GATE activities @ CRCT

Dosimetry for Nuclear Medicine and Radiotherapy

simon.luc@iuct-oncopole.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)

Geant4-DNA

- M.-C. Bordage, member of Geant4 DNA group

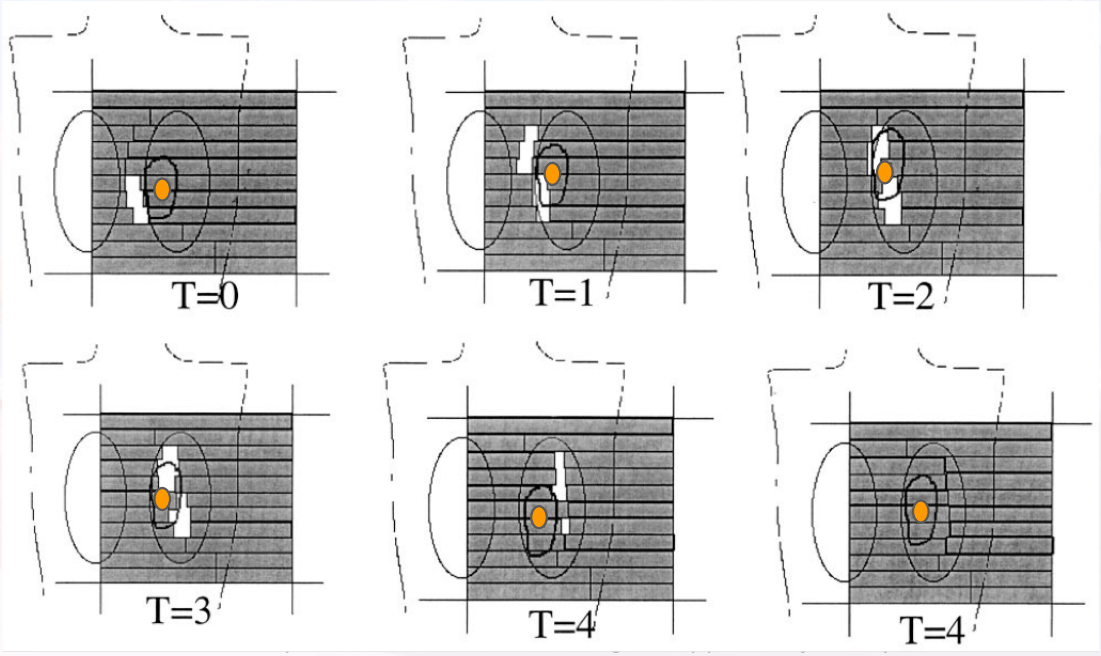
External Radiotherapy:

- New PhD student Alexia Delbaere:
  - Output correction factor (IAEA TRS-483) for new PTW ionization chambers
  - Dose to medium formalism
- SBRT - Interplay effect: Jeremy Leste (PhD)
- Finished in dec 2019 : SBRT - EPID dosimetry: A. Rita Barbeiro (Postdoc).

GATE @ Toulouse

External RT: the interplay effect in VMAT SBRT

Context: it is difficult to start VMAT (modulated RT, i.e. unpredictable beam sequence) in the context of Thoracic SBRT (lung, liver..) → Blurring and Interplay Effect.



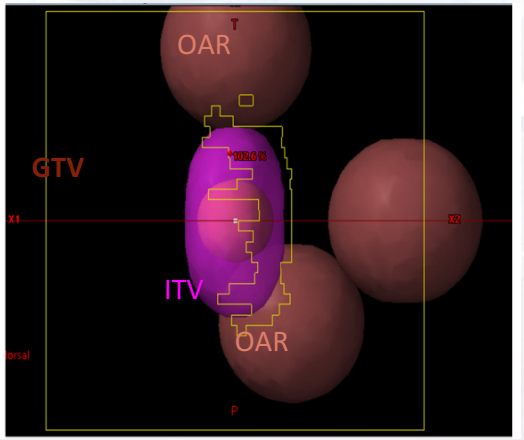
SBRT - Interplay: Jeremy Leste (PhD)

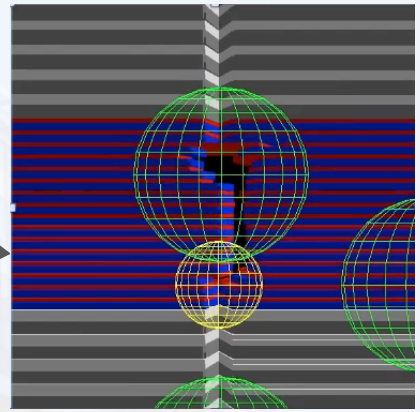
GATE TrueBeam model validation:

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

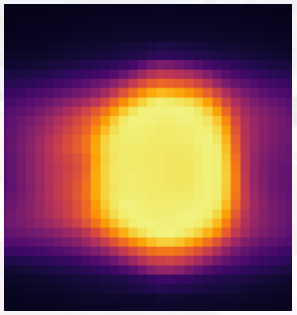
Respiratory motion (1D - SI)

Time oversampling

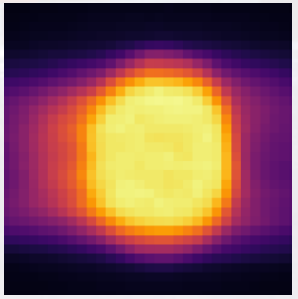




Measurement

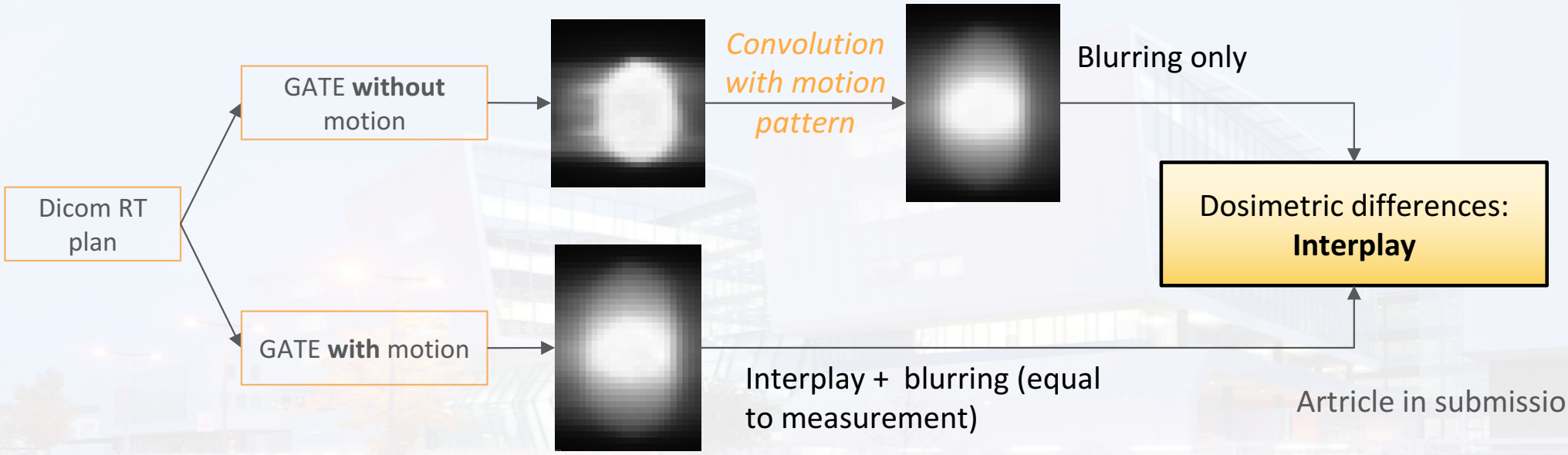


GATE



SBRT - Interplay: Jeremy Leste (PhD)

Interplay evaluation: separation of blurring and Interplay Effect



Artricle in submission

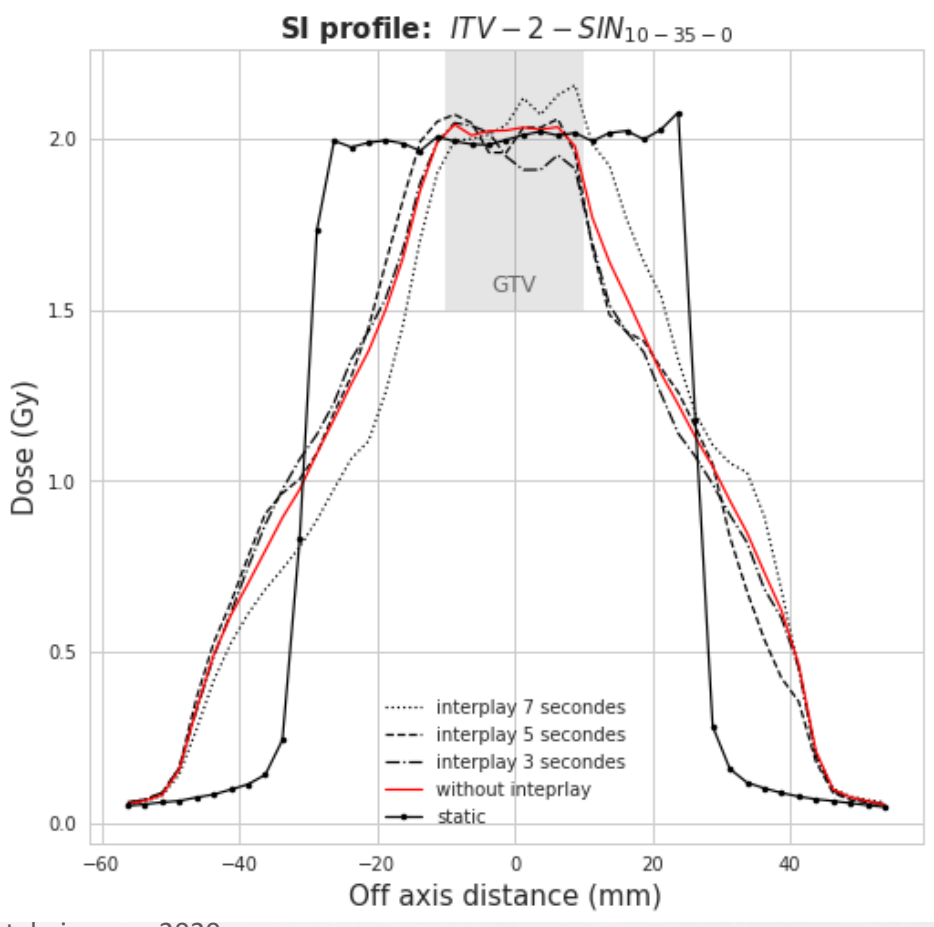
Conclusion (Interplay study)

GATE Simulation allows blurring and interplay effect to be separated (which is not possible with measurement)

Interplay can be important but only in conditions that are not really used in clinical context:

A few fractions, low dose per fraction, slow patient breathing, high dose rate...

In a nutshell: IE++ for a low total number of Breathing Cycles.



STEREPID MC EPID dosimetry for SBRT QA

Project is over (3 years grant, end in dec 2019)

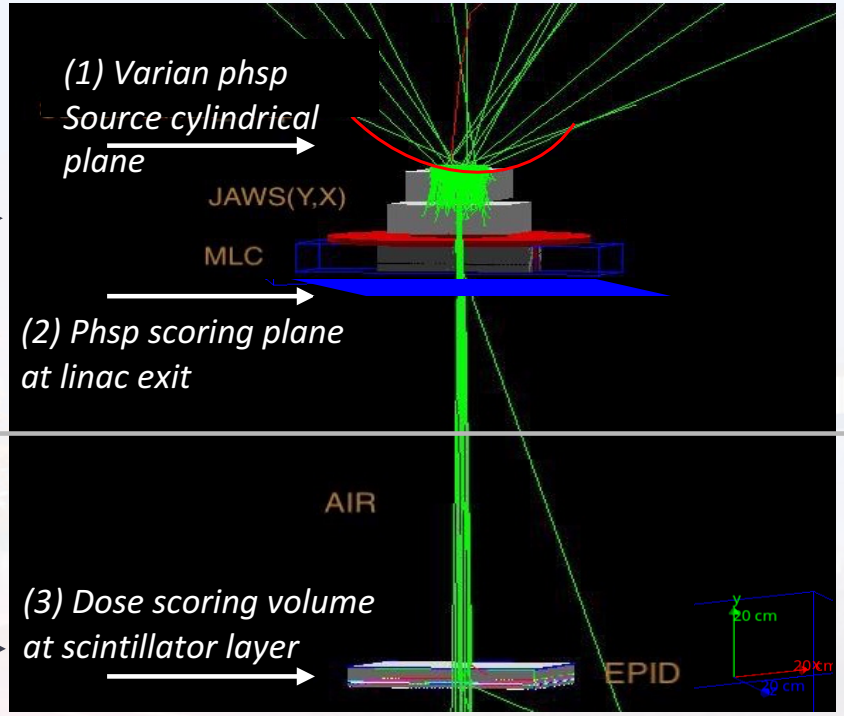
Varian **TrueBeam STx** linac with **aS1000 EPID**

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

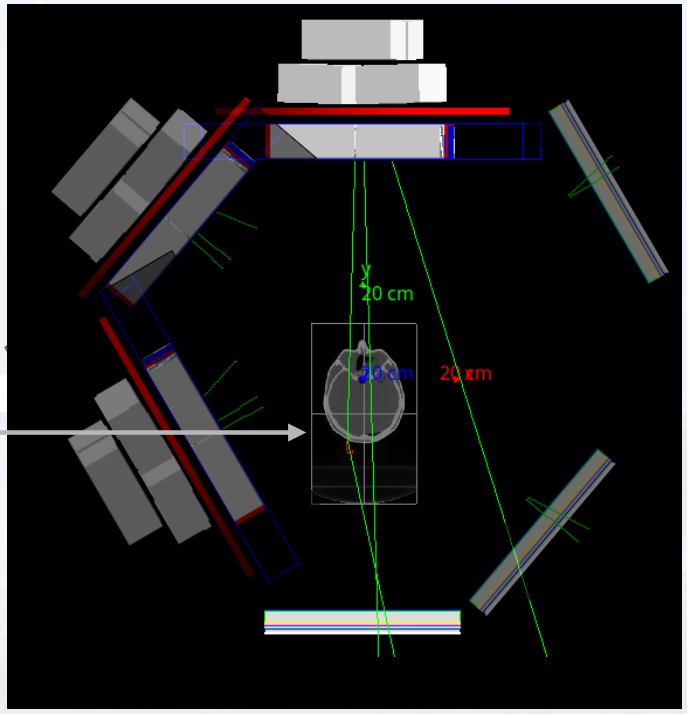
Patient/phantom transport simulation and **absorbed dose calculation**.

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

Non-transit dosimetry (pre-treatment QA)



Transit dosimetry (*in vivo*)



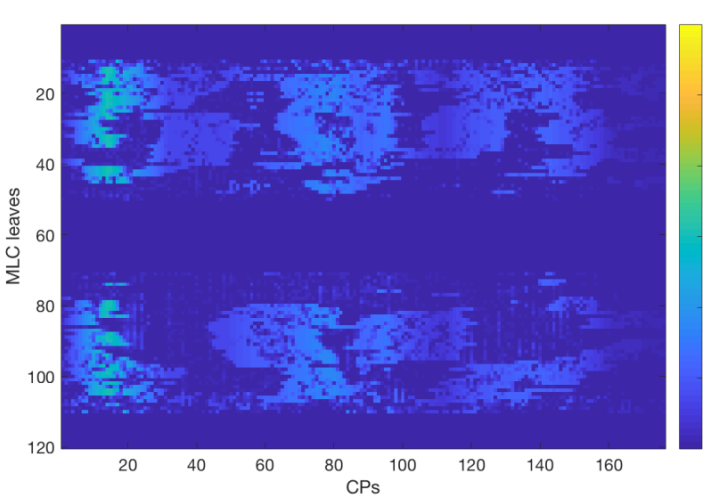
Simulations distributed on 25 quad-core CPUs @ 3.2 GHz Intel Core I5, 16GB ram; Livermore physics list; E prod.cuts: γ ≥ 1 KeV ; e^- ≥ 10 KeV.

MC EPID dosimetry for SBRT QA

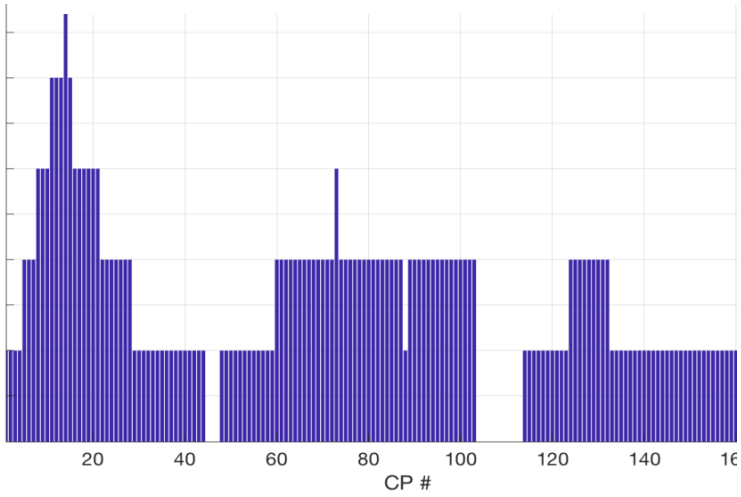
Simulated from TPS vs. delivered (EPID) parameters

Could reveal important discrepancies in treatment delivery; also useful for linac QA.

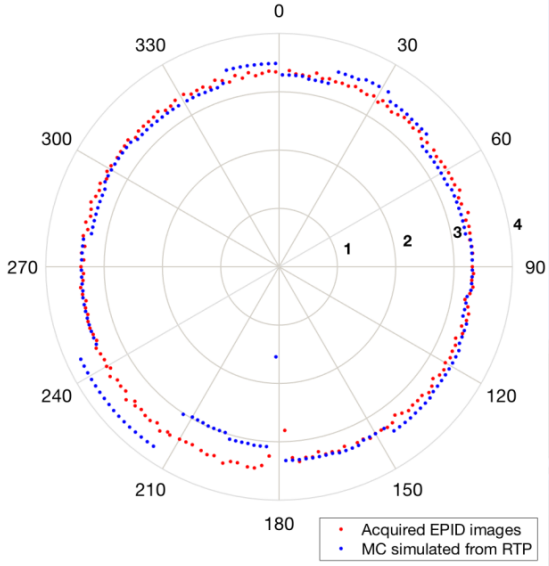
Difference sinogram: MLC positions difference (cm)



Gantry angle differences (°)



Angular MU distributions



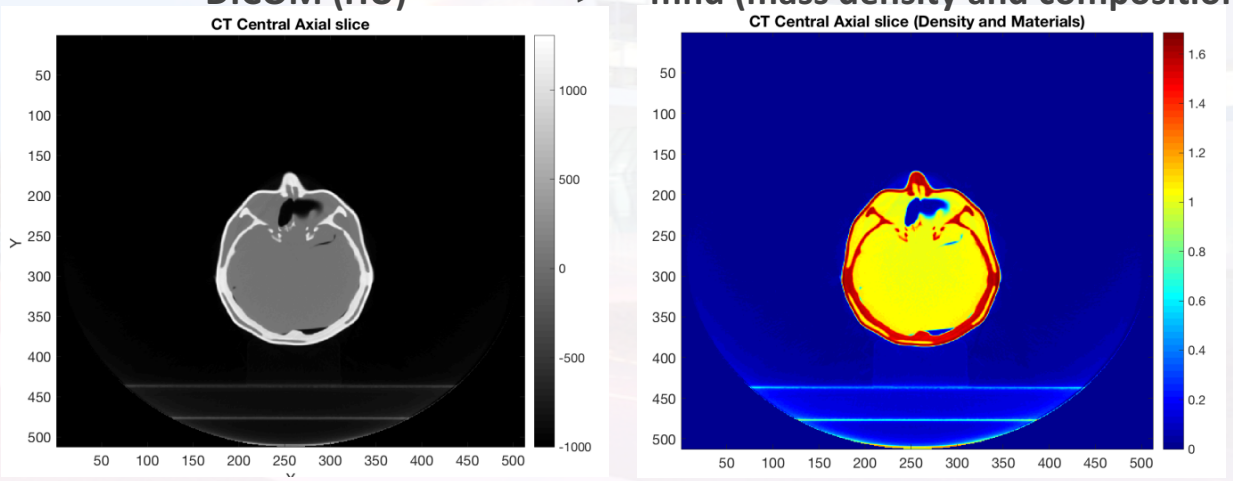
Simulation of actual delivery parameters (EPID or log files)

Transit and *in vivo* dosimetry validation

SRS DynamicArc case verified in personalized head phantom

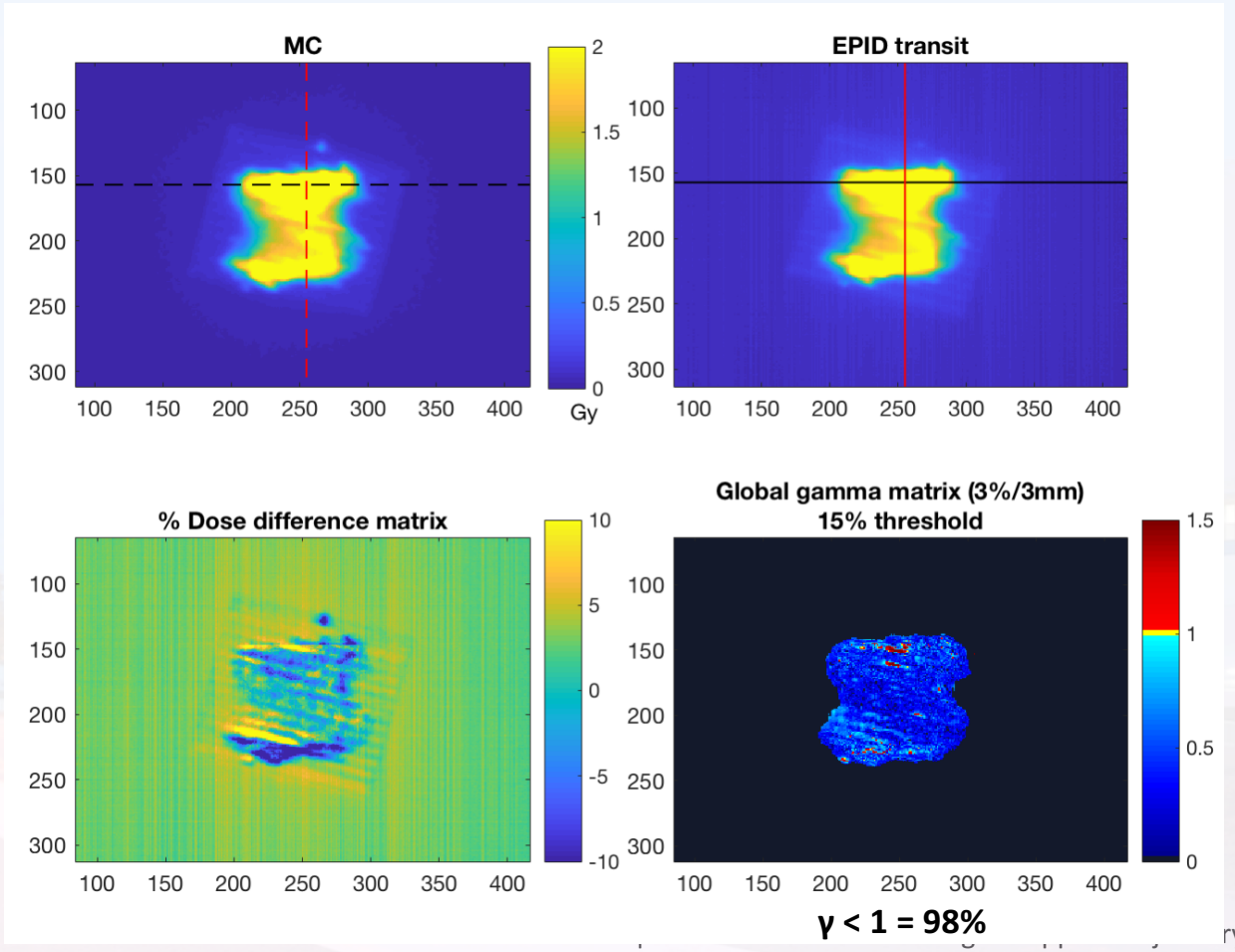
- PseudoPatient™ 3D printed head phantom (Rtsafe) for SRS verification.
- CBCT was acquired for in vivo dosimetry purposes.
- Conversion of HU into physical density and materials: composition provided by RTsafe.

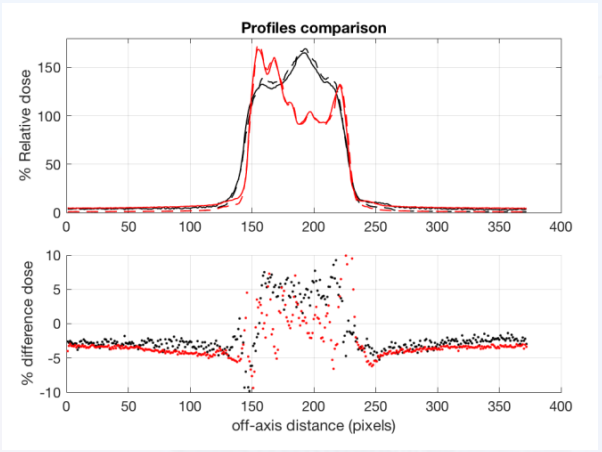
DICOM (HU) **-->** **mhd (mass density and composition)**



Transit and *in vivo* dosimetry validation

Transit MC EPID dosimetry for a SBRT-RapidArc treatment





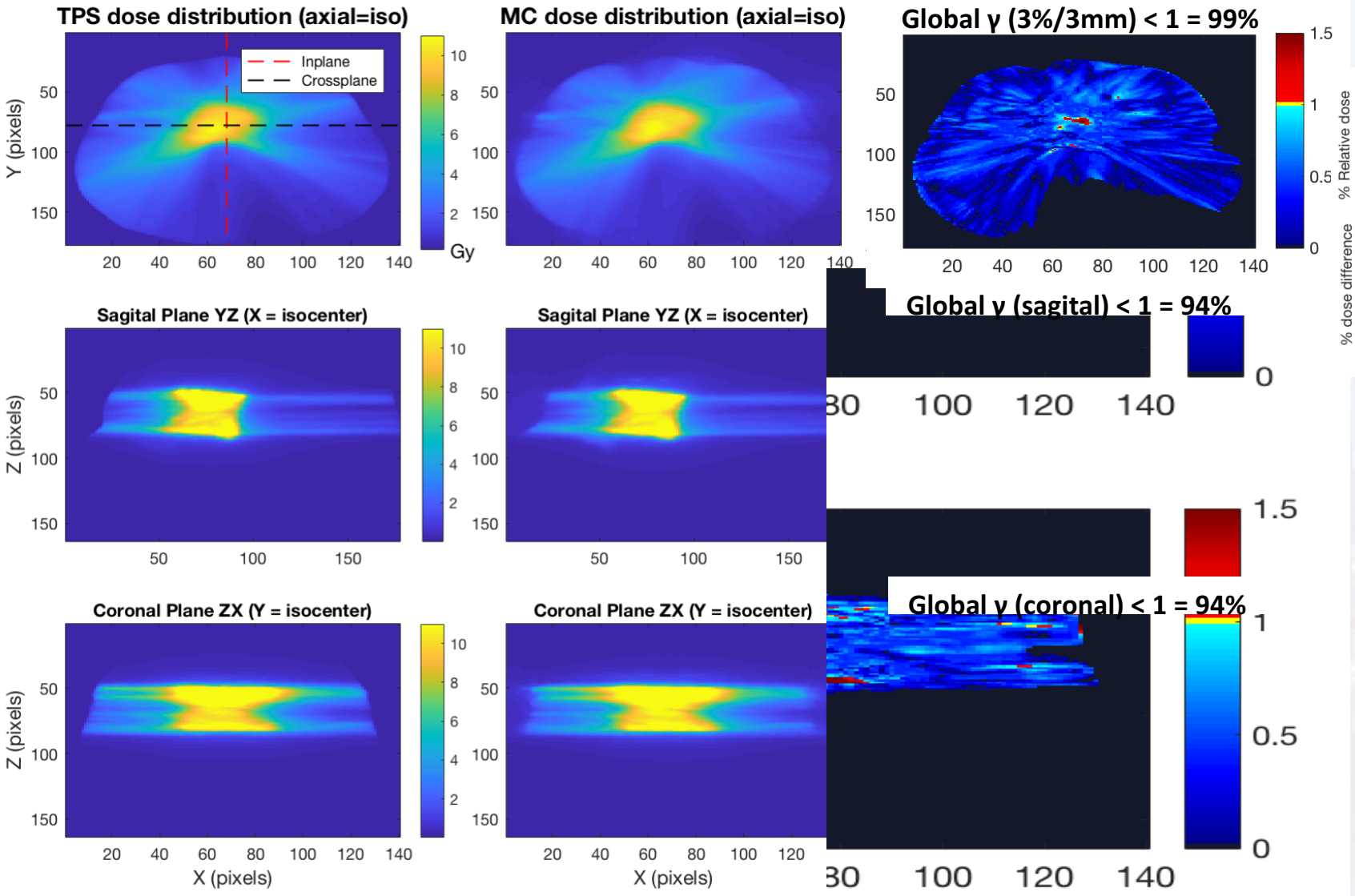
N particles/CP= ~10^8

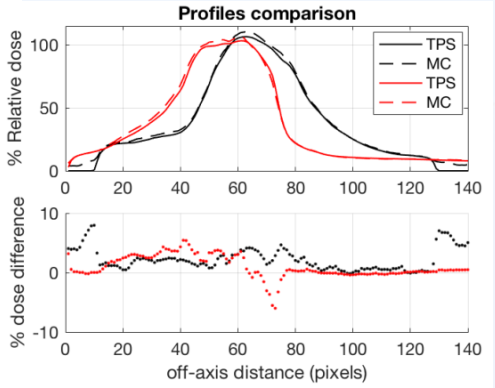
Total t_{mean} (phsp + D[epid+ct]): ~105h [75 cores] ; t_{mean} (CP/core) = 35h (178 CPs)

Voxel size: 0.8x0.8.x0.52 mm^3 (EPID); 1.25x1.25.x1.25 mm^3 (CT) =TPS cal.grid

σ_{MC} < 1 %

SBRT-RapidArc treatment: TPS vs MC (phantom's CT)





γ threshold=10% Dp

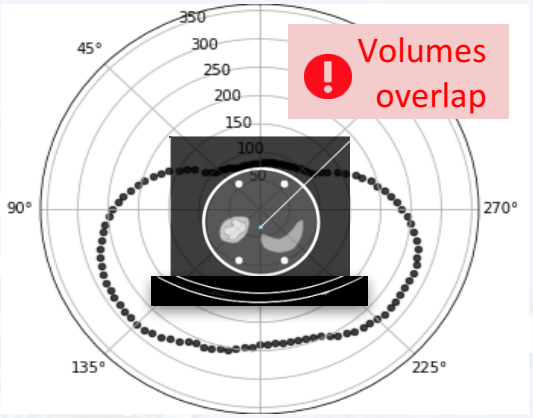
SPECT simulations: Gunjan Kayal (PhD)

Modeling SPECT:

- Modeling different gamma camera model (Siemens/GE/Philips)
- Movement of the gamma camera along phantom/patient
  - Position extraction from SPECT DICOM (Generic Repeater Move)
  - Voxelization (CT) to Tessellation (Mesh Surfaces)
- Long simulation times
  - Thanks to CALMIP Toulouse

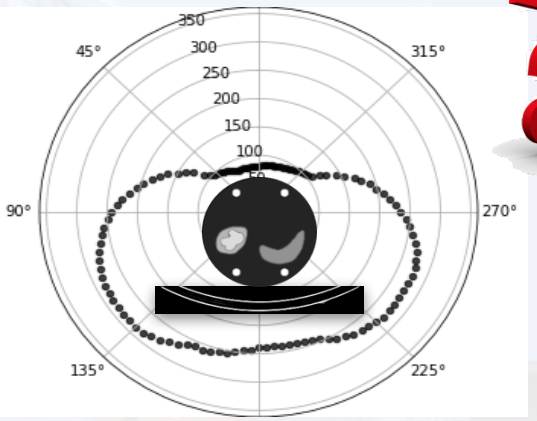
Modeling body contour gamma camera motion

Now we have:




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

What we need:

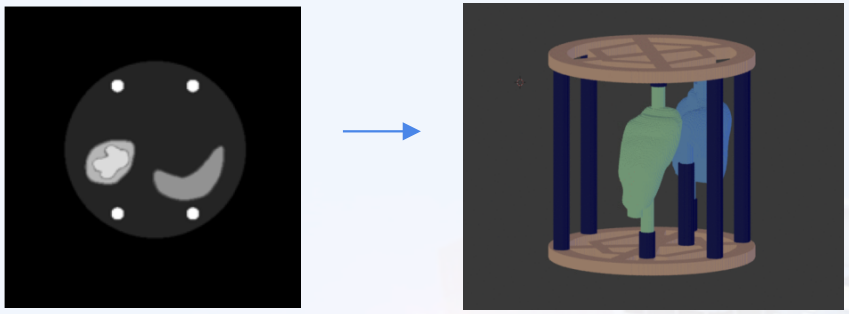


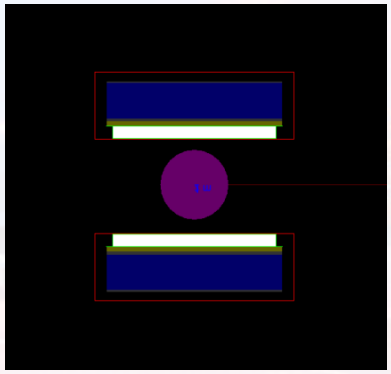
```
/gate/world/daughters/name
anyname
/gate/world/daughters/insert
tessellated
```

Work presented @ MCMA 2019

SPECT simulations: Gunjan Kayal (PhD)

Body contouring gamma camera motion
Implemented for ***PHANTOM MODEL***



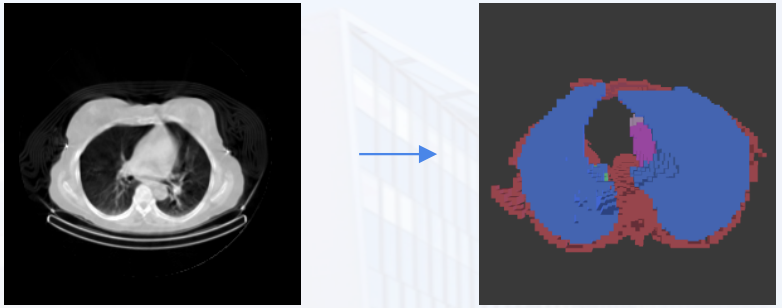


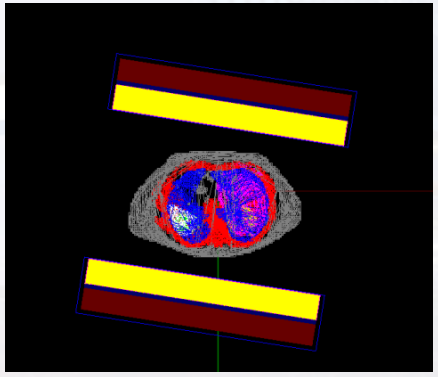
Collimator (white) ; Crystal (yellow); Electronics (blue); Phantom (purple)

Work presented @ MCMA 2019

python + blender

Body contouring gamma camera motion
Implemented for ***PATIENT MODEL***

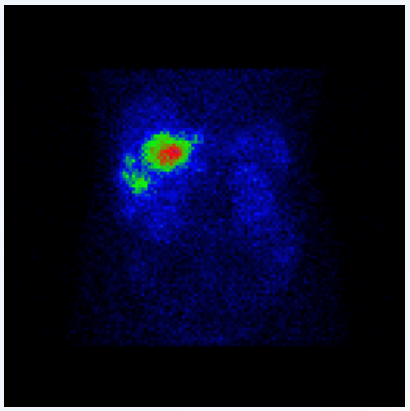




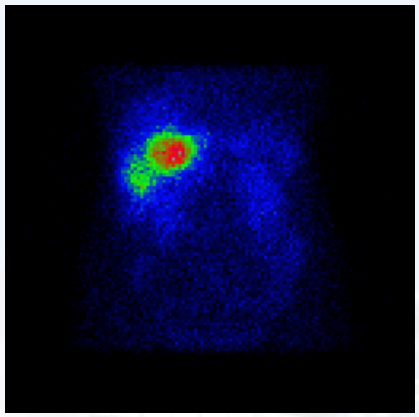
Collimator (yellow) ; Crystal (blue); Electronics (red); Patient (centre)

SPECT simulations: Gunjan Kayal (PhD)

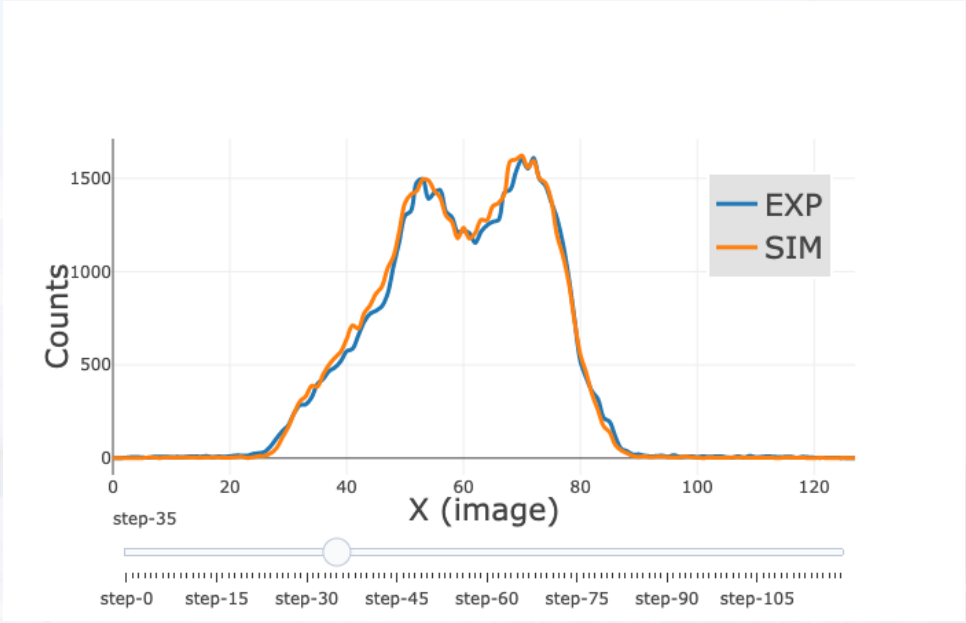
Simulation Results compared to Experimental Images (patient model)



Experimental SPECT



Simulated SPECT



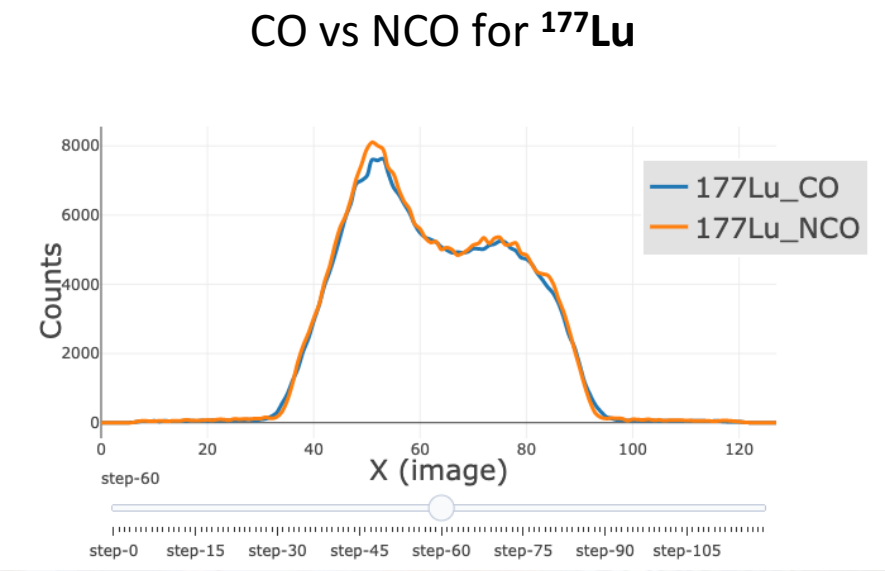
Gamma Camera:	Acquisition:	Activity:
GE Infinia II	60 proj per head	Injected activity :
2 detector heads	15s per proj	6.8 GBq
⅝” NaI crystal	^{177}Lu spectrum	Activity in the FOV:
MEGP collimator	Energy window: 208 keV (20%)	~2 GBq (after 1h)

Acknowledgements: *The work related to the phantom model and images has received funding from the* ***EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.*** *T*he patient images used were shared by the **IAEA Coordinated Research Project (CRP) on "Dosimetry in Radiopharmaceutical therapy for personalized patient treatment"(E2.30.05).**

SPECT simulations: Gunjan Kayal (PhD)

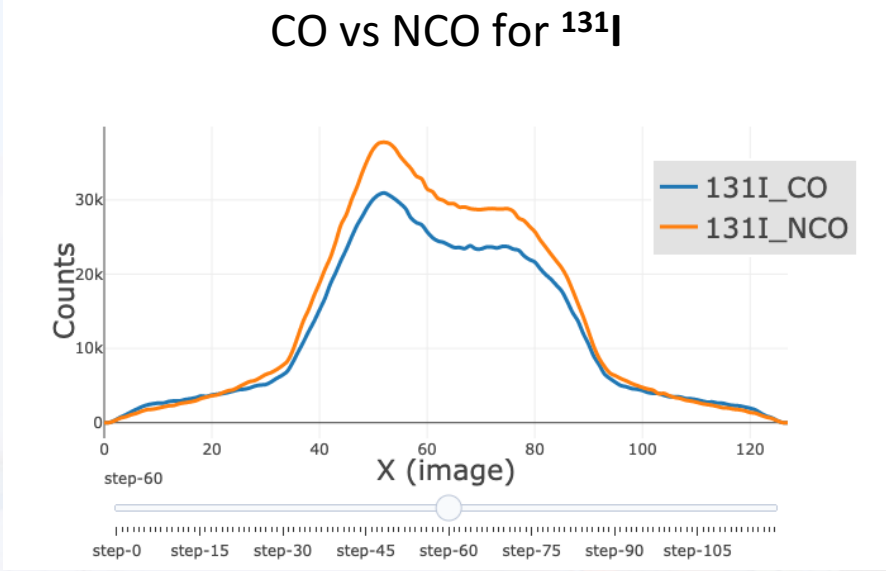
Circular Orbit (CO) vs Non circular/Body Contouring Motion (NCO)

CO vs NCO for ^{177}**Lu**



Difference in case of ^{177}Lu < 1%

CO vs NCO for ^{131}**I**

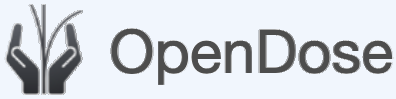


Difference in case of ^{131}I ≅ 10%
(due to septal penetration)

Highly recommend the use of Body Contouring Motion for SPECT simulations
Otherwise, there will be underestimation of counts and therefore absorbed dose (if dosimetry is performed)

OpenDose: Maxime Chauvin (Postdoc)

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



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

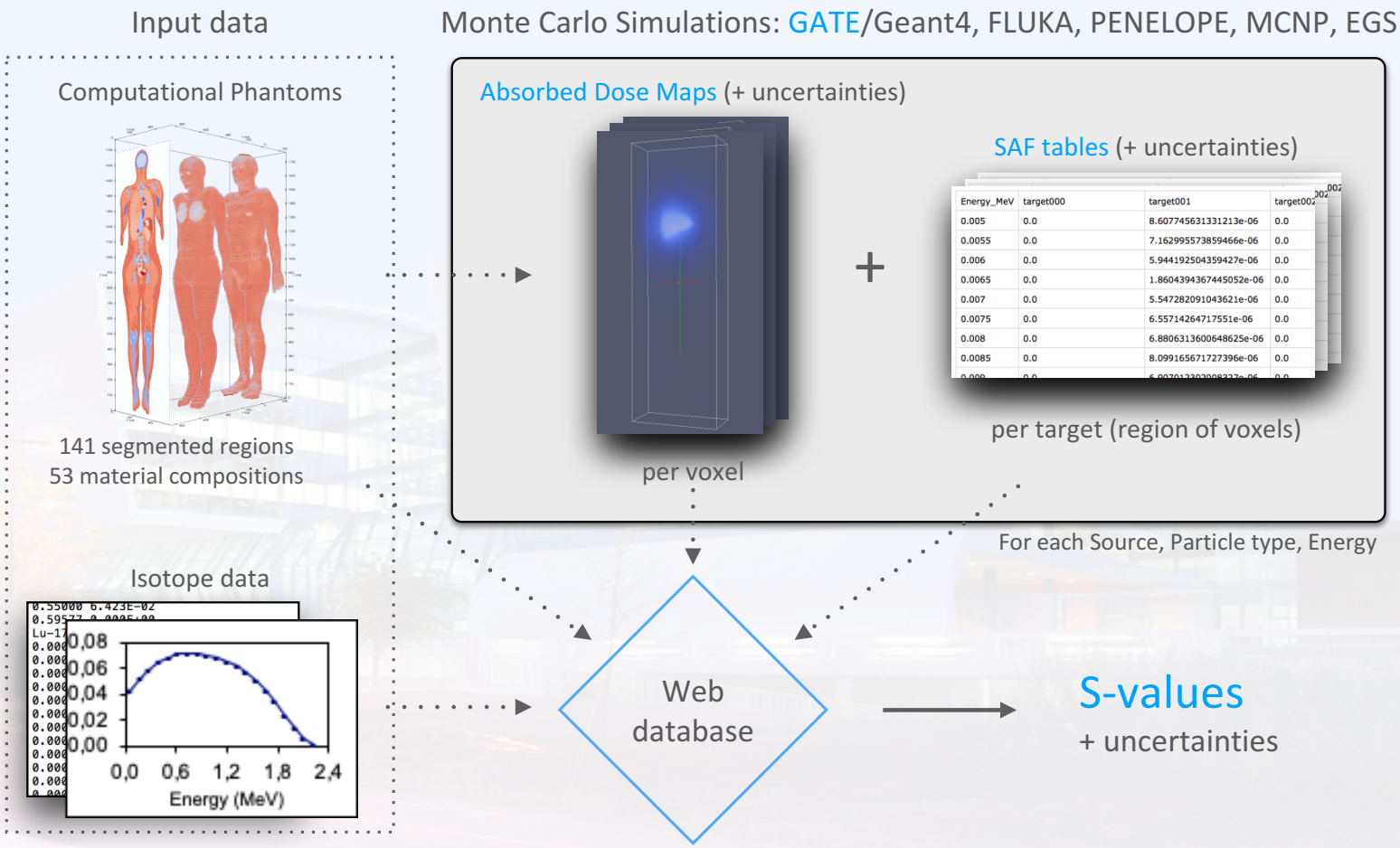
- The source code is versioned with Git in a private repository at GitLab

- 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.

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.

Future of the team ?

Team 11 - CRCT

Team 15 - CRCT

Assessment of the french research (scientific and medical)

End of the team January 1st 2021 (permanent researchers < 5)

Jan. 2021: New CRCT Team: Optimization of Radiotherapy : from mechanisms to clinical trials.
Head: E. Cohen-Jonathan Moyal (Radiation Oncologist)

Future of the team ?

Jan. 2021: New CRCT Team: **Optimization of Radiotherapy : from mechanisms to clinical trials**.
Head: E. Cohen Moyal (Radiation Oncologist)

One team, two groups

Group 1: Current "team 11" won't change.

E. Cohen-Jonathan Moyal (head of RT Department @ IUCT)

Group 2: medical physics group

Soleakhena KEN (head)

Luc SIMON
Maxime CHAUVIN
Alexia DELBAERE
Laure VIEILLEVIGNE
Marie-Claude BORDAGE
Jeremy LESTE
Xavier FRANCERIES
Regis FERRAND (head of MP Department @ IUCT)

→ Official request to the OpenGATE SC to stay in the Collaboration!

GATE trainings

Training @ Kromek company 2019

Workshop @ MCMA 2019

Training in Vietnam 2019

Introduction to GATE
Medical Physics Master 1
(10 hours - L. SIMON)

Coming soon:
Central America GATE Training
(Costa Rica ?)

Thank you