

# The new version of the GATE simulation platform

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**On behalf of the OpenGATE Collaboration**

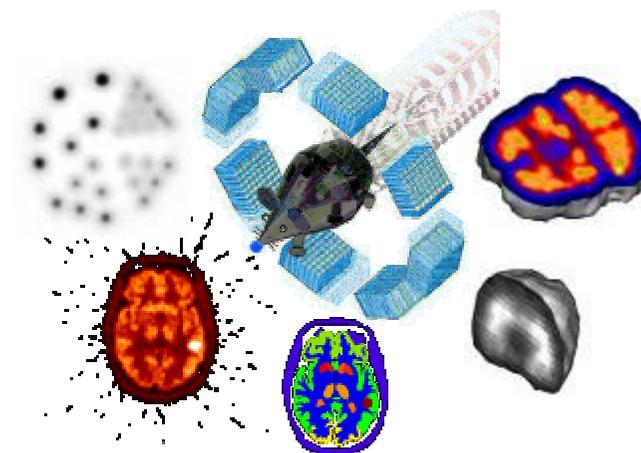


CENTRE RÉGIONAL

**LÉON BÉRARD**

Soigner, chercher, vaincre. Ensemble

*Creatis*



# Outline

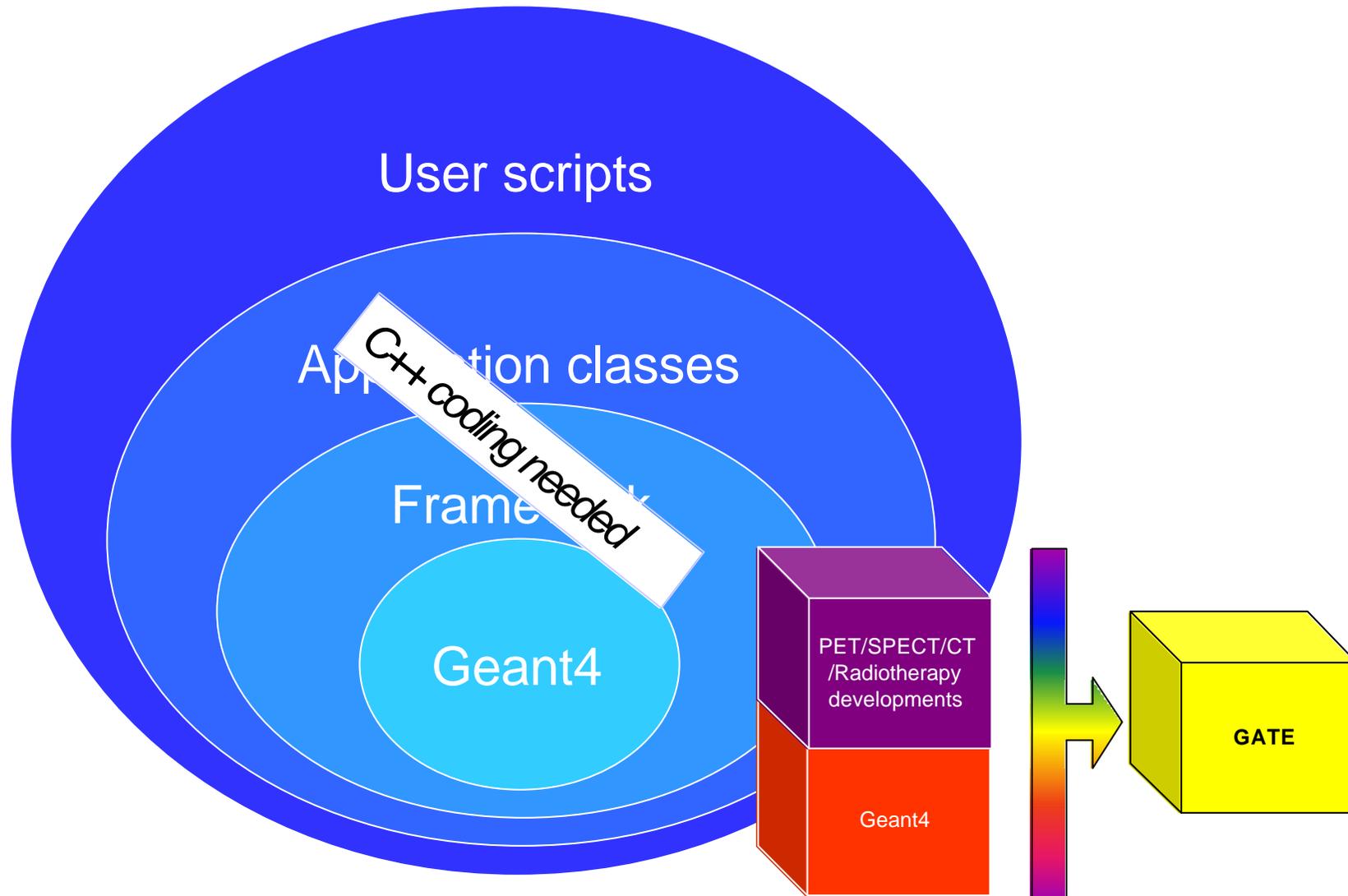
- GATE overview
- Main features
- Examples

# Outline

- **GATE overview**
- Main features
- Examples

# GATE structure

Simulation platform for medical applications



# User script example: geometry

## # BLOCK

```
/gate/module/daughters/name block  
/gate/module/daughters/insert box
```

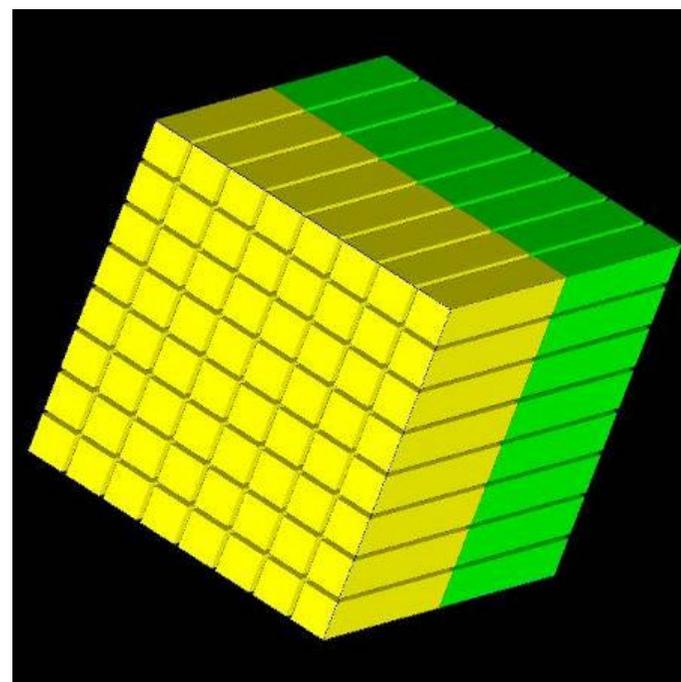
## # CRYSTAL

```
/gate/block/daughters/name crystal  
/gate/block/daughters/insert box  
/gate/crystal/placement/setTranslation 0. 0. 0. cm  
/gate/crystal/geometry/setXLength 3.0 cm  
/gate/crystal/geometry/setYLength 3.0 mm  
/gate/crystal/geometry/setZLength 3.8 mm  
/gate/crystal/setMaterial NaI  
/gate/crystal/vis/setVisible 1
```

## # REPEAT CRYSTAL

```
/gate/crystal/repeaters/insert cubicArray  
/gate/crystal/cubicArray/setRepeatNumberX 2  
/gate/crystal/cubicArray/setRepeatNumberY 8  
/gate/crystal/cubicArray/setRepeatNumberZ 8  
/gate/crystal/cubicArray/setRepeatVector 0. 3.2 4.0 mm
```

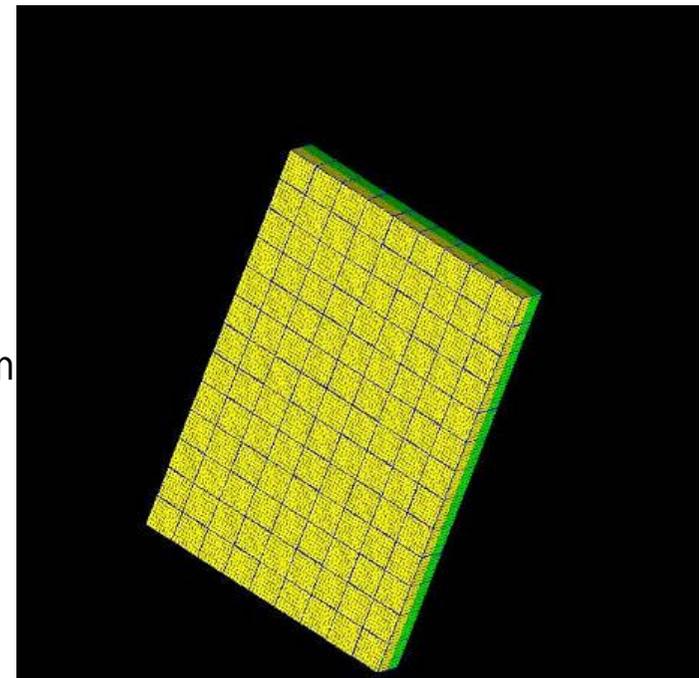
A block detector



# User script example: geometry

```
#      R E P E A T   B L O C K
/gate/block/repeaters/insert cubicArray
/gate/block/cubicArray/setRepeatNumberX 1
/gate/block/cubicArray/setRepeatNumberY 8
/gate/block/cubicArray/setRepeatNumberZ 12
/gate/block/cubicArray/setRepeatVector 0. 1.6 2.0 cm
```

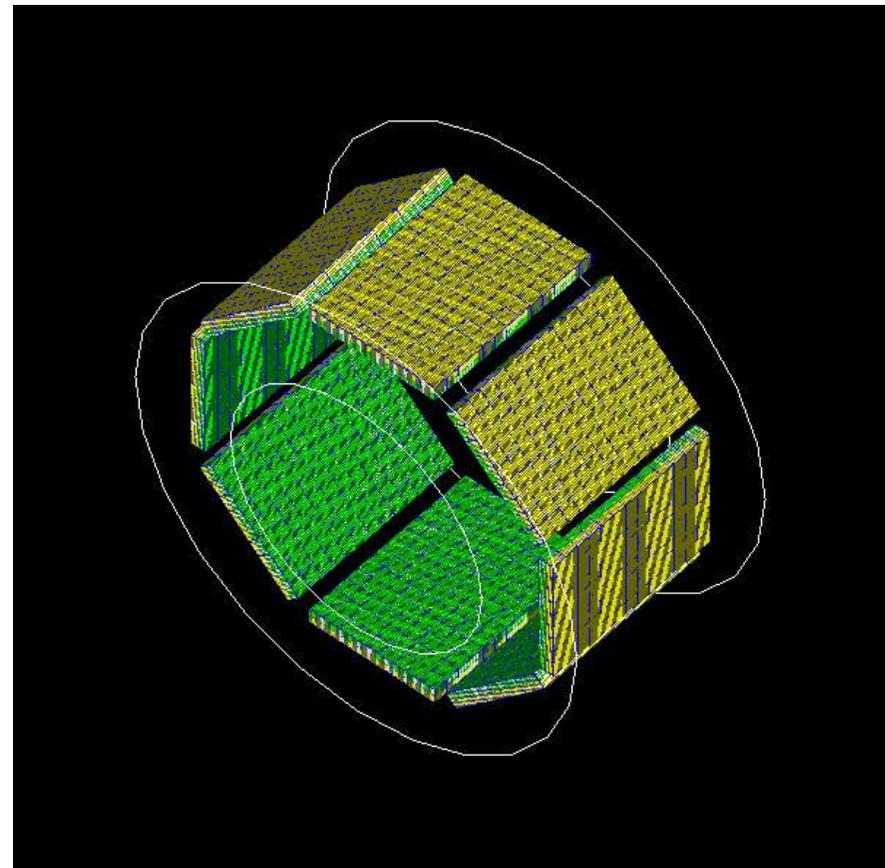
A scanner module



# User script example: geometry

```
#      R E P E A T  M O D U L E  
/gate/module/repeaters/insert ring  
/gate/module/ring/setRepeatNumber 8
```

A complete tomograph



# User script example: physics

```
/gate/physics/addProcess IonInelastic
```

```
/gate/physics/processes/IonInelastic/setModel G4BinaryLightIonReaction (All)
```

```
/gate/physics/processes/IonInelastic/setModel G4LEAlphaInelastic alpha
```

```
/gate/physics/processes/IonInelastic/G4BinaryLightIonReaction/setEmin 80 MeV alpha
```

```
/gate/physics/processes/IonInelastic/G4BinaryLightIonReaction/setEmax 20 GeV alpha
```

```
/gate/physics/processes/IonInelastic/G4LEAlphaInelastic/setEmin 0 MeV alpha
```

```
/gate/physics/processes/IonInelastic/G4LEAlphaInelastic/setEmax 80 MeV alpha
```

```
/gate/physics/processes/IonInelastic/setDataSet G4IonsShenCrossSection
```

# The OpenGATE Collaboration

21 institutes (Bulgaria, Chile, France, Germany, Greece, Holland, Korea, USA)

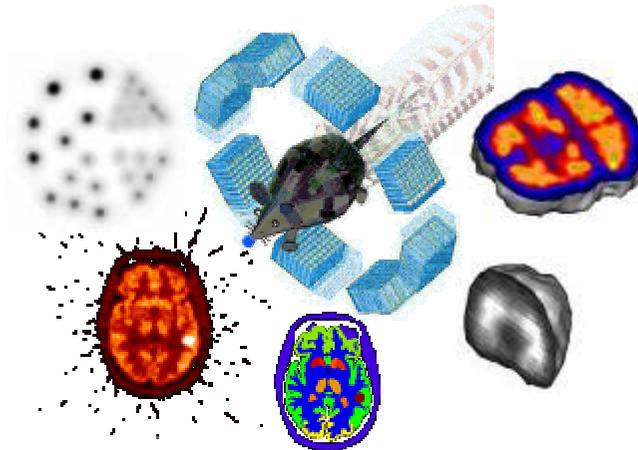
→ *development* and *validation* of the GATE software

- First public release: 2004 → 12 public versions (Open source)
- ~1500 users
- User support (mailing list – training courses – documentation)

→ **GATE community**

GATE: a simulation toolkit for PET and SPECT, Physics in Medicine and Biology, 2004

2009 "Citations Prize" award (most citations in the preceding five years)



# The OpenGATE Collaboration

Complementary to G4 → **Application oriented**

## PET/SPECT

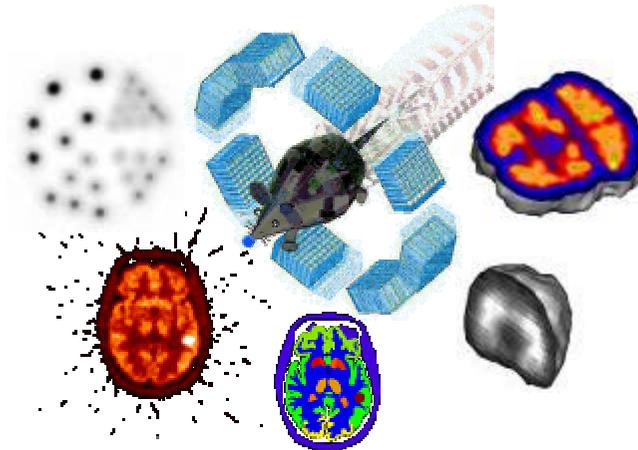
- validated
- dozens of publications



**CT scan**



**Radiotherapy/  
Hadrontherapy**



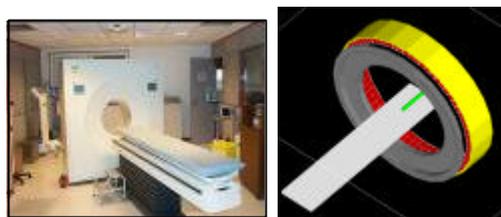
# Outline

- GATE overview
- **Main features**
- Examples

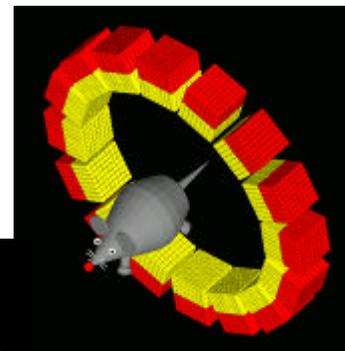
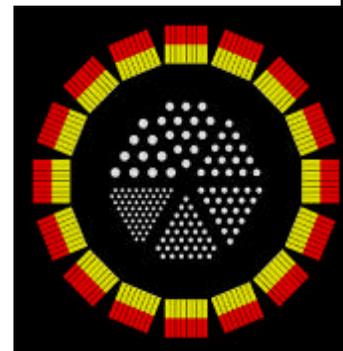
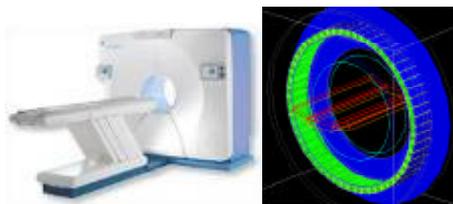
# Geometry

- Standard G4 volumes
- Voxelized images - new navigator (phantoms/patients)
- Movement
- Ionization potential
- Example of systems already modeled:

*Siemens - ECAT EXACT HR+*



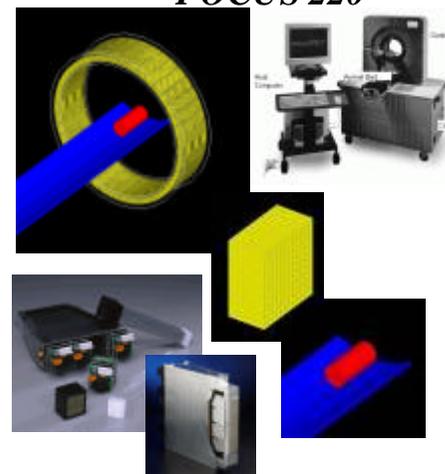
*GE - Advance*



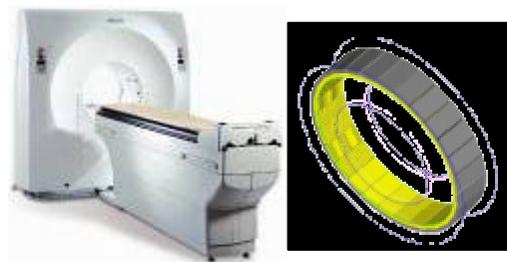
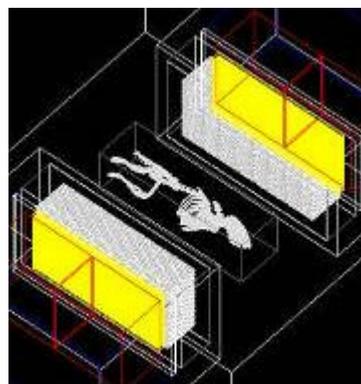
*Elekta - Precise*



*microPET FOCUS 220*



*Philips - Allegro*



*Courtesy of the OpenGATE collaboration*

# Time

Time dependent phenomena:

- system movements
  - SPECT, PET or CT detector (rotation/translation)
  - multi-leaf collimator
  - patient / phantom
- source decay kinetics

# Physics

## Processes:

- EM processes (Standard, Low energy, Penelope)
- Hadronic processes (flexible selection of models and cross sections)  
/gate/physics/addProcess IonInelastic alpha

## Optimization:

- Production cuts per region  
/gate/physics/Electron/SetCutInRegion myVolume 0.1 mm
- Step limiter  
/gate/physics/SetMaxStepSizeInRegion patient 0.1 mm
- User limits
- EM options  
/gate/physics/processes/ElectronIonisation/setStepFunction 0.2 0.1 mm

## Variance reduction

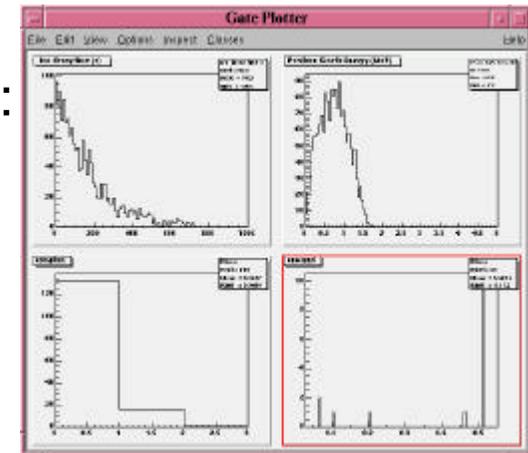
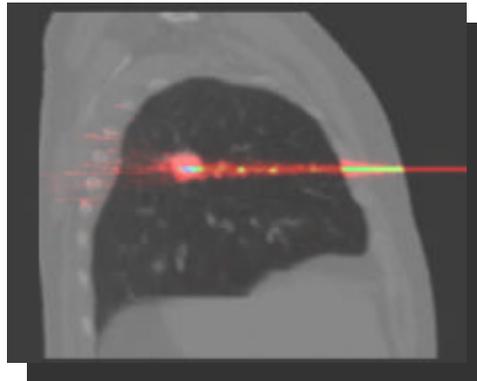
- Splitting/Russian roulette (parametrizable with filters)  
/gate/physics/processes/Bremsstrahlung/setSplitting
- Fictitious cross section  
/gate/physics/addProcess Fictitious

# Output

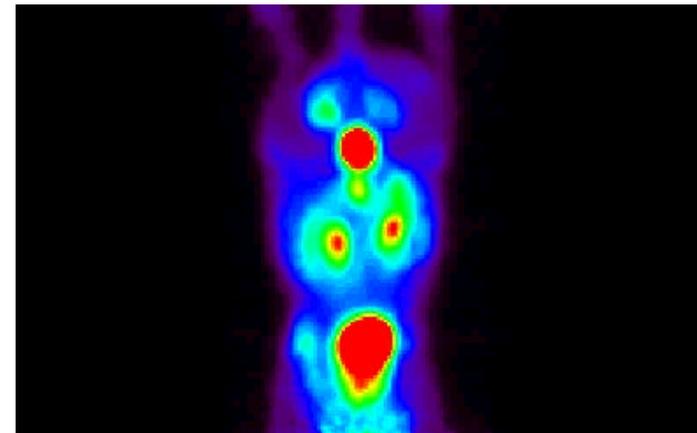
- Output file format: ROOT, ASCII, LMF, image (interfile, ECAT, Raw sinogram....)

- “Actors” + Filters (based on G4 scorers and G4Filters): allow to get any information anywhere in the simulation or to modify simulation behavior

- 3D dose scorer
- Simulation statistic
- Track killer
- .....



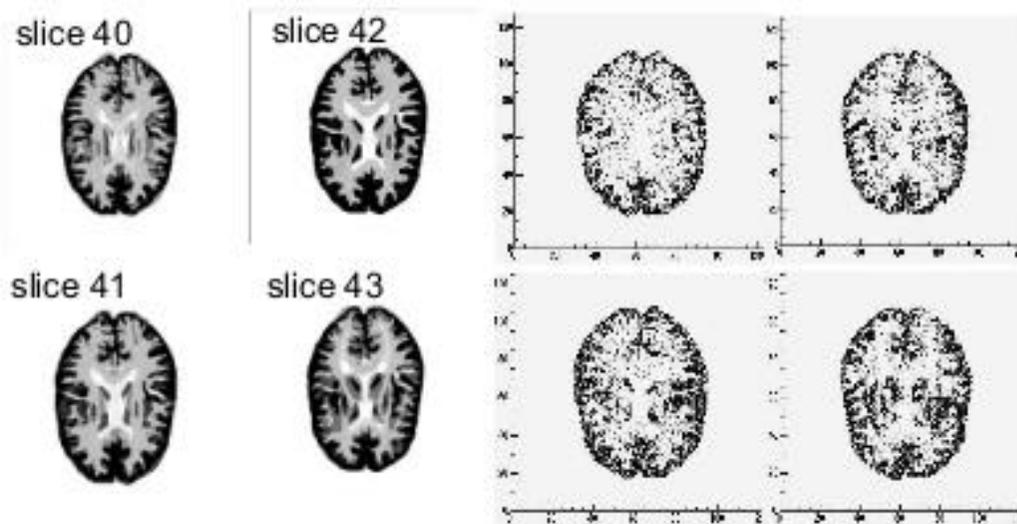
- PET/SPECT detector response and electronic treatments (front end, coincidences, blurring, dead time...)



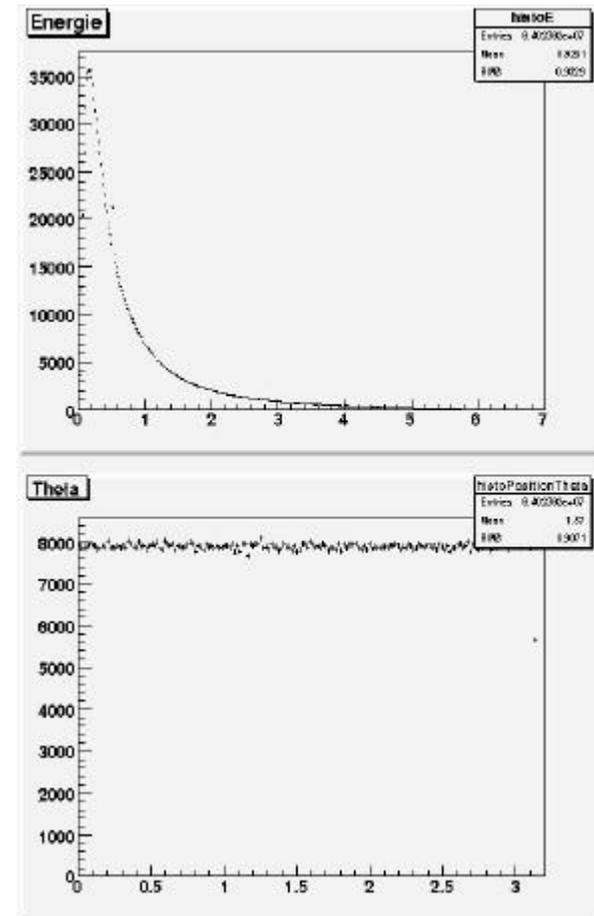
*Courtesy of the OpenGATE collaboration*

# Source

- Standard G4 GPS
- Voxelized image



- Phase space



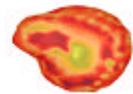
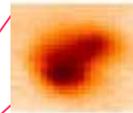
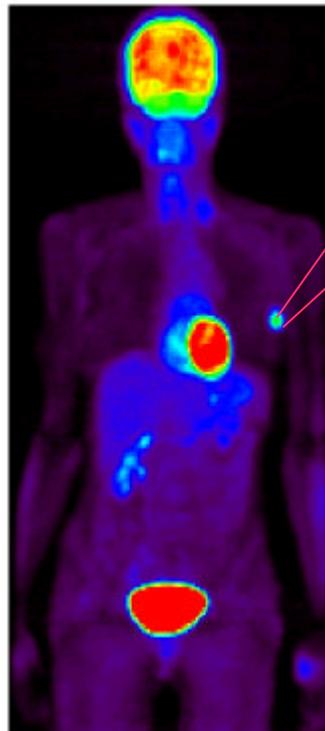
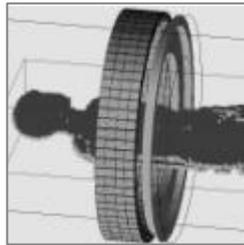
*Courtesy of the OpenGATE collaboration*

# Outline

- GATE overview
- Main features
- **Examples**

# Oncology: Simulation of a whole body PET scan

- Start acqui. : 264 MBq
- 7 bed positions
- 7' per bed position



*Tumor volume  
22 ml*

Courtesy of CEA

**2006:**

13 h. & 7000 CPUs

Including attenuation



Speed-up factor ~ 10

**2009:**

48 h. & 200 CPUs

# Molecular and pre-clinical imaging

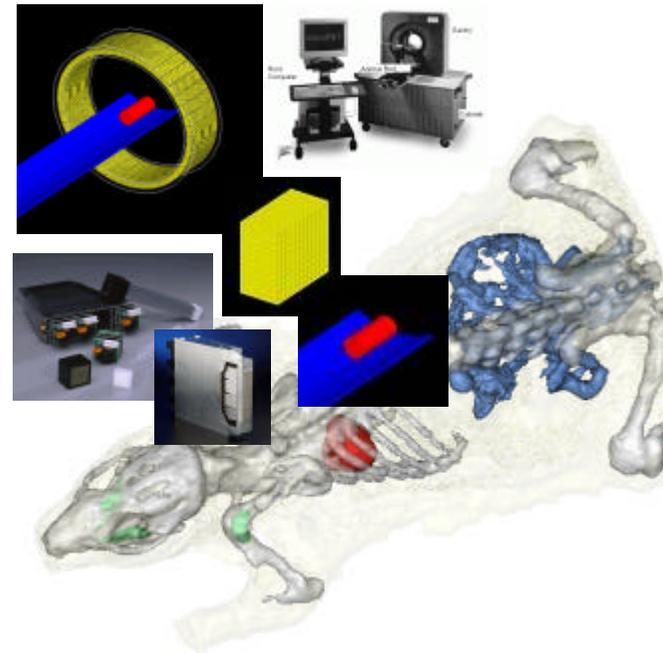
CT scan: attenuation



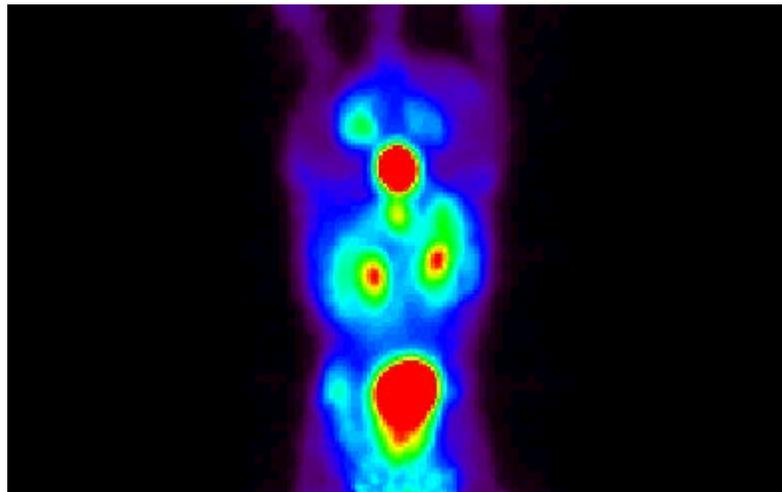
Full numerical phantom



GATE  
simulation



Simulation result



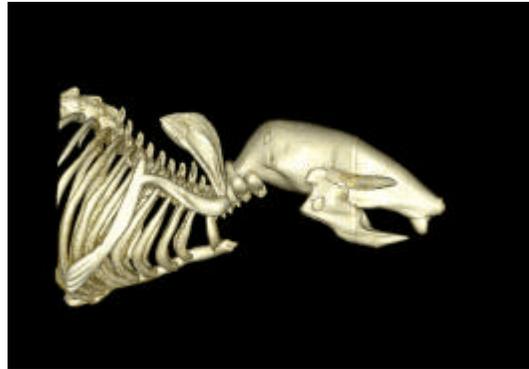
## [<sup>18</sup>F]FDG scan simulation

- microPET FOCUS 220 system
- Injected dose: 200  $\mu$ Ci
- Start acquisition: 45 min. after injection
- Acquisition time: 15'

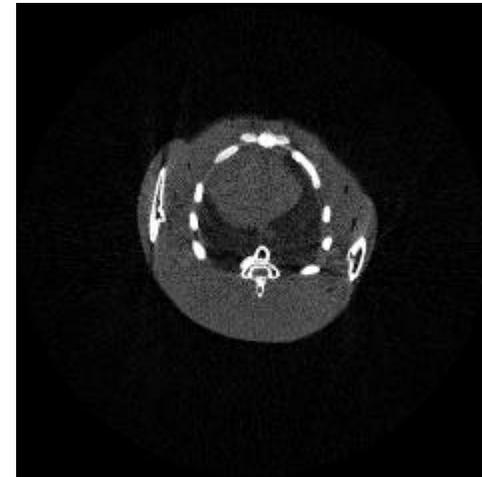
[ Jan *et al* - 2005 ]

# CT imaging

4D MOBY phantom

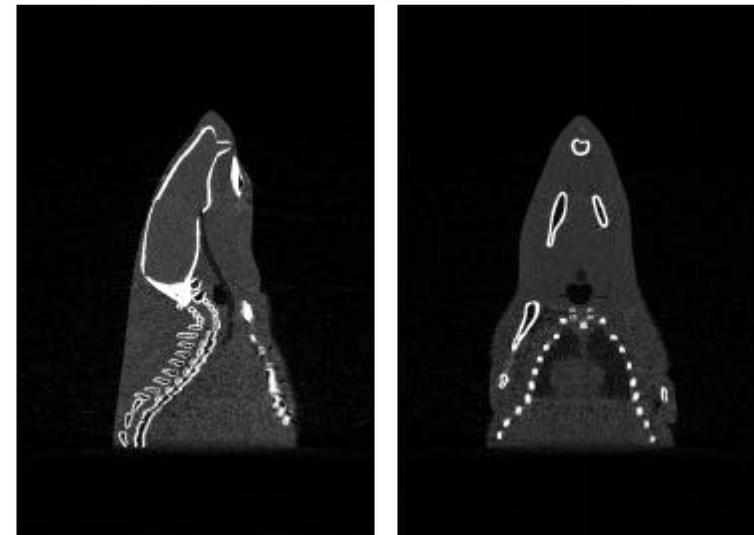
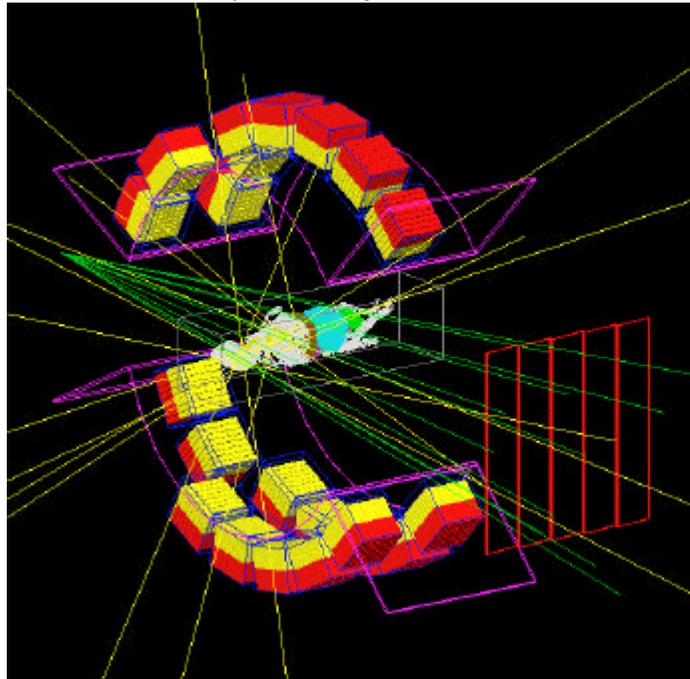


Simulation:  
24h & 10 CPU



PIXSCAN-XPAD3 (developed in CPPM, Marseille)

X-ray beam  
17 keV

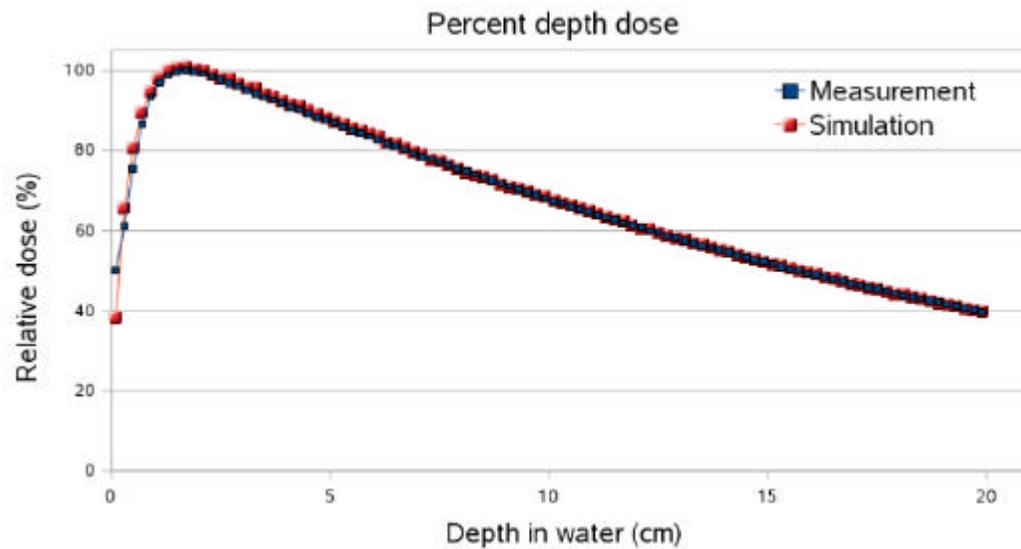
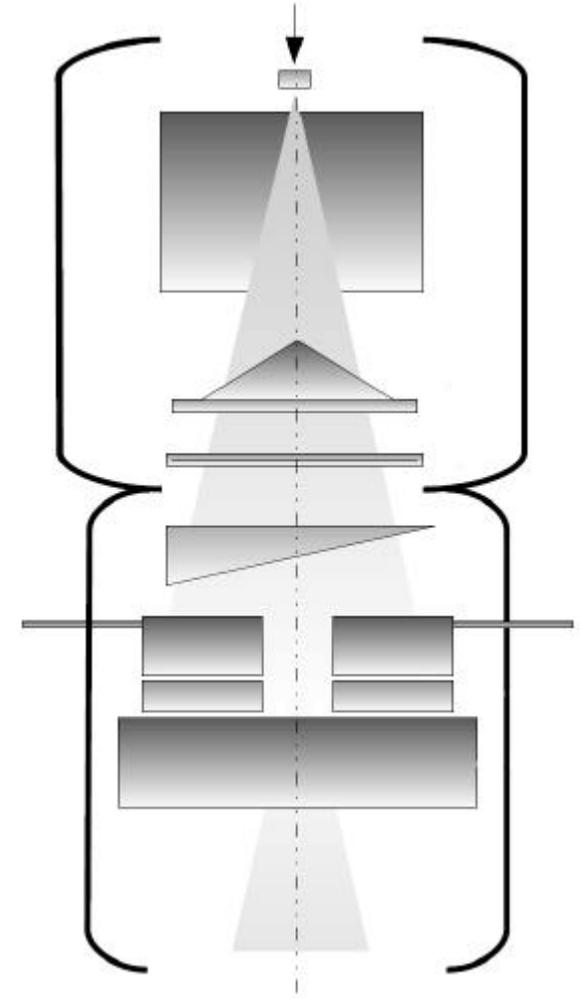
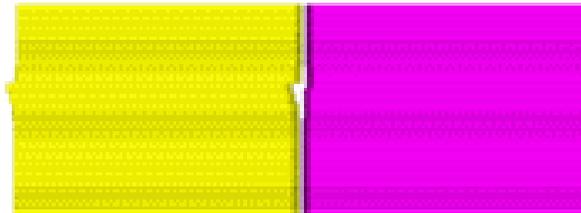


[ A. Bonissant *et al* - to be published in proceedings of ITBS09 ]

Courtesy of imXgam group (CPPM)

# Radiotherapy

Precise - Elekta



[ L. Grevillot *et al* – Submitted ]

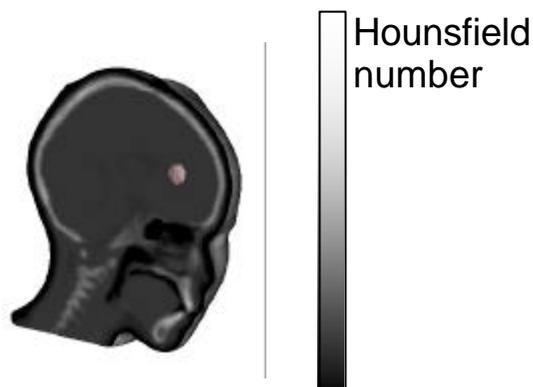
# Hadron-PET

Monitoring of the deposited dose using PET imaging for a  $^{12}\text{C}$  treatment

→ feasibility test

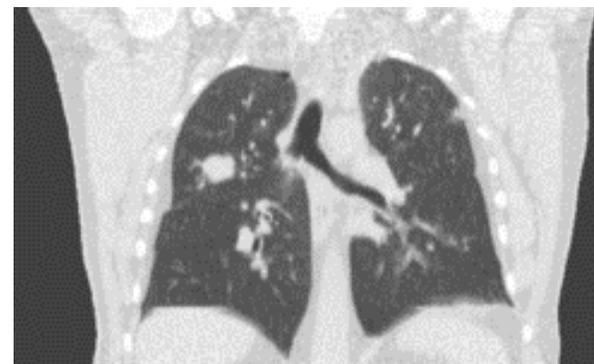


1 beam -  $9 \cdot 10^8$   $^{12}\text{C}$



3 beams  $10^8$   $^{12}\text{C}$

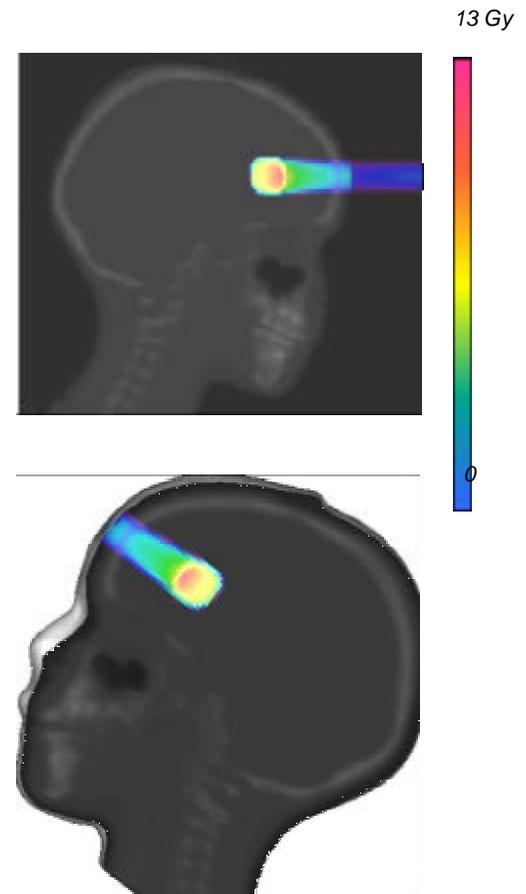
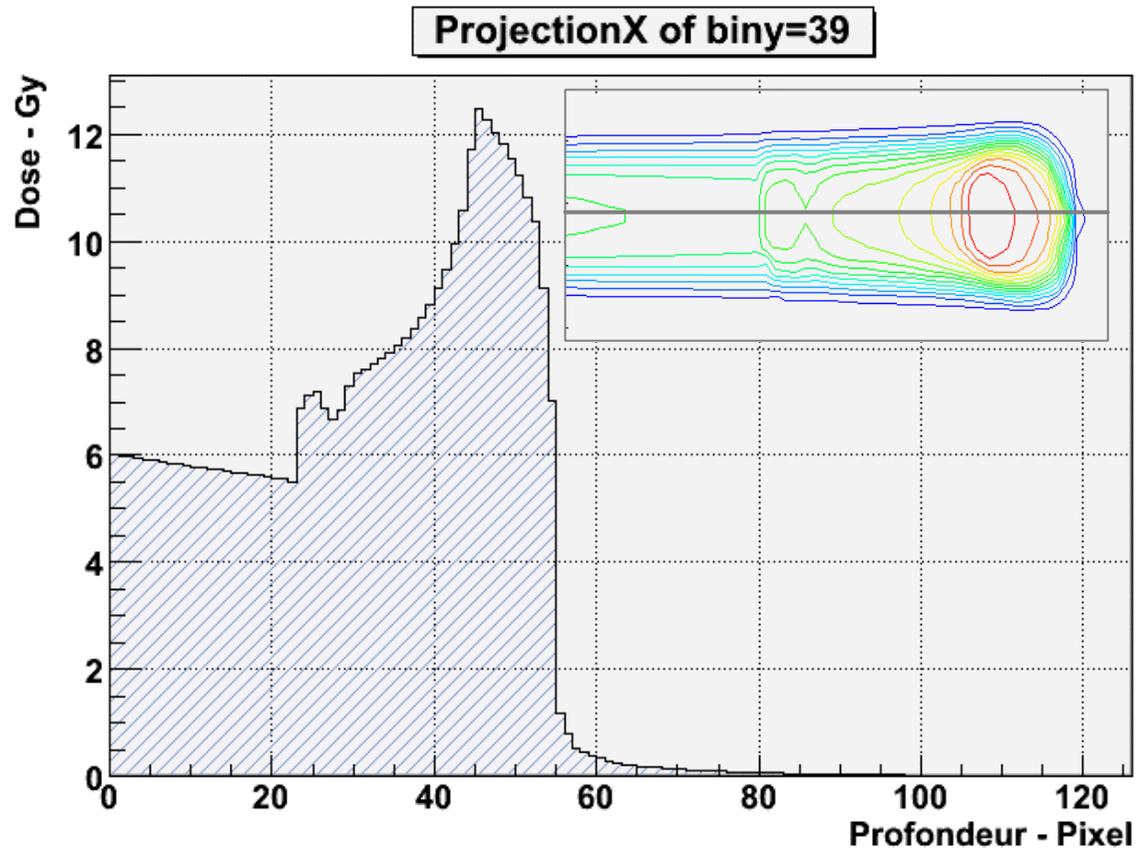
Complete breathing cycle from 4D CT



Classical PET system – 20 min post-irradiation acquisition

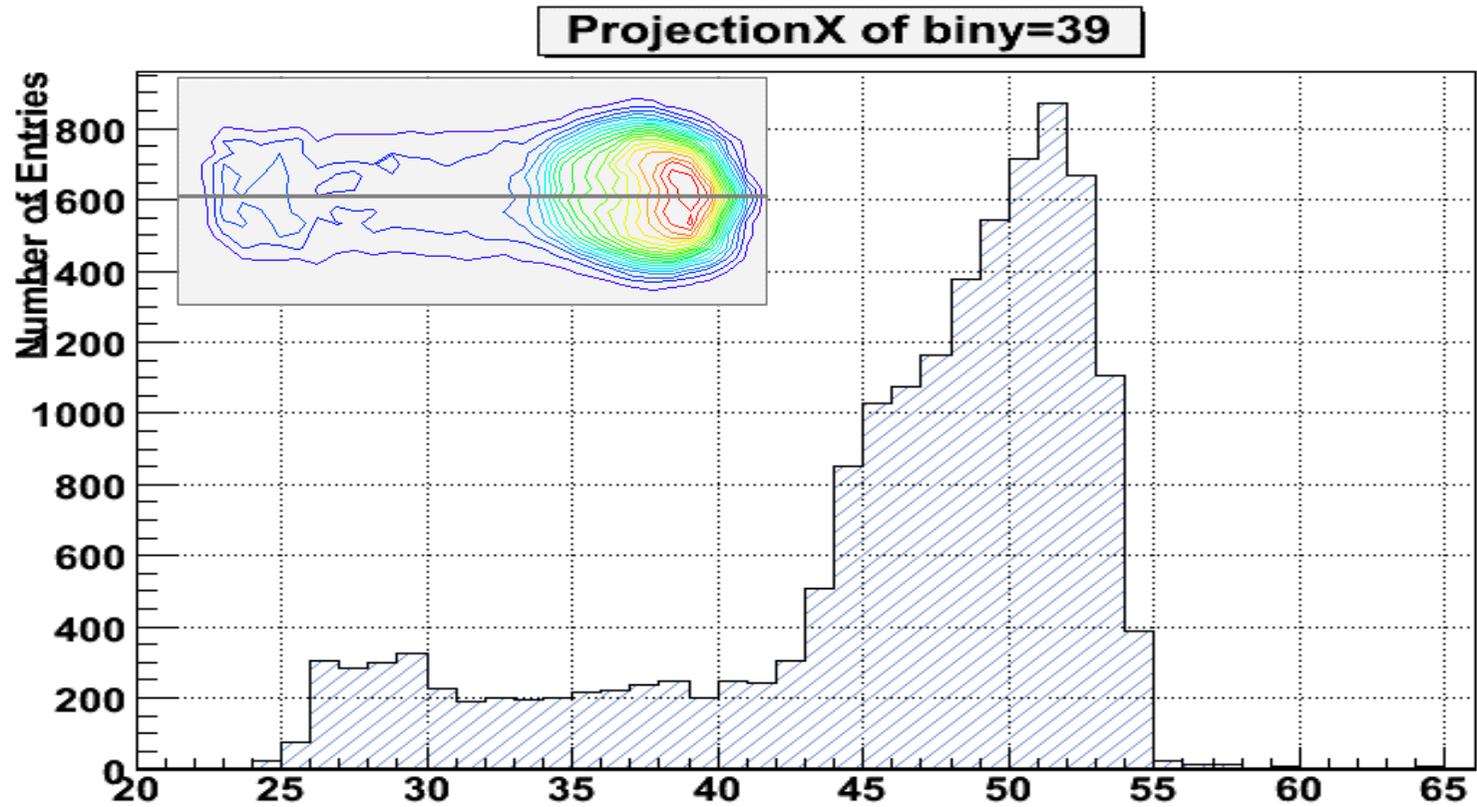
# Hadron-PET

$^{12}\text{C}$  deposited dose



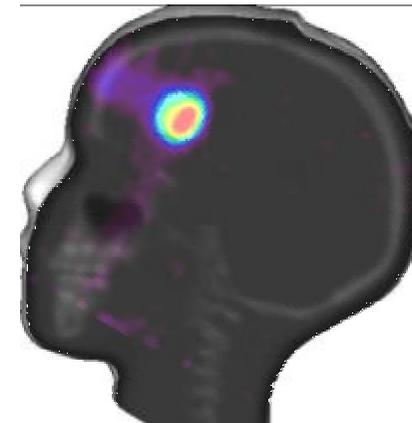
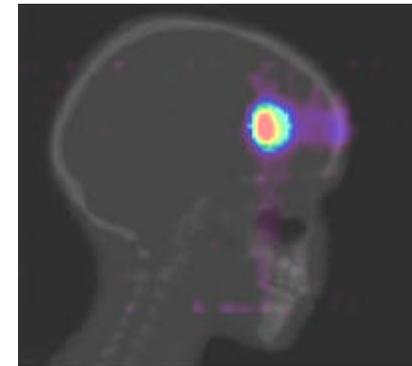
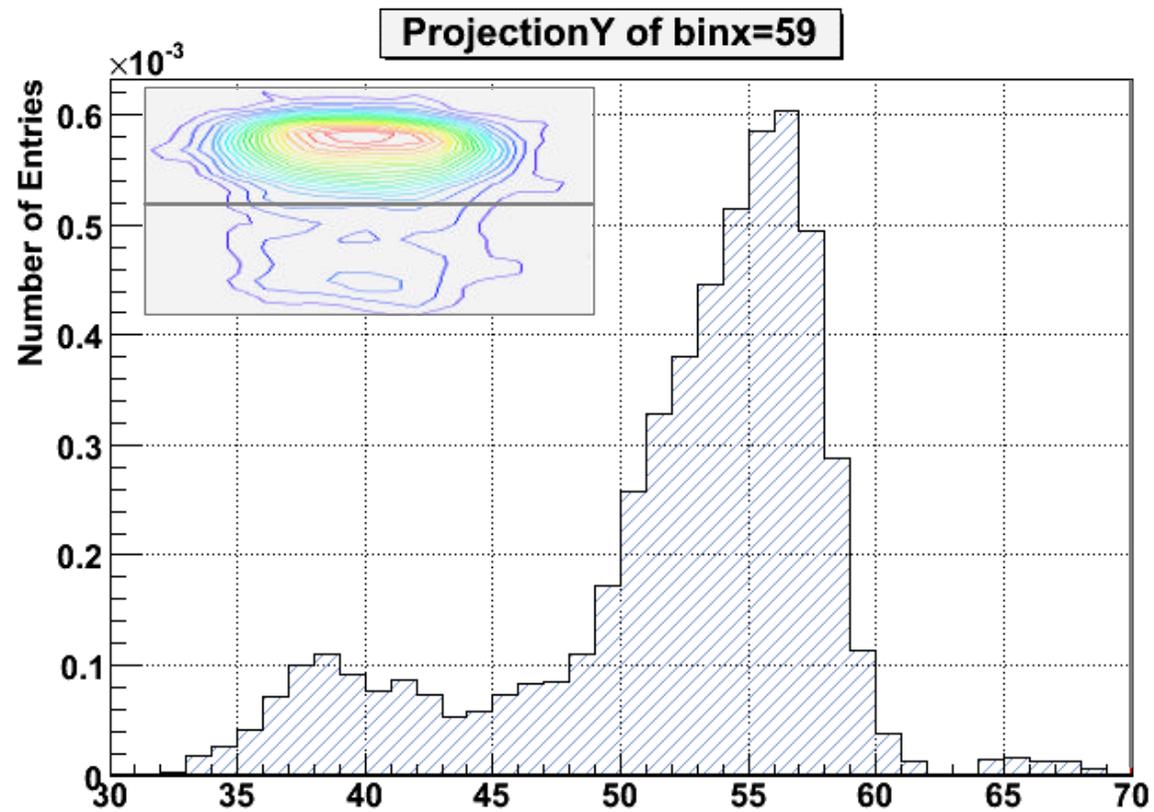
# Hadron-PET

Map of  $^{11}\text{C}$  with  $E_{\text{kin}} = 0$



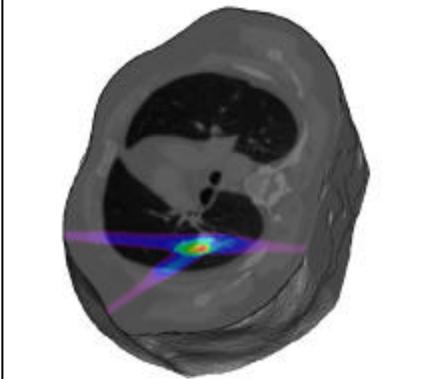
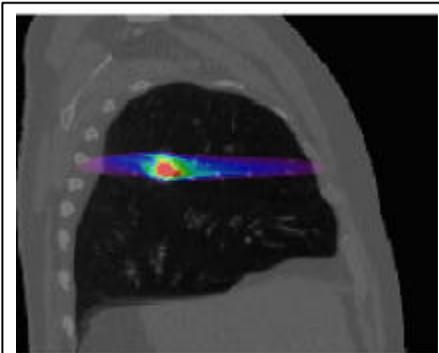
# Hadron-PET

$^{11}\text{C}$  PET imaging

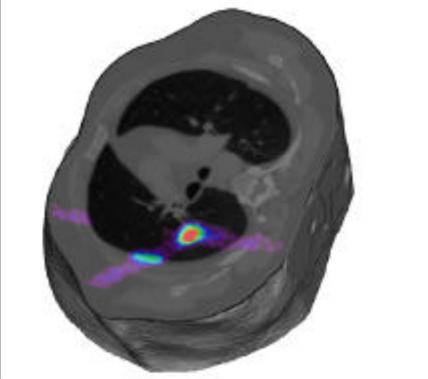
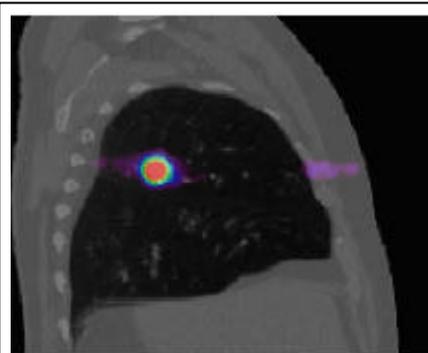


# Hadron-PET

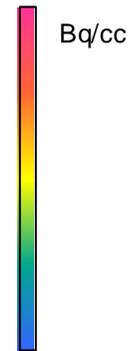
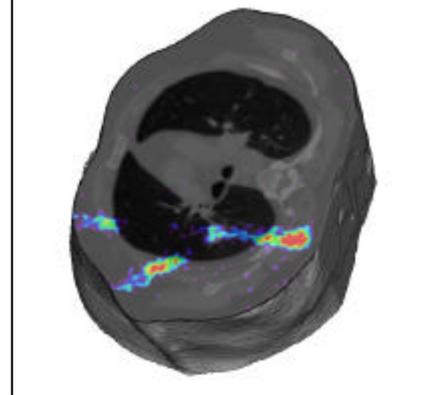
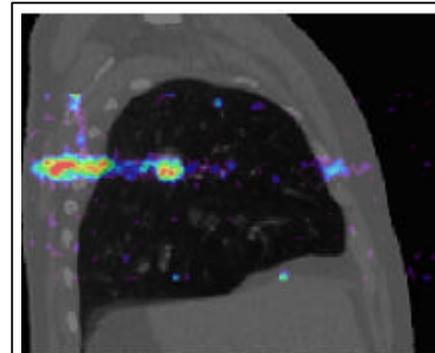
Deposited dose



$^{11}\text{C}$  PET imaging



$^{15}\text{O}$  PET imaging



Work in progress.....

# Conclusion

Simulation platform for medical applications

- Application oriented
- Complementary to G4

PET/SPECT → Validated and commonly used

CT scan

Radiotherapy / Hadrontherapy

} In development

**GATE version 6.0 → December 2009**

# Futur

## Next step:

- Optical imaging
- GPU

## Major questions:

- CAD
- Hadronic physics validation

# Contacts

<http://www.opengatecollaboration.org>

- **Irène BUVAT**, collaboration spokesperson – *buvat@imnc.in2p3.fr*
- **Sébastien JAN**, collaboration technical coordinator - *sebastien.jan@cea.fr*
- **Nicolas KARAKATSANIS**, GATE efficiency optimisation working group coordinator – *knicolas@mail.ntua.gr*
- **Dimitris VISVIKIS**, dosimetry application working group coordinator – *visvikis@univ-brest.fr*

GATE Workshop – MIC NSS IEEE 2009, Orlando – 29 october 2009