Designing Nuclear-data Measurements that Resolve Discrepancies in Existing Data

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We are applying machine learning (ML) to uncover the physics root cause of systematic discrepancies between experiments.

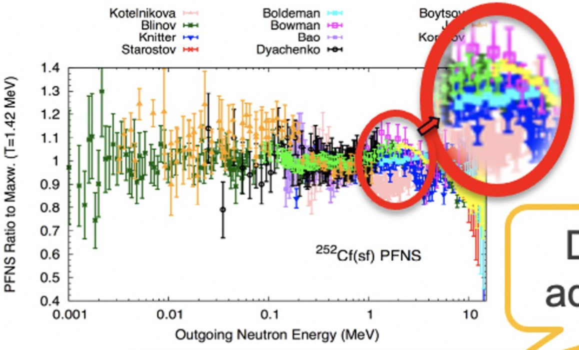
The big questions we are after:

- **What is the physical root cause for experimental discrepancies?**
- **What experiment can we perform to reduce scatter in experimental database?**

Benefit of answering questions:

- More targeted experiments reducing spread in an experimental data. This accelerates progress in understanding physics.
- Reduced uncertainties and better means for nuclear data that in turns lead to more reliable application simulation and better model fitting.

AIACHNE created a ML capability to explore discrepancies in past ^{252}Cf(sf) PFNS exp. & measures new data.



Developing advanced ML

Using state-of-the-art LANSCE equipment

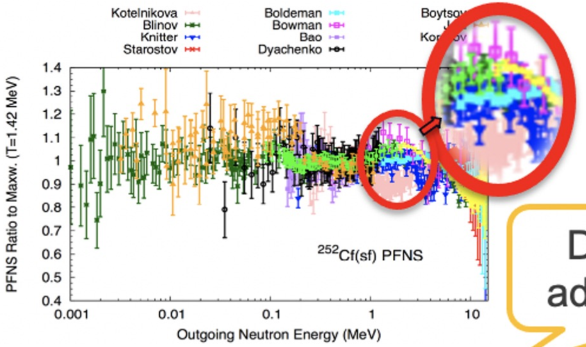
Correcting past data and assessing impact

Discrepant experiments (exp.) → ML indicates features of exp. related to bias → Simulations explore features and bias → Low-bias exp / Low-bias exp. + feature related to bias → Correction factor → Improved ND

Simulated correction factors

To that end, we used a ML capability to pin-point measurement features likely related to bias and choose most impactful experiments based on MCNP studies.

We are in Y3 and are close to delivering on planned research.



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Discrepant experiments (exp.) ✓ → **ML indicates features of exp. related to bias** ✓ → **Simulations explore features and bias** ✓ → **Low-bias exp** / **Low-bias exp. + feature related to bias** ✓ + Work in progress → **Correction factor** ✓ → **Improved ND** ✓ + Work in progress

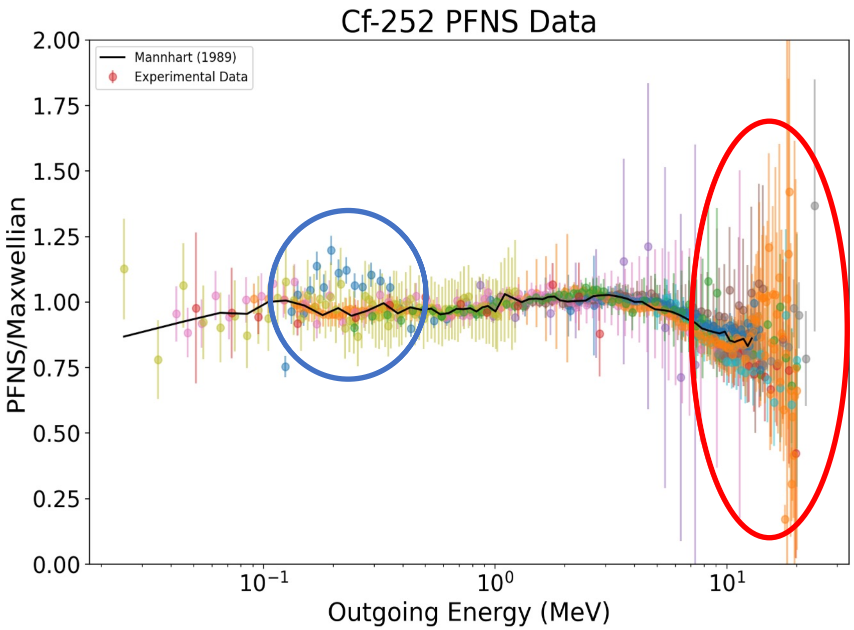
Simulated correction factors

DN, EPJ-N, **9**, 32 (2023)

N. Walton, LA-UR-24-29607 (2024), submitted.

DN, LA-UR-24-241787 (2024), in progress + evaluation submitted to Neutron Data Standards.

The problem at hand: Experimental ^{252}Cf PFNS have a wide systematic scatter of data at low and high energies.



Discrepancies at low E_{out} understood: caused by incorrect resolution of ^{6}Li resonance for detector response.

Discrepancies at high Eout **not** understood:

- Background?
- Time resolution?
- Fission fragment issues?
- Neutron detector response?

AIACHNE is using a sparse Bayesian model to identify potential sources of bias in ^{252}Cf PFNS data.

We are extending the Bayesian model with an energy-dependent, multiplicative bias. Sparsity ensures no bias for most energies but the term is active when the data indicate the need. A horseshoe prior reduces the number of potential biases.

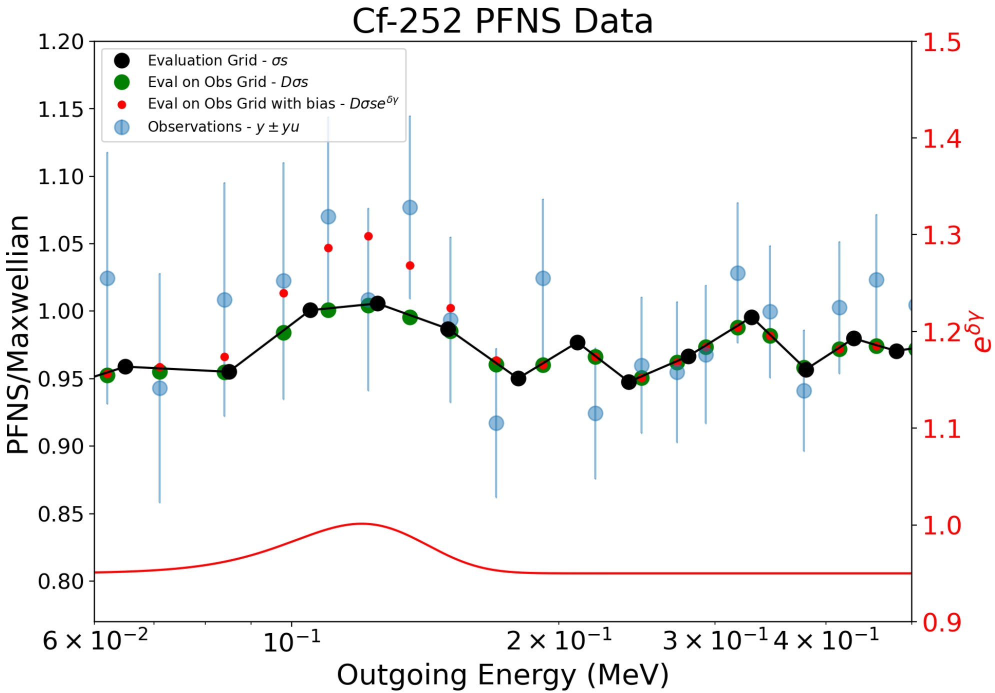
$$y = D\sigma \cdot e^{\delta} + \varepsilon$$

$\delta =$ $B\gamma =$ **relative bias**

$\mathbf{B} =$ **bias basis matrix**

$\gamma =$ **bias coefficients**

$\cdot =$ **element-wise product**



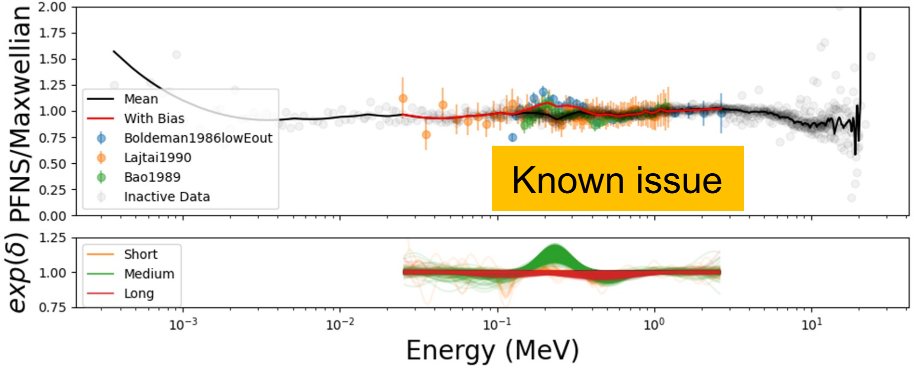
The algorithm deals well with a large number of correlated features compared to experimental data.

ML algorithm finds known and unknown features related to bias that help us correct data.

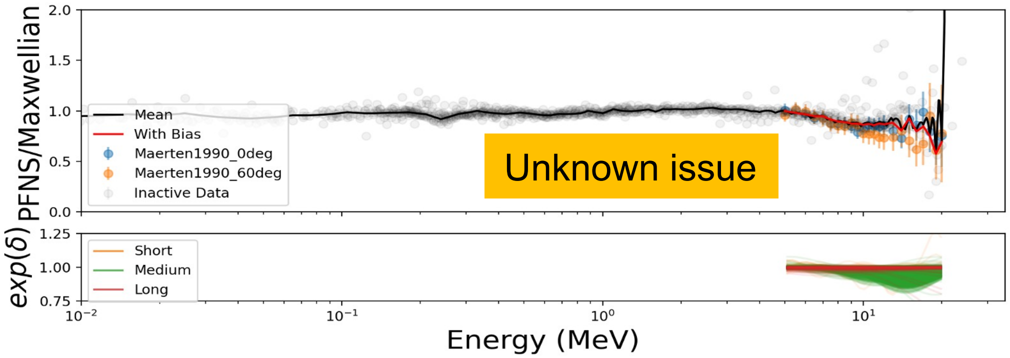
Effect at lower energies correctly attributed to incorrectly resolving ^{6}Li peak, but also clearly identifies size and energy range of bias.

The algorithm finds features related to bias at high E_{out} experts might have otherwise overlooked. The algorithm results require expert interpretation.

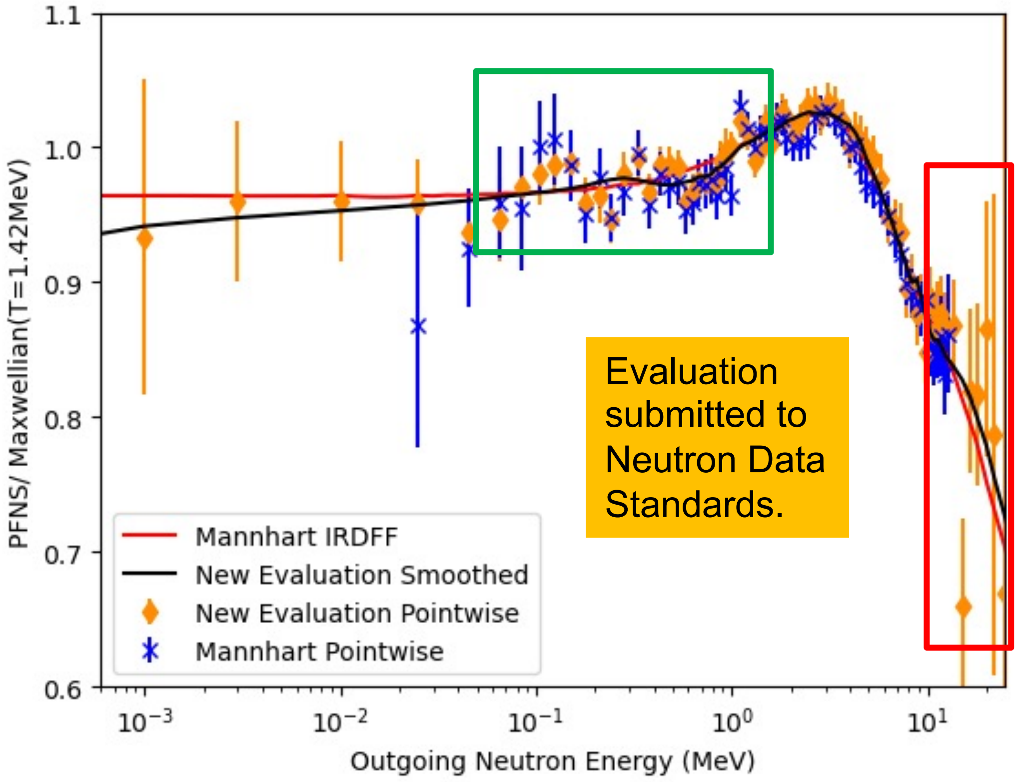
Neutron Detector: ^{6}Li

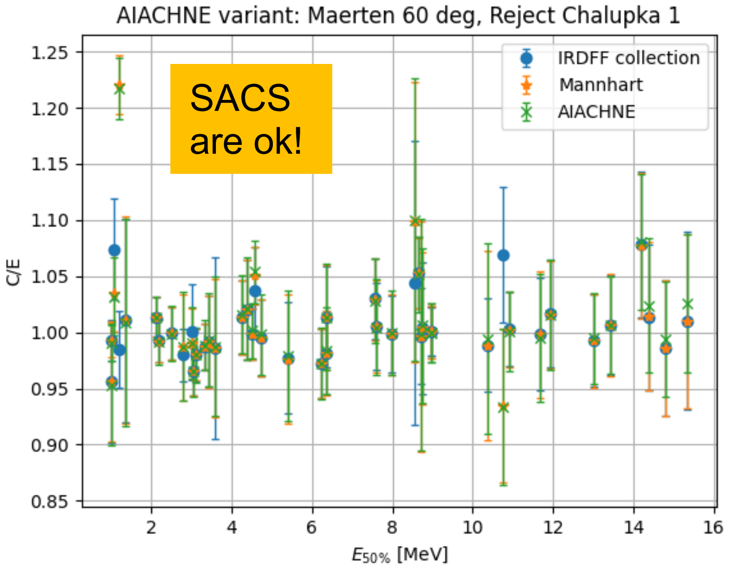


Fission Detection Efficiency Correction Method: Calculated/Measured

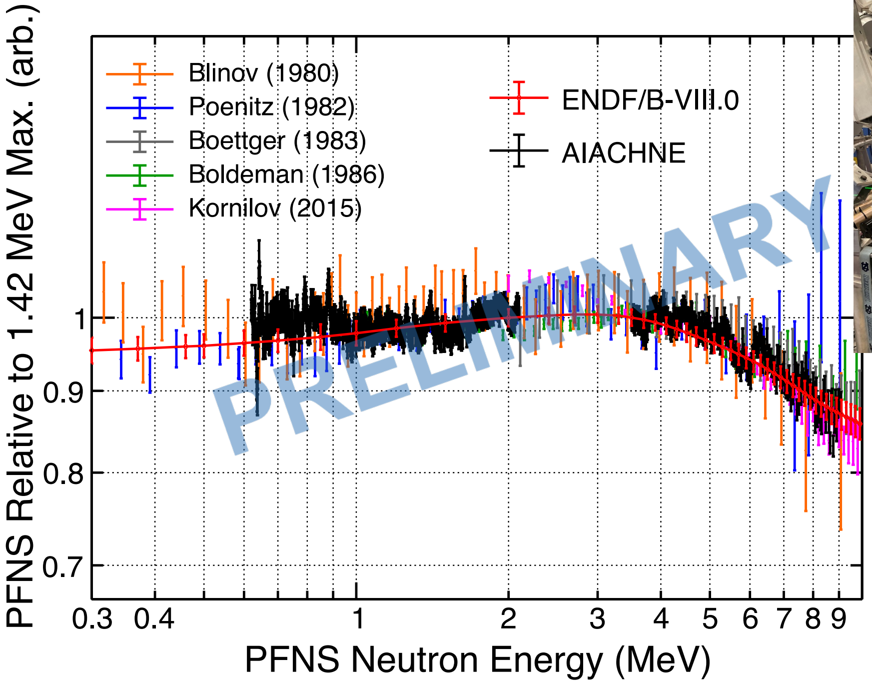


New evaluation reduces ^{6}Li peak issues and extends energy range-including more understanding at high E_{out}.

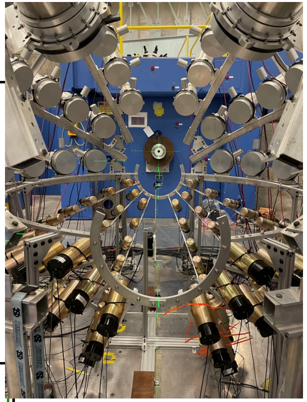




AIACHNE measurement further explores neutron detector response with new response calibration.



Total uncertainties are shown for all datasets.



- Measurement uses the CoGNAC array.
- New method developed to get at the neutron detector response; utilizes ^{9}Be and ^{12}C(n,n) elastic neutron scattering as a reference for ^{252}Cf PFNS.
- High statistical precision allowed for high granularity of results.
- Results will be available before end of project.

- Summary:

o Developed new ML technique to help pin down physical root causes of experimental discrepancies.

o New ^{252}Cf(sf) PFNS evaluation available.

o New ^{252}Cf(sf) PFNS measured & coming soon.

Impact:

o New ^{252}Cf PFNS evaluation was submitted to Neutron Data Standards for further testing.

o Experimental UQ published, ML process submitted to journal.

o New detector response calibration method will be published.

Thank you for listening!

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