AMPX Status

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Outline

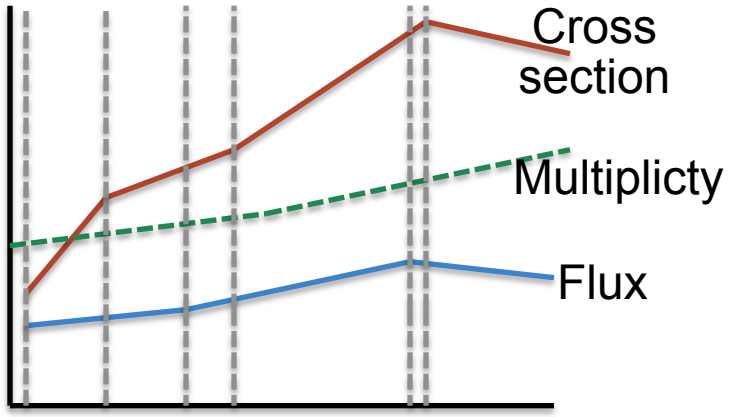
- Improvements in multi-group processing
  - Refactoring of X10 (code to generate MG libraries)
  - Improvements in f-factors
    - Refactoring of code to generate f-factors
    - Add new with-in group f-factors
    - Homogenous and heterogeneous f-factors.
  - Generate new MG libraries for SCALE 6.2
- Process File 35 covariance data (exit energy distributions)
- AMPX modernization plans

Modernized X10 code

- Complete rewrite in C++ to take advantage of
  - In-memory MG library resource (this removes the restriction on maximum number of groups)
  - Integration routines shared within AMPX
  - A SCALE/AMPX class that defines sum rules for redundant cross sections and functions that apply the rules for MG data.
- Apply more rigorous consistency, i.e. 2D are renormalized 1D to avoid numerical problems. (Integration of group-averaged 1D data is analytical, of 2D numerical – see next slide).

Integration in AMPX

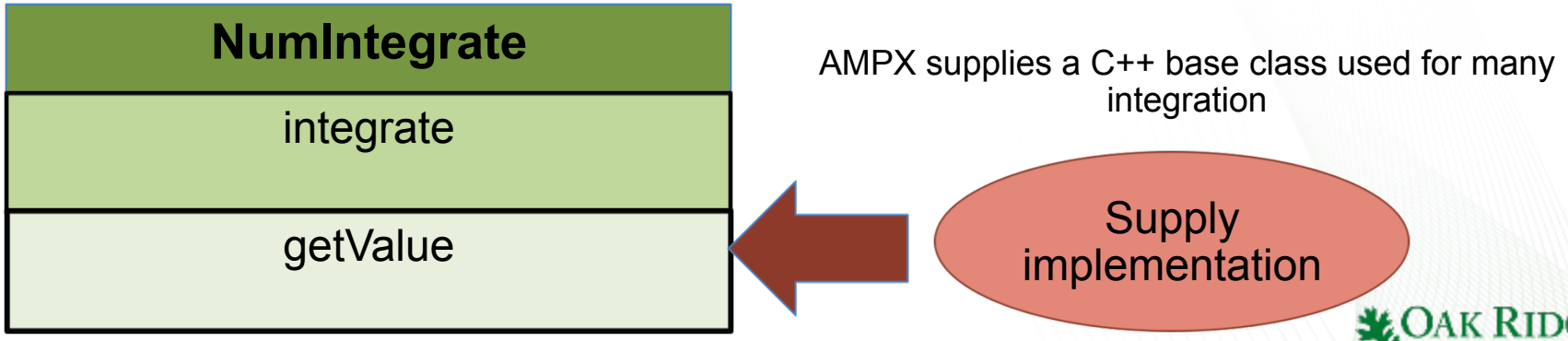
Group averages of 1D data with flux



- Generate a union grid for the data to be integrated.
- On the union grid the integral can be solved analytical if the interpolation is linear-linear.
- If distribution is not linear, we add enough points to make it linear

Integration of other data

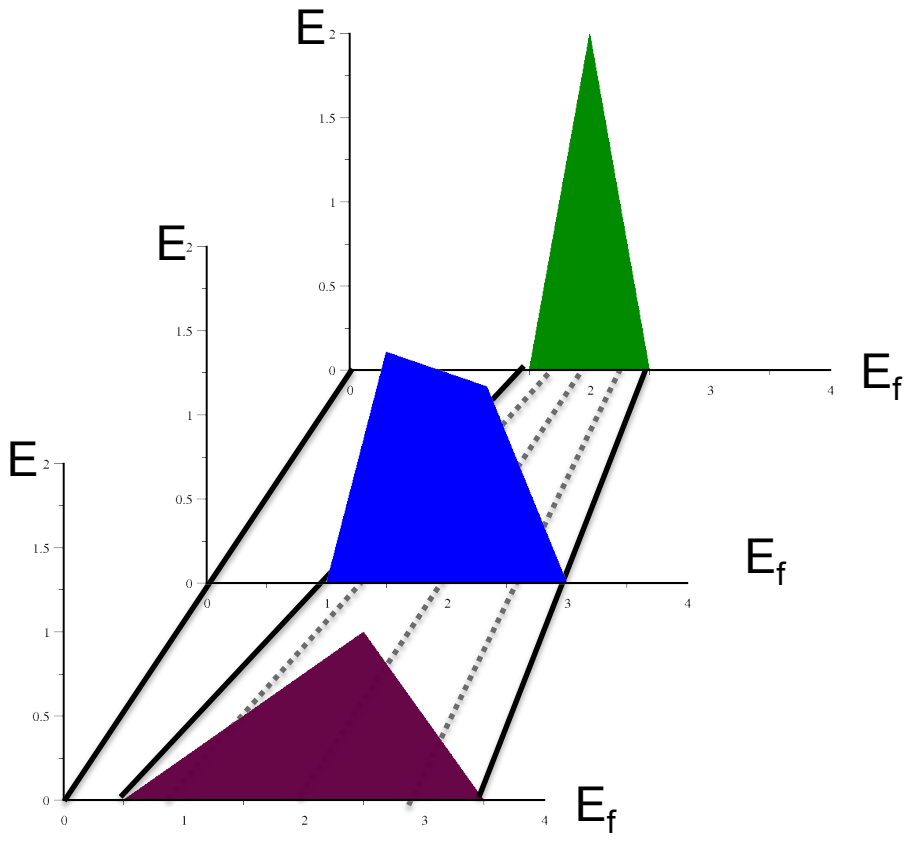
Integrals can be translated into a system of ordinary differential equations. We use a fourth-order Runge-Kutta method with adaptive step size.



Group averaged scattering matrices

$$\frac{1}{\int_{E_1}^{E_2}\varphi(E)dE}\int_{E_1}^{E_2} dEy(E)\sigma(E)\varphi(E)\int_{E'_1}^{E'_2} f_l(\,E,E')dE'$$

Translate outer integral to differential equation and then use fourth order Runge-Kutta.



- Determine energy exit energy range at incident energy E.
- Determine unit based group boundaries in bounding distributions.
- Calculate integral for groups in each bounding distribution.
- For each group interpolate between the two integrals of the bounding distribution.

Modernization of fabulous
used to calculate Bondarenko factors

Calculate problem independent cross section data as a function of background cross section σ_0 and temperature T:

$$\sigma_{x,g}^{(j)}(\sigma_0,T)=\frac{\int_g \sigma_x^{(j)}(E,T)\,\varphi(E,\sigma_0,T)\,\mathrm{dE}}{\int_g \varphi(E,\sigma_0,T)\,\mathrm{dE}}$$

Divide by a reference cross section to get factors

In a shielding calculation, determine desired background cross section and interpolate the factor from tabulated factors

Narrow resonance (NR) approximation

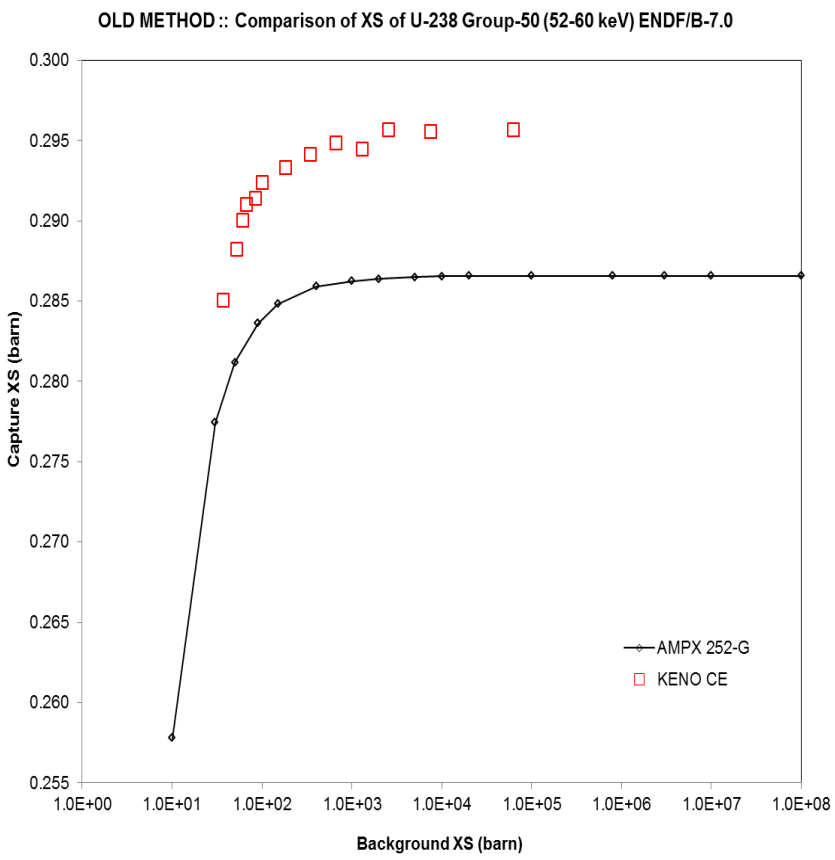
$$\varphi(E,\sigma_0,T)=\frac{\sigma_0\varphi_{ref}(E)}{\sigma_t^{(j)}(E,T)+\sigma_0}$$

Completely rewritten in C++.
All integration are done with subclasses of NumIntegrate
Additional functionality:

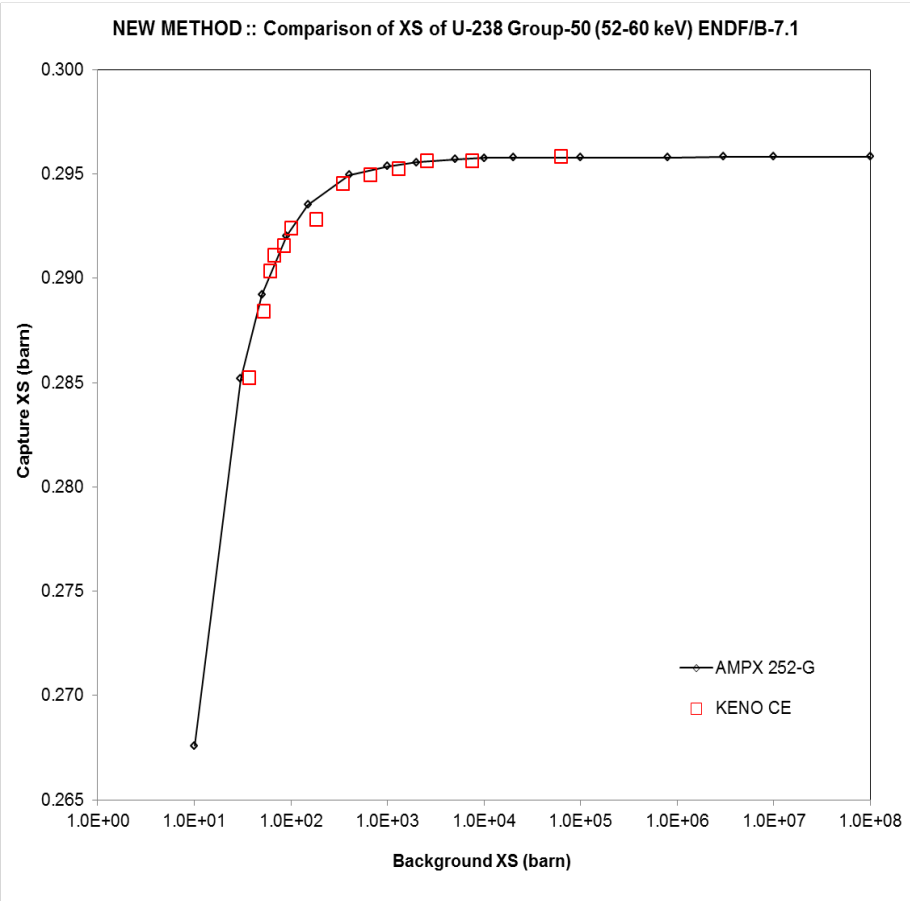
- **Generate NR f-factors in the URR from probability tables**
- **Add f-factors for within-group f-factors (see later slide)**

Generate F-Factors in URR from Probability tables

Prude



Probability table



U-238 multiplies File 2 and File 3 data in the URR

Homogenous F-Factor for Intermediate Resonance Treatment

Our Multi-Group libraries contain homogenous f-factors for nuclides with A>40 in the resolved resonance range. These are intermediate resonance (IR) f-factors. Otherwise NR f-factors are used.

Use modules PMC and CENTRM to calculate a shielded cross section, with a CE flux for a homogenous model

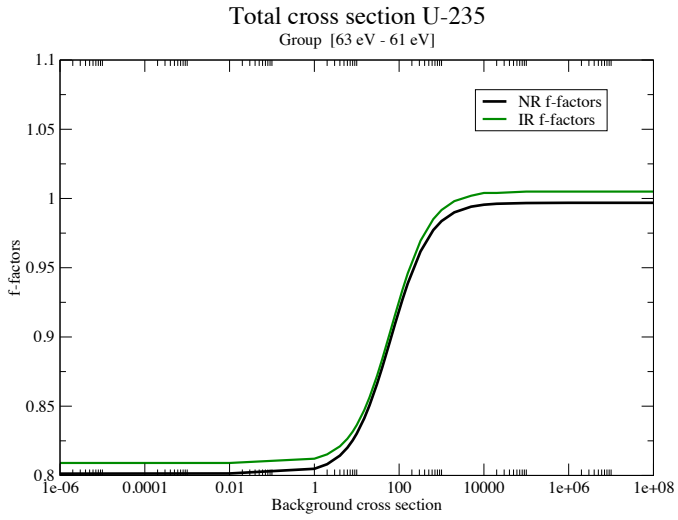
$$\left(\sigma_t^{(j)}(E,T)+\sigma_0\right)\varphi(\mathrm{E},\sigma_0,T)=\int_E^{E/\alpha^{(j)}}\frac{\sigma_s^{(j)}(E',\mathrm{T})\varphi(E',\sigma_0,\mathrm{T})}{(1-\alpha^{(j)})E'}dE'+\sigma_0\int_E^{\infty}\frac{\varphi(E',\sigma_0\,\mathrm{T})}{E'}dE'$$

$1-\alpha^{(j)}$ = the maximum fractional energy loss in an elastic collision with nuclide *j*;

$\sigma_0=\frac{N^{(H)}}{N^{(j)}}\sigma_p^{(H)}$ (the background cross section);

$\sigma_p^{(H)}$ = the potential cross section for hydrogen;

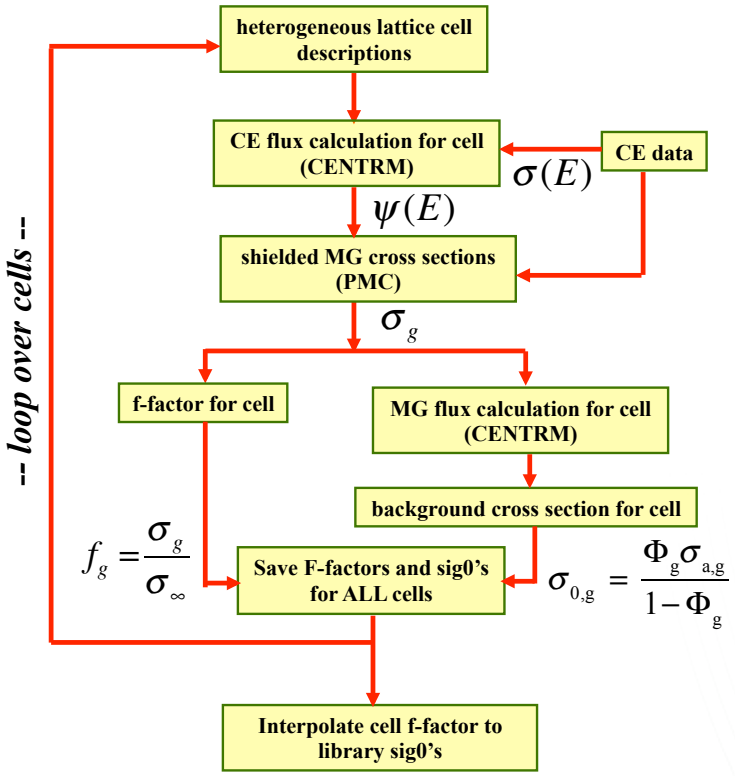
If the desired scattering nuclide is not fissionable, a small amount of U-235 is added to the homogenous model



Heterogenous F-Factor for Intermediate Resonance Treatment

Similar to homogeneous f-factors, but:

- Heterogenous models are now used
- Background cross section can not be determined in advance
- A suite of predefined models is used



Within Group Scattering F-Factors

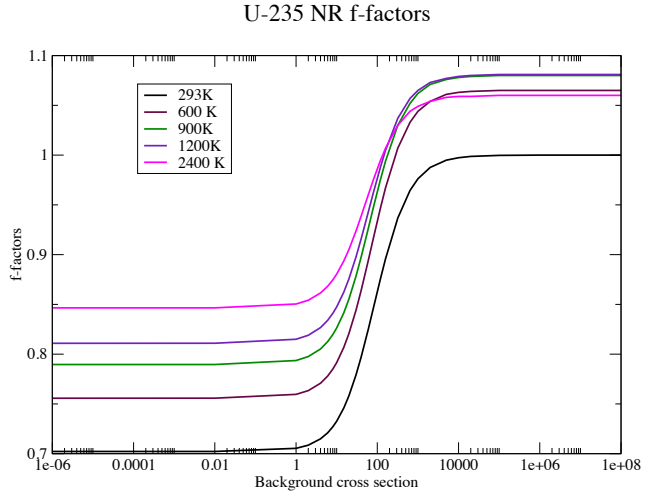
In order to account better for in-group elastic scattering, f-factors (NR and IR) are added to the MG library.

For NR:

- Calculate the diagonal elements of the elastic scattering matrix, using the NR flux and temperature dependent 1D elastic point-data.
- Calculate f-factor using the diagonal element of the elastic scattering matrix as a reference factor, i.e. infinite-dilute flux and 1D elastic at 293K.

For IR:

- The same procedure is used as for other homogeneous or heterogeneous f-factors.
- PMC generates a model dependent scattering matrix.
- Calculate f-factors using the diagonal element of the shielded matrix and the the elastic scattering matrix as a reference factor.



209.5 eV – 207.4 eV

Improvements in Polaris code results due to new within-group scattering cross section

(Matthew A. Jessee)

Polaris is a new lattice physics depletion code

Cross-section processing

- Improved ESSM for resonance treatment
- New resonance self-shielding factors for within-group scattering cross section
- Removed reactivity bias as a function of temperature

PWR BOL Pin cell eigenvalue difference

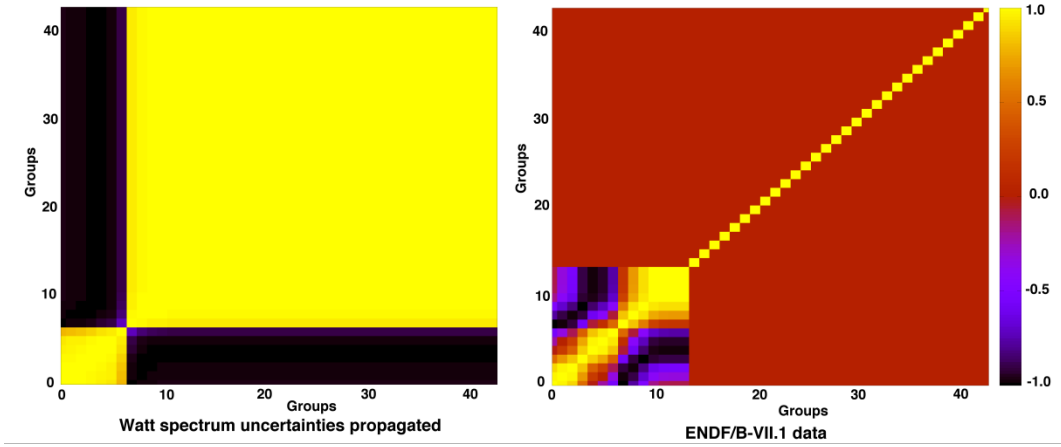
Fuel T (K)	CE-KENO k-eff	Polaris (beta3)	Polaris (beta4)
600	1.18215	-82	-11
900	1.17172	-139	-8
1200	1.16260	-178	-8

Chi Covariance Matrices

- PUFF-IV was updated to process the new covariance matrices to take advantage of the data available in ENDF/B-VII.1
- Previously uncertainties on Watt spectrum parameters where propagated to generate chi-covariance matrices for SCALE
- COVERX format does not allow covariance matrices for more than one incident energy, so we select the covariance matrix for the average energy of fission.

SCALE Covariance library uses all chi-covariance data available in ENDF/B-VII

Additional from JENDL-4.0
Pu-241 U-233 Th-232 Pa-231 Pa-233 U-234 U-236 U-237 Np-237 Am-241 Am-242 Am-243 Am-244

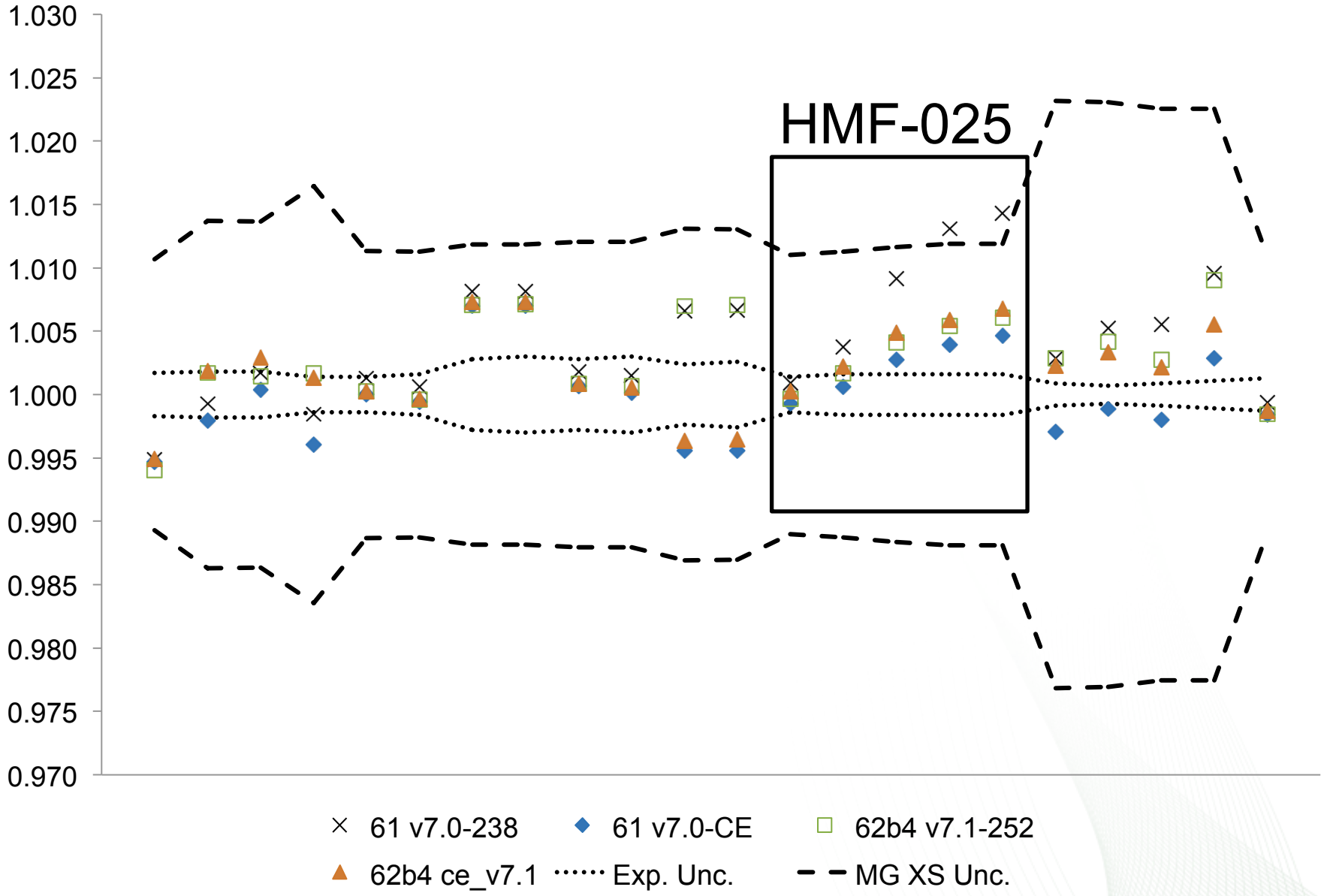


χ-Correlation Matrices for U-235 from ENDF/B-VII.1 and propagated from Watt Spectrum Parameter. 1-D χ is 0 for Groups 15–44.

Generate ENDF/B-VII MG libraries

- New MG libraries using the updated X10 and Fabulous code have been prepared
- Homogenous f-factors for A>40 and heterogeneous f-factors for selected materials are used in the RRR.
  - 252n group library
  - 56n group library
  - 200n47g shielding library
  - 28n19g shielding library
- These libraries are to be released with SCALE 6.2
- New covariance libraries based on ENDF/B-VII.1 for SCALE 6.2 have been prepared.
  - All covariance matrices from ENDF/B-VII.1 have been used
    - h1, u235, and pu239 are preliminary ENDF/B-VII.2 evaluations
  - Additional JENDL-4.0 CHI-covariance matrices
  - For all other nuclides lo-fi data from the previous SCALE covariance library have been used.

Results for HMF cases with new MG Scale libraries



AMPX modernization
What has been accomplished

- Merge with SCALE repository
- Operate under SCALE QA plan
- Operate under SCALE Continuous Integration
- Modernization of Y12 (kinematic data)
  - Reading of ENDF file data for kinematic data is now independent of processing
- Modernization of X10 (MG data)
- Modernization of Fabulous (f-factors)

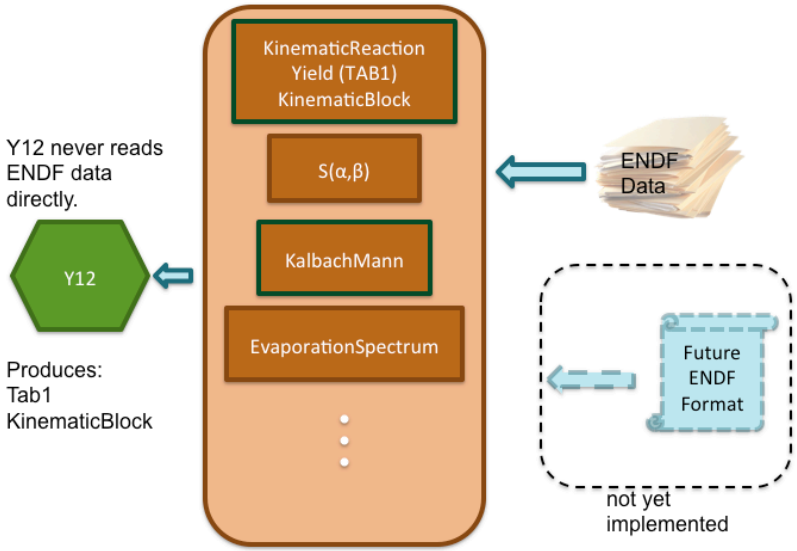
AMPX modernization
What is planned for the future

Module	Functional Capability	Estimated Completion Data
PUFF	Generate covariance data from ENDF/B evaluations	6 month
POLIDENT	Generate 1D CE data from ENDF/B evaluations	12 month
JAMAICAN	Produce CE collision kinematics PDFs and CDFs for Monte Carlo libraries	18 month
PLATINUM	Assemble CE library for Monte Carlo calculations	24 month
BROADEN	Doppler broaden 1D CE data	36 month

PLATINUM and JAMACAN will use an in-memory resource for CE Monte Carlo libraries shared between SCALE and AMPX

AMPX modernization
What is planned for the future cont.

Continue to work on implementing support for the GND format.
The plan is to add division between reading and processing of ENDF/B for all modules that read ENDF/B data. This is already done for Y12.
We will then add capabilities to read the new GND file.
The plan is to initially support the GND format for covariance data as PUFF-IV is the next module to be modernized.



Summary

- Modernization of AMPX is progressing
  - X10 code to generate MG libraries has been rewritten in C++
  - Fabulous code to generate NR f-factors has been rewritten and new functionality has been added
- ENDF/VII-1 MG libraries for SCALE have been generated using all the new features
- Added processing for CHI-Covariance (File 35) data for new SCALE covariance libraries
- AMPX is available in SCALE 6.2 beta releases and will be available in the upcoming SCALE 6.2 release.

Acknowledgement

- Thanks to the US Nuclear Criticality Safety Program (NCSP) for sponsoring this work and its presentation.