# Philosophy, Principle, and Method for the CombLayer

Stuart Ansell

European Spallation Source, Lund, Sweden.

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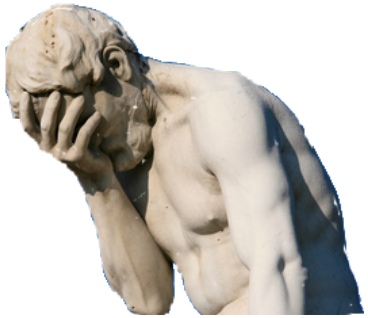
# Icons

Icons are added to slide to indicate issues

- Unexpected/Dangerous code

- Legacy Code

- Philosophy Driven decisions



# Features of MCNP(X)

MCNP(X) is a geometry/physics/variance reduced discrete Monte-Carlo transport code.

**Advantages**

- World is described in complete volume format using infinite quadratic surfaces.
- Almost every default is *best possible result* without modification.
- MCNP(X) is tally based – meaning that MCNP(X) does not calculate stuff you don't ask for.

# Features of MCNP(X)

**Consequences**

- Complete volume description allows fast simulation – but only with small cells [small $\Longrightarrow$ small number of surfaces]
- CVG implies that changing one cell requires the change of **ALL** cells that it exists directy within
- Cell-to-Cell (C2C) transport is dominated by surface crossing
- Tallys and variance reduction have to be incorperated in build

# MCNP(X) is an unforgiving code

MCNP adds a huge number of things to help build geometry.
**BUT** All of the following normally result in runtime penaty

- Complementary cells
- Universes require full computation of objects within
- Transform cards / Lattice cards
- Macrobodies
- Boolean invariances

# MCNP(X) basics

MCNP(X) allows the definition of quadratic surface types
To define a surface the input file has a line :

```
IDNumber typeID [values...]
```

## Examples

```
57 px 3.4                  A plane on the x=3.4 surface
1782 p 0.5 0.5 0 3.4         A plane on the x=y plane

983 c/x 1.2 3.4 7.0      A cylinder along x axis at y=1.2 and
                         z=3.4 radius 7.0
```

# MCNP(X) basics

MCNP(X) objects are constructed from a set of boolean operations on quadratic surface
Each object is ALSO numbered (!) and using signed surface numbers (to mean true/false).
Intersection (i.e. all have to be true for a point to be in the object) is denoted by a space
Union (i.e. only one has to be true for a point to be in the object) is denoted by a colon (:)

```
1 objectID MatID Density [surfaces ]
```

# MCNP(X) basics: Example of a cube

Making a simple cube of size 8cm in each direction :

**Examples**

```
11  px  4.0
12  px  -4.0
13  py  -4.0
14  py  -4.0
15  pz  -4.0
16  pz  -4.0

 Object with material 4 / density 0.051674 4 0.05 11 -12 13 -14 15 -16
```

These little MCNP units are the main sub-building block of CombLayer

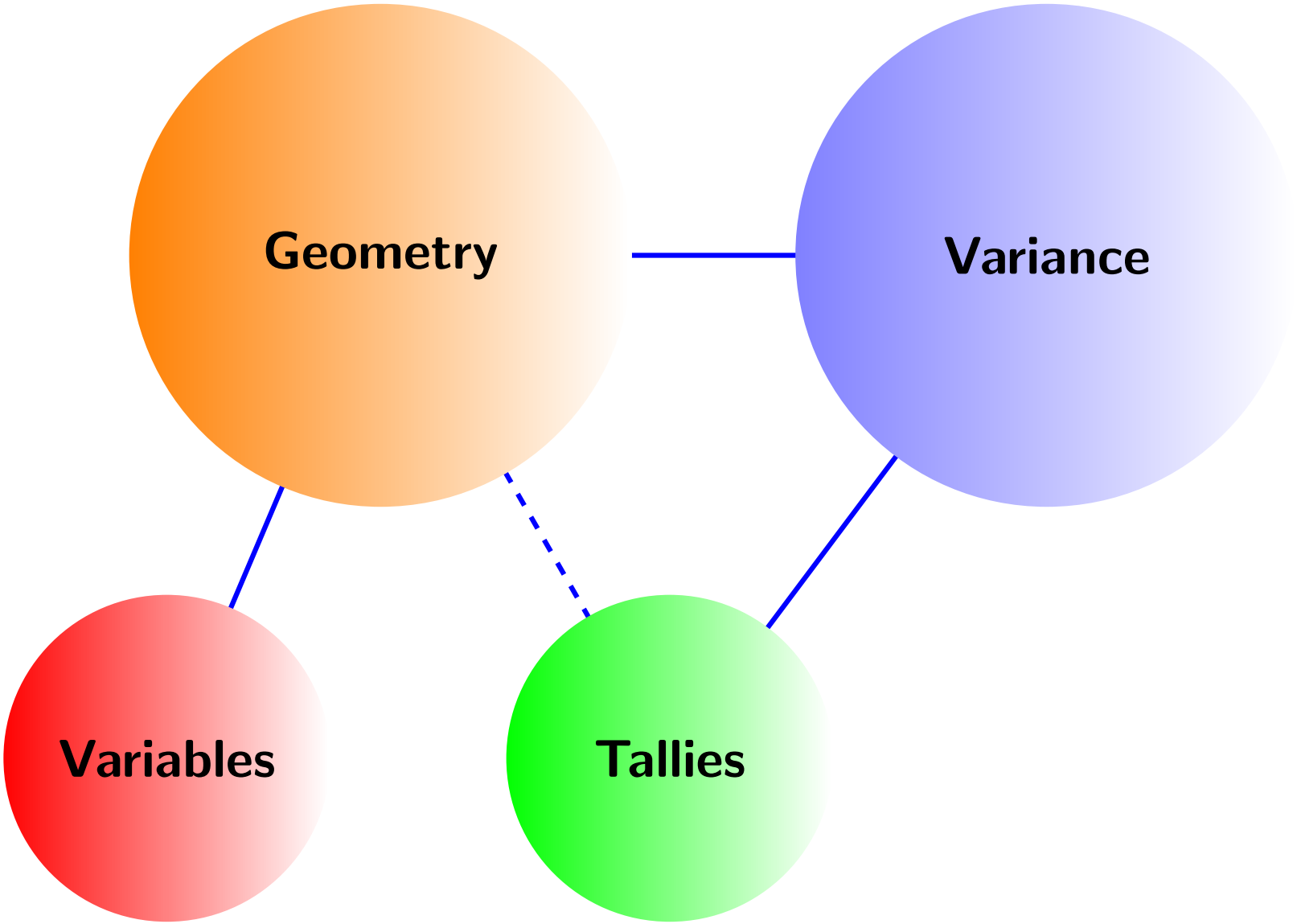
# MCNP(X) basics: Placing the cube in a sphere

Placing that cube in a sphere of radius 45 cm. **Examples**

```
25  so  45.0

  Object with material 4 / density 0.05
1674  4  0.05   11  -12  13  -14  15  -16
1872  9  0.073   -25  (-11:12:-13:14:-15:16)
```

Note the boolean negation of the original cube in the sphere object.

# CombLayer Introduction



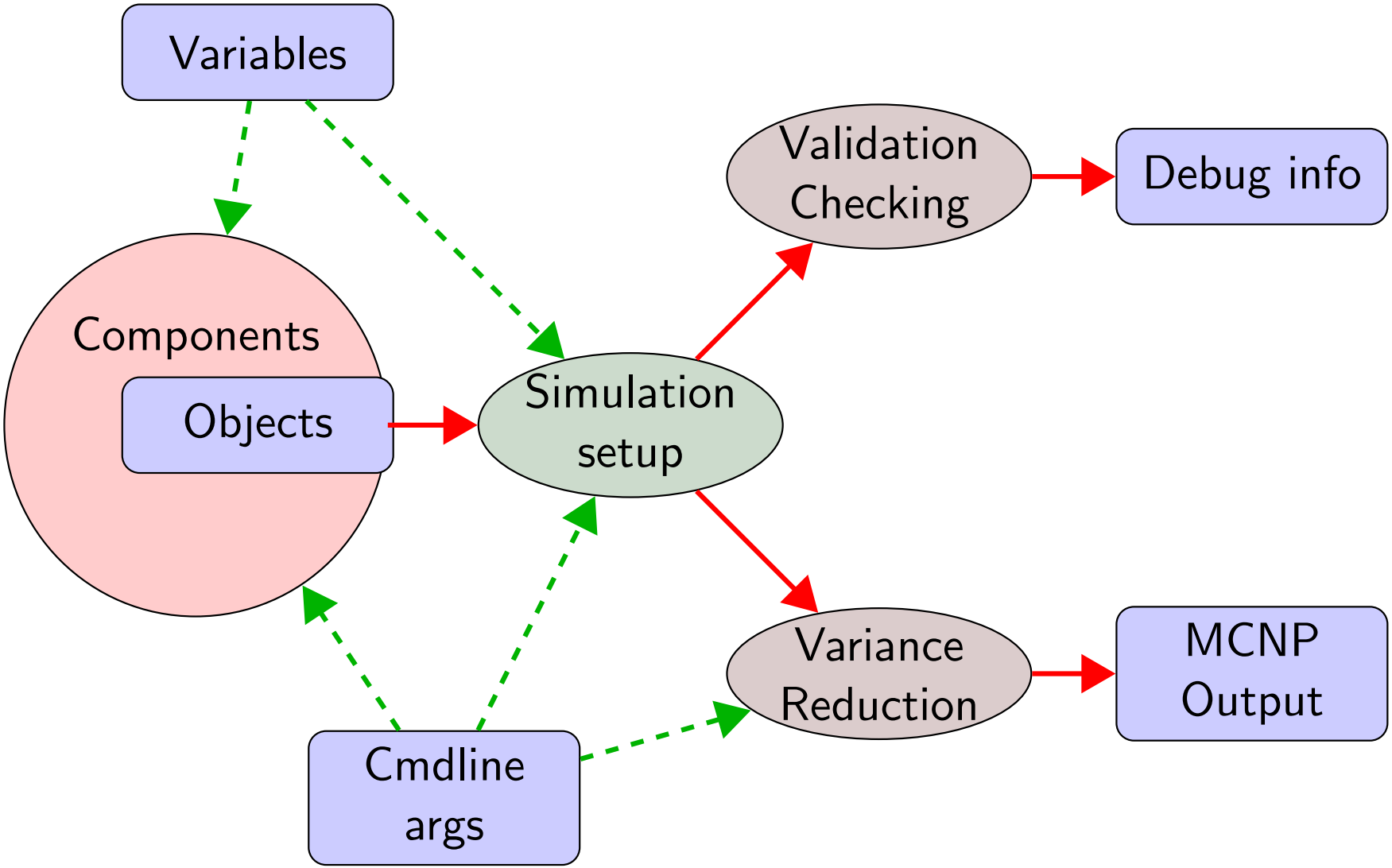
# What does CombLayer provide

- Variable system [fully Turing Complete]
- Boolean level object handler
- Higher level component system
- Variance reduction system
- Error detection

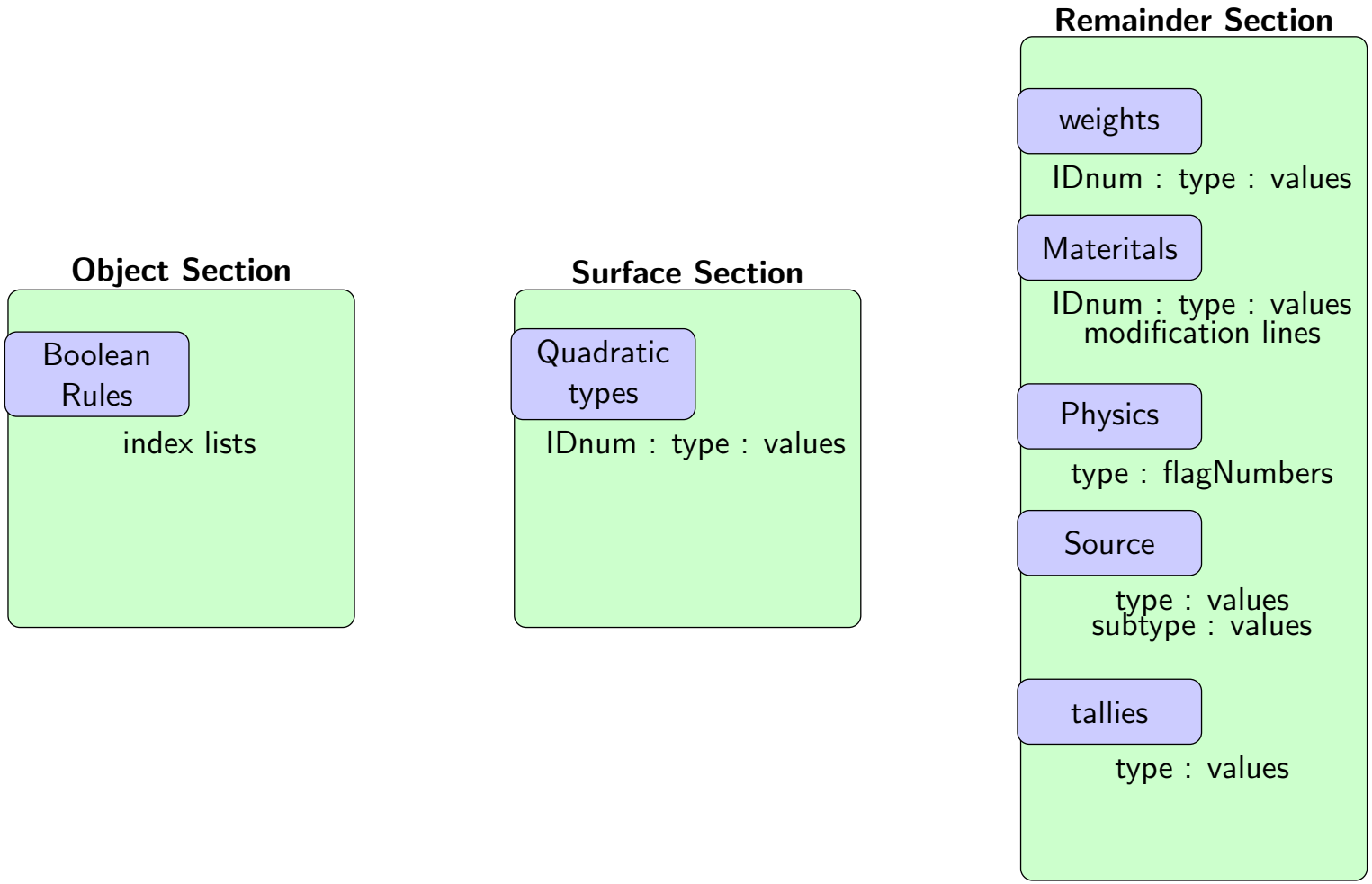
# What is NOT in CombLayer

- No minimization routines for variables
- No tally data analysis
- No error correction – immediate failure on problem

# CombLayer Process



# MCNP Layout


Remainder Section
weights
IDnum : type : values
Materitals
IDnum : type : values
modification lines
Physics
type : flagNumbers
Source
type : values
subtype : values
tallies
type : values
Object Section
Boolean Rules
index lists
Surface Section
Quadratic types
IDnum : type : values

# MCNP Layout

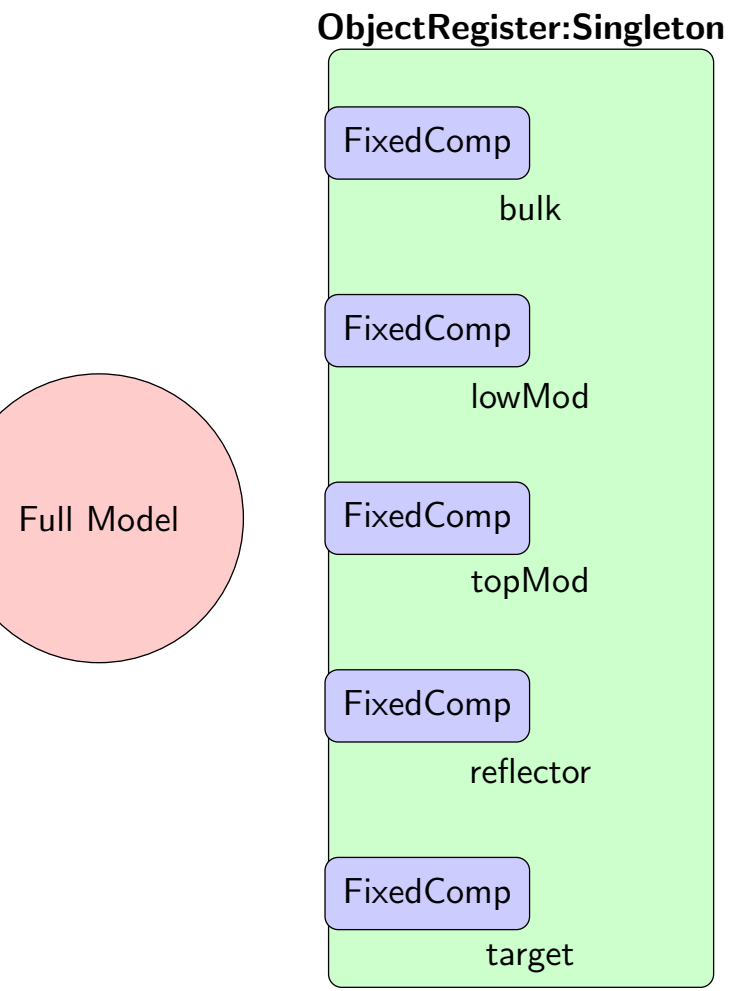
```
221 5 0.0582256  -244 245 ( -305 : 306 : 204 : 206 : ( -212 209 )
         223 : -220 ) -308 307 -215 -217  tmp=1.72346844e-09
222 5 0.0582256  3 -245 ( -305 : 306 : 205 : 206 : ( -214 211 ) )
         : -222 ) -308 307 -216 -217  tmp=1.72346844e-09

49 c/z 59.35095759 94.98138677 20
150 c/z 59.35095759 94.98138677 22
151 p 0.891006524 -0.4539905 0.0 9.26144319
152 p 0.891006524 -0.4539905 0.0 10.2614432
142 gq  1  1  23.01803079  0  0  0  -118.7019152  -189.9627735
0
         -4135.732457
```

Arrh.....

# CombLayer objective

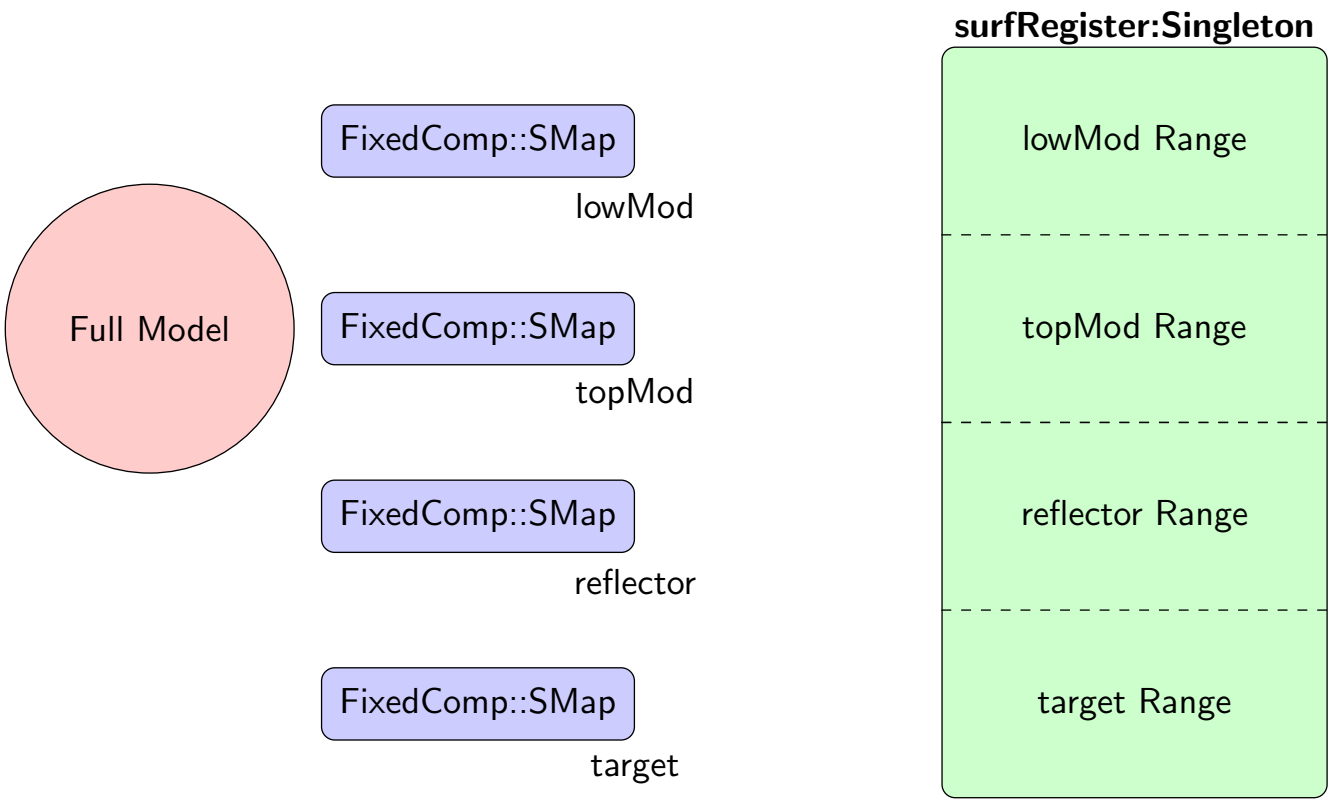
- Consider the model as a whole set of mini-models
- Provide simple interaction between the models
- Avoid the need to use global identifier numbers
- Help out on the service level (variance/tallies)

# Geometry: Objects [After Construction]




- Each component is a seperate and independent
- Components know everything about themselves (materials / surfaces / position etc.) and **nothing** about anything else
- Components all stored in a *singleton* objectRegister.

# Geometry: Surfaces [After Construction]




**LOCAL** surface map for each Component with global surface access.

# Output Logging System

std::cout output is expected to be replaced with a managed stream:

**ELog::EM**

std::endl is replaced by of choice of

- ELog::endDiag
- ELog::endCrit
- ELog::endErr
- ELog::endTrace
- ELog::endBasic

Example:

```
1     for(size_t i=0;i<10;i++)
2       ELog:EM<<"test "<<i<<" "<<sin(i*3.0)<<ELog::endDiag;
```

# Output Logging System

Adding instance of ELog::RegMethod to all methods that

1. throw exceptions
2. write output
3. call methods that do 1 or 2.

RegMethod's main constructor that takes two strings. Typically I use that for the class name and the method name.

**Example:**

```
3     void BigCave::calculate()
4     {
5       ELog::RegMethod RegA("BigCave","calculate");
6       ELog::EM<<"Some info"<<ELog::endDiag;
7       // ...
8       ELog::EM<<"HARD break"<<ELog::endErr;
9     }
```

**Output:**

Some info
HARD break
::main
makeEss::build
CSpec::createAll
BigCave::calculate

Bunker::createMainWall
Bunker::createMainWall

# Vec3D

Unsurprisingly CombLayer has a Vec3D class. However, it is unusual.

- Vec3D provides typical +,-,*,/ and [] operators
- Vec3D is a valid variable type
- It provides scalar interaction **BUT ONLY** forwards:

This is valid:

```
1
2   const Vec3D Out=Origin+X*7.9;     // VALID
3   const Vec3D OutX=Origin+7.9*X;   // ERROR
```

# Vec3D

The normal methods stuff you would expect to see

- *unit()* : return a unit vector
- *rebase(const Vec3D& A,const Vec3D& B, const Vec3D& C)* : express vector in basis set A,B,C
- *Distance(const Vec3D& A)* : distance to vector
- *dotProd(const Vec3D& A)* : dot product

# Quaternions

Working with vectors involves rotation: to avoid gimbal-lock quaternion rotation is prefered over Matrix/Eurler rotation.

Rotational Quaternions can be created/used directly as :

```
5
6   Geometry::Vec3D axis(1,0,0);
7
8   // apply rotation about Z axis:
9   const Geometry::Quaternion Qz=
10    Geometry::Quaternion::calcQRotDeg(rotAngle,Z);
11
12  Qz.rotate(axis);
```

# Quaternions (cont)

Most of the time – FixedComp will deal with it for you because you will be rotating a whole object

```
14
15    FixedComp::applyShift(xStep,yStep,zStep);
16    FixedComp::applyAngleRotate(xyAngle,zAngle);
```

# Object Component

**Object component** is a single class that provides a mechanism to produce surfaces and single material cells based on the values of variables.
Examples:

- Moderator
- Jaws
- Sample
- Detector

# Composite Component

**Composite component** is a single class holds a collection of Object components making a more complex object but for some instances wishes to be treated as a single object
Examples:

- Target
- Bunker
- Cave
- Chopper system

# Basic geometry object

A basic geometry object normally has 2-3 of the public inheritances from the namespace **attachSupport** [1]
We are going to cover:

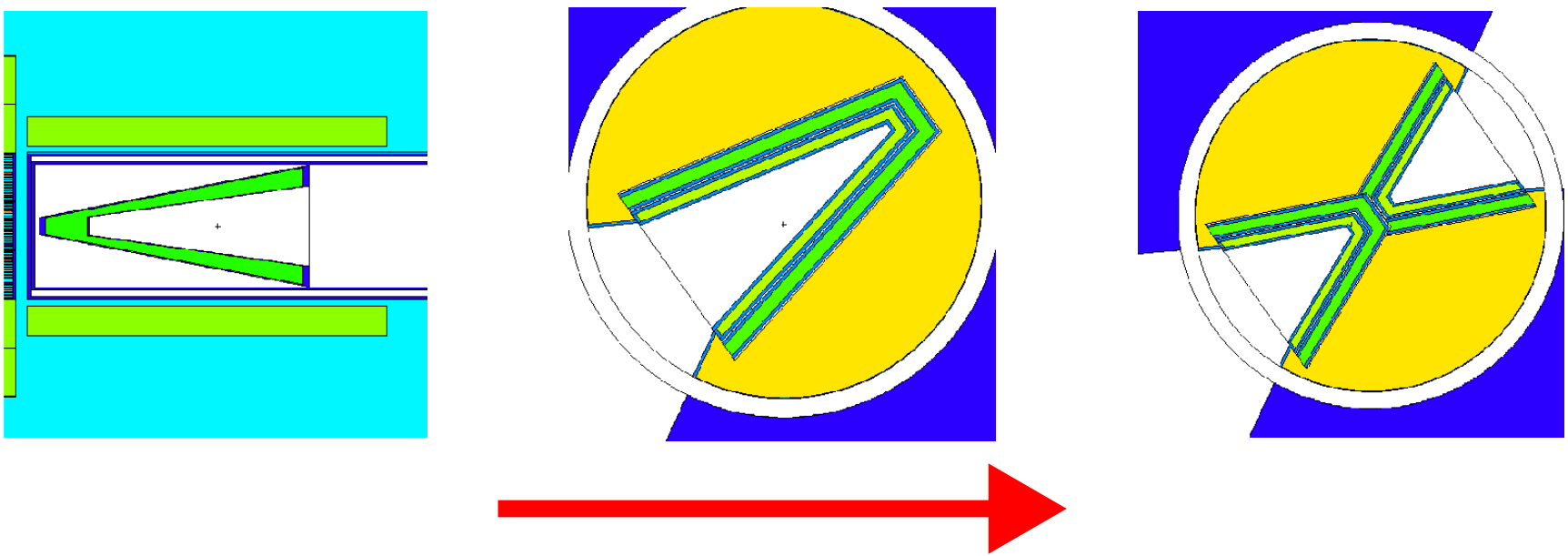
1. FixedComp / FixedGroup **Mandatory** [2]
2. ContainedComp / ContainedGroup [2]
3. LayerComp
4. CellMap
5. SurfMap

[1] Files in System/attachSupportInc
[2] This class should not be virtually inherited.

# CombLayer Component Construction

Models are made of components:

- Local parameters e.g. number of layers
- Containers that allow insertion
- Link points that allow joining



Same object

# FixedComp

Most geometry components inherrit from FixedComp
**It Provides:**

- A unique name [keyName]
- Origin for the object
- X,Y,Z basis for object
- A local name-register for surfaces
- Stores/Accesses link points for the object

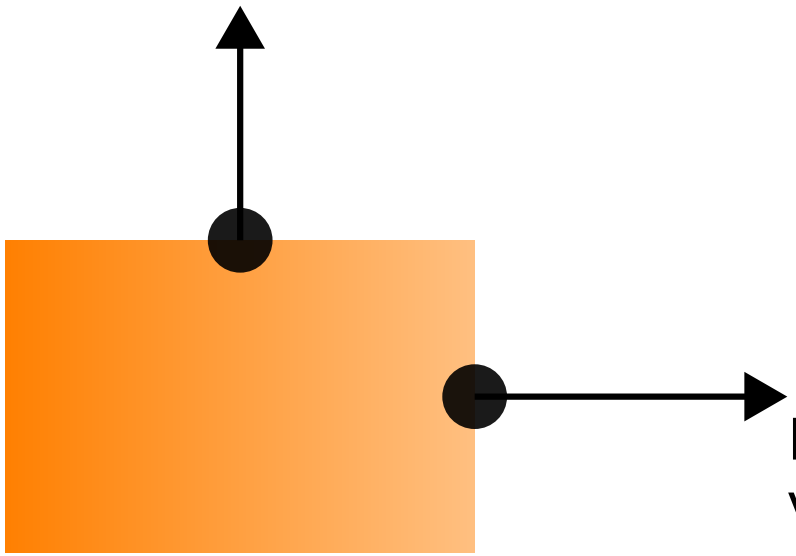
Construction of a FixedComp is done as follows:

```
36 class MyBox : public attachSystem::FixedComp
37 {
38    const int boxIndex;          ///< Index of surface offset
39    int cellIndex;               ///< Cell index
40
41   public:
42
43     MyBox(const std::string&);
44 };
45
46 MyBox::MyBox(const std::string& Key) :
47   attachSystem::FixedComp(Key,0),
48   boxIndex(ModelSupport::objectRegister::Instance().cell(Key)),
49   cellIndex(boxIndex+1)
50 {}
```

Typical FixedComp object looks like:

```
2
3  class MyBox : public attachSystem :: FixedComp ,
4    public attachSystem :: ContainedComp
5  {
6   private :
7
8    const int boxIndex;          ///< Index of surface offset
9    int cellIndex;               ///< Cell index
10
11   void createUnitVector(const attachSystem::FixedComp&,
12                         const long int);
13
14   void createSurfaces();
15   void createLinks();
16   void createObjects(Simulation &);
17
18  public :
19
20    void createAll (Simulation&,
21       const attachSystem::FixedComp&,
22       const long int);
23 }
```

# LinkComp




- Objects are constructed with links
- Other objects are realised relative to these linkages
- The outer Link Surfaces are designated the *boundary*
- Boundaries are check after construction to allow displacement construction

# Definition of a link-point

- A point int space (Geometry::Vec3D)
- An axis direction in space (Geometry::Vec3D)
- A surface(s) rule
- An extra common surface if required

# Adding/Defining Link-Points

- The number of expected link-points is defined in the constructor
- Numbers 0-9 are designated outgoing convention.
- Numbers 10-19 are designated in-going convention.

```
25
26 class MyBox : public attachSystem :: FixedComp
27 {
28  private:
29
30   // this is in most FixedComp derived classes
31   void creatLinks();
32 };
33
34   MyBox::MyBox(const std::string& Key ) :
35     attachSystem::FixedComp(Key, \tcr{{\bf 6}}),
36     boxIndex(ModelSupport::objectR egister::Instance().cell(Key)),
37    cellIndex(boxIndex+1)
38 {}
```

Typicial usage - a box with 6 sides (hence 6 link points)

# Adding/Defining Link-Points

Typically I add link points in linkCreate. Not always !!

```
39
40 void
41 MyBox::createLinks()
42 {
43   FixedComp::setConnect(0,Origin+Y*(width/2.0),Y);
44   FixedComp::setLinkSurf(0,-SMap.realSurf(boxIndex+1));
45 }
```

- setConnect :: Defines a point and a direction (Y).
- setLinkSurf :: defines the surface LEAVING the box
- **A real surface is required**

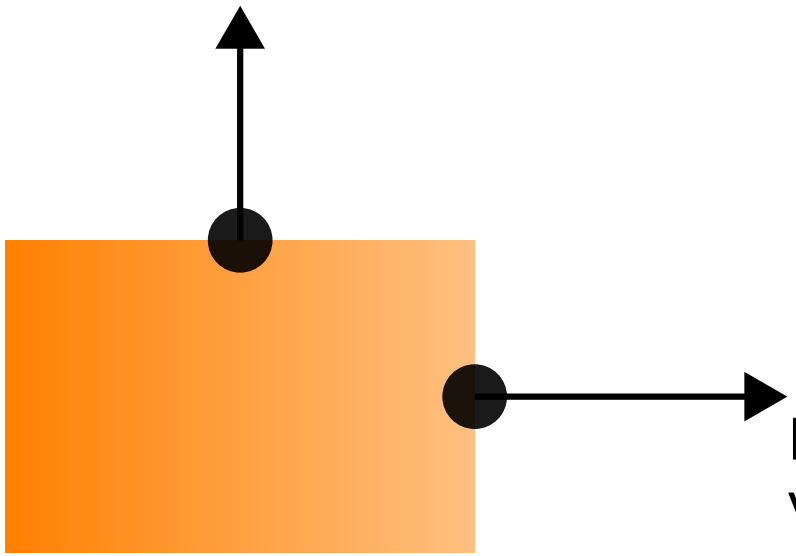
# How to use link-Points [for Geometry]

The commonest method is simple orientational construction:

```
46
47 void
48 MyBox::createUnitVector(const attachSystem::FixedComp& FC,
49                          const long int sideIndex)
50 {
51   FixedComp::createUnitVector(FC,sideIndex);
52   FixedComp::applyShift(xStep,yStep,zStep);
53   FixedComp::applyAngleRotate(xyAngle,zAngle);
54   return;
55 }
```

Creates a Vec3D Origin to be at link-Point [sideIndex]

# CombLayer Object Construction

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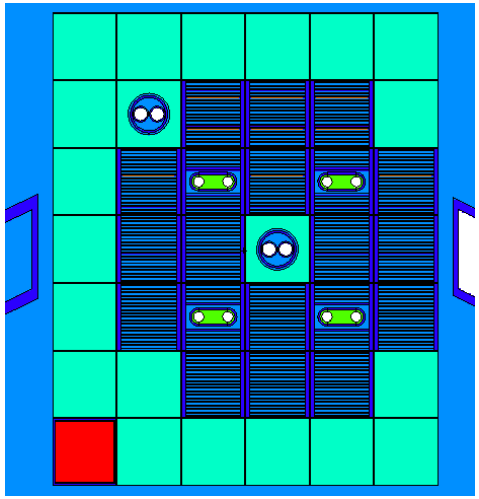
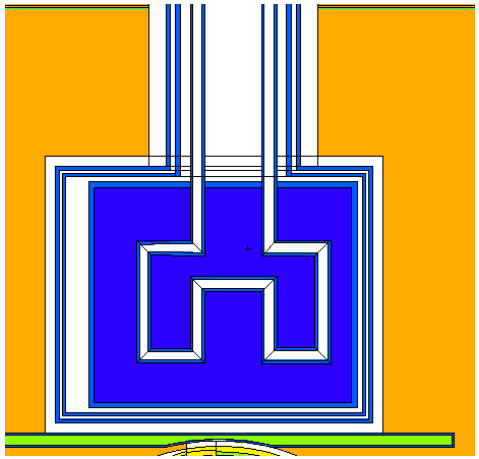
# CombLayer Component Construction





- Simple connection grid joining at common side surfaces
- Track boundary e.g. for pipe work

# ContainedComp

Many geometry components inherrit from ContainedComp/ContainedGroup

**It Provides:**

- A description of the outer boundary
- A description of the inner boundary [optional]
- An approximation to the boundary assuming this is the complete object

# ContainedComp

**Useage:**

- Inherrit into class
- Either register before/after which other objects this object is in
- Define an outerSurface using the command

```
1
2  class MyBox : public attachSystem::ContainedComp
3    public attachSystem::FixedComp
4 {
5   void createObjects(Simulation&);
6 };
7
8 void MyBox::createObjects(Simuation& System)
9 {
10   std::string Out;
11   // ...
12   Out=ModelSupport::getComposite(SMap,bnkIndex,
13          " 1 -17 4 -14 5 -6 ");
14   System.addCell(cellIndex++,matID,0.0,Out);
15 }
```

# Simulation

Models are constructed into a data-class called Simulation.

- Simulation is a base clase for the output type required [PHITS/MCNP etc]
- In principle you can have two but... **don't**
- Joins Physics - Geometry - Tallies
- Works on a *push-to / pull-from* model

**Note:** In 99% of the code, I have used this :

```
1
2 void MyBox::someFunction(Simulation& System)
```

Example use [Adding a cell]:

```
4
5 System.addCell(cellIndex++,matID,300.0," 2 -3 -4 5 6 ");
```

This adds a cell [id number cellIndex] with material type matID and temperature 300K, using the MCNP surface logical format string.

## Example use [find cell

```
7
8  // Find a cell containing a point:
9
10 MonteCarlo::Object* OCell=
11   System.findCell(Geometry::Vec3D(4,5,6),0);
```

You also used it to do things with everything in the model:

```
15
16 // Global surface replacement:
17 // BE VERY CAREFUL DOING THIS::
18 System.subsituteAllSurface(1082,283);
```

# Starting a project

1. Copy Main/pipe.cxx to Main/newProject.cxx
2. create a directories in Model/projectBuild and Model/projectBuildInc
3. Edit CMake.pl
   - Add **newProject** to masterprog
   - Copy the line **$gM->addDepUnit("pipe" , ...**
   - Change pipeBuild to projectBuild

# Starting a project (part2)

1. Copy Model/pipe/*.cxx to Model/project/
2. Copy Model/pipeInc/*.h to Model/projectInc/
3. Change each item of pipe to project

# Starting a project (part 3)

Consider the Main :