GATE activities @ CRCT

Dosimetry for Nuclear Medicine and Radiotherapy

maxime.chauvin@inserm.fr

CRCT - Team 15

“Multiscale dosimetry for radiotherapy optimization”

Internal Radiotherapy (2 Postdocs, 2 PhDs, 3 Researchers):

- SPECT simulations: Gunjan Kayal (PhD)
- Slicer tool for dosimetry: Alex Vergara Gil (PhD)
- OpenDose: Maxime Chauvin (Postdoc)

External Radiotherapy (1 Postdoc, 2 PhDs, 2 MScs, 3 Researchers):

- D_m to D_w conversion: Victoria Fonteny (MSc)
- SBRT - Interplay: Jeremy Leste (PhD)
- SBRT - EPID dosimetry: A. Rita Barbeiro (Postdoc)

7 users-developers

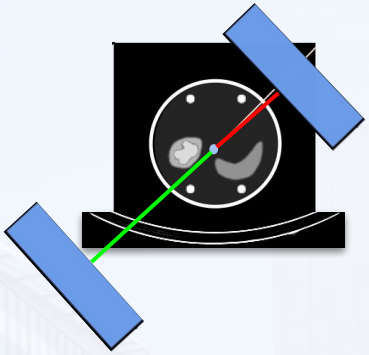
SPECT simulations: Gunjan Kayal (PhD)

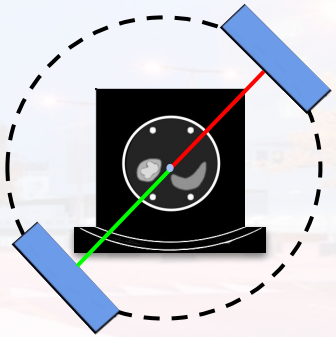
Heads Circular Orbit

Orbiting

Rotating a volume around any axis during a simulation is possible using the orbiting motion. degrees per second, the commands are:

```
/gate/SPECThead/moves/insert orbiting
/gate/SPECThead/orbiting/setSpeed N. deg/s
/gate/SPECThead/orbiting/setPoint1 0 0 0 cm
/gate/SPECThead/orbiting/setPoint2 1 0 0 cm
```





Positions extracted from DICOM files of SPECT

Heads Non Circular Orbit

Generic repeater move

You can combine generic repeater and generic move to allow different repeated configurations according to time. This is for example useful to describ which move according to each beam.

```
/gate/myvolume/moves/insert                                genericRepeaterMove
/gate/myvolume/genericRepeaterMove/setPlacementsFilename   data/myvolume.placements
/gate/myvolume/genericRepeaterMove/useRelativeTranslation 1
```

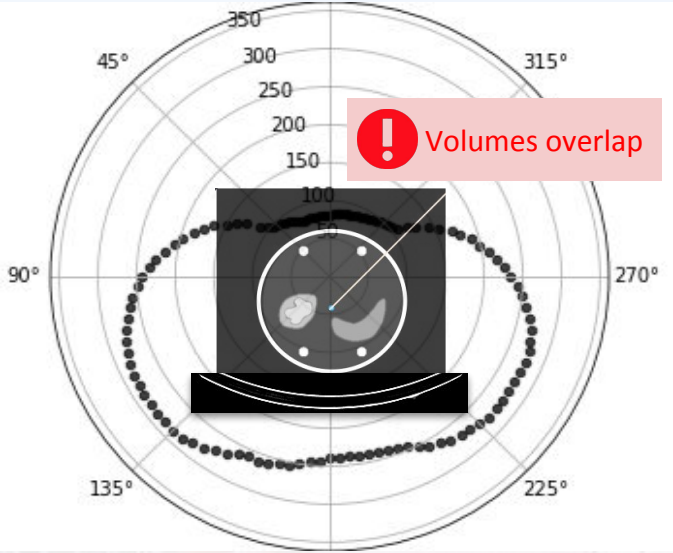
```
###### List of placement (translation and rotation)
###### Column 1      is rotationAngle in degree
###### Columns 2,3,4 are rotation axis
###### Columns 5,6,7 are translation in mm
Time s
NumberOfPlacements 3
Rotation deg
Translation mm
#Time  # Placement 1            # Placement 2            # Placement 3
0      10  0 1 0  20  0  0      10 0 1 0   80  0  0     10 0 1 0    -60  0  0
1      20  0 1 0  20 10  0      20 0 1 0   80 10  0     20 0 1 0    -60 10  0
2      30  1 1 0  20  0  0      30 1 1 0   80  0  0     30 1 1 0    -60  0  0
4      40  0 1 1  20  0 40      40 0 1 1   80  0 40     40 0 1 1    -60  0 40
```

The 'NumberOfPlacements' is needed to indicate how many different repetition are performed at each motion.

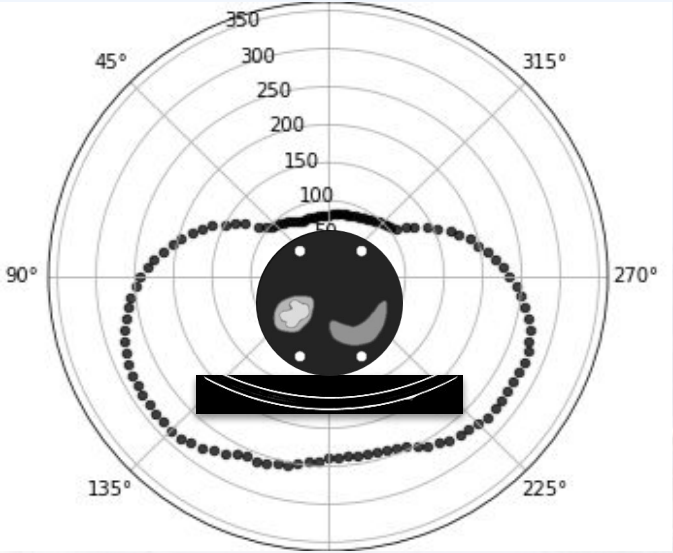
Work presented @ MCMA 2019

SPECT simulations: Gunjan Kayal (PhD)

Now we have:



What we need:



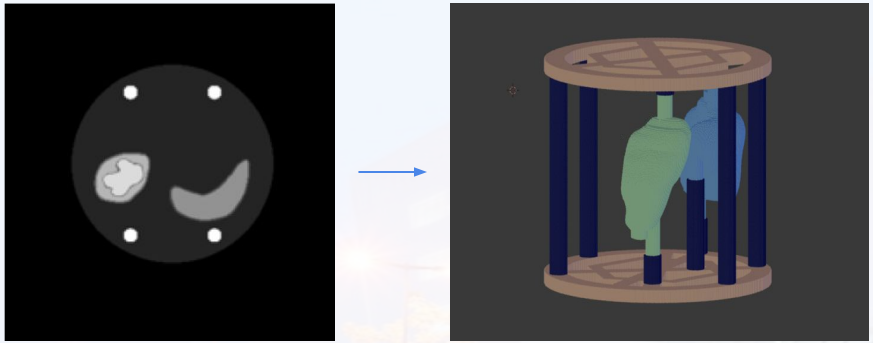
```
/gate/world/daughters/name anyname
/gate/world/daughters/insert
ImageNestedParametrisedVolume
```

```
/gate/world/daughters/name   anyname
/gate/world/daughters/insert
tessellated
```

Work presented @ MCMA 2019

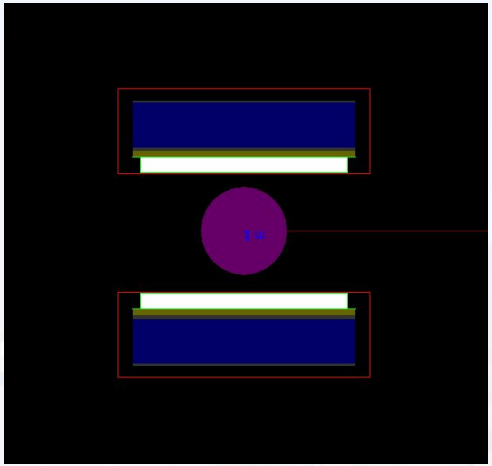
SPECT simulations: Gunjan Kayal (PhD)

From Voxelization to Tessellation:



python™ + blender®

Simulation:

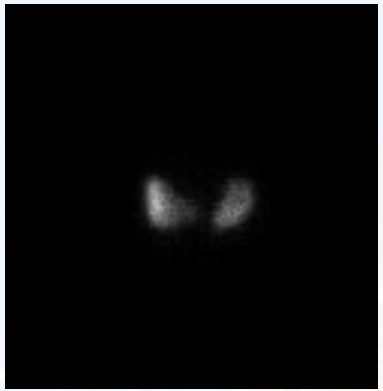


Collimator (white) ; Crystal (yellow); PMTs (blue); Electronics (red); Phantom (purple)

Work presented @ MCMA 2019

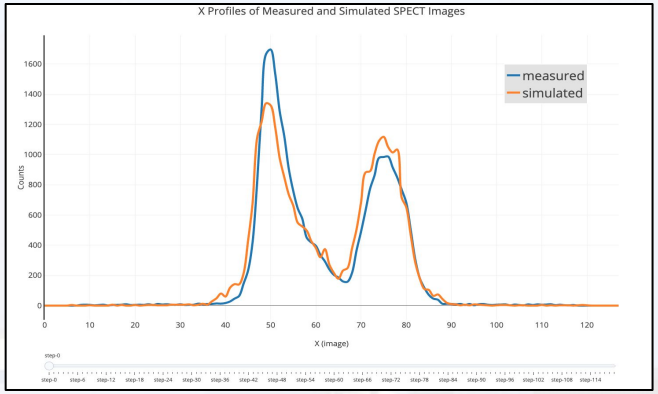
SPECT simulations: Gunjan Kayal (PhD)

Simulation Results compared to Experimental Images



Experimental SPECT

Simulated SPECT

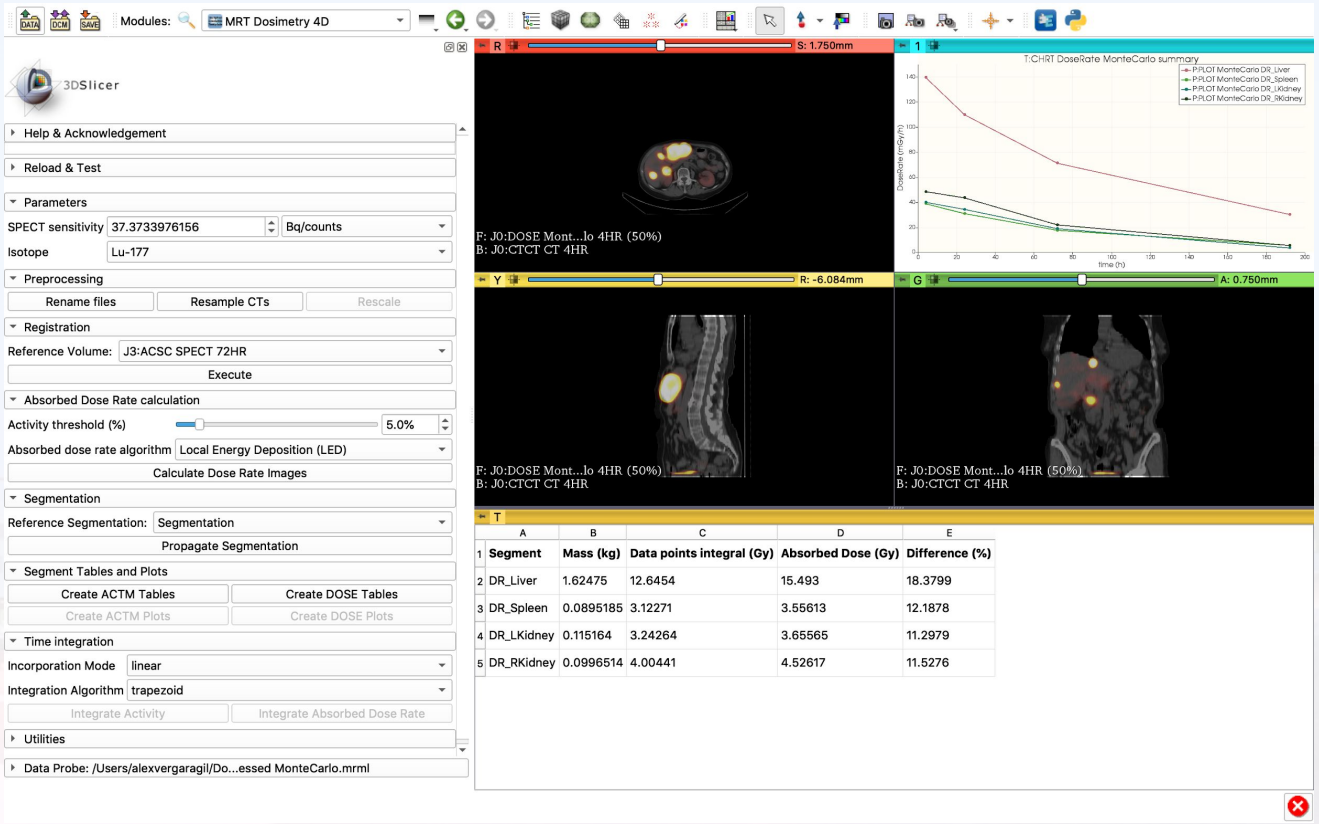


Siemens Symbia T2	2 detector heads	3 energy windows:	Activity*
⅝” NaI crystal	60 proj per head	208 keV (20%)	178.6 MBq in spleen
MEGP collimator	20s per proj	178 keV (10%)	108.7 MBq in right kidney cortex
		241 keV (10%)	16.1 MBq in right kidney medulla

Mean Squared Error (MSE): **113.001**
Structural Similarity Index (SSIM): **0.9456**
Peak Signal to Noise Ratio (PSNR): **24.952**

Work presented @ MCMA 2019

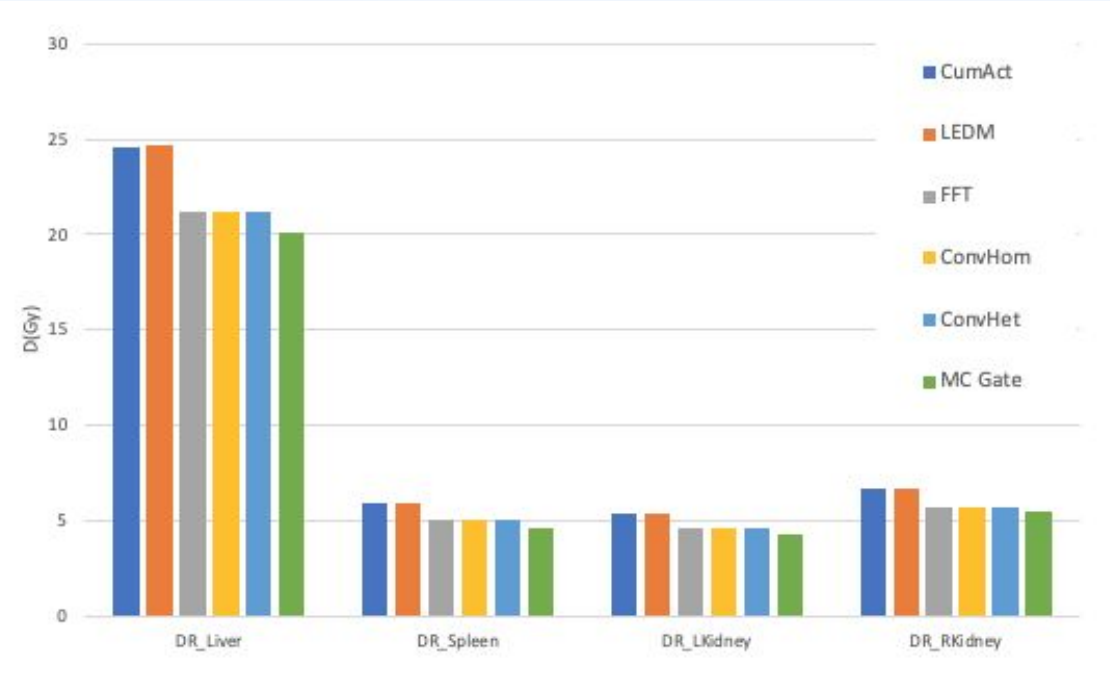
3DSlicer tool for dosimetry: Alex Vergara Gil (PhD)



	A	B	C	D	E
1	**Segment**	**Mass (kg)**	**Data points integral (Gy)**	**Absorbed Dose (Gy)**	**Difference (%)**
2	DR_Liver	1.62475	12.6454	15.493	18.3799
3	DR_Spleen	0.0895185	3.12271	3.55613	12.1878
4	DR_LKidney	0.115164	3.24264	3.65565	11.2979
5	DR_RKidney	0.0996514	4.00441	4.52617	11.5276

3DSlicer tool for dosimetry: Alex Vergara Gil (PhD)

Internal Dosimetry using Gate as gold standard:



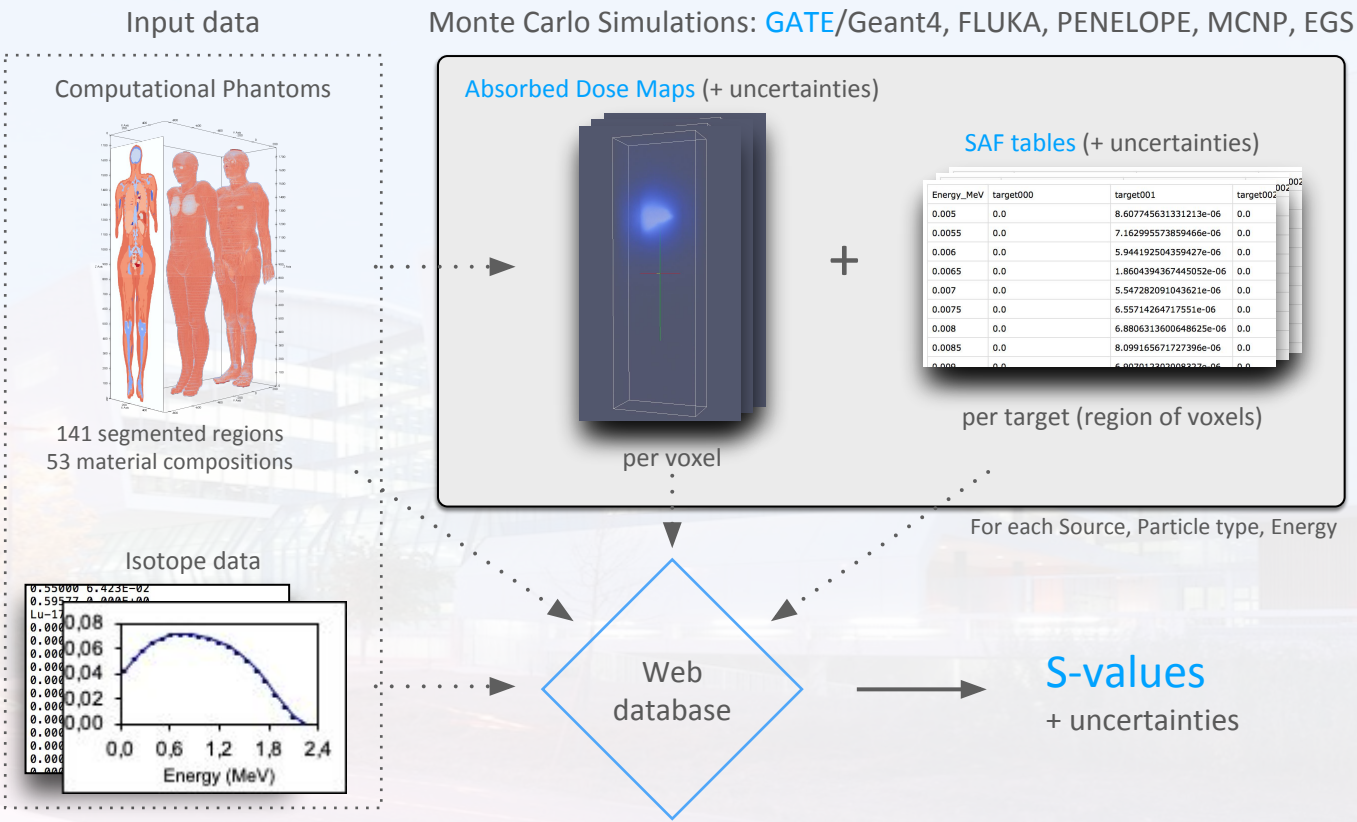
- A clinical case of Lu-177 was tested with different algorithms taking GATE as gold standard for absorbed dose calculation.
- The algorithms were implemented in a workflow[1] as a Slicer3D module.

[1]Gate can not be integrated in the workflow because requires too much time

OpenDose: Maxime Chauvin (Postdoc)

Developing a dosimetric database (SAFs, S-values) for Nuclear Medicine:

- collaborative data production (14 research teams)
- open and FAIR data
- data associated with uncertainties
- online access



OpenDose: Maxime Chauvin (Postdoc)

Data to produce for the digital models of ICRP 110:

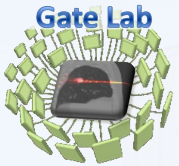
- 2 (female/male models) × 140 (sources) × 2 (particles) × 91 (energies) = 50960 simulations

Production status:

- CRCT (local cluster + EGI + GateLab):
  - **GATE 8.1**: 2 models, all sources from 5 keV to 60 keV (75% total)
  - **Geant4 10.5**: 2 models, all sources, all energies (100% total)
- CRUK (local cluster) with **PENELOPE_2014**: 1 model, 2 sources, 7 energies
- IEO-CNAO (local cluster) with **Fluka_2011**: 1 model, 2 sources, 7 energies
- IRSN (local cluster) with **MCNPXv2.6c**: 1 model, 3 sources, 7 energies
- NPL (local cluster) with **EGSnrc/EGS++ 2016**: 1 model, 2 sources, 7 energies
- SCK.CEN (local cluster) with **MCNPXv2.7**: 1 model, 2 sources, 7 energies
- SGH and UOW (local cluster) with **GATEv7.2**: 2 models, 80 sources, all energies (30% total)

OpenDose: Maxime Chauvin (Postdoc)

GateLab (VIP) developments thanks to OpenDose:



- New pipeline to update GATE releases on GateLab:
  - DockerFile which build a new image with Geant4, ROOT and GATE on CentOS
  - Script to extract the GATE binary and dependencies from the Docker image
  - Add an env.sh to ease the setup of Geant4 and ROOT environment variables
- Updated merger for the new DoseByRegions output
- New random seed behavior for split jobs when the seed is set manually:
  - The random seed is then incremented between jobs to insure no duplicates
- + now GateLab accepts command line aliases like GATE:
  - ALIAS is -a [Source_ID,95][particle,gamma][energy,0.00500][nb,10000][seed,2950001]

Work in collaboration with T. Baudier, A. Bonnet, S. Camarasu-Pop and G. Mathieu.

OpenDose: Maxime Chauvin (Postdoc)

- The website is online ! http://www.opendose.org

- It is developed in HTML5 + CSS, PHP and JavaScript

- The source code is versioned with Git in a private repository at GitLab

- The website is deployed in a Virtual Machine hosted at creatis.insa-lyon.fr :
  - Fedora 28, 4 virtual CPUs, 8 GB RAM, 250 GB disk size.

D_m to D_w conversion: Victoria Fonteny (MSc)

- Conventional algorithm such as AAA (Varian) express the absorbed dose in water (D_w)
- Deterministic algorithm such as AXB (Varian) and Monte Carlo Simulation express the absorbed dose in medium (D_m)

→ Need for a conversion

Several existing conversions dose to medium to dose to water :

$$D_w = D_m \, s^{BG}_{w,m} \text{ (Siebers, 2000)}$$

$$D_w = D_m \, s^{BG}_{w,med} \, k_\Phi \text{ (Andreo, 2014)}$$

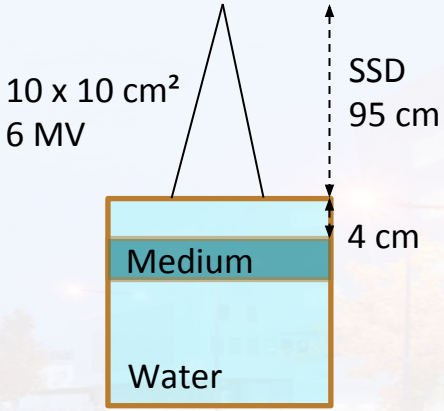
$$D_w = D_m \left(\frac{\overline{\mu_{en}}}{\rho}\right)_{w,m} \text{ (Reyneart, 2018)}$$

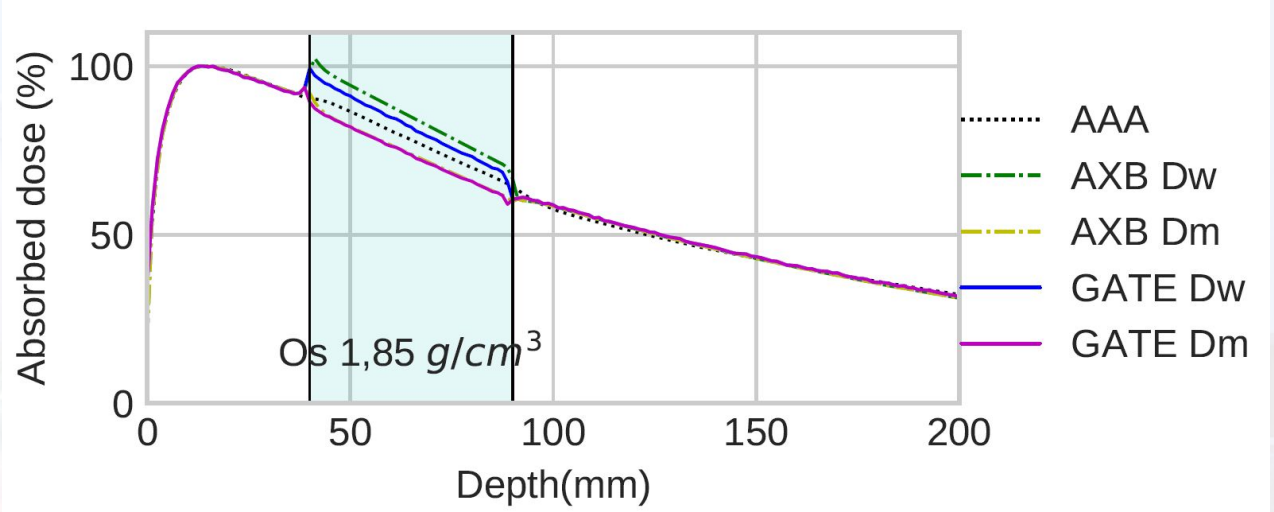
Aim of the study:

- Comparison of **D_m** and **D_w** between **GATE** and **AAA/AXB**
- Assess different conversion methods

D_m to D_w conversion: Victoria Fonteny (MSc)

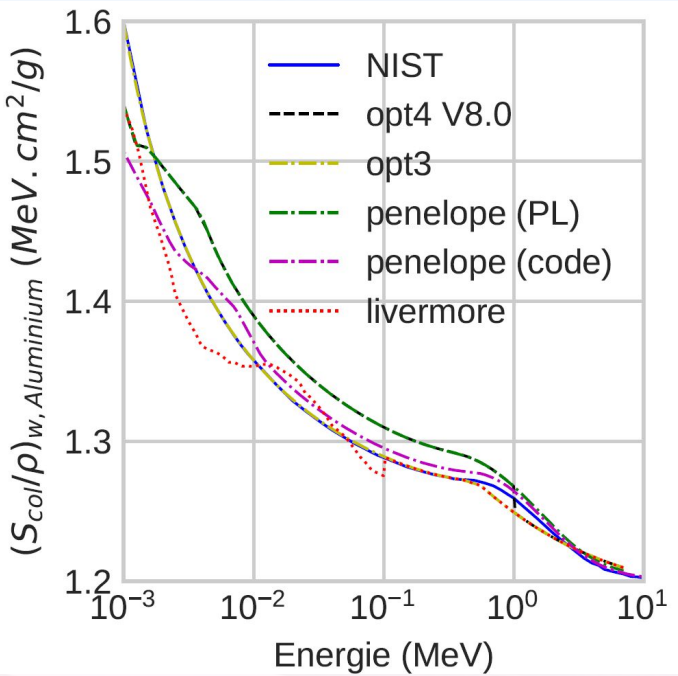
Comparison between GATE and AAA/AXB:

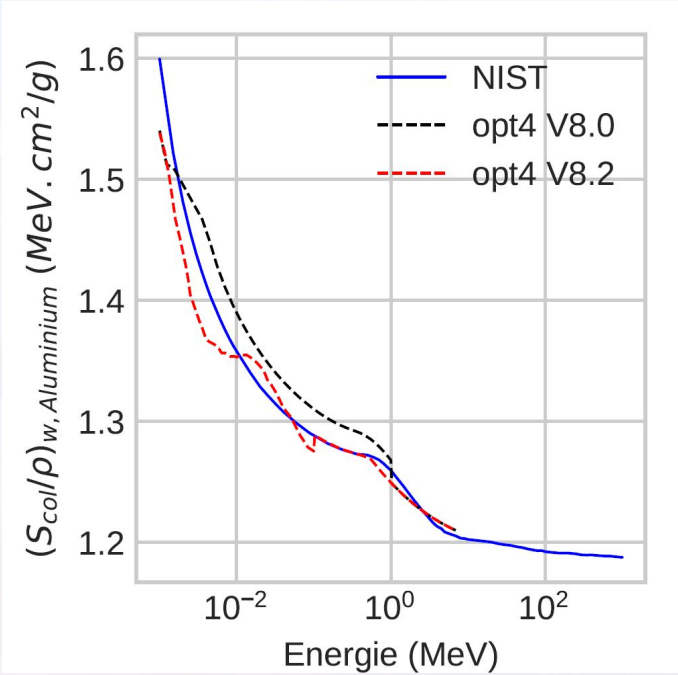




D_m to D_w conversion: Victoria Fonteny (MSc)

Questions regarding GATE physics list:

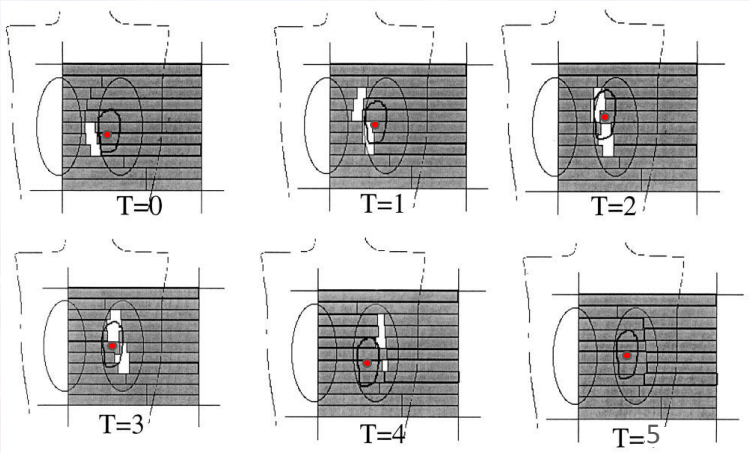




SBRT - Interplay: Jeremy Leste (PhD)

Objectives:

- Develop a GATE model to simulate respiratory motion on phantom
- Validate model against measurement
- Develop a methodology to study interplay effect

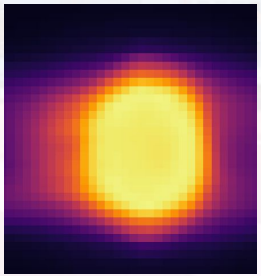


Interplay effect: under dosage of
Gross Tumor Volume (GTV)

SBRT - Interplay: Jeremy Leste (PhD)

GATE model validation:

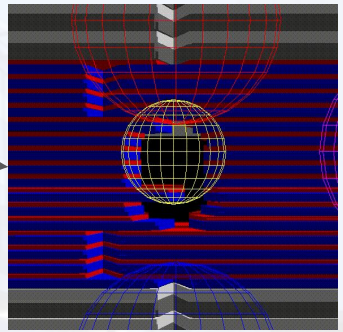
Measurement



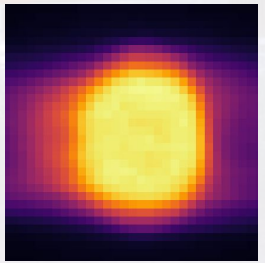
Virtual volume (GTV, ITV, OAR) →Dicom RT plan

Respiratory motion (1D - SI)

Time oversampling



GATE



Leaf sequence	Amplitude (mm)	Period (s)	Global Υ 3%-3mm
A	10	3	**93**
		5	**94**
		7	**95**
B	25	3	**92**
		5	**93**
		7	**93**

SBRT - EPID dosimetry: A. Rita Barbeiro (Postdoc)

STEREPID (*EPID for QA and in-vivo dosimetry of STEReotactic fields)* project « Physique Cancer » 2016

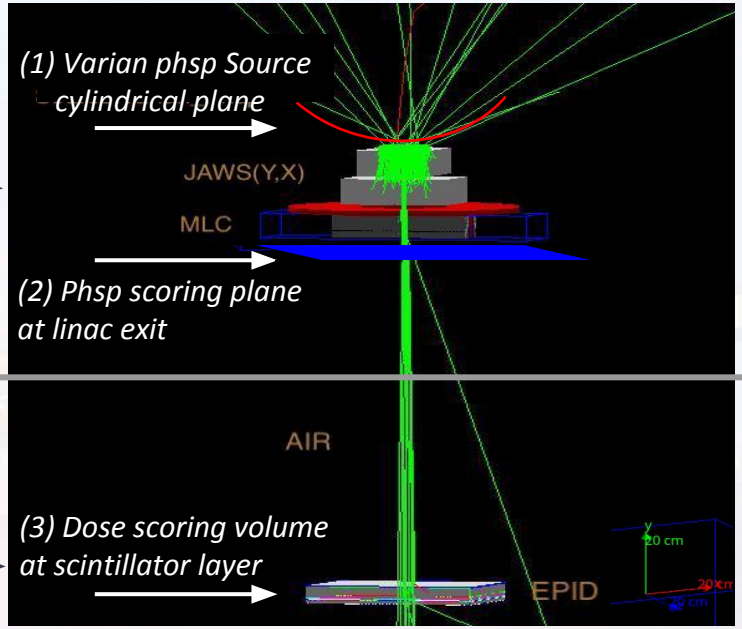
Varian **TrueBeam STx** linac with **aS1000 EPID**

Treatment-dependent part of linac head to obtain **phsp files at linac head exit**.

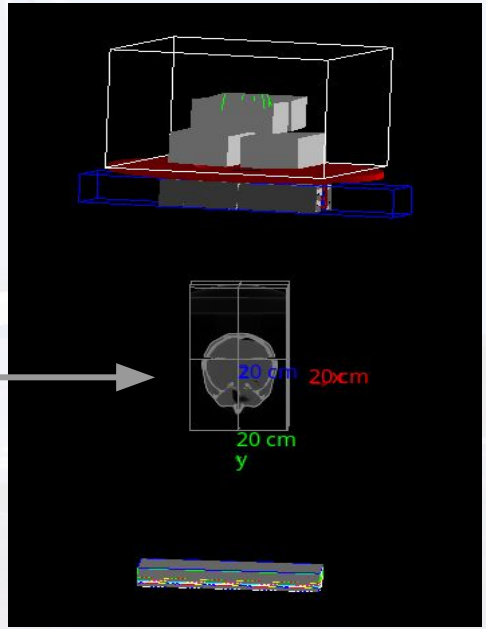
Patient/phantom transport simulation and **absorbed dose calculation**.

EPID transport simulation and **absorbed dose calculation in scintillator layer** (Gd_2O_2S:Tb).

Non-transit dosimetry (QA)



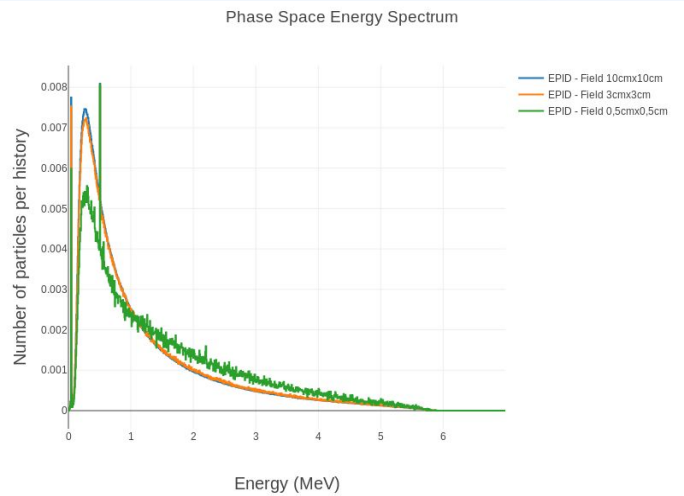
Transit dosimetry (in-vivo)



SBRT - EPID dosimetry: A. Rita Barbeiro (Postdoc)

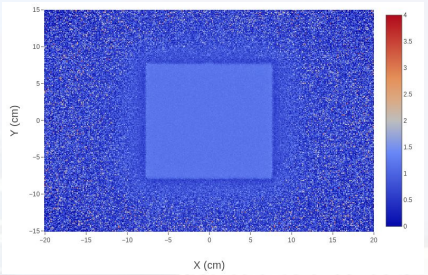
Evaluation of spectral and spatial distribution variations in non-reference conditions

Energy spectrum for different field sizes

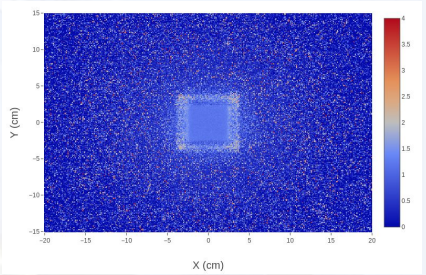


Spatial energy distribution

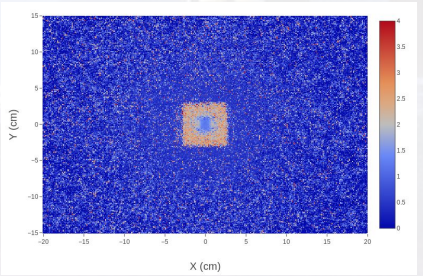
10 x 10 cm^2



3 x 3 cm^2



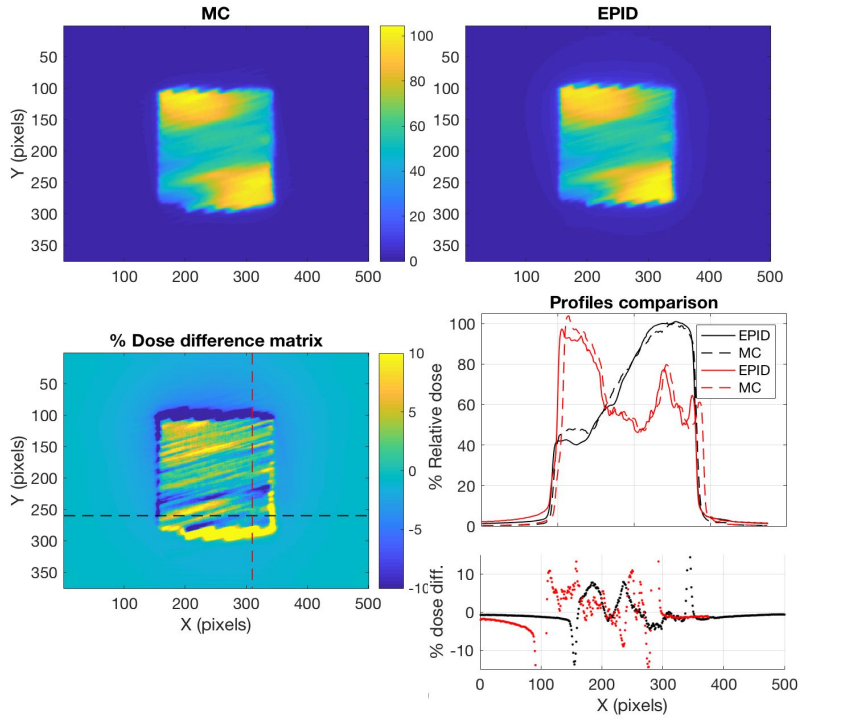
0.5 x 0.5 cm^2

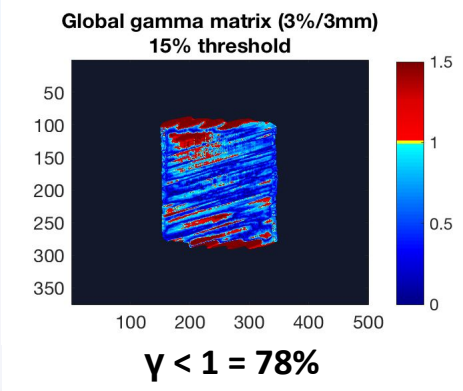


Derive different correction factors to improve clinical dosimetry with EPID.

SBRT - EPID dosimetry: A. Rita Barbeiro (Postdoc)

Non-transit MC EPID dosimetry for a SBRT-VMAT treatment (from TPS parameters)





γ < 1 = 78%

→ **Simulation of actual delivery parameters (EPID or log files)**

N particles/CP= 10^8

Total simulation time: ~23h (178 CPs [75 cores])

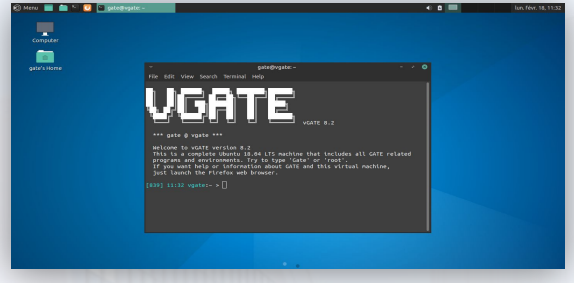
Voxel size: 0.8x0.8.x0.52 mm^3

$\sigma_{MC} < 1\ \%$

GATE technical developments

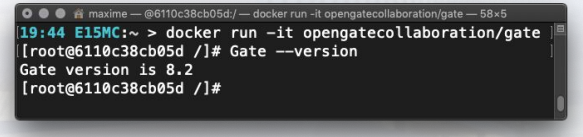
vGATE virtual machine releases:

- built on top Ubuntu 18.04 LTS
- GATE, GateContrib, Geant4, ROOT, ITK, VTK, vV, ImageJ, Python3 Notebook…
- available as .ova file (7.4 GB)



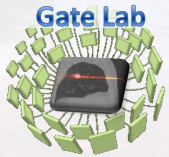
Docker image releases:

- built on top CentOS 7 with Dockerfile
- GATE, Geant4, ROOT



GateLab (VIP) binary releases:

- built from the Docker image
- GATE, Geant4, ROOT



http://gatelab.creatis.insa-lyon.fr

GATE trainings

Training @ Kromek company 2019

Workshop @ MCMA 2019

Vietnam ?