XVII Convegno Regionale AIRO Piemonte Valle d'Aosta

Asti 18 ottobre 2013 Hotel Salera

Associazione Italiana Radioterapia Oncologica

"Implementazione di un programma IMRT in un centro di Radioterapia"

Considerazioni di natura fisica

S.O.S.D. Fisica Sanitaria

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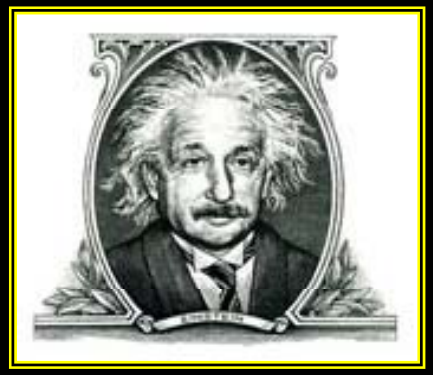
Ospedale "Cardinal Massaia"

A.S.L. AT

REGIONE PIEMONTE

IMRT
Il ruolo del fisico

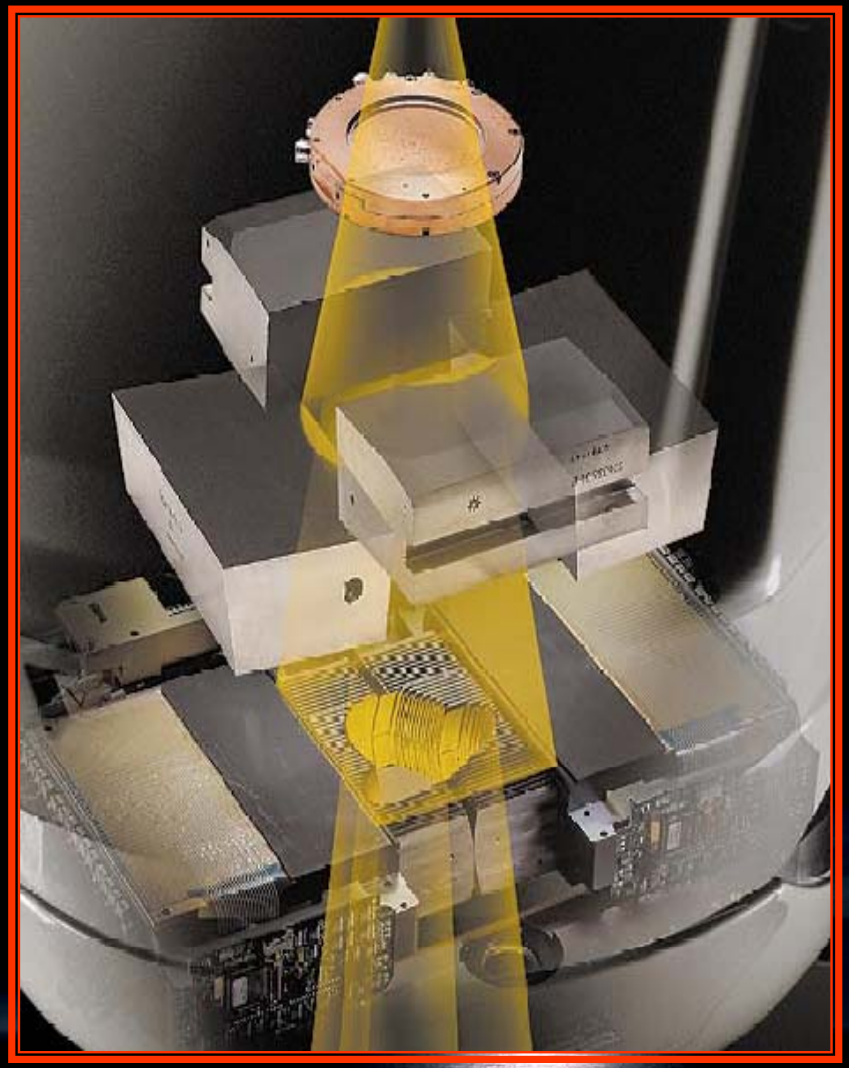


1. Commissioning LINAC
   - Dosimetria non convenzionale, MLC
2. Commissioning TPS
   - Distribuzioni modulate di dose
3. Esecuzione del piano di trattamento
   - Inverse planning
4. Verifica del piano di trattamento
   - Dosimetria 2D, 3D
5. Stesura protocolli per l'assicurazione di qualità
   - Introduzione nuovi CQ

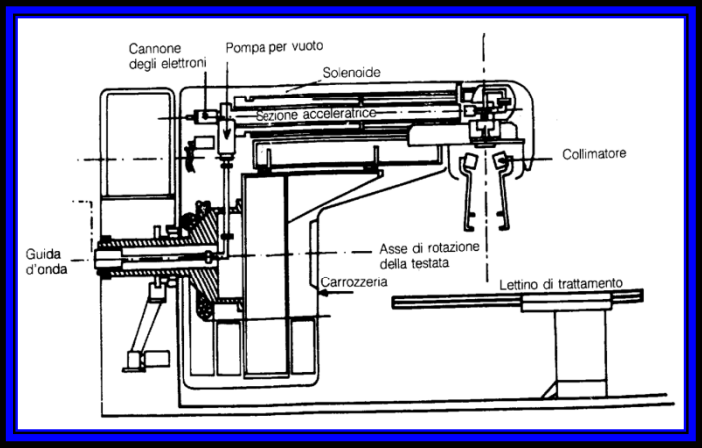
IMRT @ S.O.C. Radioterapia - ASTI

- Varian Clinac 600 DBX

  (single 6MV photon energy)
- Varian Millennium 120M
  - 60 pairs of leaves
  - Leaf width of 5 mm @ IC for the inner 40 pairs
  - Leaf width of 10 mm @ IC for the outer 20 pairs
  - Maximum leaf speed of 2.5 cm/s
- CMS XiO



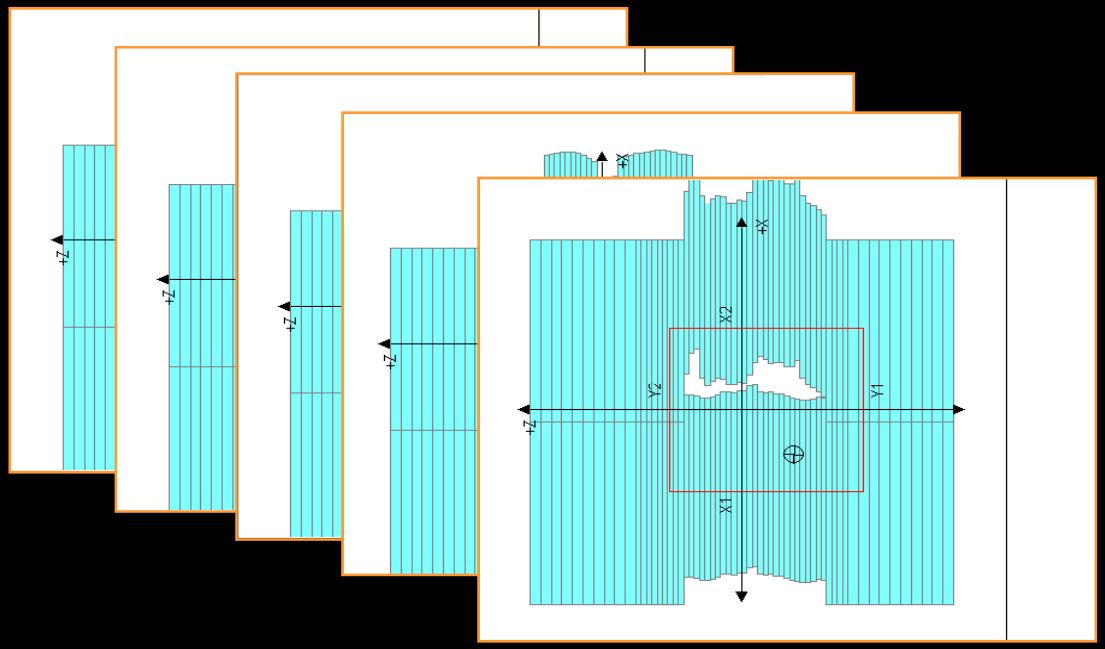
LINAC IMRT: *commissioning*



1. Small field dosimetry
2. Small MU delivery
3. MLC characterization
   - *a) Leaf positional accuracy*
   - *b) Leaves penumbra*
   - *c) Penumbra effect vs leaf position*
   - *d) Inter- and intra-leaf transmission factor*
   - *e) Tongue and groove effect*
   - *f) Leaf speed accuracy*
   - *g) Minimum leaf separation*

Small field dosimetry_I

Fluence modulation is the result of the superposition of very narrow fields (segments) both for static delivery (less segments) and for dynamic delivery (hundreds of segments)

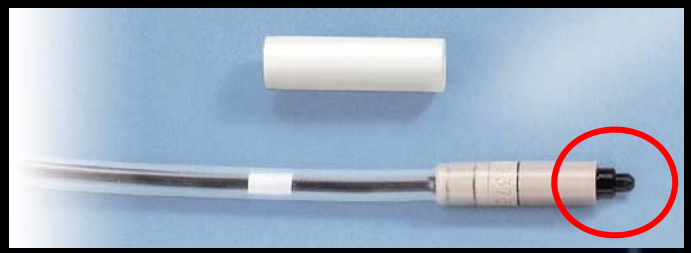


N.B.: small field (less than 3 x 3 cm^2) dosimetry is then required for the commissioning of IMRT treatment planning systems.

Small field dosimetry_II

Two cylindrical ionization chambers different in size were compared:

- IBA CC13
  a) Active volume : 0.13 cm^3
  b) inner diameter : 6 mm
- IBA CC04
  a) Active volume : 0.04cm^3
  b) Inner diameter : 4 mm



Measurements in water:

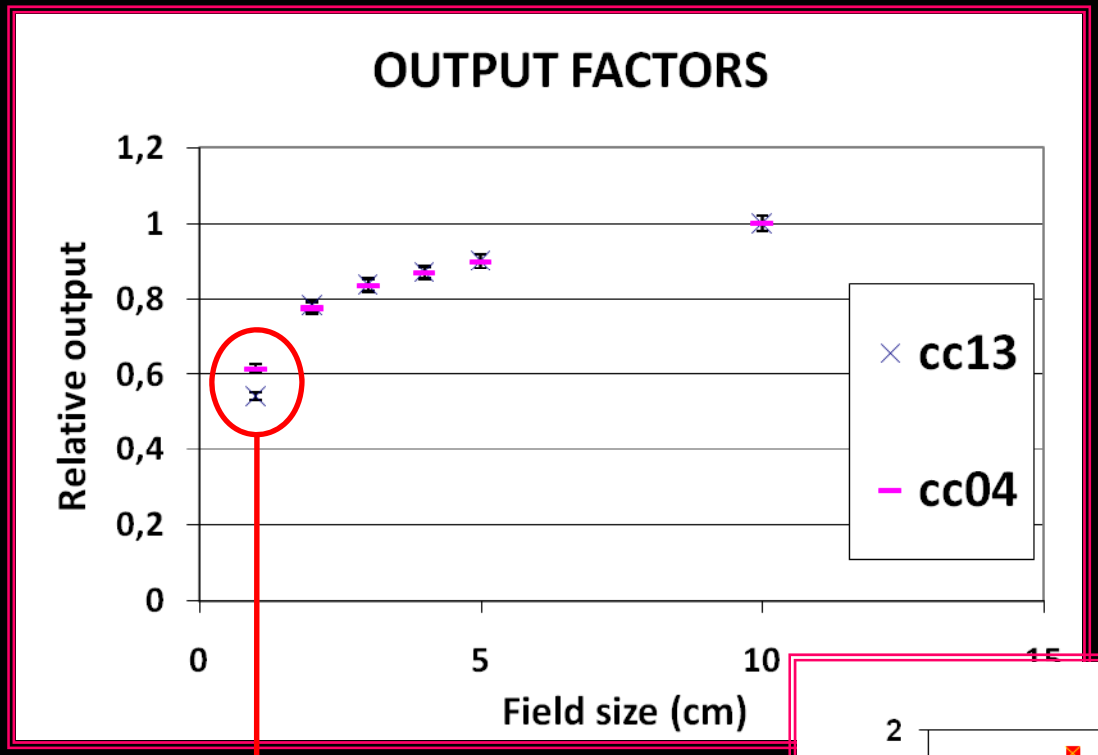
1.Output factors @ 10 cm depth for field sizes:

5 x 5 cm^2, 4x 4 cm^2, 3 x 3 cm^2, 2 x 2 cm^2, 1 x 1 cm^2

2.PDDs for field sizes:

5 x 5 cm^2, 4x 4 cm^2, 3 x 3 cm^2, 2 x 2 cm^2

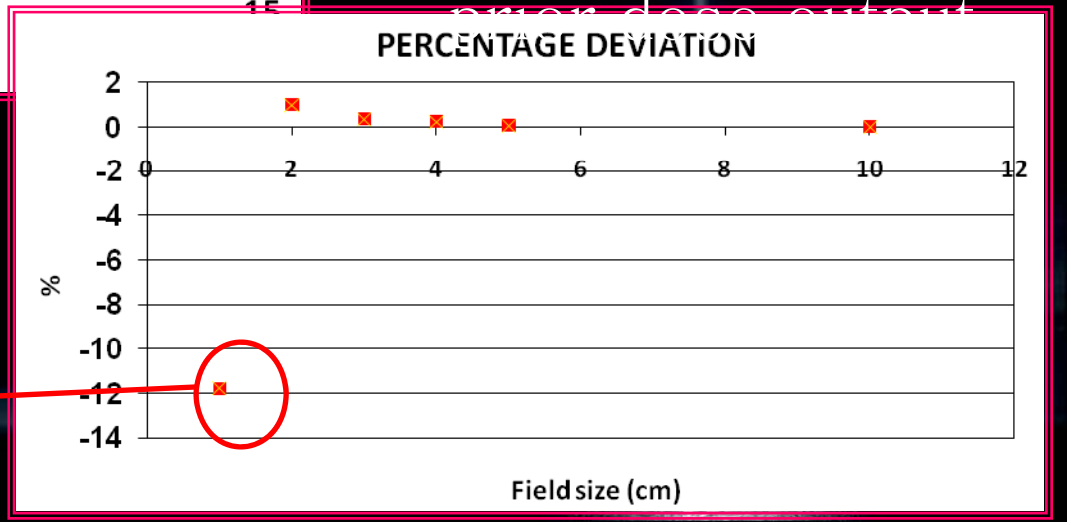
Output factors



I. Output normalized to 1 at 10 x 10 cm^2 field size

II. Five repeated measurements for each field size

III. Radiation field size measured prior dose output



CC13 underestimates dose output for a 1 x 1 cm^2 field size of about 12 %

Small MU delivery

Static segments deliver few (and even fractional) MU depending on the treatment planning

Limits of the linear accelerator need to be checked for

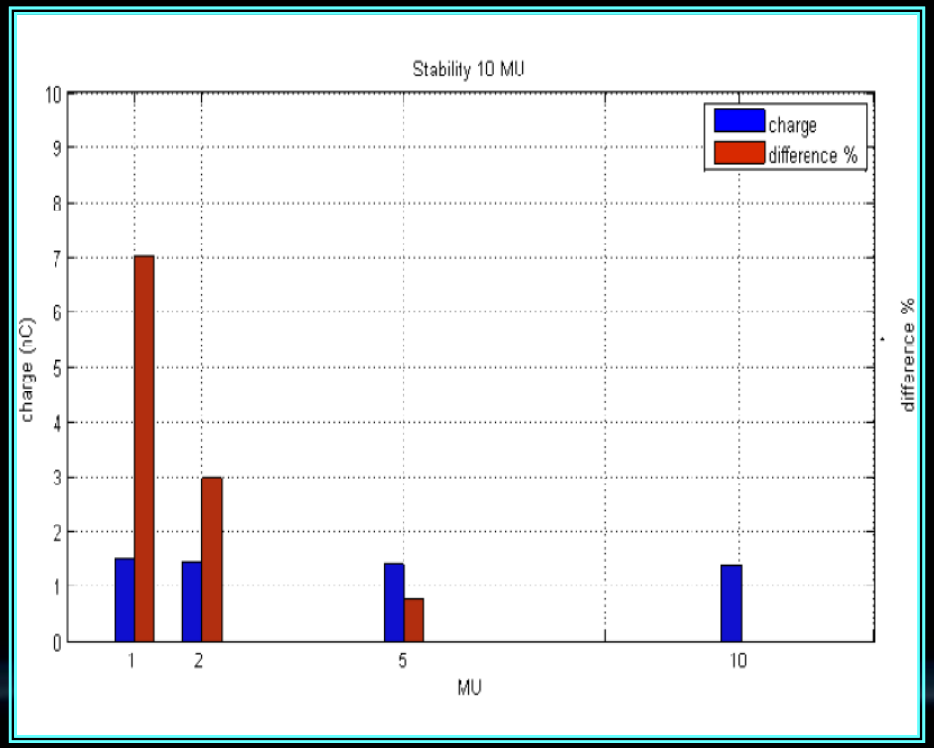
Dose *vs* MU linearity and stability
(IC Farmer-type measurements)

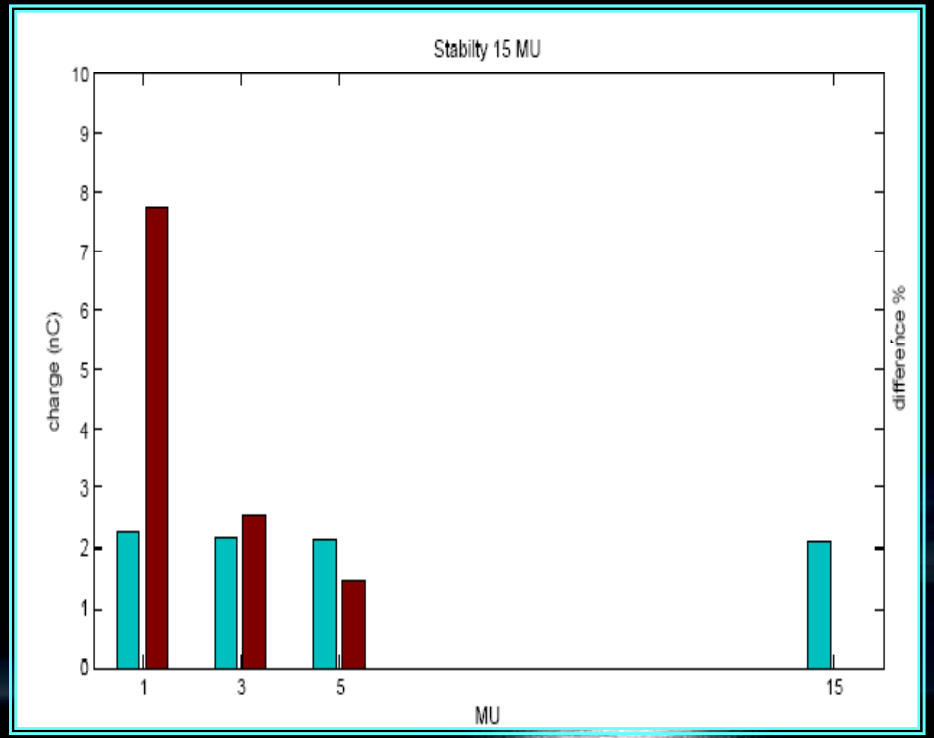
Beam uniformity (F&S) for small MU delivery
(Gafchromic EBT vs. Mapcheck SNC measurements)

Dose vs. MU stability

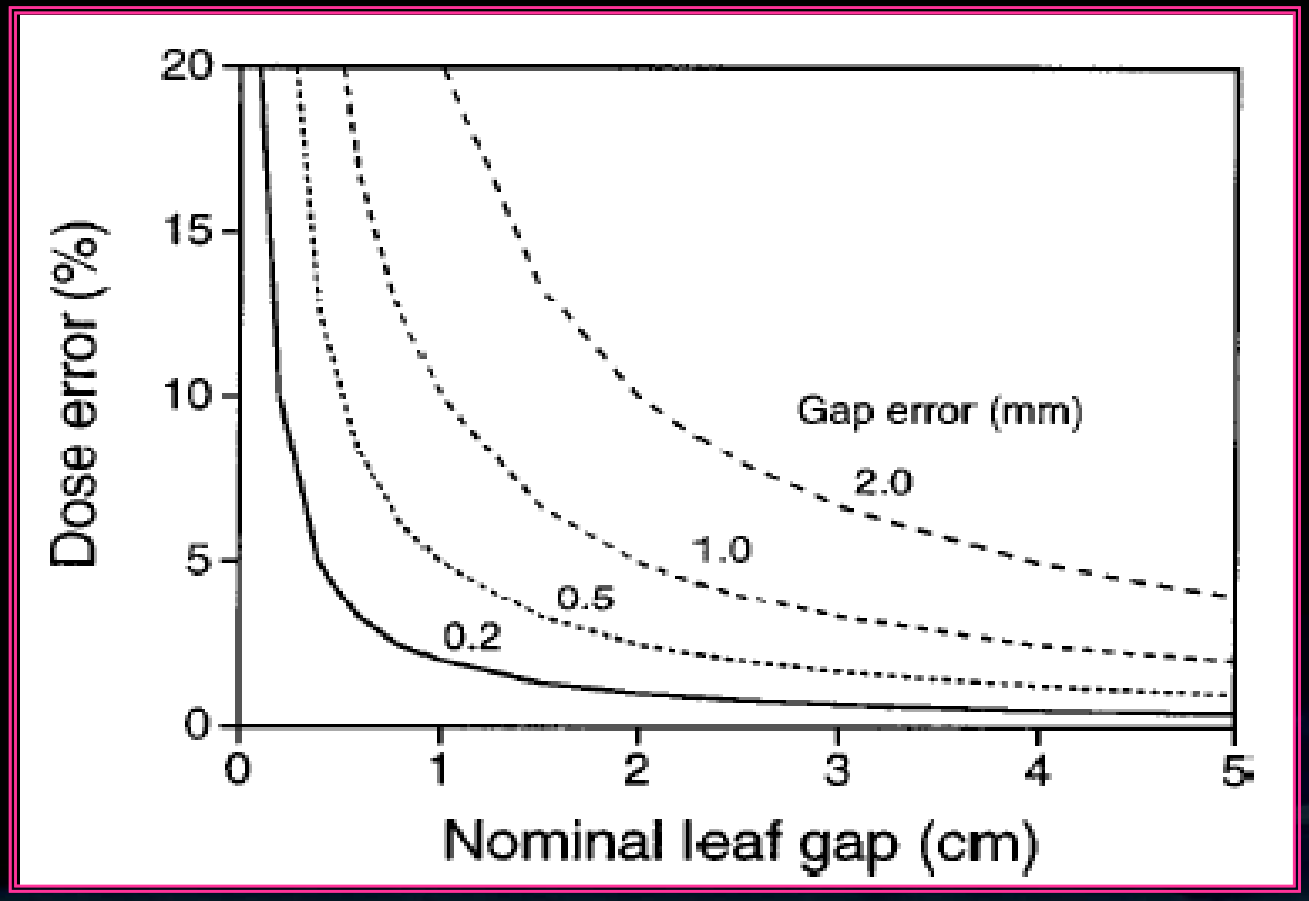
Single 10 MU delivery vs. sum of
- 1 MU delivered ten times
- 2 MU delivered five times
- 5 MU delivered two times

Single 15 MU delivery vs. sum of
- 1 MU delivered fifteen times
- 3 MU delivered five times
- 5 MU delivered three times



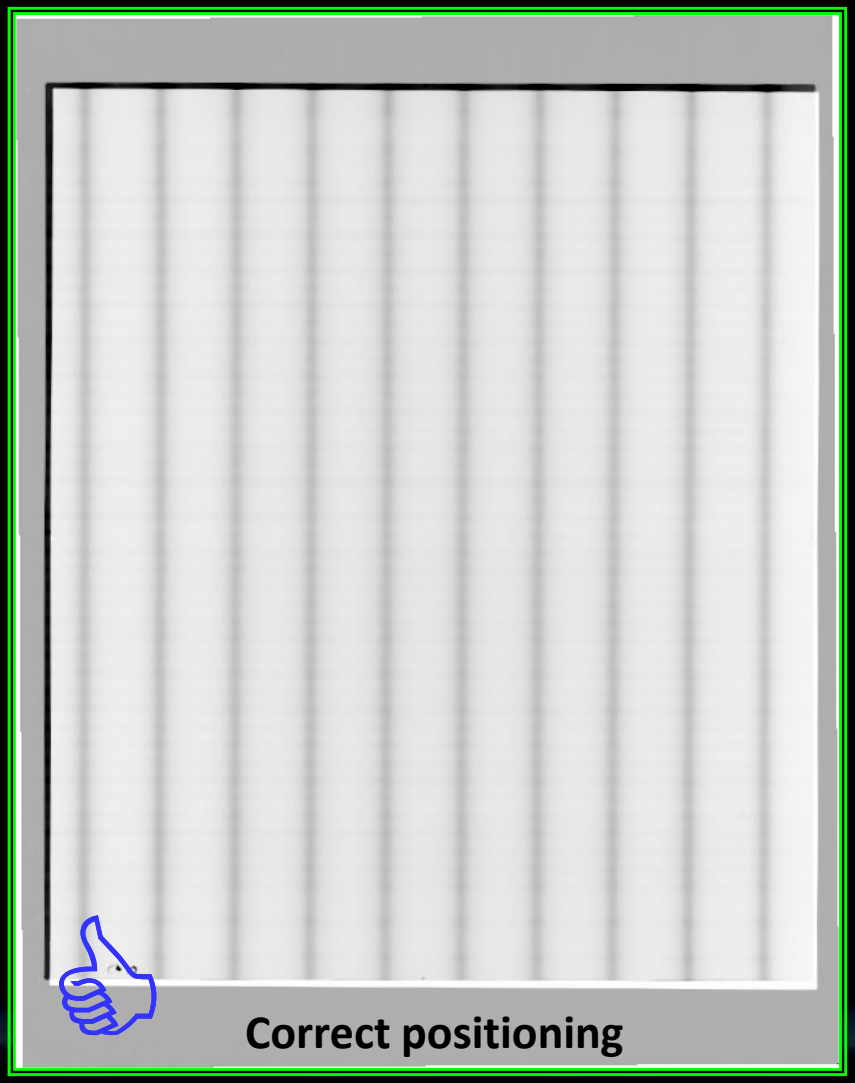


MLC
Leaf positional accuracy

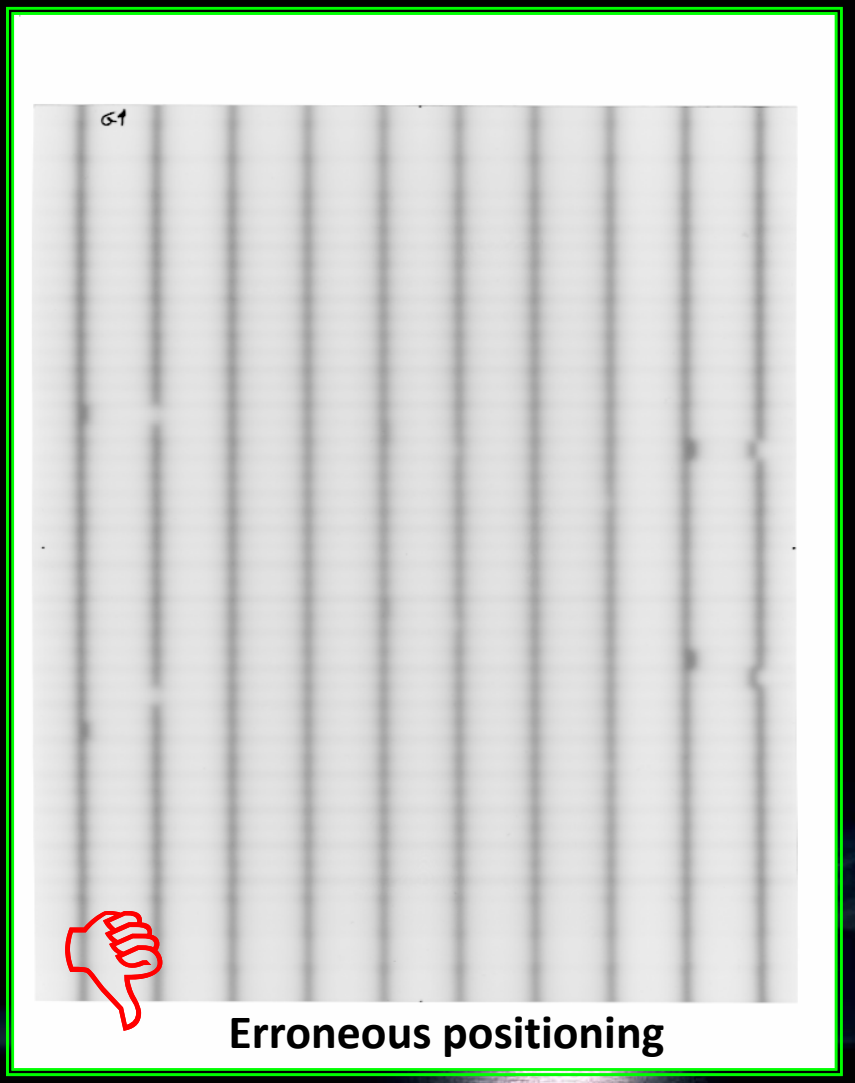


T. LoSasso et al, Med Phys (28), 2001

Leaf positional accuracy
Qualitative analysis

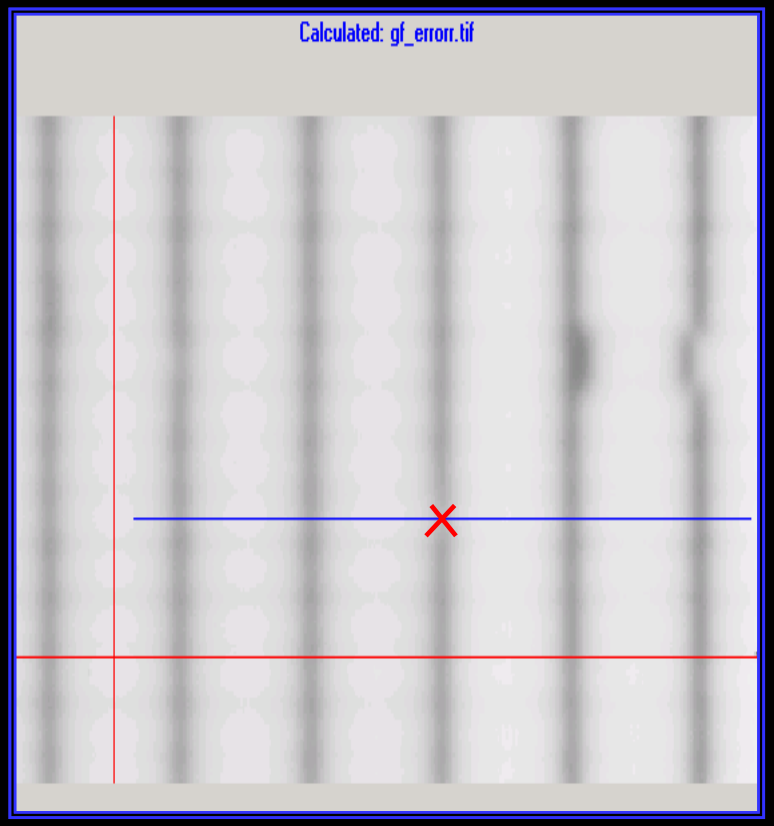


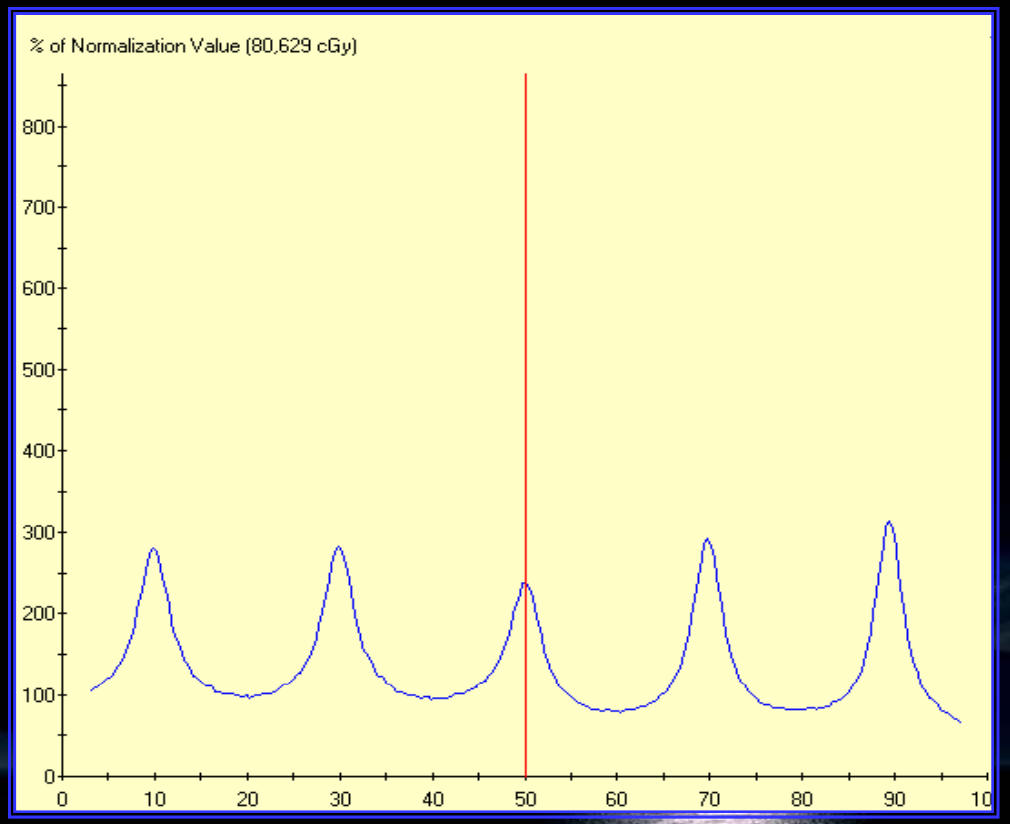
Correct positioning



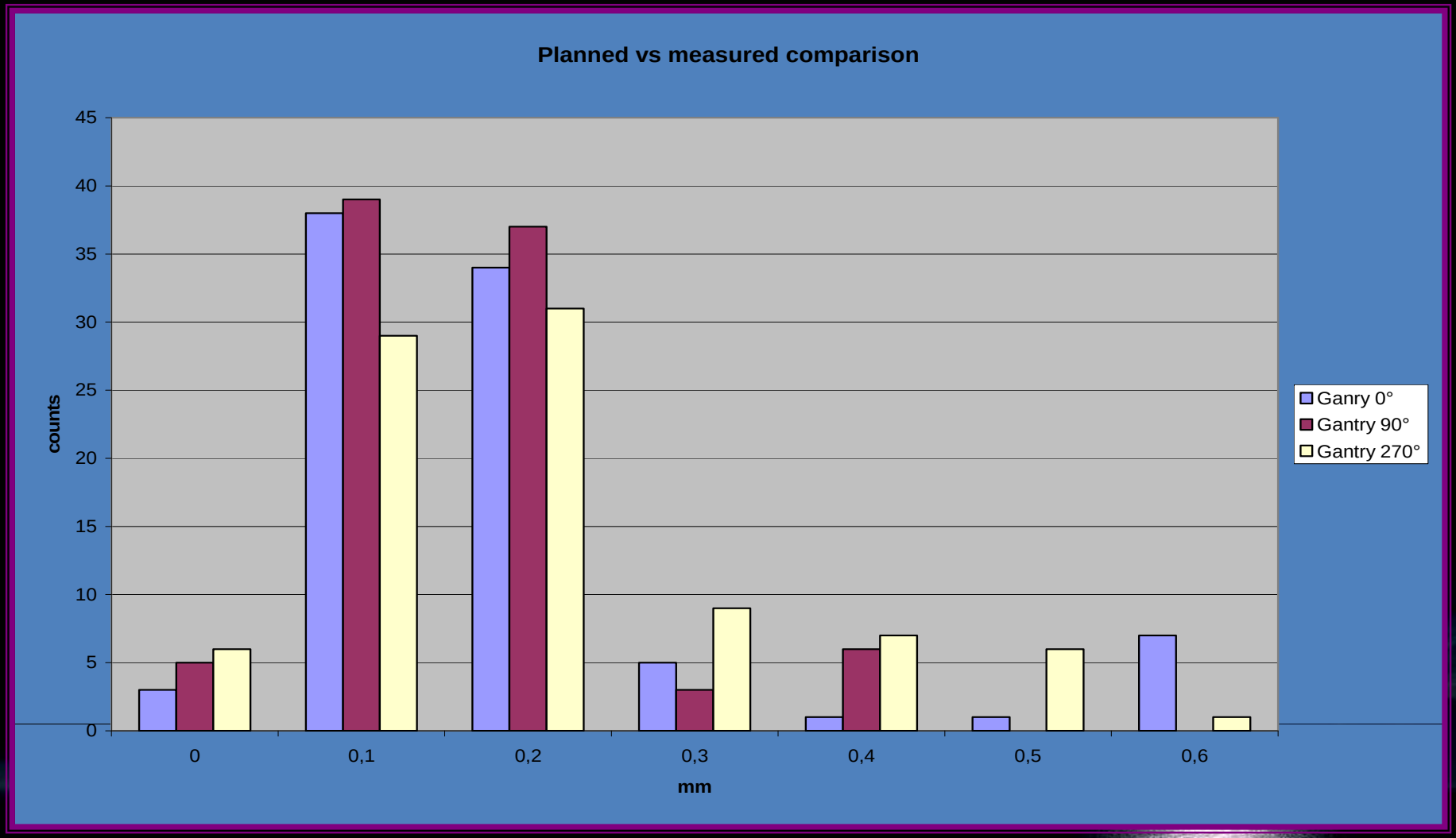
Erroneous positioning

Leaf positional accuracy
Quantitative analysis

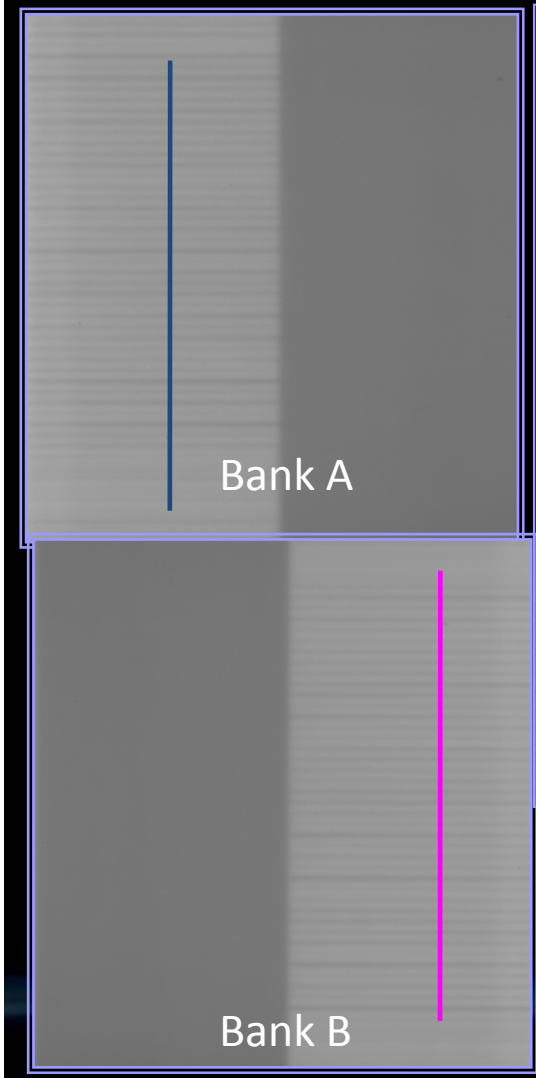


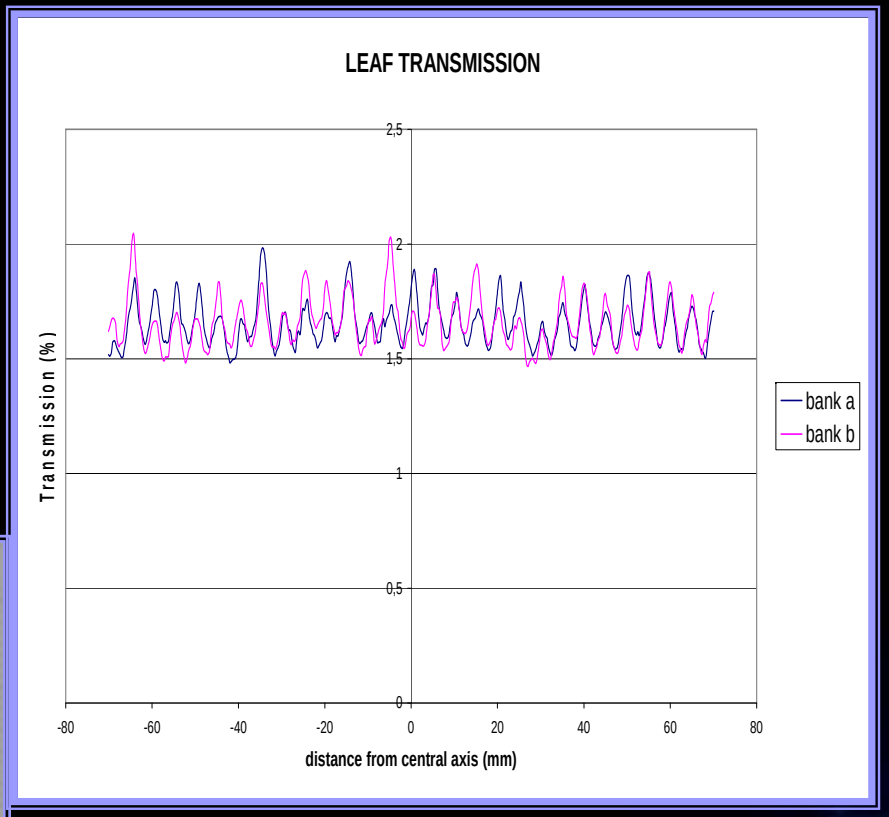


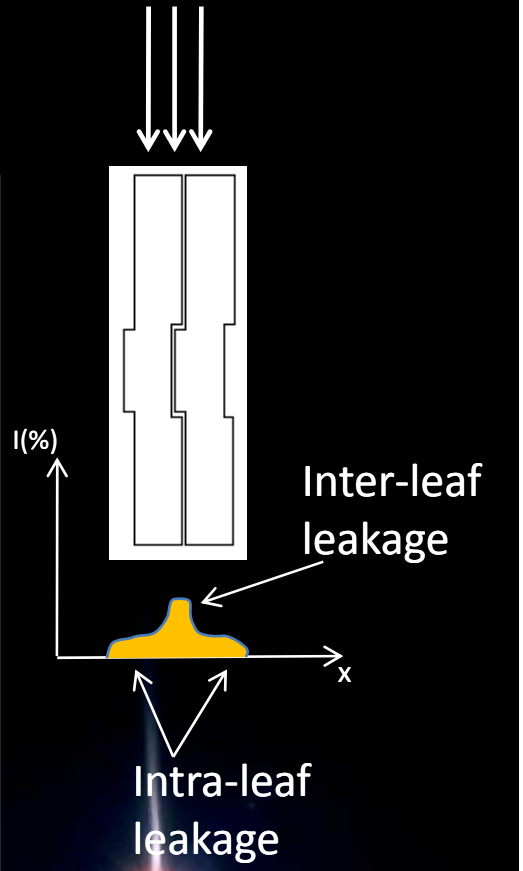
Leaf positional accuracy Quantitative analysis : Gravity effect



LEAF TF – film dosimetry

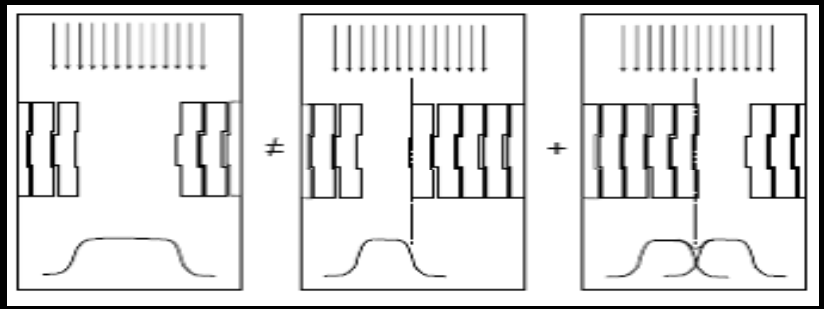




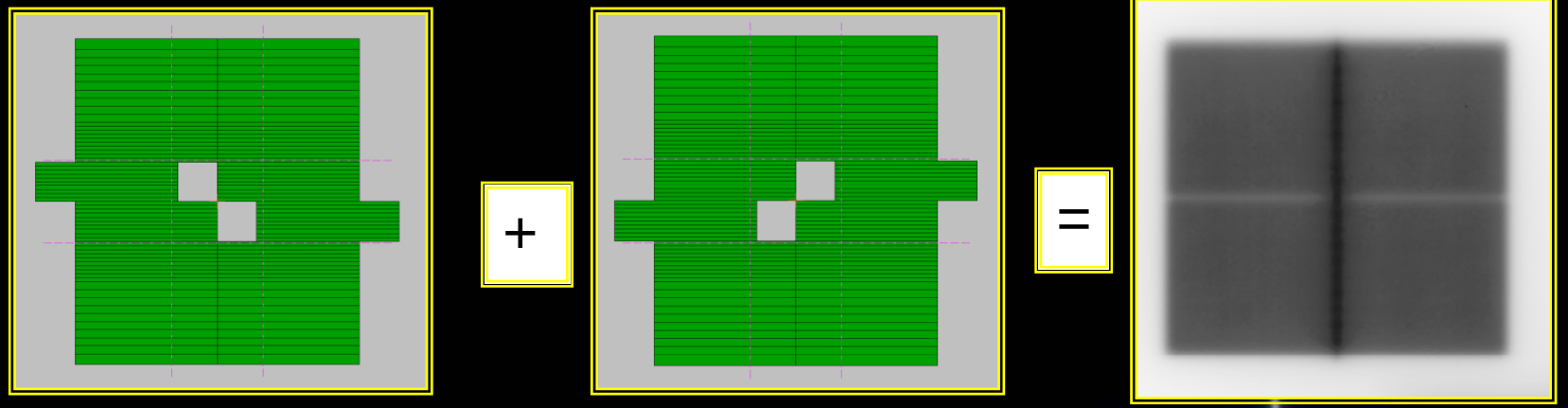


Range LEAF TF: from 1.45 % to 2.05 %
Inter-leaf ca. 0,6 % greater than intra-leaf TF

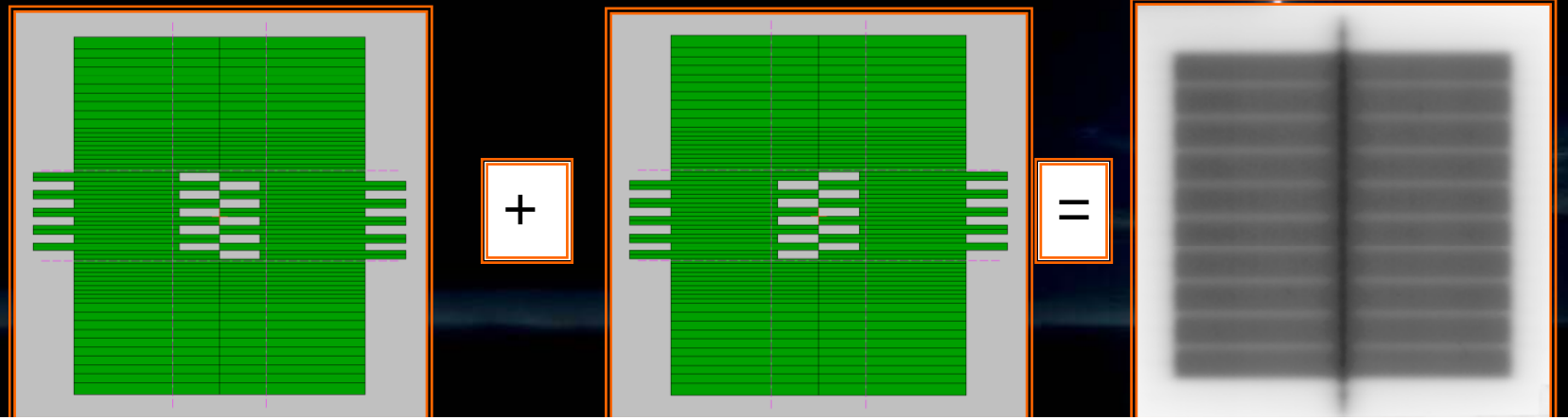
Tongue and groove effect



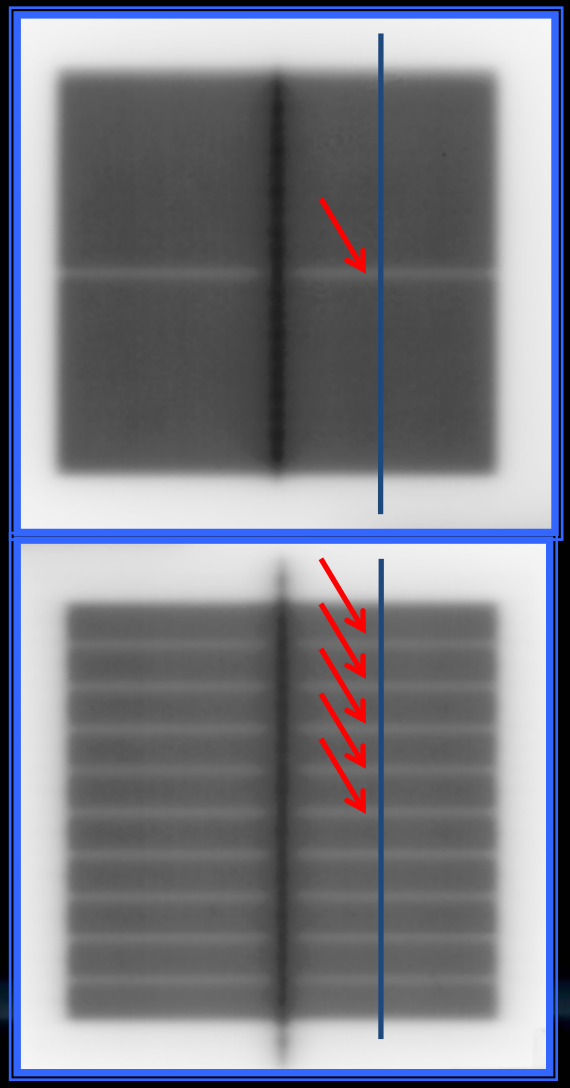
TEST A

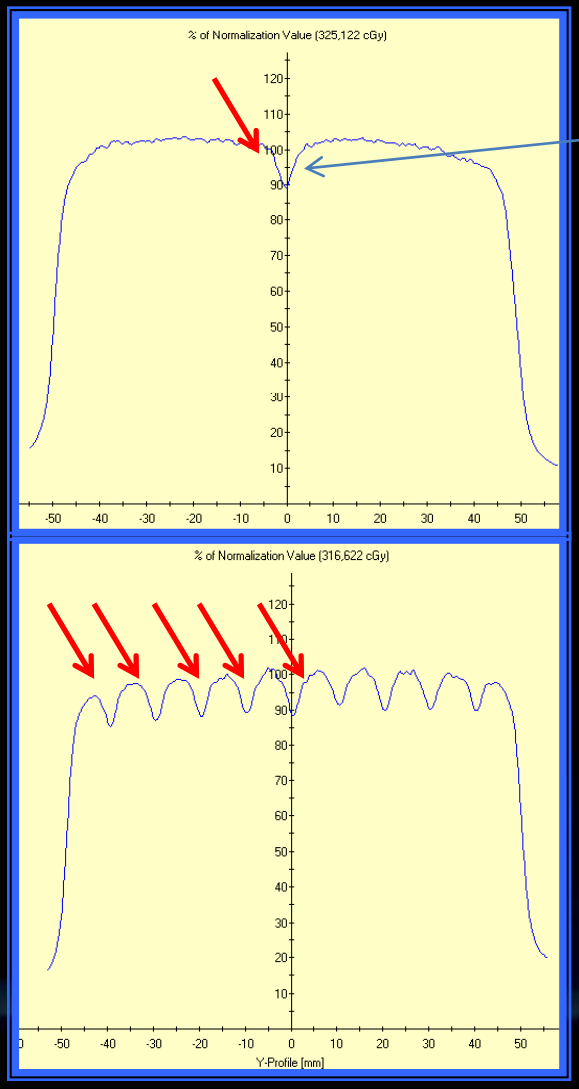


TEST B



Tongue and groove effect Results





Dose deficit: 12.5 %

Position	Dose %	FWHM (mm)
1	87,8	3,9
2	88,3	3,3
3	88,6	3
4	88,7	3
5	89,5	2,8
6	90,4	3
7	90,6	3,3
8	90,5	3,3
9	90,5	3,8

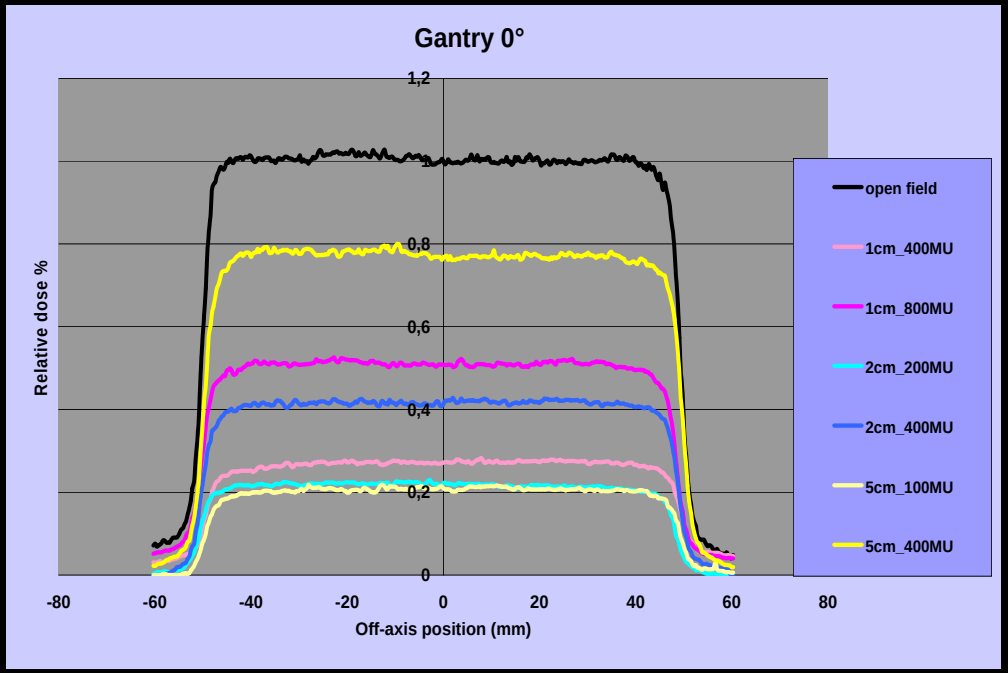
Leaf speed accuracy

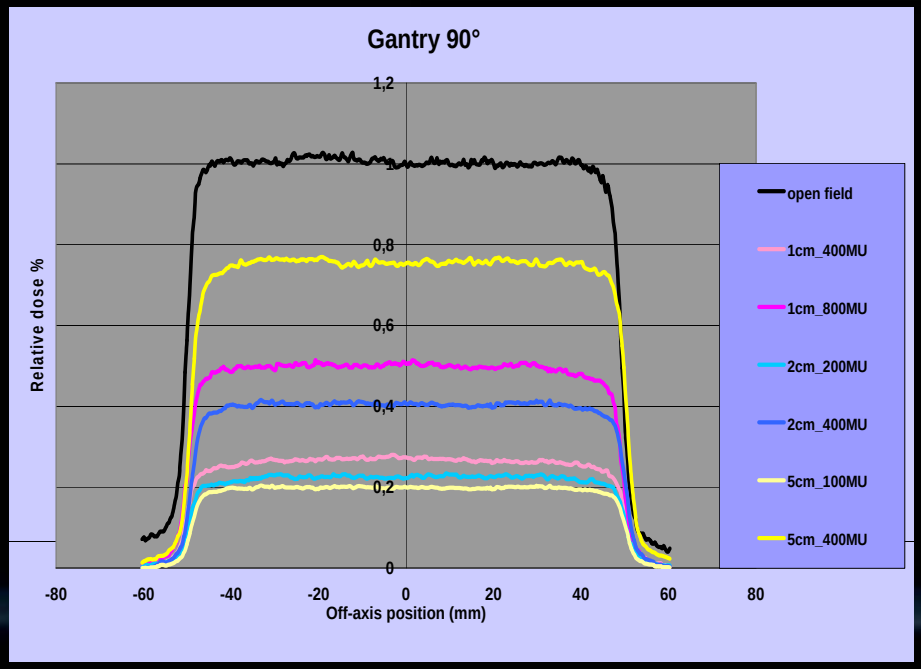
$$\text{Leaf speed (cm/s)} = \frac{\text{Segment leaf travel (cm)} \cdot \text{Dose rate (MU/s)}}{\text{Segment MU fraction} \cdot \text{Total MU}}$$

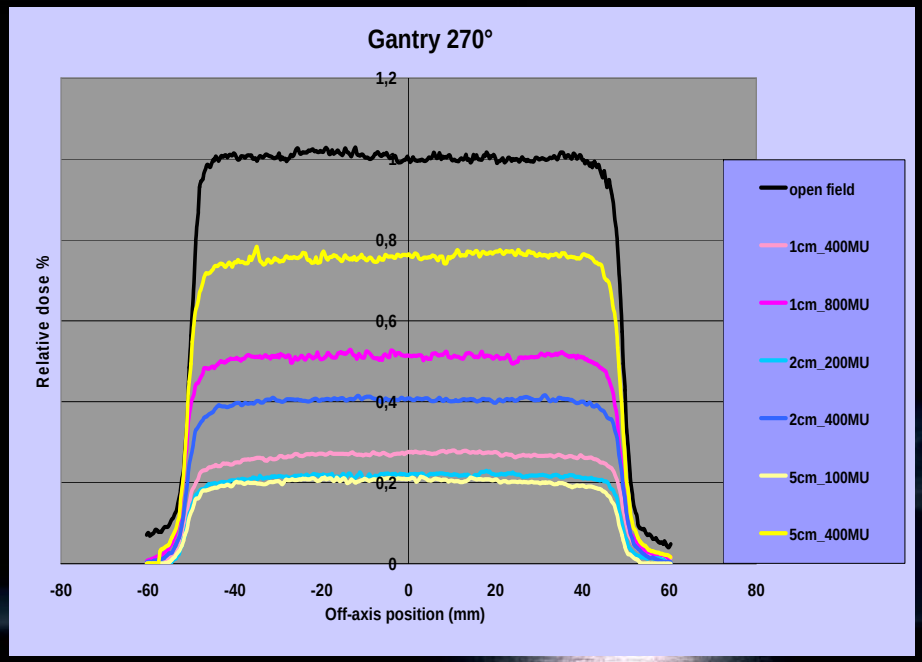
Three sweeping MLC fields across the field (10 x 10 cm^2) with constant gap but different in size were examined:

Gap width (cm)	MU fraction	Total MU	Leaf speed (cm/s)
1	0,0909	400	0,14
		800	0,07
2	0,1666	200	0,30
		400	0,15
5	0,3333	100	0,75
		400	0,19

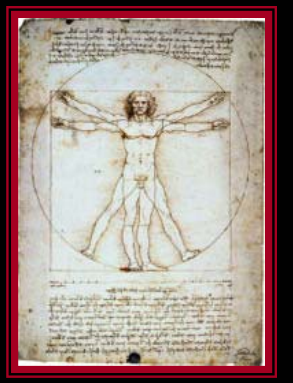
Sweeping gaps with constant speed should produce uniform fluence pattern (assumed that leaves are moving properly)


Gantry 0°
Relative dose %
1,2
1
0,8
0,6
0,4
0,2
0
-80
-60
-40
-20
0
20
40
60
80
Off-axis position (mm)
open field
1cm_400MU
1cm_800MU
2cm_200MU
2cm_400MU
5cm_100MU
5cm_400MU


Gantry 90°
Relative dose %
1,2
1
0,8
0,6
0,4
0,2
0
-80
-60
-40
-20
0
20
40
60
80
Off-axis position (mm)
open field
1cm_400MU
1cm_800MU
2cm_200MU
2cm_400MU
5cm_100MU
5cm_400MU

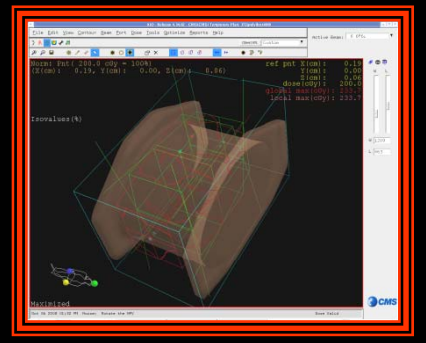

Gantry 270°
Relative dose %
1,2
1
0,8
0,6
0,4
0,2
0
-80
-60
-40
-20
0
20
40
60
80
Off-axis position (mm)
open field
1cm_400MU
1cm_800MU
2cm_200MU
2cm_400MU
5cm_100MU
5cm_400MU

First clinical patient



- 74 anni
- Adenoca. T2c, Gleason 8 (4+4), PSA 28.2 ng/ml
- Iter terapeutico: irradiazione linfonodi pelvici + (prostata e vescichette) + prostata
- 45 Gy pelvi, 57 Gy p+v, 75 Gy prostata
- 6 ultime sedute IMRT su pelvi (10,8 Gy totali, 180 cGy/die)

Piano di trattamento



- Sette fasci coplanari
- Angoli gantry

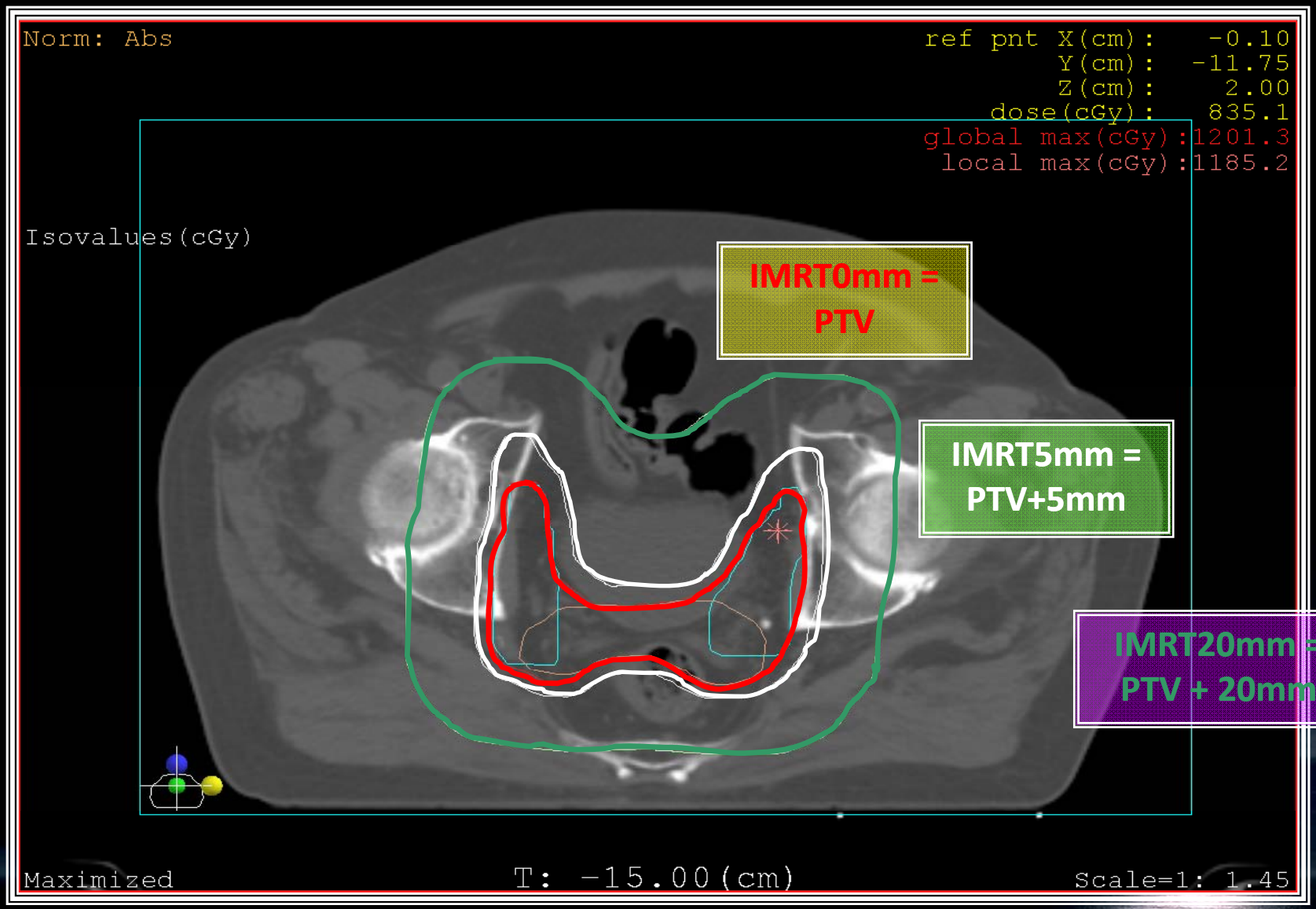
0°, 45°, 100°, 150°, 210°, 260°, 315°

- Collimatore 0°

direzione di movimento lamelle parallelo piano rotazione gantry

- Step and shoot modality
- Dimensione minima lato equivalente segmento 2 cm
- 12 livelli di intensita’

IMRT contouring

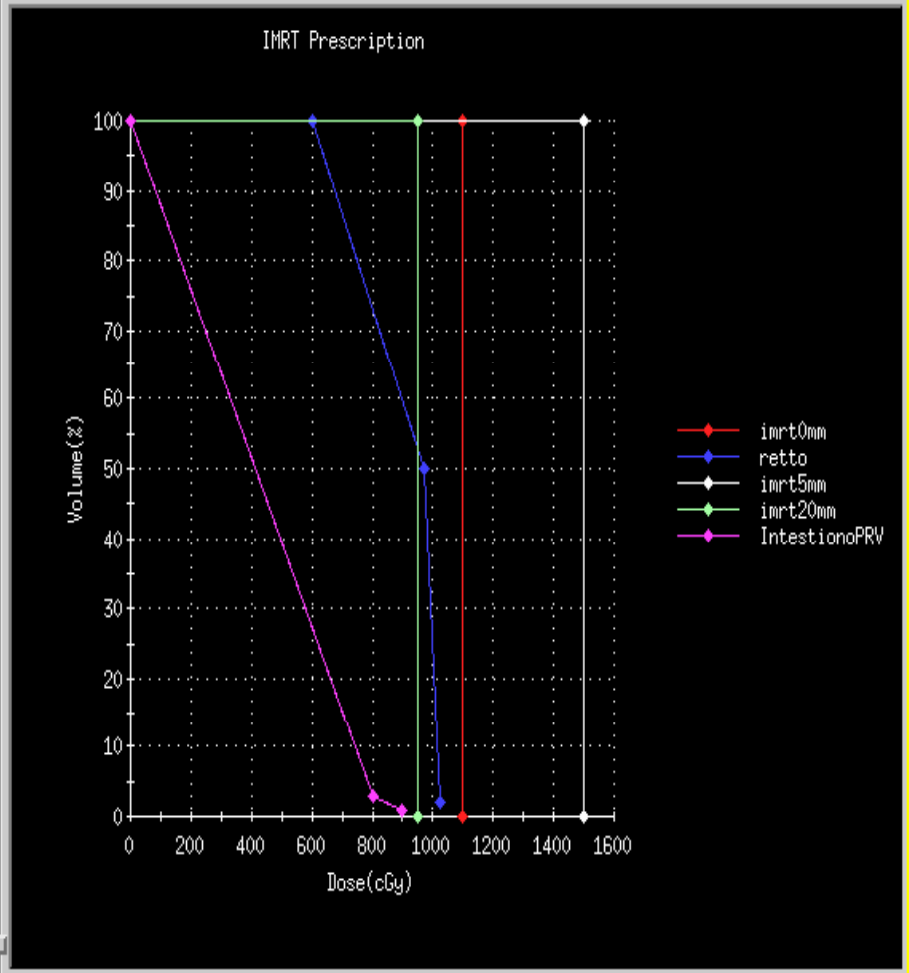


IMRT prescription

IMRT Prescription

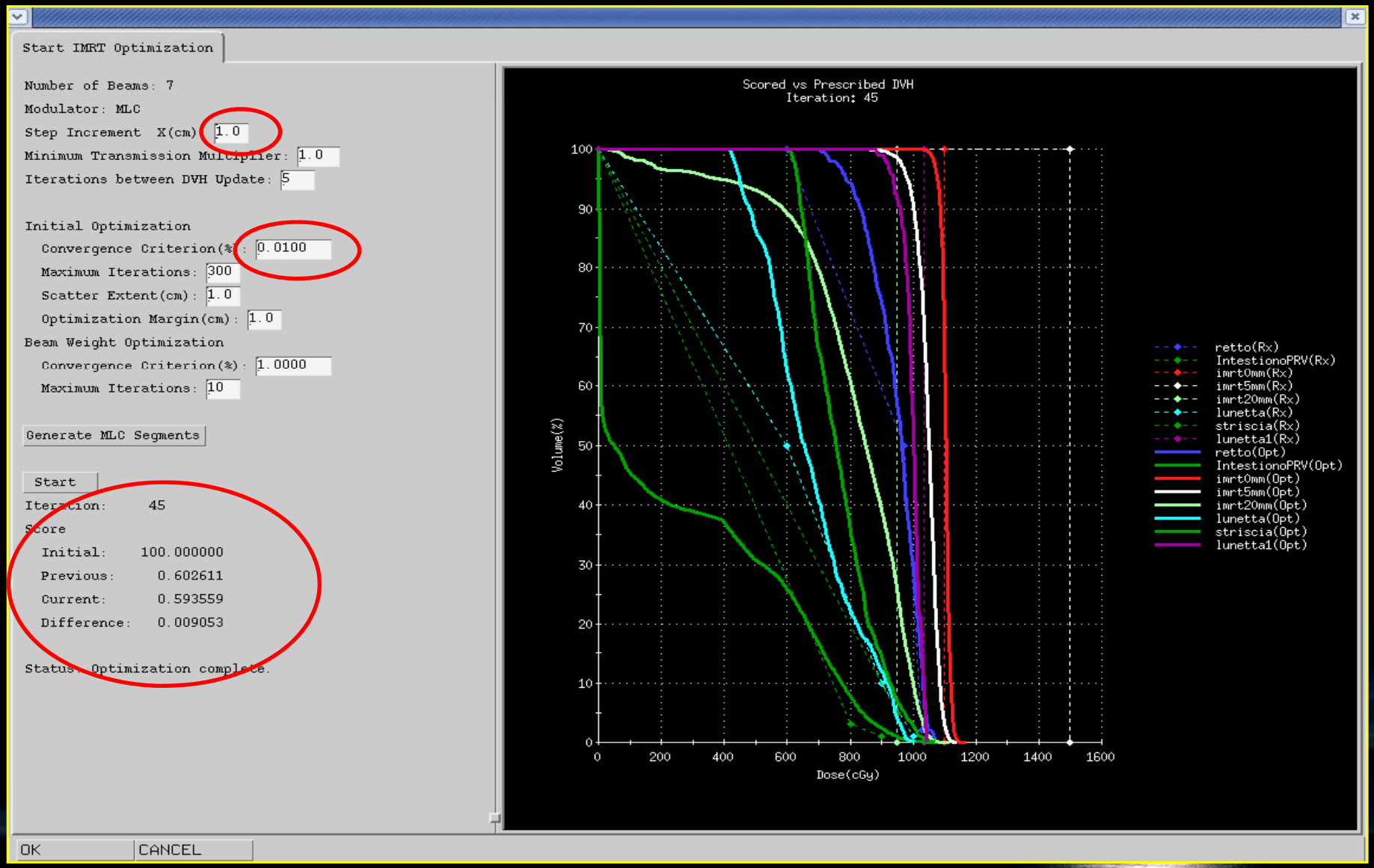
IMRT Prescription

Structure	Objective	Dose(cGy)	Volume(%)	Weight	Power	Status
imrt0mm	Maximum	1100	0	300	2.1	On
	Minimum	1100	100	300	2.3	On
retto	Dose Volume	1026	2	300	2.0	On
	Dose Volume	970	50	200	2.0	On
	Dose Volume	600	100	300	2.0	On
imrt5mm	Maximum	1500	0	100	2.0	On
	Threshold	1500	100		1.0	On
imrt20mm	Maximum	950	0	100	2.1	On
IntestionoPRV	Dose Volume	900	1	400	2.0	On
	Dose Volume	800	3	400	2.0	On



OK CANCEL

IMRT optimization



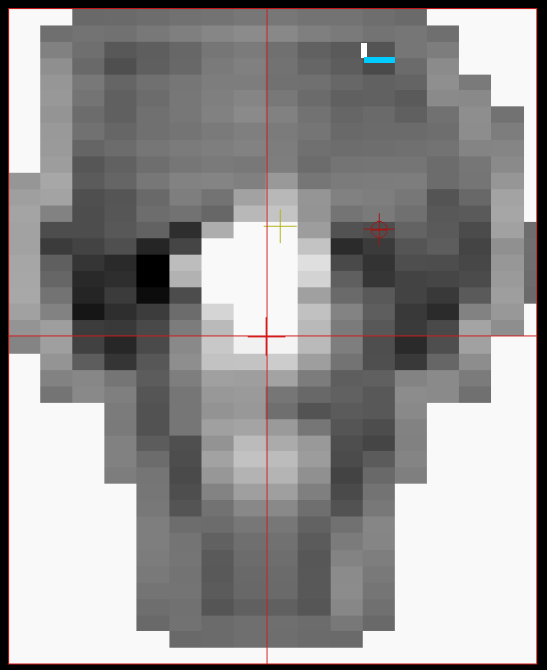
From optimal fluence to actual fluence

Leaf Motion Calculator

=

Calcolo delle traiettorie delle lamelle in funzione del limiti fisici e meccanici

Optimal Fluence



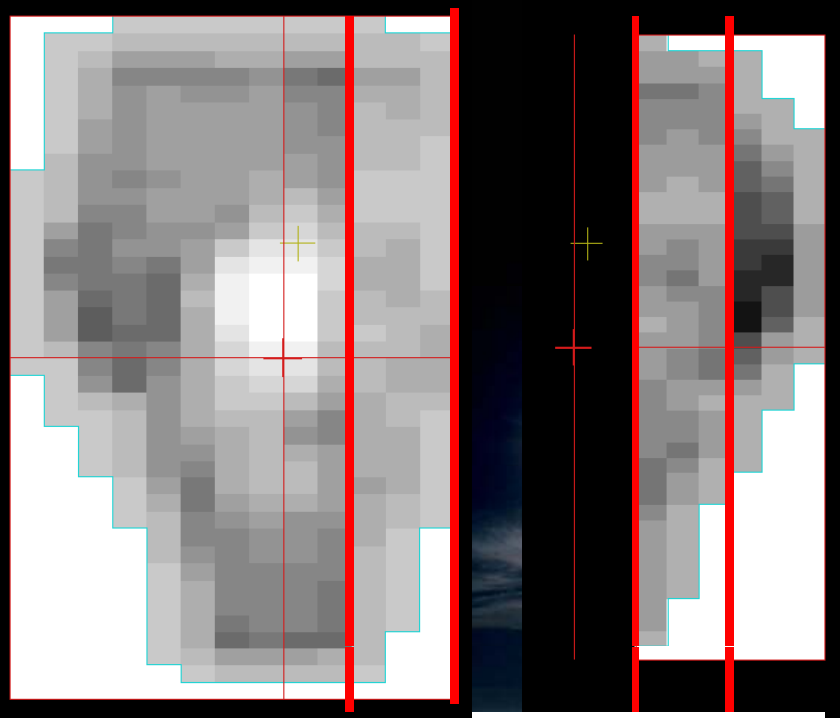
> 14,5 cm

Leaf width

Step incr.

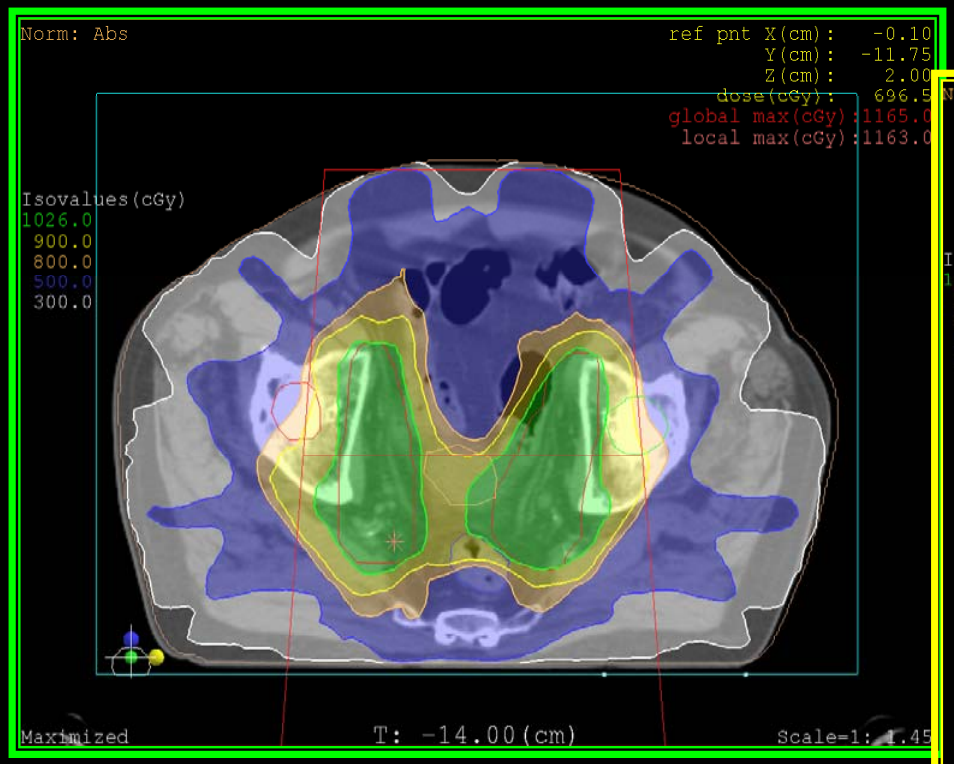
LMC

Actual Fluence

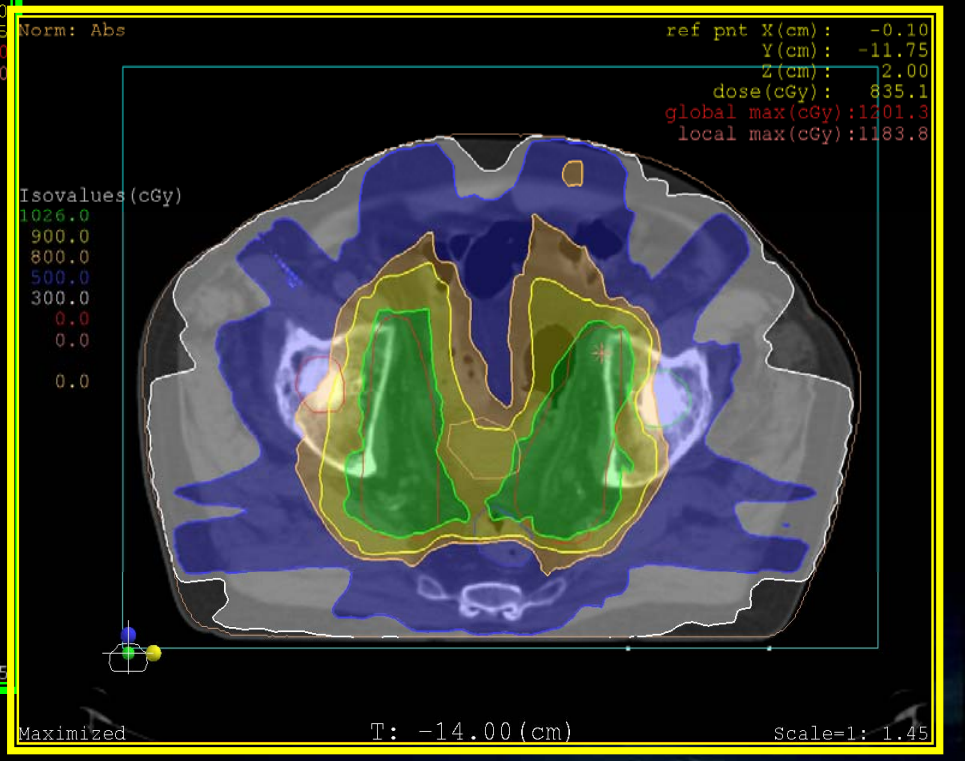


Overlapping area

From optimal dose to delivered dose

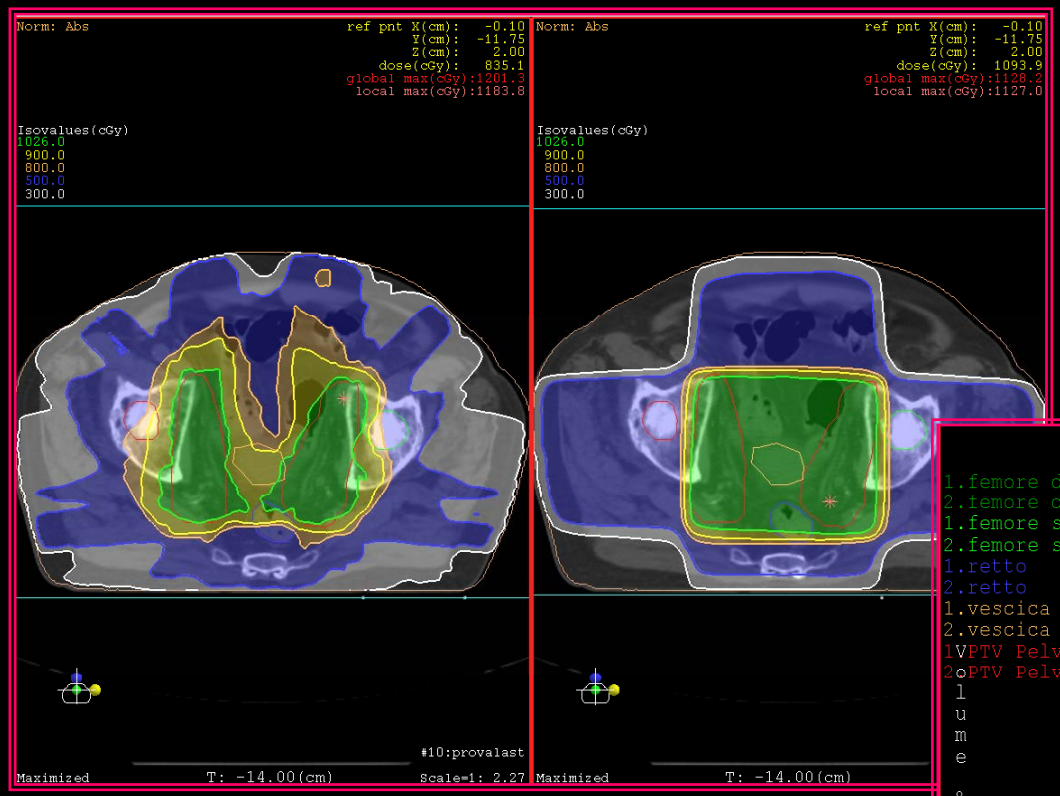


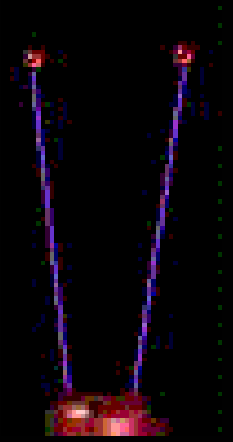
Optimal dose distribution



Delivered dose distribution

IMRT *vs* 3D-CRT

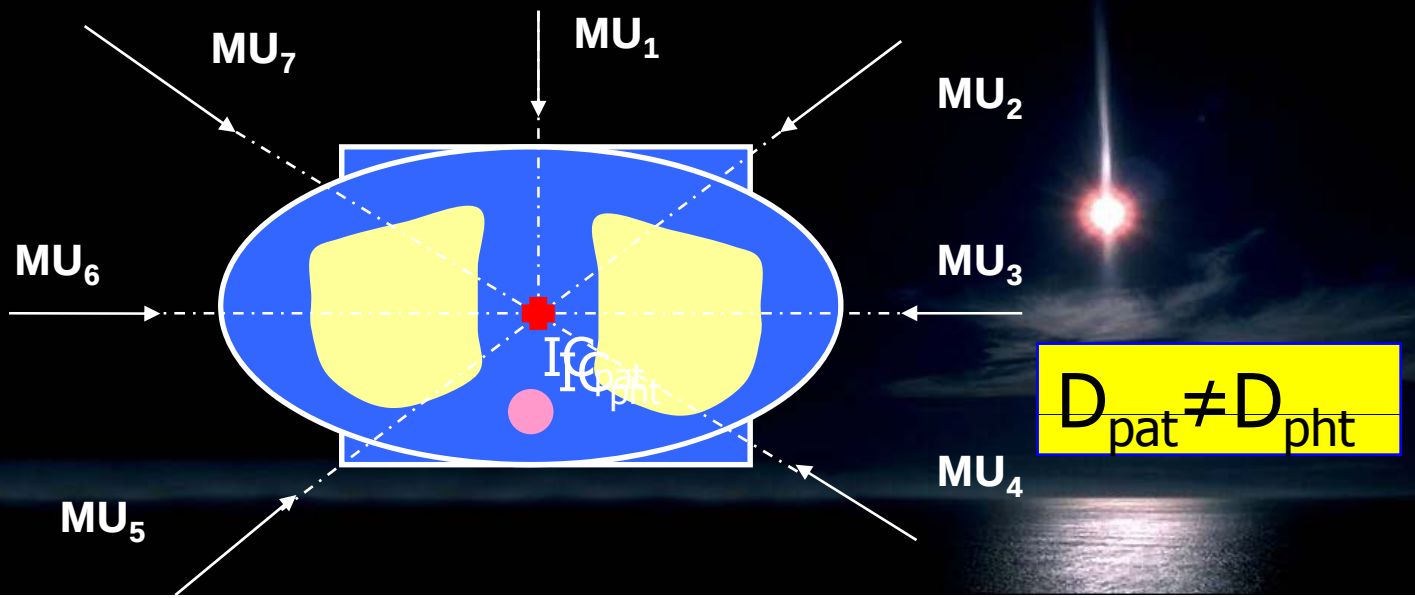




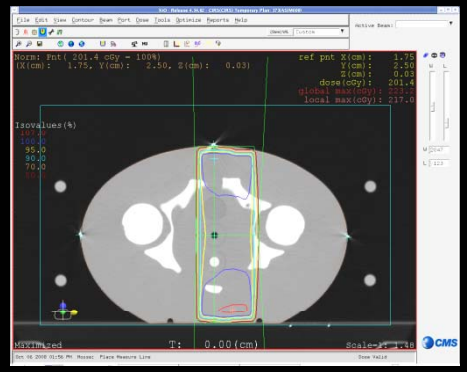
IMRT verification

Due to high complex dose distribution delivered mostly delivered by treatment fields IMRT requires 2D dose map verification rather than canonical point dose check.

Concept of **verification plan**: treatment plan with its own geometric and dosimetric characteristics is moved to "an easy to verify" patient, a cubic phantom.



IMRT verification



a) Misura di dose puntuale in fantoccio antropomorfo

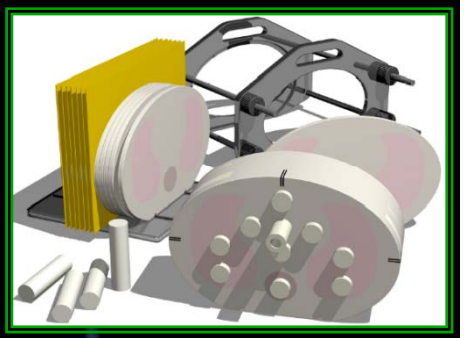
b) Misura mappe di dose con matrice di diodi (SunNuclear Mapcheck)

c) Misura mappe di dose con pellicole radiocromiche (EBT)

Misura di dose puntuale

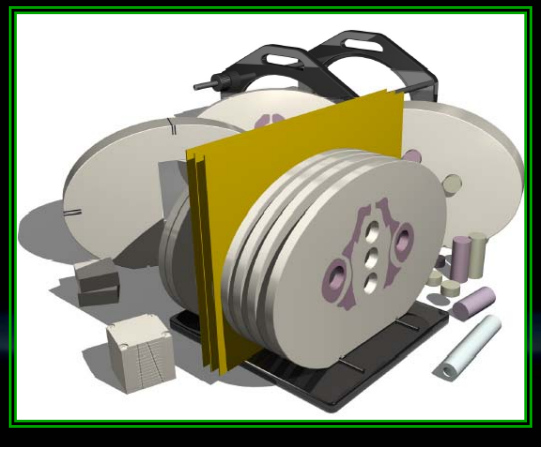
- Esecuzione dell'intero trattamento su fantoccio antropomorfo
- Confronto dose misurata / dose calcolata

A) Microcamera a ionizzazione (Scanditronix Wellhofer CC01)

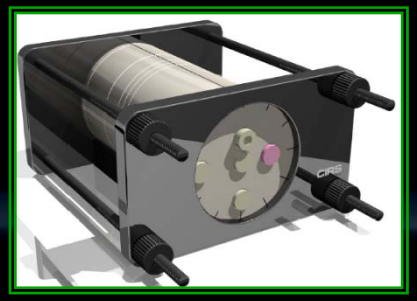


$Dose_{diff}$ < 1,4%

B) Camera a ionizzazione Farmer



$Dose_{diff}$ ~ 10 %



Misura mappe di dose - procedura

1. Posizionamento fasci di trattamento ad angolo 0° di gantry
2. Esecuzione piano di verifica su TPS
3. Esportazione mappe di dose a profondità di 5 cm per singolo fascio di trattamento
4. Misura della mappa di dose alla medesima profondità
5. Confronto delle mappe (indice γ e profili)

Mapcheck datasheet

QA File Parameter

Patient Name	:
Patient ID	: verification
Plan Date	: Oct 08 2008
SSD	:
Depth	:
Energy	:
Angle	:

Absolute Dose Comparison

% Diff	: 3,0
D to A (mm)	: 3,0
Threshold	: 10,0
Rotation Angle	: 0,0 Degs
Meas Uncertainty	: Yes
Dose Diff Thresh	: 1,0 cGy

Summary

Total Points	: 304
Passed	: 304
Failed	: 0
% Passed	: 100

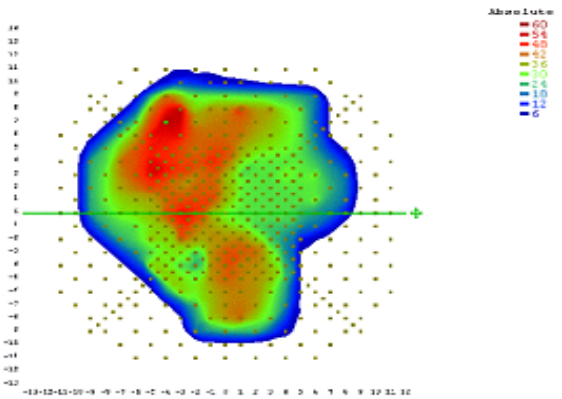
Dose Values in cGy

	Cax	Normal	Peked
Set1	29,04	58,53	29,04
Set2	29,10	58,10	29,10
Set1-Set2	-0,06	0,43	-0,06
% Diff	-0,21	0,75	-0,21
DTA(mm)	0,00	0,00	0,00
Coords (y,x) cm	0,0	7,-4	0,0

Notes

Reviewed By :

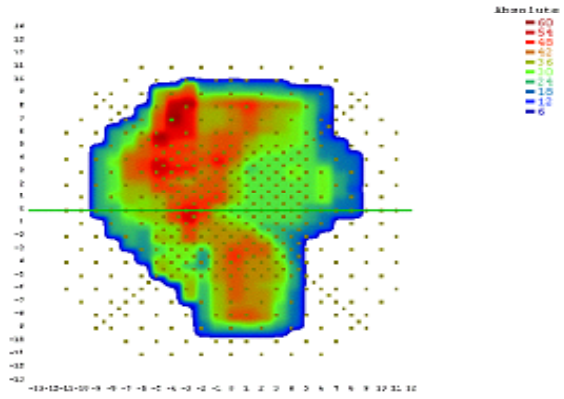
Set1



C:\SNC\MapCHECK\Data\4832417\bigatticlinical\mbigattibeam7x3y0.txt

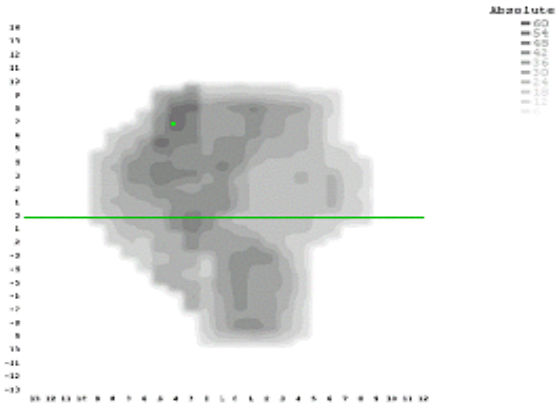
Set2

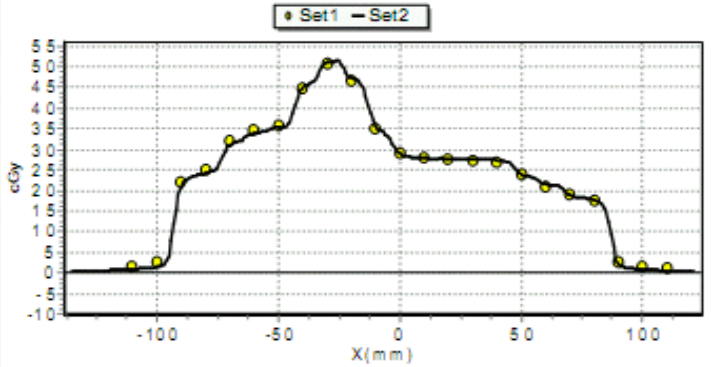
CAX Offset X=3 Y=0



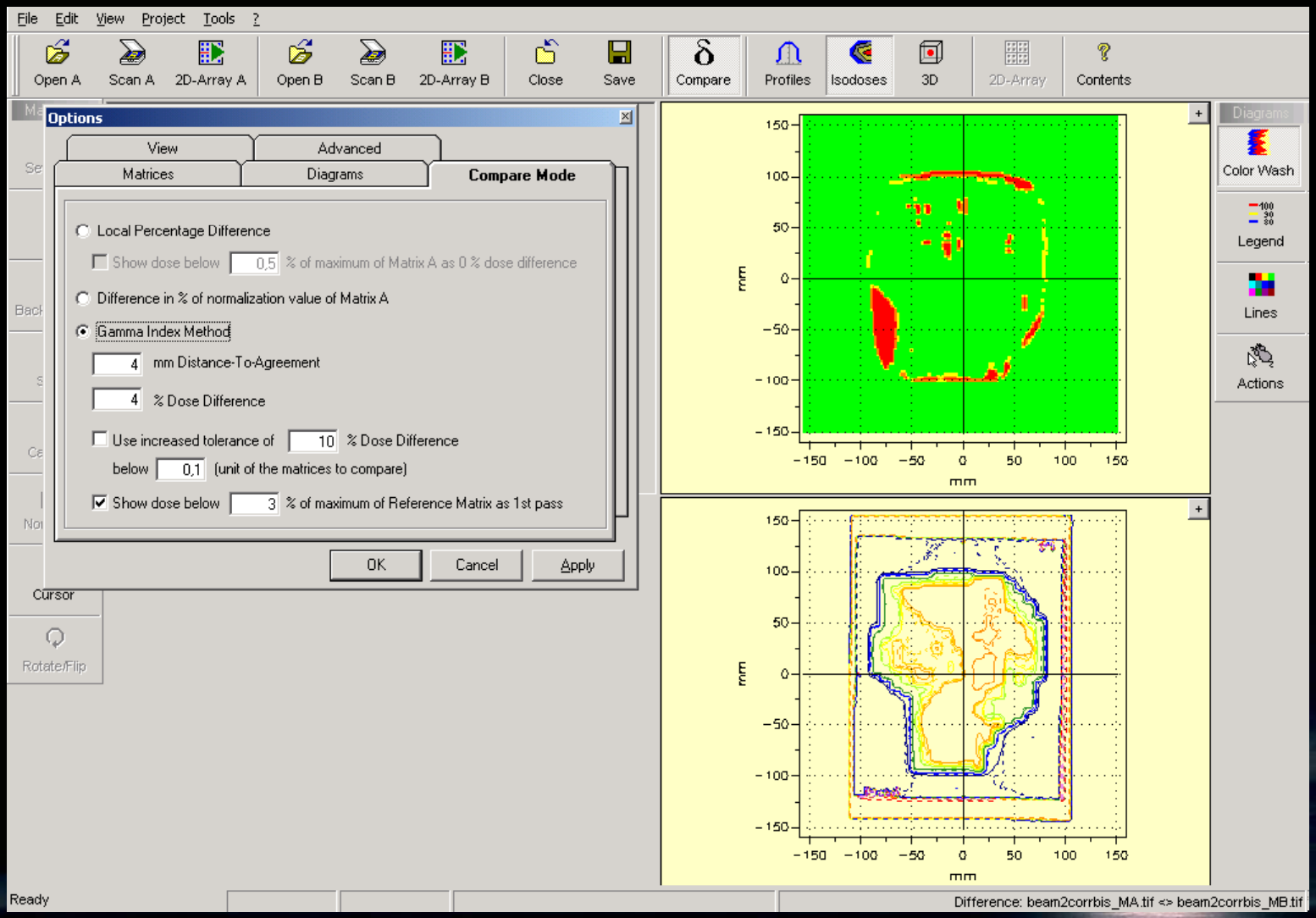
C:\SNC\MapCHECK\Data\4832417\bigatticlinical\tps\bigattibeam7.txt

Set1-Set2





EBT verification



Conclusioni

Lavoro complesso:

molto time-consuming per la Fisica Sanitaria!

Si ritengono indispensabili controlli ripetuti in tutte le fasi dell'implementazione e del commissioning.

Necessaria la collaborazione e la partecipazione dell'equipe medica di Radioterapia sia nella stesura dei protocolli ("definizione accurata dei constraints") sia nella valutazione conclusiva del piano di trattamento.

Futuro

IMRT della pelvi e della prostata per l'intero corso del trattamento;

IMRT della testa-collo.

☺ GRAZIE ☺

- Dott. **Nicola Poggi** e Ing. **Gabriele Rinaldi**

di TEMASinergie per il supporto e la disponibilità in questi mesi di lavoro

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- Dott. **Ugo Nastasi** del San Giovanni Antica Sede di Torino

per la strumentazione prestata.

E A VOI TUTTI……


GRAZIE PER
L'ATTENZIONE!