



Introduction to Geant4

Geant = « GEometry And Tracking »

Geant4 PHENIICS & IN2P3 Tutorial,
13 – 17 May 2019,
Orsay

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LLR, Ecole polytechnique

Credits

- **Large part** of presentation here is from Makoto Asai,
- And material is from many sources...

Layout

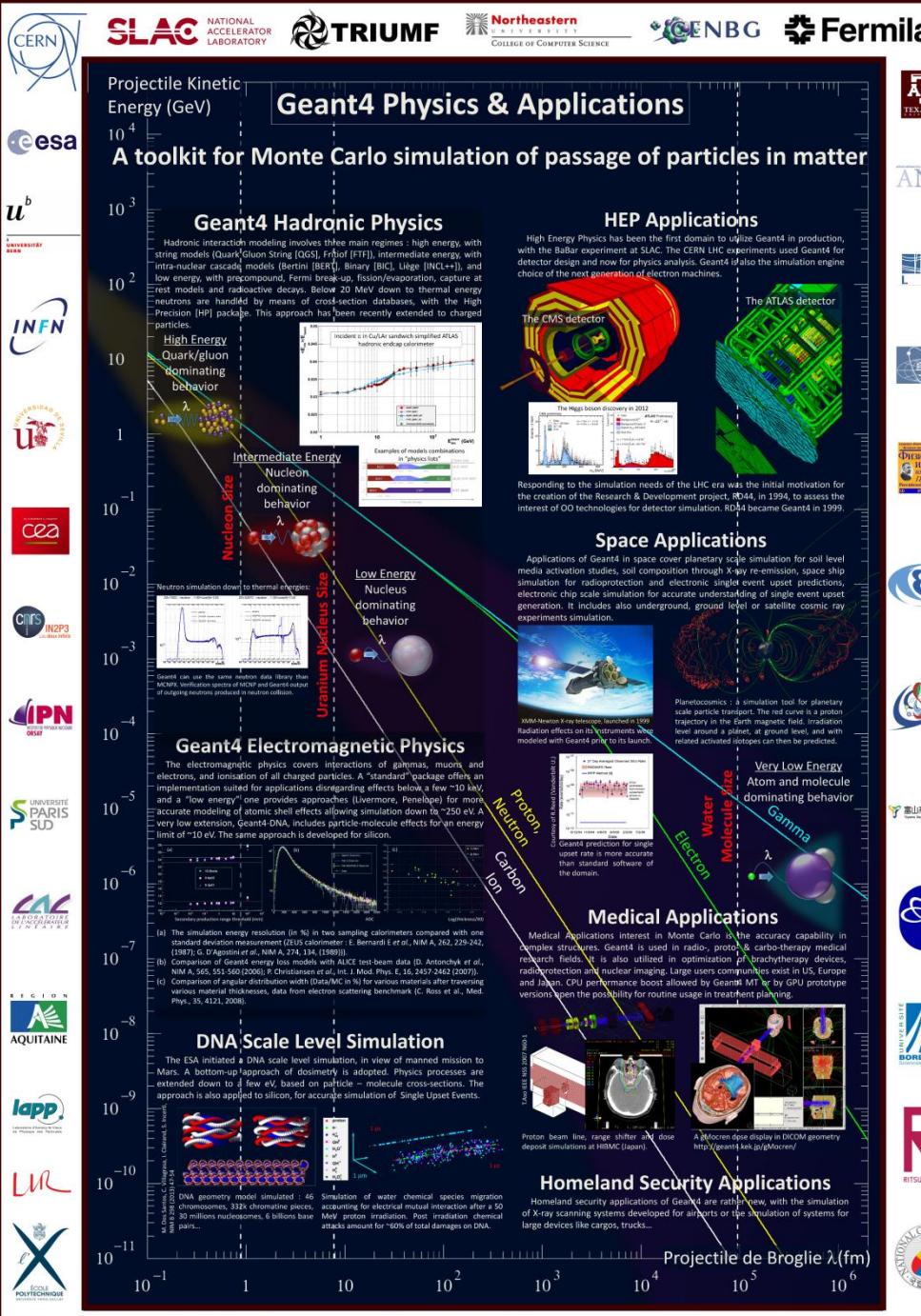
- **Geant4 Overview**

- Geant4 & its key functionalities
 - Key geometry capabilities
 - Physics models in Geant4
 - Geant4 – Brief history
 - Geant4 Collaboration

• Geant4 Application Domains

- Large Hadron Collider (LHC) @ CERN
 - Geant4 in Space
 - Geant4 in Medical Science
 - Geant4 in Homeland Security
 - Geant4 in Other fields

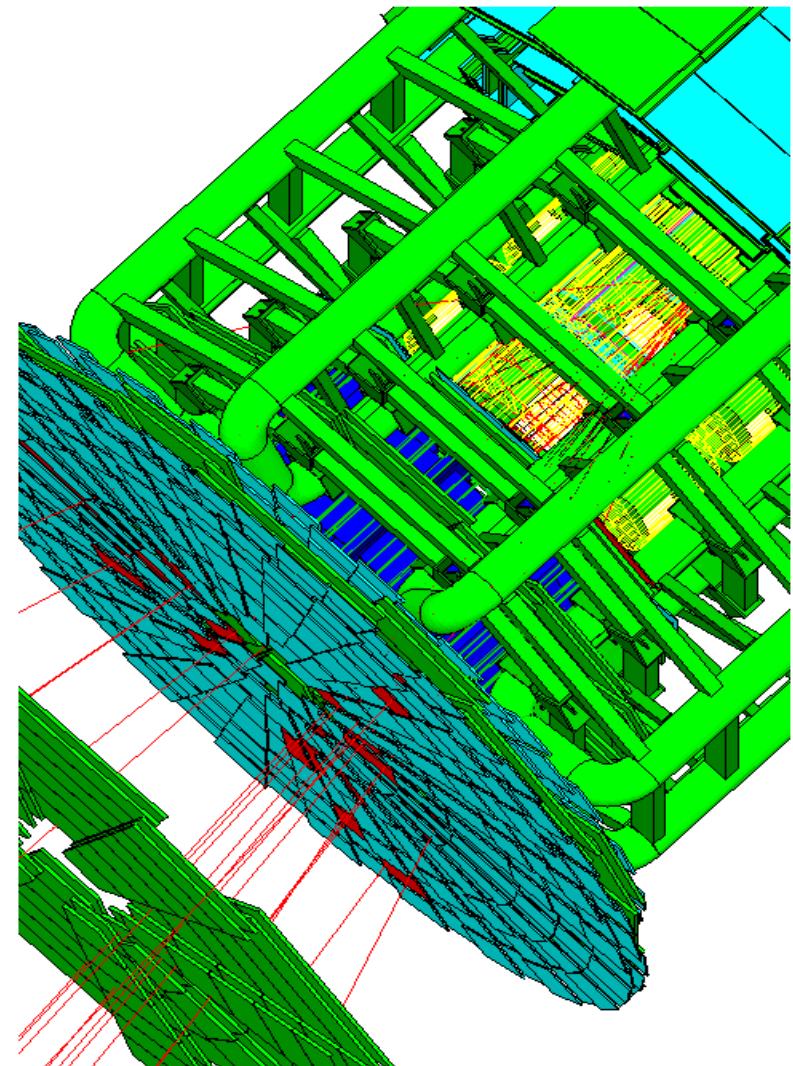
• Geant4 Toolkit Philosophy



Geant4 Overview

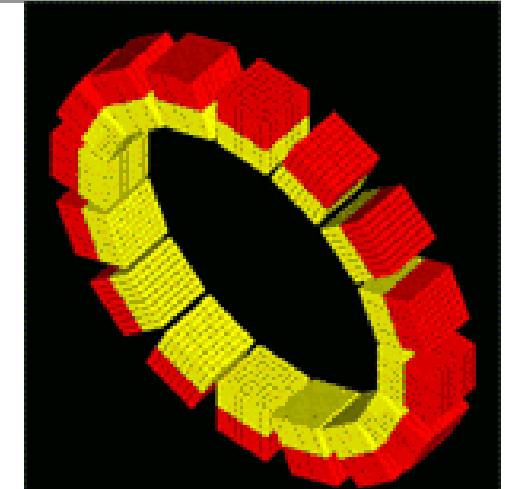
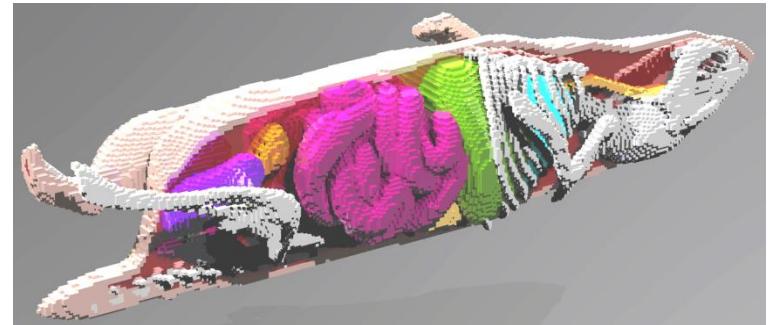
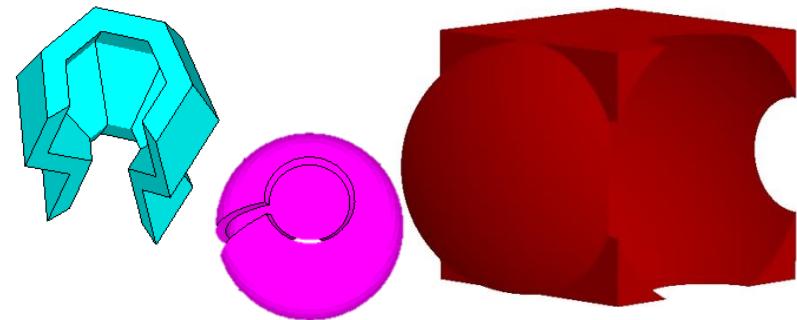
Geant4 & its key functionalities

- General purpose Monte Carlo toolkit for simulating the passage of elementary particles through and interacting with matter.
- Wide variety of user domains
 - high energy and nuclear physics,
 - space engineering
 - medical applications
 - material science
 - radiation protection and security.
- Geant4 offers lots of the functionalities required for the simulation of elementary particle and nucleus passing through and interacting with matter.
 - Kernel
 - Geometry and navigation
 - Physics processes
 - Scoring
 - GUI and Visualization drivers
- Users can easily plug-in their extensions without interfering with the other parts of Geant4.
- Extensive user guide documents and examples are provided.



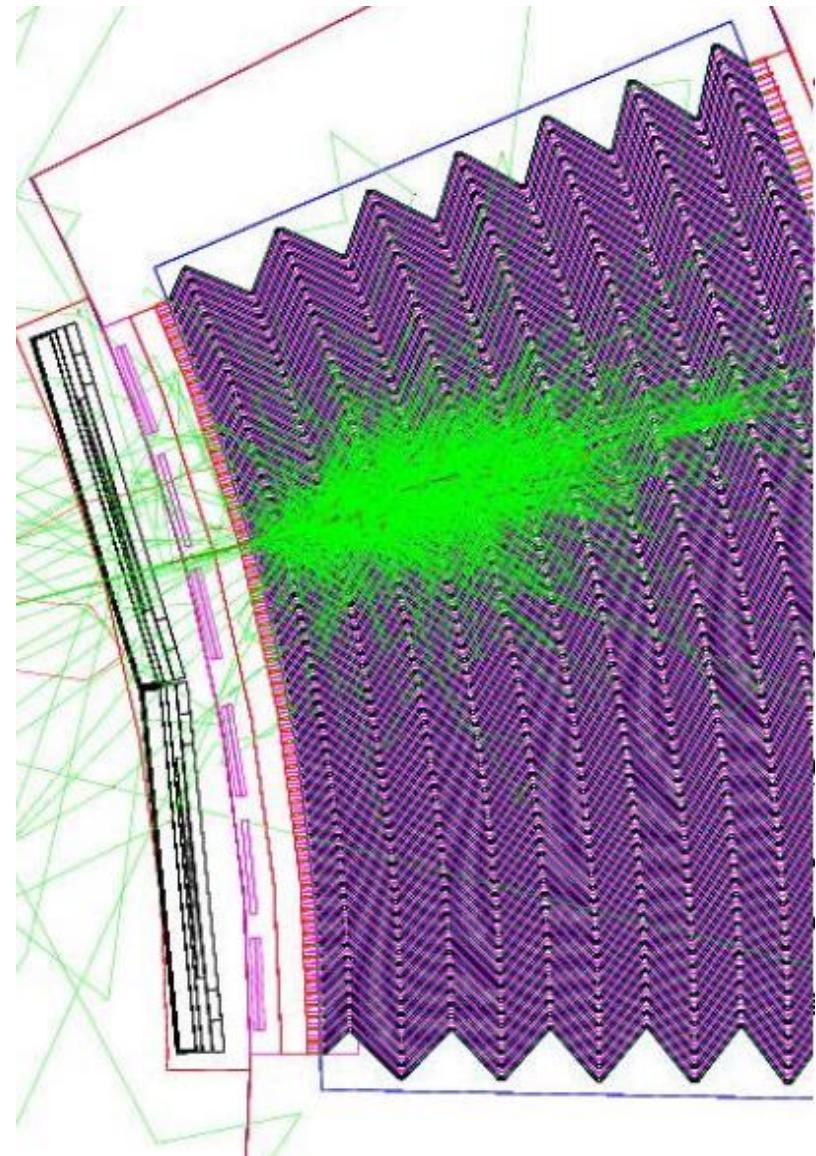
Key geometry capabilities

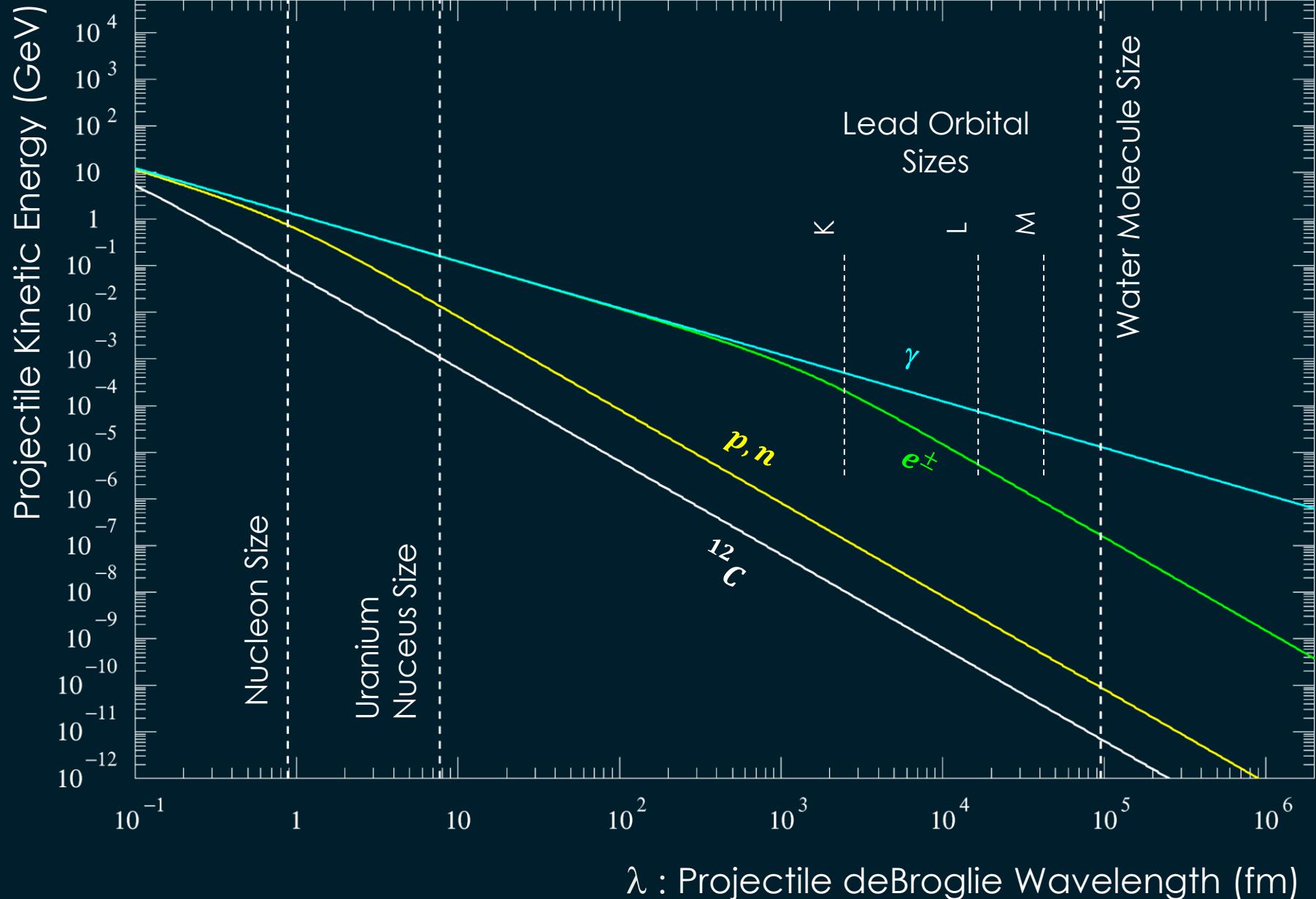
- Richest collection of shapes
 - CSG (Constructed Solid Geometry), Boolean operation, Tessellated solid, etc.
 - The user can easily extend
- Describing a setup as hierarchy or ‘flat’ structure
 - Describing setups up to billions of volumes
 - Tools for creating & checking complex structures
 - Interface to CAD
- Navigating fast in complex geometry model
 - Automatic optimization
- Geometry models can be ‘dynamic’
 - Changing the setup at run-time
 - e.g. “moving objects”

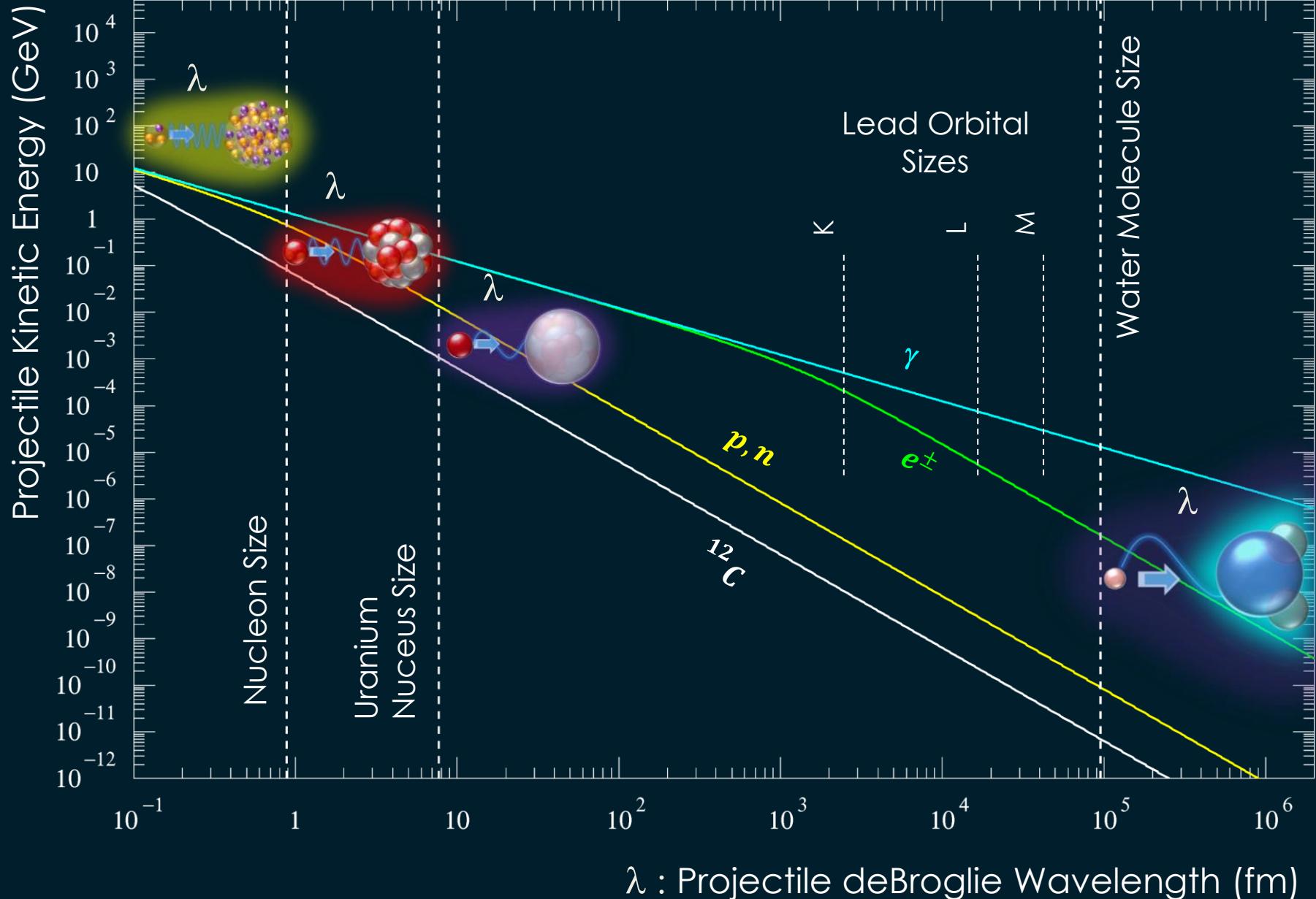


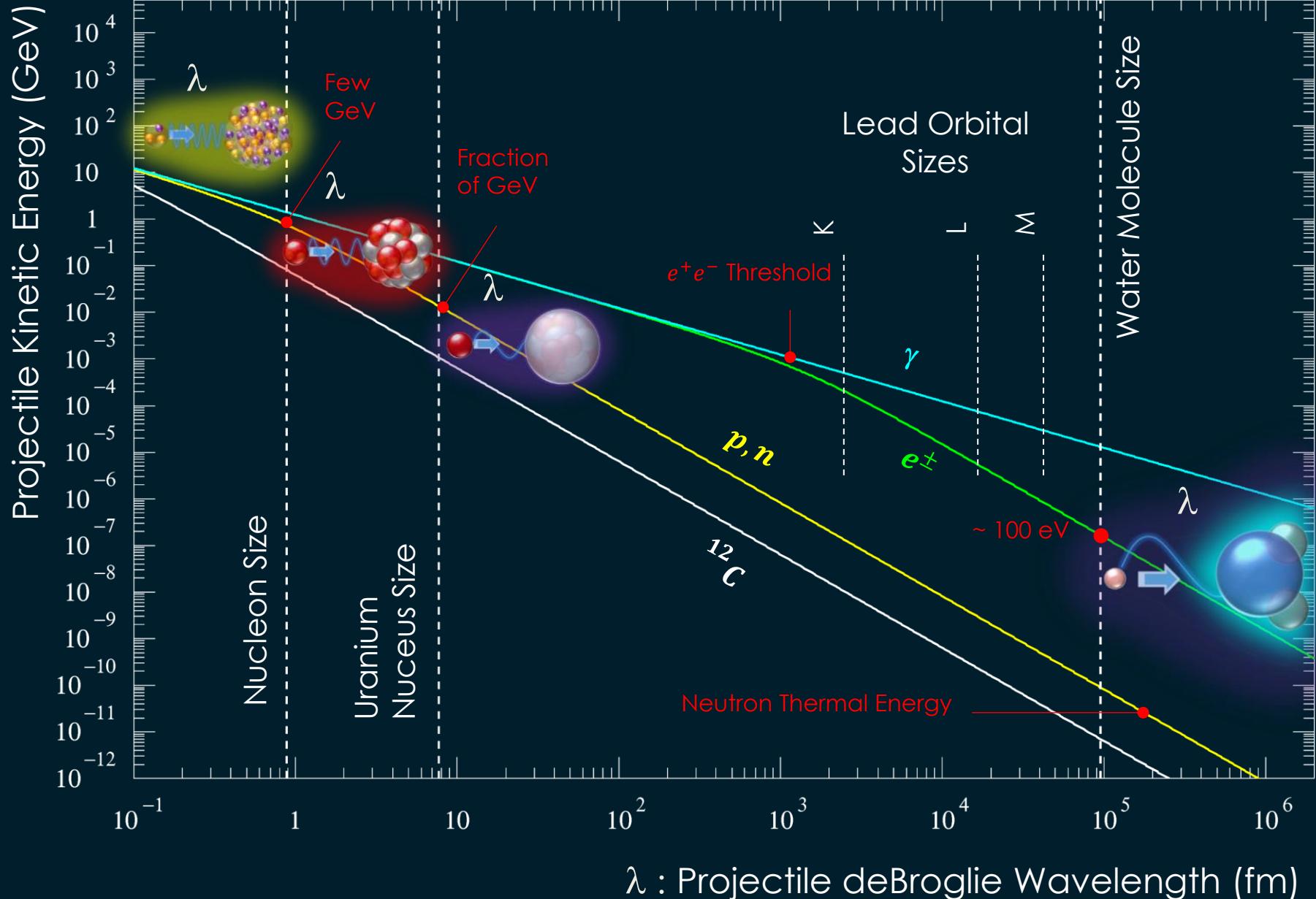
Physics models in Geant4

- Geant4 offers
 - Electromagnetic processes
 - Hadronic and nuclear processes
 - Photon/lepton-hadron processes
 - Optical photon processes
 - Decay processes
 - Shower parameterization
 - Event biasing techniques
 - And you can plug-in more
- Wide set of physics models provided
 - Complementary models with different energy range applicability
 - That can be combined to cover a wide range
 - Competing models with same energy range applicability
 - That can be selected by the user









Geant4 – Brief history

- **Dec '94 - Project start**
 - RD44 project : assess OO benefit for detector simulation, for coping with simulation complexity of the (future at that time) LHC era and from other fields.
- Apr '97 - First alpha release
- Jul '98 - First beta release
- **Dec '98 - First Geant4 public release - version 1.0**
- ...
- Several major evolutions:
 - Migration STL, “cuts per region”, parallel worlds
- **6 December 2013 : Geant4 version 10.0**
 - **First version with multi-threading support in production**
- ...
 - Oct 20th, '17 - Geant4 10.3-patch03 release
- Dec 8th, '17 – Geant4 version 10.4 release
 - Feb 8th, '19 - Geant4 10.4-patch03 release
- Dec 7th, '18 - Geant4 version 10.5 release
 - **Feb 17th, '19 - Geant4 10.5-patch01 release**
- We currently provide one public release per year.
 - Announced on Collaboration Web pages and mailing list
 - **please subscribe !** ([✉ geant4 → user support → mailing list subscription](#))

← **Retroactive patch release**

← **Current version**



GEANT4 collaboration

A SIMULATION TOOLKIT



NATIONAL
ACCELERATOR
LABORATORY



esa



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

Geant4: a simulation toolkit

S. Agostinelli *et al.*

NIM A, vol. 506, no. 3, pp. 250-303, 2003



u^b

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UNIVERSITÄT
BERN



Geant4 Developments and Applications

J. Allison *et al.*

IEEE Trans. Nucl. Sci., vol. 53, no. 1, pp. 270-278, 2006

Recent Developments in Geant4

J. Allison *et al.*

NIM A, vol. 835, pp. 186-225, 2016



Lawrence Livermore National Laboratory

Fermilab



한국과학기술정보연구원
Korea Institute of Science and Technology Information



Geant4 ASSOCIATES
INTERNATIONAL
Experts in Radiation Simulation





- An international collaboration
 - >100 active members
 - 19 countries



- An international collaboration
 - >100 active members
 - 19 countries

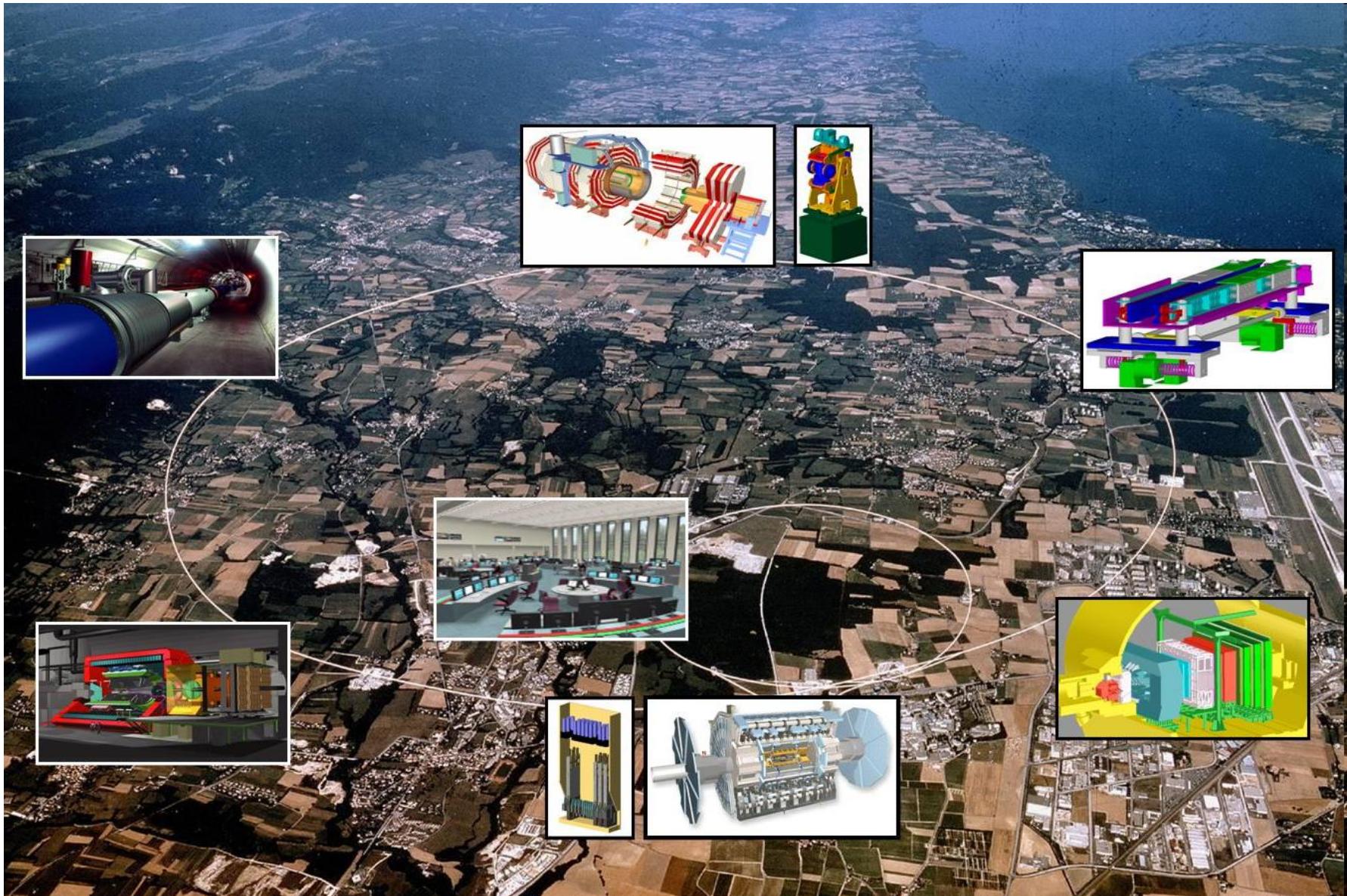


- An international collaboration
 - >100 active members
 - 19 countries

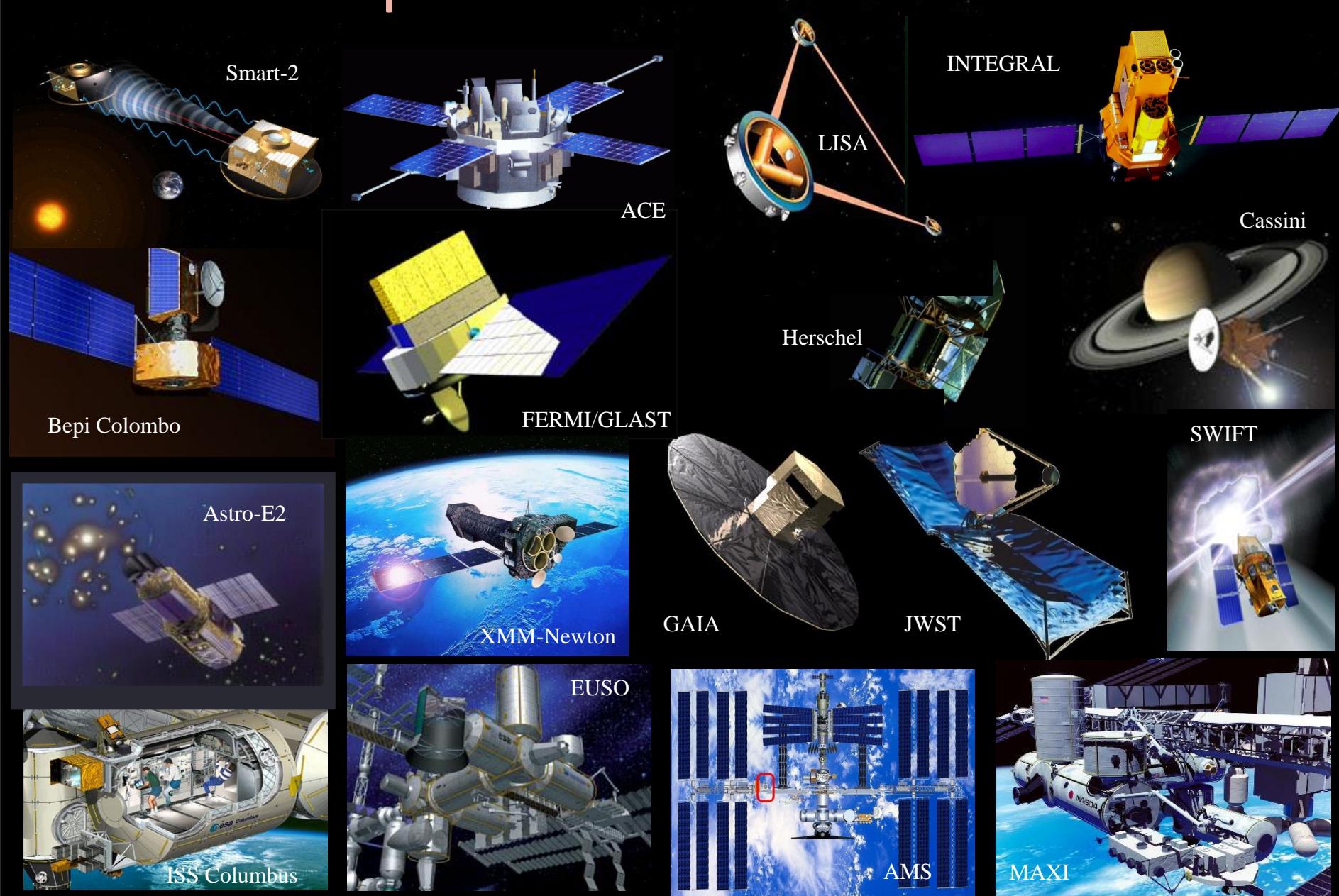
Geant4 application domains

not exhaustive

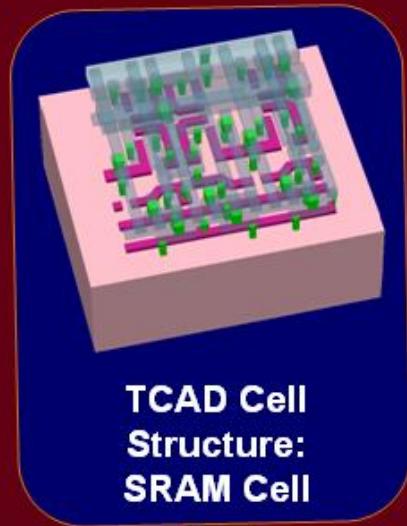
Large Hadron Collider (LHC) @ CERN



Geant4 in Space



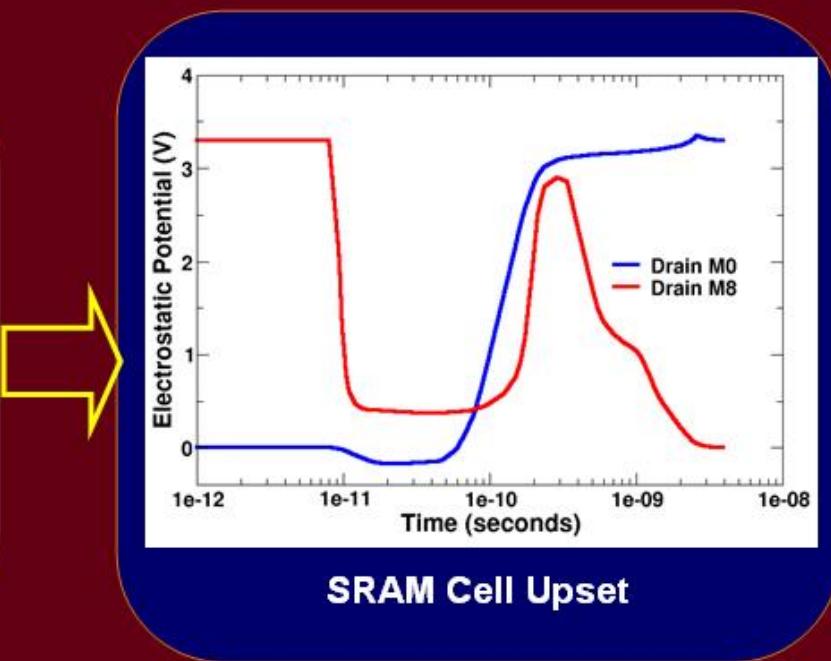
RADSAFE on SEE in SRAMs



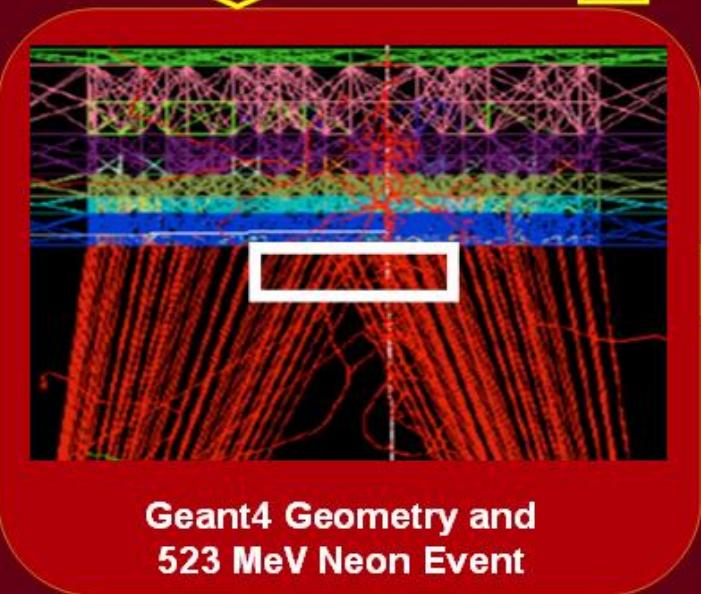
TCAD Cell
Structure:
SRAM Cell



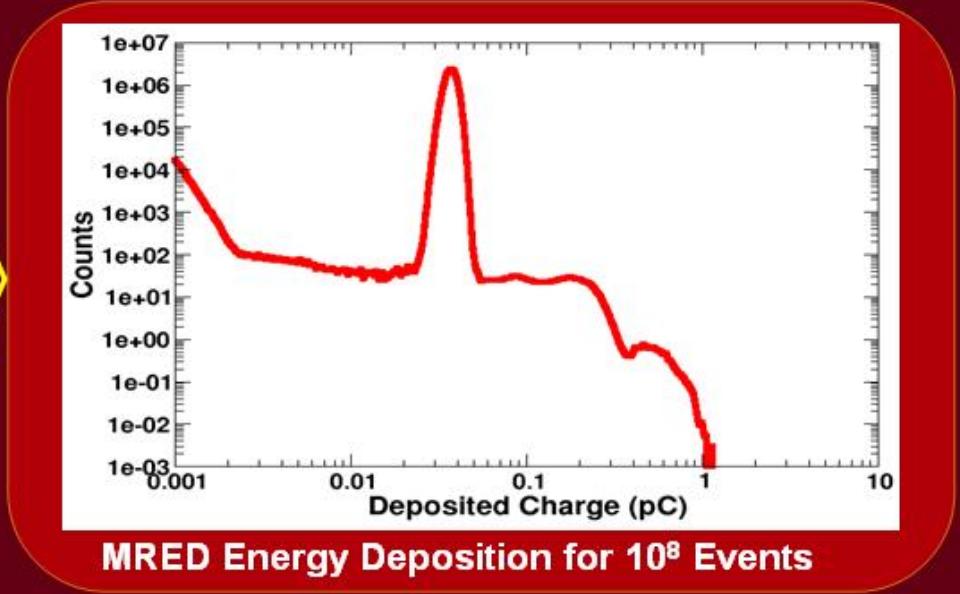
Single Charge Deposition
in TCAD: Ne+W Event



SRAM Cell Upset

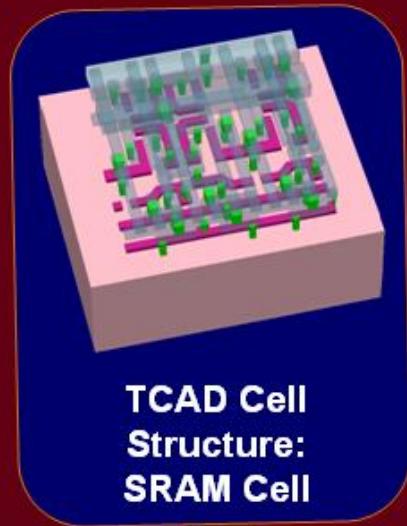


Geant4 Geometry and
523 MeV Neon Event

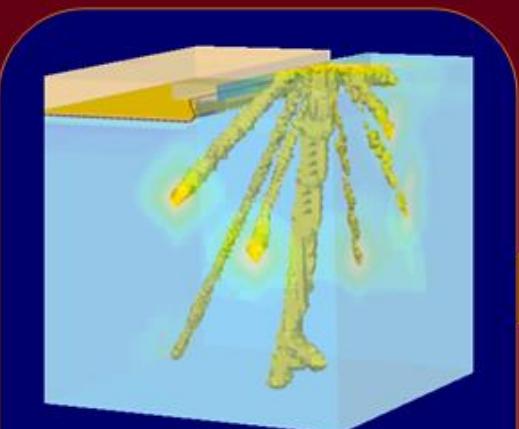


MRED Energy Deposition for 10^8 Events

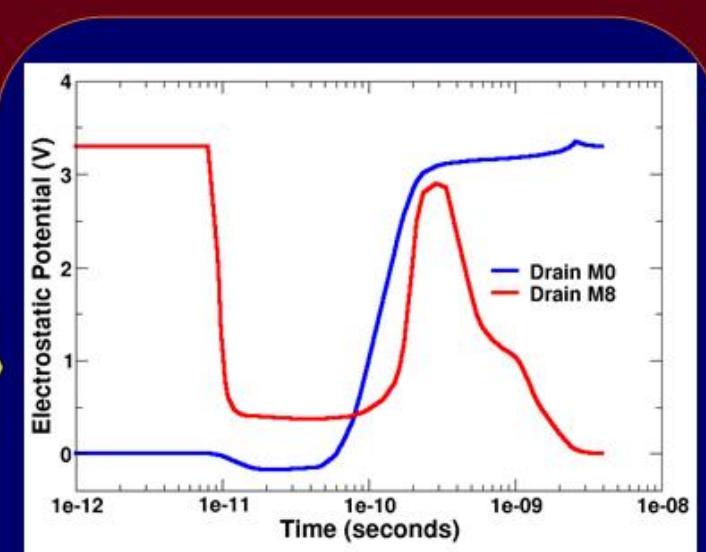
RADSAFE on SEE in SRAMs



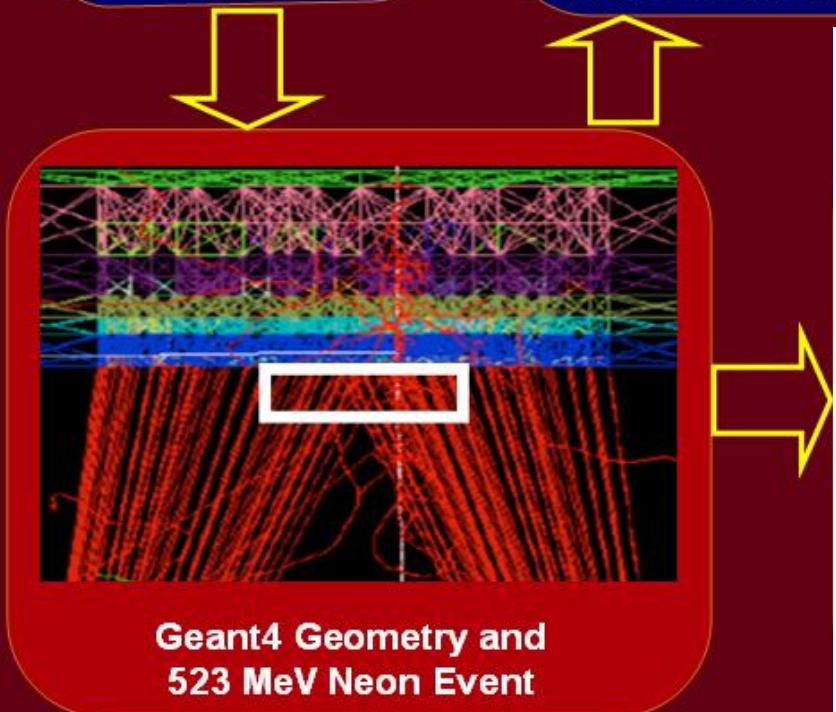
TCAD Cell
Structure:
SRAM Cell



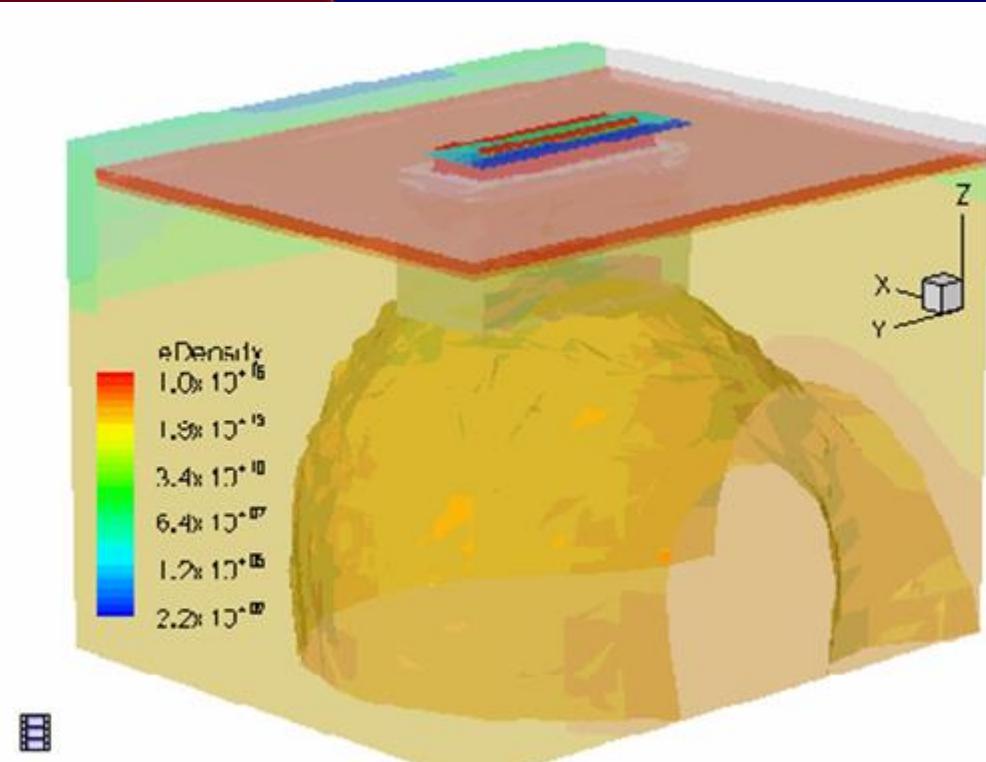
Single Charge Deposition
in TCAD: Ne+W Event



SRAM Cell Upset

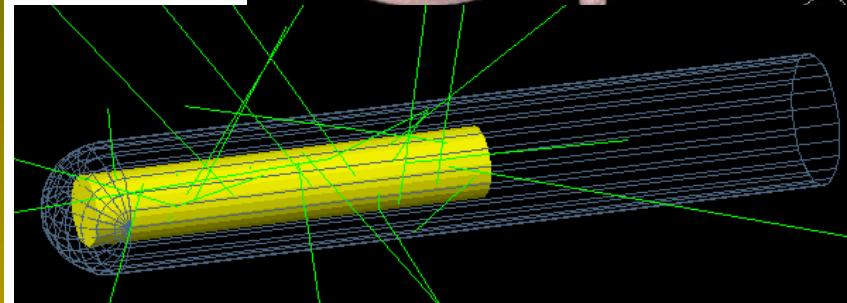
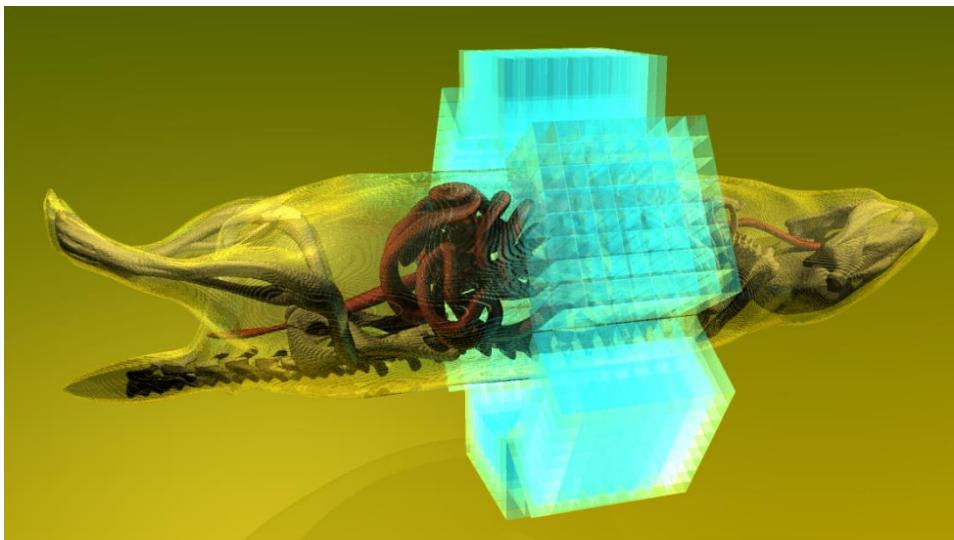
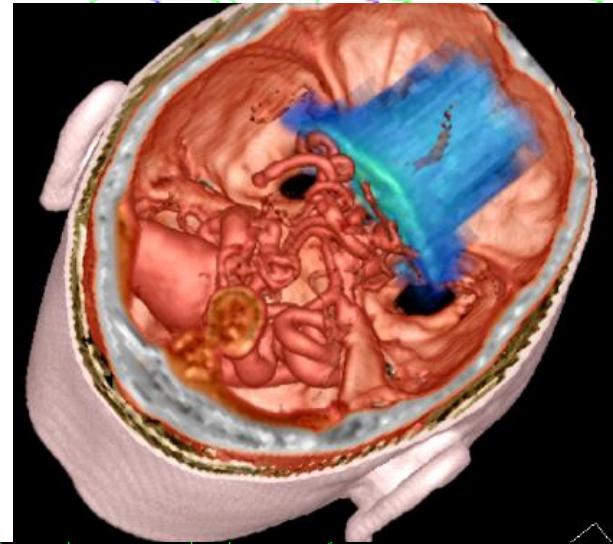
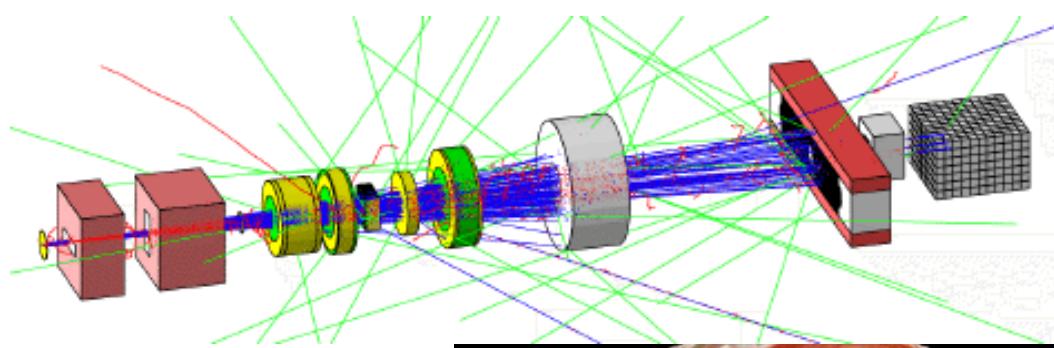


Geant4 Geometry and
523 MeV Neon Event



Geant4 in Medical Science

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





Tool for Particle Simulation

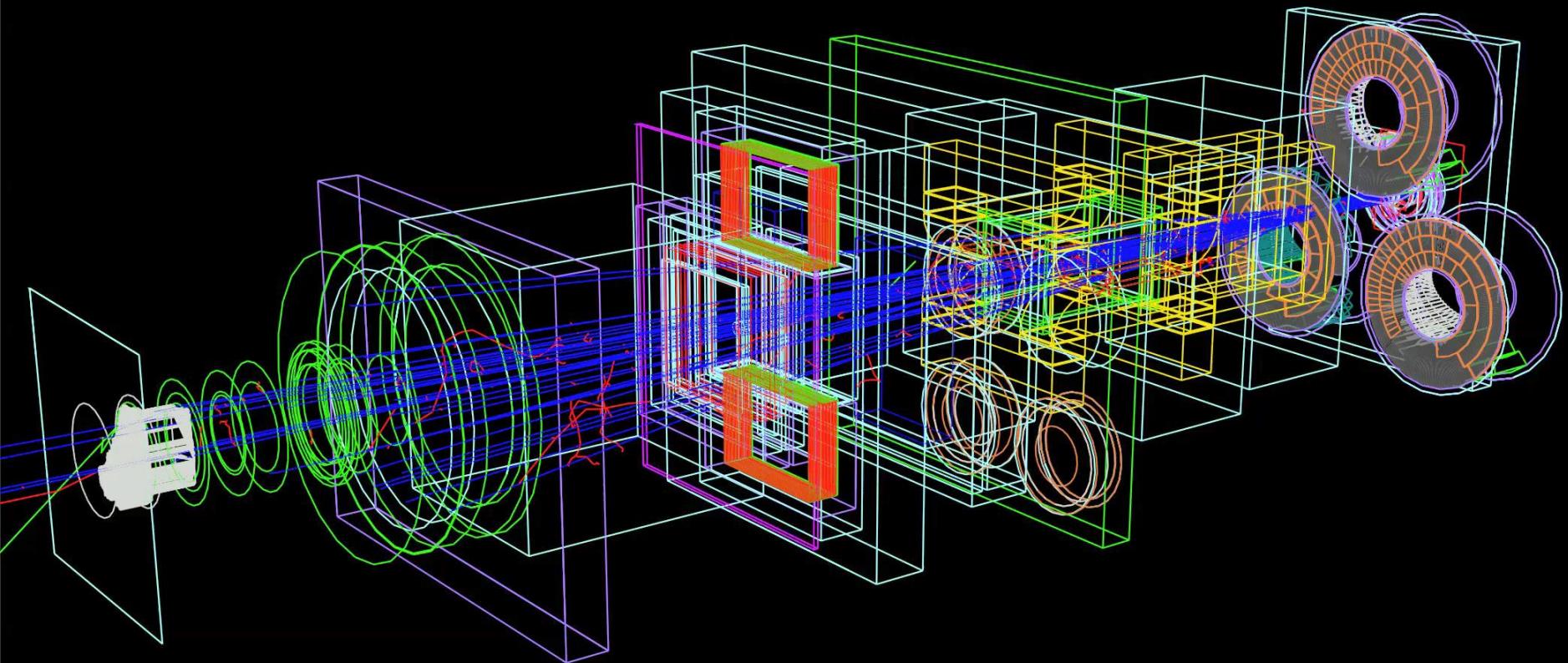
Joseph Perl - SLAC National Accelerator Laboratory

Bruce Faddegon, José Ramos - University of California San Francisco

Jungwook Shin – St Jude Children's Research Hospital

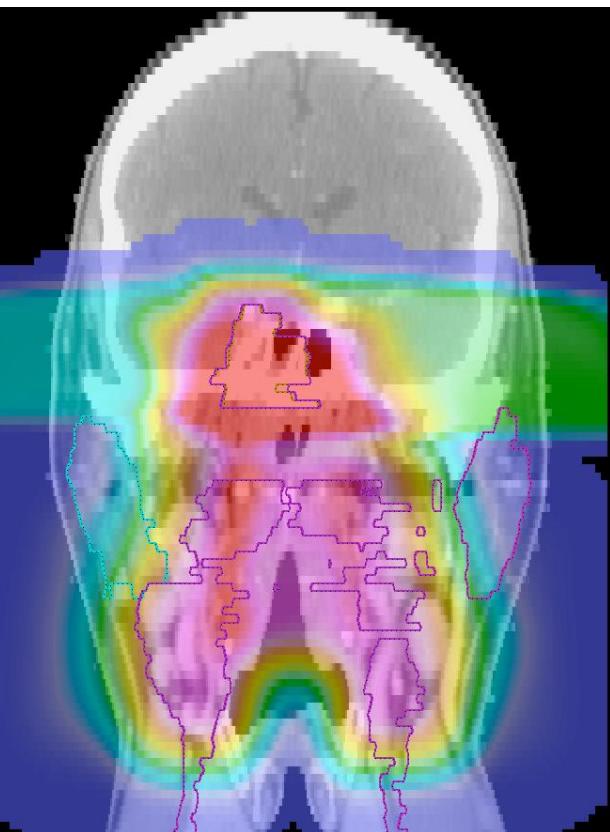
Harald Paganetti, Jan Schümann - Massachusetts General Hospital





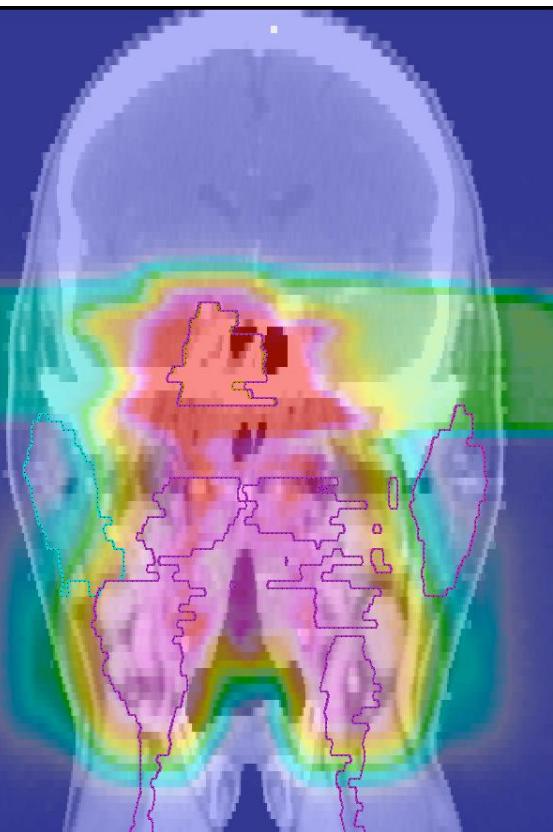
Head and Neck Study - Dose

TPS - Pencil Beam



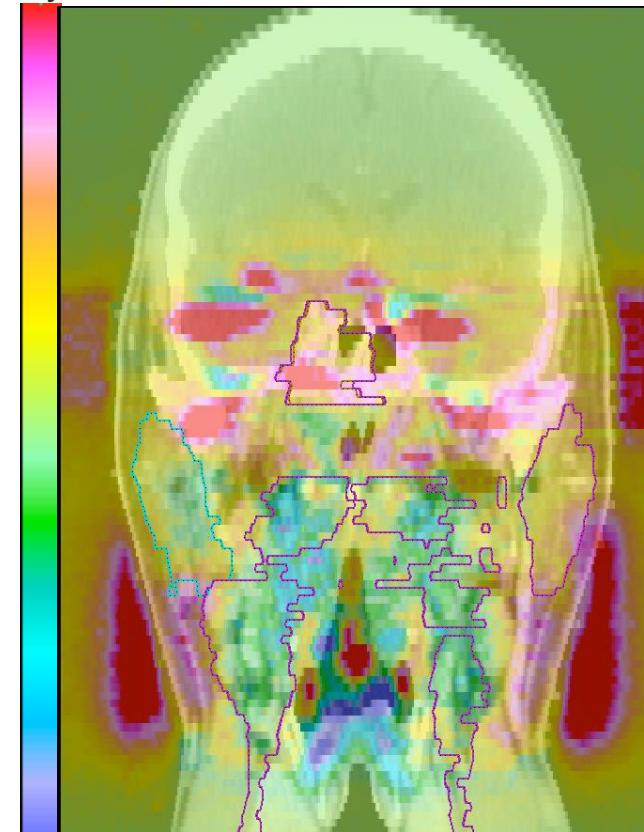
65
Gy

TOPAS - Monte Carlo



5
Gy

Difference



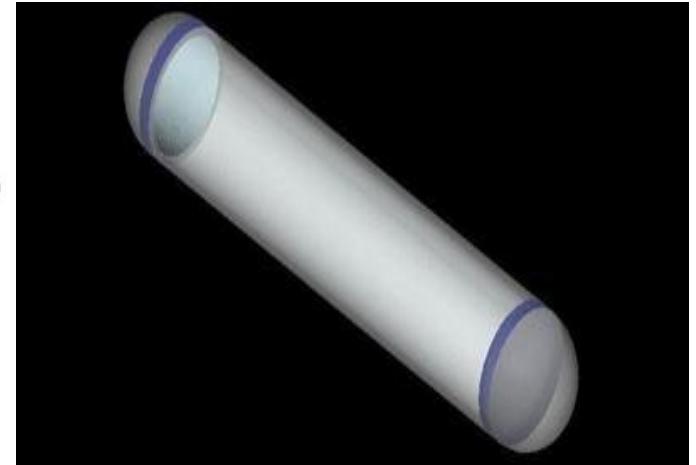
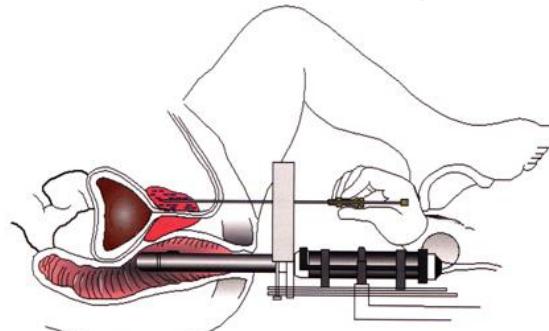
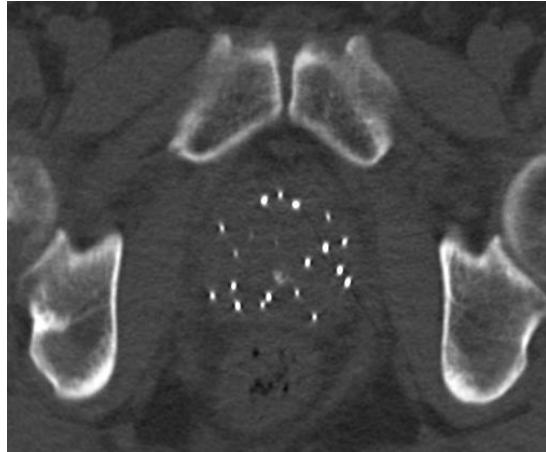
0

- 5
Gy

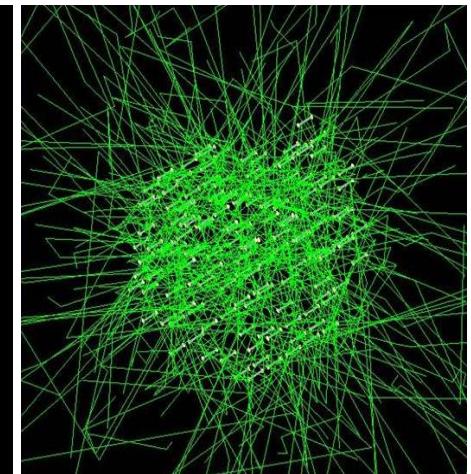
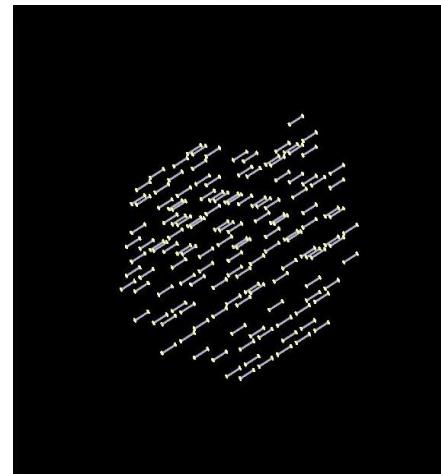
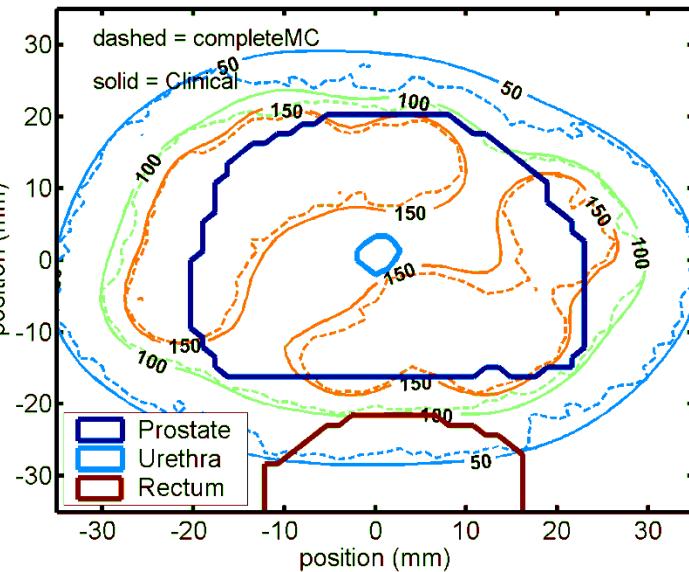
10 beams (6 directions + 4 boost)

Prostate brachytherapy

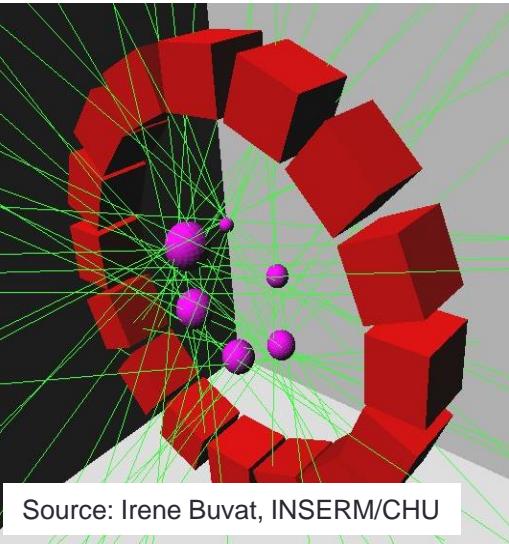
Jean-François Carrier, CHUM



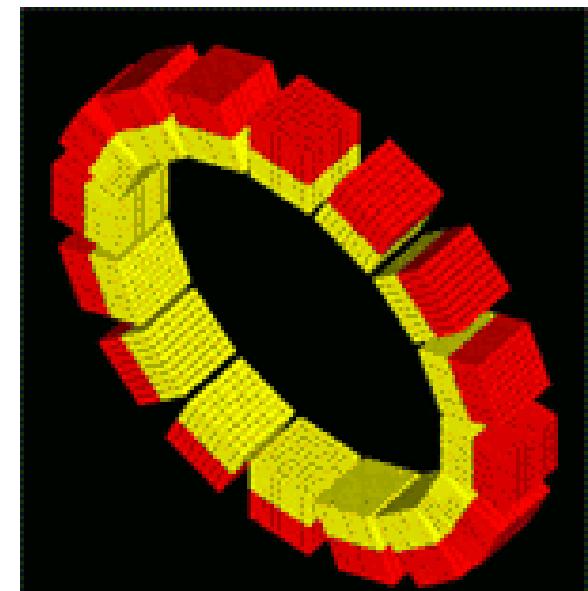
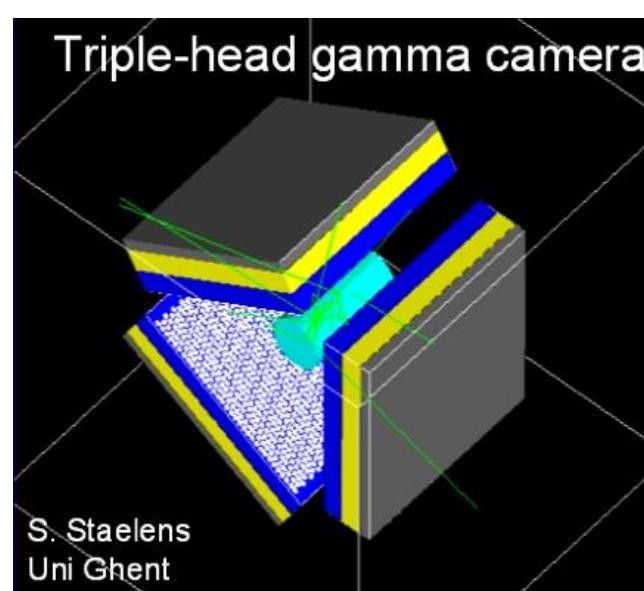
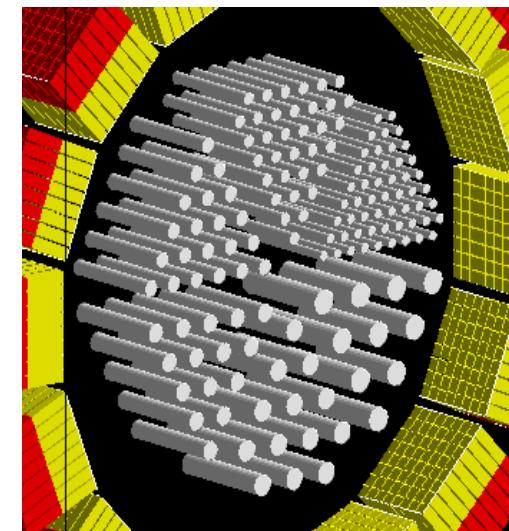
Carrier et al, IJROBP (68), 2007 pp.1190-1198



GATE: Geant4 Application for Tomography Emission



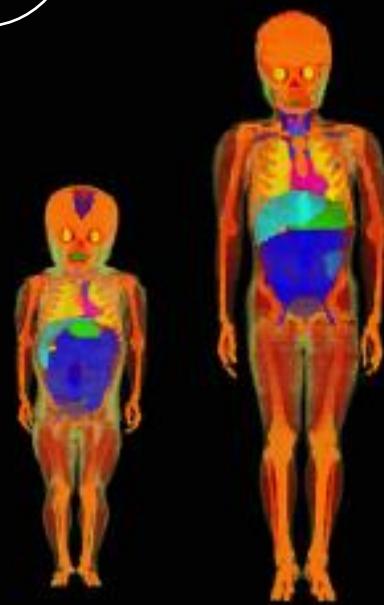
- Toolkit for Imaging applications
- based on the Geant4 toolkit
- easier to use for Imaging applications
- <http://www.opengatecollaboration.org>



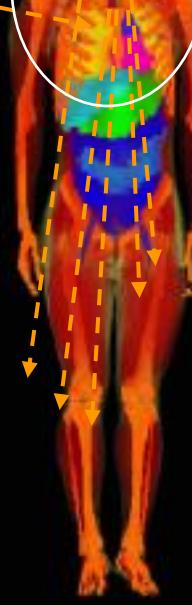
Neutron radiation issue in proton therapy

“External”

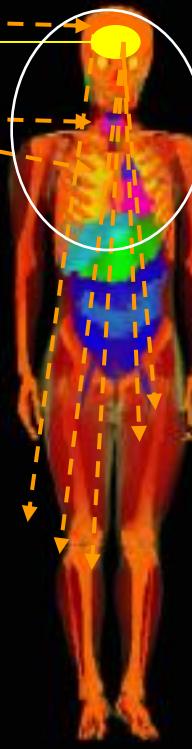
“Internal”



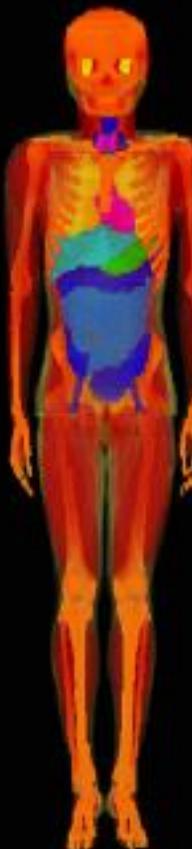
9-month male



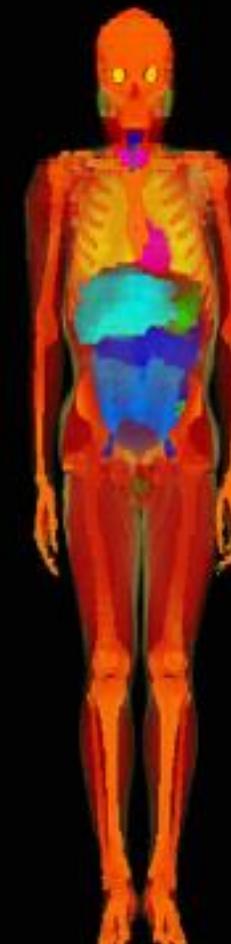
4-year female



8-year female



11-year male



14-year male



Phantoms implemented in Geant4 with dose calculation environment at MGH

Geant4 in Homeland Security : simulating x-ray cargo radiography





Los Alamos National Laboratory postdoc Elena Guardincerri, right, and undergraduate research assistant Shelby Fellows prepare a lead hemisphere inside a muon tomography machine.

Courtesy of: Los Alamos National Laboratory



feature

August 28, 2014

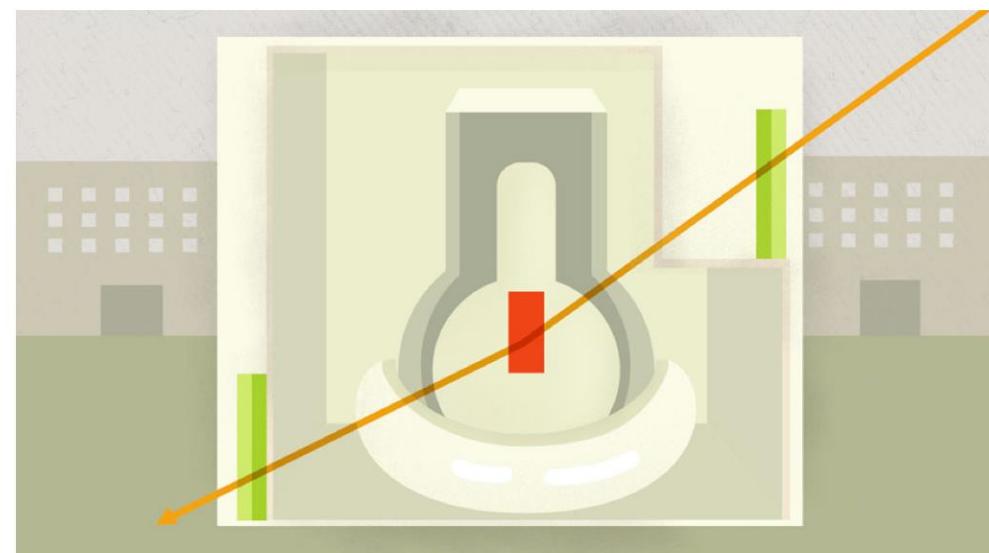
Particle physics to aid nuclear cleanup

Cosmic rays can help scientists do something no one has done before: map the interior of the nuclear reactors at the Fukushima Daiichi power plant.



Those exterior walls, made of concrete 10 feet thick, offer their own challenge. Based on computer simulations run with the particle physics software [GEANT4](#), the walls are expected to reduce the resolution to about 30 centimeters.

In addition, the team must also prepare for the high radiation levels present just outside of the reactor units.



Beginning next year, two detectors (shown here in green) on either side of Fukushima Daiichi's Unit 2 will record the path of muons (represented by the orange line) that have passed through the reactor. By determining how the muons scatter between the detectors, scientists will compile the first picture of the damaged reactor's interior.

Artwork by: Sandbox Studio, Chicago with Shawna X.

Archeology

- Same “muongraphy” technique used in the recent discovery of a big void in the Great Pyramid
- Geant4 used in the simulation of the muon detection system



- Images : courtesy of D. Attié & S. Procureur



Geant4 toolkit philosophy

The Toolkit philosophy

- Geant4 is not an application
 - applications : eg powerpoint, root, etc.

Geant4 is a toolkit

- Which means:
 - Geant4 provides tools / components
 - Many of them are defined from abstract classes
 - All are open to the users (☞ you)
 - You build your own application selecting the Geant4 components you need
 - Either selecting ready to use tools
 - Or building your own, if needed, from the base abstract classes
 - You instantiate the components in your own main program
 - That you then compile and link
- You need to have a minimal knowledge of the Geant4 structure
- And of the Geant4 base classes and existing tools
- Which is all what this week is about !

