Development of Geant4 DICOM based dose calculation for Synchrotron Microbeam Radiation Therapy

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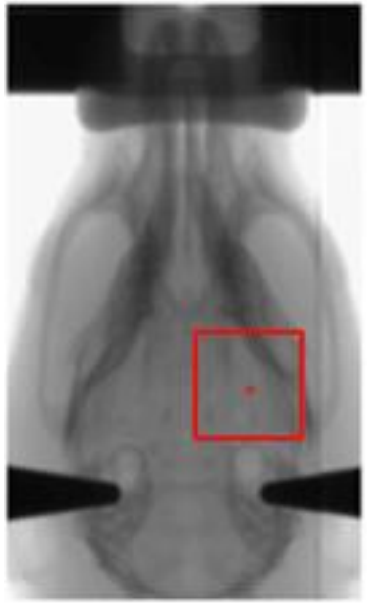
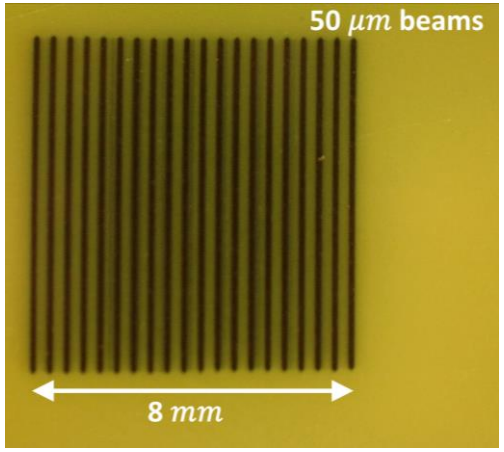
Australian Government

ANSTO

Synchrotron generated Microbeam Radiation Therapy





Commercial treatment planning system not suitable for our beam conditions

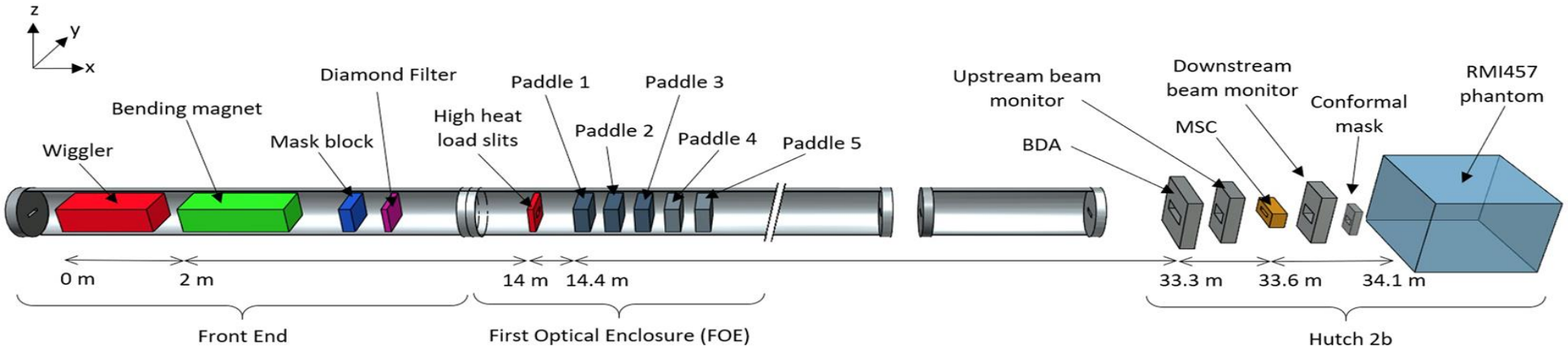
Dose rates $> 5{,}000\ Gy/s$

Small beamlets $50\ \mu m$

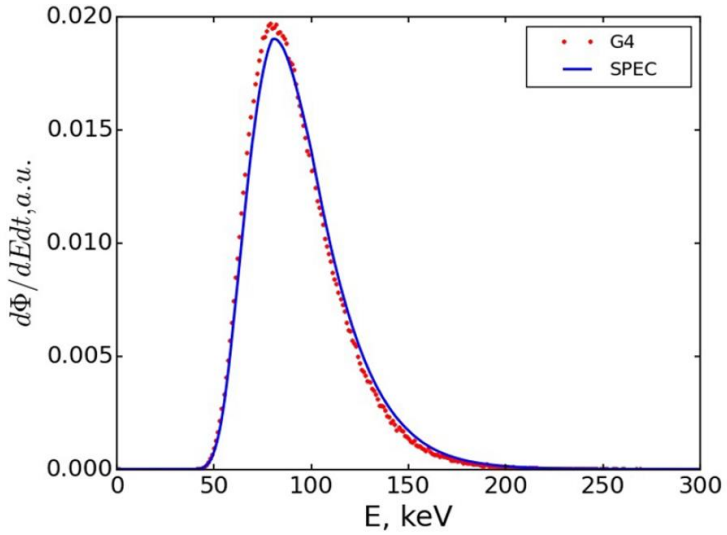
Mean energy $\approx 90\ keV$

Goal to develop dedicated GEANT4 based dose engine to support pre-clinical trials.

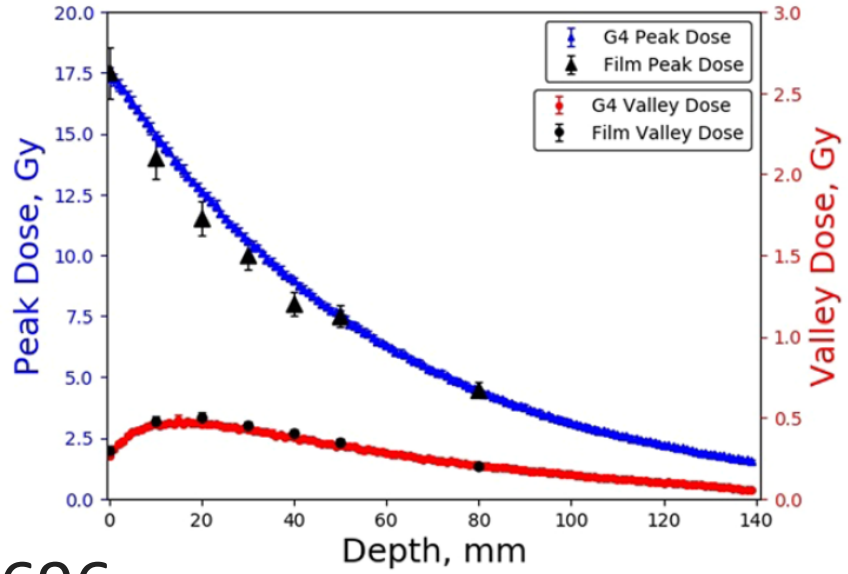
Production of Synchrotron radiation



Validating energy spectrum



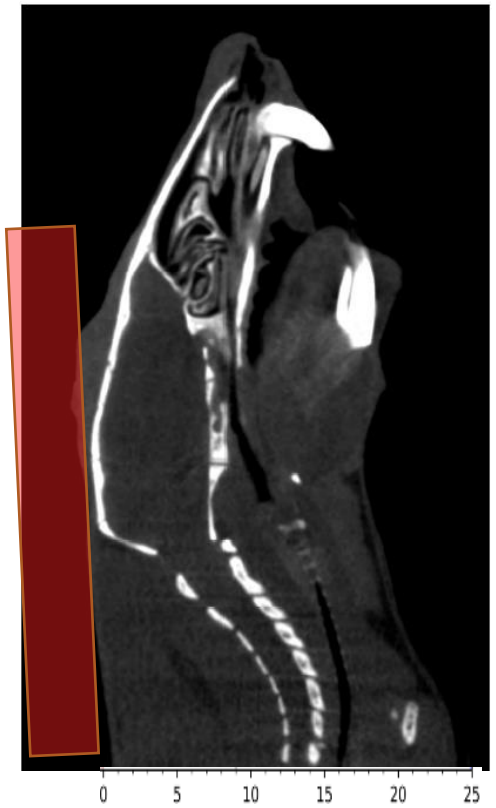
Validating microbeam dose deposition

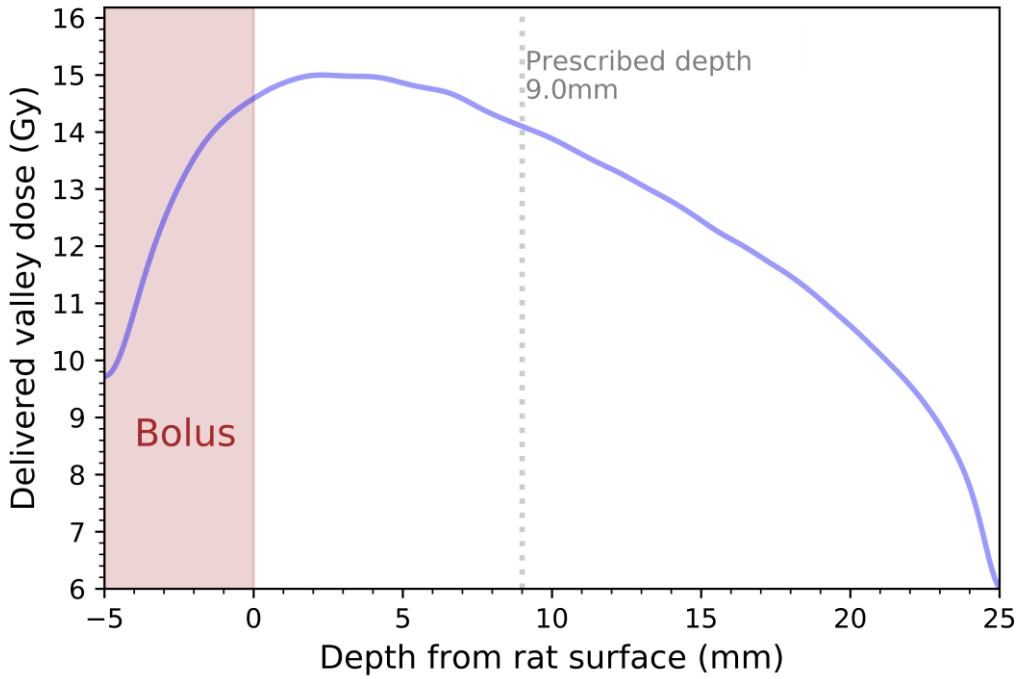


A Dipuglia, M Cameron et al 2019 *Sci Rep* 9, 17696

Simulate dose deposition

Method used to prescribe dose in Engels et al 2020 (live rats), Davis et al 2021 (in-vitro cells), Lange et al 2022 (ex vivo hearts)



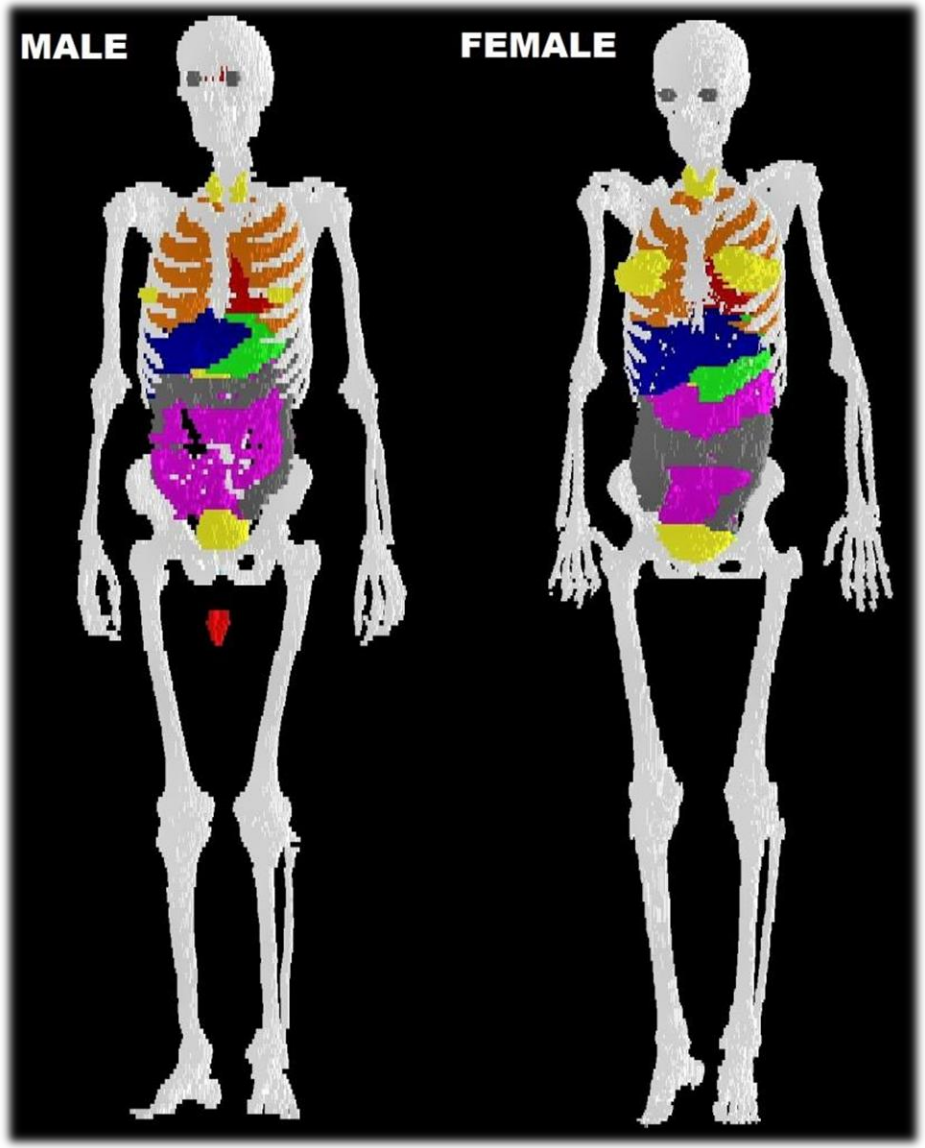


Assumed rat is water equivalent

Simple geometric shapes

We need a better method

ICRP110_HumanPhantoms Advanced Example



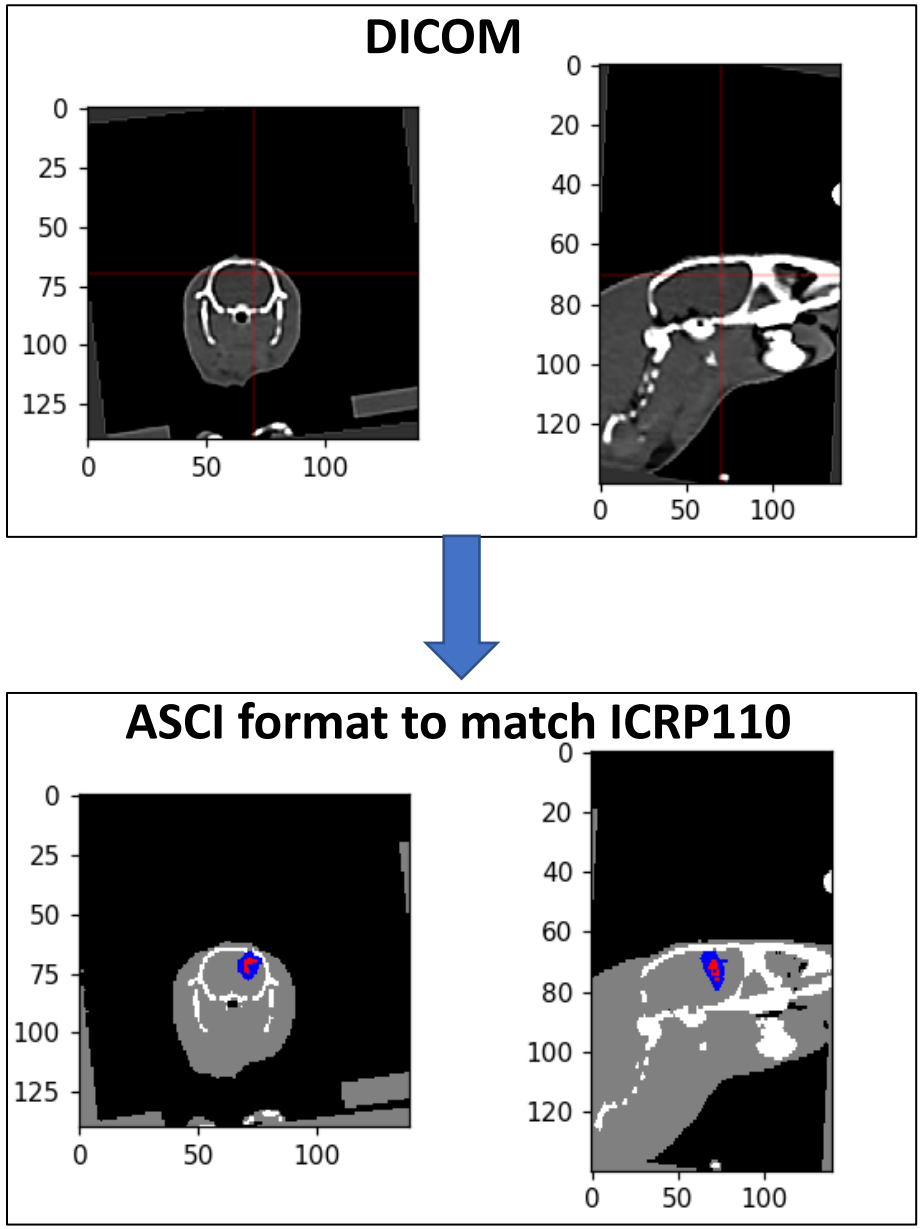
M J Large et al 2020 J. Phys.: Conf. Ser. 1662 012021

Allows for simulations of voxelized phantoms

User needs to find their own way to convert DICOM → GEANT4 compatible files

Combine accurate Synchrotron radiation production method with DICOM based voxelized phantom

Convert DICOM to GEANT4 compatible files



Custom Python code to assist user converting DICOM to G4 compatible files

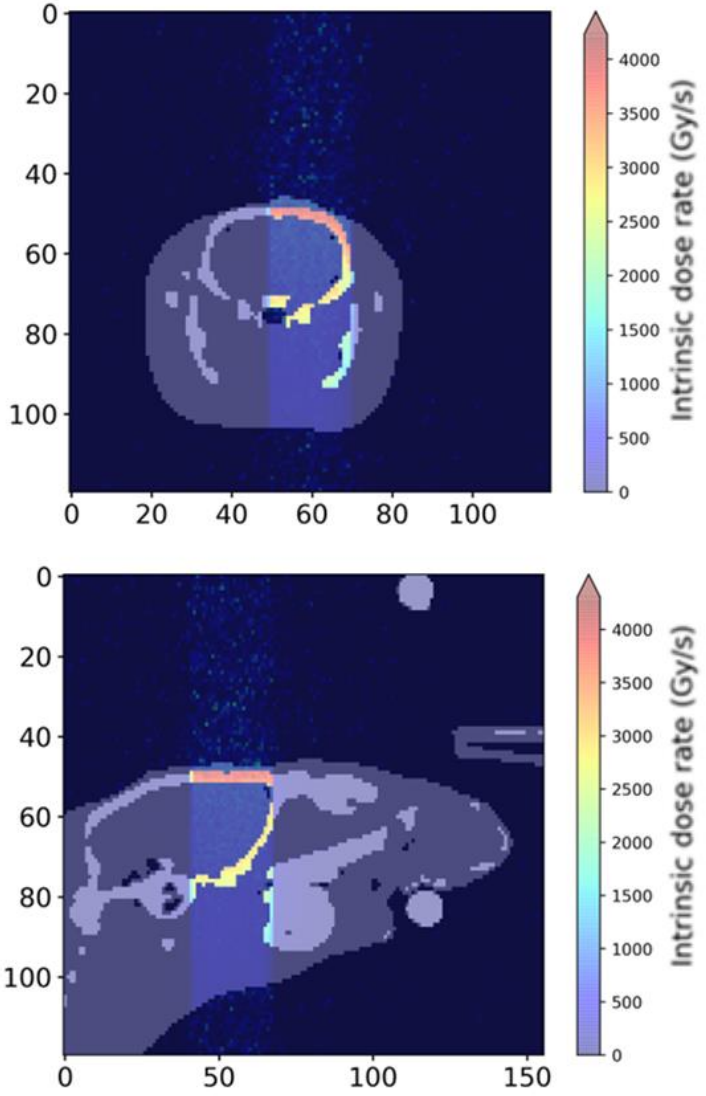
Define custom materials

Semi-automated tumour contouring (‘click and fill’ in house python script)

Scorer resolution independent of DICOM resolution to score $50\mu m$ microbeams

Each DICOM converted in < 10 minutes

Implemented for in-vivo rat brain tumour study



Simulation time ≈10 min using 20 CPUs for 200 million photons

Single user able to treatment simulate for all patients ‘on the fly’

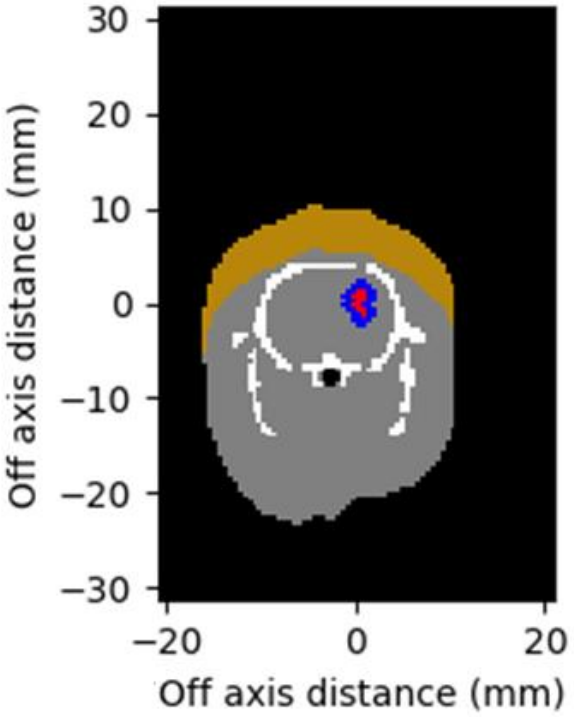
First in-vivo MRT study to provide DICOM based treatment simulations for each ‘patient’

Target output in DICOM co-ordinates to be read in by image-guidance software SyncMRT

SyncMRT, M Barnes et al 2022. Synchrotron Rad. 29, 1074-1084

Implemented for in-vivo rat brain tumour study

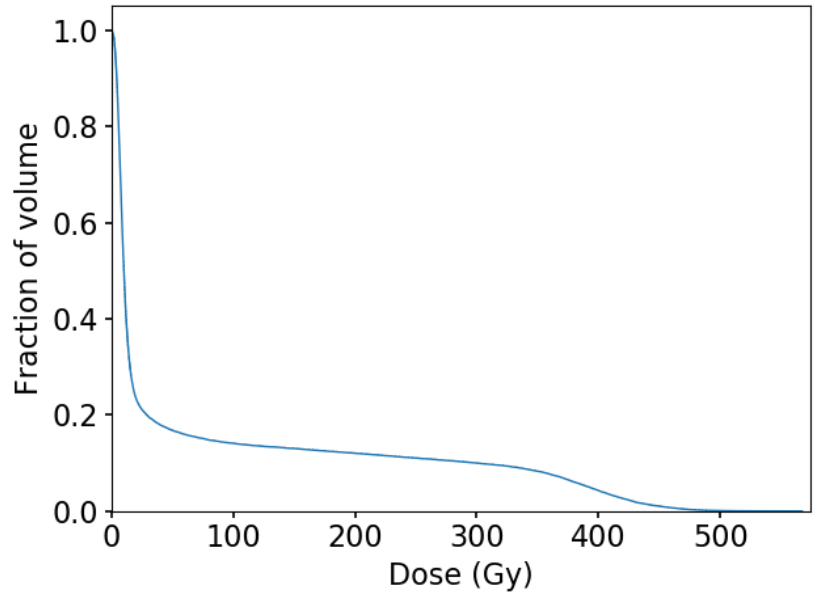
Phantom simulated



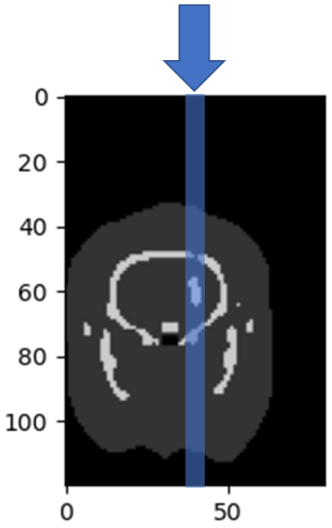
Extract from text file

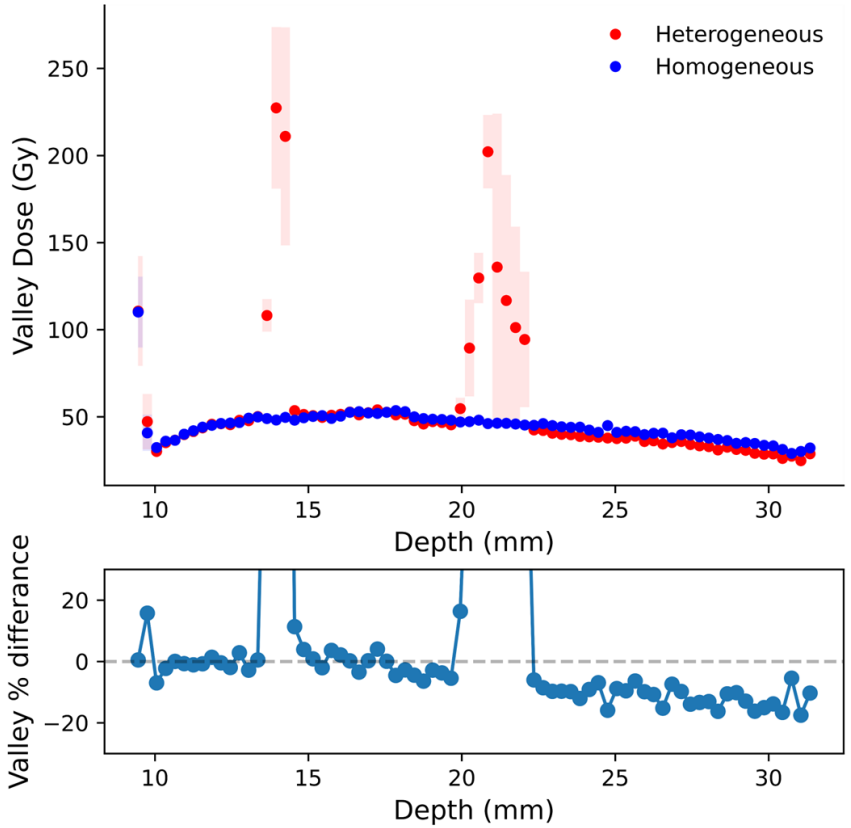
```
Tumour location in dicom frame 270 217 720
tumour voxels:                 58
tumour volume:                 4.749 mm^3
treatment planning ovlume      25.302 mm^3
tumour located 9.404 to 13.061 mm below skin
tumour located 14.106 to 17.763 mm below bolus
volume dimensions simulated    120 80 80
total volume simulated         768000 voxels
score in resolution            0.522 0.010 0.300 mm
```

Tumour DVH



Implemented for in-vivo rat brain tumour study





Used to verify assumptions made in earlier work with simple phantoms

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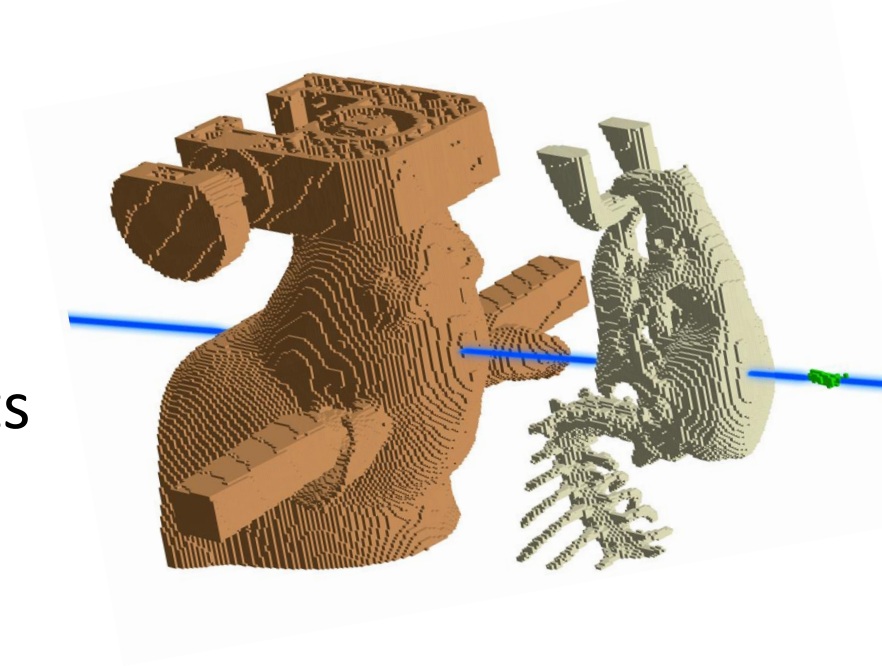
Future prospects



Implement method presented for upcoming experiments

Use this method as foundation for a MRT dose engine

Use to train dose engine based on Machine learning model (3D U-Net)
- Look Mentzel et al (2022) Medical Physics, https://doi.org/10.1002/mp.15555

Additional slides

Experimental Validation

Will be verifying dose simulation in RDS Alderson Radiotherapy Phantom next week!