

Simulations tools for medical physics and radiation biology applications

GATE 10 & Geant4-DNA

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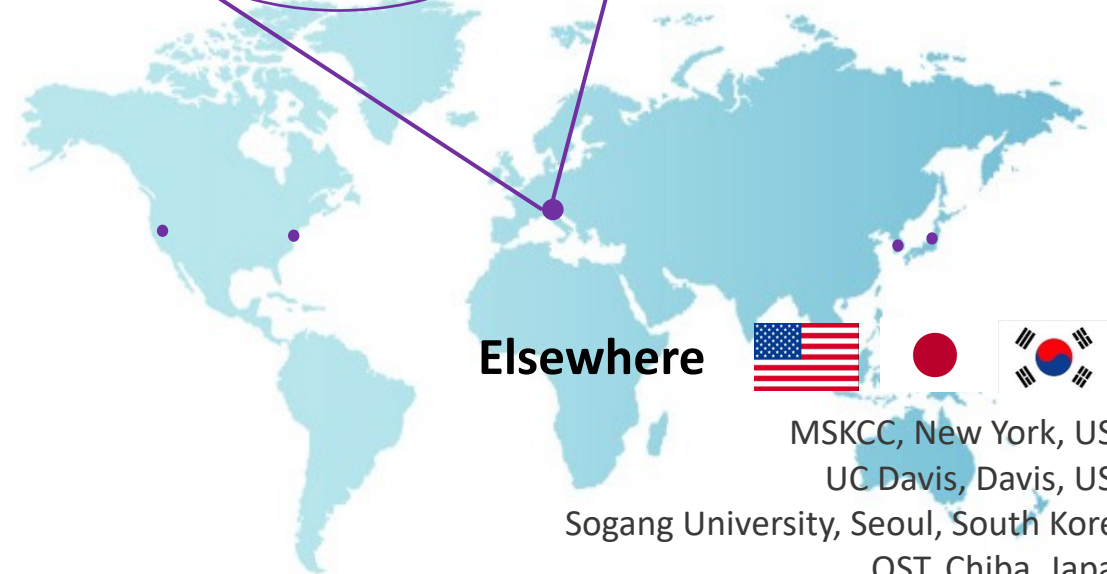
The OpenGATE collaboration

25 laboratories, companies, clinics
developing and validating an open source
platform

Europe



- FH Aachen, University of Applied Sciences, Julich, Germany
- Medisip, Ghent University, Belgium
- Medical University of Vienna, Wiener Neustadt, Austria
- MedAustron, Wiener Neustadt, Austria
- Christie Medical Physics & Engineering, Manchester, UK
- JPET collaboration, Poland
- Institute of Nuclear Physics Polish Academy of Sciences, Poland
- Univ. of Patras, Dept of Med. Phys., Greece
- BioemTech, Athens, Greece
- Paul Scherrer Institute (PSI), Switzerland



Elsewhere



- MSKCC, New York, USA
- UC Davis, Davis, USA
- Sogang University, Seoul, South Korea
- QST, Chiba, Japan

The OpenGATE collaboration in France

BioMaps, CEA, Paris Orsay

IJCLab, CNRS-IN2P3, Paris Saclay

LPCA, CNRS-IN2P3, Clermont-Ferrand

IPHC, CNRS-IN2P3, Strasbourg

CPPM, CNRS-IN2P3, Marseille

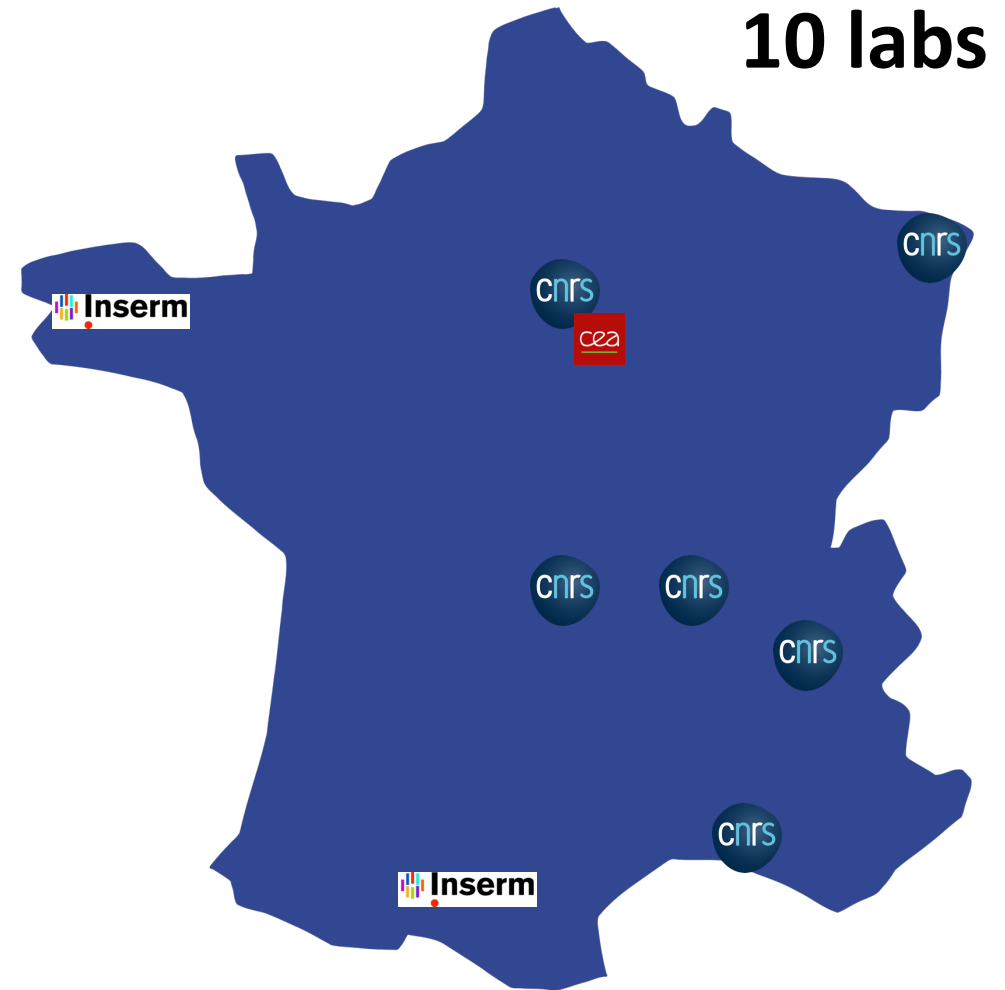
CREATIS, UMR5515 CNRS, Lyon

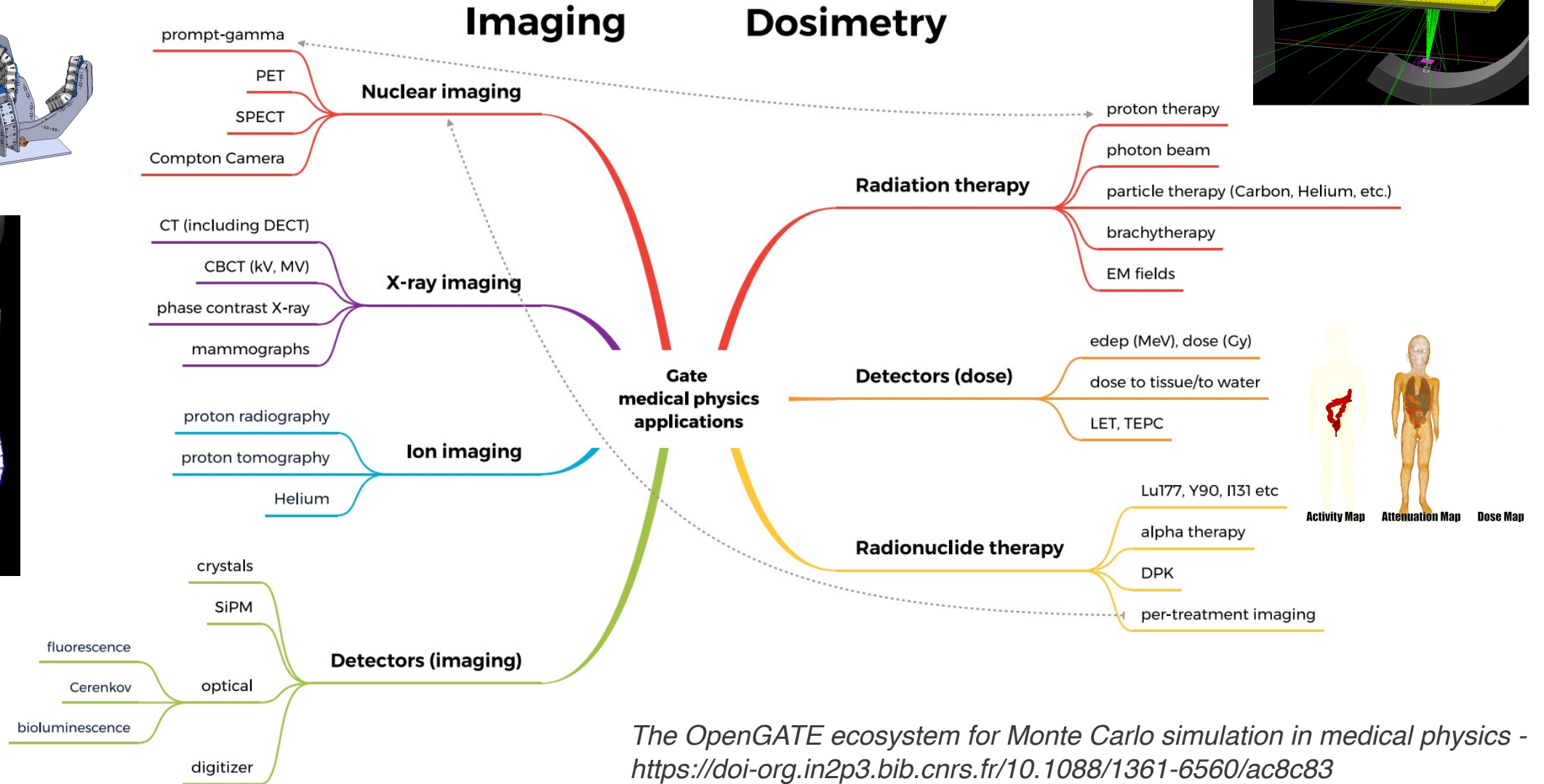
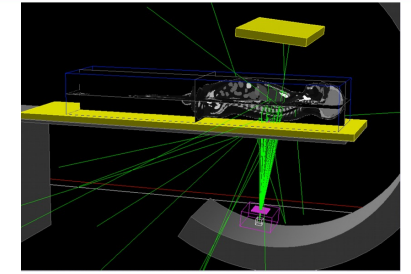
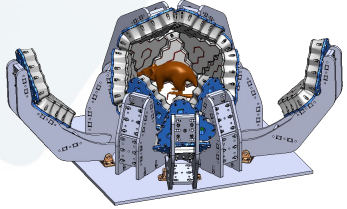
IP2I, CNRS-IN2P3, Lyon

LPSC, CNRS-IN2P3, Grenoble

CRCT, U1037 INSERM, Toulouse

LATIM, U1101 INSERM, Brest

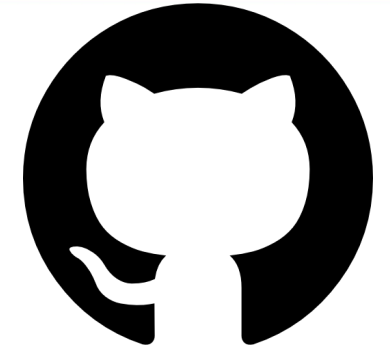




The OpenGATE ecosystem for Monte Carlo simulation in medical physics - <https://doi-org.in2p3.bib.cnrs.fr/10.1088/1361-6560/ac8c83>



Open-source Code – Examples - Tools



Source code - <https://github.com/OpenGATE/Gate>

Examples - <https://github.com/OpenGATE/GateContrib>

Python tools - <https://github.com/OpenGATE/gatetools>

Docker + VM - <https://opengatecollaboration.org>

GATE 9.4 release (April 2024)

Compatible with G4 11

More than 70 contributors (since 2012)

25+ benchmarks

GATE 10 - <https://github.com/OpenGATE/opengate>

Official release Autumn 2024



`pip install opengate
opengate_tests`

GATE USERS MAILING LIST - Information, job offers, bug reports, help <https://listserv.in2p3.fr/cgi-bin/wa?A0=OPENGATE-L>

GATE 10 - The source code

Look at Alexis Pereda, Gaëtan Raymond and Maxime Jacquet presentations and demos



`g4_bindings/`

Geant4 binding from C++ to Python
(expose functions, classes) ; *pybind11*

`opengate_lib/`

Core classes (`running`): source, scorers etc

`opengate/`

User UI (`initialisation`)

One main object : `Simulation`

3 sub-main concepts: `geometry sources actors`

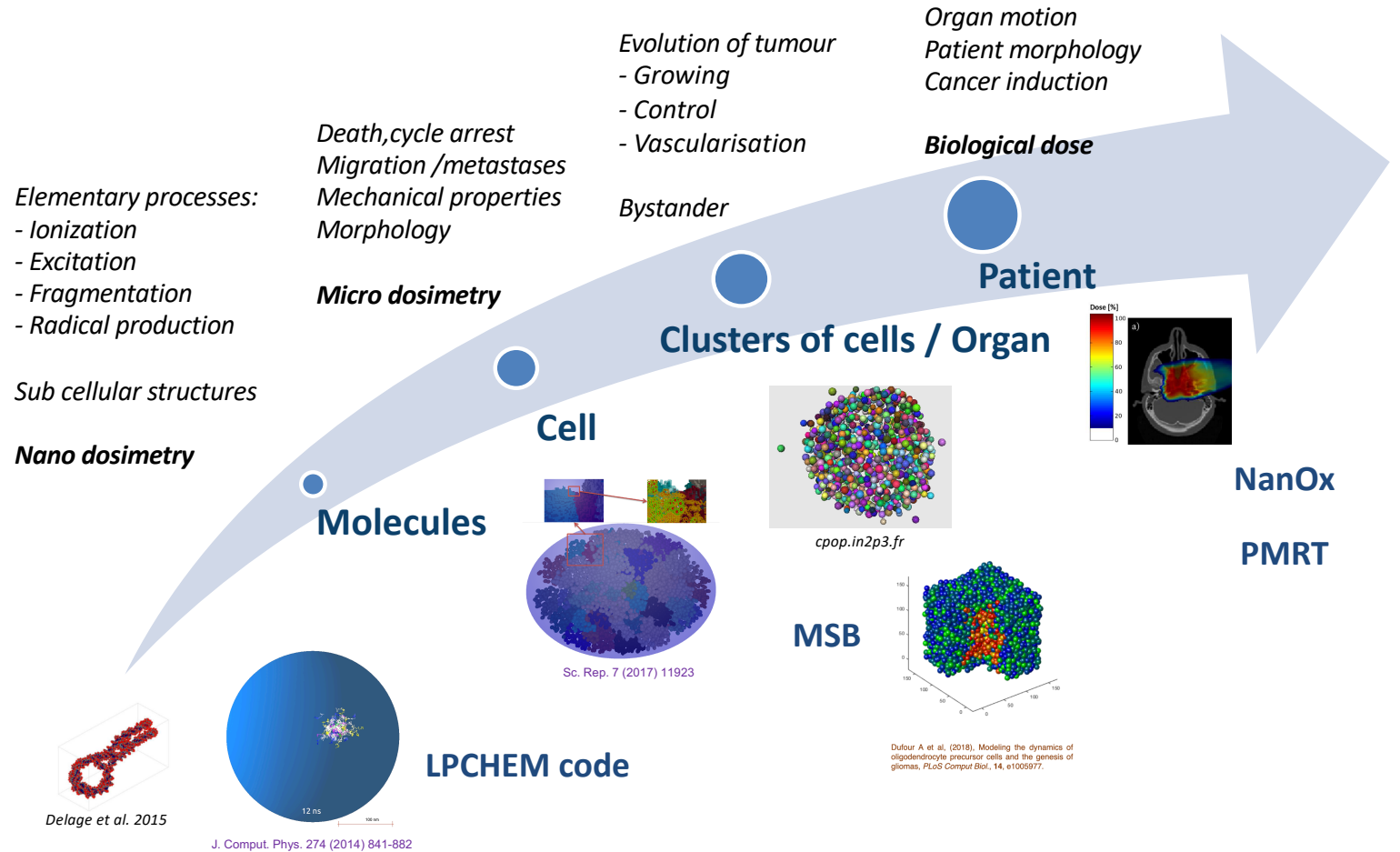
tests to help configure your scripts: `tests`



The **unique** open source and open access simulation toolkit for micro/nano dosimetry and radiation biology

- **Long term development** fully included in Geant4 releases
- International collaboration composed of 42 collaborators
- **Coordinated by IN2P3/CNRS** since 2008
- Funded by regular support from institutions and international calls
- Fruitful involvement in international conferences & tutorials
 - Geant4 International User Conference at the Physics-Medicine-Biology frontier » series of conferences initiated by IN2P3 in 2005
 - Annual international tutorials (17)
- High rank and highly cited publications (104 since 2007)

DEVELOPMENT ACCESSIBLE TO OTHER TOOLKITS, PARTICULARLY TO GATE

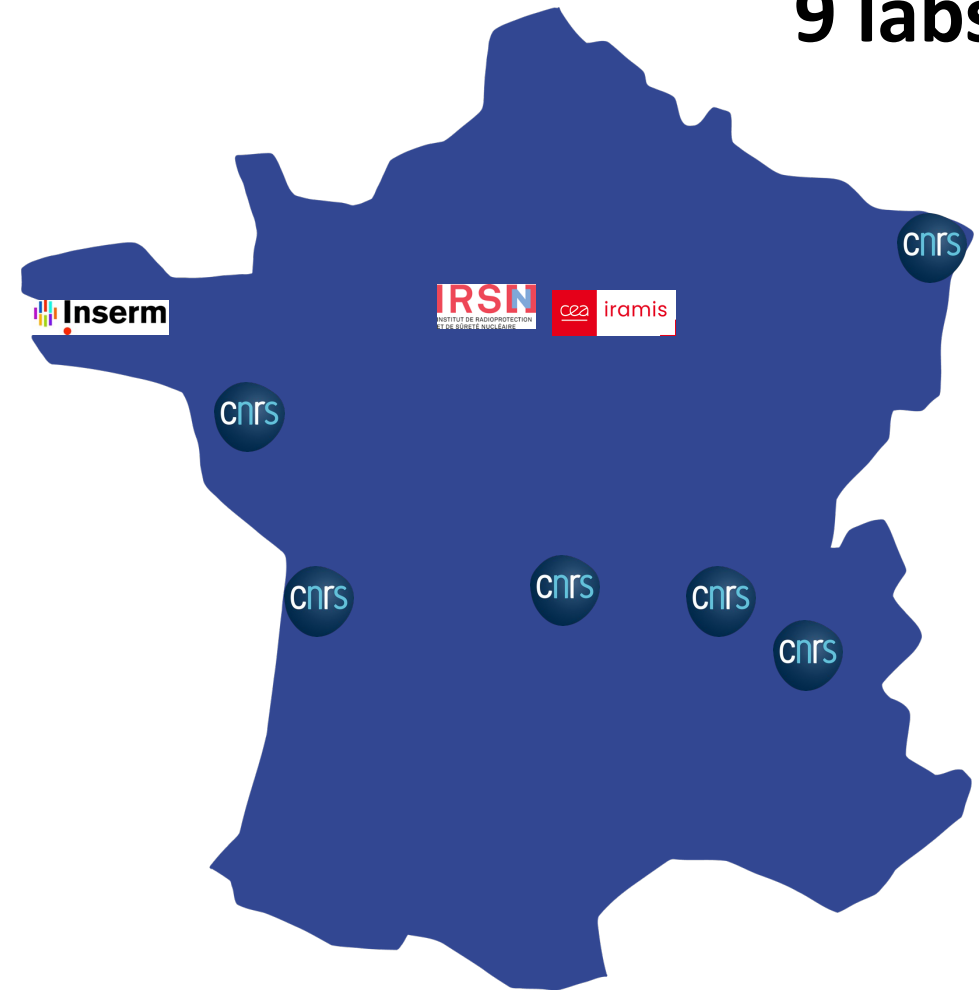


The Geant4-DNA collaboration in France

9 labs

LP2I, CNRS-IN2P3, Bordeaux
LPCA, CNRS-IN2P3, Clermont-Ferrand
IPHC, CNRS-IN2P3, Strasbourg
SUBATECH, CNRS-IN2P3, Marseille
IP2I, CNRS-IN2P3, Lyon
LPSC, CNRS-IN2P3, Grenoble
LATIM, U1101 INSERM, Brest

IRSN-LDRI, CEA-IRAMIS



62 collaborateurs en 2024, 17 countries (cf. web site)

Look at Daeun Kwon presentation
+ Sophie Chiavassa and Emeline Craff

Physics

Update of **electron inelastic models for liquid water up to 10 MeV** (dna_option4)

by I. Kyriakou et al. (Ioannina U. team)

New **electron discrete cross section models for O₂, N₂, CO₂** : excitation, ionisation, elastic

by F. Nicolanti et al. (Roma U. team) - published and not yet released (<https://doi.org/10.1016/j.ejmp.2023.102661>)

towards atmospheric physico-chemistry applications of Geant4

New **Lithium discrete cross section models for liquid water** : excitation ionisation, charge gain / loss

by J. Ramos-Mendez et al. (USCF team) - published and not yet released (<https://doi.org/10.1088/1361-6560/ad5f72>)

paves the way to other (selected) ions

UHDR irradiation

Chemistry

Complete **review of Geant4/Geant4-DNA chemistry (covering the 2012-2024 period)** by H. Tran et al.

published in Med. Phys. 51 (2024) 5873–5889 (<https://doi.org/10.1002/mp.17256>)

Prototype of software for the simulation of **water radiolysis under multi-pulse irradiation** by H. Tran et al. - <https://arxiv.org/abs/2409.11993>

Other news

Galileo Galilei Award of the European Journal of Medical Physics (<https://www.efomp.org/index.php?r=news/view&id=338>) for the development of a Geant4-DNA chain (physics, chemistry, geometry, DNA damage, repair & cell survival) by D. Sakata et al.

In 2024, reactivated international **tutorials** post-COVID : CNAO, Osaka U., Accra, Bucharest

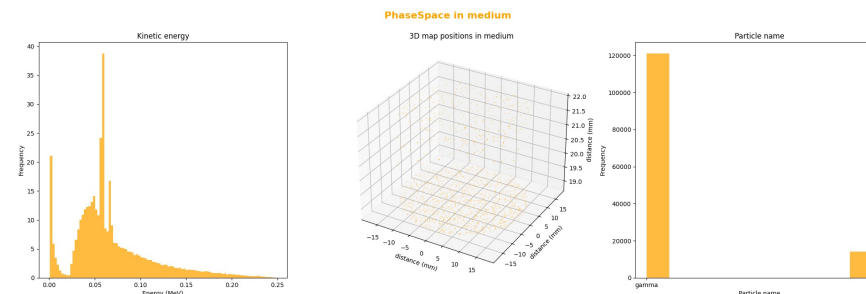
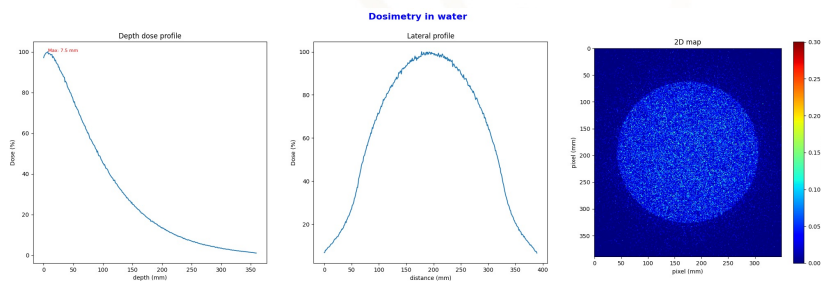
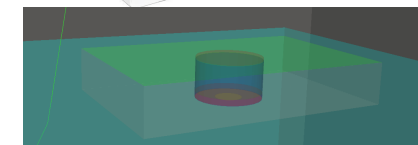
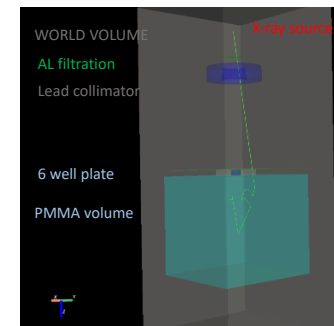
Collaboration Meeting in Osaka U. (thanks again Dousatsu !)



GATE for radiation biology applications

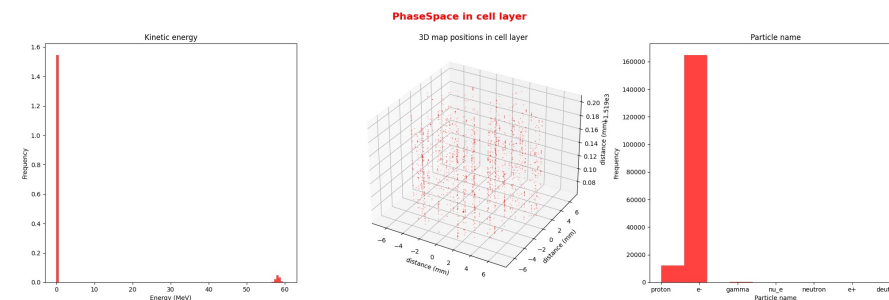
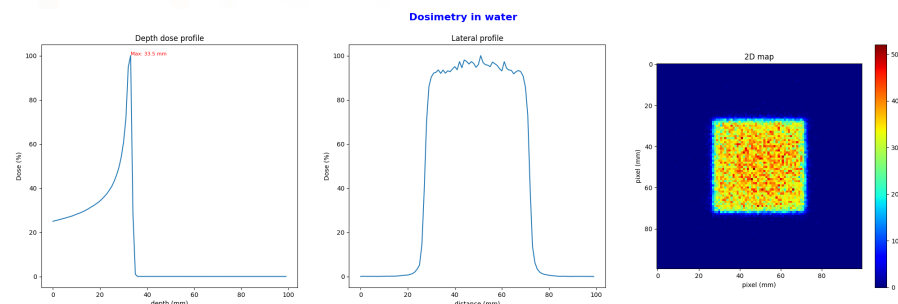
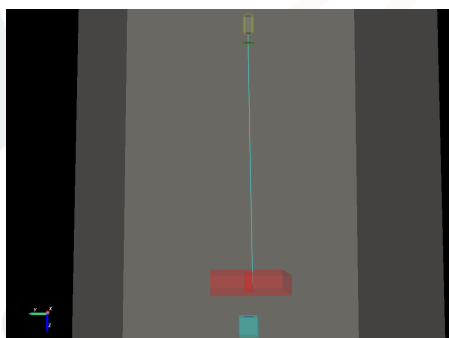
X ray irradiation

X-ray irradiator (X-Rad 320)



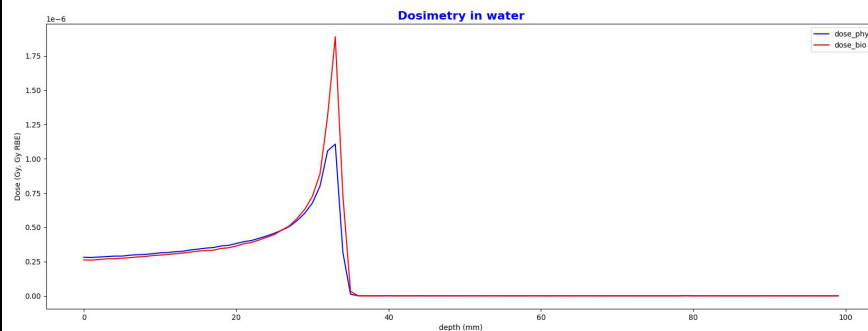
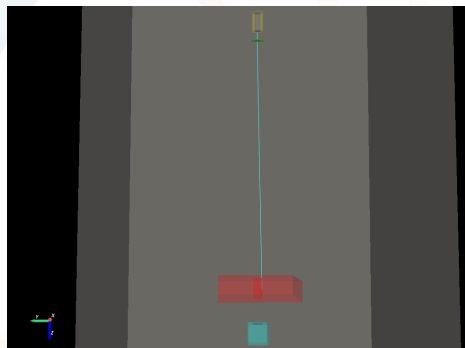
Ion beam irradiation

ARRONAX 67.5 MeV vertical proton beam line



GATE integrating Geant4-DNA official releases

Biological dose calculation



UI identical to Dose Actor

+

Cell line

+

Model (mMKM or NanOx)

+

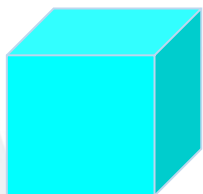
Values of survival cell parameters
 α_{ref} et β_{ref} in reference
conditions (LE photons)

GATE 10 (Python):

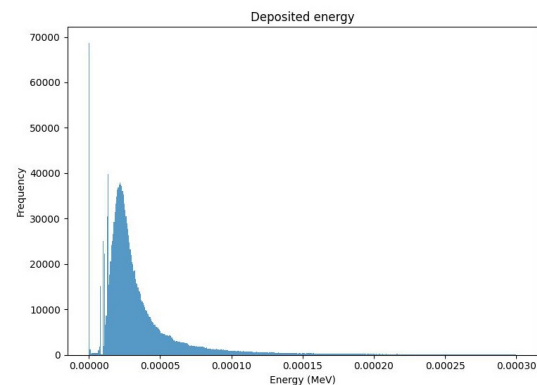
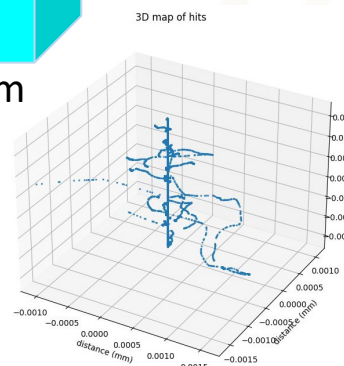
```

bi dose = sim_add_actor("BioDoseActor", "bi dose")
bi dose.mother = volume
bi dose.spacing = [1 * mm, 60 * mm, 60 * mm]
bi dose.size = [400, 1, 1]
bi dose.translation = [0, 0, 0]
bi dose.cell_line = 'HSG'
bi dose.biophysical_model = 'NanOx'
bi dose.alpha_ref = 0.313
bi dose.beta_ref = 0.0615
bi dose.dose = True
bi dose.output = "output/bi dose.mhd"
    
```

Chemistry of water radiolysis



3.2 um



chemistry actor

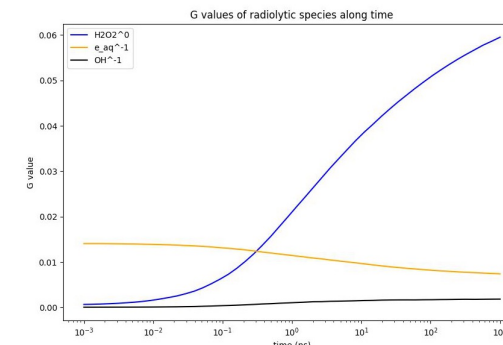
```

chem = sim.add_actor("ChemistryActor", "Chem")
chem.timestep_model = "IRT"
chem.end_time = 1 * us
chem.time_bins_count = 50
chem.reactions = [
    
```

totally diffusion-controlled (TDC)

```

[["H", "H"], ["H2", "Fix", 0.5e10, 0],
[["e_aq", "H"], ["H2", "OHm"], "Fix", 2.5e10, 0],
[["e_aq", "e_aq"], ["H2", "OHm", "OHm"], "Fix", 0.636e10, 0],
[["H3Op", "OHm"], ["H2O", "Fix", 1.13e11, 0]
    
```



PEPR Digital Health

Innovative methods and concepts, including AI approaches, to overcome hurdles in the development and use of realistic, personalized multiscale digital twins

Multiscale digital twins for the development and/or delivery of personalized therapy (post-diagnosis)

Letter of intention to be submitted on 15th of October 2024, 48-month project, 1.4 M€

WP1
Instrument
digital twins

WP2
Patient
digital twins

WP3
Multiscale
organoid
digital twins

WP4
Synthetic
data
generation

12 partners: CREATIS, UMR1030, LATIM, Biomaps, LPCA, IP2I, LPSC, CPPM, IPHC, LTSI, IJCLab, CRAN

Next GATE events

Sept. 2025

Oct. 2024



Thursday 31

GATE workshop during lunchtime

<https://nssmic.ieee.org/2024/>

<https://indico.in2p3.fr/event/33939/>

Next GATE events

Sept. 2025

Nov. 2024

Direction des Relations avec les Entreprises

CNRS FORMATION
ENTREPRISES 20 to 22

Remote GATE 10 training

<https://cnrsformation.cnrs.fr/gate-training-on-medical-imaging-dosimetry-radiation-therapy?mc=gate>

Next GATE events

Sept. 2025



Feb. 2025

2.5 days in Lyon?

GATE 10 Hackaton

(indico web site coming soon for registration)

March 2025

Direction des Relations avec les Entreprises

CNRS FORMATION
ENTREPRISES

Remote Python training for GATE simulation analysis

<https://cnrsformation.cnrs.fr/python-data-analysis-for-gate-simulations?mc=GATE%20Training>

Next GATE events

Sept. 2025

May 2025

GATE scientific meeting

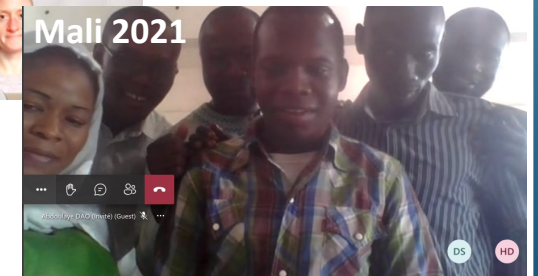
Scientific meetings:

- 22-23 May 2024, in Paris-Orsay (France) <https://indico.in2p3.fr/e/gate2024>
- 25-26 April 2023, in Krakow (Poland) <https://indico.in2p3.fr/e/gate2023>

GATE training hub for students



- 2 servers dedicated to training
- 100 simultaneous connections
- For on site or remote tutorials
- Shared course materials
- **Service open since 2021**



In 2025



Useful links

Information

Web site <http://www.opengatecollaboration.org>

GATE user mailing list <https://listserv.in2p3.fr/cgi-bin/wa?A0=OPENGATE-L>

GATE documentation

To install GATE <https://opengate.readthedocs.io/en/latest/installation.html>

To use GATE <https://opengate.readthedocs.io/en/latest/>

Accessible through Github

Source code <https://github.com/OpenGATE/Gate>

Examples <https://github.com/OpenGATE/GateContrib>

Analysis tools <https://github.com/OpenGATE/gatetools>



Scientific meetings:

- 2022 <https://indico.in2p3.fr/e/gate2022>
- 2023 <https://indico.in2p3.fr/e/gate2023>
- 2024 <https://indico.in2p3.fr/e/gate2024>

Trainings & Workshops

- 1 workshop @ main conferences : IEEE NSS-MIC, AAPM, MCMA, PTCOG...
- Trainings : 2/year
 - [GATE training \(beginner level\)](#)
 - [Python data analysis for GATE simulations](#)