

CSAS/TRITON Mesh Tallies

SCALE 6.3.1

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U.S. DEPARTMENT OF
ENERGY

Learning goals

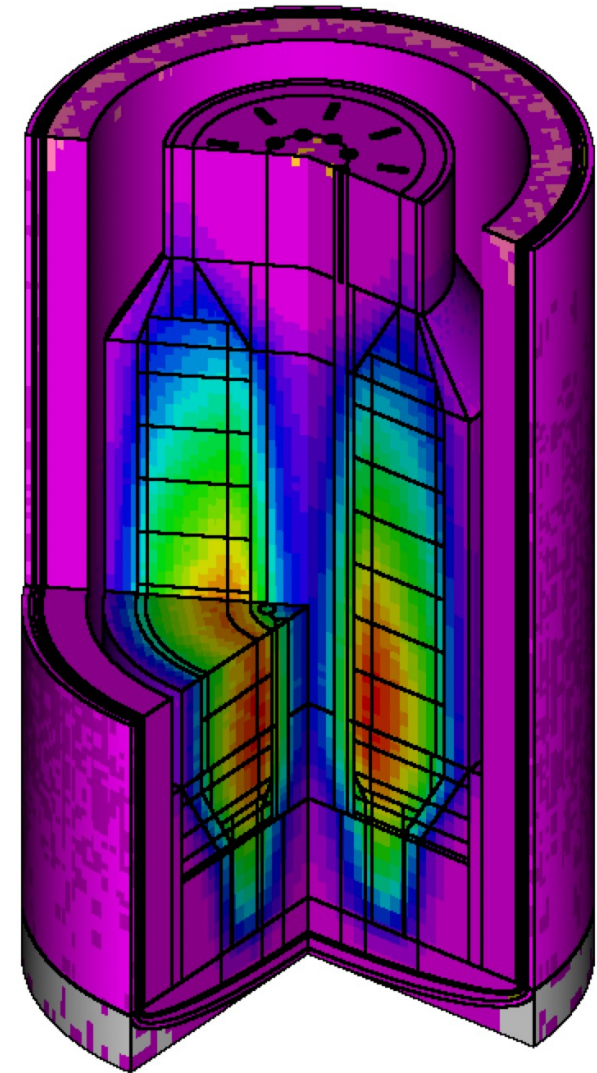
- **Understand** which responses can be tallied on which mesh in CSAS and TRITON calculations
- **Learn** how to setup a DEFINITIONS and a TALLIES block
- **Learn** how to visualize data from 3dmap files with Fulcrum

Introduction



CSAS/TRITON mesh tallies

- When used in combination with KENO or Shift, both CSAS and TRITON support the calculation of the following quantities over a mesh:
 - Neutron flux averaged over mesh volumes
 - Fission rate per voxel volume
 - Neutron production per voxel volume (fission source)
- SCALE 6.3 introduced a DEFINITIONS and a TALLIES block to CSAS and TRITON
- SCALE 6.2 already supported flux and fission source mesh responses, but with less flexibility



Flux mesh over an FHR
Fast flux, $E > 0.625$ eV

CSAS/TRITON mesh tallies

- DEFINITIONS block:
 - Spatial grids
 - Energy grids
- TALLIES block:
 - Mesh definition for response of interest

This is where we enter general definitions that can be used by multiple tallies

This is where we enter our tallies, using a grid from the DEFINITIONS block

- Deprecated (still works in 6.3, but not recommended):
 - GFX, FIS, CDS keywords directly in the parameter block
 - Root-level energy block

Definitions Block



Spatial grid – Overview

- Spatial grids are defined in the DEFINITIONS block
- As many grids as needed can be listed
- Grids are referred to by their integer identifier
- Spatial grids are limited to Cartesian grids
- There are multiple ways to specify a grid:
 - Specify explicit coordinates
 - Divide a range into a number of intervals
- All data are provided in cm

```
READ DEFINITIONS

read gridGeometry 10
...
end gridGeometry

read gridGeometry 20
...
end gridGeometry

read gridGeometry 30
...
end gridGeometry

END DEFINITIONS
```

Example CSAS/TRITON definitions block

Spatial grid – Basic input

Option 1: List explicit planes

- **xplanes** <list of x coordinates> **end**
- **yplanes** <list of y coordinates> **end**
- **zplanes** <list of z coordinates> **end**

```
READ DEFINITIONS
```

```
read gridGeometry 1  
xplanes -10 50 90 end  
yplanes 0 32 34 36 38 40 48 72 end  
zplanes -0.05 15.0 72.5 end  
end gridGeometry
```

```
END DEFINITIONS
```

Spatial grid – Basic input

Option 2: Divide range into **N** intervals

- **xlinear** **N** X_{MIN} X_{MAX}
- **ylinear** **N** Y_{MIN} Y_{MAX}
- **zlinear** **N** Z_{MIN} Z_{MAX}

```
READ DEFINITIONS
```

```
read gridGeometry 2  
xlinear 30 -10 70  
ylinear 10 -20 60  
zlinear 50 -30 40  
end gridGeometry
```

```
END DEFINITIONS
```

Spatial grid – Basic input

Option 3: Divide range into **N** intervals

- **numxcells=N** **xmin=X_{MIN}** **xmax=X_{MAX}**
- **numycells=N** **ymin=X_{MIN}** **ymax=X_{MAX}**
- **numzcells=N** **zmin=X_{MIN}** **zmax=X_{MAX}**

READ DEFINITIONS

```
read gridGeometry 3
numxcells=10 xmin=-18.5 xmax=+68.5
numycells=25 ymin=-28.5 ymax=+58.5
numzcells=10 zmin=-38.5 zmax=+48.5
end gridGeometry
```

END DEFINITIONS

Spatial grid – Basic input

The spatial grid definition can be different between the x-grid, y-grid and z-grid

```
READ DEFINITIONS
```

```
read gridGeometry 4  
xplanes -10 50 90 end  
ylinear 10 -20 60  
numzcells=10 zmin=-38.5 zmax=+48.5  
end gridGeometry
```

```
END DEFINITIONS
```

Spatial grid – Basic input

You can add multiple definitions for each axis;
the boundaries will be combined

READ DEFINITIONS

```
read gridGeometry 5  
xlinear 5 0 100  
xplanes 15 55 65 75 end  
  
ylinear 10 -20 60  
zlinear 50 -30 40  
end gridGeometry  
  
END DEFINITIONS
```

Divide range 0-100 cm into 5 intervals: 0, 20, 40, 60, 80, 100 cm

Add specific boundaries at 15, 55, 65, and 75 cm

Final x-grid: 0, **15**, 20, 40, **55**, 60, **65**, **75**, 80, 100 cm

Spatial grid – Remarks

- Each grid permits a **title**
- Shift requires the grid outermost boundaries to lie within the geometry; KENO-VI does not
- Output block “grid definitions” displays all grids that are used in the calculation, including their title

READ DEFINITIONS

```
read gridGeometry 4
title "My great group structure"
xplanes -10 50 90 end
ylinear 10 -20 60
numzcells=10 zmin=-38.5 zmax=+48.5
end gridGeometry
```

END DEFINITIONS

Energy grid – Overview

- Energy grids are defined in the DEFINITIONS block
- As many grids as needed can be listed
- Grids are referred to by their integer identifier
- There are multiple ways to specify a grid:
 - Specify explicit energy boundaries
 - Divide a range into a number of intervals
 - Use a known energy group structure
- All boundaries have unit eV
- Energy range is 1 e-5 to 2e7 eV

```
READ DEFINITIONS

read energyBounds 1
...
end energyBounds

energyBounds 2
...
end energyBounds

energyBounds 3
...
end energyBounds

energyBounds 10
...
energyBounds

END DEFINITIONS
```

Example CSAS/TRITON definitions block

Energy grid – Basic input

Option 1: List explicit energy boundaries:

- **bounds** <list of bounds> **end**

```
READ DEFINITIONS
```

```
read energyBounds 1
```

```
bounds 2e7 0.625 1e-5 end
```

```
end energyBounds
```

```
END DEFINITIONS
```

Energy grid – Basic input

Option 2: Divide energy range linearly into N intervals:

– **linear**=N $E_{\min}$ $E_{\max}$

```
READ DEFINITIONS
```

```
energyBounds 2
```

```
linear=10 1e-5 2e7
```

```
end energyBounds
```

```
END DEFINITIONS
```

Example CSAS/TRITON definitions block

Energy grid – Basic input

Option 3: Divide energy range logarithmically into N intervals:

– **logarithmic**=N $E_{\min}$ $E_{\max}$

```
READ DEFINITIONS
```

```
energyBounds 3
```

```
logarithmic=10 1e-5 2e7
```

```
end energyBounds
```

```
END DEFINITIONS
```

Example CSAS/TRITON definitions block

Energy grid – Basic input

Option 4: Use known SCALE energy group structure

- `<groups><n>` or `<groups><p>` for known neutron or (coupled) photon MG libraries
- Examples: 56n, 19p, 252n, ...
- Group structures mapped according to libraries listed in *FileNameAliases.txt*

```
READ DEFINITIONS
```

```
energyBounds 10
```

```
56n
```

```
bounds 1.1 0.11 0.011 0.0011 end
```

```
energyBounds
```

```
END DEFINITIONS
```

Example CSAS/TRITON definitions block

Energy grid – Basic input

You can add multiple definitions within one energy grid definition; the energy boundaries will be combined

```
READ DEFINITIONS
```

```
energyBounds 10
```

```
56n
```

```
bounds 1.1 0.11 0.011 end
```

```
energyBounds
```

```
END DEFINITIONS
```

Use SCALE's 56-group structure

Add specific boundaries at 1.1, 0.11, 0.011 eV

Final structure: 59-group structure with boundaries from SCALE's 56-group structure plus additional specific boundaries

Example CSAS/TRITON definitions block

Energy grid – Special case

Special case: energy grid “**DEFAULT**”

- CSAS/TRITON-**MG** tallies default to the energy group structure of the applied **MG library**
- CSAS/TRITON-**CE** tallies default to the **252-group structure**
- You can overwrite these defaults by providing an energy group structure with label “DEFAULT”
- CSAS/TRITON-MG permits only DEFAULT structures that are sub-structures of the applied MG library
- CSAS/TRITON-CE permits any group structure

```
READ DEFINITIONS
```

```
read energyBounds DEFAULT
```

```
bounds
```

```
2.00000E+07
```

```
1.05000E+02
```

```
5.00000E+00
```

```
1.00000E-05
```

```
end
```

```
end energyBounds
```

```
END DEFINITIONS
```

Energy grid – Remarks

- Each energy grid permits a **title**
- Output block “energy boundaries” shows all energy group structures used in the calculation, including their title

```
READ DEFINITIONS
```

```
read energyBounds 10
```

```
title "My 56++ structure"
```

```
56n
```

```
bounds 2.0E+07 5.2E+00 1.5E-05 end
```

```
end energyBounds
```

```
END DEFINITIONS
```

Tallies Block



Tallies – Overview

- Tallies in CSAS/TRITON are limited to **MESH** tallies (i.e., no cell tallies, no material tallies, or else)
- MESH tallies are used to tally a response (i.e., quantity of interest) over a spatial grid using an energy group structure of choice
- Output files are binary **3dmap** files that allow data visualization with Fulcrum (later slides)
- Available quantities:
 - Neutron flux averaged over mesh volumes (*flux*)
 - Fission rate per voxel volume (*fission_density*)
 - Neutron production per voxel volume (*fission_source*)
- The results are provided in units **per initial source neutron**

CSAS MESH Tallies

- Response name:
 - FLUX
 - FISSION_DENSITY
 - FISSION_SOURCE
- Spatial grid number from the definitions block
- Energy grid number from the definitions block
 - DEFAULT is permitted as well, even if you haven't overwritten it!
- Output files:
 - \${BASENAME}.<response>.3dmap
 - \${BASENAME}.meshtally_<meshID>_<response>.3dmap

READ TALLIES

```
read mesh 10
response=FLUX
grid=1
energy= 1
end mesh
```

```
read mesh 20
response=FISSION_DENSITY
grid=2
energy=2
end mesh
```

```
read mesh 30
response=FISSION_SOURCE
grid=3
energy=default
end mesh
```

END TALLIES

Example CSAS tallies block

TRITON MESH Tallies

- In addition to the records of the MESH block in a CSAS input, TRITON requires a time array:
 - List of time steps **starting with 0** for the initial neutron transport calculation
 - Shortcut **ALL** requests all time steps
 - Shortcut **LAST** requests data for the last time step
- Reminder: In TRITON, the neutron transport calculations, and thus the tallying, are performed for the initial geometry and at the *mid-point* of each depletion step
- Requesting the mesh tallies only for relevant time steps reduces the runtime and avoids unnecessary large output files (3dmap files can be many MB or even GB large)
- Output files:
 - \${BASENAME}.<response>_time<step>.3dmap
 - \${BASENAME}.meshtally_<meshID>_<response>_time<step>.3dmap

```
READ TALLIES
```

```
read mesh 10
```

```
response=FLUX
```

```
grid=1
```

```
energy=1
```

```
time=0 1 2 end
```

```
end mesh
```

```
read mesh 20
```

```
response=FISSION_DENSITY
```

```
grid=2
```

```
energy=2
```

```
time=ALL end
```

```
end mesh
```

```
read mesh 30
```

```
response=FISSION_SOURCE
```

```
grid=3
```

```
energy=default
```

```
time=0 LAST end
```

```
end mesh
```

```
END TALLIES
```

Example TRITON tallies block

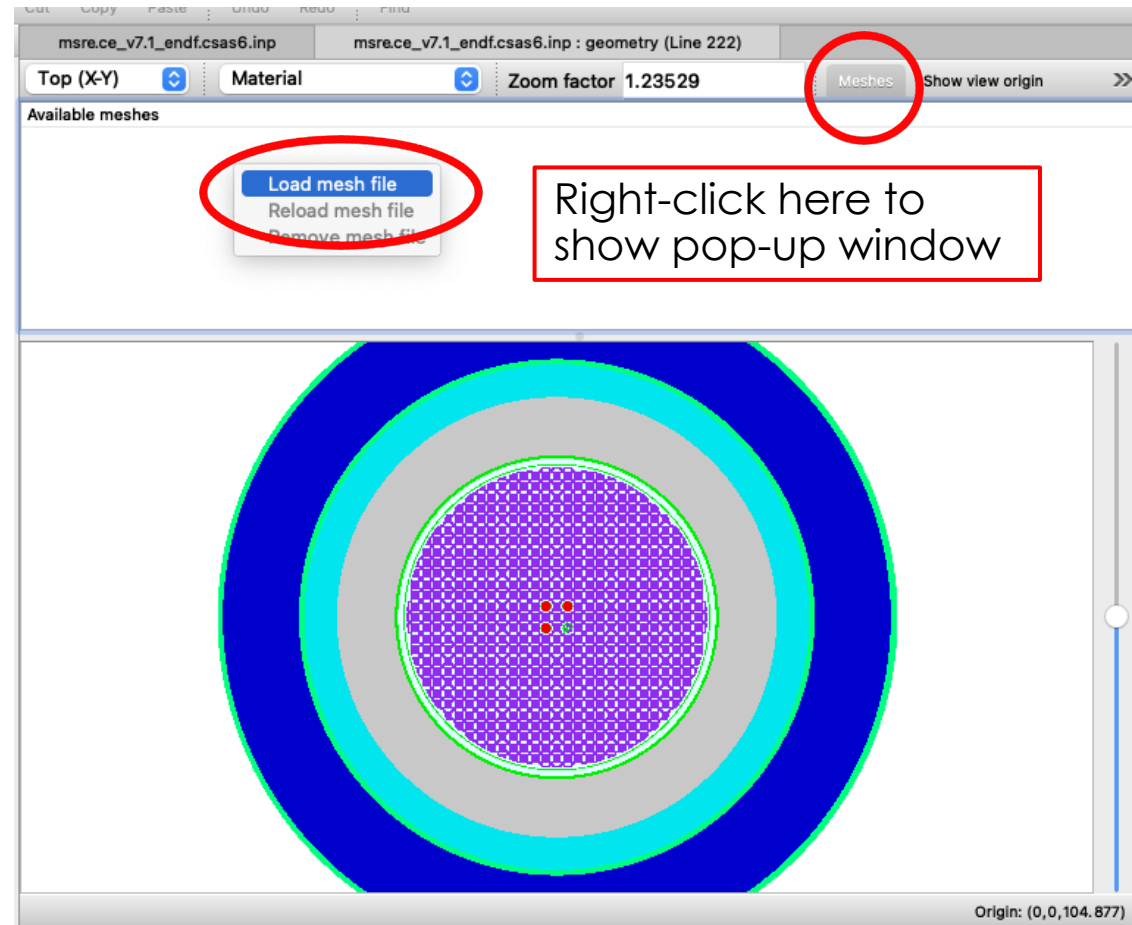
3dmap Data Visualization



Visualization

Steps to load 3dmap file in Fulcrum:

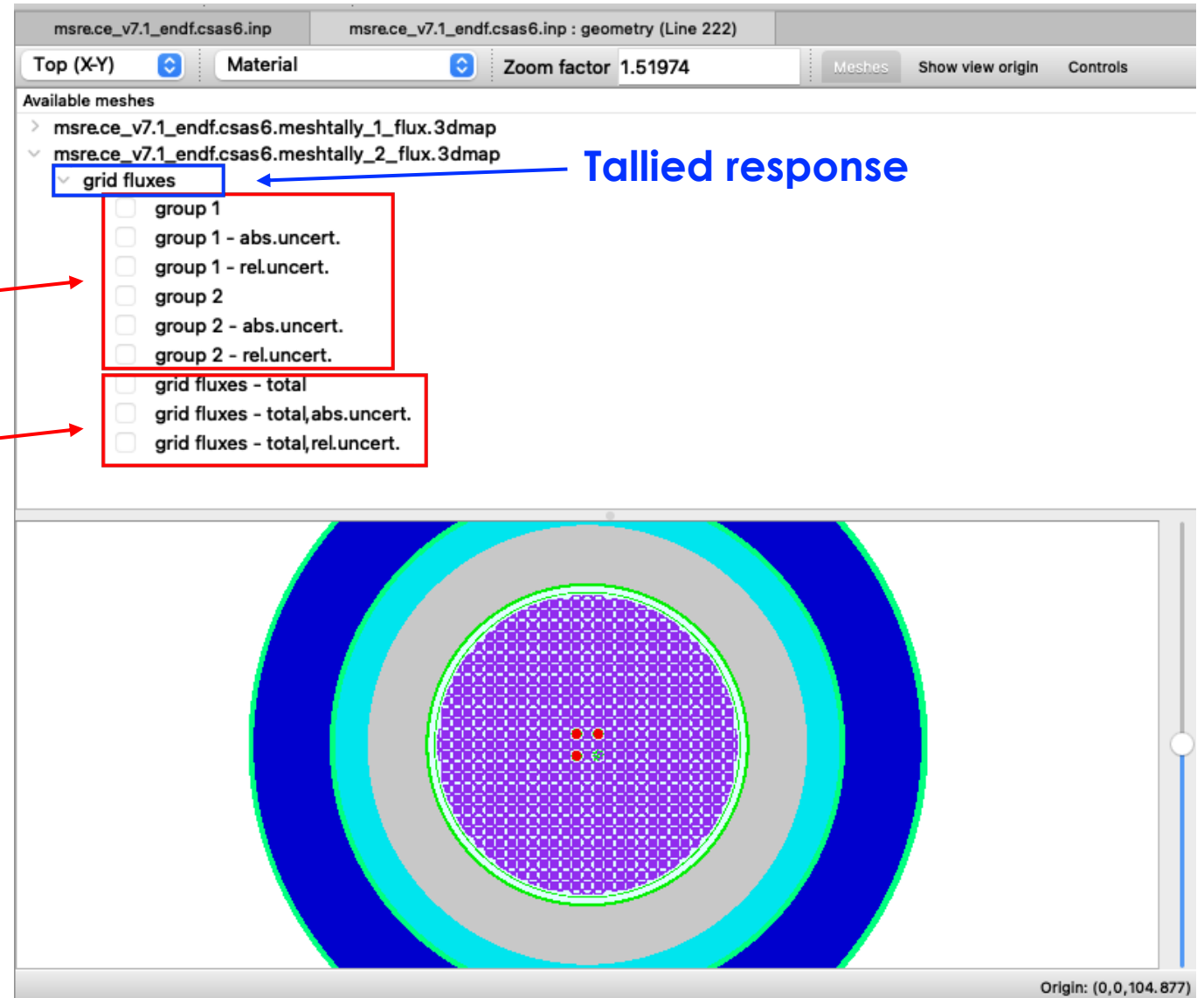
1. Visualize your geometry
2. Click “Meshes” button
3. Right-click in the empty space under “Available meshes”
4. Select “Load mesh file”, and find your 3dmap file



Visualization

Each 3dmap file includes:

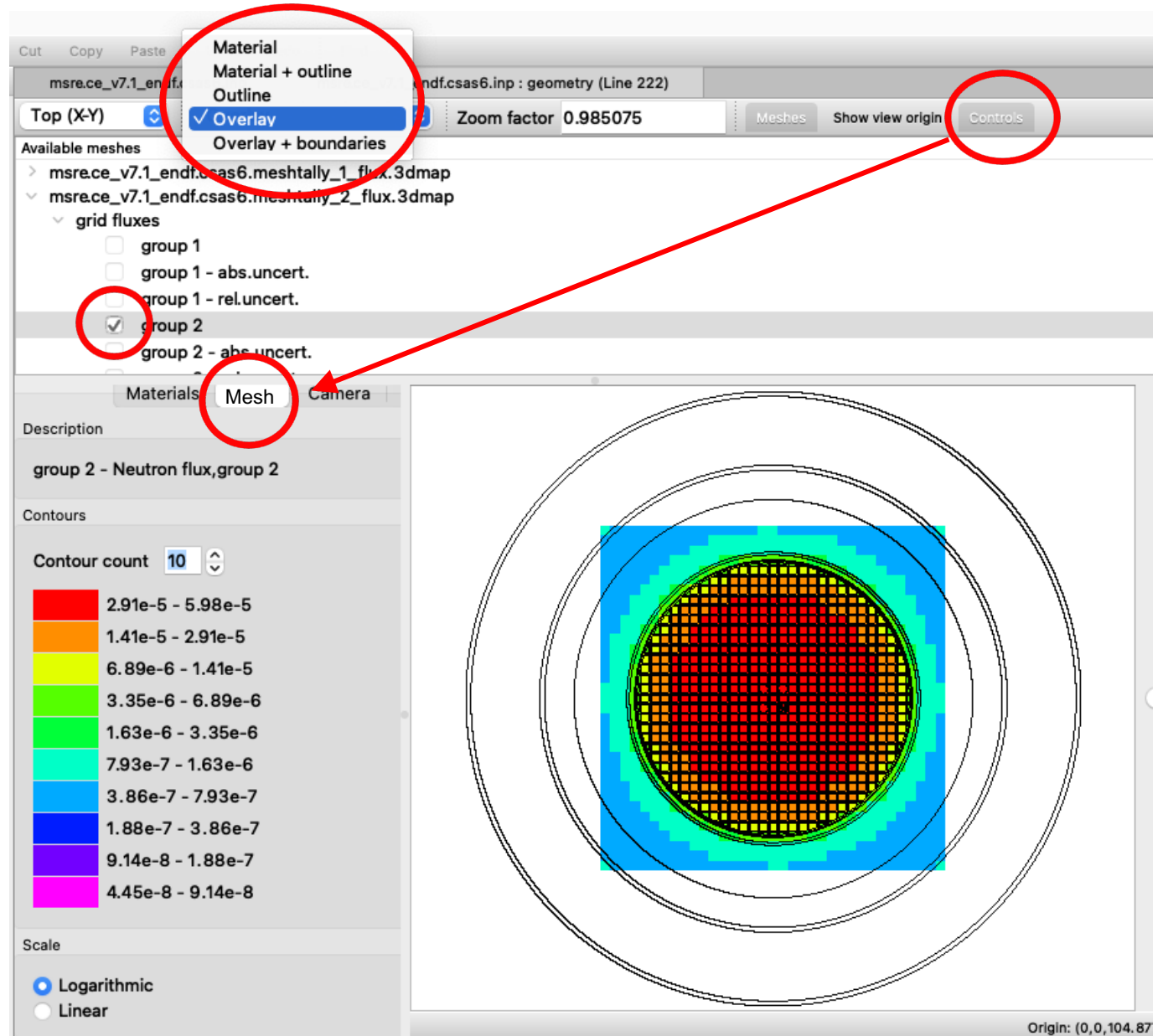
- Energy group-wise results
+ corresponding statistical error
- Total result
+ corresponding statistical error



Visualization

Generate 2D or 3D overlay plots:

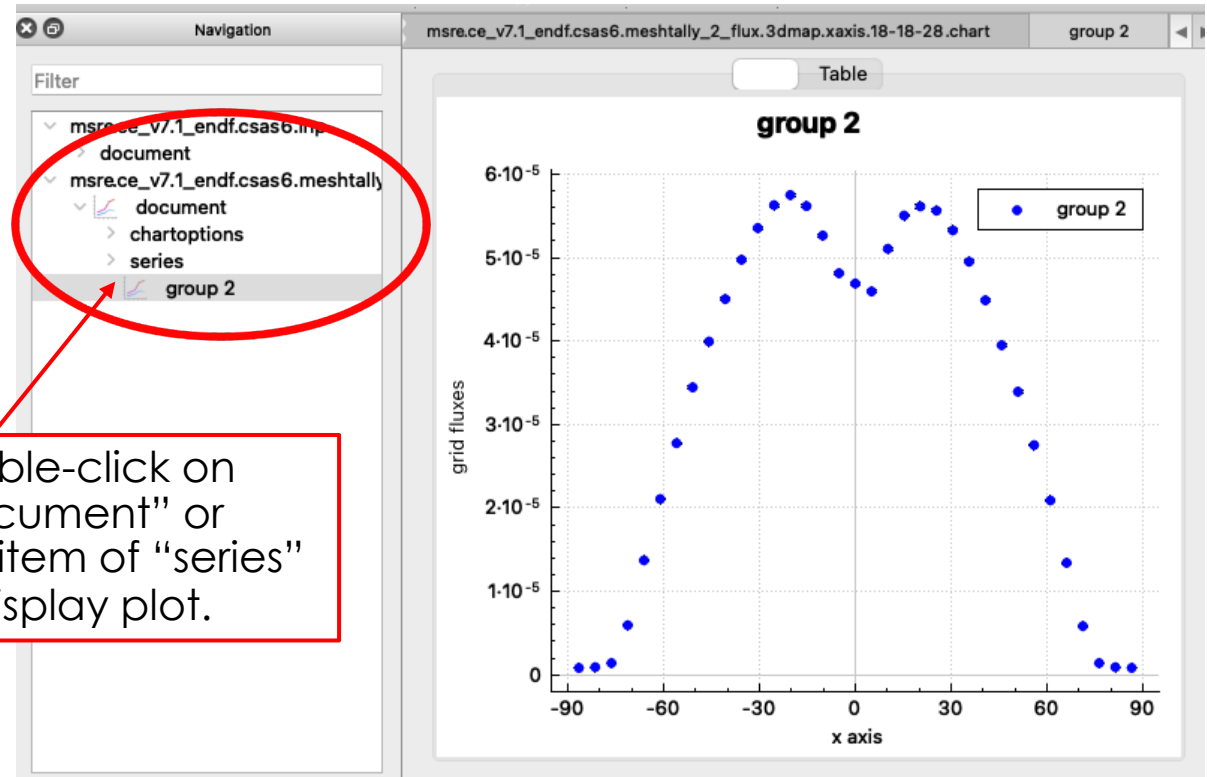
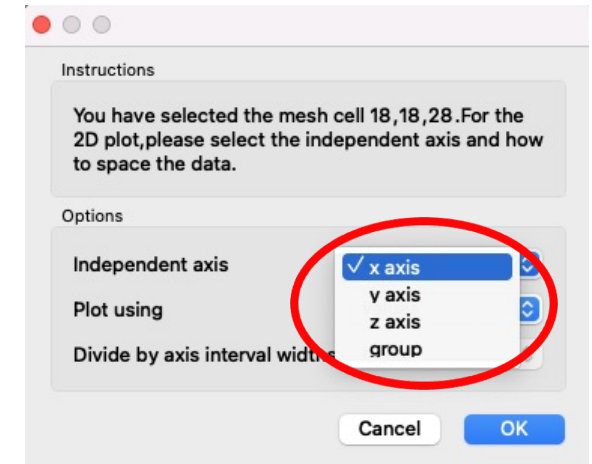
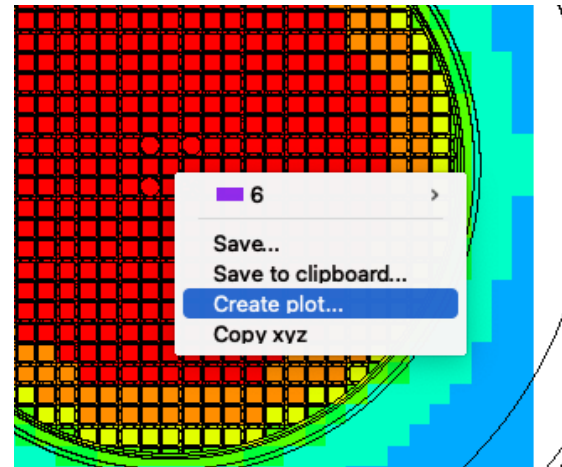
- Select response of interest and “Overlay” to generate colorful presentation of results over the geometry
- Click “Control” button to change the color scale and to modify 3D visualization
- Note the default scale is *logarithmic*
- You can choose result ranges (minimum, maximum) to display



Visualization

Plot response over x/y/z axis:

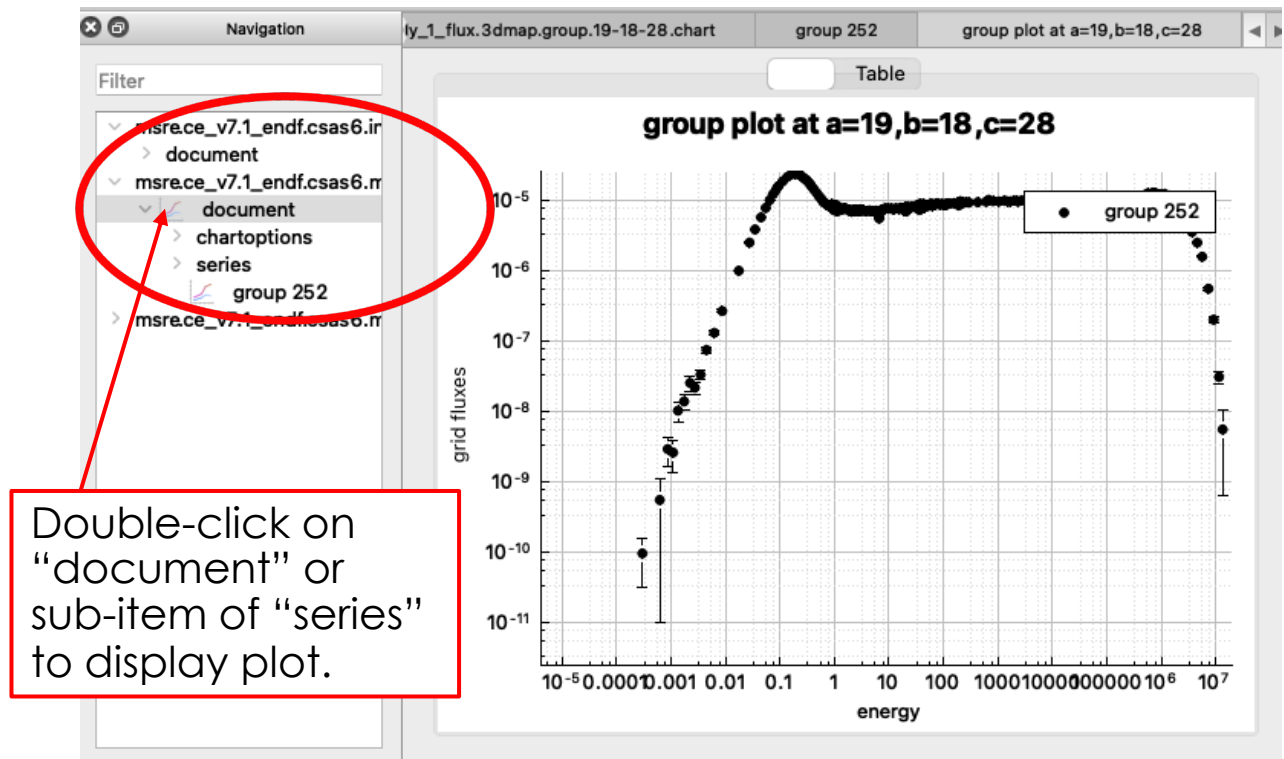
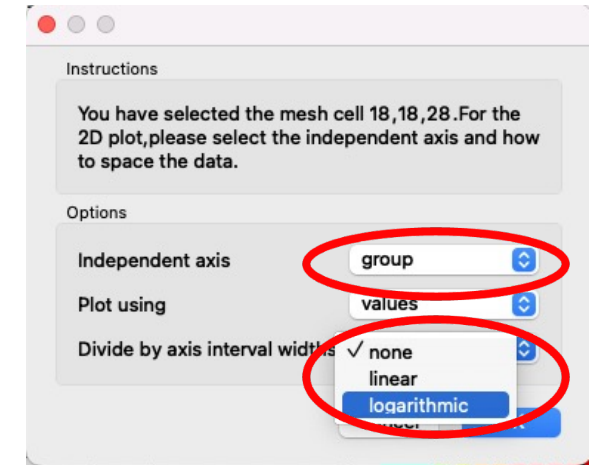
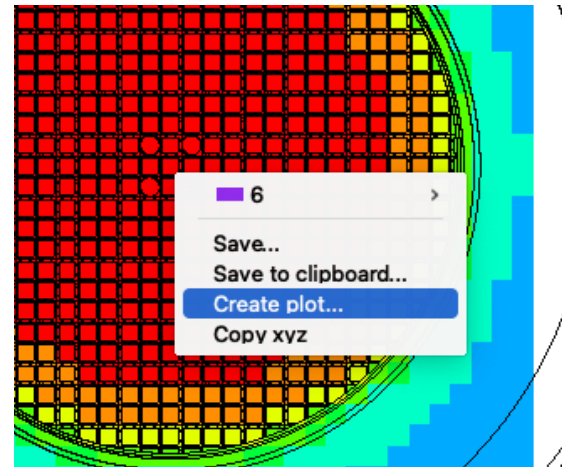
- Obtain overlay plot
- Right-click on voxel (individual mesh cell) and select the independent axis as “x axis” or y or z
- Acknowledge the generation of a chart-file that shows up in the navigation panel
- Double-click on the series you want to display to generate the plot



Visualization

Plot response as a function of energy:

- Obtain overlay plot
- Right-click on voxel (individual mesh cell) and select the independent axis as “group” and division by lethargy
- Acknowledge the generation of a chart file that shows up in the navigation panel
- Double-click on the series you want to display to generate the plot
 - Clicking “document” over “series” creates a slightly different formatted plot; for example, with a logarithmic x-scale



Visualization

- Modify your plot: right-click on plot area and then select “Plot options”
- Chart files: for each 2D plot, Fulcrum automatically creates a chart file for later re-load into Fulcrum; this does not store plot options
- SPF files: save your plot as an SPF if you want to save chosen plot options
- Create PNG files: Right-click on plot area, select “Save as...” and “PNG”; or take a screenshot

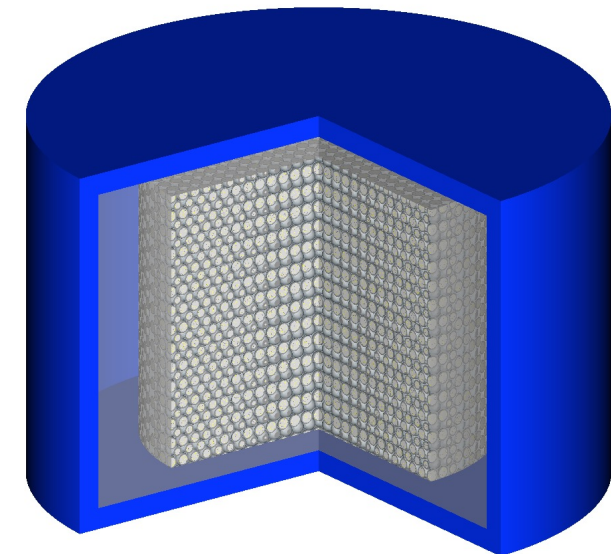
All the tips and tricks on 3dmap visualization are better explained by demonstration during the workshop.

Workshop



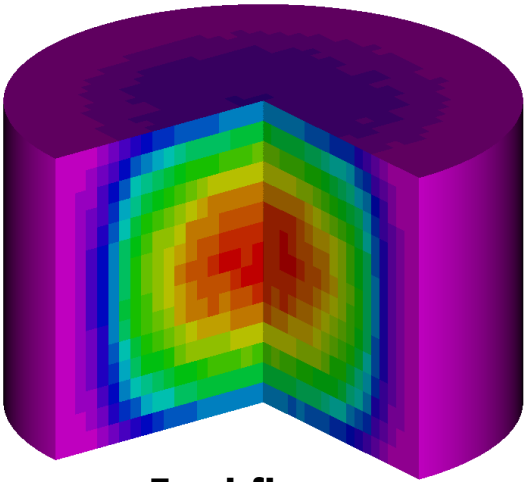
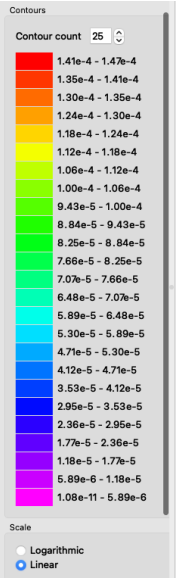
Problem: Generate a 3D flux mesh

- **Goal:** Analyze neutron flux distribution of a HTGR mini core
- **Steps:**
 - Copy starter file “htgr_core_mg.inp” to “htgr_core_mg_tallies.inp”
 - Add spatial_grid:
 - x/y: 40 intervals between -128 and +128 cm
 - z: 17 intervals between 0 and 170 cm
 - Add energy_grid:
 - 2-group structure with boundaries: 1e-5, 0.625 and 2e7 eV
 - Add flux mesh tallies:
 - Mesh 1: specified spatial and energy grid
 - Mesh 2: specified spatial grid, default energy grid
- **Analysis:**
 - Mesh 1:
 - Inspect thermal flux and fast flux in 2D and 3D mesh plots **on a linear scale**
 - Plot thermal flux as a function of the x axis (2D plot)
 - Mesh 2:
 - Plot flux per lethargy as a function of energy for the core center



HTGR mini core

Solution: Generate a 3D flux mesh



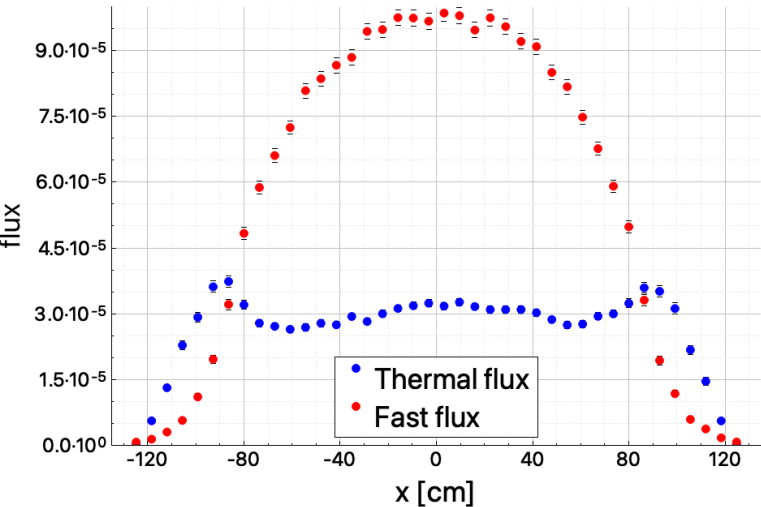
Tip: If you want to compare multiple color plots, select a custom range for the scale.

Range

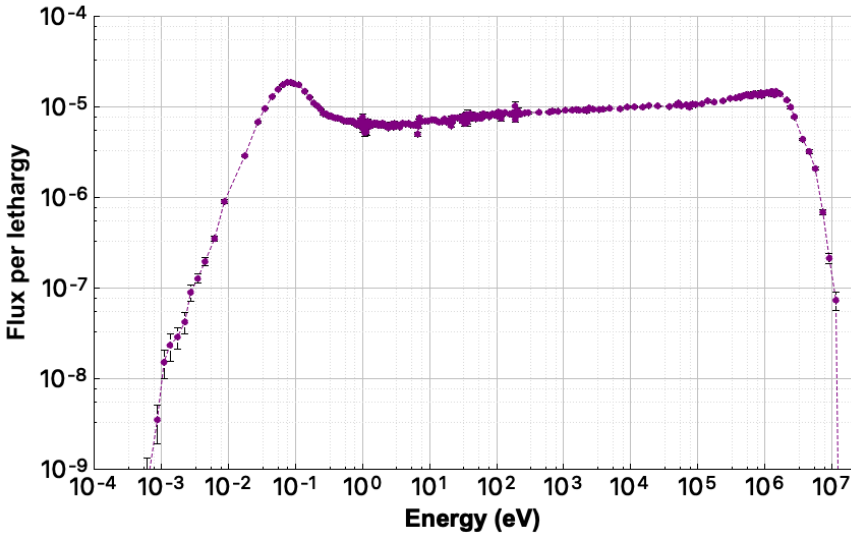
Source Custom

Maximum 1.8670000000000000e-4

Minimum 1.0480000000000000e-11



Fast and thermal flux at the axial core center as a function of the radius



Flux per unit lethargy as a function of energy in the core center

Tip: Select a precision of 0 and number format "eb" to obtain nice exponential number format

Tick Label Rotation	0.00
Tick Label Type	Number
Tick Label Precision	0
Tick Label Number Format	eb

