GEANT4 – A MONTE CARLO SIMULATION TOOLKIT PART I

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Latin American alliance for Capacity buildiNG in Advanced physics

LA-CoNGA physics

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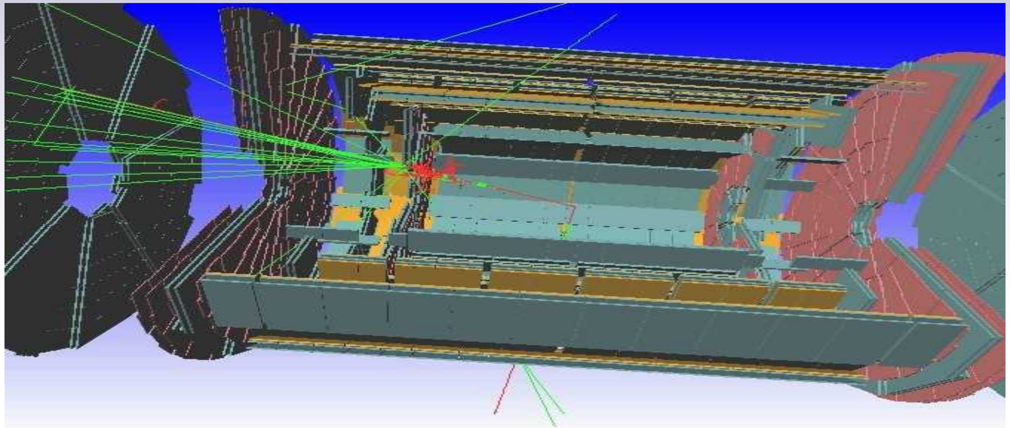
WHAT IS GEANT4

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



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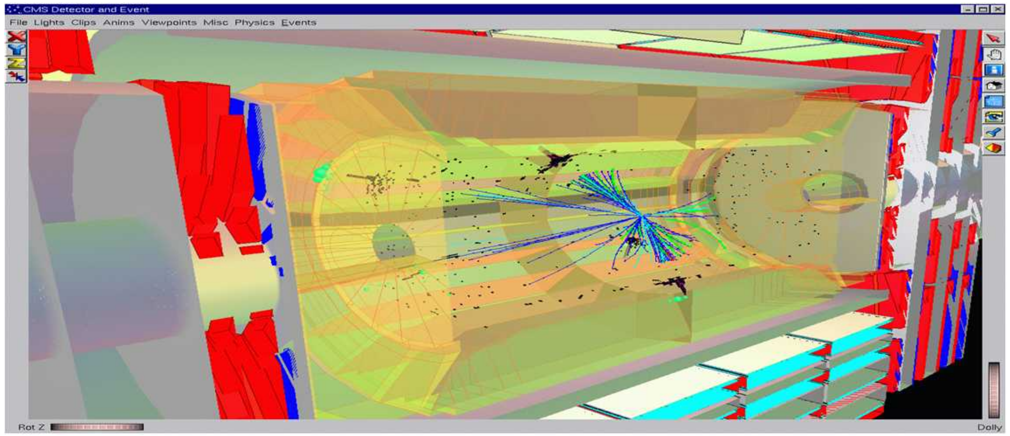
CMS experiment



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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.

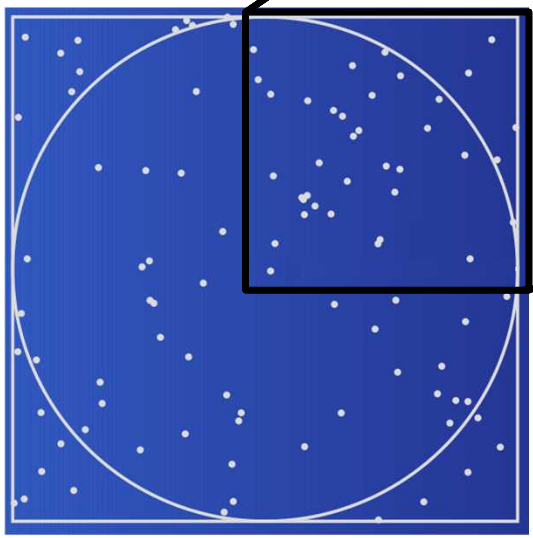
In this sense the Monte Carlo method is essentially simple in its approach... a solution to a macroscopic system through simulation of its microscopic interactions.

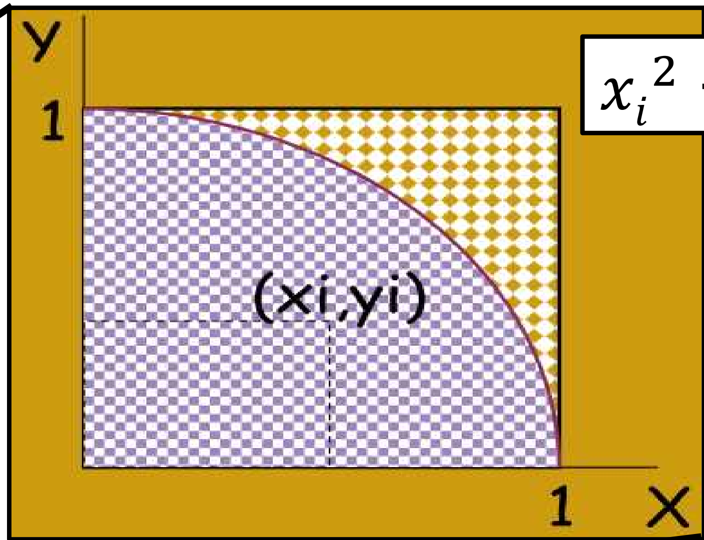
A solution is determined by random sampling of the relationships, or the microscopic interactions, until the result converges. Thus, the mechanics of executing a solution involves repetitive action or calculation.

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**.

Calculation of π

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



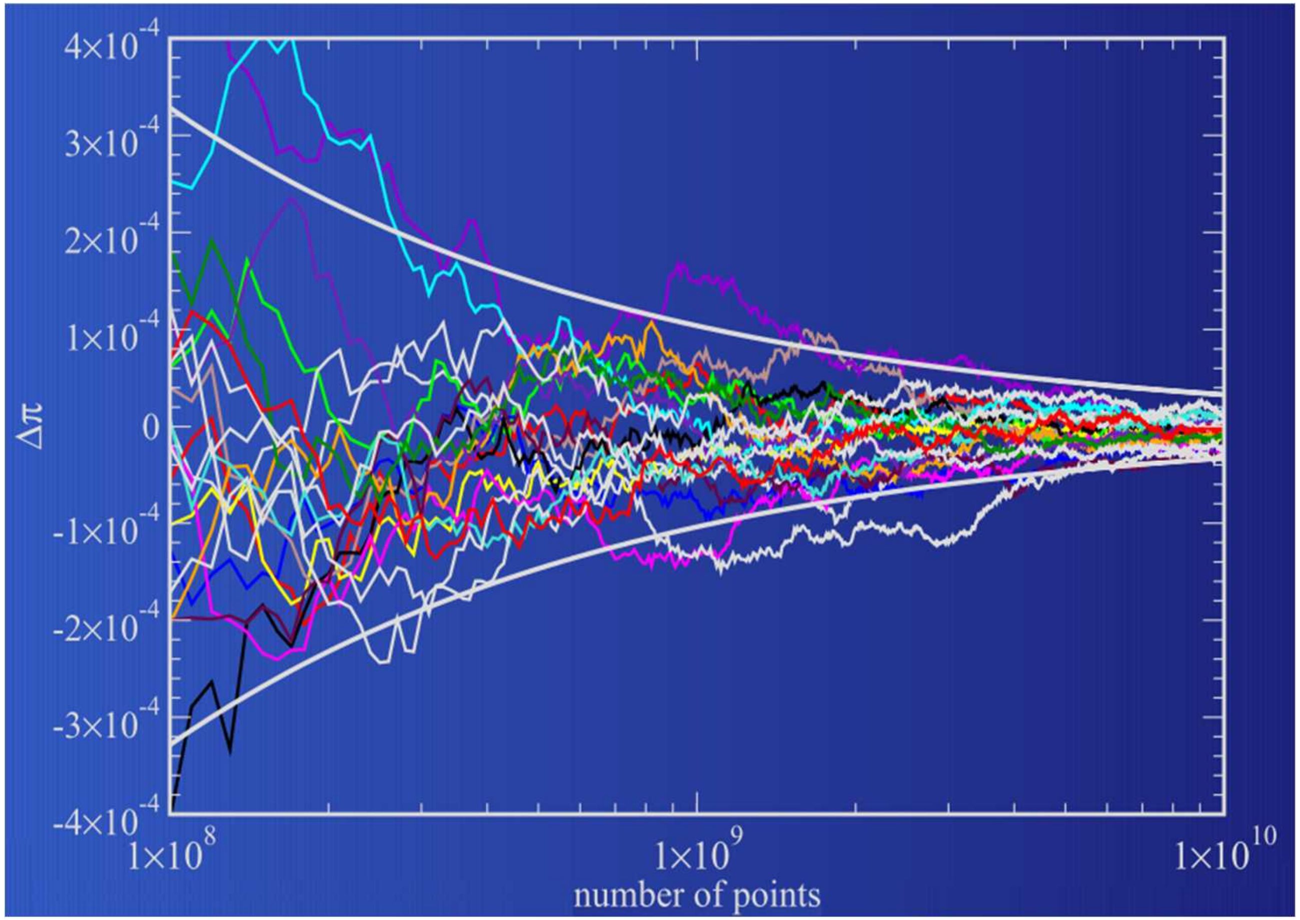


$$x_i^2 + y_i^2 \leq 1$$

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

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

MONTE CARLO METHOD (cont.)



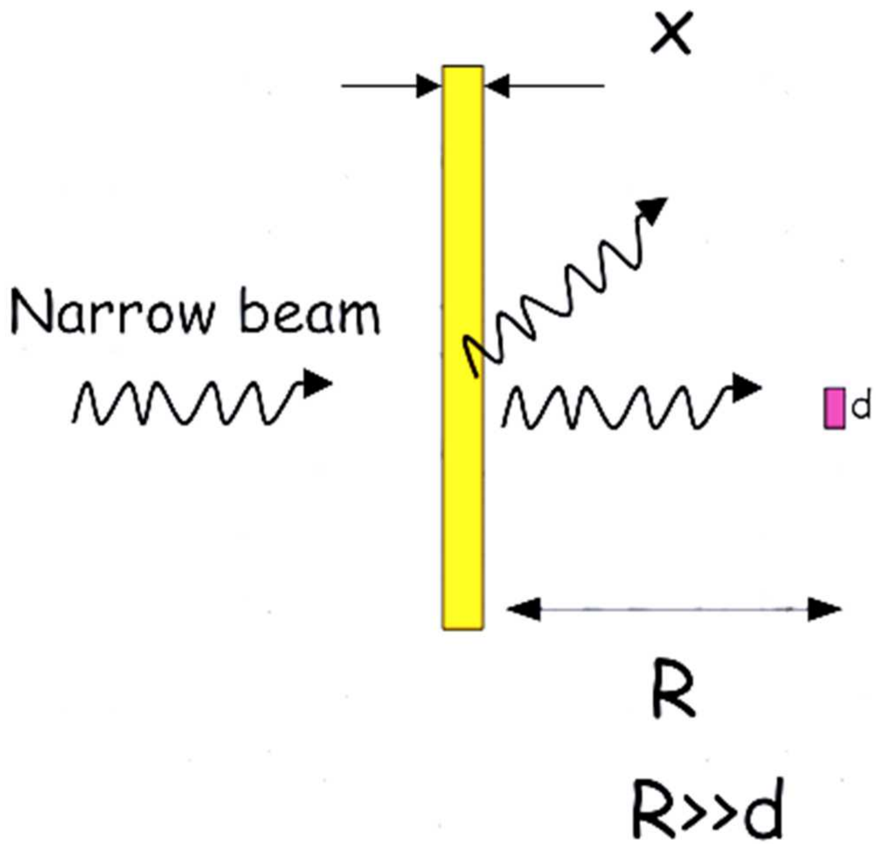
One can see from the plots that as the number of points generated by random numbers increase then $\Delta\pi$ tends to the value of π

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

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

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

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



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:

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

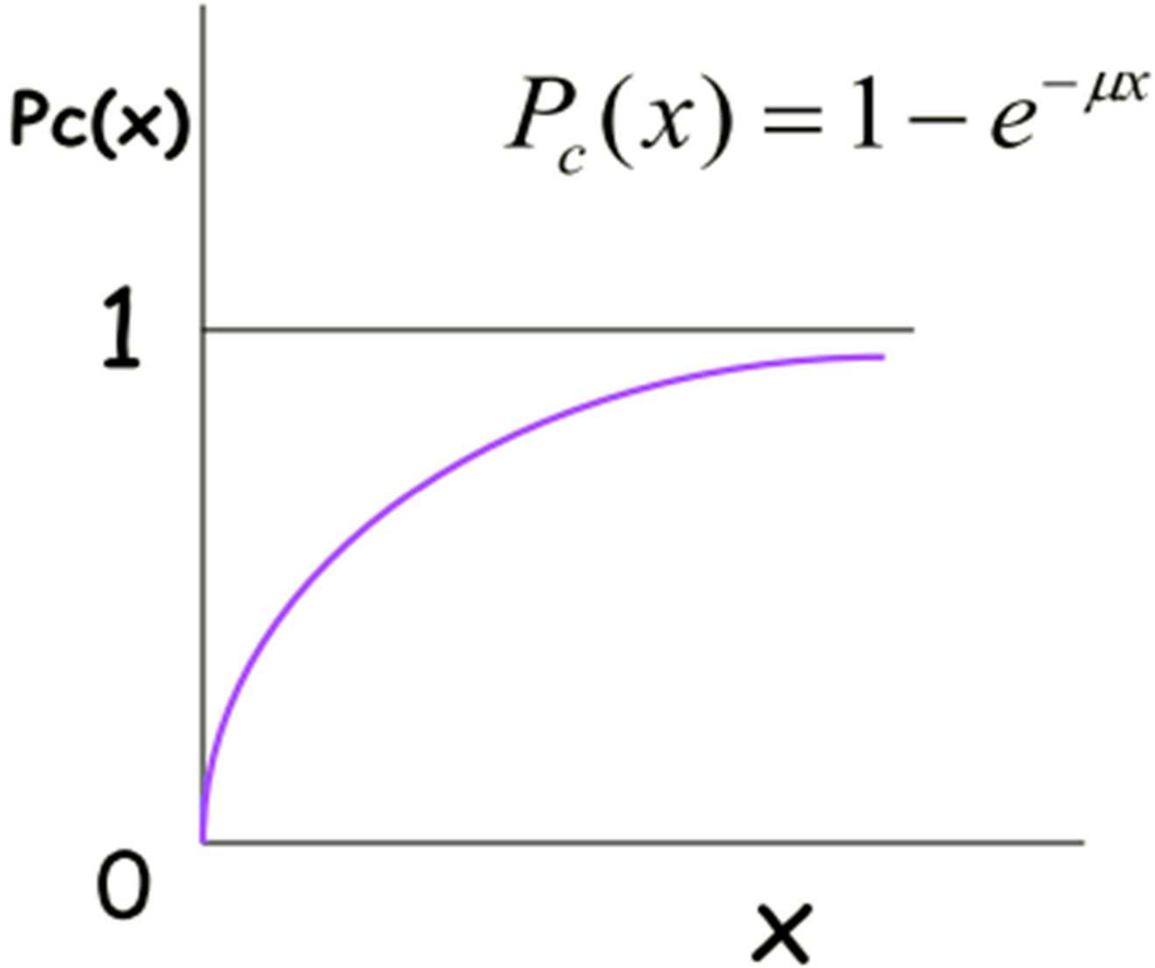
The value obtained for this probability is equal to 1 minus the value of the probability that the photon pass without interaction

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



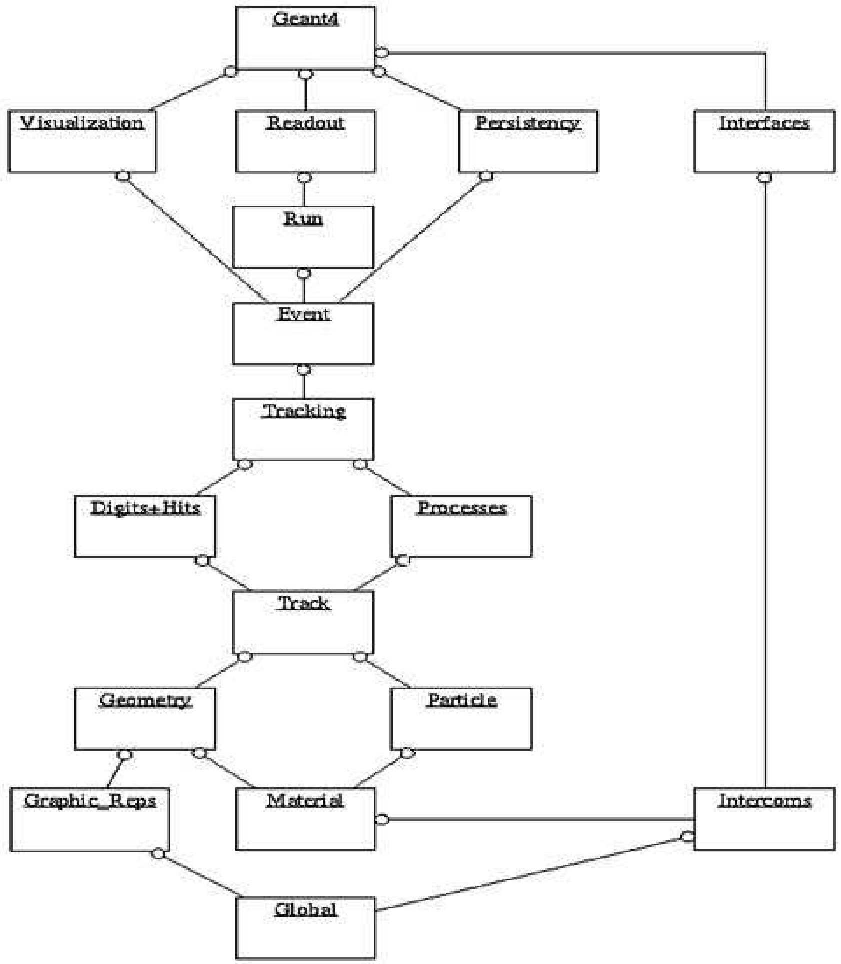
GEANT4 INTRODUCTION

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.

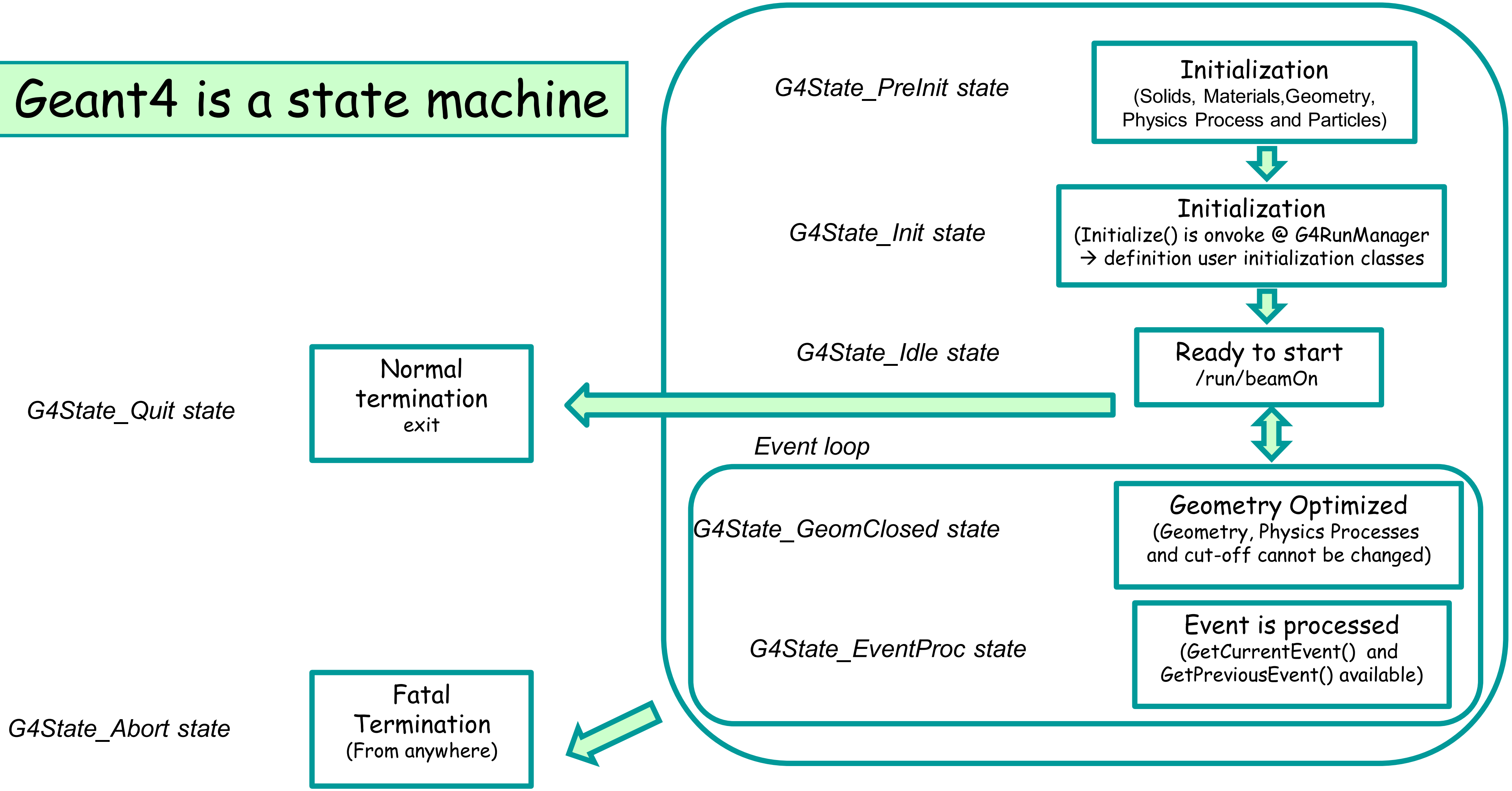
All encapsulated in classes as show on this diagram

The Geant4 class category diagram



GEANT4 INTRODUCTION

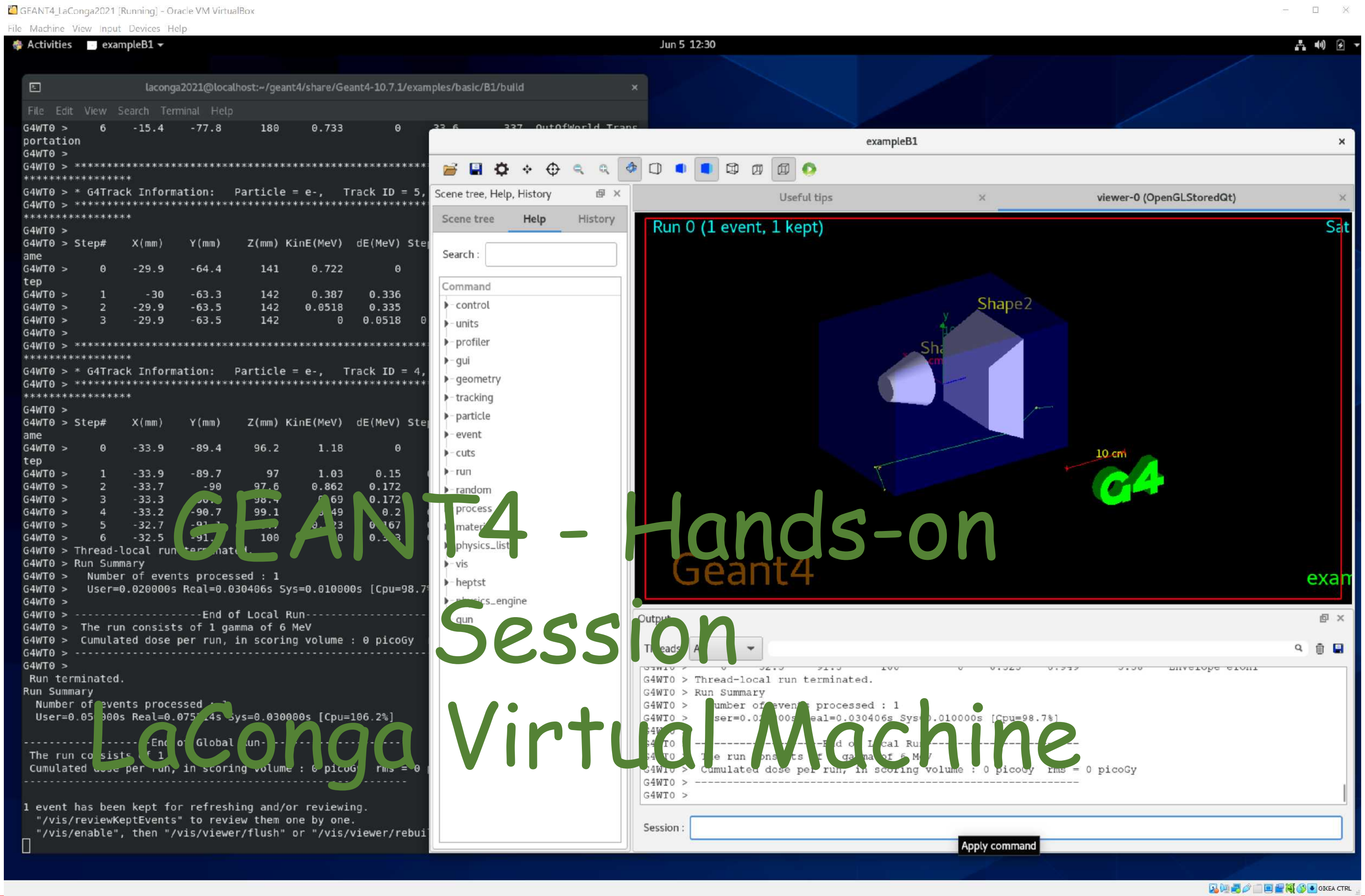
The Geant4 is a state machine



GEANT4 INTRODUCTION

GEANT4 - Hands-on Session

LaConga Virtual Machine



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