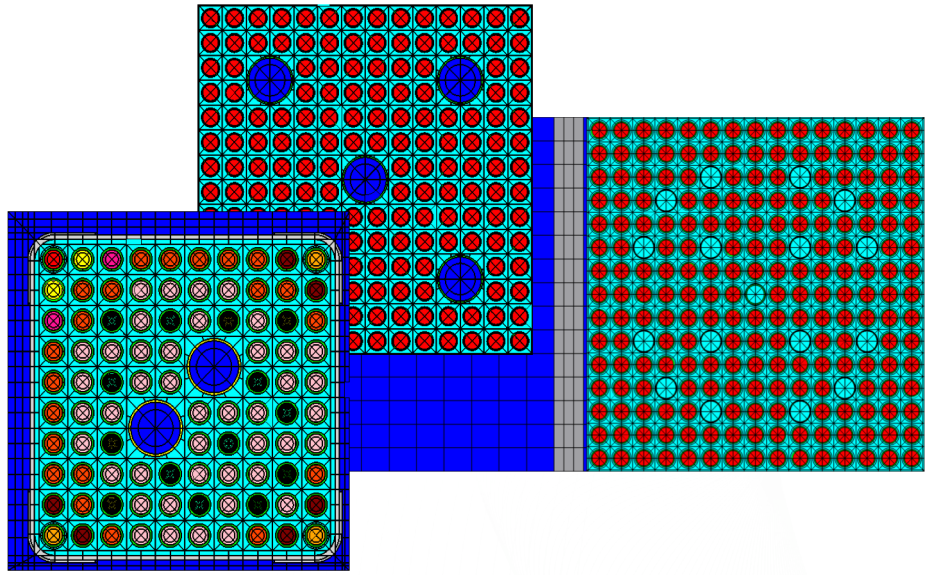
Polaris Overview

Polaris Overview

- Fast 2-D lattice physics
- Simple Input
  - Assembly geometry
  - Material definitions
  - Range of system conditions
- Output
  - Assembly-averaged few-group cross sections
    - Used as input for nodal core simulator such as PARCS
  - Depletion material isotopics
    - Used for spent fuel characterization
- Modeling Requirements
  - Accurate prediction of lattice k-eff, pin power distribution, few-group cross-sections, depletion isotopics
  - Relatively fast: 10,000s of transport calculations per core analysis



Wide range of LWR geometry support

Multigroup Reactor Physics Calculations

The Physics

- Cross Section Library
- Material Concentrations
- Geometry
- Temperature

Cross Section Processing

- MG Cross sections

- MG Cross sections
- Geometry

Multigroup Transport

- k-effective
- MG Flux
- Flux-dependent QOIs

3 fundamental physics

1. Cross section processing
2. Multigroup transport
3. Depletion

- Material Concentrations
- MG Flux
- MG Cross sections
- Power level
- Time step

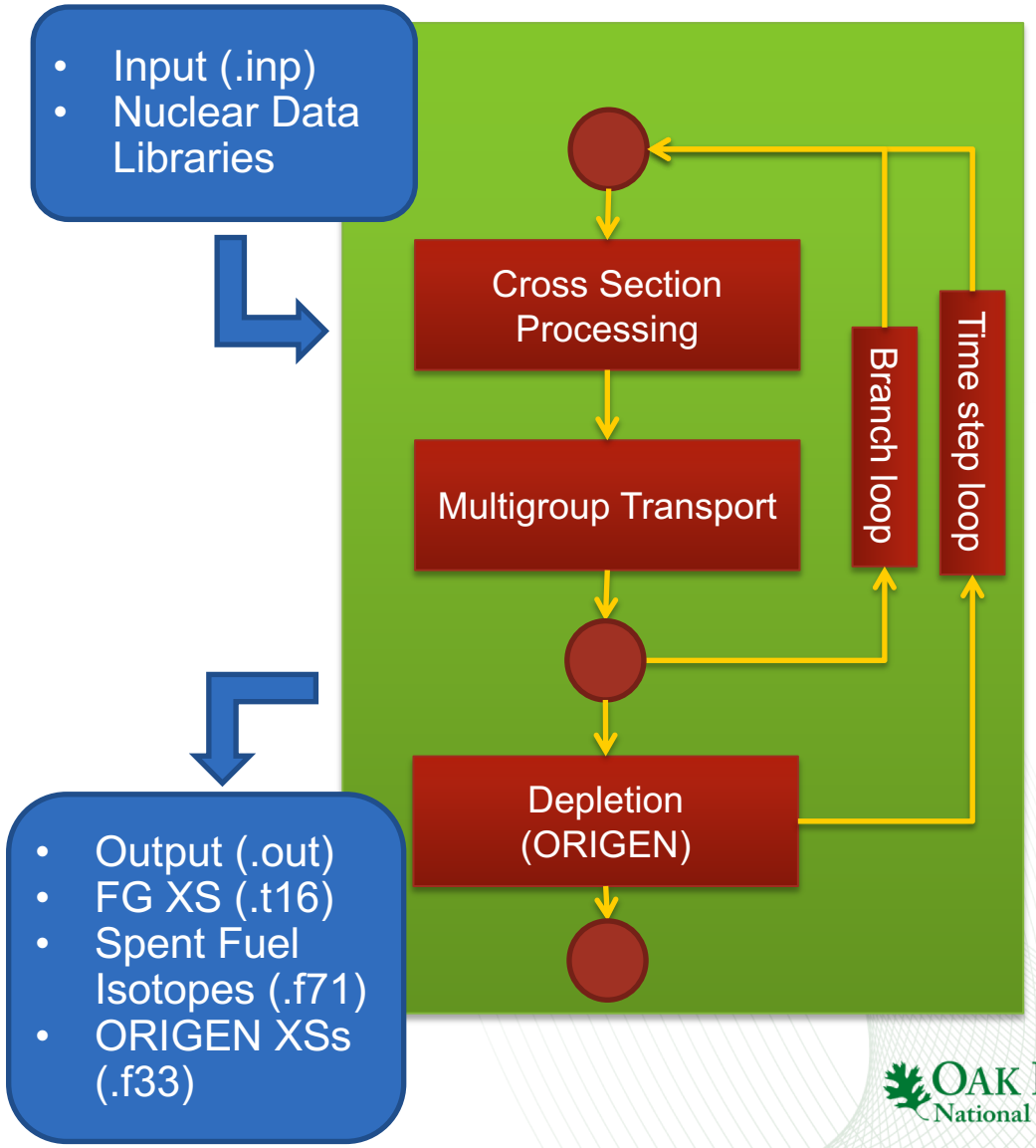
Depletion/Decay

- New Material Concentrations

Reactor Physics Calculations

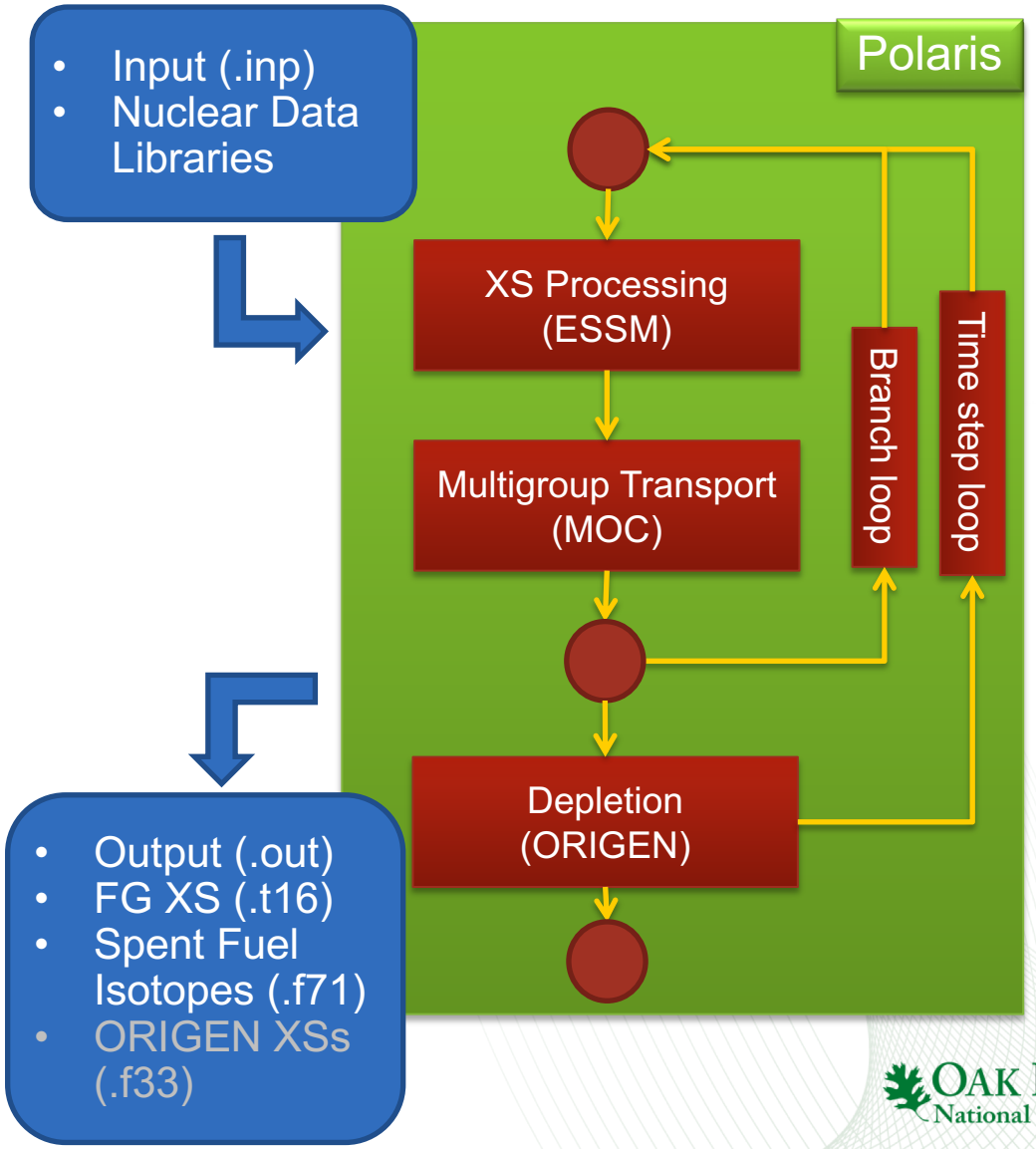
The Control Sequence

- The SCALE control sequences manage the calculation
- Functions include:
  - Transport-to-Depletion coupling
    - Normalizes power/flux levels
    - Prepares transition matrices for ORIGEN
    - Manages time-stepping (predictor-corrector)
  - Solution archival
  - Branch calculations
    - for 2-D lattice physics analysis
  - Model updates
    - Concentration changes from depletion
    - Geometry, temperature, concentrations changes (user input)



The Polaris Lattice Physics Sequence

- Nuclear Data Libraries:
  - ENDF/B-V7.1 252G and 56G
- XS Processing (ESSM)
  - Embedded Self-Shielding Method
  - Novel ORNL-developed XS processing method
  - XS processing is “embedded” into 2D geometry
  - No input requirements
  - Mark L. Williams and Kang Seog Kim. “The Embedded Self-Shielding Method.” *PHYSOR 2012*. Knoxville, Tennessee, USA
- Multigroup Transport
  - 2-D assembly calculation
  - New Method-of-Characteristics (MOC) solver



Polaris Course Objectives

1. Setup Polaris input files using Fulcrum
2. Setup and run pin, assembly, and reflector models for a wide range of LWR fuel designs
3. Setup and run single statepoint, depletion, branch, and reflector calculations with Polaris
4. Understand current modeling limitations with Polaris in SCALE 6.2
5. Execute Polaris using Fulcrum and the SCALE command window
6. Understand various Polaris output edits

Training Outline

- Basics
  - **Input**: title, lib, %, geom, comp, mat, pin
  - **Output**: k-eff, FG XS, .png file
- Assembly Geometry
  - **Input**: hgap, channel, pinmap, system, state, insert/control maps
  - **Output**: pin powers
- Depletion
  - **Input:** power, bu, t, dbu, dt, ti, bui, basis
  - **Output:** mass, power/flux edits, .f71 file
- BWR geometry
  - **Input:** box, cross, control blade, displacement maps
- Lattice Physics
  - **Input:** branch block, history block, reflector geometry
- Miscellaneous Options
  - Critical spectrum calculation
  - Print options
  - Modeling spacer grids and IFBA
  - New detector edits demo

Polaris Input Basics

```
=polaris

% Polaris input goes here!

% input format is version 6.2

end

=polaris_6.3

% Polaris input goes here!

% input format is version 6.3

end
```

Basics

- Polaris input starts with:
  - **=polaris** (SCALE 6.2.0 and all updates)
  - **=polaris_6.3** (SCALE 6.2.2 and 6.2.3)
- Polaris input terminates with:
  - **end**
- **=polaris_6.3** contains several new input cards and some modifications to original input cards such as the **pin** card
- For this overview, we use use **=polaris_6.3**

```
=polaris_6.3
%-------------------------------------%
% general options
%-------------------------------------%
title "W17x17 pin cell"
      "Polaris training"

%-------------------------------------%
% 252-group ENDF/B-VII.1 library
%-------------------------------------%
lib "v7-252"

   % or

lib "fine_n"

%-------------------------------------%
% 56-group ENDF/B-VII.1 library
%-------------------------------------%
lib "v7-56"

   % or

lib "broad_n"




end
```

Basics

- **title** - optional
  - double quotes
  - one or more titles allowed
- comment **%**
  - does not have to be first character on line
  - cannot appear INSIDE cards
- **lib** (or **library**) - optional
  - “v7-252” or “fine_n”
  - “v7-56” or “broad_n”
  - default “v7-252”

```
1 =polaris_6.3
2 %--------------------------------------%
3 % general options
4 %--------------------------------------%
5 title "W17x17 pin cell"
6 lib "broad_n"
7 %--------------------------------------%
8 % geometry
9 %--------------------------------------%
10 geometry W17 : ASSM npins=1
11                     ppitch=1.26
12                     sym=FULL
13
14    %equivalent to
15
16 geom W17 : ASSM 1 1.26 FULL
17
18    %equivalent to
19
20 geom W17 : ASSM 1 sym=FULL
21                       ppitch=1.26
22
23    %equivalent to
24
25 geom W17 : ASSM 1 1.26
26
27
28 end
29
30
```

geom card

geom GNAME : ASSM npins=Int ppitch=Real [sym=FULL|SE]

- **geom** or **geometry** – geometry card
- GNAME – user geometry name
- ASSM – indicates assembly geometry
- **npins** - # of pins on side of the assembly
- **ppitch** – pin pitch (cm)
- **sym** – optional
  - FULL or SE (southeast)
  - default FULL
- Keywords **npins=**, **ppitch=**, and **sym=**
  - Optional if in correct order
  - Required once out of order

```
=polaris_6.3
%--------------------------------------%
% general options
%--------------------------------------%
title "W17x17 pin cell"
lib "broad_n"
%--------------------------------------%
% geometry
%--------------------------------------%
geom W17 : ASSM 1 1.26 FULL
%--------------------------------------%
% comps and mats
%--------------------------------------%
composition c_f31 : UOX 3.1
material FUEL.1 : c_f31 dens=10.26
                        temp=600

    %equivalent to

comp c_f31 : UOX 3.1
mat FUEL.1 : c_f31 10.26 600

end
```

comp card and mat card

comp CNAME : UOX enr=Real

- **comp** or **composition**
- CNAME – user composition name
- UOX – indicates uranium dioxide
- **enr** – U-235 enrichment %

mat MNAME : CNAME [dens=Real] [temp=Real]

- **mat** or **material**
- MNAME – user material name (Word.Int)
- CNAME – user composition name
- **dens** – density (g/cm^3)
- **temp** – temperature (K)

Compositions and Materials

- Basic Concept
  - **composition** defines a set of isotopes and their relative distribution
  - **material** is a **composition** at a given density and temperature
  - same **composition** can define multiple **materials**
- Naming convention
  - **composition**: what is it? (zirc4)
  - **material**: what does it do? (CLAD.1)

- Several comp cards exists
  - **comp** CNAME : NUM …
    - define by atom %
  - **comp** CNAME : WT …
    - define by weight %
  - **comp** CNAME : FORM …
    - define chemical compound
  - **comp** CNAME : CONC …
    - define number densities
  - **comp** CNAME : LW …
    - define borated water

Composition Examples

```
=polaris_6.3
%---------------------------------------%
% comp examples
%---------------------------------------%

comp D2O       : FORM 1002=2 O16=1

comp c_f30     : UOX 3.0
comp c_gdfuel  : WT GD2O3=7 c_f30=-100

comp c_waba    : CONC
           5010=2.98553E-03
           5011=1.21192E-02
           6000=3.77001E-03
           8016=5.85563E-02
          13027=3.90223E-02

comp WATER     : LW borppm=1300

       %equivalent to

comp WATER     : LW 1300

end
```

Pre-defined compositions

Standard Molecular Compositions

CNAME	*Description*
H2O	light water
B4C	Boron carbide burnable poison material
ER2O3	Erbium oxide burnable poison material
GD2O3	Gadolinium oxide burnable poison material
FILLGAS	Helium gas

Standard Reactor Mixtures and Alloys

CNAME	*Description*
AIC	Ag-In-Cd control rod absorber material
PYREX	Pyrex glass
ZIRC2	Zircaloy-2 clad material
ZIRC4	Zircaloy-4 clad material
SS304	Stainless Steel 304
SS316	Stainless Steel 316
INC718	Inconel 718
WATER	Light water with trace amount of boron

Pre-defined compositions have reference density. **dens=** not required for mat card.

```
=polaris_6.3
%-------------------------------------%
% general options
%-------------------------------------%
title "W17x17 pin cell"
lib "broad_n"
%-------------------------------------%
% geometry
%-------------------------------------%
geom W17 : ASSM 1 1.26
%-------------------------------------%
% comps and mats
%-------------------------------------%
comp c_f31 : UOX 3.1
mat FUEL.1 : c_f31 10.26 600
mat GAP.1  : FILLGAS temp=600
mat CLAD.1 : ZIRC4   temp=600
comp WATER : LW 1300
mat COOL.1 : WATER 0.661 600
%-------------------------------------%
% pins
%-------------------------------------%
pin F : 0.4096 0.418 0.475
      : FUEL.1 GAP.1 CLAD.1 COOL.1
end
```

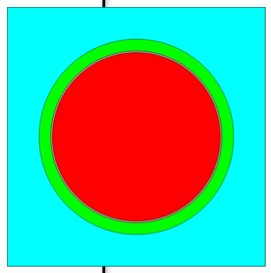
pin

pin PINID : r1 r2 … ri … rN
: M1 M2 … Mi … MN [Mout]

PINID – pin identifier

- r – zone radius (cm)
- M – zone material
- Additional value of M for outermost region (Mout)

```
=polaris_6.3
%--------------------------------------%
% general options
%--------------------------------------%
title "W17x17 pin cell"
lib "broad_n"
%--------------------------------------%
% geometry
%--------------------------------------%
geom W17 : ASSM 1 1.26
%--------------------------------------%
% comps and mats
%--------------------------------------%
comp c_f31 : UOX 3.1
mat FUEL.1 : c_f31 10.26 600
mat GAP.1  : FILLGAS temp=600
mat CLAD.1 : ZIRC4   temp=600
comp WATER : LW 1300
mat COOL.1 : WATER 0.661 600
%--------------------------------------%
% pins
%--------------------------------------%
pin F : 0.4096 0.418 0.475
      : FUEL.1 GAP.1 CLAD.1 COOL.1
end
```



Exercises

- Part 1 w17x17_pin.inp
  1. Finish pin cell input shown here
  2. Run calculation
  3. Walk through output
  4. Record transport k-eff
- Part 2 (on your own)
  1. Run with 900 K fuel w17x17_pin_900K.inp
  2. Compute reactivity coefficient
  3. Revert fuel to 600 K. Run with 1000 ppm boron w17x17_pin_1000ppm.inp
  4. Compute reactivity coefficient
- Part 3 (on your own) w17x17_pin_clad.inp
  1. Revert boron change.
  2. Let's analyze non-Zr cladding.
  3. Compute k-eff for the following clad material
  4. 7.1 g/cc with a composition of 75 wt% Fe, 20 wt% Cr, and 5 wt% Al. (See comp WT example on "Composition Examples")

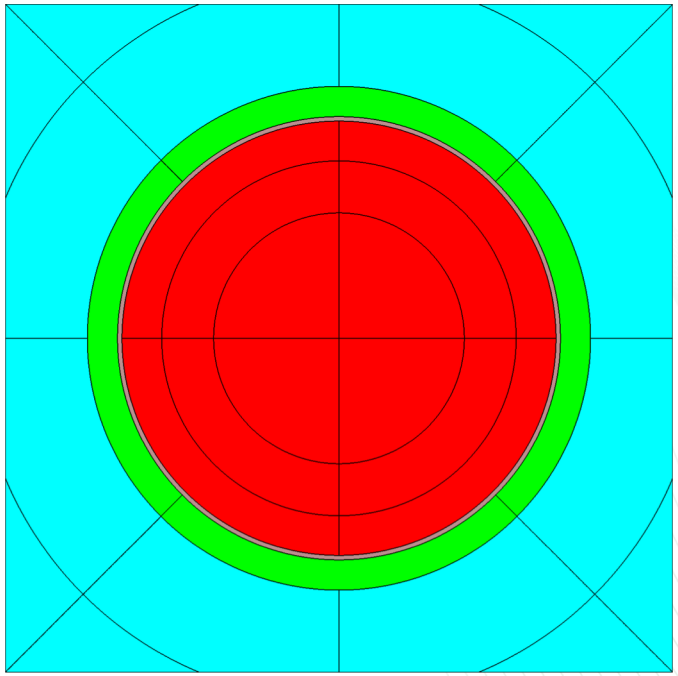
mesh and pinmap

mesh part 1

```
1 =polaris_6.3
2 %---------------------------------------%
3 % general options
4 %---------------------------------------%
5 title "W17x17 pin cell"
6 lib "broad_n"
7 %---------------------------------------%
8 % geometry
9 %---------------------------------------%
10 geom W17 : ASSM 1 1.26
11 %---------------------------------------%
12 % comps and mats
13 %---------------------------------------%
14 comp c_f31 : UOX 3.1
15 mat FUEL.1 : c_f31 10.26 600
16 mat GAP.1  : FILLGAS temp=600
17 mat CLAD.1 : ZIRC4   temp=600
18 comp WATER : LW 1300
19 mat COOL.1 : WATER 0.661 600
20 %---------------------------------------%
21 % pins and mesh
22 %---------------------------------------%
23 pin F : 0.4096 0.418 0.475
24       : FUEL.1 GAP.1 CLAD.1 COOL.1
25 mesh FUEL : nr=3 ns= 4
26 mesh CLAD :      ns=-4
27 mesh COOL : nr=2 ns= 8
28 end
29
30
```

mesh MCLASS|MNAME : [nr=Int] [ns=Int]

- MNAME – the material name
- MCLASS – the 1st part of the material name
  - e.g., COOL in COOL.1
- **nr** – # of radial mesh for a pin, must be > 0, default 1
- **ns** – # of sectors for a pin, must not equal 0, negative value implies half sector offset, default 1

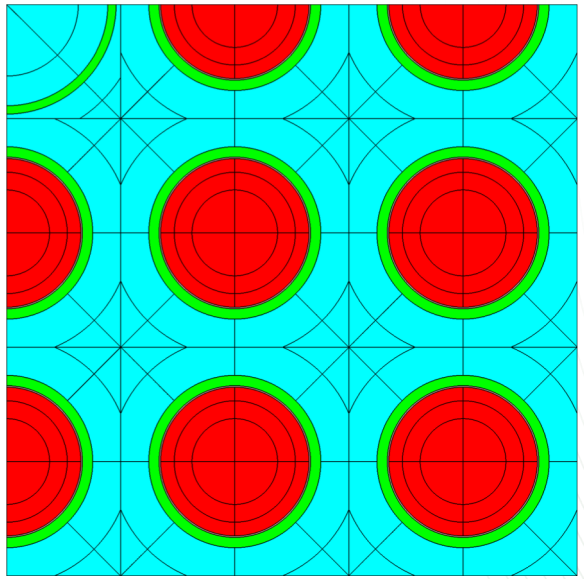


```
=polaris_6.3
title "W17x17"
lib "broad_n"
geom W17 : ASSM 5 1.26 SE
%---------------------------------------%
% comps and mats
%---------------------------------------%
comp c_f31 : UOX 3.1
mat FUEL.1 : c_f31 10.26 600
mat GAP.1  : FILLGAS temp=600
mat CLAD.1 : ZIRC4   temp=600
comp WATER : LW 1300
mat COOL.1 : WATER 0.661 600
%---------------------------------------%
% pins and mesh
%---------------------------------------%
pin F : 0.4096 0.418 0.475
      : FUEL.1 GAP.1 CLAD.1 COOL.1
pin I : 0.559 0.605
      : COOL.1 CLAD.1 COOL.1
mesh FUEL : nr=3 ns= 4
mesh COOL : nr=2 ns= 8
%---------------------------------------%
% maps
%---------------------------------------%
pinmap
 I
 F F
 F F F
end
```

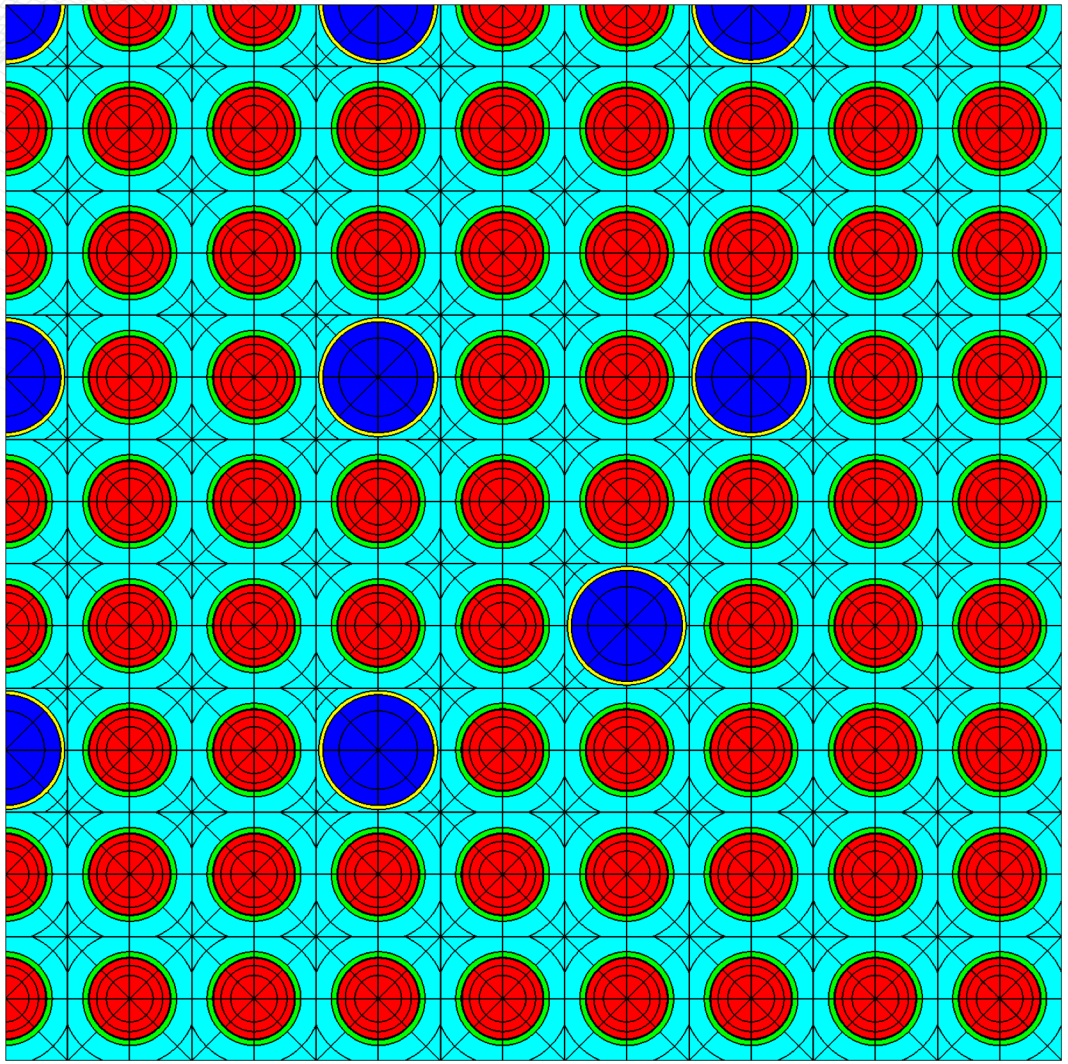
pinmap

pinmap $PINID_1$ $PINID_2$ … $PINID_i$ … $PINID_N$

- supports full, quarter, or octant symmetry
- For 5x5 assembly, the pinmap can contain
  - 25 entries (geom sym=FULL)
  - 15 entries (SW diagonal sym=FULL)
  - 9 entries (SE quadrant, geom sym=SE|FULL)
  - 6 entries (SSE octant, geom sym=SE|FULL)



Exercises



- Copy w17x17_pin.inp to w17x17_rev0.inp
  1. Copy **mat** CLAD.1 as TUBE.1
  2. Copy **mat** COOL.1 as MOD.1
  3. Add **pin** (I) for instrument tube
     - MOD.1 – 0.559 cm
     - TUBE.1 – 0.605 cm
  4. Add **pin** (G) for guide tube
     - MOD.1 – 0.561 cm
     - TUBE.1 – 0.602 cm
  5. Add **pinmap** shown here
  6. Modify **geom** card to have **npins**=17 and **sym**=SE
  7. Custom **mesh**
     1. COOL: nr=2 ns=8
     2. CLAD: ns=-4
     3. MOD: nr=2 ns=8
     4. FUEL: nr=3 ns=8
  8. Run calculation
  9. Record transport k-eff

hgap card
channel card
size=2 pins

hgap

```
=polaris_6.3

%---------------------------------------%
% geometry
%---------------------------------------%
geom W17 : ASSM 17 1.26    SE
hgap 0.04 : COOL.1

    %equivalent to

hgap 0.04    0.04
   : COOL.1 COOL.1

    %equivalent to

hgap 0.04    0.04    0.04    0.04
   : COOL.1 COOL.1 COOL.1 COOL.1
```

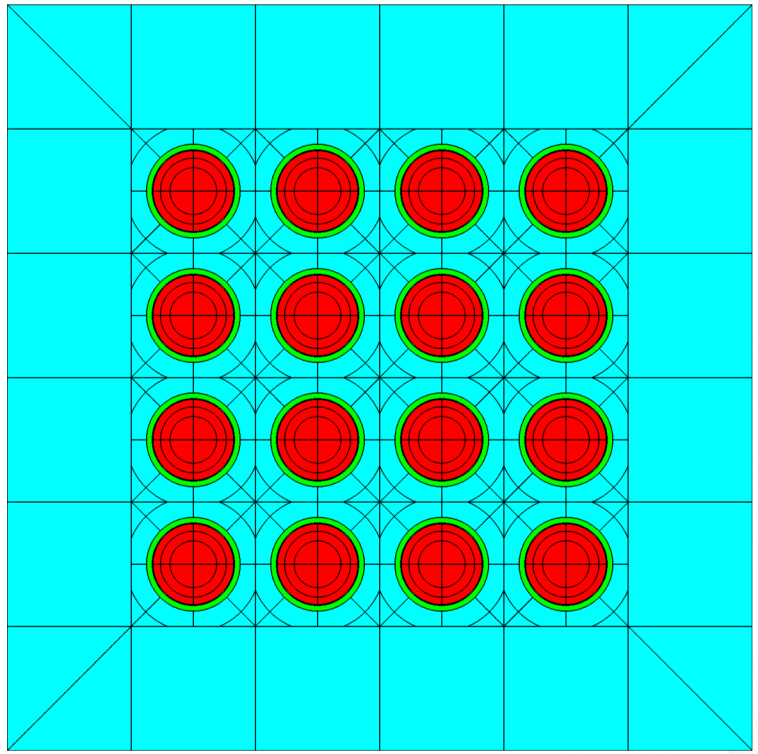
- hgap - optional
  - half distance between adjacent assemblies

```
hgap  [  dE    dN   dW    dS  ]
      [: ME    MN   MW   MS ]
```

- d – half distance (cm)
- M – material name
- 1, 2, 4 values are acceptable
  - 1: same values for all 4 faces (PWR)
  - 2: East=South and North=West (BWR)
  - 4: general case, all four sides can be different

hgap

```
=polaris_6.3
title "W17x17"
lib "broad_n"
%---------------------------------------%
% geometry
%---------------------------------------%
geom W17 : ASSM 4 1.26
hgap 1.26 : COOL.1
%---------------------------------------%
% comps and mats
%---------------------------------------%
comp c_f31 : UOX 3.1
mat FUEL.1 : c_f31 10.26 600
mat GAP.1  : FILLGAS temp=600
mat CLAD.1 : ZIRC4   temp=600
comp WATER : LW 1300
mat COOL.1 : WATER 0.661 600
%---------------------------------------%
% pins and mesh
%---------------------------------------%
pin F : 0.4096 0.418 0.475
      : FUEL.1 GAP.1 CLAD.1 COOL.1
mesh FUEL : nr=3 ns= 4
mesh COOL : nr=2 ns= 8
end
```



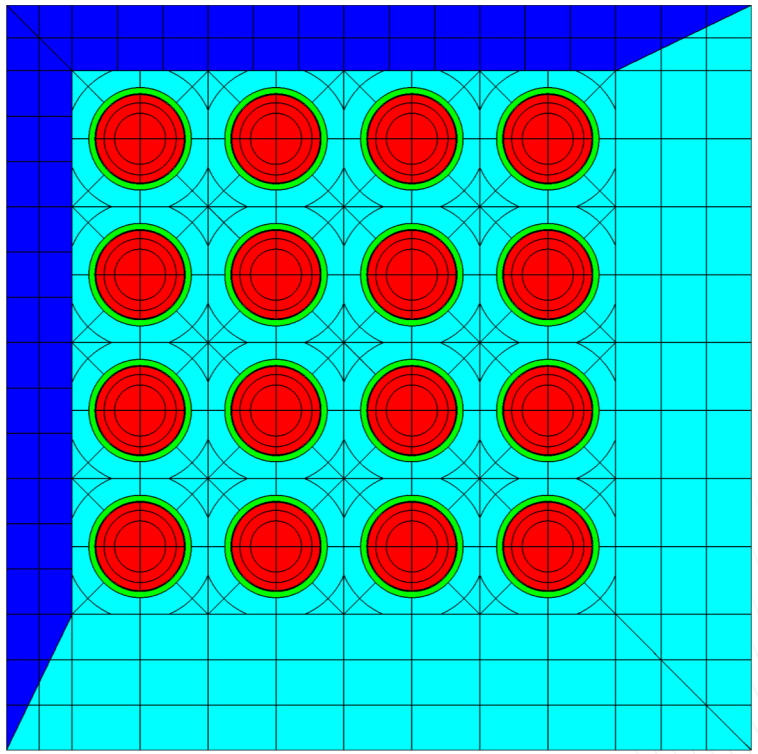
mesh part 2

```
=polaris_6.3
title "W17x17"
lib "broad_n"
%-------------------------------------%
% geometry
%-------------------------------------%
geom W17 : ASSM 4 1.26
hgap 1.26 0.61 : COOL.1 MOD.1
%-------------------------------------%
% comps and mats
%-------------------------------------%
comp c_f31 : UOX 3.1
mat FUEL.1 : c_f31 10.26 600
mat GAP.1  : FILLGAS temp=600
mat CLAD.1 : ZIRC4   temp=600
comp WATER : LW 1300
mat COOL.1 : WATER 0.661 600
mat MOD.1 : WATER 0.661 600
%-------------------------------------%
% pins and mesh
%-------------------------------------%
pin F : 0.4096 0.418 0.475
      : FUEL.1 GAP.1 CLAD.1 COOL.1
mesh FUEL : nr=3 ns= 4
mesh COOL : nr=2 ns= 8 nf=2 nd=3
mesh MOD  :            nf=3 nd=2
end
```

mesh MCLASS|MNAME : [nr=Int] [ns=Int] [nf=Int] [nd=Int]

nf – number of faces per pin, default 2

nd – number of divisions per pin, default 1



```
=polaris_6.3

%----------------------------------------%
% geometry
%----------------------------------------%
geom W17 : ASSM 1 1.26
hgap 0.04
channel COOL
```

channel

- channel – defines material for outermost **pin** region

channel [Mchan=MCLASS]

- **Mchan** – material class: the 1st part of the **mat** name
- The actual material used in the outermost pin region is the first sorted material with matching class, typically COOL.1

channel before and after

```
=polaris_6.3
title "W17x17"
lib "broad_n"
%----------------------------------------%
% geometry
%----------------------------------------%
geom W17 : ASSM 17 1.26
hgap 0.04 : COOL.1
%----------------------------------------%
% comps and mats
%----------------------------------------%
comp c_f31 : UOX 3.1
mat FUEL.1 : c_f31 10.26 600
mat GAP.1  : FILLGAS temp=600
mat CLAD.1 : ZIRC4   temp=600
mat TUBE.1 : ZIRC4   temp=600
comp WATER : LW 1300
mat COOL.1 : WATER 0.661 600
mat MOD.1  : WATER 0.661 600
%----------------------------------------%
% pins and mesh
%----------------------------------------%
pin F : 0.4096 0.418 0.475
      : FUEL.1 GAP.1 CLAD.1 COOL.1
pin I : 0.559 0.605
      : MOD.1 TUBE.1 COOL.1
pin G : 0.561 0.602
      : MOD.1 TUBE.1 COOL.1
mesh COOL : nr=2 ns= 8
mesh FUEL : nr=3 ns= 8
```

```
=polaris_6.3
title "W17x17"
lib "broad_n"
%----------------------------------------%
% geometry
%----------------------------------------%
geom W17 : ASSM 17 1.26
hgap 0.04 : COOL.1
channel COOL
%----------------------------------------%
% comps and mats
%----------------------------------------%
comp c_f31 : UOX 3.1
mat FUEL.1 : c_f31 10.26 600
mat GAP.1  : FILLGAS temp=600
mat CLAD.1 : ZIRC4   temp=600
mat TUBE.1 : ZIRC4   temp=600
comp WATER : LW 1300
mat COOL.1 : WATER 0.661 600
mat MOD.1  : WATER 0.661 600
%----------------------------------------%
% pins and mesh
%----------------------------------------%
pin F : 0.4096 0.418 0.475
      : FUEL.1 GAP.1 CLAD.1
pin I : 0.559 0.605 : MOD.1 TUBE.1
pin G : 0.561 0.602 : MOD.1 TUBE.1
mesh COOL : nr=2 ns= 8
mesh FUEL : nr=3 ns= 8

```

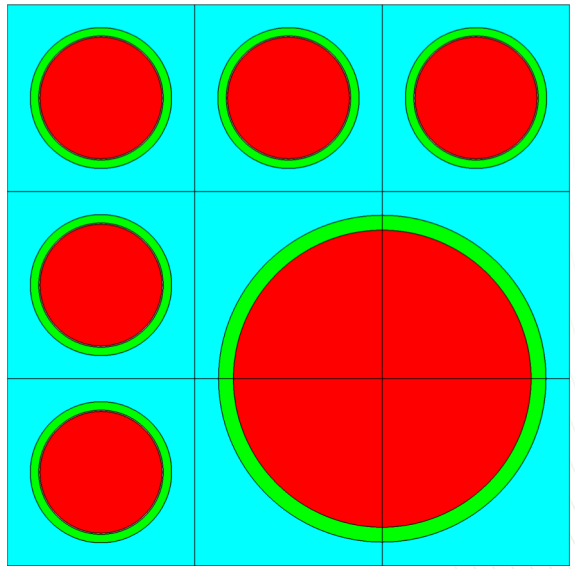
pin part 2

```
=polaris_6.3
lib "broad_n"
%---------------------------------------%
% geometry
%---------------------------------------%
geom fake : ASSM 3 1.26
channel COOL
%---------------------------------------%
% comps and mats
%---------------------------------------%
comp c_f31 : UOX 3.1
mat FUEL.1 : c_f31 10.26 600
mat GAP.1  : FILLGAS temp=600
mat CLAD.1 : ZIRC4   temp=600
comp WATER : LW 1300
mat COOL.1 : WATER 0.661 600
%---------------------------------------%
% pins
%---------------------------------------%
pin F : 0.4096 0.418 0.475
      : FUEL.1 GAP   CLAD
pin X size=2 : 1.0 1.1 : FUEL.1 CLAD

  % equivalent to

pin X 2 : 1.0 1.1 : FUEL.1 CLAD
pinmap F F F
       F X X
       F X X
end
```

pin PINID [size=Real]

: r1 r2 … ri … rN
: M1 M2 … Mi … MN [Mout]

- **size**=1 is default.
- **size**=2 creates 2x2 pin cell



pin part 2

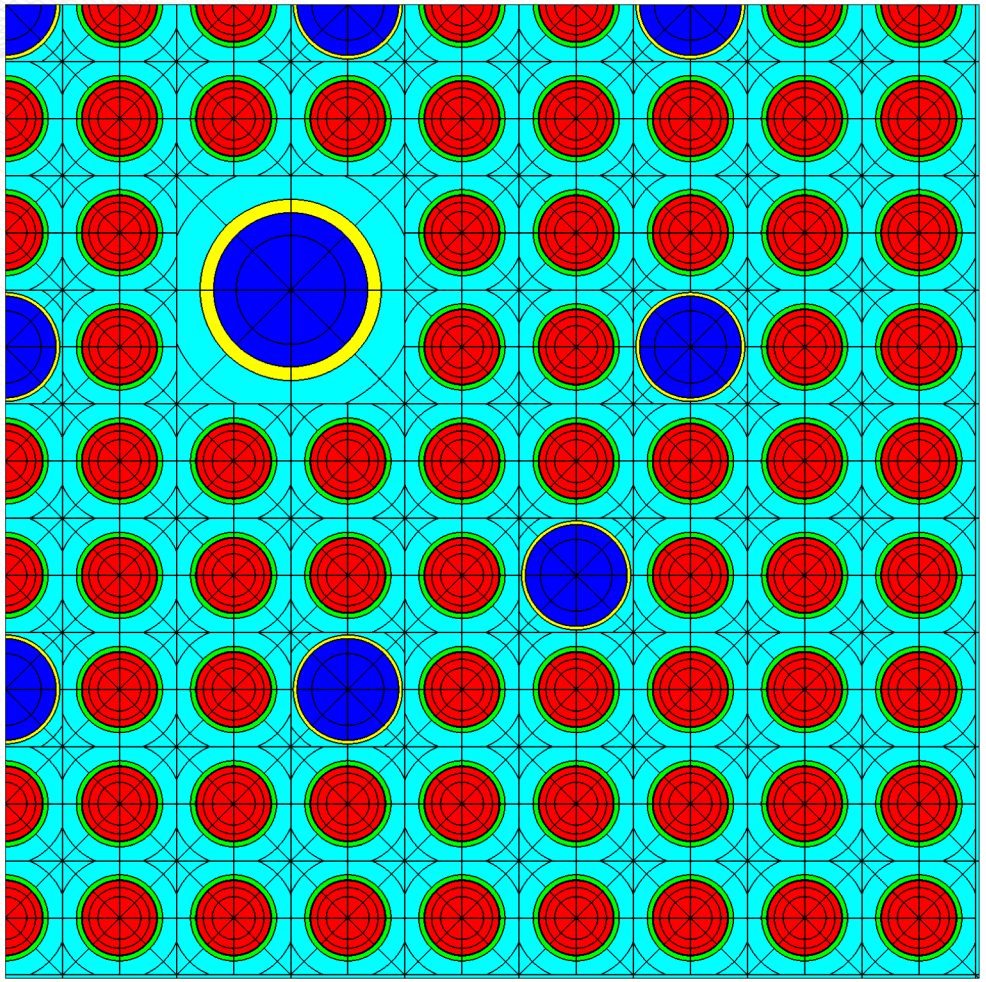
```
=polaris_6.3
lib "broad_n"
%--------------------------------------%
% geometry
%--------------------------------------%
geom fake : ASSM 3 1.26
channel COOL
%--------------------------------------%
% comps and mats
%--------------------------------------%
comp c_f31 : UOX 3.1
mat FUEL.1 : c_f31 10.26 600
mat GAP.1  : FILLGAS temp=600
mat CLAD.1 : ZIRC4   temp=600
comp WATER : LW 1300
mat COOL.1 : WATER 0.661 600
%--------------------------------------%
% pins
%--------------------------------------%
pin F : 0.4096 0.418 0.475
      : FUEL.1 GAP   CLAD
pin X size=2 : 1.0 1.1 : FUEL.1 CLAD

  % equivalent to

pin X 2 : 1.0 1.1 : FUEL.1 CLAD
pinmap F F F
       F X X
       F X X
end
```

pin PINID [size=Real]

: r1 r2 … ri … rN
: M1 M2 … Mi … MN [Mout]

- **size**=1 is default.
- **size**=2 creates 2x2 pin cell
- Material class can be used instead of material name if only a single material exist in the model
  - Error message if multiple materials share the same material class
  - GAP, CLAD, TUBE vs GAP.1 CLAD.1 TUBE.1

Exercises



- Copy w17x17_rev0.inp to w17x17_rev1.inp
  1. Add 0.04 half-gap of coolant
  2. Add **channel** card
  3. Remove outermost materials in pin F, G, and I
  4. Add **pin** (P) for a fake **size**=2 guide tube
     - MOD.1 0.85 cm
     - TUBE.1 1.0 cm
  5. Modify **pinmap** to have **pin** P in location shown on right
  6. (Optional) Modify **pin** cards: CLAD.1-> CLAD, GAP.1 -> GAP, TUBE.1 -> TUBE)
  7. Run calculation
  8. Record transport k-eff

system PWR

PWR-specific defaults

system PWR

Material	Composition	Plot Color	Additional info
Unless noted otherwise, T=565K, nr=1, ns=8, nf=2, nd=1			
COOL.1	H2O	cyan	**pin** coolant material, nr=2
COOL.2	H2O	aquamarine	use for large guide tubes with user-defined mesh
MOD.1	H2O	blue	optional, use for inner guide tube material
Water materials initialized to boron = 0 ppm, density = 0.743 g/cc			
FUEL.1	n/a	red	depletable **(deplete),** auto-expanded **(shield)**
BP.1	n/a	n/a	depletable **(deplete),** auto-expanded **(shield)**
CNTL.1	AIC	pink	auto-expanded **(shield)**
CNTL.2	B4C	cadetblue	auto-expanded **(shield)**
CLAD.1	ZIRC4	lime	
TUBE.1	ZIRC4	yellow	optional for guide tubes
GAP.1	FILLGAS	rosybrown	
STRUCT.1	SS304	goldenrod	blade sheath/central support material

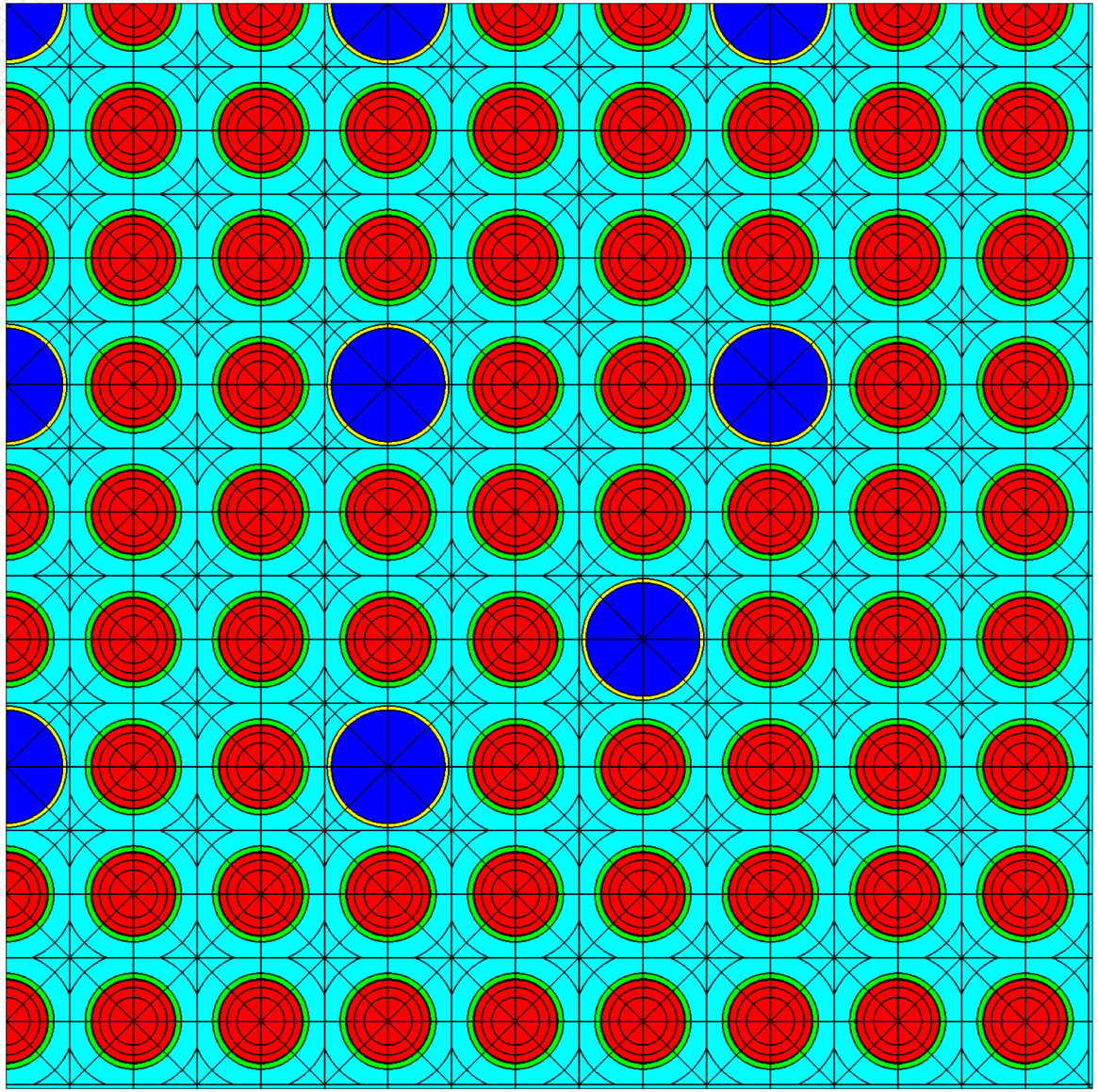
system PWR before and after

```
=polaris_6.3
title "W17x17"
lib "broad_n"
%----------------------------------------
% geometry
%----------------------------------------
geom W17 : ASSM 17 1.26
hgap 0.04 : COOL.1
channel COOL
%----------------------------------------
% comps and mats
%----------------------------------------
comp c_f31 : UOX 3.1
mat FUEL.1 : c_f31 10.26 600
mat GAP.1  : FILLGAS temp=600
mat CLAD.1 : ZIRC4   temp=600
mat TUBE.1 : ZIRC4   temp=600
comp WATER : LW 1300
mat COOL.1 : WATER 0.661 600
mat MOD.1  : WATER 0.661 600
%----------------------------------------
% pins and mesh
%----------------------------------------
pin F : 0.4096 0.418 0.475
      : FUEL.1 GAP   CLAD
pin I : 0.559 0.605 : MOD.1 TUBE
pin G : 0.561 0.602 : MOD.1 TUBE
mesh COOL : nr=2 ns= 8
mesh FUEL : nr=3 ns= 8

```

```
=polaris_6.3
title "W17x17"
lib "broad_n"
system PWR
%----------------------------------------%
% geometry
%----------------------------------------%
geom W17 : ASSM 17 1.26
hgap 0.04
%----------------------------------------%
% comps and mats
%----------------------------------------%
comp c_f31 : UOX 3.1
mat FUEL.1 : c_f31 10.26
%----------------------------------------%
% pins and mesh
%----------------------------------------%
pin F : 0.4096 0.418 0.475
      : FUEL.1 GAP   CLAD
pin I : 0.559 0.605 : MOD.1 TUBE
pin G : 0.561 0.602 : MOD.1 TUBE
mesh FUEL : nr=3


```

Note: right hand side uses default system temperatures

Exercises



- Copy w17x17_rev1.inp to w17x17_rev2.inp
  1. Remove **pin** P, revert pinmap to correct W17x17 map
  2. Add **system PWR**
  3. Remove **channel** card
  4. Remove COOL.1 from **hgap** card
  5. Remove **mat/comp** cards for default PWR materials
     - WATER, CLAD.1, GAP.1, TUBE.1, COOL.1, MOD.1
  6. Remove **mesh** cards for default PWR materials
     - COOL.1, MOD.1, CLAD.1
  7. Remove temperature from FUEL.1 **mat** card
  8. Add a new **mesh** card for FUEL.1 with nr=3
  9. Run calculation
  10. Record transport k-eff

state card to change material properties

```
%--------------------------------------%
% maps
%--------------------------------------%
pinmap
   I
   F F
   F F F
   G F F G
   F F F F F
   F F F F F G
   G F F G F F F
   F F F F F F F F
   F F F F F F F F F
%--------------------------------------%
% state
%--------------------------------------%
state ALL : temp=590
   COOL : dens=0.68 boron=1300
   MOD  : dens=0.71 boron=1300 temp=575
   FUEL : temp=900
   CLAD : temp=700 TUBE : temp=580
end
```

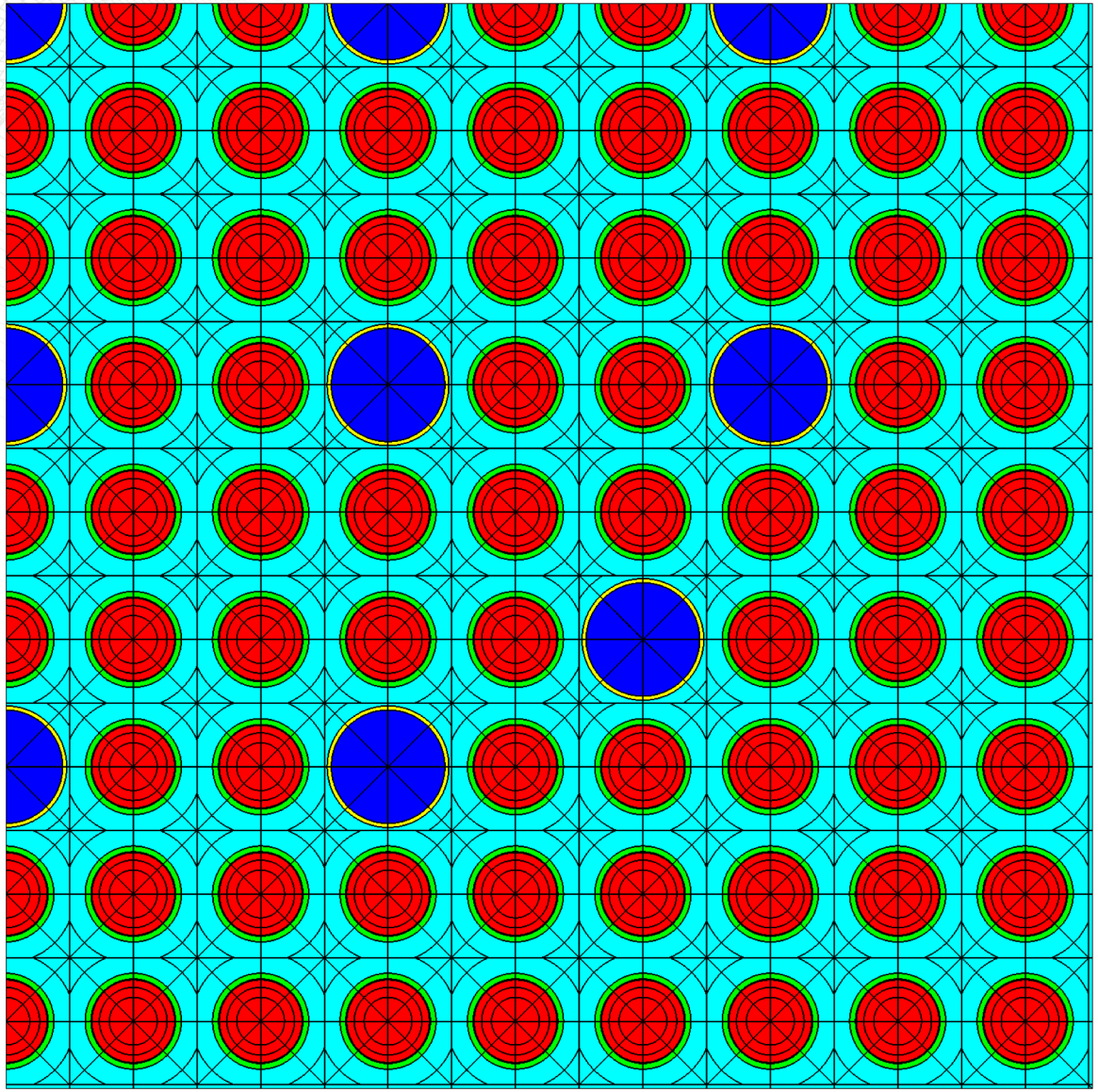
state part 1

state MNAME|MCLASS : p1=val1 p2=val2 …
MNAME|MCLASS : p1=val1 p2=val2 …
…

- MNAME or MCLASS – material name (FUEL.1) or material class (FUEL) or ALL can be used to initialize all material properties to same value
- p – property name
  - all materials have dens= and temp= properties
  - system PWR: COOL and MOD have boron= properties
  - system BWR: COOL and MOD have boron= and void= properties
- val – property value

- Whitespace before and after : is recommended

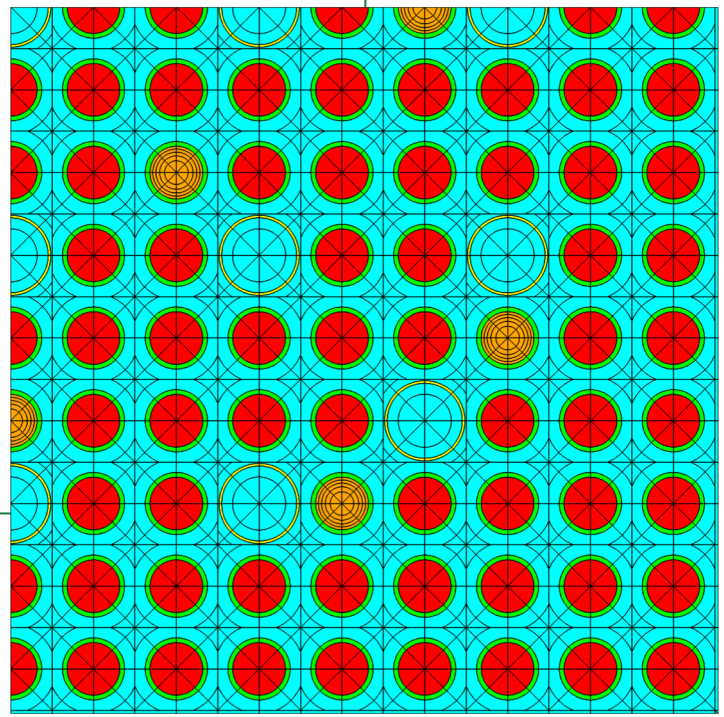
Exercises



- Part 1 of 3

1. Copy w17x17_rev2.inp to w17x17_rev3.inp
2. Add a **state** card with the following properties
   - Initialize all materials T=590 K
   - COOL and MOD boron is 1300 ppm
   - COOL density is 0.68 g/cc
   - MOD density is 0.71 g/cc
   - Clad temperature is 700 K
   - Fuel temperature is 900 K
3. Run calculation
4. Record transport k-eff

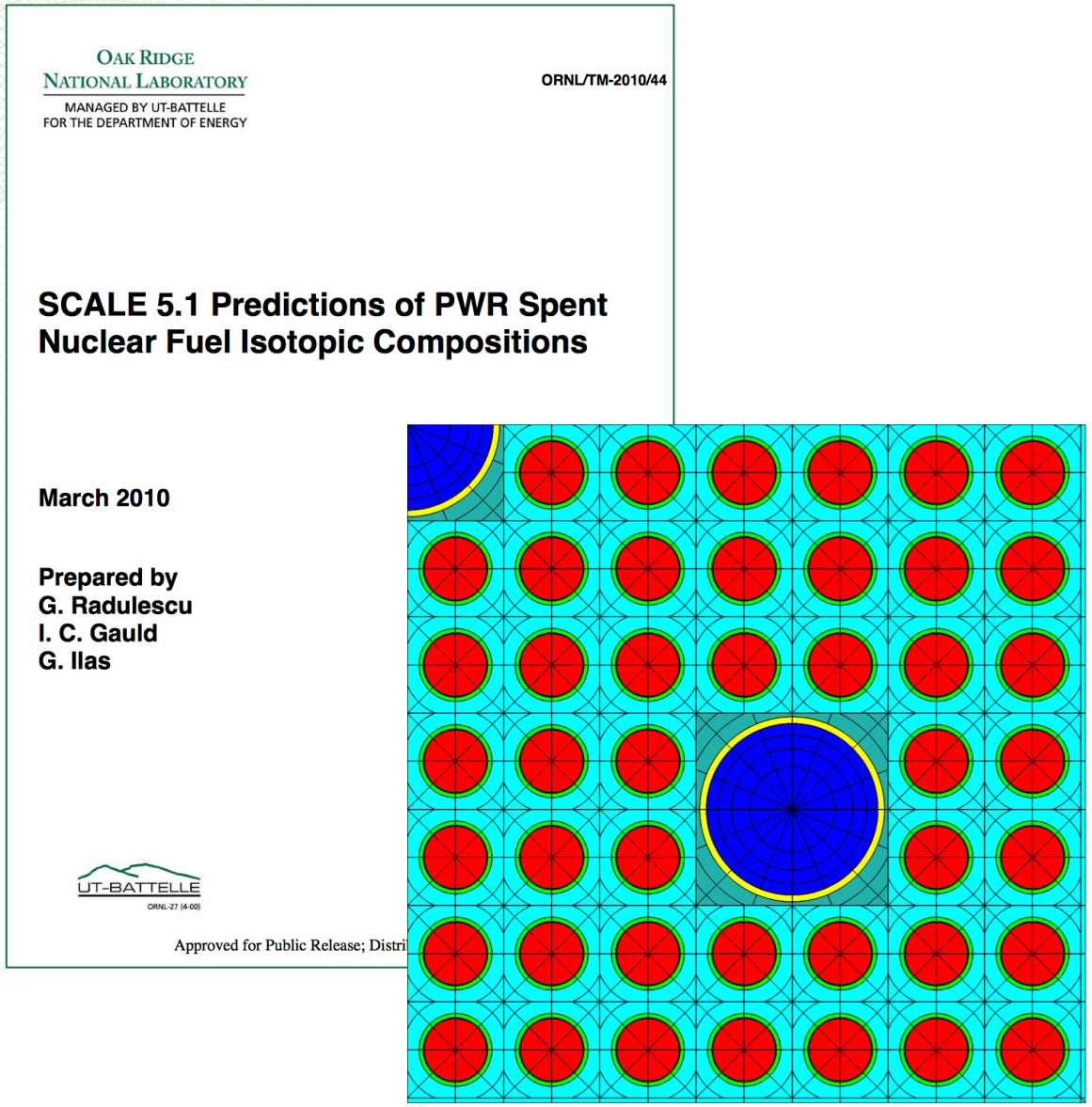
Exercises



- Part 2 of 3: Takahama assembly depletion benchmark
  1. Copy taka_starter.inp as taka.inp
  2. Add geometry info
     - 17x17, pin pitch 1.265 cm, lattice pitch 21.6126 cm, ¼ symm
     - Fuel pin: 0.4025 cm fuel radius, 0.475 cm clad radius (no gap), 1 radial fuel ring (FUEL.1)
     - Gad pin: 5 radial fuel rings (FUEL.2)
     - Guide/instrument tube: inner rad 0.573 cm (COOL.1), outer rad 0.613 cm (TUBE.1)
     - Pin map (see pic)
  3. Record transport k-eff

https://www.oecd-nea.org/science/docs/2013/nsc-doc2013-1.pdf
additional data at: http://info.ornl.gov/sites/publications/files/Pub23359.pdf

Exercises

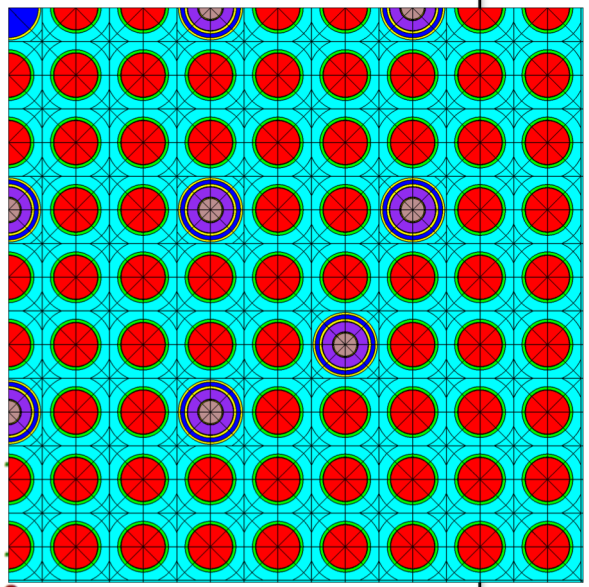


- Part 3 of 3: ce14x14.inp
  - Calvert Cliffs D047 Combustion Engineering 14x14 design
  - Rod pitch 1.4732 cm
  - Assembly pitch 20.78 cm
  - Fuel:
    - 10.045 g/cc
    - 3.038% enrichment
  - Pin Geometry
    - 0.47815 cm fuel radius
    - 0.49275 cm clad inner radius
    - 0.5588 cm clad outer radius
  - Guide tube/Instrument Tube (size=2)
    - 1.314 cm inner radius, 1.416 cm outer radius
    - 16 sectors, 3 rings on the exterior (COOL.2)
    - 16 sectors, 4 rings on the interior (MOD.1)
  - State
    - Coolant/Mod: 570 K, 0.7307 g/cc, 663 ppm
    - Fuel T=997 K
    - Other materials: 570 K

http://info.ornl.gov/sites/publications/files/Pub23359.pdf

insert card
control card

```
31 pin G : 0.561 0.602 : MOD.1 TUBE
32 pinmap
33 I
34 F F
35 F F F
36 G F F G
37 F F F F F
38 F F F F F G
39 G F F G F F F
40 F F F F F F F F
41 F F F F F F F F F
42 pin P : 0.214 0.231 0.241  0.427
43         0.437 0.484 0.561  0.602
44       : GAP   TUBE  GAP    BP
45         GAP   TUBE  MOD.1  TUBE
46 insert PYREX_MAP
47 _
48 _ _
49 _ _ _
50 P   _ _ P
51 _ _ _ _ _
52 _ _ _ _ _ P
53 P   _ _ P _ _ _
54 _ _ _ _ _ _ _ _
55 _ _ _ _ _ _ _ _ _
56 %--------------------
57 % state
58 %--------------------
59 state ALL   : temp=590
60  PYREX_MAP : in=yes
```



insert

- **insert** – define set of "inserts"--typically loaded in at BOC and removed after first cycle, e.g. WABA

insert INAME: $PINID_1$ $PINID_2$ … $PINID_i$ … $PINID_N$

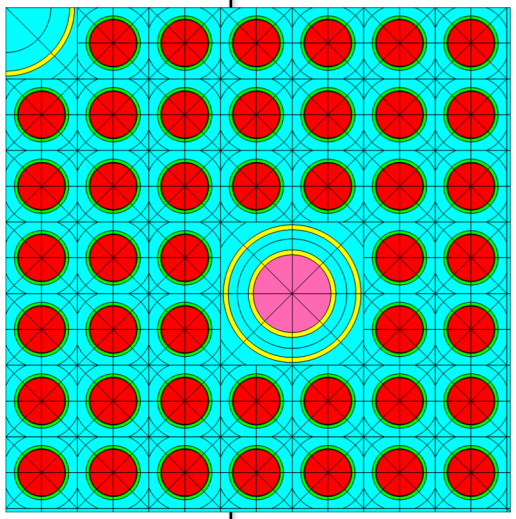
- INAME – name of insert map
- "_" indicates a map location without an insert
- **Must include enclosing guide tube**
- inserts are inserted into the problem geometry using **state** or **branch** cards

state INAME : in=*Bool*

- INAME – the name of the map
- in=yes|true – map is inserted
- in=no|false – map is not inserted

control

```
31 pin W 2 : 1.314 1.416 : COOL.1 TUBE
32 pin C 2 : 0.8    0.9  1.314  1.416
33         : CNTL.1 TUBE COOL.1 TUBE
34
35 pinmap
36  W
37  F F
38  F F F
39  F F F W
40  F F F W W
41  F F F F F F
42  F F F F F F F
43
44 control CR_MAP : RODLET
45  _
46  _ _
47  _ _ _
48  _ _ _ C
49  _ _ _ C C
50  _ _ _
51  _ _ _ _ _ _
52  _ _ _ _ _ _ _
53 state ALL : temp=570
54   CR_MAP : in=yes
55      FUEL : temp=997
56      COOL : dens=0.7307 boron=663
57
58
59
60
```



- **control** – define a control rod/blade structure

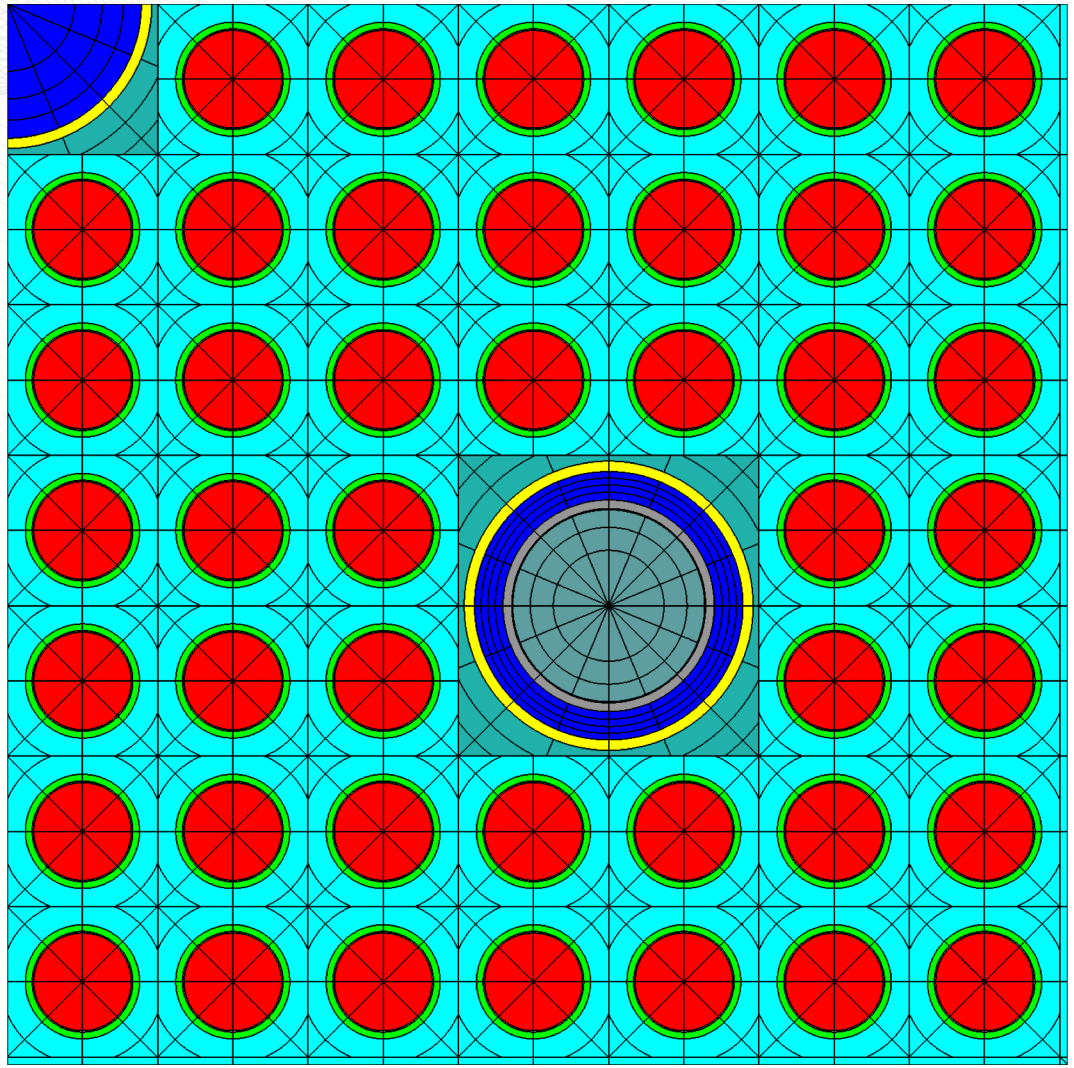
control ENAME: RODLET $PINID_1$ $PINID_2$ … $PINID_i$ … $PINID_N$

- RODLET indicates rod-type control map
- inserts are inserted into the problem geometry using **state** or **branch** cards

state ENAME : in=*Bool*

- ENAME – the name of the control structure
- in=yes|true – structure is inserted
- in=no|false – structure is not inserted

Exercises

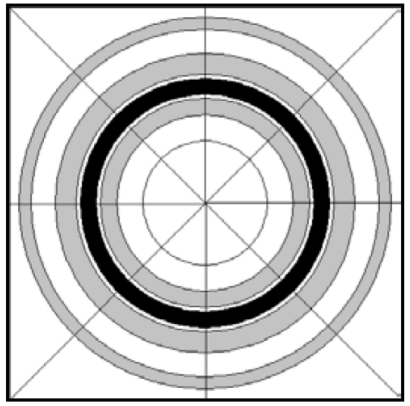


Create control rod for ce14x14 assembly

- Copy ce14x14.inp to ce14x14_cr.inp
- Control rod material
  - Use CNTL.2 (B4C)
  - Add mesh for nr=3, ns=16
- Control rod cladding
  - Define material TUBE.2 as INC718
- Control rod geometry
  - B4C radius 0.94 cm
  - Clad inner radius 0.95 cm
  - Clad outer radius 1.036 cm
- Record transport k-eff

Table 13: WABA Rod Specification

Input	Value
Poison Material	B_4C-Al_2O_3
Boron-10 Loading	6.03 mg/cm
Poison Density	3.65 g/cc
Inner Clad Inner Radius	0.286 cm
Inner Clad Outer Radius	0.339 cm
Poison Inner Radius	0.353 cm
Poison Outer Radius	0.404 cm
Cladding Inner Radius	0.418 cm
Cladding Outer Radius	0.484 cm
Annulus Material	Moderator
Cladding Material	Zircaloy-4
Plenum/Gap Material	Helium



- Copy w17x17_rev3.inp as w17x17_waba.inp
- Create WABA **comp** (WABA), **mat** (BP.1), **pin** (W), and **insert** map (WABA_MAP all 24 GT locations)
- Create PYREX **mat** (BP.2), **pin** (P), and **insert** map (PYREX_MAP all 24 GT locations)
- Create AIC control rod **pin** (A), and **control** map (AIC_MAP all 24 GT locations)
- Create B4C control rod **pin** (B), and **control** map (B4C_MAP all 24 GT locations)
- Insert WABAs, compute k-eff, proceed next slide

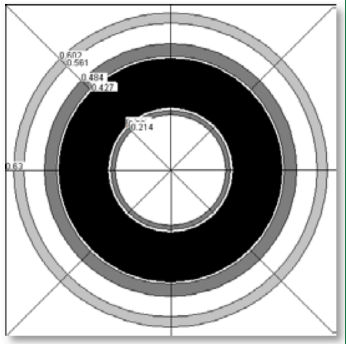
Hint: these data imply B4C is 9.49 wt%

Table 8: RCCA Rod and Drive Specification

Input	AIC	B_4C
Composition	80/15/5% Ag/In/Cd (Lower)	100% B_4C (Upper)
Poison Density	10.2 g/cc	1.76 g/cc
Poison Radius	0.382 cm	0.373 cm
Poison Height	101.6 cm	259.08 cm
Cladding Inner Radius	0.386 cm	
Cladding Outer Radius	0.484 cm	
Total Poison Height	360.68 cm	
Axial Location of Poison (when fully inserted)	17.031 cm	
Plenum Height above Poison	10.7 cm	
End Plug Height	≈ 1.9 cm	
Step Size	1.5875 cm	
Maximum number of steps	230	
Cladding Material	SS304	
Plenum Material	Helium	

Table 6: Pyrex Rod Specification

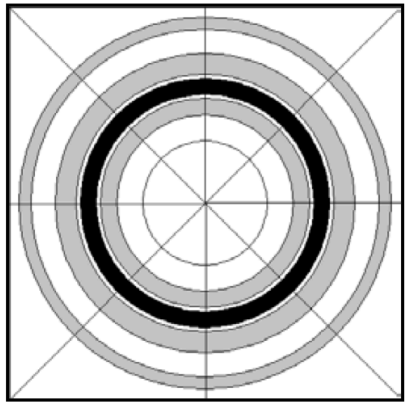
Input	Value
Enrichment	12.5 wt% B_2O_3
Boron-10 Loading	6.24 mg/cm
Pyrex Density	2.25 g/cc
Inner Tube Inner Radius	0.214 cm
Inner Tube Outer Radius	0.231 cm
Pyrex Inner Radius	0.241 cm
Pyrex Outer Radius	0.427 cm
Cladding Inner Radius	0.437 cm
Cladding Outer Radius	0.484 cm
Poison Height	360.68 cm
Plenum Height above Poison	22.2 cm
Axial Location of Poison	15.761 cm
End Plug Height	≈ 2.54 cm
Inner Tube Material	SS304
Plenum Material	Helium
Cladding Material	SS304



Reference: CASL Benchmark for WBN1

Table 13: WABA Rod Specification

Input	Value
Poison Material	B_4C-Al_2O_3
Boron-10 Loading	6.03 mg/cm
Poison Density	3.65 g/cc
Inner Clad Inner Radius	0.286 cm
Inner Clad Outer Radius	0.339 cm
Poison Inner Radius	0.353 cm
Poison Outer Radius	0.404 cm
Cladding Inner Radius	0.418 cm
Cladding Outer Radius	0.484 cm
Annulus Material	Moderator
Cladding Material	Zircaloy-4
Plenum/Gap Material	Helium



- Copy w17x17_waba.inp as w17x17_pyrex.inp
- Insert Pyrex, compute k-eff
- Copy w17x17_waba.inp as w17x17_b4c.inp
- Insert B4C CR, compute k-eff
- Copy w17x17_waba.inp as w17x17_aic.inp
- Insert AIC CR, compute k-eff

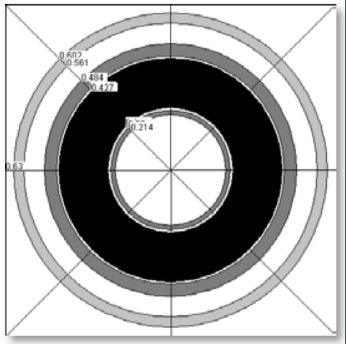
Hint: these data imply
B4C is 9.49 wt%

Table 8: RCCA Rod and Drive Specification

Input	AIC	B_4C
Composition	80/15/5% Ag/In/Cd (Lower)	100% B_4C (Upper)
Poison Density	10.2 g/cc	1.76 g/cc
Poison Radius	0.382 cm	0.373 cm
Poison Height	101.6 cm	259.08 cm
Cladding Inner Radius	0.386 cm	
Cladding Outer Radius	0.484 cm	
Total Poison Height	360.68 cm	
Axial Location of Poison (when fully inserted)	17.031 cm	
Plenum Height above Poison	10.7 cm	
End Plug Height	≈ 1.9 cm	
Step Size	1.5875 cm	
Maximum number of steps	230	
Cladding Material	SS304	
Plenum Material	Helium	

Table 6: Pyrex Rod Specification

Input	Value
Enrichment	12.5 wt% B_2O_3
Boron-10 Loading	6.24 mg/cm
Pyrex Density	2.25 g/cc
Inner Tube Inner Radius	0.214 cm
Inner Tube Outer Radius	0.231 cm
Pyrex Inner Radius	0.241 cm
Pyrex Outer Radius	0.427 cm
Cladding Inner Radius	0.437 cm
Cladding Outer Radius	0.484 cm
Poison Height	360.68 cm
Plenum Height above Poison	22.2 cm
Axial Location of Poison	15.761 cm
End Plug Height	≈ 2.54 cm
Inner Tube Material	SS304
Plenum Material	Helium
Cladding Material	SS304



Reference: CASL Benchmark for WBN1

Depletion

bu, bui, dbu cards
t, ti, dti cards

```
%--------------------------------------%
% maps
%--------------------------------------%
pinmap
I
F F
F F F
G F F G
F F F F F
F F F F F G
G F F G F F F
F F F F F F F F
F F F F F F F F F
%--------------------------------------%
% state
%--------------------------------------%
pow 40
bu 0 4 8 12 %burnup 0 is optional

   %equivalent to

pow  40   40    40
bu 4000 8000 12000 : MWD/MTIHM

   %equivalent to

pow   40  40  40
t    0 100 200 300  %time 0 is optional

```

Depletion

pow(er) p1 … pi … pN

bu b1 … bi … bN [:units=GWD/MTIHM|MWD/MTIHM]

t t1 … ti … tN [:units=SECONDS|MINUTES|HOURS|DAYS|YEARS]

- **power** is required (units are MW/MTIHM)
- **bu** vs **t**
  - user preference
  - t is required for decay steps
  - t=0 or bu=0 is optional
- Example 1, Constant power:
  - only 1 power value is needed, but multiple values are accepted
  - multiple power values: required same number of bu (or t) values (ignoring the initial 0 value)

```
%--------------------------------------%
% maps
%--------------------------------------%
pinmap
I
F F
F F F
G F F G
F F F F F
F F F F F G
G F F G F F F
F F F F F F F F
F F F F F F F F F
%--------------------------------------%
% state
%--------------------------------------%
pow 40  35  30  0
t   100 200 300 330

   %equivalent to

pow 40  35  30  0
dt  100 100 100 330

   %equivalent to

pow  40   35   30   0
dt 2400 2400 2400 720 : HOURS


```

Depletion

dbu b1 … bi … bN [: units=GWD/MTIHM|MWD/MTIHM]

dt t1 … ti … tN [:units=SECONDS|MINUTES|HOURS|DAYS|YEARS]

- **dbu** and **dt** do not support an initial 0 value
- multiple power values: required same number of **dbu** (or **dt**) values
- Example 2, Power history:
  - time-based input is required because of decay steps

```
44 %---------------------------------------%
45 % state
46 %---------------------------------------%
47 pow 40 40 40 40 20 20 20 20
48 bu  1  4  8  12 13 16 20 24
49
50    %equivalent to
51
52 pow 40 bu   1  4  8 12 %cycle 1
53 pow 20 bu  13 16 20 24 %cycle 2
54
55    %equivalent to
56
57 pow 40 bu   1   4   8  12 %cycle 1
58 pow 20 t  350 500 700 900 %cycle 2
59
60    %equivalent to
61
62 pow 40 bu   1   4   8  12 %cycle 1
63 pow 20 bui  1   4   8  12 %cycle 2
64
65
66
67
68
69
70
71
72
73
```

Depletion

- Multiple depletion histories are allowed
- **bui**, **tui** – convenient card for cycle history

bui b1 … bi … bN [:units=GWD/MTIHM|MWD/MTIHM]

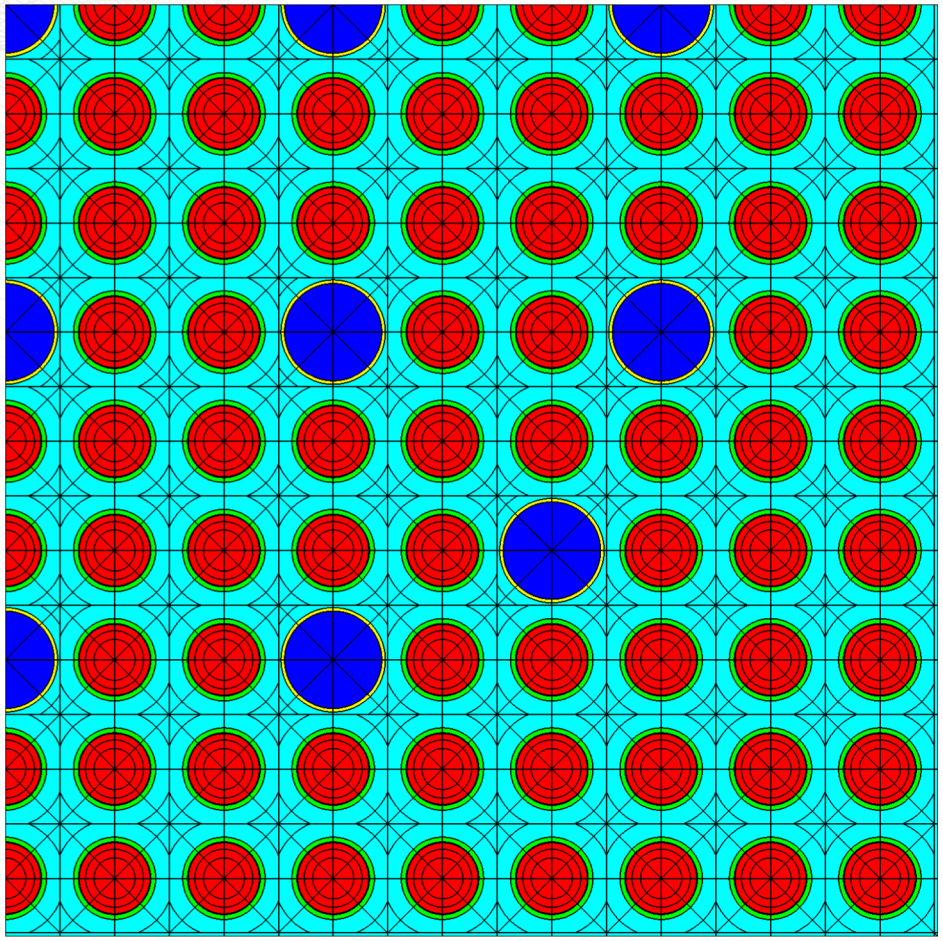
ti t1 … ti … tN [:units=SECONDS|MINUTES|HOURS|DAYS|YEARS]

- In the input, **bui** resets the origin to 0 for that card
- **bui** values are appended to previous history
- Similar behavior for **ti**

Depletion Methodology

- Polaris uses predictor-corrector depletion:
  - burnup step [bu, bu+dbu]:
    1. flux calculation at bu
    2. deplete (predictor step)
    3. flux calculation at bu+dbu
    4. re-deplete with new flux (corrector step)
    5. average isotopics at bu+dbu from step 2. and step 4.
  - decay step [t, t+dt]:
    1. flux calculation at t
    2. decay calculation to t+dt

Exercises



- Part 1
  - Copy w17x17_rev3.inp as w17x17_depl.inp
  - Power: 40 MW/MTIHM
  - Burnup steps (GWD/MTIHM): 0 0.1 5 10
  - Review depletion output
- Part 2 (on your own)
- copy w17x17_depl.inp as w17x17_depl2.inp
  - Power: 40 MW/MTIHM, 30 MW/MTIHM starting at 20 GWD/MTIHM
  - Burnup steps (GWD/MTIHM): 0 0.1 5 10 20 30

basis card
deplete card

```
%--------------------------------------%
% maps
%--------------------------------------%
pinmap
I
F F
F F F
G F F G
F F F F F
F F F F F G
G F F G F F F
F F F F F F F F
F F F F F F F F F
%--------------------------------------%
% state
%--------------------------------------%
pow 40
bu 4 8 12
deplete ALL=no FUEL=yes CLAD=yes
state ALL  : temp=590
       COOL : dens=0.68
              boron=1300
       MOD  : dens=0.71
              boron=1300
              temp=575
       FUEL : temp=900
       CLAD : temp=700
       TUBE : temp=580
end
```

deplete card

deplete M_1=yes|no M_2=yes|no … M_i=yes|no … M_N= yes|no

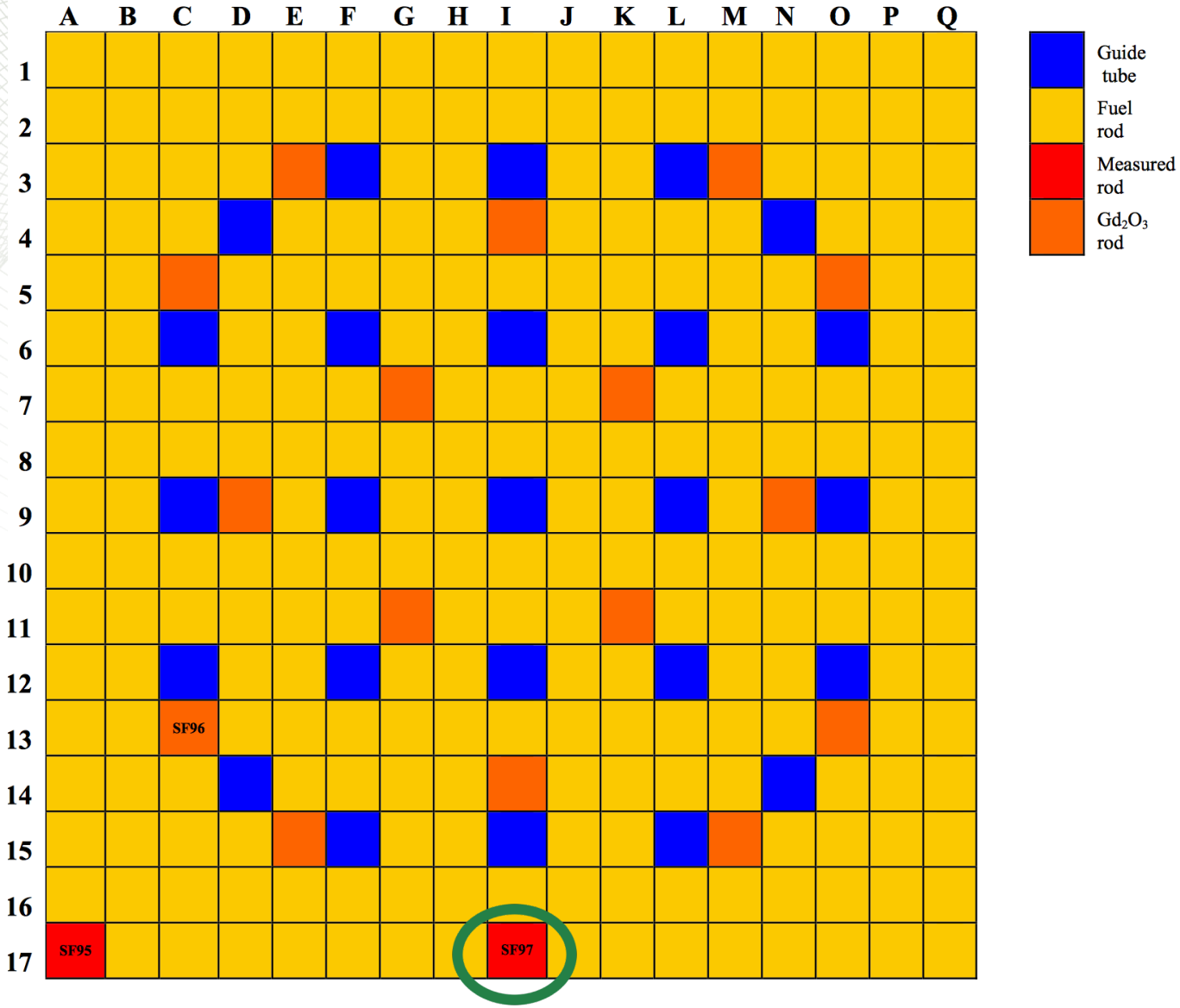
- **M_i** – Material name or Material class
  - **yes** – material is depleted
  - **no** – material is depleted
- **system PWR** defaults
  - **deplete** ALL=no FUEL=yes BP=yes
- **system BWR** defaults
  - **deplete** ALL=no FUEL=yes
- the ALL=no disables all the materials before explicit materials are enabled

```
%---------------------------------------%
% maps
%---------------------------------------%
pinmap
I
F F
F F F
G F F G
F F F F F
F F F F F G
G F F G F F F
F F F F F F F F
F F F F F F F F F
%---------------------------------------%
% state
%---------------------------------------%
pow 40
bu 4 8 12
basis ALL=no FUEL.2=yes
state ALL  : temp=590
       COOL : dens=0.68
              boron=1300
       MOD  : dens=0.71
              boron=1300
              temp=575
       FUEL : temp=900
       CLAD : temp=700
       TUBE : temp=580
end
```

basis card

basis M_1=yes|no M_2=yes|no … M_i=yes|no … M_N= yes|no

- M_i – Material name or Material class
  - **yes** – the power referenced on the power card includes this material's power (assumed deposited locally)
  - **no** – material is not part of the power basis
- Default: ALL=yes,
  meaning the power given on the power card is the power produced by all materials (power generated by fission and capture)
- If FUEL.2 is the basis material:
  - basis ALL=no FUEL.2=yes
  - the ALL=no disables all the materials before FUEL.2 is enabled



Exercises

- Takahama assembly depletion benchmark
- copy taka.inp as taka_depl_rev0.inp
- copy FUEL.1 -> FUEL.3
- duplicate **pin** card for FUEL.1 to FUEL.3 as **pin** B (for BASIS)
- duplicate **mesh** card for FUEL.1 to FUEL.3 (nr=1)
- modify **pinmap** to use new pin at circled location (SF97 sample)
- SF97 sample operating history (next slide)

https://www.oecd-nea.org/science/docs/2013/nsc-doc2013-1.pdf
additional data at: http://info.ornl.gov/sites/publications/files/Pub23359.pdf

Exercises

Table A.1: Results for actinides in assembly calculation–comparison to measured values (at discharge)

	Experimental measurement (Exp)	CEA-D	GRS	NEXIA	RRC-KI	VTT	Average (A)	RSD	(A-Exp)/Exp	Experimen uncertaint (1σ)
U234	1.872E+02	2.008E+02	1.977E+02	2.020E+02	2.073E+02	2.053E+02	2.026E+02	2%	8%	1%
U235	8.179E+03	8.235E+03	8.323E+03	8.720E+03	8.202E+03	8.288E+03	8.354E+03	2%	2%	N/A
U236	5.528E+03	5.285E+03	5.179E+03	5.270E+03	5.318E+03	5.232E+03	5.257E+03	1%	-5%	2%
U238	9.246E+05	9.265E+05	9.261E+05	9.270E+05	9.256E+05	9.267E+05	9.264E+05	0%	0%	N/A
Np237	6.604E+02	6.003E+02	6.664E+02	6.240E+02	6.480E+02	5.917E+02	6.261E+02	4%	-5%	10%
Pu238	3.199E+02	2.534E+02	2.841E+02	2.660E+02	2.677E+02	2.435E+02	2.629E+02	5%	-18%	1%
Pu239	6.037E+03	5.663E+03	5.951E+03	5.820E+03	5.958E+03	5.624E+03	5.803E+03	2%	-4%	N/A
Pu240	2.668E+03	2.672E+03	2.630E+03	2.550E+03	2.838E+03	2.697E+03	2.678E+03	4%	0%	N/A
Pu241	1.770E+03	1.601E+03	1.722E+03	1.640E+03	1.674E+03	1.639E+03	1.655E+03	2%	-6%	N/A
Pu242	8.246E+02	7.410E+02	7.721E+02	7.330E+02	7.790E+02	7.582E+02	7.567E+02	2%	-8%	N/A
Am241	5.311E+01	5.134E+01	5.482E+01	5.420E+01	5.295E+01	4.704E+01	5.207E+01	5%	-2%	2%
Am242m	1.233E+00	7.767E-01	9.929E-01	7.740E-01	8.764E-01	1.379E+00	9.597E-01	23%	-22%	10%
Am243	1.924E+02	1.622E+02	1.648E+02	1.550E+02	1.712E+02	1.298E+02	1.566E+02	9%	-19%	1%
Cm242	2.044E+01	2.231E+01	2.210E+01	2.280E+01	2.334E+01	2.237E+01	2.258E+01	2%	10%	10%
Cm243	8.721E-01	6.061E-01	5.949E-01	6.130E-01	6.262E-01	5.719E-01	6.024E-01	3%	-31%	2%
Cm244	8.810E+01	6.304E+01	5.949E+01	5.610E+01	5.831E+01	1.021E+02	6.781E+01	26%	-23%	2%
Cm245	6.042E+00	3.823E+00	3.109E+00	3.210E+00	3.176E+00	7.446E+00	4.153E+00	40%	-31%	2%
Cm246	7.440E-01	4.494E-01	3.365E-01	3.550E-01	3.728E-01	7.933E-01	4.614E-01	37%	-38%	1%
Cm247	1.098E-02	5.268E-03	4.182E-03	3.320E-03	4.537E-03	1.064E-02	5.590E-03	47%	-49%	10%

Days	Status	Power (W/gU)
385	Full power	38.6
88	Downtime	0
402	Full power	38.6
62	Downtime	0
406	Full power	38.6

```
pow 38.6 dt 1 25 25 50 50 50 50 50 84
pow 0    dt 88
pow 38.6 dt 1 50 50 100 100 101
pow 0 dt 62
pow 38.6 dt 1 50 50 100 100 105
```

- use depletion history for FUEL.3 basis shown here
- determine mass fraction of FUEL.3 IHM to system IHM on taka_depl_rev0.out
- Instructor Demo
  - determine file position of FUEL.3 on taka_depl_rev0.f71
  - setup taka_opus_rev0.inp to generate isotopics
  - compare with taka.xls

https://www.oecd-nea.org/science/docs/2013/nsc-doc2013-1.pdf
additional data at: http://info.ornl.gov/sites/publications/files/Pub23359.pdf

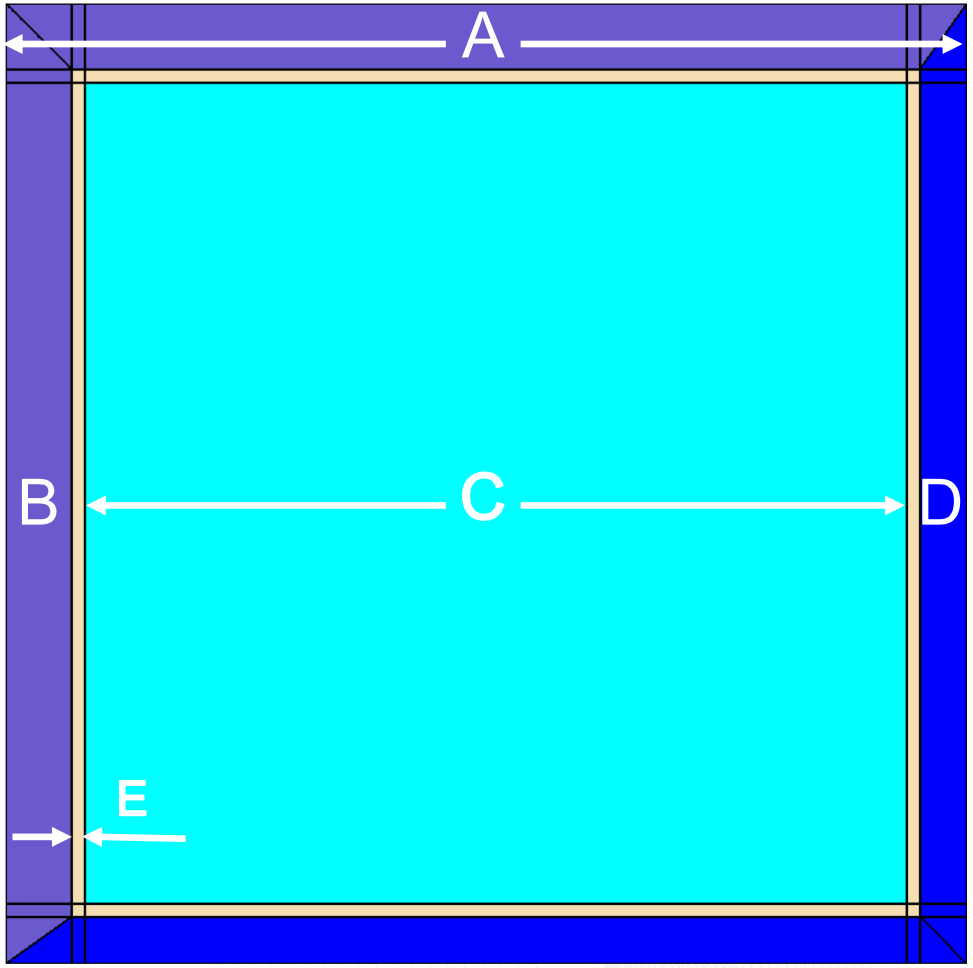
BWR assemblies

box card
system BWR

BWR Geometry Basics

A. lattice pitch
B. wide gap (north and west sides)
C. in-channel span
D. narrow gap (east and south sides)
E. channel box thickness

- Must know 4 of 5 from design documentation
- The 5th value is computed from A=B+C+D+2E
- Control blades are inserted into the wide gaps
- Detectors are inserted into the narrow gaps
- Typical values:
  - lattice pitch: 15.24 cm
  - channel box thickness: 80 mil (0.2032 cm)



$$A = B + C + D + 2E$$

```
=polaris_6.3
%-------------------------------------%
% general options
%-------------------------------------%
title "BWR 7x7"
lib "broad_n"
system BWR
%-------------------------------------%
% geometry (lattice pitch=15.24)
%-------------------------------------%
geom bwr7x7 : ASSM 7 1.88
hgap 0.47498 0.9525
box  0.2032 0.0 6.70306
%-------------------------------------%
% fuel material (2.93 enr, 10.32 g/cc)
%-------------------------------------%
comp c_e293 : UOX 2.93
mat  FUEL.1 : c_e293 10.32
%-------------------------------------%
% pins
%-------------------------------------%
pin 1 : 0.61   0.62 0.715
      : FUEL.1 GAP  CLAD
%-------------------------------------%
% state
%-------------------------------------%
state ALL   : temp=600
      MOD   : void=0
      COOL  : void=40
end
```

GE 7x7 Example (ge7x7_rev0.inp)

Source: LWR UAM Benchmark NEA/NSC/DOC(2013)7

A. lattice pitch (15.24 cm)

B. wide gap (0.9525 cm)

C. in-channel span (?)

D. narrow gap (0.47498 cm)

E. channel box thickness (0.2032 cm)

$\Rightarrow$ C = A-B-D-2E = 13.40612 cm

- Polaris input requirements:
  - narrow gap (first entry on **hgap**)
  - wide gap (second entry on **hgap**)
  - channel box thickness (first entry on **box**)
  - ½ of in-channel span (third entry on **box**)
  - lattice pitch is not needed

system BWR

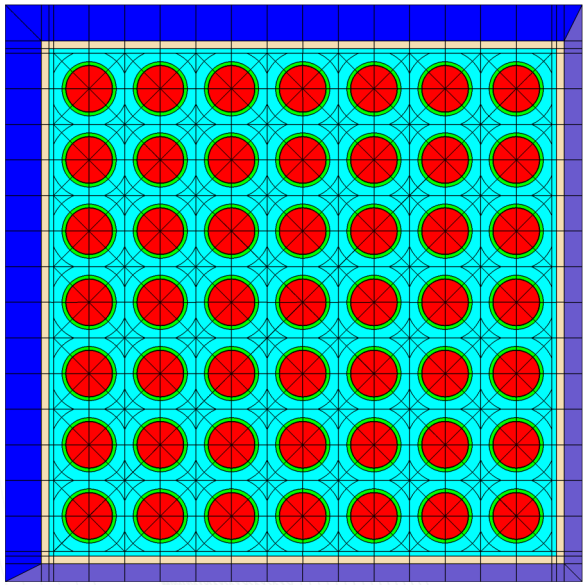
Material	Composition	Plot Color	Additional info
Unless noted otherwise, T=557K, nr=1, ns=8, nf=2, nd=1			
COOL.1	H2O	cyan	**pin** coolant material, nr=2
COOL.2	H2O	aquamarine	extra **pin** coolant material
MOD.1	H2O	blue	Wide **hgap** material, internal moderator for water rods
MOD.2	H2O	purple	Narrow **hgap** material, extra internal moderator
Water materials initialized to boron = 0 ppm, void=0, liquid_dens= 0.743 g/cc, vapor_dens= 0.0353 g/cc			
FUEL.1	n/a	red	depletable **(deplete),** auto-expanded **(shield)**
CAN.1	n/a	n/a	channel **box** material
CNTL.1	AIC	pink	auto-expanded **(shield)**
CNTL.2	B4C	cadetblue	auto-expanded **(shield)**
CLAD.1	ZIRC2	lime	
TUBE.1	ZIRC2	yellow	optional for guide tubes
GAP.1	FILLGAS	rosybrown	
STRUCT.1	SS304	goldenrod	blade sheath/central support material

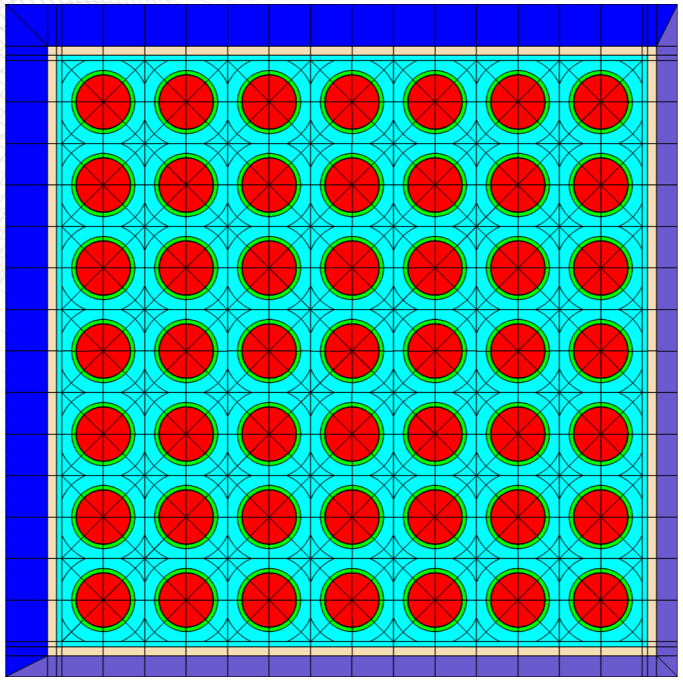
box part 1

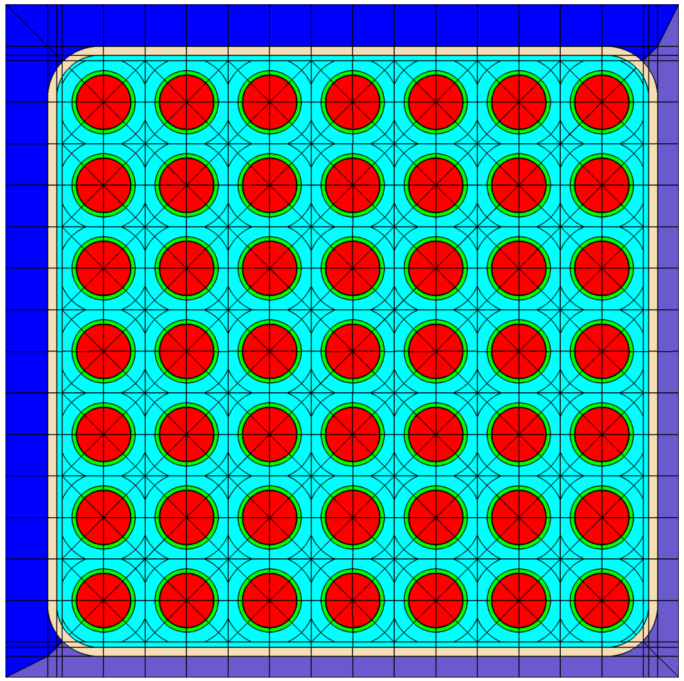
```
1 =polaris_6.3
2 %---------------------------------------%
3 % general options
4 %---------------------------------------%
5 title "BWR 7x7"
6 lib "broad_n"
7 system BWR
8 %---------------------------------------%
9 % geometry (lattice pitch=15.24)
10 %---------------------------------------%
11 geom bwr7x7 : ASSM 7 1.88
12 hgap 0.47498 0.9525 : MOD.1 MOD.2
13
14 box   0.2032 0.0 6.70306
15
16       %equivalent to
17
18 box   thick=0.2032
19       rad=0.0
20       hspan=6.70306
21       MBox=CAN.1
22
23       %equivalent to
24
25 box   0.2032 hspan=6.70306
26
27
28
29
30
```

box thick=Real [rad=Real] [hspan=Real] [Mbox=MNAME]

- **thick** - channel box thickness (cm)
  - required
  - must be > 0
- **rad** - inner corner radius (cm)
  - optional
  - must be >= 0
  - default: 0
- **hspan** - half in-channel span (cm)
  - optional
  - must be >= 0
  - default: N*pin_pitch/2
- **Mbox** – channel box material
  - optional
  - default: CAN.1 with sys BWR (which is ZIRC2)





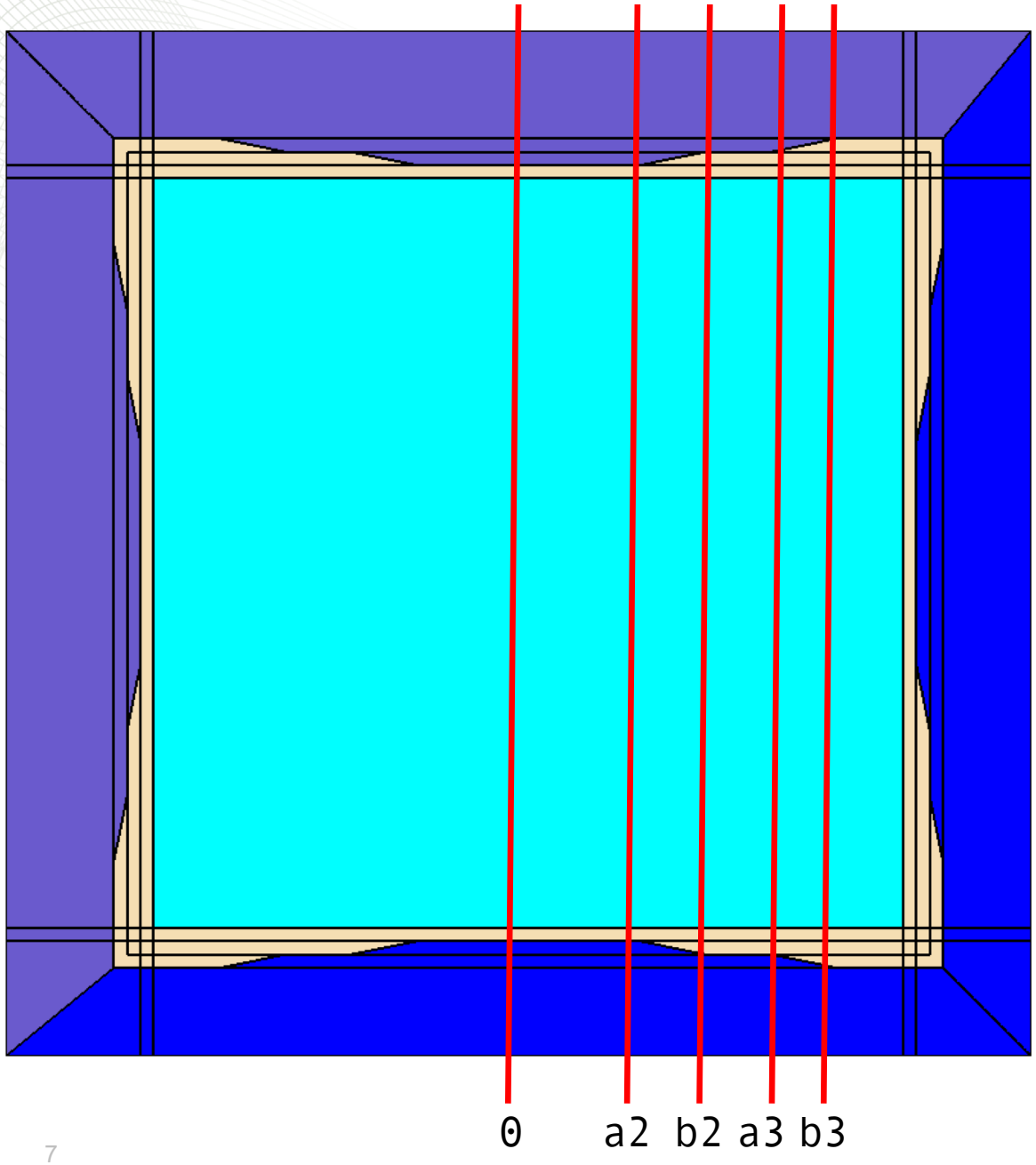


Exercise 1 of 2

Source: LWR UAM Benchmark NEA/NSC/DOC(2013)7

- run ge7x7_rev0.inp
  - should have channel box radius as 0.0
- copy ge7x7_rev0.inp -> ge7x7_rev1.inp
- modify channel box radius to be 0.9652
- run ge7x7_rev1.inp
- compare transport k-eff

box part 2



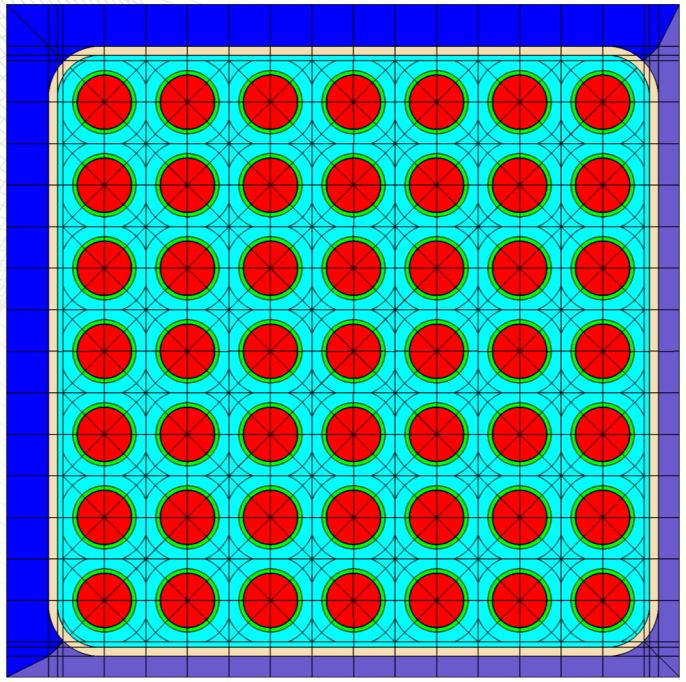
- single region channel box definition

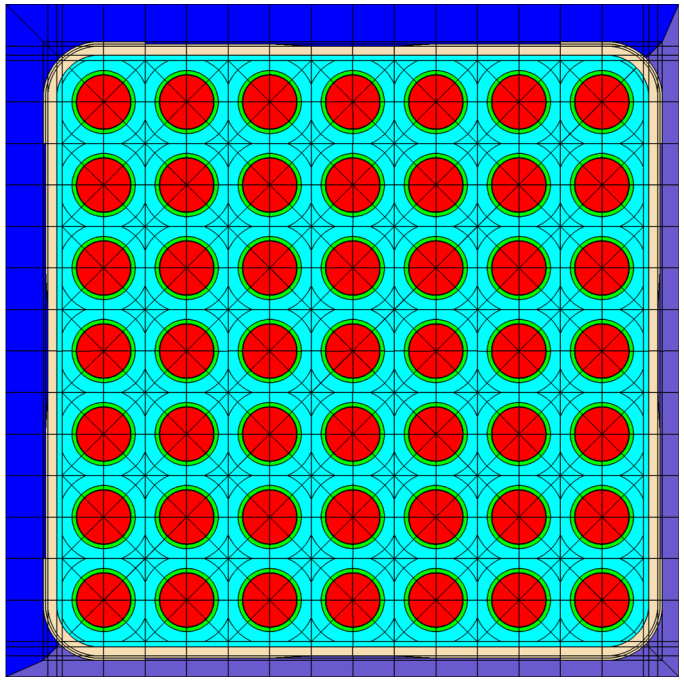
box thick=Real [rad=Real] [hspan=Real] [Mbox=MNAME]

- multiregion channel box definition

box thick=Real [rad=Real] [hspan=Real] [Mbox=MNAME]
[: t2 t3 … tN]
[: a2 a3 … aN]
[: b2 b3 … bN]

- **t2 t3 … tN** – channel box thickness for region 2, 3, … N
- regions 2 through N can have “cutout” regions (cm)
- **a2 a3 … aN** – distance from centerline to bottom of cutout region 2, 3, … N (cm)
- **b2 b3 … bN** – distance from centerline to top of cutout region 2, 3, … N (cm)
- Rules:
  - b2 >= a2, b3 >= a3, …
  - a3 >= b2, a4 >= b3, …
  - i.e., cutout regions cannot get smaller moving from region 2 to N

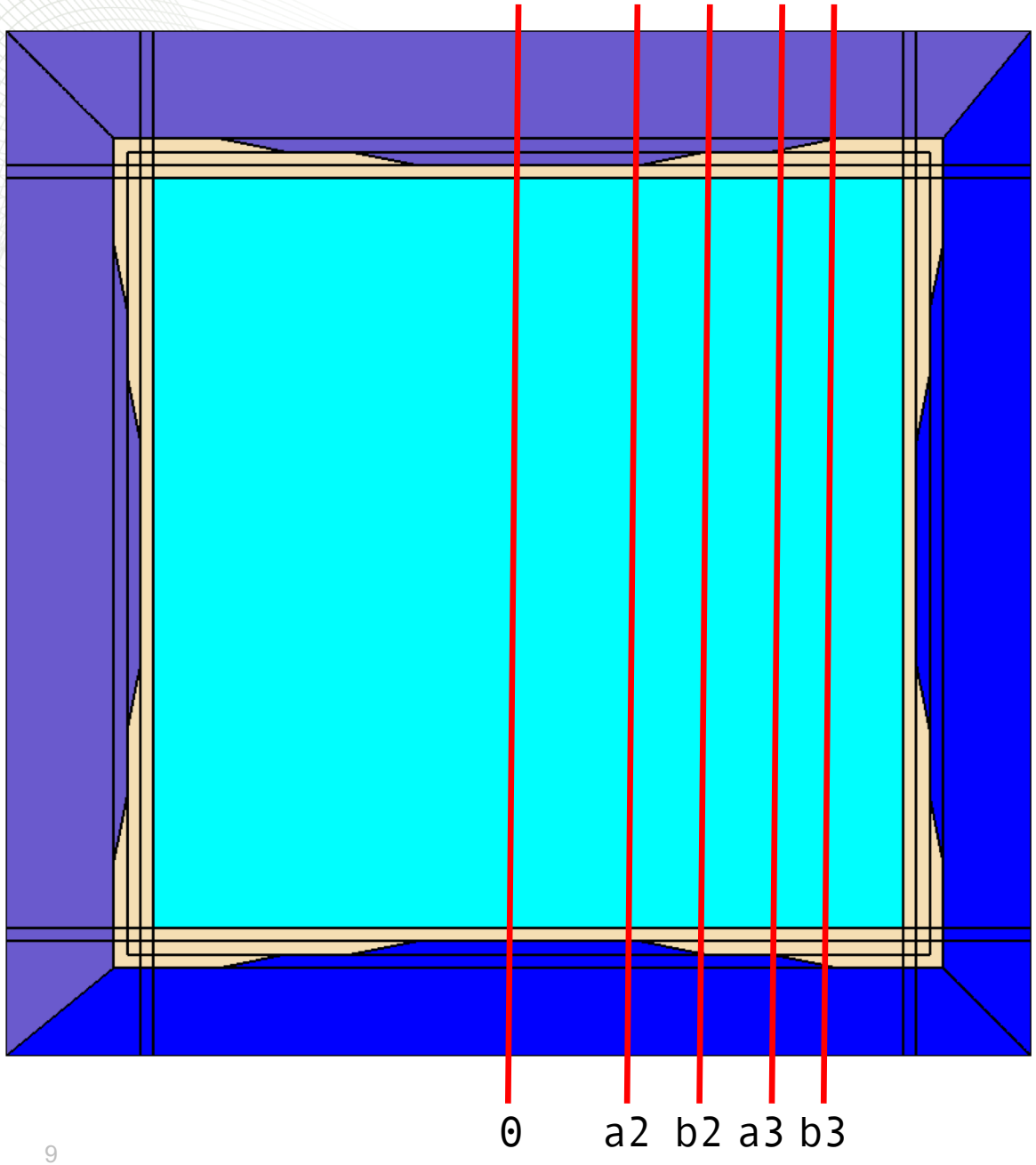




Exercise 2 of 2

- copy ge7x7_rev1.inp -> ge7x7_rev2.inp
- add two additional regions
  1. 20 mil thick a = 0.5 pitch, b = 1 pitch
  2. 20 mil thick a = b = 2.5 pitch
- run ge7x7_rev2.inp
- Compare transport k-eff

box part 3



- multiregion channel box definition

box thick=Real [rad=Real] [hspan=Real] [Mbox=MNAME]

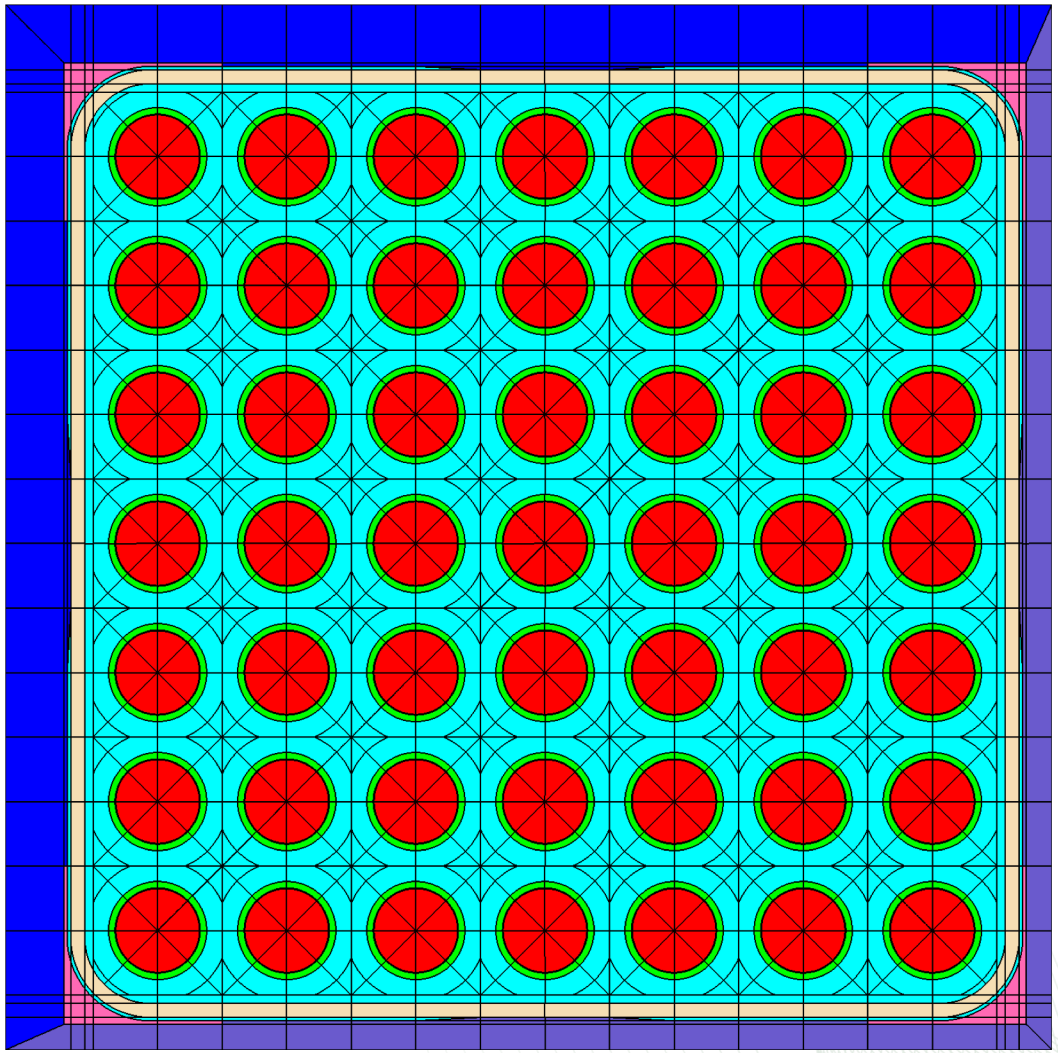
[: t_2 t_3 … t_N]
[: a_2 a_3 … a_N]
[: b_2 b_3 … b_N]
[: m_2 m_3 … m_N]
[: r_2 r_3 … r_N r_{out}]

- **m_i** – material for region i
  - default is **m_{i-1}**
- **r_i** – inner corner radius for region i
  - default is 0 if **r_{i-1}** is 0, otherwise **$r_{i-1} + t_{i-1}$**
- **r_{out}** – outer corner radius for final region
  - default is 0 if **r_N** is 0, otherwise **$r_N + t_N$**

box part 3

```
=polaris_6.3
%---------------------------------------%
% general options
%---------------------------------------%
title "BWR 7x7"
lib "broad_n"
system BWR
%---------------------------------------%
% geometry (lattice pitch=15.24)
%---------------------------------------%
geom bwr7x7 : ASSM 7 1.88
hgap 0.47498 0.9525
box  0.2032 0.9652 6.70306
   : 0.0508 0.0508
   : 0.94   4.7
   : 1.88   4.7
   : COOL.1 CNTL.1
   : 1.1684 1.2192 0.0
%---------------------------------------%
% fuel material (2.93 enr, 10.32 g/cc)
%---------------------------------------%
comp c_e293 : UOX 2.93
mat  FUEL.1 : c_e293 10.32
%---------------------------------------%
% pins
%---------------------------------------%
pin 1 : 0.61   0.62 0.715
      : FUEL.1 GAP  CLAD

```

just for fun

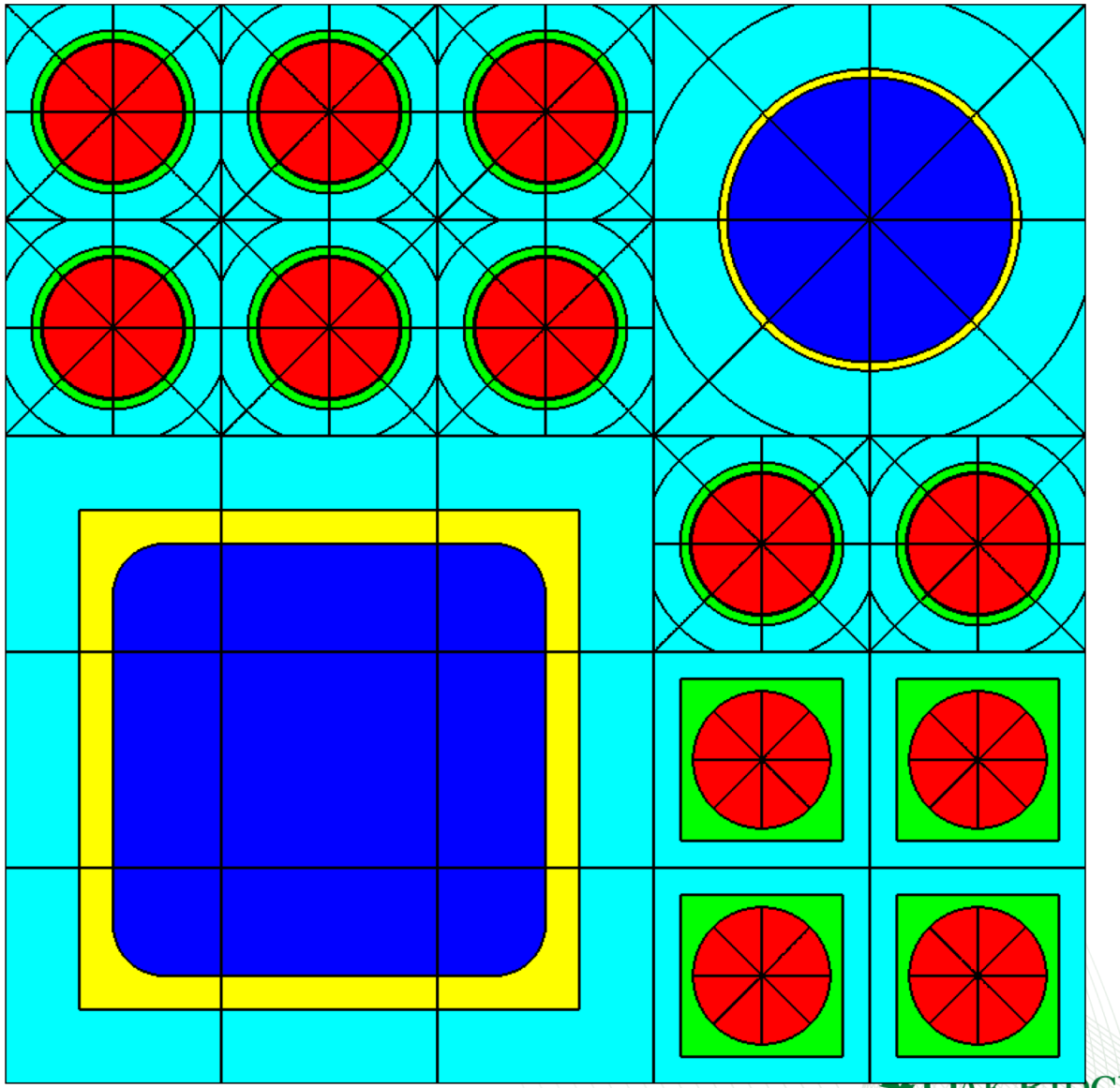


BWR Geometry

SQR option on pin card
size option on pin card

square pins

```
=polaris_6.3
title "W17x17"
lib "broad_n"
system PWR
geom W17 : ASSM 5 1.26
%-------------------------------------%
% comps and mats
%-------------------------------------%
comp c_e31 : UOX 3.1
mat FUEL.1 : c_e31  10.26
%-------------------------------------%
% pins
%-------------------------------------%
pin A : 0.4096 0.418 0.475
      : FUEL.1 GAP.1 CLAD.1
pin B 2 : 0.83  0.88  : MOD.1     TUBE.1
                      : CIR       CIR
pin C 3 : 1.26  1.46  : MOD.1     TUBE.1
                      : SQR(0.3)  SQR
pin D : 0.4     0.475
      : FUEL.1 CLAD.1
      : CIR    SQR
pinmap
 A A A B B
 A A A B B
 C C C A A
 C C C D D
 C C C D D
end

```



```
 1 =polaris_6.3
 2 title "W17x17"
 3 lib "broad_n"
 4 system PWR
 5 geom W17 : ASSM 5 1.26
 6 %--------------------------------------%
 7 % comps and mats
 8 %--------------------------------------%
 9 comp c_e31 : UOX 3.1
10 mat FUEL.1 : c_e31  10.26
11 %--------------------------------------%
12 % pins
13 %--------------------------------------%
14 pin A : 0.4096 0.418 0.475
15       : FUEL.1 GAP.1 CLAD.1
16 pin B 2 : 0.83  0.88   : MOD.1     TUBE.1
17                        : CIR       CIR
18 pin C 3 : 1.26  1.46   : MOD.1     TUBE.1
19                        : SQR(0.3)  SQR
20 pin D : 0.4     0.475
21       : FUEL.1 CLAD.1
22       : CIR    SQR
23 pinmap
24  A A A B B
25  A A A B B
26  C C C A A
27  C C C D D
28  C C C D D
29 end
30
```

square pins

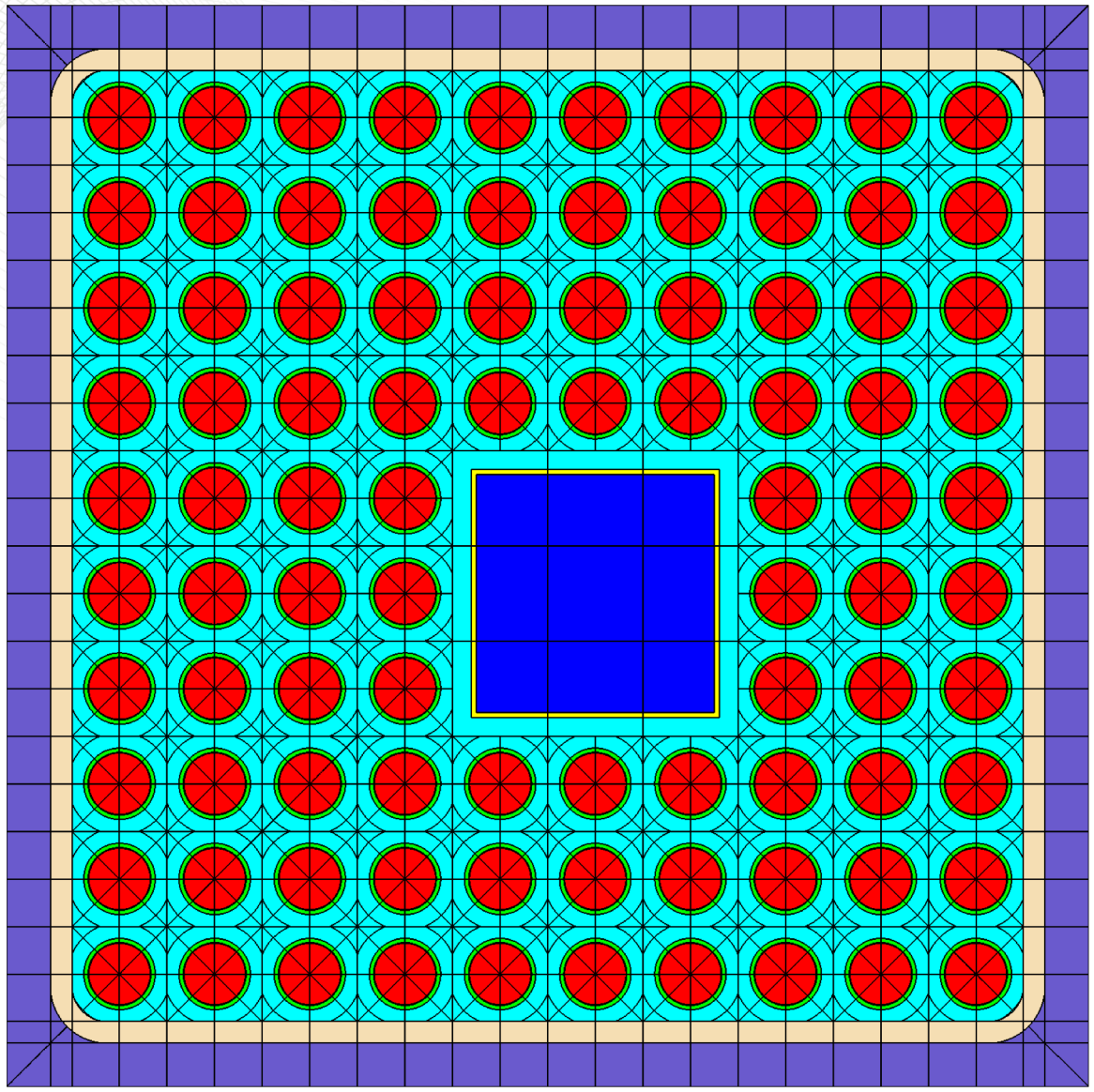
pin PINID [size=Real] : r_1 r_2 … r_N
: M_1 M_2 … M_N [M_{out}]
[: S_1 S_2 … S_N]

- **S_i** – shape for zone i
  - CIR for circle
  - SQR(X) for square, X is the inner corner radius
  - default shape is CIR, default value of X is 0.0

mesh MCLASS|MNAME : [nr=Int] [ns=Int]
[nf=Int] [nd=Int]
[nx=Int] [ny=Int]

- **nx** – number of x divisions, default 1
- **ny** – number of y divisions, default 1

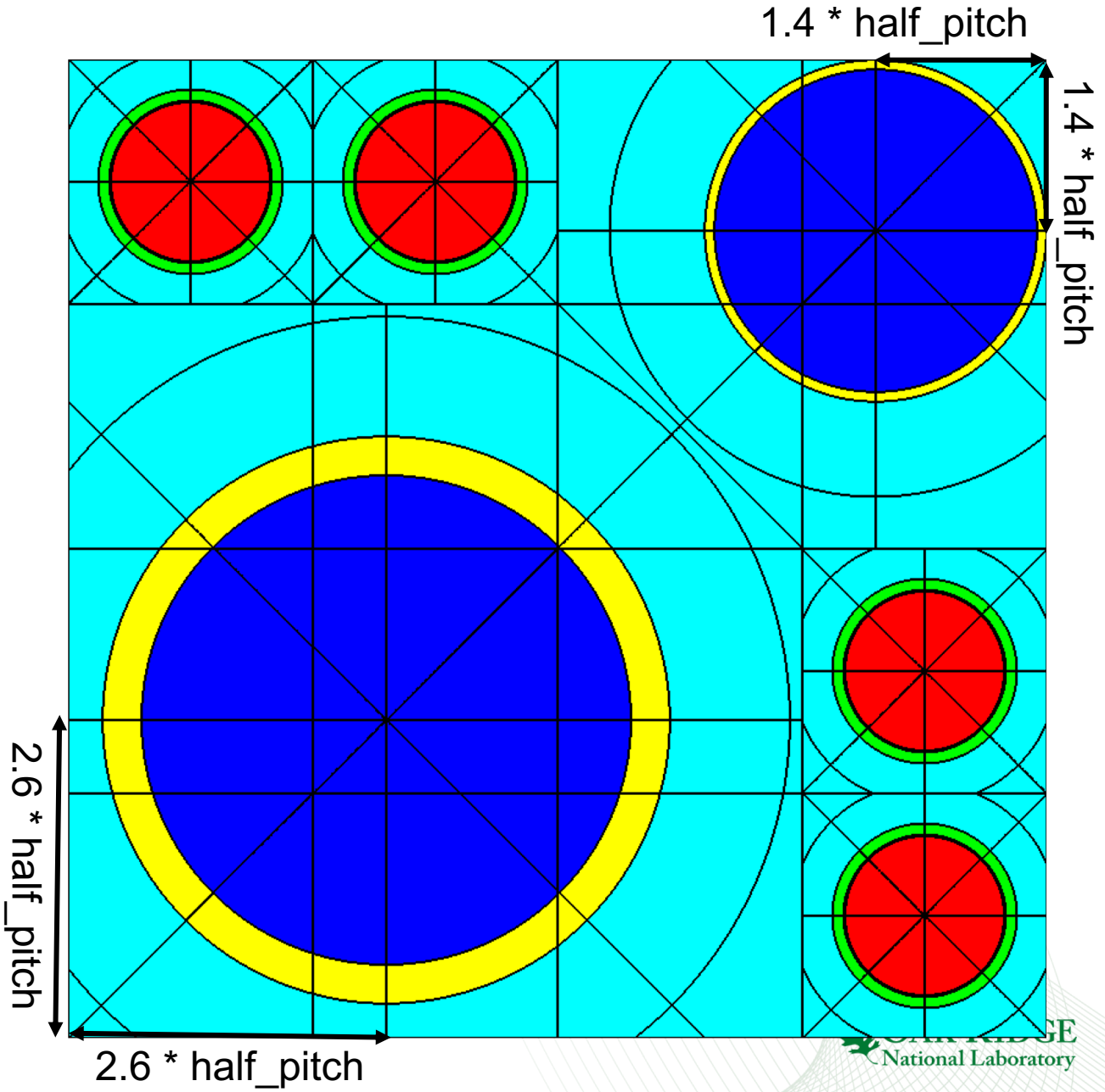
ATRIUM10 Exercise



- copy ge7x7_rev1.inp -> atrium10_rev1.inp
- change N from 7 to 10
- change pin pitch to 1.34 cm
- change box and gap based on the following design information
  - lattice pitch: 15.24 cm
  - channel box thickness: assume 0.3048 cm
  - channel box inner corner radius: assume 0.5 cm
  - half in-channel span: assume 5* pin_pitch
  - wide/narrow gap: assume uniform
- Assumed fuel pin info:
  - 2.93% enr, 10.32 g/cc
  - 0.4335 cm fuel radius
  - 0.442 cm gap radius
  - 0.5025 cm clad radius
- Water box info:
  - 3.36 cm inner width
  - 0.07 cm water box thickness
  - size=3
  - centered at (6,6) position

Noninteger pin size

```
=polaris_6.3
title "W17x17"
lib "broad_n"
system PWR
opt GEOM NumPlotRays=800
geom W17 : ASSM 4 1.26
%---------------------------------------%
% comps and mats
%---------------------------------------%
comp c_e31 : UOX 3.1
mat FUEL.1 : c_e31  10.26
%---------------------------------------%
% pins
%---------------------------------------%
pin A : 0.4096 0.418 0.475
      : FUEL.1 GAP.1 CLAD.1
pin B 1.4 : 0.83  0.88  : MOD.1  TUBE.1
pin C 2.6 : 1.26  1.46  : MOD.1  TUBE.1
pinmap
 A A B B
 C C _ B
 C C C A
 C C C A
end
```



Noninteger pin size

```
=polaris_6.3
title "W17x17"
lib "broad_n"
system PWR
opt GEOM NumPlotRays=800
geom W17 : ASSM 4 1.26
%---------------------------------------%
% comps and mats
%---------------------------------------%
comp c_e31 : UOX 3.1
mat FUEL.1 : c_e31  10.26
%---------------------------------------%
% pins
%---------------------------------------%
pin A : 0.4096 0.418 0.475
      : FUEL.1 GAP.1 CLAD.1
pin B 1.4 : 0.83  0.88  : MOD.1  TUBE.1
pin C 2.6 : 1.26  1.46  : MOD.1  TUBE.1
pinmap
 A A B B
 C C _ B
 C C C A
 C C C A
end
```

pin PINID [size=Real]

: r_1 r_2 … r_N

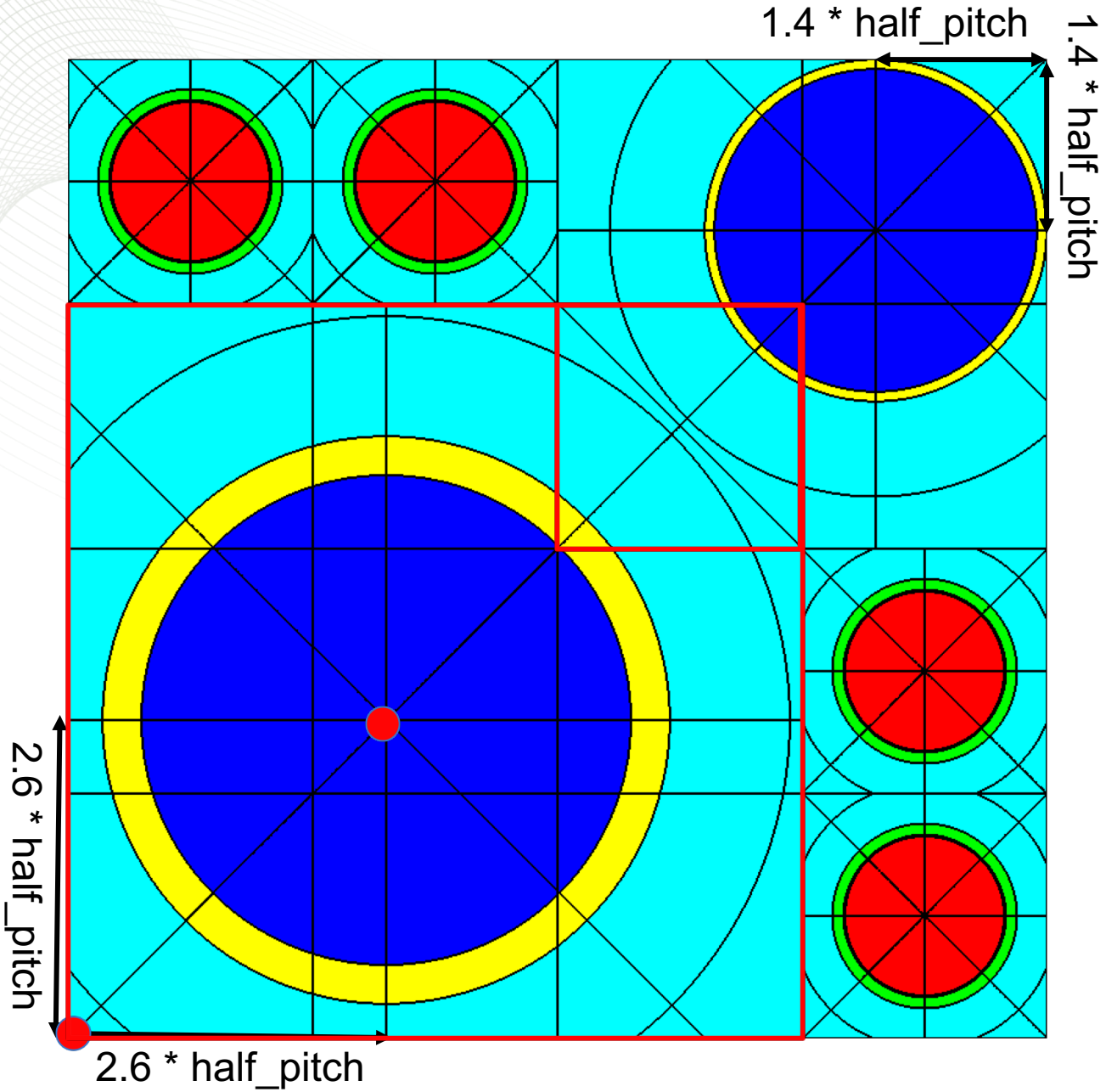
: M_1 M_2 … M_N [M_{out}]

[: S_1 S_2 … S_N]

Pin guidelines if **size** is noninteger:

- The pin fills a ceil(size) x ceil(size) subarray in the pinmap
  - Example: size=2.6 fills a 3x3 subarray in the pinmap
- The pin must share a pinmap location with another pin with noninteger size
  - Example: pin C and pin B share a common location at (row 2, col 3)
- The common location **MUST** be "_" in the pinmap

Noninteger pin size



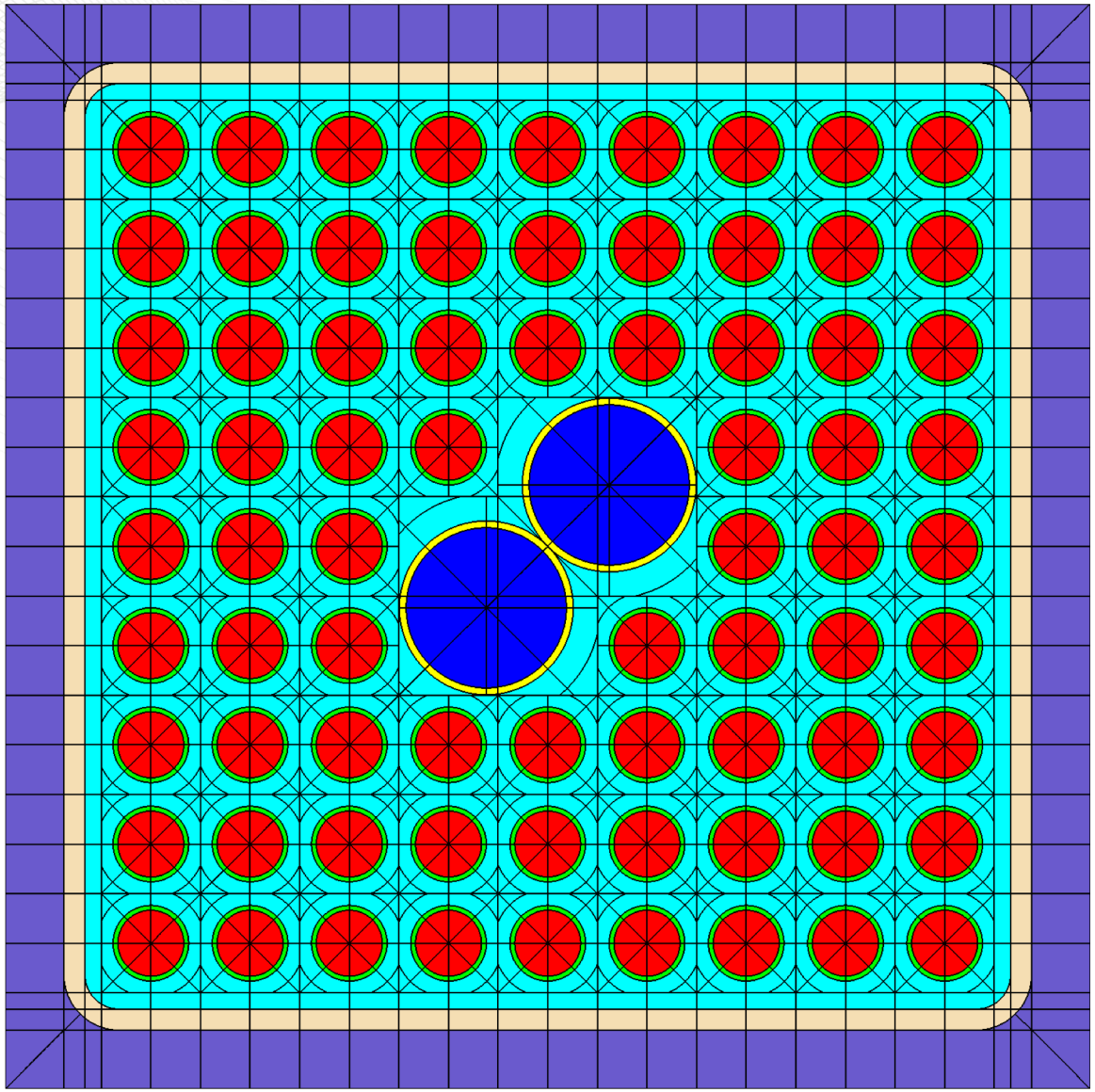
To determine the pin center (e.g. the size=2.6 pin):

1. Find the common pinmap location
2. Go to farthest corner from the common pinmap location
3. Compute d=size*half_pitch
4. From the farthest corner, move distance d in the x and y direction toward common pinmap location

- Common scenario
  - Identical water rods with 1 < size < 2
  - Pin pitch (P)
  - Outer radius (R)
  - Distance between water rods (D)

  - size = 3 – (2R+D)/P/sqrt(2)

GE 9x9 Exercise



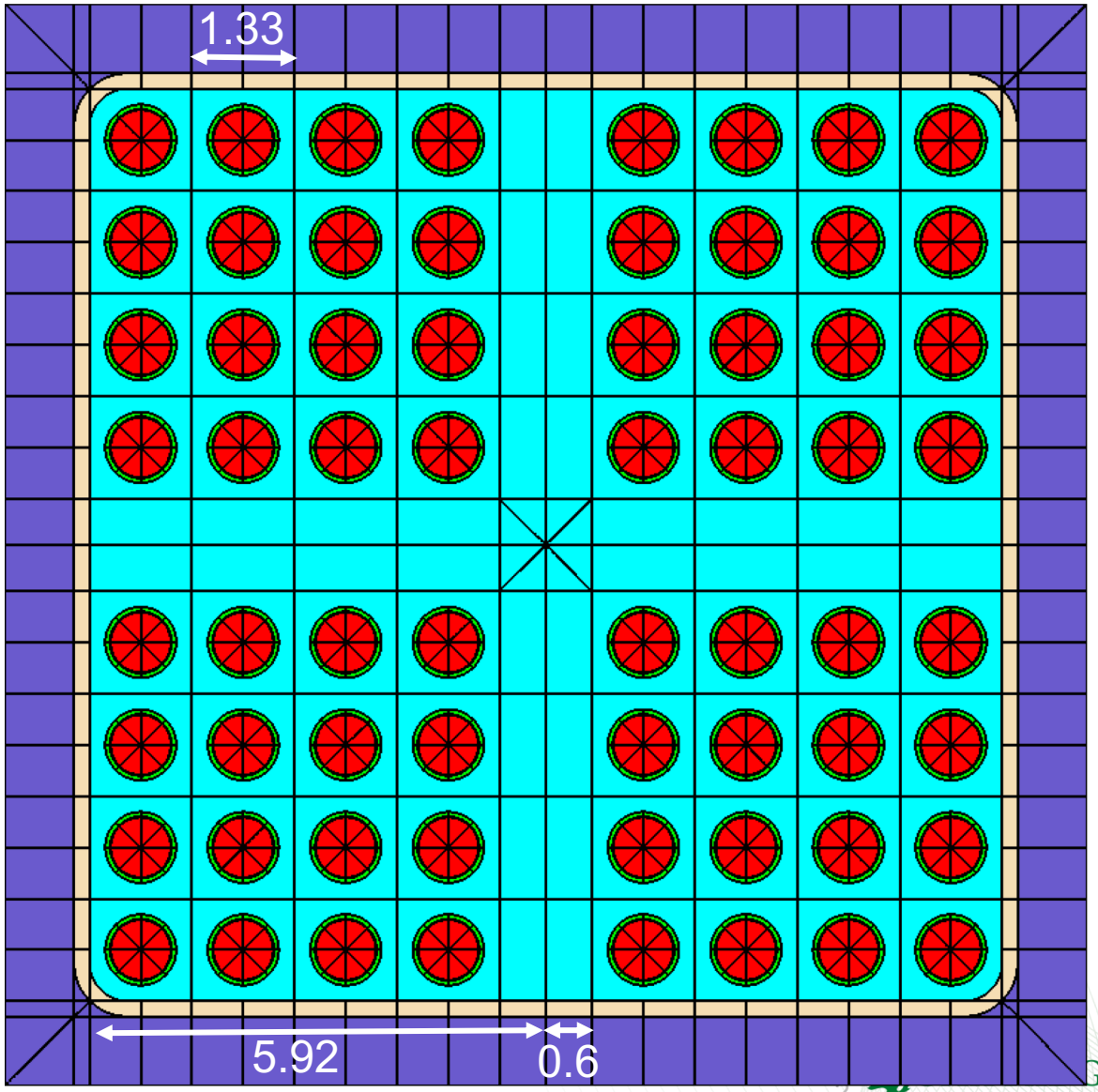
- copy ge7x7_rev1.inp to ge9x9_rev0.inp
- change N from 7 to 9
- change pin pitch to 1.437 cm
- change box and gap based on the following assumed design information
  - lattice pitch: 15.24 cm
  - channel box thickness: assume 0.3048 cm
  - channel box inner corner radius: assume 0.5 cm
  - half in-channel span: assume 4.5*pin_pitch
  - wide/narrow gap: uniform
- Assumed Fuel pin info:
  - 2.93% enr, 10.32 g/cc
  - 0.4775 cm fuel radius
  - 0.5475 cm clad radius
  - No gap
- Water pin info:
  - 1.16 cm inner radius
  - 1.259 cm outer radius
  - common location at (5,5)
  - assume D=0
  - size = 3 – (2R+D)/P/sqrt(2)

cross

defines interior cross geometry

cross

```
1 =polaris_6.3
2 %--------------------------------------%
3 % general options
4 %--------------------------------------%
5 lib "broad_n"
6 sys BWR
7 %--------------------------------------%
8 % geometry
9 %--------------------------------------%
10 geom myBWR : ASSM 8 1.33
11 hgap 0.9
12 box  0.2 0.5 5.92
13 cross 0.6 0.1
14 %--------------------------------------%
15 % fuel material (2.93 enr, 10.32 g/cc)
16 %--------------------------------------%
17 comp c_e293 : UOX 2.93
18 mat  FUEL.1 : c_e293 10.32
19 %--------------------------------------%
20 % pins
21 %--------------------------------------%
22 pin 1 : 0.39 0.40 0.46
23       : FUEL.1 GAP.1 CLAD.1
24 mesh COOL nr=1 ns=1
25 %--------------------------------------%
26 % state
27 %--------------------------------------%
28 state ALL  : temp=600 FUEL : temp=900
29       MOD  : void=0   COOL : void=40
30 end
```



```
 1 =polaris_6.3
 2 %-------------------------------------%
 3 % general options
 4 %-------------------------------------%
 5 lib "broad_n"
 6 sys BWR
 7 %-------------------------------------%
 8 % geometry
 9 %-------------------------------------%
10 geom myBWR : ASSM 8 1.33
11 hgap 0.9
12 box  0.2 0.5 5.92
13 cross 0.6 0.1
14 %-------------------------------------%
15 % fuel material (2.93 enr, 10.32 g/cc)
16 %-------------------------------------%
17 comp c_e293 : UOX 2.93
18 mat  FUEL.1 : c_e293 10.32
19 %-------------------------------------%
20 % pins
21 %-------------------------------------%
22 pin 1 : 0.39 0.40 0.46
23       : FUEL.1 GAP.1 CLAD.1
24 mesh COOL nr=1 ns=1
25 %-------------------------------------%
26 % state
27 %-------------------------------------%
28 state ALL  : temp=600 FUEL : temp=900
29       MOD  : void=0   COOL : void=40
30 end
```

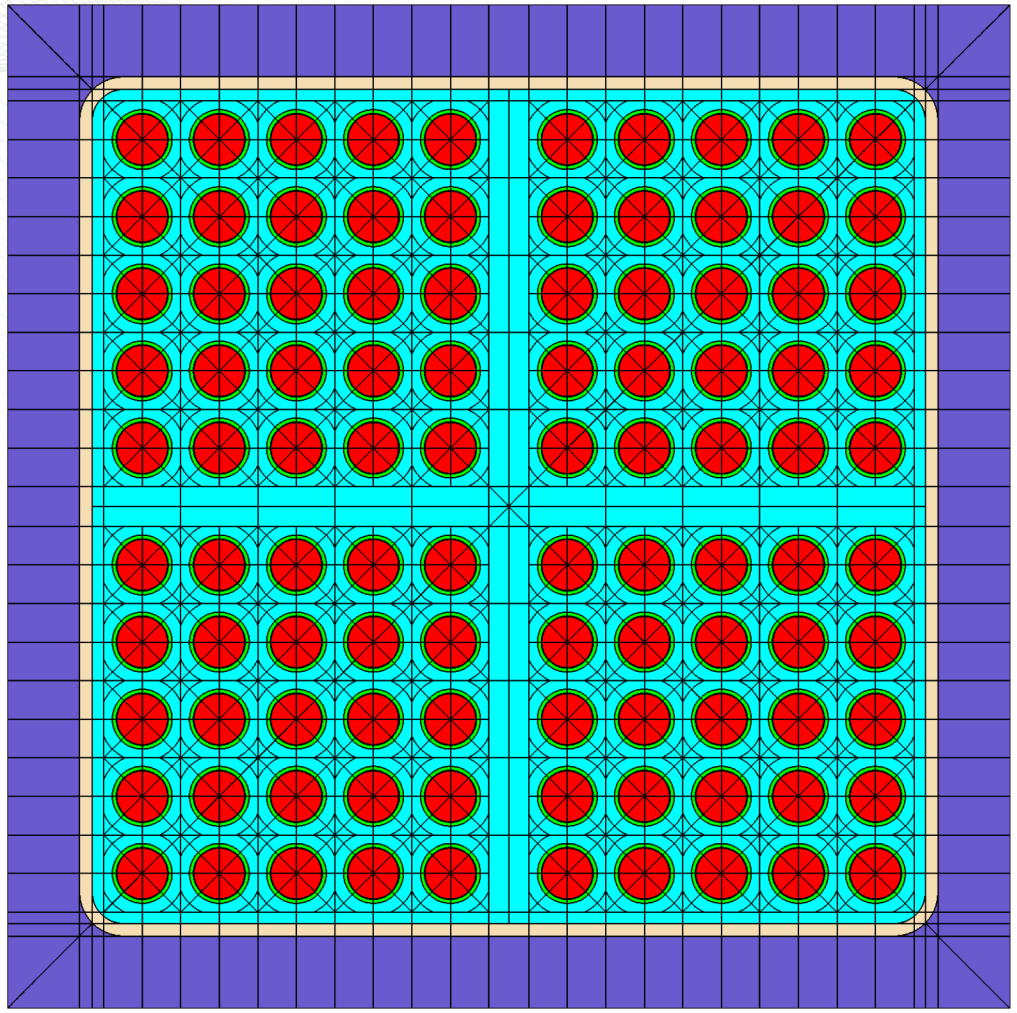
cross

cross hwidth=Real lthick=Real

- **hwidth** – half width of the interior cross region (cm)
  - required
  - must be > 0
- **lthick** – liner thickness (cm)
  - required
  - must be >= 0
  - although required, liner does not show up unless cross structure is specified

- hwidth*2 represents the spacing between 4 subchannels
- initially filled with COOL.1

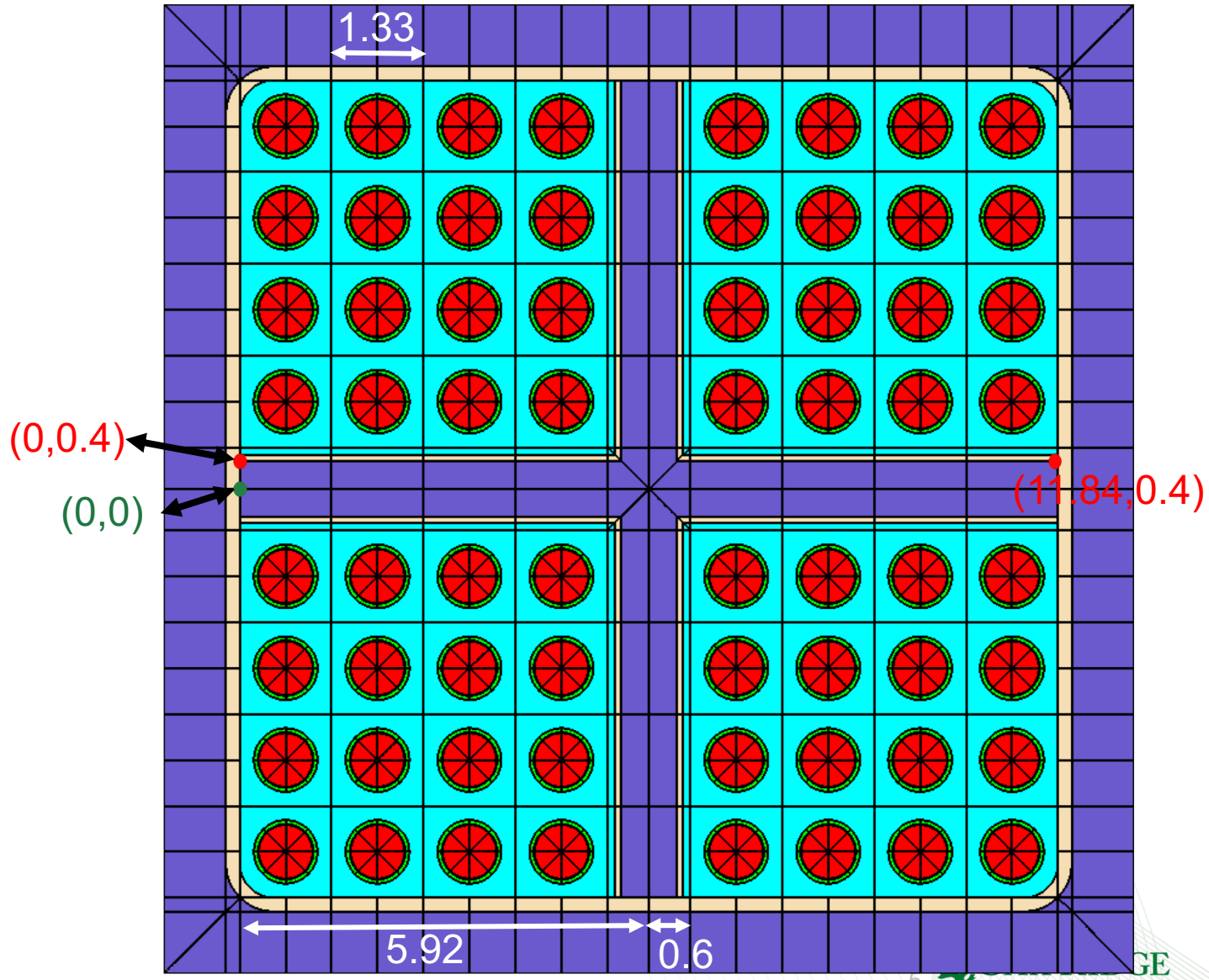
SVEA Exercise 1



- copy ge7x7_rev1.inp to svea_rev0.inp
- change N from 7 to 10
- change pin pitch to 1.24 cm
- initialize cross to have hwidth=0.28 cm and lthick=0.08 cm
- change box and gap based on the following
  - lattice pitch: 15.24 cm
  - channel box thickness: 0.11 cm
  - channel box inner corner radius: 0.9 cm
  - half in-channel span: 6.87
  - wide/narrow gap: assume uniform
- fuel pin info:
  - assume 2.93% enr, 10.32 g/cc
  - 0.4095 cm fuel radius
  - 0.418 cm gap radius
  - 0.481 cm clad radius

cross

```
1 =polaris_6.3
2 %---------------------------------------%
3 % general options
4 %---------------------------------------%
5 lib "broad_n"
6 sys BWR
7 %---------------------------------------%
8 % geometry
9 %---------------------------------------%
10 geom myBWR : ASSM 8 1.33
11 hgap 0.9
12 box  0.2 0.5 5.92
13 cross 0.6 0.1
14  : 0.00 11.84
15  : 0.40  0.40
16 %---------------------------------------%
17 % fuel material (2.93 enr, 10.32 g/cc)
18 %---------------------------------------%
19 comp c_e293 : UOX 2.93
20 mat  FUEL.1 : c_e293 10.32
21 %---------------------------------------%
22 % pins
23 %---------------------------------------%
24 pin 1 : 0.39 0.40 0.46
25       : FUEL.1 GAP.1 CLAD.1
26 mesh COOL nr=1 ns=1
27 end
28
29
30
```



```
 1 =polaris_6.3
 2 %--------------------------------------%
 3 % general options
 4 %--------------------------------------%
 5 lib "broad_n"
 6 sys BWR
 7 %--------------------------------------%
 8 % geometry
 9 %--------------------------------------%
10 geom myBWR : ASSM 8 1.33
11 hgap 0.9
12 box  0.2 0.5 5.92
13 cross 0.6 0.3
14  : 0.00 11.84
15  : 0.40  0.40
16 %--------------------------------------%
17 % fuel material (2.93 enr, 10.32 g/cc)
18 %--------------------------------------%
19 comp c_e293 : UOX 2.93
20 mat  FUEL.1 : c_e293 10.32
21 %--------------------------------------%
22 % pins
23 %--------------------------------------%
24 pin 1 : 0.39 0.40 0.46
25       : FUEL.1 GAP.1 CLAD.1
26 mesh COOL nr=1 ns=1
27 end
28
29
30
```

cross

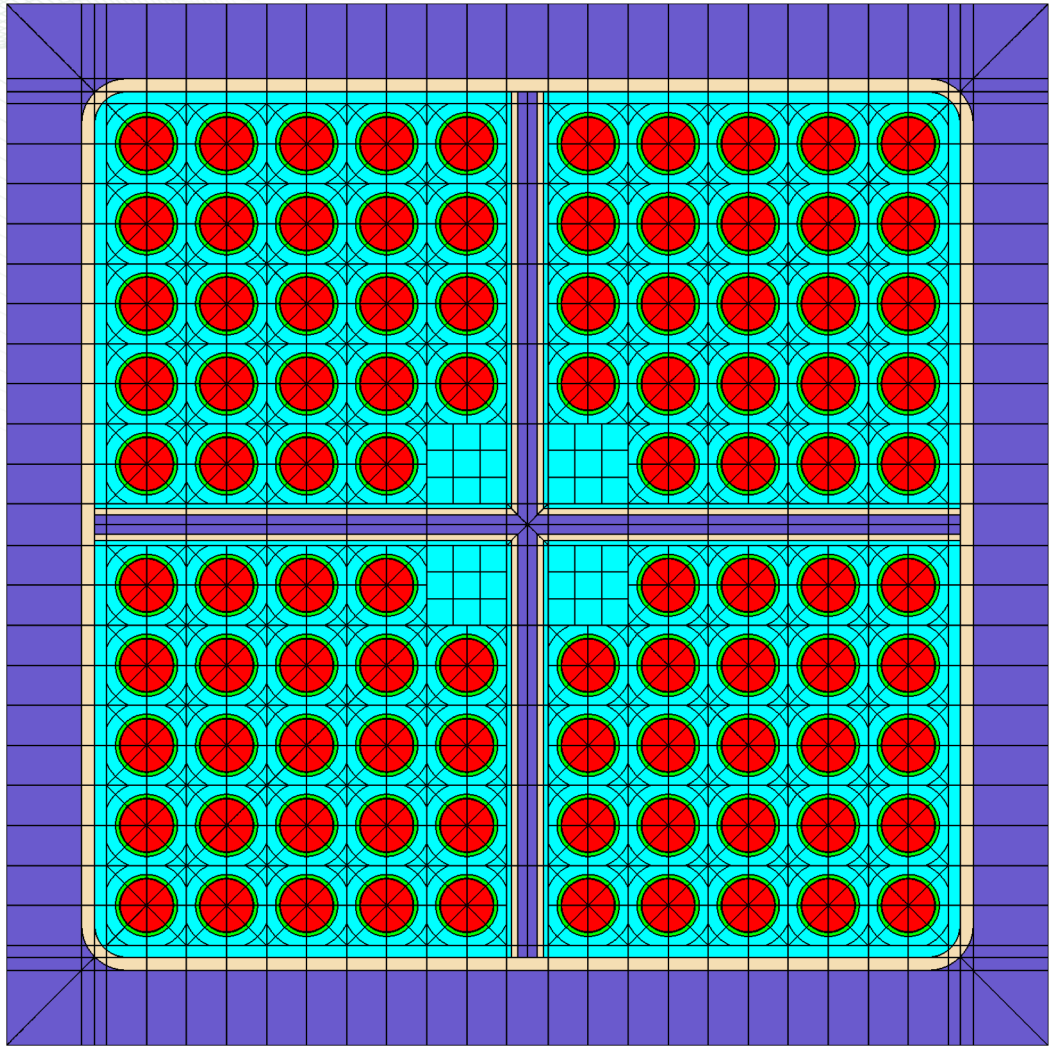
cross hwidth=Real lthick=Real

[: x_1 x_2 … x_N]

[: y_1 y_2 … y_N]

- x_i – x-coordinate of vertex i (cm)
- y_i – y-coordinate of vertex i (cm)
- user builds horizontal cross west to east in the top (north) half of the assembly
  - x_1 should be 0.0
  - x_N should be in-channel span
  - the origin (shown on previous slide)
    - along the horizontal center line of the in-channel region
    - flush with inner west wall of channel box
- horizontal half-cross reflected to the south
- horizontal cross reflected diagonally to vertical cross

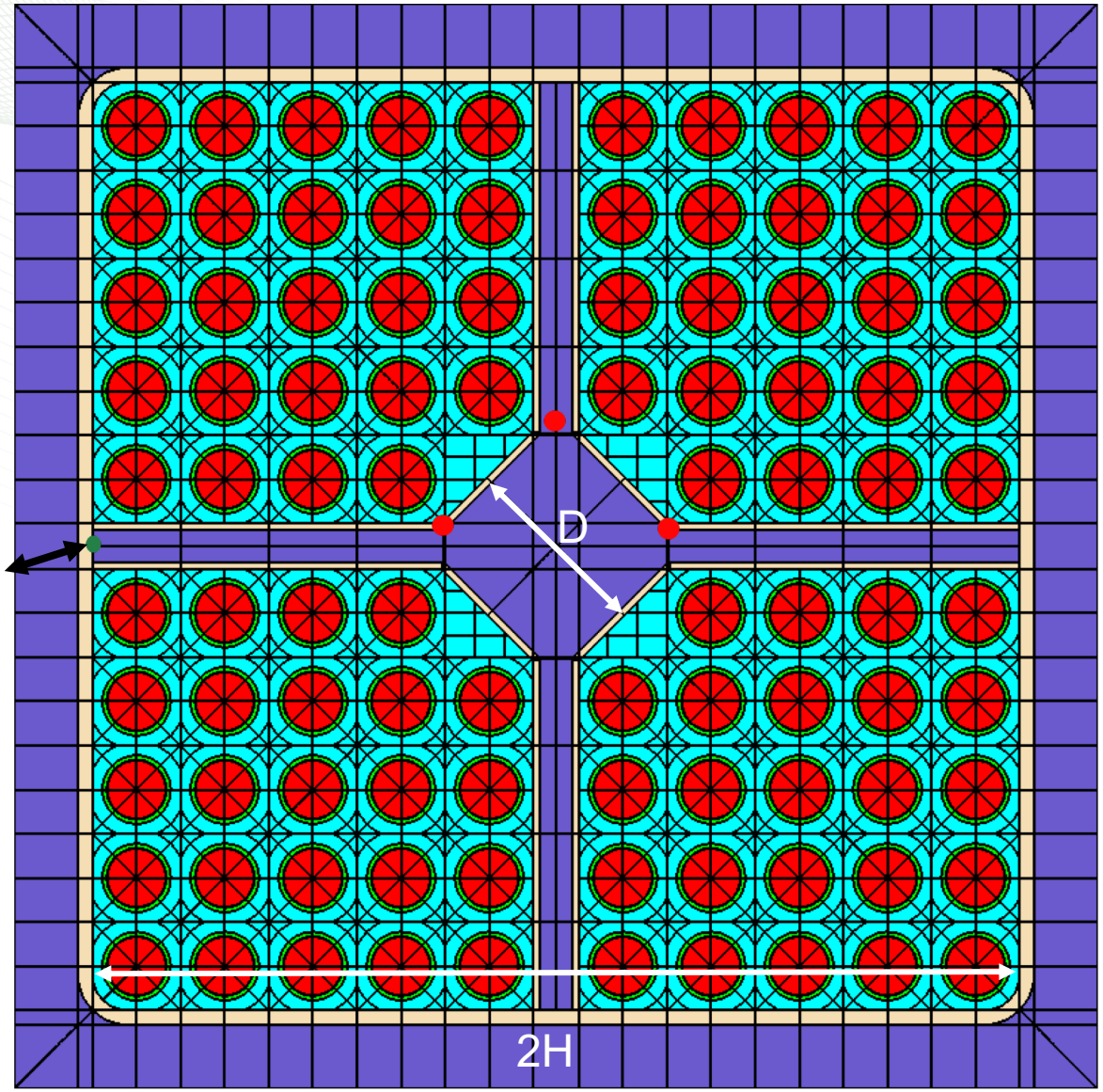
SVEA Exercise 2



- copy **svea_rev0.inp** to **svea_rev1.inp**
- create empty **pin**: pin E : 0.62 : COOL.1 : SQR
- add 3x3 cartesian **mesh** to COOL.1
- create 10x10 **pinmap** with empty pins in locations shown on left
- modify **cross** to have 0.4 cm moderator section (0.2 for half coolant width):

```
cross 0.28 0.08
   : 0.0  13.74
   : 0.2  0.2
```

cross

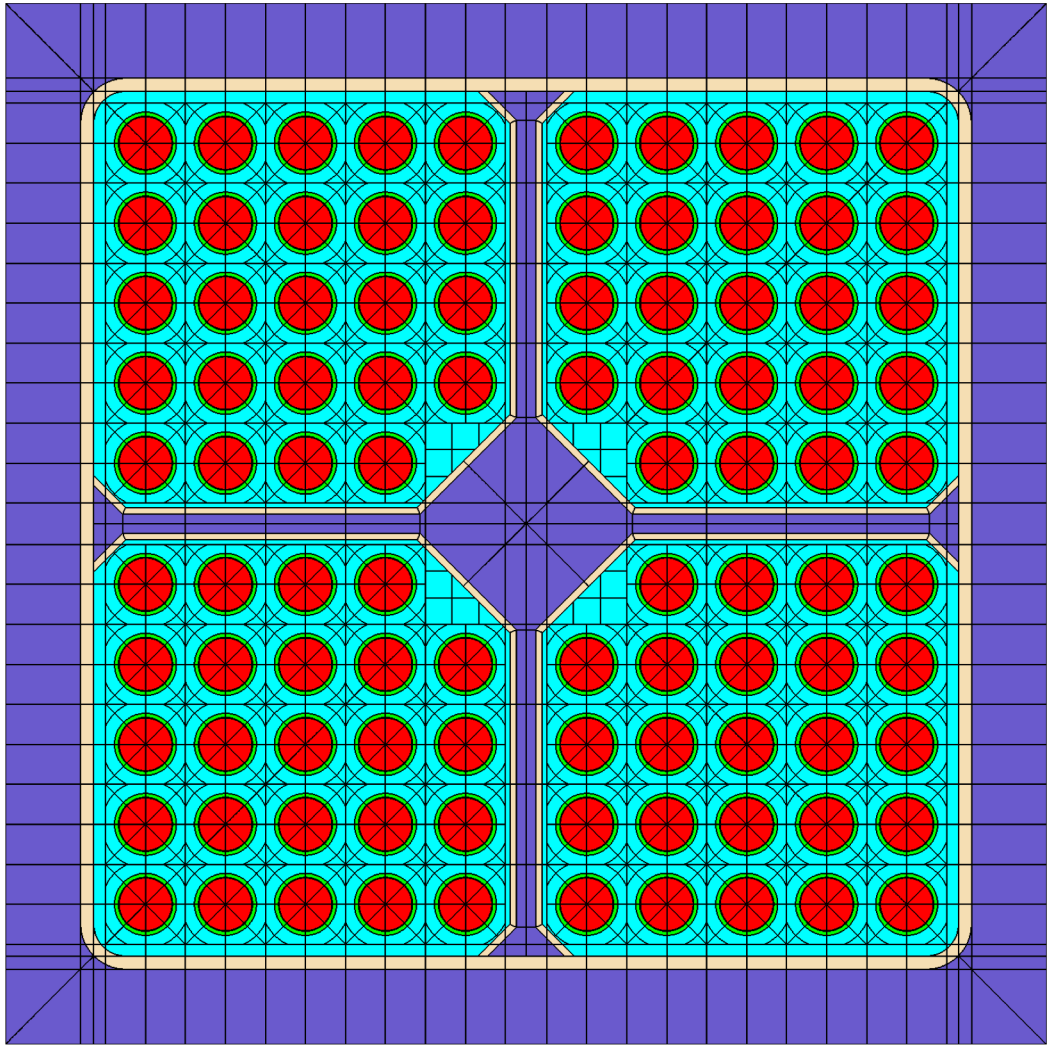


- Common Scenario: Diamond structure in the middle
- Given:
  - diamond width: D
  - half in-channel span: H
  - half coolant width: C (typically hwidth-lthick)

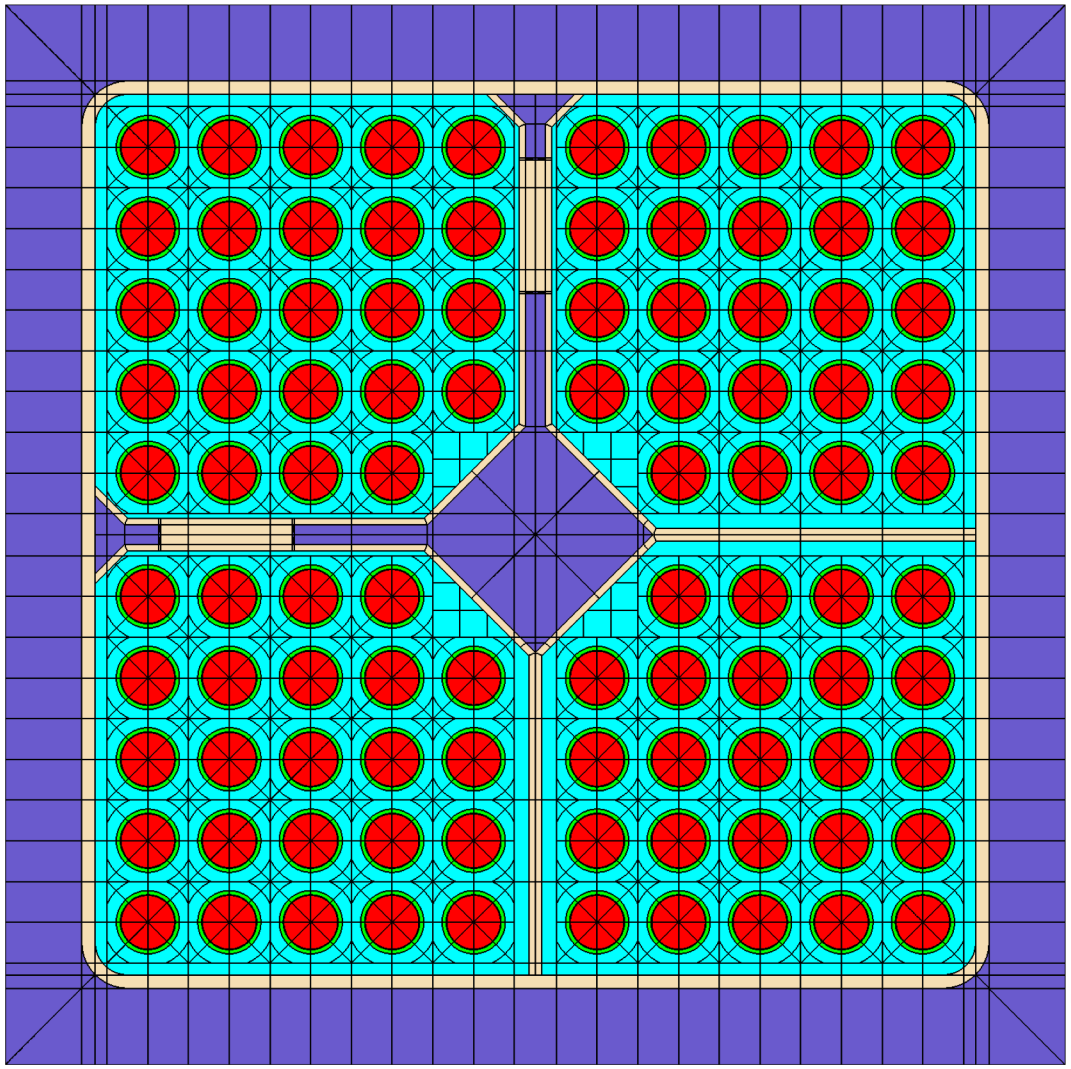
- The following three points need to be defined in the middle of the cross card:
  - Z = D/sqrt(2)
  1. x=H-Z+C, y=C
  2. x=H, y=Z
  3. x=H+Z-C, y=C

- Empty Pin Definition
  - pin PINID : half_pitch : COOL.1 : SQR
  - mesh COOL.1 nx=N ny=N

Extra Example 1



Extra Example 2



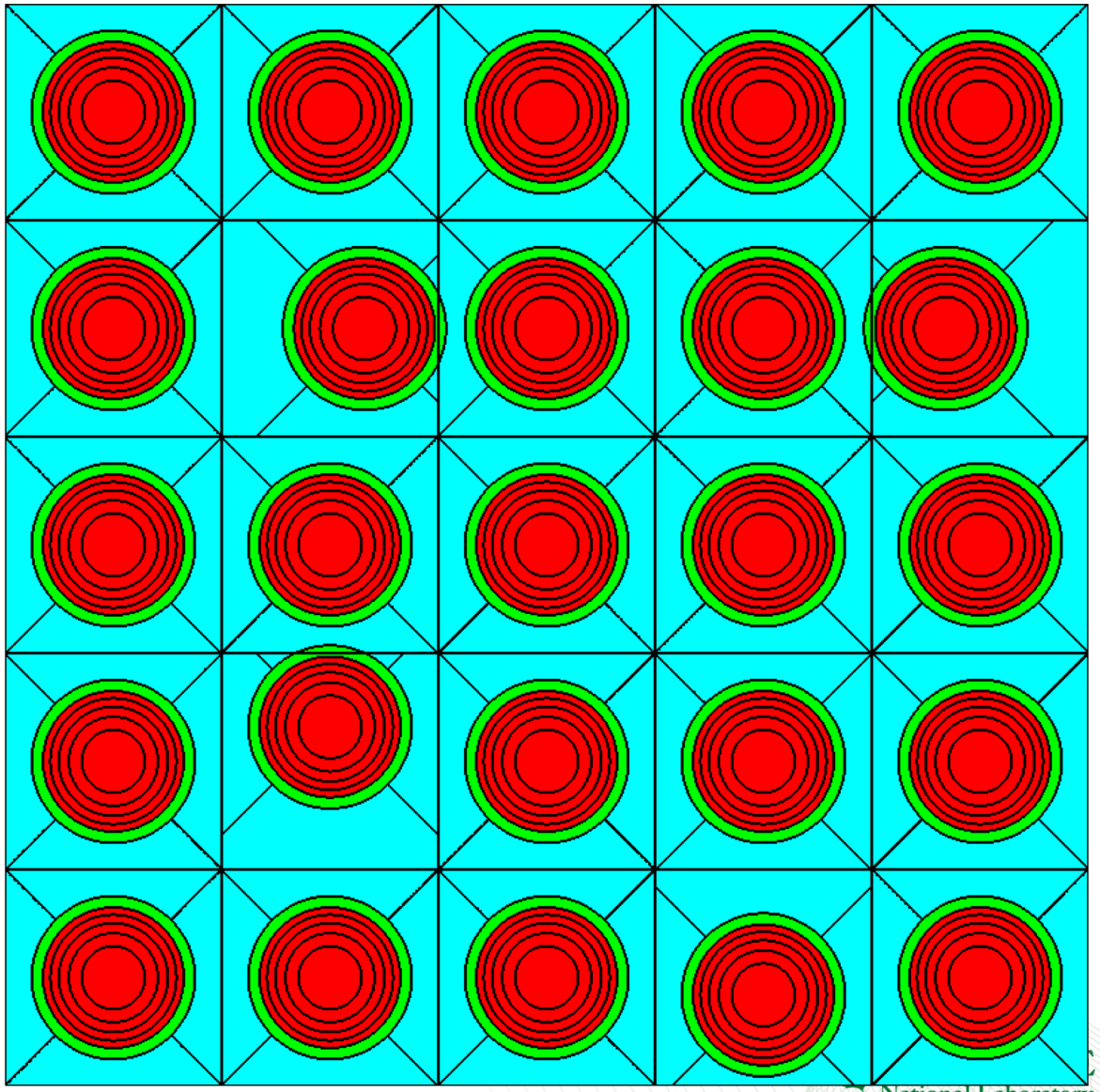
See Polaris Appendix
for complete details

dxmap dymap

displacement maps for fuel pins

dxmap dymap part 1

```
=polaris_6.3
title "W17x17"
lib "broad_n"
system PWR
geom W5x5 : ASSM 5 1.26
comp c_e31 : UOX 3.1
mat FUEL.1 : c_e31  10.26
pin F : 0.4096 0.475 : FUEL.1 CLAD.1
mesh COOL nr=1 ns=-4
mesh FUEL nr=5 ns=1
mesh CLAD ns=1
%---------------------------------------%
% displacement maps
%---------------------------------------%
dxmap
  0.0   0.0   0.0   0.0   0.0
  0.0   0.2   0.0   0.0  -0.2
  0.0   0.0   0.0   0.0   0.0
  0.0   0.0   0.0   0.0   0.0
  0.0   0.0   0.0   0.0   0.0
dymap
  0.0   0.0   0.0   0.0   0.0
  0.0   0.0   0.0   0.0   0.0
  0.0   0.0   0.0   0.0   0.0
  0.0   0.2   0.0   0.0   0.0
  0.0   0.0   0.0  -0.1   0.0


end
```



```
=polaris_6.3
title "W17x17"
lib "broad_n"
system PWR
geom W5x5 : ASSM 5 1.26
comp c_e31 : UOX 3.1
mat FUEL.1 : c_e31  10.26
pin F : 0.4096 0.475 : FUEL.1 CLAD.1
mesh COOL nr=1 ns=-4
mesh FUEL nr=5 ns=1
mesh CLAD ns=1
%--------------------------------------%
% displacement maps
%--------------------------------------%
dxmap
  0.0  0.0  0.0  0.0  0.0
  0.0  0.2  0.0  0.0 -0.2
  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0
dymap
  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0
  0.0  0.2  0.0  0.0  0.0
  0.0  0.0  0.0 -0.1  0.0


end
```

dxmap dymap part 1

dxmap x_1 x_2 … x_N
dymap y_1 y_2 … y_N

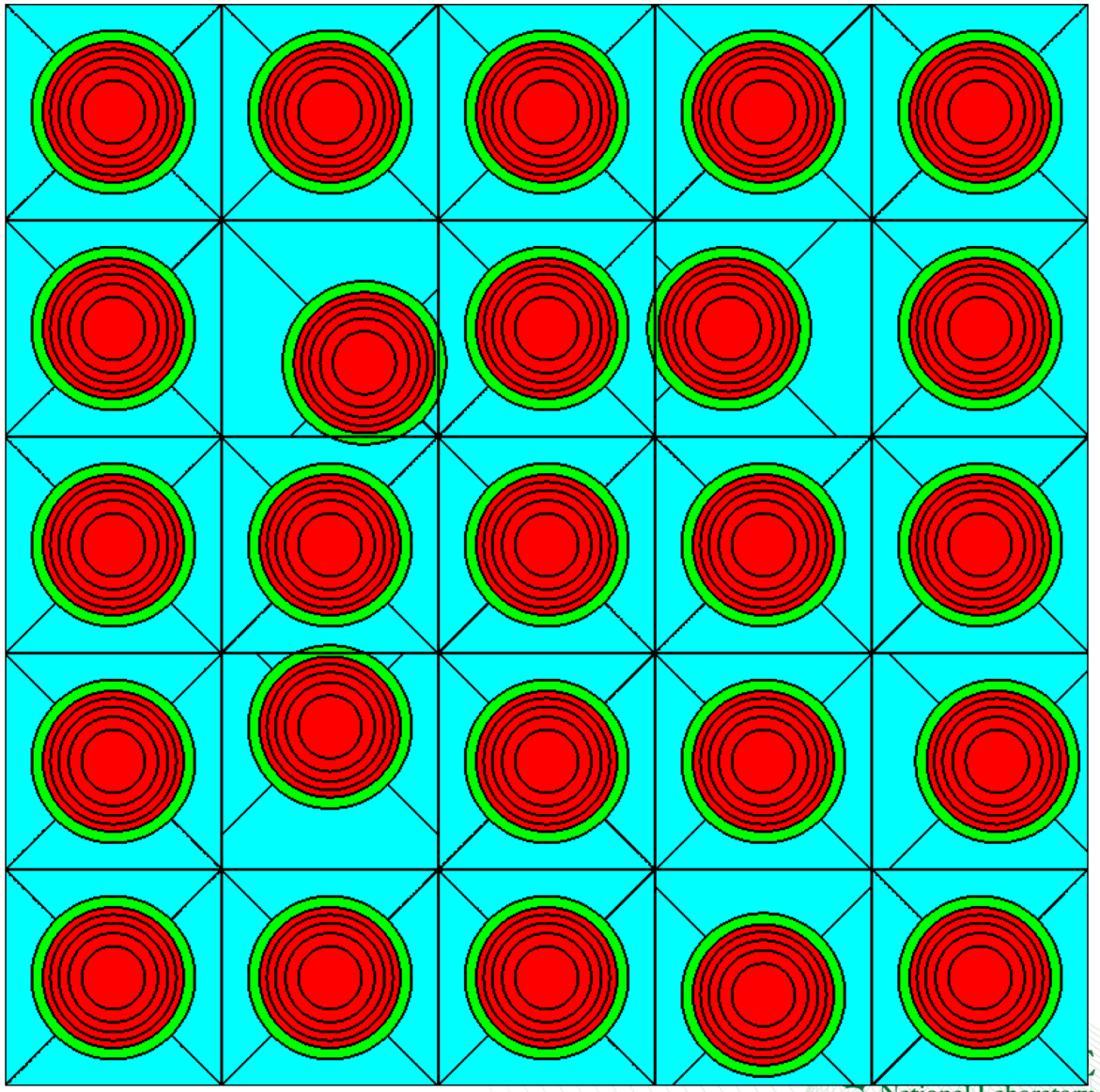
- x_i – displacement from pin center in the x-direction (cm)
- y_i – displacement from pin center in the x-direction (cm)

- full, diagonal, quarter, and octant symmetry allowed
- dxmap size must equal dymap size
- dxmap and dymap size can be different than pinmap size
- some restrictions on the displacement value based on map symmetry

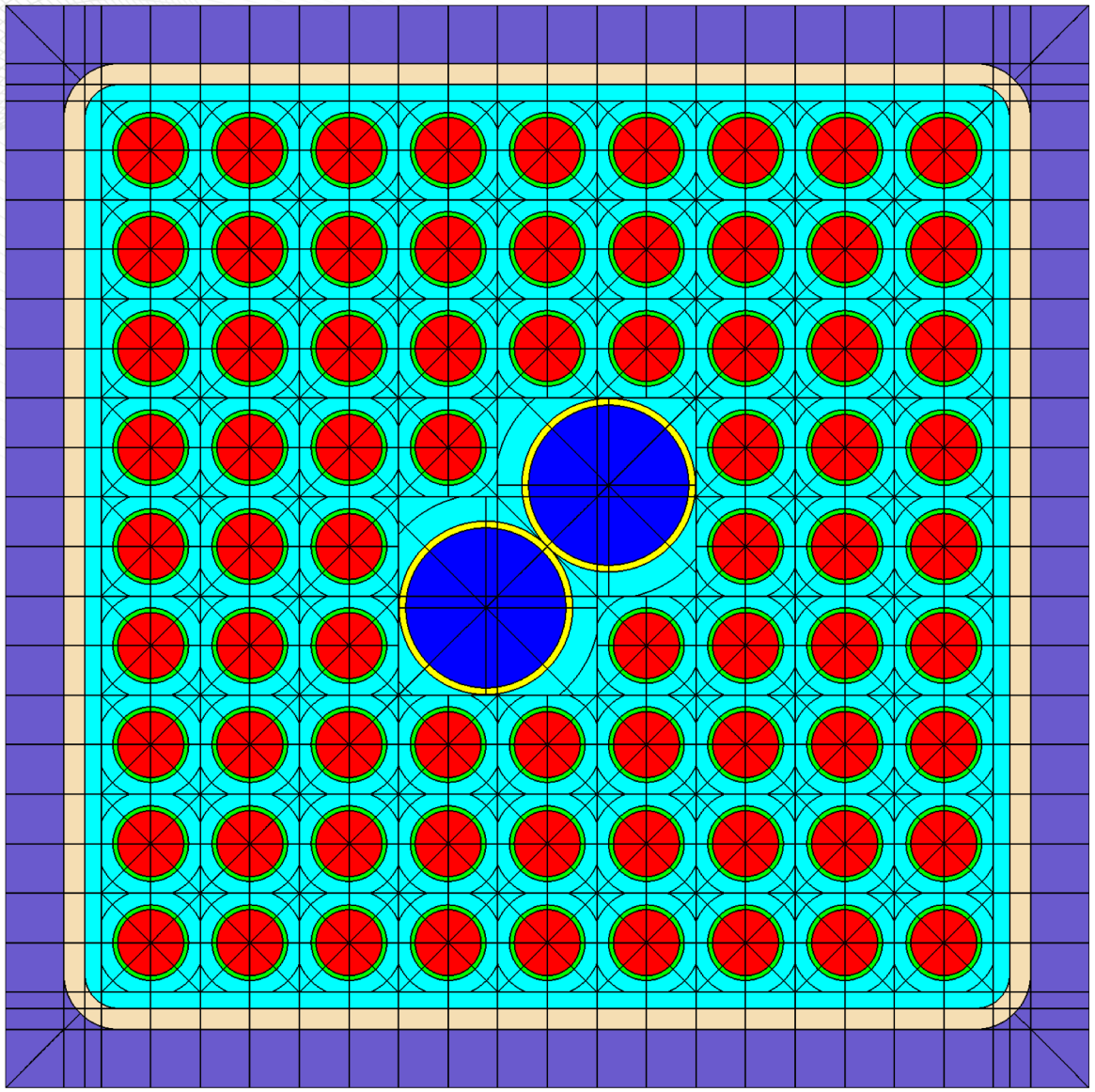
- for pins with noninteger size
  - see previous slides to determine natural pin center
  - to displace, choose the location farthest from the common pinmap location
- always review visualization to confirm intended effect (beware overlapping pins)

dxmap dymap part 2

```
=polaris_6.3
title "W17x17"
lib "broad_n"
system PWR
geom W5x5 : ASSM 5 1.26
comp c_e31 : UOX 3.1
mat FUEL.1 : c_e31  10.26
pin F : 0.4096 0.475 : FUEL.1 CLAD.1
mesh COOL nr=1 ns=-4
mesh FUEL nr=5 ns=1
mesh CLAD ns=1
%---------------------------------------%
% displacement maps
%---------------------------------------%
dxmap
   0.0
   0.0  0.2
   0.0  0.0  0.0
   0.0  0.0  0.0  0.0
   0.0  0.0  0.0  0.0  0.0
dymap
   0.0
   0.0 -0.2
   0.0  0.0  0.0
   0.0  0.2  0.0  0.0
   0.0  0.0  0.0 -0.1  0.0

end
```

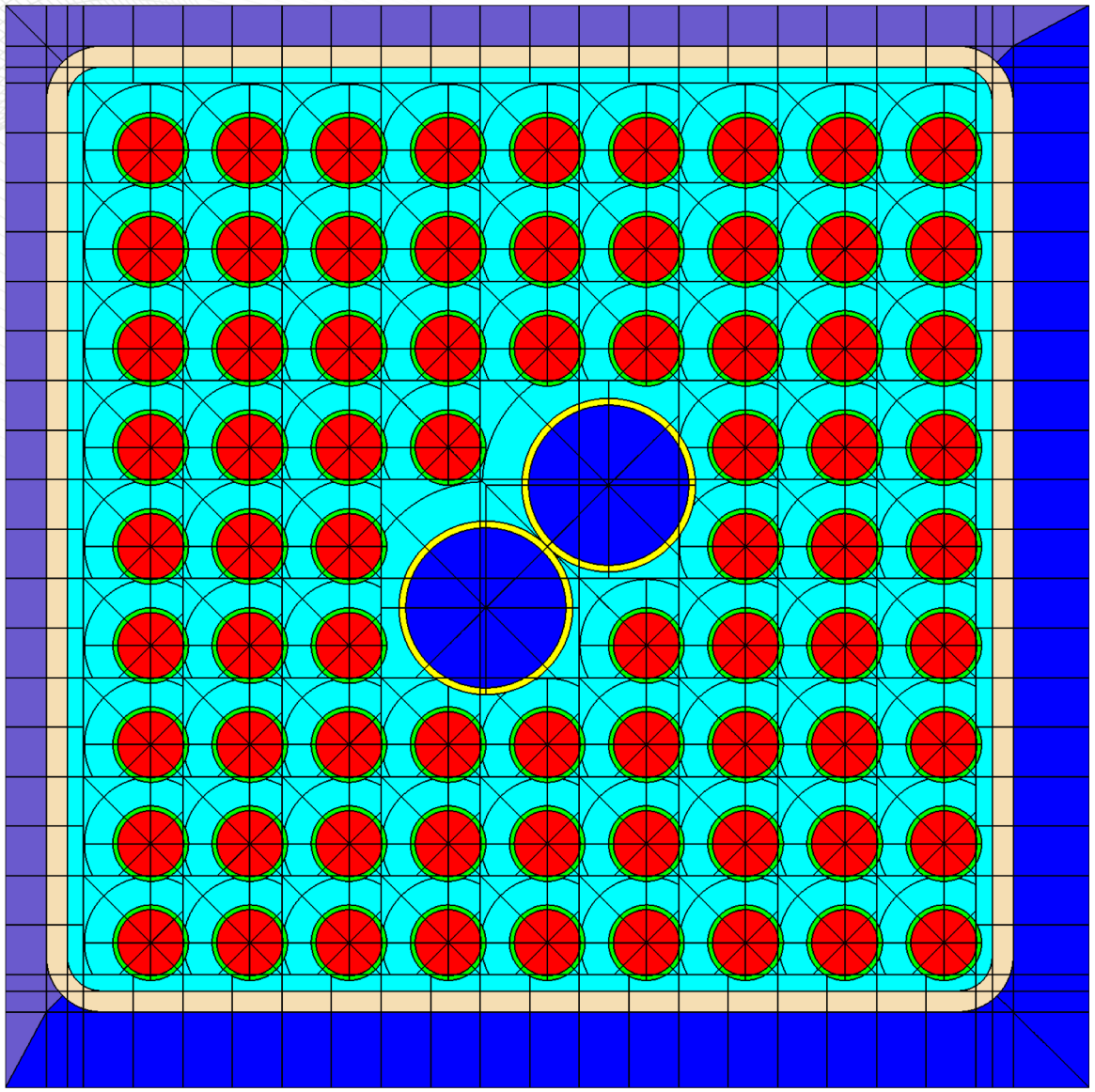


GE 9x9 Exercise 1/2



- ge9x9_rev0.inp to ge9x9_rev1.inp
- modify water rod to be size 1.5
- add displacement maps to move the water rod back to same location as before
- confirm answers are identical

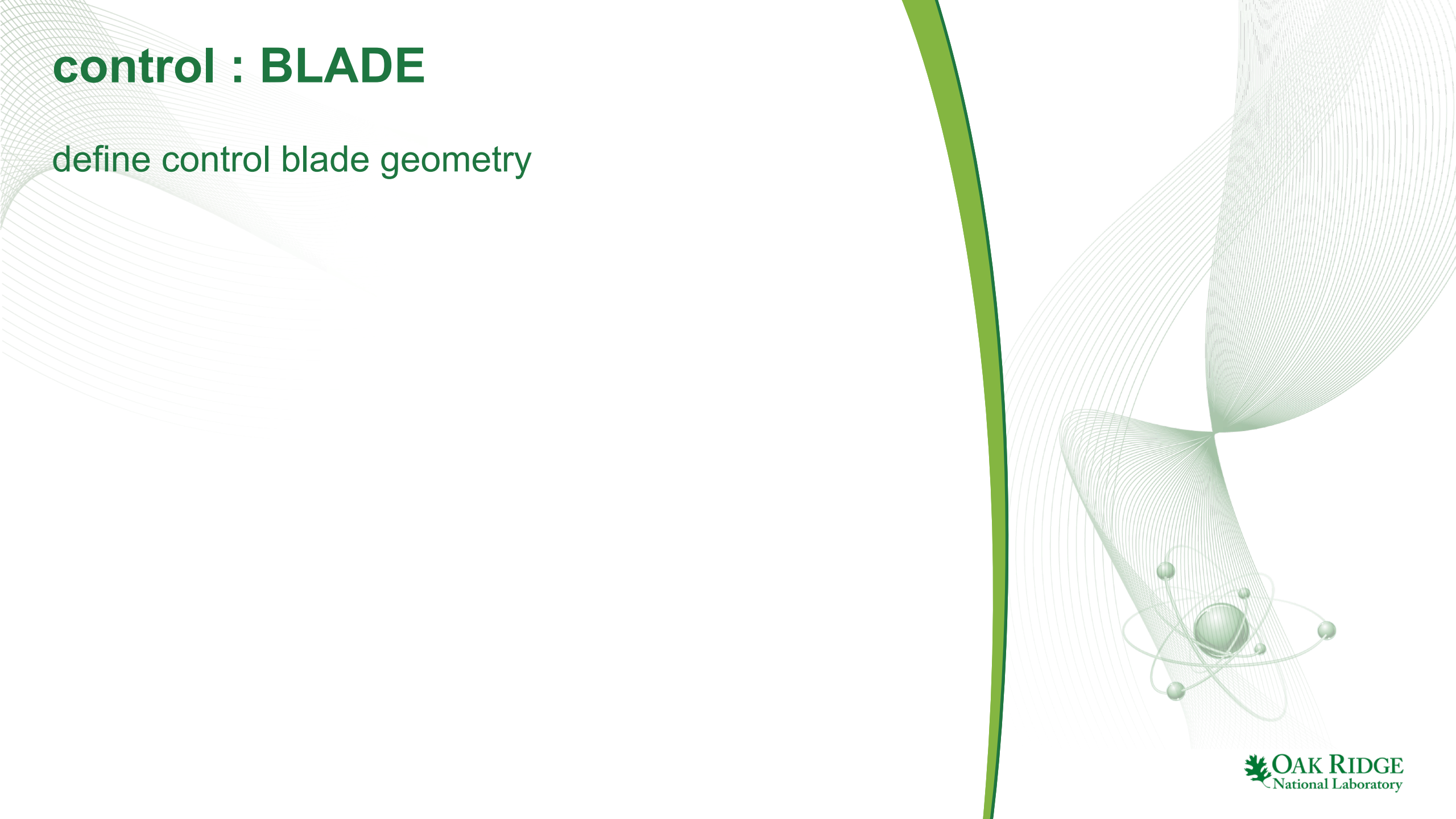
GE 9x9 Exercise 2/2



- Copy ge9x9_rev0.inp to ge9_bow.inp
- Assume under a channel bow condition that the channel box has shifted 100 mil (0.254 cm) to the west and north.
- wide gap decreases by 0.254 cm
- narrow gap increases by 0.254 cm
- the pins do not bow
- to keep the pins in the same position as the nominal case, use dxmap and dymap to shift the pins 100 mil east and south
- NOTE: need a full 9x9 map for both

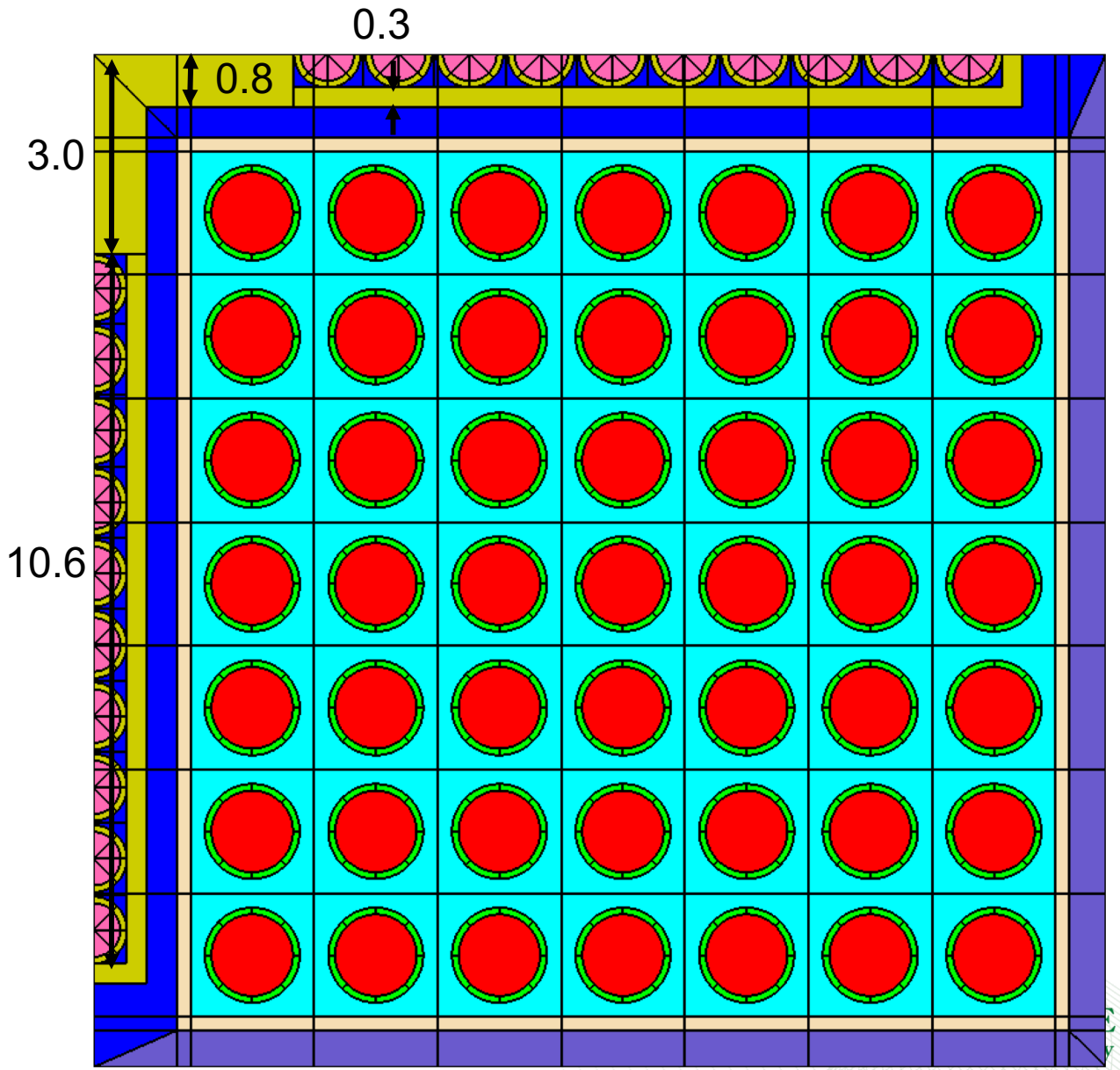
control : BLADE

define control blade geometry



blade

```
=polaris_6.3
lib "broad_n"
sys BWR
geom myBWR : ASSM 7 1.85
hgap 0.55 1.25 : MOD.2 MOD.1
box  0.2
pin 1 : 0.61 0.71 : FUEL.1 CLAD.1
mesh FUEL ns=1
mesh COOL nr=1 ns=1
mesh MOD  nf=1 nd=1 ns=1
pinmap
  1
  1 1
  1 1 1
  1 1 1 1
comp c_e293 : UOX 2.93
mat  FUEL.1 : c_e293 10.32
%---------------------------------------%
% control blade
%---------------------------------------%
pin B : 0.4 0.5
      : CNTL.1 STRUCT.1 MOD.1
control blade1 : BLADE 0.8 0.3 3.0
                 : B
                 : 10.6
                 : 10
state blade1 : in=yes


end
```



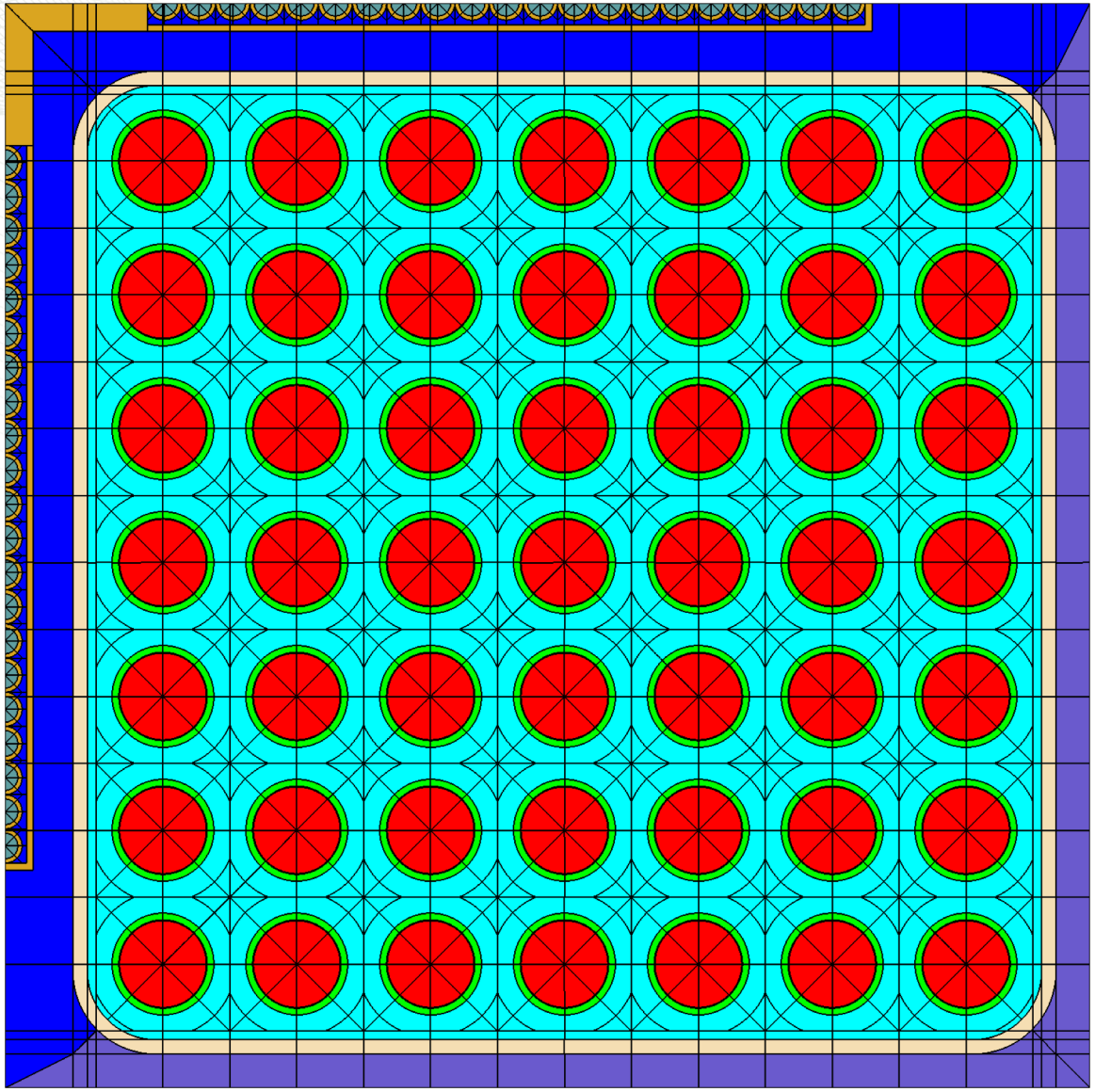
blade

```
=polaris_6.3
lib "broad_n"
sys BWR
geom myBWR : ASSM 7 1.85
hgap 0.55 1.25 : MOD.2 MOD.1
box  0.2
pin 1 : 0.61 0.71 : FUEL.1 CLAD.1
mesh FUEL ns=1
mesh COOL nr=1 ns=1
mesh MOD  nf=1 nd=1 ns=1
pinmap
  1
  1 1
  1 1 1
  1 1 1 1
comp c_e293 : UOX 2.93
mat  FUEL.1 : c_e293 10.32
%--------------------------------------%
% control blade
%--------------------------------------%
pin B : 0.4 0.5
      : CNTL.1 STRUCT.1 MOD.1
control blade1 : BLADE 0.8 0.3 3.0
                : B
                : 10.6
                : 10
state blade1 : in=yes


end
```

control : BLADE
hwgthck=Real sththck=Real cslnth=Real
: ID_1 ID_2 … ID_N
: L_1 L_2 ... L_N
: N_1 N_2 … N_N

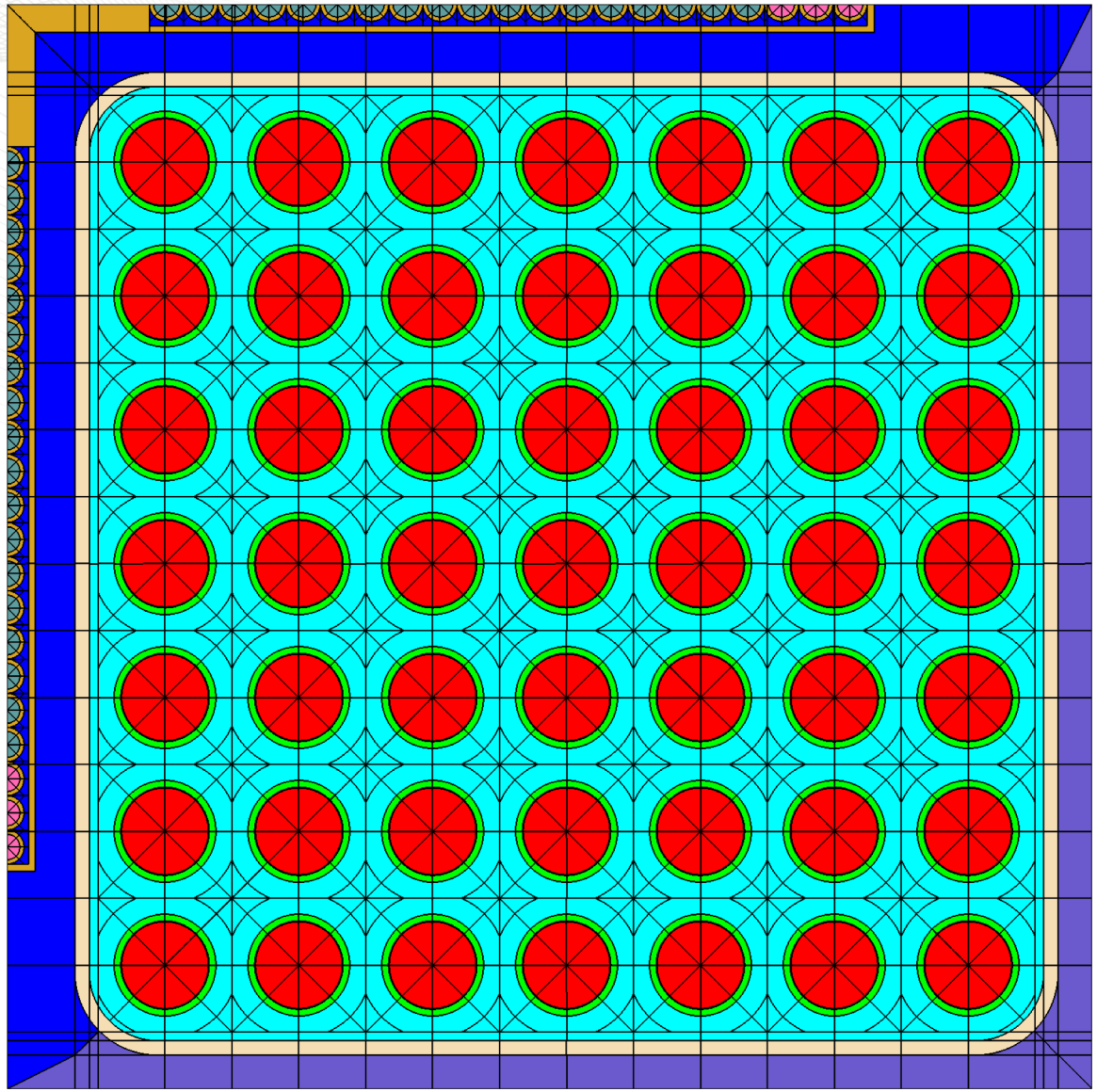
- **hwgthck** – half blade wing thickness (cm)
  - required, must be > 0
- **sththck** – blade sheath thickness (cm)
  - required, must be >= 0
- **cslnth** – central support length (cm)
  - required, must be >= **hwgthck**
- **ID_i** – PINID or SLABID for section i
- **L_i** – length of section i (cm)
- **N_i** – number of pins or slab regions in section i

Blade Exercise 1/3



- ge7x7_rev1.inp to blade_rev0.inp
- create diagonal **pinmap**, fill with “1”
- create blade **pin B**
  - B4C radius: 0.18 cm (CNTL.2)
  - SS304 radius: 0.24 cm (STRUCT)
  - outer zone: MOD.1
- create control blade (name blade1)
  - half wing thickness 0.4 cm
  - sheath thickness 0.1 cm
  - central support length 2.0 cm
  - 10.08 cm section length
  - 21 pins
- add command to **state** card to insert blade1

Blade Exercise 2/3



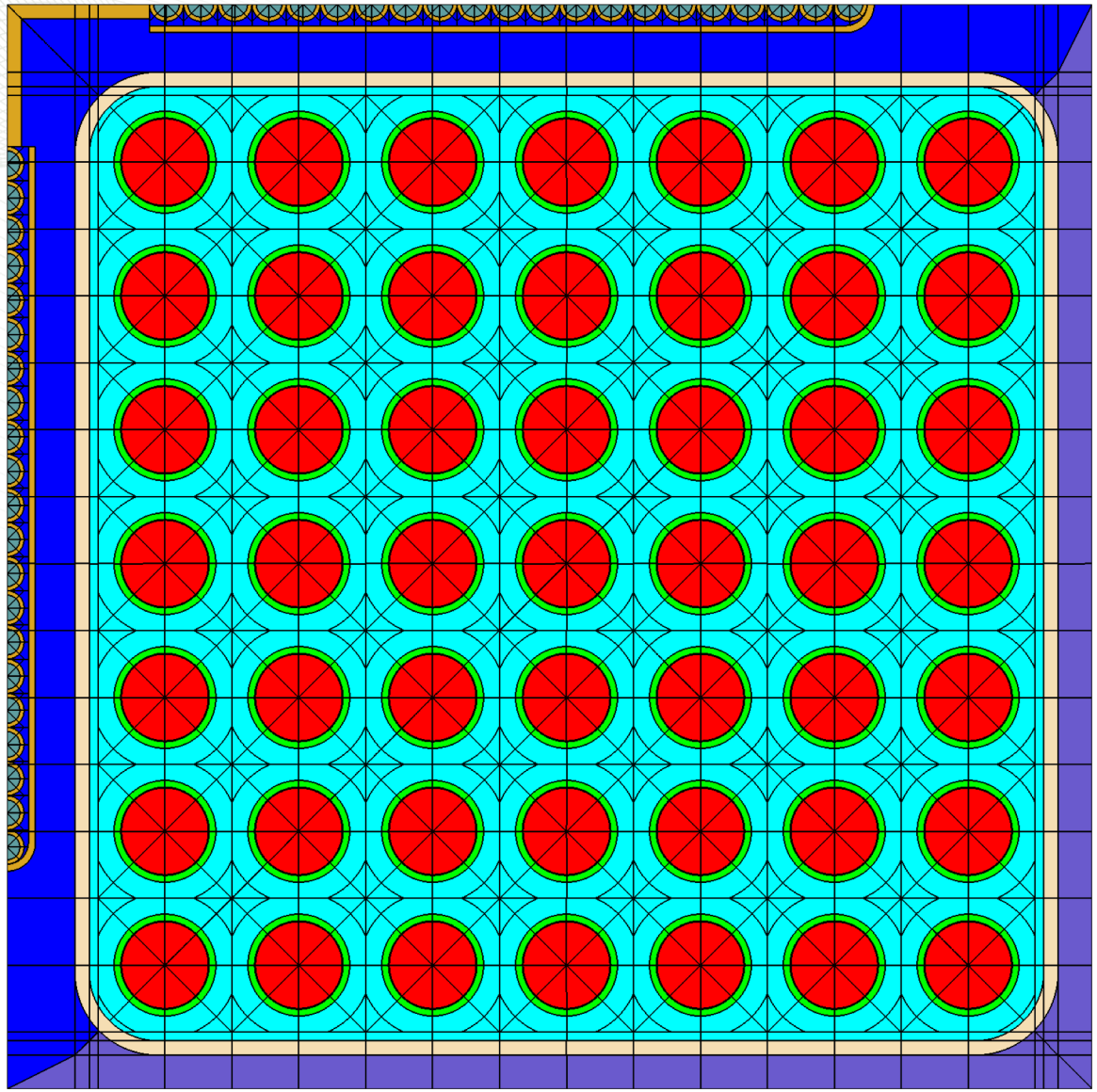
- blade_rev0.inp to blade_rev1.inp
- add new blade **pin A**
  - AIC radius: 0.18 cm (CNTL.1)
  - SS304 radius: 0.24 cm (STRUCT)
  - outer zone: MOD.1
- create control blade (name blade2)
  - Same as blade1, but the final 3 pins are AIC
  - 10.08 cm *(18/21) pin B
  - 10.08 cm *(3/21) pin A
- add command to **state** card to insert blade2

blade

```
1 =polaris_6.3
2 lib "broad_n"
3 sys BWR
4 geom myBWR : ASSM 7 1.85
5 hgap 0.55 1.25 : MOD.2 MOD.1
6 box  0.2
7 pin 1 : 0.61 0.71 : FUEL.1 CLAD.1
8 mesh FUEL ns=1
9 mesh COOL nr=1 ns=1
10 mesh MOD  nf=1 nd=1 ns=1
11 pinmap
12   1
13   1 1
14   1 1 1
15   1 1 1 1
16 comp c_e293 : UOX 2.93
17 mat  FUEL.1 : c_e293 10.32
18 %-------------------------------------%
19 % control blade
20 %-------------------------------------%
21 pin B : 0.4 0.5
22       : CNTL.1 STRUCT.1 MOD.1
23 control blade1 : BLADE 0.8 0.3 3.0
24                 : B
25                 : 10.6
26                 : 10
27 state blade1 : in=yes
28
29
30 end
```

control : BLADE
hwgthck=Real sththck=Real cslnth=Real
[sthmat=MNAME] [csmat=MNAME] [hcsthck=Real]
[wgcrv=Real]
: ID1 ID2 … IDN
: L1 L2 ... LN
: N1 N2 … NN

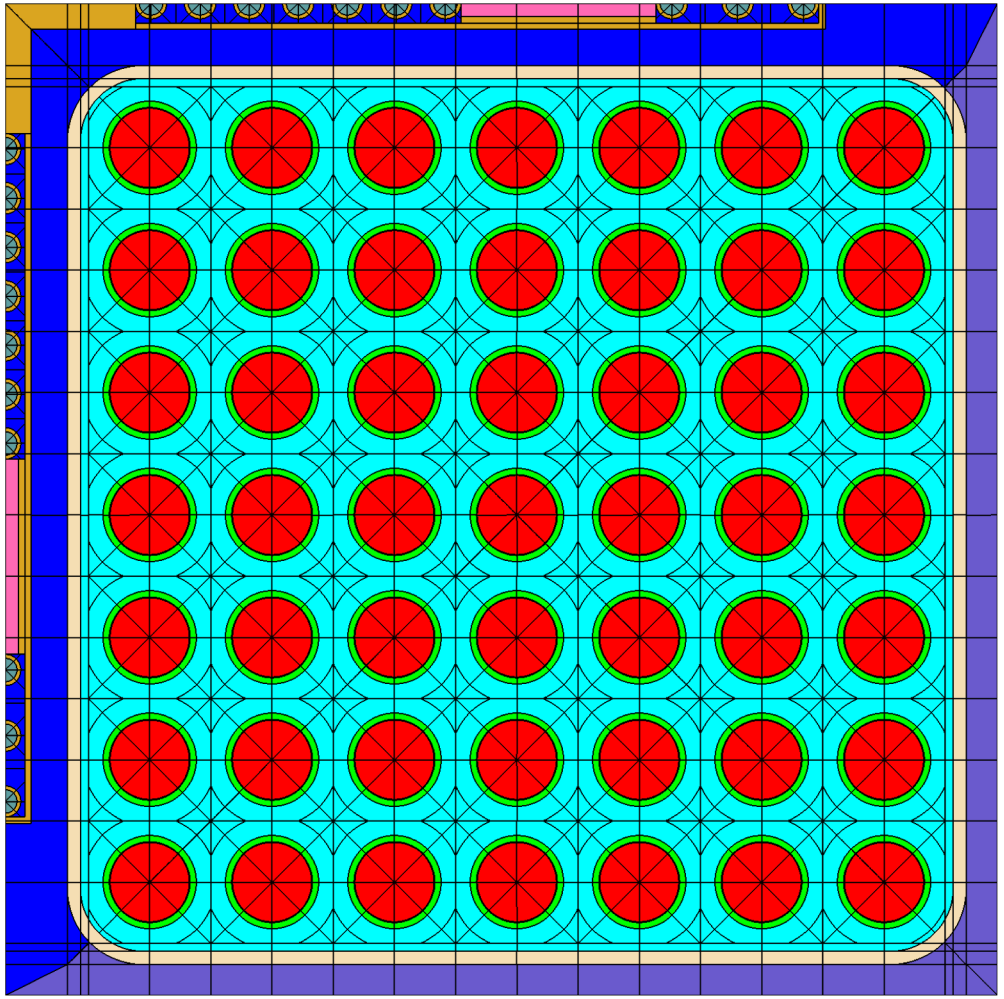
- **sthmat** – sheath material (STRUCT.1)
- **csmat** – central support material (STRUCT.1)
- **hcsthck** – half central support thickness (cm)
  - must be > 0 and must be <= **hwgthck**
  - default is **hwgthck**
- **wgcrv** – wing tip radius
  - must be >=0,
  - default is 0,
  - 0 means straight edge



Blade Exercise 3/3

- blade_rev0.inp to blade_rev2.inp
- create control blade (name blade3)
  - same as blade1, but
  - hcsthck is 0.4 cm
  - wgcrv is 0.4 cm
- add command to **state** card to insert blade3

Blade Extra Example



Slab will be covered in reflector material

```
pin  B : 0.18 0.24 : CNTL.2 STRUCT MOD.1
slab C : 0.2 0.1 : CNTL.1 STRUCT
control bladeX BLADE 0.4 0.1 2.0  : B   C   B
                                  : 5.0 3.0 2.5
                                  : 7   1   3
```

Lattice Physics

branch card

OAK RIDGE National Laboratory

Lattice Physics

- Lattice Physics: goal is to generate few-group cross sections for core calculations
  - Require **branch** calculations
    - instantaneous change in state variable at a given burnup
  - Requires **history** calculations
    - BWR fuel depleted at 0% void vs 40% void at constant power
  - Requires **reflector** calculations
- 1000s of statepoint calculations required per core calculation

- Nodal Simulators:
  - Determines few-group cross section at each ”node” based on the node state:
    - Fuel temperature
    - Coolant temperatue
    - Coolant density
    - Boron concentration
    - Control rod/blade insertion
  - Node Dimension:
    - BWR: assembly width (x,y) x 6’’ (z)
    - PWR: ¼ assembly width (x,y) x 6’’(z)
  - Each nodal simulator has their own logic to interpolate the cross sections

Branching

```
52 %--------------------------------------%
53 % state
54 %--------------------------------------%
55 %HFP as base state
56 state ALL   : temp=600
57       FUEL  : temp=900
58       COOL  : dens=0.7 boron=600
59 read branch simple
60   %branch 1 - high TF
61   add FUEL : temp=1200
62   %branch 2 and 3 - low/high PC
63   add COOL : boron=0 1500
64   %branch 4 AIC insertion
65   add AIC_MAP : in=yes
66 end branch
67 opt PRINT Xfile16=yes
68 end
69
70
71
72
73
74
75
76
77
78
79
80
81
```

- **read branch BNAME/end branch** – encloses a set of "instantaneous" state changes
  - BNAME – name of the branch set
- **add** card
  - material state branch

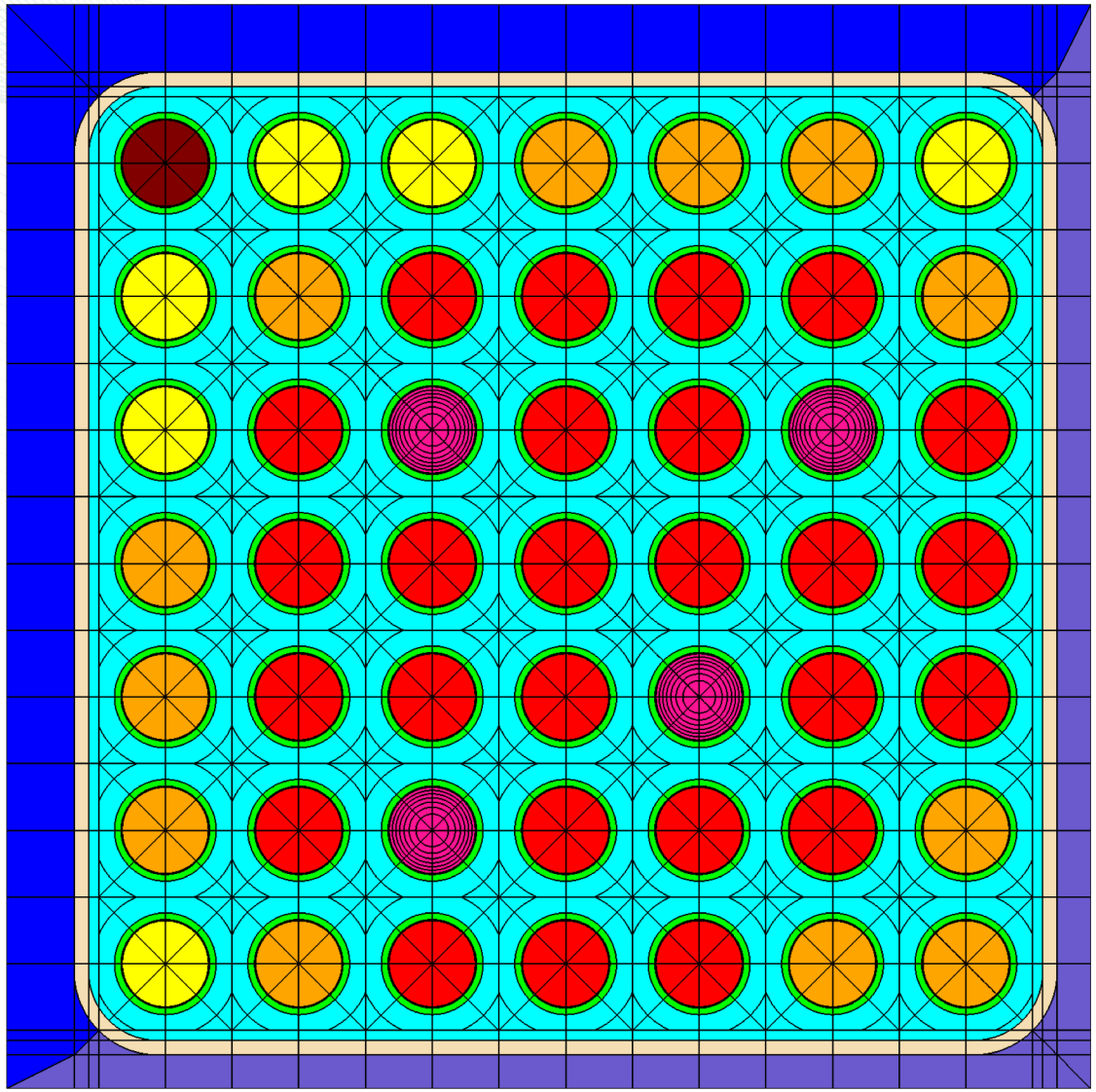
  add MCLASS/MNAME : prop=X Y Z
  - control or insert state branch

  add INAME : in=true|false or

  add INAME : in=yes|no
- To create the FG XS file for PARCS

opt PRINT XFile16=yes

Exercise



- copy from starter directory pb2_starter.inp to pb2_branch.inp
- add a 1200 K fuel branch
- add void branches 0%, 40%, and 70%
- Note: nominal state is 40% void
- view output

Exercise

```
139 ------------------------------------------------------------------------
140  Case: GE 7x7
141
142  Library: /Users/m8j/build/p/INSTALL/data/scale.rev04.xn56v7.1
143 ------------------------------------------------------------------------
144
145
146 Input echo written to file {/Users/m8j/Documents/Polaris/ORNL_training/exercises/pb2_branch.idc}.
147
148
149 Summary of Calculations
150 ----------------------
151 Total number of statepoint calculations                = 4
152 Total number of time-dependent histories               = 1
153
154 History 1                                             = 'Base'
155   Number of time-dependent calcs                       = 1
156   Number of instantaneous branches                     = 3
157   Number of statepoints                                = 4
158
159 ----------------------
```

- 4 statepoints

1. Nominal (40 void)
2. 1200 K
3. 0 void
4. 70 void

Polaris skips branches that are identical to nominal state.
In this case, the 40% void branch

Branching

```
%-------------------------------------%
% state
%-------------------------------------%
%HFP as base state
state ALL   : temp=600
      FUEL  : temp=900
      COOL  : dens=0.7 boron=600
    AIC_MAP : in=no

read branch cr
  add AIC_MAP : in=yes
end branch

read branch cobranch
  %syncronize changes to DC, TC, and CR
  add COOL : dens=0.6 temp=630 AIC_MAP : in=no
  add COOL : dens=0.8 temp=570 AIC_MAP : in=no
  add COOL : dens=0.6 temp=630 AIC_MAP : in=yes
  add COOL : dens=0.8 temp=570 AIC_MAP : in=es

     % equivalent to

  add COOL : dens=0.6 0.8 0.6 0.8
             temp=630 570 630 570
   AIC_MAP : in= no  no yes yes
end branch
pow 40 bu 1 2
opt PRINT Xfile16=yes
end
```

- Multiple branch blocks are allowed
  - convenient to organize branches
- Branch definitions can perturb multiple state properties at the same time
- Two approaches to define a table of branch calculations
  1. row represents a branch, columns represent the state properties
  2. row represents the state properties, columns represent a branch

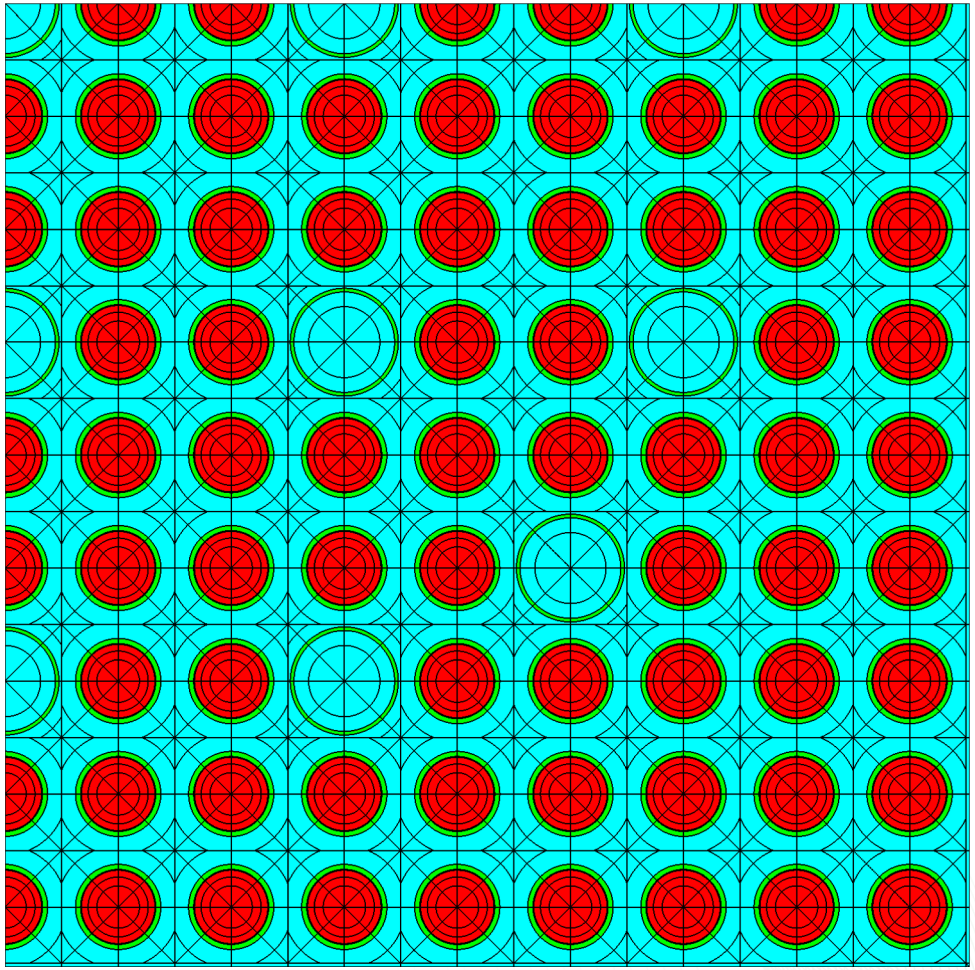
Branching

```
%-------------------------------------%
% state
%-------------------------------------%
%HFP as base state
state ALL   : temp=600
      FUEL  : temp=900
      COOL  : dens=0.7 boron=600
    AIC_MAP : in=no

read branch cr
  add AIC_MAP : in=yes
end branch

read branch cobranch
  %syncronize changes to DC, TC, and CR
  add COOL : dens=0.6 temp=630 AIC_MAP : in=no
  add COOL : dens=0.8 temp=570 AIC_MAP : in=no
  add COOL : dens=0.6 temp=630 AIC_MAP : in=yes
  add COOL : dens=0.8 temp=570 AIC_MAP : in=es

     % equivalent to

  add COOL : dens=0.6 0.8 0.6 0.8
             temp=630 570 630 570
   AIC_MAP : in= no  no yes yes
end branch
pow 40 bu 1 2
opt PRINT Xfile16=yes
end
```

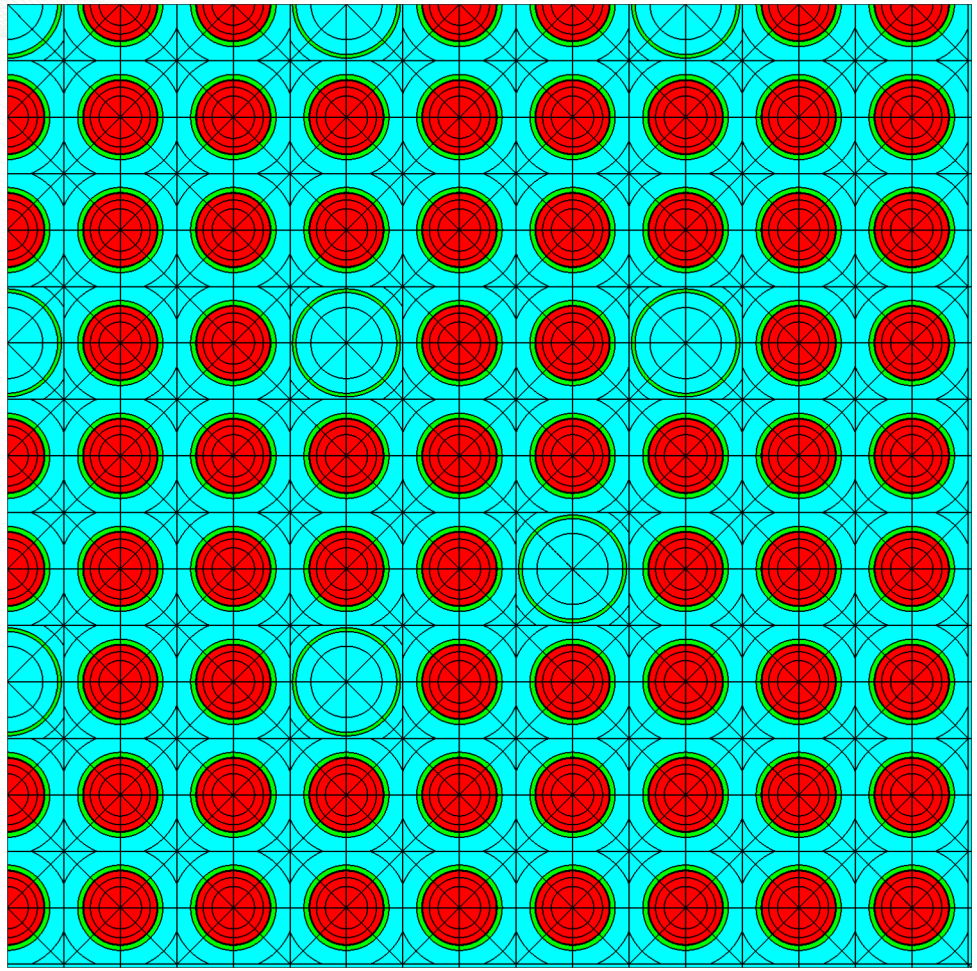
- Polaris calculation order:
  - Nominal state, Bu=0
  - Nominal state, Bu=1
  - Nominal state, Bu=2
  - Branch 1 … 5, Bu=0
  - Branch 1 … 5, Bu=1
  - Branch 1 … 5, Bu=2
- Txtfile16 order:
  - Nominal state, Bu=0
  - Branch 1 … 5, Bu=0
  - Nominal state, Bu=1
  - Branch 1 … 5, Bu=1
  - Nominal state, Bu=2
  - Branch 1 … 5, Bu=2

Exercise

- copy w17x17_aic.inp to w17x17_branch.inp
- simplify: replace MOD.1 with COOL.1
- simplify: replace TUBE with CLAD
- change nominal boron to 700 ppm
- add opt PRINT XFile16=yes
- create branch block table with the following data
- nominal branch
- 2 TF Branches (1200, 600 K)
- 2 PC Branches (1500, 0 ppm)
- 2 DC Branches, synchronize temperature change (2)
  - COOL density (g/cc): 0.8 0.6
  - COOL temp (K): 560 620
- AIC branch
- B4C branch
- AIC branch + PC branches (2)
- B4C branch + PC branches (2)
- Deplete 40 W/g with 0, 0.1, 1, 5 GWD/MTU



Exercise



- copy w17x17_branch.inp to w17x17_branch_1200K.inp
- 1200 K history calculation
- change nominal fuel temperature to 1200 K on **state** card

- For GenPMAXS, this is the only change to the input file, three keys:
  1. Use consistent branch block
  2. Just change the nominal state condition
  3. Will later instruct GenPMAXS how to order the two t16 files correctly

reflector card

```
=polaris_6.3
%-------------------------------------%
% general options
%-------------------------------------%
title "W17x17 REFL"  "Polaris training"
lib "broad_n"
%-------------------------------------%
% geometry
%-------------------------------------%
geom W17 : ASSM 17 1.26
hgap 0.04
geom radref : REFL 21.5

   %equivalent to

geom radref : REFL thick=21.5
```

reflector

- geom card for reflector

geom GNAME : REFL thick=REAL

- GNAME – reflector name
- REFL – indicates reflector geometry
- thick – total reflector thickness (cm)
- geom ASSM card must have sym=FULL

```
=polaris_6.3
%--------------------------------------%
% general options
%--------------------------------------%
title "W17x17 REFL"  "Polaris training"
lib "broad_n"
system PWR
%--------------------------------------%
% geometry
%--------------------------------------%
geom W17 : ASSM 17 1.26
hgap 0.04
geom radref : REFL 21.5
slab : 5          16.5
     : TUBE       MOD.1
     : 3          15
```

Slab

- slab – defines a series of slabs for reflector

slab [SLABID]
: t1 t2 … ti … tN
: M1 M2 … Mi … MN
[: nx1 nx2 … nxi … nxN]
[: ny1 ny2 … nyi … nyN]

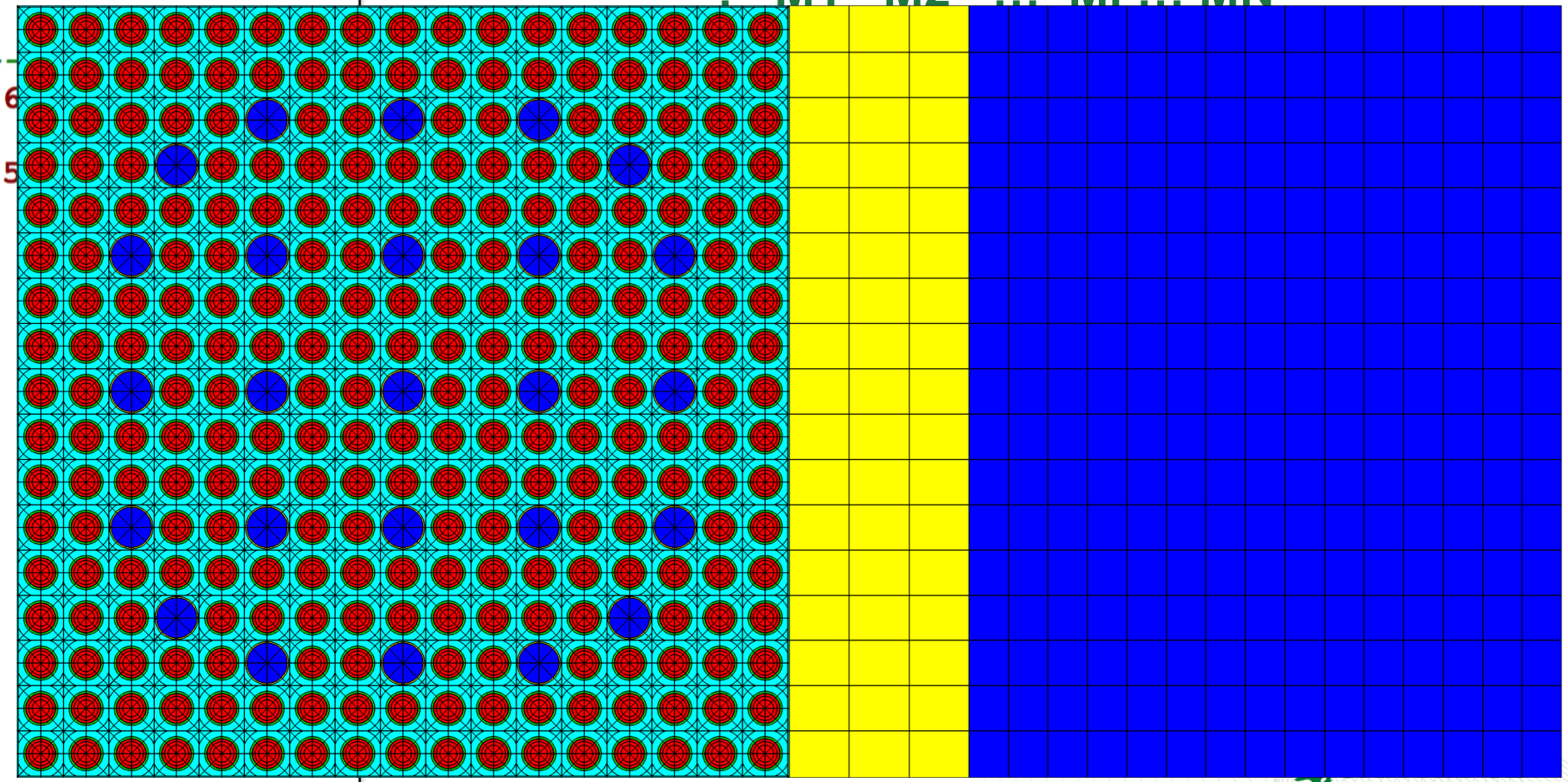
- SLABID – slab identifier, default is REFL GNAME
- t_i – slab thickness (cm)
- M_i – slab material
- nx_i – # of x-mesh
- ny_i – # of y-mesh
- Polaris preserves the horizontal planar pin boundaries of the fuel assembly … ny is not necessary

Slab

- slab – defines a series of slabs for reflector

slab [SLABID]
: t1 t2 … ti … tN
: M1 M2 … Mi … MN

```
=polaris_6.3
%---------------------------------------%
% general options
%---------------------------------------%
title "W17x17 REFL"  "Polaris training"
lib "broad_n"
system PWR
%---------------------------------------%
% geometry
%---------------------
geom W17 : ASSM 17 1.26
hgap 0.04
geom radref : REFL 21.5
slab : 5          16.5
     : TUBE       MOD.1
     : 3          15
```



Reflector Modeling

- Core analysis generally requires top, bottom, radial reflector model
- No history or branches required
  - if any: coolant dens, temp, boron
- Requires knowledge of core structure geometry dimensions and material properties for core structure
  - baffle
  - rod end plugs
  - upper plenum region
  - end spacer grids
  - upper/lower core plate
- Typical radial reflector:
  - Fuel: low enriched fuel
  - Slab zones:
    1. small gap b/w fuel and baffle
    2. baffle
    3. coolant
  - Reflector width ~ lattice pitch

Reflector Modeling

- Typical bottom reflector:
  - Fuel: determine need for end spacer grid correction
  - Coolant: inlet conditions
  - Structures:
    - end plugs
    - spacer grids
    - nozzle
    - lower core plate
- Typical top reflector:
  - Fuel: determine need for end spacer grid correction
  - Coolant: outlet conditions
  - Structures:
    - end plugs
    - fuel rod upper plenum
    - spacer grid
    - nozzle
    - upper core plate

Exercises

- copy w17x17_rev3.inp to radref.inp
- remove SE symmetry
- reduce enrichment to 1.0%
- reduce COOL and MOD boron to 700 ppm
- slabs (21.5 cm total)
  - 0.19 cm gap b/w fuel and baffle (COOL.1)
  - 2.85 cm baffle SS304 (TUBE)
  - remainder MOD.1
  - # of x-mesh: ceiling(thick/ppitch)= (1,3,15)

- copy w17x17_rev3.inp to botref.inp
- remove SE symmetry
- reduce COOL and MOD boron to 700 ppm
- slabs (21.5 cm total)
  - 10.75 cm slab 50% wt zirc4 and 50% wt 700 ppm WATER, 1.2 g/cc
  - 10.75 cm slab 80% wt ss304, 20% wt 700 ppm WATER, 2.1 g/cc
  - # of x-mesh: ceil(t/pin_pitch)

- copy w17x17_rev3.inp to topref.inp
- remove SE symmetry
- reduce COOL and MOD boron to 700 ppm
- slabs (21.5 cm total)
  - 10.75 cm slab 65% wt zirc4 and 35% wt 700 ppm WATER, 1.0 g/cc
  - 10.75 cm slab 80% wt ss304, 20% wt 700 ppm WATER, 2.3 g/cc
  - # of x-mesh: ceil(t/pin_pitch)

GenPMAXS

```
%JOB_TIT
 'w17x17.PMAX' T 3.0 'POLARIS-PMAX'
%JOB_OPT
   T   T   F   F   T   F   T   F   T   F   F   T   T   F   0
!ad,xe,de,j1,ch,Xd,iv,dt,yl,cd,gf,be,lb,dc,ups
%DAT_SRC
 8 2 1 1.0
%STA_VAR
 4
 CR DC PC TF
%HISTORY
 2 1
 'NOM'   0 .680   700   900
 'HTF'   0 .680   700 1200
%BRANCH
 13 1
 'NOM'   0 .680   700   900
 'TFH'   0 .680   700 1200
 'TFL'   0 .680   700   600
 'PCH'   0 .680 1200   900
 'PCL'   0 .680     0   900
 'DCH'   0 .800   700   900
 'DCL'   0 .600   700   900
 'CR1'   1 .680   700   900
 'CR2'   2 .680   700   900
 '1PH'   1 .680 1200   900
 '1PL'   1 .680     0   900
 '2PH'   2 .680 1200   900
 '2PL'   2 .680     0   900

```

GenPMAXS

- GENPMAXS – converter code for coupling lattice physics codes to PARCS
- Line 2:
  - w17x17.PMAX – the name of the generated PMAX file
- Line 7:
  - 8: indicates processing Polaris XS file
  - 2: number of Polaris XS files
  - 1: 1 for fuel, 0 for reflector
  - 1.0: always 1.0

```
%JOB_TIT
 'w17x17.PMAX' T 3.0 'POLARIS-PMAX'
%JOB_OPT
   T   T   F   F   T   F   T   F   T   F   F   T   T   F   0
!ad,xe,de,j1,ch,Xd,iv,dt,yl,cd,gf,be,lb,dc,ups
%DAT_SRC
 8 2 1 1.0
%STA_VAR
 4
 CR DC PC TF
%HISTORY
 2 1
 'NOM'   0 .680   700   900
 'HTF'   0 .680   700 1200
%BRANCH
 13 1
 'NOM'   0 .680   700   900
 'TFH'   0 .680   700 1200
 'TFL'   0 .680   700   600
 'PCH'   0 .680 1200   900
 'PCL'   0 .680     0   900
 'DCH'   0 .800   700   900
 'DCL'   0 .600   700   900
 'CR1'   1 .680   700   900
 'CR2'   2 .680   700   900
 '1PH'   1 .680 1200   900
 '1PL'   1 .680     0   900
 '2PH'   2 .680 1200   900
 '2PL'   2 .680     0   900

```

GenPMAXS

- HISTORY card
- Line 12:
  - 2: # of histories
  - 1: first history is the reference history
- Line 13:
  - ‘NOM’ – just a label, not used by code
  - CR DC PC TF values
- Line 14:
  - ‘HTF’ – just a label, not used by code
  - CR DC PC TF values

```
%JOB_TIT
 'w17x17.PMAX' T 3.0 'POLARIS-PMAX'
%JOB_OPT
   T   T   F   F   T   F   T   F   T   F   F   T   T   F   0
!ad,xe,de,j1,ch,Xd,iv,dt,yl,cd,gf,be,lb,dc,ups
%DAT_SRC
 8 2 1 1.0
%STA_VAR
 4
 CR DC PC TF
%HISTORY
 2 1
 'NOM'   0 .680   700   900
 'HTF'   0 .680   700 1200
%BRANCH
 13 1
 'NOM'   0 .680   700   900
 'TFH'   0 .680   700 1200
 'TFL'   0 .680   700   600
 'PCH'   0 .680 1200   900
 'PCL'   0 .680     0   900
 'DCH'   0 .800   700   900
 'DCL'   0 .600   700   900
 'CR1'   1 .680   700   900
 'CR2'   2 .680   700   900
 '1PH'   1 .680 1200   900
 '1PL'   1 .680     0   900
 '2PH'   2 .680 1200   900
 '2PL'   2 .680     0   900

```

GenPMAXS

- BRANCH card
- Line 16:
  - 13: # of branches
  - 1: first branch is the reference branch
- Line 17-29:
  - label, not used by code
  - CR DC PC TF values

```
%BURNUP
 1
 'NOM_Burn'   4
 0  0.1  1  5
 'NOM' 13*1
 'HTF' 13*1
```

GenPMAXS

- BURNUP card
- Line 32: 1 only one burnup list
- Line 33:
  - ‘NOM_Burn’ : label, not used by code
  - 4: number of burnup steps
- Line 34: the four burnup steps
- Line 35 (first history):
  - ‘NOM’: just a label to help input setup
  - 13*1: all 13 branches of history 1 use the first burnup list
- Line 36 (second history):
  - ‘HTF’: just a label to help input setup
  - 13*1: all 13 branches of history 2 use the first burnup list

```
61 %FIL_CNT
62  1 'w17x17_branch.t16' 13 0
63       1   1   1   1   4   !NOM
64       2   1   2   1   4   !TFH
65       3   1   3   1   4   !TFL
66       4   1   4   1   4   !PCH
67       5   1   5   1   4   !PCL
68       6   1   6   1   4   !DCH
69       7   1   7   1   4   !DCL
70       8   1   8   1   4   !CR1
71       9   1   9   1   4   !CR2
72      10   1  10   1   4   !1PH
73      11   1  11   1   4   !1PL
74      12   1  12   1   4   !2PH
75      13   1  13   1   4   !2PL
76  2 'w17x17_branch_1200K.t16' 13 0
77       1   2   2   1   4   !TFH
78       2   2   1   1   4   !NOM
79       3   2   3   1   4   !TFL
80       4   2   4   1   4   !PCH
81       5   2   5   1   4   !PCL
82       6   2   6   1   4   !DCH
83       7   2   7   1   4   !DCL
84       8   2   8   1   4   !CR1
85       9   2   9   1   4   !CR2
86      10   2  10   1   4   !1PH
87      11   2  11   1   4   !1PL
88      12   2  12   1   4   !2PH
89      13   2  13   1   4   !2PL
90 %JOB_END
```

GenPMAXS

- FIL_CNT card
- Line 62:
  - 1: 1st file
  - w17x17_branch.t16: name of 1st file
  - 13: 13 branches on 1st file
  - 0: always 0
- Line 63-75:
  - first number is ignored, just use the index of the branch:
  - second number: history index
  - third number: branch index
  - fourth number: always 1
  - fifth number: always number of burnup steps
  - !XXX – ignored by the code, ! denotes a comment
- Line 76:
  - 2: 2nd file
  - w17x17_branch_1200K.t16: name of 2nd file
  - 13: 13 branches on 2nd file
  - 0: always 0
- Line 77-89: see above
- Line 90: %JOB_END

```
%FIL_CNT
 1 'w17x17_branch.t16' 13 0
     1   1   1   1   4   !NOM
     2   1   2   1   4   !TFH
     3   1   3   1   4   !TFL
     4   1   4   1   4   !PCH
     5   1   5   1   4   !PCL
     6   1   6   1   4   !DCH
     7   1   7   1   4   !DCL
     8   1   8   1   4   !CR1
     9   1   9   1   4   !CR2
    10   1  10   1   4   !1PH
    11   1  11   1   4   !1PL
    12   1  12   1   4   !2PH
    13   1  13   1   4   !2PL
 2 'w17x17_branch_1200K.t16' 13 0
     1   2   2   1   4   !TFH
     2   2   1   1   4   !NOM
     3   2   3   1   4   !TFL
     4   2   4   1   4   !PCH
     5   2   5   1   4   !PCL
     6   2   6   1   4   !DCH
     7   2   7   1   4   !DCL
     8   2   8   1   4   !CR1
     9   2   9   1   4   !CR2
    10   2  10   1   4   !1PH
    11   2  11   1   4   !1PL
    12   2  12   1   4   !2PH
    13   2  13   1   4   !2PL
%JOB_END
```

GenPMAXS

- FIL_CNT card
- Line 62:
  - 1: 1st file
  - [illegible] of 1st file
  - first number is ignored, just use the index of the branch:
  - second number: history index
  - third number: branch index
  - fourth number: always 1
  - fifth number: always number of burnup steps
  - !XXX – ignored by the code, ! denotes a comment
- Line 76:
  - 2: 2nd file
  - w17x17_branch_1200K.t16: name of 2nd file
  - 13: 13 branches on 2nd file
  - 0: always 0
- Line 77-89: see above
- Line 90: %JOB_END

I use a comment to identify the order of the branches in the Polaris calculation.

GenPMAXS

```
61 %FIL_CNT
62  1 'w17x17_branch.t16' 13 0
63       1   1   1   1   4   !NOM
64       2   1   2   1   4   !TFH
65       3   1   3   1   4   !TFL
66       4   1   4   1   4   !PCH
67       5   1   5   1   4   !PCL
68       6   1   6   1   4   !DCH
69       7   1   7   1   4   !DCL
70       8   1   8   1   4   !CR1
71       9   1   9   1   4   !CR2
72      10   1  10   1   4   !1PH
73      11   1  11   1   4   !1PL
74      12   1  12   1   4   !2PH
75      13   1  13   1   4   !2PL
76  2 'w17x17_branch_1200K.t16' 13 0
77       1   2   2   1   4   !TFH
78       2   2   1   1   4   !NOM
79       3   2   3   1   4   !TFL
80       4   2   4   1   4   !PCH
81       5   2   5   1   4   !PCL
82       6   2   6   1   4   !DCH
83       7   2   7   1   4   !DCL
84       8   2   8   1   4   !CR1
85       9   2   9   1   4   !CR2
86      10   2  10   1   4   !1PH
87      11   2  11   1   4   !1PL
88      12   2  12   1   4   !2PH
89      13   2  13   1   4   !2PL
90 %JOB_END
```

- FIL_CNT card
- Line 62:
  - 1: 1st file
  - [illegible] of 1st file
  - [illegible]st use the index of the branch:
    - second number: history index
    - third number: branch index
    - fourth number: always 1
  - [illegible]r of burnup steps
  - [illegible], ! denotes a comment
- Line 76:
  - 2: 2nd file
  - w17x17_branch_1200K.t16: name of 2nd file
  - 13: 13 branches on 2nd file
  - 0: always 0
- Line 77-89: see above
- Line 90: %JOB_END

I use a comment to identify the order of the branches in the Polaris calculation. I use the same labels in %BRANCH

The branch index should match the order in %BRANCH

history

time-dependent operational changes

multiple histories in the same input file

```
=polaris_6.3
lib "broad_n"
sys PWR
geom taka : ASSM 1 1.26
comp u411 : UOX 4.11
mat FUEL.1 : u411 10.412
pin 1 : .4025  .475  : FUEL.1 CLAD
state ALL  : temp=600
      COOL : dens=0.6 boron=1100
      FUEL : temp=900
read history
%---------------------------------------%
% cycle 1
%---------------------------------------%
pow 39
state COOL : boron=900 850 700 600 400
      FUEL :  temp=900 910 920 890 880
dt                  50  50 100 100 200
pow 0
ti 70
%---------------------------------------%
% cycle 2
%---------------------------------------%
pow                 42  41  38  39  37
state COOL : boron=900 850 700 600 300
dt                  50  50  50 100 250
pow 0
ti 80
end history
end
```

history example

- history block allows for time-dependent operational changes
- similar to TIMETABLE block in TRITON

history example

```
=polaris_6.3
lib "broad_n"
sys PWR
geom taka : ASSM 1 1.26
comp u411 : UOX 4.11
mat FUEL.1 : u411 10.412
pin 1 : .4025  .475  : FUEL.1 CLAD
state ALL  : temp=600
       COOL : dens=0.6 boron=1100
       FUEL : temp=900
read history
%----------------------------------------%
% cycle 1
%----------------------------------------%
pow 39
state COOL : boron=900 850 700 600 400
       FUEL :  temp=900 910 920 890 880
dt                    50  50 100 100 200
pow 0
ti 70
%----------------------------------------%
% cycle 2
%----------------------------------------%
pow                   42  41  38  39  37
state COOL : boron=900 850 700 600 300
dt                    50  50  50 100 250
pow 0
ti 80
end history
end
```

- history block allows for time-dependent operational changes
- similar to TIMETABLE block in TRITON
- outside of history block
  - one state card to initialize state variables

- inside history block
  - power, state, and burnup/time cards are entered together
    - power – single value or array
    - state – array
    - burnup/time – array
    - all arrays must be same size
    - state must precede burnup/time
  - multiple power/state/time cards may be stacked together
- convenient for RCA benchmarks

Exercises

- copy w17x17_rev3.inp to history.inp
- reduce 17x17 to 3x3 with GT in the middle
- history 1 (avg.):
  - Pow 40
  - Bu 1 5 10 20
  - COOL and MOD boron 700 ppm
- history 2 (letdown):
  - Pow 40
  - Bu 1 5 10 20
  - COOL and MOD boron 1000 800 800 500
- compare history_avg.f71, history_letdown.f71

shield card
opt DEPL card

Options

- option cards
  - KEFF
  - ESSM
  - BOND
  - DEPL
  - CRITSPEC
  - PRINT
  - FG

- option ESSM, BOND, DEPL
  - Use default values
  - See manual for details
- **shield**: controls set of material regions with independently self-shielded cross-sections

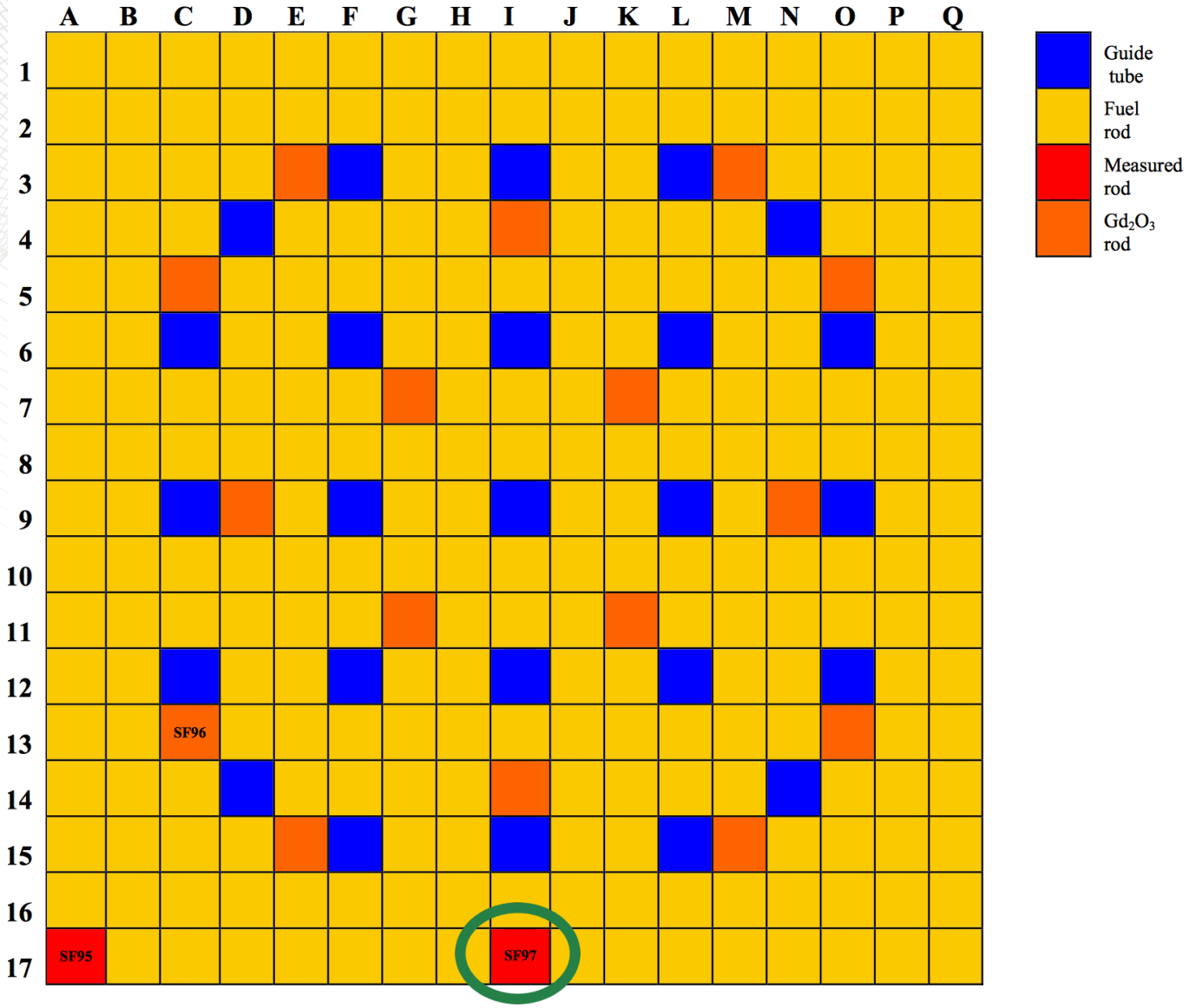
opt DEPL

opt DEPL [key_1=val_1 key_2=val_2 … key_i=val_i … key_N=val_N]

key	*value type*	*details*	*default*
TrackingSet	*String*	set of nuclides tracked in depletion calculations "None": set of nuclides present in user input "Complete": complete set of all nuclides available on ORIGEN data libraries	"Complete"
Solver	*String*	"MATREX": legacy ORIGEN solution method "CRAM": Chebyshev Rational Approximation Method	"MATREX"
Method	*String*	"PREDICTOR" "PREDICTOR_CORRECTOR"	"PREDICTOR_CORRECTOR"
StepRefinement	*Int*	divide the user input steps by this factor>0, i.e., refinement of 2 divides all steps by 2 (NOT ENABLED)	1
NumSubsteps	*Int*	Number of internal substeps for depletion calculations	4
DepleteMode	*String*	"BOSS" or "MOSS." The depletion power renormalization is done at the beginning of each substep (BOSS) or the middle of each substep (MOSS)	"BOSS"

Shield card

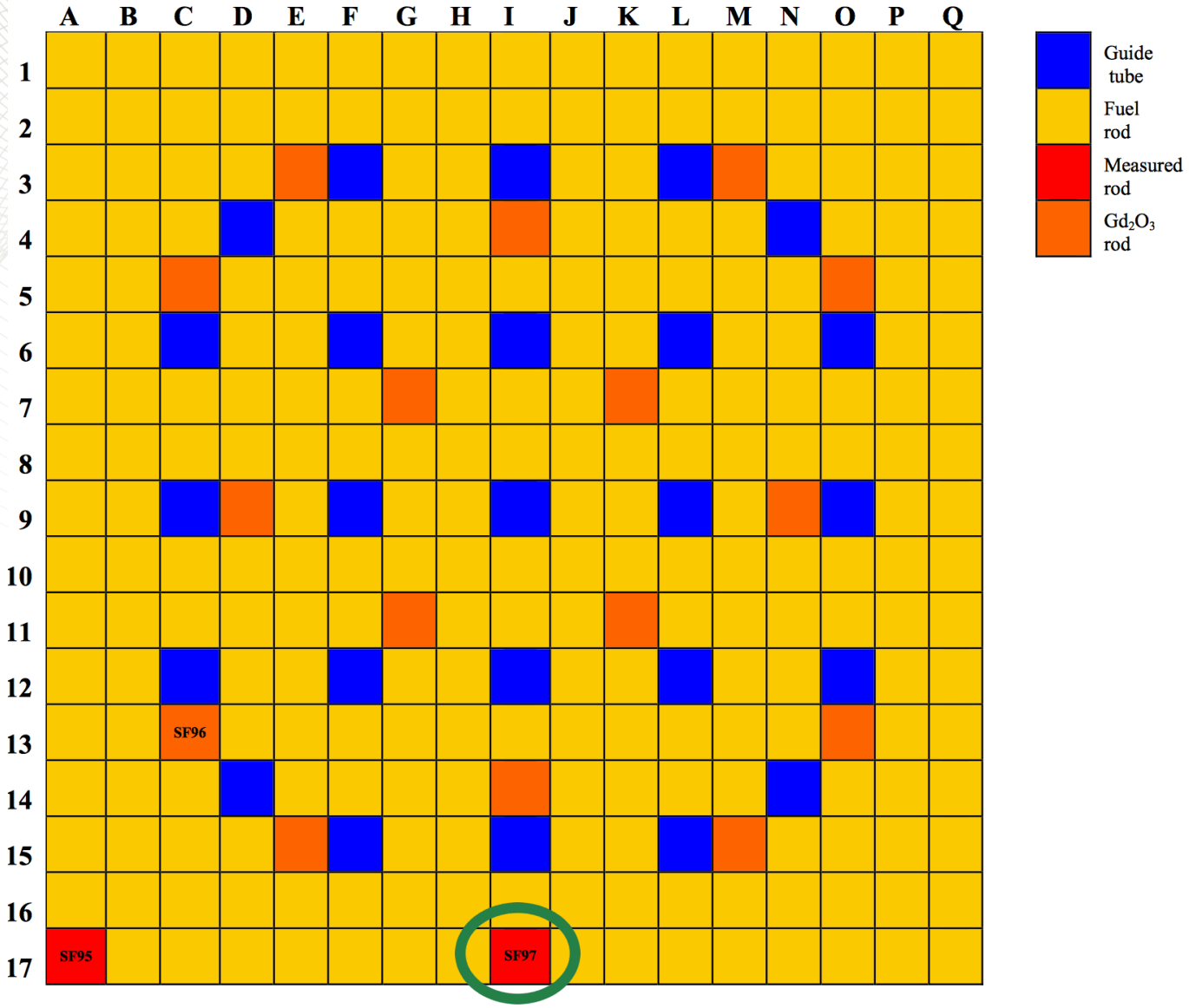
- **shield**: controls set of material regions with independently self-shielded cross-sections
- **shield** M_1=*XTYPE* M_2=*XTYPE* … M_i=*XTYPE* … M_N= *XTYPE*
- M_i – Material name (FUEL.1) or Material class (FUEL) or ALL for all materials
- XTYPE
  - N for no expansion of input materials for shielding (each input material has a single cross section set and is depleted with independent isotopics)
  - P for pin expansion (each input material **in each pin** has a single cross section set and is depleted with independent isotopics)
  - R for ring expansion (each input material **in each pin/ring** has a single cross section set and is depleted with independent isotopics)
- Default: **shield ALL=N FUEL=R CNTL=R BP=R**



Exercise 1 of 3

- Takahama assembly depletion benchmark
- copy taka_depl_rev0.inp as taka_depl_rev1.inp
- change radial mesh for FUEL.1 and FUEL.3 to nr=3
- add
  - shield ALL=N FUEL.1=P FUEL.2=R FUEL.3=P
  - note FUEL.2 is a Gd-bearing rod so “R” should be used
- compare discharge isotopics and k-eff vs burnup with taka_depl_rev0 output

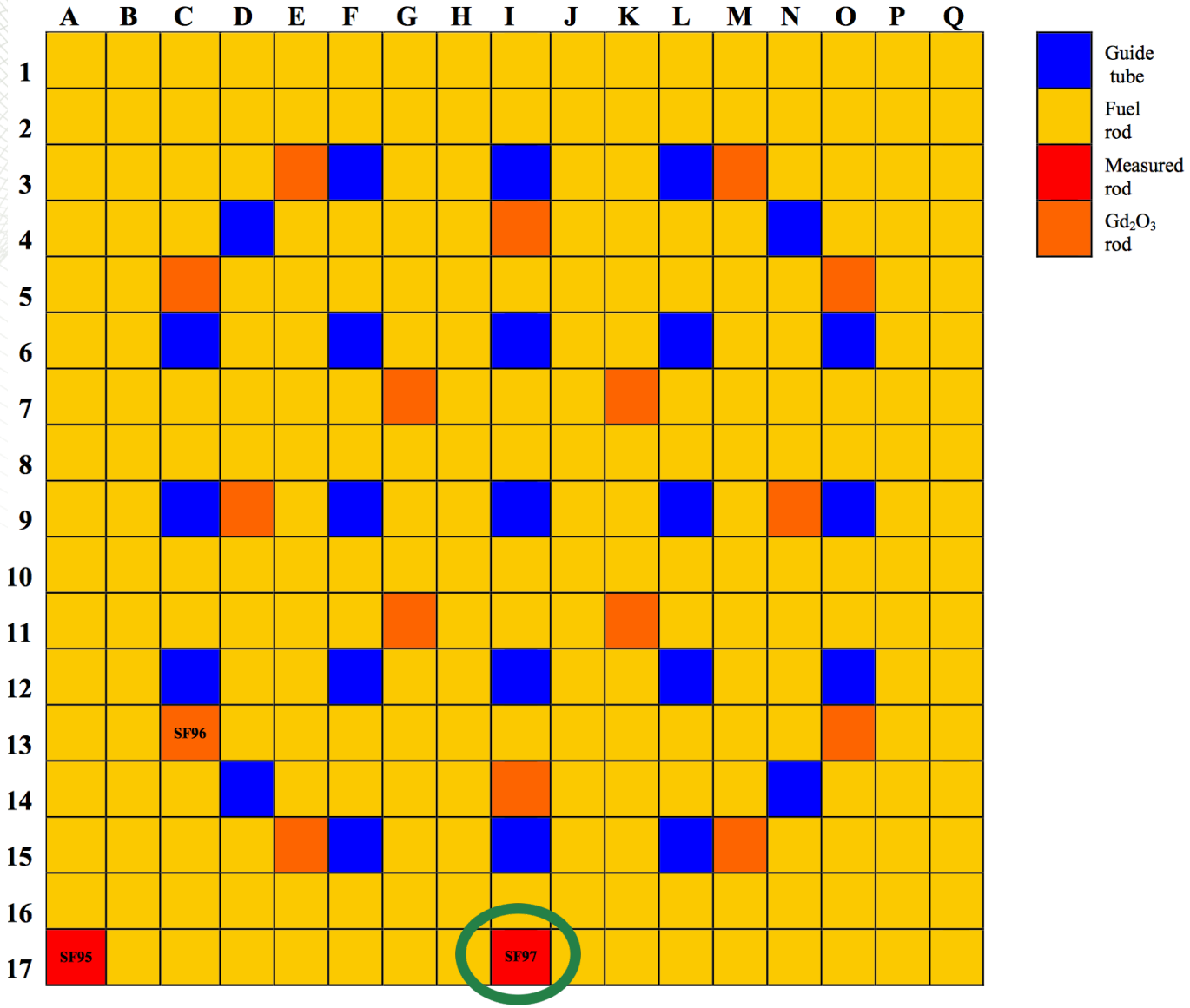
https://www.oecd-nea.org/science/docs/2013/nsc-doc2013-1.pdf
additional data at: http://info.ornl.gov/sites/publications/files/Pub23359.pdf



Exercise 2 of 3

- Takahama assembly depletion benchmark
- copy taka_depl_rev1.inp as taka_depl_rev2.inp
- add
  - shield ALL=N FUEL.2=R
  - note FUEL.2 is a Gd-bearing rod so “R” should be used
- compare discharge isotopics and k-eff vs burnup with taka_depl_rev1 and taka_depl_rev0 output (note f71 position record has changed)
- compare run-time

https://www.oecd-nea.org/science/docs/2013/nsc-doc2013-1.pdf
additional data at: http://info.ornl.gov/sites/publications/files/Pub23359.pdf



Exercise 3 of 3

- Takahama assembly depletion benchmark
- copy taka_depl_rev2.inp as taka_depl_rev3.inp
- add
  - opt DEPL Method='PREDICTOR'
- compare discharge isotopics and k-eff vs burnup with previous cases
- compare run-time

https://www.oecd-nea.org/science/docs/2013/nsc-doc2013-1.pdf
additional data at: http://info.ornl.gov/sites/publications/files/Pub23359.pdf

opt FG
opt CRITSPEC
opt PRINT

option CRITSPEC

3.2.6.5 option<CRITSPEC> – critical spectrum

opt *CRITSPEC* [key_1=val_1 key_2=val_2 … key_i=val_i … key_N=val_N]

key	*value type*	*details*	*default*
Mode	*String*	critical spectrum mode "SEARCH": search for critical mode (k-eff=1) "SPECIFIED": provide B2 below "NONE": do not use critical spectrum	"SEARCH"
B2	*Real*	value of critical buckling if Mode="SPECIFIED" units: cm^{-2}	0.0
Method	*String*	critical spectrum system "B1": solve the B_1 equations "P1": solve the P_1 equations	"P1"

Examples

```
% enable critical buckling search using B1 equations for a buckling of 1e-3
opt CRITSPEC
  Mode="SPECIFIED"
  B2=1e-3
  Method="B1"
```

- options to control the critical spectrum calculation
- by default, the critical spectrum search is enabled
- to disable

opt CRITSPEC Mode='none'

- to specify a buckling value

opt CRITSPEC B2=0.001 Mode='specified'

- P1 is default, to set to B1

opt CRITSPEC Method='B1'

option PRINT

3.2.6.6 option<PRINT> – printing

opt *PRINT* [key_1=val_1 key_2=val_2 … key_i=val_i … key_N=val_N]

key	*value type*	*details*	*default*
XSSummary	*Bool*	print a cross section summary in the output file	true
CritSpecSummary	*String*	print critical spectrum summary "NONE": no print out "BUCKLING": limited buckling info "SPECTRUM": full spectrum	"BUCKLING"
XFile16	*Bool*	output a TRITON xfile016 nodal data library	false
InputDataContainer	*Bool*	print out the input data container	true

- printing options
- to print the txtfile16

opt PRINT XFile16=yes

- to print the critical spectrum

opt PRINT CritSpecSummary='spectrum'

option FG

3.2.6.7 option<FG> – few-group cross-section generation

opt *FG*
[AdjointMode=String InvVelMode=String]
[: b_1 b_2 … b_i … b_N]
[: E_1 E_2 … E_i … E_{N-1}]

param	*type*	*details*	*default*
AdjointMode	*String*	type of adjoint calculation to use in few-group data generation "INFMED": infinite medium adjoint "CRITICAL": critical spectrum adjoint "UNIFORM": uniform adjoint	"INFMED"
InvVelMode	*String*	weighting option for few-group inverse velocities "FORWARD": forward flux weighting "ADJOINT": adjoint flux weighting	"FORWARD"
b_i	*Real*	list of burnups to include in output few-group cross section database, e.g. XFile16 output units: GWd/MTHM	all burnups available
E_i	*Real*	note descending order and only N-1 divisions are needed for an N group structure E_0 is maximum energy (typically 2e7 eV) E_N is minimum (typically 1e-5 eV) units: eV	0.625 eV division (two groups)

- Few-group XS options
- Defaults are fine
- Example:

opt FG : 0 1 5 : 1000 1

- "0 1 5" implies branch calculations are only performed at these burnups
- These must be a subset of the depletion burnups
- The txtfile16 will only have FG XS at "0 1 5" GWD/MTHM
- "1000 1" implies a 3 group XS structure
  1. 2e7 eV to 1000 eV
  2. 1000 eV to 1 eV
  3. 1 eV to 1e-5 eV

Exercises

- copy w17x17_rev3.inp to w17x17_4G.inp
- enable critical spectrum print
- use B1 critical spectrum with buckling equal to 0.0259
- edit 4G cross sections with 50 keV, 116 eV, 0.625 eV boundaries
  - opt FG : : 50000.0 116.0 0.625

```
Critical Spectrum Calculation Edit
----------------------------------

 User-defined buckling, B2 =  2.590E-02
 B1/P1 approximation: B1
 P1 scattering matrix treatment (full matrix [illegible] transport cross s
 Critical spectrum k-eff = 0.37709

 |Group | Upper     | System    | Inf.Med.  | Critical  | Diffusion|
 |  #   |Energy(eV)|  Flux     |   Flux    |   Flux    | Coef (cm)|
 |------|----------|----------|----------|----------|----------|
 |    1  | 2.000E+07| 1.902E-03| 1.902E-03| 2.218E-03| 2.416E+00|
 |    2  | 6.434E+06| 1.915E-02| 1.915E-02| 2.296E-02| 2.278E+00|
 |    3  | 4.304E+06| 3.426E-02| 3.426E-02| 4.541E-02| 1.975E+00|
 |    4  | 3.000E+06| 5.533E-02| 5.533E-02| 6.786E-02| 2.109E+00|
 |    5  | 1.850E+06| 5.088E-02| 5.088E-02| 6.623E-02| 1.818E+00|
 |    6  | 1.500E+06| 5.289E-02| 5.289E-02| 6.800E-02| 1.698E+00|
 |    7  | 1.200E+06| 4.732E-02| 4.732E-02| 6.199E-02| 1.409E+00|
 |    8  | 8.611E+05| 6.079E-02| 6.079E-02| 7.312E-02| 1.608E+00|
 |    9  | 7.500E+05| 5.445E-02| 5.445E-02| 6.309E-02| 1.587E+00|
 |   10  | 6.000E+05| 4.801E-02| 4.801E-02| 5.425E-02| 1.530E+00|
 |   11  | 4.700E+05| 3.169E-02| 3.169E-02| 3.766E-02| 1.080E+00|
 |   12  | 3.300E+05| 3.914E-02| 3.914E-02| 4.427E-02| 1.214E+00|
 |   13  | 2.700E+05| 3.215E-02| 3.215E-02| 3.543E-02| 1.196E+00|
 |   14  | 2.000E+05| 2.344E-02| 2.344E-02| 2.425E-02| 1.091E+00|
 |   15  | [illegible]
 |   16  |
 |   17  |
```

```
Broad-Group Structure
---------------------

 |Broad|  Upper    |  Lower    |# of Fine|
 |Group|Energy(eV)|Energy(eV)| Groups  |
 |-----|----------|----------|---------|
 |    1 | 2.000E+07| 5.000E+04|    14   |
 |    2 | 5.000E+04| 1.160E+02|     8   |
 |    3 | 1.160E+02| 6.250E-01|    18   |
 |    4 | 6.250E-01| 1.000E-05|    16   |
```

```
Fission Macroscopic Cross Sections
----------------------------------

 |Group |  Kappa-   |           |   Nu-     |
 |  #   |   Fis.    | Fission   | Fission   |   Chi
 |------|----------|----------|----------|----------
 |    1  | 5.302E-14| 1.676E-03| 4.614E-03| 9.955E-01
 |    2  | 4.871E-14| 1.567E-03| 3.813E-03| 4.546E-03
 |    3  | 2.410E-13| 7.752E-03| 1.889E-02| 4.721E-07
 |    4  | 1.664E-12| 5.354E-02| 1.305E-01| 2.557E-09
```

opt KEFF
IFBA Modeling

opt KEFF

3.2.6.1 option<KEFF> – eigenvalue

opt *KEFF* [key_1=val_1 key_2=val_2 … key_i=val_i … key_N=val_N]

key	*value type*	*details*	*default*
NumAzim	*Int*	number of azimuthal angles per octant	20
NumPolar	*Int*	number of polar angles per octant	3
PnOrder	*Int*	scattering order	2
RaySpacing	*Real*	spacing between MoC rays	0.04 cm
developer options (generally should not change)			
PolarScheme	*String*	polar quadrature "TY": Tabuchi-Yamamoto quadrature "DECART": DeCART quadrature "LO": Leonard optimal quadrature "CACTUS": Cactus quadrature	"TY"
EigSolver	*String*	eigenvalue solver type "CMFD" (single-assembly default) "POWER" (reflector default)	
UpscatterSolver	*String*	upscatter solver type "GAUSS_SEIDEL", (default if EigSolver="CMFD") "BICGSTAB" (default if EigSolver="POWER") "GMRES"	
DownscatterSolver, UpscatterInnerSolver	*String*	within-group solver type "SOURCE", (default if EigSolver="CMFD") "BICGSTAB" (default if EigSolver="POWER") "GMRES"	

- options to control k-eff calculation
- MOC quadrature options:
  - NumPolar: 3
  - NumAzim: 20
  - RaySpacing: 0.04
- IFBA – requires tighter ray-spacing

IFBA

```
=polaris_6.3
lib "broad_n"
system PWR
geom W17 : ASSM 3 1.26 SE
%-------------------------------------%
% comps and mats
%-------------------------------------%
comp c_f31 : UOX 3.1
mat FUEL.1 : c_f31 10.26
comp c_enrB : WT B10=50 B11=50
comp c_ifba : FORM Zr=1 c_enrB=2
mat BP.1 : c_ifba 3.85
%-------------------------------------%
% pins and mesh
%-------------------------------------%
pin B : 0.4096 0.4106 0.418 0
      : FUEL.1 BP      GAP    C
pin F : 0.4096 0.418 0.475
      : FUEL.1 GAP    CLAD
mesh FUEL : nr=3
pinmap
 B
 F F
power 40
bu 0 .1 1 2 4 6 8 10
shield ALL=N FUEL=P BP=P
state ALL  : temp=590
       COOL : dens=.68 boron=9
       CLAD : temp=700 FUEL :
end
```

- Integral Fuel Burnable Absorber
- spray-on coating of ZrB_2 with enriched B-10
- ~10 microns thick
- copy w17x17_ifba_rev0.inp from starters folder
- deplete

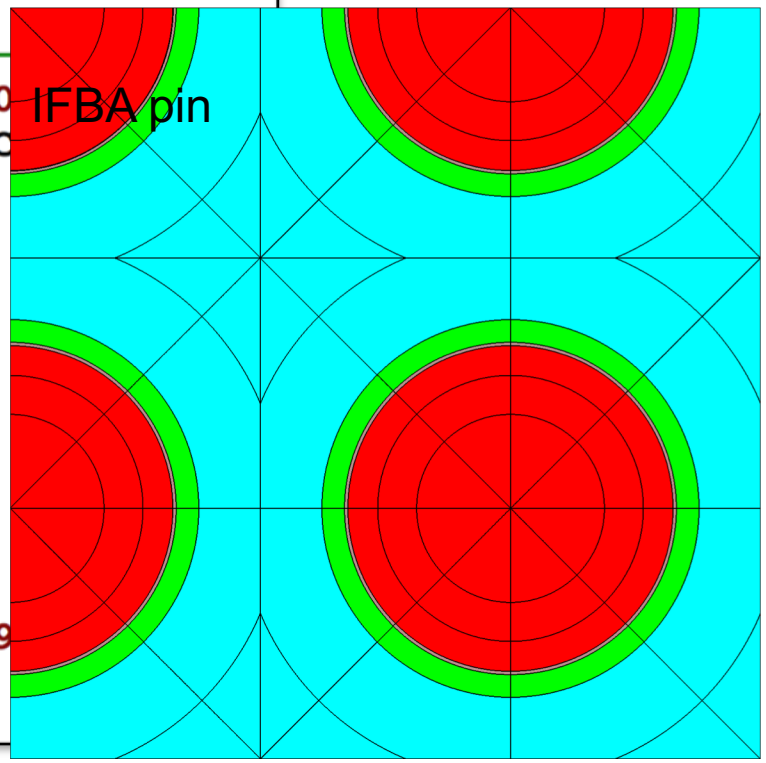
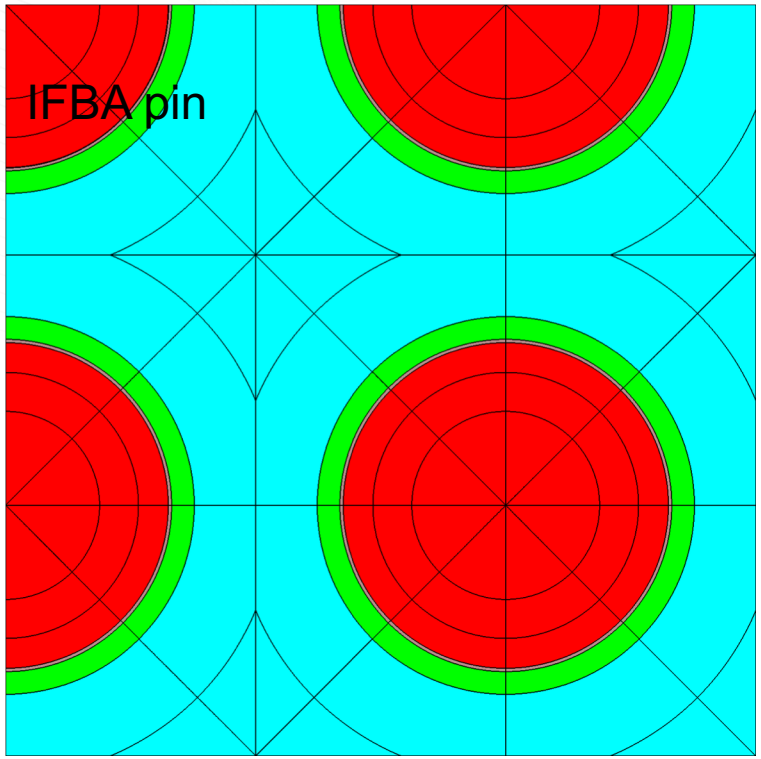


Table 11: IFBA Fuel Rod Specification

Input	Value
Poison Material	ZrB_2
Boron-10 Loading	2.355 mg/in
Boron-10 Enrichment	50%
Coating Thickness	10 μm
Coating Density	3.85 g/cc
Poison Height	304.8 cm
Poison Location	Centered axially

IFBA



- The default ray spacing in Polaris is 0.04 cm (400 microns); this is too coarse for IFBA
- To refine the ray spacing use

opt KEFF RaySpacing=X

- copy w17x17_ifba_rev0.inp w17x17_ifba_rev1.inp through w17x17_ifba_rev3.inp
- rerun with ray-spacing of 0.01 cm, 0.003 cm, and 0.001 cm

IFBA

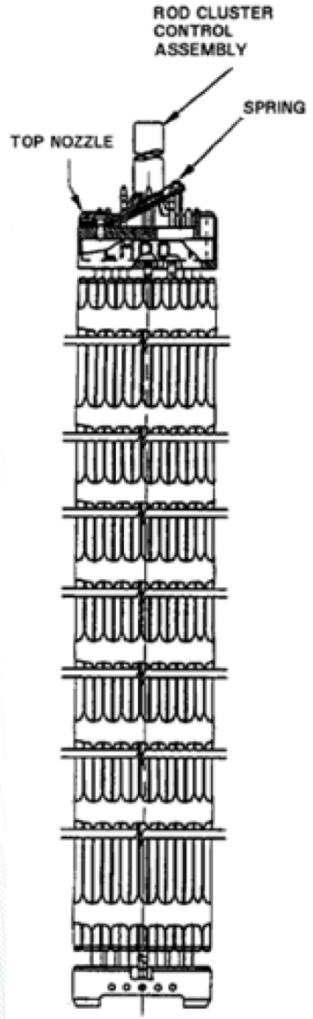
- 3x3 pin calc:
  - Internal assessments have found 0.003 cm (30 micron) ray-spacing is sufficient for 10 micron IFBA layers
- Lattice:
  - run-time vs. accuracy trade-off
  - smaller sensitivity to ray-spacing at lattice level
  - ORNL uses 0.01

spacing	0.001		0.003		0.01		0.04	
bu	k	dk (pcm)	k	dk (pcm)	k	dk (pcm)	k	dk (pcm)
0	1.14048	0	1.14052	4	1.13972	-76	1.14151	103
0.1	1.10546	0	1.10550	4	1.10477	-69	1.10643	97
1	1.10247	0	1.10249	2	1.10203	-44	1.10327	80
2	1.10297	0	1.10298	1	1.10272	-25	1.10361	64
4	1.09582	0	1.09582	0	1.09580	-2	1.09623	41
6	1.08357	0	1.08356	-1	1.08364	7	1.08382	25
8	1.06946	0	1.06945	-1	1.06953	7	1.06962	16
10	1.05469	0	1.05468	-1	1.05475	6	1.05480	11

spacer grid modeling

Modeling Spacer Grids

- Spacer grids displace coolant and absorb neutrons
- Spacer grids must be taken into account in lattice physics calculations
- Common approach:
  - Define **linear density of spacer grid** (g/cm) on input
  - Grids are automatically homogenized with the coolant volume
- SCALE 6.2 Polaris: modify the clad radius and/or material composition



Reference: CASL Benchmark for WBN1

Table 3: Spacer Grid Specification

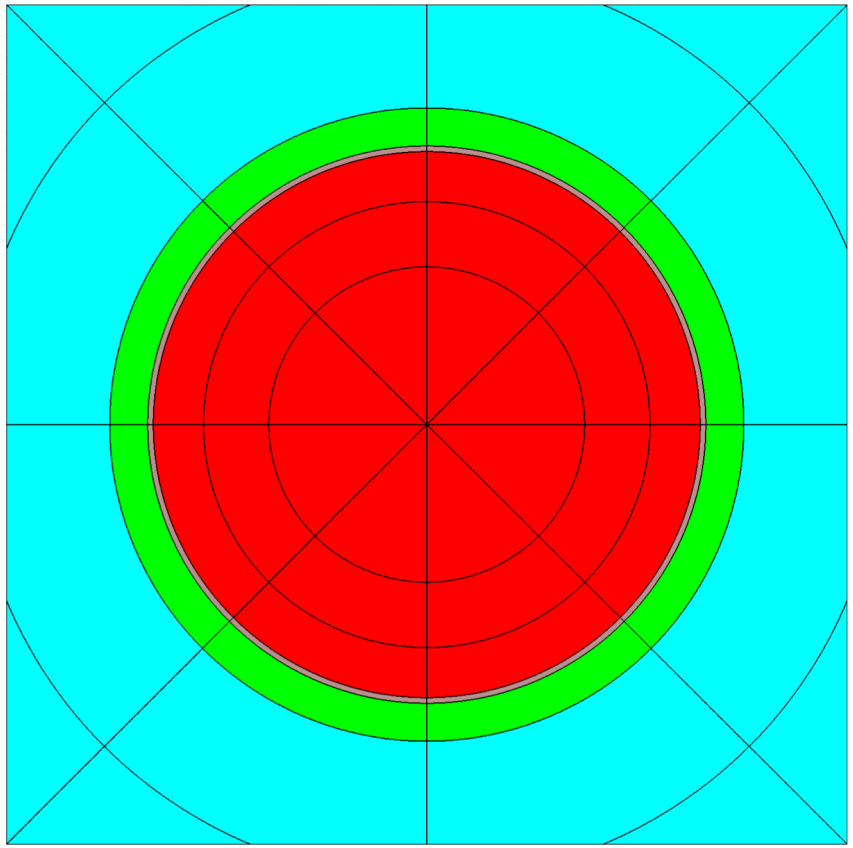
	End Grids	Intermediate Grids
Number	2	6
Material	Inconel-718	Zircaloy-4
Mass (g)	1017	875
Height (cm)	3.866	3.810
Mixing Vanes ?	No	Yes
Axial Locations (cm) (center of inner strap relative to top of lower core plate)	13.884 388.2	75.2 127.4 179.6 231.8 284.0 336.2

Reference: CASL Benchmark for WBN1

- Axially-averaged linear density for intermediate grids
  - 6 grids * 875 g / 365.76 cm fuel stack height
  - **14.4 g/cm**
  - per fuel pin: 14.4/264 = 0.05455 g/cm

- just consider intermediate grid effect
- copy w17x17_no_grid.inp from starters
- deplete
- copy w17x17_no_grid.inp to w17x17_grid_in_clad.inp
- adjust clad radius to account for 0.05455 g/cm grid density.
  - Note Zirc-4 is 6.56 g/cc:
  - 6.56/0.05455 = 0.00831 cm^2 spacer area per fuel pin
  - Clad area: pi*(.475^2-.418^2): 0.16
  - New clad area: 0.168831
  - Adjusted clad radius: ?
- deplete and compare k-eff curves

Spacer Grid Effect



bu	grid in clad	no grid	spacer grid effect
0	1.20794	1.20964	-170
0.1	1.16721	1.16887	-166
1	1.15280	1.15445	-165
2	1.14334	1.14502	-168
4	1.12144	1.12316	-172
6	1.09929	1.10100	-171
8	1.07863	1.08032	-169
10	1.05959	1.06123	-164
12	1.04202	1.04359	-157
14	1.02571	1.02721	-150
16	1.01045	1.01188	-143
18	0.99607	0.99741	-134
20	0.98245	0.98371	-126
25	0.95136	0.95238	-102
30	0.92345	0.92424	-79
35	0.89838	0.89893	-55
40	0.87593	0.87625	-32
45	0.85594	0.85604	-10
50	0.83829	0.83819	10
55	0.82276	0.82251	25
60	0.80920	0.80881	39

Version History

Polaris in SCALE 6.2

- SCALE 6.2 (April 2016)
  - Initial release of Polaris
  - PWR: Any NxN array of pins, size=2 guide tubes
  - BWR: GE 7x7 and GE 10x10 designs
  - Reflectors
- SCALE 6.2.1 (July 2016)
  - Minor updates
  - Better diffusion coefficient method
  - Improved accuracy (higher order scattering)
  - No geometry changes
- SCALE 6.2.2 (~January 2017)
  - New input cards to support BWRs
  - New input cards to support history calculations

- In addition to new input cards, several input cards were modified based on user feedback and internal design review
- To maximize backwards compatibility, new input cards and modified cards are activated using **=polaris_6.3**
- **=polaris** still supports original input cards in SCALE 6.2
- Both formats documented in manual

```
 1 =polaris
 2 %-------------------------------------%
 3 % general options
 4 %-------------------------------------%
 5 title "BWR simple"
 6 lib "broad_n"
 7 system BWR
 8 %-------------------------------------%
 9 % geometry (lattice pitch=15.24)
10 %-------------------------------------%
11 geom bwr7x7 : ASSM 7 1.88
12 hgap 0.47498 0.9525 : MOD.1 MOD.2
13 box  0.2032 0.0 0.12306
14 %-------------------
15 % fuel material (2.
16 %-------------------
17 comp c_e293 : UOX 2.93
18 mat  FUEL.1 : c_e293 10.32
19 %-------------------------------------%
20 % pins
21 %-------------------------------------%
22 pin 1 : 0.61 0.62 0.715
23       : FUEL.1 GAP.1 CLAD.1
24 %-------------------------------------%
25 % state
26 %-------------------------------------%
27 state ALL    : temp=600
28 state MOD    : void=0
29 state COOL   : void=40
30 end
```

distance from pin array edge to channel box

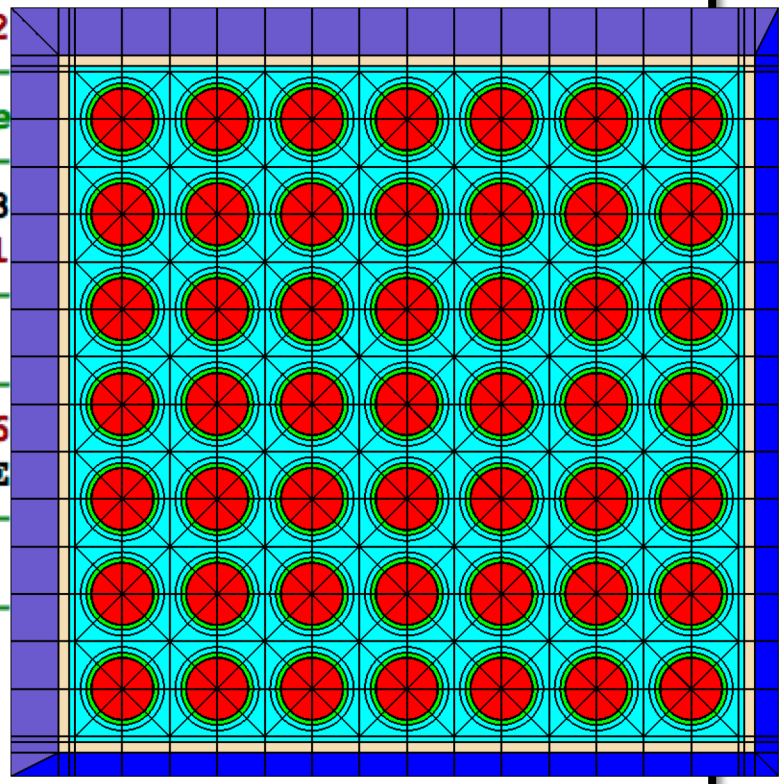
one state card per definition

```
 1 =polaris_6.3
 2 %-------------------------------------%
 3 % general options
 4 %-------------------------------------%
 5 title "BWR simple"
 6 lib "broad_n"
 7 system BWR
 8 %-------------------------------------%
 9 % geometry (lattice pitch=15.24)
10 %-------------------------------------%
11 geom bwr7x7 : ASSM 7 1.88
12 hgap 0.47498 0.9525 : MOD.1 MOD.2
13 box  0.2032 0.0 6.70306
14 %-------------------
15 % fuel material (2.
16 %-------------------------------------%
17 comp c_e293 : UOX 2.93
18 mat  FUEL.1 : c_e293 10.32
19 %-------------------------------------%
20 % pins
21 %-------------------------------------%
22 pin 1 : 0.61 0.62 0.715
23       : FUEL.1 GAP.1 CLAD.1
24 %-------------------------------------%
25 % state
26 %-------------------
27 state ALL    : temp=600
28       MOD    : void=0
29       COOL   : void=40
30 end
```

1/2 in-channel span

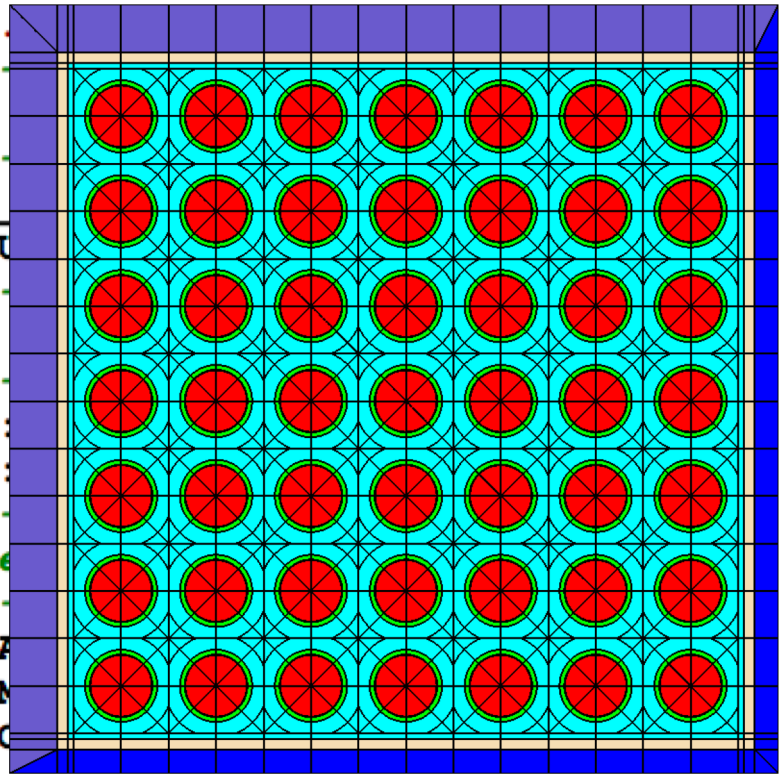
single state card

```
=polaris
%-------------------------------------%
% general options
%-------------------------------------%
title "BWR simple"
lib "broad_n"
system BWR
%-------------------------------------%
% geometry (lattice pitch=15.24)
%-------------------------------------%
geom bwr7x7 : ASSM 7 1.88
hgap 0.47498 0.9525 : MOD.1 MOD.2
box  0.2032
%---------
% fuel mate
%---------
comp c_e293
mat  FUEL.1
%---------
% pins
%---------
pin 1 : 0.6
      : FUE
%---------
% state
%---------
state ALL
state MOD
state COOL
end
```



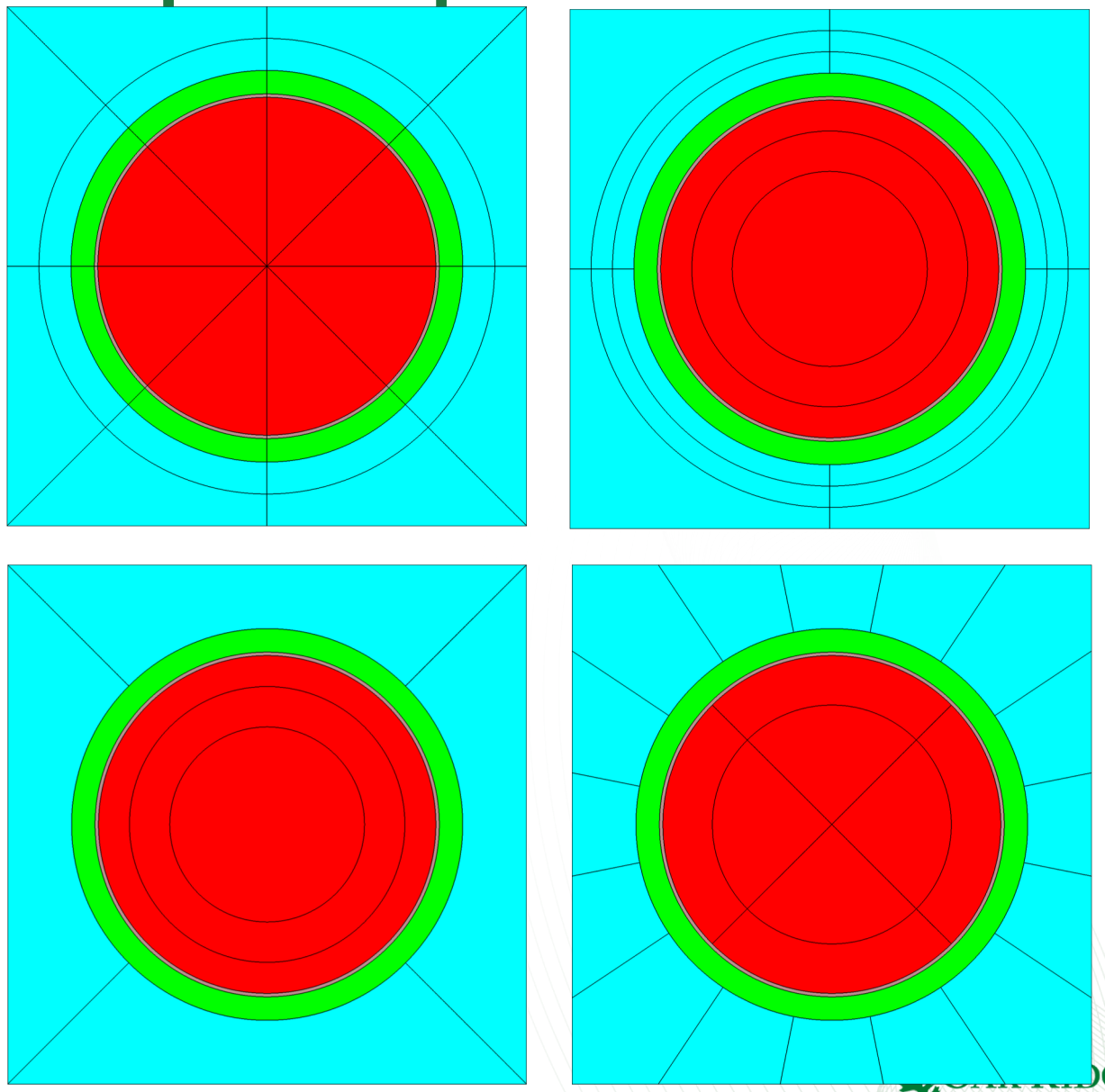
Different channel mesh treatment

```
=polaris_6.3
%-------------------------------------%
% general options
%-------------------------------------%
title "BWR simple"
lib "broad_n"
system BWR
%-------------------------------------%
% geometry (lattice pitch=15.24)
%-------------------------------------%
geom bwr7x7 : ASSM 7 1.88
hgap 0.47498 0.9525 : MOD.1 MOD.2
box  0.
%-----
% fuel
%-----
c_
FU
%-----
% pins
%-----
pin 1 :
      :
%-----
% state
%-----
state A
      M
      C
end
```



=polaris pin mesh definition

```
=polaris

%---------------------------------------%
% pin examples
%---------------------------------------%

pin A : 0.4096 0.418 0.475
      : FUEL.1 GAP.1 CLAD.1 COOL.1
      : 1      1     1      1
      : 8      8     8      8


pin B : 0.4096 0.418 0.475
      : FUEL.1 GAP.1 CLAD.1 COOL.1
      : 3      1     1      2
      : 1      1     1      4


pin C : 0.4096 0.418 0.475
      : FUEL.1 GAP.1 CLAD.1 COOL.1
      : 3      1     1      0
      : 1      1     1      -4


pin D : 0.4096 0.418 0.475
      : FUEL.1 GAP.1 CLAD.1 COOL.1
      : 2      1     1      0
      : -4     1     1      -16

```



Density and Boron Property Update
(SCALE Newsletter Volume 51)

- As shown in the following example, a Polaris input defines the coolant density (DC) as 0.6 and the coolant boron concentration (PC) as 1,000 ppm. The problems occur in SCALE version 6.2.2 if the input changes the coolant properties either through a **state** card or a **branch** card. The results shown in the table below are obtained with SCALE versions 6.2.1, 6.2.2, and 6.2.3

Case	Initial		Final		SCALE version		
					6.2.1	6.2.2	6.2.3
DC only	boron = 1000	dens = 0.6	boron = 1000	dens = 0.7	OK	OK	OK
PC only	boron = 1000	dens = 0.6	boron = 100	dens = 0.6	OK	OK	OK
PC+DC	boron = 1000	dens = 0.6	boron = 100	dens = 0.7	OK	Wrong	OK
DC+PC	boron = 1000	dens = 0.6	boron = 100	dens = 0.7	Wrong	Wrong	OK

Density and Boron Property Update
(SCALE Newsletter Volume 51)

- Polaris applies a DC change to coolant concentrations using a fractional multiplier: new_conc = old_conc* (new_dc/old_dc). The Polaris bug results in the internal coolant density variable not being updated to the new density value. For a follow-on change to PC, Polaris will compute the fractional multiplier for H, O, and B isotopes using the old coolant density value instead of the updated density.
- The coolant property update works in SCALE 6.2.1 because the state variables are updated in alphabetical order, so the PC update comes before the DC update ("boron" before "dens"). In the DC+PC case, the PC update comes after the DC update, which leads to a bad result.
- In SCALE 6.2.2, ORNL staff added the **history** card option, which required an overhaul to the manner in which state changes are stored internally. In version 6.2.2, temperatures and densities were updated before boron properties; therefore, the code bug always led to bad results using SCALE 6.2.2. This issue has been fixed in version 6.2.3.

quick calculation options

Running fast calculations

- Detailed lattice calculations with branches and/or operating history can take 3 days to 2 weeks to complete

- In early stages of model development, you want to run a calculation that simulates each statetpoint, even if the calculation is wrong, in order to verify the structure of the .f71 or .t16 files
- Scenario 1: t16 file structure important, f71 file structure not important
- Scenario 2: final f71 file structure is important

Scenario 1

```
=polaris_6.3
%-----------------------------------%
% fast options
%-----------------------------------%
lib "broad_n"
opt ESSM NumPolar=1 NumAzim=1 RaySpacing=0.08
opt KEFF NumPolar=1 NumAzim=1 RaySpacing=0.08
         PnOrder=0 TransportCorrection=no
         EigSolver='power'
         EigMaxIterations=1
         DownScatterSolver='source'
         DownScatterMaxIterations=1
         UpscatterSolver='gauss_seidel'
         UpscatterMaxIterations=1
         UpscatterInnerSolver='source'
         UpscatterInnerMaxIterations=1
opt DEPL TrackingSet='none'
         Method='predictor'
         NumSubSteps=1
opt CRITSPEC Mode='none'
shield ALL=N
opt GEOM MeshNumRings=1
         MeshNumSectors=1
         MeshNumX=1
         MeshNumY=1
%optional - comment out mesh cards
```

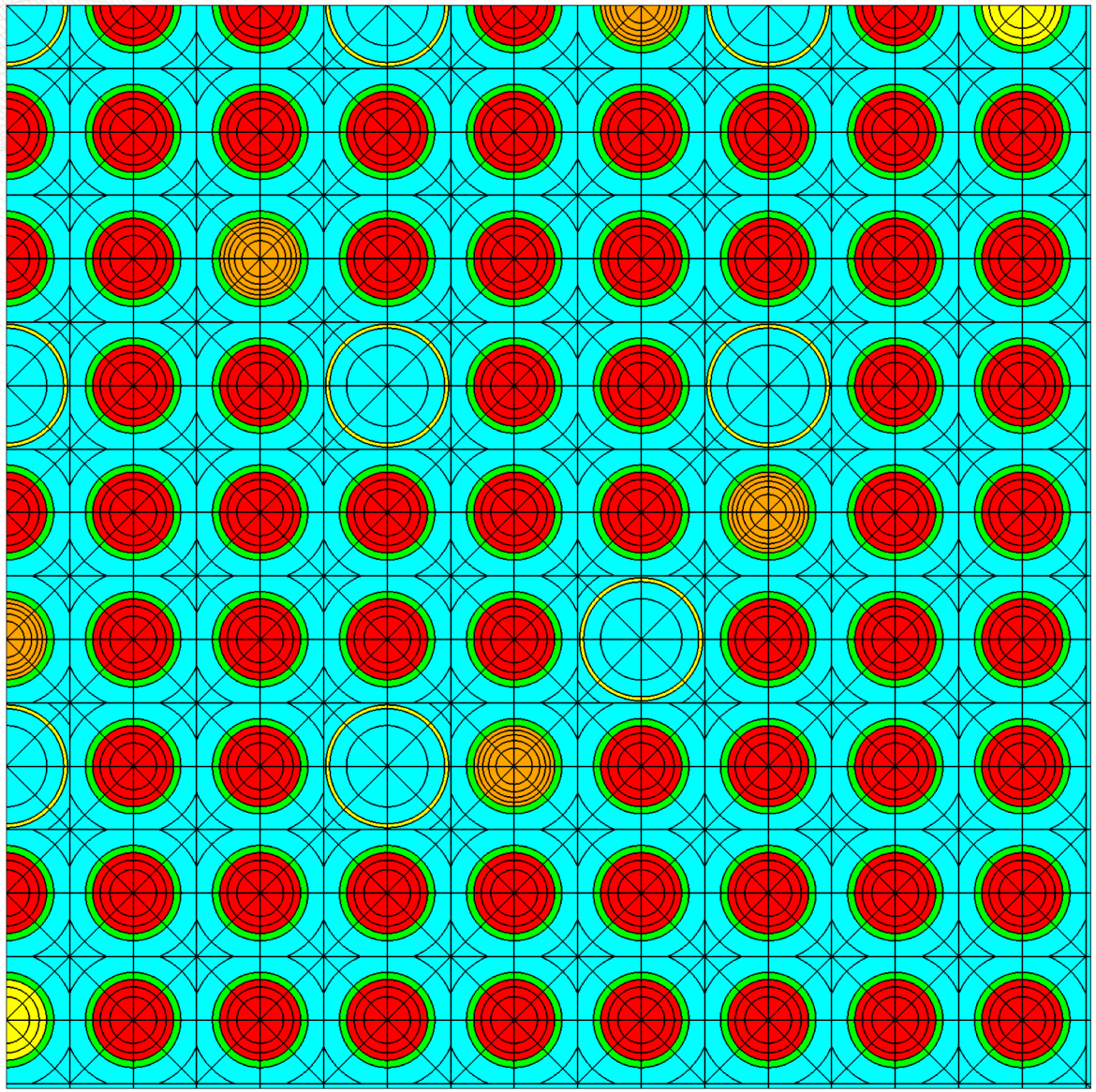
- T16 file structure important
- F71 file structure not important
- see starters/fast_options_t16.txt

```
=polaris_6.3
%---------------------------------------%
% fast options
%---------------------------------------%
lib "broad_n"
opt ESSM NumPolar=1 NumAzim=1 RaySpacing=0.08
opt KEFF NumPolar=1 NumAzim=1 RaySpacing=0.08
         PnOrder=0 TransportCorrection=no
         EigSolver='power'
         EigMaxIterations=1
         DownScatterSolver='source'
         DownScatterMaxIterations=1
         UpscatterSolver='gauss_seidel'
         UpscatterMaxIterations=1
         UpscatterInnerSolver='source'
         UpscatterInnerMaxIterations=1
opt DEPL NumSubSteps=1
opt CRITSPEC Mode='none'
```

Scenario 2

- f71 file structure important
- see starters/fast_options_f71.txt
- same as scenario 1, except shield and mesh are not modified

Exericse



- taka_depl_rev1.inp should be the slowest running depletion calculation
- copy to taka_depl_fast.inp
- copy/paste starters/fast_options.txt into input file, remove duplicate cards
- run and compare run-times