Montecarlo Methods for Medical Physics

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Summary of the Course

- Part1 (Today)
  - General (and brief) introduction to Monte Carlo methods
  - Montecarlo methods in Medical Physics
- Part2 (Today – 1st part)
  - Introduction to the Geant4 toolkit
- Part3
  - Fundamentals of a Geant4 application (Today – 2nd part)
  - Geometry, Physics, Particle Flux, Scoring needs (Thursday)
- Laboratory (Next weeks)
  - Realisation of an example relevant to Medical Physics

Evaluation for the "Laboratory"

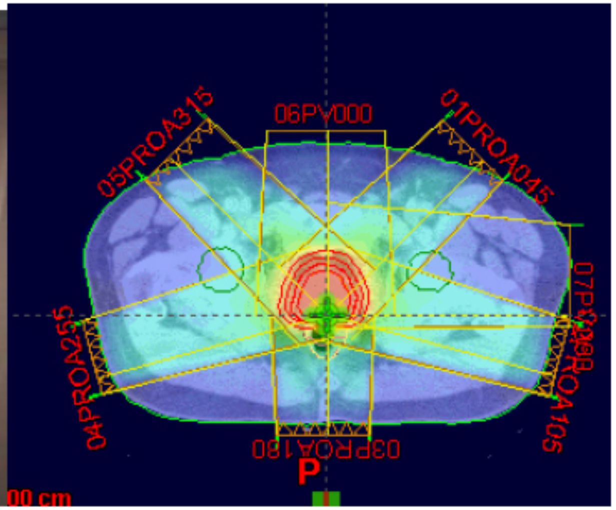
- Discussion of Geant4 example
  - G4 example relevant to Medical Physics
- Discussion of requirements and methods
  - Medical Physics "environment"
  - Geant4 modeling
  - "Basic" analysis of results
- Realization of "new" example – Laboratory
  - Might just be an improvement of the existing G4 examples

Part 1

Montecarlo in Medical Physics

Montecarlo for Medical Physics

Overview of Medical Physics Applications

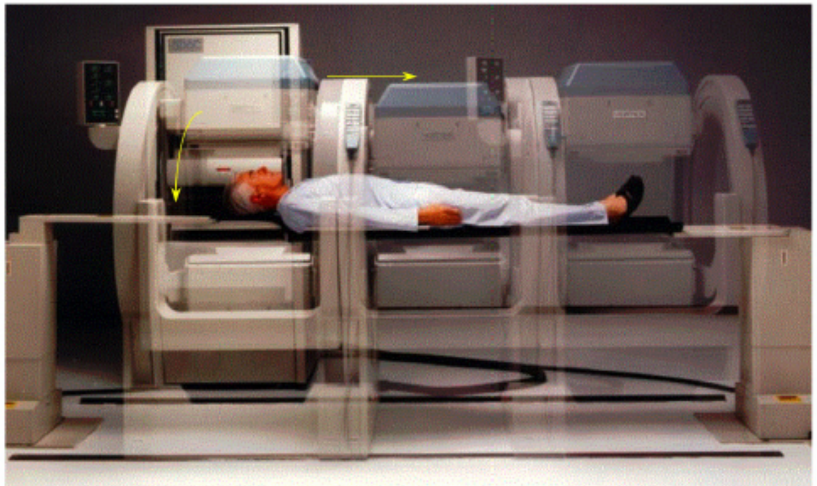


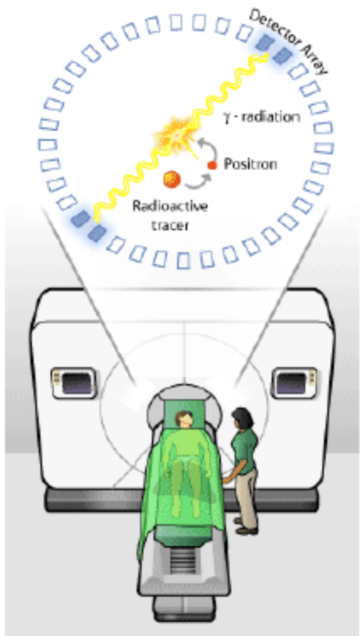
Radiotherapy physics

- external/internal sources and dosimetry
- phantom simulations
- treatment planning

Montecarlo for Medical Physics

Single Photon Emission Computer Tomography (SPECT)

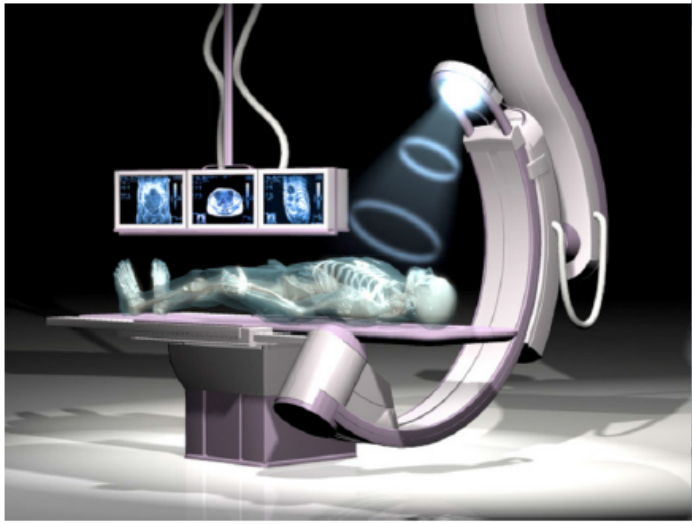




Nuclear medicine

- detectors
- imaging correction
- absorbed dose

Montecarlo for Medical Physics



Diagnostic radiology

- detection systems
- physical quantities
- radiation protection

Montecarlo in Treatment Planning Systems

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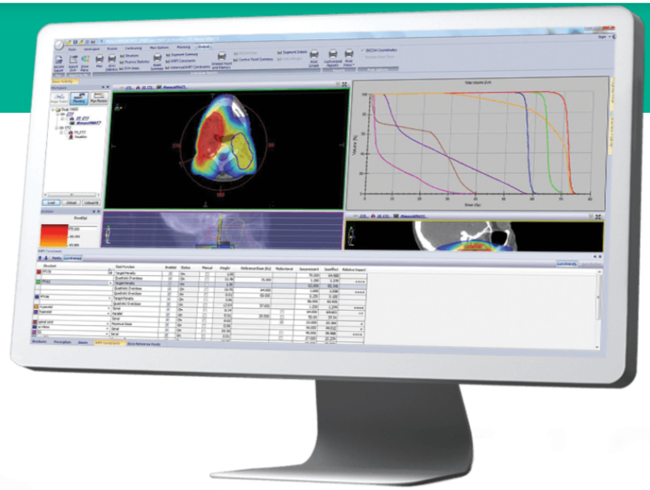


Precision planning for photon and electron based plans

Monaco delivers high performance and high precision radiotherapy treatment planning for all major treatment techniques for photon and electron based plans.

Its rich, intuitive tools make the radiotherapy planning process faster, easier and clinically reliable.

By combining the superior accuracy of Monte Carlo and Collapsed Cone algorithms with the richness of advanced optimization tools in a modern, intuitive user workspace, Monaco delivers highly accurate 3D, IMRT, VMAT and SRS plans in a single, easy to use solution.

Monaco can handle very complex plans and exquisite dose distribution available in one rotation with its high dose modulation capabilities.

Monaco provides superior quality assurance with Monte Carlo used as the gold standard from which to compare other third party plans. Simply import a plan from any treatment planning system and re-calculate with Monte Carlo for a secondary check.

VIEW BROCHURE

WATCH VIDEO

ADDITIONAL RESOURCES

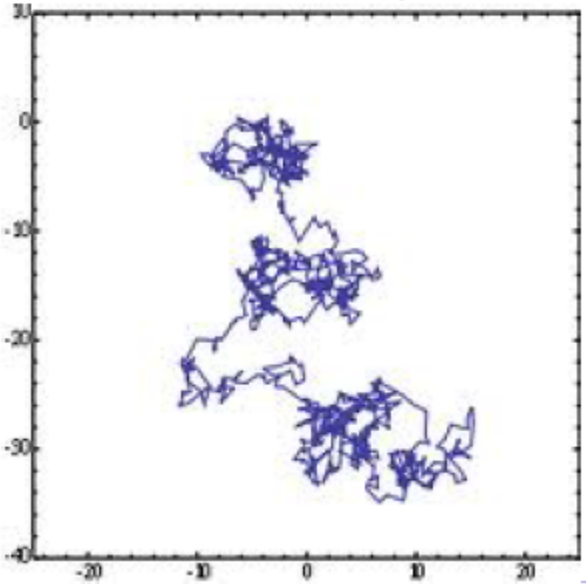
What is a Montecarlo program?

- Numerical method
- Random sampling of probability distributions
- Simulate stochastic processes in nature
  - Market fluctuations
  - Population studies
  - Weather forecasting
  - Radiation transport
  - Traffic flows
  - Astrophysics and Cosmology …
  - …

Stochastic processes

- Random, probabilistic processes
- Physical parameters vary according to probability distribution
- Not "single" outcome but more/less probable outcome are possible …

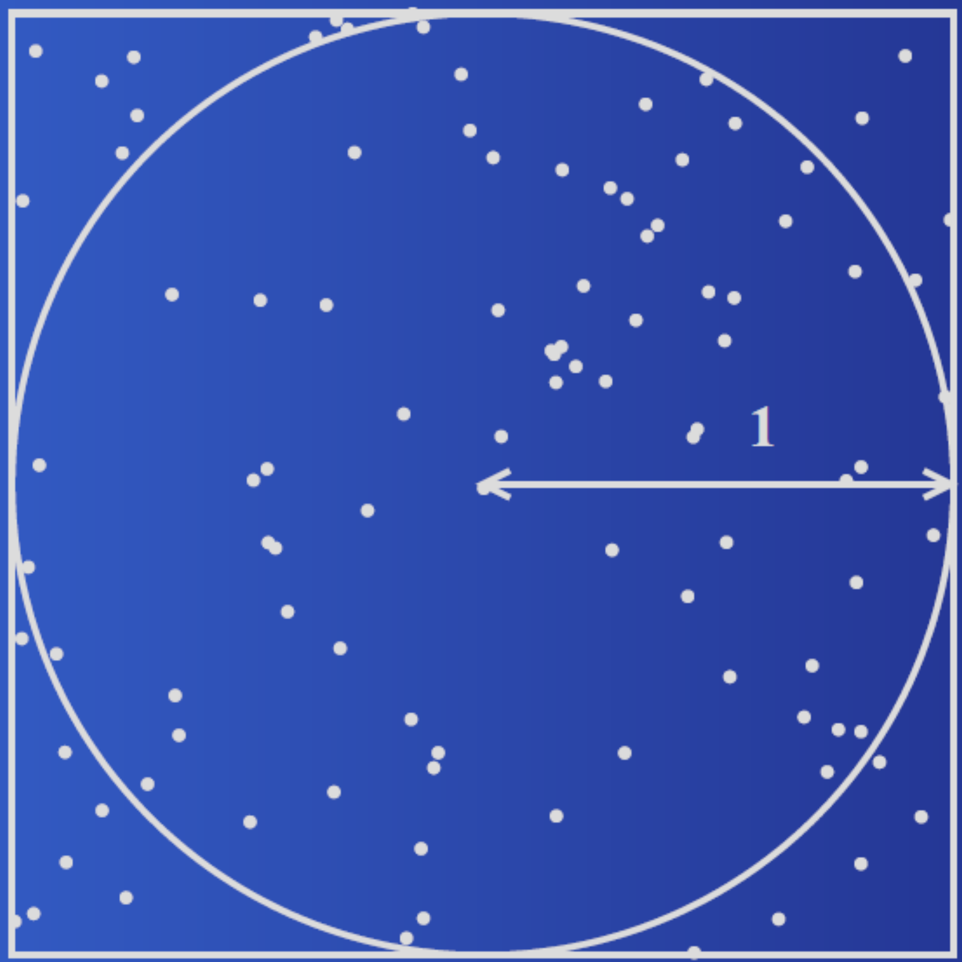
Example: Brownian motion (a.k.a. random walk)



A brief history

- Comte du Buffon (1777): needle tossing experiment to calculate π
- Laplace (1886): random points in a rectangle to calculate π
- Fermi (1930): random method to calculate the properties of the newly discovered neutron
- Manhattan project (40's): simulations during the initial development of thermonuclear weapons. von Neumann and Ulam coined the term "Monte Carlo"
- Exponential growth with the availability of digital computers
- Berger (1963): first complete coupled electron-photon transport code that became known as ETRAN
- Exponential growth in Medical Physics since the 80's

A brief history



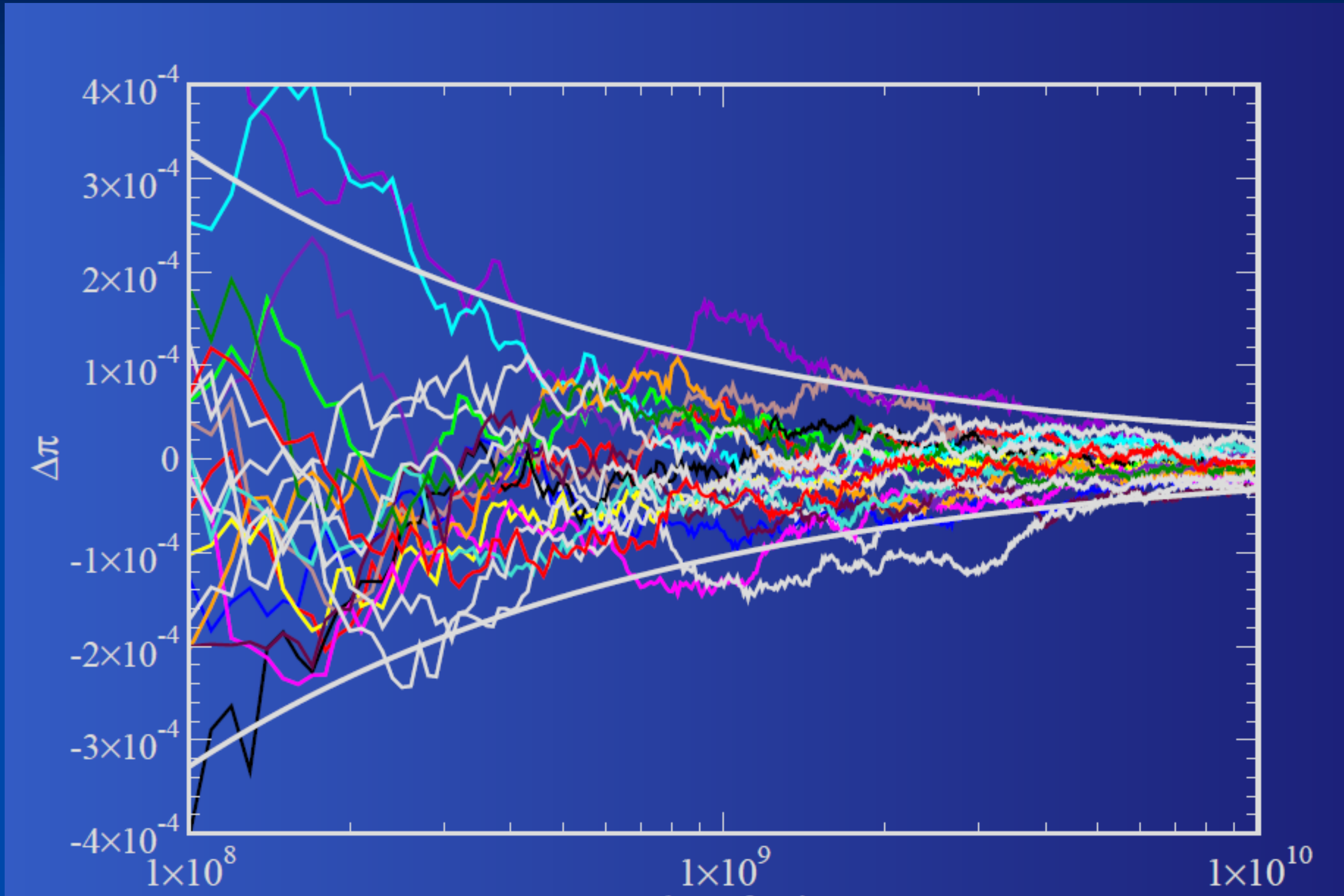
Area of square: $A_s = 4$
Area of circle: $A_c = \pi$
Fraction p of random points inside circle:

$$p = \frac{A_c}{A_s} = \frac{\pi}{4}$$

Random points: N
Random points inside circle: N_c

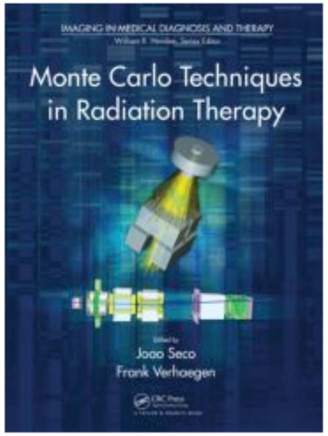
$$\Rightarrow \quad \pi = \frac{4N_c}{N}$$

A brief history



Montecarlo for Medical Physics

Home » Physics » Medical Physics » Monte Carlo Techniques in Radiation Therapy



Monte Carlo Techniques in Radiation Therapy

Series: Imaging in Medical Diagnosis and Therapy
Published: March 25, 2013 by CRC Press
Content: 342 Pages | 20 Color & 177 B/W Illustrations
Editor(s): Joao Seco, Frank Verhaegen

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Description | Table of Contents | Editor Bio(s) | Reviews

Features

- Provides a broad practical guide to the rapidly growing field of Monte Carlo simulations used in medical physics in radiotherapy
- Includes the mathematical and technical background required for understanding Monte Carlo simulations and variance reduction techniques
- Covers real medical applications of Monte Carlo methods in proton/light ion therapeutics, beam models, quality assurance, radiation dosimetry, and patient dose calculation
- Incorporates examples to help illustrate key points

Summary

Modern cancer treatment relies on Monte Carlo simulations to help radiotherapists and clinical physicists better understand and compute radiation dose from imaging devices as well as exploit four-dimensional imaging data. With Monte Carlo-based treatment planning tools now available from commercial vendors, a complete transition to Monte Carlo-based dose calculation methods in radiotherapy could likely take place in the next decade. **Monte Carlo Techniques in Radiation Therapy** explores the use of Monte Carlo methods for modeling various features of internal and external radiation sources, including light ion beams.

Montecarlo for Medical Physics

< Previous Article | January 2017 Volume 33, Pages 179–181 | Next Article >

Monte Carlo simulations for medical physics: From fundamental physics to cancer treatment

S. Guatelli*
Centre For Medical Radiation Physics (CMRP), University of Wollongong (UOW), Wollongong, NSW, Australia
S. Incerti
CENBG, CNRS/IN2P3, France

PlumX Metrics

DOI: https://doi.org/10.1016/j.ejmp.2017.01.002 | Check for updates

Article Info

Abstract | Full Text | References

Highlights

- Focus Issue (FI) dedicated to the Monte Carlo (MC) Workshop for Medical Physics.
- The Monte Carlo workshop took place in April 2016.
- The event was organised by the Centre For Medical Radiation Physics, Wollongong.
- The FI contains 12 original, peer reviewed scientific contributions.
- The papers concern the projects presented in some oral presentations of the event.
- The contributions include research performed in Europe, US, Asia and Australia.

The 2016 Monte Carlo Workshop for Radiotherapy, Imaging and Radiation Protection, 28–30 April, was organised by the Centre For Medical Radiation Physics (CMRP), University of Wollongong (UOW), Wollongong, NSW, Australia. The Chair was S. Guatelli (CMRP, UOW), with two supporting Co-chairs, S. Incerti (CENBG, CNRS/IN2P3, France) and J. Brown (Queen's University Belfast, Northern Ireland, UK). The event, already at its third edition (http://eis.uow.edu.au/cmrp/workshops-seminars/UOW204211.html), is unique in Australia and South Pacific region as it is devoted to the development, validation and use of Monte Carlo radiation transport codes in medical physics.

Montecarlo for Medical Physics

In: Medical Physics
Editor: Marcin Balcerzyk

ISBN: 978-1-62257-590-9
2013 Nova Science Publishers, Inc.

Chapter V

Applications of the Monte Carlo Method in Medical Physics

Ernesto Amato[1], Domenico Lizio[2] and Sergio Baldari[1]

[1]Department of Radiological Sciences, University of Messina, Italy
[2]Research Center of Saluggia, Institute of Radiological Protection, ENEA, Italy

ABSTRACT

The Monte Carlo simulation of particle transport and interaction in matter finds growing applications in medical radiation physics. Dosimetric applications in radiation therapy span from internal dosimetry in radionuclide therapy of nuclear medicine, to the treatment planning in external beam radiation therapy with photons, electrons or fast heavy ions, to the assessment of radiation dose distribution in heterogeneous media such as lungs, bones or renal parenchyma.

Part 2

Introduction to Geant4

Geant 4

A Simulation Tool for Multi-disciplinary Applications

http://cern.ch/geant4/

An simple introduction to Geant4 with emphasis on medical physics.

The seminar will touch some aspects of Geant4 from basic description to advanced topics.

The seminar should be of interest to complete novices with no familiarity with Geant4.

Participants are expected to have a basic knowledge of C++.

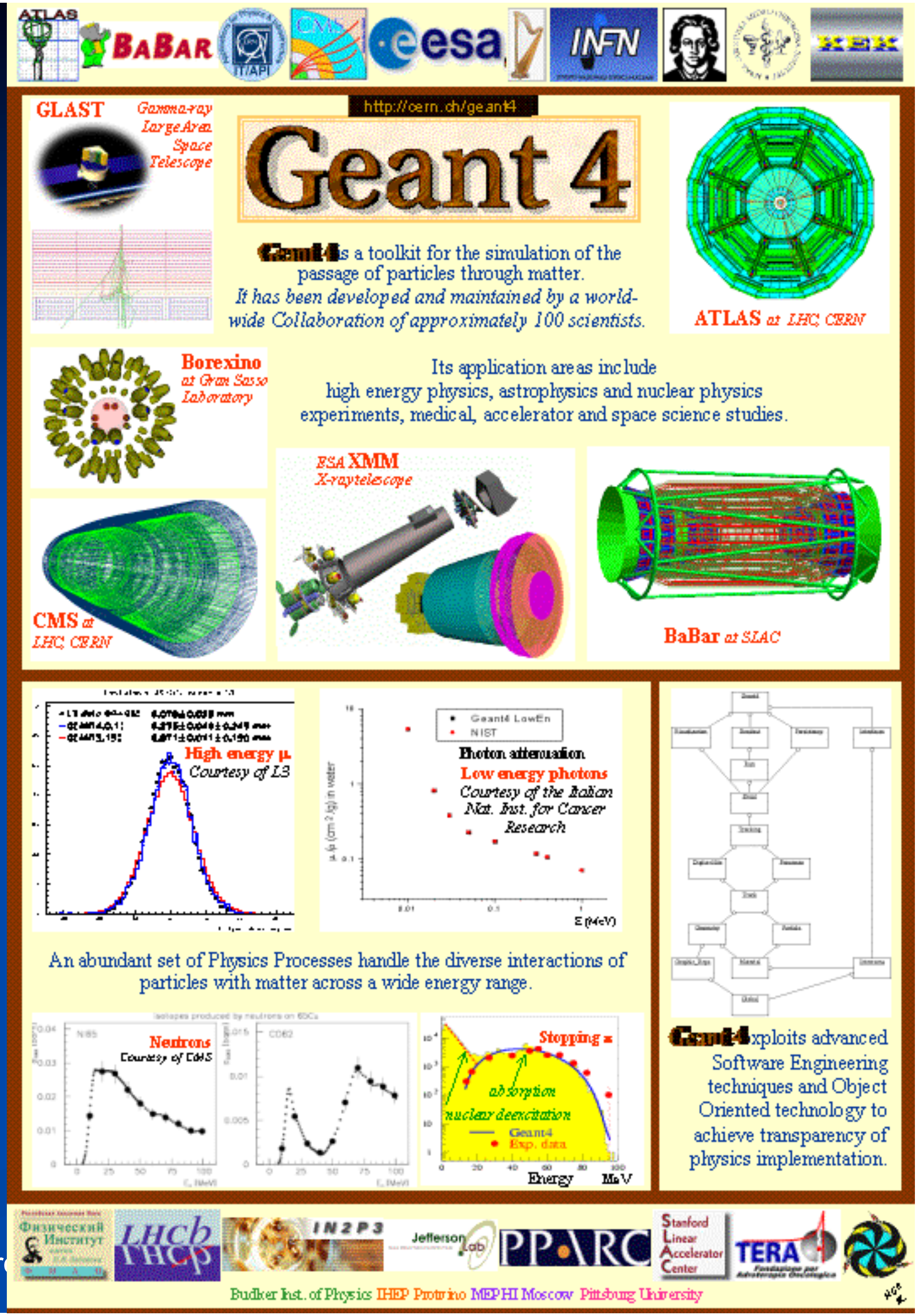
Based on Training Lectures by the G4 collaboration

Outline of Part2

- General Introduction to G4
  - What is G4 ?
  - Review of user documentation
  - Geant4 as a toolkit
- Basics of OO programming
- Geant4 Kernel and basics of the toolkit
  - Run, Event, Step
  - Particle and Physics processes
  - User classes

Geant4 toolkit

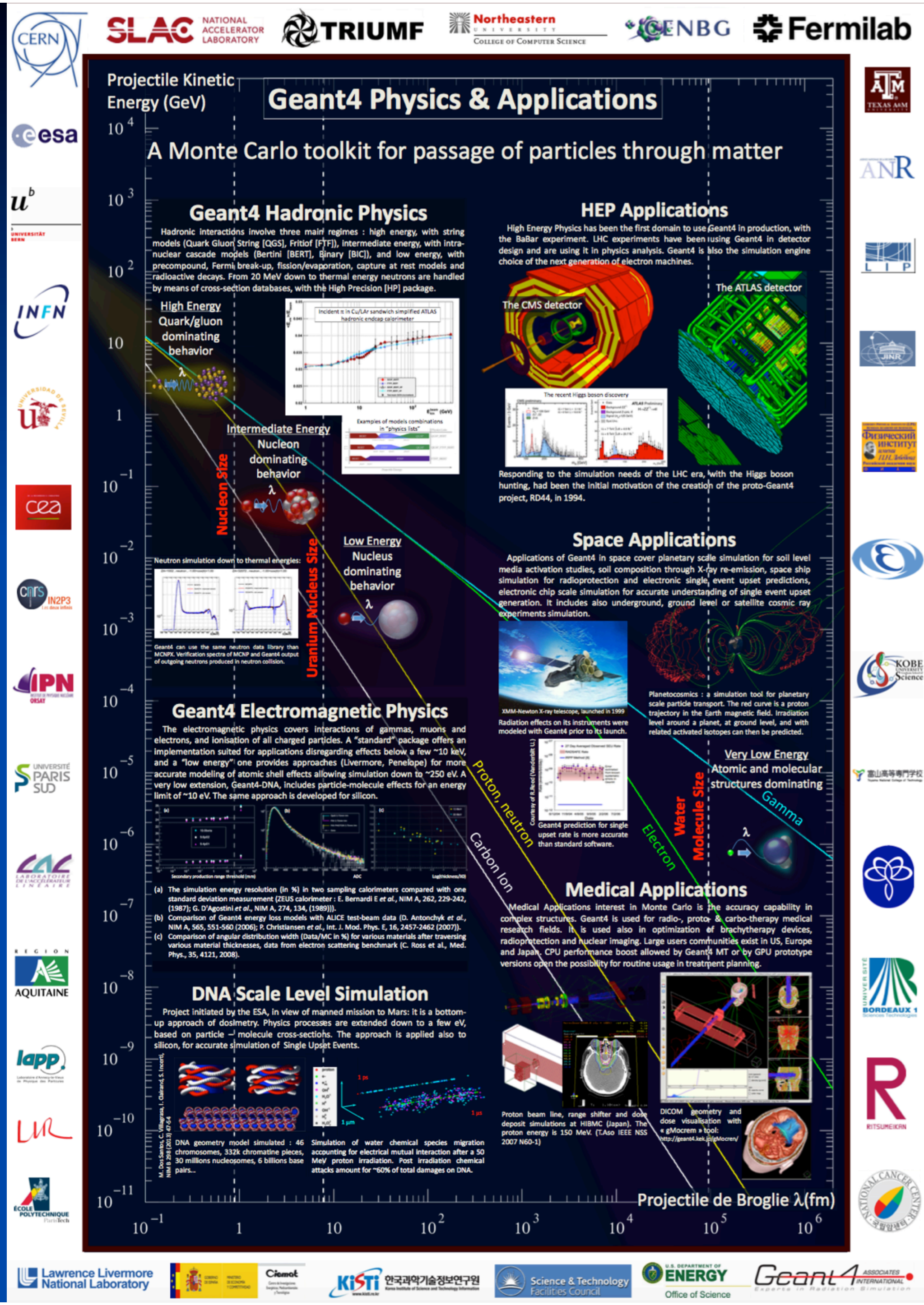
- Highlights of user applications
- General introduction and brief history
- User Documentation
- The main program



Geant4

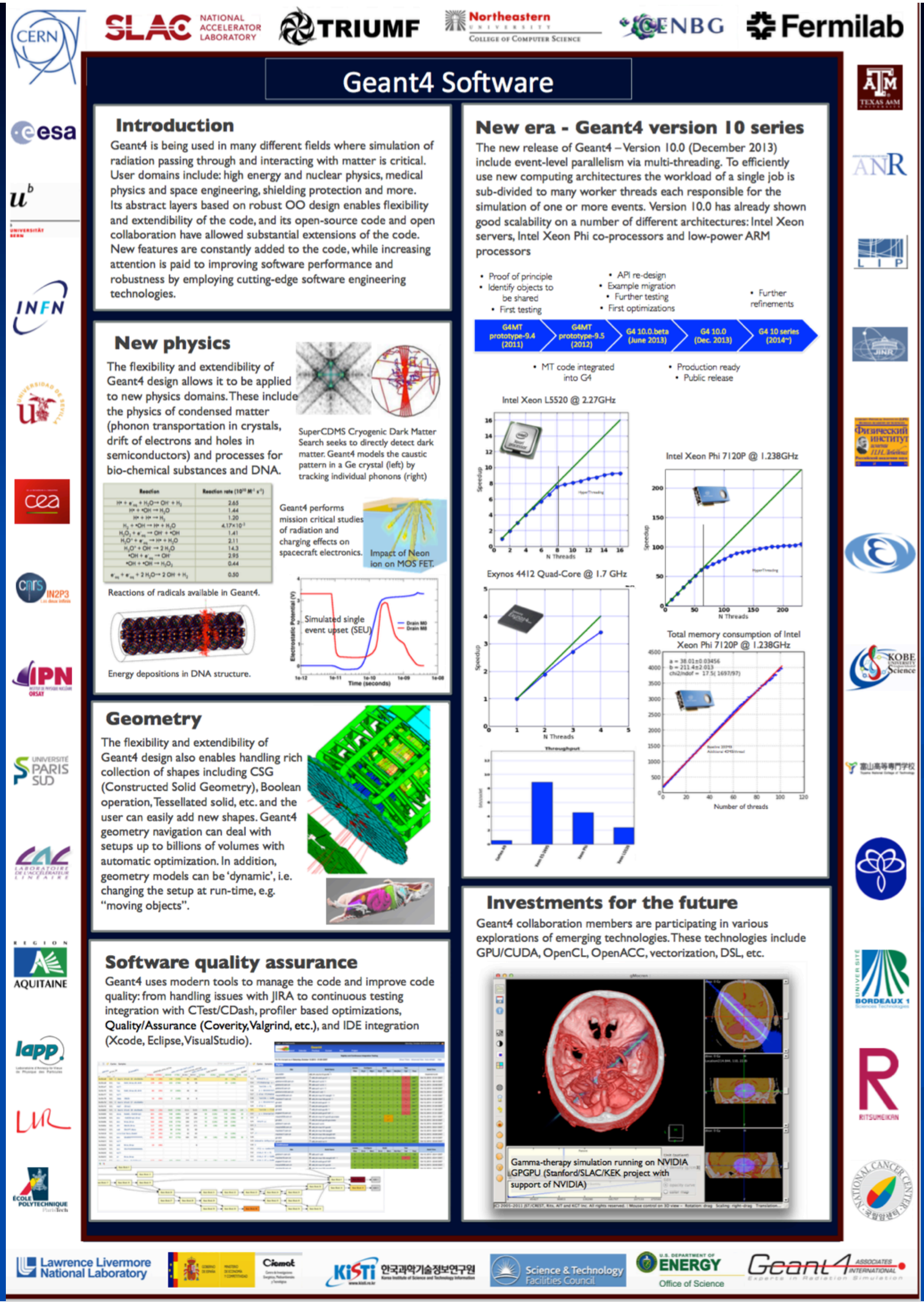
http://knowledgetransfer.web.cern.ch/technology-transfer/external-partners/geant4

Geant4



Geant4 Physics & Applications
A Monte Carlo toolkit for passage of particles through matter
Projectile Kinetic Energy (GeV)
Projectile de Broglie λ(fm)
Geant4 Hadronic Physics
HEP Applications
The CMS detector
The ATLAS detector
High Energy Quark/gluon dominating behavior
Intermediate Energy Nucleon dominating behavior
Low Energy Nucleus dominating behavior
Nucleon Size
Uranium Nucleus Size
Space Applications
Geant4 Electromagnetic Physics
Very Low Energy Atomic and molecular structures dominating
Water Molecule Size
Proton, neutron
Carbon Ion
Electron
Gamma
Medical Applications
DNA Scale Level Simulation

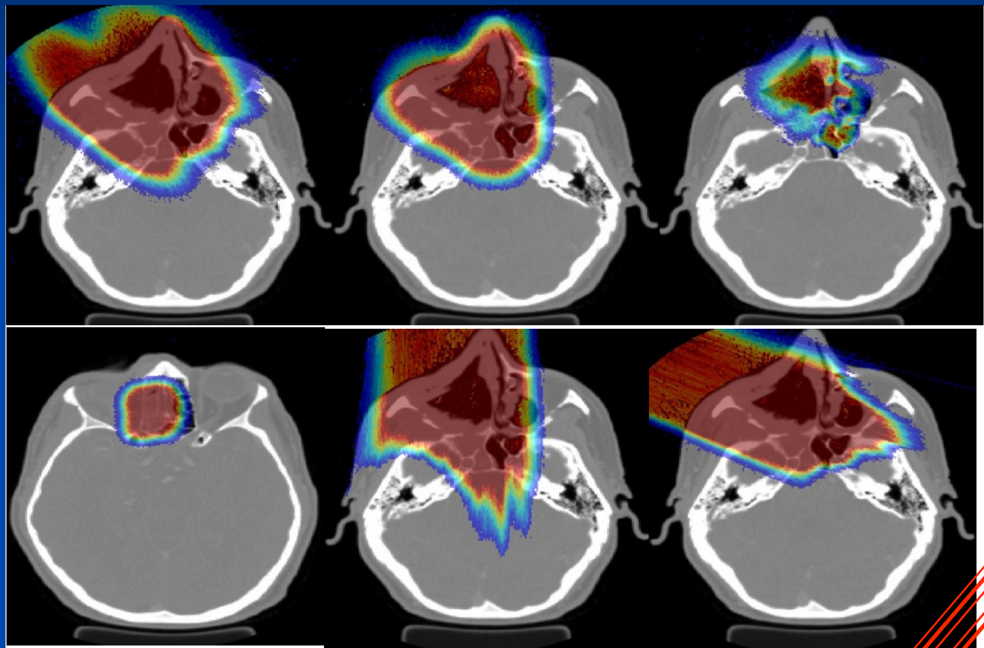
Geant4

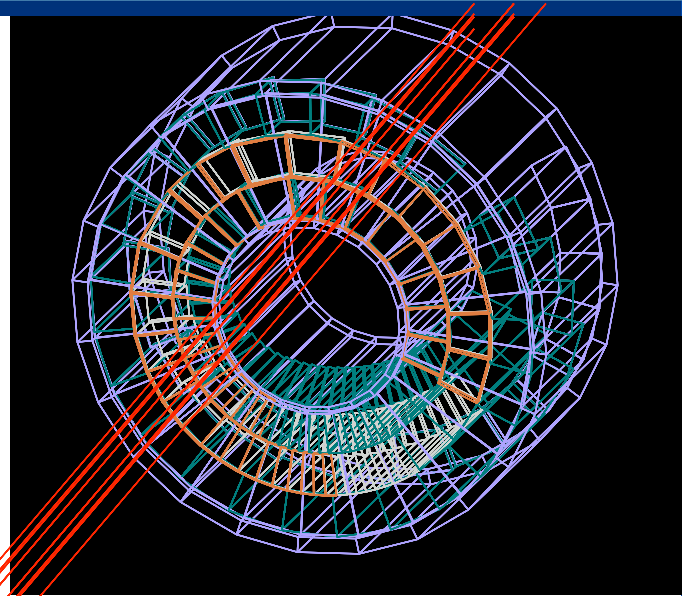

Geant4 Software
Introduction
Geant4 is being used in many different fields where simulation of radiation passing through and interacting with matter is critical. User domains include: high energy and nuclear physics, medical physics and space engineering, shielding protection and more. Its abstract layers based on robust OO design enables flexibility and extendibility of the code, and its open-source code and open collaboration have allowed substantial extensions of the code. New features are constantly added to the code, while increasing attention is paid to improving software performance and robustness by employing cutting-edge software engineering technologies.
New physics
The flexibility and extendibility of Geant4 design allows it to be applied to new physics domains. These include the physics of condensed matter (phonon transportation in crystals, drift of electrons and holes in semiconductors) and processes for bio-chemical substances and DNA.
SuperCDMS Cryogenic Dark Matter Search seeks to directly detect dark matter. Geant4 models the caustic pattern in a Ge crystal (left) by tracking individual phonons (right)
Geant4 performs mission critical studies of radiation and charging effects on spacecraft electronics.
Impact of Neon ion on MOS FET.
Reactions of radicals available in Geant4.
Energy depositions in DNA structure.
Geometry
The flexibility and extendibility of Geant4 design also enables handling rich collection of shapes including CSG (Constructed Solid Geometry), Boolean operation, Tessellated solid, etc. and the user can easily add new shapes. Geant4 geometry navigation can deal with setups up to billions of volumes with automatic optimization. In addition, geometry models can be 'dynamic', i.e. changing the setup at run-time, e.g. "moving objects".
Software quality assurance
Geant4 uses modern tools to manage the code and improve code quality: from handling issues with JIRA to continuous testing integration with CTest/CDash, profiler based optimizations, Quality/Assurance (Coverity, Valgrind, etc.), and IDE integration (Xcode, Eclipse, VisualStudio).
New era - Geant4 version 10 series
The new release of Geant4 – Version 10.0 (December 2013) include event-level parallelism via multi-threading. To efficiently use new computing architectures the workload of a single job is sub-divided to many worker threads each responsible for the simulation of one or more events. Version 10.0 has already shown good scalability on a number of different architectures: Intel Xeon servers, Intel Xeon Phi co-processors and low-power ARM processors
G4MT prototype-9.4 (2011)
G4MT prototype-9.5 (2012)
G4 10.0.beta (June 2013)
G4 10.0 (Dec. 2013)
G4 10 series (2014~)
Intel Xeon L5520 @ 2.27GHz
Intel Xeon Phi 7120P @ 1.238GHz
Exynos 4412 Quad-Core @ 1.7 GHz
Total memory consumption of Intel Xeon Phi 7120P @ 1.238GHz
Investments for the future
Geant4 collaboration members are participating in various explorations of emerging technologies. These technologies include GPU/CUDA, OpenCL, OpenACC, vectorization, DSL, etc.
Gamma-therapy simulation running on NVIDIA GPGPU (Stanford/SLAC/KEK project with support of NVIDIA)

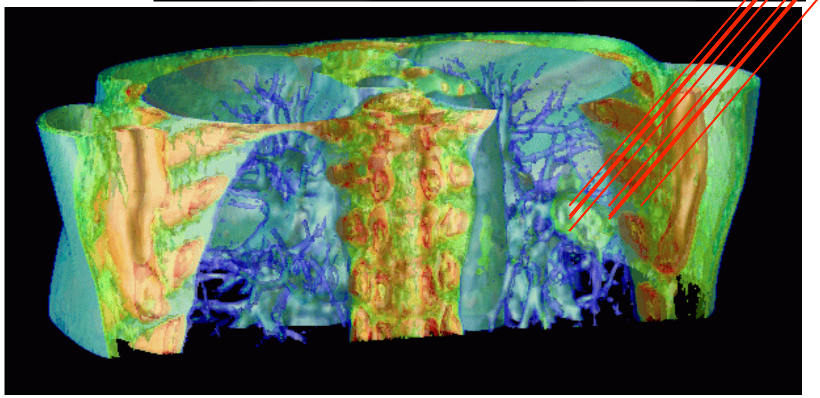
Highlights of Users Applications

To provide you some ideas how Geant4 would be utilized…

GEANT4 based proton dose calculation in a clinical environment: technical aspects, strategies and challenges







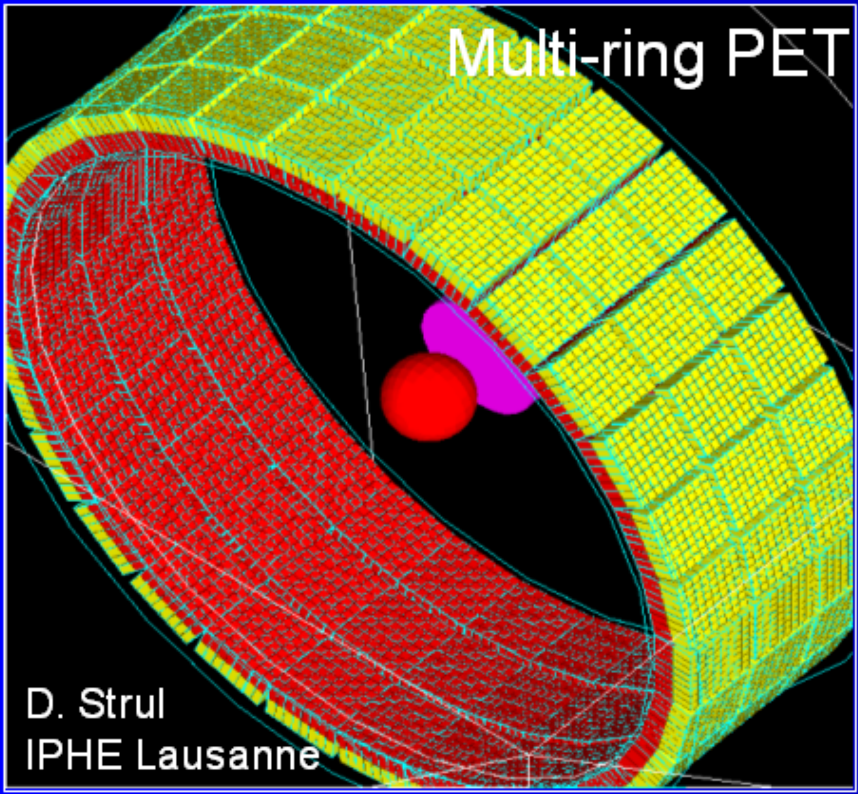
Harald Paganetti

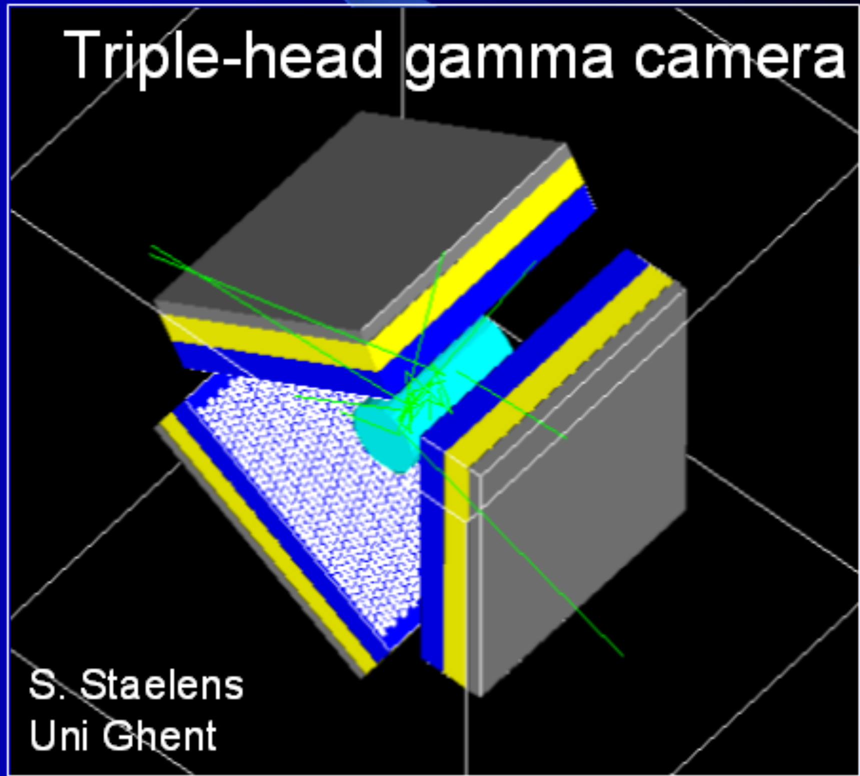
MASSACHUSETTS GENERAL HOSPITAL

HARVARD MEDICAL SCHOOL

March

Geometry examples of GATE applications





Advanced Topics

GATE
Simulations of Preclinical and Clinical Scans in Emission Tomography, Transmission Tomography and Radiation Therapy

Home | Download | Documentation | Collaborative Wiki | Mailing-list | Training | Publications | Meetings | Opportunities | Awards | About GATE

User login

Username *

Password *

Request new password

Log in

PMB Citations Prize

Members of the OpenGATE collaboration have won the Physics in Medicine & Biology Citations Prize twice, in 2009 for their paper 'GATE: a simulation toolkit for PET and SPECT' and in 2015 for their paper 'GATE V6: a major enhancement of the GATE simulation platform enabling modelling of CT and radiotherapy'.

Forewords

GATE is an advanced opensource software developed by the international OpenGATE collaboration and dedicated to numerical simulations in medical imaging and radiotherapy. It currently supports simulations of Emission Tomography (Positron Emission Tomography - PET and Single Photon Emission Computed Tomography - SPECT), Computed Tomography (CT), Optical Imaging (Bioluminescence and Fluorescence) and Radiotherapy experiments. Using an easy-to-learn macro mechanism to configurate simple or highly sophisticated experimental settings, GATE now plays a key role in the design of new medical imaging devices, in the optimization of acquisition protocols and in the development and assessment of image reconstruction algorithms and correction techniques. It can also be used for dose calculation in radiotherapy experiments.

If you are interested in contributing to GATE, here are a few tips regarding what you can do to be part of this collaborative effort:

- Reply to the mailing list
- Contribute to the documentation: ask for a login/password and then modify the documentation on the wiki
- Report bugs

GATE project is now publicly available on GitHub. So, any people identified as a GATE contributor on GitHub can create, assign and close an issue

- Add/modify the source code or fix bugs
  - Start by copying the GATE public repository from GitHub

```
git clone https://github.com/OpenGATE/Gate.git
```

  - Create a specific branch on your repository copy and commit your modifications in that branch
  - Create your own copy (fork) of GATE public repository inside your GitHub account so as to be able to push your branch onto this copy
  - Once your code is ok,

1. Create a pull-request from your Gate repository to the official Gate repository

Shortcuts

Subscribe to GATE-users mailing-list

Request account on GATE collaborative wiki

GitHub
Access to GATE project on GitHub

SurveyMonkey
GATE users survey

Download

http://www.opengatecollaboration.org/

G4 documentation basics

G4 home page

- https://geant4.web.cern.ch/

Download | User Forum
Contact Us | Bug Reports

GEANT4
A SIMULATION TOOLKIT

Geant4

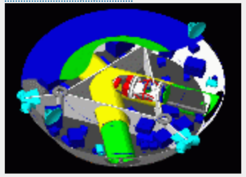
Overview

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 three main reference papers for Geant4 are published in Nuclear Instruments and Methods in Physics Research A 506 (2003) 250-303 , IEEE Transactions on Nuclear Science 53 No. 1 (2006) 270-278 and Nuclear Instruments and Methods in Physics Research A 835 (2016) 186-225 .

Applications

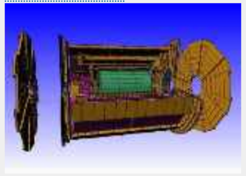
A sampling of applications, technology transfer and other uses of Geant4

User Support



Getting started, guides and information for users and developers

Publications



Validation of Geant4, results from experiments and publications

Collaboration

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

News

2021-03-10
2021 planned developments.

2021-02-05
Patch-01 to **release 10.7** is available from the Download area.

2020-11-06
Patch-03 to release **10.6** is available from the Download archive area.

G4 Application Developer

Book For Application Developers

10.5

Search docs

Docs » Geant4 Book For Application Developers

Geant4 Book For Application Developers

Scope of this manual

The User's Guide for Application Developers is the first manual the reader should consult when learning about GEANT4 or developing a GEANT4 -based detector simulation program. This manual is designed to:

- introduce the first-time user to the GEANT4 object-oriented detector simulation toolkit,
- provide a description of the available tools and how to use them, and
- supply the practical information required to develop and run simulation applications which may be used in real experiments.

This manual is intended to be an overview of the toolkit, rather than an exhaustive treatment of it. Related physics discussions are not included unless required for the description of a particular tool. Detailed discussions of the physics included in GEANT4 can be found in the Physics Reference Manual. Details of the design and functionality of the GEANT4 classes can be found in the User's Guide for Toolkit Developers.

G4 Application Developer

GEANT4

A SIMULATION TOOLKIT

Book For Application Developers

Release 10.5

Geant4 Collaboration

G4 Physics manual

Physics Reference Manual

10.5

Search docs

General Information
Particle Decay
Electromagnetic Interactions
Solid State Physics
Hadronic Physics in GEANT4
Gamma- and Lepto-Nuclear Interactions
Solid State Physics

Docs » Physics Reference Manual

Physics Reference Manual

Scope of this Manual

The Physics Reference Manual provides detailed explanations of the physics implemented in the GEANT4 toolkit.

The manual's purpose is threefold:

- to present the theoretical formulation, model, or parameterization of the physics interactions included in GEANT4,
- to describe the probability of the occurrence of an interaction and the sampling mechanisms required to simulate it, and
- to serve as a reference for toolkit users and developers who wish to consult the underlying physics of an interaction.

This manual does not discuss code implementation or how to use the implemented physics interactions in a simulation. These topics are discussed in the *User's Guide for Application Developers*. Details of the object-oriented design and functionality of the GEANT4 toolkit are given in the *User's Guide for Toolkit Developers*. The *Installation Guide for Setting up |Geant4| in Your Computing Environment* describes how to get the GEANT4 code, install it, and run it.

G4 Physics manual

GEANT4

A SIMULATION TOOLKIT

Physics Reference Manual

Release 10.5

Geant4 Collaboration

Geant4 Cross Reference

GEANT4 A SIMULATION TOOLKIT

Geant4 LXR

Geant4 Cross Reference

Cross-Referencing Geant4
Geant4/

Version: [ReleaseNotes] [1.0] [1.1] [2.0] [3.0] [3.1] [3.2] [4.0] [4.0.p1] [4.0.p2] [4.1] [4.1.p1] [5.0] [5.0.p1] [5.1] [5.1.p1] [5.2] [5.2.p1] [5.2.p2] [6.0] [6.0.p1] [6.1] [6.2] [6.2.p1] [6.2.p2] [7.0] [7.0.p1] [7.1] [7.1.p1] [8.0] [8.0.p1] [8.1] [8.1.p1] [8.1.p2] [8.2] [8.2.p1] [8.3] [8.3.p1] [8.3.p2] [9.0] [9.0.p1] [9.0.p2] [9.1] [9.1.p1] [9.1.p2] [9.1.p3] [9.2] [9.2.p1] [9.2.p2] [9.2.p3] [9.2.p4] [9.3] [9.3.p1] [9.3.p2] [9.4] [9.4.p1] [9.4.p2] [9.4.p3] [9.4.p4] [9.5] [9.5.p1] [9.5.p2] [9.6] [9.6.p1] [9.6.p2] [9.6.p3] [9.6.p4] [10.0] [10.0.p1] [10.0.p2] [10.0.p3] [10.0.p4] [10.1] [10.1.p1] [10.1.p2] [10.1.p3] [10.2] [10.2.p1] [10.2.p2] [10.2.p3] [10.3] [10.3.p1] [10.3.p2] [10.3.p3] [10.4] [10.4.p1] [10.4.p2] [10.4.p3] [10.5] [*10.5.p1*]

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digits_hits/		2019-04-17 07:34:31	
environments/		2019-04-17 07:34:33	
error_propagation/		2019-04-17 07:34:32	
event/		2019-04-17 07:34:32	
examples/		2019-04-17 07:34:31	
externals/		2019-04-17 07:34:32	
g3tog4/		2019-04-17 07:34:32	
geometry/		2019-04-17 07:34:32	
global/		2019-04-17 07:34:33	
graphics_reps/		2019-04-17 07:34:32	

User Forum

GEANT4 at hypernews.slac.stanford.edu Forum List by Category

GEANT4 A SIMULATION TOOLKIT

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Category: Applications

Educational Applications | Industrial instruments | Medical Applications | Space Applications

Category: Control of runs, events, tracks, particles

Event and Track Management | Multithreading | Particles | Run Management

Category: Experimental Setup

Biasing and Scoring | Fields: Magnetic and Otherwise | Geometry | Hits, Digitization and Pileup

Category: General matters

Documentation and Examples | HyperNews System Announcements | Hypernews Testing | Installation and Configuration | User Requirements

Category: Interfaces

(Graphical) User Interfaces | Analysis | Persistency | Visualization

Category: Physics

Biasing and Scoring | DNA/Very Low Energy | Electromagnetic Processes | Fast Simulation, Transportation & Others | Hadronic Processes
Physics List | Processes Involving Optical Photons

This site runs SLAC HyperNews version 1.11-slac-98, derived from the original HyperNews

Basics of OO programming in C++

Class and Object

Class and Object

Object: is characterized by attributes (which define its state) and operations

A **class** is the blueprint of objects of the same type

```
class Rectangle {
  public:
  Rectangle (double,double); // constructor
  ~Rectangle() { // empty; } // destructor
  double area () { return (width * height); } // member function
  private:
  double width, height; // data members
};
```

```
Rectangle  rectangleA (3.,4.); // instantiate an object of type "Rectangle"
Rectangle* rectangleB = new Rectangle(5.,6.);
cout << "A area: "  <<  rectangleA.area()   << endl;
cout << "B area: "  <<  rectangleB->area() << endl;
delete rectangleB;              // invokes the destructor
```

Inheritance

Inheritance

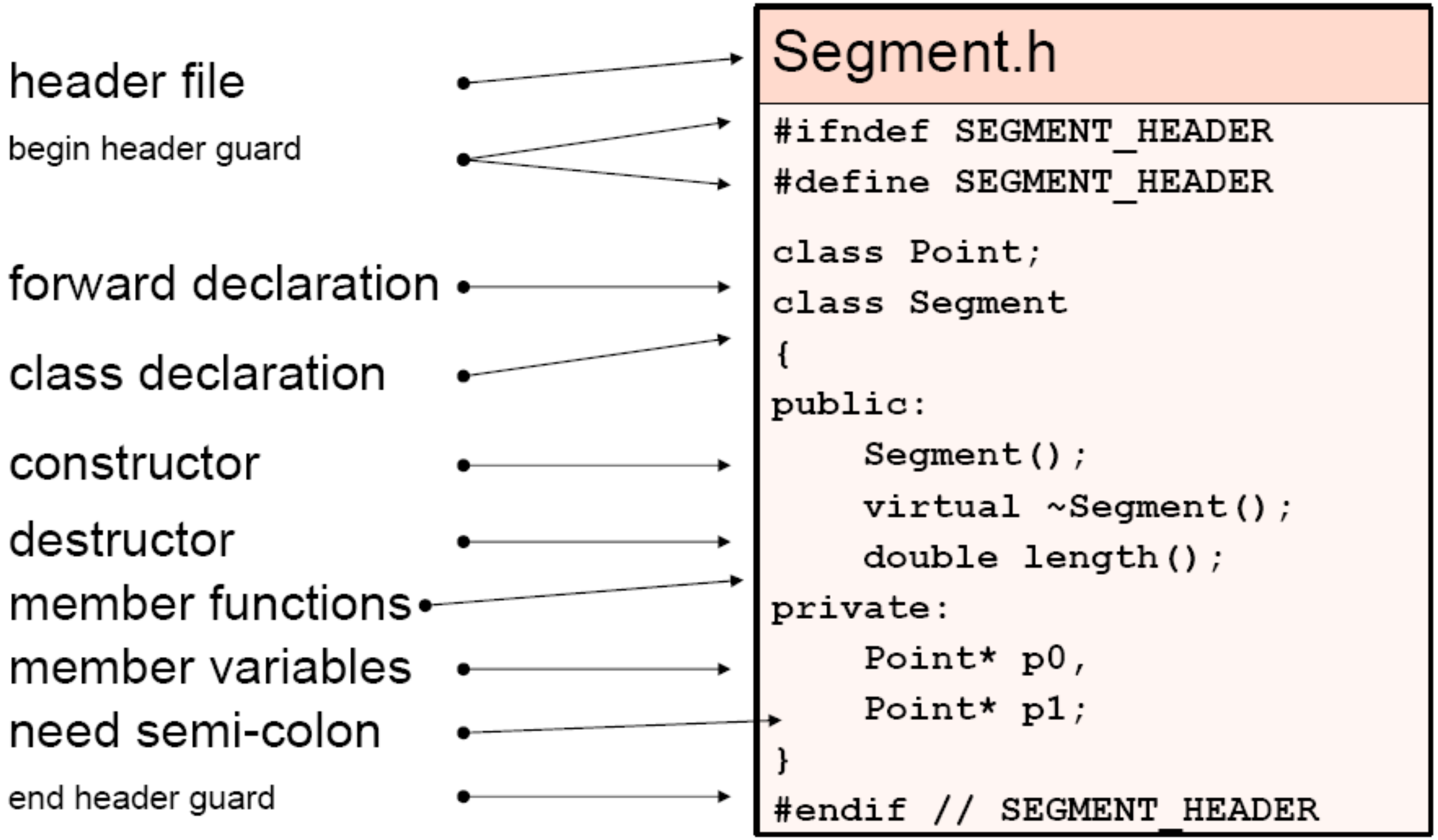
- A key feature of C++
- Inheritance allows to create classes derived from other classes
- Public inheritance defines an **"is-a"** relationship
  - *In other words: what applies to a base class applies to its derived classes*

```
class Base {
  public:
    virtual ~Base() {}
    virtual void f() {…}
  protected:
    int a;
  private:
    int b; …
};
```

```
class Derived : public Base {
 public:
   virtual ~Derived() {}
   virtual void f() {…}
   …
};
```

Header File

How a Header File looks like



Implementation

Header file and implementation

File Segment.hh

```
#ifndef SEGMENT_HEADER
#define SEGMENT_HEADER

class Point;
class Segment
{
public:
    Segment();
    virtual ~Segment();
    double length();
private:
    Point* p0,
    Point* p1;
};
#endif // SEGMENT_HEADER
```

File Segment.cc

```
#include “Segment.hh”
#include “Point.hh”
Segment::Segment() // constructor
{
    p0 = new Point(0.,0.);
    p1 = new Point(1.,1.);
}
Segment::~Segment() // destructor
{
    delete p0;
    delete p1;
}
double Segment::length()
{
    function implementation …
}
```

OOP programming

OOP basic concepts

- **Object, Class**
  - A class defines the abstract characteristics of a thing (object), including the thing's attributes and the thing's behaviour
- **Inheritance**
  - "Subclasses" are more specialized versions of a class, which ***inherit*** attributes and behaviours from their parent classes (and can introduce their own)
- **Encapsulation**
  - Each object exposes to any class a certain ***interface*** (i.e. those members accessible to that class)
  - Members can be **public**, **protected** or **private**
- **Abstraction**
  - Simplifying complex reality by modelling classes appropriate to the problem
  - One works at the most appropriate level of inheritance for a given aspect of the problem
- **Polymorphism**
  - It allows one to treat derived class members just like their parent class' members

Maria Grazia Pia

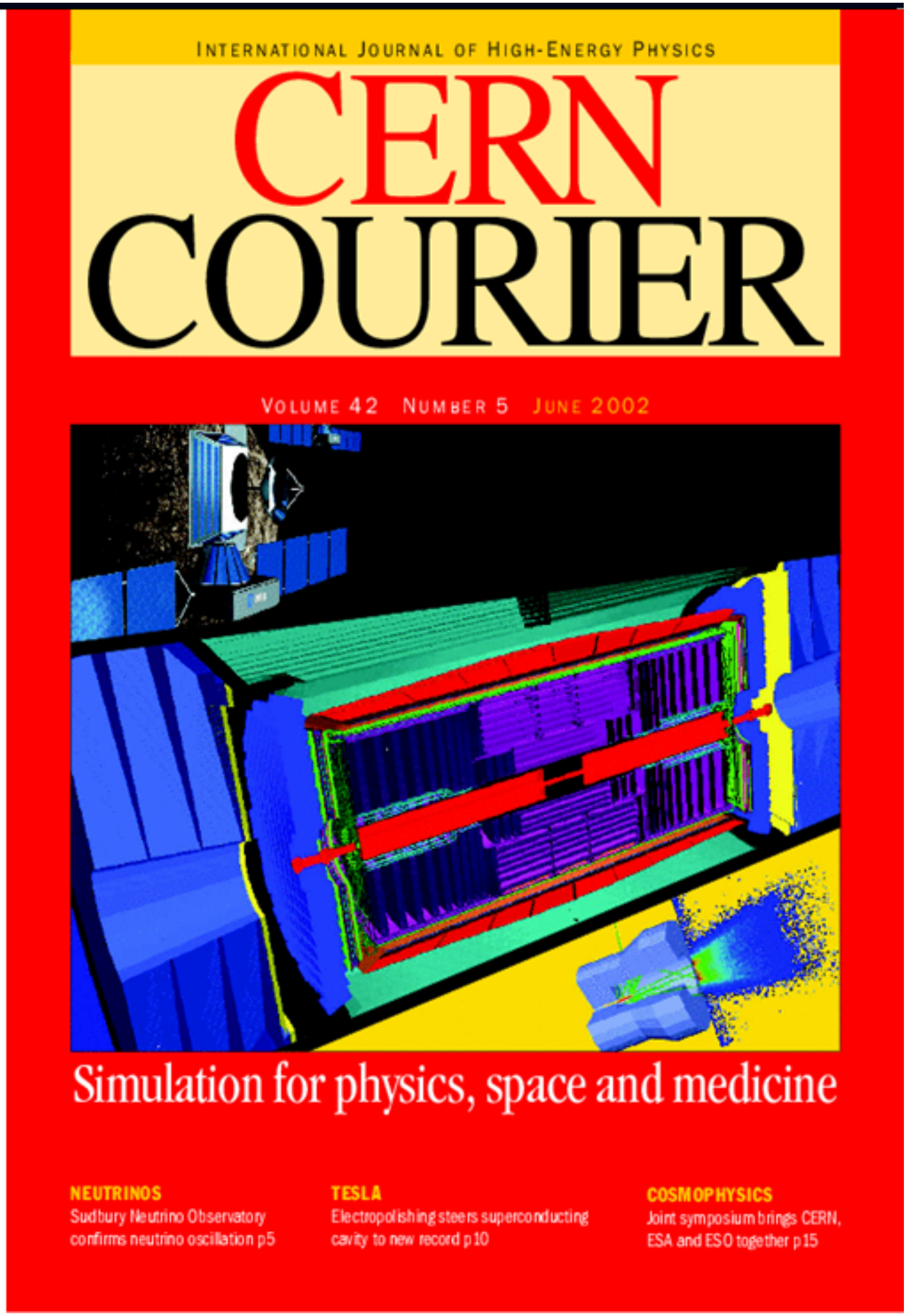
General Introduction to Geant4

Technology transfer

Particle physics software aids space and medicine

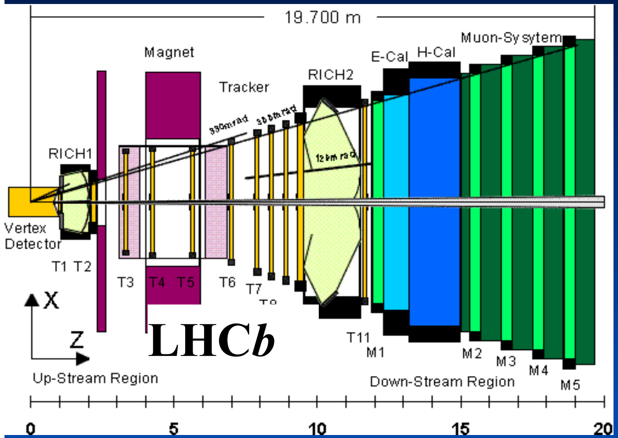
Geant4 is a showcase example of technology transfer from particle physics to other fields such as space and medical science [...].

CERN Courier, June 2002

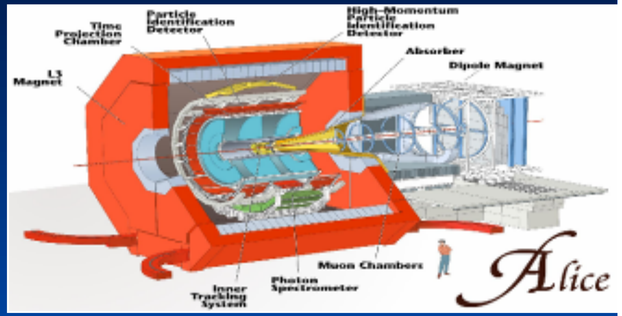


Globalisation

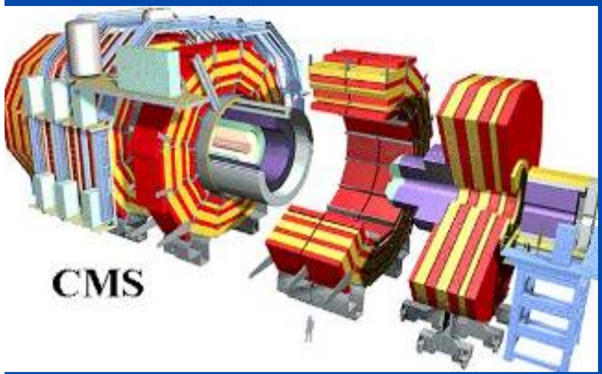
Sharing requirements and functionality across diverse fields

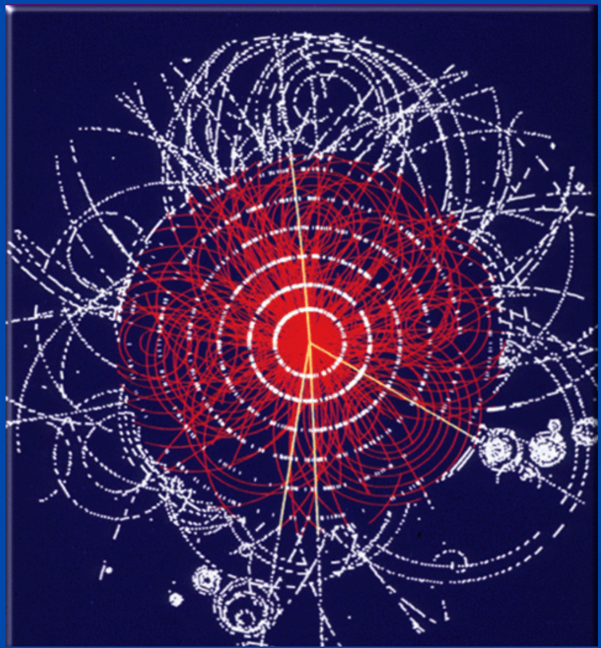


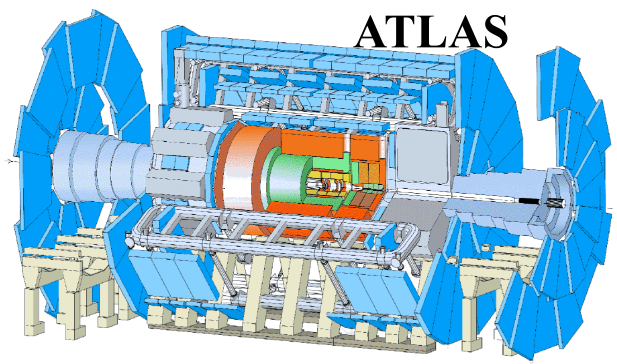
Complex physics
Complex detectors
20 years
software life-span



LHC

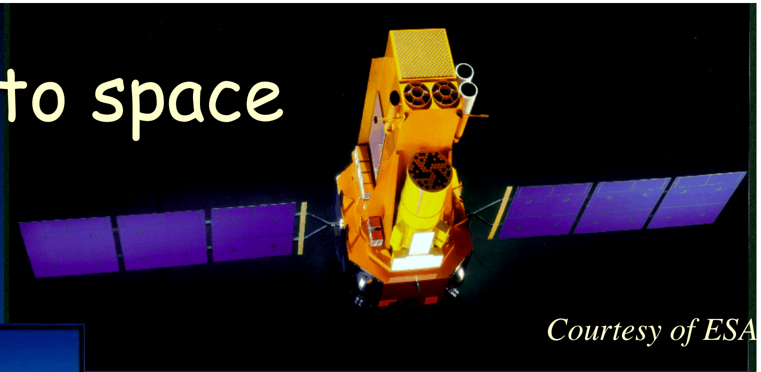






From deep underground…

…to space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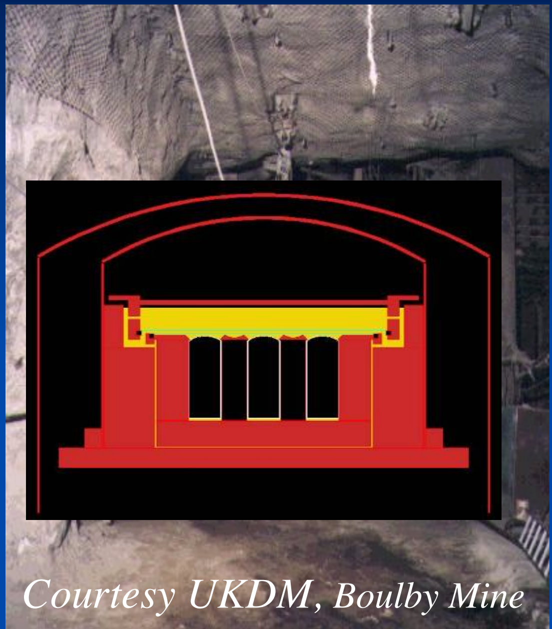
Dark matter and ν experiments


Courtesy UKDM, Boulby Mine

Courtesy of Auger

X and γ astronomy, gravitational waves, radiation damage to components etc.

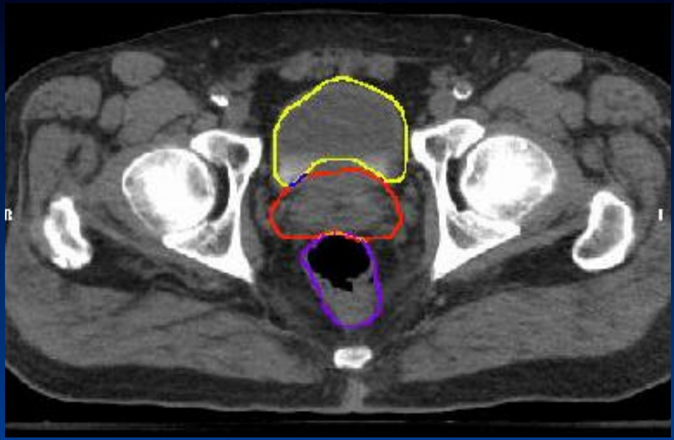
Cosmic ray experiments

Variety of requirements from diverse applications

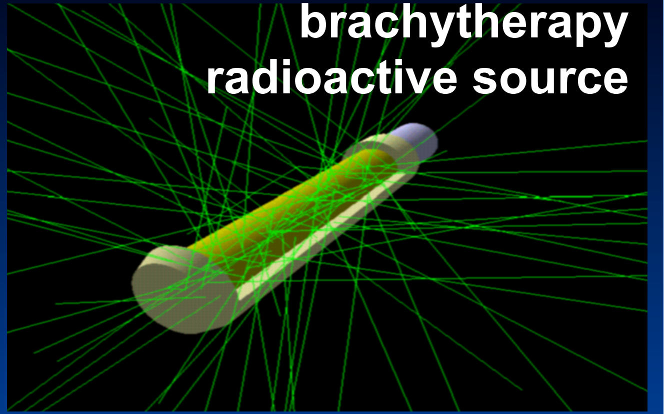
Physics from the eV to the PeV scale	Detectors, spacecrafts and environment

For such experiments software is often **mission critical**

Require reliability, rigorous software engineering standards



Medical Physics



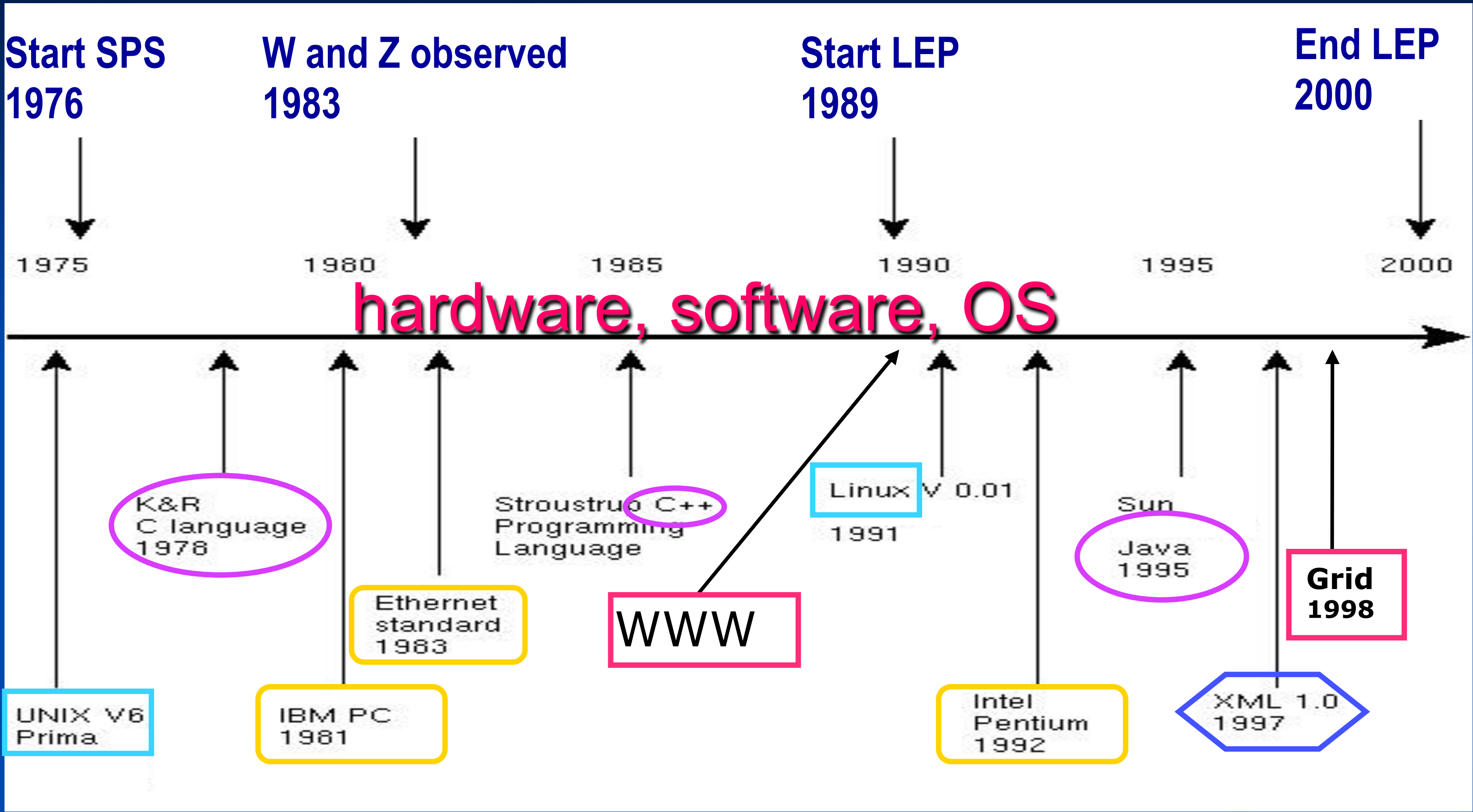
from hospitals…

…to Mars

- Accurate modelling of radiation sources, devices and human body
- Precision of physics
- Reliability

- Easy configuration and friendly interface
- Speed

…in a fast changing computing environment



…and don't forget changes of requirements!

Evolution towards greater diversity ➔ we must anticipate changes

Strategic vision

OO technology

- Openness to **extension** and **evolution**

new implementations can be added w/o changing the existing code

- Robustness and ease of **maintenance**

protocols and well defined dependencies minimize coupling

Toolkit

A set of compatible components

- each component is **specialised** for a specific functionality
- each component can be **refined** independently to a great detail
- components can be **integrated** at any degree of complexity
- it is easy to provide (and use) **alternative** components
- the user application can be **customised** as needed

Geant4 official publications

Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment
Volume 506, Issue 3, 1 July 2003, Pages 250-303

GEANT4—a simulation toolkit

S. Agostinelli [ae], J. Allison [as], K. Amako [e], J. Apostolakis [a], H. Araujo [aj], P. Arce [l, m, x, a], M. Asai [g, ai], D. Axen [i, t], S. Banerjee [bi, l], G. Barrand [an], F. Behner [l], L. Bellagamba [c], J. Boudreau [bd], L. Broglia [ar], A. Brunengo [c], H. Burkhardt [a], S. Chauvie [bj, bl], J. Chuma [h] … D. Zschiesche [af]

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https://doi.org/10.1016/S0168-9002(03)01368-8

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Geant4 developments and applications

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73 Author(s) J. Allison ; K. Amako ; J. Apostolakis ; H. Araujo ; P. Arce Dubois ; M. Asai ; G. Barrand ; R. Capra ; S. Ch... View All Authors

Abstract

Document Sections

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 and radiation protection. Its functionality and modeling capabilities continue to be extended, while its performance is enhanced. An overview of recent developments in diverse areas of the toolkit is presented. These include performance optimization for complex setups; improvements for the propagation in fields; new options for event biasing; and additions and improvements in geometry, physics processes and interactive capabilities

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Geant4 official publications

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

Volume 835, 1 November 2016, Pages 186-225

Recent developments in GEANT4

J. Allison [a, b], K. Amako [c, a], J. Apostolakis [d], P. Arce [e], M. Asai [f], T. Aso [g], E. Bagli [h], A. Bagulya [i], S. Banerjee [j], G. Barrand [k], B.R. Beck [l], A.G. Bogdanov [m], D. Brandt [n], J.M.C. Brown [o], H. Burkhardt [d], Ph. Canal [j], D. Cano-Ott [p], S. Chauvie [q] … H. Yoshida [bs, a]

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