MLC MODELING IN RAYPHYSICS

RayStation 11B

ADVANCING CANCER TREATMENT

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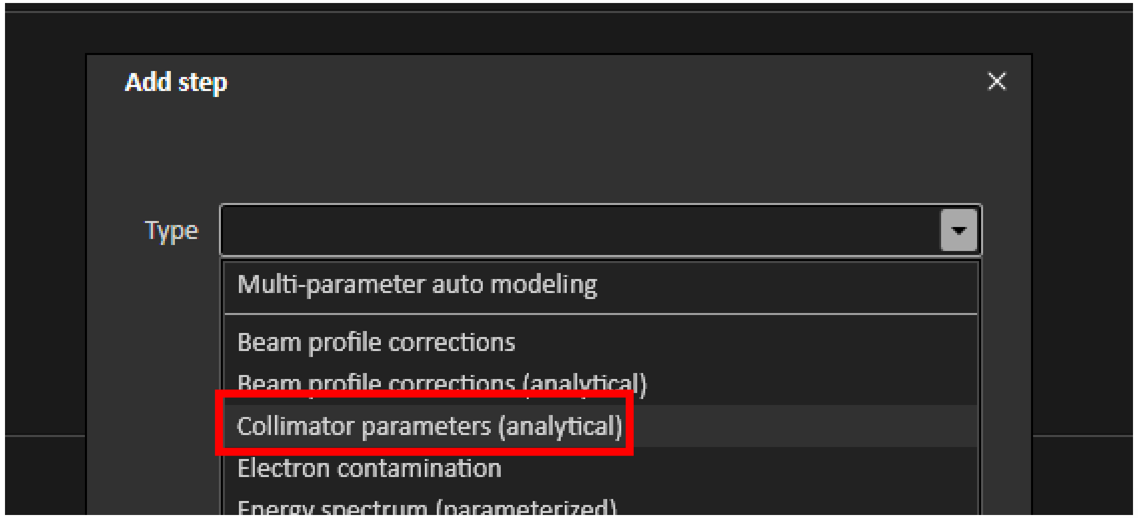
PROJECTIONS

- All distances for the different parameters are the distances projected on the isocenter plane.

AUTO-MODELING

- The auto-modeling adjusts parameters to make computations match data better.
- Relevant generalizations outside the data in beam commissioning must be verified thoroughly before the model can be used clinically.

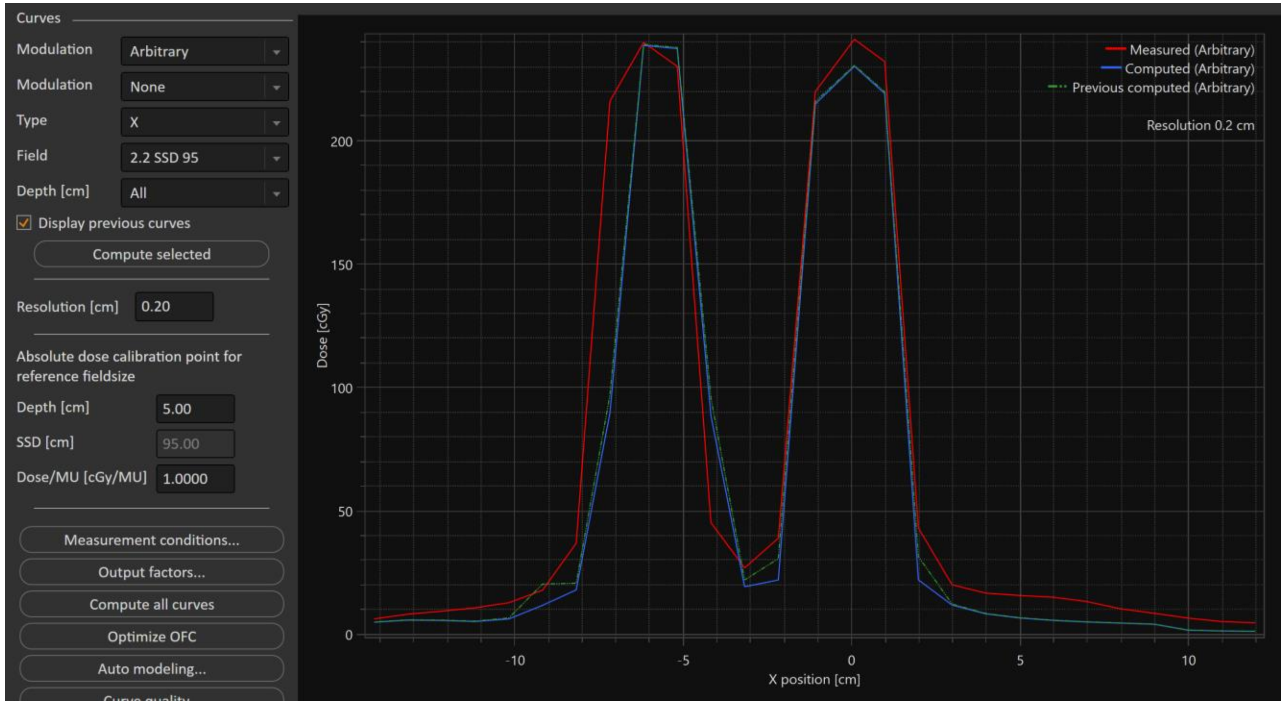


TWO OPTIONS IN MLC MODELING

- Two possible workflows for MLC modeling, either importing arbitrary fields or work in the Beam 3D modeling module and external.
- From Raystation 10A, it is possible to import arbitrary fields to the Beam commissioning module to model the MLC parameters.
- MLC modeling should always be performed with any of the suggested workflow before commissioning for clinical use

ARBITRARY FIELDS IN BEAM COMMISSIONING

- Import of arbitrary fields allows for modeling of the MLC parameters directly in the beam commissioning module.
- Possible to add any photon fields with couch and gantry angle 0°
  - No wedge, blocks or cones supported
  - No depth dose curves needed
  - Supports 3DCRT, SMLC, DMLC fields
- The list of fields for arbitrary fields is stored in the patient database and can only be accessed with scripting.
- Not possible to import dose curves for arbitrary fields in *.xmcdat format.



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ARBITRARY FIELDS IN BEAM COMMISSIONING

- All dose curves belonging to the same arbitrary field must have the same SSD, but can have a different SSD than the rectangular fields.
- Several depths and curve types can be imported for one field.
- Each dose curve needs a scale factor that converts the measured dose to cGy.
- The arbitrary fields are not included in machine backups.
- Important that fields contain all the relevant information on the MLC property that is modeled and do not depend on several parameters for proper modeling, such as picket fence fields.

Scale factors

Scale factors for arbitrary fields. Dose values in the imported dose curve files will be scaled with this factor. Enter a factor such that dose values in the curve file multiplied with this factor correspond to the delivered dose in cGy. Output factor depth is not used for arbitrary fields.

ADMINISTRATION OF THE ARBITRARY FIELD LIST

- Can be done either through Raystation or Beam 3D modeling.

- In the command console:
  - **Add a beam from a plan:**

    patient_db.CopyBeamToBeamCommissioningField(BeamToCopy= beam, FieldName=’name', Description=’description of field’)

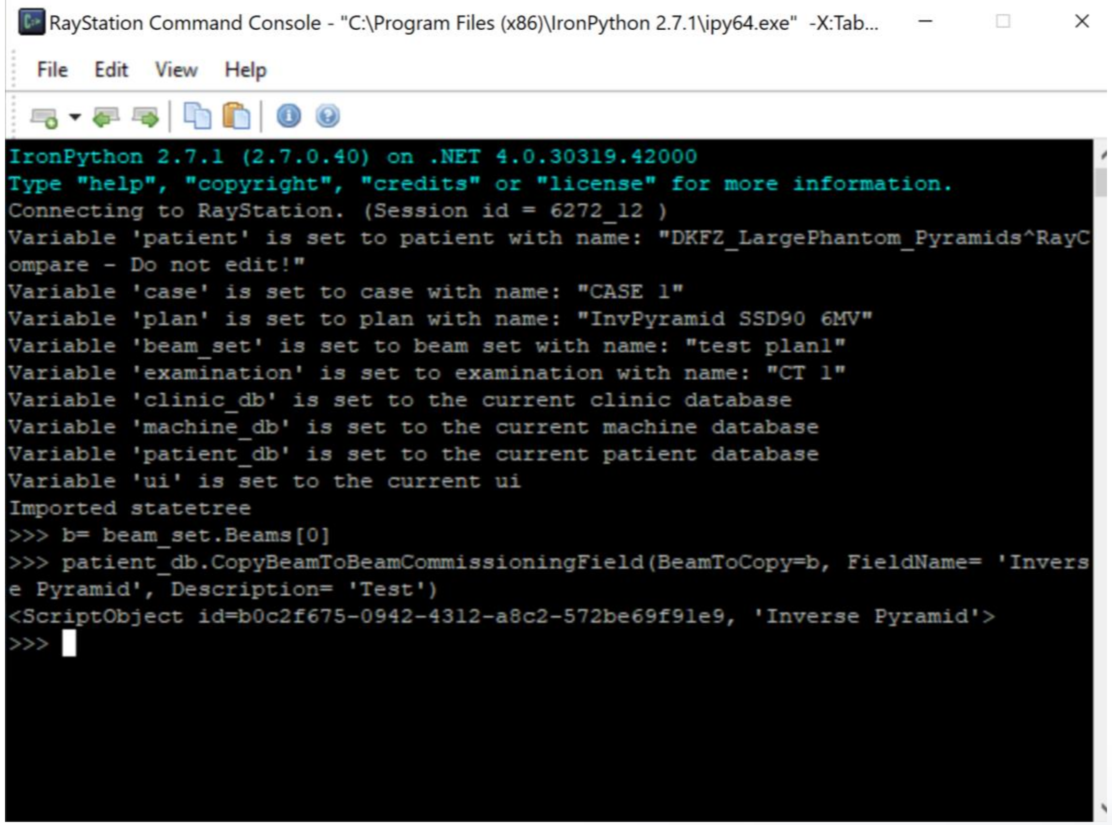
  - **Remove a beam:**

    patient_db.RemoveBeamCommissioningField(FieldName = ’name’)

  - **List all beams in field list:**

    patient_db.ListAllBeamCommissioningFieldNames

  - **More Information in RayStation 11B RayPhysics Manual → AppendixC**



- After being added into the list, measurements can be imported to the beam model in RayPhysics

TRANSMISSION PARAMETER

TRANSMISSION

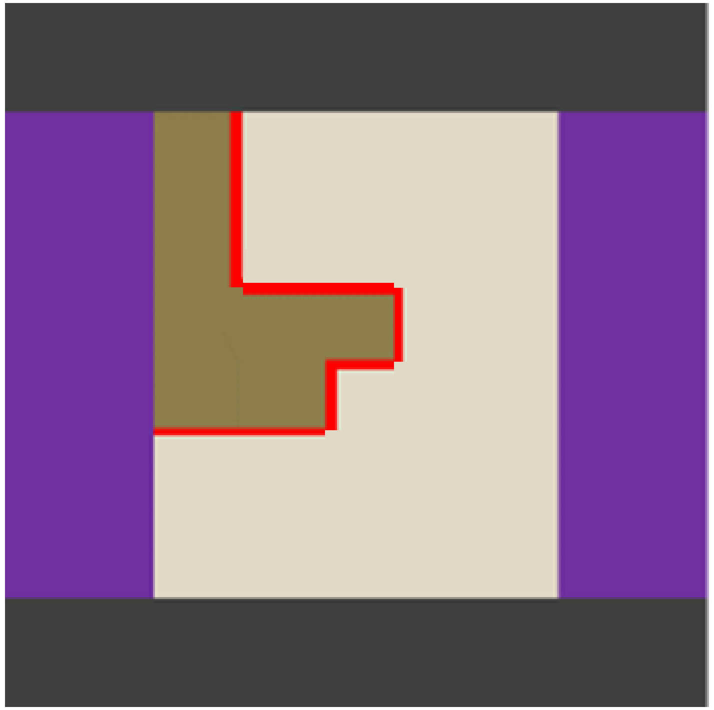
Open: transmission 1

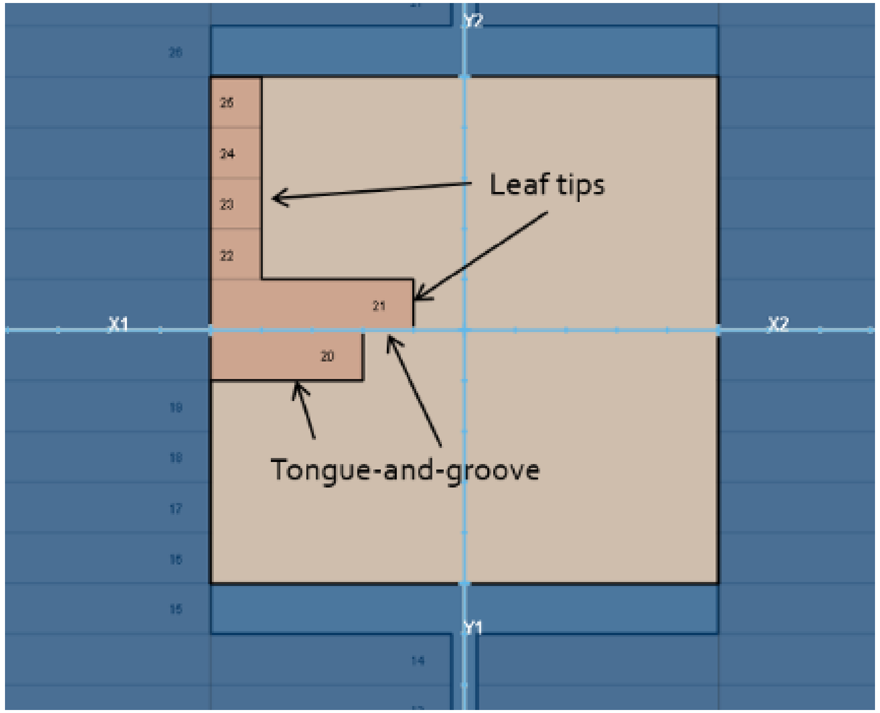
Under Y-jaw: transmission 0

Under MLC: transmission t_{MLC}

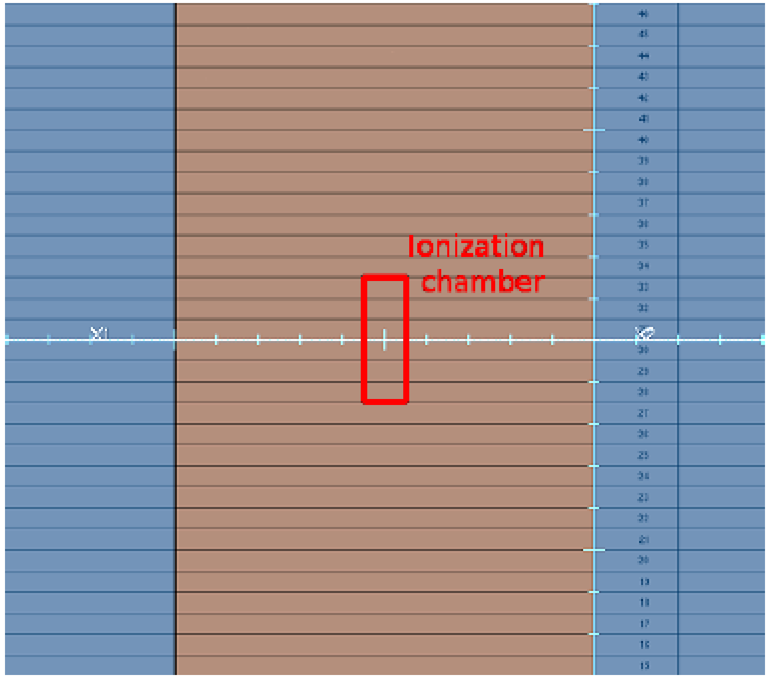
Under MLC + X-jaw: $t_{MLC} \ * \mathrm{t}_{\mathrm{X-jaw}}$

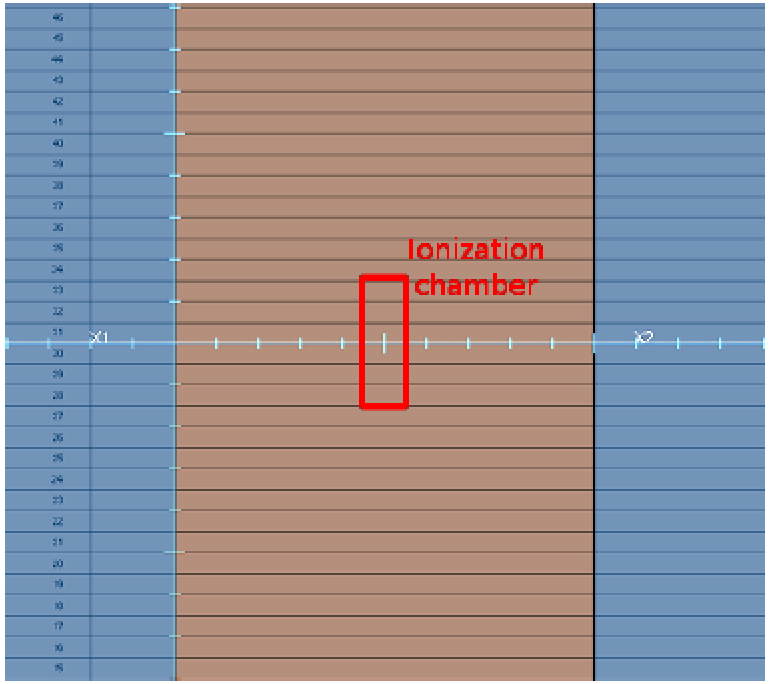
Leaf tip or T&G: transmission $\sqrt{t_{MLC}}$





MLC TRANSMISSION PARAMETER

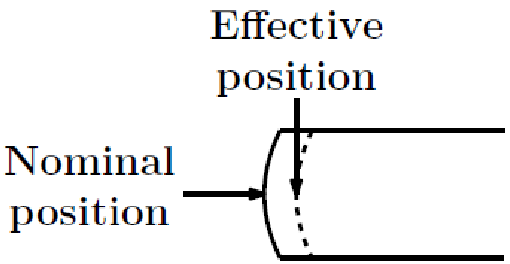




- Transmission measured on both leaf bank at 1.5 cm depth

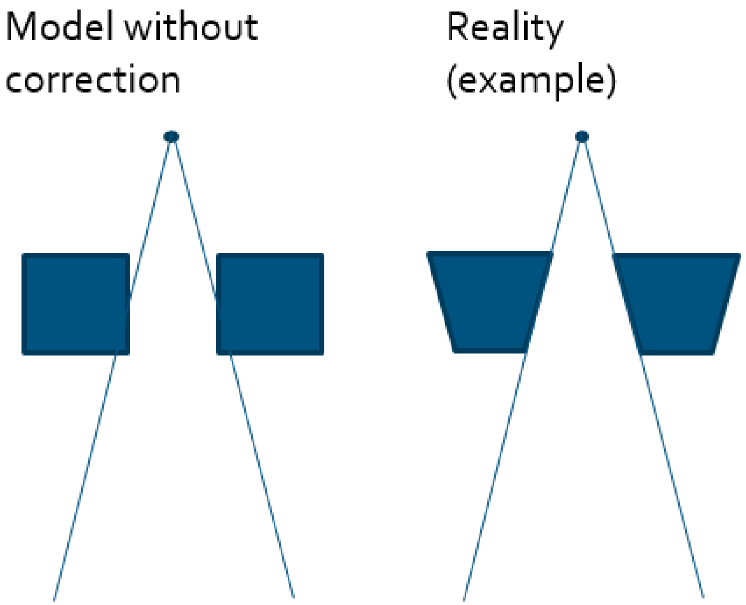
EXAMPLES ON TEST FIELDS FOR MLC MODELING

OFFSET, GAIN AND CURVATURE



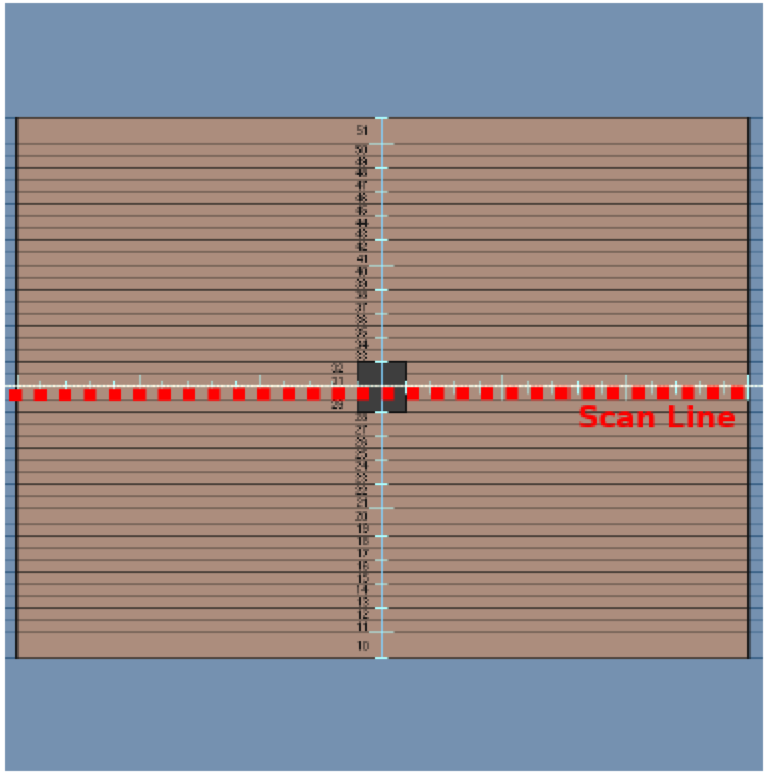
$$x_{effective} = x - offset + gain \cdot x - curvature \cdot x^2 \qquad left\ MLC\ bank$$

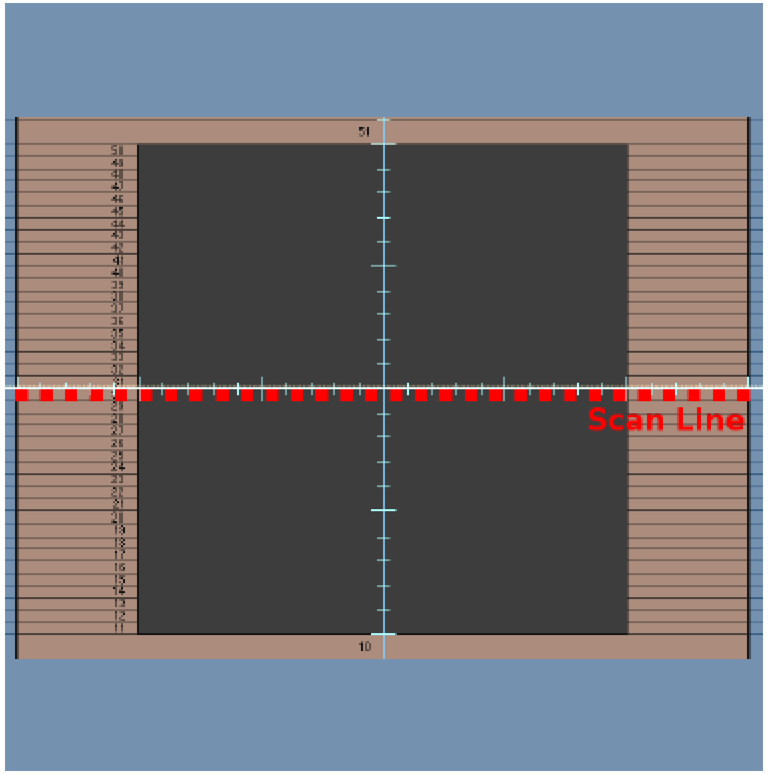
$$x_{effective} = x + offset + gain \cdot x + curvature \cdot x^2 \qquad right\ MLC\ bank$$



	Positive	Negative	Effect	Range
Offset	Shifts both sides outwards	Shifts both sides inwards	All field sizes are shifted equally much	-0.0X to 0.0X
Gain			The shifts increases linearly with field size	-0.00X to 0.00X
Curvature			The shifts increases quadratic with field size	-0.000X to 0.000X

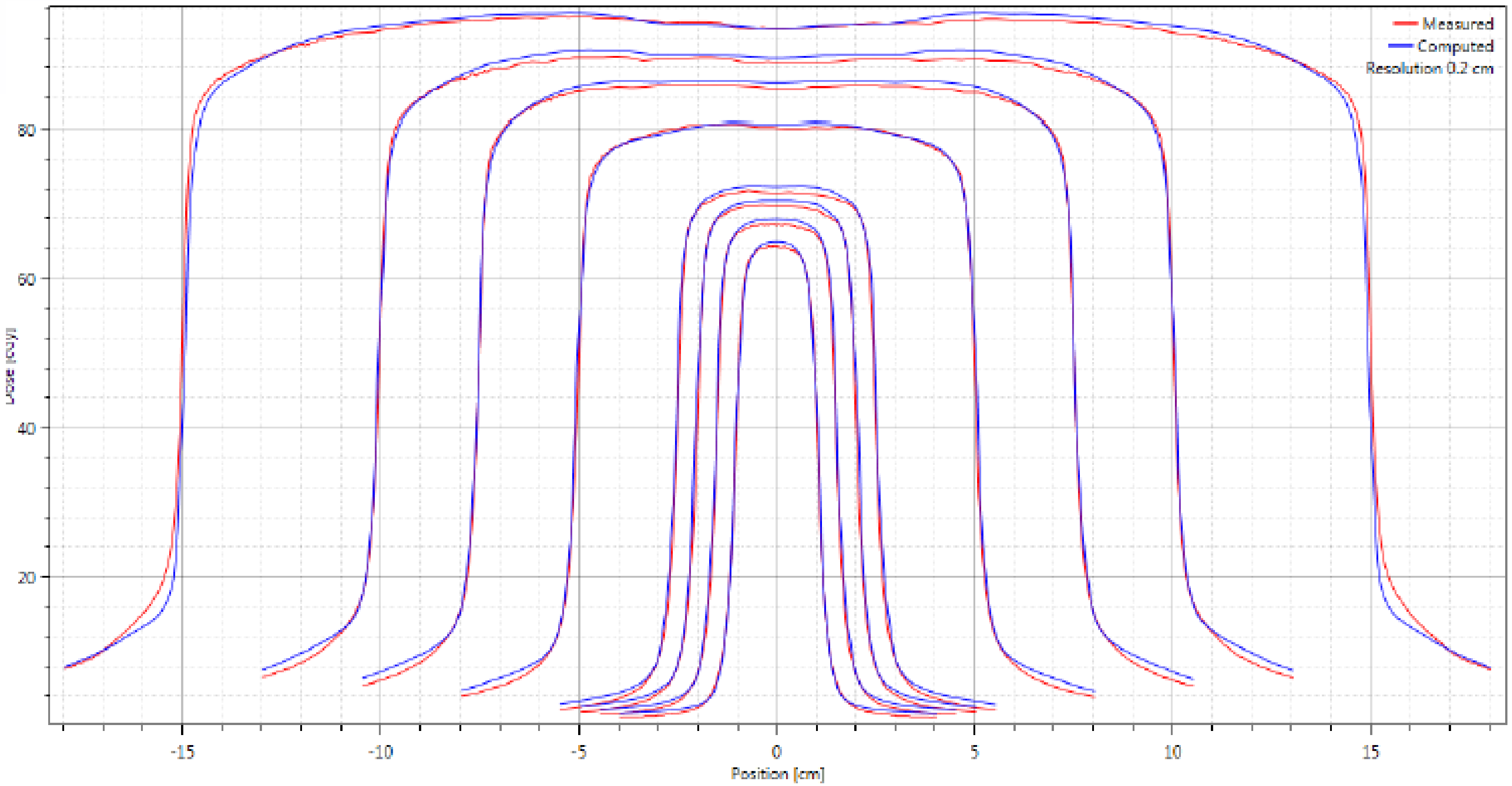
OFFSET, GAIN AND CURVATURE





- Profiles of square MLC-collimated fields taken at 5, 10 and 20 cm depth
- Field dimensions 2x2, 3x3, 4x4, 5x5, 10x10, 15x15, 20x20 and 30x30 cm^2
- Sources modeled with jaws only collimated fields

EXAMPLES RESULTS – OFFSET, GAIN AND CURVATURE



- Optimal values: Offset: 0.04 cm, Gain: 0.0 cm^{-1}, Curvature: 0.0cm^{-2}

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LEAF TIP WIDTH

- Rounded lead tip model
  - Region in cm (at isocenter plane), cut from the leaf tip for which the transmission equals the square root of the full leaf transmission

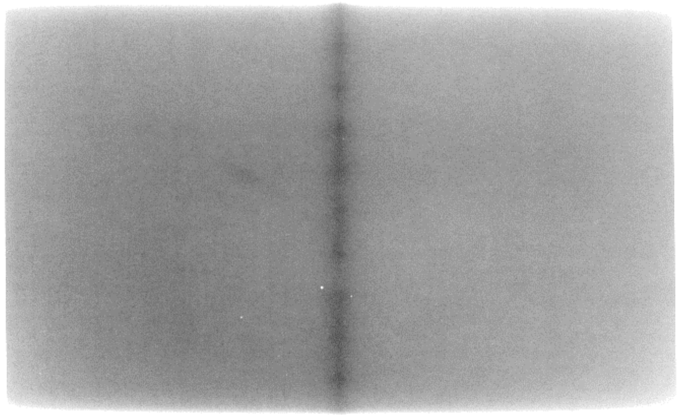
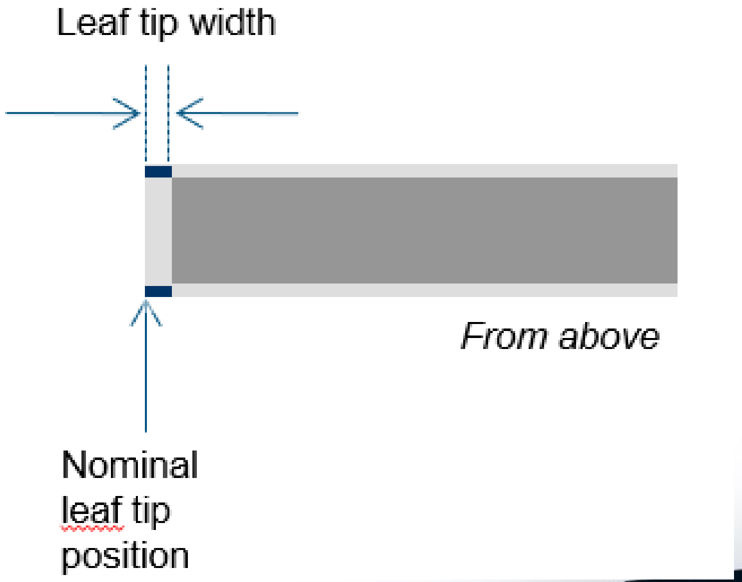


Fig. 11. Radiograph showing the high dose line that appears when a film is double exposed with the leaves abutted at the field midline. Notice also the diamond shaped pattern that results from the beveling at the front face of the leaves.

Ga[illegible] et al 1993, Int J [illegible]tion Oncology Biol Phys [illegible]55, 181-192



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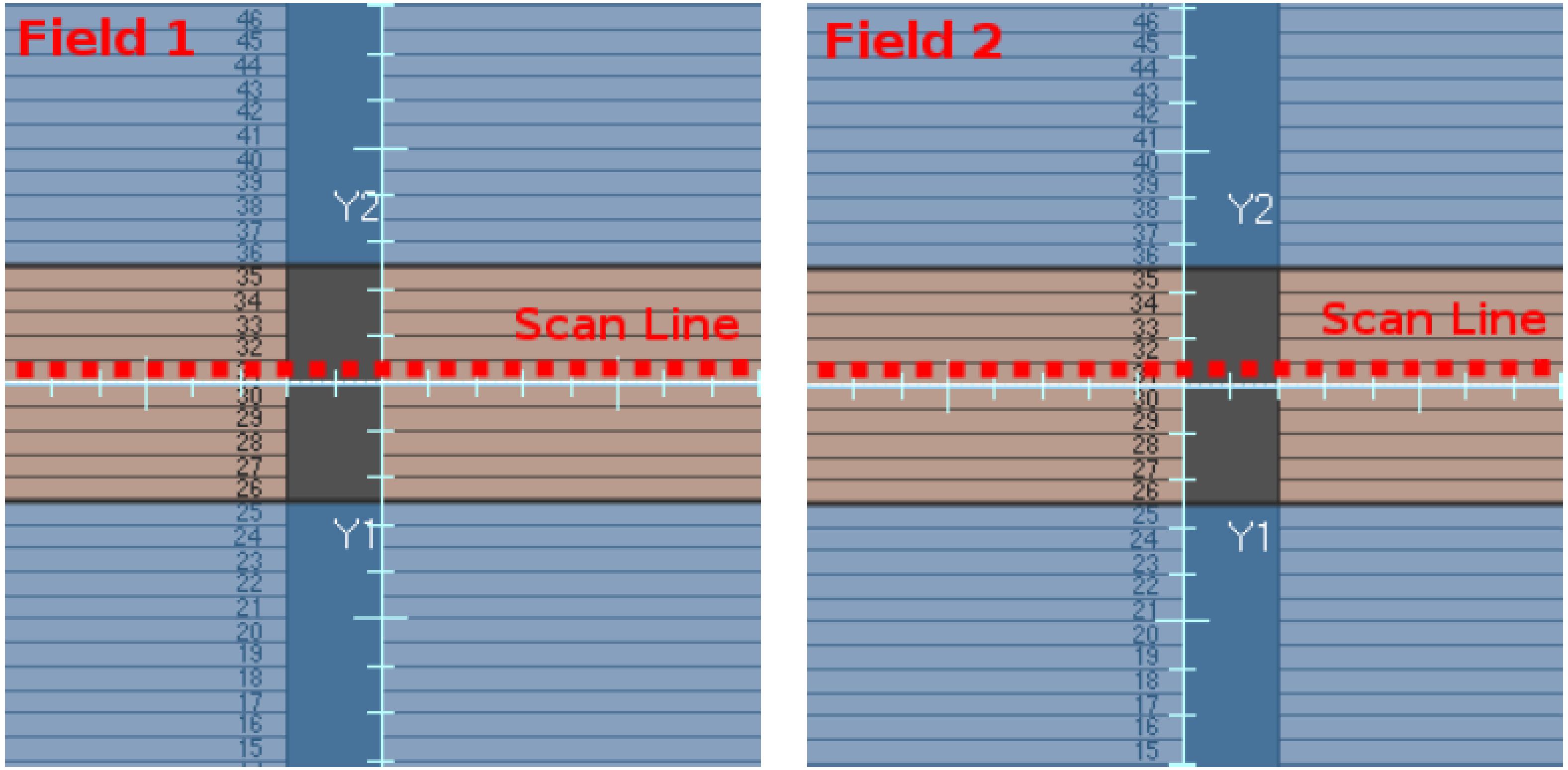
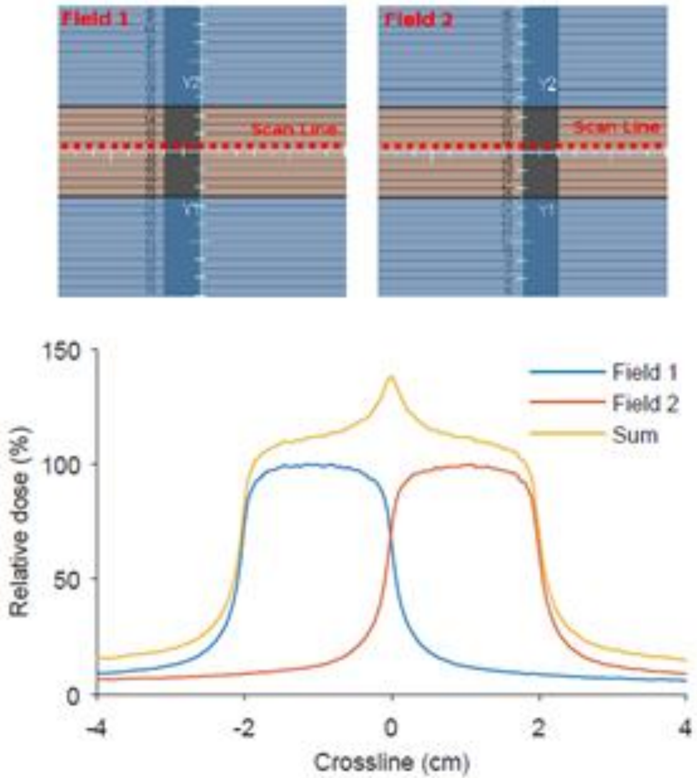
EXAMPLE: LEAF TIP WIDTH

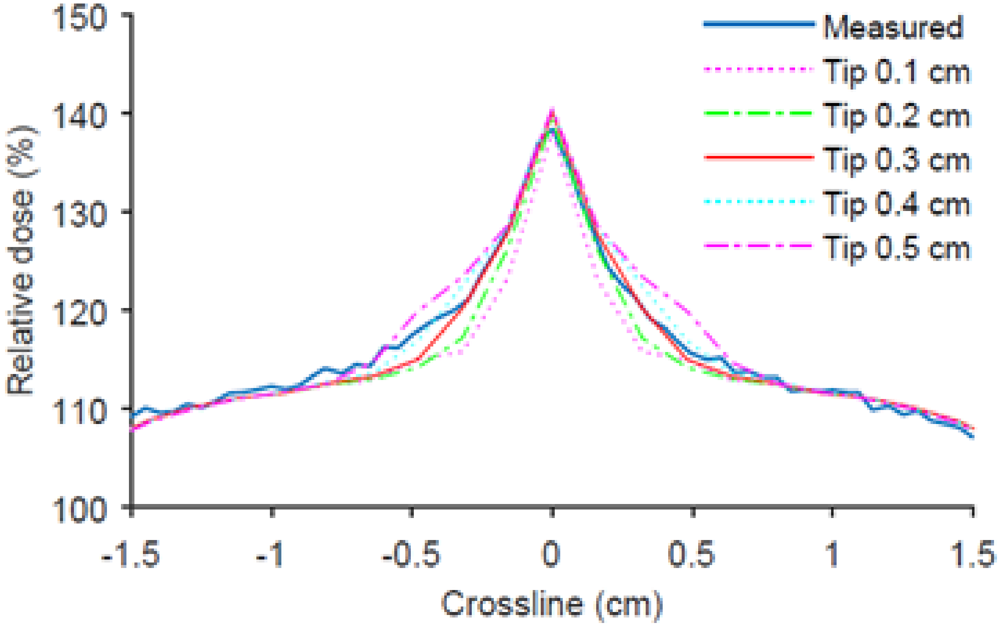


- Create an abutment using the leaf tip
- Profiles taken at 10 cm depth

EXAMPLE RESULT – LEAF TIP WIDTH - BEAM 3D MODELING

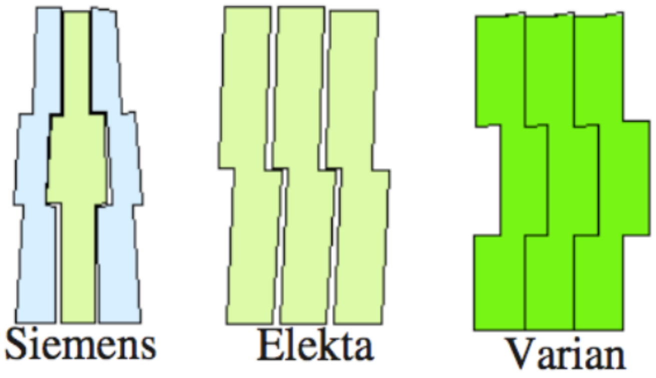
Optimal value: leaf tip = 0.3 cm

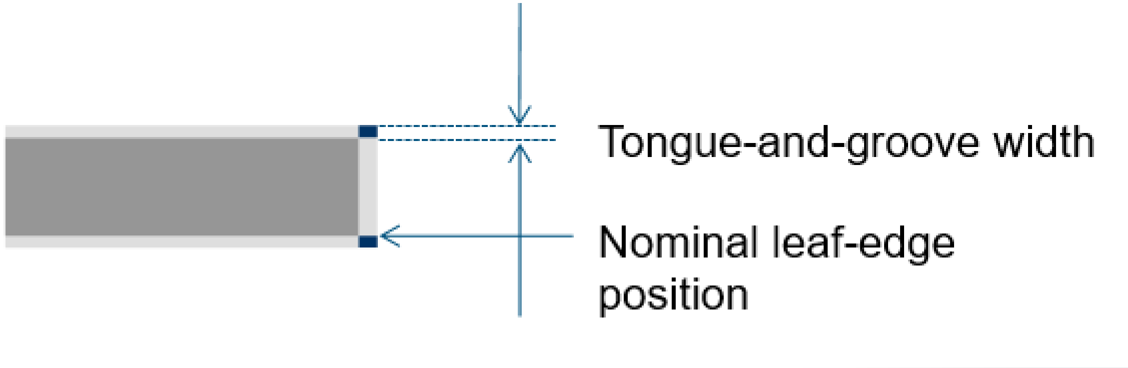




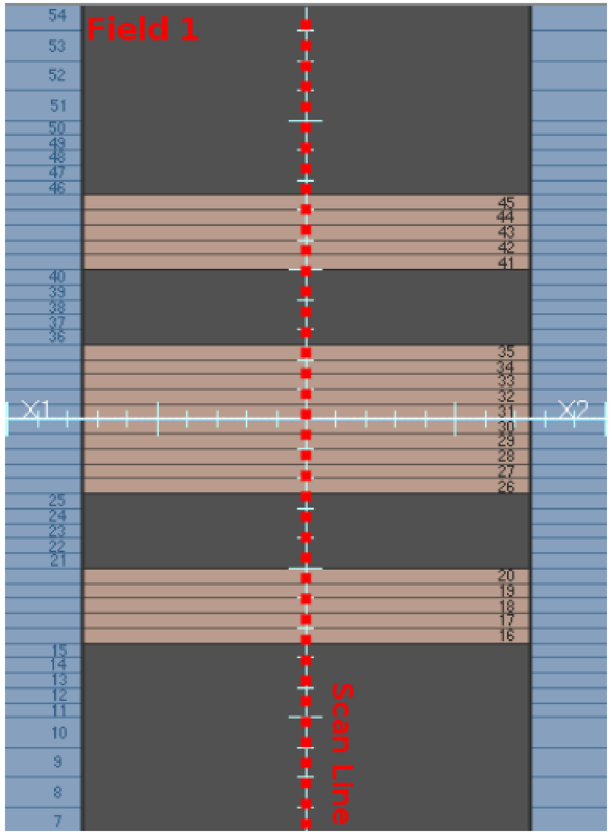
TOUNGE AND GROOVE

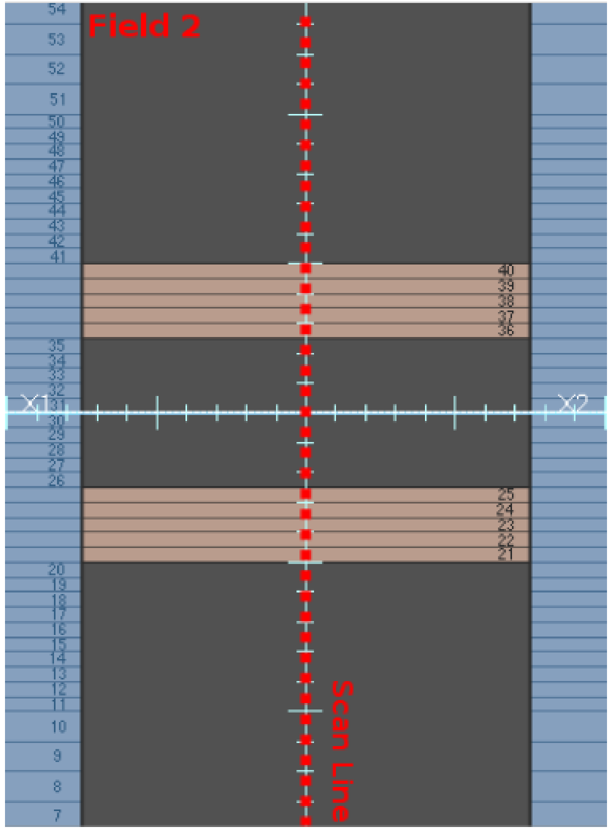
- Tounge and Groove model
  – Region in cm (at isocenter plane), extended on the leaf side for which the transmission equals the square root of the full leaf transmission





EXAMPLE: TOUNGE AND GROOVE REGION

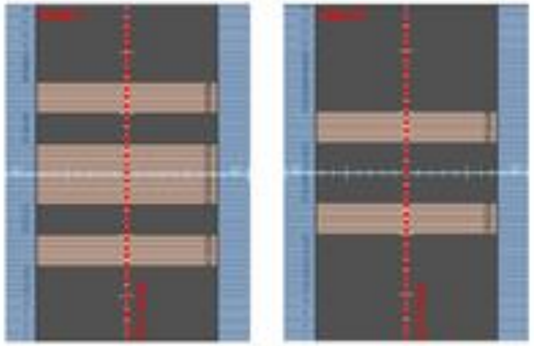


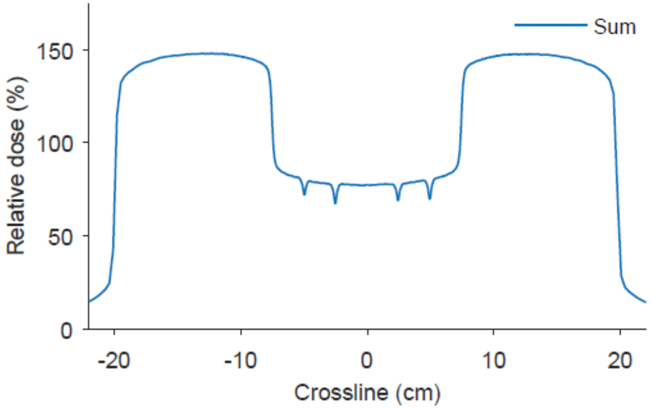


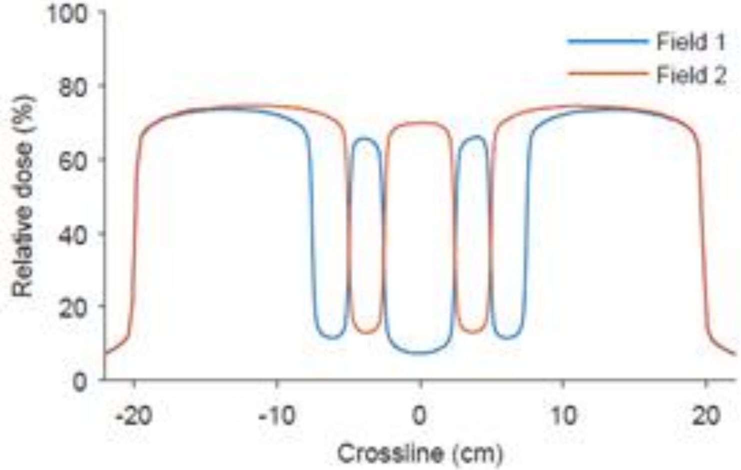
- Create an abutment using the leaf side
- Profiles taken at 10 cm depth

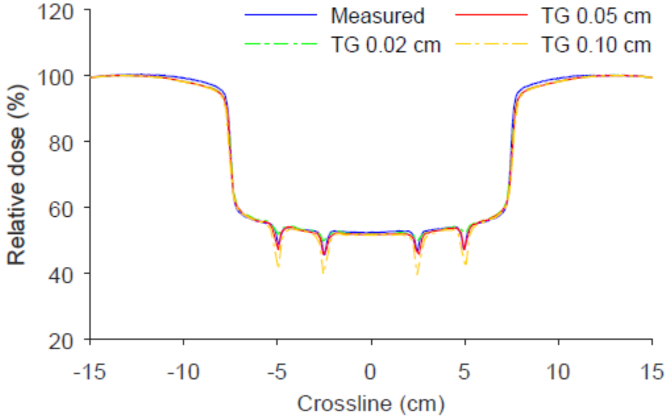
EXAMPLE RESULT – TOUNGE AND GROOVE BEAM 3D MODELING

Optimal value: TG = 0.05 cm









R[illegible] from [illegible], M[illegible] physics d[illegible]rtment Hosp[illegible] G.M[illegible] [illegible]4, Teramo - Italy

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RAYSTATION DATA FROM GLENN ET AL

		Tongue and Groove		Leaf tip width		MLC transmission		MLC Offset		MLC gain		MLC Curvature		Sample size
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	
Energy	Type													
6	Elekta Agilty	0.065	0-0.11	0.293	0.1-1	0.0043	0-0.016	0.0321	-0.02-0.12	0.0187	0-0.075	0.0175	-0.0006-0.08	40
10	Elekta Agilty	0.0792	0-0.5	0.285	0.01-0.7	0.0038	0-0.01	0	-0.02-0.02	0.0017	0-0.0047	0.0001	0-0.0004	23
15	Elekta Agilty	0.0569	0-0.1	0.239	0.1-0.65	0.0046	0-0.007	0.0565	-0.015-0.1	0.0429	0.003-0.075	0.0539	0-0.1	17
18	Elekta Agilty	0.06	0.05-0.1	0.086	0.01-0.2	0.0145	0.001-0.0365	0.0212	0.003-0.03	0.00322	0.0012-0.0085	-0.000066	-0.0006-0.00009	5
6 FFF	Elekta Agilty	0.053	0.05-0.08	0.1408	0.008-0.4	0.00276	0.001-0-005	0.017	0.01-0.025	-0.00166	-0.0046-0.0009	0	0	9
10 FFF	Elekta Agilty	0.0375	0-0.05	0.2025	0.01-0.5	0.005	0.001-0.0095	0	0	0	0	0.000175	0-0.00035	8
6	Elekta MLCi	0.064	0-0.15	0.22	0.2-0.3	0.0094	0.005-0.012	0.0233	0.0-05	0.0033	0-0.008	0.0004667	0.0002-0.0007	5
10	Elekta MLCi	0.025	0-0.05	0.2	0.2-0.2	0.0075	0.005-0.01	0.02	0.02-0.02	0	0-0	0.00035	0.00035-0.00035	2
15	Elekta MLCi	0.025	0-0.05	0.2	0.2-0.2	0.0075	0.005-0.01	0.02	0.02-0.02	0	0-0	0	0-0	5
6	Millenium 120	0.0396	0.01-0.05	0.2744	0.165-0.5	0.01723	0.007-0.025	0.03463	0-0.12	0.0028	-0.0004-0.015	0.000448	0-0.001	27
10	Millenium 120	0.0353	0.01-0.05	0.259	0.01-0.5	0.0181	0.01-0.0294	0.028	0-0.1	0.008	0-0.02	0.00016	0-0.0008	7
15	Millenium 120	0.0425	0.02-0.05	0.24125	0.165-0.3	0	0-0	0	0-0	0	0-0	0.0004	0-0.0008	4
18	Millenium 120	0.045	0.02-0.05	0.2275	0.165-0.3	0.0192	0.015-0.025	0.0456	0-0.12	0.00124	0-0.0031	0.00061	0-0.0008	6
6 FFF	Millenium 120	0.03889	0.01-0.05	0.6111	0.2-1	0.008878	0.0005-0.02	0.0115	0-0.042	-0.000375	-0.0015-0	0.00083	0-0.00166	9
6	Millenium HD-120	0.05	0.05-0.05	0.3	0.2-0.4	0.01627	0.01254-0.02	no data	no data	no data	no data	no data	no data	2
10	Millenium HD-120	0.05	0.05-0.05	0.25	0.2-0.3	0.02175	0.0141-0.0294	no data	no data	no data	no data	no data	no data	2

Glenn et al.: Reference dataset of users' photon beam modeling parameters for the Eclipse, Pinnacle and RayStation treatment planning systems. Medical Physics 47 (1), January 2020

RAYSTATION DATA FOR VARIAN MACHINES FROM JORDI SAEZ ET AL 2020

- Proposed workflow to determine MLC values from: Jordi Saez *et al* 2020 *Phys. Med. Biol.* **65** 155006

Table 1. Summary of the optimal MLC configuration parameters obtained with the proposed procedure.

	MLCHD		Millennium		
	6 WFF	6 FFF	6 WFF	10 WFF	15 WFFF
T (%)	1.19	1.03	1.46	1.69	1.64
w_{TG} (mm)	0.44	0.43	0.44	0.44	0.44
l_{tip} (mm)	1.19	1.05	1.64	1.81	1.85
x_{off} (mm)	0.12	0.12	0.46	0.50	0.49
DLG (mm)	0.47	0.41	1.28	1.41	1.40
k (Gy/(MU mm^2))	0.262 9	0.248 2	0.132 5	0.147 3	0.154 4

Image: Jordi Saez *et al* 2020 *Phys. Med. Biol.* **65** 155006

ASYNCHRONOUS SWEEPING GAPS

- Users meeting 2020.
  - Presentation in community.
- Publication can be found by link from RaySearch webpage (or Google).
- Plans, scripts and analysis excel sheet provided upon request from RaySearch or the authors.

Assessment and improvement of MLC models

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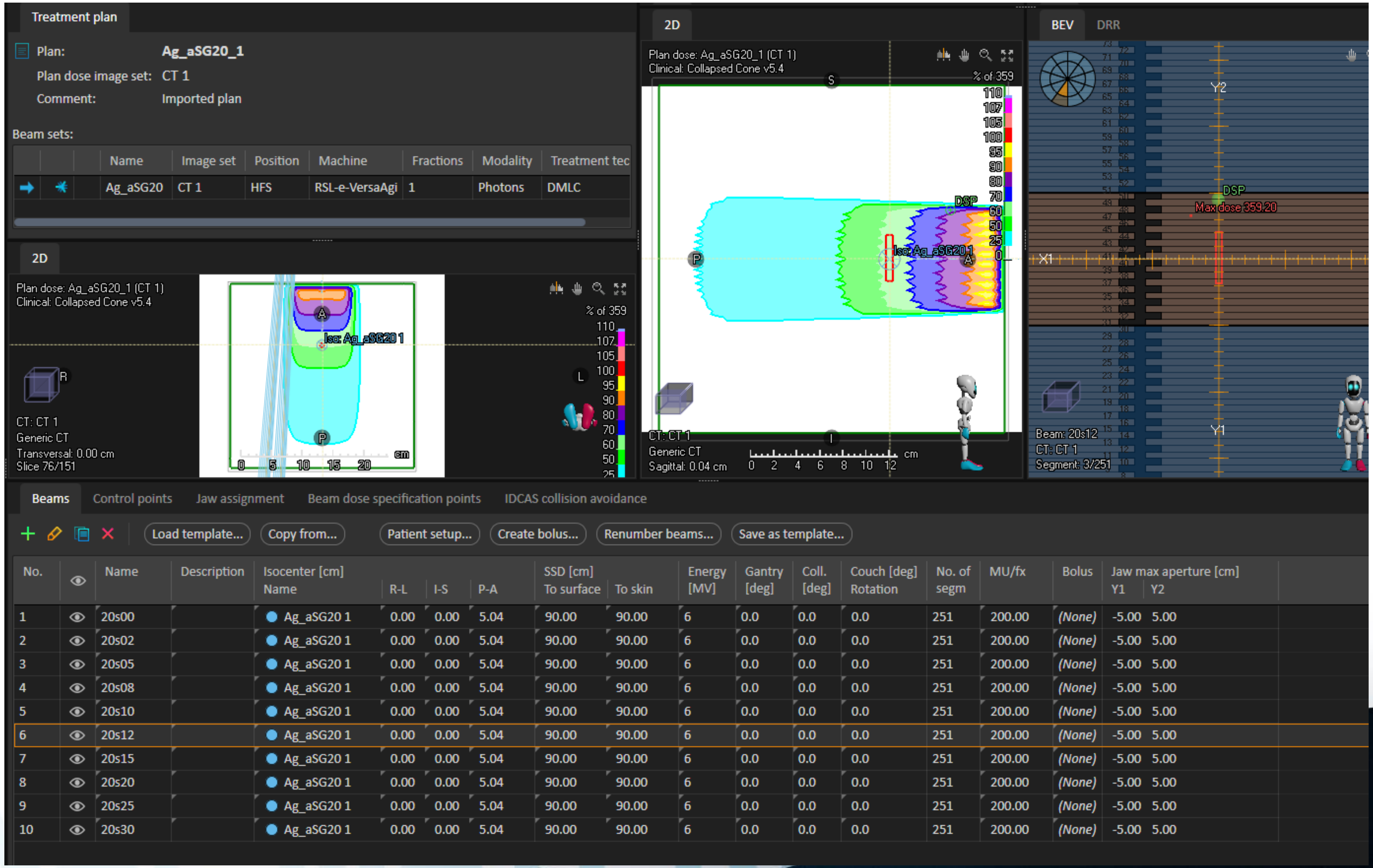
- Workflow to find MLC parameters
- Instead of high spatial accuracy work with average doses.
- In x by sweeping different gaps.
- In y by having a large detector, Farmer.

Saez J, Hernandez V, Goossens J, De Kerf G, Verellen D, A novel procedure for determining the optimal MLC configuration parameters in treatment planning systems based on measurements with a Farmer chamber, Phys. Med. Biol. 2020;(65):155006.

ASYNCHRONOUS SWEEPING GAPS

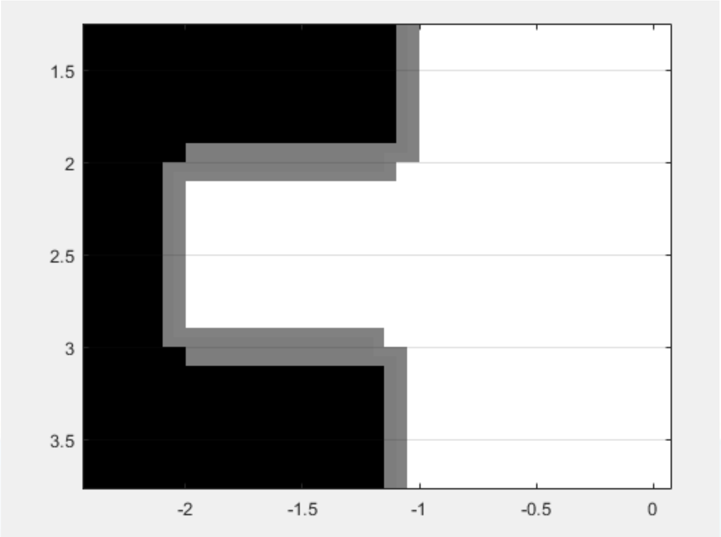
- Sweeping gaps
  - Dose versus gap size gives dose to be added by leaftip and offset
- Asynchronous sweeping gaps, aSG.
  - Fixed gaps, different extension of every second leaf, s.

- Farmer chamber measurement in solid water. Per beam.
- Extract computed dose using script. Per beam.



ASYNCHRONOUS SWEEPING GAPS

- Increasing s -> increases shadowing -> decreases dose.
- RayStation
  - While s < wLT, we are only exposing the corner giving no dose decrease.
  - When s > wLT open and leaf regions are replaced with TG-regions. Linear dose decrease.



- Reshuffle measured dose to transmission reduction at one leafside . ΔΦ(s) = (D(s=0)-D(s))/2k.

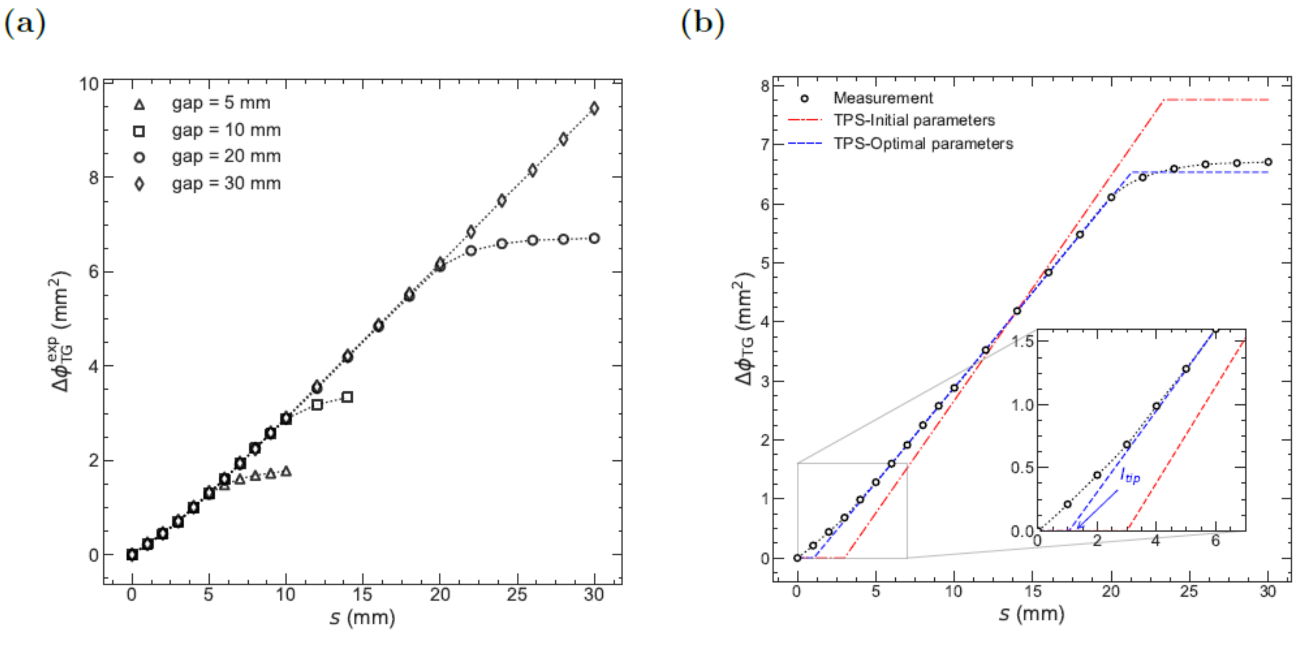
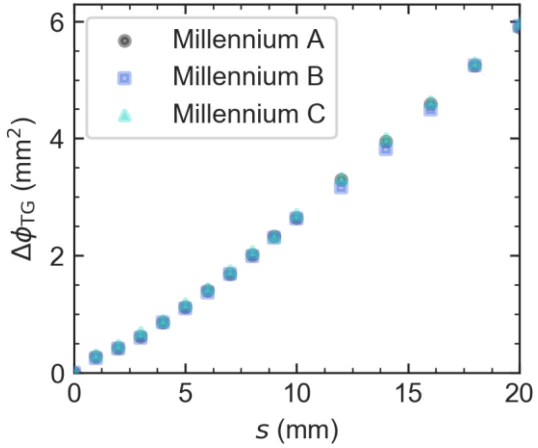
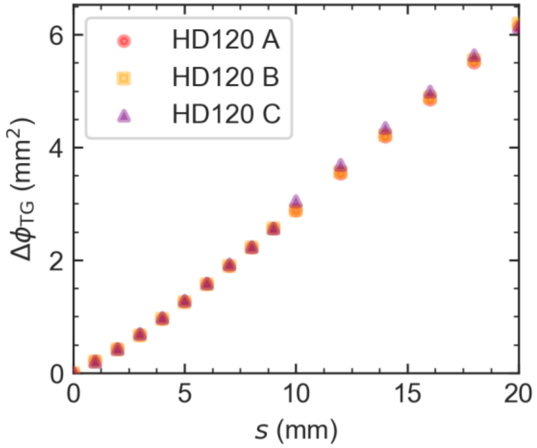


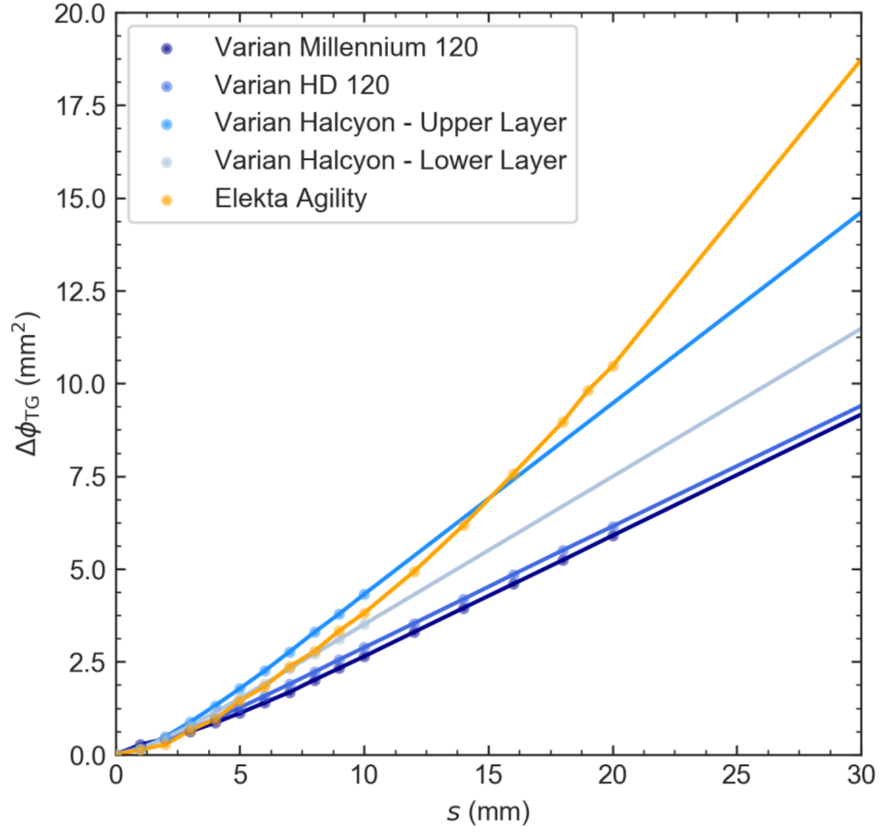
FIG. 5: (a) Experimental fluence reduction for the aSG tests obtained for different sweeping gap sizes for the 6FFF beam and the HDMLC. (b) Experimental fluence reduction for the aSG test with a 20 mm gap and the corresponding fit for the MLC model in RayStation.

FINDINGS

- Same shape for same treatment device
  - MLC, energy, linac type, FF/FFF.
- Varians – constant + linear fit is good
- Agility
  - Tilted TG + rounded LT gives dose reduction curve where it is not obvious which is the best constant + linear fit.
  - Comb/TG fields fits the region far from tip.
- Offset must be tuned to the LINAC.
  - First fix T, wLT and wTG.
  - Fine tune offset using patient plans but with ionization chambers rather than only PSQA-device.
    - Independency
    - Higher dose accuracy





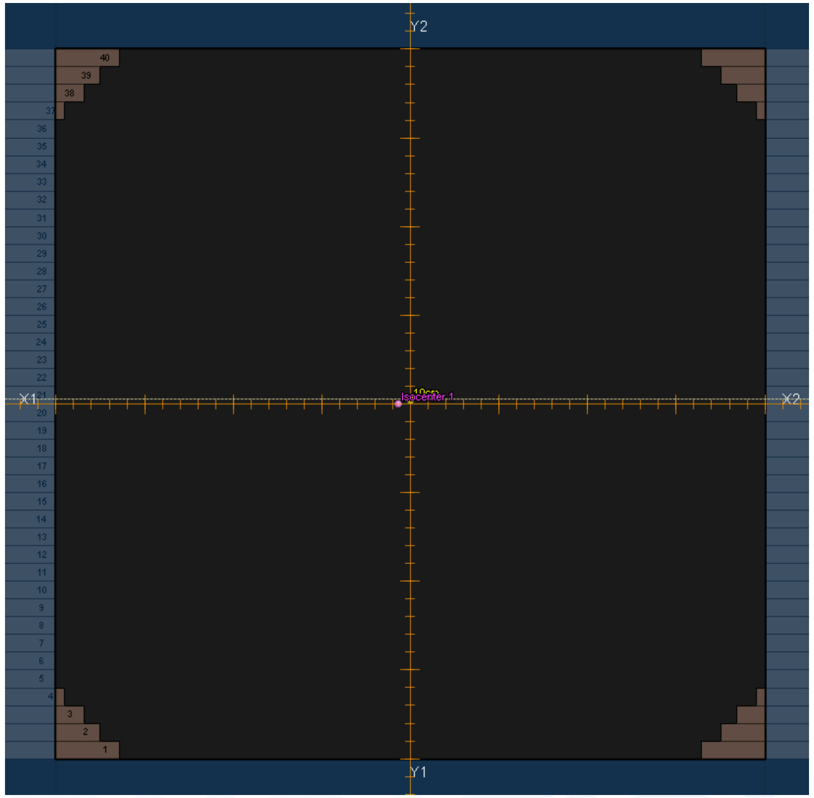


Saini et al. Unlocking a closed system: dosimetric commissioning of a ring gantry linear accelerator in a multivendor environment, Rad. Onc. Phys. 22(2921) 21-34.

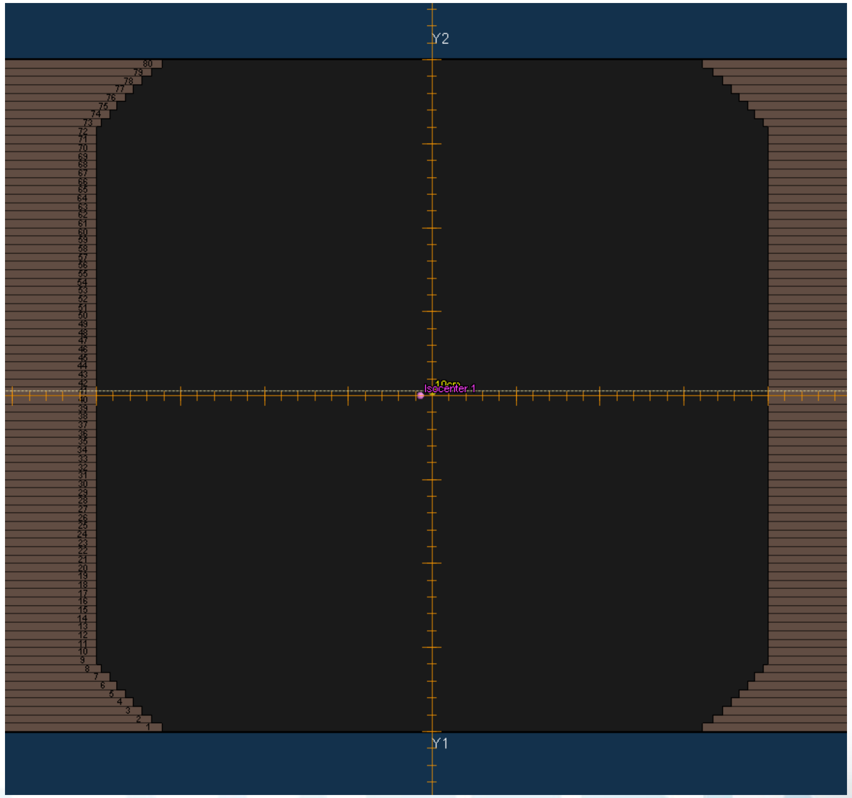
Koger et al., Impact of the MLC leaf-tip model in a commericial TPS: Dose calculation limitations and IROC-H phantom faillures, Rad. Onc. Phys. 21 (2929) 82-88.

MODELING ELEKTA CORNER BEHAVIOR

- Standard Elekta



- Elekta Agility



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MODELING ELEKTA CORNER BEHAVIOR

- Three options...

OPTION 1 – SET MAXIMUM LEAF POSITION IN MLC TAB (RECOMMENDED)

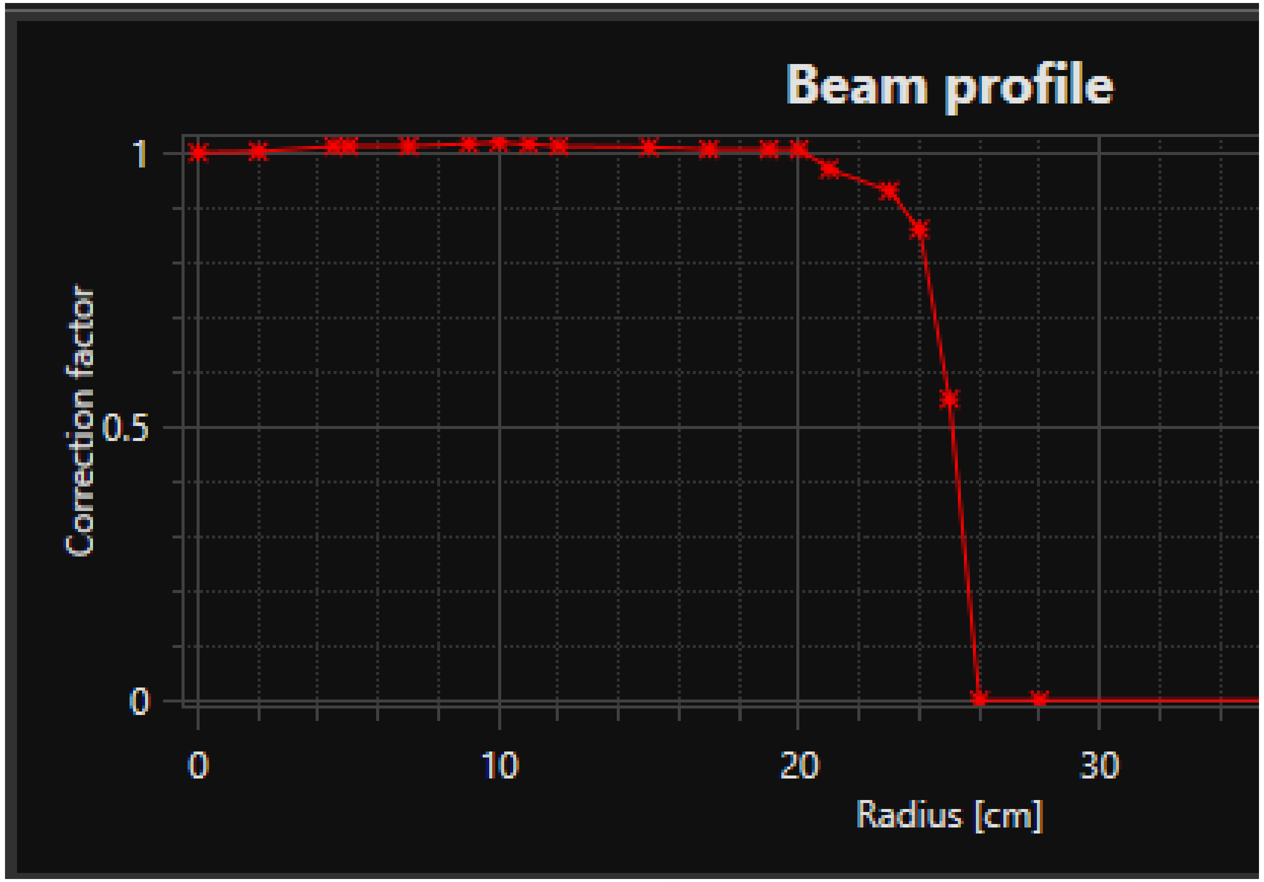
From v10A

- Possible to set minimum and maximum leaf position for individual leaves in the MLC tab.
- Possible to properly model the Elekta corners behavior by accurately constrain the leaf position.
- This is the recommended way to model the Elekta corners

	Leaf center position [cm]	Width [cm]	Minimum tip position [cm]	Maximum tip position [cm]
1	-19.75000	0.5000	-15.00	16.10
2	-19.25000	0.5000	-15.00	16.70
3	-18.75000	0.5000	-15.00	17.30
4	-18.25000	0.5000	-15.00	17.80
5	-17.75000	0.5000	-15.00	18.30
6	-17.25000	0.5000	-15.00	18.80
7	-16.75000	0.5000	-15.00	19.20
8	-16.25000	0.5000	-15.00	19.70

OPTION 2 – CONSTRAIN THE BEAM PROFILE CORRECTIONS

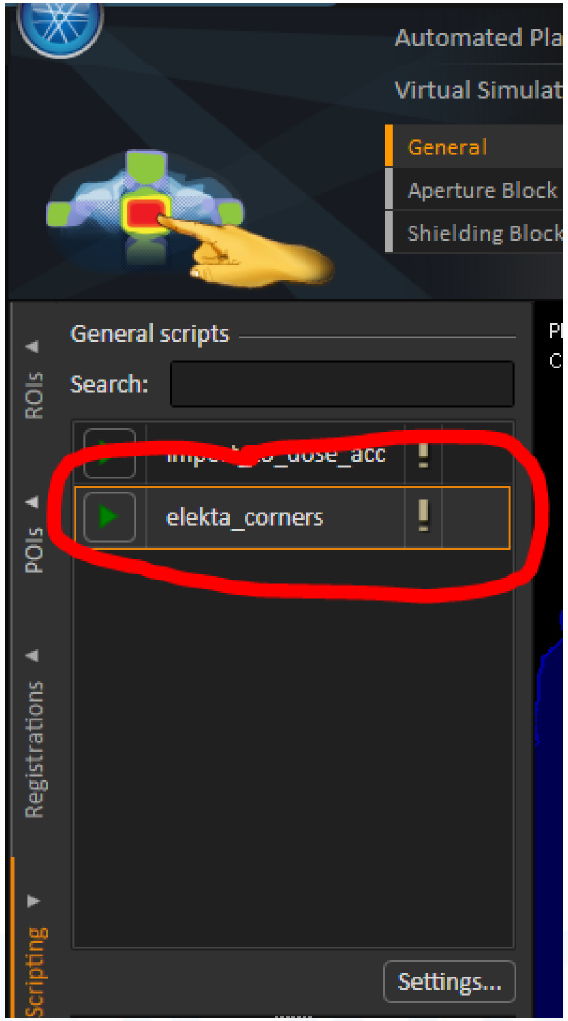
From v9A



- Model the BPC using diagonal measurements.
- Add a point in the Beam Profile at the relevant distance and set it to zero.
- Might be destroyed by auto modeling.
- Diagonal profile should always be included even though the leaf constraint is possible from v10A

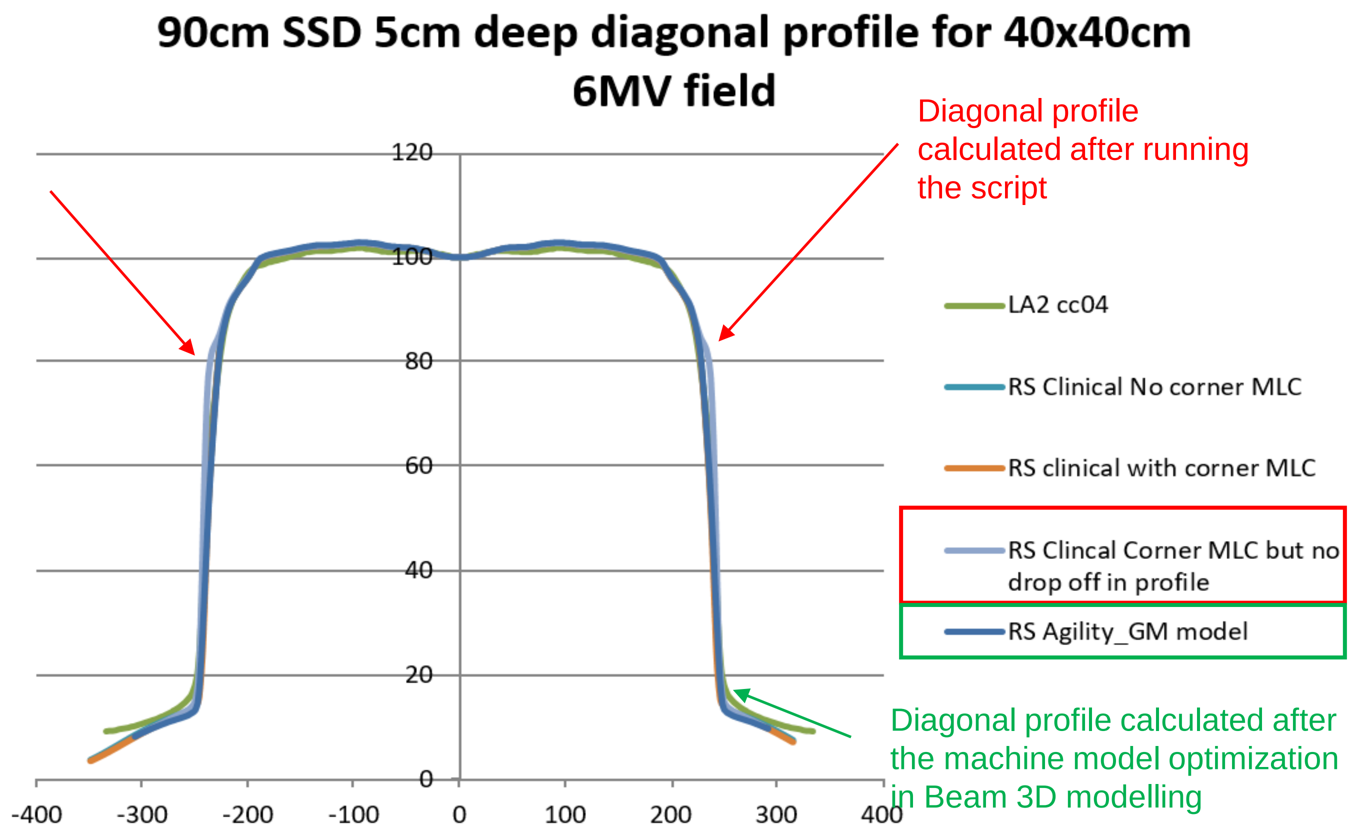
OPTION 3 - SCRIPTING

Previous versions



- The script will examine all fields and indent the MLC in relevant fields.
- Dose will be recomputed and the plan quality can be evaluated.
- Drawbacks: Not possible to optimize with the MLC indented.

COMPARISON FOR AN ELEKTA AGILITY HEAD



- Beam Profile Corrections for radius > 20 cm must be modelled in the ”Beam 3D Modelling” tab comparing calculated and measured diagonal profiles
- Tuning the beam model fits better with measurements compared to the script

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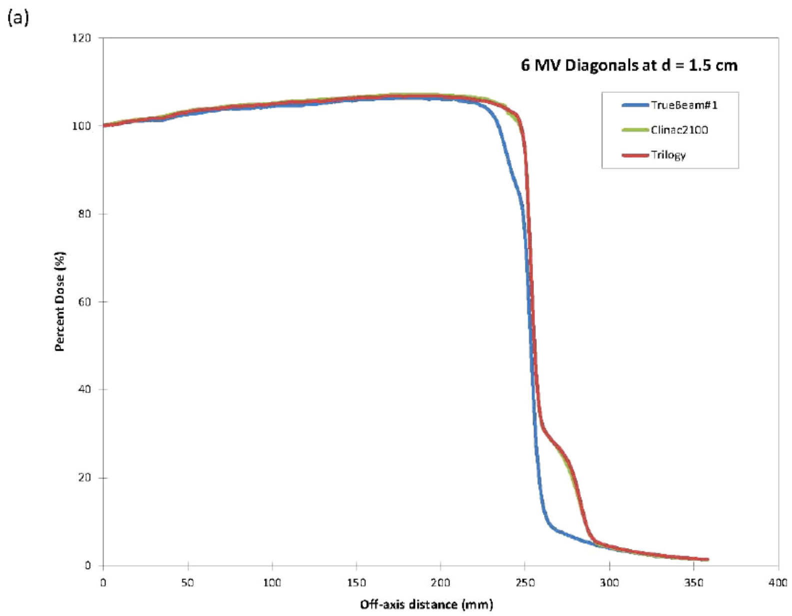
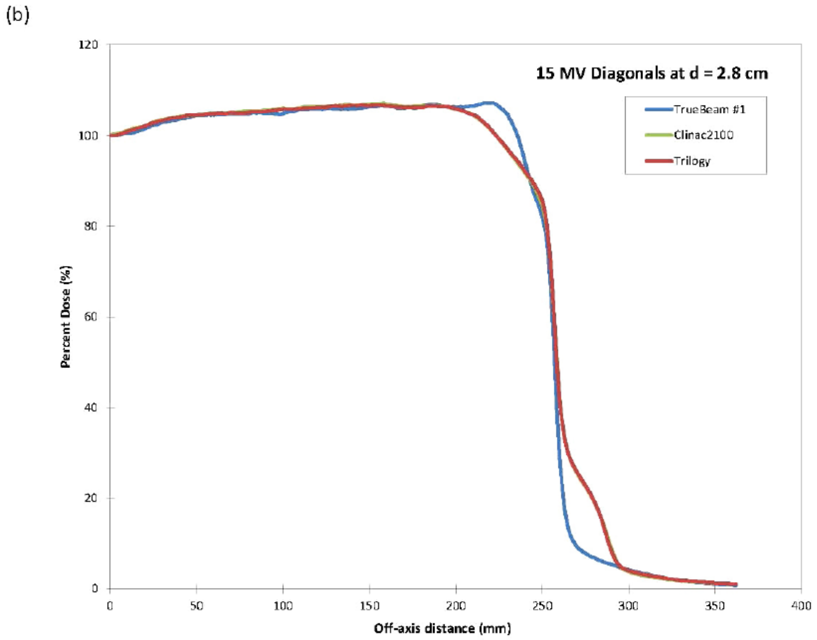
MODELING VARIAN MACHINE CORNERS

- Different Varian machine models can have a different behavior at the corner
- The cutoff for Varian machines is due to the primary collimator





Beyer G.P., Commissioning measurements for photon beam data on three TrueBeam linear accelerators, and comparison with Trilogy and Clinac 2100 linear accelerators. JACMP (2013)

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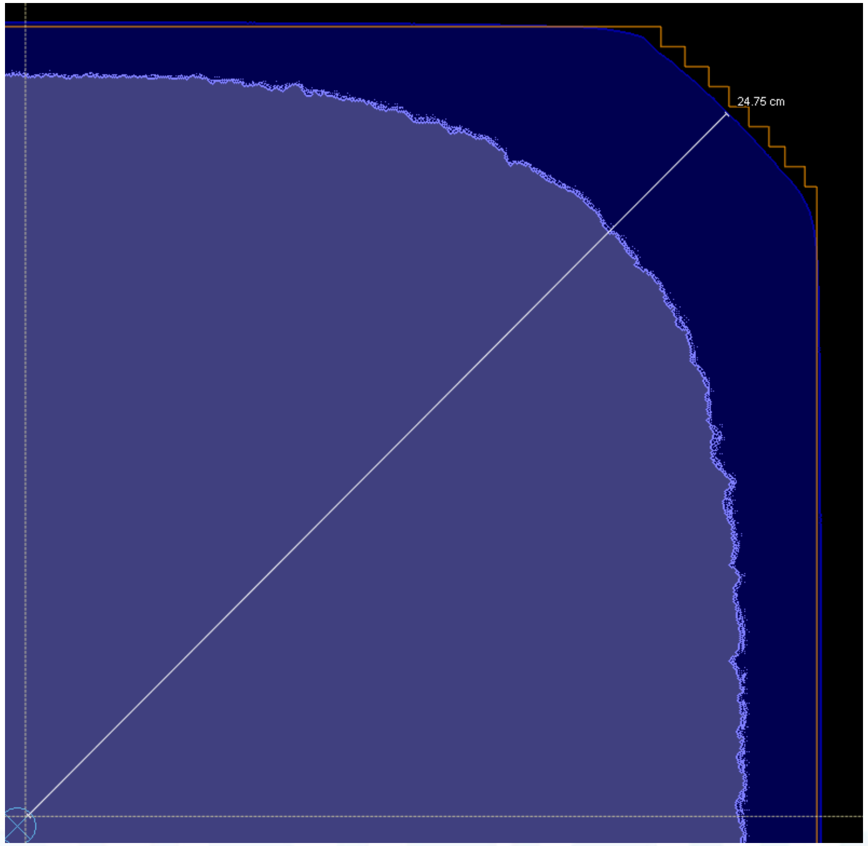
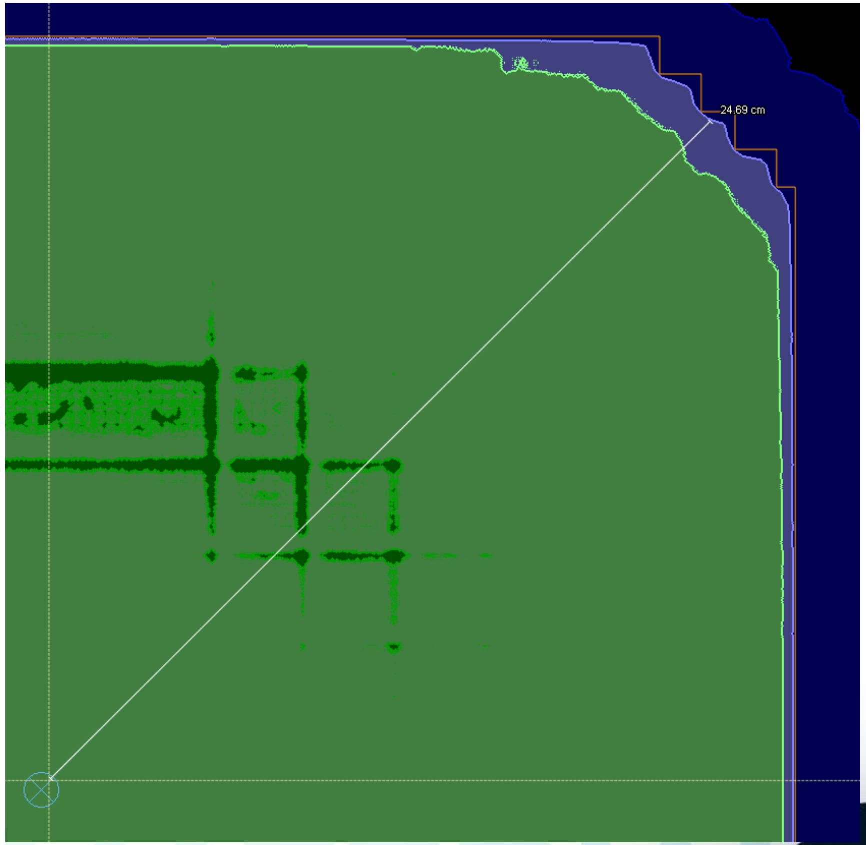
ELEKTA AGILITY

- SSD = 100 cm Cut Off = 24.8 cm



STANDARD ELEKTA

- SSD = 100 cm Cut Off = 24.7 cm

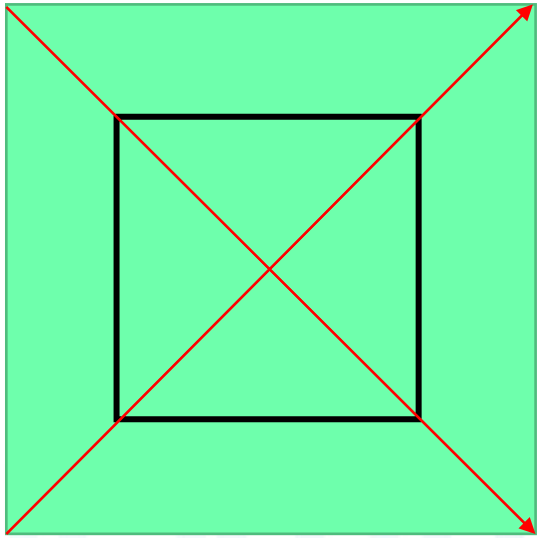


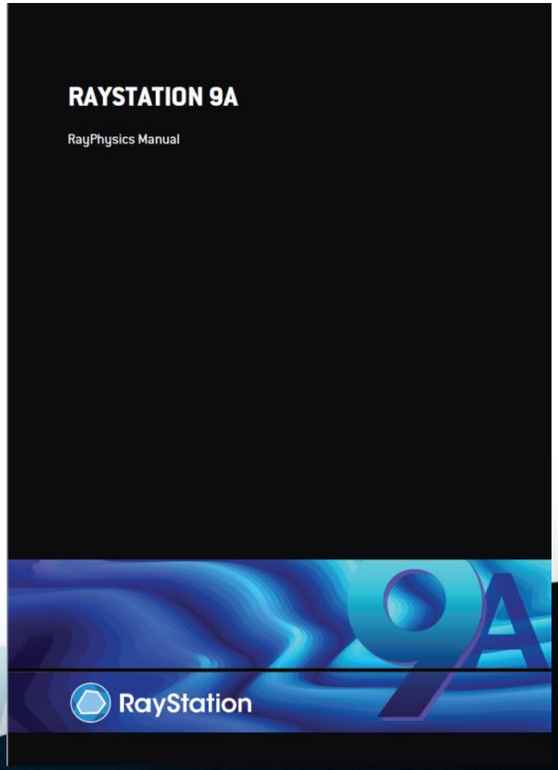
BEAM PROFILE CORRECTIONS AND OFF-AXIS SOFTENING FOR RADIUS > 20 CM

As of V9A and over!

- Beam Profile Corrections and Off-axis softening for radius > 20 cm – import diagonal profiles and model in "Beam Commissioning" tab
- **Note**: coordinates should be changing in both X and Y

Tank 0°
Collimators 0°
Diagonal measurements





RayStation 9A RayPhysics Manual → AppendixB

THANK YOU!

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