

# Introduction to Geant4

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# Very basic of Geant4

- Geant4 is not Geant version 4, but Geant4 is our brand name
  - Geant4.5.1 stands for Geant4 version 5.1, not Geant version 4.5.1
  - Except G, other letters should be in smaller case
    - c.f. GEANT3 (all in upper case letters)
    - Originally GEANT stands for GEometry ANd Tracking
      - Named by Rune Brun

# The design principles

- Ease of obtaining correct results rather than ease of starting up
  - Geant4 is not a mighty black box, but the toolkit
  - Even though learning curve might be slow, you have less chance to use Geant4 as not expected
- Generalize everything for extendability
- We expect two levels of users
  - Application developer
    - We support these people
  - End users
    - Application developers should support them

# Why we started Geant4?

- GEANT3 was not sufficient for SSC/LHC
  - No design document
    - Almost no chance to make an enhancement in users side
    - Long term maintenance is necessary
  - Only two or three people in the world could enhance physics processes or geometry description (e.g. new solids)
    - Still there are many requirements
- GEANT3 was the unique solution to describe very complicated geometry

# Who made Geant4?

- Geant4 collaboration
  - Very international
    - Still there is a weight in Europe
  - GEANT3 developers and users joined the project
    - GEANT3 was frozen after Geant4 started
  - The collaboration always welcomes people who wants to contribute for Geant4
    - You can be a developer anytime if you have interests

# What is MC, anyway?

- Monte Carlo is the method to predict something by interpolate/extrapolate known facts/theories/measurements
  - We cannot predict anything what we do not know well
  - Many of physics processes are model dependent because no theoretical predictions are given
- The results are not guaranteed and users should validate their results
  - Most of physics processes in Geant4 are well validated
    - Applicable ranges are different for each processes
    - Still there are infinite combinations of them

# Pre-Geant4 history

- Prof. Watase invited a professor from US to KEK and we learned a lot about Object Oriented Technology in 1991 and 1992
- Katsuya Amako and myself started the activity to develop a new simulation software based on Object Oriented Technology in 1992
  - Takaiwa and Kanzaki were together with us at that time
- We have presented our achievement at CHEP94 and Rune Brun approached us
- CERN and us are agreed to start over the new project as Geant4
- Makoto Asai, the current spoke person of Geant4, insisted that GEANT3 is enough and he refused to join us at the first time
  - He soon learned that how new technologies are powerful
  - It was rather nightmare to integrate the FORTRAN program parts developed by distributed people, but we did not have any major problem when we made a prototype of Geant4
  - OO helped us to save our time

# Introduction to Geant4

These slides are provided by  
Makoto Asai (SLAC)

The logo for Geant 4, featuring the word "Geant" in a serif font and the number "4" in a larger, bold serif font. The text is rendered in a brown color with a halftone or dithered texture.

# Contents

- General introduction and brief history
- Highlights of user applications
- Geant4 license
- Geant4 kernel
  - Basic concepts and kernel structure
  - User classes

<http://cern.ch/geant4>

**GLAST** *Gamma-ray Large Area Space Telescope*

## Geant 4

Geant4 is a toolkit for the simulation of the passage of particles through matter. It has been developed and maintained by a world-wide Collaboration of approximately 100 scientists.

**ATLAS at LHC, CERN**

**Borexino** *at Gran Sasso Laboratory*

Its application areas include high energy physics, astrophysics and nuclear physics experiments, medical, accelerator and space science studies.

**ESA XMM X-ray telescope**

**CMS** *at LHC, CERN*

**BaBar at SLAC**

**High energy  $\mu$**   
Courtesy of L3

**Photon attenuation**  
Low energy photons  
Courtesy of the Italian Nat. Inst. for Cancer Research

An abundant set of Physics Processes handle the diverse interactions of particles with matter across a wide energy range.

**Neutrons**  
Courtesy of CMS

**Stopping  $\kappa$**   
absorption  
nuclear deexcitation

**Geant4** exploits advanced Software Engineering techniques and Object Oriented technology to achieve transparency of physics implementation.

General introduction  
and brief history

**Geant 4**

# What is Geant4?

- Geant4 is the successor of GEANT3, the world-standard toolkit for HEP detector simulation.
- Geant4 is one of the first successful attempt to re-design a major package of HEP software for the next generation of experiments using an Object-Oriented environment.
- A variety of requirements have also taken into account from heavy ion physics, CP violation physics, cosmic ray physics, astrophysics, space science and medical applications.
- In order to meet such requirements, a large degree of functionality and flexibility are provided.
- G4 is not only for HEP but goes well beyond that.

# Flexibility of Geant4

- In order to meet wide variety of requirements from various application fields, a large degree of functionality and flexibility are provided.
- Geant4 has many types of geometrical descriptions to describe most complicated and realistic geometries
  - CSG, BREP and Boolean solids
  - Placement, replica, divided, parameterized, reflected and grouped
  - XML interface
- Everything is open to the user
  - Choice of physics processes/models
  - Choice of GUI/Visualization/persistency/histogramming technologies

# Physics in Geant4

- It is rather unrealistic to develop a uniform physics model to cover wide variety of particles and/or wide energy range.
- Much wider coverage of physics comes from mixture of theory-driven, parameterized, and empirical formulae. Thanks to polymorphism mechanism, both cross-sections and models (final state generation) can be combined in arbitrary manners into one particular process.
- Geant4 offers
  - EM processes
  - Hadronic processes
  - Photon/lepton-hadron processes
  - Optical photon processes
  - Decay processes
  - Shower parameterization
  - Event biasing techniques
  - And you can plug-in more

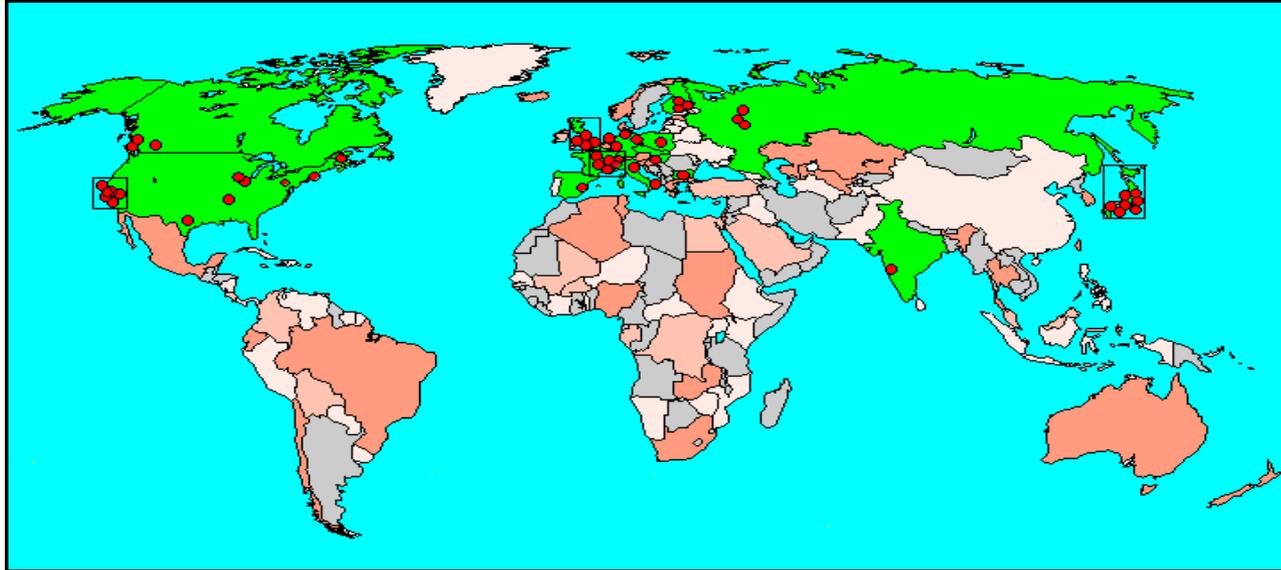
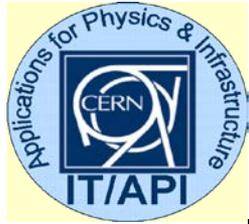
# Physics in Geant4

- Each cross-section table or physics model (final state generation) has its own applicable energy range. Combining more than one tables / models, one physics process can have enough coverage of energy range for wide variety of simulation applications.
- Geant4 provides sets of alternative physics models so that the user can freely choose appropriate models according to the type of his/her application.
  - In other words, it is the user's responsibility to choose reasonable set of physics processes/models that fits to his/her needs.
  - For example, some models are more accurate than others at a sacrifice of speed.

# Geant4 – Its history

- Dec '94 - Project start
- Apr '97 - First alpha release
- Jul '98 - First beta release
- Dec '98 - First Geant4 public release - version 1.0
- ...
- Dec 19<sup>th</sup>, '08 - Geant4 version 9.2 release
  - Feb 19<sup>th</sup>, '10 - Geant4 9.2-patch03 release
- Dec 18<sup>th</sup>, '09 - Geant4 version 9.3 release
  - Sep 24<sup>th</sup>, '10 - Geant4 9.3-patch02 release
- Dec 17<sup>th</sup>, '10 – Geant4 9.4 release
- Dec ,11 – Geant4 9.5 release
- We currently provide one to three public releases every year.
  - Beta releases are also available to the registered beta-testers.

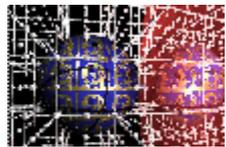
# Geant4 Collaboration



TRIUMF



Lebedev



J.W.Goethe  
Universität



Collaborators also from non-member institutions, including  
Budker Inst. of Physics  
IHEP Protvino  
MEPHI Moscow  
Pittsburg University

# Technology transfer

## Particle physics software aids space and medicine

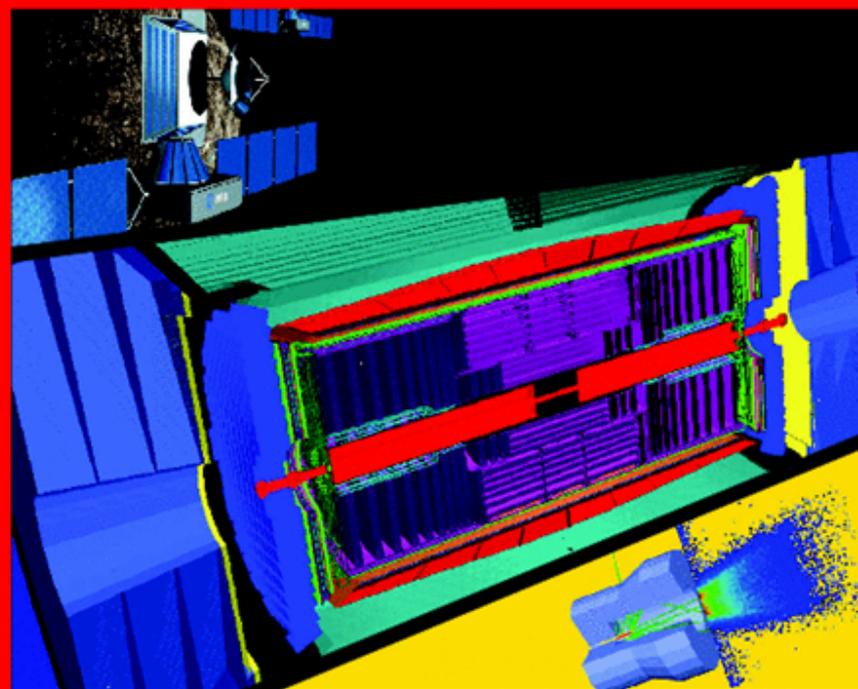
Geant4 is a showcase example of technology transfer from particle physics to other fields such as space and medical science [...].

CERN Courier, June 2002

**Geant 4**



VOLUME 42 NUMBER 5 JUNE 2002



Simulation for physics, space and medicine

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Agostinelli, S.; Allison, J.; Amako, K.; Apostolakis, J.; Araujo, H.; Arce, P.; Asai, M.; Axen, D.; Banerjee, S.; Barrand, G.; Behner, F.; Bellagamba, L.; Boudreau, J.; Broglia, L.; Brunengo, A.; Burk
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## Engineering

(Sorted by citations, 3 of 128)

1 Citations: 133

Title: GEANT4-A SIMULATION TOOLKIT

Authors: AGOSTINELLI S; ALLISON J; AMAKO K; APOSTOLAKIS J; ARAUJO H; ARCE P; ASAI M; AXEN D; BANERJEE S; BARRAND G; BEHNER F; BELLAGAMBA L; BOUDREAU J; BROGLIA L; BRUNENGO A; BURKHARDT H; CHAUVIE S; CHUMA J; CHYTRACEK R; COOPERMAN G; COSMO G; DEGTYARENKO P; DELL'ACQUA A; DEPAOLA G; DIETRICH D; ENAMI R; FELICIELLO A; FERGUSON C; FESEFELDT H; FOLGER G; FOPPIANO F; FORTI A; GARELLI S; GIANI S; GIANNITRAPANI R; GIBIN D; CADENAS JGG; GONZALEZ I; ABRIL GG; GREENIAUS G; GREINER W; GRICHINE V; GROSSHEIM A; GUATELLI S; GUMPLINGER P; HAMATSU R; HASHIMOTO K; HASUI H; HEIKKINEN A; HOWARD A; IVANCHENKO V; JOHNSON A; JONES FW; KALLENBACH J; KANAYA N; KAWABATA M; KAWABATA Y; KAWAGUTI M; KELNER S; KENT P; KIMURA A; KODAMA T; KOKOULIN R; KOSSOV M; KURASHIGE H; LAMANNA E; LAMPEN T; LARA V; LEFEBURE V; LEI F; LIENDL M; LOCKMAN W; LONGO F; MAGNI S; MAIRE M; MEDERNACH E; MINAMIMOTO K; DE FREITAS PM; MORITA Y; MURAKAMI K; NAGAMATU M; NARTALLO R; NIEMINEN P; NISHIMURA T; OHTSUBO K; OKAMURA M; O'NEALE S; OOHATA Y; PAECH K; PERL J; PFEIFFER A; PIA MG; RANJARD F; RYBIN A; SADILOV S; DI SALVO E; SANTIN G; SASAKI T; SAVVAS N; SAWADA Y; SCHERER S; SEIL S; SIROTENKO V; SMITH D; STARKOV N; STOECKER H; SULKIMO J; TAKAHATA M; TANAKA S; TCHERNIAEV E; TEHRANI ES; TROPFANO M; TRUSCOTT P; UINO H; URRAN I; URRAN P; VERDERT M; WALKDEN A; WANDER W; WEBER H; WELLSCH ID;



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(2003) *Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, 506 (3), pp. 250-303.

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Geant4 license

**Geant 4**

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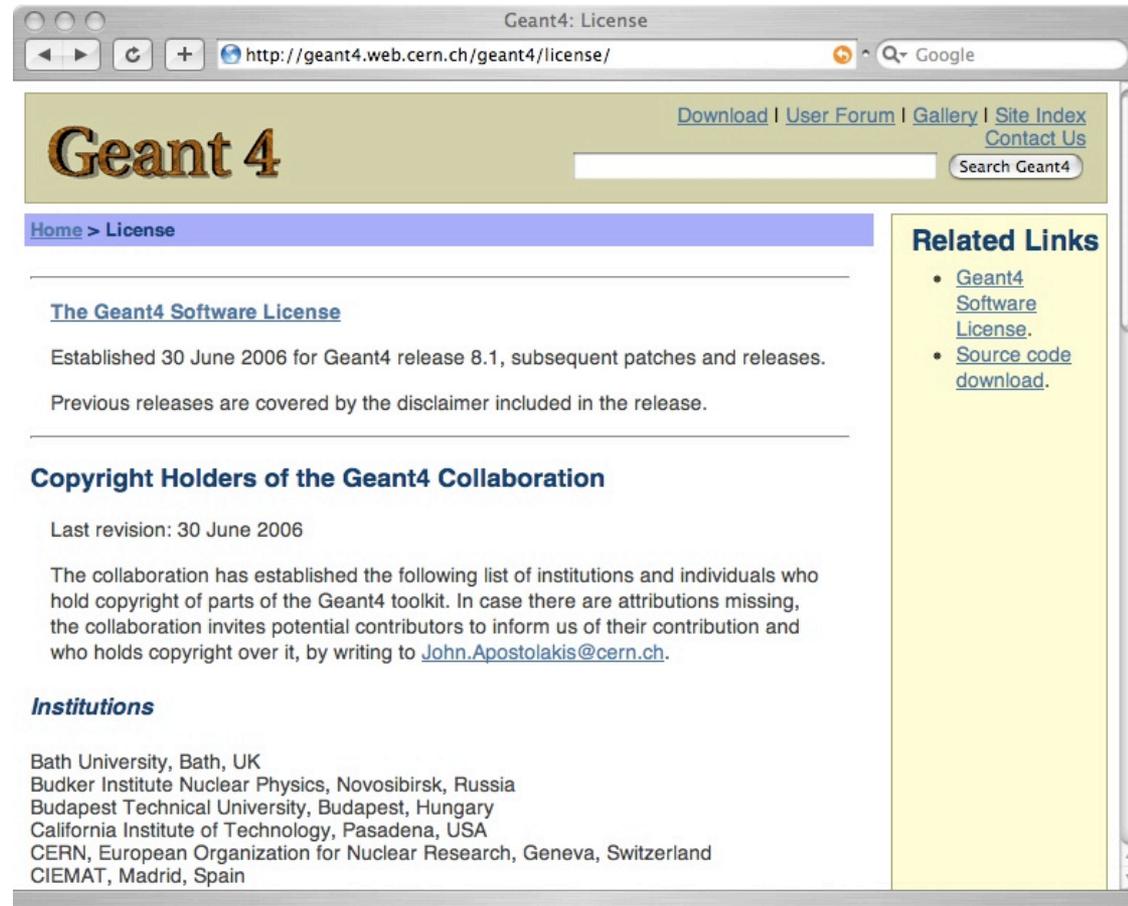
In response to user requests for clarification of Geant4's distribution policy, the collaboration recently announced a new license.

- Makes clear the user's wide-ranging freedom to use, extend or redistribute Geant4, even as part of some for-profit venture.

- The license was released along with the latest Geant4 release 8.1.

- Simple enough that you can read and understand it.

- <http://cern.ch/geant4/license/>



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Basic concepts  
and kernel structure

**Geant 4**

# Terminology (jargons)

- Run, event, track, step, step point
- Track  $\leftrightarrow$  trajectory, step  $\leftrightarrow$  trajectory point
- Process
  - At rest, along step, post step
- Cut = production threshold
- Sensitive detector, score, hit, hits collection,
  - Run: Events correspond to the same beam fill
  - Event: a collision or overlapped collisions some time

# Run in Geant4

- As an analogy of the real experiment, a run of Geant4 starts with “Beam On”.
- Within a run, the user cannot change
  - detector setup
  - settings of physics processes
- Conceptually, a run is a collection of events which share the same detector and physics conditions.
  - A run consists of one event loop.
- At the beginning of a run, geometry is optimized for navigation and cross-section tables are calculated according to materials appear in the geometry and the cut-off values defined.
- **G4RunManager** class manages processing a run, a run is represented by **G4Run** class or a user-defined class derived from G4Run.
  - A run class may have a summary results of the run.
- **G4UserRunAction** is the optional user hook.

# Event in Geant4

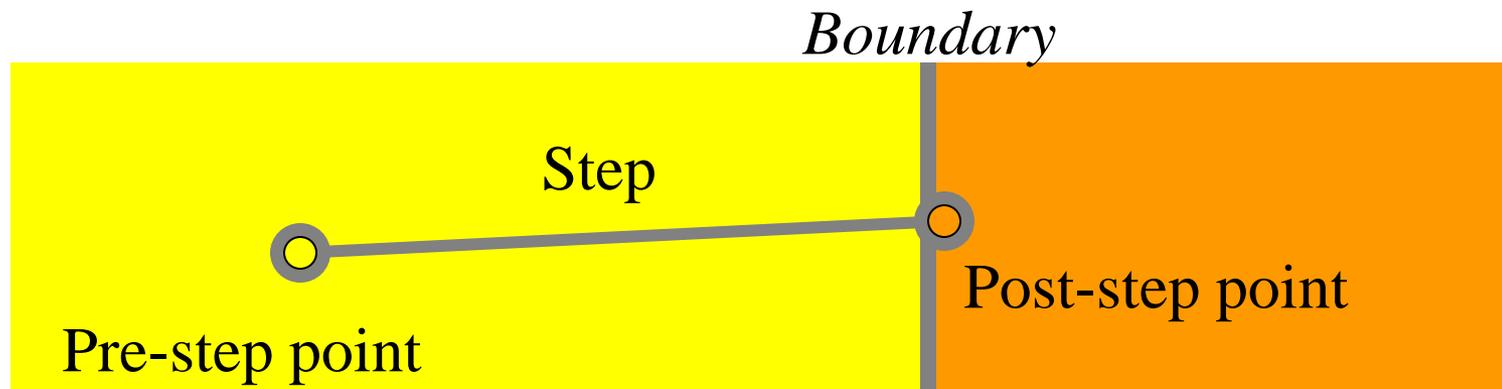
- An event is the basic unit of simulation in Geant4.
- At beginning of processing, primary tracks are generated. These primary tracks are pushed into a stack.
- A track is popped up from the stack one by one and “tracked”. Resulting secondary tracks are pushed into the stack.
  - This “tracking” lasts as long as the stack has a track.
- When the stack becomes empty, processing of one event is over.
- **G4Event** class represents an event. It has following objects at the end of its (successful) processing.
  - List of primary vertices and particles (as input)
  - Hits and Trajectory collections (as output)
- **G4EventManager** class manages processing an event. **G4UserEventAction** is the optional user hook.

# Track in Geant4

- Track is a **snapshot** of a particle.
  - It has physical quantities of **current instance** only. It does not record previous quantities.
  - **Step is a “delta” information to a track. Track is not a collection of steps. Instead, a track is being updated by steps.**
- Track object is deleted when
  - it goes out of the world volume,
  - it disappears (by e.g. decay, inelastic scattering),
  - it goes down to zero kinetic energy and no “AtRest” additional process is required, or
  - the user decides to kill it artificially.
- **No track object persists at the end of event.**
  - For the record of tracks, use trajectory class objects.
- **G4TrackingManager** manages processing a track, a track is represented by **G4Track** class.
- **G4UserTrackingAction** is the optional user hook.

# Step in Geant4

- Step has two points and also “delta” information of a particle (energy loss on the step, time-of-flight spent by the step, etc.).
- Each point knows the volume (and material). In case a step is limited by a volume boundary, the end point physically stands on the boundary, and it **logically belongs to the next volume**.
  - Because one step knows materials of two volumes, boundary processes such as transition radiation or refraction could be simulated.
- **G4SteppingManager** class manages processing a step, a step is represented by **G4Step** class.
- **G4UserSteppingAction** is the optional user hook.



# Trajectory and trajectory point

- Track does not keep its trace. No track object persists at the end of event.
- **G4Trajectory** is the class which copies some of G4Track information.  
**G4TrajectoryPoint** is the class which copies some of G4Step information.
  - G4Trajectory has a vector of G4TrajectoryPoint.
  - At the end of event processing, G4Event has a collection of G4Trajectory objects.
    - /tracking/storeTrajectory must be set to 1.
- Keep in mind the distinction.
  - $G4Track \leftrightarrow G4Trajectory$ ,  $G4Step \leftrightarrow G4TrajectoryPoint$
- Given G4Trajectory and G4TrajectoryPoint objects persist till the end of an event, you should be careful not to store too many trajectories.
  - E.g. avoid for high energy EM shower tracks.
- G4Trajectory and G4TrajectoryPoint store only the minimum information.
  - You can create your own trajectory / trajectory point classes to store information you need. G4VTrajectory and G4VTrajectoryPoint are base classes.

# Particle in Geant4

- A particle in Geant4 is represented by three layers of classes.
- **G4Track**
  - Position, geometrical information, etc.
  - This is a class representing a particle to be tracked.
- **G4DynamicParticle**
  - "Dynamic" physical properties of a particle, such as momentum, energy, spin, etc.
  - Each G4Track object has its own and unique G4DynamicParticle object.
  - This is a class representing an individual particle.
- **G4ParticleDefinition**
  - "Static" properties of a particle, such as charge, mass, life time, decay channels, etc.
  - G4ProcessManager which describes processes involving to the particle
  - All G4DynamicParticle objects of same kind of particle share the same G4ParticleDefinition.

# Tracking and processes

- Geant4 tracking is general.
  - It is independent to
    - the particle type
    - the physics processes involving to a particle
  - It gives the chance to all processes
    - To contribute to determining the step length
    - To contribute any possible changes in physical quantities of the track
    - To generate secondary particles
    - To suggest changes in the state of the track
      - e.g. to suspend, postpone or kill it.

# Processes in Geant4

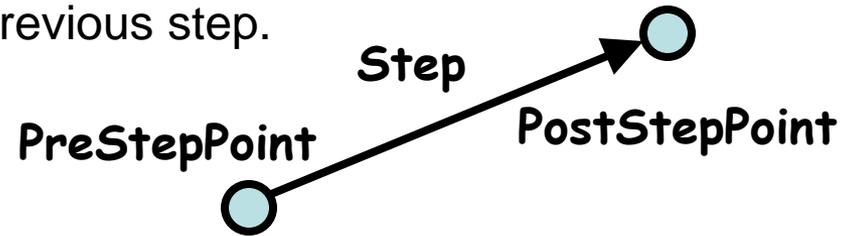
- In Geant4, particle transportation is a process as well, by which a particle interacts with geometrical volume boundaries and field of any kind.
  - Because of this, shower parameterization process can take over from the ordinary transportation without modifying the transportation process.
- Each particle has its own list of applicable processes. At each step, all processes listed are invoked to get proposed physical interaction lengths.
- The process which requires the shortest interaction length (in space-time) limits the step.
- Each process has one or combination of the following natures.
  - AtRest
    - e.g. muon decay at rest
  - AlongStep (a.k.a. continuous process)
    - e.g. Celenkov process
  - PostStep (a.k.a. discrete process)
    - e.g. decay on the fly

# Track status

- At the end of each step, according to the processes involved, the state of a track may be changed.
  - The user can also change the status in **UserSteppingAction**.
  - Statuses shown in **green** are artificial, i.e. Geant4 kernel won't set them, but the user can set.
- fAlive
  - Continue the tracking.
- fStopButAlive
  - The track has come to zero kinetic energy, but still AtRest process to occur.
- fStopAndKill
  - The track has lost its identity because it has decayed, interacted or gone beyond the world boundary.
  - Secondaries will be pushed to the stack.
- **fKillTrackAndSecondaries**
  - Kill the current track and also associated secondaries.
- **fSuspend**
  - Suspend processing of the current track and push it and its secondaries to the stack.
- **fPostponeToNextEvent**
  - Postpone processing of the current track to the next event.
  - Secondaries are still being processed within the current event.

# Step status

- Step status is attached to G4StepPoint to indicate why that particular step was determined.
  - Use “**PostStepPoint**” to get the status of this step.
  - “**PreStepPoint**” has the status of the previous step.
- fWorldBoundary
  - Step reached the world boundary
- fGeomBoundary
  - Step is limited by a volume boundary except the world
- fAtRestDoltProc, fAlongStepDoltProc, fPostStepDoltProc
  - Step is limited by a AtRest, AlongStep or PostStep process
- fUserDefinedLimit
  - Step is limited by the user Step limit
- fExclusivelyForcedProc
  - Step is limited by an exclusively forced (e.g. shower parameterization) process
- fUndefined
  - Step not defined yet
- If you want to identify **the first step in a volume**, pick **fGeomBoundary** status in **PreStepPoint**.
- If you want to identify **a step getting out of a volume**, pick **fGeomBoundary** status in **PostStepPoint**



# Cuts in Geant4

- A Cut in Geant4 is a **production threshold**.
  - Not tracking cut, which does not exist in Geant4 as default.
    - **All tracks are traced down to zero kinetic energy.**
  - It is applied **only** for physics processes that have infrared divergence
- Much detail will be given at later talks on physics.

# Extract useful information

- Given geometry, physics and primary track generation, Geant4 does proper physics simulation “silently”.
  - You have to add a bit of code to **extract information useful to you**.
- There are two ways:
  - Use user hooks (G4UserTrackingAction, G4UserSteppingAction, etc.)
    - You have an access to almost all information
    - Straight-forward, but do-it-yourself
  - Use Geant4 scoring functionality
    - Assign **G4VSensitiveDetector** to a volume
    - **Hits collection** is automatically stored in G4Event object, and automatically accumulated if **user-defined Run** object is used.
    - Use user hooks (G4UserEventAction, G4UserRunAction) to get event / run summary

# Unit system

- Internal unit system used in Geant4 is completely hidden not only from user's code but also from Geant4 source code implementation.

- Each hard-coded number must be multiplied by its proper unit.

```
radius = 10.0 * cm;
```

```
kineticE = 1.0 * GeV;
```

- To get a number, it must be divided by a proper unit.

```
G4cout << eDep / MeV << " [MeV]" << G4endl;
```

- Most of commonly used units are provided and user can add his/her own units.

- By this unit system, source code becomes more readable and importing / exporting physical quantities becomes straightforward.

- For particular application, user can change the internal unit to suitable alternative unit without affecting to the result.

# G4cout, G4cerr

- **G4cout** and **G4cerr** are *ostream* objects defined by Geant4.
  - **G4endl** is also provided.

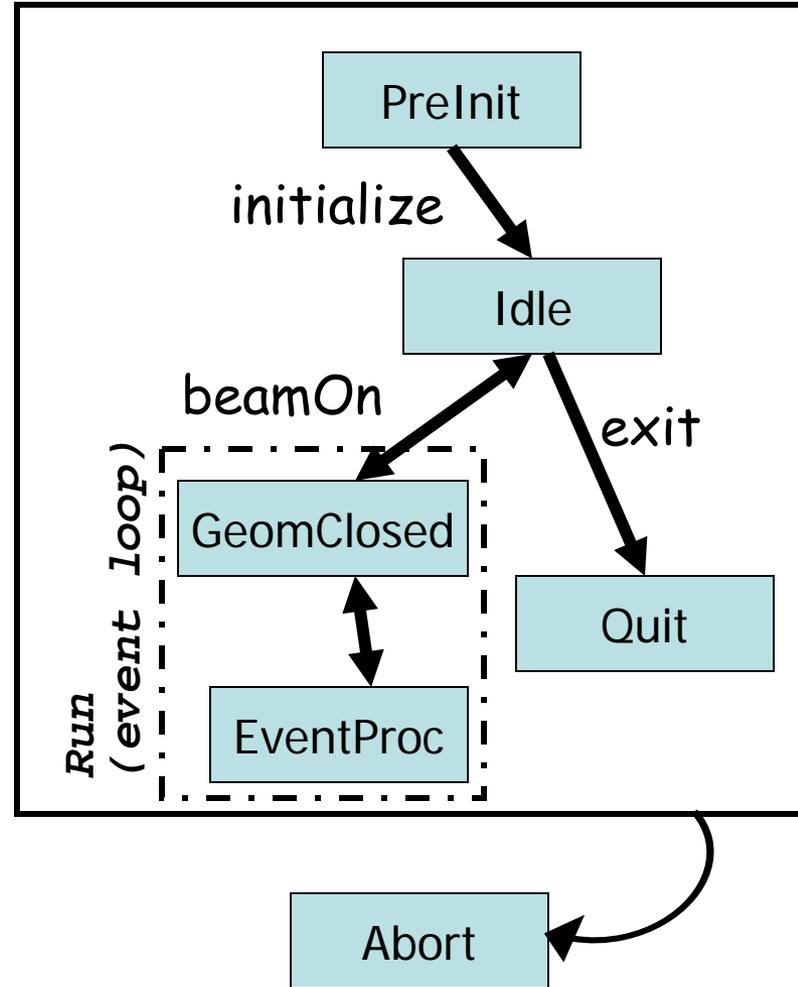
```
G4cout << "Hello Geant4!" << G4endl;
```

- Some GUIs are buffering output streams so that they display print-outs on another window or provide storing / editing functionality.
  - The user should not use `std::cout`, etc.
- The user should not use `std::cin` for input. Use user-defined commands provided by intercoms category in Geant4.
  - Ordinary file I/O is OK.



# Geant4 as a state machine

- Geant4 has six application states.
  - G4State\_PreInit
    - Material, Geometry, Particle and/or Physics Process need to be initialized/defined
  - G4State\_Idle
    - Ready to start a run
  - G4State\_GeomClosed
    - Geometry is optimized and ready to process an event
  - G4State\_EventProc
    - An event is processing
  - G4State\_Quit
    - (Normal) termination
  - G4State\_Abort
    - A fatal exception occurred and program is aborting



User classes

**Geant 4**

# Users of Geant4

- Toolkit provides-> Geant4 developers
- Application Developers
  - “users” of Geant4
    - Develop an application in their problem domain
    - Deep knowledge in the problem domain and physics related
- Application Users
  - Often, not necessary to know about the detail of Geant4

# To use Geant4, you have to...

- Geant4 is a toolkit. You have to build an application.
- To make an application, you have to
  - Define your geometrical setup
    - Material, volume
  - Define physics to get involved
    - Particles, physics processes/models
    - Production thresholds
  - Define how an event starts
    - Primary track generation
  - Extract information useful to you
- You may also want to
  - Visualize geometry, trajectories and physics output
  - Utilize (Graphical) User Interface
  - Define your own UI commands
  - etc.

# User classes

- `main()`
  - Geant4 does not provide *main()*.
- Initialization classes
  - Use `G4RunManager::SetUserInitialization()` to define.
  - Invoked at the initialization
    - `G4VUserDetectorConstruction`
    - `G4VUserPhysicsList`
- Action classes
  - Use `G4RunManager::SetUserAction()` to define.
  - Invoked during an event loop
    - `G4VUserPrimaryGeneratorAction`
    - `G4UserRunAction`
    - `G4UserEventAction`
    - `G4UserStackingAction`
    - `G4UserTrackingAction`
    - `G4UserSteppingAction`

Note : classes written in **red** are mandatory.

# The main program

- Geant4 does not provide the *main()*.
- In your *main()*, you have to
  - Construct G4RunManager (or your derived class)
  - Set user mandatory classes to RunManager
    - G4VUserDetectorConstruction
    - G4VUserPhysicsList
    - G4VUserPrimaryGeneratorAction
- You can define VisManager, (G)UI session, optional user action classes, and/or your persistency manager in your *main()*.

# Describe your detector

- Derive your own concrete class from **G4VUserDetectorConstruction** abstract base class.
- In the virtual method *Construct()*,
  - Instantiate all necessary materials
  - Instantiate volumes of your detector geometry
  - Instantiate your sensitive detector classes and set them to the corresponding logical volumes
- Optionally you can define
  - Regions for any part of your detector
  - Visualization attributes (color, visibility, etc.) of your detector elements

# Select physics processes

- Geant4 does not have any default particles or processes.
  - Even for the particle transportation, you have to define it explicitly.
- Derive your own concrete class from `G4VUserPhysicsList` abstract base class.
  - Define all necessary particles
  - Define all necessary processes and assign them to proper particles
  - Define cut-off ranges applied to the world (and each region)
- Geant4 provides lots of utility classes/methods and examples.
  - "Educated guess" physics lists for defining hadronic processes for various use-cases.

# Generate primary event

- Derive your concrete class from **G4VUserPrimaryGeneratorAction** abstract base class.
- Pass a G4Event object to one or more primary generator concrete class objects which generate primary vertices and primary particles.
- Geant4 provides several generators in addition to the G4VPrimaryParticlegenerator base class.
  - G4ParticleGun
  - G4HEPEvtInterface, G4HepMCInterface
    - Interface to /hepevt/ common block or HepMC class
  - G4GeneralParticleSource
    - Define radioactivity

# Optional user action classes

- All user action classes, methods of which are invoked during “Beam On”, must be constructed in the user’s *main()* and must be set to the RunManager.
- **G4UserRunAction**
  - G4Run\* GenerateRun()
    - Instantiate user-customized run object
  - void BeginOfRunAction(const G4Run\*)
    - Define histograms
  - void EndOfRunAction(const G4Run\*)
    - Analyze the run
    - Store histograms
- **G4UserEventAction**
  - void BeginOfEventAction(const G4Event\*)
    - Event selection
  - void EndOfEventAction(const G4Event\*)
    - Output event information

# Optional user action classes

- **G4UserStackingAction**
  - void PrepareNewEvent()
    - Reset priority control
  - G4ClassificationOfNewTrack ClassifyNewTrack(const G4Track\*)
    - Invoked every time a new track is pushed
    - Classify a new track -- priority control
      - Urgent, Waiting, PostponeToNextEvent, Kill
  - void NewStage()
    - Invoked when the Urgent stack becomes empty
    - Change the classification criteria
    - Event filtering (Event abortion)

# Optional user action classes

- **G4UserTrackingAction**

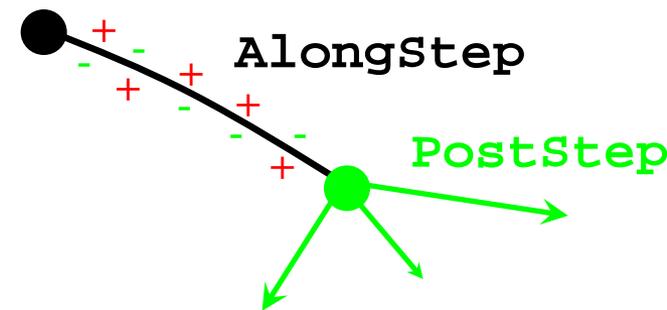
- void PreUserTrackingAction(const G4Track\*)
  - Decide trajectory should be stored or not
  - Create user-defined trajectory
- void PostUserTrackingAction(const G4Track\*)
  - Delete unnecessary trajectory

- **G4UserSteppingAction**

- void UserSteppingAction(const G4Step\*)
  - Kill / suspend / postpone the track
  - Draw the step (for a track not to be stored as a trajectory)

# G4VProcess: 3 kind of actions (1/2)

- Abstract class defining the common interface of **all processes** in Geant4:
  - Used by all « physics » processes
  - but is also used by the transportation, etc...
  - Defined in `source/processes/management`
- Define **three kinds of actions**:
  - **AtRest** actions:  
    - Decay,  $e^+$  annihilation ...
  - **AlongStep** actions:
    - To describe continuous (inter)actions, occurring along the path of the particle, like ionisation;
  - **PostStep** actions:
    - For describing point-like (inter)actions, like decay in flight, hard radiation...



# G4VProcess: 3 kind of actions (2/2)

- A process can implement **any combination** of the three **AtRest**, **AlongStep** and **PostStep** actions:
  - eg: decay = **AtRest** + **PostStep**
- Each action defines **two methods**:
  - **GetPhysicalInteractionLength( )**:
    - Used to **limit the step**:
      - either because the process « triggers » an interaction, a decay
      - or any other reasons, like fraction of energy loss, geometry boundary, user's limit ...
  - **DoIt( )**:
    - Implements the **actual action** to be applied on the track;
    - And the related production of secondaries.

# How the Stepping handles processes

- The stepping treats processes ***generically***:
  - The stepping does not know<sup>(\*)</sup> what processes it is handling;
- The stepping makes the processes to:
  - Cooperate for **AlongStep** actions;
  - Compete for **PostStep** and **AtRest** actions;

<sup>(\*)</sup> almost: some exception for transportation

- Beyond this, for completeness, particular treatments are also possible on process request, which can ask to be
  - **forced**:
    - **PostStepDoIt()** action applied anyway;
      - e.g. transportation to update **G4Track** geom. info
  - **conditionallyForced**:
    - **PostStepDoIt()** applied if **AlongStep** has limited the step;
  - etc ...

# G4VUserDetectorConstruction

```
...  
// $Id: G4VUserDetectorConstruction.hh,v 1.4 2001/07/11 10:08:33 gunter Exp $  
// GEANT4 tag $Name: geant4-08-00-patch-01 $  
//  
  
#ifndef G4VUserDetectorConstruction_h  
#define G4VUserDetectorConstruction_h 1  
  
class G4VPhysicalVolume;  
  
// class description:  
//  
// This is the abstract base class of the user's mandatory initialization class  
// for detector setup. It has only one pure virtual method Construct() which is  
// invoked by G4RunManager when it's Initialize() method is invoked.  
// The Construct() method must return the G4VPhysicalVolume pointer which represents  
// the world volume.  
//  
  
class G4VUserDetectorConstruction  
{  
public:  
    G4VUserDetectorConstruction();  
    virtual ~G4VUserDetectorConstruction();  
  
public:  
    virtual G4VPhysicalVolume* Construct() = 0;  
};  
  
#endif
```

**Construct() should return the pointer of the world physical volume. The world physical volume represents all of your geometry setup.**

# Your detector construction

```
#ifndef MyDetectorConstruction_h
#define MyDetectorConstruction_h 1
#include "G4VUserDetectorConstruction.hh"
class MyDetectorConstruction
    : public G4VUserDetectorConstruction
{
public:
    G4VUserDetectorConstruction();
    virtual ~G4VUserDetectorConstruction();
    virtual G4VPhysicalVolume* Construct();
public:
    // set/get methods if needed
private:
    // granular private methods if needed
    // data members if needed
};
#endif
```

# Describe your detector

- Derive your own concrete class from **G4VUserDetectorConstruction** abstract base class.
- Implement the method Construct()
  - 1) Construct all necessary materials
  - 2) Define shapes/solids
  - 3) Define logical volumes
  - 4) Place volumes of your detector geometry
  - 5) Associate (magnetic) field to geometry (*optional*)
  - 6) Instantiate sensitive detectors / scorers and set them to corresponding volumes (*optional*)
  - 7) Define visualization attributes for the detector elements (*optional*)
  - 8) Define regions (*optional*)
- Set your construction class to G4RunManager
- It is suggested to **modularize** Construct() method w.r.t. each component or sub-detector for easier maintenance of your code.

# Select physics processes

- Geant4 does not have any default particles or processes.
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- Derive your own concrete class from `G4VUserPhysicsList` abstract base class.
  - Define all necessary particles
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  - Kill / suspend / postpone the track
  - Draw the step (for a track not to be stored as a trajectory)

# Let me remind you...

- Define material and geometry
  - G4VUserDetectorConstruction
  - Material and Geometry lectures
- Select appropriate particles and processes and define production threshold(s)
  - G4VUserPhysicsList
  - Physics lectures
- Define the way of primary particle generation
  - G4VUserPrimaryGeneratorAction
  - Primary particle lecture
- Define the way to extract useful information from Geant4
  - G4UserSteppingAction, G4UserTrackingAction, etc.
  - G4VUserDetectorConstruction, G4UserEventAction, G4Run, G4UserRunAction
  - G4SensitiveDetector, G4VHit, G4VHitsCollection
  - Scoring lectures

# Geant4 space users workshop and training course 2011

- Tsukuba, Japan
- December 7-9: Space users workshop
- December 12-14: Training course
  - 3 days lectures and private discussion with developers in parallel
- <http://geant4.kek.jp/G4SUW2011/>