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Title: MCNP6.3 Unstructured Mesh Verification: Godiva and CANDU Models

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Los Alamos NATIONAL LABORATORY

MCNP6.3 Unstructured Mesh Verification: Godiva and CANDU Models

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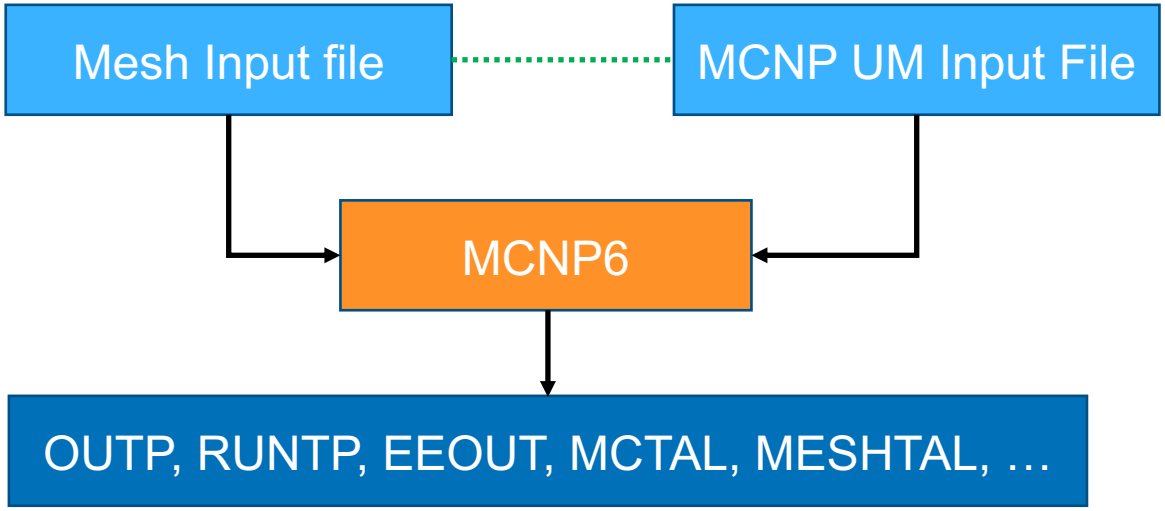
MCNP User Symposium
October 17-21, 2022

MCNP Unstructured Mesh Feature



inputs

outputs

Mesh Input File Format:

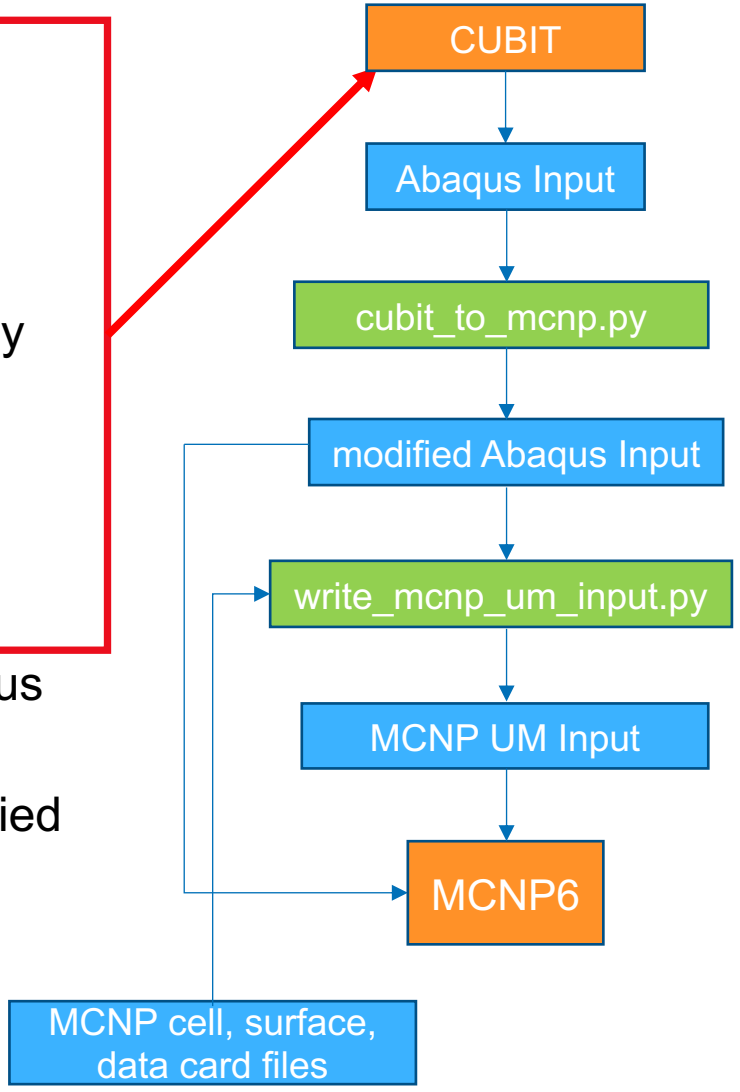
- Abaqus Input (ASCII; MCNP 6.0 - 6.3 versions)
- HDF5 (binary; MCNP 6.3 version)

EEOUT (Elemental Edit OUTput) File Format:

- Flat File (ASCII or binary; MCNP 6.0 - 6.3 versions)
- HDF5 (binary; MCNP 6.3 version)

Using CUBIT to create Abaqus Input Files for MCNP UM Calculations

1. Create solid 3D geometry or import CAD model.
2. Prepare model for meshing.
3. Generate mesh.
4. Check mesh qualities and volumes. If they are not good enough, go to 1, 2, or 3.
5. Create materials.
6. Create blocks and assign materials.
7. Export a mesh model as an Abaqus file.
8. Run cubit_to_mcnp.py to create an Abaqus file satisfying the MCNP requirement.
9. Run write_mcnp_um_input.py on a modified Abaqus input file to create an MCNP (skeleton) input file.
10. Run an MCNP UM Calculation.
11. Postprocess and analyze MCNP results.



Godiva Sphere Reflected by Water (HEU-MET-FAST-004)

A model taken from the International Handbook of Evaluation Criticality Safety Benchmark Experiments

Constructive Solid Geometry (CSG) Setup

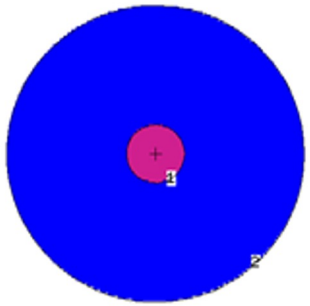
```
Oy sphere (97.67 w/o) in sphere of H2O  HEU-MET-FAST-004
 1      1  0.048143     -1                    $ oralloy sphere
 2      2  0.10021       1    -2               $ water sphere
 3      0                   2

 1      so     6.5537                  $ radius of oralloy sphere
 2      so    33.4717                  $ radius of water sphere

c       Oy (97.675 w/o) 18.74
m1       92234.80c     0.011150      92235.80c     0.97694
         92236.80c     0.0019919     92238.80c     0.0099250
c       Water    0.998207
m2       1001.80c     0.66667
         8016.80c     0.33320       8017.80c     1.3333e-4
```

Experimental benchmark keff = 0.9985 +/- 0.0011

Calculated Keff: 0.99983 +/- 0.00059
Volume: 157,080.372 cm^3
Computing Time: 12.42 minutes



The MCNP code cannot be used to create UM models.

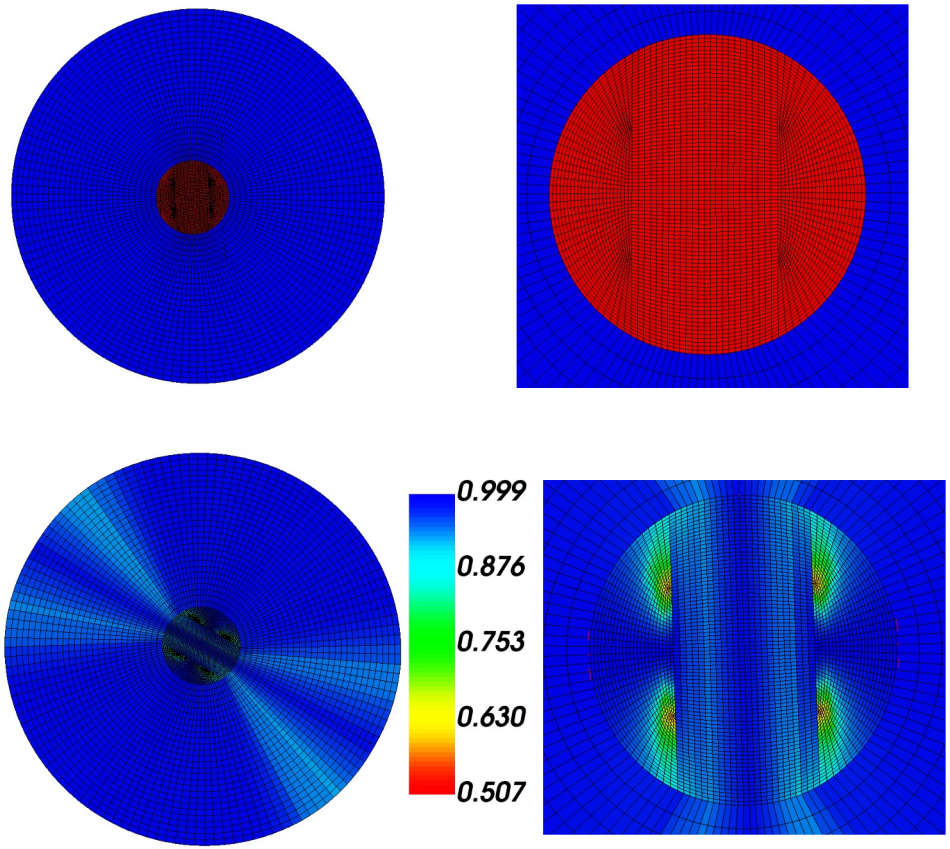
Create Linear Hex UM Model by CUBIT: Godiva

Abaqus Model Exported From Cubit

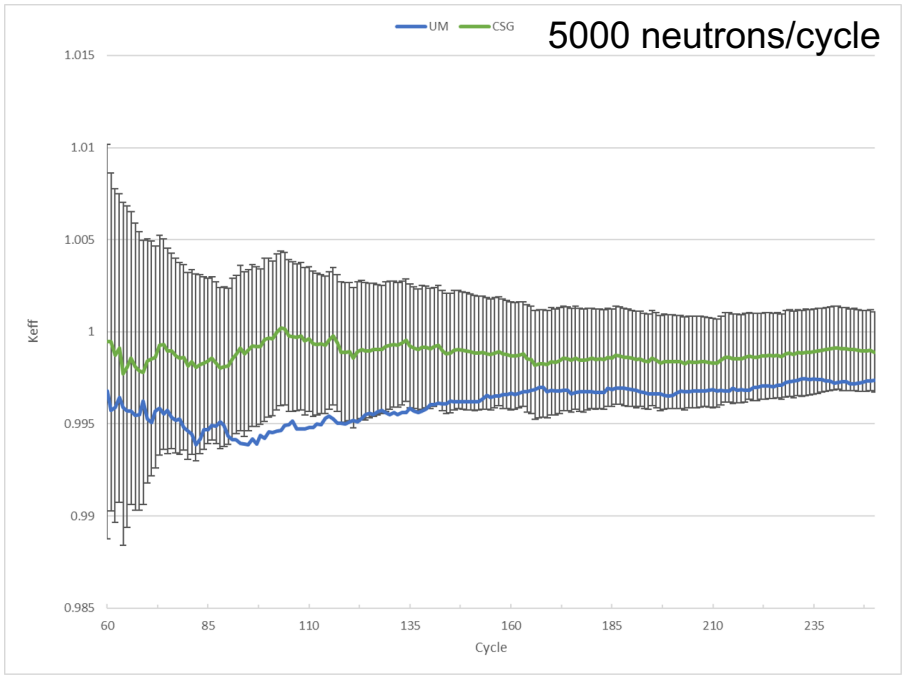
----------List Summary----------
Number of entities: 2
Total Volume: 157,080.152cm^3
Volume Meshed: 156,845.1251cm^3 99.85%

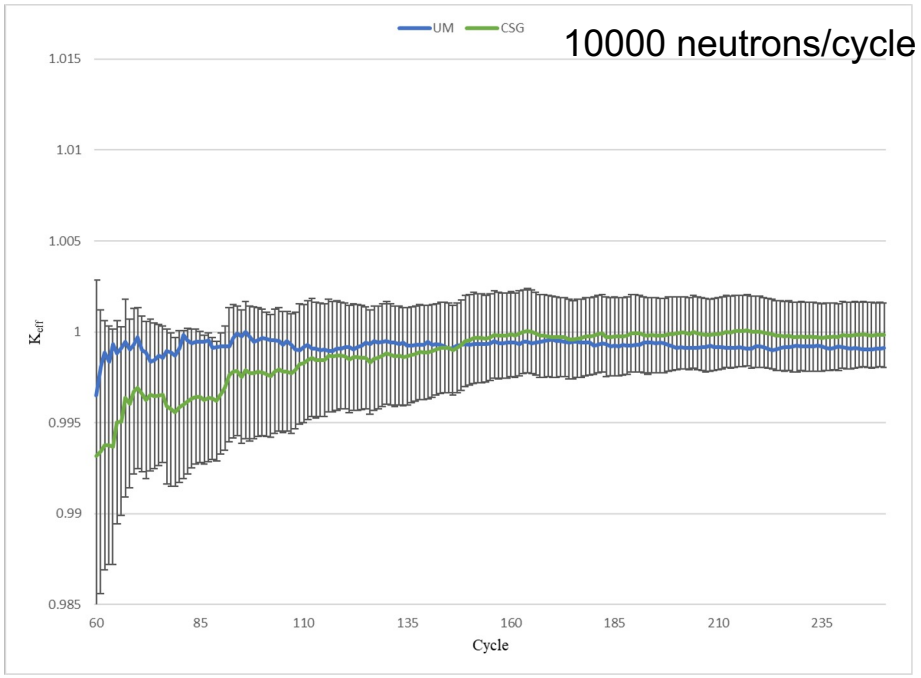
HEU Sphere is 99.89719% meshed volume
H2O Sphere is 99.84962% meshed volume
HEX Mesh : Hex quality 253,616 elements

Keff: 0.999127 +/- 0.000525
Computing Time: 55.46 minutes



MCNP Results: Godiva





Calculated Keff: for 10,000 neutrons

CSG 0.999832 +/- 0.000590

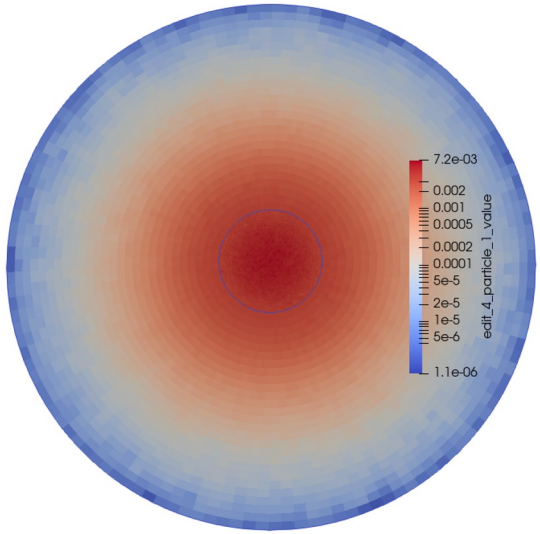
UM 0.999127 +/- 0.000525

Geometry	68% confidence	95% confidence	99% confidence
CSG	0.99924 - 1.00042	0.99866 -1.00101	0.99827 - 1.00139
UM	0.99860 - 0.99965	0.99808 - 1.00017	0.99774 - 1.00052

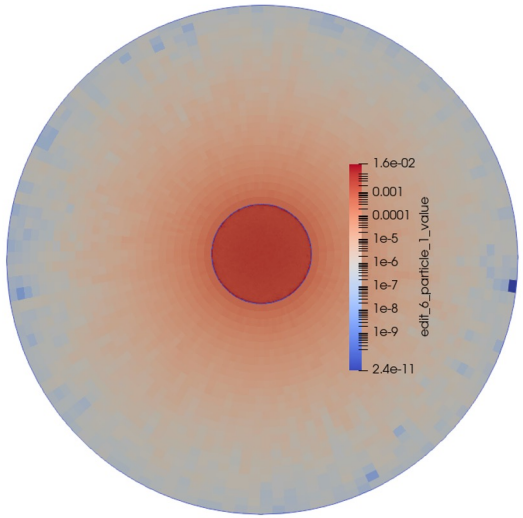
Visualization by ParaView: Godiva

Using MCNP HDF5 Elemental Edit Output (EEOUT) file

Flux



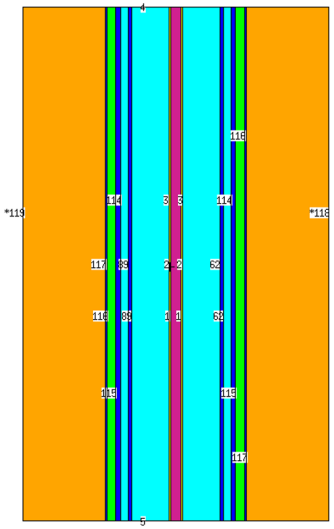
Energy Deposition

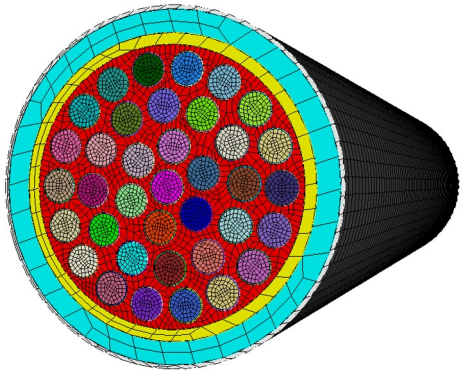


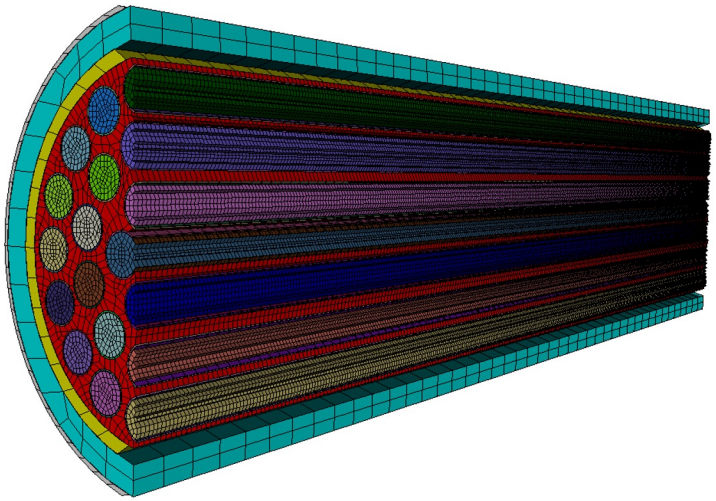
CANDU

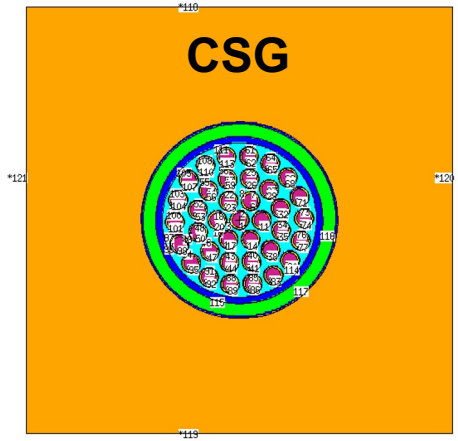
Canadian Deuterium natural Uranium reactor fuel bundle
37-element

- Requires that the UM bundle is inside a CSG cell which is then reflected
  - Representing full core
- Geometric Meshes are grouped by material
  - Representing a cell geometry



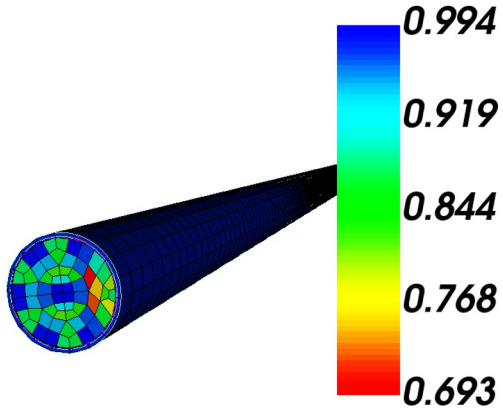


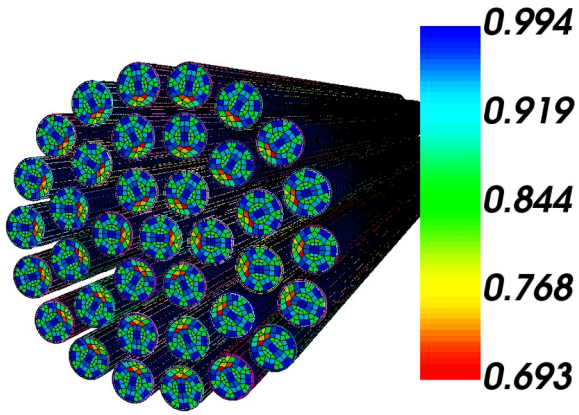




UM generated by CUBIT

Meshed Bundle

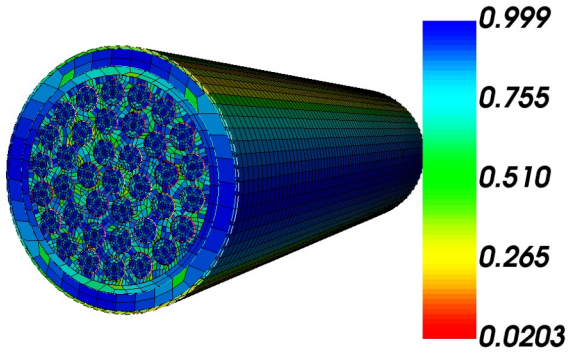




Single Fuel Pin
Fuel 20,274 hexes 98.864%
Air & Clad 3,888 hexes 97.981%
37 PINs 893,994 hexes

Total
1,086,339 hex elements 100.082% Meshed

Fuel-1
Difference % 1.1354
Air-2
Difference % 2.0191
Clad-3
Difference % 0.5365
Coolant-4 *Mesh is overcompensated
Difference % -2.3171
CO2-5
Difference % 0.0894

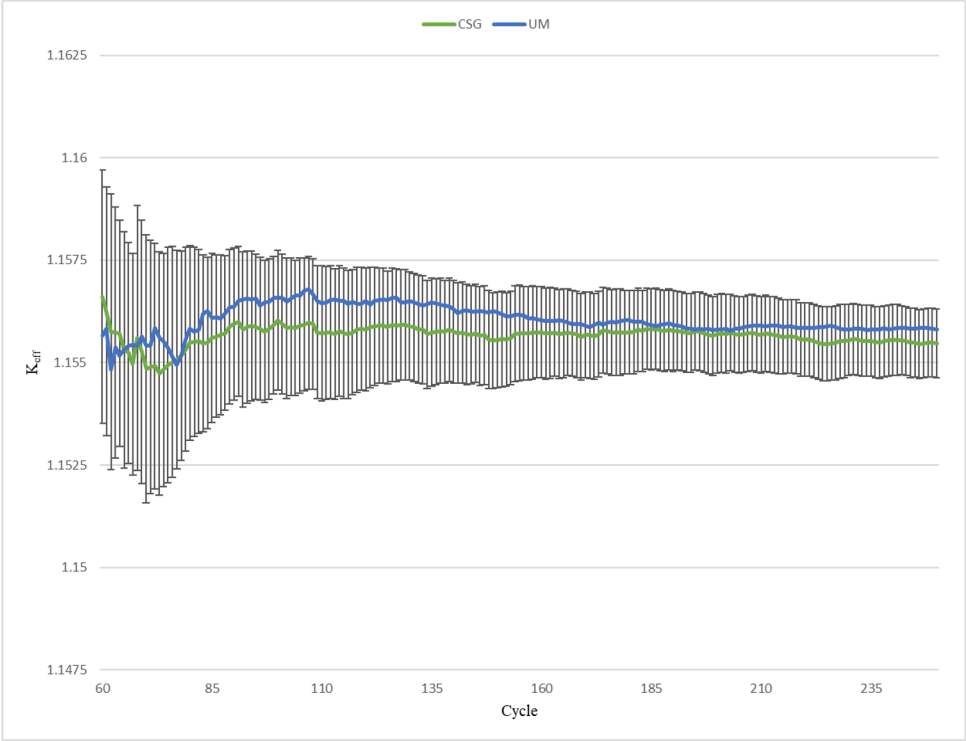


Quality of meshes

MCNP Results: CANDU

CSG:
final keff = 1.155468 +/- 0.000279

UM:
final keff = 1.155801 +/- 0.000281



Geometry	68% confidence	95% confidence	99% confidence
CSG	1.15519 - 1.15575	1.15491 - 1.15602	1.15473 - 1.15621
UM	1.15552 - 1.15608	1.15524 - 1.15636	1.15506 - 1.15654

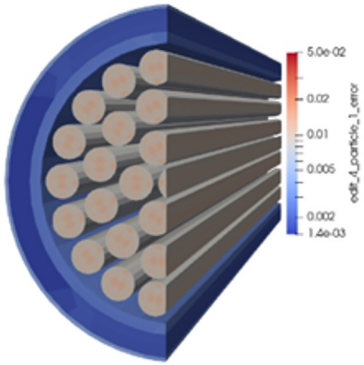
Visualization by ParaView: CANDU

Edit 4 and error

embee4:n

embed=1 errors=yes

Error 5e-2 max

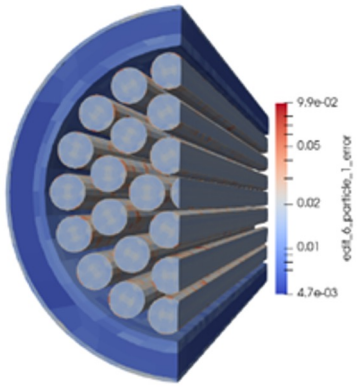


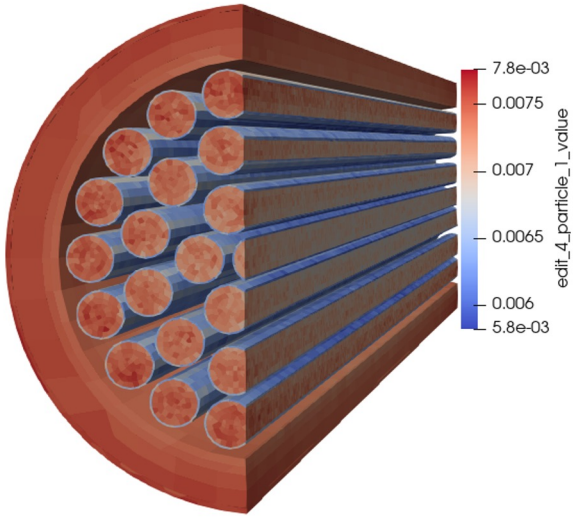
Edit 6 and error

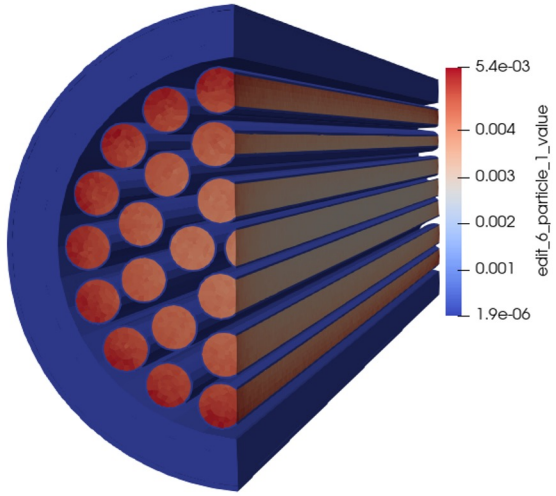
embee6:n

embed=1 errors=yes

Error 2e-1 max







High fidelity 3D results

Conclusion

- Cubit was used to create unstructured mesh models for Godiva reflected by water and CANDU fuel bundle. Linear hexahedral element models were created.
- The KCODE calculations were run for both CSG and UM models to compare the results. The results are comparable.
- HDF5 EEOUT files created by MCNP6.3 can be visualized by ParaView without post-processing.