The development of Monte Carlo techniques for the verification of radiotherapy treatments

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Project Overview

- Software has been developed to import a treatment plan and simulate it using the EGSnrc / BEAMnrc / DOSXYZnrc Monte Carlo suite
- Developed in the Java programming language
- Operates on the QUT computing cluster

Monte Carlo simulation

- Accurate simulation of a treatment delivery requires two things:
  - An accurate representation of the field incident on the patient or phantom
    - Commissioned linear accelerator models
  - An accurate representation of the patient or phantom
    - CT image conversion and use

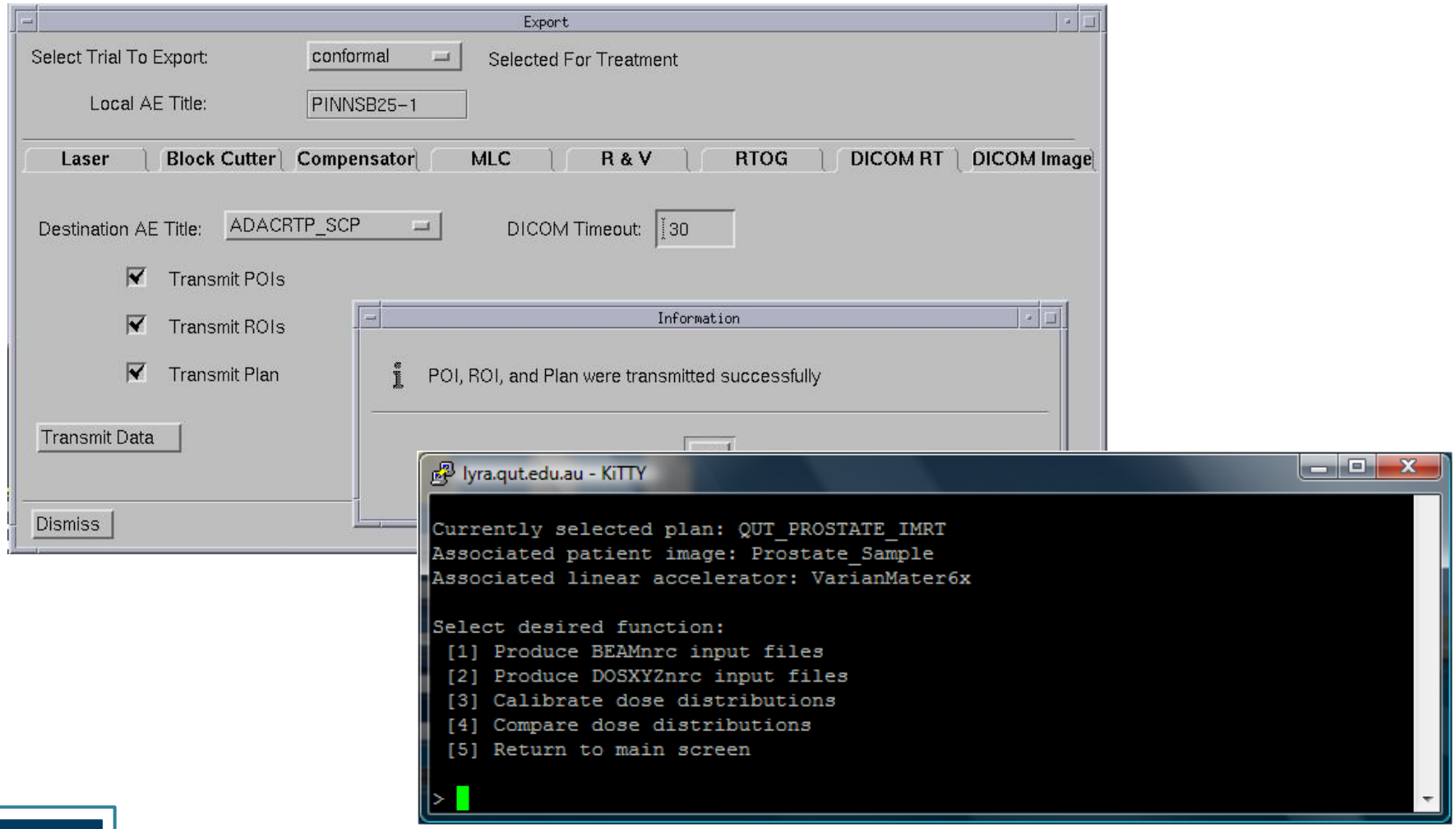
Linear Accelerator Models

- Commissioned accelerators:
  - Varian Clinac 2100CD (6x and 10x)
  - Elekta Precise (6x)
- Treatments use irregular fields: asymmetric, wedged, collimated and intensity modulated
- Manually entering parameters for a multi-field or IMRT treatment would be slow

Treatment Plans & DICOM

- **D**igital **I**maging and **Co**mmunication in **M**edicine
- Framework that allows the sharing of images, dose grids, structure sets (ROIs) and treatment plans
- Exported files are like records in a database: arrays of attributes having identifiers and values
- PixelMed Java DICOM Toolkit accesses attributes
- Images, dose grids and plans are stored in Java classes designed for this purpose

Screenshot of Process



Creating BEAMnrc input files

- BEAMnrc input files are created using the beam configuration data in the treatment plan files
- Database of commissioned linear accelerator template models stored on system
- Plan parameters (jaw and leaf positions, wedge angles, etc) are inserted
- Submitted to the cluster work queue

CT data preparation and use

- DOSXYZnrc packaged with CTCREATE: a utility for converting CT data to a phantom geometry
- Conversion ramp used to convert HU into mass densities
- Electron density calculated using mass density and material definitions (air, lung, tissue and bone)
- Reimplemented in Java to allow removal of the couch and arbitrary coordinate shifts

Dose results

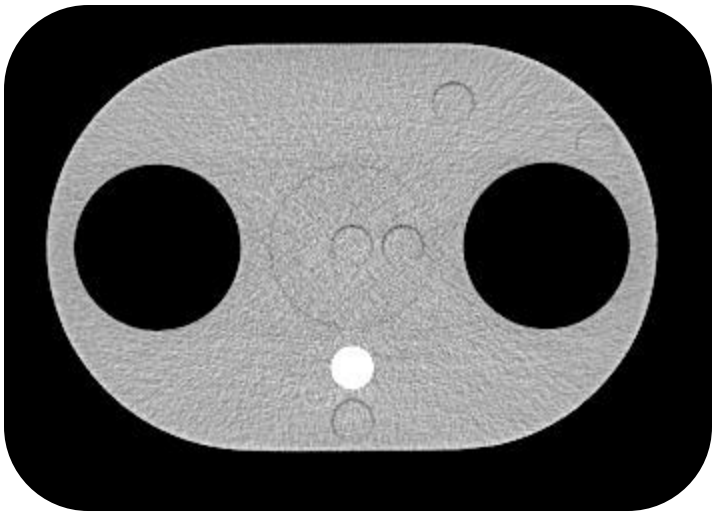
- Simulated field is transmitted through the patient or phantom geometry
- Dose is expressed as Gray per incident particle
- Absolute dose requires calibration:

$$D_{xyz,abs} = D_{xyz} \times \frac{D_{ch}^{frwd} + D_{ch}^{back}{}_{(10\times10)}}{D_{ch}^{frwd} + D_{ch}^{back}} \times \frac{D_{xyz,abs}^{cal}}{D_{xyz}^{cal}} \times MU$$

- Dose difference, gamma evaluation and MADD techniques have been implemented

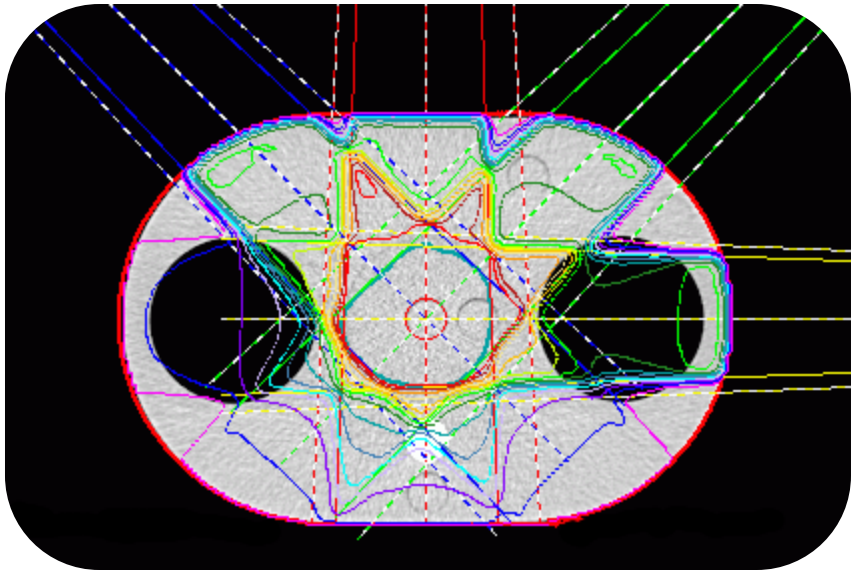
Phantom Test Simulation

- Simulated treatments on QUASAR™ Multi-Purpose Body Phantom (courtesy of Princess Alexandra Hospital in Brisbane)

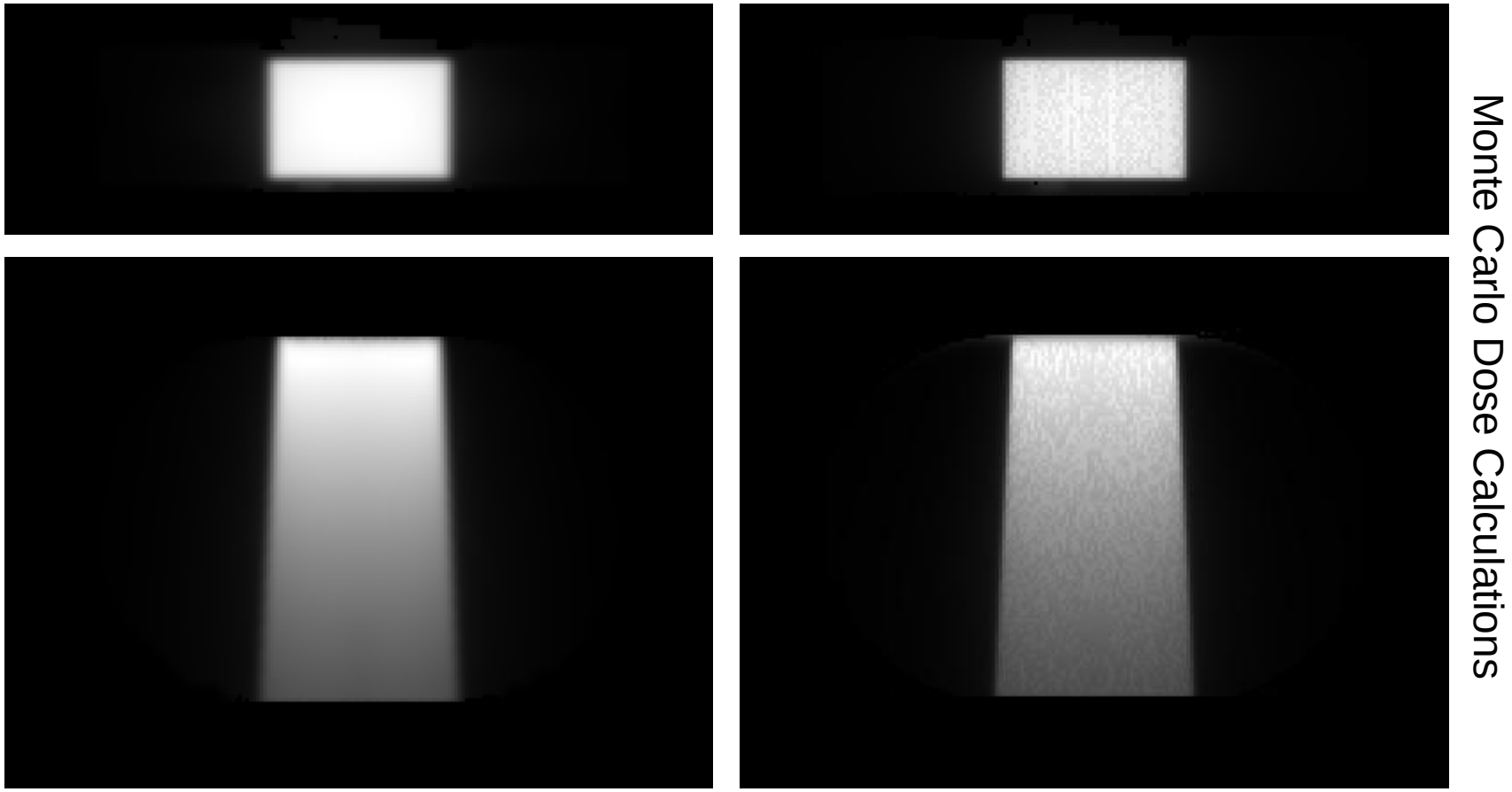


Phantom Test Simulation

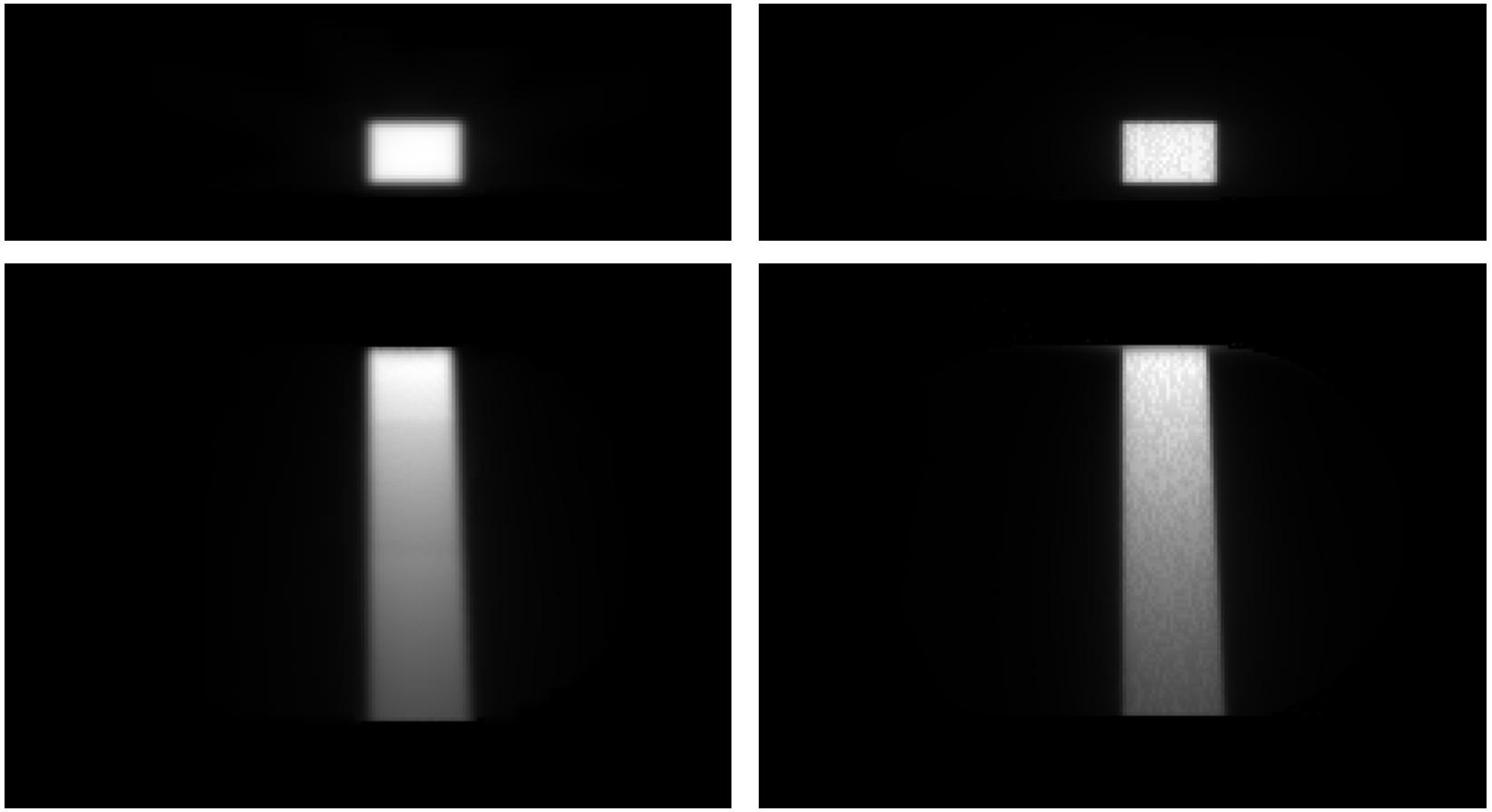
- CT scan of phantom containing inserts used
- 4 treatment plans created on Pinnacle TPS
  - 1 square field
  - 1 asymmetric square field
  - 1 collimated field
  - 4 collimated fields



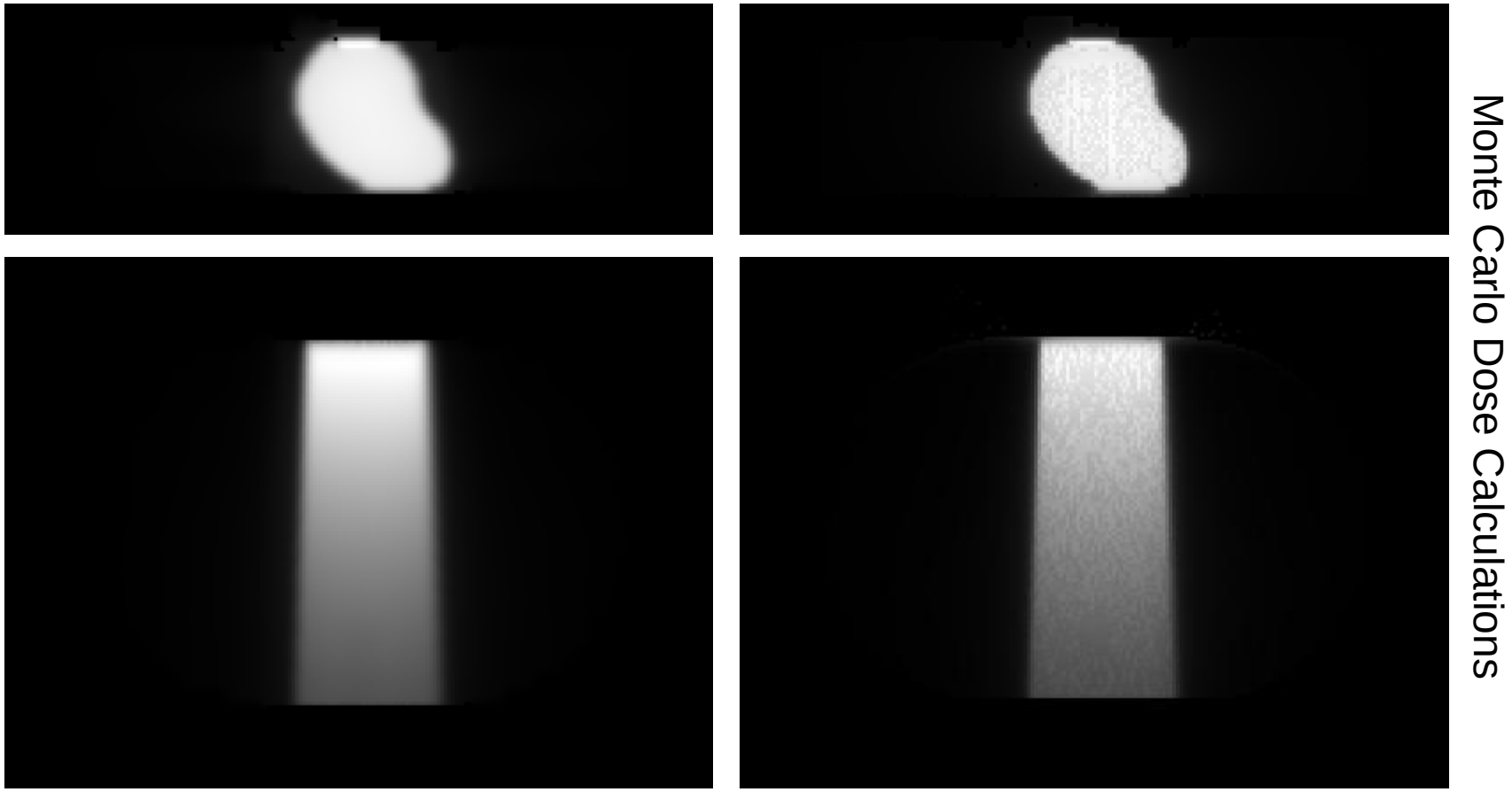
Symmetric Square Field Plan



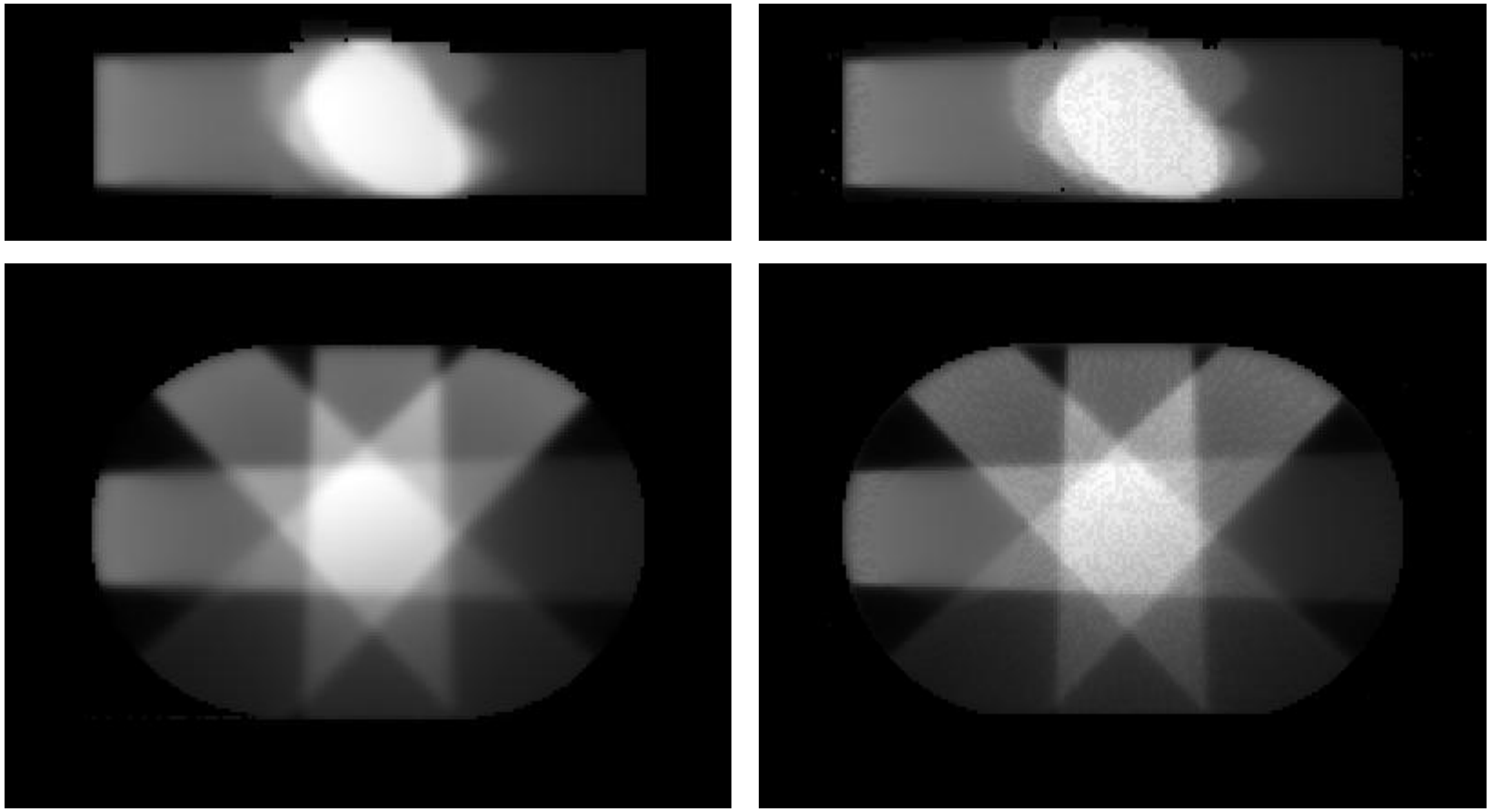
Asymmetric Square Field Plan



Collimated Field Plan



4x Collimated Field Plan



Future Activity

- Optimisation of simulation runs
- Physical measurements (QUASAR phantom)
- Simulation of clinical treatment plans:
  - Head and neck (esp. esophageal) and lung treatments
  - Step-and-shoot IMRT treatments
  - Assess biological significance of any deviations between Monte Carlo and TPS calculations

Acknowledgements

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