



Workshop 7 : GATE



Extending GATE for dosimetry : radiotherapy and hadrontherapy applications

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CENTRE RÉGIONAL

LÉON-BÉRARD

Soigner, chercher, vaincre. Ensemble

Creatis



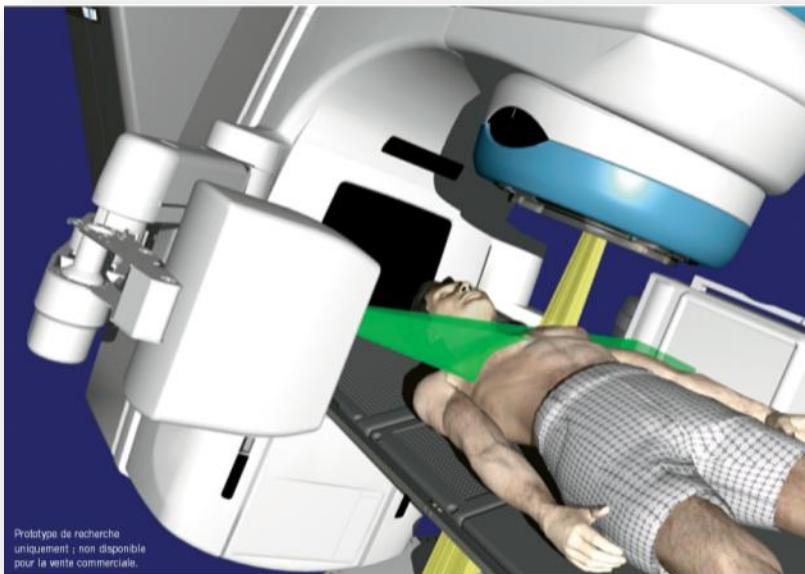
- Goal : provide extended tools for dosimetry needs
 - Radiotherapy
 - Hadrontherapy (e.g. Hadron-PET)
 - *Next Gate Release (2009)*

- Associated goal :
 - tools must be as simple as possible
 - **KISS** method : “Keep It Stupid & Simple”



Radiation therapy

- Cancer treatment : kill tumor cells
 - Radiotherapy : photon beam
 - Hadrontherapy : proton/carbon beam



LINAC (photon beam)

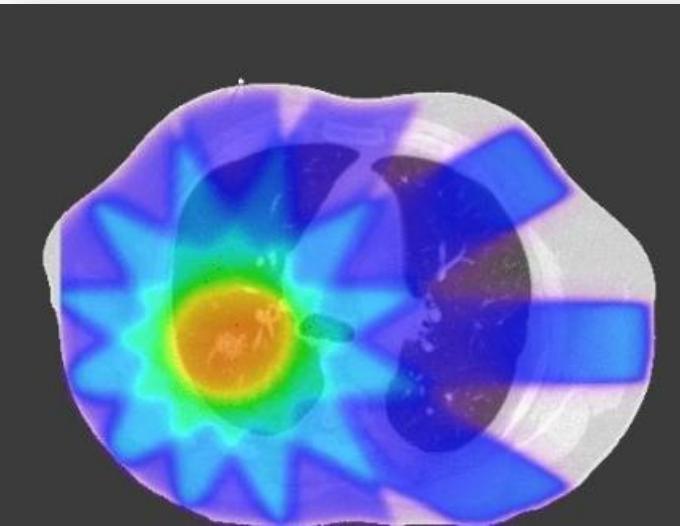


Cyclo/Synchro-tron (carbon beam)

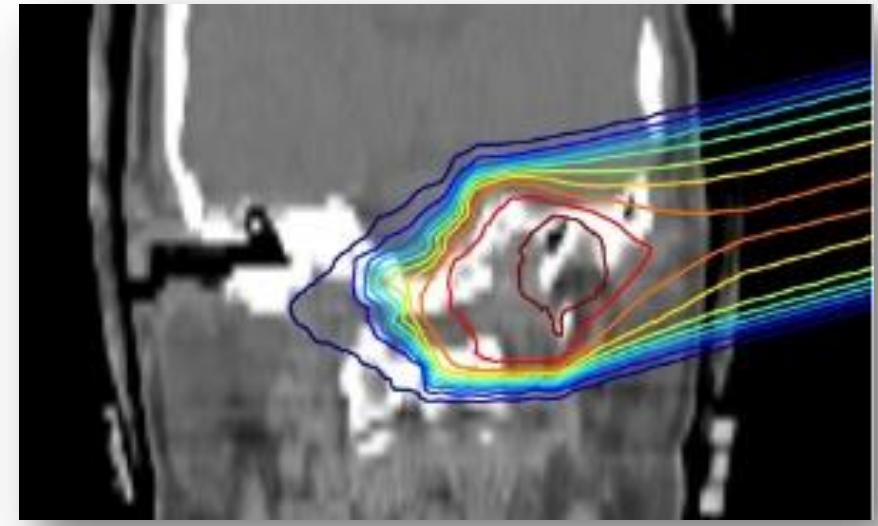


Radiation therapy

- Cancer treatment
 - 3D dose distribution
 - Patient = from CT image
 - External source of particles



Dose from 12 photons beam fields



Dose from 1 carbon beam



Radiation therapy

- **Codes :**
 - BeamNrc (EGS4), Penelope, Fluka, MCNPX, Peregrine, etc.
- **Radiation therapy simulations with G4**
 - Well adapted : time, complex geometry, hadronic processes
 - A lot of papers, but few code sharing



New GATE functionalities for radiotherapy and dosimetry applications



Added tools

- Particles – processes
 - Extended to hadron
 - Macro to set hadronic processes, models & cross-section tables

```
/gate/physics/addProcess IonInelastic
/gate/physics/processes/IonInelastic/setDataSet G4IonsShenCrossSection
/gate/physics/processes/IonInelastic/setModel G4BinaryLightIonReaction
```



Added tools

- 3D dose map (separated from geometry)
 - Voxels = from the image geometry
 - Doselets = volume element for dose

/gate/actor/addActor	DoseActor dose
/gate/actor/dose/attachTo	volumeName
/gate/actor/dose/attachTo	100 100 100
/gate/actor/dose/saveIn	doseFile.hdr
/gate/actor/dose/saveEveryNEvents	1000

- 1D/2D/3D dose map
- Dose / deposited energy / # of hits
- Statistical relative uncertainty
- Squared values (for job splitting)
- Output formats : **Root** or **3D image**



Added tools

- Variance reduction

- Splitting : generate n particles with weight <1
- Russian Roulette : generate 1/n particle with weight >1



**Warning : your
scorer/digitizer**

**must be able to deal with
particle's weight !
*(previous 3D doser does !)***

/gate/physics
/gate/physics

/gate/physics

/gate/physics

/gate/physics

/gate/physics

/gate/physics

vf

10 MeV

20 MeV



Added tools

- Different **cuts** in different volumes

```
/gate/physics/Gamma/SetCutInVolume world 0.5 mm  
/gate/physics/Electron/SetCutInVolume patient 0.1 mm
```



By default, cuts values are inherited from mother volume (except if specified)

- Kill particles inside a given volume

```
/gate/actor/addActor KillActor killer  
/gate/actor/killer/attachTo volumeName
```



Added tools

- 3D images management
 - Alternative voxel navigator
 - region-based + distance map
 - Sometimes faster (to be benchmarked)
 - [Sarrut et al. Med Phys 2008]
 - Very simple to use

/gate/world/daughters/ name	mypatient
/gate/world/daughters/ insert	ImageRegionVolume
/gate/mypatient/geometry/ setImage	myimage.hdr
/gate/mypatient/geometry/ setMaterialsTable	myHU2mat.txt



Added tools

- **Phase-Space**

- Store every particle passing in a volume
(type, position, direction, energy ...)
- Output in Root file
(files can be very large ...)

ROOT

An Object-Oriented
Data Analysis Framework



/gate/actor/**addActor**

PhaseSpaceActor **phsp**

/gate/actor/**phsp/attachTo**

volumeName

/gate/actor/**phsp/save**

myphasespace.root



Two (quick) examples

- Linac accelerator head simulation
- Respiratory motion in carbon ion beam irradiation



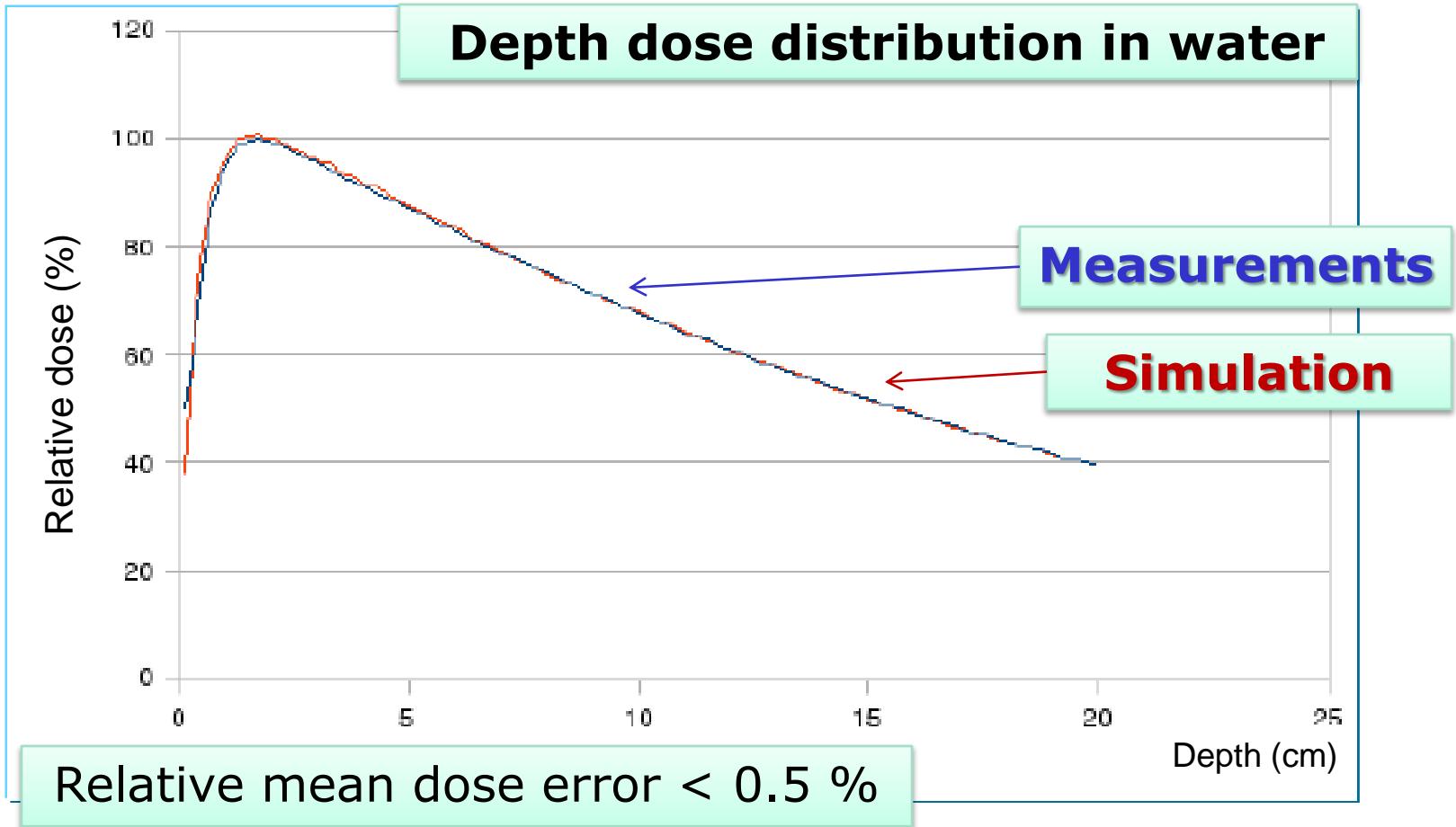
Example n°1 : linac simulation

- Linac = Elekta Precise
- Goal : to predict output Photon beam
- 2 parts :
 - From e- source to collimator (phase-space)
 - From collimator to patient (source model)
- Used tools : splitting, phase-space, cuts by volume ...





Example n°1 : linac simulation

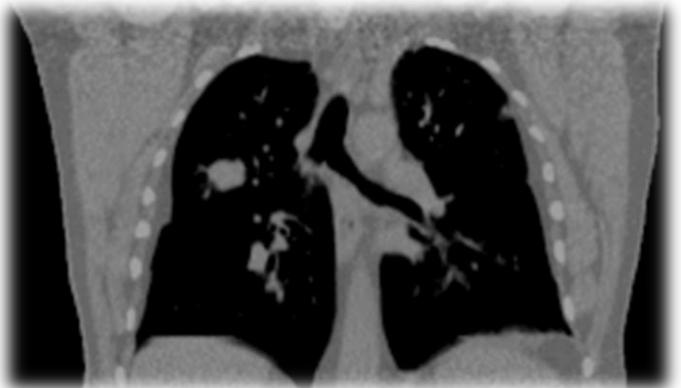


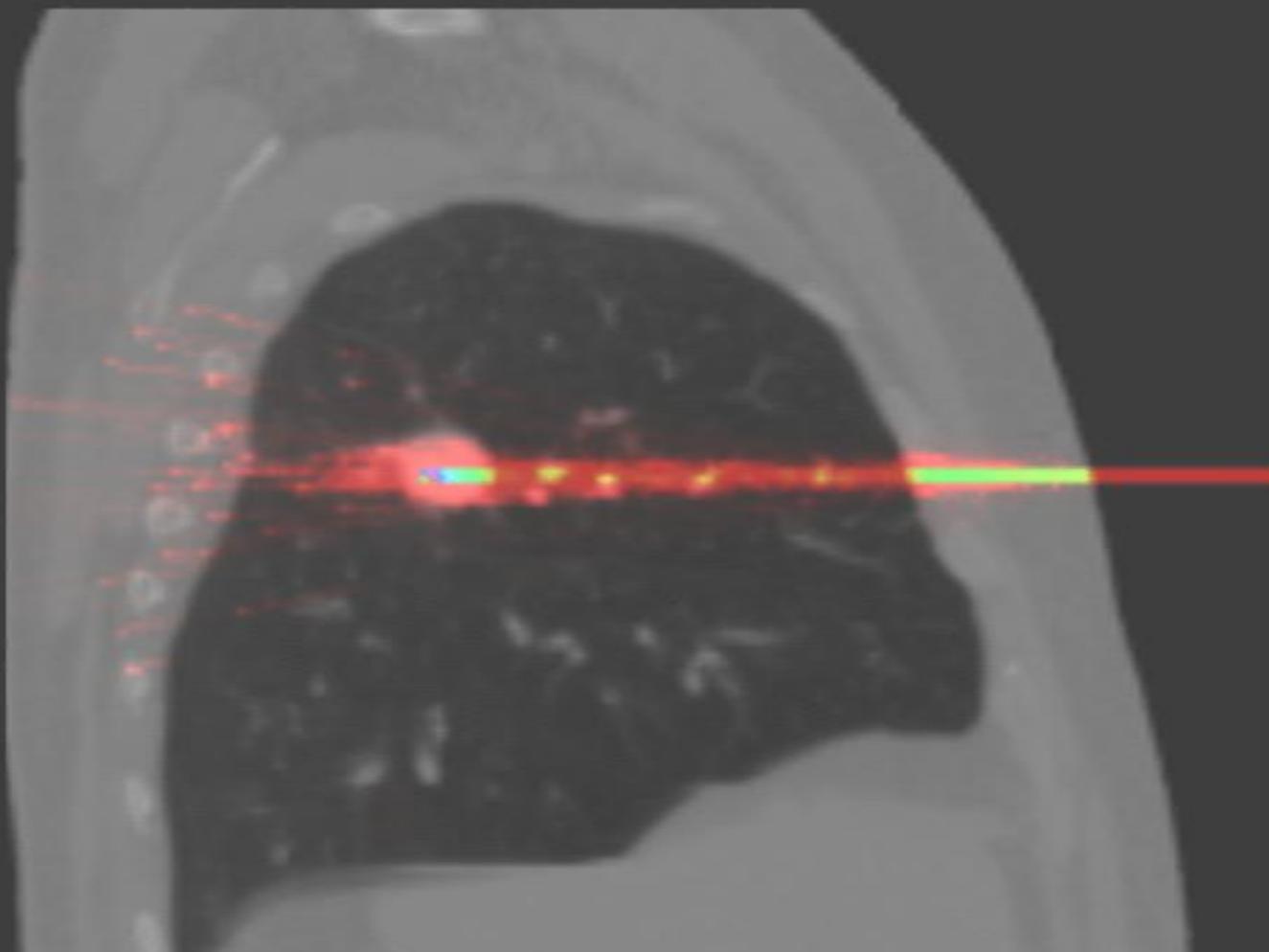


Example n°2 : Hadrontherapy

- Hadrontherapy
 - Carbon ion beam (290 MeV/u)
 - CT image
- Difficulty with moving organ : lung tumor moves due to patient breathing
 - 4D CT image

Goal :
compute 3D+t dose distribution





3D deposited energy distribution in breathing patient with 290 MeV/u carbon ion beam

- 4D CT dataset, 10 simulations
- $10k C^{12} = 1 \text{ hour (1 CPU)}$
- **only about 150 lines of macro commands**



Conclusion

- Set of tools « à la GATE »
- Designed for specific applications
 - All macros names presented here can (probably will) be modified in the final release.
 - But useful for other applications
 - splitting, phase-space, ...
- Available in the next release of Gate



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Creatis



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