Geant 4

Visualisation, (G)UI and Analysis

http://cern.ch/geant4

The full set of lecture notes of this Geant4 Course is available at
http://www.ge.infn.it/geant4/events/nss2003/geant4course.html

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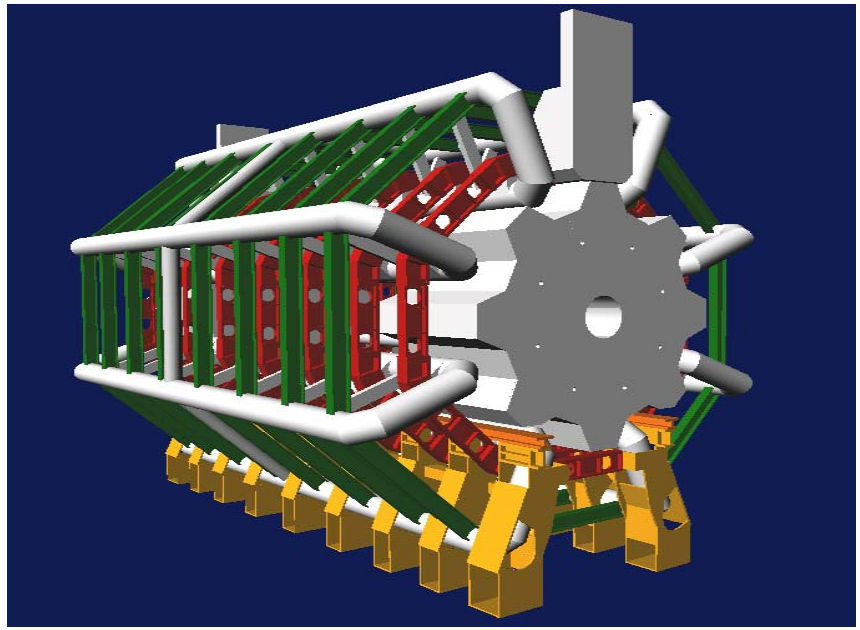
PART 1

Geant4 Visualisation



1. Introduction

- Geant4 Visualisation must respond to varieties of user requirements
  - Quick response to survey successive events
  - Impressive special effects for demonstration
  - High-quality output to prepare journal papers
  - Flexible camera control for debugging geometry
  - Highlighting overlapping of physical volumes
  - Interactive picking of visualised objects
  - …

2. Visualisable Objects (1)

- Simulation data can be visualised such as:
  - Detector components
  - A hierarchical structure of physical volumes
  - A piece of physical volume, logical volume, and solid
  - Particle trajectories and tracking steps
  - Hits of particles in detector components
- Visualisation is performed either with commands or by writing C++ source codes of user-action classes

2. Visualisable Objects (2)

- You can also visualise other user defined objects such as:
  - A polyline, that is, a set of successive line segments (example: coordinate axes)
  - A marker which marks an arbitrary 3D position (example: eye guides)
  - Texts
    - character strings for description
    - comments or titles …

3. Visualisation Attributes

- Necessary for visualisation, but not included in geometrical information
  - Colour, visibility, forced-wireframe style, etc
  - A set of visualisation attributes is held by the class `G4VisAttributes`
- A `G4VisAttributes` object is assigned to a visualisable object with its method `SetVisAttributes()`:
  - `experimentalHall_logical`

    `-> SetVisAttributes (G4VisAttributes::Invisible)`

3.1 Constructors of `G4VisAttributes`

The following constructors are supported by class `G4VisAttributes`:

- `G4VisAttributes G4VisAttributes ()`
- `G4VisAttributes (G4bool visibility)`
- `G4VisAttributes (const G4Colour& colour)`
- `G4VisAttributes (G4bool visibility,`
  `const G4Colour& colour)`

3.2 Visibility

- A boolean flag (`G4bool`) to control the visibility of objects
- Access function
  - `G4VisAttributes::SetVisibility (G4bool visibility)`
  - If `false` is given as argument, visualisation is skipped for objects for which this set of visualisation attributes is assigned.
    The default value of visibility is `true`.

3.3 Colour (1)

- Class `G4VisAttributes` holds its colour entry as an instance of class `G4Colour`
  - An equivalent class name, `G4Color`, is also available
- `G4Colour` is instantiated by giving RGB components to its constructor:
  - `G4Colour::G4Colour(G4double r = 1.0,`
    `G4double g = 1.0,`
    `G4double b = 1.0 )`
  - `0.0 <= r,g,b <= 1.0`
  - The default arguments define “white” color

3.3 Colour (2)

- Access functions of `G4VisAttributes` to set `G4Colour`
  - `SetColour(const G4Colour& colour)`
  - `SetColour( G4double r ,`
    `G4double g ,`
    `G4double b)`

3.4 Assigning `G4VisAttributes` to a logical volume

- Class `G4LogicalVolume` holds a pointer of `G4VisAttributes`
- Access functions of `G4LogicalVolume`
  - `SetVisAttributes (`
    `const G4VisAttributes* pva )`

Sample C++ Code:

//----- C++ source codes: Assigning G4VisAttributes to a logical volume

```
// Instantiation of a logical volume
myTargetLog =
    new G4LogicalVolume( myTargetTube,BGO,
                         "TLog", 0, 0, 0);
// Instantiation of a set of visualization
// attributes with cyan colour
G4VisAttributes * calTubeVisAtt =
    new G4VisAttributes(G4Colour(0.,1.,1.));
// Set the forced wireframe style
calTubeVisAtt->SetForceWireframe(true);
// Assignment of the visualization attributes
// to the logical volume
myTargetLog->SetVisAttributes(calTubeVisAtt);
```

4. Polyline and Marker

- Polyline and marker are defined in the graphics_reps category
- They are available to model 3D scenes for visualisation

4.1 Polyline

- A set of successive line segments
- Defined with a class `G4Polyline`
- Used to visualise tracking steps, particle trajectories, coordinate axes, etc
- `G4Polyline` is defined as a list of `G4Point3D` objects. Elements of the list define vertex positions of a polyline.

Sample C++ Code:

```
//-- C++ source code: An example of defining a line segment

// Instantiation
  G4Polyline x_axis;

//    Vertex positions
  x_axis.append ( G4Point3D ( 0., 0., 0.) );
  x_axis.append ( G4Point3D ( 5. * cm, 0., 0.) );

//    Color
  G4Colour red ( 1.0, 0.0, 0.0 ); // color for x-axis
  G4VisAttributes att ( red );
  x_axis.SetVisAttributes( att );

//-- end of C++ source code
```

4.2 Marker (1)

- Set a mark to an arbitrary 3D position
- Usually used to visualise hits of particles
- Designed as a 2-dimensional primitive with shape (square, circle, etc), color, and special properties of
  - (a) always facing the camera and
  - (b) having the possibility of its size (diameter) defined either in real 3D or 2D screen units (pixels)

4.2 Marker (2)

- Kinds of markers
  - Square : `G4Square`
  - Circle : `G4Circle`
  - Text : `G4Text`
- Constructors
  - `G4Circle (const G4Point3D& pos)`
  - `G4Square (const G4Point3D& pos)`
  - `G4Text (const G4String& text, const G4Point3D& pos)`

4.2 Marker (3)

- Each marker class inherits class `G4VMarker`
- All access functions of `G4VMarker` are available. For example,
  - `SetPosition( const G4Point3D& )`
  - `SetWorldSize( G4double real_3d_size )`
  - `SetScreenSize( G4double 2d_size_pixel )`
  - etc.

Sample C++ Code:

Definition of a small red circle as a marker :

```
G4Circle circle(position);
 // Instantiate a circle with its 3D position. The
 // argument "position" is defined as G4Point3D instance
circle.SetScreenDiameter (1.0);
circle.SetFillStyle (G4Circle::filled);
 // Make it a filled circle
G4Colour colour(1.,0.,0.);          // Define red color
G4VisAttributes attribs(colour);
 // Define a red visualization attribute
circle.SetVisAttributes(attribs);
 // Assign the red attribute to the circle
//-- end of C++ source code
```

5. Visualisation Drivers

- Visualisation drivers are interfaces to 3D graphics software
- You can select your favorite one(s) depending on your purposes such as
  - Demo
  - Preparing precise figures for journal papers
  - Publication of results on Web
  - Debugging geometry
  - Etc

5.1 Available Graphics Software

- Geant4 provides visualisation drivers:
  - DAWN : Technical High-quality PostScript output
  - OPACS: Interactivity, unified GUI
  - OpenGL: Quick and flexible visualisation
  - OpenInventor: Interactivity, virtual reality, etc
  - RayTracer : Photo-realistic rendering
  - VRML: Interactivity, 3D graphics on Web

5.2 Available Visualisation Drivers

- DAWN → Fukui Renderer DAWN
- OPENGLX → OpenGL with Xlib
- HepRep → HepRep graphics
- OIX → OpenInventor with Xlib
- RayTracer → JPEG files
- VRML → VRML 1.0/2.0
- etc

5.3 How to Use Visualisation Drivers

- Users can select/use visualisation driver(s) by setting environmental variables before compilation:
  - setenv G4VIS_USE_DRIVERNAME 1
- Example (DAWN, OpenGLXlib, and VRML drivers):
  - setenv G4VIS_USE_DAWN 1
  - setenv G4VIS_USE_OPENGLX 1
  - setenv G4VIS_USE_VRML 1
- Note that Geant4 library should be installed with setting the corresponding environmental variables G4VIS_BUILD_DRIVERNAME_DRIVER to “1” beforehand , e.g.,
  - setenv G4VIS_BUILD_DAWN_DRIVER 1

6. main() Function (1)

- Derive your own concrete class from `G4VisManager` according to your computer environments
- Describe the followings in the `main()` :
  - Include the header file of the chosen visualisation manager
  - Instantiate and initialize the visualisation manager. The `Initialize()` method do the initialization
  - Delete the visualisation manager at the end
- You can use the C macro "`G4VIS_USE`", which is automatically set if you incorporate a visualisation driver in compilation

6. main() Function (2)

- A typical form of main( ) function :

```
// Include the header file of your
// visualisation manager
  #ifdef G4VIS_USE
    #include “ExN03VisManager.hh”
  #endif
// Instantiate and initialize the
// visualisation manager
  #ifdef G4VIS_USE
    G4VisManager* visManager = new ExN03VisManager;
    visManager->Initialize();
  #endif
// Delete the visualisation manager
  #ifdef G4VIS_USE
    delete visManager;
  #endif
```

7. Visualisation commands

- Here, we introduce some frequently-used built-in visualisation commands
- For simplicity, we assume that the Geant4 executable is compiled, incorporating DAWN, OPENGLX, and VRML drivers
  - `setenv G4VIS_USE_DAWN    1`
  - `setenv G4VIS_USE_OPENGLX 1`
  - `setenv G4VIS_USE_VRML    1`

7.1 Scene, Scene Hander, Viewer

- In order to use visualisation commands, ideas of "scene", "scene handler", and "viewer" must be understood.
- **Scene**: *A set of visualizable 3D data*
- **Scene handler**: *Computer Graphics data modeler, which uses raw data in a scene*
- **Viewer**: *Image generator*
- Each scene handler is assigned to a scene
- Each viewer is assigned to a scene handler
- "visualisation driver"
  = "scene_handler" + "viewer"

7.2 Steps of Visualisation

- Step 1: Create a scene handler and a viewer
- Step 2: Create an empty scene
- Step 3: Add 3D data to the created scene
- Step 4: Attach the current scene handler to the current scene
- Step 5: Set camera parameters, drawing style (wireframe/surface), etc
- Step 6: Make the viewer execute visualisation
- Step 7: Declare the end of visualisation

7.3 An Example of Visualising Detector

```
# Invoke the OGLIX driver:
# Create a scene handler and a viewer.
  /vis/open OGLIX
# Set camera and drawing style
  /vis/viewer/reset
  /vis/viewer/viewpointThetaPhi 70 20
  /vis/viewer/set/style    wireframe
# Visualize of the whole detector geometry
# The "/vis/drawVolume"  create a scene, add the
# world volume to it, and let viewer execute
# visualisation.
  /vis/drawVolume
# Declare the end of visualisation
  /vis/viewer/update
```

7.4 An Example of Visualizing Events

```
# Store particle trajactories for visualisation
  /tracking/storeTrajectory
# Invoke the DAWN driver: Create a scene
# handler and a viewer.
  /vis/open DAWN
# Camera setting, and drawing style selection,
# if necessary …

# Create a new empty scene
  /vis/scene/create
# Add the world volume and trajectories to the
# current scene
  /vis/scene/add/volume
  /vis/scene/add/trajectories
# Let the viewer visualise the scene, and declare
# the end of visualisation
  /run/beamOn 10
```

7.5 /vis/open Command

- Command
  - `Idle> /vis/open <driver_tag_name>`
  - The “driver_tag_name” is a name which shows “driver name” + “mode”
- Action: Create a visualisation driver
  - In other words, create a scene hander and a viewer
- Example: Creating the OPENGLX driver in the immediate mode:
  - `Idle> /vis/open OGLIX`
- How to list available driver_tag_name
  - `Idle> help /vis/open`
    or
    `Idle> help /vis/sceneHandler/create`

7.6 /vis/viewer/… Commands

- Commands
  - Viewpoint setting:
    ```
    Idle> /vis/viewer/viewpointThetaPhi
                <theta_deg> <phi_deg>
    ```
  - Zooming
    ```
    Idle> /vis/viewer/zoom <scale_factor>
    ```
  - Initialization of camera parameters:
    ```
    Idle> /vis/viewer/reset
    ```

7.7 /vis/viewer/set/style Command

- Command
  - `Idle> /vis/viewer/set/style <style_name>`
  - The “style_name” can be “wireframe” or “surface”

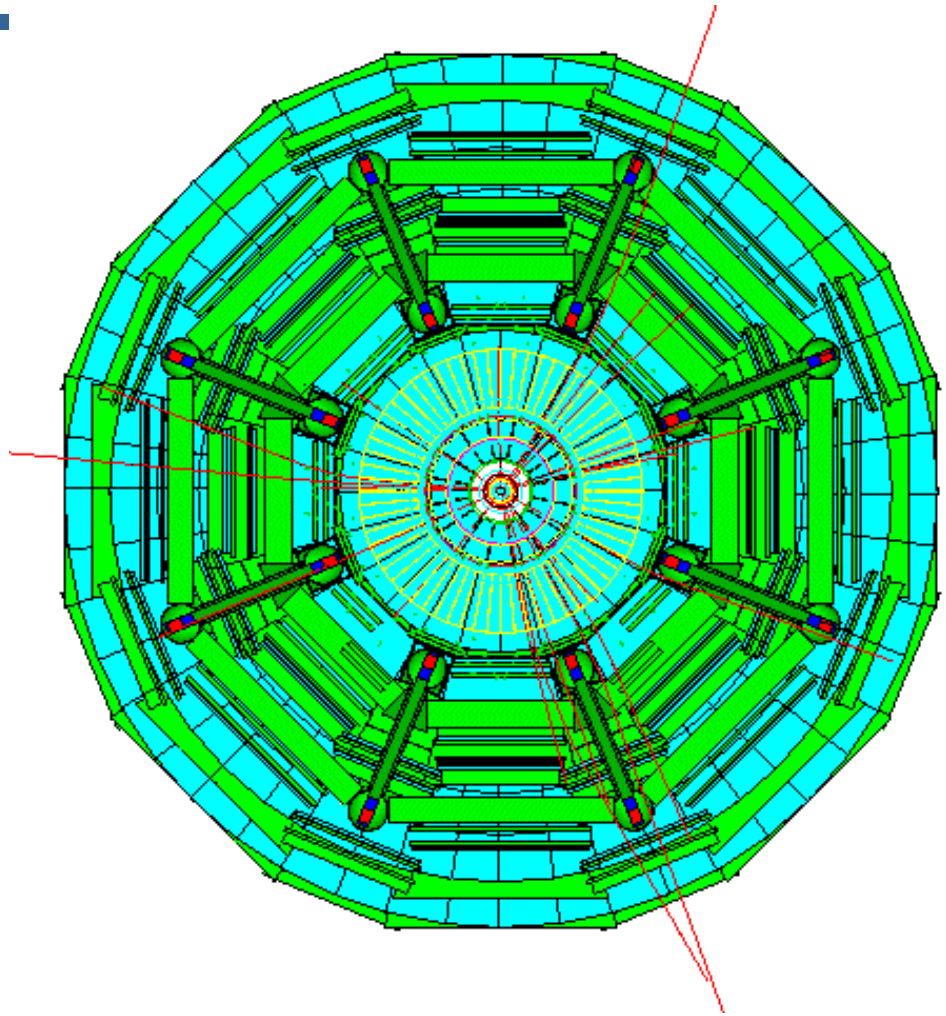
7.8 /vis/drawVolume and /vis/viewer/update Commands

- Commands:
  - `Idle> /vis/drawVolume <physical-volume-name>`
    `(Default: world)`
    `Idle> /vis/viewer/update`
  - Note that `/vis/viewer/update` should be executed to declare end of visualisation.
- You can add visualisation commands of, say, coordinate axes between the two commands. For example,
  - `Idle> /vis/drawVolume`
    `Idle> /vis/scene/add/axes <Ox> <Oy> <Oz>`
    `<length> <unit>`
  - `Idle> /vis/viewer/update`

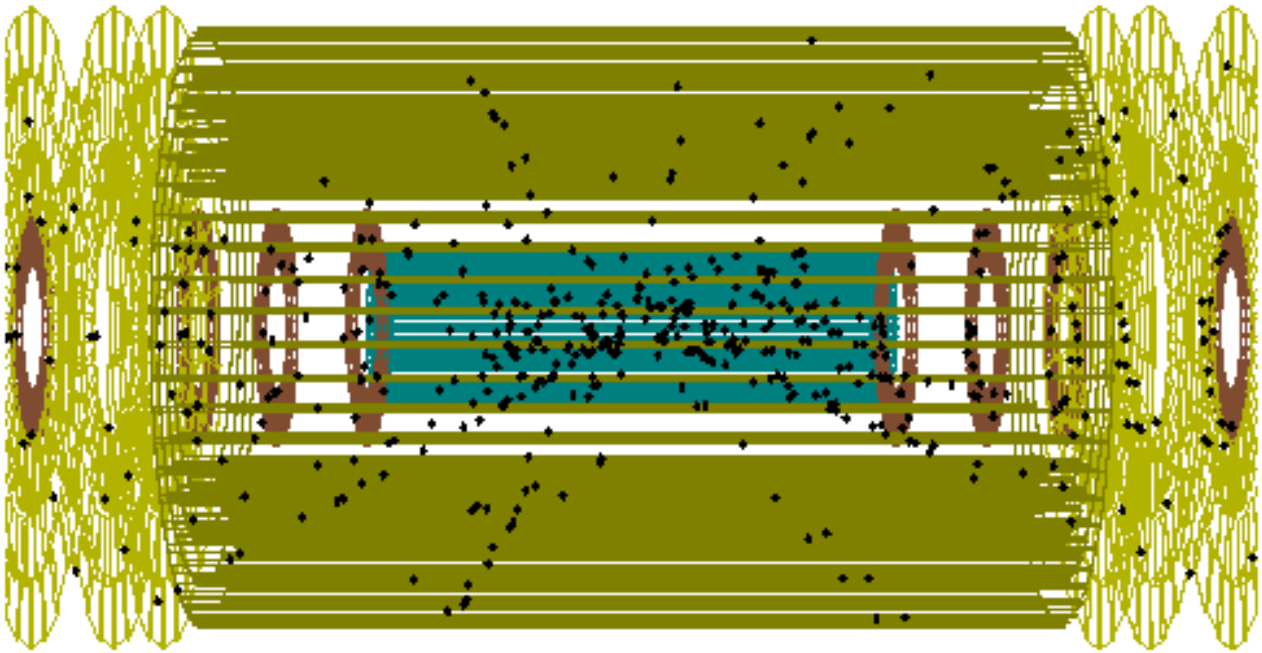
7.9 Commands to Visualize Events

- Commands
  - `Idle> /tracking/storeTrajectory 1`
    `Idle> /vis/scene/add/trajectories`
    `Idle> /run/beamOn <number_of_events>`
- Action:
  - Automatic visualisation of events

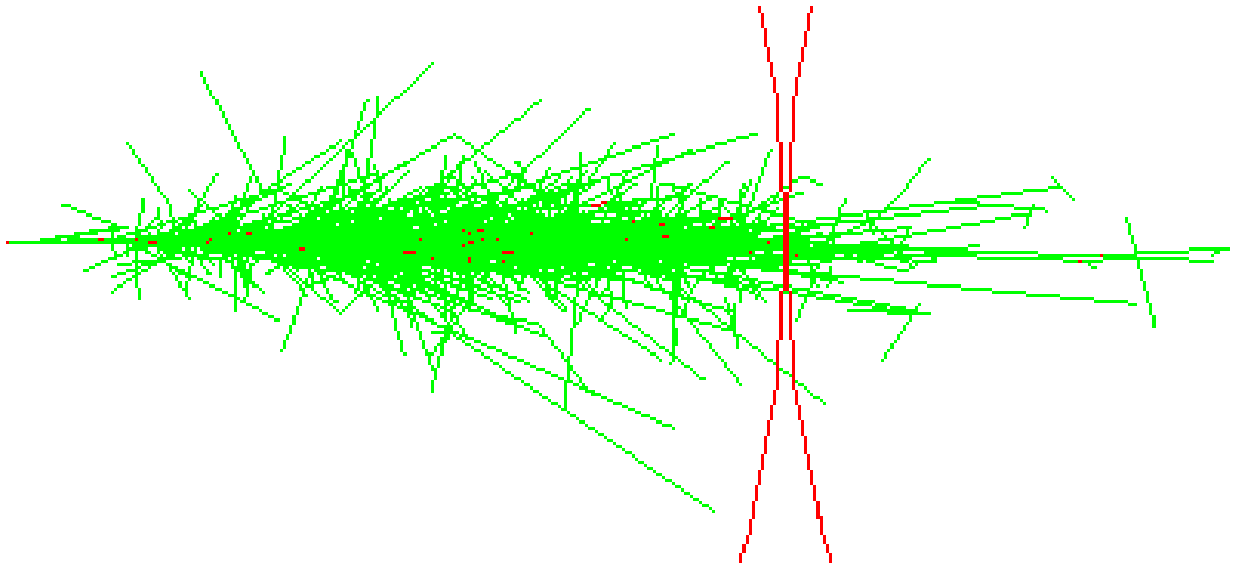
Sample Visualisation (1)



Sample Visualisation (2)



Sample Visualisation (3)



8. Visualisation from C++ codes

- It is also possible to perform visualisation from the C++ code
- You can describe the visualisation commands in C++ codes via the `ApplyCommand()` method of the UI manager, as for any other command:
  - `pUI->ApplyCommand("/vis/…");`
- Or you can use `Draw()` methods of visualizable classes

9. Exercises

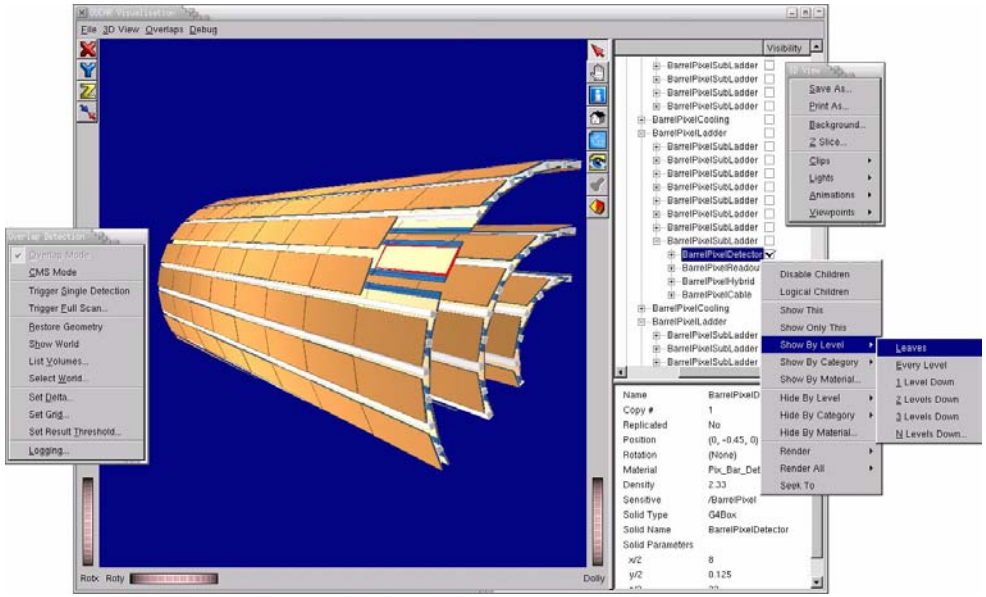
- Read and execute sample visualisation macros for examples/novice/N03
  - The macro files are “exN03VisX.mac”, where X=0,1,2,…
  - Explanation of macros is all described in the macro files as comment lines

10. Information

- Geant4 User Guide (and source codes)
- README file:
  - geant4/source/visualisation/README
- On-line documentation on Geant4 visualisation
  - http://cern.ch/geant4/G4UsersDocuments/UsersGuides/ForApplicationDeveloper/html/Visualization

PART 2

Geant4 GUI



1. Select (G)UI (1)

- In the `main()`, according to the computer environments, construct a `G4UIsession` concrete class provided by Geant4 and invoke its `sessionStart()` method.
- Example:
  - ```
    G4UIsession* session=0;
    if (argc==1)
    // Define UI session for interactive mode.
    {
       // G4UIterminal is a (dumb) terminal
       session = new G4UIterminal;
    }
    ```
    ```

1. Select (G)UI (2)

- Geant4 provides the following interfaces for various (G)UI:
  - **G4UIterminal**: C-shell like character terminal
  - **G4UItcsh**: tcsh-like character terminal with command completion, history, etc
  - **G4UIGAG**: Java based GUI
  - **G4UIXm**: Motif-based GUI, command completion, etc
- Note for G4UItcsh:
  - Use G4UIterminal with argument G4UItcsh* :

```
session = new G4UIterminal (new G4UItcsh);
```

2. Environmental Variables

- Users can select and plug in (G)UI by setting environmental variables before compilation
  - `setenv G4UI_USE_GUINAME`
- Example:
  - `setenv G4UI_USE_TERMINAL  1`
  - `setenv G4UI_USE_GAG  1`
  - `setenv G4UI_USE_XM  1`
- Note that Geant4 library should be installed with setting the corresponding environmental variable `G4VIS_BUILD_GUINAME_SESSION` to “1” beforehand

3. Useful GUI Tools Released by Geant4 Developers

- **GGE**: Geometry editor based on Java GUI
  - http://erpc1.naruto-u.ac.jp/~geant4
- **GPE**: Physics editor based on Java GUI
  - http://erpc1.naruto-u.ac.jp/~geant4
- OpenScientist: Interactive environment
  - http://www.lal.in2p3.fr/OpenScientist

PART 3

Geant4
DAVID & DTREE

1. Volume-Overlapping Detection with DAVID (1)

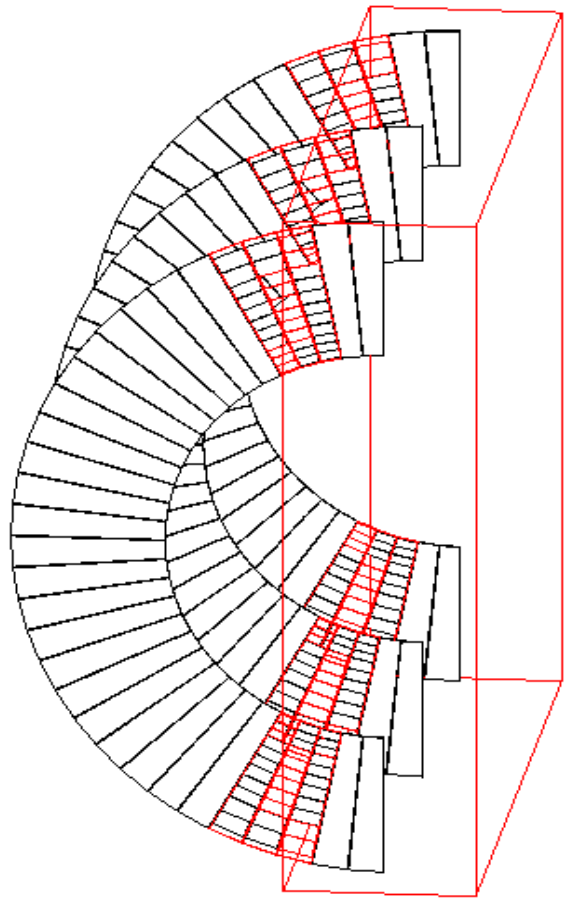
- DAVID (DAWN-based Visual Volume Intersection Debugger)
  - Automatically detects and highlights overlapping volumes
    - Precise visualization with DAWN
    - Interactive visualisation with VRML
  - DAVID also generates log files describing detailed information on the detected overlaps
  - Info & source:
    - http://geant4.kek.jp/~tanaka

1. Volume-Overlapping Detection with DAVID (2)

- Usage of DAVID
  - Switch the viewer of the DAWNFILE driver from renderer DAWN (default) to DAVID.
    - `setenv G4DAWNFILE_VIEWER david`
  - Then visualize volumes as usual with the DAWNFILE driver
  - Overlapping volumes (if any) are visualized
    - The view is stored in files `g4david.prim` (DAWN format) and `g4david.eps` (PostScript format)
    - Log file: `g4david.log`

1. Volume-Overlapping Detection with DAVID (3)

- Sample visualisation with overlapping volumes highlighted



1. Volume-Overlapping Detection with DAVID (4)

- Log file format
  - `PhysVolName.CopyNo Shape line_num`
  - The "line_num" is the line number of the overlapping volume in the DAWN-fomat file "g4.prim file" generated by Geant4
- Sample log file :

```
.....
!!! INTERSECTED VOLUMES !!!
caloPhys.0: Tubs: line 17
caloPhys.1: Tubs: line 25
.....
```

1. Volume-Overlapping Dection with DAVID (5)

- If no overlaps are detected, DAVID displays the following message:

```
-------------------------------------------------
!!! Number of intersected volumes : 0  !!!
!!! Congratulations ! \(^o^)/ !!!
-------------------------------------------------
```

2. DTREE:Visualising Detector Geometry Tree (1)

- DTREE is the function to visualise detector-geometry tree.
- Selection of outputs:
  - ASCII-text format
  - GAG-window
  - XML file
- How to display a tree:
  - `Idle> /vis/drawTree ! XXXTree`
    `(XXX = ATree, GAGTree, XMLTree, etc)`

2. DTREE:Visualising Detector Geometry Tree (2)

- How to display a tree:
  - `Idle> /vis/drawTree ! XXXTree`
  - XXX = ATree, GAGTree, XMLTree, etc
- Detail level is controlled with the "verbose" command:
  - /vis/XXXTree/verbose n

2. DTREE:Visualising Detector Geometry Tree (3-1)

- ASCII Tree (ATree) : verbose level 0 (default)

Format: PV_name + copy_number

```
World
  "Calorimeter", copy no. 0
    "Layer", copy no. -1 (10 replicas)
      "Absorber", copy no. 0
        "Gap", copy no. 0
```

2. DTREE:Visualising Detector Geometry Tree (3-2)

- ASCII Tree (ATree) : verbose level 1

Format: PV_name + copy_number + LV_name

"World", copy no. 0, belongs to logical volume "World"
 "Calorimeter", copy no. 0, belongs to logical volume "Calorimeter"
  "Layer", copy no. -1, belongs to logical volume "Layer" (10 replicas)
   "Absorber", copy no. 0, belongs to logical volume "Absorber"
   "Gap", copy no. 0, belongs to logical volume "Gap"

2. DTREE:Visualising Detector Geometry Tree (3-3)

- ASCII Tree (ATree) : verbose level 2

Format: PV_name + copy_number + LV_name
+ solid_name + solid_type

```
"World", copy no. 0, belongs to logical volume "World" and is composed of solid "World" of type "G4Box"
  "Calorimeter", copy no. 0, belongs to logical volume "Calorimeter" and is composed of solid "Calorimeter" of type "G4Box"
    "Layer", copy no. -1, belongs to logical volume "Layer" and is composed of solid "Layer" of type "G4Box" (10 replicas)
      "Absorber", copy no. 0, belongs to logical volume "Absorber" and is composed of solid "Absorber" of type "G4Box"
      "Gap", copy no. 0, belongs to logical volume "Gap" and is composed of solid "Gap" of type "G4Box"
```

2. DTREE:Visualising Detector Geometry Tree (3-4)

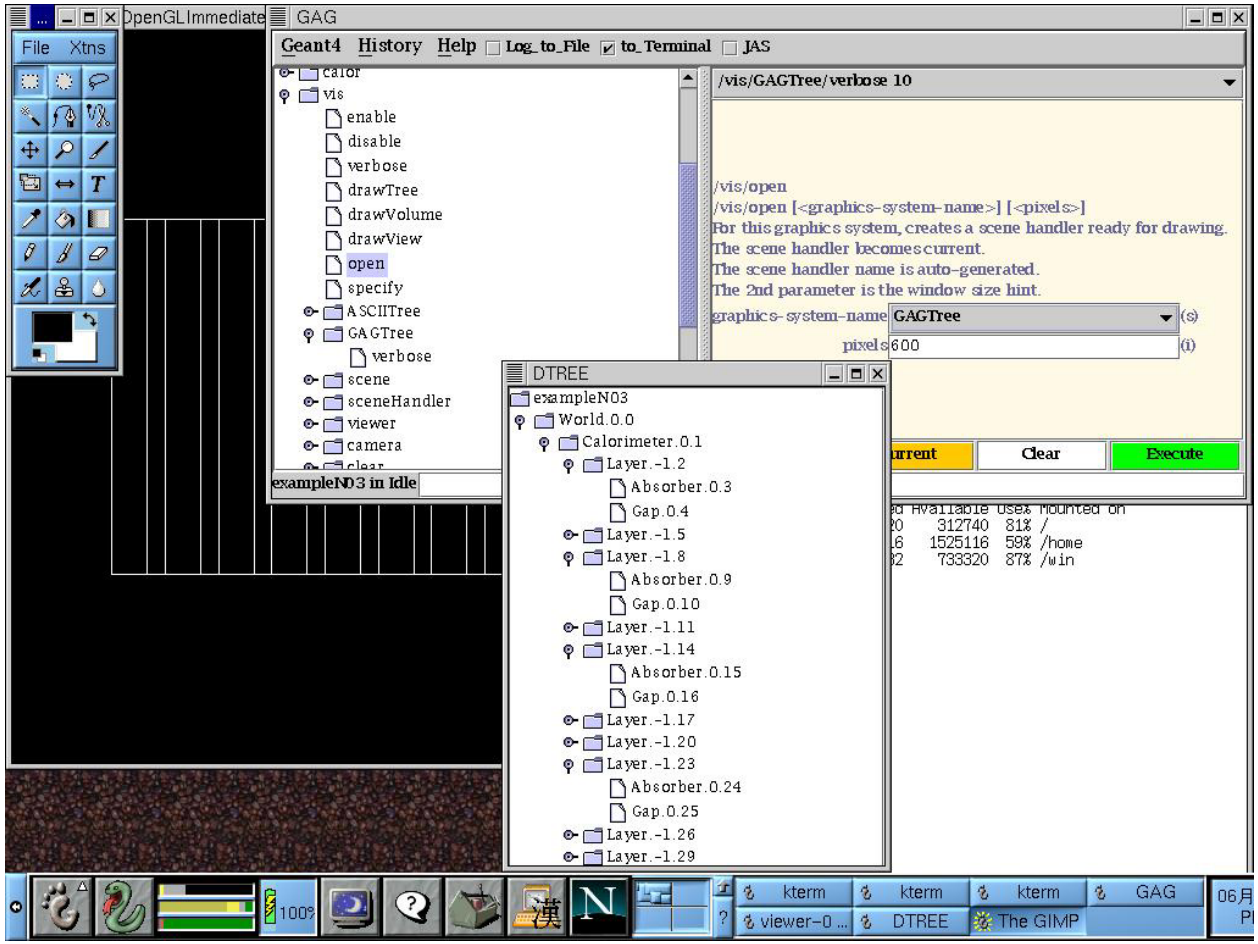
- ASCII Tree (ATree) : verbose level 10

Format: PV_name + copy_number (replicas etc. expanded)

```
"World", copy no. 0
  "Calorimeter", copy no. 0
    "Layer", copy no. -1
      "Absorber", copy no. 0
      "Gap", copy no. 0    "Layer", copy no. -1
   "Layer", copy no. -1
      "Absorber", copy no. 0
      "Gap", copy no. 0    "Layer", copy no. -1
    …..
```

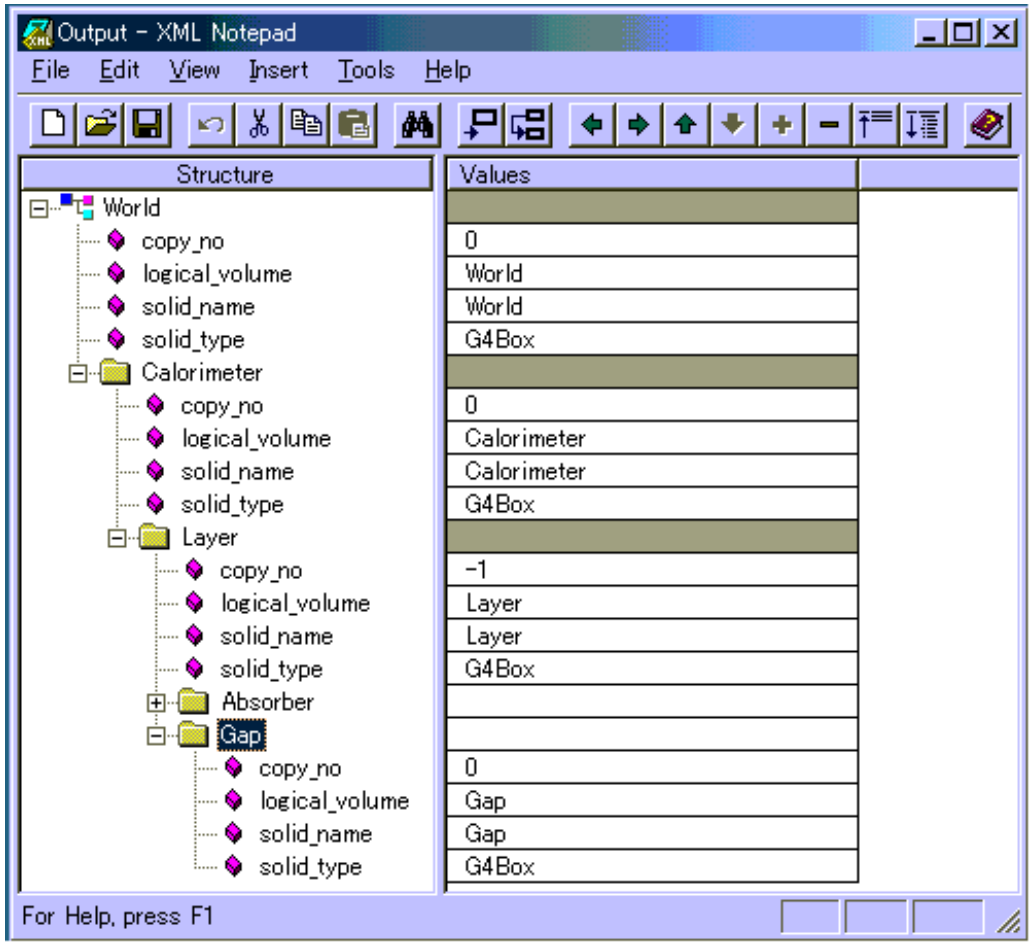
2. DTREE:Visualising Detector Geometry Tree (4)

- GAG Tree



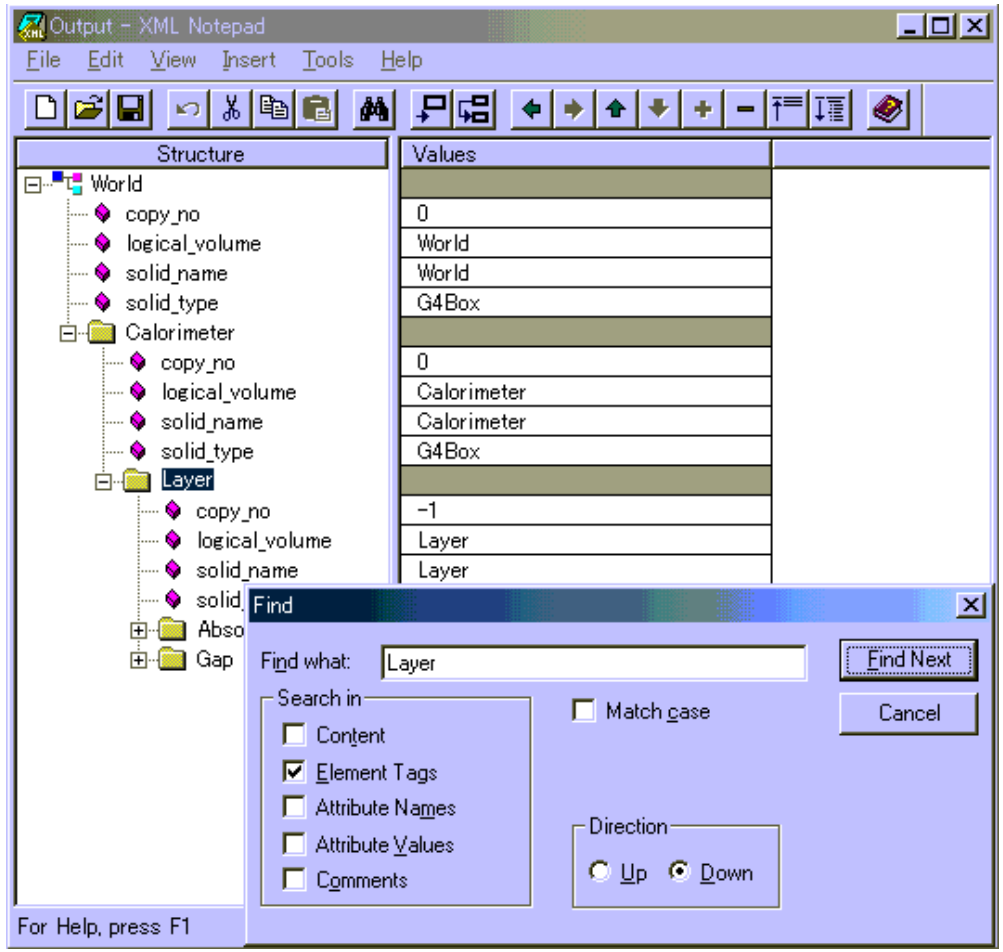
2. DTREE:Visualising Detector Geometry Tree (5-1)

- XML Tree



2. DTREE:Visualising Detector Geometry Tree (5-2)

- XML Tree (find)



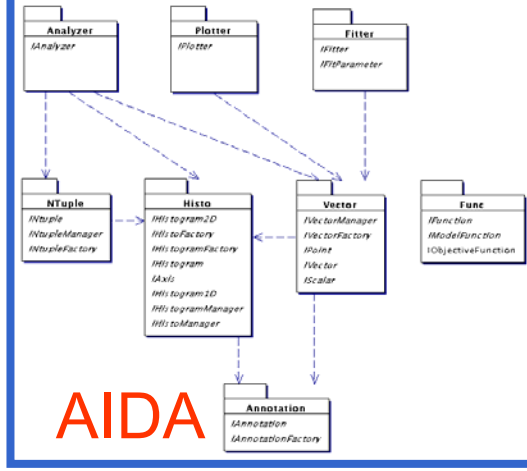
PART 4

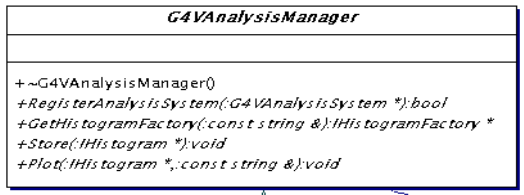
Geant4
AIDA & analysis

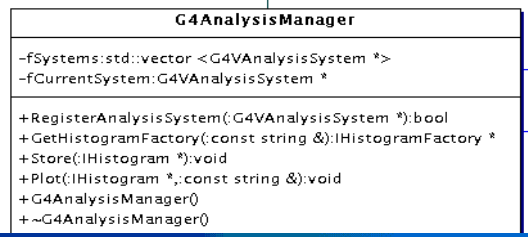
1. Interface to AIDA

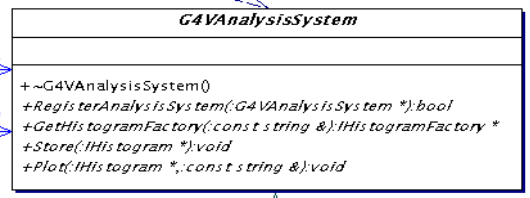
Through abstract interfaces

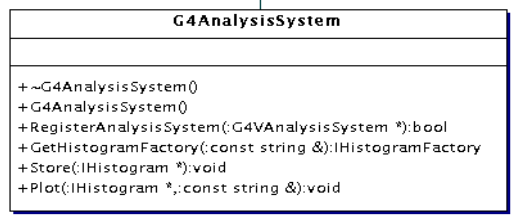
- *No dependence*
- *Minimize coupling of components*



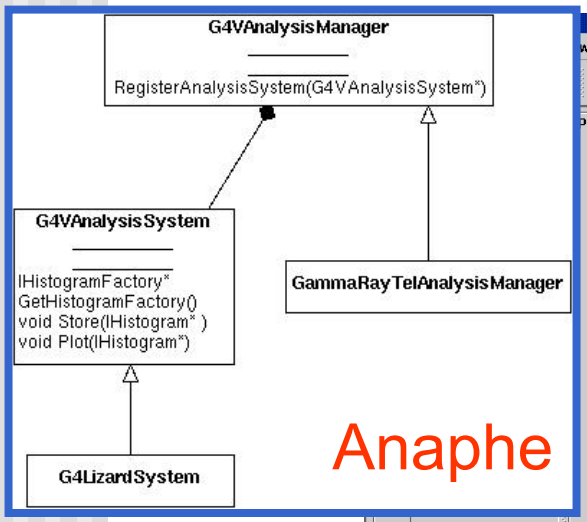


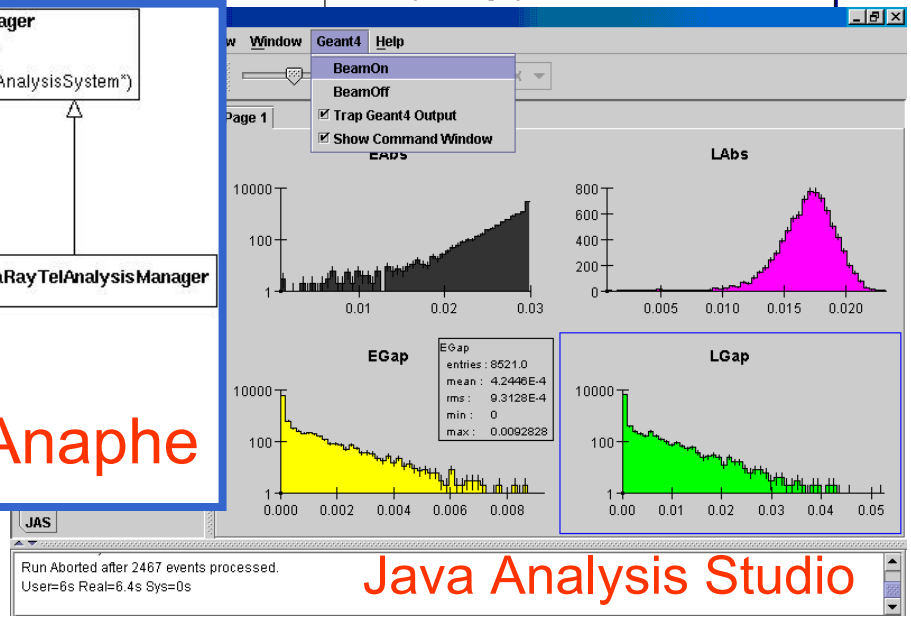






AIDA & Analysis Tools





2. Interfacing to Geant4

- AIDA (Abstract Interfaces for Data Analysis) can be used in Geant4 by selecting the environmental variable `G4ANALYSIS_USE`
  - Requires AIDA headers installed in the system
  - Requires an AIDA compliant tool for analysis
- Tools for analysis compliant with AIDA interfaces currently are:
  - Anaphe
  - JAS (Java Analysis Studio)
  - Open Scientist Lab

3. References …

- AIDA
  - http://aida.freehep.org
- Anaphe
  - http://cern.ch/anaphe/
- JAS (Java Analysis Studio)
  - http://jas.freehep.org
- Open Scientist Lab
  - http://www.lal.in2p3.fr/OpenScientist