Recent Attila Applications for ATR

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INL

November 18, 2005

Idaho National Laboratory

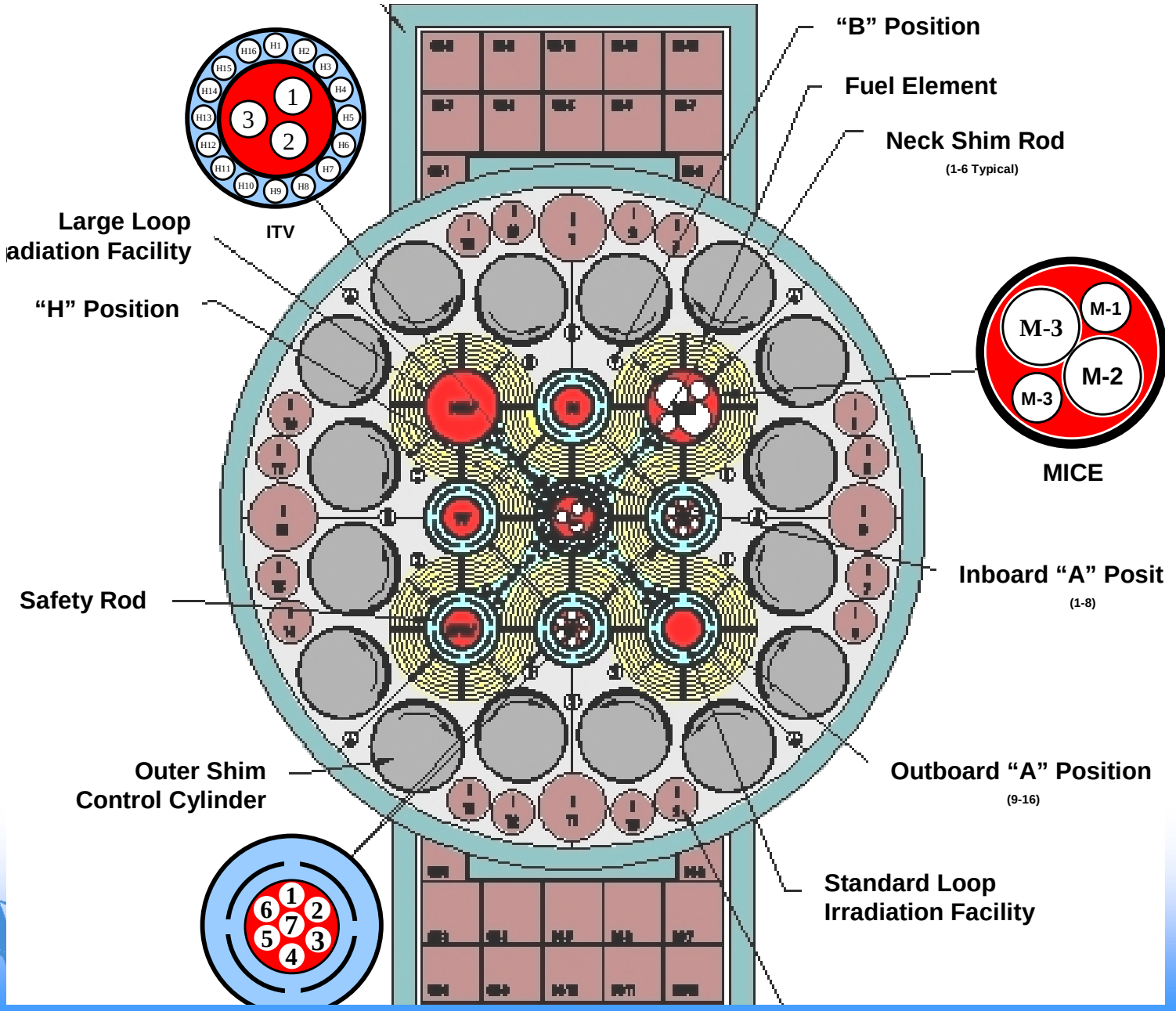
Talk

- Why Attila?
- Core Safety Analysis Program (CSAP)
- PDQ Diffusion (2D)
- ESAP MCNP
- Methods
- Models
- Results
- Summary

Idaho National Laboratory

The Advanced Test Reactor

- Largest materials test reactor (<250MWt)
- HEU in al matrix, plate fuel, water cooled, Be reflector
- Loaded with a mixture of new and recycled elements
- Not very symmetric, highly heterogeneous
- 9 flux traps, some with independent coolant loops
- Variable operating cycles (2-60 days)
- Positive void coefficient in loops


"B" Position
Fuel Element
Neck Shim Rod
(1-6 Typical)
ITV
Large Loop
adiation Facility
"H" Position
M-3
M-1
M-2
M-3
MICE
Inboard "A" Posit
(1-8)
Safety Rod
Outer Shim
Control Cylinder
Outboard "A" Position
(9-16)
Standard Loop
Irradiation Facility

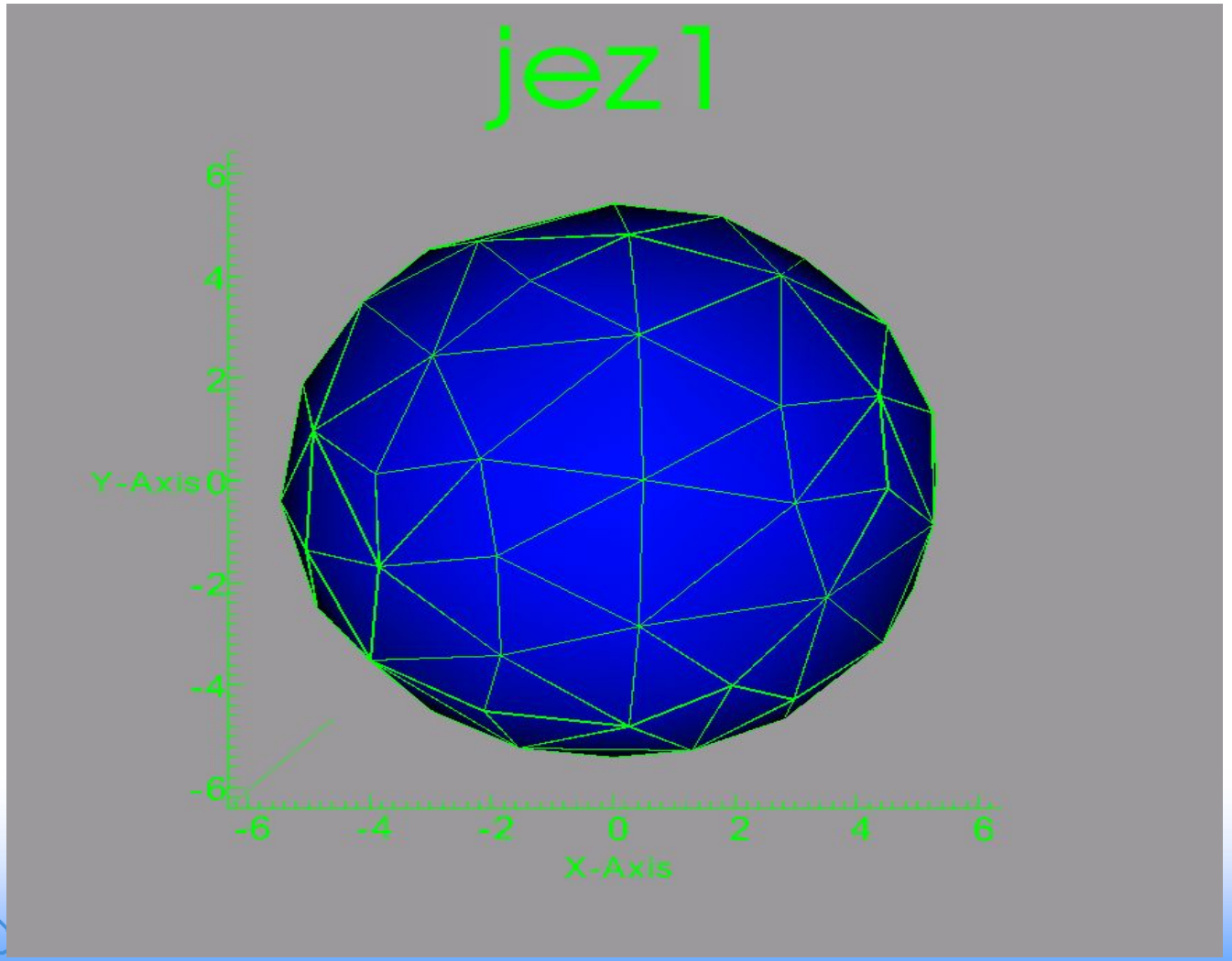
For the Reactor Physicist…Attila

- **Solves the discrete ordinates (S_n) transport equation on a 3D unstructured finite element mesh**
- **Discontinuous Galerkin method for higher order flux and current solution (3rd order accurate)**
- **Source Iteration with Diffusion Synthetic Acceleration**

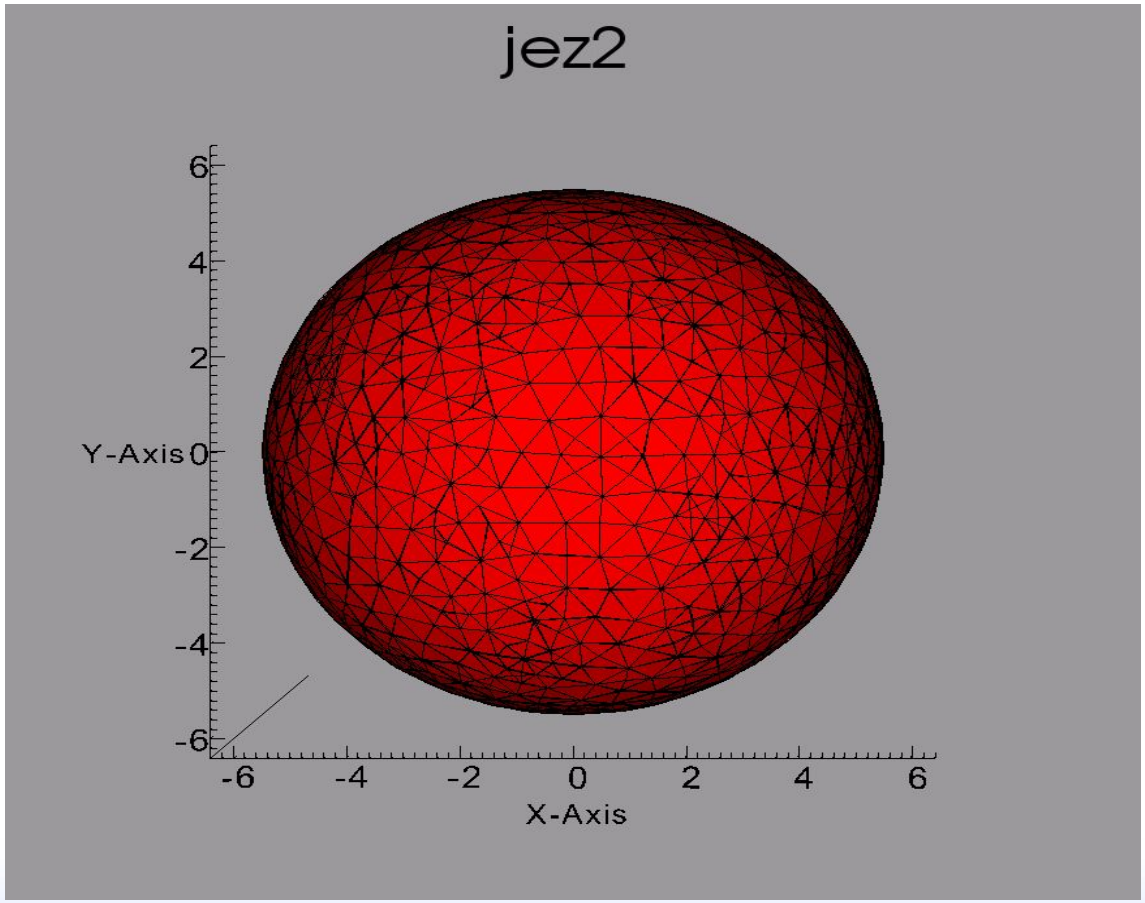
For the Core Safety Analyst…

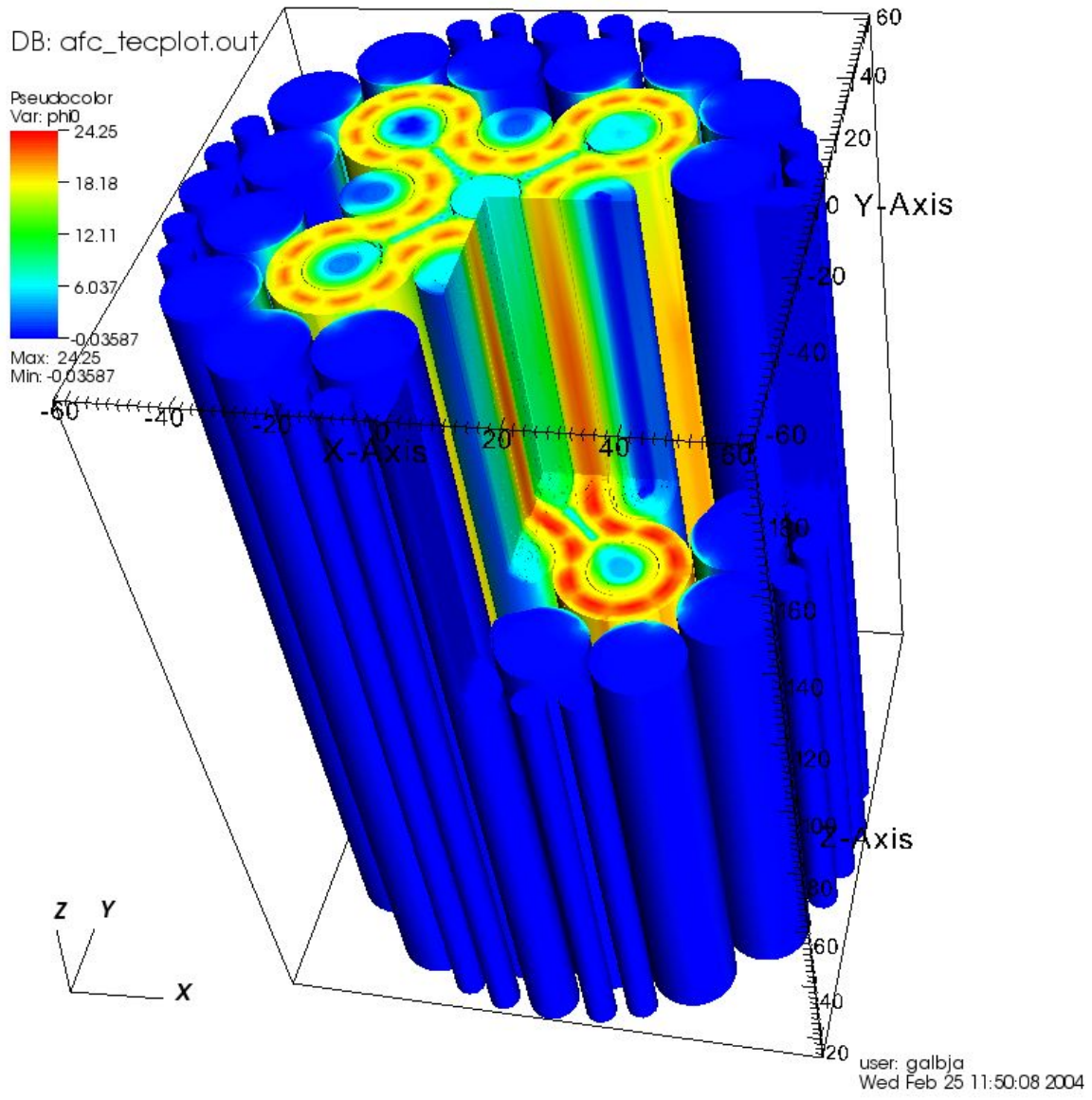
- **FE mesh generated on a CAD model (Solidworks)**
- **Output amenable to visualization techniques (VisIt)**
- **Demonstrated on many platforms (~Opteron)**
- **Depletion module being tested**

Jezebel Pu Sphere- Crude Mesh Keff=0.978



Jezebel Pu Sphere Fine Mesh Keff=1.00065

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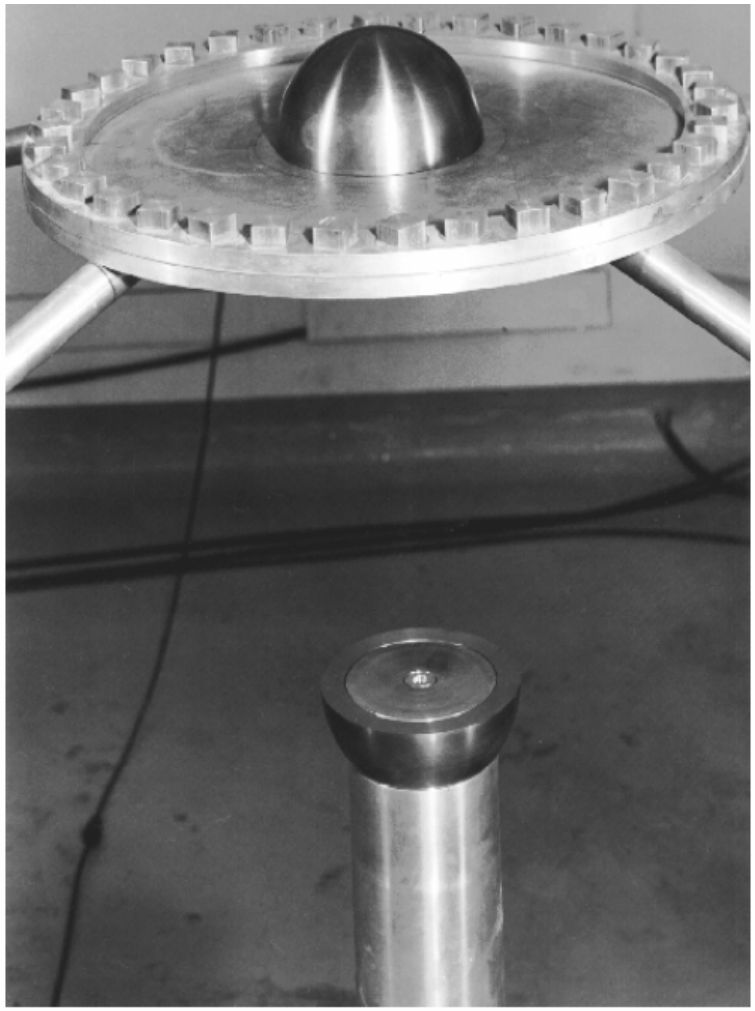
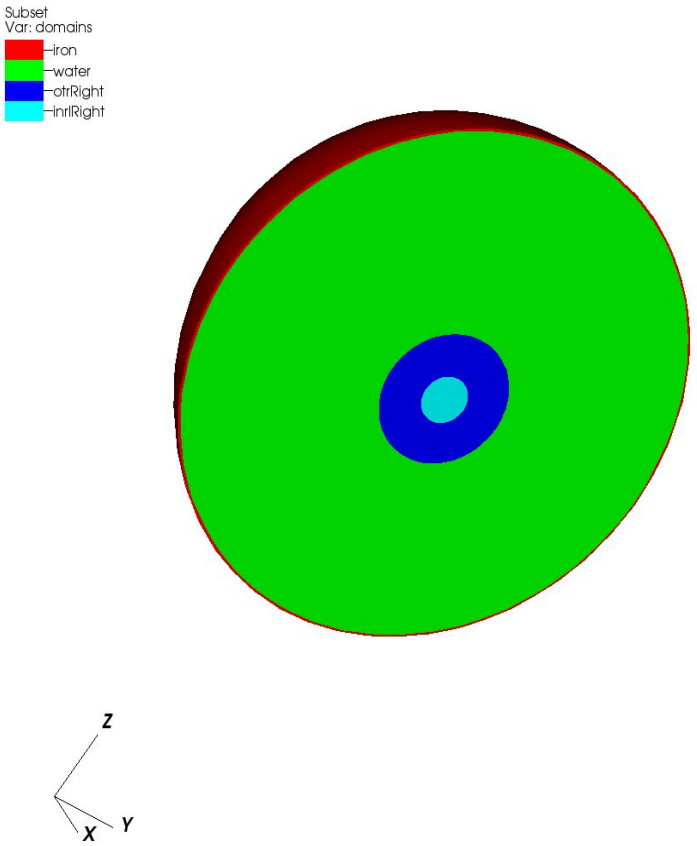
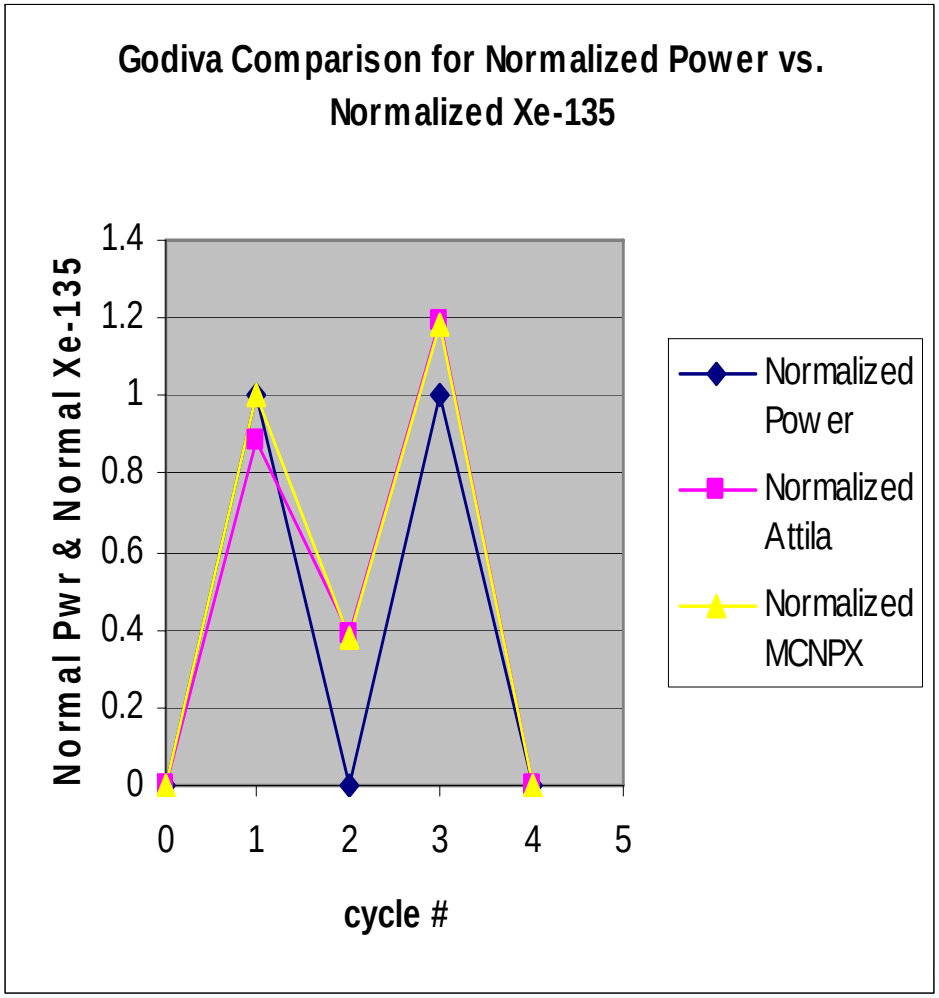
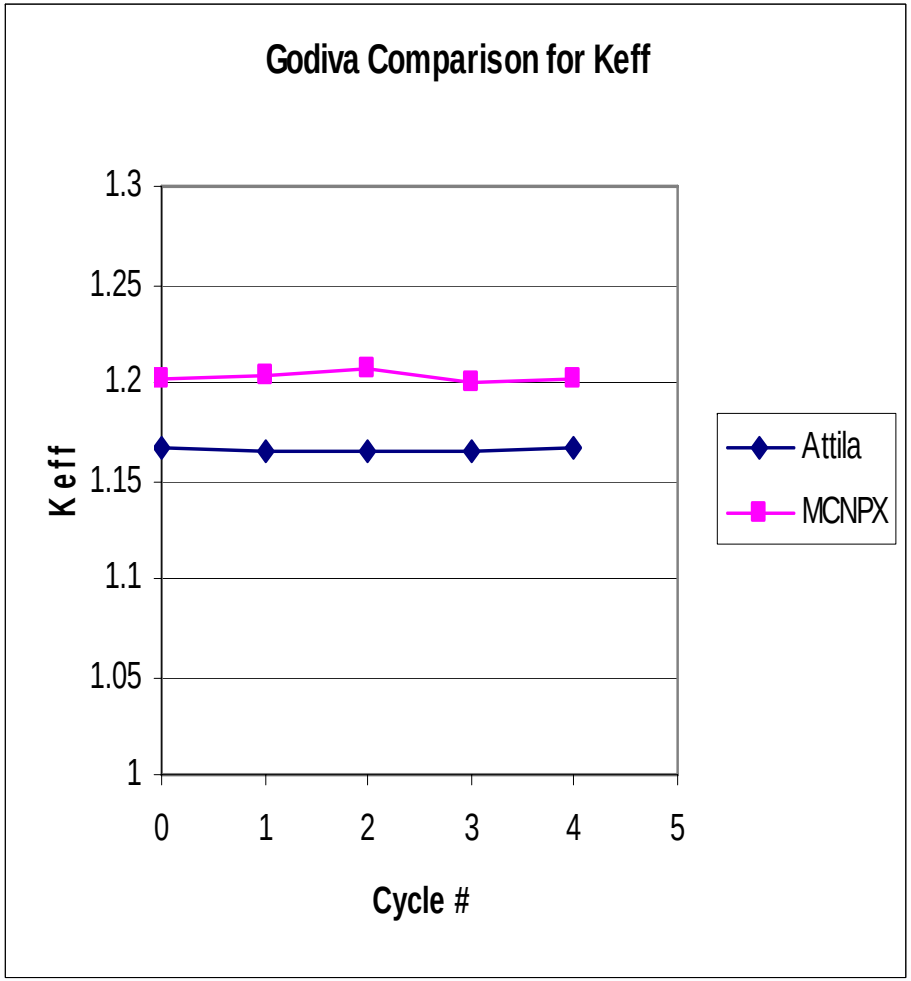
Pseudocolor
Var: phi0
24.25
18.18
12.11
6.037
-0.03587
Max: 24.25
Min: -0.03587
X-Axis
Y-Axis
Z-Axis
Z Y
X
user: galbja
Wed Feb 25 11:50:08 2004

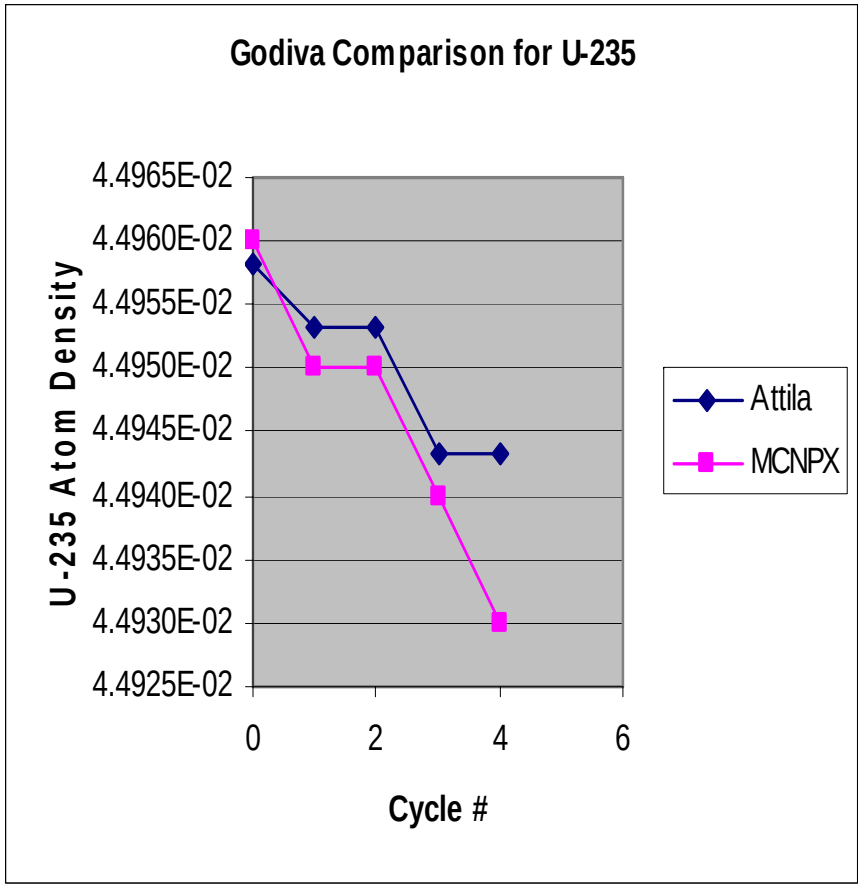
Godiva

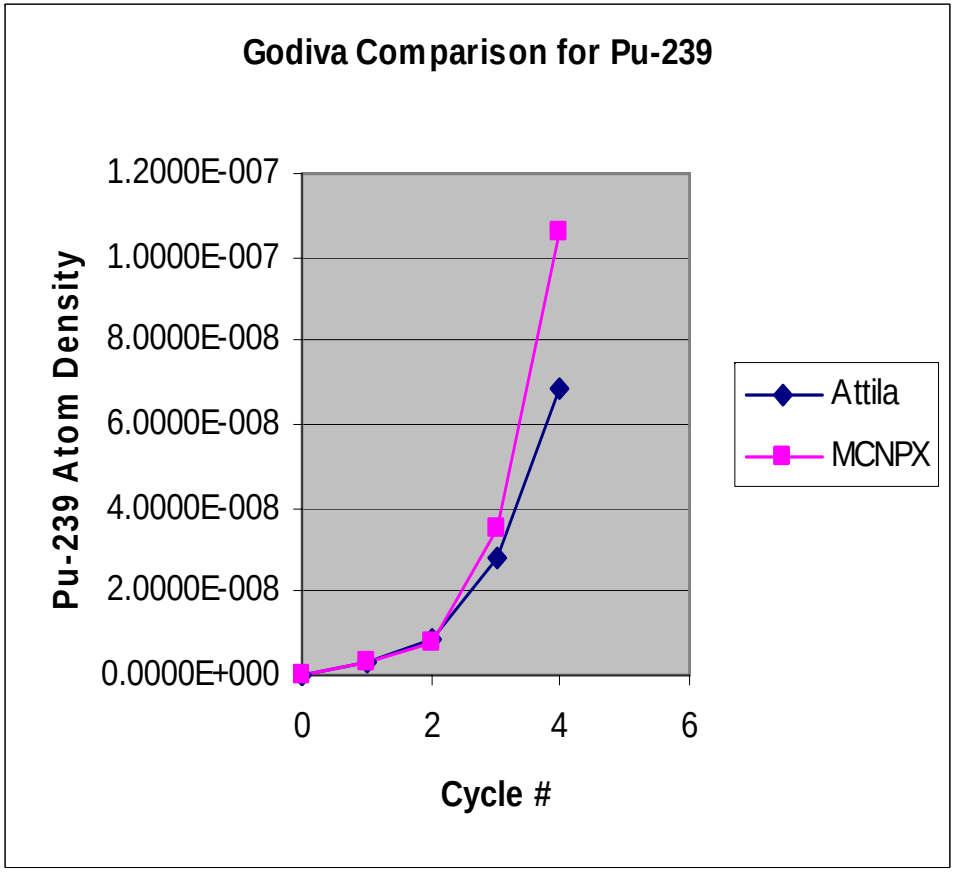





Godiva Comparison for Normalized Power vs. Normalized Xe-135
Normal Pwr & Normal Xe-135
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
cycle #
Normalized Power
Normalized Attila
Normalized MCNPX


Godiva Comparison for Keff
Keff
1.3
1.25
1.2
1.15
1.1
1.05
1
0
1
2
3
4
5
Cycle #
Attila
MCNPX


Godiva Comparison for U-235
U-235 Atom Density
4.4965E-02
4.4960E-02
4.4955E-02
4.4950E-02
4.4945E-02
4.4940E-02
4.4935E-02
4.4930E-02
4.4925E-02
0
2
4
6
Cycle #
Attila
MCNPX

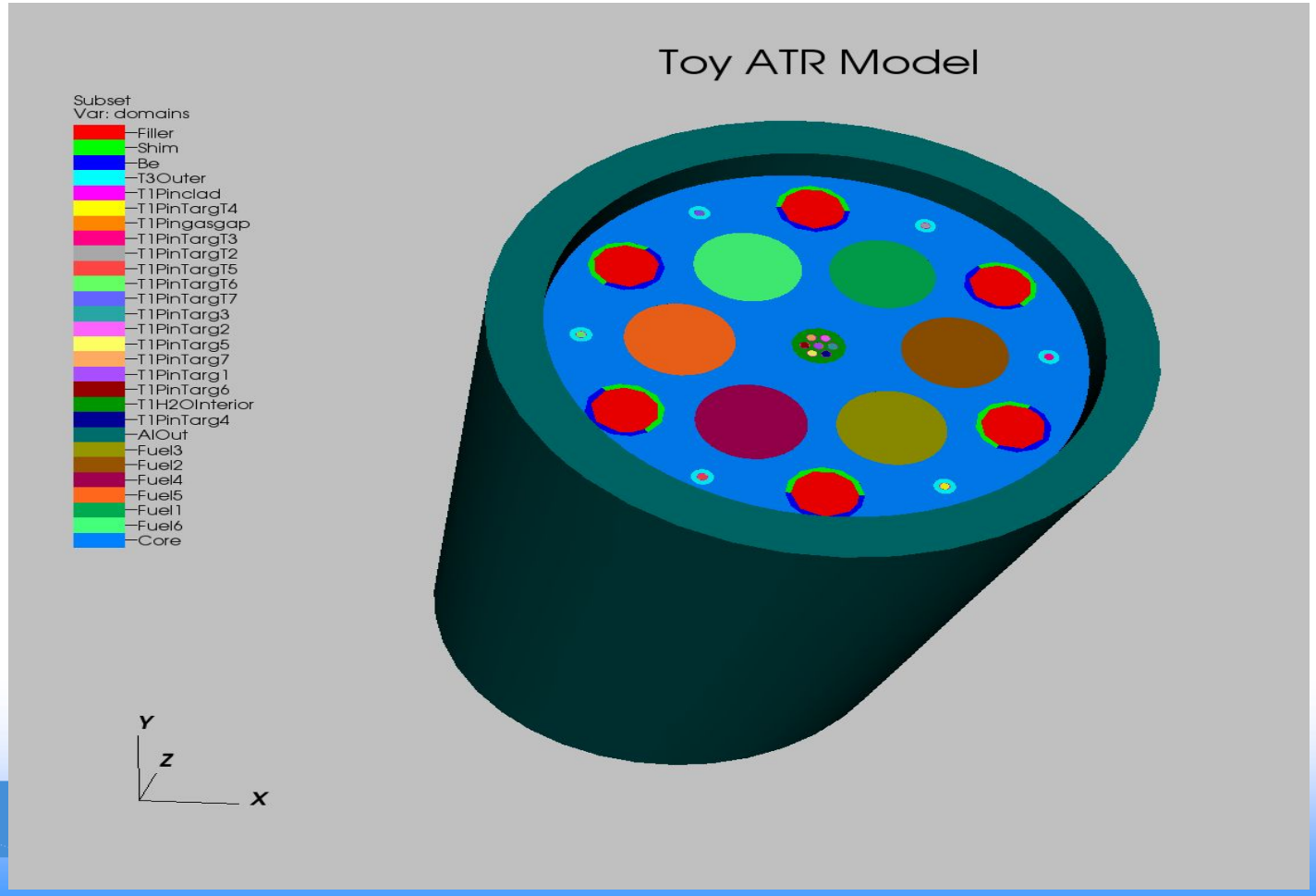

Godiva Comparison for Pu-239
Pu-239 Atom Density
1.2000E-007
1.0000E-007
8.0000E-008
6.0000E-008
4.0000E-008
2.0000E-008
0.0000E+000
0
2
4
6
Cycle #
Attila
MCNPX

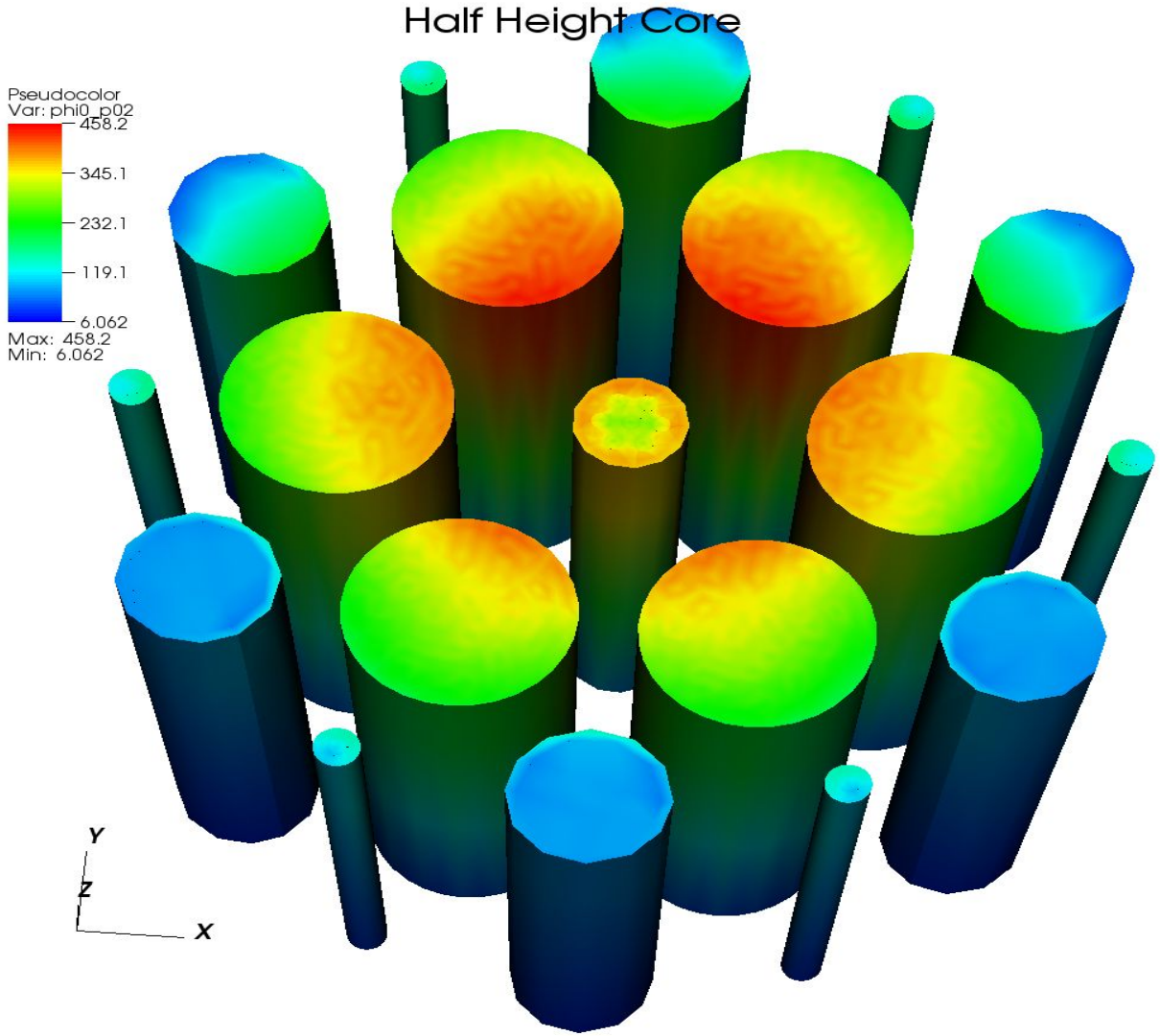
Attila

- **Deterministic Finite Element Method (FEM) Sn Linearized Boltzmann Neutron (Radiation) Transport Code**
- **Linear Discontinuous Galerkin FEM, 3rd Order Spatial Accurate**
- **Similar to Diamond Difference, Upwind or Downwind with Particle Flow, Decouples Equations for Iterative Solution**
- **Allows Negative Flux during Iteration, presents no problems for convergence**

Problem – Verify Depletion Capability

- B. Schnitzler developed Toy ATR MCNP Model
- D. S. Lucas built SW and Attila Toy Model

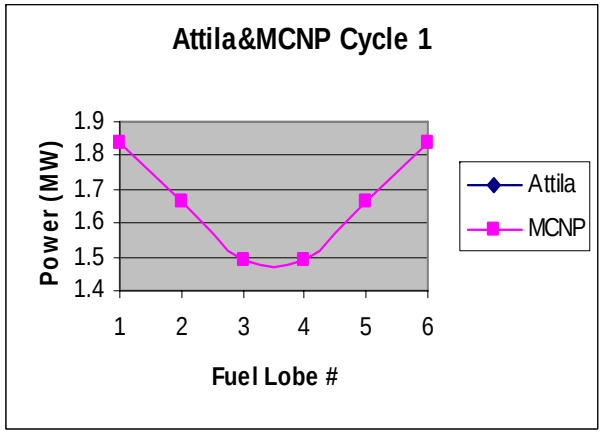


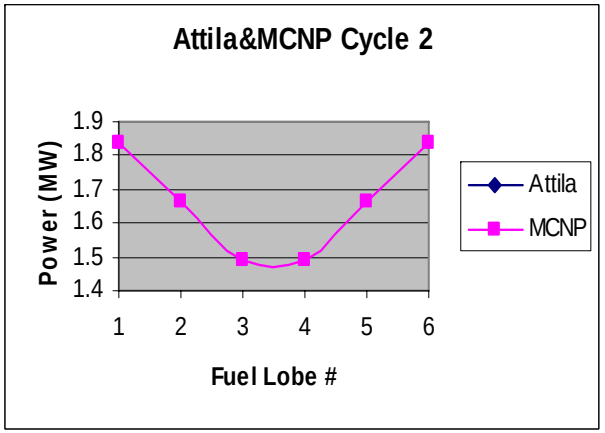

Half Height Core
Pseudocolor
Var: phi0_p02
458.2
345.1
232.1
119.1
6.062
Max: 458.2
Min: 6.062
Y
Z
X

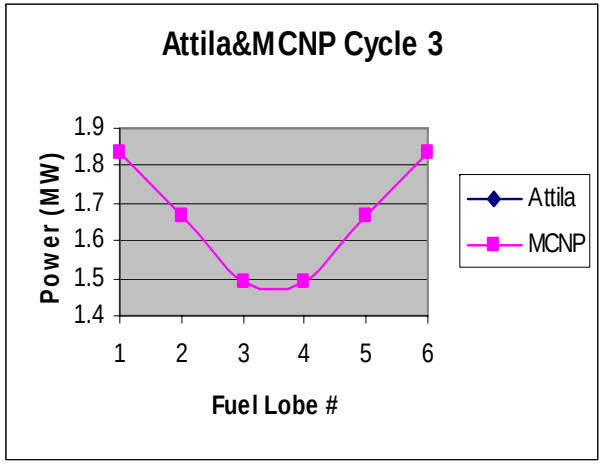
- **Six Fuel Lobes**
- **Np-237 Targets at the Center and around Periphery**
- **Shims turned facing fuel at the bottom**
- **Shims turned away from fuel at the top**
- **140000 Tets in FEM Mesh**
- **27 groups for Neutrons and 5 groups for Photons in XS Library**
- **Fission on for U-235 and Np-237**
- **No B.C.’s needed since Attila is 3D Transport**

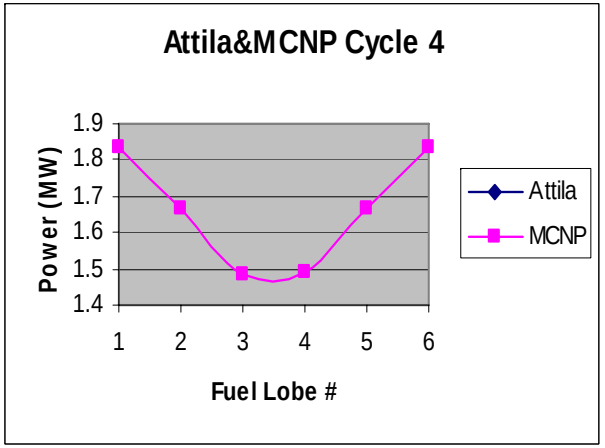
Power Comparisons

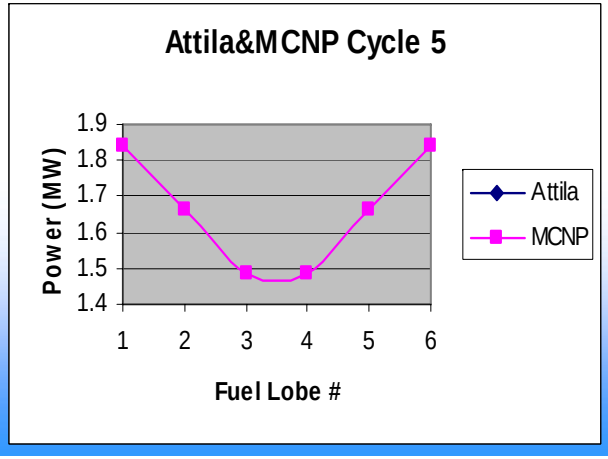
- Five Burn Cycles modeled
- First cycle is 2 Days for Xenon-135
- Next four cycles are seven days each for a total of 30 days
- Total Power is 10 MW
- Attila Power was normalized to 10 MW
- Power Comparisons on Lobe by Lobe basis for the six fuel lobes
- Attila Depletes every Cell in the Specified Burn Region


Attila&MCNP Cycle 1
Power (MW)
1.9
1.8
1.7
1.6
1.5
1.4
1
2
3
4
5
6
Fuel Lobe #
Attila
MCNP

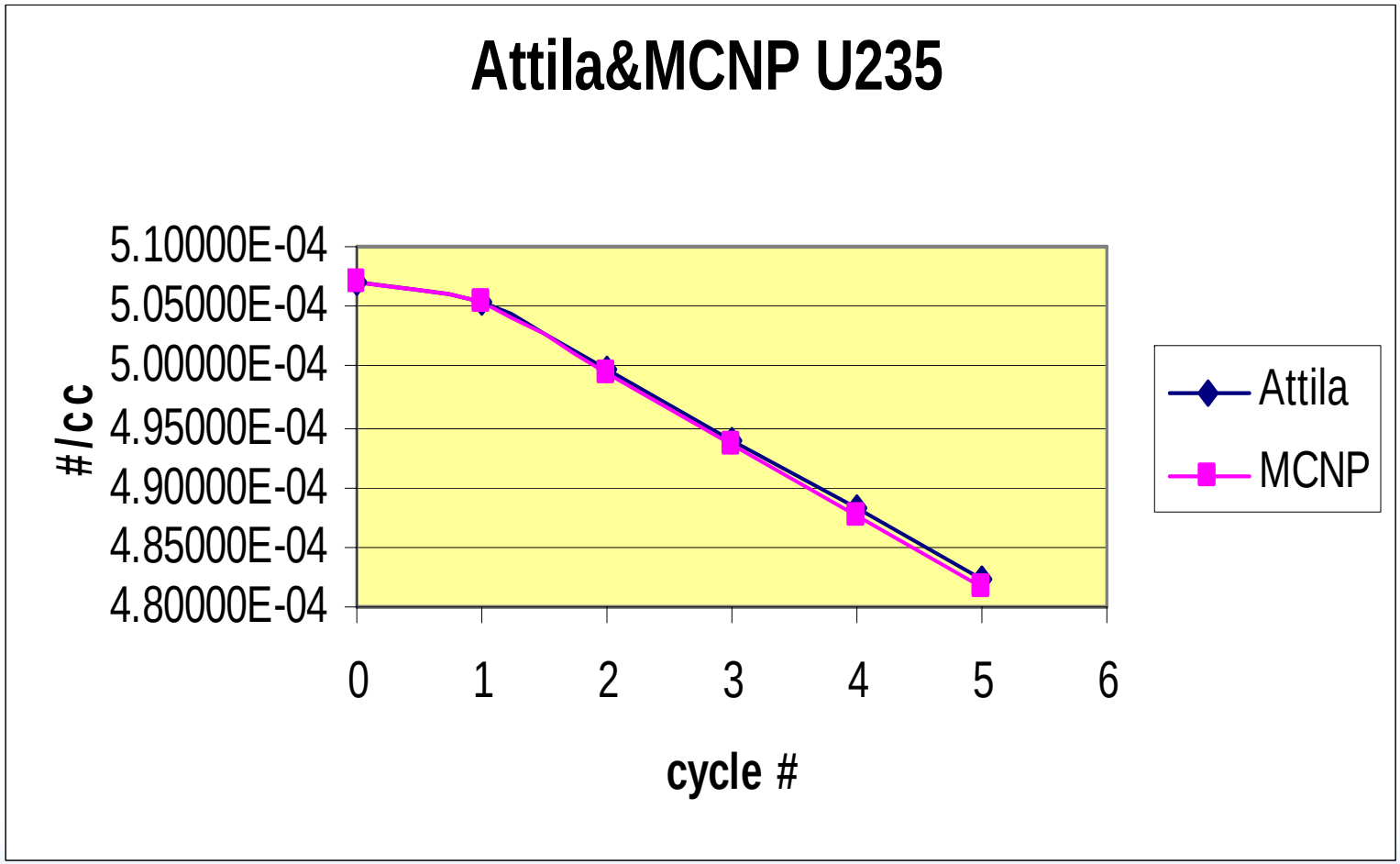

Attila&MCNP Cycle 2
Power (MW)
1.9
1.8
1.7
1.6
1.5
1.4
1
2
3
4
5
6
Fuel Lobe #
Attila
MCNP


Attila&MCNP Cycle 3
Power (MW)
1.9
1.8
1.7
1.6
1.5
1.4
1
2
3
4
5
6
Fuel Lobe #
Attila
MCNP

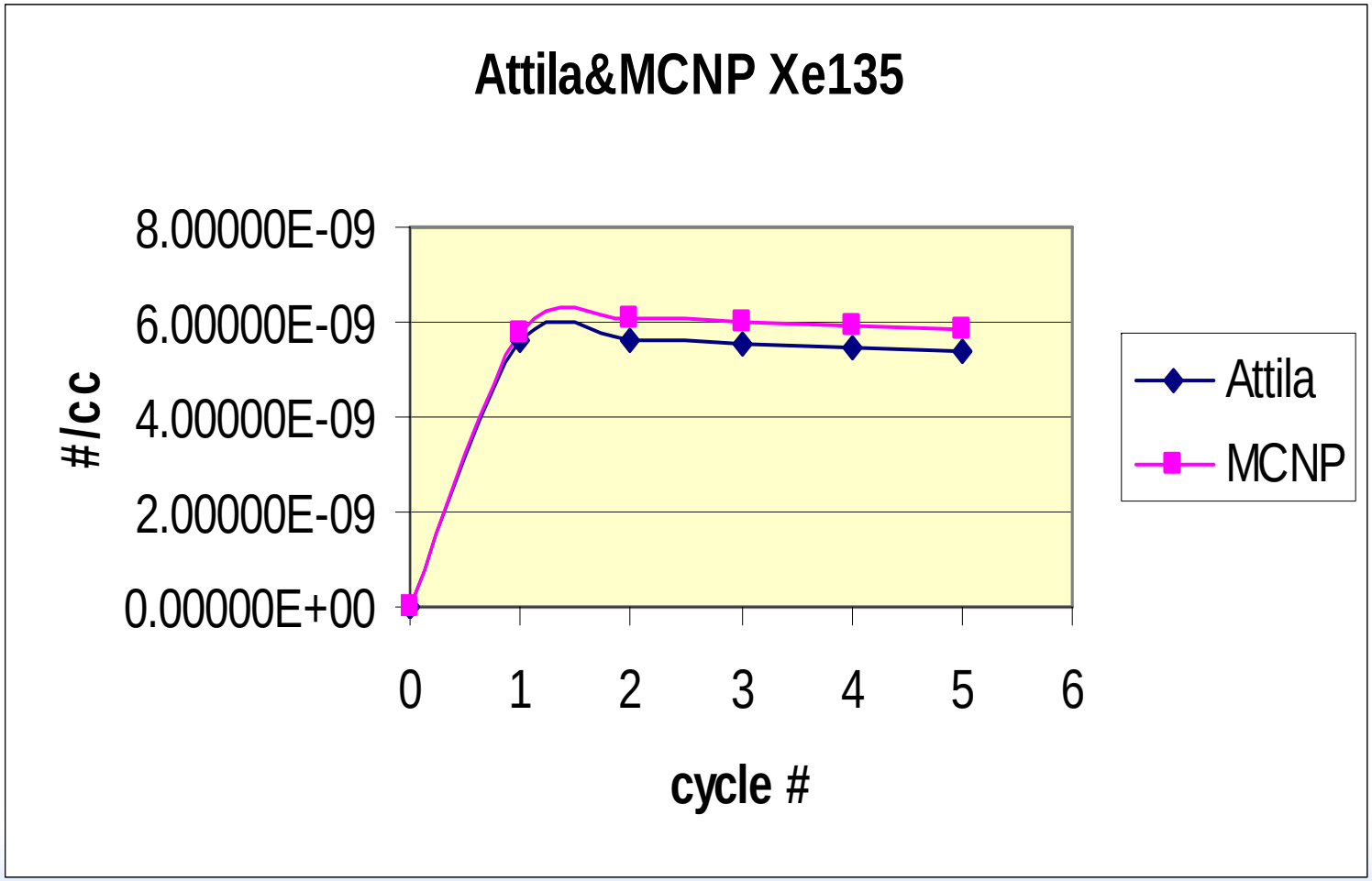

Attila&MCNP Cycle 4
Power (MW)
1.9
1.8
1.7
1.6
1.5
1.4
1
2
3
4
5
6
Fuel Lobe #
Attila
MCNP


Attila&MCNP Cycle 5
Power (MW)
1.9
1.8
1.7
1.6
1.5
1.4
1
2
3
4
5
6
Fuel Lobe #
Attila
MCNP

U-235 Atom Density Depletion Comparison



Xe-135 Comparison



Cross Section Library

- Present Library does not use ATR Thermal Spectrum, showed some problems during BUCR1B benchmark – derived from NJOY
- Working with StudsVik to compute regional XS Library using HELIOS, 2D Transport Code with Diffusion Approximation Bn (Buckling) in Axial Direction
- Also, we are using SCALE for AMPX XS Lib
- Planned Toy Comparisons with AMPX Libs

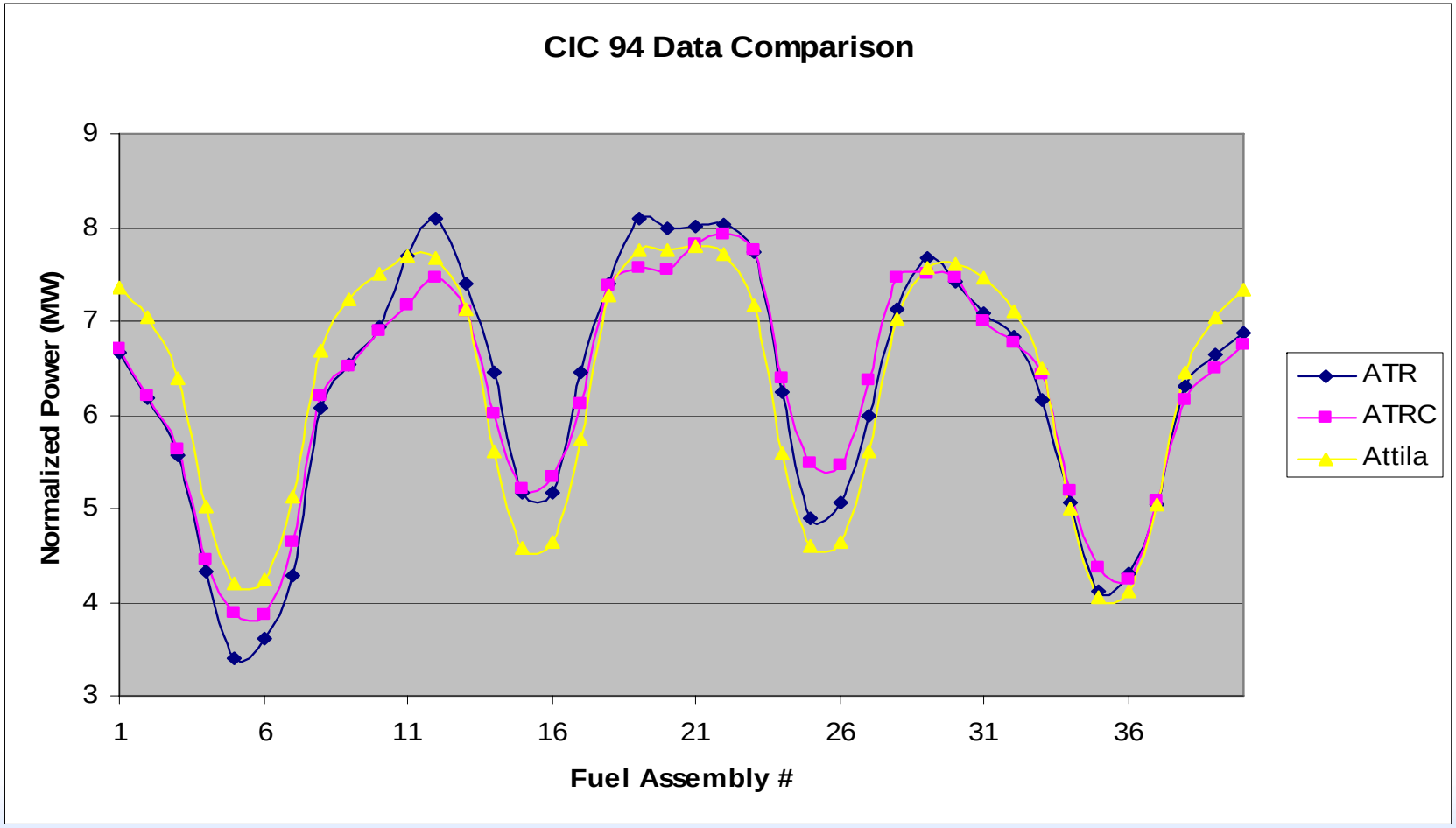
New ATR Models

- Based on Report INL/EXT-05-00780, 9/05
- “Advanced Test Rx: Serpentine Arrangement of Highly Enriched Water-Moderated UAL Fuel Plates Reflected by Be, “ Kim & Schnitzler
- Excellent Report Describing MCNP Model for ATR Comparison to CIC-94
- Exact SW & Attila Model Based on this report, used for HELIOS XS Models
- Analysis being performed for 3 Region & 19 plate fuel

Recent New Features in Attila

- Rotating Shims – Ability to Rotate Shims between Cycle Calculations
- Verified for 3 Region Fuel
- In process of Verification for 19 Plate Fuel
- Comparisons to CIC 94 done for 3 Region Fuel, runs approximately 12 hours on 2 CPU Opteron, 10 hours on 4 CPU Opteron
- In process for 19 Plate Fuel, this model “Doubles” the Mesh Size, longer run times
- New GUI in Attila to circumvent Data Input
- New Edit Features for Checking Power & Atom Density Edits
- Next Slide, CIC 94 Data Comparison Rotating Shims 58.1 Degrees for 3 Region Fuel
- Recall XS Lib not correct for ATR, Expect Better Results from Helios Work

CIC 94 New Attila to Data Comparison



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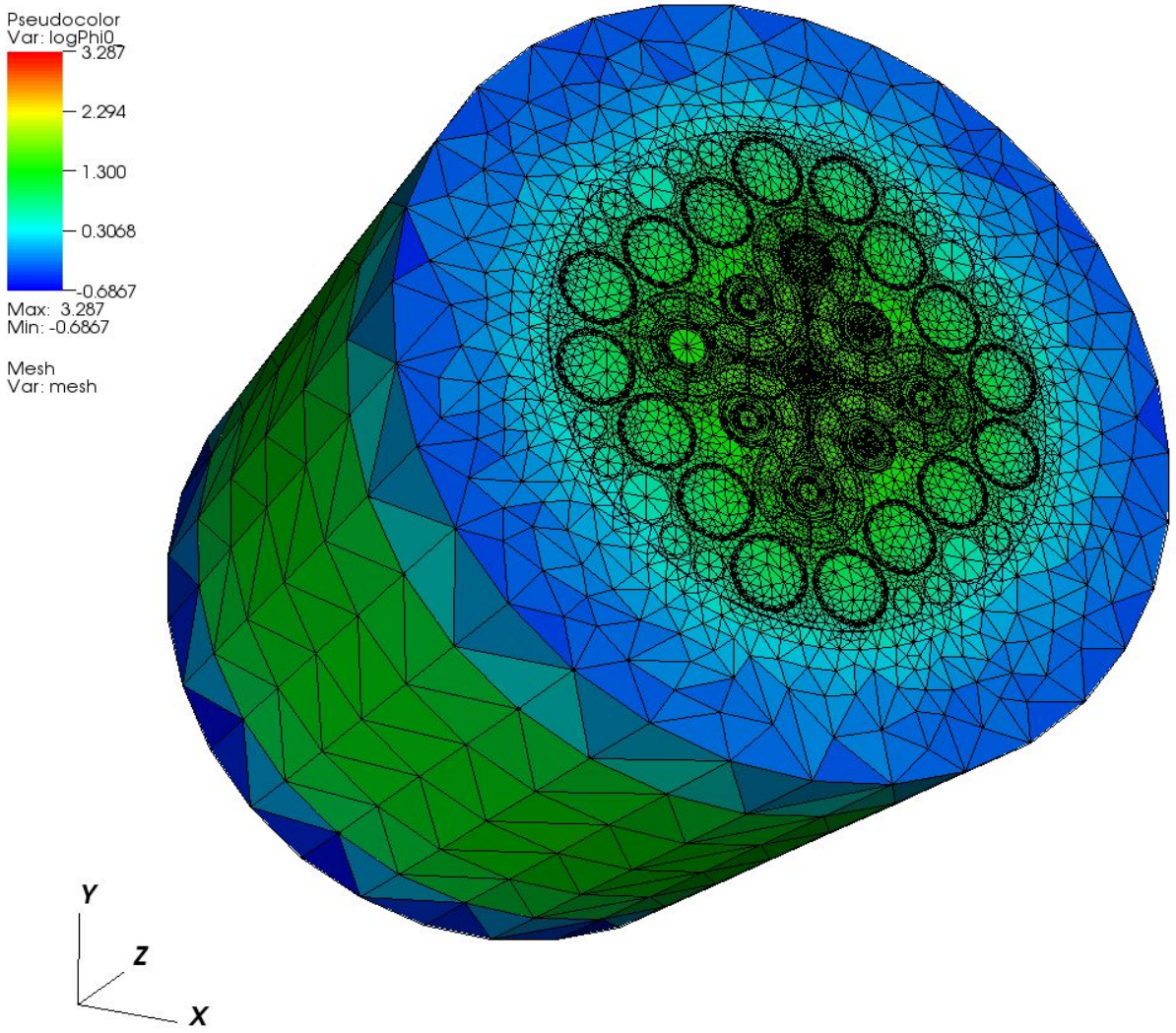
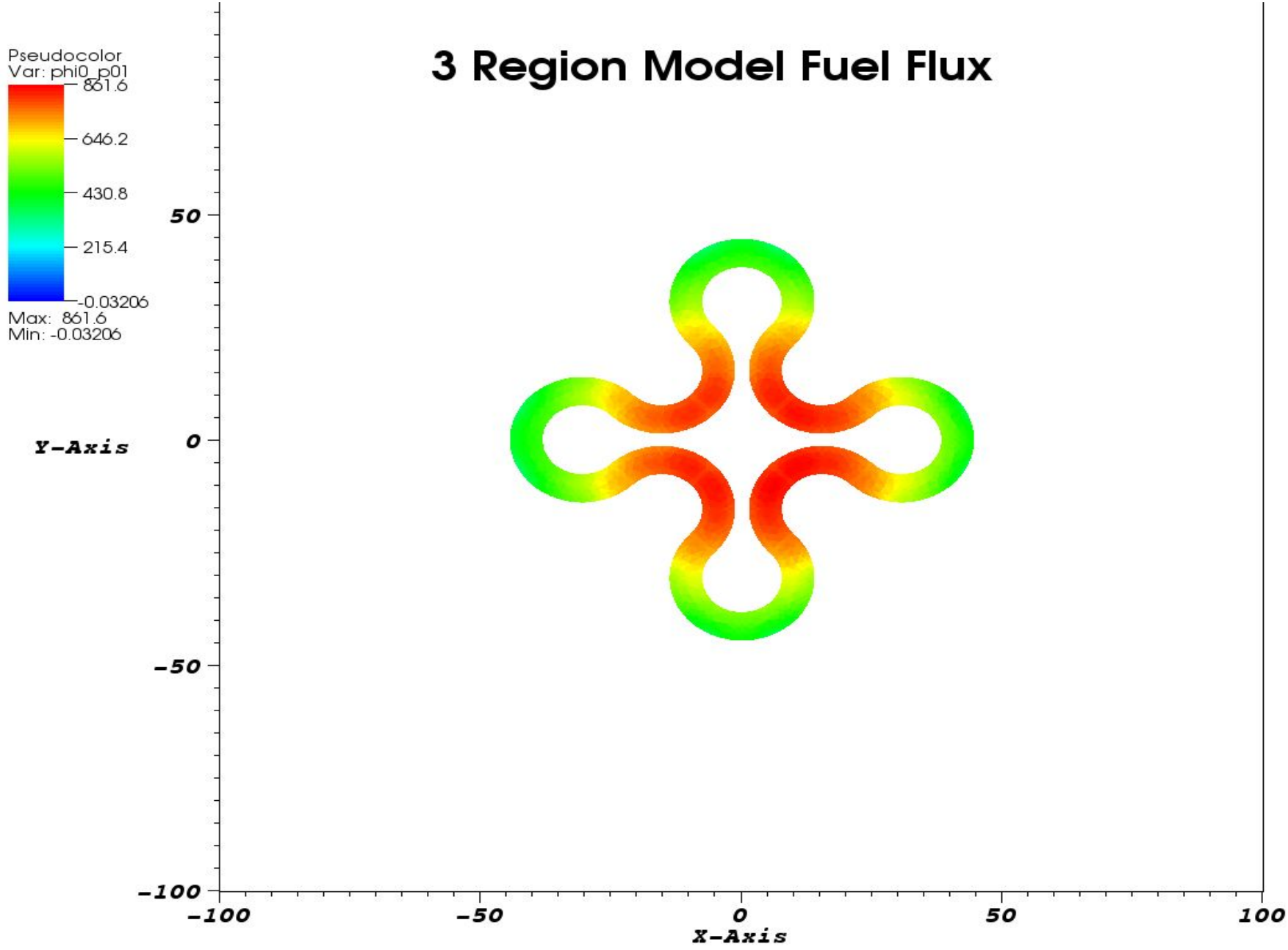
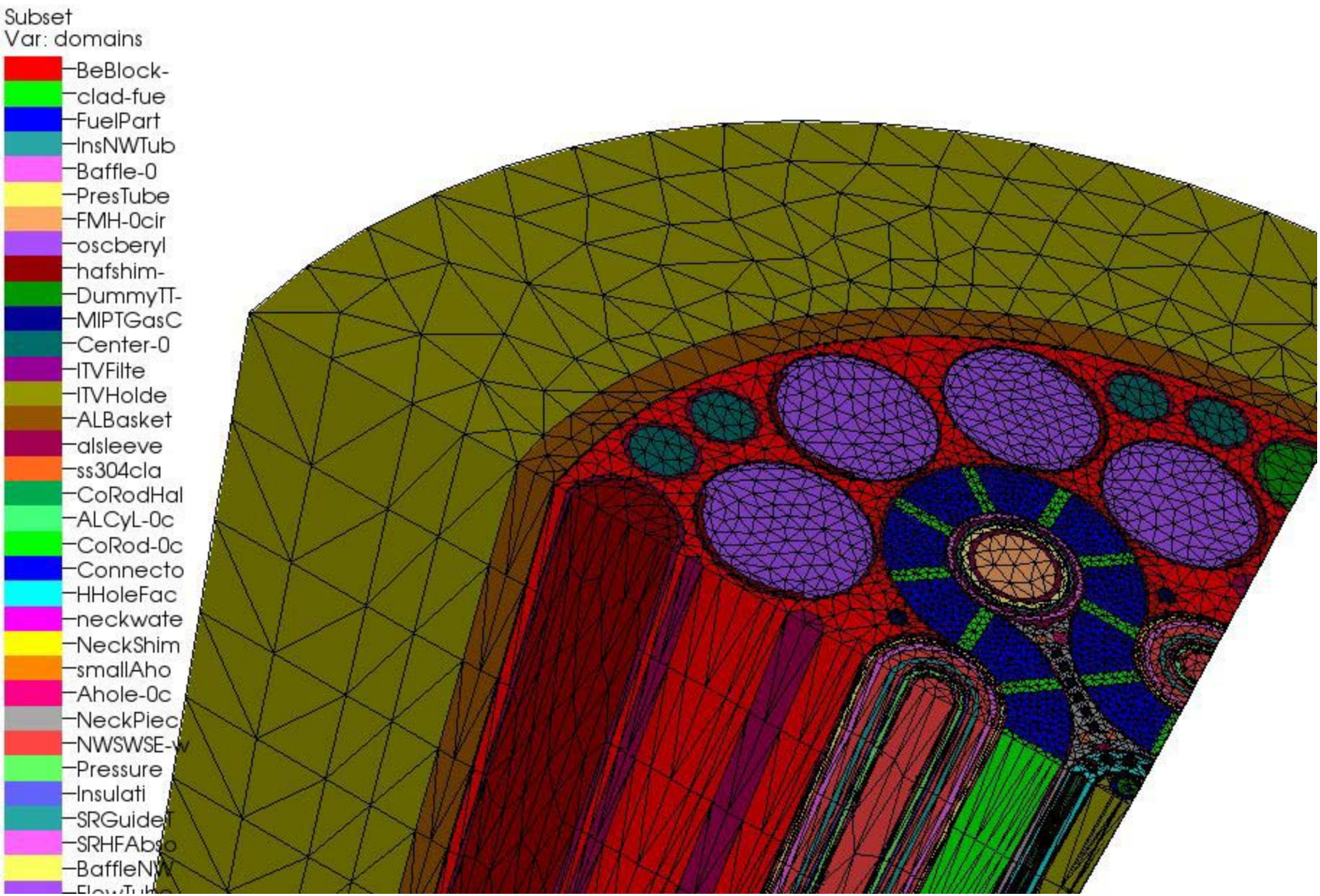
3 Region Model Mesh & Log Flux




3 Region Model Fuel Flux
Pseudocolor
Var: phi0_p01
861.6
646.2
430.8
215.4
-0.03206
Max: 861.6
Min: -0.03206
Y-Axis
50
0
-50
-100
-100
-50
0
50
100
X-Axis

ATRC NW155 Test

- NW Loop
- Procedures
- Aluminum
- Water
- Air
- Test Vehicle
- Qtr Core Model 4Layers & 8 Layers + Reflectors
- Keff 47.3 1.0019
- Keff 104.2 0.9999 Total Test Change $1.7


Subset
Var: domains
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clad-fue
FuelPart
InsNWTub
Baffle-0
PresTube
FMH-0cir
oscberyl
hafshim-
DummyTT-
MIPTGasC
Center-0
ITVFilte
ITVHolde
ALBasket
alsleeve
ss304cla
CoRodHal
ALCyL-0c
CoRod-0c
Connecto
HHoleFac
neckwate
NeckShim
smallAho
Ahole-0c
NeckPiec
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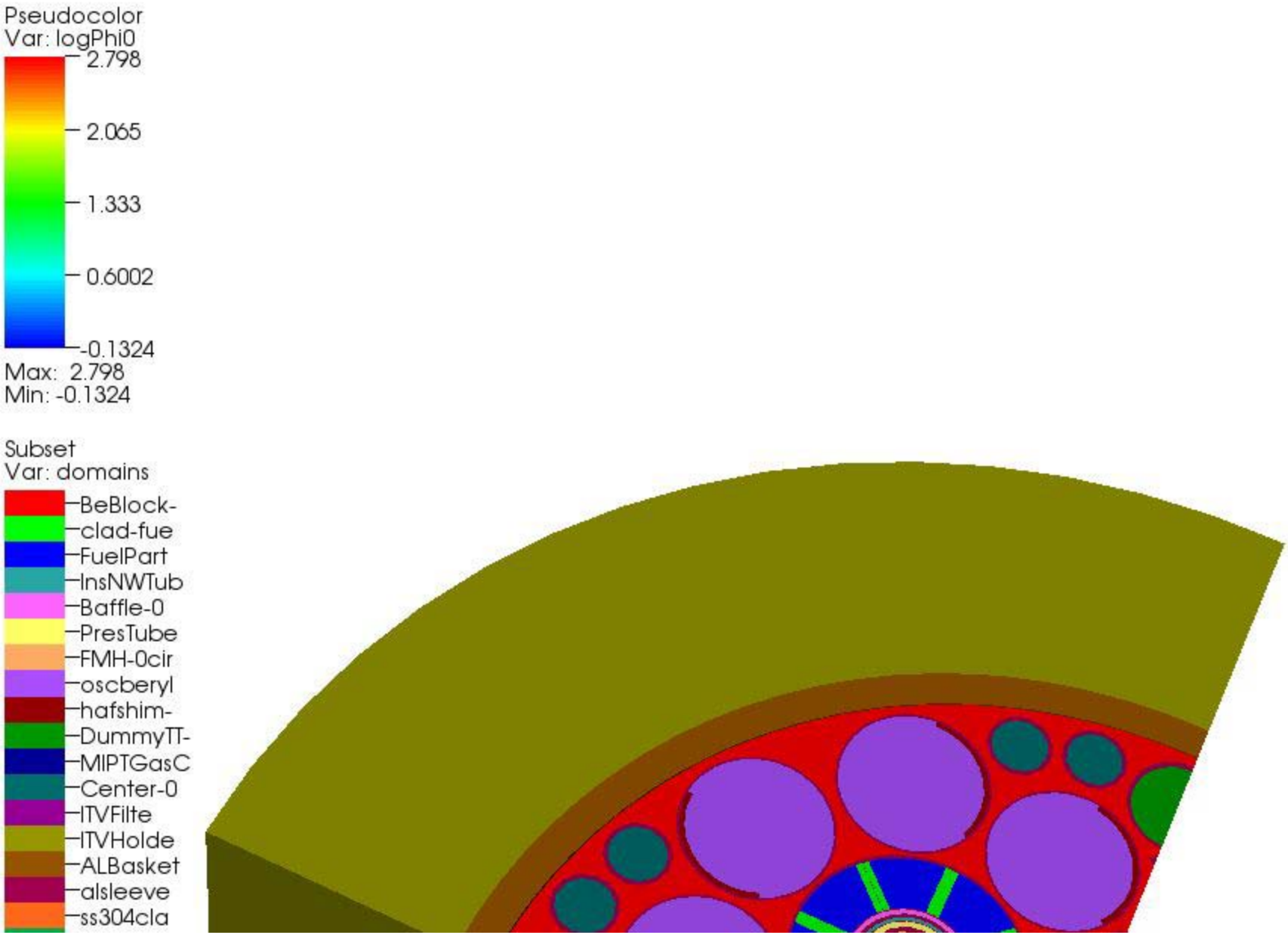
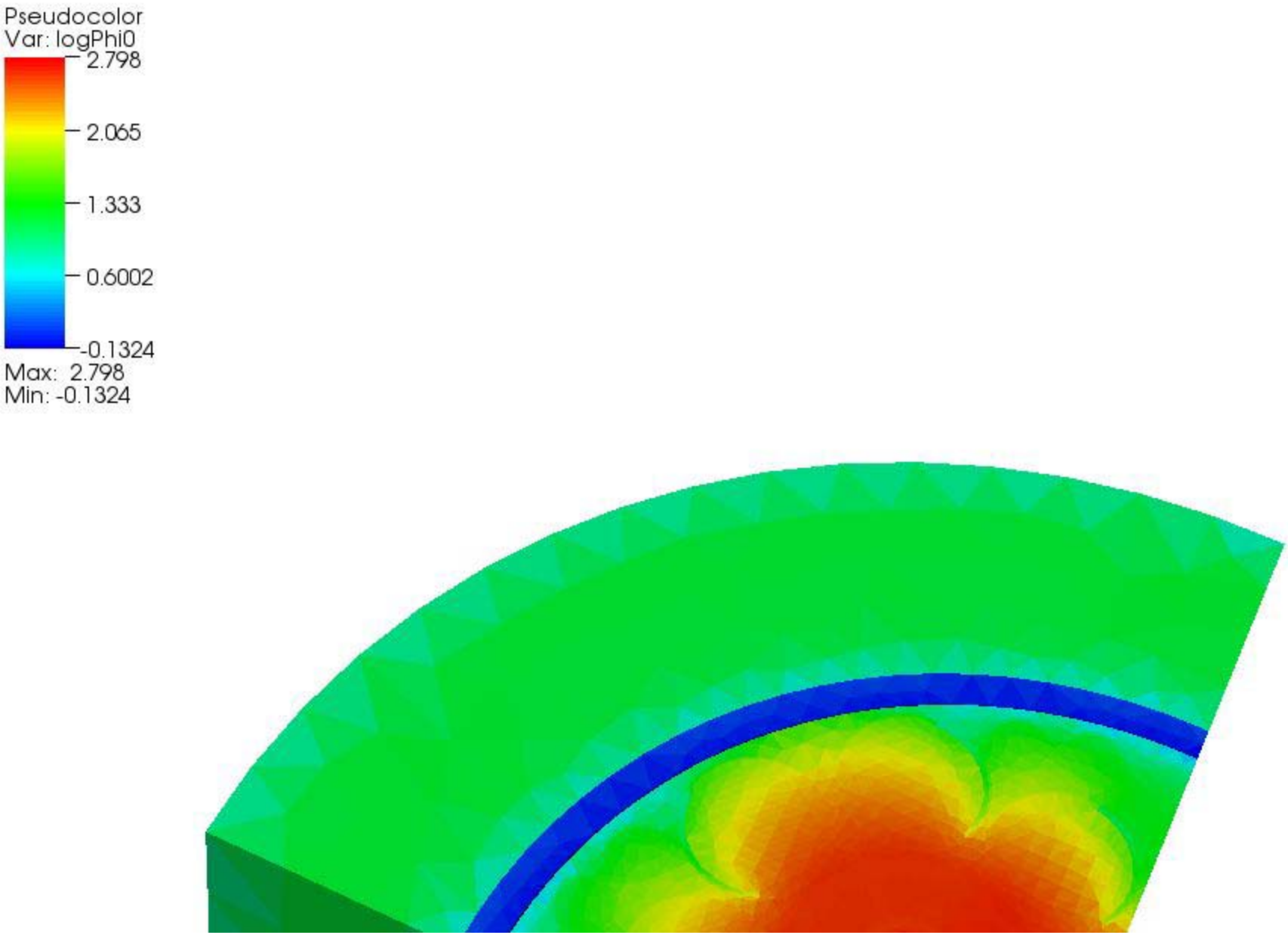
Pressure
Insulati
SRGuidet
SRHFAbso
BaffleNW


Pseudocolor
Var: logPhi0
2.798
2.065
1.333
0.6002
-0.1324
Max: 2.798
Min: -0.1324
Subset
Var: domains
BeBlock-
clad-fue
FuelPart
InsNWTub
Baffle-0
PresTube
FMH-0cir
oscberyl
hafshim-
DummyTT-
MIPTGasC
Center-0
ITVFilte
ITVHolde
ALBasket
alsleeve
ss304cla


Pseudocolor
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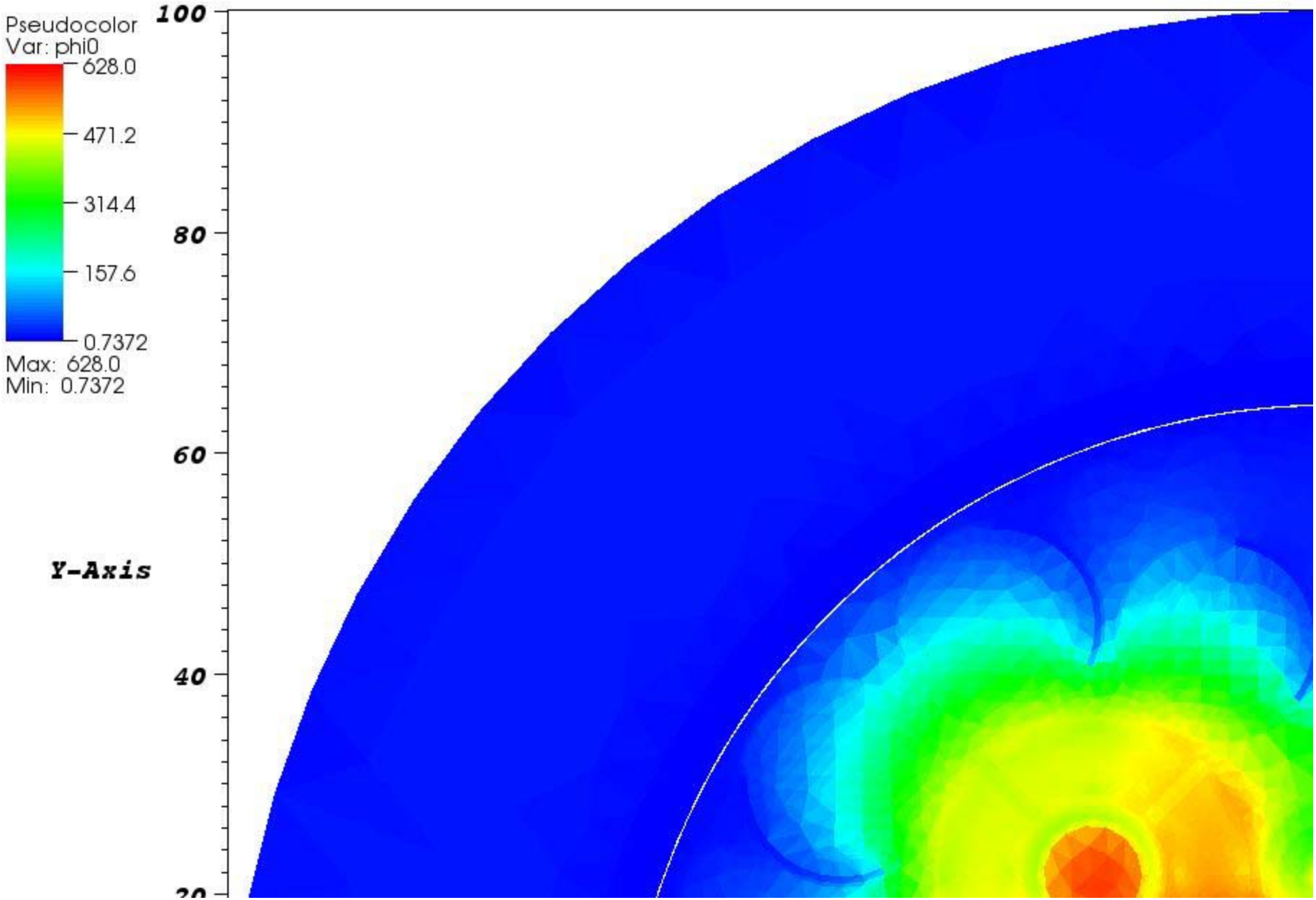
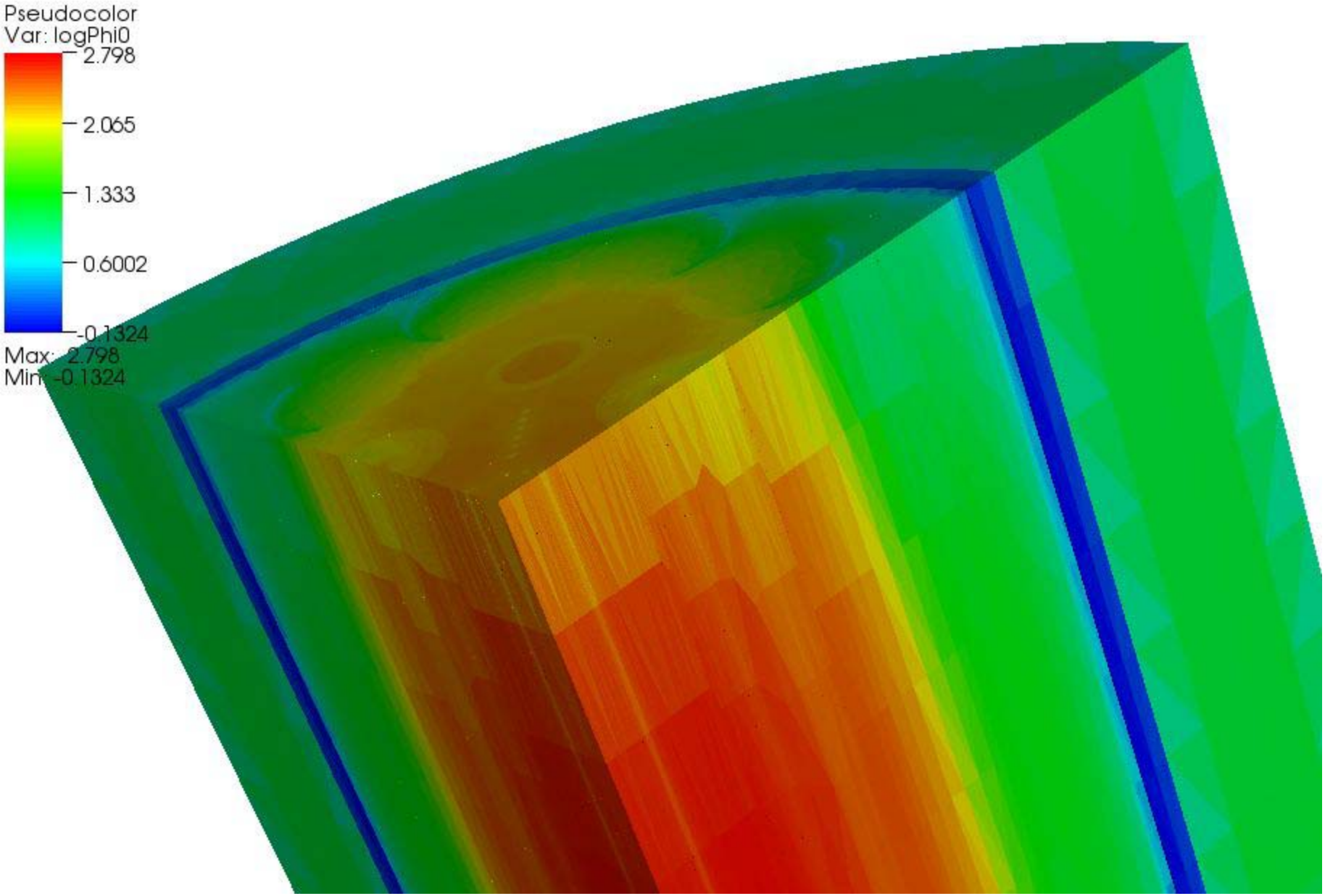
2.065
1.333
0.6002
-0.1324
Max: 2.798
Min: -0.1324


Pseudocolor
Var: phi0
628.0
471.2
314.4
157.6
0.7372
Max: 628.0
Min: 0.7372
100
80
60
40
Y-Axis


Pseudocolor
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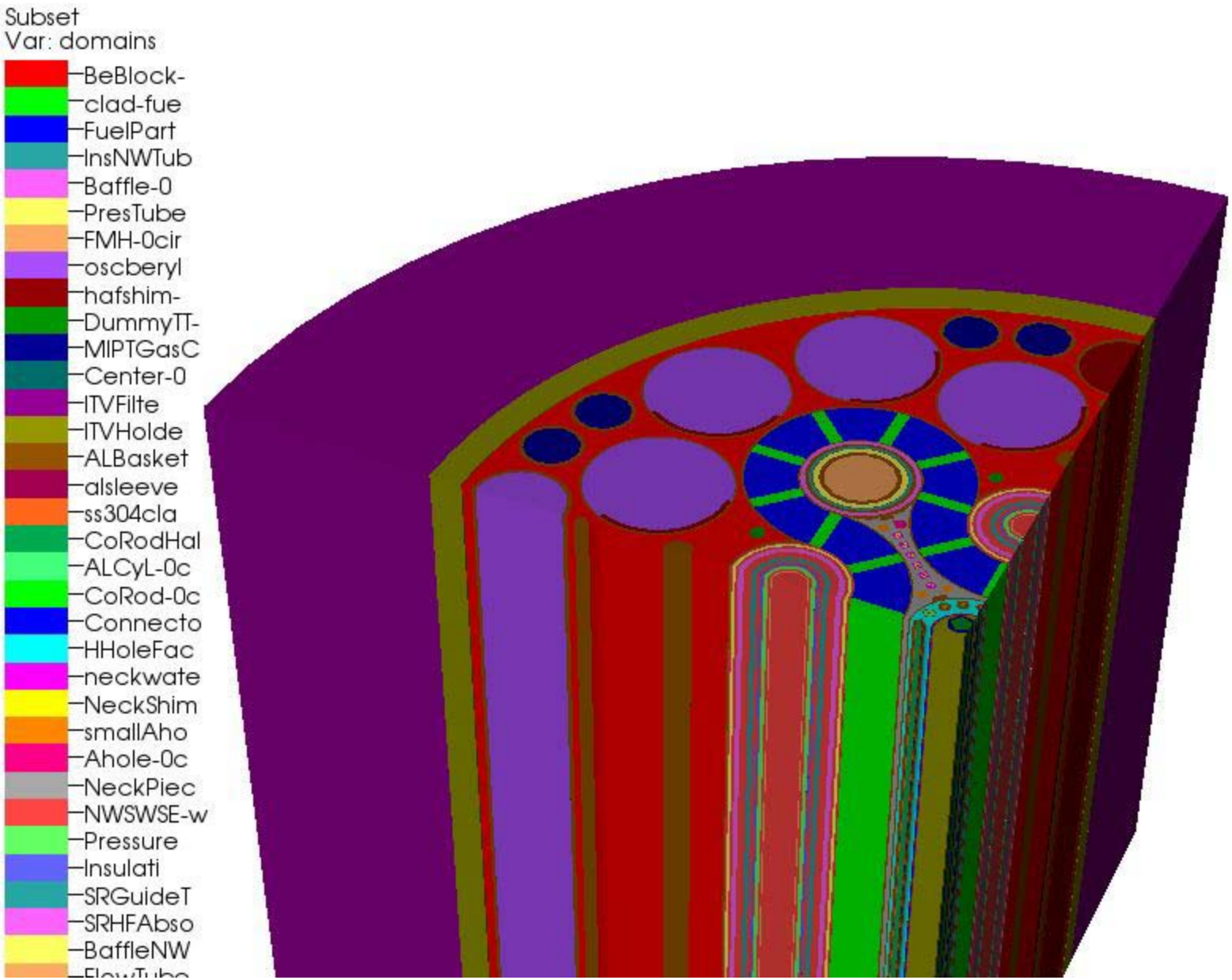
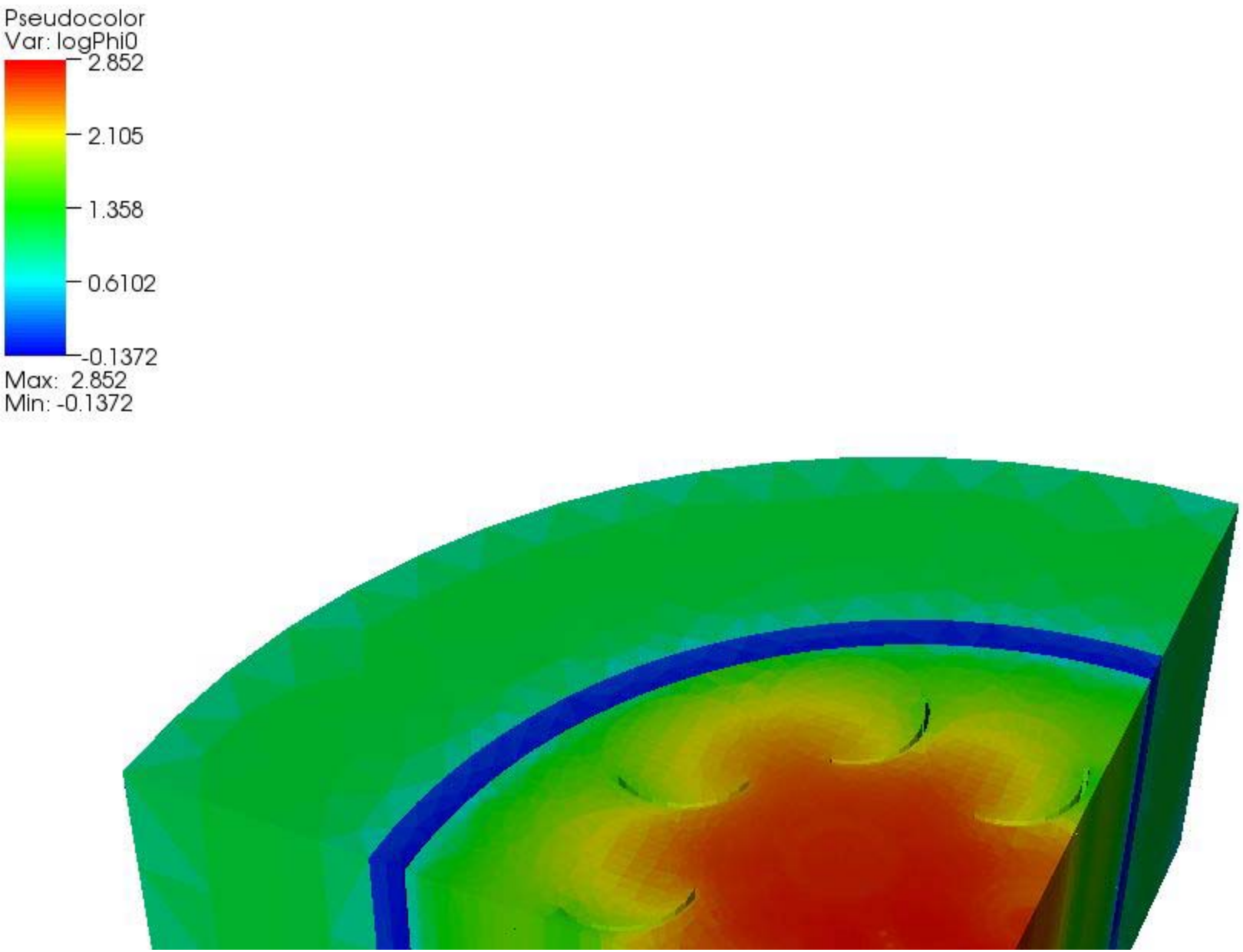
2.065
1.333
0.6002
-0.1324
Max: 2.798
Min: -0.1324


Subset
Var: domains
BeBlock-
clad-fue
FuelPart
InsNWTub
Baffle-0
PresTube
FMH-0cir
oscberyl
hafshim-
DummyTT-
MIPTGasC
Center-0
ITVFilte
ITVHolde
ALBasket
alsleeve
ss304cla
CoRodHal
ALCyL-0c
CoRod-0c
Connecto
HHoleFac
neckwate
NeckShim
smallAho
Ahole-0c
NeckPiec
NWSWSE-w
Pressure
Insulati
SRGuideT
SRHFAbso
BaffleNW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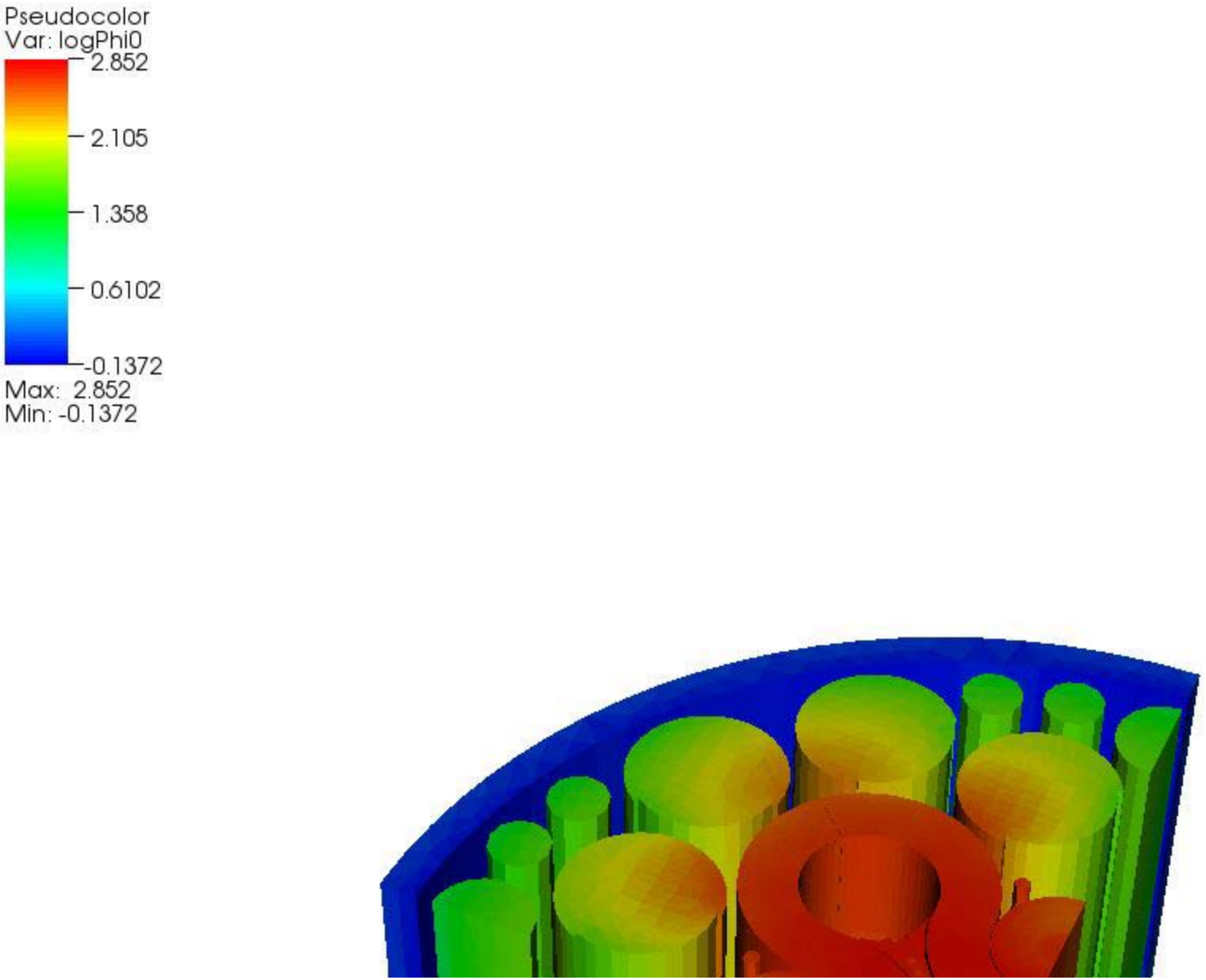
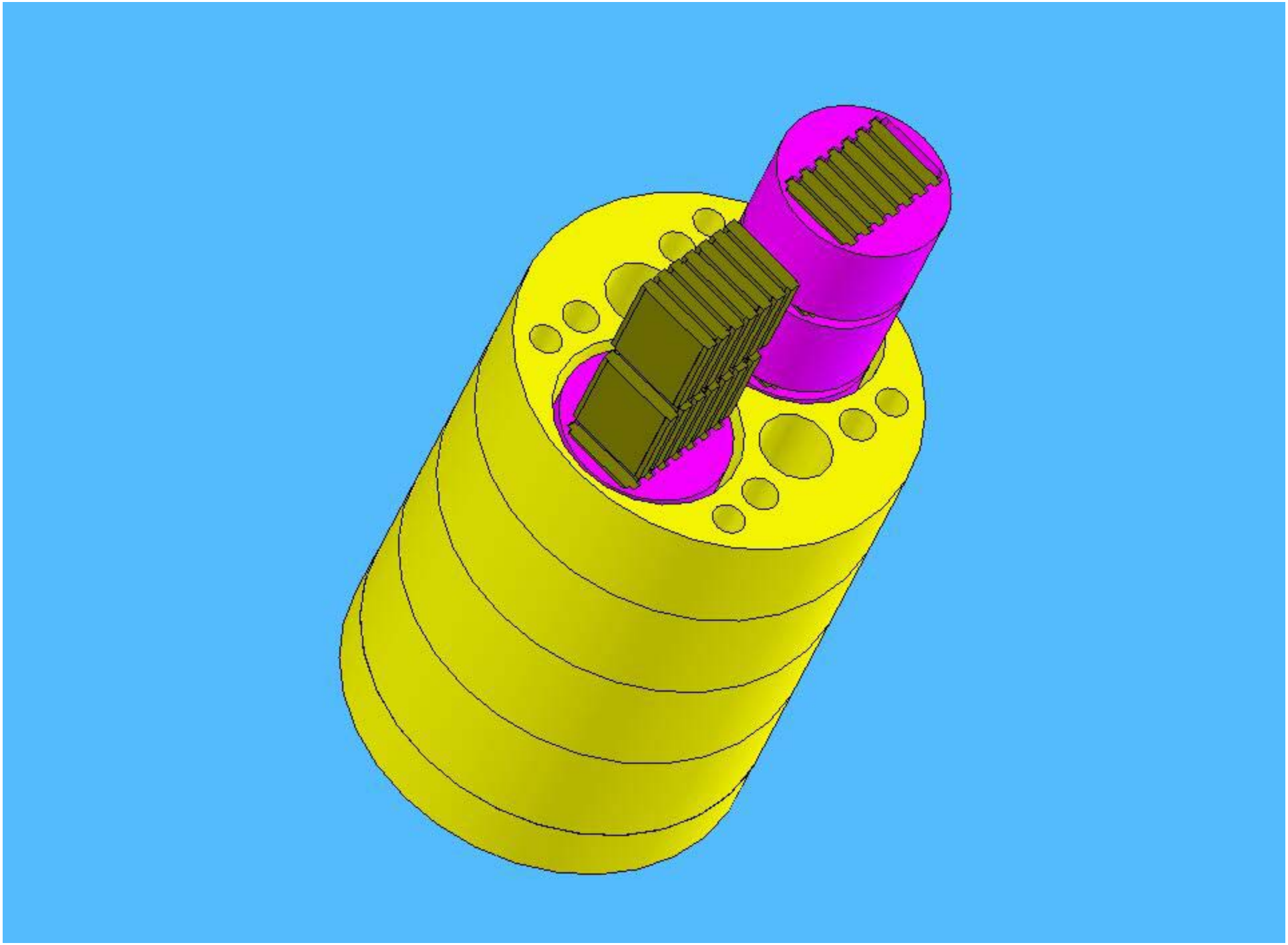
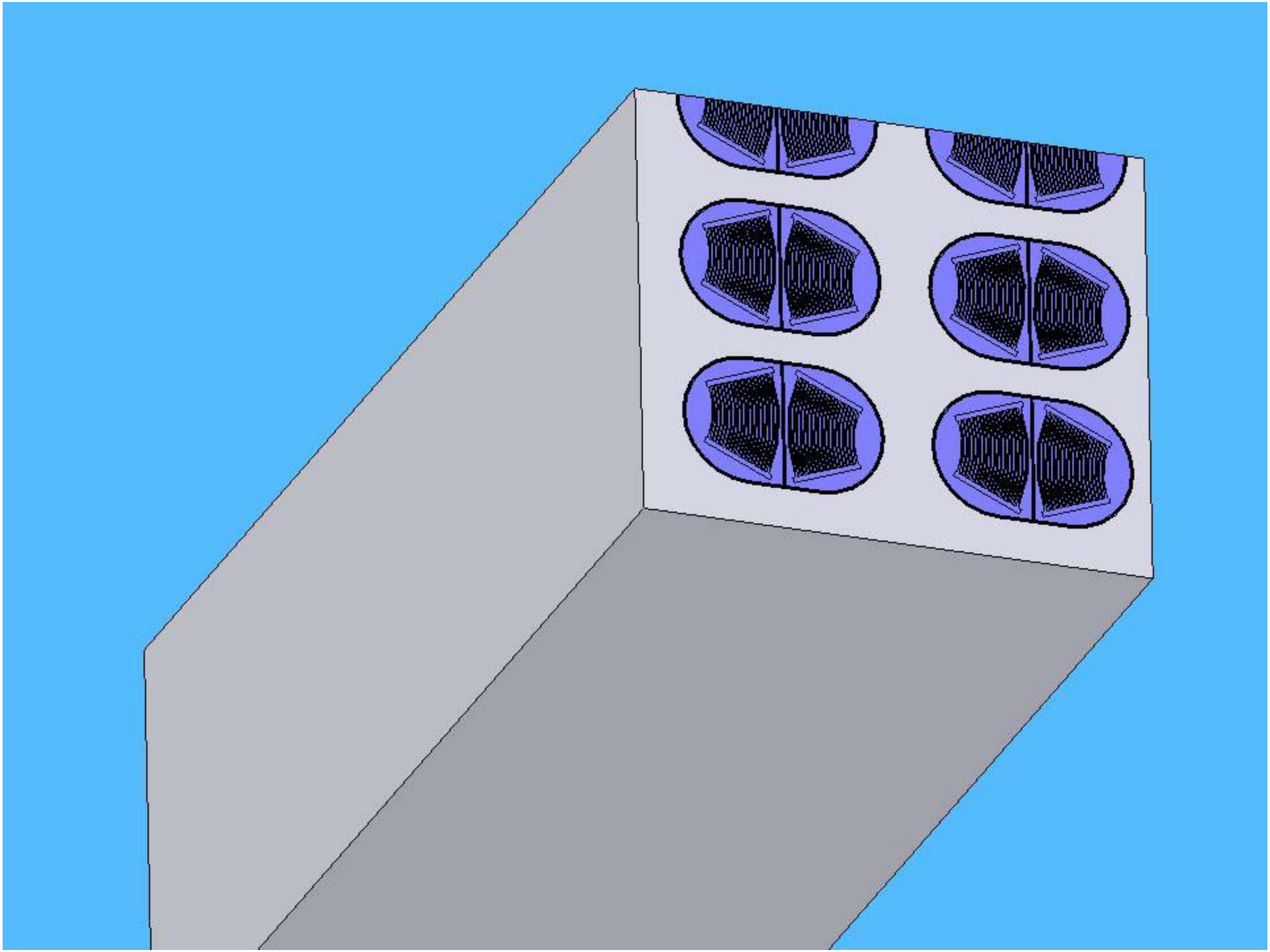
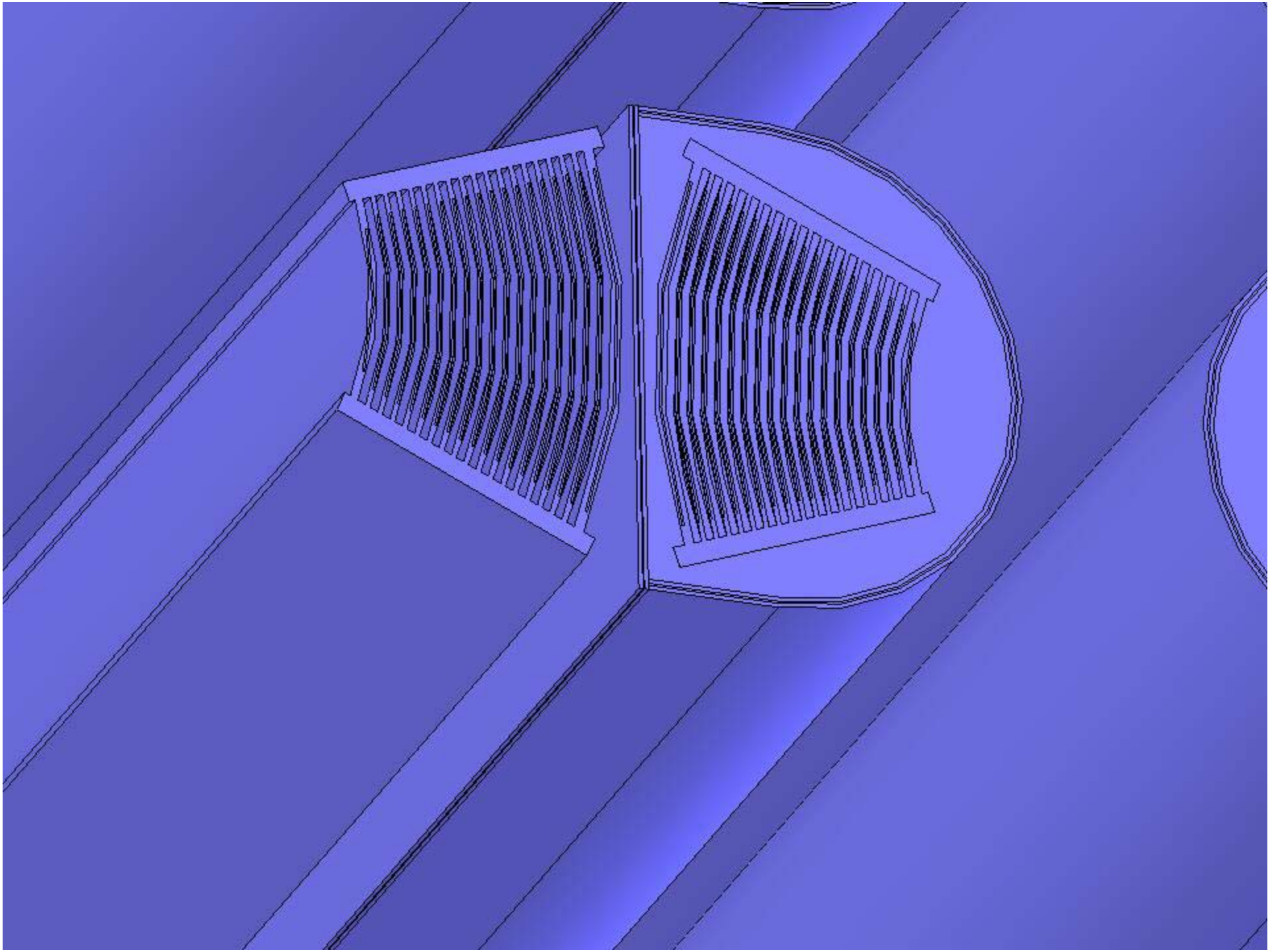
2.105
1.358
0.6102
-0.1372
Max: 2.852
Min: -0.1372


Pseudocolor
Var: logPhi0
2.852
2.105
1.358
0.6102
-0.1372
Max: 2.852
Min: -0.1372







Summary & Plans

- ICAPP Summary Paper
- SCALE Training Course
- SCALE XS LIB superior to NJOY for NW155
- 248 group – collapsed to 44
- ATR Core Thermal Spectrum
- Redo All Benchmarks with SCALE XS LIB
- Burn & Non Burn
- Compare to NW155 for Air & Coupons