User Documents and Examples II

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Most slides from Dennis Wright's talk at SLAC Geant4 Tutorial, May 2007

Outline

- User Documents
  - Toolkit Developers' Guide
  - Physics Reference Manual
- Extended Examples
  - Testing and Validation
  - Demonstrating Geant4 tools
  - Extending Geant4
- Advanced Examples
  - Practical applications
  - Examples from outside HEP (space, medical, etc.)

Toolkit Developers' Guide

- URL: cern.ch/geant4/UserDocumentation/UsersGuides/ForToolkitDeveloper/html/index.html
- A description of the object-oriented design of the Geant4 toolkit
  - class diagrams (some UML, some other)
  - philosophy behind design choices
- A guide for users who want to extend the functionality of Geant4
  - adding new solids, modifying the navigator, creating new fields, etc.

Toolkit developers manual

- Purpose: guide users who wish to extend Geant4 functionality
- Gives overview of design of key components, as a basis for extending them or creating your own.
- Examples:
- Create your own shape (solid)
- Create a physics process

Extending the geometry

- Creating your own solid
  - for an unusual shape which is important for your setup (functionality or performance)
    - What methods the solid must implement
      - EInside Inside(G4ThreeVector point)
      - G4double DistanceToIn(G4ThreeVector point)
      - …
    - The capabilities needed
  - New solids have been created by many users
    - Some were donated, and appear in Geant4
      - G4TwistedTubs, G4Tet(rahedron), G4Ellipsoid, ..

Physics Reference Manual

- URL: cern.ch/geant4/UserDocumentation/UsersGuides/PhysicsReferenceManual/html/PhysicsReferenceManual.html
- A reference for toolkit users and developers who wish to consult the underlying physics of an interaction
- Presents the theoretical formulation, model or parameterization of the physics interactions provided by Geant4

Physics Reference Manual

- Electromagnetic Interactions
  - Gamma Incident
  - Common to All Charged Particles
  - Electron Incident
  - ...
- Hadronic Interactions
  - ...
  - Coherent elastic scattering
  - Chiral Invariant Phase Space Decay.
  - Bertini Intranuclear Cascade Model in GEANT4
  - The GEANT4 Binary Cascade
  - ...

PRM: example Electron Incident

Bremsstrahlung

- provides the energy loss of electrons and positrons due to the radiation of photons in the field of a nucleus according to the approach described in Section 7.1.
- Above a given threshold energy the energy loss is simulated by the explicit production of photons.
- Below the threshold the emission of soft photons is treated as a continuous energy loss. In GEANT4 the Landau-Pomeranchuk-Migdal effect has also been implemented.

- **Cross Section and Energy Loss**
  - is the differential cross section for the production of a photon of energy by an electron of kinetic energy in the field of an atom of charge . If is the energy cut-off below which the soft photons are treated as continuous energy loss, then the mean value of the energy lost by the electron is

$$E_{Loss}^{brem}(Z,T,k_c) = \int_0^{k_c} k \frac{d\sigma(Z,T,k)}{dk} dk.$$

Cross Section and Energy Loss

$d\sigma(Z,T,k)/dk$ is the differential cross section for the production of a photon of energy k by an electron of kinetic energy T in the field of an atom of charge Z. If k_c is the energy cut-off below which the soft photons are treated as continuous energy loss, then the mean value of the energy lost by the electron is

$$E_{Loss}^{brem}(Z,T,k_c) = \int_0^{k_c} k \frac{d\sigma(Z,T,k)}{dk} dk. \tag{8.18}$$

The total cross section for the emission of a photon of energy larger than k_c is

$$\sigma_{brem}(Z,T,k_c) = \int_{k_c}^{T} \frac{d\sigma(Z,T,k)}{dk} dk. \tag{8.19}$$

Parameterization of the Energy Loss and Total Cross Section

The cross section and energy loss due to bremsstrahlung have been parameterized using the EEDL (Evaluated Electrons Data Library) data set [1] as input.

The following parameterization was chosen for the electron bremsstrahlung cross section :

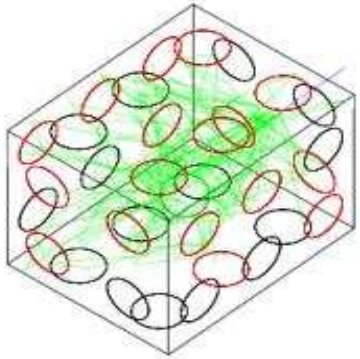
$$\sigma(Z,T,k_c) = Z(Z+\xi_\sigma)(1 - c_{sigh} Z^{1/4}) \left[\frac{T}{k_c}\right]^a \frac{f_s}{N_{Avo}} \tag{8.20}$$

Extended Examples

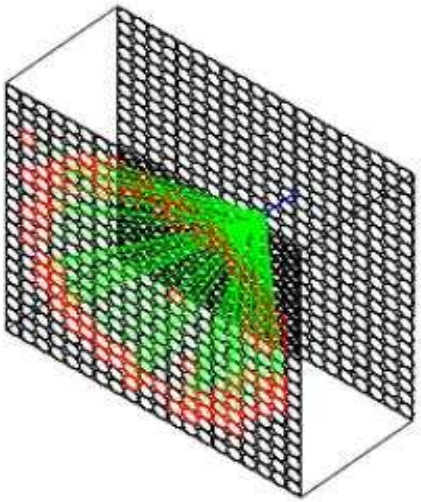
- Testing and validation of processes and tracking
  - Electromagnetic (TestEm1 – TestEm10)
  - Field (field01 – field03)
  - Geometry (olap)
- Demonstration of Geant4 tools
  - Analysis (A01) ,event generator, g3tog4, persistency
  - Biasing (B01-B03), optical, run and event
- Extensions of Geant4
  - GDML
  - Medical (DICOM files)
  - Parallel computing (ParN02, ParN04)

Optical Photons

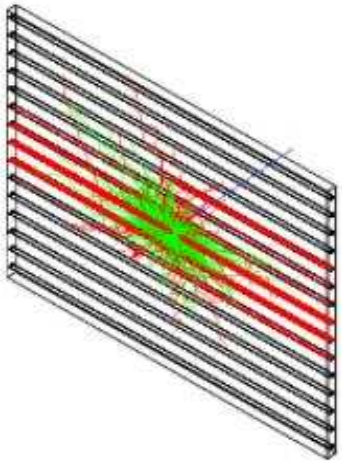
/examples/extended/optical/LXe



Scintillation



Cerenkov



WaveLengthShifting

Gamma Therapy

- 50 MeV electrons incident on target produce gammas
- Charged particles removed from beam, gammas irradiate a water phantom
- Gamma beam properties are scored in a check volume in front of the phantom
- Scoring inside the phantom to record radial radiation dose distribution

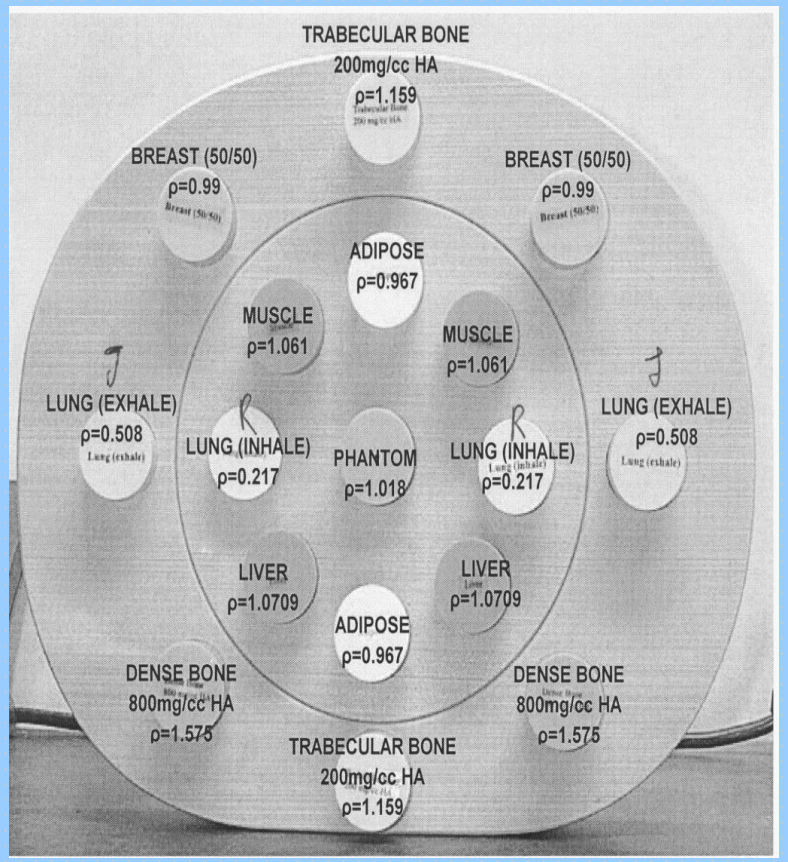
Parallel Computing

- Introduction to parallel computing using TopC
  - parallel version of novice example N02
  - parallel version of novice example N04
- Parallelized version of brachytherapy advanced example
  - application can be run parallel or sequential
  - uses Diane (DIstributed ANalysis Environment)

DICOM

- Uses Geant4 interface to read DICOM files
- uses inforamtion to construct phantom geometry
- displays image with Geant4 visualization

- h



GDML Example

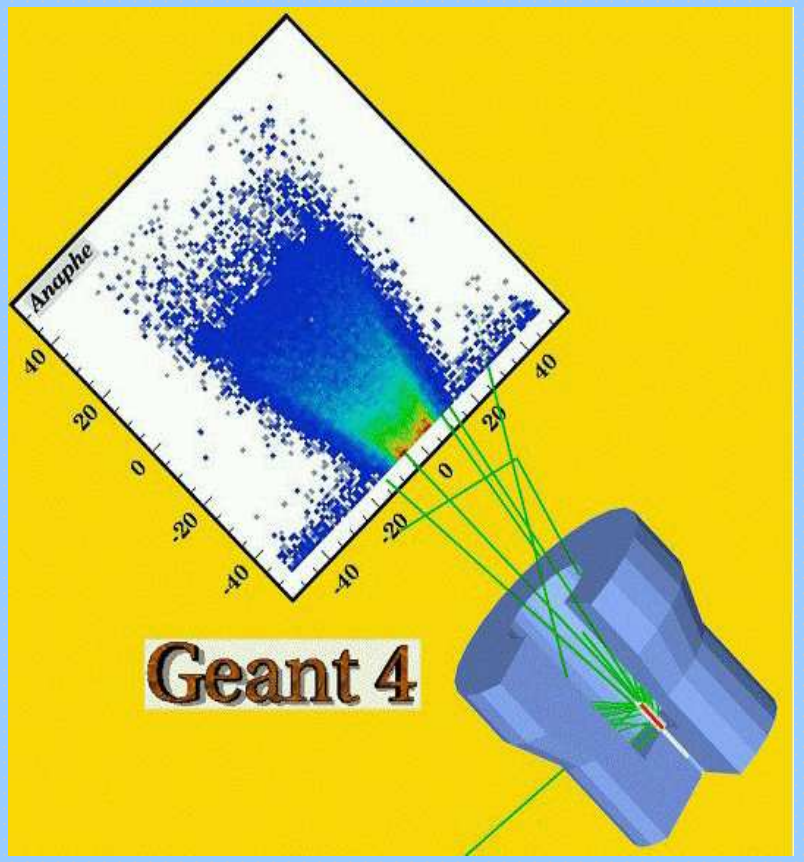
- Identical to example N03 (sampling calorimeter), except
  - GDML used for geometry description
- GDML schema supports:
  - Numerical expressions, constants, rotations, translations, units
  - Materials
  - CSG + boolean solids
  - Geometrical structure (volumes, placements)
- Uses Xerxes-C XML parser (linux only)
  - Installation instructions included in example

Advanced Examples

- HEP detectors
  - CMS hadron calorimeter test beam
  - ATLAS Forward Liquid Ar Calorimeter
  - LHCb Rich test beam
- Neutron Shielding
- Medical (brachytherapy)
- Space applications
  - Gamma ray telescope
  - X-ray telescope
  - X-ray fluorescence
- Underground physics (liquid Xe dark matter detector)

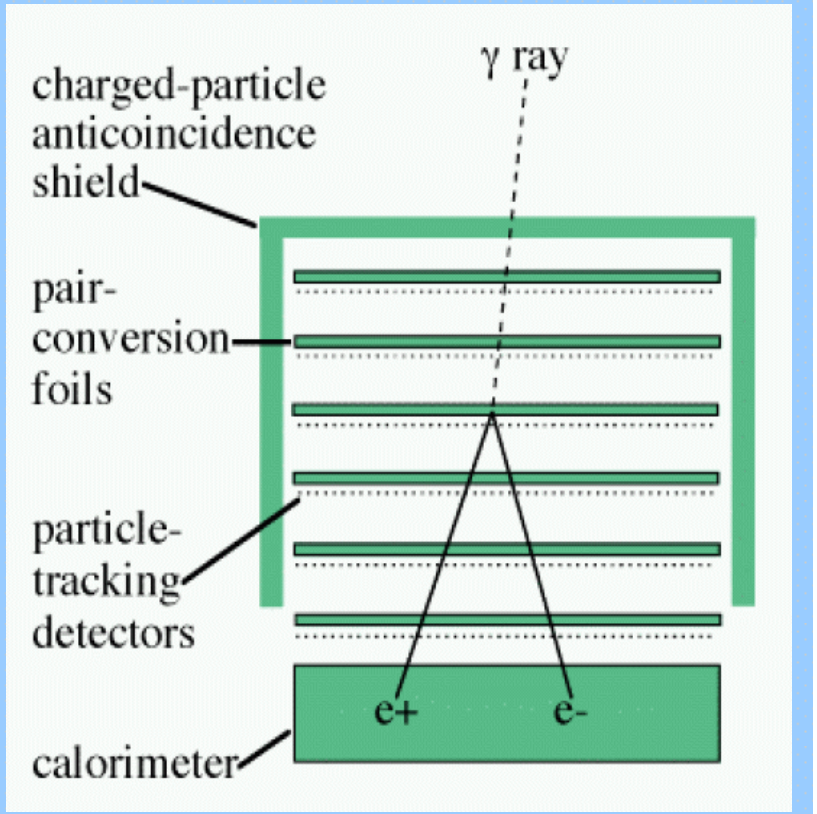
Brachytherapy Example

- Physics
  - Low energy EM processes for e-, γ
  - 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

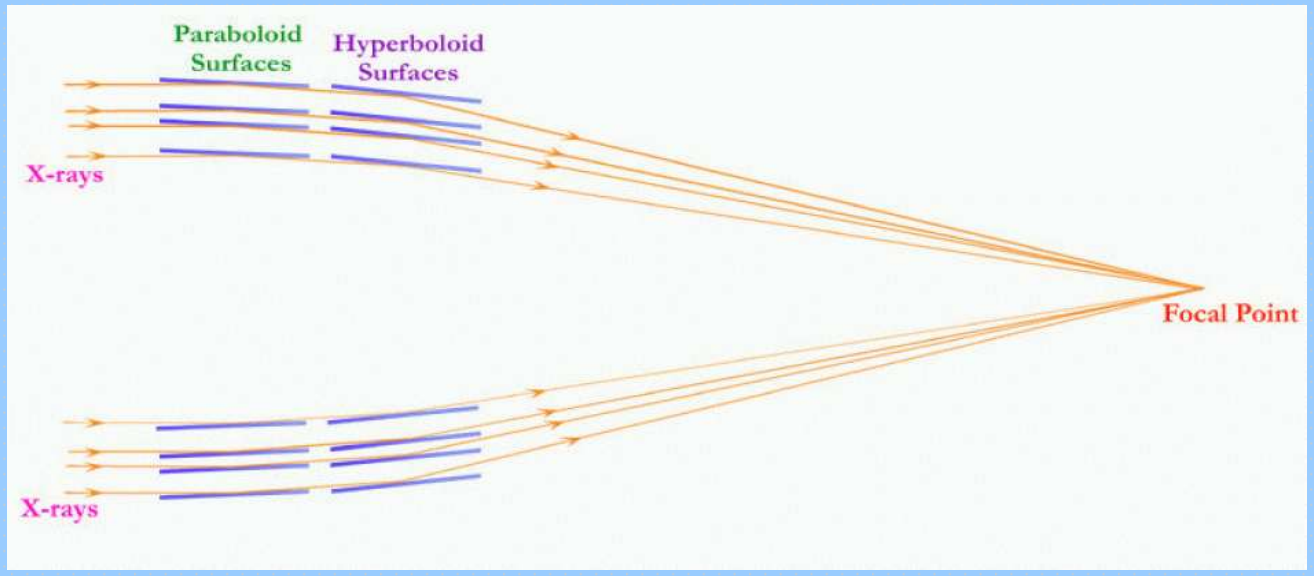


Gamma Ray Space Telescope

- 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 (1)



Simple model of x-ray telescope to study proton damage

Geometry:

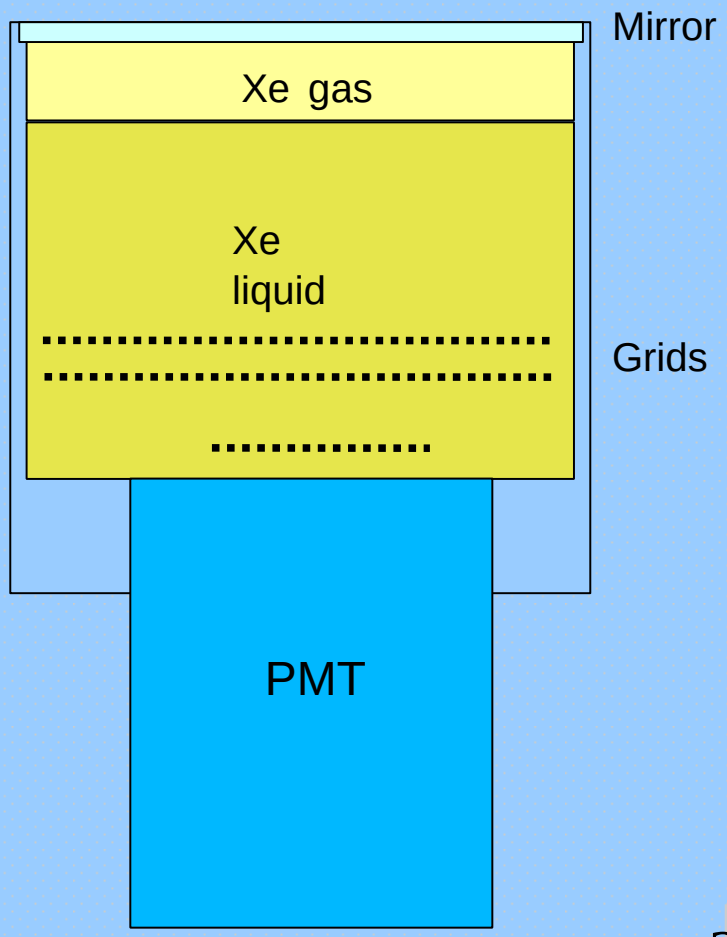
- single shell nickel-gold mirror
- two cones for paraboloid, two for hyperboloid sections
- aluminum baffle
- main telescope: carbon fiber tube, aluminum end caps

X-ray Telescope (2)

- 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

Underground Physics

- Realistic example of underground dark matter search experiment
- Detailed geometry, including optional file describing laboratory
- Physics
  - Low energy, standard EM
  - Optical processes
  - Radioactive decay
- General particle source
- Many macro files for various run conditions



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

Summary

- Toolkit Developers' Guide
  - for OO design and extension of toolkit
- Physics Reference Manual
  - reference to the underlying physics of Geant4
- Many extended examples
  - Users' Guide for Application Developers, Chapter 9.2
  - Code in geant4/examples/extended
- 15 advanced examples
  - Users' Guide for Application Developers, Chapter 9.3
  - Code in geant4/examples/advanced