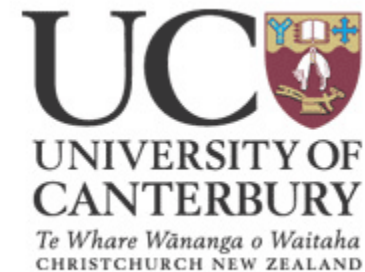


GATE MONTE CARLO DOSIMETRY SIMULATION OF MARS SPECTRAL CT

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MARFO, Emmanuel

Geant4 User Workshop 2017, Wollongong

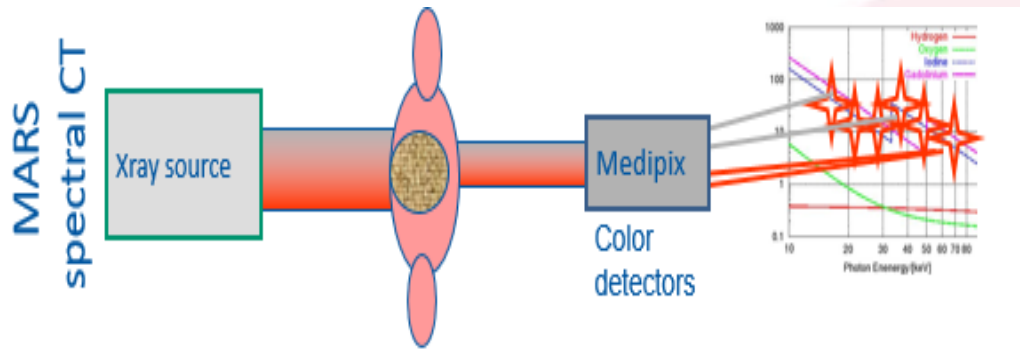


Overview

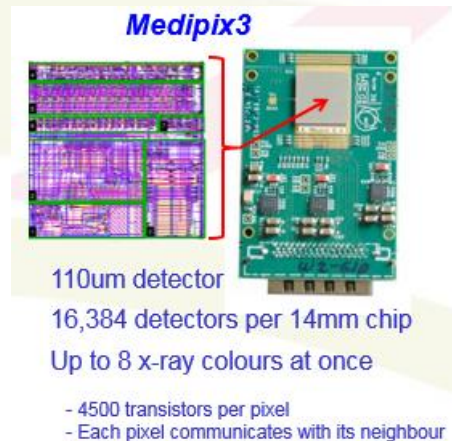
- ❖ MARS scanner and its applications
- ❖ *In-silico* modelling of MARS scanner using GATE
Monte Carlo toolkit
- ❖ Validation of MARS scanner x-ray spectrum in GATE

INTRODUCTION(1/4)

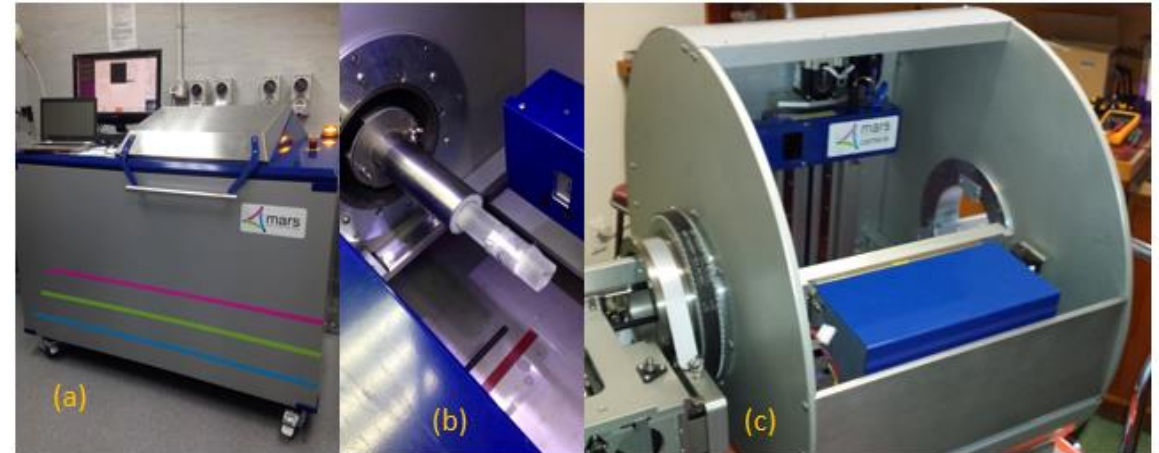
MARS Scanner



Identification of Multiple High Z materials



Detector



(a) MARS small bore animal scanner. (b) Inside view showing a phantom mounted on a sample holder between the x-ray source and MARS camera. (c) MARS gantry removed from the scanner.

INTRODUCTION(2/4)

❖ Areas of preclinical research using MARS-CT

- Soft tissue quantification
- Biological specimen imaging(Multiple targeted agents)
- Cancer research
- Dosimetry

INTRODUCTION(3/4)

❖ Areas of preclinical research using MARS-CT

- Dosimetry

INTRODUCTION(4/4)

❖ GATE: Geant4 Application for Emission Tomography

❖ Why GATE was Chosen

Open source software and User-friendly

Imaging application, Radiation therapy and Dosimetry

Widely validated and frequently used

SIGNIFICANCE OF STUDY

- ❖ Implementation of MARS scanner into GATE platform
- ❖ Understand the radiation deposition through simulation and actual measurement
- ❖ Reduce experimental (dosimetry) and time cost

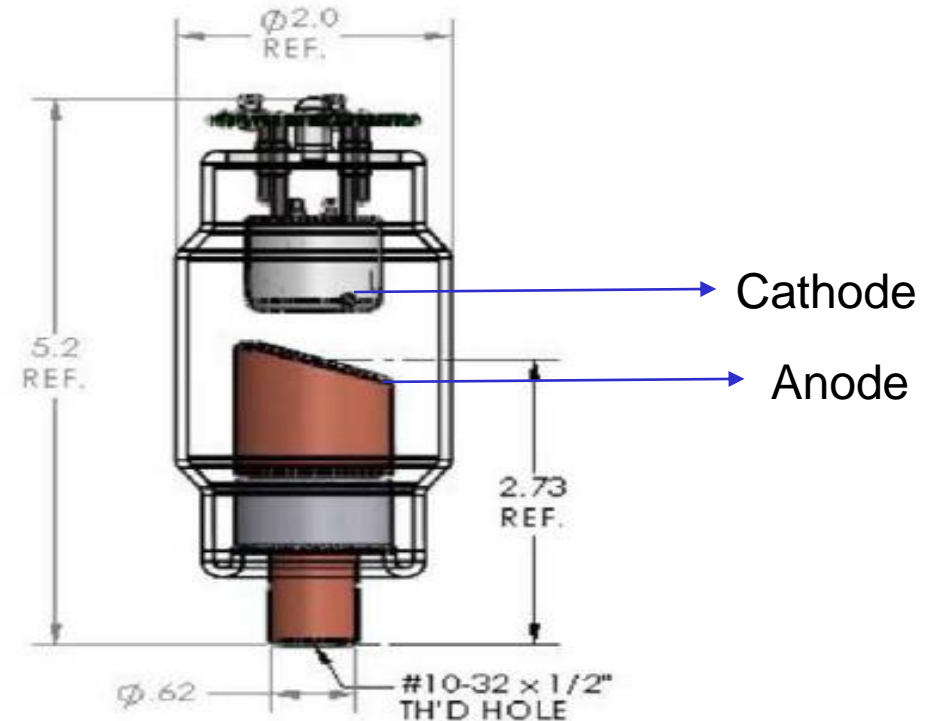
OBJECTIVES

- To implement a MARS scanner model into GATE
- To validate the simulated results with the experimental data.
- To integrate a voxelised phantom from MARS scans into GATE for 3D spatial dose mapping.

MATERIALS AND METHODS(1/10)

❖ Specification of MARS scanner X-ray tube

- 1 mm Tungsten target
- 20° anode angle
- 1.8 mm Aluminium equivalent inherent filtration at 120 kVp
- 0.073 mm electron focal spot
- 60-120 KVp range
- 10-350 uA range



x-ray tube in the source unit (Adapted from Manez, 2012)

MATERIALS AND METHODS (2/10)

GATE TOOLKIT(v7.2)

❖ MAIN STEPS IN GATE DOSIMETRIC APPLICATION

- Four major steps

MATERIALS AND METHODS (3/10)

GATE TOOLKIT(v7.2)

MAIN STEPS IN GATE DOSIMETRIC APPLICATION

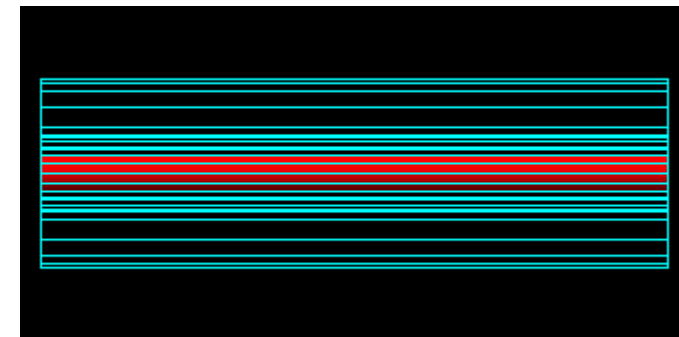
Phantom description

TLD and CTDI PMMA phantom

MATERIALS AND METHODS(4/10)

ION CHAMBER AND CTDI PHANTOM

- CTDI Phantom specification
 - PMMA
 - 30 mm outer diameter and
 - 12 mm inner diameter and
 - 100 mm long



Red: CTDI ion chamber, Cyan: CTDI phantom



- Ion chamber specification
 - ~6 mm diameter and
 - 100 mm long



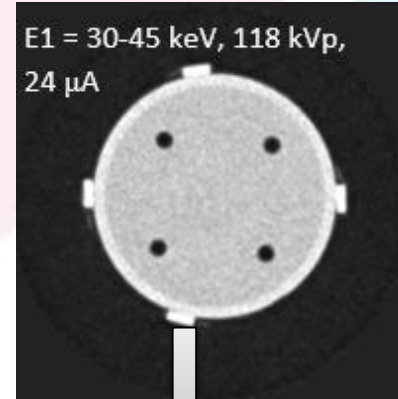
Unfors Raysafe Solo CT detector

MATERIALS AND METHODS(5/10)

PHANTOM WITH TLD100



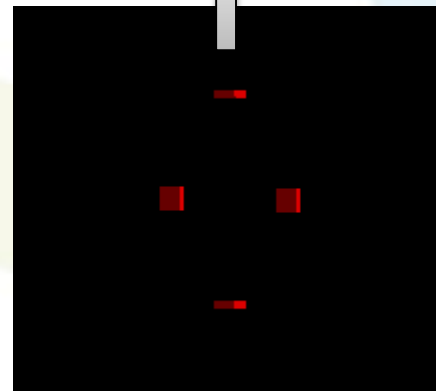
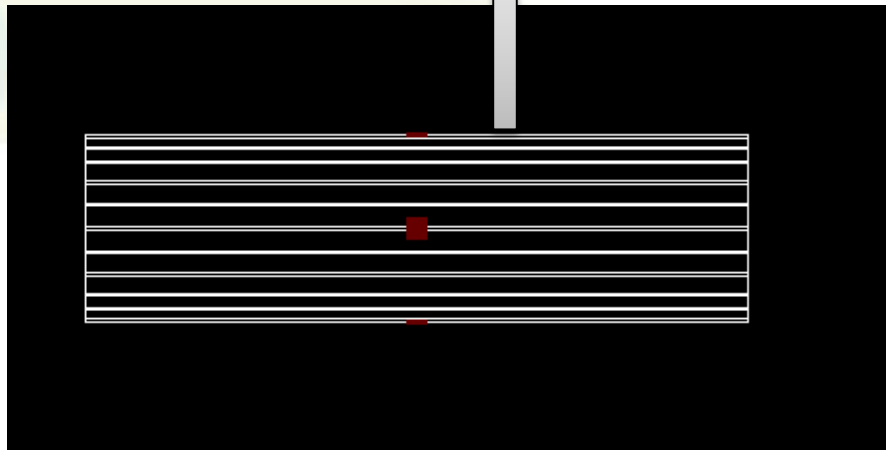
Phantom



TLD

□ TLD and Phantom Specification

- TLD100(3.2mm×3.2mm×0.9mm)
- Composition(2.635g/cm³, Li(0.26), F(0.73))
- 28mm diameter phantom



MATERIALS AND METHODS (6/10)

GATE TOOLKIT(v7.2)

MAIN STEPS IN GATE DOSIMETRIC APPLICATION

Physics definition

emstandard_opt3

MATERIALS AND METHODS (7/10)

GATE TOOLKIT(v7.2)

MAIN STEPS IN GATE DOSIMETRIC APPLICATION

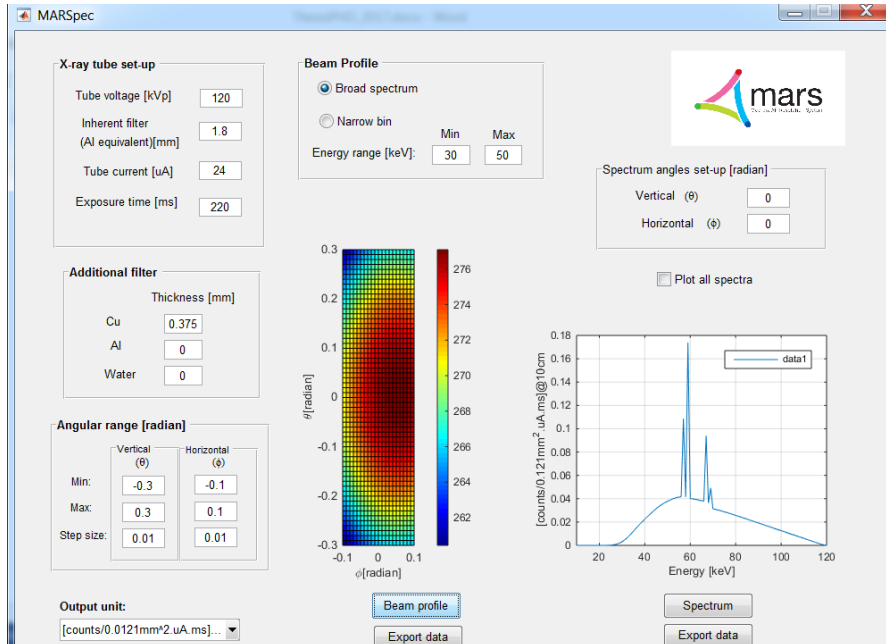
Actors

Energy spectrum actor

Dose actor

MATERIALS AND METHODS (8/10)

MAIN STEPS IN GATE DOSIMETRIC APPLICATION



Source description

Calculated x-ray energy spectrum from BeamNRC as GPS in GATE

MATERIALS AND METHODS (9/10)

HELICAL AND CIRCULAR SCANNING

$$TCR = N_p(DT + ET) \quad (1)$$

$$RR = 360 / TCR \quad (2)$$

$$TR = \frac{(S_L * B_{CL})}{TCR(S_L + B_{CL})} \quad (3)$$

Where;

TCR= total time for complete rotation(s/rotation)

N_p =Number of projection frames

DT=detector dead time per step (ms)

ET=exposure time per step (ms)

RR= rotation rate (deg/s)

TR= translation rate (mm/s)

S_L = sample scan length (mm)

B_{CL} = beam collimation width (mm)

MATERIALS AND METHODS(10/10)

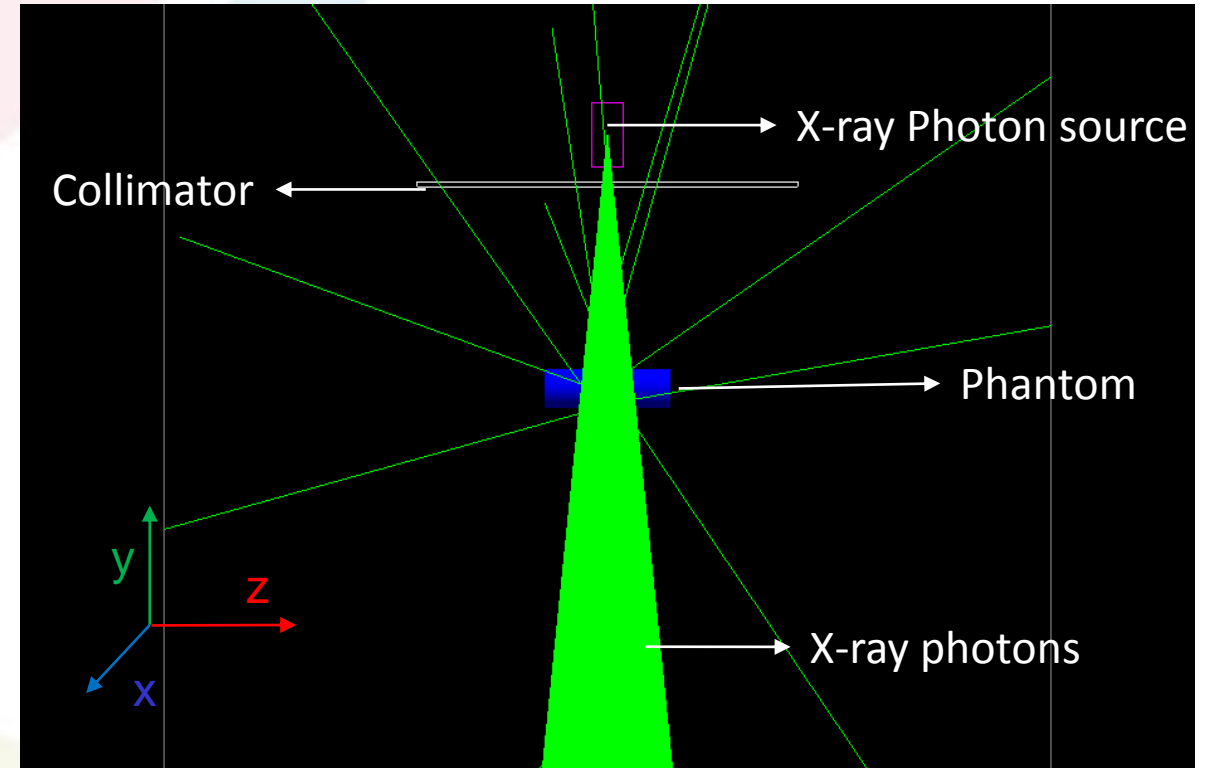
SCAN PARAMETERS

COMMON SCAN PARAMETERS

- Brass filter protocol
- 118 kVp
- SDD = 250mm
- Exposure time = 220ms
- Circular Projections = 720

Scan parameters

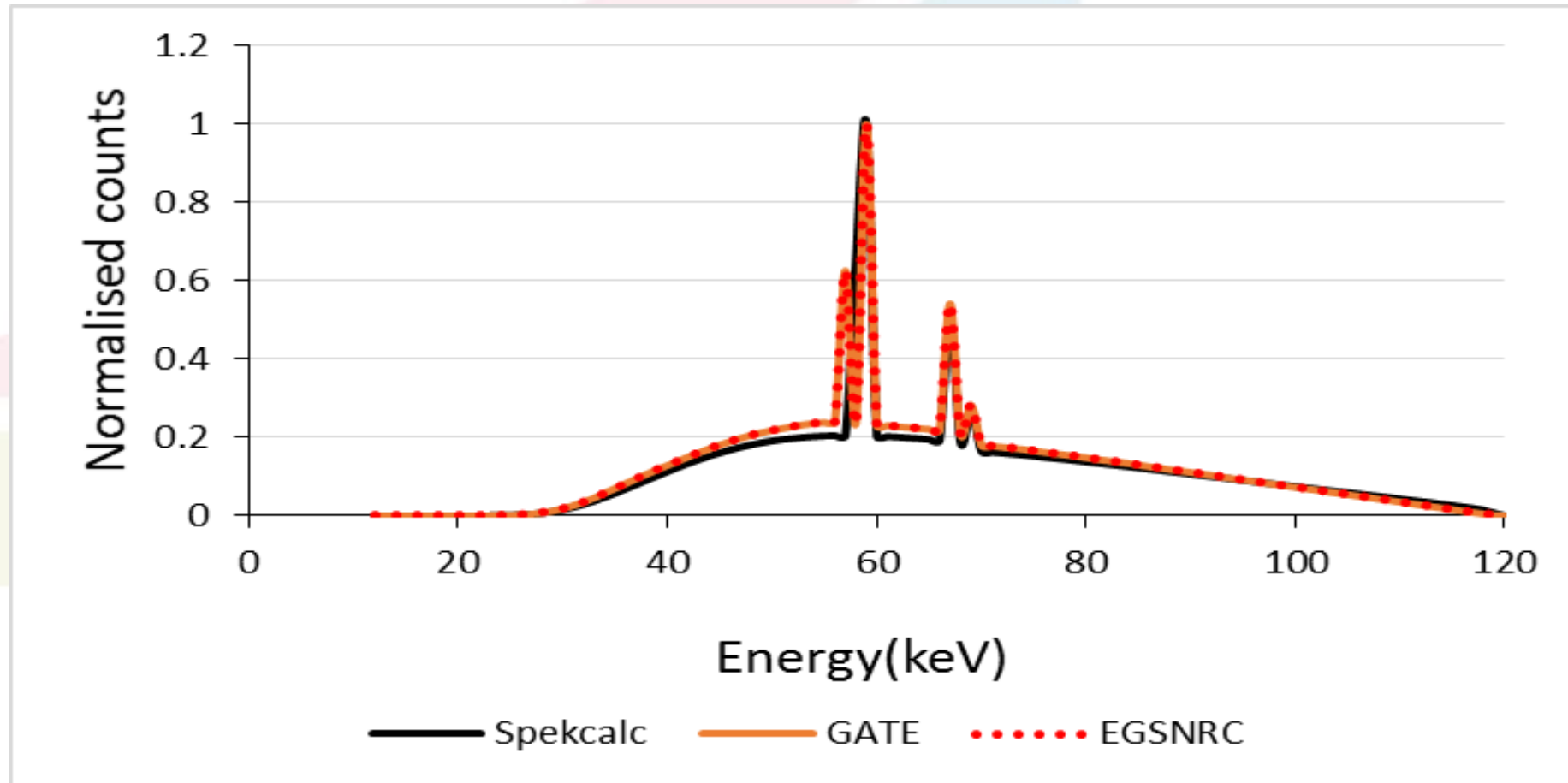
CTDI detector/TLD	Tube current(μ A)
TLD	24,34,44,54
CTDI detector	65,70,80



GUI OF GATE dosimetry of MARS scanner

RESULTS AND DISCUSSIONS

VALIDATION OF GATE SPECTRUM



RESULTS AND DISCUSSIONS

EXPERIMENTAL RESULTS VS SIMULATED RESULTS

Phantom with TLD

Tube current(μA)	Experimental Absorbed dose(mGy)	Simulated Absorbed dose(mGy)
24	23.04	-
34	33.96	-
44	46.08	-
54	61.92	-

SUMMARY

COMPLETED TASK

- To implement a MARS-CT model into GATE
- ✓ Implementation of source model
- ✓ Implementation of scanner geometry

UNCOMPLETED TASK

- To validate the simulated results with the experimental data.
- To integrate a patient data from MARS scans into GATE for 3D spatial dose mapping.
- Scatter dose in voxelised phantom(patient data)