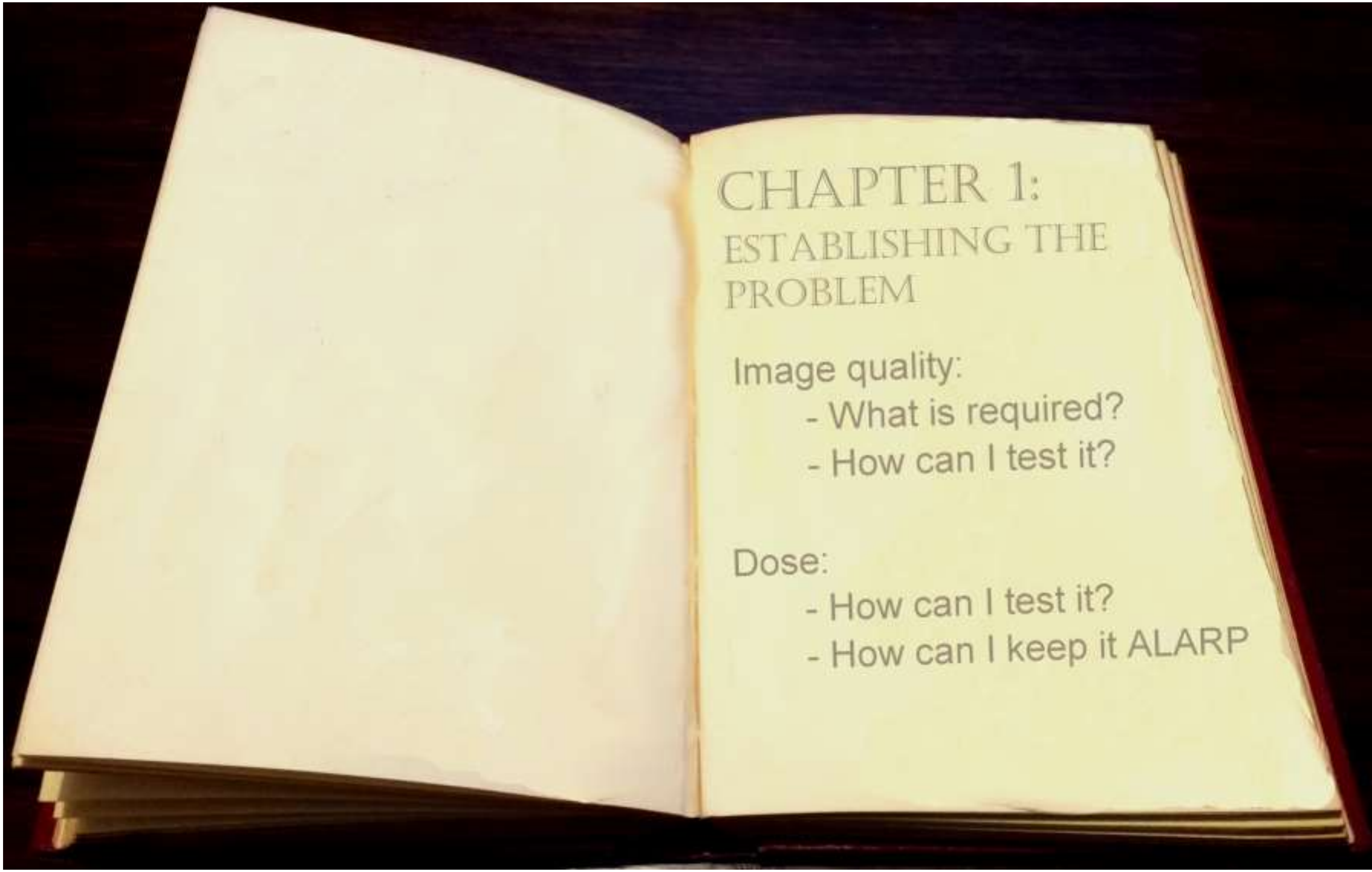
4D CT:

Image quality and dose in a moving target

John Loveland

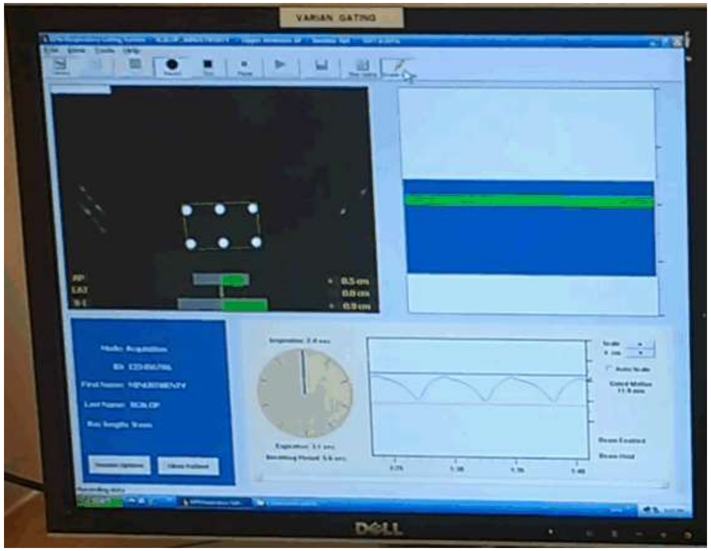

CHAPTER 1:
ESTABLISHING THE PROBLEM
Image quality:
- What is required?
- How can I test it?
Dose:
- How can I test it?
- How can I keep it ALARP

A moving platform

Motorised platform moves in a basic 3D respiratory pattern

CATPHAN or dosimeter can be positioned on the moving platform during scanning

The motion was symmetric and periodic and therefore had no impact on measured doses.



Defining the imaging task

In this project the imaging task was to visualise the pancreas in order to contour pancreatic cancer tumours

Reviewing existing images the task is a low contrast one and thus likely to be limited by the noise within the image

Visualisation within current cases is very difficult

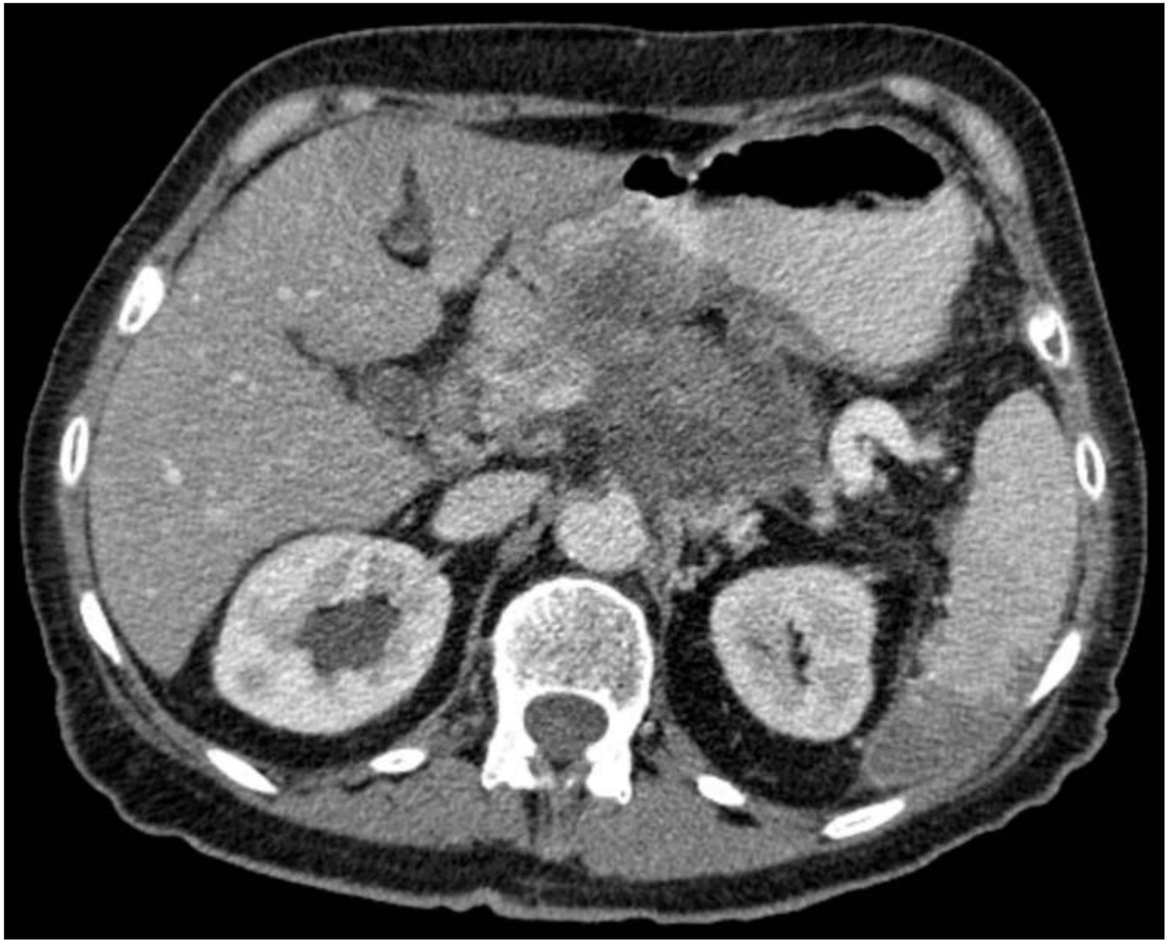


Image source: Wikimedia Commons, Author: Hellerhoff

Why 4D?

The PTV includes a margin to account for uncertainties introduced by motion. By gaining information about the motion we can potentially reduce the PTV and thus reduce the dose to healthy tissues.

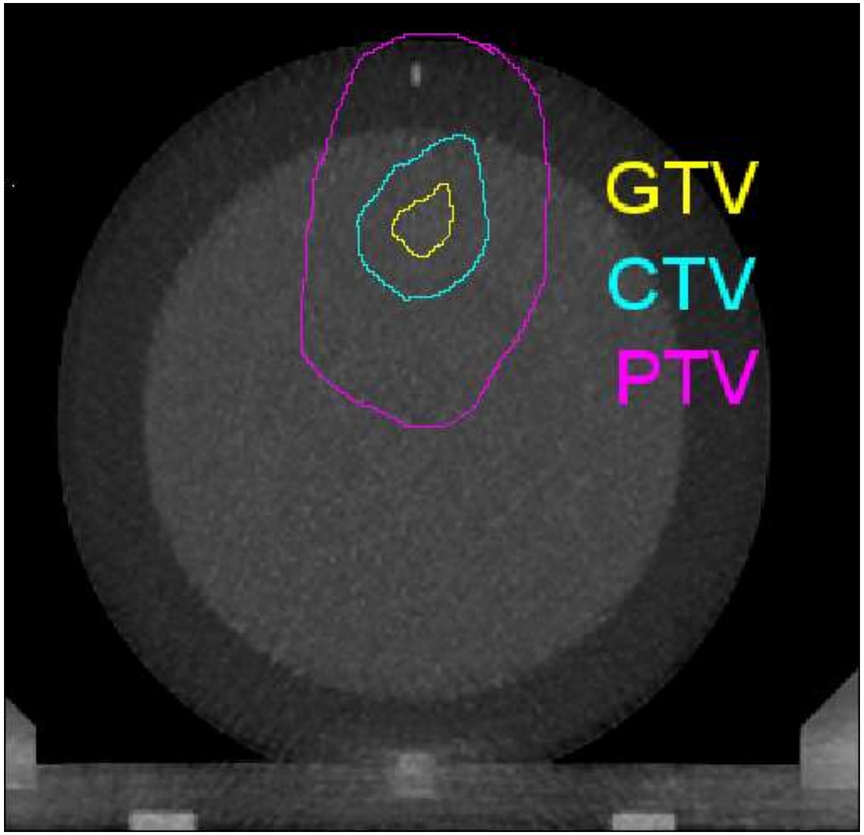


Image the CATPHAN

Scan with the conventional pancreatic cancer protocol (both with phantom static and with phantom moving)

Scan with various mA, rotation time, pitch settings

Low contrast module of the CATPHAN, Uniformity module (for NPS) and MTF module for resolution. Calculate NEQ and threshold contrast resolution.

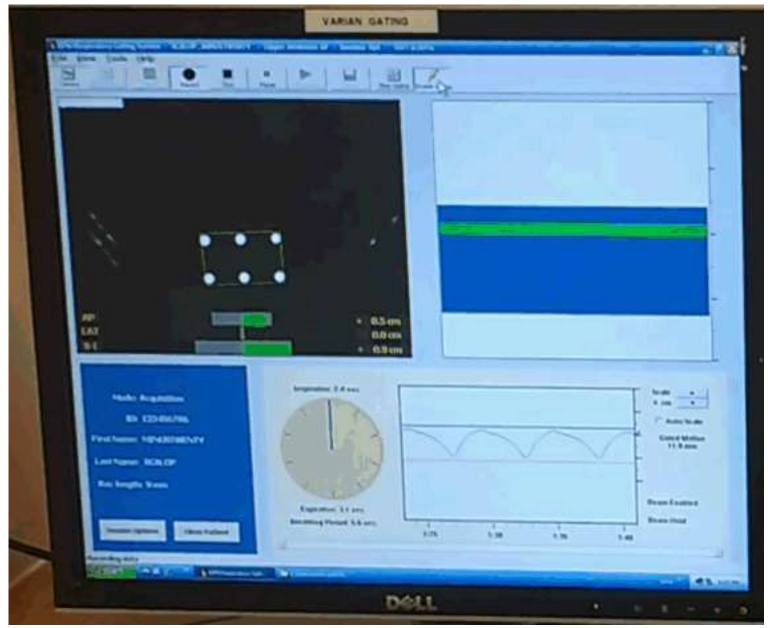
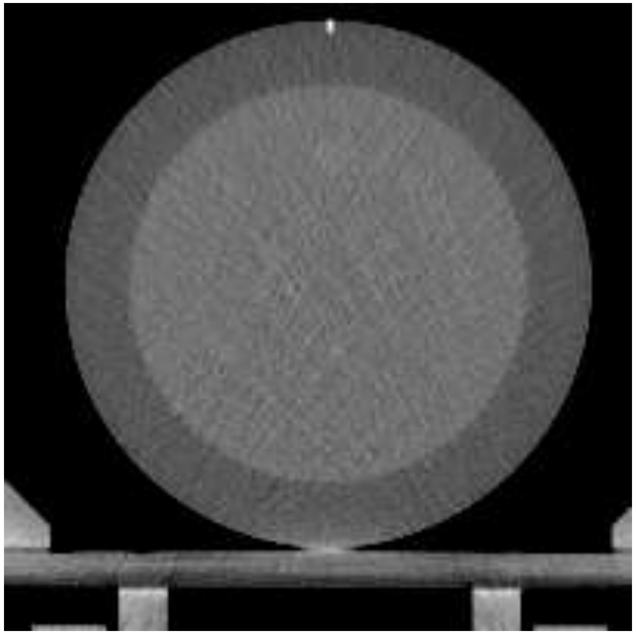


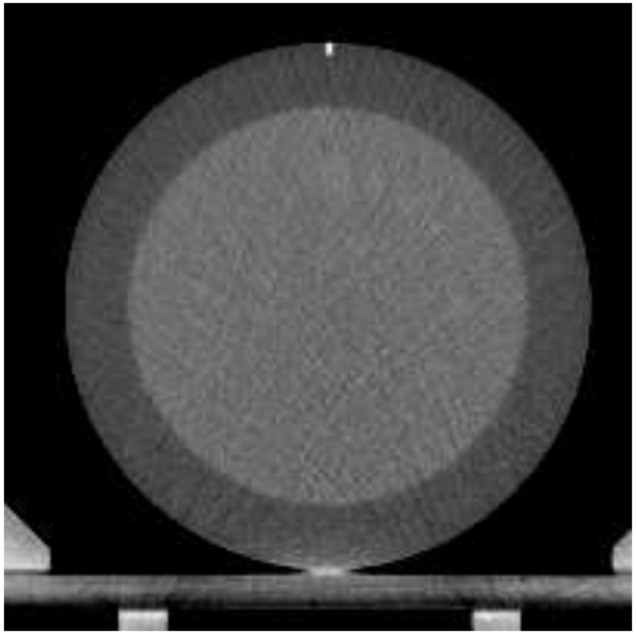
Image quality results?

Very limited number of images available by time of CTUG due to RT access difficulties.

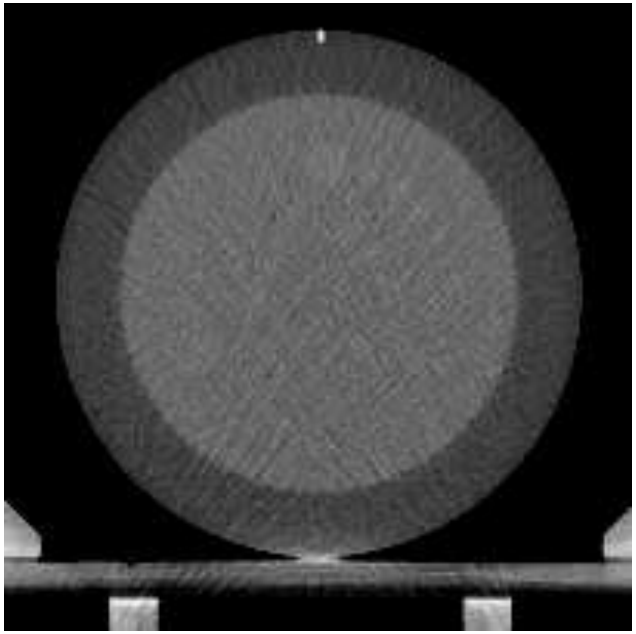
Motion correction along z axis



Low dose 4D (20% reduction)

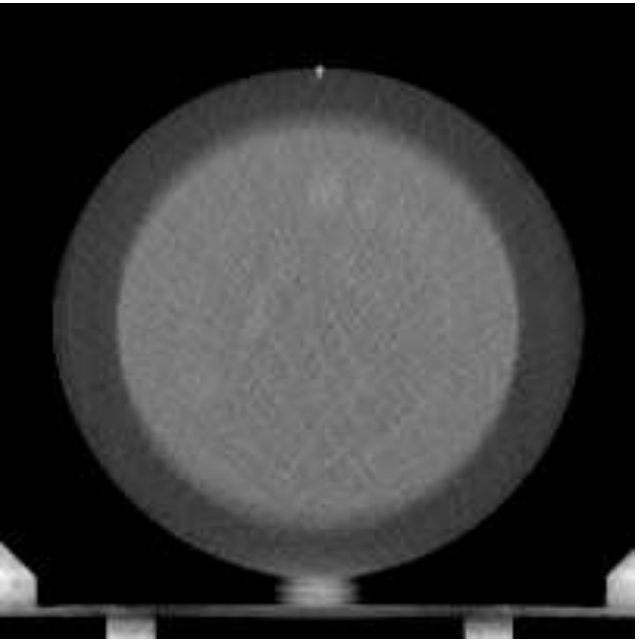


Standard 3D

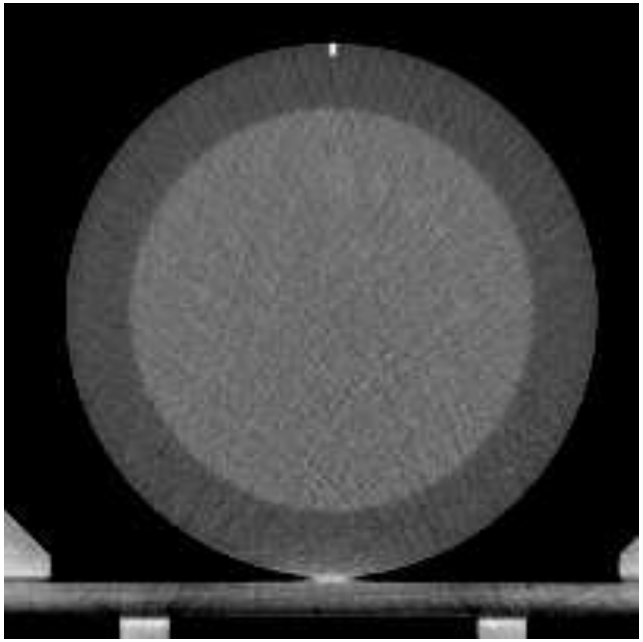


4D to match 3D

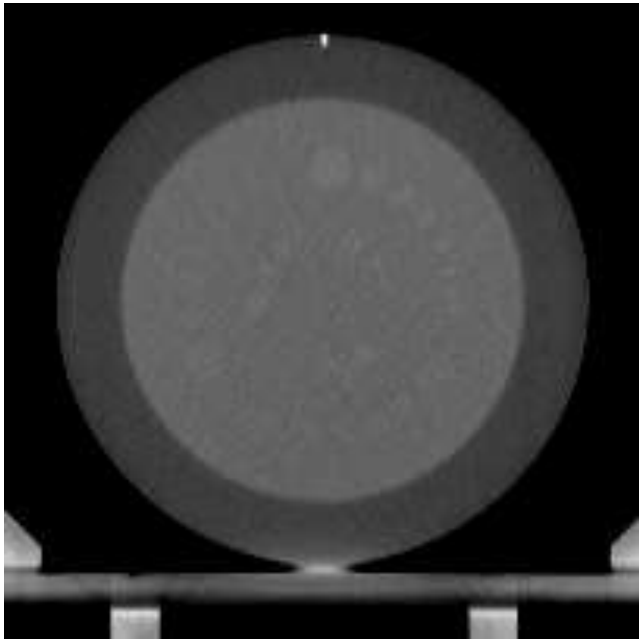
Custom 3D motion correction



Average 4D



Standard 3D



Custom motion correction average

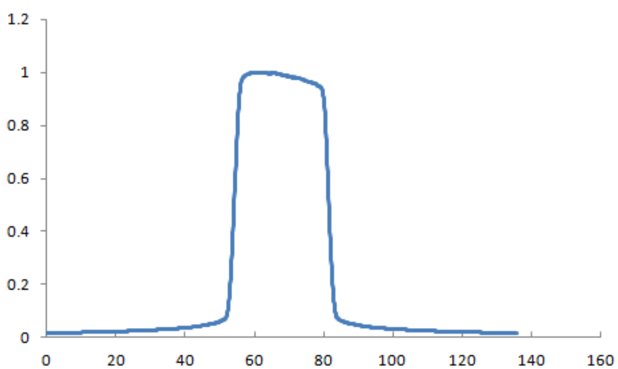
Dose

- Expected DLP for 3D pancreas of ~ 280mGycm
- Therefore expected 2800mGycm for 4D with 10 phases each with equivalent image quality to 3D scan
- But displayed DLP for 4D -> 750mGycm
- ?

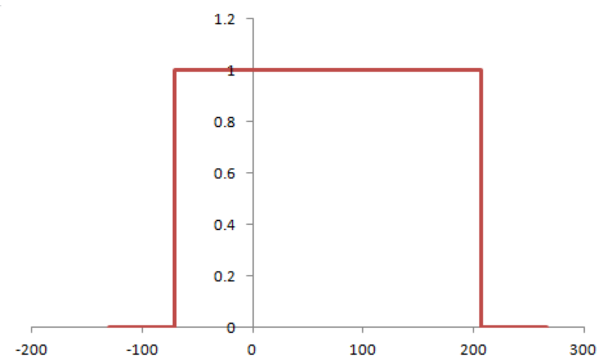
Dose?

Use linearised gafchromic film to measure beam profile (in air, axial scan) at collimation used in 4D CT scan. Note the $CTDI_{100,air}$ for this scan.

Convolve with RECT function of length of 4D CT scan.



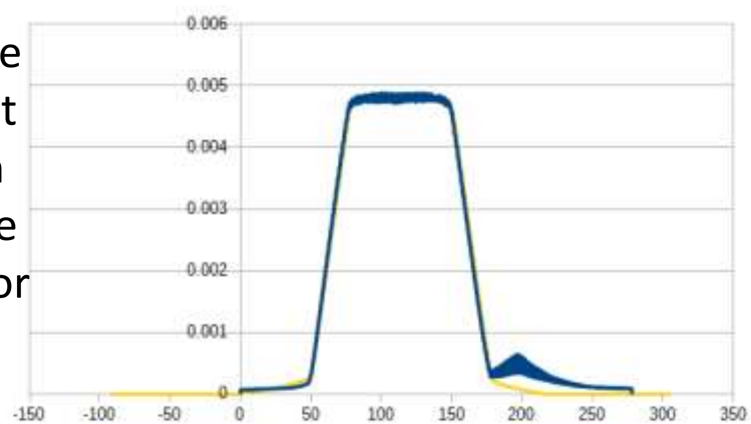
⊗



⇨ ?

Compare the convolved function with the measured function. Re-scale the axial scan profile and repeat until match between convolved (yellow) and measured (blue). The scaled dose profile before convolution will correspond to the input dose profile that is propagated through the 4D-CT scan in air. Integrating over the central 100mm gives the equivalent $CTDI_{100,air}$

Use real-time dose rate measurement during 4D CT scan (in air) to calculate the dose profile for the 4D CT (Blue curve on right).



Dose

Preliminary results suggest that the CTDIvol displayed is an under-estimate.

Dose: The easy way

- Use the displayed mA, rotation time and pitch combined with physics QC measurements to predict the $CTDI_{vol}$ and DLP for the 4D scan.

- Compare to the displayed $CTDI_{vol}$

Dose

- Further investigation into the pancreas protocols suggested that the $CTDI_{vol}$ for the 3D scans was far too low.
- When the applications specialist had set up the 4D CT protocol they had simply based it on the 3D scan
- The doses really were very low for the 4D scans – probably too low.

Conclusions

- The 4D CT dose was indeed 10 times the 3D dose it's just that the 3D dose had been set up too low (much lower than expected)
- The other protocols on the scanner should also be reviewed
- Good communication is required between Radiotherapy physics and Diagnostic Radiology physics

Ongoing work…

- More image analysis is outstanding and will be performed as additional images become available
- Use results to direct the optimisation process
- Audit and review after changes to protocols