Documentation & Examples

XV Seminar on Software for Nuclear, Subnuclear and Applied Physics
Hotel Porto Conte, Alghero
16.04.2018 - 20.04.2018

Geant4 web pages

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GEANT4 A SIMULATION TOOLKIT

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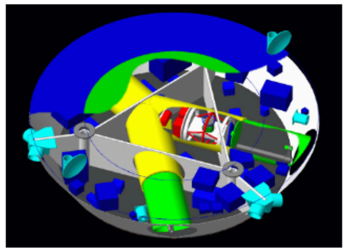
Overview

Geant4 is a toolkit for the simulation of the passage of particles through matter. Its areas of application include high energy, nuclear and accelerator physics, as well as studies in medical and space science. The three main reference papers for Geant4 are published in Nuclear Instruments and Methods in Physics Research A 506 (2003) 250-303, IEEE Transactions on Nuclear Science 53 No. 1 (2006) 270-278 and Nuclear Instruments and Methods in Physics Research A 835 (2016) 186-225.

Applications

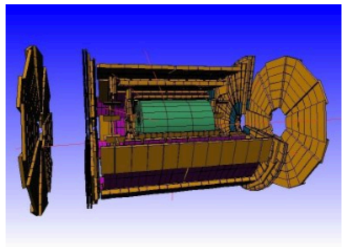
A sampling of applications, technology transfer and other uses of Geant4

User Support



Getting started, guides and information for users and developers

Publications



Validation of Geant4, results from experiments and publications

Collaboration

Who we are: collaborating institutions, members, organization and legal information

printer-friendly version

News

- *12 Mar 2018*
  2018 planned developments
- *6 Mar 2018*
  Patch-01 to **release 10.4** is available from the Download area.
- *20 Oct 2017*
  Patch-03 to release 10.3 is available from the source archive area.

Events

- Geant4 Beginners Course, at TUM University, Munich (Germany), **16-20 April, 2018**.
- Geant4 tutorial at Universite Paris-Saclay/LAL, Orsay (France), **14-18 May 2018**.
- Geant4 Course at the 15th Seminar on Software for Nuclear, Sub-nuclear and Applied Physics, Porto Conte, Alghero (Italy), **27 May - 1 June, 2018**.

User support

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User Support

Submitted by Anonymous (not verified) on Wed, 06/28/2017 - 11:23

1. Getting started
2. Training courses and materials
3. Source code
   a. Download page
   b. LXR code browser
   c. doxygen documentation
   d. GitHub
   e. GitLab @ CERN
4. Frequently Asked Questions (FAQ)
5. Bug reports and fixes
6. User requirements tracker
7. User Forum
8. Documentation
   a. Introduction to Geant4 [pdf]
   b. Installation Guide: [pdf]
   c. Application Developers [pdf]
   d. Toolkit Developers Guide [pdf]
   e. Physics Reference Manual [pdf]
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11. Contact Coordinators & Contact Persons

Related Links

- Object Oriented Analysis & Design
- Archive
- Mailing list subscription
- User requirements document (pdf)
- Technical Forum

Application developers' guide

- URL: http://geant4-userdoc.web.cern.ch/geant4-userdoc/UsersGuides/ForApplicationDeveloper/html/index.html
- Introduces new Users to the Geant4 toolkit
- Describes the most useful tools
- Describes hoot set-up and run a simulation application
- Intended as an overview of the toolkit, not an exhaustive treatment
  - Physics reference manual
  - Toolkit developer guide

Toolkit developers' guide

- URL: http://geant4-userdoc.web.cern.ch/geant4-userdoc/UsersGuides/ForToolkitDeveloper/html/index.html
- A description of the object-oriented design of the Geant4 toolkit
  - Class diagrams
  - Philosophy behind the design choices
- A guide for Users' who want to extend the functionality of Geant4
  - Adding new solids, modifying the navigator, creating new fields, …

Physics reference manual

- URL: http://geant4-userdoc.web.cern.ch/geant4-userdoc/UsersGuides/PhysicsReferenceManual/html/index.html
- A reference for toolkit Users and developers who wish to consult and study the physics of an interaction/model
- Present the theoretical formulation, model or parameterisation of the physics interactions provided by Geant4

Physics list Guide: http://geant4-userdoc.web.cern.ch/geant4-userdoc/UsersGuides/PhysicsListGuide/html/index.html

Overview of the examples

Basic
Extended
Advanced

The Geant4 Examples

This module collects 3 sets of user examples aimed to demonstrate to the user how to make correct use of the GEANT4 toolkit by implementing in a correct way those user-classes which the user is supposed to customize in order to define his/her own simulation setup.

- **Basic** → set of examples is oriented to novice users and covering the most typical use-cases of a Geant4 application with keeping simplicity and ease of use
- **Extended** → set of examples may require some additional libraries besides of Geant4. This set covers many specific use cases for actual detector simulation
- **Advanced** → set of examples covers the use-cases typical of a "toolkit"-oriented kind of development, where real complete applications for different simulation studies are provided; may require additional third party products to be built

The Geant4 Examples

Most of the examples can be run in:

- interactive
- batch mode

input macro files (*.in) and reference output files (*.out) are provided

- Basic and most of the extended examples are considered part of the system testing suite for validation of the official releases of the GEANT4 toolkit.

- Basic and some of the extended and advanced examples are also used as "acceptance"-tests for the release process

The Geant4 Examples

….Where??

* geant4.10.04/examples/advanced
* geant4.10.04/examples/basic
* geant4.10.04/examples/extended

Basic Examples

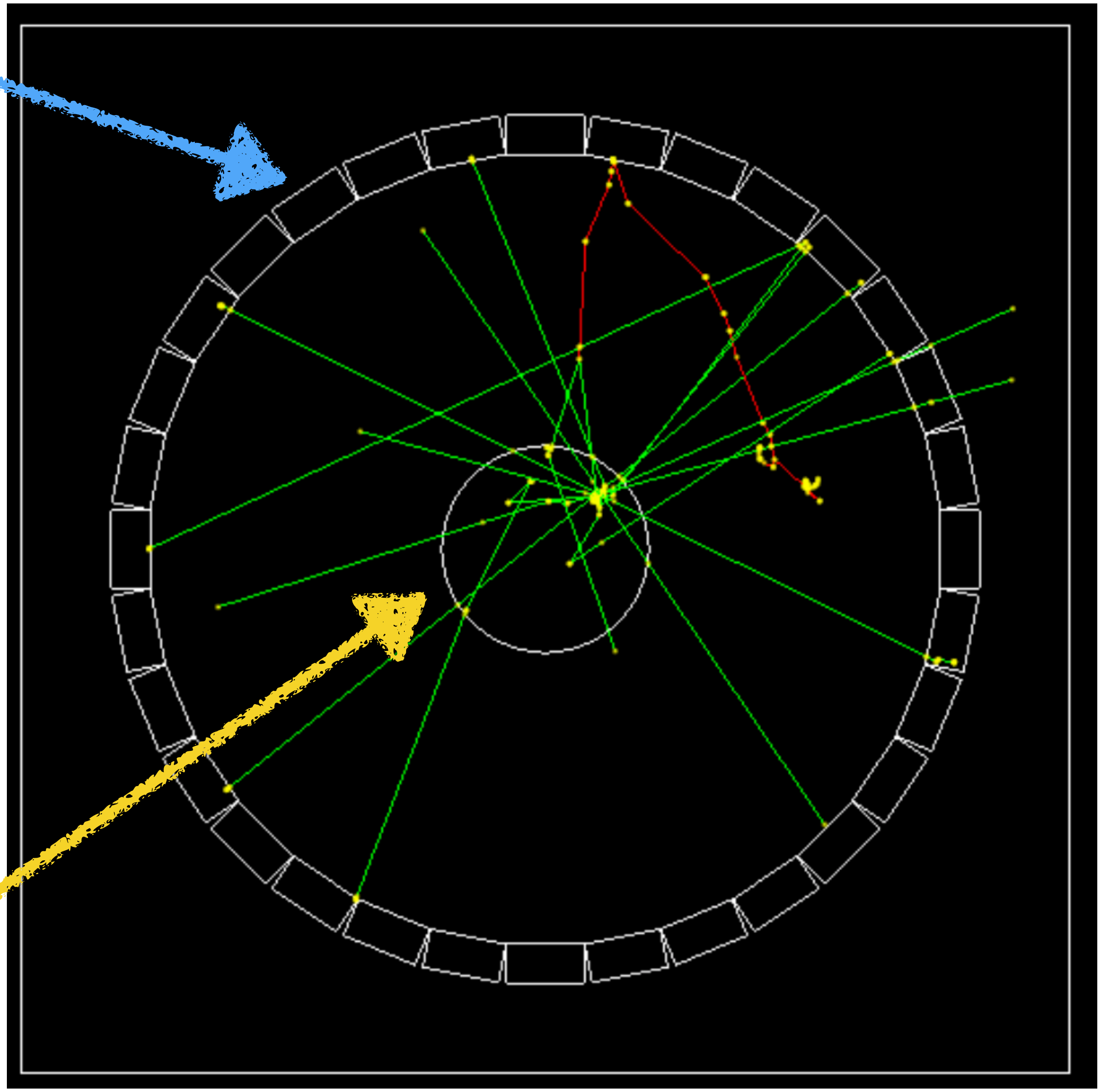
Code name	Few Characteristics
Example B1	• Simple geometry with a few solids • Geometry with simple placements (G4PVPlacement) • Scoring total dose in a selected volume user action classes • Geant4 physics list (QBBC)
Example B2	• Simplified tracker geometry with global constant magnetic field • Geometry with simple placements (G4PVPlacement) and parameterisation (G4PVParameterisation) • Scoring within tracker via G4 sensitive detector and hits • Geant4 physics list (FTFP_BERT) with step limiter • Started from novice/N02 example
Example B3	• Schematic Positron Emitted Tomography system • Geometry with simple placements with rotation (G4PVPlacement) • Radioactive source • Scoring within Crystals via G4 scorers • Modular physics list built via builders provided in Geant4
Example B4	• Simplified calorimeter with layers of two materials • Geometry with replica (G4PVReplica) • Scoring within layers in four ways: via user actions, via user own objects via G4 sensitive detector and hits and via scorers • Geant4 physics list (FTFP_BERT) • Histograms (1D) and ntuple saved in the output file • Started from novice/N03 example
Example B5	• A double-arm spectrometer with wire chambers, hodoscopes and calorimeters with a local constant magnetic field • Geometry with placements with rotation, replicas and parameterisation • Scoring within wire chambers, hodoscopes and calorimeters via G4 sensitive detector and hits • Geant4 physics list (FTFP_BERT) with step limiter • UI commans defined using G4GenericMessenger • Histograms (1D, 2D) and ntuple saved in the output file • Started from extended/analysis/A01

Basic Examples

	Code name	Few Characteristics
Basic!	Example B1	• Simple geometry with a few solids • Geometry with simple placements (G4PVPlacement) • Scoring total dose in a selected volume user action classes • Geant4 physics list (QBBC)
	Example B2	• Simplified tracker geometry with global constant magnetic field • Geometry with simple placements (G4PVPlacement) and parameterisation (G4PVParameterisation) • Scoring within tracker via G4 sensitive detector and hits • Geant4 physics list (FTFP_BERT) with step limiter • Started from novice/N02 example
A bit complex	Example B3	• **Schematic Positron Emitted Tomography system** • Geometry with simple placements with rotation (G4PVPlacement) • Radioactive source • Scoring within Crystals via G4 scorers • Modular physics list built via builders provided in Geant4
	Example B4	• Simplified calorimeter with layers of two materials • Geometry with replica (G4PVReplica) • Scoring within layers in four ways: via user actions, via user own objects via G4 sensitive detector and hits and via scorers • Geant4 physics list (FTFP_BERT) • Histograms (1D) and ntuple saved in the output file • Started from novice/N03 example
	Example B5	• **A double-arm spectrometer with wire chambers, hodoscopes and calorimeters with a local constant magnetic field** • Geometry with placements with rotation, replicas and parameterisation • Scoring within wire chambers, hodoscopes and calorimeters via G4 sensitive detector and hits • Geant4 physics list (FTFP_BERT) with step limiter • UI commans defined using G4GenericMessenger • Histograms (1D, 2D) and ntuple saved in the output file • Started from extended/analysis/A01

Example B3 - the geometry

- ☑ The support of gamma detection are scintillating crystals. A small number of such crystals are optically grouped in a matrix of crystals.
- ☑ Individual crystals are not described; only the matrix of crystals is and it is still called 'Crystal' hereafter.
- ☑ Crystals are circularly arranged to form a ring. Few rings make up the full detector (gamma camera).
- ☑ This is done by positionning Crystals in Ring with an appropriate rotation matrix. Several copies of Ring are then placed in the full detector.



- ☑ The head of a patient is schematised as a homogeneous cylinder of brain tissue, placed at the center of full detector.

The Crystal material, Lu2SiO5, is not included in the G4Nist database. Therefore, it is explicitly built in DefineMaterials().

Example B3 - the output

DETECTOR RESPONSE : scorers

A 'good' event is an event in which an identical energy of 511 keV is deposited in two separate Crystals.
A count of the number of such events corresponds to a measure of the efficiency of the PET system.
The total dose deposited in a patient during a run is also computed.

Scorers are defined in **B3DetectorConstruction::ConstructSDandField()**.
There are two G4MultiFunctionalDetector objects:
- ☑ the Crystal (EnergyDeposit)
- ☑ the Patient (DoseDeposit)

Two variants of accumulation event statistics in a run are demonstrated in this example:

B3a:
At the end of event, the values acummulated in **B3aEventAction** are passed in **B3aRunAction** and summed over the whole run (see B3aEventAction::EndOfevent()).

B3b:
B3bRun::RecordEvent(), called at end of event, collects informations event per event from the hits collections, and accumulates statistic for **B3bRunAction::EndOfRunAction()**.

Example B5 - the geometry

The spectrometer consists of two detector arms (see → **B5DetectorConstruction**)

two arms

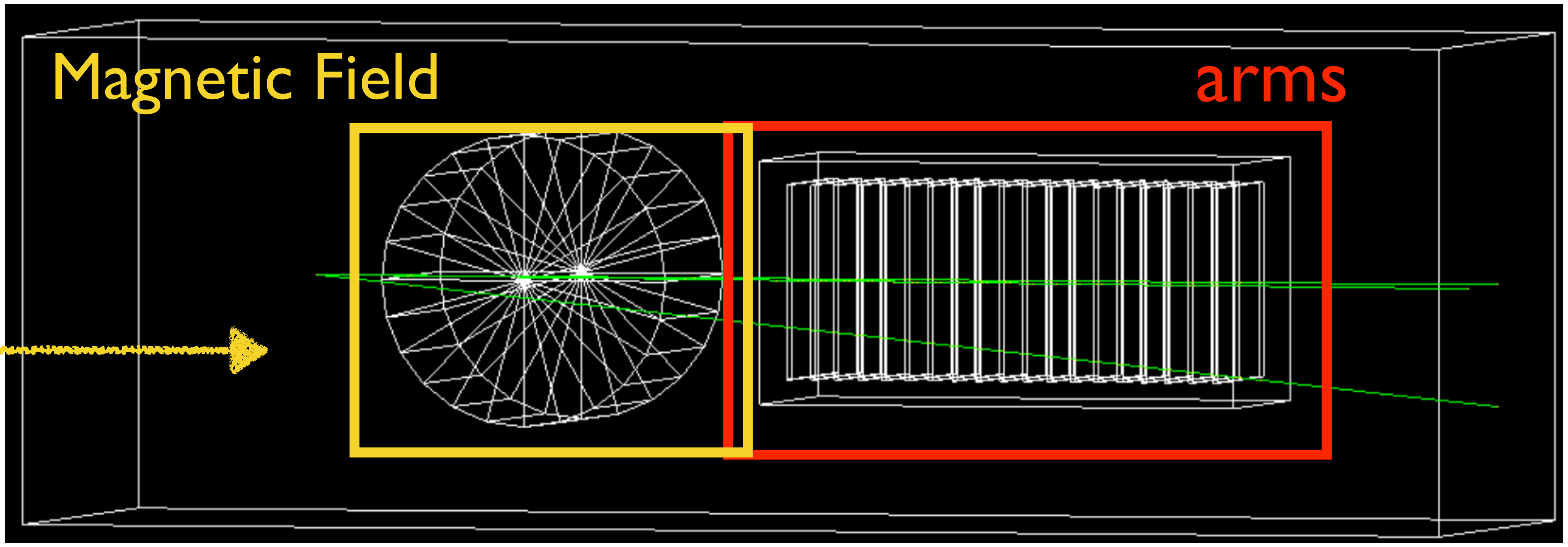
Provides position and timing information

First arm:
- 1 hodoscope (15 vertical strips of plastic scintillator)
- 1 drift chamber (5 horizontal argon gas layers with a "virtual wire" at the center of each layer)

Position, timing and energy information

Second arm:
- 1 hodoscope (25 vertical strips of plastic scintillator)
- 1 drift chamber (5 horizontal argon gas layers with a "virtual wire" at the center of each layer)
- 1 electromagnetic calorimeter: a box sub-divided along x,y and z axes into cells of CsI
- 1 hadronic calorimeter: a box sub-divided along x,y, and z axes into cells of lead

Magnetic field region: air-filled cylinder which contains the field



Example B5 - the output

DETECTOR RESPONSE

All the information required to simulate and analyze an event is recorded in hits. This information is recorded in the following sensitive detectors:

- hodoscope:
  - particle time
  - strip ID, position and rotation
    - see **B5HodoscopeSD**, **B5HodoscopeHit**
- drift chamber:
  - particle time
  - particle position
  - layer ID
    - see **B5DriftChamberSD**, **B5DriftChamberHit** classes
- electromagnetic calorimeter:
  - energy deposited in cell
  - cell ID, position and rotation
    - see **B5EmCalorimeterSD**, **B5EmCalorimeterHit** classes
- hadronic calorimeter:
  - energy deposited in cell
  - cell column ID and row ID, position and rotation
    - see **B5HadCalorimeterSD**, **B5HadCalorimeterHit** classes

ANALYSIS

The analysis tools are used to accumulate statistics. Histograms and an ntuple are created in **B5RunAction::B5RunAction()** constructor for the following quantities:

- 1D histograms:
  - Number of hits in Chamber 1
  - Number of hits in Chamber 2
- 2D histograms:
  - Drift Chamber 1 X vs Y positions
  - Drift Chamber 2 X vs Y positions
- Ntuple:
  - Number of hits in Chamber 1
  - Number of hits in Chamber 2
  - Total energy deposit in EM calorimeter
  - Total energy deposit in Hadronic calorimeter
  - Time of flight in Hodoscope 1
  - Time of flight in Hodoscope 2
  - Vector of energy deposits in EM calorimeter cells
  - Vector of energy deposits in Hadronic calorimeter cells

The histograms and ntuple are saved in the output file in a format according to a technology selected in B5Analysis.hh !

Extended level Examples

Code name	Few Characteristics
analysis	Histogramming through the AIDA interface
biasing	Examples of event biasing, scoring and reverse-MC-
common	A set of common classes which can be reused in other examples demonstrating just a particular feature
electromagnetic	Specific EM physics simulation with histogramming
errorpropagation	Use of the error propagation utility (Geant4e)
eventgenerator	variousprimary event generation: Particle gun, general particle source, and interface to HepMC and Pythia
exoticphysics	Exotic simulation applications (classical magnetic monopole, etc...)
field	Specific simulation setups in magnetic field
g3tog3	Examples of usage of the g3tog4 converter tool
geometry	Specific geometry examples and tools, OLAP tool for detection of overlapping geometries,
hadronic	Specific hadronic physics simulation with histogramming
medical	Specific examples for medical physics applications
optical	Examples of generic optical processes simulation setups
parallel	Examples of event-level parallelism in Geant4 using the TOP-C distribution, and MPI technique
parameterisations	Examples for fast shower parameterisations according to specific models (gflash)
persistency	Persistency of geometry (GDML or ASCII) and simulation output
polarisation	Use of physics processes including polarization
radioactivedecay	Examples to simulate the decays of radioactive isotopes and induced radioactivity resulted from nuclear interactions
runAndEvent	Examples to demonstrate how to connect the information between primary particles and hits
visualization	Specific visualization features and graphical customisations

Extended: Medical

Specific examples for medical physics applications are demonstarted

DICOM

This example serves first to convert a DICOM file to a simple ASCII file, where the Hounsfield numbers are converted to materials and densities so that it can be used by GEANT4. It serves also to create a GEANT4 geometry based on the DICOM file information using the G4PhantomParameterisation.

Electron Scattering

These example demonstrate electron scattering benchmarks. ElectronScattering2 simulates the experiment with a minimum of user code, whereas the other version of this example shows how to do more of the work directly as the user.

GammaTherapy

his example demonstrates a gamma therapy application.

DNA

Set of examples using the Geant4-DNA physics processes and models.

FanoCavity

This example computes the dose deposited in an ionization chamber by a monoenergetic photon beam.

FanoCavity2

This example computes the dose deposited in an ionization chamber by an extended (one dimensional) monoenergetic electron source. This variante of the Fano cavity test make use of an reciprocity theorem.

Medical: Fano Cavity

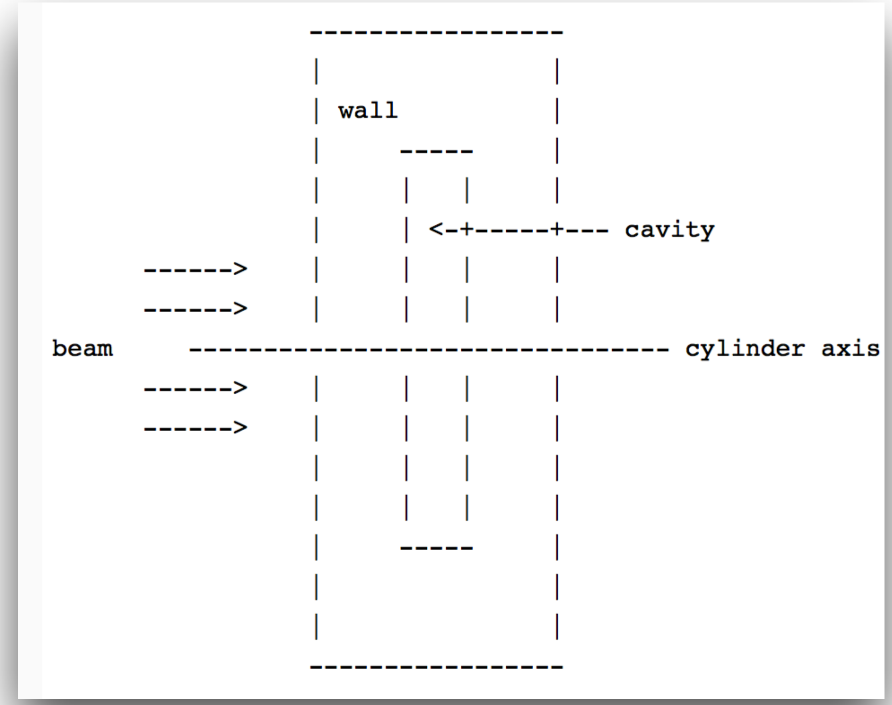
GEOMETRY

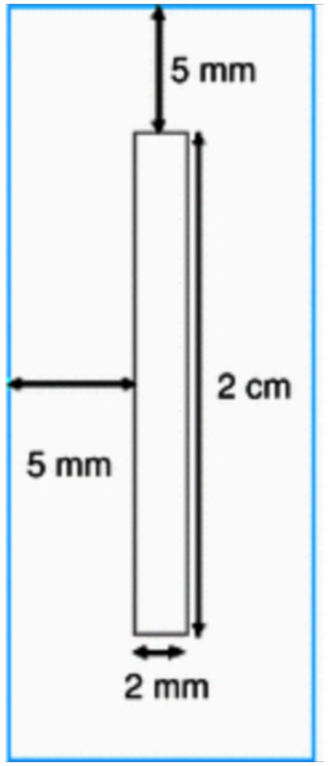
The chamber is modelized as a cylinder with a cavity in it.
6 parameters define the geometry :

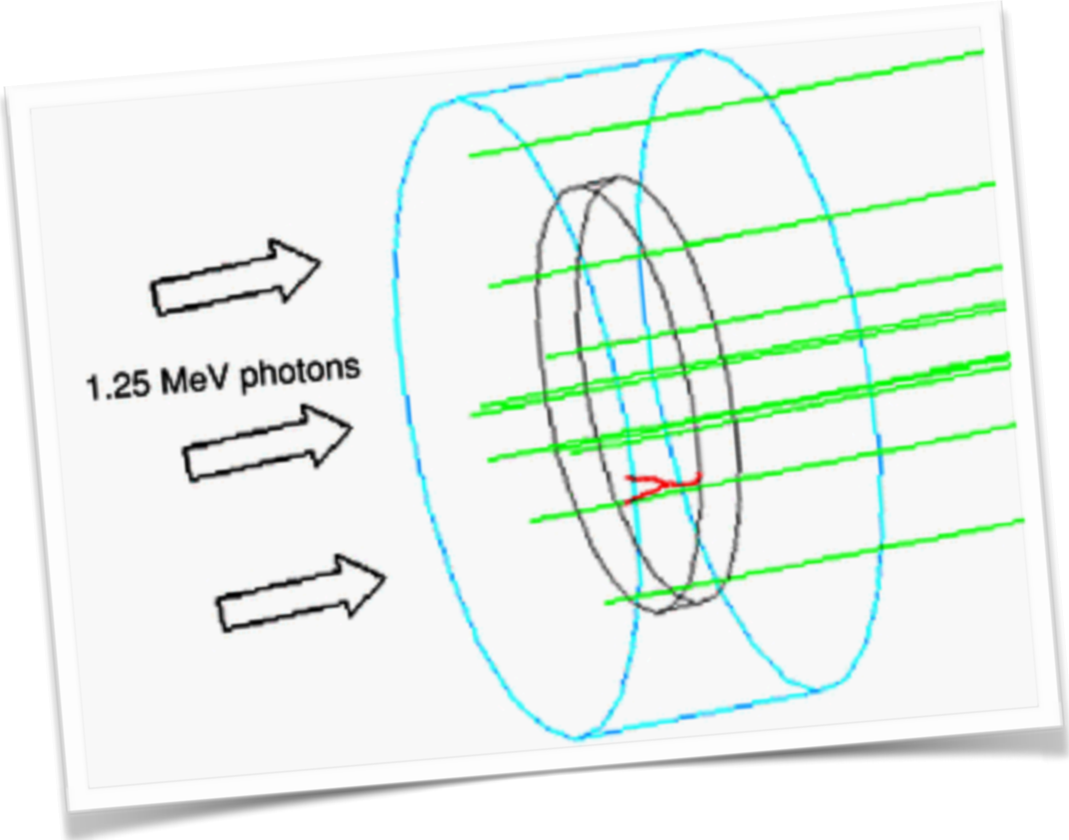
- the material of the wall of the chamber
- the radius of the chamber and the thickness of the wall
- the material of the cavity
- the radius and the thickness of the cavity

Wall and cavity must be made of the same material, but with different density
All above parameters can be redifined via the UI commands built in DetectorMessenger class

The model of ionization chamber







Medical: Fano Cavity

Description of the electron transport algorithms

Besides geometrical limits, the electron step size is limited by several competitive constraints.

- The first limitation is due to the production threshold (**CUT**) for ionization and bremsstrahlung.
- The second limitation is related to the computation of the mean energy loss per step. A ***Step function*** is controlled by two parameters: the maximum reduction of fraction of stopping range ***dRoverRange*** and the minimum range value ***finalRange***. The step limitation is defined by:

$$\mathrm{Step}/\mathrm{Range} < dRoverRange$$

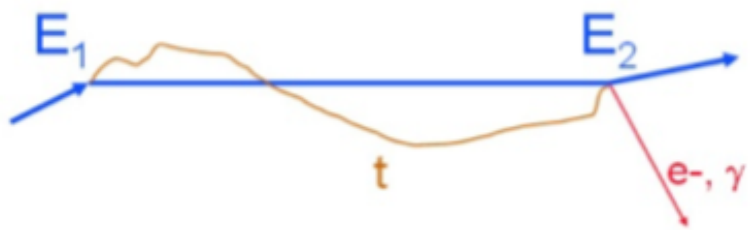
The step size decreases gradually until the stopping range becomes lower than the finalRange value. In this case, the remaining range of an electron is done in one step.
Multiple scattering introduces an additional step limitation. This depends on the range and geometry and is controlled by three parameters: **RangeFactor** and **GeomFactor**. The initial step limit is defined at the beginning of the track by:

$$\mathrm{Step} = RangeFactor * \max(\mathrm{Range}, \lambda)$$

where λ is the transport mean free path derived from the multiple scattering model and **Range** is an electron range.
RangeFactor limits the maximum size of the step to a fraction of the particle mean free path or range.
The second parameter, **GeomFactor,** is applied to ensure that a minimum number of steps is done in any geometrical volume, independently of its thickness. **This constraint is necessary to control the step size in a low density medium or for very thin layers.**

Medical: Fano Cavity

Once the step size for the electron has been determined, the multiple scattering process is invoked to compute the true path length t, which is larger than the distance between the initial and final points.



The mean energy loss along this true path length is calculated, and then its fluctuation is sampled. Next the multiple scattering model is invoked again to compute the angular deflection and lateral displacement of the primary electron at the end point. If any interaction is happen at the end point, then a secondary particle is generated.

$$E_1 - E_2 = \langle \Delta E \rangle + dE + T_{kin}$$

where:

E1, E2 are the energies of the electron at the beginning and the end of the step

<ΔE> is the mean energy loss calculated for the path length **t**

dE is the energy loss fluctuation (this fluctuation can be positive or negative)

Tkin is the energy of the generated secondary (e- or γ), if any.

Medical: Fano Cavity

BEAM

Monoenergetic incident photon beam is uniformly distribued

Beam regeneration : after each Compton interaction, the scattered photon is reset to its initial state, energy and direction. Consequently, interaction sites are uniformly distribued within the wall material.

This modification must be done in the ParticleChange of the final state of the Compton scattering interaction. Therefore, a specific model (MyKleinNishinaCompton) is assigned to the ComptonScattering process in PhysicsList. MyKleinNishinaCompton inherites from G4KleinNishinaCompton; only the function SampleSecondaries() is overwritten.

HISTOGRAMS

fanoCavity has several predefined 1D histograms :

- 1 : emission point of e+-
- 2 : energy spectrum of e+-
- 3 : theta distribution of e+-
- 4 : emission point of e+- hitting cavity
- 5 : energy spectrum of e+- when entering in cavity
- 6 : theta distribution of e+- before enter in cavity
- 7 : theta distribution of e+- at first step in cavity
- 8 : track segment of e+- in cavity
- 9 : step size of e+- in wall
- 10 : step size of e+- in cavity
- 11 : energy deposit in cavity per track

Extended: RadioactiveDecay

Examples demonstrating the use of some features of the Radioactive-Decay hadronic model

rdecay01

This example allows to display basic feature of the radioactive decay of nuclei:

- Energy spectrum of emitted particles;
- Time of life
- Activity

rdecay02

This example illustrates more advanced features of the package:

- Selected decay channels;
- Time window;
- Bias;
- Variance reduction technique;

Activation

Compute and plot time evolution of each nuclide in an hadronic cascade. Compute and plot activity of emerging particles

RadioactiveDecay: Rdecay01

Physics list

PhysicsList.cc defines only G4RadioactiveDecay, G4Transportation processes, and relevant particle definitions. Therefore, once created, particles or ions travel as geantino.

Physics

All particles and ions behave as geantino, eg. no energy loss.
A flag:
`/rdecay01/fullChain (true or false)`
allows to limit to single decay or full decay chain (default).
In case of full decay chain, G4TrackStatus of ions is set to fStopButAlive in order to force decay at rest. In case of single decay, G4TrackStatus of secondary ion is set to fStopAndKill.

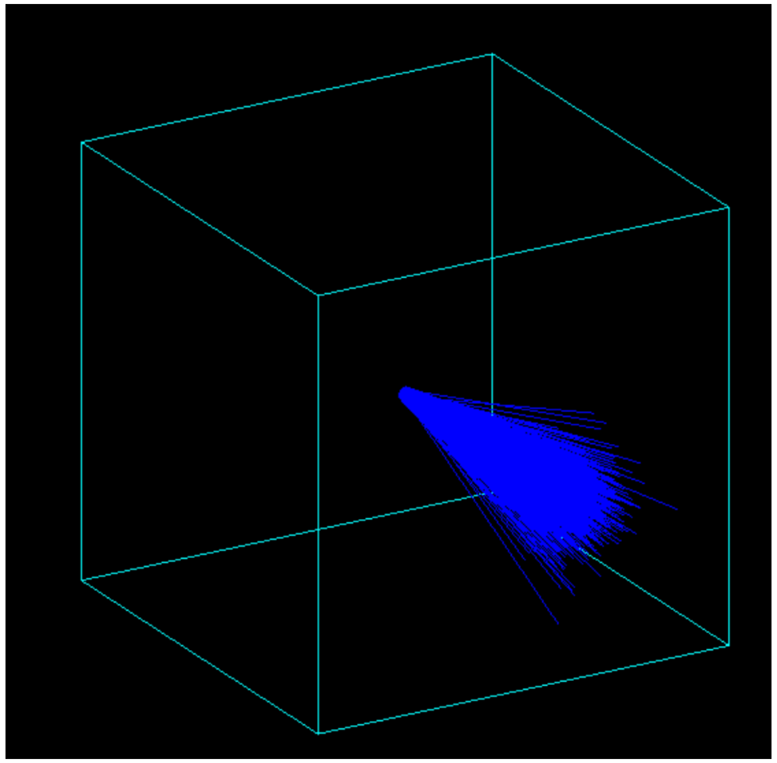
At each decay, one counts and plots energy spectrum of created particles and ions, and energy-momentum balance of that decay.
Total time of life of decay chain is plotted. Activity is computed.

The command
`/rdecay01/timeWindow`
allows to survey activity of each nuclide in a specified time window [t1,t2] : population at t1 and t2, nb of decays within [t1,t2], mean activity. See timeWindow.mac
Few macros are given in example. Debug.mac is to be run in interactive mode.

User data files

Users can redefine RadioactiveDecay and PhotonEvaporation data, via commands:
`/grdm/setRadioactiveDecayFile`
`/grdm/setPhotoEvaporationFile`

Examples of such files are given in subdirectory UserData.
Formats are described in readme
Examples in macros Cf238.mac and No252.mac

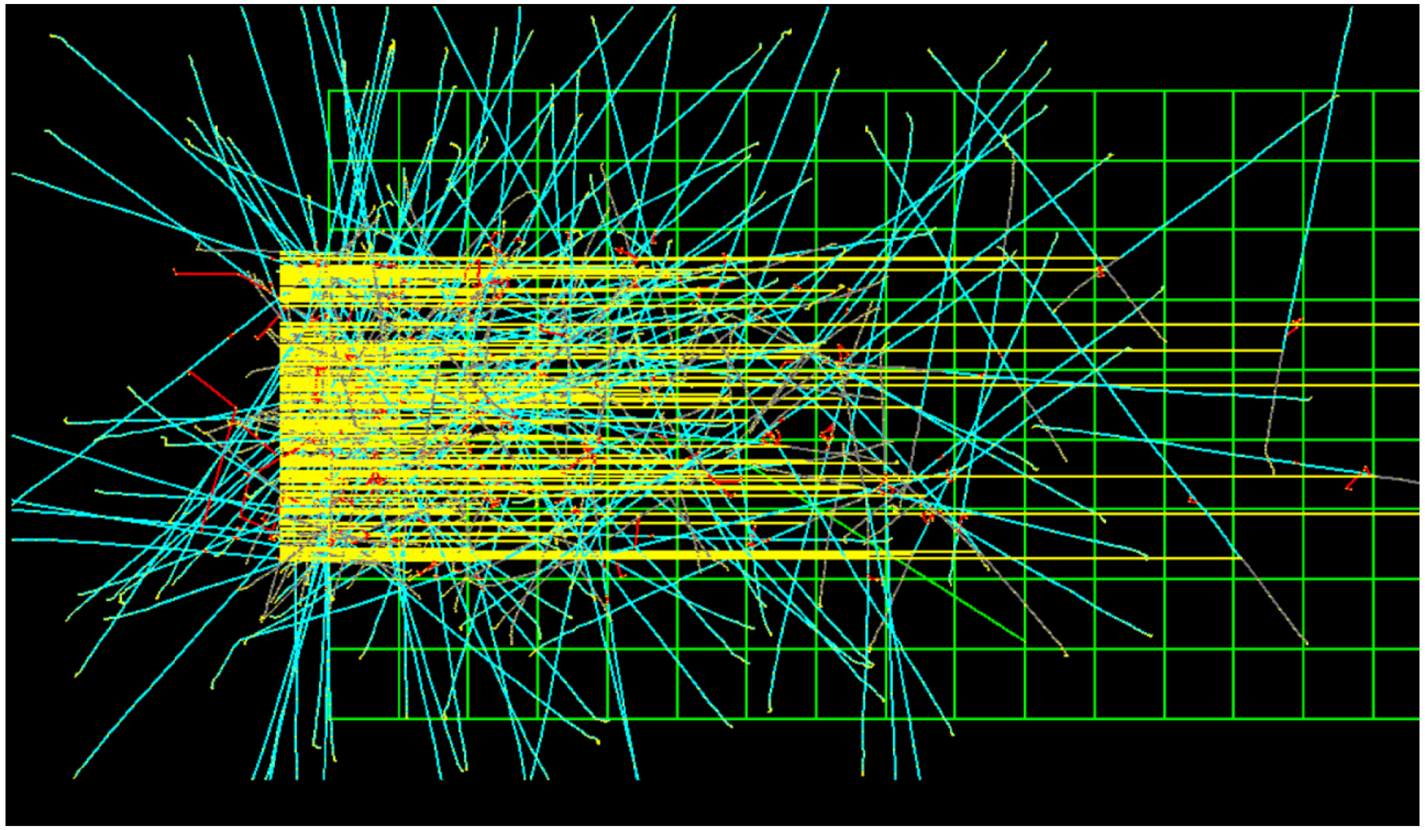


The Geometry is a simple box which represent an "infinite" homogeneus medium

RadioactiveDecay: Rdecay02

Rdecay02 is created to show how to use the G4RadioactiveDecay process to simulate the decays of radioactive isotopes as well as the induced radioactivity resulted from nuclear interactions.

In this example a simple geometry consists of a cylindric target placed in the centre of a tube detector. Various primary event generation and tallying options are available.



PHYSICS

- Standard electromagnetic
- Decay
- Radioactive Decay

By default radioactive decay is applied through out the geometry.

The user can limit it to just the target by commands :

/grdm/noVolumes

/grdm/selectVolume Target

- Hadronic processes

GEOMETRY

☑ **Target:** A cylinder placed at the origin along the z-axis. The default size of the cylinder is 0.5 cm radius and 1 cm length, and its default material is "CsI".

☑ **Detector:** A tube centered at the origin along the z-axis, with inner radius matching the radius of the target. The default thickness of the tube is 2 cm and it is 5 cm long. The default material is "Germanium".

RadioactiveDecay: Rdecay02

DETECTOR RESPONSE

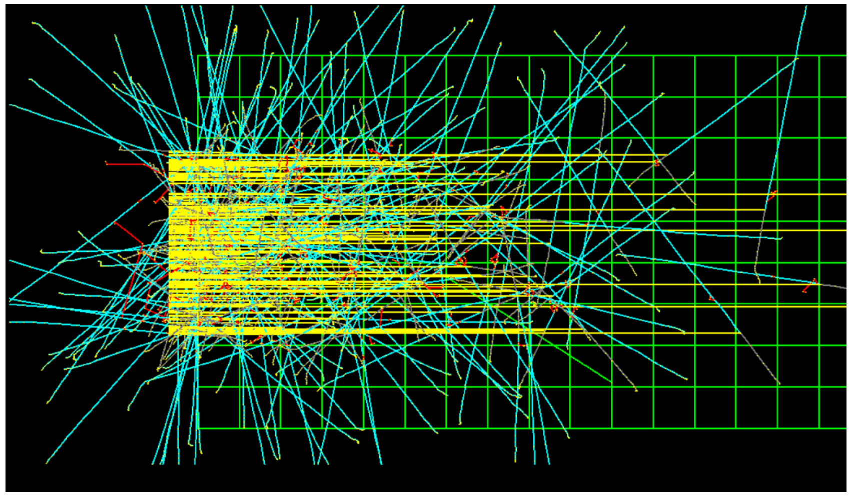
The relevant informations are collected in TrackingAction or SteppingAction. These include:

- **Emission particles in the RadioactiveDecay process:**
  particle PDGcode,
  particle kinetic energy,
  particle creation time,
  particle weight.

  Note: the residual nuclei is not considered as an emitted particle.

- **Radio-Isotopes.** All the radioactive isotopes produced in the simulation:
  isotope PDGcode,
  isotope creation time,
  isotope weight.

- **Energy depositions in the target and detector** by prodicts of the RadioactiveDecay process:
  energy depostion (positive value for target and negative for detector),
  time,
  weight.



```
histogram 0: The Pulse Height Spectrum (PHS) of the target.
histogram 1: The PHS of the detector.
histogram 2: The combined PHS of the target and detector.
histogram 3: The anti-coincidece PHS of the target.
histogram 4: The anti-coincidece PHS of the detector.
histogram 5: The coincidece PHS between the target and detector.
histogram 6: The emitted particle energy spectrum.
```

RadioactiveDecay: Activity

Geometry

The "absorber" is a box. You can change easily: Size and Material

A function, and its associated UI command, allows to build a material directly from a single isotope.

To be identified by the ThermalScattering module, the elements composing a material must have a specific name

(see G4ParticleHPThermalScatteringNames.cc)

Physics

The physics list contains a "full" set of physics processes. It is defined in the PhysicsList class as a Geant4 modular physics list with registered physics constructors (builders).

Physics constructors include : HadronElastic, HadronInelastic, IonsInelastic, GammaNuclear, RadioactiveDecay and Electomagnetic. (see geant4/source/physics_lists/constructors)

HadronElasticPhysicsHP include a model for thermalized neutrons, under the control of a command defined in NeutronHPMesseger.

GammmaNuclearPhysics is a subset of G4BertiniElectroNuclearBuilder.

ElectromagneticPhysics is a simplified version of G4EmStandardPhysics.

Output

```
1     "total energy deposit"
2     "Edep (MeV/mm) profile along beam direction"
3     "total kinetic energy emerging"
4     "energy spectrum of emerging gamma"
5     "energy spectrum of emerging e+-"
6     "energy spectrum of emerging neutrons"
7     "energy spectrum of emerging protons"
8     "energy spectrum of emerging deuterons"
9     "energy spectrum of emerging alphas"
10    "energy spectrum of all others emerging ions"
11    "energy spectrum of all others emerging baryons"
12    "energy spectrum of all others emerging mesons"
13    "energy spectrum of all others emerging leptons (neutrinos)"
14    "dN/dt (becquerel) of emerging gamma"
15    "dN/dt (becquerel) of emerging e+-"
16    "dN/dt (becquerel) of emerging neutrons"
17    "dN/dt (becquerel) of emerging protons"
18    "dN/dt (becquerel) of emerging deuterons"
19    "dN/dt (becquerel) of emerging alphas"
20    "dN/dt (becquerel) of all others emerging ions"
21    "dN/dt (becquerel) of all others emerging baryons"
22    "dN/dt (becquerel) of all others emerging mesons"
23    "dN/dt (becquerel) of all others emerging leptons (neutrinos)"
```

A root file by default

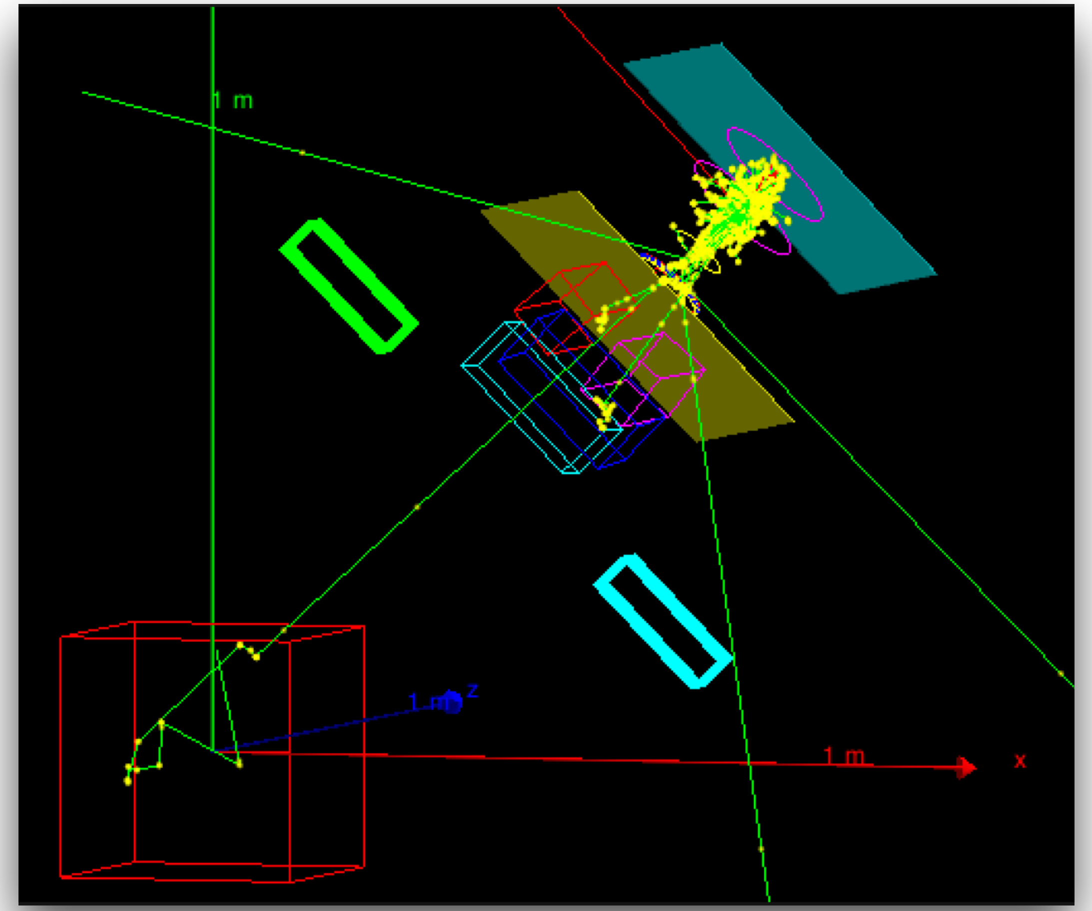
Advanced Examples

Medical physics and radioprotection	Generical nuclear physics applications
brachytherapy	air_shower
gammaknife	ams_Ecal
hadrontherapy	chargeExchangeMC
human_phantom	composite_calorimeter
iort_therapy	eRosita
medical_linac	gammaray_telescope
microbeam	microelecronics
nanobeam	purging_magnet
radioprotection	xray_fluorescence
	xray_telescope
	underground physics

Extended: Medical_Linac

The example is based on a typical structure of a medical linear accelerator for Intensity Modulated Radiation Therapy (IMRT), such as Varian Clinac 2100 accelerator.

The user may choice a cubic phantom filled with water or a phantom filled with an equivalent lung-tissue with a inhomogeneity (a 6 cm sided PMMA cube) located in the centre of the phantom.

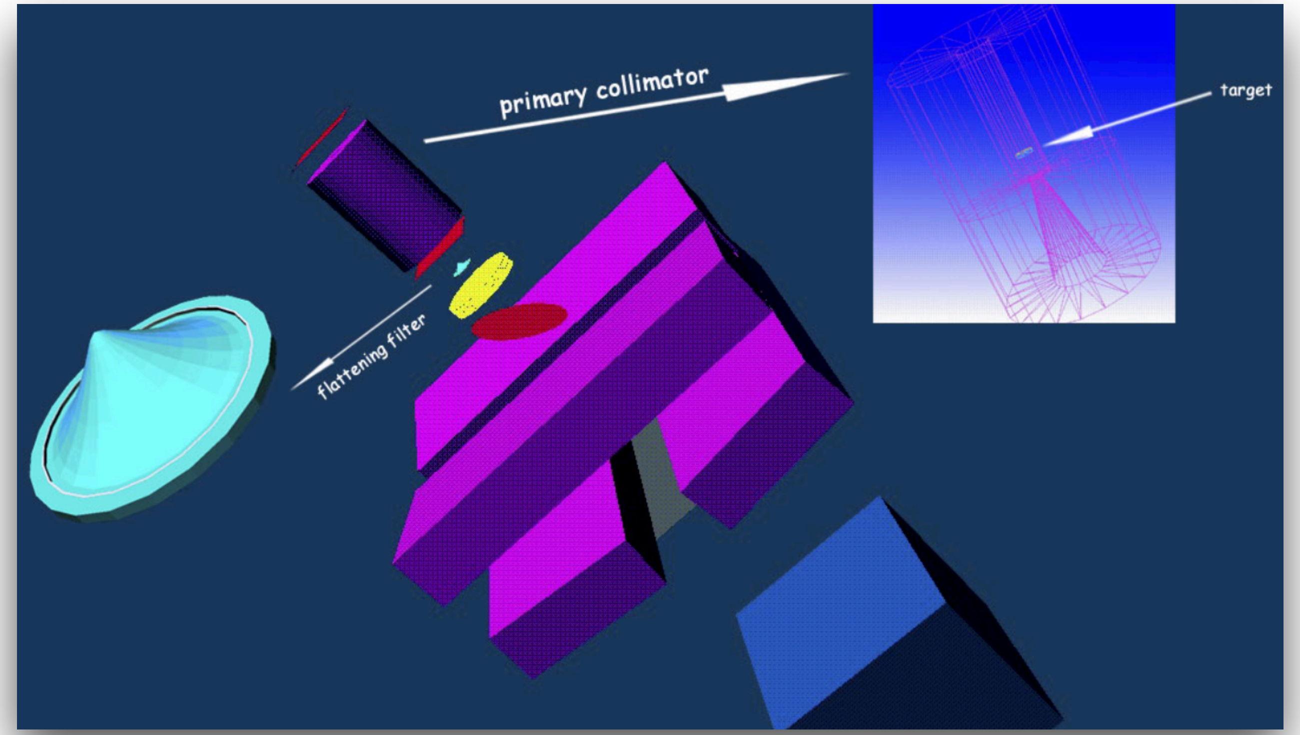


Two type of particle sources may be chosen, **a random generator of electrons gun** shooting the target or **particles loaded from a phase space**. The program allows the generation of a plane phase space. However since the mother volume of this plane phase space is the accelerator volume it can be positioned only inside the accelerator main volume.

Extended: Medical_Linac - Geometry

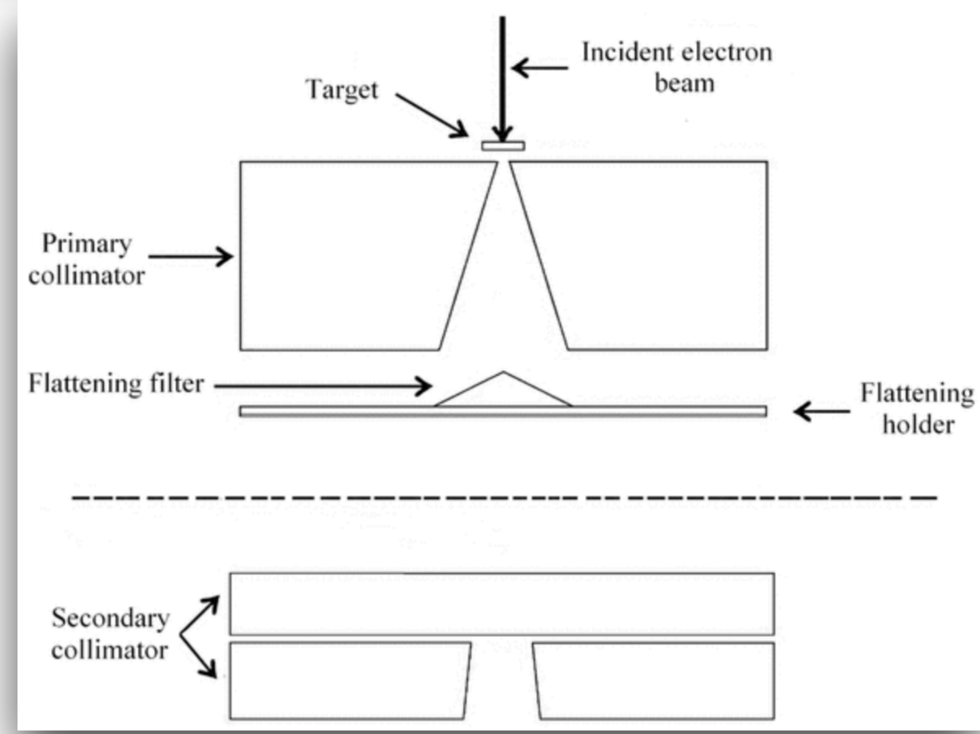
The elements simulated are:

- A source of electrons
- A target
- A primary collimator
- A flattening filter
- A ion chamber
- Secondary movable collimators
- A simple Multi Leaf Collimator



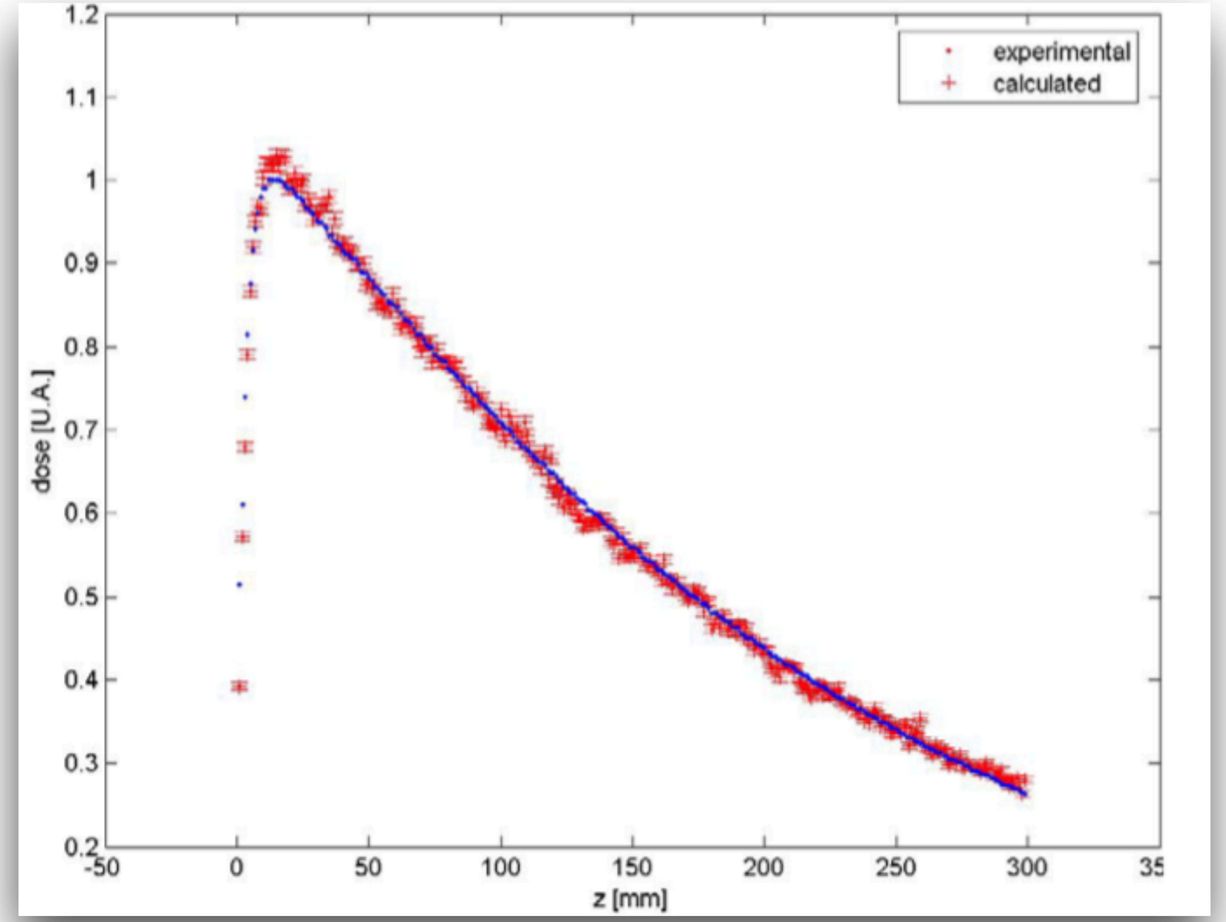
Two Phantoms:

- Phantom1 ("fullWater") filled with water (cube of 60 cm sided)
- Phantom2 ("BoxInBox") filled with G4_ICRP lung tissue (cube of 30 cm sided) with a inhomogeneity (PMMA 6 cm sided cube) in the centre and a PLEXIGLASS slab 1 cm thick on the surface of the phantom.



Extended: Medical_Linac - Geometry

- **A phase space file containing the data of the particles hitting the plane phase space.** The file contains:
  - a progressive number, position, direction, kinetic energy, PDGE code of the particle, PDGE code of the primary particle, progressive number of the primary particle generating the event in the phase space



- **An output file written in matlab format generated from an experimental data file (if provided).** The file contains:
  - position of the voxels and experimental dose values as given in the experimental data file, cumulative dose, cumulative square dose, number of events in the voxels, cumulative dose normalized to the experimental data (if provided), cumulative square dose normalized to the experimental data (if provided)

- **An output file containing the ROG results**. The file contains:
  - name of the physical volume, position, indexes of the voxel according to the voxelization of the ROG, cumulative dose, cumulative square dose, number of events in the voxel

Extended: Hadrontherapy

INFN laboratories:
- ☑ LNS (CATANA - ZD)
- ☑ TIFPA

Several physics list:
- ☑ HADRONTHERAPY_1
- ☑ HADRONTHERAPY_2

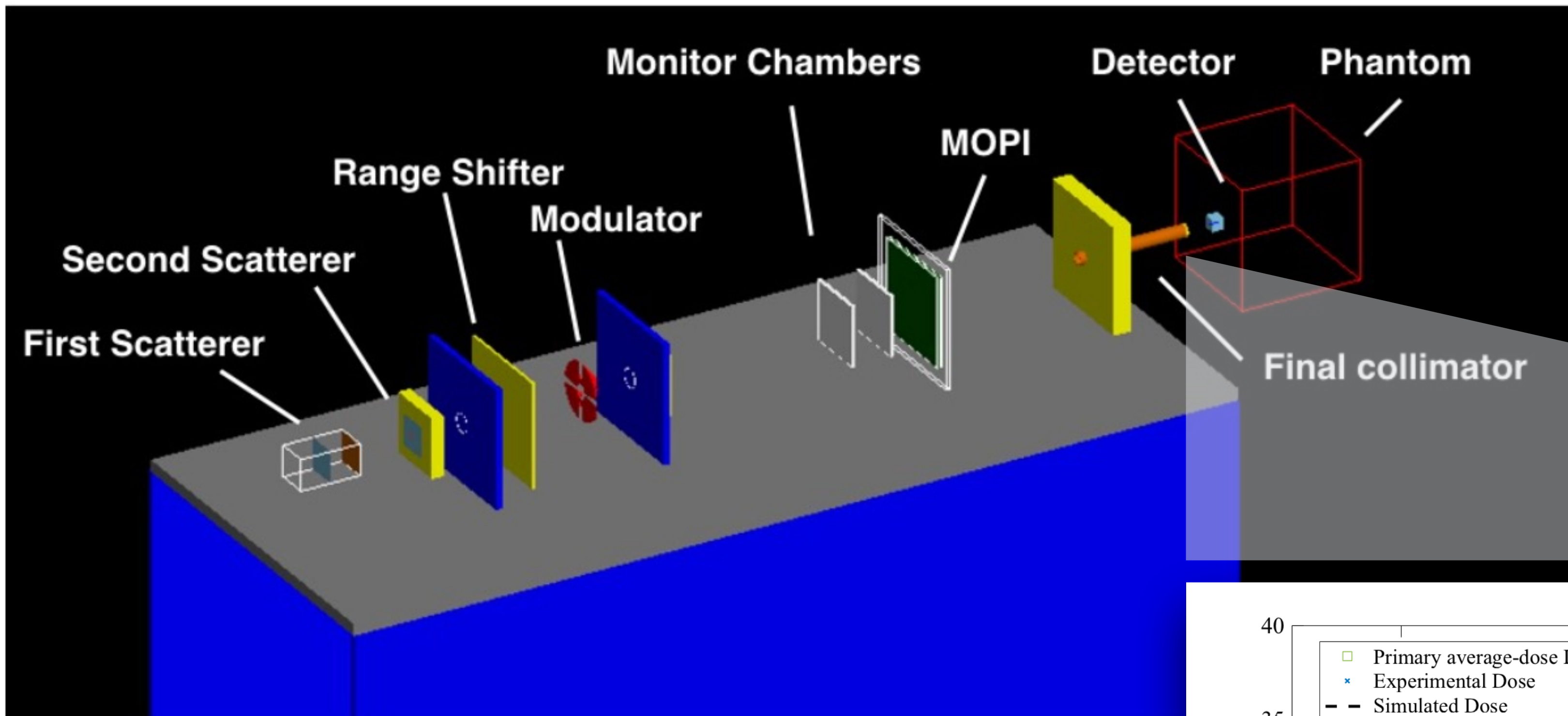
Hadrontherapy

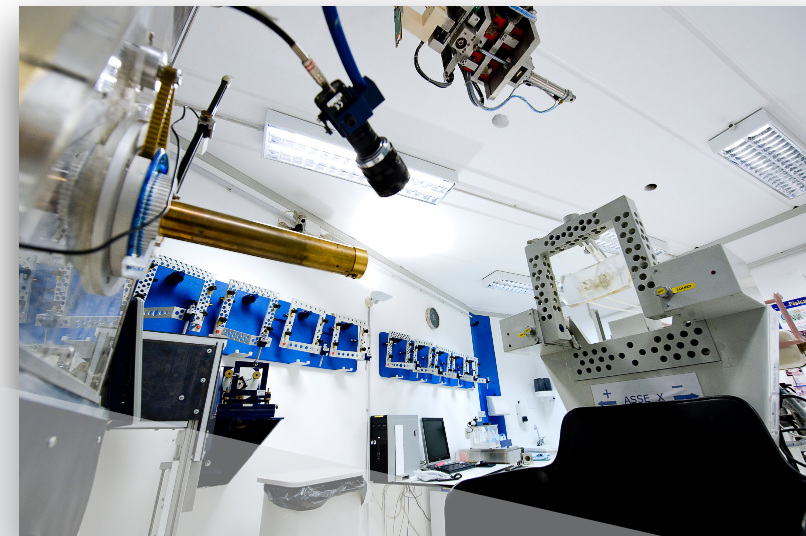
Voxelizes geometry:
- ☑ general informations
- ☑ Dose
- ☑ LET
- ☑ RBE (next Release)

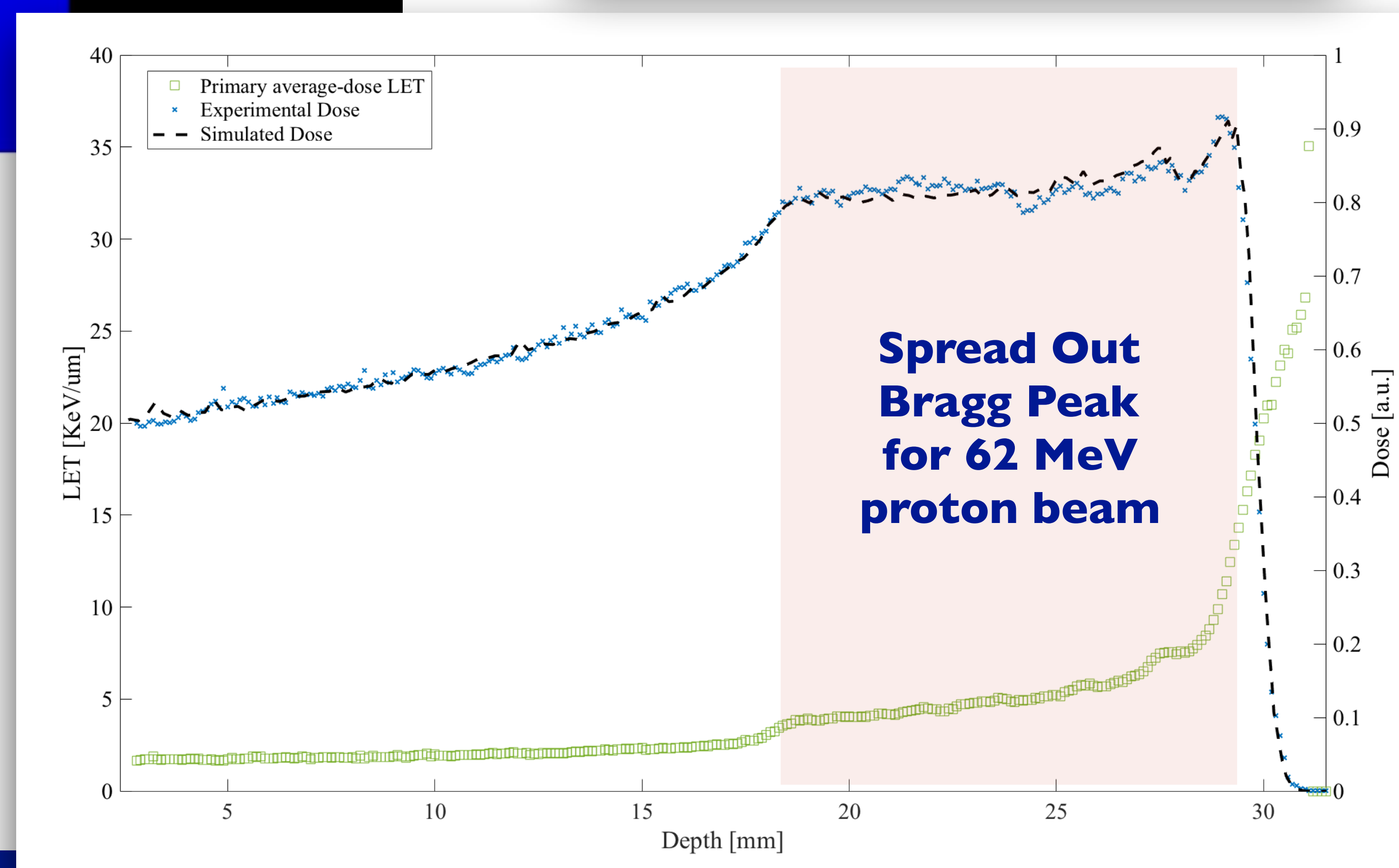
Short computation time
- ☑ MultiThreadh modality
- ☑ External source (next Release)

Extended: Hadrontherapy - CATANA

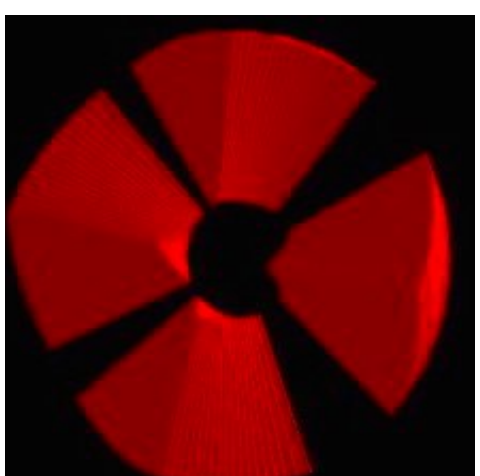
Centro di AdroTerapia e Applicazioni Nucleari Avanzate



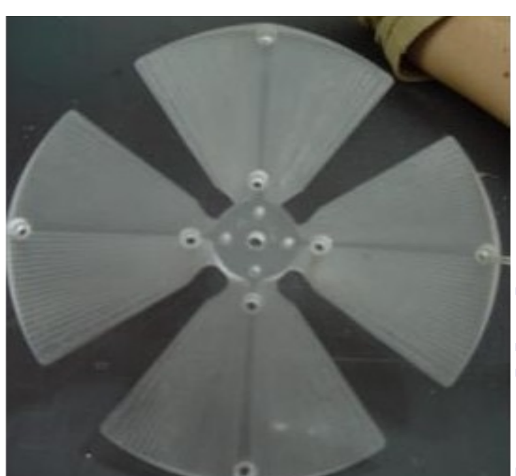




A dedicated class to the modulation system



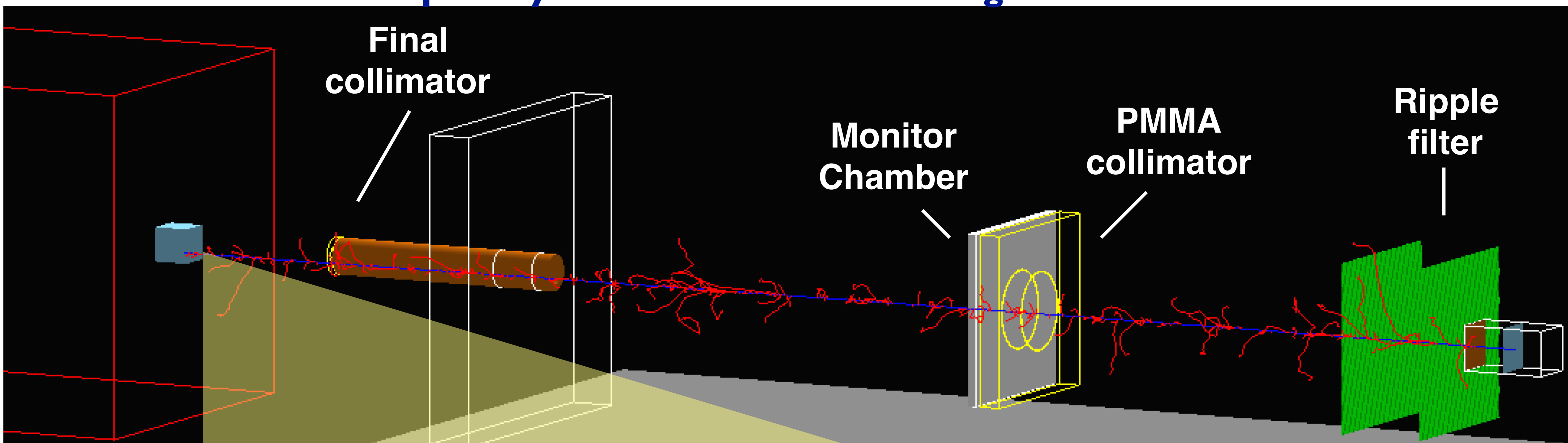
Monte Carlo Simulation

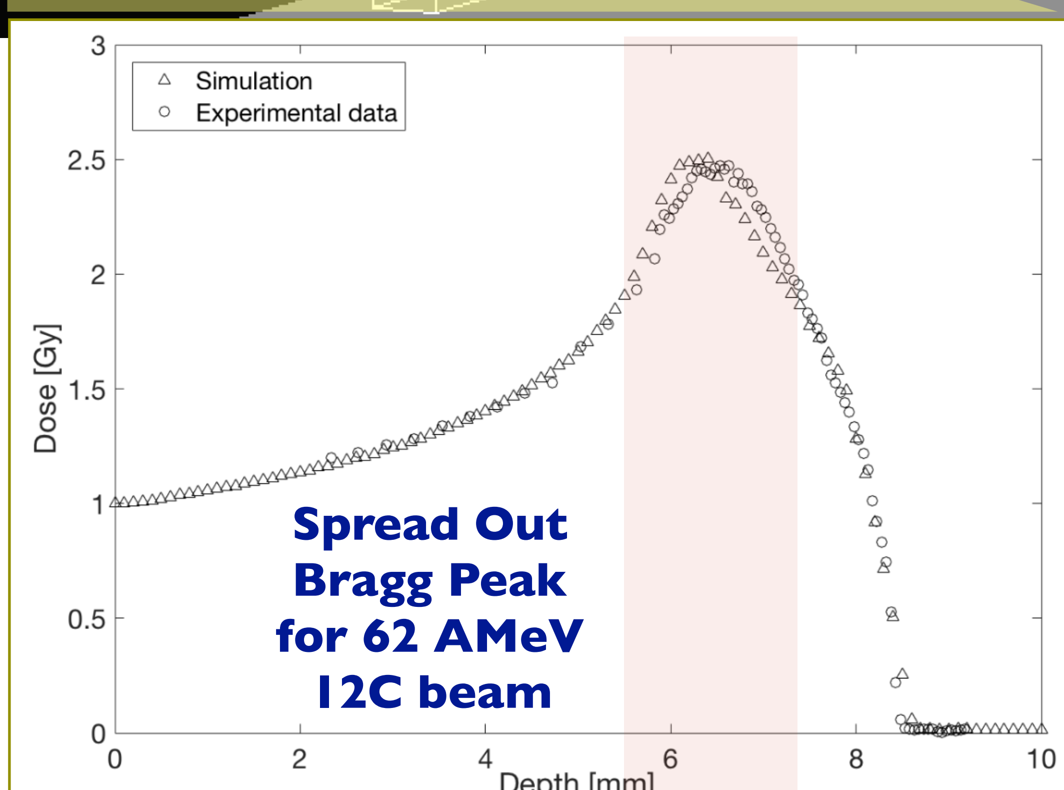


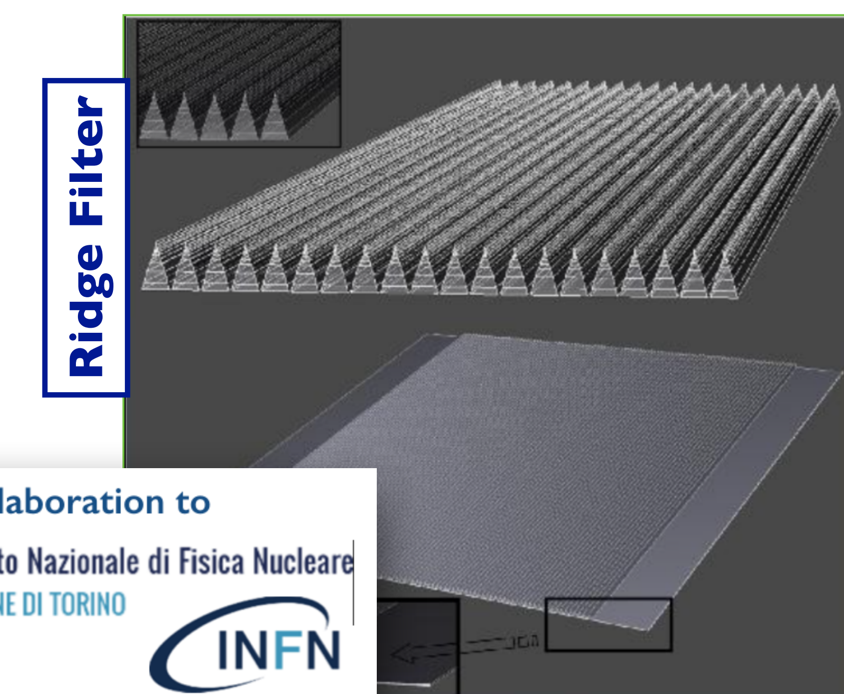
Real Modulator

Extended: Hadrontherapy - zero degree beam line

Multidisciplinary Passive beam line for light ions beams



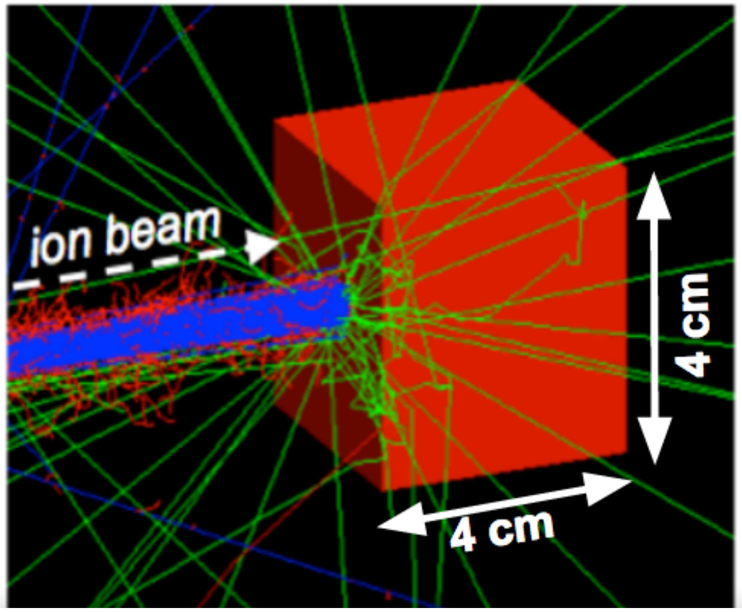


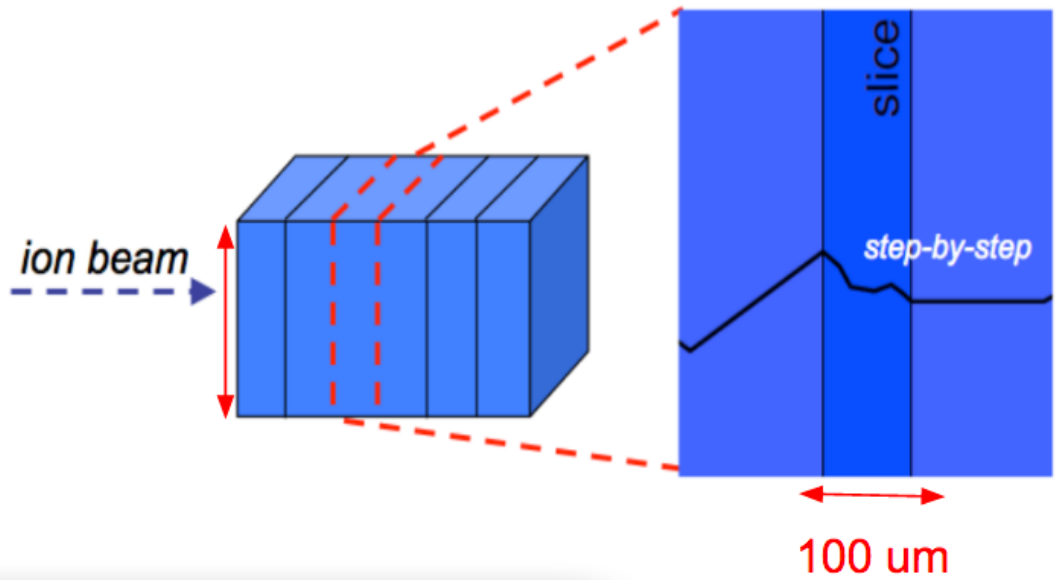


Collaboration to

Istituto Nazionale di Fisica Nucleare
SEZIONE DI TORINO
INFN

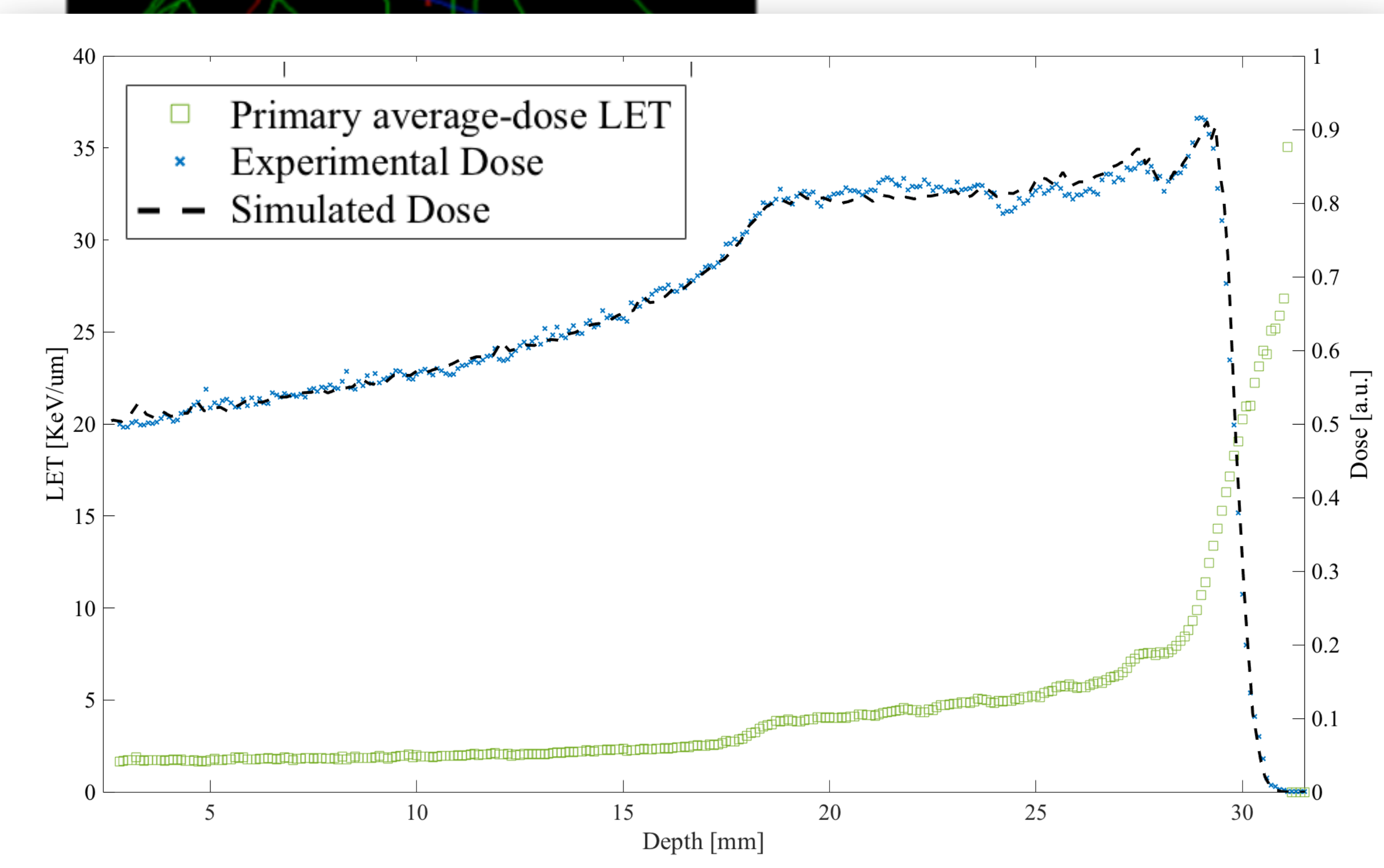
Extended: Hadrontherapy - LET & dose calculation





Step-by-step:

- Energy deposit
- Track length
- Secondary particles



Linear Energy Transfer

$$\mathrm{LET}_d = \sum_{i=1}^{n} \left(\frac{\varepsilon_i}{l_i}\right) w_{i,d} = \frac{\sum_{i=1}^{n} \left(\frac{\varepsilon_i}{l_i}\right) \varepsilon_i}{\sum_{i=1}^{n} \varepsilon_i} = \frac{\sum_{i=1}^{n} \frac{\varepsilon_i^2}{l_i}}{\sum_{i=1}^{n} \varepsilon_i}$$

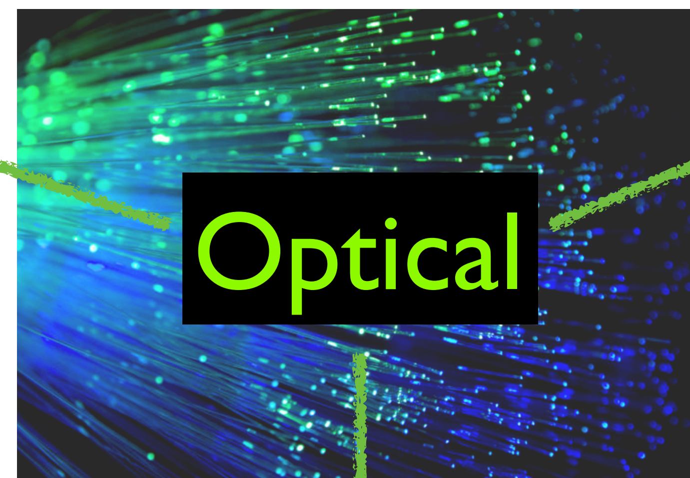
Dose

$$dose = \frac{d\bar{\varepsilon}}{dm}$$

Thank you!

Extended: Optical

Examples demonstrating the use of optical processes



OpNovice

Simulation of optical photons generation and transport. Defines optical surfaces and exercises optical physics processes (Cerenkov, Scintillation, Absorption, Rayleigh, …). Uses stacking mechanism to count the secondary particles generated.

LXe

Multi-purpose detector setup implementing:

1. scintillation inside a bulk scintillator with PMTs
2. large wall of small PMTs opposite a Cerenkov slab to show the cone
3. plastic scintillator with wave-length-shifting fiber readout.

wls

This application simulates the propagation of photons inside a Wave Length Shifting (WLS) fiber.

Optical: OpNovice

This example presently illustrates the following basic concepts, and how to use G4 for optical photon generation and transport

G4VUserPhysicsList

- Define particles; including - *** G4OpticalPhoton ***
- Define processes; including
  - *** G4Cerenkov ***
  - *** G4Scintillation ***
  - *** G4OpAbsorption ***
  - *** G4OpRayleigh ***
  - *** G4OpBoundaryProcess ***

dedicated processes

G4VUserDetectorConstruction

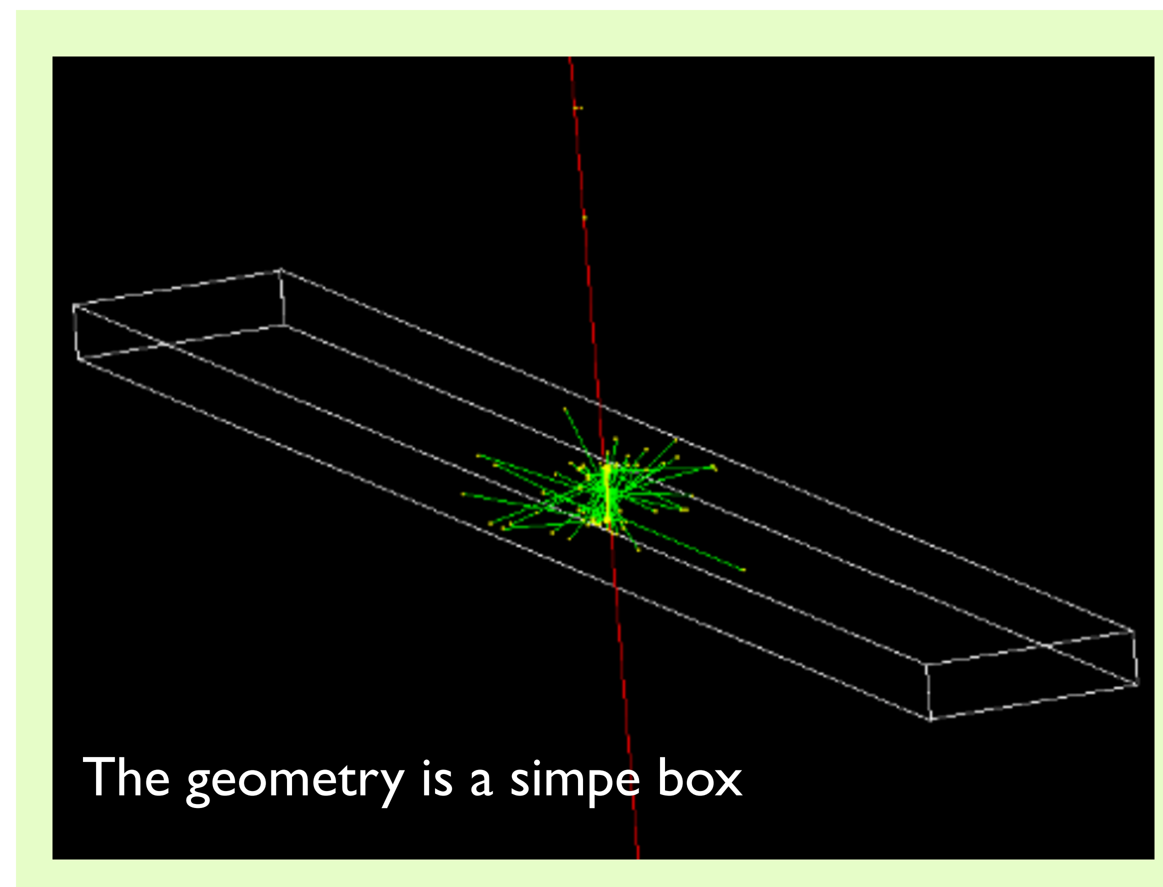
- Define material: Air and Water
- Define simple G4box geometry
  - *** add G4MaterialPropertiesTable to G4Material ***
  - *** define G4LogicalSurface(s) ***
  - *** define G4OpticalSurface ***
  - *** add G4MaterialPropertiesTable to G4OpticalSurface ***

G4VUserPrimaryGeneratorAction

Use G4ParticleGun to shoot a charge particle into a Cerenkov radiator
A messenger command allows to define interactivly the polarization of an primary optical photon (see for instance **optPhoton.mac**

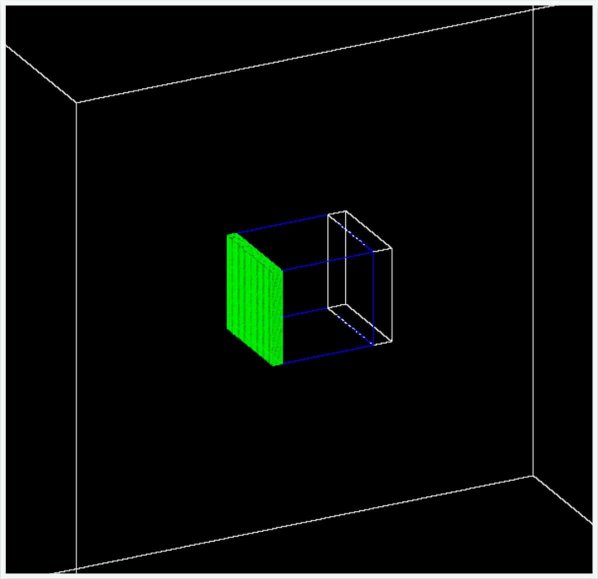
G4UserRunAction

- Define G4Timer (start/stop)



Optical: LXe - Geometry

It seperates the concept of how a volume is built from where it is placed.
Each major volume in the geometry is defined as a class derived from G4PVPlacement.

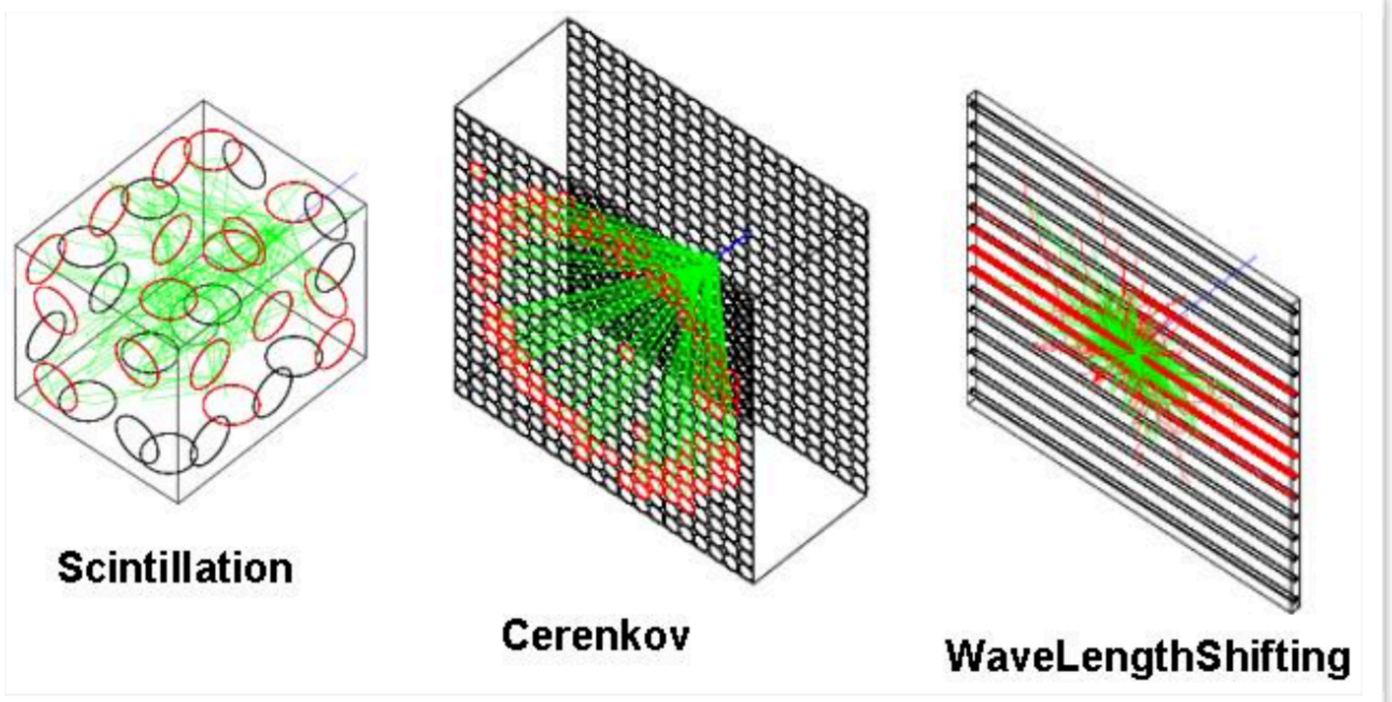


You can use:

- ☑ the main LXe volume,
- ☑ the WLS scintillator slab
- ☑ the WLS fibers were chosen.

To place one of these volumes, simply create an instance of it with the appropriate rotation, translation, and mother volumes.

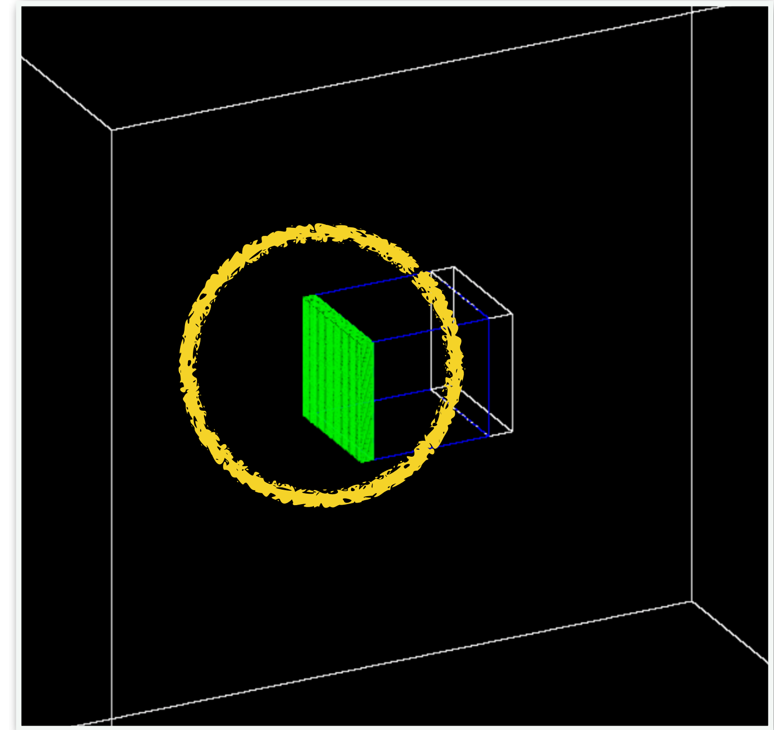
```
LXeMainVolume(G4RotationMatrix *pRot,
              const G4ThreeVector &tlate,
              G4LogicalVolume *pMotherLogical,
              G4bool pMany,
              G4int pCopyNo,
              LXeDetectorConstruction* c);
```



Optical: LXe - PMT sensitive detector

The PMT sensitive detector cannot be triggered like a normal sensitive detector because the sensitive volume does not allow photons to pass through it.
Rather, it detects them in the **OpBoundary** process based on an efficiency set on the skin of the volume.

```
G4OpticalSurface* photocath_opsurf =new
G4OpticalSurface("photocath_opsurf",glisur,polished,
                                    dielectric_metal);
  G4double photocath_EFF[num]={1.,1.};
  G4double photocath_REFL[num]={0.,0.};
  G4MaterialPropertiesTable* photocath_mt = new G4MaterialPropertiesTable();
  photocath_mt->AddProperty("EFFICIENCY",Ephoton,photocath_EFF,num);
  photocath_mt->AddProperty("REFLECTIVITY",Ephoton,photocath_REFL,num);
  photocath_opsurf->SetMaterialPropertiesTable(photocath_mt);
  new G4LogicalSkinSurface("photocath_surf",photocath_log,photocath_opsurf);
```



A normal sensitive detector would have its ProcessHits function called for each step by a particle inside the volume. So, to record these hits with a sensitive detector we watched the status of the OpBoundary process from the stepping manager whenever a photon hit the sensitive volume of the pmt. If the status was 'Detection', we retrieve the sensitive detector from G4SDManager and call its ProcessHits function.

```
boundaryStatus=boundary->GetStatus();
 if(thePostPoint->GetStepStatus()==fGeomBoundary){
   switch(boundaryStatus){
     case Detection:
//Note, this assumes that the volume causing detection
//is the photocathode because it is the only one with non-zero-efficiency
        {
          //Trigger sensitive detector manually since photon is
          //absorbed but status was Detection
          G4SDManager* SDman = G4SDManager::GetSDMpointer();
          G4String sdName="/LXeDet/pmtSD";
          LXePMTSD* pmtSD = (LXePMTSD*)SDman
            ->FindSensitiveDetector(sdName);
          if(pmtSD)
            pmtSD->ProcessHits_constStep(theStep,NULL);
          break; }
```

Optical: WIn

Geometry Definition

The default geometry is as follow:

- A perfect, bare, PMMA fiber: 0.5mm radius, 2m length at center(0,0,0) of the World.
- A circular MPPC with 0.5mm radius at the +z end of the fiber
- World and coupling materials are G4_AIR
- Photons will always refracted out to coupling material before reaching MPPC
- There are many flexible parameters that the user could specify

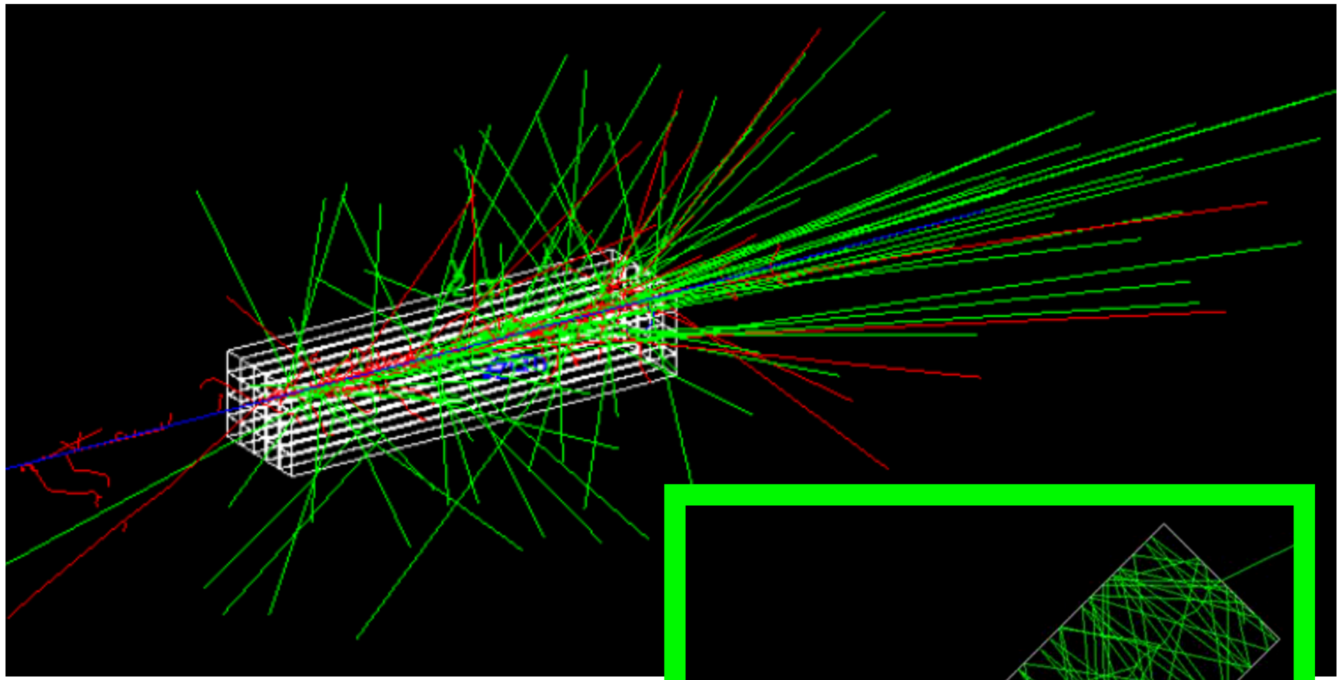
Material Choices

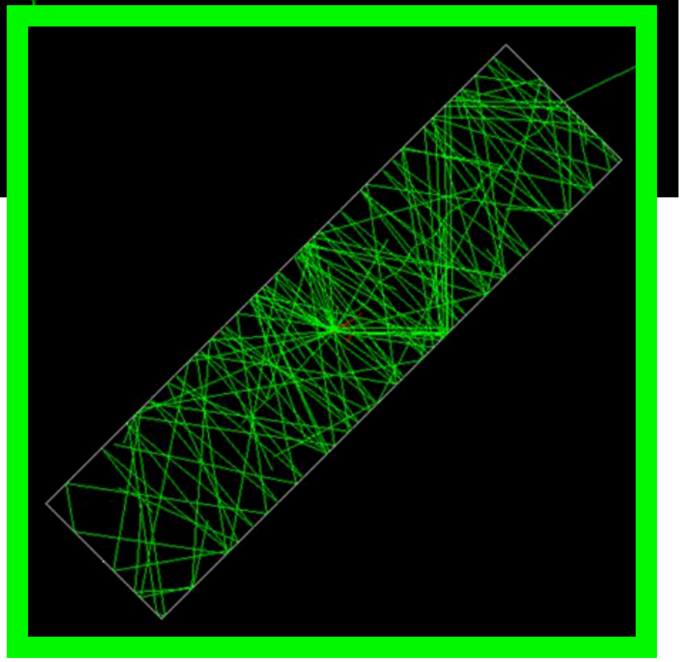
There are several materials that the user can use for the fiber core, world and coupling.
They are:

- Vacuum (G4_Galactic)
- Air (G4_AIR)
- PMMA, n = 1.60
- Pethylene, n = 1.49
- FPethylene, n = 1.42
- Polystyrene, n = 1.60
- Silicone, n = 1.46

Photon Source

Uses the General Particle Source (G4GeneralParticleSource)
The energy of the photon must be within 2.00 eV to 3.47 eV.





A hit is registered when the photon is absorbed on the MPPC surface. Information stored in hit includes the local coordinate of the location the photon is absorbed on the MPPC, the global coordinate where the photon left the fiber and the transit time of the photon.

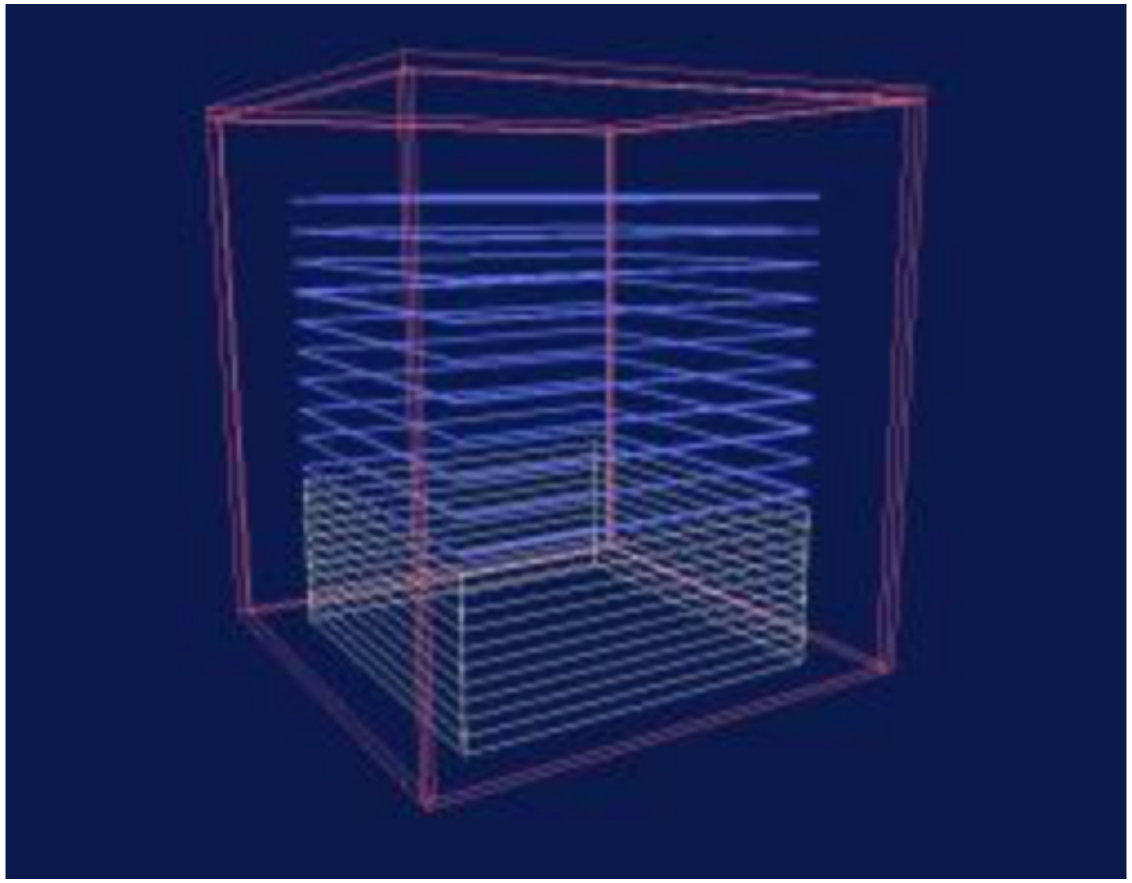
Extended: GammaRay_Telescope

GammaRayTel is an example of application of Geant4 in a space envinronment.

the hits on the tracker strips are registered and relevant information (energy deposition, position etc) are dumped to an external ASCII file for subsequent analysis.

The main features of this example are

- Macros for the visualization of geometry and tracks with OpenGL, VRML and DAWN drivers
- Implementation of messengers to change some parameters of the detector geometry, the particle generator and the analysis manager (if present) runtime
- Readout geometry mechanism to describe an high number of subdivisions of the planes of the tracker (strips) without affecting in a relevant way the simulation performances
- Histogramming for Linux and Solaris platform via the Lizard system (tested on Linux platform); this is a preliminary feature of GEANT4, so expect some changes and/or improvements in future releases
- User interfaces via Xmotif or normal terminal provided



the detector setup is composed by a tracker made with silicon planes, subdivided in ladders and strips, a CsI calorimeter and an anticoincide nce system.

Extended: GammaRay_Telescope

Physics processes
Standard Electromagnetic processes.

Source
The GammaRayTelParticleGenerationAction and its Messenger let the user define the incident flux of particles, from a specific direction or from an isotropic background.
The user can define also between two spectral options: monochromatic or with a power-law dependence.

Hit
In this version only the hits from the TKR are recorded. Each hit contains the following information

- ID of the event (this is important for multiple events run)
- Energy deposition of the particle in the strip (keV)
- Number of the strip
- Number of the plane
- Type of the plane (1=X 0=Y)
- Position of the hit (x,y,z) in the reference frame of the payload