Radiation Oncology
UNIVERSITY OF TORONTO

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TPS Commissioning and QA:
A Process Orientation & Application of Control Charts

Michael B Sharpe, PhD
Radiation Medicine Program

TECHNA

UHN Princess Margaret Cancer Centre

DISCLOSURE

- Customer, collaborator, licensing:
  - Elekta AB, Raysearch Laboratories AB, MODUS Medical Devices
- Leadership position:
  - Cancer Care Ontario

ACKNOWLEDGEMENTS

- Tim Craig, Jean-Pierre Bissonnette, Stephen Breen, David Jaffray, Daniel Letourneau, BeiBei Zhang, Stuart Rose, Gavin Disney,
- Miller MacPherson, Katharina Sixel,
- Jake Van Dyk, Jerry Battista, Benedict Fraas

- Anything I say might be superseded by next two speakers

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Objectives

- Introduction & Review
- Acceptance & Commissioning
- Periodic Quality Assurance
- "New" Definition of Quality
- Quality Tools

- Highlight the current reference documents; summarize key aspects
- **FOCUS:**
  - **Configure and assure TPS is ready *clinical integration.***
- Scope does not include:
  - Staff orientation/training
  - Development and documentation of clinical procedures

Acceptance & Commissioning

Organizational Choices

Systems

Support:

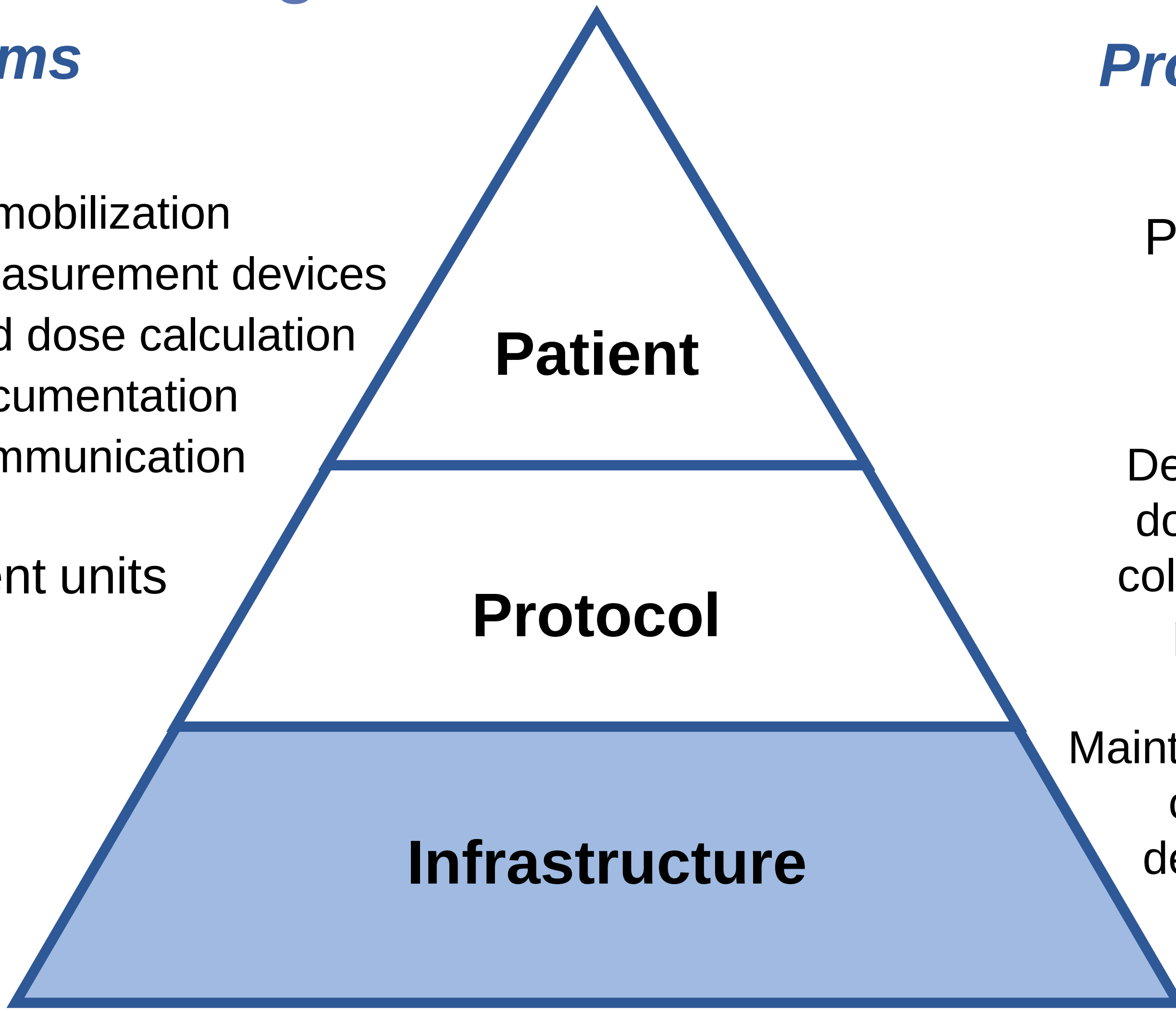
Immobilization
measurement devices
2nd dose calculation
documentation
communication

Treatment units

ROIS

TPS

Imaging



Processes

Plans are reviewed

Developed & documented by collaboration and peer-review

Maintain procedures & criteria to plan + deliver appropriate treatments.

References

- AAPM TG 53 (Report 62):
  - QA for Clinical Radiotherapy Treatment Planning, Med. Phys. 25 (10) 1998.
- AAPM TG 62 (Report 85)
  - Tissue Inhomogeneity Corrections For Megavoltage Photon Beams (2004)
- IAEA Technical Reports Series No. 430
  - Commissioning and QA of Computerized Planning Systems for Radiation Treatment of Cancer (2004)
- AAPM TG 119:
  - IMRT Commissioning: Multiple institution planning & dosimetry comparisons, Med.Phys. 36 (11) 2009.
  - IMRT planning and QA test data via aapm.org
- IAEA Technical Document 1540
  - Specification and Acceptance Testing of Radiotherapy TPS (2007)
- IAEA Technical Doc. 1583
  - Commissioning of Radiotherapy TPS: Testing for Typical External Beam Treatment Techniques (2008)

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Commissioning

AAPM Task Group 53

Task Group	Topic	Inception	Completed	Report
65	Tissue Heterogeneities in Photon Beams		2004	85
66	CT Simulators		2003	83
71	MU Calculations		2014	258
100	QA – Evaluate Needs	2003		
105	Monte Carlo Clinical Implementation		2007	
106	Accelerator Commissioning		2008	
114	MU Calculations (non-IMRT)		2011	
117	MRI – In SRS Treatment Planning	2005		
119	IMRT - Commissioning		2009	
120	IMRT - Tools & Techniques		2011	
132	Image Registration	2006		
145	PET - Quantitation	2006		
155	Dosimetry – Small Fields	2007		
157	TPS – Monte Carlo Commissioning	2007		
163	IT - Disaster Preparedness	2007		
166	Use and QA of Biological Models		2012	
174	PET - Monitoring	2008		
189	MRI - DCE			

AAPM TG53 Responsibilities – Vendors, Users

- Specification, Design, Management
  - Best practices, policies - e.g. SLA, Security, Redundancy
- Service Contract
- Documentation & Training
- Software validation (safety, QA)
- Communication (bugs, risks, feature enhancements)

- Related relationships
  - Vendor
  - IT personnel
  - Administration
  - Therapists/Planners, Physicians

Acceptance

TPS Operation Standards

- Format of displays, units, date & time
- Data limits, transfer
- Saving and archiving data
- Equipment and source model
- Patient model
- Treatment planning
- Dose calculation
- Documentation - Treatment plan report

“The consultants recommend that the procedure for **acceptance testing of treatment planning systems should be made more similar to that of other equipment** used in a radiotherapy department. After installation of a planning system in a hospital, the vendor should perform a series of tests, together with the user, to demonstrate that the system performs according to its specifications….”

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Commissioning

- Qualified medical physicist readies system for stable & routine clinical use.
- TPS models and interacts with devices used for imaging and treatment.
  - Document & configure geometric, functional information.
  - Collect internally consistent data (CT#, dose distributions)
  - Configure interfaces to devices & ROIS.
- Validate availability and proper function of features (per vendor specifications, clinical requirements).

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Commissioning

AAPM Task Group 53

- **Non-Dosimetric**
  - Positioning & immobilization
  - Image acquisition (all sources)
  - Anatomical description
    - Dataset registration
  - Beams
  - **Operational aspects of dose calculations**
  - Plan evaluation
  - Documentation (HCO)
  - Plan implementation & verification (ROIS)
    - Coordinates & Scales
    - Data transfer
    - Reference Images
- **Dosimetric**
  - Consistent measurements
  - Data input into the RTP system
  - Dose model parameters
  - Methods for comparison & verification
  - Verify Calculations
  - Absolute dose & plan normalization
  - Clinical verifications

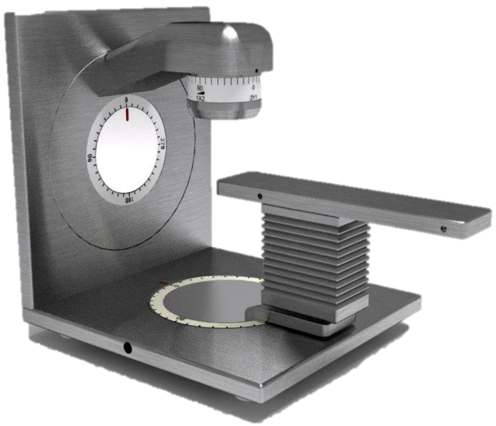
Technology Advances

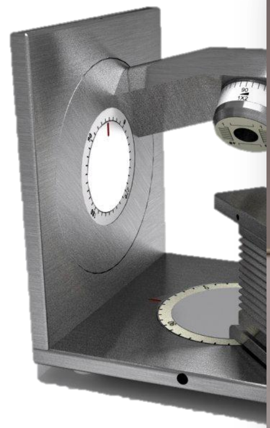
Our collective thinking evolves

- Many other AAPM Guidelines

Coordinates, Movements & Scales

Machine Characterization





- Movements, scales, limits, accessories.
- Allowed mechanical movements, speeds,
- Identification (coding) of machines, moda
  (linking of TPS, ROIS and Machine).
- Should be understood and configured prior to commissioning dose algorithms - Requires careful verification.
- Effort is often taken for granted.
- Mistakes could cause systematic errors.
- IEC 61217, 60601

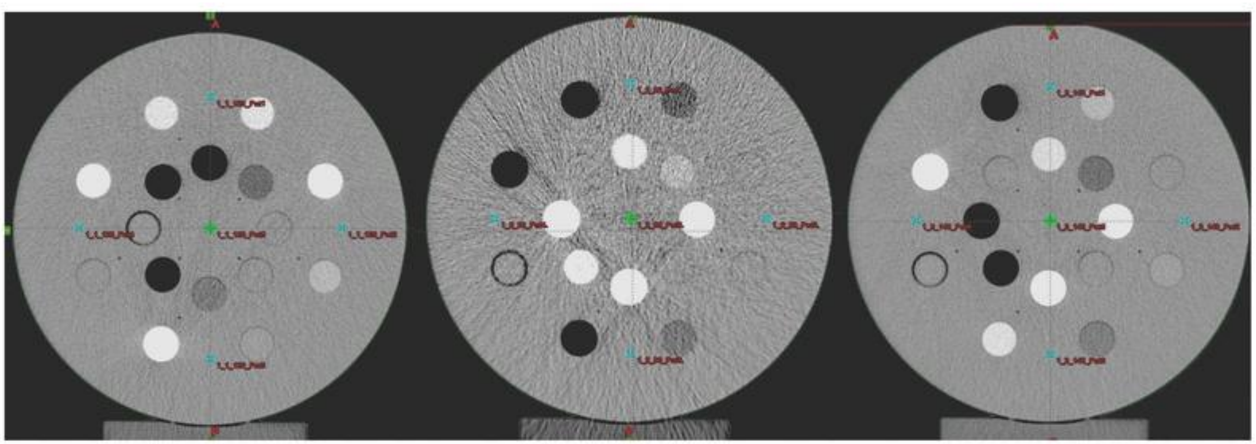
Craig, Tim, *et al* IJROBP 44.4 (1999): 955-966.

Tissue Density Calibration

- For dose computation, derive high-energy radiation interaction properties of materials from CT Images - Hounsfield Units:

$$\mathrm{HU} = 1000\left(\frac{\mu - \mu_{\mathrm{w}}}{\mu_{\mathrm{w}}}\right)$$

Nohbah A *et al,* JACMP, 12(3) (2011)



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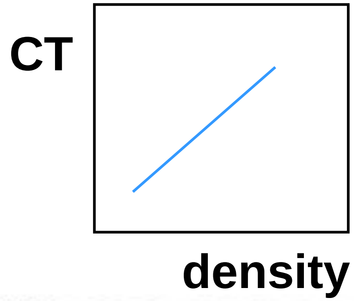
Images Support Dose Calculations



μ/ρ lookup table

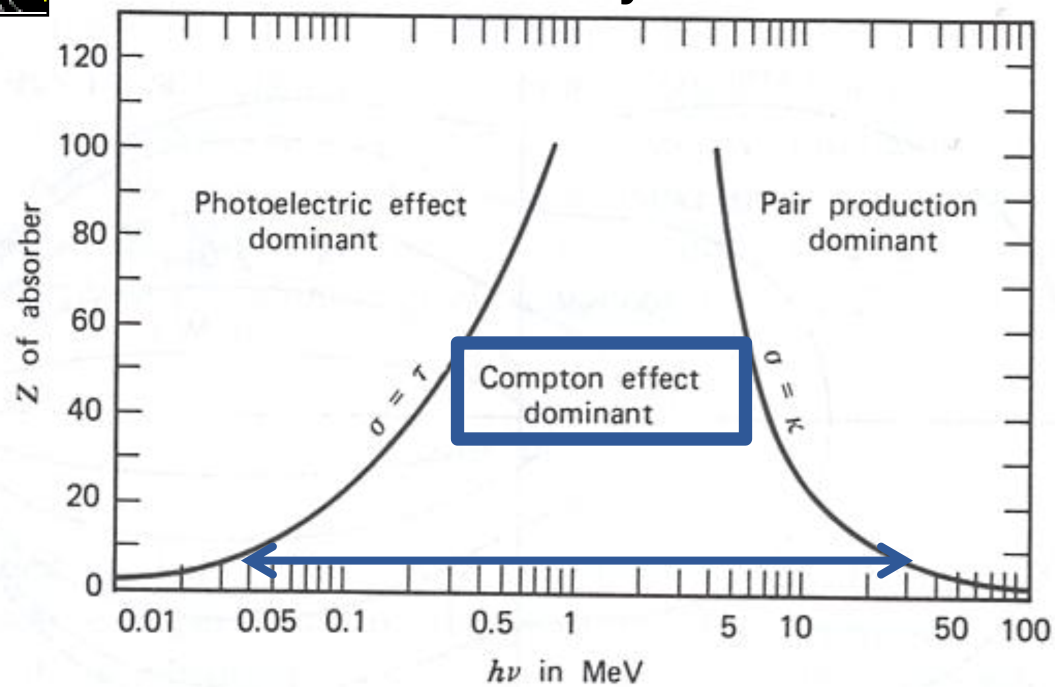
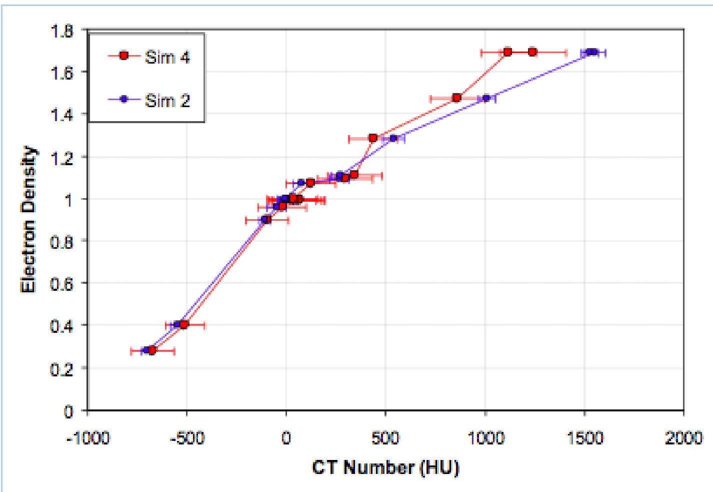


Figure 2-20 The relative importance of the three major types of gamma-ray interaction. The lines show the values of Z and $h\nu$ for which the two neighboring effects are just equal. (From *The Atomic Nucleus* by R. D. Evans. Copyright 1955 by the McGraw-Hill Book Company. Used with permission.)

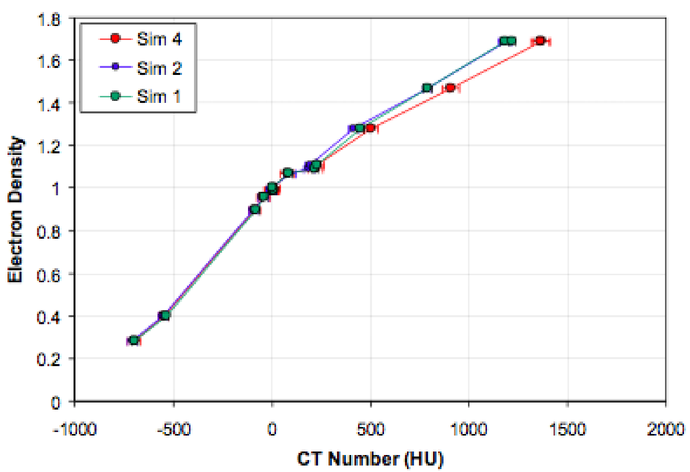
Tissue Density Calibration

Figure 1: Electron Density vs. CT Number at different tube energies.

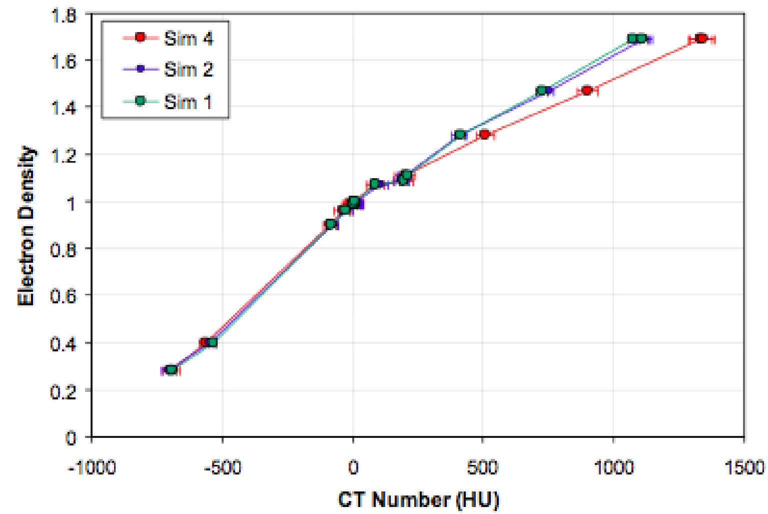
80 kVp



120 kVp



140 kVp



Error depends on
dose gradient, attenuation estimate, path length

$$\Delta D = -s \Delta\mu \Delta l$$

S - dose gradient
Δμ – atten. variation
Δl – spatial extent

With thanks to Robert Weersink, PhD

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Tissue Density Calibration

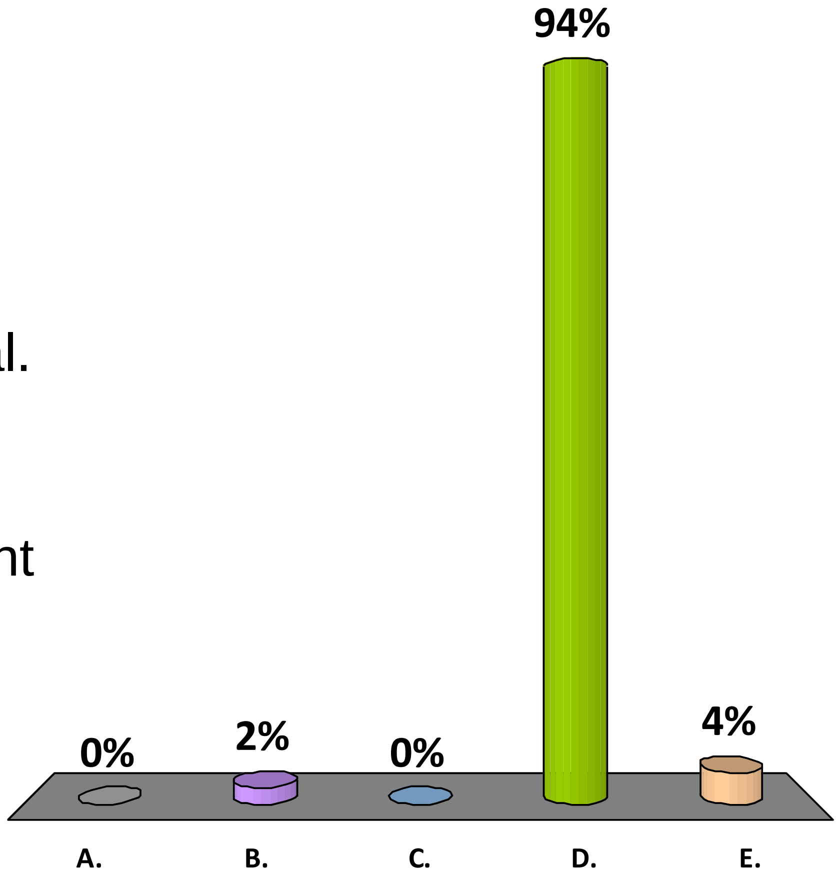
- Derived high-energy radiation coefficients may occasionally be in error by 10% (e.g. bone & low kVp)
- The uncertainty in the dose distribution due to these errors is <1% for photon; 2%/2mm for electrons.
- 8% to 10% CT# error leads to less than 1% dose error.

  - Huizenga H. *et al*, Acta Radiol. Oncol. 24 509-519 (1985)
  - Thomas SJ, BJR. 72 781-786 (1999)
  - Kilby W. *et al, PMB 47 1485–1492 (2002)*
  - Nohbah A *et al*, JACMP, 12(3) (2011)

QUESTION

Why are CT numbers a good way to estimate radiological properties of tissue?

A. We get to see inside the patient!
B. The angular momentum of the dipole distribution is similar.
C. The power to weight ratio is ideal.
D. In water-like materials, attenuation is dominated by the Compton Effect over the pertinent range of photon energies, creating a direct estimate of electron density.
E. None are true



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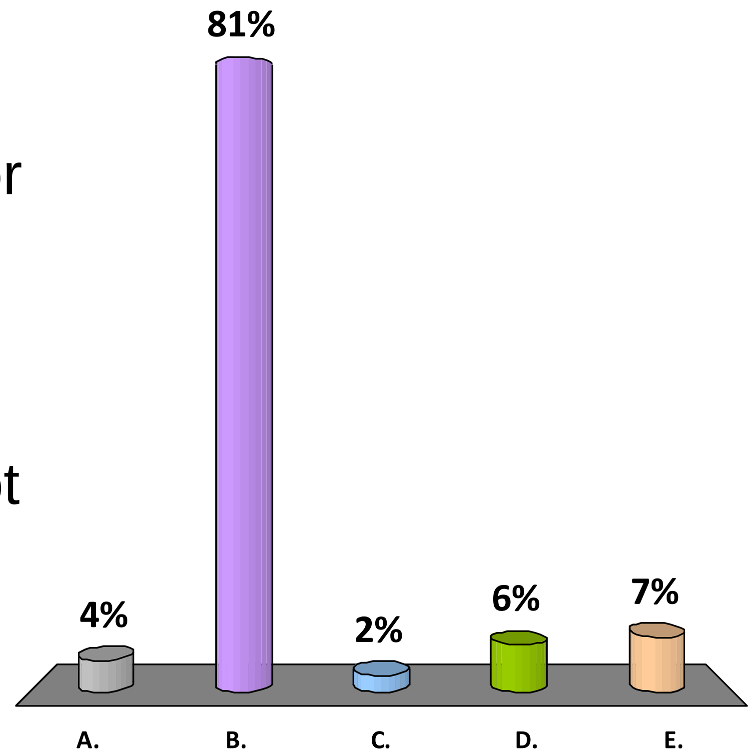
Attix, Frank Herbert. *Introduction to radiological physics and radiation dosimetry*. John Wiley & Sons, 2008.

QUESTION

Regarding tolerances for relationship between CT numbers to tissue density, which of the following is TRUE?

A. It must be monitored closely and carefully
B. An 8% error in estimating tissue density will cause a 1% dose error
C. A 1% error in estimating tissue density will cause an 8% dose error
D. Electron dose distributions are not sensitive to CT numbers
E. All are true.



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- Regarding tolerances for relationship between CT numbers to tissue density, which of the following is TRUE?
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Kilby W. *et al, PMB 47 1485–1492 (2002)*

AAPM Task Group 53

Non-Dosimetric

- Positioning & immobilization
- Image acquisition (all sources)
- Anatomical description
  - Dataset registration
- Beams
- **Operational aspects of dose calculations**
- Plan evaluation
- Documentation (HCO)
- Plan implementation & verification (ROIS)
  - Coordinates & Scales
  - Data transfer
  - Reference Images

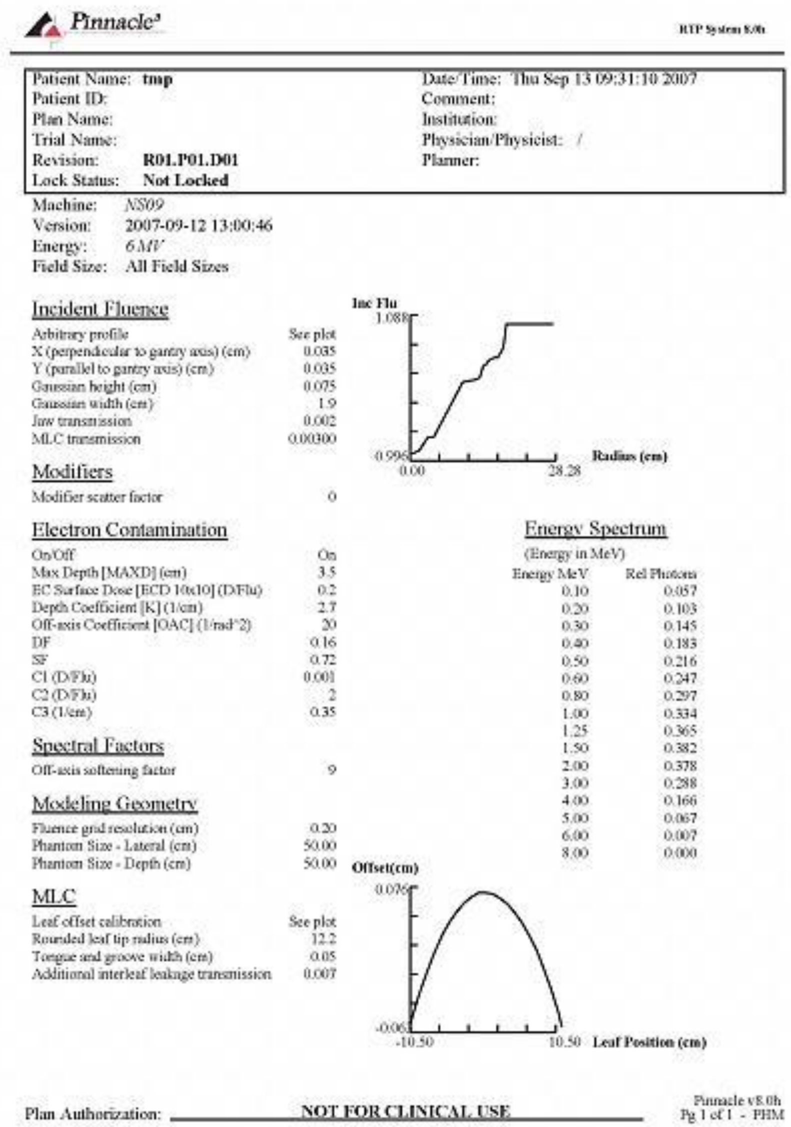
Dosimetric

- Consistent measurements
- Data input into the RTP system
- Dose model parameters
- Methods for comparison & verification
- Verify Calculations
- Absolute dose & plan normalization
- Clinical verifications

Beam Modeling

Parameters

- Head/collimator geometry
- Energy Spectrum
- Fluence profile
- Collimator transmission
- Focal spot (penumbra)
- Extra-focal contribution
- Electron contamination
- Reference Dose Rate
- Measured Output Factors



Pinnacle³ RTP System 8.0h

Patient Name:	tmp	Date/Time:	Thu Sep 13 09:31:10 2007
Patient ID:		Comment:	
Plan Name:		Institution:	
Trial Name:		Physician/Physicist:	/
Revision:	R01.P01.D01	Planner:	
Lock Status:	Not Locked		

Machine: NS09
Version: 2007-09-12 13:00:46
Energy: 6 MV
Field Size: All Field Sizes

Incident Fluence

Arbitrary profile	See plot
X (perpendicular to gantry axis) (cm)	0.035
Y (parallel to gantry axis) (cm)	0.035
Gaussian height (cm)	0.075
Gaussian width (cm)	1.9
Jaw transmission	0.002
MLC transmission	0.00300

Modifiers

Modifier scatter factor	0

Electron Contamination

On/Off	On
Max Depth [MAXD] (cm)	3.5
EC Surface Dose [ECD 10x10] (D/Flu)	0.2
Depth Coefficient [K] (1/cm)	2.7
Off-axis Coefficient [OAC] (1/rad^2)	20
DF	0.16
SF	0.72
C1 (D/Flu)	0.001
C2 (D/Flu)	2
C3 (1/cm)	0.35

Spectral Factors

Off-axis softening factor	9

Modeling Geometry

Fluence grid resolution (cm)	0.20
Phantom Size - Lateral (cm)	50.00
Phantom Size - Depth (cm)	50.00

MLC

Leaf offset calibration	See plot
Rounded leaf tip radius (cm)	12.2
Tongue and groove width (cm)	0.05
Additional interleaf leakage transmission	0.007

Energy Spectrum

(Energy in MeV)

Energy MeV	Rel Photons
0.10	0.057
0.20	0.103
0.30	0.145
0.40	0.183
0.50	0.216
0.60	0.247
0.80	0.297
1.00	0.334
1.25	0.365
1.50	0.382
2.00	0.378
3.00	0.288
4.00	0.166
5.00	0.067
6.00	0.007
8.00	0.000

Plan Authorization: NOT FOR CLINICAL USE

Pinnacle v8.0h
Pg 1 of 1 - PHM

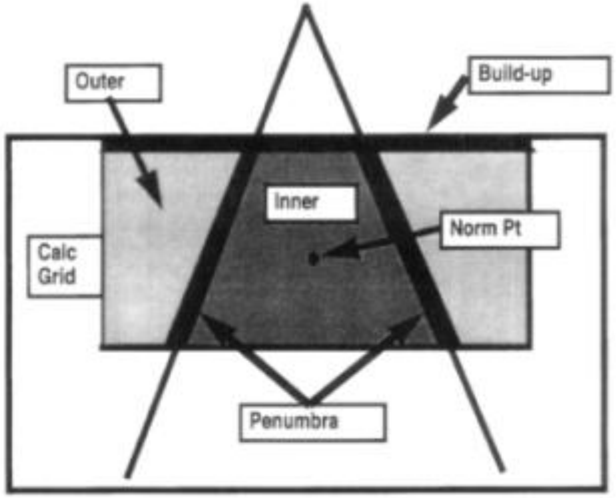
Adjustment to model parameters to fit non-clinical beams

Verify & Document

Specifying tolerance levels

- TPS calculations, at discrete points, are compared with measured profiles and depth-dose curves.
- TPS will give a reproducible deviation from the measured value at certain points within the beam.
- IAEA TRS430 provides detailed test suite in Chapter 9.

Typical tolerance levels from AAPM TG53, IAEA TRS430 (examples)



- Square field CAX: 1%
- MLC penumbra: 3%
- Wedge outer beam: 5%
- Buildup-region: 30%
- 3D inhomogeneity CAX: 5%

For analysis of agreement between calculations and measurements, consider several regions.

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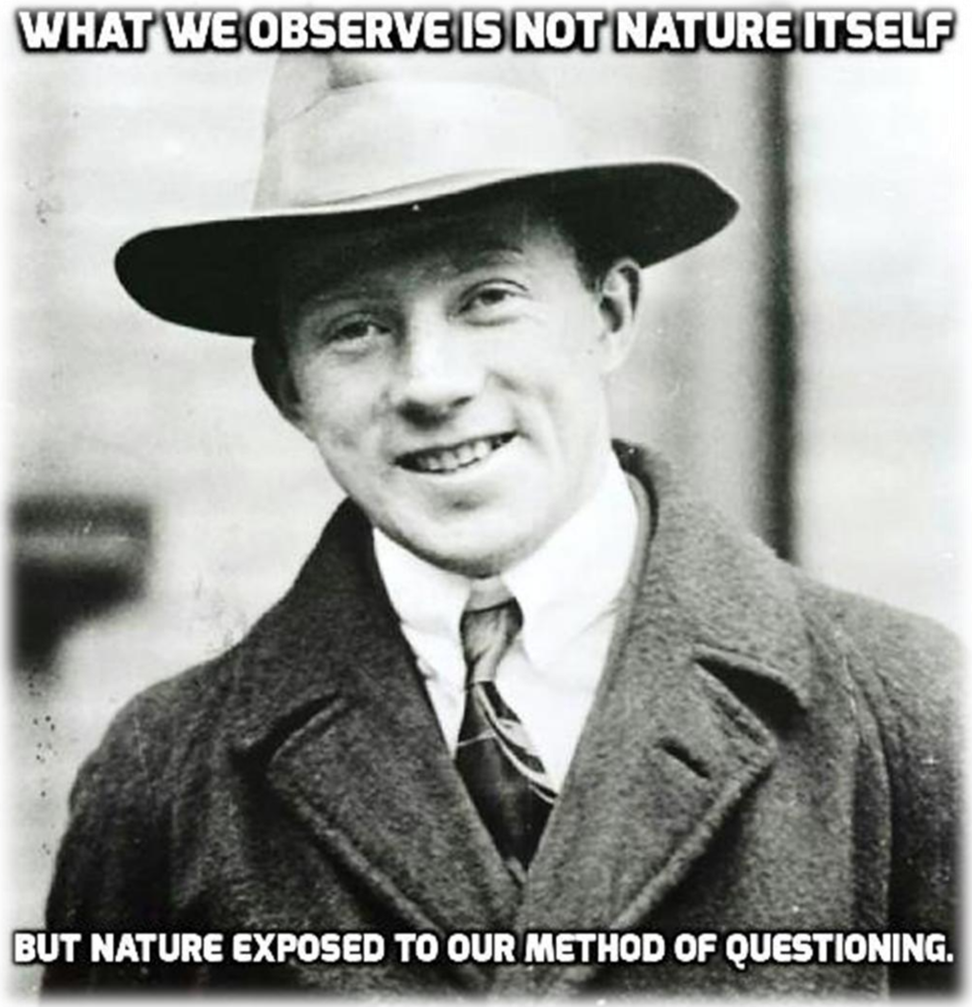
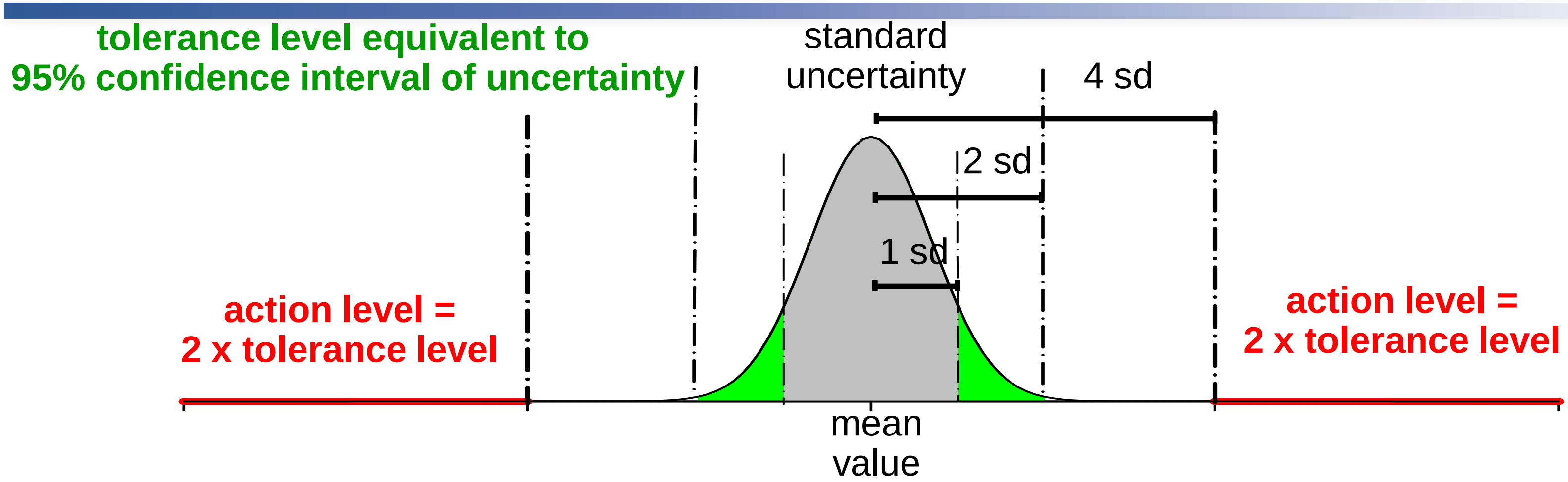
Self-Consistent Measurements

Werner Heisenberg, 1958



Verify & Document

IAEA TRS 430



- Measurements for commissioning & performance of TPS are the baseline for future routine QA.
- Configuration is benchmarked against measurements to characterize capacity to model treatment unit (geometry, dose).
- **Uncertainty** addresses confidence in the result of measurements; the dispersion of the values that could be observed.
- **Error** is deviation from the expected value.
- Both can be random or systematic.
- Only significant if they exceed a specified tolerance.

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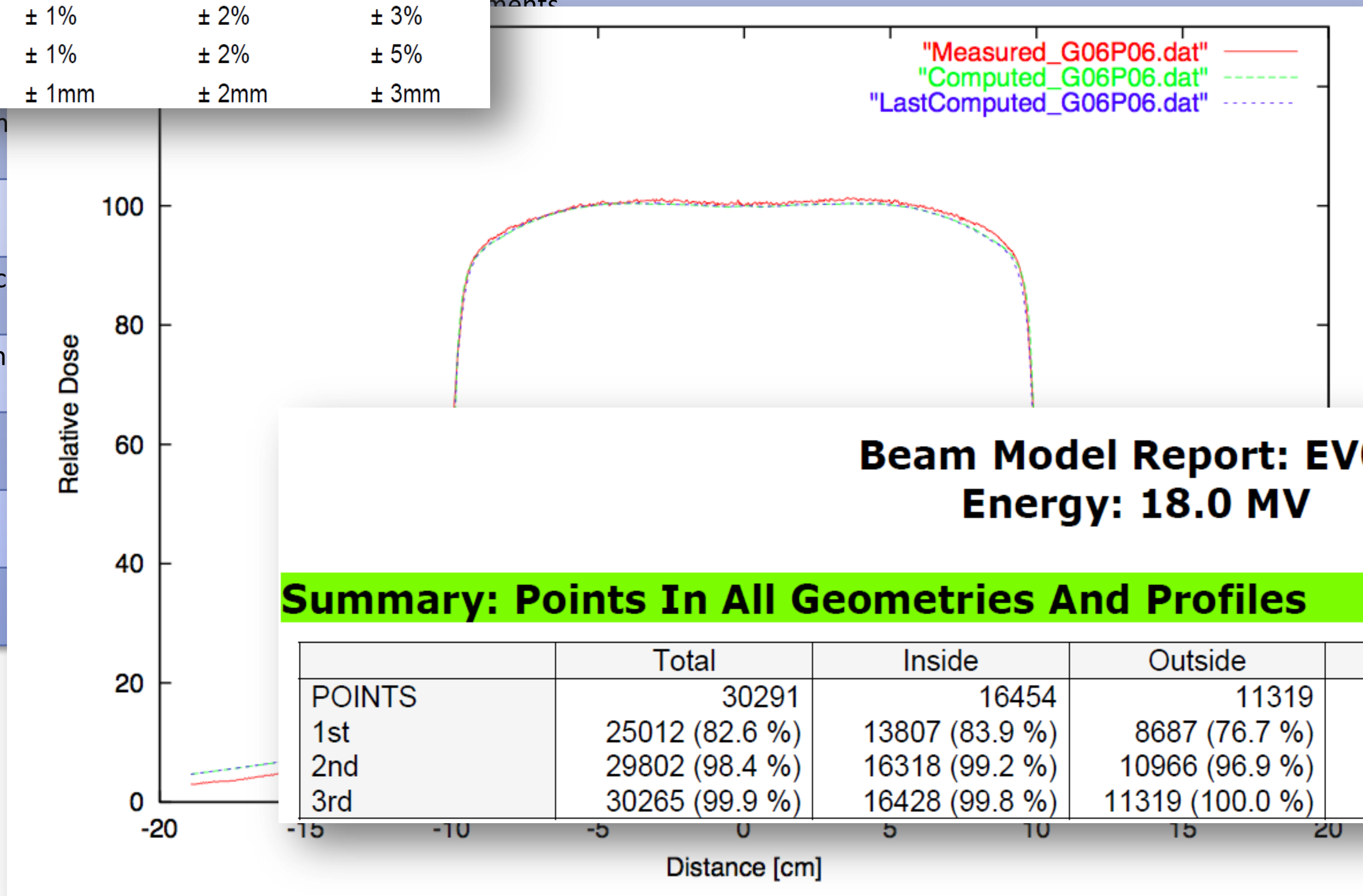
Dose Testing – Relative Distribution

Function to be tested	Regular field dosimetry
	…files, and relative dose factors (RDF) calculated on XXX are validated against …ments
Test environ…	
Use cases	
Test specific…	
Test referen…	
Result	
Procedure	
Date	

Criteria for assessing computed points (1st/2nd = Pass, 3rd = Marginal)

	1st	2nd	3rd
Inside:	± 1%	± 2%	± 3%
Outside:	± 1%	± 2%	± 5%
Gradient:	± 1mm	± 2mm	± 3mm



Beam Model Report: EV06
Energy: 18.0 MV

Summary: Points In All Geometries And Profiles

	Total	Inside	Outside	Transit
POINTS	30291	16454	11319	2518
1st	25012 (82.6 %)	13807 (83.9 %)	8687 (76.7 %)	2518 (100.0 %)
2nd	29802 (98.4 %)	16318 (99.2 %)	10966 (96.9 %)	2518 (100.0 %)
3rd	30265 (99.9 %)	16428 (99.8 %)	11319 (100.0 %)	2518 (100.0 %)

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Dose Testing – Dose Calibration

- Add Reference Calibration and Output Factors by performing MU comparisons on central axis for
  - (
  - .

Test specificati	
Test reference	
Result	
Procedure	ofiles, and MU an appendix. MU
Date	

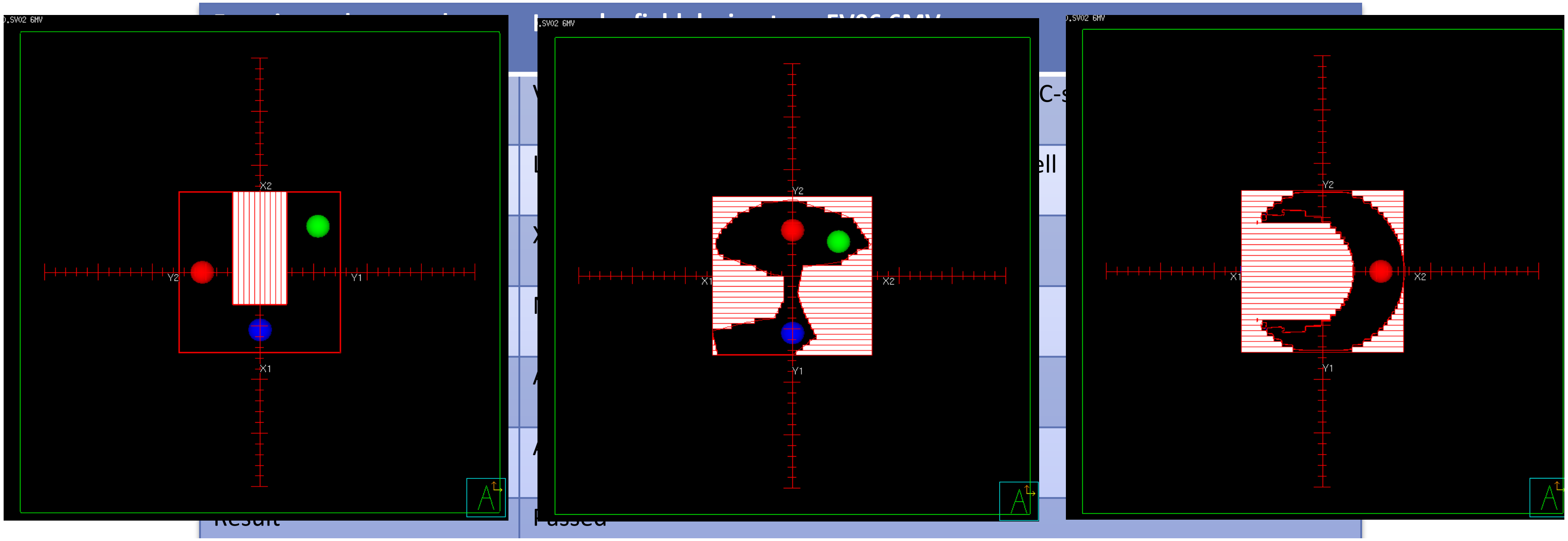
		Agreement Between RadCalc and Manual Calculation				
		<1%	<2%	<3%	<4%	<5%
ES07	6 MV	75	96	100	100	100
	18 MV	84	100	100	100	100
EV06	6 MV	92	98	100	100	100
	18 MV	82	99	100	100	100
SV01	6 MV	57	96	100	100	100
	6 MV FFF	78	99	100	100	100
NA09	6 MV	55	97	98	100	100
	18 MV	64	99	100	100	100

Table 9 – Summary of agreement between RadCalc and manual calculations for all beam models

		Agreement Between RadCalc and Pinnacle Calculation				
		<1%	<2%	<3%	<4%	<5%
ES07	6 MV	63	90	99	100	100
	18 MV	76	99	100	100	100
EV06	6 MV	62	93	99	100	100
	18 MV	61	86	99	100	100
SV01	6 MV	70	97	100	100	100
	6 MV FFF	73	92	100	100	100
NA09	6 MV	35	79	96	99	100
	18 MV	81	94	99	100	100

Table 10 – Summary of agreement between RadCalc and Pinnacle calculations for all beam models

Dose Testing – Irregular Fields



U-shape		Pnt 1 3cm depth	7cm depth	15 cm depth	Pnt 2 3cm depth	7cm depth	15 cm depth	Pnt 3 3cm depth	7cm depth	15 cm depth
EV06	6 MV	-1.7	-1.1	-0.9	-1.2	-0.6	-0.4	-2.0	-1.6	-1.8
	18 MV	0.6	-2.1	-1.5	0.6	-1.9	-1.3	1.0	-2.6	-1.8
ES07	6 MV	0.6	0.2	0.5	0.6	0.2	0.5	0.1	-0.7	-0.3
	18 MV	0.1	-0.5	0.1	-0.3	-0.8	-0.2	-0.6	-1.9	-0.6
SV01	6 MV	-0.1	0.0	0.2	0.5	0.7	1.2	0.2	0.0	-0.1
	FFF6 MV	0.4	-0.4	-1.3	0.4	0.1	-0.9	0.5	-0.5	-2.0
NA09	6 MV	0.4	0.3	0.3	0.9	0.9	0.7	-0.1	-0.4	-0.6
	18 MV	0.8	0.0	0.1	0.9	0.2	0.1	0.3	-1.0	-0.9

Table 12 - U-Shape irregular field percent agreement in monitor units calculated by [redacted] for each geometry and beam model

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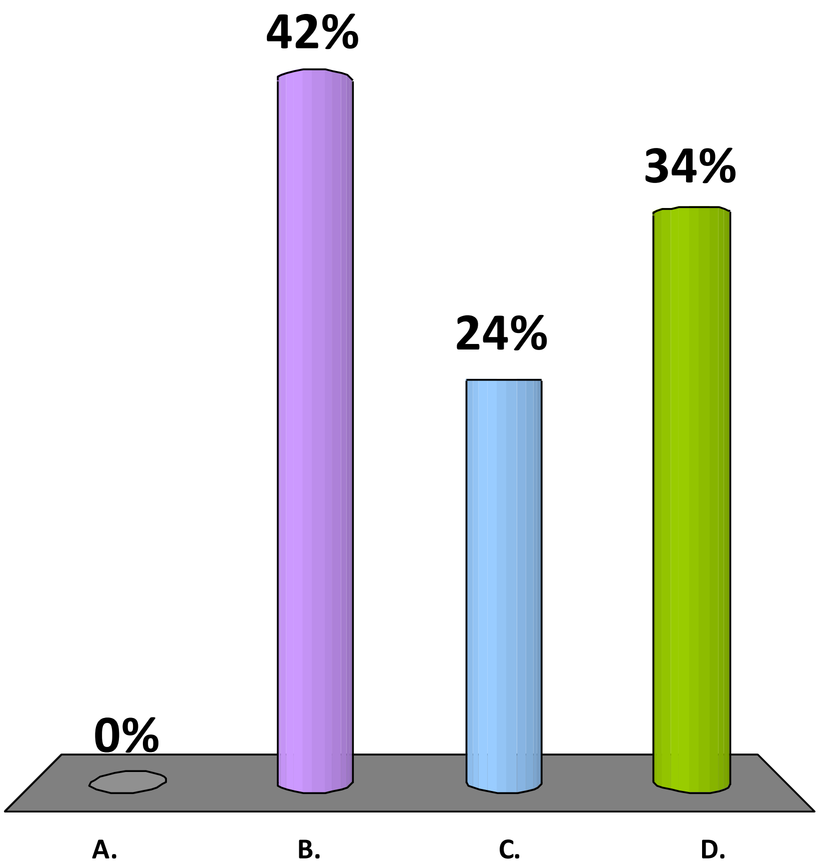
QUESTION

Detailed description of dosimetric tests are provided by:

A. Your Boss.
B. Fraas et al, “AAPM Radiation Therapy Committee **TG53**: Quality assurance program for radiotherapy treatment planning",
Med Phys 25,1773-1836 (1998)
C. IAEA, "Commissioning and quality assurance of computerized planning systems for radiation treatment of cancer", **TRS 430**
D. All of the Above



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  C. **IAEA, "Commissioning and quality assurance of computerized planning systems for radiation treatment of cancer", TRS 430**
  D. All of the Above

  Answer is C
- Reference – Chapter 9 IAEA Technical Reports Series No. 430
  - Commissioning and QA of Computerized Planning Systems for Radiation Treatment of Cancer (2004)

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Routine Quality Control

AAPM TG53 – Report 62 - 5-1. Periodic RTP Process QA Checks

Frequency	Item
Daily	Error logs Hardware/software change logs
Weekly	Digitizer Hardcopy output Computer files Review clinical treatment planning
Monthly	CT data input Problem review Review hardware, software and data files
Annually	Dose Calculations Review digitizer, CT/MRI input, printers, etc. Review BEV/DRR accuracy, CT geometry, density conversions, DVH calculations, data files and other critical data
Variable	Repeat commissioning due to machine changes or software upgrade

http://www.cpqr.ca/wp-content/uploads/2015/04/TPS-2015-02-02.pdf

CPQR
Canadian Partnership for Quality Radiotherapy
PCQR
Partenariat canadien pour la qualité en radiothérapie

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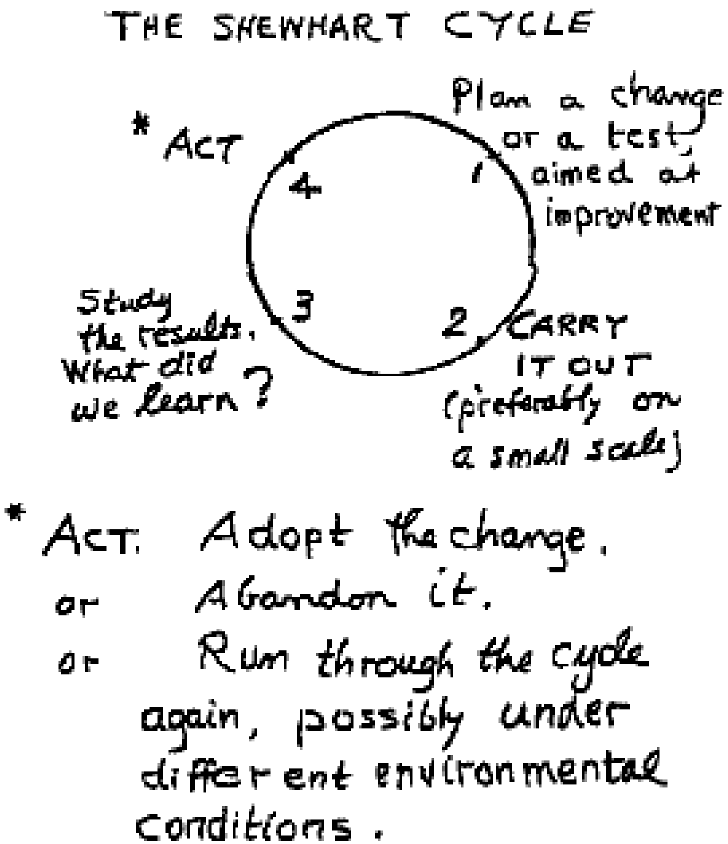
Hypothesis

- Variation in dosimetric performance within or between groups of patients planned with a common strategy will aid in improvement of dosimetric accuracy and precision.

Theory of Knowledge - PDSA

Deming's Sketch of the Shewhart Cycle for Learning and Improvement - 1985



Dr. Walter Shewhart
Bell Labs, 1930

A “New” Definition od Quality

- Variation is to be expected
- Common or special causes
- Tools to learn from variation

- Goal: On target with minimum variance
- This requires a different way of thinking of our processes.
- It is achieved only when a process displays a reasonable degree of *statistical control*

W. Edwards Deming
1900 - 1993

Deming’s System of Profound Knowledge

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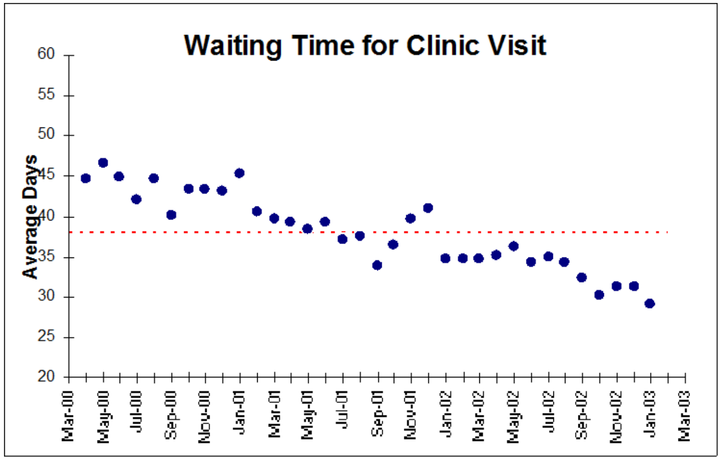
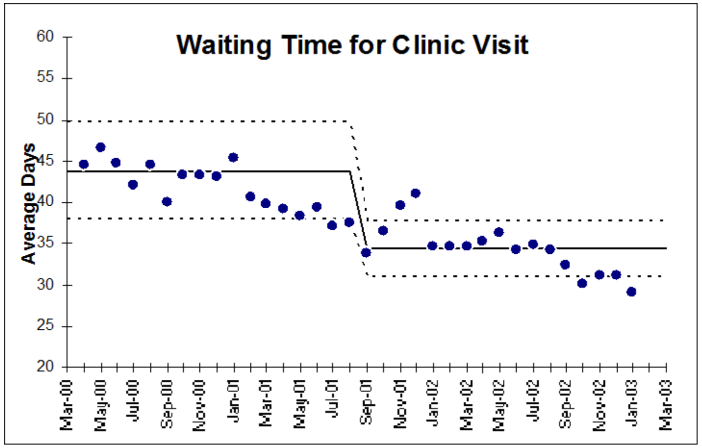
Understanding Variation: Tools

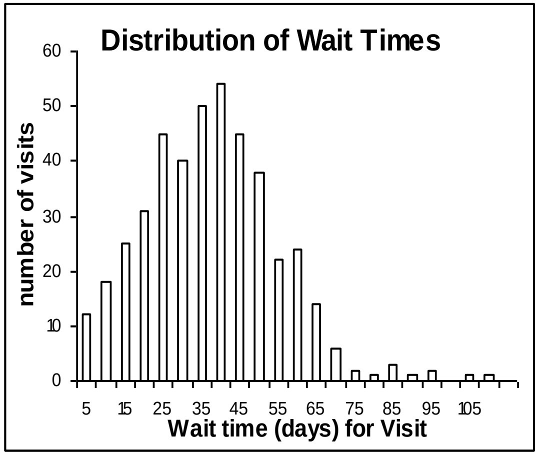
- Run Chart



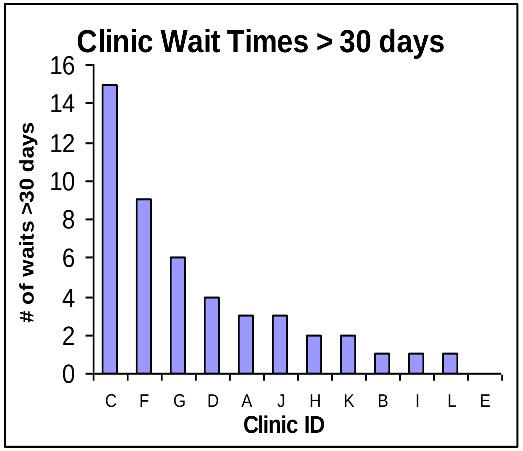
- Shewhart Chart



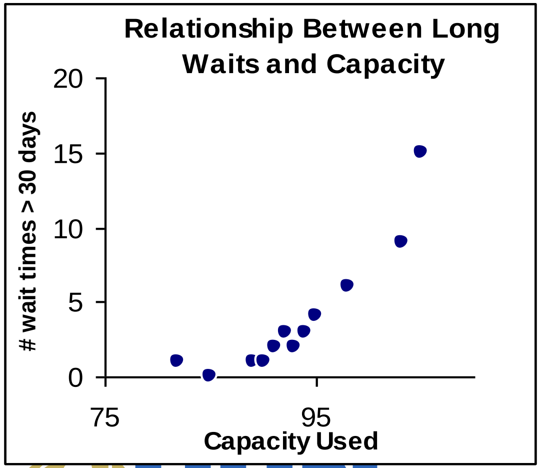
- Frequency Plot



- Pareto Chart



- Scatterplot



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Statistical Process Control

Breen SL, *et al* Med Phys 35:4417-4425 (2008)

- Statistical techniques to document, correct, and improve process performance.
- A *control chart* monitors variation over time;
  - Compare current process performance with historical performance - based on ~25 samples.
- SPC differs from setting specifications, although it informs process improvement and the ability to meet stated specifications.
- A process is described as “in control” when its performance is predictable in a statistical sense.

SPC Basic Procedure

- Choose an appropriate metric, time period for collection and plotting.
- Choose patient/plan cohort that is reasonably similar.
  - literature suggests need ~25 samples.
- Construct plot and analyze.
- Look for "out of control" events, investigate the cause.
  - Are there valid reason to exclude events?
- Are there systematic differences?

QUESTION

Process capability is a measure of the ability of a process to operate within its specification range.
How many samples are needed to establish control limits to monitor IMRT using a control chart?

3%	A.	5
13%	B.	10
71%	C.	~25
9%	D.	>100
4%	E.	350

QUESTION

- Process capability is a measure of the ability of a process to operate within its specification range.
- How many samples are needed to establish control limits to monitor IMRT using a control chart?
  A. 5
  B. 10
  C. **~25**
  D. >100
  E. 350

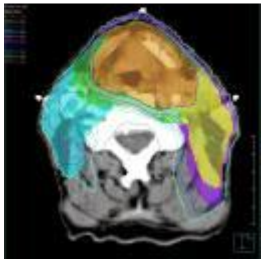
ANSWER: C

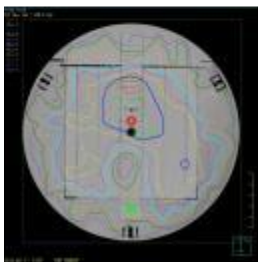
- Breen SL, et al Med Phys 35:4417-4425 (2008)

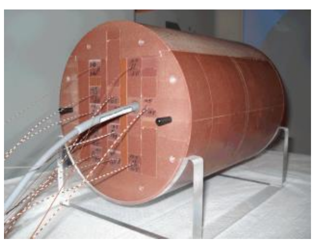
"Although we have demonstrated the requirement for about 25 measurements to characterize our head and neck IMRT process, there is a need to continue to monitor the process to ensure stability over a longer period of time."

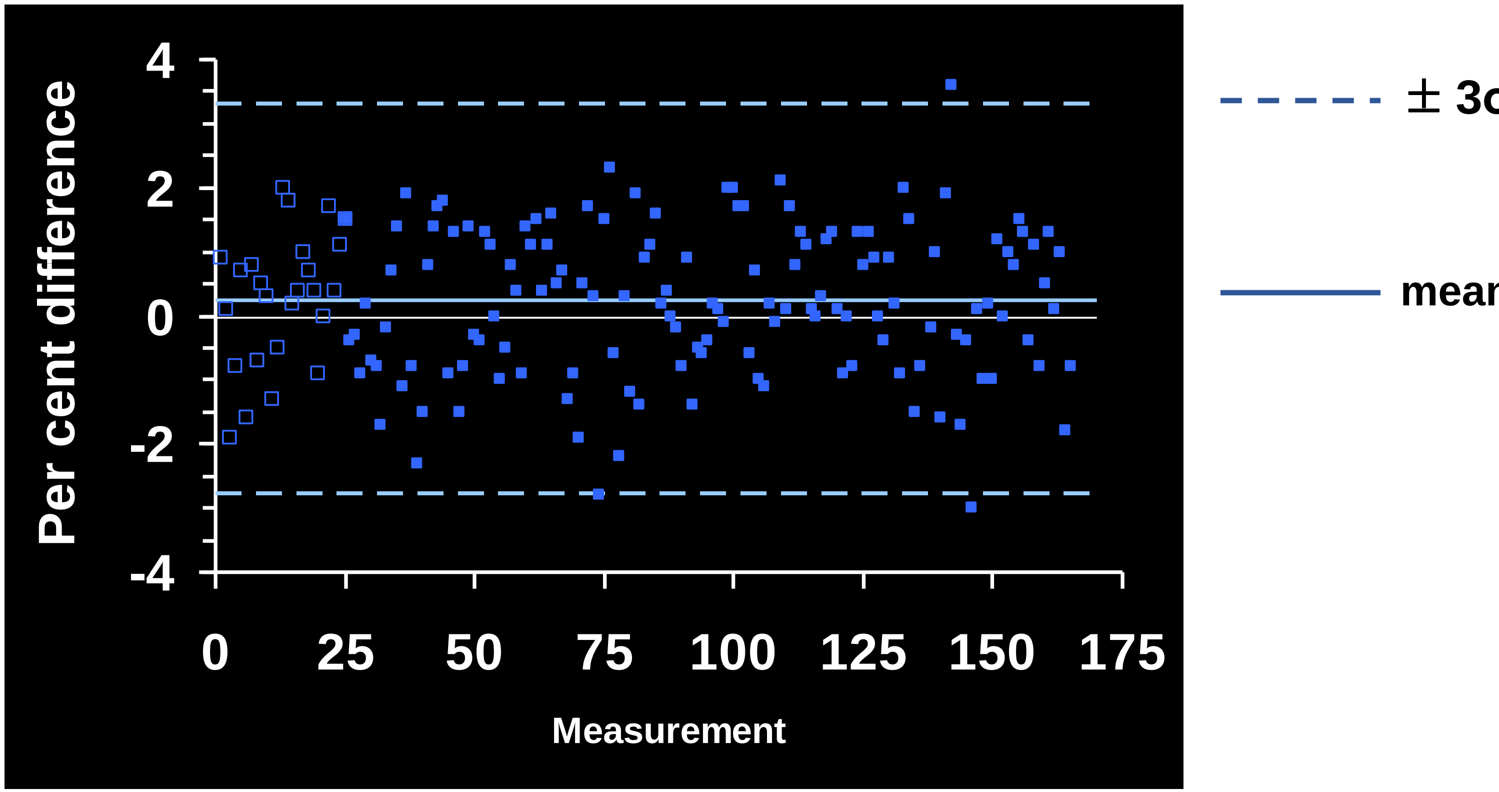
IMRT Process Monitoring

165 high-dose measurements - Head and neck IMRT
Pinnacle 7.6c (Sept – Dec, 2005)





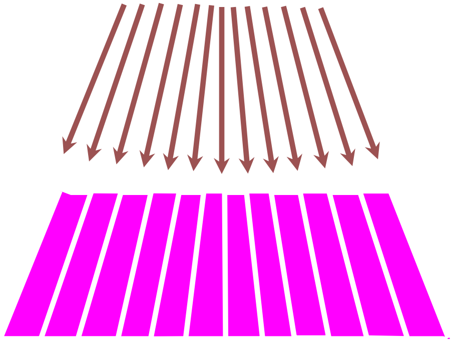




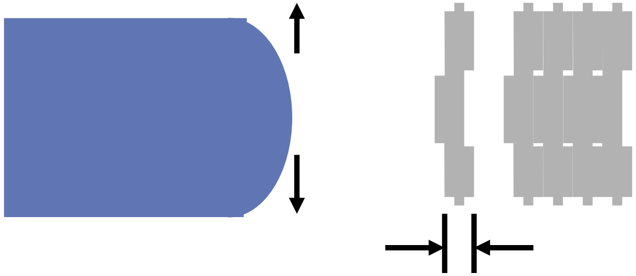
Breen SL, Moseley DJ, Zhang B, Sharpe MB. Med Phys 35:4417-4425 (2008)

Process Change

- Old TPS Version
  - Beam modulated as an intensity matrix
  - Secondary conversion to MLC delivery
  - MLC modeled as an “ideal” collimator



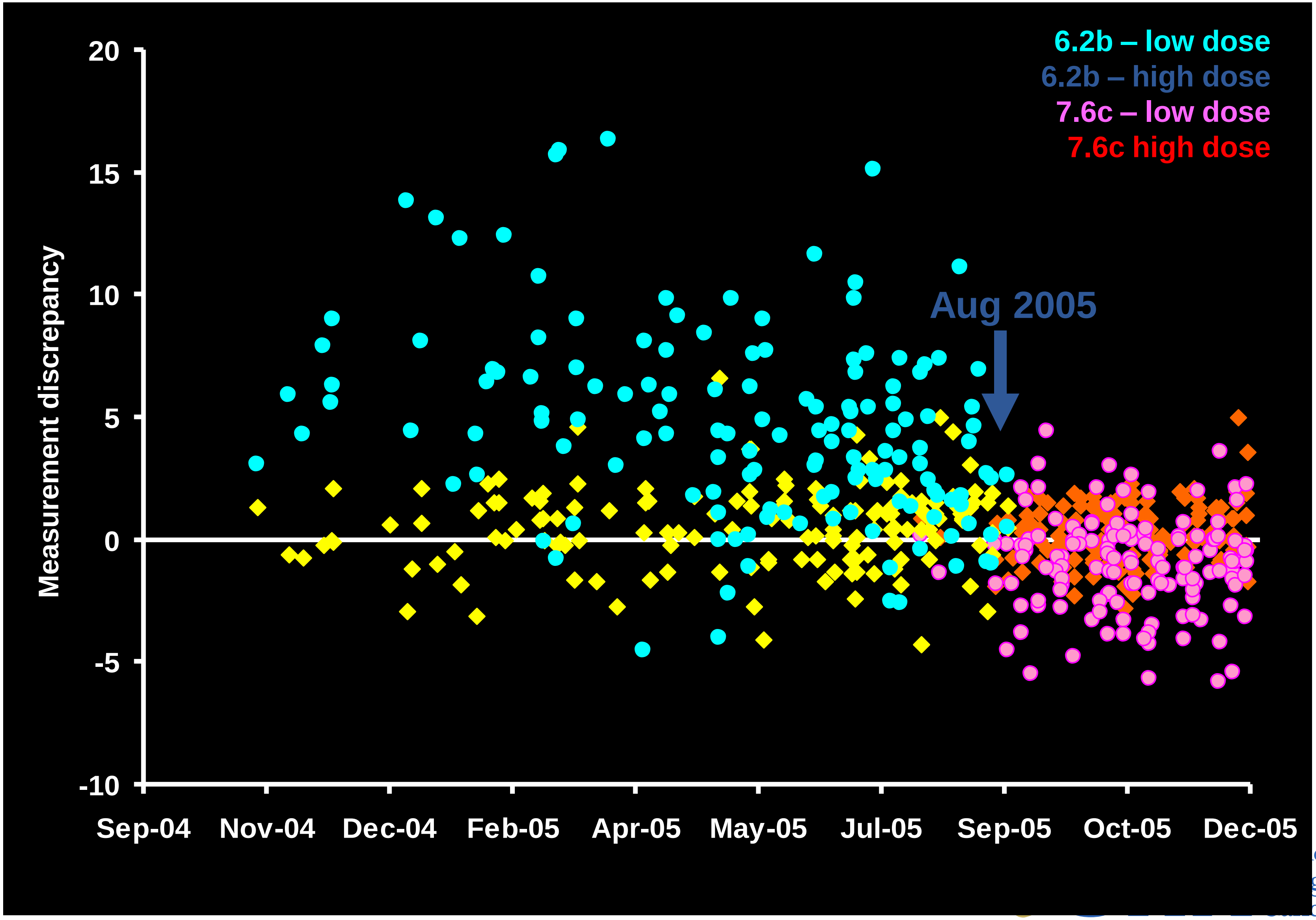
- New TPS Version
  - Incorporates physical MLC model
    - Single-focus
    - Curved leaf face
    - transmission
    - “tongue and groove”



IMRT Verification Measurements

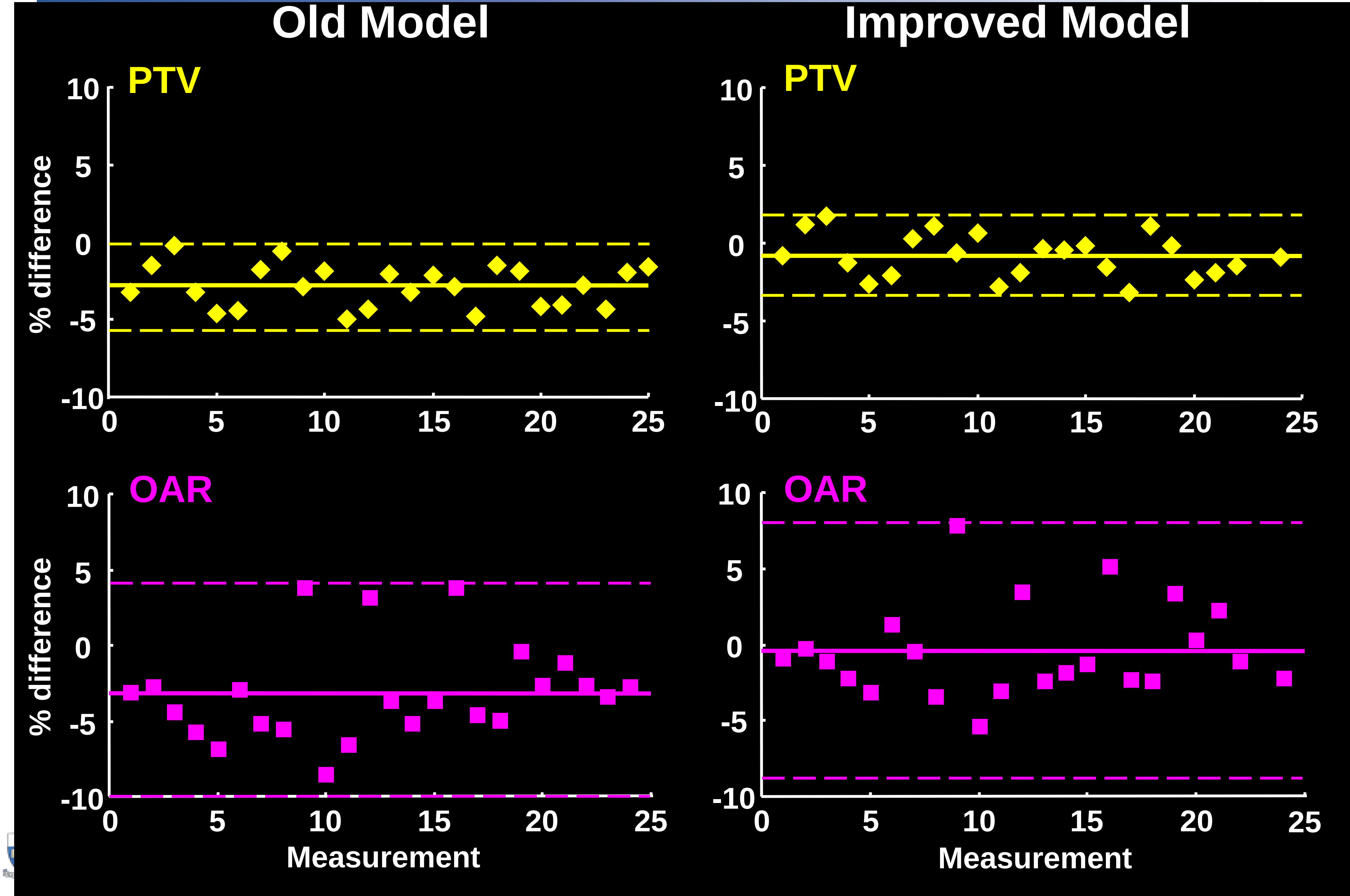
Head & Neck Cancers

Breen *et al*, Med. Phys. Oct 2008



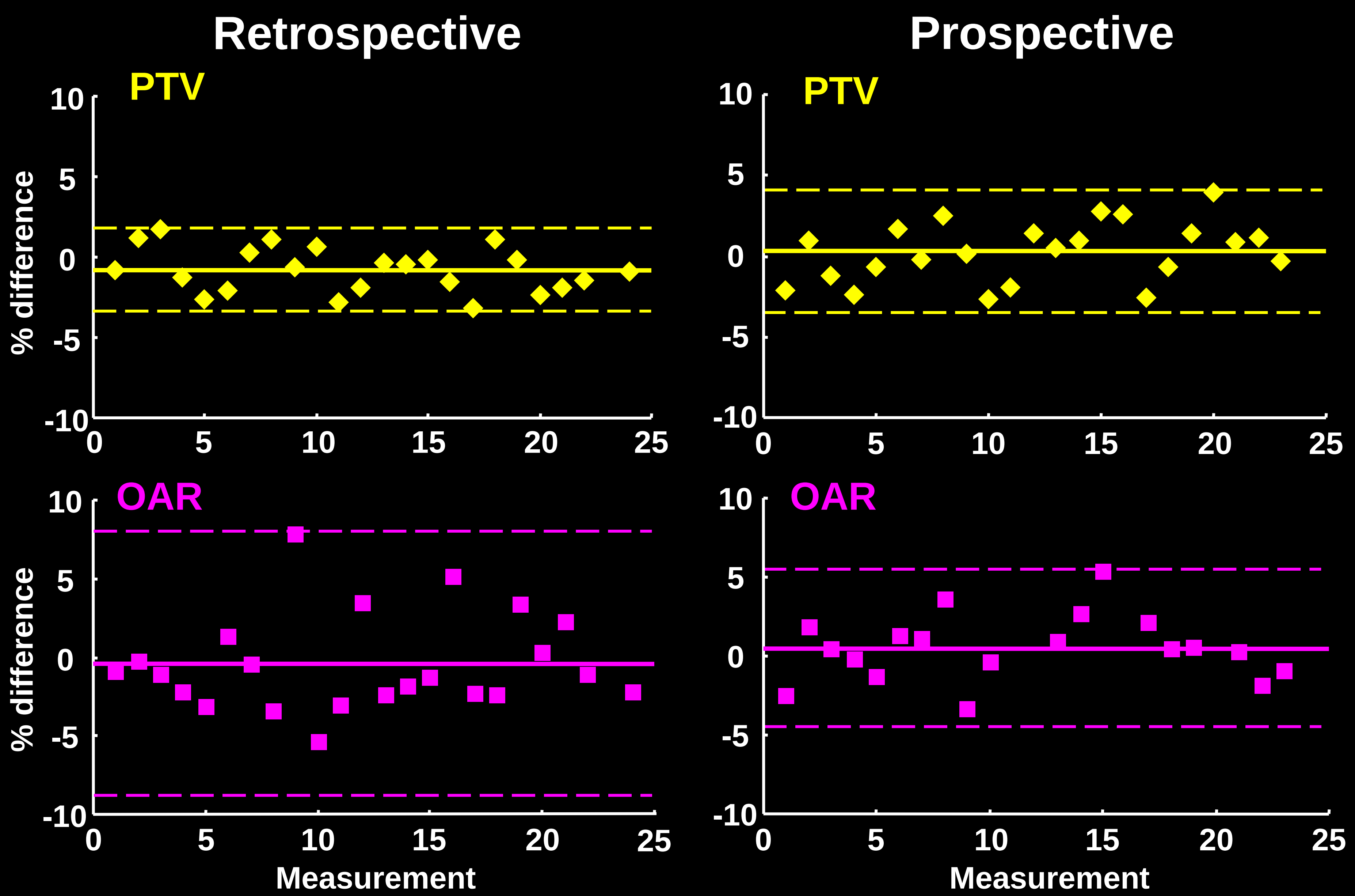
Breen *et al*, Med. Phys. Oct 2008

Improved beam model



Breen *et al*, Med. Phys. Oct 2008

Improve beam model: verification

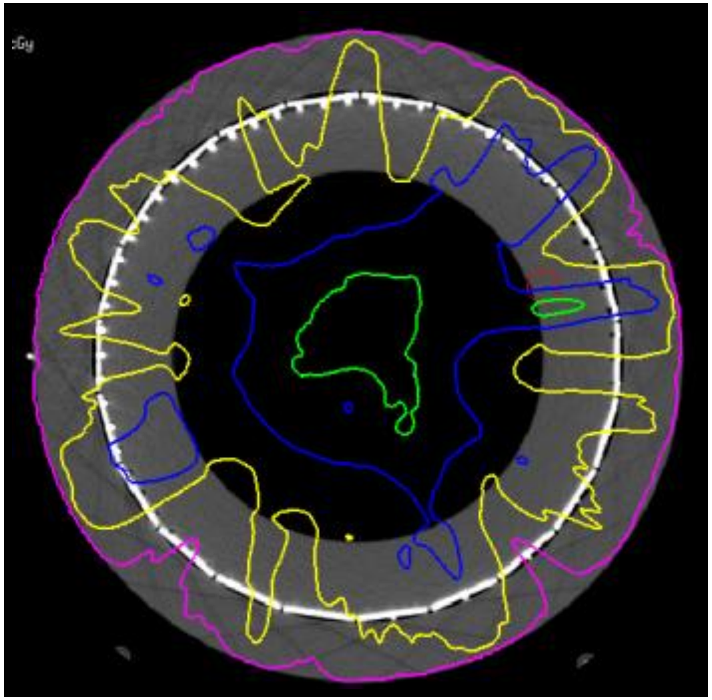


Patient-Specific QC

Measured-Calculated Dose Agreement:

Prostate: 91.4% ± 4.1%

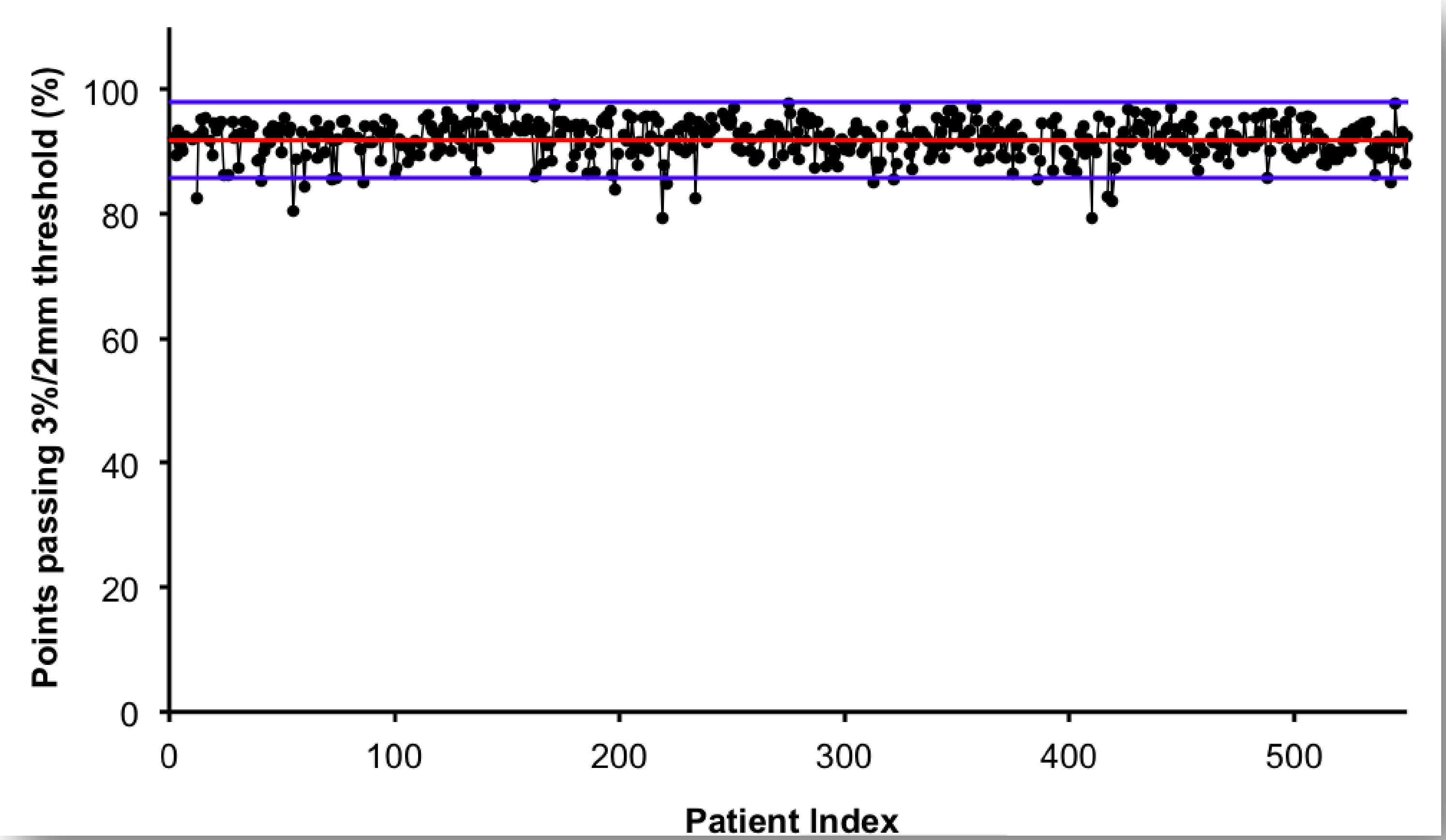
(25 patients, 175 beams) (3%/2mm)

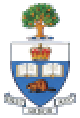


Dose Computed on Phantom

Patient-Specific QC

All VMAT - Pelvis Site Groups (GU, GI, GYN)
Arc Check - Absolute Dose – 3%/2mm





Patient-Specific QC

MapCheck

Measured-Calculated Dose Agreement:

Prostate: 91.4% ± 4.1%
(25 patients, 175 beams) (3%/2mm)

Spine SBRT: 77.1% ± 9.7%
(25 patients, 214 beams) (3%/2mm)

Why the Difference in Agreement?

Same Accelerator.
Same Measurement Device.
Beam Model?

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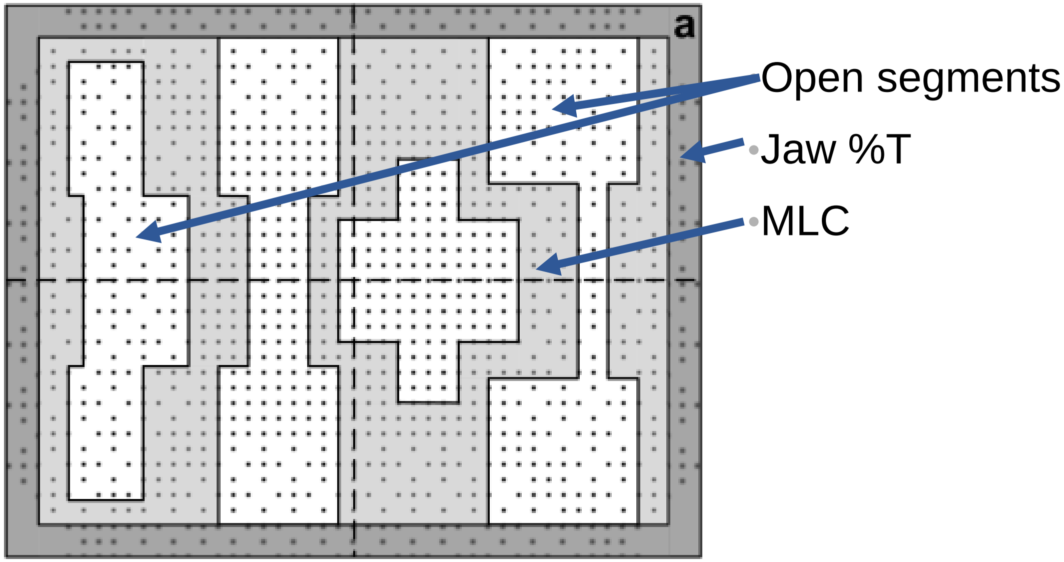
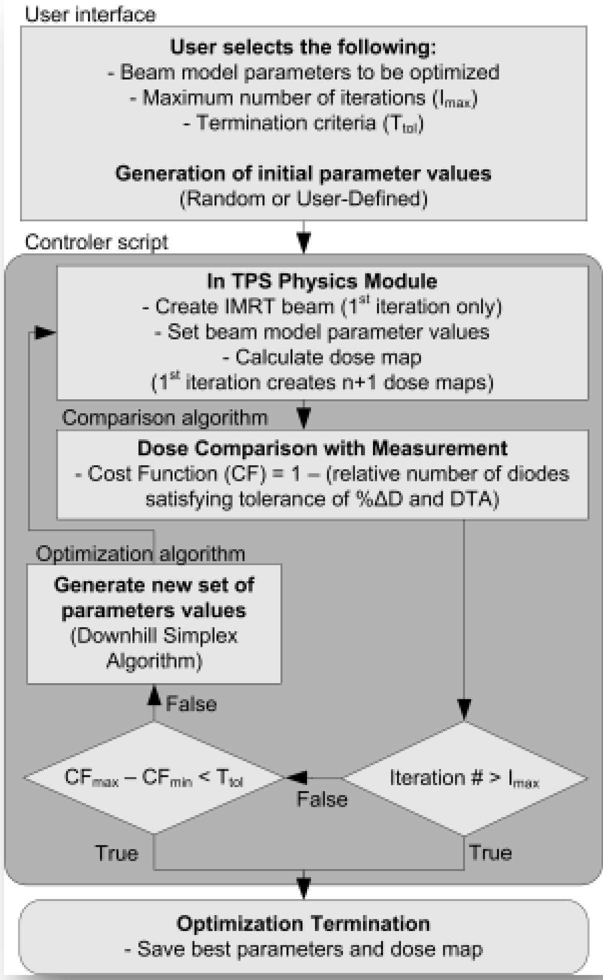
Automated Beam Model Optimization

ABMOS

- Concept: Employ clinically relevant (IMRT-like) delivery in the beam modeling process.
- Challenge: Isolate key parameters; manipulate to enhance accuracy & precision of model across IMRT-type beams.
- Approach: Employ automated optimization methods.

IMRT Test Beam





ABMOS Results

Date: 4/7/2015 | MapCHECK QA of Dose Distribution | Hospital Name:

QA File Parameter

Patient Name	: ABMOS
Patient ID	: 9999999
Plan Date	: 7/4/2015
SSD	: 913.5
SDD	: 1000.0
Depth	: 86.5
Energy	: 0
Angle	:

Relative Comparison

Difference (%)	: 2.0
Distance (mm)	: 1.0
Threshold (%)	: 5.0
Meas Uncertainty	: No

Summary (DTA Analysis)

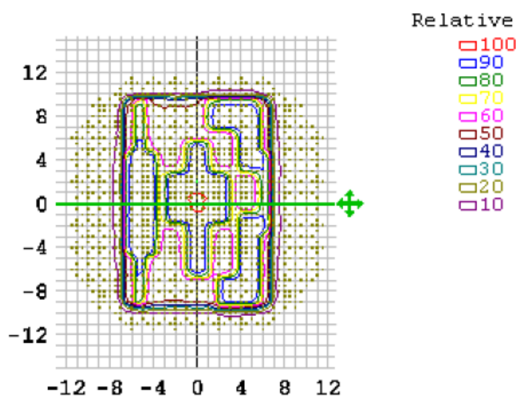
Total Points	: 1079
Passed	: 933
Failed	: 146
% Passed	: 86.5

Dose Values in cGy

	CAX	Norm	Sel	Max
MapCheck measurement March 2015	222.76	221.25	222.76	223.34
RayStation calculation	220.10	221.56	220.10	221.67
MapCheck measurement March 2015-RayStation calculation	2.66	0.70	2.66	1.67
% Diff	1.21	0.31	1.21	0.75
DTA(mm)	0.00	0.00	NA	
Coords (y,x) cm	0,0	2,0	0,0	

Notes

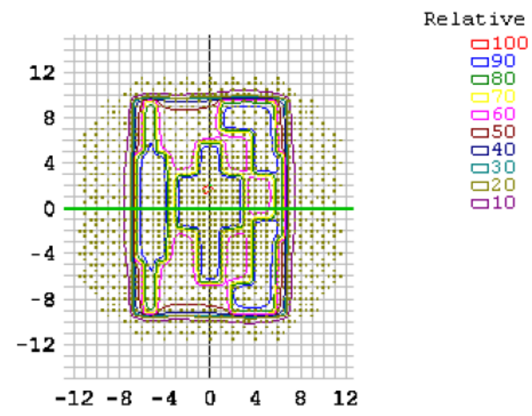
MapCheck measurement March 2015



Q:\RayStation\Commissioning\Varian IX\AB...\EV06 18x Merged 31-Mar-2015.txt

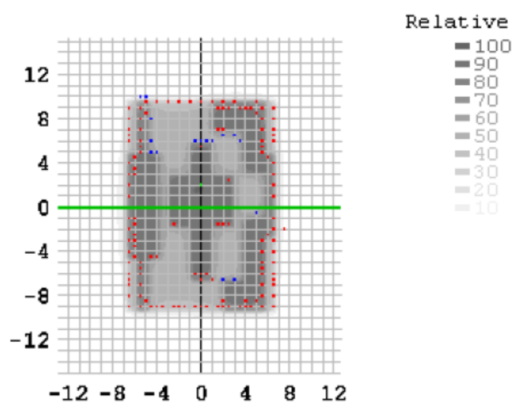
RayStation calculation

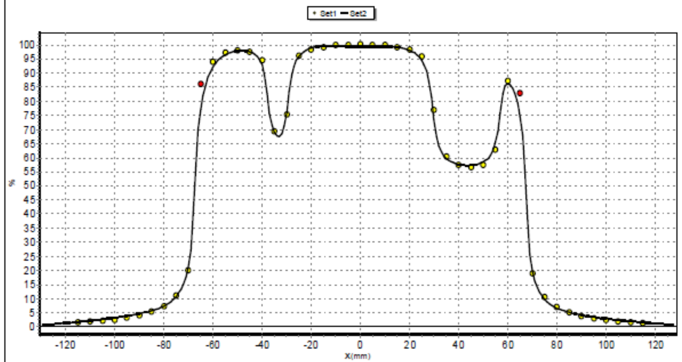
CAX Offset X=0 Y=-1



Q:\Ray...\RD1.2.826.0.1.3680043.8.176.20154717448509.41.7265205358.dcm

MapCheck measurement March 2015-RayStation calculation





Letourneau-D *et al* Med. Phys. 37(5) 2110-2120 (2010)

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ABMOS vs. Previous Model

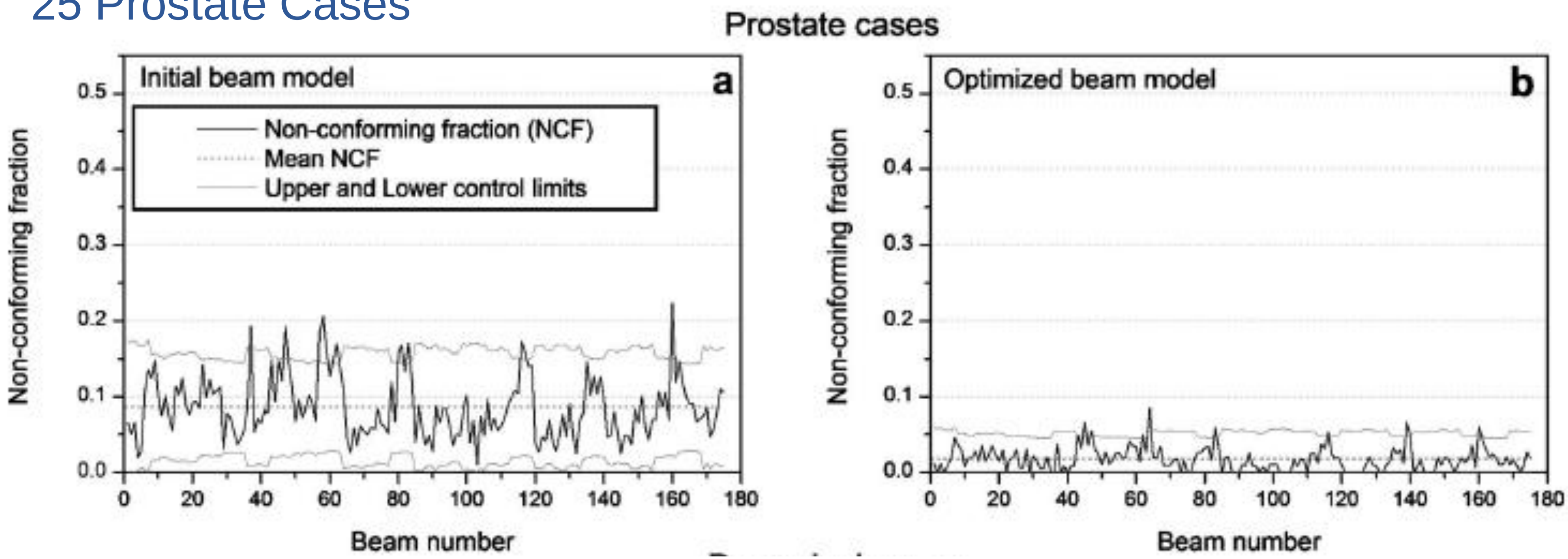
Measured-Calculated Dose Agreement

	Clinical	ABMOS
Prostate: (25 patients, 175 beams)	91.4% ± 4.1%	98.2% ± 1.6%
Spine SBRT: (25 patients, 214 beams)	77.1% ± 9.7%	96.4% ± 2.8%

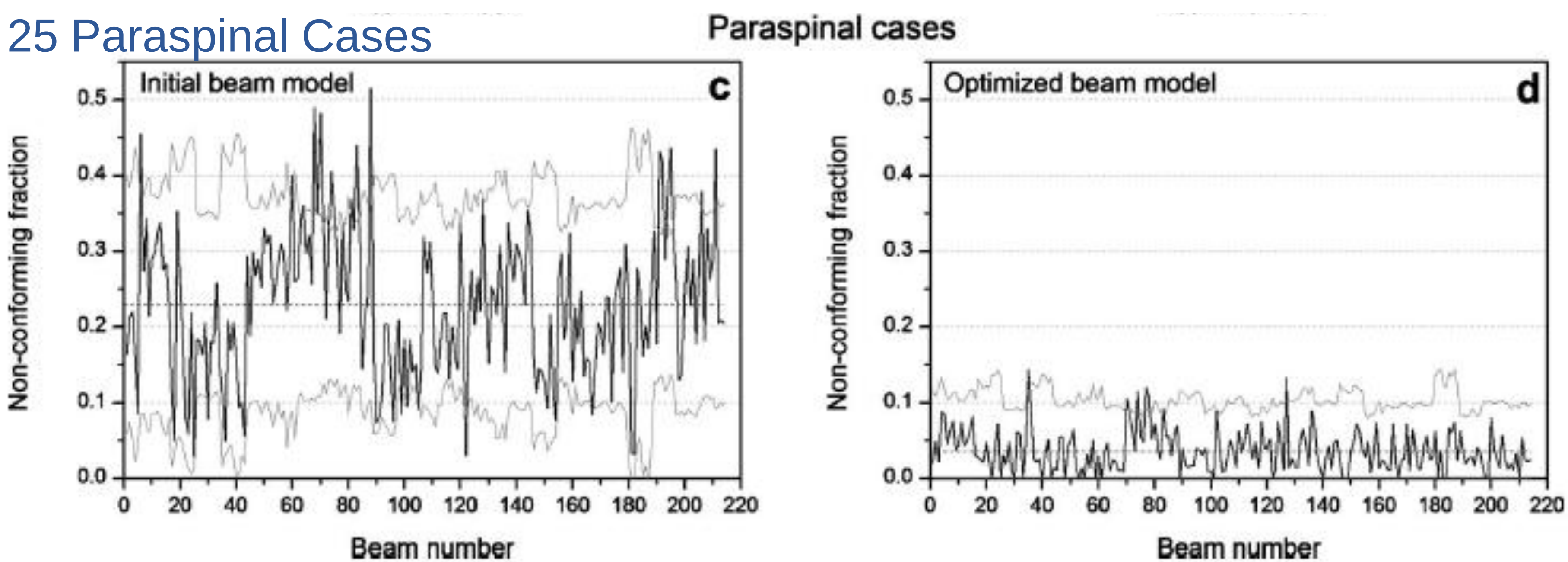
Relative pass rate (±SD)	Initial model	Optimized model
Prostate cases (n=175 beams)	91.4% ± 4.1%	98.2% ± 1.6%
%ΔD/DTA: 3%/2 mm (2%/1 mm)	(73.1% ± 6.7%)	(89.4% ± 4.9%)
Paraspinal cases (n=214 beams)	77.1% ± 9.7%	96.4% ± 2.8%
%ΔD/DTA: 3%/2 mm (2%/1 mm)	(48.8% ± 10.0%)	(77.8% ± 7.2%)

Letourneau-D *et al* Med. Phys. 37(5) 2110-2120 (2010)

25 Prostate Cases



25 Paraspinal Cases



Independent dose calculation

A representative point for each field and composite

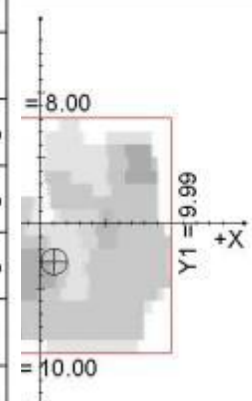
±3%? Tolerance ±5%?

Point Name	ICRU B
Coordinates (X, Y, Z)	(1.32, -46.45, 2.80)
Total Dose (cGy)	170.9
RTP Calculated Dose (cGy)	170.4
Percent Difference	0.3%

Beam Description	Offsets X / Z	SSD / Depth	Point Dose (cGy)	RTP Dose (cGy)	% Diff
Ph2 RPO 200	-0.88 / 3.02	88.91 / 10.37	9.1	9.6	-4.6%
Ph2 RPO 240	-1.16 / 3.00	84.27 / 15.75	13.2	13.2	0.2%
Ph2 RAO 280	-0.90 / 2.98	92.71 / 8.07	22.7	22.0	3.4%
Ph2 RAO 320	-0.22 / 2.97	94.90 / 6.29	21.0	21.5	-2.7%
Ph2 ANT 0 X1	0.55 / 2.97	96.01 / 5.06	23.9	24.5	-2.6%
Ph2 LAO 40	1.08 / 2.99	96.37 / 4.10	17.2	17.4	-1.6%
Ph2 LAO 80	1.11 / 3.01	94.40 / 5.27	21.0	20.6	1.7%
Ph2 LPO 120	0.61 / 3.03	87.06 / 11.99	16.9	16.6	1.9%
Ph2 LPO 160	-0.18 / 3.03	85.78 / 13.12	26.0	25.0	4.1%

Pati
Field Descript
Ph2 ANT (
Field ID
Calc Pt: ICRU
Dose Per Treat
Iso. @ Calc P
RTP Dose @ Cal
Wedge Factor
Sc
ISF
Primary x OAF
Scatter
Inhomo. Corr
Cal. Factor
Dose Per MU
MU
Plan MU
Percent Diff

35
S12
e: 6 MV
y: 40
Couch: 0
Depth: 4.10
Eff. Depth: 4.25
ALPO: 6.89



Mod Factor = 0.211

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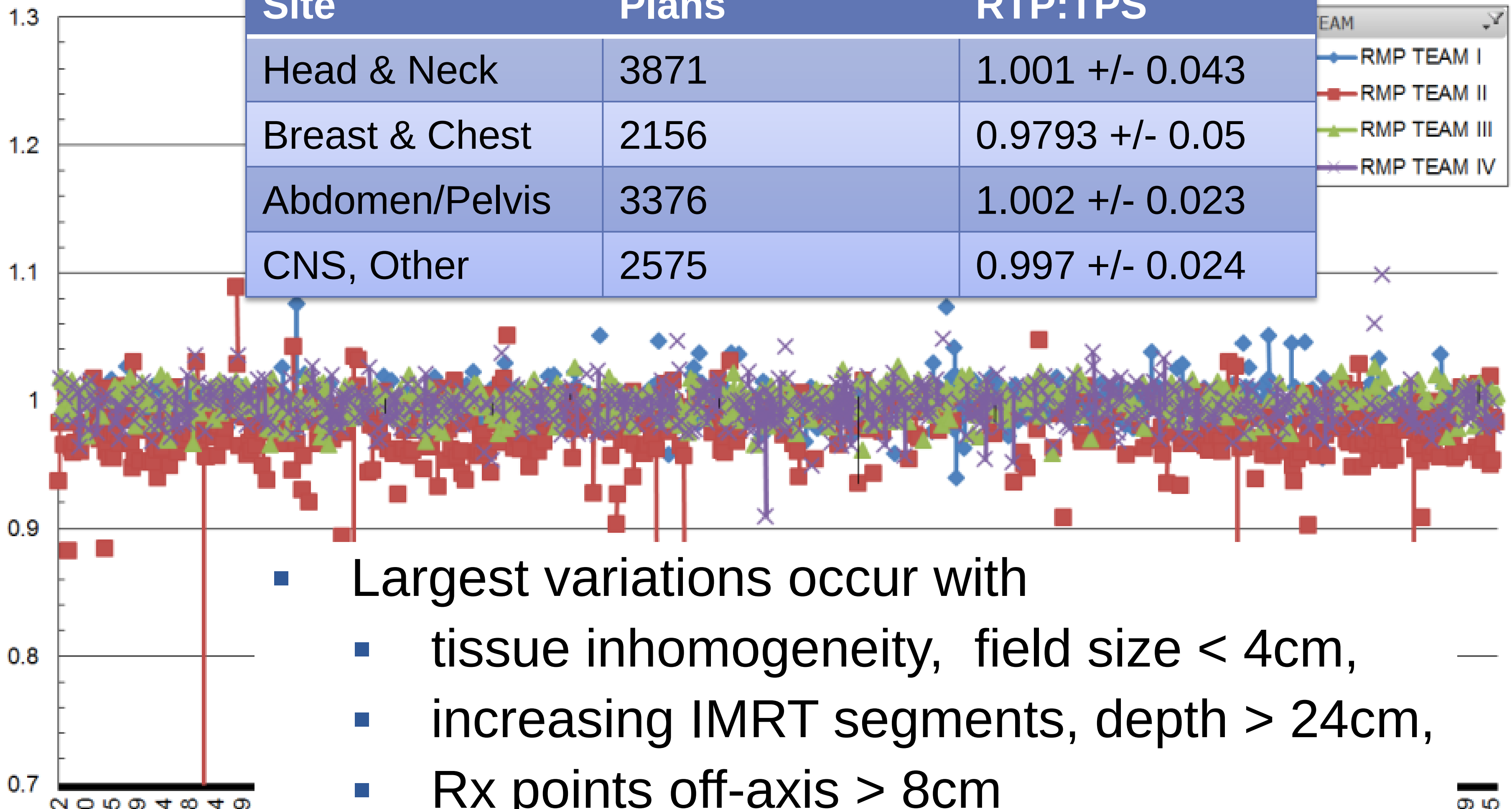
TPS vs 2nd Calculation

Pinnacle v9.2 - Elekta Agility - 6MV - July 2012 – Feb 2015



Site	Plans	RTP:TPS
Head & Neck	3871	1.001 +/- 0.043
Breast & Chest	2156	0.9793 +/- 0.05
Abdomen/Pelvis	3376	1.002 +/- 0.023
CNS, Other	2575	0.997 +/- 0.024

- Largest variations occur with
  - tissue inhomogeneity, field size < 4cm,
  - increasing IMRT segments, depth > 24cm,
  - Rx points off-axis > 8cm

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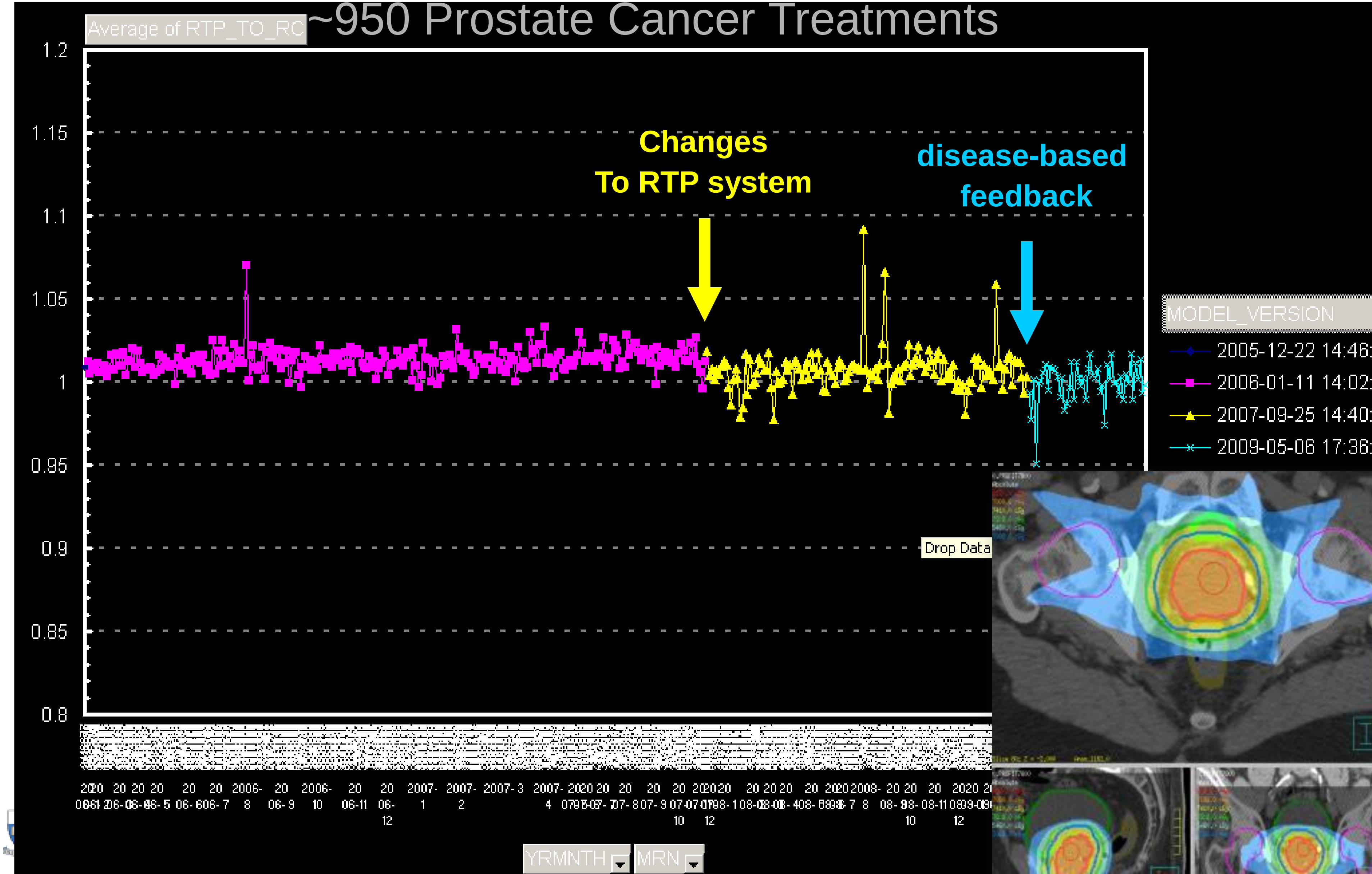
TPS vs 2nd Calculation, One Beam Model



SUMMARY

- Showed examples of non-dosimetric tests
  - imaging, orientation and scales
- Use of TG53 criteria to assess commissioning
- Implementing routine quality assurance
  - Continuous Quality Improvement
  - Statistic Process Control
  - On Target, minimum variation
- Anticipate several new Reports from AAPM.
- If you “feel good” about patient-specific QC results, reduce your specification and seek improvement!

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