

**A Comparative Analysis Between Conventional
MLC Based and Solid Compensator Based IMRT
Treatment Techniques.
A Clinical Review After 5 Years**

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ABSTRACT

Purpose: The goals of this study were to evaluate the **clinical differences of solid and MLC based IMRT treatments**. A dosimetric comparison of the **dose outside the target volume at 3 planes** were carried out. The investigation was extended to compare the **delivery time** and **monitor unit** requirements for the IMRT techniques.

Methods and Material: The ADAC Pinnacle inverse planning system was used to generate MLC based IMRT plans. Using .decimal software, ADAC was also used to generate compensator based IMRT plans. Plans were generated for the following target volumes, prostate, adrenal gland, brain, and head and neck. The delivery time, number of monitor units and the fluence intensity maps were compared. Dose points outside the target volume were compared to determine out of target doses. Delivery of treatment plans was performed on a **Rando phantom** and **mosfet** dosimeters, **GAF chromic film** and **TLDs** were used to compare measured doses of MLC and solid IMRT treatments.

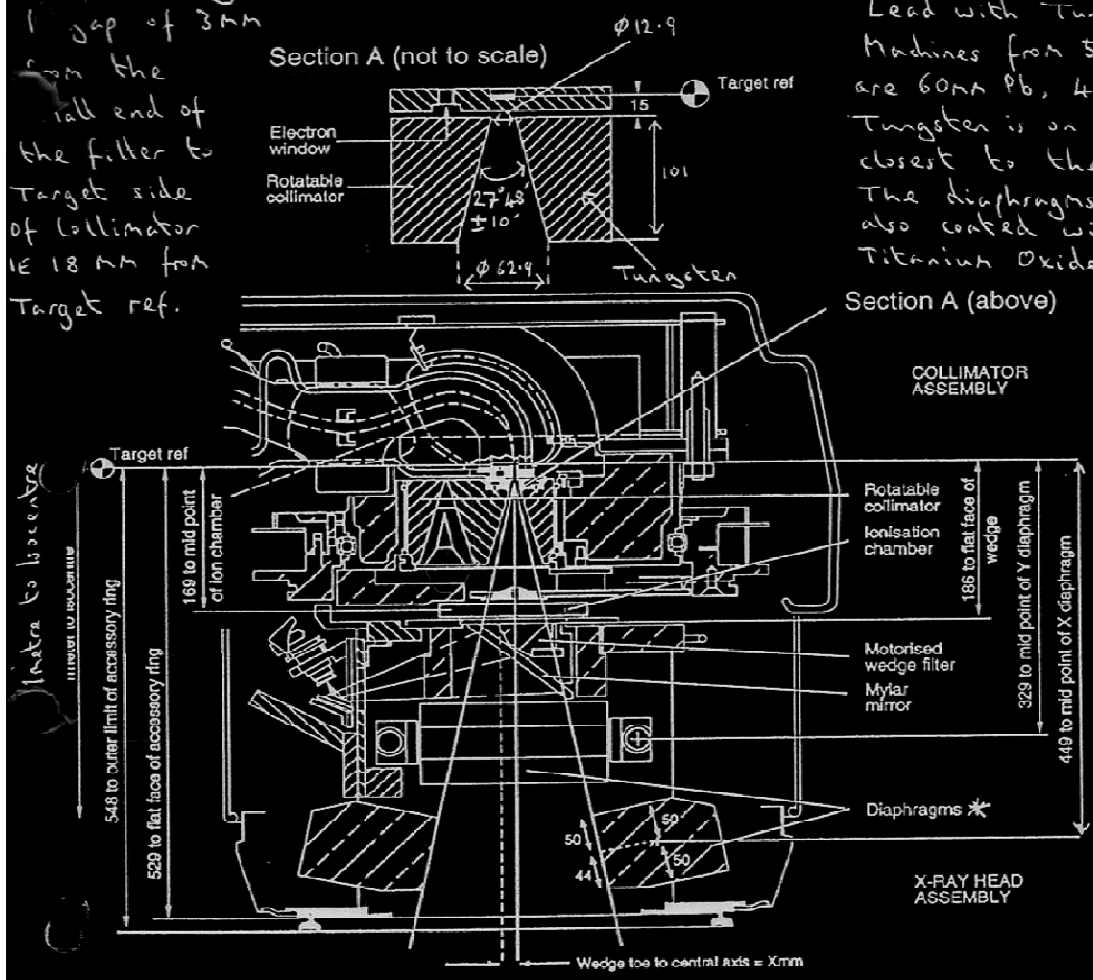
History of IMRT planning & delivery at UT-MC

- 1994 - In-house development of a full 3D treatment planning software package with dose optimization algorithm module to compute 3D dose compensator
- 1995 - Development & implementation of IMRT solid compensator using granule materials through application of a milling machine
- 1995 - Commissioning and clinical implementation of the dose compensator for IMRT treatments using our in-house developed TPS;
- 2000 - Clinical application of segmental MLC-IMRT;
- 2005 - Made available the Dot decimal solid compensator as an alternative for IMRT treatments.

7.3.2 SL series radiation head reference dimensions

Beam Hardening Filter
 1 gap of 3mm
 from the
 full end of
 the filter to
 target side
 of collimator
 is 18 mm from
 target ref.

* Diaphragms:
 Lead with Tung
 Machines from 51
 are 60% Pb, 40%
 Tungsten is on
 closest to the
 The diaphragms
 also coated with
 Titanium Oxide



Intra to isocentre
 548 to outer limit of accessory ring
 168 to mid point of ion chamber
 529 to flat face of accessory ring

NOTE: all dimensions are nominal mm
 X = 30mm for the large wedge
 X = 17mm for the standard wedge

Target to base of primary collimator = 47mm 116mm
 Target to base of secondary filter carrier = 46mm 150mm
 Target to primary scattering foil = 12mm
 Target to base of 6 or 8MV
 Low Energy Filter (in 2° filter carrier)

Figure 7.4 SL Series radiation head reference dimensions

Lead = 96% Pb, 4% Sb. Density = 11.1 gcm⁻³
 Tungsten = 95% W, 3.75% Ni, 1.25% Fe. Density = 18

DISCLAIMER
 I am not involved in any
 joint venture by any
 manufacturer of solid
 compensators and
 have not received
 financial assistance in
 performing this
 research.

We wish to thank
 .decimal company for
 providing us the
 necessary software &
 the compensating
 filters needed to do this
 project

Myth about the compensator based IMRT

1. Compensator is not true IMRT

“It doesn’t give results as good as MLC-IMRT”.

2. Compensator dosimetry is inaccurate.

“It has beam hardening effect.”

3. Compensator-IMRT is too slow for clinical use.

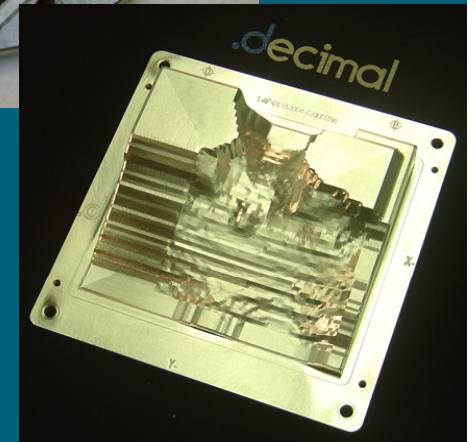
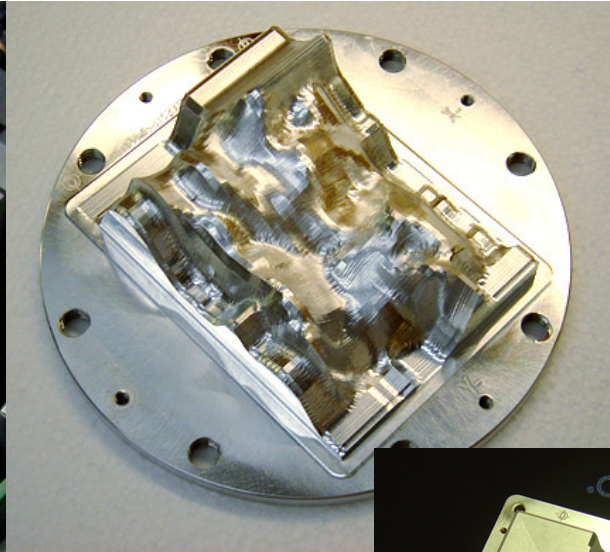
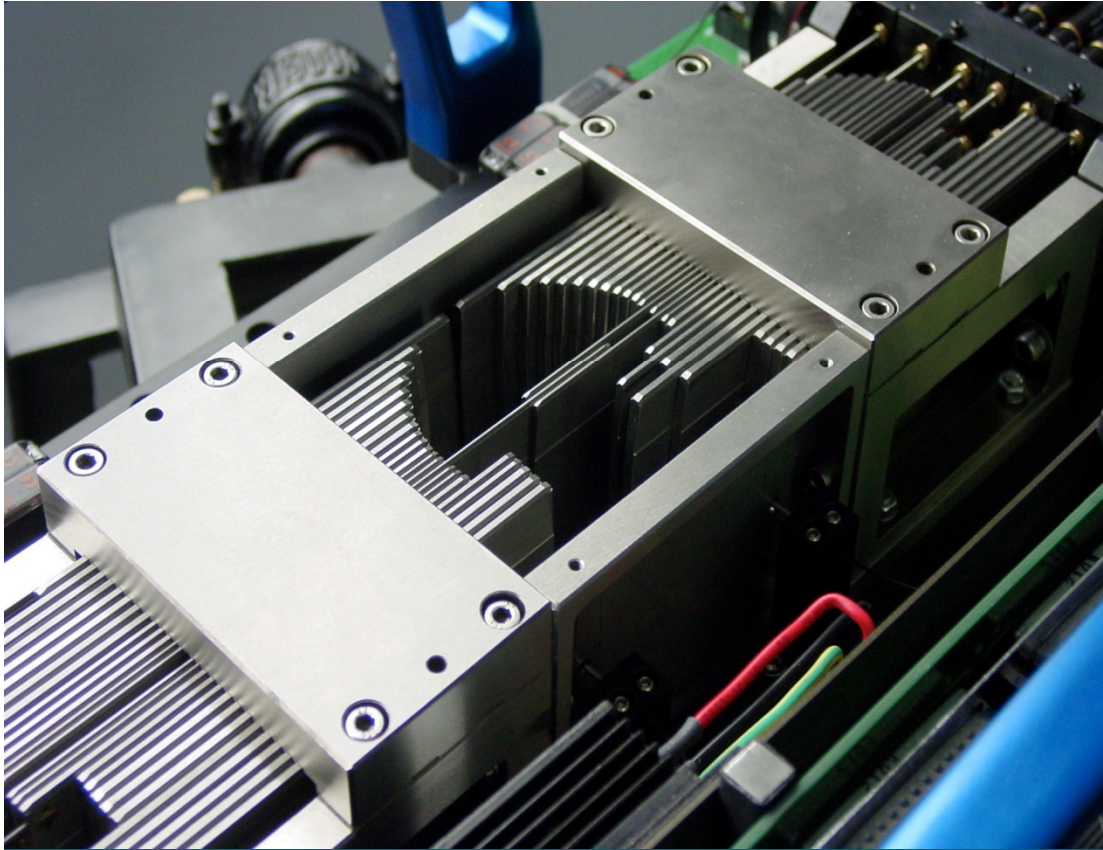
“It is not automated”.

4. Compensator-IMRT is too labor-intensive for routine clinical use.

“It takes too long a time to manually make the compensator”.

No Myth, research based:

- *Compensator based IMRT is a legitimate technique in delivering IMRT treatments,*
- *Affordable, by ANY Radiation Oncology Center*
- *Usable on ANY Teletherapy Machine*
- *It is a WELL DEVELOPED technique and not in the R&D stage!*
- *\$\$\$*



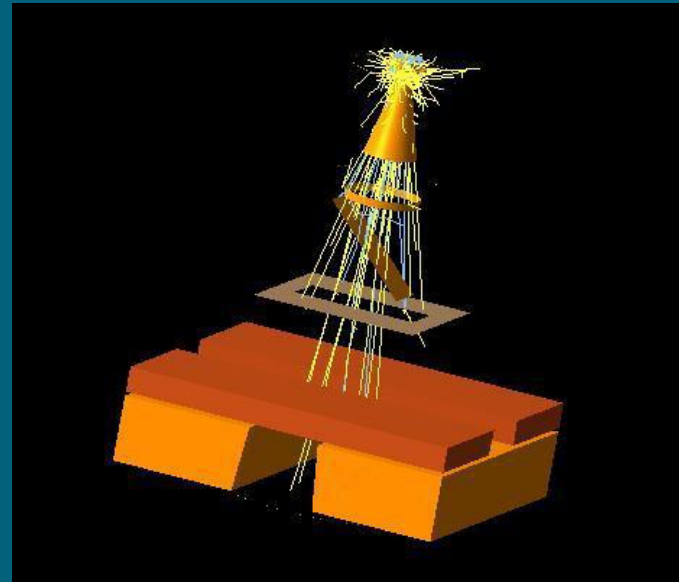
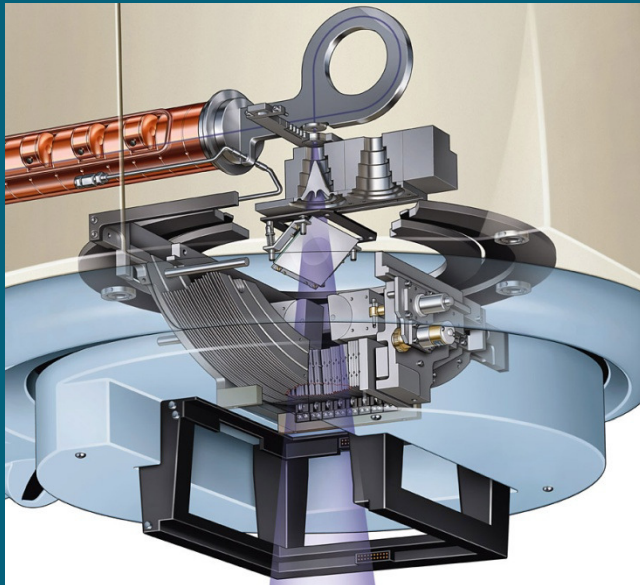
MLC-IMRT

- Computer controlled
- Fully automated
- High target conformity rating

Solid Compensator-IMRT

- Simpler non automated delivery technique
- Comfortable physical concept
- Intensity modulation achieved by varying thickness of compensator
- Ability to produce high resolution intensity maps
- Faster QA
- Closest to deliver the theoretical intensity map

Scatter/Out of Field Dose



- The unwanted out-of-field dose is as a result of stray photons; generated from photon interactions in the head of the accelerator with various materials of high density and high Z ...
- Medical Physicists are more and more concerned with this unwanted delivered lower energy ionizing radiation which causes significant dose deposition at the surface and shallower regions exposed.

- The objectives of this project was to provide dosimetric analysis of scattered radiation resulting from IMRT delivery with tungsten leafs as compared to compensator filters.
- This analysis was performed at different planes in and outside of the target volume using film dosimetry and point dose with small volume ionization chambers.

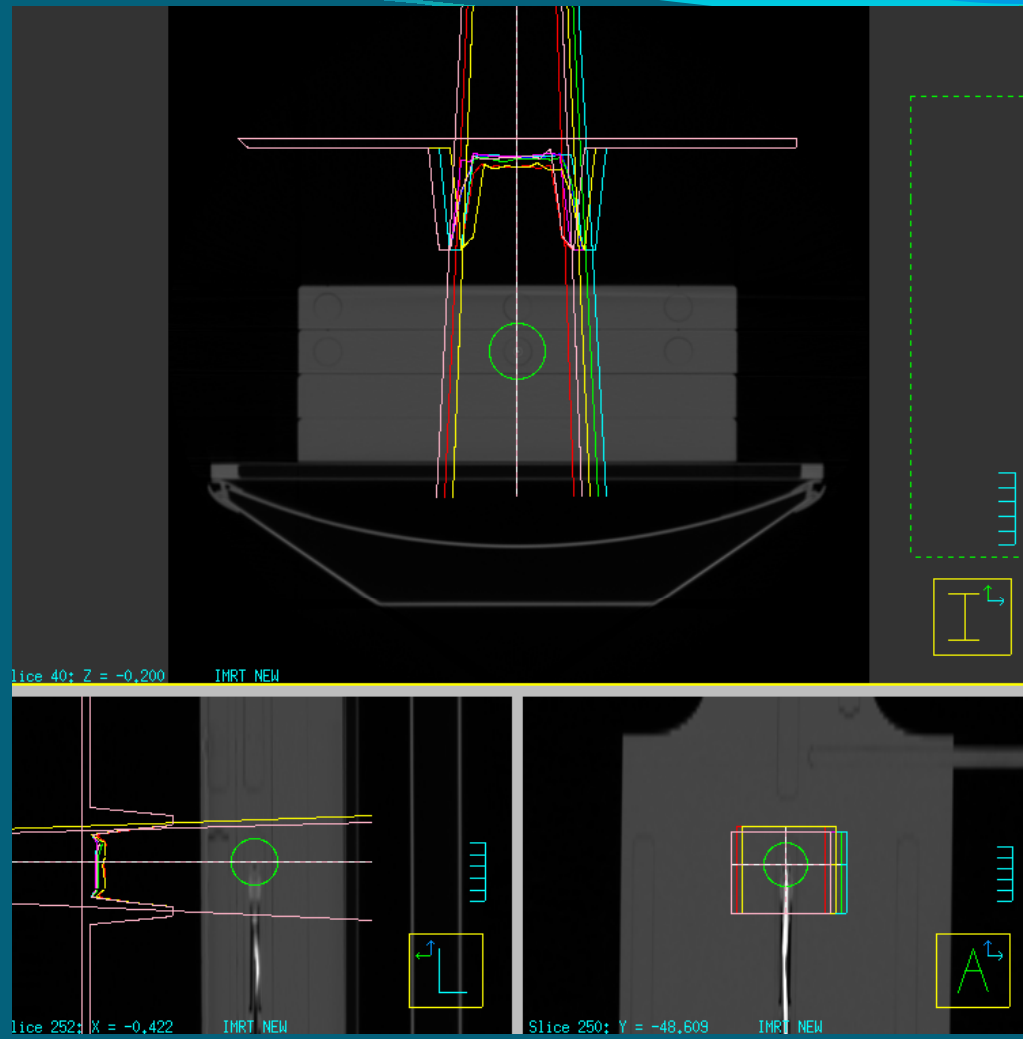
Investigation

- Head and Neck, brain , adrenal, prostate
- Physician delineated target volumes
- Physics delineated all other structures
- Optimization engine run, then deliverable MLC and compensator based plans were created
- MUs, Time, Dose

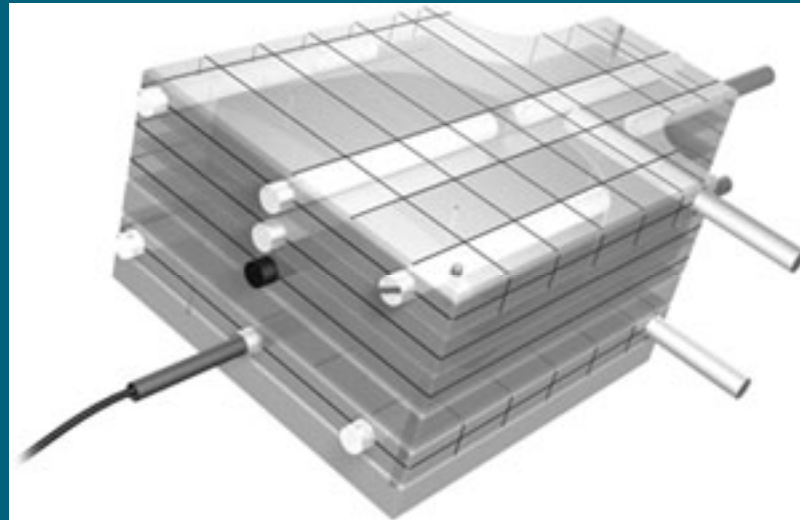
Create the compensator and order it from .decimal

The screenshot displays a medical planning software interface with the following components:

- Regions Of Interest:** A list on the left includes Prostate, Bladder, Rectum, and Rt Femoral Head. The 'Bladder' is selected, with its name highlighted in a blue box. Below this, the 'Data Set' is set to a patient ID, and the '# of Contours' is 21. The 'Volume' is currently unknown, with a 'Recompute volume' button.
- Display Options:** A section with checkboxes for 'Color', '2D Display', '3D Display', 'Box Size', and 'Line Width'. The 'Color' option is checked and highlighted in yellow.
- Edit Options:** Includes 'Autocontour thresholds' (800 and 4096), 'Auto-close painted contours' (Yes/No), 'Copy contours from last edited slice', 'Undo last contouring', 'Interpolate between contours', 'Delete all interpolated contours', and 'ROI Expansion/Contraction...'
- Main View:** A 3D visualization of the bladder and surrounding structures with various colored contours and beam paths. A white arrow points from this view to the 'p.d Scripts' window.
- p.d Scripts:** A window showing a script for 'Edwards, Lee' with parameters like 'Plan ID: complan', 'Modulator Material: Brass', and 'Thickness (cm): 7.62'. It also includes a 'BEV ODM' and 'BEV MOD' section with a grid of 'X' and 'Y' markers.
- BEV ODM and BEV MOD:** Two side-by-side views showing the bladder's cross-section in yellow against a black background, representing the ODM and MOD respectively.
- File or Array Contents:** A text window showing technical details such as 'Version: 7.46', 'Partname: Edwards, Lee', 'Plan Name: complan', and a list of coordinates.
- Bottom Right:** A photograph of a physical brass compensator with the '.decimal' logo and a part number '341041182042200288' visible.



The point dose measurement



Data Analysis – Point Dose Measurement

IMRT Physics QA

Patient information

Name: QA PLAN Dot Decimal Compensators
 DOB:
 ID: 05-342

Chamber used: A-14
 Chamber type: microchamber
 Chamber serial number
 Chamber Calibration Factor 1394.7 cGy/nC
 Pressure: 748.4 mmHg
 Temp: 23 C
 Ptp: 1.0189398

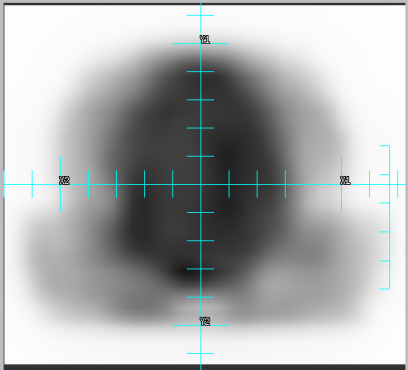
MU	Field No.	Readings(nC)	Dose (cGy)	beam angle (actually used <i>0 for all beams</i>)
104	1comp	0.007	9.95	0
140	2comp	0.052	73.90	51
190	3comp	0.044	62.53	102
167	4comp	0.013	18.47	153
104	5comp	0.036	51.16	204
177	6comp	0.049	69.63	255
182	7comp	0.056	79.58	306
	Sum	0.257	365.23	

Prescribed Dose 360 cGy
 %error 1.45 %

Physicist MK/MA
 Today's Date 6/20/2006

EDR2 film used for measurements with compensators and MLC

Trial Trial_1



Export Planar Dose

Directory: /home/p3rtp/RIT Browse...

File name: [redacted]

Format: ASCII Binary

Export Plane To File

Export All Planes To File

Print Window

Scale: 1 Print Using 1:1 Scale...

DICOM Print Preview

DICOM Print...

Planes Dose

Add Plane Delete Plane Add Plane Per Beam Delete

Current	Name	Resolution (cm)	Dimension X	Dimension Y	Dose Units	Color	Dose Status
◆	DosePlane_1	0.250	58	51	cGy	inverse_grey	Computed

Level: Lin. Full Palette: 2

Co-Register Type: Apply Template to Target

Registration Points

- Pl.1 Targ.: Col:72 Row:40 Ref.: Col:357 Row:428
- Pl.2 Targ.: Col:40 Row:72 Ref.: Col:357 Row:428
- Pl.3 Targ.: Col:8 Row:40 Ref.: Col:357 Row:428
- Pl.4 Targ.: Col:40 Row:8 Ref.: Col:357 Row:428

File: inplates\Bx8 along axis.pts

Cancel Registration

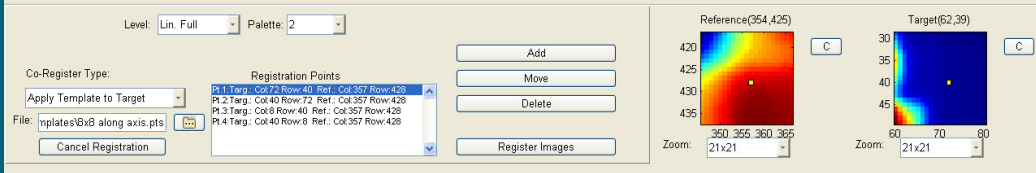
Add Move Delete Register Images

Reference(354,425)

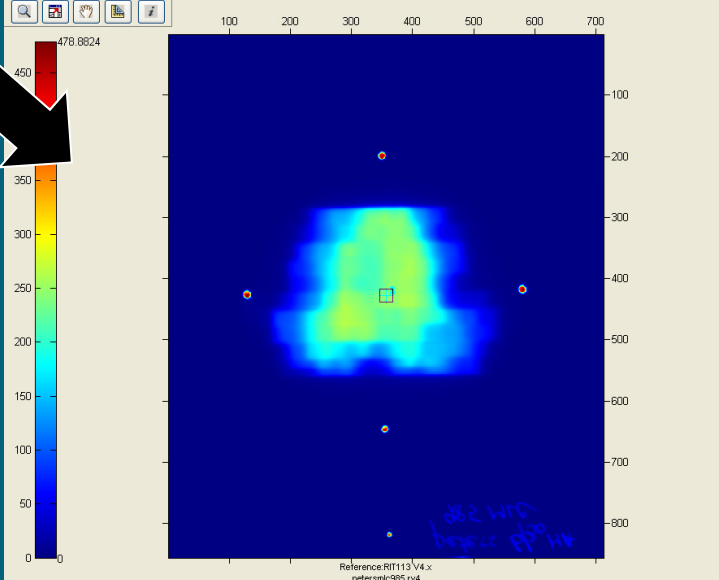
Target(62,39)

Zoom: 350 355 360 365 21x21

Zoom: 60 70 80 21x21



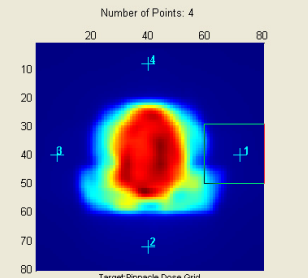
478 8824



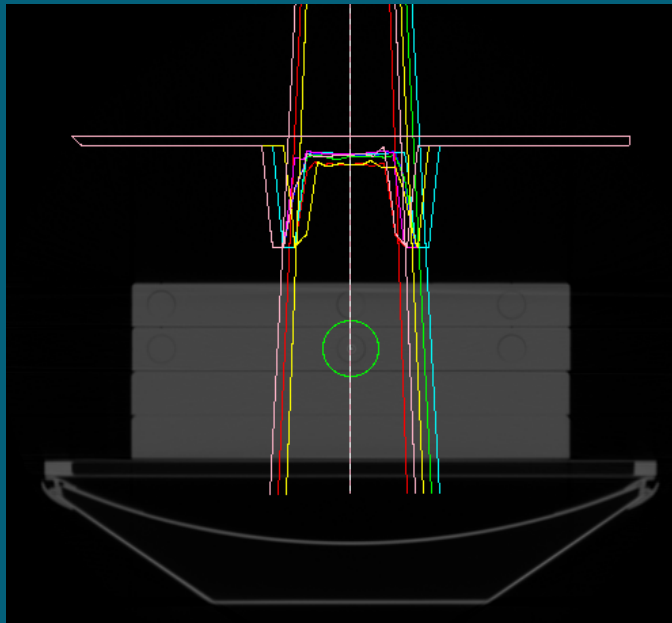
Reference RIT113 V4.x
petersmlc955.rv4

082 WFO
082 WFO
082 WFO

Number of Points: 4



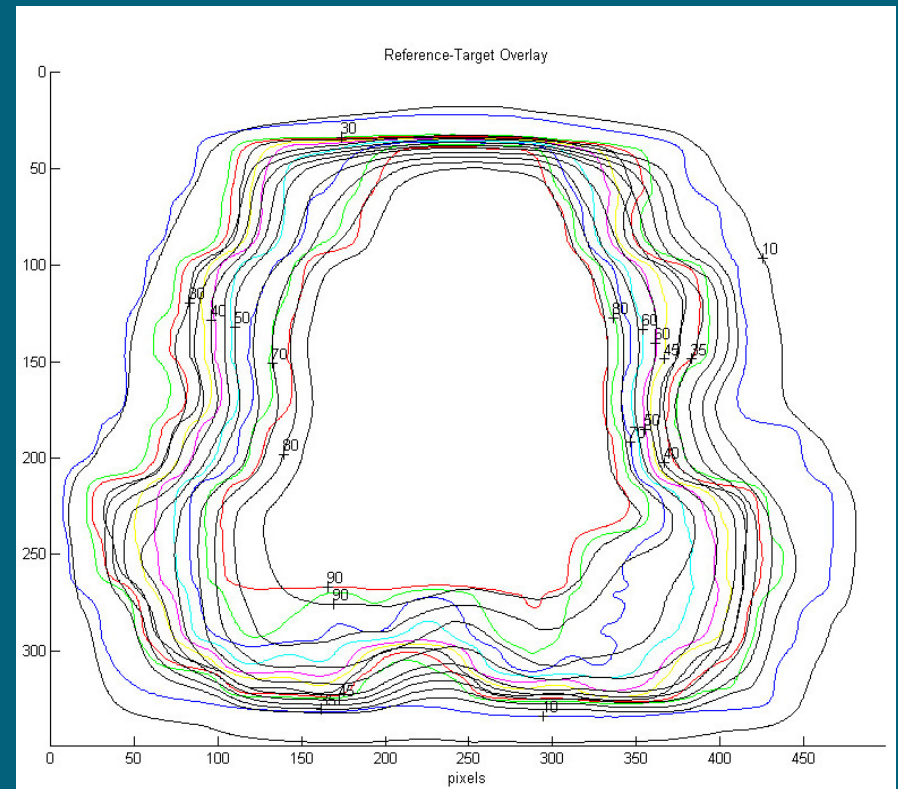
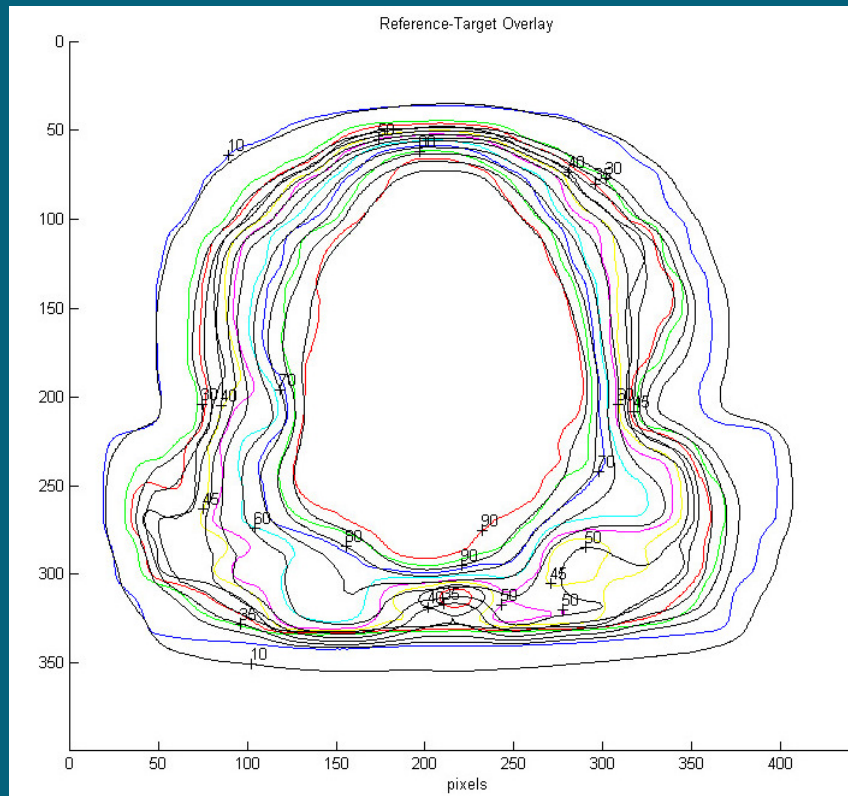
Target Pinnacle Dose Grid
peterscomp955.header



Data Analysis – Film Measurements

Compensators

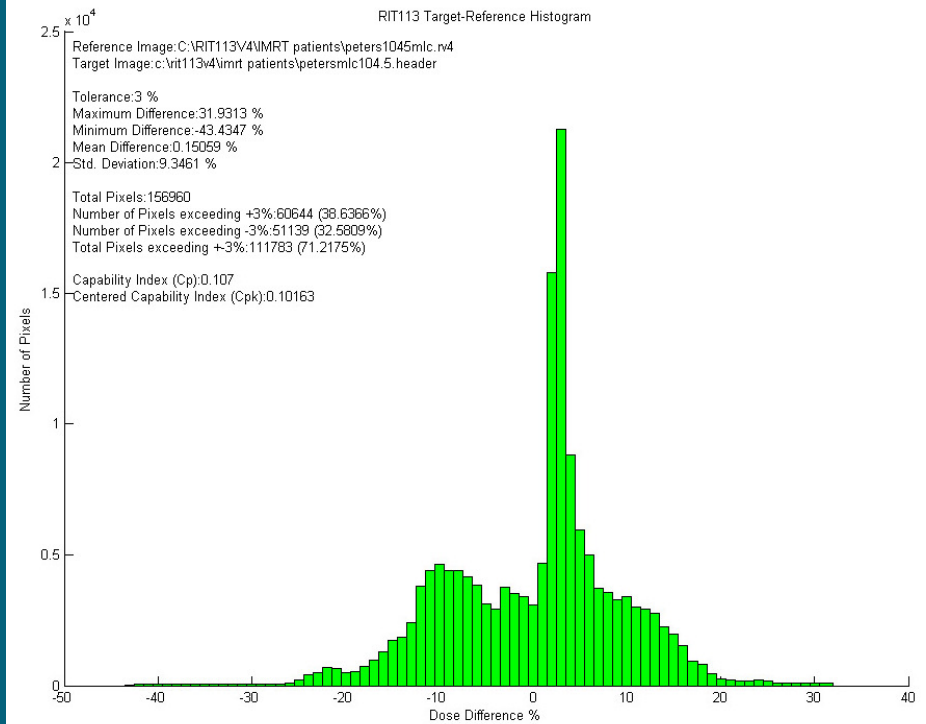
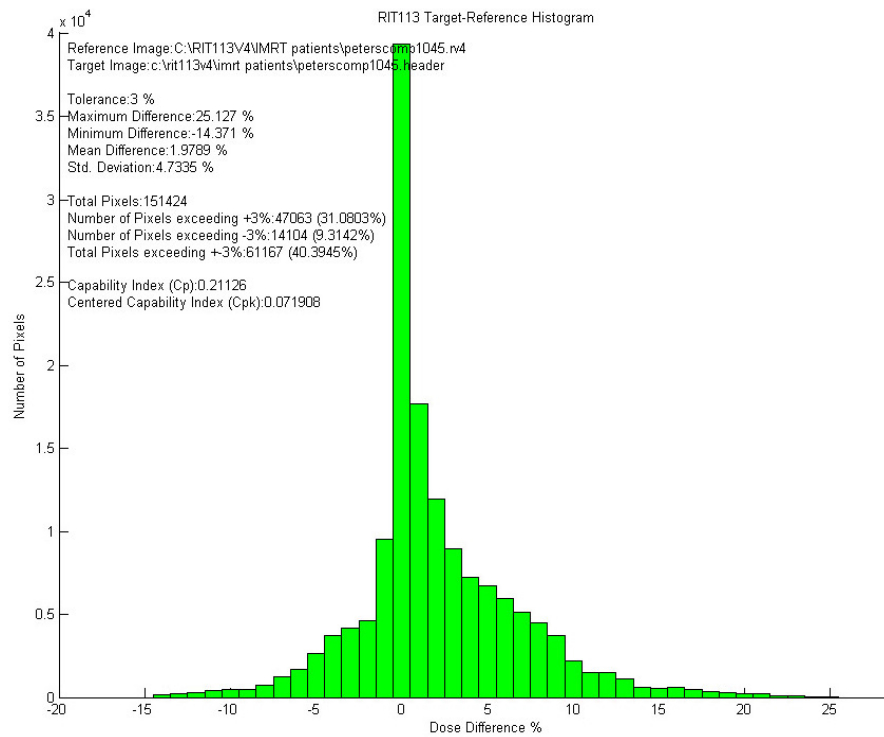
MLC



Data Analysis – Film Measurements

Compensators

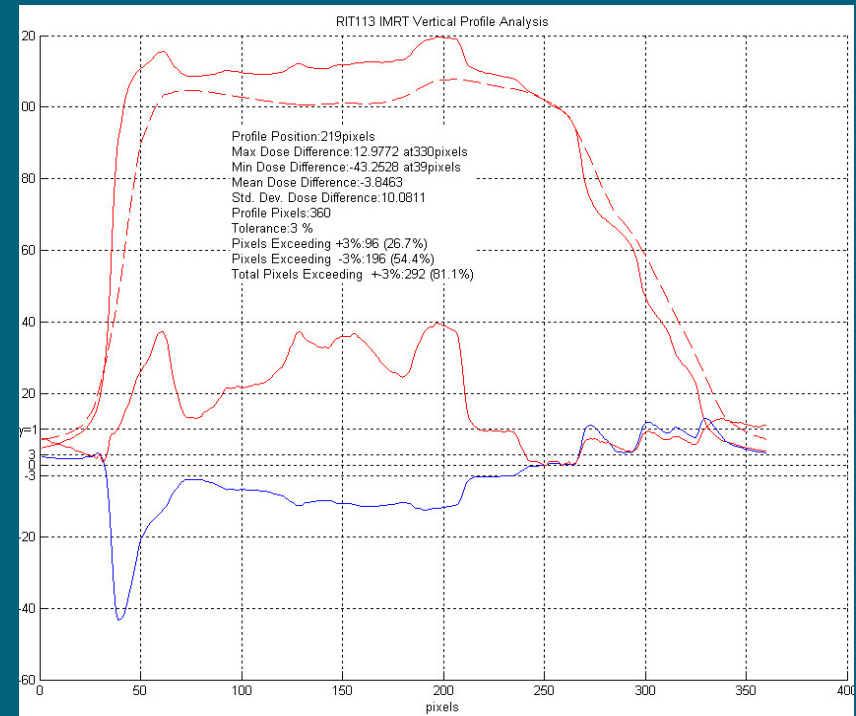
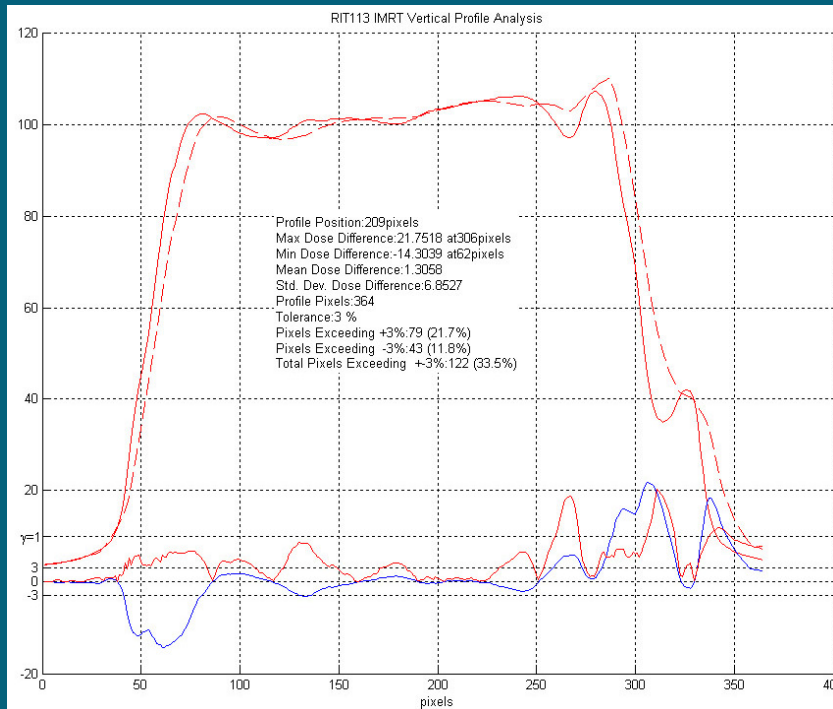
MLC



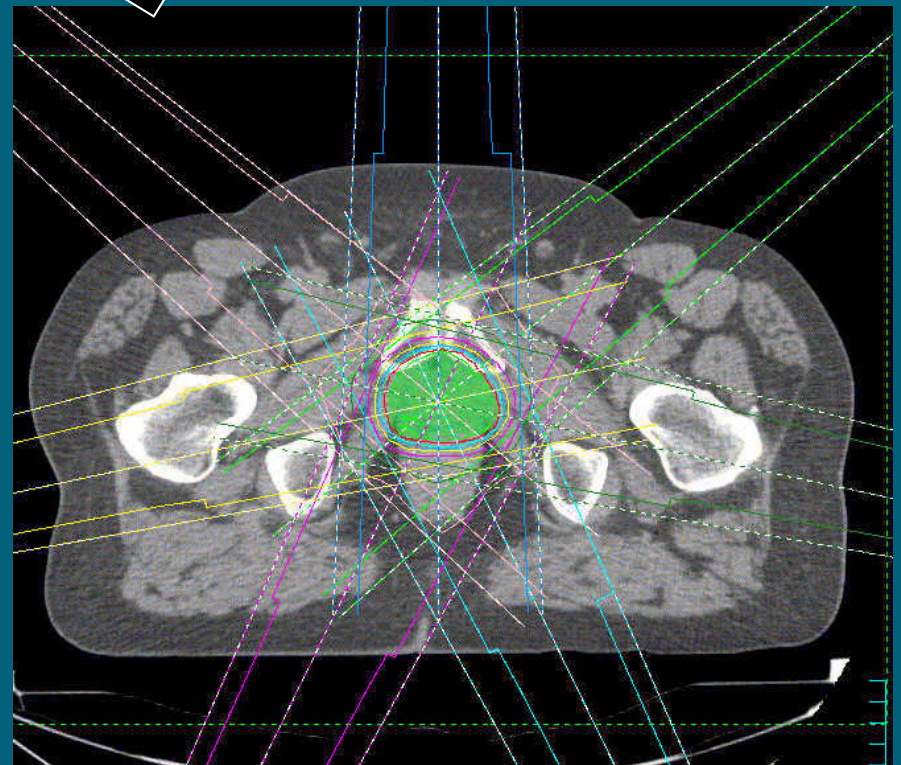
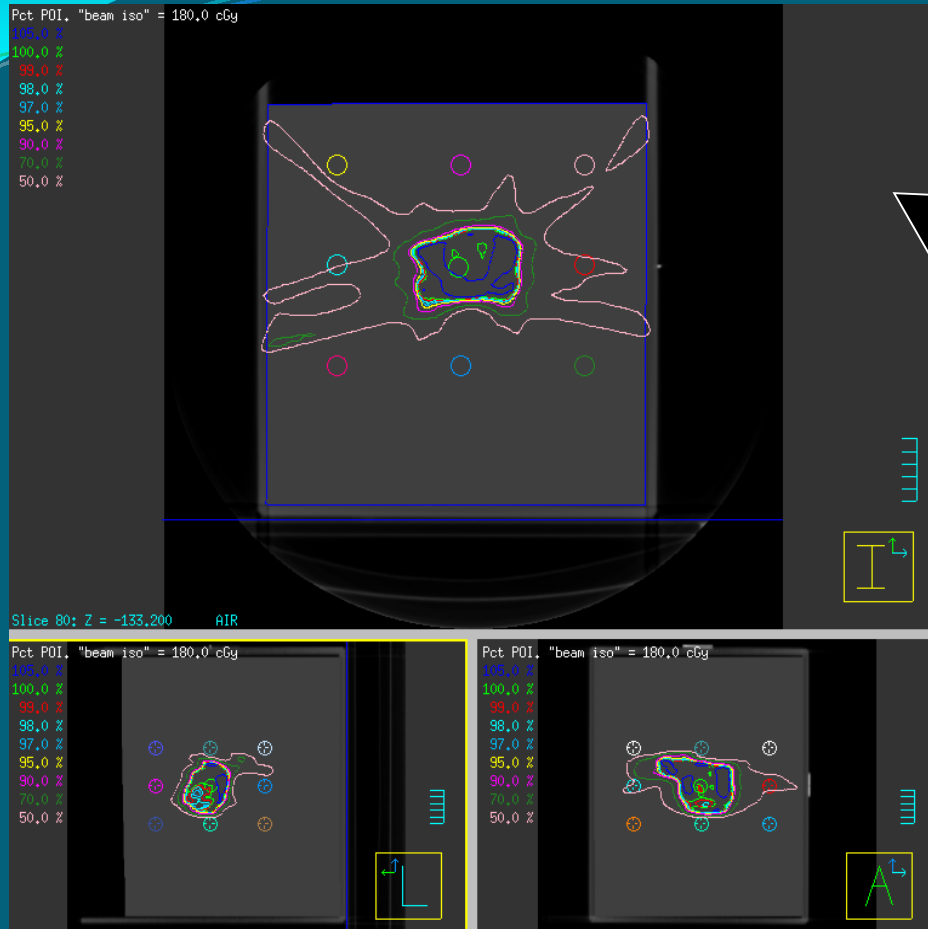
Data Analysis – Film Measurements

Compensators

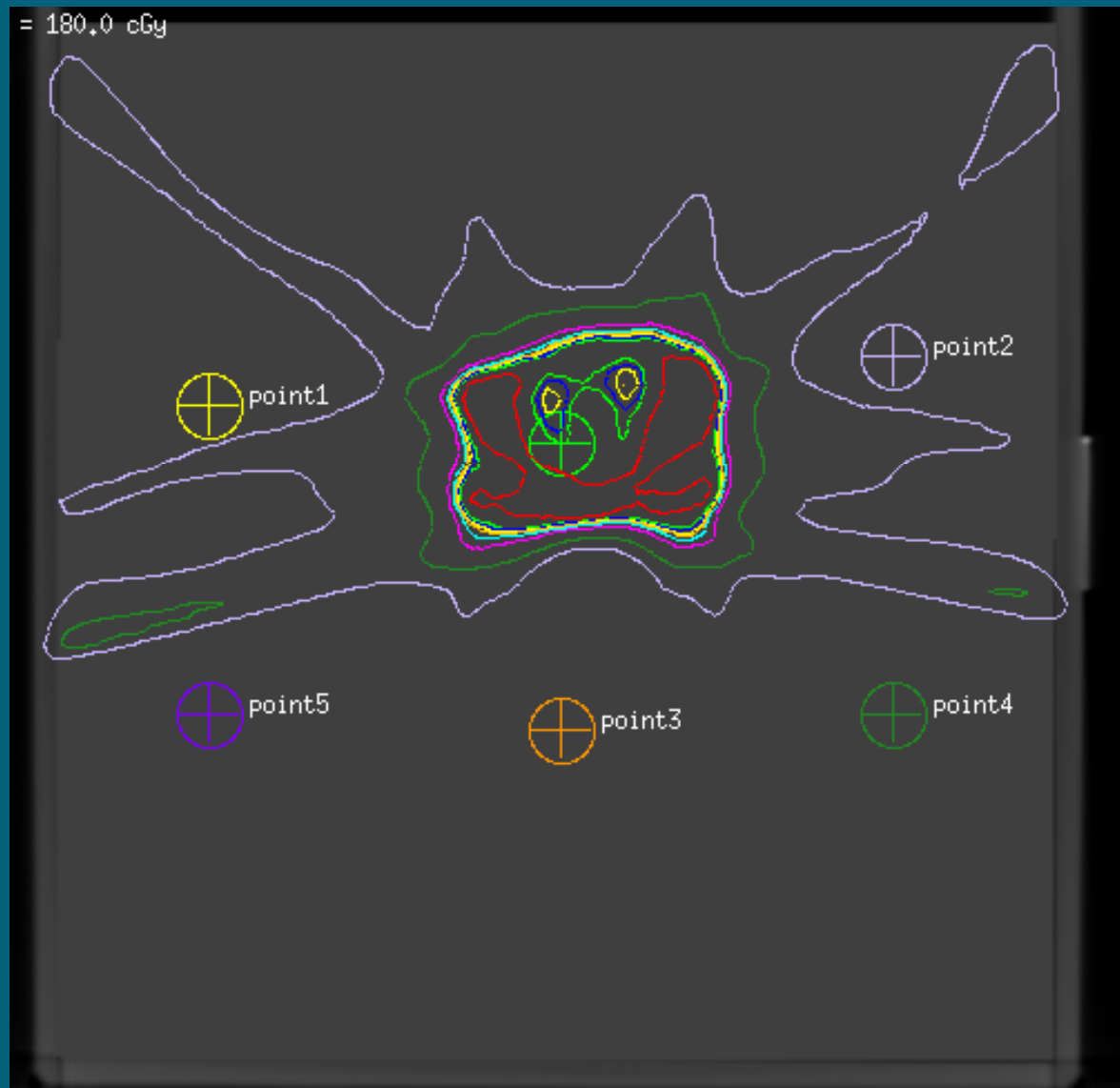
MLC



Three-dimensional point analysis with small water phantom

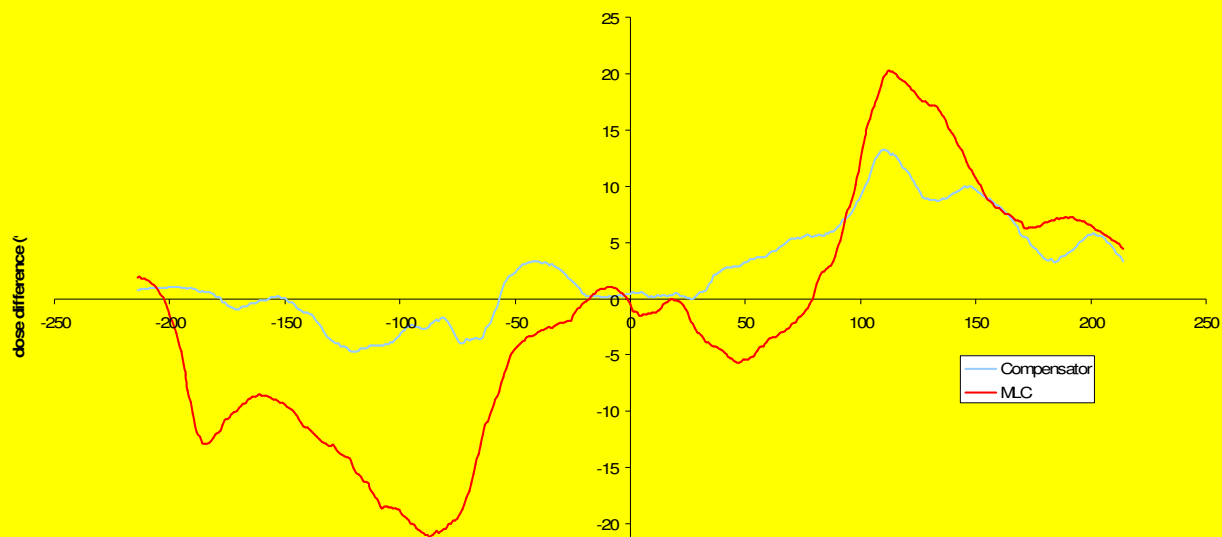


Planar Point Dose Measurement

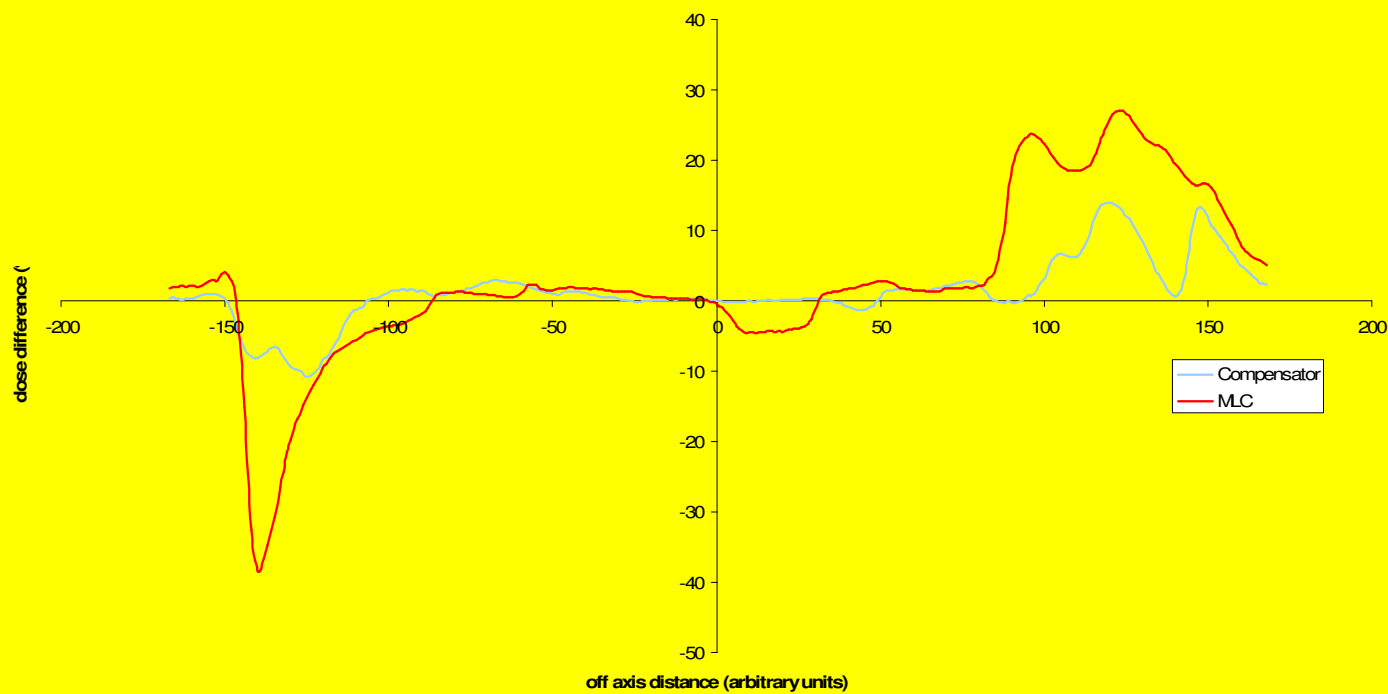


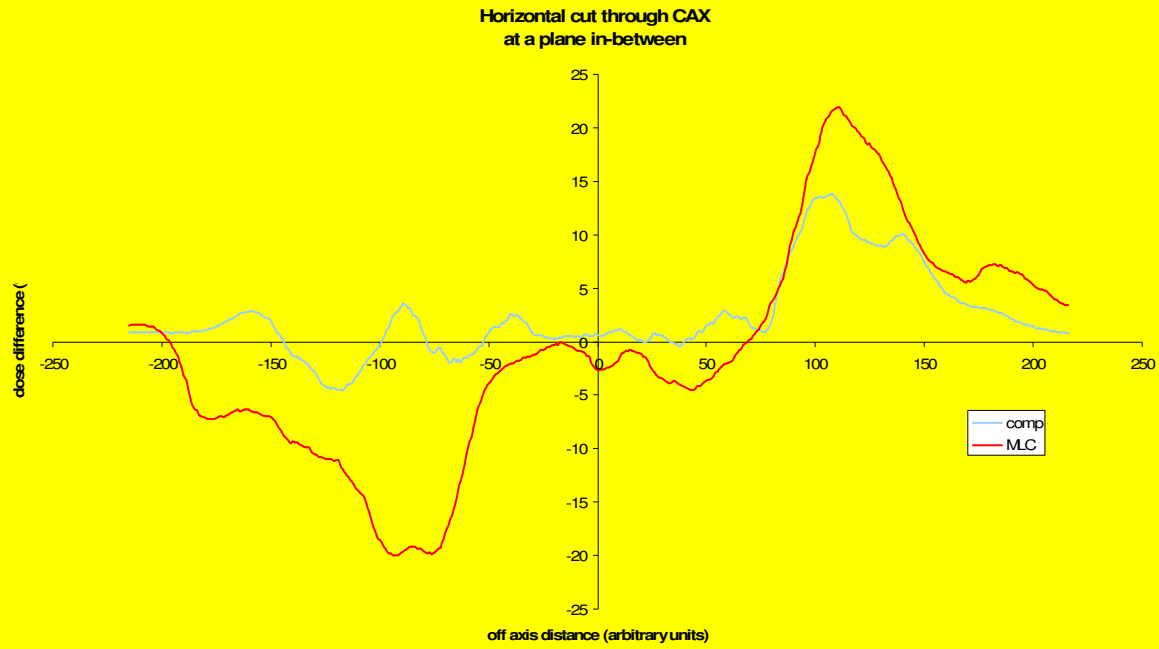
Planar out of field fluence profiles at the target mid-plane

Horizontal cut through CAX at the target mid-plane

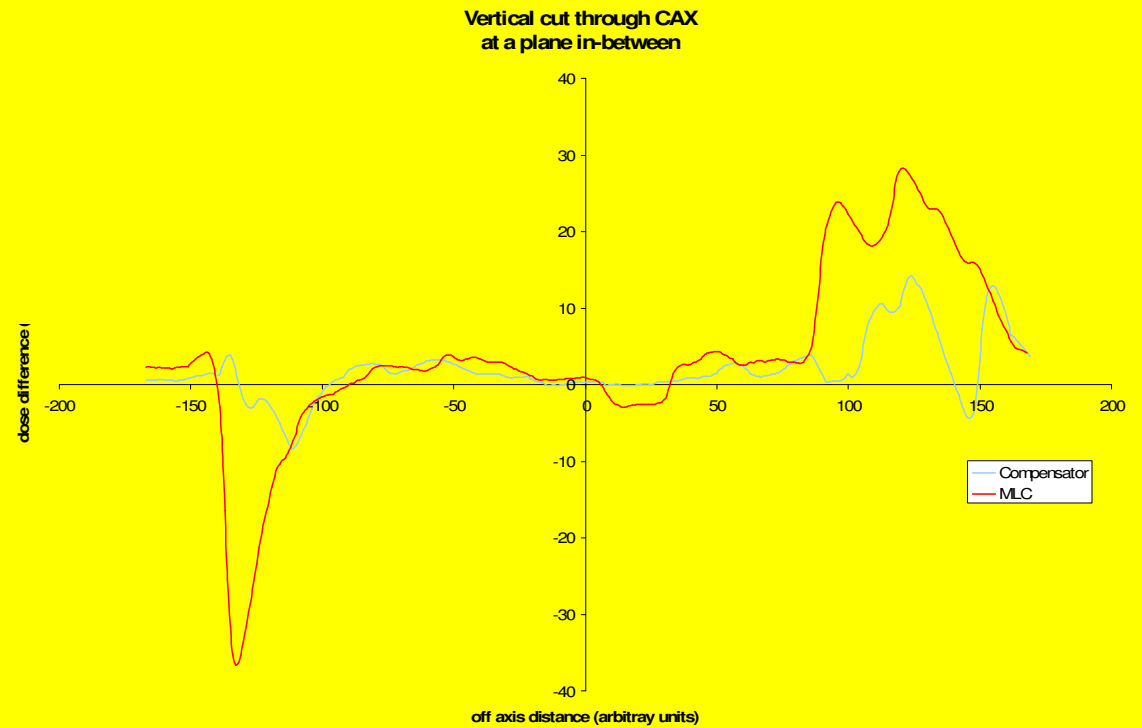


Vertical cut through CAX at the target mid-plane

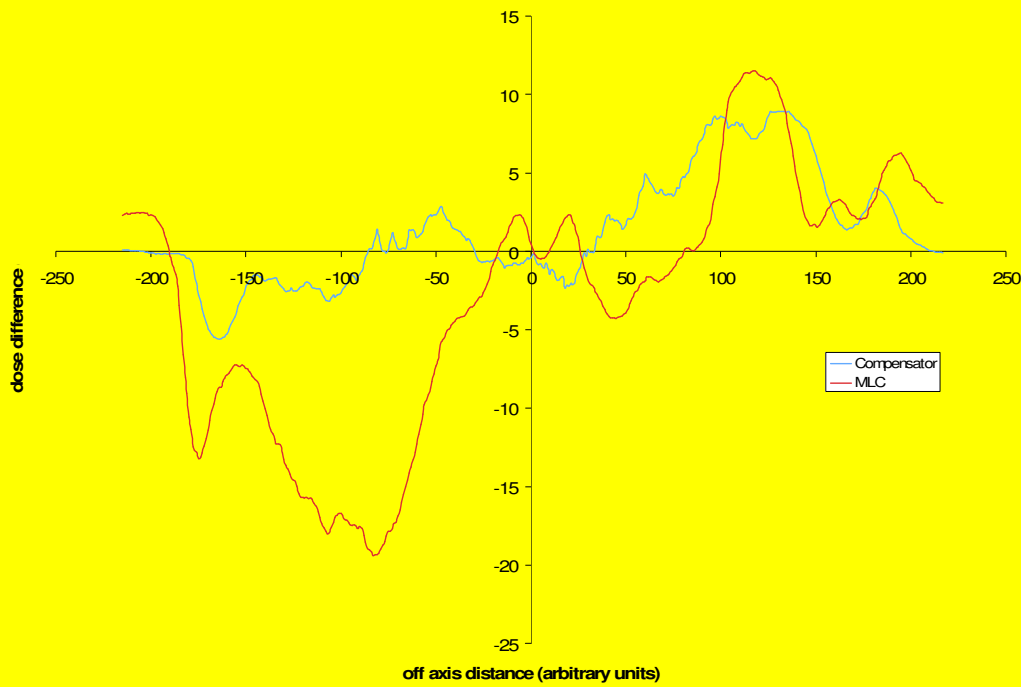




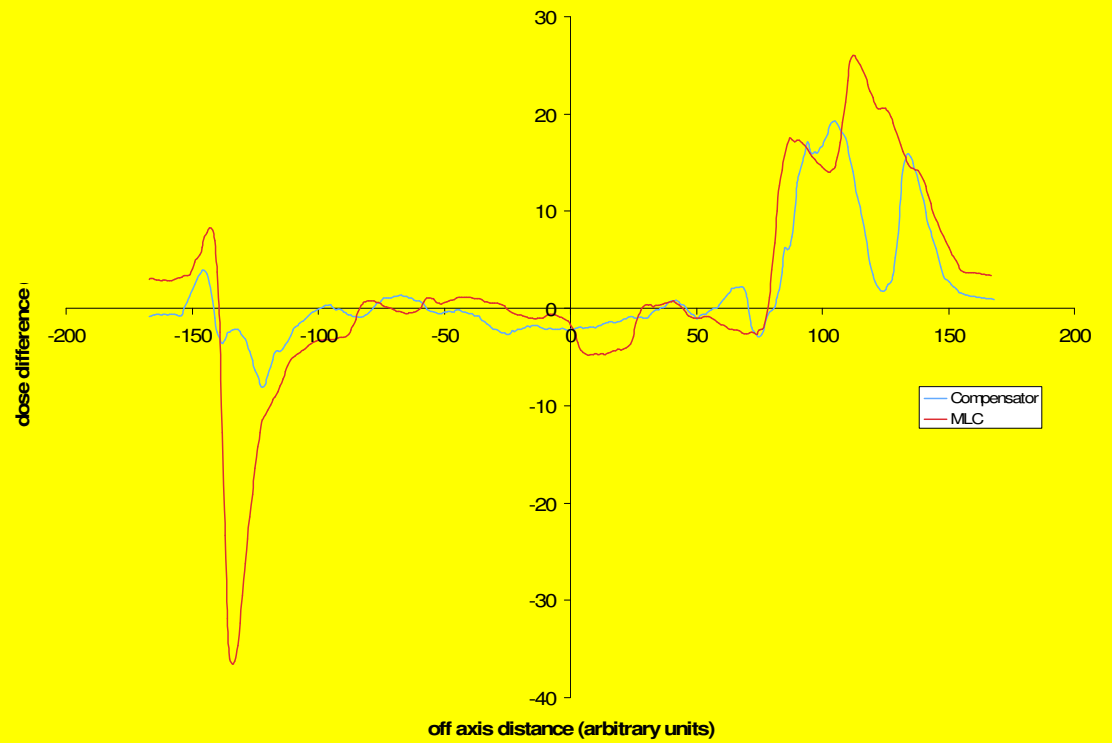
Planar out of field fluence profiles at a plane in-between dmax & target mid-plane



Horizontal cut through CAX at plane of dmax



Vertical cut through CAX at plane of dmax

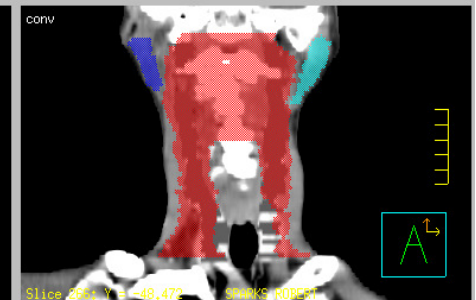
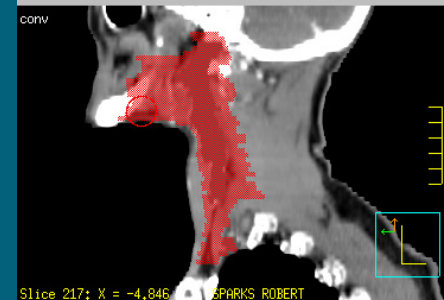
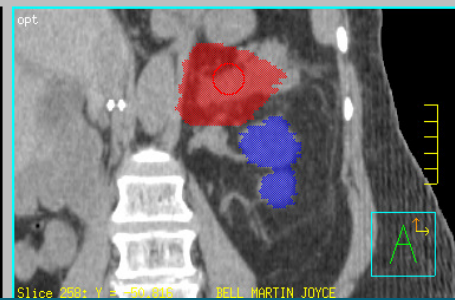
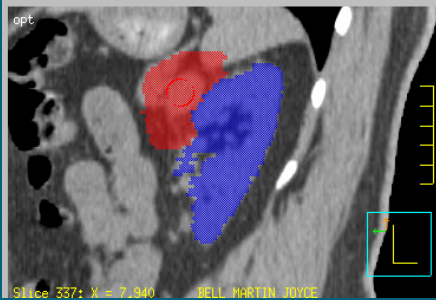
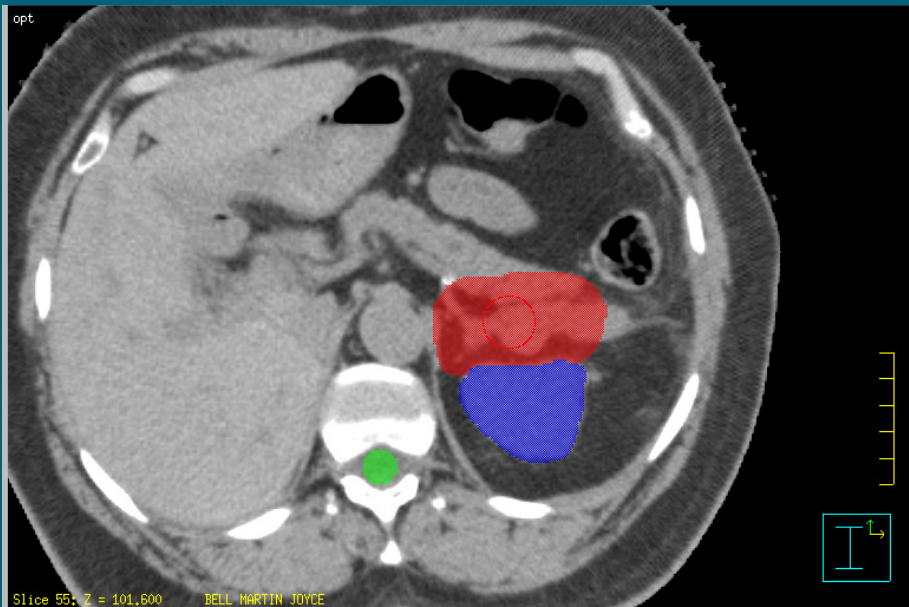


Planar out of field fluence profiles at dmax level

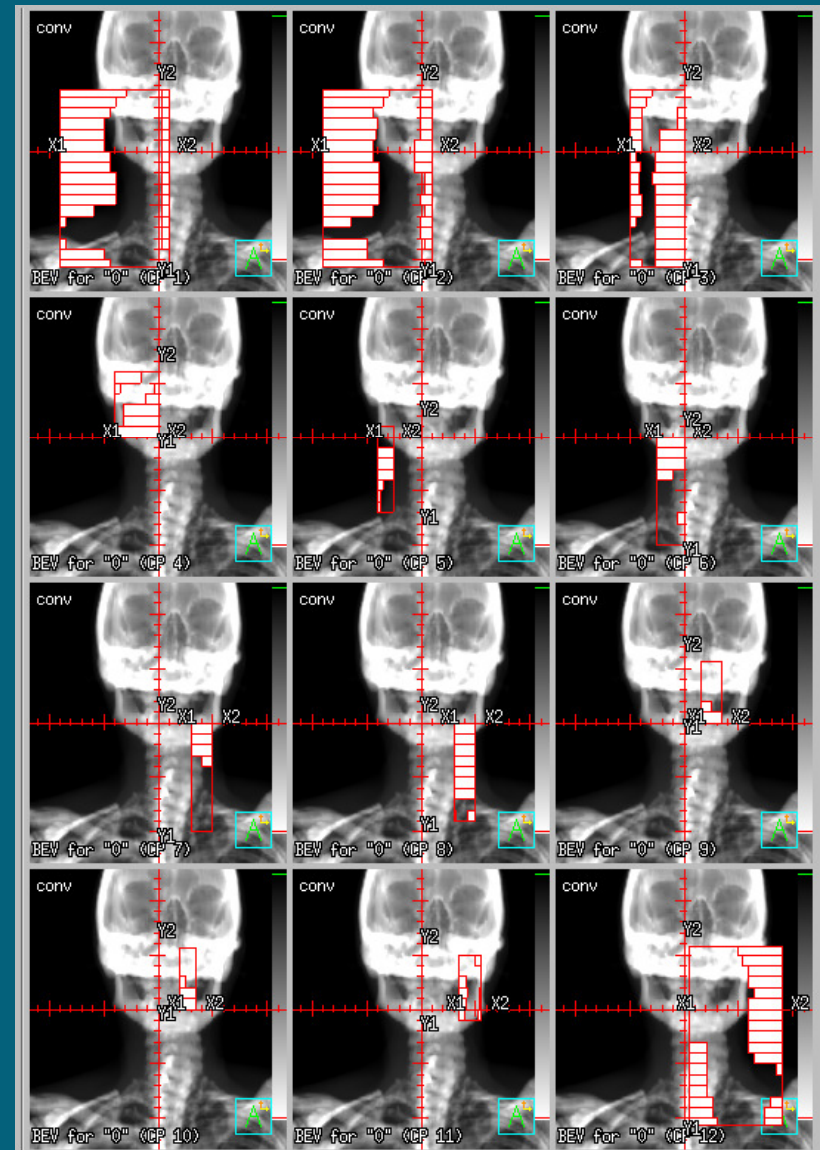
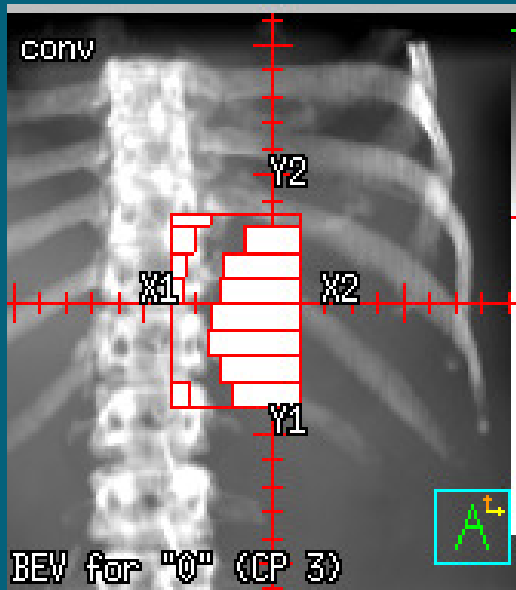
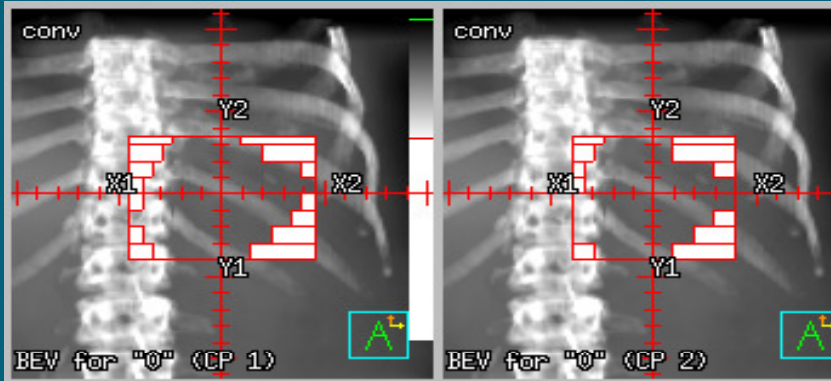
RESULTS

- For the more complex plans such as in H&N, the solid compensators resulted in 26.7% fewer monitor units, and **delivery time was reduce in half** when compared with MLC plans.
- For relatively simple IMRT plans, however, such as prostate boosts or adrenal gland plans where the target has a relatively simple cylindrical shape the MLC plans in average result in about the same or some times fewer MUs and required about 16% less time to deliver than the solid compensator plans.
- Mosfet skin dose analysis showed that the solid compensators resulted in an average of **17.5% less skin dose**.

Simple vs Complex plan



Simple vs. Complex cont.



MU Comparison

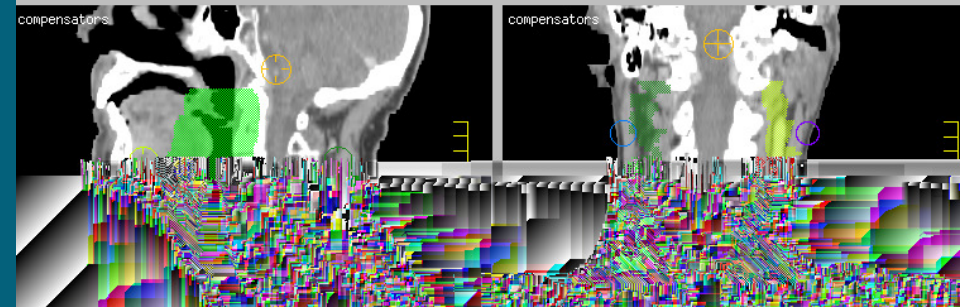
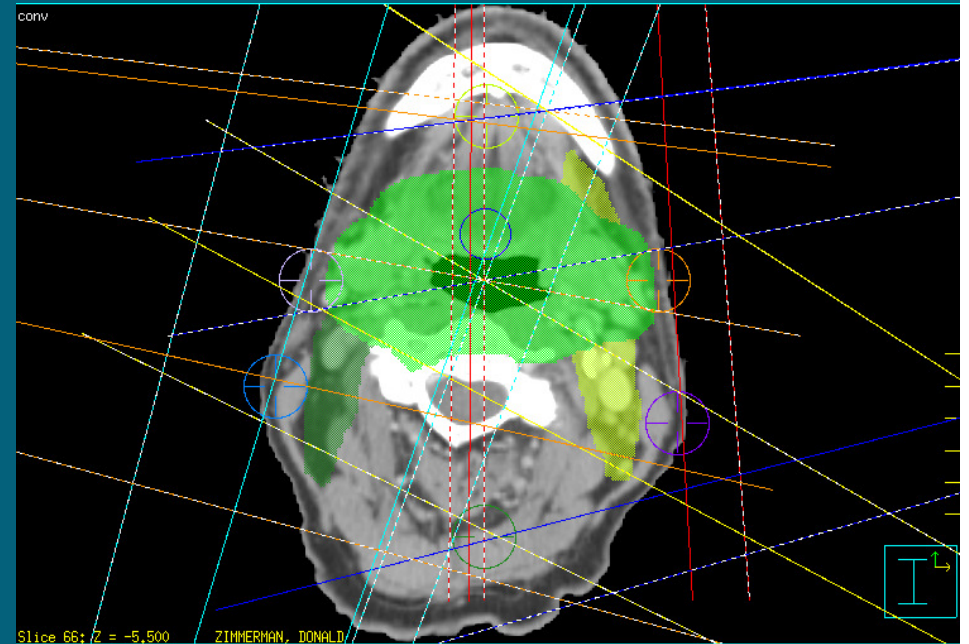
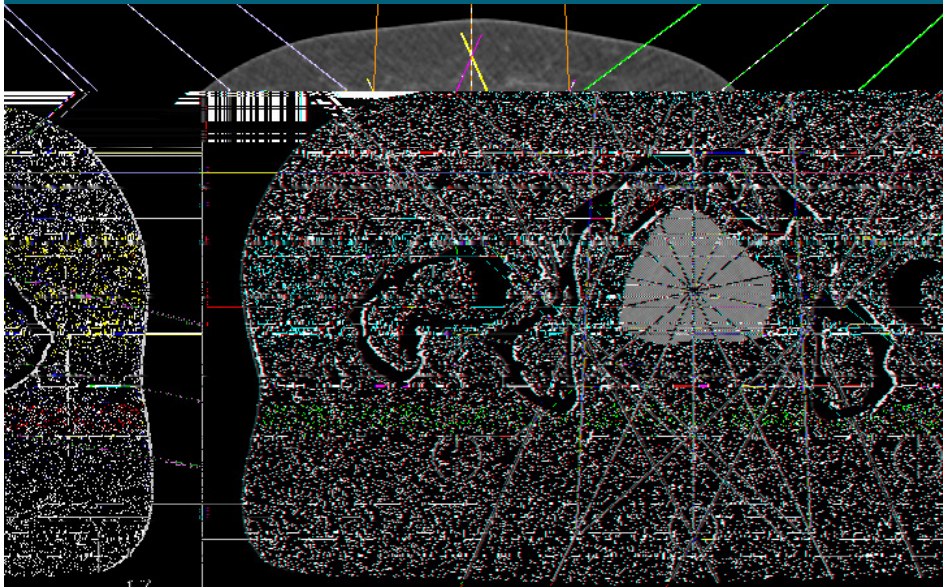
Port	Head and Neck Boost		Head and Neck		Brain boost		Prostate		Prostate Boost		Adrenal Gland	
	Solid IMRT	MLC IMRT	Solid IMRT	MLC IMRT	Solid IMRT	MLC IMRT	Solid IMRT	MLC IMRT	Solid IMRT	MLC IMRT	Solid IMRT	MLC IMRT
1	141.8	163.4	66.9	97.3	48.1	65.2	73.6	167.8	50.4	33.2	53.3	39
2	57.5	155	70.6	120.4	35.9	77.4	98.4	100.5	62.5	46.9	55.5	36.2
3	110.2	100	58	86.1	83.7	110.4	134.5	241.9	105.6	73.4	53.7	35.8
4	106.2	125.7	57.1	128.2	115.2	47.2	117.7	137.4	54.2	36.7	52.1	35.6
5	141.3	159.9	59.9	123.1	88.4	93.8	73.1	136.4	54.5	37.2	52.3	36
6	120.4	123.5	66.5	115.9	49.3	91.8	124.9	136.2	99.9	78.8	69.1	50
7	97.2	107.9	60.5	104	44.8	78.1	128.3	161.3	61.4	51.4	58	36.1
8	84.6	108.6	47.7	105.7	76.1	88.9						
9	66.5	160	60.7	143.8	129.2	65						
SUM	925.7	1204	547.9	1024.5	670.7	717.8	750.5	1081.5	488.5	357.6	394	268.7

Delivery Time Comparison

	Time in Minutes							
	Head and Neck		Prostate Boost		Adrenal Gland		Prostate	
	Solid IMRT	MLC IMRT	Solid IMRT	MLC IMRT	Solid IMRT	MLC IMRT	Solid IMRT	MLC IMRT
1	15.0	35.8	10.2	8.4	8.5	6.9	11.9	19.6
2	13.4	34.4	9.1	9.0	8.3	6.8	12.0	19.5
3	13.5	32.9	9.2	8.7	8.4	6.8	11.8	19.1
Average	14.0	34.4	9.5	8.7	8.4	6.9	11.9	19.4

1. For MLC delivery, from initial beam on time until final beam turn off
2. For Comp., stop watch started from time tech went into the room to mount the compensators on gantry and stopped at the beam turn off

CT Point Dose Analysis



CT Based Point Dose Analysis

	Brain boost			Prostate boost			Adrenal gland		
Point	Solid	MLC	Diff cGy	Solid	MLC	Diff cGy	Solid	MLC	Diff cGy
1.0	16.6	18.6	-2.0	46.2	45.0	1.2	20.2	21.6	-1.4
2.0	72.2	77.8	-5.6	30.3	31.1	-0.8	13.0	14.1	-1.1
3.0	52.5	61.6	-9.1	36.2	49.8	-13.6	27.1	25.9	1.2
4.0	105.2	108.1	-2.9	15.7	18.3	-2.6	0.0	0.0	0.0
5.0	65.2	69.0	-3.8	15.1	17.8	-2.7	17.3	18.3	-1.0
6.0	61.2	67.3	-6.1						
Point	Prostate			Head and Neck			Head and Neck boost		
1.0	Solid	MLC	Diff cGy	Solid	MLC	Diff cGy	Solid	MLC	Diff cGy
2.0	21.8	26.6	-4.8	148.4	152.4	-4.0	130.2	137.1	-6.9
3.0	47.0	68.3	-21.3	157.8	158.9	-1.1	143.3	148.8	-5.5
4.0	56.6	67.0	-10.4	77.6	64.9	12.7	55.2	43.8	11.4
5.0	27.6	67.0	-39.4	132.8	133.0	-0.2	82.3	78.3	4.0
6.0	21.0	27.7	-6.7	143.4	143.5	-0.1	81.6	75.1	6.5
7.0	26.9	20.7	6.2	147.9	146.6	1.3	77.1	72.9	4.2
8.0	14.4	16.1	-1.7	47.8	48.3	-0.5	31.7	34.1	-2.4
9.0	11.3	17.9	-6.6	22.5	26.0	-3.5	24.2	31.3	-7.1

Physical Dose Measurement

	Prostate			Head and Neck		
mosfet (cGy)	solid	MLC	%diff	solid	MLC	%diff
1	31.8	35.5	-10.3	90.0	79.1	13.8
2	16.4	35.5	-53.8	52.7	55.5	-4.9
3	10.0	9.1	10.0	43.6	40.0	9.1
4	35.5	40.9	-13.3	80.9	63.6	27.1
5	33.6	41.8	-19.6	24.5	10.9	125.0
TLD(cGy)	solid	MLC	%diff	solid	MLC	%diff
1	42.5	61.9	-31.3	12.6	6.8	84.4
2	40.2	37.9	6.1	131.7	137.7	-4.4
3	35.9	39.2	-8.2	92.2	78.3	17.8
4	15.3	24.2	-37.0	9.8	6.2	58.4
5	5.3	10.0	-47.2	8.7	5.7	51.9
6	5.8	12.1	-51.7	63.7	59.8	6.6
Gaf film (cGy)	solid	MLC	%diff	solid	MLC	%diff
1	28.8	26.7	7.6	76.6	78.3	-2.1
2	16.7	10.4	61.5	32.2	34.0	-5.3
3	28.1	26.6	5.7	7.3	4.8	54.2
4	26.9	23.2	16.1	30.1	26.5	13.7
5	28.6	35.4	-19.3	64.2	59.6	7.7

Conclusions

- Compensators are a viable IMRT treatment options
- *To our experience, compensator based IMRT is not more labor-intensive than MLC for clinical physicist and the patient put through is about the same if not quicker for therapists*
- For simple plans compensators showed no advantage over MLC in regards to MUs and treatment time.
- For complex plans there was a significant decrease in treatment time and delivered MU
- *Careful dosimetry shows that with solid IMRT comes reduced treatment time and monitor units*
- *The planar dose analysis for out of field areas show a statistically significant difference between the MLC delivery and the compensator method*