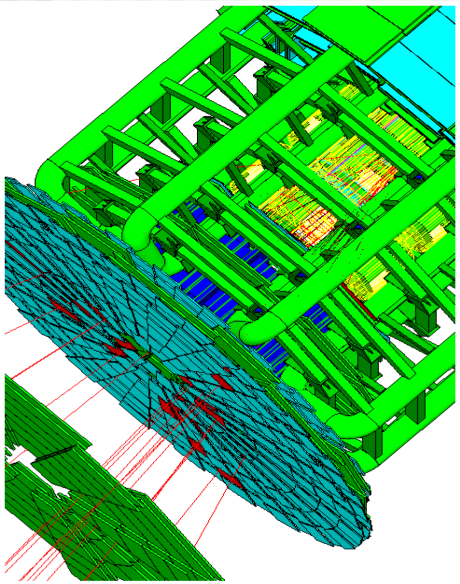
Detector Description:

Geant 4

Visualization Attributes
Optimisation & Debugging techniques



http://cern.ch/geant4

PART IV

Visualization

- *Visualization attributes*
- *GGE & geometry tree*

Visualization of Detector

- Each logical volume can have associated a **`G4VisAttributes`** object
  - Visibility, visibility of daughter volumes
  - Color, line style, line width
  - Force flag to wire-frame or solid-style mode
- For parameterised volumes, attributes can be dynamically assigned to the logical volume
- Lifetime of visualization attributes must be at least as long as the objects they're assigned to

Visualization of hits & trajectories

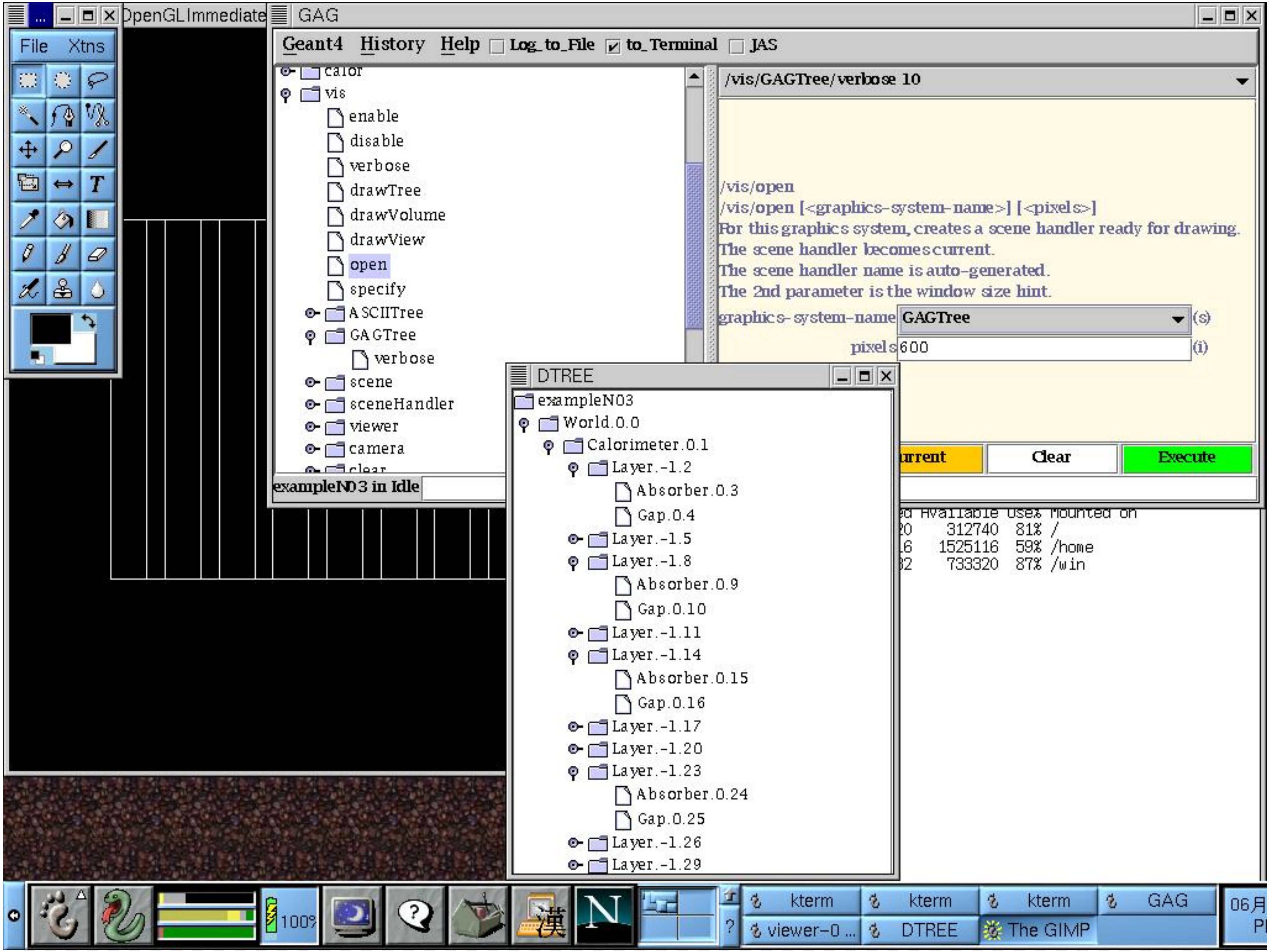
- Each **`G4VHit`** concrete class must have an implementation of ***`Draw()`*** method.
  - Colored marker
  - Colored solid
  - Change the color of detector element
- **`G4Trajectory`** class has a ***`Draw()`*** method.
  - Blue : positive
  - Green : neutral
  - Red : negative
  - You can implement alternatives by yourself

GGE (Graphical Geometry Editor)

- Implemented in JAVA, GGE is a graphical geometry editor compliant to Geant4. It allows to:
  - Describe a detector geometry including:
    - materials, solids, logical volumes, placements
  - Graphically visualize the detector geometry using a Geant4 supported visualization system, e.g. DAWN
  - Store persistently the detector description
  - Generate the C++ code according to the Geant4 specifications
- GGE is provided as a separate tool in Geant4
  - As part of the MOMO Java environment suite
  - `geant4/environments/MOMO/MOMO.jar`

Visualizing detector geometry tree

- Built-in commands defined to display the hierarchical geometry tree
  - As simple ASCII text structure
  - Graphical through GUI (combined with GAG)
  - As XML exportable format
- Implemented in the visualization module
  - As an additional graphics driver
- G3 DTREE capabilities provided and more



OpenGLImmediate
File Xtns
GAG
Geant4 History Help Log_to_File to_Terminal JAS
calor
vis
enable
disable
verbose
drawTree
drawVolume
drawView
open
specify
ASCIITree
GAGTree
verbose
scene
sceneHandler
viewer
camera
clear
exampleN03 in Idle
/vis/GAGTree/verbose 10
/vis/open
/vis/open [<graphics-system-name>] [<pixels>]
For this graphics system, creates a scene handler ready for drawing.
The scene handler becomes current.
The scene handler name is auto-generated.
The 2nd parameter is the window size hint.
graphics-system-name GAGTree (s)
pixels 600 (i)
Clear
Execute
DTREE
exampleN03
World.0.0
Calorimeter.0.1
Layer.-1.2
Absorber.0.3
Gap.0.4
Layer.-1.5
Layer.-1.8
Absorber.0.9
Gap.0.10
Layer.-1.11
Layer.-1.14
Absorber.0.15
Gap.0.16
Layer.-1.17
Layer.-1.20
Layer.-1.23
Absorber.0.24
Gap.0.25
Layer.-1.26
Layer.-1.29
312740 81% /
1525116 59% /home
733320 87% /win
kterm
kterm
kterm
GAG
viewer-0 ...
DTREE
The GIMP
100%

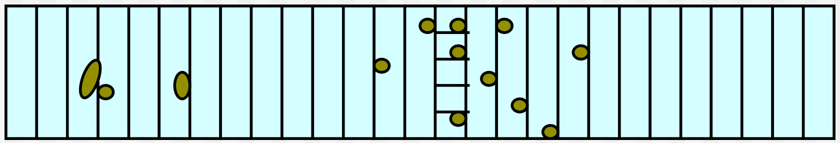
PART IV

Optimisation Techniques

- *Smart voxels*

Smart voxels

- For each mother volume
  - a one-dimensional virtual division is performed
    - the virtual division is along a chosen axis
    - the axis is chosen by using an heuristic
  - Subdivisions (slices) containing same volumes are gathered into one
  - Subdivisions containing many volumes are refined
    - applying a virtual division again using a second Cartesian axis
    - the third axis can be used for a further refinement, in case
- *Smart voxels* are computed at initialisation time
  - When the detector geometry is *closed*
  - Do not require large memory or computing resources
  - At tracking time, searching is done in a hierarchy of virtual divisions



Detector description tuning

- Some geometry topologies may require ‘special’ tuning for ideal and efficient optimisation
  - for example: a dense nucleus of volumes included in very large mother volume
- Granularity of voxelisation can be explicitly set
  - Methods `Set/GetSmartless()` from `G4LogicalVolume`
- Critical regions for optimisation can be detected
  - Helper class `G4SmartVoxelStat` for monitoring time spent in detector geometry optimisation
    - Automatically activated if `/run/verbose` greater than `1`

```
Percent      Memory    Heads    Nodes   Pointers    Total CPU    Volume
-------      ------    -----    -----   --------    ---------    -----------
  91.70          1k        1       50         50         0.00    Calorimeter
   8.30          0k        1        3          4         0.00    Layer
```

Visualising voxel structure

- The computed voxel structure can be visualized with the final detector geometry
  - Helper class **`G4DrawVoxels`**
  - Visualize voxels given a logical volume
    - `G4DrawVoxels::DrawVoxels(const G4LogicalVolume*)`
  - Allows setting of visualization attributes for voxels
    - `G4DrawVoxels::SetVoxelsVisAttributes(…)`
  - useful for debugging purposes
  - Can also be done through a visualization command at run-time:
    - `/vis/scene/add/logicalVolume <logical-volume-name> [<depth>]`

Customising optimisation

- Detector regions may be excluded from optimisation (ex. for debug purposes)
  - Optional argument in constructor of `G4LogicalVolume` or through provided set methods
    - `SetOptimisation/IsToOptimise()`
  - Optimisation is turned on by default
- Optimisation for parameterised volumes can be chosen
  - Along one single Cartesian axis
    - Specifying the axis in the constructor for `G4PVParameterised`
  - Using 3D voxelisation along the 3 Cartesian axes
    - Specifying in `kUndefined` in the constructor for `G4PVParameterised`

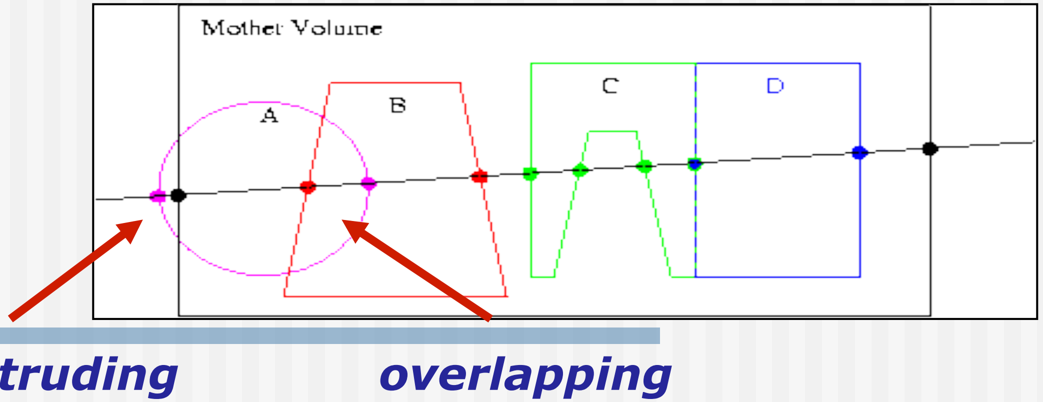
PART IV

Debugging geometries

Debugging tools

- *Optional checks at Construction*
- *DAVID*
- *Run-time commands*
- *OLAP*

Debugging geometries



- An ***overlapping* volume** is a contained volume which actually protrudes from its mother volume
  - Volumes are also often positioned in a same volume with the intent of not provoking intersections between themselves. When volumes in a common mother actually intersect themselves are defined as overlapping
- Geant4 **does not allow** for malformed geometries
- The problem of detecting overlaps between volumes is bounded by the complexity of the solid models description
- Utilities are provided for detecting wrong positioning
  - Graphical tools
  - Kernel run-time commands

Debugging tools:
Overlapping check at Construction

- Constructors of **`G4PVPlacement`** and **`G4PVParameterised`** have an optional argument **`pSurfChk`**:

```
G4PVPlacement(G4RotationMatrix* pRot, …, G4bool pSurfChk=false);
```

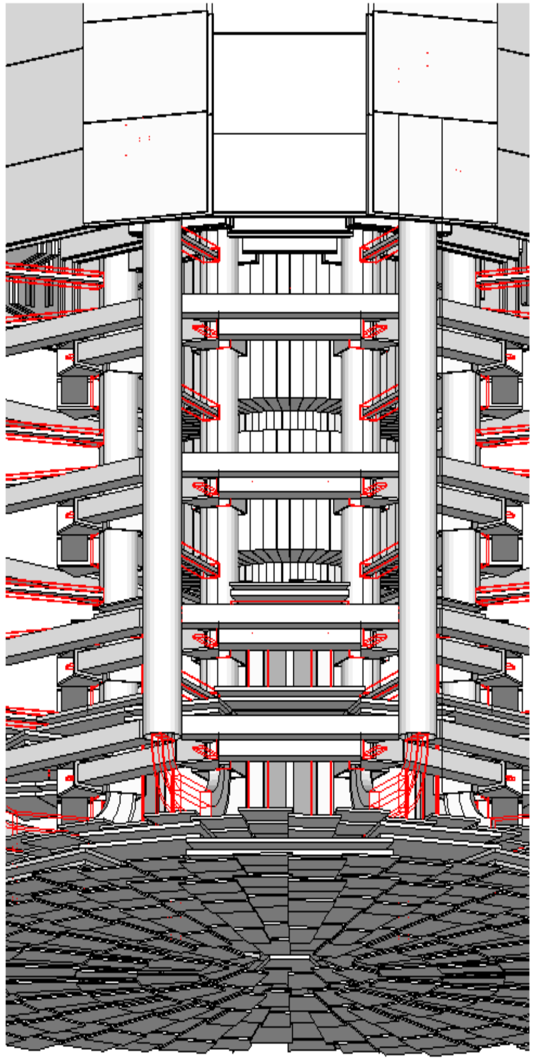
- If this flag is true, overlap check is done at construction
  - A number of points (1000 by default) are randomly sampled on the surface of the volume being created
  - Each of these points are examined
    - if outside of the mother volume, or
    - if inside of already existing other volumes in the same mother volume
  - NOTE: this check may requires lots of **CPU time**
    - Depending on the complexity of geometry
  - Can also be forced on a specific physical volume though the method:

```
G4bool CheckOverlaps(G4int points=1000, G4double tol=0, G4bool verbose=true);
```

- <u>**Worth to try** when first implementing a geometry of some complexity</u> !

Debugging tools: DAVID

- DAVID is a graphical debugging tool for detecting potential intersections of volumes
- Accuracy of the graphical representation can be tuned to the exact geometrical description.
  - physical-volume surfaces are automatically decomposed into 3D polygons
  - intersections of the generated polygons are parsed.
  - If a polygon intersects with another one, the physical volumes associated to these polygons are highlighted in color (red is the default).
- DAVID can be downloaded from the Web as external tool for Geant4
  - http://geant4.kek.jp/GEANT4/vis/DAWN/About_DAVID.html



Debugging run-time commands

- Built-in run-time commands to activate verification tests for the user geometry. Tests can be applied recursively to all depth levels (may require CPU time!): `[recursion_flag]`

`geometry/test/run [recursion_flag]` or

`geometry/test/grid_test [recursion_flag]`

- to start verification of geometry for overlapping regions based on a standard grid setup

`geometry/test/cylinder_test [recursion_flag]`

- shoots lines according to a cylindrical pattern

`geometry/test/line_test [recursion_flag]`

- to shoot a line along a specified direction and position

`geometry/test/position` and `geometry/test/direction`

- to specify position & direction for the `line_test`

- Resolution/dimensions of grid/cylinders can be tuned

Debugging run-time commands - 2

- Example layout:

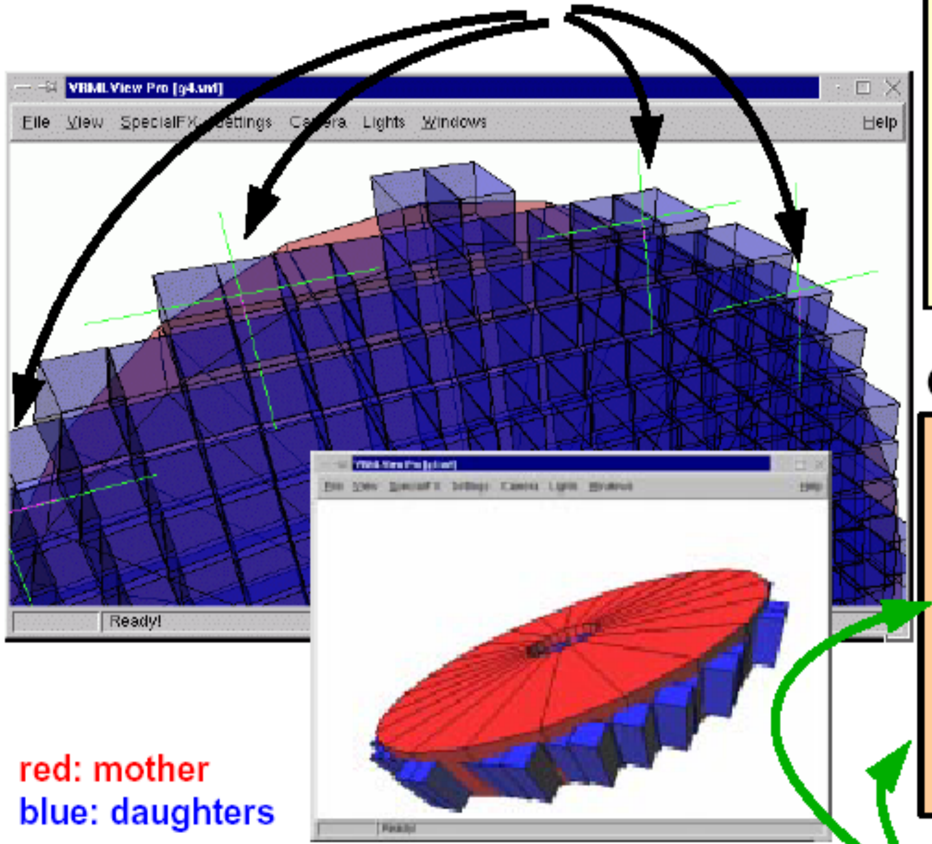
```
GeomTest: no daughter volume extending outside mother detected.
GeomTest Error: Overlapping daughter volumes
    The volumes Tracker[0] and Overlap[0],
    both daughters of volume World[0],
    appear to overlap at the following points in global coordinates: (list truncated)
  length (cm)    ----- start position (cm) -----   ----- end position (cm) -----
    240           -240      -145.5      -145.5     0       -145.5      -145.5
Which in the mother coordinate system are:
  length (cm)    ----- start position (cm) -----   ----- end position (cm) -----
    . . .
Which in the coordinate system of Tracker[0] are:
  length (cm)    ----- start position (cm) -----   ----- end position (cm) -----
    . . .
Which in the coordinate system of Overlap[0] are:
  length (cm)    ----- start position (cm) -----   ----- end position (cm) -----
    . . .
```

Debugging tools: OLAP

- Adopt tracking of neutral particles to verify boundary crossing in opposite directions
- Stand-alone batch application
  - Provided as extended example
  - Can be combined with a graphical environment and GUI
    - ex. Qt library
  - Integrated in the CMS Iguana Framework

Debugging tools: OLAP

graphical indication of
detected overlaps



red: mother
blue: daughters

daughters are protruding their mother

Geant4 Macro:

```
/vis/scene/create
/vis/sceneHandler/create VRML2FILE
/vis/viewer/create
/olap/goto ECalEnd
/olap/grid 7 7 7
/olap/trigger
/vis/viewer/update
```

Output:

```
delta=59.3416
vol 1: point=(560.513,1503.21,-141.4)
vol 2: point=(560.513,1443.86,-141.4)
A -> B:
[0]:  ins=[2]  PVName=[NewWorld:0] Type=[N] ...
[1]:  ins=[0]  PVName=[ECalEndcap:0] Type=[N] ..
[2]:  ins=[1]  PVName=[ECalEndcap07:38] Type=[N]

B -> A:
[0]:  ins=[2]  PVName=[NewWorld:0] Type=[N] ...
```

NavigationHistories of points of overlap
(including: info about translation, rotation, solid specs)