GEANT4 BEGINNERS COURSE

GSSI, L'Aquila (Italy)
12-16 May 2014

Visualization

Geant 4 tutorial course

Introduction

- Geant4 Visualization must respond to varieties of **user requirements**
  - Quick response to survey geometry and events
  - Impressive special effects for demonstration
  - High-quality output for publications
  - Flexible camera control for debugging geometry
  - Tools for highlighting overlapping of physical volumes
  - Interactive picking of visualised objects
  - ...
- To get such a flexibility Geant4 supports several different external visualization systems

Visualizable Objects

- Simulation data you may like to see:
  - Detector components
  - Geometry hierarchy
  - A piece of physical volume, logical volume, and solid
  - Particle trajectories and tracking steps
  - Hits of particles in detector components
- Can also visualize 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)
  - Text
    - character strings for description
    - comments or titles ...
- Visualisation is performed either with commands (macro or interactive) or by writing C++ source codes of user-action classes

Visualization Attributes

- Necessary for visualization, but not included in geometry
  - Colour, visibility, wireframe/solid style, etc
- A **`G4VisAttributes`** class holds all visualization attributes to be assigned to a visualizable object

```
G4VisAttributes* myVisAtt = new G4VisAttributes();
```

- To set attributes:

```
G4bool visibility = false;
```

boolean visibility flag

by defalut is true

```
myVisAtt->SetVisibility(visibility);
```

visualization is skipped

```
G4Color red(1,0,0);
myVisAtt->SetColor(red);
…
```

- Default attributes are used if a visualisable object was not assigned its own attributes

Color

- Class **`G4Color`** allows to build colors; it is instantiated by giving RGB components to its constructor:

```
G4Colour::G4Colour(G4double r = 1.0,
                   G4double g = 1.0,
                   G4double b = 1.0 )
```

  - The default arguments define "white" color
  - For instance:

```
G4Color red(1.0, 0.0, 0.0);
G4Color blue(0.0, 0.0, 1.0);
G4Color yellow(1.0, 1.0, 0.0);
```

- Class **`G4VisAttributes`** can be instantiated directly with a color of your choice:

```
G4VisAttributes* myVisColor =
       new G4VisAttributes(G4Color(1.,0.,0.));
```

Assigning G4VisAttributes to a Logical Volume

- Once you have defined visualization attributes, they have to be assigned to the visualizable object, for example a volume of your detector
- Class **G4LogicalVolume** holds a pointer of **G4VisAttributes**

```
G4Colour brown(0.7, 0.4, 0.1);
G4VisAttributes* copperVisAtt =
   new G4VisAttributes(brown);
copperLV->SetVisAttributes(copperVisAtt);
```

Polyline

- A set of successive line segments
- Defined with a class **`G4Polyline`**
- Used to visualize tracking steps, particle trajectories, coordinate axes, any other user-defined polyline
- **`G4Polyline`** is defined as a list of **`G4Point3D`** objects → polygonal line vertices

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

// Instantiation
  G4Polyline x_axis;

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

//    Color
  G4Colour red ( 1.0, 0.0, 0.0 );
  G4VisAttributes att ( red );
  x_axis.SetVisAttributes( &att );
```

Marker

- Set a mark to an arbitrary 3D position
- Usually used to visualize hits of particles
- 2-dimensional primitive with **shape** (square, circle, text), **color**.
- Set marker properties with
  - `SetPosition( const G4Point3D& )`
  - `SetWorldSize( G4double real_3d_size )`
  - `SetScreenSize( G4double 2d_size_pixel )`
- 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)`

Drawn only by OpenGL drivers (excluding Windows OpenGL)

Example C++ code for marker:

```
G4Point3D position(0,0,0);
G4Circle circle(position);
```

Create a circle in a given position

```
circle.SetScreenDiameter(1.0);
circle.SetFillStyle (G4Circle::filled);
```

Set diameter and style

```
G4Colour colour(1.,0.,0.);
G4VisAttributes attribs(colour);
circle.SetVisAttributes(attribs);
```

Set colour and vis attributes

G4 Visualisation Drivers

- **Visualization drivers** are interfaces of Geant4 to 3D graphics software
- You can select your favorite one(s) depending on your purposes
  - Demo
  - Preparing precise figures for journal papers
  - Publication of results on Web
  - Debugging geometry
  - Etc.

Available visualization drivers

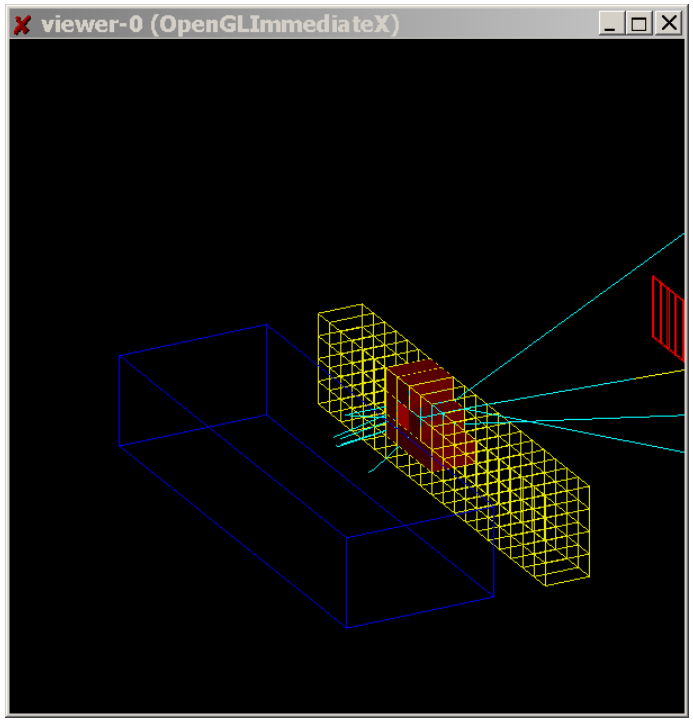
Geant4 provides several visualization drivers tailored to different purposes

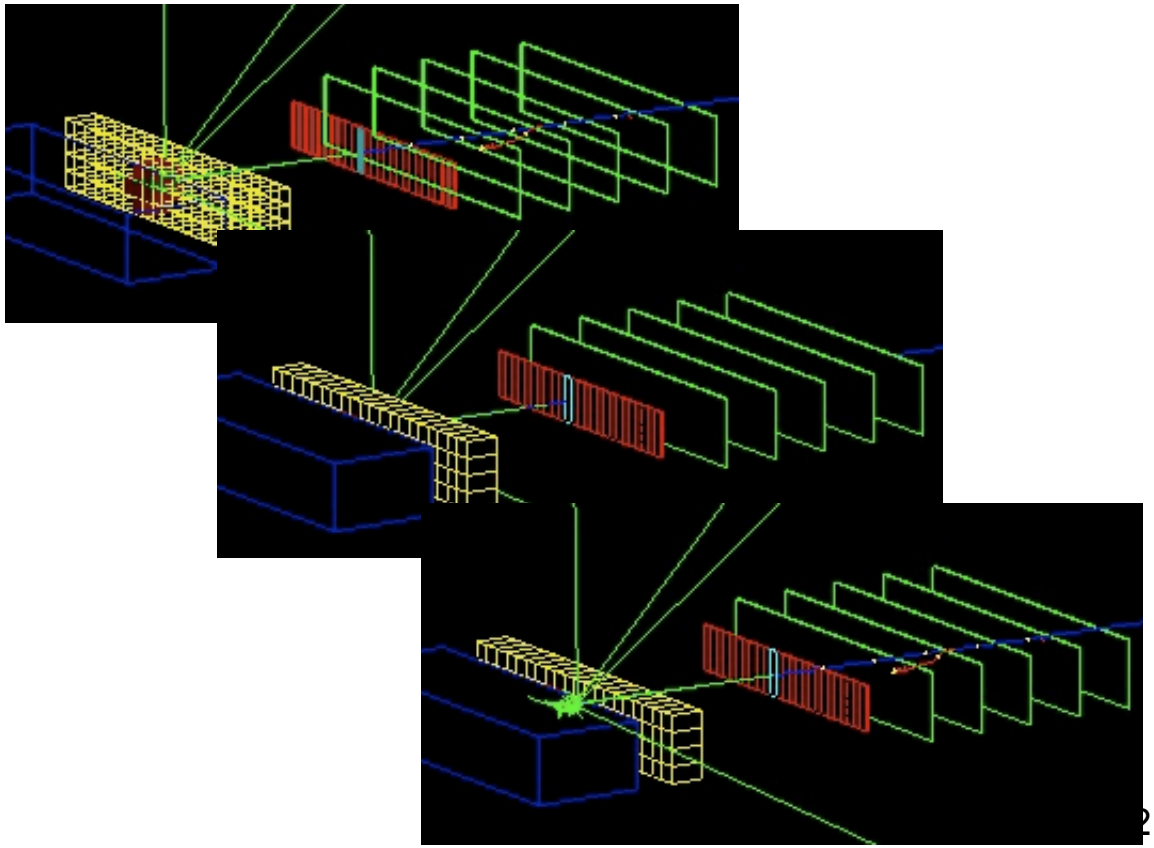
- Some of them work directly from Geant4
  - **OpenGL**
  - **Qt**
  - **OpenInventor**
  - **RayTracer**
  - **ASCIITree**
  - **Wt → Experimental, use with caution**
- For other, Geant4 will dump a file in a specific format that you can later visualize
  - **HepRep**
  - **DAWN**
  - **VRML**
  - **gMocren**

A quick overview ...

OpenGL

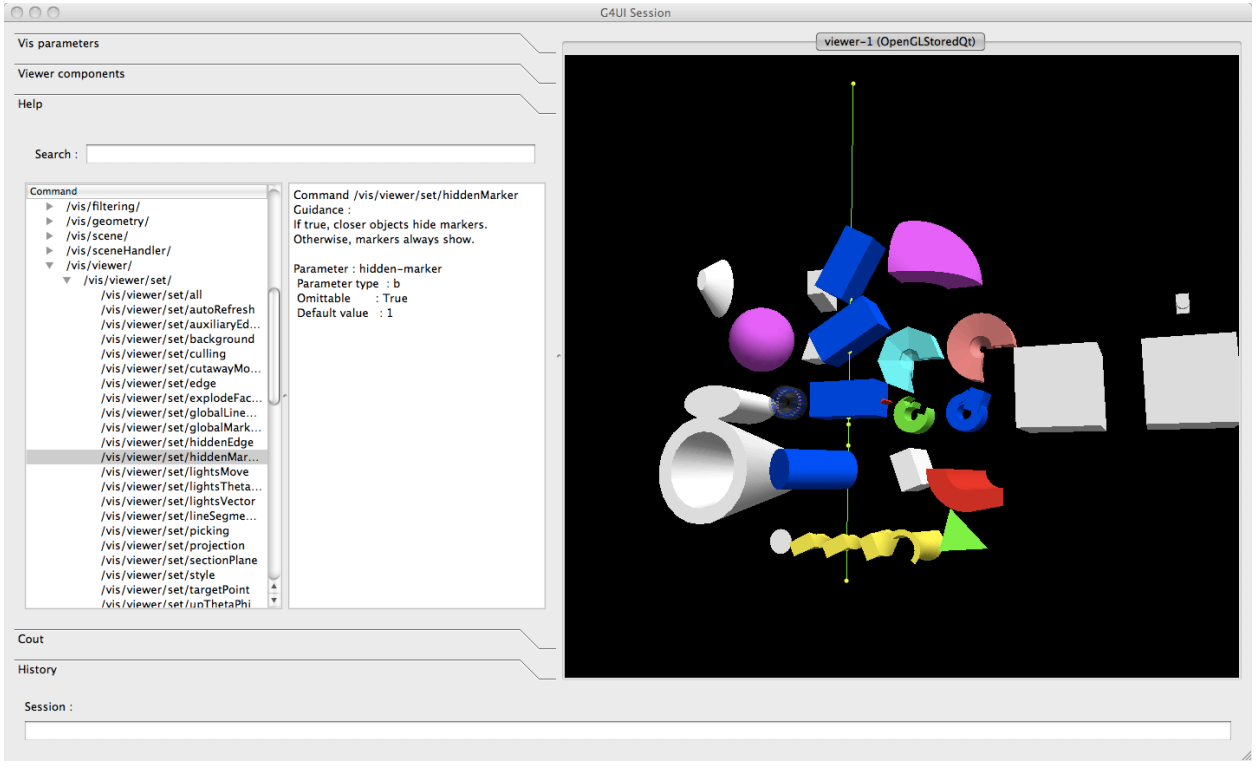
- View directly from Geant4
- Requires additional GL libraries (already included on most Linux and Windows systems)
- Rendered, photorealistic image with some interactive features
- zoom, rotate, translate
- Fast response
- Print to vector or pixel graphics
- Movies





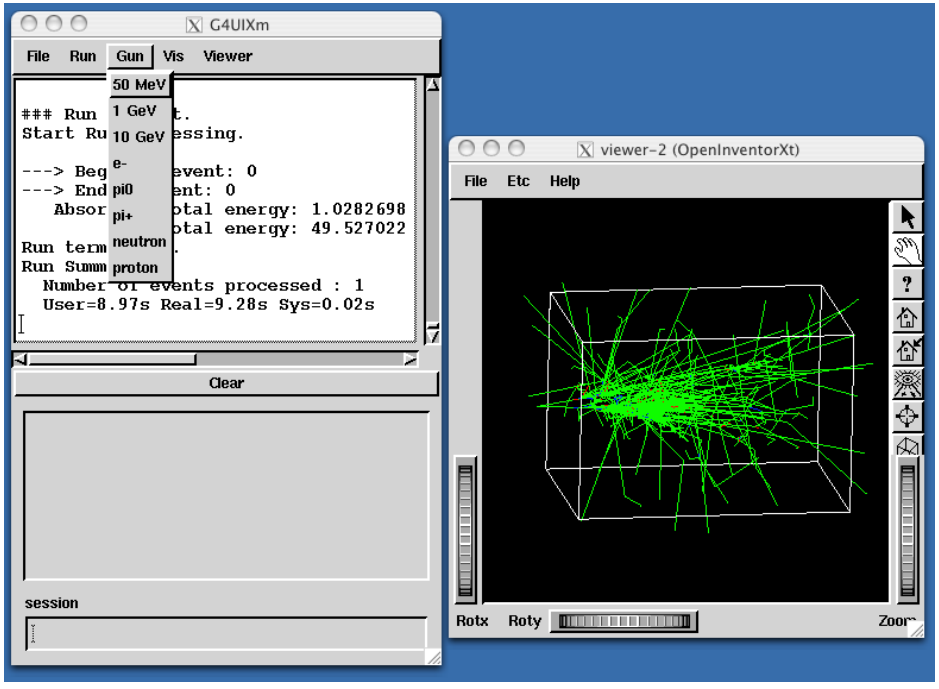
Qt

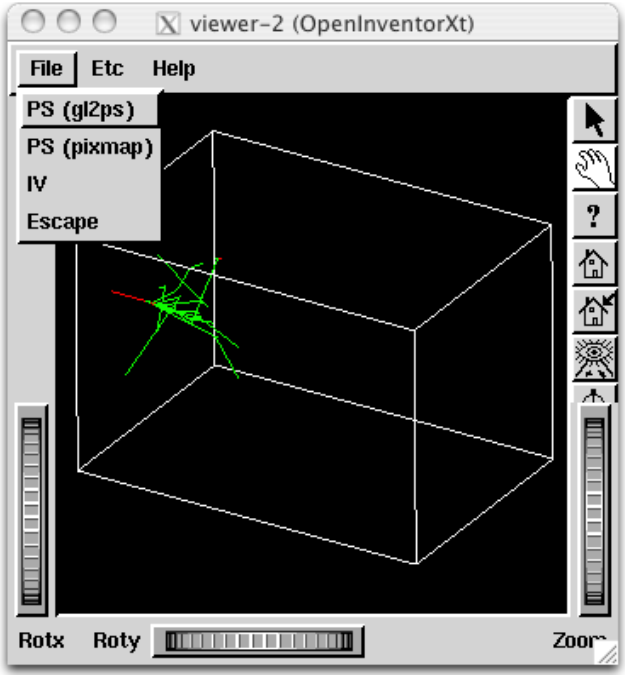
- View directly from Geant4
- Requires addition of Qt and GL libs (freely available on most operating systems)
- Rendered, photorealistic image
- Many interactive features
- zoom, rotate, translate
- Fast response
- Expanded printing ability (vector and pixel graphics)
- Easy interface to make Movies



OpenInventor

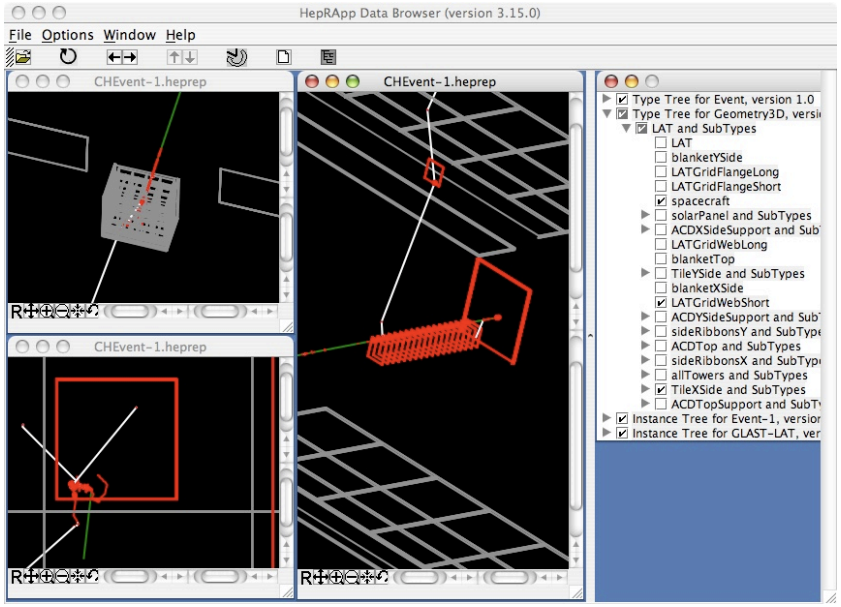
- Control from the OpenInventor GUI (view direclty from Geant4)
- Requires addition of OpenInventor libs (freely available for most Linux and Windows systems)
- Rendered, photorealistic image
- Many interactive features
  - zoom, rotate, translate
  - click to "see inside" opaque volumes
  - click to show attributes (momentum, etc., dumps to standard output)
- Fast response
- Expanded printing ability (vector and pixel graphics)

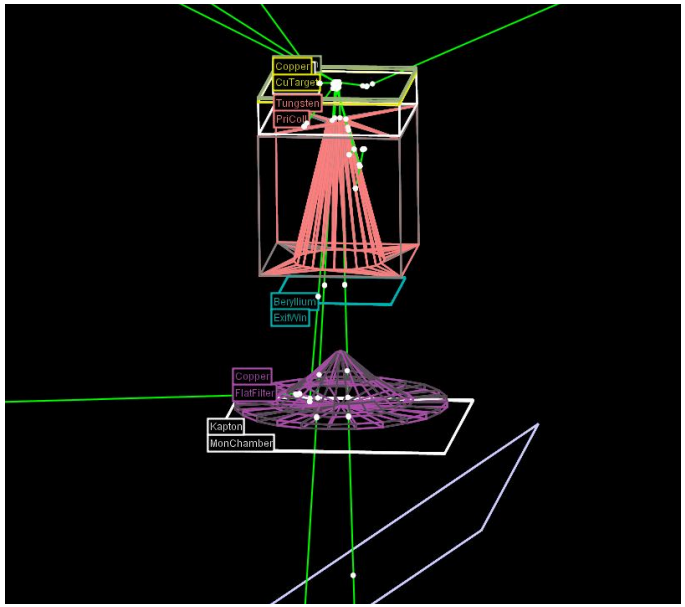




HepRep

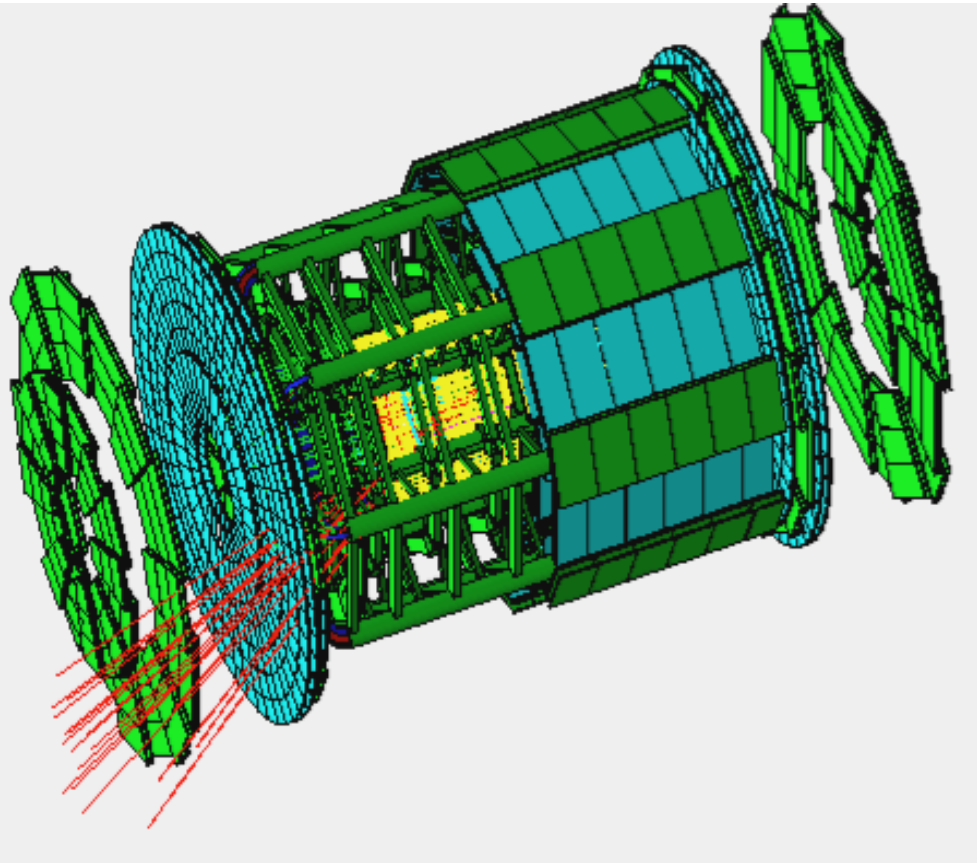
- Create a file to view in the HepRApp HepRep Browser, WIRED4 Jas Plugin or FRED Event Display
- Requires one of the above browsers (freely available for all systems)
- Wireframe or simple area fills (not photorealistic)
- Many interactive features
  - zoom, rotate, translate
  - click to show attributes (momentum, etc.)
  - special projections (FishEye, etc.)
  - control visibility from hierarchical (tree) view of data
- Hierarchical view of the geometry
- Export to many vector graphic formats (PostScript, PDF, etc.)

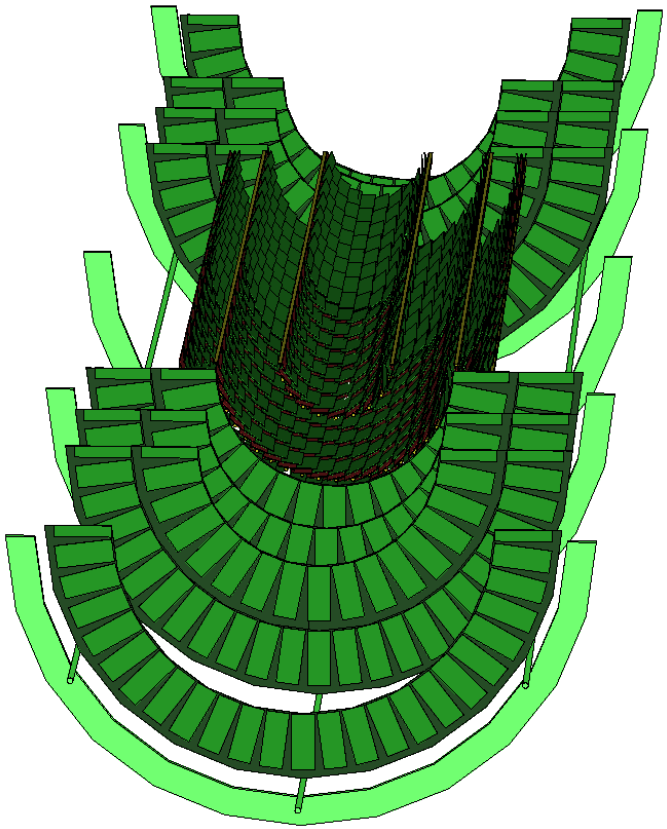




Dawn

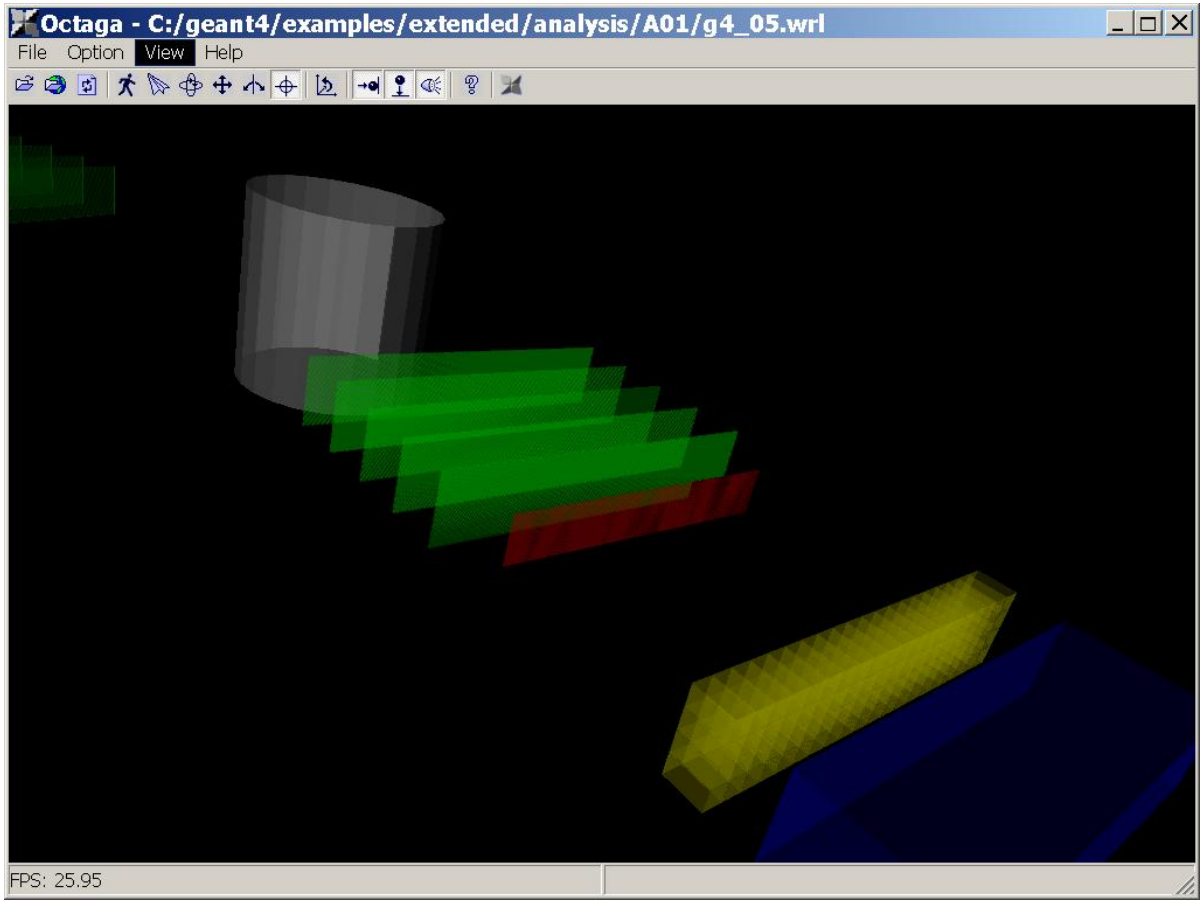
- Create a file to view in the DAWN Renderer
- Requires DAWN, available for all Linux and Windows systems.
- Rendered, photorealistic image
- No interactive features once at PostScript stage
- Highest quality technical rendering - vector PostScript
- View or print from your favorite PostScript application





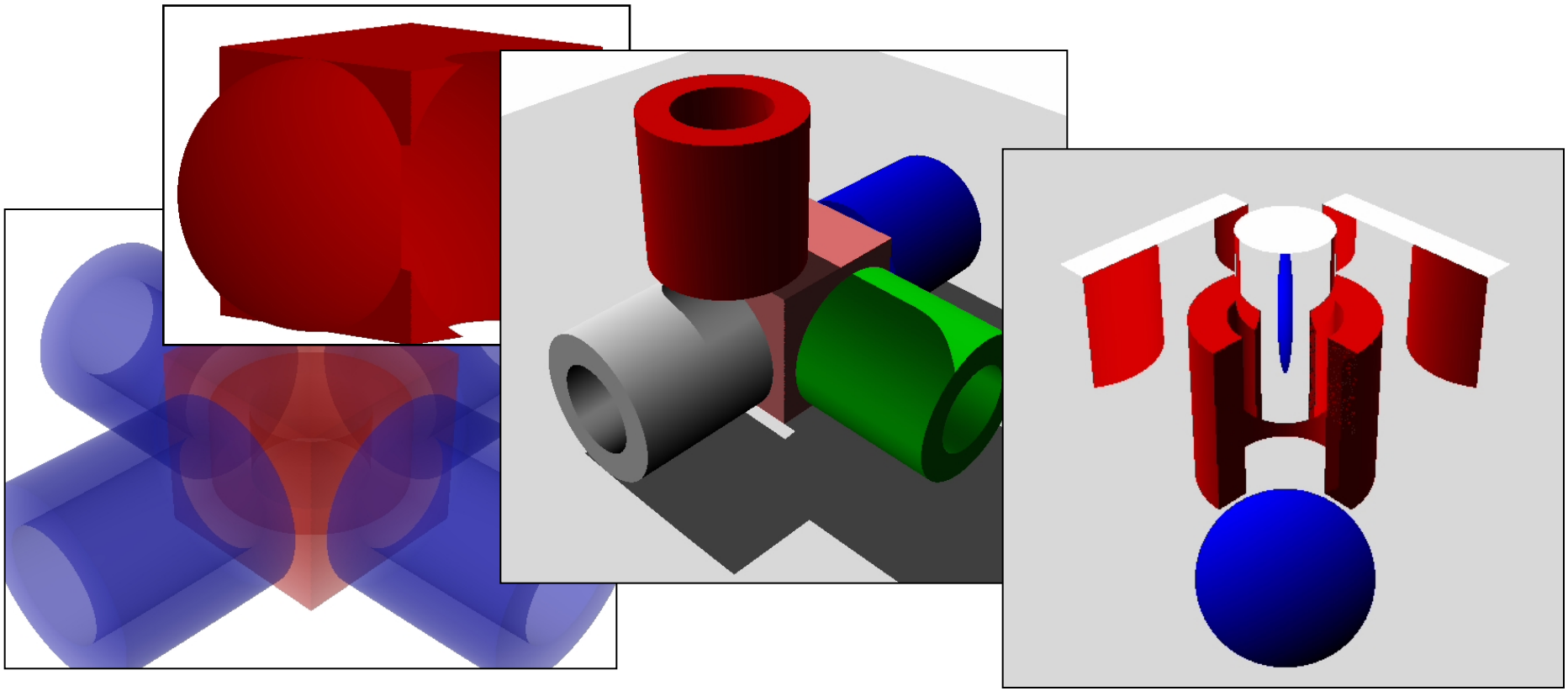
VRML

- Create a file to view in any VRML browser (some as web browser plug-ins).
- Requires VRML browser (many different choices for different operating systems).
- Rendered, photorealistic image with some interactive features
  - zoom, rotate, translate
- Limited printing ability (pixel graphics, not vector graphics)



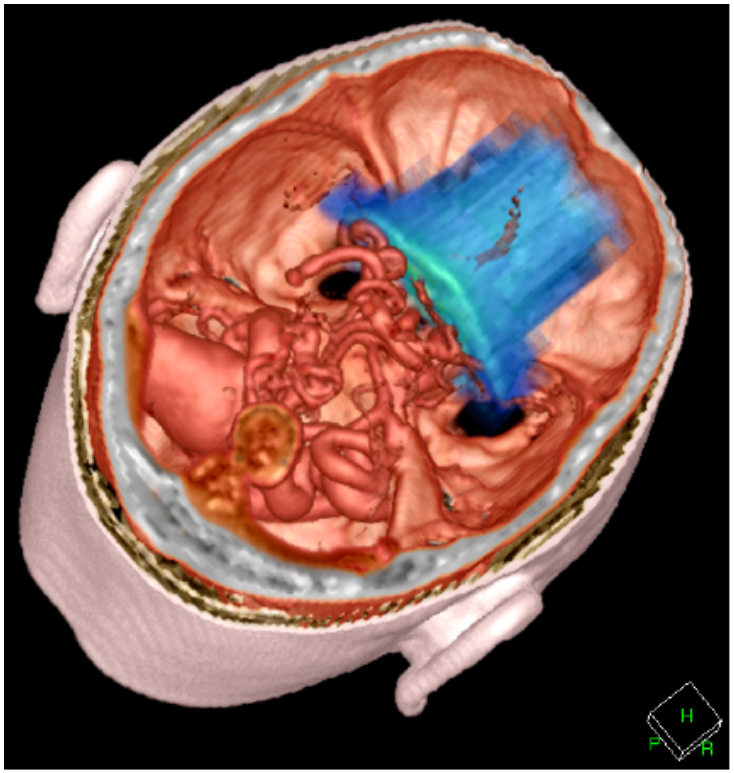
RayTracer

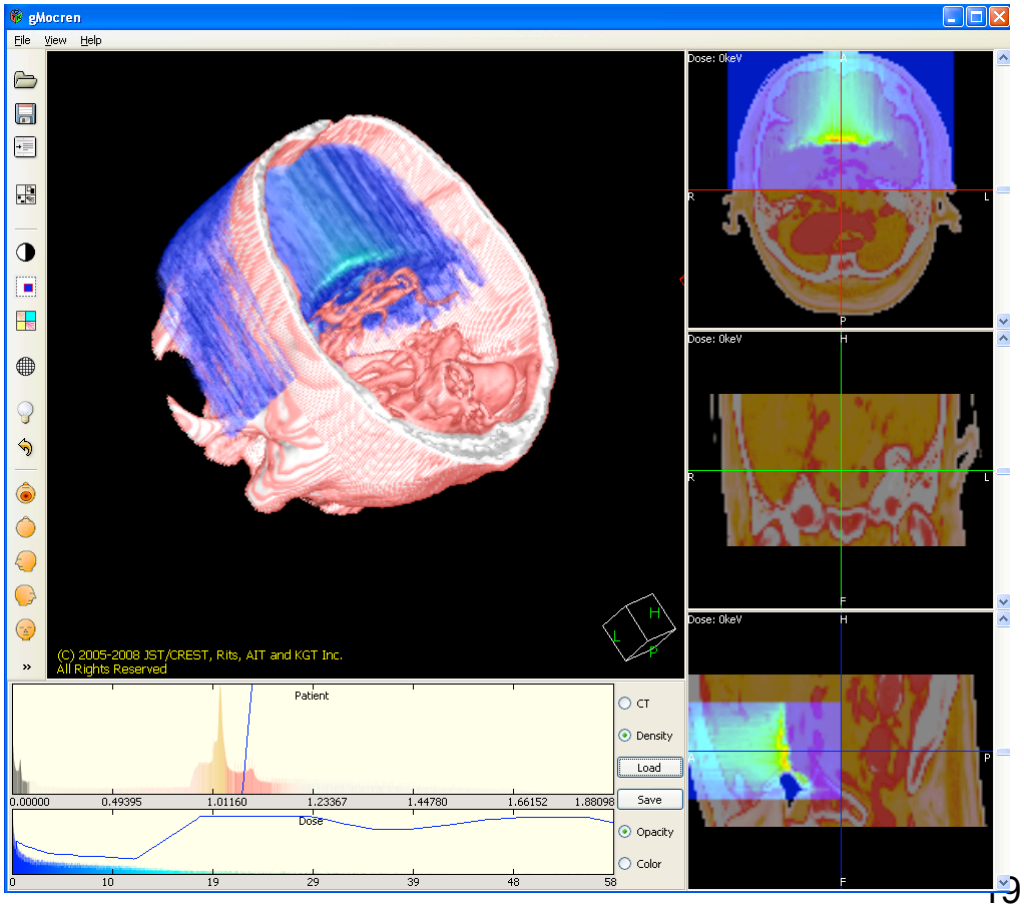
- Create a jpeg file (and with RayTracerX option, also draws to x window)
- Forms image by using Geant4's own tracking to follow photons through the detector
- **Can show geometry but not trajectories**
- **Can render any geometry that Geant4 can handle** (such as Boolean solids)
  - no other Vis driver can handle every case
- Supports shadows, transparency and mirrored surfaces



gMocren

- Create a file to be viewed in the gMocren browser.
- Requires gMocren, available for all Linux and Windows systems (with Mac coming soon)
- Can overlay patient scan data (from DICOM) with Geant4 geometry, trajectories and dose





ASCIITree

- Text dump of the geometry hierarchy (not graphical)
- Control over level of detail to be dumped
- **Can calculate mass and volume of any hierarchy of volumes**

Ex.:

/vis/viewer/flush
- "worldPhysical":0
- "magneticPhysical":0
- "firstArmPhysical":0
- "hodoscope1Physical":0
- ...

/vis/viewer/flush
- "worldPhysical":0
- "magneticPhysical":0
- "firstArmPhysical":0
- "hodoscope1Physical

Calculating mass(es)...
- Overall volume of "worldPhysical":0, is 2400 m3
- Mass of tree to unlimited depth is 22260.5 kg

Wt

- View directly from Geant4 across a Web browser.
- Requires addition of Wt libs (freely available on most operating systems)
- Require a Web browser with WebGL enable.
- Rendered, photorealistic image
- Many interactive features
- zoom, rotate, translate
- Fast response

WARNING: this driver is experimental and should be used with caution

How to use visualization drivers

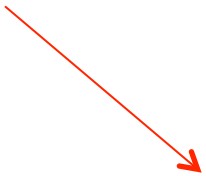
- Visualization should be switched on using the variable `G4VIS_USE`
- To select/use visualization driver(s) it is needed the proper environmental variable that you either set by hand or that is set for you by GNUMake or Cmake support scripts

- Example (DAWN, OpenGLXlib, and VRML drivers):
  - `setenv G4VIS_USE_DAWN  1`
  - `setenv G4VIS_USE_OPENGLX  1`
  - `setenv G4VIS_USE_VRML  1`

G4VisManager

- To make your Geant4 application perform visualization, you must instantiate and initialize "your" Visualization Manager in the main() function.

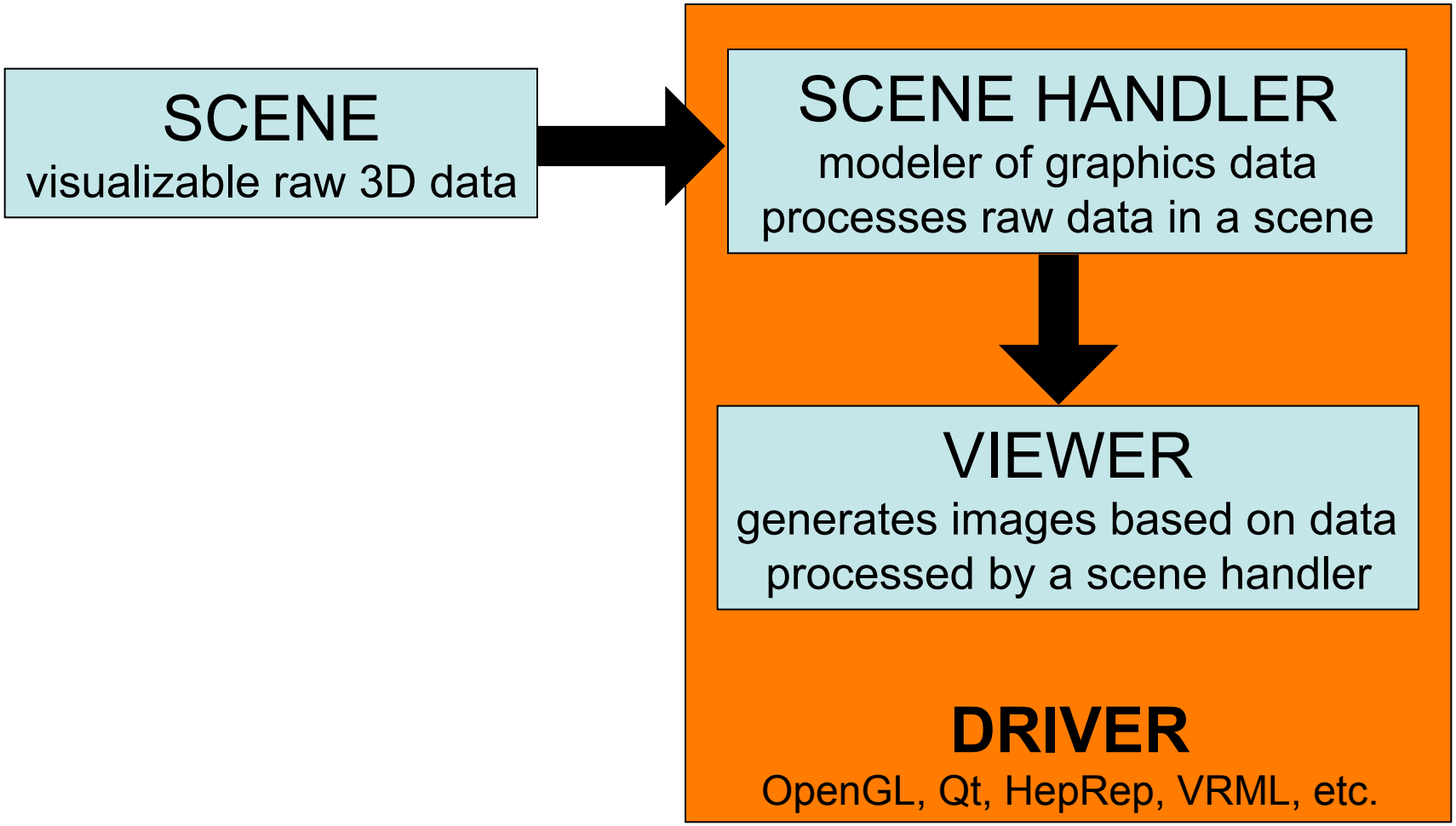
```
.....
// Your Visualization Manager
#include "G4VisExecutive.hh"
.....

// Instantiation and initialization of the Visualization Manager
#ifdef G4VIS_USE
G4VisManager* visManager = new G4VisExecutive;
visManager->Initialize();
#endif
.....
#ifdef G4VIS_USE
delete visManager;
#endif
```



Derive your own from `G4VisManager` or simply use `G4VisExecutive`

Useful definitions

In using the visualization in Geant4, it is useful to know the concept of "scene", "scene handler", and "viewer”



Visualization commands

There are some frequently-used built-in visualization commands in Geant4, that you may like to try

```
Command directory path : /vis/
 Sub-directories :
   /vis/ASCIITree/              Commands for ASCIITree control.
   /vis/heprep/                 HepRep commands.
   /vis/rayTracer/              RayTracer commands.
   /vis/gMocren/                gMocren commands.
   /vis/ogl/                    G4OpenGLViewer commands.
   /vis/modeling/               Modeling commands.
   /vis/filtering/              Filtering commands.
   /vis/geometry/               Operations on vis attributes of Geant4 geometry.
   /vis/set/                    Set quantities for use in future commands where appropriate.
   /vis/scene/                  Operations on Geant4 scenes.
   /vis/sceneHandler/           Operations on Geant4 scene handlers.
   /vis/touchable/              Operations on touchables.
   /vis/viewer/                 Operations on Geant4 viewers.
 Commands :
   verbose *                    Simple graded message scheme - digit or string (1st character defines):
   initialize *                 Initialise visualisation manager.
   abortReviewKeptEvents *      Abort review of kept events.
   enable *                     Enables/disables visualization system.
   disable *                    Disables visualization system.
   list *                       Lists visualization parameters.
   reviewKeptEvents *           Review kept events.
   drawTree * (DTREE)           Creates a scene consisting of this physical volume and
                                produces a representation of the geometry hieracrhy.
   drawView *                   Draw view from this angle, etc.
   drawVolume *                 Creates a scene containing this physical volume and asks the
                                current viewer to draw it.  The scene becomes current.
   open *                       Creates a scene handler ready for drawing.
   specify *                    Draws logical volume with Boolean components, voxels and readout geometry.
```

Guidance is hierarchical, providing full detail on all commands

Commands to visualize detectors

`/vis/open OGLIX`	create scene handler + viewer (driver)
`help /vis/open`	show available drivers

`/vis/viewer/reset`
`/vis/viewer/set/viewpointThetaPhi 70 20`
`/vis/viewer/set/style wireframe`
	set camera parameters
	set drawing style

`/vis/drawVolume`
or
`/vis/specify logicLAr`
	set detector geometry as obj to visualize, and registers it
	set specific logical volume for visualization

`/vis/viewer/flush`	close visualization

These commands can be given interactively or executed via macro. Most Geant4 examples include a vis.mac that you can inspect and use.

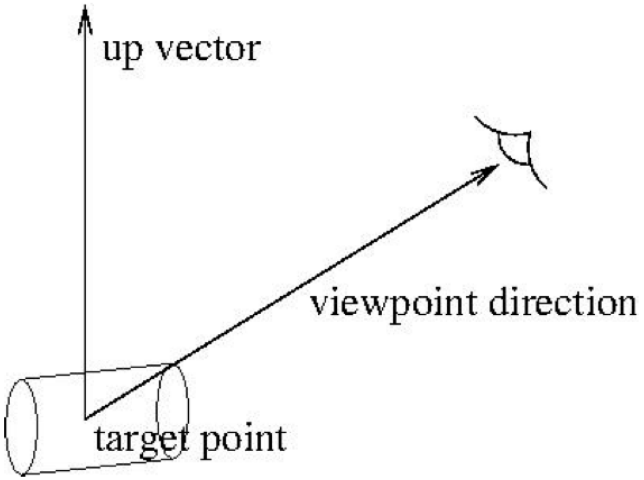
Commands to Visualize Events

`/tracking/storeTrajectory`	Store trajectories for visualization
`/vis/open DAWNFILE`	Scene handler and viewer (for ex. DAWN)
`/vis/scene/add/axes 0 0 0 500 mm`	
/…	Optional settings (axes, viewpoint, etc.)
`/vis/scene/create`	Creates an empty scene
`/vis/scene/add/volume`	Adds world volume
`/vis/scene/add/trajectories`	Adds trajectoriies
`/vis/scene/add/hits`	Adds hits
`/run/beamOn 10`	Shoots events (end of visualization)

Some /vis/viewer/… commands

Camera settings

```
/vis/viewer/reset
/vis/viewer/viewpointThetaPhi <theta> <phi>
/vis/viewer/set/upVector   <x> <y> <z>
/vis/viewer/set/targetPoint <x> <y> <z>
```



Zooming

```
/vis/viewer/zoom <scale_factor>
/vis/viewer/zoomTo <absolute_scale_factor>
```

Trajectory Filtering

Useful if you only want to view interesting trajectories discarding uninteresting ones.

- Soft filtering: trajectories are marked as invisible (but still written). Some drivers allows to toggle them back to visible
- Hard filtering: uninteresting trajectories are not even written. Useful to avoid huge graphics file

Available trajectory filtering models:

- G4TrajectoryChargeFilter (chargeFilter) → by electric charge
- G4TrajectoryParticleFilter (particleFilter) → by particle type
- G4TrajectoryOriginVolumeFilter (originVolumeFilter) → by trajectory originating volume
- G4TrajectoryAttributeFilter (attributeFilter) → by trajectory attribute

Multiple filters are automatically chained together

Filters can be configured either by commands or in compiled code

Filtering example I

Filter by particle type

```
/vis/filtering/trajectories/create/particleFilter
/vis/filtering/trajectories/particleFilter-0/add gamma
```
only gammas pass

```
/vis/filtering/trajectories/particleFilter-0/invert true
```
invert to pass anything other than gammas

```
/vis/filtering/trajectories/particleFilter-0/active false
```
inactivate filter

Filter by charge

```
/vis/filtering/trajectories/create/chargeFilter
/vis/filtering/trajectories/chargeFilter-0/add 0
```
only neutrals pass

```
/vis/filtering/trajectories/chargeFilter-0/reset true
```
reset filter

```
/vis/filtering/trajectories/chargeFilter-0/add -1
```
reconfigure to pass only negatively charged trajectories

List all configured filters

```
/vis/filtering/trajectories/list
```

Filtering example I

Filter by attribute

Only particle with momentum in 2.5MeV and 1000 MeV range pass

```
/vis/filtering/trajectories/create/attributeFilter
/vis/filtering/trajectories/attributeFilter-0/setAttribute IMag
/vis/filtering/trajectories/attributeFilter-0/addInterval 2.5 MeV 1000 MeV
```

Trajectory Drawing

- Trajectory drawing styles are specified through trajectory drawing models
- A user-defined trajectory drawing model can override the default context according to the properties of a given trajectory

Available trajectory drawing models:

- G4TrajectoryGenericDrawer (generic)
- G4TrajectoryDrawByCharge (drawByCharge)→ by electric charge
- G4TrajectoryDrawByParticleID (drawByParticleID)→ by particle type
- G4TrajectoryDrawByOriginVolume (drawByOriginVolume) → by trajectory originating volume
- G4TrajectoryDrawByAttribute (drawByAttribute) → by trajectory attribute

Drawing Modeling Examples

Modeling by charge

Set positively and negatively charged trajectories green; set neutral trajectories to white

```
/vis/modeling/trajectories/create/drawByCharge
/vis/modeling/trajectories/drawByCharge-0/set 1 green
/vis/modeling/trajectories/drawByCharge-0/set -1 red
/vis/modeling/trajectories/drawByCharge-0/set 0 green
```

Modeling by attribute

Set red color for particles created by Bremsstrahlung

```
/vis/modeling/trajectories/create/drawByAttribute
/vis/modeling/trajectories/drawByAttribute-0/setAttribute CPN
/vis/modeling/trajectories/drawByAttribute-0/addValue brem_key eBrem
/vis/modeling/trajectories/drawByAttribute-0/brem_key/setLineColour red
```

Thanks for your attention

Summary

- Geant4 can be used to visualize set-ups, tracks and other objects (e.g. axes, markers)
- A number of visualization drivers is available, each with its pros and cons
- Visualization can be controlled interactively or by macro, using Geant4 built-in commands
- Several advanced commands for specific visualization requirements are available

Polyline and Marker

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

Filtering by attribute example

```
/vis/modeling/trajectories/drawByAttribute-0/setAttribute IMag
```

Momentum filter

```
/vis/modeling/trajectories/drawByAttribute-0/addInterval interval1 0.0 keV 2.5MeV
/vis/modeling/trajectories/drawByAttribute-0/addInterval interval2 2.5 MeV 5 MeV
/vis/modeling/trajectories/drawByAttribute-0/addInterval interval3 5 MeV 7.5 MeV
/vis/modeling/trajectories/drawByAttribute-0/addInterval interval4 7.5 MeV 10 MeV
/vis/modeling/trajectories/drawByAttribute-0/addInterval interval5 10 MeV 12.5 MeV
/vis/modeling/trajectories/drawByAttribute-0/addInterval interval6 12.5 MeV 10000 MeV
```

Momentum interval based colour scale

```
/vis/modeling/trajectories/drawByAttribute-0/interval1/setLineColourRGBA 0.8 0 0.8 1
/vis/modeling/trajectories/drawByAttribute-0/interval2/setLineColourRGBA 0.23 0.41 1 1
/vis/modeling/trajectories/drawByAttribute-0/interval3/setLineColourRGBA 0 1 0 1
/vis/modeling/trajectories/drawByAttribute-0/interval4/setLineColourRGBA 1 1 0 1
/vis/modeling/trajectories/drawByAttribute-0/interval5/setLineColourRGBA 1 0.3 0 1
/vis/modeling/trajectories/drawByAttribute-0/interval6/setLineColourRGBA 1 0 0 1
```

Configure visualisation properties

```
/vis/filtering/trajectories/create/attributeFilter
/vis/filtering/trajectories/attributeFilter-0/setAttribute IMag
/vis/filtering/trajectories/attributeFilter-0/addInterval 2.5 MeV 1000 MeV
```

Momentum filter

```
/vis/filtering/trajectories/create/particleFilter
/vis/filtering/trajectories/particleFilter-0/add gamma
```

Gamma filter