SCIENTIFIC VISUALIZATION AND DATA ANALYSIS OF THE MCNP6 EEOUT FILE WITH VISIT

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Abstract

A new geometry capability has been implemented in MCNP that permits the existence of an unstructured mesh geometry with its legacy Constructive Solid Geometry (CSG) capability. Neutron and photon transport edit results, along with a generic mesh description appear in an output file with an eeout extension. The generated output file can contain up to six different element types and multiple edit results for analysis. Visualization of these complex meshes and results requires advanced software such as VisIt, a graphical analysis tool available from Lawrence Livermoore National Lab (LLNL). Along with VisIt's ability to plot these elements and edit results, some other features include: Selectable cutaway features, 2-D / 3-D contour plotting, individual node and cell picking for data values, data organization in spreadsheet form, and time varying animations, all which can be important for data analysis. In order to visualize with VisIt, the MCNP eeout file must be transformed into a file format that VisIt can read, such as VTK, HDF5, or SILO. Several test files have been converted into VTK format and successfully read by VisIt. This work demonstrates how the VisIt program can be used to visualize the mesh geometry and the edit results.

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Background

- **Abaqus CAE can create unstructured mesh representations of geometries**

    - **Used for particle transport in MCNP6**

- **Would like to use an advanced visualization package ideal for analysis of these results**

Purpose

- **Develop the means for importing the MCNP6 EEOUT file into VisIt for data analysis**

Why VisIt

- **VisIt is a scientific visualization package developed by LLNL**

- **Important features:**
  - **Ability to plot 1st and 2nd order elements**
    - Hexahedrons, Wedges, Tetrahedrons for Abaqus geometries
  - **Advanced plotting features**
    - Calculational results (e.g., Energy Deposition, Flux, Fission Energy), Mesh, Materials
  - **Simulations and time dependent animations**
  - **Cutaway features**
    - Slices, Onion Peel, Selectable Regions
  - **Data analysis**
    - Spreadsheets, Node / Zone Picking, 2D Lineout

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Why VisIt

- **FREE and Open Source!!!!!!!!**
  - **Abaqus CAE, EnSight, others $$$$$$$**

- **Plugins for multiple file formats**
  - **Pre-developed by users**

- **Works on Mac, Linux, and Windows**

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Getting Data into VisIt

- **Convert EEOUT file to VisIt Recognizable Formats**
  - **VTK, HDF5, SILO, etc..**
  - **Use pre-developed plug-ins**

- **Develop a Plug-in**
  - **Ability to directly read in each EEOUT file**
  - **Call the VisIt source code functions**

- **I chose to create files in VTK format for VisIt to read**

- **Working towards the development of a plug-in**

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Getting Data into VisIt

- **Scan through the EEOUT file and create a file in VTK format**
  - **Simple, used for proof-of-concept**

- **Written in C++**

EEOUT Format	VTK Format
MetaData	POINTS ncells float
Xnodes	Xnodes, Ynodes, Znodes
MetaData	CELLS ncells (nconndata +ncells)
Connectivity Data	nconnpoints
connectivity	
MetaData	CELL_TYPES ncells
Element Type (#)	VTK Element Type (#)

Getting Data into VisIt

- **Connectivity ordering different in Abaqus & VTK**
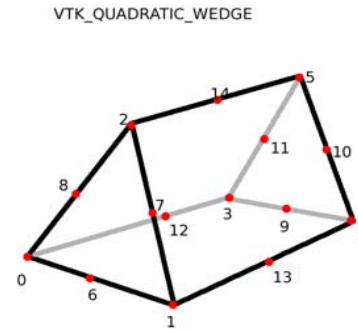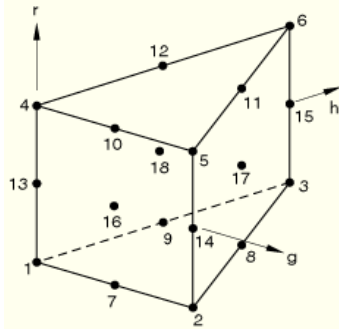
- **Cell indicies different**
  - **VTK begins at 0, Abaqus at 1**

- **Cell type #'s different**
  - **First order Hex - 6 for the EEOUT file, 12 for VTK**

- **Generalized for many cases**
  - **Multiple meshes, Data Sets**

Getting Data into VisIt : Creating the VTK File

- **Code was compiled and created a vtkfile executable**

- **Execute the vtkfile, and it will ask for a file to convert**

./**vtkfile**

Enter File to Convert : *filename*

- **If file Scanned through correctly, will get this message :**

Output File Successfully Created!!! *filename*.vtk ** **VisIt Readable**

```
-rw-------+  1 casey_a x1  2178070 Aug 10 16:19 vcube_sm.eeout_av2
-rw-------+  1 casey_a x1   731332 Aug 10 16:19 vcube_sm.eeout_av2.vtk
```

Opening VisIt / Files

- **Navigate to the VisIt source directory & execute visit**
  - **i.e., /home/usr/visit2.0.1/src/bin/visit**

- **Click on File --> Select File in the main window**
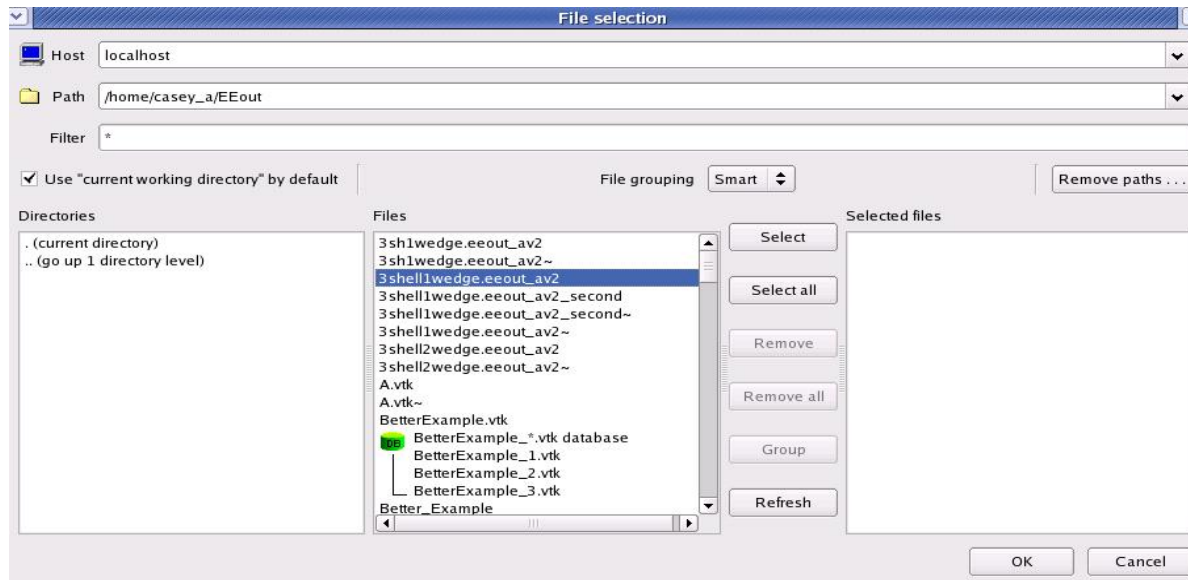
Opening VisIt / Files

- **Navigate to the directory of your the VTK files you created**

- **Select the files you wish to view and click OK**

- **The files should appear in the file selection window**
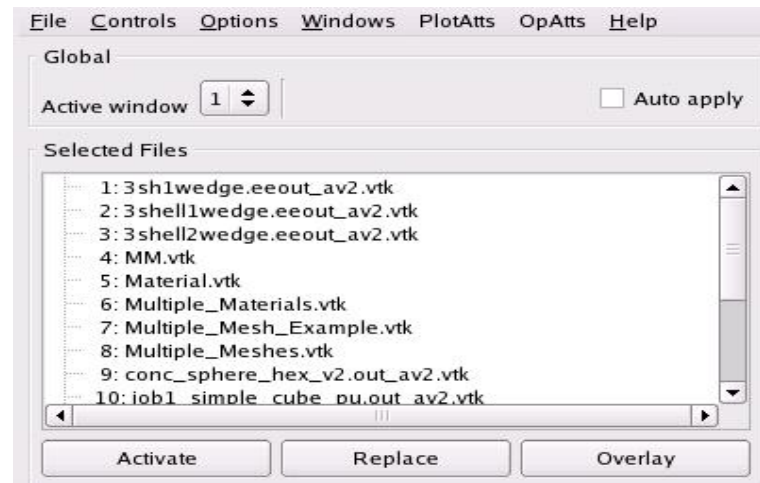
- **Select the Individual file, and click Activate (or ReOpen)**
  - **That file is now selected, and analyzing can begin**

Visualization and Analysis : Database Plots

Database Plots are plots of the data in the file

e.g., Mesh, Energy / Flux, Material, Density

Pseudocolor Plots : Data Sets

(Flux, Dose and Energy Deposition, Fission Energy)
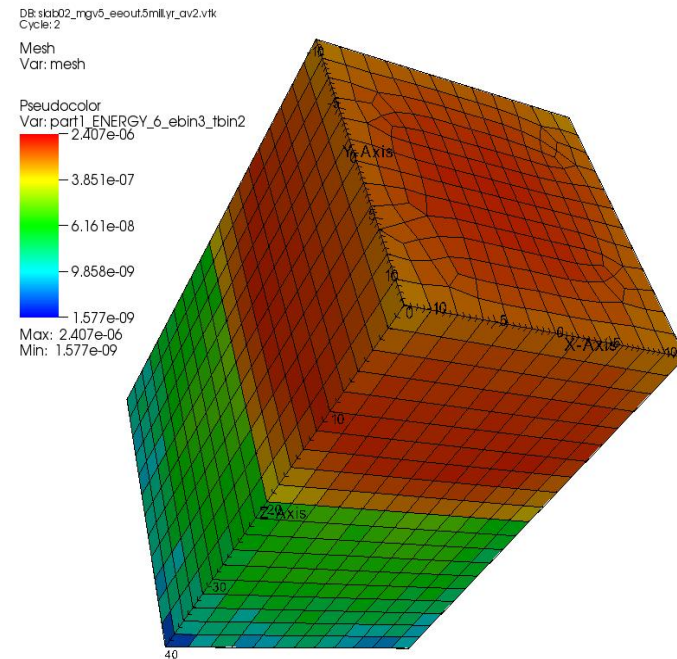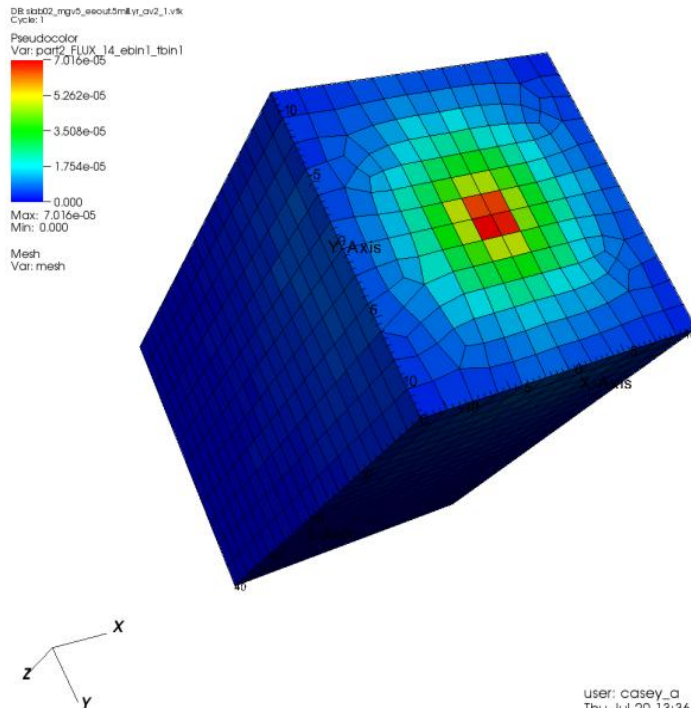
** Concrete Slab : Point Source

Mesh Plots

1st & 2nd Order Tets & Hexs
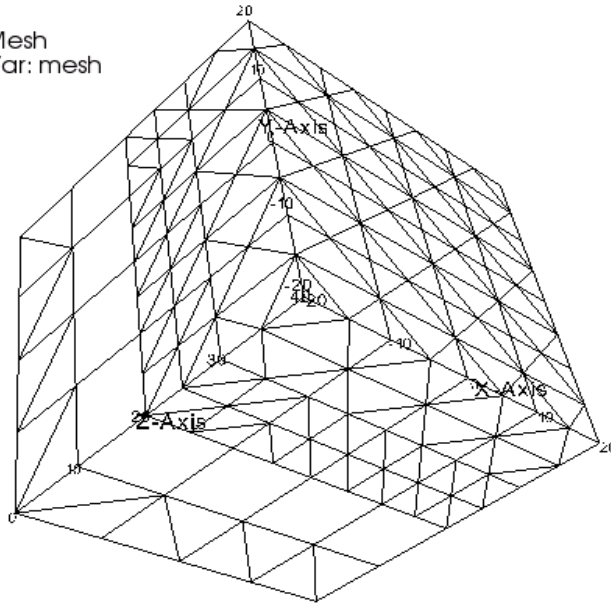
1st & 2nd Order Wedges
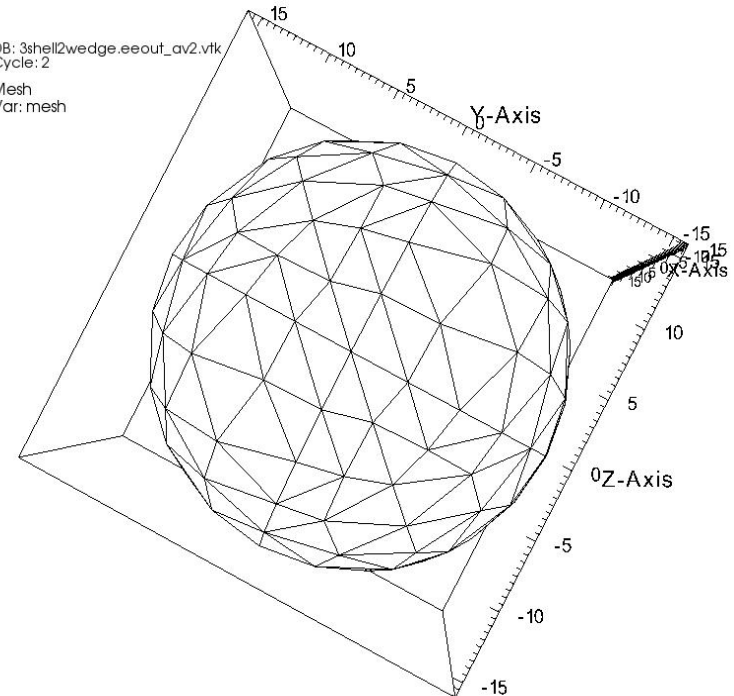
* Version 2.0 or later needed for 2nd Order Wedges

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Materials

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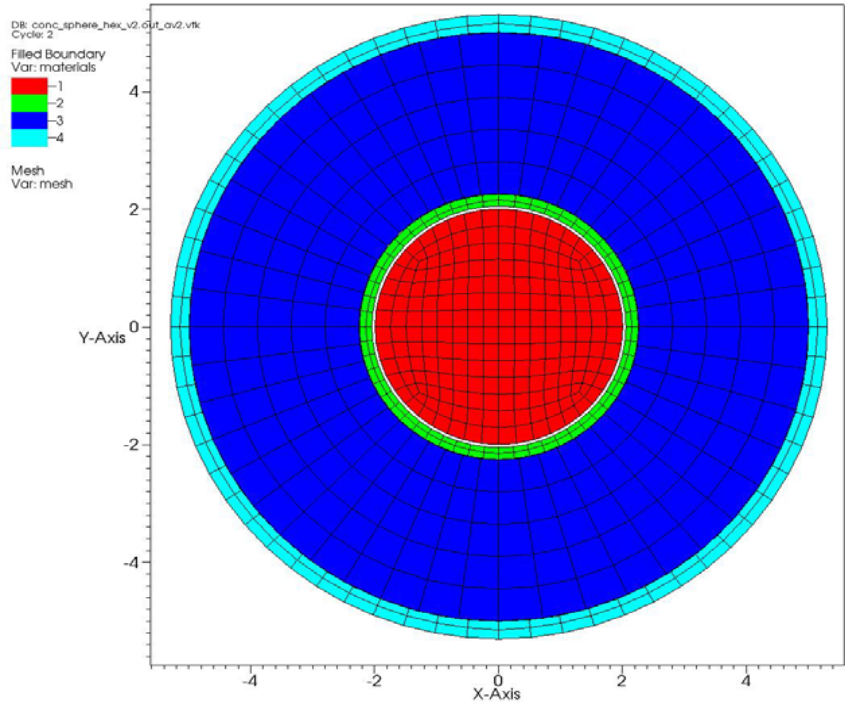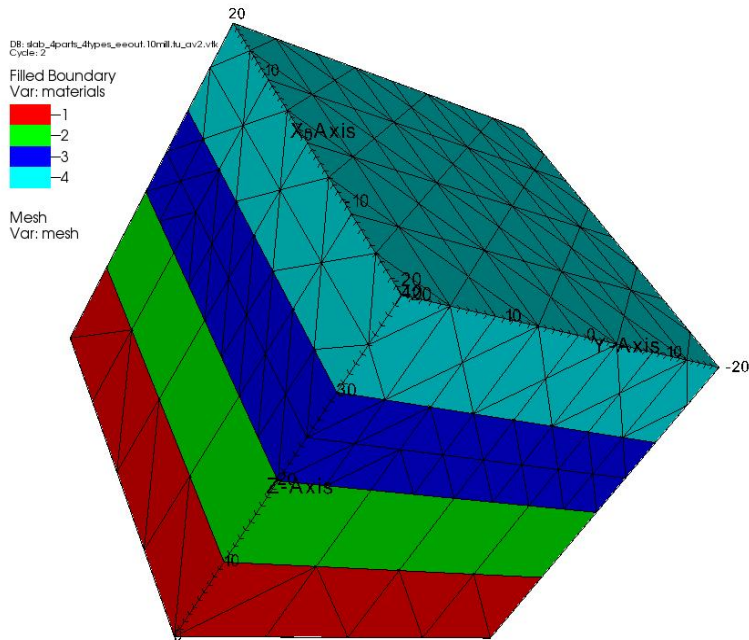
Data Plots

Histogram
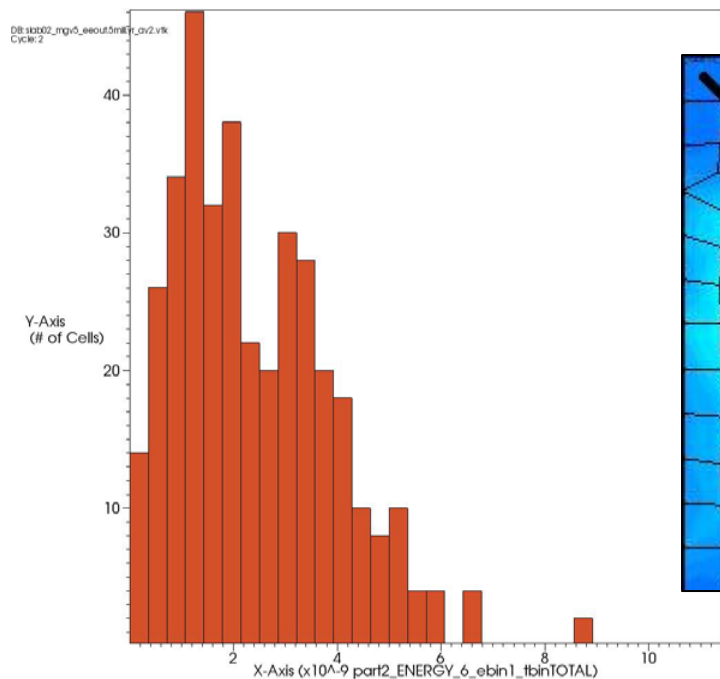
Lineout Mode
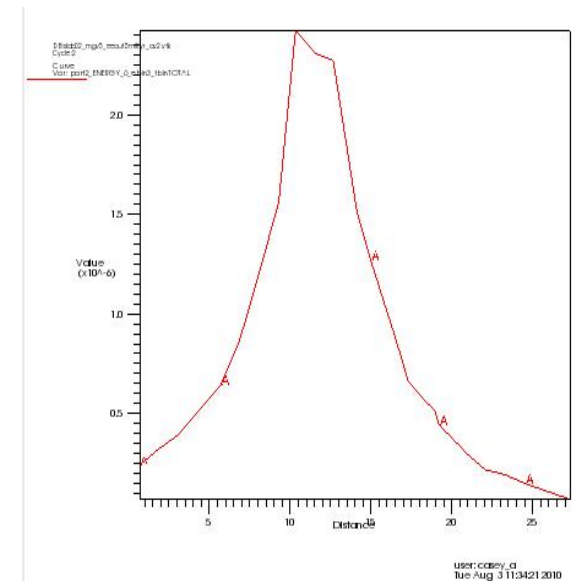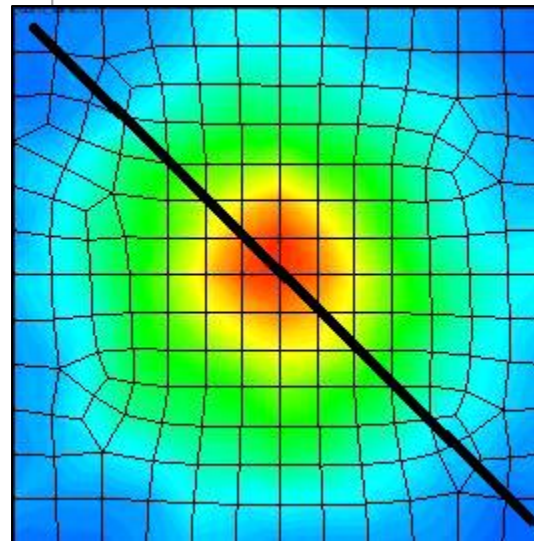
Data Plots

Cell Labels

Spreadsheet

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Data Plots

Zone / Node Picking

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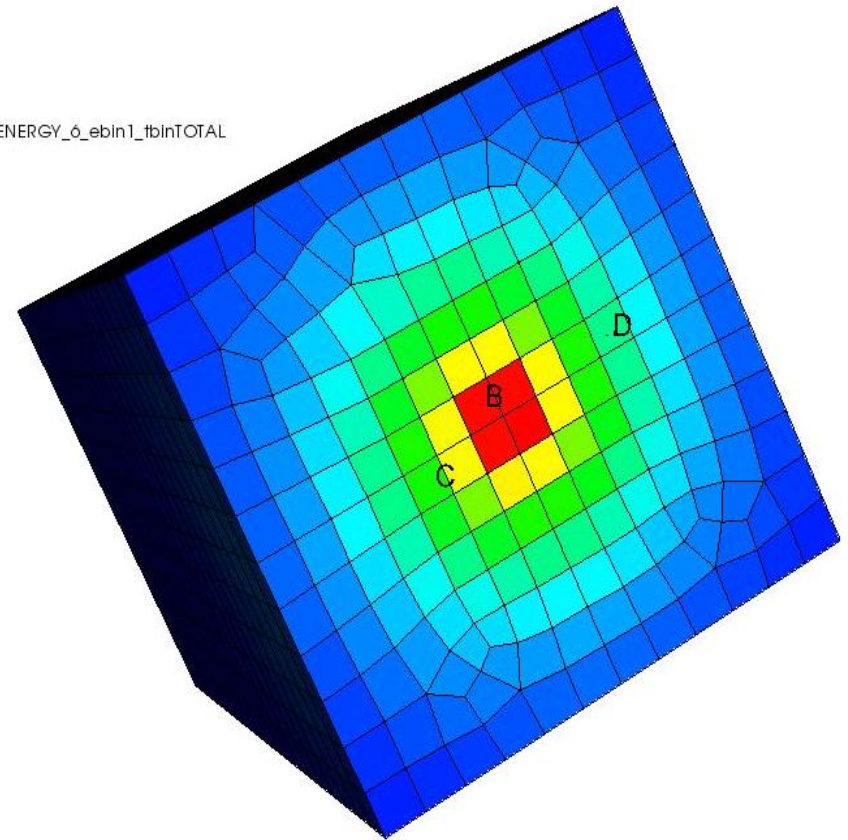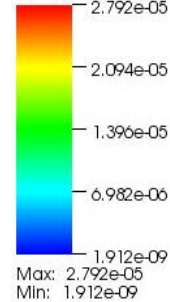
Visualization and Analysis : Database Plots

- **Boundary**   Coordinates

- **Contour**   Subset

- **Curve**   Tensor

- **Molecule**   Volume

- **Coordinates**   Vector

- **Scatter**

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Visualization and Analysis : Operators

An Operator is a filter applied to a plot

e.g., Selections, Slicing, Transforming, Geometry

Visualization and Analysis : Operators

Slicing

Single Slice
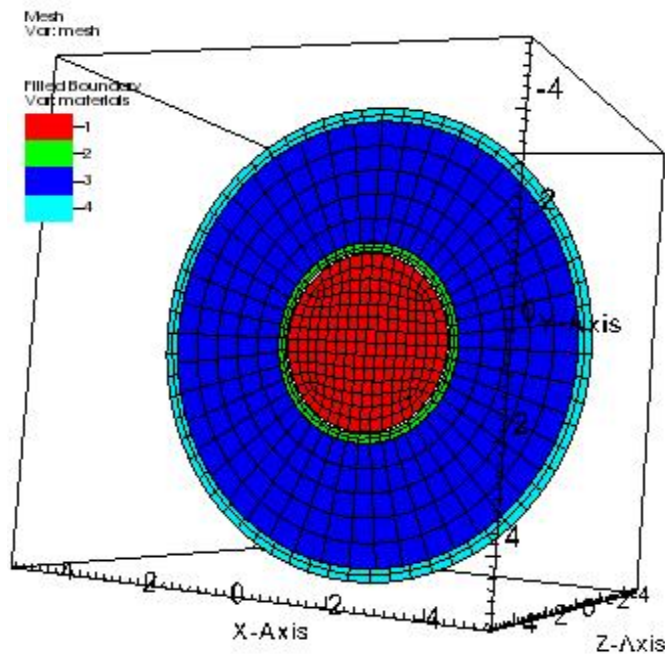
Three Slice
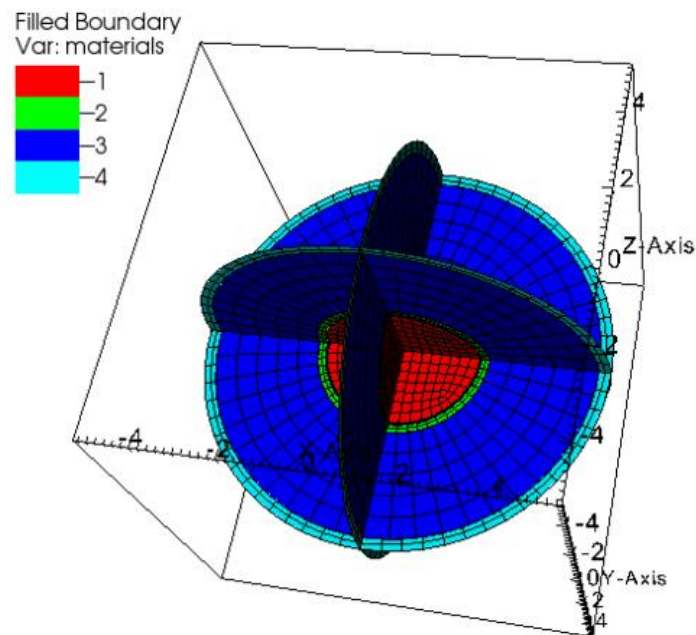
Other Slices : Cone, Boundary, Spherical, Isosurface

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Visualization and Analysis : Operators

Selection
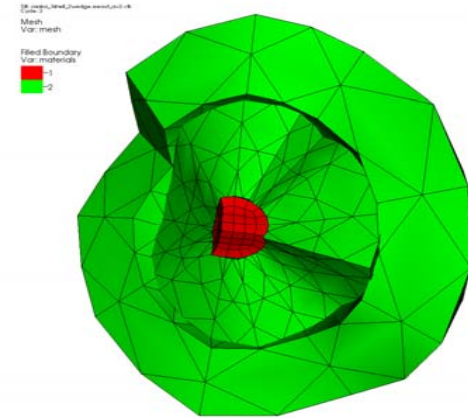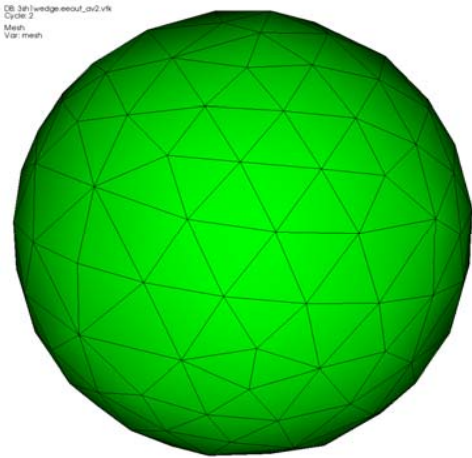
None

Box (Area)

Onion Peel (Cell)
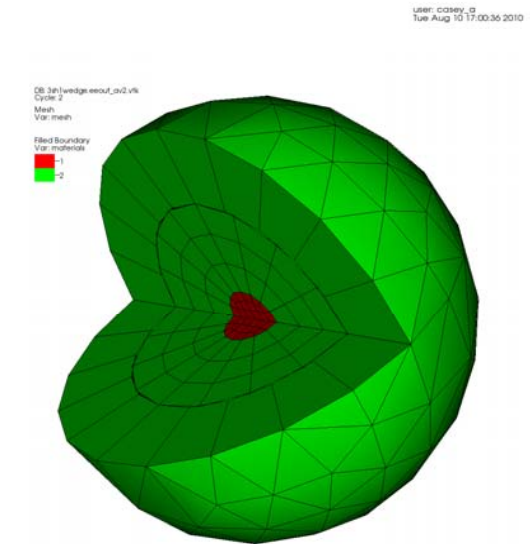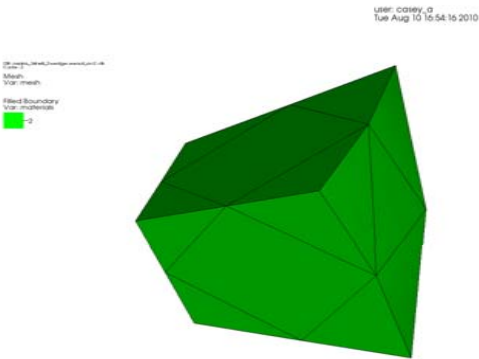
Clip (Hemisphere)

From the Osaka ball model

Less Common Operators

- # Geometry Operators
  - Edge, Resample, Revolve

- # Transform Operators
  - Displace, Elevate, Project, Reflect, Replicate, Transforms
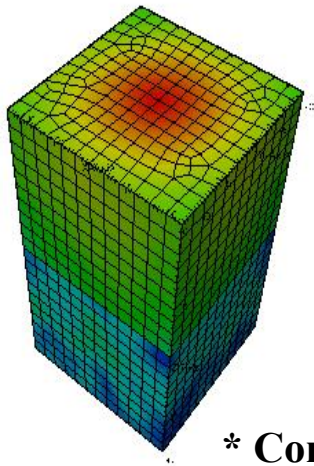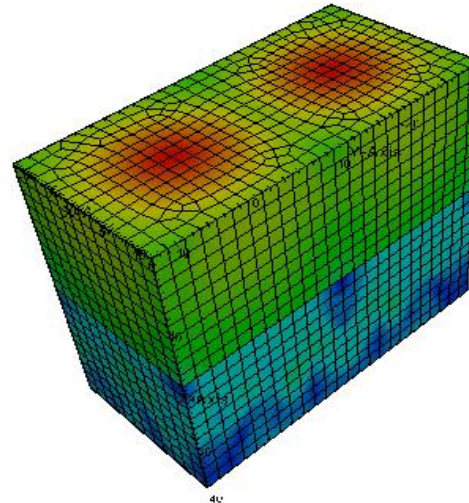
Reflect Operator Example

* Concrete Slab

Visualization and Analysis : Attributes

Attributes change the configuration of plots and operators

e.g., Smoothing, Log / Linear values, Cell Selection
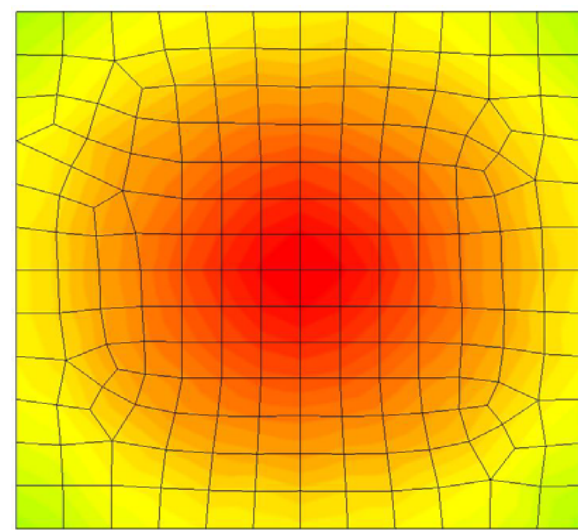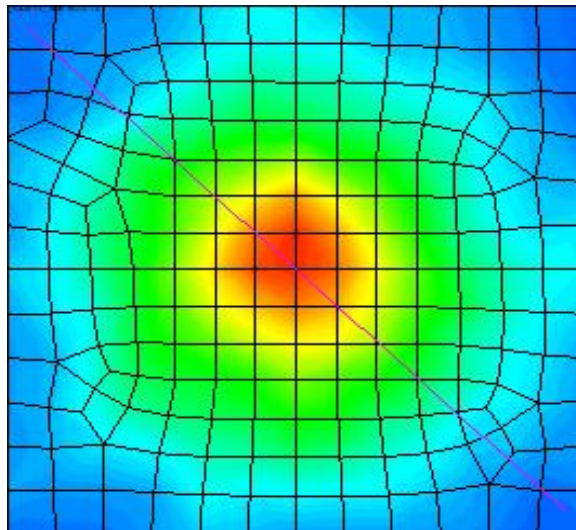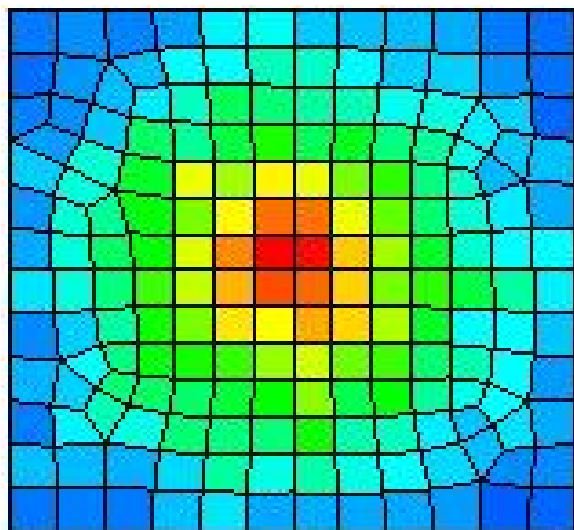
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Smoothing / Scale

Default ---------------- > Smoothing -------------> Log Scale

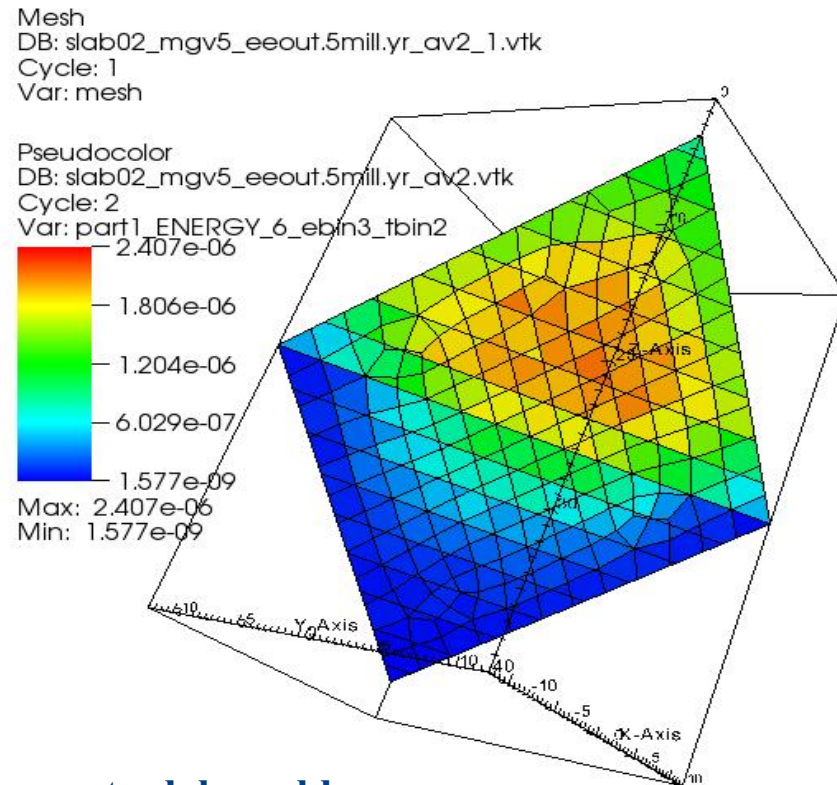**2D slice of the concrete slab problem**

LA-UR-10-05815

Slicing

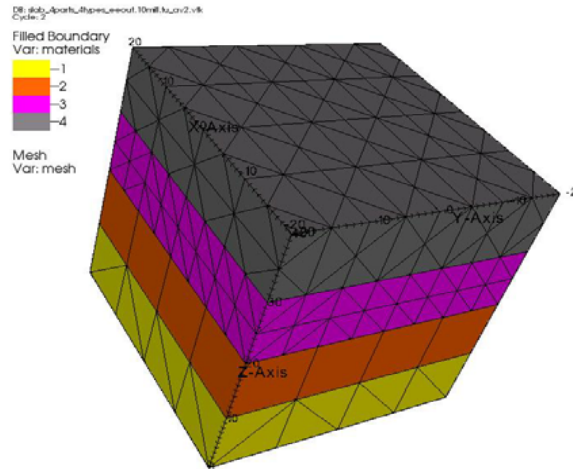## Orthogonal Slice (default)
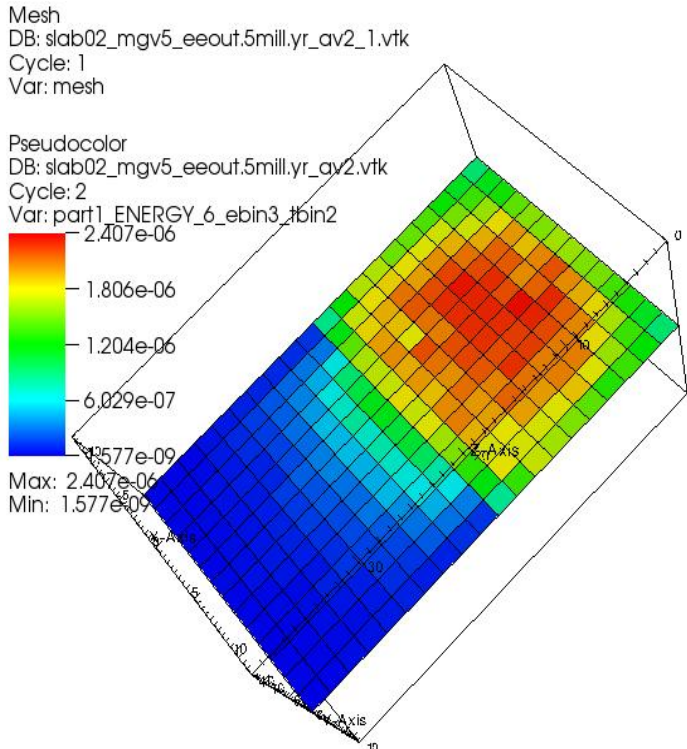
Arbitrary Slice (Ø = 45, θ = 45)

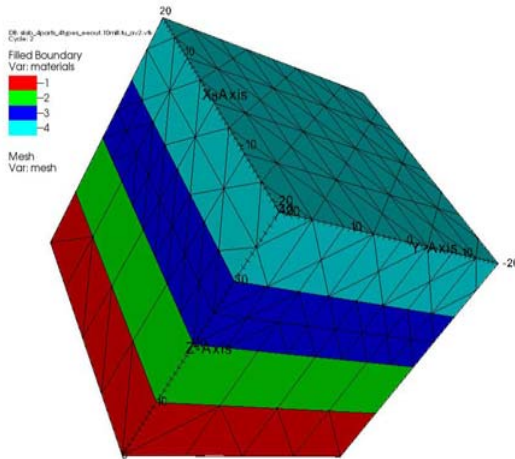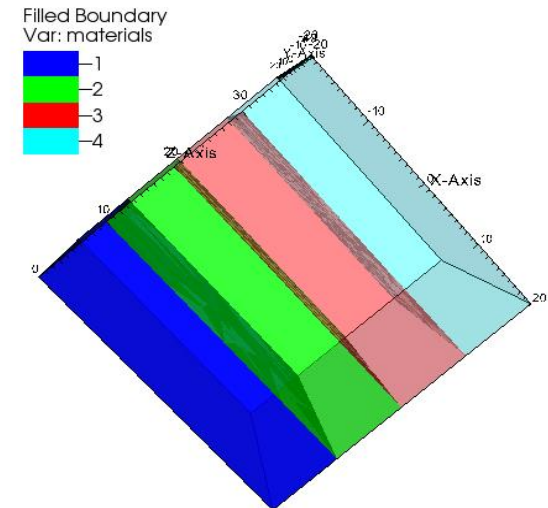**Slice from the concrete slab problem**

Visualization and Analysis : Attributes

Material Colors

Opacity

Example : Changing Opacity and Color to represent Water

Visualization and Analysis : Attributes

Color Scheme

| Hot (default) | Hot- Saturated | Hot – Cold | Grey-Scale |
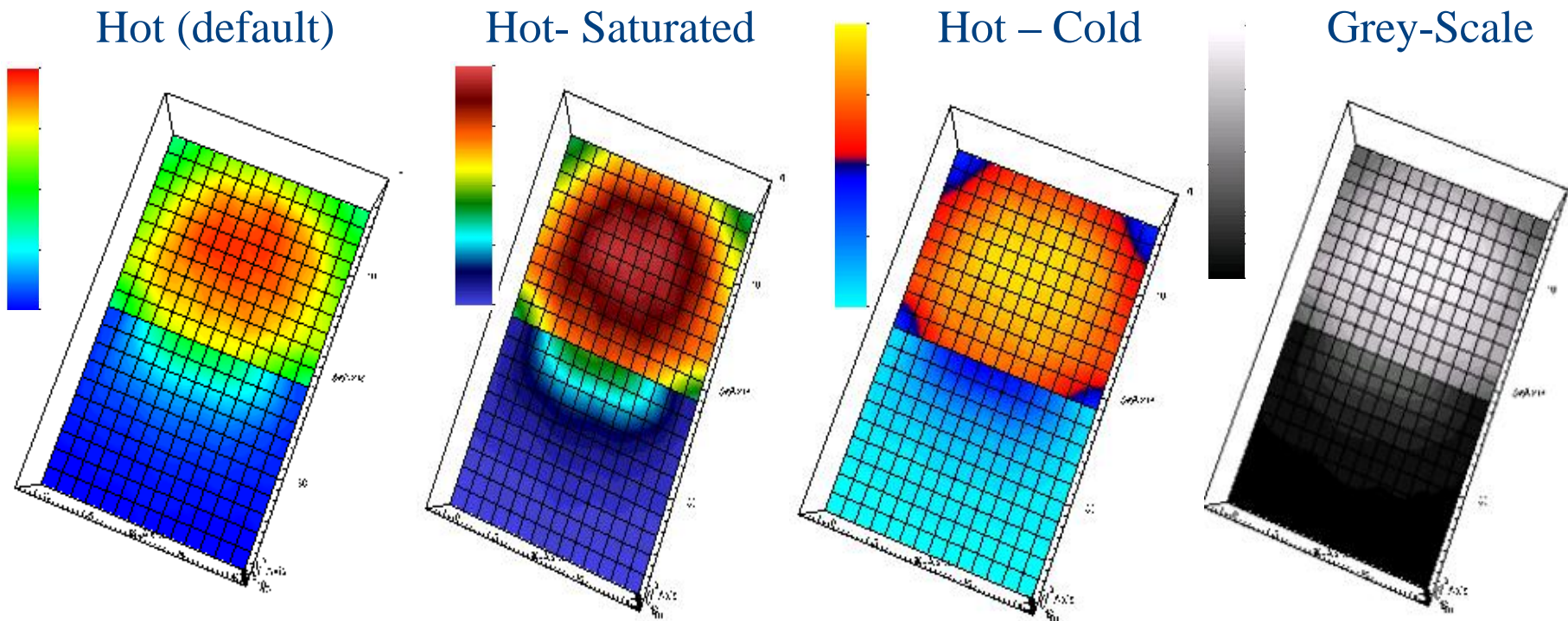
Can make your own Color Scheme

Slice from the concrete slab problem

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Visualization and Analysis : Attributes

Lighting On (Default)
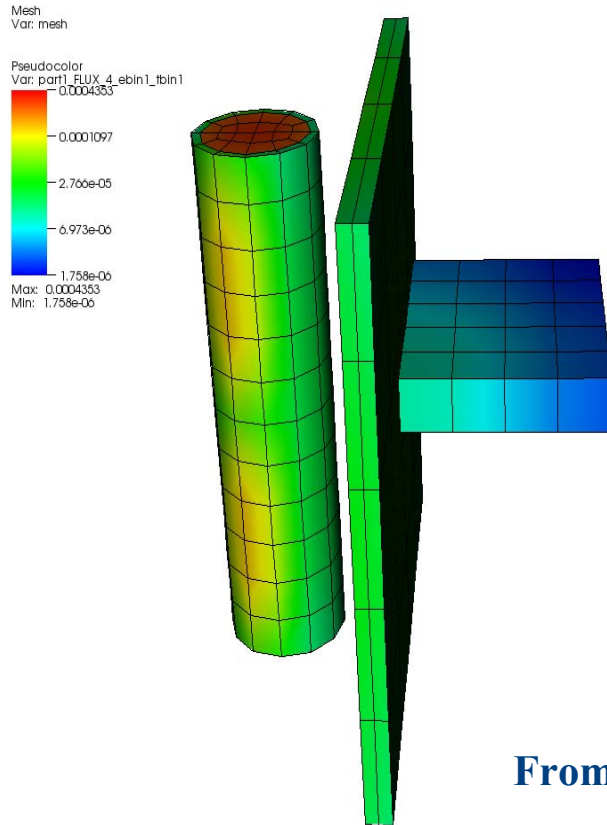
Lighting Off
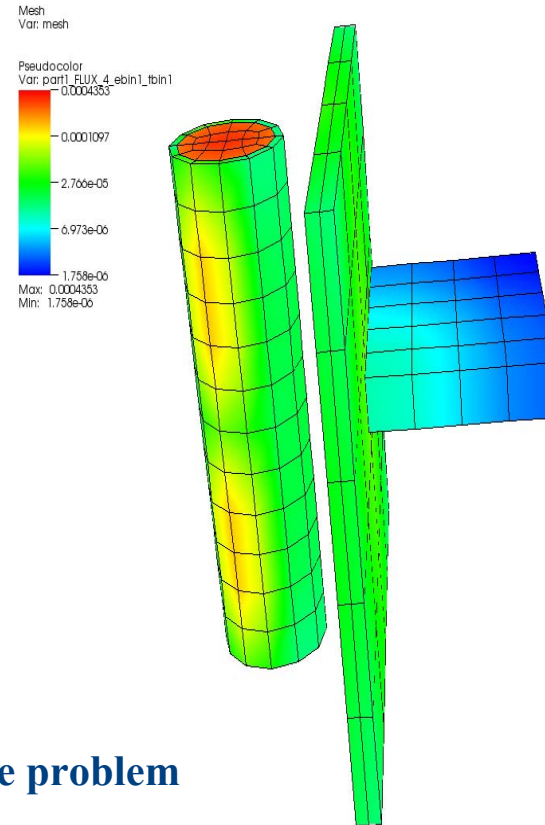
From the reactor pipe problem

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Many other Attributes

- **Removing Scales & Axes, Changing Colors, Adding Layers**

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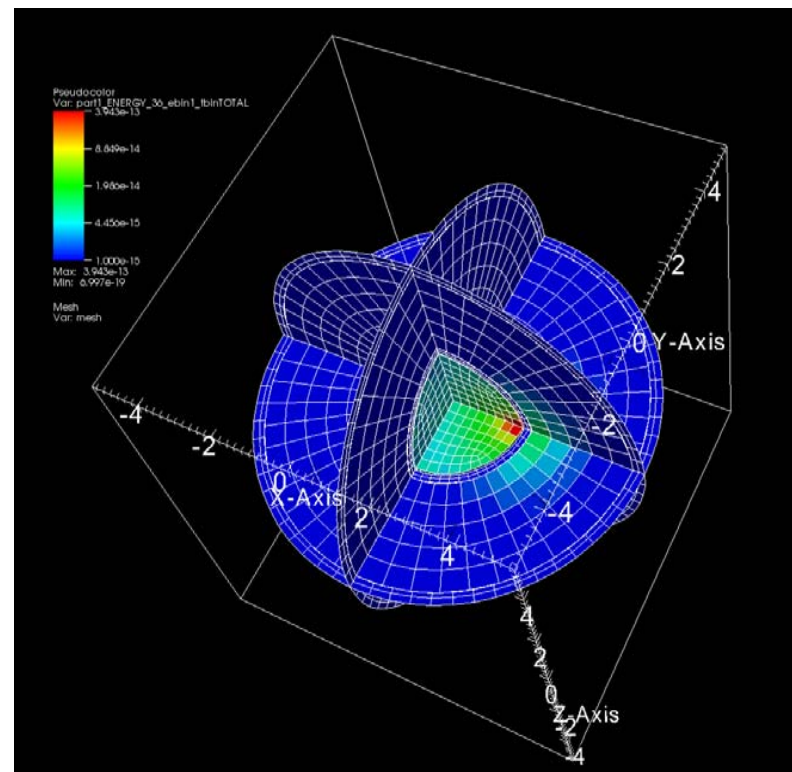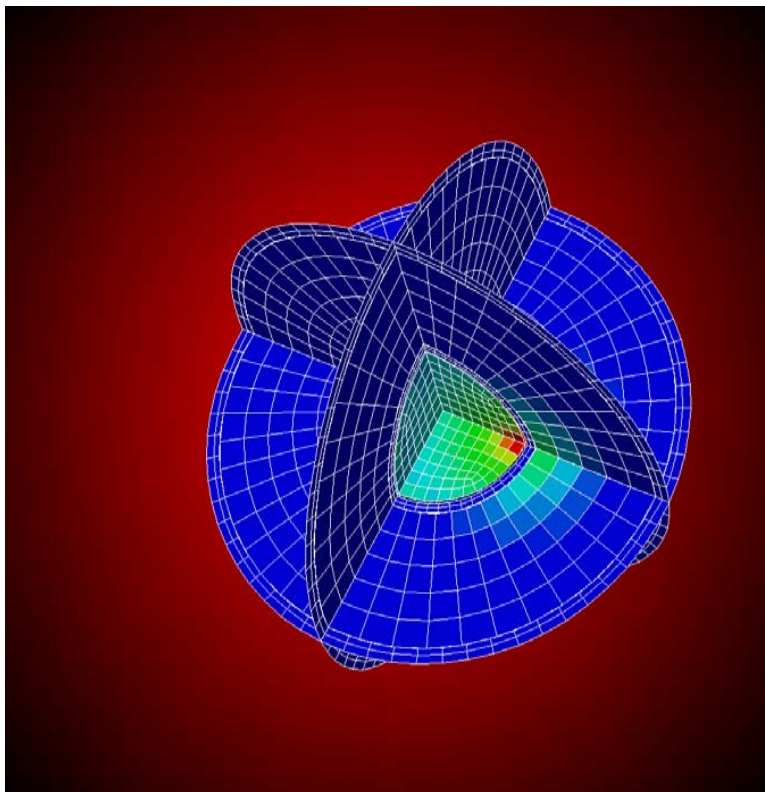
Visualization and Analysis :

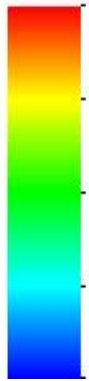# Helpful Hints

Using Plots, Operators, and Attributes
for
Visualization and Analysis

Visualization and Analysis : Helpful Hints
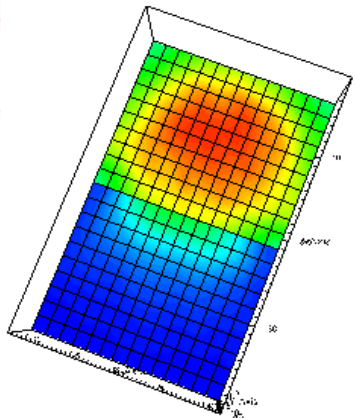
- **Plot colors are all normalized by default**
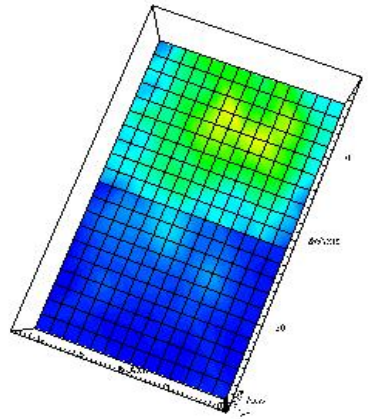 - **Adjust the Scale in the Attributes Section**

Default

Particle 1   Particle 2

Adjusted
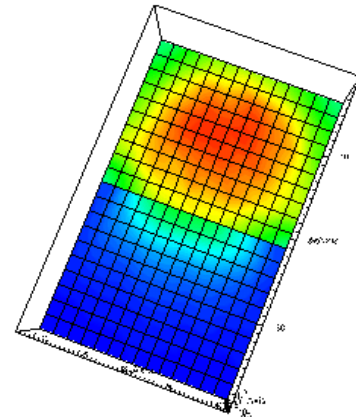
Particle 1   Particle 2
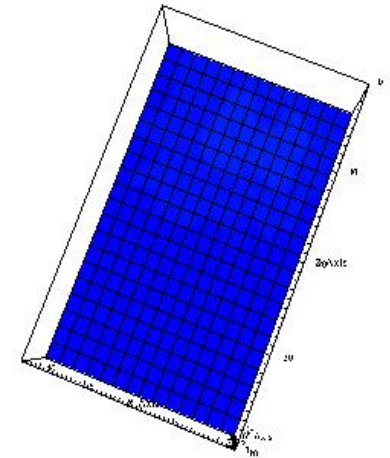
Slice of from the concrete slab problem

Visualization and Analysis : Helpful Hints

- ## File -> Save Window
  - Save the plot window to the current directory as visitXXX.png
  - Change this directory by using **File -> Set Save Options**

- ## Controls / Options
  - Similar to Attributes, have adjustable settings

- ## Log plots give errors if there are cells with a zero value
  - Adjust Minimum Value in Attributes Section

- ## Up to nine windows for plotting
  - **Great for Side by Side comparison, different Time bins**

Problems / Potential Changes

- **Some operators produce errors with 2nd order Wedges**
  - **Slice / Clip operators not working with Osaka sphere**
  - **Onion Peel / Cell operators plot correctly, show correct connectivity**
    - Maybe a bug in VisIt, since 2nd order Wedges are new.

- **VTK Format specifies Materials as integers**
  - **Haven't found a way to change legend to name**

- **Data Set Plot Naming:**
  - **Current Format:** part1_ENERGY_6_tbin2_ebinTOTAL

- **Change format to: Executable *filename* (MCNP style)**
  - **Example :   vtkfile *3shell2wedge.eeout_av2***

Filled Boundary
Var: materials
—1
—2
—3
—4

Problems / Potential Changes

- ## Very Sensitive Code

  - ### Slight differences in EEOUT file may cause VTK conversion to fail

    - Due to evolution of the EEOUT file format

  - ### VTK file also very sensitive in VisIt

- ## Connectivity Data

  - ### Current EEOUT file has the connectivity data stored as :

    [(Node 1 Cell 1), (Node 1 Cell 2), (Node 1 Cell 3) ... (Node 2 Cell 1), (Node 2 Cell 2) ...]

  - ### Would prefer:

    [(Node 1 Cell 1), (Node 2 Cell 1), (Node 3 Cell 1)....]

    [(Node 1 Cell 2), (Node 2 Cell 2), (Node 3 Cell 2) ...]

  - ### Would require changing both codes, but more intuitive

  - ### Scheduled for Next EEOUT format revision
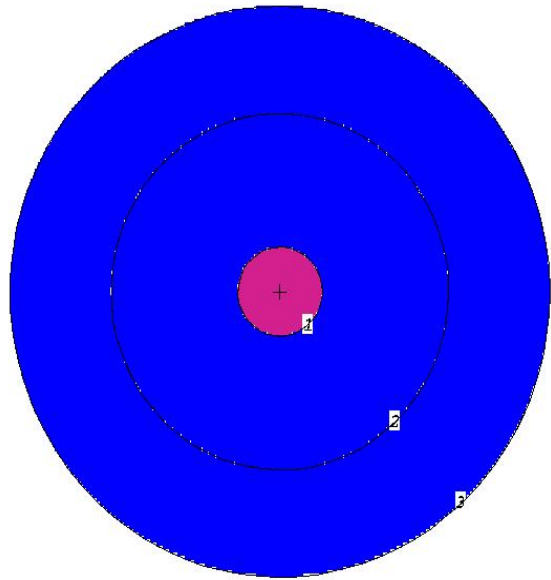
Future Work

- **Develop a Plugin**
  - **Call VisIt's functions to directly read in the EEOUT file**
    - Eliminates need for VTK format conversion
  - **Much of the code already written**
  - **Allow for time dependencies, material naming, etc...**

- **Further V & V and debugging of the Code**
  - **Attempt various files**

- **Read in binary versions of EEOUT file**
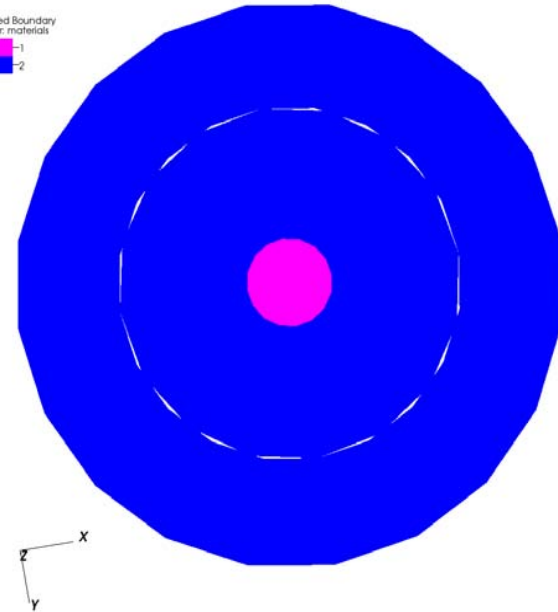 - **Currently only reads in ASCII**

Comparison

MCNP Plotter

VisIt

From the Osaka Nickel Sphere model

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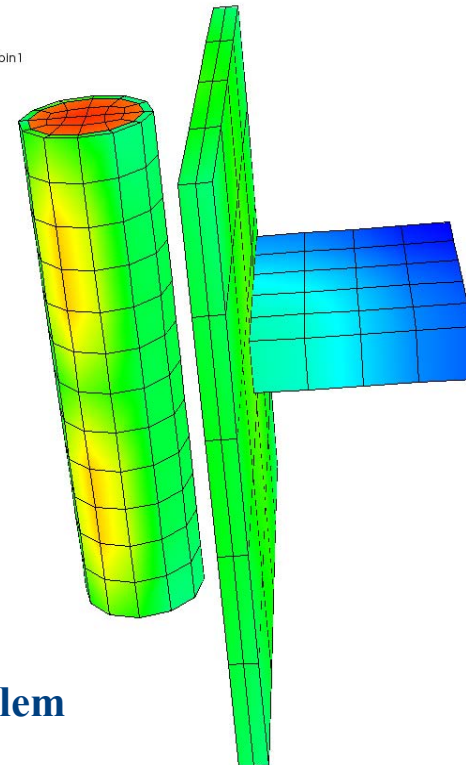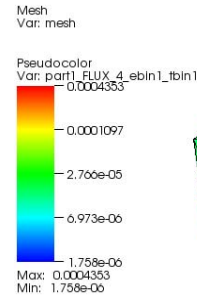# Comparison

Abaqus CAE
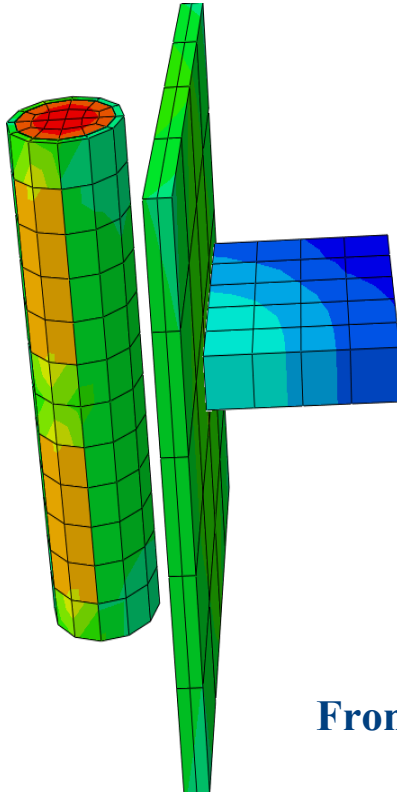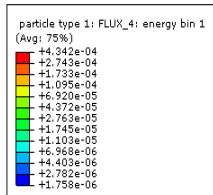
VisIt

From the reactor pipe problem

Conclusions

- **VisIt has great capabilities for plotting MCNP EEOUT data**

- **EEOUT -> VTK conversion works for multiple examples**

- **I believe there's great potential with this new capability of MCNP for very detailed geometries and data analysis**

My Experience

- **Had a great time here, good community, and enjoyable work**

- **Apparently I have a northern accent**

- **Serious lack of cheese curds in this state**
  - **Makes it up though with green chili**

- **As you can see, there are normal people from Wisconsin....**

U N C L A S S I F I E D

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Any Questions?