



GATE

A Geant4-based simulation platform for medical physics

Lydia Maigne on behalf of the OpenGATE collaboration
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PTCOG58

58th annual conference of the particle therapy co-operative group

The collaboration & Partners

20 members, public laboratories and companies developing an open source platform

Spokesperson: Lydia Maigne

Technical coordinator: David Sarrut



Cross validation with the Geant4 collaboration
Susanna Guatelli & Sébastien Incerti

The collaboration is looking for new members

Elsewhere



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

France



- U892 Inserm, Nantes
- U1101 Inserm, Brest
- IMNC –CNRS-IN2P3, Paris-Orsay
- LPC –CNRS-IN2P3, Clermont-Ferrand
- IPHC –CNRS-IN2P3, Strasbourg
- CPPM –CNRS-IN2P3, Marseille
- UMR5515 CNRS, CREATIS, Lyon
- SHFJ CEA, Paris-Orsay
- CRCT - U1037 Inserm, Toulouse



Europe



- University of Applied Science, Julich, Germany
- University of Wuppertal, Germany
- Technological Educational Institute of Athens, Greece
- BioemTech, Athens, Greece
- Medical University of Vienna, Wiener Neustadt, Austria
- MedAustron, Wiener Neustadt, Austria
- ACMIT, Wiener Neustadt, Austria

A large community of users

Around 2000 registered users

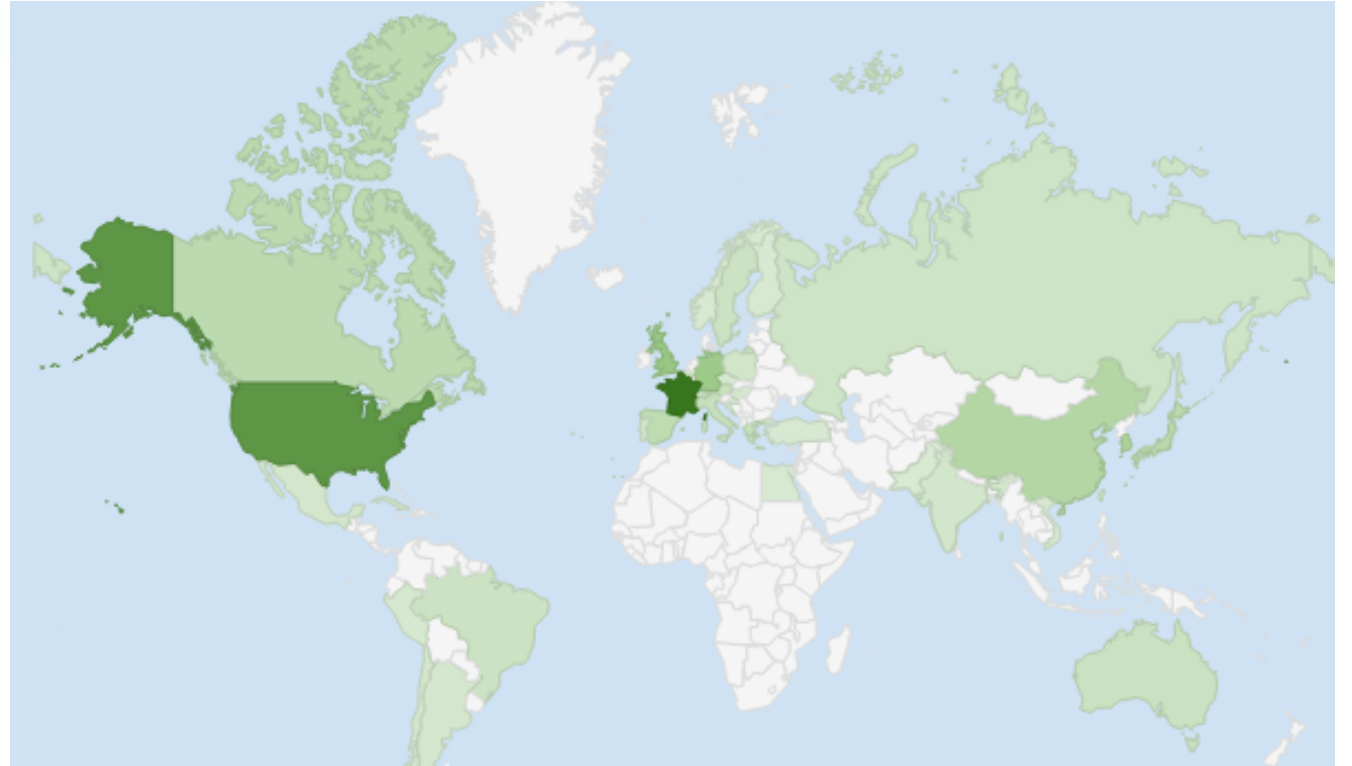
- Large communities in France and USA
- Increasing number in Asia: China, Japan and South Korea

GATE USERS MAILING LIST

What is for?

- The mean for the collaboration to send information about releases, job offers, interesting papers
- The mean for users to ask any question regarding GATE: bugs, compilation problems, good practice for using or developing the platform

To register to the mailing-list: <http://opengatecollaboration.org/maillinglist>



What is GATE?

- GATE: **Geant4** Application for Emission Tomography, Transmission Tomography, Radiotherapy and Optical Imaging
- GATE is an **open source** software (GNU LGPL) fully based on the Geant4 toolbox
- 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, radiotherapy treatments (internal, external) and **ion beam therapy**
- **1 release / year**, after the Geant4 release, now **GATE 8.2**

GATE source code on GitHub Release 8.2

How to post your devs?

- Get an account on GitHub
- Fork Gate repository
- Make your fix
- Submit a pull request

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



OpenGATE / Gate

Watch 39 Star 84 Fork 108

Code Issues 65 Pull requests 3 Projects 0 Wiki Security Insights

Official public repository of Gate <http://www.opengatecollaboration.org>

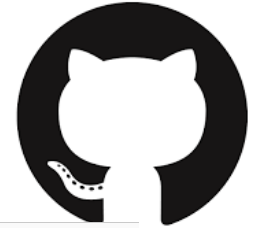
physics-simulation medical-physics gate opengate pet spect radiation-therapy medical-imaging

2,685 commits 11 branches 9 releases 34 contributors LGPL-3.0

Branch: develop New pull request Find File Clone or download

David Boersma make sure that Gate compiles if GateDebugMessage is enabled Latest commit 68ec5d8 21 days ago

benchmarks	new reference data (PET does not work yet, mac file needs to be fixed...	6 months ago
cluster_tools	jobsplitter: add SLURM support	4 months ago
cmake-modules	Use latest version of RTK which is now an ITK module	4 months ago
release_notes	update log	4 months ago
source	make sure that Gate compiles if GateDebugMessage is enabled	21 days ago
AUTHORS	add Baran Jakub	4 months ago
CMakeLists.txt	new version 8.2	4 months ago
CTestConfig.cmake	Added CMake configuration to enable CDash tests.	5 years ago
Gate.cc	correct cmd line grammar in doxygen docs	4 months ago
GateConfiguration.h.in	Merge branch 'develop' into zhenjie	a year ago
GateMaterials.db	delte trailing whitespaces	2 years ago
GateMaterialsGPU.db	trailing spaces, tabs to spaces, consistent alignment for GateMateria...	6 years ago
LICENSE.md	Create LICENSE.md	2 years ago
Materials.xml	minor updates	4 years ago

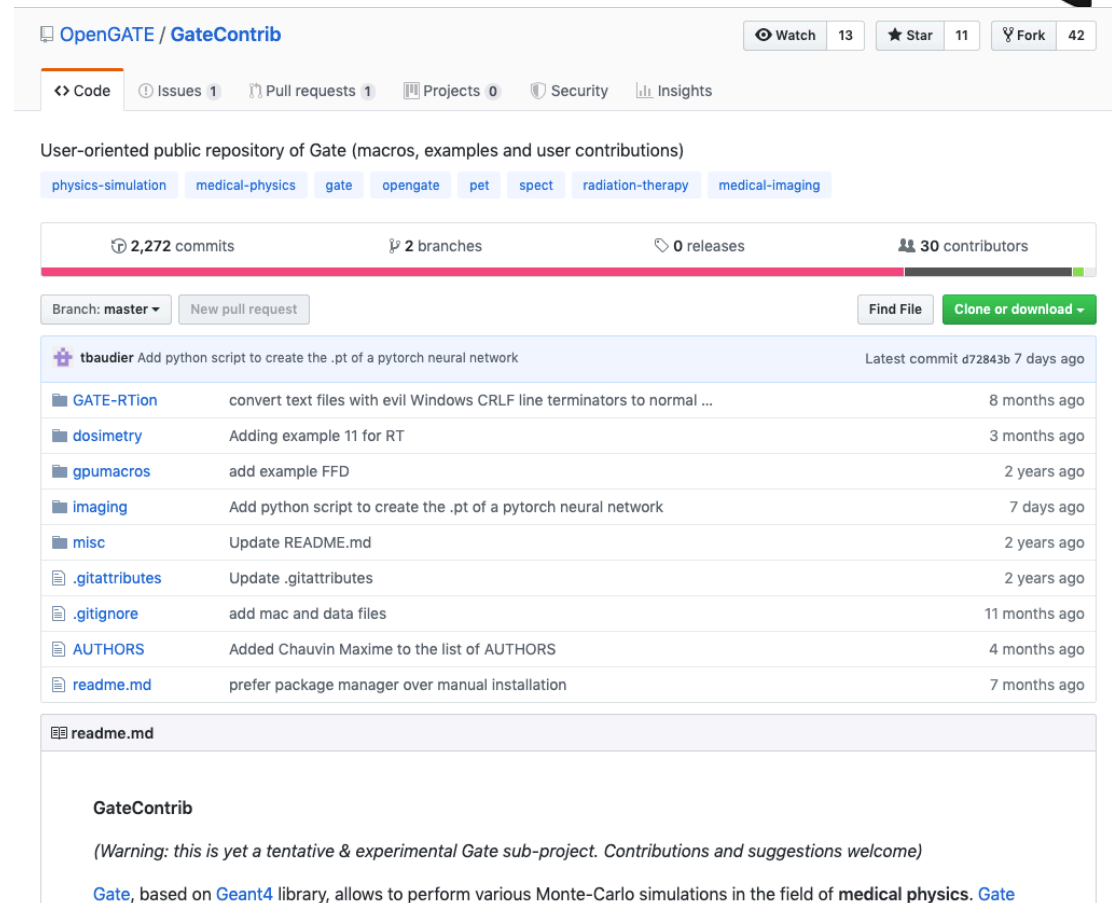


Play with GATE examples

- **Dosimetry:** Radiotherapy, DNA, LET, doseactor, dosebyregions, ...
- **Imaging:** CT, PET, SPECT, SPECT_FFD, fluorescence, ProtonRadiography...
- **Misc:** mesh geometry, STL geometry...

How to contribute?

- Prepare your example as a pull-request
- Clone the repository in your GitHub account
- Commit your example
- New pull request



OpenGATE / GateContrib

Watch 13 Star 11 Fork 42

Code Issues 1 Pull requests 1 Projects 0 Security Insights

User-oriented public repository of Gate (macros, examples and user contributions)

physics-simulation medical-physics gate opengate pet spect radiation-therapy medical-imaging

2,272 commits 2 branches 0 releases 30 contributors

Branch: master New pull request Find File Clone or download

Commit	Message	Time
tbaudier	Add python script to create the .pt of a pytorch neural network	Latest commit d72843b 7 days ago
GATE-RTion	convert text files with evil Windows CRLF line terminators to normal ...	8 months ago
dosimetry	Adding example 11 for RT	3 months ago
gpumacros	add example FFD	2 years ago
imaging	Add python script to create the .pt of a pytorch neural network	7 days ago
misc	Update README.md	2 years ago
.gitattributes	Update .gitattributes	2 years ago
.gitignore	add mac and data files	11 months ago
AUTHORS	Added Chauvin Maxime to the list of AUTHORS	4 months ago
readme.md	prefer package manager over manual installation	7 months ago

readme.md

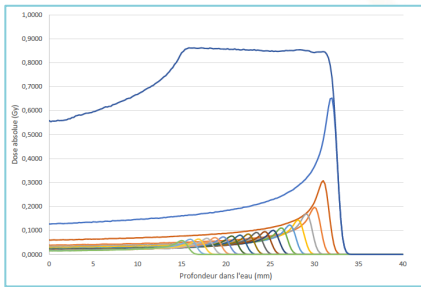
GateContrib

(Warning: this is yet a tentative & experimental Gate sub-project. Contributions and suggestions welcome)

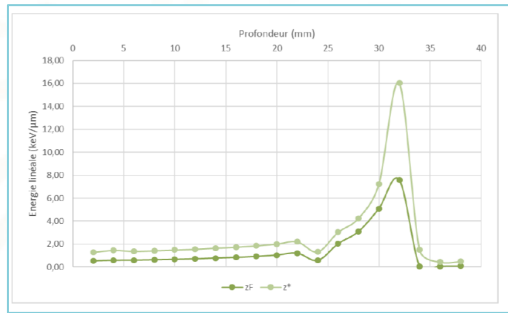
Gate, based on [Geant4](#) library, allows to perform various Monte-Carlo simulations in the field of **medical physics**. [Gate](#)

Some practical functionalities

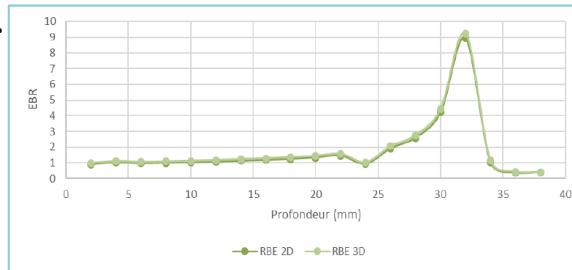
GATE has been designed to fully cover your needs in treatment planning in ion beam therapy



from dose



To specific and lineal energies...



To RBE...

Voxelized and mesh images

Dedicated actors

Variance reduction techniques

Tools for ion beam therapy

To come soon: tools for radiation biology

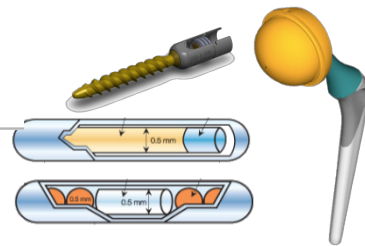
Voxelized and mesh imaging: new approaches to define a virtual patient

- ▶ Generic voxelised volume (patient / phantom): multi-scale description, mixing high and low resolution



```

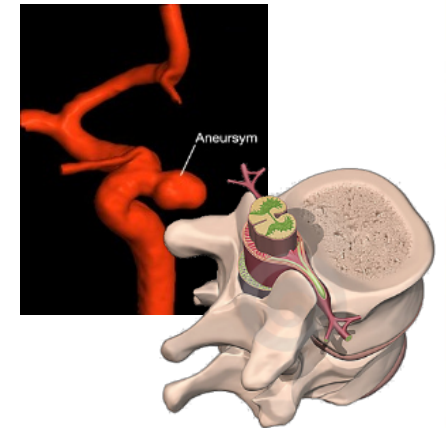
-1050 -950 Air_0
-950 -852 Lung_1
-852 -755 Lung_2
-755 -658 Lung_3
-658 -561 Lung_4
-561 -464 Lung_5
-464 -367 Lung_6
-367 -270 Lung_7
-270 -173 Lung_8
-173 -120 Lung_9
-120 -82 AT_AG_SI1_10
-82 -52 AT_AG_SI2_11
-52 -22 AT_AG_SI3_12
-22 8 AT_AG_SI4_13
8 19 AT_AG_SI5_14
19 80 SoftTissus_15
80 120 ConnectiveTissue_16
120 200 Marrow_Bone01_17
200 300 Marrow_Bone02_18
300 400 Marrow_Bone03_19
400 500 Marrow_Bone04_20
500 600 Marrow_Bone05_21
600 700 Marrow_Bone06_22
700 800 Marrow_Bone07_23
800 900 Marrow_Bone08_24
900 1000 Marrow_Bone09_25
1000 1100 Marrow_Bone10_26
1100 1200 Marrow_Bone11_27
1200 1300 Marrow_Bone12_28
1300 1400 Marrow_Bone13_29
    
```



Artificial implants



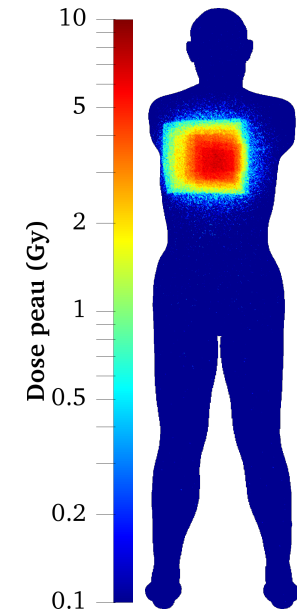
- ▶ Combining voxelised and analytical phantom description – Merging Mesh volume within a voxelised volume



Anatomical details

Dedicated actors

- Dedicated tools for the collection of information during the simulation (with associated uncertainties).
 - Simulation statistics
 - EmCalculator
 - Dose
 - Tet-MeshDose
 - Kill
 - TrackLength
 - Production and Stopping particle position
 - Secondary particle
 - StoppingPower
 - CrossSectionProduction
 - PhS file
 - LET
 - Energy spectrum
 - TEPC
 -



Easy usage in few lines:

```

/gate/actor/addActor DoseActor           MyActor
/gate/actor/MyActor/save                 MyOutputFile.mhd
/gate/actor/MyActor/attachTo             MyVolume
/gate/actor/MyActor/stepHitType          random
/gate/actor/MyActor/setSize               5 5 5 m
/gate/actor/MyActor/setResolution         1 1 3000
/gate/actor/MyActor/enableEdep            true
/gate/actor/MyActor/enableUncertaintyEdep true
/gate/actor/MyActor/enableSquaredEdep     false
/gate/actor/MyActor/enableDose            false
/gate/actor/MyActor/normaliseDoseToMax    false

```

Variance reduction techniques

Hybrid MC-analytical methods to speed-up the computation

IOP Publishing | Institute of Physics and Engineering in Medicine

Physics in Medicine & Biology

Phys. Med. Biol. **60** (2015) 8067–8086

doi:10.1088/0031-9155/60/20/8067

Monte Carlo simulation of prompt γ -ray emission in proton therapy using a specific track length estimator

W El Kanawati¹, J M Létang¹, D Dauvergne², M Pinto²,
D Sarrut¹, É Testa² and N Freud¹

¹ CREATIS, Université de Lyon, CNRS UMR5220, Inserm U1044, INSA-Lyon, Université Lyon 1, Centre Léon Bérard, 69007 Lyon, France

² IPNL, Université de Lyon, CNRS/IN2P3 UMR5822, Université Lyon 1, 69007 Lyon, France

- Fast computation of prompt-gamma yield distribution during proton beam
- Based on low statistic Monte-Carlo and pre-computed tables
- About 10^5 time faster than analog Monte-Carlo

TLE (Track Length Estimator) and seTLE for low E photons

[Baldacci2015, Smekens2014 PMB]

Fast-Prompt Gamma (vpgTLE) yield

[Kanawati2015 PMB] [Huisman2016 PMB]

FFD (Fixed Forced Detection) for SPECT

[Cajgfinger2017 PMB]

FFD Scatter CBCT simulations

[Zolner2017 PIRO]

Neural Network based ARF for SPECT

[Sarrut2018 PMB]

Fast neutron TLE

[Elazhar 2018 PMB]

The GATE-RTion project

Passive and PBS proton and carbon beams easily configured

Clinical applications

Cross validation with TPS

IOP PUBLISHING
Phys. Med. Biol. 57 (2012) 4223–4244

PHYSICS IN MEDICINE AND BIOLOGY
doi:10.1088/0031-9155/57/13/4223

GATE as a GEANT4-based Monte Carlo platform for the evaluation of proton pencil beam scanning treatment plans

L Grevillot^{1,2,3}, D Bertrand³, F Dessy³, N Freud^{1,2} and D Sarrut^{1,2}

¹ CREATIS, CNRS UMR5220, Inserm U1044, INSA-Lyon, Université Lyon 1, Université de Lyon, Lyon, France

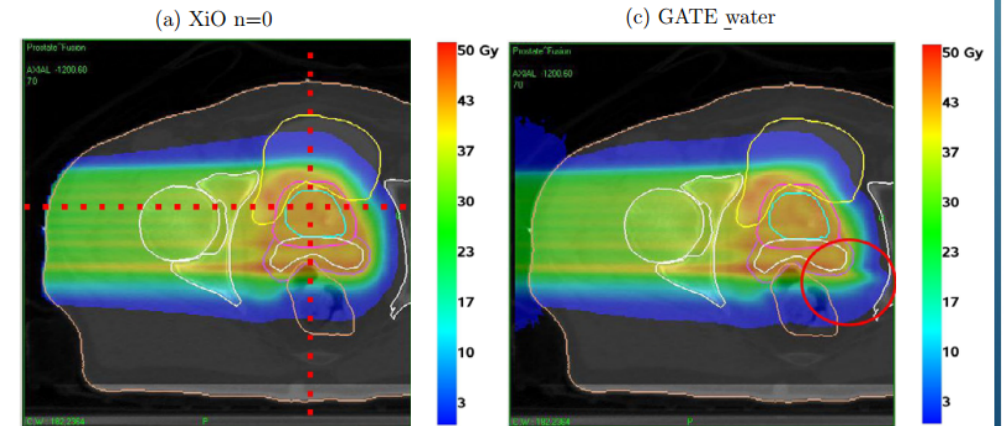
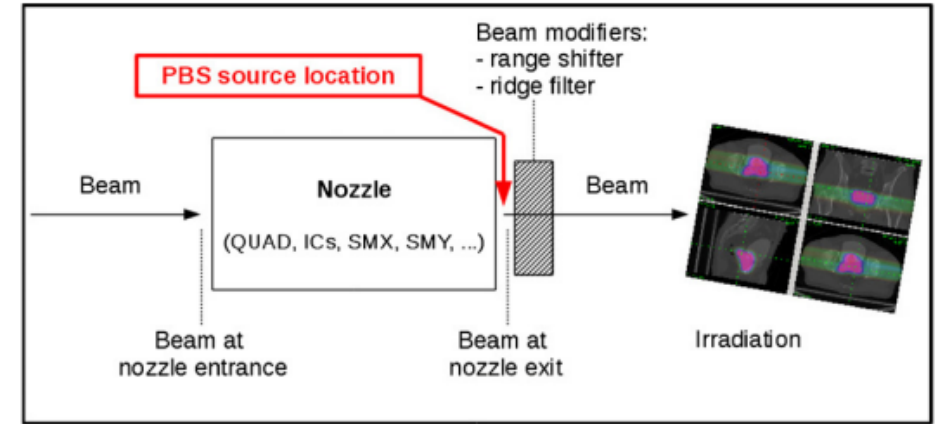
² Centre Léon Bérard, Université de Lyon, Lyon, France

³ IBA, B-1348, Louvain-la-Neuve, Belgium

```
#TREATMENT-PLAN-DESCRIPTION
#PlanName
CARAMEL_Profil 170 MeV
#NumberOfFractions
1
##FractionID
1
##NumberOfFields
1
###FieldsID
1
#TotalMeterSetWeightOfAllFields.
1421

#FIELD-DESCRIPTION
##FieldID
1
##FinalCumulativeMeterSetWeight
1421
##GantryAngle
0
##PatientSupportAngle
0
##IsocenterPosition
0 0 0
##NumberOfControlPoints
2

#SPOTS-DESCRIPTION
###ControlPointIndex
0
###SpotTunedID
Spot1
###CumulativeMeterSetWeight
0
###Energy (MeV)
170
###NbOfScannedSpots
1421
###X Y Weight
98.7943 94.7148 1
92.8682 94.7148 1
86.926 94.7148 1
80.9919 94.7148 1
75.0578 94.7148 1
69.1237 94.7148 1
63.1895 94.7148 1
57.2554 94.7148 1
51.3213 94.7148 1
45.3871 94.7148 1
39.453 94.7148 1
33.5189 94.7148 1
27.5848 94.7148 1
21.6506 94.7148 1
15.7165 94.7148 1
9.78238 94.7148 1
3.84825 94.7148 1
-2.08588 94.7148 1
-8.02001 94.7148 1
-13.9541 94.7148 1
-19.8883 94.7148 1
```



GATE on social networks



<https://www.researchgate.net/project/GATE-Collaboration>

Project page updated with the last advances in the fields of imaging, therapy and computing efficiency
Papers available there



[@GATE_MC](https://twitter.com/GATE_MC)

Twitts to follow GATE events/talks @ conferences



Coming soon

To be in touch with the user community



Coming soon

To build a network of research labs and companies to connect experts in medical physics using GATE

GATE events in 2019

WORKSHOPS:

- June 22 (after **MCMA conference**) in Montreal (McGill University Health Centre) from 9:30 am to 1 pm, please [REGISTER](#)
- October 31 @ **IEEE NSS-MIC conference** in Manchester, programme and registration available soon

TRAININGS:

- July 9-11 (3 days with 3 teachers): **Python data analysis for GATE simulations** in Clermont-Fd (France), **registrations opened till June 15**, please [REGISTER](#) urgently
- November 19-21 (3 days with 3 teachers): **GATE training for beginners** in Clermont-Fd (France), programme and registration site coming soon

TRAININGS FOR BEGINNERS IN ASIA coming soon: South Korea, Japan and China

SPECIAL EVENTS:

- July 3: **Hackathon day** in Lyon (France), please [REGISTER](#)
- July 4: **GATE technical meeting** in Centre Léon Bérard, Lyon (France), you are invited to participate to our technical meeting and present your work using GATE, please [REGISTER](#)

[Characterization of EBT3 radiochromic films for dosimetry of proton beams in the presence of magnetic fields.](#)

Padilla-Cabal F, Kuess P, Georg D, Palmans H, Fetty L, Fuchs H.
Med Phys. 2019 May 4. doi: 10.1002/mp.13567.

[Evaluation of electromagnetic and nuclear scattering models in GATE/Geant4 for proton therapy.](#)

Resch AF, Elia A, Fuchs H, Carlino A, Palmans H, Stock M, Georg D, Grevillot L.
Med Phys. 2019 May;46(5):2444-2456. doi: 10.1002/mp.13472. Epub 2019 Apr 15.

[Monte Carlo simulation of the relative biological effectiveness and DNA damage from a 400 MeV/u carbon ion beam in water.](#)

Ou H, Zhang B, Zhao S
Appl Radiat Isot. 2018 Jun;136:1-9. doi: 10.1016/j.apradiso.2018.01.038. Epub 2018 Jan 31.

[Organ doses from a proton gantry-mounted cone-beam computed tomography system characterized with MCNP6 and GATE.](#)

Ardenfors O, Henry T, Gudowska I, Poludniowski G, Dasu A.
Phys Med. 2018 Sep;53:56-61. doi: 10.1016/j.ejmp.2018.08.011. Epub 2018 Aug 16.

[A beam model for focused proton pencil beams.](#)

Almhagen E, Boersma DJ, Nyström H, Ahnesjö A.
Phys Med. 2018 Aug;52:27-32. doi: 10.1016/j.ejmp.2018.06.007. Epub 2018 Jun 18.

[A pencil beam algorithm for magnetic resonance image-guided proton therapy.](#)

Padilla-Cabal F, Georg D, Fuchs H.
Med Phys. 2018 May;45(5):2195-2204. doi: 10.1002/mp.12854. Epub 2018 Mar 30.

[Dosimetric evaluation of a commercial proton spot scanning Monte-Carlo dose algorithm: comparisons against measurements and simulations.](#)

Saini J, Maes D, Egan A, Bowen SR, St James S, Janson M, Wong T, Bloch C.
Phys Med Biol. 2017 Sep 12;62(19):7659-7681. doi: 10.1088/1361-6560/aa82a5.

[Benchmarking GATE/Geant4 for ¹⁶O ion beam therapy.](#)

Resch AF, Fuchs H, Georg D.
Phys Med Biol. 2017 Sep 5;62(18):N474-N484. doi: 10.1088/1361-6560/aa807e.

[Theoretical dosimetric evaluation of carbon and oxygen minibeam radiation therapy.](#)

González W, Peucelle C, Prezado Y.
Med Phys. 2017 May;44(5):1921-1929. doi: 10.1002/mp.12175. Epub 2017 Mar 30.

[Optimization of the mechanical collimation for minibeam generation in proton minibeam radiation therapy.](#)

Guardiola C, Peucelle C, Prezado Y.
Med Phys. 2017 Apr;44(4):1470-1478. doi: 10.1002/mp.12131. Epub 2017 Mar 11.

[Magnetic field effects on particle beams and their implications for dose calculation in MR-guided particle therapy.](#)

Fuchs H, Moser P, Gröschl M, Georg D.
Med Phys. 2017 Mar;44(3):1149-1156. doi: 10.1002/mp.12105. Epub 2017 Feb 28.

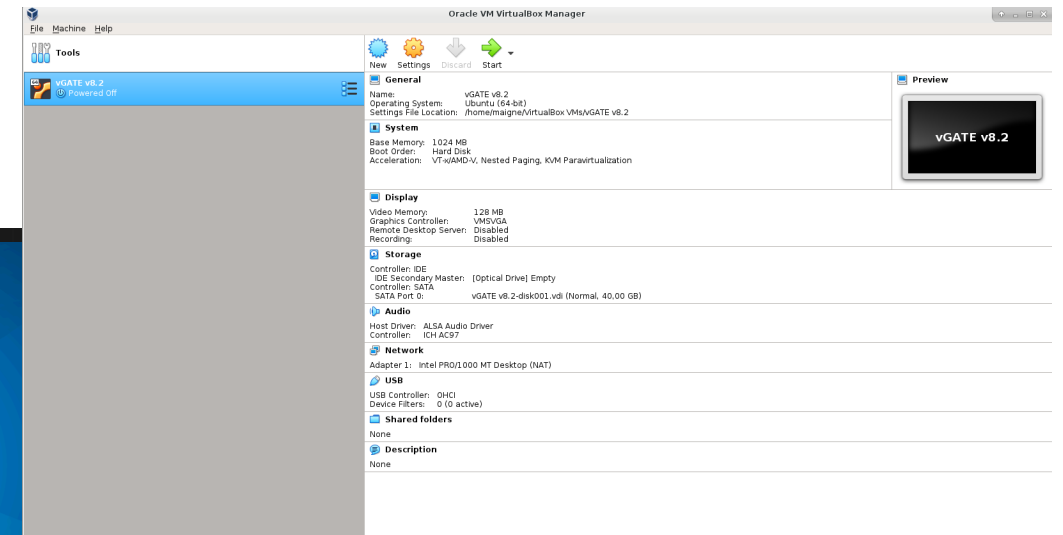
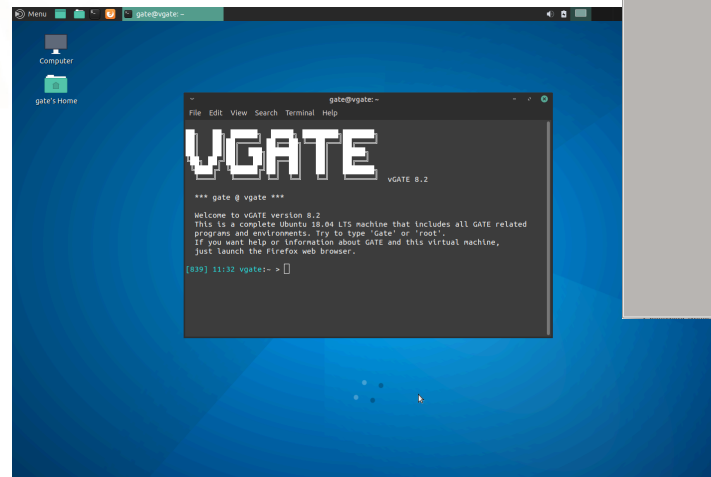
How to use GATE, different ways:

- For beginners: use the GATE virtual machine vGATE8.2
- For advanced users: Install GATE from scratch
 - Compilation instructions available on the [Wiki](#)
- When you need large computing resources
 - Install GATE on a cluster (Microsoft Azure, Amazon...) using the Docker framework

vGATE: the GATE virtual machine

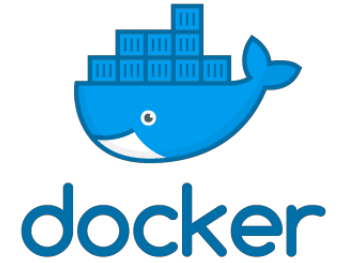
- Install VirtualBox on your laptop <https://www.virtualbox.org/>
- [Download](#) and import vGATE on VirtualBox
- Adjust the appliance Import Settings depending on your computer and enable Hardware virtualization

- Login credentials (sudoer):
 - User: gate
 - Password: virtual



GATE on Microsoft Azure or Amazon Web services

- A new Docker image is proposed following every release
 - <https://hub.docker.com/r/opengatecollaboration/gate>

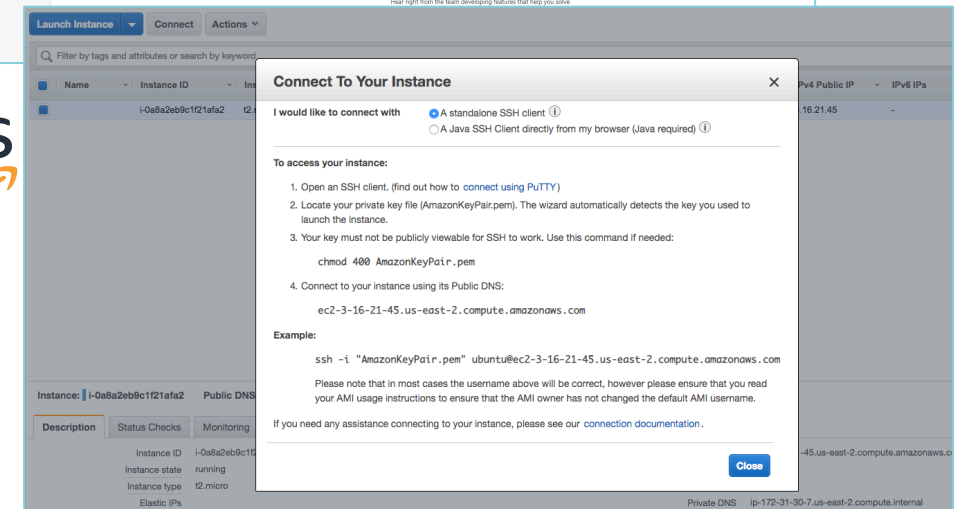
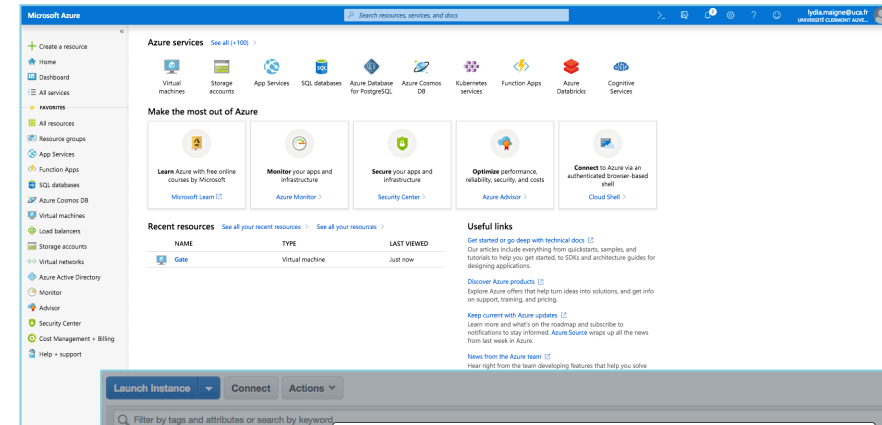


- **Compatible on every web services providers**

- Create an account on MS Azure or AWS
- Configure your virtual machine
- Install Docker
- Install the GATE Docker image
- Run your simulations

- **Tutorial for installation available on our web site**

- **Contact the collaboration for any help**



References

- Web site: <http://www.opengatecollaboration.org> **New web site coming soon**
- GATE user mailing list: gate-users@lists.opengatecollaboration.org
- GATE documentation (wiki):
To install GATE: <http://www.opengatecollaboration.org/InstallingGATE>
To use GATE: <http://www.opengatecollaboration.org/Documentation>
- GitHub:
Through the issue tracker: <https://github.com/OpenGATE/Gate/issues>
Through the code: <https://github.com/OpenGATE/Gate>
Through the examples : <https://github.com/OpenGATE/GateContrib>
- GATE publications: <http://www.opengatecollaboration.org/Publications>