FPY Evaluation at LANL

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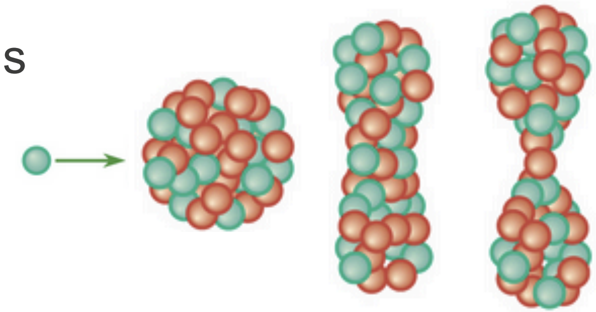
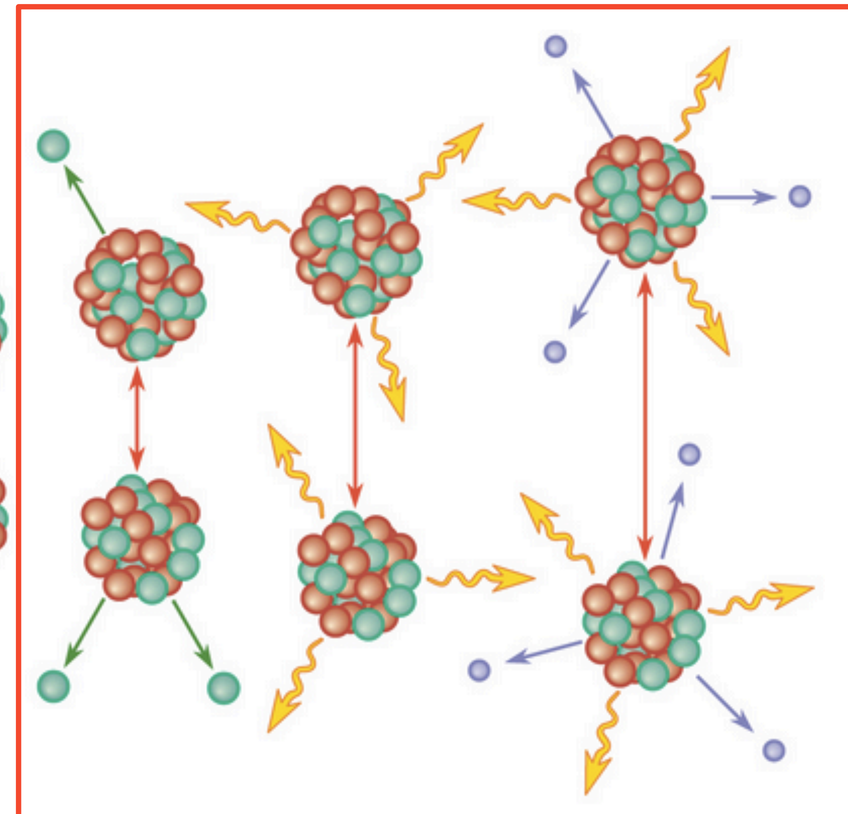
BeoH has can now be used to calculate multi-chance fission

BeoH – the LANL-developed (T. Kawano) deterministic fission fragment decay code – has been extended for multi-chance fission calculations.

The decay of fission fragments is followed through both prompt and delayed emission.





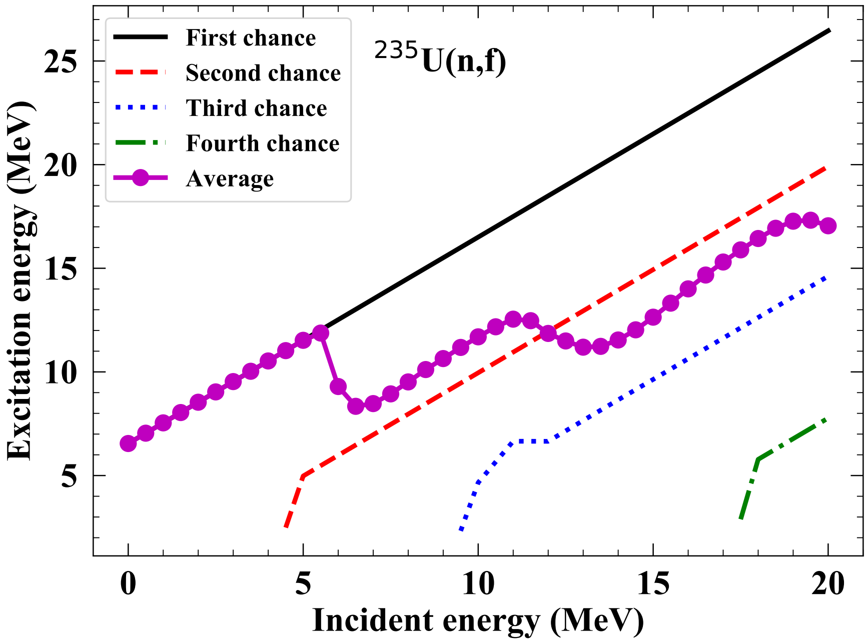
In this way, low-yield observables are calculated to the same accuracy as high-yield observables.

arXiv:2010.13919v1 [nucl-th] 26 Oct 2020 (*PRC*, in review)

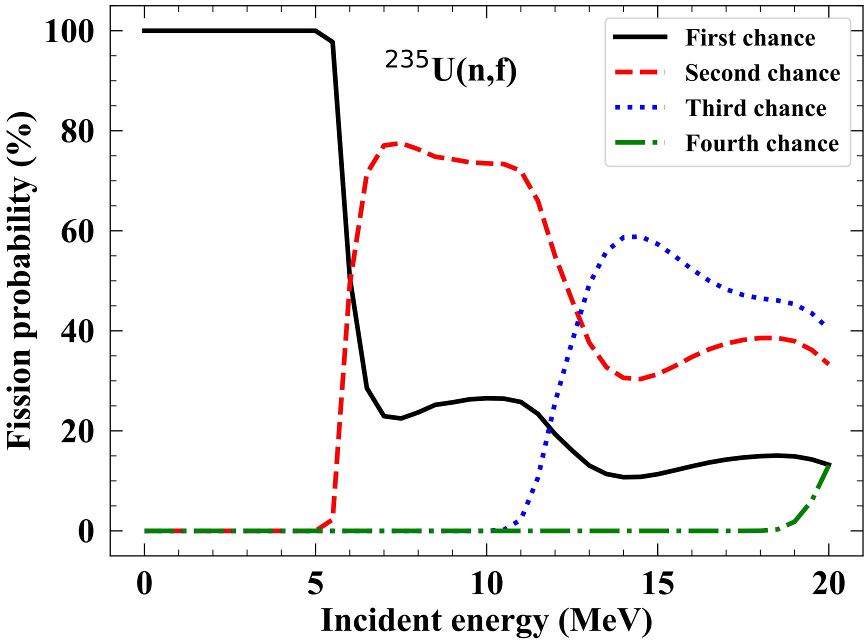
Pre-scission calculations are taken from CoH

Most probable excitation energy causing fission

$$\langle E_f \rangle(m) = \frac{\int \sigma_f(m, E_x) E_x dE_x}{\int \sigma_f(m, E_x) dE_x}$$

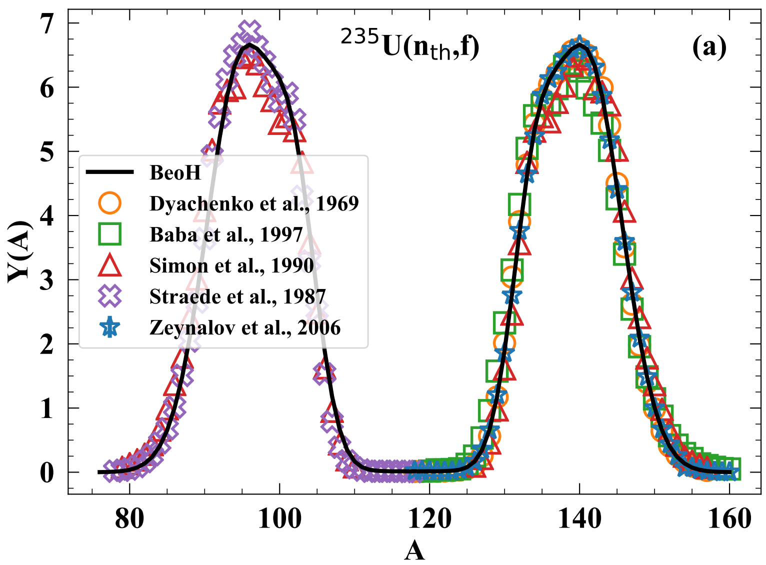


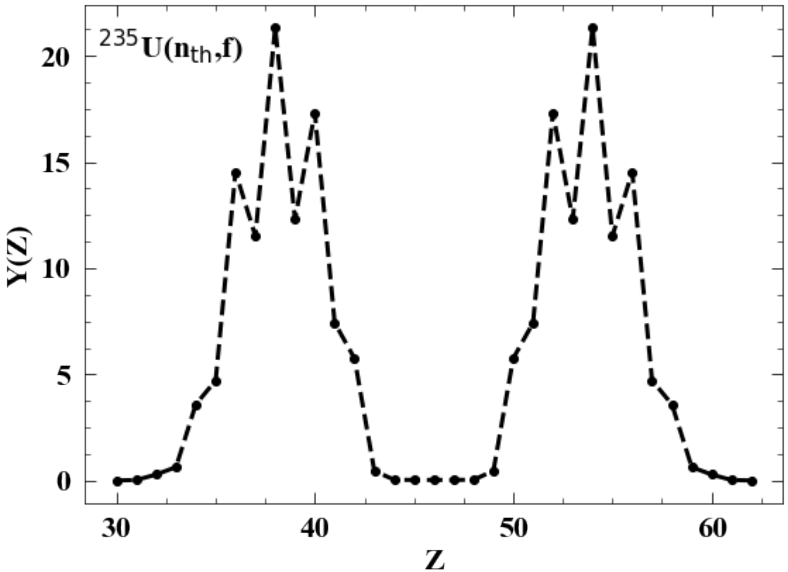
Fission probabilities (fission barriers and level densities can be fit to cross sections)



Fission fragment initial conditions are parametrized and fit to available experimental data, Y(A,Z,TKE,J,π)

Mass yields, Y(A), are taken to be a sum of Gaussians; each weight, mean, and standard deviation is a function of incident energy (similar to CGMF/FREYA/etc.).

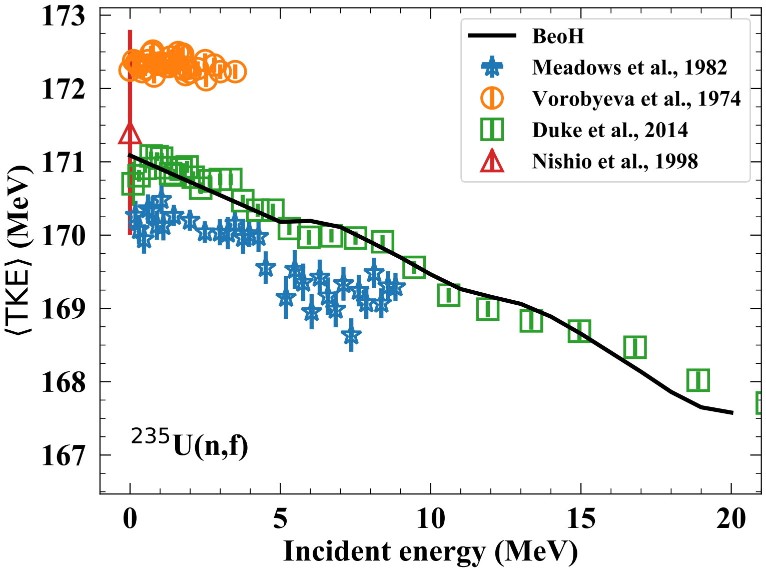




The Wahl systematics are used to calculate the charge distribution, Y(Z|A).

Fission fragment initial conditions are parametrized and fit to available experimental data, Y(A,Z,TKE,J,π)

<TKE>(E_{inc}) was parametrized to reproduce the shape of the data of Duke, et al., up to E_{inc}=20 MeV.
<TKE>(A) is Gaussian, with the means and widths fit to data as a function to mass.



The spin distribution is proportional to the available states in the level density formula, with an adjustable scaling factor on the spin cut-off parameter, f.

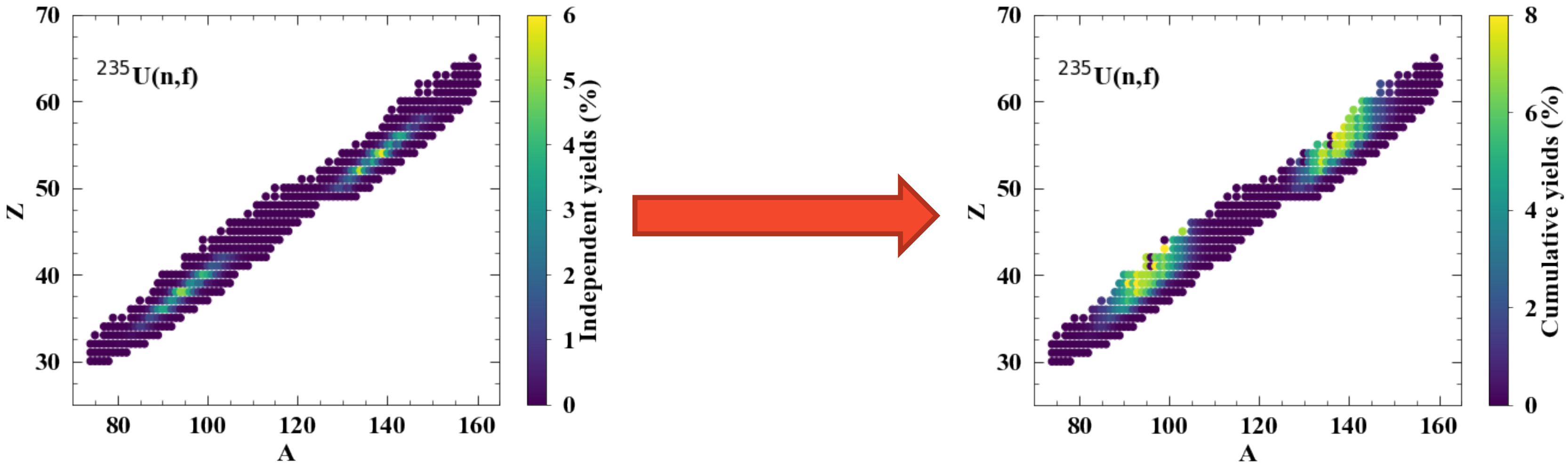
$$R_{l,h}(J) = \frac{J+1/2}{f^2\sigma_{l,h}(U)} \exp\left\{-\frac{(J+1/2)^2}{2f^2\sigma^2_{l,h}(U)}\right\}$$

Positive and negative parities are taken to be equally probable.

Calculating independent and cumulative yields

Once the initial conditions of each fragment are determined, the Hauser-Feshbach statistical decay is performed for each fission fragment.

Then, a time-independent calculation is performed, using decay data library information (from ENDF/B-VIII.0) to calculate the cumulative yields from the independent yields. Isomeric states are kept track of for the independent and cumulative yields.

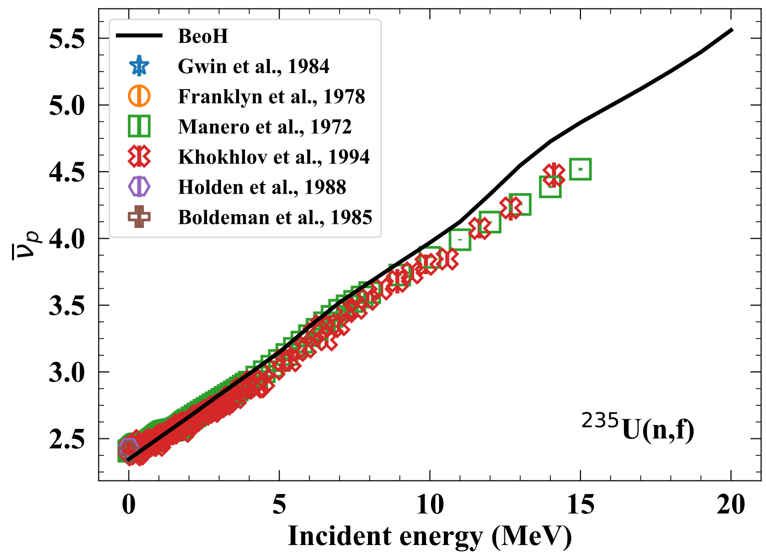


Further optimization is underway

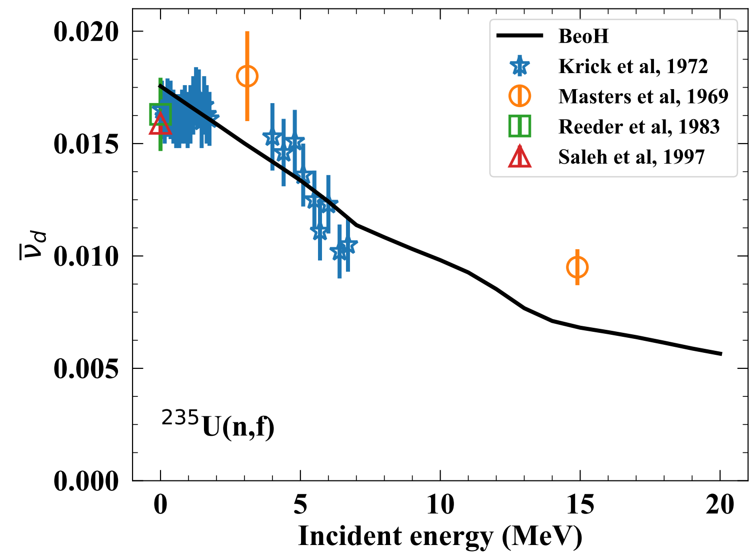
- ^{235}U(n,f): optimization at thermal to cumulative mass yields with low uncertainties (from the England and Rider evaluation), along with prompt and delayed $\bar{\nu}$.
  - A Kalman filter was written to optimize these parameters, which is general enough to be used for further optimizations (including energy dependence and for other observables/isotopes).
  - Gaussian Process emulators are being investigated to cover a larger parameter space and explore highly correlated parameters.
- Bulk parameter studies are underway (covering the spread in experimental TKE, explore excitation energy sharing, etc.).
- S. Okumura (IAEA) has been working on optimization of ^{235}U, ^{238}U, and ^{239}Pu below second-chance fission.

Prompt and delayed neutron observables can be calculated

Average prompt neutron multiplicity



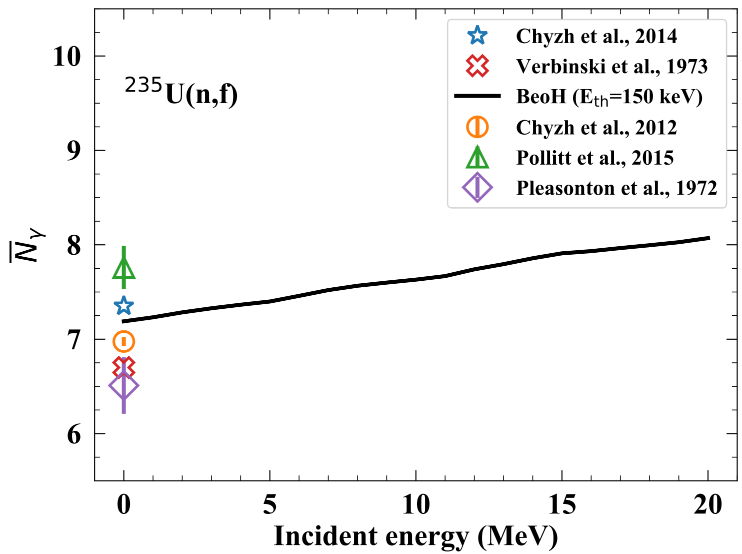
Average delayed neutron multiplicity



There is good agreement between the BeoH calculations as a function of incident energy and the experimental data but still room in the model space for improvement

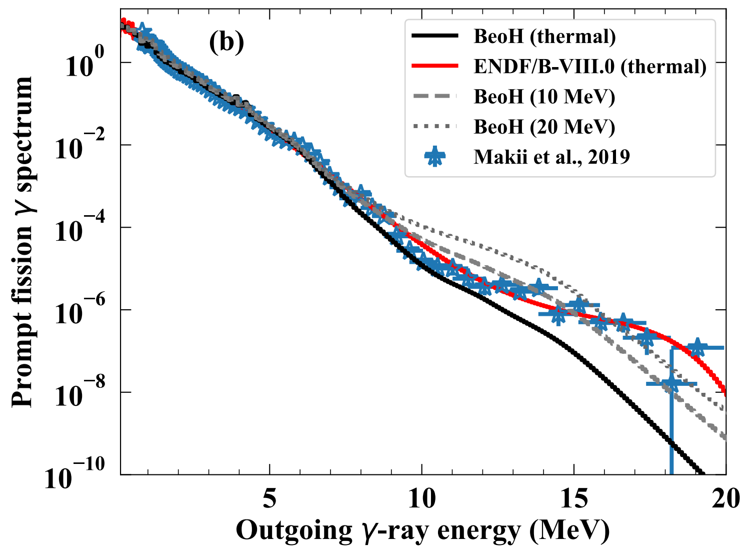
Prompt γ-ray observables can be calculated

Average prompt γ-ray multiplicity



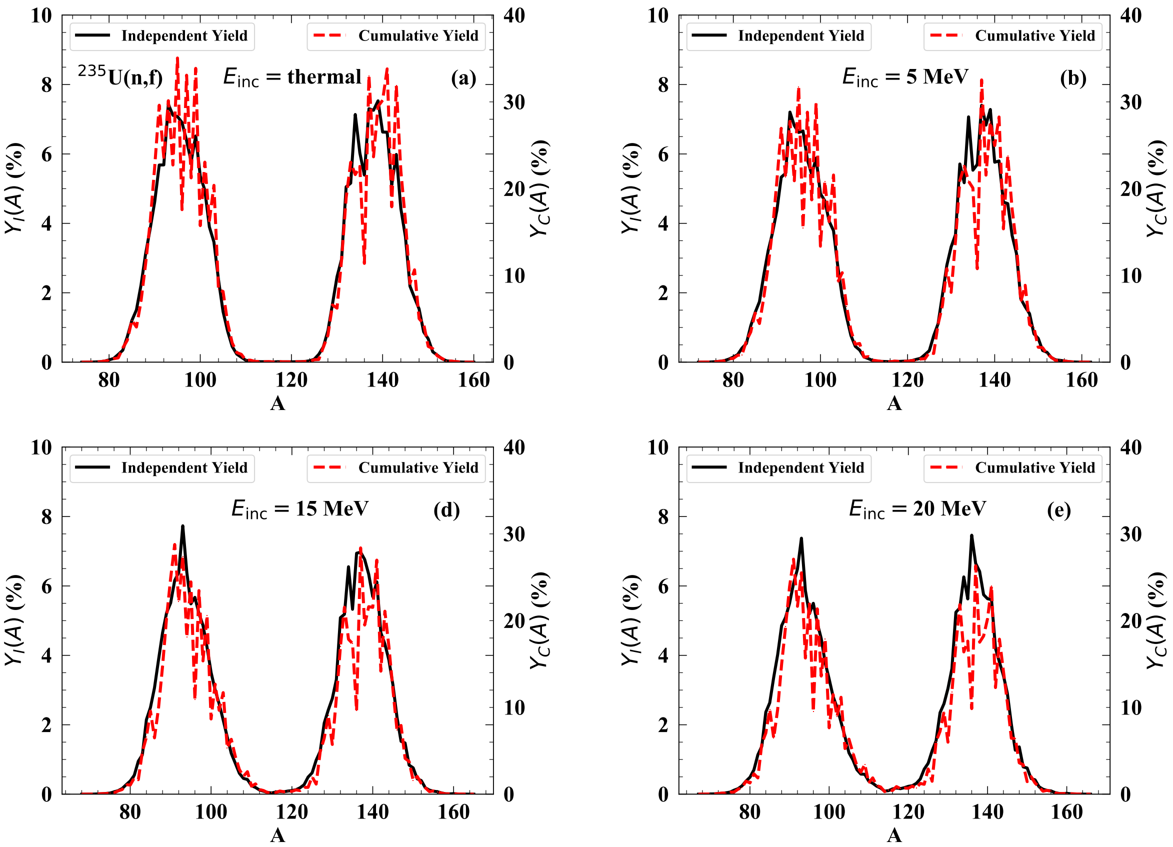
Experimental energy cut-offs can be included, for better comparison to data

Prompt γ-ray energy spectrum



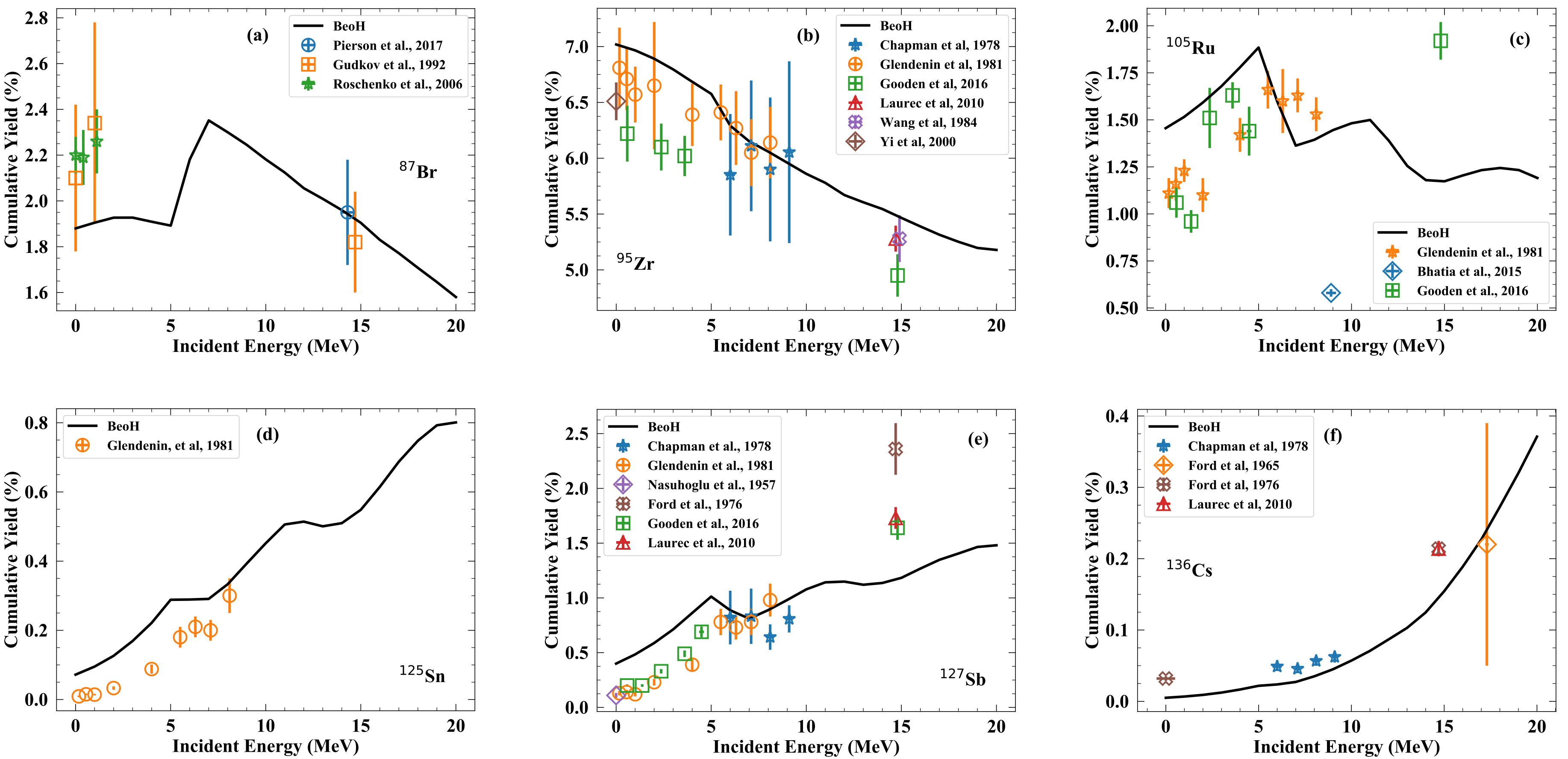
Using BeoH, we can see trends in the tail of the spectrum as the incident energy increases (not currently included in ENDF/B-VIII.0)

Independent and cumulative mass yields are calculated



Both independent and cumulative yields show changes as the incident neutron energy is increased

Cumulative fission product yields show good agreement between BeoH and data



Summary

- BeoH (T. Kawano, deterministic Hauser-Feshbach fission fragment decay code) has been expanded to be able to calculate multi-chance fission for the fission product yield evaluation work
- A combination of pre-scission input (from CoH) and post-scission input (parametrized yields) are used as initial conditions to perform the Hauser-Feshbach decay to calculate prompt neutron and γ-ray observables (multiplicities, energy spectra, independent yield)
- A time-independent calculation of the delayed emission is performed to calculated the cumulative fission yields
- The results compare well with data, but further optimizations of the input are underway