Performances evaluation of Siemens Healthineers scanners with GATE

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Scanners ?

Scanner ?

+

Préfou ?

=

Bread crust

Bread crumb

Lardon

Butter / garlic

Air bubble
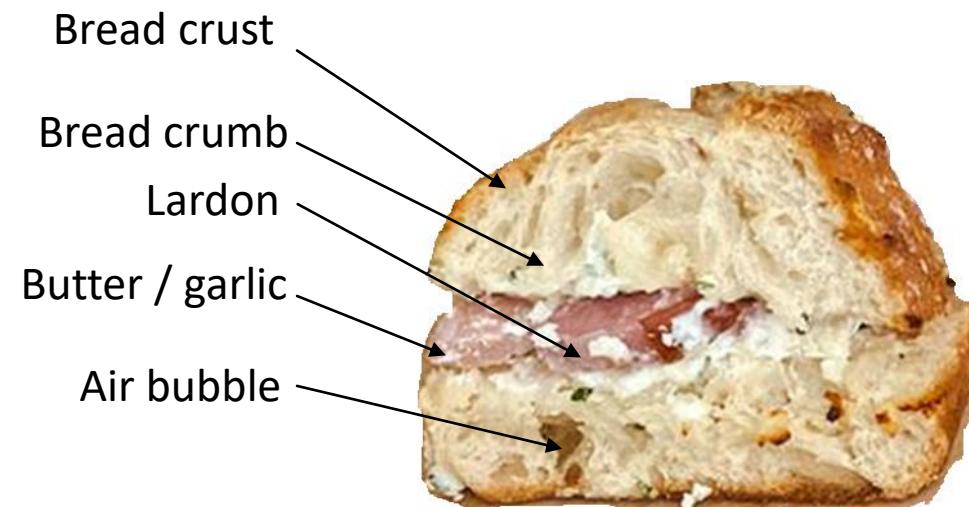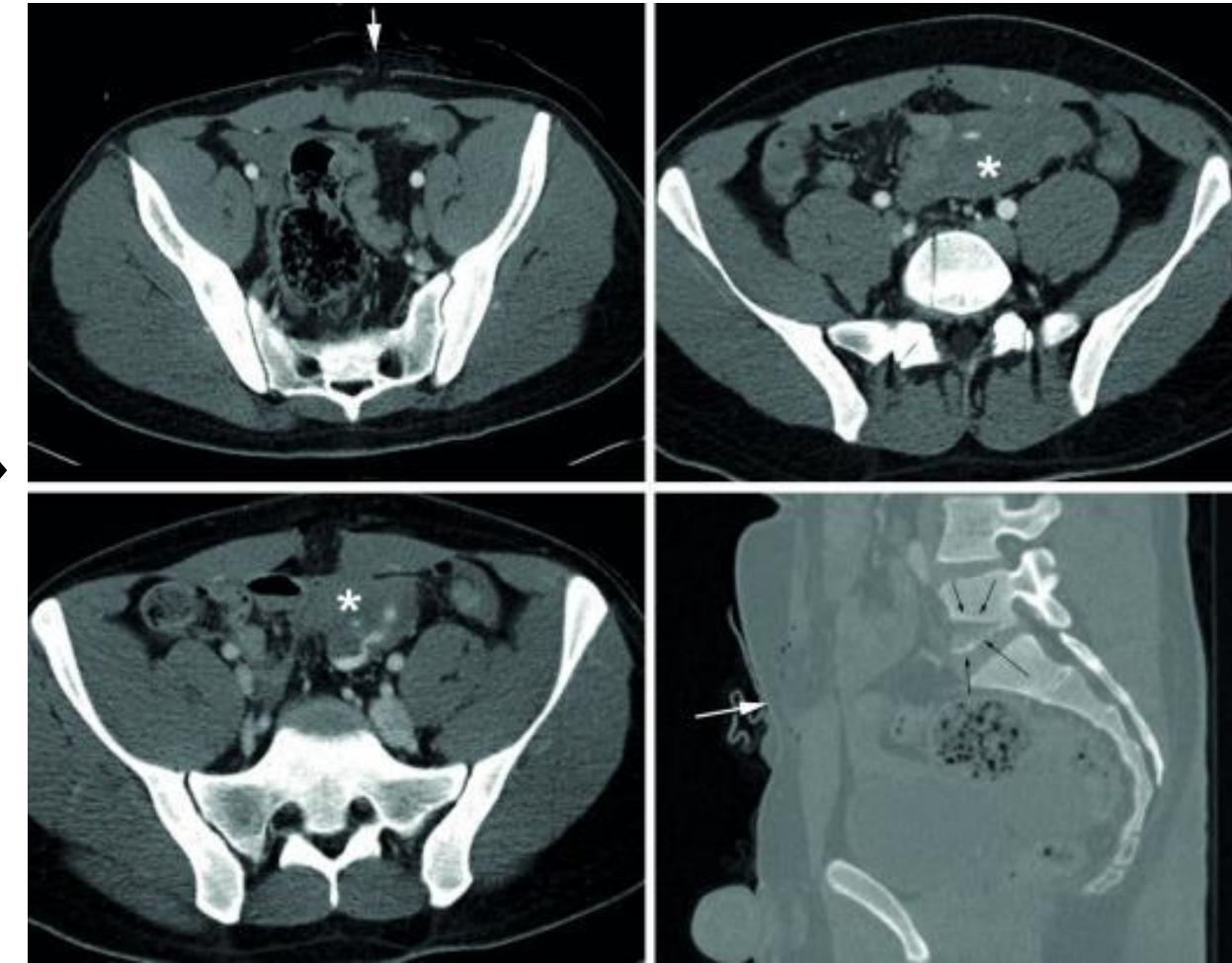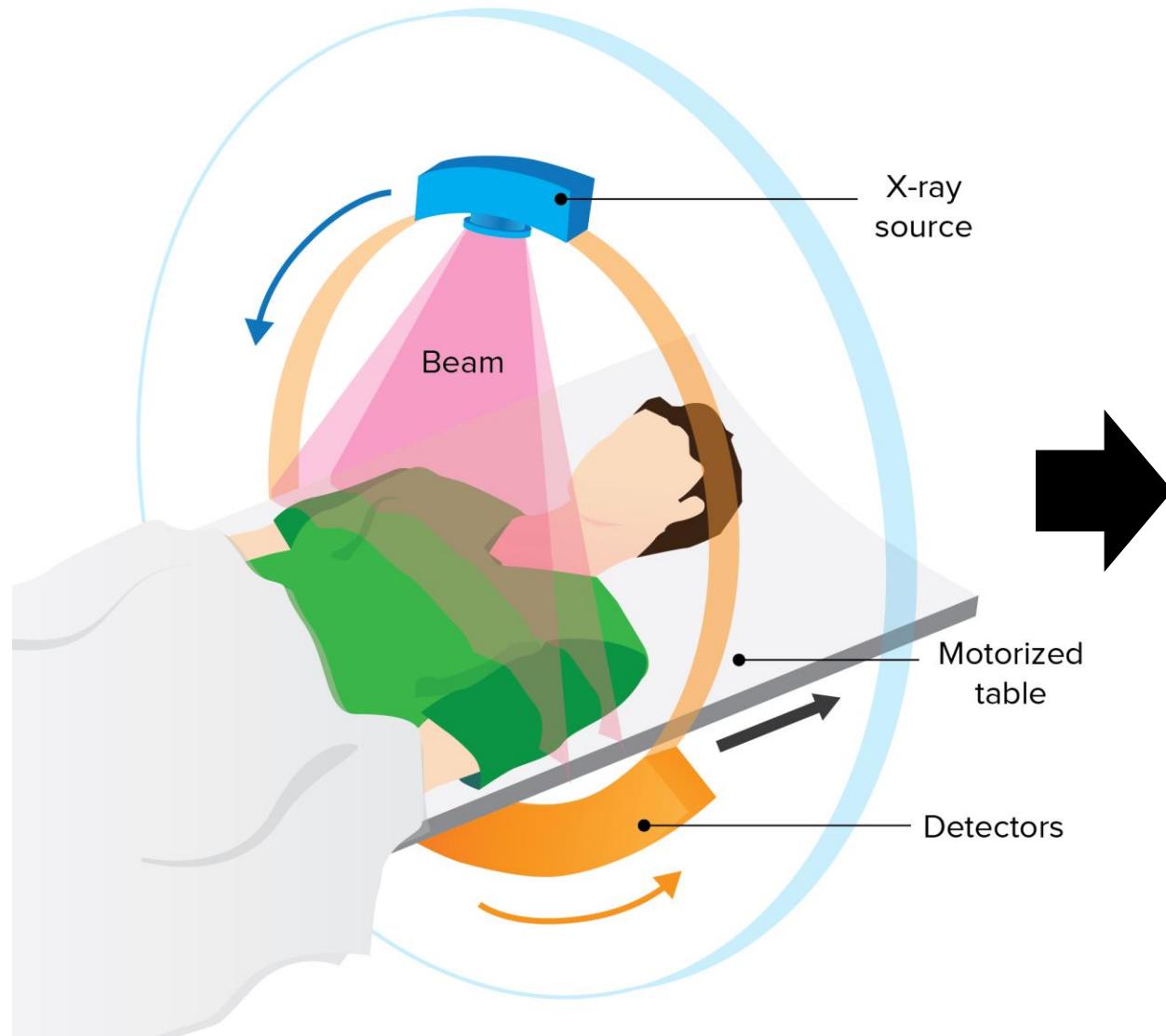
NOP for both

Medical scanner objective

X-ray source

Beam

Motorized table

Detectors
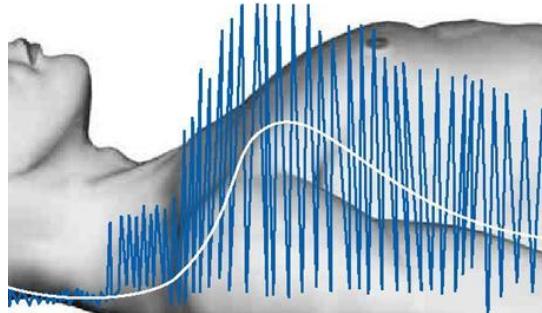
Answer a medical question

Broken bone ? Internal bleeding ? ...

https://www.lecturio.com/concepts/computed-tomography-ct/
https://ebulletin.radiologie.fr/lundi/place-du-scanner-traumatismes-penetrants

Siemens Healthineers scanners evolution

Diagnostic

Radiotherapy treatment planning

Software and tools for :
- dosimetry reduction
- improvement of image quality

CARE Dose4D

Tin filter

Spectral imaging
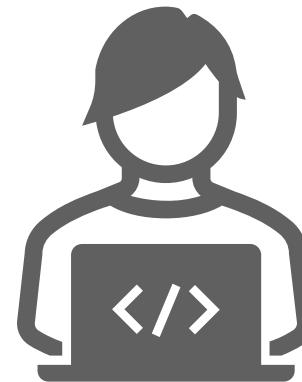
How it's work ?

PhD objectives

Dosimetry reduction
Public Health issue [1]

Image quality improvement
Impact on radiotherapy treatment tools
and diagnosis

Multicentric measurements
Data consistency
QA protocols unification

Monte-Carlo GATE
simulation

Measurements
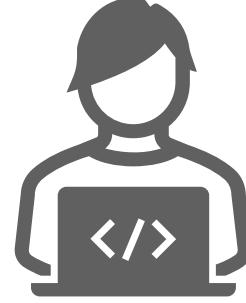
Comparison and
optimisation

[1] https://www.irsn.fr/rapport-dexpertise/analyse-des-donnees-relatives-la-mise-jour-des-niveaux-de-reference-4

Monte Carlo GATE simulation
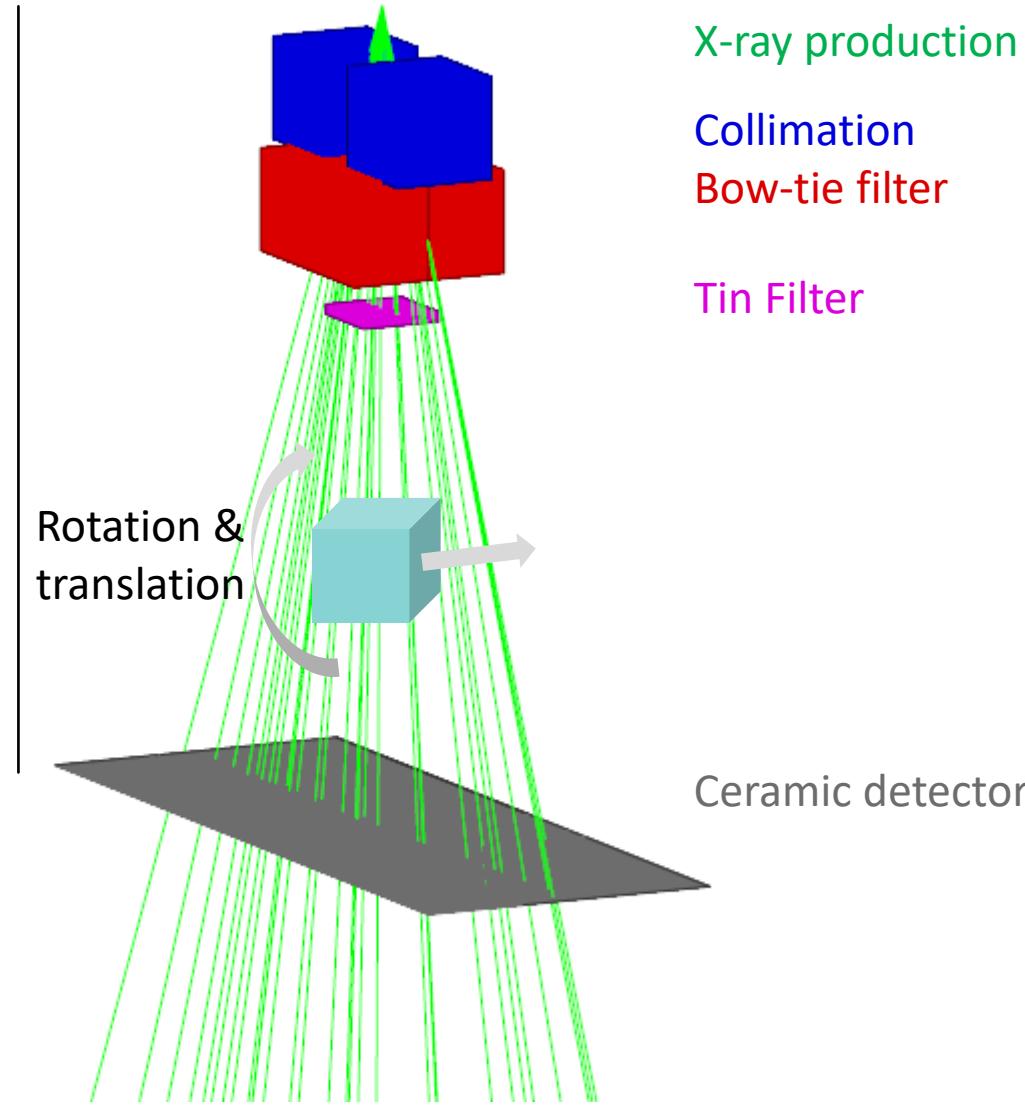
| Python librairies	Functionality	Improvements
GATE beta v10 (New)	Based on GEANT4 with « simple » user interface	• Python binding • Multithreading • Insight ToolKit (ITK) for images
Numpy Pandas Mathplotlib	Data analysis : • dose calculation • images comparison	Inside the simulations code
CUDA (Nvidia GPU) ITK / Reconstruction Tool Kit (RTK)	Images reconstruction	Easy workflow with python
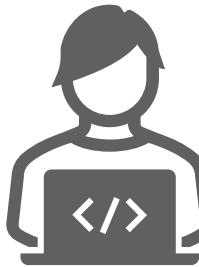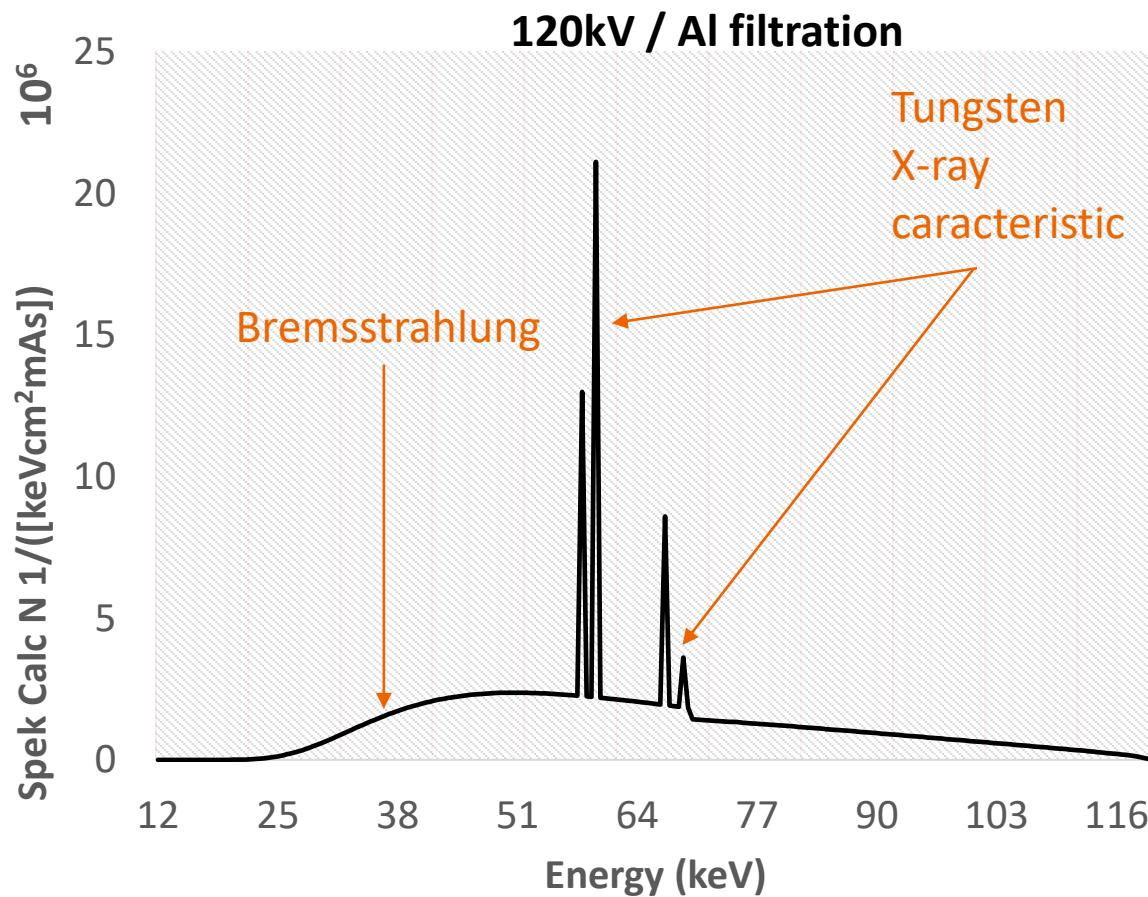
GATE geometry approximation

X-ray production + filtration

Collimation
Bow-tie filter

Tin Filter

≈ 1 m

Rotation &
translation

Ceramic detector

X-Ray spectra

120kV / Al filtration

100 kV / Sn filtration

Tungsten
X-ray
caracteristic

Bremsstrahlung

Bow Tie Filter

Photons / a.u.

Spek Calc N 1/([keVcm²mAs])

10^6

25

20

15

10

5

0

12   25   38   51   64   77   90   103   116

**Energy (keV)**
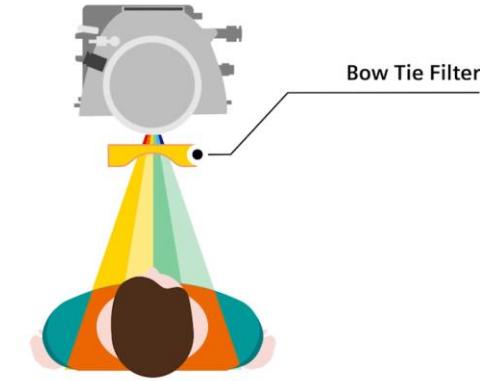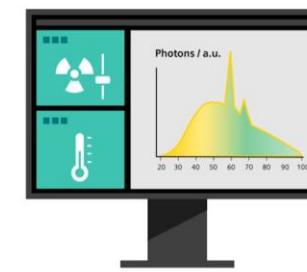
**Modeling X-Ray Spectra** :   SpekCalc[1,2,3]   Siemens Healthineers data missing
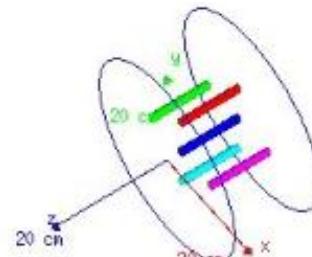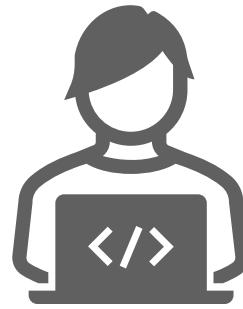
[1] Med Phys. 2007 34(6):2164-74
[2] Med Phys. 2007 34(6):2175-86
[3] Phys Med Biol. 2009 54(19):433-38

CTDI phantom : dose calculation with GATE v9.3

Position de l'insert rouge au cours du temps
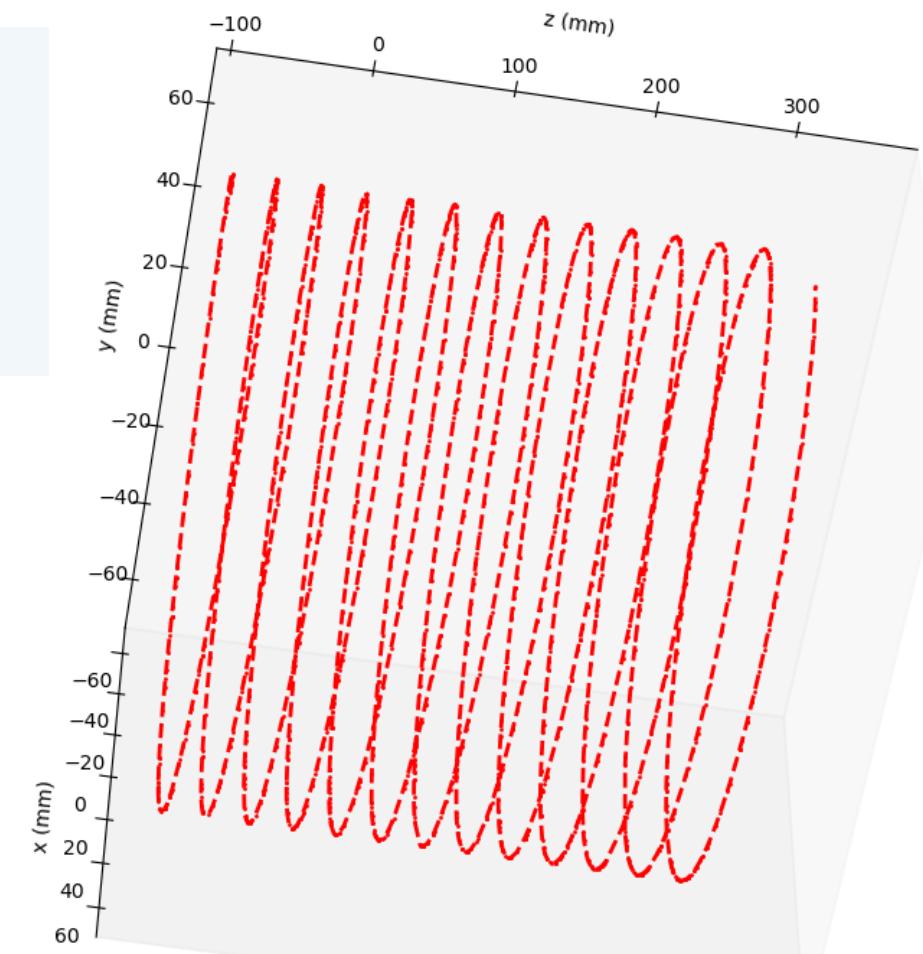
Energie deposition inside rodes

➡ **~ 30 % differences with Siemens Healthineers results**

Waiting for more technical datas

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Projections reconstructions with GATE beta v10
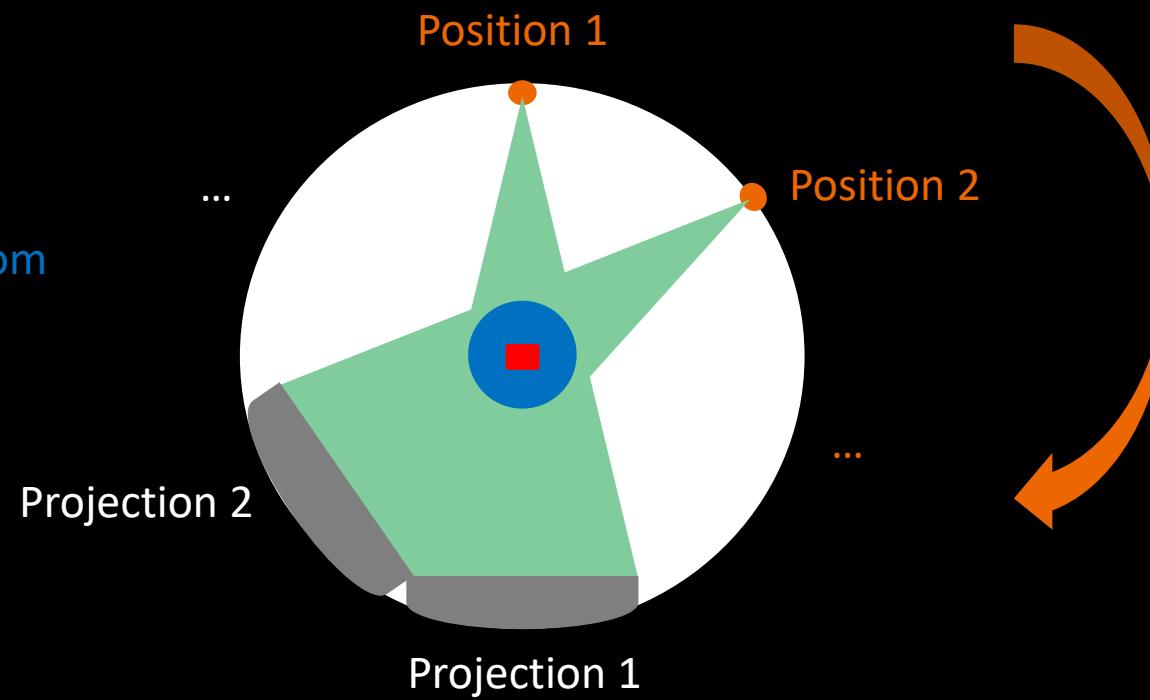
X-ray tube

X-ray beam
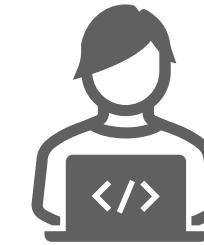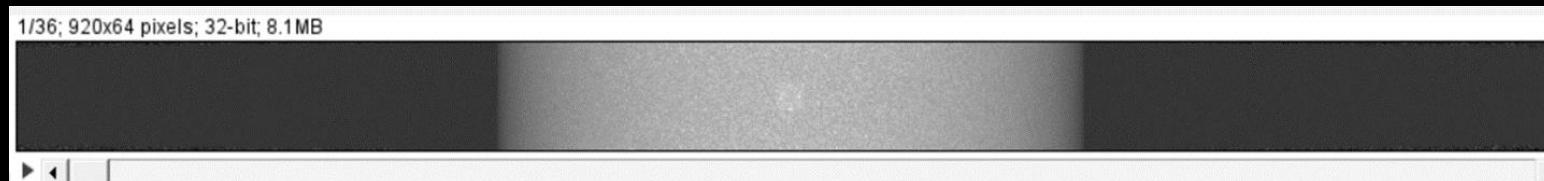
Water phantom

Copper cube

Detector

Position 1

Position 2

...

...

Projection 2

Projection 1

Projection 0° with GATE simulation

1/36; 920x64 pixels; 32-bit; 8.1MB

Detector : 920 * 64 pixels
Detector material : céramic (UFC)

2 simulations for x-ray attenuation in matter
- with phantom
- without phantom.

For each pixel :
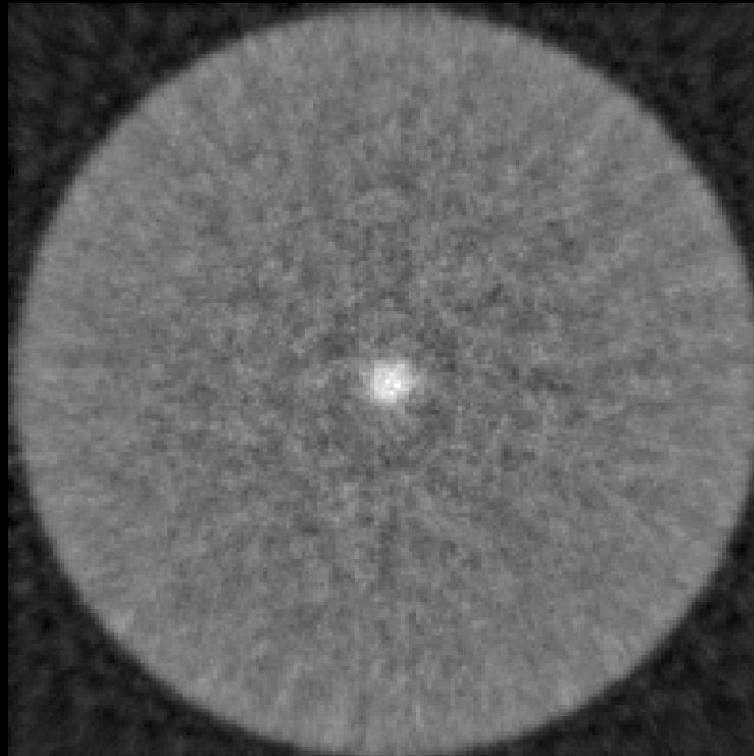
$$\ln\left(\frac{I}{I_0}\right) = \mu\, x$$

I = Signal with phantom
I_0 = Signal without phantom
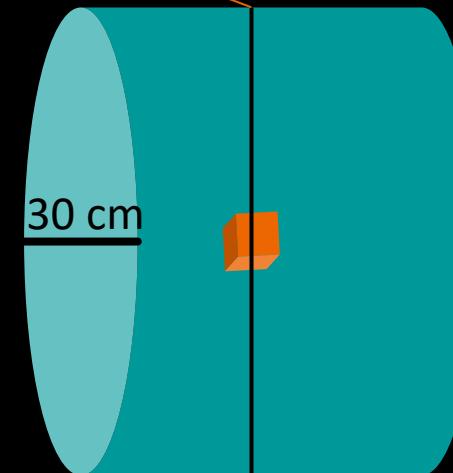
3D images reconstruction for water phantom

GATE beta v10

Water cylinder

30 cm

**Coronal image from 36 projections (10°)
with reconstruction tool kit (rtk) software**

GATE image very noisy :
↑ projections number (36 ➜ 360)
↑ primaries photons (1^e8 / projection ➜1^e10)

Low spatial resolution:
↑ projections number
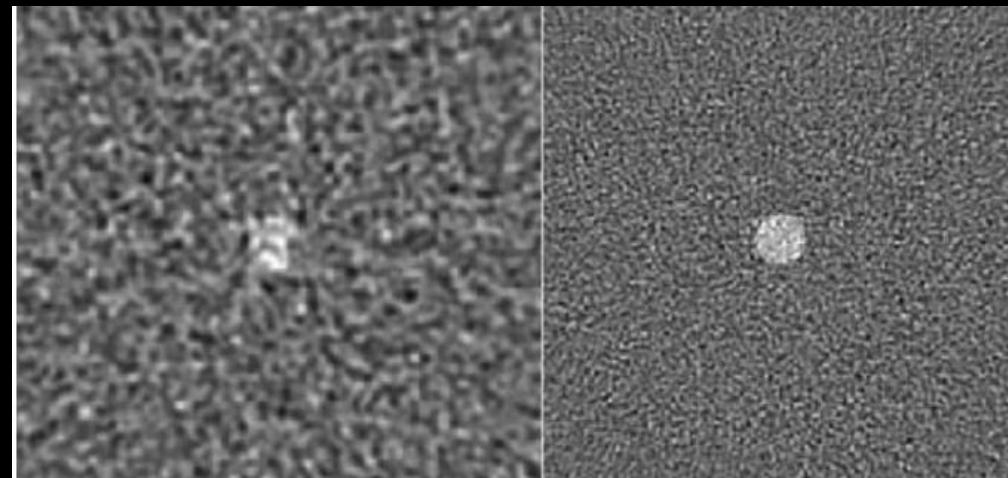
Objective image quality evaluation

Example of « classical » metric

$$SNR = \frac{Signal_{ROI}}{Noise_{ROI}}$$

....

Signal (mean value of X-ray attenuation in a region of interest) and noise (standard deviation inside the ROI) do not inform physicist of image texture

➔ **Same value for SNR but look very different**

How can we compare and analyse images with objective calculation ?

....

SNR = 2.5   SNR = 2.6

Objective image quality evaluation

Example of « advance » metric

NPS = noise power spectrum
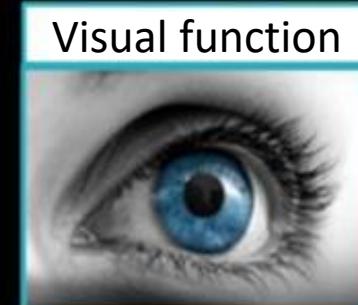
MTF$_{task}$ = modulation transfert function

Noise texture and amplitude

+

Spatial resolution

Calculation in images

Scanner

Clinical task

Visual function

$$d'^2_{NPWEi} = \frac{\left[\iint MTF^2_{task}(u,v) \, W^2_{task}(u,v) \, E^2(u,v) \, dudv \right]^2}{\iint NPS(u,v) MTF^2_{task}(u,v) \, W^2_{task}(u,v) \, E^4(u,v) + MTF^2_{task}(u,v) \, W^2_{task}(u,v) \, N_i(u,v) \, dudv}$$

detectability index : **d'**

....

detectability index (d') : objectif estimation of human capability to distinguish a lesion inside a scanner image

➔ scanner technical performances (NPS + TTF)
➔ Human visual system (radiologist eye)
➔ Clinical task (shape, size, contrast …)

....

Greffier et al.

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Phantom and quality controls

CATPHAN 500
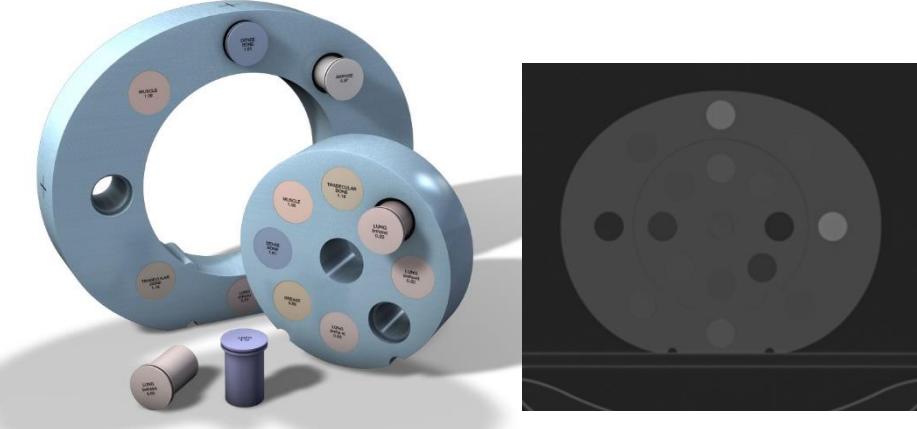
CTDI

CIRS electron density

**Image quality**

Dosimetry
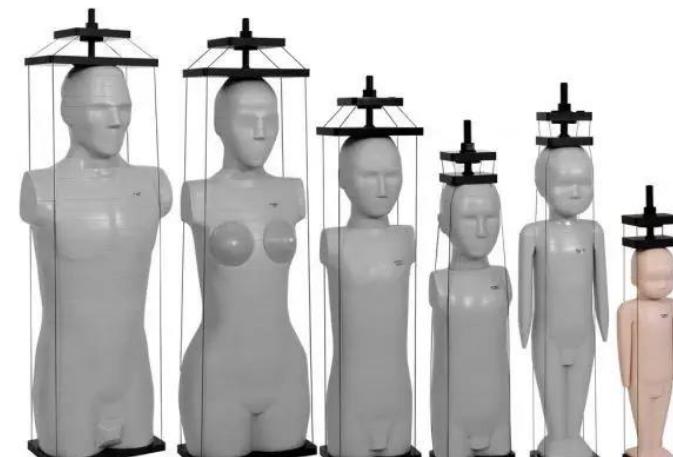
Spectral imaging

Quality control: all operations designed to assess whether the performance claimed by the manufacturer or the ANSM director is maintained

Objective : ↑ the number of control/regulatory points in multicenter protocols to improve patient care in French cancer centers

Anthropomorphic

Somatom Go Open pro images from ICO
https://www.medicalexpo.fr/prod/sun-nuclear/product-80076-664892.html
https://www.meditest.fr/produit/catphan-500/
https://www.cirsinc.com/products/radiation-therapy/electron-density-phantom/
https://www.medicalexpo.fr/prod/cirs/product-95901-721731.html

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Diffusion restreinte © Siemens Healthcare SAS, 2023

Conclusion and perspectives

Monte Carlo GATE simulations require :
- precise technical data
- increased statistics, number of projections

Data acquisition and measurement protocols :
- access to french cancer center
- clinical image analysis

The aim is always to improve patient care in scanners

Thanks for your attention !

Nous façonnons l'innovation dans la santé.
Pour chacun. Où qu'il soit.