Documentation & Examples

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Geant4 web pages

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GEANT4
A SIMULATION TOOLKIT

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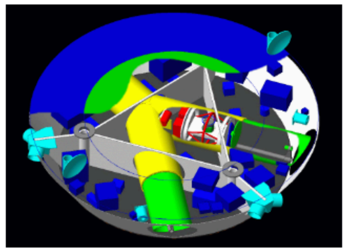
Overview

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

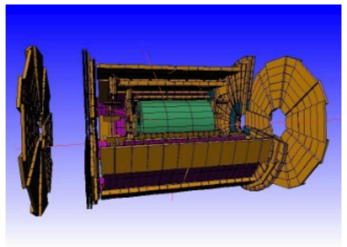
A sampling of applications, technology transfer and other uses of Geant4

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]
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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??

* geant4.10.05/examples/advanced
* geant4.10.05/examples/basic
* geant4.10.05/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

Basic!

A bit complex

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
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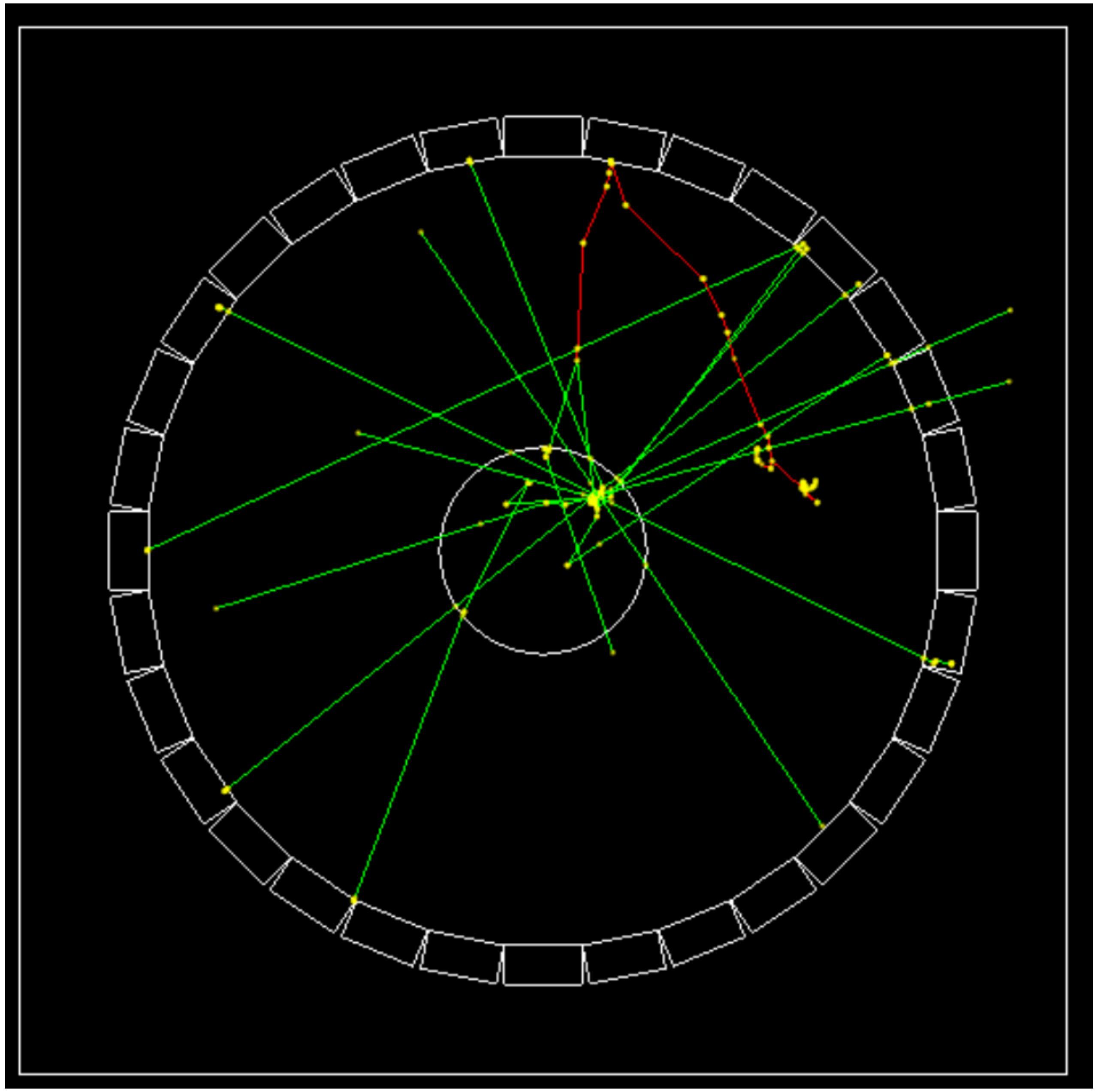
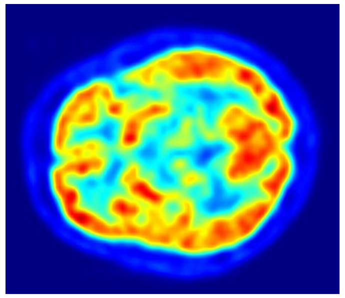
Example B3 - the geometry

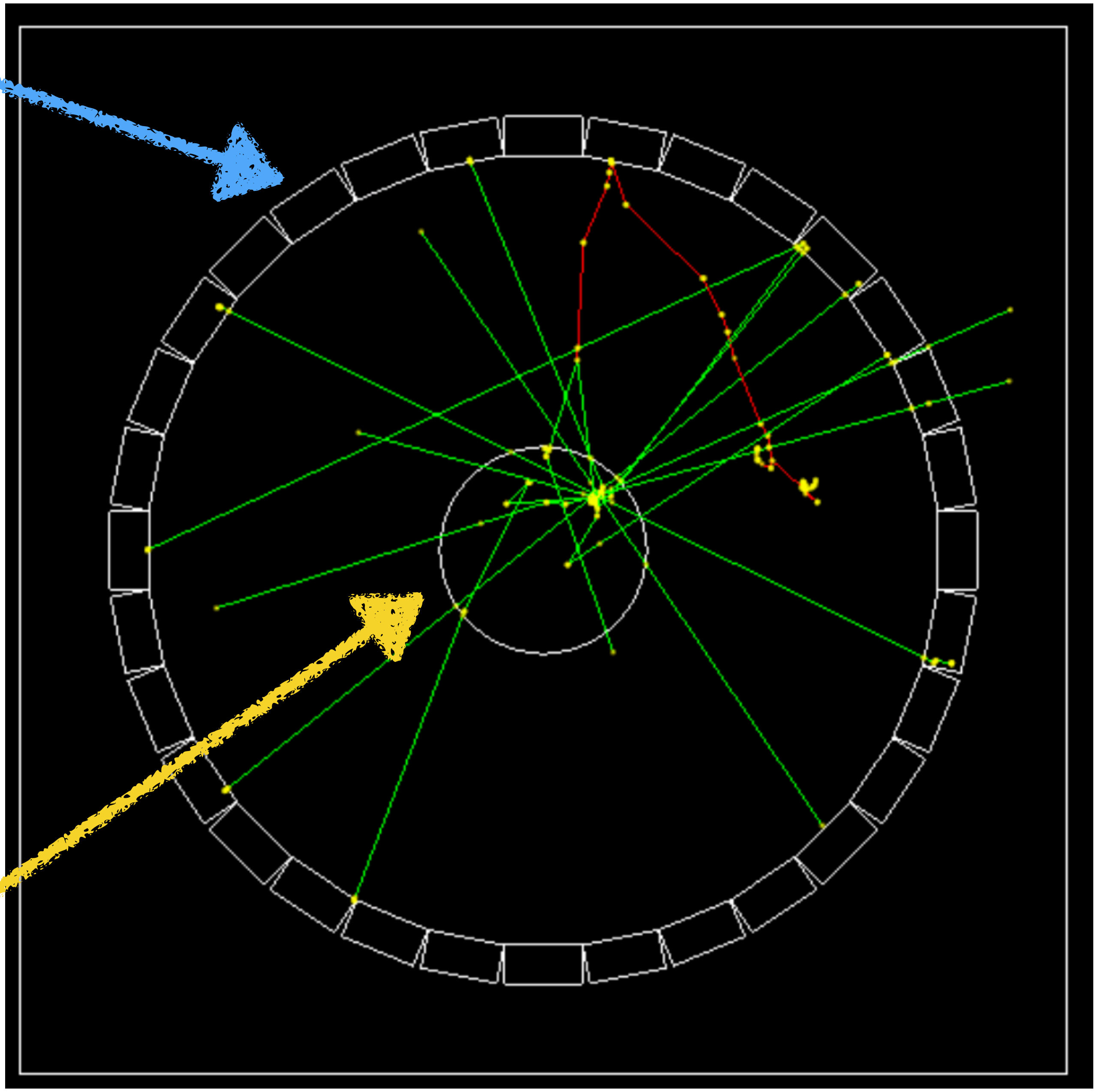
PET is a nuclear medicine functional imaging technique that is used to observe metabolic processes in the body as an aid to the diagnosis of disease. The system detects pairs of gamma rays emitted indirectly by a positron-emitting radionuclide, most commonly fluorine-18, which is introduced into the body on a biologically active molecule called a radioactive tracer.





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()**.

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

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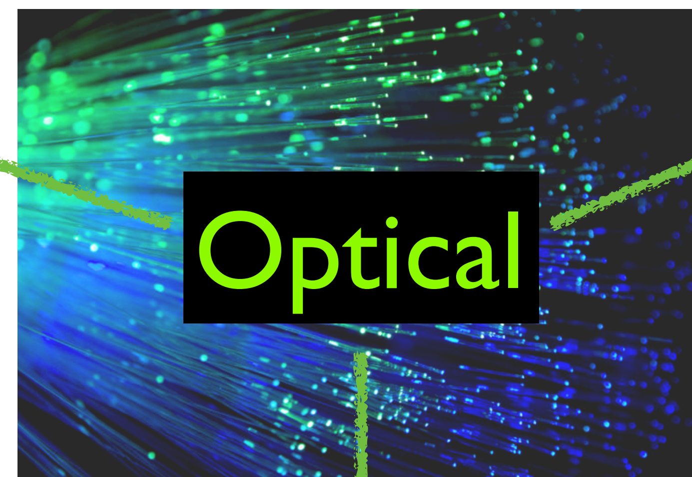
Extended: Optical

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

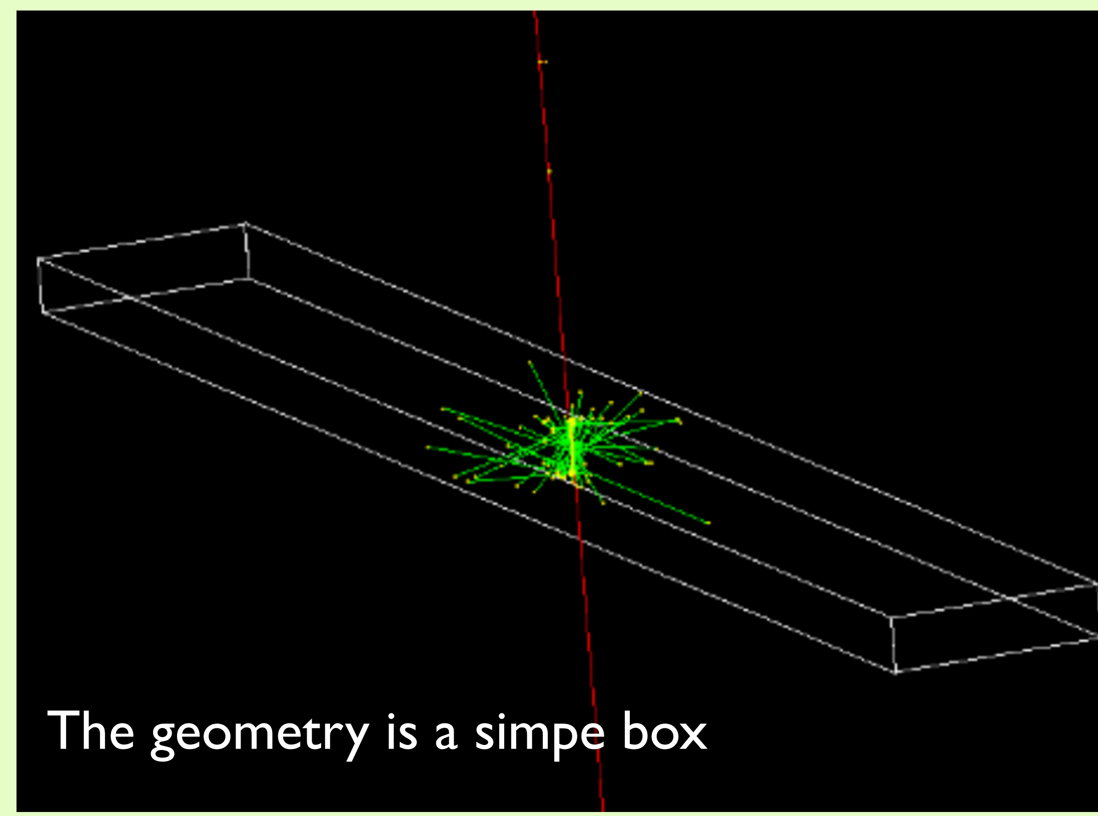
- Define material: Air and Water
- Define simple G4box geometry
  - *** add G4MaterialPropertiesTable to G4Material ***
  - *** define G4LogicalSurface(s) ***
  - *** define G4OpticalSurface ***
  - *** add G4MaterialPropertiesTable to G4OpticalSurface ***

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**

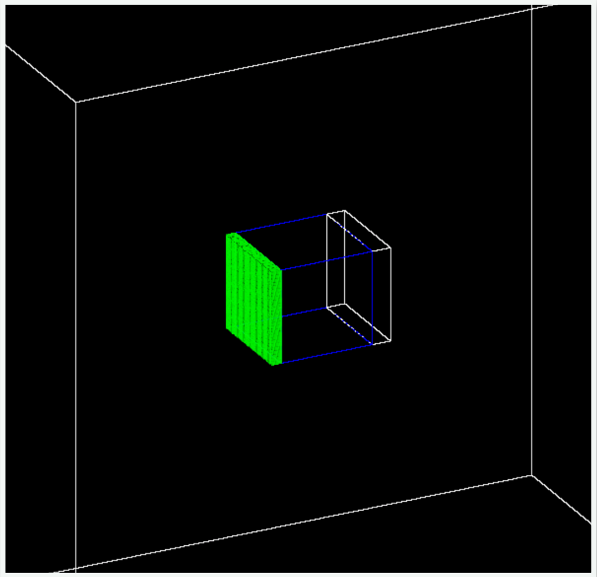
G4UserRunAction

- 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.

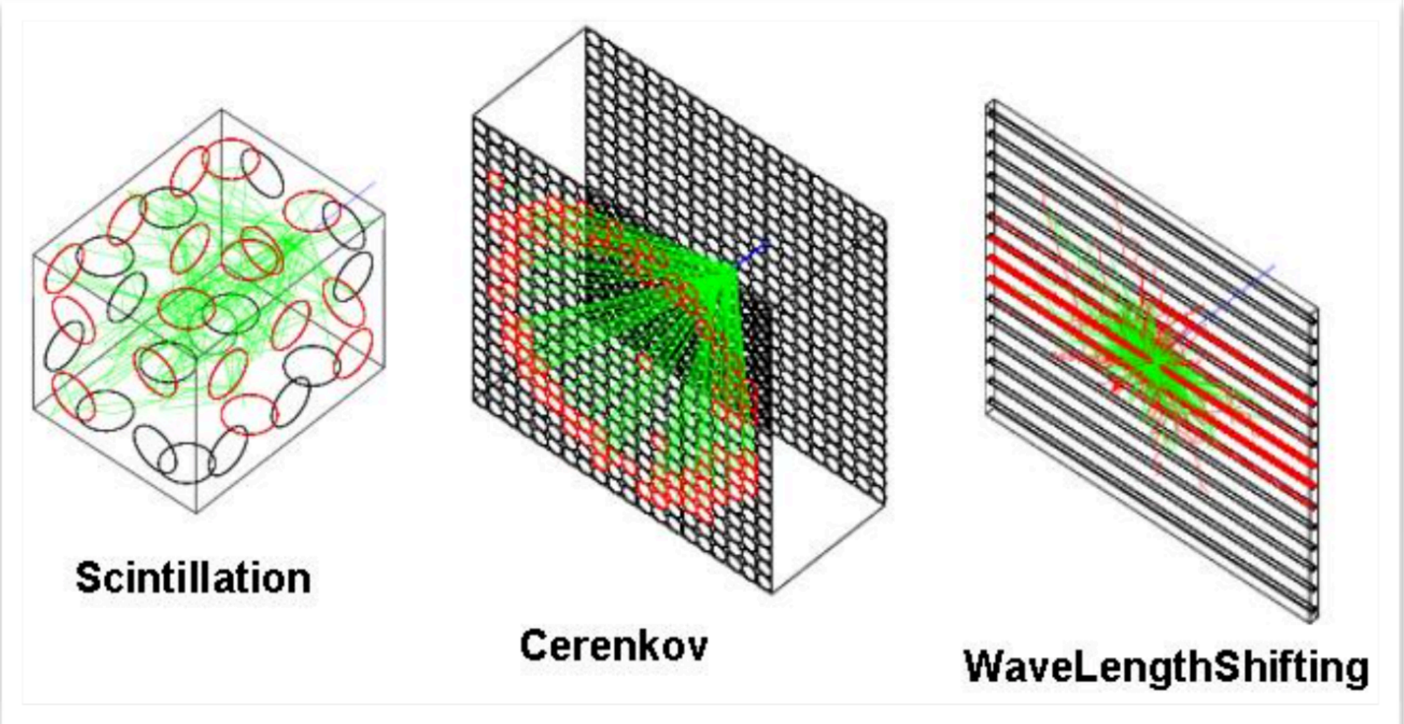


You can use:

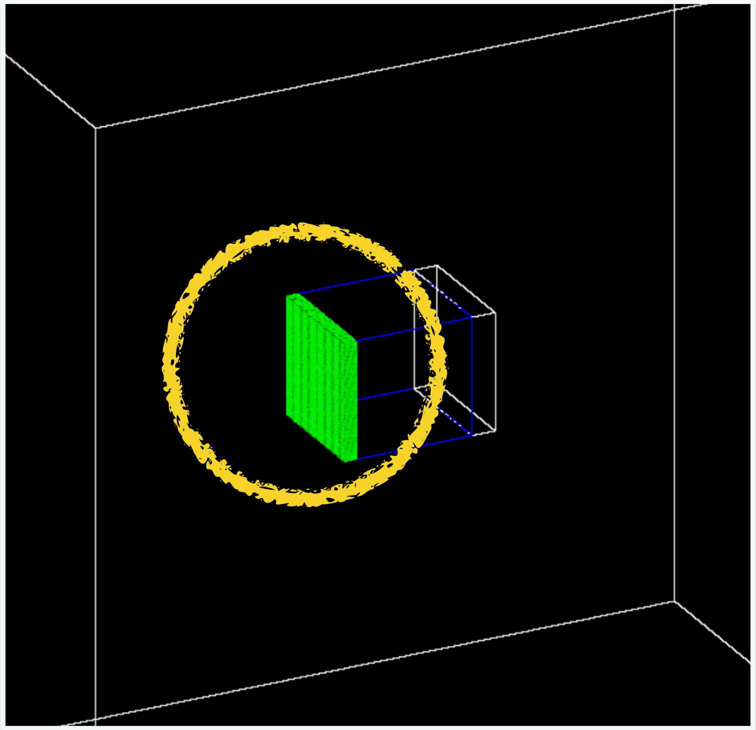
- ☑ the main LXe volume,
- ☑ the WLS scintillator slab
- ☑ the WLS fibers were chosen.

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

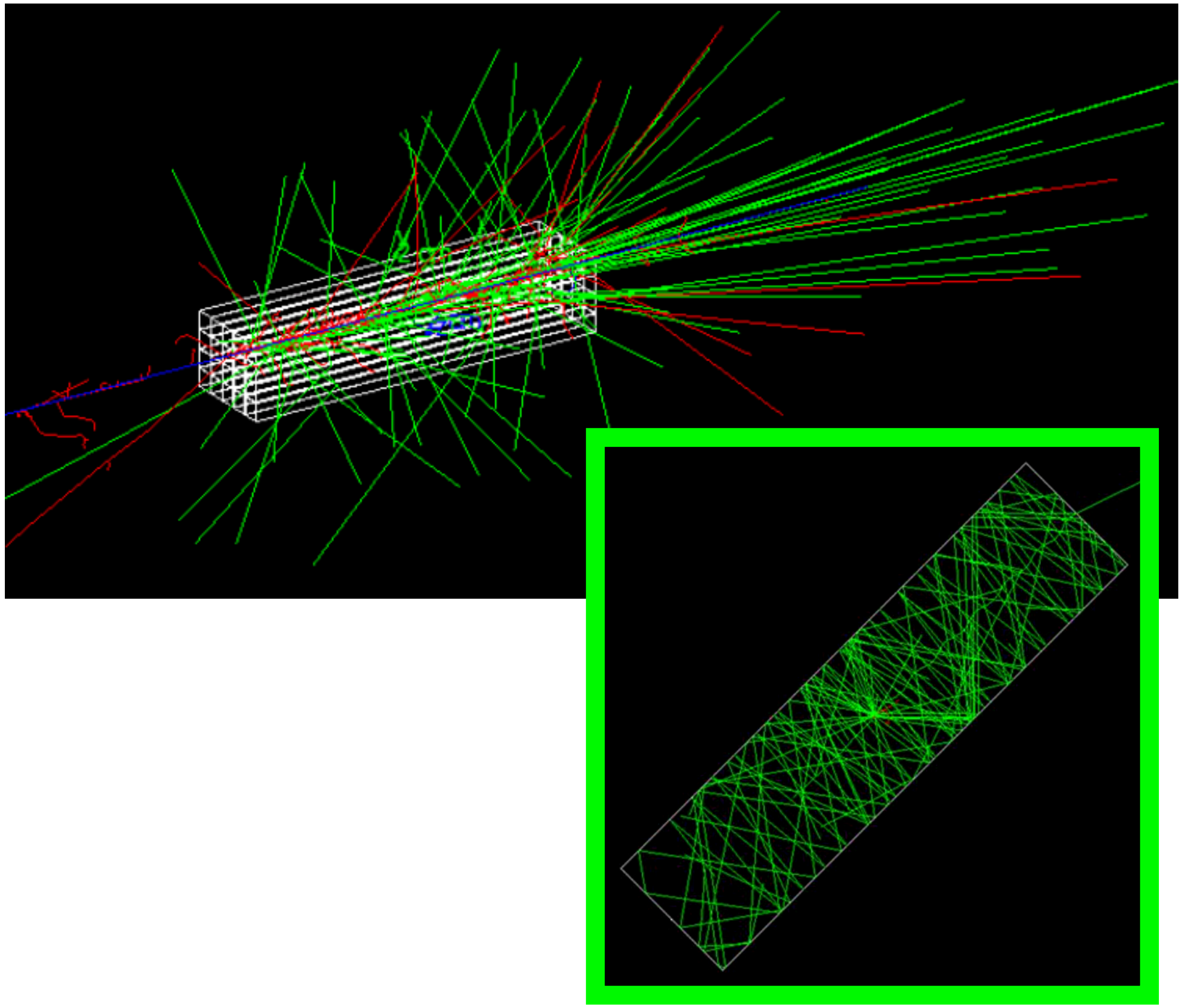
Material Choices

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.

Advanced Examples

Medical physics and radioprotection

- brachytherapy
- gammaknife
- hadrontherapy
- human_phantom
- iort_therapy
- medical_linac
- microbeam
- nanobeam
- radioprotection

Generical nuclear physics applications

- air_shower
- ams_Ecal
- chargeExchangeMC
- composite_calorimeter
- eRosita
- gammaray_telescope
- microelecronics
- purging_magnet
- xray_fluorescence
- xray_telescope
- underground physics

Extended: Hadrontherapy

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

Several physics list:
- ☑ HADRONTHERAPY_1
- ☑ HADRONTHERAPY_2

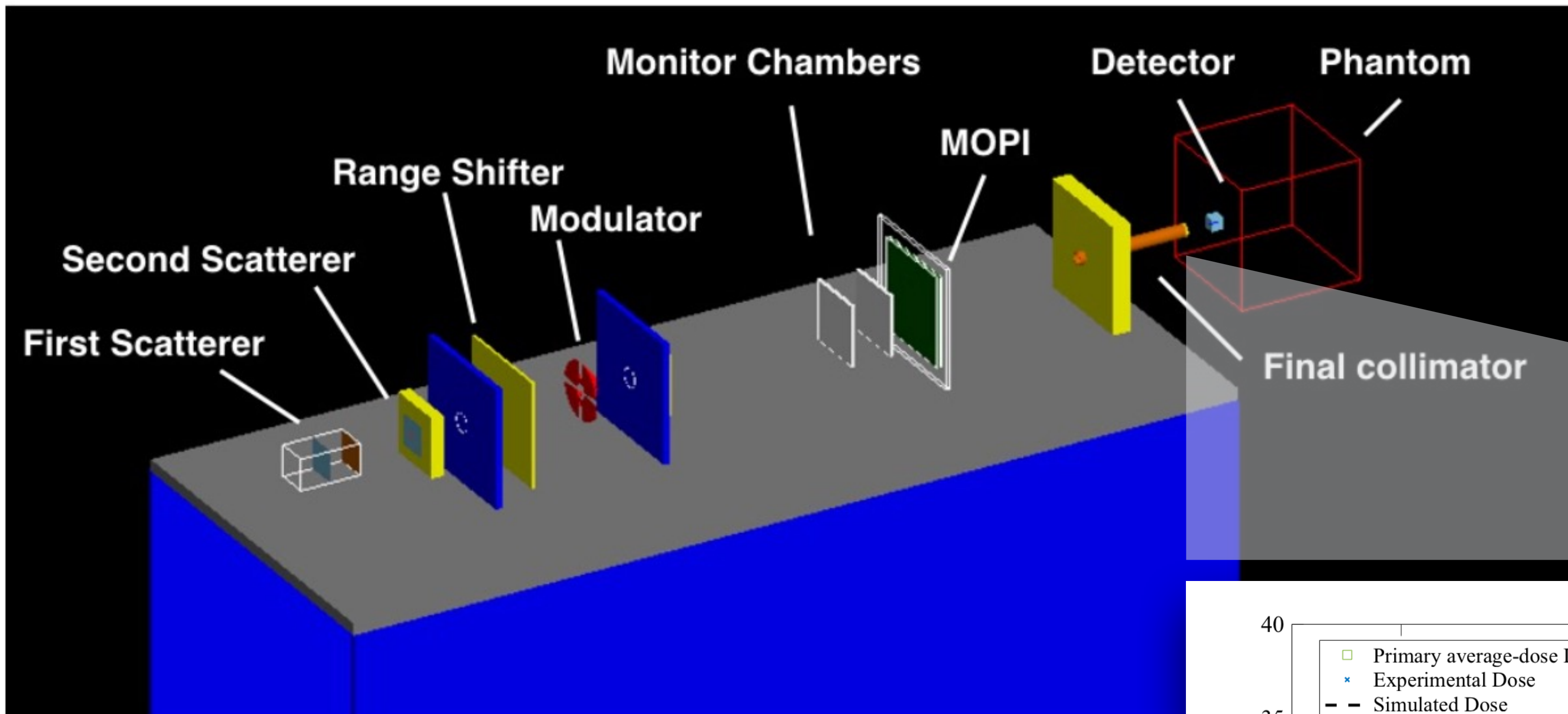
Hadrontherapy

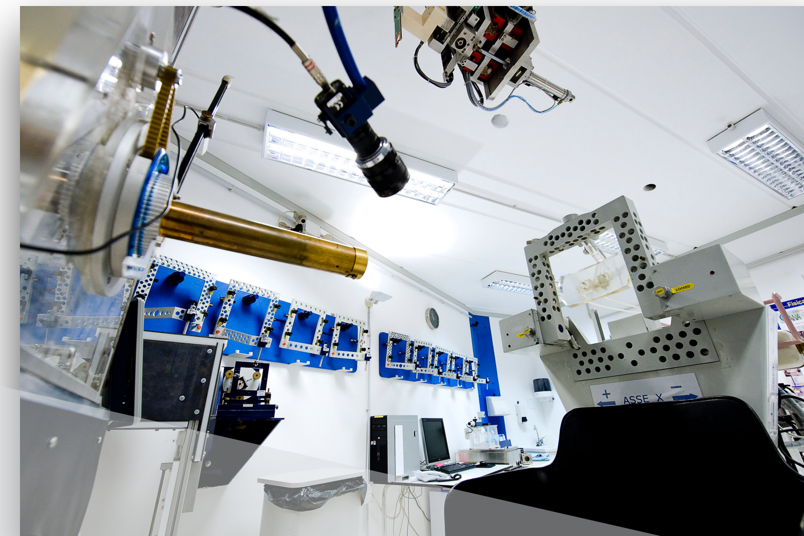
Voxelizes geometry:
- ☑ general informations
- ☑ Dose
- ☑ LET
- ☑ RBE

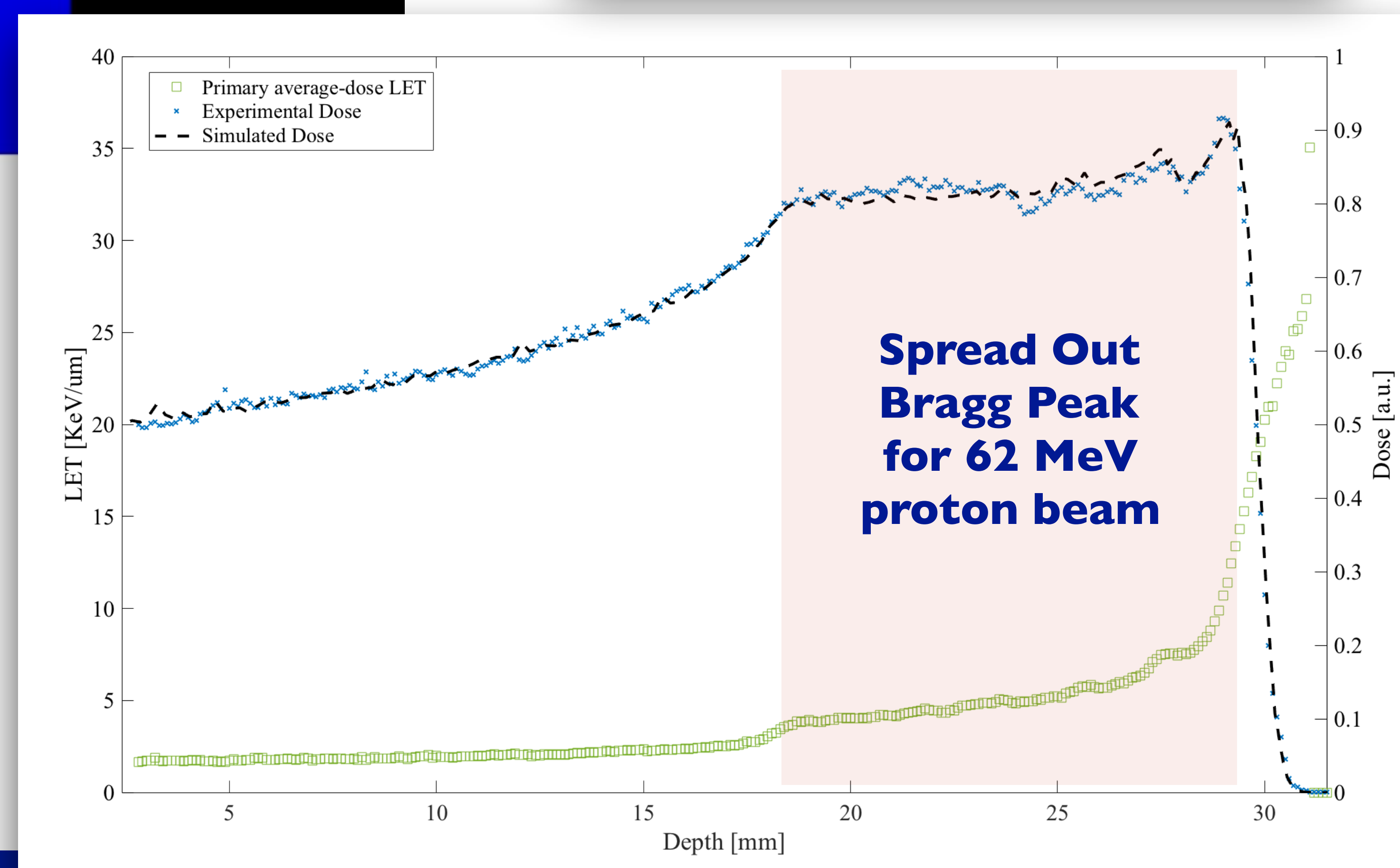
Short computation time
- ☑ MultiThreadh modality
- ☑ External source

Extended: Hadrontherapy - CATANA

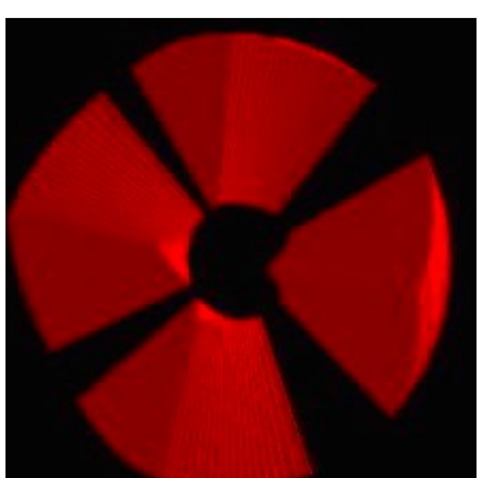
Centro di AdroTerapia e Applicazioni Nucleari Avanzate



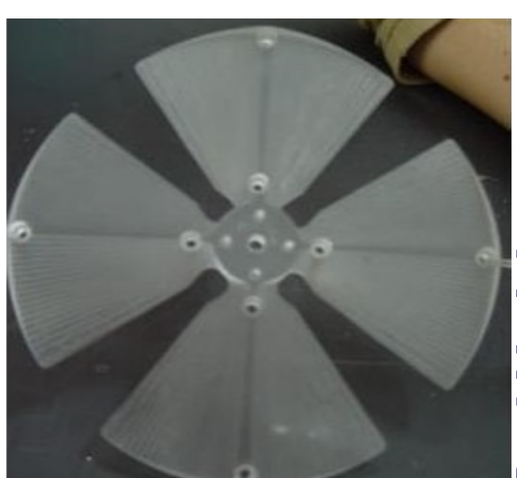




A dedicated class to the modulation system



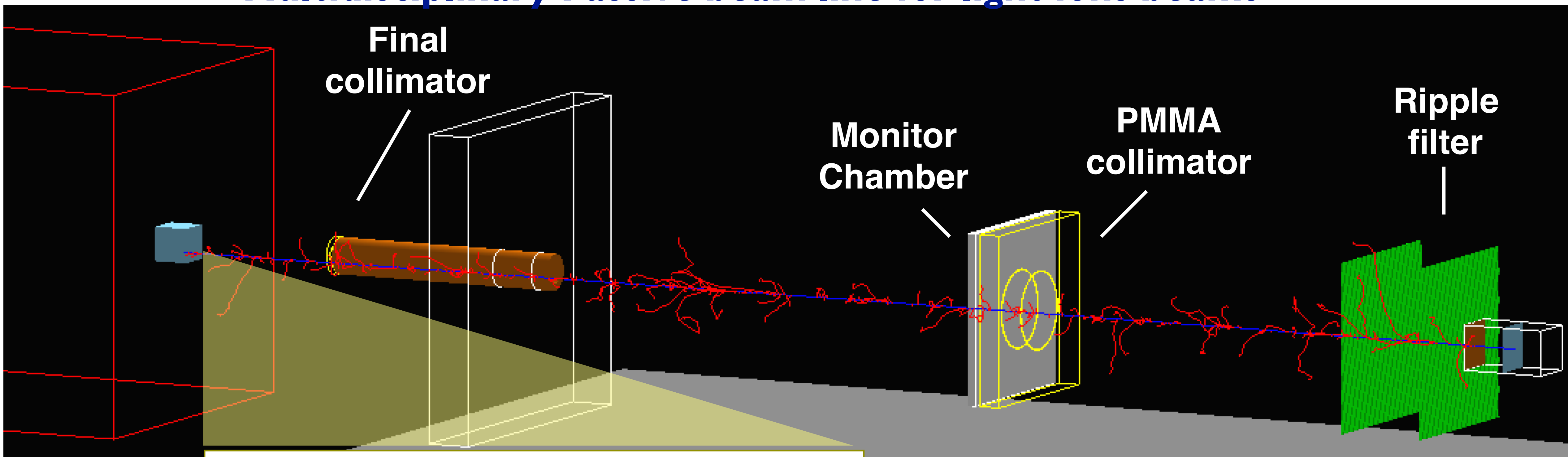
Monte Carlo Simulation

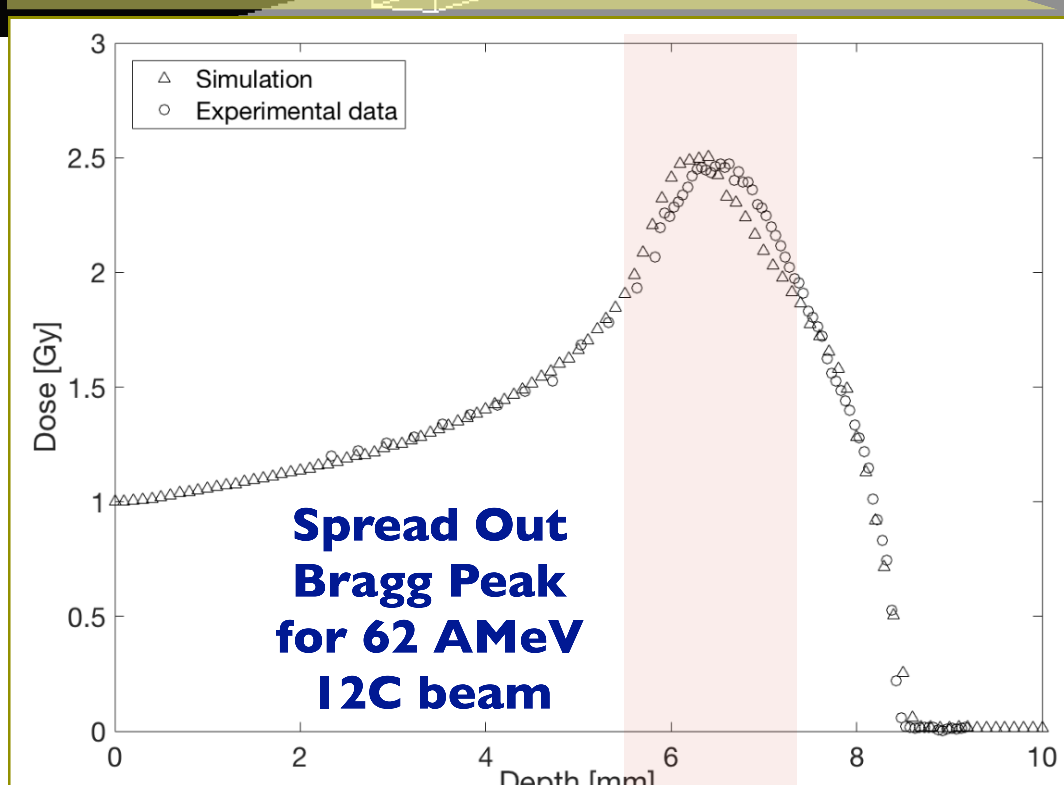


Real Modulator

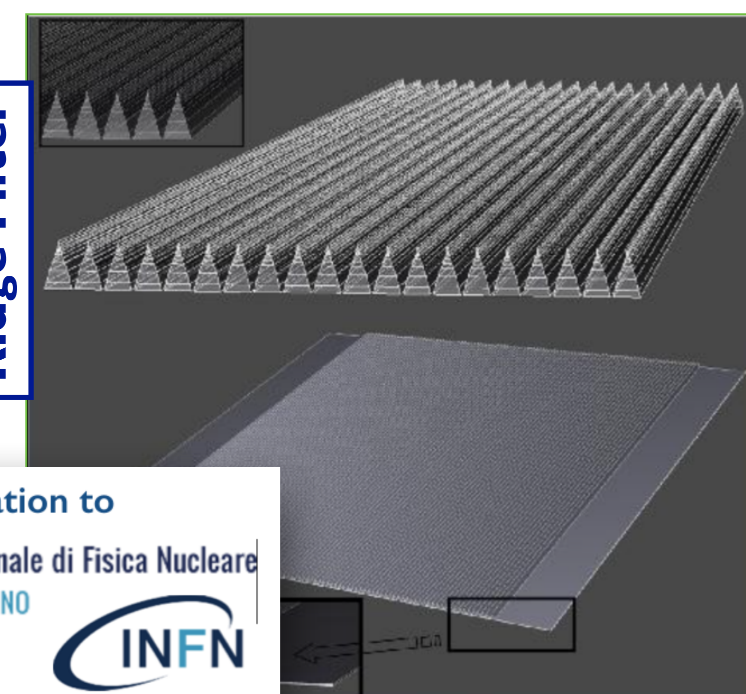
Extended: Hadrontherapy - zero degree beam line

Multidisciplinary Passive beam line for light ions beams





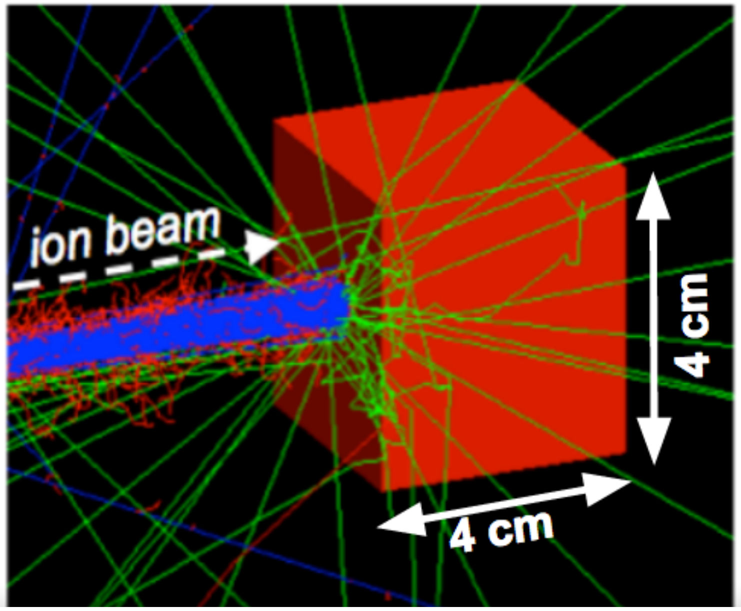
Ridge Filter

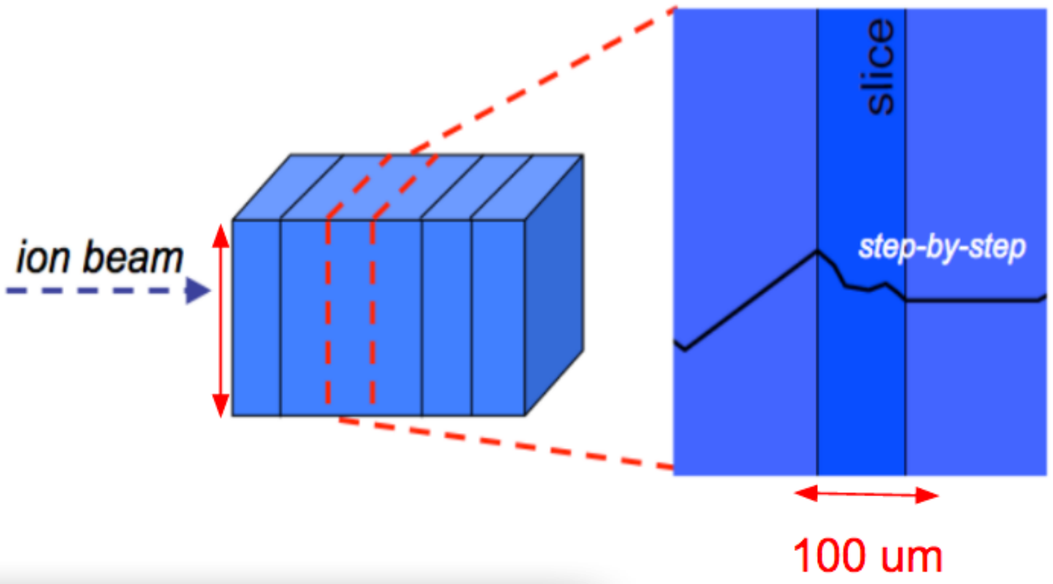


Collaboration to

Istituto Nazionale di Fisica Nucleare
SEZIONE DI TORINO

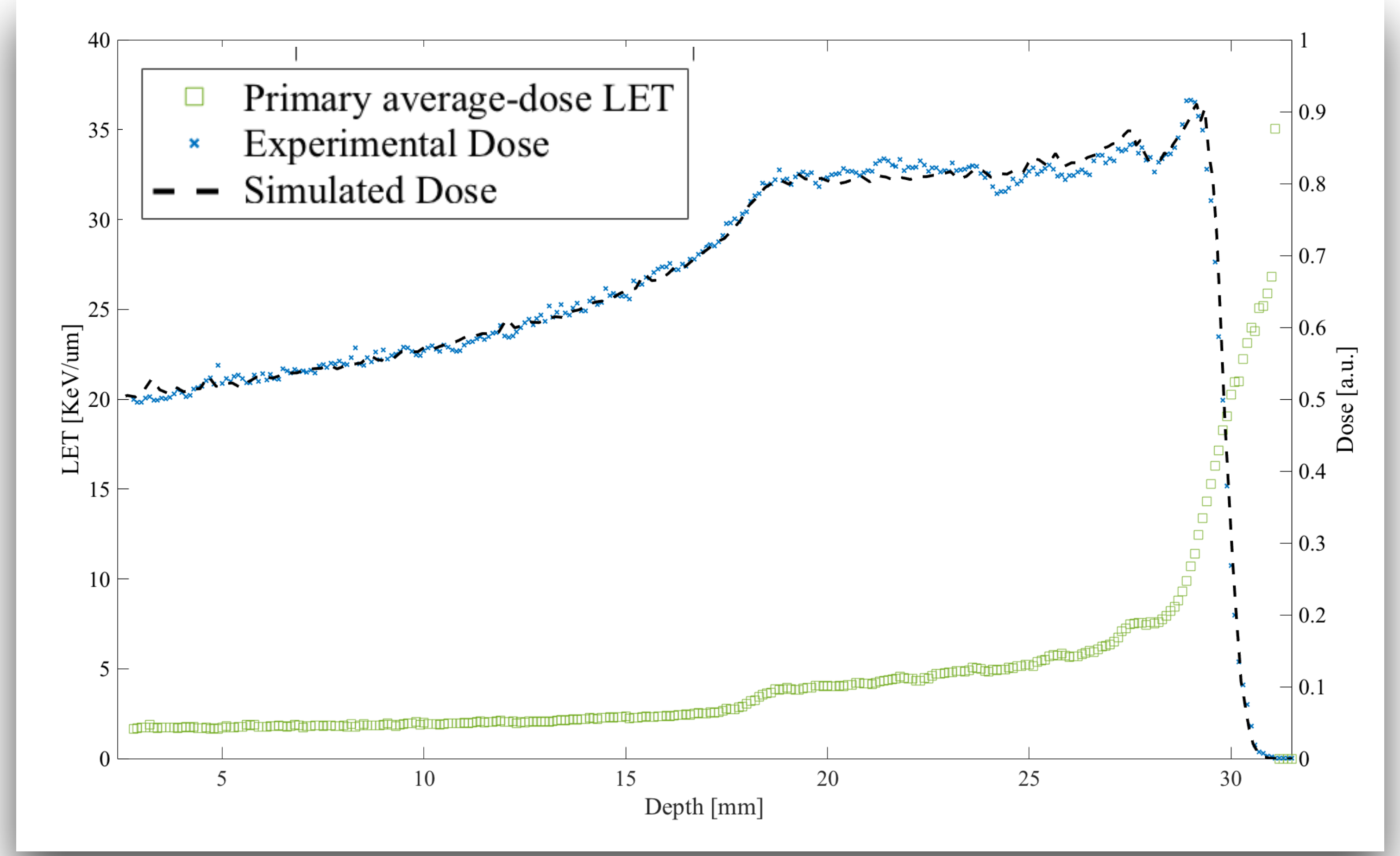
Extended: Hadrontherapy - LET & dose calculation





Step-by-step:

- Energy deposit
- Track length
- Secondary particles



Linear Energy Transfer

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

Dose

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

Thank you!