Bio-1 New developments of the Geant4 Monte Carlo simulation toolkit

Takashi SASAKI (KEK, Japan) Sébastien INCERTI (CNRS/IN2P3/CENBG, France)

- on behalf of all collaborators -



France-(CNRS-CEA: LAPP, LLR, LPNHE, LAL, IRFU); Japan-KEK

France Japan Particle Physics Laboratory

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The Geant4 Monte Carlo toolkit

Bio-1 collaboration activities

- Educational applications for Physics teaching
- Medicine and Biology applications
- Computing grids
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The Geant4 toolkit : GEometry ANd Tracking

Geant4 : a set of general purpose libraries to simulate interactions of particles with matter

- Initiated by CERN for HEP (LHC), successor of Geant3 (20 years)
- R&D RD44, 1994-1998, 1st release in December 1998
- More than 80 worldwide collaborators today
- Object-Oriented technology (C++)
- Libraries, not a user code
- Constantly updated, entirely open and free

Geant4 : simulation of a particle physics experiment

- Define a flexible geometry
- Model interaction processes (electromagnetic, hadronic)
- Generate initial particles and follow them within the geometry
- Save physics quantities and analyze them

Capabilities

- Visualization
- Interactivity
- Extensibility









Development of educational applications based on Geant4

Geant4 for Education

- Simulation is an effective tool for both teaching and learning particle interactions
 - Visualization of invisible world
 - radiation, particle interaction in matter
 - Geant4 contains a large phenomenological and empirical knowledge of interactions of particles with matter
 - not to teach Geant4, but use Geant4 to teach Physics
- Educational courseware for learning particle physics using Geant4 has been developed
 - Composite e-learning system of
 - Course materials (online textbooks)
 - Geant4 virtual laboratory application
 - Web service
 - All-in-packed virtual machine image available

Courtesy of K. Murakami et al.





Geant4 Educational Box

- Geant4 VMware image for education
 - Just download and run
 - Player is freely available (VMware Player)
 - Everything for Geant4 is preinstalled
 - An educational courseware is contained
 - play with particle interaction in matter
 - web documentation is available.



Courtesy of K. Murakami et al.



Extension of Geant4 for applications in Biology and Medicine

Medicine and Biology with the Geant4 toolkit

Medical applications

- Identify the best Geant4 Physics models in order to reproduce experimental data in hadrontherapy
- Radiobiology applications
 - 3D rendering and dosimetry on high resolution cellular phantoms with gMocren
 - The Geant4-DNA project

Improvements on ion Physics for hadrontherapy

 Electromagnetic ion Physics improved very recently

The Bragg peak positions agree well within 1% difference (less than 1 mm) between the experiment and the Geant4 simulation

Comparison with <u>HIBMC</u> (Hyogo) data 320 MeV/n ¹²C



NIRS-HIMAC 290 & 400 MeV/n

Modelling of biological cells

- define realistic cellular geometries for the Geant4 toolkit
- obtained from high resolution confocal microscopy of human keratinocyte cells (HaCat) and from quantitative ion beam analysis techniques available at the CENBG-AIFIRA : PIXE, RBS, STIM
- these geometries can be used with the very low energy EM extensions of Geant4 for track structure simulations in cells and microdosimetry in radiobiology : the Geant4-DNA project

Building cellular models

- Selection of four "phantoms" reconstructed from 128×128 2D confocal imaging.
- Incubation :
 - 4 hours for cells a and b
 - 24 hours for cells c and d
- The cytoplasm and nucleoli appear in red while the nucleus is shown in blue.

The gMocren tool

- The Japanese groups have provided the state-of-the-art gMocren visualization tool that allows
 - a full 3D rendering of structures at the cellular scale : nucleus, cytoplasm, nucleoli...
 - dose distribution within cells obtained from Geant4 simulations
- Hadrontherapy → radiobiology

- Thanks to
 - Akinori Kimura, Ashikaga Institute of Technology
 - Ayumu Saitoh, University of Hyogo
 - Satoshi Tanaka, Ritsumeikan University

gMocren results

- single HaCat cell
- 3 MeV alpha⁺ particles
- 512 x 512 x 60 phantom resolution 90 x 90 x 160 nm³ per voxel
- see Rad. Prot. Dos. 133, 1 (2009) 2-11

Deployment of Geant4 on computing grids

Status on grid deployment

 GRID deployment in both Japan and France has been achieved

- The infrastructure for executing the application software is maintained
- Deployment of GATE-Geant4 rpms on the EGEE grid infrastruture

GRID web portal for particle therapy simulation at KEK

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Information and resource sharing

Workplan 1/2

- Geant4 Education applications
 - continue effort for creation of courseware
 - conversion of existing Geant4 materials to Web Courseware
 - creation of an educational package
- Physics-Medicine interface
 - continue investigation on improving electromagnetic Physics in Geant4 for hadrontherapy simulation
 - integration of the vizualization tool gMocren to GATE, a Monte Carlo simulation platform for clinical, preclinical scans in emission tomography and radiotherapy treatments.

Workplan 2/2

- Physics-Biology interface, in the framework of the Geant4-DNA project
 - develop cellular phantoms for several cellular configuration : normal cells, cancer cells, confluent cells, 3D tissues
 - deliver corresponding advanced examples to Geant4 toolkit for dosimetry applications at the cellular scale
 - The Geant4-DNA project :
 - testing and validation of new Physics, Chemistry and Molecular geometry models
 - the Japanese groups will apply the achievements of the Geant4-DNA project to particle therapy simulation to predict biological effects at cellular level. Ritsumeikan and Ashikaga IT will provide their expertise in visualization to French groups for visualizing microdosimetry and also outputs from medical imaging devices simulated by Geant4.
- Deployment of Geant4 on computing grids
 - development of the common application software
 - deployment of GATE-Geant4 rpms on the EGEE grid infrastruture : tests and validation
 - deployment of a secured web portal for GATE/Geant4 Monte Carlo simulations: the HOPE (Hospital Platform for E-health portal) platform

Collaboration administration

Bio1 meetings

- 3 meetings have been organised so far since 2007
 - 3rd Geant4 FJPPL IN2P3-KEK workshop September 3-5, 2008 - Annecy, France
 - 2nd Geant4 FJPPL IN2P3-KEK workshop April 17-19, 2008 - Tokushima, Japan
 - 1st Geant4 FJPPL IN2P3-KEK workshop December 12-14, 2007 - Bordeaux, France
- Please, see full details of meetings at <u>http://geant4.in2p3.fr</u>
- Financial support definitely needed

Team

• 18 collaborators	(researchers	+ engineers)
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APU Ritsumeikan Asia Pacific University

🏶 Shikoku University

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Toba National College of Maritime Technology

Budget request for 2009-2010

	French Teams			Japanese Teams				
Budget Plan	Item	Q.	Euro	Supported by	Item	Q.	kYen	Supported by
	Invitation of Japanese colleagues to LPC Clermont	2	2x3000	IN2P3	Nb of travels to France	4	4×350	KEK
	Nb of travels to Japan	4	4×3000		Workshop in Japan	4	4x50	
	Total		18000€		Total		1600 kYen	

Thank you for your attention & support

