Introduction to Geant4 II

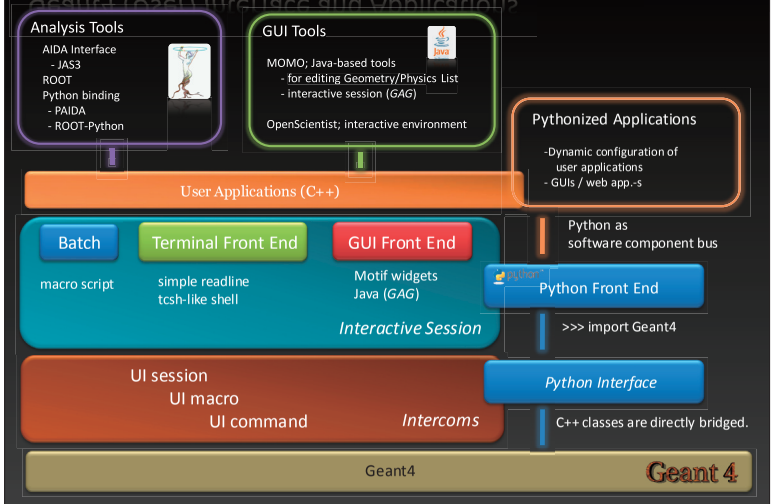
User Interface
Examples
User Support

Geant4 Seminar
Koichi Murakami (KEK/CRC)

Overall structure
UI terminal
Batch mode
Python interface
Momo

USER INTERFACE

Geant4 (User) Interface and Applications



Interactive Front End

Command Line Interface

G4UIterminal – simple readline front end

- runs on all Geant4-supported platforms
- *G4UItcsh* – tcsh-like front end with command completion, history, etc.
  - ✓ as a functional module of G4UIterminal
  - ✓ runs only on Linux/Solaris/Win-Cygwin

GUI Interface

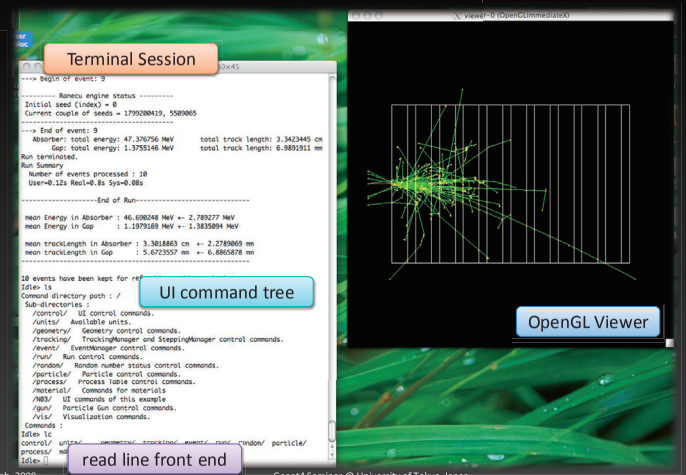
G4UIXm, G4UIXaw, G4UIXWin32

- G4UIterminal implemented over Motif, Athena and WIN32 widgets
- runs on Unix/Linux and Windows, respectively

G4UIGAG

- interface with GAG/MOMO, Java-based GUI interface
- runs on all Geant4 platforms

A Simple Geant4 User Session



Geant4 UI command

A command consists of

- Command directory
- Command
- Parameter(s)

```
/run/verbose 1
/vis/viewer/flush
```

A parameter can be a type of string, boolean, integer or double.

- Space is a delimiter.
- Use double-quotes ("") for string with space(s).

A parameter may be "omittable".

- A default value will be taken if you omit the parameter.
- Default value is either 'predefined default value' or 'current value' according to its definition.
- A default value can be specified by "!";

```
/dir/command ! second
```


Built-in Commands

There are built-in commands roughly organized according to Geant4 categories.

```
Idle> ls
Command directory path : /
 Sub-directories :
   /control/      UI control commands.
   /units/        Available units.
   /geometry/     Geometry control commands.
   /tracking/     TrackingManager and SteppingManager control commands.
   /event/        EventManager control commands.
   /run/          Run control commands.
   /random/       Random number status control commands.
   /particle/     Particle control commands.
   /process/      Process Table control commands.
   /material/     Commands for Materials
   /vis/          Visualization commands.
   /gun/          Particle Gun control commands.
 Commands :
```


Extra UI Command Functionality

G4UI command takes care of

- Wrong application state
- Wrong type of parameter
- Insufficient number of parameters
- Parameter out of its range
  - ✓ For integer or double type parameter
- Parameter out of its candidate list
  - ✓ For string type parameter
- Command not found

UI Macro and Batch Mode

Macro file contains a series of UI commands.

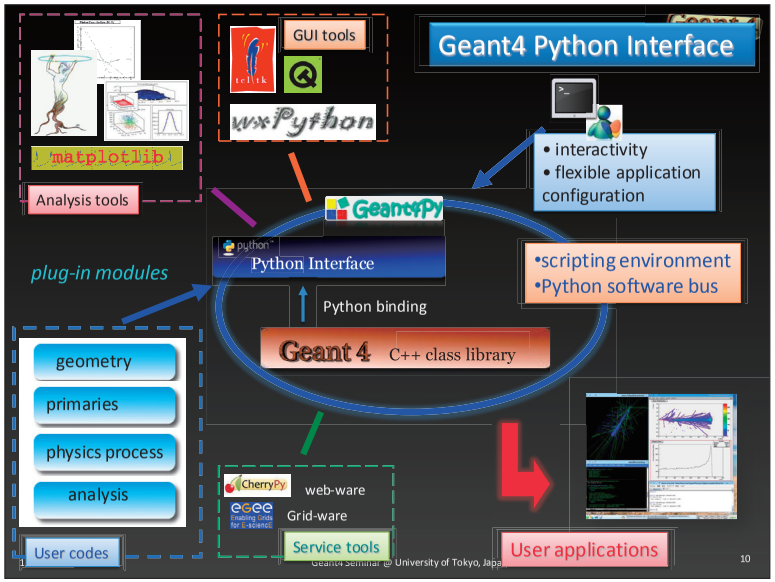
- "#" is used for a comment line.
  - ✓First "#" to the end of the line will be ignored.
  - ✓Comment lines will be echoed if /control/verbose is set to 2.
- Macro file can be executed
  - ✓interactively or in another macro file

```
/control/execute file_name
```

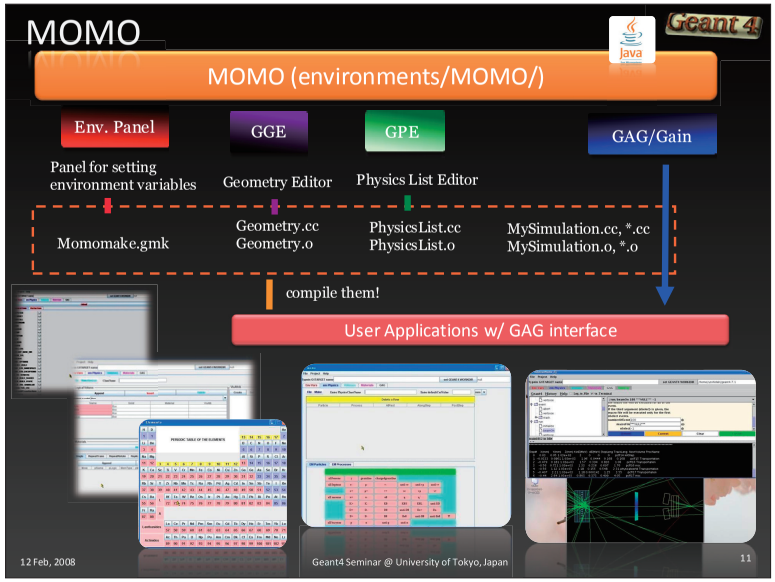
A Geant4 simulation can be executed in a batch mode.

- A macro file can be specified as an argument.

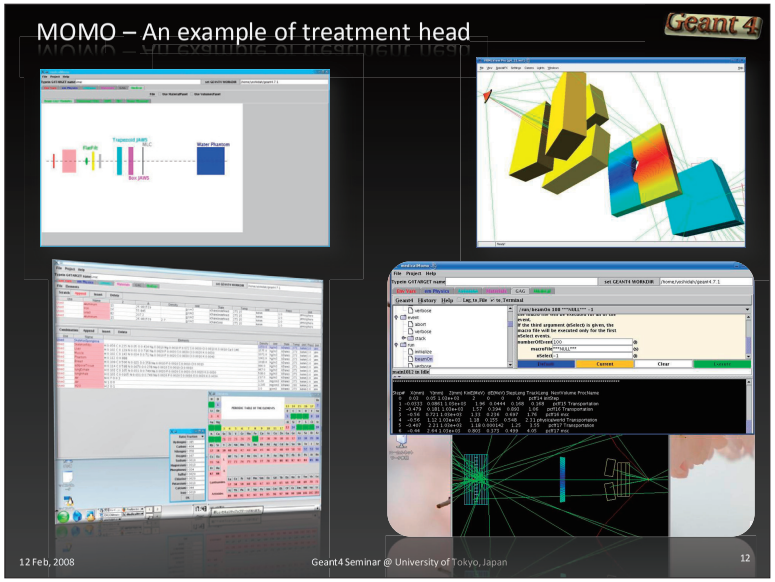
```
$ hoge.exe myrun.mac >& myrun.log  (csh)
```

MOMO



MOMO – An example of treatment head



Novice examples
Extended examples
Advanced examples

EXAMPLES

Novice example N01

Available in Live DVD

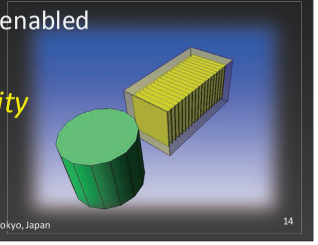
Fixed geometry

- *Ar* gas mother volume with *Al cylinder* and Pb block with Al slices

Incident particle is a *geantino*

- no physics interactions
- only the transportation process is enabled

Hard coded batch job and verbosity



Novie Example N02

Available in Live DVD

Pb target, Xe gas chambers (parameterized volumes)

All EM processes + decay including charged leptons and charged hadrons

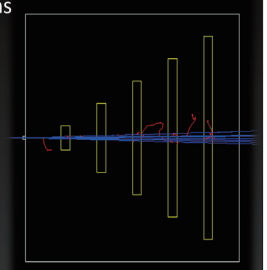
Detector response

- Trajectories and chamber hit collections may be stored

Visualization of detector and event

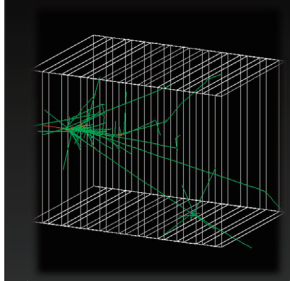
Command interface introduced

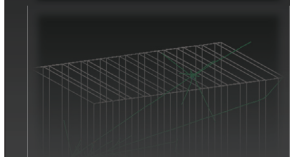
- Can change target, chamber materials, magnetic field, incident particle type, momentum, etc. at run time



Novice Example N03

Available in Live DVD





- Sampling calorimeter with layers of Pb absorber and liquid Ar detection gaps (replicas)
- Exhaustive material definitions
- Command interface
- Randomization of incident beam
- All EM processes + decay, with separate production cuts for γ, e+, e-
- Detector response: E deposit, track length in absorber and gap
- Visualization tutorial
- Random number seed handling

Novie Example N04

Available in Live DVD

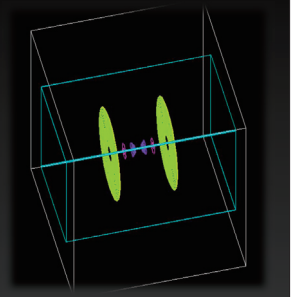
Simplified collider detector
- all kinds of volume definitions

Magnetic field

PYTHIA primary event generator
- Higgs decay by Z0, lepton pairs

Packaged physics list (QGSP)

Event filtering by using stacking mechanism



Novice Example N05

Available in Live DVD

Fast simulation with *parameterized showers*
- EM showers (derived from G4VFastSimulationModel)
- Pion showers (for illustration only – not used)

EM physics only
- Use of G4FastSimulationManagerProcess

Simplified collider detector geometry
- Drift chamber
- EM, hadronic calorimeter
- *Ghost volume*

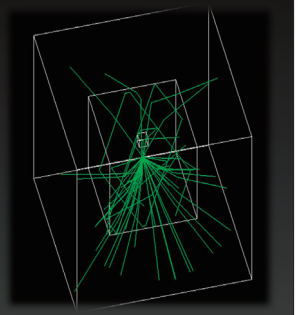
Novice Example N06

Available in Live DVD

Water Cerenkov detector with air "bubble"

Materials
- Specification of optical properties
- Specification of scintillation spectra

Physics
- *Optical processes*
- Generation of Cerenkov radiation, energy loss collected to produce scintillation



Novice Example N07

Available in Live DVD

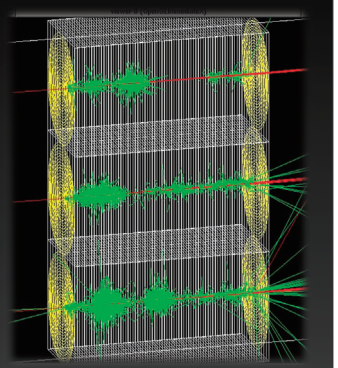
3 simplified sandwich calorimeters (Pb, Al, Ar)

Cylindrical ghost volume for scoring

Run-based (as opposed to event-based) hit accumulation

Changing geometries without rebuilding world

Setting different secondary production cuts for each calorimeter using G4Region



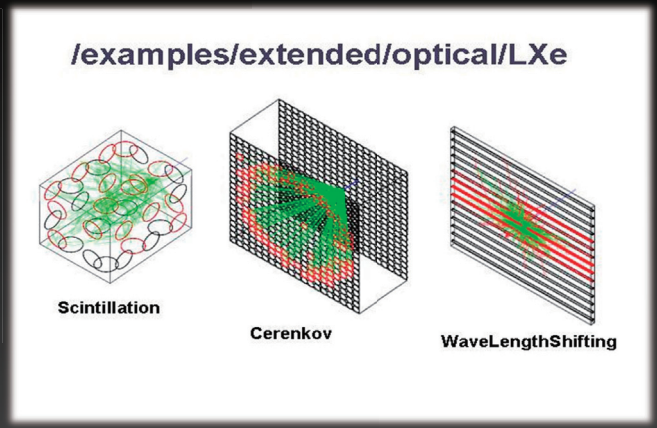
Extended Examples

Testing and validation of physics processes and tracking
- Electromagnetic physics testing suites
- Field propagation
- Geometry overlapping

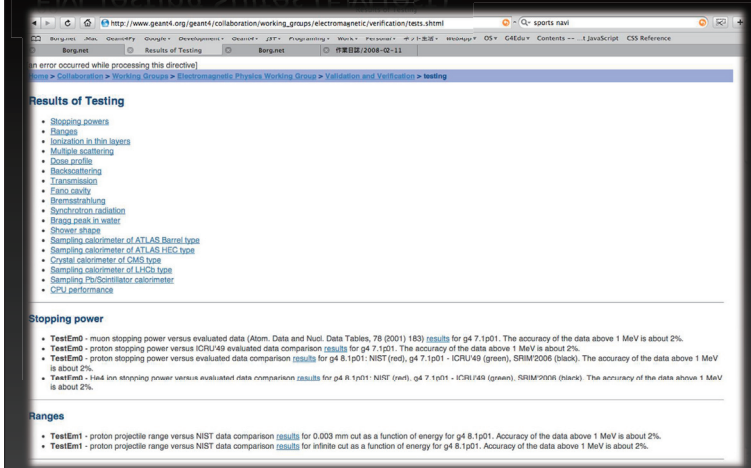
Demonstration of Geant4 tools
- Analysis, event generator, g3tog4, persistency
- Event biasing, optical, run and event

Extensions of Geant4
- GDML I/O
- Medical (DICOM I/O)
- Parallel computing

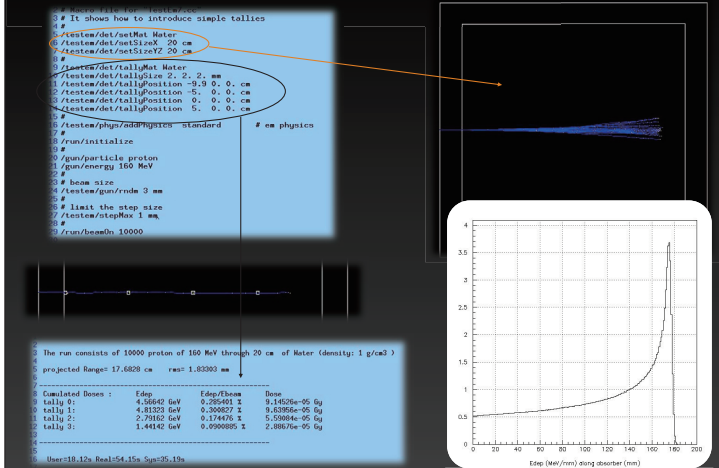
Optical Photons



EM Testing Suites (EMTest)



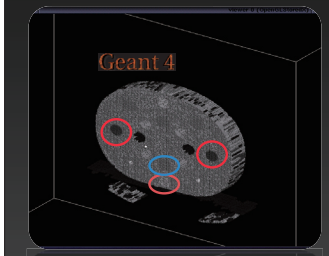
TestEm7 : Bragg curve and tallies



DICOM Interface

Reading DICOM image format

Conversion from CT values to densities / organ types



Voxel placement (parameterization)

Parallel Computing

Geant4 Paralleirization using *Top-C*

DIANE example

- using *DIANE* (DIstributed ANalysis Environment)
- Parallelized version of brachytherapy advanced example

Parallelization using "*native*" MPI

- available with various MPI-compliant libraries
  - ✓ LAM/MPI, MPICH, OpenMPI, …
- alternative G4 MPI session

GDML Example

Identical to example N03 (sampling calorimeter), except

- GDML used for geometry description

GDML schema supports:

- Numerical expressions, constants, rotations, translations, units
- Materials
- CSG + boolean solids
- Geometrical structure (volumes, placements)

Advanced Examples (1)

	brachytherapy	**Dosimetry** for endocavitary, interstitial and superficial brachytherapy	Class diagram
	composite calorimeter	A composite **electromagnetic** and **hadronic calorimeter**, similar to a *CMS* test beam set-up	Class diagram
	cosmicray charging	**Electrostatic charging** of isolated test masses by galactic cosmic ray protons and helium nuclei, similar to the *LISA mission*	
	gamma-ray telescope	A simplified typical **g-ray telescope** (*such as GLAST*), with advanced description of the **detector response** (hits + digitisation)	Class diagram
	hadrontherapy	A **beam line** for hadrontherapy	Class diagram
	lAr calorimeter	A **liquid Argon calorimeter**, similar to an *ATLAS* test beam set-up	Class diagram

Advanced Examples (2)

	medical LINAC	A typical **LINAC** for Intensity Modulated RadioTherapy, similar to one used in clinical practice	Class diagram
	purging_magnet	Electrons traveling through the **magnetic field** of a strong purging magnet in a radiotherapy treatment head	
Moon habitat	radioprotection	Dose distributions in interplanetary space radiation environment, for the **radioprotection of astronauts** in space vehicles and planetary habitats	Class diagram
	RICH	A **RICH detector** in a set-up similar to a *LHCb test beam*	
	Tiara	An example of **neutron shielding**, such as the *TIARA experiment*, demonstrating how to apply **geometrical importance sampling** (geometrical splitting and Russian roulette)	
	underground experiment	A simplified typical **Dark Matter detector** (such as the *Boulby Mine experiment*)	Class diagram
	X-ray fluorescence	Elemental composition of material samples through **X-ray fluorescence** spectra	Class diagram
	X-ray telescope	A simplified typical **X-ray telescope** (such as *XMM-Newton* or *Chandra*)	Class diagram

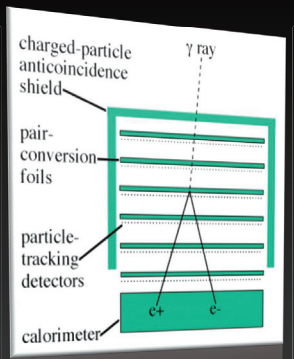
Brachytherapy Example

Physics
- Low energy EM processes for e-, gamma
- Standard EM for e+

Sensitive detector
- "phantom" consisting of soft tissue

Analysis
- Energy deposition stored in n-tuple
- Store primary particle energy spectra
- 1D, 2D histograms of energy deposition

Gamma Ray Space Telescope (GLAST)



Use of messengers to change geometry interactively

Modular physics list

Particle generator with monochromatic or power law spectrum

Readout geometry of Si tracker strips

Hits collection stored in ascii file

Simple digitization using hits collection to produce digi collections

X-ray Telescope

Simple model of x-ray telescope to study proton damage

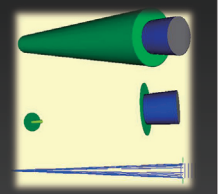
Geometry:
- single shell nickel-gold mirror
- two cones for paraboloid, two for hyperboloid sections aluminium baffle
- main telescope: carbon fiber tube, aluminium end caps

Main physics process is
- multiple scattering of protons from mirror surfaces also e+, e-, gamma physics processes

General particle source
- many methods available to customize event generation

Visualization of proton tracks

AIDA interface for analysis
- energy distribution histograms of protons reaching detector

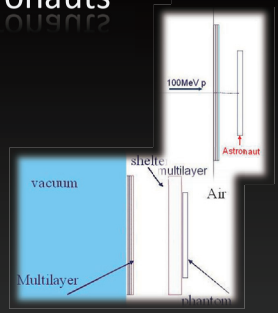


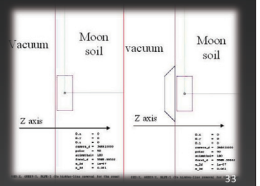
Radiation Protection for Astronauts

Evaluate dose to astronauts in interplanetary radiation environment
- in space vehicles
- in lunar surface habitats

User can calculate dose to a water phantom due to
- galactic cosmic rays
- solar particle events

Different shielding configurations available
- inflatable sphere with water shielding
- habitat buried in lunar soil





Documentations
User support process
License

USER SUPPORT

Geant4 Web Pages

Geant4 Documents

Introduction of Geant4

Installation Guide

User's Guide: For Application Developers
- *You must read it!!*

User's Guide: For Toolkit Developers

Physics Reference Manual

Software Reference Manual

Installation Guide

http://geant4.web.cern.ch/geant4/G4UsersDocuments/UsersGuides/InstallationGuide/html/index.html

List of *required* software
- C++ compiler, CLHEP, GNU make, Geant4 toolkit
- choices for visualization software

How to install on Linux
Tips for installing on Windows

SLAC team provides a good practical installation guide:
http://geant4.slac.stanford.edu/installation/

In the practical viewpoint, we recommend Geant4 on

Application Developper Guide

http:// geant4.web.cern.ch/geant4/G4UsersDocuments/UsersGuides/ForApplicationDeveloper/html/index.html

Most important document both for novice & advanced users.
- Step-by-step tutorial for novice users
- Describes how to set up and run a simulation application with a lot of example codes
- *You should read this first if you are new to G4.*

Intended as an overview of the toolkit, not an exhaustive treatment. For more details:
- *Physics Reference Manual*
- *Toolkit Developers Guide*

Physics Reference Manual

http://geant4.web.cern.ch/geant4/UserDocumentation/UsersGuides/PhysicsReferenceManual/html/PhysicsReferenceManual.html

Dedicated to the detail description of the physics model used in each Geant4 interaction process.
- separate physics topics from how to use the toolkit
- Dedicated to physics models, theories, etc
  - ✓ There are no C++ codes.
  - ✓ *You should read this when you start to wonder what is going on behind the scene.*

LXR Code Browser

http://www-geant4.kek.jp/LXR/

Search the entire Geant4 source trees by
- *filename (e.g. G4Track.hh)*
- *text*
- *identifier*

Source files fully hyper-linked to classes and methods;
- tells where classes and methods are defined
- also where they are referenced

User Supports

Geant4 Collaboration offers extensive user supports.

- Technical Forum
- Users workshops and Tutorial courses
- HyperNews and mailing list
- Problem tracking system
- Daily "private" communications
- Mailing list for Japanese

Technical Forum

The Technical Forum is open to all interested parties

- To be held at least 4 times per year

The purpose of the forum is to:

- Achieve, as much as possible, a mutual understanding of the needs and plans of users and developers.
- Provide the Geant4 Collaboration with the clearest possible understanding of the needs of its users.
- Promote the exchange of information about physics validation performed by Geant4 Collaborators and Geant4 users.
- Promote the exchange of information about user support provided by Geant4 Collaborators and Geant4 user communities.

Geant4 Users/Collaboration Workshop and Tutorials

Users/Collaboration workshops were held.

- Catania - Oct. 2004
- Bordeaux - Nov.2005
- Lisbon - Oct. 2006
- Manchester - Sep. 2007
- Kobe - Oct. 2008

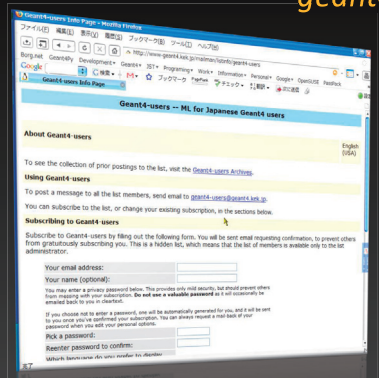
Local workshops/tutorials were organized various places *for different user communities.*

- SLAC/FNAL/ Jefferson : users workshops, tutorials
- NASA/ESA : space users workshops
- KEK : users workshops, tutorials
- IN2P3: tutorials
- INFN : tutorials
- IEEE/MIC : tutorials
- ...

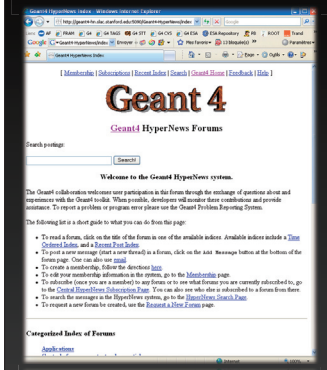
Geant4-users : ML for Japanese Geant4 users

http://www-geant4.kek.jp/mailman/listinfo/geant4-users

geant4-users@geant4.org



HyperNews User Forum

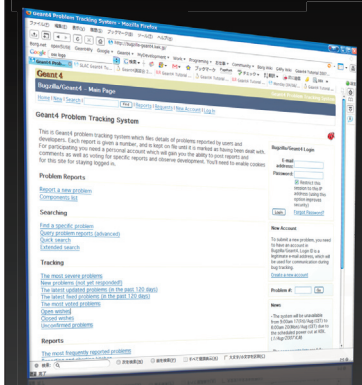


http://geant4-hn.slac.stanford.edu:5090/Geant4-HyperNews/index

Discuss problems with other users, post questions for experts, etc.

- 18 forums roughly based on Geant4 categories
- 4 forums for specific application areas (education, medicine, space, industry)
- New forums may be requested by users

Geant4/Bugzilla



http://bugzilla-geant4.kek.jp/

Geant4 Problem Tracking System based on *Bugzilla*

- *Archives and tracks details of problems reported by users and developers*

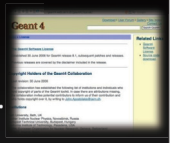
Geant4 Reference Papers

The two main reference papers for Geant4:

Geant4—a simulation toolkit
Nuclear Instruments and Methods in Physics Research Section A: Volume 506, Issue 3, 1 July 2003, Pages 250-303

Geant4 developments and applications
Nuclear Science, IEEE Transactions Publication Date: Feb. 2006 Volume: 53, Issue: 1, Part 2 On page(s): 270- 278

The Geant4 License



The collaboration presets *the Geant4 license*.

- *Makes clear the user's wide-ranging freedom to use, extend or redistribute Geant4, even as part of some for-profit venture.*
- The license was released along with the latest Geant4 release 8.1.
- Simple enough that you can read and understand it.

http://cern.ch/geant4/license/

Introduction to Geant4 Visualization Tools

Akinori Kimura
Ashikaga Institute of Technology

Contents

- Visualization drivers and tools
- Sample UI commands
- Another tool for volume visualization

Functionality of Visualization Drivers

- Simulated data can be visualized
  - Geometrical components
  - Particle trajectories and tracking steps
  - Hits of particles in the geometry
- Other user defined objects can be visualized
  - Polylines
    - such as coordinate axes
  - 3D markers
    - such as eye guides
  - Text
    - descriptive character strings
    - comments, titles, etc.

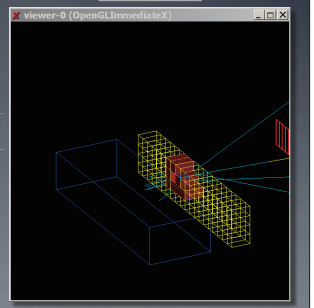
Geant4 Visualization Drivers

- Seven visualization drivers of Geant4:
  - Different drivers are appropriate for different needs.
    - OpenGL
    - OpenInventer
    - HepRep
    - DAWN
    - VRML
    - RayTracer
    - ASCIITree
- The set of commands are consistent regardless of these drivers.

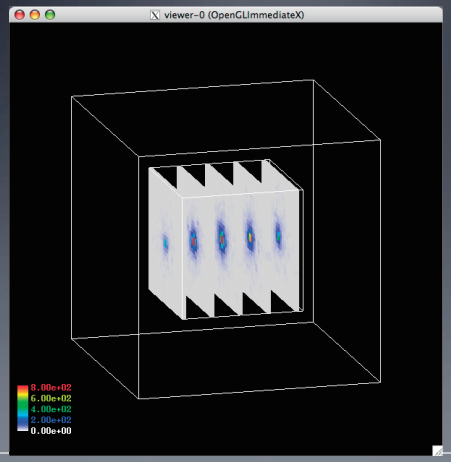
OpenGL

- Quick response with flexible camera control to study geometries, trajectories and hits
  - Control directly from Geant4
  - Uses OpenGL library
    - hardware rendering
  - Affine transform
    - zoom, rotate, translate
  - Saves as pixel image or vector EPS
  - OpenGL with Motif GUI
    - /vis/open OGLIXm

OpenGL



OpenGL Sample



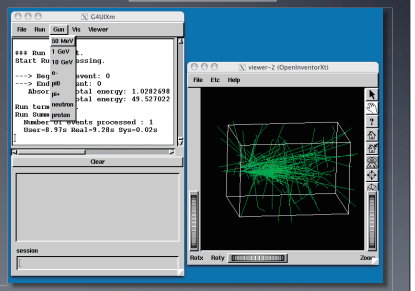
OpenGL Additional Modes

- OpenGL drivers
  - OGLxy
    - x : I (immediate) or S (stored)
    - y : X, Xm (Motif) or Win32
    - Immediate mode: draws only to screen, no "memory"
    - Stored mode: creates graphical database (display lists)
    - Also note: OpenGL supports
      - smooth shading and transparency
      - asymmetric scaling

OpenInventor

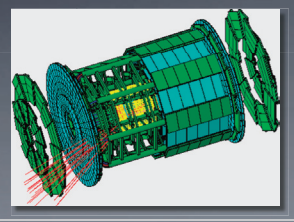
- Control Geant4 from the OpenInventor GUI
- Fast response
  - OpenGL for rendering
- Interactivity
  - zoom, rotate, translate
  - picking
  - show attributes
- Open source project
  - http://openscientist.lal.in2p3.fr/

OpenInventor



DAWN

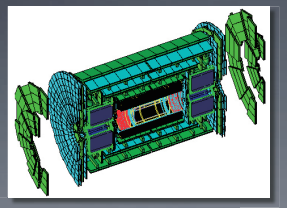
- High-quality output for publications
  - There are actually two DAWN drivers:
    - Creates a *.prim file (DAWNFILE) or connects directly to the DAWN renderer (DAWN)
  - Saves as a vectorized PostScript file
  - developed specifically for Geant4
    - supports all Geant4 primitives



DAWNCUT and DAVID

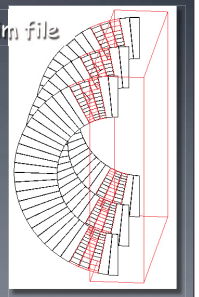
- Standalone programs for processing a DAWN, *.prim, file
- DAWNCUT
  - Volume clipping through a prim file
- DAVID
  - Verifying geometry overlap errors through a prim file

DAWNCUT



- http://geant4.kek.jp/~tanaka/

DAVID

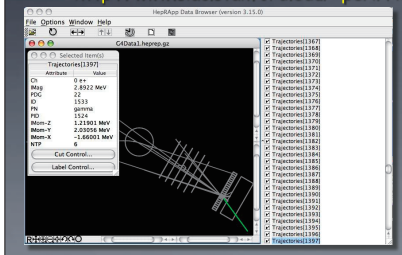


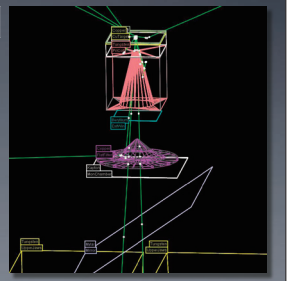
HepRep

- Driver: HepRepFile
- Creates a *.heprep file
  - Viewers: HepRApp HepRep Browser, WIRED4 JAS plug-in, FRED event display
- Wireframe or simple area fills
- Many interactive features
  - zoom, rotate, translate, click to show attributes
  - hierarchical view of the geometry

HepRApp

- Interactive picking to get more information on visualized objects
- Explores the hierarchical geometry, pick to show attributes, apply cuts and labels.
- Saves as EPS, PDF, JPEG, PNG, etc. format file
- Java application
- http://www.slac.stanford.edu/~perl/HepRApp/

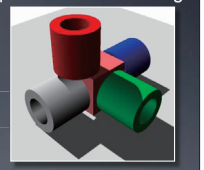




RayTracer

- Understand complex Boolean solids and transparent reflective surfaces
- Reuses Geant4's own tracking to shoot photons through the geometry
- Saves as a jpeg file, or displays image on X Window with the RayTracerX driver

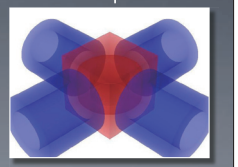
photorealistic shading



Boolean solid

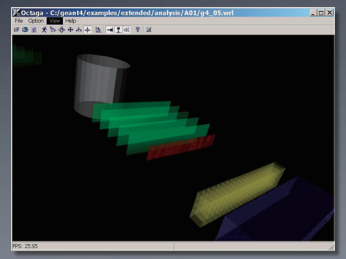
mirrored surface

transparent

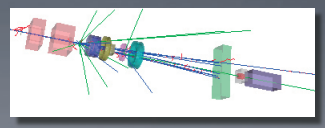


VRML

- Two drivers: VRML1FILE, VRML2FILE
- 3D format suitable for web distribution
  - Many VRML browsers are available with web browser plug-ins or standalone programs.
    - Octaga, Cortona, OpenVRML, etc.



VRML

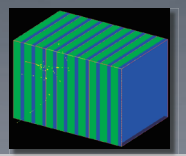


ASCIITree

- Understand geometry hierarchies by text
  - /vis/ASCIITree/verbose 3
    - verbose level 3: prints volume and mass for each volume
  - /vis/drawTree

- "World":0 / "World" / "World"(G4Box), 2592 cm3, 1e-22 mg/cm3 (Galactic)
- "Calorimeter":0 / "Calorimeter" / "Calorimeter"(G4Box), 1500 cm3, 1e-22 mg/cm3 (Galactic)
- "Layer":0-9 (10 replicas) / "Layer" / "Layer"(G4Box), 150 cm3, 1e-22 mg/cm3 (Galactic)
- "Lead":0 / "Lead" / "Absorber"(G4Box), 100 cm3, 11.35 g/cm3 (Lead)
- "liquidArgon":0 / "liquidArgon" / "Gap"(G4Box), 50 cm3, 1.39 g/cm3 (liquidArgon)

- (exampleN03)



Choose Your Suitable Driver

- OpenGL
  - Very responsive graphics
- OpenInventor
  - Very responsive graphics with more interactivity
- HepRep
  - GUI control, picking items, etc.
- DAWN
  - Highest quality image
- VRML
  - A interactive 3D image viewing
- RayTracer
  - Photorealistic image, Boolean geometry, none trajectories
- ASCIITree
  - Quickly checking the geometry hierarchy

Sample: UI Command Sequences

- Visualize detectors in the OpenGL driver
  - /vis/open OGLIX
  - /vis/drawVolume
- Visualize trajectories and hits for 100 events using DAWN
  - /vis/open DAWNFILE
  - /vis/drawVolume
  - /vis/scene/add/trajectories
  - /vis/scene/add/hits
  - /run/beamOn 100

/vis/open Command

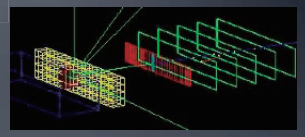
- Choose drivers
  - /vis/open <driver-name>
    - /vis/open OGLIX
    - Driver names:
      - ATree, DAWNFILE, HepRepFile, RayTracer, VRML1FILE, VRML2FILE, DAWN, OGLIX, OGLSX, RayTracerX, VRML1, VRML2, etc.
- Application
  - Multiple drivers can be opened at a time.
    - /vis/open OGLIX
    - /vis/open DAWNFILE
    - /vis/viewer/select viewer-0
    - /vis/viewer/select viewer-1

/vis/viewer/* Commands

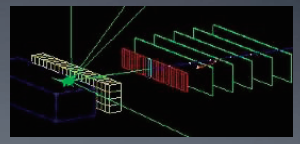
- Camera parameters
  - /vis/viewer/set/*
    - dolly, dollyTo, pan, panTo, scale, scaleTo, zoom, zoomTo
- Reset viewer
  - /vis/viewer/reset [<viewer>]
- Set view direction from target to camera
  - /vis/viewer/set/viewpointThetaPhi <theta> <phi>
  - /vis/viewer/set/viewpointVector <x> <y> <z>
- Set drawing style
  - /vis/viewer/set/style <style>
    - Styles: wireframe, surface

Hidden Line Removal

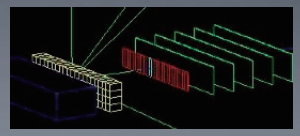
- OpenGL supports hidden line removal
  - Default: Disabled



- To hide geometries,
  - /vis/viewer/set/hiddenEdge 1



- To hide trajectories and hits,
  - /vis/viewer/set/hiddenMarker 1

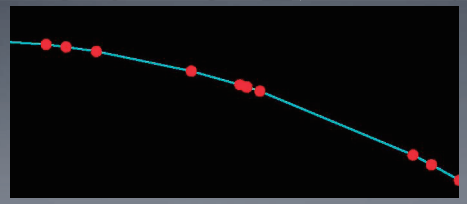


Accumulating Trajectories and Hits

- To add trajectories or hits to the scene
  - /vis/scene/add/trajectories
  - /vis/scene/add/hits
- Refresh accumulation
  - /vis/scene/endOfEventAction <accumulate | refresh>
    - accumulate: accumulates hits, etc., in all events
    - refresh: refreshes before drawing the next event
  - /vis/scene/endOfRunAction
    - for run as well as the endOfEventAction command
- Refreshing and initiating post-processing for graphics systems
  - /vis/viewer/flush
    - = "/vis/viewer/refresh" + "/vis/viewer/update"

Generic Trajectory Model

- Create a generic model (default name: generic-0)
  - /vis/modeling/trajectories/create/generic
- Configure the generic model
  - /vis/modeling/trajectories/generic-0/default/setDrawStepPts true
  - /vis/modeling/trajectories/generic-0/default/setStepPtsSize 16
  - /vis/modeling/trajectories/generic-0/default/setLineColour cyan
  - /vis/modeling/trajectories/generic-0/default/setStopPtsColour red

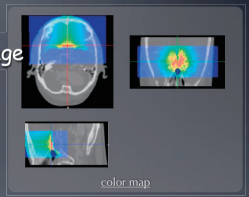


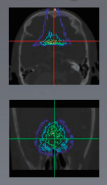
gMocren : A Volume Visualization Tool

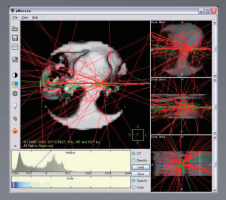
- gMocren is developed for a simulation study of radiotherapy.
  - This development is supported by our JST CREST project.
- A Standalone program for volume visualization
  - Freely available with registration at the web site

Functionality

- Visualizing volume data
  - e.g., patient geometry based on a CT image
- Dose distributions
  - superimposed on the patient image
- Trajectories
  - colored lines
- Future release
  - Detector geometries
  - Other calculated physical information
  - Volume clipping

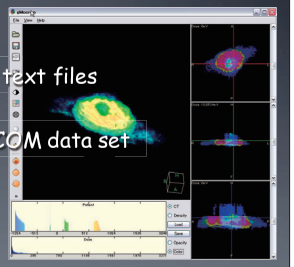

color map


contour map


Trajectories

Utility Tools for gMocren Data File

- A class library to process gdd file
  - gdd file: gMocren dedicated data format file
- Tools based on the class library
  - dumpgdd: dump a gdd file
  - makegdd: create a gdd file from some text files
  - mergegdd: merge two gdd files
  - dicom2gdd: create a gdd file from DICOM data set



- gMocren web site
  - http://geant4.kek.jp/gMocren/
    - Manuals
    - gMocren program, utility tools and sample data are available.

Summary

- Seven visualization drivers
  - OpenGL
    - Very responsive graphics
  - OpenInventor
    - Very responsive graphics with more interactivity
  - HepRep (HepRApp, WIRED,4 etc.)
    - GUI control, picking items, etc.
  - DAWN (DAWN, DAWNCUT, DAVID)
    - Highest quality image
  - VRML
    - A interactive 3D image viewing
  - RayTracer
    - Photorealistic image, Boolean geometry, none trajectories
  - ASCIITree
    - Quickly checking the geometry hierarchy
- Volume visualization tool
  - gMocren

Geant4 Visualization Resources

- Geant4 Installation Guides
  - http://geant4.slac.stanford.edu/installation
- Hands on HepRApp Tutorial
  - http://geant4.slac.stanford.edu/Presentations/vis/G4HepRAppTutorial/G4HepRAppTutorial.html
- Hands on DAWN Tutorial
  - http://geant4.slac.stanford.edu/Presentations/vis/G4DAWNTutorial/G4DAWNTutorial.html
- Hands on OpenGL Tutorial
  - http://geant4.slac.stanford.edu/Presentations/vis/G4OpenGLTutorial/G4OpenGLTutorial.html
- Introduction to Geant4 Visualization
  - http://geant4.slac.stanford.edu/Presentations/vis/G4VisIntroduction.ppt
- Geant4 Visualization Commands
  - http://geant4.slac.stanford.edu/Presentations/vis/G4VisCommands.ppt
- Geant4 Advanced Visualization
  - http://geant4.slac.stanford.edu/Presentations/vis/G4VisAdvanced.ppt
- How to Make a Movie
  - http://geant4.slac.stanford.edu/Presentations/vis/HowToMakeAMovie.ppt
- Visualization Chapter of the Geant4 User's Guide for Application Developers
  - http://geant4.web.cern.ch/geant4/UserDocumentation/UsersGuides/ForApplicationDeveloper/html/
- List of Visualization Commands:
  - http://geant4.web.cern.ch/geant4/UserDocumentation/UsersGuides/ForApplicationDeveloper/html/AllResources/Control/UICommands/_vis_.html
- For Questions or Comments: Geant4 Visualization Online Forum:
  - http://geant4-hn.slac.stanford.edu:5090/HyperNews/public/get/visualization.html