



# GATE

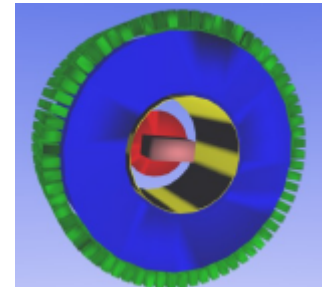
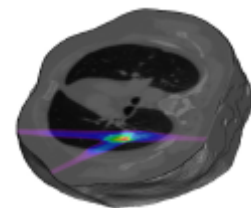
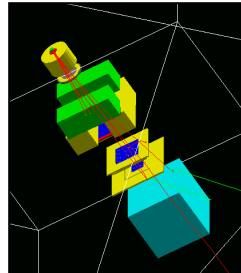
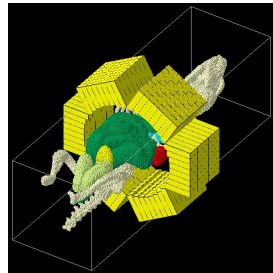
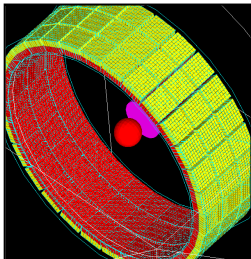
Simulation of Preclinical and Clinical Scans in Emission Tomography, Transmission Tomography and Radiation Therapy

## FCPPL Workshop – Marseille, May 2018

### GATE

a **GEANT4**-based simulation toolkit  
for medical physics applications

supported by Uwe Pietrzyk, spokesperson of the  
OpenGATE collaboration



# What is GATE ?

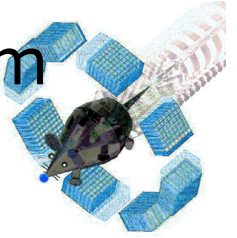
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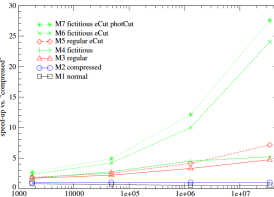
[www.opengatecollaboration.org](http://www.opengatecollaboration.org)

- GATE: *Geant4* Application for Emission Tomography, Transmission Tomography, Radiotherapy and Optical Imaging
- GATE is an **Open source software (GNU LGPL)** dedicated to the **simulation** of **imaging** (SPECT, PET, CT, Optical) and radiotherapy, and based on the Geant4 toolbox
- First release of GATE in May 2004  
22 releases since that date  
Currently GATE V8.1
- Broad range of applications:
  - Detector design
  - Optimisation of acquisition and processing protocols
  - Assessment of quantification methods
  - Estimation of the system matrix used in tomographic reconstruction
  - Dosimetry, Radiation Therapy
  - ...

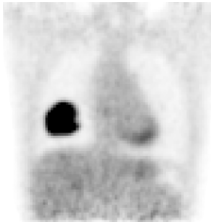
# GATE 2004-2014: a constantly-upgraded platform



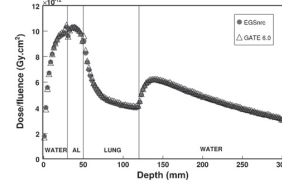
Acceleration  
(2009)



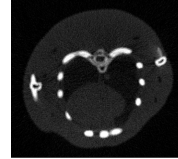
Planar  
SPECT  
PET (2004)



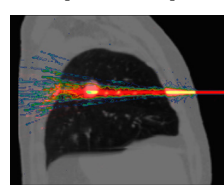
Dosimetry  
(2011)



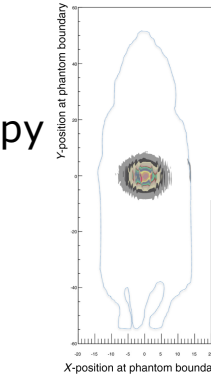
CT (2011)



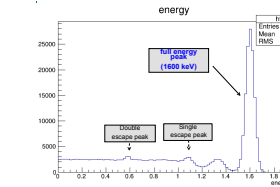
Radiation therapy  
(2011)



Optical imaging  
(2011)



EduGATE (2011)



GPU (2014)



G4 DNA processes  
(2014)



19 releases

2004

1st  
GATE  
public  
release

2011

GATE V6

2014

GATE V7

2017

GATE V8

**GATE: a simulation toolkit for PET and SPECT**

S. Jani, G. Sarrut<sup>1,2</sup>, D. Struelens<sup>3</sup>, S. Staelens<sup>4</sup>, K. Assadi<sup>5</sup>, D. Aerts<sup>6</sup>, S. Avner<sup>7</sup>, R. Barber<sup>8</sup>, M. Bardia<sup>9</sup>, P. M. Boisard<sup>10</sup>, D. Bracco<sup>11</sup>, V. Bruneau<sup>12</sup>, F. Brunet<sup>13</sup>, J. Buvat<sup>14</sup>, J. F. Chastagnier<sup>15</sup>, J. Hama<sup>16</sup>, Y. H. Chang<sup>17</sup>, C. Comtat<sup>18</sup>, D. D'Asselerio<sup>19</sup>, L. Ferret<sup>20</sup>, C. F. Gosselin<sup>21</sup>, D. Guo<sup>22</sup>, P. H. Hoang<sup>23</sup>, S. Karimov<sup>24</sup>, A. S. Kovacs<sup>25</sup>, V. Kozlowski<sup>26</sup>, M. Kozlowski<sup>27</sup>, J. Leclercq<sup>28</sup>, P. Lemaire<sup>29</sup>, G. Levesque<sup>30</sup>, C. Lefevre<sup>31</sup>, D. Lefevre<sup>32</sup>, L. Malaret<sup>33</sup>, P. Marquet<sup>34</sup>, C. Marin<sup>35</sup>, J. M. Martin<sup>36</sup>, J. P. Metzger<sup>37</sup>, T. Y. Ng<sup>38</sup>, J. E. Ojeda<sup>39</sup>, R. C. Schmittler<sup>40</sup>, E. Simeoni<sup>41</sup>, T. Y. Song<sup>42</sup>, J. M. Valdes<sup>43</sup>

**2009 PMB Citation Prize**

**2015 PMB Citation Prize**

**2017 PMB Citation Prize**

**GATE V6: a major enhancement of the GATE simulation platform enabling modelling of CT and radiotherapy**

S. Jani, D. Benoit, E. Becheva, T. Carlier, F. Casadei, P. De Smet, F. Fournier, J. Geurts, J. Gignoux, J. Hama, C. Marin, P. Marquet, N. Rebellin, D. Sarrut, D. Schmittler, S. Simeoni, U. Pfeiffer, S. Staelens, N. Zamboni and Buvat

**2015 PMB Citation Prize**

**2017 PMB Citation Prize**

**Extension of the GATE Monte-Carlo simulation package to model bioluminescence and fluorescence imaging**

Vanni Calzavara, Fabrice Gaudin, Patrick Pons, and Sébastien Jani

**2017 PMB Citation Prize**

**EduGATE – basic examples for educative purpose using the GATE simulation platform**

Use Patryk<sup>1,\*</sup>, Abdelmalik Zakhari<sup>2,3</sup>, Markus Auer<sup>4</sup>, Sophie Szwarczewski<sup>5</sup>, Didier Besson<sup>6</sup>, Michaela Gama<sup>7</sup>

**2017 PMB Citation Prize**

**A review of the use and potential of the GATE Monte Carlo simulation code for radiation therapy and dosimetry applications**

David Sarrut<sup>1</sup>, Christophe Marin<sup>2</sup>, Jean-François Lebesqye<sup>3</sup>, Jean-François Chastagnier<sup>4</sup>, Jean-François Buvat<sup>5</sup>, Jean-François Chastagnier<sup>6</sup>, Jean-François Chastagnier<sup>7</sup>, Jean-François Chastagnier<sup>8</sup>, Jean-François Chastagnier<sup>9</sup>, Jean-François Chastagnier<sup>10</sup>, Jean-François Chastagnier<sup>11</sup>, Jean-François Chastagnier<sup>12</sup>, Jean-François Chastagnier<sup>13</sup>, Jean-François Chastagnier<sup>14</sup>, Jean-François Chastagnier<sup>15</sup>

# Main technical features of GATE (1)

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- GATE is based on Geant4: <http://www.geant4.org>
- GATE is written in C++
- GATE is **user-friendly** as simulations can be designed and controlled using **macros**, **without any C++ writing**
- GATE can **simulate** SPECT, PET, CT and optical scans and **radiotherapy** treatments
- GATE is **flexible** enough to model almost any detector design, including prototypes
- GATE explicitly **models time**, hence makes it possible to model detector motion, patient motion, radioactive decay, optical photon tracking, dead time, time of flight, tracer kinetics
- GATE can handle **analytical or voxelized phantoms**
- GATE **can run on a cluster architecture and on a grid**

## Main technical features of GATE (2)

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- GATE can be freely downloaded, including sources
- GATE can be run on many platforms (Linux, MAC OS, Windows)
- Online documentation about GATE, including FAQ
- Help about the use of GATE can be obtained through the [gate-user mailing list](#) (**more than 1500 subscribers**)
- Many commercial or prototype systems have already been modeled using GATE and most models have been thoroughly validated (list available at the address: <http://www.opengatecollaboration.org>)
- **The GATE project is mostly based on volunteer participation and on the active contribution of GATE developers and users**

# The OpenGATE collaboration



- 18 labs, sharing developments and validation studies regarding GATE, and working together to make these developments publicly available

## France



- ❑ U892 Inserm, Nantes
- ❑ LaTIM, U1101 Inserm, Brest
- ❑ **IMNC, CNRS/IN2P3, Orsay**
- ❑ **LPC, CNRS/IN2P3, Clermont-Fd**
- ❑ **IPHC, CNRS/IN2P3, Strasbourg**
- ❑ **CPPM, CNRS/IN2P3, Marseille**
- ❑ CREATIS, CNRS, Lyon
- ❑ SHFJ-CEA, Orsay
- ❑ U1037 Inserm, Toulouse

## Europe



- ❑ Delft University of Technology, Delft, The Netherlands
- ❑ Forschungszentrum Juelich, Germany
- ❑ National Technical University of Athens, Greece
- ❑ Medical University of Vienna, Austria
- ❑ MedAustron, Wiener Neustadt, Austria
- ❑ University of Gent, Belgium

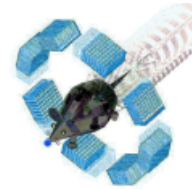
## Rest of the world



- ❑ Memorial Sloan-Kettering Cancer Center, New York, USA
- ❑ UC Davis, Davis, USA
- ❑ Sogang University, Seoul, South Korea

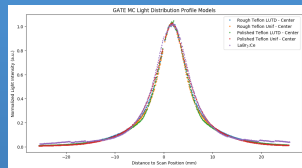
-> Need to foster collaborations with China

# Research topics developed in IN2P3 labs

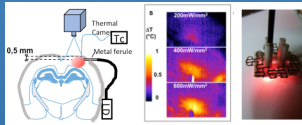


## IMNC (Imaging & Thermotherapy)

Distribution of light within monolithic scintillators (miniaturized gamma camera)



Study of optimal parameters for photostimulation



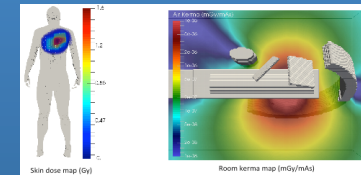
## IPHC (Dosimetry and radiation protection)

Dosimetry using scintillating fiber in radiology  
 Dosimetry for radiation protection in interventional radiology

Variance reduction technique for the calculation of dose using neutrons (nTLE)

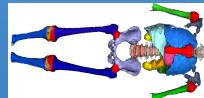
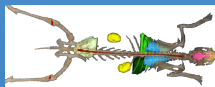
Nuclear activation of materials irradiated with high energy X-rays

Dosimetry using CMOS detectors in protontherapy

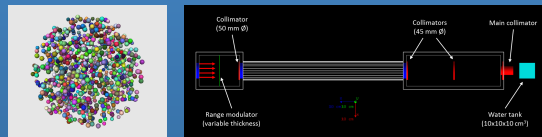


## LPC Clermont (Dosimetry & Radiobiology)

Pre-clinical and clinical dosimetry for internal radiation therapy (new theranostic molecules)

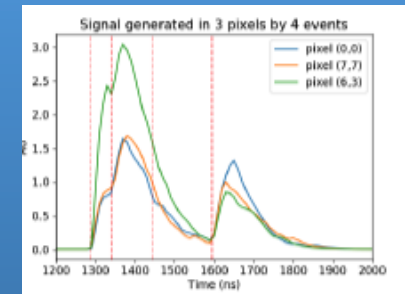


Evaluation of the biological dose in hadrontherapy  
 Radiobiology: evaluation of cell and DNA damage



## CPPM (Imaging)

Compton camera:  
 Modelling of SiPM arrays  
 Performance study and development of new reconstruction algorithms



$\mu$ CT imaging:  
 Simulation of hybrid pixel detectors

# Partnerships with chinese particle physics labs

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- ▶ **Foster research partnerships & enlarge the OpenGATE collaboration to Chinese labs**
  - ▶ GATE is now a powerful and recognized platform for medical physics applications, but it needs to be **maintained** and **developed** in the long term through research partnerships (PhD thesis)



# Partnerships with chinese particle physics labs

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## ▶ Foster education on simulation and modelling in medical physics through dedicated workshops and tutorials

- French students are trained to use GATE in medical physics Master programs in order to help their understanding of particle physics interactions and operation of medical devices
- The OpenGATE collaboration is willing to develop dedicated workshops to train Master students and open new collaborations all around the world -> FCPPL could help in finding new partners

# Contact & References

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- Contact: Lydia Maigne, associate professor @ LPC Clermont-Ferrand, [Lydia.Maigne@clermont.in2p3.fr](mailto:Lydia.Maigne@clermont.in2p3.fr)
- References:
- **GATE URL:** <http://www.opengatecollaboration.org>
- GATE user **mailing list:**  
[gate-users@lists.opengatecollaboration.org](mailto:gate-users@lists.opengatecollaboration.org)
- **GATE documentation** (wiki):
- To install GATE:  
<http://www.opengatecollaboration.org/InstallingGATE>
- To use GATE:  
<http://www.opengatecollaboration.org/Documentation>
- GATE publications:  
<http://www.opengatecollaboration.org/Publications>