Criticality Benchmark Comparisons for DAGMC

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ANS National Conference

June 27, 2011

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Overview

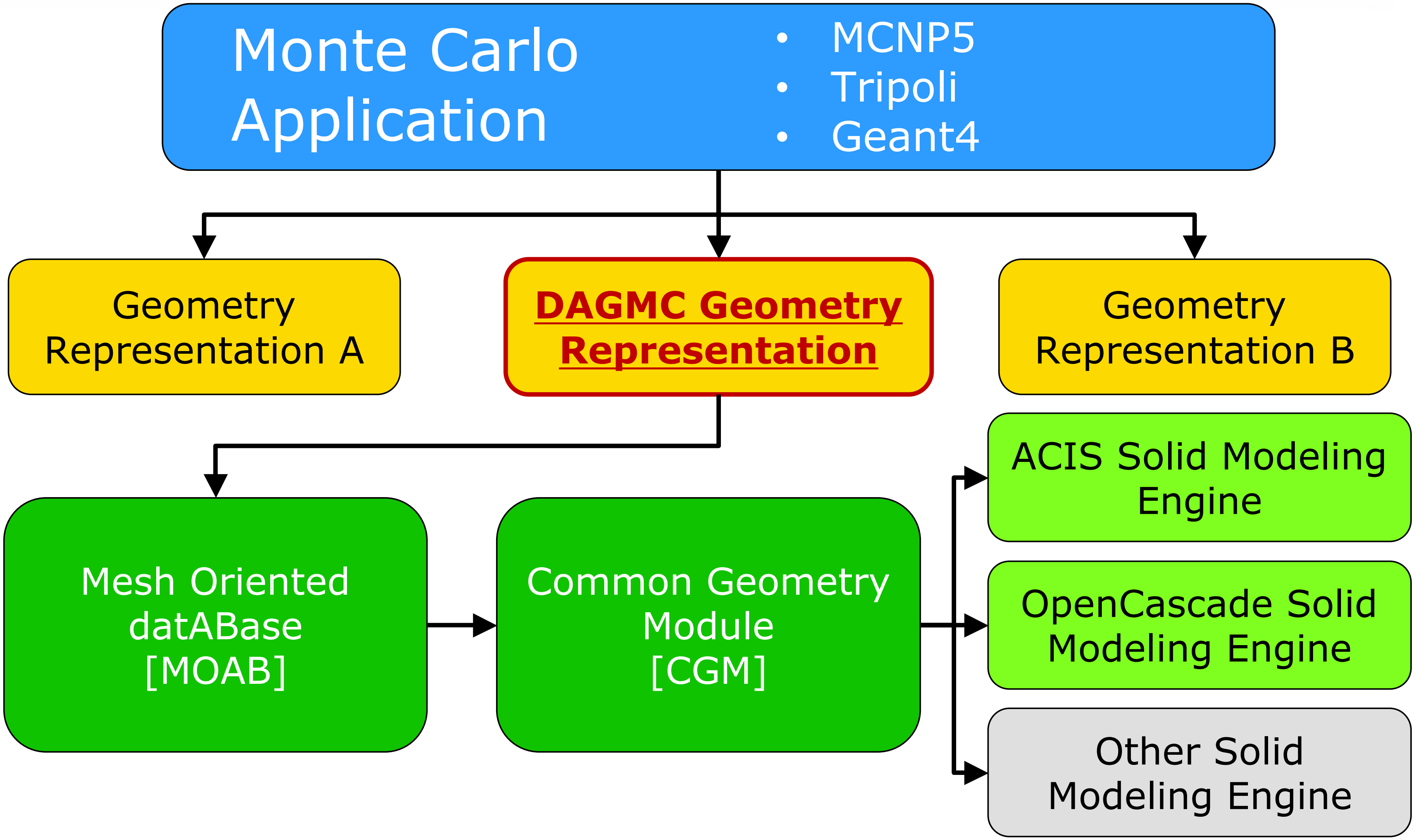
- What is DAGMC
- Project objectives
- Define faceting tolerance
- Problem descriptions
- Results
- Conclusions
- Future work
- Questions

DAGMC Overview

- Direct Accelerated Geometry Monte Carlo
  - Direct use of CAD geometries without conversion
  - Simpler workflow
  - Richer geometric representation
  - Provide common domain for coupling to other analyses

Direct Accelerated Geometry Monte Carlo

Software Infrastructure

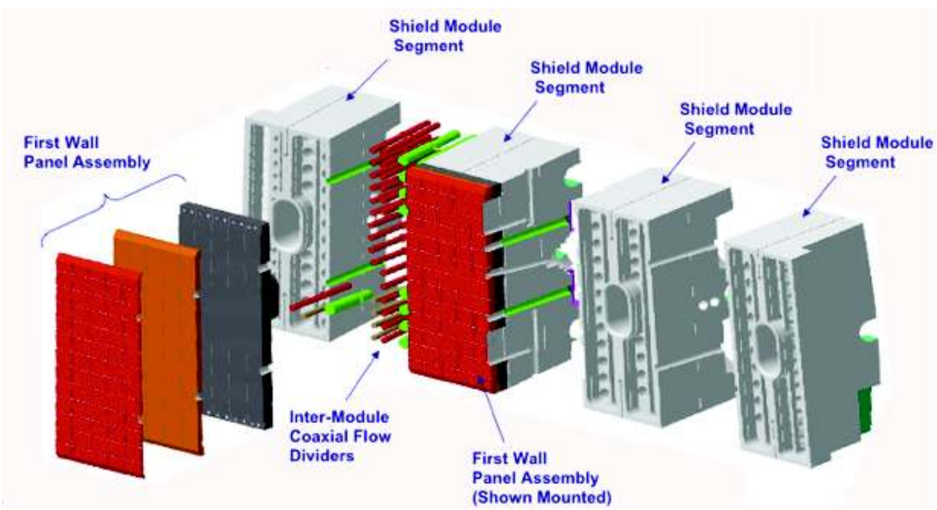


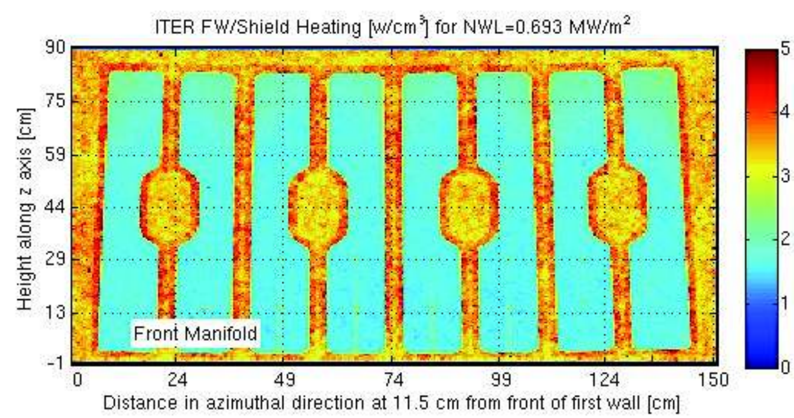
Accelerations necessary

- CAD geometry by solid modeler facets
  - Accelerates ray-firing vs. high-order root finding
  - Preserves nominal accuracy
  - Introduces millions of surfaces
- Oriented bounding box tree
  - Accelerates search of millions of facets

Overview of DAG-MCNP5

- Limited input
  - Only need data cards
- Uses MCNP5.1.51 physics
- Used for fusion neutronics shielding





Project Objectives

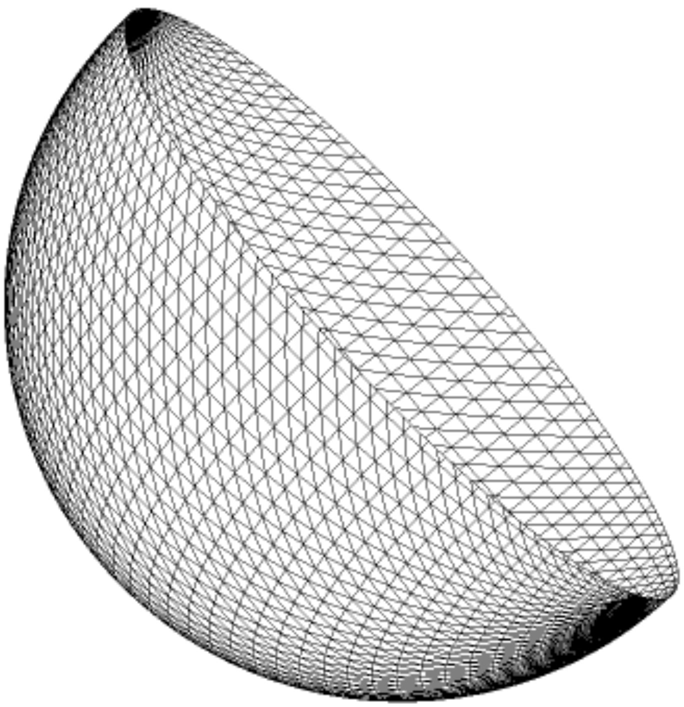
- Validate DAG-MCNP5 with criticality experiments
- Determine the effect of faceting tolerances on k_{eff}
- Determine faceting tolerance guidelines for users

Faceting Tolerances

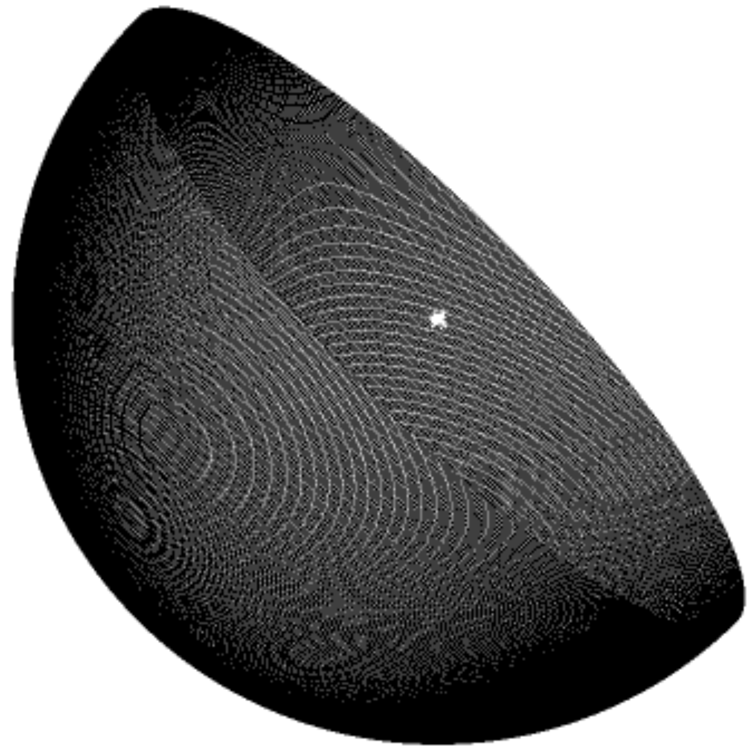
- Approximate cells with planar facets
  - Introduces volume discrepancies into model
- User sets faceting tolerance on the command line
  - Maximum distance facets can be from the analytical surface
  - Usually set to 10 microns
- Lower faceting tolerances have smaller volume discrepancies but longer run times

Faceting Differences Example

10^{-2} cm faceting tolerance
10212 facets
2792.13 cm^3



10^{-4} cm faceting tolerance
398348 facets
2796.44 cm^3



Analytic Volume: 2796.55 cm^3

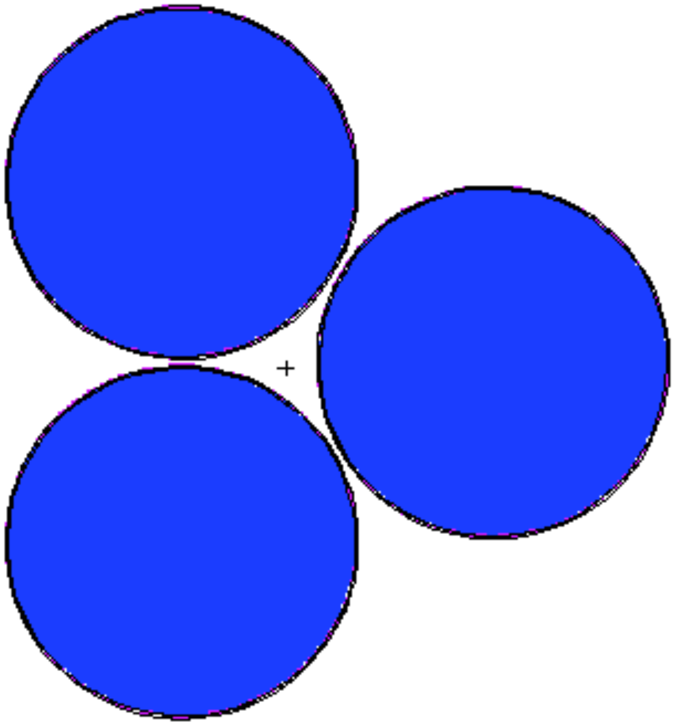
Test Problems

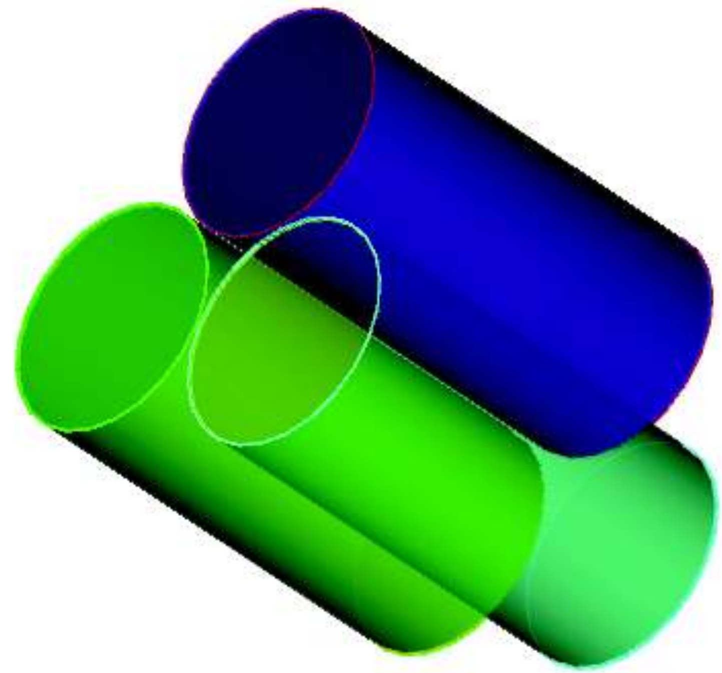
- Three test problems
  - 3 uranium cylinders
  - Plutonium buttons
  - Godiva
- Ran DAG-MCNP5 with faceting tolerances of 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, and 10^{-6} cm and compared to MCNP5 and benchmark results

3 Uranium Cylinders

- Three unreflected uranium cylinders containing a solution of UO_2F_2 and water
  - Solution in 10.15 cm radius cylinder 41.1 cm tall
  - Al 0.15 cm thick on all sides
  - U enriched to 93.2% U^{235}
  - 0.090 g of U^{235}/cm^3
  - H to U^{235} ratio of 309
  - Cylinders in equilateral triangle with a surface separation of 0.38 cm
- 30 inactive cycles, 3270 total cycles, 40000 particles per cycles

3 Uranium Cylinders

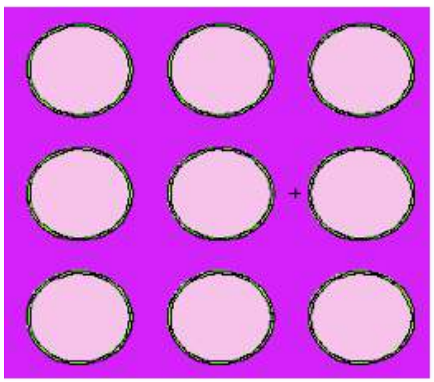


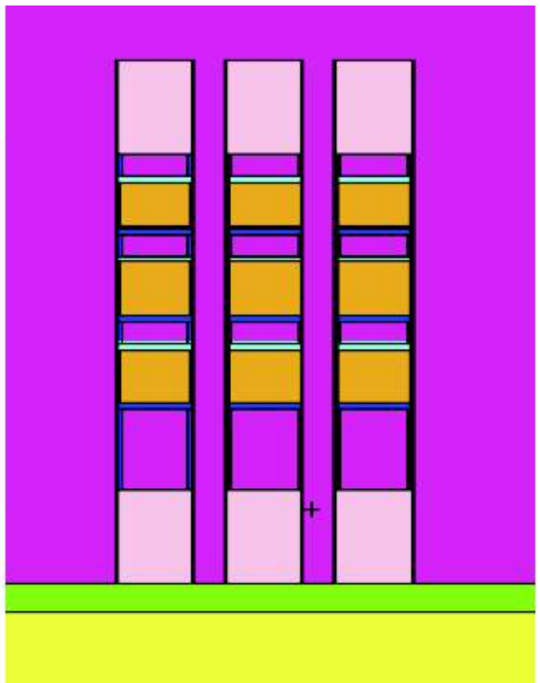


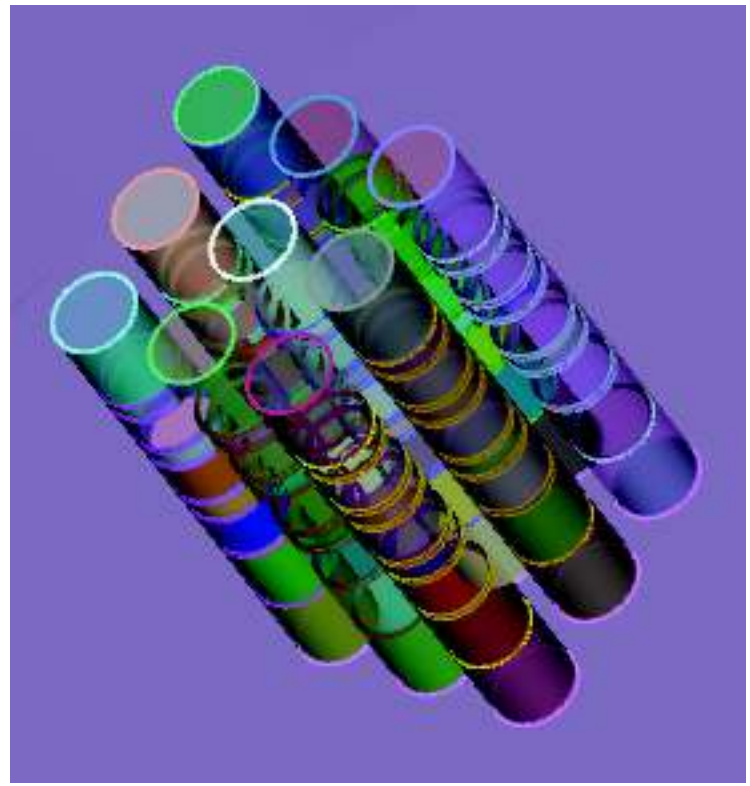
Plutonium Button Array

- 3x3 array of rods on a table
- Each rod contains three Pu cells separated by 7.70 cm center-to-center vertical spacing
- 9.60 cm center-to-center rod spacing
- Pu enriched to 93.56% Pu^{239}, 5.97% Pu^{240}, 0.46% Pu^{241}, and 0.01% Pu^{242}
- Rods have various spacers and heat sinks
- Modeled without walls
- 60 inactive cycles, 150 total cycles, 432000 particles per cycles

Plutonium Button Array



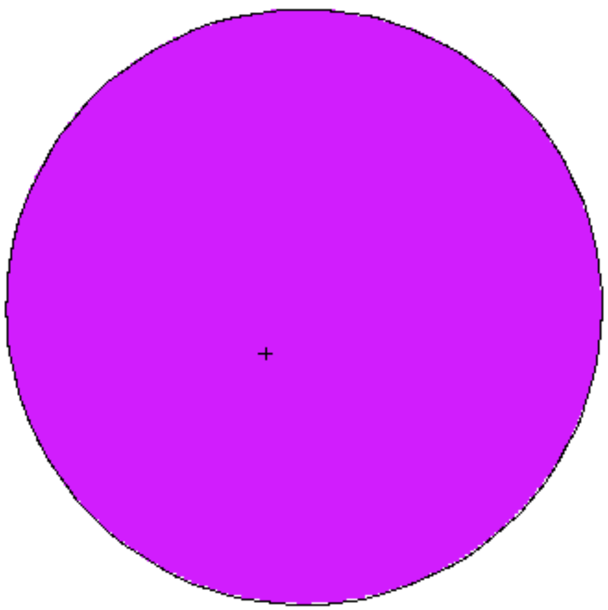


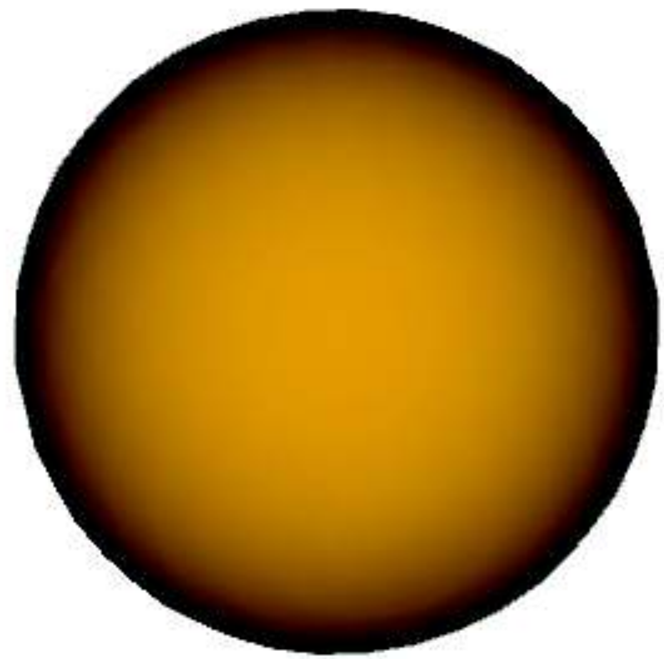


Godiva

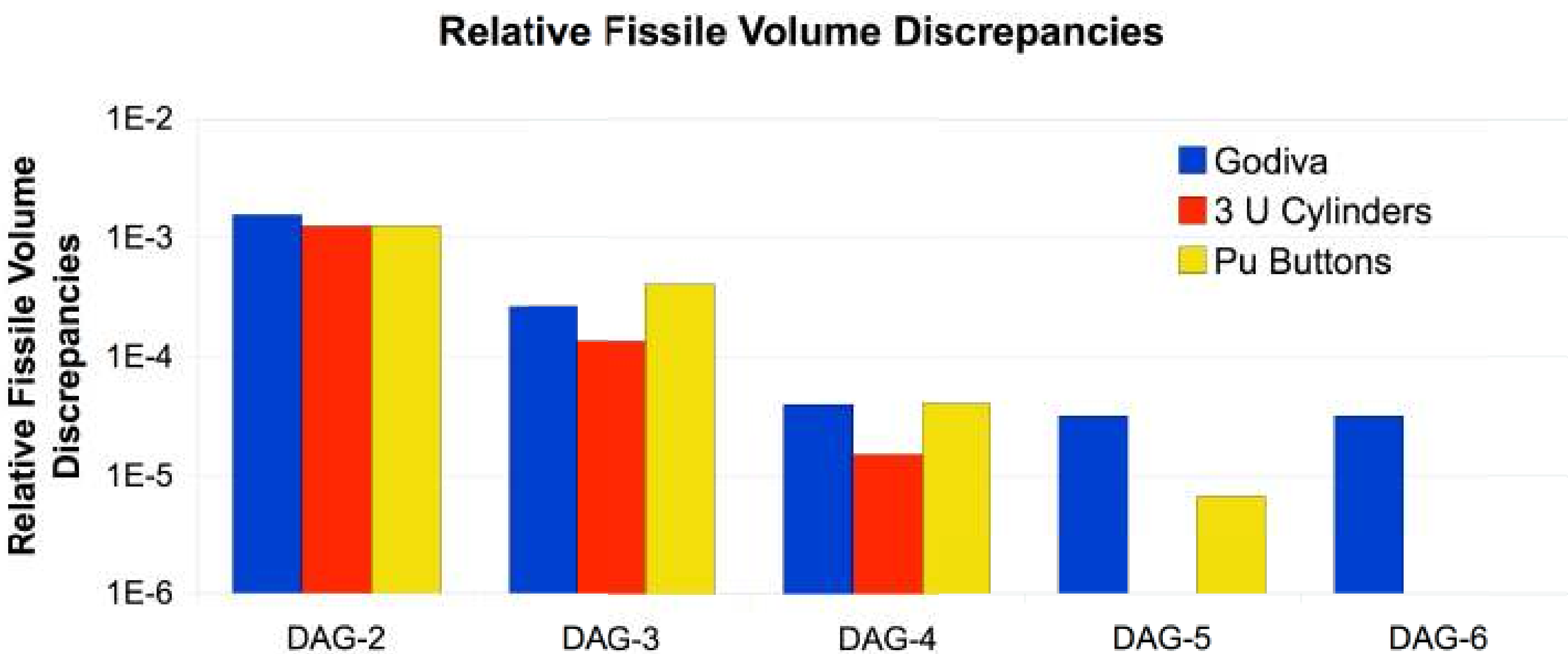
- Bare uranium sphere
- Enriched to 93.71% U^{235}
- 8.741 cm radius
- 60 inactive cycles, 150 total cycles, 432000 particles per cycles

Godiva



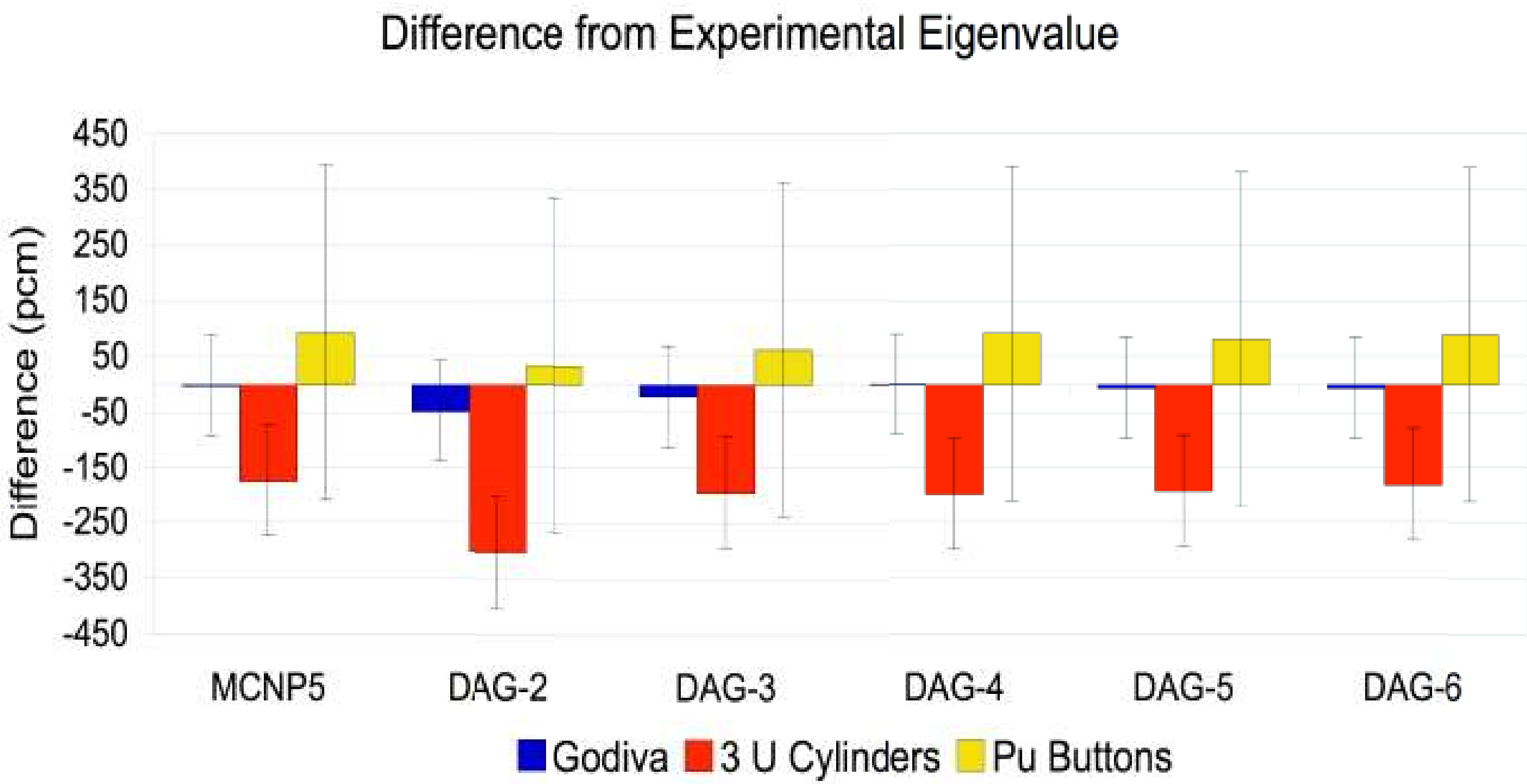


Results



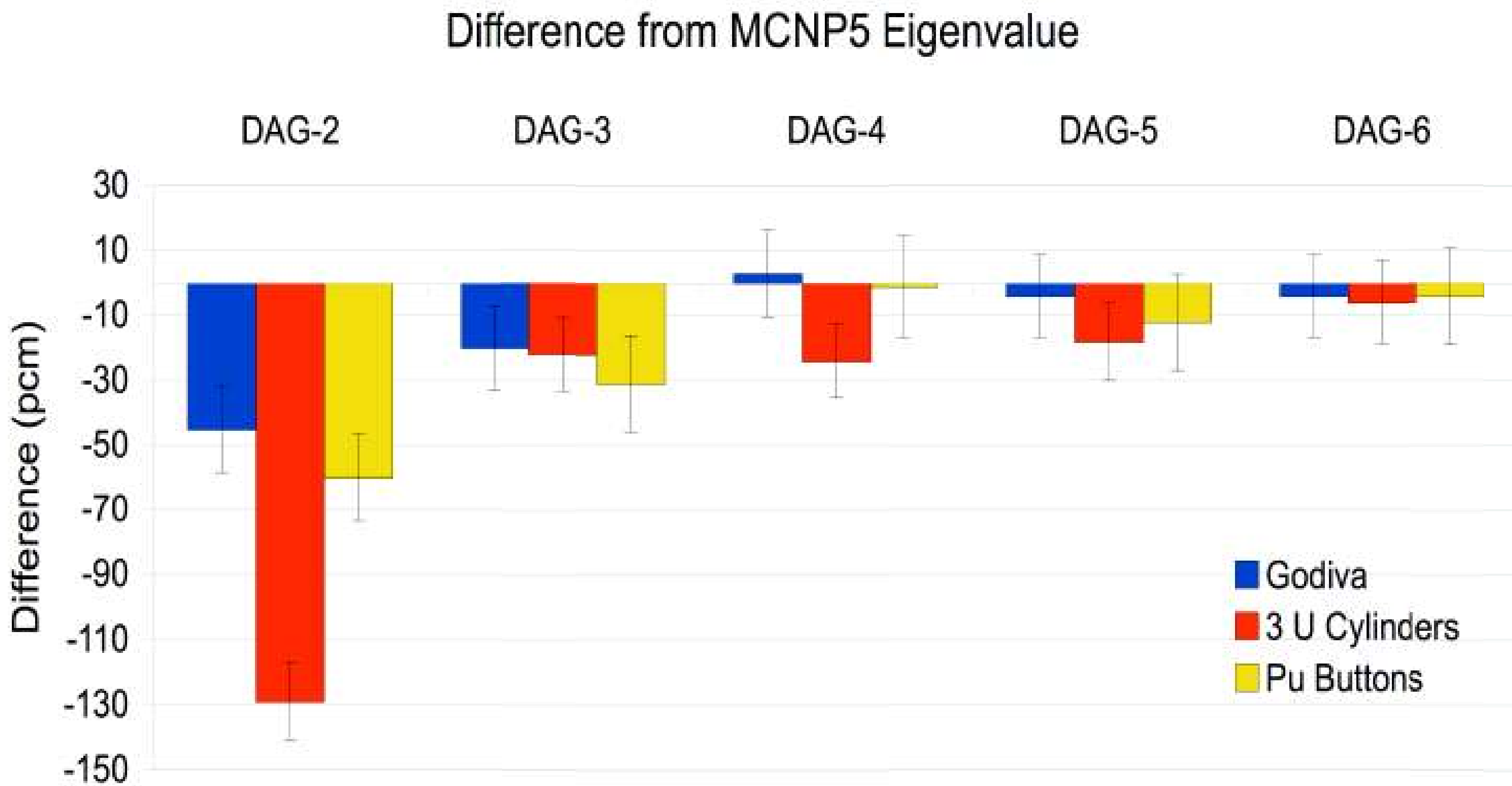
Relative Fissile Volume Discrepancies
Relative Fissile Volume Discrepancies
1E-2
1E-3
1E-4
1E-5
1E-6
Godiva
3 U Cylinders
Pu Buttons
DAG-2
DAG-3
DAG-4
DAG-5
DAG-6

Results



Difference from Experimental Eigenvalue
Difference (pcm)
450
350
250
150
50
-50
-150
-250
-350
-450
MCNP5
DAG-2
DAG-3
DAG-4
DAG-5
DAG-6
Godiva
3 U Cylinders
Pu Buttons

Results


Difference from MCNP5 Eigenvalue
DAG-2
DAG-3
DAG-4
DAG-5
DAG-6
30
10
-10
-30
-50
-70
-90
-110
-130
-150
Difference (pcm)
Godiva
3 U Cylinders
Pu Buttons

Conclusions

- Faceting tolerance significantly changes the results for DAG-MCNP5
- High faceting tolerances result in poor agreement with the MCNP5 results
- Optimal faceting tolerance is between 10^{-4} cm and 10^{-5} cm
- DAG-MCNP5 appears to be as valid as MCNP5 if an appropriate faceting tolerance is used

Future Work

- Document DAG-MCNP5 with more critical systems, shielding applications, and analytical problems
- Investigate why lower faceting tolerances does not necessarily mean better agreement with MCNP5
- Research alternative faceting schemes to preserve volume better

References

1. T.J. TAUTGES, P.P.H. Wilson, et al, "Acceleration Techniques for Direct Use of CAD-Based Geometries in Monte Carlo Radiation Transport," Proc. of the 2009 Int'l Conf. on Mathematics, Computational Methods & Reactor Physics, Saratoga Springs, NY, May 3-7 (2009).

2. T.J. TAUTGES, "CGM: A geometry interface for mesh generation, analysis, and other applications," Engineering with Computers, 17, pp. 299-314 (2001)

3. T.J. TAUTGES, R. MEYERS, K. MERKLEY, et al, "MOAB: A Mesh Oriented Database," SAND2004-1592, Sandia National Laboratories, April (2004)

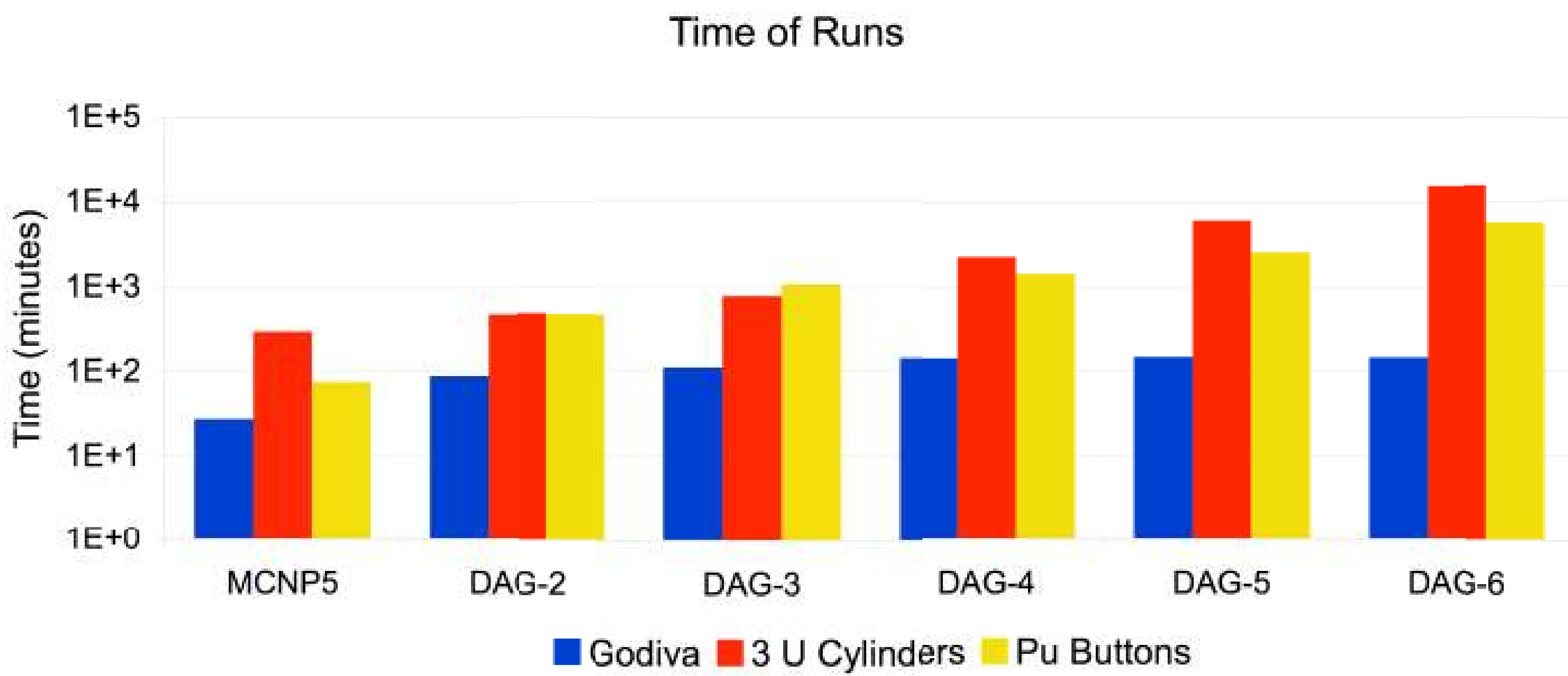
4. X-5 Monte Carlo Team, "MCNP-A General Monte Carlo N-Particle Transport Code, Version 5 - Vol. I: Overview and Theory," LA-UR-03-1987

5. D.J. WHALEN, D. A. CARDON, J. L. UHLE, J. S. HENDRICKS, MCNP: Neutron Benchmark Problems, Los Alamos Report LA-12212, Los Alamos National Laboratory, Los Alamos, NM, (1991).

6. NEA NUCLEAR SCIENCE COMMITTEE, International Handbook of Evaluated Criticality Safety Benchmark Experiments, NEA/NSC/DOC(95)03, Idaho National Laboratory, Idaho Falls, ID (2007).

Questions?

Time Data



Time of Runs
1E+5
1E+4
1E+3
1E+2
1E+1
1E+0
Time (minutes)
MCNP5
DAG-2
DAG-3
DAG-4
DAG-5
DAG-6
Godiva
3 U Cylinders
Pu Buttons

Table of Keff Results

	Godiva	U Cylinders	Pu Buttons
Experiment	1.0000 ± 0.0010	1.000 ± 0.0010	1.000 ± 0.0030
MCNP5	0.99998 ± 0.00009	0.99827 ± 0.00008	1.00093 ± 0.00010
DAG-2	0.99953 ± 0.00010	0.99698 ± 0.00009	1.00033 ± 0.00009
DAG-3	0.99978 ± 0.0009	0.99805 ± 0.00008	1.00062 ± 0.00011
DAG-4	1.00001 ± 0.00010	0.99803 ± 0.00008	1.00092 ± 0.00011
DAG-5	0.99994 ± 0.00009	0.99809 ± 0.00009	1.00081 ± 0.00011
DAG-6	0.99994 ± 0.00009	0.99821 ± 0.00009	1.00089 ± 0.00011