Verification and Validation Activities with OpenMC

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What is OpenMC?

A community developed, open source Monte Carlo particle transport code, primarily targeted at applications in nuclear science and engineering

OpenMC: Overview of features

- **Modes**: Fixed source, *k*-eigenvalue calculations, volume calculations, geometry plotting
- **Geometry**: Constructive solid geometry, CAD-based, unstructured meshes
- **Solvers**: Neutron and photon transport, depletion
- **Data**: Continuous energy or multigroup cross sections, multipole for Doppler broadening
- **Parallelism**: Distributed/shared-memory via MPI/OpenMP

OpenMC: Unique attributes

What sets OpenMC apart from other codes?

- Programming interfaces (C/C++ and Python)
- Nuclear data interfaces and representation
- Tally abstractions
- Parallel performance
- Development workflow and governance

OpenMC: Community Resources

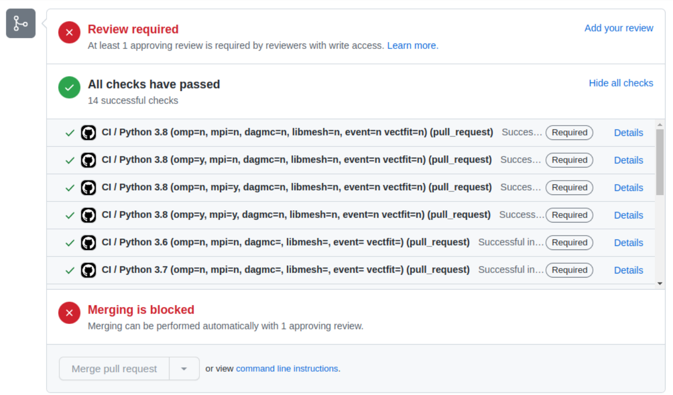
- Code: https://github.com/openmc-dev/openmc
- Documentation: https://docs.openmc.org
- Nuclear Data: https://openmc.org
- Forum: https://openmc.discourse.group
- Slack: https://join.slack.com/t/openmc/signup

V&V and QA Activities

1. Continuous integration testing
2. Criticality benchmarks
3. Depletion comparisons
4. Shielding benchmarks
5. Automated model conversion

Continuous integration testing

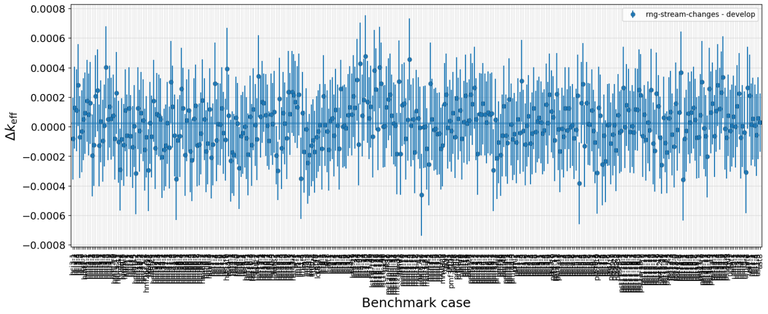
Every time a pull (change) request is made, a comprehensive set of regression and unit tests are run for a matrix of build/run configurations



Works well when no changes are expected in reference results

Changes in reference results

When a change in our reference results *are* expected (new physics, random number stream, etc.), we kick off a set of benchmark simulations to ensure everything agrees within uncertainty:



ICSBEP Benchmarks

- MIT hosts a collection of reactor physics benchmark models for OpenMC, including ∼400 ICSBEP models:

Fuel	COMP	MET	SOL	MISC
HEU	7	72	48	0
LEU	6	0	32	0
IEU	1	12	0	0
PU	1	39	121	0
U233	1	10	7	0
MIX	8	27	0	0

Fuel	THERM	INTER	FAST	MIXED
HEU	48	11	68	0
LEU	38	0	0	0
IEU	0	0	13	0
PU	121	2	38	0
U233	7	1	10	0
MIX	6	1	28	0

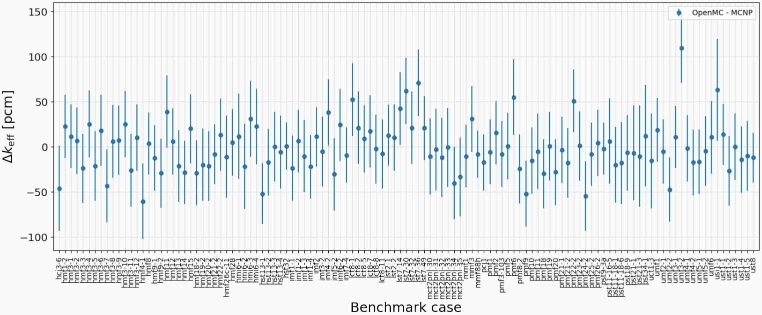
CoNDERC Contributions

- A collection of ICSBEP/IRPhEP benchmark models were contributed to CoNDERC under the "beyond k_{eff}" section
- Emphasis placed on utilizing additional functionality:
    - Plotting flux spectra in various materials
    - Built-in energy group structures
    - Radial flux profile in a spherical mesh
    - Automated volume/mass checks compared to benchmark specifications
    - Complex modeling functionality in OpenMC
    - Use of third-party Python packages
    - Automated generation of parameterized models

Benchmark Automation

- We also maintain a repository of validation scripts
  - `openmc-run-benchmarks` — Run a collection of ICSBEP benchmarks using either OpenMC or MCNP and collect results
  - `openmc-plot-benchmarks` — Plot results from `openmc-run-benchmarks`
- Running hundreds of benchmarks is as simple as executing a single command (and having a big computer!)

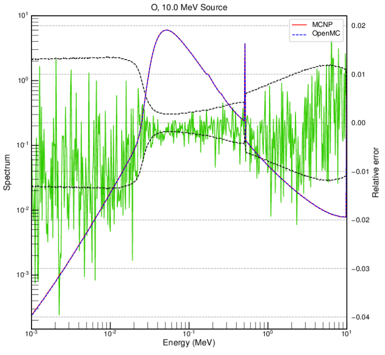
- OpenMC 0.13.1 vs MCNP 6.2 on ICSBEP benchmarks:

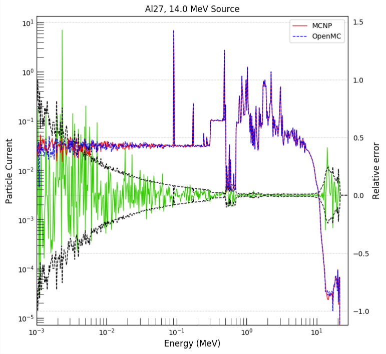


Simple Physics Comparisons

Validation scripts also include simple physics comparisons:

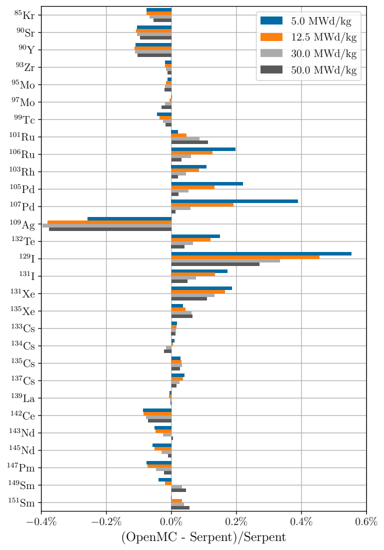
- Neutron/photon spectrum from a monoenergetic point source in a sphere
- Secondary photon spectrum in broomstick model (coupled n–γ)





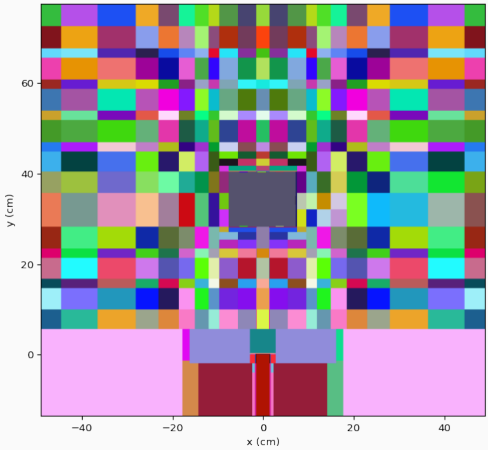
Depletion Code-to-code Comparison

Extensive code-to-code comparisons for depletion have been carried out with OpenMC and Serpent

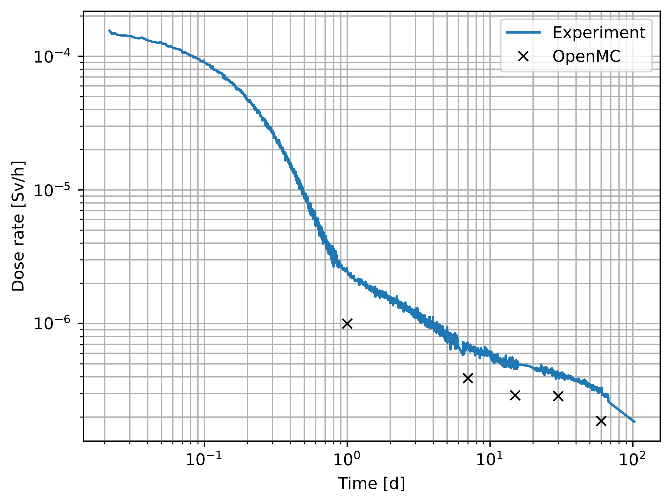


SINBAD Benchmarks

- As part of a new project funded by DOE/Fusion Energy Sciences, OpenMC models for SINBAD benchmarks are being developed
- First one is “FNG dose”:



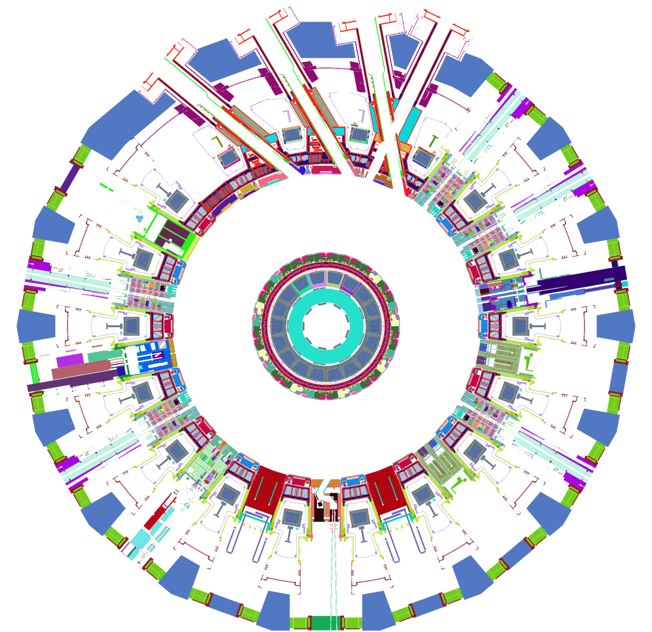
FNG Dose: Early Results



Automated Model Conversion

- Recently, we released a utility for converting MCNP models to OpenMC
- Unlike csg2csg, directly utilizes OpenMC's Python API
- Some MCNP features are not supported:
  - Periodic boundary conditions
  - Hexagonal lattices
  - Some macrobodies
  - Source definitions, tallies, and most cards in the "data" section

Model Conversion: ITER E-lite



Model Conversion Opportunities

- General capability for model conversion opens up new opportunities:
  - Maintaining a single “canonical” set of inputs
  - Minimizing/eliminating model differences
  - Volume comparisons
  - Mass comparisons
- Many code-to-code differences (esp. outliers) I’ve seen tend to be a result of modeling errors or inconsistencies
- Study different approaches in csg2csg, t4_geom_convert, and openmc_mcnp_adapter to learn from one another

Thank you!

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