

KENO V.a Geometry

SCALE 6.3.2

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Learning Objectives

- Familiarize with the KENO V.a geometry syntax and logic
- Apply holes and arrays in KENO V.a inputs for repetitive geometries
- Perform exercises using KENO and new Shift capabilities

Outline

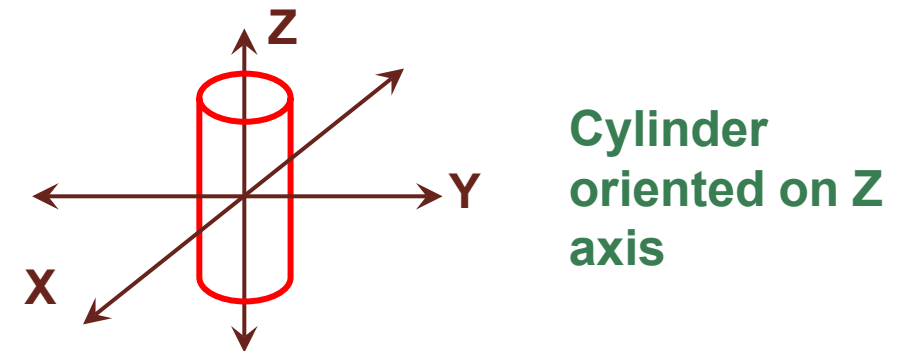
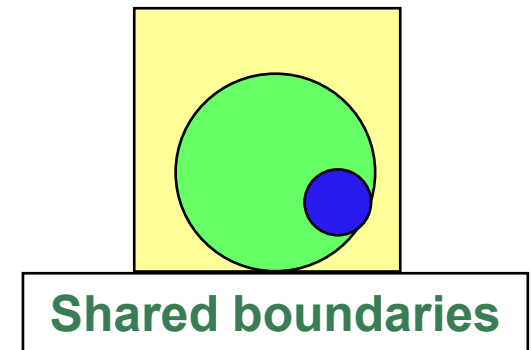
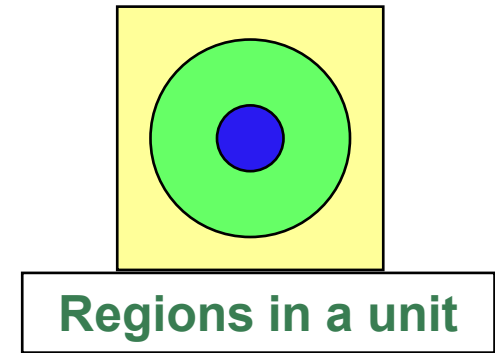
- Sub module 1: Basic KENO V.a geometry
- Sub module 2: Basic KENO V.a geometry exercises
- Sub module 3: Compound single unit KENO V.a geometry exercises
- Sub module 4: Holes in KENO V.a
- Sub module 5: Arrays in KENO V.a
- Sub module 6: Advanced KENO V.a geometry exercises
- Sub module 7: Additional advanced KENO V.a geometry exercises

Sub module 1: **Basic KENO V.a geometry**



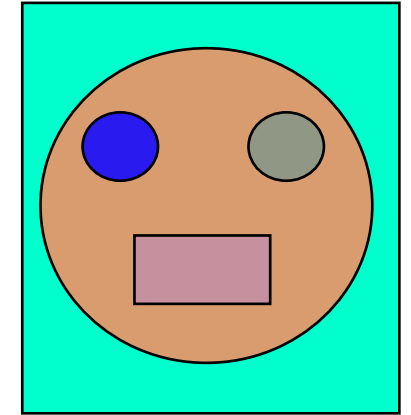
KENO V.a Geometry Rules

1. *Volumes are built in sections called UNITS.* Each UNIT is independent of all other units and has its own coordinate system.
2. *UNITS are built from the inside out using regions.* Regions are made using the KENO V.a geometry shapes. Each region must fully enclose all previously defined regions in the unit.
3. *Regions may share boundaries, but may not intersect.*
4. *All regions are oriented along a major axis (X, Y, or Z). Regions cannot be rotated.*

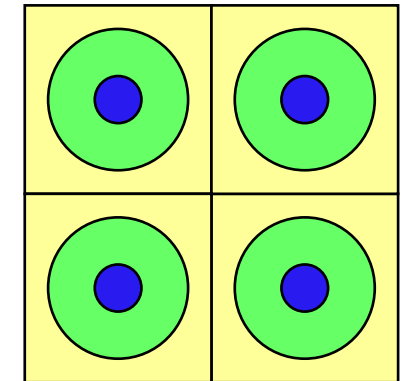


KENO V.a Geometry Rules (cont'd)

5. *A HOLE may be used to place a unit within a different unit.* The HOLE must be completely contained within a region of the different unit. As many HOLES as required may be placed in a unit as long as they do not intersect other HOLES or regions.
6. *An ARRAY is an ordered stack of units.* The touching faces of adjacent units in an array must be rectangular and must be the same size. Only one array may be placed directly in a unit. Additional arrays may be placed in units using HOLES.
7. *A GLOBAL unit or array, which defines the outermost boundary of the problem, must be specified for each problem.*

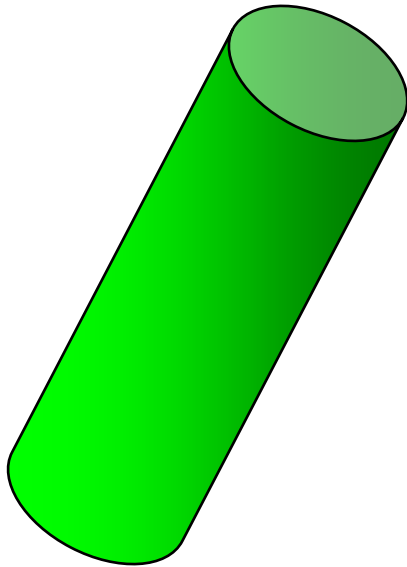


Unit Containing HOLES

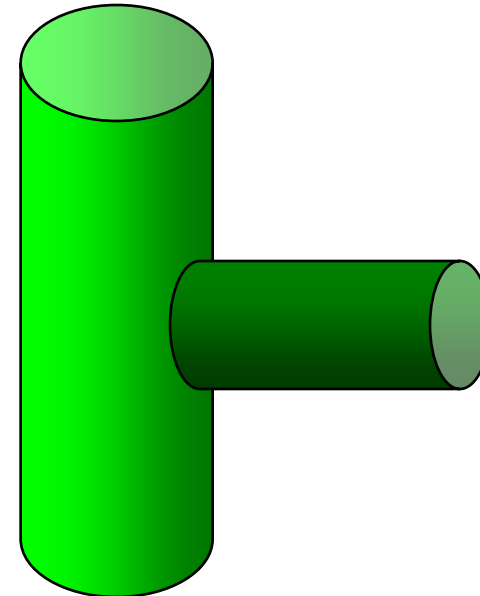


Array of units

Examples of Geometry Not Allowed in KENO V.a

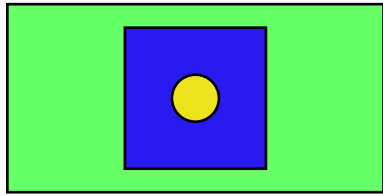


Rotated Region

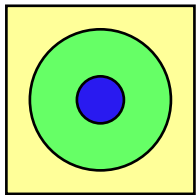


Intersecting Regions

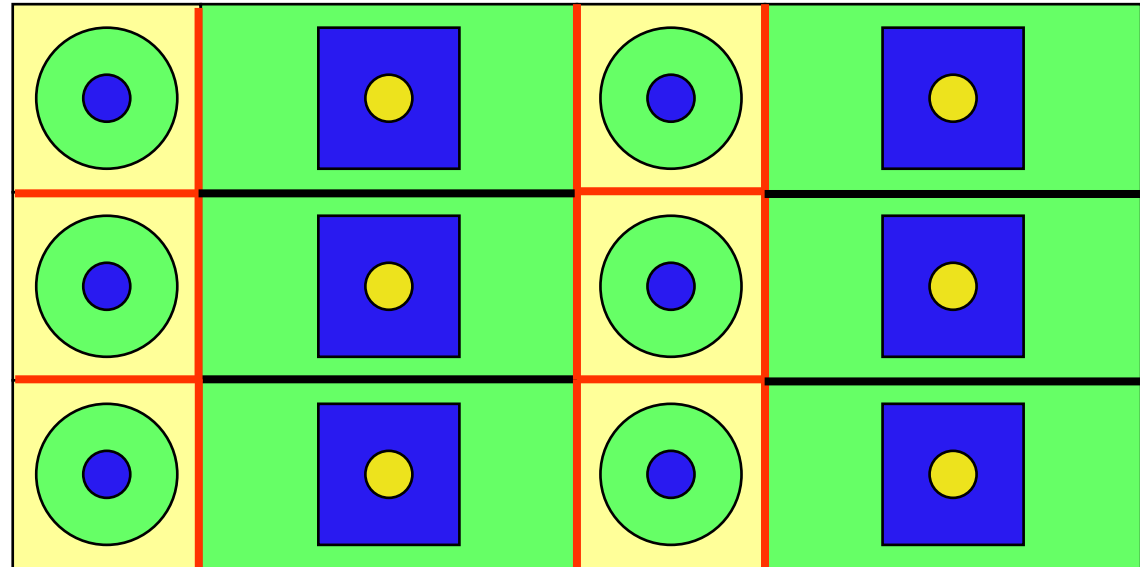
Example of an Array Composed of Units



UNIT 2



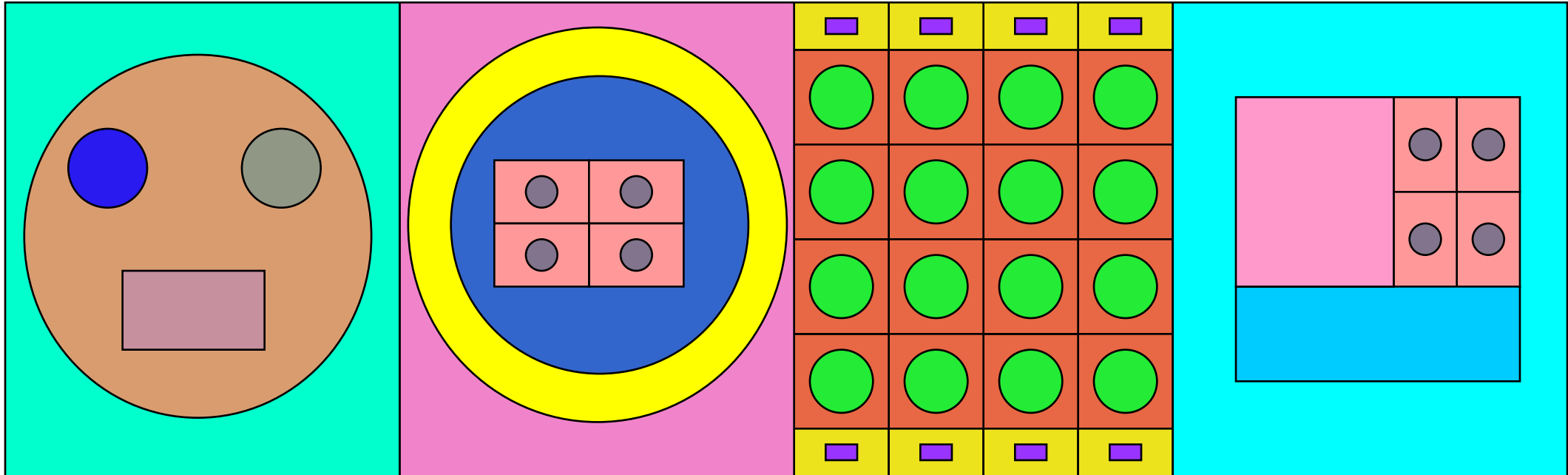
UNIT 1



STACK THE UNITS TO FORM AN ARRAY

Faces that touch must be the same size!

Array Composed of Units Containing Arrays and Holes



**Unit Containing
HOLES**

**Unit Containing
an ARRAY**

**Unit Containing
an ARRAY**

**Unit Containing
an ARRAY**

General Freeform Input

Count Field	Option Field	Operand Field	Comment
i	r, *, \$	j	Stores j in the next i positions and if in an array increments the array position by position i.
i	p	j	Stores j in the next i positions alternating the sign each time.
i	z		Stores zero in the next i positions.

Examples:

3R2.5 is equivalent to: 2.5 2.5 2.5

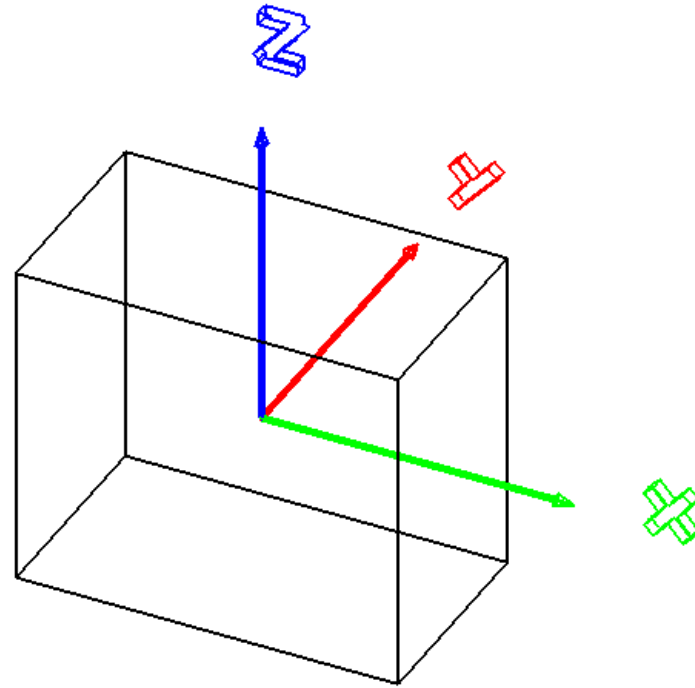
4P3 is equivalent to: 3 -3 3 -3

5Z is equivalent to: 5R0 or 0 0 0 0 0

See Table 8.1.19 of the SCALE Manual for more information

<https://scale-manual.ornl.gov/Keno.html#tab8-1-17>

KENO V.a Geometry Shapes: Cuboid



CUBOID **Mixture** **BiasID** **+x** **-x** **+y** **-y** **+z** **-z**

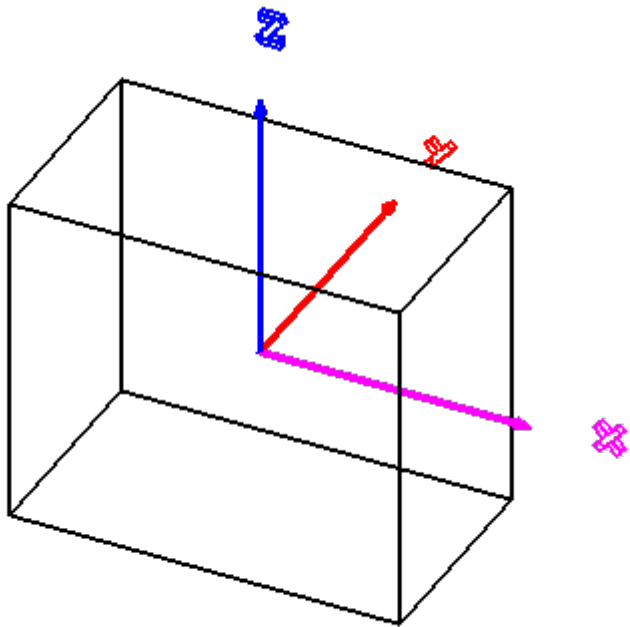
or for cubes:

CUBE **Mixture** **BiasID** **+x** **-x**

*Mixture:
BiasID:

ID number of the material to be placed in the region
For KENO, always 1

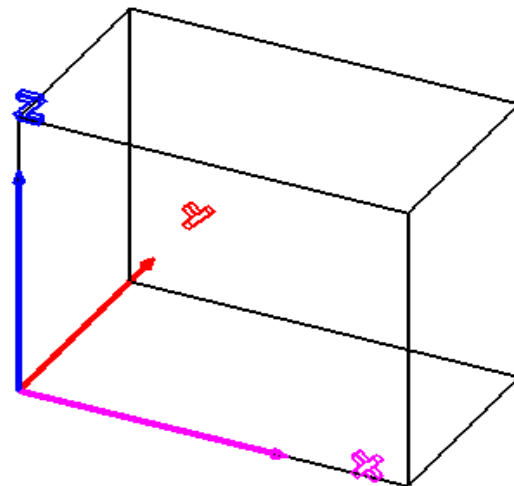
Cuboid Examples



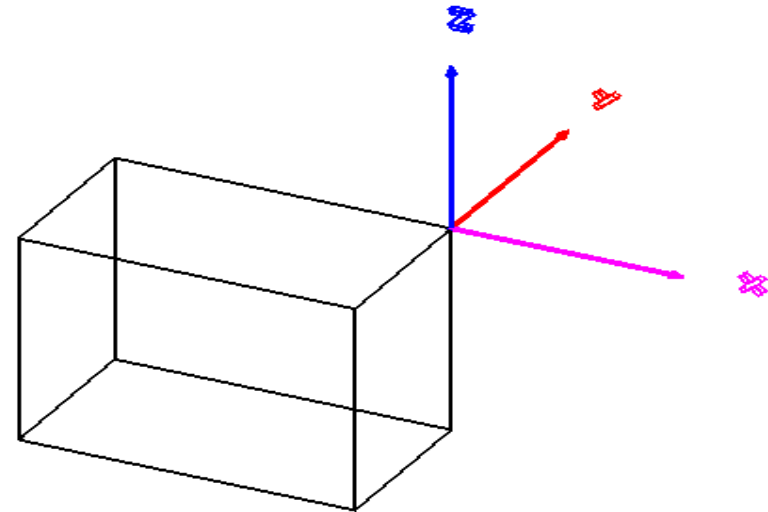
cuboid 2 1 7 -7 4 -4 6 -6

or

cuboid 2 1 2p7 2p4 2p6

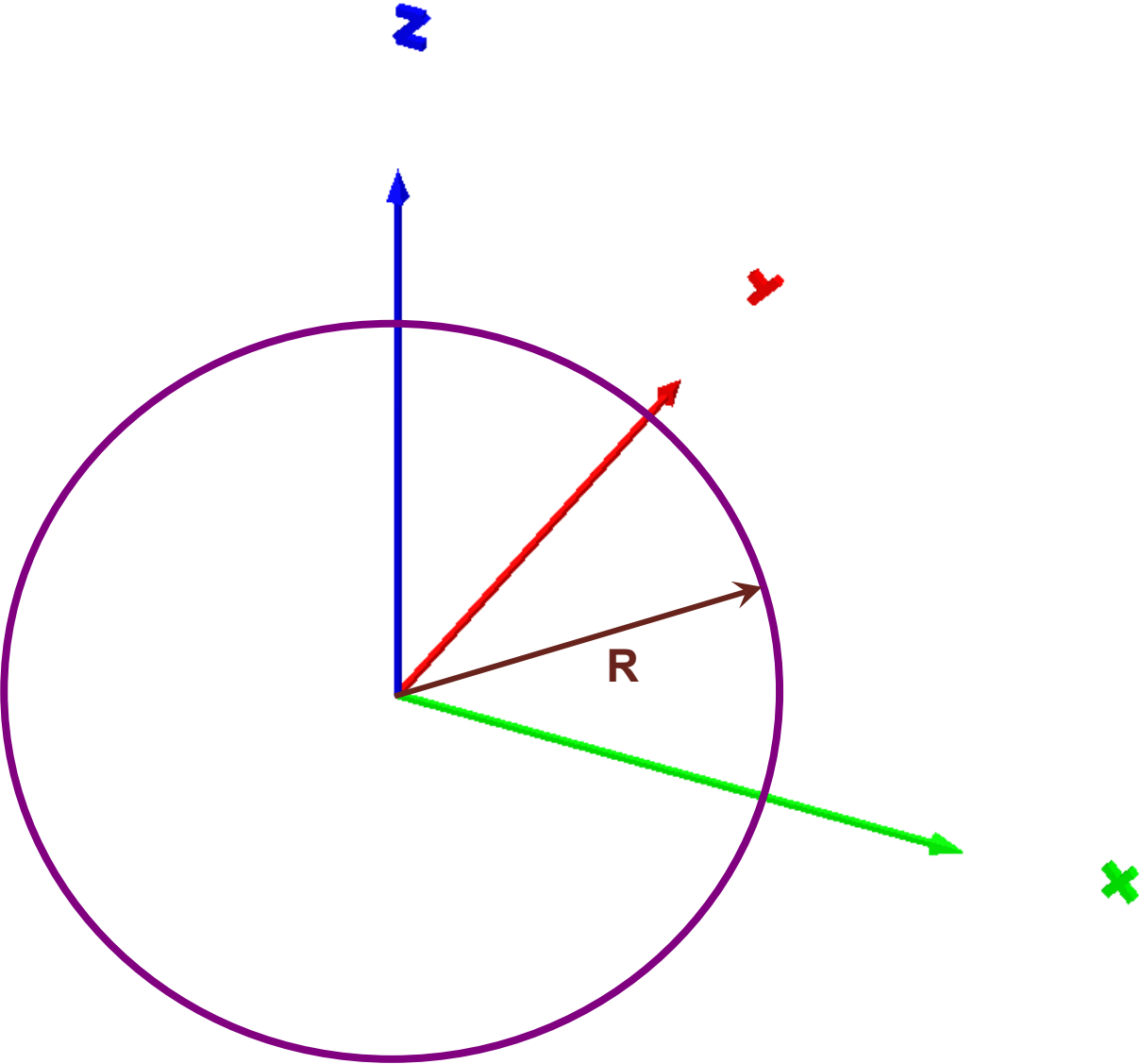


cuboid 2 1 14 0 8 0 12 0



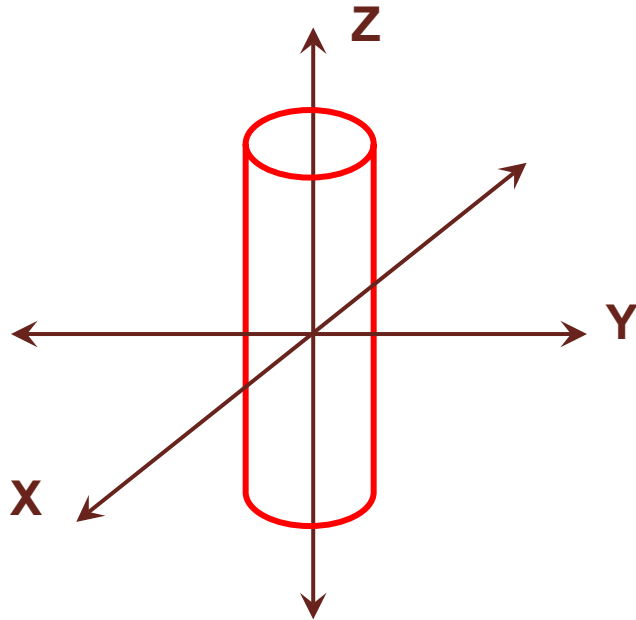
cuboid 2 1 0 -14 0 -8 0 -12

Sphere

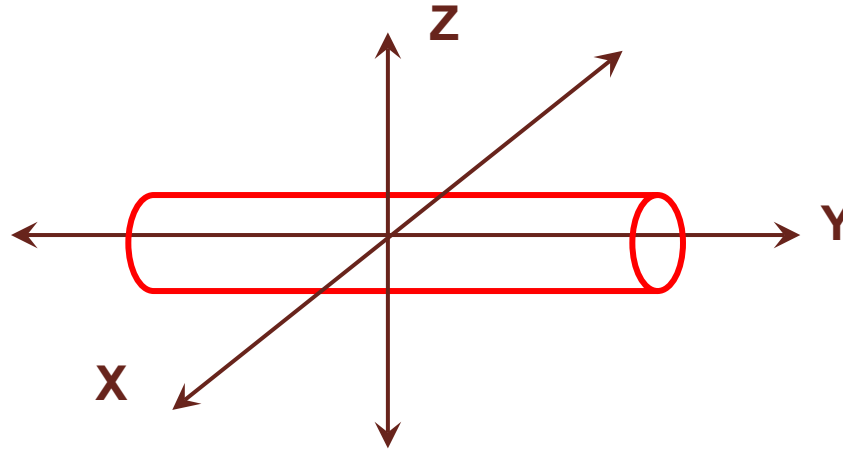


SPHERE **Mixture** **BiasID** **Radius** **ORIGIN** **x-orig** **y-orig** **z-orig**

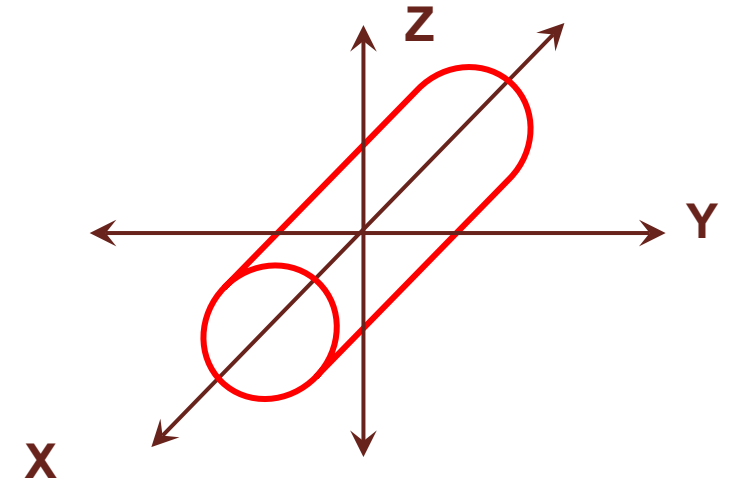
Cylinder



CYLINDER
ZCYLINDER



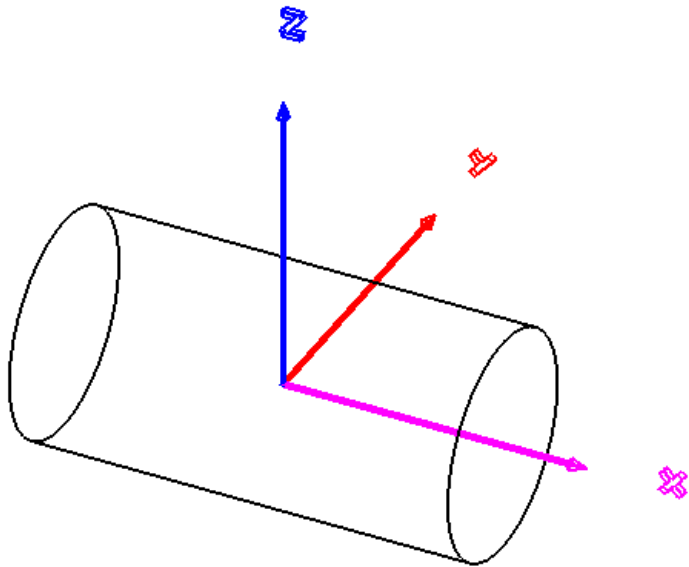
YCYLINDER



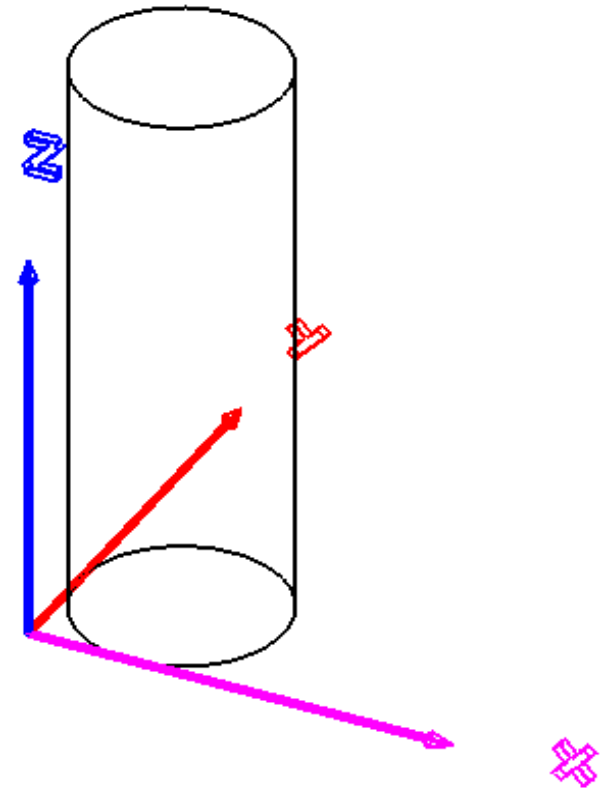
XCYLINDER

CYLINDER	Mixture	BiasID	Radius	+z	-z	ORIGIN	x-orig	y-orig
ZCYLINDER	Mixture	BiasID	Radius	+z	-z	ORIGIN	x-orig	y-orig
YCYLINDER	Mixture	BiasID	Radius	+y	-y	ORIGIN	x-orig	z-orig
XCYLINDER	Mixture	BiasID	Radius	+x	-x	ORIGIN	y-orig	z-orig

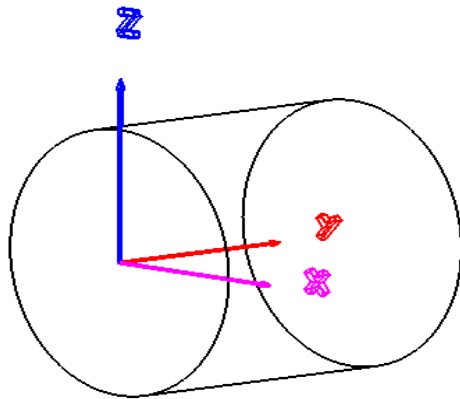
Cylinder Examples



XCYLINDER 1 1 7 14 -14



CYLINDER 3 1 5 30 0 ORIGIN 5 5

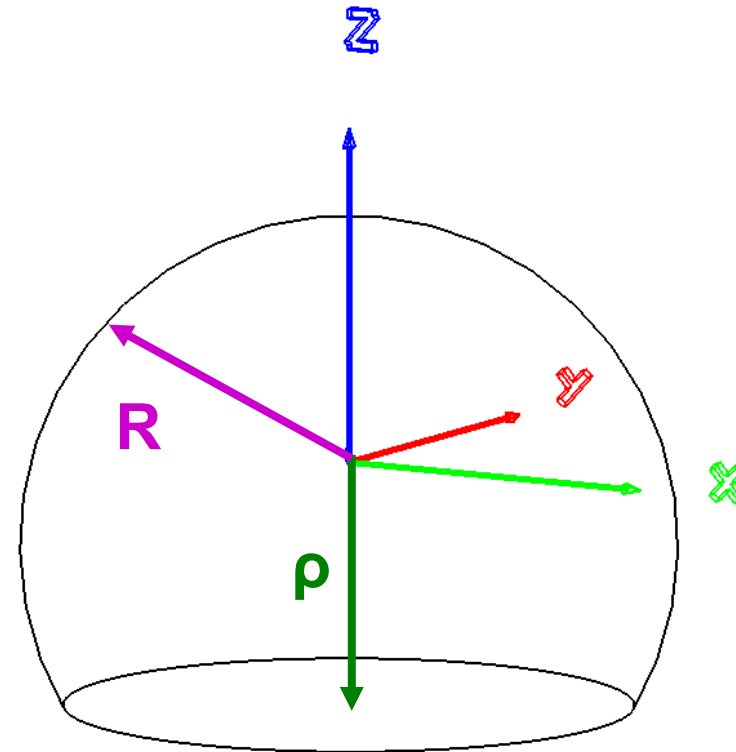


YCYLINDER 2 1 15 30 0

Hemisphere

If ρ is:

- Negative: keep *less* than half of the sphere
- Positive: keep *more* than half of the sphere



HEMISPHERE Mixture BiasID Radius ORIGIN x-orig y-orig z-orig
CHORD ρ

Other orientations:

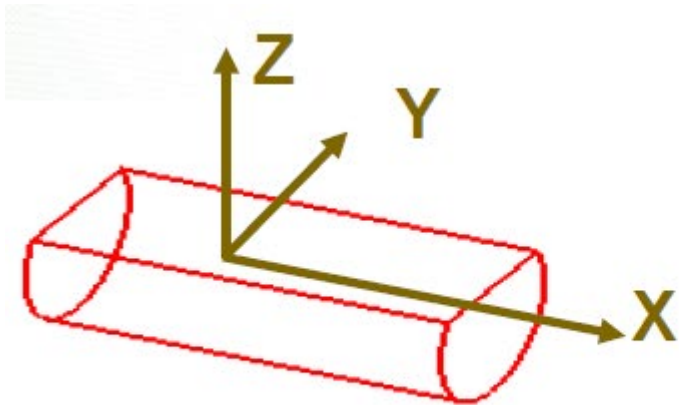
HEMISPHE+X
HEMISPHE-X

HEMISPHE+Y
HEMISPHE-Y

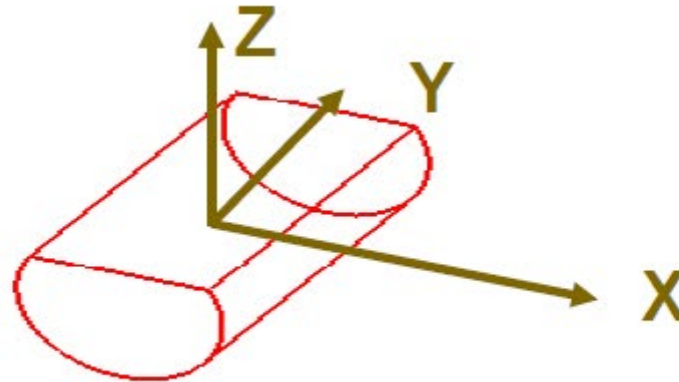
HEMISPHE+Z*
HEMISPHE-Z

**same as HEMISPHERE*

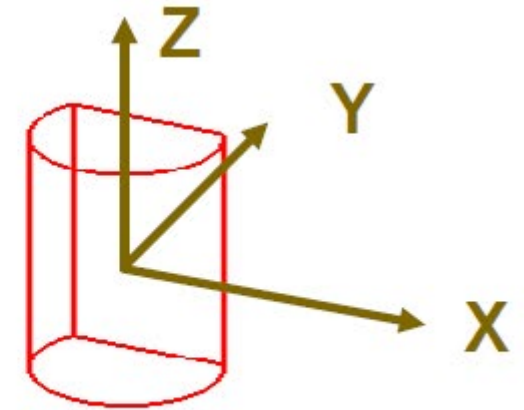
Hemicylinder



X-Hemicylinder



Y-Hemicylinder



Z-Hemicylinder

XHEMICYL-Z Mixture BiasID Radius +x -x CHORD ρ ORIGIN y-orig z-orig

XHEMICYL+Z

XHEMICYL-Y

XHEMICYL+Y

YHEMICYL-Z Mixture BiasID Radius +y -y CHORD ρ ORIGIN x-orig z-orig

YHEMICYL+Z

YHEMICYL-X

YHEMICYL+X

ZHEMICYL-Y Mixture BiasID Radius +z -z CHORD ρ ORIGIN x-orig y-orig

ZHEMICYL+Y

ZHEMICYL-X

ZHEMICYL+X

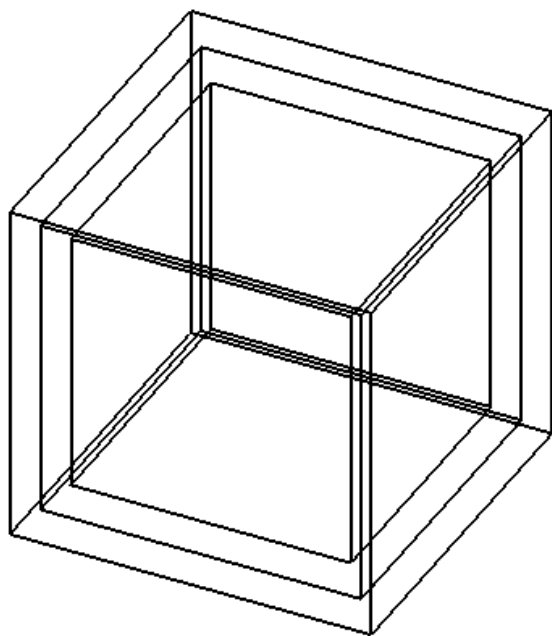
REPLICATE

- This geometry keyword reproduces or replicates the shape of the region before it
 - Creates a cylinder if it follows a cylinder, etc.
- It encloses the previous region with a layer of specified thickness for each dimension
- The layer can be repeated several times with one REPLICATE command
- Especially useful in adding "reflector" regions around an array

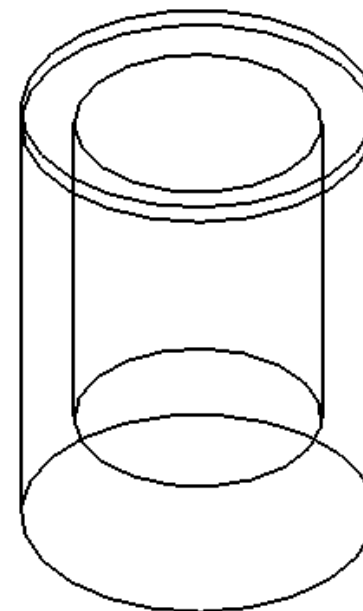
REPLICATE Examples

REPLICATE Mixture BiasID Thickness* Number of Repeats

**Thickness is input for each dimension of shape being replicated, even if the thickness is 0*



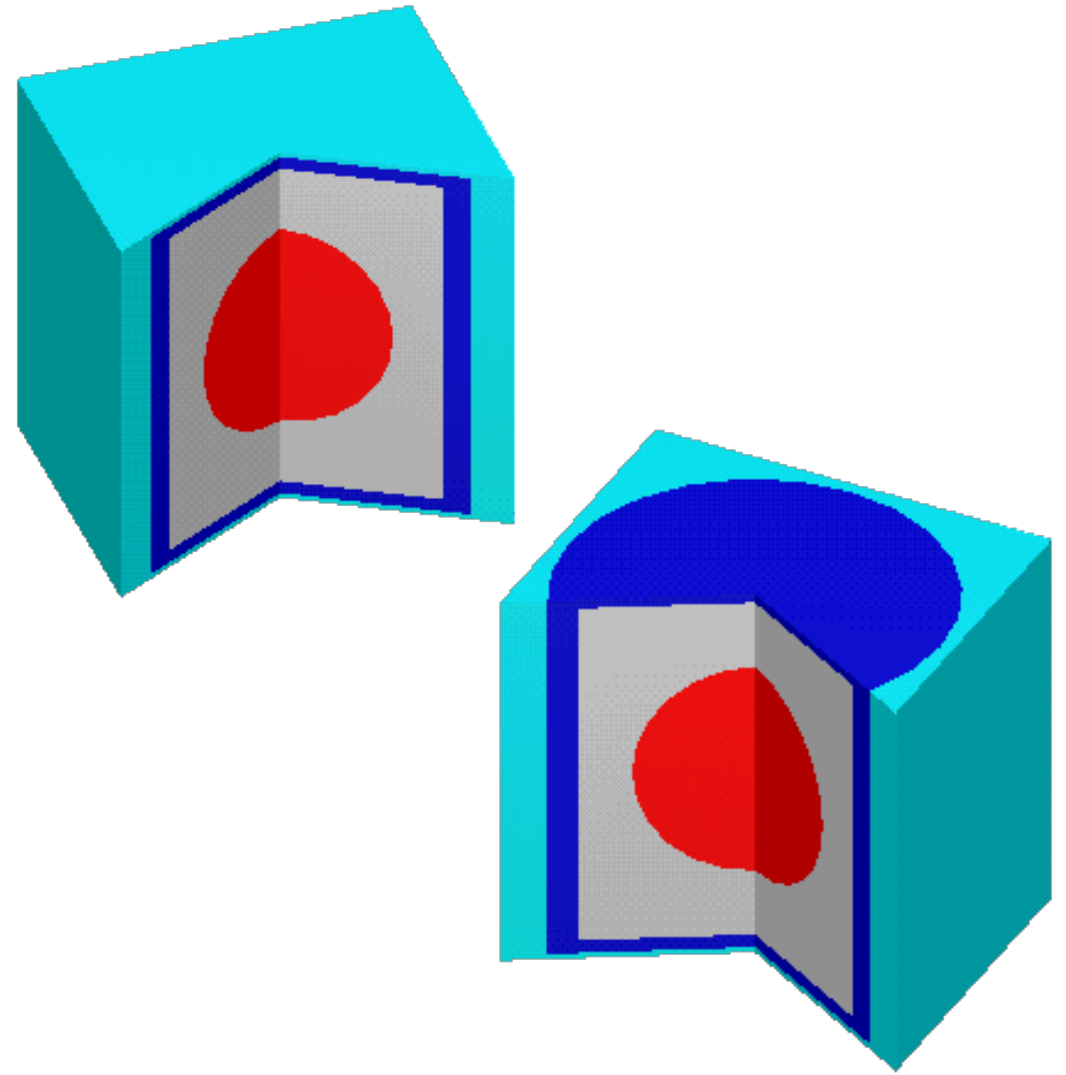
```
cuboid      1 1 6.87 -6.87 6.87 -6.87 6.505 -6.505
replicate 2 1 6R1.0 2
```



```
cylinder    1 1 7 20 0
replicate 2 1 3 0 6.5 1
replicate 3 1 0 1 0 1
```

Building a Unit in KENO V.a

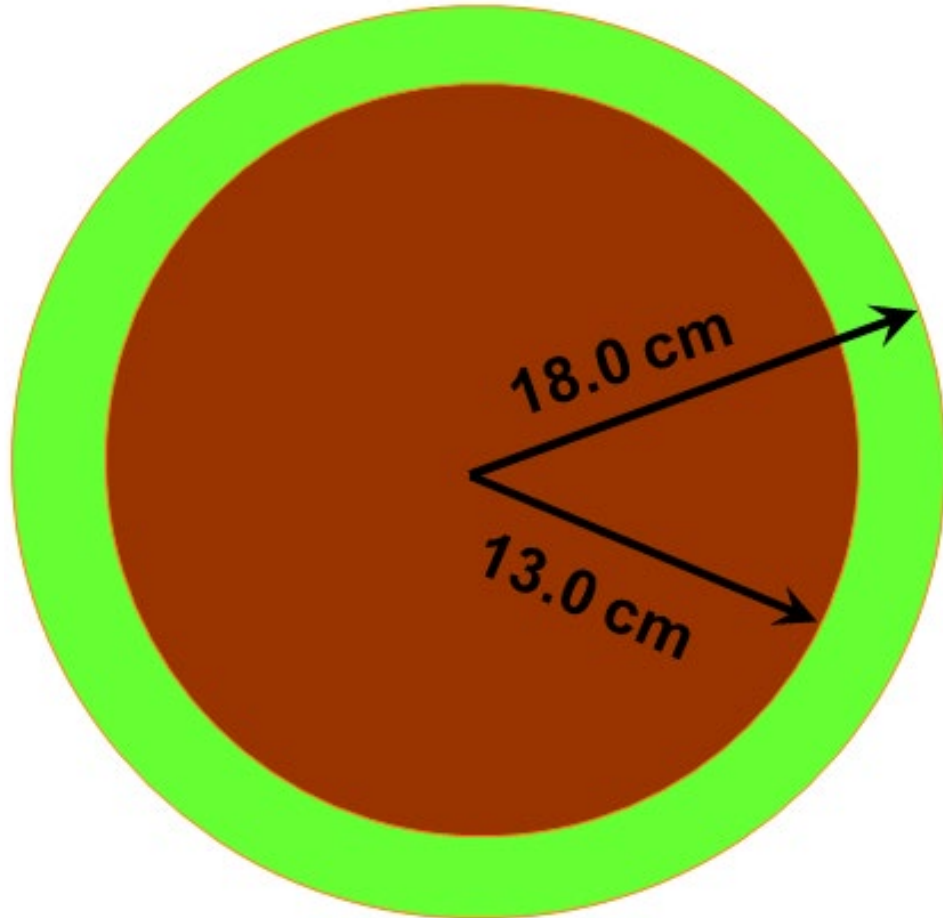
```
unit 1  
com=!simple unit example!  
sphere 5 1 4.0  
cylinder 1 1 5.748 2P6.505  
cylinder 2 1 6.758 2P7.0  
cuboid 3 1 6p7.2
```



Exercise: Reflected Uranyl Nitrate Solution Sphere



Reflected Uranyl Nitrate Solution Sphere



$\text{UO}_2(\text{NO}_3)_2$ Solution Sphere

13.0 cm radius Solution

18.0 cm radius Plexiglas(s) Reflector

Specific Gravity: 1.555

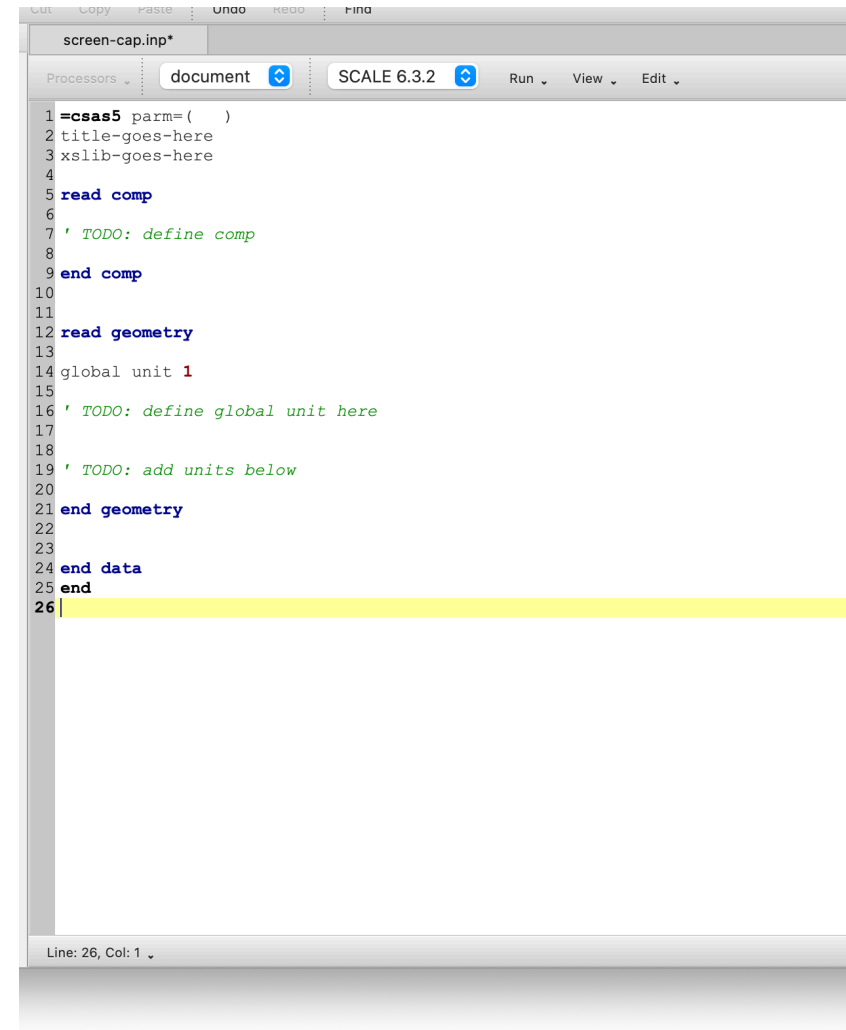
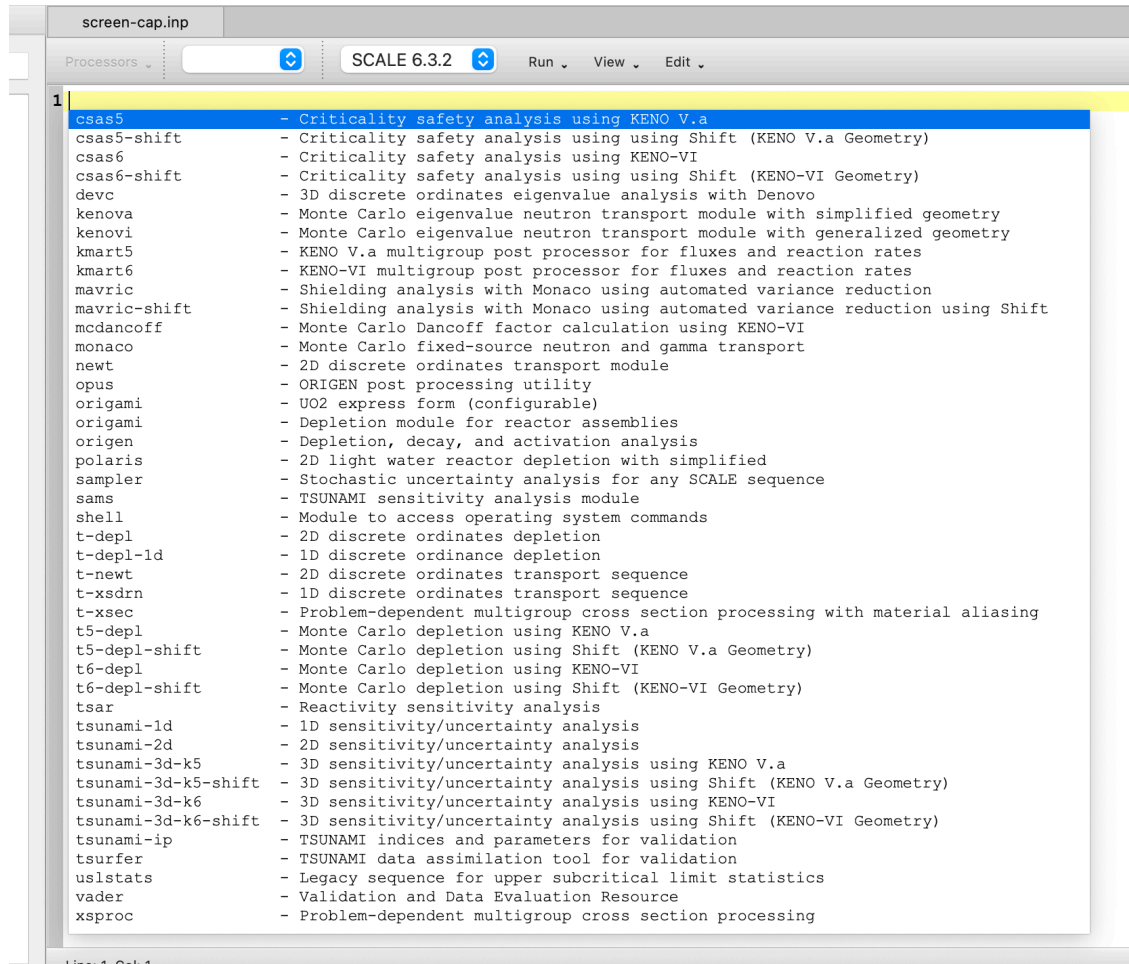
Uranium Density: 415 gm/liter

Excess Acid: 0.009783 Molar

Enrichment:

U-234	1.0 wt%
U-235	92.6 wt%
U-236	0.5 wt%
U-238	5.9 wt%

Autocomplete CSAS5 Skeleton



Add title and cross section library

```
=csas5 parm=( )  
Class Exercise: Reflected Solution Sphere  
ce_v8.0_endf
```

Create Solution Composition

- Autocomplete solution

```
solution mix=1 rho[uo2f2]=1.0 92235 95.5  
92238 4.5 density=1.0 temp=300 volfrac=1.0  
end solution
```

- Update provided data

- Fissile component
- Uranium density
- Enrichment
- Solution density

```
solution mix=1 rho[uo2(no3)2]=415  
92234 1.0 92235 92.6 92236 0.5 92238 5.9  
density=1.555 temp=300 volfrac=1.0  
end solution
```

- Add excess acid

- molar[hno3]=

```
solution mix=1 rho[uo2(no3)2]=415  
92234 1.0 92235 92.6 92236 0.5 92238 5.9  
density=1.555 temp=300 volfrac=1.0  
molar[hno3]=0.009783 end solution
```

Create Plexiglas(s) Composition

scale stdcomp - basic (configurable) ? X

Composition

Mixture

☐ Theoretical Density

☒ Volume Fraction

☐ Temperature

☐ Isotopic Weight Percents

+/-	Isotope	Weight Percent
-----	---------	----------------

plexiglas 2 1.0 end

Results Log Template

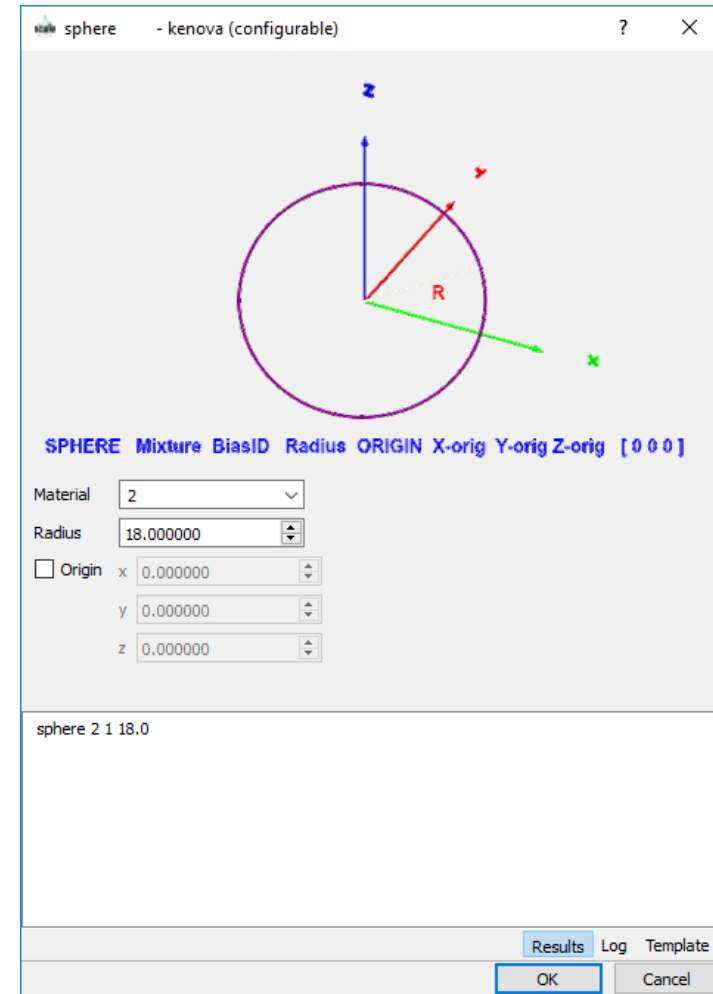
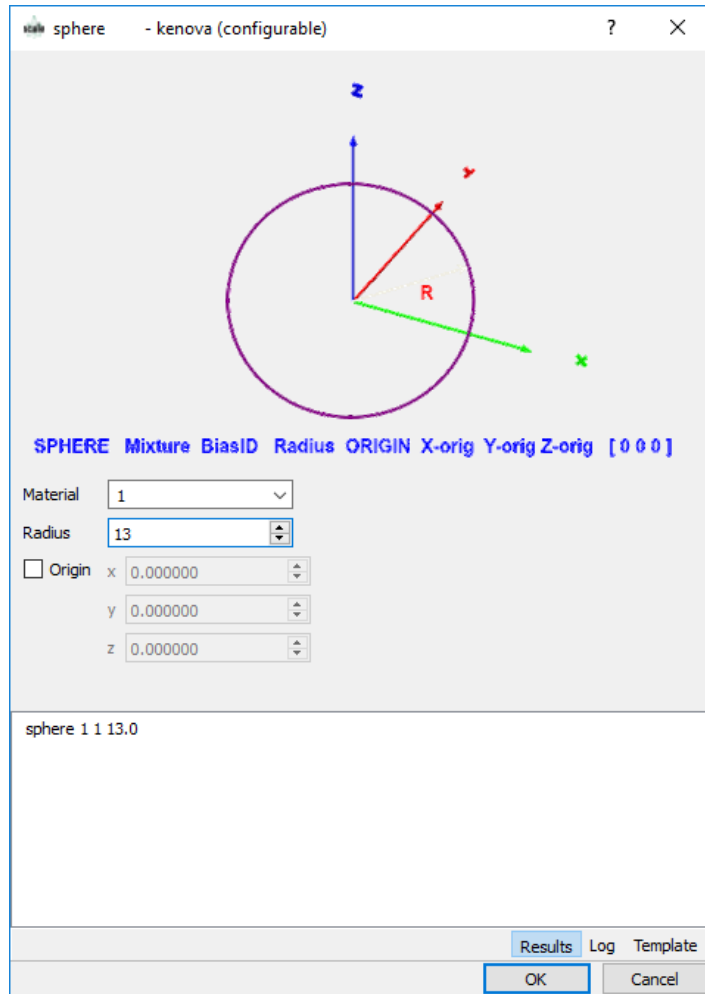
OK Cancel

Complete comp block

```
read comp
solution mix=1 rho[uo2(no3)2]=415
          92234 1.0 92235 92.6 92236 0.5 92238 5.9
          density=1.555 temp=300 volfrac=1.0
          molar[hno3]=0.009783
          end solution
plexiglas 2 1.0 end
end comp
```

White space doesn't matter, so organize your input in a way that you like!

Create geometry

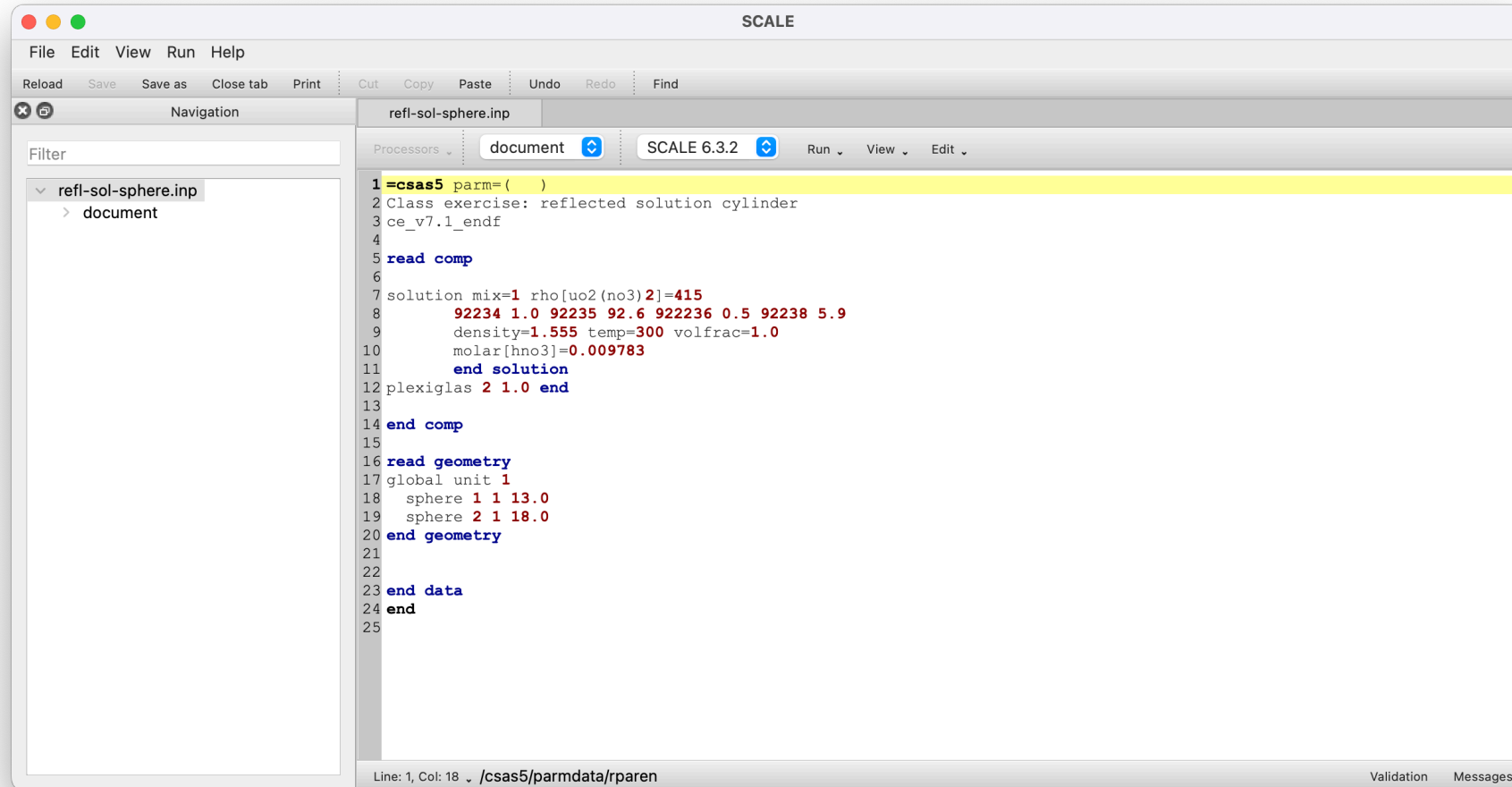


1 configurable for each shape

Solution sphere – global unit

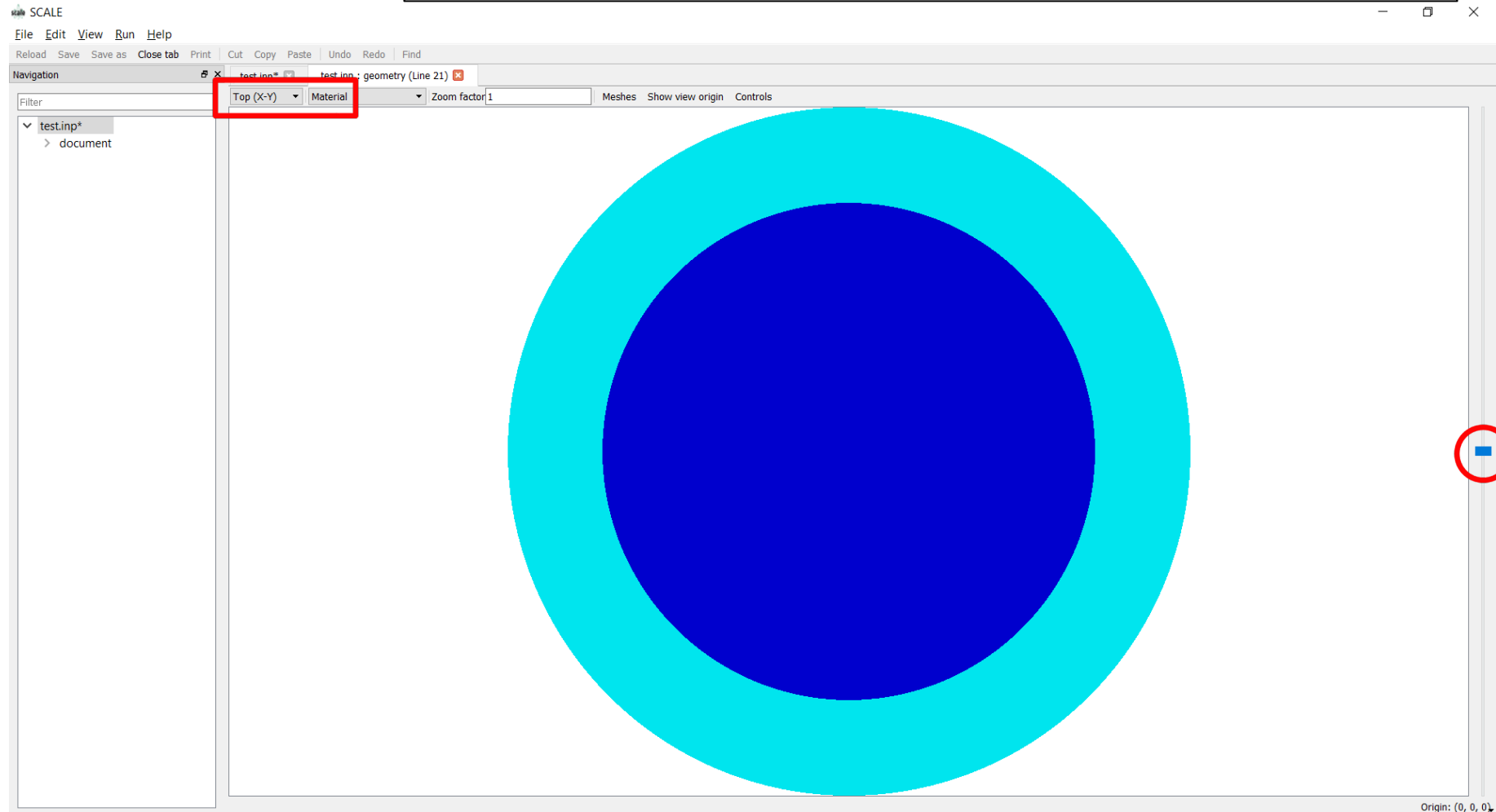
```
read geometry
global unit 1
  sphere 1 1 13.0
  sphere 2 1 18.0
end geometry
```

Save and visualize



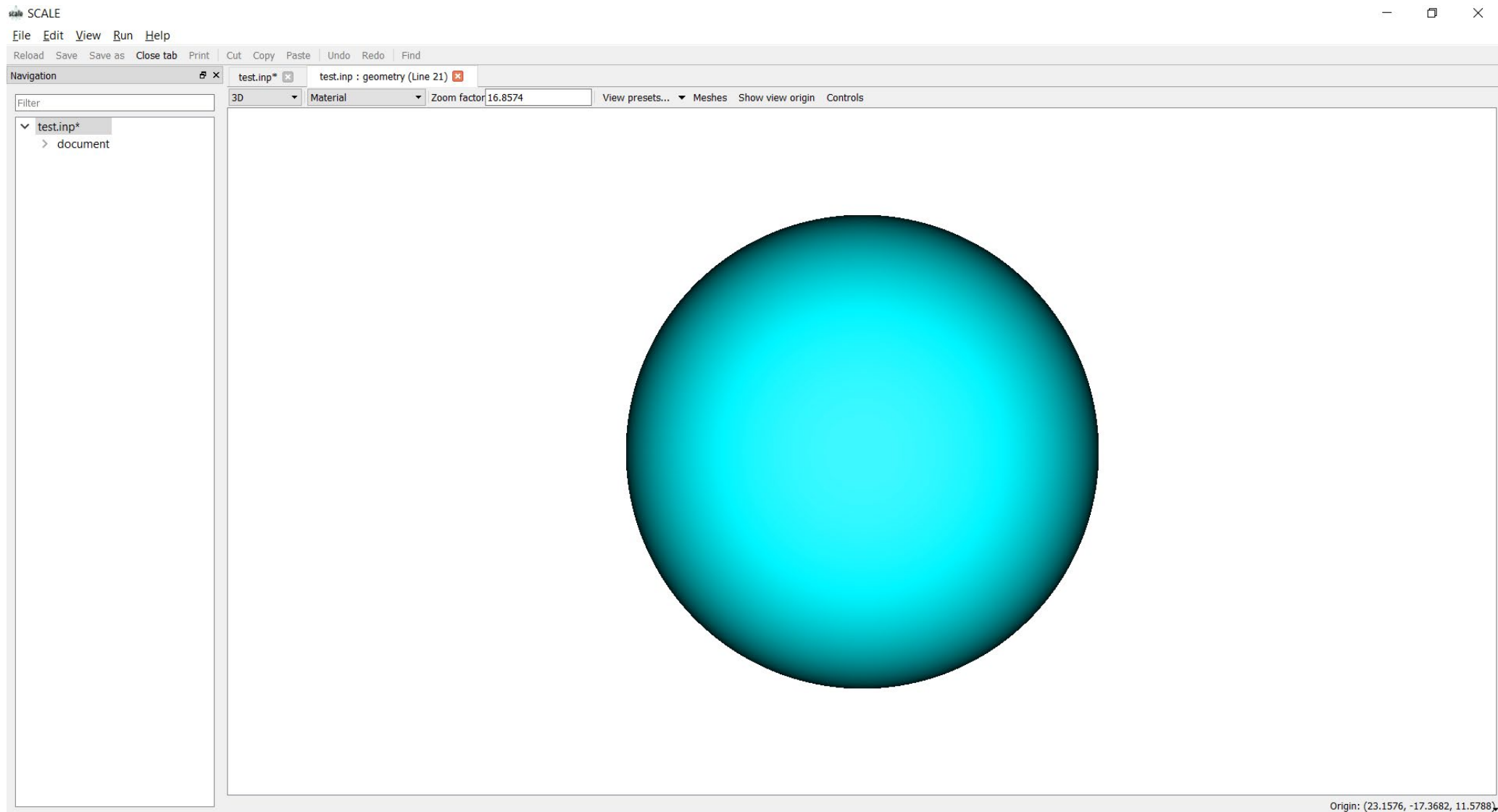
Visualize – 2D

Red box: the dropdown menu is used to select different views – Top (X-Y), Front (X-Z), Side (Y-Z), or 3D



Red circle: moves the view along the third axis

Visualize – 3D



Run in Fulcrum!

The screenshot shows the SCALE 6.3.2 interface with the file `refl-sol-sphere.inp` open. The input file contains the following code:

```
1 =csas5 parm=( )
2 Class exercise: reflected solution cylinder
3 ce_v7.1_endf
4
5 read comp
6
7 solution mix=1 rho[uo2(no3)2]=415
8 92234 1.0 92235 92.6 922 $ 36 0.5 92238 5.9
9 density=1.555 temp=300 volfrac=1.0
10 molar[hno3]=0.009783
11 end solution
12 plexiglas 2 1.0 end
13
14 end comp
15
16 read geometry
17 global unit 1
18 sphere 1 1 13.0
19 sphere 2 1 18.0
20 end geometry
```

The output window shows the results of the simulation, including the best estimate system k-eff value circled in red:

```
577
578 203 1.02649E+00 1.02702E+00 2.05249E-03 5.22818E+00 2.45833E-01
579
580
581 class exercise: reflected solution cylinder
582 final results table *****
583 best estimate system k-eff 1.0270 ± 0.0020
584
585 Energy of average fission (eV) 2.55077E-01 ± or - 1.92252E-03
586 k-effective satisfies the chi**2 test for normality at the 95 % level
587
588 Scale job /Users/6tg/Desktop/refl-sol-sphere.inp is finished.
589 Output is stored in /Users/6tg/Desktop/refl-sol-sphere.out
590
591 Process finished with 0 return code; ran in 16 secs, finished at Tue Oct 1 14:56:47 2024
```

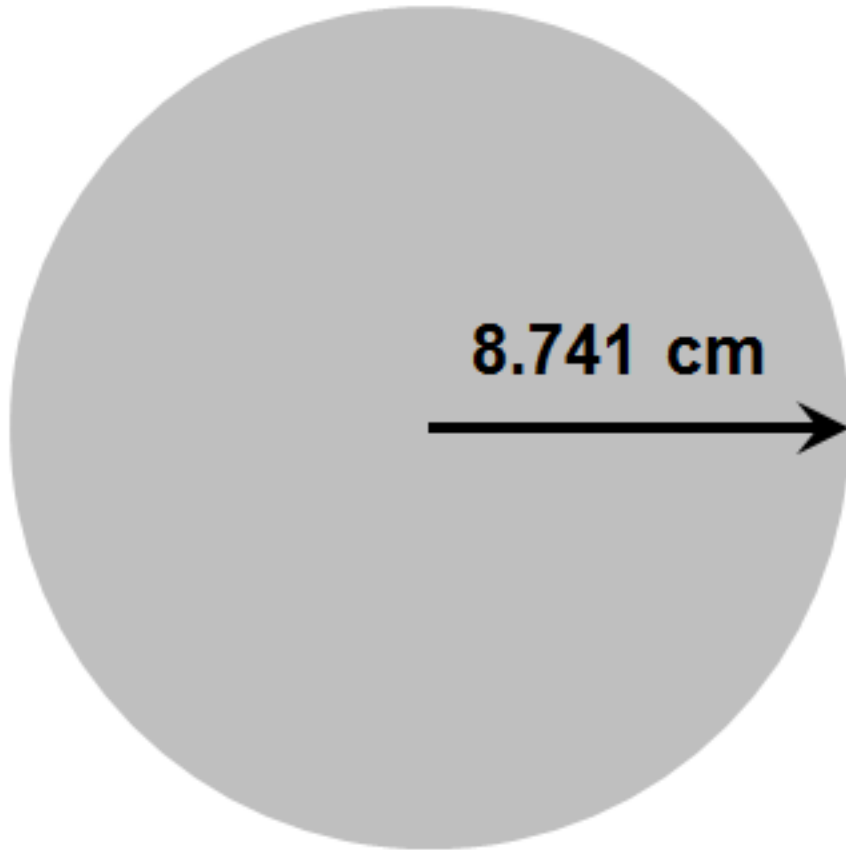
Best estimate k_{eff} :
 1.0270 ± 0.0020

Sub module 2: **Basic KENO V.a geometry exercises**

- Lady Godiva
- Green Block



Lady Godiva

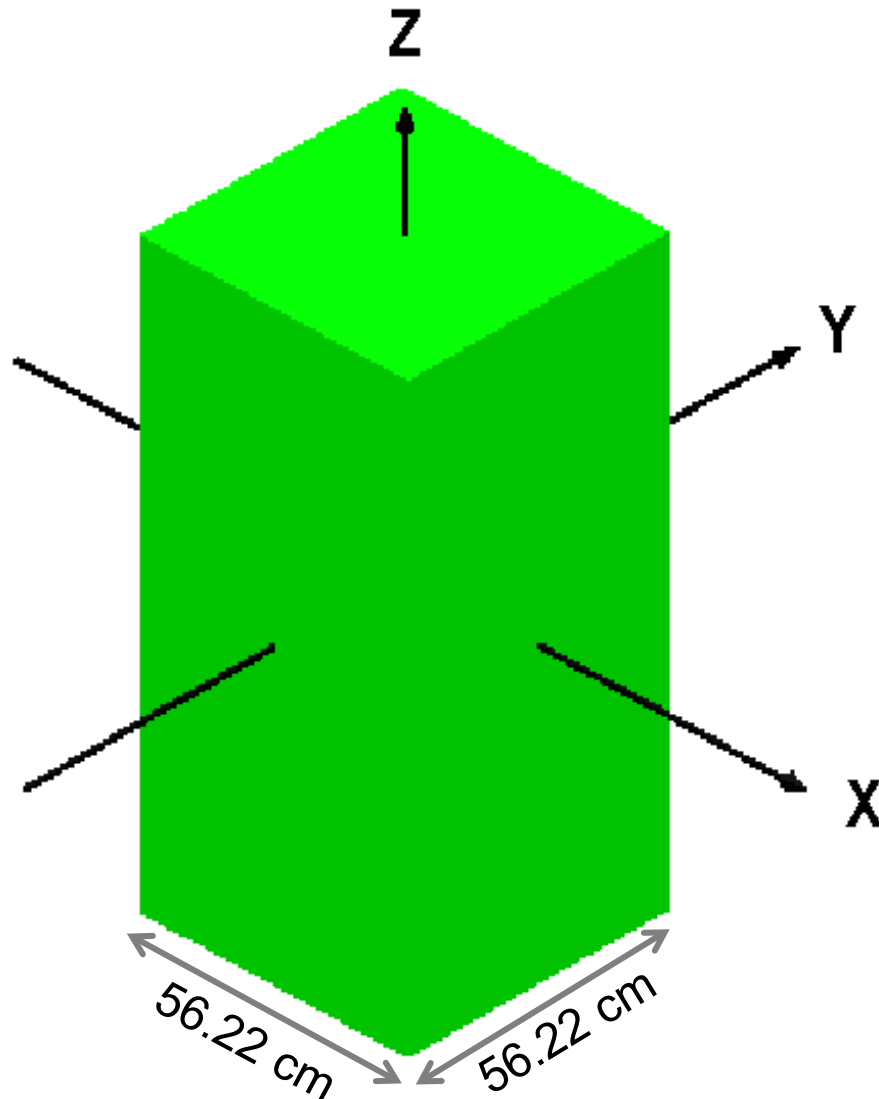


Bare Uranium Metal Sphere

Density 18.74 gm/cc

Enrichment:	U-235	93.7112 wt%
	U-238	5.2686 wt%
	U-234	1.0202 wt%

Green Block



Material

Temperature = 300 K

UF₄ – 51.13 vol%

U-235 2.0 wt%

U-238 98.0 wt%

Paraffin – 48.87 vol%

Hint: remember if DEN is not the same for both components of a mixture, the density multiplier works as a *volume fraction*.

Dimensions (Whole face)

X : 56.22 cm

Y : 56.22 cm

Z : 122.47 cm

Calculated k-eff values (CE ENDF/B-VII.1)

	KENO V.a	Shift
Godiva	1.0022 +/- 0.0017	0.998142 +/- 0.001746
Green block	1.0068 +/- 0.0014	1.008642 +/- 0.001800

Your results may differ based on the options and computer used

Godiva

=csas5

godiva

ce_v7.1_endf

read comp

uranium 1 den=18.742 1 300 92235 93.7112 92238 5.2686 92234 1.0202 end

end comp

read geometry

global unit 1

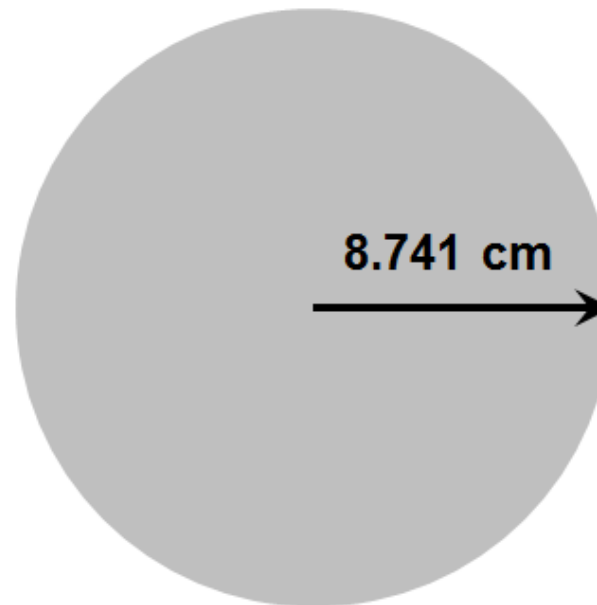
sphere 1 1 8.741

end geometry

end data

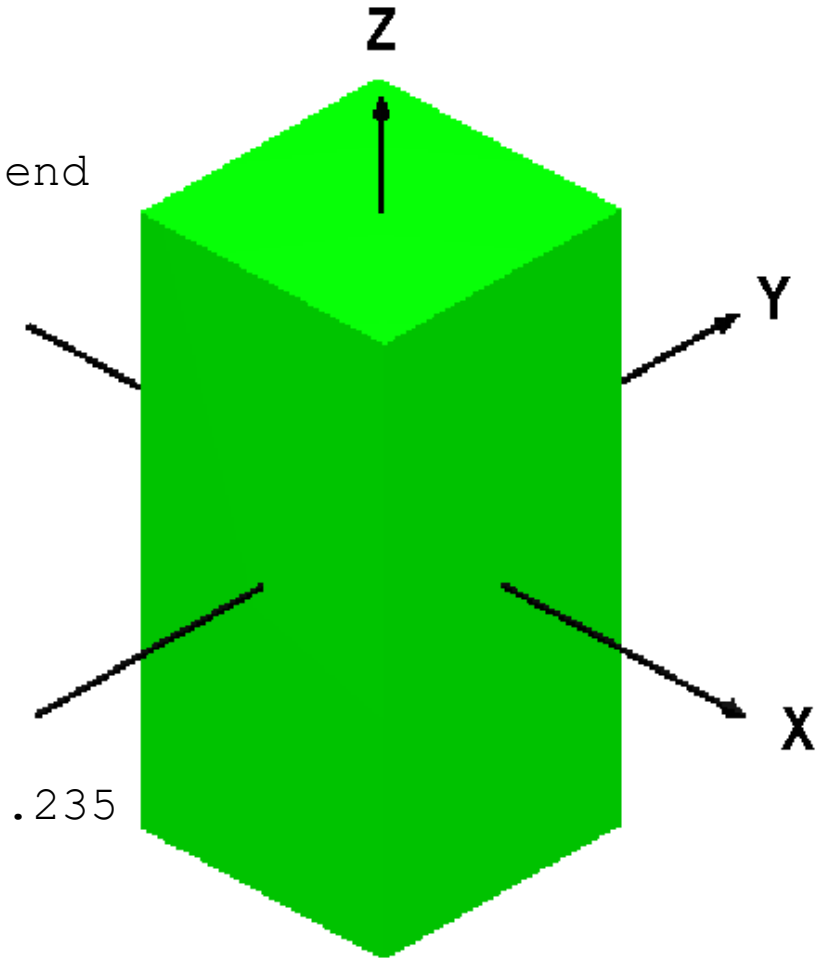
end

*Default parameters utilized



Green Block

```
=csas5
raffety and mihalczu u(2)f4-2 unreflected green block
ce_v7.1_endf
read comp
  uf4          1 den=3.8655 0.8862 300 92235 2 92238 98 end
  paraffin     1 den=3.8655 0.1138 300 end
'
  uf4          2 0.5113 300 92235 2 92238 98 end
  paraffin     2 0.4887 300 end
end comp
read parameter
  npg=2000  fdn=yes
end parameter
read geometry
global unit 1
  cuboid 1 1 28.11 -28.11 28.11 -28.11 61.235 -61.235
end geometry
end data
end
```



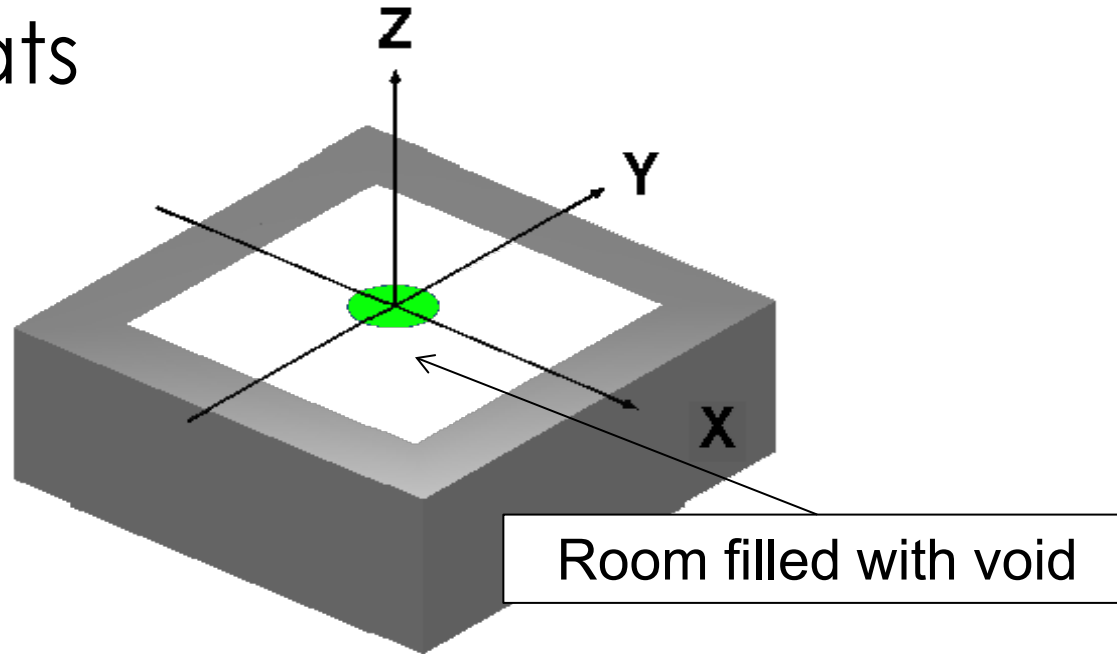
Parameter block uses 2,000 particles per generation and asks for the fission density for each geometry region

Sub module 3: **Compound single unit KENO V.a geometry exercises**

- Rocky Flats
- Cylindrical Solution Tank
- Cylinder in Annulus



Rocky Flats



Al Tank

14.005 cm inner radius, solution height 28.6 cm

0.32 cm wall and bottom thickness

30.0 cm total length

Filled with $\text{UO}_2(\text{NO}_3)_2$ solution

Distance **from the tank inside bottom center**

to the 25.7 cm thick Concrete walls, floor, and ceiling

+ X : 64.6 cm -X : -57.4 cm

+ Y : 57.4 cm -Y : -64.8 cm

+ Z : 80.0 cm -Z : -41.1 cm

Materials : Room Temperature

$\text{UO}_2(\text{NO}_3)_2$ Solution default density

gm U/l : 334.77

Acid Molarity : 0.521

U-234 : 1.022 wt%

U-235 : 93.172 wt%

U-236 : 0.434 wt%

U-238 : 5.372 wt%

Al density = 2.702 gm/cc

Concrete density = 2.32 gm/cc

oxygen: 48.49 wt%

calcium: 23.31 wt%

silicon: 15.5 wt%

carbon: 5.52 wt%

aluminum: 2.17 wt%

magnesium: 1.25 wt%

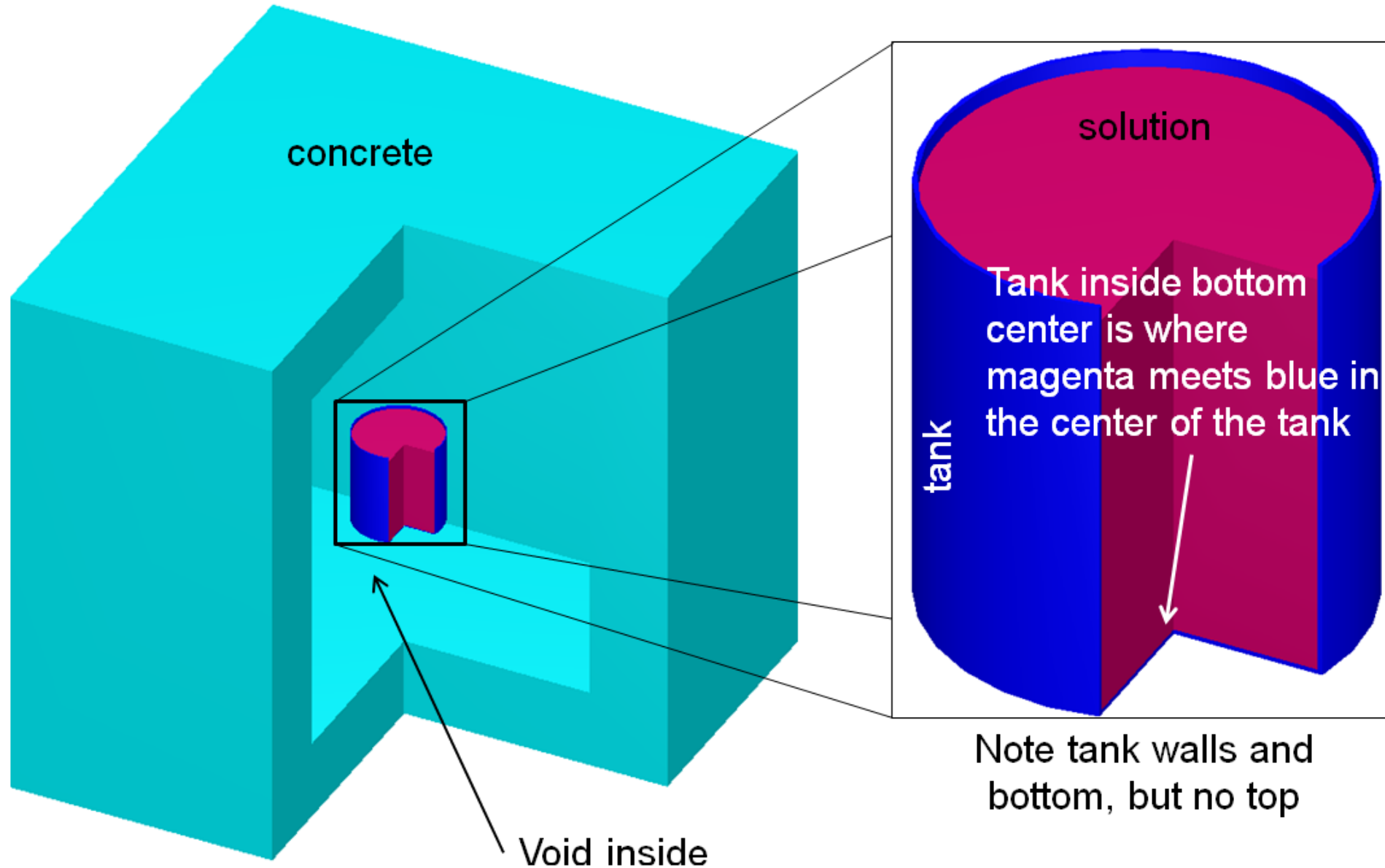
potassium: 1.37 wt%

iron: 1.01 wt%

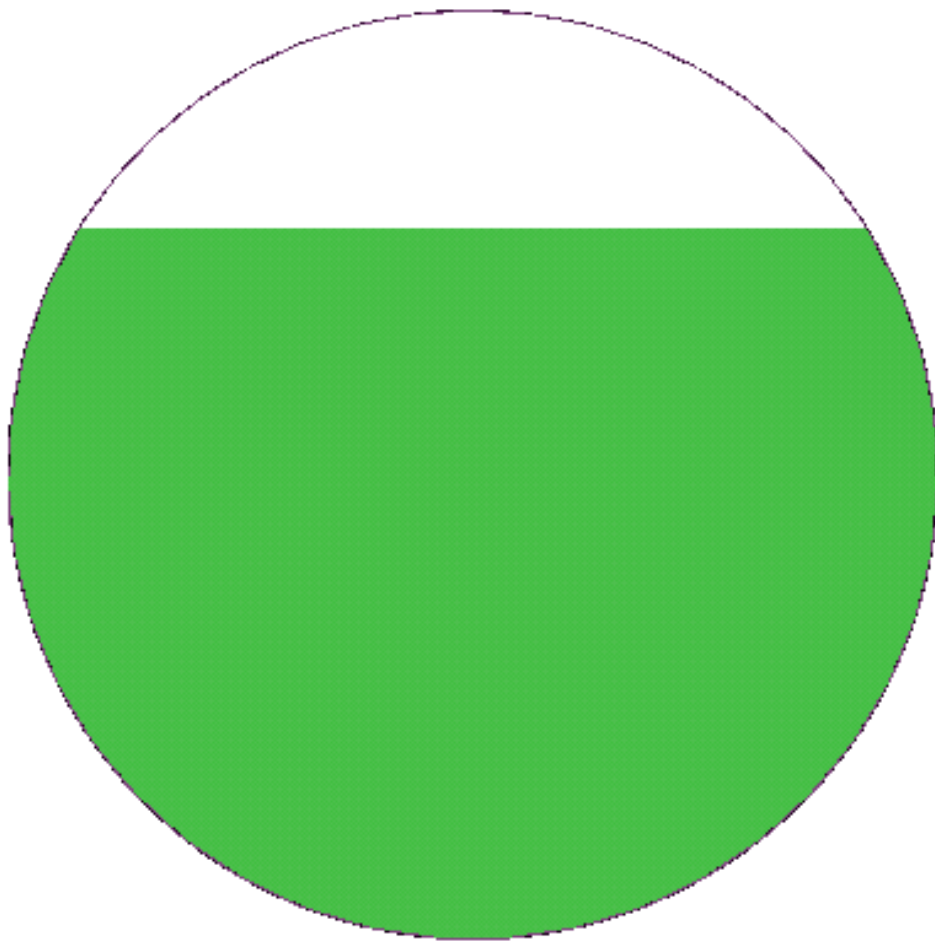
hydrogen: 0.75 wt%

sodium: 0.63 wt%

Rocky Flats



Cylindrical Solution Tank



Materials : Room Temperature

uo2f2 Solution

density = 1.56

gm U/l : 494.0

No excess acid

U-234 : 0.02 wt%

U-235 : 4.89 wt%

U-238 : 95.09 wt%

Al: default density

Horizontal Cylindrical Tank

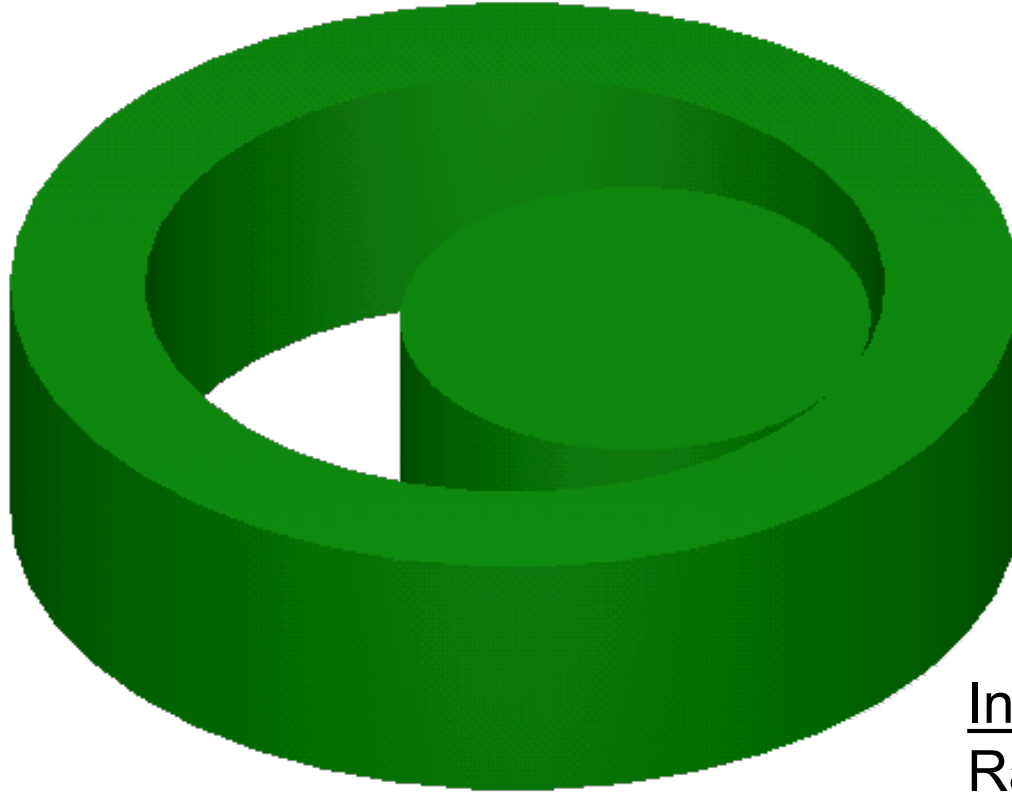
Inner radius: 34.6 cm

Length: 69.2 cm

Solution height: 53.1 cm

Wall Thickness: 0.159 cm

Cylinder in Annulus



Outer Ring

Inner radius: 13.97 cm
Outer radius: 19.05 cm
Height: 10.109 cm

Material

Uranium Metal
Density: 18.69 gm/cc
U-234: 1.0 wt%
U-235: 93.2 w%
U-236: 0.2 wt%
U-238: 5.6 wt%

Inner Cylinder

Radius: 8.89 cm
Height: 10.109 cm
Offset to just touch inner wall of outer ring

Calculated k-eff values (CE ENDF/B-VII.1)

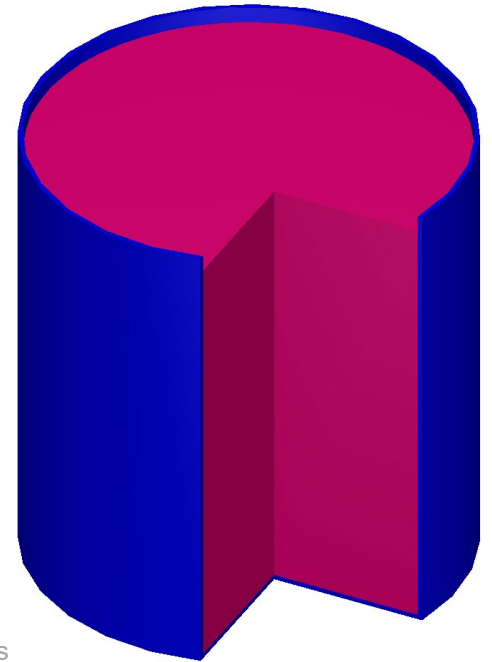
	KENO V.a	Shift
Rocky Flats	1.0033 +/- 0.0022	0.997278 +/- 0.004644
Cylindrical solution tank	0.9969 +/- 0.0018	1.001405 +/- 0.002674
Cylinder in annulus	0.9967 +/- 0.0024	0.996477 +/- 0.001844

Your results may differ based on the options and computer used

Rocky Flats

```
=csas5
rocky flats uo2(no3)2 soln 334.77 g u/l 28.01 cm dlam refl 2 conc refl
ce_v7.1_endf
read comp
  solution mix=1 rho[uo2(no3)2]=334.77 92234 1.022 92235 93.172
92236 0.434 92238 5.372 molar[hno3]=0.521 density=? temperature=293
  end solution
  al 2 1 293 end
  wtptconcrete 3 2.32 10 26000 1.01 1001 0.75 6000 5.52 8016 48.49 12000 1.25
  13027 2.17 14000 15.5 19000 1.37 11023 0.63 20000 23.31 1 293 end
end comp
read geometry
global unit 1
  zcylinder 0 1 14.005 29.68 28.6
  zcylinder 1 1 14.005 29.68 0
  zcylinder 2 1 14.325 29.68 -0.32
  cuboid 0 1 64.6 -57.4 57.4 -64.8 80.0 -41.1
  replicate 3 1 25.7 25.7 25.7 25.7 25.7 25.7 1
  \ equivalent to:
  \ replicate 3 1 6r25.7 1
end geometry
end data
end
```

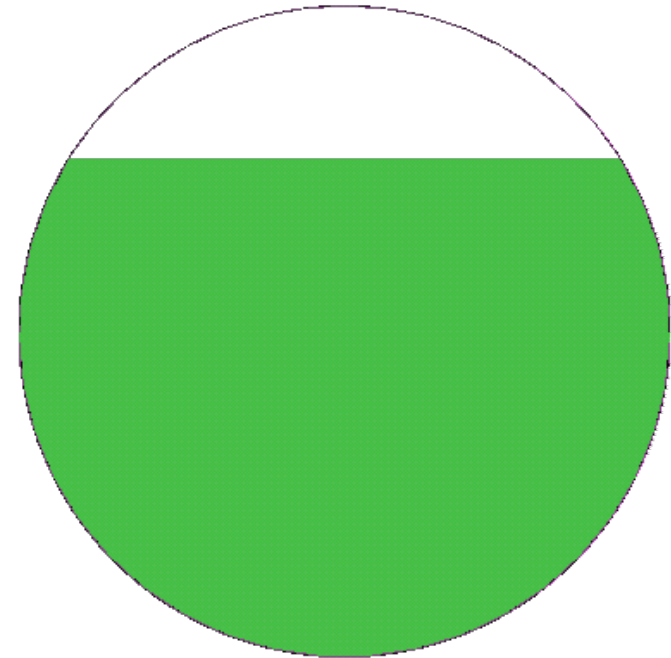
Replicate command repeats the previous geometry before it (cuboid for this example)



Cylindrical Solution Tank

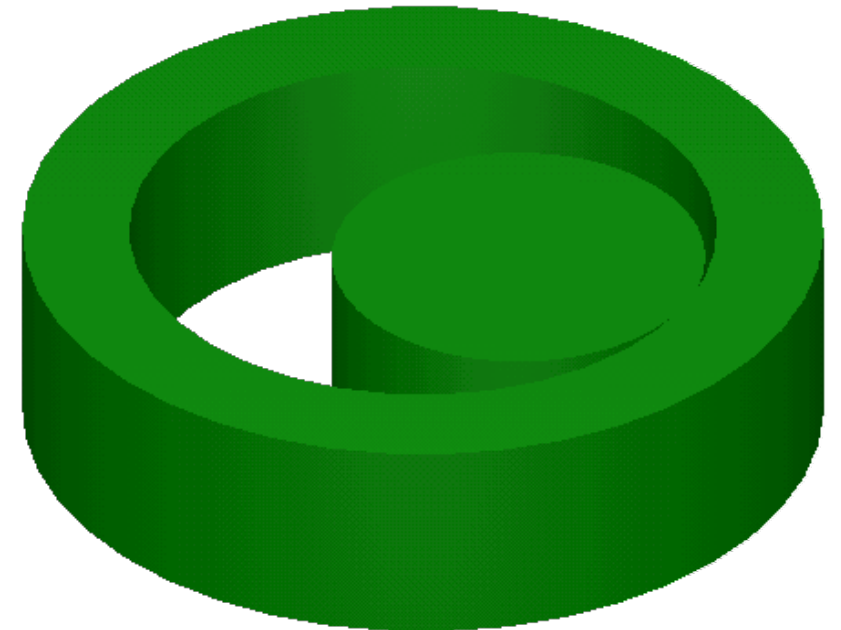
```
=csas5
partially filled cylindrical tank
ce_v7.1_endf
read comp
  solution      mix=1  rho[uo2f2]=494 92235 4.89
              92238 95.09 92234 0.02    density=1.56 temperature=293
  end solution
  al            2 1 293 end
end comp
read geometry
global unit 1
  xhemicyl-z 1 1 34.6 34.6 -34.6 chord 18.5
  xcylinder 0 1 34.6 34.6 -34.6
  xcylinder 2 1 34.759 34.759 -34.759
end geometry
end data
end
```

Chord command removes the desired portion of the geometry region



Cylinder in annulus

```
=csas5
u metal cylinder in an annulus
ce_v7.1_endf
read comp
  uranium      1 den=18.69 1 293 92235 93.2 92238 5.6 92234 1 92236 0.2 end
end comp
read geometry
global unit 1
  zcylinder 1 1 8.89 10.109 0 origin 5.0799 0
  zcylinder 0 1 13.97 10.109 0
  zcylinder 1 1 19.05 10.109 0
end geometry
end data
end
```



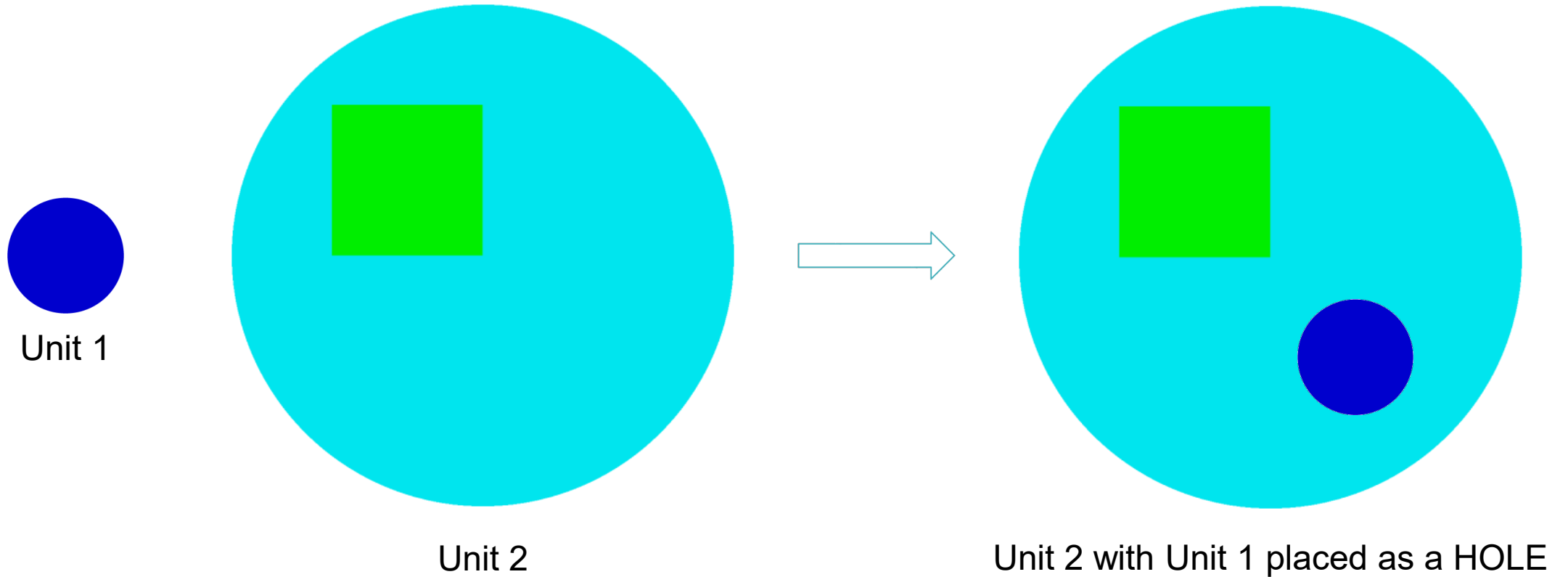
Sub module 4: **Holes in KENO V.a**

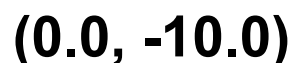


HOLES

- Holes combine multiple units in a problem by inserting one complete unit into another
 - One step process, *not* creating a hole and putting another unit in it
- HOLES may not intersect
- A HOLE may be inserted inside another UNIT subsequently used as a HOLE (i.e., nested)
- As many HOLES as are needed may be placed in a region
- HOLE must be entered directly after the region into which it is being inserted

Example of HOLE

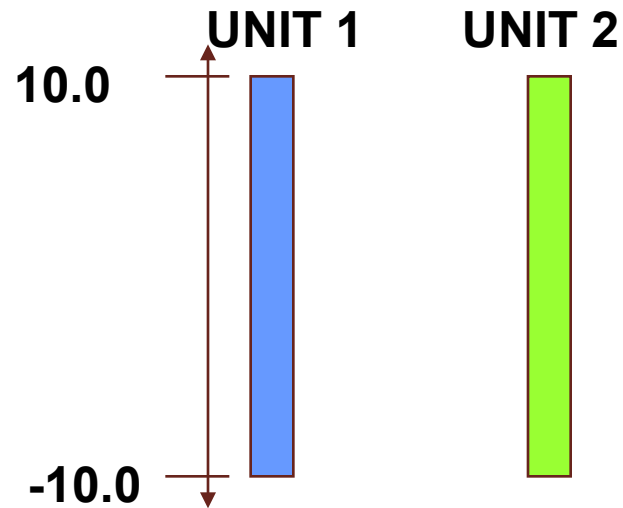




CYLINDER 3 1 0.98 20.0 0.0

HOLE	2	2R-7.071	0.0
------	---	----------	-----

Hole Demonstration 2: (Mixed origin cylinders)

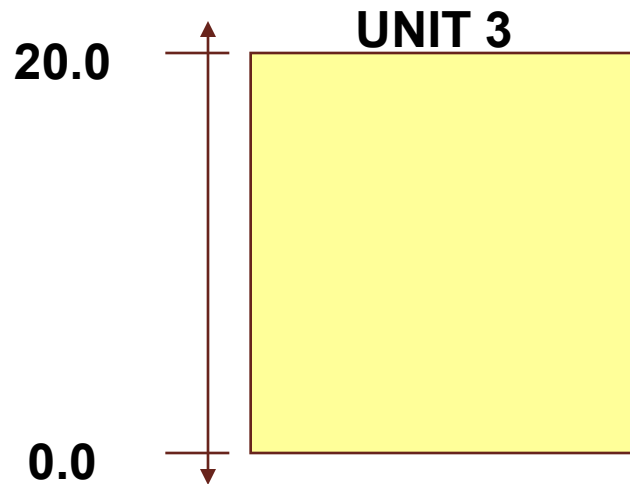


UNIT 1

CYLINDER 2 1 0.98 10.0 -10.0

UNIT 2

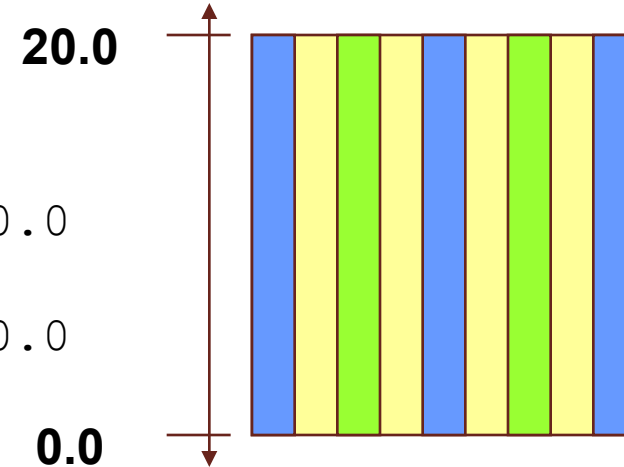
CYLINDER 3 1 0.98 10.0 -10.0



UNIT 3

CYLINDER 0 1 9.0 20.0 0.0

CYLINDER 1 1 11.0 20.0 0.0



GLOBAL UNIT 3

CYLINDER 0 1 9.0 20.0 0.0

CYLINDER 1 1 11.0 20.0 0.0

HOLE 1 -10.0 0.0 10.0

HOLE 2 -7.071 7.071 10.0

HOLE 1 0.0 10.0 10.0

HOLE 2 7.071 7.071 10.0

HOLE 1 10.0 0.0 10.0

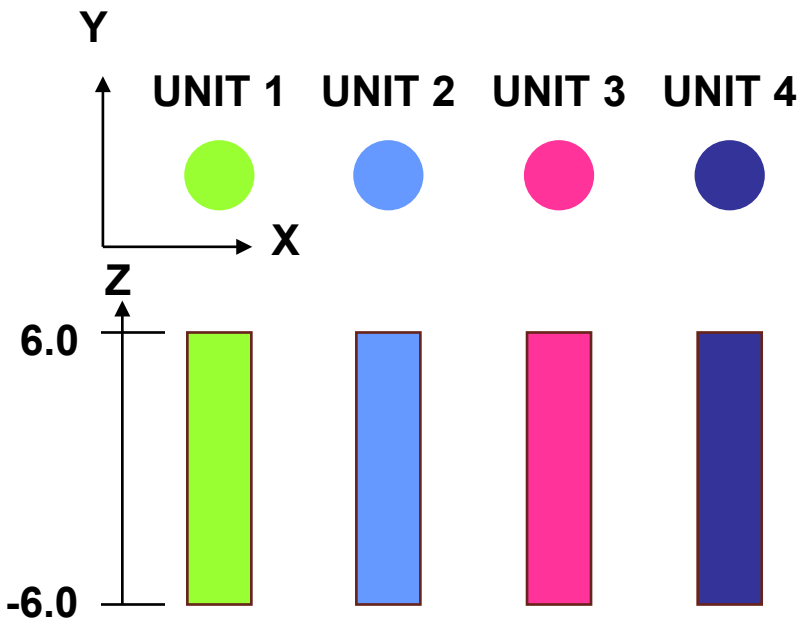
HOLE 2 7.071 -7.071 10.0

HOLE 1 0.0 -10.0 10.0

HOLE 2 -7.071 -7.071 10.0

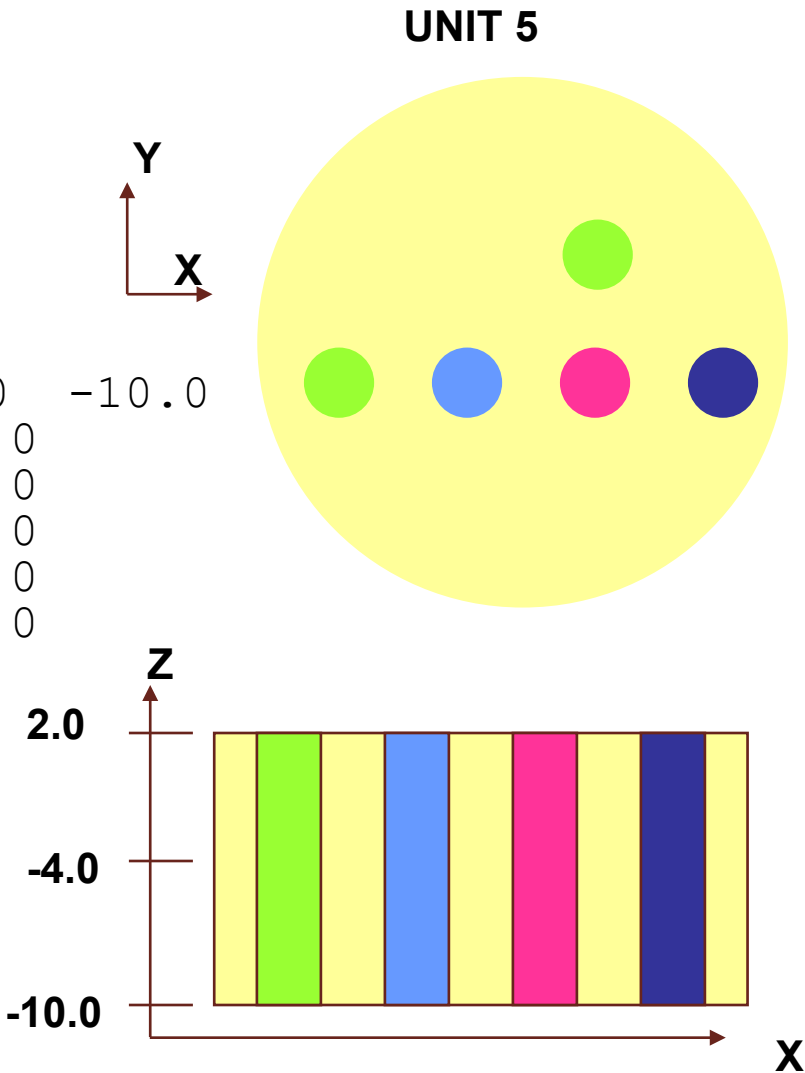
The origin of each hole is offset 10 cm above the origin of UNIT 3

Hole Demonstration 3

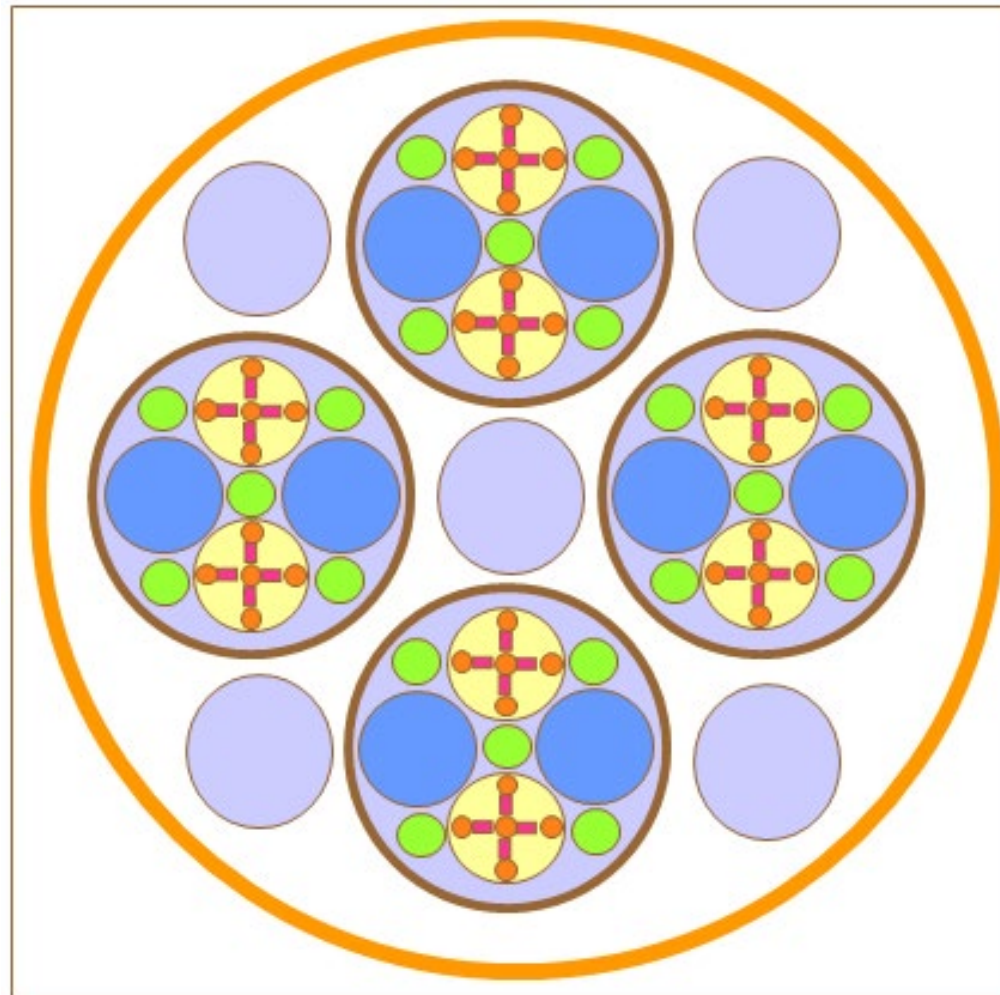


GLOBAL	UNIT	5			
CYLINDER	3	1	8.0	2.0	-10.0
HOLE	1		-6.0	-1.0	-4.0
HOLE	2		-2.0	-1.0	-4.0
HOLE	3		2.0	-1.0	-4.0
HOLE	1		2.0	3.0	-4.0
HOLE	4		6.0	-1.0	-4.0

UNIT 1					
CYLINDER	0	1	1.0	6.0	-6.0
UNIT 2					
CYLINDER	2	1	1.0	6.0	-6.0
UNIT 3					
CYLINDER	1	1	1.0	6.0	-6.0
UNIT 4					
CYLINDER	4	1	1.0	6.0	-6.0



The Ultimate Hole Demonstration



Review this demonstration later if you're interested



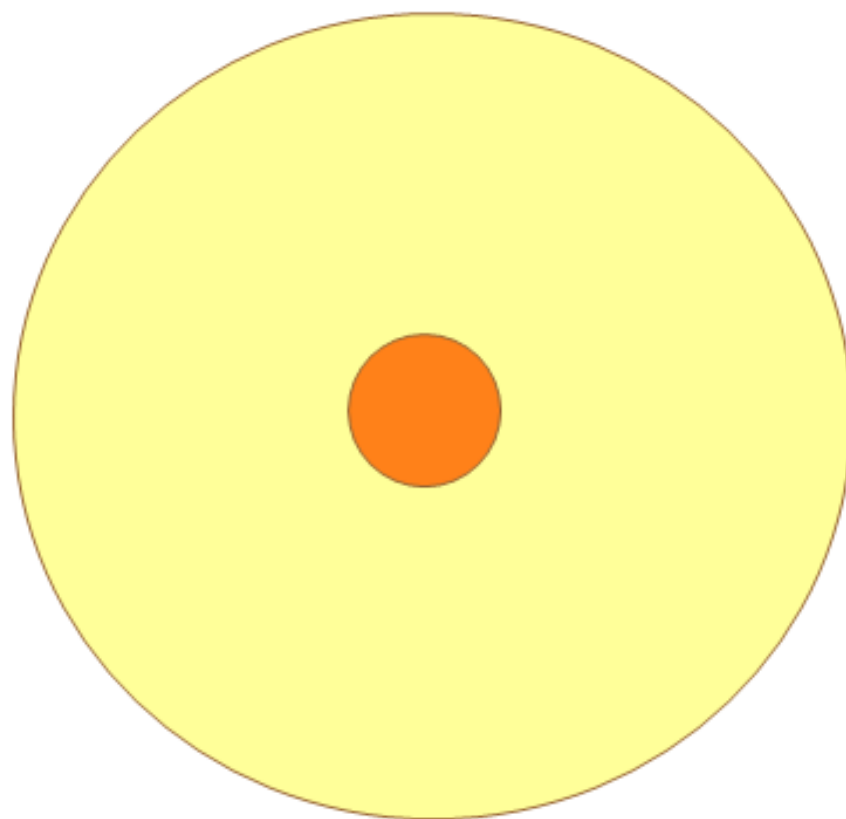
```
UNIT 1  
CYLINDER 1 1 0.1 2P15.0
```



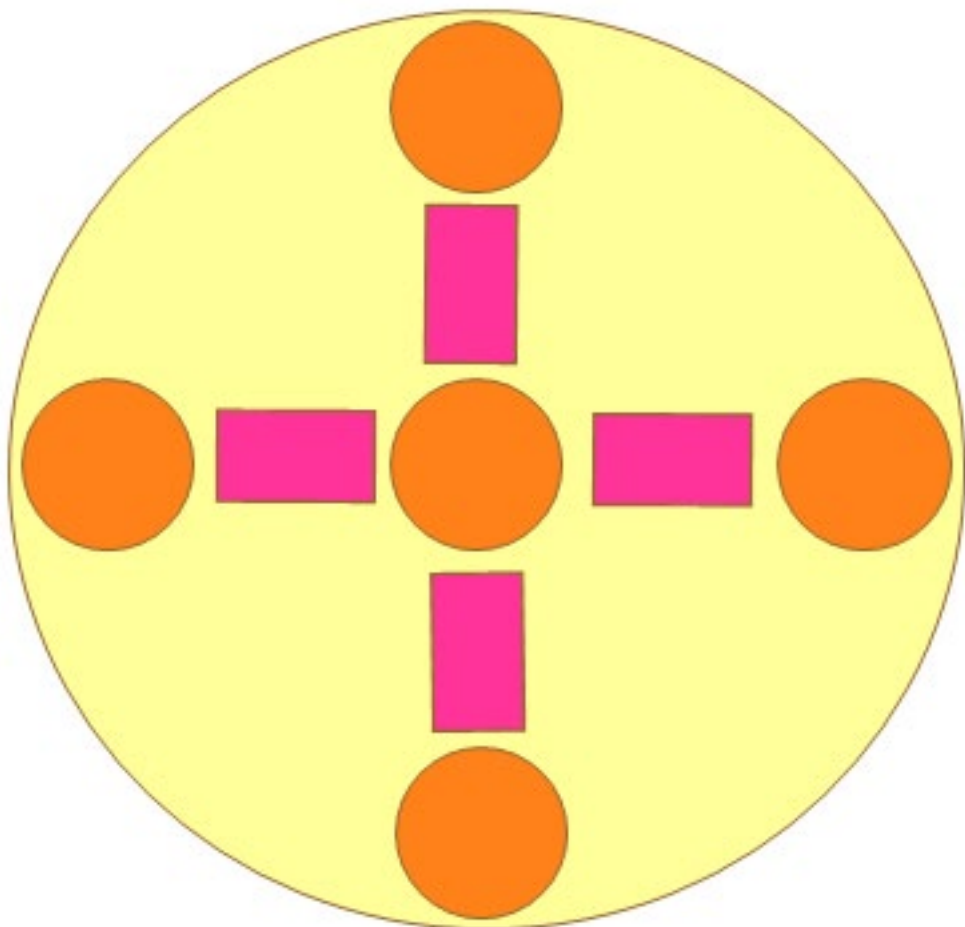
```
UNIT 2  
CUBOID 2 1 2P0.1 2P0.05 2P15.0
```



```
UNIT 3  
CUBOID 2 1 2P0.05 2P0.1 2P15.0
```



```
UNIT 4  
CYLINDER 1 1 0.1 2P15.0  
CYLINDER 3 1 0.5 2P15.0
```



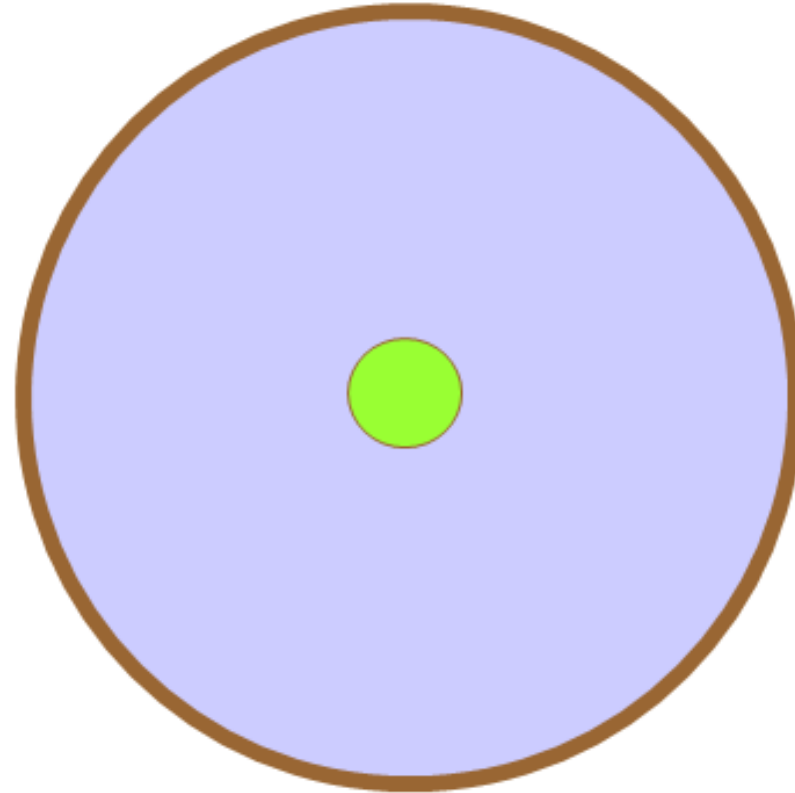
```
UNIT 4
CYLINDER 1 1 0.1 2P15.0
CYLINDER 3 1 0.5 2P15.0
HOLE 1 0.0 -0.4 0.0
HOLE 1 0.4 0.0 0.0
HOLE 1 0.0 0.4 0.0
HOLE 1 -0.4 0.0 0.0
HOLE 2 -0.2 0.0 0.0
HOLE 2 0.2 0.0 0.0
HOLE 3 0.0 -0.2 0.0
HOLE 3 0.0 0.2 0.0
```



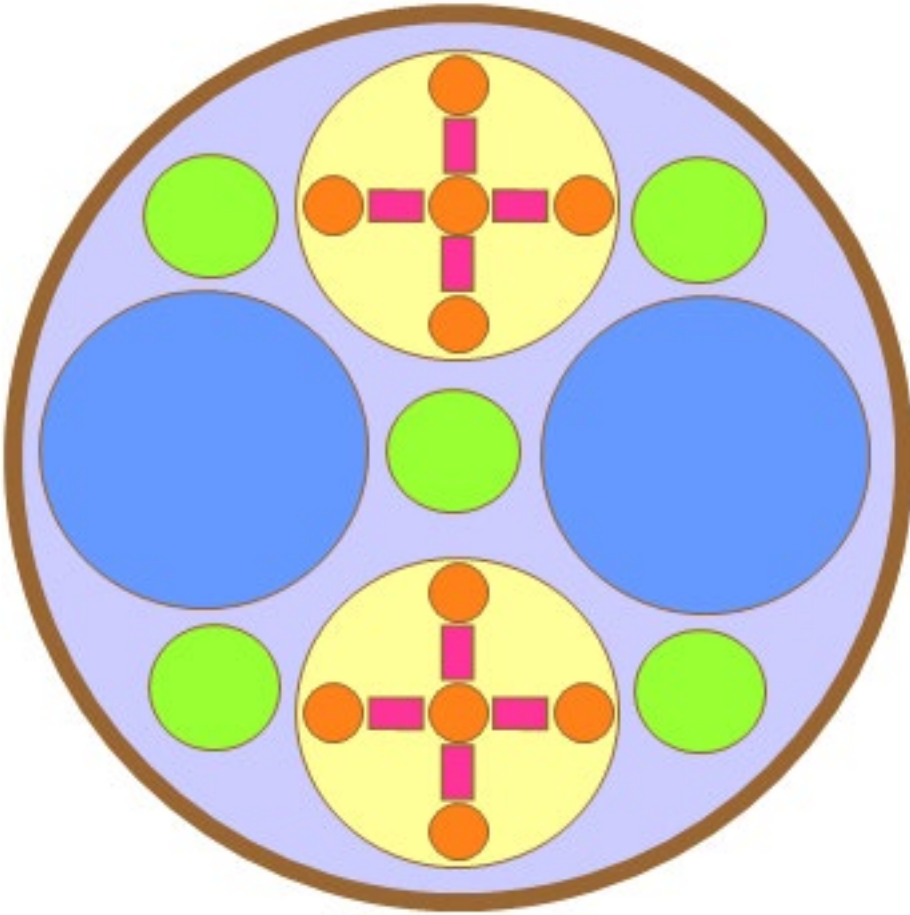
```
UNIT 5  
CYLINDER 1 1 0.5 2P15.0
```



```
UNIT 6  
CYLINDER 2 1 0.2 2P15.0
```



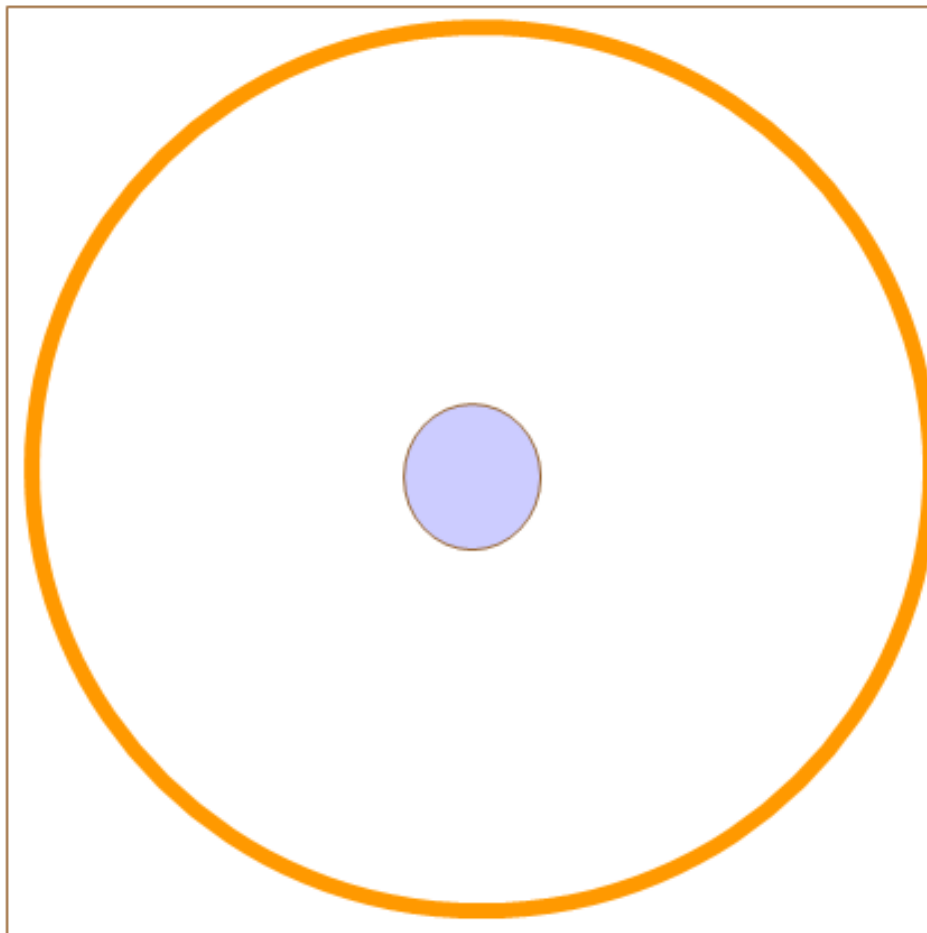
```
UNIT 7  
CYLINDER 2 1 0.2 2P15.0  
CYLINDER 0 1 1.3 2P15.0  
CYLINDER 4 1 1.4 2P15.0
```



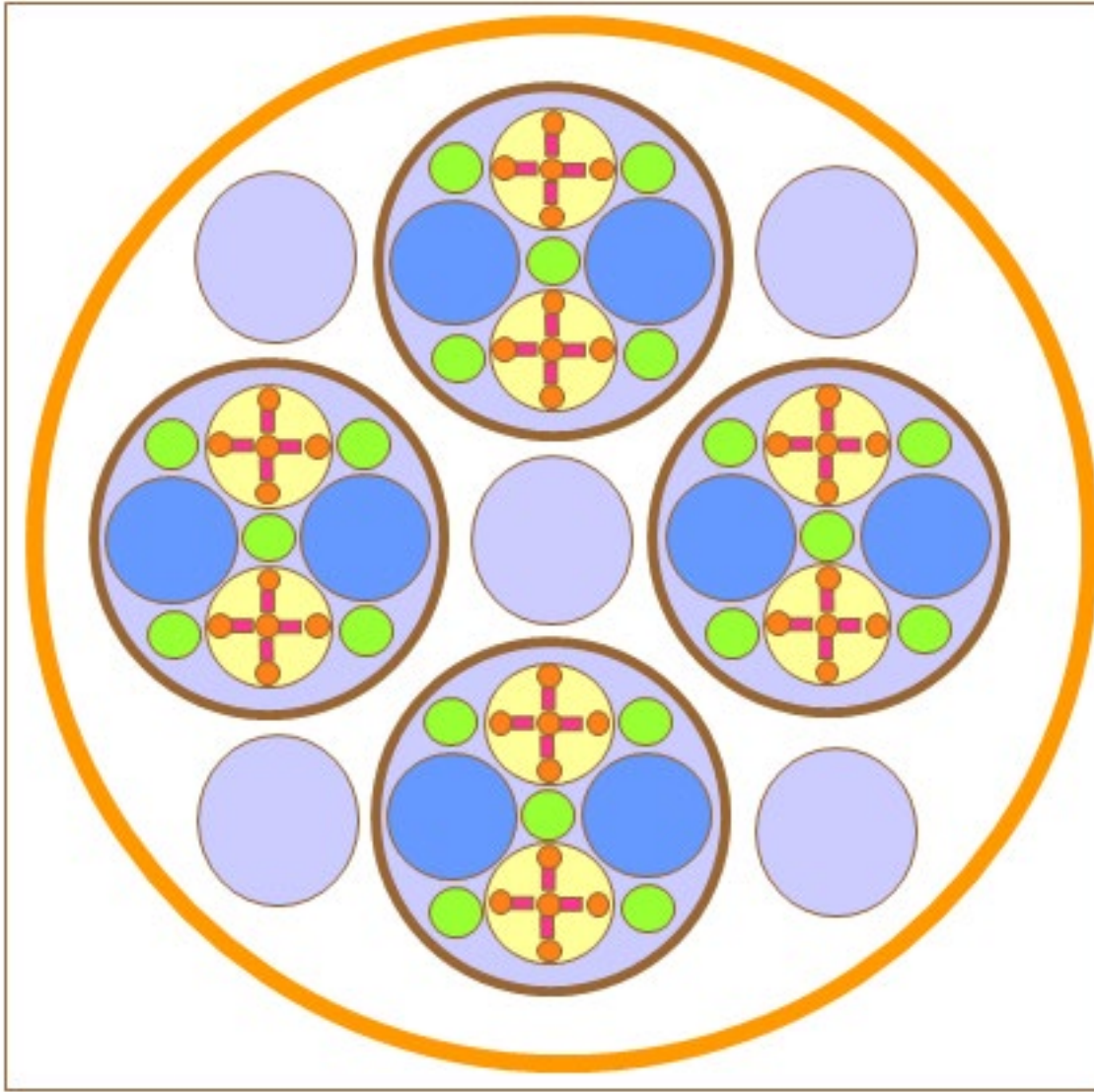
```
UNIT 7
CYLINDER 2 1 0.2 2P15.0
CYLINDER 0 1 1.3 2P15.0
HOLE 5 0.7071068 0.0 0.0
HOLE 6 0.7071068 0.7071068 0.0
HOLE 4 0.0 0.7071068 0.0
HOLE 6 -0.7071068 0.7071068 0.0
HOLE 5 -0.7071068 0.0 0.0
HOLE 6 -0.7071068 -0.7071068 0.0
HOLE 4 0.0 -0.7071068 0.0
HOLE 6 0.7071068 -0.7071068 0.0
CYLINDER 4 1 1.4 2P15.0
```



```
UNIT    8  
CYLINDER 2  1  0.6  2P15.0
```



```
UNIT    9  
CYLINDER 2  1  0.6  2P15.0  
CYLINDER 0  1  3.6  2P15.0  
CYLINDER 4  1  3.8  2P15.0  
CUBOID  0  1  4P4.0  2P15.0
```



```

UNIT    9
CYLINDER 2 1 0.6 2P15.0
CYLINDER 0 1 3.6 2P15.0
HOLE 7 2.0 0.0 0.0
HOLE 8 2*2.0 0.0
HOLE 7 0.0 2.0 0.0
HOLE 8 -2.0 2.0 0.0
HOLE 7 -2.0 0.0 0.0
HOLE 8 -2.0 -2.0 0.0
HOLE 7 0.0 -2.0 0.0
HOLE 8 2P2.0 0.0
CYLINDER 4 1 3.8 2P15.0
CUBOID 0 1 4P4.0 2P15.0

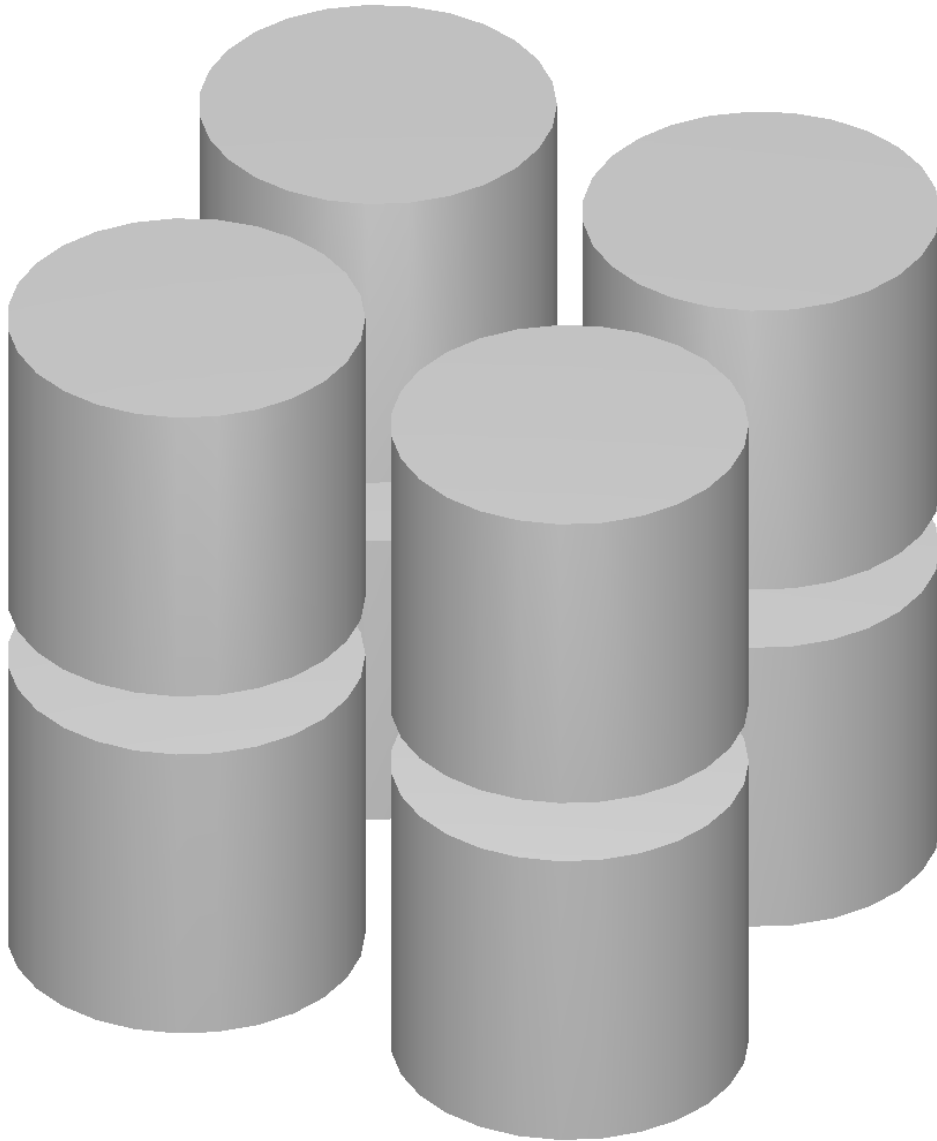
```

Holes application demo

- 2c8 – Take 1



2c8



8 Uranium Cylinders

5.748 cm radius

10.765 cm length

13.74 cm center to center spacing in X and Y dimensions

13.01 cm center to center spacing in Z dimension

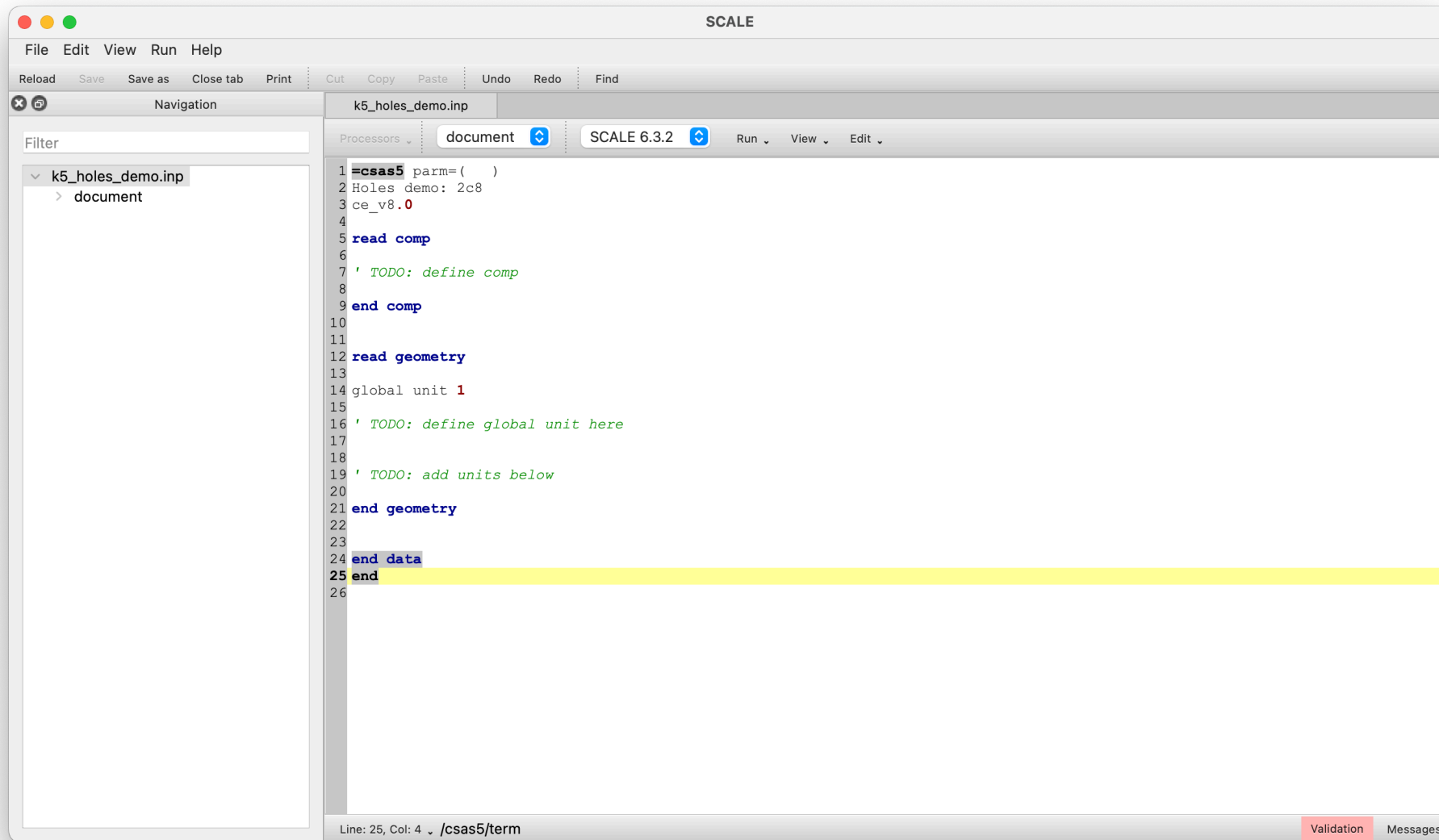
Uranium Metal

Density = 18.764 gm / cc

Enrichment:

93.2%	U-235
5.6%	U-238
1.0%	U-234
0.2%	U-236

General Problem Data



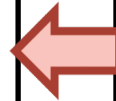
The screenshot displays the SCALE 6.3.2 application window. The title bar reads "SCALE". The menu bar includes "File", "Edit", "View", "Run", and "Help". Below the menu bar is a toolbar with icons for "Reload", "Save", "Save as", "Close tab", "Print", "Cut", "Copy", "Paste", "Undo", "Redo", and "Find". The main window is divided into three panes. The left pane, titled "Navigation", shows a tree view with "k5_holes_demo.inp" expanded, revealing a "document" sub-entry. The middle pane shows the text editor with the file "k5_holes_demo.inp" open. The text is as follows:

```
1 =csas5 parm=( )
2 Holes demo: 2c8
3 ce_v8.0
4
5 read comp
6
7 ' TODO: define comp
8
9 end comp
10
11
12 read geometry
13
14 global unit 1
15
16 ' TODO: define global unit here
17
18
19 ' TODO: add units below
20
21 end geometry
22
23
24 end data
25 end
26
```

The status bar at the bottom indicates "Line: 25, Col: 4" and the terminal path "/csas5/term". On the right side of the status bar, there are buttons for "Validation" and "Messages".

Composition data

```
5 read comp
6 uranium 1 den=18.764000 1.0 293.0
7      92234 1.0
8      92235 93.2
9      92236 0.2
10     92238 5.6 end
11 end comp
```



stdcomp - basic (configurable)

Composition: uranium

Mixture: 1

☒ Theoretical Density: 18.764000

☒ Volume Fraction: 1.000000

☒ Temperature: 293.000000

☒ Isotopic Weight Percents

	+/-	Isotope	Weight Percent
1	+ -	92234	1.000000
2	+ -	92235	93.200000
3	+ -	92236	0.2
4	+ -	92238	5.600000

Add row

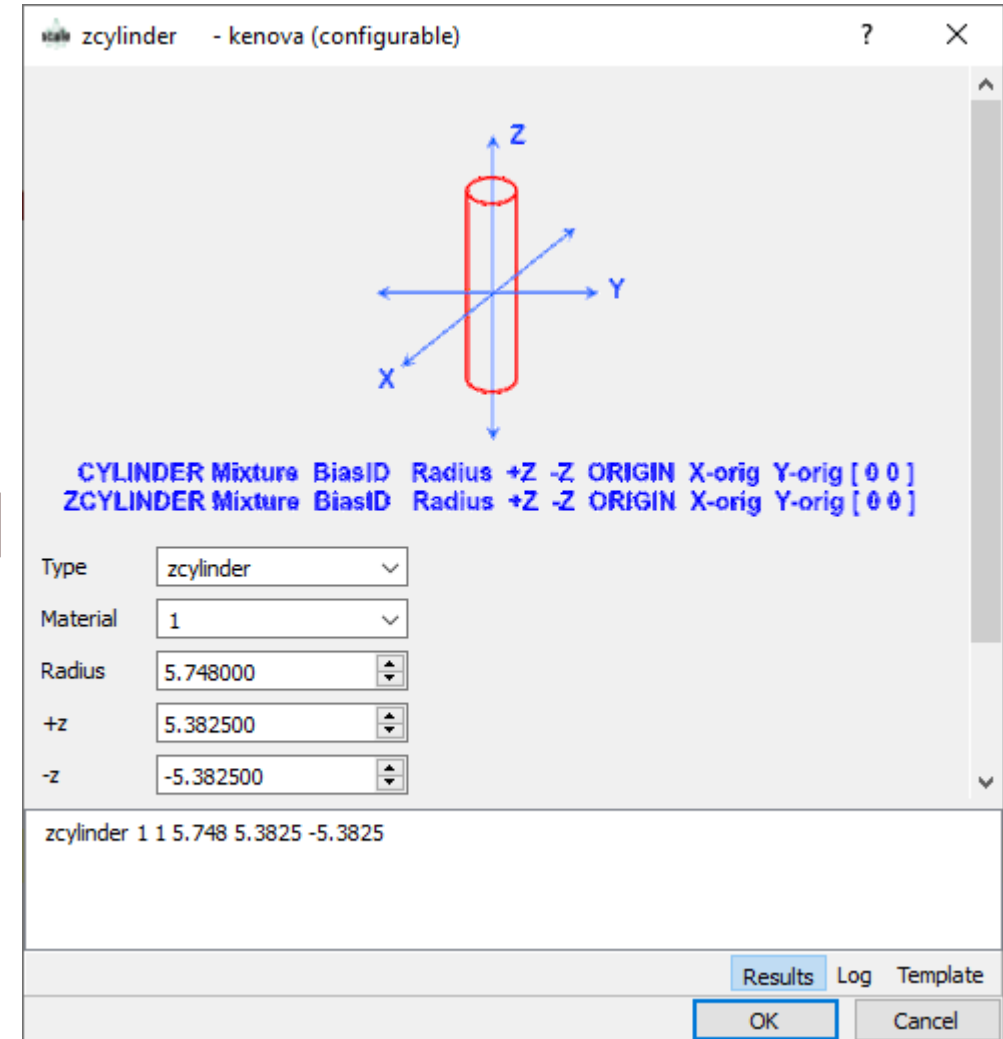
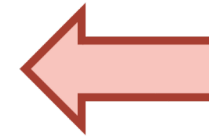
uranium 1 den=18.764000 1.0 293.0
92234 1.0
92235 93.2
92236 0.2
92238 5.6 end

Results Log Template

OK Cancel

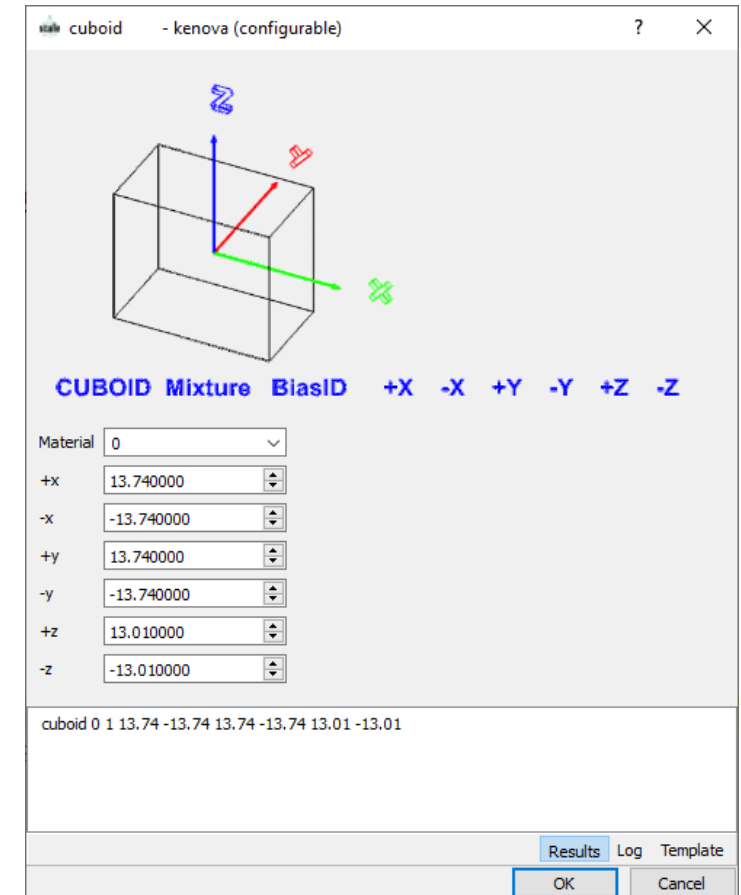
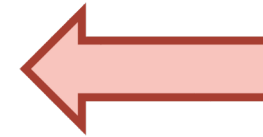
Unit 1: Metal casting

```
17 unit 1  
18 zcylinder 1 1 5.748 5.3825 -5.3825
```



Global Unit 2: Void space

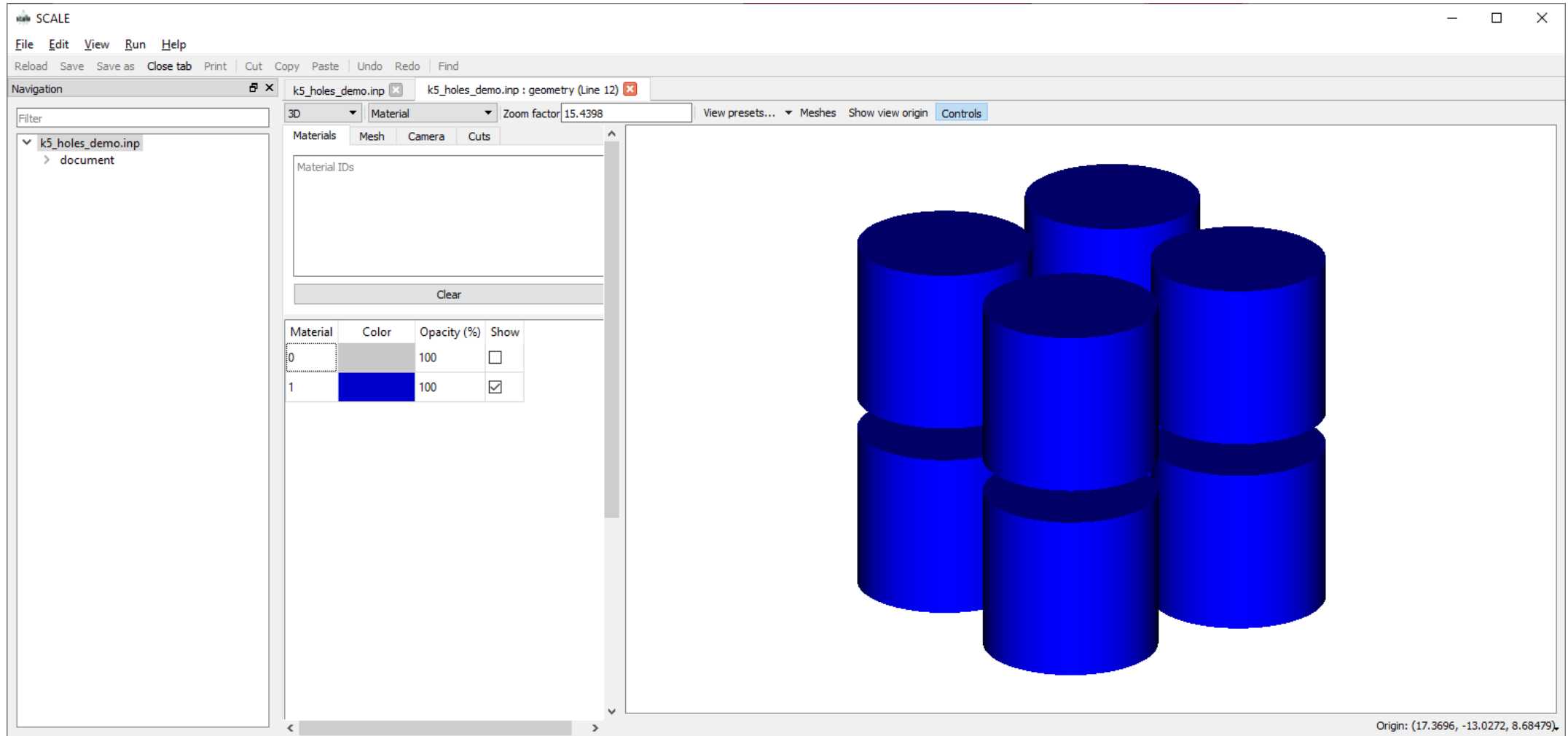
```
19 global unit 2
20 cuboid 0 1 13.74 -13.74 13.74 -13.74 13.01 -13.01
```



Global Unit 2: Add holes

```
19 global unit 2
20   cuboid 0 1 13.74 -13.74 13.74 -13.74 13.01 -13.01
21   hole 1 -6.87 -6.87 -6.505
22   hole 1 6.87 -6.87 -6.505
23   hole 1 -6.87 6.87 -6.505
24   hole 1 6.87 6.87 -6.505
25 '
26 hole 1 -6.87 -6.87 6.505
27 hole 1 6.87 -6.87 6.505
28 hole 1 -6.87 6.87 6.505
29 hole 1 6.87 6.87 6.505
30 end geometry
```

3D Rendering in Fulcrum, void not shown



Click Run:

The screenshot shows the SCALE 6.3.2 application window. The title bar is "SCALE". The menu bar includes "File", "Edit", "View", "Run", and "Help". Below the menu bar is a toolbar with "Reload", "Save", "Save as", "Close tab", "Print", "Cut", "Copy", "Paste", "Undo", "Redo", and "Find". The main window is divided into three panes. The left pane is a "Navigation" pane with a "Filter" box and a tree view showing "k5_holes_demo.inp" and "document". The middle pane is a code editor showing the input file "k5_holes_demo.inp" with the following content:

```
1 =csas5 parm=( )
2 Holes demo: 2c8
3 ce_v8.0
4
5 read comp
6 uranium 1 den=18.764000 1.0 293.0
7           92234 1.0
8           92235 93.2
9           92236 0.2
10          92238 5.6 end
11 end comp
12
13
14 read geometry
15 unit 1
16   zcylinder 1 1 5.748 5.3825 -5.3825
17 global unit 2
18   cuboid 0 1 13.74 -13.74 13.74 -13.74 13.01 -13.01
19   hole 1 -6.87 -6.87 -6.505
```

The right pane shows the output of the simulation, starting with a timestamp "Tue Oct 1 15:29:42 2024". The output includes a table of results for the "holes demo: 2c8" simulation, followed by a "final results table" and a summary of the simulation results. The simulation was completed successfully with a return code of 0.

```
1407 202 9.89491E-01 1.00006E+00 1.92856E-03 6.37985E+00 5.91667E-02
1408
1409 203 9.76552E-01 9.99941E-01 1.94636E-03 6.37895E+00 5.93333E-02
1410
1411
1412 holes demo: 2c8
1413 ***** final results table *****
1414 best estimate system k-eff 0.9997 + or - 0.0019
1415
1416 Energy of average lethargy of Fission (eV) 8.42553E+05 + or - 2.36573E+03
1417 k-effective satisfies the chi*2 test for normality at the 95 % level
1418
1419 Scale job /Users/6tg/Desktop/k5_holes_demo.inp is finished.
1420 Output is stored in /Users/6tg/Desktop/k5_holes_demo.out
1421
1422 Process finished with 0 return code; ran in 5 secs, finished at Tue Oct 1 15:29:48 2024
```

The status bar at the bottom shows "Line: 14, Col: 14" and the file path "/csas5/geometry/decl". There are "Validation" and "Messages" buttons on the right.

Sub module 5: **Arrays in KENO V.a**



Arrays

- An array is an ordered set of rectangular units
- Arrays are defined in the array block
 - nux, nuy, nuz and unit numbers to fill array
- Faces that *touch* in array must have the **same dimensions**
- Arrays are then placed in a unit in the geometry block
- *Replicate* can be used to add regions outside the array instead of using additional cuboids
 - Helpful if *thickness* of surrounding regions is known instead of dimensions

Array definition

- Array definitions are contained in the array block
- Each array gets an integer identifier
- Size of array is declared based on the number of units in the x (nux), y (nuy), and z (nuz) dimensions

```
ara=1 nux=1 nuy=1 nuz=8
```

FILL Data

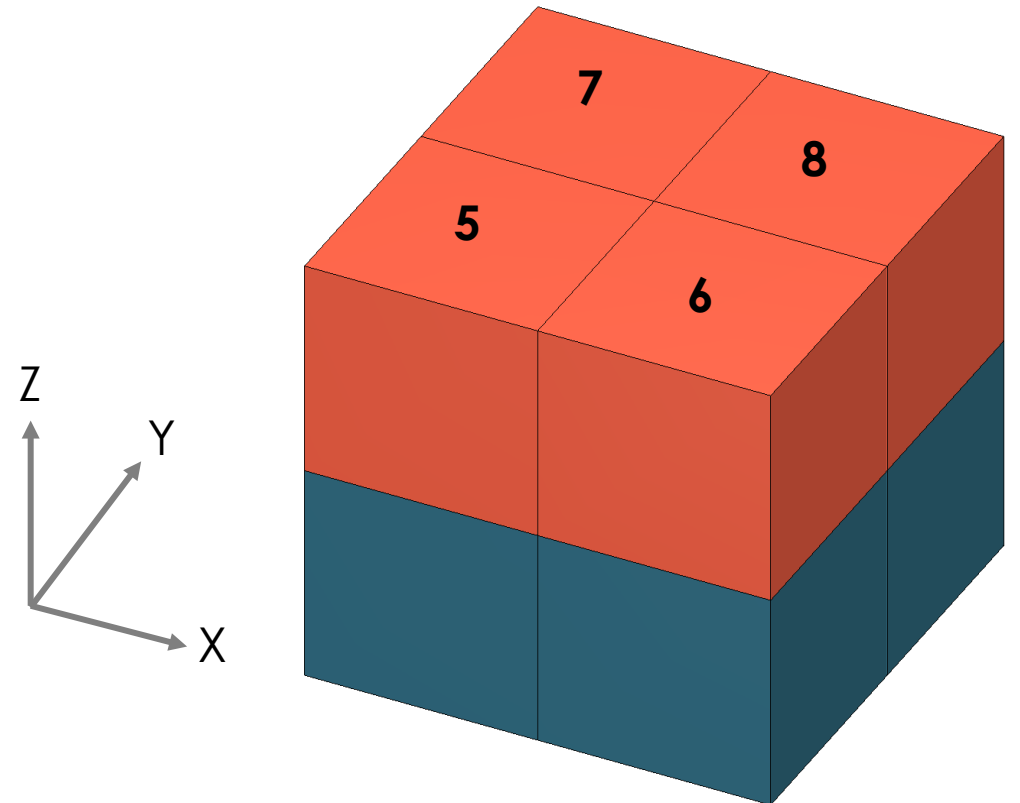
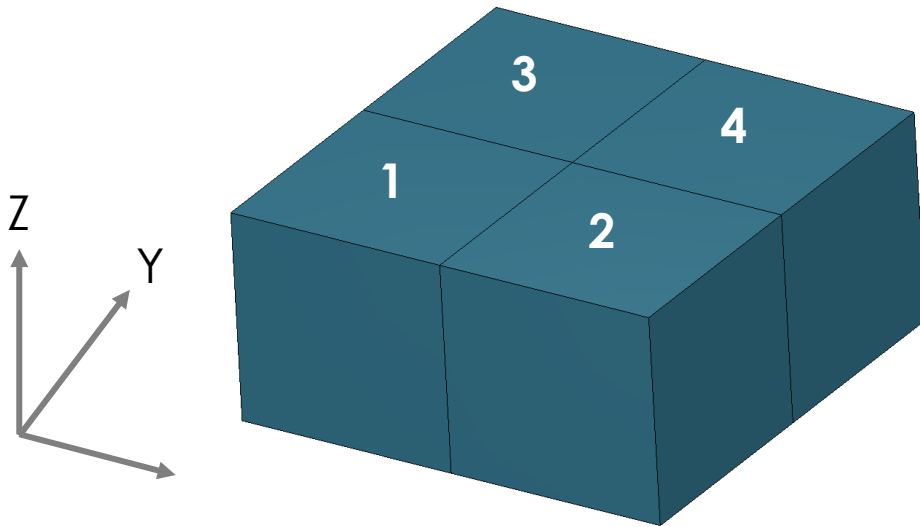
- Fills the array with the unit numbers in the specified order
- Begins with keyword “fill”
- Ends with keywords “end fill”
- Fills the array by incrementing
 - x from 1 to nux
 - then y from 1 to nuy
 - then z from 1 to nuz

FILL Data

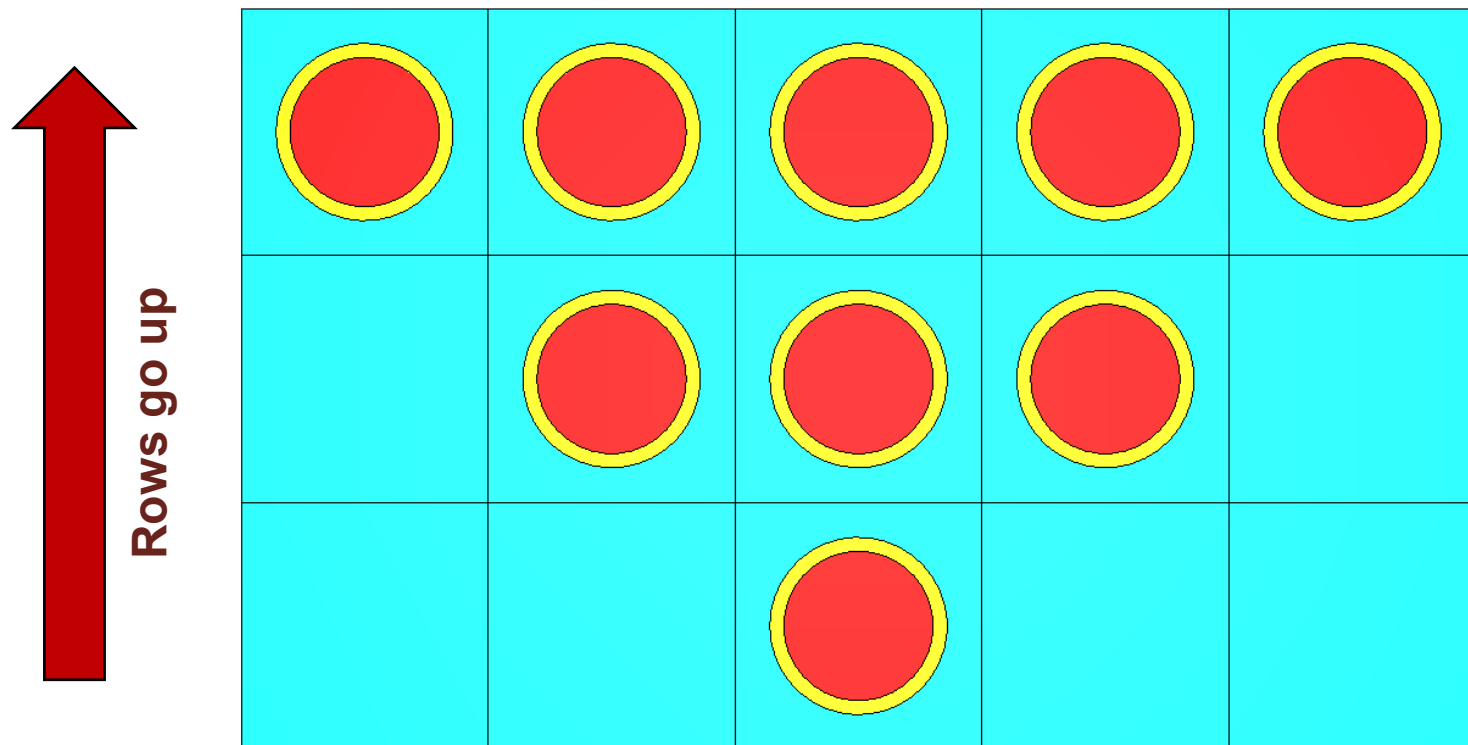
- For a 2 x 2 x 2 array, the order of the units stored in the array using the FILL parameter is:

(1,1,1) (2,1,1) (1,2,1) (2,2,1)

(1,1,2) (2,1,2) (1,2,2) (2,2,2)



Rectangular Array



```
read array
ara=1 nux=5 nuy=3 typ=square
  fill
    2  2  1  2  2
    2  1  1  1  2
    1  1  1  1  1
  end fill
end array
```

Rows go down

FIDO-Like Shortcuts for FILL

<u>Count Field</u>	<u>Option Field</u>	<u>Operand Field</u>	<u>Comment</u>
		j	Stores j in current array position and increments array position by 1.
	F	j	Fills the remainder of the array with j, starting with the current position and increments the array to the last array position + 1.
I	R or *	j	Repeats entry j a total of i times

Refer to Table 8.1.19 for complete list of options: <https://scale-manual.ornl.gov/index.html>

Array Placement

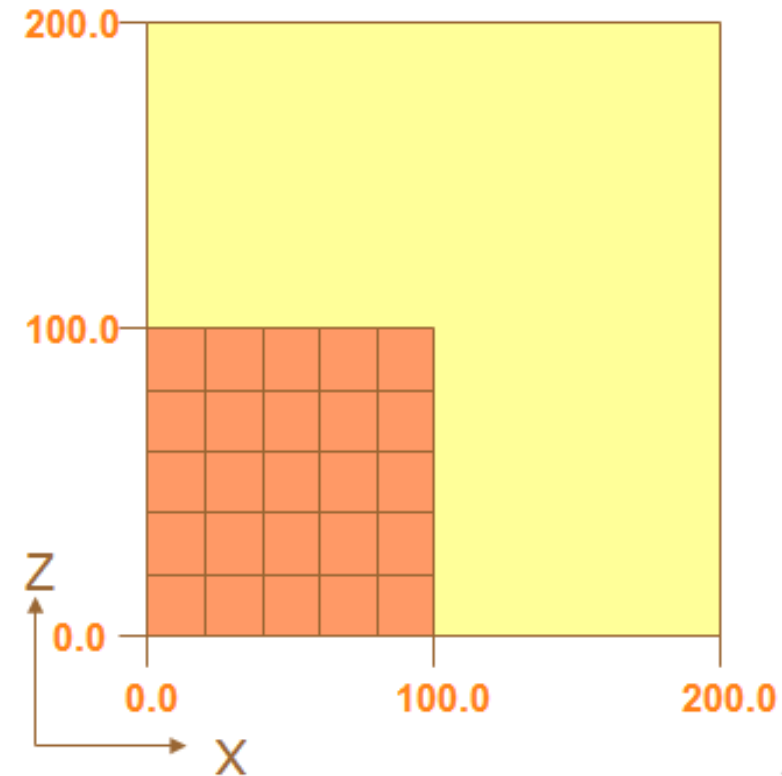
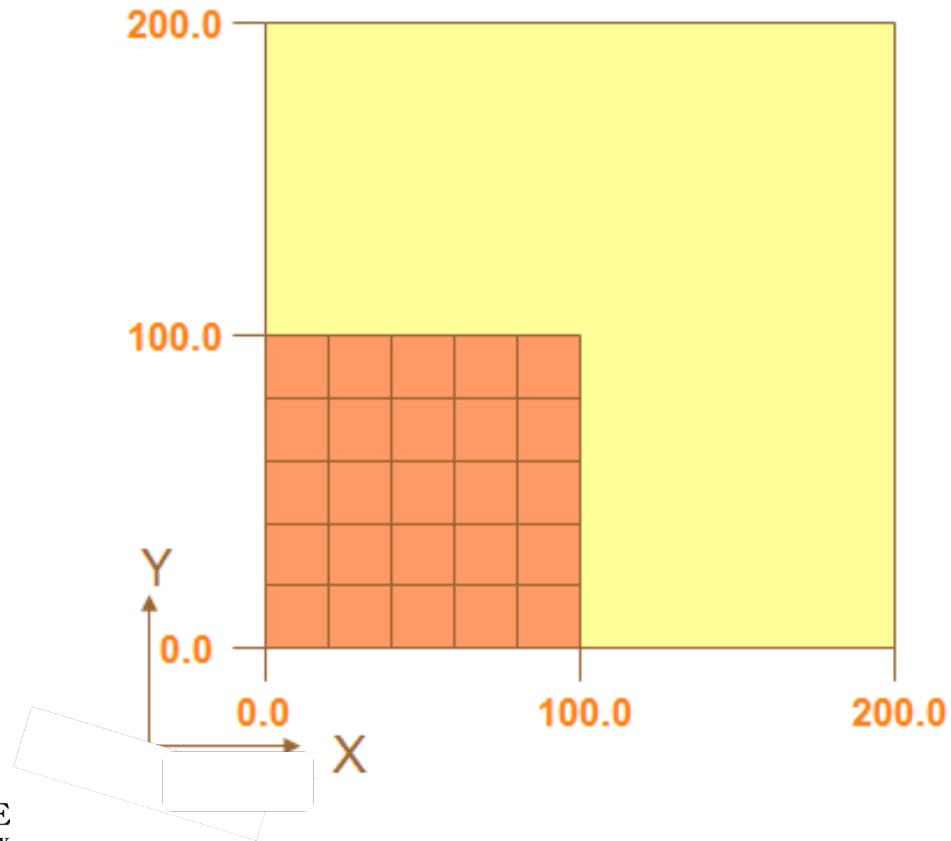
- Array is positioned within a unit by defining the (x,y,z) position of the left, front, bottom corner of the array
 - In other words – the most negative point in the array
 - In other words – the minimum x, minimum y, and minimum z point
- For the following examples:
 - UNIT 1 is a 20 x 20 x 20 cm cuboid
 - Array 1 is a 5 x 5 x 5 matrix of UNIT 1's
 - Array 1 is placed in UNIT 2, which is a 200 x 200 x 200 cm cuboid

+X	-X	+Y	-Y	+Z	-Z
100.0	0.0	100.0	0.0	100.0	0.0

UNIT 2

ARRAY 1 0.0 0.0 0.0

CUBOID 0 1 200.0 0.0 200.0 0.0 200.0 0.0



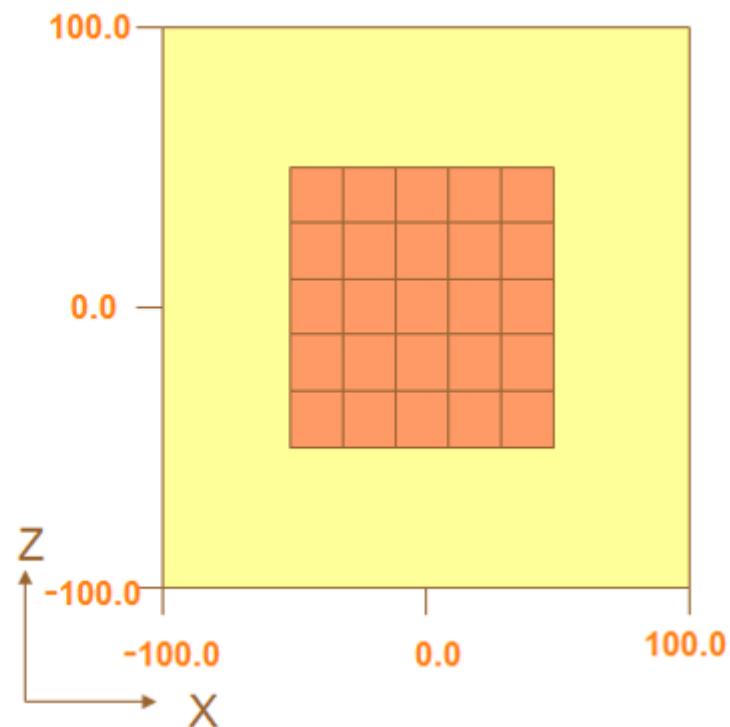
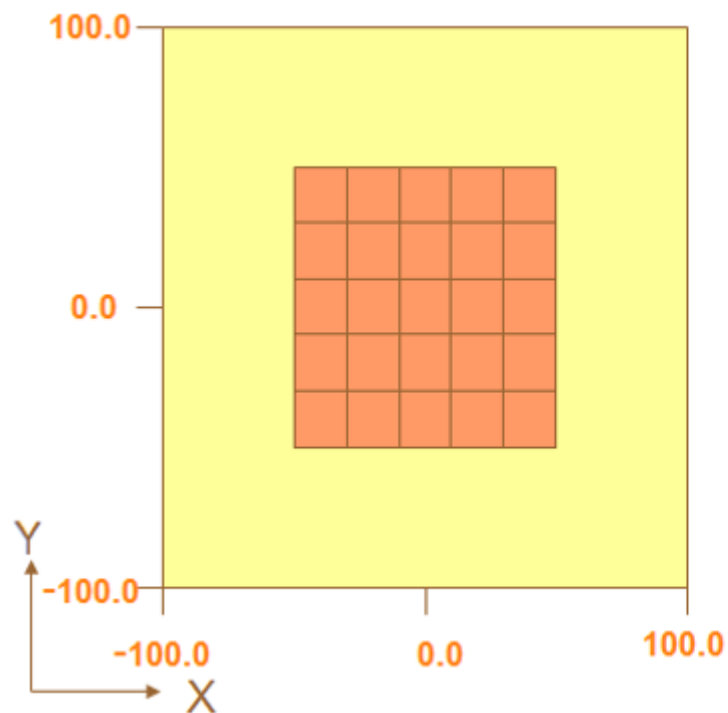
Case 2 Outer Dimensions of the Array

+X	-X	+Y	-Y	+Z	-Z
50.0	-50.0	50.0	-50.0	50.0	-50.0

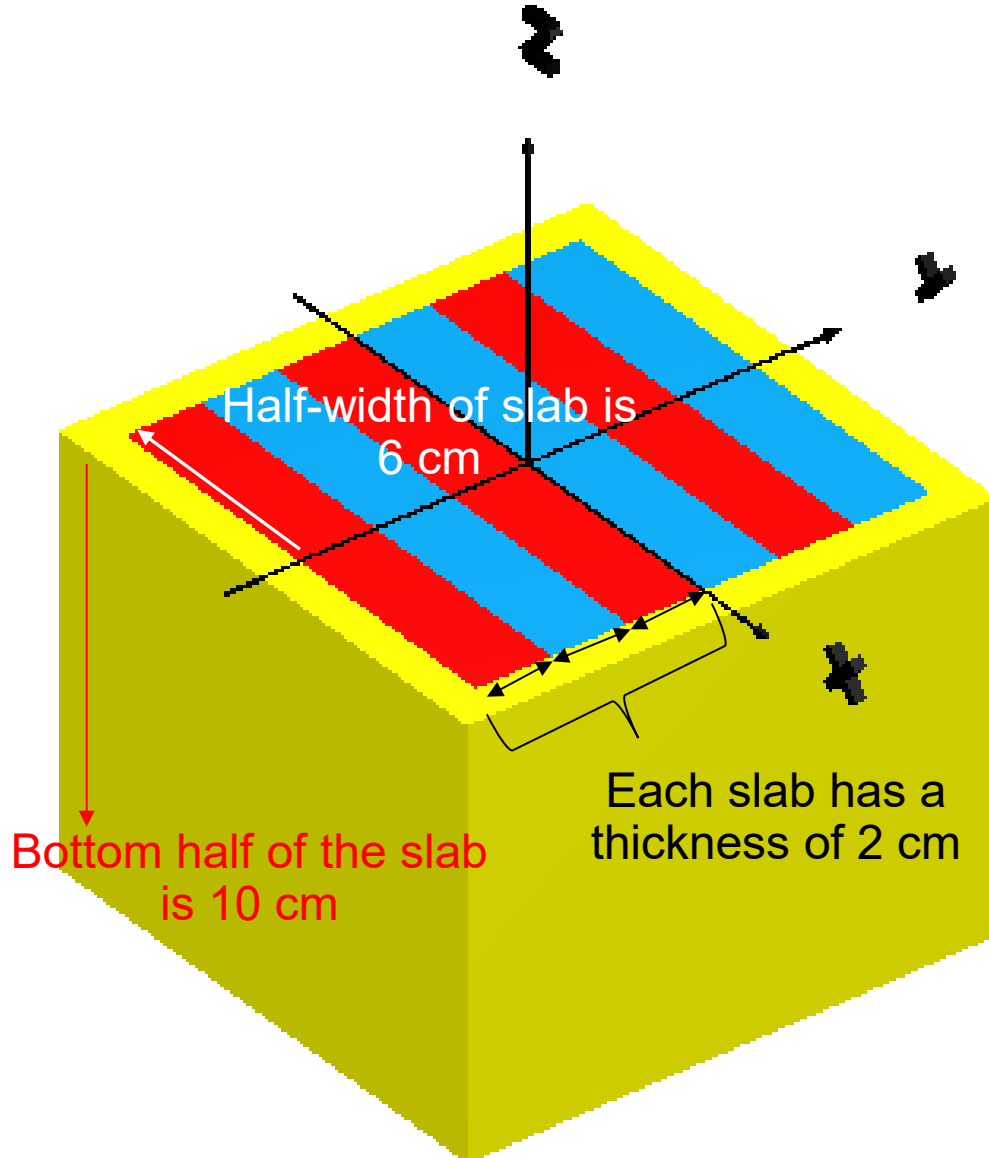
UNIT 2

ARRAY 1 -50.0 -50.0 -50.0

CUBOID 0 1 100.0 -100.0 100.0 -100.0 100.0 -100.0

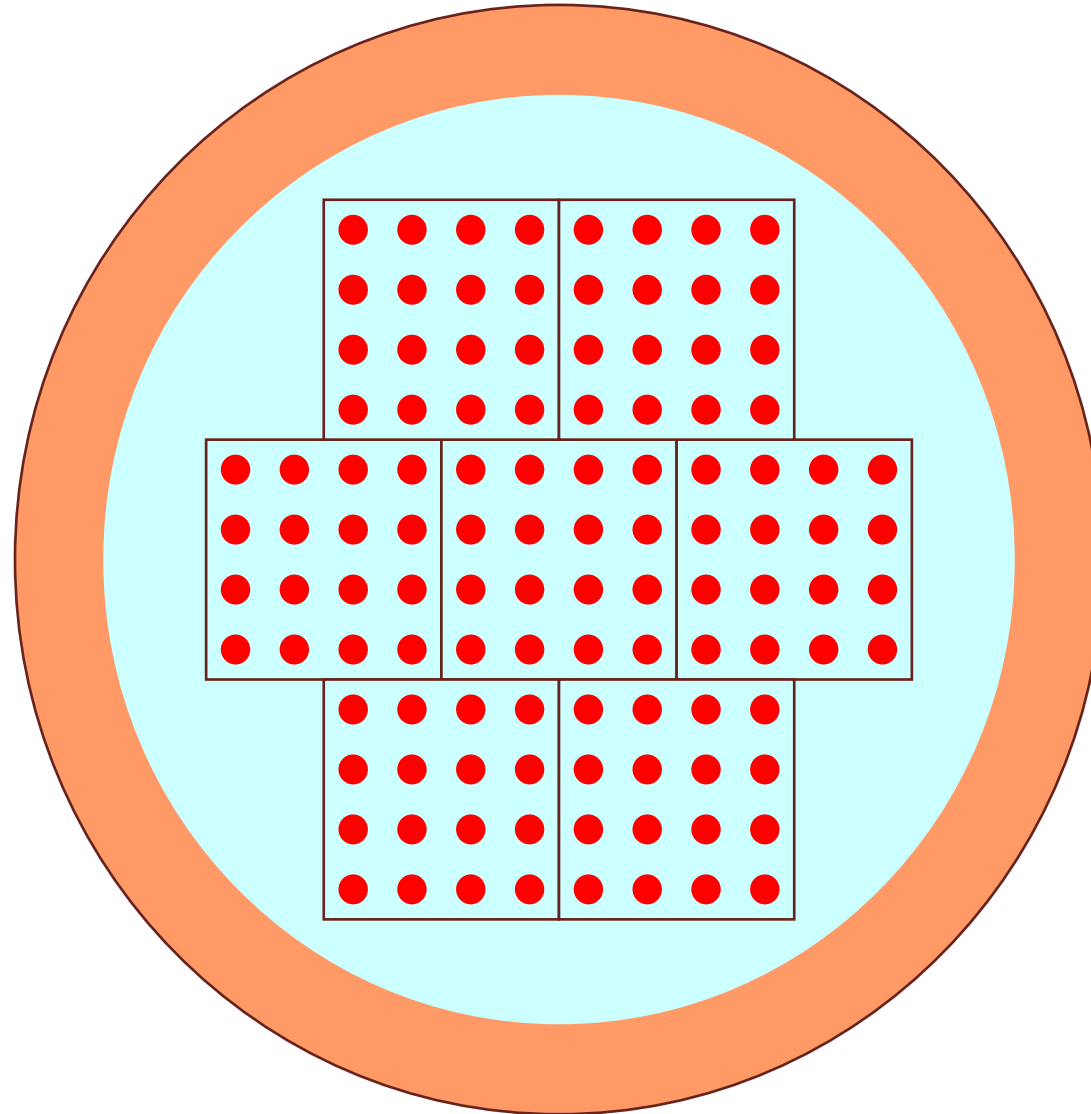


1D array of slabs



```
read geometry
unit 1
cuboid 1 1 2p6.0 2p1.0 2p10.0
\
unit 2
cuboid 2 1 2p6.0 2p1.0 2p10.0
\
global unit 3
array 1 -6 -6 -10
cuboid 3 1 4p7.0 2p11.0
\
end geometry
read array
ara=1 nux=1 nuy=6 nuz=1
fill 1 2 1 2 1 2 end fill
end array
```

Array-of-Arrays Example

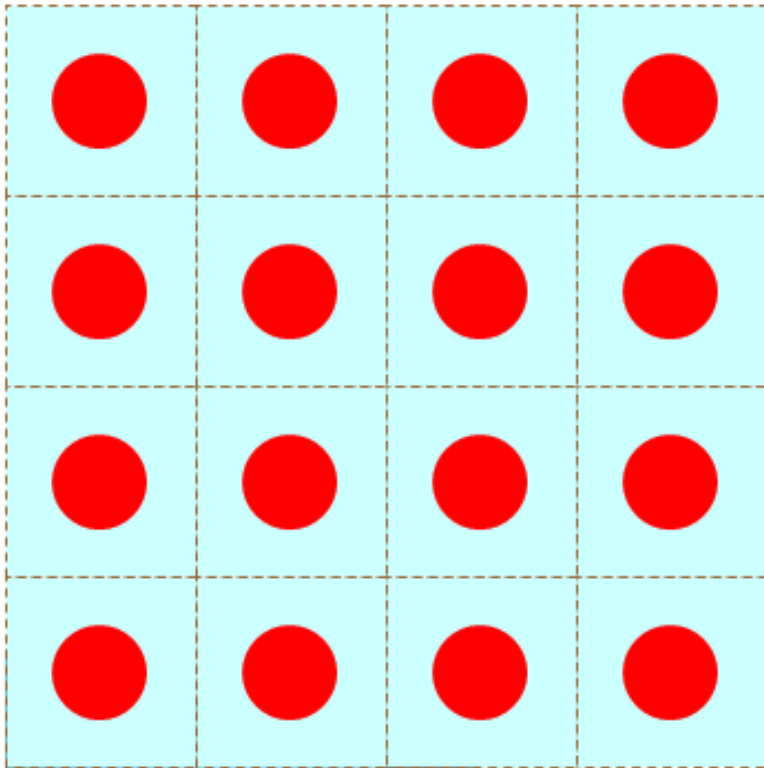


UNIT 1



```
UNIT 1
COM=' SINGLE FUEL ROD'
CYLINDER 1 1 1.75 2P10.0
CUBOID 0 1 4P3.0 2P10.0
```

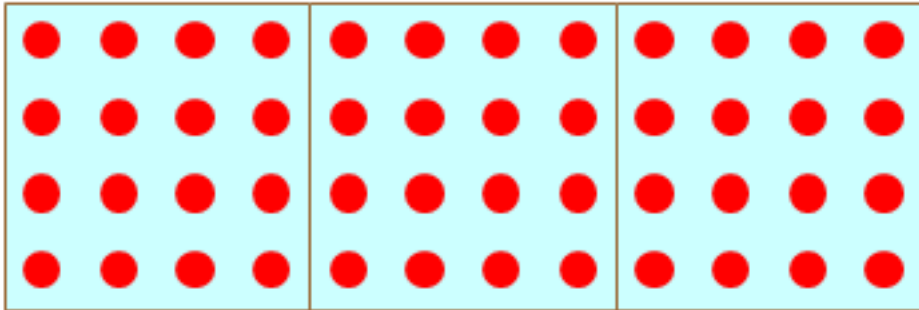
UNIT 2 (ARRAY 1)



```
UNIT 2
COM='4x4x1 ARRAY OF RODS'
ARRAY 1 2*-12.0 -10.0
REPLICATE 2 1 6R0.25 1
```

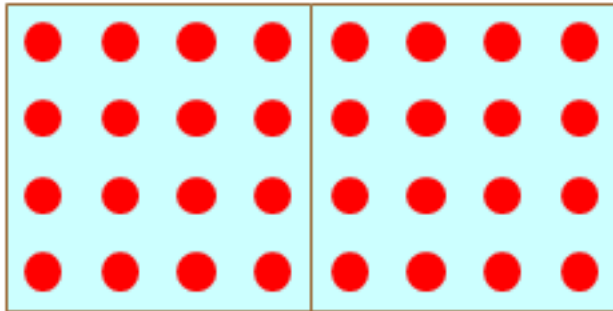
```
READ ARRAY
ARA=1 NUX=4 NUY=4 NUZ=1
FILL F1 END FILL
```

(ARRAY 2)



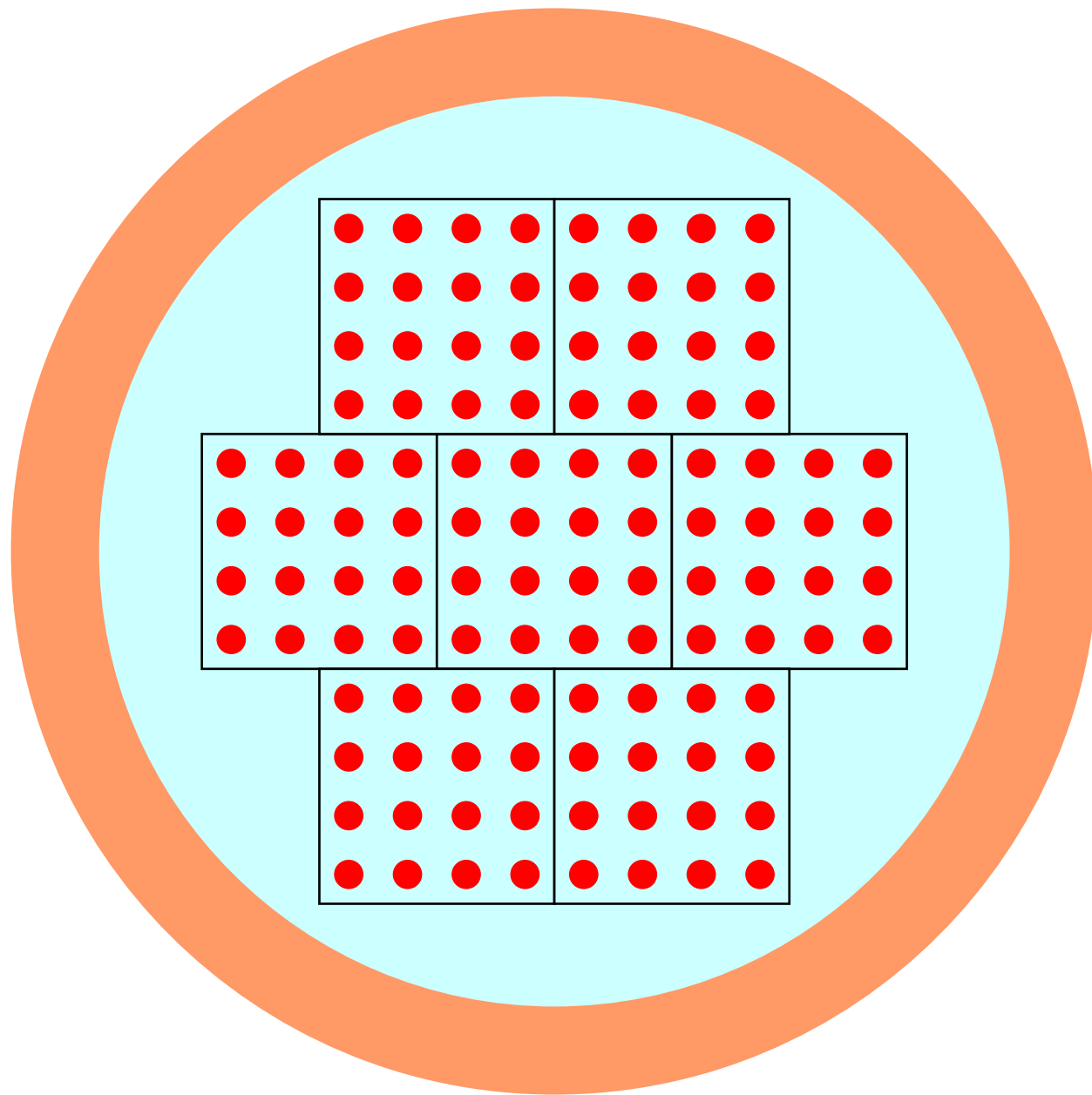
```
ARA=2  NUX=3  NUY= 1  NUZ=1  
FILL F2 END FILL
```

UNIT 3 (ARRAY 3)



```
ARA=3  NUX=2  NUY=1  NUZ=1  
FILL F2 END FILL
```

```
UNIT 3  
COM='2x1x1 ARRAY OF SS BOXES  
ARRAY 3 -24.5 -12.25 -10.25
```



```
GLOBAL UNIT 4  
COM='ARRAY OF FUEL IN CASK'  
ARRAY 2 -36.75 -12.25 -10.25  
CYLINDER 0 1 44.5 2P10.25  
HOLE 3 0.0 24.5 0.0  
HOLE 3 0.0 -24.5 0.0  
CYLINDER 2 1 65.0 2P30.75
```

Triangular Pitched Arrays



```
UNIT 1
ZHEMICYL-Y 1 1 2.0 2P50.0
```



```
UNIT 2
ZHEMICYL+Y 1 1 2.0 2P50.0
```



```
UNIT 3
ZHEMICYL-X 1 1 2.0 2P50.0
```



```
UNIT 4
ZHEMICYL+X 1 1 2.0 2P50.0
```



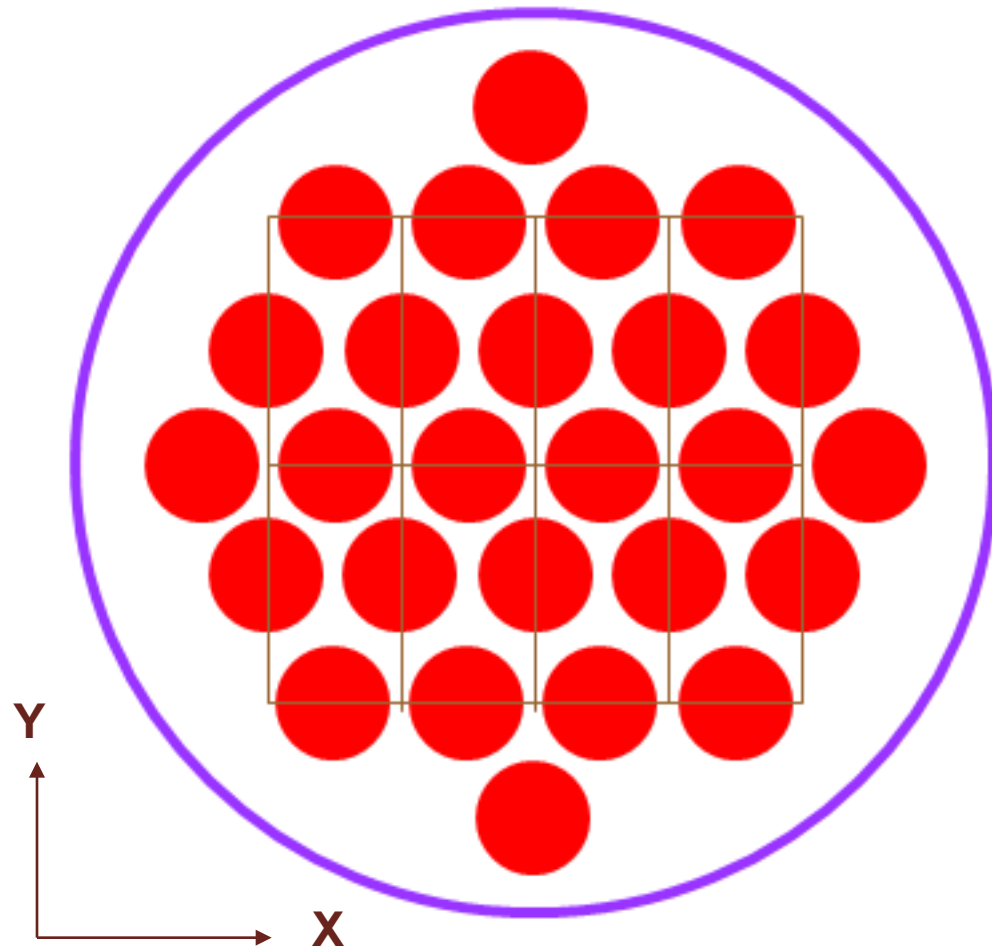
```
UNIT 5
ZHEMICYL+X 1 1 2.0 2P50.0 ORIGIN -2.0 0.0
CUBOID 0 1 2P2.0 2P3.46411 2P50.0
HOLE 1 0.0 3.46411 0.0
HOLE 2 0.0 -3.46411 0.0
HOLE 3 2.0 0.0 0.0
```



```
UNIT 6
CYLINDER 1 1 2.0 2P50.0
```

**Assume the rods described
in the array are 2.0 cm in
radius, 100 cm tall and
composed of mixture 1.**

Triangular Pitched Arrays in a Cylinder



*Array 1 is filled with Unit 5
from previous slide

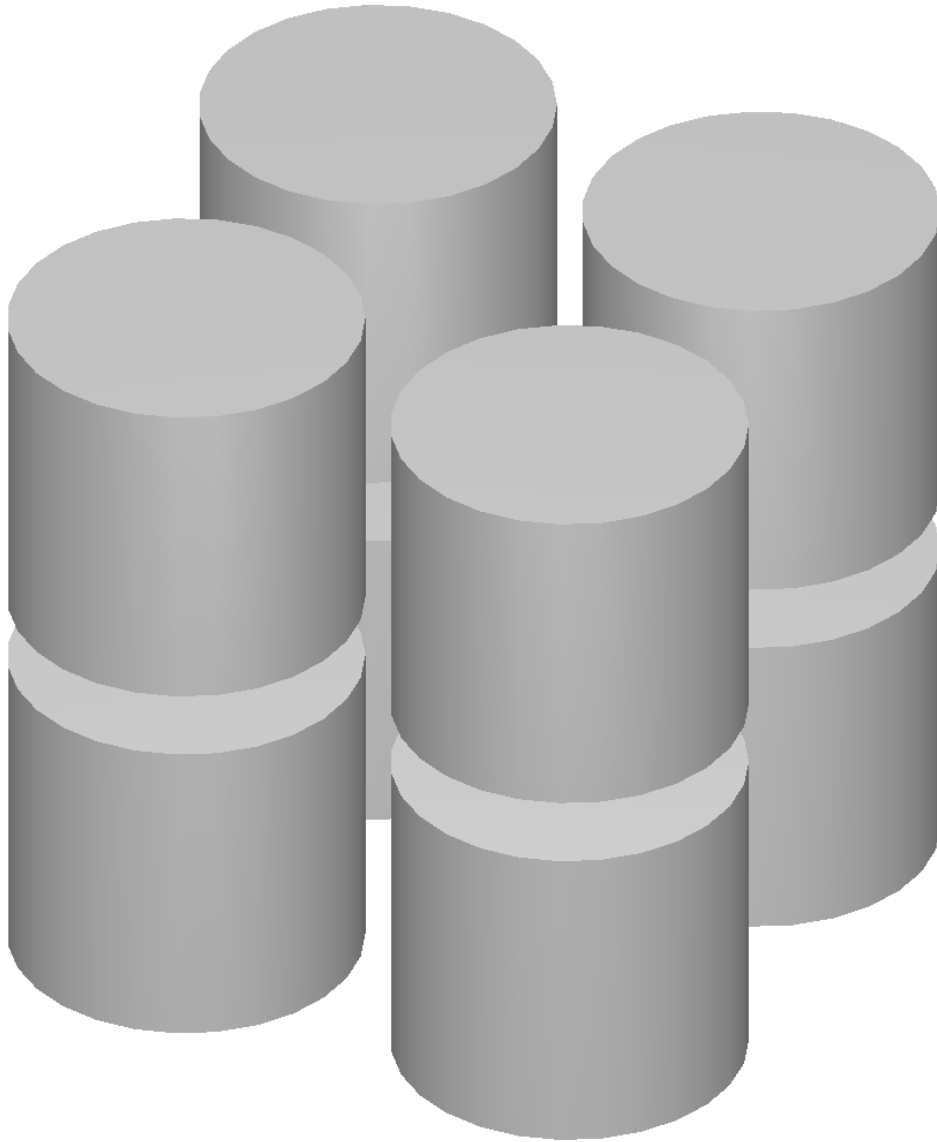
```
GLOBAL UNIT 7
ARRAY 1 -8.0 -6.92822 -50.0
CYLINDER 0 1 12.4 2P50.0
HOLE 1 -6.0 -6.92822 0.0
HOLE 1 -2.0 -6.92822 0.0
HOLE 1 2.0 -6.92822 0.0
HOLE 1 6.0 -6.92822 0.0
HOLE 2 -6.0 6.92822 0.0
HOLE 2 -2.0 6.92822 0.0
HOLE 2 2.0 6.92822 0.0
HOLE 2 6.0 6.92822 0.0
HOLE 3 -8.0 -3.46411 0.0
HOLE 3 -8.0 3.46411 0.0
HOLE 4 8.0 -3.46411 0.0
HOLE 4 8.0 3.46411 0.0
HOLE 6 -10.0 0.0 0.0
HOLE 6 0.0 10.39233 0.0
HOLE 6 10.0 0.0 0.0
HOLE 6 0.0 -10.39233 0.0
CYLINDER 2 1 12.65 2P50.0
END GEOM
READ ARRAY
ARA=1 NUX=4 NUY=2 NUZ=1
FILL F5 END FILL
END ARRAY
```

Array application demo

- 2c8 – Take 2



2c8



8 Uranium Cylinders

5.748 cm radius

10.765 cm length

13.74 cm center to center spacing in X and Y dimensions

13.01 cm center to center spacing in Z dimension

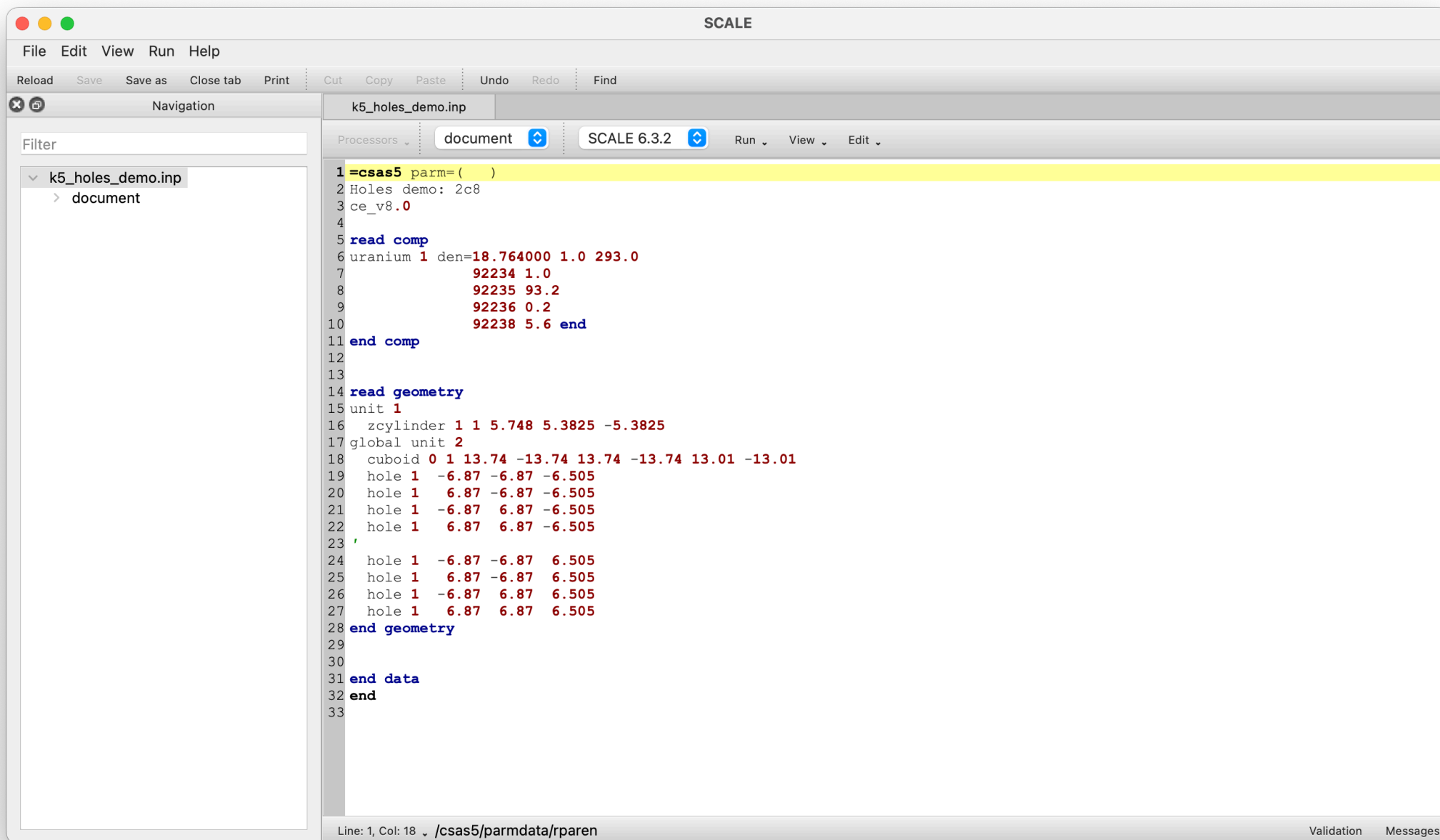
Uranium Metal

Density = 18.764 gm / cc

Enrichment:

93.2%	U-235
5.6%	U-238
1.0%	U-234
0.2%	U-236

Open input from HOLEs version

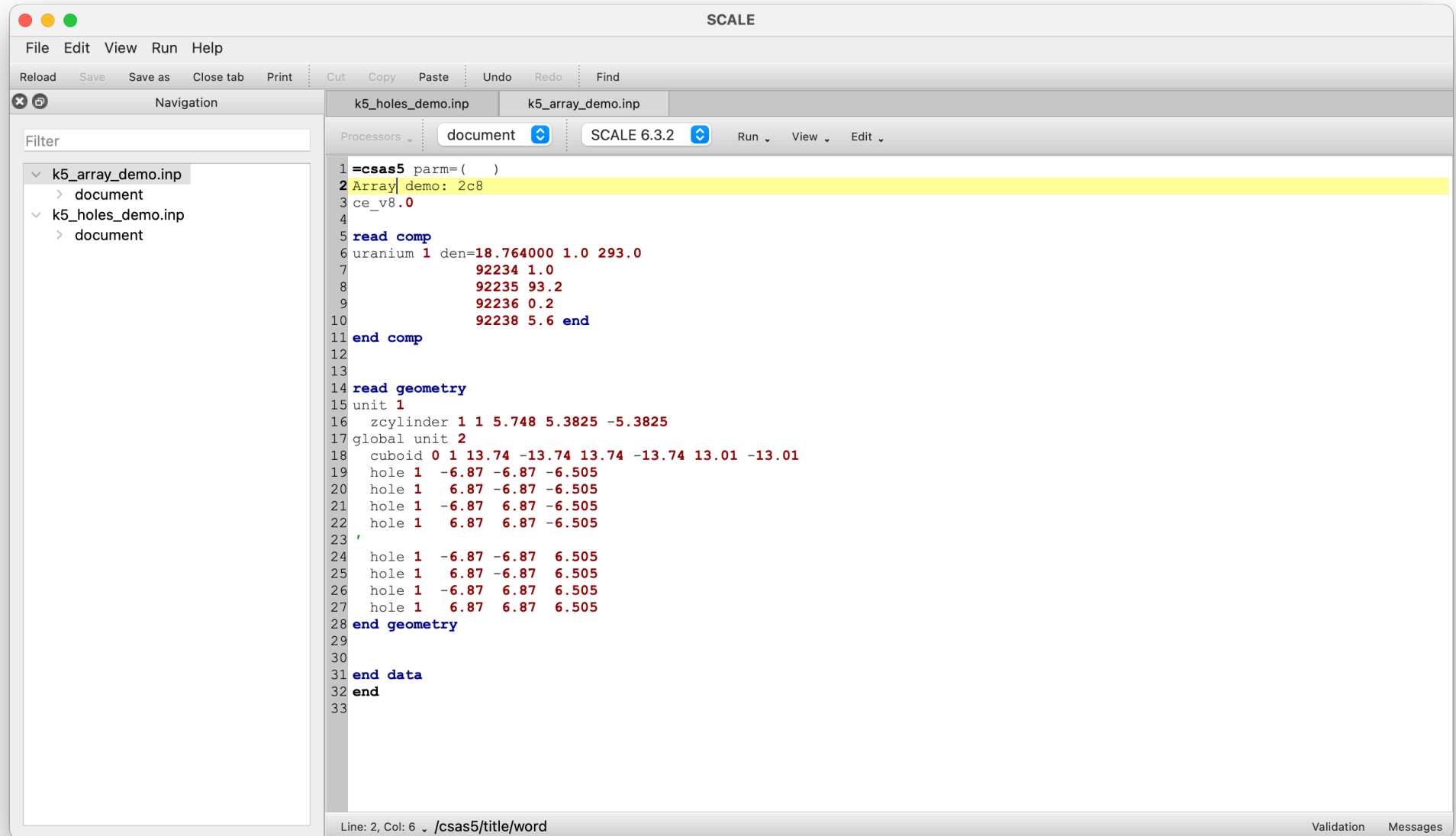


The screenshot displays the SCALE 6.3.2 application window. The title bar reads "SCALE". The menu bar includes "File", "Edit", "View", "Run", and "Help". Below the menu bar is a toolbar with buttons for "Reload", "Save", "Save as", "Close tab", "Print", "Cut", "Copy", "Paste", "Undo", "Redo", and "Find". The main interface is divided into three panes. The left pane, titled "Navigation", shows a tree view with "k5_holes_demo.inp" expanded, revealing a sub-entry "document". The top right pane shows the active document "document" and the version "SCALE 6.3.2". The bottom right pane displays the input file content, which is a text file with the following text:

```
1 =csas5 parm=( )
2 Holes demo: 2c8
3 ce_v8.0
4
5 read comp
6 uranium 1 den=18.764000 1.0 293.0
7           92234 1.0
8           92235 93.2
9           92236 0.2
10          92238 5.6 end
11 end comp
12
13
14 read geometry
15 unit 1
16 zcylinder 1 1 5.748 5.3825 -5.3825
17 global unit 2
18 cuboid 0 1 13.74 -13.74 13.74 -13.74 13.01 -13.01
19 hole 1 -6.87 -6.87 -6.505
20 hole 1 6.87 -6.87 -6.505
21 hole 1 -6.87 6.87 -6.505
22 hole 1 6.87 6.87 -6.505
23 '
24 hole 1 -6.87 -6.87 6.505
25 hole 1 6.87 -6.87 6.505
26 hole 1 -6.87 6.87 6.505
27 hole 1 6.87 6.87 6.505
28 end geometry
29
30
31 end data
32 end
33
```

The status bar at the bottom indicates "Line: 1, Col: 18" and the file path "/csas5/parmdata/rparen". On the right side of the status bar, there are links for "Validation" and "Messages".

Save a copy and change title



Unit 1: Add cuboid for array

- Only units with cuboid as outer shape can be used in arrays
- Size is selected to establish pitch of array
 - $\pm$ half pitch in X, Y, and Z

```
17 unit 1
18   zcylinder 1 1 5.748 5.3825 -5.3825
19   cuboid 0 1 6.87 -6.87 6.87 -6.87 6.505 -6.505
```

Add array block, then create array

```
22 read array
23   ara=1
24   prt=yes
25   nux=2
26   nuy=2
27   nuz=2
28   fill
29 ' z = 1
30     1 1
31     1 1
32 ' z = 2
33     1 1
34     1 1
35 end fill
```



array - kenova basic (configurable) ? X

ara	1
gbl	
prt	yes
nux	2
nuy	2
nuz	2
fill id	1
com	

```
ara=1
prt=yes
nux=2
nuy=2
nuz=2
fill
' z = 1
  1 1
  1 1
' z = 2
  1 1
  1 1
end fill
```

Results Log Template

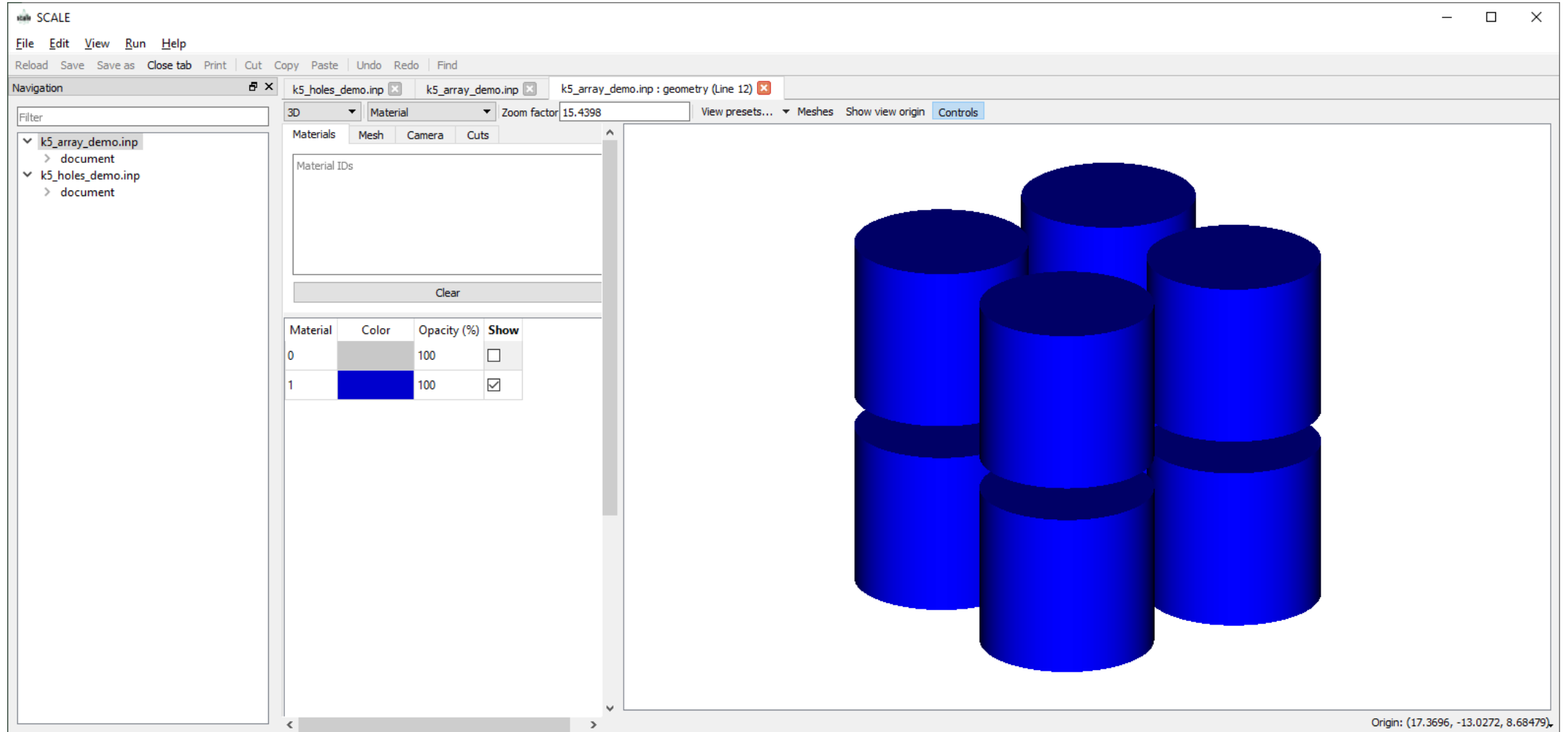
OK Cancel

Global Unit 2: Add array to unit

- Position most negative corner of array in unit coordinate system
 - Here it is irrelevant since there is nothing else in the unit
 - Choose position so that origin is at center of array
- In this case, could also have used global array instead of global unit

```
20 global unit 2
21 array 1 -13.74 | -13.74 -13.01
```

3D Rendering in Fulcrum, void not shown



Click Run:

The screenshot displays the SCALE 6.3.2 application window. The title bar reads "SCALE". The menu bar includes "File", "Edit", "View", "Run", and "Help". Below the menu bar is a toolbar with buttons for "Reload", "Save", "Save as", "Close tab", "Print", "Cut", "Copy", "Paste", "Undo", "Redo", and "Find". The main window is divided into three panes. The left pane, titled "Navigation", shows a tree view with two files: "k5_array_demo.inp" and "k5_holes_demo.inp", each containing a "document" sub-entry. The middle pane shows the input file "k5_holes_demo.inp" with the following content:

```
3 ce_v8.0
4
5 read comp
6 uranium 1 den=18.764000 1.0 293.0
7           92234 1.0
8           92235 93.2
9           92236 0.2
10          92238 5.6 end
11 end comp
12
13
14 read geometry
15 unit 1
16   zcylinder 1 1 5.748 5.3825 -5.3825
17   cuboid 0 1 6.87 -6.87 6.87 -6.87 6.505 -6.505
18 global unit 2
19   array 1 -13.74 -13.74 -13.01
20 end geometry
21
22 read array
```

The right pane shows the output of the execution, starting with the date "Tue Oct 1 15:41:19 2024". The output includes a table of results and a summary of the execution:

```
1448
1449 203 9.76552E-01 9.99941E-01 1.94636E-03 6.37895E+00 6.05000E-02
1450
1451
1452 array demo: 2c8
1453 ***** final results table *****
1454 best estimate system k-eff 0.9997 + or - 0.0019
1455
1456 Energy of average lethargy of Fission (eV) 8.42553E+05 + or - 2.36573E+03
1457 k-effective satisfies the chi**2 test for normality at the 95 % level
1458
1459 Scale job /Users/6tg/Desktop/k5_array_demo.inp is finished.
1460 Output is stored in /Users/6tg/Desktop/k5_array_demo.out
1461
1462 Process finished with 0 return code; ran in 5 secs, finished at Tue Oct 1 15:41:25 2024
```

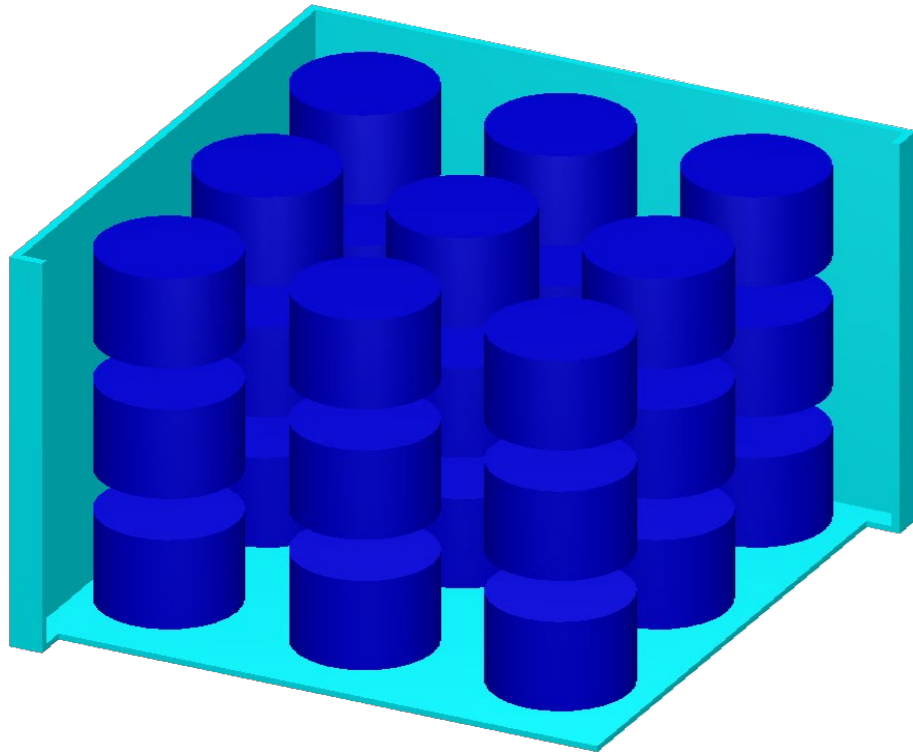
The status bar at the bottom indicates "Line: 14, Col: 14" and the file path "/csas5/geometry/decl". There are also buttons for "Validation" and "Messages".

Sub module 6: **Advanced KENO V.a** **geometry exercises**

- 1F27 Array
- Lollypop Tank
- 4 Aqueous – 4 Metal Array



1F27 Array



Container Pitch

29.08 cm in X and Y dimensions
27.81 cm in Z dimension

Material: Room Temperature

UO₂(NO₃)₂ Solution

Uranium density 415 g/L

Specific Gravity: 1.555

Excess acid: 0.009783 Molar

Enrichment:	U-234	1.0 wt%
	U-235	92.6 wt%
	U-236	0.5 wt%
	U-238	5.9 wt%

Plexiglas Cylinders

Density: default

ID: 19.04 cm

Outside Height: 19.05 cm

Wall Thickness: 0.64 cm

Solution Height 17.5609 cm

Plexiglas Reflector

On all six sides

Density: default

Thickness: 1.27 cm

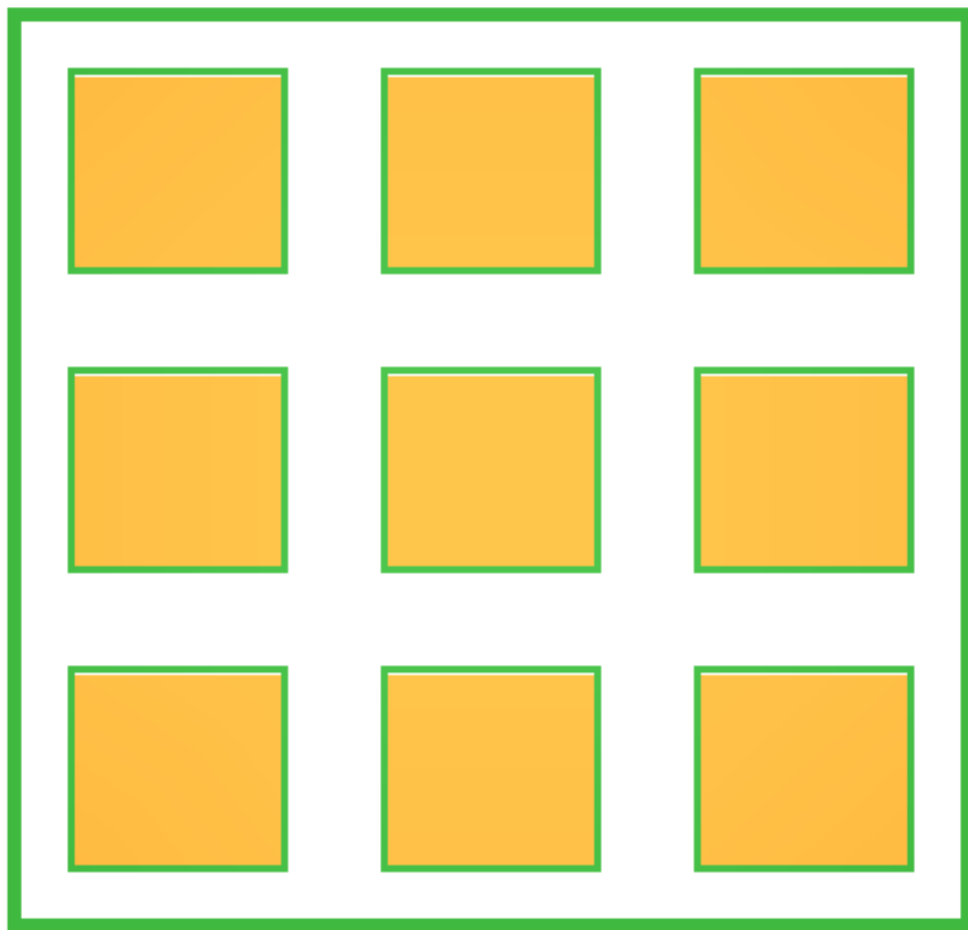
Distance from center of central container to

Inner surface of the reflector in X and Y: 43.620 cm

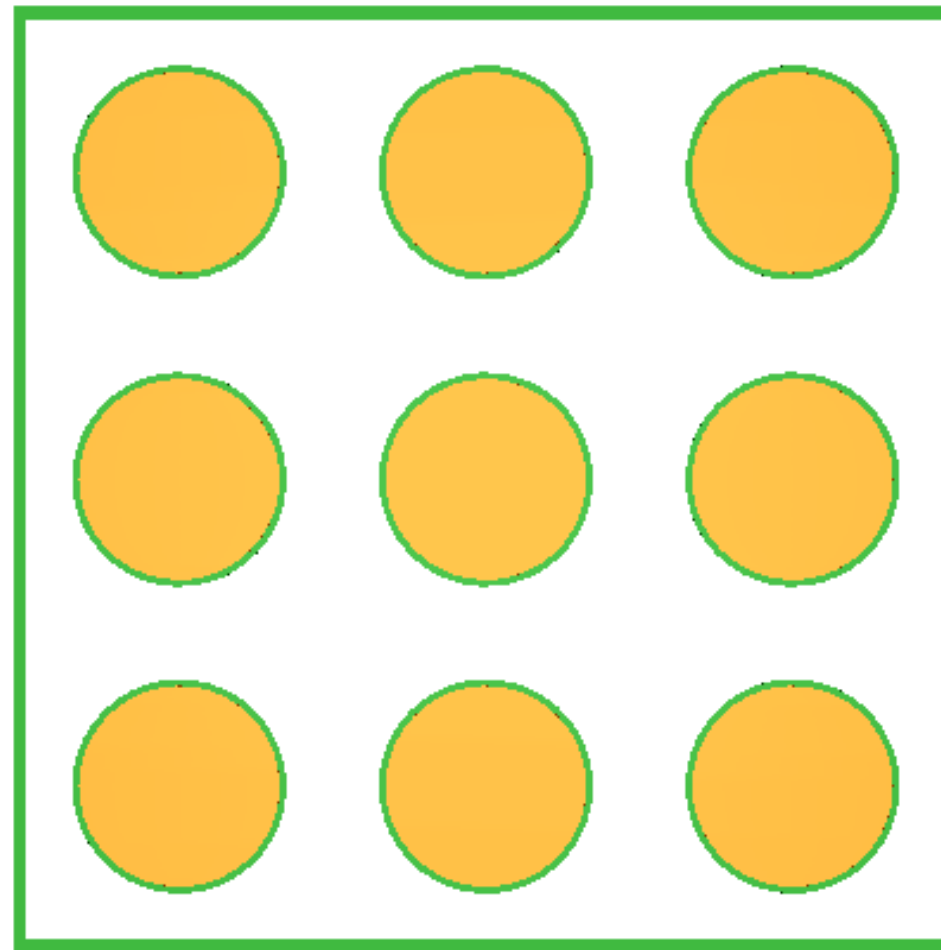
Distance from top of top unit and bottom of bottom
unit to reflector in Z: 4.38 cm

1F27 Array

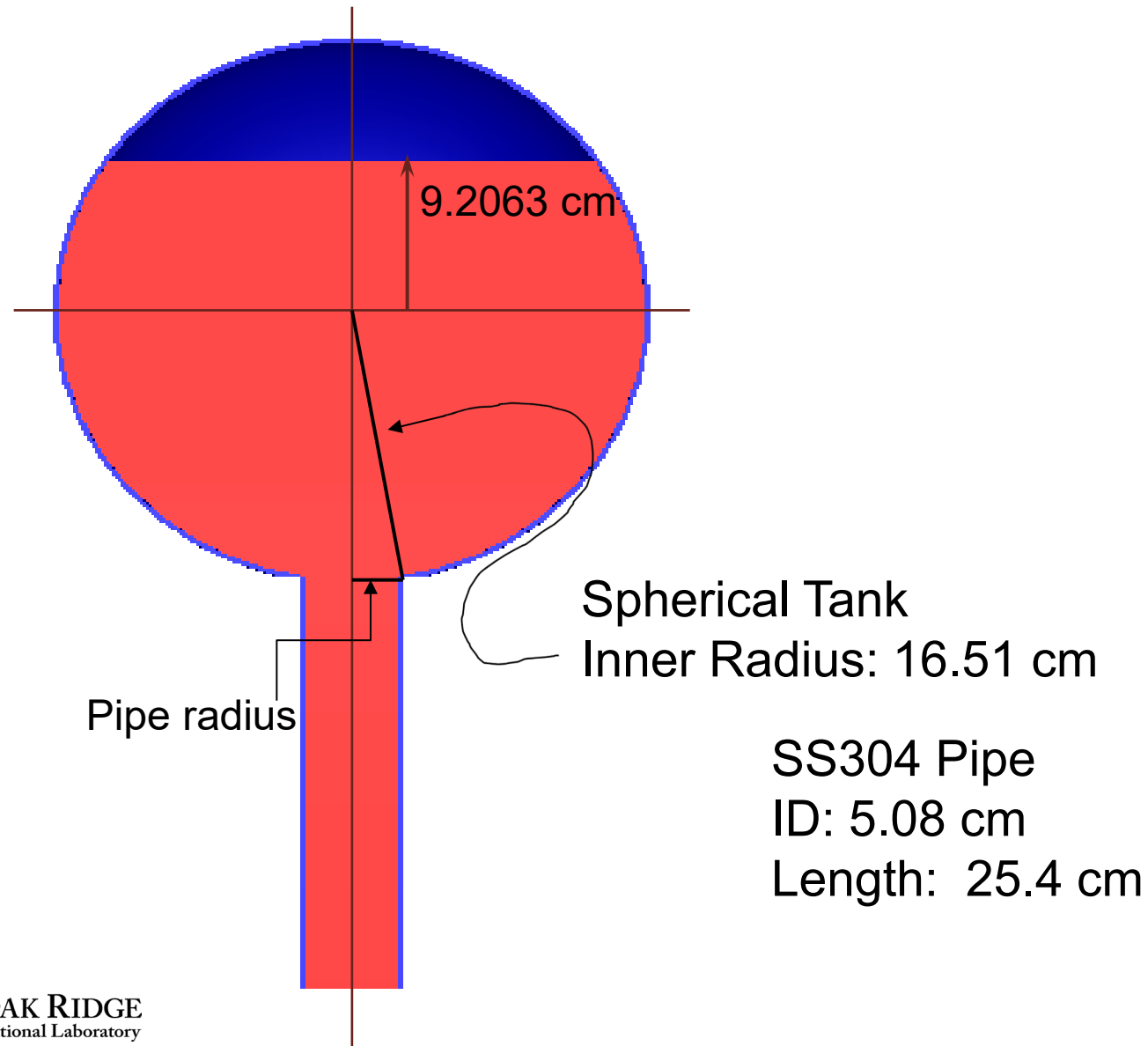
X-Z or Y-Z View



X-Y View



Lollypop Tank



Material:

Room Temperature

$\text{UO}_2(\text{NO}_3)_2$ Solution

345 g U/I Solution

Specific Gravity: default

Acid Molarity: 0.5 M

U-235 93.2 wt%

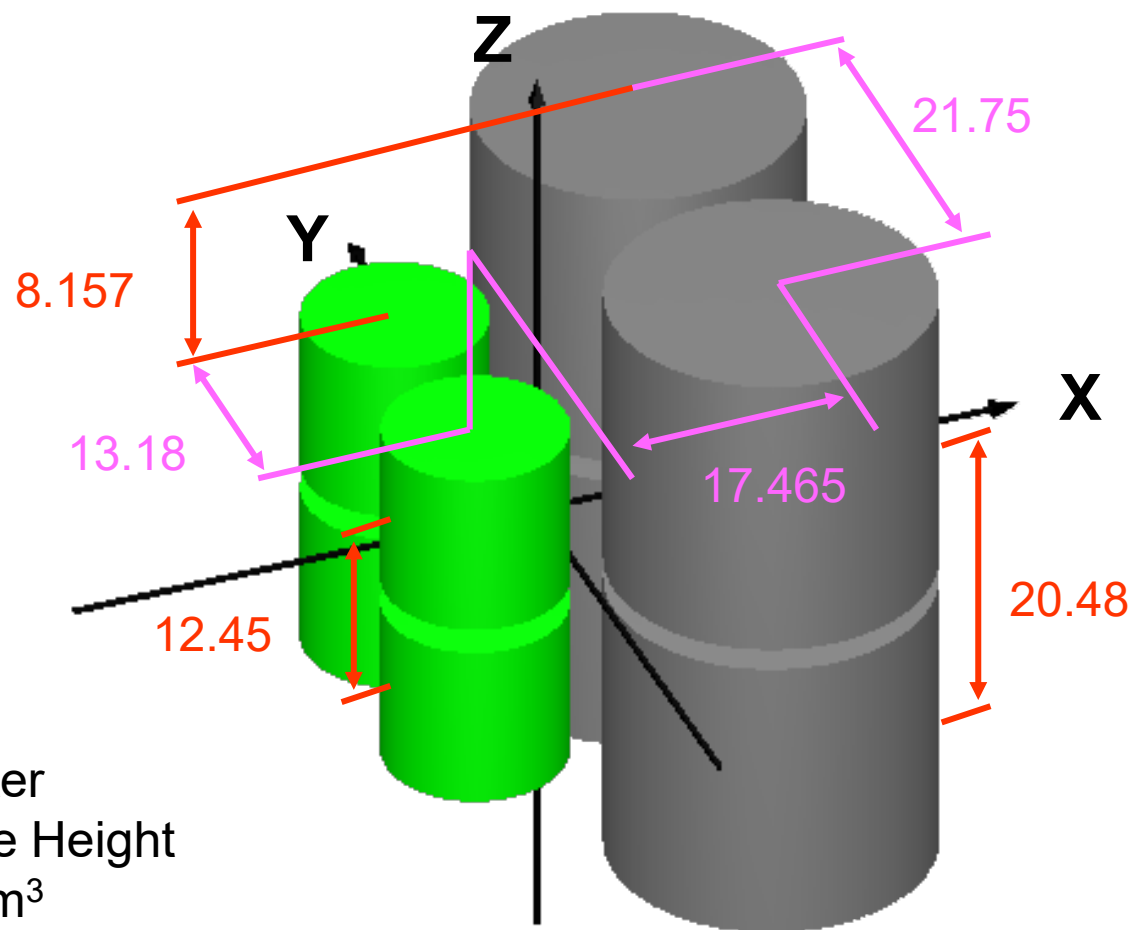
U-238 6.8 wt%

SS304 Stainless Steel Walls

Default density

Wall thickness: 0.3175 cm

4 Aqueous – 4 Metal Array



Metal Cylinders

11.496 cm Diameter

10.765 cm Outside Height

Density 18.76 g/cm³

Enrichment: U-234 1.0 wt%
U-235 93.2 wt%
U-236 0.2 wt%
U-238 5.6 wt%

UO₂(NO₃)₂ Solution

415 g U/I Solution

Density: 1.555 g/cm³

0.009783 M excess HNO₃

UO₂(NO₃)₂ Enrichment:

U-234 1.0 wt%

U-235 92.6 wt%

U-236 0.5 wt%

U-238 5.9 wt%

Plexiglas Containers

19.05 cm ID

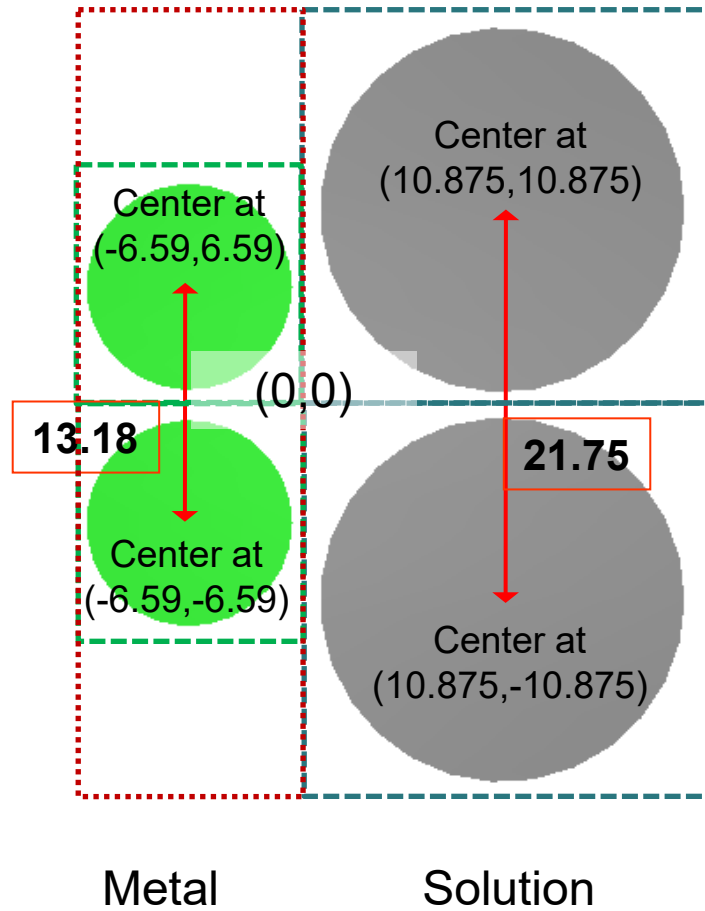
19.05 cm Outside Height

0.635 cm thick wall & ends

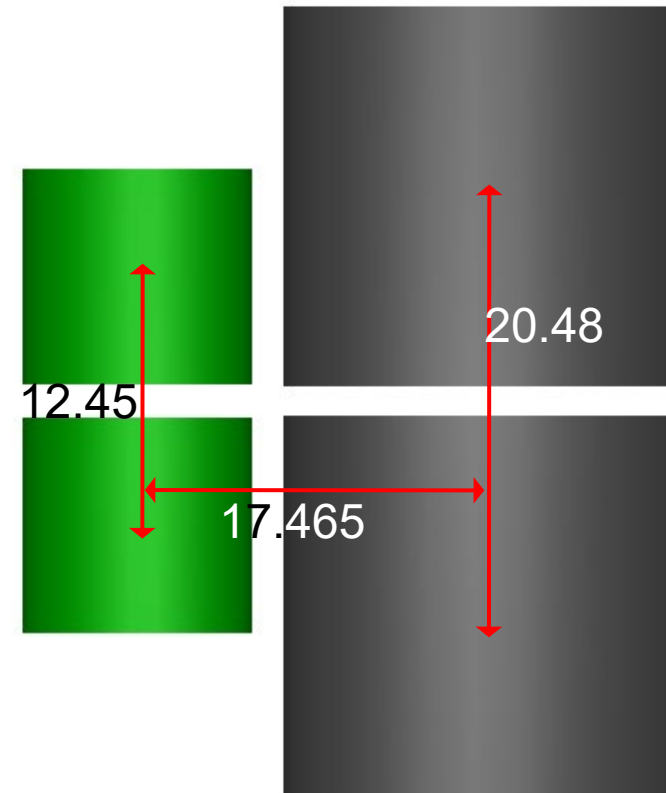
Filled with UO₂(NO₃)₂ Solution

4A-4M Array

X-Y View



X-Z View



Calculated k-eff values (CE ENDF/B-VII.1)

	KENO V.a	Shift
1F27 Array	0.9872 +/- 0.0026	0.985581 +/- 0.003499
Lollypop	0.9953 +/- 0.0024	0.985813 +/- 0.004123
4 Aqueous/4 Metal Array	1.0016 +/- 0.0022	0.999000 +/- 0.003184

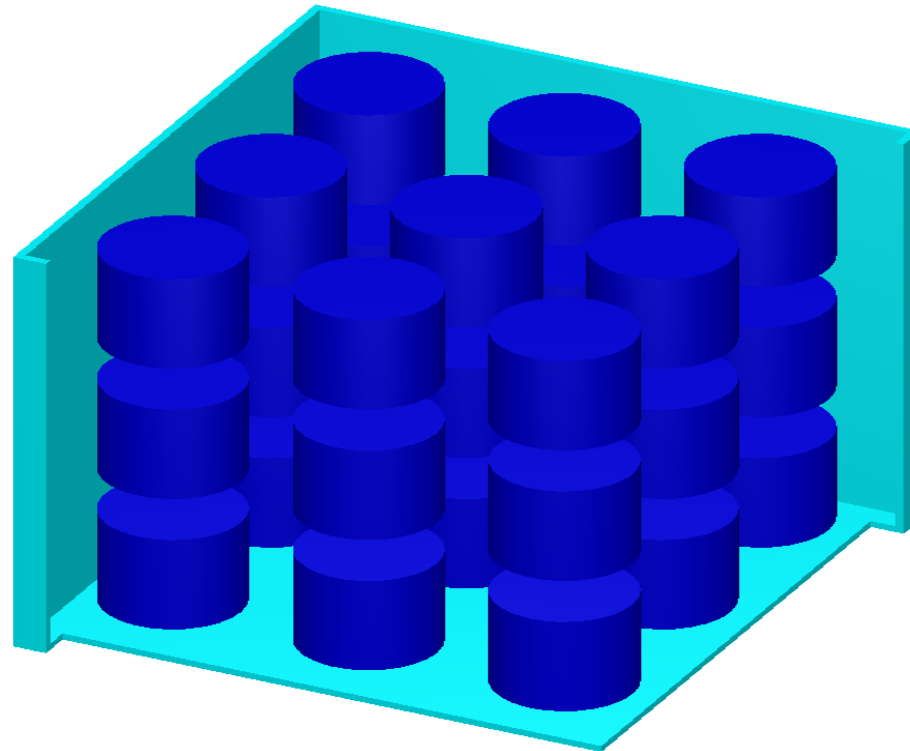
Your results may differ based on the options and computer used

1F27 Array

```
=csas5
1f27
ce_v7.1_endf
read comp
  solution    mix=1  rho[uo2(no3)2]=415 92235 92.6    92238 5.9  92234 1  92236 0.5
    molar[hno3]=0.009783  density=1.555 temperature=293    end solution
  plexiglas    2 1 293 end
end comp
read geometry
unit 1
com='1f unit - solution in a plexiglas container'
  zcylinder 1 1 9.52  17.5609  0
  zcylinder 0 1 9.52  17.77  0
  zcylinder 2 1 10.16  18.41  -0.64
  cuboid 0 1  14.54  -14.54  14.54  -14.54  22.79  -5.02
```

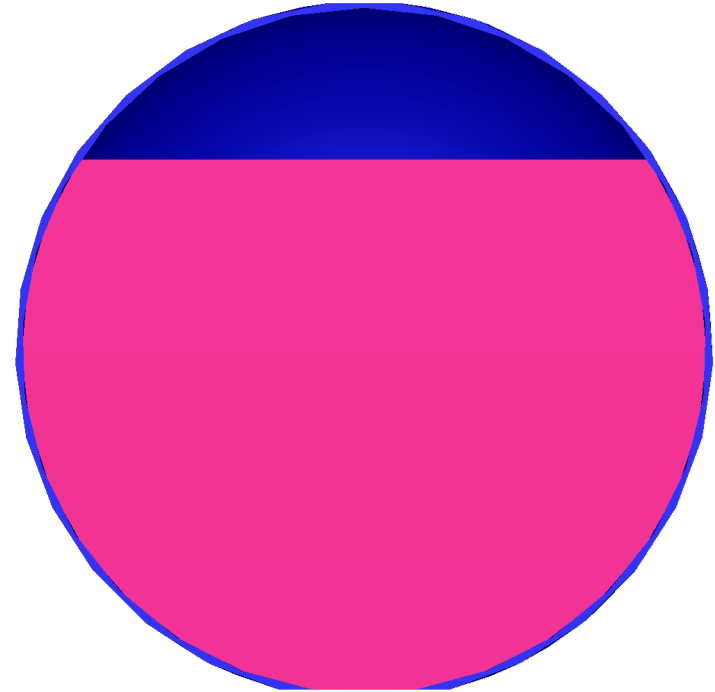
1F27 Array (cont.)

```
global unit 2
com='3x3x3 array of 1f units with a 1/2 inch plexiglas reflector'
  array 1 0 0 0
  replicate 2 1 1.27 1.27 1.27 1.27 1.27 1.27 1
end geometry
read array
ara=1 nux=3 nuy=3 nuz=3
fill 27*1 end fill
end array
end data
end
```



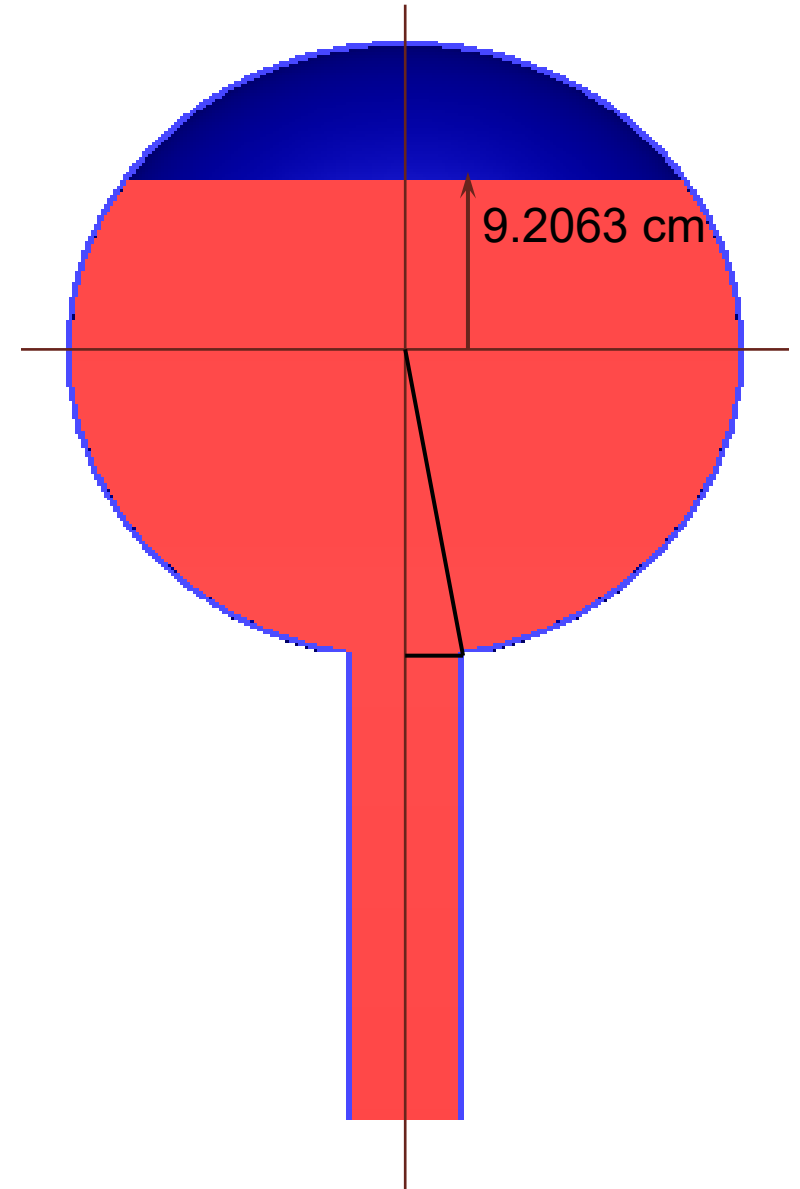
Lollypop

```
=csas5
lollypop
ce_v7.1_endf
read comp
  solution      mix=1  rho[uo2(no3)2]=345 92235 93.2
              92238 6.8 molar[hno3]=0.5 density=? temperature=293
  end solution
  ss304          2 1 293 end
end comp
read geometry
unit 1
com='spherical tank with bottom cut off'
hemisphe+z 0 1 16.51 chord -9.2063
hemisphe+z 1 1 16.51 chord 16.3134
hemisphe+z 2 1 16.8275 chord 16.3134
cuboid 0 1 17 -17 17 -17 17 -16.3134
```



Lollypop (cont.)

```
unit 2
com='cylindrical pipe '
  zcylinder 1 1 2.54 25.4 0
  zcylinder 2 1 2.8575 25.4 0
  cuboid 0 1 17 -17 17 -17 25.4 0
end geometry
read array
ara=1 nux=1 nuy=1 nuz=2 gbl=1
fill 2 1
end fill
end array
end data
end
```

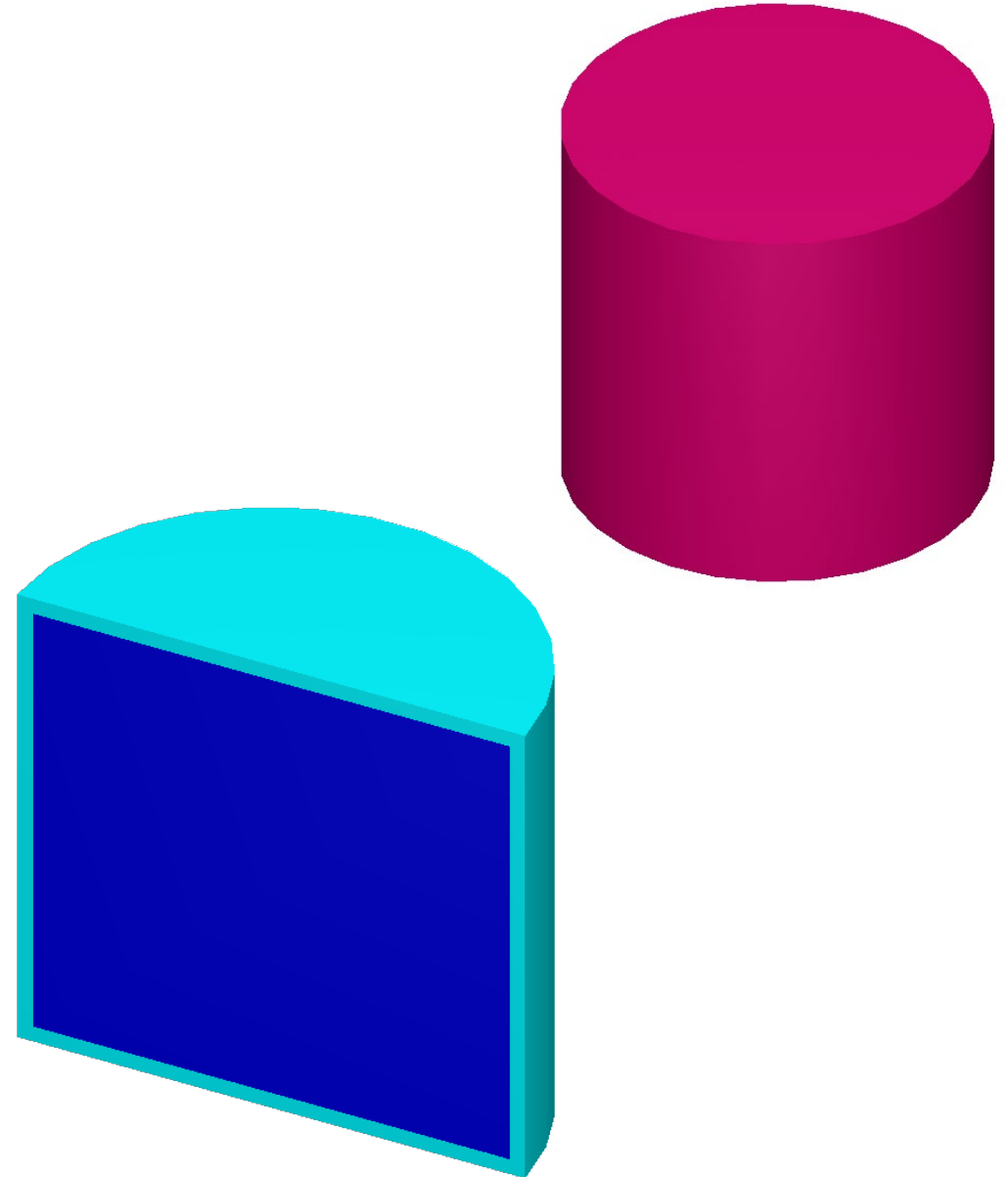


4A-4M

```
=csas5 parm=( )  
Class exercise: 4a-4m  
ce_v7.1  
  
read comp  
u 1 den=18.76 1.0 293 92234 1.0 92235 93.2 92236 0.2 92238 5.6 end  
solution mix=2  
    rho[uo2(no3)2]=415.0 92234 1.0 92235 92.6 92236 0.5 92238 5.9  
    molar[hno3]=0.009783  
    density=1.555 temp=293 volfrac=1.0  
end solution  
plexiglas 3 end  
end comp
```

4A-4M (cont.)

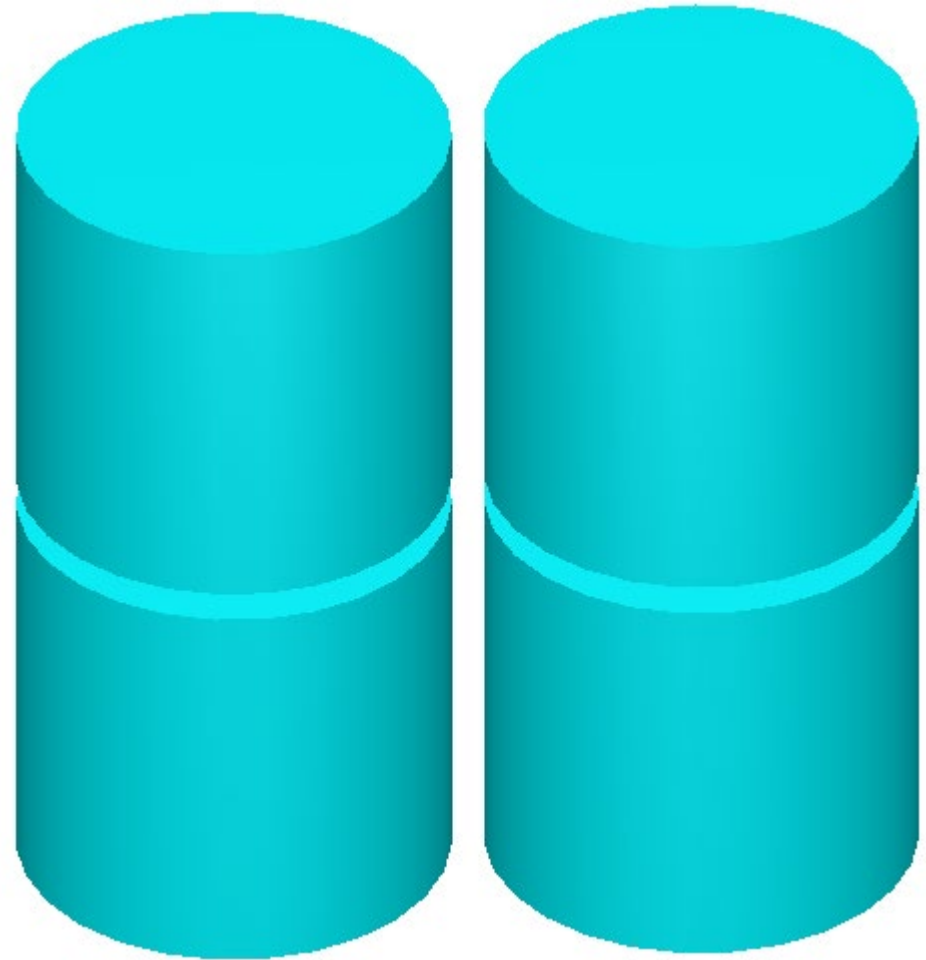
```
unit 1
com='metal cylinders'
  cylinder 1 1 5.748 5.3825 -5.3825
  cuboid 0 1 4p6.59 2p6.225
unit 2
com='solution cylinders'
  cylinder 2 1 9.525 8.889 -8.889
  cylinder 3 1 10.16 9.525 -9.525
  cuboid 0 1 4p10.875 10.24 -10.24
```



4A-4M (cont.)

```
unit 3
com='array of solution tanks'
array 2 0 0 0

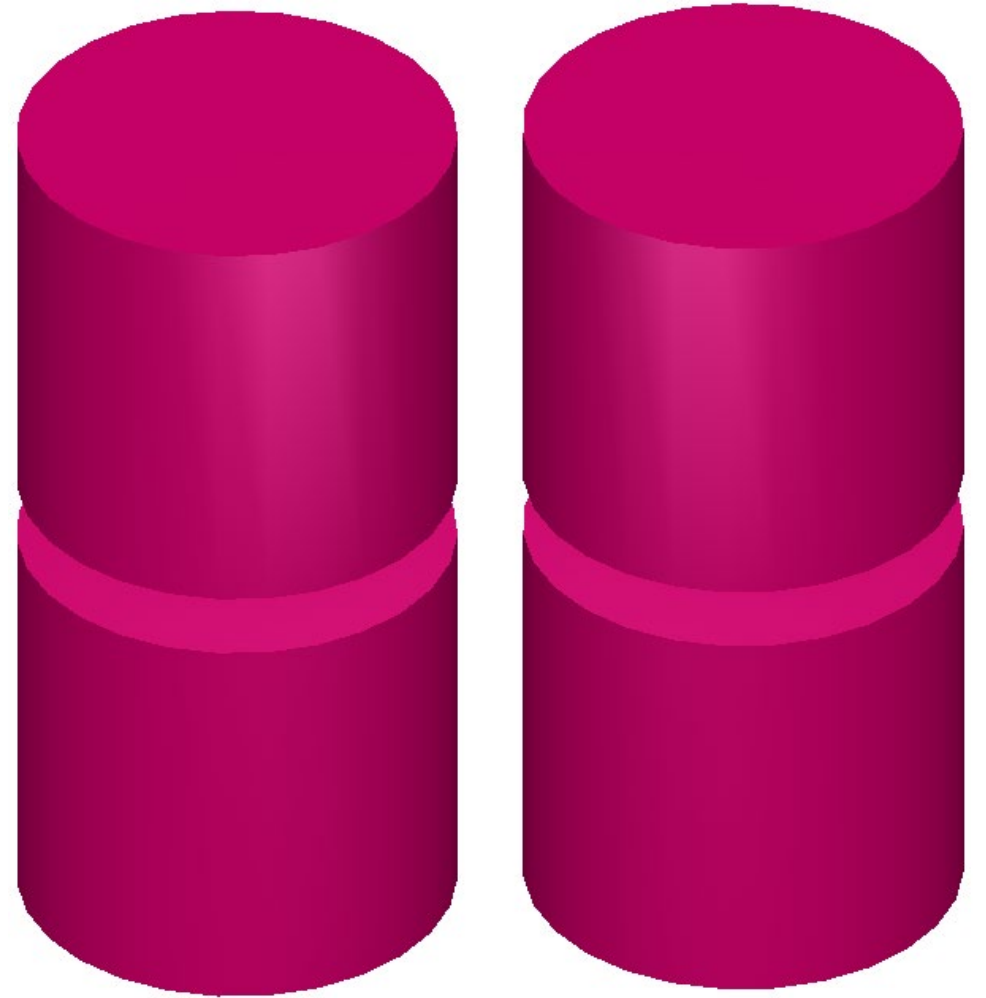
ara=2
prt=yes
nux=1
nuy=2
nuz=2
com="Array of solution tanks"
fill
' z = 1
2
2
' z = 2
2
2
end fill
```



4A-4M (cont.)

```
unit 4
com='array of metal cylinders'
  array 1 -6.59 -13.18 -12.45
  cuboid 0 1 6.59 -6.59 21.75 -21.75 20.48 -20.48
```

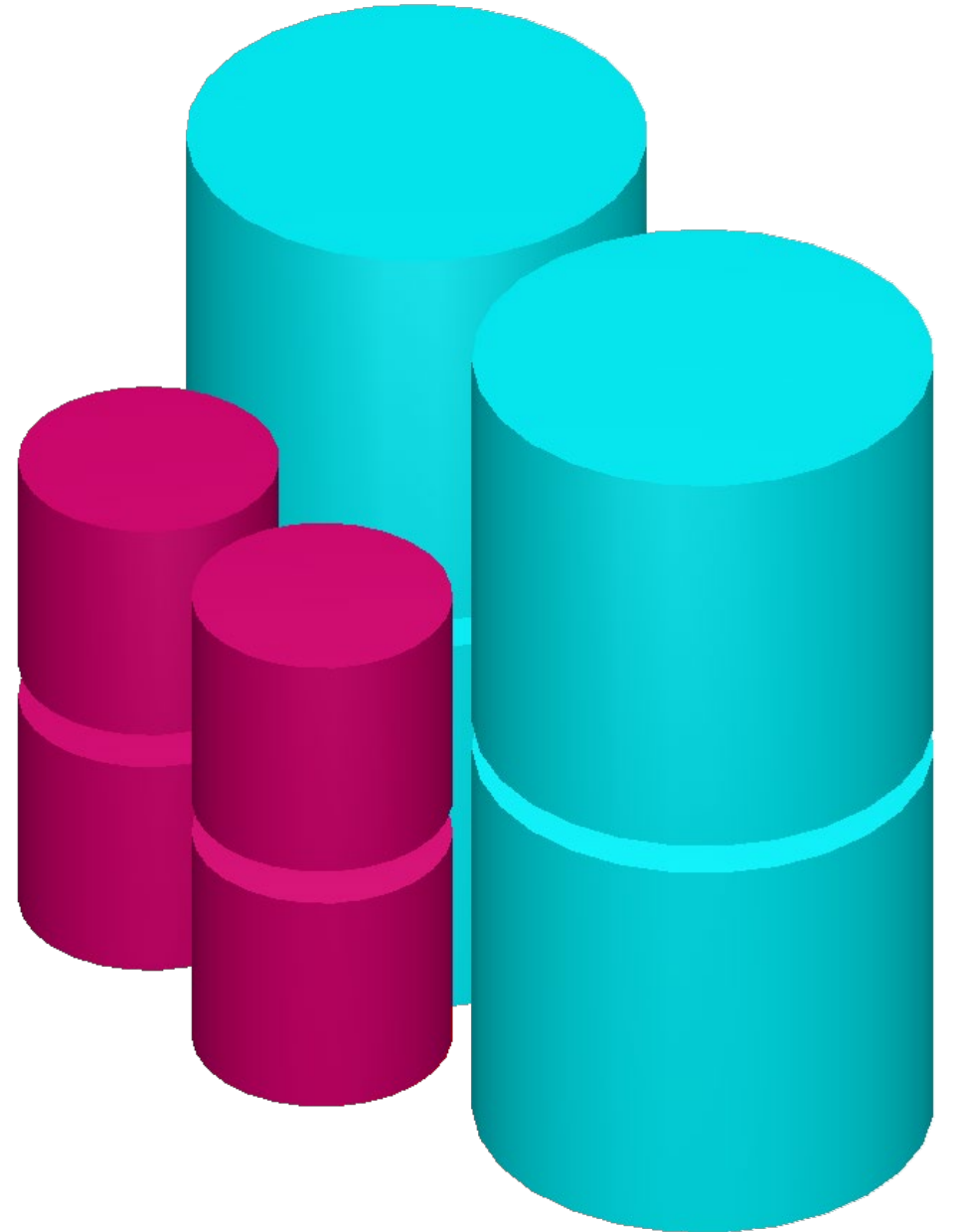
```
ara=1 nux=1 nuy=2 nuz=2
com='array of metal cylinders'
fill 1 1
      1 1 end fill
```



4A-4M (cont.)

```
global unit 5  
com='global, containing array of arrays'  
array 3 0 0 0
```

```
ara=3 nux=2 nuy=1 nuz=1  
com='array of arrays'  
fill 4 3 end fill
```



Sub module 7: **Additional advanced KENO V.a geometry exercises**

- Pins in a Tank
- Shipping Cask



Pins in a Tank

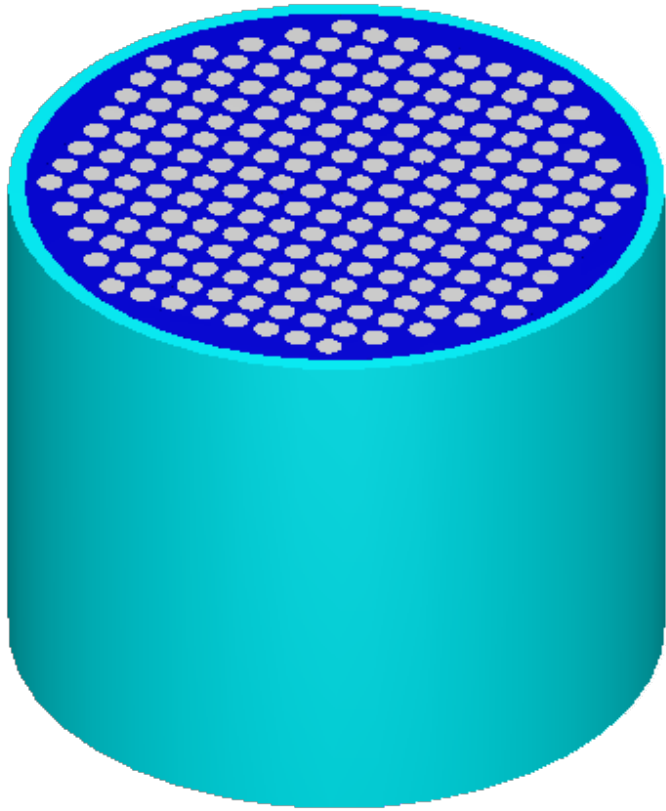


Figure shows tank cut in half
(in Z) without the reflector

RODS

0.75 cm OD X 30.0 cm long

Pitch: 1.0 cm

Fuel: 20 wt% enriched U metal
default density
(No ^{234}U or ^{236}U in fuel)

TANK

18 cm ID

60 cm Inside Height

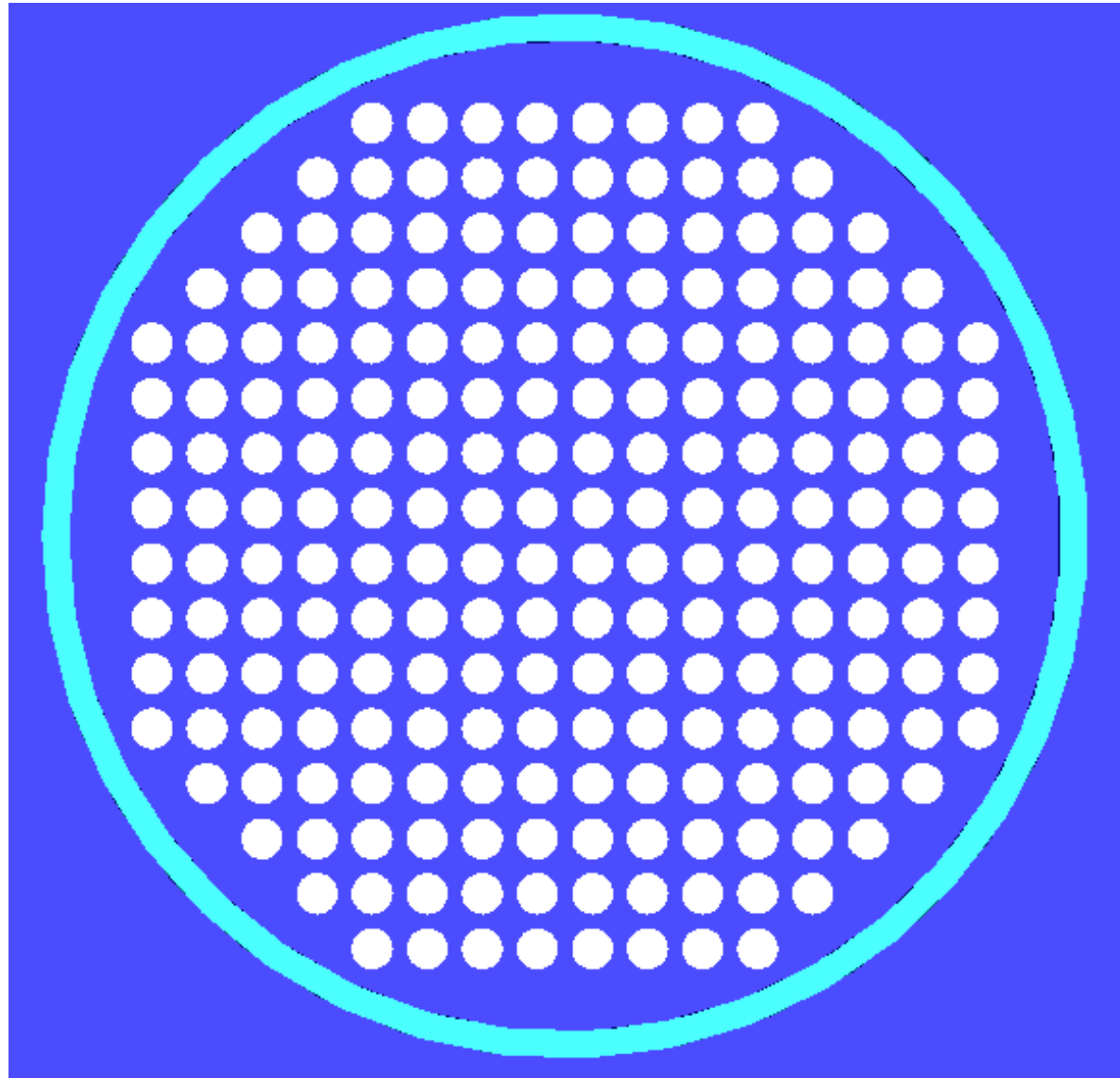
Wall & Bottom 0.5 cm Aluminum

Tank is filled to 45 cm with H_2O

Tank is reflected on the bottom and
sides with 30 cm H_2O

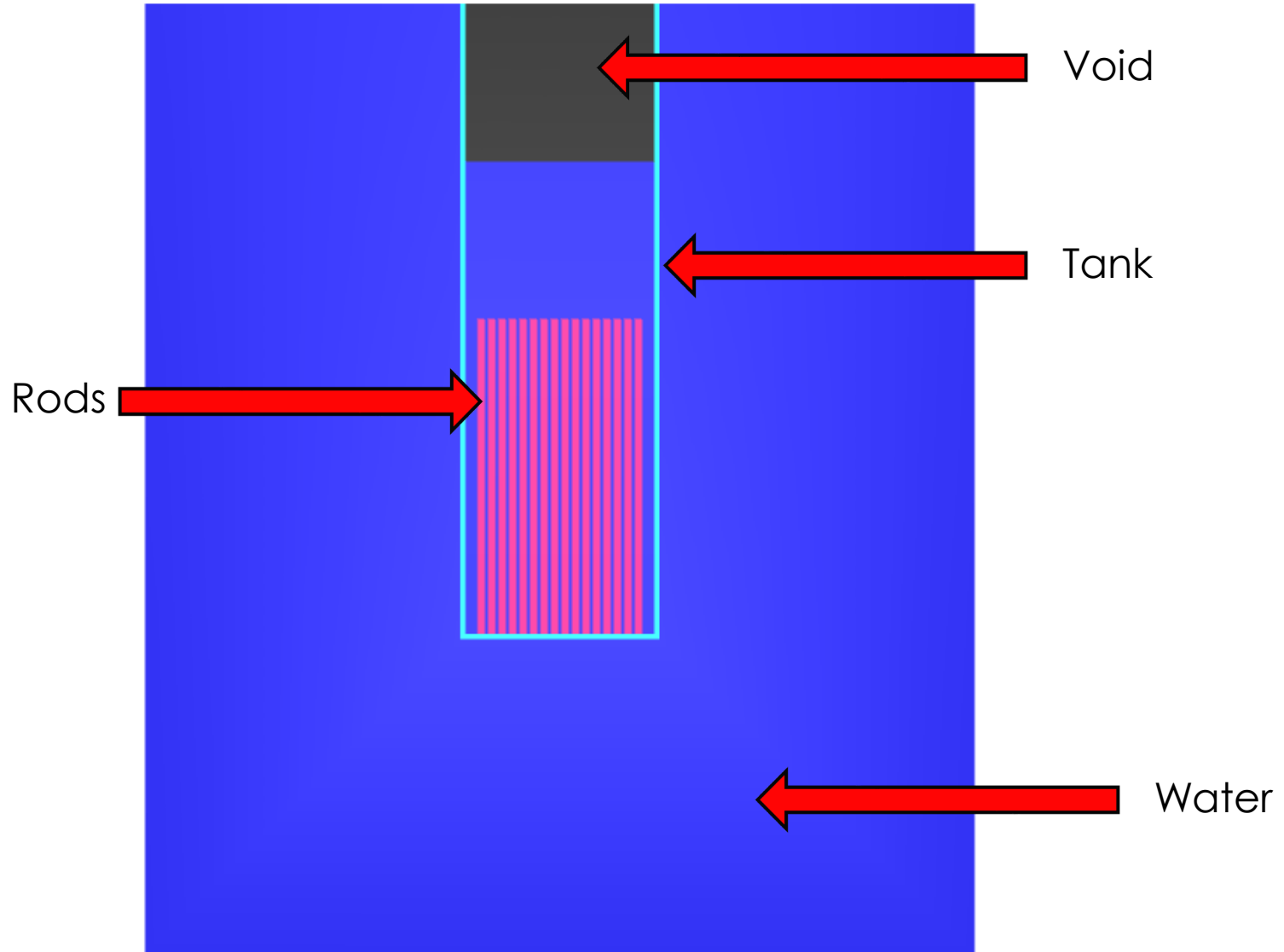
Fuel rods sit on the tank bottom

Pins in a Tank (radial view)

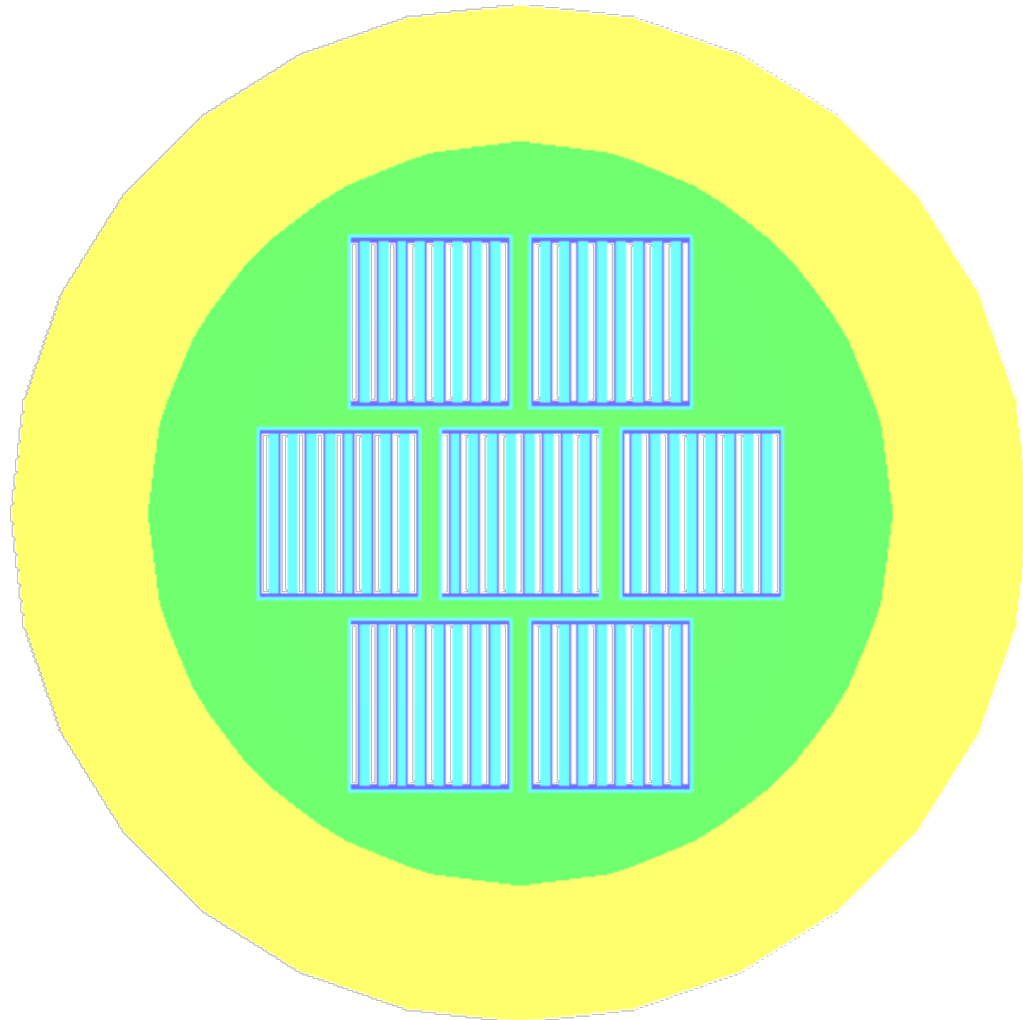


**Reflector is
not shown
completely**

Pins in a Tank (axial view)



Shipping Cask



SS304 Fuel Cask

30.0cm radius x 100 cm length (outer)

22 cm radius x 80 cm length (inner)

SS-304 density = 7.92 g/cm^3

Cask cavity filled with Al (2.70 g/cm^3)

U-Al Fuel Plates

density = 3.78 g/cm^3

93.36 wt% Aluminum

6.64 wt% Uranium

U-235: 92.85 wt %

U-238: 7.15 wt %

Fuel Plate Dimensions:

0.4 cm fuel thickness

9.4 cm fuel width

60.0 cm length

0.05 cm Al cladding on all sides

Al density = 2.7 g/cm^3

Use NPG ≥ 2000

Shipping Cask (continued)

Fuel Assembly

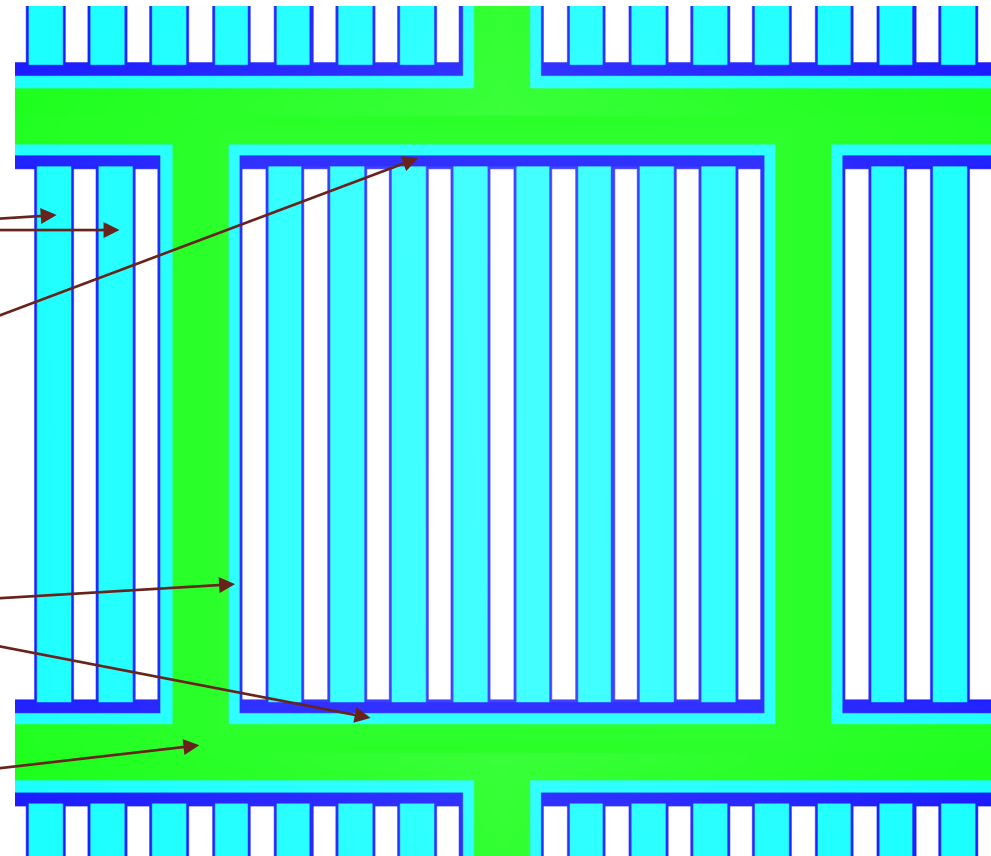
9 fuel plates

0.6 cm H₂O gap between plates

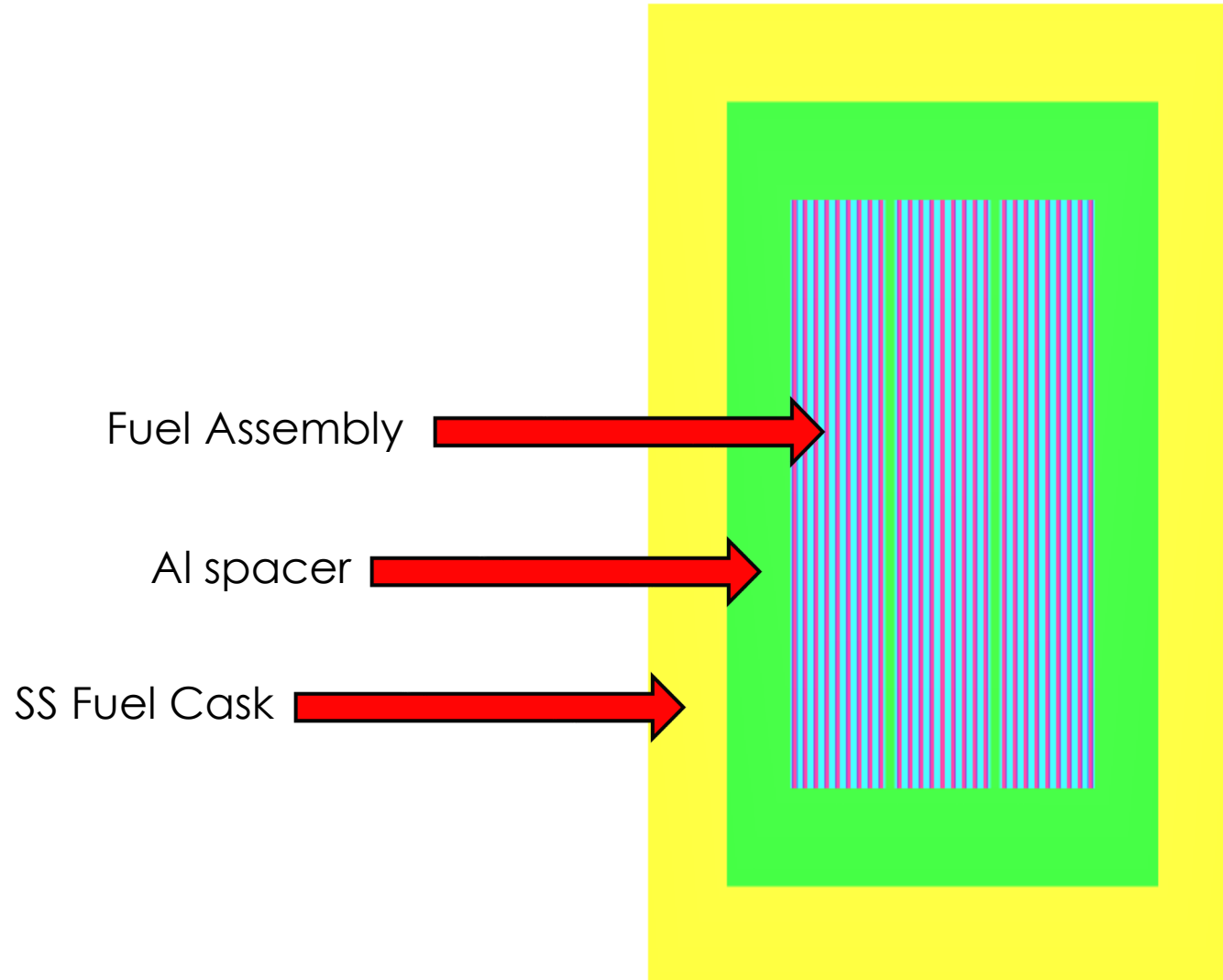
0.2 cm thick Al plate connects fuel plates

0.2 cm H₂O on all 4 sides

1 cm Al (2.70 g/cm³) spacer between assemblies



Shipping Cask (continued)



Calculated k-eff values (ENDF/B-VII.1)

KENO V.a	k_{eff}	Std Dev	Run-time (s)	Comparison (MG-CE)
Pins in a tank (CE)	0.8720	0.0019	220.70	-0.0065 $\pm$ 0.0030 (~2.2 σ difference)
Pins in a tank (MG)	0.8655	0.0023	100.25	
Shipping cask (CE)	0.8769	0.0014	171.39	0.0066 $\pm$ 0.0021 (~3.0 σ difference)
Shipping cask (MG)	0.8835	0.0017	57.07	

Your results may differ based on the options and computer used

Calculated k-eff values (ENDF/B-VII.1)

Shift	k_{eff}	Std Dev	Run-time (s)	Comparison (MG-CE)
Pins in a tank (CE)	0.867806	0.002607	414.34	-0.005721 $\pm$ 0.003755 (~1.5 σ difference)
Pins in a tank (MG)	0.862085	0.002703	362.58	
Shipping cask (CE)	0.878309	0.002356	264.01	0.002905 $\pm$ 0.003045 (~1.0 σ difference)
Shipping cask (MG)	0.881214	0.001929	163.58	

Your results may differ based on the options and computer used

Calculated k-eff values

	KENO V.a	Shift
Pins in a tank (CE)	0.8720 +/- 0.0019	0.867806 +/- 0.002607
Pins in a tank (MG)	0.8655 +/- 0.0023	0.862085 +/- 0.002703
Shipping cask (CE)	0.8769 +/- 0.0014	0.878309 +/- 0.002356
Shipping cask (MG)	0.8835 +/- 0.0017	0.881214 +/- 0.001929

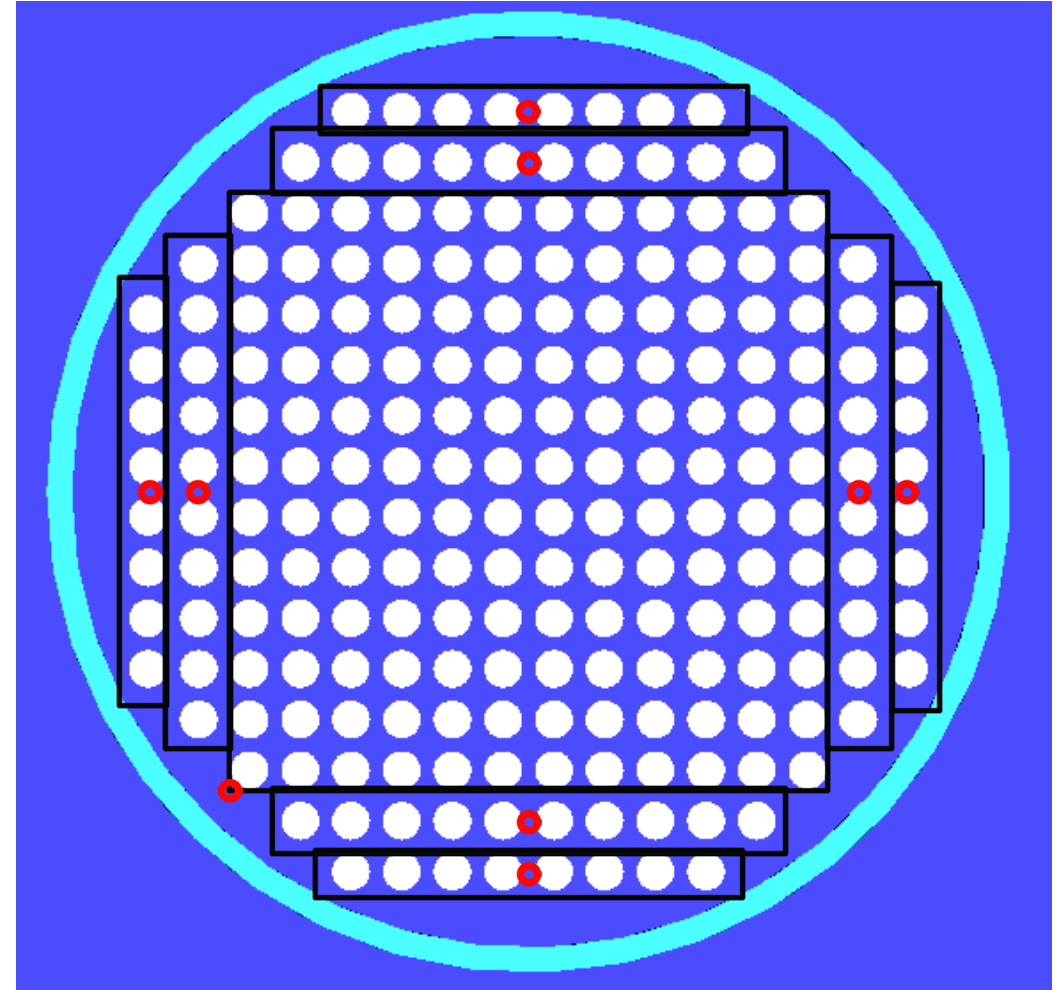
Your results may differ based on the options and computer used

Pins in a Tank

```
=csas5
pins in a tank
ce_v7.1_endf
read comp
  uranium      1 1 293 92235 20 92238 80 end
  h2o          2 1 293 end
  al           3 1 293 end
end comp
read geometry
unit 1
com='individual pin cell'
  zcylinder 1 1 0.375 30 0
  cuboid 2 1 0.5 -0.5 0.5 -0.5 30 0
unit 2
com='short (8 units) vertical array of pins'
  array 2 -0.5 -4 0
unit 3
com='long (10 units) vertical array of pins'
  array 3 -0.5 -5 0
unit 4
com='short (8 units) horizontal array of pins'
  array 4 -4 -0.5 0
unit 5
com='long (10 units) horizontal array of pins'
  array 5 -5 -0.5 0
```

Pins in a Tank (cont.)

```
global unit 6
  array 1 -6 -6 0
  zcylinder 2 1 9 30 0
  hole 3 -6.5 0 0
  hole 2 -7.5 0 0
  hole 3 6.5 0 0
  hole 2 7.5 0 0
  hole 5 0 -6.5 0
  hole 4 0 -7.5 0
  hole 5 0 6.5 0
  hole 4 0 7.5 0
  zcylinder 2 1 9 45 0
  zcylinder 0 1 9 60 0
  zcylinder 3 1 9.5 60 -0.5
  replicate 2 1 3 0 3 10
end geometry
```



Pins in a Tank (cont.)

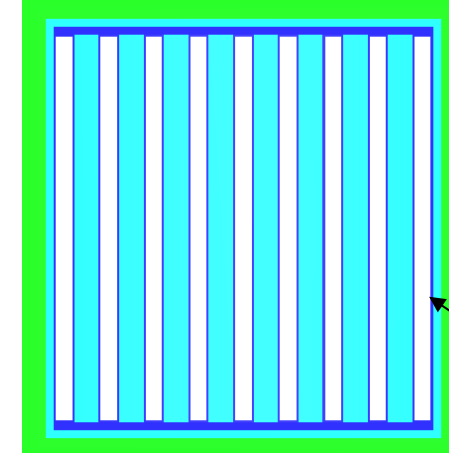
```
read array
ara=1 nux=12 nuy=12 nuz=1
fill 144*1 end fill
ara=2 nux=1 nuy=8 nuz=1
fill 8*1 end fill
ara=3 nux=1 nuy=10 nuz=1
fill 10*1 end fill
ara=4 nux=8 nuy=1 nuz=1
fill 8*1 end fill
ara=5 nux=10 nuy=1 nuz=1
fill 10*1 end fill
end array
end data
end
```

Shipping Cask

```
=csas5
shipping cask    containing 92.85 w% u-235/al plate fuel
ce_v7.1_endf
read comp
  uranium        1 den=3.78 0.0664 293 92235 92.85 92238 7.15 end
  al              1 den=3.78 0.9336 293 end
  al              2 den=2.7 1 293 end
  h2o             3 1 293 end
  al              4 den=2.7 1 293 end
  ss304           5 1 293 end
end comp
read parameter
  npg=2000
end parameter
read geometry
unit 1
com='fuel slab'
  cuboid 1 1 0.2 -0.2 4.7 -4.7 30 -30
  cuboid 2 1 0.25 -0.25 4.75 -4.75 30.05 -30.05
unit 2
com='h2o slab'
  cuboid 3 1 0.3 -0.3 4.75 -4.75 30.05 -30.05
```

Shipping Cask (cont.)

```
unit 3
com='single assembly'
  array 1 -4.65 -4.75 -30.05
  cuboid 2 1 4.65 -4.65 4.95 -4.95 30.05 -30.05
  cuboid 3 1 4.85 -4.85 5.15 -5.15 30.05 -30.05
  cuboid 4 1 5.35 -5.35 5.65 -5.65 30.05 -30.05
unit 4
com='2 assemblies stacked in x'
  array 2 -10.7 -5.65 -30.05
global unit 10
  array 3 -16.05 -5.65 -30.05
  zcylinder 4 1 22 40 -40
  hole 4 0 11.3 0
  hole 4 0 -11.3 0
  zcylinder 5 1 30 50 -50
end geometry
```



```
read array
ara=1 nux=17 nuy=1 nuz=1
fill 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1
end fill
ara=2 nux=2 nuy=1 nuz=1
fill 2*3
end fill
ara=3 nux=3 nuy=1 nuz=1
fill 3*3
end fill
end array
end data
end
```

Conclusions

- KENO V.a geometry rules (review)
 1. Volumes are built in sections called UNITS.
 2. Units are built from the inside out using REGIONS.
 3. Regions may share boundaries but may not intersect.
 4. All regions are oriented along a major axis (X, Y, or Z).
 5. A HOLE is used to place a unit within a region in a different unit.
 6. An ARRAY is an ordered stack of units.
 7. A GLOBAL unit or array, which defines the outermost boundary of the problem, must be specified for each problem.

Questions?