



FLUKA

Combinatorial Geometry

FLUKA Beginner's Course

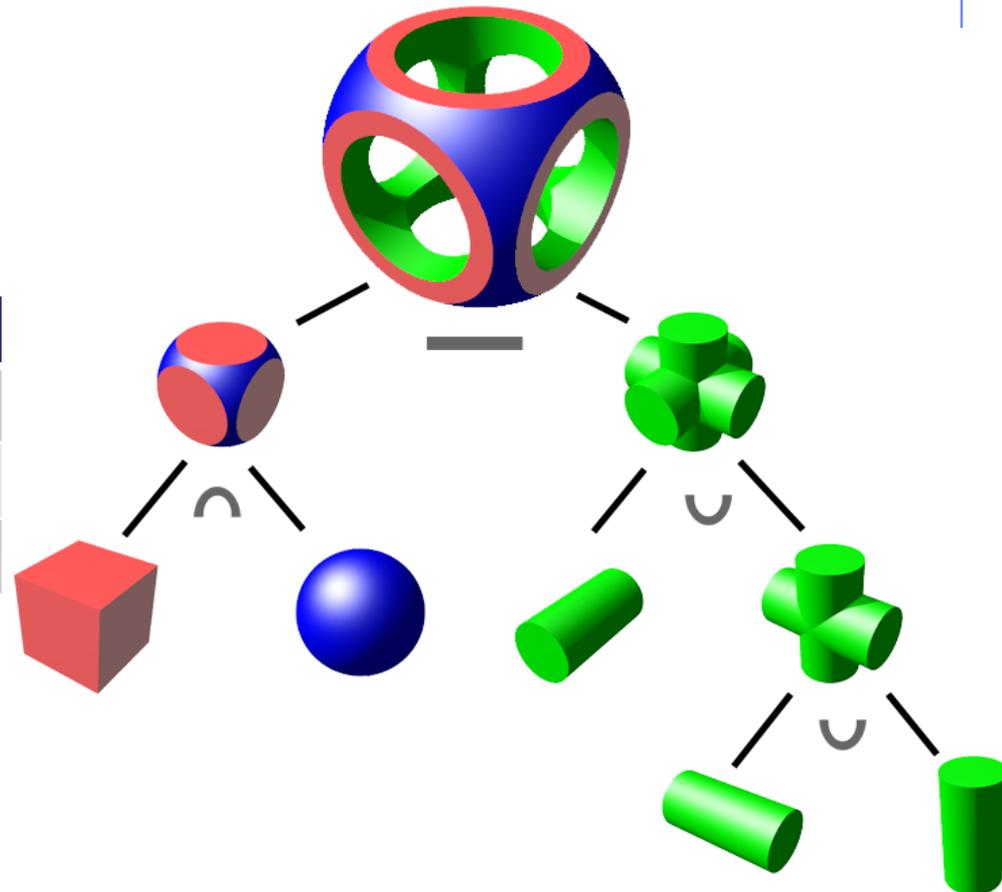
Introduction

Principle of Combinatorial Geometry

Basic objects called **bodies** (such as cylinders, spheres, parallelepipeds, etc.) are combined to form more complex objects called **regions**

This combination is done using Boolean operations:

| Math | Operation | FLUKA |
|--------|--------------|-------|
| \cup | Union | |
| \cap | Intersection | + |
| $-$ | Subtraction | - |



Introduction

Initially, **FLUKA Combinatorial Geometry** was similar to the package developed at ORNL for the neutron and gamma-ray transport program Morse (M.B. Emmett ORNL-4972 1975).

In the original CG (Morse) bodies were convex solid bodies (i.e. finite portions of space completely delimited by surfaces of first or second degree, i.e. planes or quadrics)

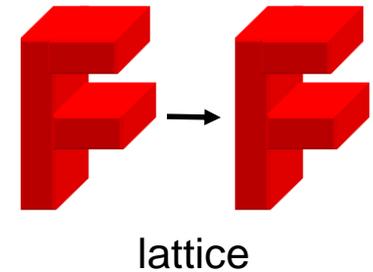
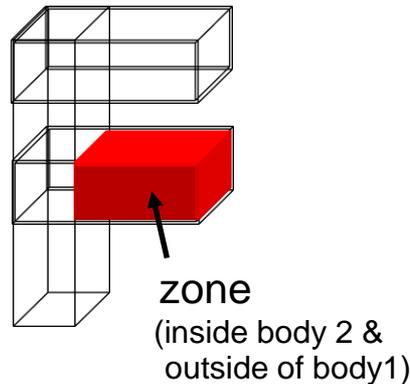
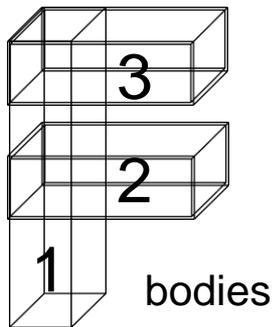
The present FLUKA CG package has been highly improved:

- addition of **"infinite bodies"**
- possibility of using **body and region names** instead of numbers and **getting rid of alignment rules**,
- availability of **parentheses**
- **expansion** and **roto-translation** of bodies
- **comments**
- **repetition of patterns** (lattices)
- **voxels**

Basic Concepts

Four concepts are fundamental in the FLUKA *CG*:

- **Bodies**: basic convex objects, plus infinite planes (half-spaces), infinite cylinders (circular and elliptical), and generic quadric surfaces (surfaces described by 2nd degree equations)
- **Zones**: sub-regions defined only via bodies intersection and subtraction
- **Regions**: defined as Boolean operations on bodies (union of zones)
- **Lattices**: duplication of existing objects (translated & rotated), will be explained in a separate lecture



Use of "infinite bodies" is encouraged: input are less error-prone and tracking is faster and more accurate.

Combinatorial Geometry Input

CG input must respect the following structure:

GEOBEGIN card

VOXELS card (optional, see advanced geometry lecture)

Geometry title (and reading format options)

Body data

END card

Region data

END card

LATTICE cards (optional, see advanced geometry lecture)

Region volumes (optionally requested by a flag in the Geometry title,
used together with the **SCORE** command)

GEOEND card

Reminder for txt format input files:

an asterisk (*) in the 1st column comments the line

GEOBEGIN card

| | | | |
|--|------------------|----------------|---------------------------|
| GEOBEGIN | Log: ▼ Inp: ▼ | Acc: Out: ▼ | Opt: ▼ Fmt: COMBNAME ▼ |
| Title: | | | |
| *...+...1...+...2...+...3...+...4...+...5...+...6...+...7...+... | | | |
| GEOBEGIN | | | COMBNAME |
| 0 | 0 | | |

WHAT(1) not used

WHAT(2) set accuracy parameter - **use with extreme care !**

WHAT(3) logical unit for the geometry input.
Geometry input can be read from file; should be >20.0

WHAT(4) logical unit for the geometry output
Log feature; should be >20.0 ; Default is standard output

WHAT(5) Parenthesis optimization level (see FLUKA manual)

WHAT(6) not used

SDUM **COMBNAME** or **COMBINAT**

COMBNAME selects name based format, **COMBINAT** fixed format

Default: **COMBINAT (!)**

Is overwritten by **WHAT(5)** of a possible **GLOBAL** card

Geometry input format

- The input file format for the geometry is different from the one adopted anywhere else in FLUKA (i.e. the number and length of the input fields is different)
- Different formats can be used (due to backward compatibility)
 - **Fixed format**
 - ◆ Alignment is mandatory
 - ◆ Bodies and regions are identified by numbers (rather than names), this makes geometry editing more difficult
 - **Name based format**
 - ◆ **It is the recommended format**
 - ◆ **It is NOT the default!**

Name based format

It has many advantages, the main are:

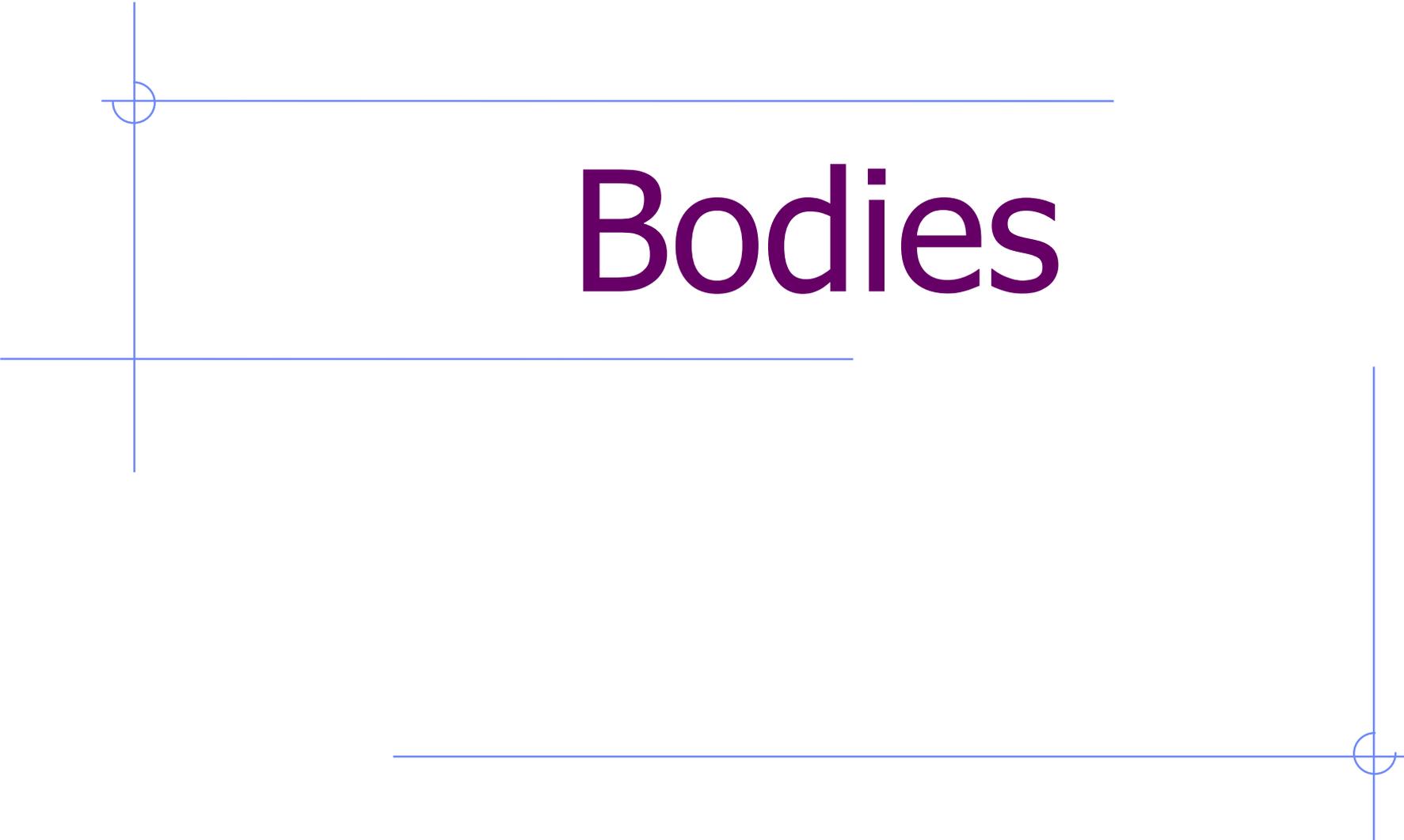
- input parameter alignment is not necessary
- bodies and regions are identified by **names**
- possible to edit the input sequence without affecting the region description (e.g. inserting a new body)
- **parentheses can be used to perform complex Boolean operations** in the description of regions.

Name based format input is used for both body and region

It is activated

either by a **GLOBAL** command at the beginning of the input file
or putting **SDUM = COMBNAME** in the **GEOBEGIN** card

| | | | |
|--|------------------|----------------|---------------------------|
| GEOBEGIN | Log: ▼ Inp: ▼ | Acc: Out: ▼ | Opt: ▼ Fmt: COMBNAME ▼ |
| Title: | | | |
| *...+...1...+...2...+...3...+...4...+...5...+...6...+...7...+... GEOBEGIN 0 0 | | | COMBNAME |

The slide features a minimalist design with blue lines and corner markers. A vertical line on the left and a horizontal line at the top intersect at the top-left corner, with a small blue circle at their intersection. A horizontal line at the bottom and a vertical line on the right intersect at the bottom-right corner, also with a small blue circle at their intersection. The word "Bodies" is centered in a large, bold, purple font.

Bodies

Bodies

- Each body divides the space into two domains: **inside** and **outside**.
- 3-character code of available bodies:
 - **RPP**: Rectangular Parallelepiped
 - **SPH**: SPHERE
 - **XYP, XZP, YZP**: Infinite half space delimited by a coordinate plane
 - **PLA**: Generic infinite half-space, delimited by a PLANE
 - **XCC, YCC, ZCC**: Infinite Circular Cylinder, parallel to coordinate axis
 - **XEC, YEC, ZEC**: Infinite Elliptical Cylinder, parallel to coordinate axis
 - **RCC**: Right Circular Cylinder
 - **REC**: Right Elliptical Cylinder
 - **TRC**: Truncated Right angle Cone
 - **ELL**: ELLipsoid of revolution
 - **QUA**: QUADric
- Other (deprecated) bodies: **ARB, RAW, WED, BOX**
Do not use them, because they can cause rounding problems

Bodies

- The input for each **body** consists of:
 - the 3-letter code indicating the body type (RPP, ZCC...)
 - a unique "**body name**" (alphanumeric identifier, 8 character maximum, **case sensitive**)
 - a set of geometrical quantities defining the body (the number depends on the body type, see next slides)
- Different items can extend over as many lines as needed (Maximum 132 characters per line accepted)
- Different items have to be separated by **one or more blanks**, or by one of the separators **, / ; :**
- Each body divides the space in two. Inside and Outside
The normal vector points towards Outside

All values are in cm!

Infinite half-space parallel to coordinate axis

There are 4 kinds of infinite half-spaces

Three are delimited by planes perpendicular to the coordinate axes:

1. Delimited by a plane \perp to the x -axis. **Code: YZP**
2. Delimited by a plane \perp to the y -axis. **Code: XZP**
3. Delimited by a plane \perp to the z -axis. **Code: XYP**

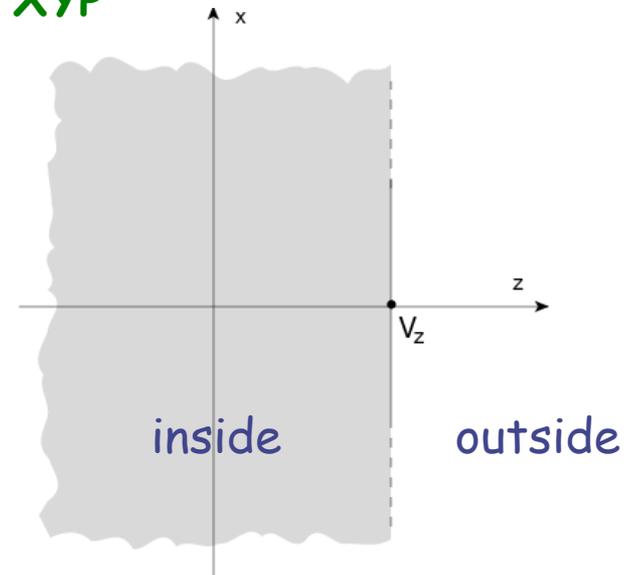
All defined by a single number:

V_x (resp. V_y , or V_z),
coordinate of the plane on the
corresponding perpendicular axis

Points for which:

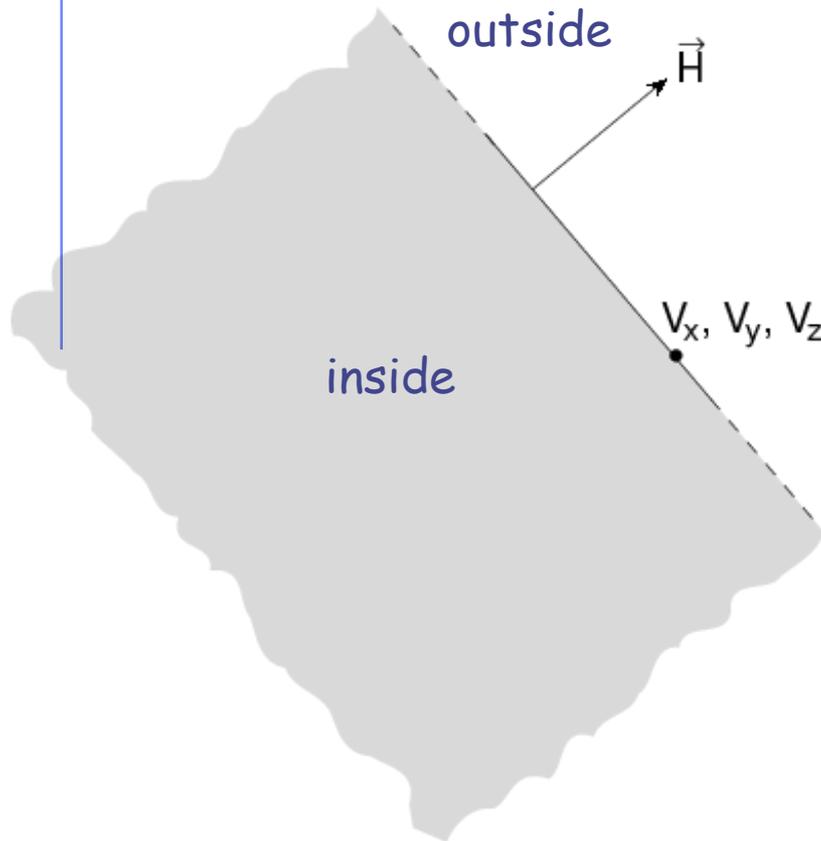
$x < V_x$ (resp. $y < V_y$, or $z < V_z$)

are "inside the body"



```
XYP          eg_XYP          z:10.0
*...+...1...+...2...+...3...+...4...+...5...+...6...+...7...+...
XYP eg_XYP    10.0
```

Arbitrarily orientated infinite half-space: **PLA**



A **PLA** defines the infinite half space delimited by a generic plane

A **PLA** is defined by 6 numbers:
 H_x, H_y, H_z (vector \perp to the plane, arbitrary length);

V_x, V_y, V_z (any point lying on the plane)

The half-space "**inside the body**" is that from which the vector is pointing (i.e. **the vector points "outside"**).

```
PLA      eg_PLA      Nx:0.0      Ny:1.0      Nz:1.0
          x:1.        y:2.        z:3.
+...+...1...+...2...+...3...+...4...+...5...+...6...+...7...+...
PLA eq_PLA  0.0 1.0 1.0 1. 2. 3.
```

Rectangular Parallelepiped: **RPP**

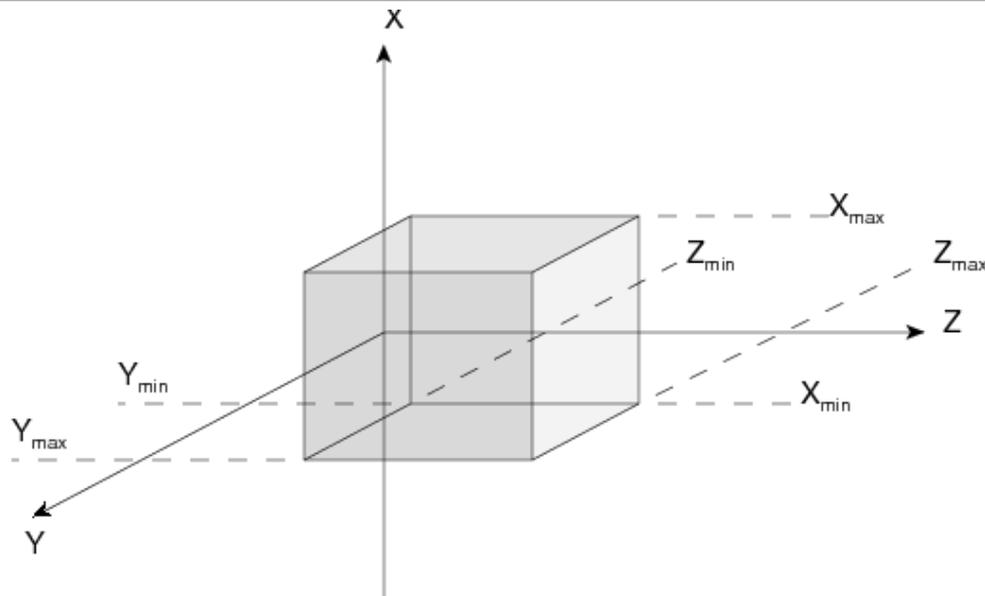
An **RPP** has its edges parallel to the coordinate axes
It is defined by 6 numbers in the following order:

X_{\min} , X_{\max} , Y_{\min} , Y_{\max} , Z_{\min} , Z_{\max}

(min and max coordinates delimiting the parallelepiped)

```
RPP      eg_RPP      Xmin: -5.0      Xmax: 5.0
          Ymin: 0.0      Ymax: 10.0
          Zmin: -30.0     Zmax: 30.0

*...+...1...+...2...+...3...+...4...+...5...+...6...+...7...+...
RPP eg_RPP      -5.0 5.0 0.0 10.0 -30.0 30.0
```



Rectangular Parallelepiped: **RPP**

```

RPP      eg_RPP      Xmin: -5.0      Xmax: 5.0
          Ymin: 0.0      Ymax: 10.0
          Zmin: -30.0     Zmax: 30.0
  
```

```

* . . . + . . . 1 . . . + . . . 2 . . . + . . . 3 . . . + . . . 4 . . . + . . . 5 . . . + . . . 6 . . . + . . . 7 . . . + . . .
RPP eg_RPP      -5.0 5.0 0.0 10.0 -30.0 30.0
  
```

An **RPP** definition extends over one single card in default fixed format, or over two cards in high-accuracy body fixed format

Example in **fixed format** (the comment lines shown are allowed input lines):

```

* . . . + . . . 1 . . . + . . . 2 . . . + . . . 3 . . . + . . . 4 . . . + . . . 5 . . . + . . . 6 . . . + . . . 7 . . . + . . .
RPP      4      -20.0      +20.0      -50.0      +50.0      -38.5      +38.5
  
```

* (a parallelepiped centered on the origin)

High-accuracy fixed format

```

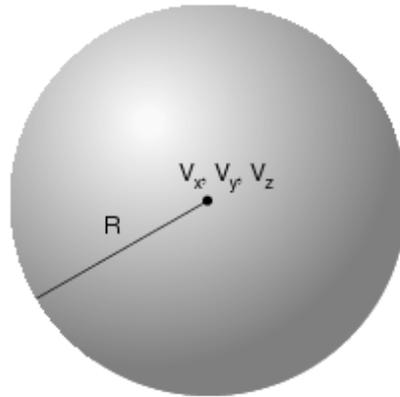
* . . . + . . . 1 . . . + . . . 2 . . . + . . . 3 . . . + . . . 4 . . . + . . . 5 . . . + . . . 6 . . . + . . . 7 . . . + . . .
RPP      4      -20.0      +20.0      -50.0
          +50.0      -38.5      +38.5
  
```

Sphere

Sphere: SPH

A SPH is defined by 4 numbers:

V_x , V_y , V_z (coordinates of the centre), R (radius)



| | | | | |
|-----|--------|--------|-------|-------|
| SPH | eg_SPH | x:0.0 | y:0.0 | z:0.0 |
| | | R:10.0 | | |

```
*...+...1...+...2...+...3...+...4...+...5...+...6...+...7...+...
SPH eg_SPH 0.0 0.0 0.0 10.0
```

Circular cylinder

Right circular cylinder: RCC

An **RCC** can have any orientation in space

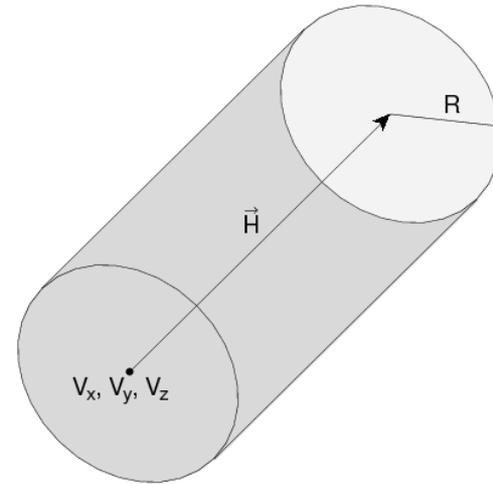
Limited by a cylindrical surface and two plane faces \perp to its axis.

Each **RCC** is defined by 7 numbers:

V_x, V_y, V_z (centre of one face);

H_x, H_y, H_z (vector corresponding to the cylinder height, pointing toward the other face);

R (cylinder radius).



| | | | | |
|------------|--------|--------|---------|---------|
| RCC | eg_RCC | x:0.0 | y:0.0 | z:0.0 |
| | | Hx:0.0 | Hy:10.0 | Hx:10.0 |
| | | R:2.0 | | |

```
* . . . + . . . 1 . . . + . . . 2 . . . + . . . 3 . . . + . . . 4 . . . + . . . 5 . . . + . . . 6 . . . + . . . 7 . . . + . . .
RCC eg_RCC 0.0 0.0 0.0 0.0 10.0 10.0 2.0
```

Infinite cylinders

- Infinite Circular Cylinder parallel to coordinate axis:

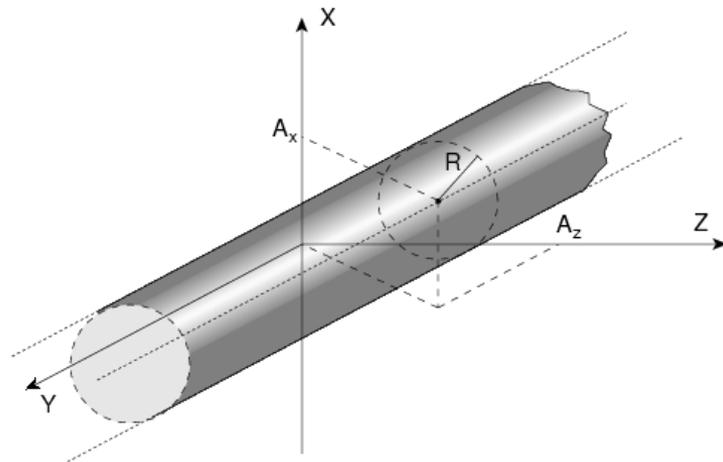
XCC, YCC, ZCC

Each XCC (YCC, ZCC) is defined by 3 numbers:

A_y, A_z for XCC

(A_z, A_x for YCC, A_x, A_y for ZCC)
(coordinates of the cylinder axis),

R (cylinder radius)



- Infinite Elliptical Cylinder parallel to coordinate axis:

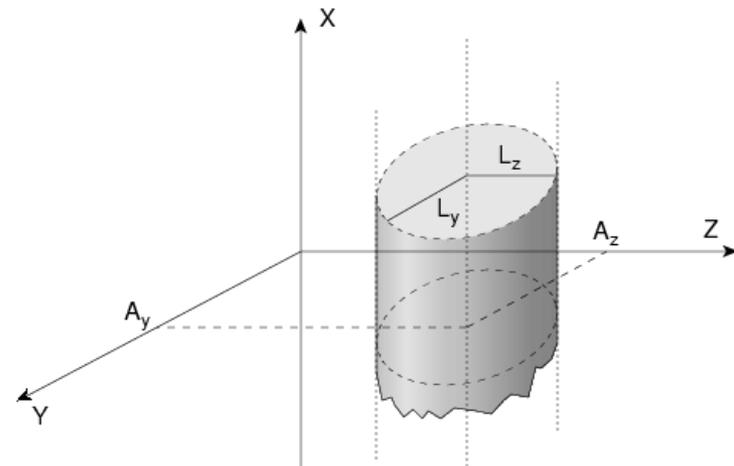
XEC, YEC, ZEC

Each XEC (YEC, ZEC) is defined by 4 numbers: A_y, A_z for XEC

(A_z, A_x for YEC, A_x, A_y for ZEC)
(coordinates of the cylinder axis);

L_y, L_z for XEC

(L_z, L_x for YEC, L_x, L_y for ZEC)
(semi-axes of the ellipse)



| | | | | |
|---|--------------|-------|-------|--------|
| ZCC | eg_ZCC | x:0.0 | y:0.0 | R:20.0 |
| * ..+...1...+...2...+...3...+...4...+...5...+...6...+...7...+.... | | | | |
| ZCC eg_ZCC | 0.0 0.0 20.0 | | | |

Arbitrary generic quadric: **QUA**

A **QUA** allows to insert a quadric surface

This is defined by a 2nd degree equation $F(x,y,z) = 0$

Each **QUA** is defined by 10 numbers:

$A_{xx}, A_{yy}, A_{zz}, A_{xy}, A_{xz}, A_{yz}, A_x, A_y, A_z, A_0$

corresponding to the equation:

$$A_{xx} x^2 + A_{yy} y^2 + A_{zz} z^2 + A_{xy} xy + A_{xz} xz + A_{yz} yz + \\ + A_x x + A_y y + A_z z + A_0 = 0$$

A **QUA** definition extends over two cards in default fixed format,
and over 4 cards in high-accuracy body fixed format.

The slide features a decorative layout of thin blue lines. A vertical line on the left and a horizontal line at the top intersect at a small circle in the top-left corner. Another horizontal line is positioned below the top one, extending from the left edge to the center. A third horizontal line is at the bottom, extending from the center to the right edge, where it intersects a vertical line on the right at a small circle in the bottom-right corner.

Regions

Concept

Regions are defined as combinations of bodies obtained by boolean operations:

| | Union | Subtraction | Intersection |
|-------------------|--------|-------------|--------------|
| Name based format | | - | + |
| Fixed format | OR | - | + |
| Mathematically | \cup | - | \cap |

Regions but must be of homogeneous material composition.



Each point of space must belong to one and only one region!

Regions

Input for each region starts on a new line and extends on as many continuation lines as are needed. It is of the form:

```
REGNAME NAZ boolean-zone-expression
```

or

```
REGNAME NAZ boolean-zone-expression | boolean-zone-expression | ...
```

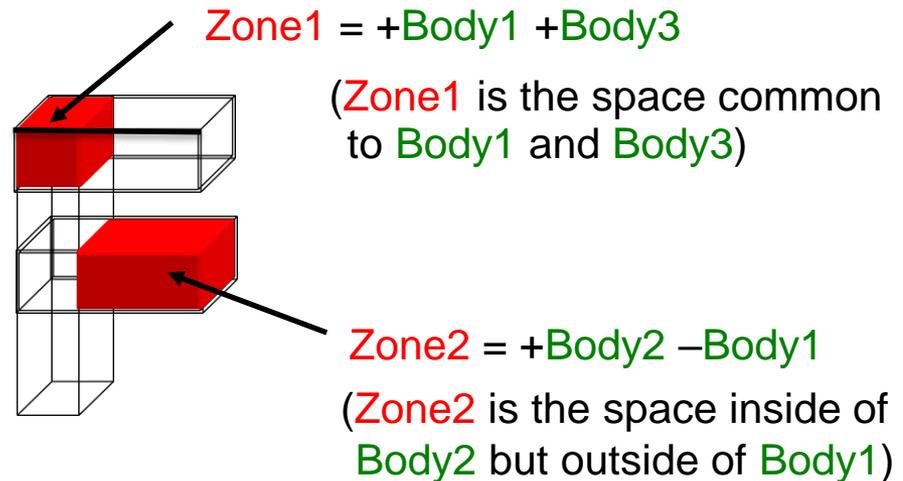
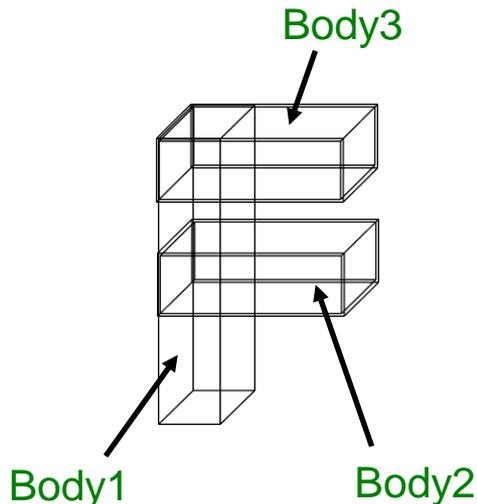
- **REGNAME** is the **region "name"**
alphanumeric identifier, 8 character maximum, **case sensitive**
Must start by an alphabetical character
- **NAZ** See next slide
- **"boolean-zone-expression"** See next slides

Regions

- **NAZ** (Number of Adjacent Zones) is a rough estimate of the number of zones a particle can enter when leaving the current region zones (5 by default). What actually matters is the NAZ sum over all regions, defining the size of the *contiguity list*
- While tracking, the program searches in the contiguity list for the neighbor zones of each zone. If the zone is not yet in the list, the whole geometry is scanned and it is added to the list with its neighbor zones
- When the NAZ limit is reached (i.e. the list is full) the code prints a warning: GEOMETRY SEARCH ARRAY FULL. This is not lethal: the calculation continues but with a reduced efficiency
- If you have more than 1000 regions, you must issue a **GLOBAL** card putting in **WHAT(1)** a higher limit (not beyond 10000)

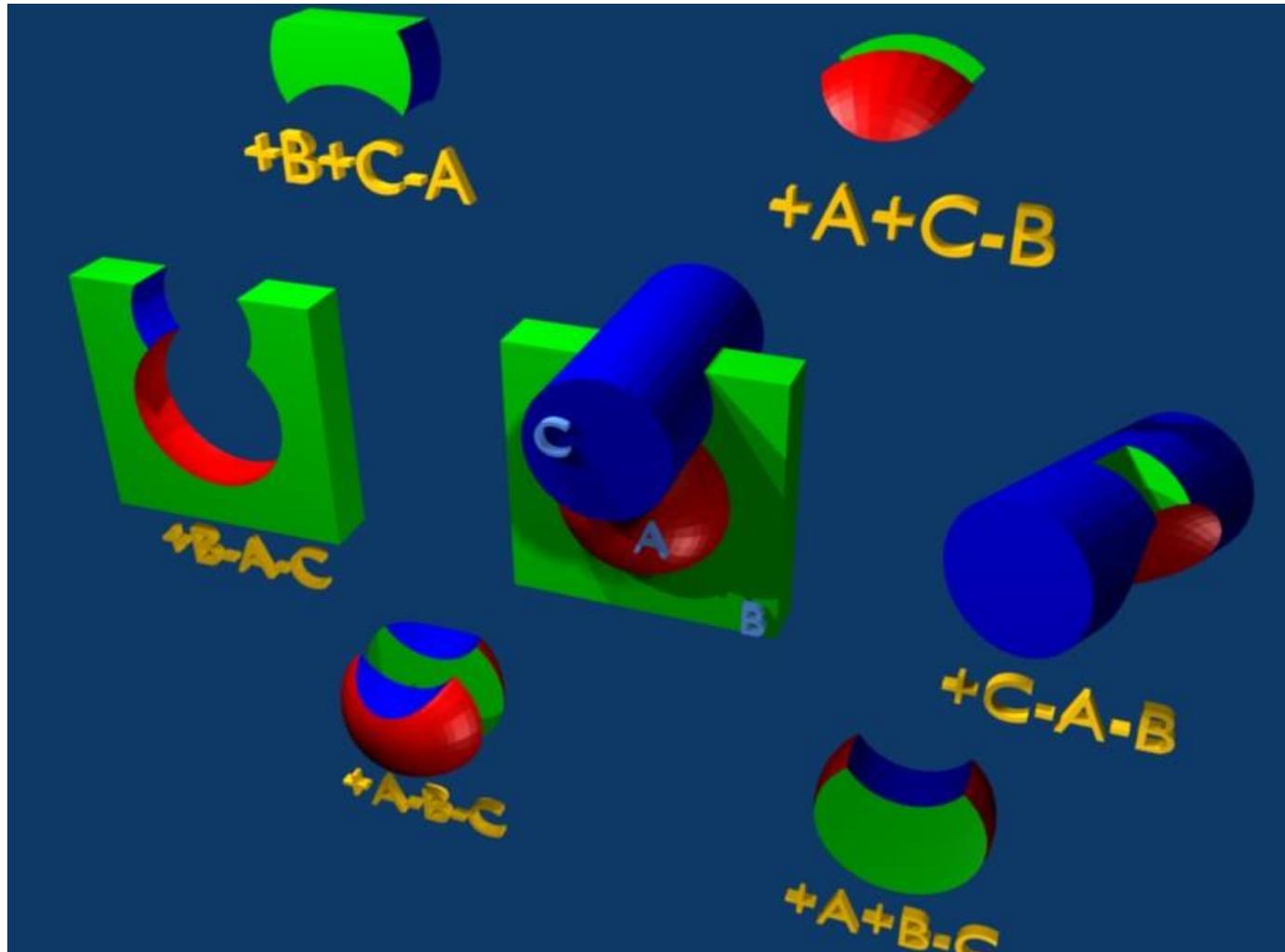
Boolean zone expressions (+/- operators)

- **Zones** are defined by intersections and/or subtraction of **bodies**
 - ◆ Zones are described by a sequence of one or more bodies each being preceded by its + or - sign
 - ◆ **+body**: only the inner part of the body can belong to the zone (means that the **zone** being described is **fully contained inside** this body)
 - ◆ **-body**: only the outside of the body can belong to the zone (means that the **zone** being described is **fully outside** this body)



Zones must be finite: normally in the description of each **zone**
Zones can overlap → Points in space could belong to more than one zone **BUT** of the **SAME** region!

Boolean zone expressions (+/- operators)



Combining zones (| operator)

- The | (or OR) operator is used as a Boolean **union** operator in order to combine **zones**
- Such combination of zones forms a **region**
 - ◆ In its simplest form a region just consist of one zone
 - ◆ Regions are **not necessarily simply connected**, i.e. they can consist of zones which are not contiguous
 - ◆ On the other hand, zones belonging to the same region can be partially **overlapping**

Example:

```
Ground 5 | +Body9 | +Body15 | +Body1 | +Body8 -Body2 | +Body8 -Body3
*          <- 1st -><- 2nd -><- 3rd -><----- 4th -----><----- 5th ---->
          | +Body8 +Body18 | +Body12 -Body10 -Body11 -Body13 -Body14
*          <----- 6th -----><----- 7th and last zone ----->
```

In name based format one can also use parenthesis to form more complex Boolean operations

In evaluating the expressions, the highest operator precedence is given to parentheses, followed by +, - and the | operator

Special Region: The Black Hole

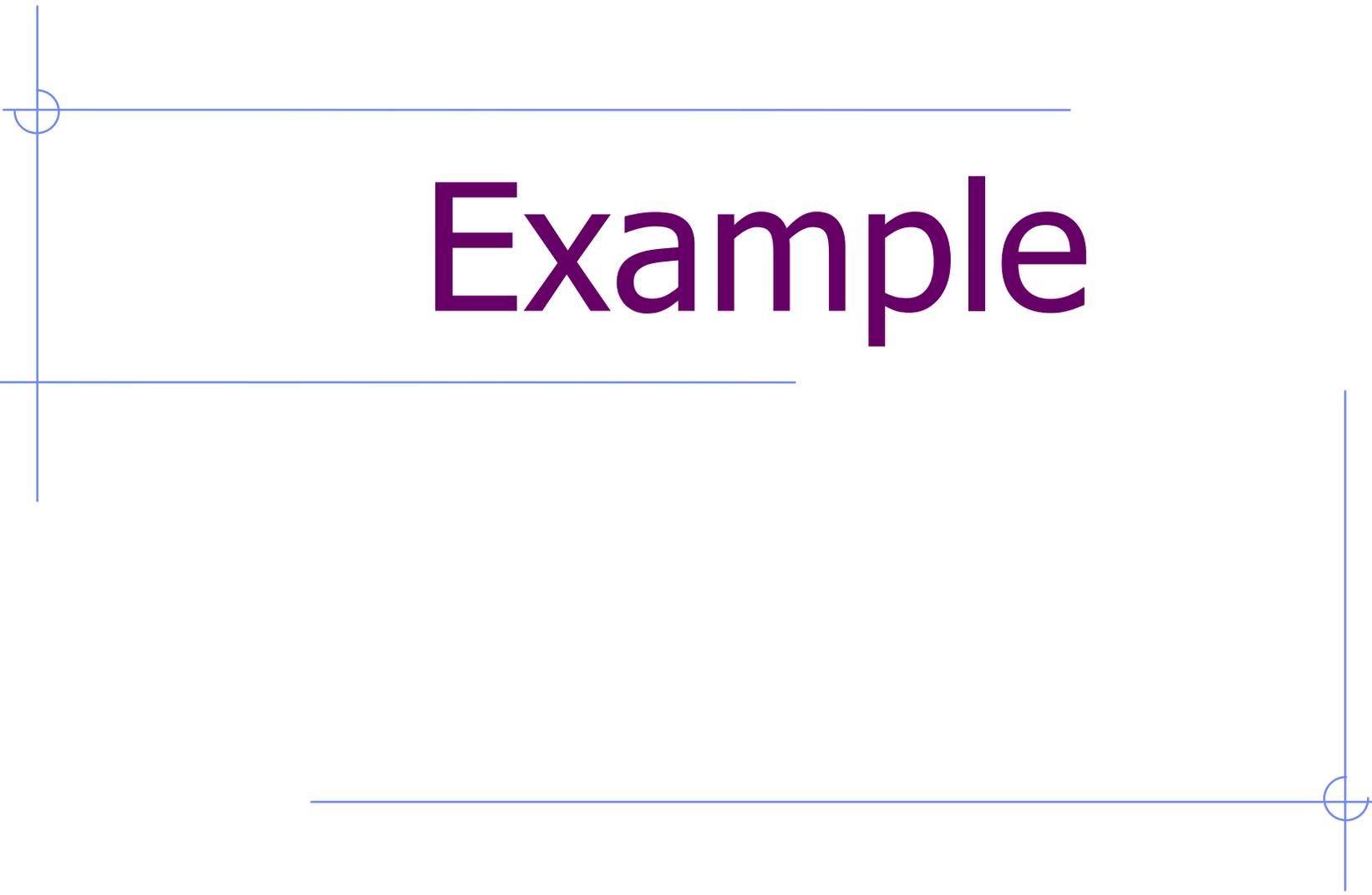
All particles entering a black-hole are absorbed (they vanish)

FLUKA geometry MUST be embedded into a **BLCKHOLE** region
(to avoid tracking particles to infinity)

The outer surface of the **BLCKHOLE** region must be a single closed body (e.g. a sphere).

Further black-hole regions can be defined by the user if desired

BLCKHOLE region: has material BLCKHOLE assign to it

The slide features a decorative layout of thin blue lines. A vertical line on the left and a horizontal line at the top intersect at a small circle in the top-left corner. Another horizontal line is positioned below the top one, and a vertical line on the right intersects it at a small circle in the bottom-right corner. The word "Example" is centered in the space between the top and middle horizontal lines.

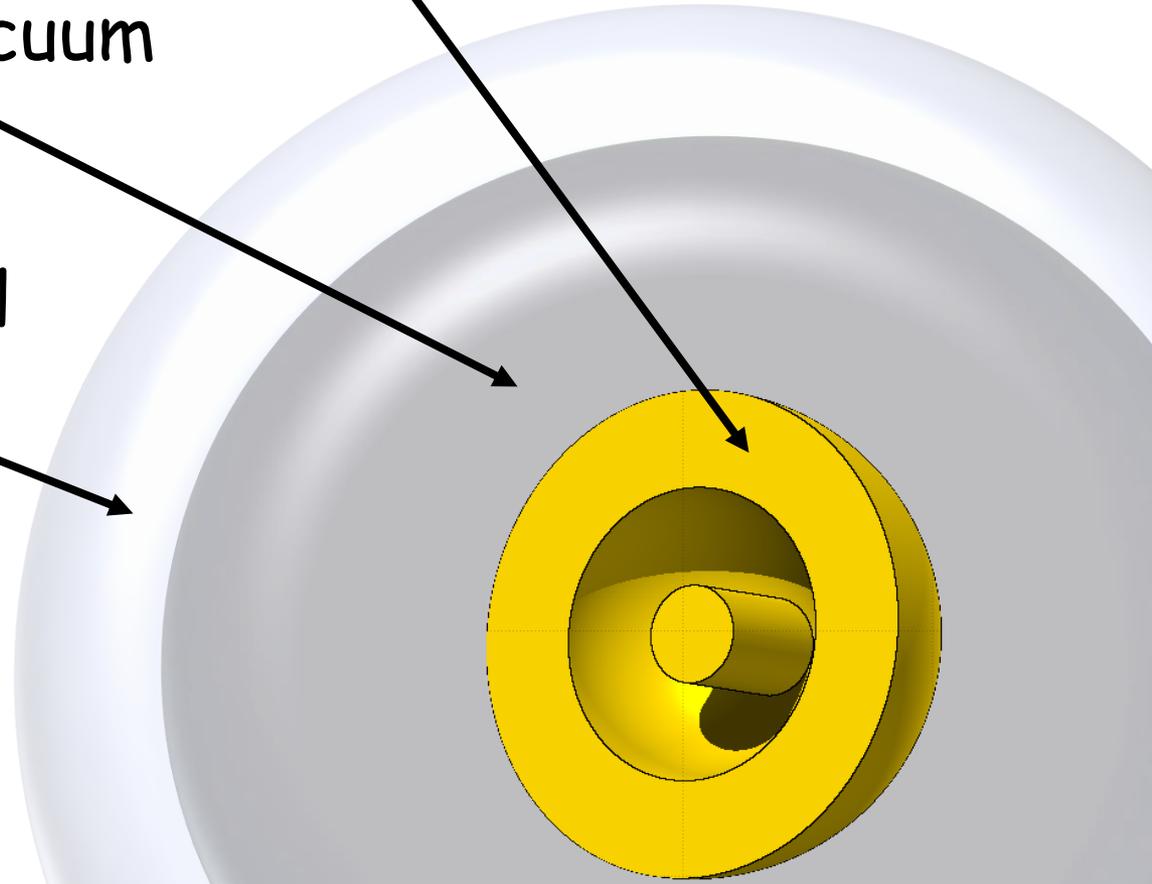
Example

Geometry Example

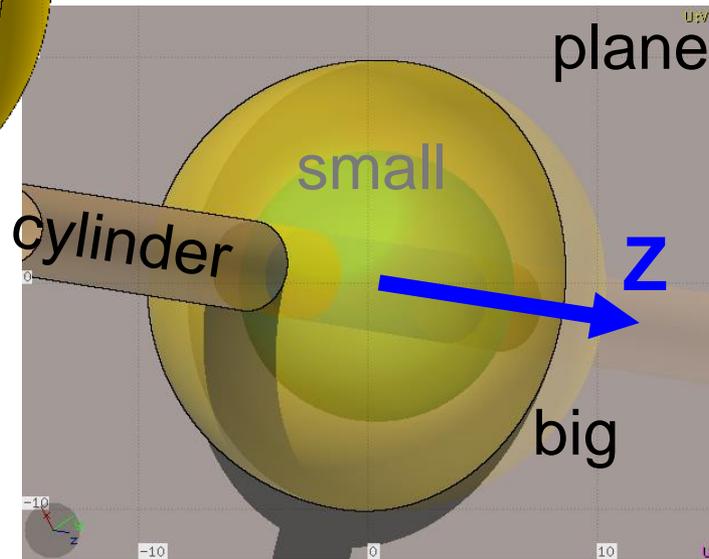
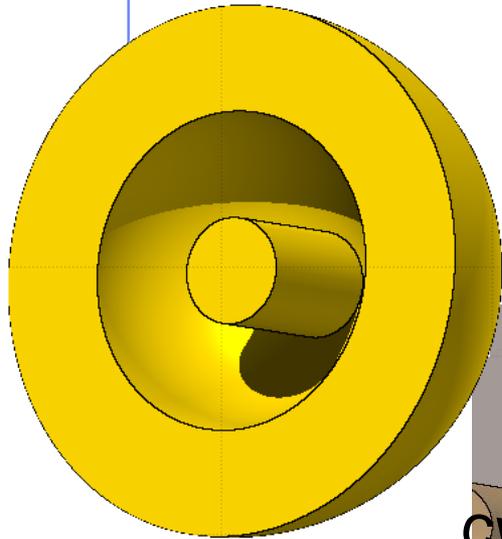
Target made of Gold

Surrounded by vacuum

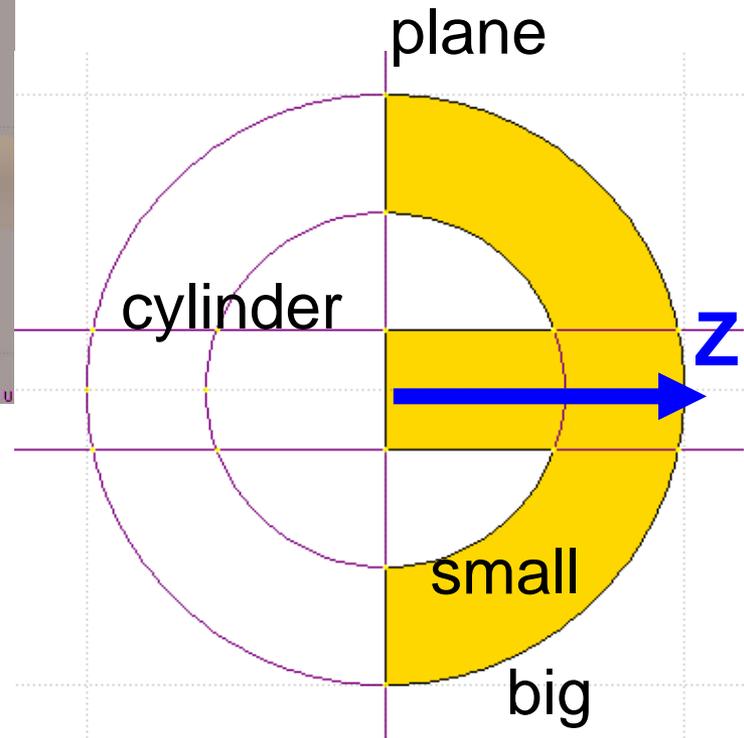
Black hole: spherical
shell from 1000 to
10000 cm radius



Geometry example: Target Bodies



2 spheres: big, small
1 infinite cylinder // Z
1 infinite plane \perp Z



Geometry example: input file

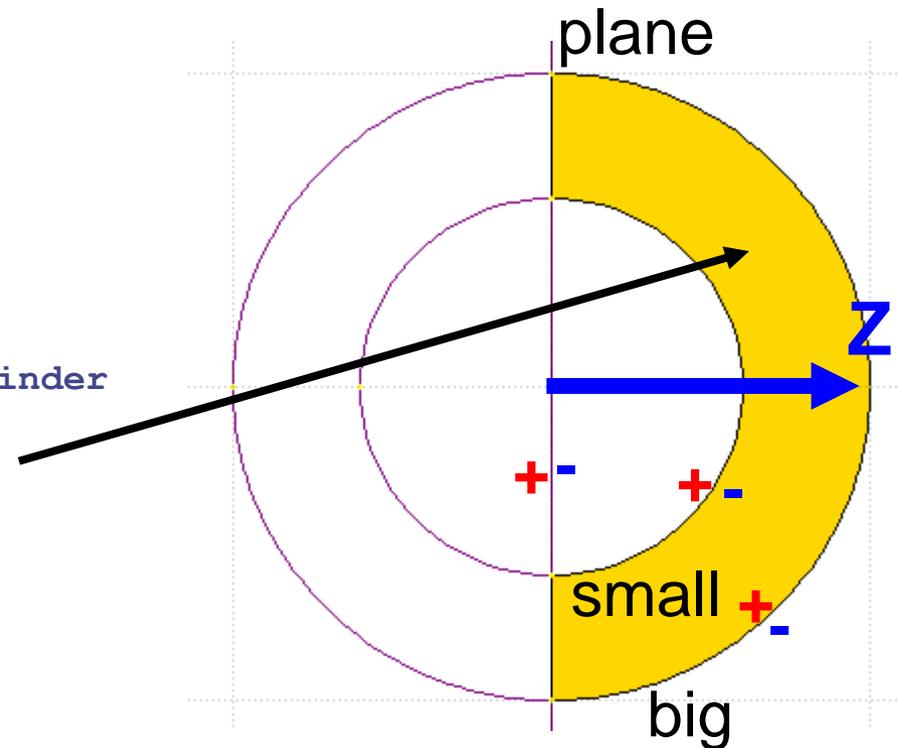
```

GEOBEGIN
    0    0          The golden target
SPH spout    0 0 0 10000.
SPH spin    0 0 0 1000.
SPH big     0 0 0 10
SPH small   0 0 0 6
XYP plane   0
ZCC cylinder 0 0 2
END
* Black hole
BLKBODY     5 +spout -spin
* Void around
VOID        5 +spin -big
            | +big +plane
            | +small -plane -cylinder

* Target
TARGET     5 +big -small -plane

END
GEOEND
ASSIGNMA    BLCKHOLE    BLKBODY
ASSIGNMA    VACUUM      VOID
ASSIGNMA    COPPER      TARGET
    
```

COMBNAME



Geometry example: input file

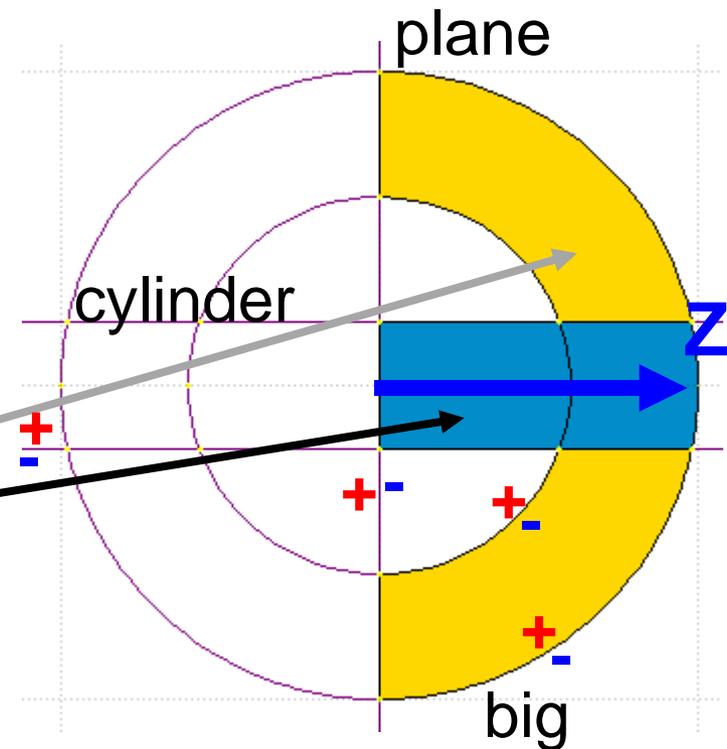
```

GEOBEGIN
    0    0
    The golden target
SPH spout    0 0 0 10000.
SPH spin    0 0 0 1000.
SPH big     0 0 0 10
SPH small   0 0 0 6
XYP plane   0
ZCC cylinder 0 0 2
END
* Black hole
BLKBODY     5 +spout -spin
* Void around
VOID        5 +spin -big
            | +big +plane
            | +small -plane -cylinder

* Target
TARGET     5 +big -small -plane
            | +big +cylinder -plane

END
GEOEND
ASSIGNMA    BLCKHOLE    BLKBODY
ASSIGNMA    VACUUM      VOID
ASSIGNMA    COPPER      TARGET
    
```

COMBNAME



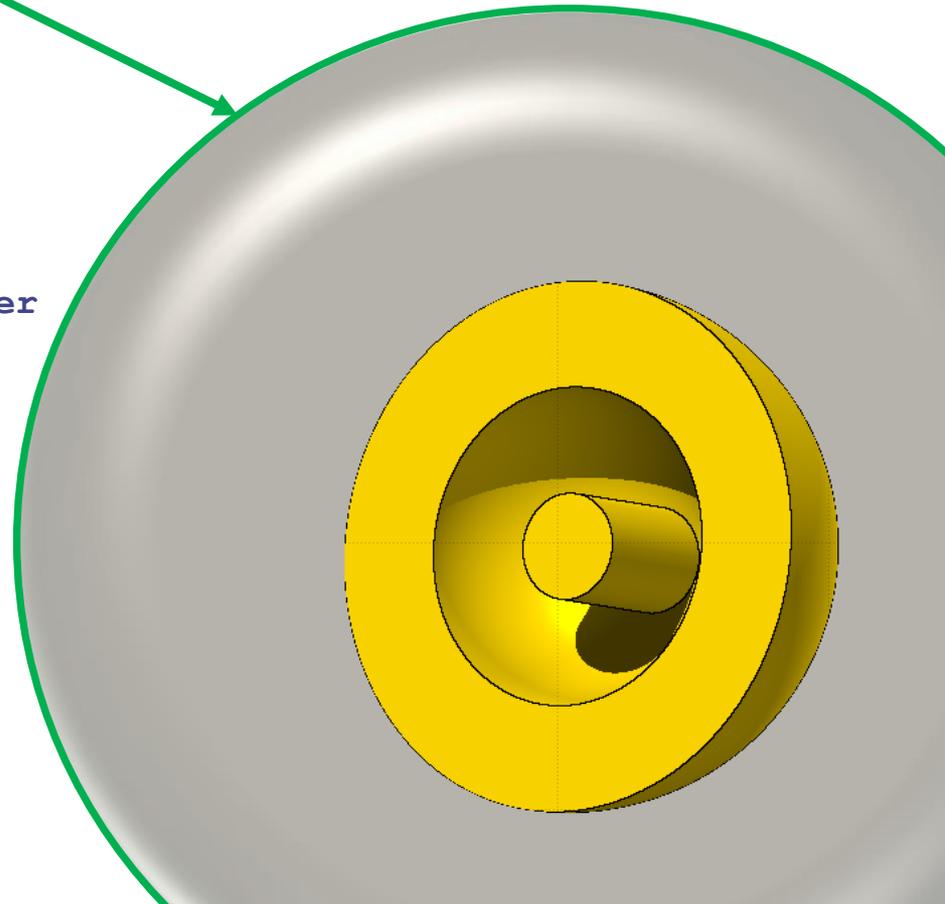
Geometry example: input file

```
GEOBEGIN
    0    0          The golden target
SPH spout    0 0 0 10000.
SPH spin    0 0 0 1000.
SPH big     0 0 0 10
SPH small   0 0 0 6
XYP plane   0
ZCC cylinder 0 0 2
END
* Black hole
BLKBODY     5  +spout -spin
* Void around
VOID        5  +spin -big
            | +big +plane
            | +small -plane -cylinder

* Target
TARGET      5  +big -small -plane
            | +big +cylinder -plane

END
GEOEND
ASSIGNMA    BLCKHOLE    BLKBODY
ASSIGNMA    VACUUM      VOID
ASSIGNMA    COPPER      TARGET
```

COMBNAME

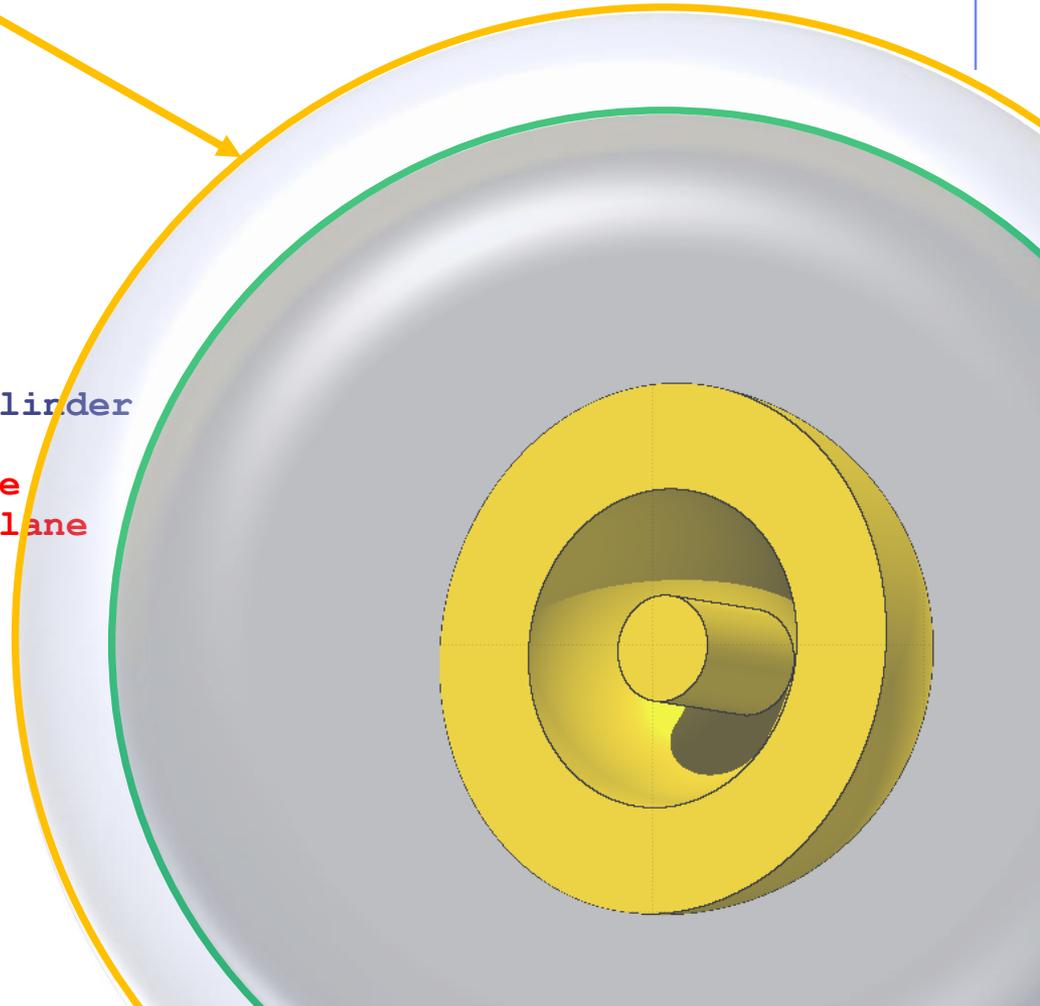


Geometry example: input file

```
GEOBEGIN COMBNAME
    0      0      The golden target
SPH spout  0 0 0 10000.
SPH spin   0 0 0 1000.
SPH big    0 0 0 10
SPH small  0 0 0 6
XYP plane  0
ZCC cylinder 0 0 2
END
* Black hole
BLKBODY    5  +spout -spin
* Void around
VOID       5  +spin -big
           | +big +plane
           | +small -plane -cylinder

* Target
TARGET     5  +big -small -plane
           | +big +cylinder -plane

END
GEOEND
ASSIGNMA   BLCKHOLE   BLKBODY
ASSIGNMA   VACUUM     VOID
ASSIGNMA   COPPER     TARGET
```



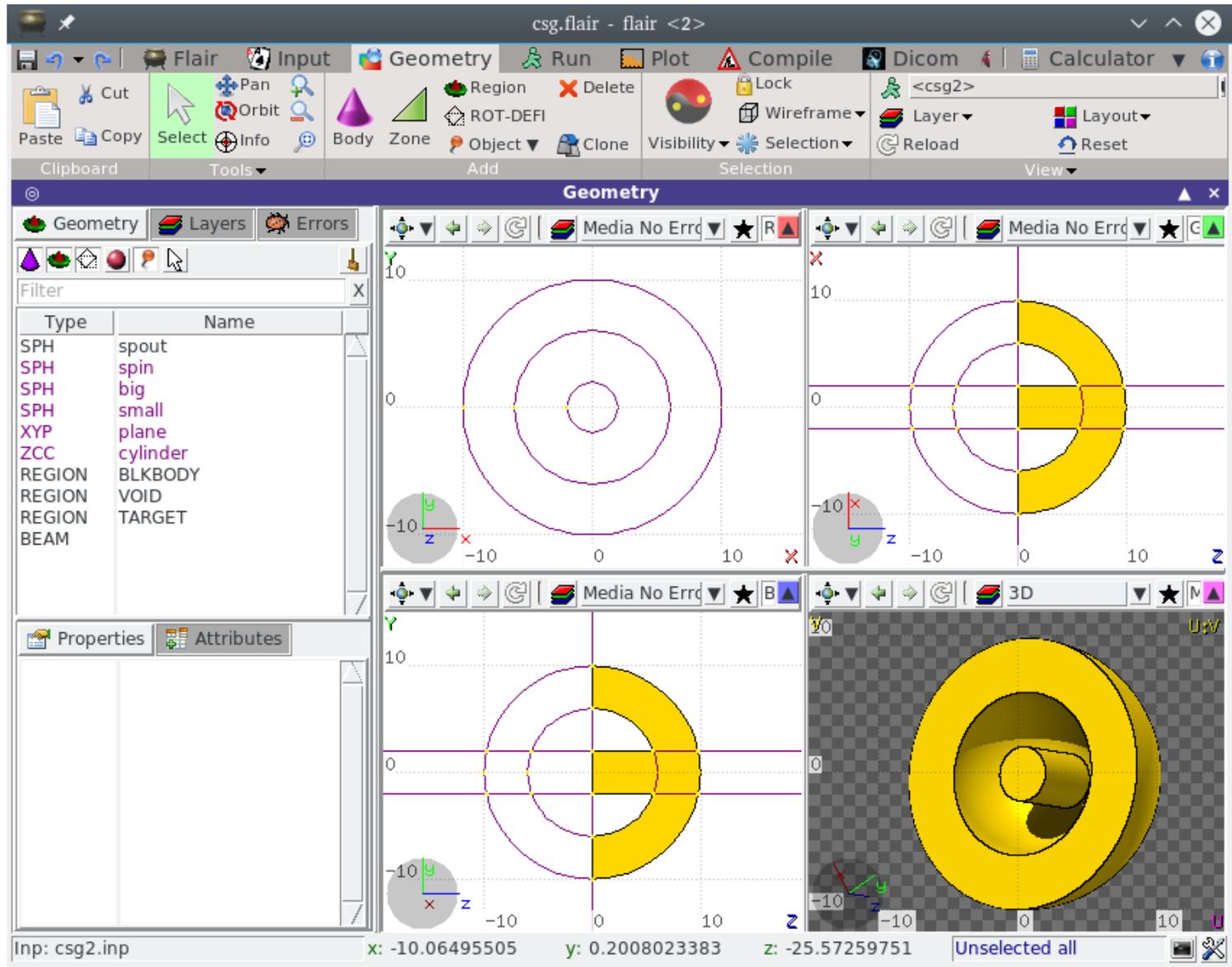
Geometry example: input Flair

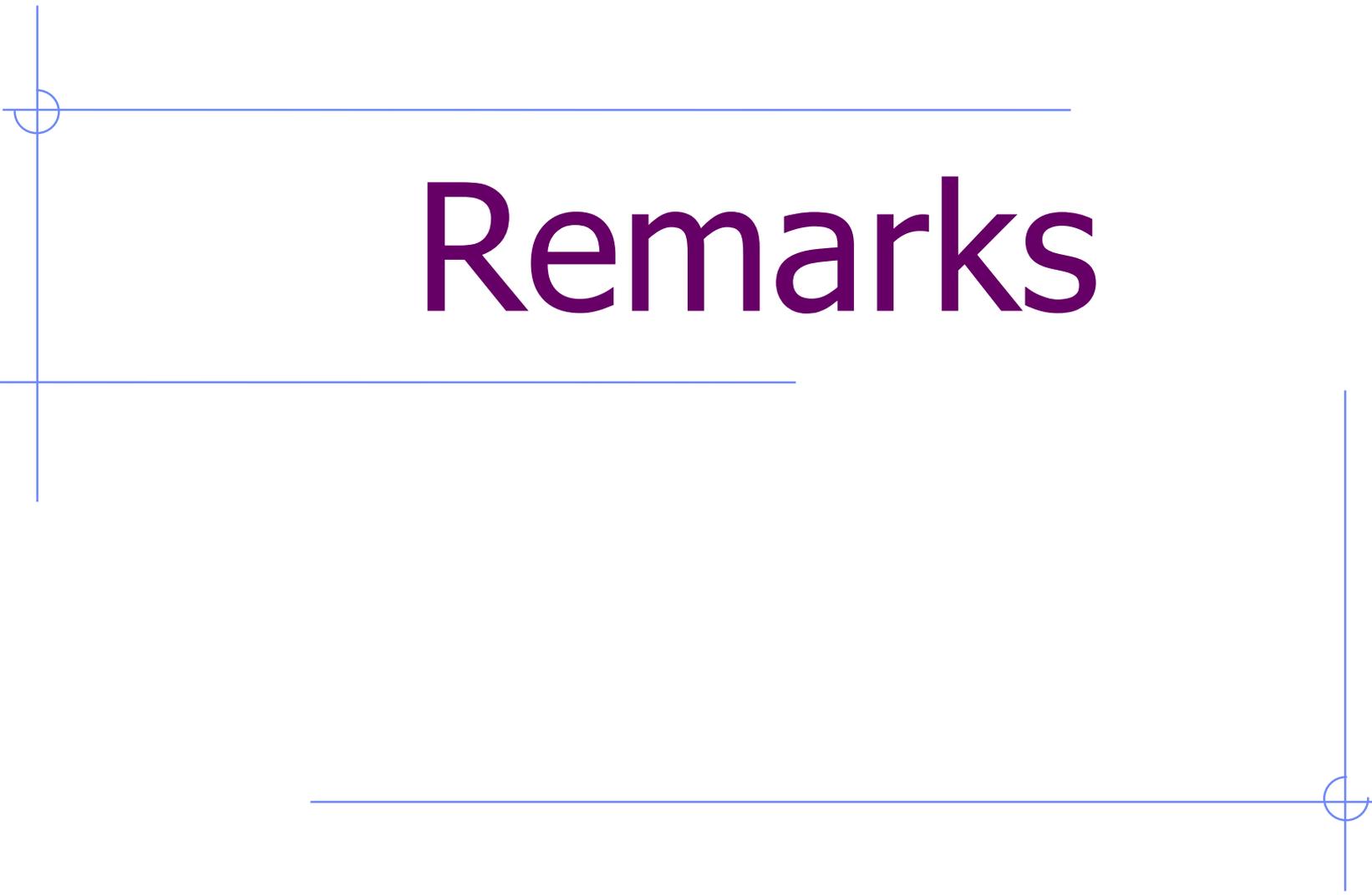
The screenshot displays the Flair software interface with the following components:

- Menu Bar:** Includes options like Flair, Input, Geometry, Run, Plot, Compile, Dicom, and Calculator.
- Toolbar:** Contains icons for Cut, Copy, Paste, New, Load, Save, Export, Import, Add, Change, Delete, Show, Comment, Refresh, Move Up, and Move Down.
- Left Sidebar:** A tree view showing the project structure with folders for General, Primary, Geometry (highlighted), Media, Physics, Transport, Biasing, Scoring, Flair, Developers, and Preprocessor.
- Main Text Area:** Displays the input file content, which includes:
 - Geometric Objects:**
 - Black body:** SPH spout, x:0, y:0, z:0, R:100000
 - Void sphere:** SPH spin, x:0, y:0, z:0, R:10000
 - SPH big:** x:0, y:0, z:0, R:10
 - SPH small:** x:0, y:0, z:0, R:6
 - XYP plane:** z:0
 - ZCC cylinder:** x:0, y:0, R:2
 - Regions:**
 - REGION BLKBODY:** Neigh: 5, expr: +spout -spin
 - REGION VOID:** Neigh: 5, expr: +spin -big | +big +plane | +small -plane -cylinder
 - REGION TARGET:** Neigh: 5, expr: +big -small -plane | +big +cylinder -plane
 - Control Cards:** END, GEOEND, and ASSIGNMA ... STOP: 6 cards hidden

At the bottom of the window, the status bar shows: Inp: csg2.inp, Active:18-23, Displayed:13, Total:23.

Geometry example: input Flair



The page features a decorative layout of thin blue lines. A vertical line on the left and a horizontal line at the top intersect at a small circle in the upper-left corner. Another horizontal line is positioned below the top one, and a vertical line on the right intersects it at a small circle in the lower-right corner. The word "Remarks" is centered between the top and middle horizontal lines.

Remarks

Important Notes

- Whenever it is possible, the following bodies should be preferred:

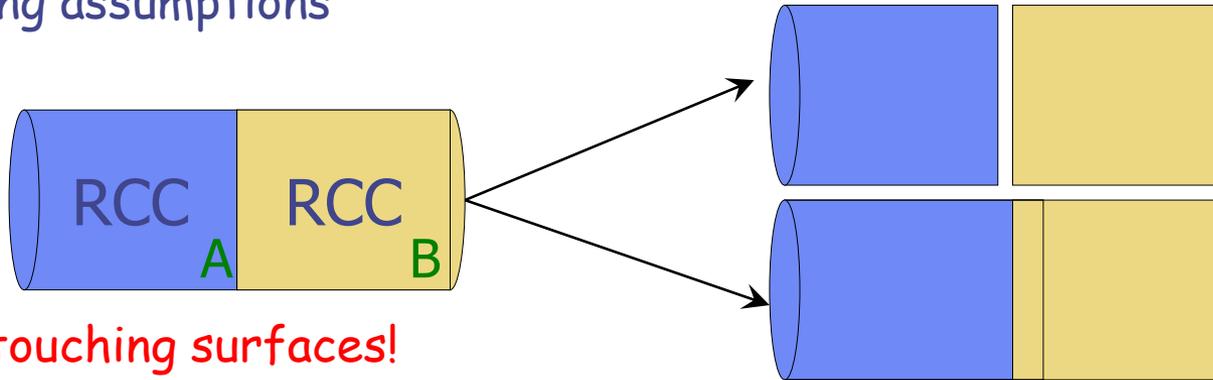
PLA, RPP, SPH, XCC, XEC, XYP
XZP, YCC, YEC, YZP, ZCC, ZEC, QUA

These bodies make the tracking faster, since for them extra coding ensures that unnecessary boundary intersection calculations are avoided when the length of the next step is smaller than the distance to any boundary of the current **region**.

- Always **use as many digits as possible** in the definition of the body parameters, particularly for body heights (RCC, REC, TRC), and for direction cosines of bodies with slant surfaces. The name based format or the high-accuracy fixed format should always be used in these cases.

Precision Errors

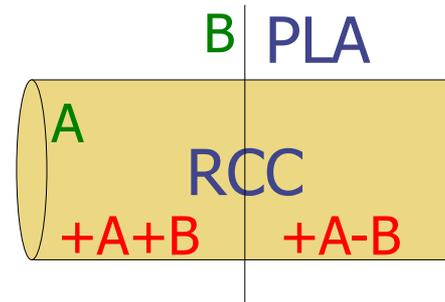
Modeling assumptions



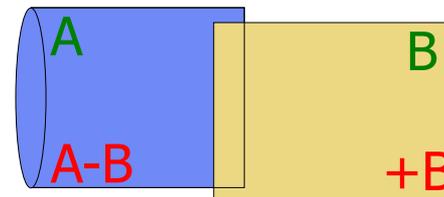
Avoid touching surfaces!

When floating point operations are involved.

- Use cutting surface **B** instead

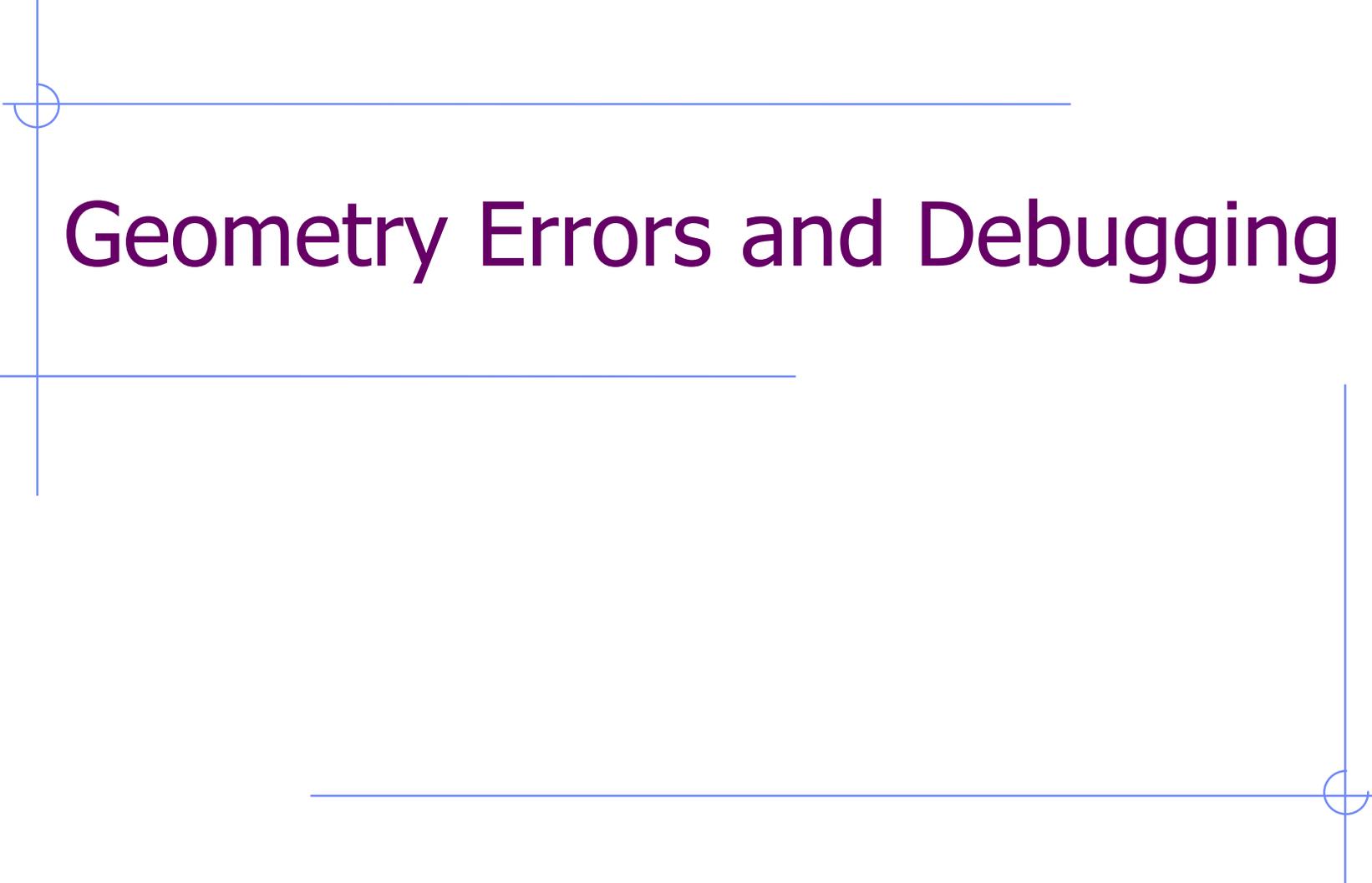


- Or force partial overlap of bodies



Tracking accuracy

- ❑ FLUKA uses systematically double precision mathematic (i.e. 16 significant digits)
- ❑ GEOBEGIN's WHAT(2)*10⁻⁶cm is the *absolute accuracy (AA)* requested for tracking and boundary identification
- ❑ The *relative accuracy (RA)* achievable in double precision is of the order of 10⁻¹⁴-10⁻¹⁵.
- ❑ AA should be larger than $RA * L$, being L the largest coordinate value in the considered problem, i.e. the whole geometry size (The outer blackhole shell containing the system does not count)
- ❑ For very large and very small geometries, you may, respectively, need to increase or decrease the WHAT(2).

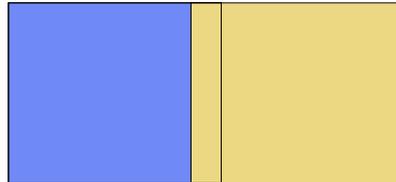
The slide features a decorative layout of blue lines and corner markers. A vertical line on the left and a horizontal line at the top intersect at the top-left corner, with a small blue circle marking the intersection. A horizontal line at the bottom and a vertical line on the right intersect at the bottom-right corner, also with a small blue circle marking the intersection. The title text is centered between these lines.

Geometry Errors and Debugging

Geometry Errors

During execution the code always needs to know the region where a particle is located at every step

- The program will **stop** only if a particle position **does not belong to any region**
An error message will be printed in the **.err** file with the particle position
- **IMPORTANT!** It will **not stop** if a particle position **belongs to more than one region**. It will accept the first region it finds but the results will completely unreliable!!



Geometry Errors

Further types of errors

- Problem space not enclosed by a black body region
- Never start a primary particle along a surface. You could get a geometry error even if the geometry is correct because FLUKA cannot determine the region
- Precision errors
- Lattice replica \leftrightarrow basic cell mismatch
(see advanced geometry lecture)

Debugging Tools

- **GEOEND** card with the **DEBUG** option
- Error messages during simulation in the **.err** file
- Geometry plotting by Flair
(automatically invoking the **PLOTGEOM** card)
- **FLAIR Geometry Editor** (very powerful! See dedicated lecture)
- Simplegeo

Debugging with FLUKA

GEOEND card activates the geometry debugger. Detects both undefined or multiple defined points in a selected X,Y,Z mesh

- Two cards are needed
First card

WHAT(1)=X_{max}
WHAT(4)=X_{min}
SDUM = DEBUG

WHAT(2)=Y_{max}
WHAT(5)=Y_{min}

WHAT(3)=Z_{max}
WHAT(6)=Z_{min}

- Second Card

WHAT(1)=Nx
SDUM = &

WHAT(2)=Ny

WHAT(3)=Nz

```
GEOEND Xmax Ymax Zmax Xmin Ymin Zmin DEBUG
GEOEND Nx Ny Nz &
```

```
↑ GEOEND DEBUG ▼
Xmin: Xmax: NX:
Ymin: Ymax: NY:
Zmin: Zmax: NZ:
```

WARNING!

The program stops if too many errors are found
A message will be issued on the output unit

Debugging with FLUKA

- If **no error** is found, no **.err** file will be created
- **REMINDER**: If the debugger does not find any error it does not mean that the geometry is error free!
- One has to test, changing the **GEOEND** settings especially for critical and complicated regions
- Errors will be listed in the **.err** file in the form:
 - **** Lookdb: Geometry error found ****
**** The point: -637.623762 -244.554455 -96.039604 ****
 - **Point is contained in more than one region**
**** is contained in more than 1 region ****
**** (regions: 6 7) ****
 - **Not contained in any region**
**** is not contained in any region

The slide features a minimalist design with blue lines and corner markers. A vertical line on the left and a horizontal line at the top meet at a small circle in the top-left corner. Another horizontal line is positioned below the top one, and a vertical line on the right meets a horizontal line at the bottom at a small circle in the bottom-right corner. The text 'Spare Slides' is centered between the top and bottom horizontal lines.

Spare Slides

Geometry TITLE card

This card has no keyword, it is the line that follows the *GEOBEGIN* card (unless voxels are used) and its format is (2I5, 10X, A60)

The card gets three inputs: *IVLFLG*, *IDBG*, *TITLE*

IVLFLG (Input VoLumes FLAG) triggers the normalization of the quantities scored in regions by the option *SCORE*

IVLFLG= 0 → no normalization applied

IVLFLG= 3 → results divided by region volumes given before *GEOEND*.
Volume value for each region must be provided, format: (7E10.5).

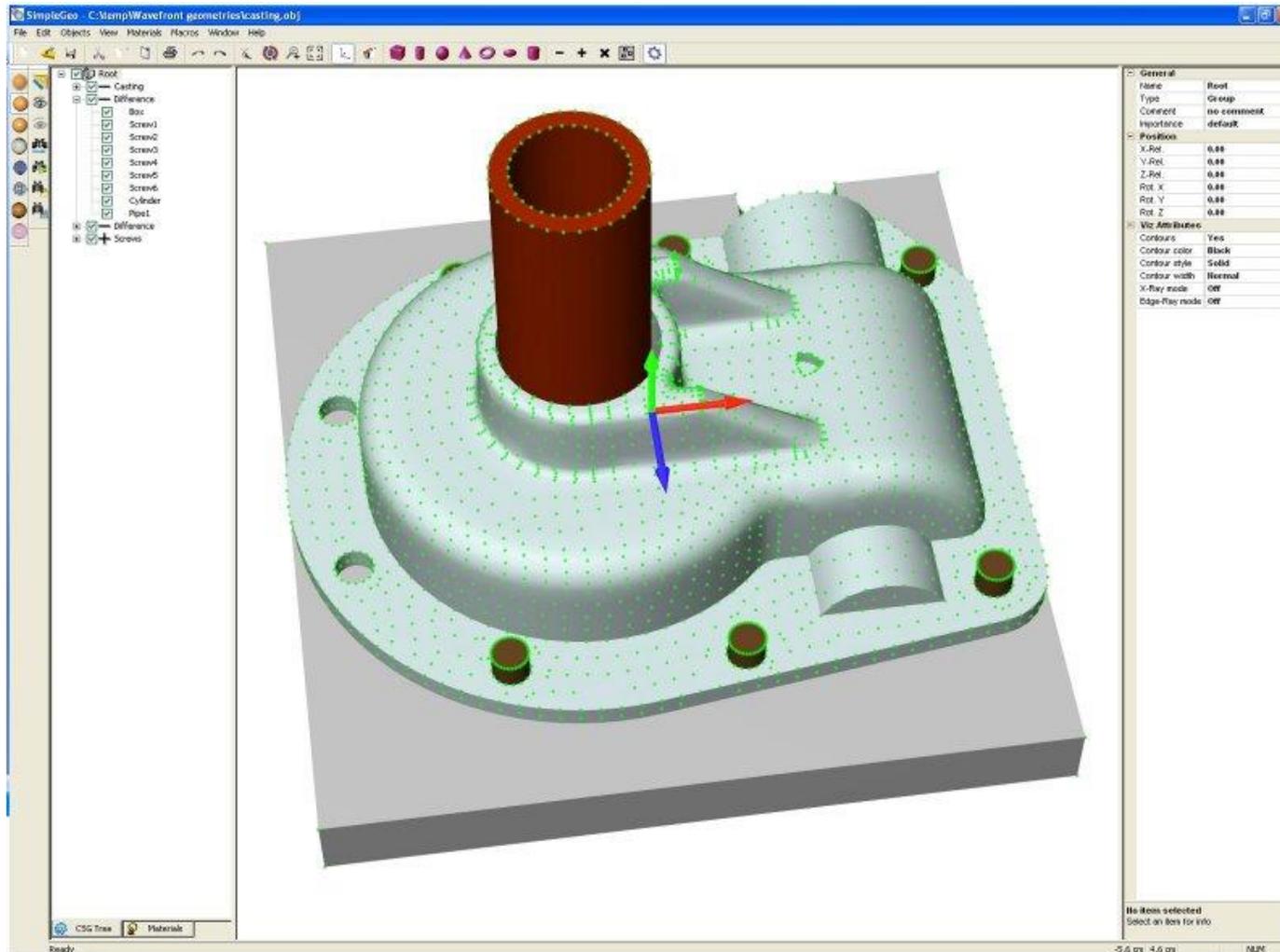
IDBG select different kinds of geometry *fixed* format input:

IDBG = 0 : default fixed format

IDBG = -10 or -100 : high accuracy fixed format

| | | | |
|--|---------------------|----------------|---------------------------|
| GEOBEGIN | Log: ▼ Inp: 21 ▼ | Acc: Out: ▼ | Opt: ▼ Fmt: COMBNAME ▼ |
| Title: Geometry title | | | |
| *...+...1...+...2...+...3...+...4...+...5...+...6...+...7...+... | | | |
| GEOBEGIN | 21. | | COMBNAME |
| 0 0 | Geometry title | | |

Auxiliary program: *SimpleGeo*



Auxiliary program: *SimpleGeo*

- SimpleGeo is an interactive solid modeler which allows for flexible and easy creation of the models via drag & drop, as well as on-the-fly inspection
- Imports existing geometries for viewing
- Creating new geometries from scratch
- Export to various formats (FLUKA, MCNP, MCNPX)
- Download, Tutorials, etc.:
<http://theis.web.cern.ch/theis/simplegeo>
- Operating system: Windows only

