THE UNIVERSITY OF ALABAMA AT BIRMINGHAM

Knowledge that will change your world

Acceptance testing, commissioning and routine QA of the Varian TrueBeam

Richard Popple

Disclosure

- UAB has Varian research contracts
- Honorarium from Varian

Not your father's Chevy…

Not your father's Chevy…

Not your father's Chevy…

Not your father's ~~Chevy~~ Linac…

TrueBeam – distinquishing characteristics

- Completely digital control system
- Waveguide and filter design allows 5 flattened photon energies up to 20 MV.
- Electron scattering foils are of a new design.
- Implements 6 MV and 10 MV flattening filter free (FFF) beams that provide dose rates up to 2400 monitor units per minute.

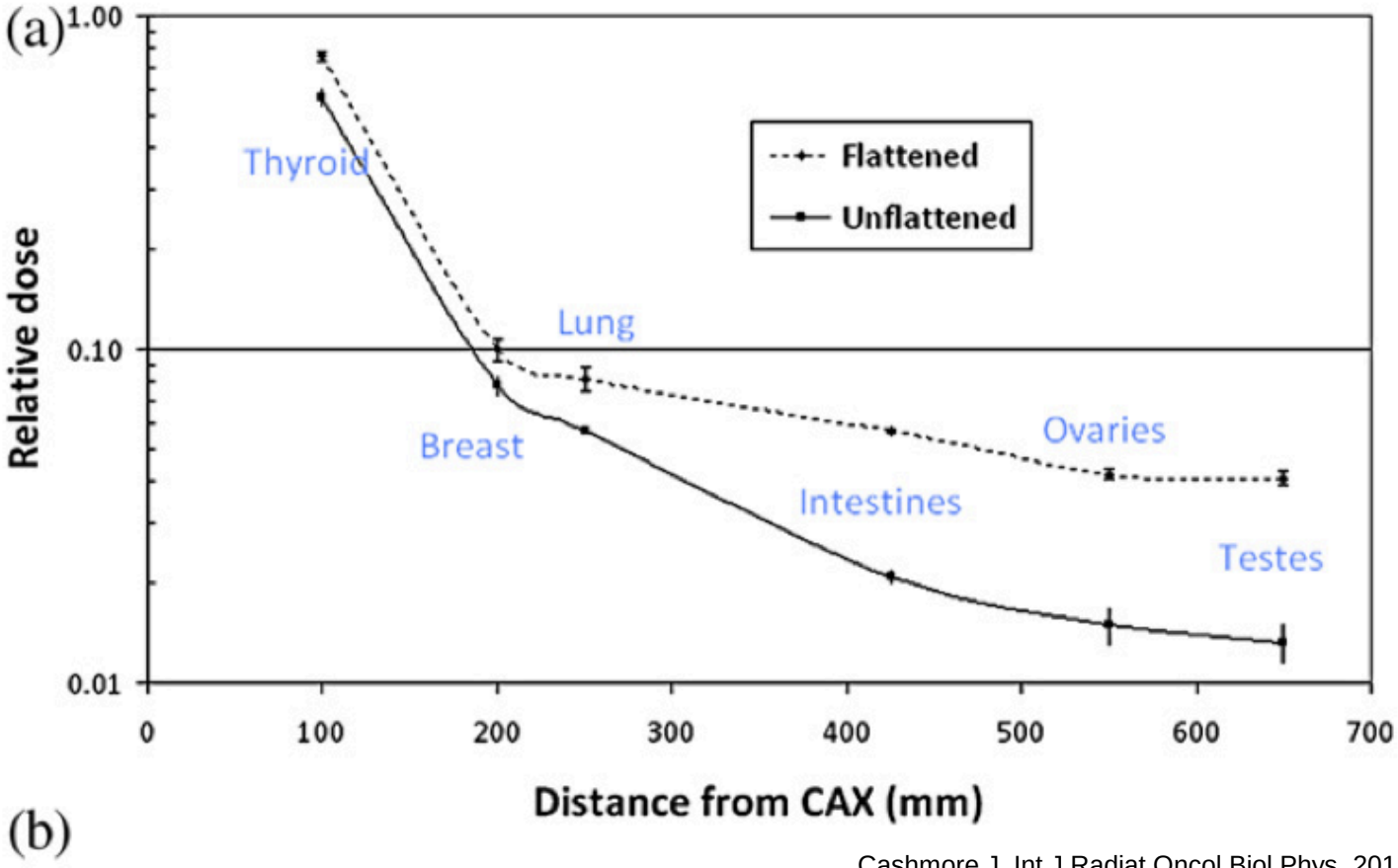
Possible Benefits of a FFF

- Efficiency
- More accurate beam modeling due to decreased head scatter
- Decreased leakage and dose outside field

> *The study showed that removing the filter increased the dose rate on the central axis by a factor of 2.31 (6 MV) and 5.45 (18 MV) at a given target current. Because the flattening filter is a major source of head scatter photons, its removal from the beam line could reduce the out-of-field dose.*

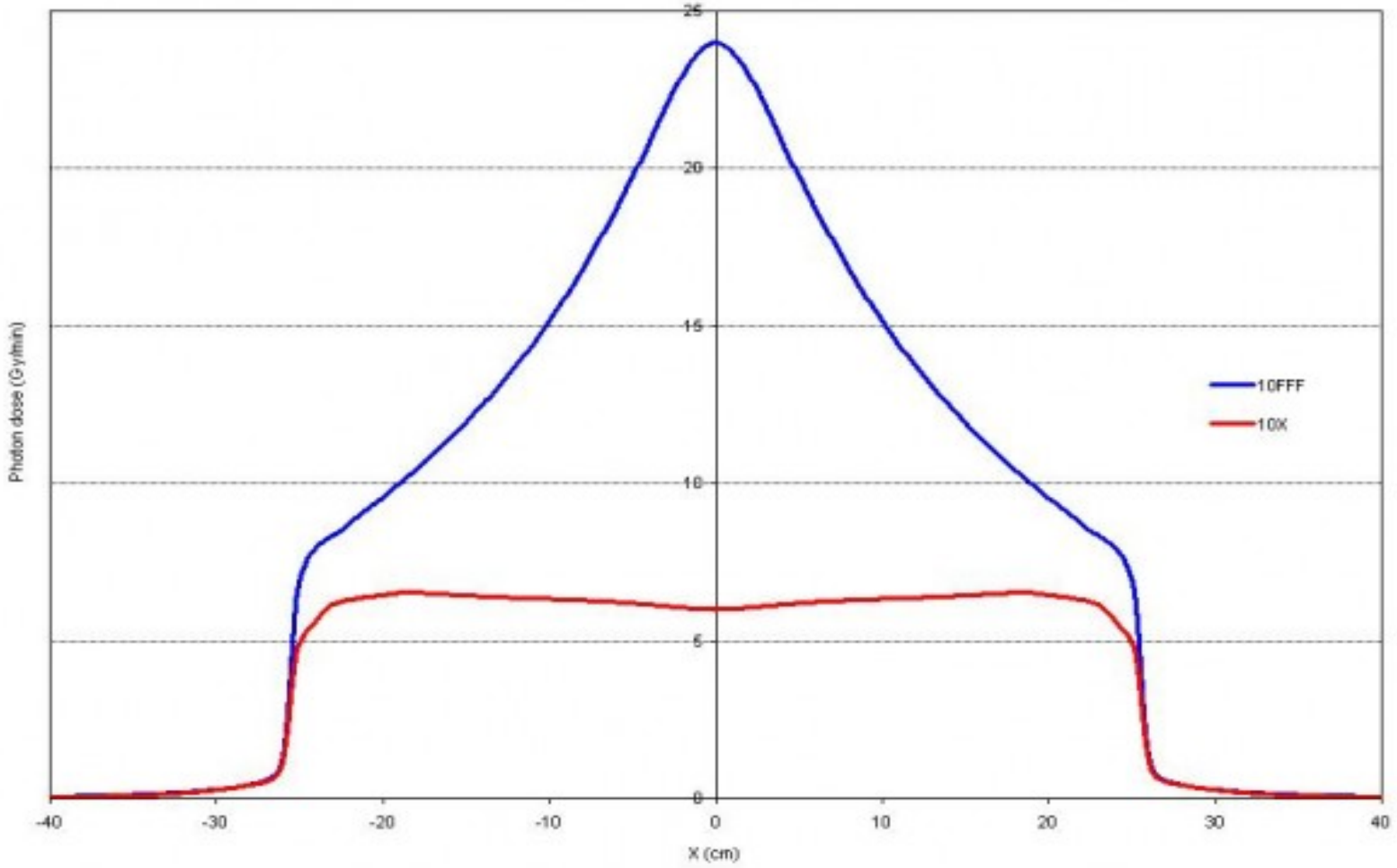
Vassiliev ON, Titt U, Kry SF, Pönisch F, Gillin MT, Mohan R Med Physics 2006 vol. 33 (4) pp. 820-7

Unflattened Beam Has a Lower Risk of Secondary Tumors



Cashmore J, Int J Radiat Oncol Biol Phys. 2011

Beam Profile – Flattening Filter



Depth Dose with Flattened Beam

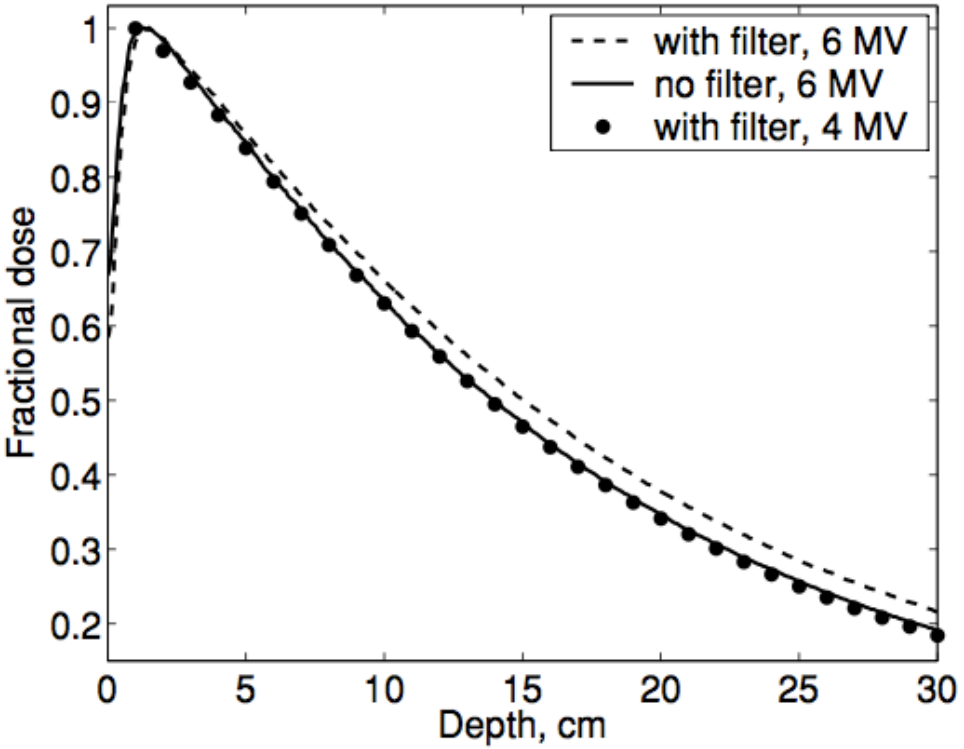


Figure 1. Depth dose dependence for a 10 × 10 cm^2 field. 6 MV with the flattening filter (dashed line), 6 MV without the filter (solid line), 4 MV with the filter (circles).

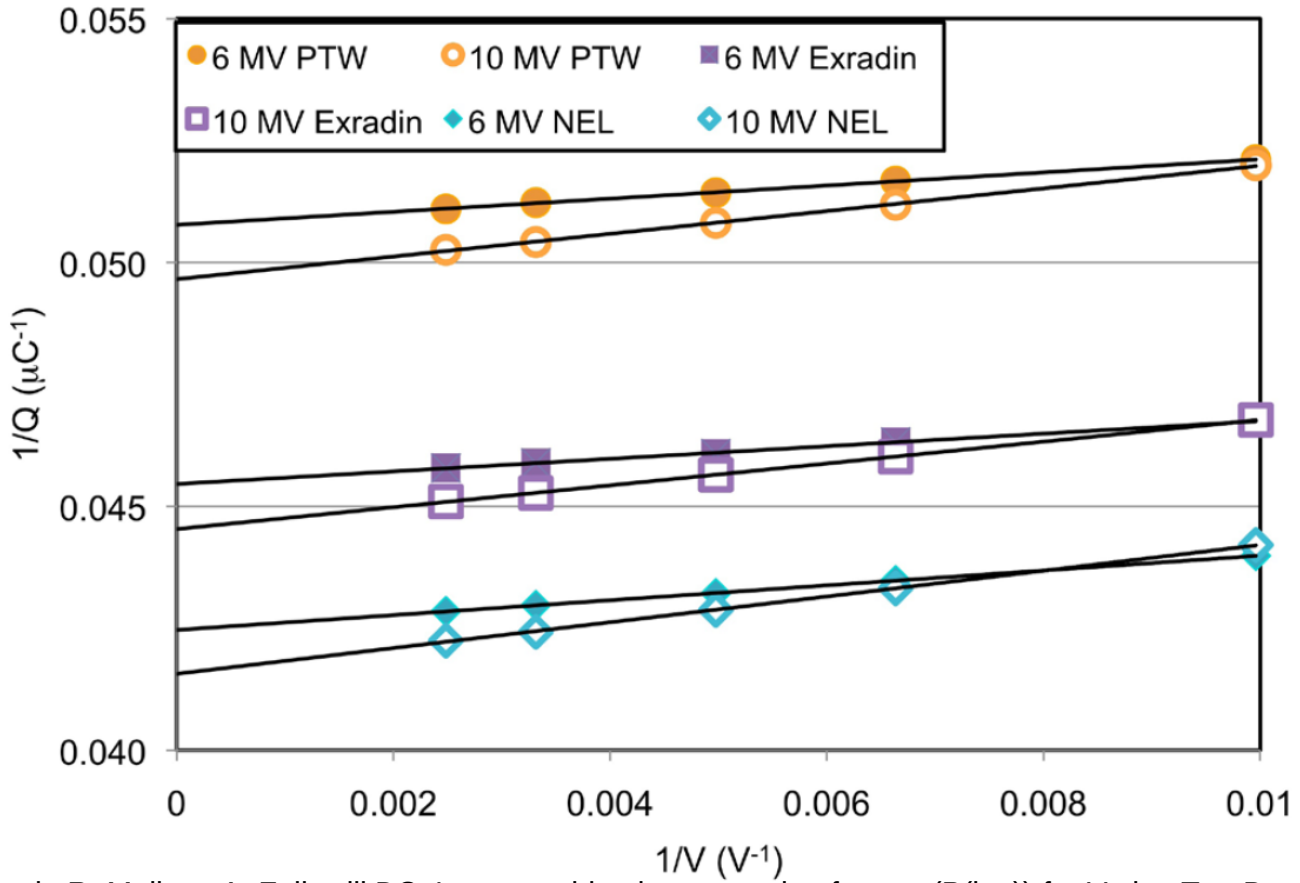
2004 Phys. Med. Biol. 49 1535

Calibration

- No difference for FFF
- Polarity and recombination corrections small

Energy	Dose rate	Ppol	Pion
6X	600	1.000	1.004
15X	600	1.000	1.005
6X FFF	1400	1.000	1.006
10X FFF	2400	1.000	1.013

Calibration



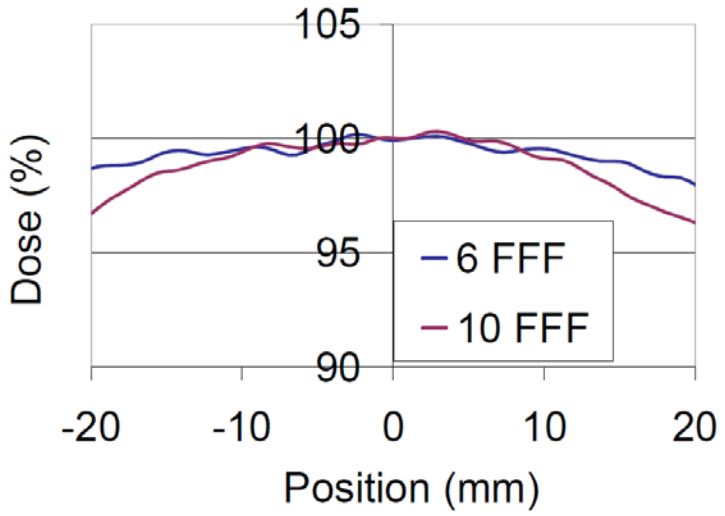
Kry SF, Popple R, Molineu A, Followill DS. Ion recombination correction factors (P(ion)) for Varian TrueBeam high-dose-rate therapy beams. J Appl Clin Med Phys. 2012 Nov 8;13(6):3803. doi: 10.1120/jacmp.v13i6.3803. PubMed PMID: 23149774.

Calibration

TABLE 5. Recombination factors at 300 V based on the two-voltage technique (P_{ion}), and based on a Jaffé-plot (1/V versus 1/Q curve).

	6 MV FFF		*10 MV FFF*	
Ion Chamber	P_{ion}	*Jaffé-plot*	P_{ion}	*Jaffé-plot*
Exradin A-12	1.009	1.009	1.014	1.017
PTW TN30013	1.008	1.008	1.013	1.015
NEL 2571	1.013	1.011	1.018	1.020

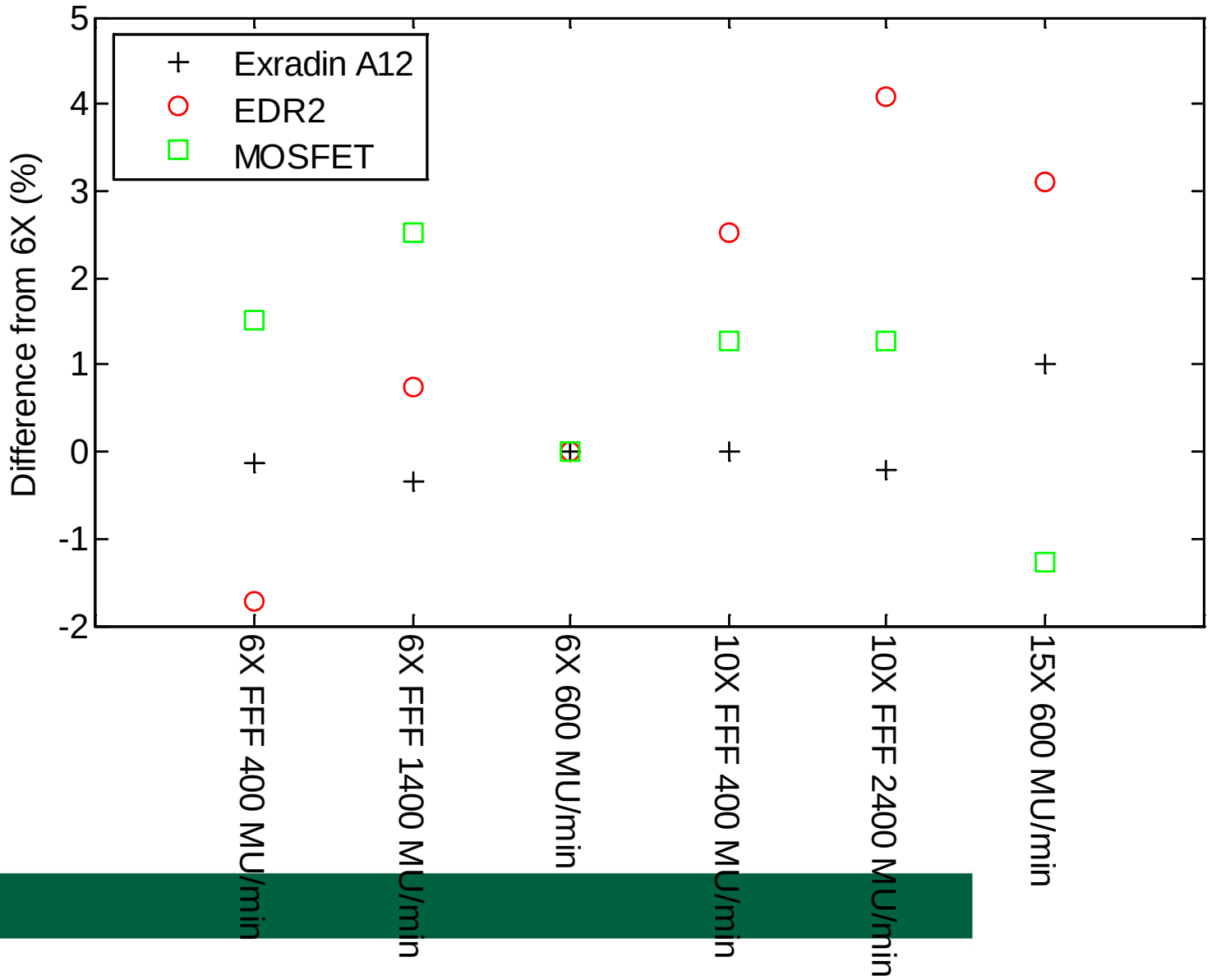
Kry SF, Popple R, Molineu A, Followill DS. Ion recombination correction factors (P(ion)) for Varian TrueBeam high-dose-rate therapy beams. J Appl Clin Med Phys. 2012 Nov 8;13(6):3803. doi: 10.1120/jacmp.v13i6.3803. PubMed PMID: 23149774.



Calibration – use Pb foil for <u>all</u> FFF beams

$$\%dd(10)_x = [0.8905 + 0.00150\%dd(10)_{Pb}]\%dd(10)_{Pb}$$
$$[\text{foil at } 50 \text{ cm}, \%dd(10)_{Pb} \geqslant 73\%], \qquad (13)$$

Calibration sanity check

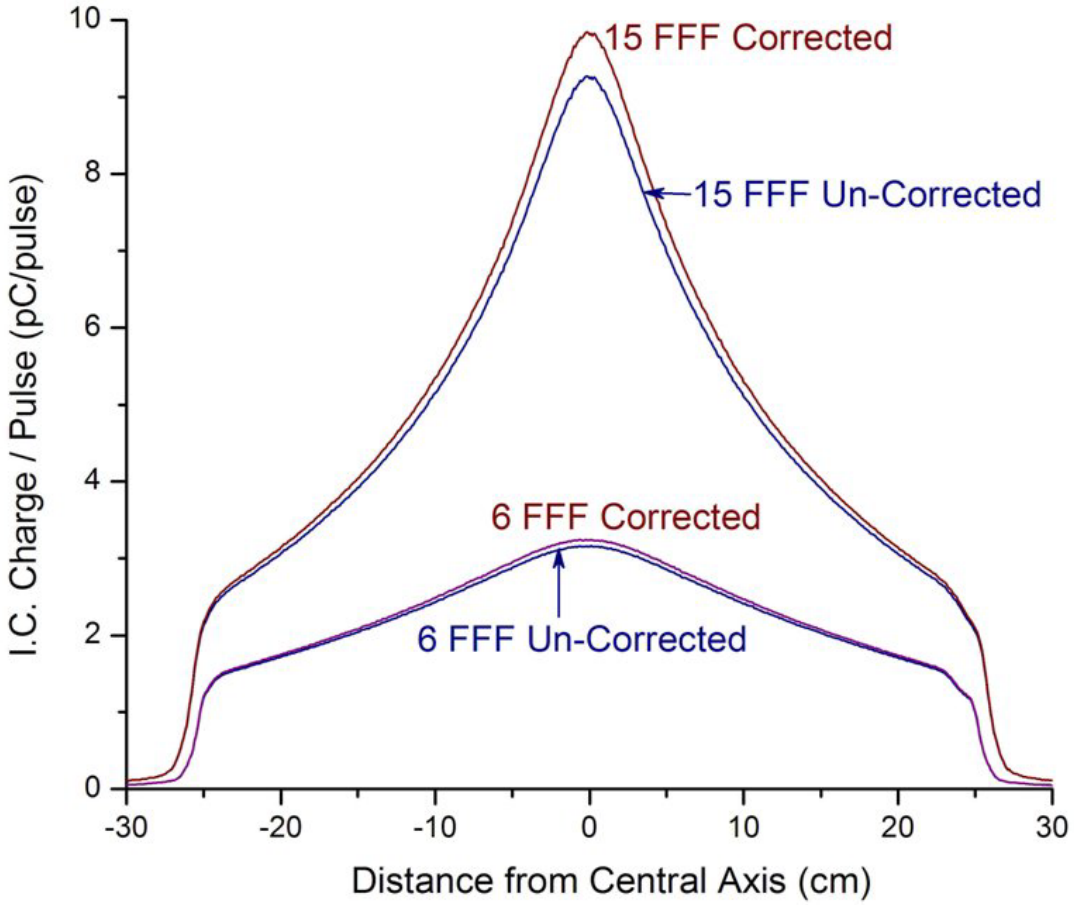


IROC Calibration check

- RPC OSLD measurement / Institution
  - 6X FFF = 0.99
  - 10X FFF = 0.99

Profile and depth dose correction for recombination

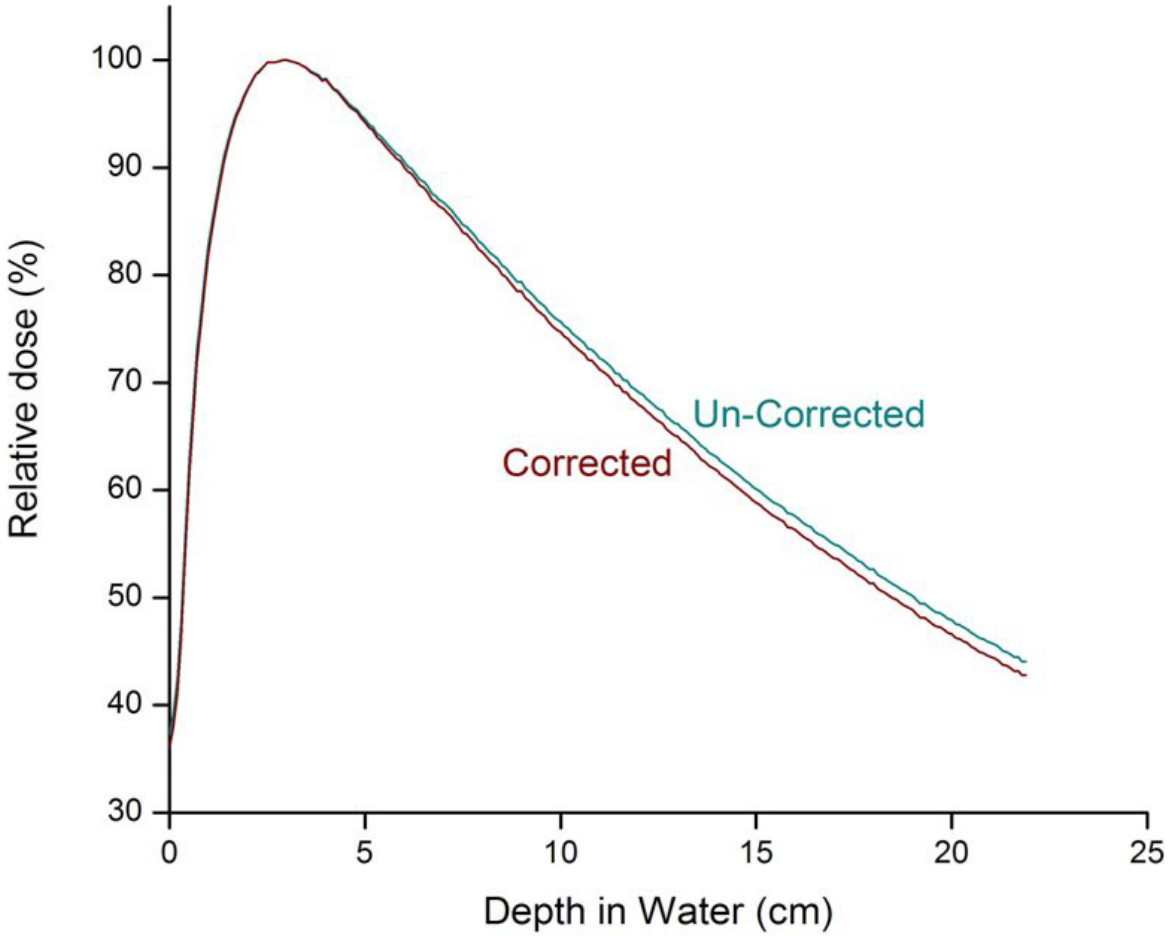
Measured x-ray distributions of 6FFF and 15FFF beams plotted against charged collected per beam pulse. Also plotted are the results from applying corrections for the ion chamber collection efficiency. The distributions were measured at 100 cm SSD with the 0.1 cm^3 chamber at D_{max} and biased with 300 V.



S Johnsen "Ion Chamber Collection Efficiency Considerations for Un-Flattened X-Ray Beams," Med. Phys. 35, 2770 (2008)

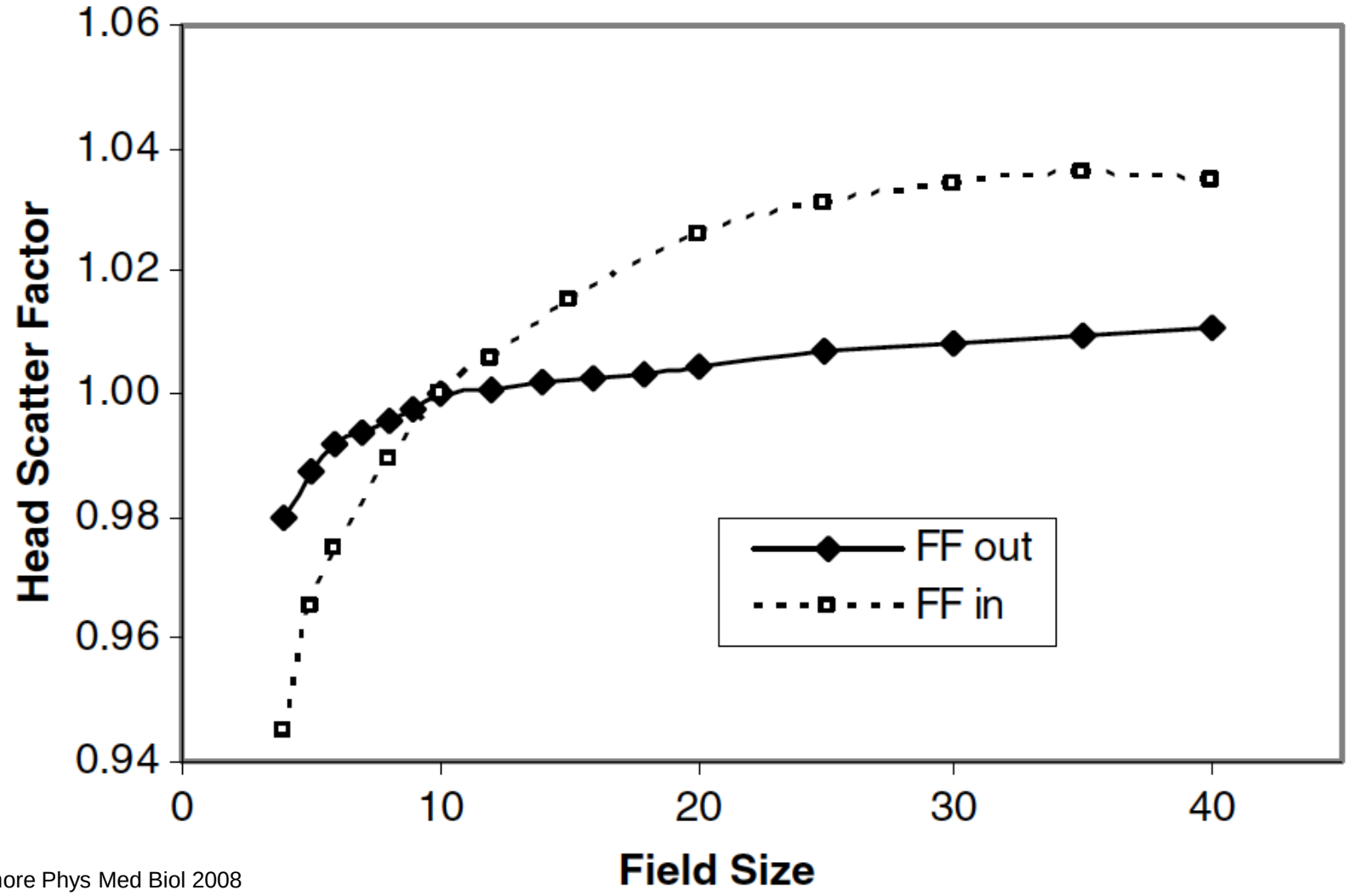
Profile and depth dose correction for recombination

Measured 15 FFF x-ray depth-dose distribution and distribution resulting from corrections for ion chamber collection efficiency. Each curve is normalized to 100% at D_{max}. Data is for a 0.1 cm^3 chamber biased to 300 V; 10x10 cm^2 field at 100 cm SSD.



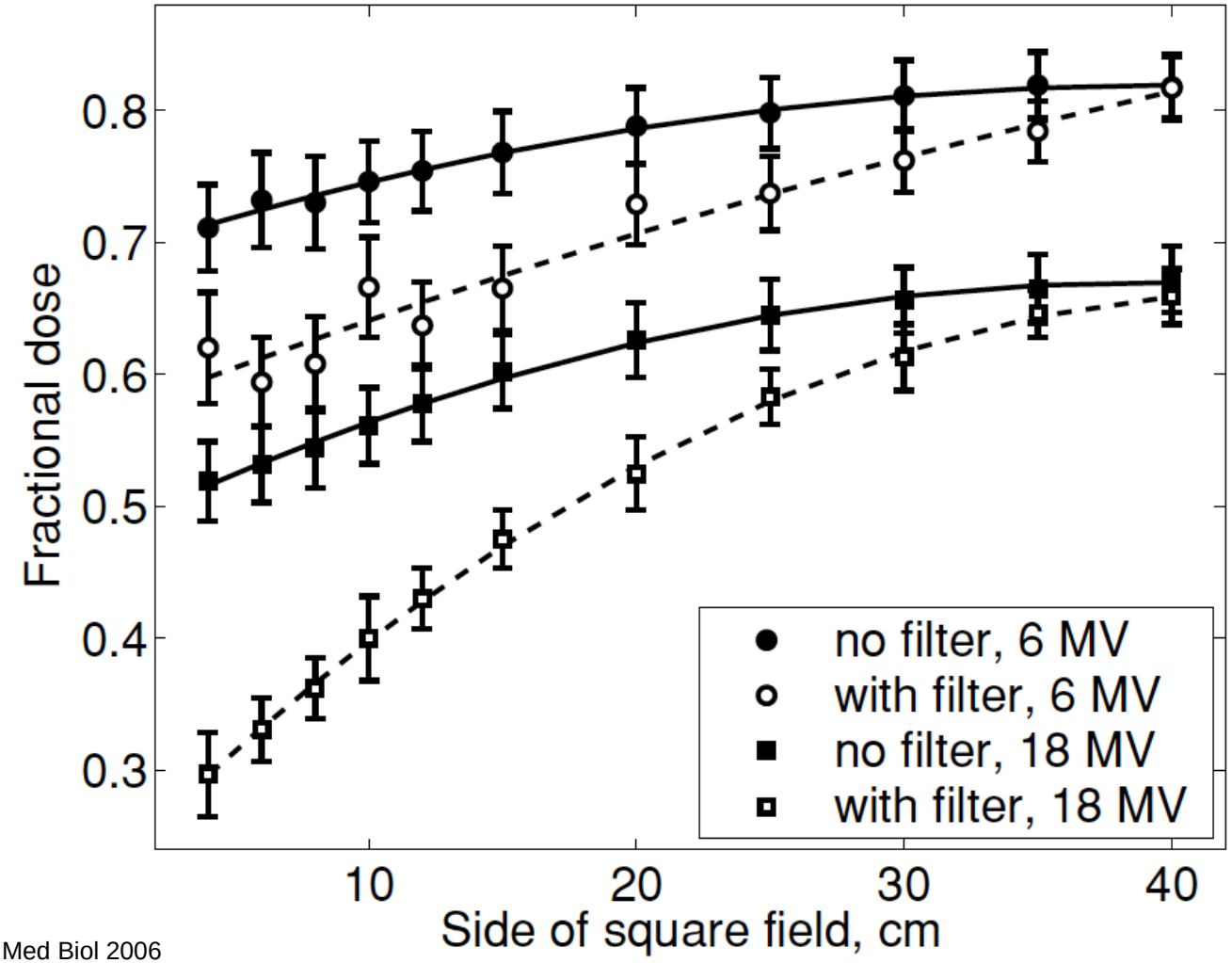
S Johnsen "Ion Chamber Collection Efficiency Considerations for Un-Flattened X-Ray Beams," Med. Phys. 35, 2770 (2008)

FFF head scatter



Cashmore Phys Med Biol 2008

FFF surface dose

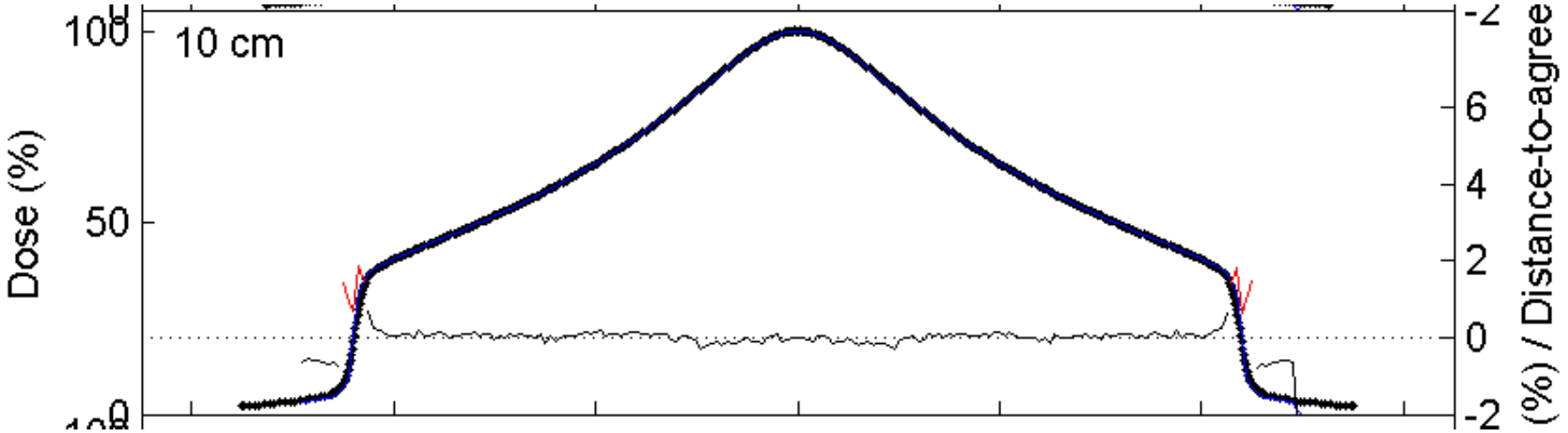


Vassiliev et al. Phys Med Biol 2006

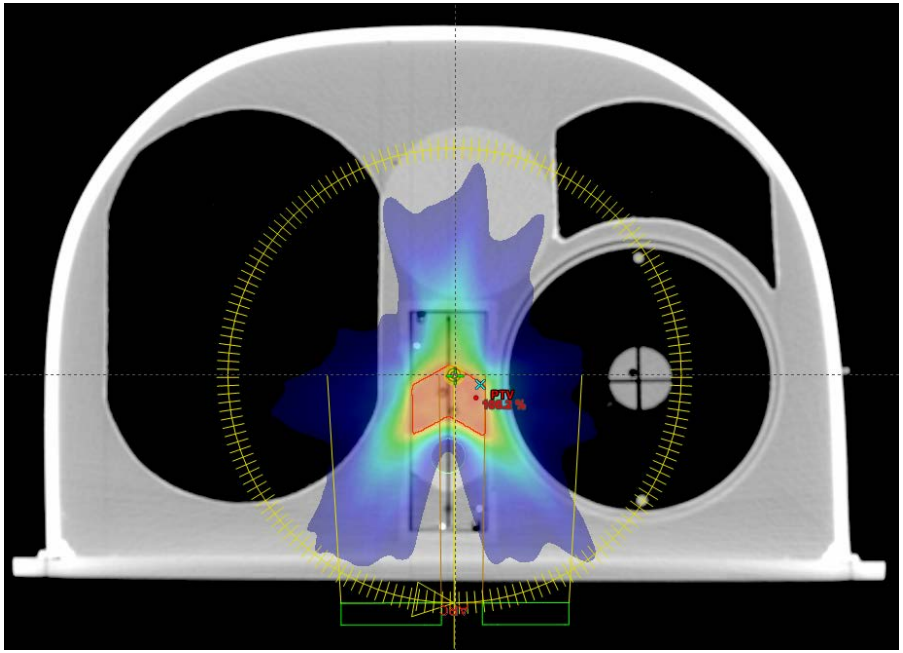
Photon commissioning

- AAA Data requirements are the same
- No additional data required for FFF

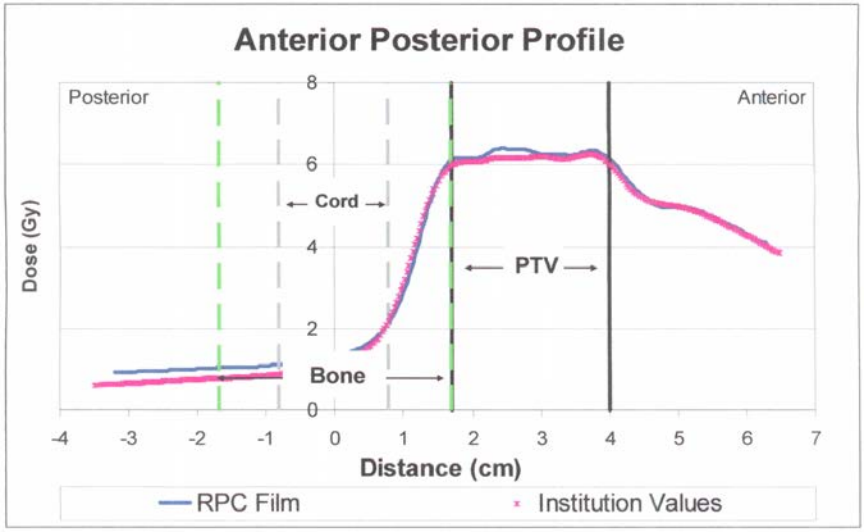
10X FFF profile

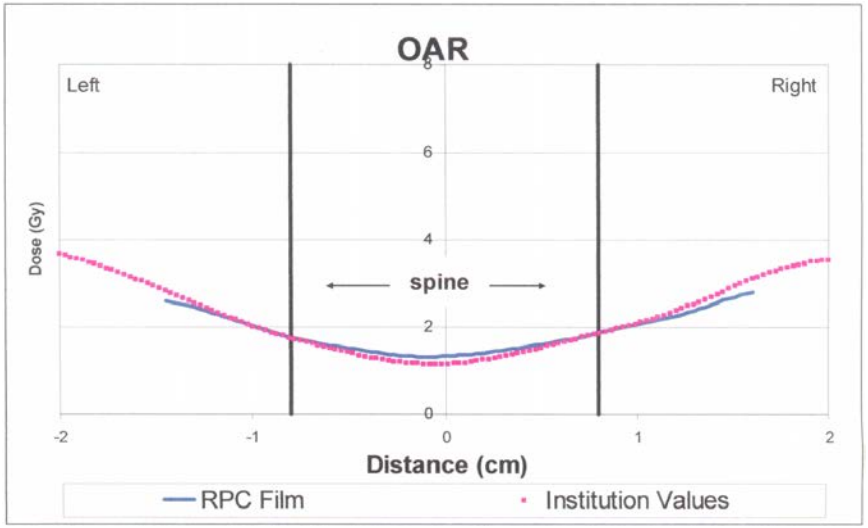


IROC VMAT Spine

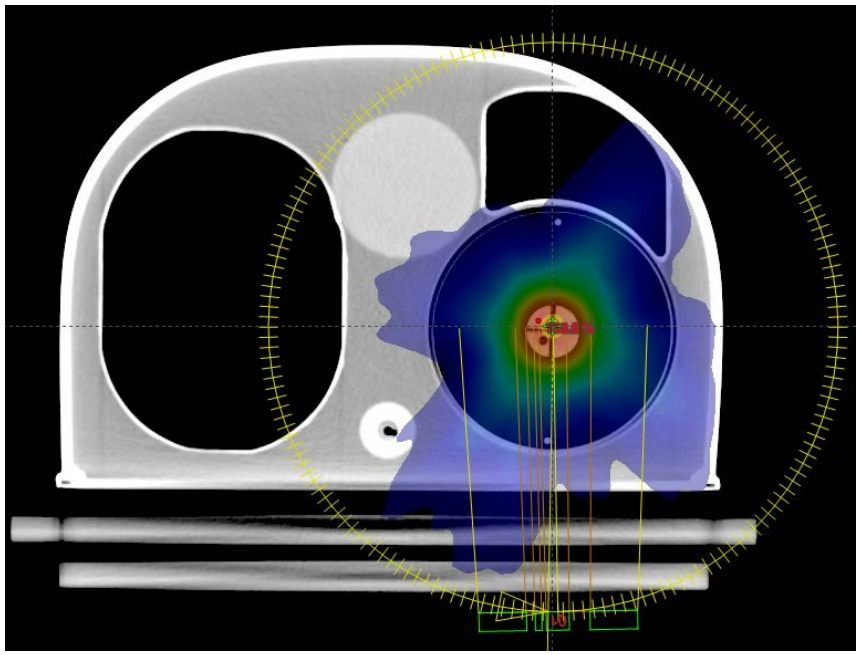


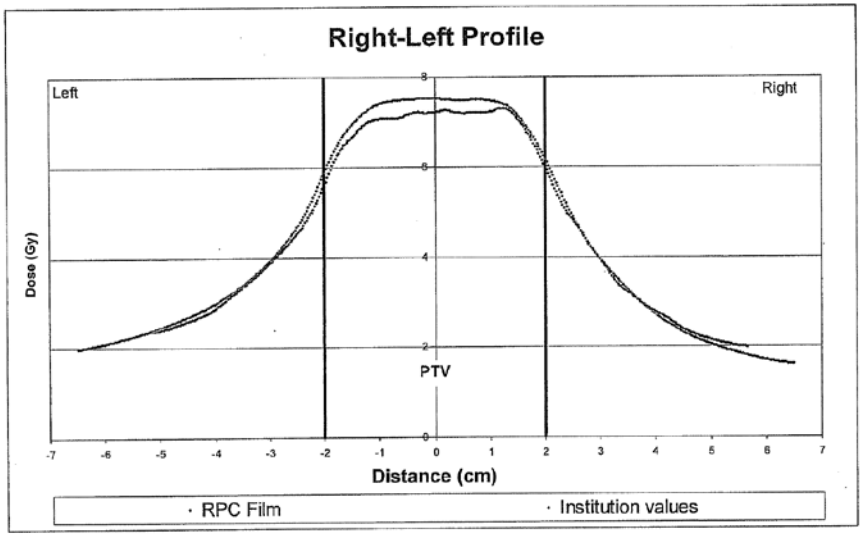
Location	Institution Reported Doses (cGy)	TLD Dose (cGy)	Measured/Institution
PTV_TLD_sup_ant	612	618	1.01
PTV_TLD_inf_ant	614	619	1.01
PTV_TLD_sup_post	616	619	1.00
PTV_TLD_inf_post	620	627	1.01
HEART_TLD	134	135	1.01

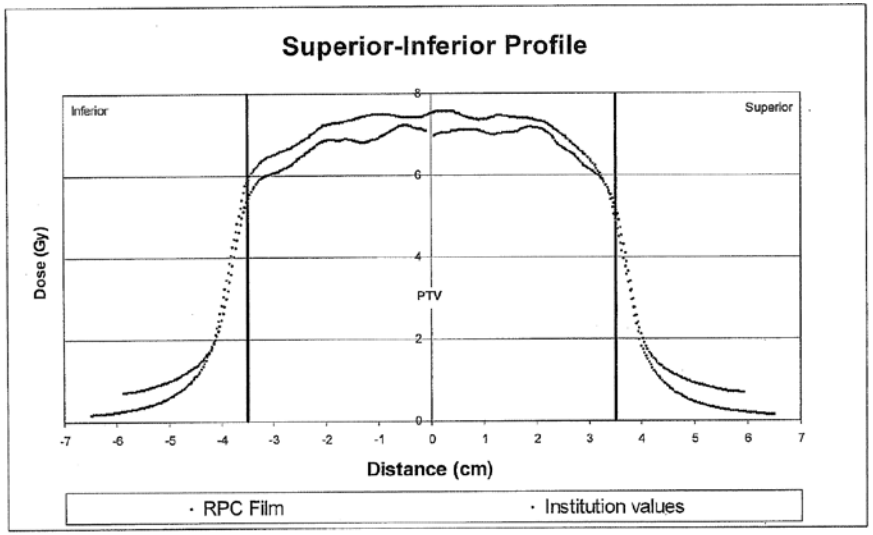




IROC Gated VMAT Lung







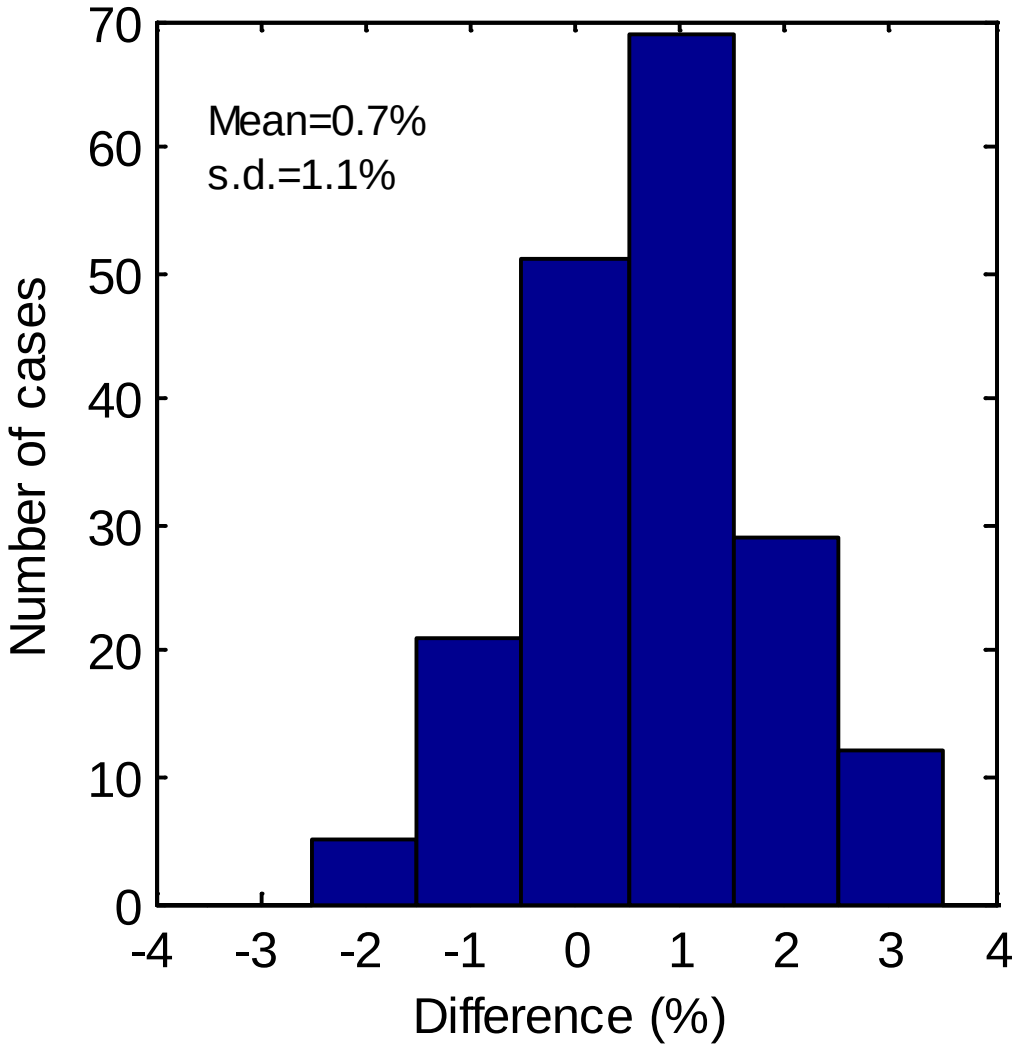
Summary of TLD and film results:

Location	RPC vs. Inst.	Criteria	Acceptable
PTV_TLD_sup	0.96	0.92 – 1.02	Yes
PTV_TLD_inf	0.96	0.92 – 1.02	Yes

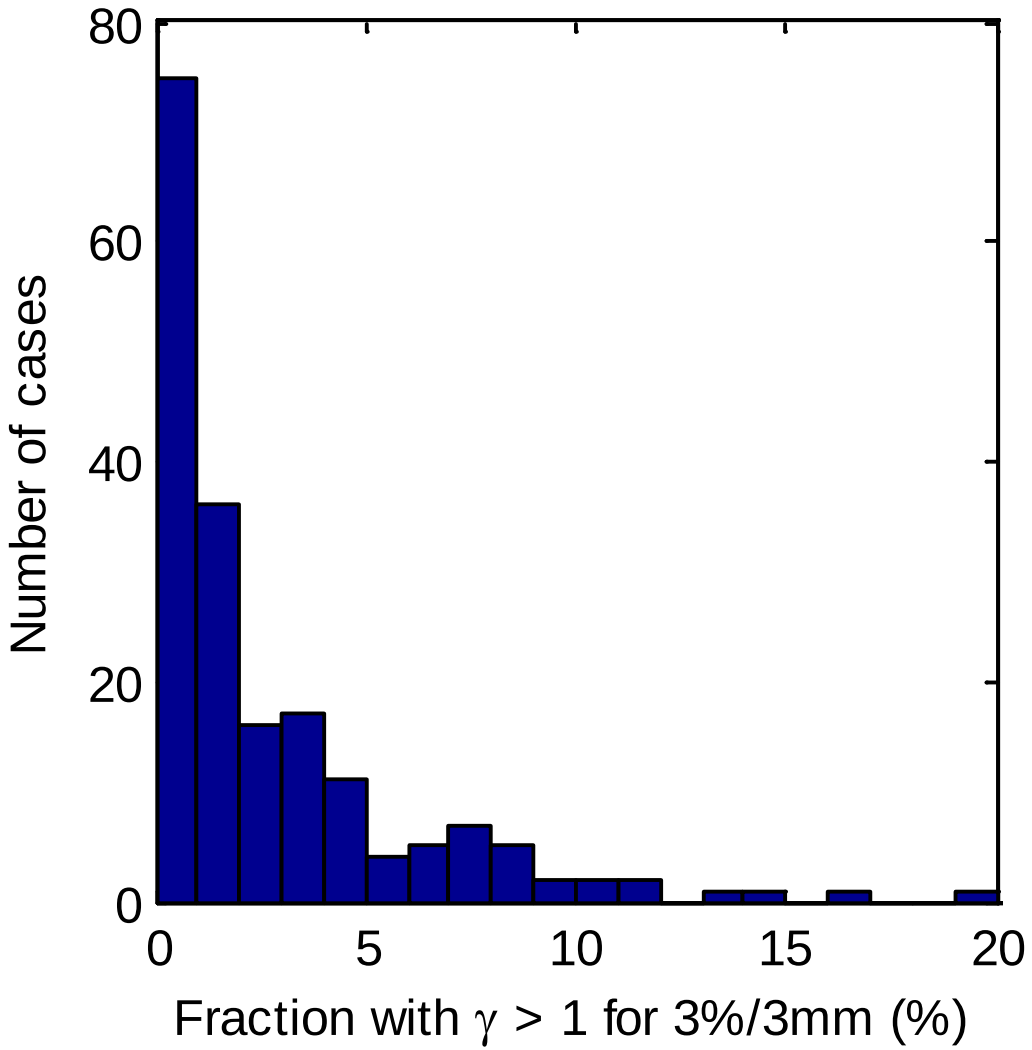
Film Plane	Gamma Index*	Criteria	Acceptable
Axial	100	≥ 80%	Yes
Coronal	99	≥ 80%	Yes
Sagittal	98	≥ 80%	Yes
Average over 3 planes	99	≥ 85%	Yes

*Percentage of points meeting gamma-index criteria of 5% and 5 mm

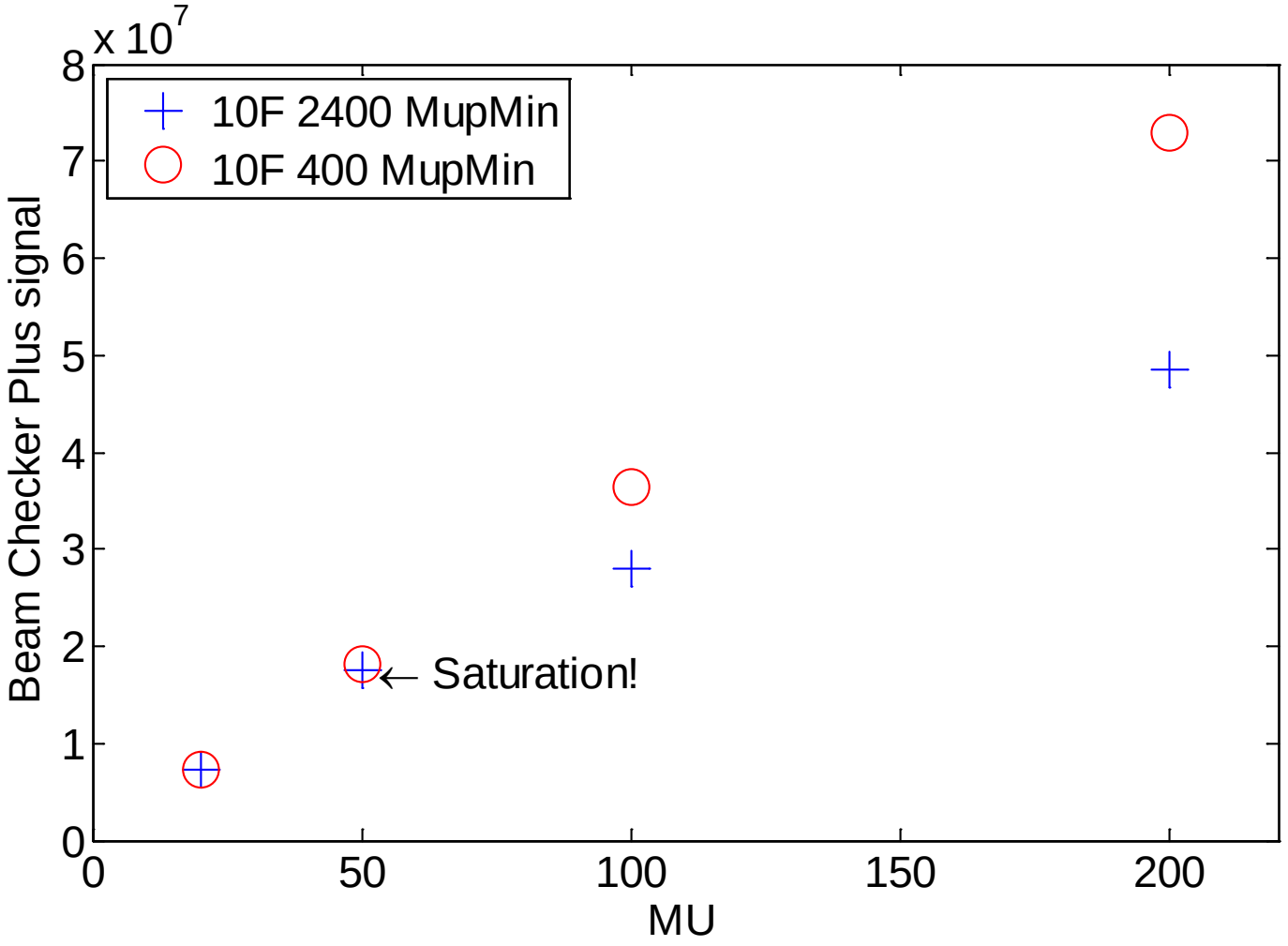
IMRT QA results



IMRT QA results



Daily QA device




Varian engineer
fixing UAB TrueBeam
piggly wiggly

Machine performance check

Machine Performance Check

Change Mode

- **6xFFF** Beam Check
- **10xFFF** Beam Check
- **15x** Beam Check
- **6x** Beam & Geometry Check

Tools | Create Report

Richard Popple, Physicist
1005
1:32 PM Wednesday, April 22, 2015

Do not use for Treatment

VARIAN medical systems

Fix phantom to couch, then press Prepare to apply beam parameters.

Preview | Prepare | Ready | Beam-on

Beam

	Plan	Delivered
Energy	None	
MU1	351.0	
MU2	351.2	

Imaging

MV Detector	≠
kV Detector	≠
kV Source	≠

Couch

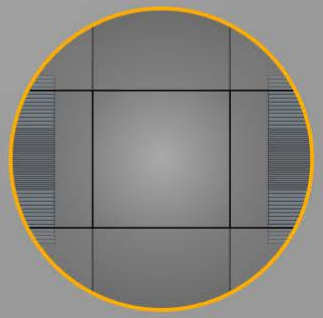
	Plan	Actual
Vrt	-16.57	-53.11
Lng	+25.00	+29.64
Lat	-0.06	-0.07
Rtn	0.0	0.0
Pitch	0.0	+0.1
Roll	0.0	+360.0

Gantry

	Plan	Actual
Rtn	+360.0	

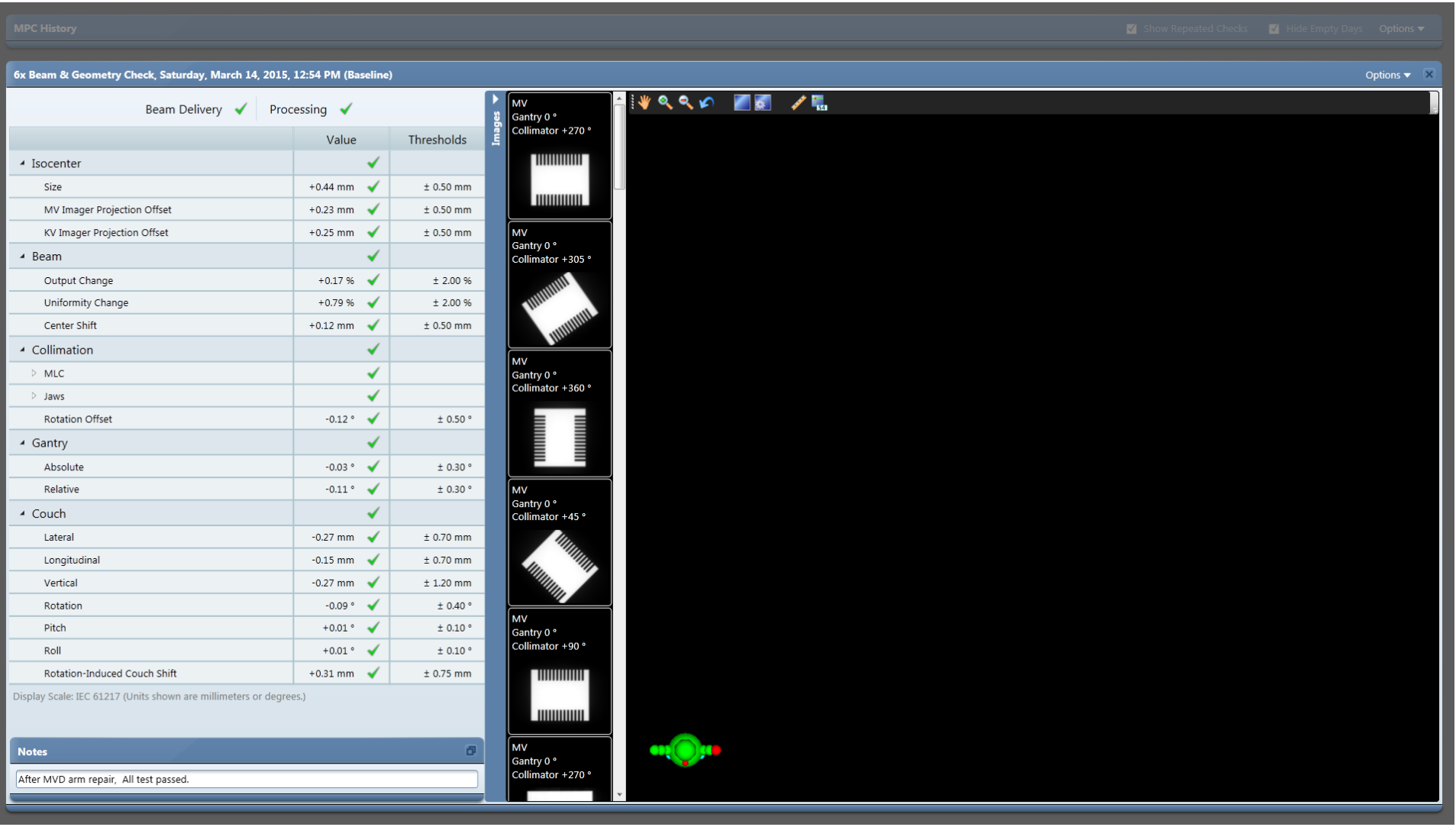
Collimation

	Plan	Actual
Rtn	+270.0	0.0
Y1	-9.0	
Y2	+9.0	
X1	-9.0	
X2	+9.0	



Couch Representation: Isocentric Standard, Display Scale: IEC 61217 (Units shown are centimeters, degrees or MU.)

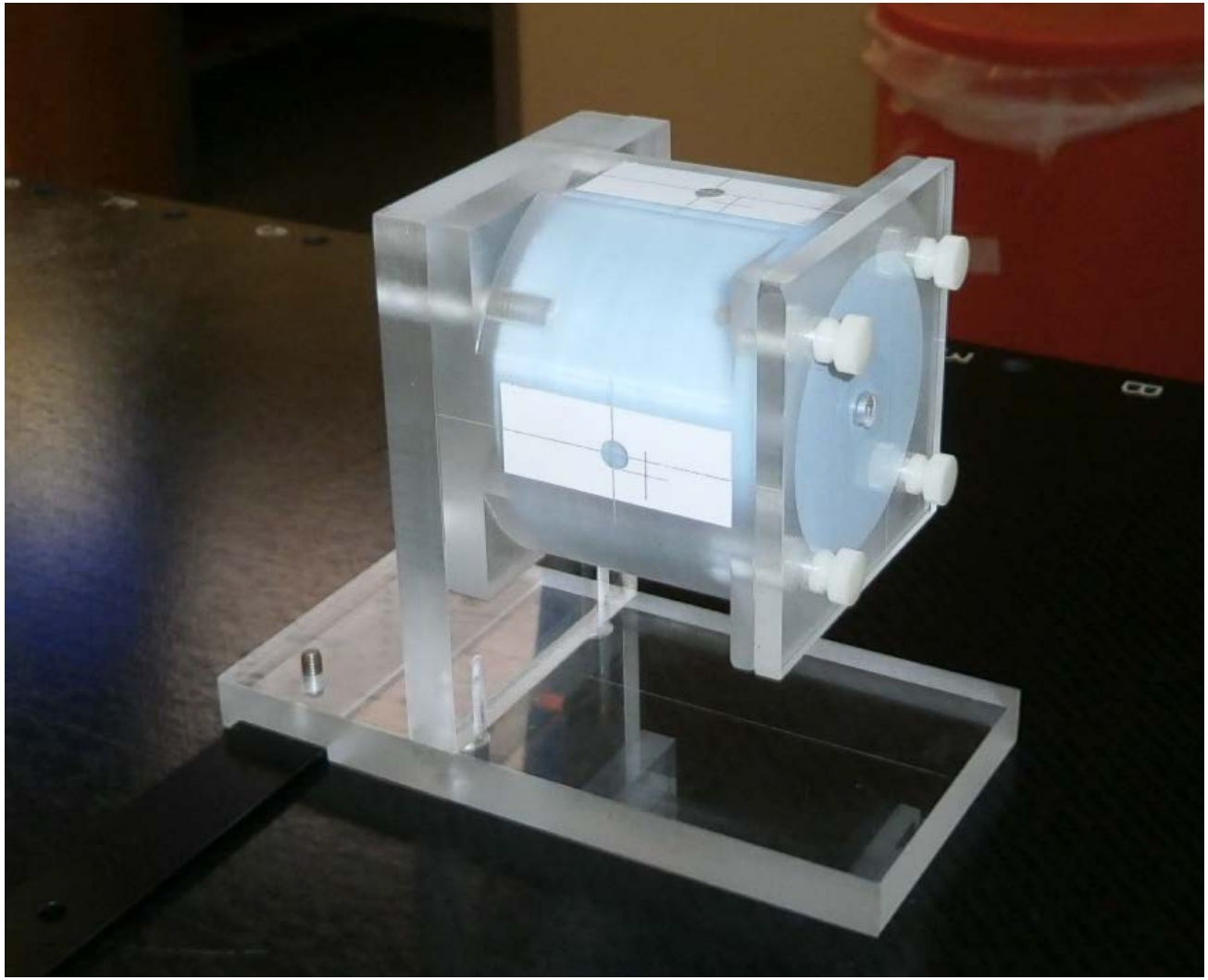
Machine performance check



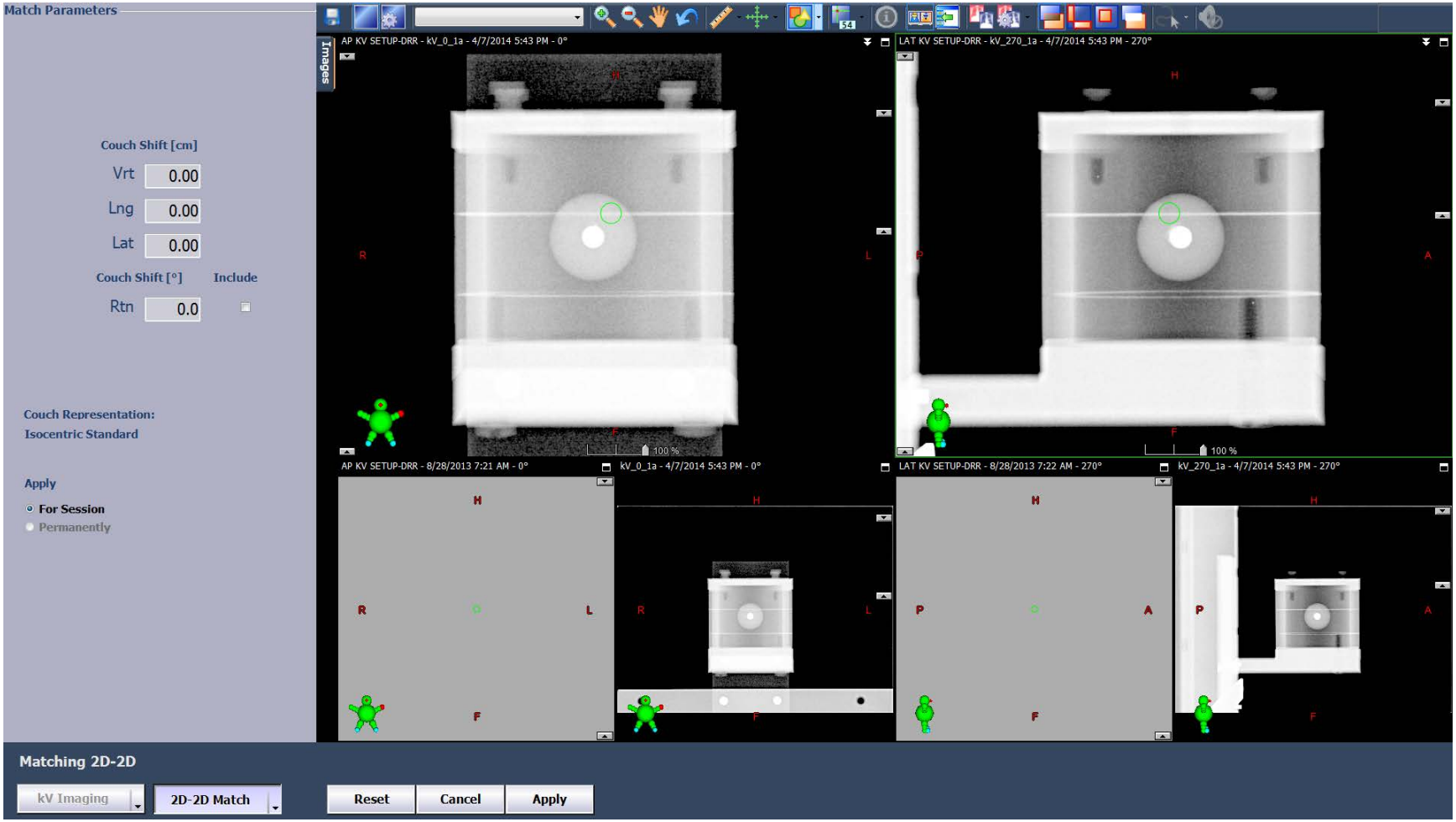
AAPM TG-142

TABLE VI. Imaging.

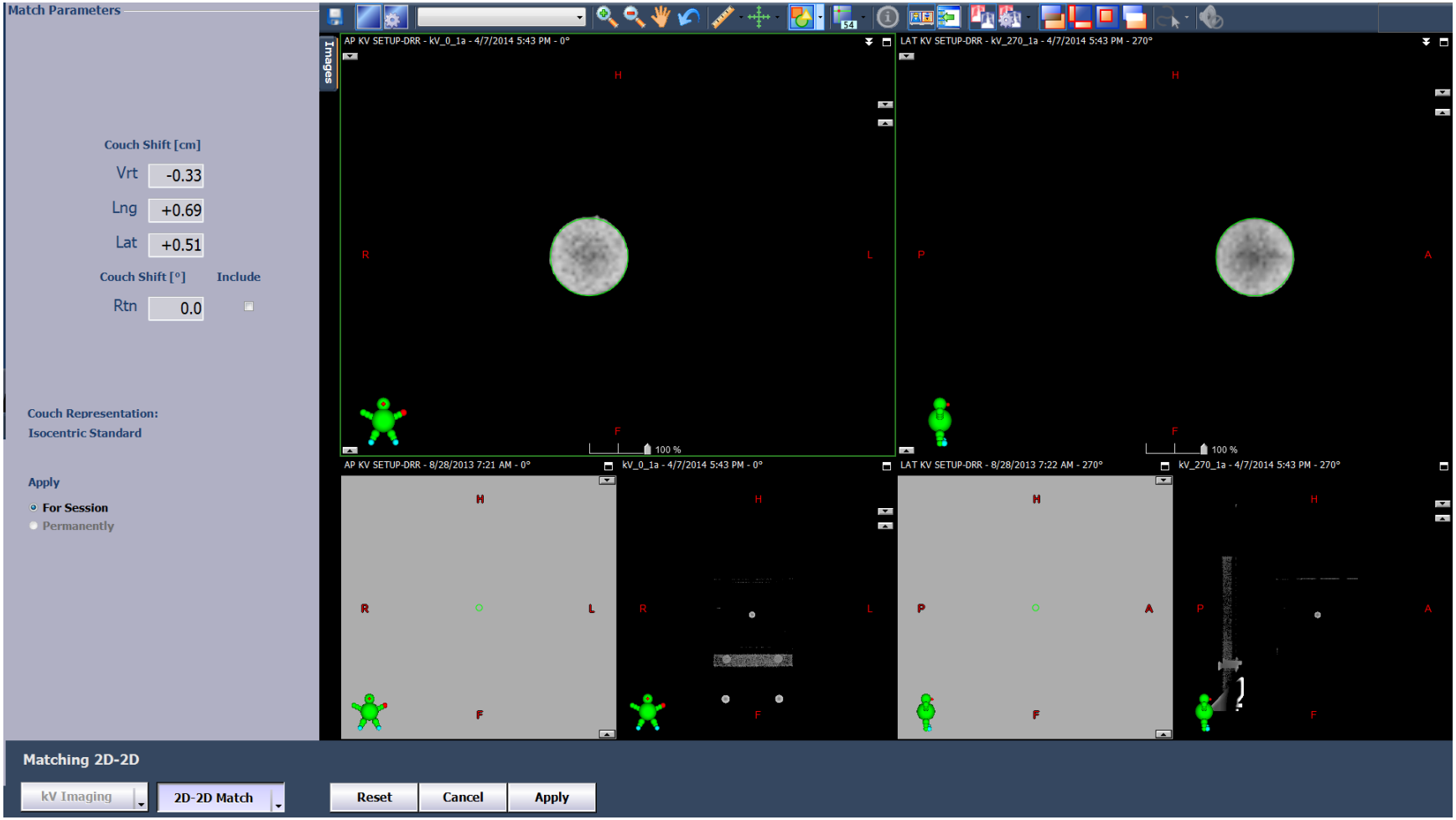
Procedure	Application-type tolerance: non-SRS/SBRT	Application-type tolerance: SRS/SBRT
Daily[a]		
Planar kV and MV (EPID) imaging		
Collision interlocks	Functional	Functional
Positioning/repositioning	≤2 mm	≤1 mm
Imaging and treatment coordinate coincidence (single gantry angle)	≤2 mm	≤1 mm
Cone-beam CT (kV and MV)		
Collision interlocks	Functional	Functional
Imaging and treatment coordinate coincidence	≤2 mm	≤1 mm
Positioning/repositioning	≤1 mm	≤1 mm



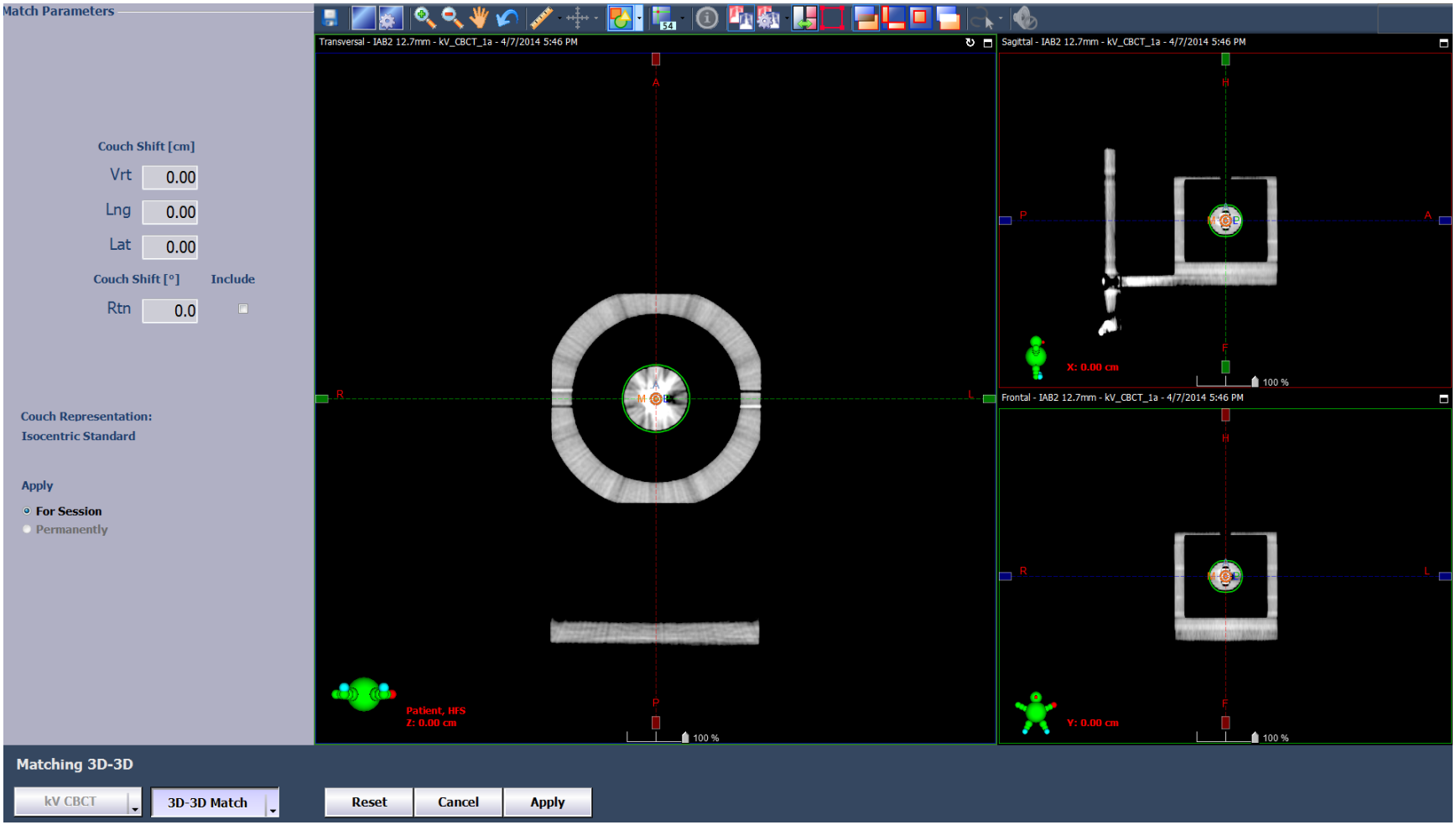
Orthogonal kV images



Orthogonal kV images



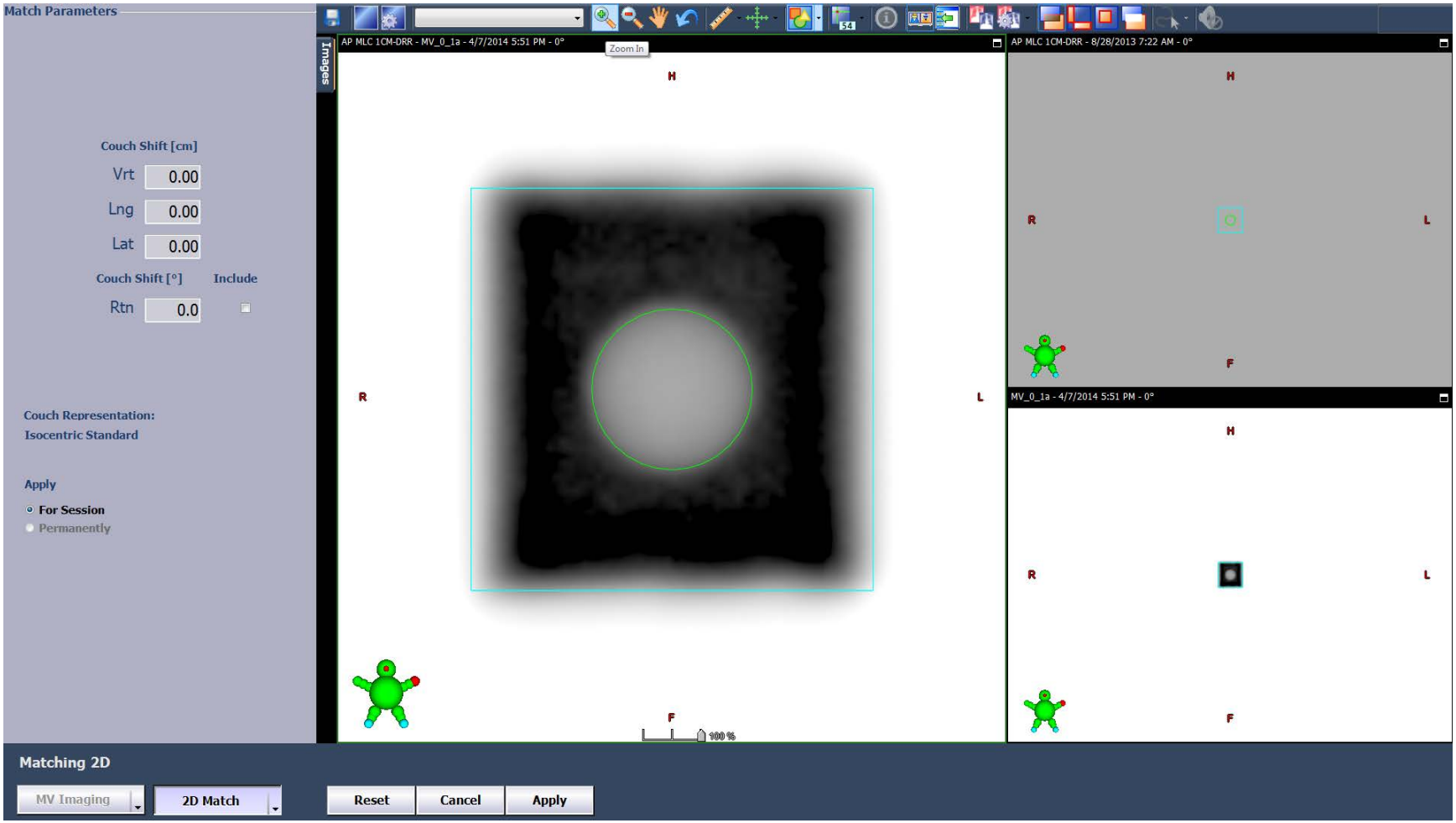
Cone beam CT


Match Parameters
Couch Shift [cm]
Vrt 0.00
Lng 0.00
Lat 0.00
Couch Shift [°] Include
Rtn 0.0
Couch Representation:
Isocentric Standard
Apply
For Session
Permanently
Transversal - IAB2 12.7mm - kV_CBCT_1a - 4/7/2014 5:46 PM
Sagittal - IAB2 12.7mm - kV_CBCT_1a - 4/7/2014 5:46 PM
Frontal - IAB2 12.7mm - kV_CBCT_1a - 4/7/2014 5:46 PM
Patient, HFS
Z: 0.00 cm
X: 0.00 cm
Y: 0.00 cm
100 %
Matching 3D-3D
kV CBCT
3D-3D Match
Reset
Cancel
Apply

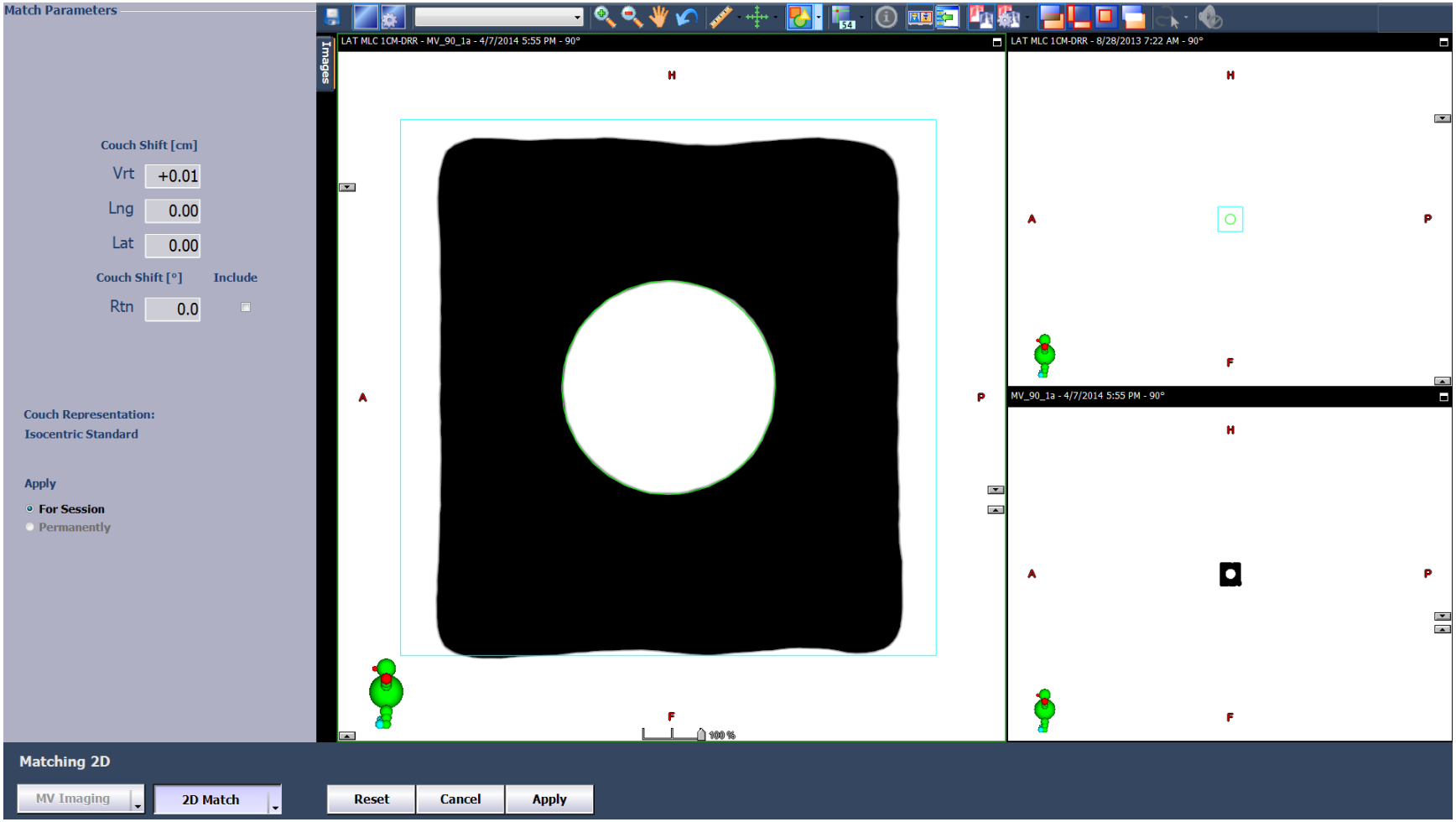
Cone beam CT


Match Parameters
Couch Shift [cm]
Vrt 0.00
Lng 0.00
Lat +0.01
Couch Shift [°]
Include
Rtn 0.0
Couch Representation:
Isocentric Standard
Apply
For Session
Permanently
Transversal - IAB2 12.7mm - kV_CBCT_1a - 4/7/2014 5:46 PM
Sagittal - IAB2 12.7mm - kV_CBCT_1a - 4/7/2014 5:46 PM
Frontal - IAB2 12.7mm - kV_CBCT_1a - 4/7/2014 5:46 PM
X: 0.00 cm
Y: 0.00 cm
Patient, HFS
Z: 0.00 cm
100 %
Matching 3D-3D
kV CBCT
3D-3D Match
Reset
Cancel
Apply

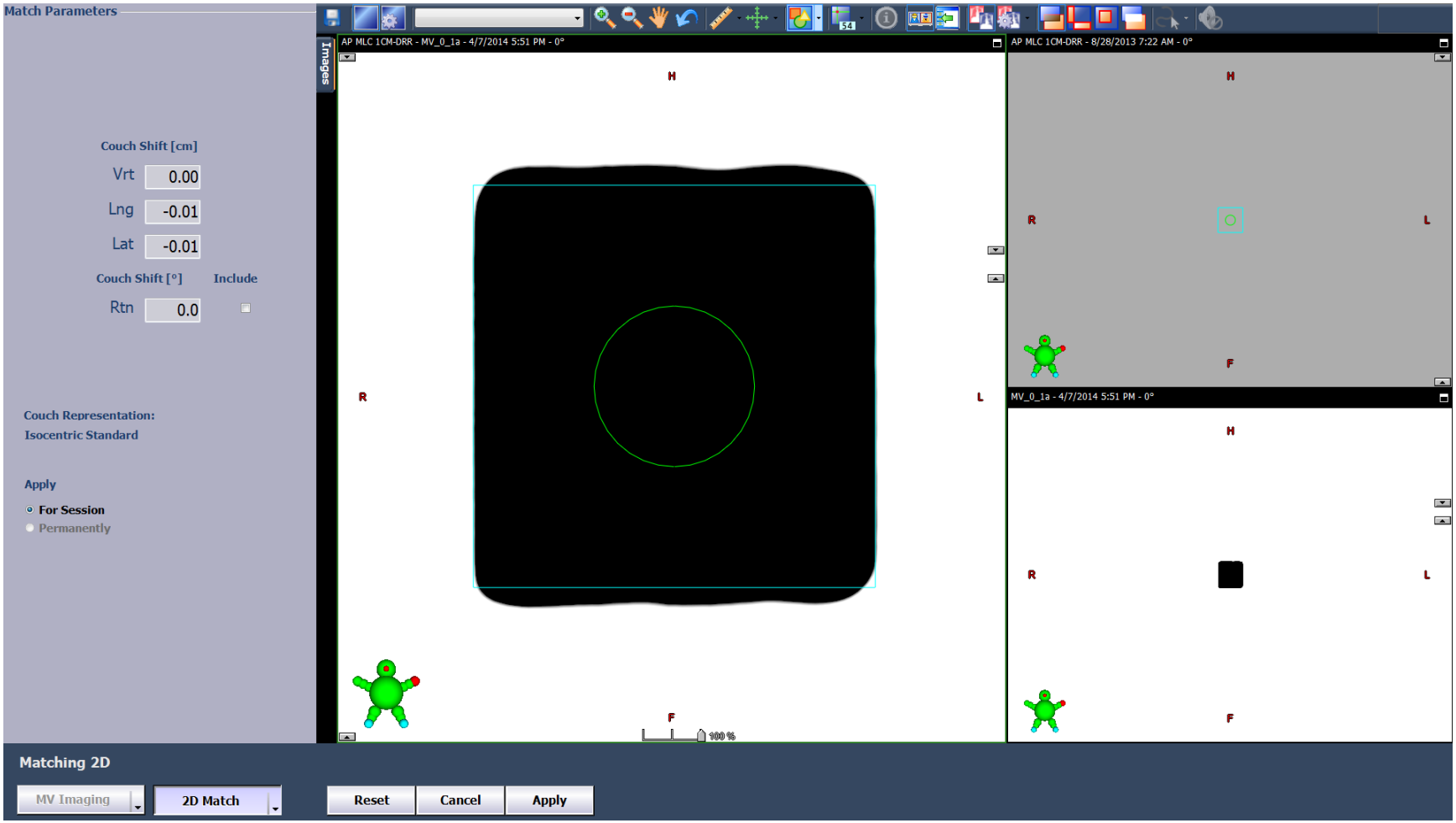
MV image

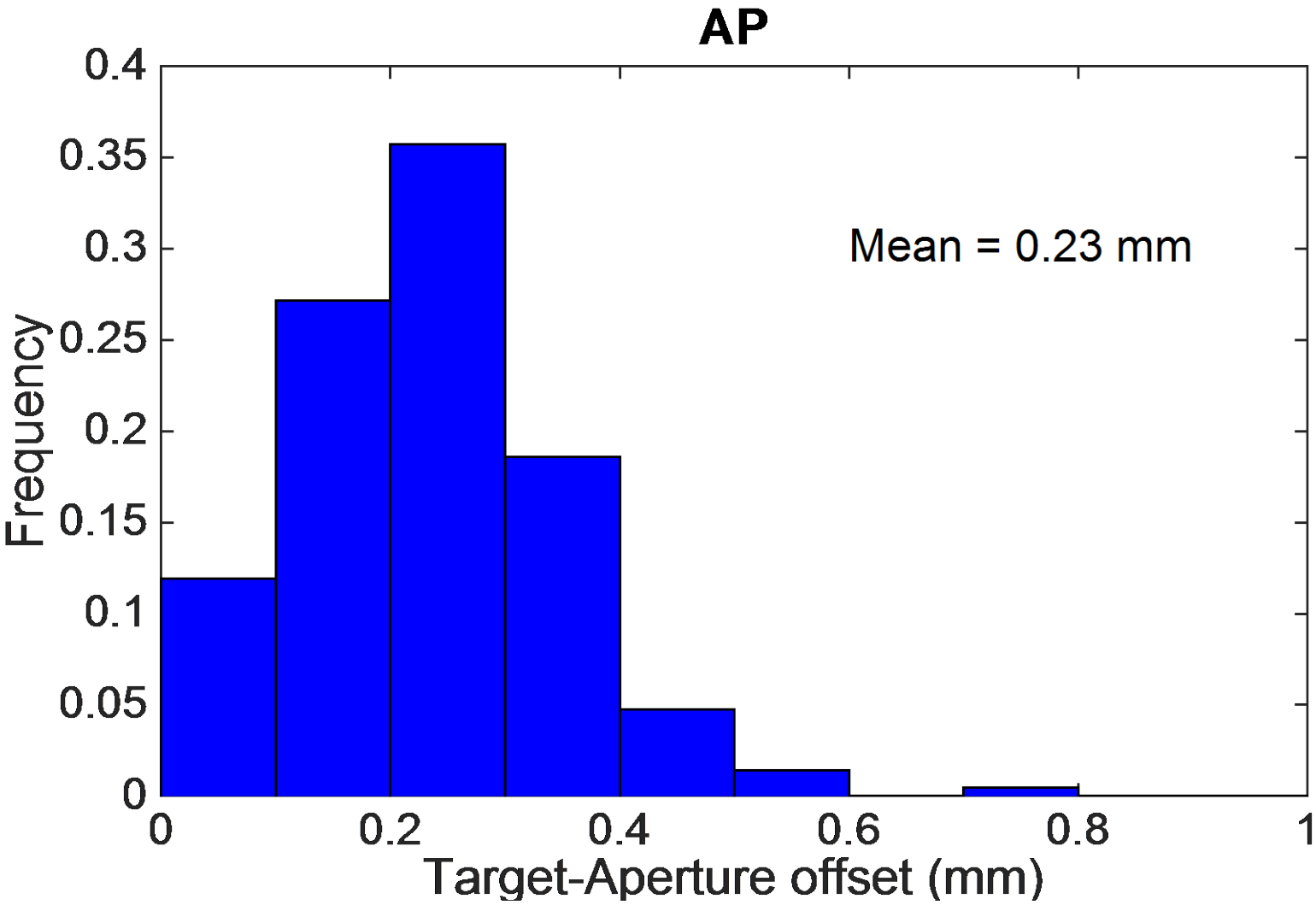

Match Parameters
Couch Shift [cm]
Vrt 0.00
Lng 0.00
Lat 0.00
Couch Shift [°] Include
Rtn 0.0
Couch Representation:
Isocentric Standard
Apply
For Session
Permanently
Images
AP MLC 1CM-DRR - MV_0_1a - 4/7/2014 5:51 PM - 0°
Zoom In
AP MLC 1CM-DRR - 8/28/2013 7:22 AM - 0°
MV_0_1a - 4/7/2014 5:51 PM - 0°
H
R
L
F
100 %
Matching 2D
MV Imaging
2D Match
Reset
Cancel
Apply

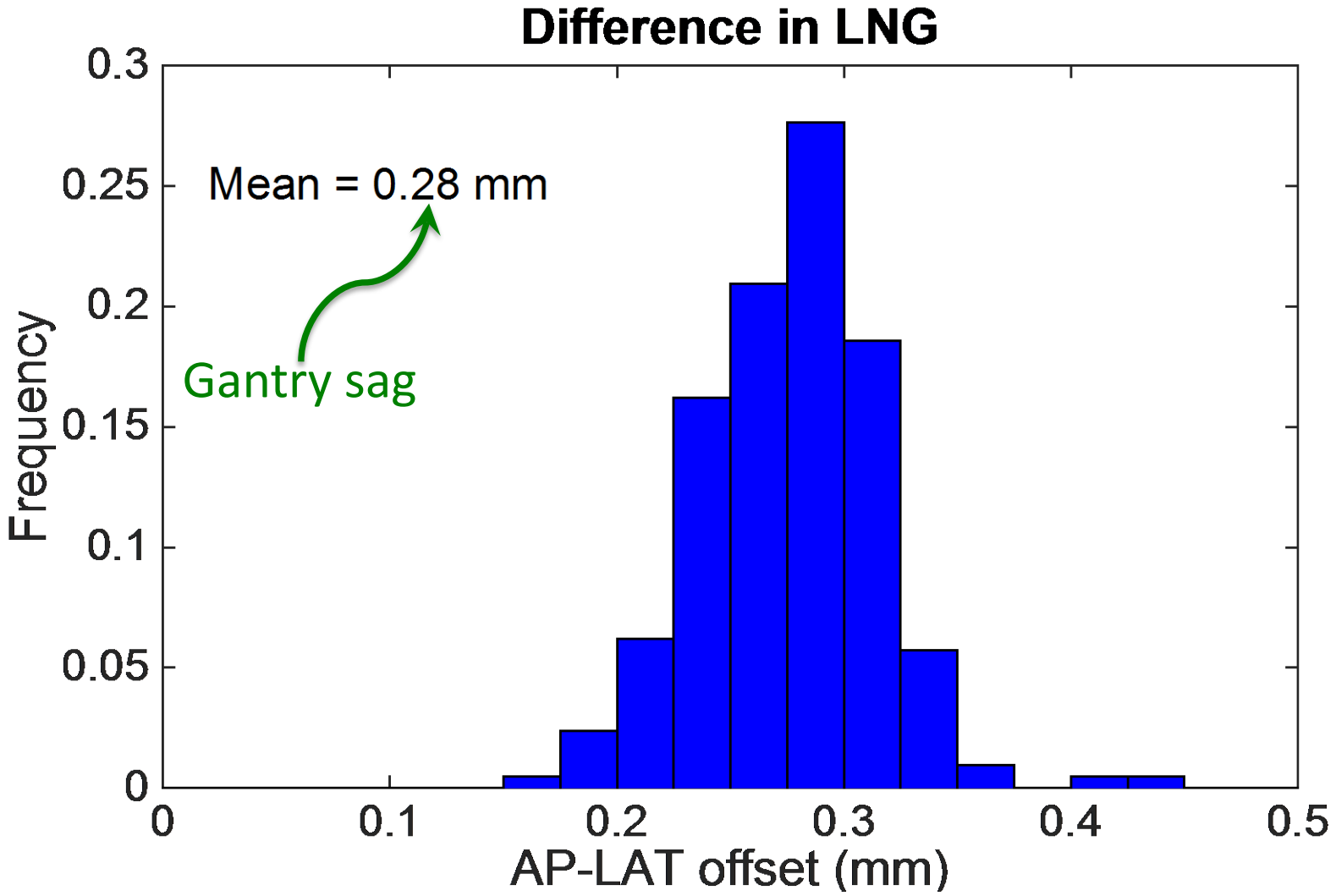
MV image


Match Parameters
Couch Shift [cm]
Vrt +0.01
Lng 0.00
Lat 0.00
Couch Shift [°] Include
Rtn 0.0
Couch Representation:
Isocentric Standard
Apply
For Session
Permanently
Images
LAT MLC 1CM-DRR - MV_90_1a - 4/7/2014 5:55 PM - 90°
LAT MLC 1CM-DRR - 8/28/2013 7:22 AM - 90°
MV_90_1a - 4/7/2014 5:55 PM - 90°
H
A
P
F
100 %
Matching 2D
MV Imaging
2D Match
Reset
Cancel
Apply

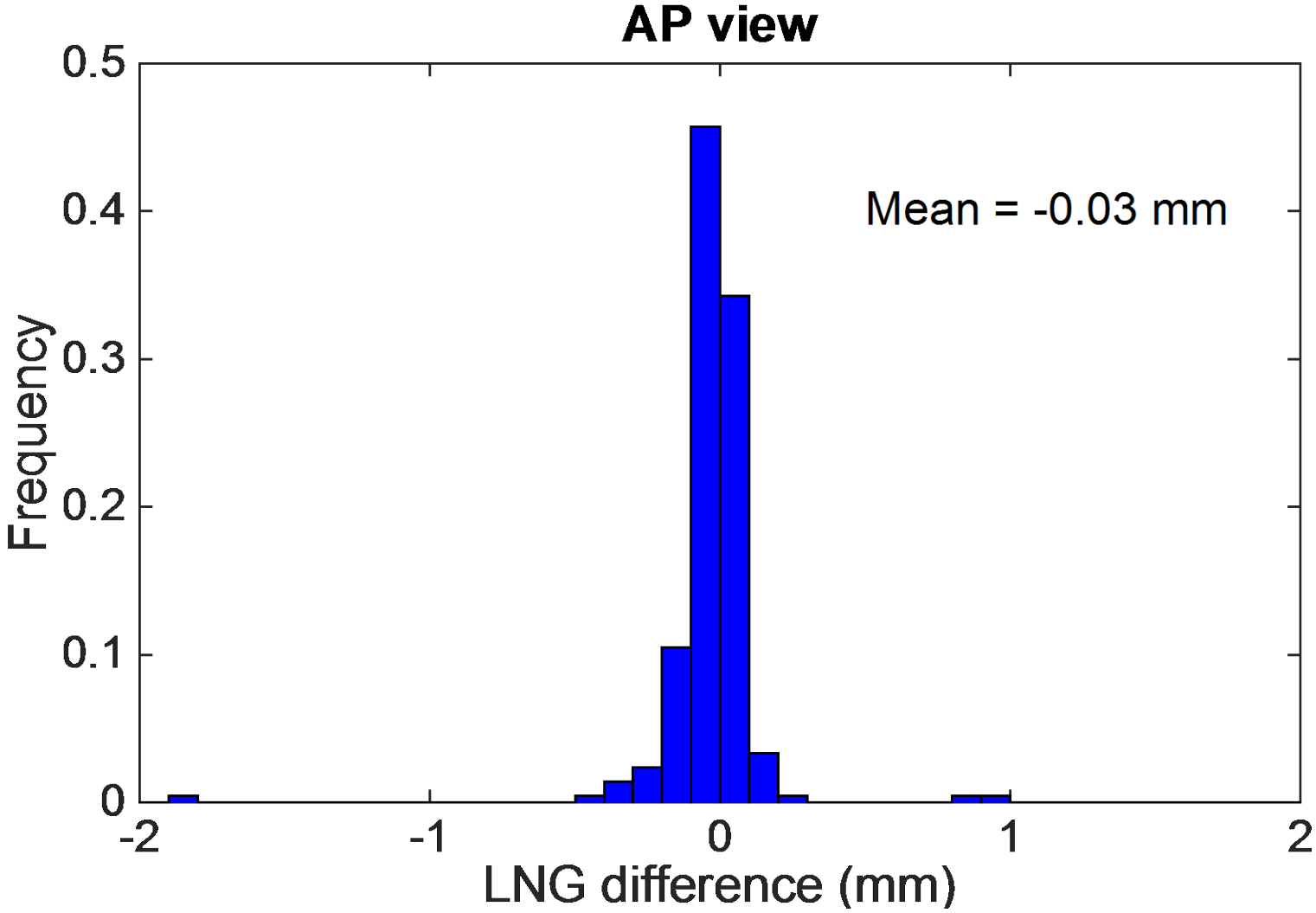
MV image


Match Parameters
Couch Shift [cm]
Vrt 0.00
Lng -0.01
Lat -0.01
Couch Shift [°] Include
Rtn 0.0
Couch Representation:
Isocentric Standard
Apply
For Session
Permanently
Images
AP MLC 1CM-DRR - MV_0_1a - 4/7/2014 5:51 PM - 0°
AP MLC 1CM-DRR - 8/28/2013 7:22 AM - 0°
MV_0_1a - 4/7/2014 5:51 PM - 0°
H
R
L
F
100 %
Matching 2D
MV Imaging
2D Match
Reset
Cancel
Apply


AP
Mean = 0.23 mm
Frequency
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.2
0.4
0.6
0.8
1
Target-Aperture offset (mm)


Difference in LNG
Mean = 0.28 mm
Gantry sag
Frequency
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.1
0.2
0.3
0.4
0.5
AP-LAT offset (mm)

Difference between automatic and manual



Automated QA Consortium

Jeremy Booth &
Mario Perez

Tim Ritter

Richard Popple

Hania Al-Hallaq
& Karl Farrey

Toby Eckhause,
Don Roberts,
Brett Schultz
& Jean Moran

Vijeshwar Sharma
& Sung Park

Todd Pawlicki
& Grace Kim

John DeMarco

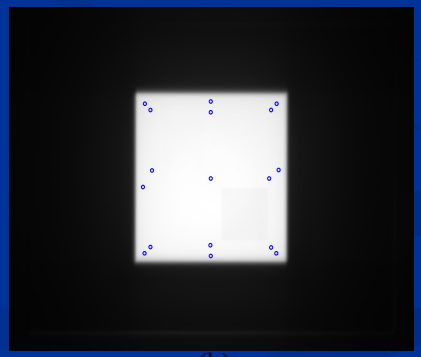
TBD via Dan Low

Courtesy Jean Moran

Phase 1 QA Test Suite

- Standardize tests and QA test suite so to evaluate the performance of TrueBeam linacs and compare our results across multiple institutions
- Use both trajectory log files and EPID measurements

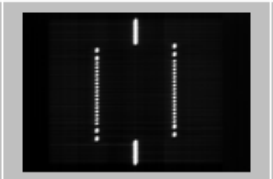
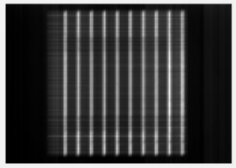
(a)



(b)

Courtesy Jean Moran

Example Fields of QA Test Suite

Field Description	Test Image	TG-142 Table (Klein et al[8])	Procedure(s) Tested	EPID Analysis	Log File Analysis
1.Jaw-defined field*		Table II (monthly)	Gantry sag; collimator rotation; Jaw position	Field edge, angle; phantom position	Jaw and collimator
2.MLC defined static pattern*		Table V (monthly)	Leaf positions	Leaf edge positions	Leaf position
3.Interleaf static MLC pattern*		Table V (annual)	MLC transmission	Image-to-image-comparison	Leaf position
4.Picket-fence test – static gantry*		Table V static gantry Quantitative (monthly)	Leaf position (IMRT)	Leaf positions for all pickets, cardinal gantry angles	Leaf position, velocity

+ picket fence for VMAT with variable gantry speed, variable gantry speed and dose rate
Both HDMLC and Millennium MLC supported

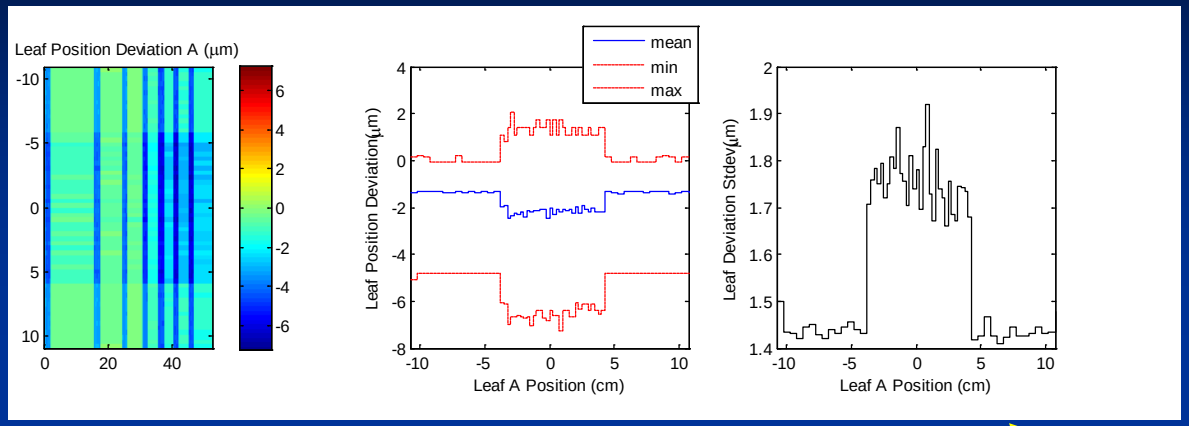
Courtesy Jean Moran

Automated QA Analysis

- Software analysis developed in MatLab primarily developed by Toby Eckhause (former post-doc)
- Test suite takes ~15 minutes to deliver; 1 flood field + enter room once to setup phantom
- All analysis from the original test suite is automated and results can be exported
- Less than a minute to analyze all data

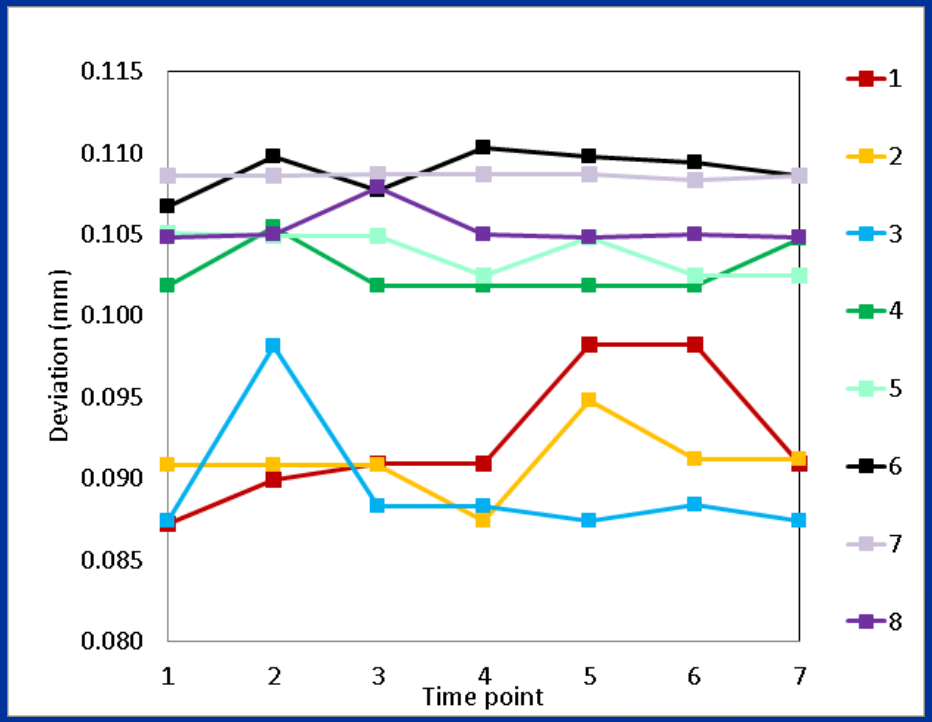
Courtesy Jean Moran

Trajectory Log File & EPID Analysis



Test suite included all MLC monthly tests in Table V of TG 142, VMAT tests, plus imaging tests.

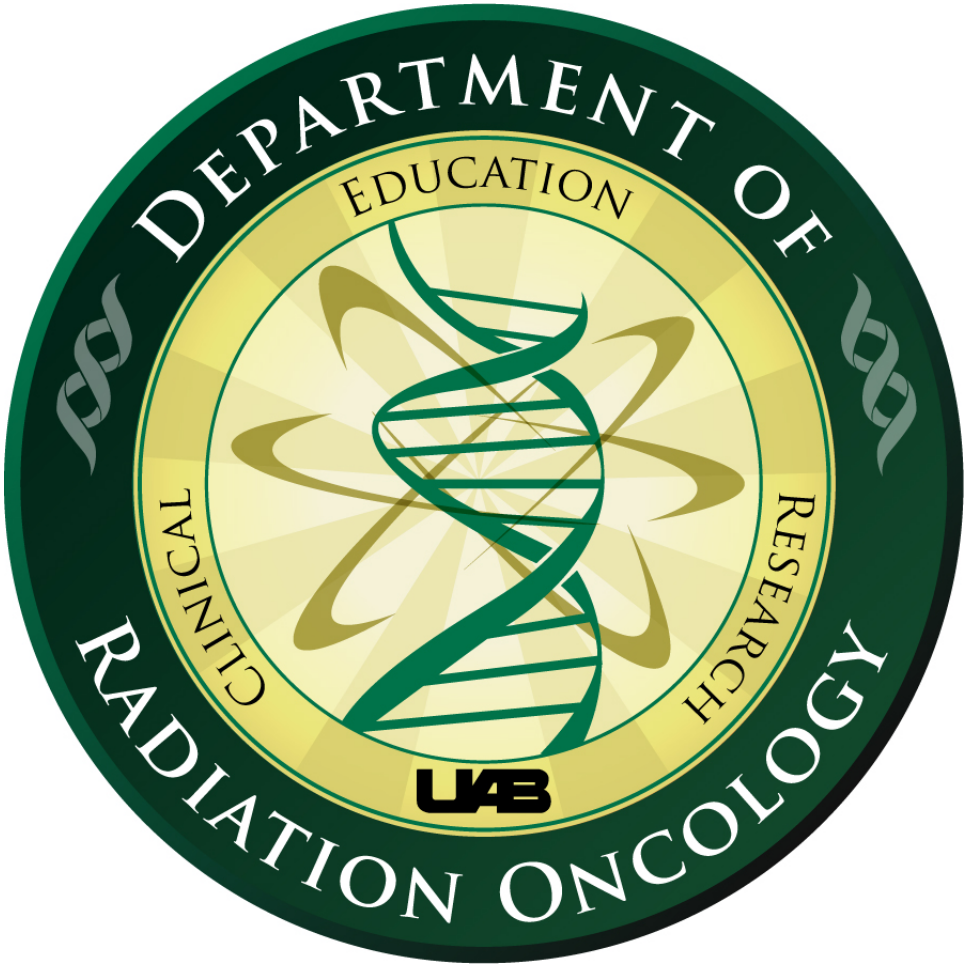
Analysis of Trajectory Log Files



Maximum difference for leaf position accuracy
From Phase 1 of our project with 8 linacs measured over 6 months

Courtesy Jean Moran

Questions?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