(H02) Introduction of medical application examples in Geant4 and the Hands-on code

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Outline

- Introduction of the Geant4 bundled medical application examples

- How to build and run the Geant4 application [Hands-on]
  - Basics of file structures
  - Basics of user-interface commands
    - /run, /vis, /tracking

  - Exercise

The example medical applications bundled in the Geant4 distribution (1)

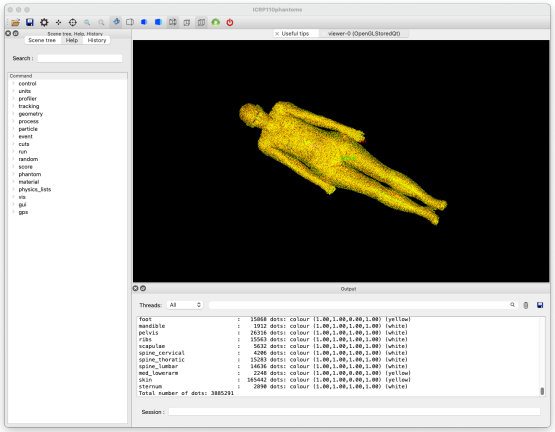
- /opt/geant4/src/geant4-v11.1.2/examples/
  - basic/B3
    - B3a and B3b, (Simple PET system w/ two scoring implementations)
  - extended/medical/
    - DICOM (The DICOM handler for building a voxelated CT geometry)
    - DICOM2 (Extended scoring implementation in the DICOM example)
    - GammaTherapy, (A gamma therapy application)
    - dna, (The Geant4-DNA physics/chemistry processes and models)
    - electronScattering (Electron scattering benchmark w/simple condition)
    - electronScattering2 (Electron scattering benchmarks for the NRCC experiment)
    - fanoCavity (The dose deposited ionization chamber by a photon beam)
    - fanoCavity2 (The dose deposited in an ionization chamber by an electron beam)

The sample medical applications bundled in the Geant4 distribution (2)

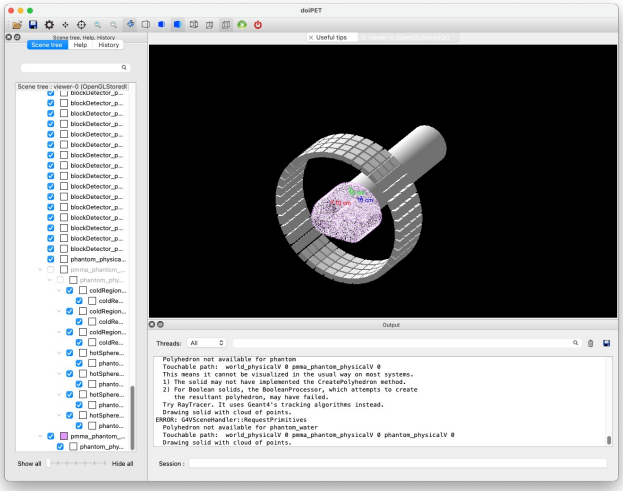
- /opt/geant4/src/geant4-v11.1.2/examples/
  - advanced/
    - **doiPET**, (The depth-of-interaction enabled PET scanner and NEMA NU phantoms)
    - **ICRP110_HumanPhantoms**, (ICRP110 anthropomorphic phantoms)[See Sep.27th J.Archer]
    - **ICRP145_HumanPhantoms**, (ICRP145 anthropomorphic phantoms)[See Sep.27th J.Archer]
    - brachytherapy, (A brachytherapy example w/ a water phantom)
    - **eFLASH_radiotherapy**, (A low-energy electron FLASH beamline in the CPFR at Pisa)
    - gammaknife, (A Leksell Gamma-knife in Catania for stereotactic radiosurgery)
    - hadrontherapy, (A hadron therapy beamline of the passive proton therapy at INFN)
    - human_phantom, (Analytical anthropomorphic phantoms of MIRD and ORNL models)
    - iort_therapy, (A typical intraoperative electron radiation therapy beamline)
    - medical_linac, (A typical medical linear accelerator for IMRT, Varian clinac 2100 accelerator)

Examples

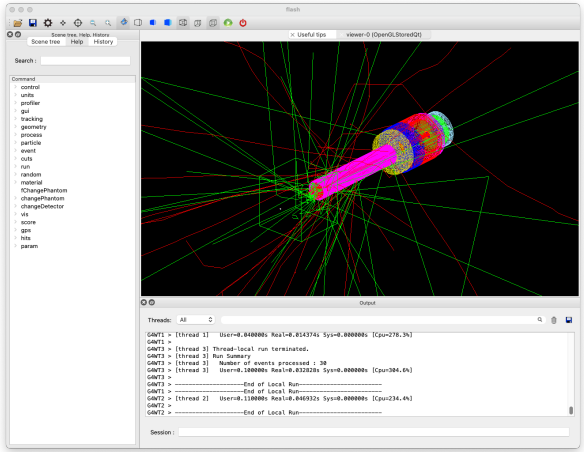
ICRP110_HumanPhantoms



doiPET



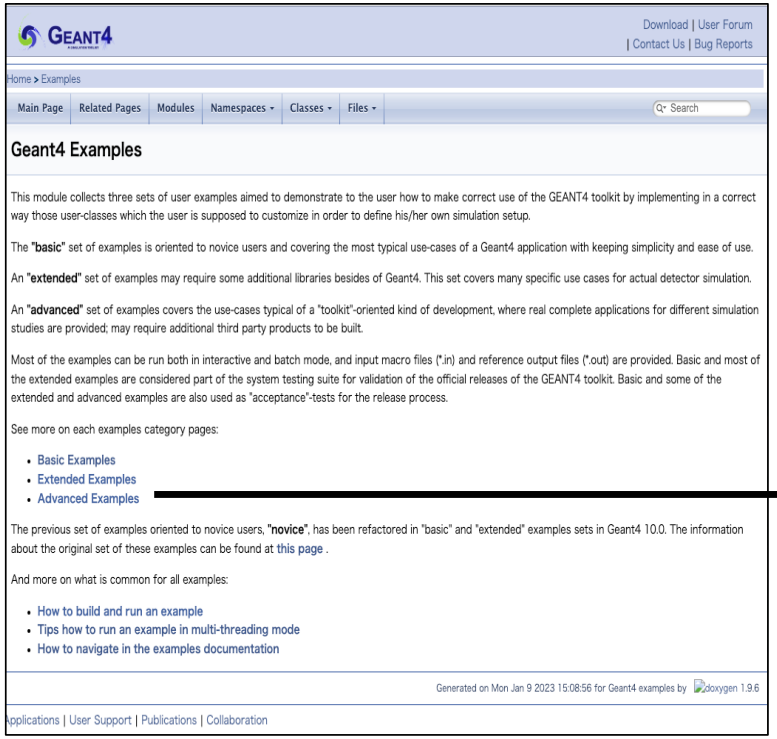
eFLASH_radiotherapy



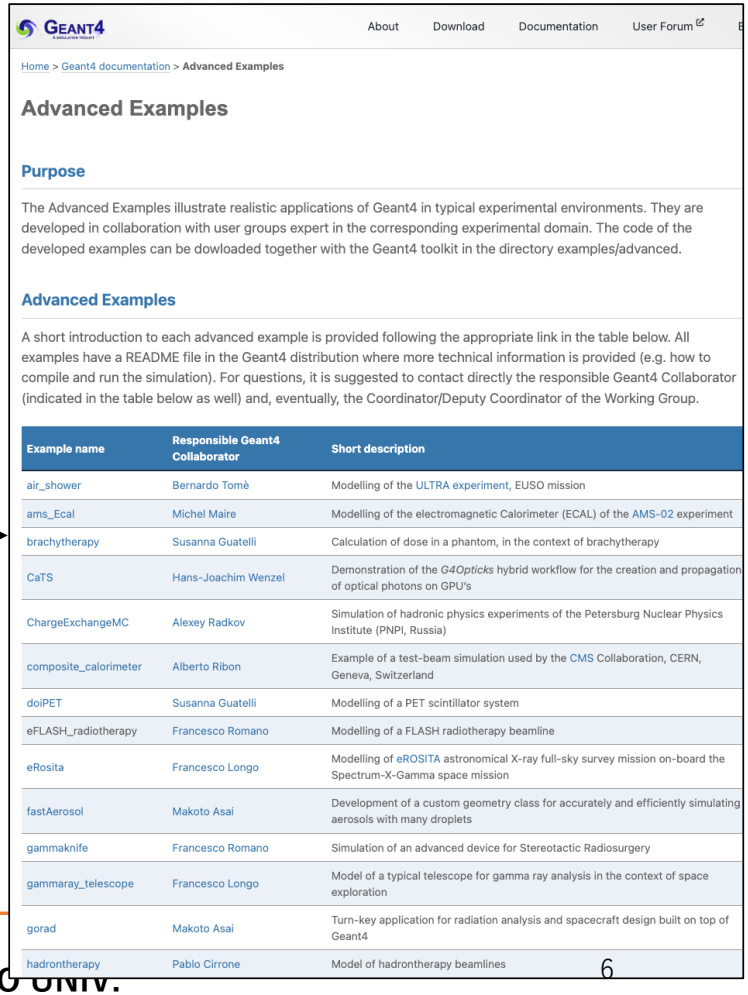
More information about these medical example applications

- The Geant4 documentation
- The detail description about these example applications are Here

Geant4 Examples



Geant4 Advanced Examples



(Tips) Unix commands

$ pwd (Print working directory)

$ ls -l (Show list of files in the current directly)

$ cd (Change directory to your home directory. e.g. /home/g4user)

$ mkdir *directoryname* (Create a new directory w/ the name of *directoryname*)

$ cd *directoryname* (Change directory to *directoryname*)

$ cd .. (Change directory to an upper directory)

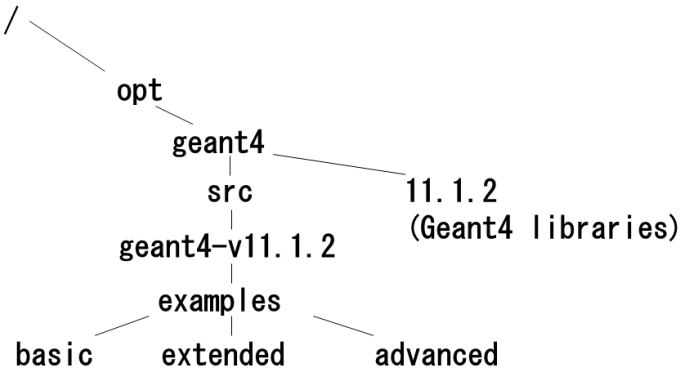
$ less *filename* (Show the file content. scroll by [space]. End by [q])

$ code *filename* (Edit the file in vscode. At first time, you may be required passwd. !!g4user)

$ cp -r *sourceDir* . (Copy a directory from the *sourceDir* to the current directory)

Your login directory

It is called as "home directory.



(Tips) Geant4 w/ visualization

- Depending on machine conditions, we may have problem of visualization such as very slow response, hang-up of application.

- If you have such problem, set the Geant4 RunManager type to serial by:
  $ export G4FORCE_RUN_MANAGER_TYPE=Serial

  - This command forces the Geant4 to run with a single thread mode.

- When you want to use the multithreading mode, clear it by:
  $ export -n G4FORCE_RUN_MANAGER_TYPE

How to build and run an example application (1) [Hands-on]

- We start from a basic example of B3a and assume we work at the home directory
- Check the current directory
  $ cd
  $ pwd (Should be /home/g4user)
- Copy the B3a example code from Geant4 source code to your current directory
  $ cp -r /opt/geant4/src/geant4-v11.1.2/examples/basic/B3/B3a .
- Create a build directory
  $ mkdir B3a-build
- Change directory to the building directory. (e.g. /home/g4user/B4a-build)
  $ cd B3a-build
- Prepare the Makefile using cmake command with the source directory of the example code.
  $ cmake ../B3a
- Build the application using the make command
  $ make

How to build and run an example application (2) [Hands-on]

- Check the executable filename

  $ ls -l

  (You will find something like …)

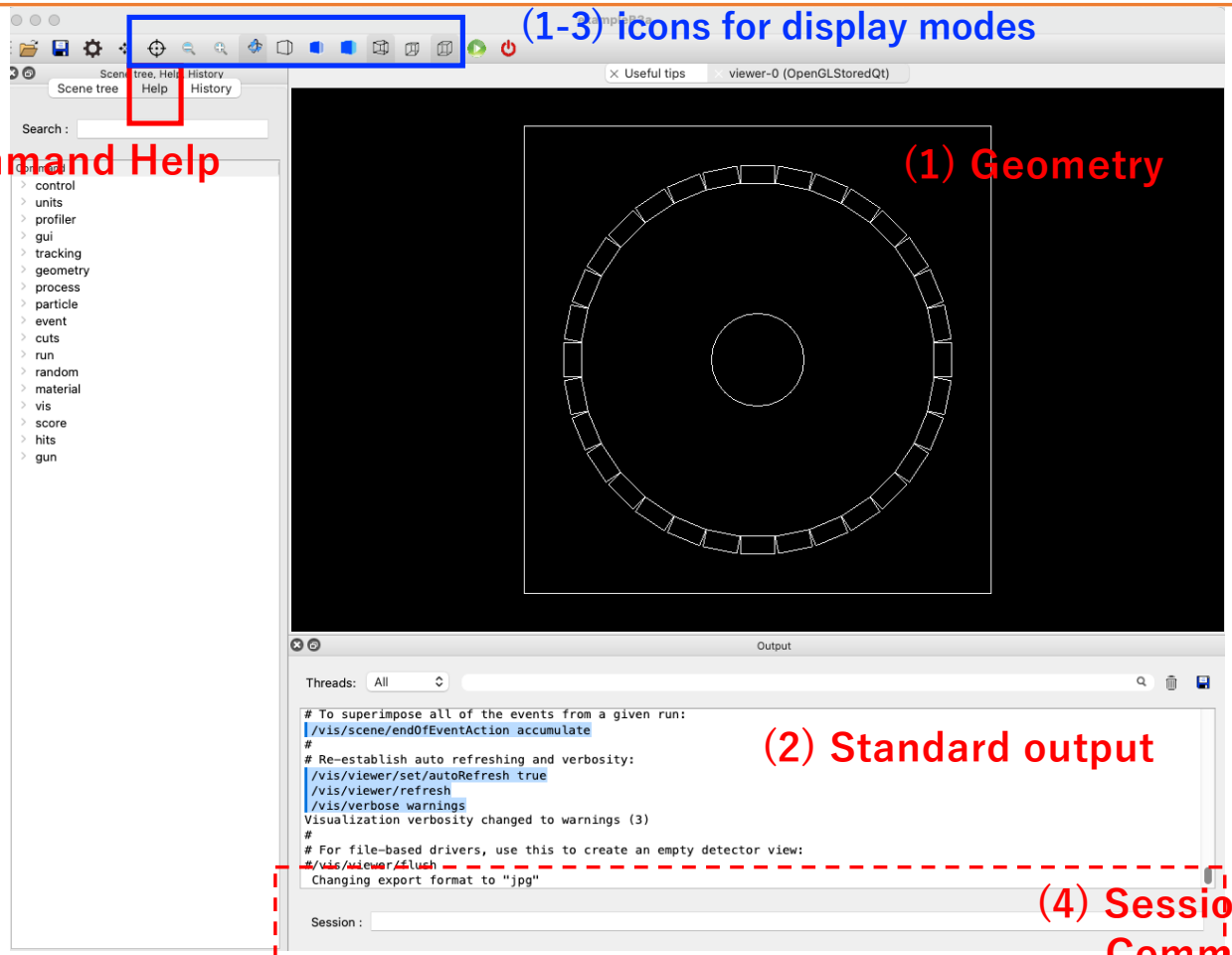
  ```
  -rwxr-xr-x   1 g4user  staff  600263  9  9 12:22 exampleB3a
  ```

- Run the application

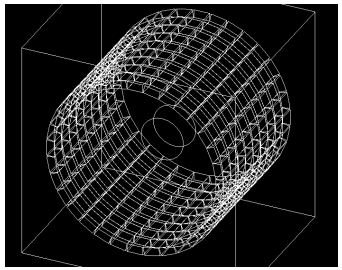
  $ ./exampleB3a

Qt GUI interface w/ example3a (1)　[Hands-on]

- Qt window



(1-1)Drag, rotate the geometry



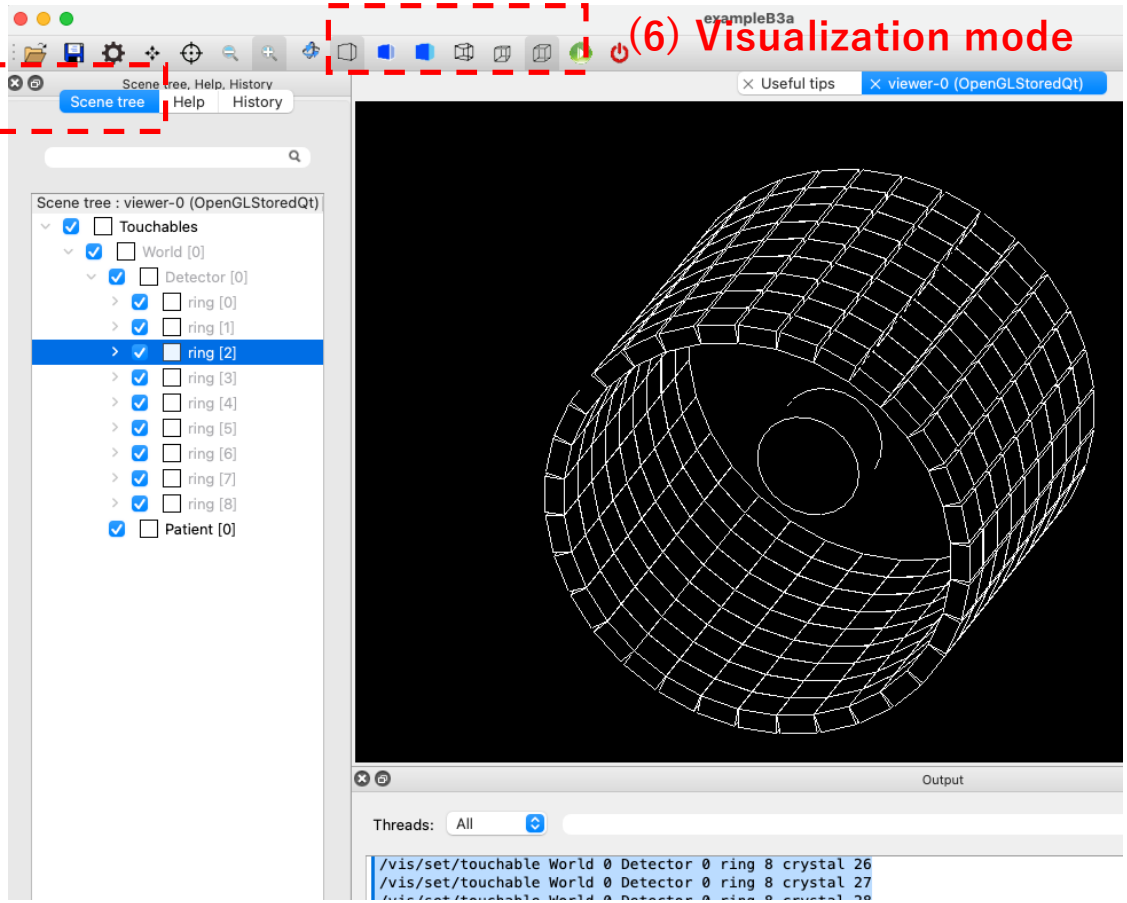
(1-2) Right click opens a menu

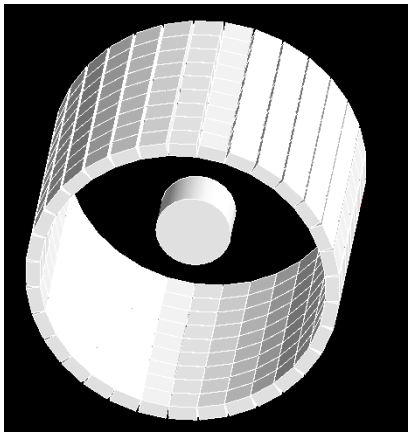
Qt GUI interface w/ example3a (2) [Hands-on]

- Qt window

(5) Scene tree

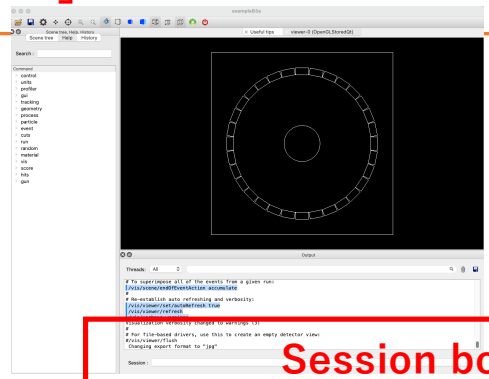
The geometrical structure



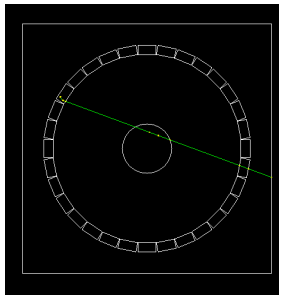


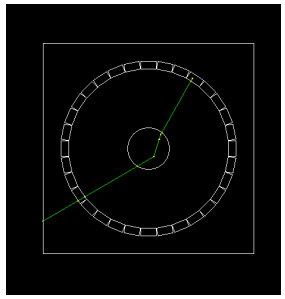
Geant4 basic commands (1) [Hands-on]

- Try to use the commands in **session box**



- Viewer reset
  - **/vis/viewer/reset**
- Geometry overlapping checker
  - **/geometry/test/run**
- Generate primary particles
  - **/run/beamOn 1**
  - /run/beamOn 1
- Visualization OFF/ON
  - **/vis/disable**
  - /run/beamOn 1
  - **/vis/enable**
  - /vis/beamOn 1





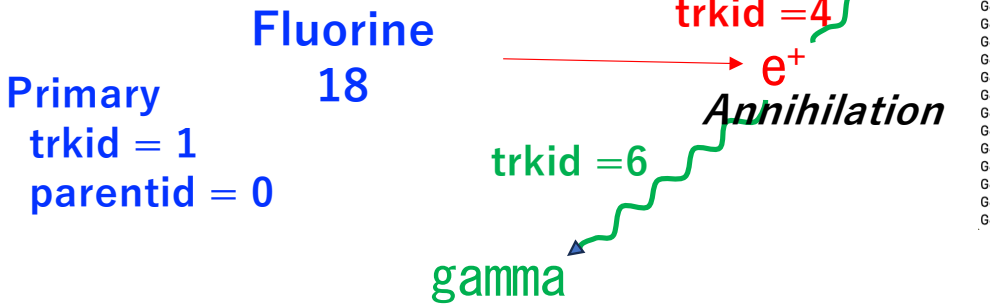
Geometry overlapping checker

```
/geometry/test/resolution
/geometry/test/recursion_start
/geometry/test/recursion_depth
/geometry/test/run
/geometry/test/run
Running geometry overlaps check...
Checking overlaps for volume Detector:0 (G4Tubs) ... OK!
Checking overlaps for volume ring:0 (G4Tubs) ... OK!
Checking overlaps for volume crystal:0 (G4Box) ... OK!
Checking overlaps for volume crystal:1 (G4Box) ... OK!
Checking overlaps for volume crystal:2 (G4Box) ... OK!
Checking overlaps for volume crystal:3 (G4Box) ... OK!
Checking overlaps for volume crystal:4 (G4Box) ... OK!
Checking overlaps for volume crystal:5 (G4Box) ... OK!
Checking overlaps for volume crystal:6 (G4Box) ... OK!
Checking overlaps for volume crystal:7 (G4Box) ... OK!
Checking overlaps for volume crystal:8 (G4Box) ... OK!
Checking overlaps for volume crystal:9 (G4Box) ... OK!
Checking overlaps for volume crystal:10 (G4Box) ... OK!
Checking overlaps for volume crystal:11 (G4Box) ... OK!
Checking overlaps for volume crystal:12 (G4Box) ... OK!
Checking overlaps for volume crystal:13 (G4Box) ... OK!
Checking overlaps for volume crystal:14 (G4Box) ... OK!
Checking overlaps for volume crystal:15 (G4Box) ... OK!
Checking overlaps for volume crystal:16 (G4Box) ... OK!
Checking overlaps for volume crystal:17 (G4Box) ... OK!
Checking overlaps for volume crystal:18 (G4Box) ... OK!
Checking overlaps for volume crystal:19 (G4Box) ... OK!
```

Geant4 basic commands (2) [Hands-on]

- Dump the track information for debugging purpose
  - **/tracking/verbose 1**
  - /run/beamOn 1
  - **/tracking/verbose 0**
  - /run/beamOn 1

- Exit the application
  - exit




```
G4WT1 > /tracking/verbose 1

================================================================================
--> G4TaskRunManager::CreateAndStartWorkers() --> Creating 1 tasks with 1 events/task...
================================================================================

Adding task 0 to task-group...
G4WT0 > ### Run 0 starts on worker thread 0.
G4WT0 > ### Run 0 start.
G4WT0 > ... set ntuple merging row mode : row-wise - done
G4WT0 >
G4WT0 > ********************************************************************************
G4WT0 > * G4Track Information:   Particle = F18,   Track ID = 1,   Parent ID = 0
G4WT0 > ********************************************************************************
G4WT0 >
G4WT0 > Step#       X          Y          Z         KineE        dEStep    StepLeng   TrakLeng    Volume     Process
G4WT0 >     0   3.653 cm   4.229 cm   3.895 cm       1 eV          0 eV       0 fm       0 fm    Patient   initStep
G4WT0 >     1   3.653 cm   4.229 cm   3.895 cm       0 eV          1 eV   1.372 nm   1.372 nm    Patient     ionIoni
G4WT0 >     2   3.653 cm   4.229 cm   3.895 cm       0 eV          0 eV       0 fm   1.372 nm    Patient   RadioactiveDecay
G4WT0 >
G4WT0 > ********************************************************************************
G4WT0 > * G4Track Information:   Particle = e+,   Track ID = 4,   Parent ID = 1
G4WT0 > ********************************************************************************
G4WT0 >
G4WT0 > Step#       X          Y          Z         KineE        dEStep    StepLeng   TrakLeng    Volume     Process
G4WT0 >     0   3.653 cm   4.229 cm   3.895 cm   214.2 keV          0 eV       0 fm       0 fm    Patient   initStep
G4WT0 >     1   3.667 cm   4.227 cm   3.917 cm       0 eV       214.2 keV  467.5 um   467.5 um    Patient       eIoni
G4WT0 >     2   3.667 cm   4.227 cm   3.917 cm       0 eV          0 eV       0 fm   467.5 um    Patient     annihil
G4WT0 >
G4WT0 > ********************************************************************************
G4WT0 > * G4Track Information:   Particle = gamma,   Track ID = 6,   Parent ID = 4
G4WT0 > ********************************************************************************
G4WT0 >
G4WT0 > Step#       X          Y          Z         KineE        dEStep    StepLeng   TrakLeng    Volume     Process
G4WT0 >     0   3.667 cm   4.227 cm   3.917 cm     511 keV          0 eV       0 fm       0 fm    Patient   initStep
G4WT0 >     1   7.487 cm    2.82 cm   2.483 cm     511 keV          0 eV   4.316 cm   4.316 cm    Patient   Transportation
G4WT0 >     2   29.97 cm  -5.462 cm  -5.956 cm     511 keV          0 eV    25.4 cm   29.72 cm      World   Transportation
G4WT0 >     3   29.97 cm  -5.463 cm  -5.958 cm     511 keV          0 eV   42.14 um   29.72 cm       ring   Transportation
G4WT0 >     4   32.82 cm  -6.513 cm  -7.028 cm     511 keV          0 eV    3.22 cm   32.94 cm    crystal   Transportation
G4WT0 >     5   32.97 cm   -6.57 cm  -7.085 cm     511 keV          0 eV   1.738 mm   33.11 cm       ring   Transportation
```

Primary particle

Position

Volume

Exercise (1) [Hands-on]

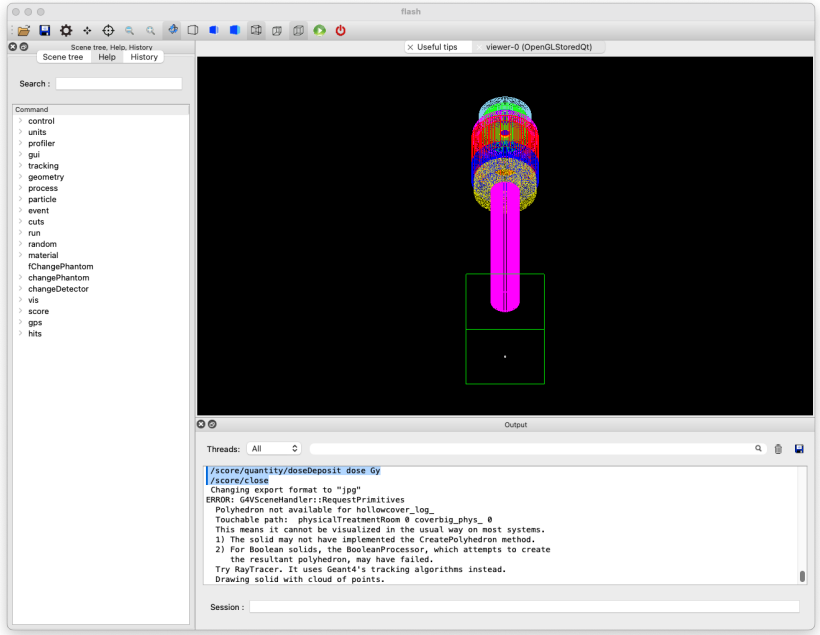
- Build and run the other example application
  - Recommend **eFLASH_radiotherapy**
  - Source files: /opt/geant4/src/geant4-v11.1.2/examples/advanced/eFLASH_radiotherapy

Answer

```
$ cd
$ pwd  (Check the current directory)
$ cp  -r  /opt/geant4/src/geant4-v11.1.2/examples/advanced/eFLASH_radiotherapy   .
$ mkdir  eFLASH_radiotherapy-build
$ cd  eFLASH_radiotherapy-build
$ pwd   (Check the current directory)
$ cmake   ../eFLASH_radiotherapy
$ make
$ ls -l   (Check the filename of executable)
$ ./flash
```

Exercise (2) [Hands-on]

- Session:
  - /geometry/test/run
  - /tracking/verbose 1
  - /run/beamOn 1
  - /tracking/verbose 0
  - /run/beamOn 10
  - exit



A Hands-on example code of this tutorial [Hands-on]

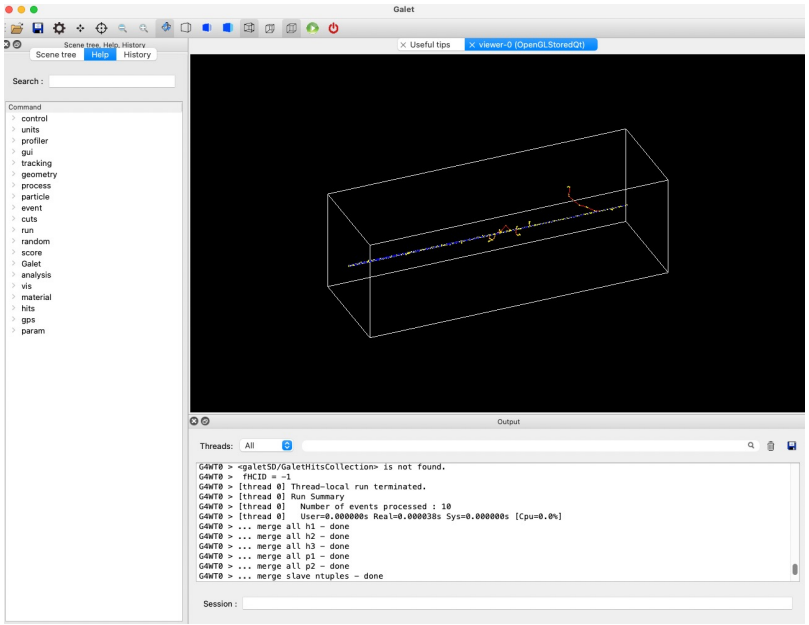
- ***Galet***, *Geant4 application templet*
  - A simple Skelton code for rapid prototyping of a Geant4 application
  - Download from the Indico of this lecture using your browser in VM.
    - Galet-v11-MedEx-01.tar.gz
  - Then extract the tarball (Ensure you are in your home-directory)

    ```
    $ cd
    $ tar zxvf  ~/Downloads/Galet-v11-MedEx-01.tar.gz
    or $ tar xvf ~/Downloads/Galet-v11-MedEx-01.tar
    ```
  - Build the *Galet*

    ```
    $ cd
    $ mkdir Galet-v11-MedEx-01-build
    $ cd Galet-v11-MedEx-01-build
    $ cmake ../Galet-v11-MedEx-01
    $ make
    ```

Galet run options [Hands-on]

- Help of run options
  $ ./Galet -h
    - Usage: $ Galet [-m macro] [-u UIsession] [-t nThreads]
- Run the Galet w/ GUI mode
  $ ./Galet
  Session: /run/beamOn 10
  Session: exit
- Run the Galet w/ CUI
  $ ./Galet -u tcsh
  Idle> /run/beamOn 10
  Idle> exit
- Run the Galet in batch mode w/ run0.mac
  $ ./Galet -m run0.mac
- Run the Galet w/ two threads in batch made.
  $ ./Galet -t 2 -m run0.mac



Directories and Files [Hands-on]

- Directory structure
  - Check files in the source directory
    $ cd ~/Galet-v11-MedEx-01
    $ ls -l
  - It shows:
    - REAME.md
    - CMakeLists.txt
    - Galet.cc (main program)
    - init.mac (Macro for initialization commands)
      - phys.mac (Macro for choosing physics constructors)
      - gps.mac (Macro for primary particle)
    - vis.mac (Macro for visualization commands)
    - run0.mac (Sample macro for batch mode)
    - include/ (Directory for .hh files)
    - src/ (Directory for .cc files)

Macro files specialized in Galet

run0.mac (for batch mode)

```
## Mandatory for initialization
/control/execute init.mac
#
## Start simulation
/run/beamOn 10
```

init.mac

```
#
# Galet macro: init.mac
#
/control/verbose 2
/control/saveHistory
/run/verbose 1
#
# physics list
/control/execute phys.mac
#
# Initialize kernel
/run/initialize
#
# Primary particle
/control/execute gps.mac
#
```

phys.mac

```
###################################################
# EM processes including generic ions.
###################################################
#/Galet/physics/register G4EmStandardPhysics
#/Galet/physics/register G4EmStandardPhysics_option1
#/Galet/physics/register G4EmStandardPhysics_option2
/Galet/physics/register G4EmStandardPhysics_option3
#/Galet/physics/register G4EmStandardPhysics_option4
#/Galet/physics/register G4EmLivermorePhysics
#/Galet/physics/register G4EmPenelopePhysics
#/Galet/physics/register G4EmDNAPhysics
###################################################
…snipped
```

gps.mac

```
#-----
# Proton pencil beam
#-----
/gps/position 0. 0.  150. cm
/gps/direction 0. 0. -1.
/gps/energy   200. MeV
/gps/particle  proton
..snipped
```

Basics about Directories and Files in Galet-v11-MedEx

- File structure (Only important files for the first step are listed here)

  - Galet.cc (main program)

$ ls src

- DetectorConstruction.cc
- PhysicsList.cc
- ActionInitialization.cc

runManager->
SetUserInitializtion()

actionInitialization->
SetUserAction()

- PrimaryGenaratorAction.cc
- RunAction.cc
- EventAction.cc
- SteppingAction.cc
- TrackingAction.cc

Take a look at the main program, Galet.cc [Hands-on]

```
$ less Galet.cc
```

type [space] to scroll down,

type [b] to scroll back,

type [q] to exit

runManager->
SetUserInitializtion()

```
  //
  // Construct the default run manager
  auto* runManager =
    G4RunManagerFactory::CreateRunManager(G4RunManagerType::Default);
#ifdef G4MULTITHREADED
  if ( nThreads > 0 ) {
    runManager->SetNumberOfThreads(nThreads);
  }
#endif

  //
  // Scoring Manager
  G4ScoringManager* scManager = G4ScoringManager::GetScoringManager();
  scManager->SetVerboseLevel(1);

  //
  // Set mandatory initialization classes
  // Detector-Construction and ParallelWorld-Construction
  auto detConstruction = new Galet::DetectorConstruction();
  //
  // Parallel world geometry registration.
  //G4String paraWorldName = "paraWorld1";
  //auto* paraWorld = new Galet::ParallelWorldConstruction(paraWorldName);
  //detConstruction->RegisterParallelWorld(paraWorld);
  runManager->SetUserInitialization(detConstruction);

  //
  // PhysicsList
  auto physicsList = new Galet::PhysicsList;
  runManager->SetUserInitialization(physicsList);

  //
  // ActionInitializtion
  auto actionInitialization = new Galet::ActionInitialization();
  runManager->SetUserInitialization(actionInitialization);

  //
  // Initialize visualization
  auto visManager = new G4VisExecutive;
```

Take a look at the ActionInitialization.cc [Hands-on]

```
$ less  src/ActionInitialization.cc
```

type [space] to scroll down,

type [b] to scroll back,

type [q] to exit

actionInitialization->
SetUserAction()

```
/// ActionInitialization
///
/// (Authors)
/// 2023-04-21 T.Aso, C.Omachi, T.Toshito, T. Yamashita
///

#include "ActionInitialization.hh"
#include "PrimaryGeneratorAction.hh"
#include "RunAction.hh"
#include "EventAction.hh"
#include "SteppingAction.hh"
#include "TrackingAction.hh"

namespace Galet{
//....oooOOOOOooo........oooOOOOOooo........oooOOOOOooo........oooOOOOOooo.
void ActionInitialization::BuildForMaster() const
{
  SetUserAction(new RunAction);
}
//....oooOOOOOooo........oooOOOOOooo........oooOOOOOooo........oooOOOOOooo.
void ActionInitialization::Build() const
{
  SetUserAction(new PrimaryGeneratorAction);
  SetUserAction(new RunAction);
  SetUserAction(new EventAction);
  SetUserAction(new SteppingAction);
  SetUserAction(new TrackingAction);
}
//....oooOOOOOooo........oooOOOOOooo........oooOOOOOooo........oooOOOOOooo.
}
(END)
```

Summary

- You briefly learn about the medical example applications in the Geant4 distribution

- Now you can build and run these examples
  - make a build directory
  - using commands of cmake and then make

- You can check the simulation on GUI
  - Qt viewer
  - UI commands, /run/beamOn, /tracking/verbose, /vis/disable etc.

- You are ready for the next hands-on with an example code, Galet
  - Galet run options
  - macro files (and /control/execute command)
  - File structure of Galet example code