Evaluations for Nuclear Criticality Safety Program

^{12}C, ^{139}La, minor actinides, ^{235}U

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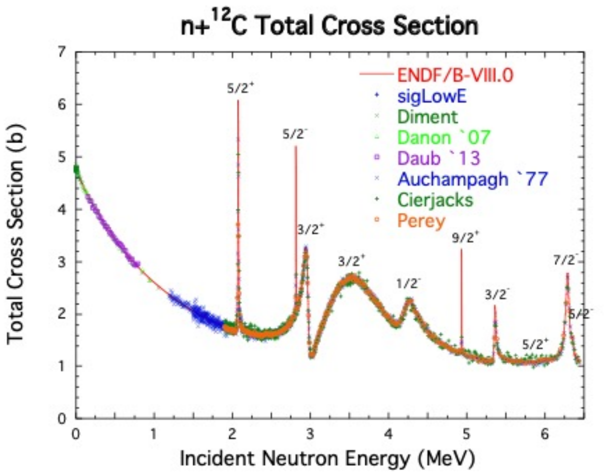
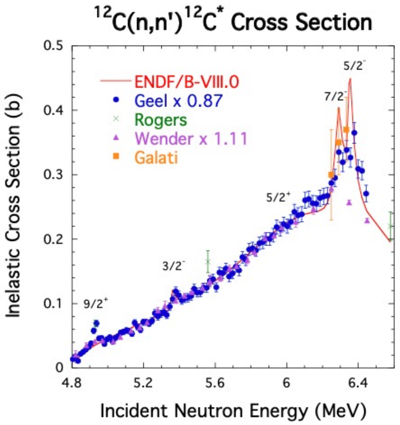
Outline

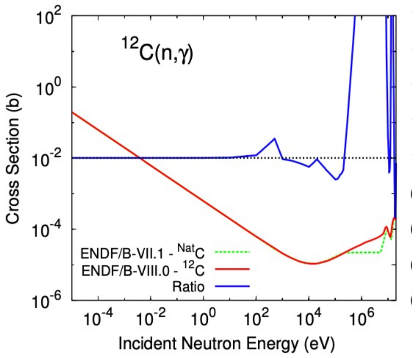
- Light-element R-matrix evaluation work (Sasaki, Hale & Paris)
  - n+^{12}C: extension from previous 7 MeV to 10 MeV; adding recent (and other) data
- Fission product
  - ^{139}La
- Minor actinides
  - Fission product initial conditions
- Major actinide
  - ^{235}U: re-evaluation (except fission)

^{12}C+n evaluation in ENDF

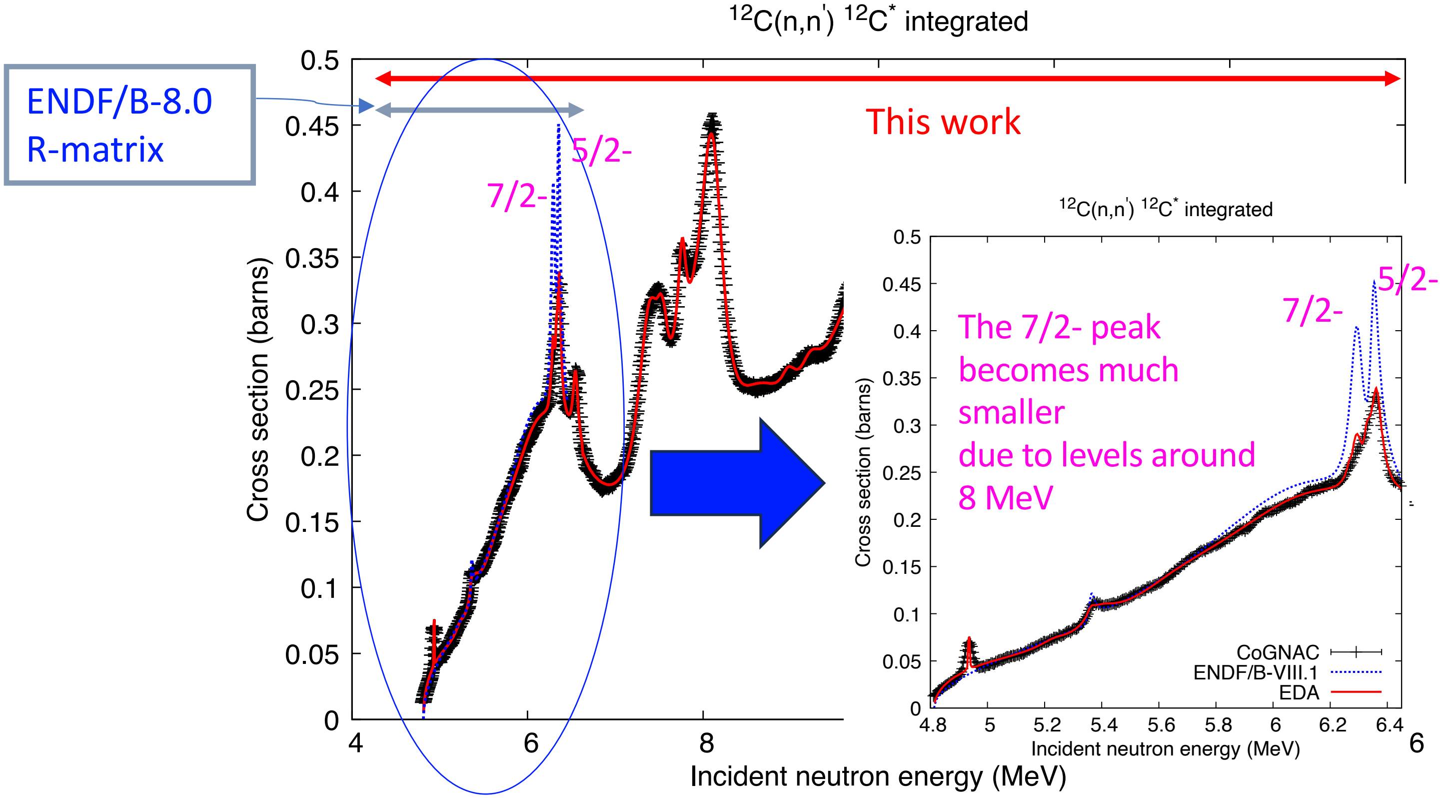
- R-matrix evaluation has been done up to 6.5 MeV neutron in the current ENDF/B-VIII.1 library
- Extending the upper neutron energy is important for applications in standards work, nuclear energy, nuclear criticality safety, nuclear security and basic science
- R-matrix evaluation up to high neutron energy can benefit for the future ENDF
- We present preliminary results of our evaluation work extending to 10 MeV neutron





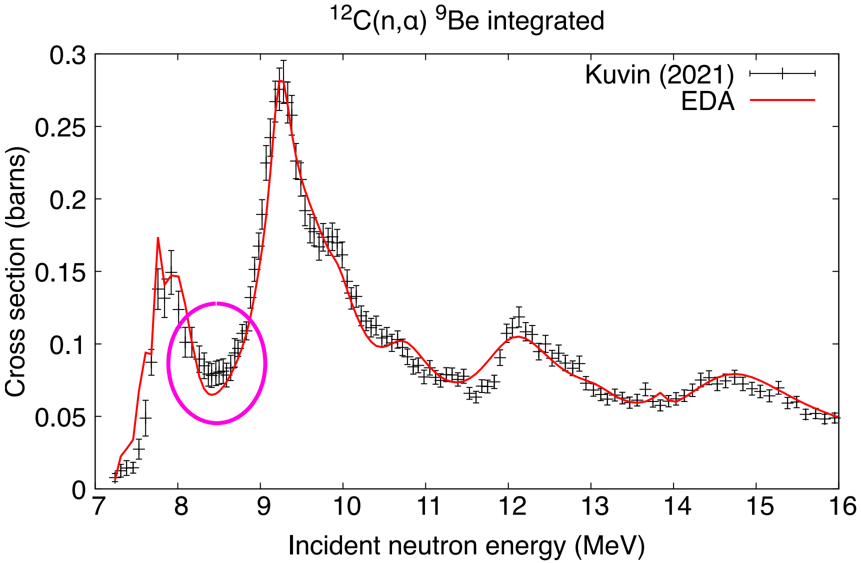


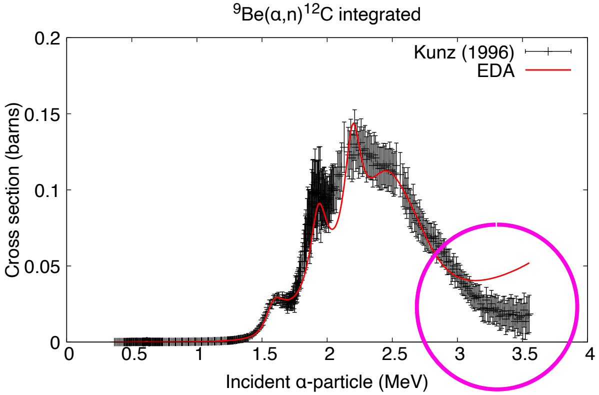
Integrated cross section of inelastic scatterings

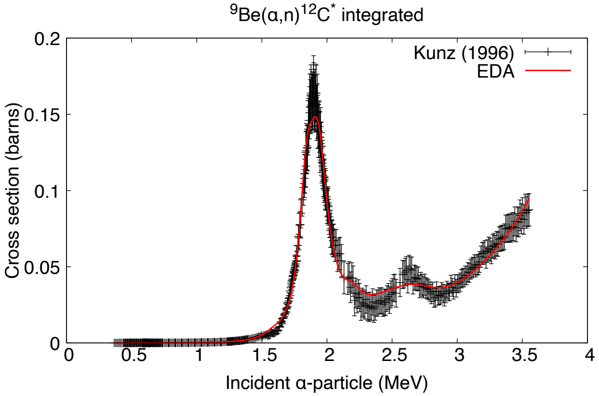


We found R-matrix parameters reproducing CoGNAC data up to 16 MeV neutron

Integrated cross sections of $^{12}C^{(*)} + n \rightleftarrows {}^{9}Be + {}^{4}He$





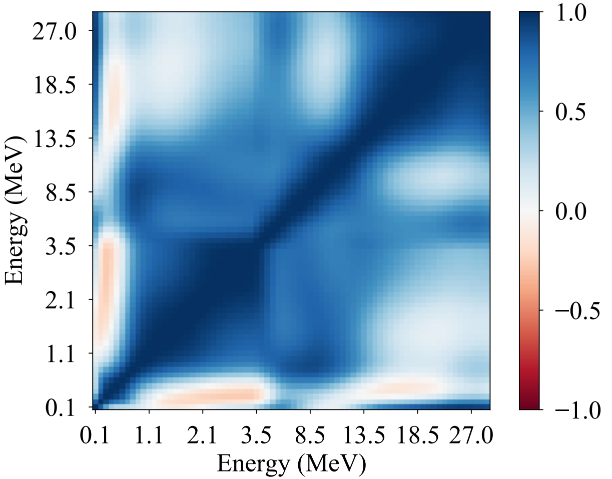


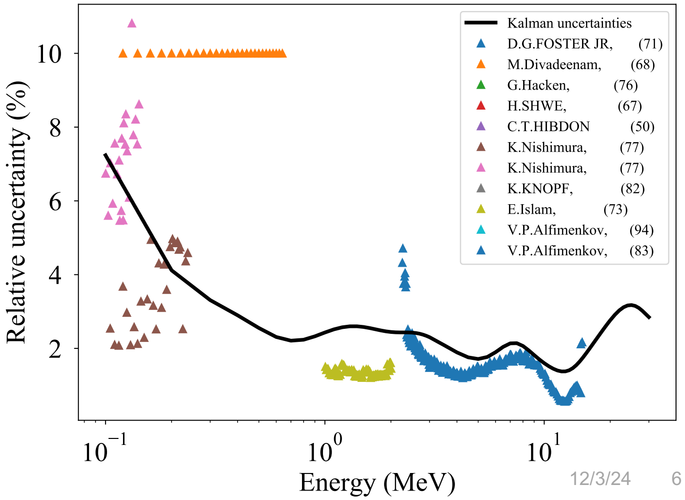
EDA can reproduce overall structure of $^{12}C(n,{}^{4}He){}^{9}Be$ and that of $^{9}Be({}^{4}He,n)\,{}^{12}C^{(*)}$

The fit does not work well around 3.5 MeV α-particle for $^{9}Be(n,\alpha)\,{}^{12}C$ due to the restriction from ～8.5 MeV neutron in the inverse reaction

^{139}La Covariance evaluation

- Correlations and uncertainties for MT=1 missing in ENDF/B-VIII.0
- Based on CoH_3 calculated sensitivities
- Sensitivities were calculated with respect to all parameters
- Kalman filter to evaluate covariances





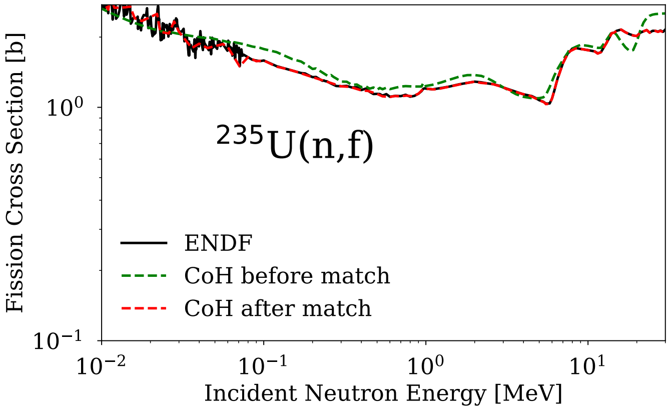
Head start on minor U nubar evaluation

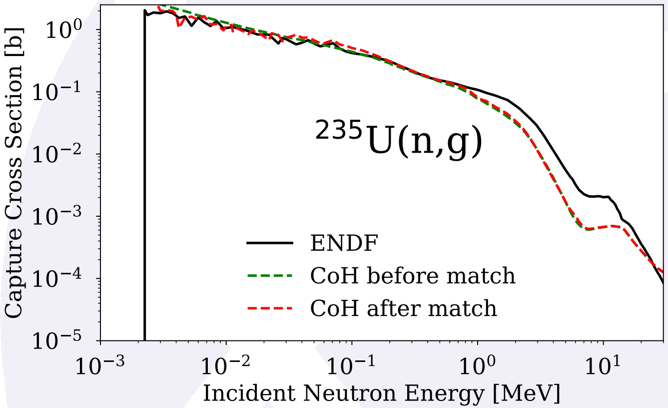
- U isotopes are scheduled for FY25-26
- Cole Fritsch (student at UTK working with Vlad Sobes) has been working on UQ uncertainties for minor U isotopes nubar.
- Cole applied templates of expected uncertainties for in-depth experimental UQ of minor U nu-bar data. (See talk by D. Neudecker)
- CGMF was updated to include parametrizations of fission fragment initial conditions for ^{232}U, ^{236}U, ^{237}U, and ^{239}U.
- Cole gathered TKE data and performed a global (as a function of A) fit to the available U isotopes; resulting nubars will be used as a prior for the FY25 consistent evaluation.

Work on quasi-integral data for 235U

- The RPI quasi-integral data provide an important test for cross sections and angular distributions
- We have re-evaluated ^{235}U using CoH3 calculations, with the exception of the fission channel.
- For fission channel, we have readjusted the transmission coefficients so that we reproduce exactly the ENDF/B-VIII.0 fission cross section
- The new evaluation file, in which all but fission cross sections were updated, including angular distribution was tested against RPI data.

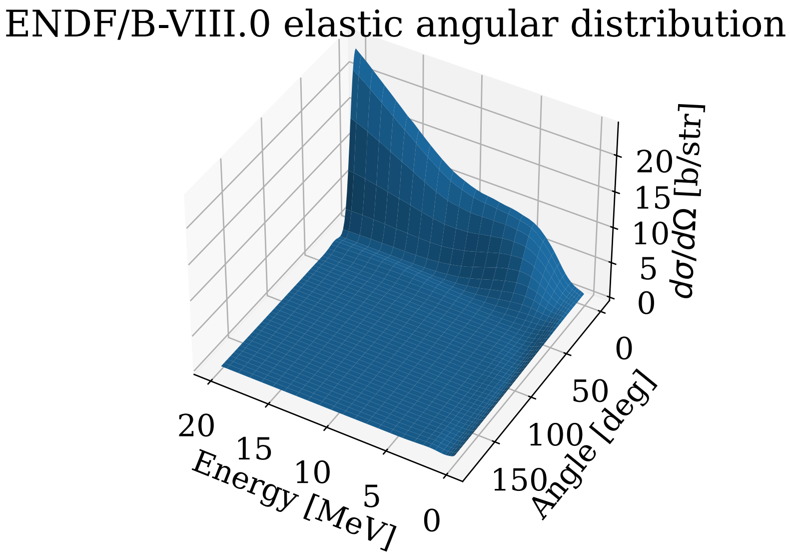
CoH3 calculation with fission match

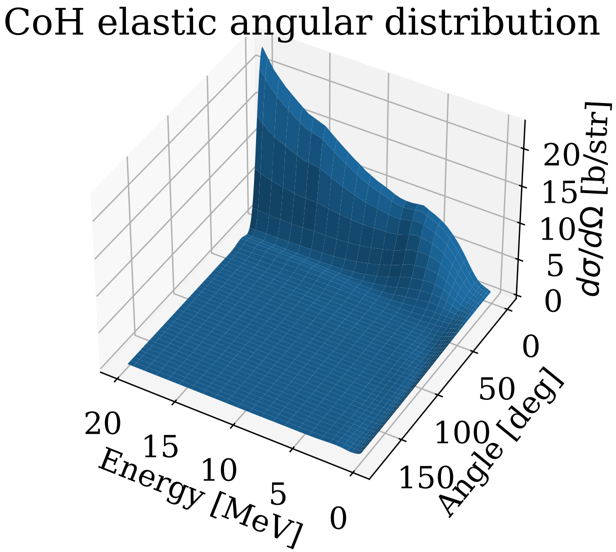




Except for the match, no additional tweaking of the evaluation

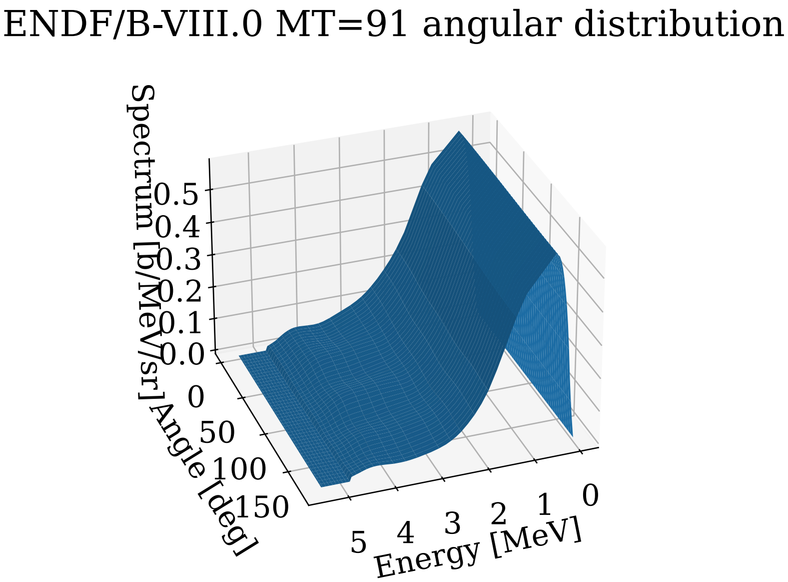
Elastic angular distributions

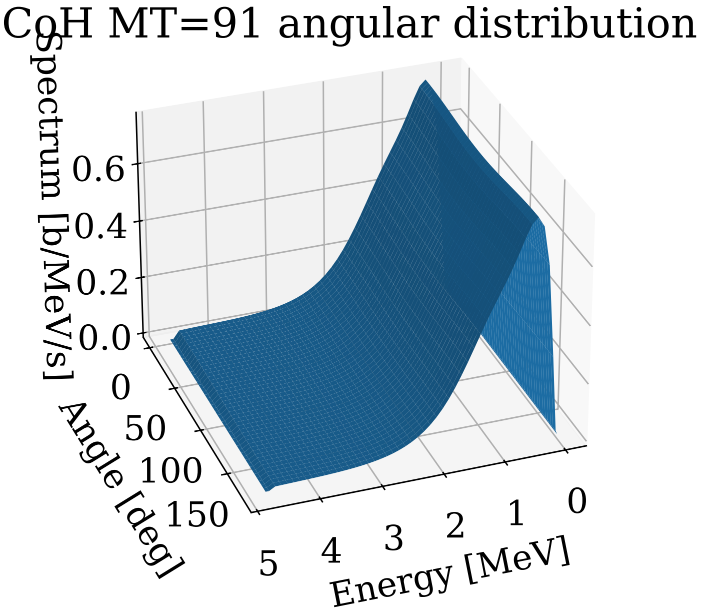




Very similar angular distributions

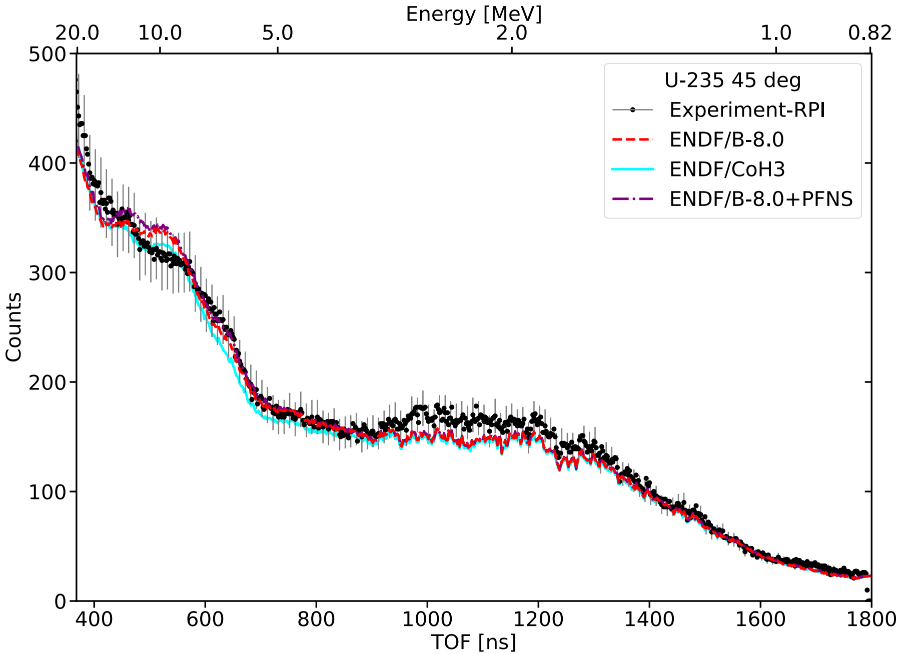
Inelastic angular distributions at 5 MeV (MT=91)





CoH$_3$ outgoing energy spectrum is isotropic as expected for a compound reaction

Test against RPI data for select three angles



- In general, CoH-based evaluation improves below 5 MeV the agreement with the data
- It is striking the disagreement above about 8-9 MeV
  - Could be explained by inadequate angular distributions for neutrons produced in fission and (n,2n).
- We have included a third evaluation based on B8 and the PFNS from ENDF/B-VII.1

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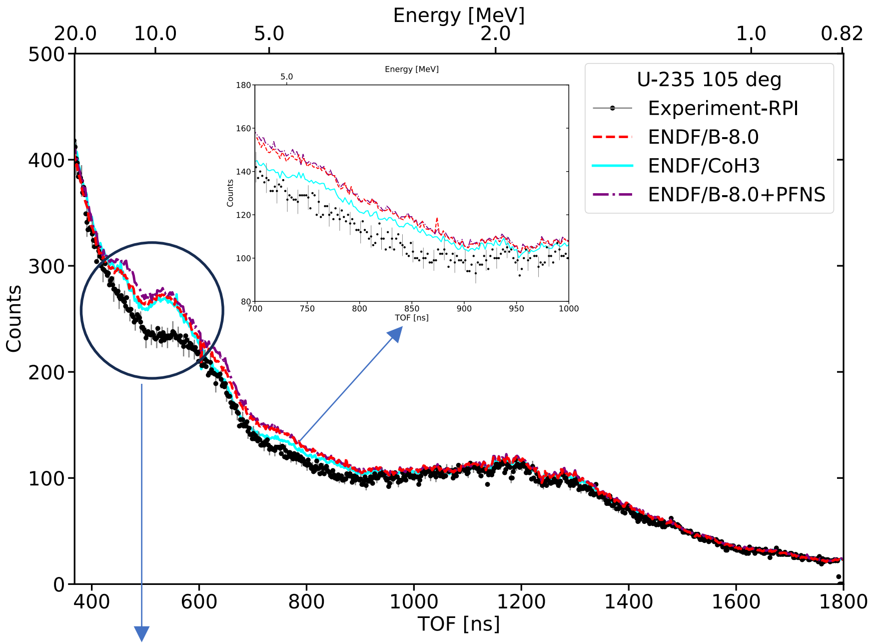

Very little change: still challenging

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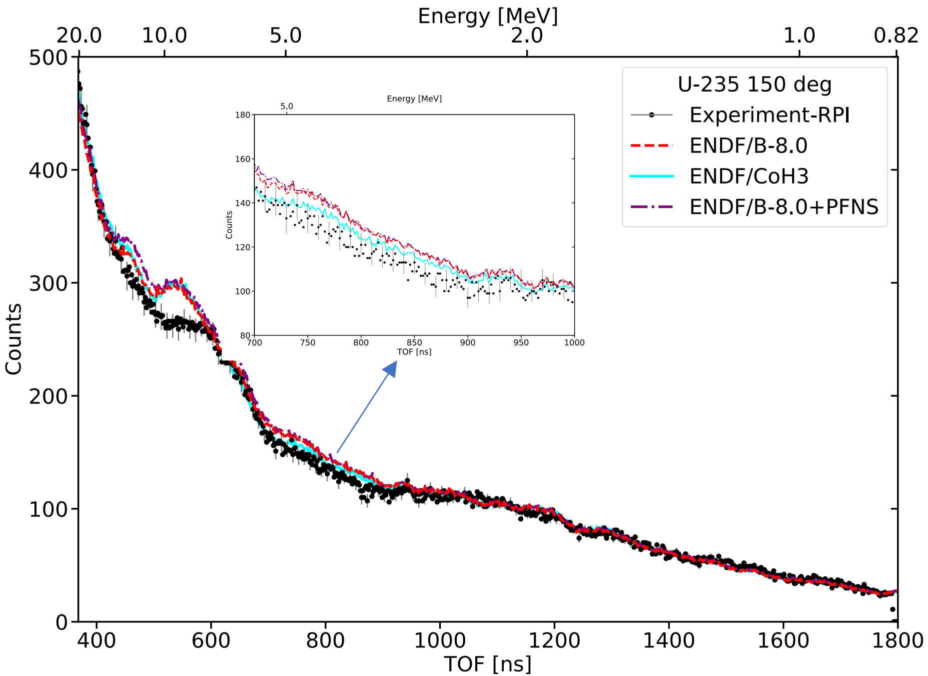

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Lessons from RPI data simulations

- CoH improves the agreement with data around 5 MeV
- Angular distributions (n,el), (n,n'), (n,2n), PFNS
  - (n,n'): we could tweak Kalbach parameters to see the effect on modeling the RPI data
  - PFNS angular distribution: above 12 MeV, the pre-equilibrium sets in, and the pre-equilibrium neutrons emitted before fission are peak forwarded, which is not taken into account in the current evaluation. This needs a more involved revision of the PFNS evaluation to isolate the pre-equilibrium component.
- Formatting issues
  - The more exclusive processes cannot be captured in the limited ENDF-6 format

Summary

- Light nuclei
  - Preliminary work extends the evaluation from 6.5 MeV to ~ 10 MeV
- ^{139}La: delivered full evaluation in fast region to ORNL, including covariances
- ^{235}U: RPI data simulations
  - Performed simulations and showed some improvement for neutrons below 5 MeV
  - Some of the changes needed for more improvement might not be supported by the current format
  - Some of the changes above 12 MeV to account for the angular distribution of pre-equilibrium neutrons require a change in the PFNS evaluation procedure

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