V&V of Multigroup Cross Section Generation Code MC^2-3 for Fast Reactor Analysis

CSEWG, November 9, 2012

Changho Lee
Argonne National Laboratory

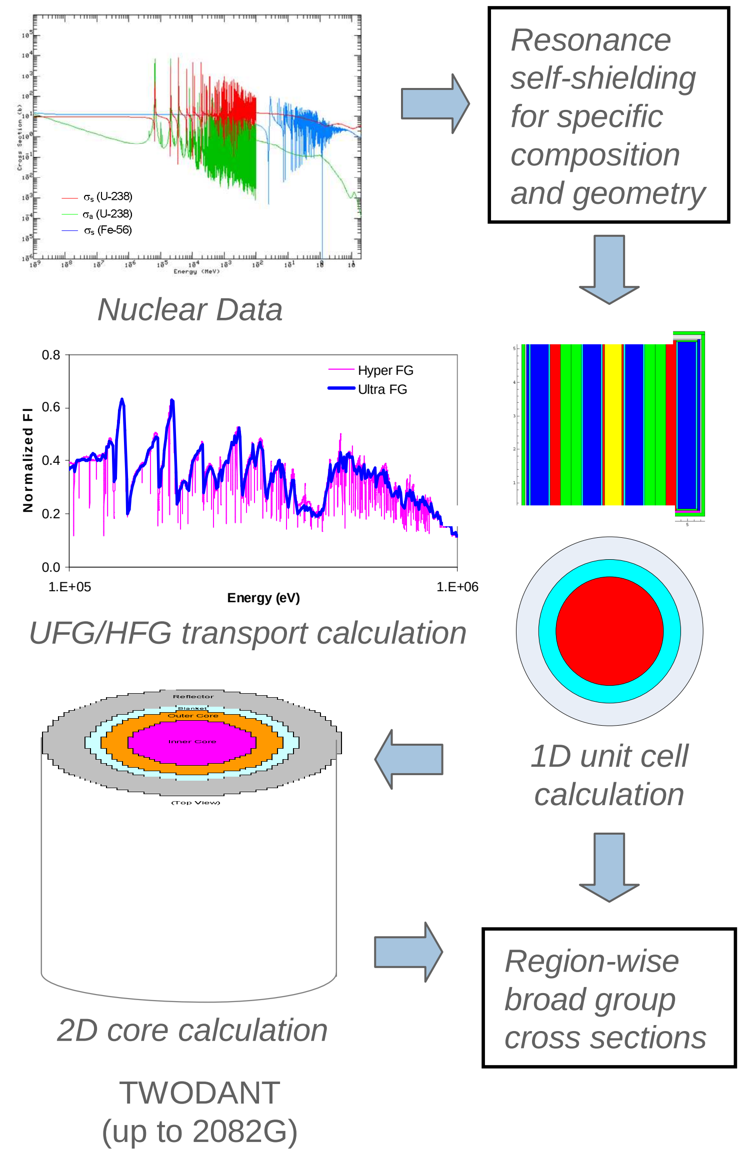
ETOE-2 / MC^2-2 / SDX (Old Procedure)

- ETOE-2
  - Generate MC^2 libraries by processing ENDF/B data based on the 2,082 ultrafine groups with constant lethargy from 15 MeV to 0.4 eV
  - Screen out wide and narrow resolved resonances to smooth cross sections
  - Convert the resolved resonances in the Reich-Moore formalism to those in the multi-pole formalism
- MC^2-2
  - Self-shield unresolved and resolved resonances using the analytic integral method based on the narrow resonance (NR) approximation
  - Perform the ultrafine group transport spectrum calculations
    - Multigroup method for above resolved resonance energy range
    - Continuous slowing down method for the resolved resonance energy range
  - Adjust the ultrafine group solutions with the hyperfine group slowing-down calculation (RABANL) based on isotropic elastic scattering: applicable below ~tens keV
- SDX
  - Perform the 1D integral transport calculation to account for the heterogeneity effect

Features and Capabilities of MC^2-3

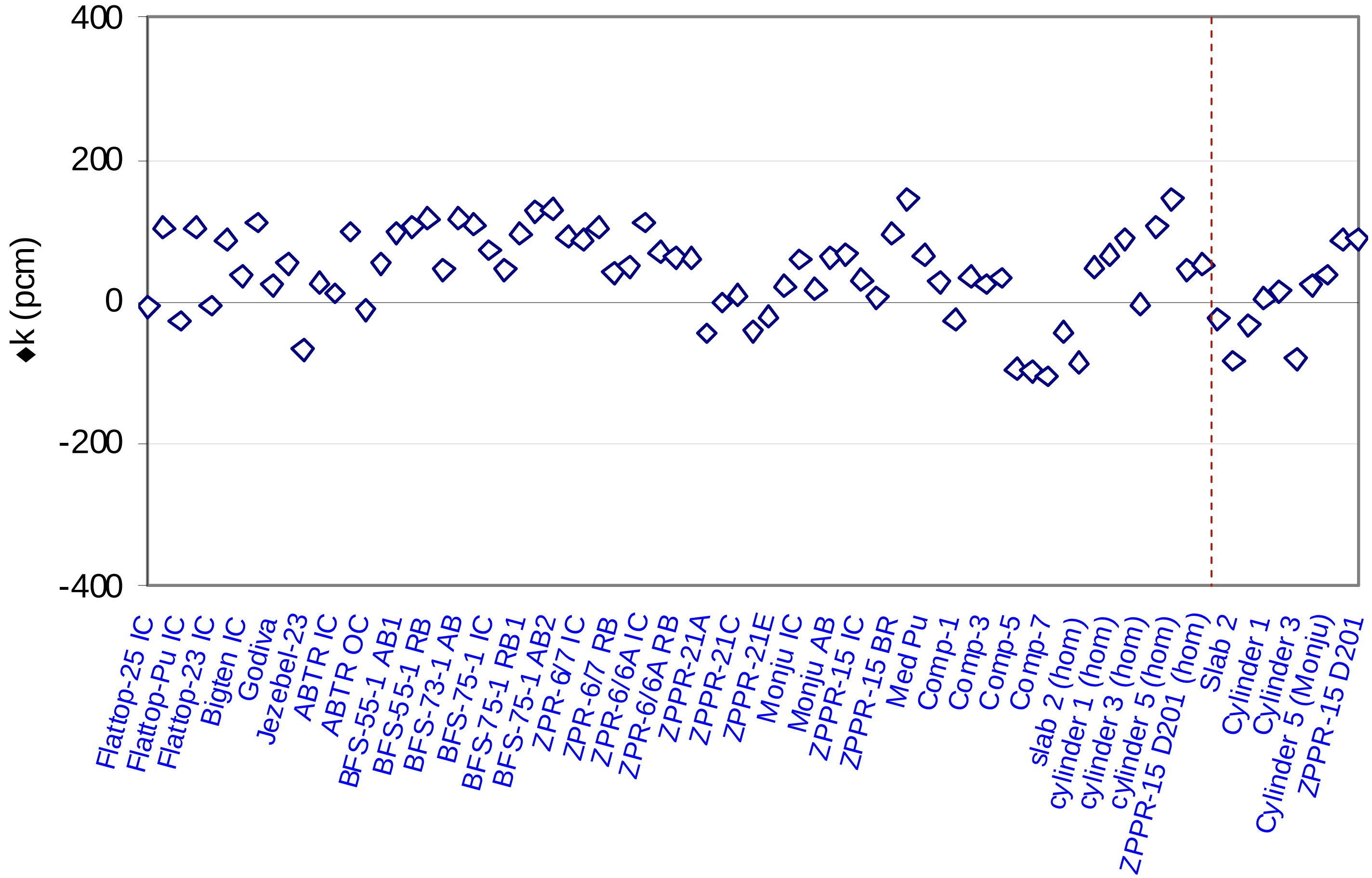
- Resonance self-shielding using the numerical integration based on the pointwise cross section, ultrafine group (~2000) 0D or 1D transport calculation

  [Optionally, use of PENDF from NJOY]
- Hyperfine group (~400,000) 0D or 1D transport calculation
- Use of high-order anisotropic scattering source in the LS and CMS
- Use of anisotropic inelastic scattering and incident energy dependent fission spectrum
- Self-shielding of resonance-like scattering cross section of Fe, Ni, Cr, etc.
- Ultrafine group 2D whole-core transport calculation for region dependent cross section generation
- Processed ENDF/B-VII data by ETOE-2



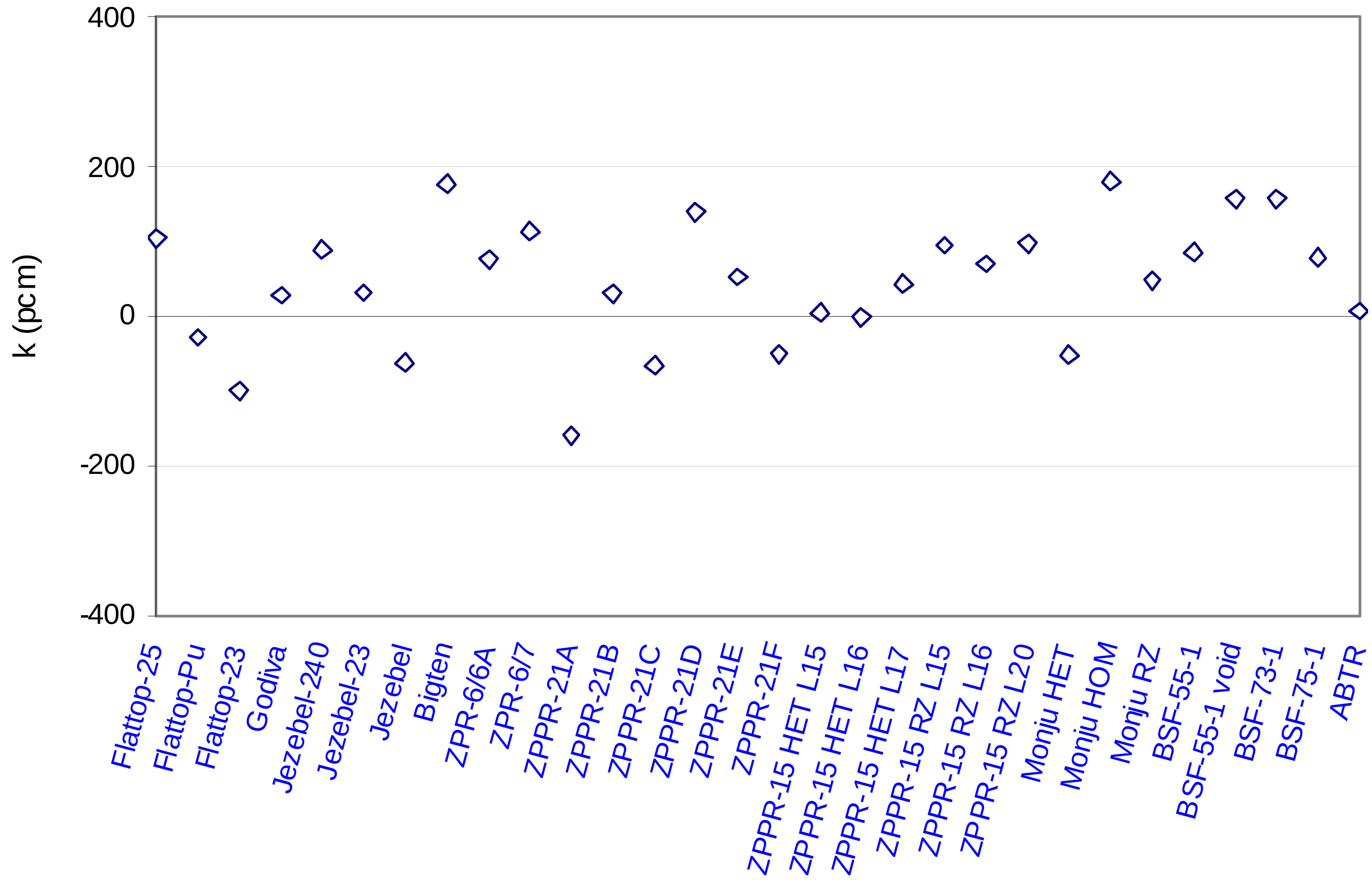
0D/1D Verification Tests

- Comparison of k_∞ between MC^2-3 and Monte Carlo codes for Homogeneous (59 cases) and 1D (10 cases) Compositions using ENDF/B-VII.0 showed MC^2-3 results consistent with Monte Carlo (within 0.2%)

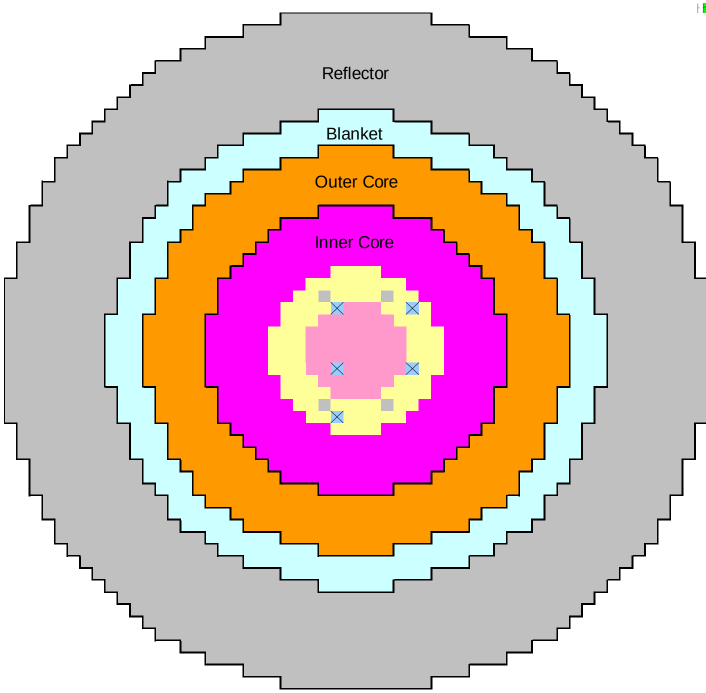


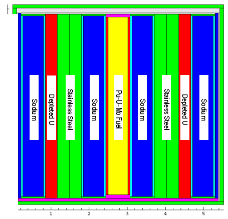
Verification Tests for Criticality Benchmarks

- For ~30 core problems, the core eigenvalues are estimated < 200 pcm from Monte Carlo: deterministic core calculations with TWODANT ($S_{24}P_3$) or DIF3D (P_5P_3)



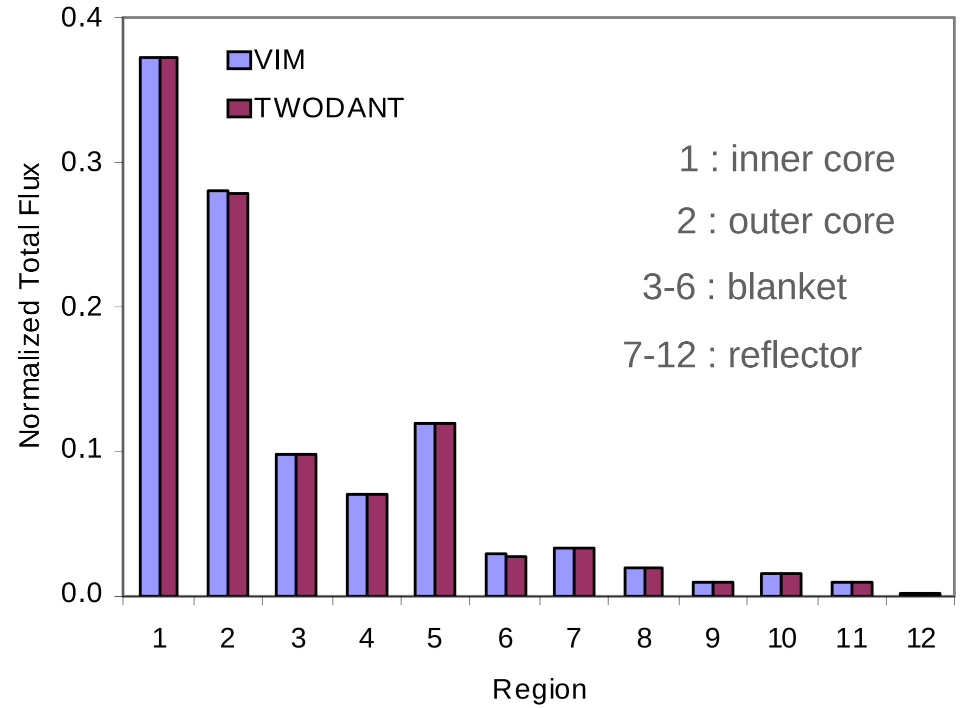
ZPPR-15A Critical Experiments





Loading	Experiment	VIM	MC^2-3
15	1.00046	0.99985	4
16	0.99627	0.99571	-1
17	0.99853	0.99780	43

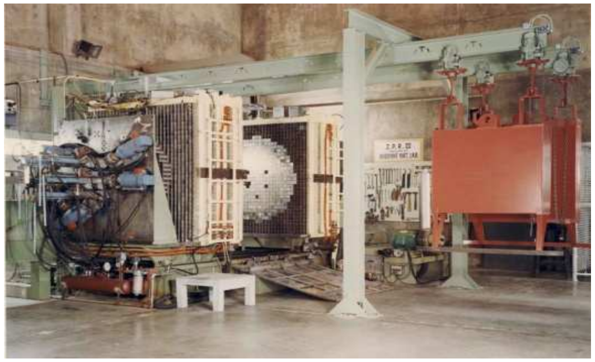
* Experiment < ±0.00180, VIM < ±0.00020

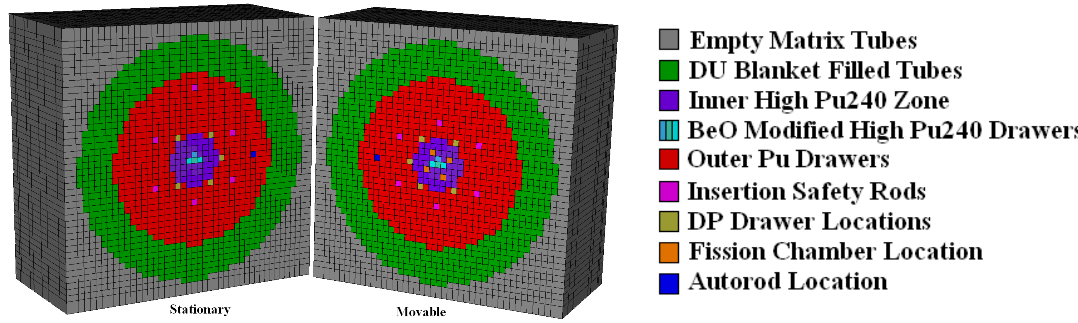


Regionwise Total Flux of Loading 15

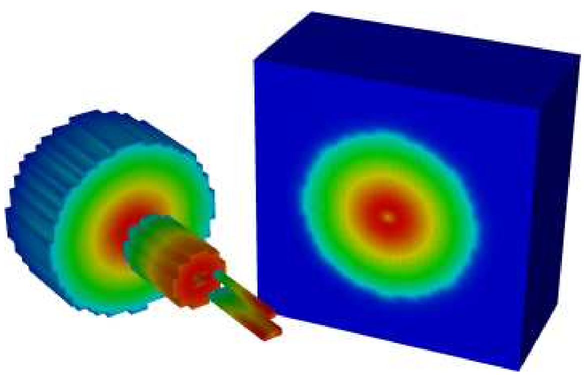
Validation: MC²-3/UNIC

ZPR-6/7





- MC²-3/UNIC (SN2ND) Calculation
  - 70 energy groups, 1M spatial meshes, 72 angular directions, P_3 scattering order
  - Core reactivity within 1 sigma of experimental uncertainty (~80 pcm), *comparable to accuracy of MCNP explicit geometry solution*



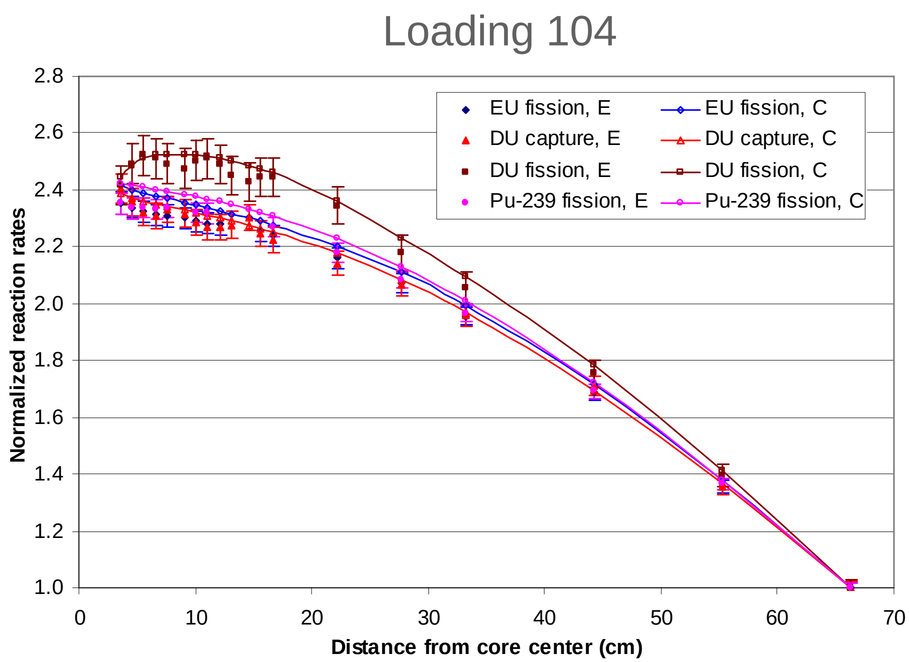
Flux in group 1 of 70 (10 MeV to 14 MeV)
Loading 106

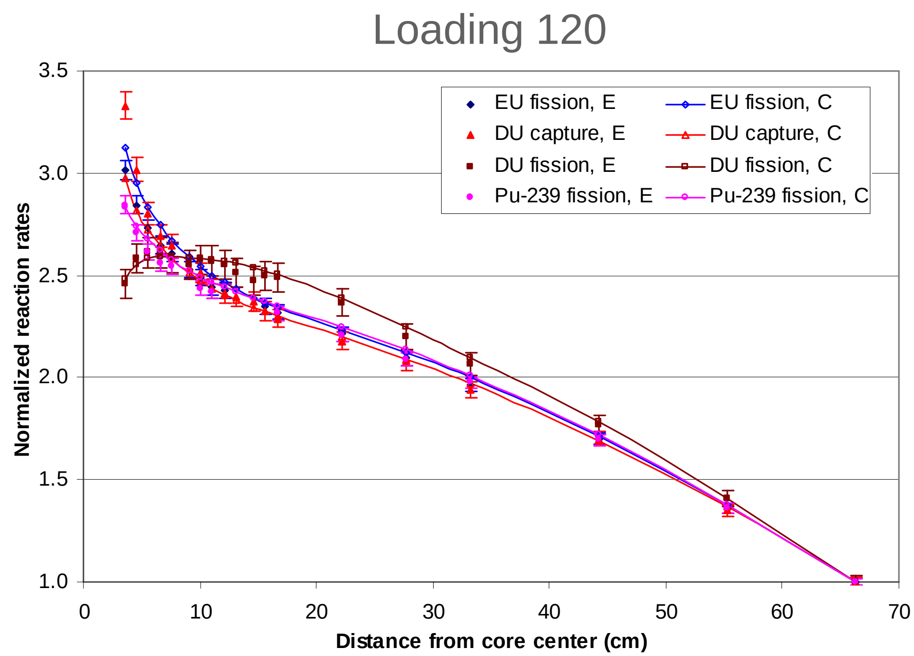
Calculated and Measured Eigenvalues

Loading	MC²-3/UNIC	MCNP	Experimental†
104	1.00147	1.00016 ± 0.00007	1.00072 ± 0.00002
106	1.00134	1.00049 ± 0.00007	1.00091 ± 0.00003
120	1.00127	0.99967 ± 0.00007	1.00099 ± 0.00003
132	1.00016	1.00040 ± 0.00007	1.00040 ± 0.00002

ZPR6-7 Foil Measurements

- 69 foil activation measurements were analyzed
- Calculated reaction rates agreed very well with the measurements except for a couple of depleted uranium (DU) capture rates near the BeO plates
- Results for loadings 104 and 120 using foil cross sections from MC^2-3 were equivalent in accuracy to that using MCNP based foil cross sections





Summary

- The V&V results with various compositions, numerical benchmark problems, and criticality experiments show that the eigenvalues from the deterministic calculations with the MC^2-3 cross sections agree well with Monte Carlo solutions within ~200 pcm
- The MC^2-3 code was released to RSICC in September, 2012
- Processing ENDF/B-VII.1 data and gamma library will be performed