A Geant4 introduction

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Where you can find more material?

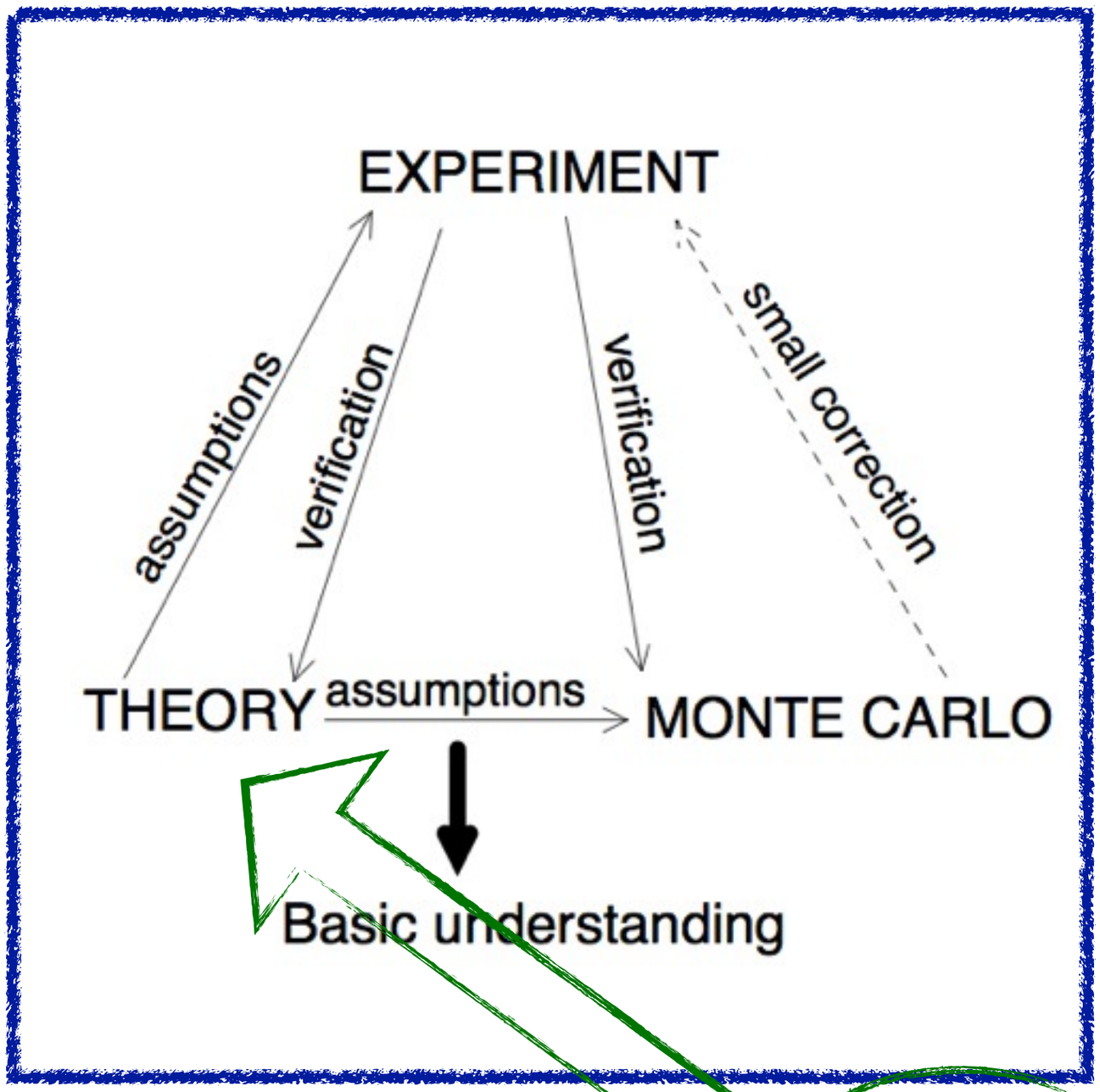
Pablo Cirrone and LNS Group:

- Advanced Examples coordinator
- Low Energy physics Deputy
- Member of the Steering Board

- We (as Geant4 Collaboration and as other Geant4 Members) regularly **offer tutorials and schools** - see Official Geant4 pages
- The official **Geant4 web pages**
  www.cern.ch/geant4
- The **Italian Geant4 group**:
  http://geant4.lngs.infn.it/

Monte Carlo for particle tracking

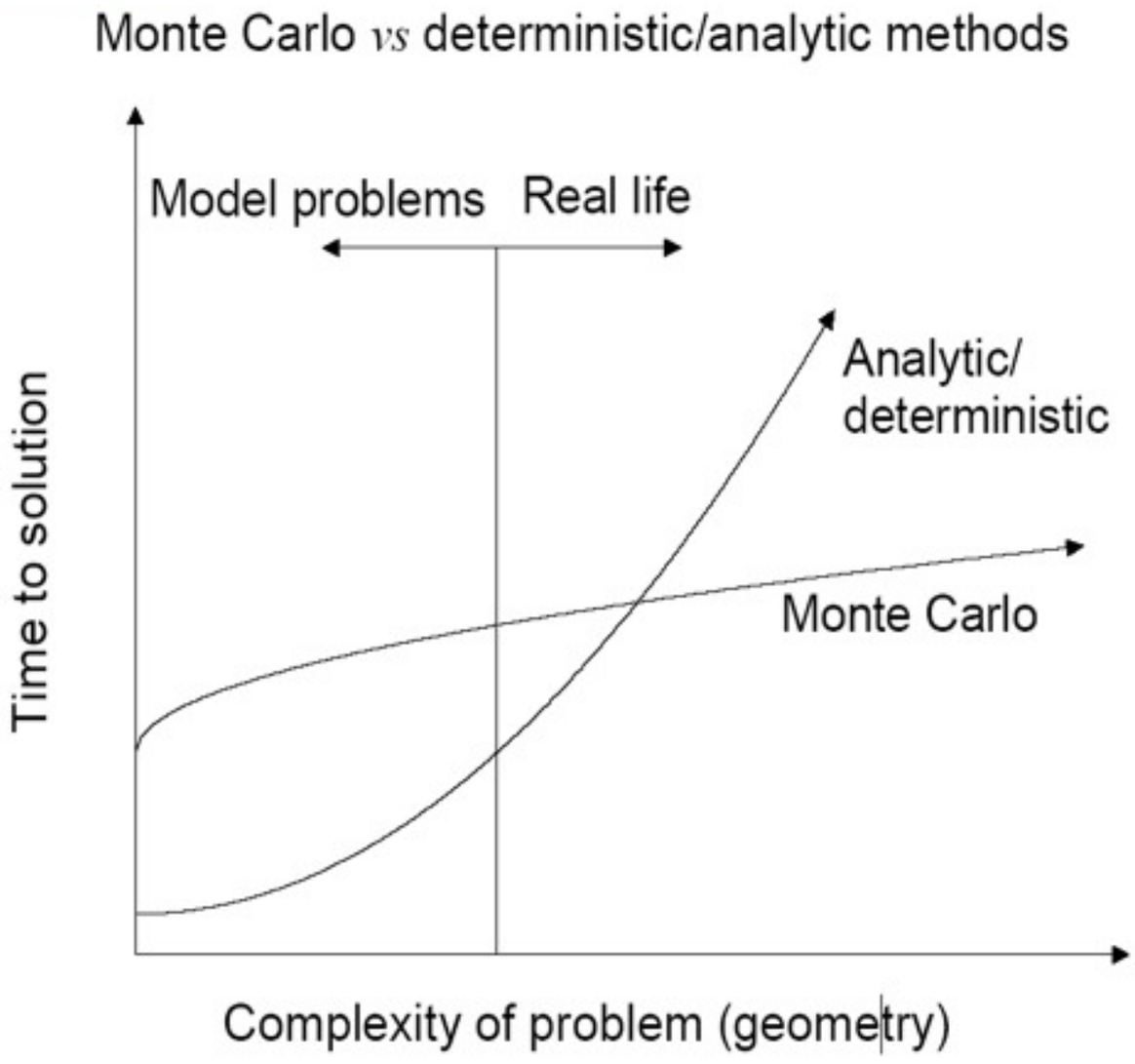
Why Monte Carlo in physics?



- Monte Carlo helps
  - To verify a theory if physics models are in development
  - To develop or verify an experiment in the other case
- Monte Carlo is very time consuming but ... sometime necessary and much more useful than analytic

In particle transport theory is known

The Monte Carlo method



Mathematical proofs exist demonstrating that MC is the most efficient way of estimate quantity in 3D when compared to first-order deterministic method

Plot from Alex F. Bielajew, 2001

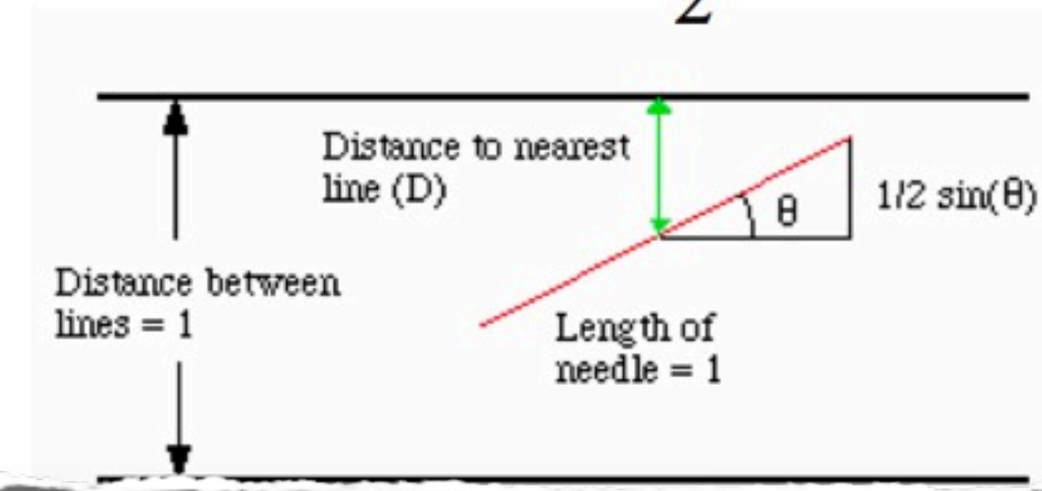
We need a computer for a Monte Carlo calculation?

The Buffon experiment: The Monte Carlo approach for the π estimation

Two variables: θ and D

$$0 \le \vartheta \le \pi$$

$$0 \le D \le \frac{1}{2}$$



Georges Louis Leclerc
Comte de Buffon
(07.09.1707.-16.04.1788.)

The needle will hit the line if the closest distance to a line D is

$$D \le \frac{1}{2}\sin(\vartheta)$$

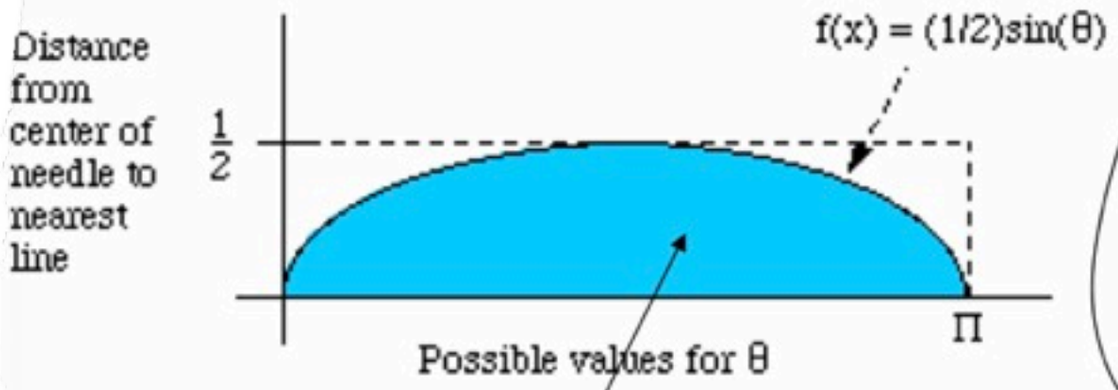
The Buffon experiment: The Monte Carlo approach for the π estimation

The probability of an hit is the ratio of the blue area (S_{blue}) to the entire rectangle R

$$S_{blue} = \int_0^{\pi} \frac{1}{2}\sin(\vartheta) = 1$$

$$R = \frac{1}{2} \cdot \pi$$

$$\frac{S_{blue}}{R} = \frac{2}{\pi}$$



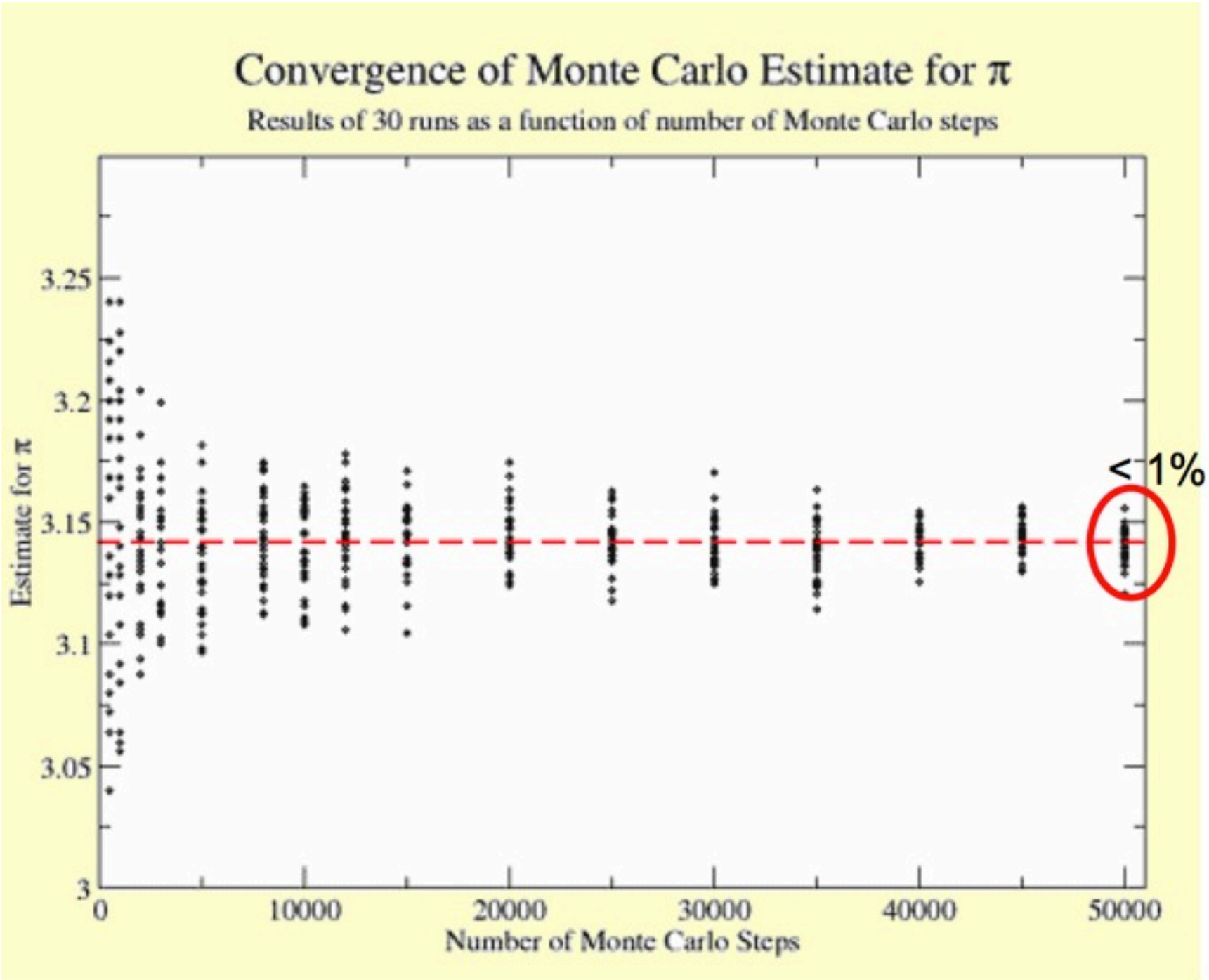
$$D \le \frac{1}{2}\sin(\vartheta)$$

N_0 times the needle was shot

N times the needle hit the line

$$\frac{N}{N_0} = \frac{2}{\pi}; \rightarrow \pi = 2 \cdot \frac{N_0}{N}$$

The Buffon experiment: The Monte Carlo approach for the π estimation



The Monte Carlo origins

JOURNAL OF THE AMERICAN STATISTICAL ASSOCIATION

Number 247 SEPTEMBER 1949 *Volume 44*

THE MONTE CARLO METHOD

NICHOLAS METROPOLIS AND S. ULAM
Los Alamos Laboratory

THE JOURNAL OF CHEMICAL PHYSICS VOLUME 21, NUMBER 6 JUNE, 1953

Equation of State Calculations by Fast Computing Machines

NICHOLAS METROPOLIS, ARIANNA W. ROSENBLUTH, MARSHALL N. ROSENBLUTH, AND AUGUSTA H. TELLER,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico

AND

EDWARD TELLER,* *Department of Physics, University of Chicago, Chicago, Illinois*

(Received March 6, 1953)

Nick Metropolis enjoying a break in the quantum Monte Carlo conference, September 1985.

With MANIAC: the first electronic digital computer

Fermi's work on pion-proton phase shift analysis

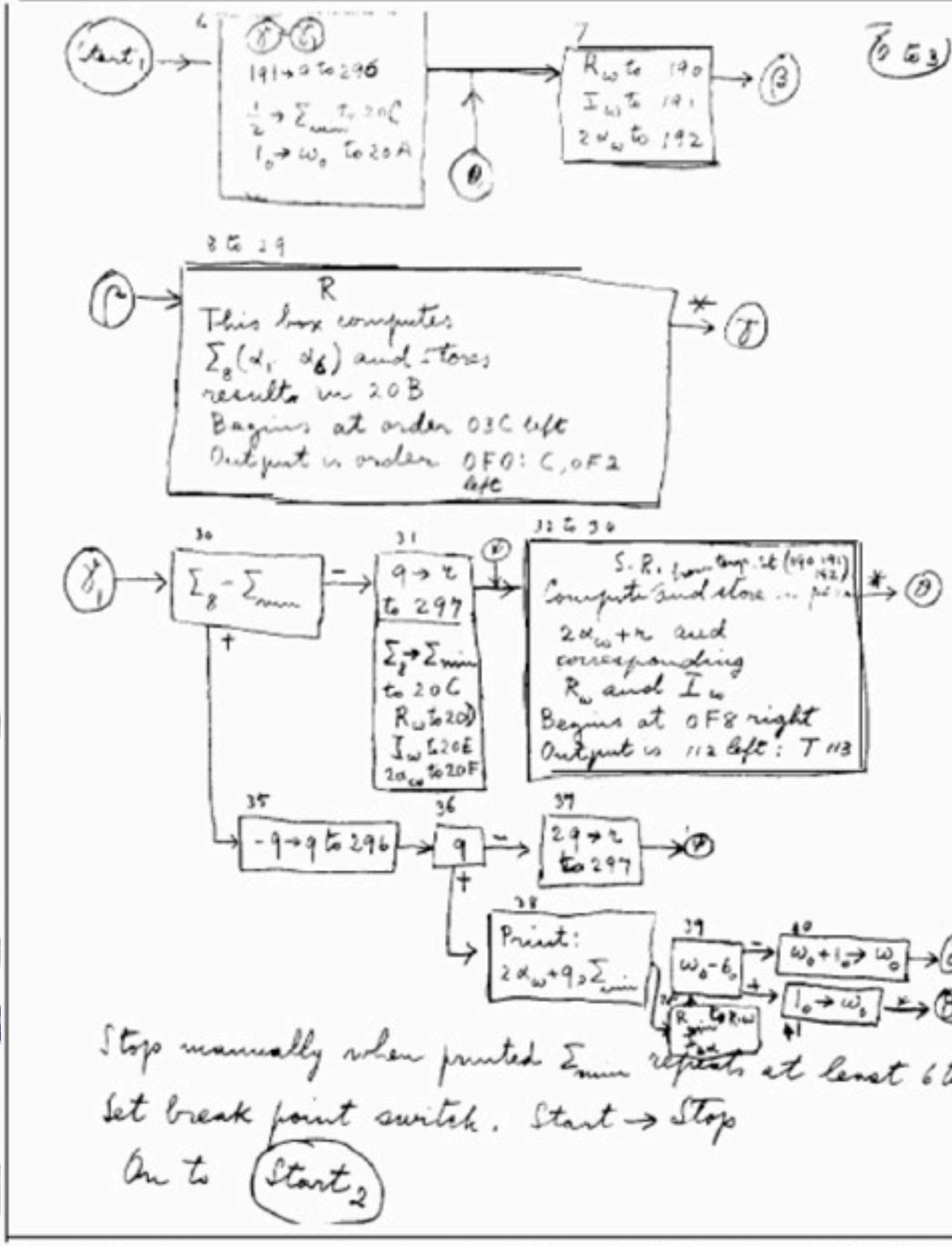
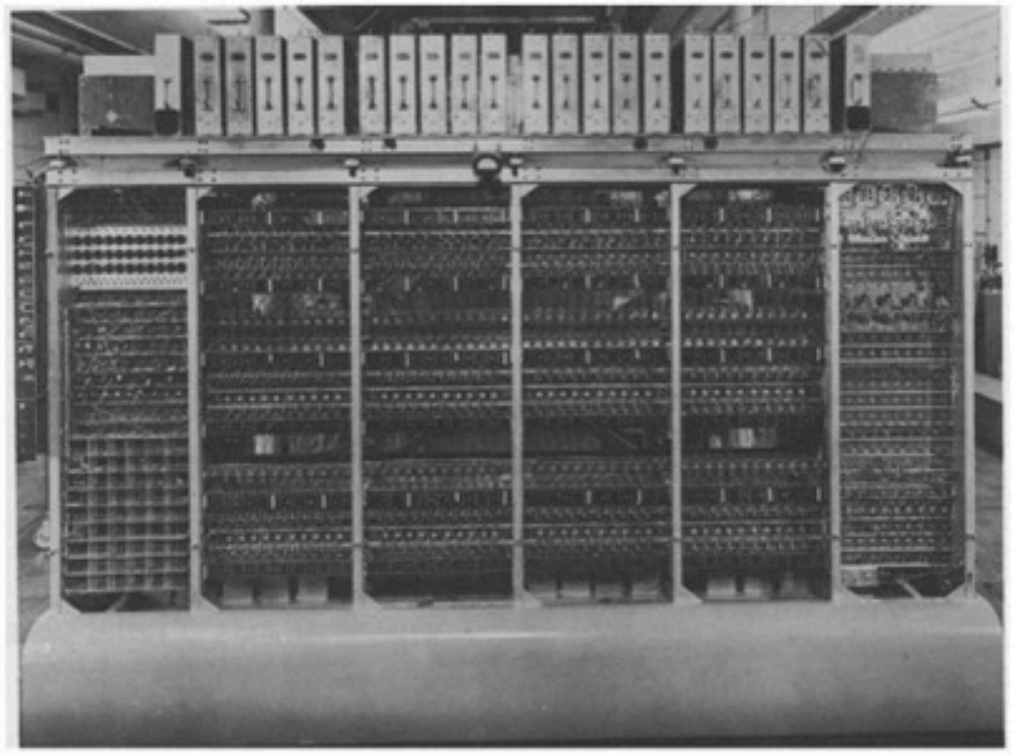


Fig. 4. A subprogram written by Fermi for calculating phase shifts by finding a minimum chi-squared in a fit to the data.



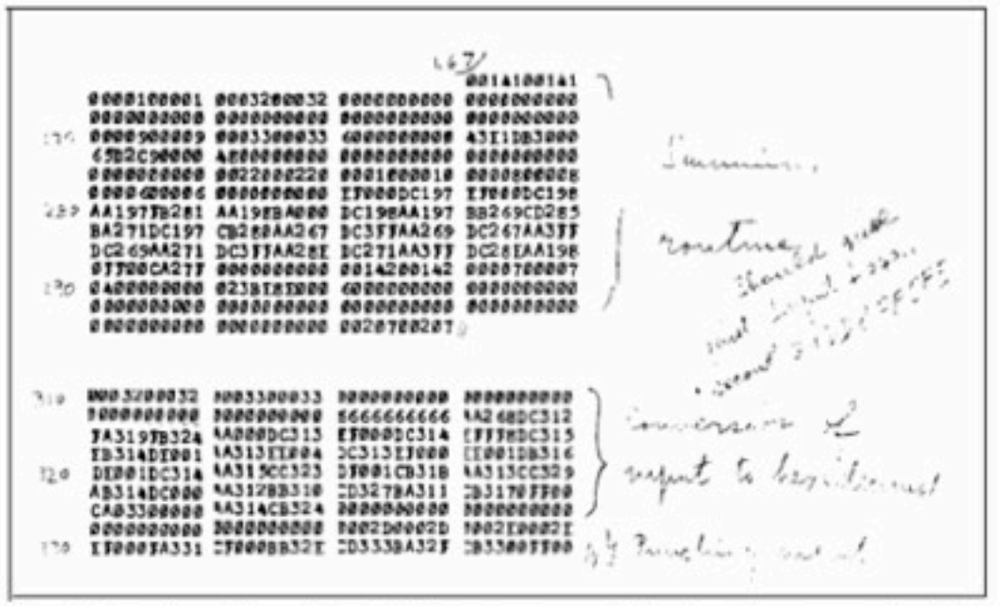


Fig. 5. A portion of the printout of the program containing the subprograms described in Figs. 3 and 4. The program is written in machine language in hexadecimal numbers.

LOS ALAMOS SCIENCE Fall 1986

Monte Carlo codes on the market

- MCNP (neutrons mainly)
- Penelope (e- and gamma)
- PETRA (protons)
- EGSnrc (e- and gammas)
- PHIT (protons/ions)
- FLUKA (any particle)

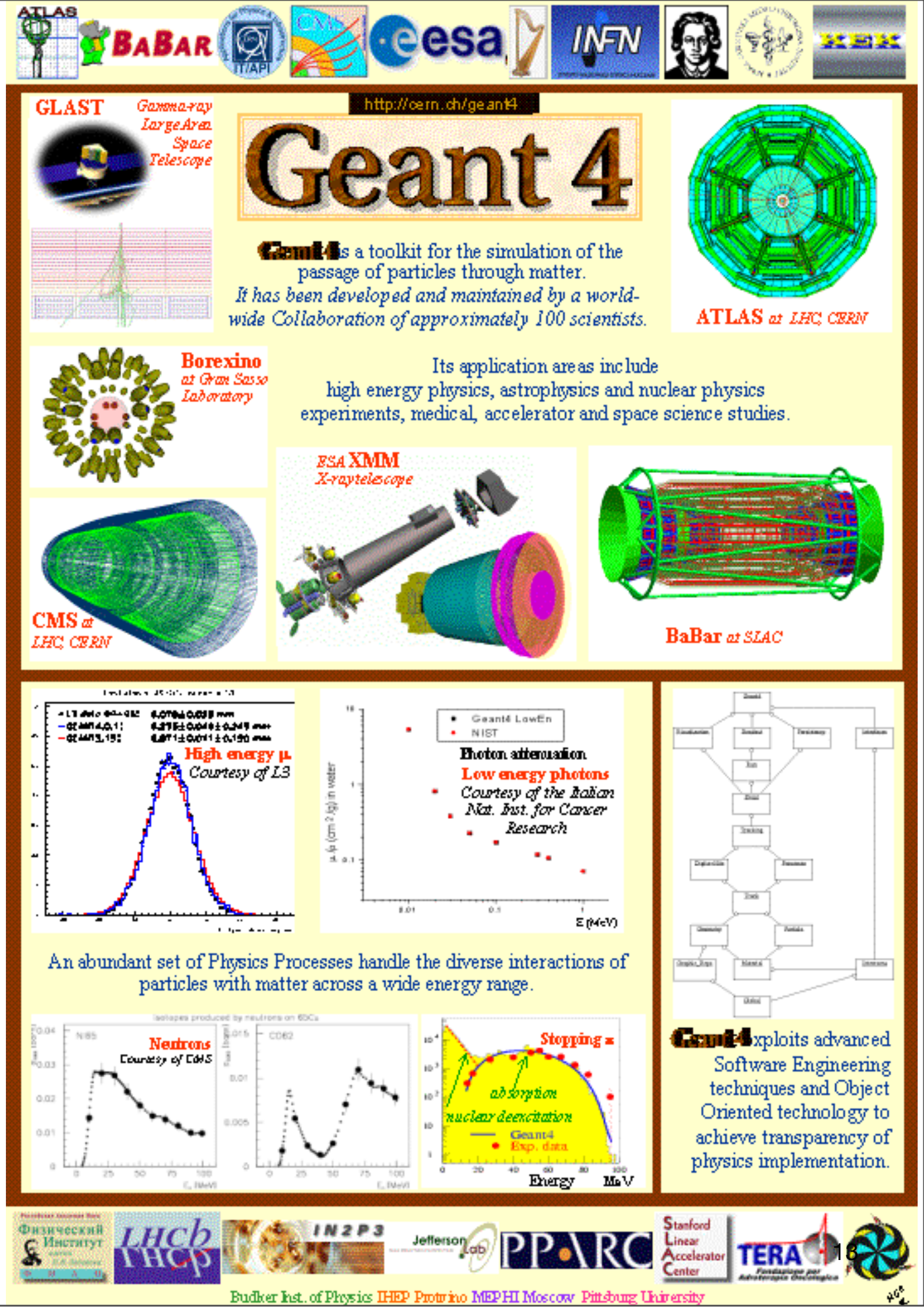
Geant4

- GEometry ANd Traking

- *Geant4 - a simulation toolkit* Nucl. Inst. and Methods Phys. Res. A, 506:250:303

- *Geant4 developments and applications* Transaction on Nuclear Science 53, 270-278

What is Geant4?



What is Geant4?

Geant4

From Wikipedia, the free encyclopedia

For other uses, see Geant (disambiguation).

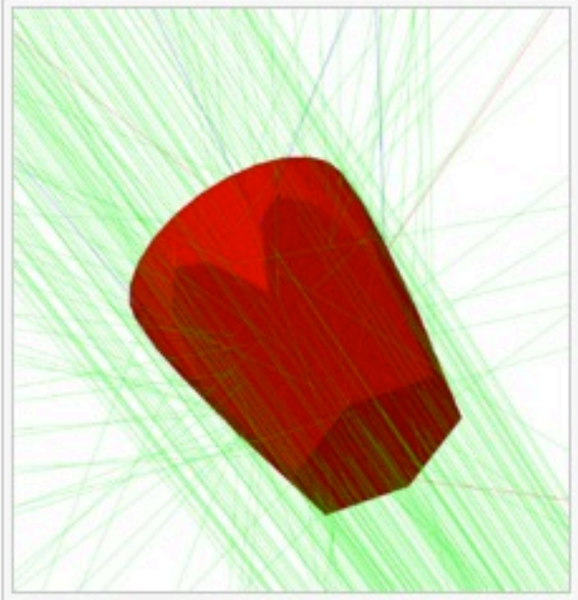
Geant4 [1][2] (for **GEometry ANd Tracking**) is a platform for "the simulation of the passage of particles through matter," using Monte Carlo methods. It is the successor of the GEANT series of software toolkits developed by CERN, and the first to use Object oriented programming (in C++). Its development, maintenance and user support are taken care by the international Geant4 Collaboration. Application areas include high energy physics and nuclear experiments, medical, accelerator and space physics studies. The software is used by a number of research projects around the world.

The Geant4 software and source code is freely available from the project web site; until version 8.1 (released June 30, 2006), no specific software license for its use existed; Geant4 is now provided under the Geant4 Software License.

Geant4

Developer(s)	Geant4 Collaboration
Stable release	9.5 / December 2, 2011; 5 months ago
Operating system	Cross-platform
Type	Computational physics
License	Geant4 Software License
Website	http://geant4.org/

Contents [hide]



Visualisation of a simulation. The detector is red and radiation is green.

Features [edit]

This unreferenced section requires citations to ensure verifiability.

Geant4 includes facilities for handling geometry, tracking, detector response, run management, visualization and user interface. For many physics simulations, this means less time need be spent on the low level details, and researchers can start immediately on the more important aspects of the simulation.

GEANT4: www.cern.ch/Geant4

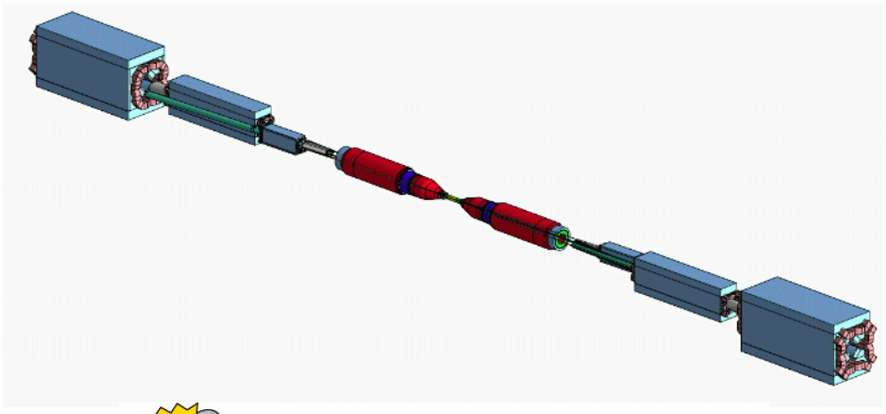
- It is a toolkit, i.e. a **collection of tools** the User can use for his/her simulation
- Consequences:
  - **There are not** such concepts as **"Geant4 defaults"**
  - You **must** provide the necessary the **necessary information** to configure your simulation
  - You must choose the **Geant4 tool** to use
- Guidance: many examples are provided:
  - **Novice examples**: overview of the Geant4 tools
  - **Advanced Examples:** Geant4 tools in real-life applications
- C++ language
- Object Oriented
- Open Source
- One per year released

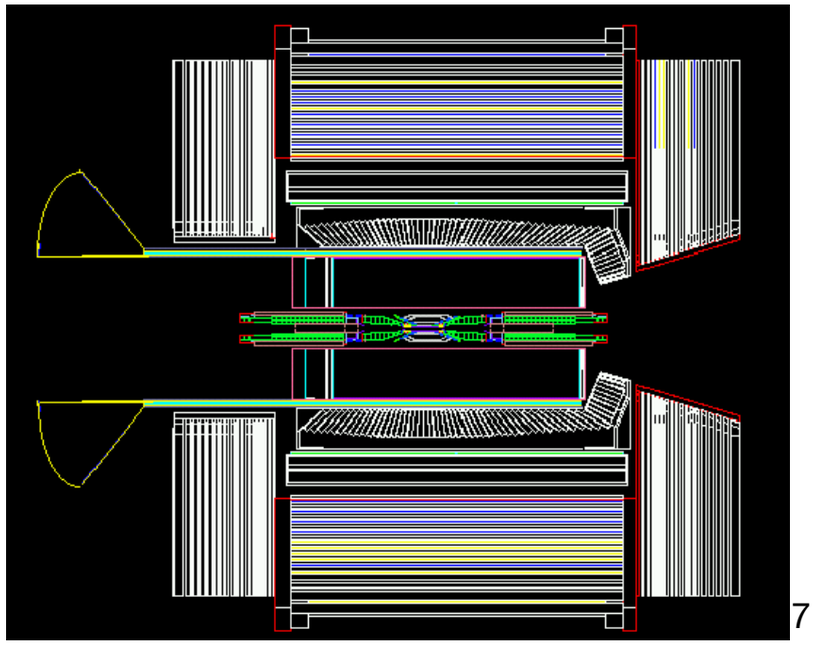
Geant4 - past and present

- **Geant4 started at CHEP 1994 @ San Francisco**
  - "Geant steps into the future", R Brun et al.
  - "Object oriented analysis and design of a Geant based detector simulator", K Amako et al
- **Dec '94 - CERN RD44 project starts**
- Apr '97 - First alpha release
- Jul '98 - First beta release
- Dec '98 - First Geant4 public release - version 1.0
- .....
- Dec 2nd, 2011 - Geant4 9.5 release ← Current version
  - Mar 27th, 2012 - Geant4 9.5-patch01 release
- We currently provide one public release every year

BaBar

- BaBar is the pioneer HEP experiment in use of OO technology and the first customer of Geant4
  - During the R&D phase of Geant4 a lot of evaluable feedbacks were provided
- BaBar started its simulation production in 2000 and had produced more than 10 billion events at more than 20 sites in Europe and North America.

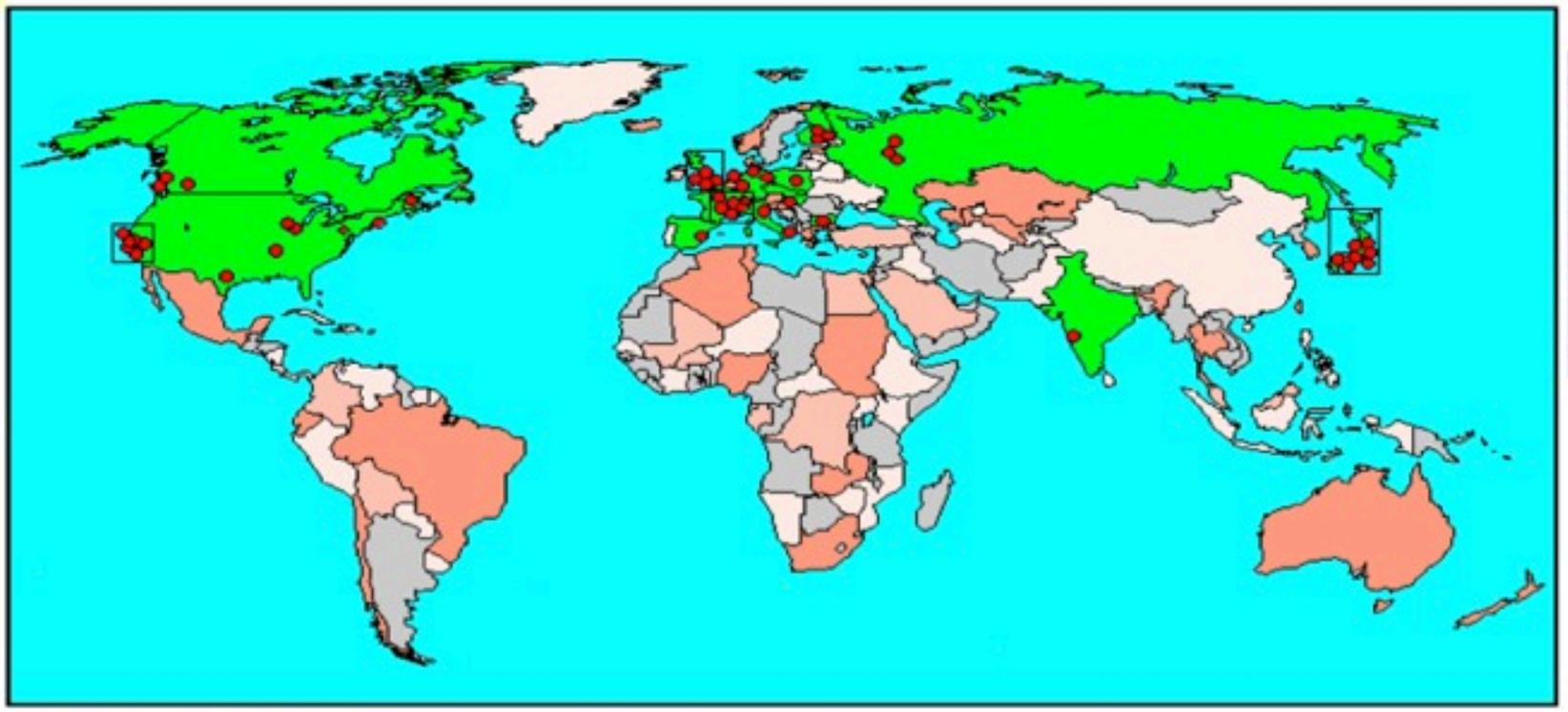




Flexibility of Geant4

- In order to meet the wide variety of requirements from various application fields, a large degree of functionalities and flexibilities are provided
- Geant4 has many types of geometrical tools to describe complicated and realistic geometries
  - CGS, BREP, Boolean solids
  - Placement, replica divided, reflected, grouped ...
  - XML interface
- **Everything is open to the users**
  - Choice of physics processes/models
  - Choice of GUI/Visualisation/histogramming technologies

The Collaboration



TRIUMF

Lebedev

J.W.Goethe Universität

Fermilab

UNIVERSITAT DE BARCELONA

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

Geant4 Homepage

Geant4: A toolkit for the simulation of the passage of particles through matter

http://geant4.cern.ch/

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Geant 4

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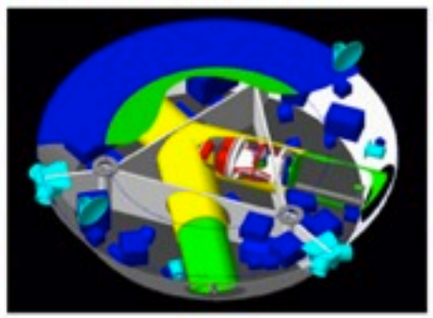
Geant4 is a toolkit for the simulation of the passage of particles through matter. Its areas of application include high energy, nuclear and accelerator physics, as well as studies in medical and space science. The two main reference papers for Geant4 are published in *Nuclear Instruments and Methods in Physics Research* A 506 (2003) 250-303, and *IEEE Transactions on Nuclear Science* 53 No. 1 (2006) 270-278.

Applications

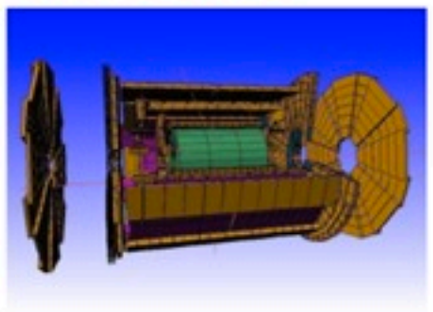
A sampling of applications, technology transfer and other uses of Geant4

User Support



Getting started, guides and information for users and developers

Results & Publications



Validation of Geant4, results from experiments and publications

Collaboration

Who we are: collaborating institutions, members, organization and legal information

News

- *20 April 2012* - **Patch-04** to **release 9.4** is available from the archive download area.
- *27 March 2012* - **Patch-01** to **release 9.5** is available from the download area.
- *8 March 2012* - 2012 planned developments.
- *4 November 2011* - **Geant4-MT prototype 9.4.p01** is available from the download area.

Events

- Geant4 Tutorial at Jefferson Lab, Newport News, Virginia (USA), **9-13 July 2012**.
- 17th Geant4 Collaboration Meeting, Chartres (France), **10-14 September 2012**.
- **Past events**

Top 25 Hottest Articles

http://top25.sciencedirect.com/journal/01689002/

Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment

January to December 2011 full year

RSS Blog This! Print **Show condensed**

1. **Geant4-a simulation toolkit**
   Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 506, Issue 3, July 2003, Pages 250-303
   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.; Coope
   Cited by SciVerse Scopus (3266)
2. **Big-bang nucleosynthesis: A probe of the early Universe**
   Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 611, Issue 2-3, December 2009, Pages 224-230
   Coc, A.
   Cited by SciVerse Scopus (1)
3. **Neutron detection gamma ray sensitivity criteria**
   Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 654, Issue 1, October 2011, Pages 412-416
   Kouzes, R.T.; Ely, J.H.; Lintereur, A.T.; Mace, E.K.; Stephens, D.L.; Woodring, M.L.
4. **Application of PWO crystals for detection of low-activity gamma-radiation in the energy range above 3MeV**
   Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 537, Issue 1-2, January 2005, Pages 439-442
   Drobychev, G.Y.; Baryshevsky, V.G.; Fedorov, A.A.; Khruschinsky, A.A.; Korjik, M.V.; Lecoq, P.; Missevitch, O.V.

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Scholar Articles and patents anytime include citations Create email alert

GEANT4—a simulation toolkit [PDF] from kobe-u.ac.jp
S Agostinelli, J Allison, K Amako... - Nuclear Instruments and ..., 2003 - Elsevier
Geant4 is a toolkit for simulating the passage of particles through matter. It includes a complete range of functionality including tracking, geometry, physics models and hits. The physics processes offered cover a comprehensive range, including electromagnetic, ...
Cited by 5000 - Related articles - All 29 versions

Geant4 developments and applications [PDF] from neu.edu
J Allison, K Amako, J Apostolakis... - Nuclear Science, ..., 2006 - ieeexplore.ieee.org
Abstract **Geant4** is a software toolkit for the simulation of the passage of particles through matter. It is used by a large number of experiments and projects in a variety of application domains, including high energy physics, astrophysics and space science, medical physics ...
Cited by 929 - Related articles - BL Direct - All 16 versions

[CITATION] **Geant4**: a simulation toolkit
J **Geant4** Collaboration - Nucl. Instr. and Methods A, 2003
Cited by 70 - Related articles

Geant4 low energy electromagnetic physics [PDF] from infn.it
S Chauvie, S Guatelli, V Ivanchenko... - ... Record, 2004 IEEE, 2004 - ieeexplore.ieee.org
Abstract The **Geant4** simulation toolkit includes a specialised package, implementing a precise treatment of electromagnetic interactions of particles with matter below 1 keV. The **Geant4** low energy electromagnetic package provides a variety of models describing the ...
Cited by 98 - Related articles - All 7 versions

GATE: A **Geant4**-based simulation platform for PET and SPECT integrating movement and time management [RTF] from ciemat.es
G Santin, D Strul, D Lazaro, L Simon... - Nuclear Science, ..., 2003 - ieeexplore.ieee.org
Abstract GATE, the **Geant4** application for tomographic emission, is a simulation platform developed for PET and SPECT. It combines a powerful simulation core, the **Geant4** toolkit, with newly developed software components dedicated to nuclear medicine. In particular, it ...
Cited by 92 - Related articles - BL Direct - All 11 versions

Basic principles and capabilities and the KERNEL

Main Geant4 capabilities

- Transportation of a particle 'step-by-step' taking into account all the possible interactions with materials and fields

- **The transport ends if the particle**
  - reaches a zero kinetic energy
  - disappears in some interaction
  - reaches the end of the simulation volume

Geant4: basic concepts

- What you MUST do:
  - Describe your **experimental set-up**
  - Provide the **primary particles** input to your simulation
  - Decide which **particles** and **physics models** you want to use out of those available in Geant4 and the precision of your simulation (cuts to produce and track secondary particles)
- You MAY ALSO WANT:
  - To interact with the Geant4 kernel to **control** your simulation
  - To **visualise** your simulation set-up and particles
  - To produce **histograms, tuples**, etc. to be further analysed

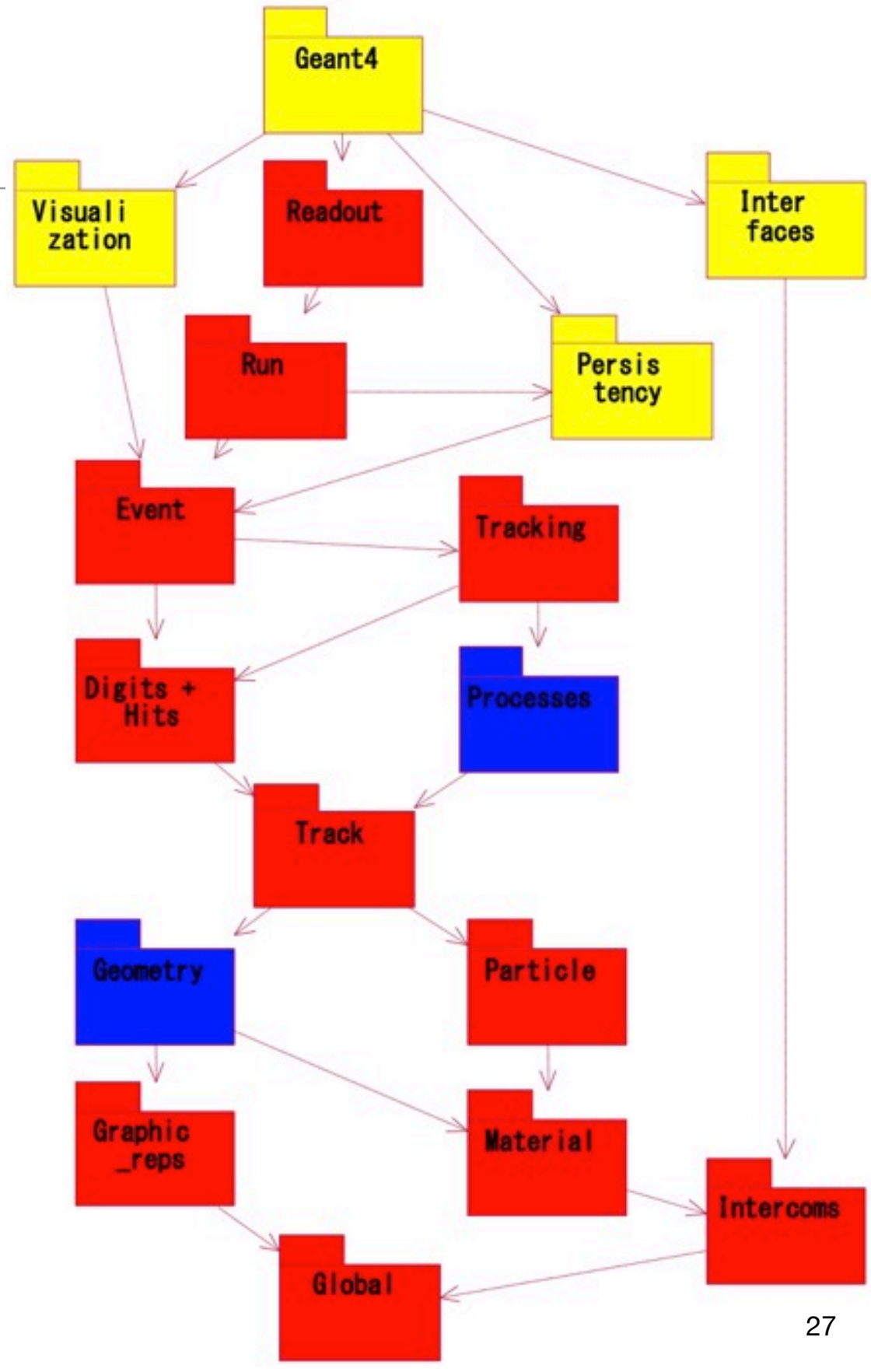
Terminology

- Step - the smallest unit of a Geant4 simulation:
  a particle is transported from one point to another
- Trajectory and Trajectory Point - collection of steps and step points
- Process - the physics that happens along a step
- Track - a snapshot of a particle at some point along the path
  (not the same as trajectory)
- Event - a collection of info from tracks and particle trajectories
- Run - a collection of events

Step -> Track -> Event -> Run

Geant4 Kernel

- Geant4 consists of 17 categories
  - Independently developed and maintained by WGs responsible to each category
- Geant4 Kernel handles
  - Run, event, track, step, hit, trajectory
  - Provide frameworks for the geometry and physics processes



Run in Geant4

- As an analogy with a real experiment, a run of geant4 starts with '/run/BeamOn' command

- Within a Run, the user cannot change

  - the detector

  - the setting of the physics processes

- A Run is a collection of Events

- At the beginning of a run geometry and cross-sections tables are calculated

- The G4RunManager class manages processing a run. A run is represented by the G4Run class that contains the summary of the run eventually passed to the G4UserRunAction User class

The Event

- G4Event class represents an event
  - It has e.g. primary vertex of particles
- The G4EventManager class manages processing an event and the G4UserEventAction is the optional User hook

The Track

- A track is a snapshot of a particle
  - It has physical quantities of current instance only and not record previous quantities
- The G4Track object is deleted when
  - it goes out of the world
  - it disappears (decays? inelastic scatt ?)
  - it goes down to zero Kin and no AtRest process is required
  - the user decides to kill it
- G4TrackingManager manages a Track and the G4UserTrackingAction is the User optional hook

The Track

- The Track status
  - fAlive - continue to be tracking
  - fStopButAlive - Zero Kin but an AtRest process will occur
  - fStopAndKill - the track has (e.g.) decayed but secondary still are tracked
  - fKillTrackAndSecondaries - kill the current track and secondaries
  - fSuspend - suspend the current track and push it and secondaries to the stack
  - fPostponeToNextEvent - postpone the processing of the current track to the next event

The Step

- Step has two points and also 'delta' information of a particle (energy loss, TOF in the step)
- It is represented by the G4Step and G4StepPoint classes
- 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 but logically belongs to the next volume
  - As one step knows materials of two volumes, boundary processes such as transition radiation or refraction could be simulated
- G4SteppingManager class manages a step
- G4UserSteppingAction is the optional hook

The Physics, of course

The Philosophy

- **G4VPhysicsList.cc**

- Provide a **general model framework** that allows implementation of processes and models

- Separate models and cross sections implement processes

  - **MULTIPLE MODELS FOR THE SAME PROCESS**

- Provide processes containing

  - Many possible models and cross sections

  - Default cross sections for each model

Models under continuous development

The Physics

- Different levels of complexity for its implementation

  - You can work at code level (Error prone)

  - You can use 'Builders' (process-related)

  - You can use 'Reference Physics Lists' (complete package of Physics)

Case 1 - Physics at code level

- Example

```
class MyPhysicsList: public G4VUserPhysicsList {
public:
MyPhysicsList();
~MyPhysicsList();
void ConstructParticle();
void ConstructProcess();
void SetCuts();
}
```

```
G4ProcessManager* pmanager
if ( particleName == "gamma"  )
{
  pmanager->AddDiscreteProcess(new G4PhotoElectricEffect);
  pmanager->AddDiscreteProcess(new G4ComptonScattering);
  pmanager->AddDiscreteProcess(new G4GammaConversion);
  pmanager->AddDiscreteProcess(new G4RayleighScattering);
}
```

Case 2 - Physics with 'Builders'

G4EmStandardPhysics – default
G4EmStandardPhysics_option1 – HEP fast but not precise
G4EmStandardPhysics_option2 – Experimental
G4EmStandardPhysics_option3 – medical, space

G4EmLivermorePhysics
G4EmLivermorePolarizedPhysics
G4EmPenelopePhysics
G4EmDNAPhysics

Combined Physics
Standard > 1 GeV
LowEnergy < 1 GeV

- **`$G4INSTALL/source/physics_list/builders`**
- Advantage of using of these classes – they are tested on regular basis and are used for regular validation

Case 2 - Physics with 'Builders'

In your PhysicsList.cc file

```
if (name == "standard_opt3") {
    emName = name;
    delete emPhysicsList;
    emPhysicsList = new G4EmStandardPhysics_option3();

} else if (name == "LowE_Livermore") {
  emName = name;
  delete emPhysicsList;
  emPhysicsList = new G4EmLivermorePhysics();

} else if (name == "LowE_Penelope") {
  emName = name;
  delete emPhysicsList;
  emPhysicsList = new G4EmPenelopePhysics();
```

Case 3 - Reference Physics List

- Can be called inside the PhysicsLists.cc
- Or in the main file: in this case the PhysicsLists.c can be skipped

- **Full set of physics:**
  - Shielding
  - Hadrontherapy (next future)
  - Many other divided by application field

Case 3 - Reference Physics List

Reference Physics Lists
$G4INSTALL/source/
physics_lists/lists

In your main

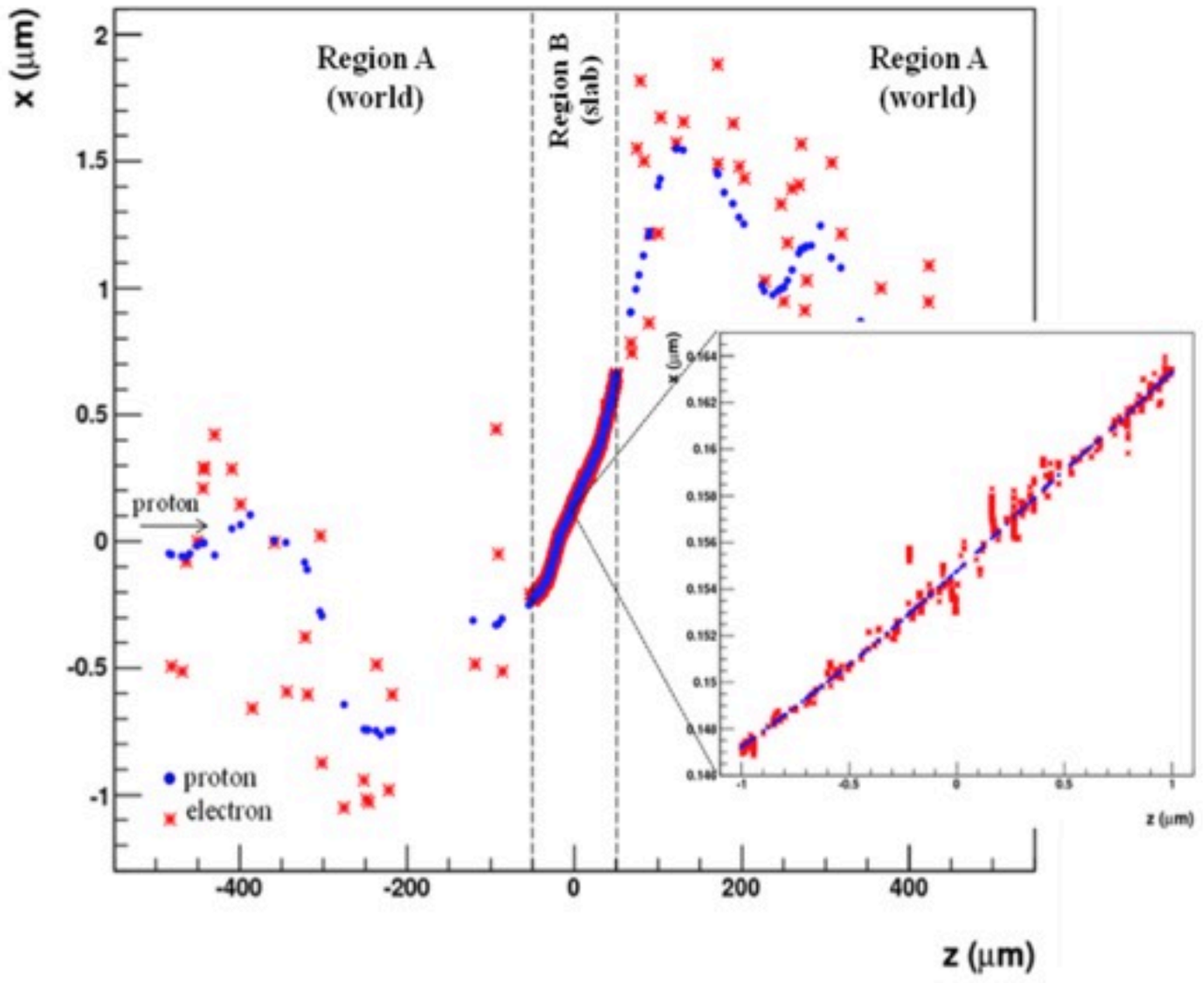
```
include <QGSP_BERT.hh>

int main(int,char**)
{
//....
   runManager->SetUserInitialization( new QGSP_BERT );
}

OR

#include <G4PhysListFactory.hh>
int main(int,char**)
{
//....
 G4PhysListFactory factory;
 G4VModularPhysicsList* physList = factory.ReferencePhysList();
 runManager->SetUserInitialization( physList );
}
```

What physics is provided

- **Electromagnetic**
  - "Standard" processes valid from 1 keV to PeV
  - "Low-Energy" from 250 eV to PeV
  - Optical photons
- **Weak physics**
  - Decay of subatomic particles
  - radioactive decay of nuclei
- **Hadronic physics**
  - Pure hadronic processes valid from 0 to TeV
  - Electro- and gamma- nuclear valid from 10 MeV to TeV
- **Parameterized or 'fast simulation' physics**

Physics flexibility

- Different models, for different particles, for different energy ranges and also ...
- ... for different regions



e.g. DNA models are enabled only for small G4region and below 10 MeV

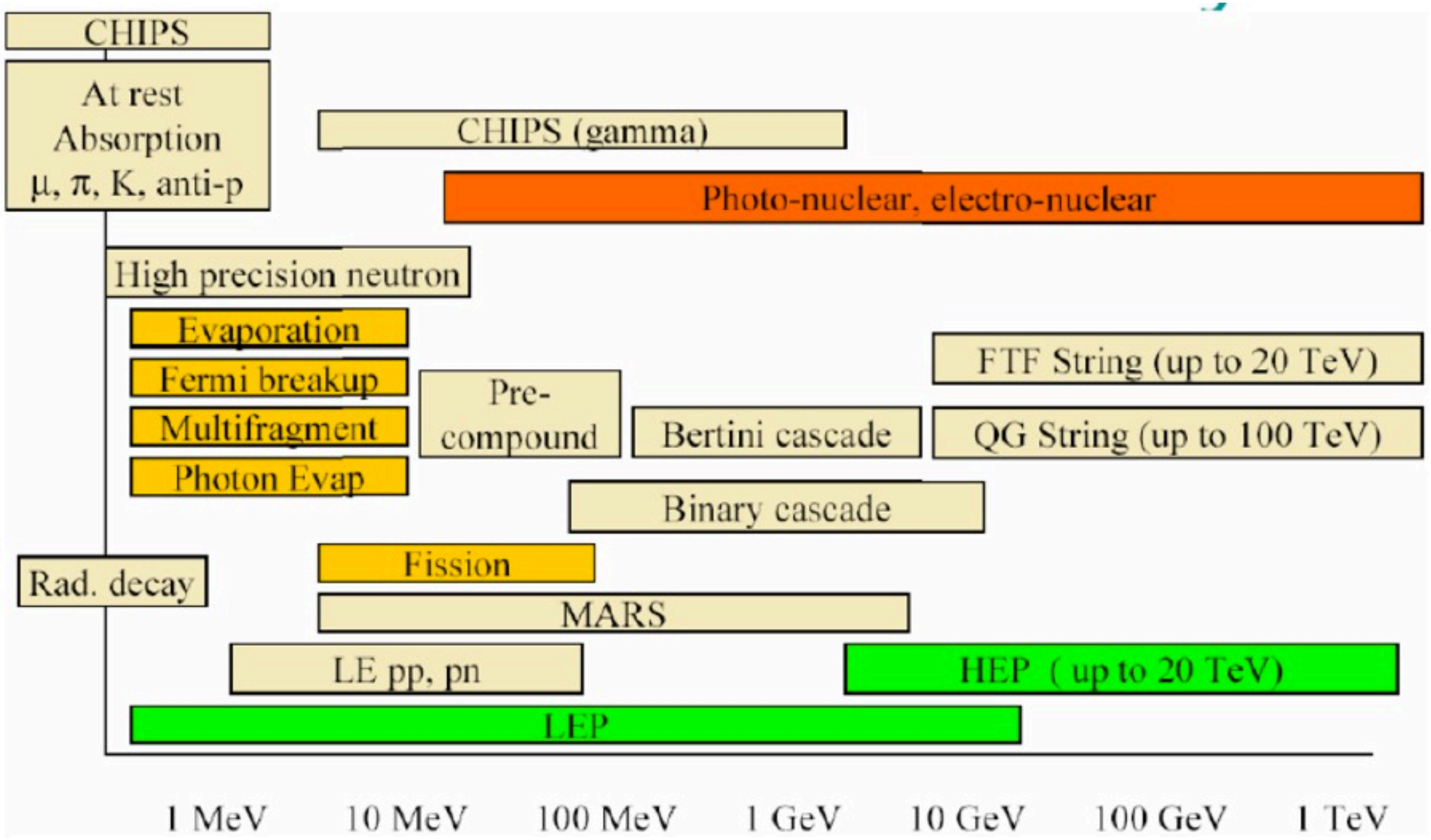
Physics can be extracted

- A nice feature of Geant4 is that is possible to retrieve Physics quantities using a G4EMCalculator object
  - Cross sections
  - Stopping powers
- **A good example**
  - $G4INSTALL/examples/extended/electromagnetic/TestEm14

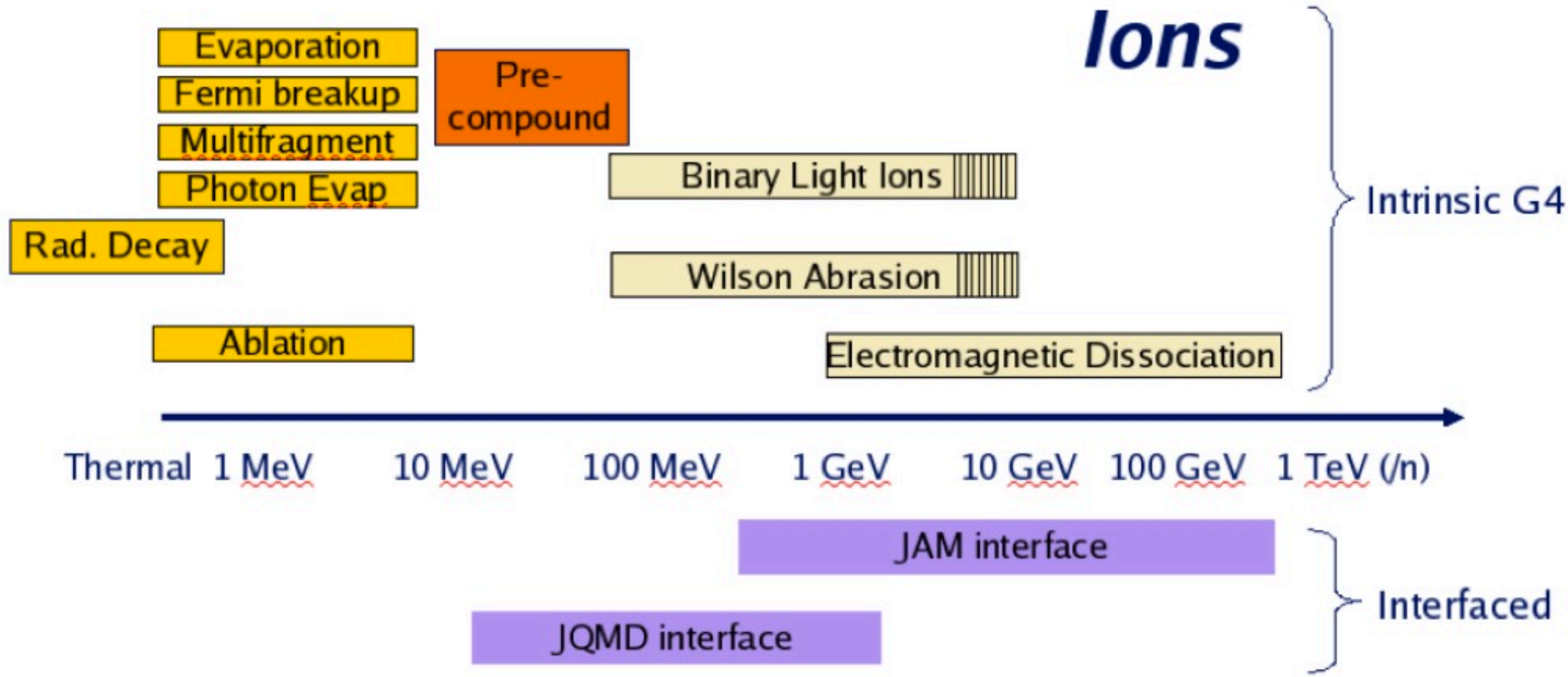
Physics: the example of the Low-Energy models

sics cess	Process Class	Model Class	Low Energy Limit	High Energy Limit
	G4ComptonScattering	G4LivermoreComptonModel	250 eV	100 GeV
Compton	G4ComptonScattering	G4LivermorePolarizedComptonModel	250 eV	100 GeV
	G4RayleighScattering	G4LivermoreRayleighModel	250 eV	100 GeV
Rayleigh	G4RayleighScattering	G4LivermorePolarizedRayleighModel	250 eV	100 GeV
n	G4GammaConversion	G4LivermoreGammaConversionModel	1.022 MeV	100 GeV
n	G4GammaConversion	G4LivermorePolarizedGammaConversionModel	1.022 MeV	100 GeV
ctric	G4PhotoElectricEffect	G4LivermorePhotoElectricModel	250 eV	100 GeV
ctric	G4PhotoElectricEffect	G4LivermorePolarizedPhotoElectricModel	250 eV	100 GeV
s				
	G4eIonisation	G4LivermoreIonisationModel	250 eV	100 GeV
hlung	G4eBremsstrahlung	G4LivermoreBremsstrahlungModel	250 eV	100 GeV

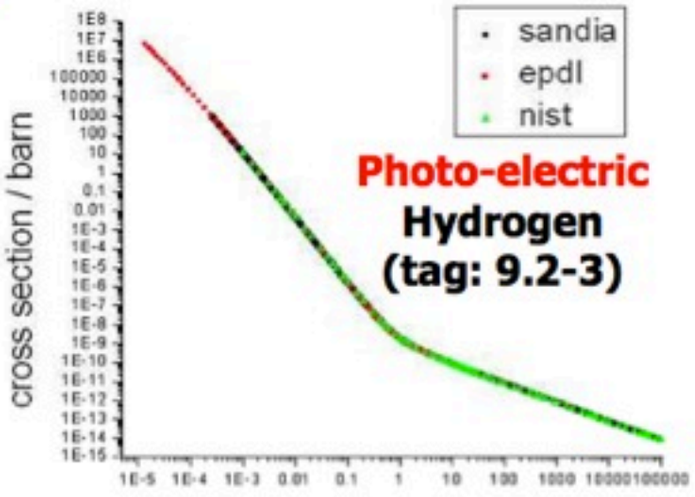
Hadronic model inventor

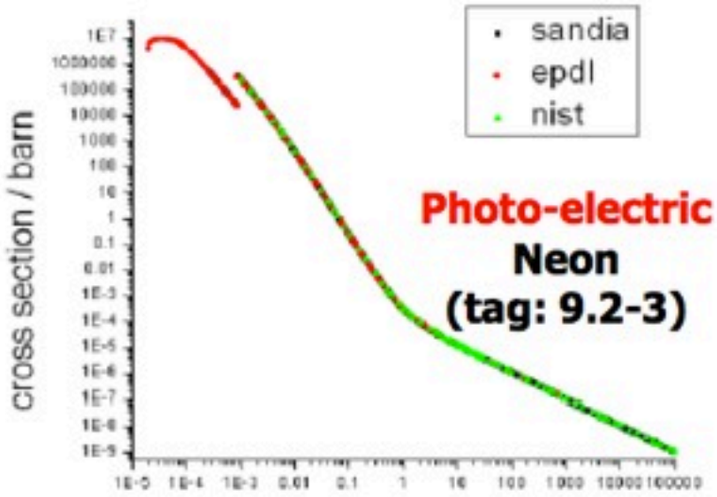


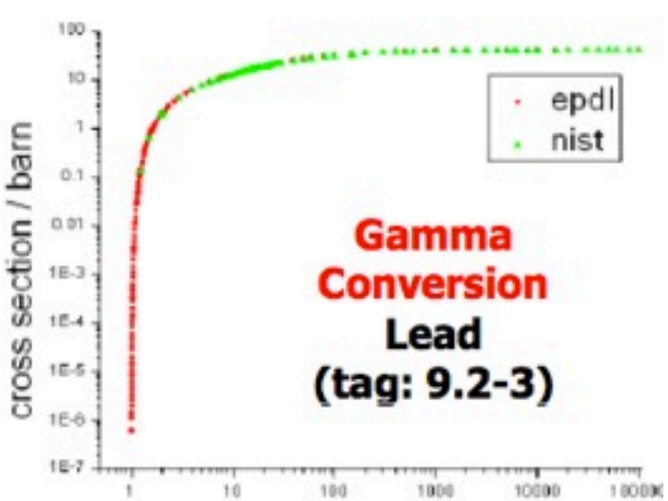
Ion models inventor

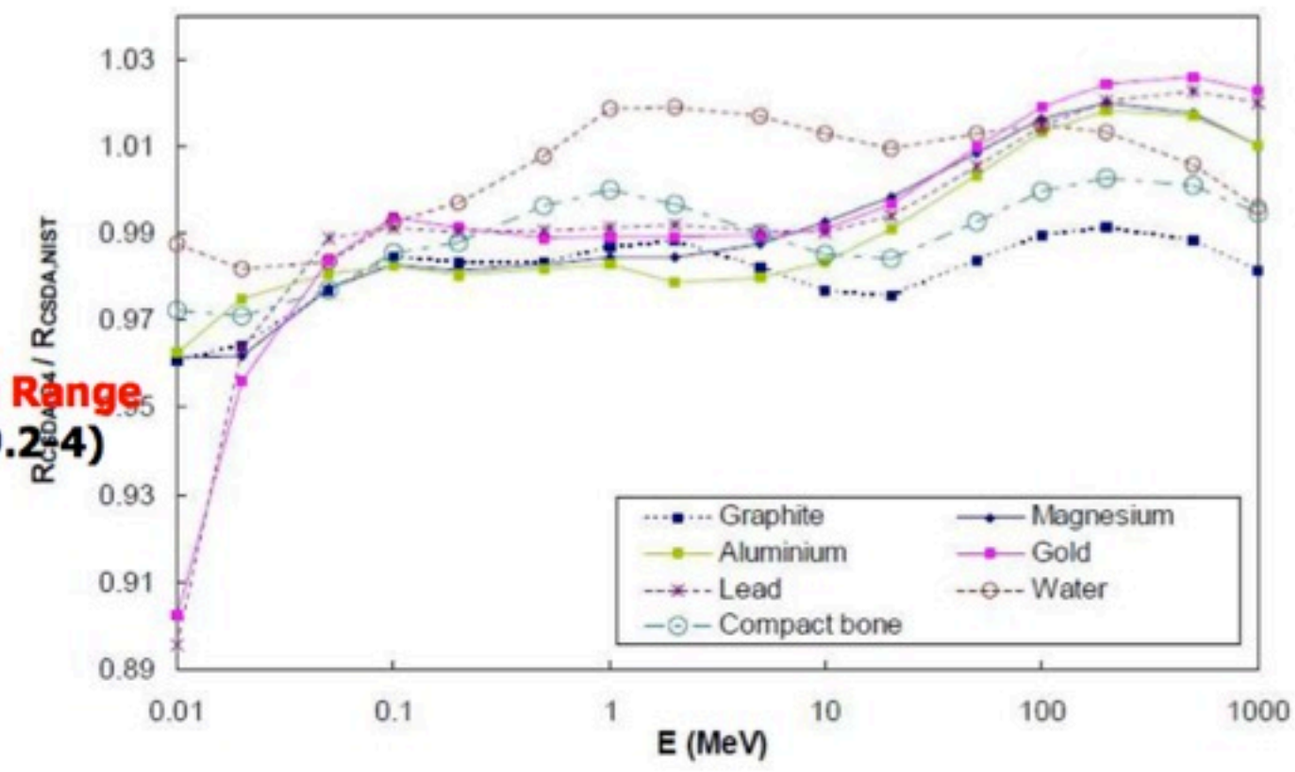


Example of validation





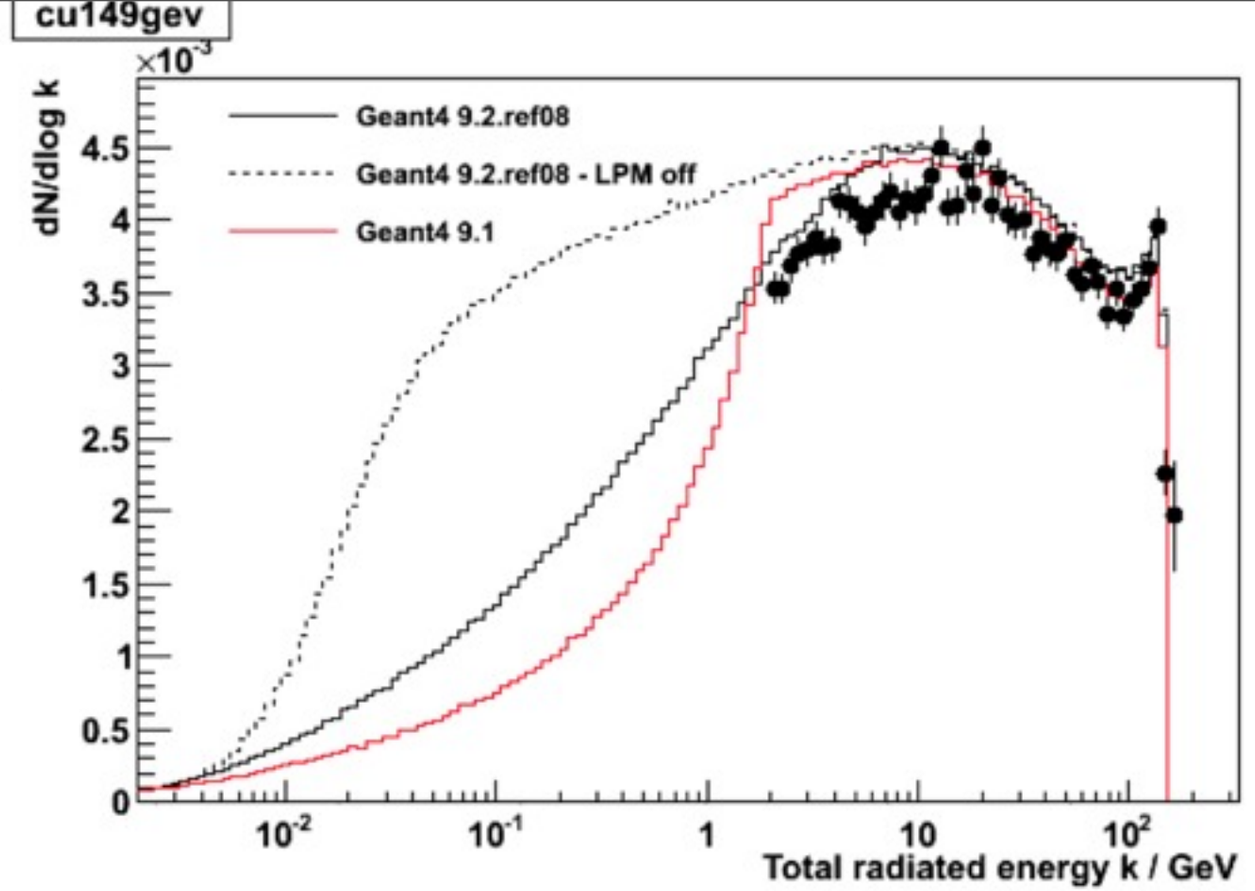


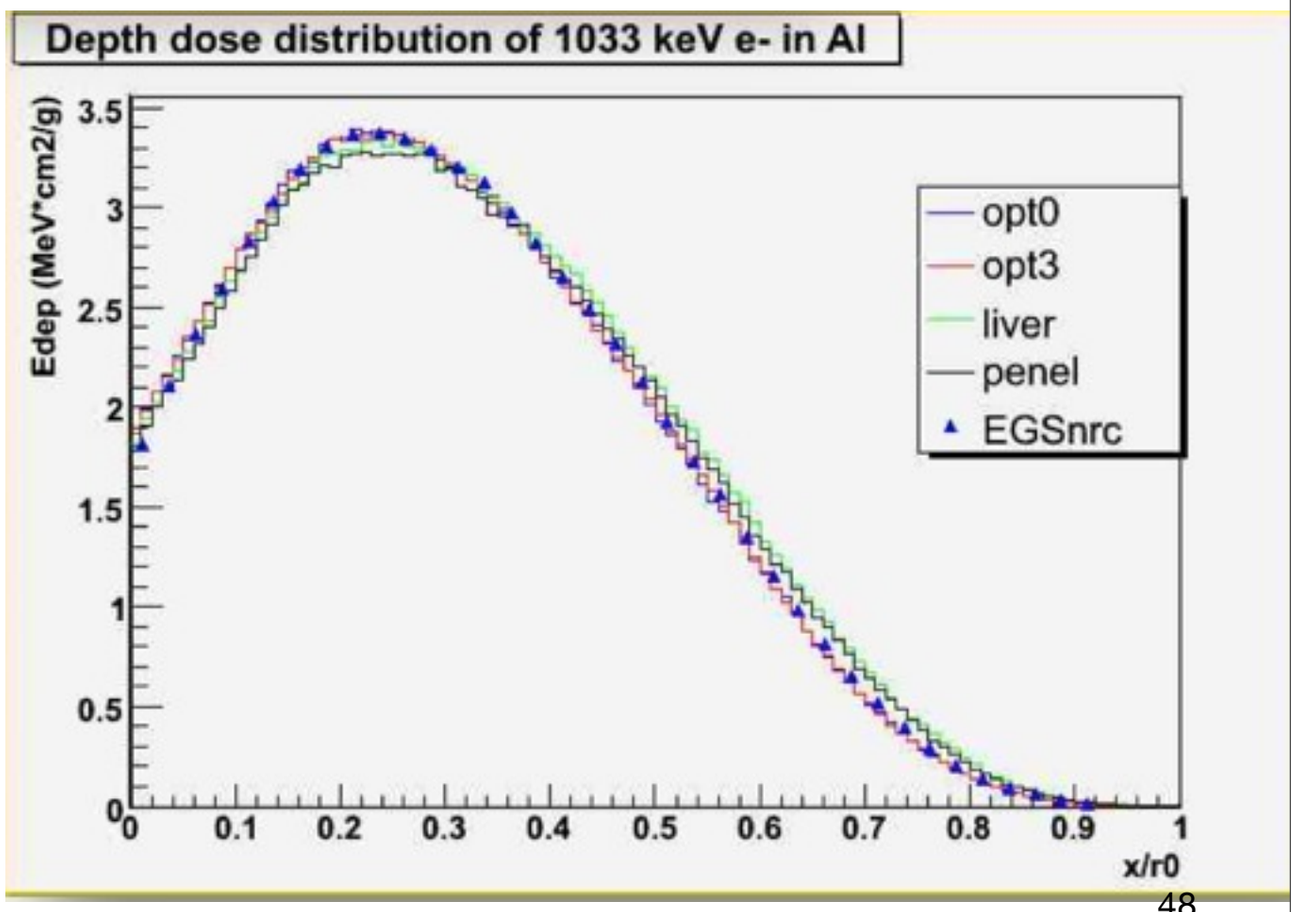


Validation repository

- A web-based validation tool has been developed for easy comparison of EM simulations and results

- http://www-zeuthen.desy.de/geant4/web/





To learn more: extended examples

Check basic quantities	
Total cross sections, mean free paths ...	TestEm0, Em13, Em14
Stopping power, particle range ...	Em0, Em1, Em5, Em11, Em12
Final state : energy spectra, angular distributions	Em14
Energy loss fluctuations, fluorescence	Em18
Multiple Coulomb scattering	
as an isolated mechanism	Em15
as a result of particle transport	Em5
More global verifications	
Single layer: transmission, absorption, reflexion	Em5
Bragg curve, tallies	Em7
Depth dose distribution	Em11, Em12
Shower shapes, Moliere radius	Em2
Sampling calorimeters, energy flow	Em3
Crystal calorimeters	Em9
Other specialized programs	
High energy muon physics	Em17
Other rare, high energy processes	Em6
Synchrotron radiation	Em16
Transition radiation	Em8
Photo-absorption-ionization model	Em10

How to start with Geant4

- Installation tips since the 9.5 version (2011)
- How a typical Geant4 application works

What you need to start with Geant4

- C++
  - A basic knowledge is required being Geant4 a collection of C++ libraries
  - It is complex but also no C++ experts can use Geant4
- **Object oriented technology (OO)**
  - Very basic knowledge
  - Expertise needed for the development of complex applications
- **Unix/Linux**
  - These are the standard OSs for Geant4 and a basic knowledge is required
  - Principal shell commands
  - How to compile a program
  - How to install from source code

Supported and tested platforms

- Linux with gcc 4.1.2 or 4.3 and Intel icc 11 or 12

  - Tested on Scientific Linux CERN 5(SLC5) but also successful compile
    on other Linux distributions, including Debian, Ubuntu and OpenSUSE

- Mac OSX 10.7 (Lion) and 10.6 (Snow Leopard) with gcc 4.2.1

- Windows 7 and XP with Visual Studio 9 and 10

Geant4 Software Download

Geant4 9.5

released 2 December 2011

The Geant4 source code is freely available. See the licence conditions.

Please read the **Release Notes** before downloading or using this release.

Source files

Please choose the archive best suited to your system and archiving tool:

Download GNU or Linux tar format, compressed using gzip (27Mbytes, 28458437 bytes).
After downloading, gunzip, then unpack using GNU tar.

Download ZIP format (39Mbytes, 40826089 bytes).
After downloading, unpack using e.g. WinZip.

Data files (*)

For specific, optional physics processes some of the following files are required. The file format is compatible with Unix, GNU, and Windows utilities.

Download Neutron data files with thermal cross sections - version 4.0 (381Mbytes, 400001140 bytes) NEW

Download Neutron data files without thermal cross sections - version 0.2 (12Mbytes, 12465281 bytes)

Download Data files for low energy electromagnetic processes - version 6.23 (15Mbytes, 15960390 bytes) NEW

Download Data files for photon evaporation - version 2.2 (7.3Mbytes, 7704178 bytes) NEW

Download Data files for radioactive decay hadronic processes - version 3.4 (716Kbytes, 732861 bytes) NEW

Download Data files for nuclear shell effects in INCL/ABLA hadronic model - version 3.0 (54Kbytes, 54909 bytes)

Download Data files for evaluated neutron cross sections on natural composition of elements - version 1.1 (1.2Mbytes, 1247160 bytes) NEW

Download Data files for shell ionisation cross sections - version 1.3 (4.1Mbytes, 4293607 bytes) NEW

Download Data files for measured optical surface reflectance - version 1.0 (1.2Mbytes, 1257863 bytes)

Pre-compiled Libraries

These are compiled with Geant4 default settings and optimization turned on. Please choose according to your system/compiler:

Download compiled using gcc 4.1.2 on Scientific Linux CERN 5 (SLC5, based on Redhat Linux Enterprise 5), 64 bits - (32Mbytes, 33212295 bytes)

Download compiled using gcc 4.2.1 on Mac (MacOSX 10.7), 64 bits - (31Mbytes, 32039379 bytes)

Related Links

- Geant4-MT **prototype.**
- **Previous Releases** of Geant4 (since release 8.3).
- LXR source code browser.
- Installation Guide tutorials for Linux, Mac and Windows.
- **Windows CygWin installation note.**

Download and installation tips for the 9.5 version

- You can download the compiled libraries of Geant4 but **the compilation in your computer is strongly suggested**

- **Download the source file** from the Geant4 web site

- Two way to proceed:

  - Using cmake via terminal

  - Using the GUI version of cmake

cmake Geant4 installation

- **cmake** version greater than 2.8.3
- Locate the **source folder**
  Ex: `/home/Username/geant4-09-05`
- Create the **build folder**
  Ex: `/home/Username/geant4-09-05-build`
- Create the **install folder**
  Ex: `/home/Username/geant4-09-05-install`
- `cmake -DCMAKE_INSTALL_PREFIX=/home/Username/geant4-09-05-install/`
- Define and/or activate the **additional features/package you require** using the same cmake interface
- make -jN

cmake Geant4 installation

```
[  4%] Building CXX object source/global/CMakeFiles/G4global.dir/management/src/G4Physics2DVector.cc.o
[  4%] Building CXX object source/global/CMakeFiles/G4global.dir/management/src/G4Physics2DVectorCache.cc.o
[  4%] Building CXX object source/global/CMakeFiles/G4global.dir/management/src/G4Pow.cc.o
[  4%] Building CXX object source/global/CMakeFiles/G4global.dir/management/src/G4SliceTimer.cc.o
[  4%] Building CXX object source/global/CMakeFiles/G4global.dir/management/src/G4StateManager.cc.o
[  4%] Building CXX object source/global/CMakeFiles/G4global.dir/management/src/G4Timer.cc.o
[  4%] Building CXX object source/global/CMakeFiles/G4global.dir/management/src/G4UnitsTable.cc.o
[  4%] Building CXX object source/global/CMakeFiles/G4global.dir/management/src/G4VExceptionHandler.cc.o
[  4%] Building CXX object source/global/CMakeFiles/G4global.dir/management/src/G4VNotifier.cc.o
[  4%] Building CXX object source/global/CMakeFiles/G4global.dir/management/src/G4VStateDependent.cc.o
[  4%] Building CXX object source/global/CMakeFiles/G4global.dir/management/src/G4coutDestination.cc.o
[  4%] Building CXX object source/global/CMakeFiles/G4global.dir/management/src/G4ios.cc.o
Linking CXX shared library ../../outputs/library/Darwin-g++/libG4global.dylib
[  4%] Built target G4global
Scanning dependencies of target G4analysis
Scanning dependencies of target G4intercoms
[  4%] Building CXX object source/intercoms/CMakeFiles/G4intercoms.dir/src/G4UIaliasList.cc.o
[  4%] Building CXX object source/analysis/CMakeFiles/G4analysis.dir/src/G4AnalysisVerbose.cc.o
[  4%] Building CXX object source/intercoms/CMakeFiles/G4intercoms.dir/src/G4UIbatch.cc.o
[  4%] Building CXX object source/analysis/CMakeFiles/G4analysis.dir/src/G4CsvAnalysisManager.cc.o
[  4%] Building CXX object source/intercoms/CMakeFiles/G4intercoms.dir/src/G4UIcmdWith3Vector.cc.o
[  4%] Building CXX object source/intercoms/CMakeFiles/G4intercoms.dir/src/G4UIcmdWith3VectorAndUnit.cc.o
[  4%] Building CXX object source/analysis/CMakeFiles/G4analysis.dir/src/G4VAnalysisManager.cc.o
[  5%] Building CXX object source/analysis/CMakeFiles/G4analysis.dir/src/G4RootAnalysisManager.cc.o
[  5%] Building CXX object source/intercoms/CMakeFiles/G4intercoms.dir/src/G4UIcmdWithABool.cc.o
[  5%] Building CXX object source/intercoms/CMakeFiles/G4intercoms.dir/src/G4UIcmdWithADouble.cc.o
[  5%] Building CXX object source/intercoms/CMakeFiles/G4intercoms.dir/src/G4UIcmdWithADoubleAndUnit.cc.o
[  5%] Building CXX object source/intercoms/CMakeFiles/G4intercoms.dir/src/G4UIcmdWithAString.cc.o
[  5%] Building CXX object source/intercoms/CMakeFiles/G4intercoms.dir/src/G4UIcmdWithAnInteger.cc.o
[  5%] Building CXX object source/intercoms/CMakeFiles/G4intercoms.dir/src/G4UIcmdWithoutParameter.cc.o
[  5%] Building CXX object source/intercoms/CMakeFiles/G4intercoms.dir/src/G4UIcommand.cc.o
```

cmake Geant4 installation

- If GEANT4_INSTALL_DATA is ON
  the additional external data libraries are automatically downloaded

- If GEANT4_INSTALL_EXAMPLES is ON
  Examples are installed

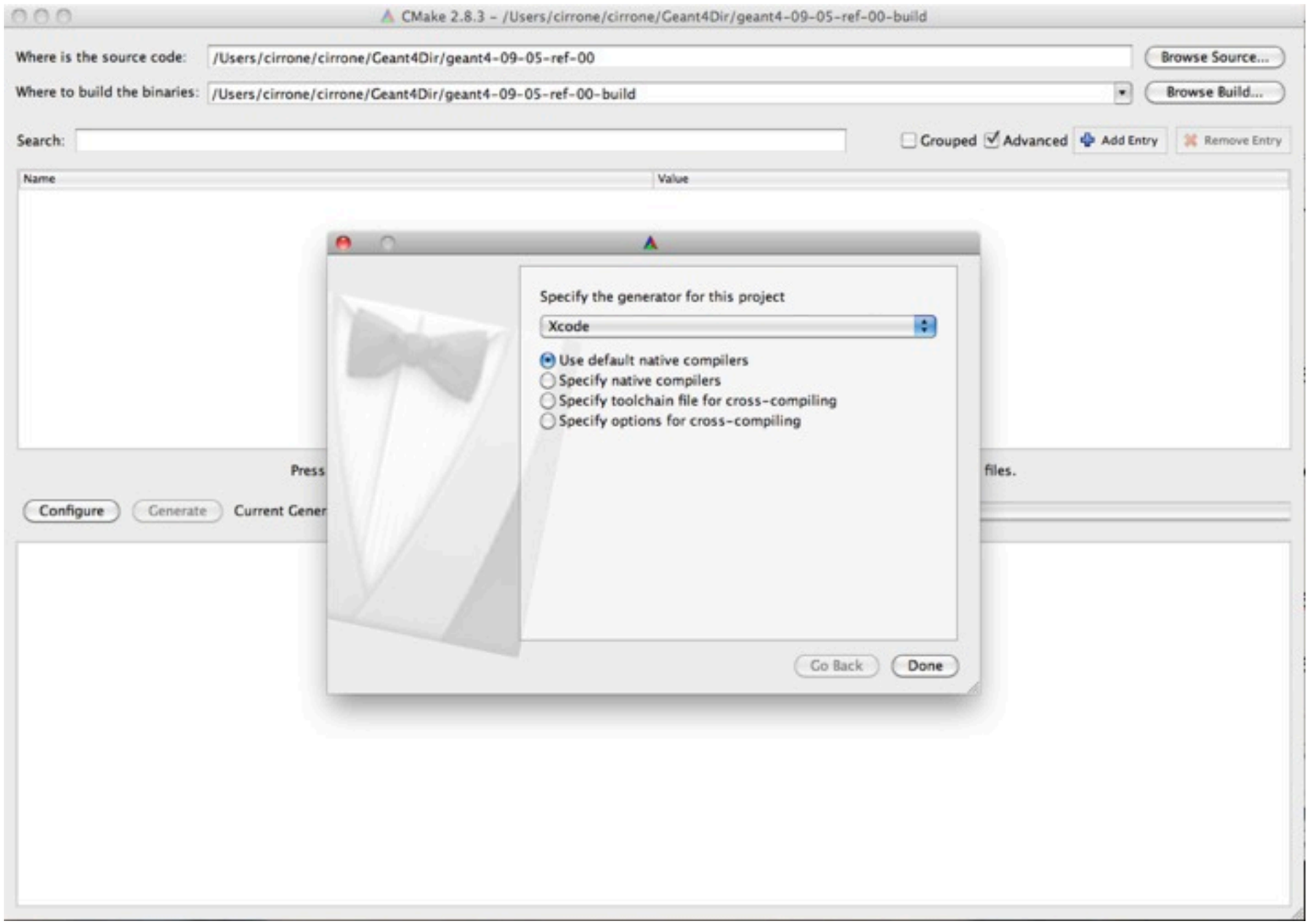
- If GEANT4_USE_SYSTEM_CLHEP is ON
  external CLHEP are searched

- See documentation for details for the complete variables list and explanation

cmake Geant4 installation

```
Linking CXX shared library ../../outputs/library/Darwin-g++/libG4physicslists.dylib
[100%] Built target G4physicslists
geant4-09-05-ref-00-build Lavora! > make -j2
Scanning dependencies of target G4ABLA
Scanning dependencies of target G4EMLOW
[  0%] [  0%] Creating directories for 'G4ABLA'
Creating directories for 'G4EMLOW'
[  0%] [  0%] Performing download step (download, verify and extract) for 'G4EMLOW'
Performing download step (download, verify and extract) for 'G4ABLA'
-- downloading...
     src='http://geant4.cern.ch/support/source/G4EMLOW.6.23.tar.gz'
     dst='/Users/cirrone/cirrone/Geant4Dir/geant4-09-05-ref-00-build/Externals/G4EMLOW-6.23/src/G4EMLOW.6.23.tar.gz'
     timeout='none'
-- downloading...
     src='http://geant4.cern.ch/support/source/G4ABLA.3.0.tar.gz'
     dst='/Users/cirrone/cirrone/Geant4Dir/geant4-09-05-ref-00-build/Externals/G4ABLA-3.0/src/G4ABLA.3.0.tar.gz'
     timeout='none'
-- [download 0% complete]
-- [download 2% complete]
-- [download 10% complete]
-- [download 34% complete]
-- [download 81% complete]
-- [download 100% complete]
```

GUI version of cmake



A friendly way to do the same things

If everything is ok install tree should appear so structured

```
+- CMAKE_INSTALL_PREFIX
   +- bin/
   |   +- geant4-config    (UNIX ONLY)
   |   +- geant4.csh       (UNIX ONLY)
   |   +- geant4.sh        (UNIX ONLY)
   |   +- G4global.dll     (WINDOWS ONLY)
   |   +- ...
   +- include/
   |   +- Geant4/
   |      +- G4global.hh
   |      +- ...
   |      +- CLHEP/        (WITH INTERNAL CLHEP ONLY)
   |      +- tools/
   +- lib/                 (MAY BE lib64 on LINUX)
   |   +- libG4global.so   (AND/OR .a, OR G4Global.lib ON WINDOWS)
   |   +- ...
   |   +- Geant4-9.5.0/
   |      +- Geant4Config.cmake
   |      +- Geant4ConfigVersion.cmake
   |      +- Geant4LibraryDepends.cmake
   |      +- Geant4LibraryDepends-Release.cmake
   |      +- UseGeant4.cmake
   |      +- Linux-g++     (OR Darwin-g++ UNIX ONLY SOFTLINK -> ..)
   +- share
      +- Geant4-9.5.0
         +- data/          (IF GEANT4_INSTALL_DATA WAS SET)
         +- geant4make/
            +- geant4make.csh
            +- geant4make.sh
            +- config/
```

cmake Geant4 installation

- How to **compile a User application**:

  - source CMAKE_INSTALL_PREFIX/share/geant4make/geant4make.(c)sh

- Where **data** and **examples** are located

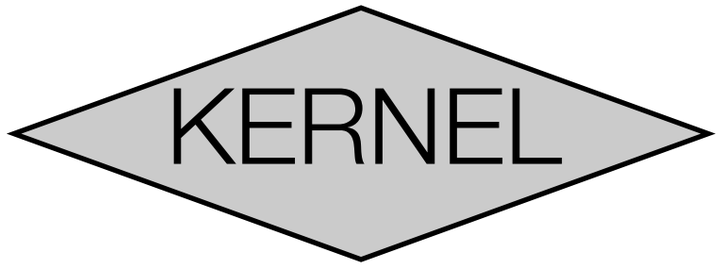
  - data libraries CMAKE_INSTALL_PREFIX/share/Geant4Version/data

  - examples CMAKE_INSTALL_PREFIX/share/Geant4Version/examples

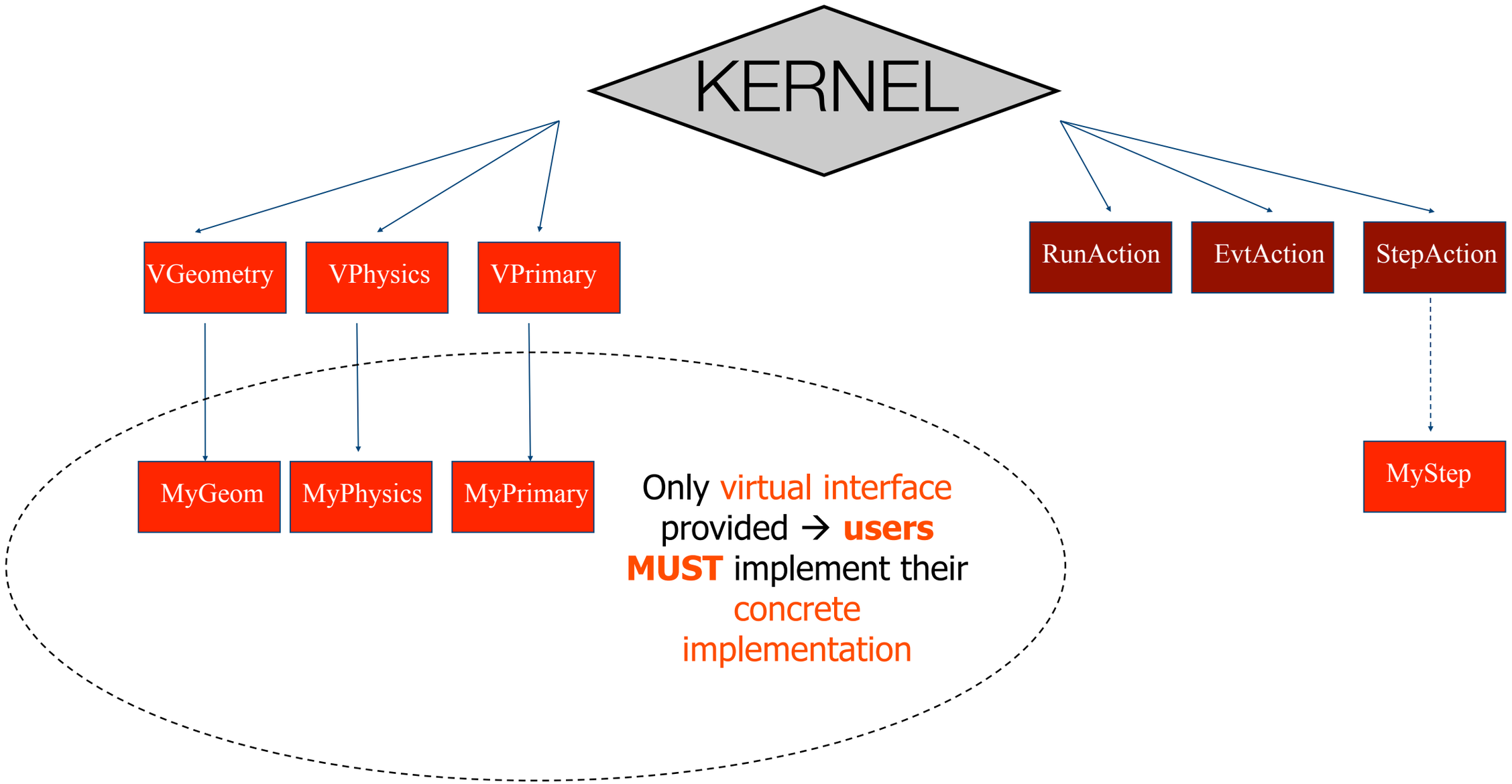
Files composing a Geant4 application

- Main() file
- Sources files (*.cc)
  - usually included in the /src folder
- Header files (*.hh)
  - usually included in the /include files
- Three couples of files are necessary (with the Main.cc)
  - The PrimaryGeneratorAction (.cc and .hh)
  - The DetectorConstruction (.cc and .hh)
  - The PhysicsList (.cc and .hh)

Geant4 general concept



Geant4 general concept



How we can simulate a detector?

Data scoring in Geant4

- User can work at the User Action level -- CASE I
  - G4Step - G4Event - G4Run - G4Track ....
  - Full access to all the information (GEOMETRICAL AND PHYSICS) but, '**do-it-yourself**' approach
- Sensitive detectors -- CASE II
  - Native SD
  - ReadOut geometry
- Scoring -- CASE III
  - Based on simple macro commands
  - Almost **no-code to write**

CASE I - Do-it-by-yourself

1.Get the position of a step:

```
G4StepPoint *point1 = step -> GetPreStepPoint()
```

2.Get the particle name and energy deposited

```
G4ParticleName *name= step->GetTrack()-GetDynamicParticle()
->GetDefinition()->GetParticleName()
G4double eDeposit = step->GetTotalEnergyDeposit()
```

3.Manage these quantities as you want

CASE II - Sensitive detector

- **A sensitive detector can be used to simulate the read-out of your detector:**

  - It is a way to declare a geometric element "sensitive" to the passage of particle

  - It give the user an handle to collect quantities from these elements at stepping time

    ✓ energy deposited, position, etc

CASE II - Sensitive detector

- At stepping time, Geant4 kernel checks for you is a particle is in a sensitive detector

  - If yes, give you the control to:
    `G4VSensitiveDetector::ProcessHits()`

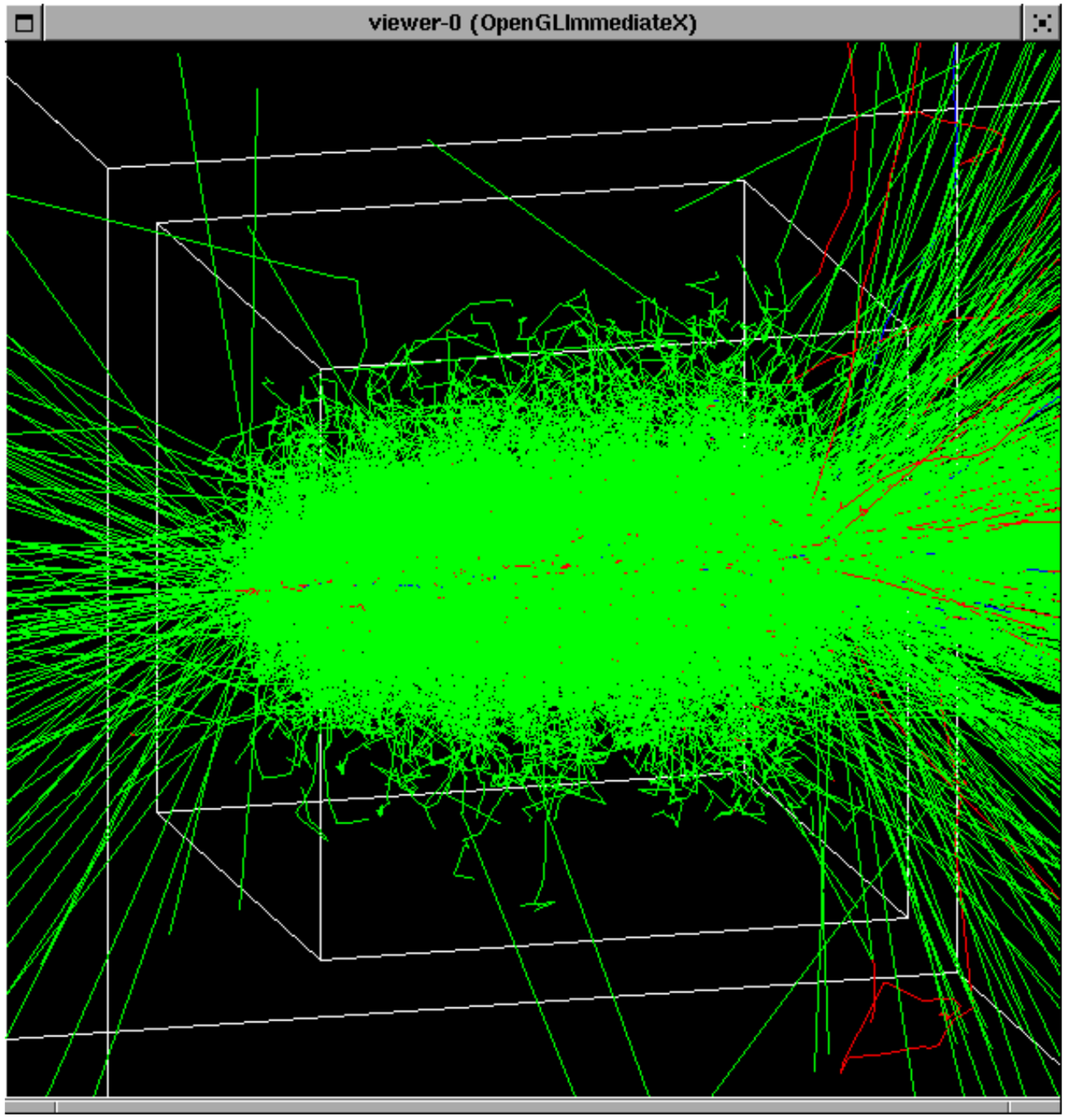
  - do what you want in **`ProcessHits()`** using hooks

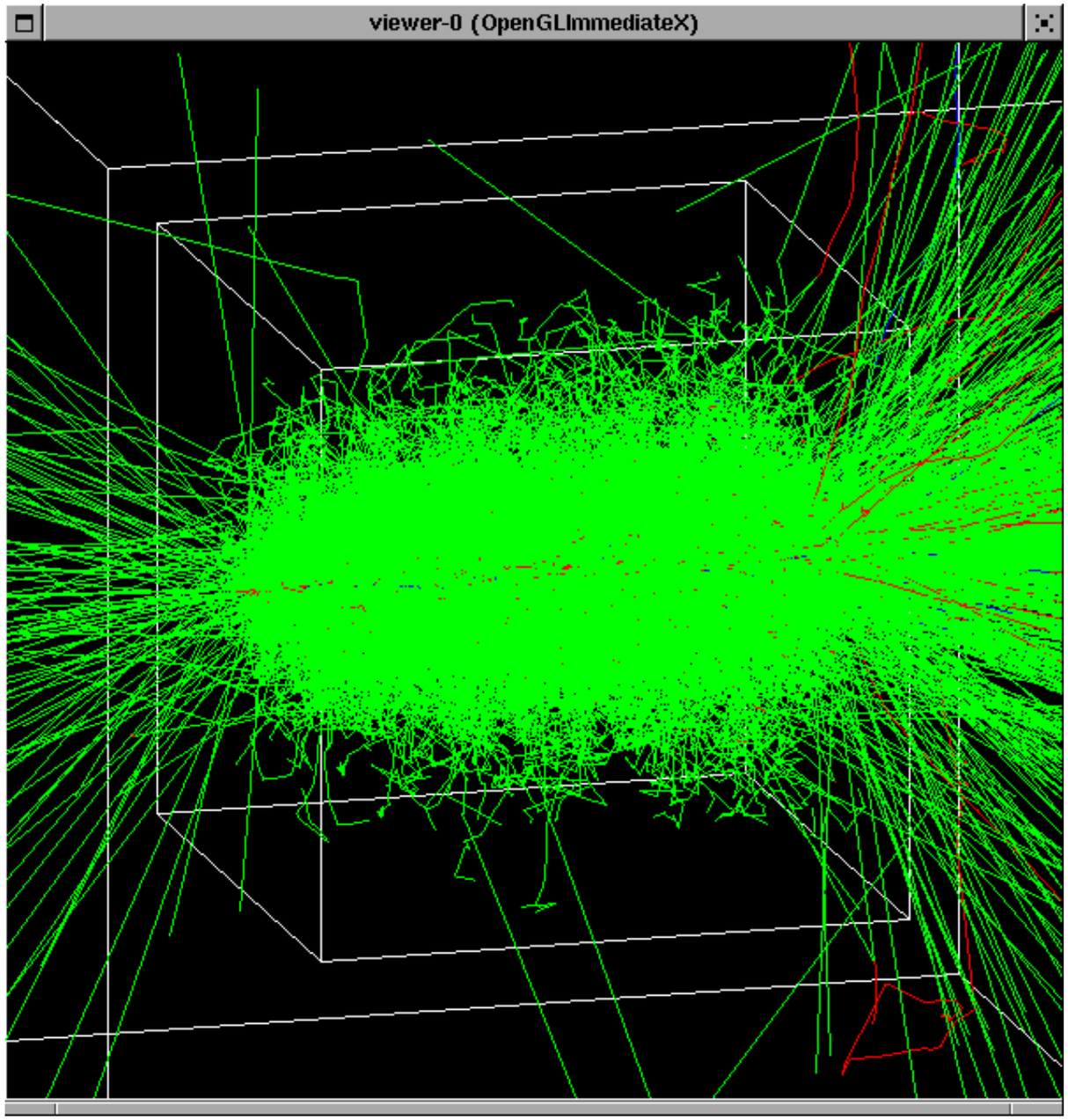
CASE III - Command-based scoring

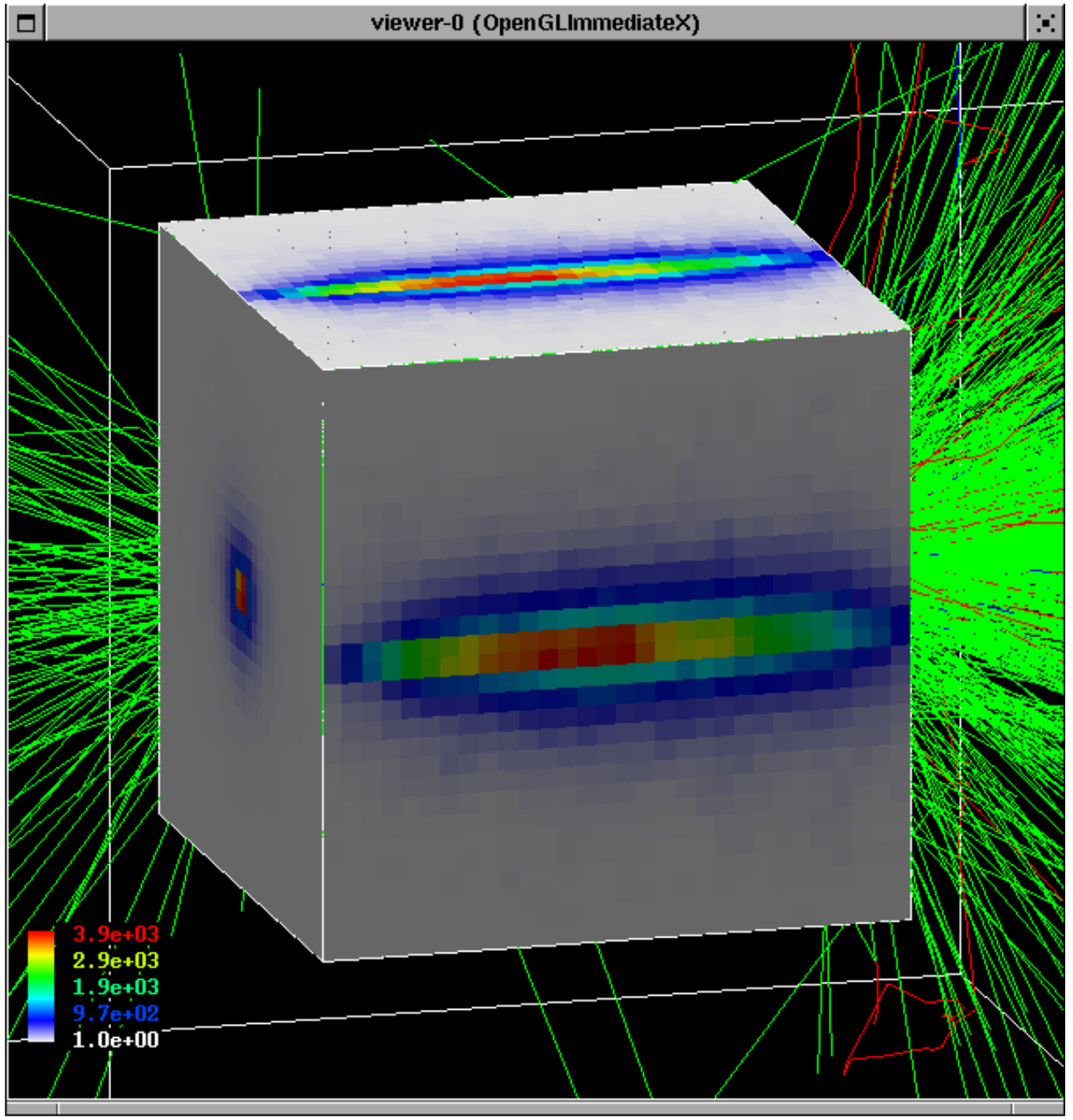
- Provides various scorers for commonly-used physics quantities such as dose, flux, etc

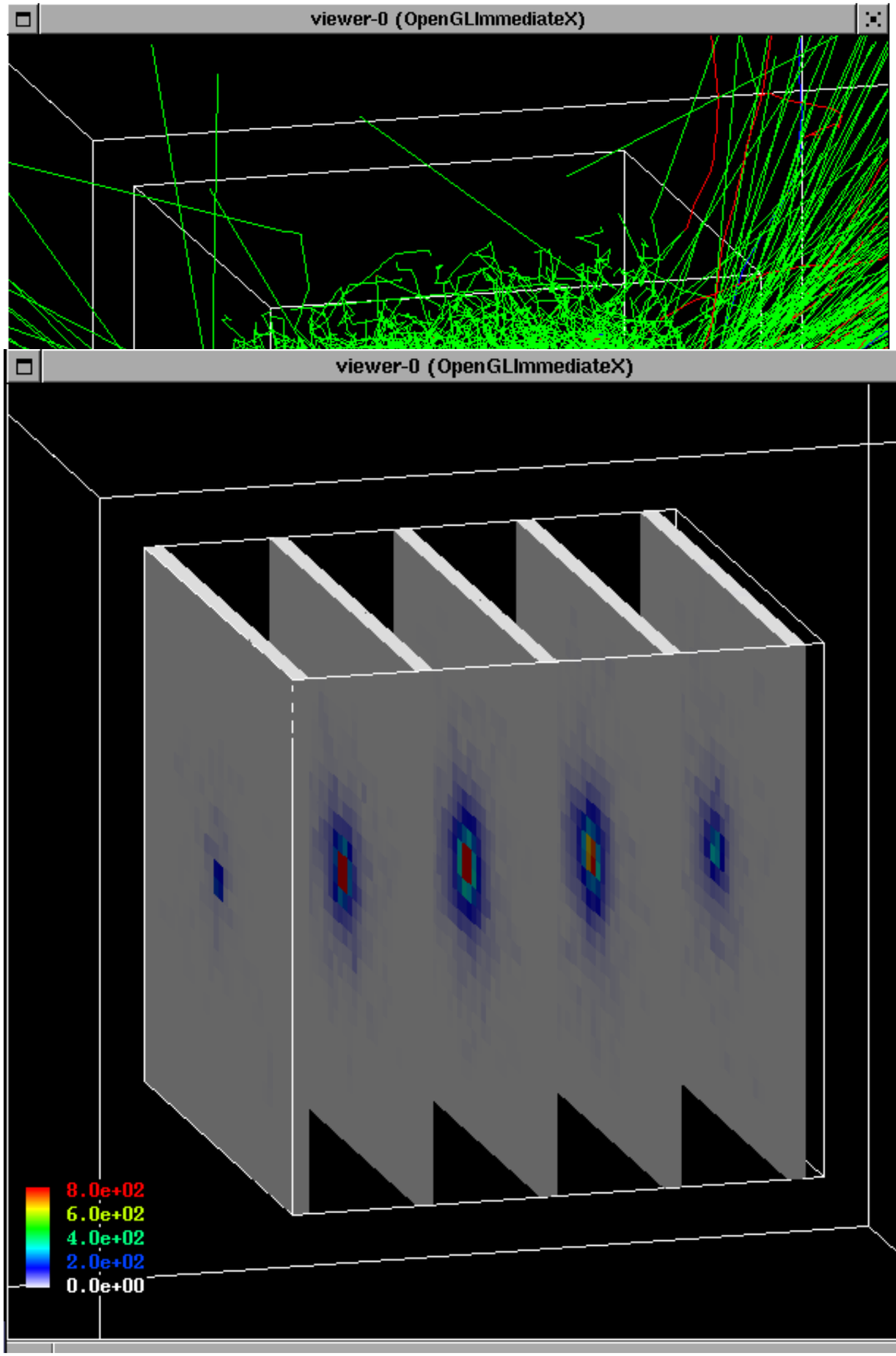
- Add this functionality in the `main()`

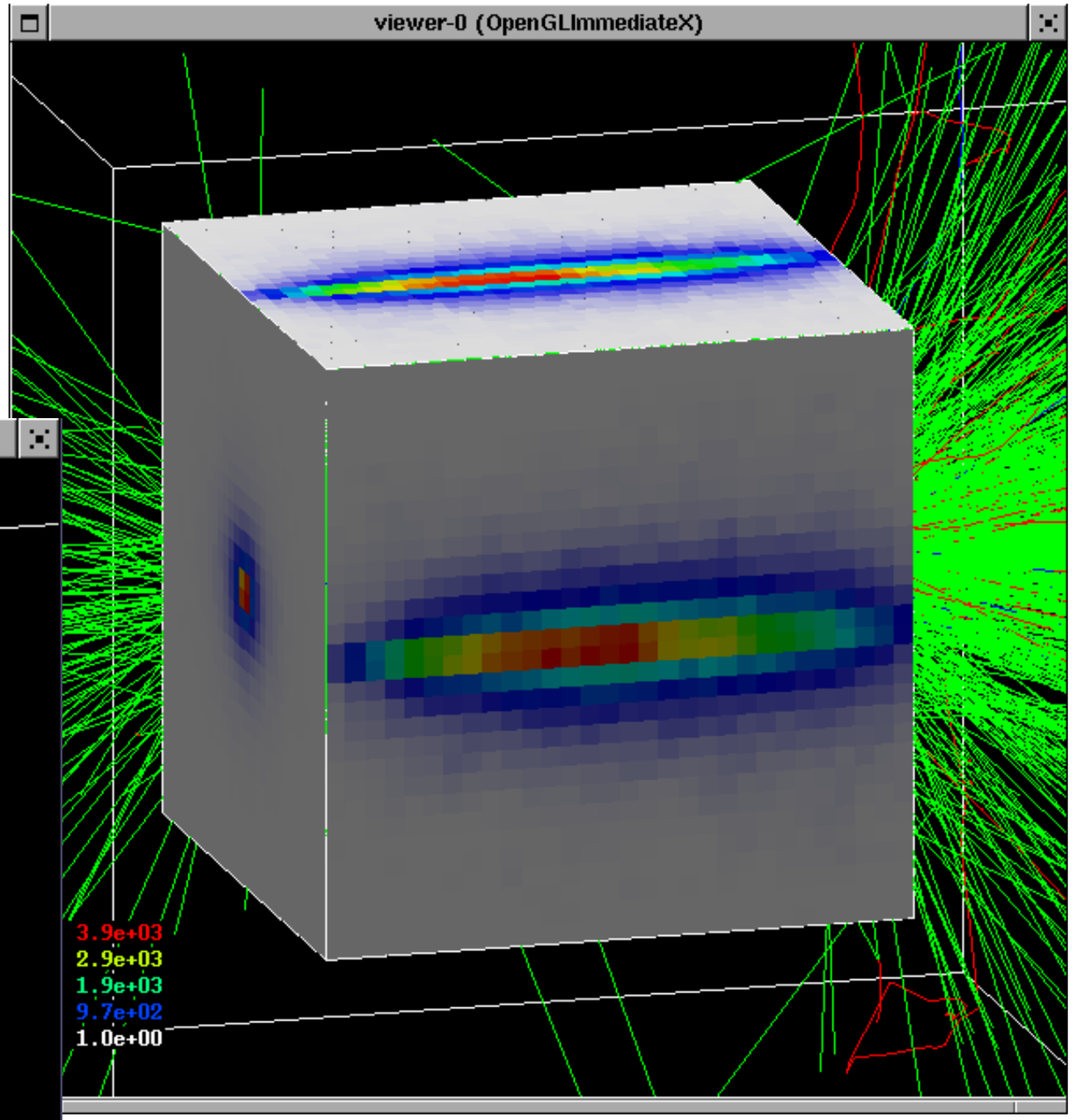
- /examples/extended/runAndEvent/RE03

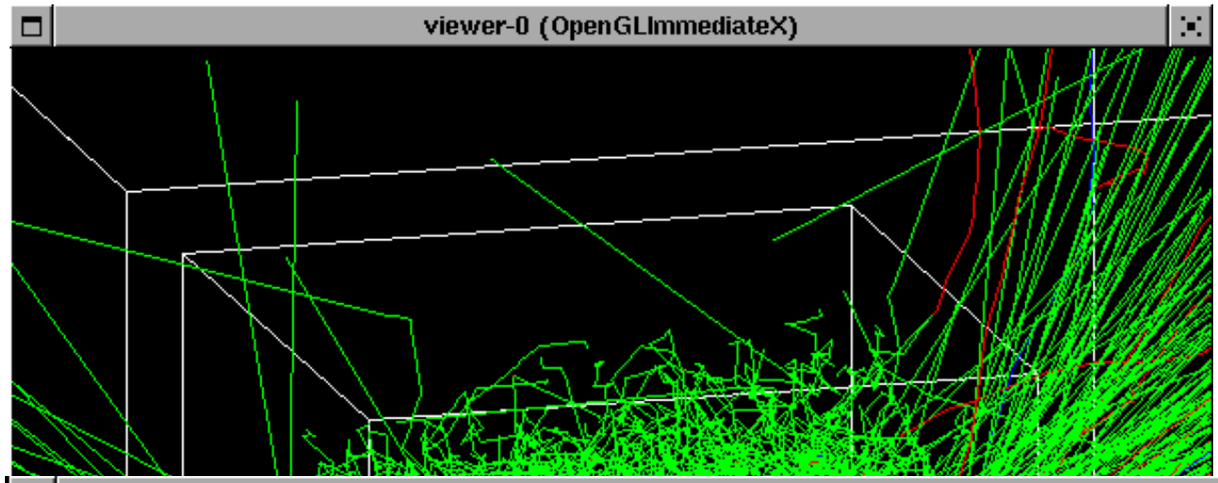

viewer-0 (OpenGLImmediateX)

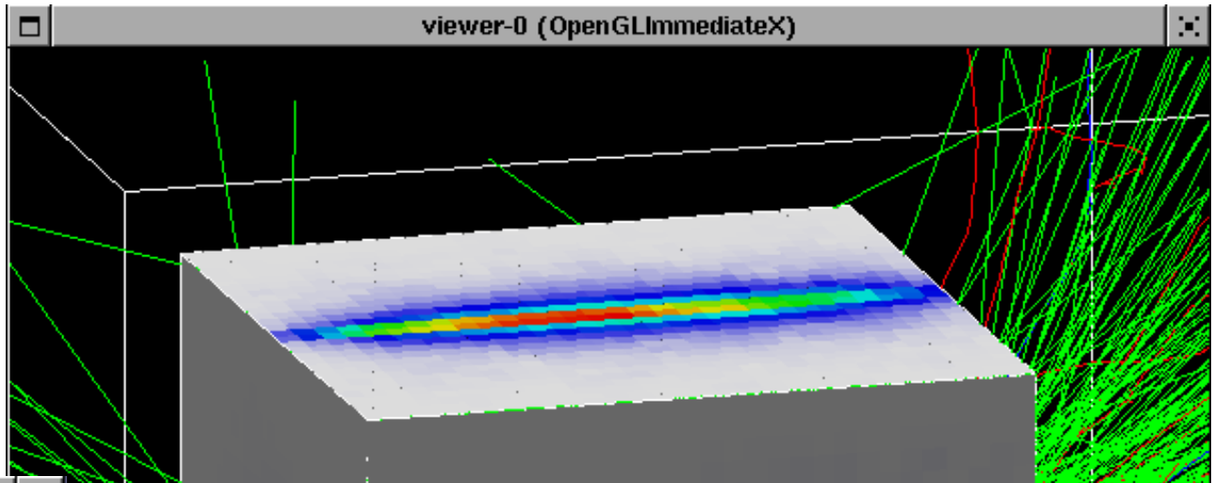

viewer-0 (OpenGLImmediateX)

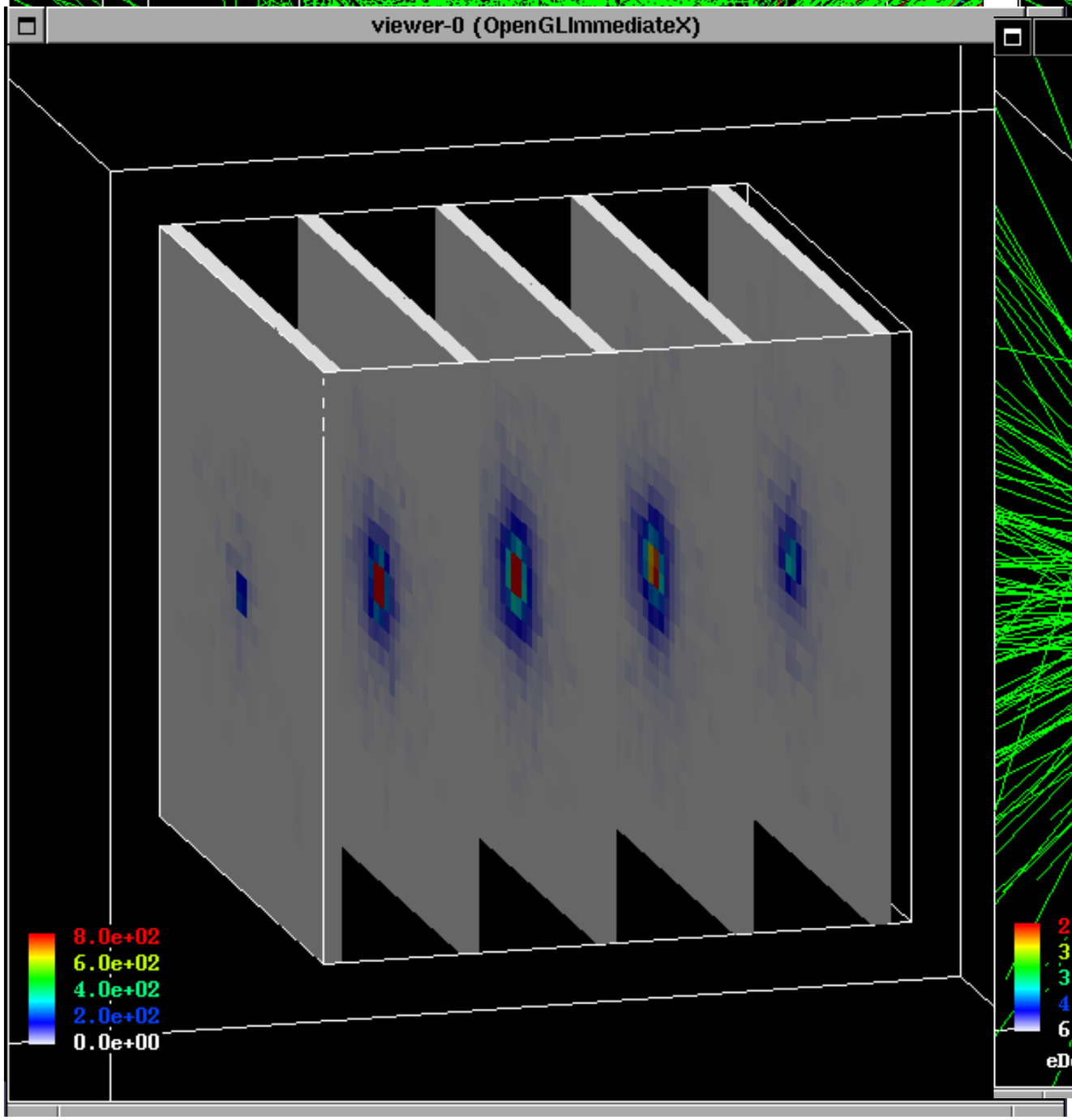

viewer-0 (OpenGLImmediateX)
3.9e+03
2.9e+03
1.9e+03
9.7e+02
1.0e+00

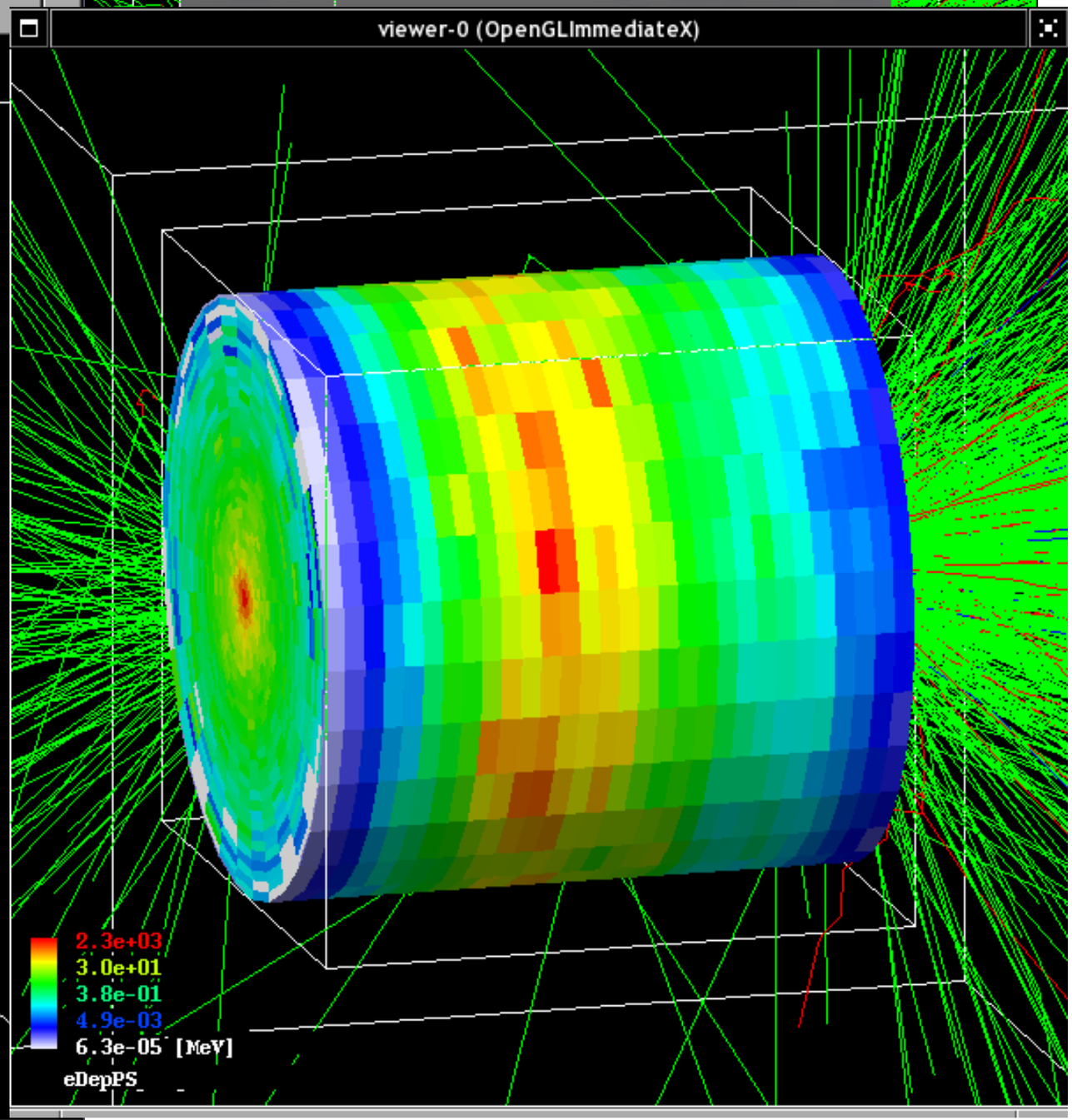

viewer-0 (OpenGLImmediateX)
8.0e+02
6.0e+02
4.0e+02
2.0e+02
0.0e+00


viewer-0 (OpenGLImmediateX)
3.9e+03
2.9e+03
1.9e+03
9.7e+02
1.0e+00


viewer-0 (OpenGLImmediateX)


viewer-0 (OpenGLImmediateX)


viewer-0 (OpenGLImmediateX)
8.0e+02
6.0e+02
4.0e+02
2.0e+02
0.0e+00

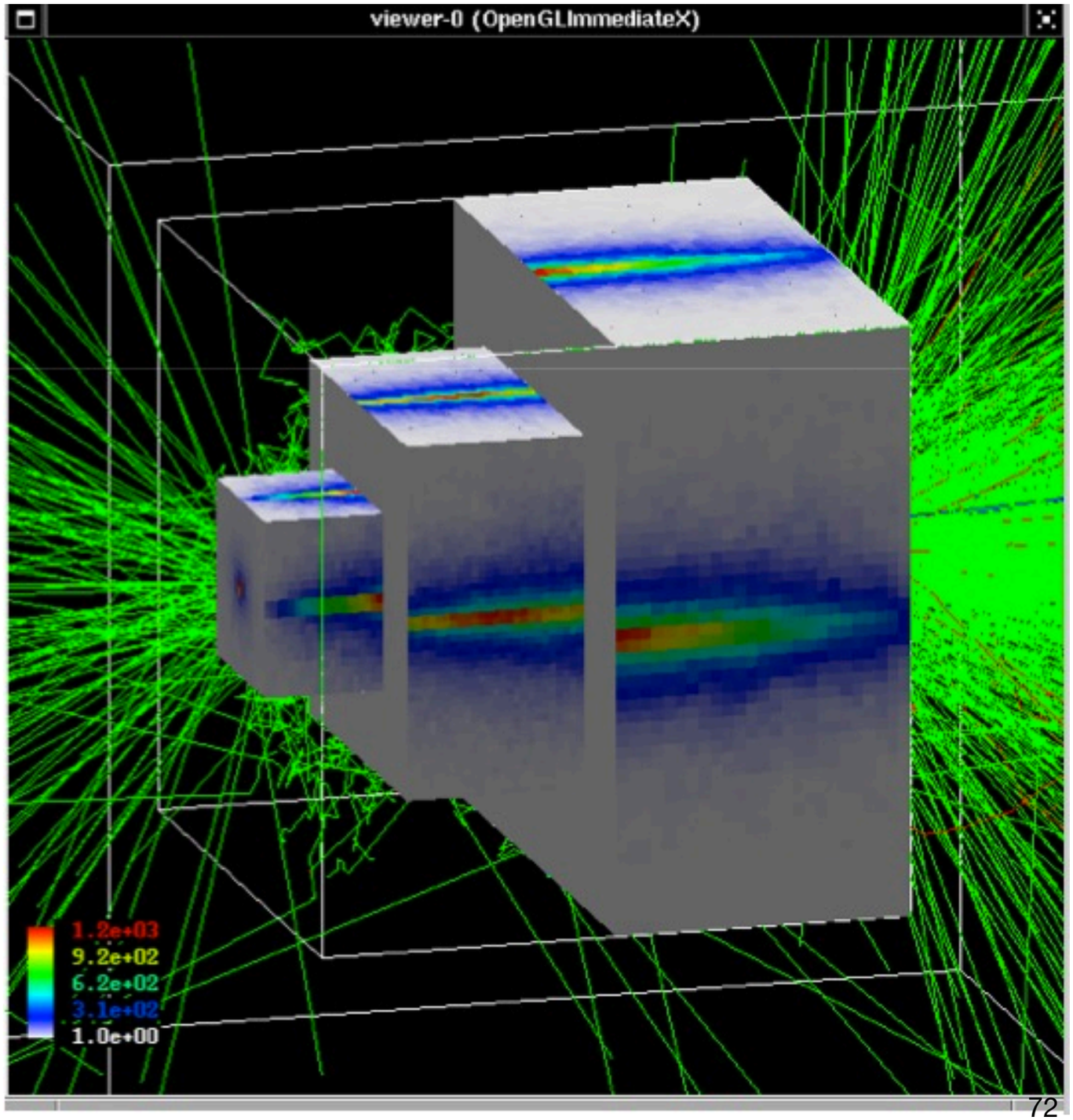

viewer-0 (OpenGLImmediateX)
2.3e+03
3.0e+01
3.8e-01
4.9e-03
6.3e-05 [MeV]
eDepPS

CASE III - Command-based scoring

- A mesh may have arbitrary number of scorers. Each scorer scores one physic quantity.
  - energyDeposit * Energy deposit scorer.
  - cellCharge * Cell charge scorer.
  - cellFlux * Cell flux scorer.
  - passageCellFlux * Passage cell flux scorer
  - doseDeposit * Dose deposit scorer.
  - nOfStep * Number of step scorer.
  - nOfSecondary * Number of secondary scorer.
  - trackLength * Track length scorer.
  - passageCellCurrent * Passage cell current scorer.
  - passageTrackLength * Passage track length scorer.
  - flatSurfaceCurrent * Flat surface current Scorer.
  - flatSurfaceFlux * Flat surface flux scorer.
  - nOfCollision * Number of collision scorer.
  - population * Population scorer.
  - nOfTrack * Number of track scorer.
  - nOfTerminatedTrack * Number of terminated tracks scorer.

CASE III - Command-based scoring

- More than one mesh
- Step limited to any boundary
- Scorers can be wrote to a file
- Too many meshes:
  - Memory consumption
  - Computing speed



Highlights of user applications

BaBar

- BaBar at SLAC is the pioneer experiment in HEP in the use of Geant4

  - First Geant4 simulated experiment, started in 2000

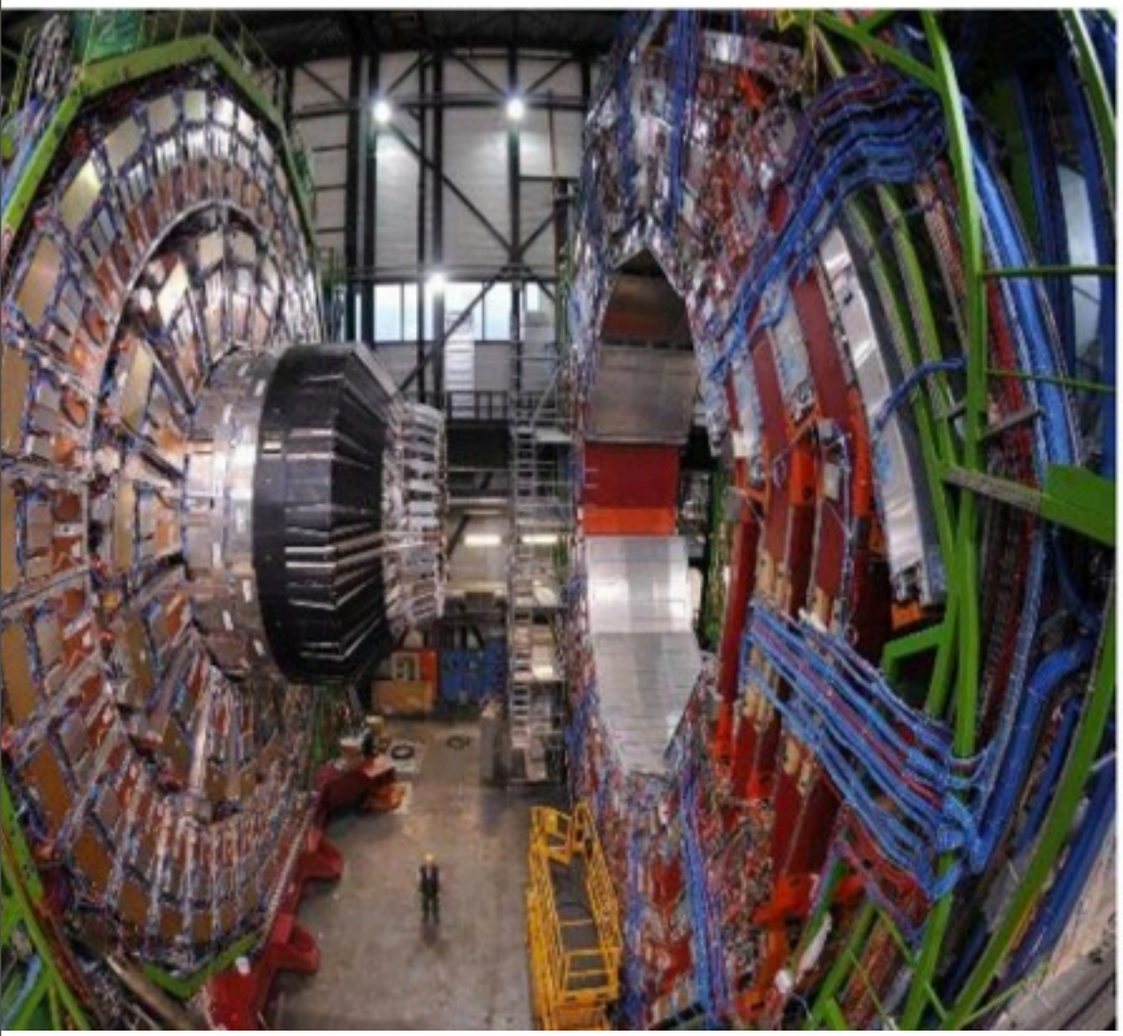
  - Simulated ab 2*10^10 events so far

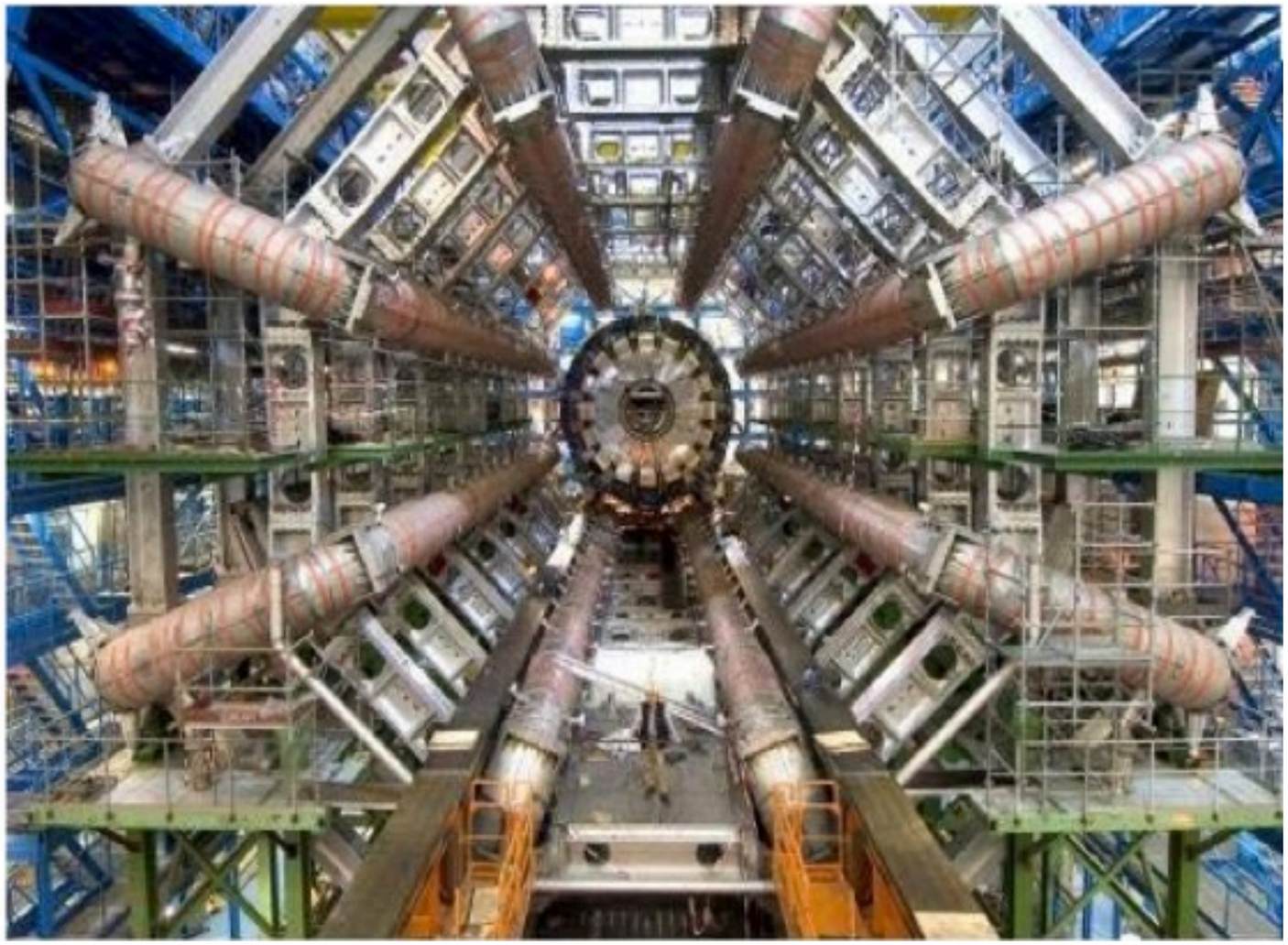
  - Produced at 20 sites in North America and Europe

  - Essential feedback for the Geant4 development

INFN Geant4

LHC





- **Used for all detectors**
  - ATLAS, CMS - greatest detectors
  - LHCb, ALICE - large specific detectors

Smart-2

ACE

LISA

INTEGRAL

Cassini

Bepi Colombo

GLAST

Herschel

SWIFT

Astro-E2

XMM-Newton

GAIA

JWST

ISS Columbus

EUSO

AMS

MAXI

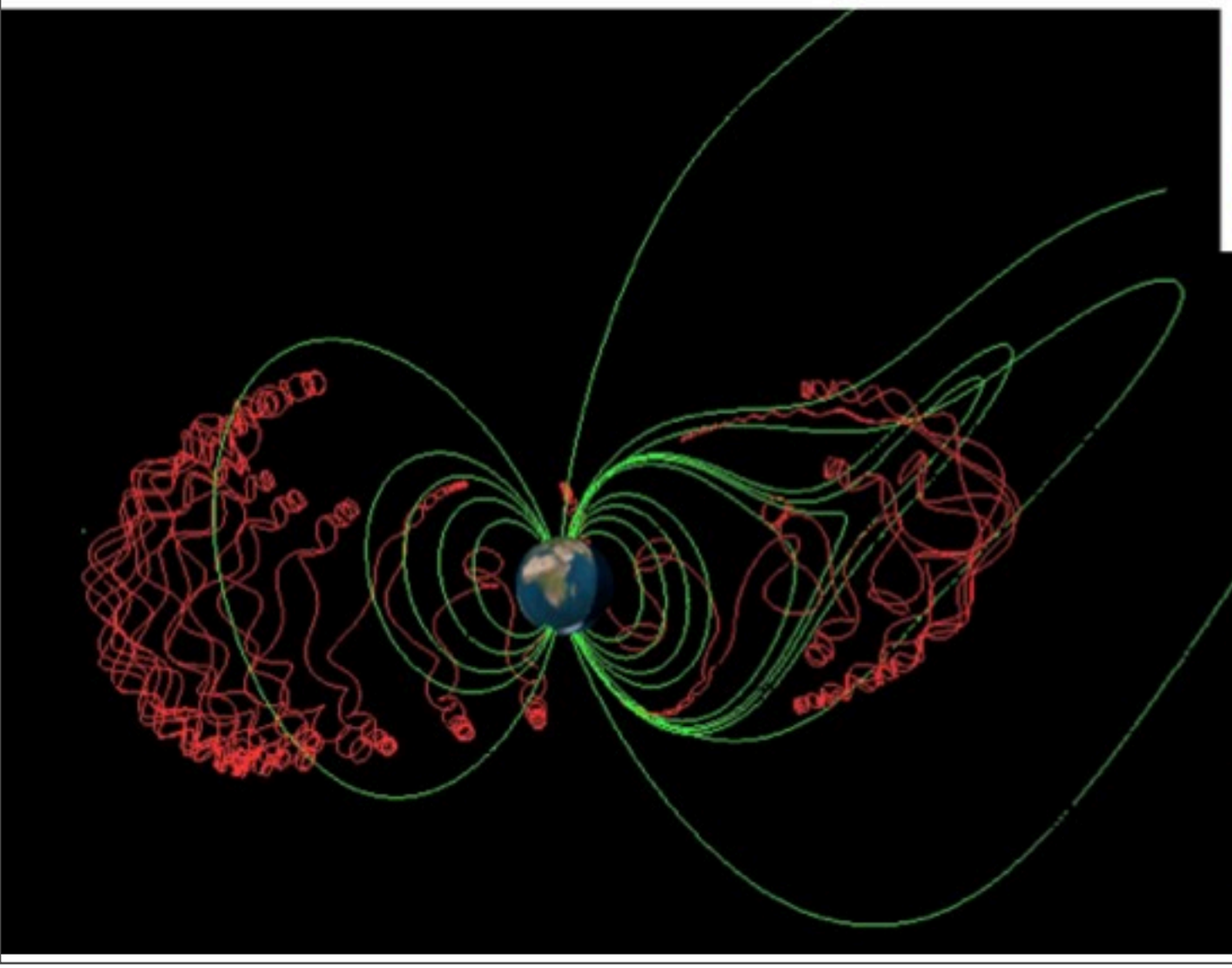
PlanetoCosmics

Geant4 simulation of Cosmic Rays in planetary Atmo-/Magneto- spheres

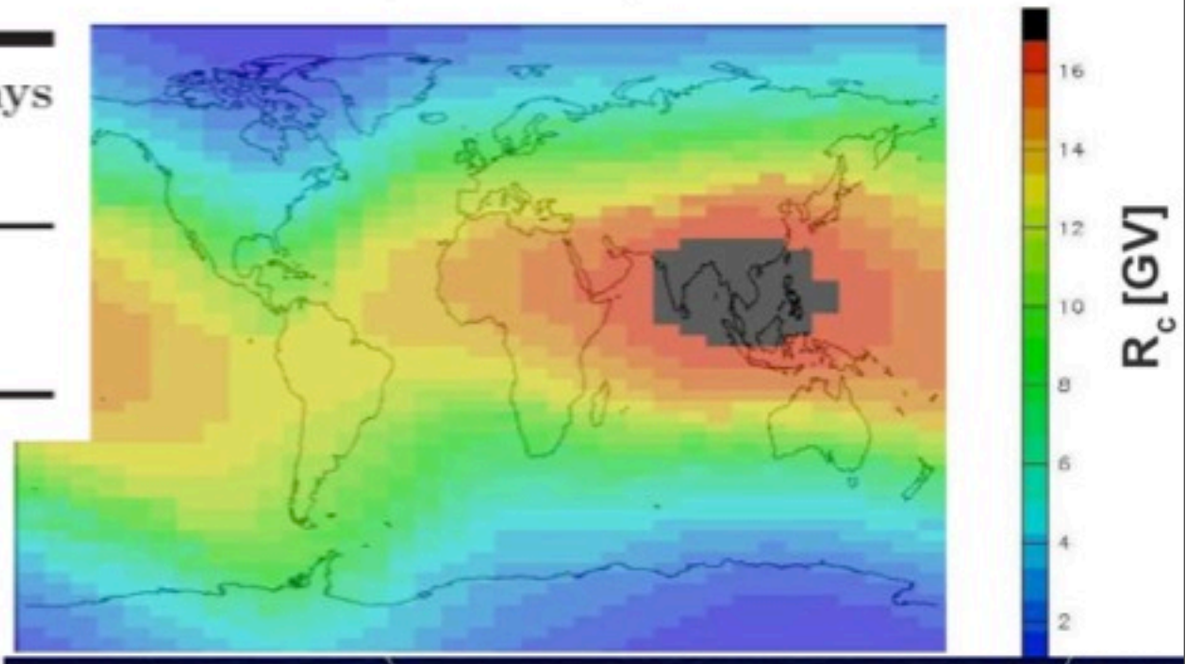
28th International Cosmic Ray Conference — 4277

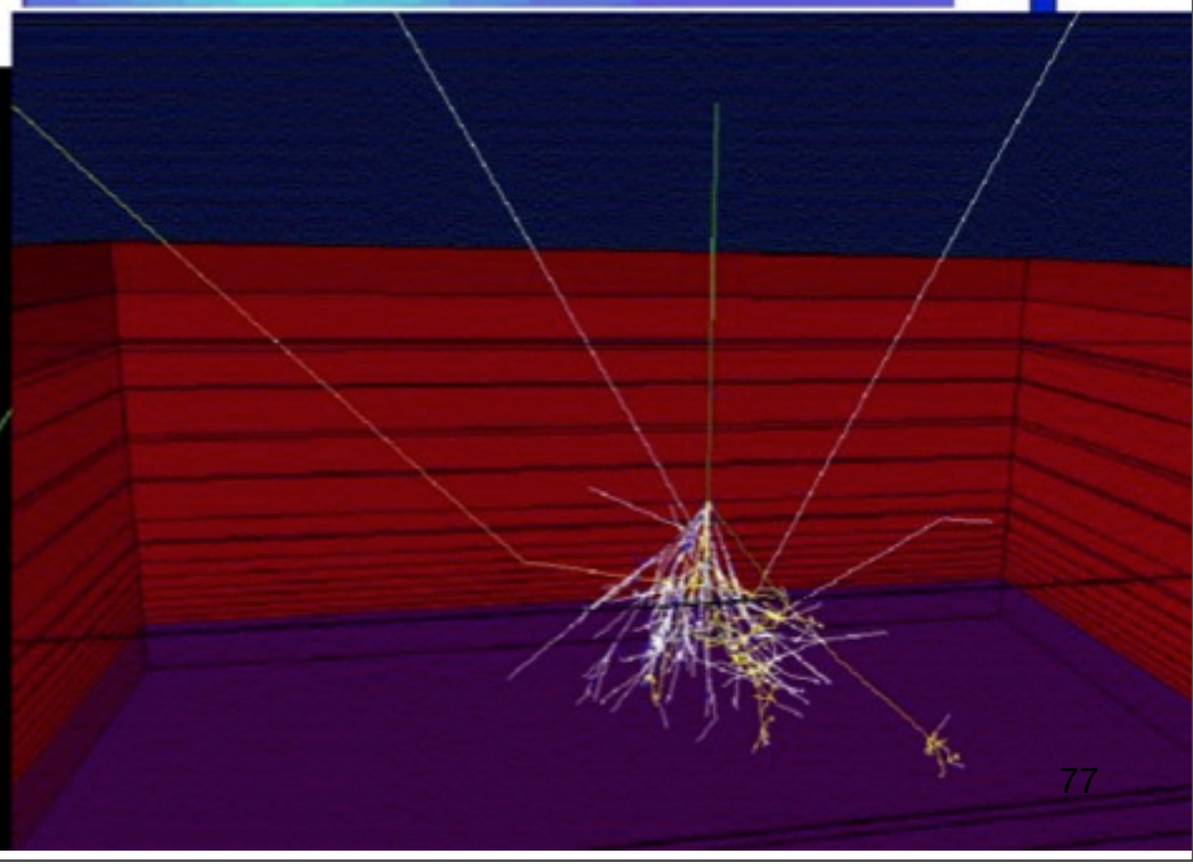
Geant4 Simulation of the Propagation of Cosmic Rays through the Earth's Atmosphere

L. Desorgher, E. O. Flückiger, M. R. Moser, and R. Bütikofer
Physikalisches Institut, University of Bern, CH-3012 Bern, Switzerland

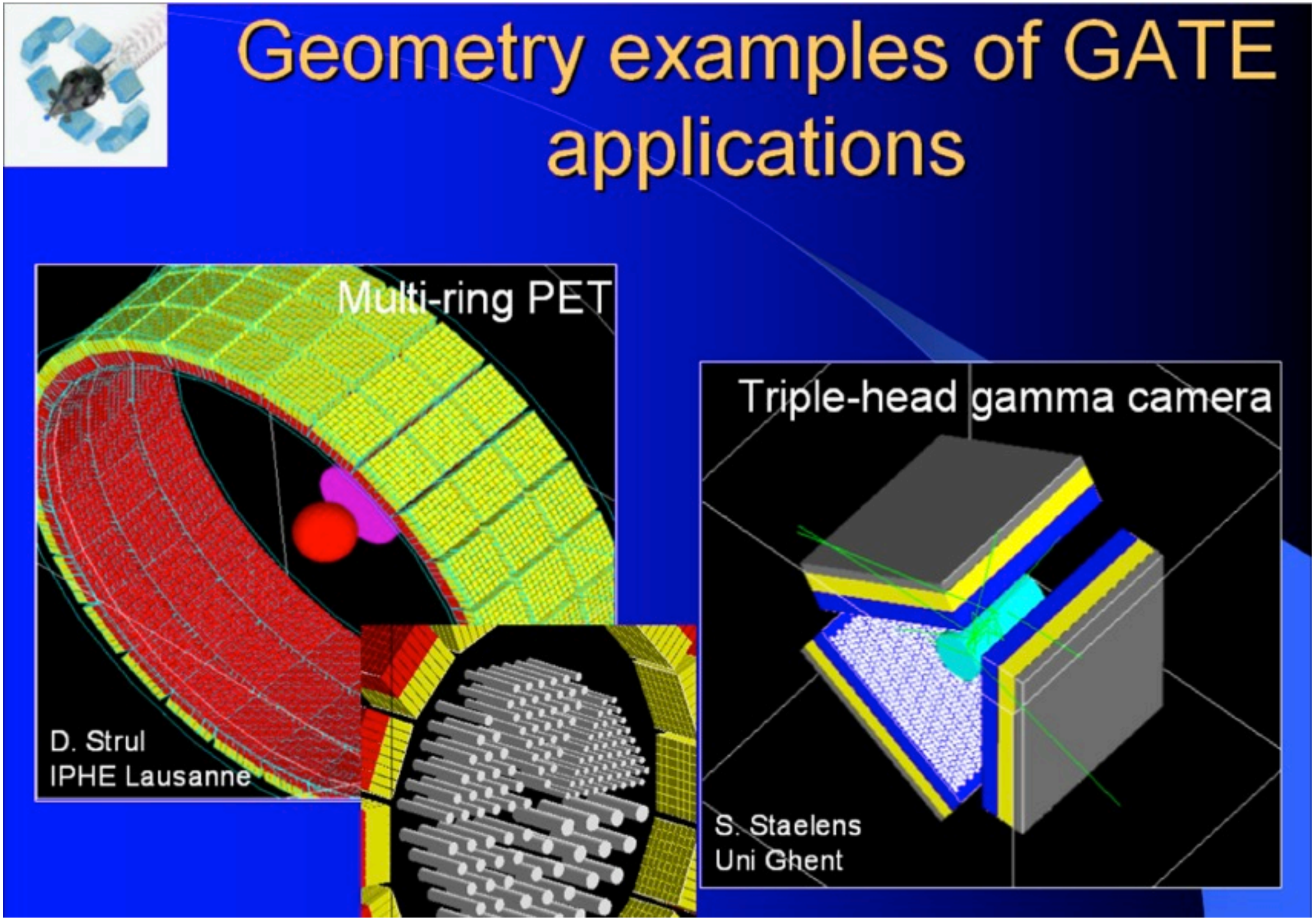


Cutoff Rigidities vs position

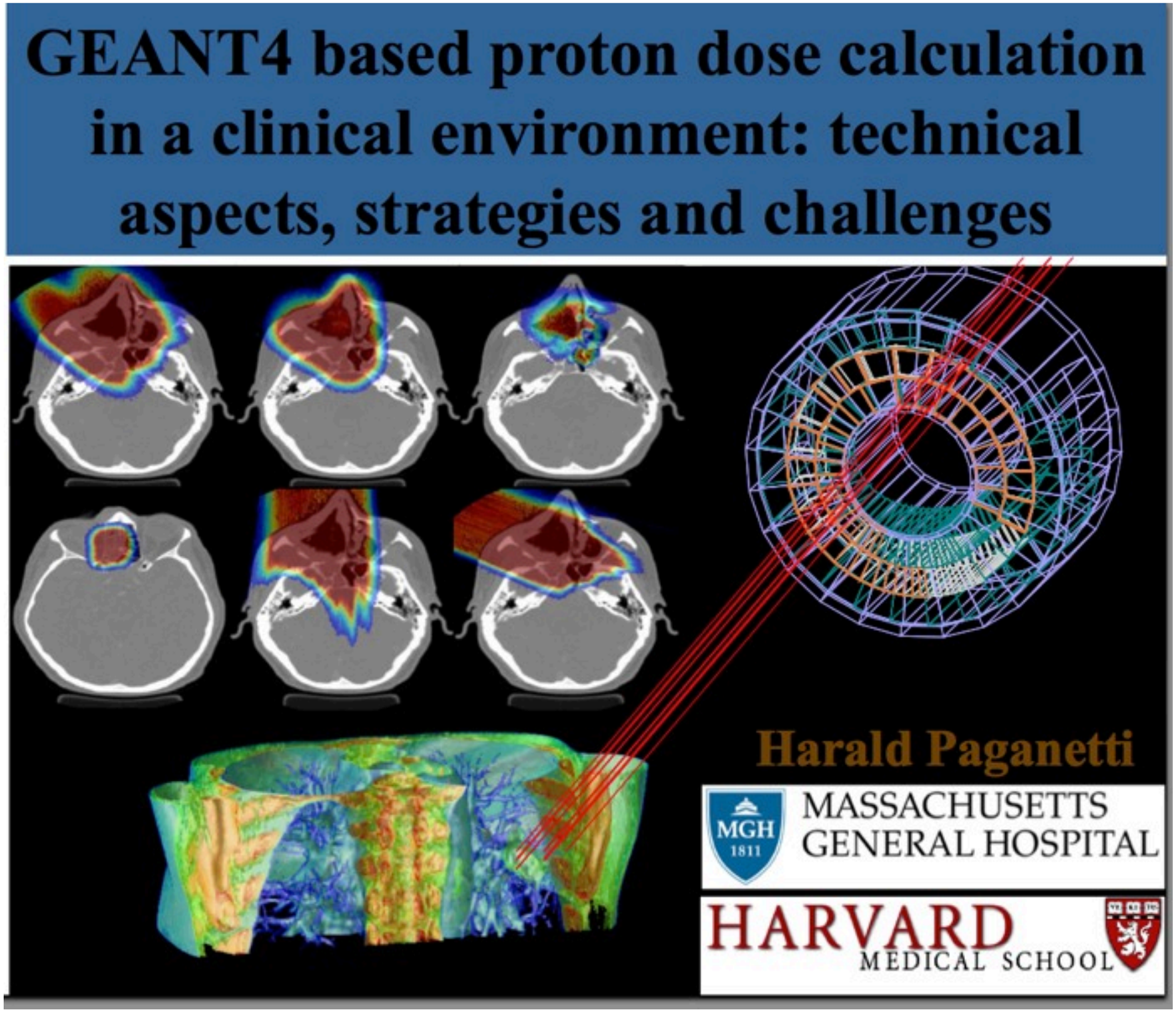




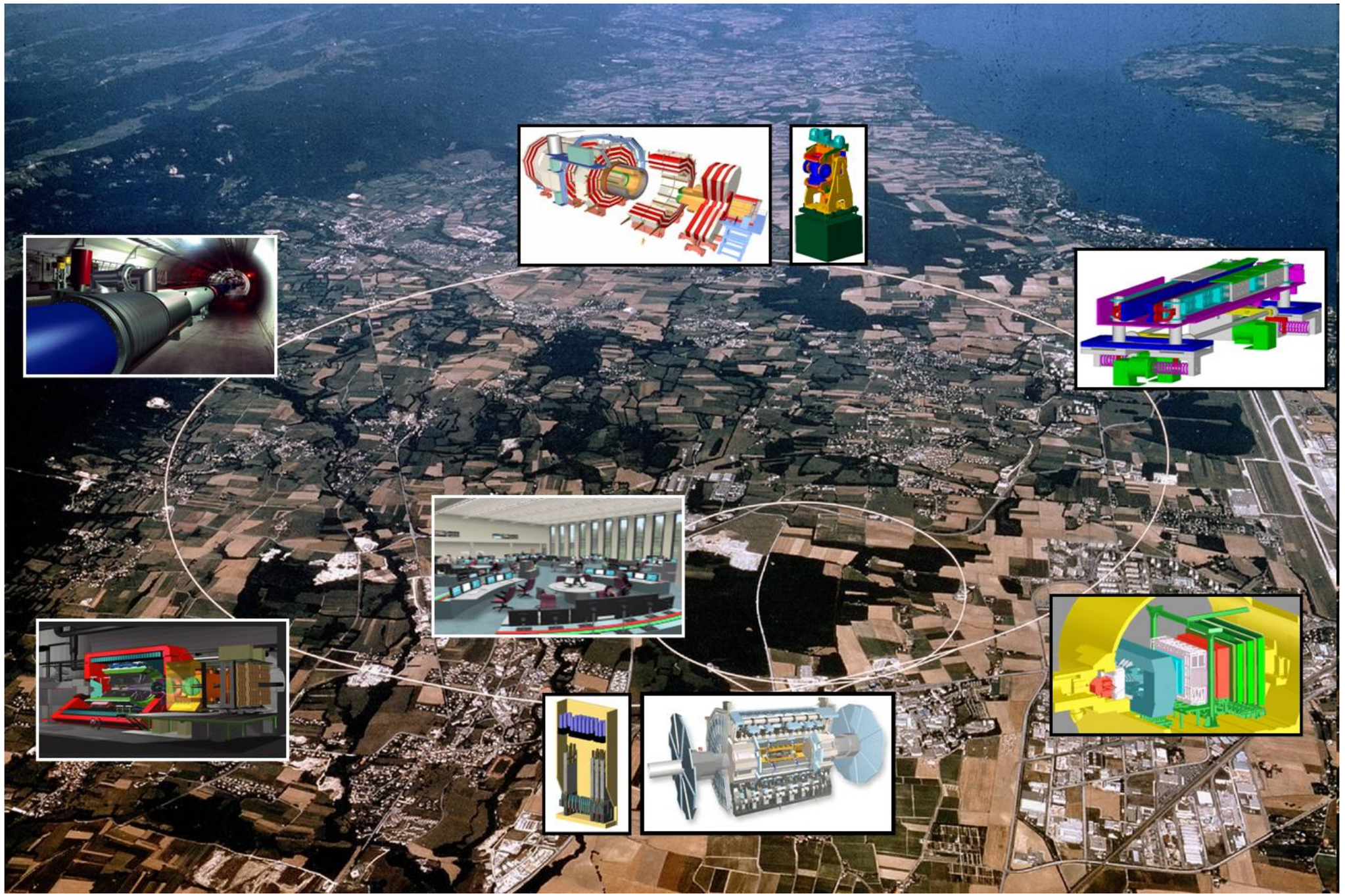
Medical applications



Medical applications



Large Hadron Collider @ CERN



Geant4 in Space (NASA, ESA, JAXA)

Smart-2

ACE

LISA

INTEGRAL

Cassini

Bepi Colombo

GLAST/Fermi

Herschel

SWIFT

Astro-E2

XMM-Newton

GAIA

JWST

Columbus

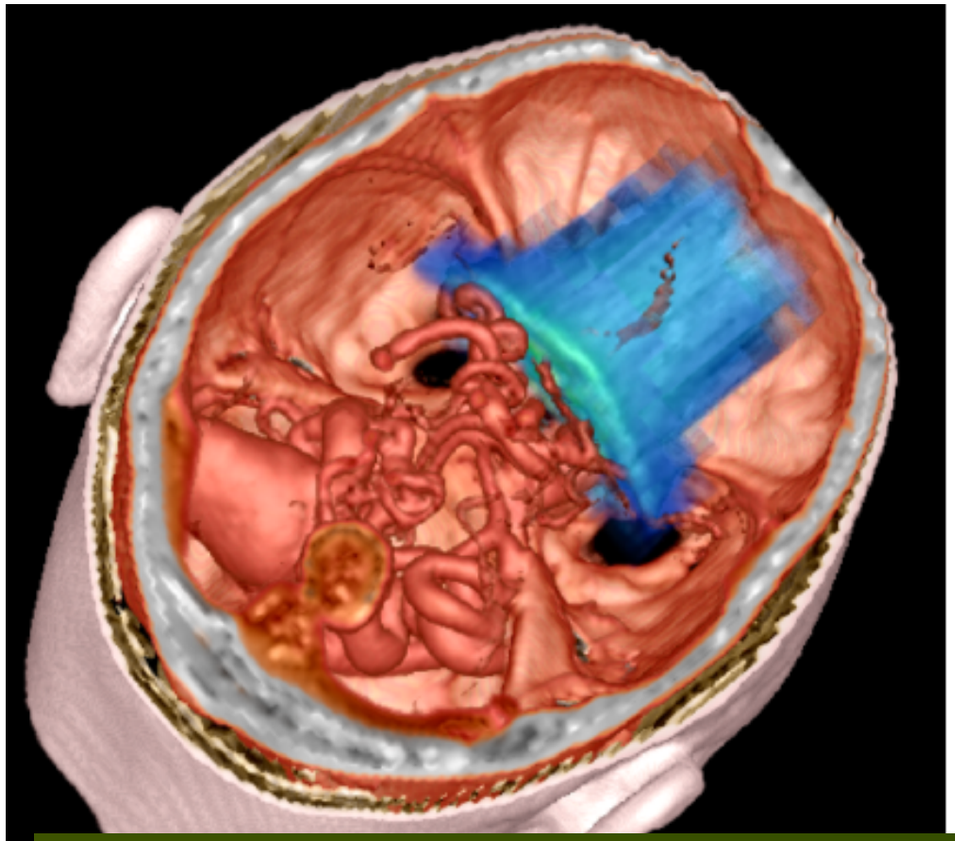
EUSO

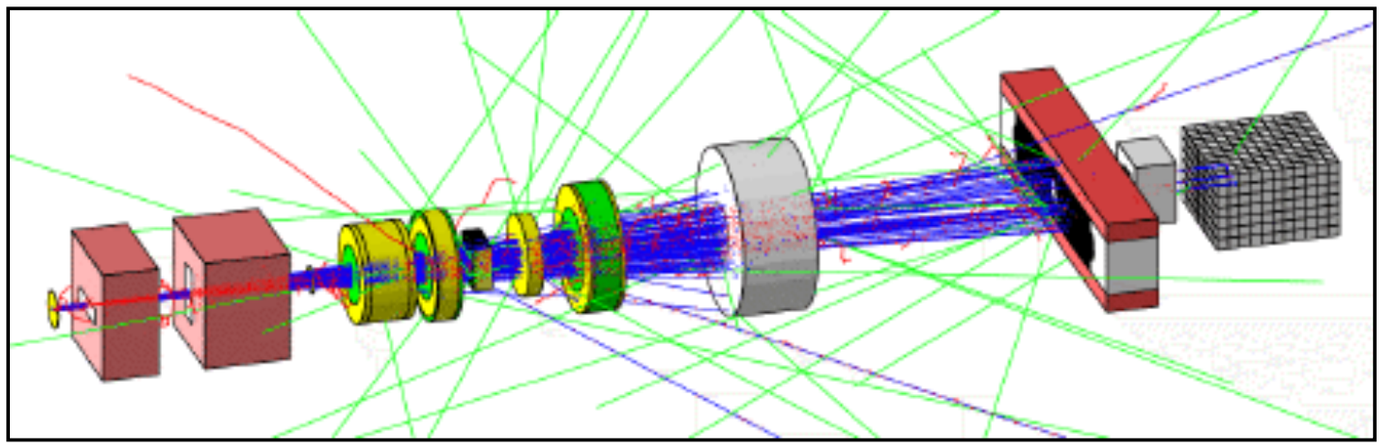
AMS

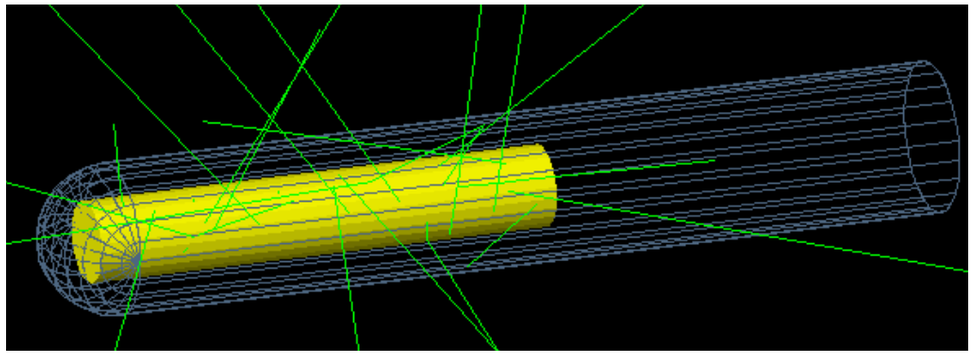
MAXI

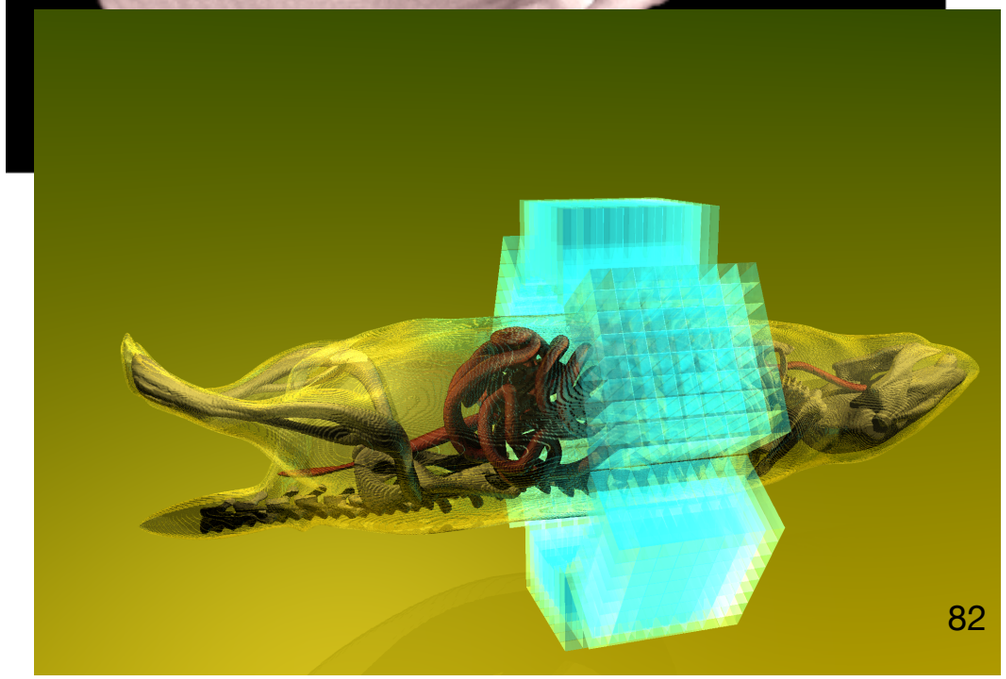
Geant4 and medical science

- Four major use cases
  - Beam therapy
  - Brachytherapy
  - Imaging
  - Irradiation study









The Italian Geant4 Group (MC-INFN Collaboration)

MC-INFN

- INFN project funded by the Interdisciplinary commission CSNV
- Benchmark table for a wide collaboration between Monte Carlo experts inside the INFN
- **FLUKA, Geant4 and people interested in Monte Carlo**
  - Discussions and exchanges on different topics
  - Data/validations common works
  - Dissemination

MC-INFN

- 11 Sezioni
  - Gruppo collegato dell'Istituto Superiore di Sanità
  - Laboratori Nazionali del Gran Sasso, del Sud e di Legnaro
  - Sezione di Bologna
  - Sezione di Genova
  - Sezione di Milano
  - Sezione di Pavia
  - Sezione di Perugia
  - Sezione di Roma III
  - Sezione di Torino

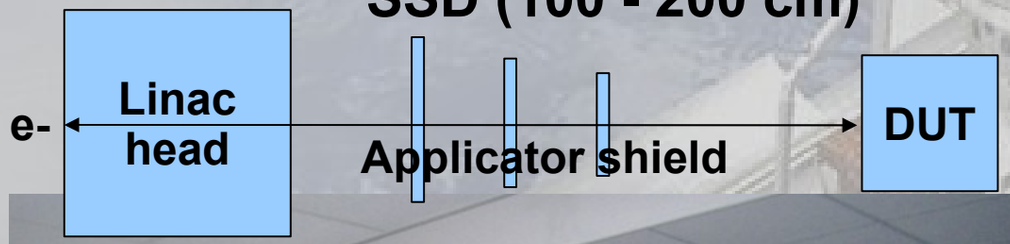
Space app
Medicals
Radiation damage
DNA-level simulations
New detector
Hadrontherapy
Nuclear physics

MC-INFN - Geant4, thanks B. Alpat (INFN-PG)

Terni Hospital e-Linac

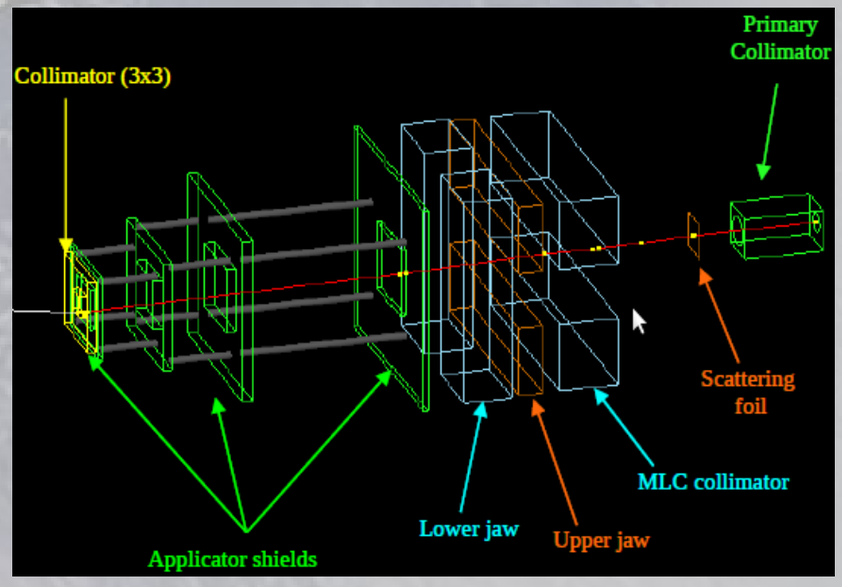
Advanced Markus Chamber
PTW-34045

Source to Surface Distance
SSD (100 - 200 cm)



Entrance window thickness 0.03 mm
Sensitive volume 20 mm³

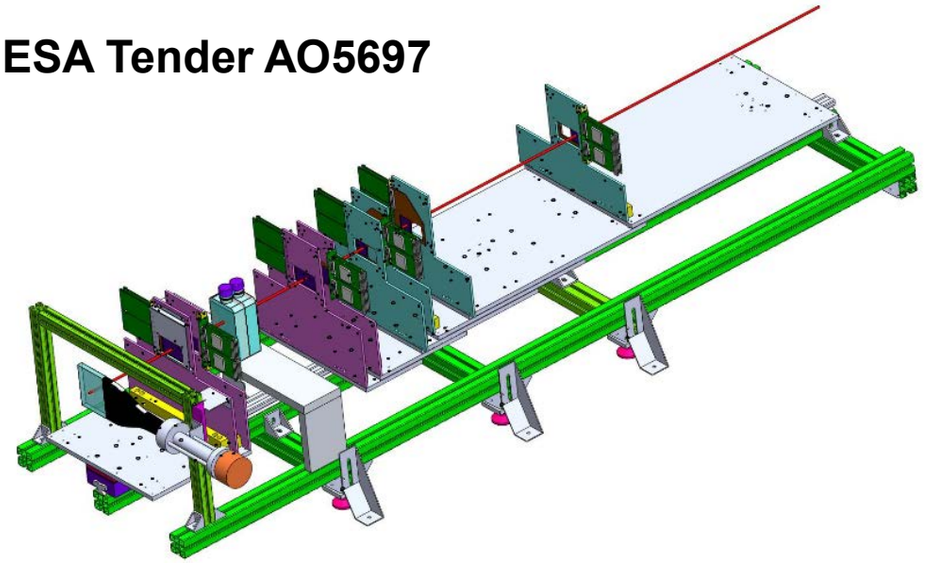
Simulated Accelerator Head



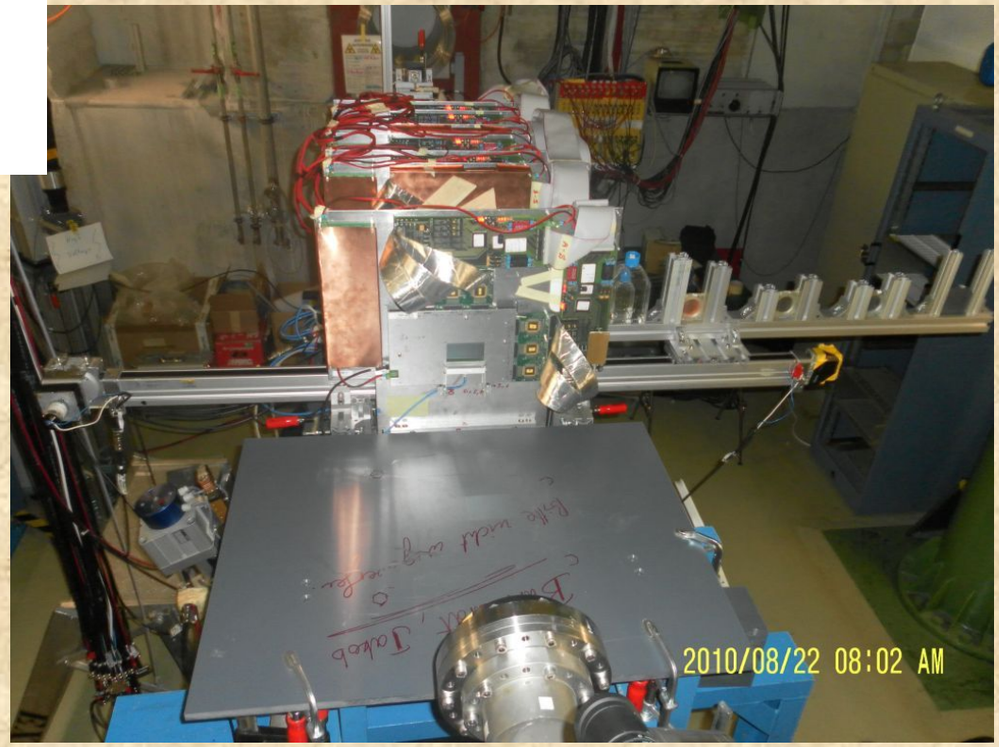
MC-INFN - Geant4, thanks B. Alpat (INFN-PG)

Experimental Set-up

ESA Tender AO5697



On left,CAD rendition of the set-up assembly as used at GSI on August 2009; the red line represents the beam, going through the triggering scintillator, the target and all the silicon sensors.
On bottom, photos of experimental set-up on August 2009 (at left), and during beam sessions in 2010.



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MC-INFN - Geant4, thanks B. Alpat (INFN-PG)

Simulation: MXGS

The MXGS (on ASIM mission to be installed on ISS in 2011) detector full simulation with Geant4 to study the prompt and radioactive backgrounds.

GEANT4 simulation of MXGS, ASIM's main detector.

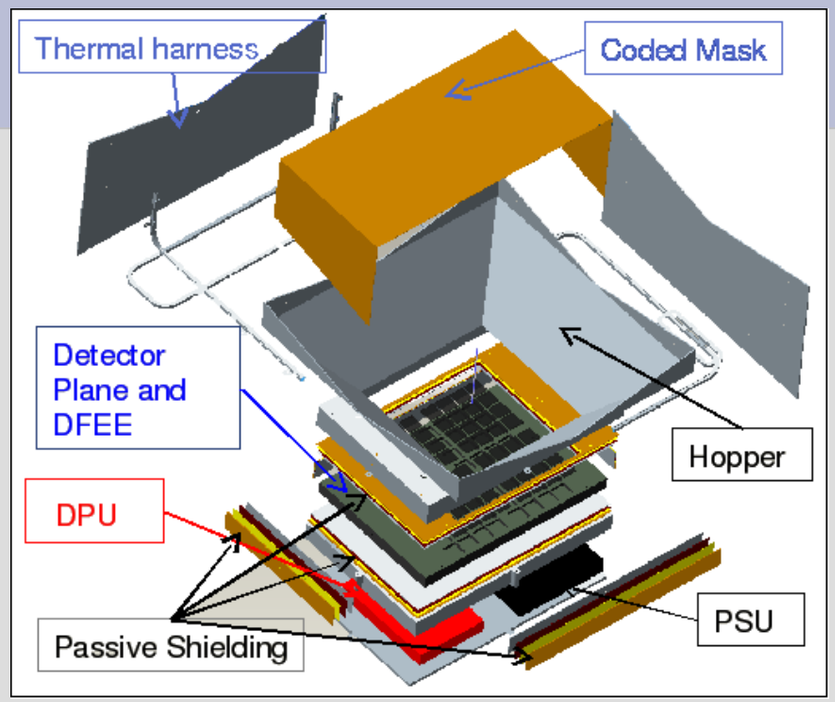
Cosmic and Trapped Particle fluxes are studied, also taking into account:

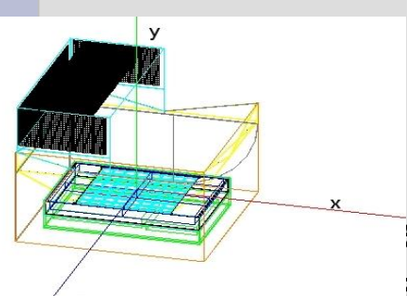
Flux alteration due to ASIM ancillary detectors

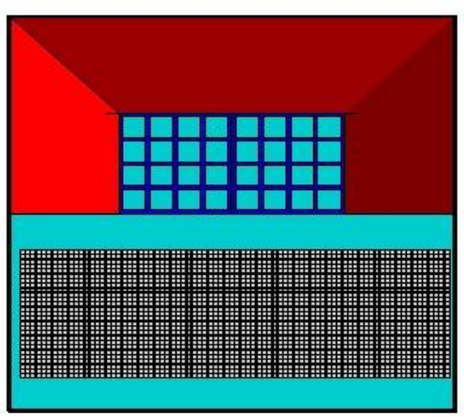
Flux alteration due to ISS Modulus Columbus where the experiment will be attached,

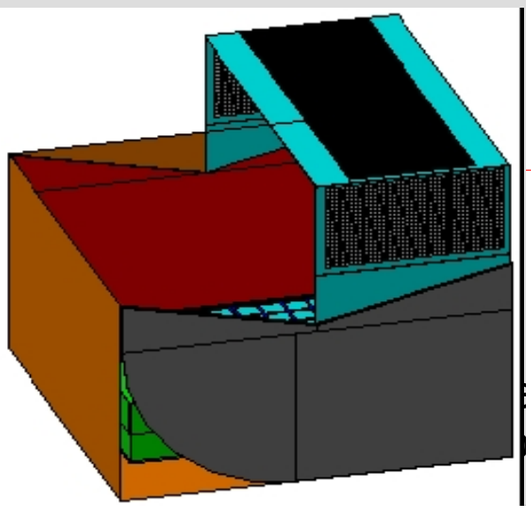
Experiment materials activation and subsequent decay.

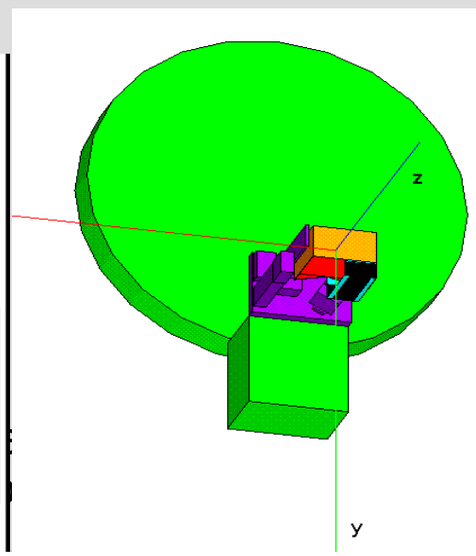
Daily modulation of fluxes along the orbit



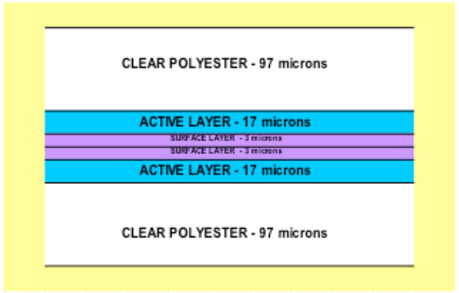




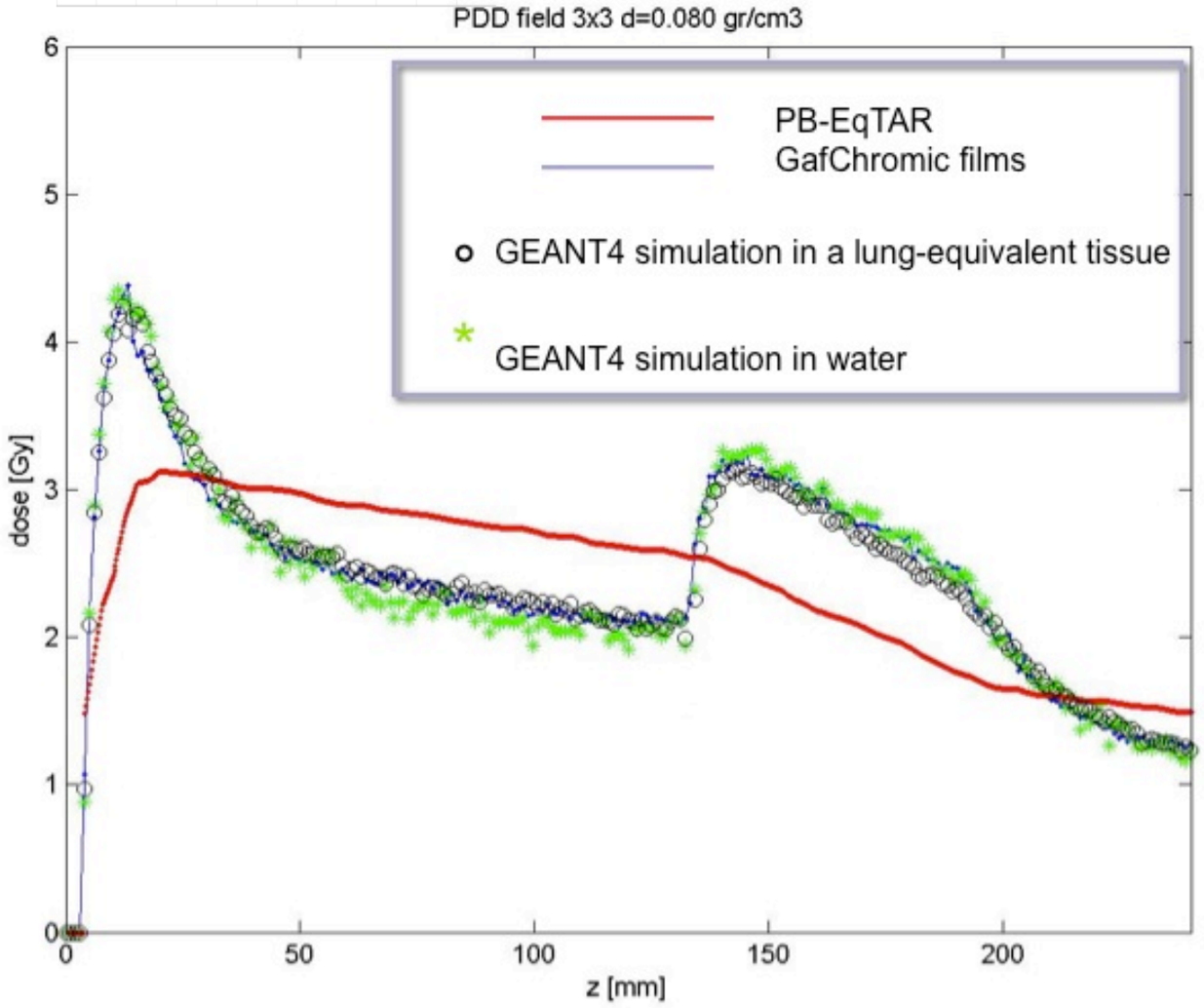


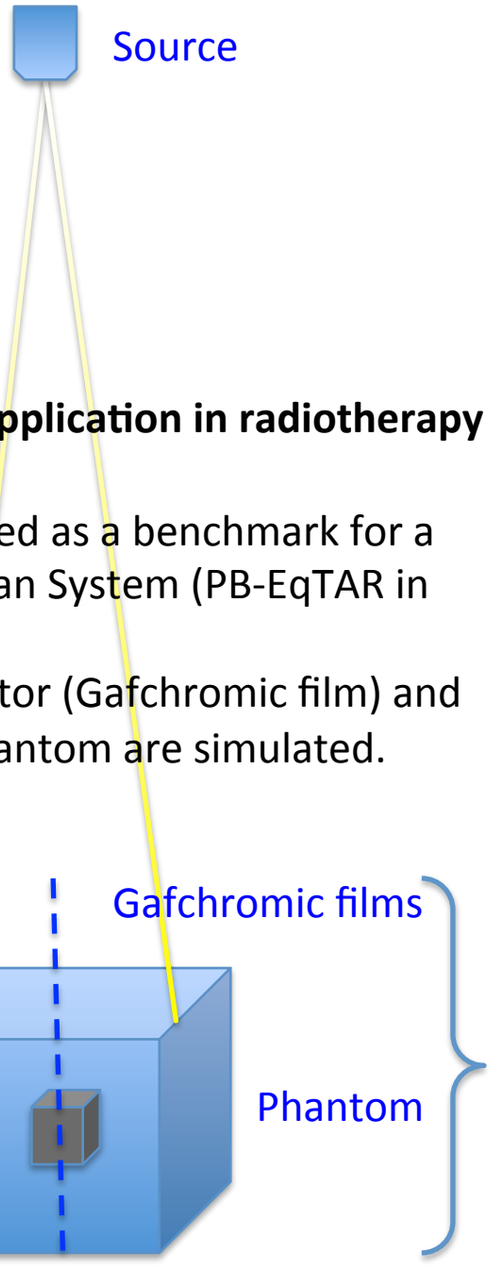


Detectors simulation in a clinical context
Thanks to B. Caccia, ISS Rome



Gafchromic EBT film is a well-known and common tool to measure dose distributions: its main features are high spatial resolution, tissue equivalence and weak energy dependence





An example of application in radiotherapy

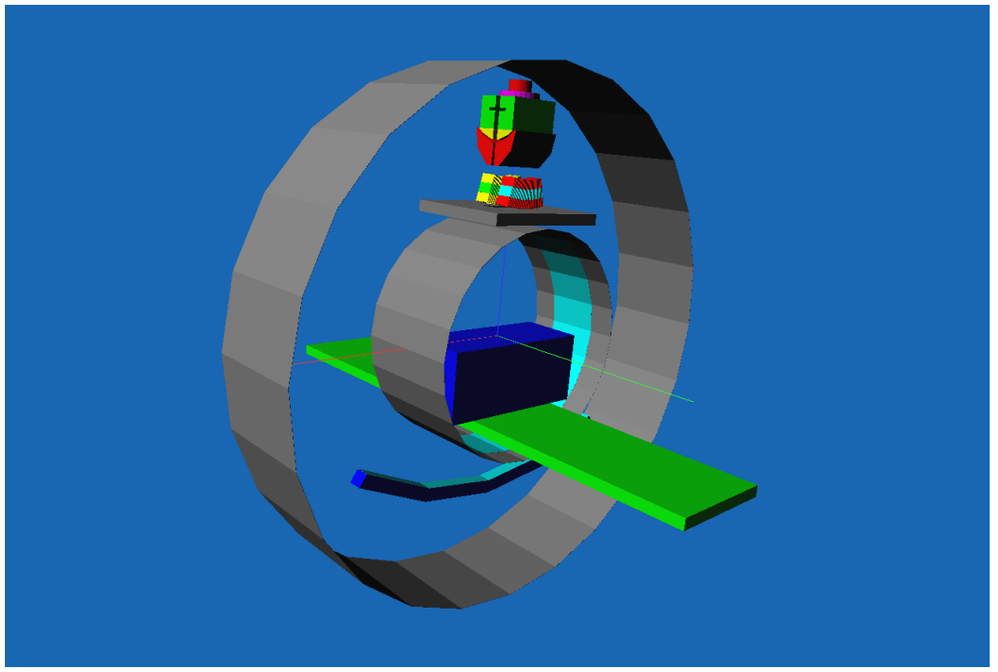
GEANT4 is used as a benchmark for a Treatment Plan System (PB-EqTAR in this case)
Clinical detector (Gafchromic film) and the entire phantom are simulated.

Detectors simulation in a clinical context
Thanks to B. Caccia, ISS Rome

Helical Tomotherapy unit Geant4 simulation

Helical tomotherapy, one of the most advanced form of conformal radiotherapy, combines a 360° fan-beam delivery of intensity-modulated radiation with a megavoltage CT imaging in order to treat and target complex tumors.

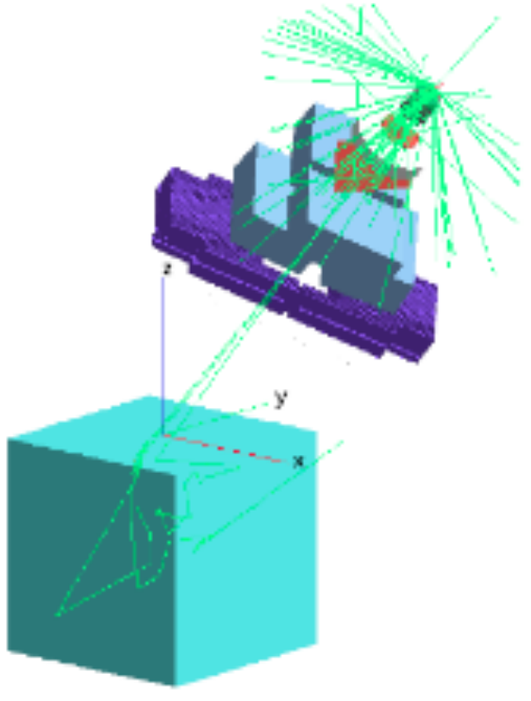
The dose distribution evaluation for such complex technique is an outstanding problem requiring sophisticated computing technologies to optimize the clinical results and the Quality Assurance (QA) requirements.



Medical Linac Advanced Example

The example is based on a typical structure of a medical linear accelerator for Intensity Modulated Radiation Therapy (IMRT), such as Varian Clinac 2100 accelerator.

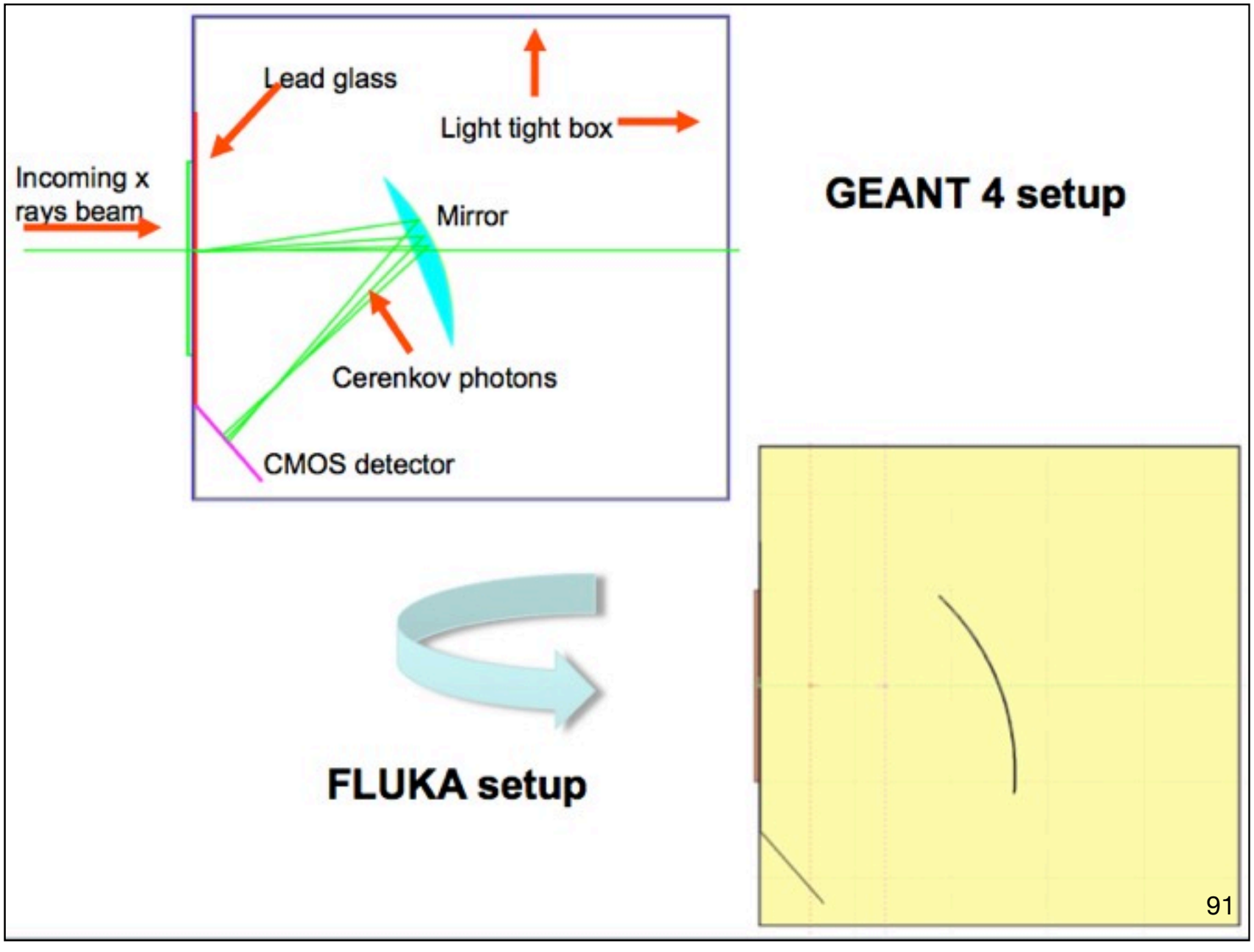
Two types of particle sources may be chosen, a random generator of electrons gun shooting the target or particles loaded from a phase space.
The Advanced example allows the generation of a plane phase space.
The user may choose different types of phantoms.



***Documentation about the Geant4 medical linac advanced example:*
http://geant4advancedexampleswg.wikispaces.com/ExamplesDocumentation

Research in Medical Applications Thanks to T. Rovelli, INFN-BO

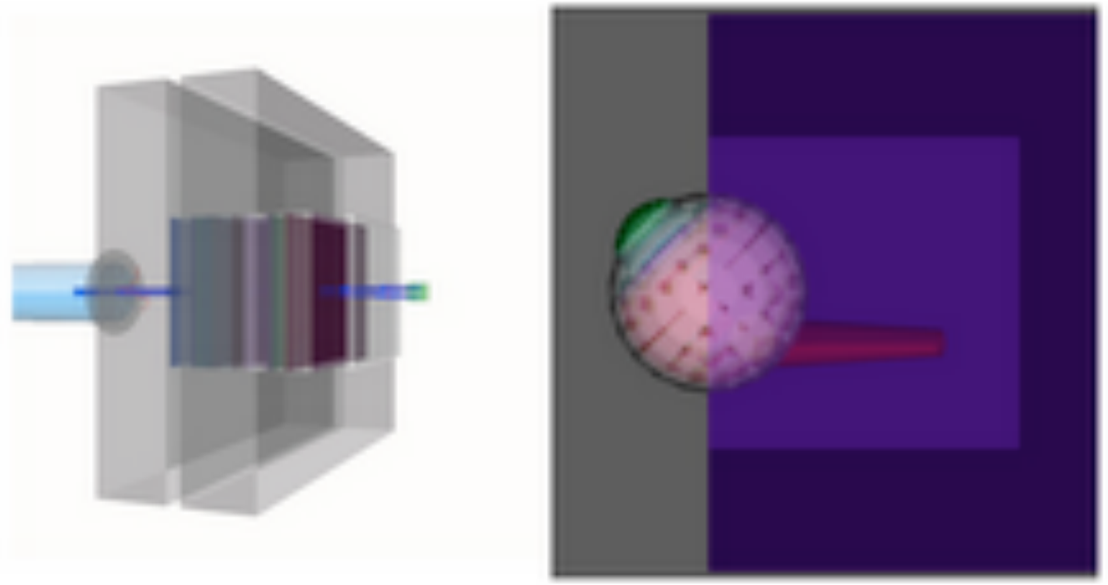
- A novel Cherenkov detector for radiotherapy applications

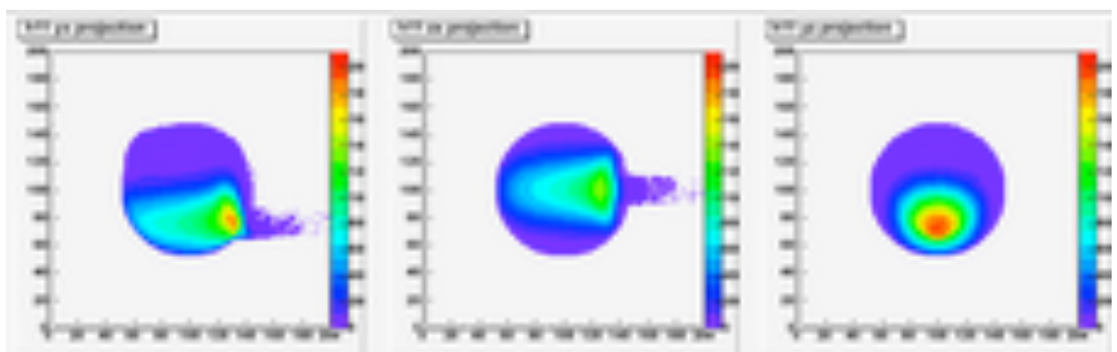


New ideas in ocular protontherapy
Thanks to A. Rimoldi, INFN-PV

- Ocular protonterapy wit a scanning beam

  - CNAO facility, Italy

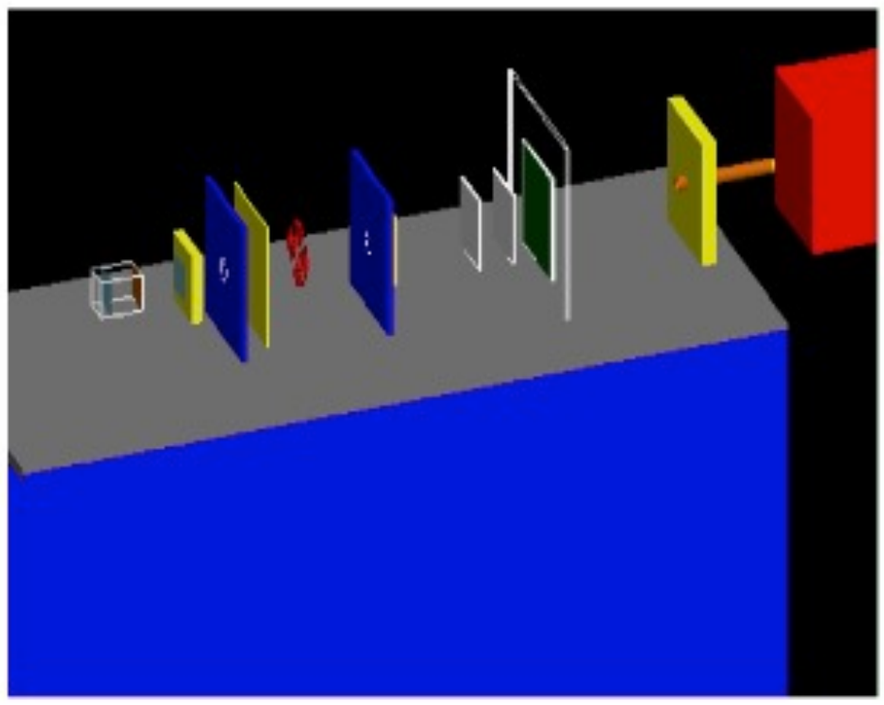




Hadrontherapy applications at the CATANA facility; Thanks to Dr. F. Romano

- Geant4 Advanced example
- Ocular proton treatment beam line

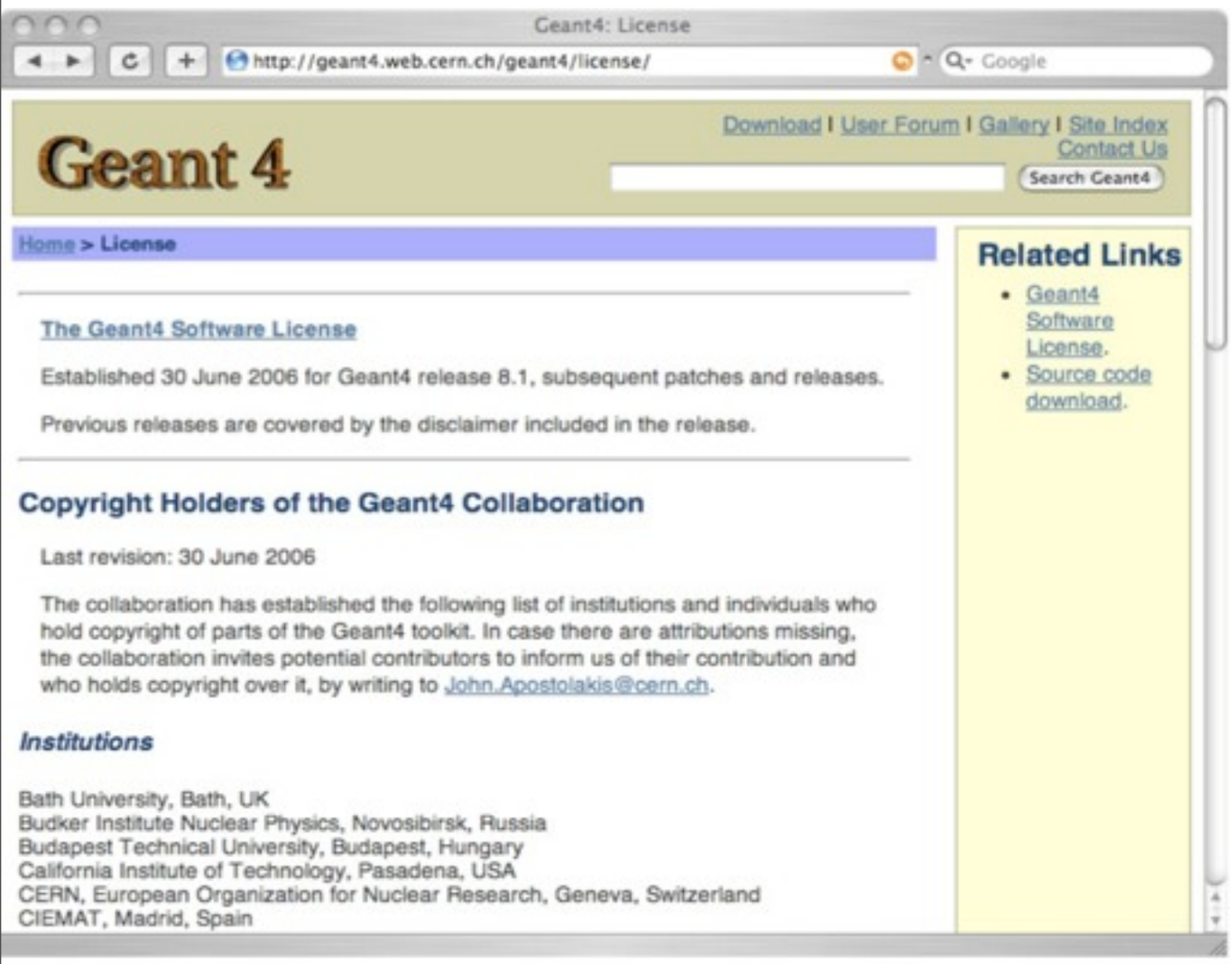
- Different geometries and physics options



The Geant4 License

The Geant4 License

In response to the Users requests of the Geant4 distribution policy



- Makes clear the user's wide - ranging freedom to use, extend or redistribute Geant4, even as part of some for- profit venture.
- Simple enough that you can read and understand it.
- http://cern.ch/geant4/license/

The Geant4 Licence

- Establishes the Geant4 copyright
- Prohibits others from claiming that they are Geant4
- If you develop something in or based on Geant4 and give it away, Geant4 can have it for free, too
- Any documentation you produce must refer to Geant4
- You cannot patent the part already written by the collaboration
- Geant4 is fully Open Source

Trajectory is not the Track

- Track does not keep its trace. No Track object, in fact, persists at the end of event

- G4Trajectory is the class that copy some G4Track information and G4TrajectoryPoint copies some G4Step information

  - G4Trajectory has a vector of G4TrajectoryPoint

  - At the end of event processing, G4Event has a collection of G4Trajectory objects

    ✓ /traking/storeTrajectory must be 1

- G4Trajectory and G4TrajectoryPoint store information up to the end of the event and they contain only the minimum information

Geant4 as a state machine

- Geant4 has six application states
  - G4State_Preinit
  - G4State_Idle
  - G4State_GeomClosed
  - G4State_EventProc
  - G4State_Quit
  - G4State_Abort