Recommendations of MPPG #5 and Practical Implementation Strategies

(MPPG #5.a.: Commissioning and QA of Treatment Planning Dose Calculations: Megavoltage Photon and Electron Beams)

TG 244 Subcommittee

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Status July 2015

- Internal review = ✓
- Public review = ✓
- SPG vote = ✓
- CPC vote = ✓
- PC vote = ✓
- JACMP edit = ✓

Publication expected Sept 1 2015

“Companion” manuscript for JACMP in the works on initial implementation experience at UW and MUSC.

University of Wisconsin
SCHOOL OF MEDICINE
AND PUBLIC HEALTH

What is a MPPG?

A. **M**inimum **P**hysics **P**ractice **G**uideline

B. **M**eaningful **P**iece of **P**hysics **G**

C. **M**aybe, **P**ossibly, **P**robably a **G**ood thing to do

D. **M**edical **P**hysics **P**ractice **G**uideline

E. I have no clue, that's why I am here….

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What is an MPPG?

Medical **P**hysics **P**ractice **G**uideline

Approved 2011 under Professional Council, 5 year "sunset"

Vision: "The AAPM will lead the development in collaboration with other professional societies....freely available to the general public. Accrediting organizations, regulatory agencies and legislators will be encouraged to reference these MPPGs when defining their respective requirements."

Scope: "…minimum level of medical physics support that the AAPM would consider to be prudent in all clinical practice settings."

1.a.: CT Protocol Management and Review Practice Guideline, 2013

2.a: Commissioning and QA of X-ray–based IGRT systems, 2014

3a: Levels of Supervision for Medical Physicists in Clinical Training, 2015

4a: Safety Checklists, 2015

6: Dose monitoring software (in progress)

7: Medical Physicist Assistants (in progress)

8: Linac QA (in progress)

http://www.aapm.org/pubs/MPPG/

MPPG #5 in a Nutshell

- Outlines minimum requirements for external beam TPS dose algorithm commissioning/validation and QA in a clinical setting (limited to gantry mounted linacs)

- Tolerances & Evaluation criteria (2 tier approach)
  - –Wanted minimum acceptable tolerance for TPS "basic" dose calculation.
  - –Did **not** want to state or use any minimum tolerance values that are not widely accepted/published.
  - –Wanted to push the limit on some evaluation criteria (for IMRT/VMAT) to expose limitations of dose calculations.

- In the spirit of "practice guidelines", this MPPG is a summary of what the AAPM considers prudent practice for <u>what a clinical medical physics should do </u>with respect to. dose algorithm commissioning/validation.

What to do/check?

The MPPG report only covers dose calculation, the term “commissioning” includes beam data acquisition, modeling, and validation.

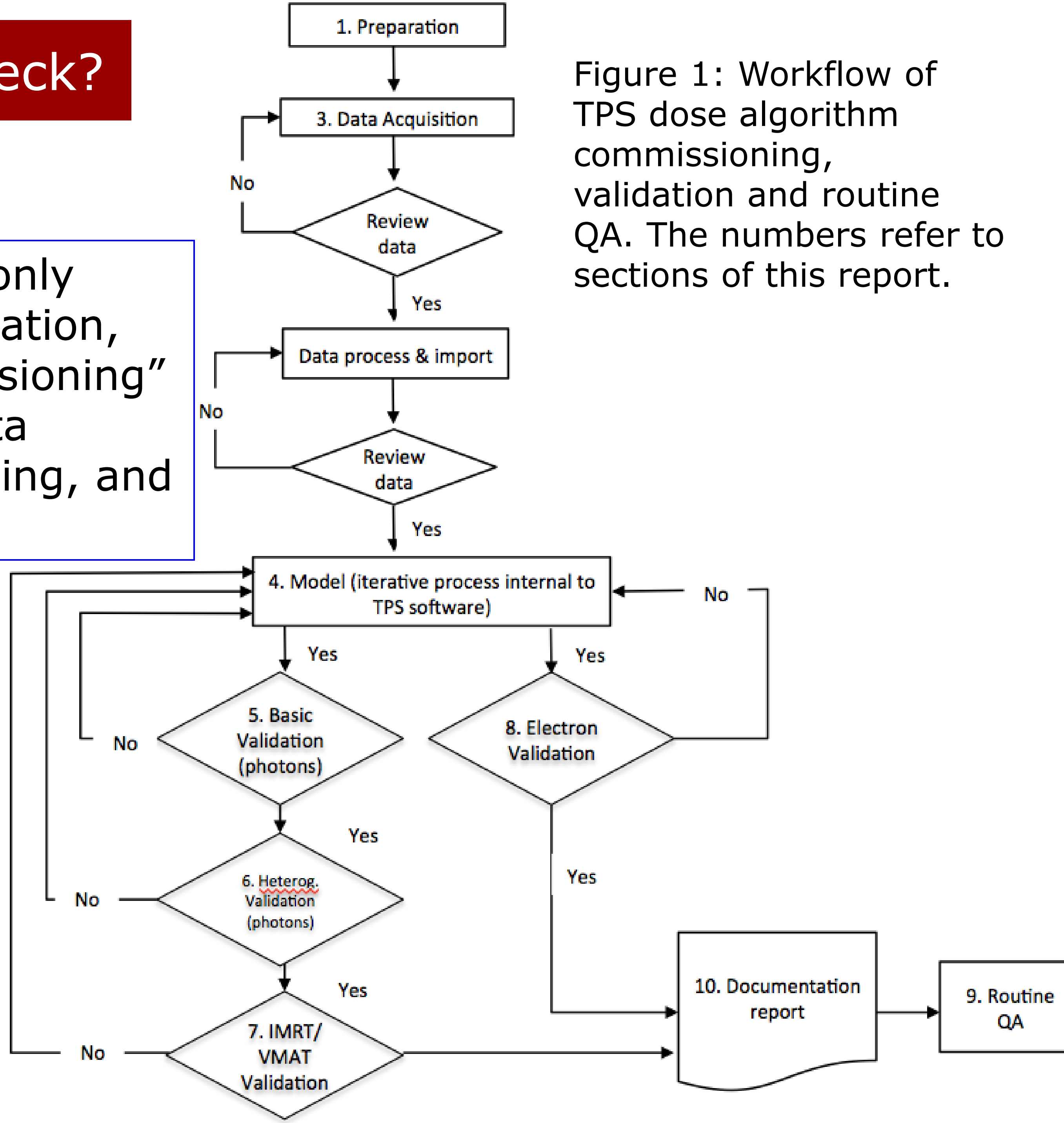
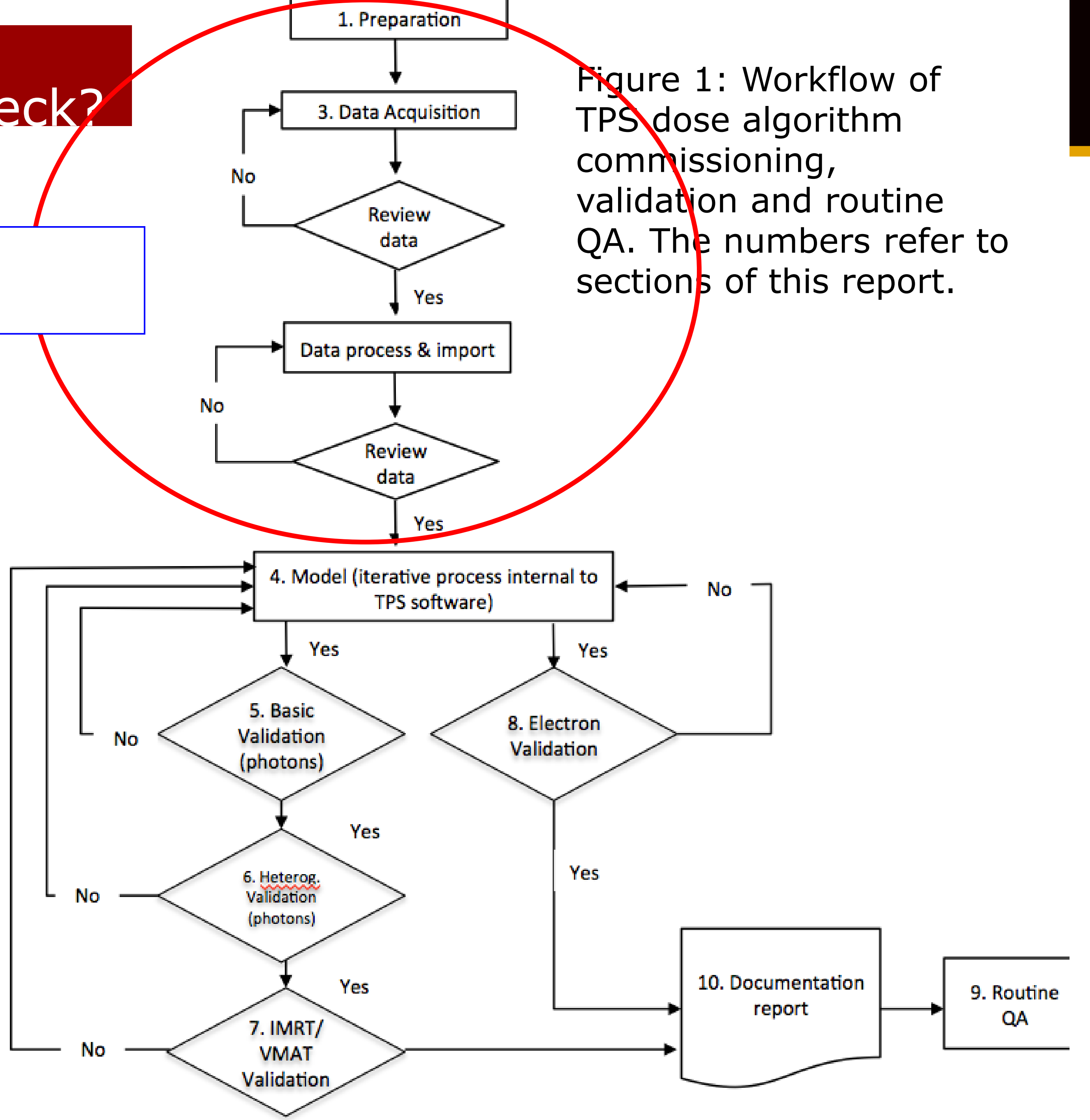


Figure 1: Workflow of TPS dose algorithm commissioning, validation and routine QA. The numbers refer to sections of this report.

MPPG #5: What to do/check?

Follow vendor recommendations



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MPPG #5: What to do/check?

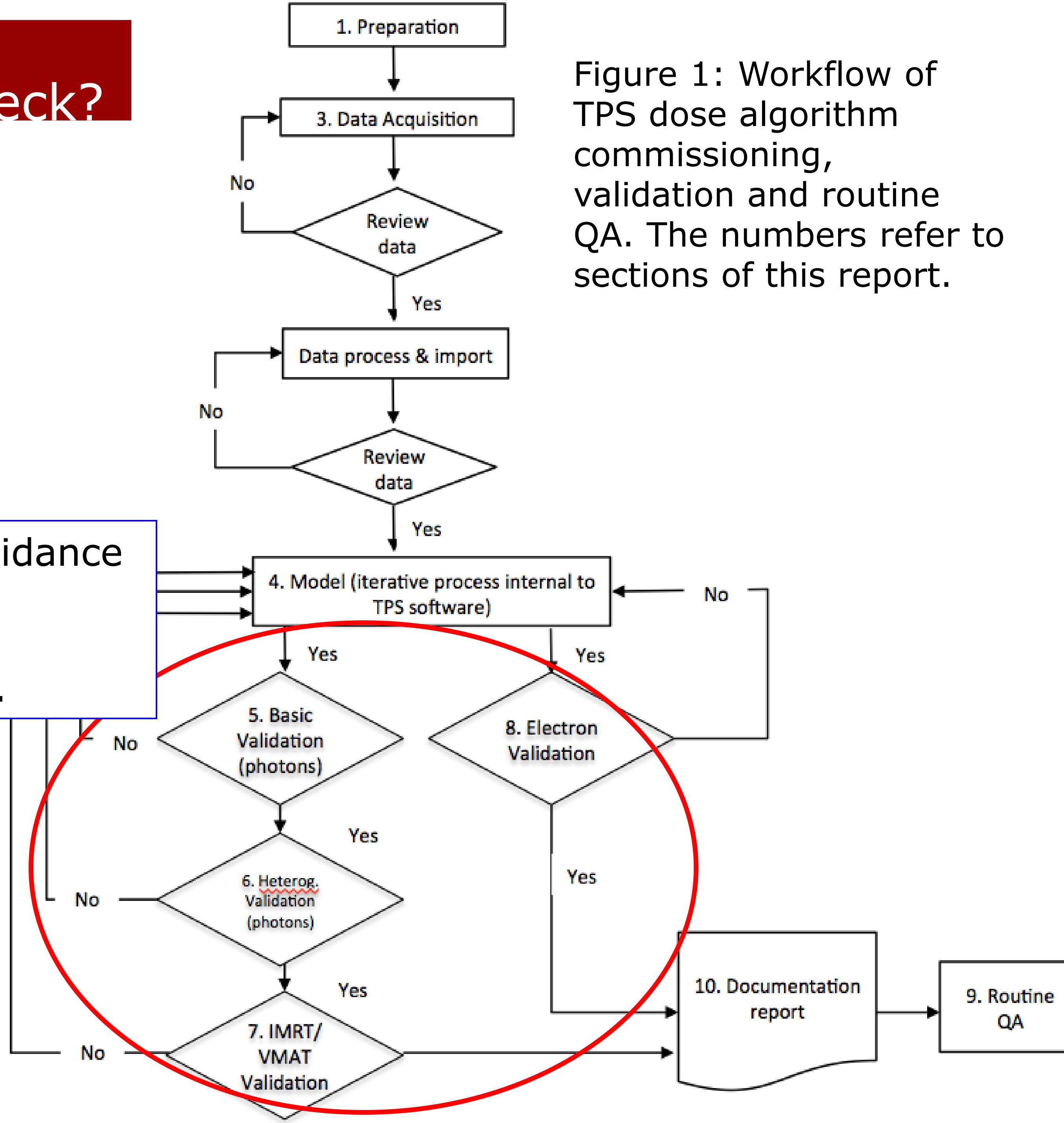


Figure 1: Workflow of TPS dose algorithm commissioning, validation and routine QA. The numbers refer to sections of this report.

This talk covers guidance and experience implementing the validation sections.

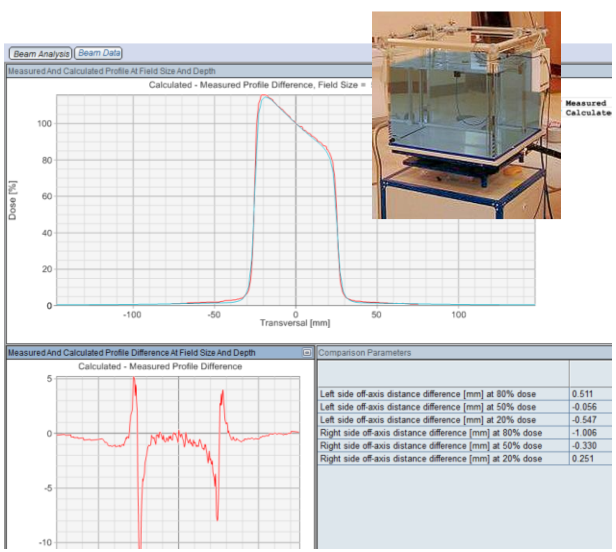
Problem statement: Validation, what does it mean to you???

Model

•TPS-specific software

•Limited analysis tools (often can’t set values) and output reporting

•Standard (not tx) fields One (or a few) time (s) only

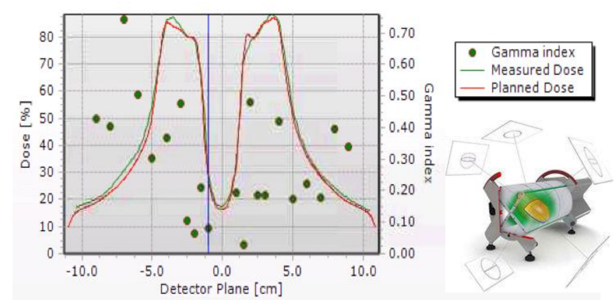


“Validation”

-Realistic Tx fields
-Includes components of both model and DQA
-Water tank scans, IC measurements (we all have different tools and linacs)
-Includes IMRT QA measurements
-Sanity checks
-Software upgrades
-Trouble shooting
-TPS QA
-What criteria to use?

Pt. specific QA (DQA)

- Ubiquitous 3%/3mm tolerance
- Commercial products (Eg: MapCheck, ArcCheck (Sun Nuclear), Delta4 (ScandiDos)
- Not water tank, no always intuititive
- Each IMRT patient



The right tools and a bit of forethought makes implementation much easier!

- MPPG #5 Report was written such that user has freedom to use any suitable/available combination of phantoms and detectors. Specific field design is not included in report.
- It is recommended to take data at time of commissioning.
- Create standard test plans for use with upgrades and routine QA.
- Organize the data using a master spreadsheet template for all linacs in clinic.
- Water tank profiles in representative (non-IMRT) treatment fields are difficult to analyze.
- As part of the implementation at UW and MUSC we created a robust, open source MatLab code for Profile Analysis

Initial Implementation Experience

5. Basic Photon	5.1 Physics module versus planning module dose
	5.2 Clinical calibration dose
	5.3 Planning module dose versus commission data
	5.4-5.9 Basic photon tests *
6. Inhomogeneity	6.1 CT to Density calibration
	6.2 Heterogeneity correction
7. IMRT/VMAT	7.1 Small field PDD
	7.2 Small MLC defined field output
	7.3 -7.4 TG-119 and clinical tests
	7.5 External Review
8. Electrons	8.1-8.2 Electron basic tests and obliquity tests
	8.3 Electron heterogeneity correction

- Sanity checks
- Scanning tests, analyze using the MatLab code

(The 4 validation MPPG #5 sections.)

Tolerances levels for Basic Photon Validation

Test	Comparison	Description	Tolerance
5.1	Dose distributions in planning module vs. modeling (physics) module	Comparison of dose distribution for large (>30x30cm^2) field.	Identical *
5.2	Dose in test plan vs. clinical calibration condition**	Reference calibration condition check	0.5%
5.3	Dose distribution calculated in planning system vs. commissioning data	PDD and off axis factors for a large and a small field size	2%

Tests 5.4-5.9 – Profiles

Region	Evaluation Method	Tolerance* (consistent with IROC Houston)
High dose	Relative dose with one parameter change from reference conditions	2%
	Relative dose with multiple parameter changes **	5%
Penumbra	Distance to agreement	3 mm
Low dose tail	Up to 5 cm from field edge	3% of maximum field dose

Test 5.2: Clinic Calibration Dose

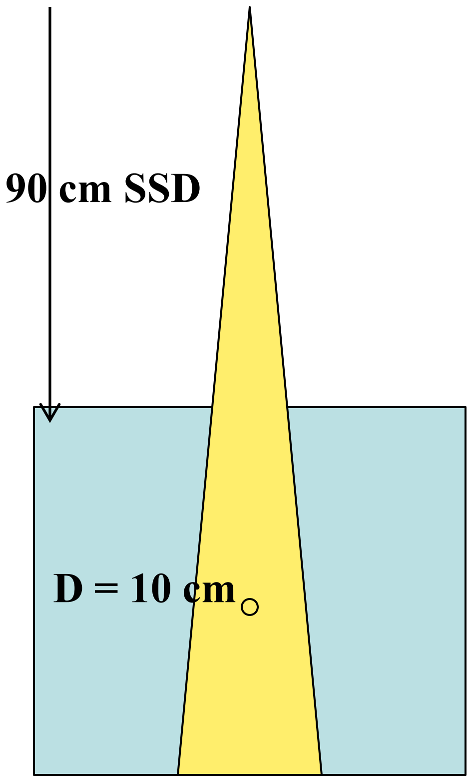
Eclipse TPS

Parameters - Parameter View

Absolute dose reference field size [mm]	100.000000
Absolute dose calibration source-phantom distance [mm]	950.000000
Absolute dose calibration depth [mm]	50.000000
Reference dose at calibration depth [Gy]	1.000000
Reference MU at calibration depth [MU]	100.000000
Machine type	

Pinnacle TPS

Calibration Point Depth (cm):	10
Source To Calibration Point Distance (cm):	100
Dose/MU at Calibration Point (cGy/MU):	0.81027



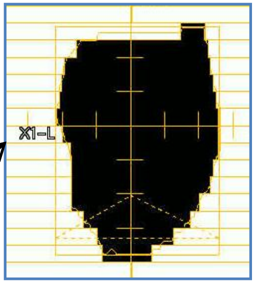
Results from our TrueBeam

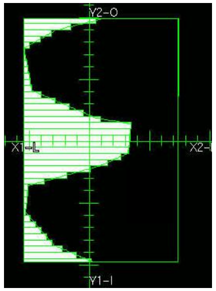
Point Dose Results:	measurement (nC)			Pinnacle 9.8	
Field Name	Ave (nC)	M_{corr}	**Dose**	**Calc Dose.**	**% Difference**
5.2 06MV	12.3	12.420	0.662	0.663	-0.12%
5.2 10MV	13.7	13.888	0.731	0.731	0.07%

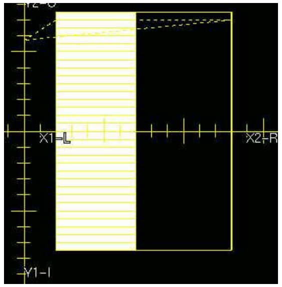
Within 0.5%?
Yes
Yes

5.4-5.9 Basic photon field validation

Test	Description
5.4	Small MLC shaped field (non SRS)
5.5	Large MLC shaped field with extensive blocking (e.g.: mantle) *
5.6	Off-axis MLC shaped field, with maximum allowed leaf over travel.
5.7	Asymmetric MLC shaped field at minimal anticipated SSD
5.8	MLC shaped field at oblique incidence (30°)
5.9	Large (>15cm) MLC field for each a non-physical wedge angle**







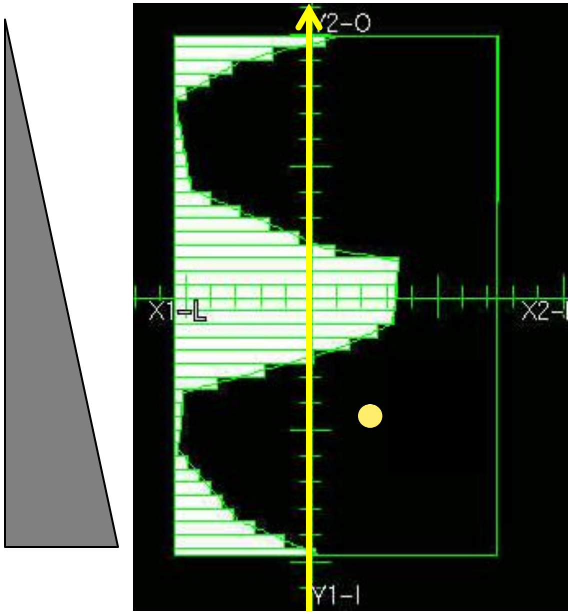
* Show the workflow for 5.5

Test 5.5: Large MLC/jaw field for 6 MV, with hard wedge

1. In TPS
   a. Adjust field for model (e.g.: energy, wedge)
   b. Calculate
   c. Export DICOM files: dose per beam (RD files) & plan file (RP), 2mm dose grid

2. Scan in 3D water tank with Exradin CC13
   a. 3 inline profiles, 1 crossline and an off axis PDD
   b. Export W2CAD (.asc) file

3. Gamma analysis with open source MatLab Profile Analysis Tool

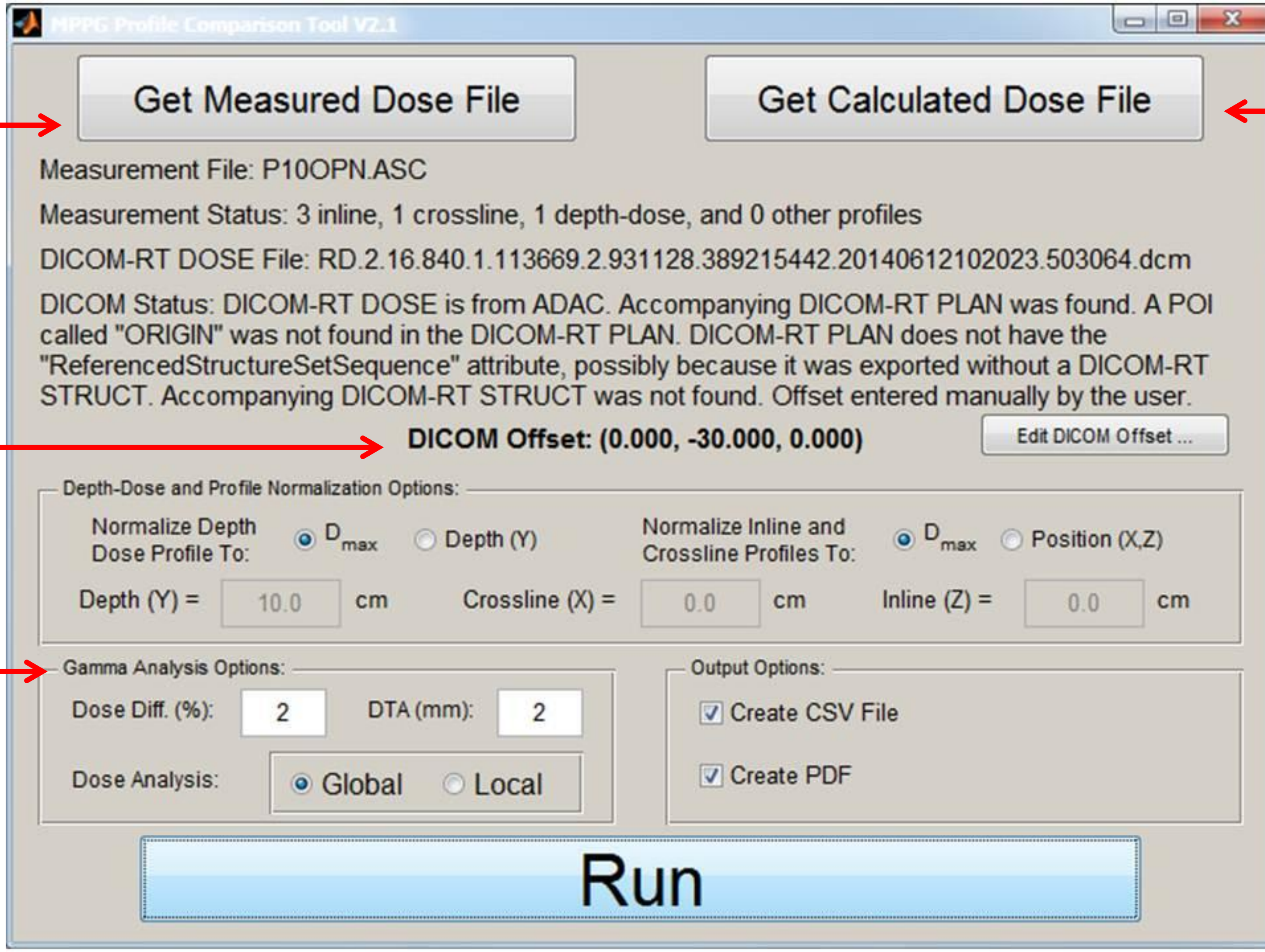


MatLab Profile Analysis Code

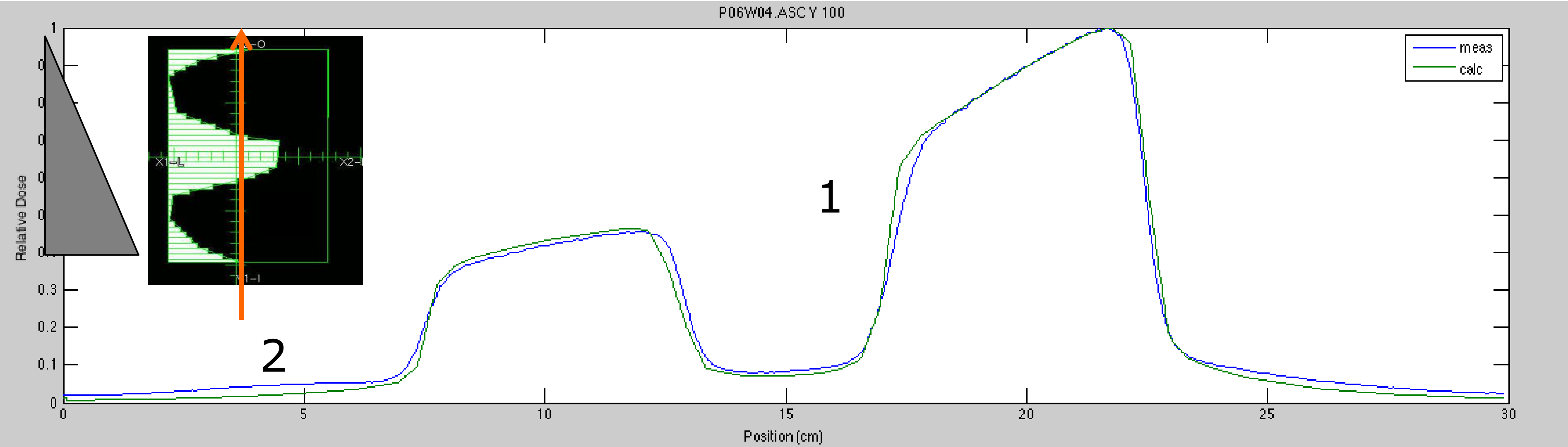
Water tank data

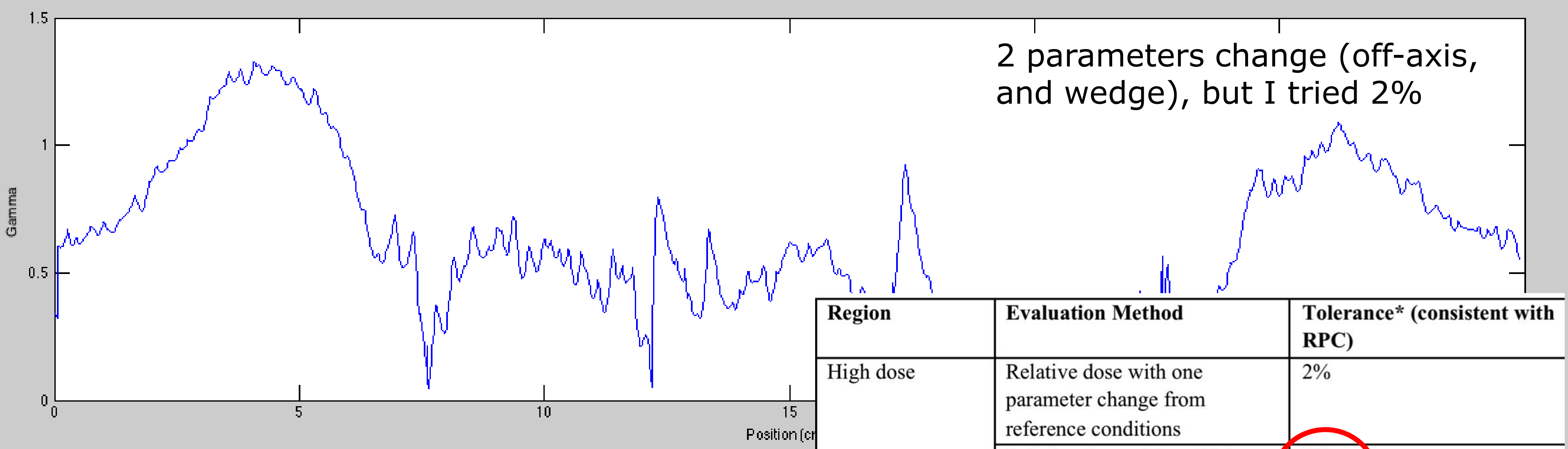
DICOM dose

Offsets come from RP



Results from Test 5.5 Large MLC:
d=10 cm inline profile for 60° wedged 6MV field, γ = 2%/3mm





Region	Evaluation Method	Tolerance* (consistent with RPC)
High dose	Relative dose with one parameter change from reference conditions	2%
	Relative dose with multiple parameter changes **	5%
Penumbra	Distance to agreement	3 mm
Low dose tail	Up to 5 cm from field edge	3% of maximum field dose

1. Problem in leaf penumbra (T&G) region
2. Problem with jaw/MLC leakage?

Results for static photons tests

- Revealed limitations with out-of-field dose modeling, but still satisfied 2%/2mm (one parameter change from calibration setup)
- Field size dependent models may be preferred but were decided against.
- Hard wedges added an enormous amount of work (extra 4 models to be verified and QA'd per beam!) – recommendation to replace with EDW
- Excellent static results but (as I will show) still fail DQA in some situations…therefore, a passing MPPG static profile analysis is necessary but not sufficient to validate for modulated (multi-segment) delivery.

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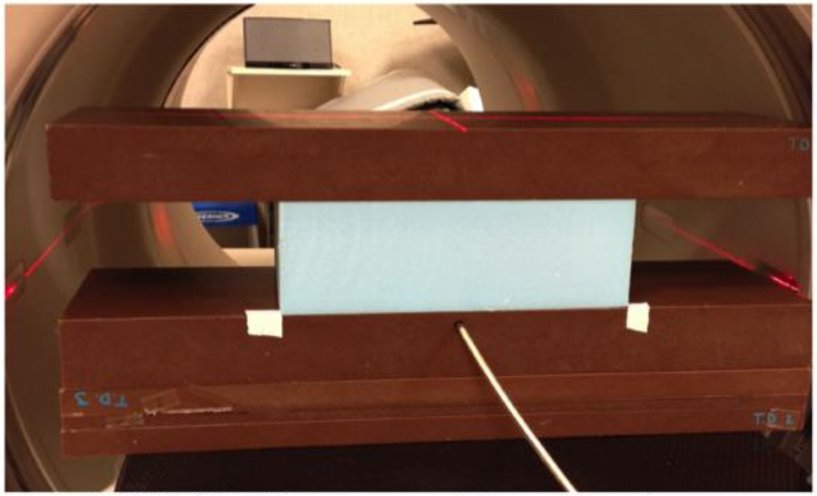
- Verify correct CT/density table and performing a simple point measurement

Section 6: Heterogeneity Corrections (C/S. MC, GBBS, no PB)

Test	Objective	Description	Tolerances*	Reference
6.1	Validate planning system reported electron (or mass) densities against known values.	CT-density calibration for air, lung, water, dense bone, and possibly additional tissue types.	--	TG 65 [23]; IAEA TRS-430 [7]
6.2	Heterogeneity correction distal ~~and proximal~~ to lung tissue	5x5 cm2, measure dose ratio above and below heterogeneity outside of the buildup region	3%	Carrasco et al. [52]

- Test 6.2 only tests beyond heterogeneity (not in, or at, boundaries, areas at which it is difficult to measure) and only low density tissue


a) UW (Solid water and Styrofoam)

b) UMSC (solid water and cork)

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- Small field measurements
- Patient specific QA
- E.g.: RTOG or IROC test

What does the MPPG recommend for small field dosimetry validation?

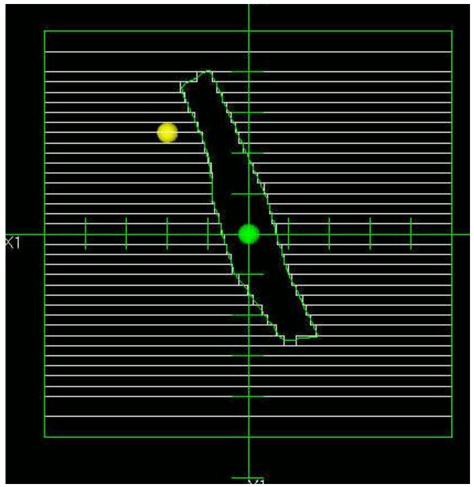
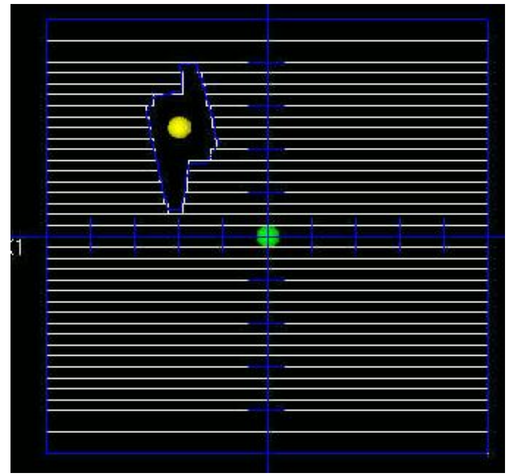
- Dosimetry for small fields is often extrapolated by TPSs. Verification measurements for small fields and MLC characteristic are recommended.
- MLC
  - Intra-leaf & inter-leaf transmission and leaf gap –large detector if an average value is specified.
  - A small chamber should be used under the leaf, and film should be used for inter-leaf leakage measurements.
- Leaf-end penumbra should be obtained with a small detector (such as a diode or micro-chamber) to avoid volume-averaging effects.
- Even if not specified by the TPS vendor, the QMP should measure percent depth dose (PDD) with a small volume detector down to a field size of 2x2 cm^2 or smaller for comparison with dose calculation.
- Small field output factors (down to 2x2 cm^2 or smaller) should be measured for beam modeling and/or verification.
- TG119 and Clinical Case IMRT QA test suite and external E2E IMRT testing.

Evaluation Criteria for IMRT/VMAT Validation

Measurement Method	Region	Tolerance
Ion Chamber	Low gradient target region	2% of prescribed dose
	OAR region	3% of prescribed dose
Planar/Volumetric Array	All regions	2%/2mm*, no pass rate tolerance, but areas that do not pass need to be investigated
End-to-End	Low gradient target region	5% of prescribed dose

*Application of a 2%/2 mm gamma criterion can result in the discovery of easily correctable problems with IMRT commissioning that may be hidden in the higher (and ubiquitous) 3%/3 mm passing rates (Opp, Nelms, Zhang, Stevens, & Feygelman, 2013).

7.2 Small MLC Defined Field OF - Pass

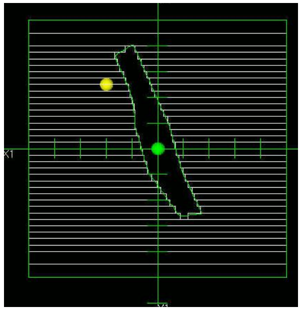



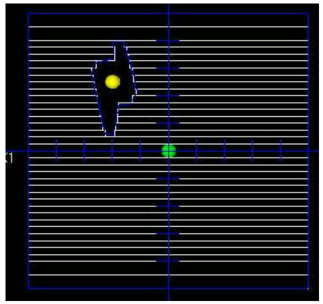
IBA EF Diode, 10 cm depth

Point dose:	Pinnacle 9.8									
Tolerance - 2% for one parameter change		measurement (nC)					Calculated (Gy)			
Field Name	**Description**	rdg 1	rdg 2	rdg 3	average	OF	Dose	OF	% diff	**Within 2 %?**
7.2_0 10MV	open	197.1	197.1	197.1	197.1		1.8			
7.2_1 10MV	banana	154.4	154.4	154.3	154.4	0.7832	1.4	0.7955	-1.57	Yes
7.2_2 10MV	bolt	154.4	154.4	154.4	154.4	0.7834	1.4	0.7784	0.63	Yes

- MPPG recommends “small field not used for commissioning”
- Passed on our new TrueBeam, but proved to be a difficult test on validation testing for “newly matched” older 21EX machines…

7.2 Small MLC Defined Field OF- failure





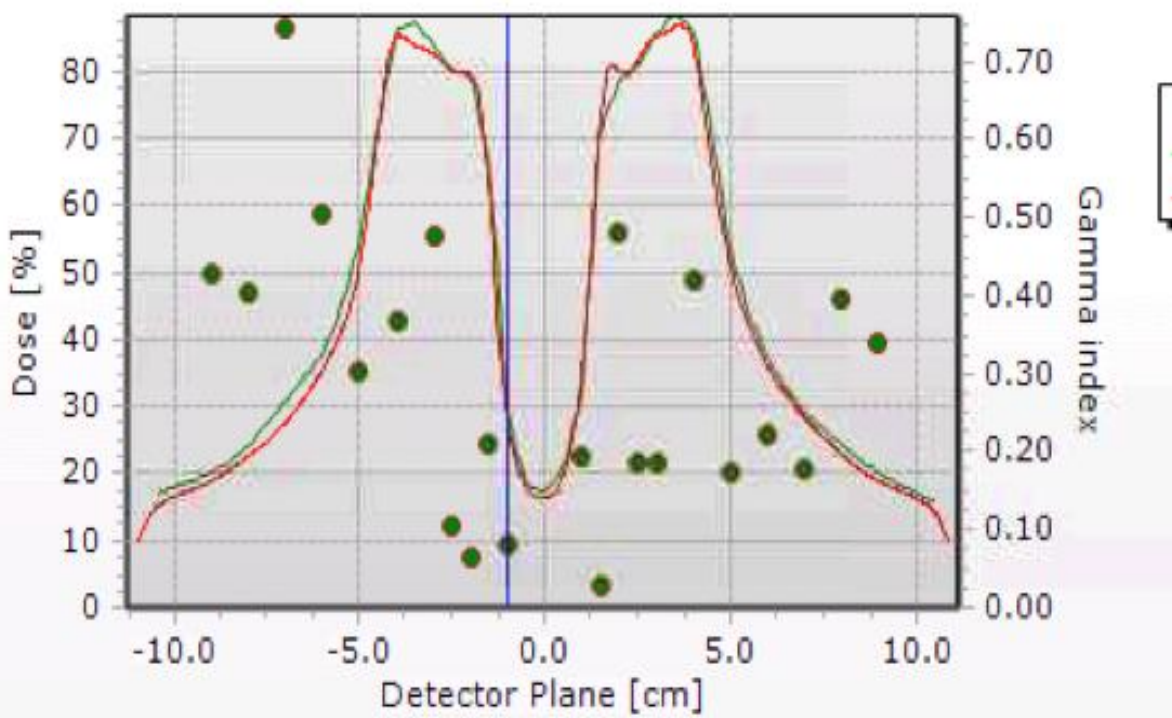
IBA EF Diode, 10 cm depth

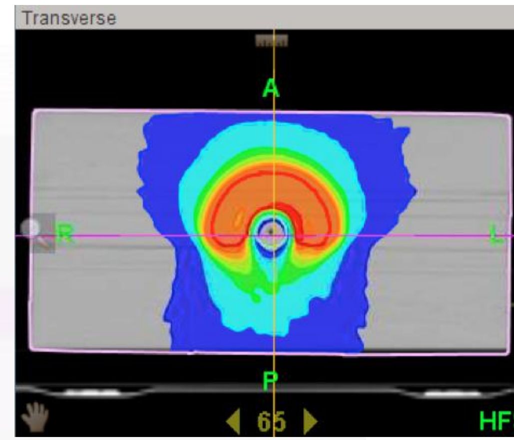
Point dose:	Pinnacle 9.8									
Tolerance - 2% for one parameter change		measurement (nC)					Calculated (Gy)			
Field Name	**Description**	rdg 1	rdg 2	rdg 3	average	**OF**	Dose	OF	% diff	**Within 2 %?**
7.2_0 06MV	open	182.4	182.5	182.5	182.5		0.795			
7.2_1 06MV	banana	146.9	146.9	146.9	146.9	0.8051	0.657	0.8264	-2.65	No
7.2_2 06MV	bolt	145.2	145.1	145.2	145.2	0.7956	0.645	0.8113	-1.98	Yes
7.2_0 10MV	open	194.8	194.7	194.7	194.7		0.880			
7.2_1 10MV	banana	158.2	158.1	158.2	158.2	0.8122	0.720	0.8182	-0.73	Yes
7.2_2 10MV	bolt	156.8	156.7	156.7	156.7	0.8049	0.708	0.8045	0.04	Yes

*updated calc data, 4/21/15, jbs

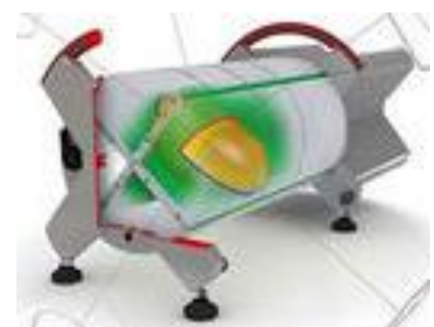
- Matched model for older machines with less well modeled MLCs (non VMAT)
- Validation fields will be recreated that are > 2 cm in all directions
- Avoid highly modulated IMRT plans with highly weighted very small segments

7.3 TG-119 (2009) Tests





- TG119 C-Shape, Tomotherapy example
- Delta4 2%2mm (global) gamma analysis
- Use only detectors with >20% signal
- Excellent results, 100% pass



7.4 Clinical Tests – Delta4 Diode Phantom

ose Measurement

		Pinnacle 9.8											
		Percent Passing										Number Failing	Comment
		Beam											
Patient	Level	01	02	03	04	05	06	07	08	09	Composite		
Test11	3%/3mm	100.0	99.4	99.0	100.0	100.0					100.0	0	Single fraction brain SRS
	2%/2mm	99.3	93.6	94.9	100.0	100.0					99.4	2	
Test12	3%/3mm	96.9	95.0	96.6	98.3	92.9	99.3	99.1		*	88.7	1	Brain, 7 field, large PTV, GBM?
	2%/2mm	87.1	84.2	85.0	95.6	80.0	97.7	91.8			71.7	5	
Test13	3%/3mm	100.0	100.0	99.4	99.5						99.5	0	4 field lung SBRT
	2%/2mm	98.1	97.8	98.9	96.8						98.5	0	
Test14	3%/3mm	99.8									99.8	0	single arc, abdomen
	2%/2mm	98.9									98.9	0	
Test15	3%/3mm	100.0	100.0								100.0	0	2 arc abdomen
	2%/2mm	99.6	99.6								99.4	0	
Test16	3%/3mm	99.7	99.6								99.5	0	Prone prostate
	2%/2mm	97.2	92.6								95.3	1	
Test17	3%/3mm	100.0	99.7								99.5	0	HN, 4 PTVs
	2%/2mm	98.8	97.4								96.2	0	
Test18	3%/3mm	100.0	100.0	100.0	100.0	100.0	100.0				100.0	0	6 beam, large lung PTV
	2%/2mm	100.0	100.0	99.7	100.0	100.0	100.0				99.4	0	
Test19	3%/3mm	99.4	99.9								99.3	0	Prostate with nodes
	2%/2mm	95.9	97.0								95.2	0	
Test20	3%/3mm	100.0	100.0	99.9	99.8						99.5	0	Brain with hippocampal sparing
	2%/2mm	99.1	99.4	98.6	98.1						97.4	0	

***Further investigation revealed that this plan pushed the limits of deliverability in terms of small segment size and large beam quantity (MU) combinations**

Thoughts from IMRT/VMAT tests

- In Pinnacle, we found that one could get excellent profile fits and still not have passing standard IMRT QA.
- Due to suitable choice of Gaussian Width and Gaussian Height parameter values, was well as MLC transmission and additional interleaf leakage.
- Iterated several times until we got passed DQA, then re-ran the static beam calculations.
- Therefore, a passing MPPG static profile analysis is necessary but not sufficient to validate for modulated (multi-segment) delivery.
- For our matching linac exercise, we opted for more clinical cases in lieu of doing all TG 119

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8. Electrons	8.1-8.2 Electron basic tests and obliquity tests
	8.3 Electron heterogeneity correction

- Use MatLab code
- Same as photon

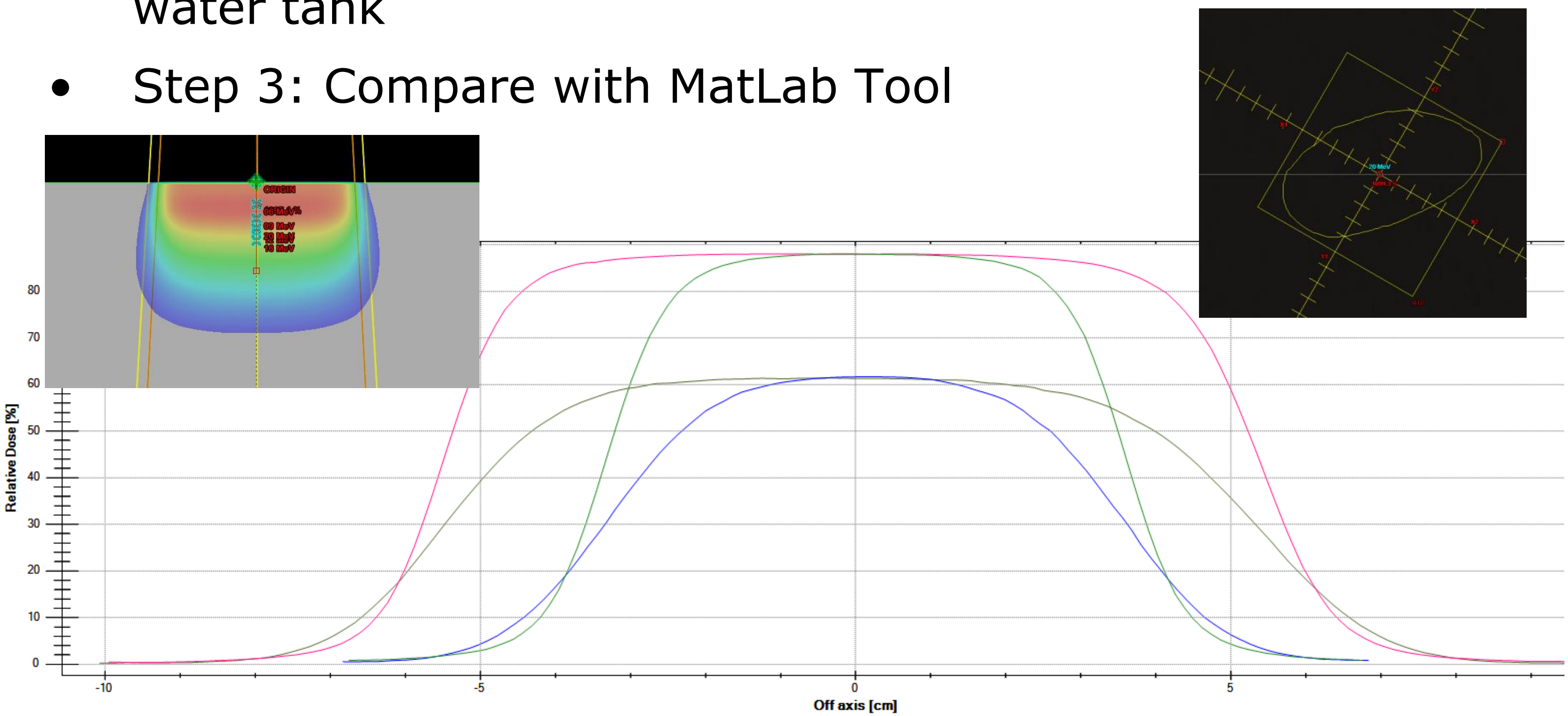
Tolerances levels for electron beam validation

Table 9: Basic TPS validation tests for electron beams and minimum tolerance values

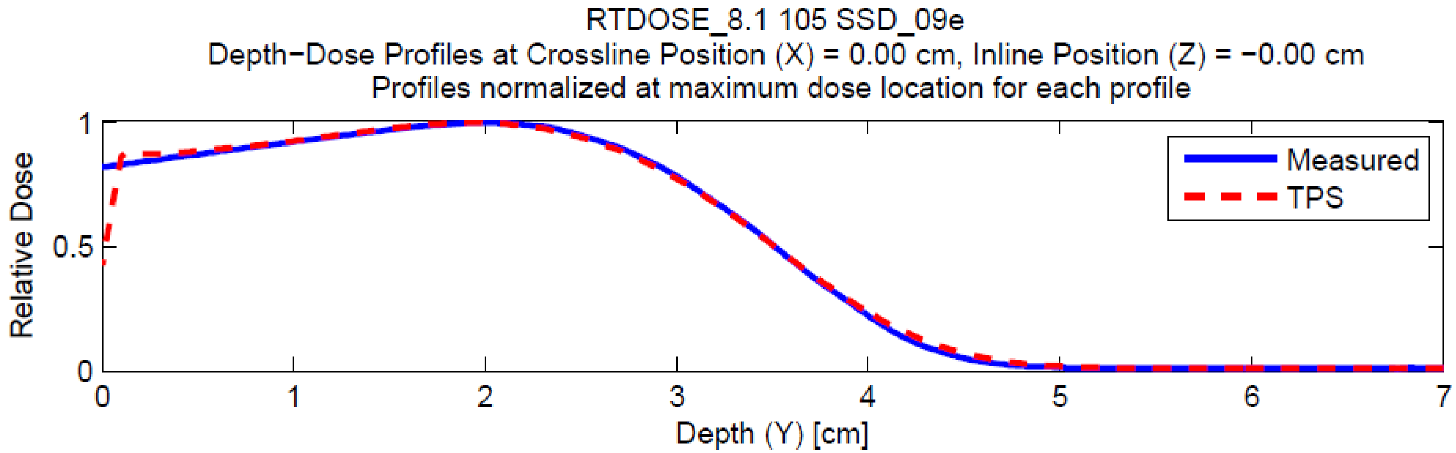
Test	Objective	Description	Tolerance
8.1	Basic model verification with shaped fields	Custom cutouts at standard and extended SSDs	3%/3 mm
8.2	Surface irregularities-obliquity	Oblique incidence using reference cone and nominal clinical SSD	5%
8.3	Inhomogeneity test	Reference cone and nominal clinical SSD	7%

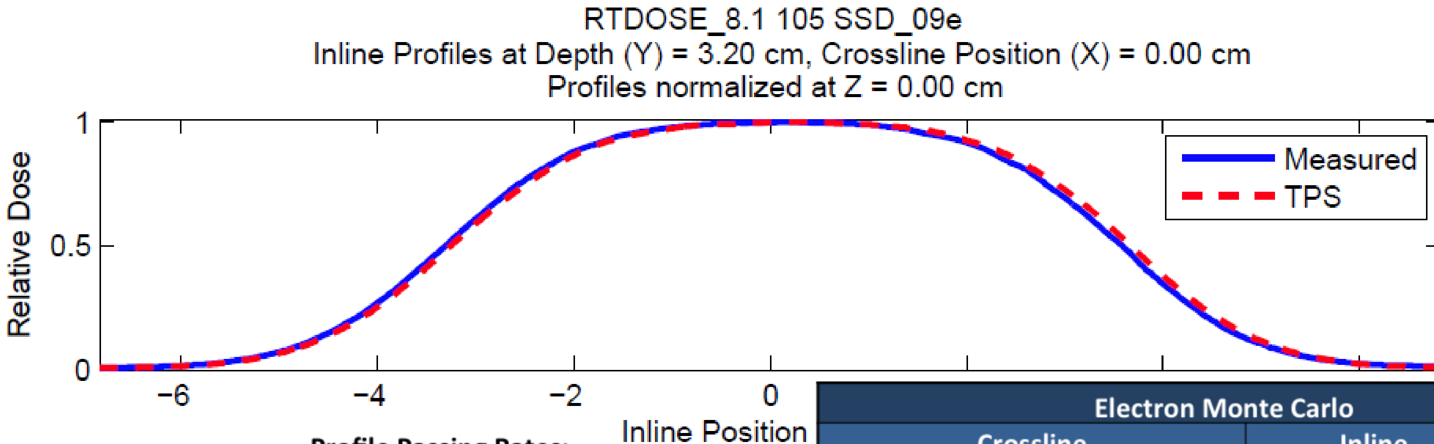
Test 8.1: Custom Cutout

- Step 1: Create and compute beams in TPS
  - 10x10 applicator with custom cutout, 100 SSD & 105 SSD
- Step 2: Measure PDD and profiles with CC04 chamber in water tank
- Step 3: Compare with MatLab Tool



Test 8.1: Custom Cutout





Profile Passing Rates:

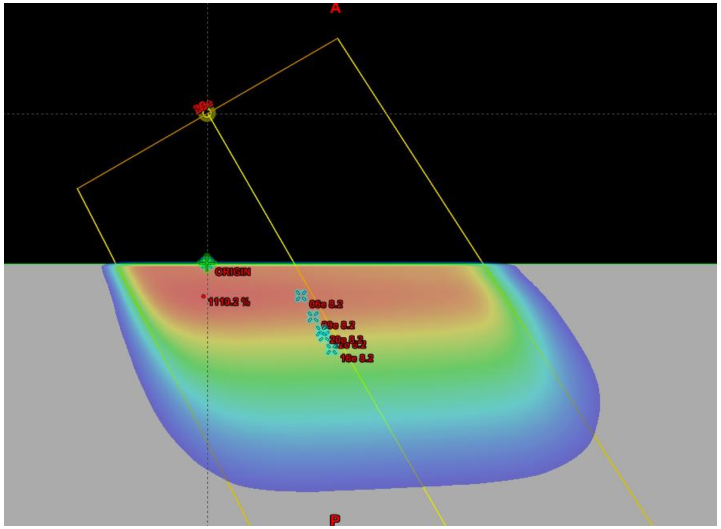
Criteria: 3%/3mm Global

		Electron Monte Carlo				
		Crossline		Inline		PDD
		Depth 1	Depth 2	Depth 1	Depth 2	
8.1 105 SSD	06e	90.7	100.0	100.0	92.8	96.0
8.1 105 SSD	09e	100.0	97.6	100.0	100.0	98.6
8.1 105 SSD	12e	100.0	100.0	100.0	100.0	98.9
8.1 105 SSD	16e	100.0	100.0	100.0	100.0	99.2
8.1 105 SSD	20e	100.0	95.1	100.0	100.0	99.1

Results from MUSC, courtesy of Dustin Jacqmin

Test 8.2: Oblique Beam Incidence

- 10x10 applicator with standard cutout, 105 SSD, 30° obliquity, 3%/3mm gamma



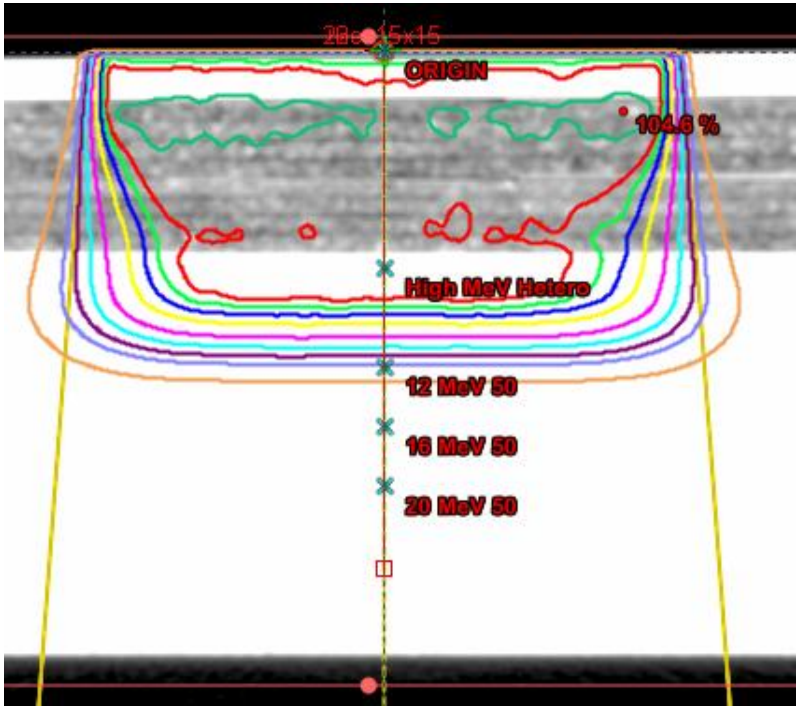
Profile Passing Rates:

Criteria: 3%/3mm Global

		Electron Monte Carlo					
		Crossline		Inline		PDD	Diagonal
		Depth 1	Depth 2	Depth 1	Depth 2		
8.2 105 SSD	06e	100.0	100.0	95.9	88.0	97.7	98.1
8.2 105 SSD	09e	100.0	100.0	100.0	100.0	98.7	98.7
8.2 105 SSD	12e	100.0	100.0	100.0	100.0	98.7	98.7
8.2 105 SSD	16e	100.0	100.0	100.0	100.0	99.0	99.0
8.2 105 SSD	20e	100.0	100.0	100.0	100.0	99.2	99.2

Test 8.3: Heterogeneity Correction

- 15x15 open applicator
- 100 SSD
- Dose near **depth of maximum dose** and **50% isodose line**



	Measurements near Dmax in Heterogenity Phantom						Electron Monte Carlo		
Energy	Depth	T	P	M	M_{corr}	Rel. Dose	Calc Dose.	Rel. Dose	% Diff
6 MeV	2	23.4	768	-3.749	-3.728	0.978	193.3	0.974	-0.46%
9 MeV	3.5	23.4	769	-3.766	-3.740	0.975	191.2	0.958	-1.77%
12 MeV	5.5	23.4	769	-3.657	-3.631	0.938	186	0.932	-0.60%
16 MeV	5.5	23.4	769	-3.765	-3.739	0.949	186.7	0.934	-1.57%
20 MeV	5.5	23.4	769	-3.847	-3.820	0.944	188.3	0.946	0.18%

Routine QA

- Why:
  - ensure TPS has not been unintentionally modified
  - Dose calculation is consistent with any TPS upgrades
- When: Annually or after major TPS upgrades
- Reference plans selected at the time of commissioning and re-calculated for routine QA comparison.
  - Photons: representative plans from validation tests
  - Electrons: for each energy use a heterogeneous dataset with reasonable surface curvature.
- No new measurements required!
- The routine QA re-calculation should agree with the reference dose calculation to within 1%/1mm. A complete re-commissioning (including validation) may be required if more significant deviations are observed.

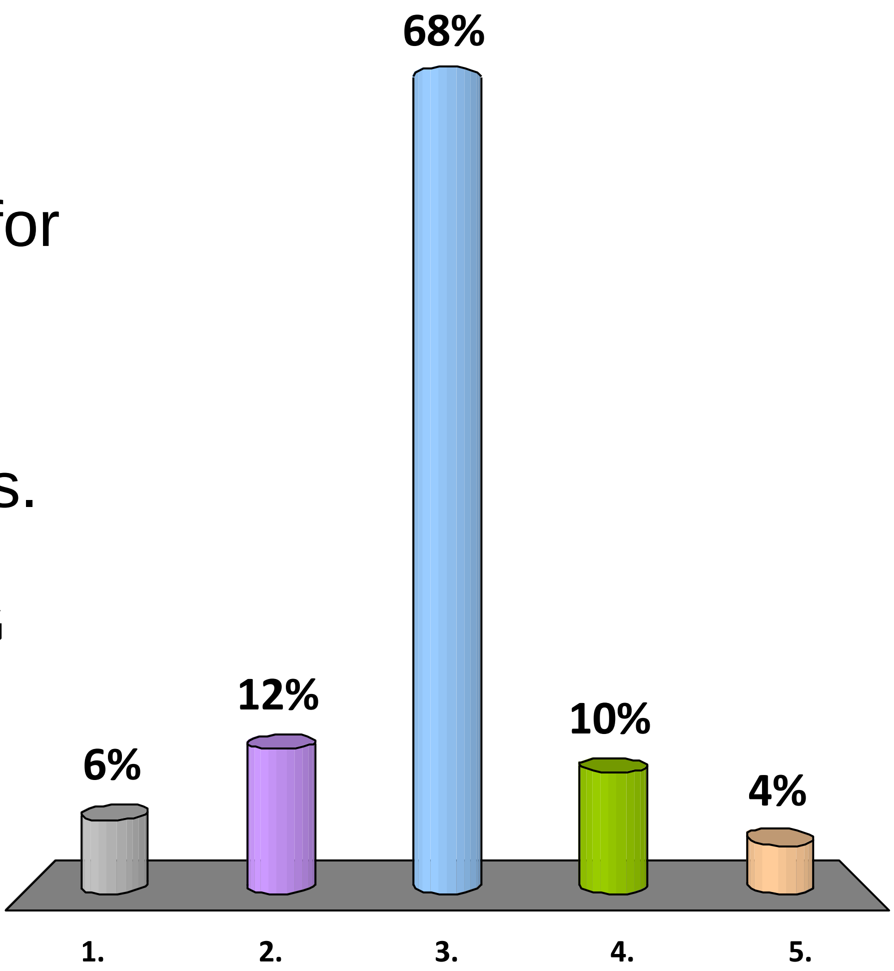
Conclusion

- Do-able, well organized approach to dose calculation validation
- Creation of robust infastructure so you can re-use tests, measurements and analysis tools for routine QA and/or upgrade validation.
- MPPG #5 will have a webpage with downloadable datasets if a center did not want to use create their own test cases.
- Fills the space between commissioning and patient DQA and routine machine QA
- Thanks to Jeremy Bredfelt, Sean Frigo and Dustin Jacqmin (co-authors of implementation manuscript)
- Many thanks to UW and MUSC clinical physics groups for help on validation tests!

- Thanks for your attention!

Why does MPPG #5 recommend 2%/2mm gamma analysis criteria for IMRT/VMAT TPS validation?

1. 1%/1mm is not clinically achievable.
2. 2%/2 mm is the current standard in the literature for patient specific QA.
3. 2%/2 mm criteria can highlight commissioning and/or planning limitations.
4. 2%/2 mm is the existing recommendation from TG 53.
5. 3%/3 mm is the recommendation from accrediting bodies



Why does MPPG #5 recommend 2%/2mm gamma analysis criteria for IMRT/VMAT TPS validation ?

1. ~~1%/1mm is not clinically achievable~~

In many cases 1%/1mm is possible, and can be used to further stress the system.

2. ~~2%/2 mm is the current standard in the literature for patient specific QA~~

The literature does not report a standard for patient specific QA

3. A 2%/2 mm criteria can highlight commissioning and/or planning limitations.

4. ~~2%/2 mm is the existing recommendation from TG 53~~.

TG 53 did not address IMRT/VMAT analysis

5. ~~3%/3 mm is the recommendation from accrediting bodies~~

Accrediting bodies do not require limits on IMRT/VMAT analysis

- AAPM MEDICAL PHYSICS PRACTICE GUIDELINE 5. a.:Commissioning and QA of Treatment Planning Dose Calculations: Megavoltage Photon and Electron Beams (anticipated JACMP September 2015)
  - **Section 7.b:**"Planar or volumetric measurements (film or an electronic array with appropriate effective resolution) should be evaluated with 2%/2 mm gamma analysis to emphasize areas of disagreement. Application of a 2%/2 mm gamma criterion can result in the discovery of easily correctable problems with IMRT commissioning that may be hidden in the higher (and ubiquitous) 3%/3 mm passing rates.[39]"

- Opp, D, B E Nelms, G Zhang, C Stevens, and V Feygelman. "Validation of measurement-guided 3D VMAT dose reconstruction on a heterogeneous anthropomorphic phantom." *J. Appl. Clin. Med. Phys.* 14, no. 4 (Jul 2013): 4154.

The MPPG recommended testing condition for heterogeneity correction:

31%	1.	Beyond low density material, 5x5 cm2 field
26%	2.	Beyond low density material, 10x10 cm^2 field
19%	3.	Beyond high density material, 5x5 cm^2 field
17%	4.	Within low density material, 10x10 cm^2 field
6%	5.	Within high density material, 5x5 cm^2 field

The MPPG recommended testing condition for heterogeneity correction:

1. Beyond low density material, 5x5 cm^2 field
2. ~~Beyond low density material, 10x10 cm^2 field~~

5x5 cm^2 is recommended because errors tend to be exacerbated at small fields

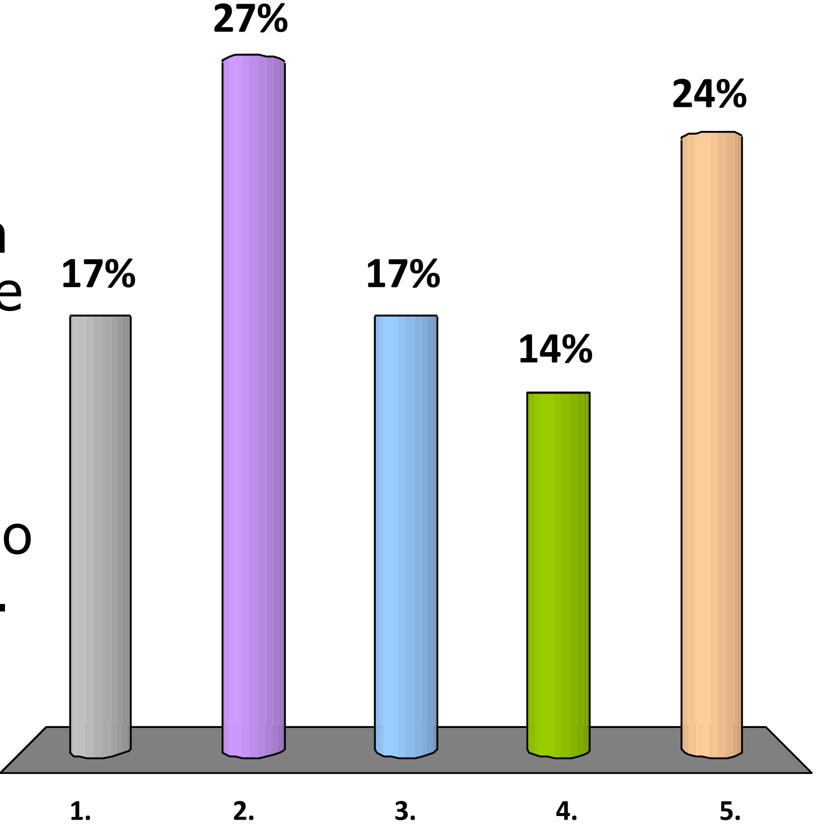
3. ~~Beyond high density material, 5x5 cm^2 field~~
4. ~~Within low density material, 10x10 cm^2~~
5. ~~Within high density material, 5x5 cm^2~~

Only simple testing beyond beyond low density heterogeneity is recommended. Further tests deemed appropriate by the QMP to challenge the accuracy of the particular calculation algorithm being employed should be used to bring a better understanding of the limitations of dose calculation in the vicinity of heterogeneities.

- AAPM MEDICAL PHYSICS PRACTICE GUIDELINE 5. a.:Commissioning and QA of Treatment Planning Dose Calculations: Megavoltage Photon and Electron Beams (anticipated JACMP September 2015) Section 6:
  - Measurements should be made outside of the buildup/builddown regions.[25] This simple test allows for the direct study of the calculation accuracy through the heterogeneity.
  - The recommended field size is 5 × 5 cm^2 because discrepancies due to low-density material tend to be exacerbated at smaller field sizes.
  - Further tests deemed appropriate by the QMP to challenge the accuracy of the particular calculation algorithm being employed should be used to bring a better understanding of the limitations of dose calculation in the vicinity of heterogeneities.

Which of the following is NOT recommended by MPPG 5 for small field dosimetry validation?

1. PDD measurement with a small volume detector down to a field size of 2x2 cm2 or smaller.
2. Film should be used for inter-leaf leakage measurements.
3. Small field output factors (down to 2x2 cm^2 or smaller) should be measured for beam modeling and/or verification.
4. Leaf-end penumbra should be obtained with a small detector to avoid volume-averaging effects.
5. External validation, such as IROC OSL, should be used for small field size validation.



Which of the following is NOT recommended by MPPG 5 for small field dosimetry validation?

1. ~~PDD measurement with a small volume detector down to a field size of 2x2 cm^2 or smaller.~~
2. ~~Film should be used for inter-leaf leakage measurements.~~
3. ~~Small field output factors (down to 2x2 cm^2 or smaller) should be measured for beam modeling and/or verification.~~
4. ~~Leaf-end penumbra should be obtained with a small detector to avoid volume-averaging effects.~~

Items 1-4 are the recommendations of the MPPG.

5. External validation, such as IROC OSL, should be used for small field size validation.

External validation is only recommended for end-to-end testing for IMRT/VMAT planning, not small field dosimetry.

Small field validation

- AAPM MEDICAL PHYSICS PRACTICE GUIDELINE 5. a.:Commissioning and QA of Treatment Planning Dose Calculations: Megavoltage Photon and Electron Beams (anticipated JACMP July 2015) **Section 7**

- The QMP should measure output factors down to a field size of 2 x 2 cm^2 (and preferably smaller) for a clinically relevant depth, then compare the measured results to the treatment planning system calculations .
  Followill, D S, et al. "The Radiological Physics Center's standard dataset for small field size output factors." J. Appl. Clin. Med. Phys. 13, no. 5 (Aug 2012): 3962.