Version 11.3.2

Geant4 Tutorial Course

Jefferson Lab, Newport News, VA, USA
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User Documentation and Examples

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Introduction

- **Geant4 Installation**
- **Examples**
  - Build, shoot particles and look at some code of basic example B1
  - Basic, Extended and Advanced examples. See also README in each top and subdir
- **Documentation**
  - Geant4 Guides
  - LXR / Doxygen Documentation
- **User Support**

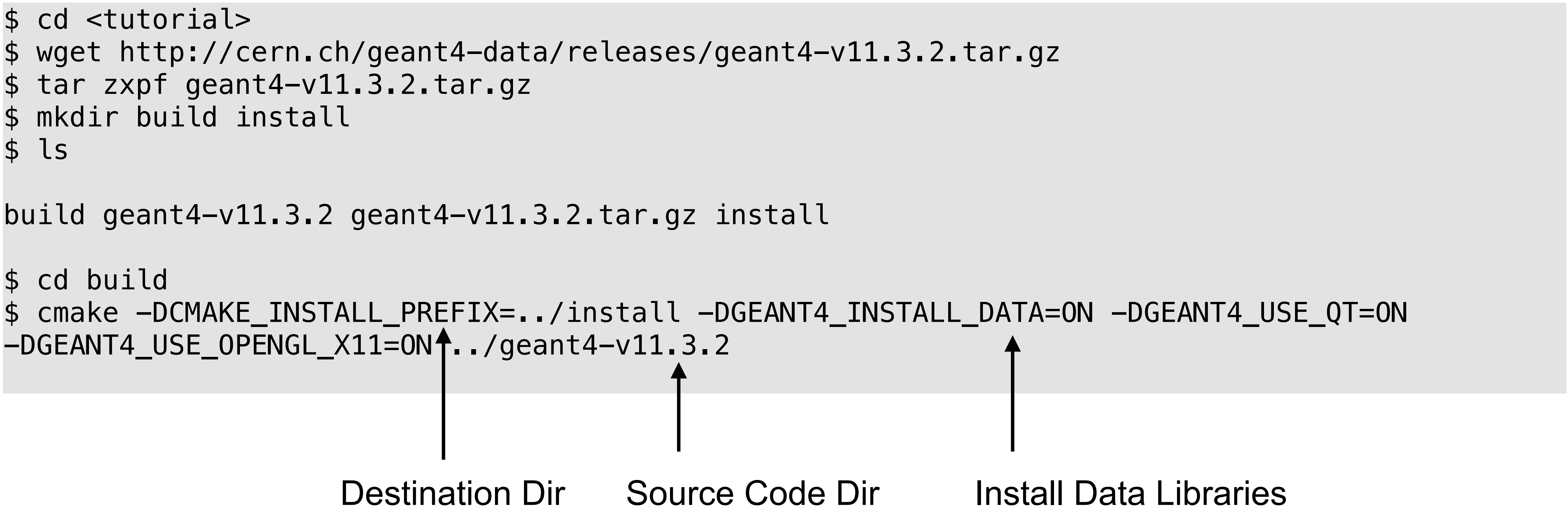
Installation: from source code

Geant4 Main Page → Docs → Installation Guide

I recommend to download and install Geant4 from source if you want to create your own simulation.

- Direct link to download and release notes on the Geant4 Homepage
- Refer to the guide for the *installation dependencies, and then Building and Installing from Source*

1. *Download tarball and CMake Configuration*



```
$ cd <tutorial>
$ wget http://cern.ch/geant4-data/releases/geant4-v11.3.2.tar.gz
$ tar zxpf geant4-v11.3.2.tar.gz
$ mkdir build install
$ ls

build geant4-v11.3.2 geant4-v11.3.2.tar.gz install

$ cd build
$ cmake -DCMAKE_INSTALL_PREFIX=../install -DGEANT4_INSTALL_DATA=ON -DGEANT4_USE_QT=ON
-DGEANT4_USE_OPENGL_X11=ON ../geant4-v11.3.2
```

Destination Dir

Source Code Dir

Install Data Libraries

-DGEANT4_USE_QT_QT6=ON   If you have QT6 installed

Installation: from source code

Many additional notes in the Tutorial Page

2. *Compilation*

```
$ make -j N
$ make install
```

Recommended: use all your cores as N. Try this to find out how many cores you have:

```
$ cat /proc/cpuinfo | grep processor | wc -l
$ getconf _NPROCESSORS_ONLN
```

After Geant4 has been compiled and installed the content of the <tutorial>/install directory should contain the directories:

```
bin data include lib[64]
```

3. *Post-installation environment*

The <tutorial>/install/bin directory has the .csh and the .sh environment script. Source the one you need to setup the environment. This will basically just add bin to your PATH so `geant4-config` can be found.

Installation: package managers

Geant4 Main Page → Docs → Installation Guide

ⓘ **NOTE**: Developed by Geant4 users but not maintained by Geant4 developers

- ✦ Spack
- ✦ Conda
- ✦ Various Linux Distributions Repos
- ✦ Guix
- ✦ CVMS releases for CentOS/Alma/Ubuntu Linux and macOS

Docker

Geant4 Main Page → Docs → Installation Guide

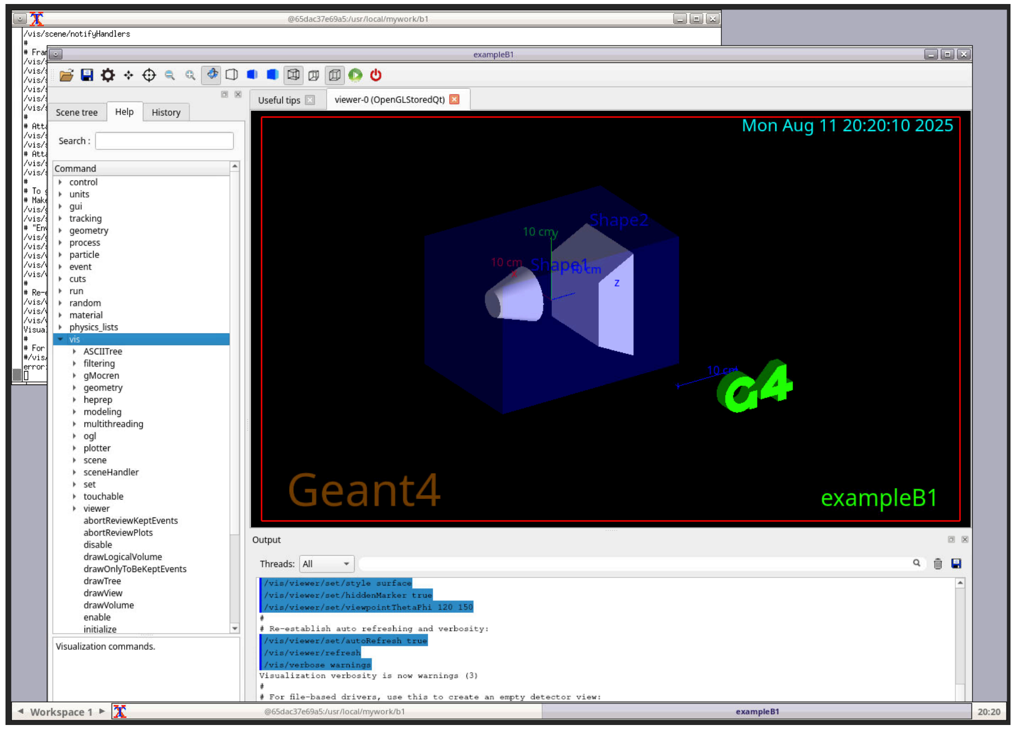
- jeffersonlab/geant4:g4v11.3.2-fedora36
- jeffersonlab/geant4:g4v11.3.2-fedora40
- jeffersonlab/geant4:g4v11.3.2-ubuntu24
- jeffersonlab/geant4:g4v11.3.2-almalinux94

Recommended use with a ~/mywork directory for permanent storage

```
$ mkdir ~/mywork
$ docker run --platform linux/amd64 -it --rm -v ~/mywork:/usr/local/mywork jeffersonlab/
geant4:g4v11.3.2-fedora40 bash
```

Interactively:

```
$ docker run --platform linux/amd64 -it --rm -p 8080:8080
-v ~/mywork:/usr/local/mywork
jeffersonlab/geant4:g4v11.3.2-fedora40
```



```
/vis/viewer/set/style surface
/vis/viewer/set/hiddenMarker true
/vis/viewer/set/viewpointThetaPhi 120 150
#
# Re-establish auto refreshing and verbosity:
/vis/viewer/set/autoRefresh true
/vis/viewer/refresh
/vis/verbose warnings
Visualization verbosity is now warnings (3)
#
# For file-based drivers, use this to create an empty detector view:
```

Build Example B1

Here **G4INSTALL** points to the Geant4 installation.

1. *Environment:*

```
source $G4INSTALL/bin/geant4.sh
```

2. *Create install dir and cd to it:*

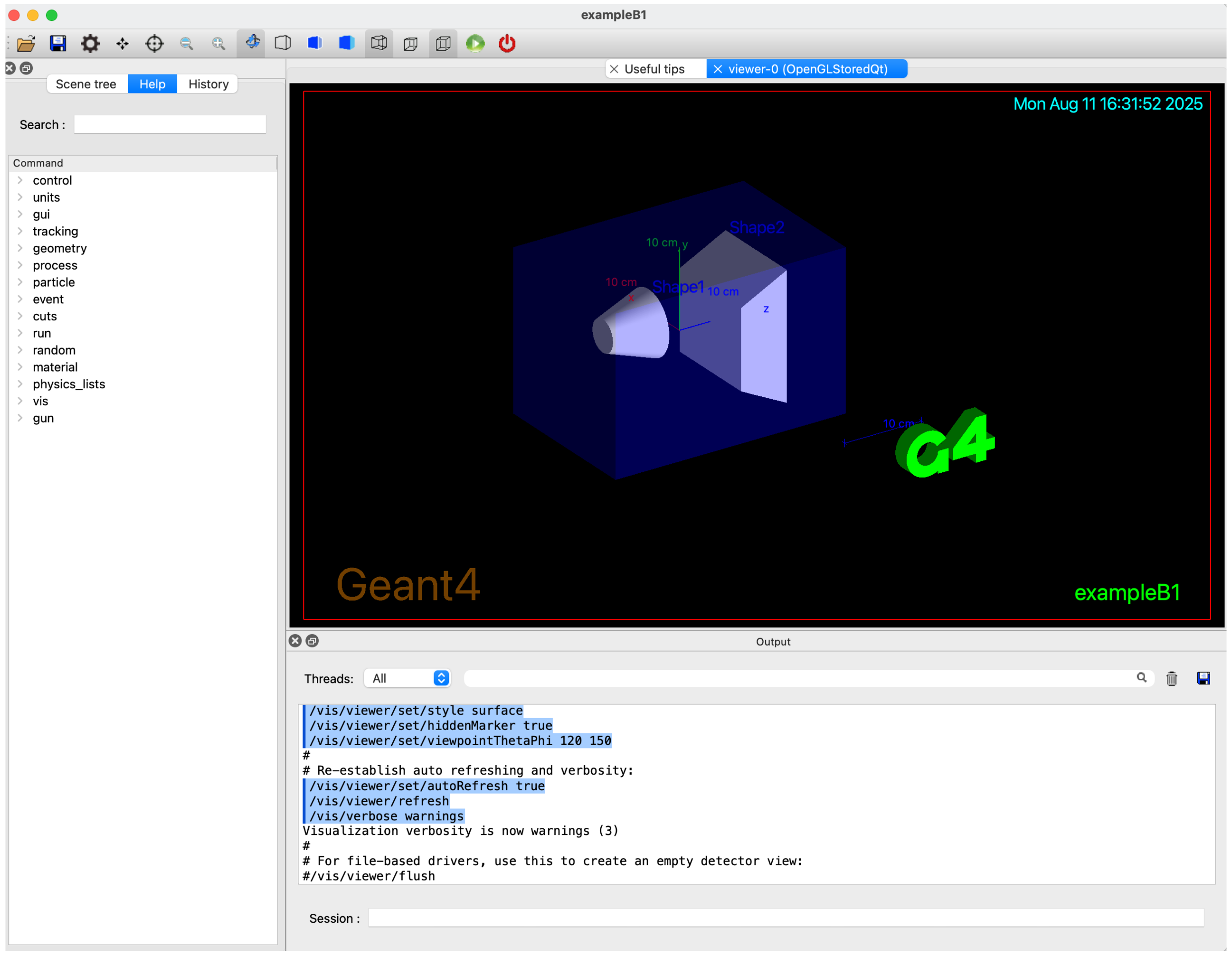
```
mkdir B1 ; cd B1
```

3. *Configure and make (this will also copy the relevant macros)*

```
cmake $G4INSTALL/data/Geant4/examples/basic/B1
make -j6
```

4. *Run*

```
./exampleB1
```



```
/vis/viewer/set/style surface
/vis/viewer/set/hiddenMarker true
/vis/viewer/set/viewpointThetaPhi 120 150
#
# Re-establish auto refreshing and verbosity:
/vis/viewer/set/autoRefresh true
/vis/viewer/refresh
/vis/verbose warnings
Visualization verbosity is now warnings (3)
#
# For file-based drivers, use this to create an empty detector view:
#/vis/viewer/flush
```

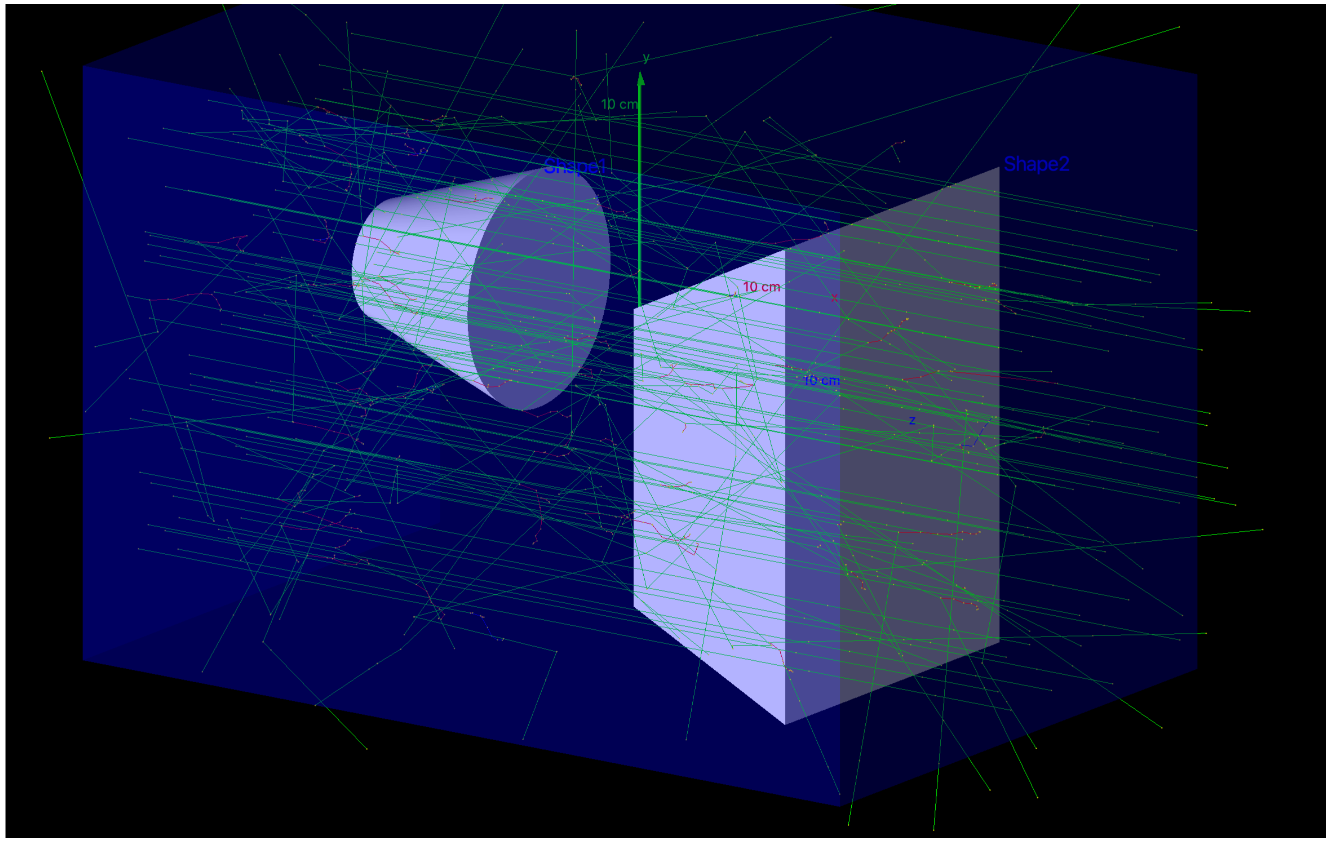
NOTE: In the HandsOn, we are copying the source in a separate dir and running `cmake .` because we are playing with / modifying the code. In general, we want to separate the build dir from the install dir

Example B1: Shoot Particles 1/2

PrimaryGeneratorAction.cc

```
void PrimaryGeneratorAction::GeneratePrimaries(G4Event* event) {

  […]
  G4double envSizeXY = 0;
  G4double envSizeZ = 0;

  G4double size = 0.8;
  G4double x0 = size * envSizeXY * (G4UniformRand() - 0.5);
  G4double y0 = size * envSizeXY * (G4UniformRand() - 0.5);
  G4double z0 = -0.5 * envSizeZ;

  fParticleGun->SetParticlePosition(G4ThreeVector(x0, y0, z0));

  fParticleGun->GeneratePrimaryVertex(event);
}
```

```
/run/beamOn 100
```



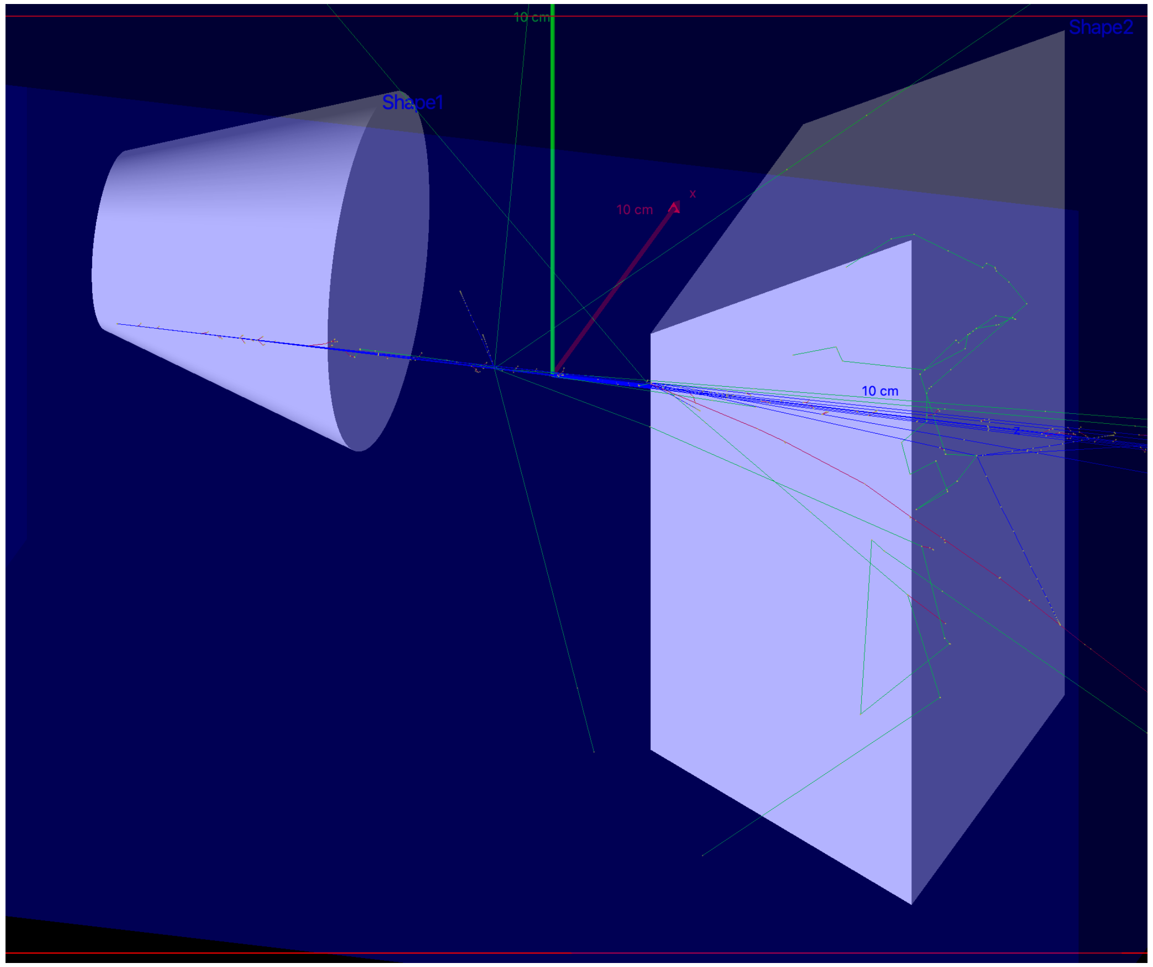
100 6 MeV gammas distributed on a plane

```
PrimaryGeneratorAction::PrimaryGeneratorAction()
{
 […]
  G4ParticleDefinition* particle = particleTable->FindParticle(particleName = "gamma");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleMomentumDirection(G4ThreeVector(0., 0., 1.));
  fParticleGun->SetParticleEnergy(6. * MeV);
}
```

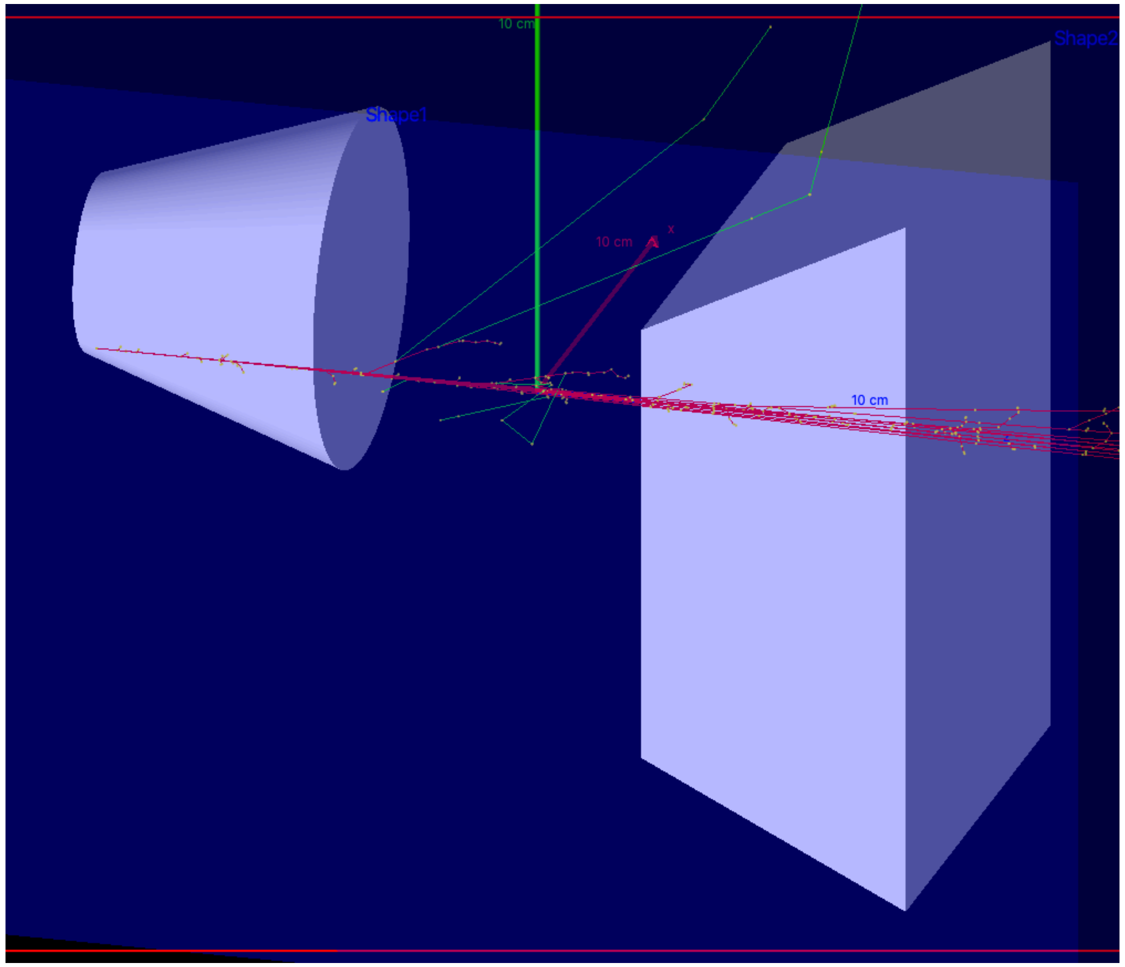
Example B1: Shoot Particles 2/2

```
void PrimaryGeneratorAction::GeneratePrimaries(G4Event* event) {

  […]

  // fParticleGun->SetParticlePosition(G4ThreeVector(x0, y0, z0));

}
```

```
/gun/particle proton
/gun/energy 1.0 GeV
/gun/position 0 0 -10
/run/beamOn 10
```



```
/gun/particle mu-
/gun/energy 1.0 GeV
/gun/position 0 0 -10
/run/beamOn 10
```



Example B1: main()

exampleB1.cc

Every Geant4 application has a run manager

There are different run manager types (single-threaded vs. multi-threaded)

Both the detector geometry and the physics list are passed to the run manager

and user actions too…

```
int main(int argc, char** argv)
{
  […]

  auto runManager =
    G4RunManagerFactory::CreateRunManager(G4RunManagerType::Default);

  // Set mandatory initialization classes
  //
  // Detector construction
  runManager->SetUserInitialization(new DetectorConstruction());

  // Physics list
  auto physicsList = new QBBC;
  physicsList->SetVerboseLevel(1);
  runManager->SetUserInitialization(physicsList);

  // User action initialization
  runManager->SetUserInitialization(new ActionInitialization());

  […]
}
```

Example B1: DetectorConstruction()

Users are responsible for creating the simulated geometry

Geant4 provides virtual classes to be inherited by user code that overrides the virtual methods

include/DetectorConstruction.hh

```
class DetectorConstruction : public G4VUserDetectorConstruction
{
  […]

  public:
    DetectorConstruction() = default;
    ~DetectorConstruction() override = default;

    G4VPhysicalVolume* Construct() override;

  […]

};
```

Solids, logical volumes and physical volumes are created in the ::Construct() method, which must return the pointer to the world G4VPhysicalVolume

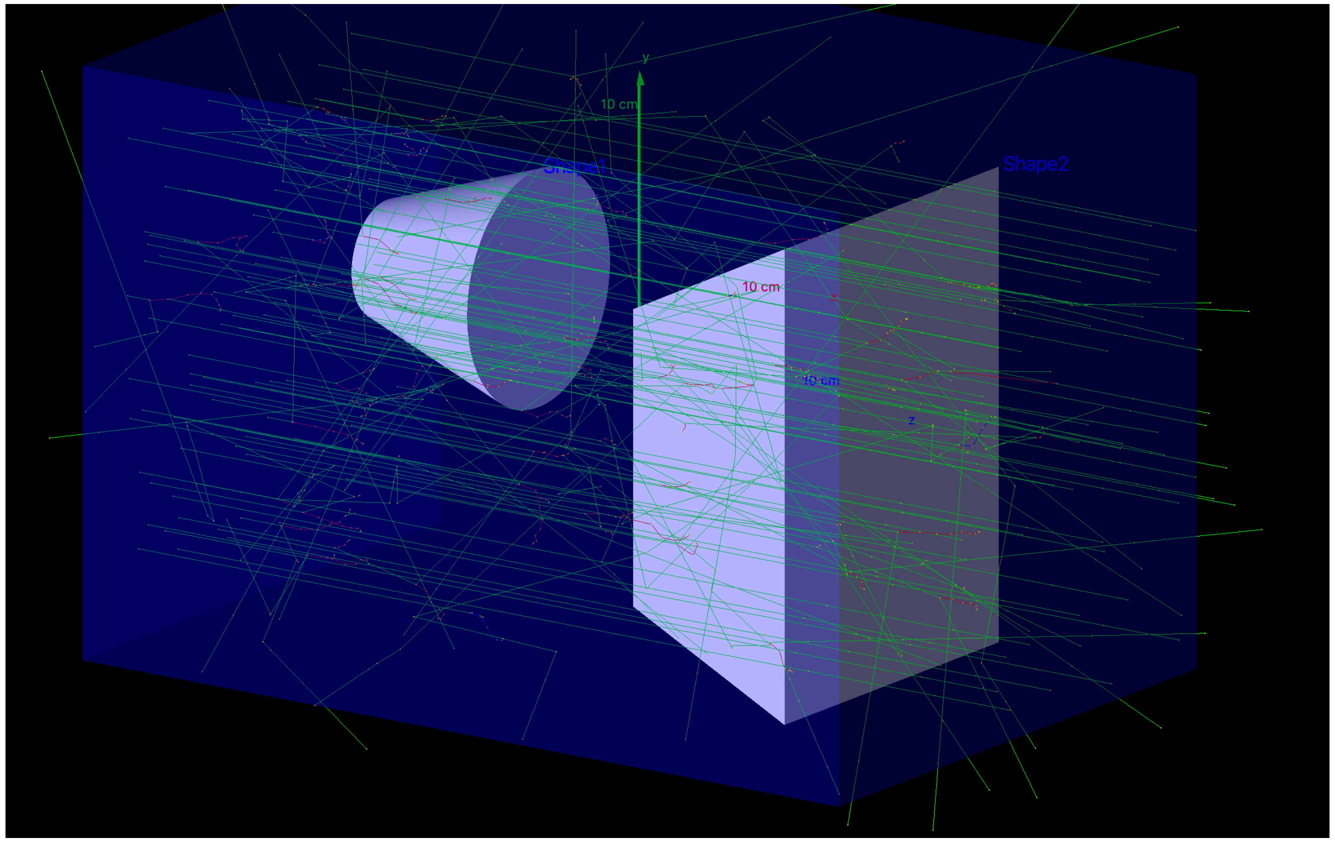
src/DetectorConstruction.cc

```
G4VPhysicalVolume* DetectorConstruction::Construct()
{


  auto solidWorld = …
  auto logicWorld = …
  auto physWorld = …


  // always return the physical World
  return physWorld;
}
```

Basic Examples

complete applications demonstrating simple features of toolkit – good for tutorials

- **Example B1** (previous slides): simple volumes, scoring dose with stepping action



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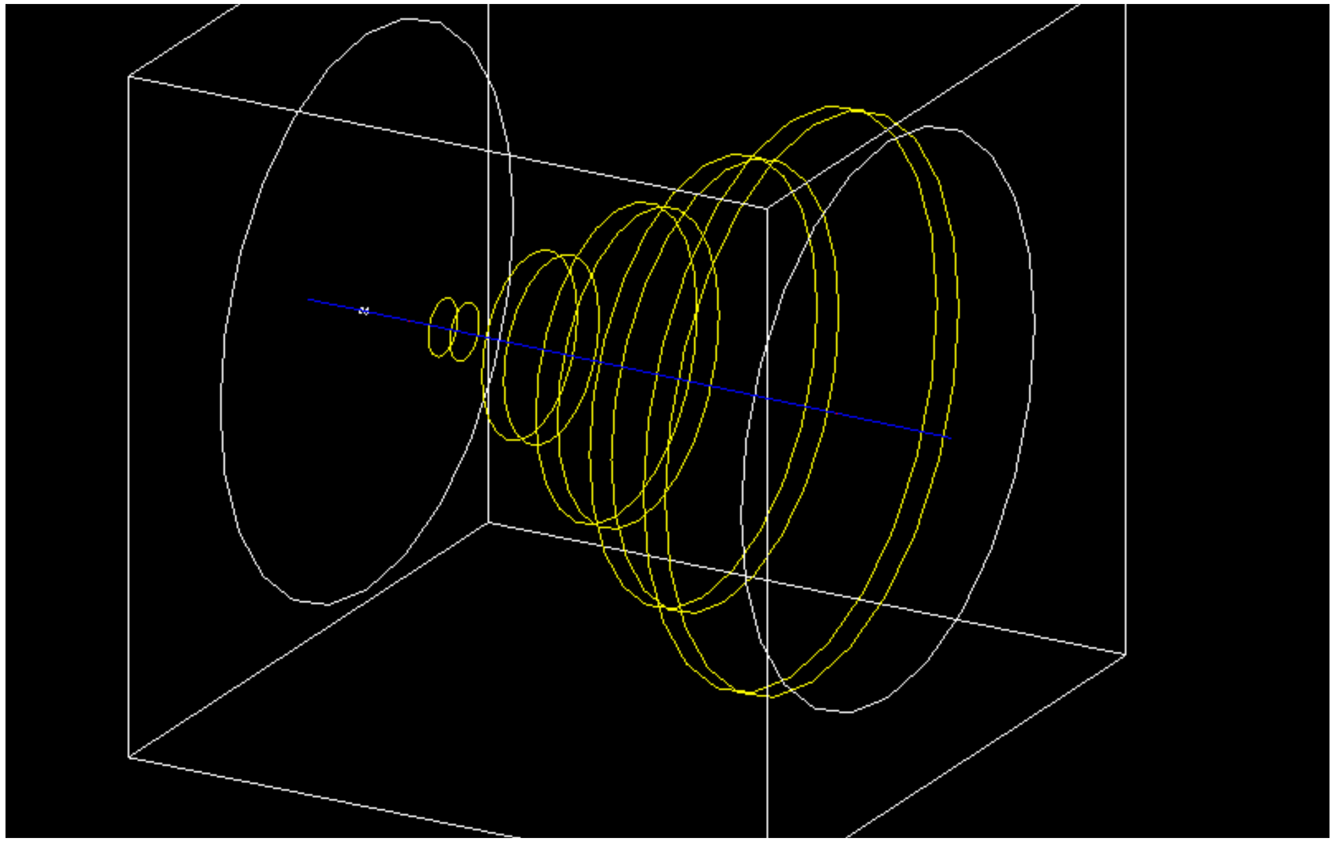
- **Example B2**: global constant magnetic field, scoring with sensitive detectors and hits, step limiter



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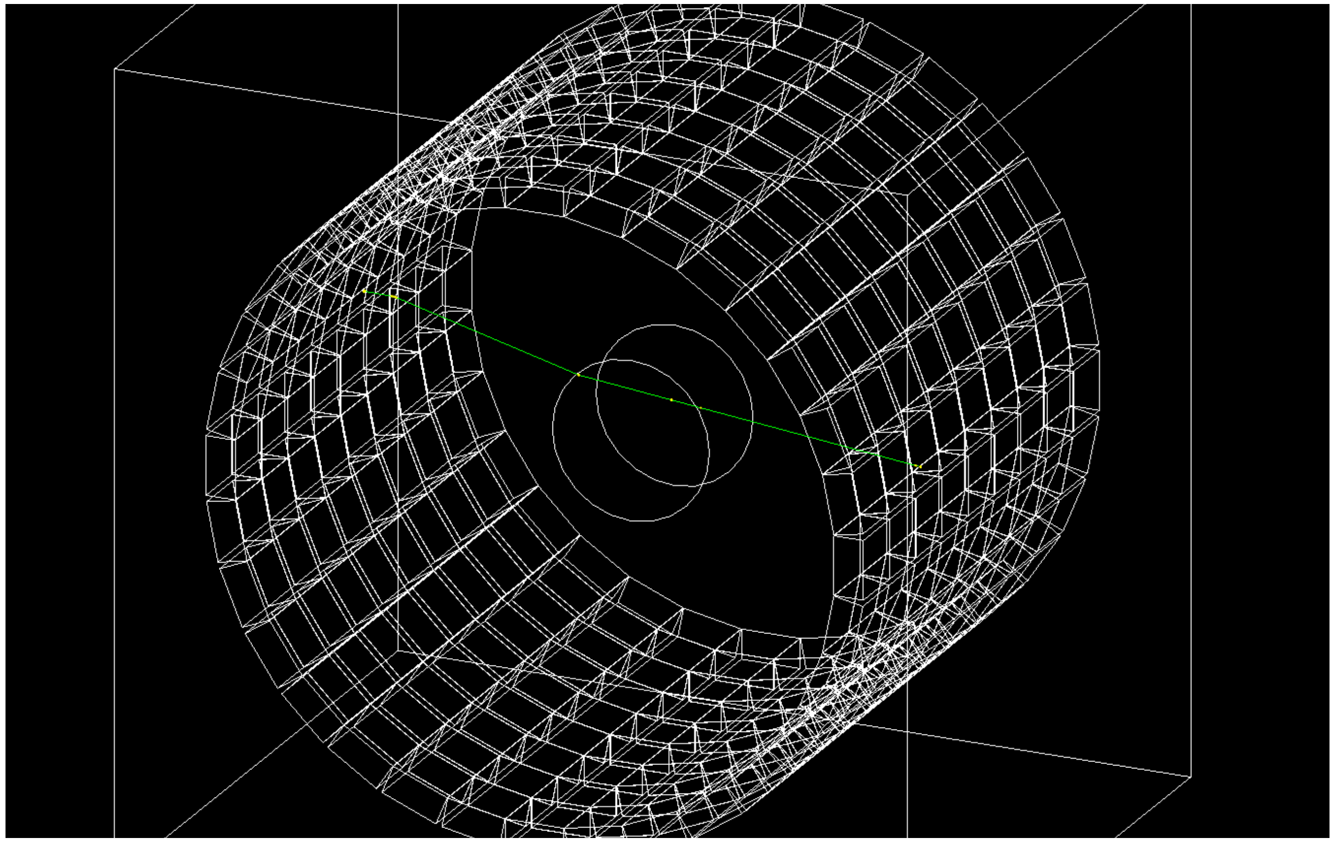

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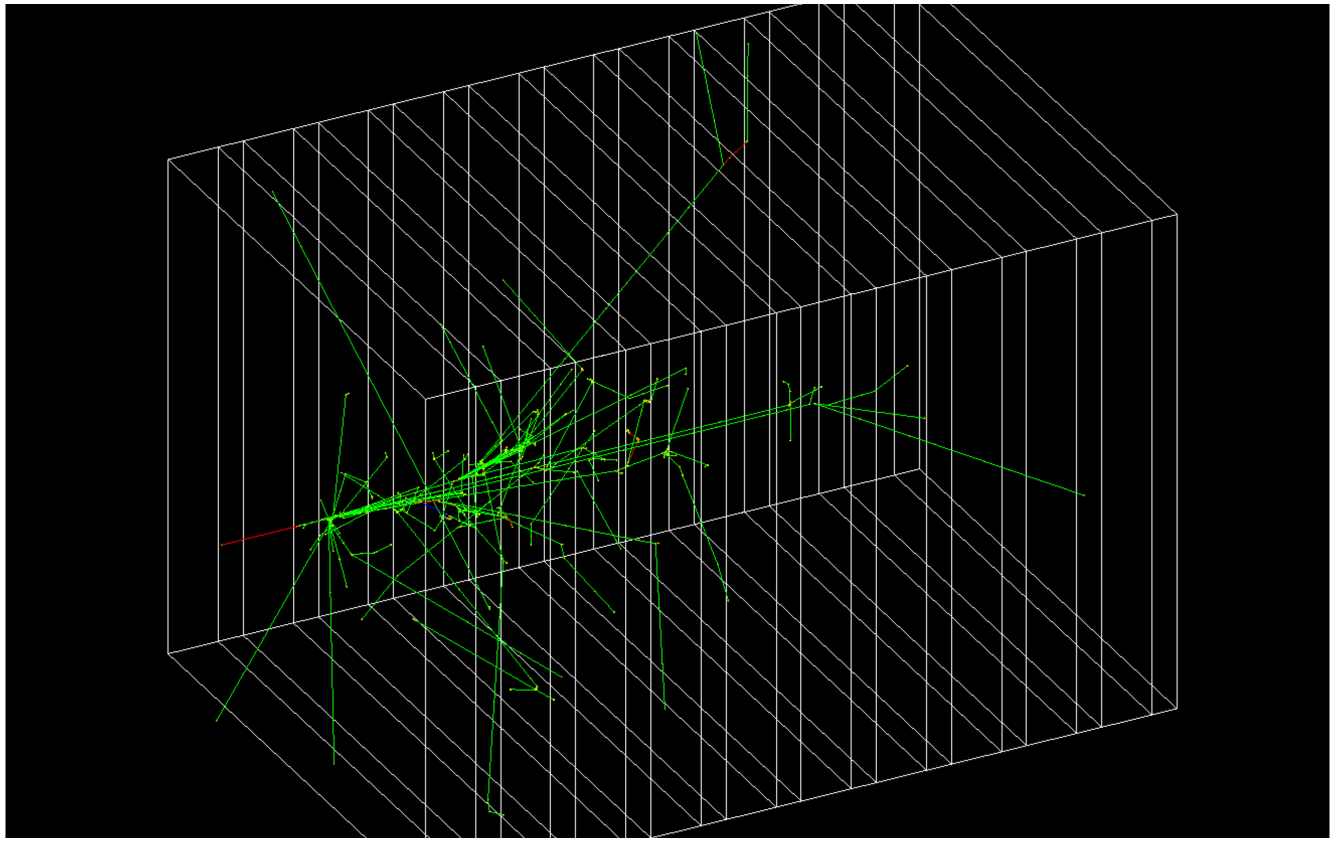

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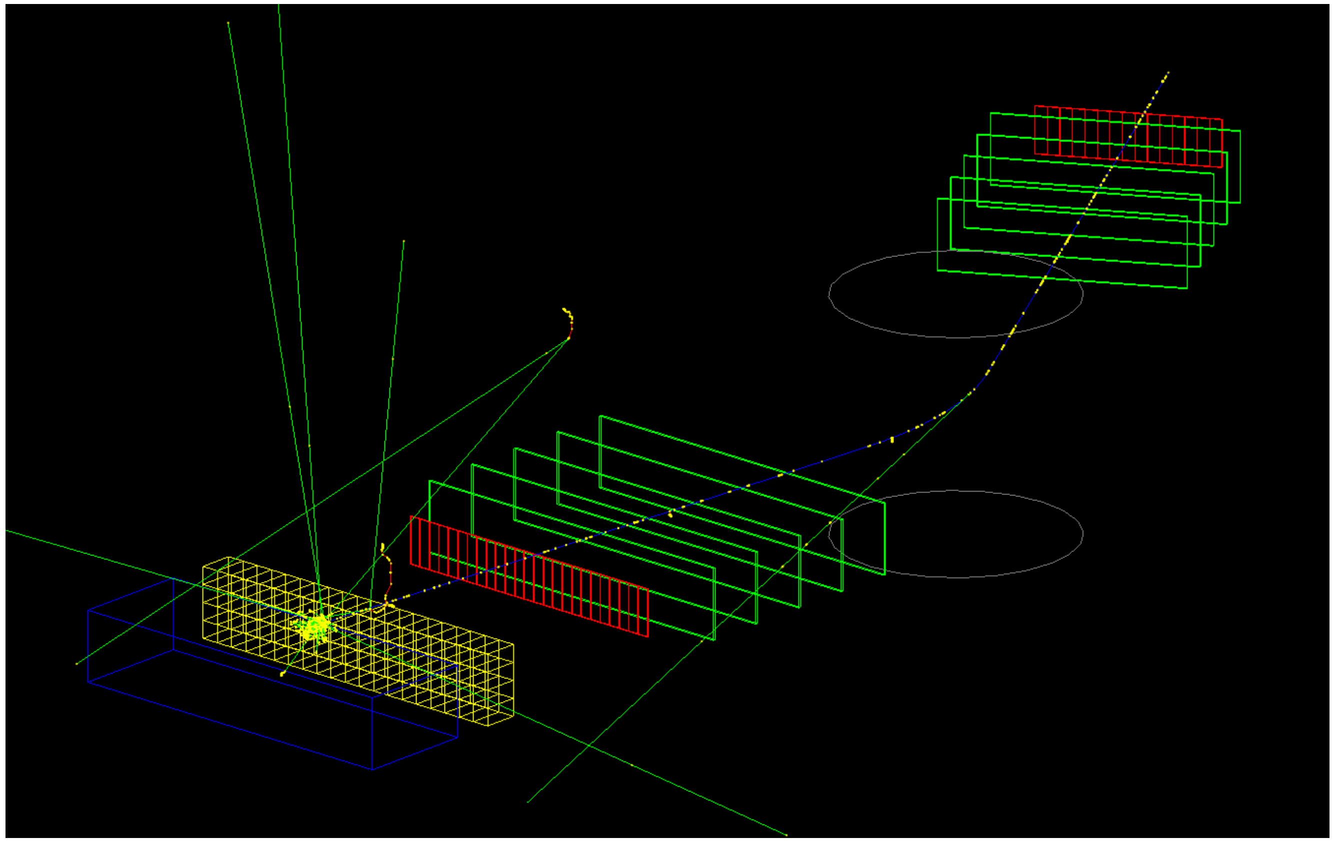
- **Example B4**: geometry with replicas, saving histograms and ntuples with g4analysis
- **Example B5**: double-arm spectrometer with wire chambers, hodoscopes and calorimeters, replicas and parameterisation, G4GenericMessenger, drawing with TSG



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complete applications demonstrating simple features of toolkit – good for tutorials

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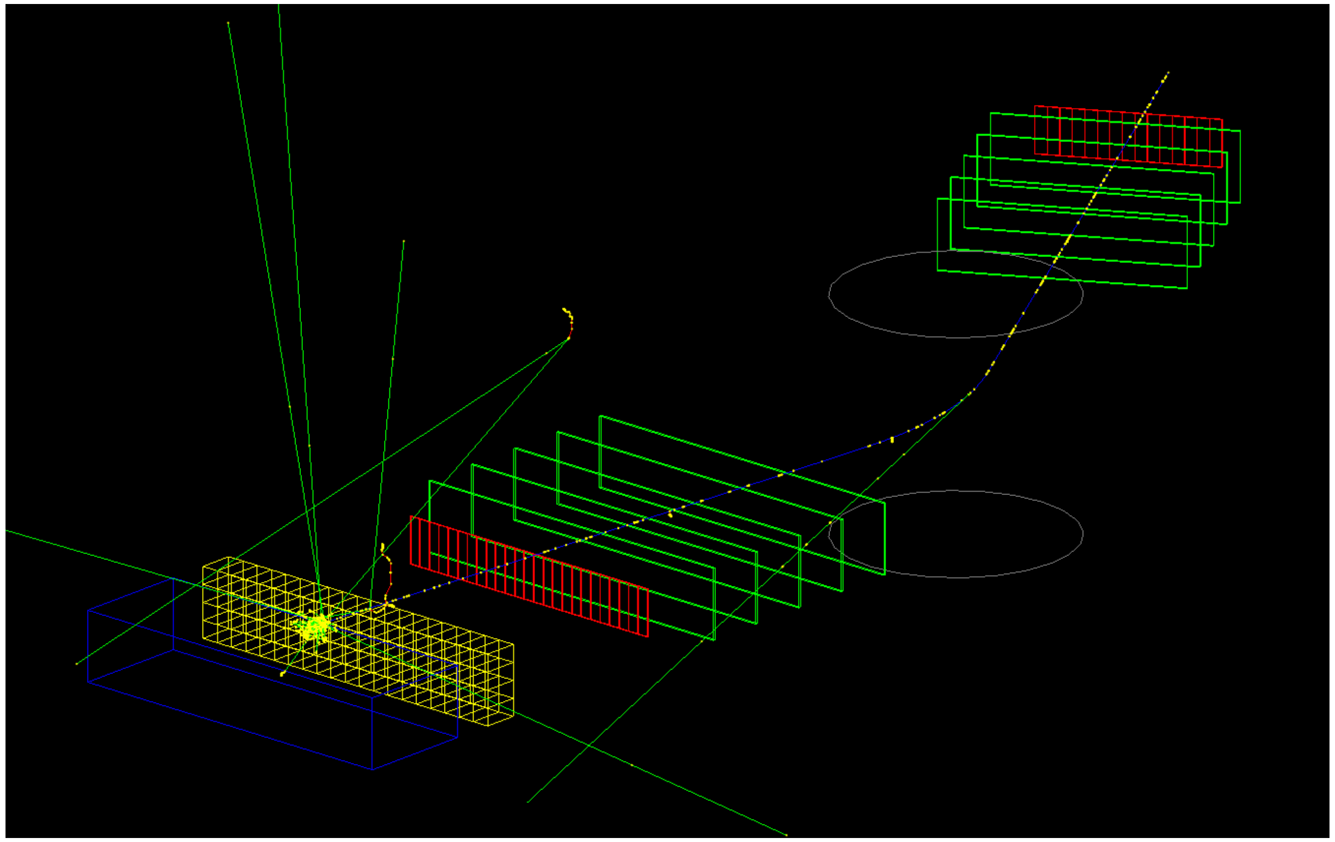
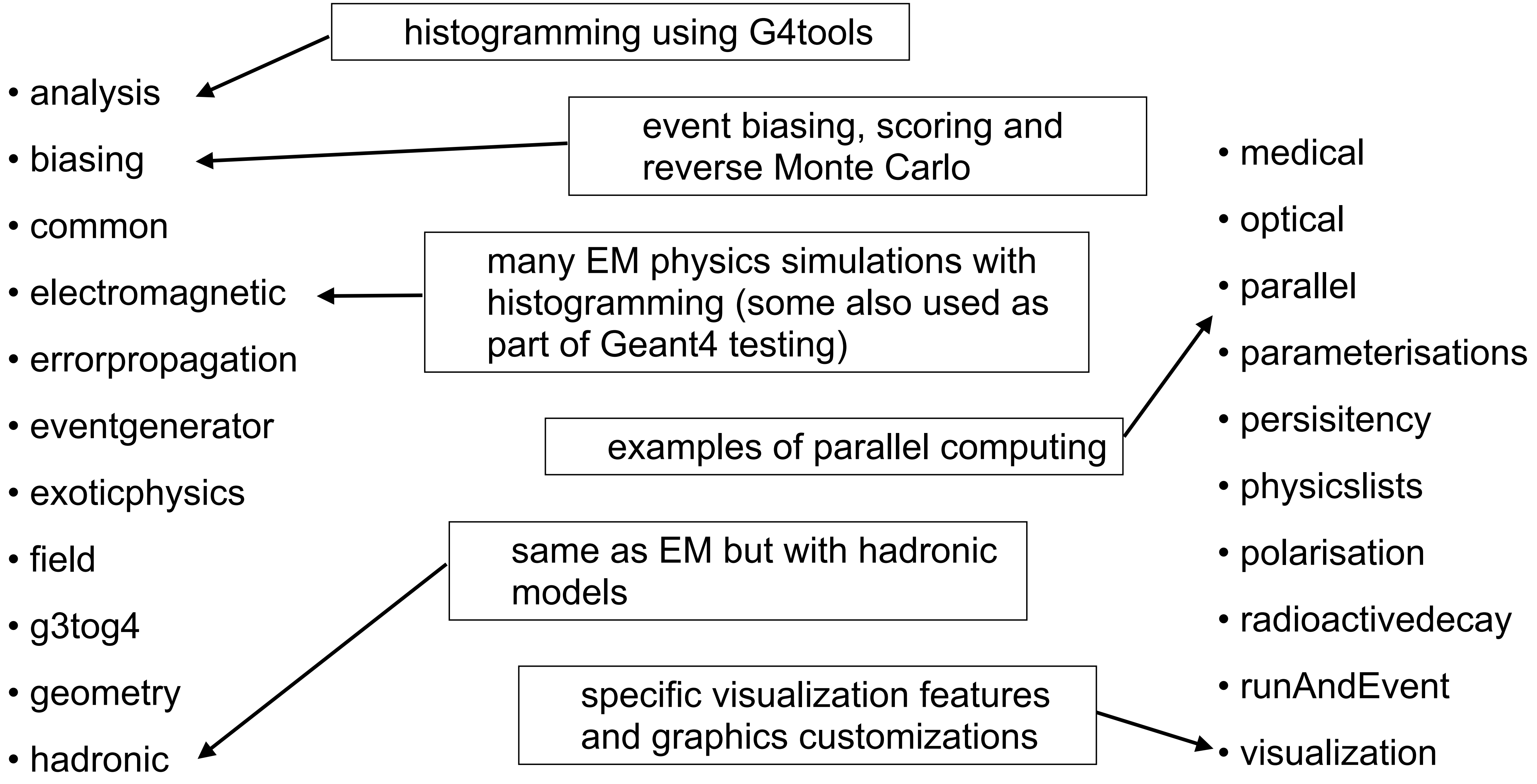


Extended Examples

demonstrating specific features of Geant4 and more complex use cases – some require external libraries

21 Extended Examples organized in macro areas:



- analysis
- biasing
- common
- electromagnetic
- errorpropagation
- eventgenerator
- exoticphysics
- field
- g3tog4
- geometry
- hadronic

histogramming using G4tools

event biasing, scoring and reverse Monte Carlo

many EM physics simulations with histogramming (some also used as part of Geant4 testing)

examples of parallel computing

same as EM but with hadronic models

specific visualization features and graphics customizations

- medical
- optical
- parallel
- parameterisations
- persisitency
- physicslists
- polarisation
- radioactivedecay
- runAndEvent
- visualization

Advanced Examples

complex, “real life” applications with complex geometries and physics focused on specific user communities

35 Extended Examples

air_shower

ChargeExchangeMC

doiPET

fastAerosol

gorad

human_phantom

lAr_calorimeter

nanobeam

stim_pixe_tomography

xray_telescope

amsEcal

eFLASH_radiotherapy

gammaknife

hadrontherapy

ICRP110_HumanPhantoms

medical_linac

purging_magnet

underground_physics

xray_TESdetector

brachytherapy

composite_calorimeter

eRosita

gammaray_telescope

HGCal_testbeam

ICRP145_HumanPhantoms

microbeam

xray_fluorescence

CaTS

dna

exp_microdosimetry

iort_therapy

microelectronics

STCyclotron

xray_SiliconPoreOptics

All the Geant4 Examples can be compiled exactly like B1

Geant4 Guides

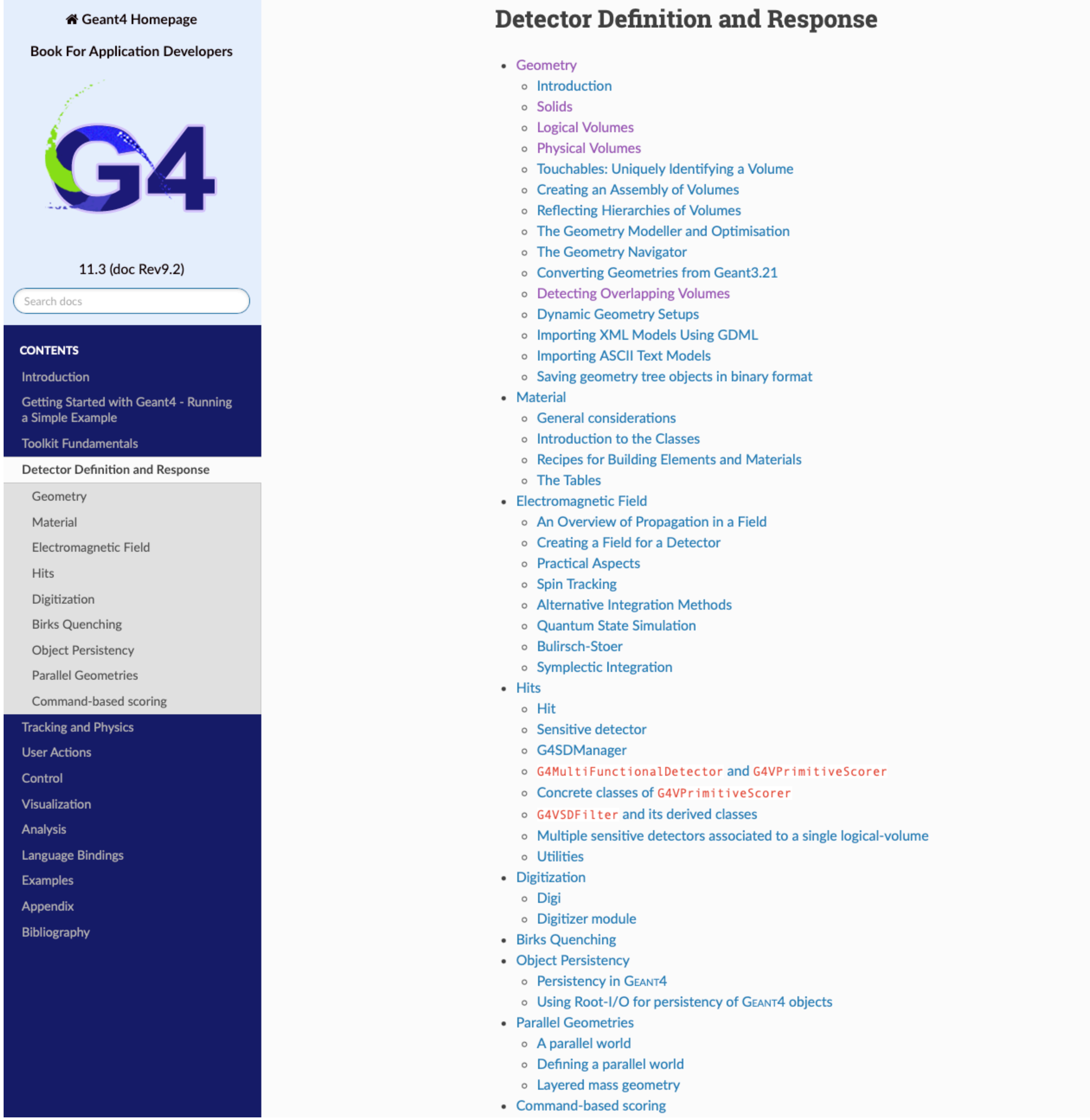
Available in **html** - pdf - epub - kindle

Geant4 Main Page → Docs

Book for Application Developers

Introduces the first-time user to Geant4, provides a description of the available tools and supply the practical information required to develop and run simulation applications.

A must read reference for new and advanced users.



Detector Definition and Response

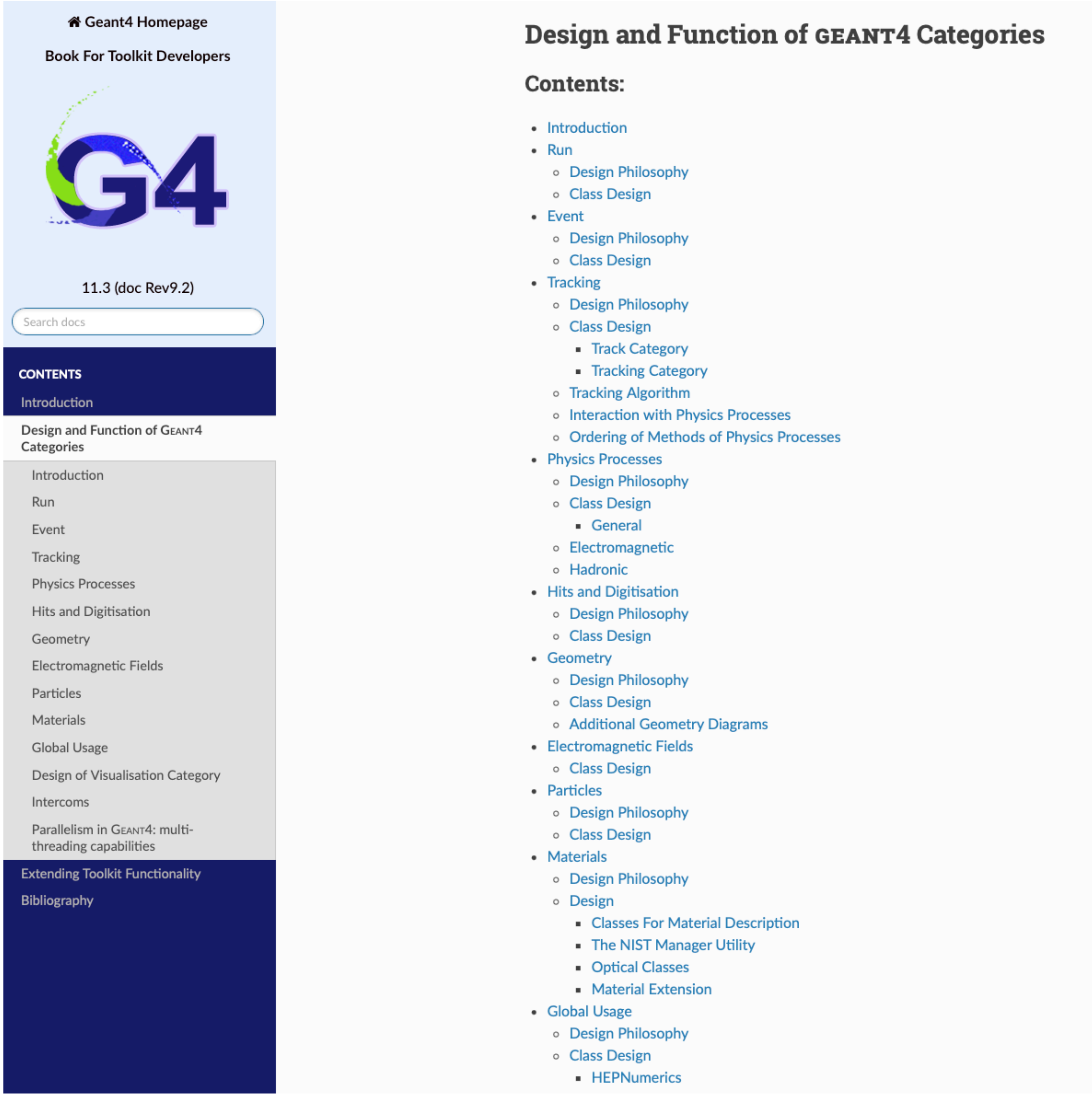
Geant4 Guides

Available in **html** - pdf - epub - kindle

Geant4 Main Page → Docs

Book for Toolkit Developers

Provides information for those who want to understand or refer to the detailed design of the toolkit, as well as procedures for extending the functionality of the toolkit



Geant4 Homepage

Book For Toolkit Developers

11.3 (doc Rev9.2)

Search docs

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- Design and Function of GEANT4 Categories
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  - Run
  - Event
  - Tracking
  - Physics Processes
  - Hits and Digitisation
  - Geometry
  - Electromagnetic Fields
  - Particles
  - Materials
  - Global Usage
  - Design of Visualisation Category
  - Intercoms
  - Parallelism in GEANT4: multi-threading capabilities
- Extending Toolkit Functionality
- Bibliography

Design and Function of GEANT4 Categories

Contents:

- Introduction
- Run
  - Design Philosophy
  - Class Design
- Event
  - Design Philosophy
  - Class Design
- Tracking
  - Design Philosophy
  - Class Design
    - Track Category
    - Tracking Category
  - Tracking Algorithm
  - Interaction with Physics Processes
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- Physics Processes
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  - Class Design
- Geometry
  - Design Philosophy
  - Class Design
  - Additional Geometry Diagrams
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  - Class Design
- Materials
  - Design Philosophy
  - Design
    - Classes For Material Description
    - The NIST Manager Utility
    - Optical Classes
    - Material Extension
- Global Usage
  - Design Philosophy
  - Class Design
    - HEPNumerics

Geant4 Guides

Available in **html** - pdf - epub - kindle

Geant4 Main Page → Docs

Physics Reference Manual

Presents the theoretical formulation, model, or parameterization of the physics interactions and describes the probability of the occurrence of an interaction and the sampling mechanisms required to simulate it

Physics List Guide

A brief guide to physics lists:

- ✦ Lists the Reference Physics Lists
- ✦ Lists the electromagnetic physics constructors
- ✦ Hadronic physics options and extra features

Advanced Examples

FAQ

Geant4 Source Code: Doxygen

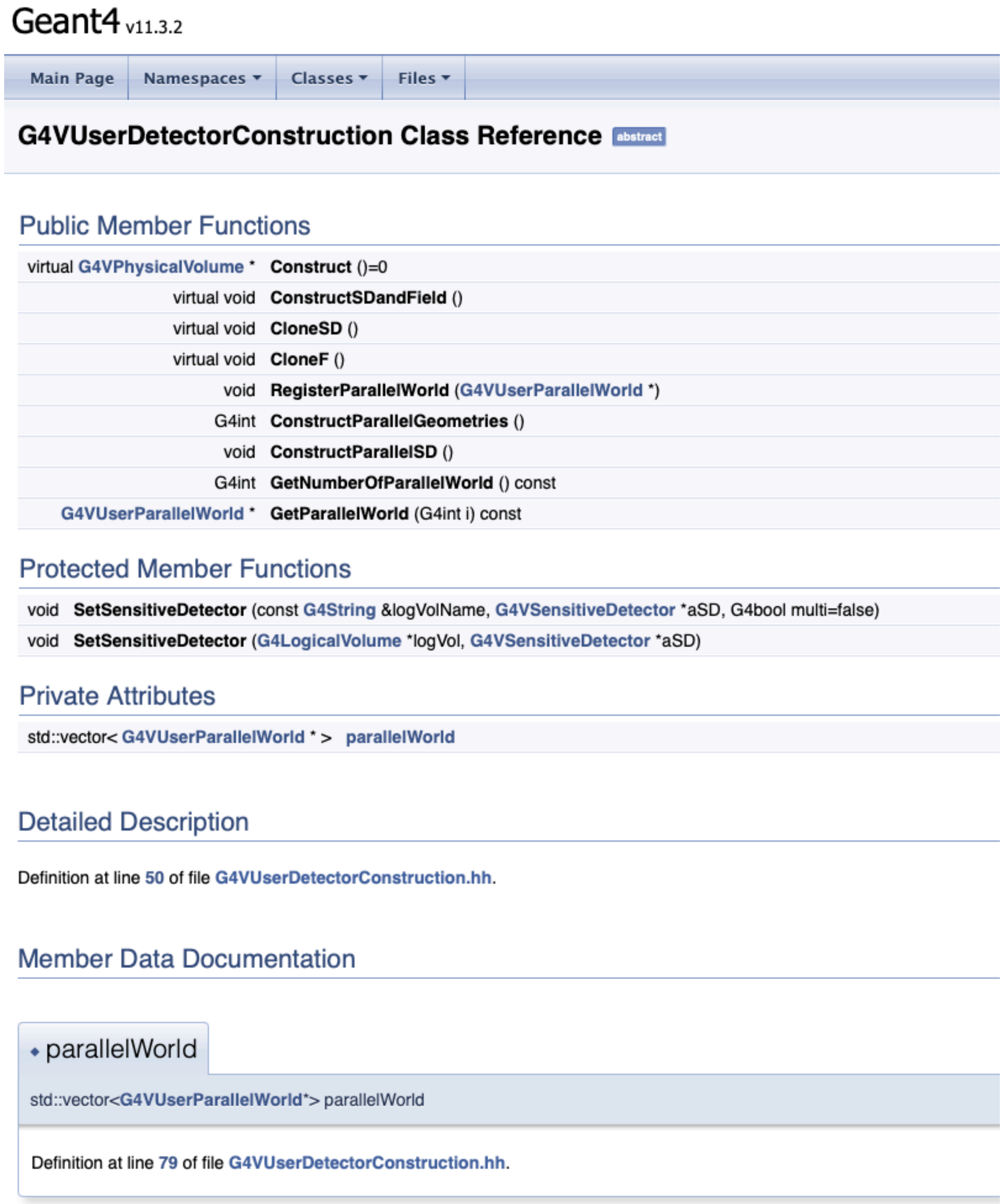
Geant4 Main Page → Docs

Classes and Members Reference Guide

Every class and file is available and fully hyper-linked.

Very useful overviews of the Geant4 classes and methods

Past versions are available as well.



Geant4 v11.3.2

G4VUserDetectorConstruction Class Reference

Public Member Functions

virtual G4VPhysicalVolume *	**Construct** ()=0
virtual void	**ConstructSDandField** ()
virtual void	**CloneSD** ()
virtual void	**CloneF** ()
void	**RegisterParallelWorld** (G4VUserParallelWorld *)
G4int	**ConstructParallelGeometries** ()
void	**ConstructParallelSD** ()
G4int	**GetNumberOfParallelWorld** () const
G4VUserParallelWorld *	**GetParallelWorld** (G4int i) const

Protected Member Functions

void	**SetSensitiveDetector** (const G4String &logVolName, G4VSensitiveDetector *aSD, G4bool multi=false)
void	**SetSensitiveDetector** (G4LogicalVolume *logVol, G4VSensitiveDetector *aSD)

Private Attributes

std::vector< G4VUserParallelWorld * >	**parallelWorld**

Detailed Description

Definition at line 50 of file G4VUserDetectorConstruction.hh.

Member Data Documentation

◆ parallelWorld

std::vector<G4VUserParallelWorld*> parallelWorld

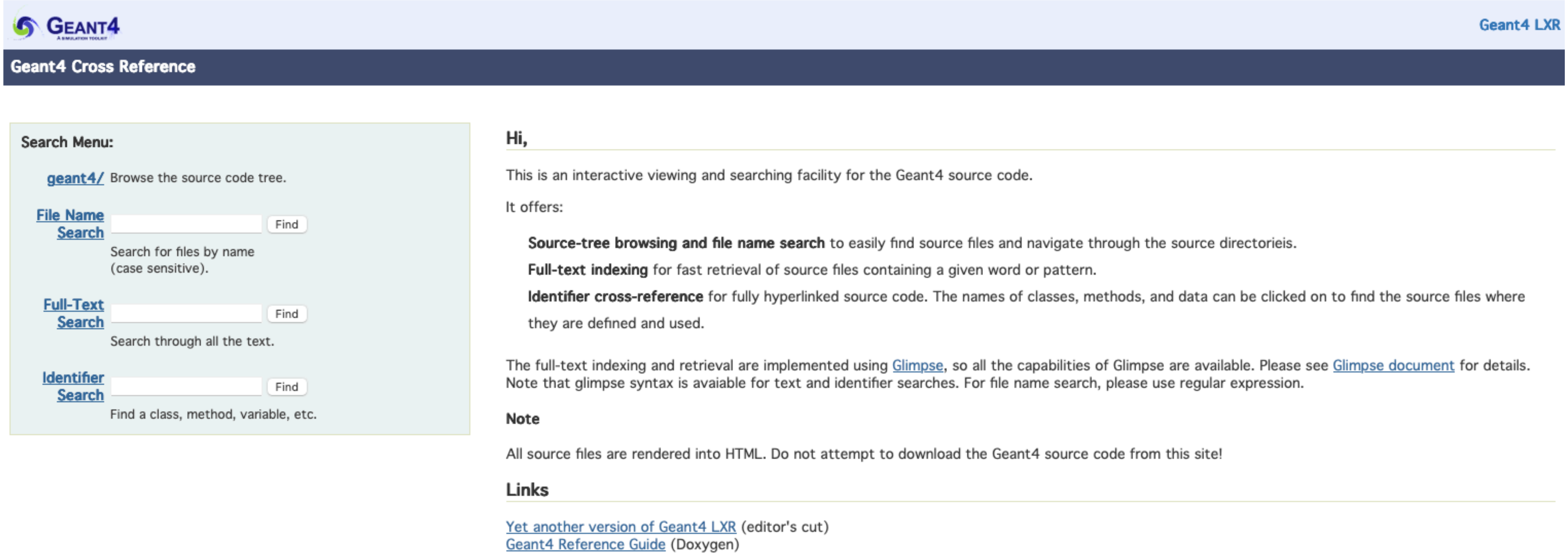
Definition at line 79 of file G4VUserDetectorConstruction.hh.

Geant4 Source Code: LXR

Geant4 Main Page → Docs

Linux Cross-Referencer

Web-browser tool that helps developers understand and explore codebases by providing clickable links between different parts of the code.



Geant4 Cross Reference

Search Menu:

geant4/ Browse the source code tree.

File Name Search
Search for files by name (case sensitive).

Full-Text Search
Search through all the text.

Identifier Search
Find a class, method, variable, etc.

Hi,

This is an interactive viewing and searching facility for the Geant4 source code.

It offers:

Source-tree browsing and file name search to easily find source files and navigate through the source directorieis.

Full-text indexing for fast retrieval of source files containing a given word or pattern.

Identifier cross-reference for fully hyperlinked source code. The names of classes, methods, and data can be clicked on to find the source files where they are defined and used.

The full-text indexing and retrieval are implemented using Glimpse, so all the capabilities of Glimpse are available. Please see Glimpse document for details. Note that glimpse syntax is avaiable for text and identifier searches. For file name search, please use regular expression.

Note

All source files are rendered into HTML. Do not attempt to download the Geant4 source code from this site!

Links

Yet another version of Geant4 LXR (editor's cut)
Geant4 Reference Guide (Doxygen)

User Support

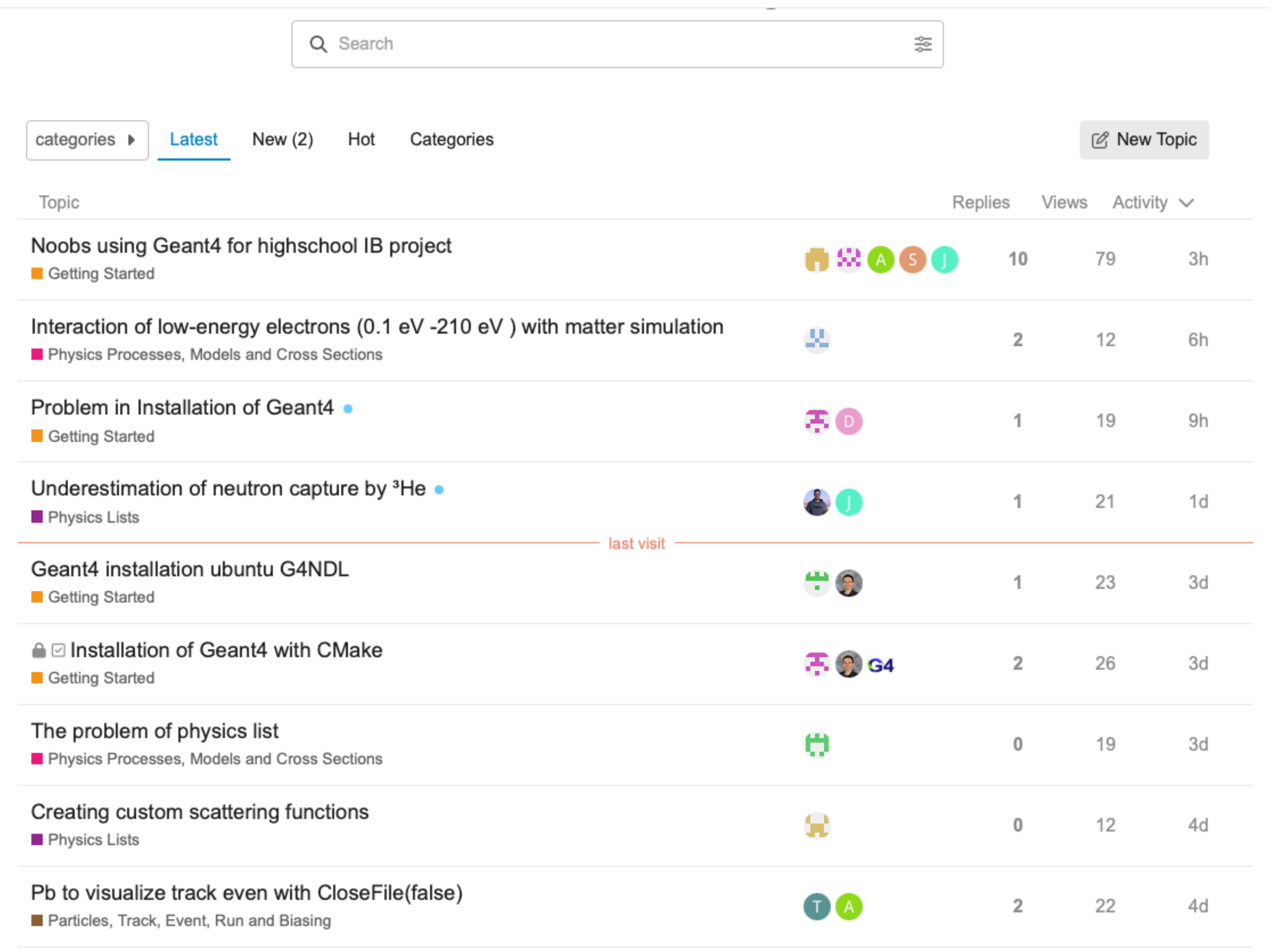
Geant4 Main Page → User Forum

User Forum

Active Geant4 Community forum

Organized in categories.

Signing-up is required to post a topic



Search

categories ▸ | Latest | New (2) | Hot | Categories | New Topic

Topic		Replies	Views	Activity
Noobs using Geant4 for highschool IB project 🟧 Getting Started	A S J	10	79	3h
Interaction of low-energy electrons (0.1 eV -210 eV) with matter simulation 🟥 Physics Processes, Models and Cross Sections		2	12	6h
Problem in Installation of Geant4 ● 🟧 Getting Started	D	1	19	9h
Underestimation of neutron capture by ³He ● 🟪 Physics Lists	J	1	21	1d
last visit				
Geant4 installation ubuntu G4NDL 🟧 Getting Started		1	23	3d
🔒 ☑ Installation of Geant4 with CMake 🟧 Getting Started	G4	2	26	3d
The problem of physics list 🟥 Physics Processes, Models and Cross Sections		0	19	3d
Creating custom scattering functions 🟪 Physics Lists		0	12	4d
Pb to visualize track even with CloseFile(false) 🟫 Particles, Track, Event, Run and Biasing	T A	2	22	4d

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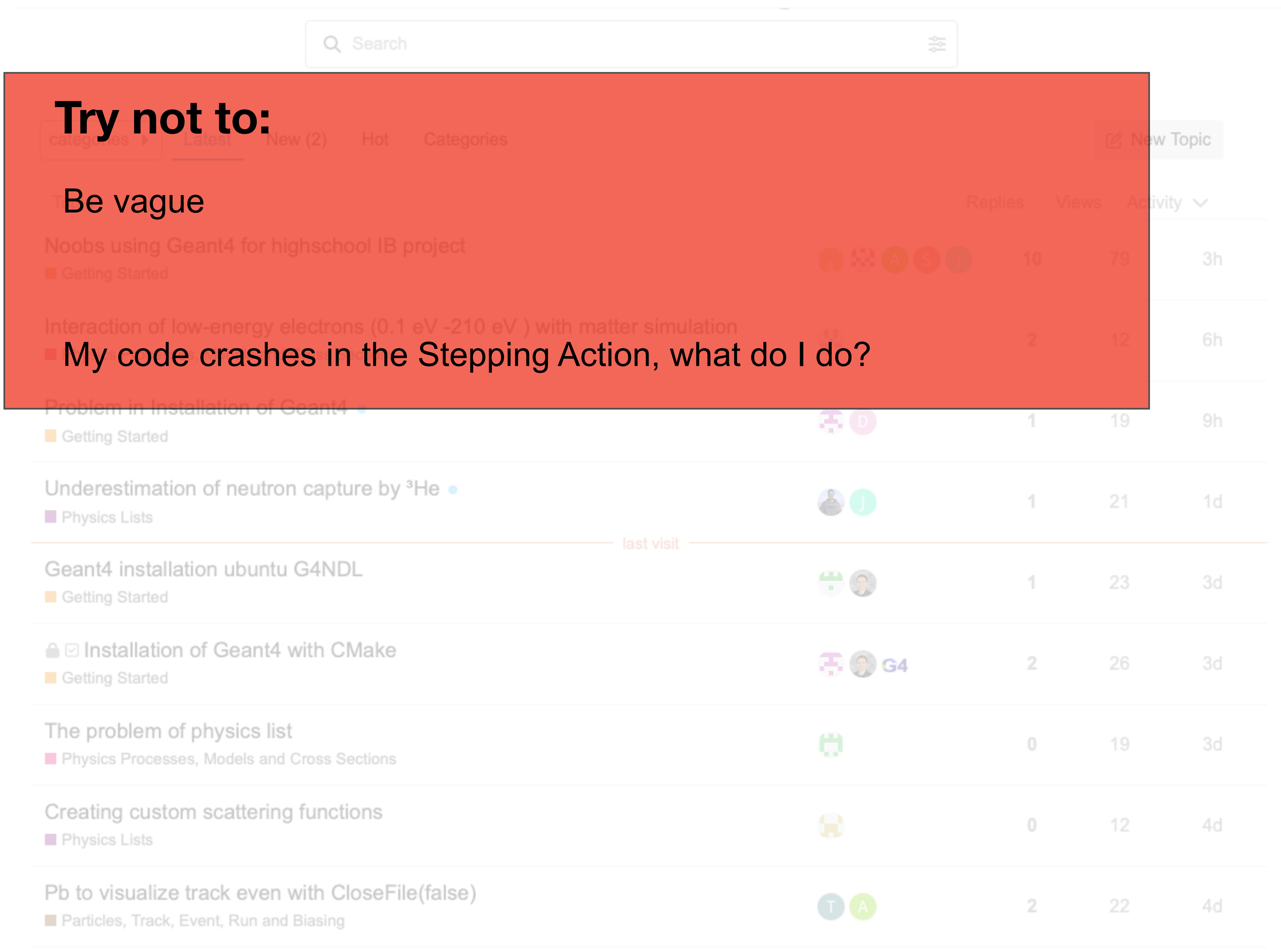

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categories ▸ Latest New (2) Hot Categories New Topic

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Noobs using Geant4 for highschool IB project Getting Started	10	79	3h
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The problem of physics list Physics Processes, Models and Cross Sections	0	19	3d
Creating custom scattering functions Physics Lists	0	12	4d
Pb to visualize track even with CloseFile(false) Particles, Track, Event, Run and Biasing	2	22	4d

Try not to:

Be vague

My code crashes in the Stepping Action, what do I do?

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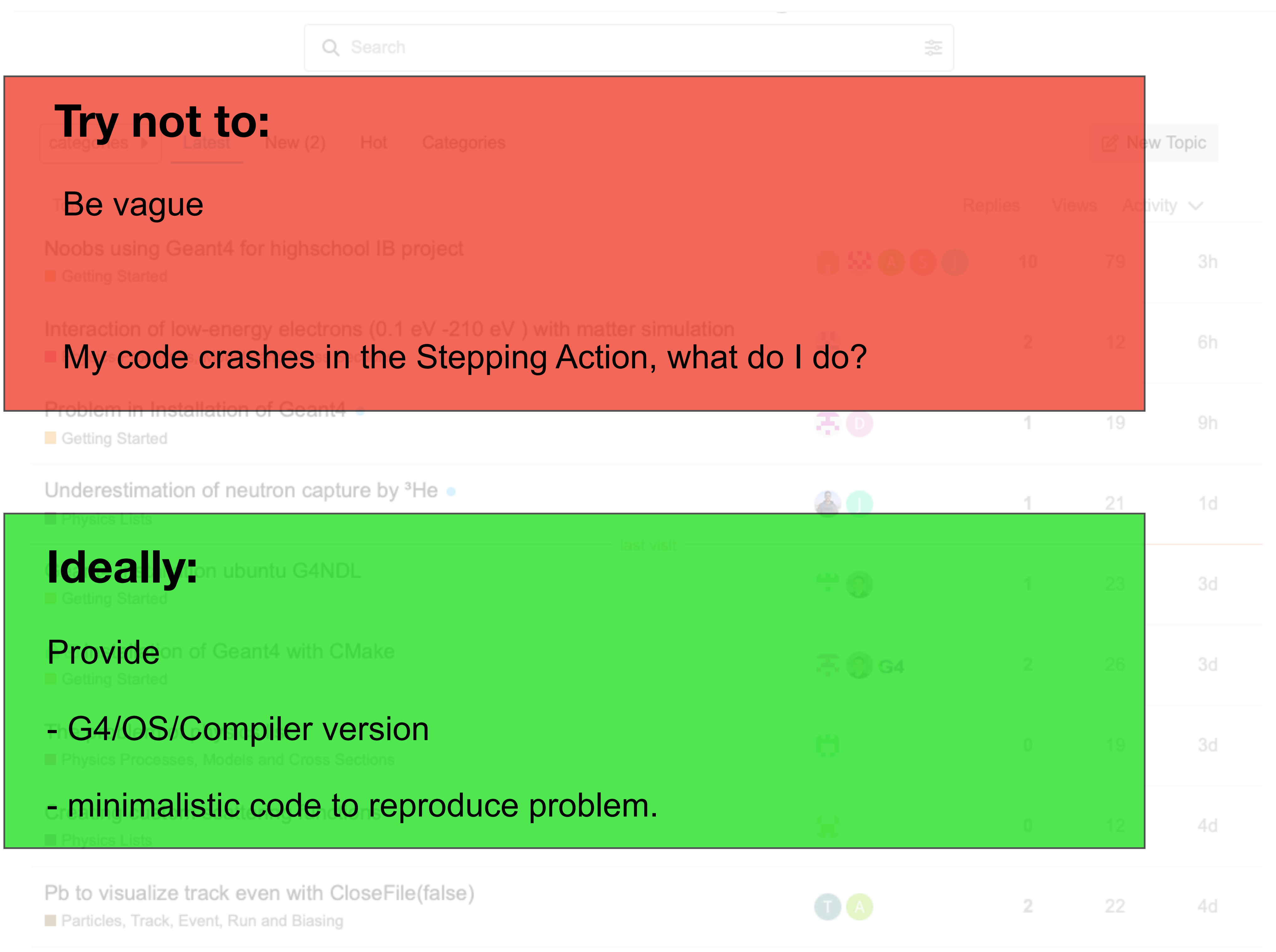

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on of Geant4 with CMake Getting Started	2	26	3d
Physics Processes, Models and Cross Sections	0	19	3d
Physics Lists	0	12	4d
Pb to visualize track even with CloseFile(false) Particles, Track, Event, Run and Biasing	2	22	4d

Try not to:

Be vague

My code crashes in the Stepping Action, what do I do?

Ideally:

Provide

- G4/OS/Compiler version

- minimalistic code to reproduce problem.

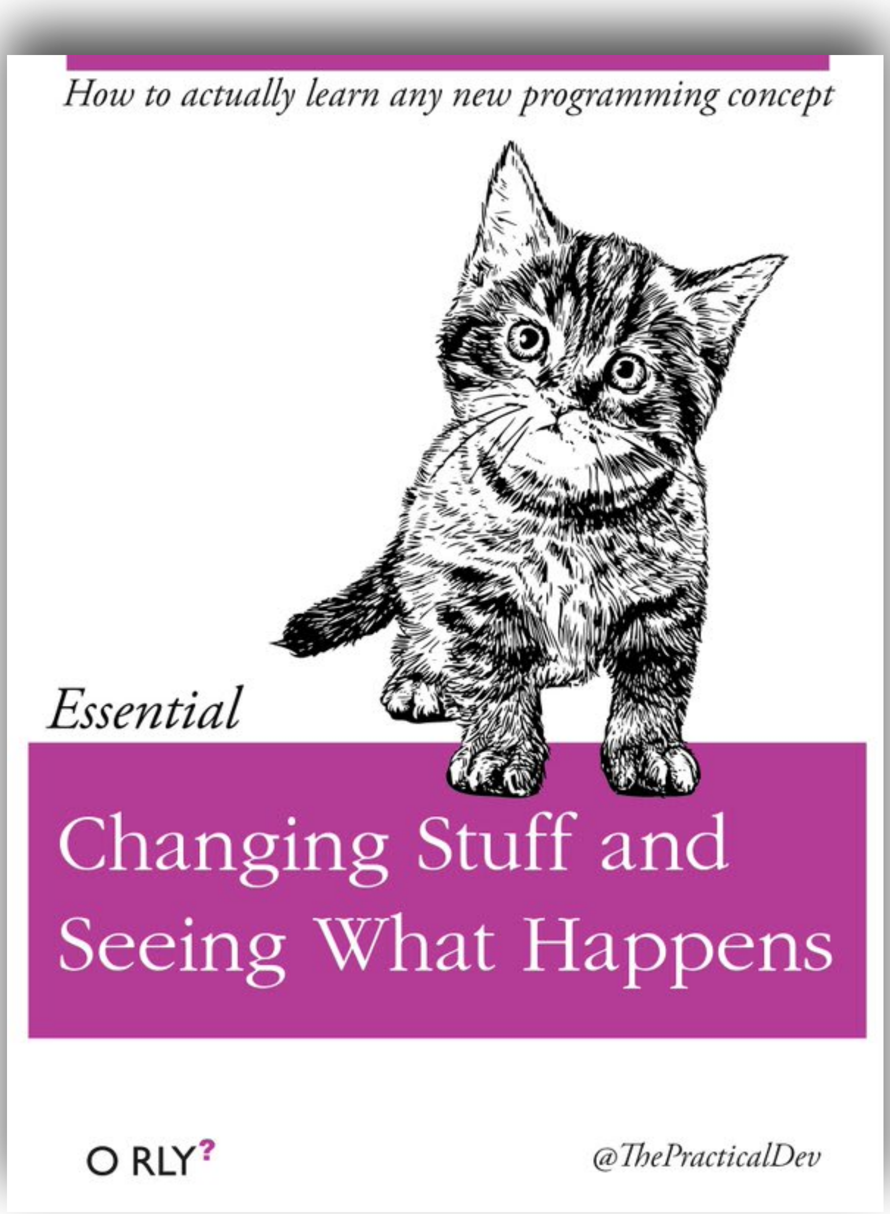
Summary

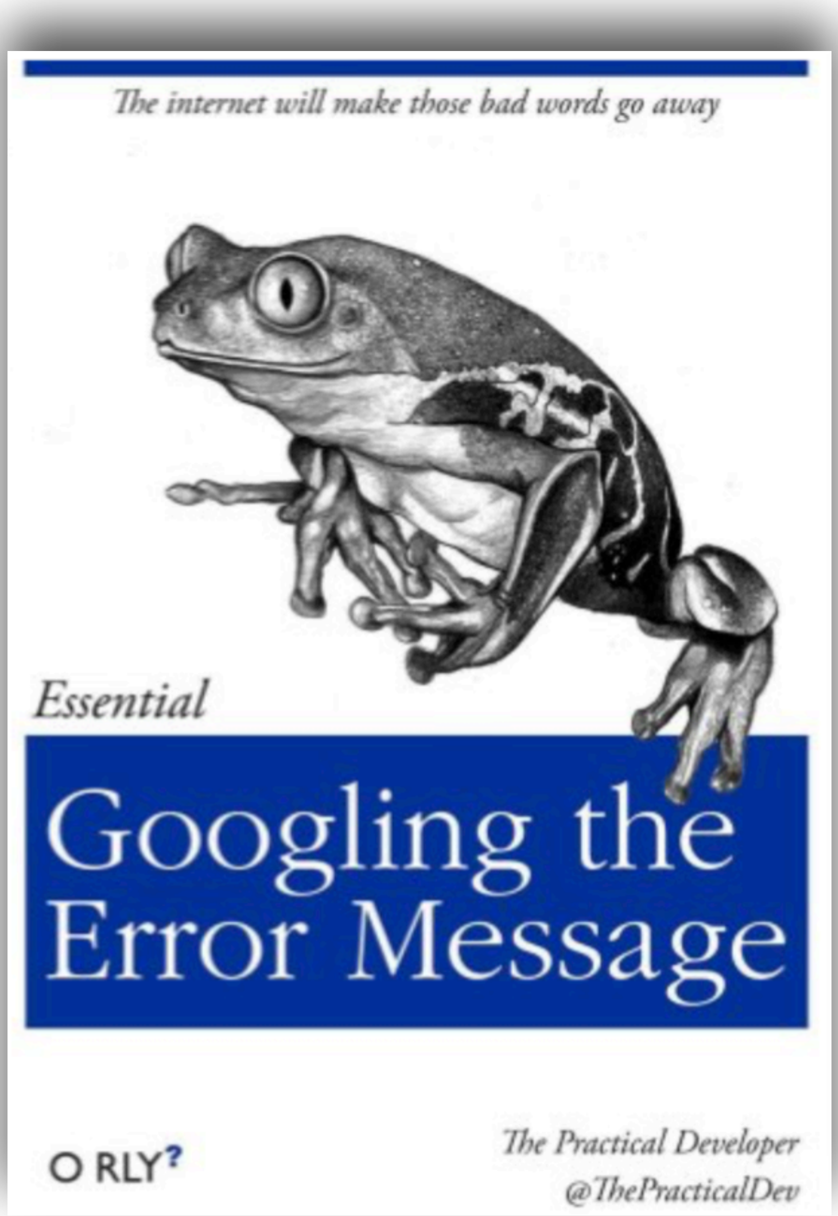
Geant4 is a modular code made of ~2 million lines of code → be patient, it takes time to master it

Few recommended steps:

- Start from the basic examples
  - Isolate their building blocks
  - Adopt the *“change something and see what happens”* mind
- The User Guide: **For Application Developers** is the essential reference
- Inspect `Geant4` *classes* on Doxygen
- Refer to the documentation or post your questions on the **User Forum**

Essential References


How to actually learn any new programming concept
Essential
Changing Stuff and Seeing What Happens
O RLY?
@ThePracticalDev


The internet will make those bad words go away
Essential
Googling the Error Message
O RLY?
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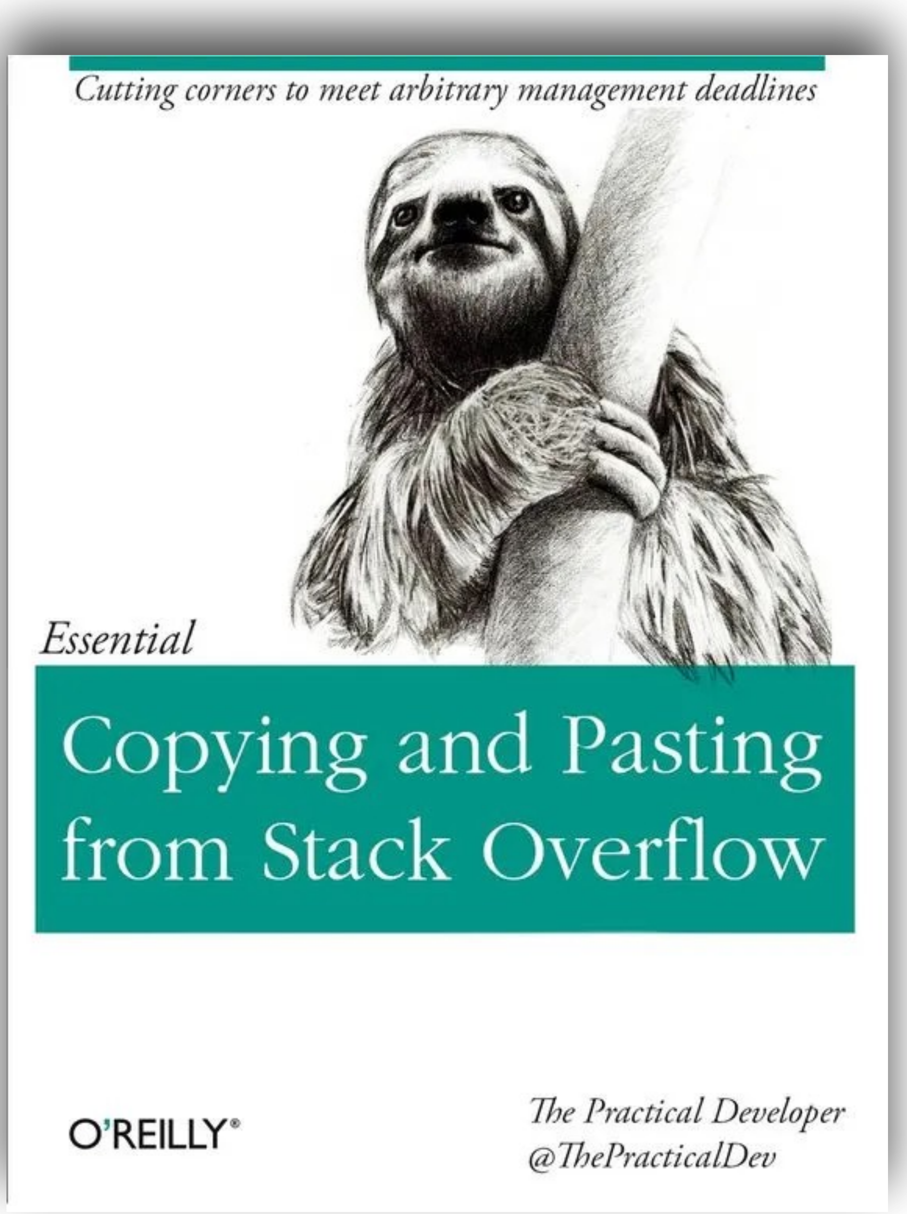
Cutting corners to meet arbitrary management deadlines
Essential
Copying and Pasting from Stack Overflow
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