

Impressions from the “Third Geant4 International User Conference”

THE GEANT4 TOOLKIT AT THE PHYSICS-MEDICINE-BIOLOGY FRONTIER
BORDEAUX, 29-31 OCTOBER 2018

Overview

- ▶ Background about the meeting
- ▶ Session topics
- ▶ Trends
- ▶ Using 'other' hardware – GPUs and beyond
- ▶ Selected developments



The meeting

- ▶ Third Geant4 International User Conference
 - ▶ previous held in 2005 and 2013
 - ▶ 111 attendants this year
- ▶ Format
 - ▶ Only plenary session
 - ▶ Slides not publicly available – some pre-publication results shown
 - ▶ Paper submission until end 2018 for special issue of PBiM
- ▶ Noticeable
 - ▶ Diversity of topics
 - ▶ Involvement of many researchers beyond those developing / validating
 - ▶ Strong discussions during sessions

Topics of sessions

- ▶ Geant4 Developments
- ▶ Imaging & instrumentation
- ▶ Nanoparticles
- ▶ Protons & hadrons
- ▶ Tools
- ▶ Radiotherapy & clinical dosimetry
- ▶ Geant4-DNA & related

- ▶ Full agenda at <http://geant4.in2p3.fr/2018/resources/Agenda.pdf>

Caveat: Slides of the talks are not available.

Trends – a personal view

- ▶ Strong involvement from many Universities, Research Institutes
 - ▶ UK, US, France, Italy, Austria, India
- ▶ Use of MC in commissioning of proton-therapy centers in Europe
 - ▶ Austria, Germany, France, Italy
- ▶ ‘Platform’ applications for **Ion Beam Therapy** investigations
 - ▶ GATE RTion
- ▶ Nanoparticles a bigger topic
 - ▶ Use of (gold) **nanoparticles** as radiosensitizer in proton therapy
- ▶ Increased interest in accelerators for dosimetry
 - ▶ Different hardware: GPU today, FPGA tomorrow

Hardware and developments

- ▶ Talk by team at KEK on newest GPU developments
 - ▶ Reported speedup of 3000x for Geant4-DNA physics (dominated by elastic scattering – minimal ‘warp’ divergence.)
 - ▶ First implementation of a full set of physics models for protons (< 300 MeV ?) – initial speedup of 30x before optimization.
 - ▶ Closed source – available for a fee. License under draft.
- ▶ Other developments on acceleration of G4 / MCs

FRED – GPU MC for dosimetry

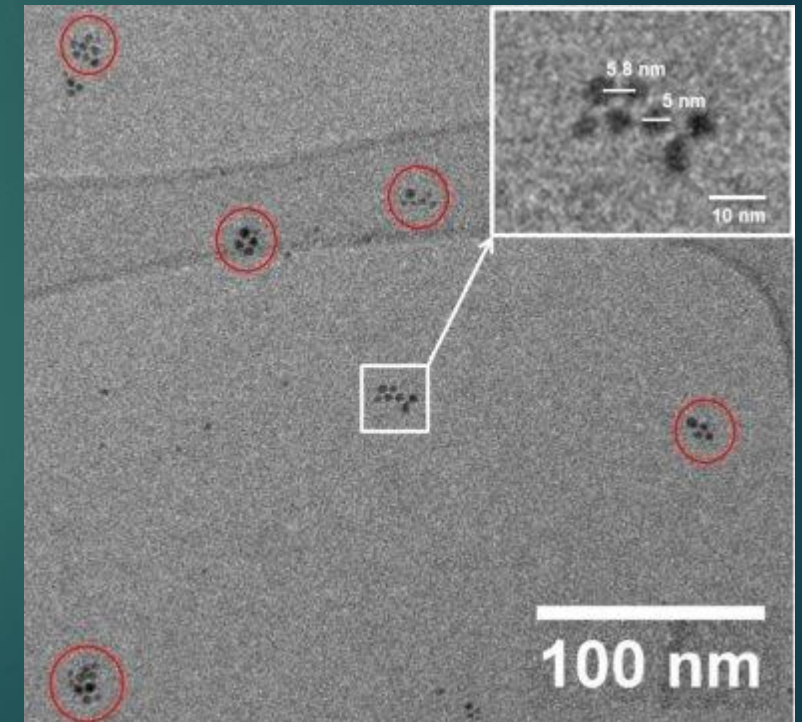
- ▶ [Fred](#) – an alternative GPU based MC from a collaboration of INFN, La Sapienza, Krakow, CREATIS (Lyon)
 - ▶ Proton physics relevant to proton dosimetry
 - ▶ 1M primaries / second – 1000x speedup
- ▶ ‘Fred – bio’ biology modelling
- ▶ Validation –
- ▶ Purposes
 - ▶ Independent dose computation tool
 - ▶ Treatment planning 1.5-2 min per configuration
 - ▶ Research

Hardware and developments

- ▶ Using FPGAs – project “Monte Carlo Processing on a Chip (MCoaC)”
- ▶ Towards “optimal hardware for TOPAS/Geant4 to drive discovery”
 - ▶ 5 year project funded by NIH grant
 - ▶ Investigate whether a system based on FPGA deliver large price-performance (or heat-performance) leaps
- ▶ Preliminary steps
 - ▶ Built small scale prototype of G4PhysicsVector method(s) in VHDL
 - ▶ Targeting

Nanoparticles

- ▶ Gold nanoparticles act to enhance dose in their close vicinity
- ▶ Work to quantify the effect
 - ▶ Requires 'low-energy' physics (in G4), Auger
- ▶ Nanoparticles cluster in tissue
 - ▶ This is an important factor
- ▶ Simulation
 - ▶ Macroscopic simulation is very slow – large volume
 - ▶ Microscopic simulation
 - ▶ Cross comparison of Geant4 physics lists (Penelope, G4-DNA, TOPAS/G4-DNA @MGH) and other codes PARTRAC, MCNP6, MDM





Geant4 Low Energy Electromagnetic Physics: overview of recent developments

Sébastien INCERTI

CNRS / IN2P3 / Bordeaux U. / CENBG – France

representing the efforts of Geant4 & Geant4-DNA colleagues

Third Geant4 International User Conference at the Physics-Medicine-Biology Frontier

October 29-31, 2018 – Bordeaux, France

Motivation

- To push the **limits** of Geant4 EM interactions **down to (very) low energies & small scale**
- Geant4 **low energy EM « Physics lists »** are mainly used as **alternative** to Standard EM Physics Lists when users
 - need **precise treatment** of EM interactions at low-energy (**keV** scale or below)
 - are interested in **atomic effects**, as fluorescence X-rays & Auger electrons, Doppler broadening, etc.
 - can afford a **more CPU-intensive** simulation
 - want to **cross-check** another simulation (e.g. with a different Physics List)
 - are interested in **specific low energy applications** (Track Structure: **Geant4-DNA**, **MicroElec**)
- Over the years, we thus try to **improve the accuracy of Geant4 models especially at low energy**
 - some **components** are introduced into the « **best** » Geant4 CH Physics List : **Standard EM “option 4”**
- A **selection of recent improvements & new functionalities** is presented today
 - Some will be the subject of **dedicated talks** during the conference

Courtesy of
Sébastien INCERTI
G4 EM & G4-DNA teams

See talk...

See suggested publication ...

3) Very low energy extension towards radiobiology:

Geant4-DNA

Int. J. Model. Simul. Sci. Comput. 1 (2010) 157 ([link](#))



PHYSICAL STAGE

step-by-step modelling of physical interactions of incoming & secondary ionising radiation with biological medium (liquid water mainly)

- Excited water molecules
- Ionised water molecules
- Solvated electrons

PHYSICO-CHEMICAL/CHEMICAL STAGES

- Radical species production
- Diffusion
- Mutual chemical interactions

GEOMETRICAL MODELS

DNA strands, chromatin fibres, chromosomes, whole cell nucleus, cells...

DIRECT DNA DAMAGE

INDIRECT DNA DAMAGE

REPAIR

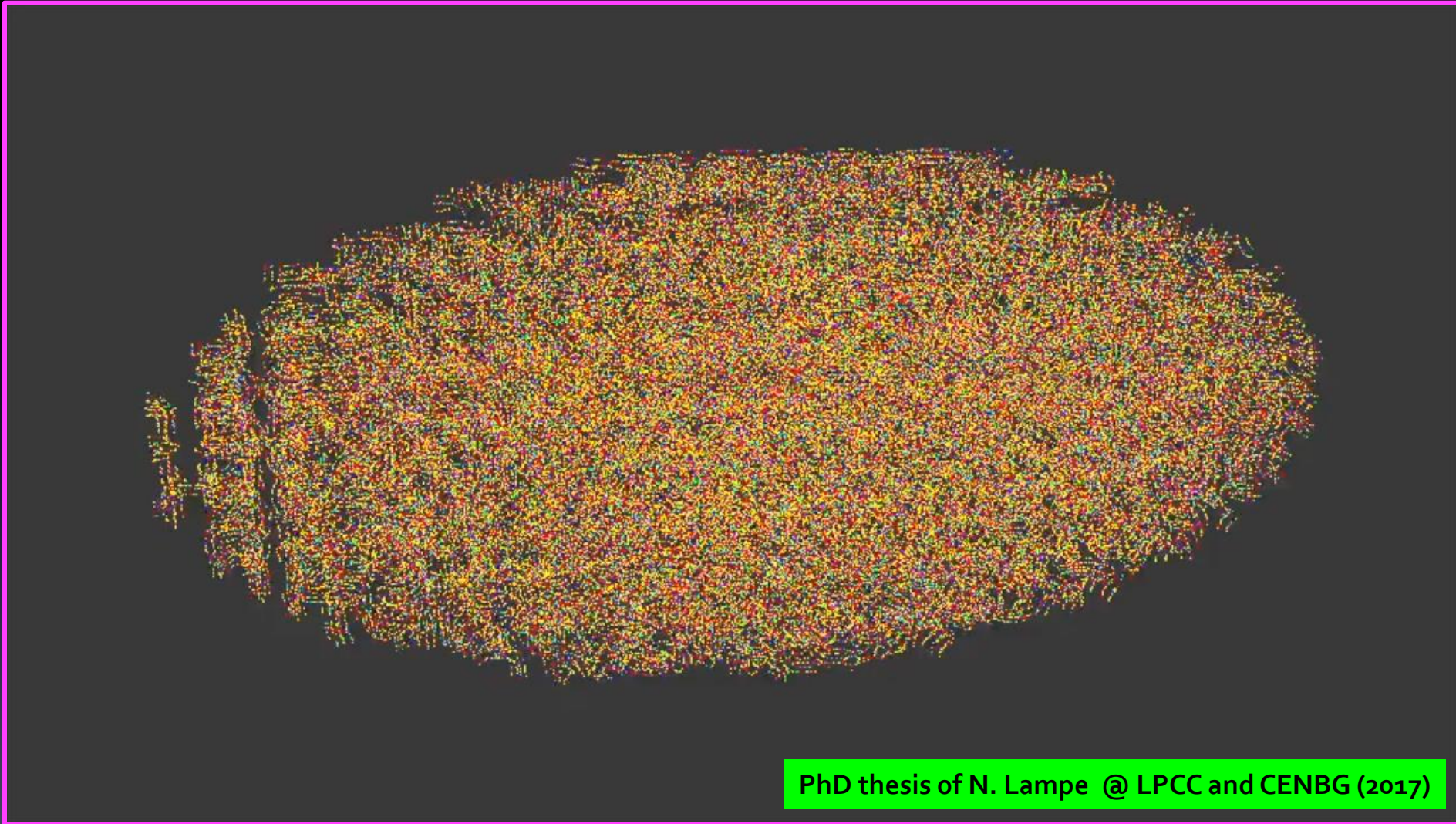
$t=0$

$t=10^{-15}$ s

$t=10^{-6}$ s

Courtesy of
Sébastien INCERTI
G4 EM & G4-DNA teams

Bacterium: modeling *E. coli*... in 2017



Hilbert, 1.9 mm x 0.8 mm, 4.63 Mbp

Phys. Med. 48 (2018) 146 ([link](#))

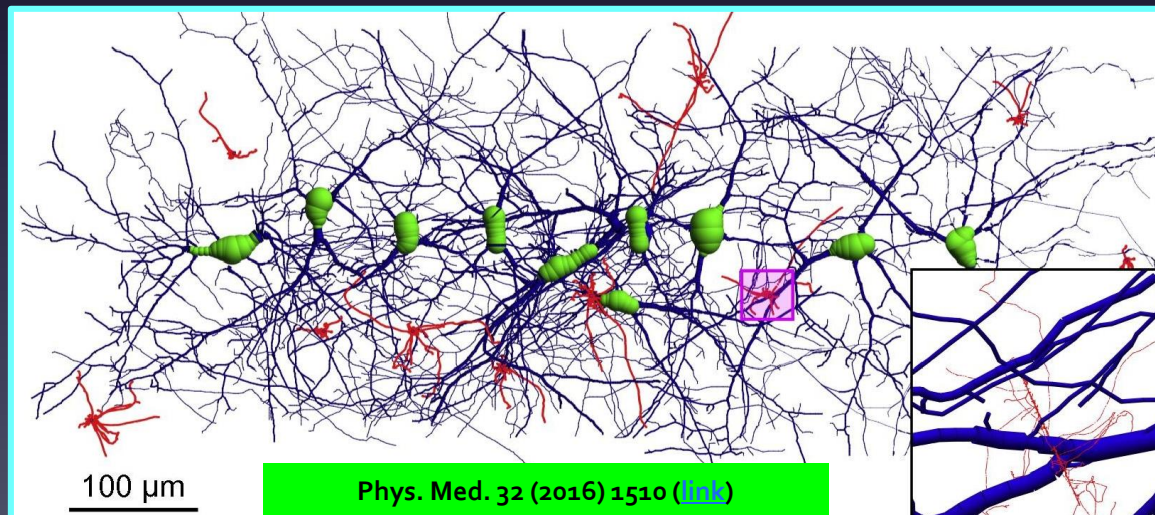
Courtesy of
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More geometries : neurons

- G₄ EM & G₄-DNA teams • Radiation damage to the Central Nervous System is an active research domain in relation to brain radiotherapy and radiation protection for astronauts during space travel.
- A new activity in Geant₄-DNA initiated by Dr Oleg Belov (JINR, Dubna) in collaboration with B. Munkhbataar & Pr. O. Lkhagva (National U. of Mongolia)
- Now possible to investigate early biological damage induced by ionising radiation in a simple neural network by means of modelling physico-chemical processes occurring in the medium after exposure, thanks to Geant₄-DNA
- « neuron » extended example released in Geant₄



Pr Oidov Lkhagva



National University of Mongolia, Oulan Baator, June 2015

Thank you for your attention !

We presented a **selection of recent developments**

They result from the work and dedication of many
Geant4 and Geant4-DNA (young and not-so-young) **colleagues**

Things take time to develop, test, validate, and release **in Geant4**,

Manpower and funding are usual issues....

External tools such as **TOPAS/TOPASnBio – GATE – GAMOS** etc.
fully benefit from all these open source developments.

We appreciate and encourage **any backporting from these tools to Geant4**,
as a **benefit to the whole community !**

Courtesy of
Sébastien INCERTI
G4 EM & G4-DNA teams

Thank you for your patience & support

- ▶ Geant4's DNA module is an important tool in many investigations