
# BEAM MODEL VALIDATION

RayStation 11B

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# PREAMBLE

- Described methodology in this presentation is only a proposition from RaySearch Labs.

**WARNING!**

**Beam models must be validated before clinical use.** It is the responsibility of the user to validate and commission all beam models before they are used to create clinical treatment plans.



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# SUMMARY

- Quality of a photon beam model with respect to measurements is depending on several parameters
- The modification of one parameter can have consequences on others
  - For example the MLC transmission with Tongue&Groove and Leaf-Tip width
- A certain order in the control of the different techniques must be respected in order to work efficiently and in the end not to use some aberration values to permit to have good VMAT QA results
- This presentation is not a magic recipe, some points may be contradicted depending on particular situations
  - *It won't help if the data used for beam modeling are not appropriate.*
- QA device and software settings (%/DTA for Gamma index comparison, isodose threshold, dose grid size, etc.) should be similar to daily practice



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# INTRODUCTION

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# WORKFLOW

- A correct validation process should valid the complexity step by step…


- …where each technique will validate some part of the beam model
- At the end if you have good results for a VMAT QA but not for 3D-CRT, something is wrong!



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# WORKFLOW – TIPS&TRICKS

- In *RayStation*, do the computation directly on the phantom CT instead of using the QA preparatory tool: you will be able to use the capability of *Beam 3D Modeling* to recompute dose with an uncommissioned machine
- *Beam 3D Modeling* is capable to recompute a dose planning from other TPS, if all mechanical parameters are identical between both
  - A first step of the beam model validation could be to compare dose distribution for real and QA-quality known patients

# 3D-CRT

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# 3D-CRT

| | |
|---|---|
| ANT 10*10 FS | • Calibration of the detector vs linac<br>• Out-of-field dose |
| ANT realistic MLC+jaws collimated field (ie prostate case) | • MLC transmission |
| 10*10 at 45°/90°/135°/180°/215°/etc. | • Detector ability to correct its response due to beam obliquity (2D detector)<br>• Couch model |
| 2*2/5*5/…/25*25 FS | • Output factor |
| Realistic dose planning (5-7 fields prostate for example) | • 3D-CRT technique validated for treatment |



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# 3D-CRT

- Instead of simple square fields, MLC+jaws with a realistic collimation can be used
- If wedges are modeled for the machine, a realistic treatment plan can be added
- Each type of detector (ion chamber, diodes, diamond, etc.) has a different sensibility regarding out-of-field dose. Depending on the detector, you used for measuring the MLC or jaws transmission you might have discrepancies compared to your 2D/3D array results
  - *2D/3D array will be used for daily control and so, will be your « reference » for further controls so out-of-field dose should match with this detector*
  - Transmission factor can be modified but don't multiply by 1,5 or 2
    - *3D-CRT treatment can pass, but it will have a huge impact for DMLC/VMAT plans*
  - Changing the effective distance of the flattening filter can help to modify the out-of-field dose
    - *Be careful with the symmetry of this parameter: same effect for X and Y profiles in contrast to Y-jaw transmission factor and so on…*



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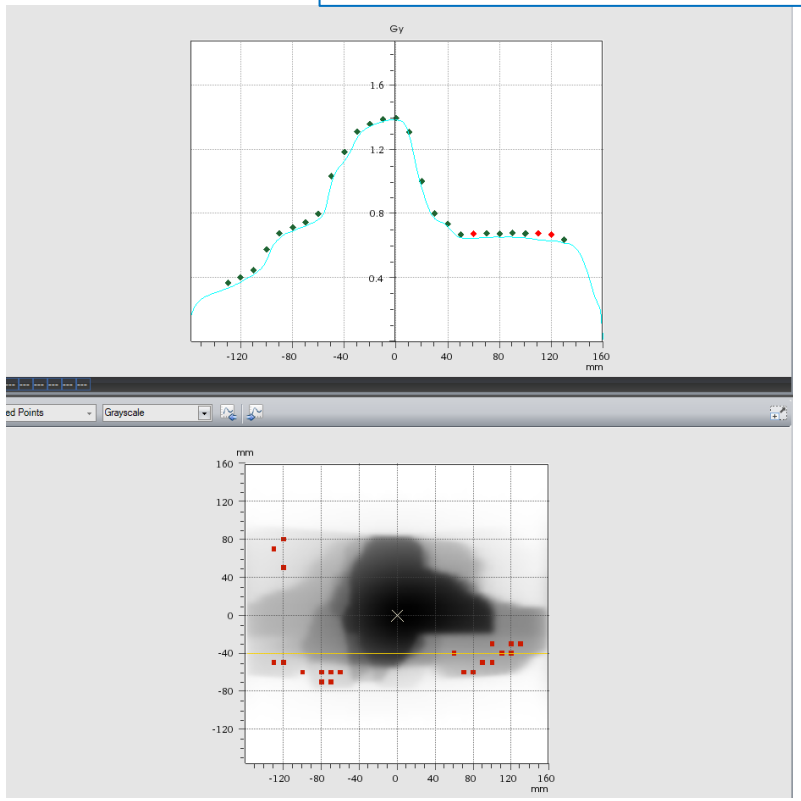
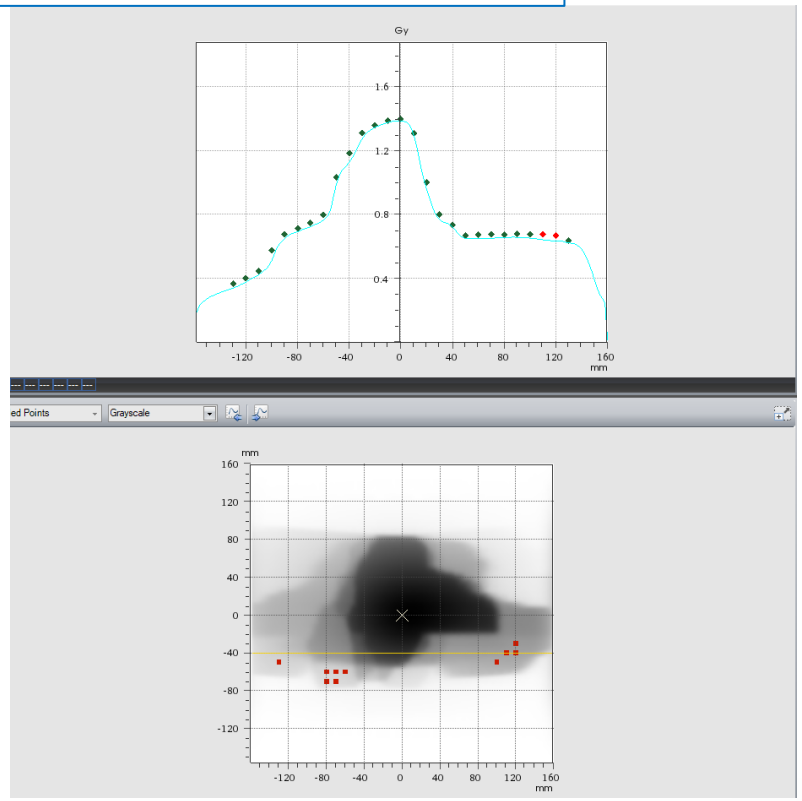
# 3D-CRT

Impact of the FF effective distance to modify out-of field dose (Gamma index 3%/3mm, local, threshold 10%)




*FF Effective distance = 13 cm*




*FF Effective distance = 21 cm*

/!\ MLC transmission must be checked first!



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# IMRT – STEP & SHOOT (SMLC)

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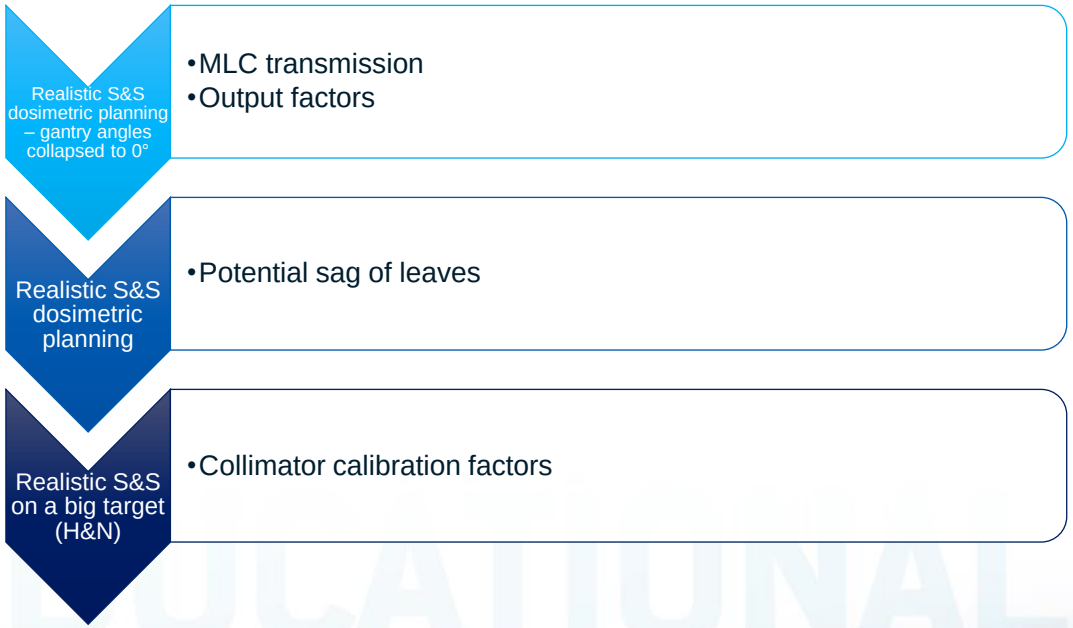
# IMRT – STEP&SHOOT

- In theory everything should go well if the beam model showed good results for 3D-CRT plans
  - As S&S is a static technique, it can be considered « just » like 3D-CRT but with a lot more fields
- The increase of the number of fields with complex MLC shape will permit to finetune the MLC transmission



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# IMRT – STEP&SHOOT

- In the case of complex segmentation on a large target (head&neck for example), dose discrepancies can be found because of a not-sufficiently precise collimator calibration
  - Perform deeper analysis by comparing small fields or fences (1 or 2 cm wide) at high off-axis distance (from -15 cm to +15 cm for example)

# CONFORMAL ARC

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# CONFORMAL ARC

- Validating Conformal arc technique will ensure the correspondence between RayStation and the linac when the gantry is rotating, which is also necessary for VMAT technique
- Conformal arc technique is usually used for spherical lesions (i.e., mets) when the user doesn't want intensity modulation or to avoid interplay effects for lung localizations
  - MLC segmentation is not complex
- Conformal arc is often used for SRS treatment, i.e., irradiating with very high dose. Arc properties (min gantry angle speed, min MU per gantry degree) will influence the capability to send a large number of MUs per arc

**Conformal arc treating spherical target**

- Couch model
- Linac feasibility for rotational treatment

**Conformal Arc treating spherical target at higher/lower dose**

- To test the linac with other dose rate
- Min/max dose MU threshold per arc



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# IMRT – DMLC

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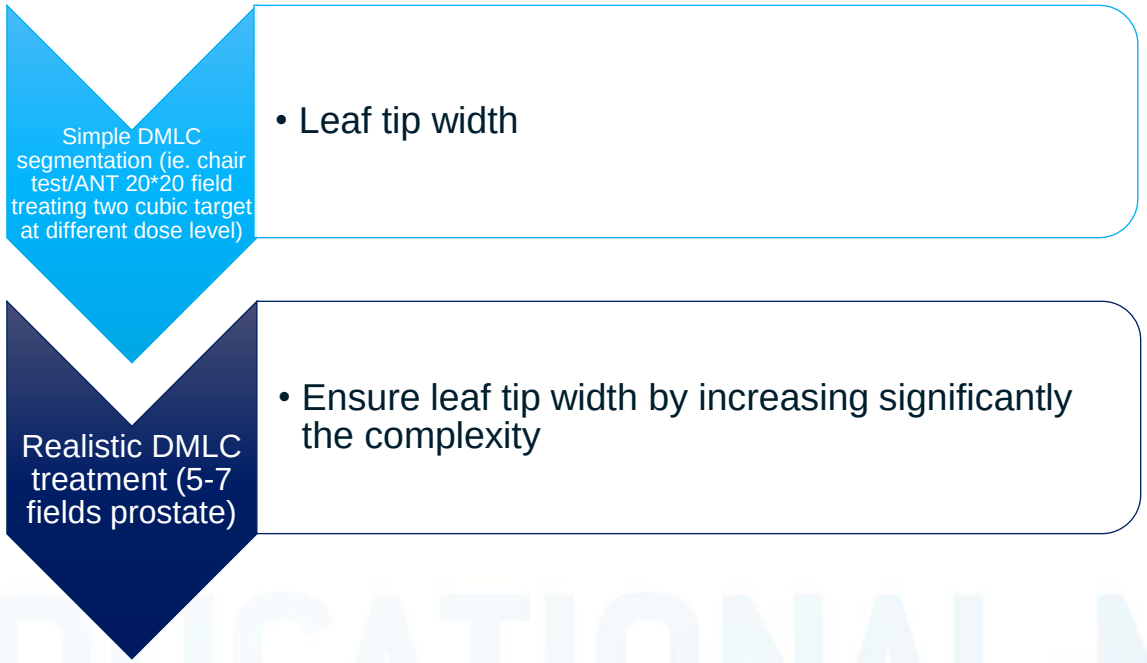
# IMRT – DMLC

- DMLC technique will add MLC movements during irradiation. However, the RayStation optimizer tends to make a one-way travel for the MLC (ie from right to left or the contrary)
  - If MLC leaves are +/- parallel, Leaf Tip width will have the biggest impact (compared to tongue & groove)



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# IMRT – DMLC

- Start from the value of the leaf tip measured by the methodology proposed in the *”7 - MLC modeling in RayStation.pdf”* presentation and modify it step by step in order to find the optimum value
  - A wrong leaf tip width is easily visible: it will over/under-dose your target if it is too small/big
  - The physical length can also be used in first intention
- Other methods exist in the literature, for example Saez et al “A novel procedure for determining the optimal MLC configuration parameters in TPS based on measurements with a Farmer chamber”
  - Test fields for this method can be provided by Raysearch Labs
  - Results from Saez et al studies are used in machine template since 10A

- Modifying the MLC transmission will have an impact on the leaf tip effect (because $\sqrt{T}$ is used)
  - It will have an impact on every technique previously validated, modify it at your own risk!



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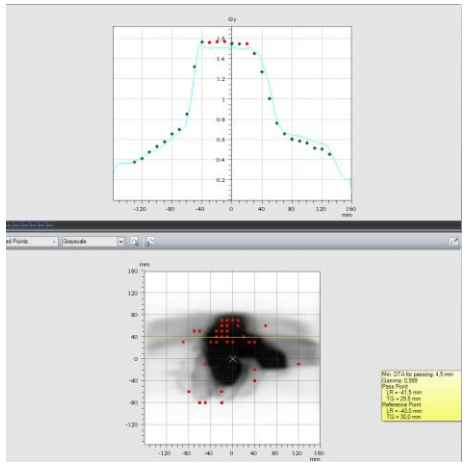
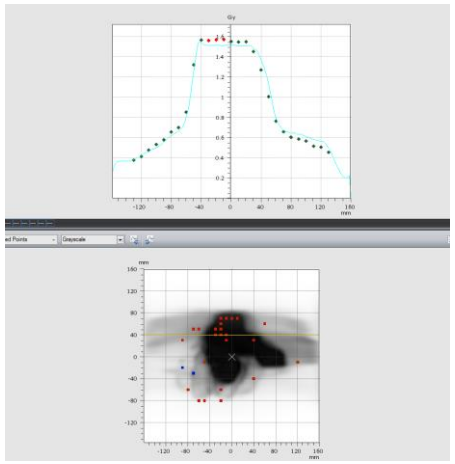
# DMLC

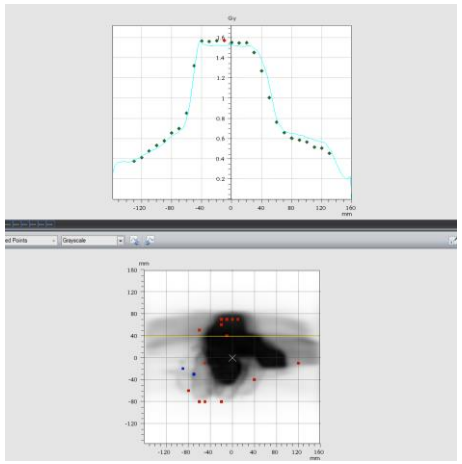
Impact of the leaf-tip width to modify in-field dose, then out-of field dose when too high (Gamma index 3%/3mm, local, threshold 10%)



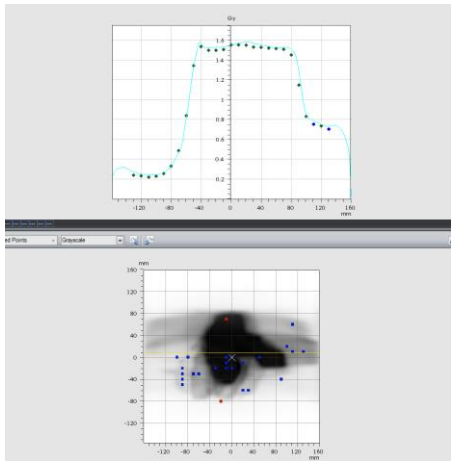
*Leaf-Tip width 0,08 cm*



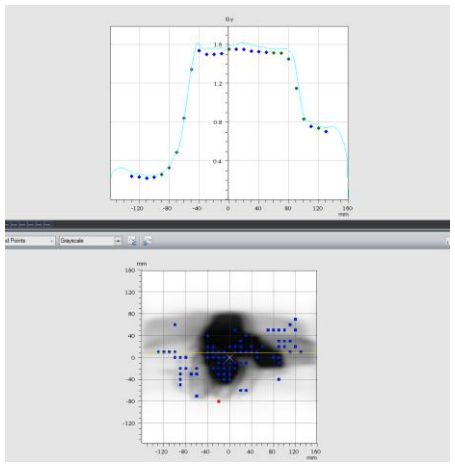
*Leaf-Tip width 0,10 cm*



*Leaf-Tip width 0,13 cm*



*Leaf-Tip width 0,15 cm*



*Leaf-Tip width 0,3 cm*

/!\ These results are for a specific beam model, LT width may not be applicable to your machine due to other parameter values (MLC transmission among others).



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# VMAT

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# VMAT

- VMAT technique is bringing rotation of the arm during a DMLC treatment, but also dose rate modification is possible
  - Depending on how the linac interprets data from TPS, the linac can modify the arm speed instead of the dose rate
- In theory, the last parameter which hasn't been tuned and has an impact on VMAT is the tongue & groove distance
  - Start from the value of the tongue & groove measured by the methodology proposed in the *"7 - MLC modeling in RayStation.pdf"* presentation and modify it step by step in order to find the optimum value



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# VMAT – PRO-TIP

- For Varian users who don’t have the linac RapidArc license, a VMAT treatment with fixed dose rate is considered as a conformal arc from the machine point of view. It can be set in Rayphysics and so give the opportunity to achieve *almost-as-good-as* VMAT treatment.

# VMAT

- Because the T&G effect is located on leaf edges, the impact of it is dependent on how much leaves are going « in » and « out » the target volume
  - It’s thus difficult to know in advance the impact of it, and the effect after modification (under/over dosage)
  - Only complex segmentation will show the impact of the T&G effect

| | |
|---|---|
| Simple VMAT realistic case, ie prostate | • Ensure your beam model is ready for simple but common localization |
| Realistic H&N with integrated boost | •Optimize T&G width, verify MLC parameters offset/gain/curvature for complex segmentation |
| Realistic VMAT breast+nodes treatment | •Ensure your beam model is ready for large target volume and complex segmentations |



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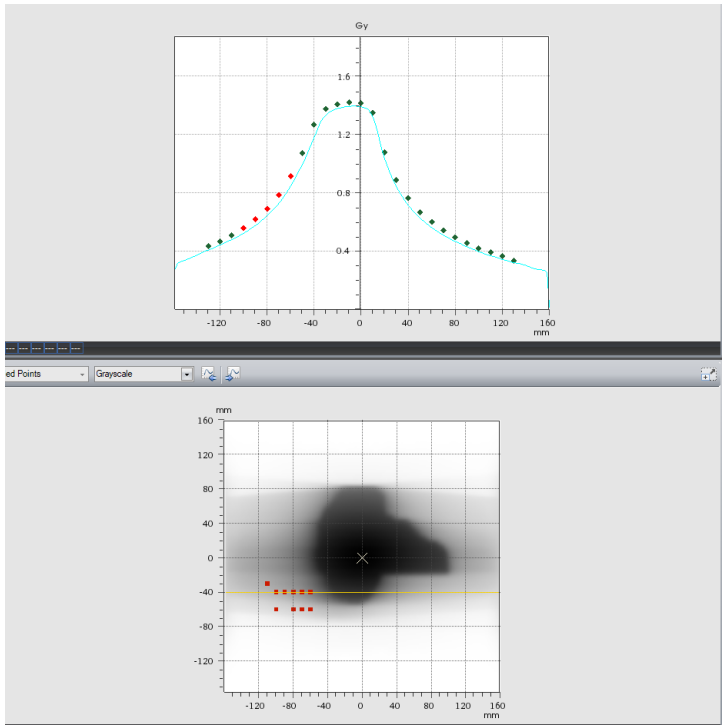
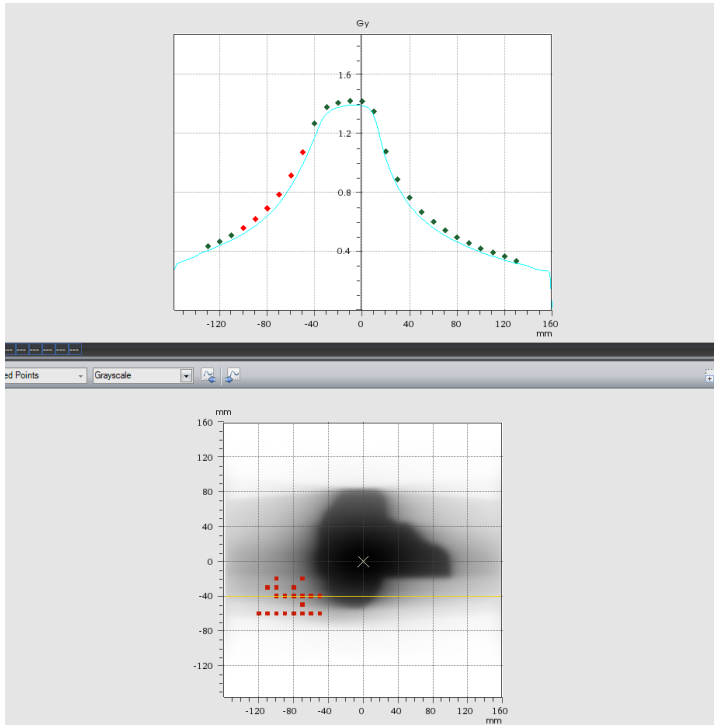
# VMAT

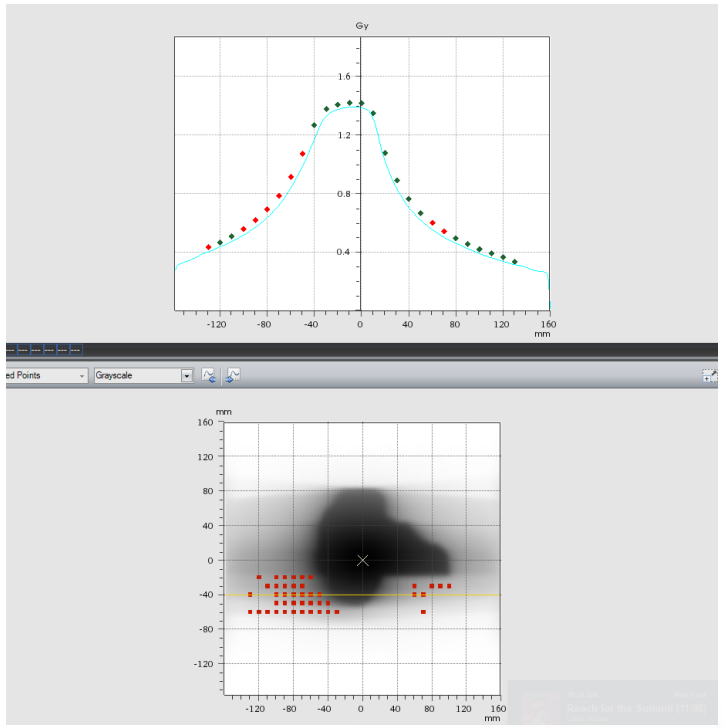
Impact of the T&G width (Gamma index 3%/3mm, local, threshold 10%)




*T&G 0,025 cm*




*T&G 0,045 cm*




*T&G 0,065 cm*



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# LITERATURE

JOURNAL OF APPLIED CLINICAL MEDICAL PHYSICS

AAPM Reports & Documents | Open Access

## AAPM Medical Physics Practice Guideline 5.a.: Commissioning and QA of Treatment Planning Dose Calculations — Megavoltage Photon and Electron Beams

Jennifer B. Smilowitz, Indra J. Das, Vladimir Feygelman, Benedick A. Fraass, Stephen F. Kry, Ingrid R. Marshall, Dimitris N. Mihailidis, Zoubir Ouhib, Timothy Ritter, Michael G. Snyder, Lynne Fairobent

First published: 08 September 2015 | https://doi.org/10.1120/jacmp.v16i5.5768 | Citations: 85

QMP as defined in AAPM Professional Policy 1. Definition of a Qualified Medical Physicist. Available from: http://www.aapm.org/org/policies.

IROC Houston (formerly the Radiological Physics Center, RPC) has a long history of conducting TPS validation-style tests at a wide range of institutions in support of clinical trials. Tolerances referred to in this document from IROC Houston are based primarily on empirically achievable agreement between TPS calculations and point doses measured with ion chambers during on-site audits by IROC Houston.

File integrity checksums use a computation algorithm that can periodically be run on a set of files to verify that their contents have not been altered. For TPS, checksums are run on all executable, library, and other configuration or database content that is used for dose calculation.

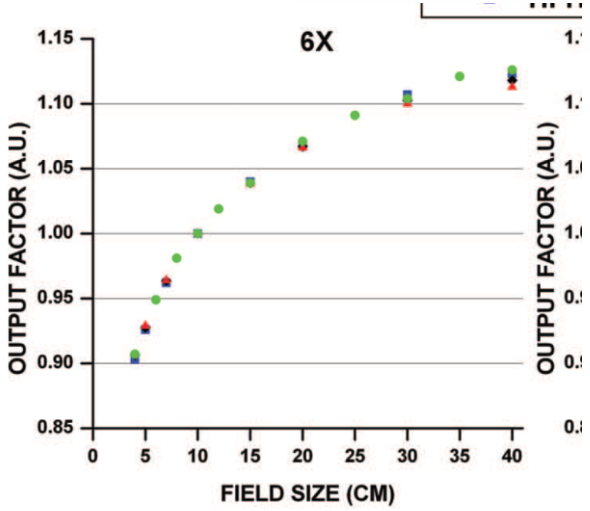
# SHARE MODELS

- Double-check all machine parameters
  - Leaf width, leaf speeds etc.
- Replace beam data, output factors, absolute calibration
  - Remember measurement conditions.
  - Adjust beam model normalization. If large field OFCs are very different, have a look at BPC.
  - Recompute. Is the match similar/good?
- Expect variations in offset
  - DLG variations by [Ghazal], [Glide-Hurst] are similar to variations found in beam models by [Glenn].
- Example fresh from the press

Frigo et al. Interinstituational beam model portability study in a mixed vendor environment, Rad. Onc. Phys. 2021, 1-14.

Glide-Hurst et al, Multi-institutional commissioing of five TrueBeam linear accelerators, Med. Phys. 40 (2013). 031719-1

| | Dosimetric leaf gap Mean ± StDev (mm) |
|---|---|
| 6X FFF | 1.16 ± 0.22 |
| 6X | 1.33 ± 0.23 |
| 10X FFF | 1.44 ± 0.30 |
| 10X | 1.57 ± 0.24 |
| 15X | 1.61 ± 0.26 |




Ghazal et al, Dosimetric and mechanical equivalency of Varian TrueBeam linear accelarators, Journal of Appl. Clin. Med. Phys. 21 (2020). 1- 11.

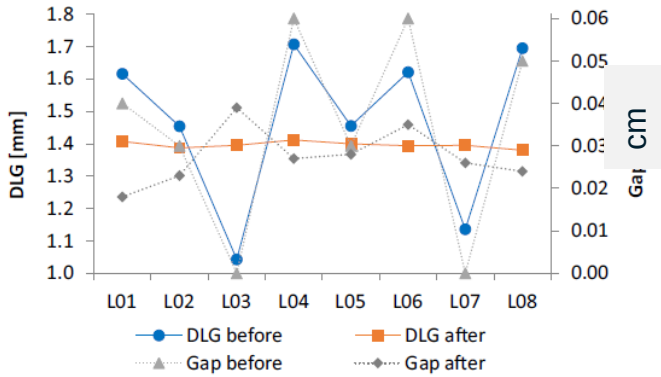



FIG. 5. DLG values for 6 MV beams before and after calibration, with corresponding Gap values for eight linacs (L01–L08). The connecting lines are illustrative.

Glenn et al. Reference dataset of users photons beam modeling parameters for the Eclipse, Pinnacle and RayStation treatment planning systems, Med. Phys. 47. (2929) 282.



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# THANK YOU!

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