Overview of SCALE 6.2

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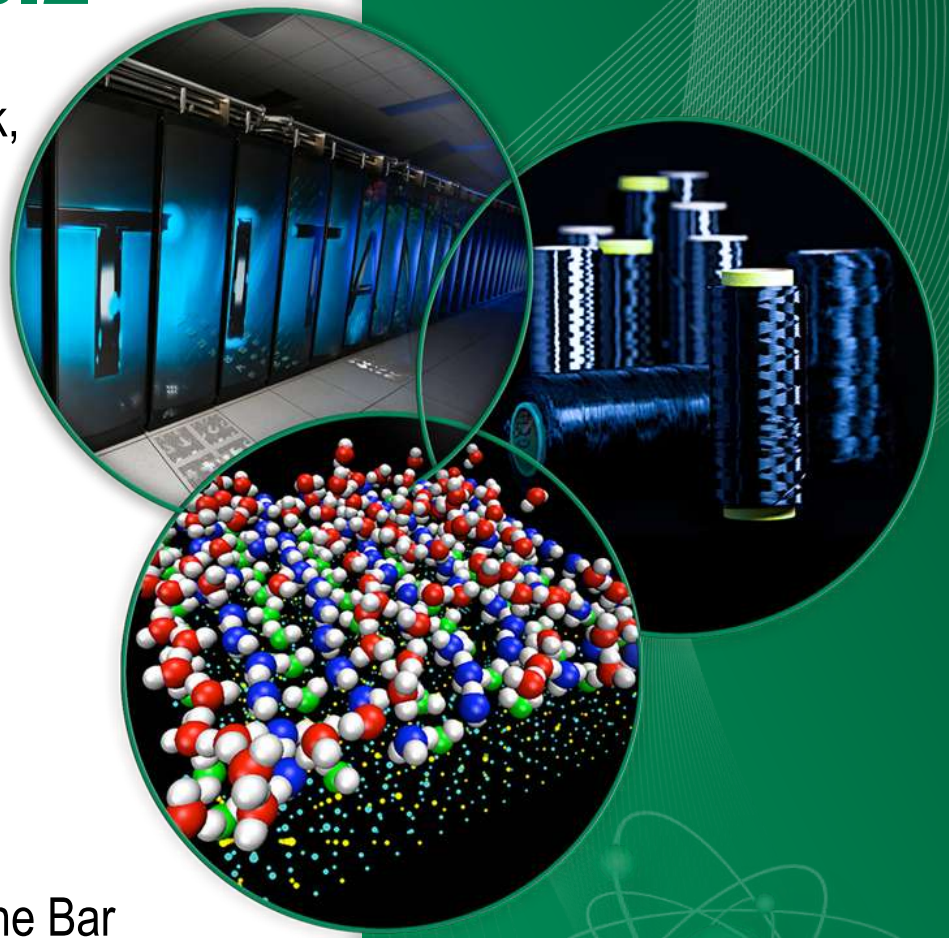


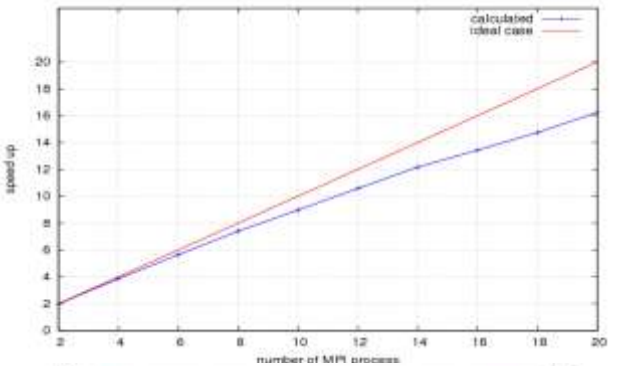
ANS NCSD 2013
Criticality Safety in the Modern Era: Raising the Bar
Wilmington, NC

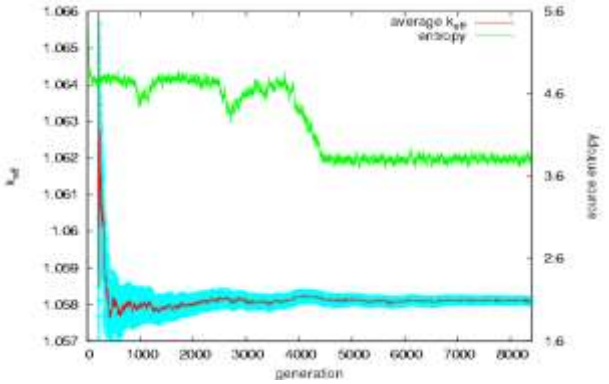
SCALE 6.2 Preview

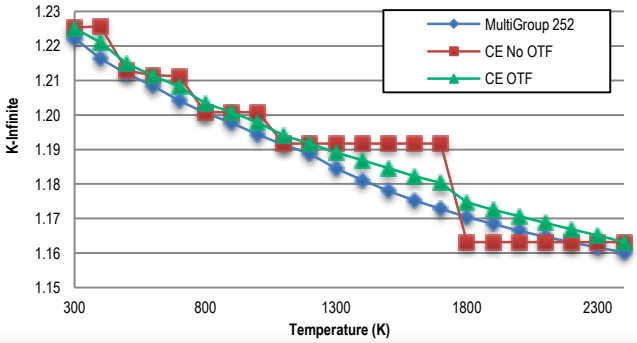
- Significant updates since SCALE 6.1 in June 2011
- Focus on improved fidelity of solutions
- Significant improvements in Monte Carlo capabilities
  - Comprehensive review and update of CE nuclear data, with orders of magnitude increase in testing for improved quality (sponsored by NRC)
  - CE TSUNAMI (sponsored by NCSP)
  - CE MAVRIC/Monaco (sponsored by NRC)
  - CE TRITON (other sponsor)
  - Hybrid source convergence tool
- Modular development, parallel computing, and integration with other code packages (NEAMS, CASL, external development)
- New sampling methods for uncertainty analysis and generation of experimental correlations (joint NCSP and DOE NE support)
- New nuclear data libraries in MG and CE
- Modernized resonance self-shielding tools

Monte Carlo Improvements for Criticality

- Parallel KENO
  - Significant speedups with MPI on Linux clusters
- Improved CE efficiency
  - Memory footprint reduced by 20-95%, depending on problem
  - Coding revised to provide improved consistency across platforms
- Source Convergence
  - Shannon Entropy test in KENO
  - Hybrid deterministic starting source methodology in Sourcerer for improved k_{eff} reliability
- Problem-Dependent Doppler broadening for CE calculations
- Doppler Broadened Rejection Correction
  - Significant improvement in elevated temperature CE Monte Carlo



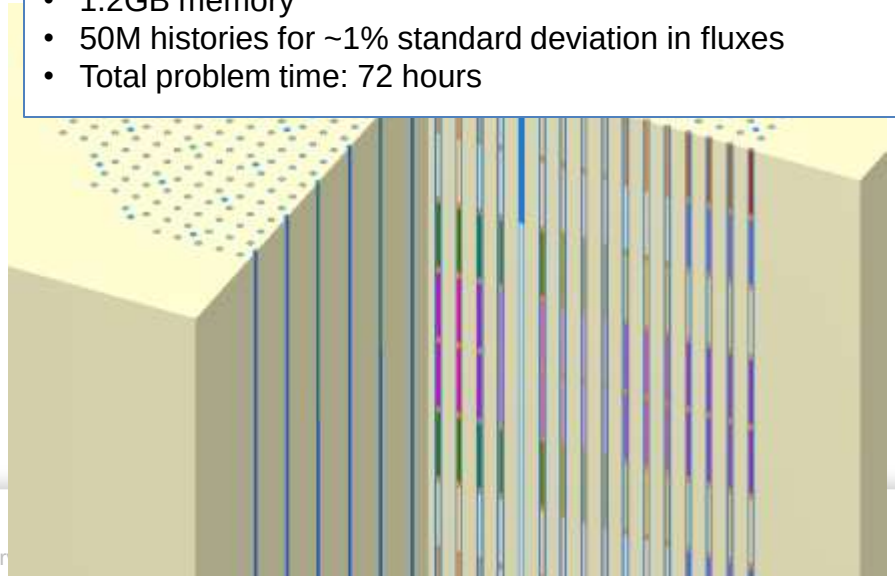




CE Monte Carlo Depletion

- Designed for high-fidelity analysis of full core reactors
- MG reaction and flux tallies from CE data
- Efficient memory management
- Coupling with ORIGEN

Graphite Reactor Benchmark Calculation
- 7,930 depletion zones
- ~10,000 units, ~32,000 regions
- 1.2GB memory
- 50M histories for ~1% standard deviation in fluxes
- Total problem time: 72 hours

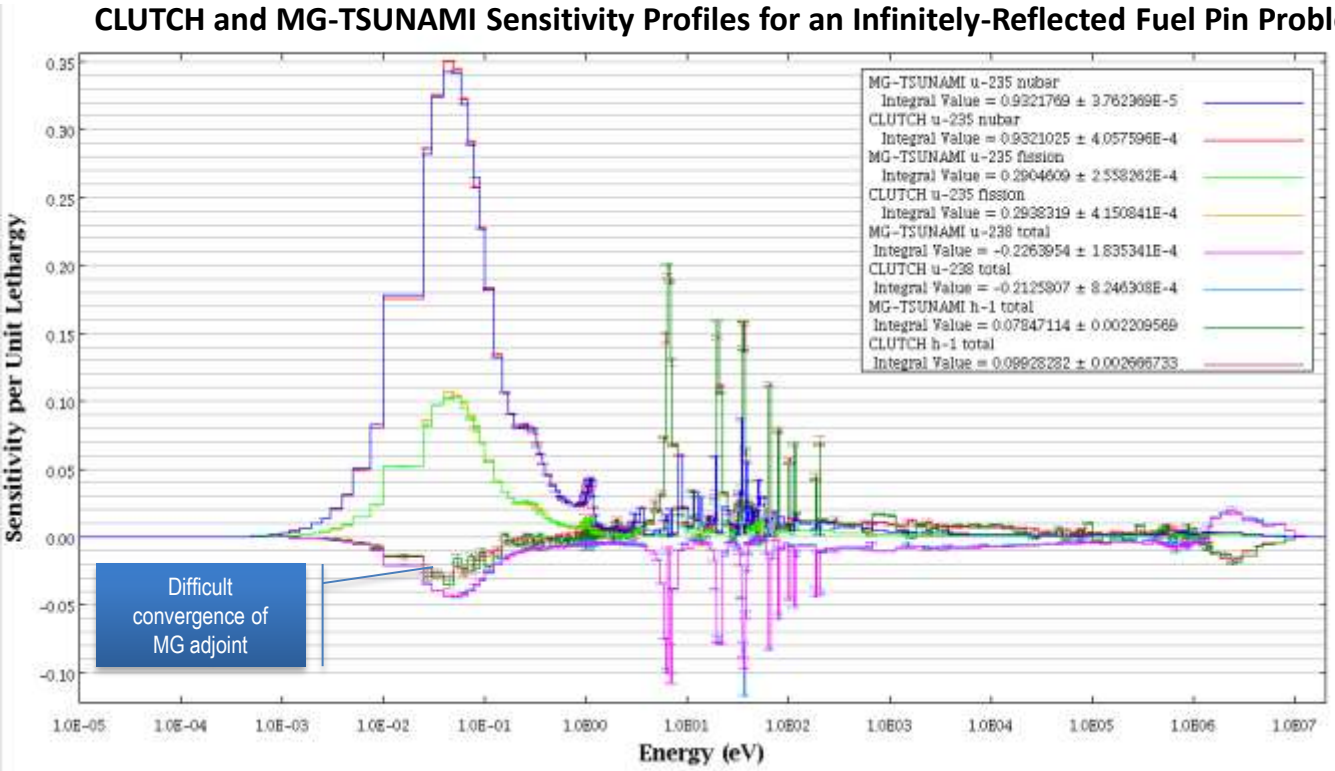


C/E -1 (%) for Calvert Cliffs sample MKP109-P

	MG KENO	CE KENO
U-234	3.0	3.2
U-235	3.1	4.6
U-236	0.1	1.4
U-238	-1.7	-0.1
Pu-238	-10.5	-10.2
Pu-239	4.9	9.1
Pu-240	1.5	1.8
Pu-241	-1.1	1.5
Pu-242	-9.1	-8.2
Np-237	2.7	3.1
Am-241	-8.2	-5.8
Cs-133	-0.8	0.7
Cs-135	3.0	4.2
Cs-137	-4.3	-3.3
Nd-143	0.5	2.1
Nd-144	-4.7	-3.1
Nd-145	-4.4	-3.1
Nd-146	-1.5	0.3
Nd-148	-1.5	-0.1
Nd-150	1.0	2.5

CE Sensitivity Analysis with TSUNAMI

CLUTCH and MG-TSUNAMI Sensitivity Profiles for an Infinitely-Reflected Fuel Pin Problem



Runtime Parameter Comparison for the Fuel Pin Problem

	CLUTCH	MG-TSUNAMI
Memory Increase over Eigenvalue Calculation	2 MB	305 MB
Runtime	352.3 min	626.9 min

→ **The CE-KENO + CLUTCH run was faster than the MG-KENO + TSUNAMI run and it had a small memory footprint!**

Energy-Integrated Sensitivity Coefficient Comparison

Nuclide	Direct Pert.	MG-TSUNAMI	CLUTCH
U-235	0.1660	0.1595	0.1642
U-238	-0.2207	-0.2264	-0.2126
H-1	0.0946	0.0785	0.0993
O-16	-0.0147	-0.0250	-0.0139

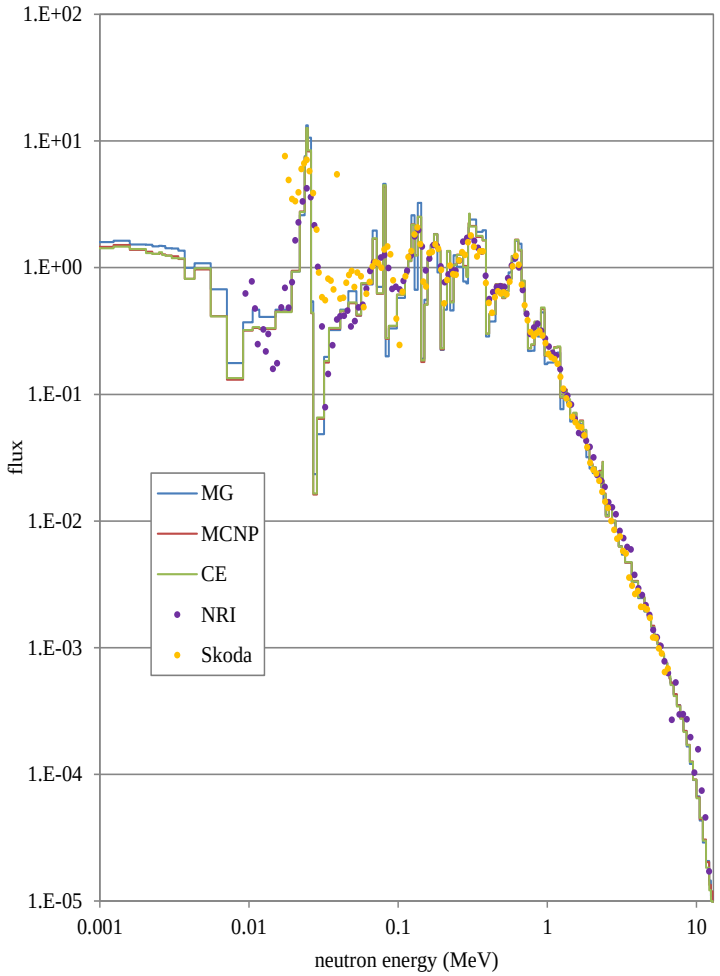
Energy-Integrated Sensitivity Coefficient Differences (in number of $\sigma_{effective}$)

Nuclide	MG-TSUNAMI	CLUTCH
U-235	-0.79	-0.22
U-238	-0.64	0.91
H-1	-4.39	1.18
O-16	-7.49	0.51

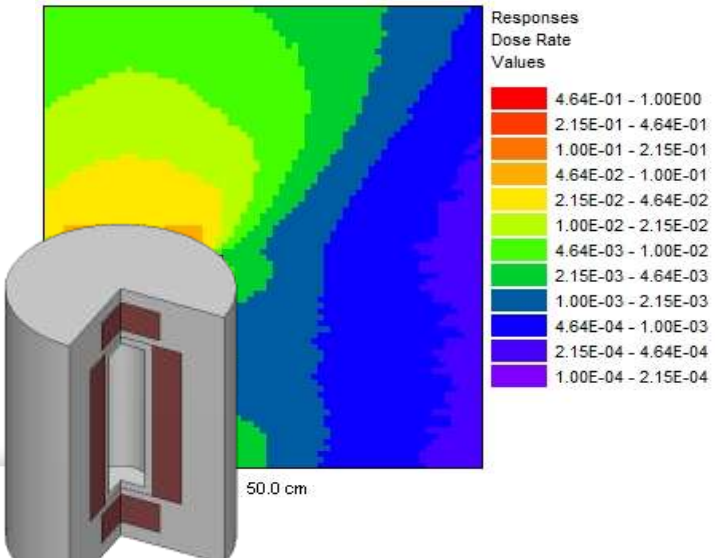
CE Shielding with MAVRIC/Monaco

- All hybrid capabilities supported with CE fidelity
- SCALE Continuous-Energy Modular Physics Package (SCEMPP)
  - Application Programmer Interface (API) for CE physics for next-generation Monte Carlo codes
- 6300 fixed-source transmission tests used in V&V

Flux results for iron sphere transmission experiment

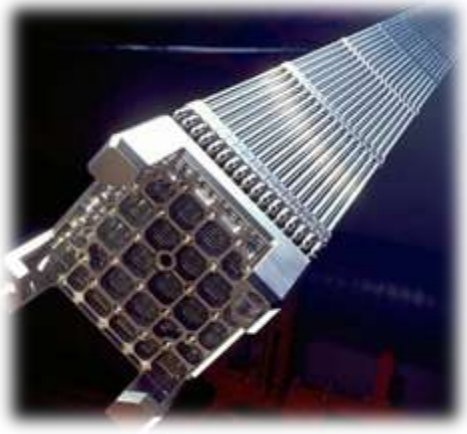


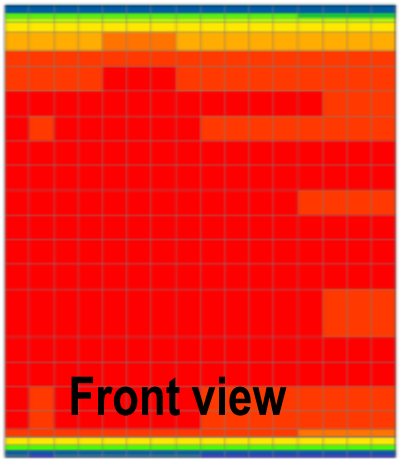
Dose rate from ^{60}Co source in transportation package

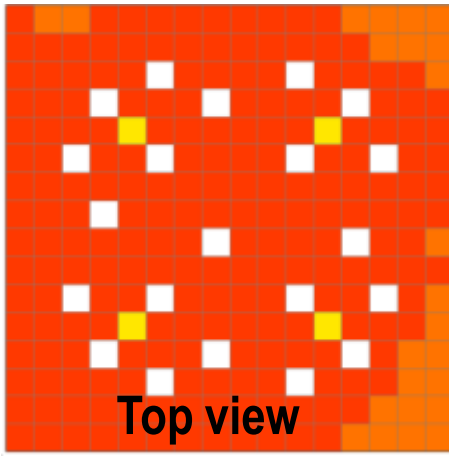


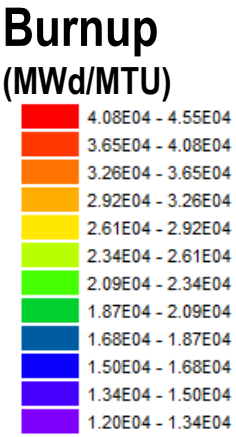
Modular ORIGEN

- ORIGEN restructured to provide Application Programmer Interface (API) and parallel capabilities
- New ORIGAMI tool developed to rapidly characterize spent fuel.







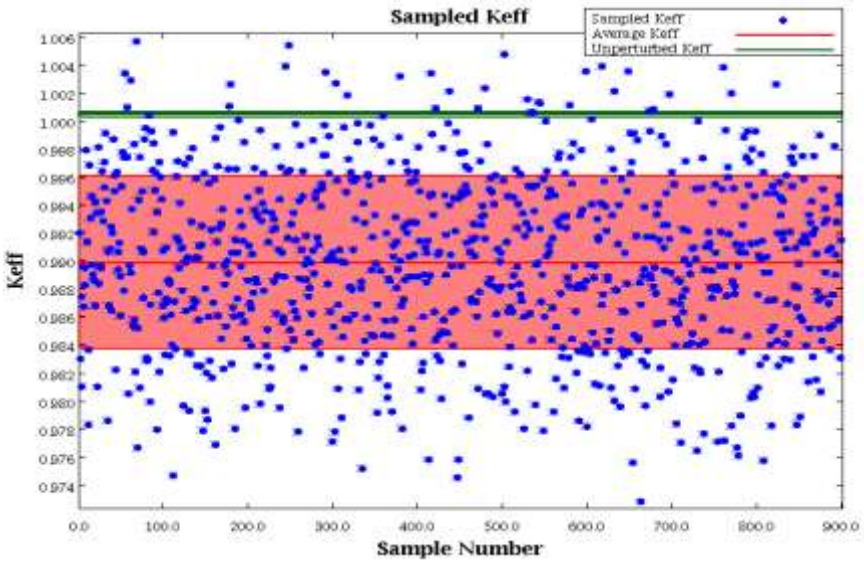


235 pins, 26 axial zones
6,110 depletion nodes

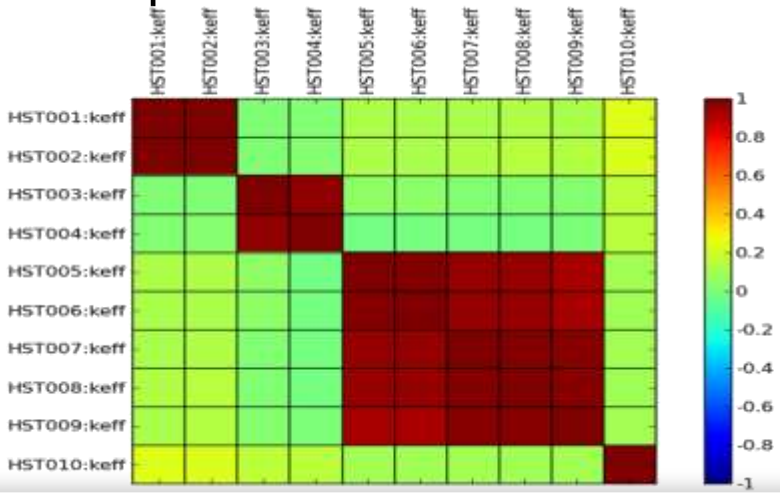
- ~50 hours runtime
- OpenMPI implementation with (near)-linear speed-up

Sampler: A Module for Statistical Uncertainty Analysis with SCALE Sequences

- Sampler provides uncertainty in any computed result from any SCALE sequence due to uncertainties in:
  - neutron cross sections
  - fission yield and decay data
  - geometry and composition
- Sampler propagates uncertainties through complex analysis sequences such depletion calculations
- Correlations between systems are also computed

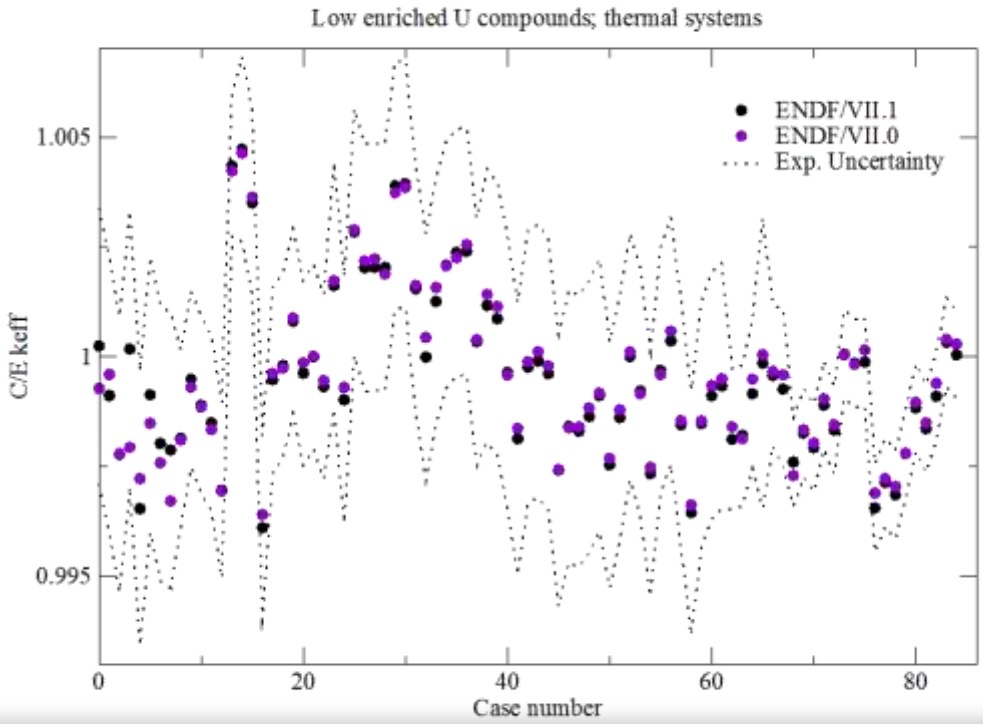


Experimental Correlations



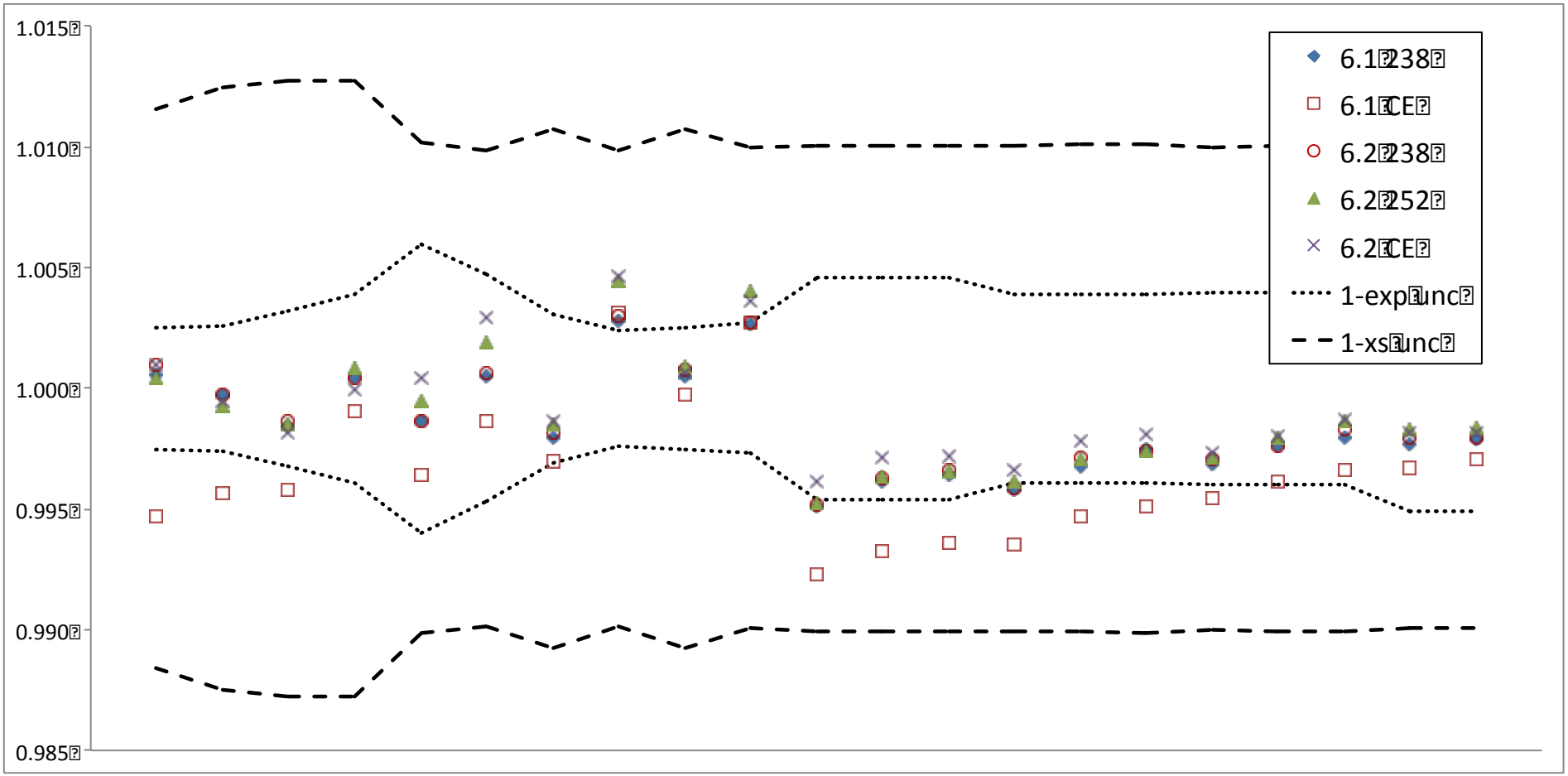
New Data Libraries

- New CE cross-section data for neutron interactions, gamma yield, and gamma interactions (sponsored by NRC)
- New MG neutron libraries
  - Provides parameters for intermediate resonance approximation for rapid resonance self-shielding techniques
  - 252-group energy structure (sponsored by NRC)
  - 56-group energy structure (sponsored by NRC and DOE NE)
- Extensive test suite
  - 381 VALID benchmarks
  - 6300 transmission tests
  - 5000 infinite medium tests
- ENDF/B-VII.0 libraries released with SCALE 6.2 beta1
- ENDF/B-VII.1 libraries under QA review for release with SCALE 6.2 beta2



AMPX Processing Improvements Provide Improved C/E Especially for CE Calculations for MOX Benchmarks

Up to 1000 pcm improvement for burned fuel

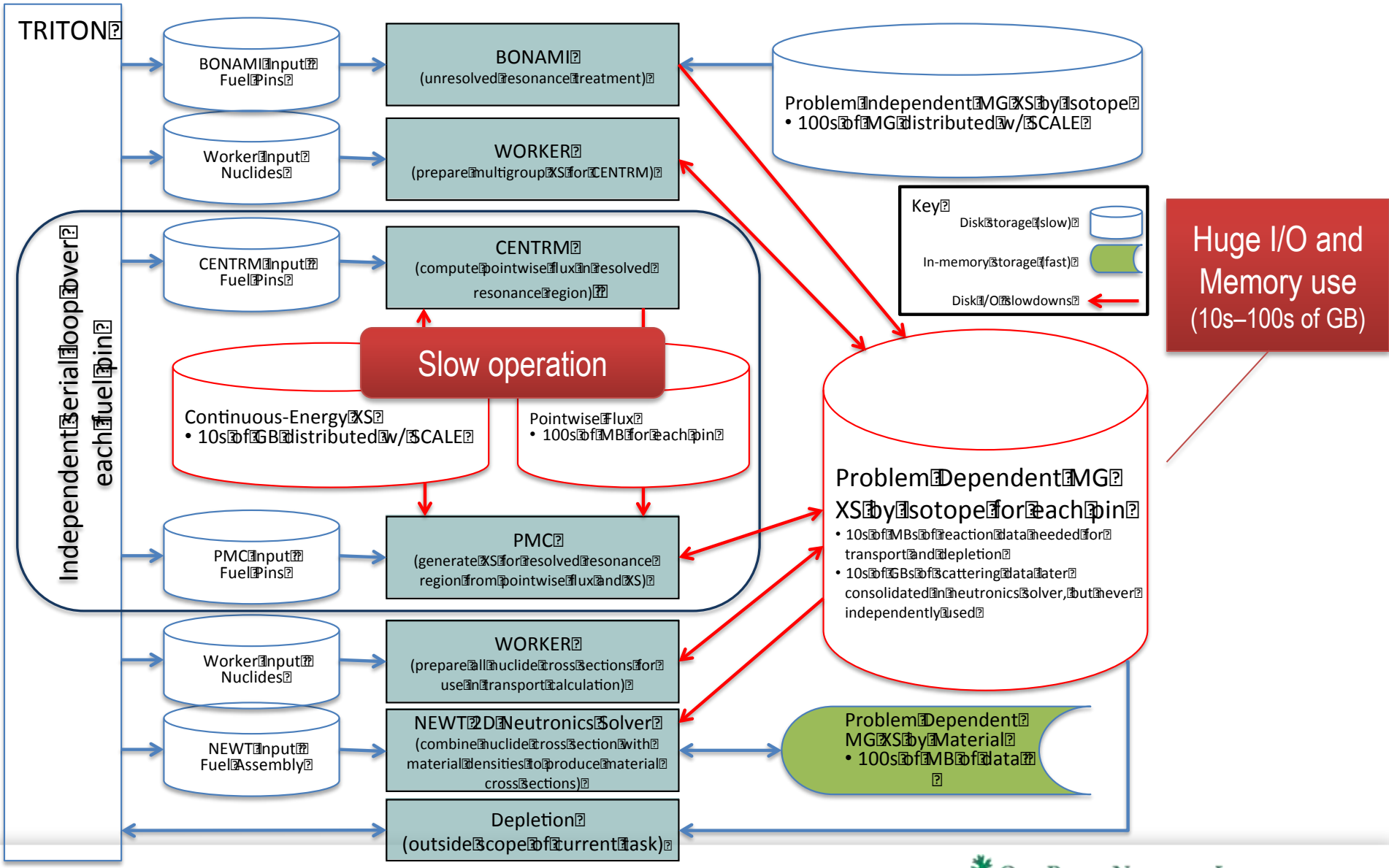


SCALE 6.2 beta1 Data Libraries

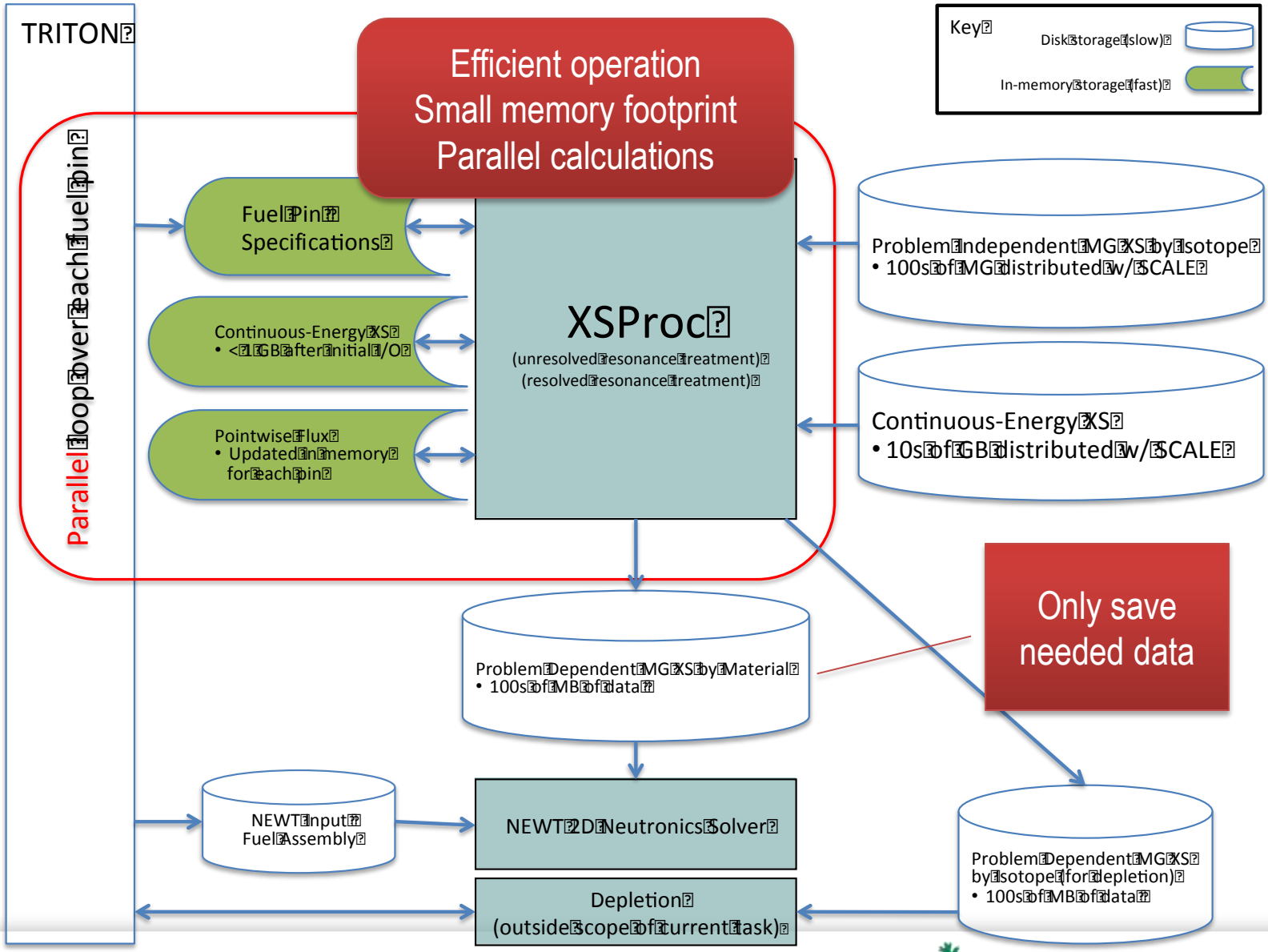
Alphanumeric name	Primary data source/format
v7-238	ENDF/B-VII.0 238-group neutron library
v7-252	ENDF/B-VII.0 252-group neutron library
v7-56	ENDF/B-VII.0 56-group neutron library
v7-200n47g	ENDF/B-VII.0 200 neutron/47 gamma library
v7-27n19g	ENDF/B-VII.0 27 neutron/19 gamma library
ce_v7_endf[b]	ENDF/B-VII.0 Continuous-energy neutron and gamma library

SCALE 6.1 Resonance Self-Shielding

(somewhat simplified view)



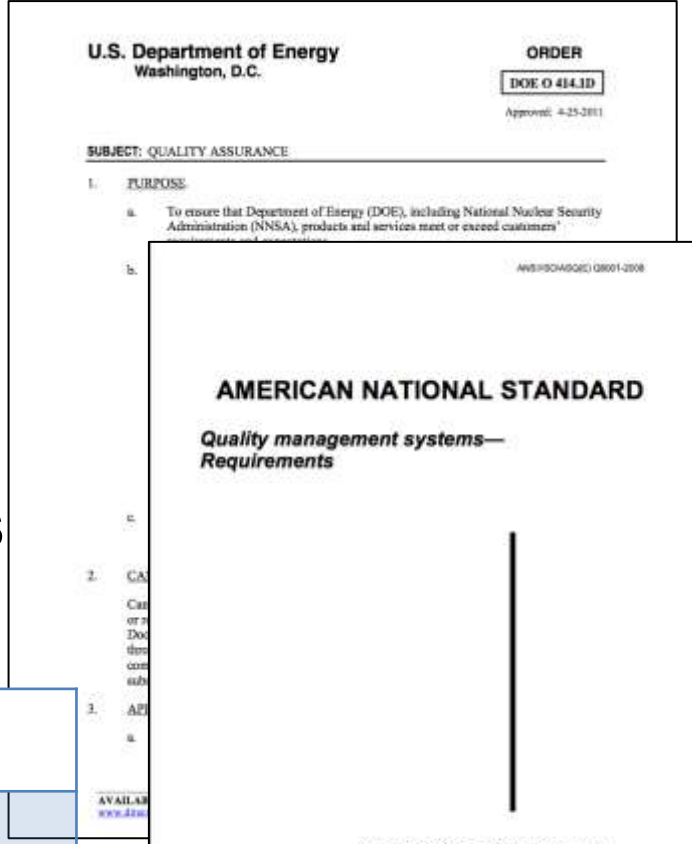
SCALE 6.2 Resonance Self-Shielding



Updated QA Program

- Designed for Compliance with:
  - ISO 9001-2008
  - DOE 414.1D
  - ORNL SBMS
  - Consistent with ASME NQA-1
- Capabilities are tracked with the *Kanban* process through the *FogBugz* electronic *collaborative development environment*

Kanban Category	Meaning
Proposed	Task has been proposed for management approval
Approved	Task has been approved by management and assigned to a developer for implementation
In Progress	Developer is actively working to implement the feature
Ready for Testing	Developer has completed the implementation and the feature is ready for comprehensive testing
Ready to Ship	Item has passed all tests and is a candidate feature for quality assurance implementation
Shipped	Feature is implemented in quality-assured version


U.S. Department of Energy
Washington, D.C.

ORDER
DOE O 414.1D

SUBJECT: QUALITY ASSURANCE

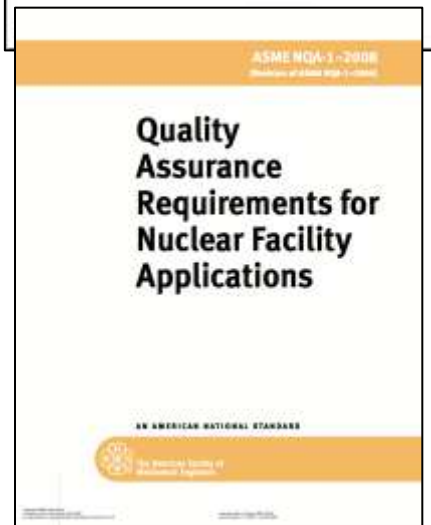
1. PURPOSE

a. To ensure that Department of Energy (DOE), including National Nuclear Security Administration (NNSA), products and services meet or exceed customers'

AMERICAN NATIONAL STANDARD

Quality management systems—Requirements

AMERICAN SOCIETY FOR QUALITY
P.O. BOX 3005
MILWAUKEE, WI 53201-3005


ASME NQA-1-2008

Quality Assurance Requirements for Nuclear Facility Applications

AN AMERICAN NATIONAL STANDARD

Improved SCALE V&V

- Routine Test Suite
  - Run dozens of times each day
  - 263 Sample Problems
  - 379 Regression Problems
  - ~1000 Unit Tests
  - 381 VALID Benchmarks
- Supported Platforms:
  - Linux, Mac, Windows
    - Intel Release
    - Intel Debug
    - GNU Release
    - GNU Debug
  - Suite repeated with MPI on Linux and Mac

Conclusions

- SCALE 6.2 continues a 30-year legacy of nuclear systems modeling and simulation by providing comprehensive, verified and validated, user-friendly capabilities for criticality safety, reactor physics, spent fuel and radioactive source term characterization, radiation shielding, and sensitivity/uncertainty analysis.
- The new capabilities within SCALE 6.2 provide significant advances over previous versions
  - CE Monte Carlo capabilities for criticality safety, shielding, depletion, and sensitivity/uncertainty analysis,
  - Modularity for CE physics and depletion
  - Stochastic sampling with Sampler
  - Improved CE and MG data.

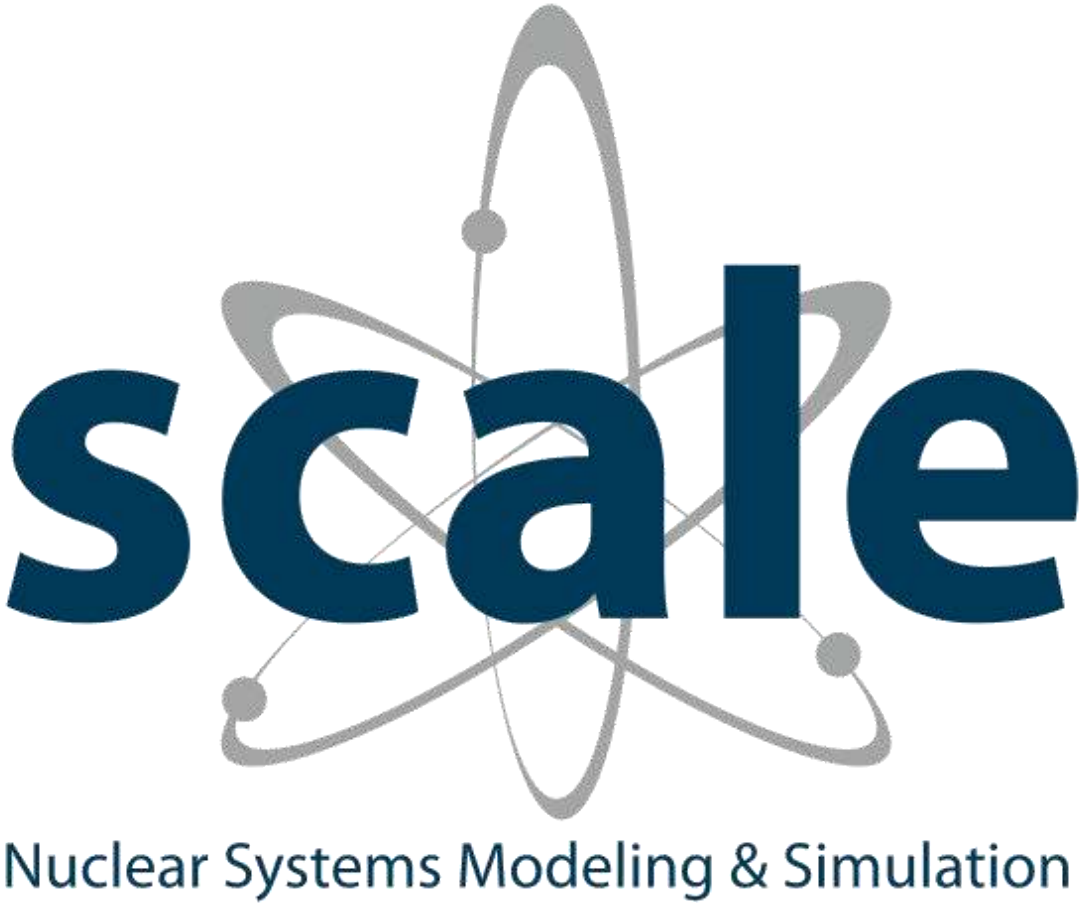
SCALE 6.2 Tentative Schedule

- Beta1 – currently under limited release
- Beta2 – broader release expected by December 2013
- Beta3 – expected in Spring 2014
- Production release – expected in Summer 2014

Questions?

http://scale.ornl.gov

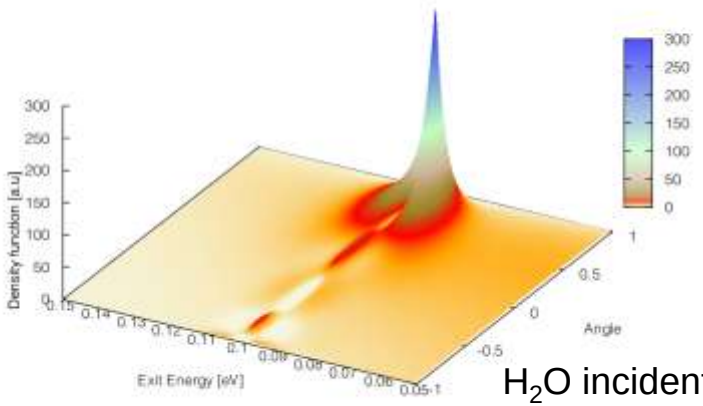
scalehelp@ornl.gov



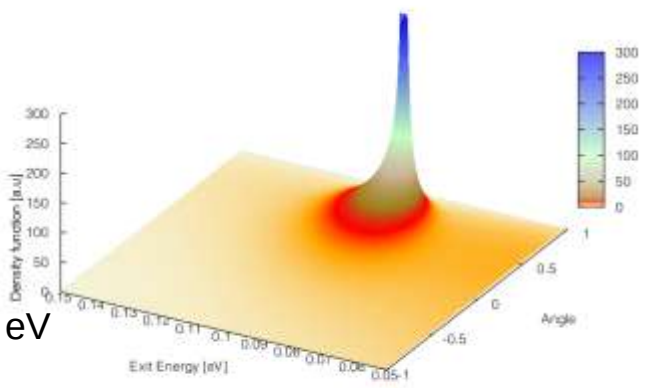
Improved Collision Kinematics Processing in AMPX

Since primarily used for MG:

Y12->MONTEGO

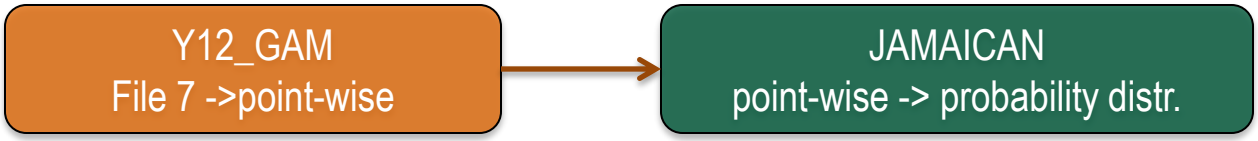


Y12_GAM



H_2O incident energy 0.1 eV

Updated for CE library



Refined energy grid is used → thinned to keep library size manageable

New 252-Group Library for SCALE

- 252 instead of 238 neutron groups, refined for LWRs
- Implements data needed for *Intermediate Resonance* approximation rapid self-shielding calculations with Bondarenko and Embedded Self-Shielding Methodology (SCALE and CASL)

- Weighted with CE flux for actinides and thermal H_2O
- Add Lambda-factors for all isotopes
- Add heterogeneous IR-factors for actinides
- Homogeneous IR-factors for other materials