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 (May 3 - 5)
  - Introduction to the Geant4 toolkit
  - Fundamentals of a Geant4 application
    - Geometry, Physics, Particle Flux, Scoring
- Part3 (May 5 – 12)
  - Realisation of an example relevant to Medical Physics

Evaluation for the “Laboratory”

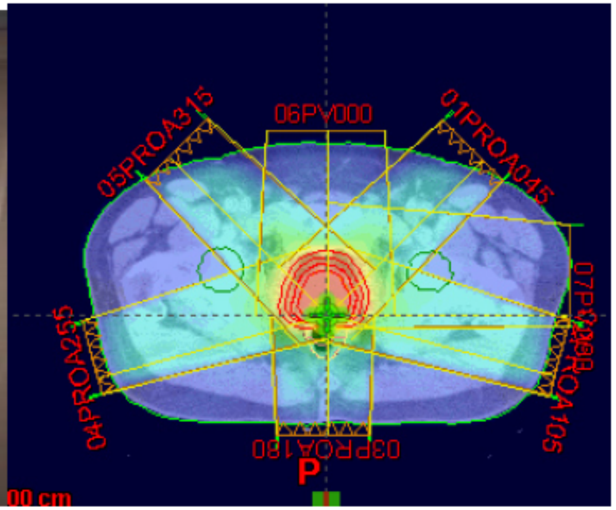
- Discussion of Geant4 example
  - G4 example relevant to Medical Physics
- Discussion of requirements and methods
  - Medical Physics “environment”
  - Geant4 modeling
  - “Basic” analysis of results
- Realization of “new” example – Laboratory
  - Might just be an improvement of an existing G4 example

Part 1

Montecarlo in Medical Physics

Montecarlo for Medical Physics

Overview of Medical Physics Applications

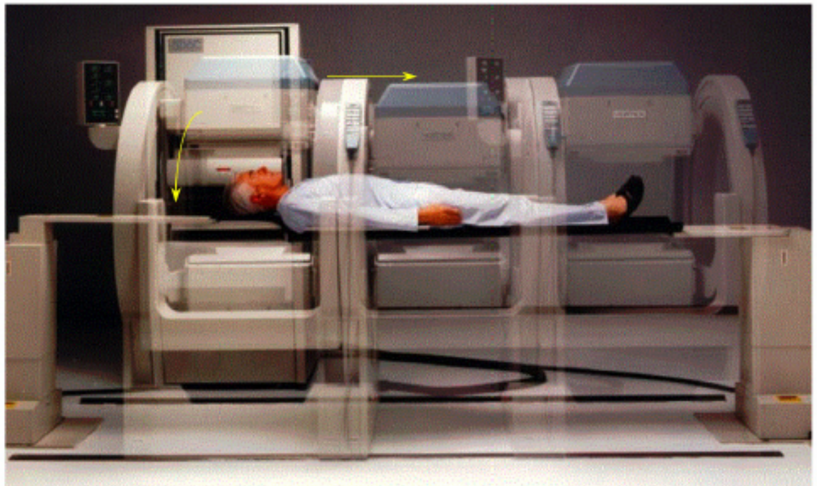


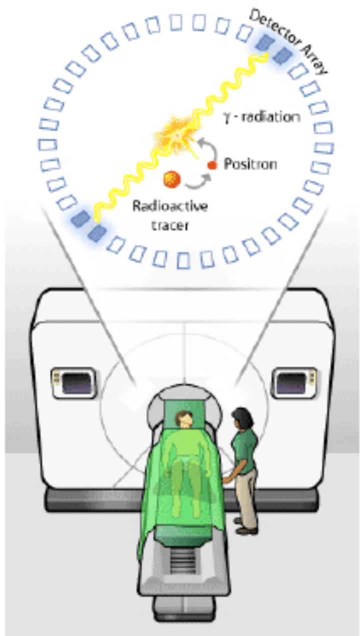
Radiotherapy physics

- 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

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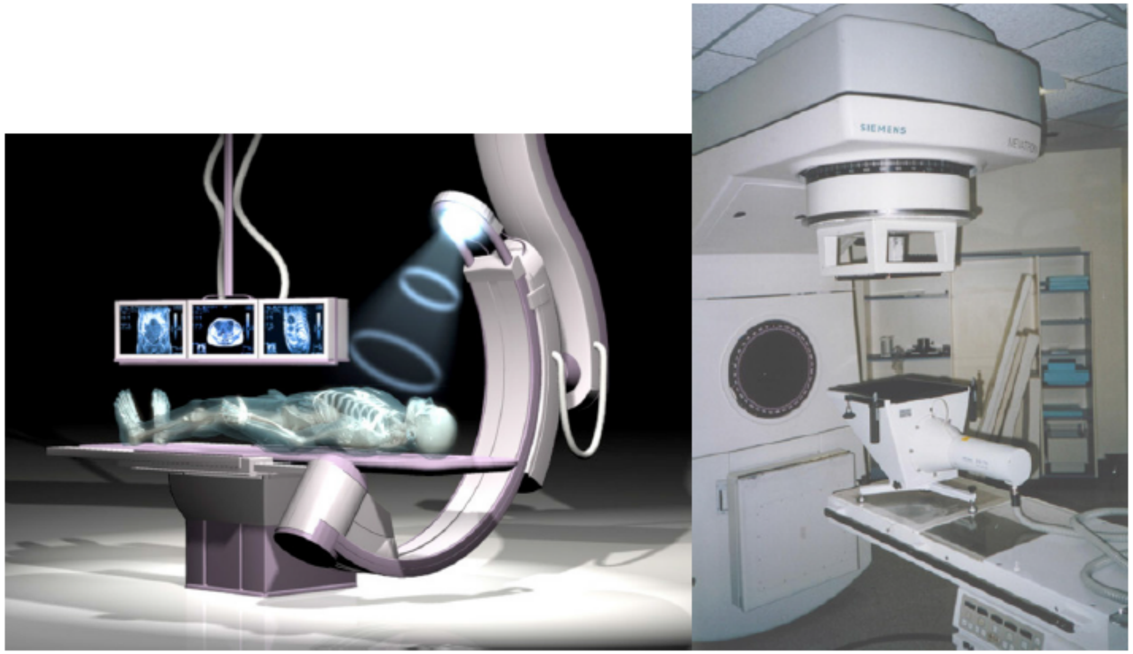

Diagnostic radiology

- detection systems
- physical quantities
- radiation protection

Montecarlo in Treatment Planning Systems

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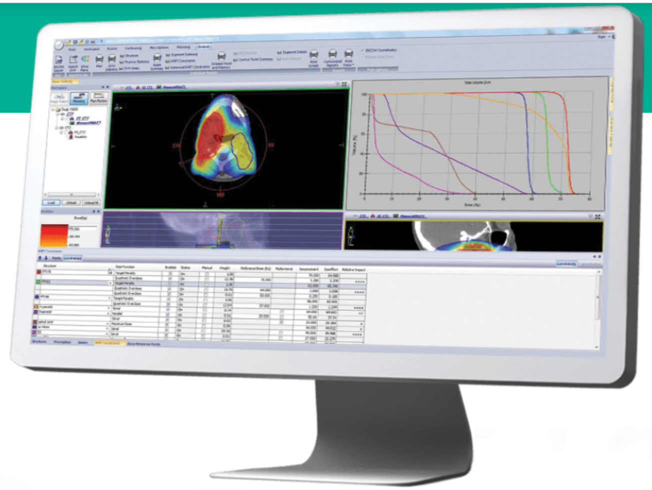


Precision planning for photon and electron based plans

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

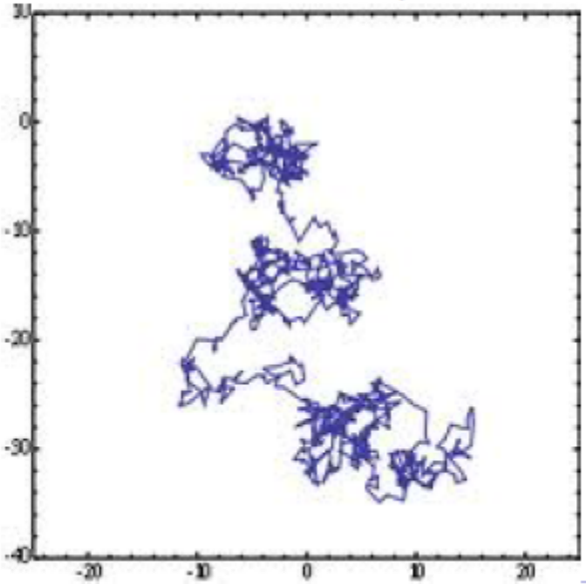
What is a Montecarlo program?

- 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 …

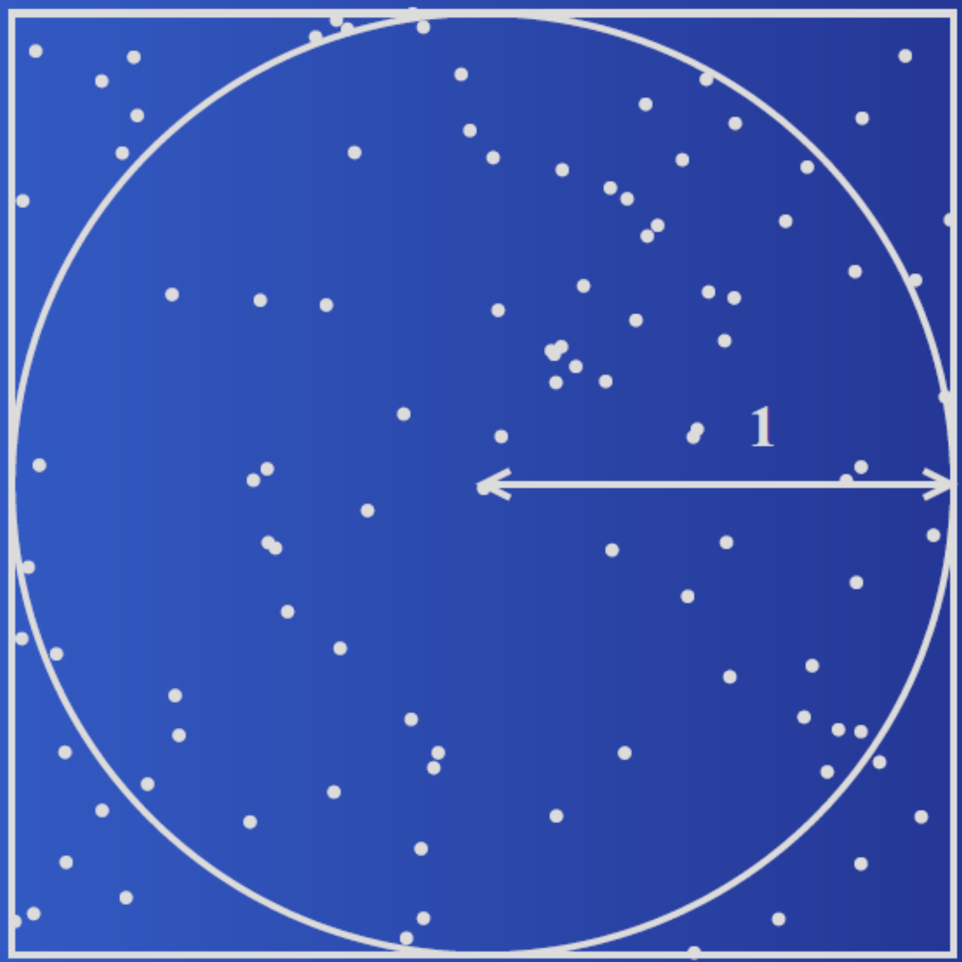
Example: Brownian motion (a.k.a. random walk)



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



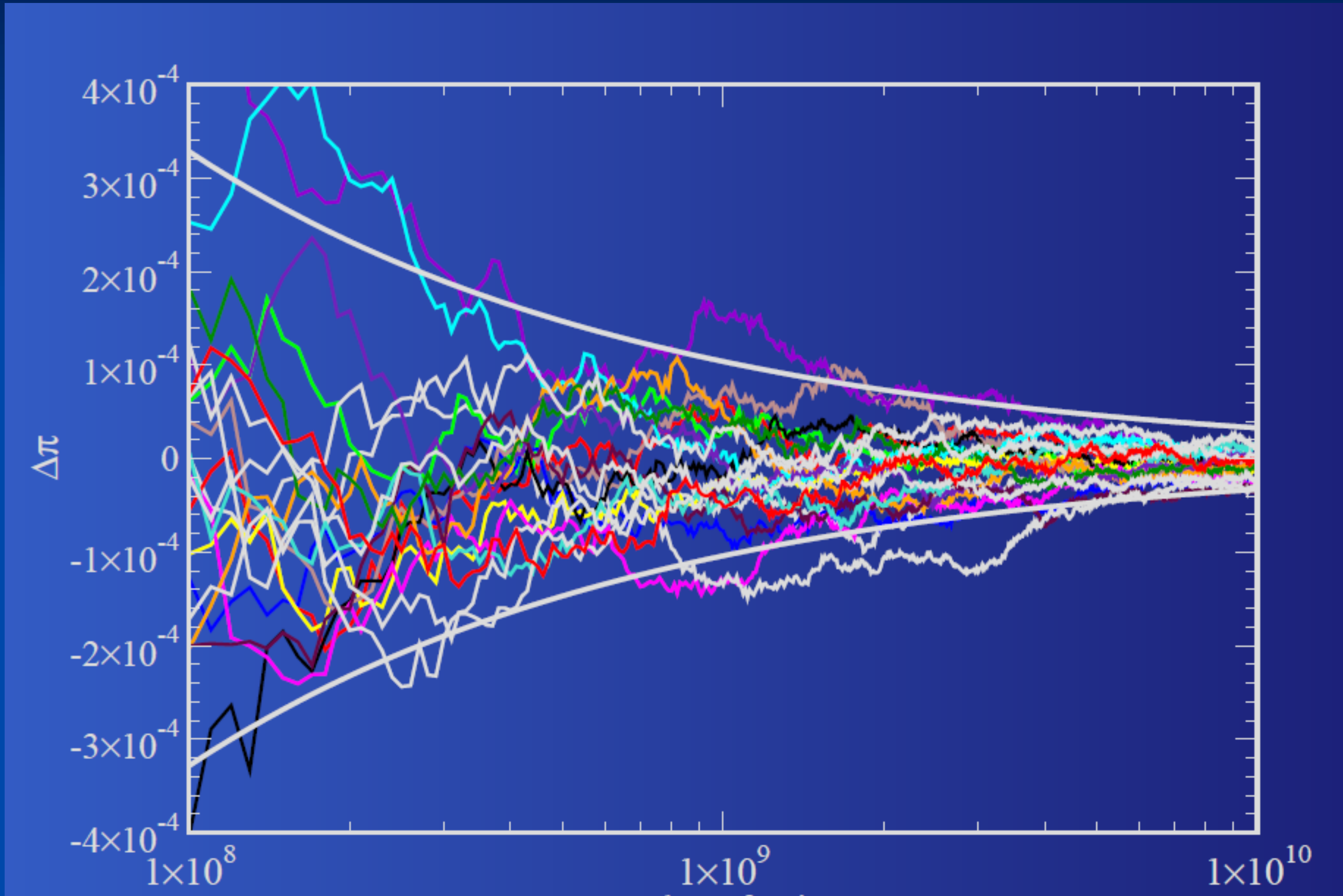
Area of square: $A_s = 4$
Area of circle: $A_c = \pi$
Fraction p of random points inside circle:

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

Random points: N
Random points inside circle: N_c

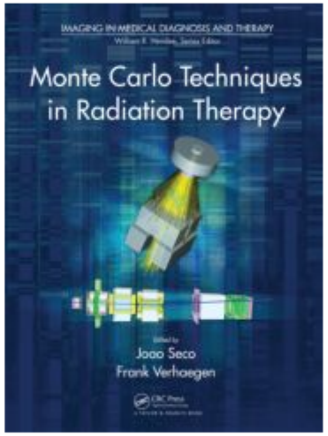
$$\Rightarrow \quad \pi = \frac{4N_c}{N}$$

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

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

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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

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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.

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

Geant4

European Organization for Nuclear Research

Geant4

A toolkit to simulate the interaction of particles with matter

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

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http://cern.ch/TTdb

Concept

Geant4 simulates the passage of particles through matter.
It provides a complete set of tools for all domains of radiation transport:

- Geometry and Tracking
- Physics processes and models
- Biasing and Scoring
- Graphics and User Interfaces
- Propagation in fields.

Geant4 physics processes describe electromagnetic and nuclear interactions of particles with matter, at energies from eV to TeV.
A choice of physics models exists for many processes providing options for applications with different accuracy and time requirements.

A visualization of the CMS detector (Courtesy of I. Osborne, CMS Collaboration)

The toolkit is developed, maintained and supported by Geant4, a world-wide collaboration of about 100 scientists from many institutions, contributing in their area of expertise. Developers interact constantly with users, and combine efforts to validate physics results for application in high energy physics experiments, space and medical studies.

Applications

High energy and nuclear physics detectors
- ATLAS, CMS, HARP and LHCb at CERN and BaBar at SLAC

Accelerator and shielding
- Linacs for medical use

Medicine
- **Radiotherapy**
  - photon, proton and light ion beams
  - brachytherapy
  - boron and gadolinium neutron capture therapy
- **Simulation of scanners**
  - PET & SPECT with GATE (Geant4 Application for Tomographic Emission)

Space
- **Satellites**
  - effect of space environment on components (especially electronics)
  - shielding of instruments
  - charging effects
- **Space environment**
  - cosmic ray cut-offs
- **Astronauts**
  - dose estimates

The BepiColombo Mercury orbiter (Courtesy of ESA)

Simulation of small PET scanner using GATE (Courtesy of the OpenGATE collaboration)

A view of the ATLAS detector (Courtesy of S. Tanaka, ATLAS collaboration)

Advantages

- Simulates the geometries of complex setups efficiently
- Provides configurations of physics processes for application areas
- Enables user to tailor simulation components and address accuracy needs
- Performant and adaptable
- Easy to embed into specific applications

XMM-Newton X-ray telescope: the effects of the radiation environment on its instruments was modeled with Geant4 prior to launch in 1999 (Courtesy of ESA)

The European Organization for Nuclear Research (CERN), one of the world's foremost particle physics laboratories, has introduced an active Technology Transfer policy to establish its competence in European industrial and scientific environments, and to demonstrate clear benefits of the results obtained from the considerable resources made available to particle physics research.

Technology Transfer is an integral part of CERN's principal mission of fundamental research.

CERN Technology Transfer

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

The Geant4 toolkit

About | Download | Documentation | User Forum | Bug Reports | Events | Contact Us

Geant4

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.

Getting started

Get started

Everything you need to get started with Geant4.

I'm ready to start!

Download

Geant4 source code and installers are available for download, with source code under an open source license.

Latest: 11.1.1

Docs

Documentation for Geant4, along with tutorials and guides, are available online.

Read documentation

News

» More

23 Mar 2023
2023 Planned Features

03 Mar 2023
Release 11.0.4

10 Feb 2023

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