

GEANT4 - A MONTE CARLO SIMULATION TOOLKIT PART I

F. García

Helsinki Institute of Physics

07.06.2021



Latin American alliance for
Capacity building in Advanced physics
LA-CoNGA physics



Cofinanciado por el
programa Erasmus+
de la Unión Europea



OUTLINE

- ❑ WHAT IS GEANT4
- ❑ MONTE CARLO METHOD
- ❑ MONTECARLO METHOD IN PARTICLE TRANSPORT
- ❑ GEANT4 TOOLKIT - CLASES & STURCTURE
- ❑ GEANT4 - Hands-on



Latin American alliance for
Capacity building in Advanced physics
LA-CoNGA physics



Cofinanciado por el
programa Erasmus+
de la Unión Europea

2

UAN
UNIVERSIDAD ANTONIO MARIÑO

Universidad
Industrial de
Saragosa

Universidad
San Francisco
de Quito

YACHAY
REAL

UNIVERSIDAD
NACIONAL DE
INGENIERIA

UNMSM

UNIVERSIDAD SIMÓN BOLÍVAR

UNIVERSIDAD
NACIONAL DE
CIENCIAS Y TECNOLOGÍA

Université
de Paris

TECHNISCHE
UNIVERSITÄT
DRESDEN

UNIVERSITÉ
TOULOUSE III
PAUL SABATIER

cevale2

CNRS

DESY

INFN

The New York
Academy of Sciences

Red
CLARA

ASOCIACIÓN COLOMBIANA
DE INGENIEROS Y ARQUITECTOS

CLARA

ICTP

INTERNATIONAL
INSTITUTE OF
HIGH ENERGY PHYSICS

www.dbaaccess.com
DBACCESS

frontier x
analytics

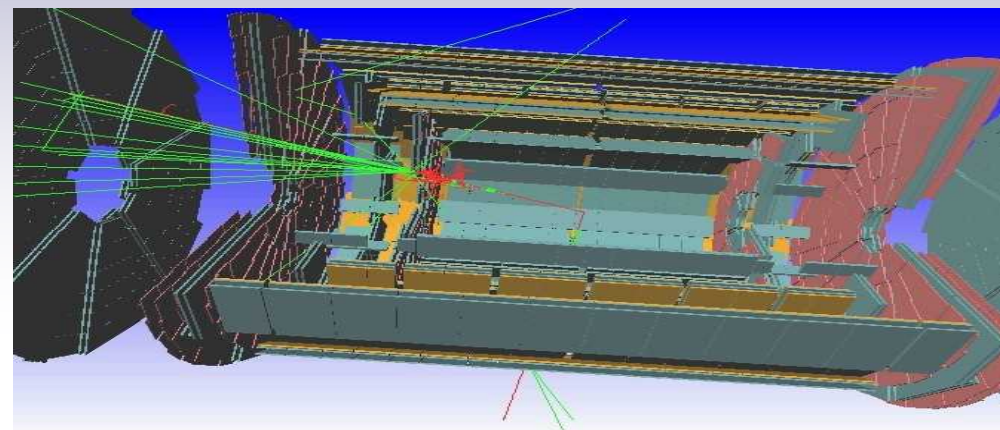
CAEN
Tools for Discovery



WHAT IS GEANT4

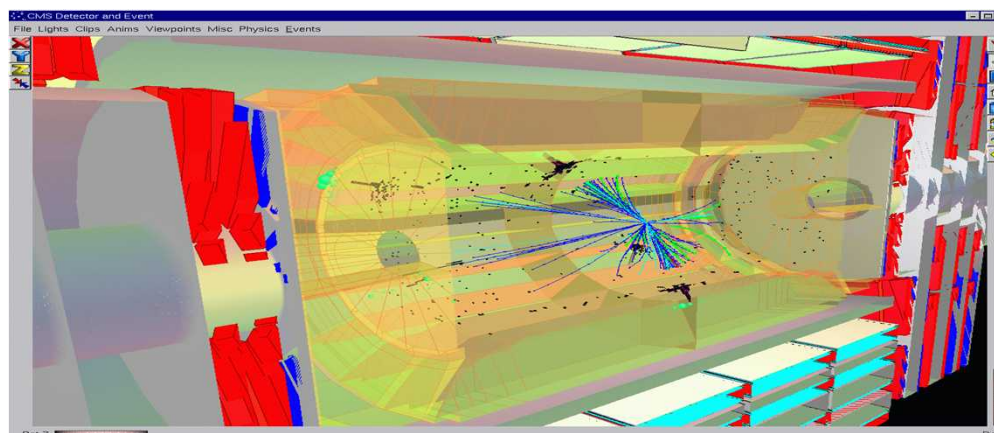
Geant4 is a toolkit for the simulation of the passage of particles through matter. Its areas of application include high energy, nuclear and accelerator physics, as well as studies in medical and space science

ATLAS experiment



No to scale

CMS experiment



No to scale



MONTE CARLO METHOD

The **Monte Carlo method** is a numerical solution to a problem that models objects interacting with other objects or their environment based upon simple relationships.

It represents an attempt to model nature through direct simulation of the essential dynamics of the system in question.

In this sense the Monte Carlo method is essentially simple in its approach... a solution to a macroscopic system through simulation of its microscopic interactions.

A solution is determined by random sampling of the relationships, or the microscopic interactions, until the result converges. Thus, the mechanics of executing a solution involves repetitive action or calculation.

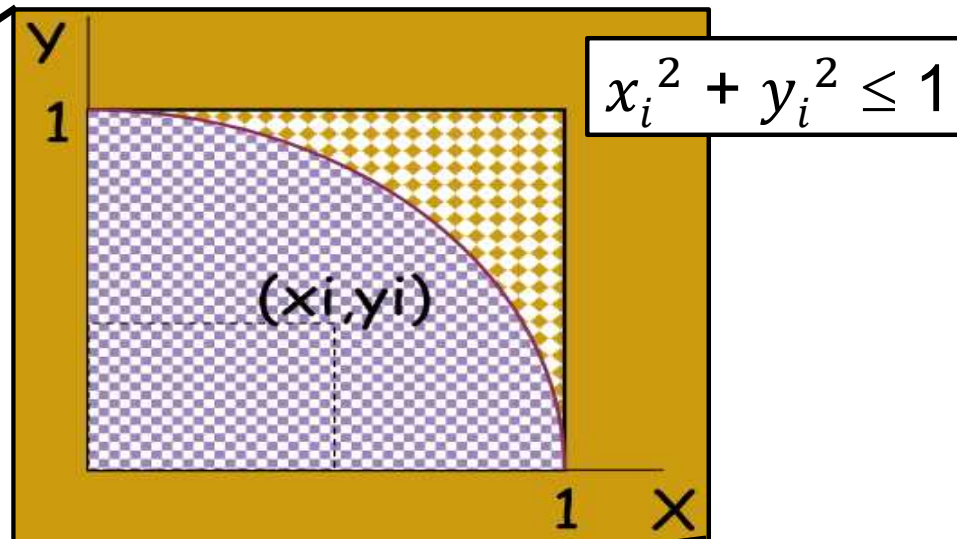
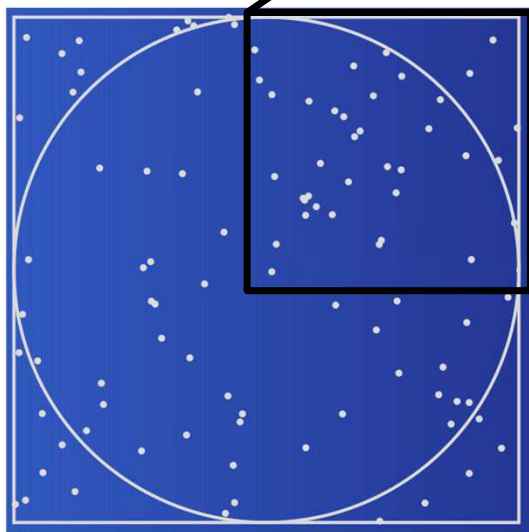
There are many examples of the use of the Monte Carlo method that can be drawn from social science, traffic flow, population growth, finance, genetics, quantum chemistry, radiation sciences, radiotherapy, radiation dosimetry and **for this particular case: transport of particles throughout matter of our detector and its surroundings.**



MONTE CARLO METHOD (cont.)

Calculation of π

Now we generate random numbers from 0 .. 1 for X and Y axes

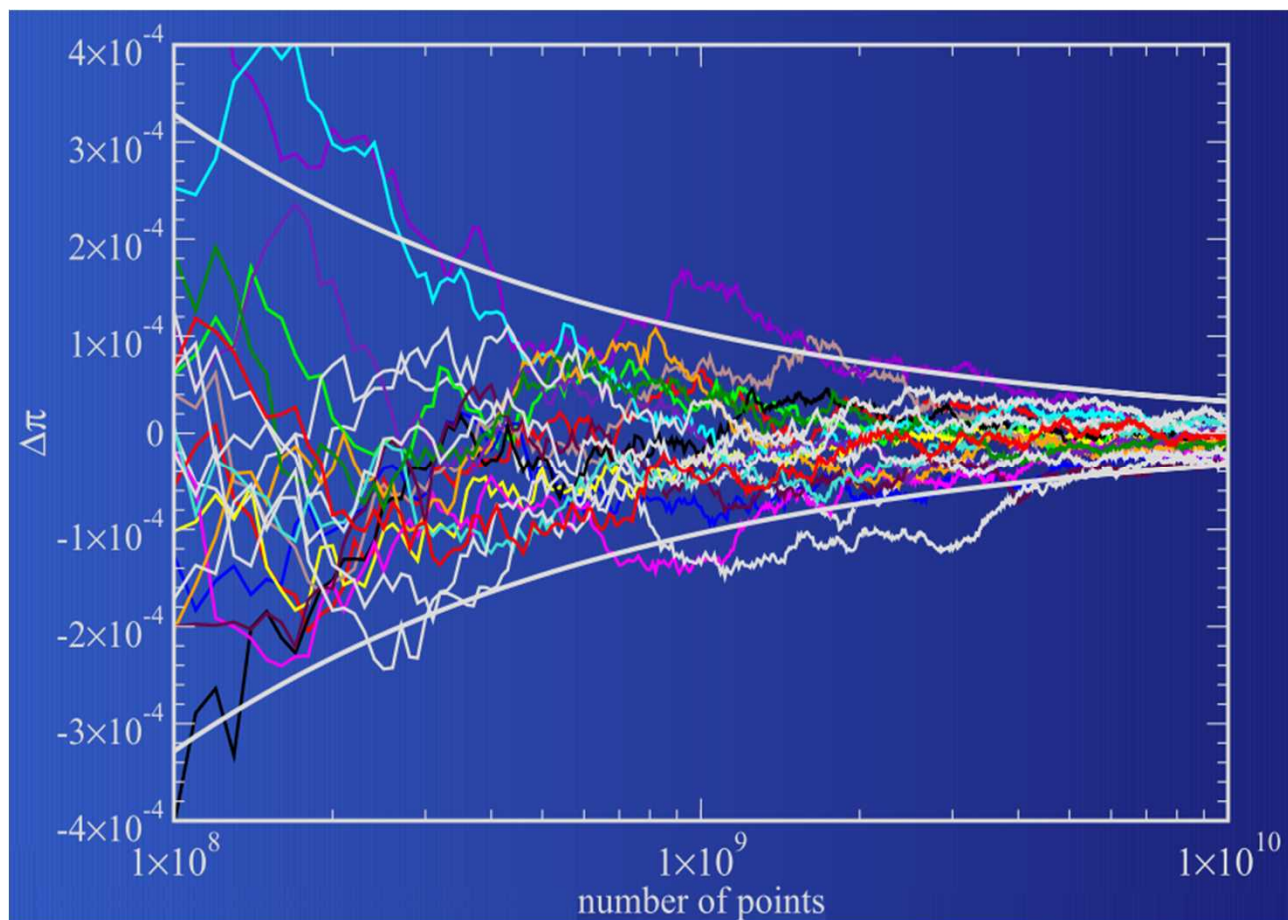


$$\frac{\text{Area of the semicircle}}{\text{Area of the square}} = \frac{\frac{\pi r^2}{4}}{r^2} = \frac{\pi}{4} = \frac{\text{\# of dots in the semicircle}}{\text{\# of dots in the square}}$$

$$\pi = \frac{4 \cdot \text{\# of dots in the semicircle}}{\text{\# of dots in the square}}$$



MONTE CARLO METHOD (cont.)



One can see from the plots that as the number of points generated by random numbers increase then $\Delta\pi$ tends to the value of π

In addition to that different seeds of the random generator will produce different fluctuations of the $\Delta\pi$

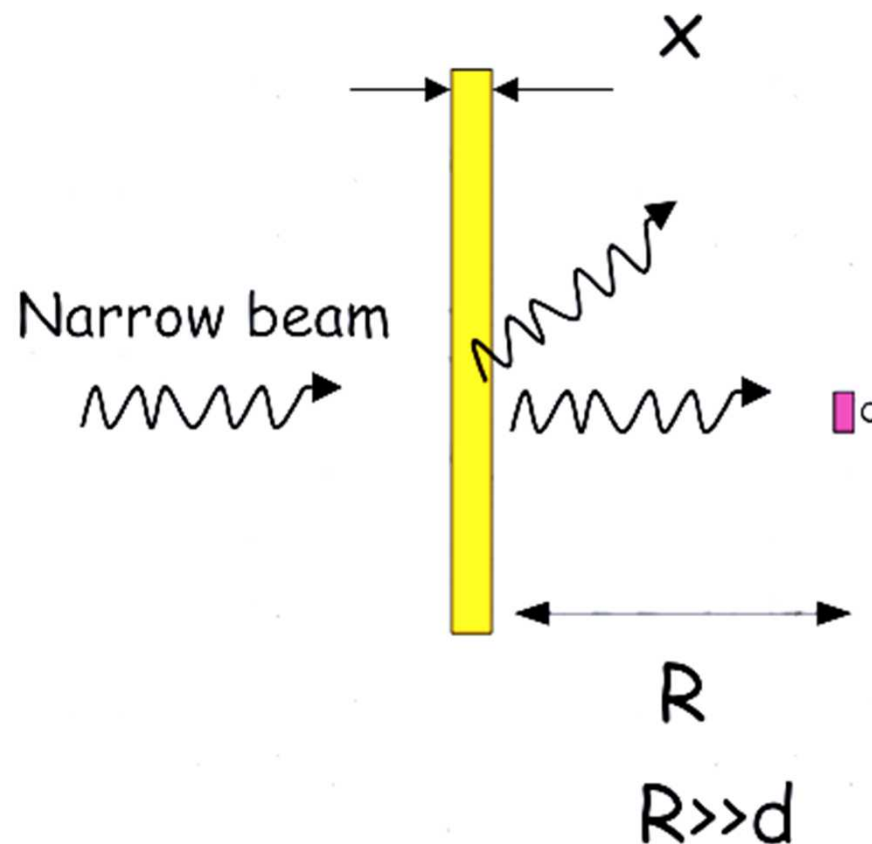


MONTE CARLO METHOD IN PARTICLE TRANSPORT

$$I(x) = I_0 \cdot e^{-\mu x}$$

The probability that normally incident photon will reach the depth x in a material slab without interaction is:

$$P(x) = e^{-\mu x}$$





MONTE CARLO METHOD IN PARTICLE TRANSPORT (Cont.)

The probability that the first interaction of an incident photon will take place at the depth between x and $x+dx$ is:

$$P_1(x)dx = P(x) \cdot \mu dx$$

The probability that photon will reach the depth x

The probability that photon will interact at dx



MONTE CARLO METHOD IN PARTICLE TRANSPORT (Cont.)

The cumulative probability that the incident photon will interact before reaching a depth x is:

$$P_c(x) = \int_0^x P_1(x) dx = \mu \int_0^x e^{-\mu x} dx = 1 - e^{-\mu x}$$

The value obtained for this probability is equal to 1 minus the value of the probability that the photon pass without interaction

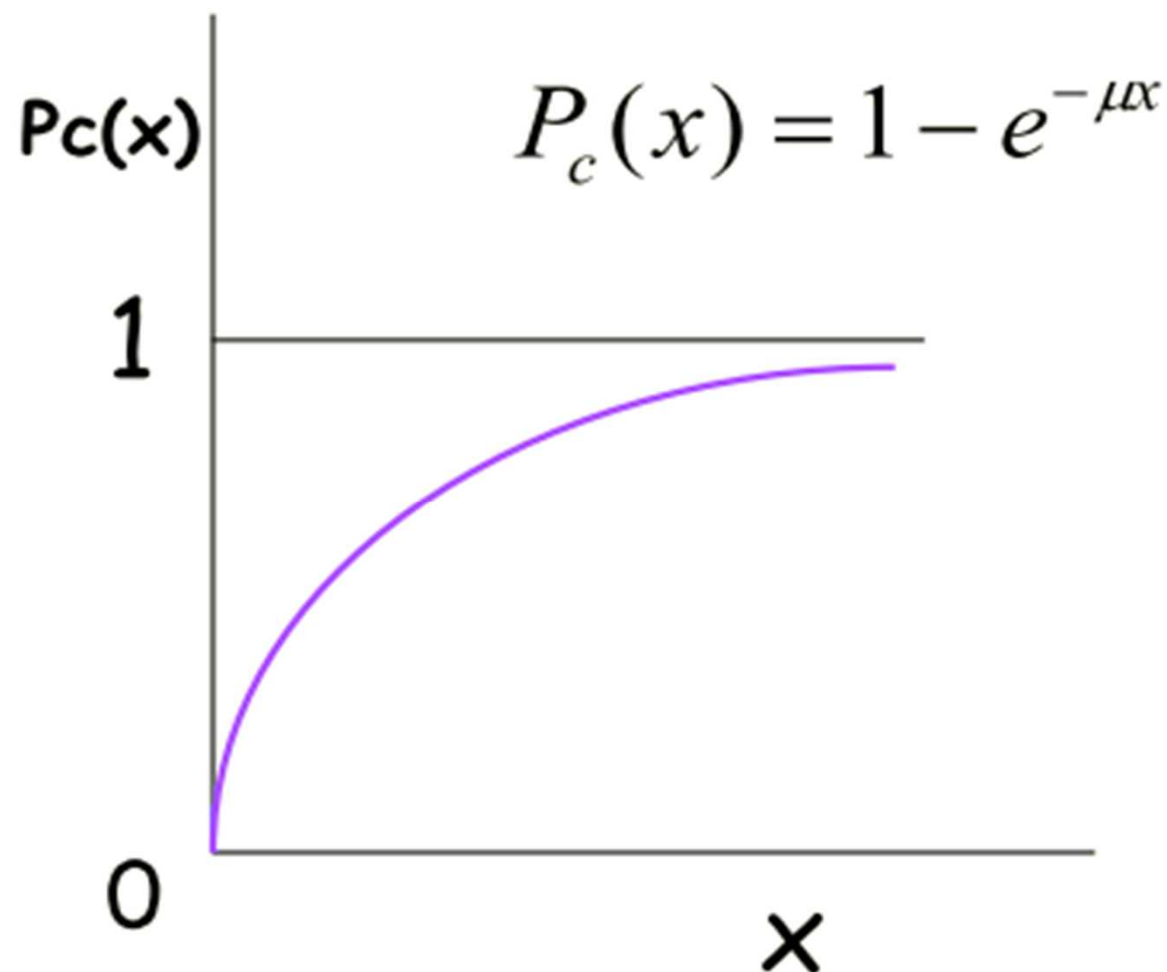


MONTE CARLO METHOD IN PARTICLE TRANSPORT (Cont.)

The probability that the incident photon reach a depth x is shown.

The magenta curve tells us that at very small x the probability is small and for large x the probability tends to reach 1

The μ value is called linear attenuation coefficient





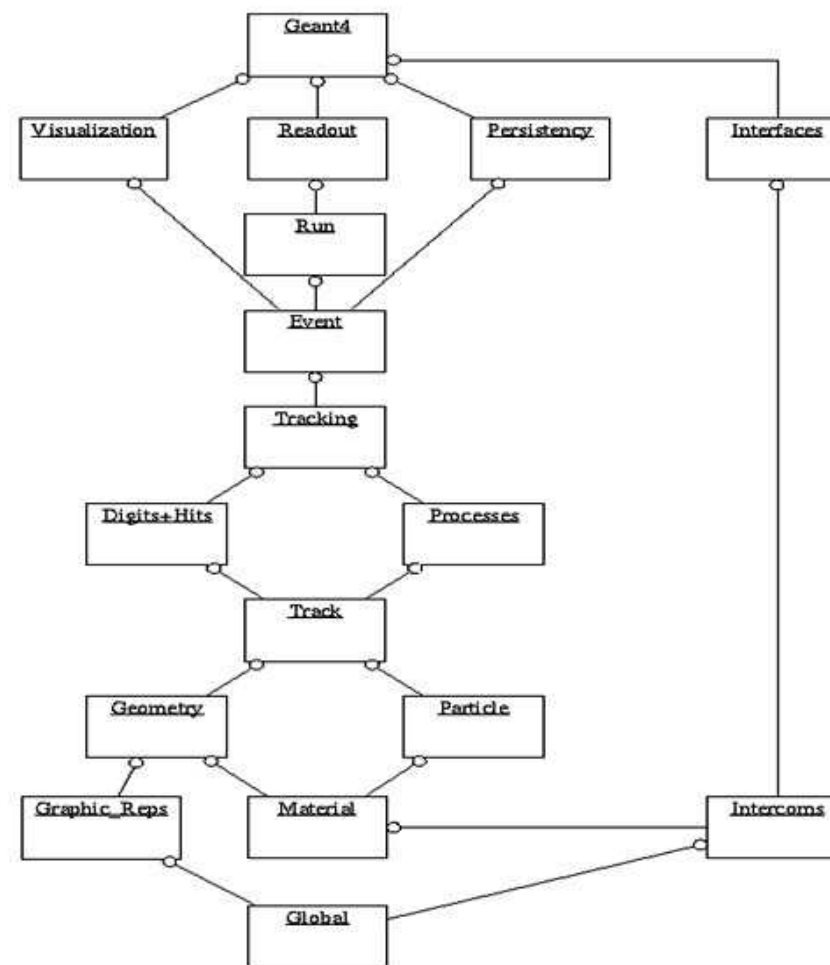
GEANT4 INTRODUCTION

All aspects of the simulation process have been included in the toolkit: the geometry of the system, the materials involved, the fundamental particles of interest, the generation of primary events, the tracking of particles through materials.

In addition to that the physics processes governing particle interactions, electromagnetic fields, the response of sensitive detector components, the generation of event data, the storage of events and tracks, the visualization of the detector and particle trajectories.

All encapsulated in classes as show on this diagram

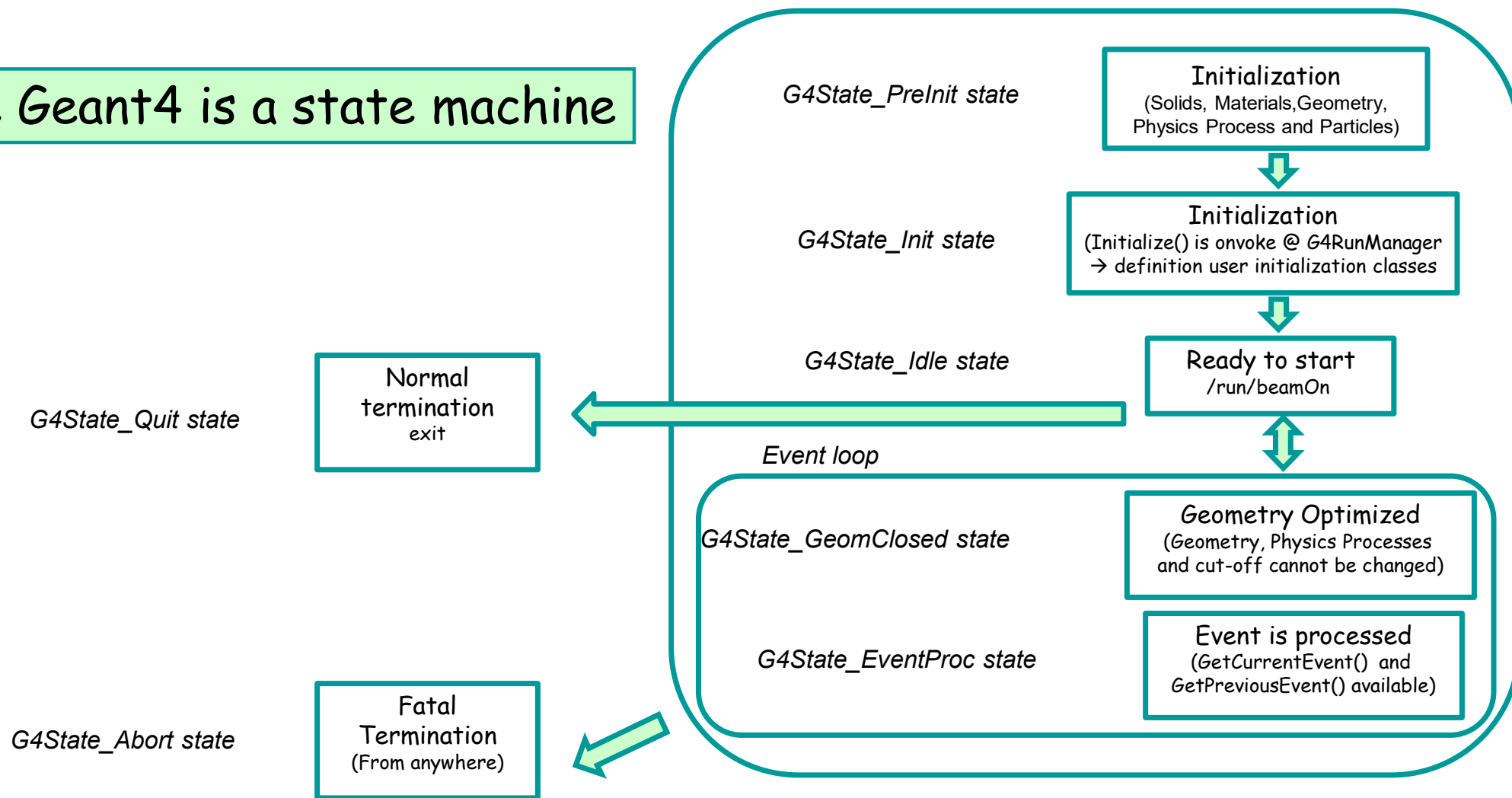
The Geant4 class category diagram





GEANT4 INTRODUCTION

The Geant4 is a state machine





GEANT4 INTRODUCTION

The screenshot shows a virtual machine environment with two main windows:

- Terminal Window:** Displays the execution of a GEANT4 simulation. It shows track information for two particles (ID 5 and ID 4) and a summary of the run. The summary indicates that 1 event was processed, consisting of 1 gamma of 6 MeV, with a cumulated dose of 0 picroGy.
- Viewer Window:** Displays a 3D visualization of the detector geometry. A red arrow indicates a 10 cm scale. The text "G4" is visible in green. The viewer shows a blue rectangular volume with a white cylindrical component and a white rectangular component labeled "Shape2".

Overlaid on the screenshot is the text: "GEANT4 - Hands-on Session LaConga Virtual Machine".



<http://laconga.redclara.net>



contacto@laconga.redclara.net



lacongaphysics



Latin American alliance for
Capacity building in Advanced physics

LA-CoNGA physics



Cofinanciado por el
programa Erasmus+
de la Unión Europea

El apoyo de la Comisión Europea para la producción de esta publicación no constituye una aprobación del contenido, el cual refleja únicamente las opiniones de los autores, y la Comisión no se hace responsable del uso que pueda hacerse de la información contenida en la misma.