Monte Carlo Portal Dosimetry for IMRT Verification

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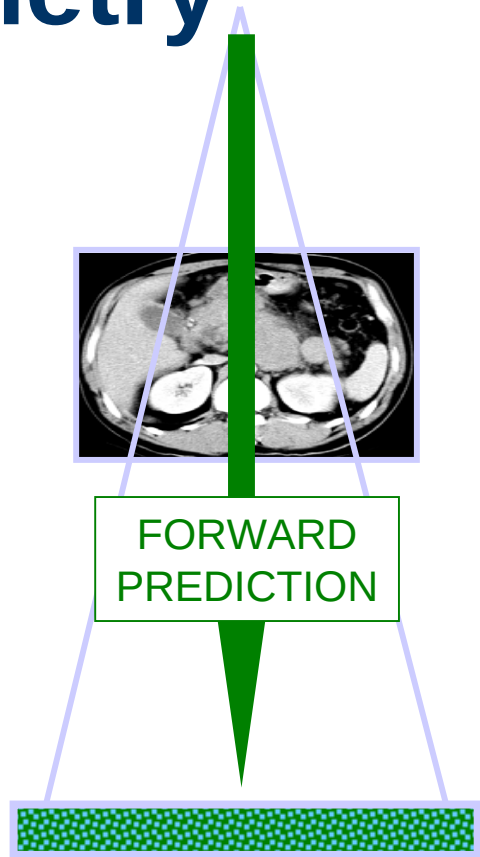
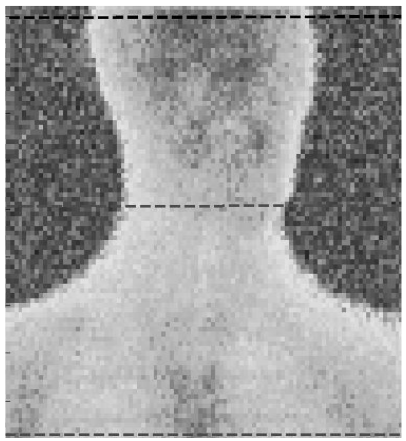
Monte Carlo Portal Dosimetry

- Potential treatment verification solution
- Detailed MC model of the linac in combination with Electronic Portal Imaging Device (EPID) enables the dose to the detector to be accurately predicted



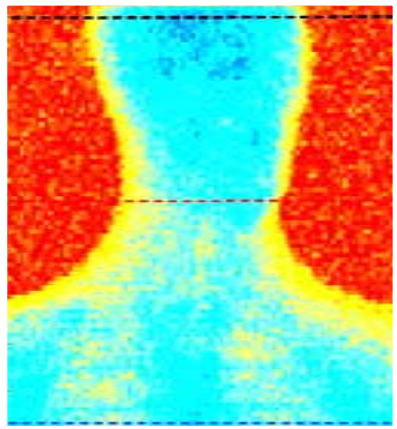
GIVEN THE TREATMENT PLAN, WHAT WOULD THE IMAGE LOOK LIKE?

ACTUAL
(measured)



↔
COMPARE

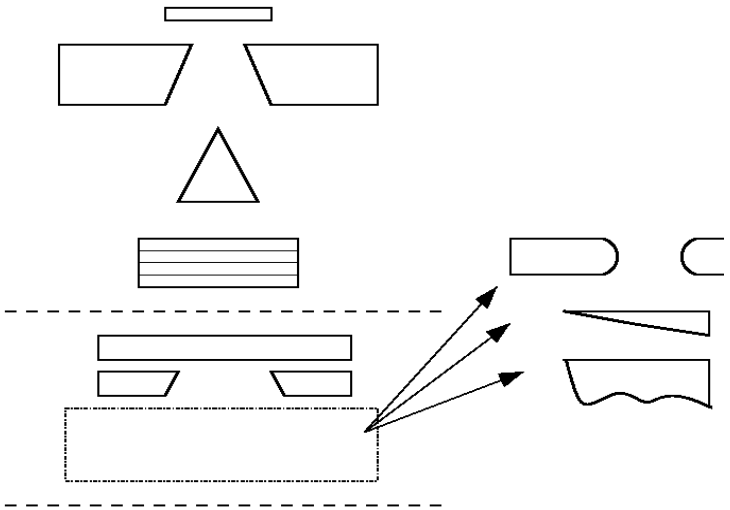
PREDICTED
(Monte Carlo)



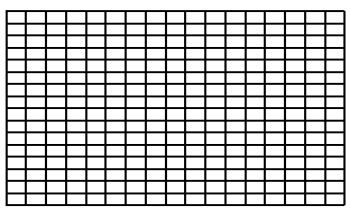
- Currently working towards pre–treatment delivery verification
- Technique also has the potential to be used at varying gantry angles and during treatment to verify delivery (transit dosimetry)[1]

[1] Chin P.W., Cardiff University PhD Thesis 2005

- 1st stage was to construct a Monte Carlo model of Varian 2100CD linear accelerator (10 MV)



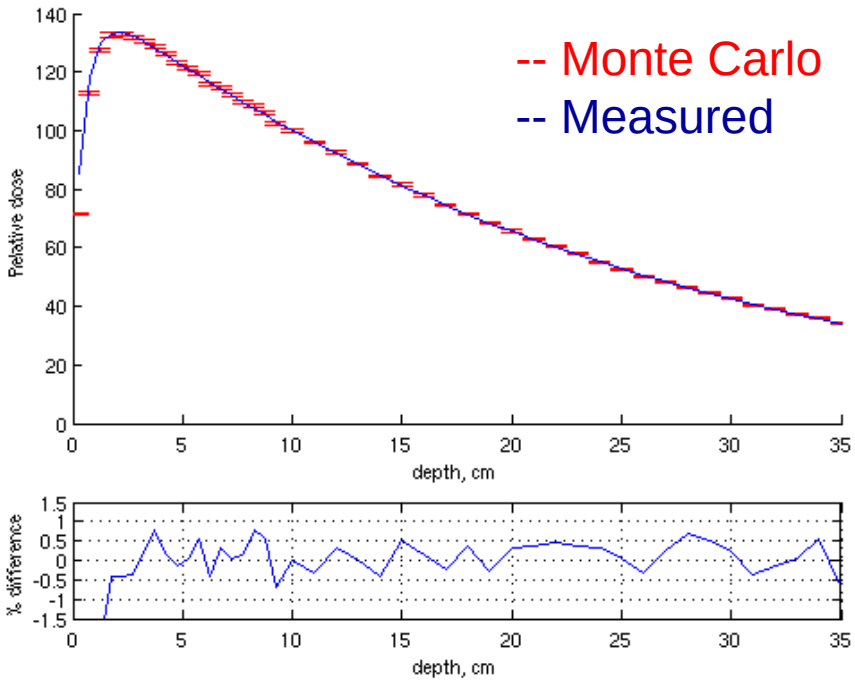
Accelerator simulations using BEAMnrc code



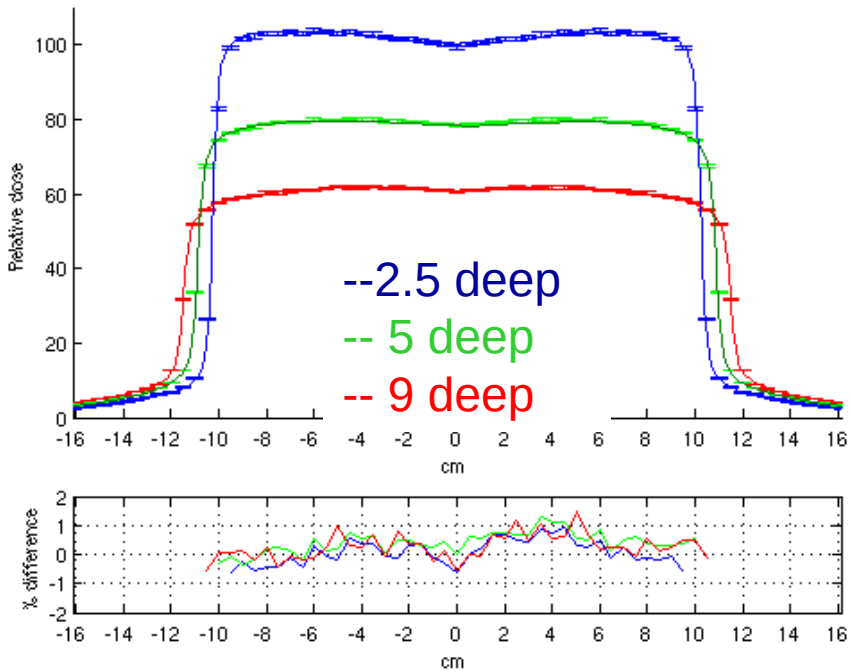
Phantom / EPID simulations using DOSXYZnrc code

Comparison of measured (water tank) and Monte Carlo data

Depth dose for a 20 cm x 20 cm field



Profiles for a 20 cm x 20 cm field at 3 depths



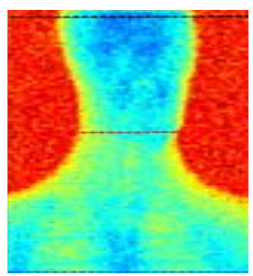
Next stage:

- Run DOSXYZnrc EPID simulations for simple fields
- Construct the portal image pixel intensity to Monte Carlo dose calibration curve
- Use technique to verify simple fields

pixel value

CALIBRATE

portal dose



Amorphous Silicon EPID Model

Converts Photons to Electrons

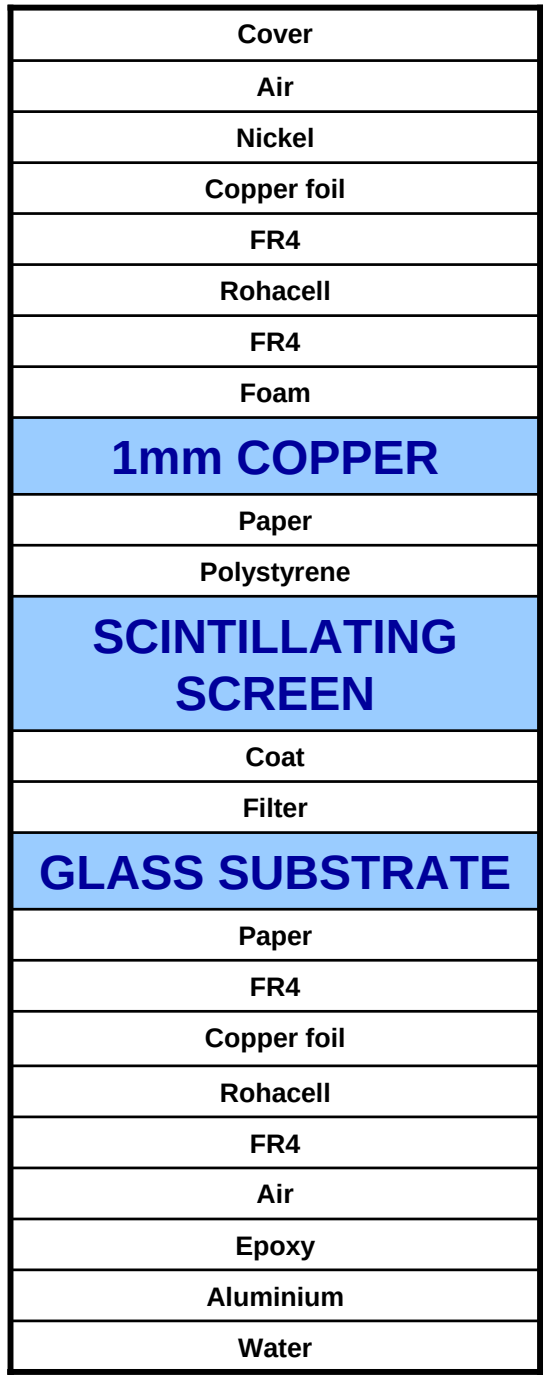
Converts Electrons to Light

Containing aSi Photodiodes and TFT Switches

- 512 x 384 pixels of 0.784 mm x 0.784 mm

- Each of 384 rows is scanned in sequence by read-out electronics

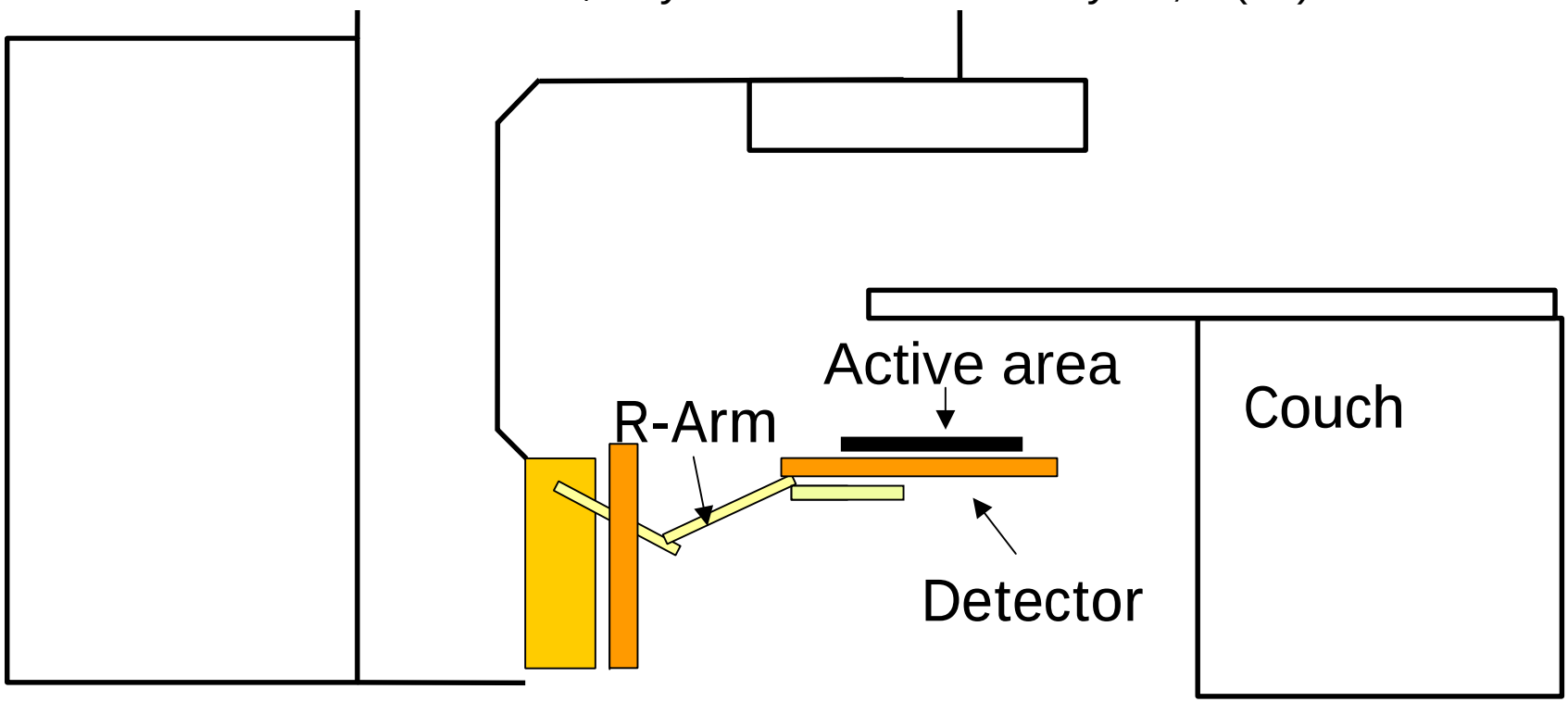
- High acquisition rate (3 frames/sec)



- PCUT (photon cut off energy) is set to 0.01 MeV for simulations
- The following processes are not simulated:
  - Conversion to light
  - Transport of optical photons from scintillator to photodiode
  - Photodiode signals
- However, photodiode response is proportional to energy deposited in phosphor screen

- The detector arm and backscatter material are currently modelled as a slab of water of uniform thickness (2 cm)
- In reality the detector arm provides non-uniform backscatter in the Gun – Target direction[1,2,3]

[1]Siebers J.V. et al, Med Phys. 2004 Jul;31(7):2135-46
[2] Ko L. et al, Phys Med Biol. 2004 May 7;49(9):1723-38
[3] Moore J.A and Siebers J.V., Phys Med Biol. 2005 May 21;50(10):2341-50

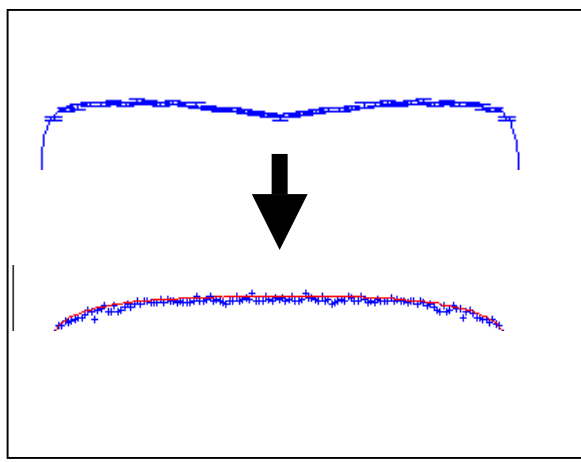


- For symmetric fields the non-uniform backscatter in the Gun – Target direction is not significant as it is cancelled out by the flood field calibration procedure
- However, measurements have shown very asymmetric small fields to show greater discrepancies
- If this backscatter proves to be significant a more accurate representation of the detector arm will be required

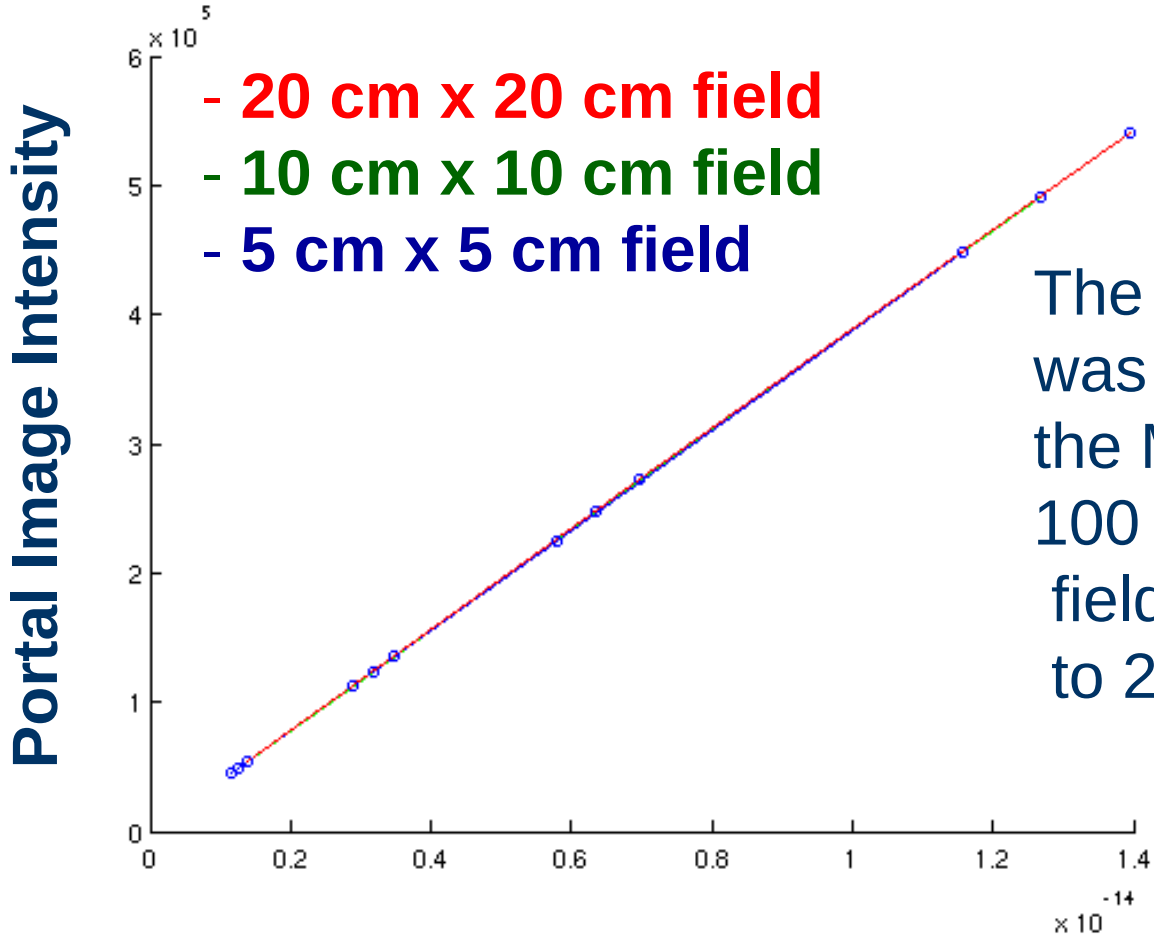
Portal Image Calibration Procedure

$$\frac{\left[\text{Portal Image} - \text{Dark Field Image}\right]}{\text{Flood field}} \times K_{FFmean}$$

- The portal image calibration procedure results in removal of the beam ‘horns’
- Therefore all Monte Carlo simulation images are similarly divided by a Monte Carlo ‘Flood’ image



Monte Carlo Dose to Portal Image Intensity Calibration Curve

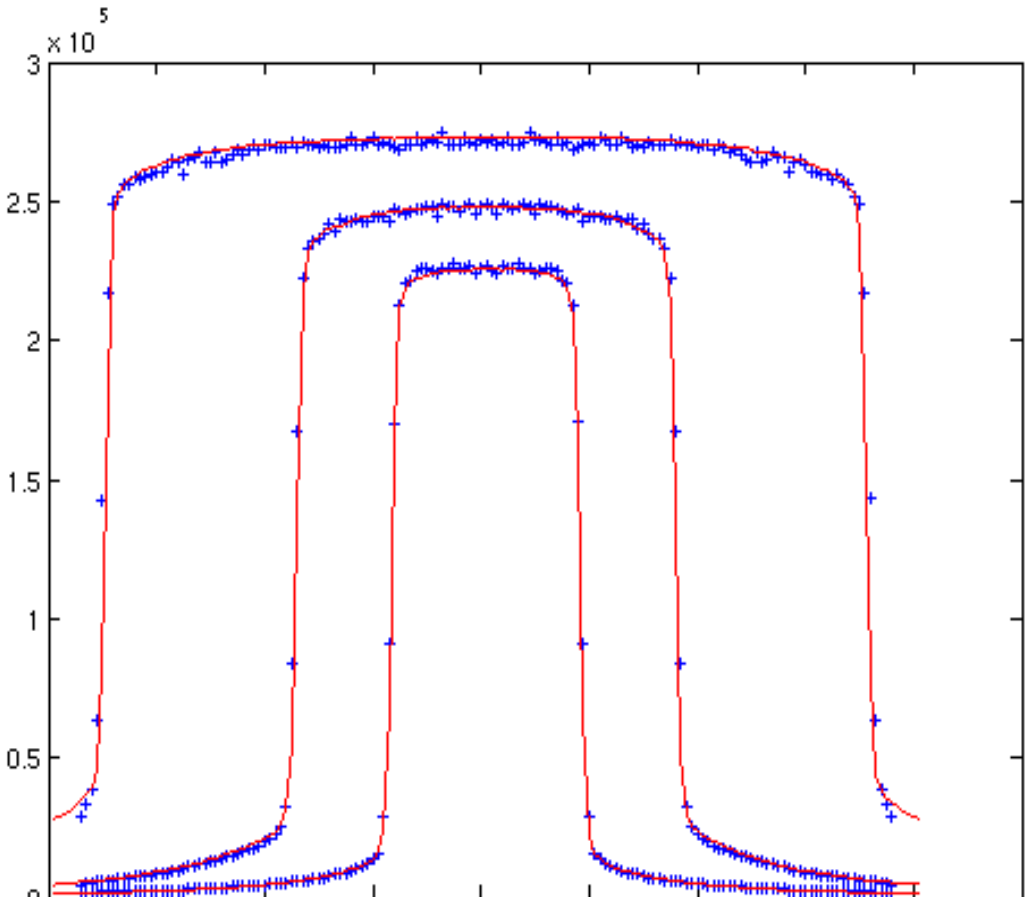


The range of intensities was achieved by increasing the MU from 10 MU to 100 MU and changing the field size from 5 cm x 5 cm to 20 cm x 20 cm

Monte Carlo Prediction of Simple Fields

(20 cm x 20 cm, 10 cm x 10 cm and 5 cm x 5 cm)

- Method predicts simple portal images to within ± 1.5% for the range of field sizes and MU tested

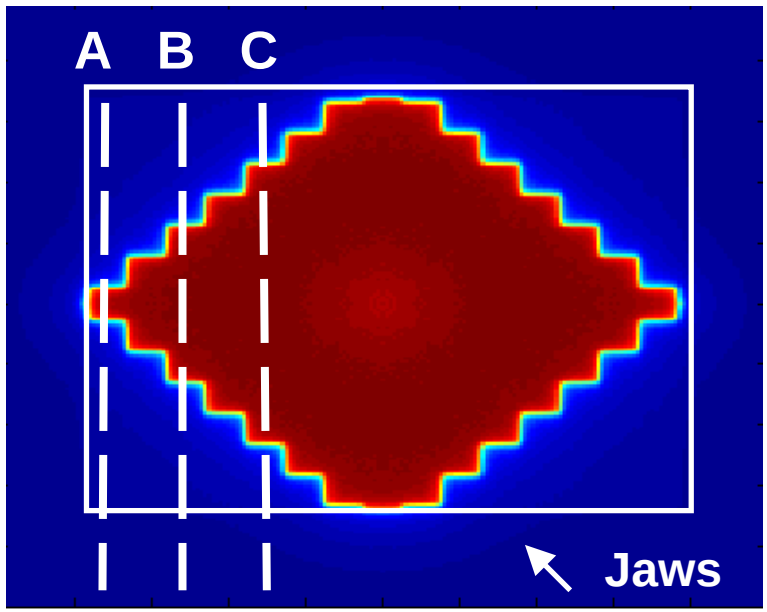


-Acquired portal image

- Monte Carlo

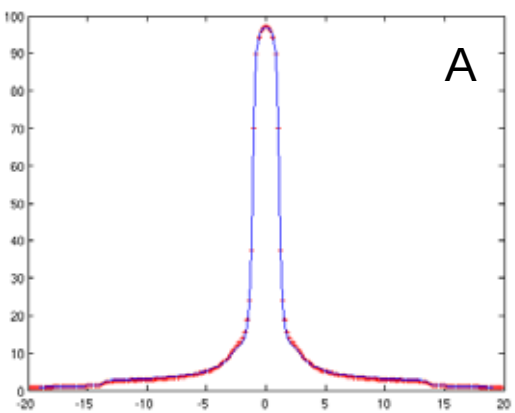
- To enable the progression to verification of IMRT fields it was then necessary to model the Varian120 leaf Millennium MLC
- This was done using Varian data and the new DYNVMLC component module (Emily Heath, McGill University)

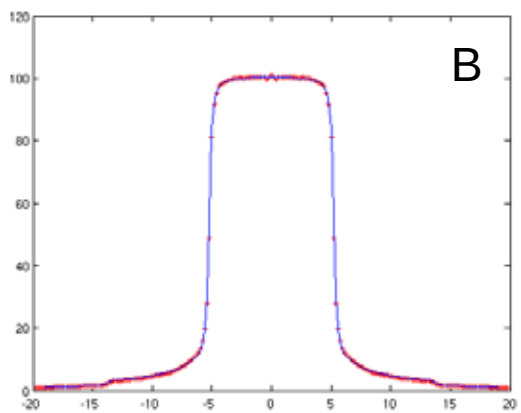
Sample MLC Model Commissioning Images

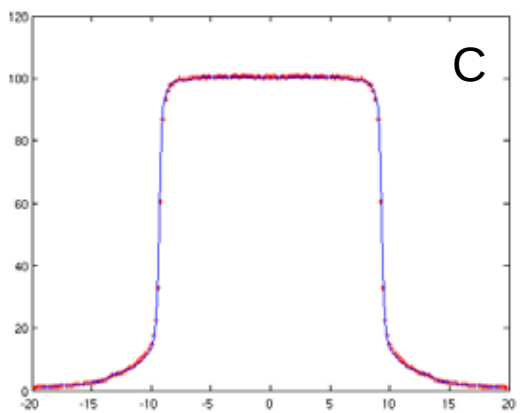


- Monte Carlo simulation

- Measured data

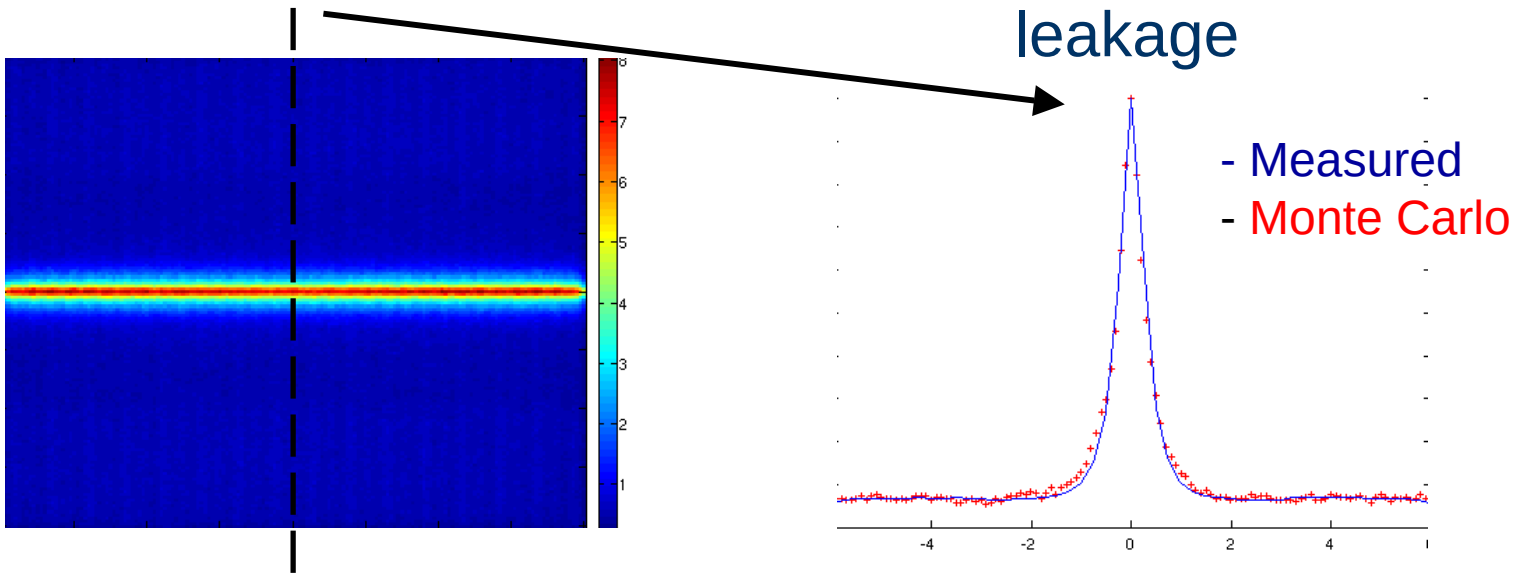






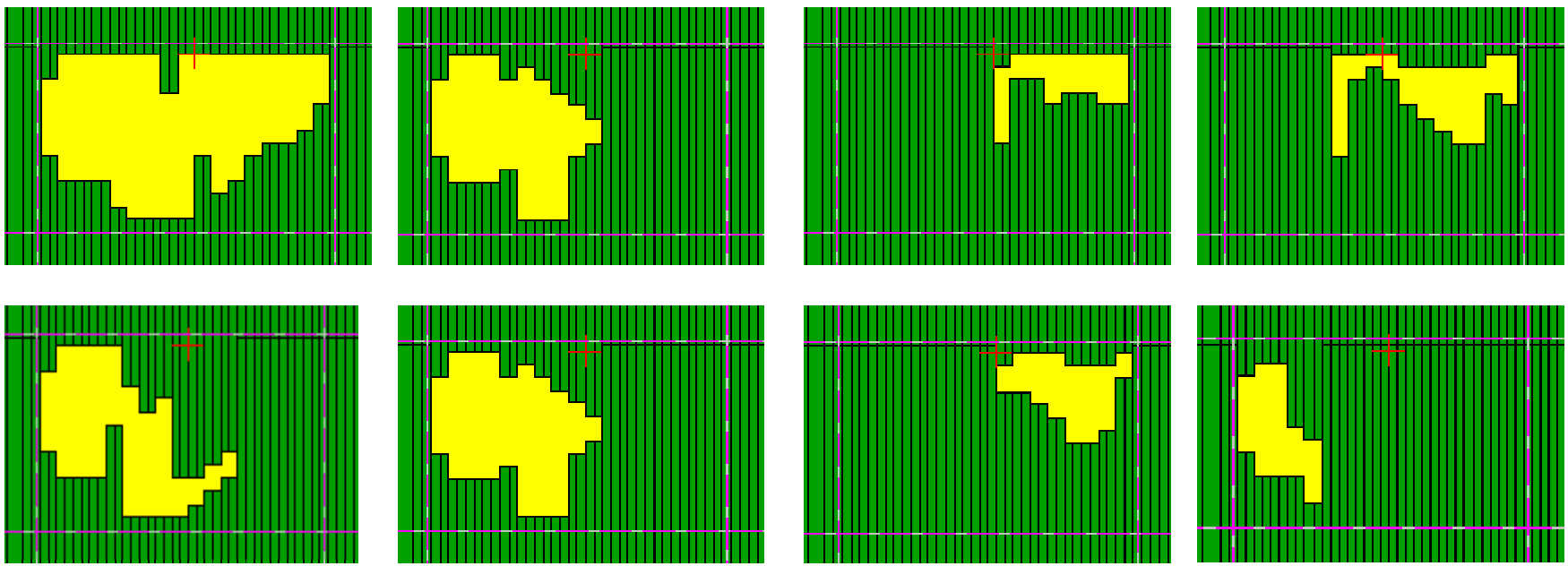
MLC Model Commissioning

- Must verify:
  - Leaf end abutment leakage
  - Inter-leaf leakage
  - Leaf Transmission

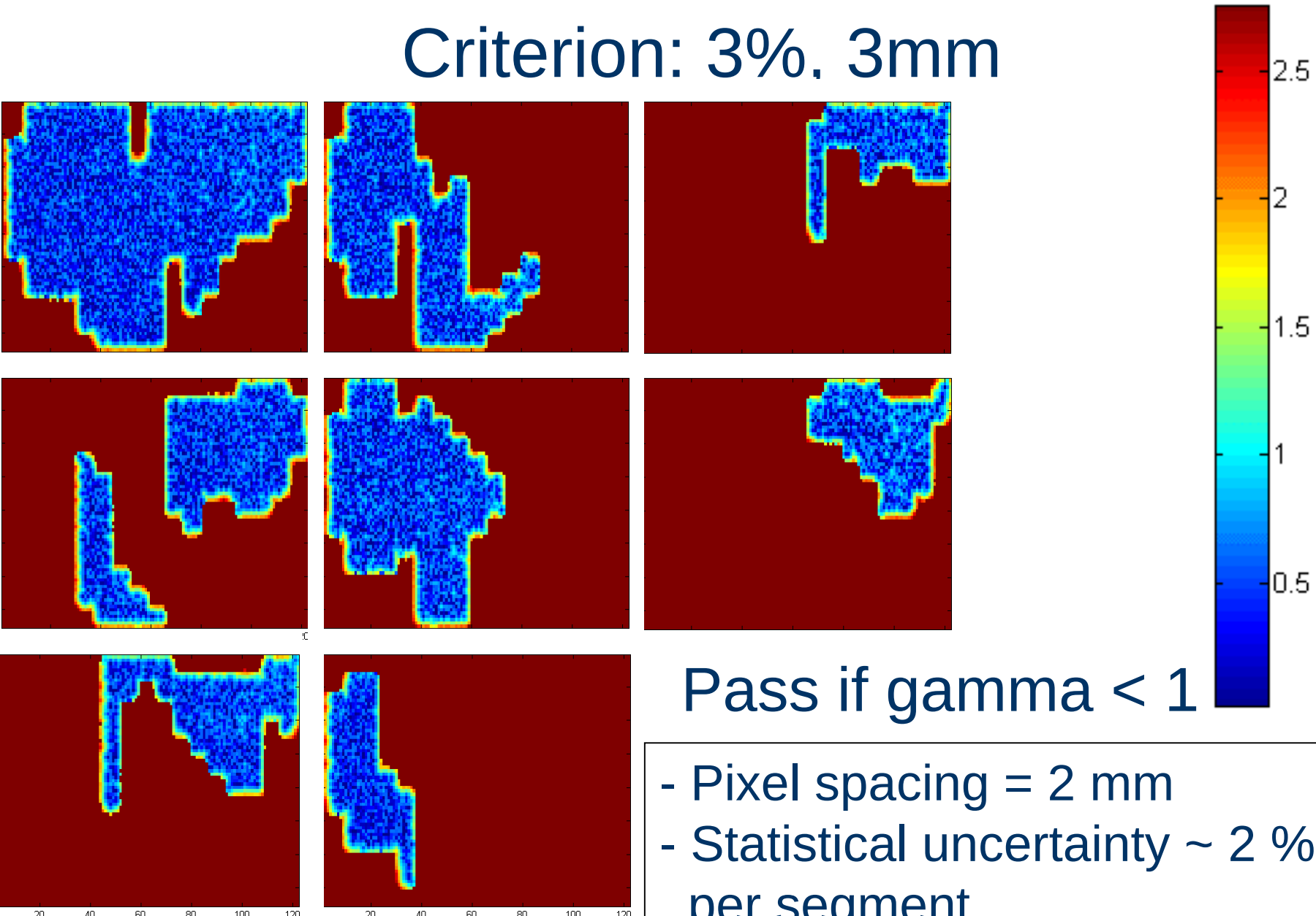


Portal Verification of IMRT Fields

- This talk looks at the verification of an IMRT beam consisting of 8 segments shaped by MLC (from a 10 MV prostate treatment plan)



Segment by Segment Gamma Analysis
Criterion: 3%, 3mm

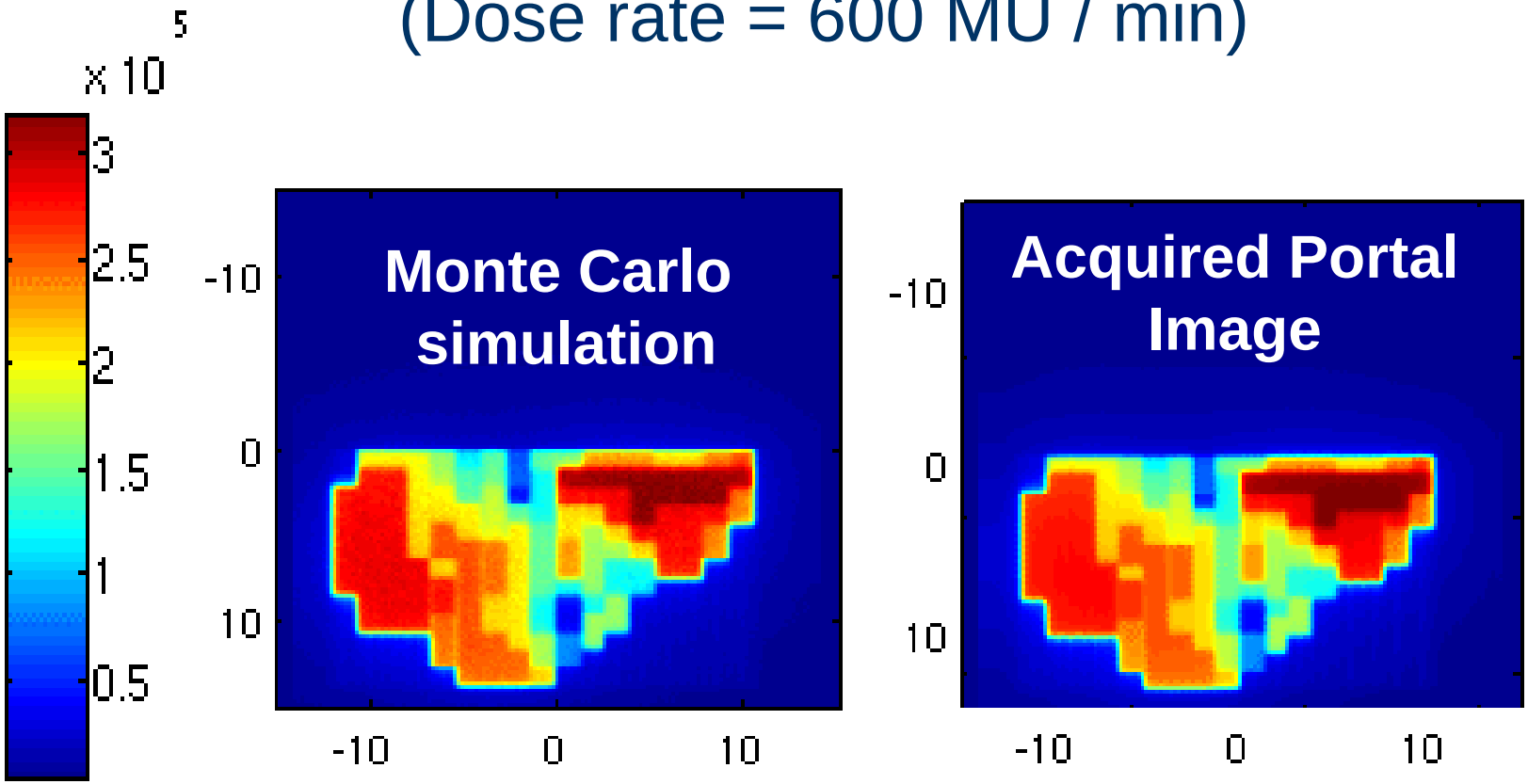


Pass if gamma < 1

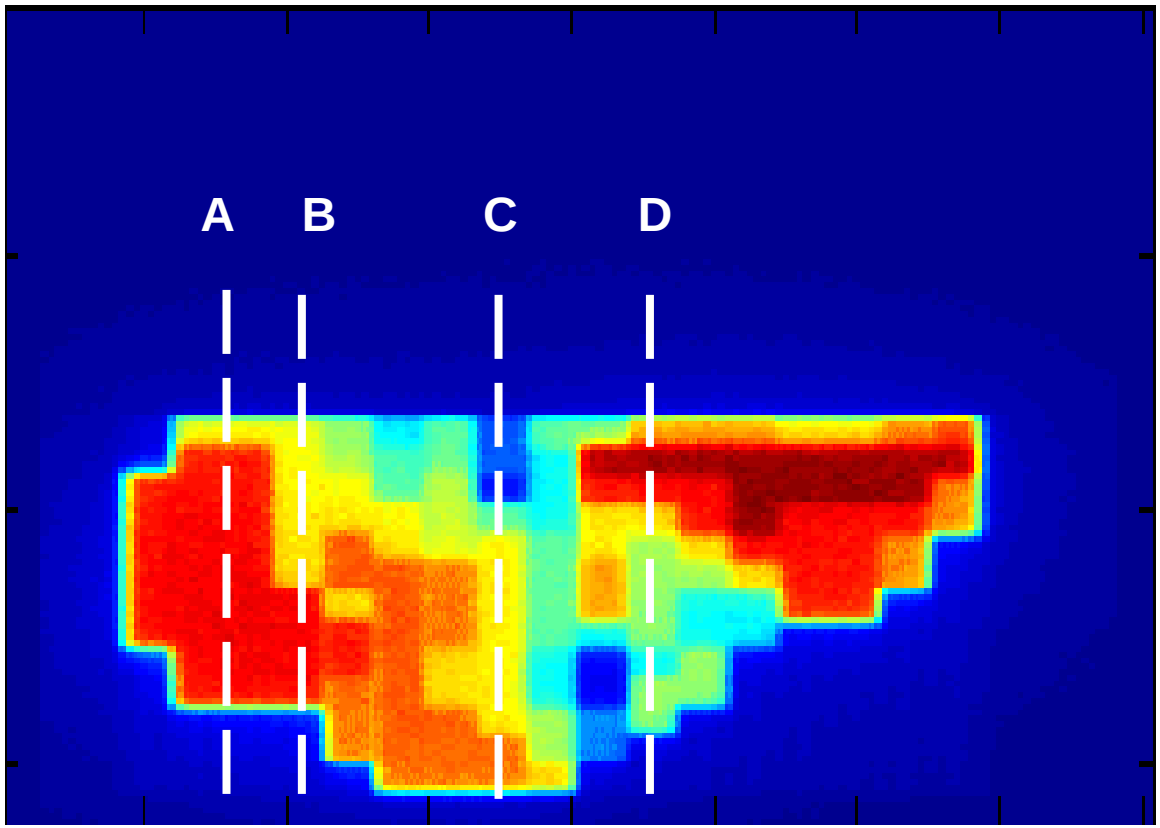
- Pixel spacing = 2 mm
- Statistical uncertainty ~ 2 % per segment

Verification of Complete IMRT Irradiation

(Dose rate = 600 MU / min)

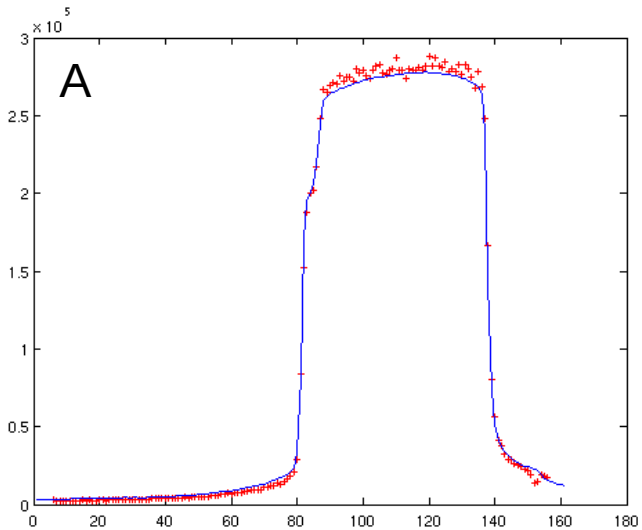


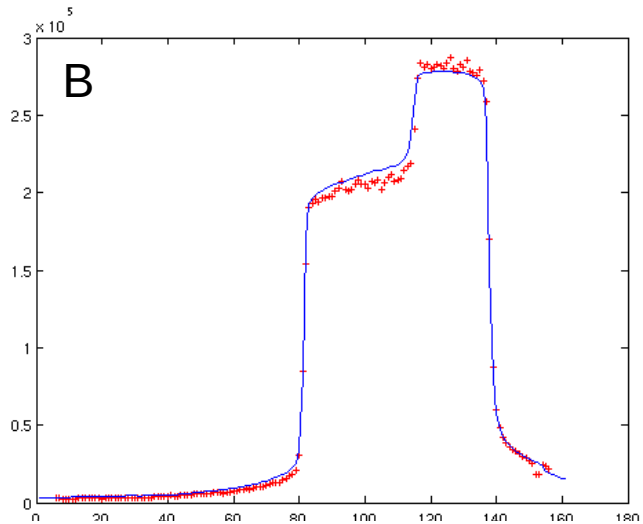
Profiles taken across IMRT image

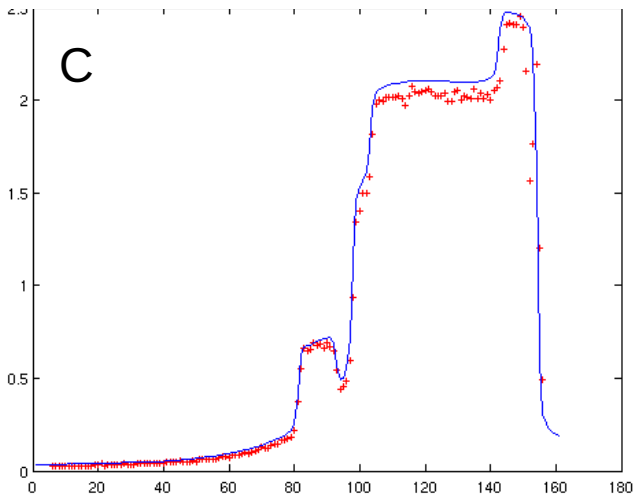


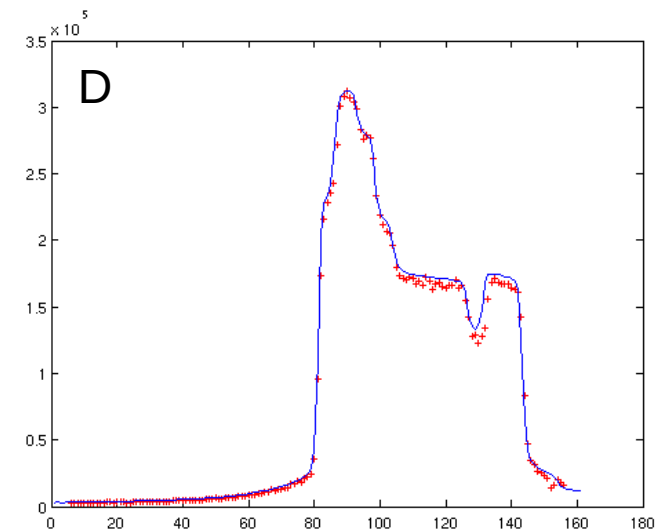
Profiles across IMRT Field, 600 MU / min

- Monte Carlo
- Acquired Image



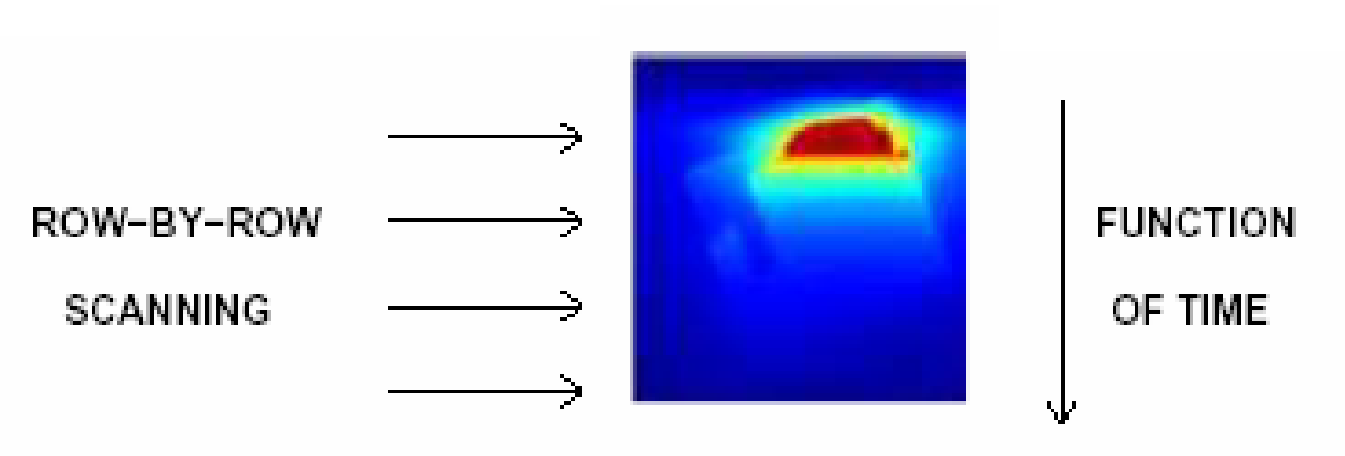






Discrepancies could be due to:

- Actual treatment delivery error
- Segments starting after or ending before every imager row has been scanned

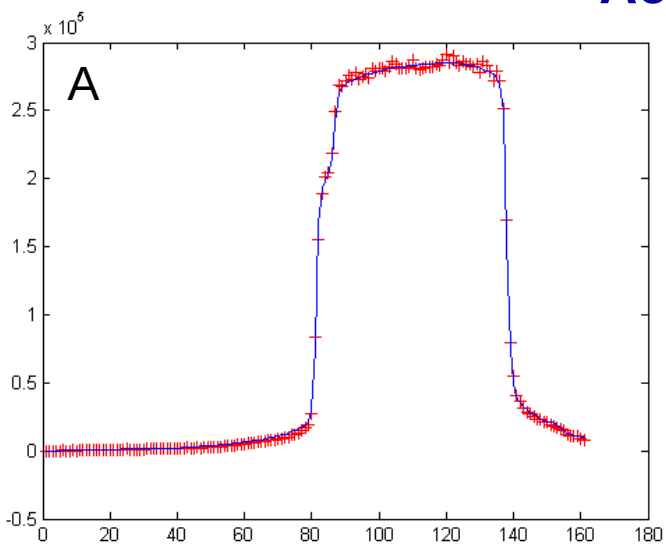


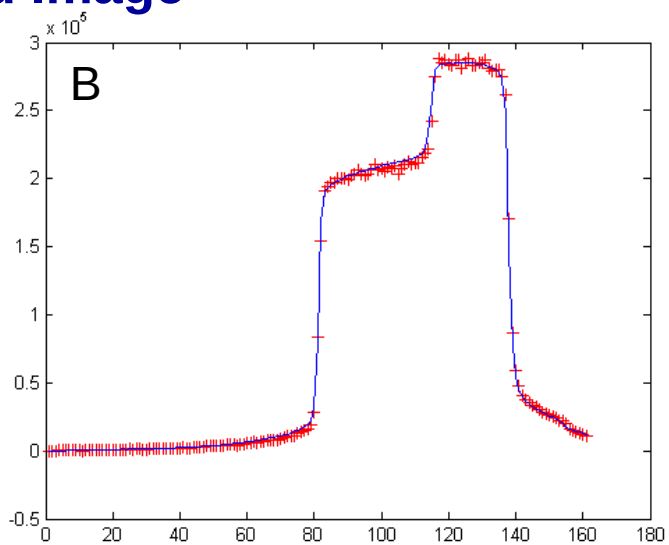
IMRT segment ends before all 384 imager rows scanned

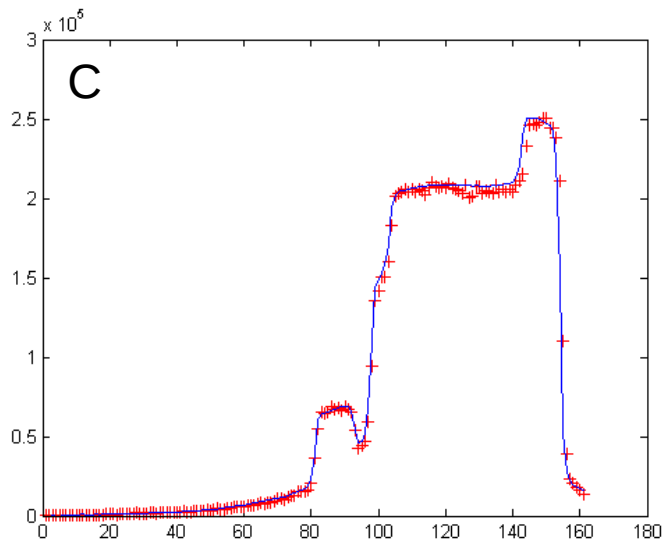
Image from “Chin P.W., Cardiff University PhD Thesis 2005”

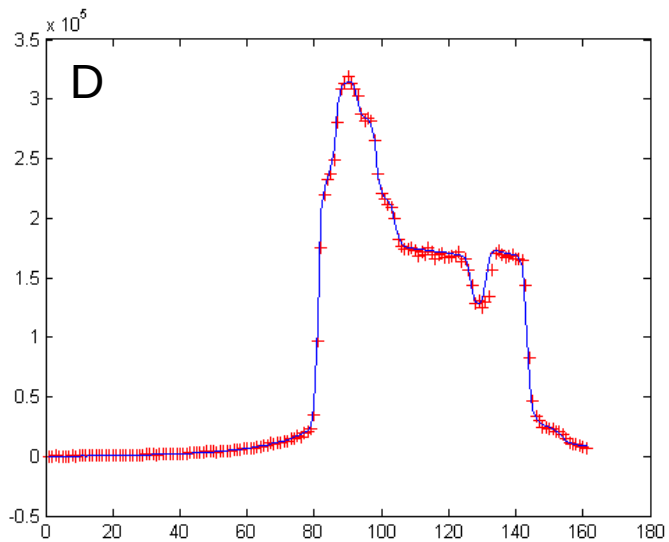
Profiles across IMRT Field, 100 MU / min

- Monte Carlo
- Acquired Image

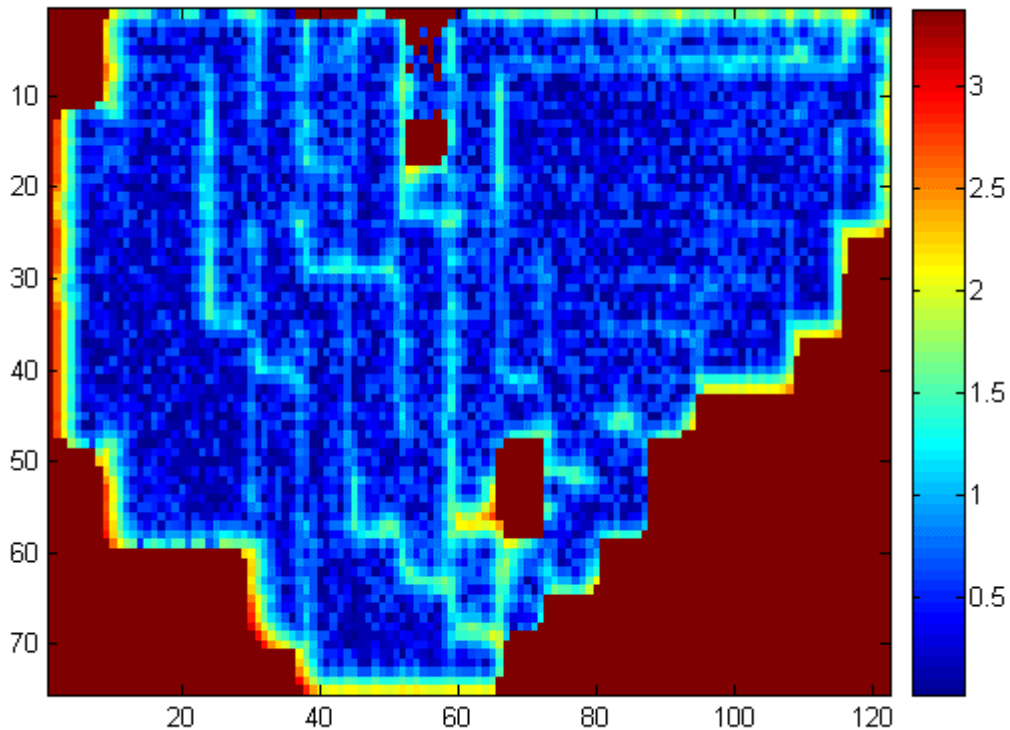








Gamma analysis image, 100 MU / min
Criterion: 3%, 3mm



Pass: 87 %

Acquisition	Gamma Criterion	Pass
Segment by Segment	3 %, 3mm	87 %
	4%, 4 mm	95 %
100 MU / min	3 %, 3mm	87 %
	4%, 4 mm	95 %
400 MU / min	3 %, 3mm	78 %
	4%, 4 mm	90 %
600 MU / min	3 %, 3mm	73 %
	4%, 4 mm	80 %

- **It is likely that discrepancies are caused by segments starting after or ending before every imager row has been scanned**

- **Initial investigations suggest that lowering the dose rate minimises these effects**

- **However, work needs to be carried out to prove that IMRT delivery does not change with dose rate**

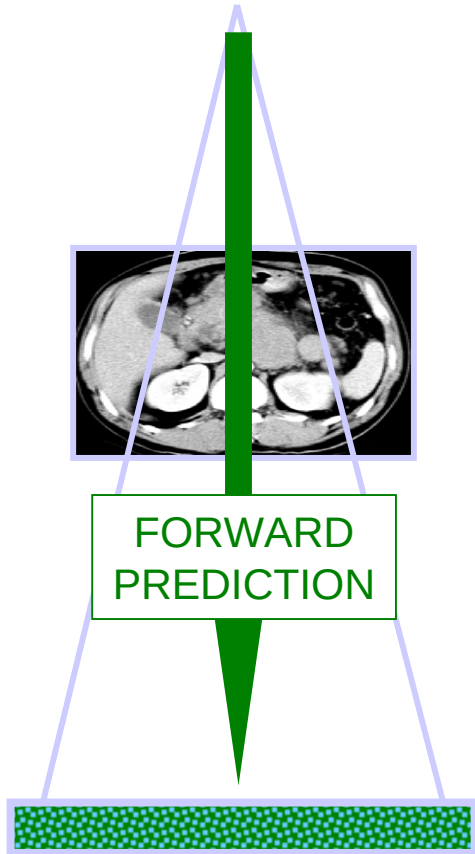
Future Aims

- **Make calculations quicker**

  - Use simplified EPID models

  - ECUT currently 0.521 MeV, is 0.7 MeV accurate?

  - More computing resources



- **Progress to verification of delivery during treatment (transit dosimetry)**

Acknowledgement

Thanking Cancer Research Wales & Yr Ysgol Uwchradd Tregaron for PhD support.