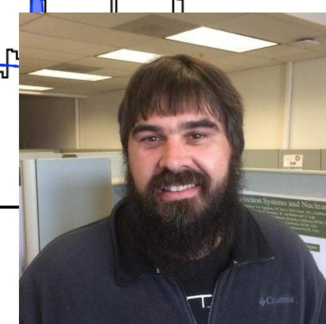


Josh Brown

Neutron-gated ^{238}U Off-yrast Transitions

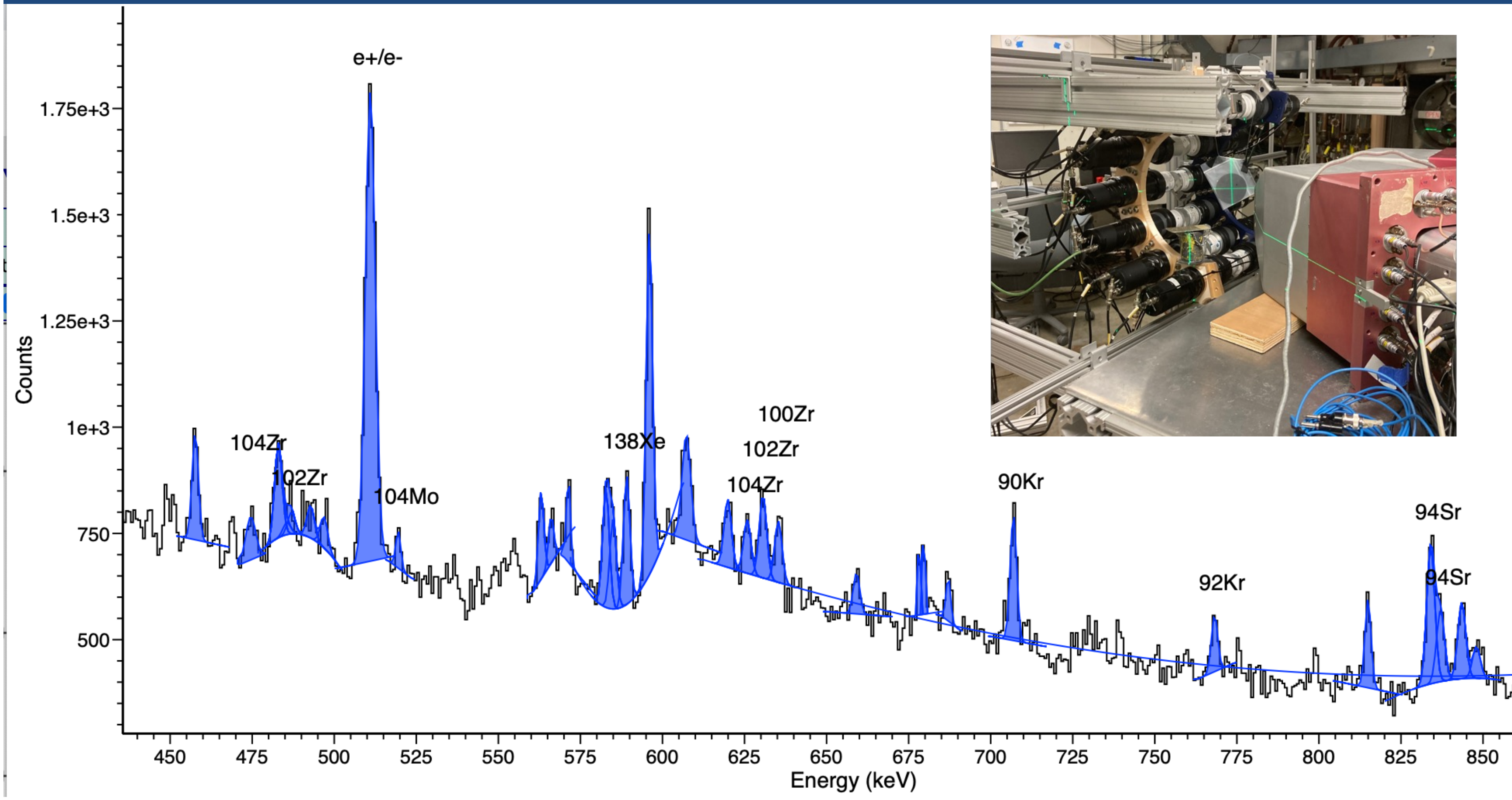


Analysis to be completed in CY23



Josh Brown

We just completed a run using beam sweeping with 10 s on and 1 s off run to measure β-delayed and prompt γ-rays with a new compact geometry to increase neutron-gamma coincidences



Josh Brown

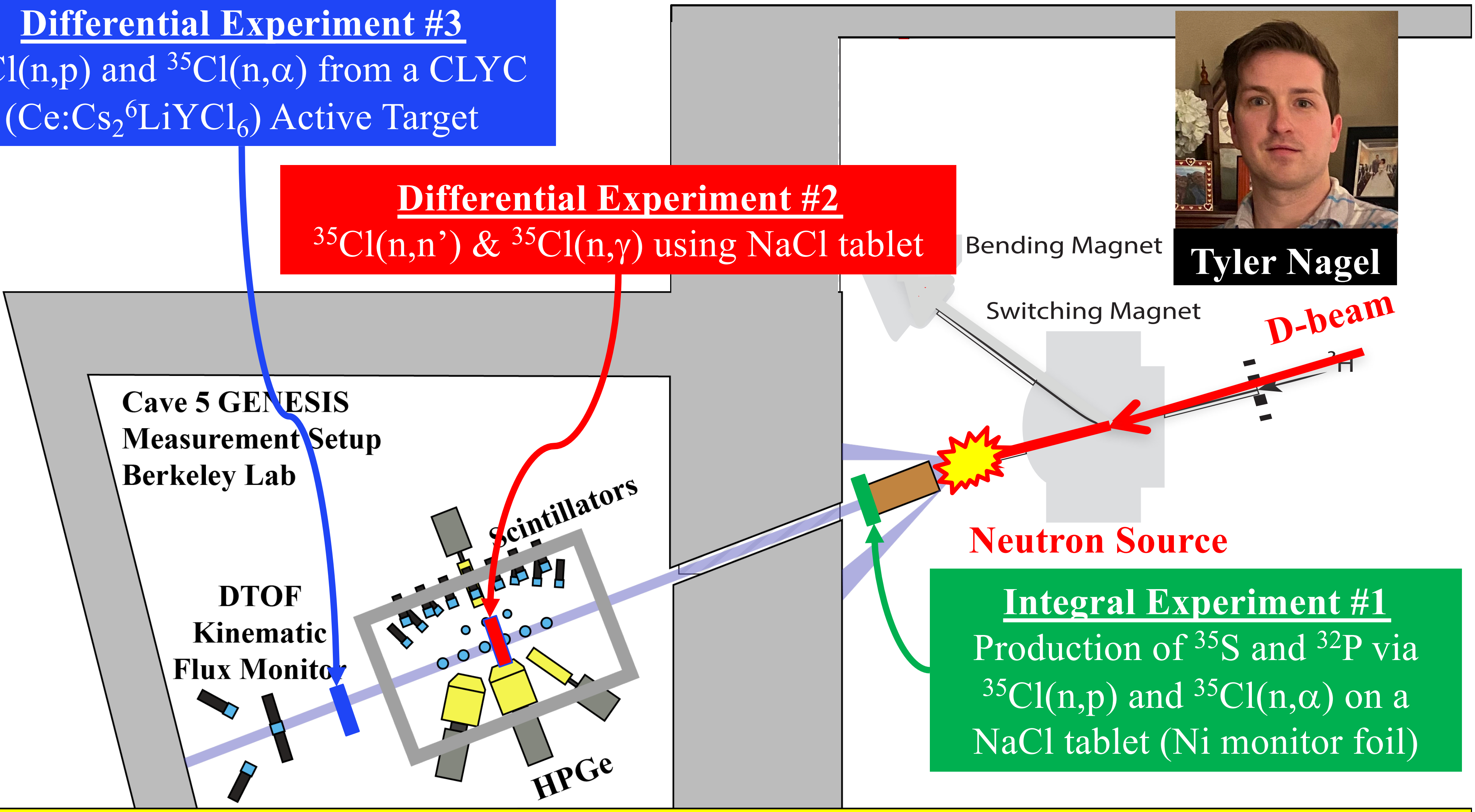
The in-beam and beam-off (n,fγ) data is being analyzed by NSSC graduate student Preston Awedisean

Preston Awedisean

We also ran ^{35}Cl(n,x)* 8/21 and 10/22

Differential Experiment #3
^{35}Cl(n,p) and ^{35}Cl(n,α) from a CLYC ($Ce:Cs_2{}^6LiYCl_6$) Active Target

Differential Experiment #2
^{35}Cl(n,n') & ^{35}Cl(n,γ) using NaCl tablet



Integral Experiment #1
Production of ^{35}S and ^{32}P via ^{35}Cl(n,p) and ^{35}Cl(n,α) on a NaCl tablet (Ni monitor foil)

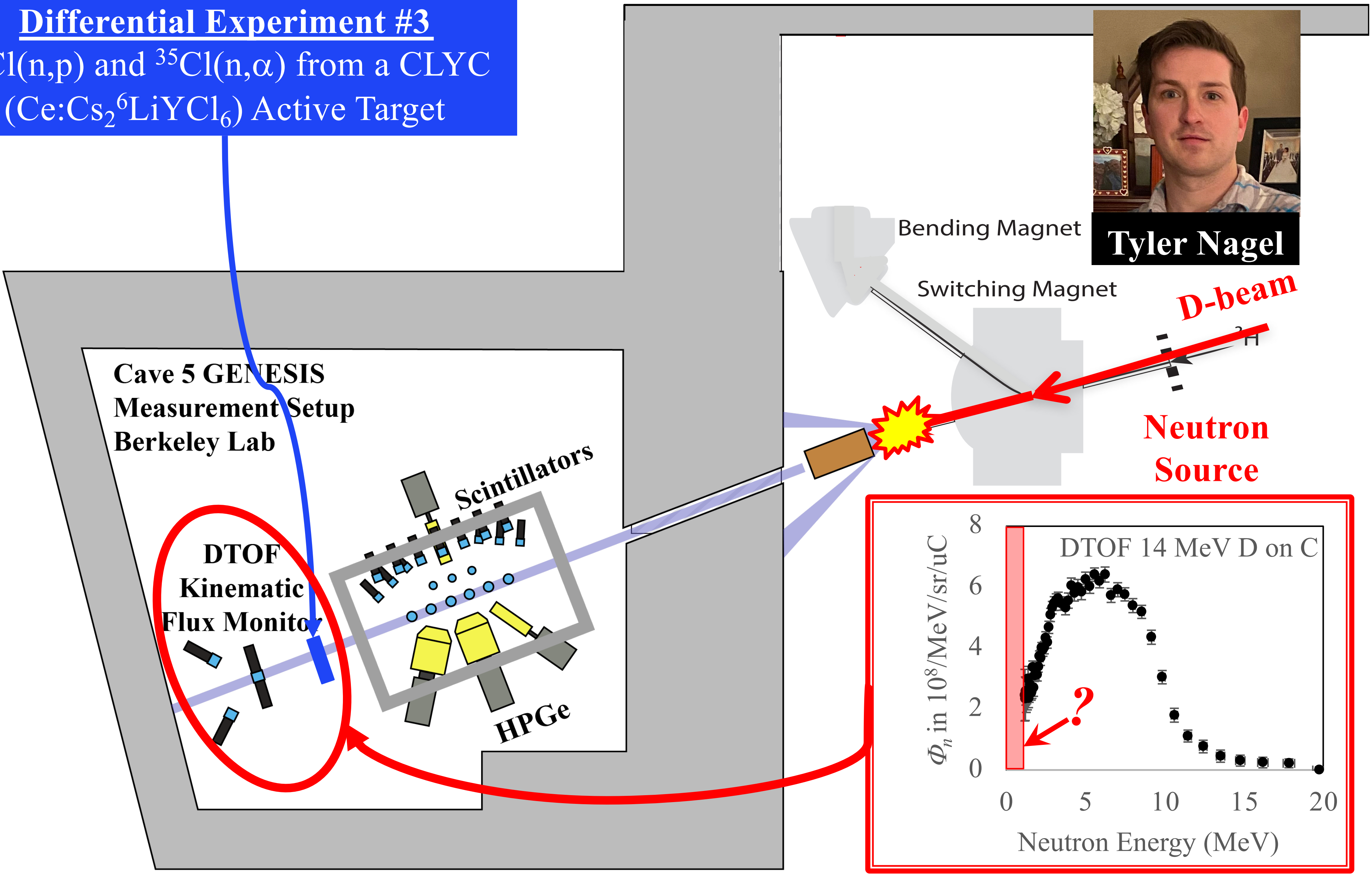
Simultaneous measurements of multiple exit channels should help address compensating uncertainties in reaction modeling

*Funded under an NEUP Grant

This part of the experiment is allowing us to determine $\Phi(E_n < 1\ MeV)$

Differential Experiment #3

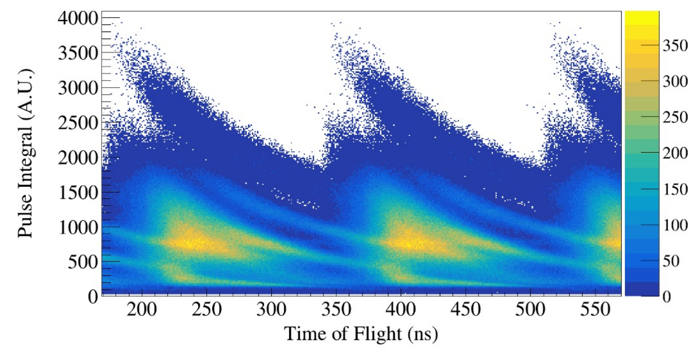
$^{35}Cl(n,p)$ and $^{35}Cl(n,\alpha)$ from a CLYC ($Ce:Cs_2{}^6LiYCl_6$) Active Target



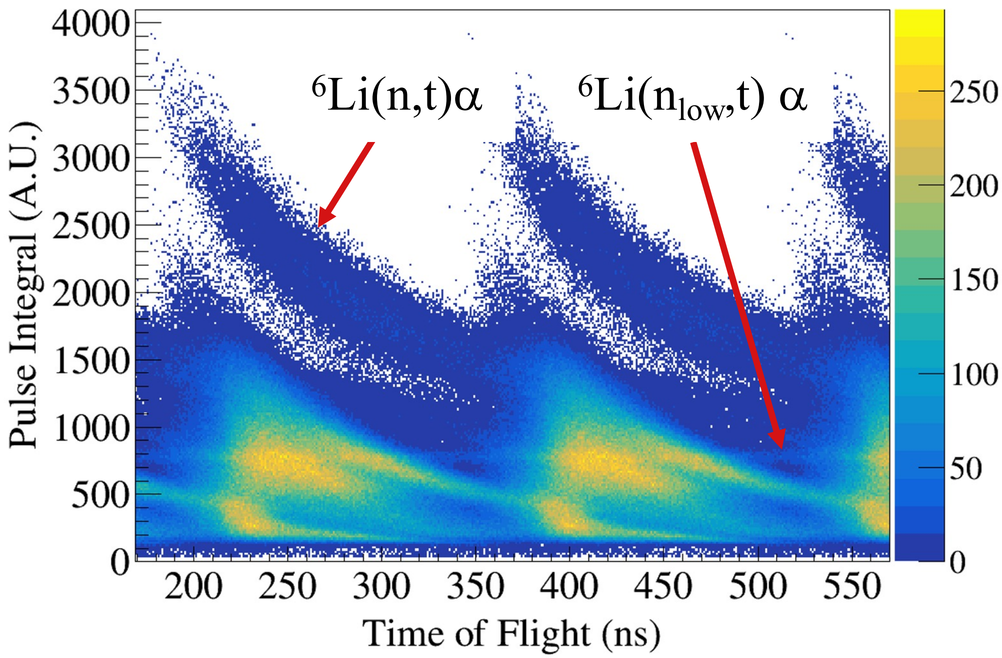
*Funded under an NEUP Grant

Improving low-energy neutron spectroscopy using CLYC

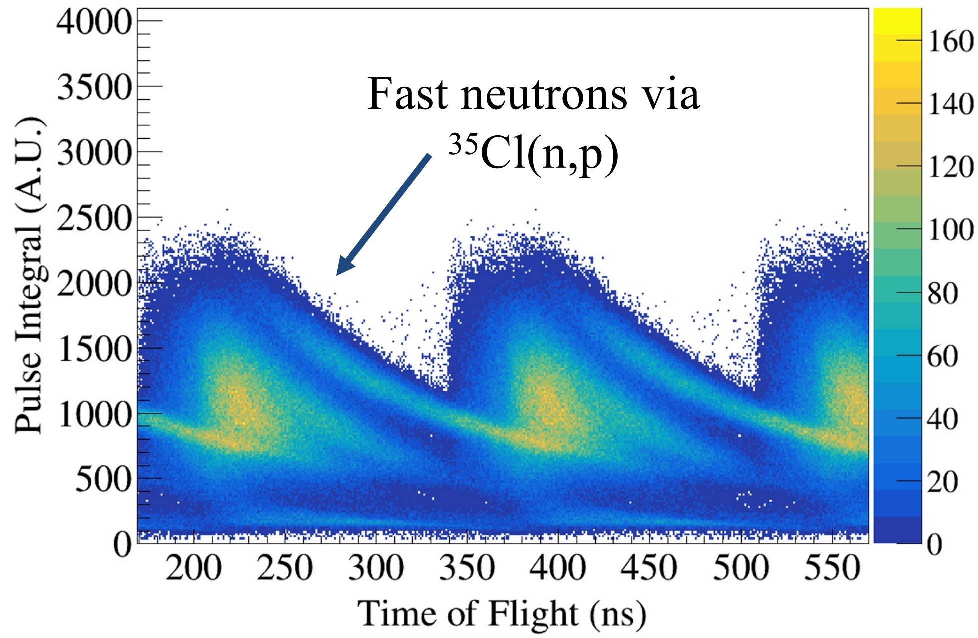
- Traditional PSD methods for CLYC provide poor separation between alphas and protons (making fast neutron spectroscopy difficult)
- Our new technique provides clean separation, allowing extension of neutron spectrum measurements down to 10s of keV



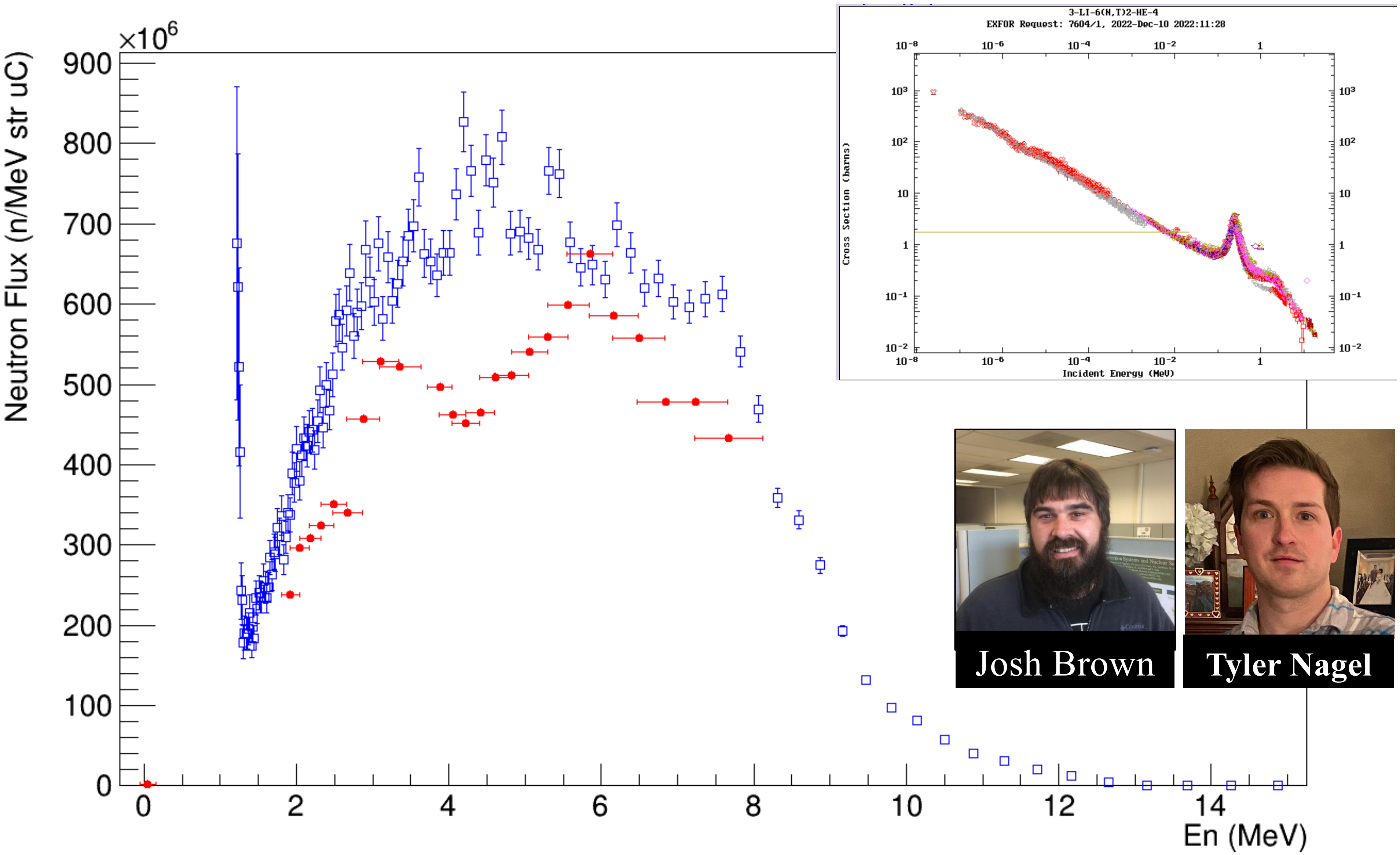
Alpha gated



Proton gated



CLYC-6 (Ce:Cs_2***^{6}Li***YCl_6) *allows for determination of the neutron flux using the well-known ^{6}Li(n,t)α reaction*



*Funded under an NEUP Grant

Collaborators on the work you've seen today

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