Geant4 Best Practices

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Purpose and Structure of this Talk

• Your applications probably started as a copy of some specific Geant4 code from a published example or another user

• More robust solutions may now be available for much of what you're doing

• I'll start from the particle source and work my way towards the scoring

G4GeneralPartcleSource

More convenient than the default G4ParticleGun for most applications

- Developed by QinetiQ in the UK for European Space Agency

    – included in the Geant4 release

    – detailed documentation at: http://reat.space.qinetiq.com/gps/

> **Spectrum**: linear, exponential, power-law, Gaussian, blackbody, or piece-wise fits to data.
> **Angular distribution**: unidirectional, isotropic, cosine-law, beam or arbitrary (user defined).
> **Spatial sampling**: on simple 2D or 3D surfaces such as discs, spheres, and boxes.
> **Multiple sources**: multiple independent sources can be used in the same run.

- Create from a single line in your EventGenerator

    – particleGun = new G4GeneralParticleSource();

- Control from Macro:
    – /gps/energy 13.00 MeV
    – /gps/particle e-
    – /gps/direction 0. 0. 1.
    – /gps/pos/type Beam
    – /gps/pos/shape Circle
    – /gps/pos/sigma_r 0.042 cm
    – /gps/pos/centre 0. 0. -57.7 cm

Import of CAD Designs through GDML

Another advance that came through the aerospace community

• Still requires a fairly complex chain to convert: STEP files (from CAD) to GDML (for Geant4) via a converter such as Fastrad

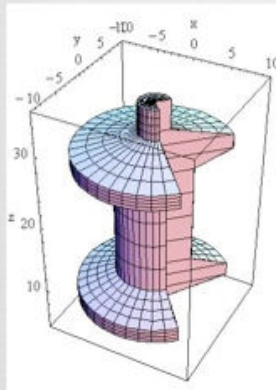– but capable of modeling imported structures in great detail

NIST Materials Database

An easier and less error-prone way to specify your materials

```
void ElectronBenchmarkDetector::DefineMaterials(){
    // Use NIST database for elements and materials whereever possible.
    G4NistManager* man = G4NistManager::Instance();
    man->SetVerbose(1);

    // Define elements from NIST
    G4Element* C  = man->FindOrBuildElement("C");
    G4Element* Cr = man->FindOrBuildElement("Cr");
    ...

    // Define pure NIST materials
    man->FindOrBuildMaterial("G4_Al");
    man->FindOrBuildMaterial("G4_Ti");

    // Define other NIST materials
    man->FindOrBuildMaterial("G4_WATER");
    man->FindOrBuildMaterial("G4_KAPTON");

    // Define materials not in NIST
    G4double density;
    G4int ncomponents;
    G4double fractionmass;
    G4Material* StainlessSteel = new G4Material("StainlessSteel", density= 8.06*g/cm3, ncomponents=6);
    StainlessSteel->AddElement(C, fractionmass=0.001);
    StainlessSteel->AddElement(Si, fractionmass=0.007);
    StainlessSteel->AddElement(Cr, fractionmass=0.18);
    StainlessSteel->AddElement(Mn, fractionmass=0.01);
    StainlessSteel->AddElement(Fe, fractionmass=0.712);
    StainlessSteel->AddElement(Ni, fractionmass=0.09);
```

- makes your papers easier to write
    - "we used NIST materials specifications..."

Physics

- EM

  - G4StandardPhysics may be the best option now for many applications such as medical that previously used the low energy processes

  - Multiple Scattering has improved greatly in recent releases

  - Standard and LowE groups working together closely now
    - shared interfaces, allowing single physics list to mix processes from both domains

- Hadronics

  - Heavy development in many areas, such as ion physics, driven by medical and aerospace

  - Continuing development of new models (such as QMD)

Physics is Your Job

- Geant4 is a toolkit
    - It is not a ready-made and nicely packaged application.
    - It is not meant to be used by a technician.
    - It assumes that a physicist is checking the results, adjusting options, paying attention (what all of you in this room are paid to do)
    - Particularly at Medical Physics and Aerospace energies, Geant4 physics is being actively developed at every release.
- You need to read the release notes
    - Because Geant4 has so many different application domains, there will be a lot in those notes that doesn't matter to you (e.g. for a medical physicist, processes above 100 GeV, exotic particles, etc.). You'll have to wade through that.
    - Nothing can take the place of you reading those full release notes.
- And though we test a large number of example applications at every release, there may be something in your particular application that we did not test.
    - You need to be watchful.

DICOM Navigation

G4NestedParameterization and G4RegularParameterization are both reasonable options for handling large numbers of voxels with reasonable speed and memory

- Bring typical DICOM memory footprints down from 1GB to 25MB

- G4RegularNavigation

  – A navigator that takes advantage of regularity of voxel geometries

  – See DICOM example for details

  – Option to skip boundaries if next voxel is of same material type

    - First release did not correctly handle dose sharing when skipping boundaries

    - Corrected in DICOM example in 4.9.3.beta1 and will be in December release

Smart Particle Stack

New option in particle stack allows you to iterate to next particle of a given type rather than just next particle

- Reduces time cost of swapping cross section tables in and out of cache
    - Even if have plenty of RAM, local cache is a constraint

- Not yet in release, but can be made available by request from SLAC group and will be in December release

Scoring

For most cases, it is no longer necessary to score dose by hand,
from hand-coded "sensitive detectors" or from user stepping actions

- Standard scorers can be called from C++ or can be invoked by commands

  - Energy

  - Flux

  - Charge

  - Surface Current

  - Population, etc., etc.

  - See geant4/digits_hits/scorer
    for all the options

- Standard filters

  - control which kinds
    of particles get scored

- Geometry options

  - Rectangular

  - Cylindrical

  - Spherical

viewer-0 (OpenGLImmediateX)
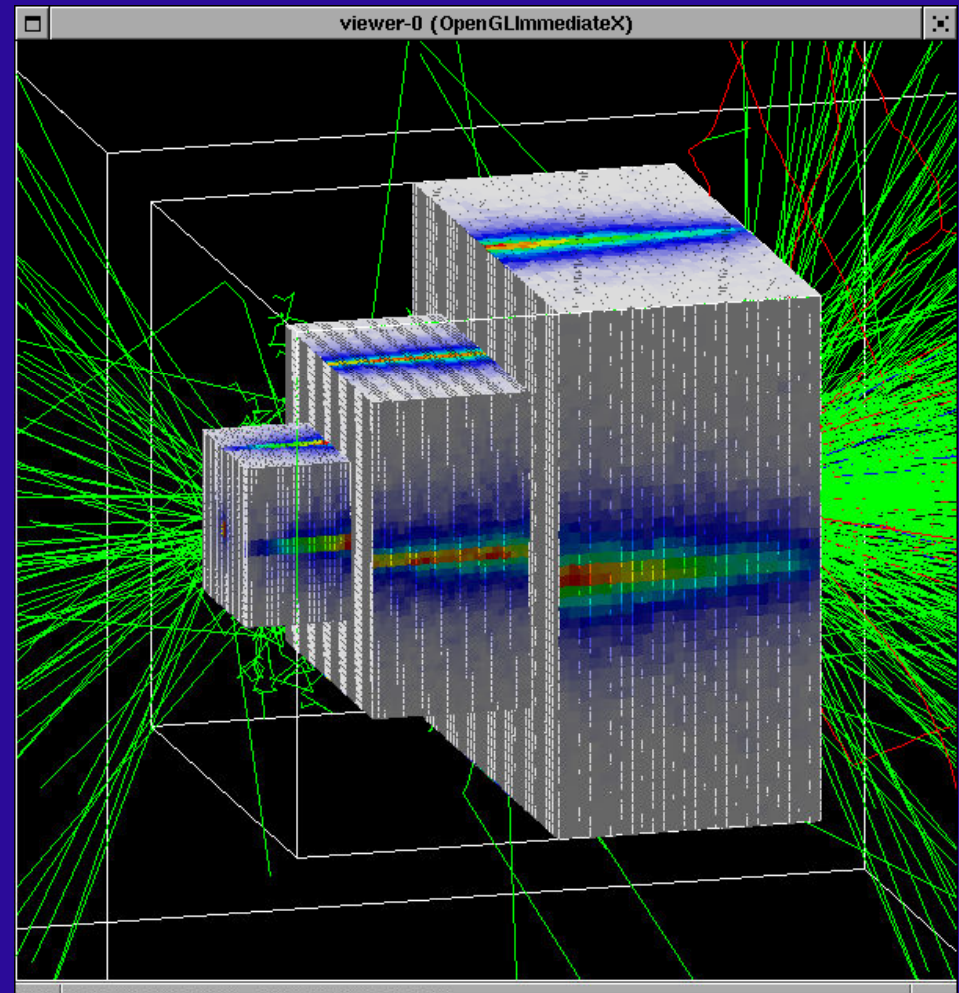
Control Scoring from Commands

For command-based scoring, add the following in your main:

- #include "G4ScoringManager.hh"

- G4ScoringManager::GetScoringManager();

Then control from macro

```
# Define mesh
/score/create/boxMesh inputMesh
/score/mesh/boxSize 20. 20. .1 cm
/score/mesh/translate/xyz 0. 0. -180. cm
/score/mesh/nBin 100 100 40
#
# Specify quantity to score
# Can include filtering to score only specific particles
/score/quantity/flatSurfaceFlux fluxTotal 1
/score/quantity/flatSurfaceFlux fluxProton 1
/score/filter/particle protonFilter proton
/score/quantity/flatSurfaceFlux fluxNeutron 1
/score/filter/particle neutronFilter neutron
#
/score/close
```

```
# Define as many additional meshes as you wish
/score/create/boxMesh outputMesh
/score/mesh/boxSize 20. 20. .1 cm
/score/mesh/translate/xyz -180. 0. 0. cm
/score/mesh/rotate/rotateY 90.
/score/mesh/nBin 1 1 1
#
/score/quantity/flatSurfaceFlux fluxTotal 1
/score/quantity/flatSurfaceFlux fluxProton 1
…
# Perform the run
/run/beamOn 500000
#
# Dump scored results to files
/score/dumpAllQuantitiesToFile inputMesh outputAt1.txt
/score/dumpAllQuantitiesToFile outputMesh outputAt2.txt
```

Details on Scoring

- Command-based option currently only implemented for rectangular geometry
  - For cylindrical or spherical geometries, invoke these scorers from C++

- For cylindrically parameterized geometries, area is not correctly computed.
  - all rings are treated as if had area of entire cylinder face
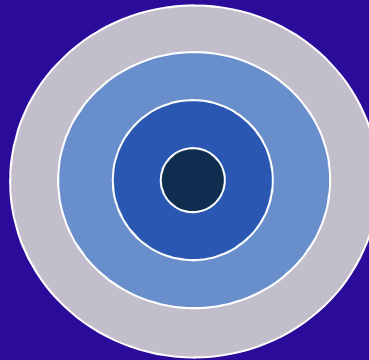
  - still worthwhile using these ready-made scorers
  - simple matter to rescale to correct ring area yourself during or after output
  - will be corrected in December release

Visualization

If you have your own G4VisManager, you can almost certainly remove it

- G4VisExecutive
  - Generic Vis Manager
  - Provides all reasonable defaults (probably more than you currently have)
  - Respects flags you set during Geant4 ./Configure -build
  - Makes it so when we add new Visualization options, they'll automatically be available to you

- Just add the following in your main:

```
#include "G4VisExecutive.hh"
...
G4VisManager* visManager = new G4VisExecutive;
visManager->Initialize();
```

- G4Trajectory
  - If you implemented your own Trajectory, it was probably to assign some visualization attributes. These are done better now by the default trajectory.
  - Default trajectory understands wide set of vis options to control trajectory representation from commands

gMocren

Great tool available for volume visualization

- From JST/CREST project (Japan) to improve Geant4 for medical physics

- Able to visualize:

  – Volume data
     (including overlay of more than one set)

  – Trajectories

  – Geometry

- Runs on:

  – Windows and Linux

  – Mac will likely happen soon

  – Based on a commercial package but offered freely to all Geant4 users

  – http://geant4.kek.jp/gMocren

  – Installation is straightforward, follow the Download link on the above page

    - First run gMocren's one-click installer

    - Then, inside C:\Program Files\gMocren\gtk, you will find the one-click installer for gtk
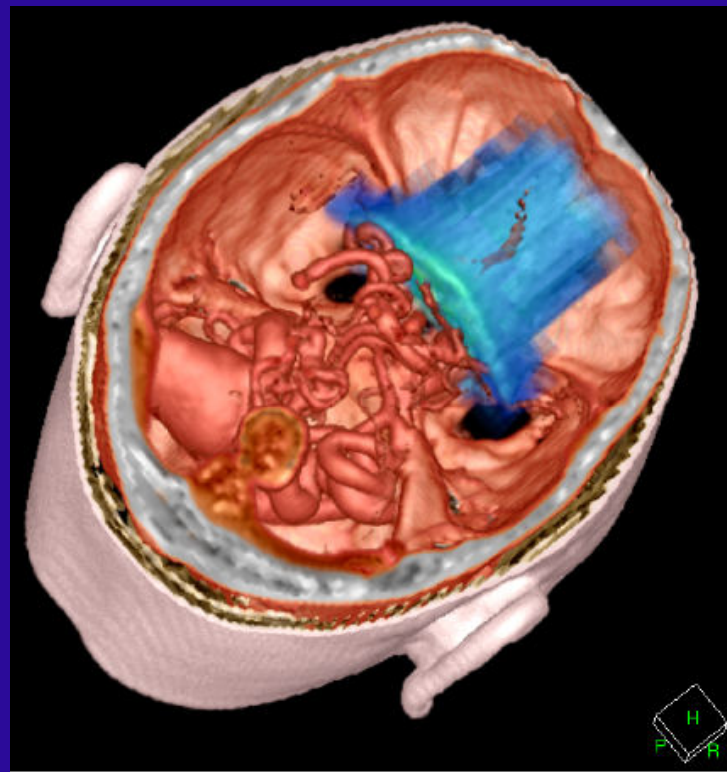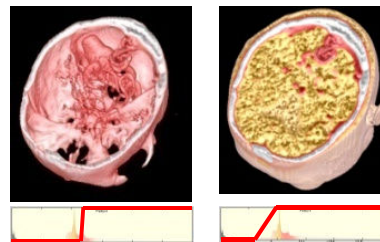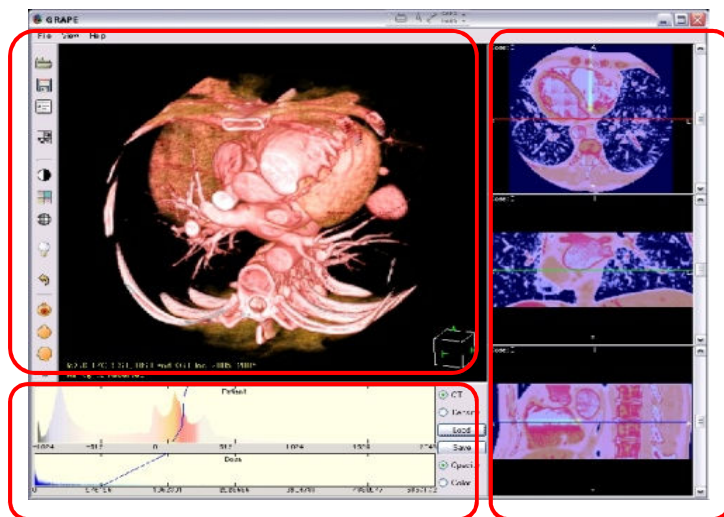
gMocren : A Visualization Tool

3D (ray casting) 2D (MPR)

Opacity curve and color map editor

Functionality Requirements :

- To visualize
  - the modality image used by the simulation,
  - the calculated dose distribution and
  - the particle trajectories
  - in an agreeable speed
- Transfer function editor
- Multi-platform

Opacity curve and color map editor

free hand or templates with WW&WL editing

gMocren and utility software are freely available.

Supported system :
- Windows 2k/XP or PC Linux OS
- Pentium 4 or faster
- more than 1 GB (recommend)

Calculated dose distribution
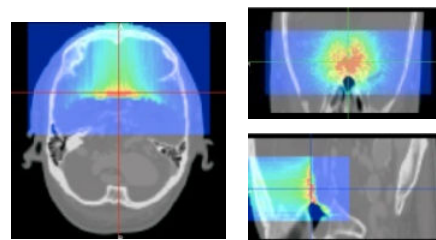
color mapping

contour plot

Particle trajectories
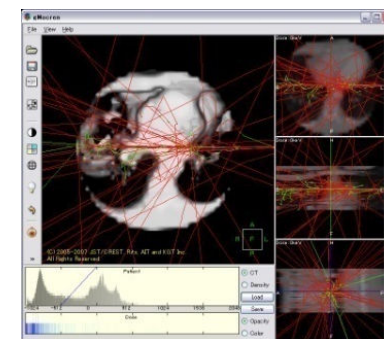
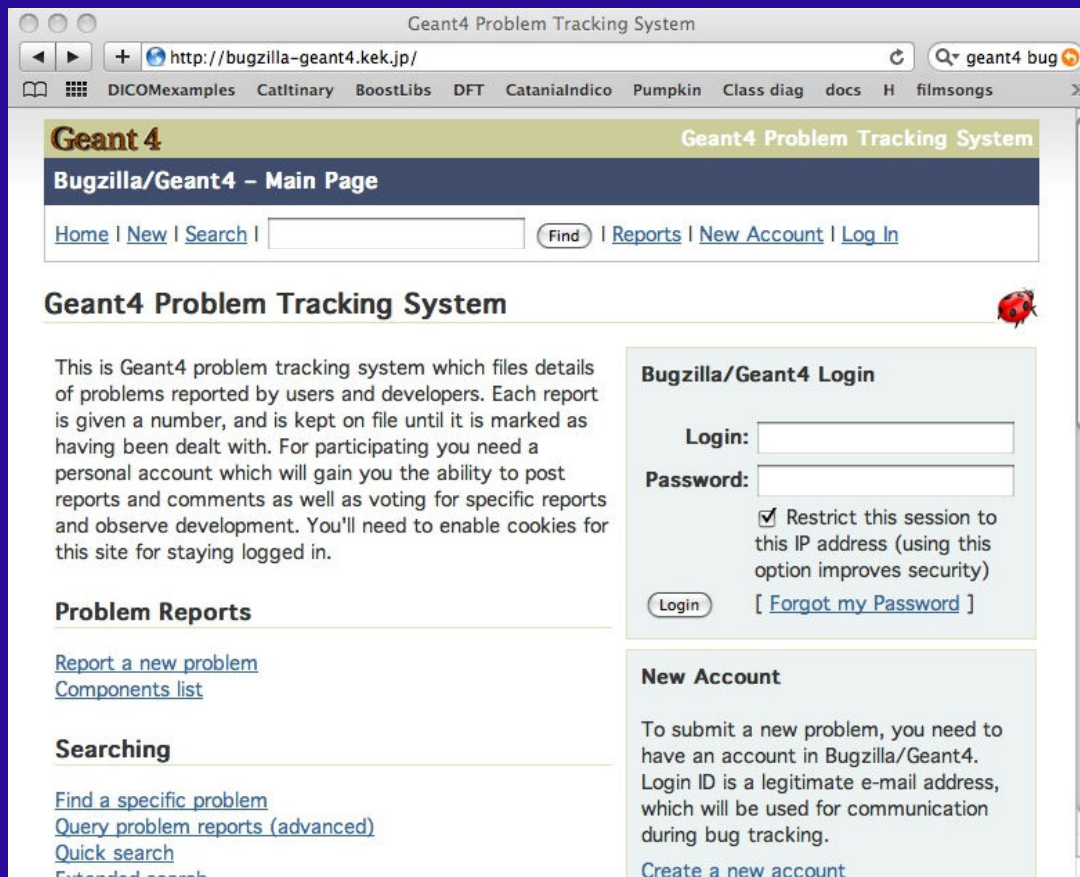Trajectory information in the simulation is available.

Building

If you're currently using some private method to build your Geant4, consider using the standard Configure script to do the job

- ./Configure -build
  - The script encapsulates years of accumulated expertise in the best way to build Geant4 on a wide variety of platforms
  - Use it unless you have a good reason to do otherwise

Complaining

If you find a bug, submit it to the Geant4 bug tracking system

•Problems reported to this system are NOT ignored

•Once you submit a problem here, the Geant4 bug team will mercilessly harass the relevant Geant4 developers until the problem is addressed

Source Browsing

Geant4/digits_hits/scorer/src/G4PSFlatSurfaceCurrent.cc

http://www-geant4.kek.jp/lxr/source//digits_hits/scorer/src/G4PSFlatSurfac

Q- Google

DICOMexamples CatItinary BoostLibs DFT CataniaIndico Pumpkin Class diag docs H

```
55
56
57  G4PSFlatSurfaceCurrent::G4PSFlatSurfaceCurrent(G4String name,
58                                                  G4int direction, G4int depth)
59      :G4VPrimitiveScorer(name,depth),HCID(-1),fDirection(direction),
60       weighted(true),divideByArea(true)
61  {;}
62
63  G4PSFlatSurfaceCurrent::~G4PSFlatSurfaceCurrent()
64  {;}
65
66  G4bool G4PSFlatSurfaceCurrent::ProcessHits(G4Step* aStep,G4TouchableHistory*)
67  {
68    G4StepPoint* preStep = aStep->GetPreStepPoint();
69    G4VPhysicalVolume* physVol = preStep->GetPhysicalVolume();
70    G4VPVParameterisation* physParam = physVol->GetParameterisation();
71    G4VSolid * solid = 0;
72    if(physParam)
73    { // for parameterized volume
74      G4int idx = ((G4TouchableHistory*)(aStep->GetPreStepPoint()->GetTouchable()
75                  ->GetReplicaNumber(indexDepth);
76      solid = physParam->ComputeSolid(idx, physVol);
77      solid->ComputeDimensions(physParam,idx,physVol);
78    }
79    else
80    { // for ordinary volume
81      solid = physVol->GetLogicalVolume()->GetSolid();
82    }
83
84  //  if( solid->GetEntityType() != "G4Box" ){
85  //     G4Exception("G4PSFlatSurfaceCurrentScorer. - Solid type is not supported.
86  //     return FALSE;
87  //  }
88    G4Box* boxSolid = (G4Box*)(solid);
89
90    G4int dirFlag =IsSelectedSurface(aStep,boxSolid);
91    if ( dirFlag > 0 ) {
92     if ( fDirection == fCurrent InOut || fDirection == dirFlag ){
```

Cross-Reference

License
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