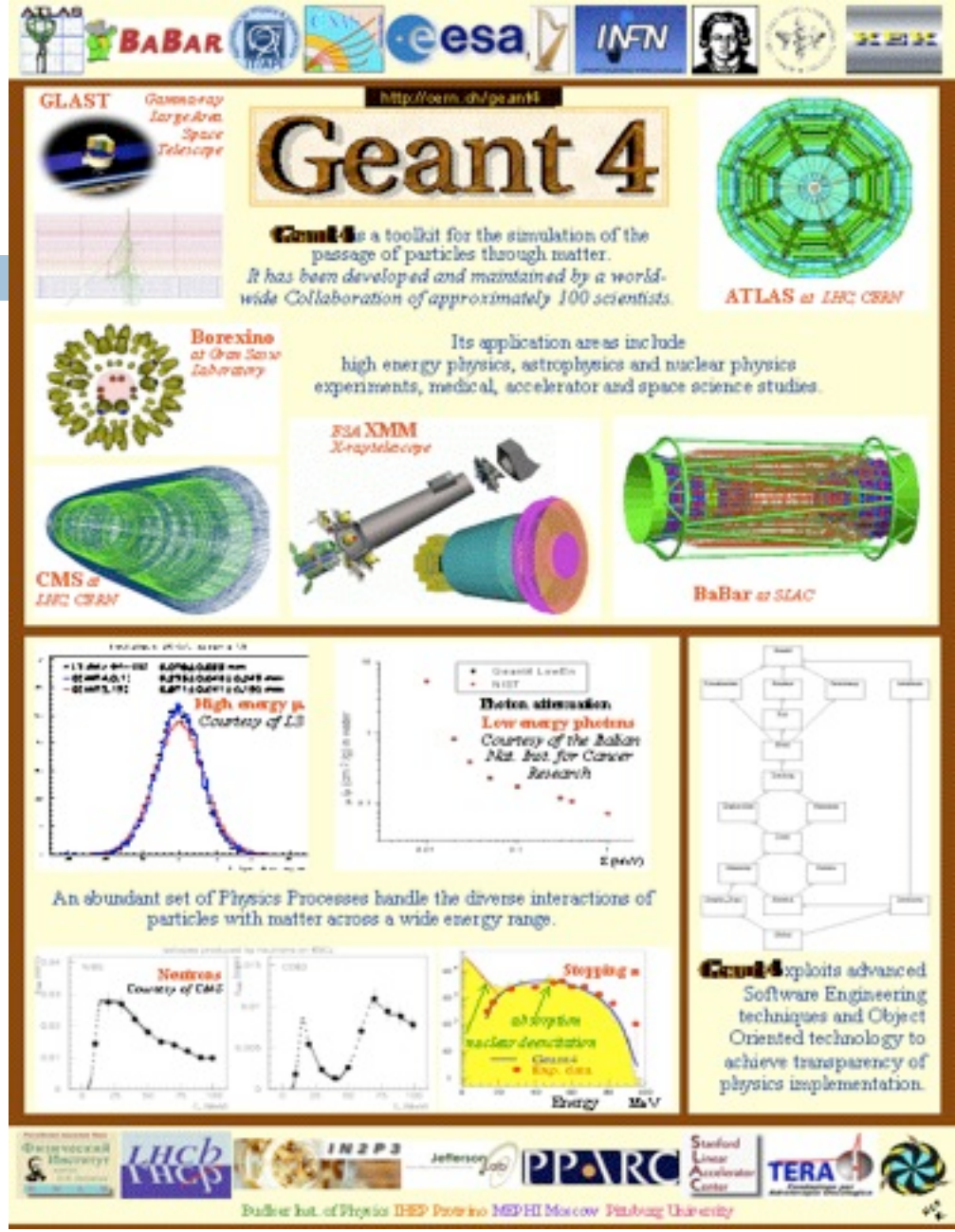
GENERAL INTRODUCTION

Geant4 Training event
Desy Zeuthen, 10-13 May 2011
A. Schälicke
adaptation of the original lecture of
Makoto Asai (SLAC)

Outline

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



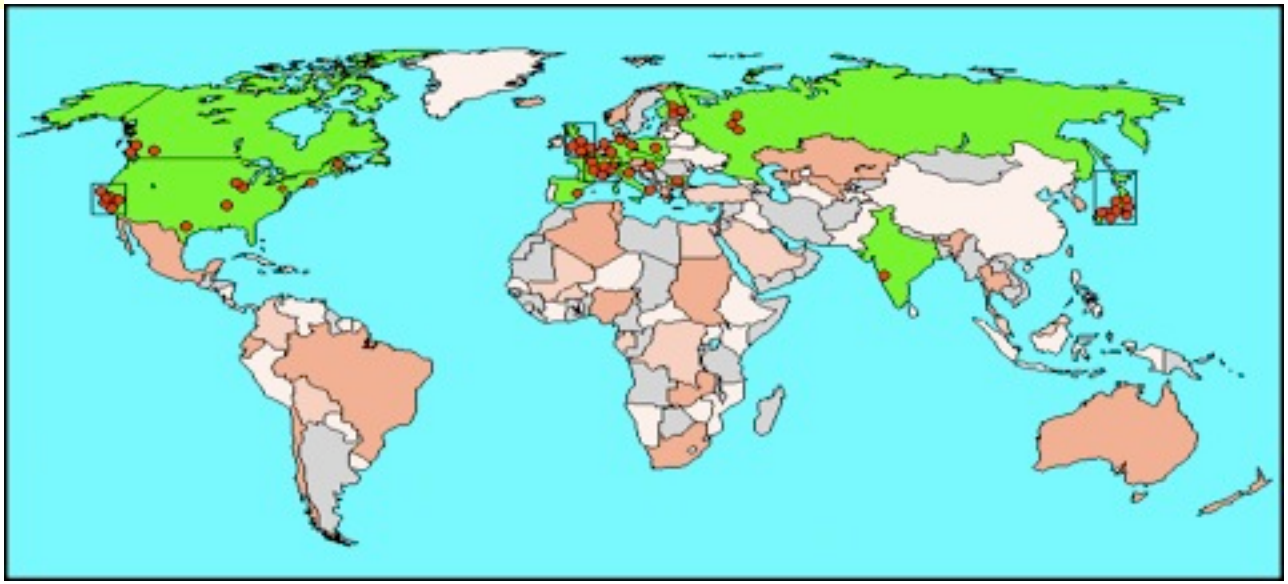
Geant4 – Its history

- Dec '94 – Project start
- Apr '97 – First alpha release
- Jul '98 – First beta release
- Dec '98 – First Geant4 public release – version 1.0
- …
- Dec 19th, '08 – Geant4 version 9.2 release
- Dec 18th, '09 – Geant4 version 9.3 release
  - Sep 24th, '10 – Geant4 9.3-patch02 release
- Dec 17th, '10 – Geant4 version 9.4 release
  - Feb 25th, '11 – Geant4 9.4-patch01 release ← Current version
- We currently provide one public release every year.
  - Beta releases are also available.
  - Release announcements on Collaboration Web pages and through the announcement mailing list

Flexibility of Geant4

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

Geant4 Collaboration

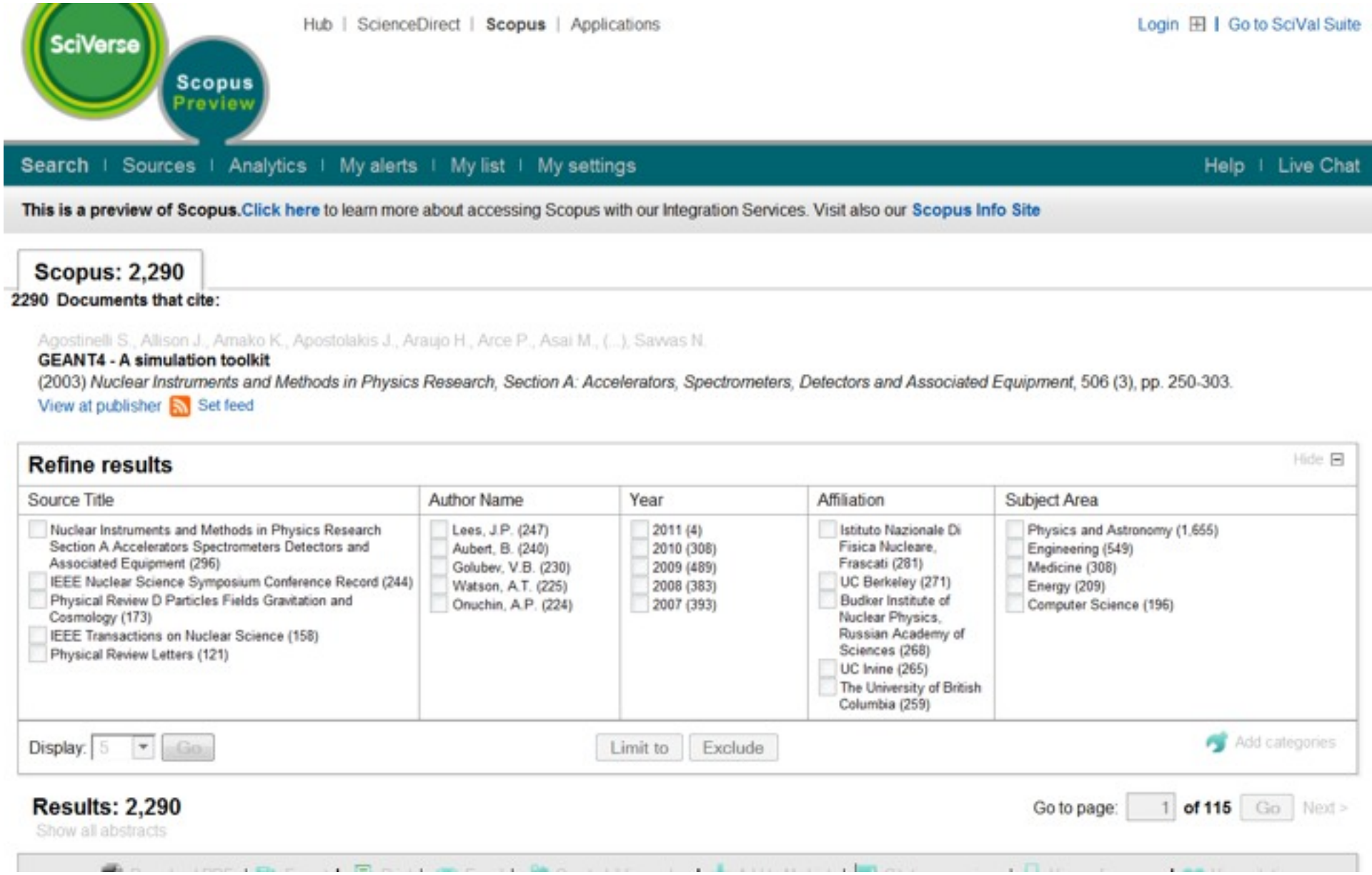


TRIUMF

Lebedev

J.W.Goethe Universität

Collaborators also from non-member institutions, including
Budker Inst. of Physics
IHEP Protvino
MEPHI Moscow
Pittsburg University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2290 Documents that cite:
Agostinelli S., Allison J., Amako K., Apostolakis J., Araujo H., Arce P., Asai M., (...), Sawas N.
GEANT4 - A simulation toolkit
(2003) Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 506 (3), pp. 250-303.
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Nuclear Instruments and Methods in Physics Research Section A Accelerators Spectrometers Detectors and Associated Equipment (296)
IEEE Nuclear Science Symposium Conference Record (244)
Physical Review D Particles Fields Gravitation and Cosmology (173)
IEEE Transactions on Nuclear Science (158)
Physical Review Letters (121)
Author Name
Lees, J.P. (247)
Aubert, B. (240)
Golubev, V.B. (230)
Watson, A.T. (225)
Onuchin, A.P. (224)
Year
2011 (4)
2010 (308)
2009 (489)
2008 (383)
2007 (393)
Affiliation
Istituto Nazionale Di Fisica Nucleare, Frascati (281)
UC Berkeley (271)
Budker Institute of Nuclear Physics, Russian Academy of Sciences (268)
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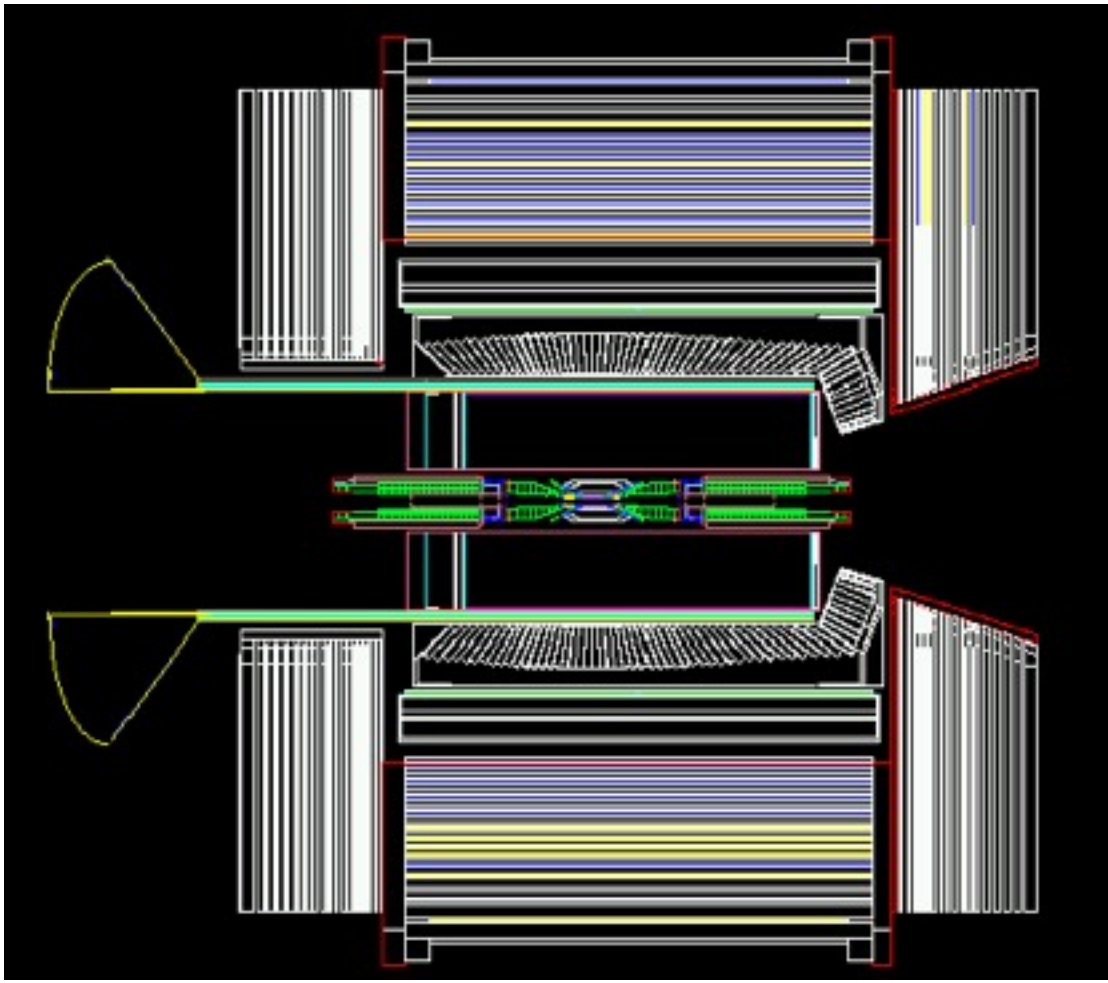
HIGHLIGHTS OF USERS APPLICATIONS

To provide you some ideas how Geant4 would be utilized…

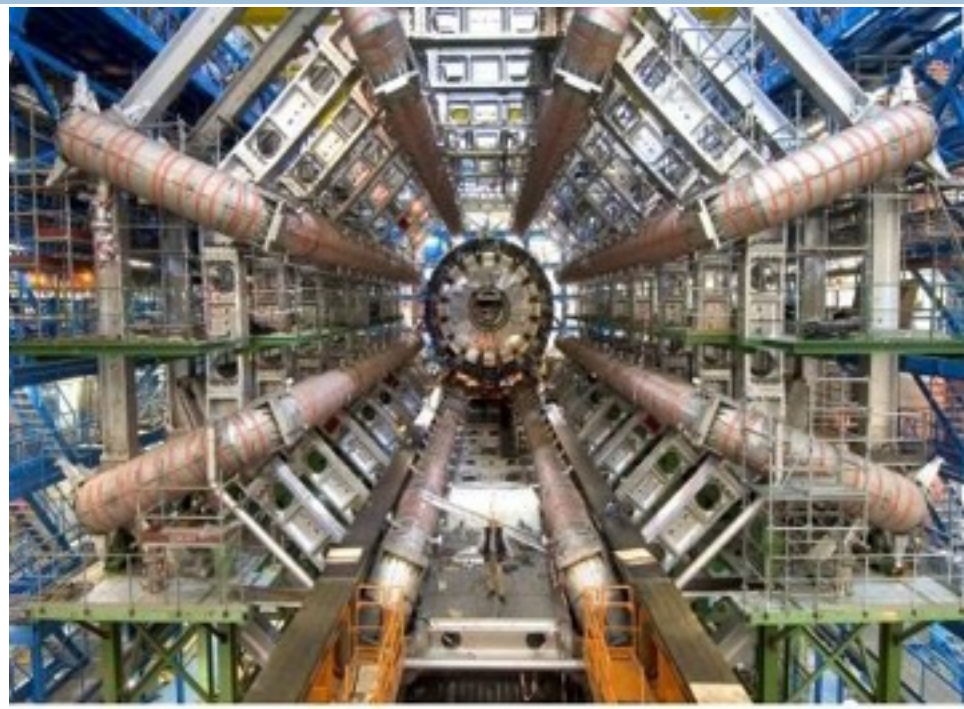
BaBar

Courtesy of D.Wright (SLAC)

- BaBar at SLAC is the pioneer experiment in HEP in use of Geant4
  - Started in 2000
  - Simulated ~$2*10^{10}$ events so far
  - Produced at 20 sites in North America and Europe

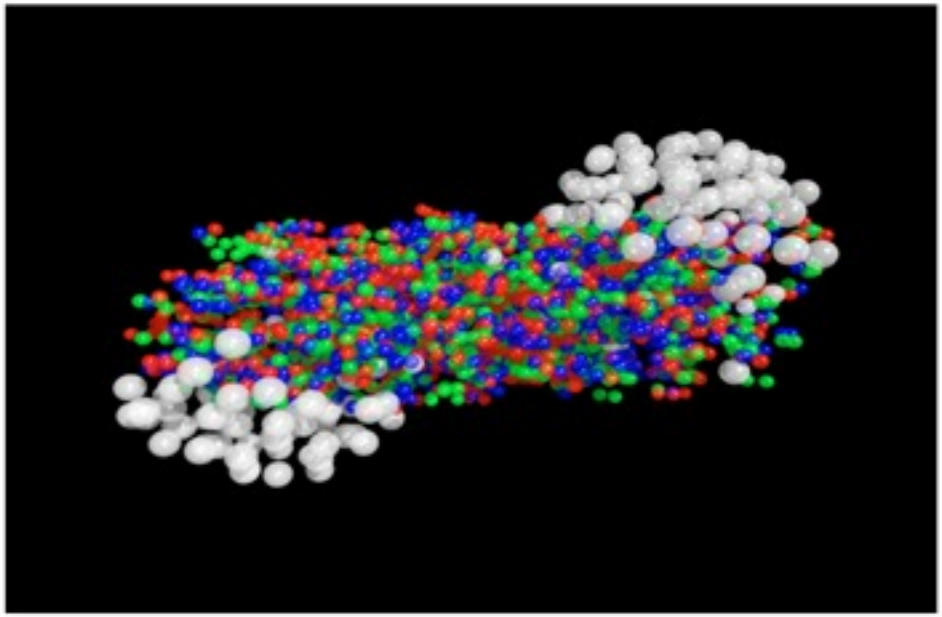


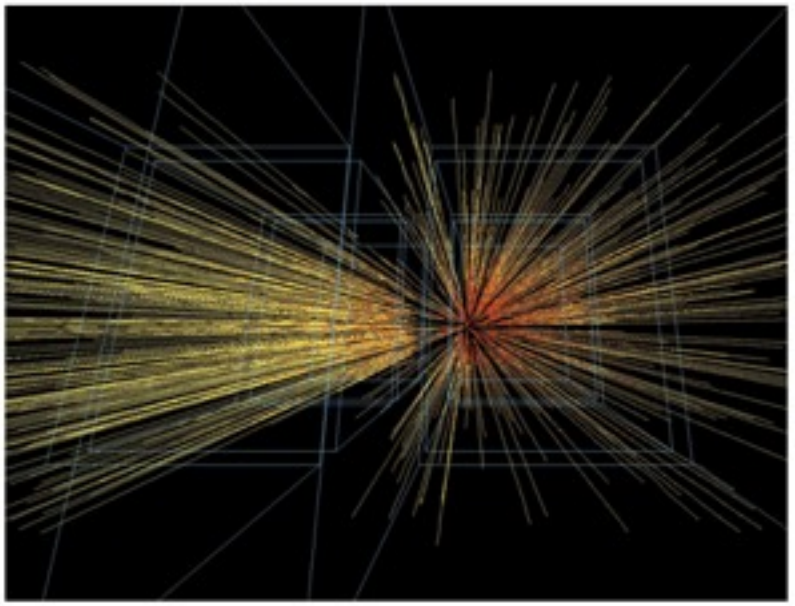
Geant4 now used by all LHC detectors



- ATLAS, CMS – greatest detectors
- LHCb, ALICE – large specific detectors

Pushing G4 to the limits: Heavy Ions

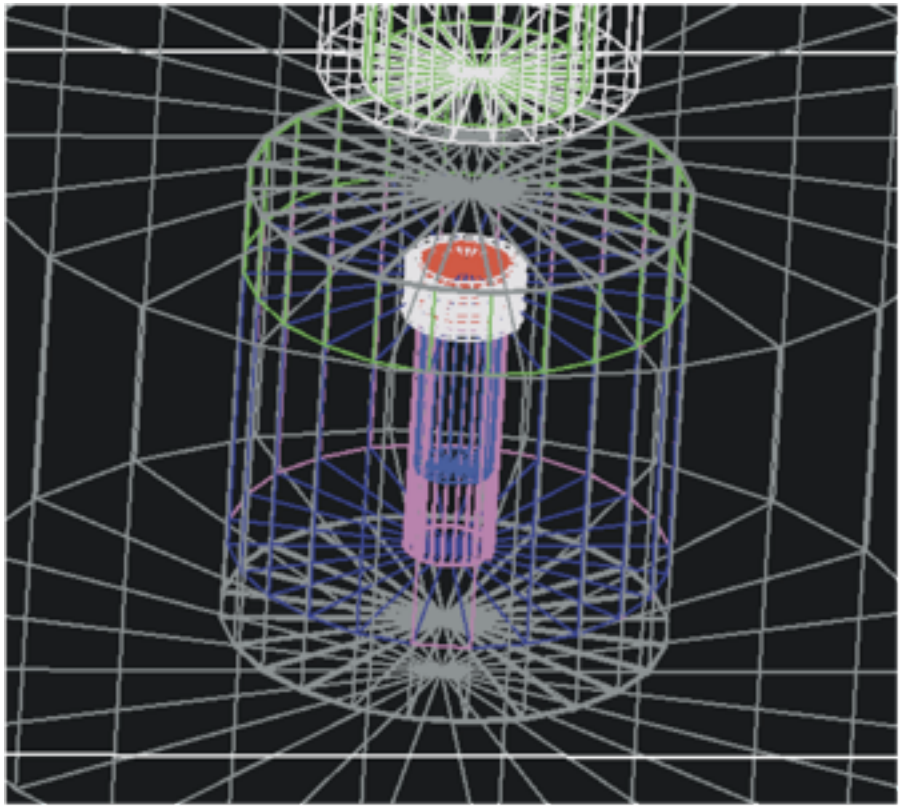




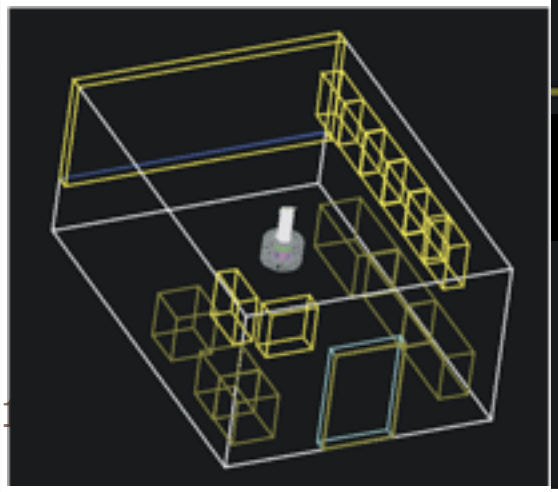
Events with > 50000 particles/event in detector acceptance

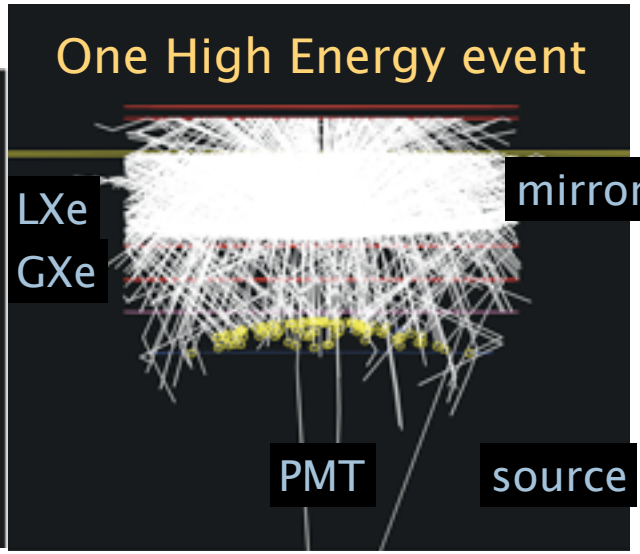
Albert De Roeck (CERN) 27

Boulby Mine dark matter search Prototype Simulation



Courtesy of H. Araujo, A. Howard, IC London





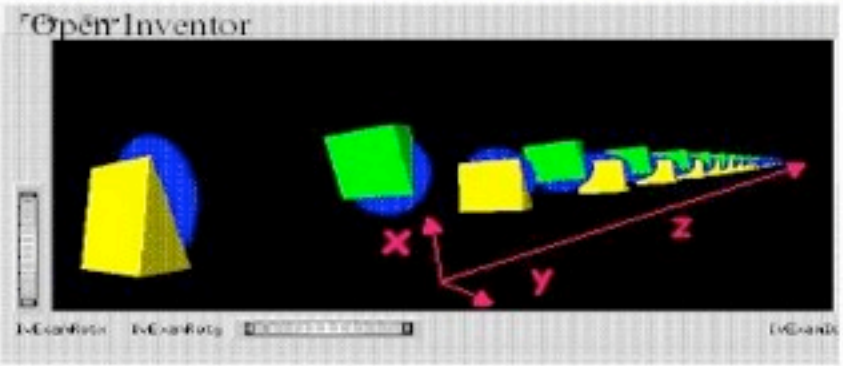
Geant4 for beam transportation

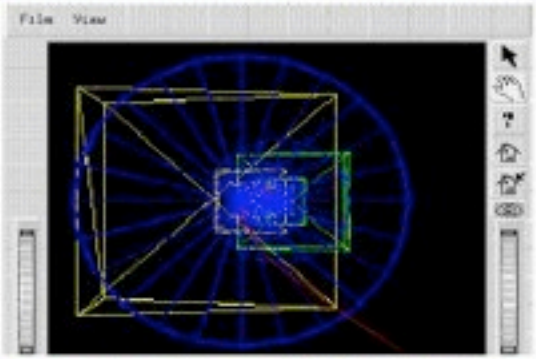
Example: Helical Channel

Published in proc. of PAC 2001 (Fermilab-Conf-01-182-T)

72 m long solenoidal + dipole field with wedge absorbers and thin cavities

$$B_{x,y} = B_T \cos,\sin\left(\frac{2p}{L} z\right) \qquad B_z = B_0$$





Other simulations:

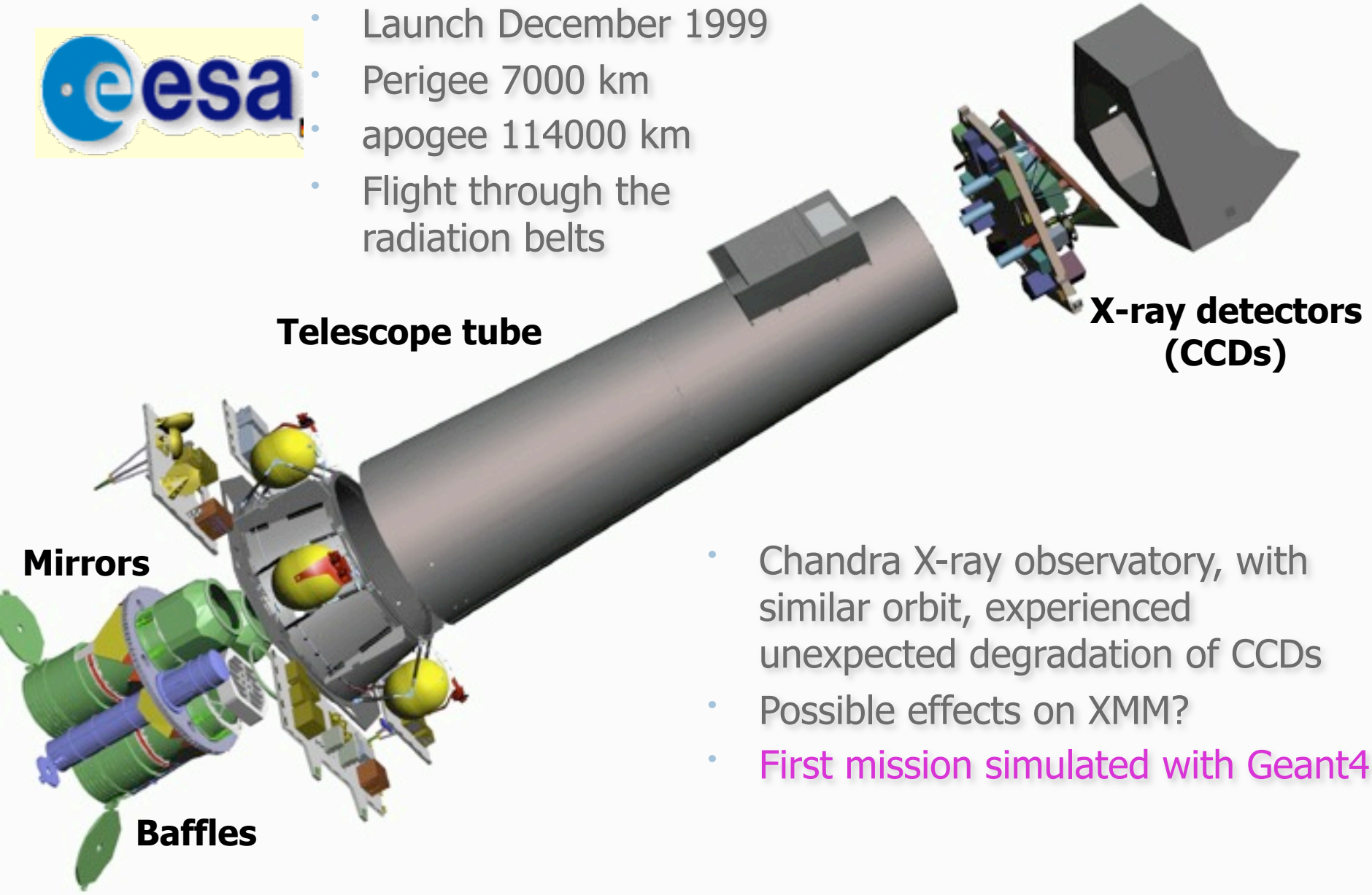
- Alternate Solenoid Channel (sFoFo), published in proceedings of PAC2001 and Feasibility Study II for a Neutrino Factory at BNL (2001)
- Bent Solenoid Channel, presented at Emittance Exchange Workshop, BNL 2000
- Low Frequency r.f. Cooling Channel, presented at International Cooling Experiment Workship, CERN 2001
- Cooling Experiment (MICE) Simulation (in progress)

G4 Users Meeting, February 21st, 2002 *V. Daniel Elvira, Fermilab*

Courtesy of V.D.Elvira (FNAL)

X-ray Multi-Mirror mission (XMM)

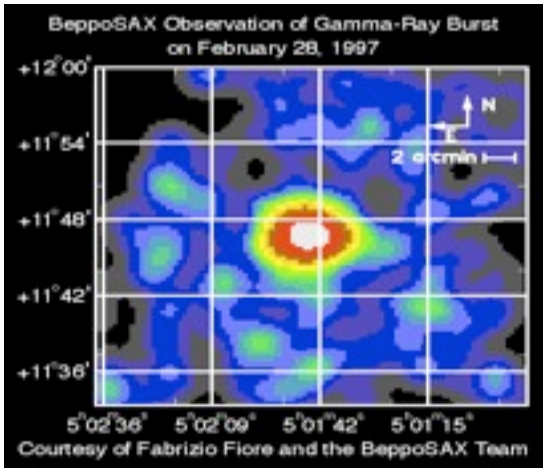
- Launch December 1999
- Perigee 7000 km
- apogee 114000 km
- Flight through the radiation belts

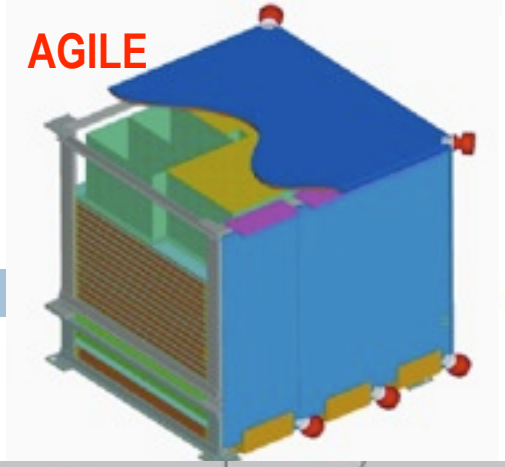


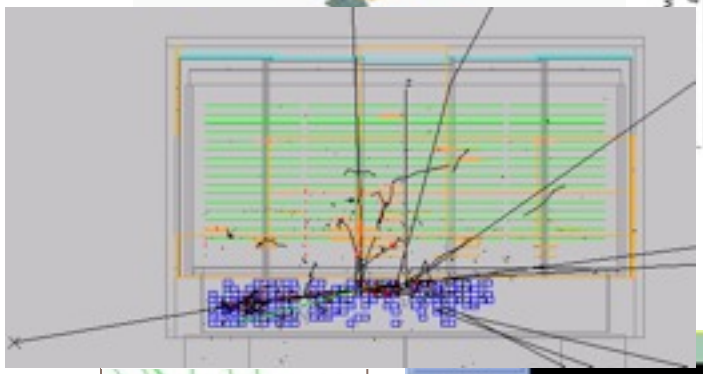
- Chandra X-ray observatory, with similar orbit, experienced unexpected degradation of CCDs
- Possible effects on XMM?
- First mission simulated with Geant4

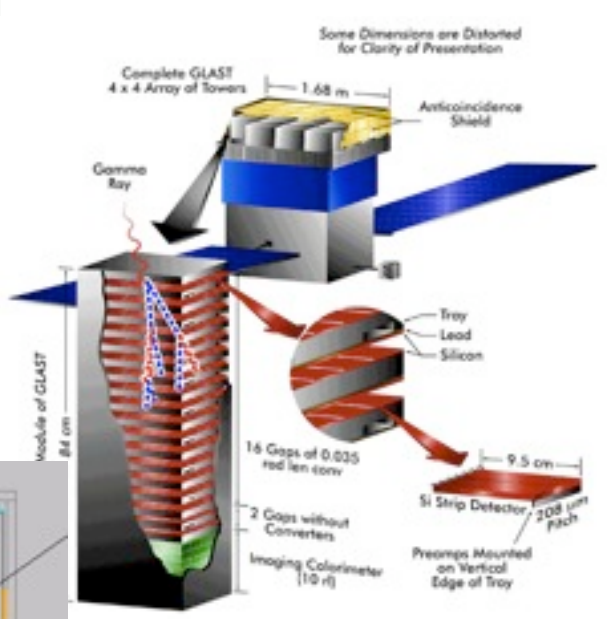
γ astrophysics

γ-ray bursts

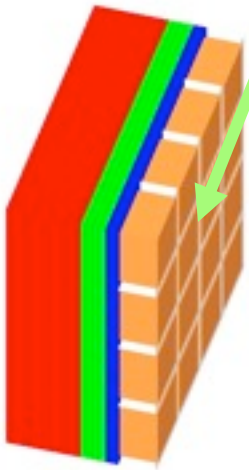






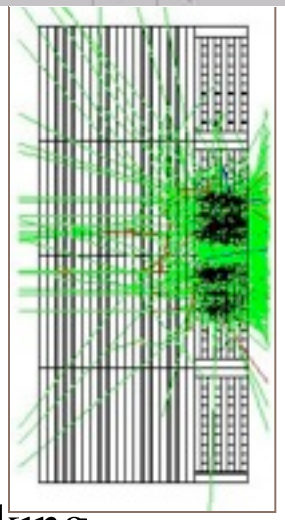


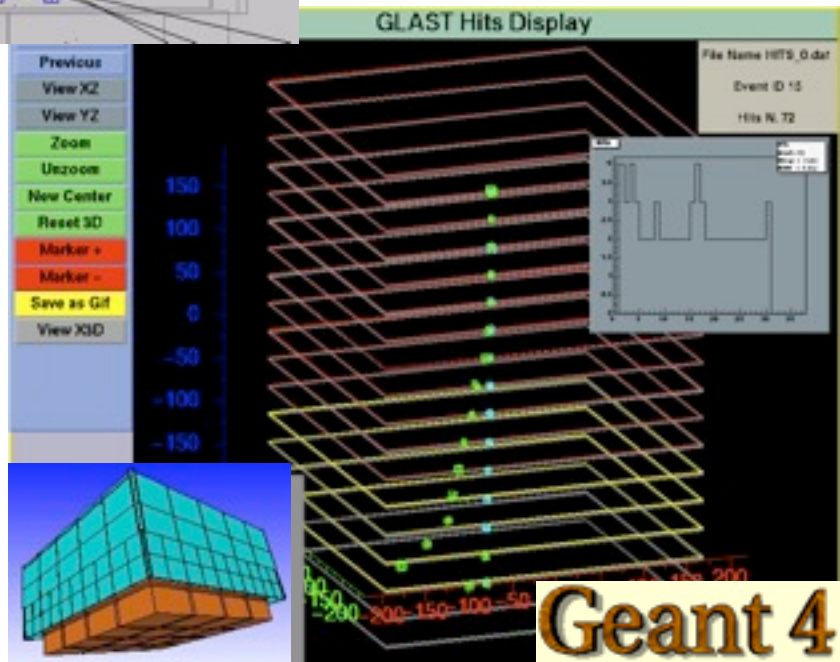
Fermi Mission

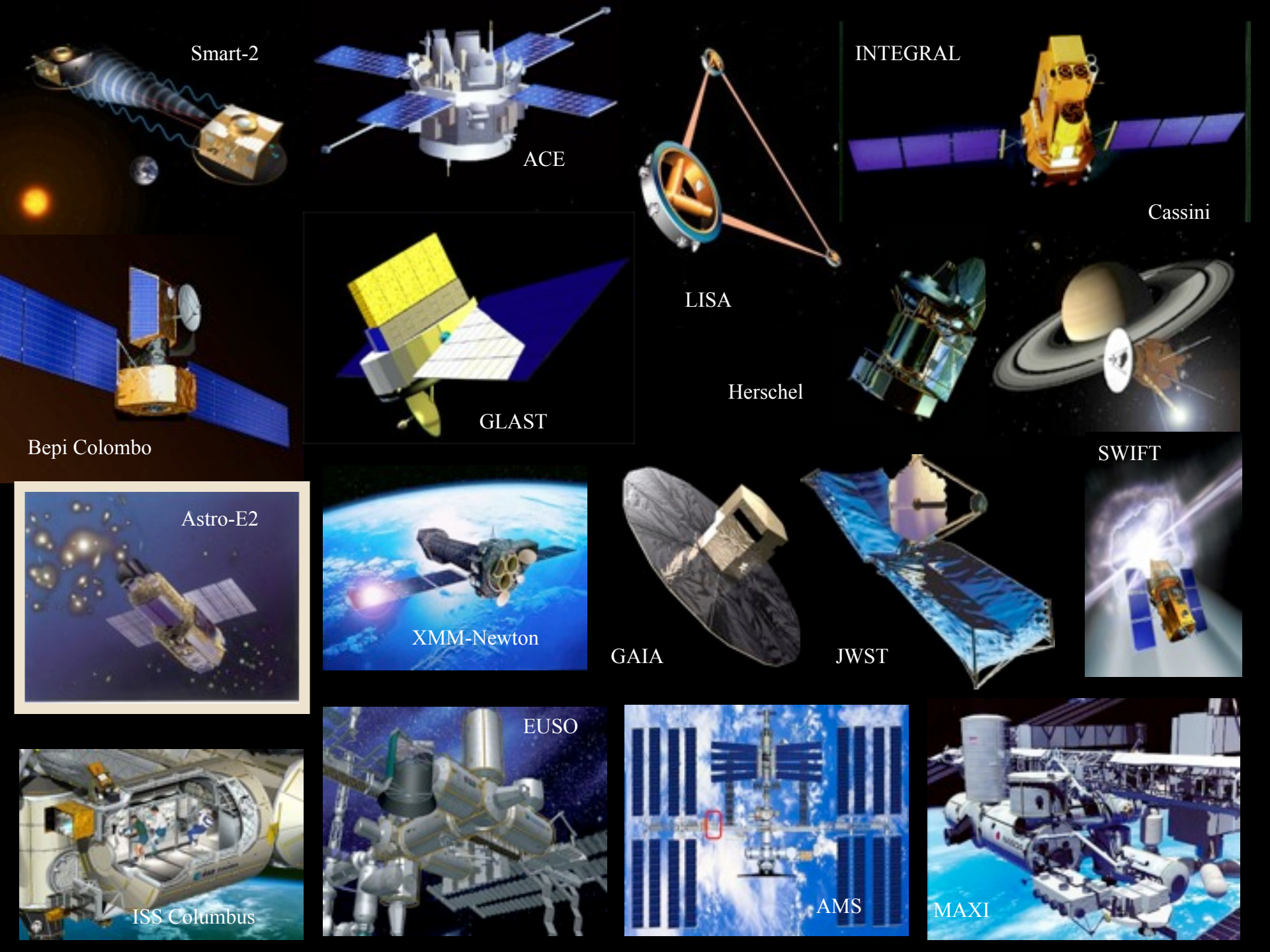


Typical telescope:
Tracker
Calorimeter
Anticoincidence

- γ conversion
- electron interactions
- multiple scattering
- δ-ray production
- charged particle tracking






Smart-2
ACE
INTEGRAL
Cassini
LISA
GLAST
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Astro-E2
XMM-Newton
GAIA
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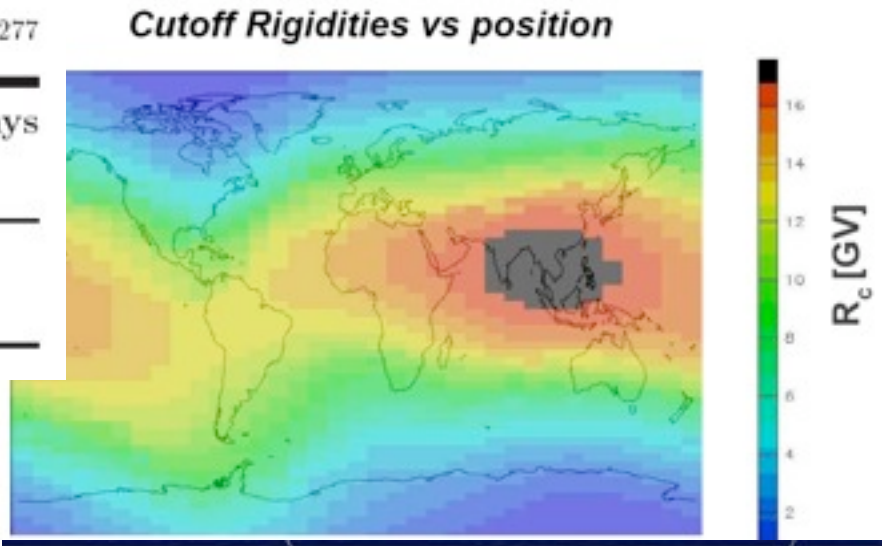
MAXI

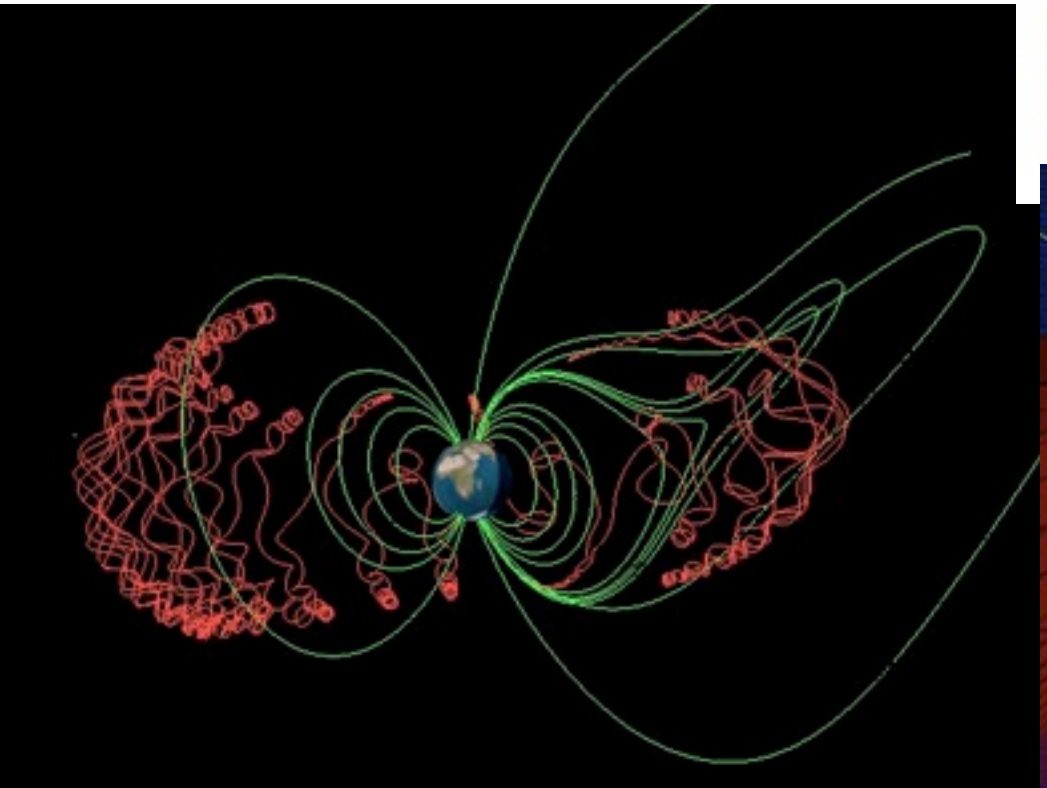
PlanetoCosmics

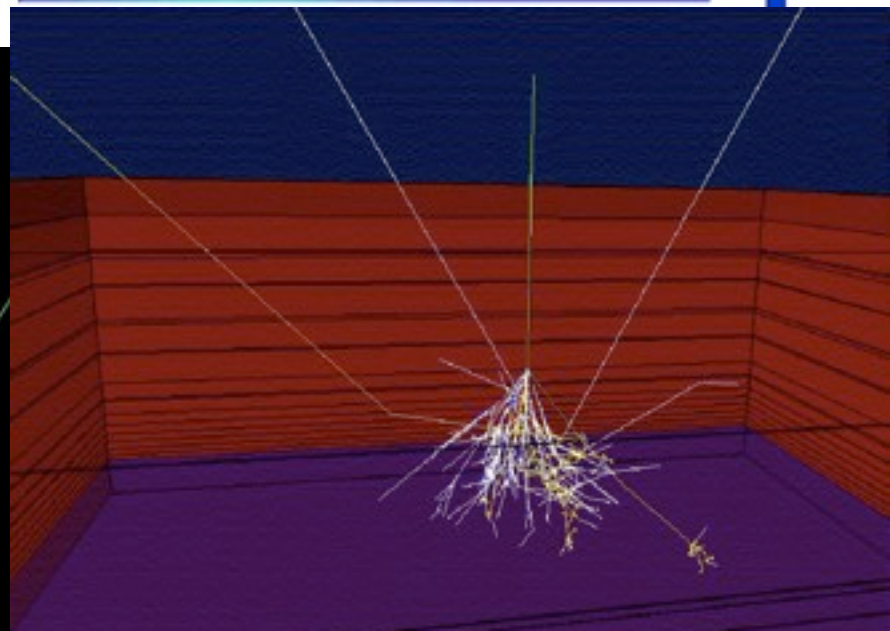
Geant4 simulation of Cosmic Rays in planetary Atmo-/Magneto- spheres

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

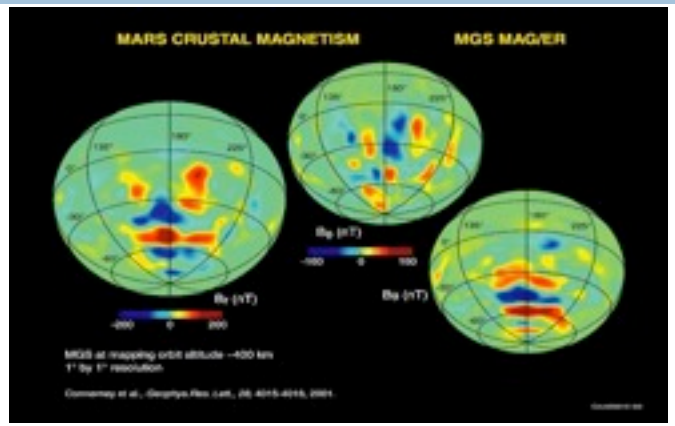






PlanetoCosmics

Mars field and atmosphere



- MGS observation Br @ 400 km
- Connerney et al., Geophys.Res.Let. 28, 21, 4015-4018, 2001
- Cain 50-degree spherical harmonic model (2003)

- NASA Mars-GRAM2001 model

  p,n, T in function of :

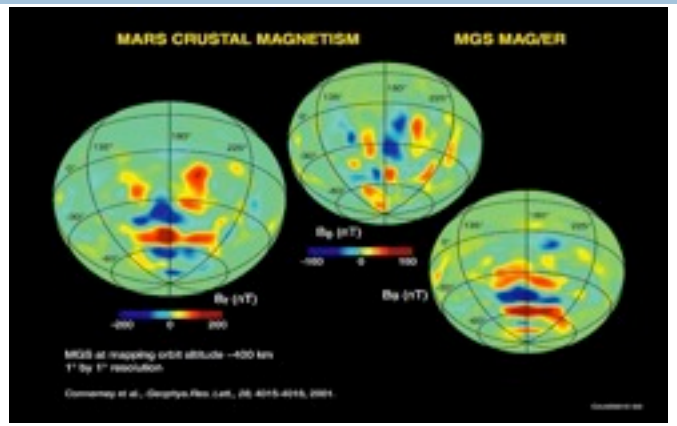
  - Lat., long. (topography from MOLA)
  - Altitude, season, local time, F10.7
  - Dust models

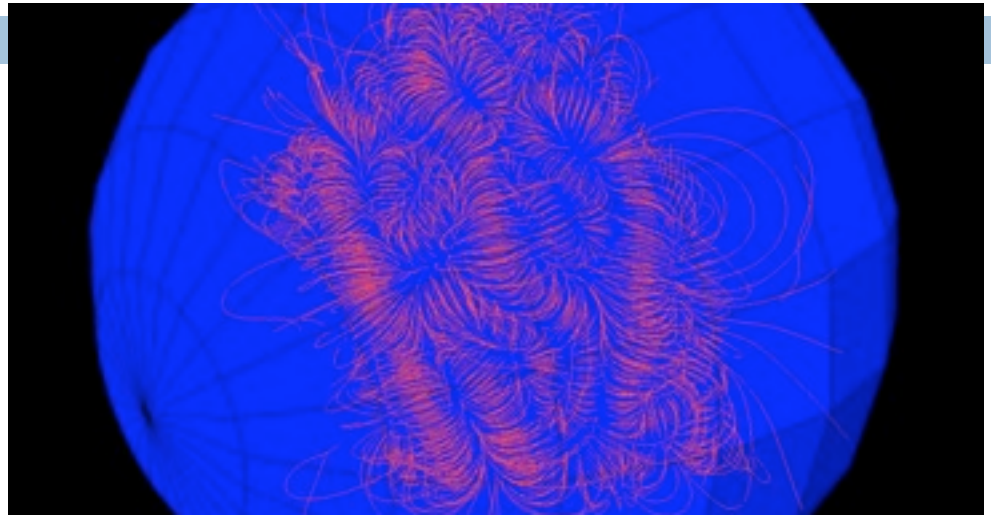
  Based on :

  - NASA MGCM 0-80 km
  - Univ. of Arizona MTGCM 80-170 km

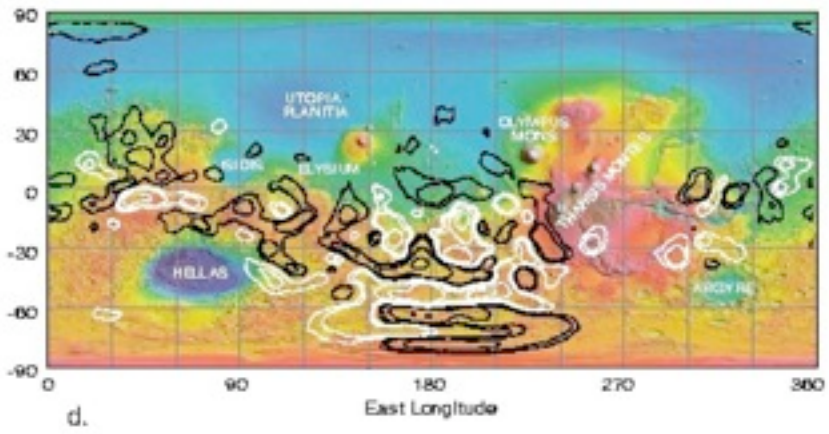
PlanetoCosmics

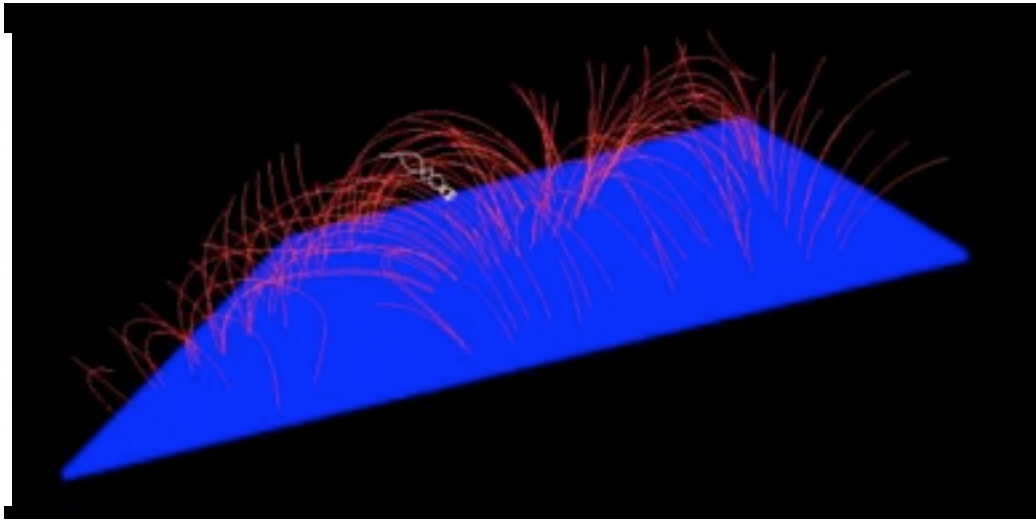
Mars field and atmosphere



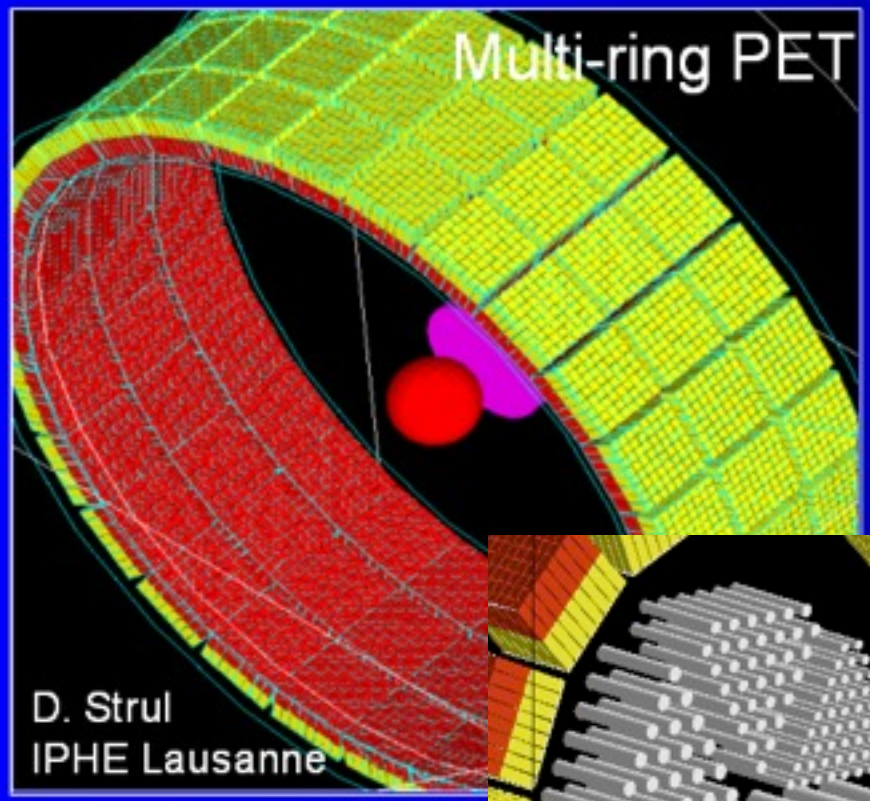


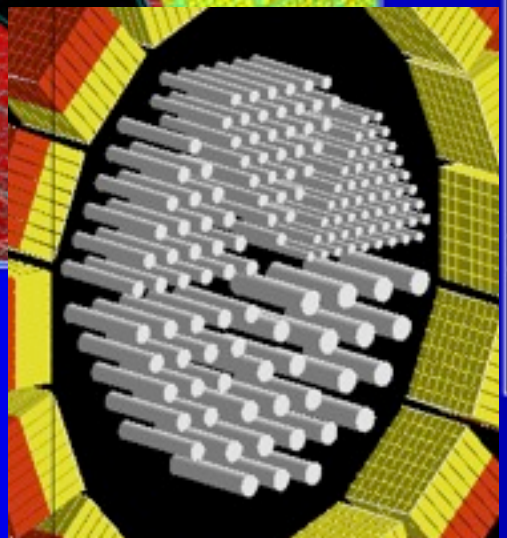
- NASA Mars-GRAM2001 model

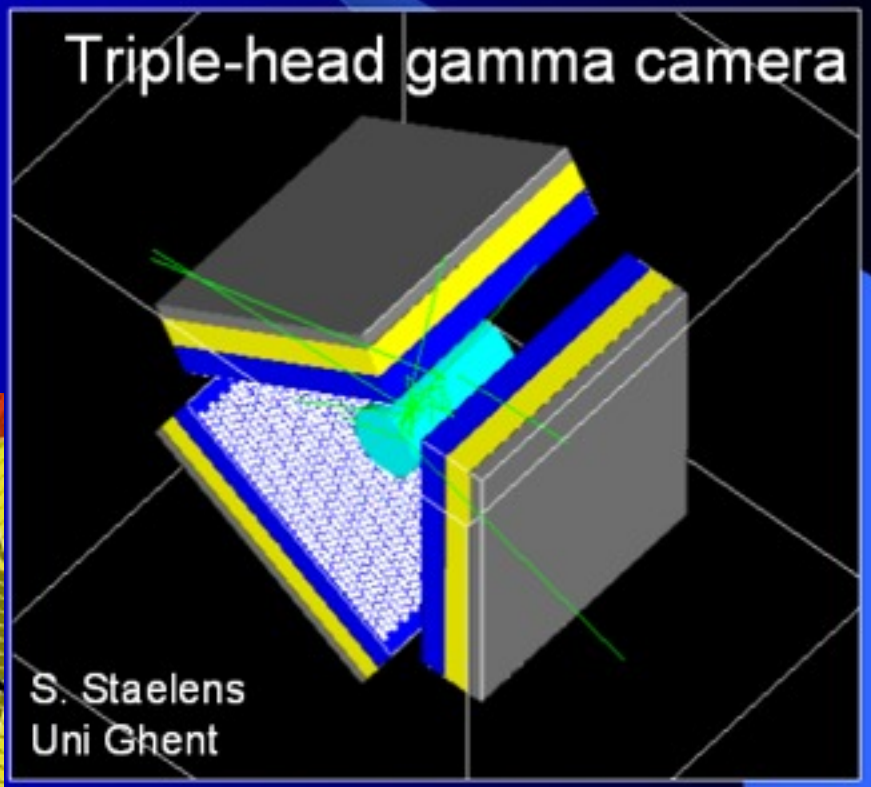




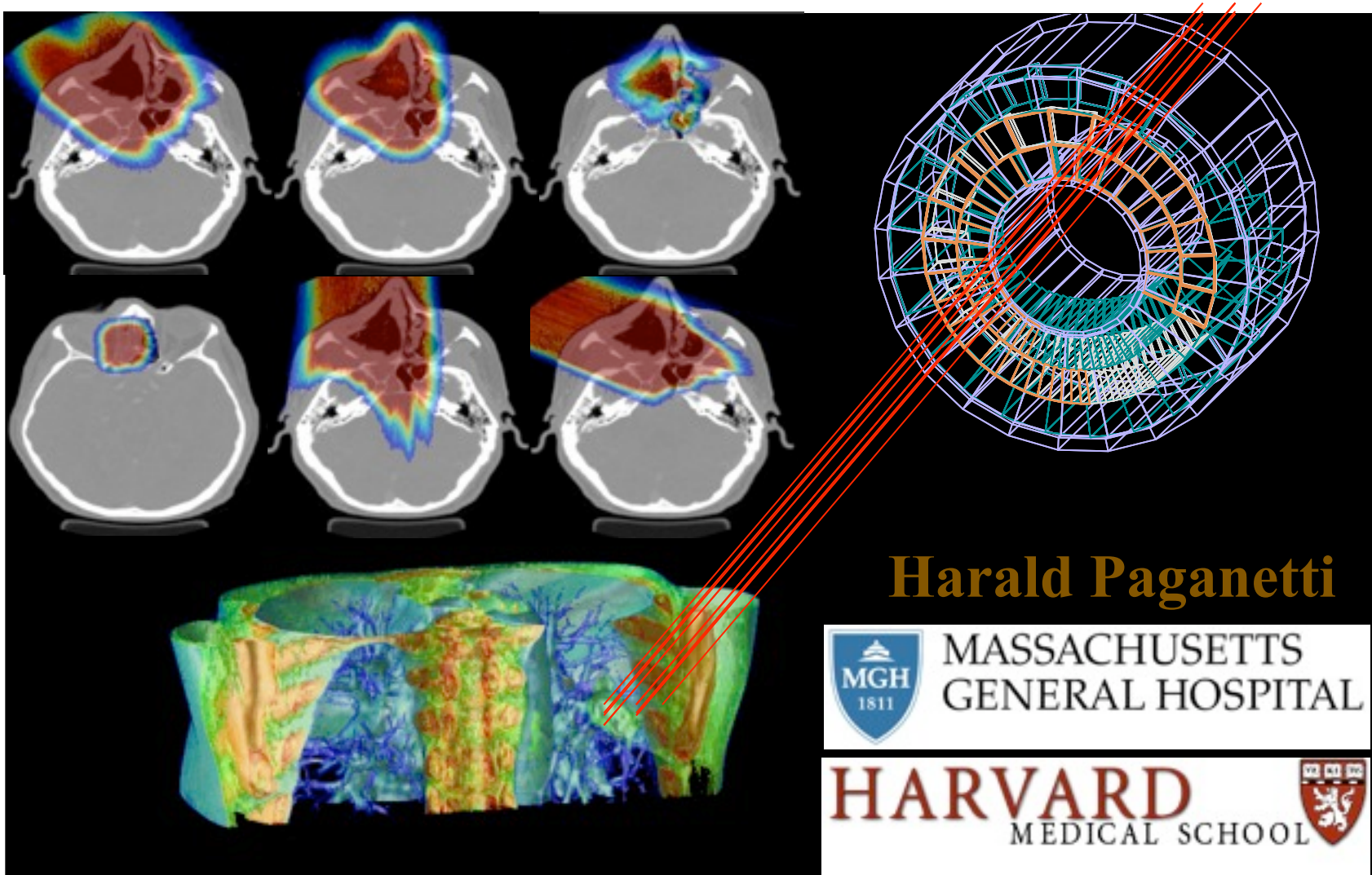
Geometry examples of GATE applications







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

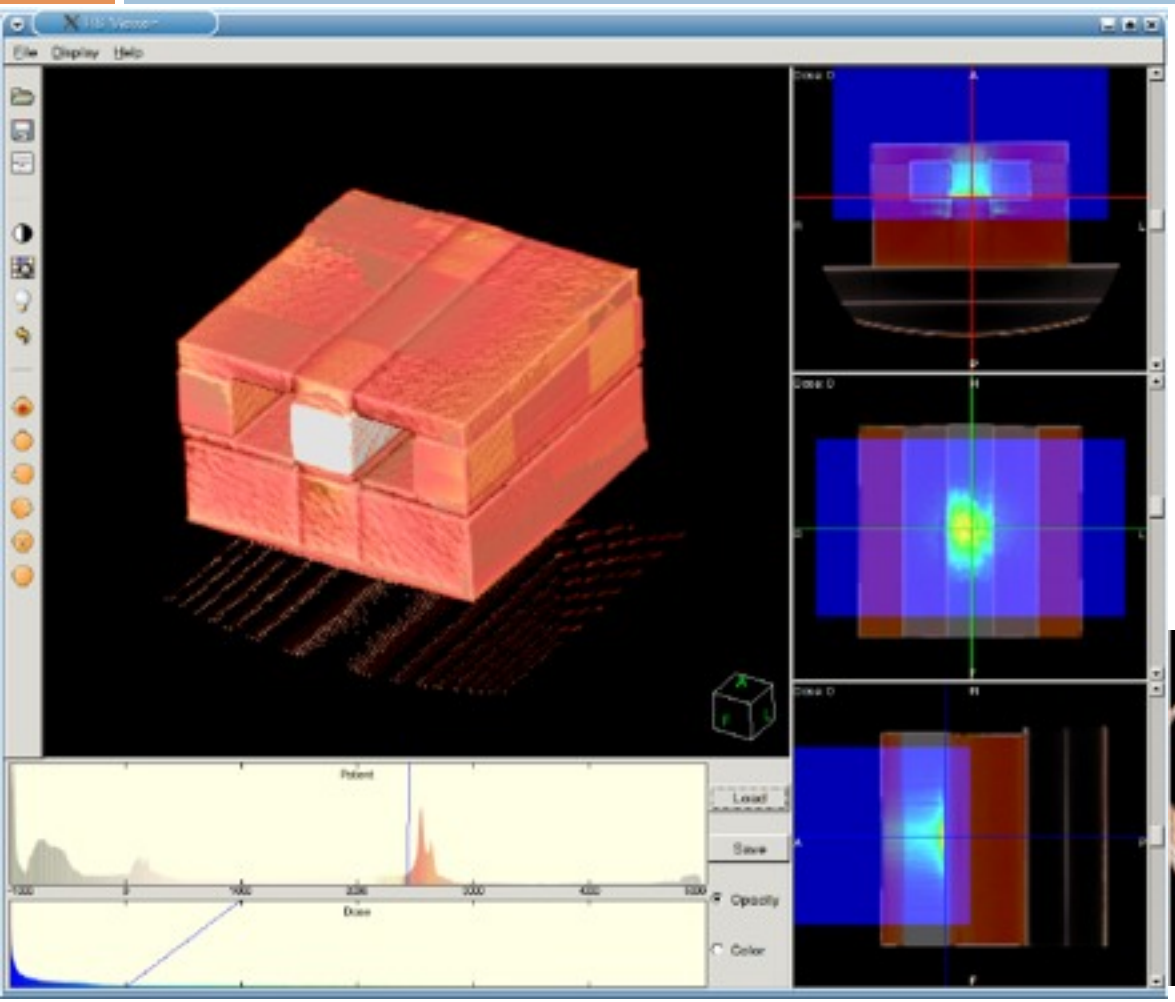


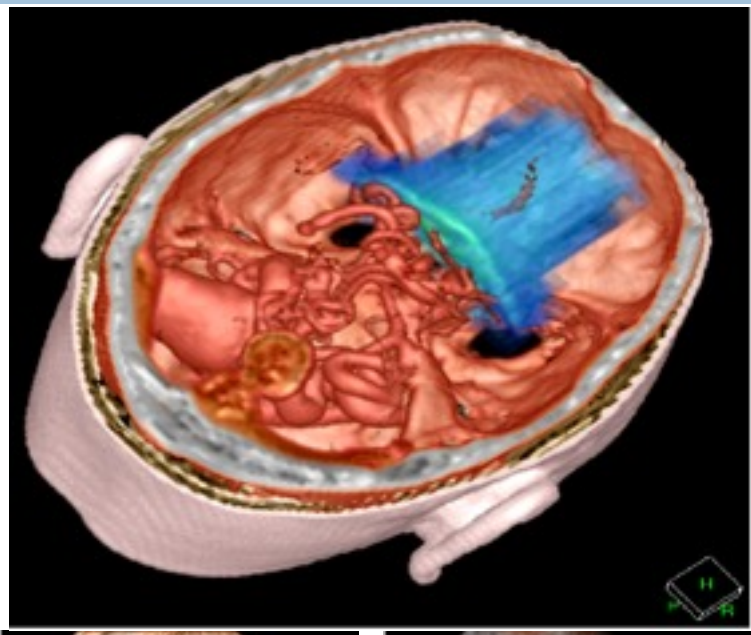
Harald Paganetti

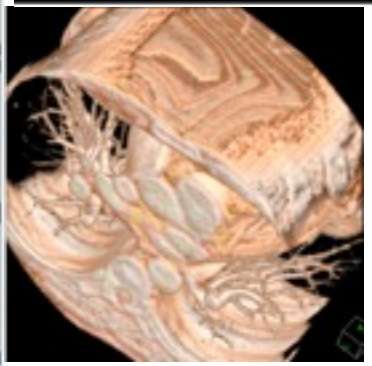
MASSACHUSETTS GENERAL HOSPITAL

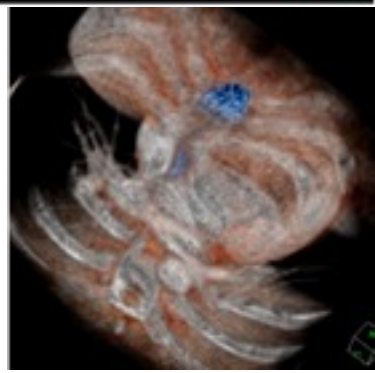
HARVARD MEDICAL SCHOOL

Screen shots of gMocren









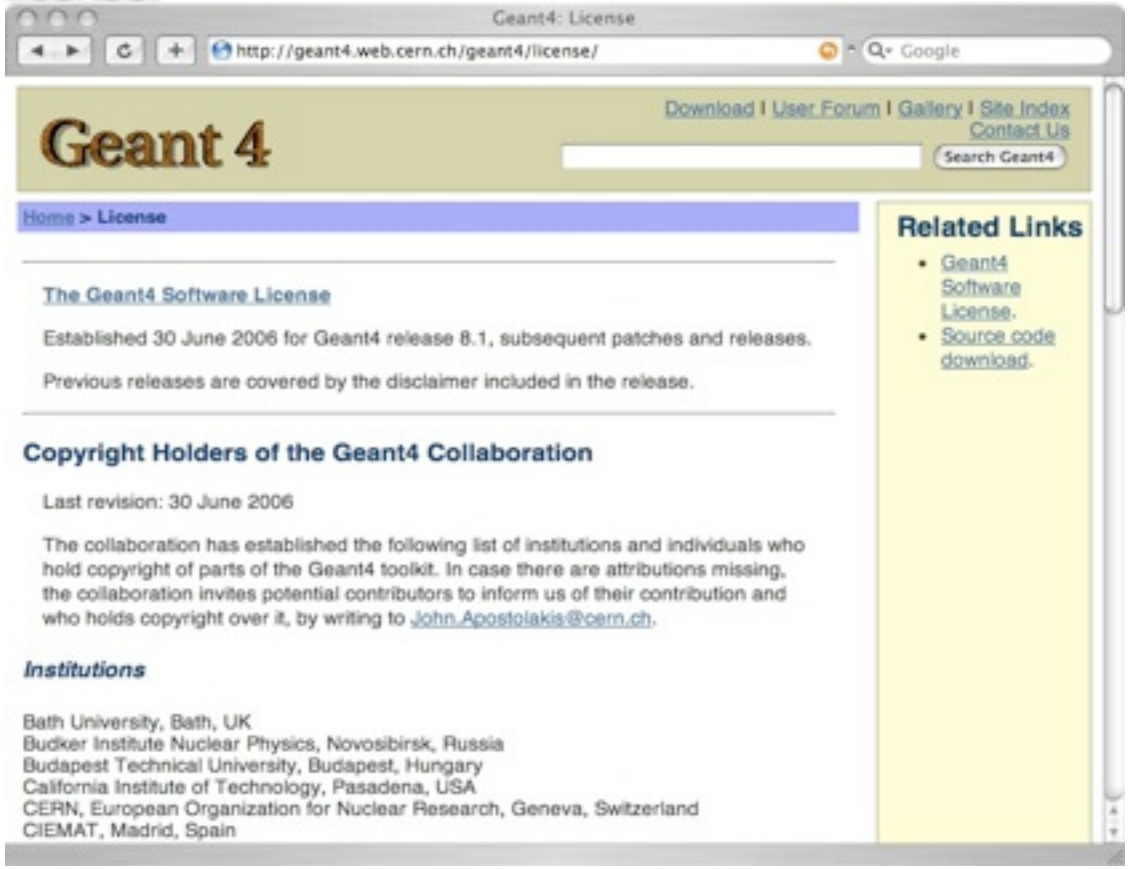
GEANT4 LICENSE

The Geant4 License

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

- 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/



Geant4 License Highlights

- 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 parts already written by the collaboration

- We don't claim that it works, and we're not responsible if it doesn't

BASIC CONCEPTS AND KERNEL STRUCTURE

Unit system

- Internal unit system used in Geant4 is completely hidden not only from user's code but also from Geant4 source code implementation.
- Each hard-coded number must be multiplied by its proper unit.

```
radius = 10.0 * cm;
kineticE = 1.0 * GeV;
```

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

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

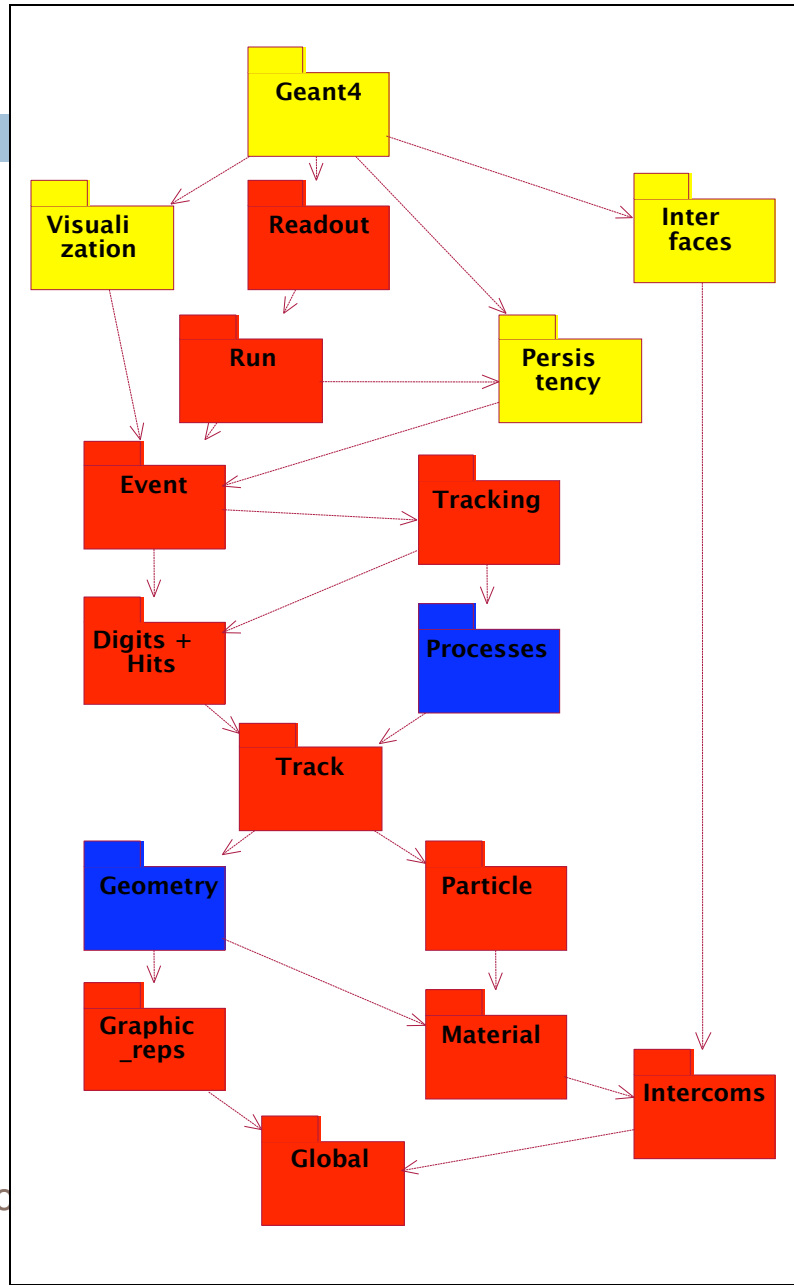
- Most of commonly used units are provided and user can add his/her own units.
- By this unit system, source code becomes more readable and importing / exporting physical quantities becomes straightforward.
  - For particular application, user can change the internal unit to suitable alternative unit without affecting to the result.

Terminology

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

Geant4 kernel

- Geant4 consists of 17 categories.
  - Independently developed and maintained by WG(s) responsible to each category.
  - Interfaces between categories (e.g. top level design) are maintained by the global architecture WG.
- Geant4 Kernel
  - Handles run, event, track, step, hit, trajectory.
  - Provides frameworks of geometrical representation and physics processes.



The main program

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