LANL Evaluation Progress in FY 2020

NUCLEAR CRITICALITY SAFETY PROGRAM (NCSP) TECHNICAL PROGRAM REVIEW

M. Paris and I. Stetcu

ND Group T-2

LANL ND1 (Nuclear Data Evaluation and Testing)

Managed by Triad National Security, LLC for the U.S. Department of Energy's NNSA

Outline

- Light-element work (M. Paris)
  - n+^{9}Be evaluation work
  - n+^{9}Be benchmarks & testing
- Evaluation of minor actinides (I. Stetcu)
  - ^{234,236}U(n,x) reactions

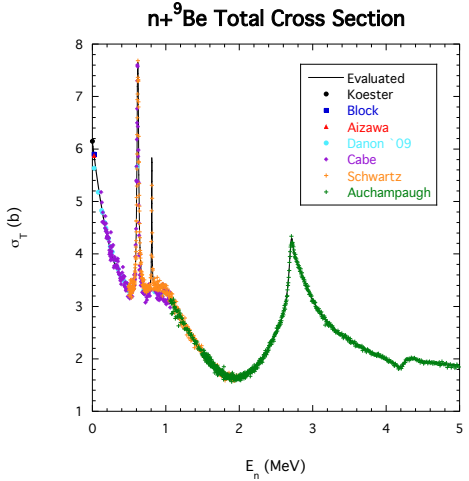
n+^{9}Be
New evaluation

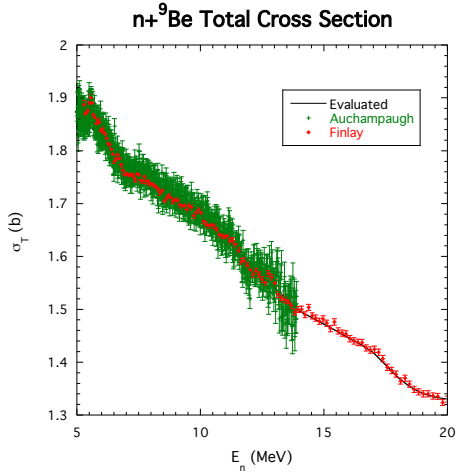
- Added data: elastic, (n,α), (n,n$_1$)

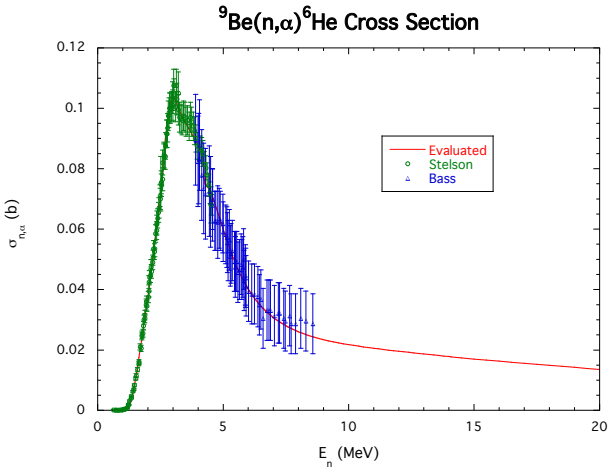
Channel	a_c(fm)	$\ell_{\max}$
n+^{9}Be($\frac{3}{2}^-$)	4.67	3
^{4}He+^{6}He(0^+)	5.00	4
$(nn)_0$+^{8}Be(2^+)	5.20	3
n +^{9}Be*($\frac{5}{2}^-$)	5.20	1

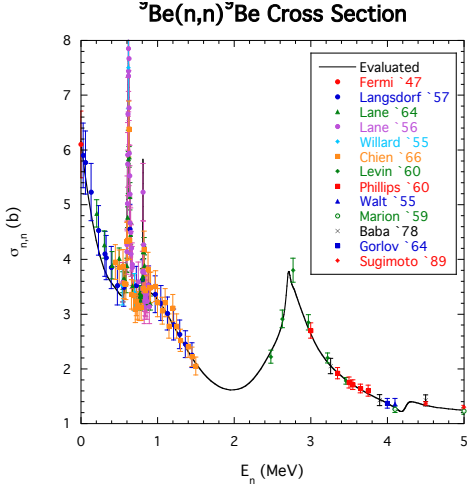
Process	E_n range	Observables	$N_{\rm dat}$	$\chi^2/N_{\rm dat}$
^{9}Be$(n,n_0)^{9}$Be	(1.25 eV, 15.4 MeV)	$\sigma_{\rm tot}, \sigma, \sigma(\theta), A_y(\theta)$	5782	1.65
^{9}Be$(n,^{4}$He$)^{6}$He	(0.63, 8.5) MeV	$\sigma, \sigma(\theta)$	178	1.40
^{9}Be$(n,2n)^{8}$Be	(1.8, 14.7) MeV	σ	40	NA
^{9}Be$(n,n_1)^{9}$Be*	(2.7, 5.0) MeV	$\sigma(\theta)$	83	1.65
Total			6083	1.75

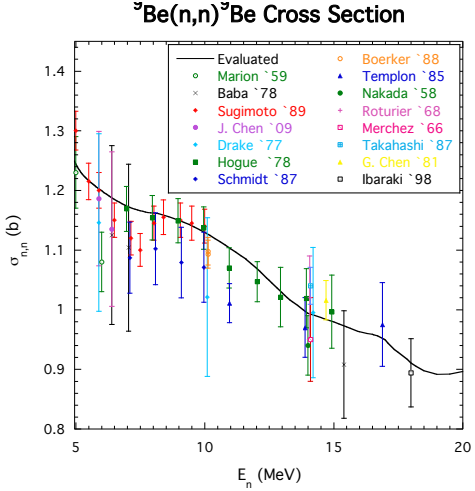
n+^{9}Be Integrated Cross Sections

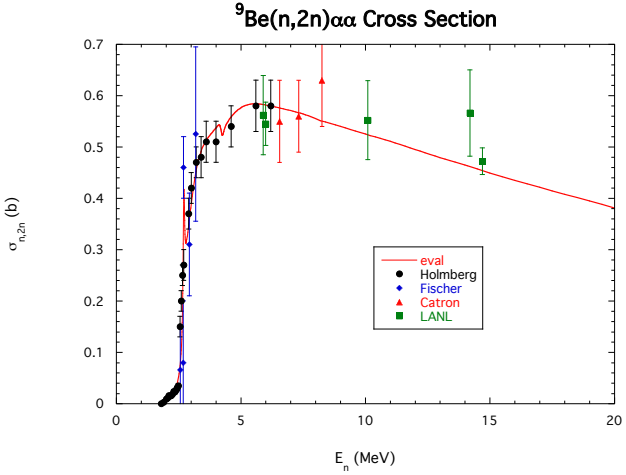




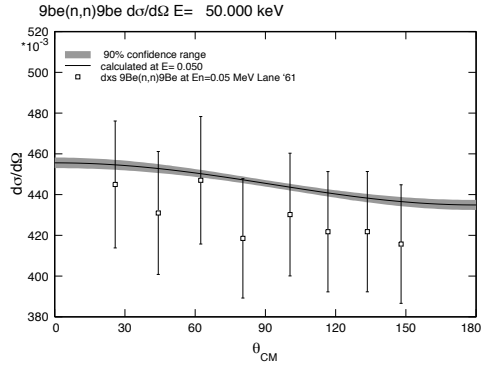


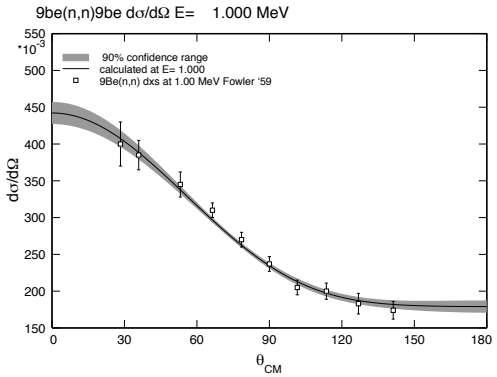


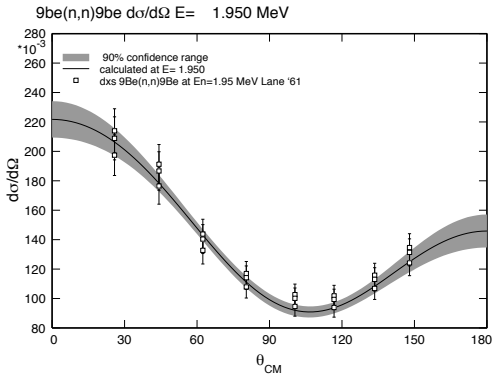


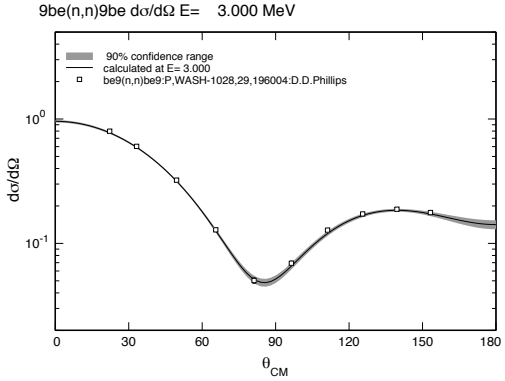


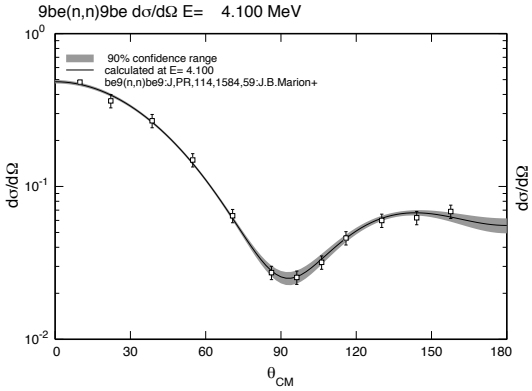
$^{9}Be(n,n)^{9}Be$ Differential Cross Sections

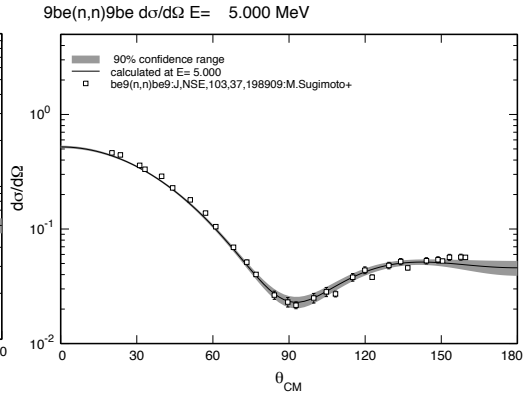




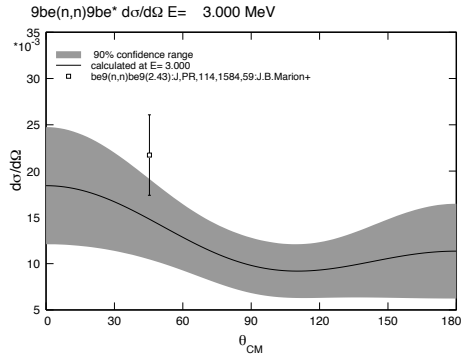


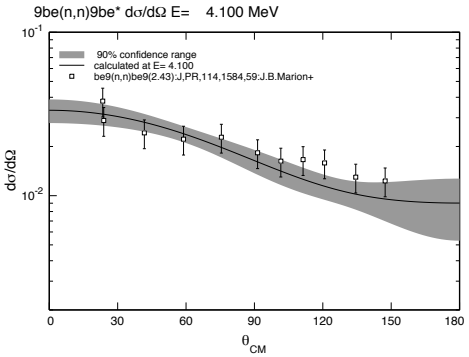


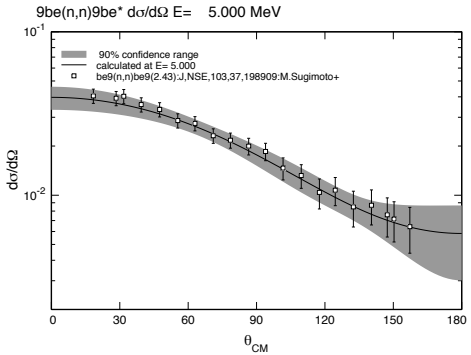




$^{9}Be(n,n_2)^{9}Be^{*}$ Differential Cross Sections



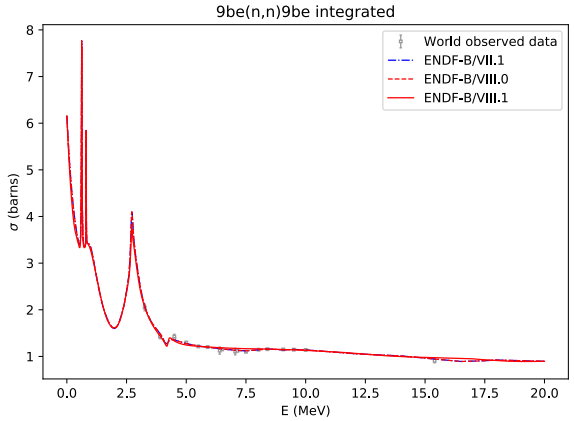


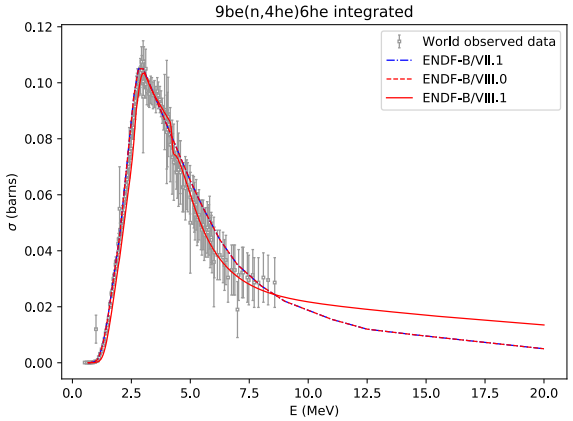


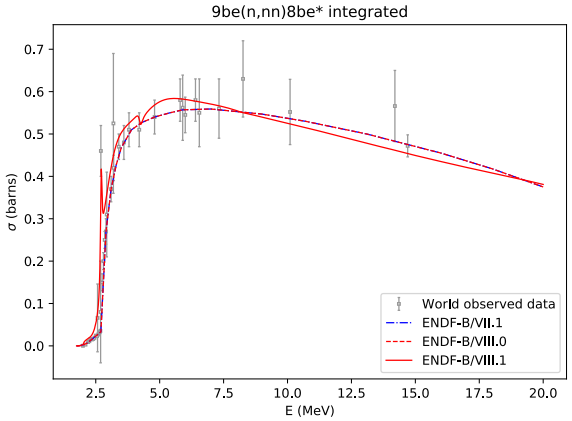
Summary of new evaluation:

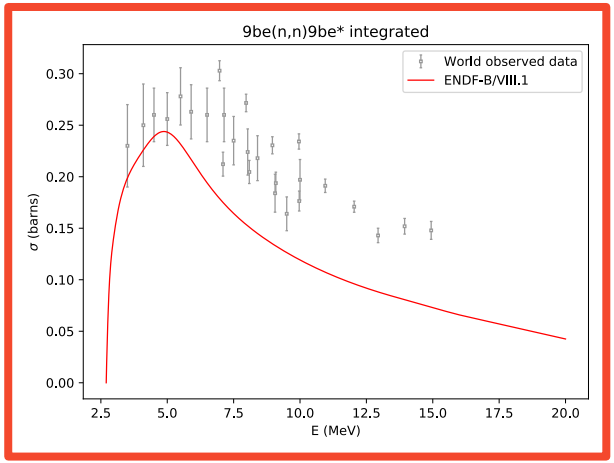
- ^{10}Be analysis has produced a consistent set of cross sections and angular distributions that are in agreement with most of the experimental data at energies up to 5 MeV. Extensions above that energy were based on the experimental data alone.
- Level assignments for the overlapping resonances near E_n=2.7 MeV have the opposite parity ($4^-,3^+ \rightarrow 4^+,3^-$).
- Excited states of ^{9}Be make important contributions to the (n,2n) cross section (MT=16 → 24 in the new evaluation).
- Testing/benchmarking: @LANL and thick-target angular neutron yields (Y. Danon, RPI) on the following slides

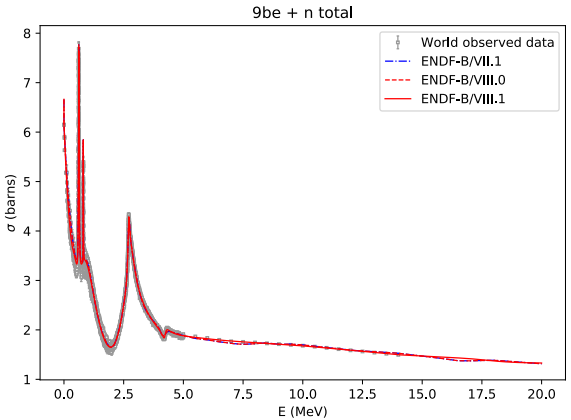
Comparison to previous ENDF/B
Integrated cross sections





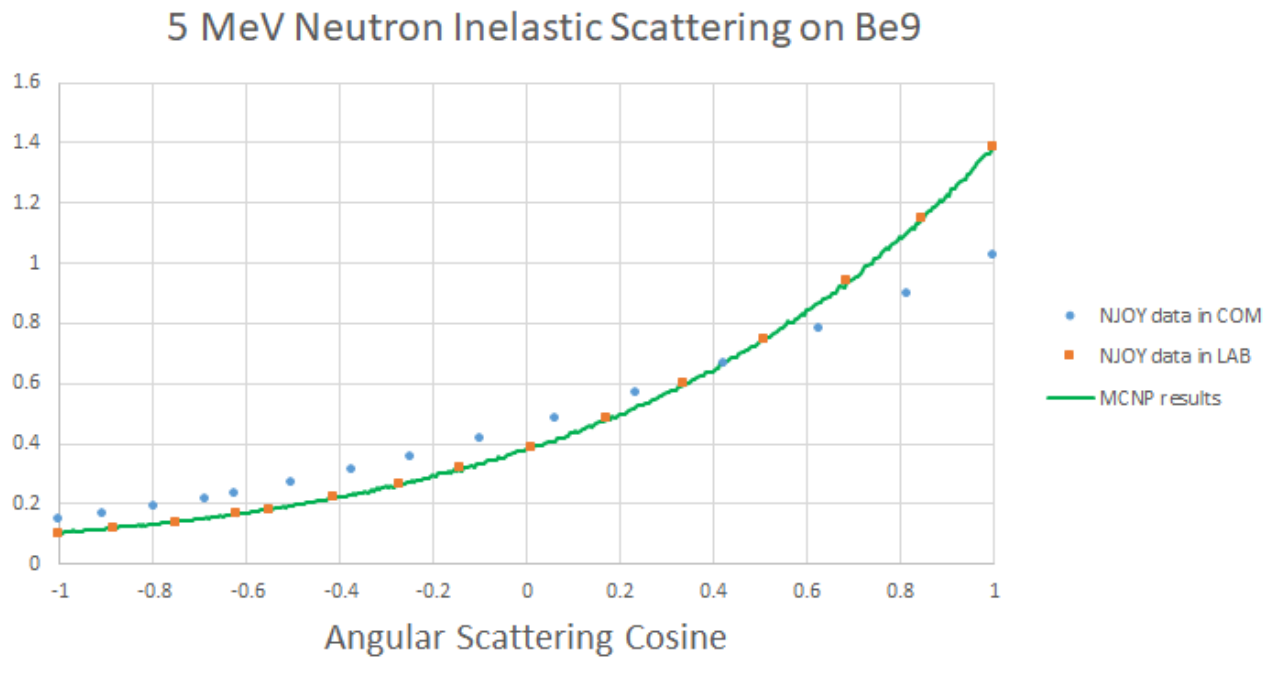






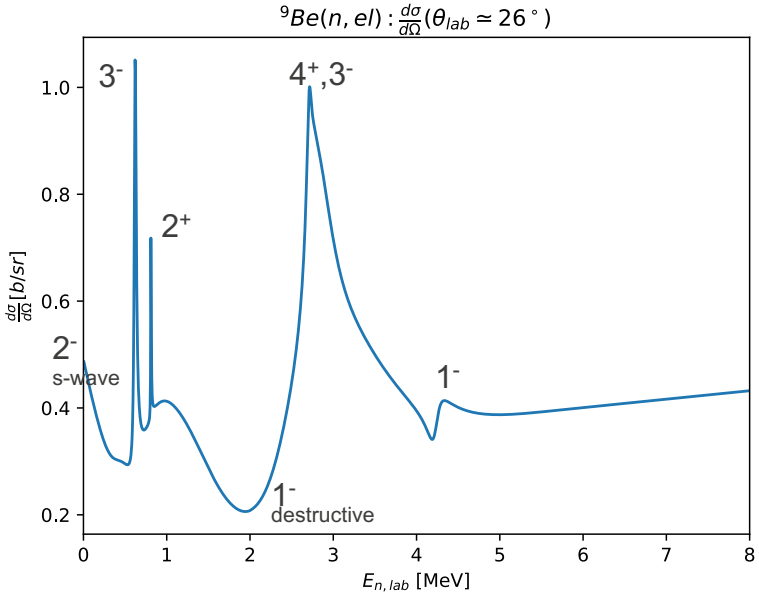
Testing/benchmarks
Pencil-beam study

- MCNP simulation **`MF=6 MT=52`** (inelastic) (K. Parsons/LANL)

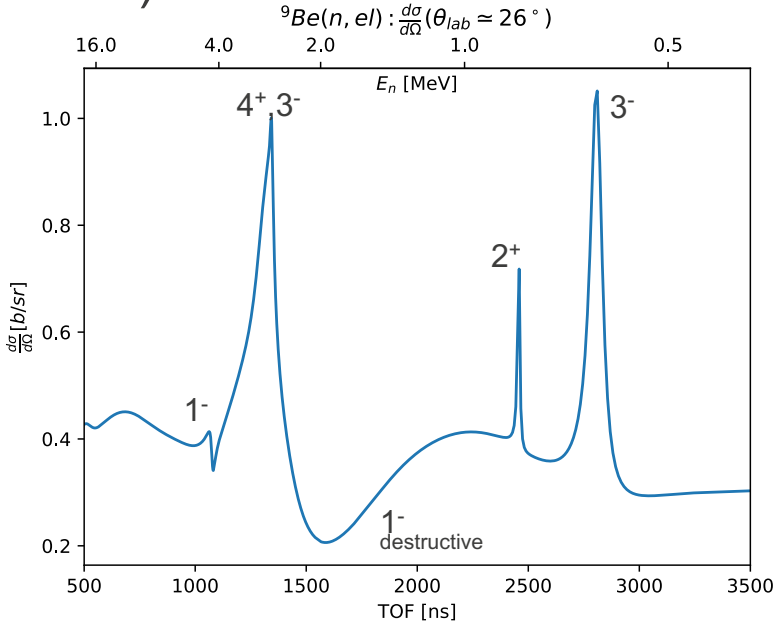


Testing/benchmarks
Lab spectra

- Theoretical model expectation (G. Hale/LANL)



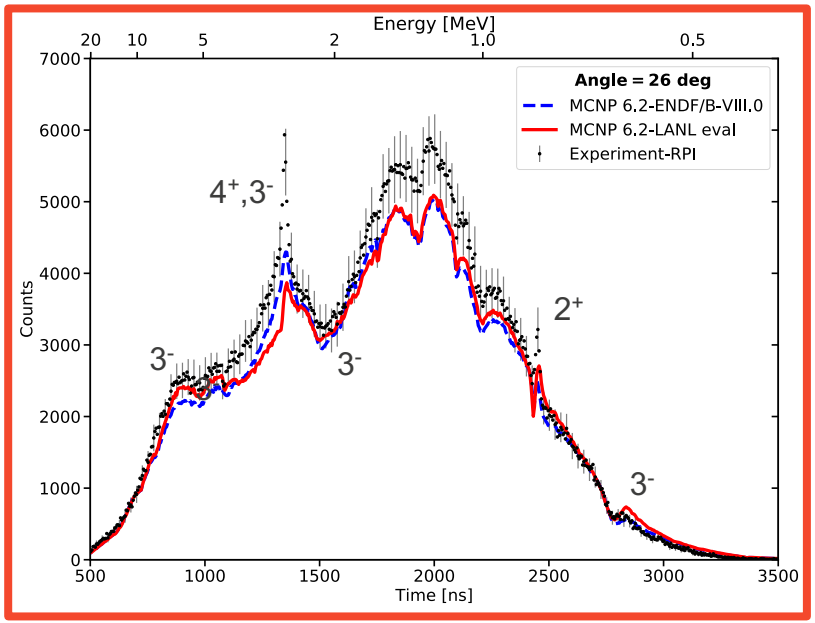
Lab elastic diff. scattering cross section *excitation function* (b/sr) at 26° as a function of E', the outgoing lab neutron energy (MeV).

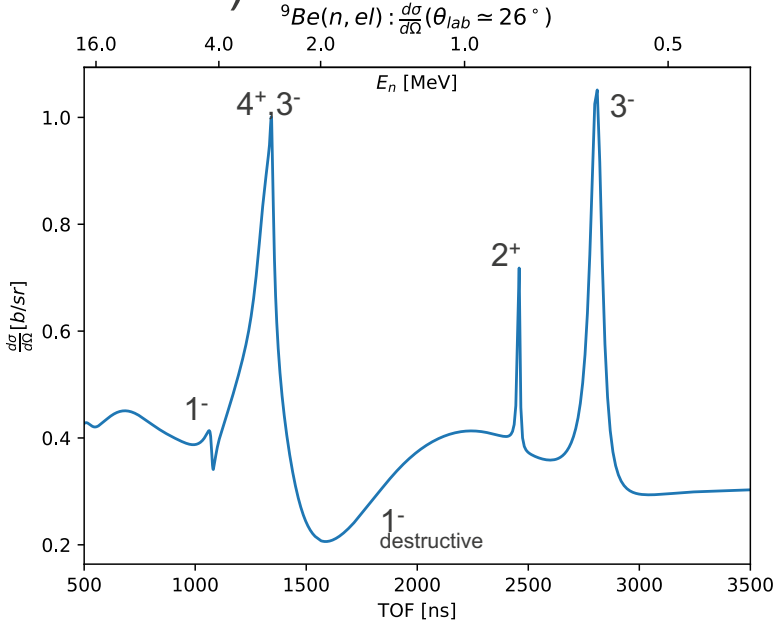


Outgoing neutron TOF spectrum at 26° vs. **t= 2236/sqrt(E')** in ns. Incident energy (top axis), the first two resonances give structures at about 2400 and 2800 ns.

Testing/benchmarks
Lab spectra

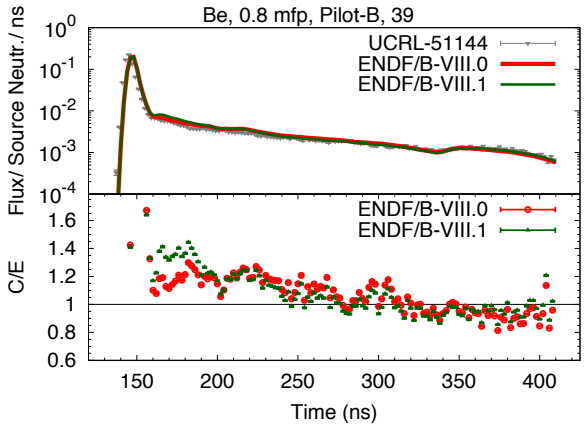
- Quasi-integral simulation in MCNP (Y. Danon/RPI)

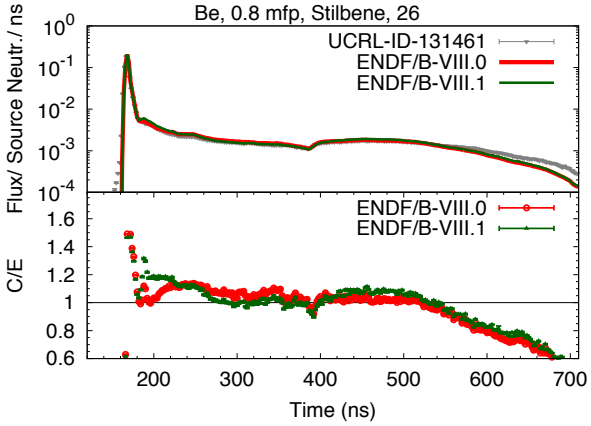


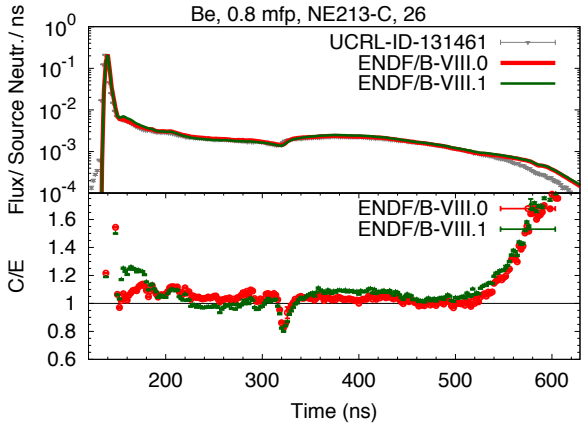


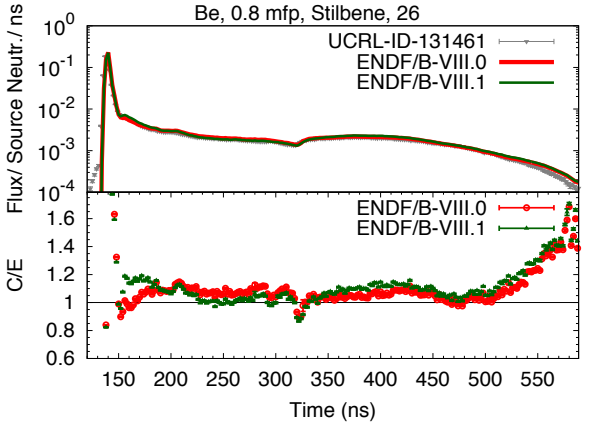
Outgoing neutron TOF spectrum at 26° vs. **t= 2236/sqrt(E')** in ns. Incident energy (top axis), the first two resonances give structures at about 2400 and 2800 ns.

Testing/benchmarks
Pulsed Be spheres









- MCNP simulations (D. Neudecker/LANL)
  - Due to change (n,2n) & (n,n') evident near elastic peak
  - (n,2n) should probably be (has not been) reduced by (n,n')

Evaluation of minor actinides (I. Stetcu)

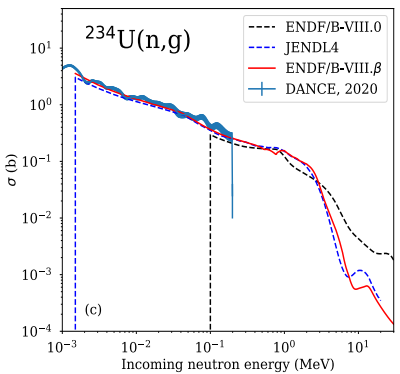
Evaluation of minor actinides: summary of changes

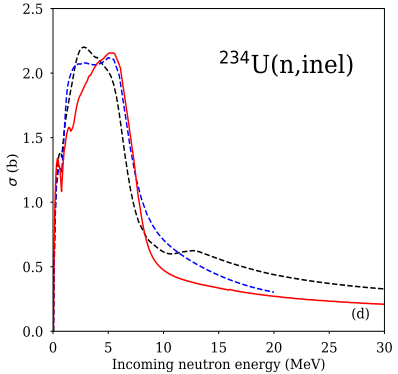
- Cross sections for all open channels reevaluated based on CoH_3 calculations
- CoH_3 tweaked to reproduced the evaluated fission cross sections
  - ^{234}U fission cross section re-evaluated to include Tovesson data
  - ^{236}U fission cross section from ENDF/B-VIII.0 has been preserved
- LSSF flag has been set to 1, the URR parameters will be used for self shielding only, pointwise cross sections in file 3.
- Updated angular distributions
- Adopted the JENDL4.0 PFNS and its covariance for both $^{234,236}U$
- Reevaluated the cross section covariances for all channels based on a Kalman filter
- Nubar is the same as in ENDF/B-VIII.0
- Some capture parameters calibrated for the $^{238}U(n,g)$ reaction
- The goal for this evaluation did not include using consistent parameters for all U isotopes. A different study has been pursued with the goal of determining consistent parameters for all U isotope suite.

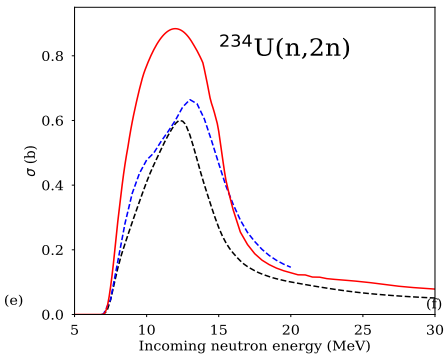
✓ Evaluation files submitted to NNDC

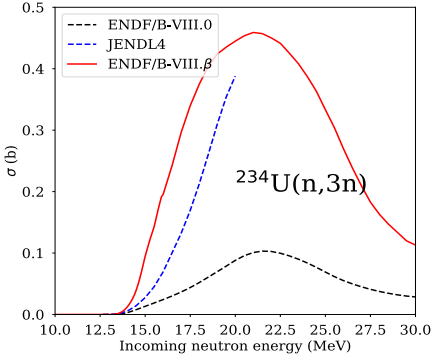
^{234,236}U

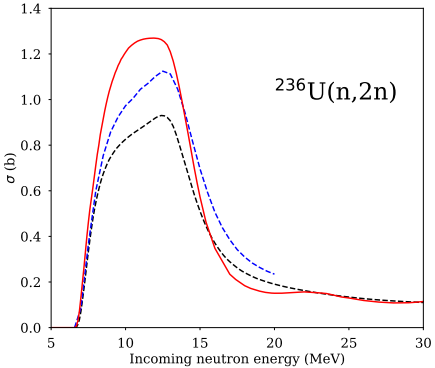
- The final analysis of the capture data is still not available for ^{234}U
- Preliminary analysis shows that the capture resonance parameters need to be updated
- Significant changes in some channels with respect to ENDF/B-VIII.0
- No significant changes in the fission cross section

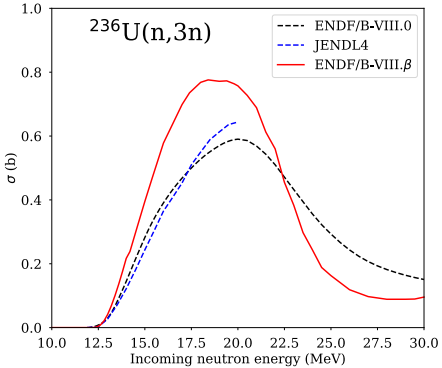






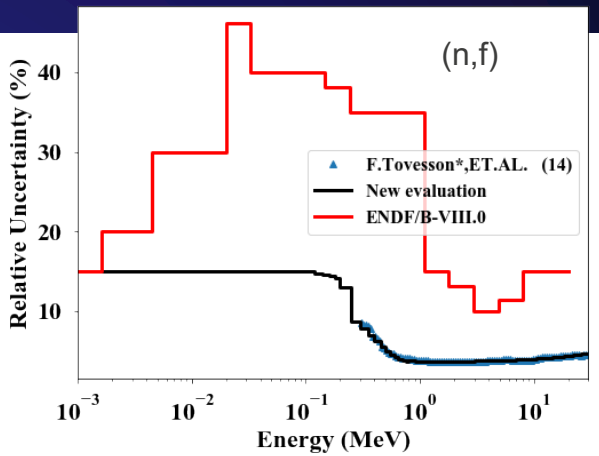


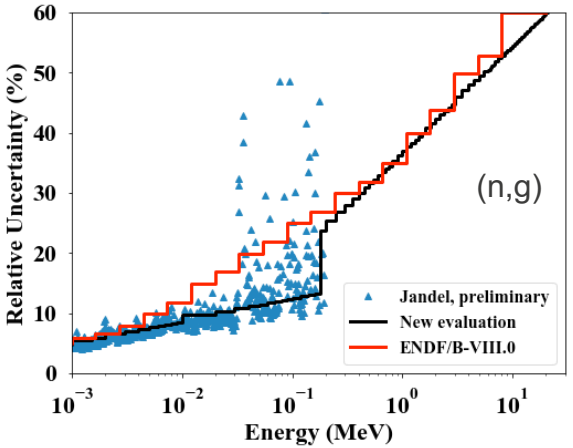




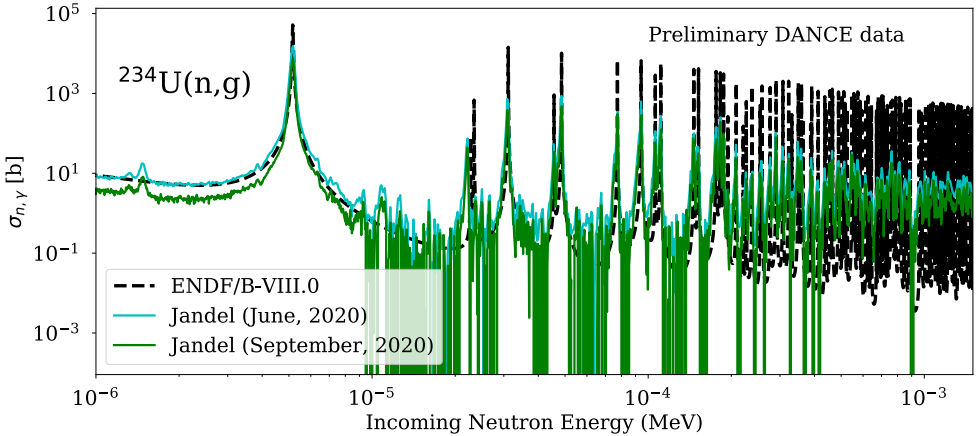
Covariances ^{234}U

- All correlations between the incident energies are taken from a Kalman filter calculation, based on experimental uncertainties/correlations and CoH_3 sensitivity calculations
- ***Fission:*** the shape of the uncertainties for the fission cross section are fit to Tovesson above 300 keV and are scaled to match the ENDF/B-VIII.0 uncertainties at 1 keV.
- ***Capture:*** The uncertainties are fit to the preliminary DANCE uncertainties below 200 keV using a log function. Above 200 keV, the uncertainties are fit, again to a log function, to reproduce the uncertainties in ENDF/B-VIII.0.
- ***Total:*** The shape of the uncertainties is kept from the Kalman filter calculation below 20 keV and above 20 keV, the magnitude is kept at the value of the relative uncertainty at 20 keV. The magnitude of the uncertainties from Kalman are scaled by a factor of two (around 4%).





Data analysis in progress

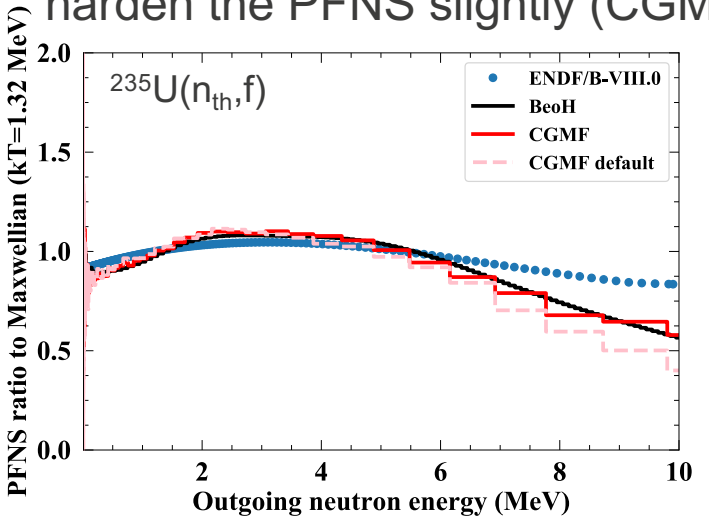


- New and shifted resonances seen in latest analysis

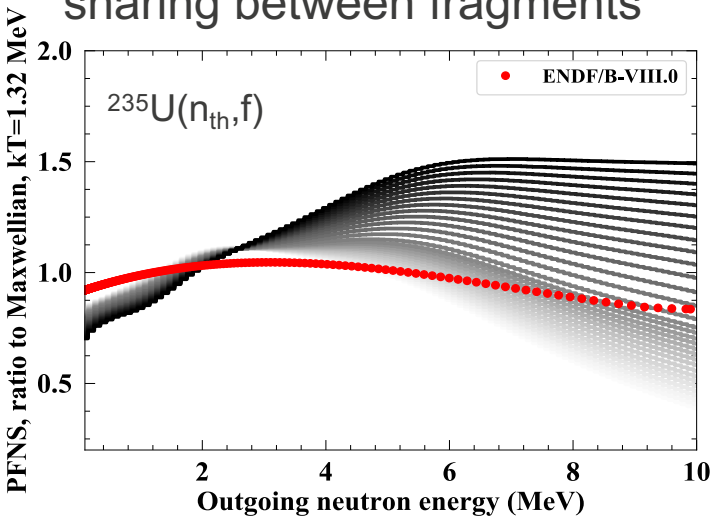
Model investigations into changing the shape of the PFNS

Talk by A. Lovell

Changes to the spin distribution harden the PFNS slightly (CGMF)



Changes to the excitation energy sharing between fragments



Also investigating:

- Optical model potential
- Level densities
- Fission fragment mass yields

The PFNS cannot be changed in a vacuum – the effect on the neutron multiplicity and γ-ray observables must also be taken into account. Having multiple observables narrows down the possible parameter space.

Summary

- Light nuclei: n+^{9}Be new evaluation
  - Includes more complete elastic data; inelastic data – requires improvement
  - Testing/benchmark indicates comparable performance; crit testing: coming
  - New **EDAf90** evaluation code break-up spectra ^{9}Be(n,nn)**αα** under development.

- Actinides:
  - Re-evaluated reaction channels for neutrons on ^{234,236}U (fission special)
  - (Re-)evaluated covariances for all channels based on models and experimental input
  - Investigating how to improve the PFNS

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