IMRT dinamica: esperienza dell'IRCC. *Aspetti fisici*.

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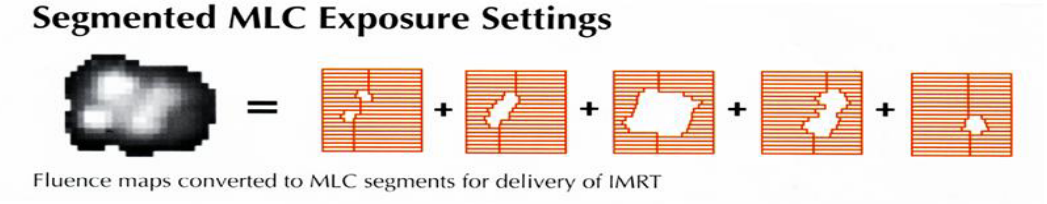
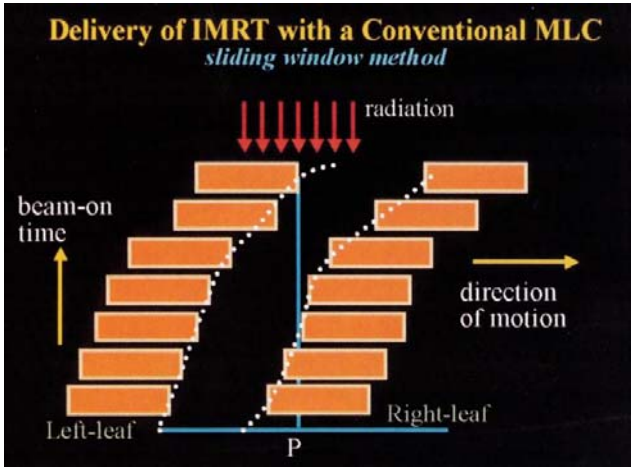
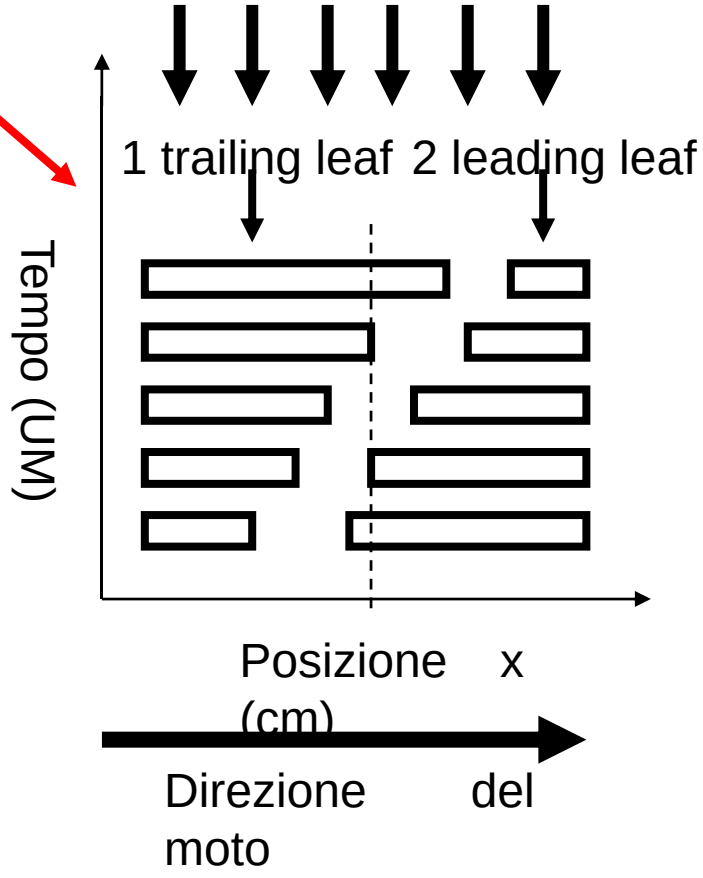
Metodi per modulare l'intensità

- Tecnica "Step and Shoot" (*Segmental MLC – sMLC)*
- Modulazione dinamica (*sliding window, d-MLC*)
- Terapia ad arco con modulazione d'intensità (*IMAT*)
- Tomoterapia (fan beam)





Entrambe le lamelle partono dallo stesso margine del campo e raggiungono l'altro, con moto continuo.



TPS e Inverse Planning tools presso l'IRCC

Pinnacle v. 8.0k, Eclipse v.8.0

- CT-simulazione virtuale
- fusione d'immagini/contouring
- field arrangement (class solution, constraints)
- sequencer e d-MLC, calcolo della dose

Definizione constraints PTV/OAR

- PTV max – min dose (107-95% ICRU)
- dose - volume constraints (es. dose prescritta al 95% vol PTV)
- definizione di constraints basata su letteratura e esperienza 3D-CRT
- dati radiobiologici da letteratura (EUD, α/β)

Dose Max/min PTV

Dose-volume restrictions OAR

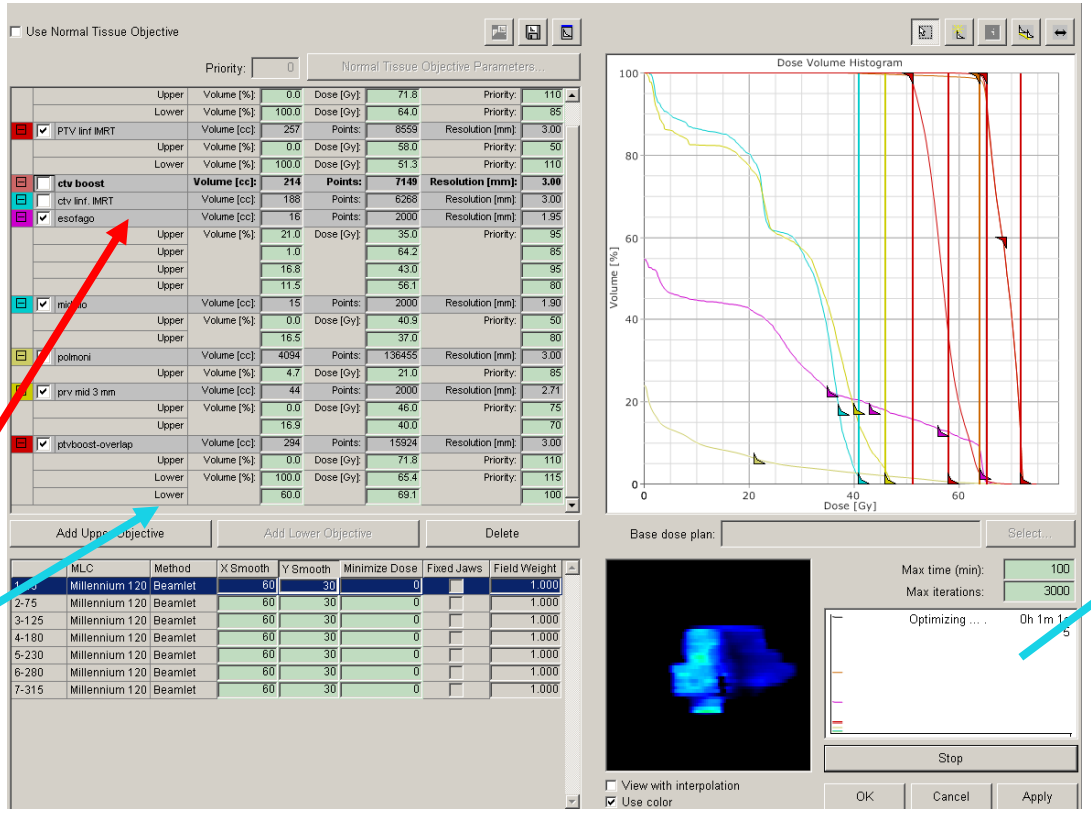


Grafico fluenza e DVH interattivo

Priority factor (0-1000)

- specificato per ogni constraints
- definisce l' importanza del constraint
- "penalty factor" per la funzione di ottimizzazione

Body	Volume [cc]:	5957	Points:	58835	Resolution [mm]:	4.50
Bones of Skull	Volume [cc]:	694	Points:	23141	Resolution [mm]:	3.00
CTV	**Volume [cc]:**	**329**	**Points:**	**10975**	**Resolution [mm]:**	**3.00**
Upper	Volume [%]:	0.0	Dose [Gy]:	55.5	Priority:	50
Lower	Volume [%]:	100.0	Dose [Gy]:	53.0	Priority:	50
PTV	Volume [cc]:	808	Points:	26933	Resolution [mm]:	3.00
Spinal Cord	Volume [cc]:	33	Points:	2000	Resolution [mm]:	2.47
Parotid r	Volume [cc]:	15	Points:	2000	Resolution [mm]:	1.90
Parotid l	Volume [cc]:	14	Points:	2000	Resolution [mm]:	1.83
Brain stem	Volume [cc]:	13	Points:	2000	Resolution [mm]:	1.78
Brain	Volume [cc]:	352	Points:	11717	Resolution [mm]:	3.00
PTV without CTV	Volume [cc]:	479	Points:	15954	Resolution [mm]:	3.00
PTV wo parotid l	Volume [cc]:	477	Points:	15899	Resolution [mm]:	3.00
Parotidl and PTV	Volume [cc]:	1	Points:	1314	Resolution [mm]:	1.00

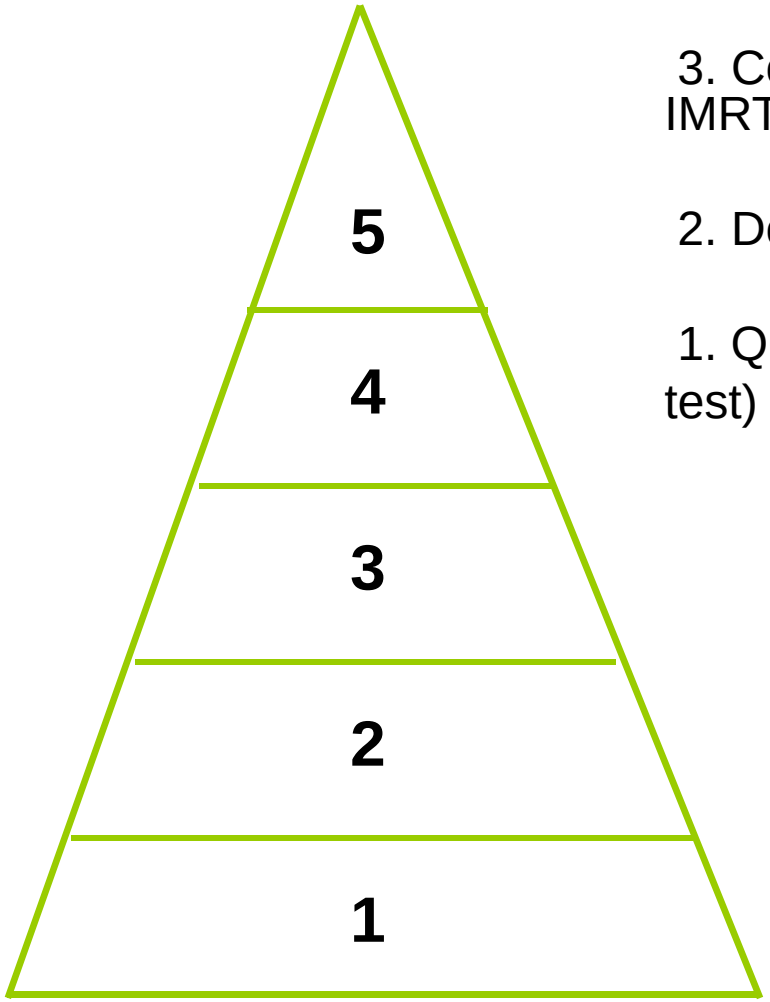
Smoothing (X, Y)

X: ↓MU

Y: ↓ "tongue&groove"

	MLC	Method	X Smooth	Y Smooth	Minimize Dose	Fixed Jaws	Field Weight
Field 1	Millenniu...	Full Ray	40	30	0		1.000
Field 2	Millennium_1...	Full Ray	40	30	0		1.000
Field 3	Millennium_1...	Full Ray	40	30	0		1.000
Field 4	Millennium_1...	Full Ray	40	30	0		1.000
Field 5	Millennium_1...	Full Ray	40	30	0		1.000
Field 6	Millennium_1...	Full Ray	40	30	0		1.000
Field 7	Millennium_1...	Full Ray	40	30	0		1.000

QA per IMRT: 5 livelli



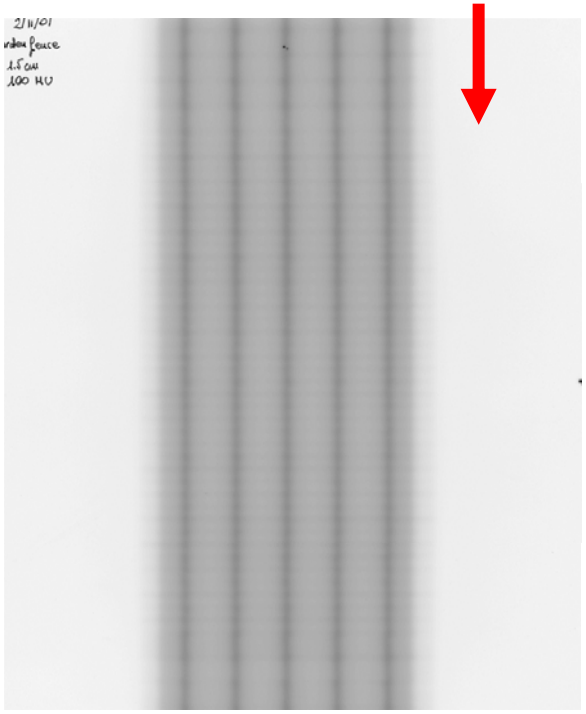
5. Controlli di qualità su paziente (setup prima del trattamento)

4. Verifica pre-trattamento del piano IMRT (mappe di fluenza, UM, isodosi)

3. Commissioning TPS/IP e simulazione di trattamenti IMRT su fantoccio con verifica dosimetrica

2. Dosimetria di campi piccoli

1. QC di base su Linac e d-MLC (es. Gardenfence test)

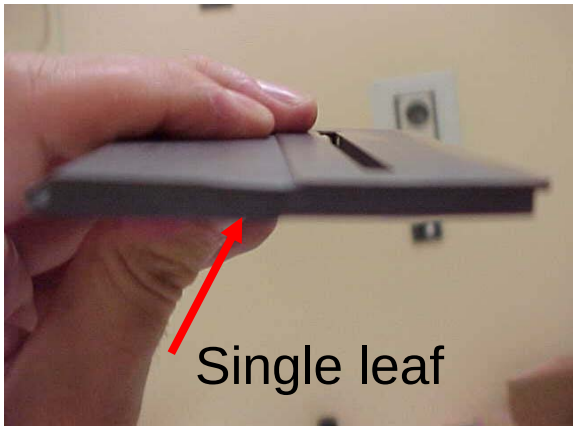


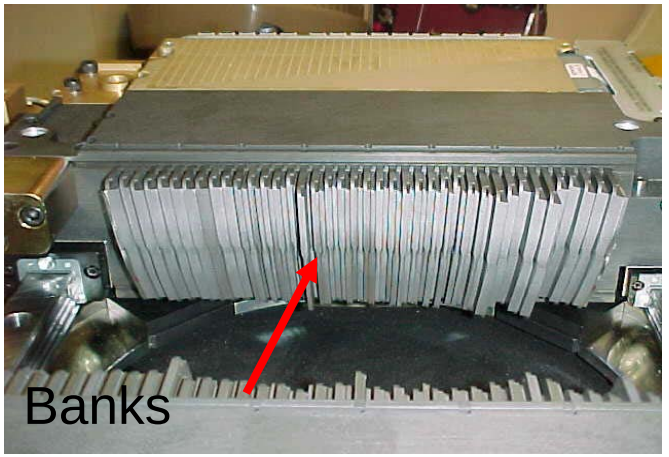
Acceptance test MLC Millennium 120-leaf (Varian, 600 CD)

Chui CS, Spirou S, LoSasso T. Testing of dynamic multileaf collimation. Med. Phys. 23:635-641 (1996)

LoSasso T, Chui CS, Clifton LC. Physical and dosimetrical aspects of a multileaf collimation system used in the dynamic mode for implementing intensity modulated radiotherapy. Med Phys 25:1919-1927 (1998)

1. Caratterizzazione d-MLC: leaf calibration
2. Leaf transmission
3. Dosimetric leaf separation
4. Leaf Tolerance
5. Gravity test
6. Leaf speed stability
7. Leaf acceleration-deceleration
8. OF campi piccoli con MLC





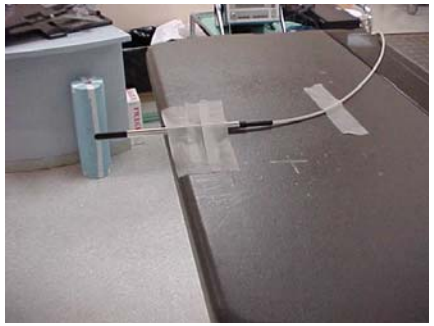
eseguiti fine 2001

Leaf transmission

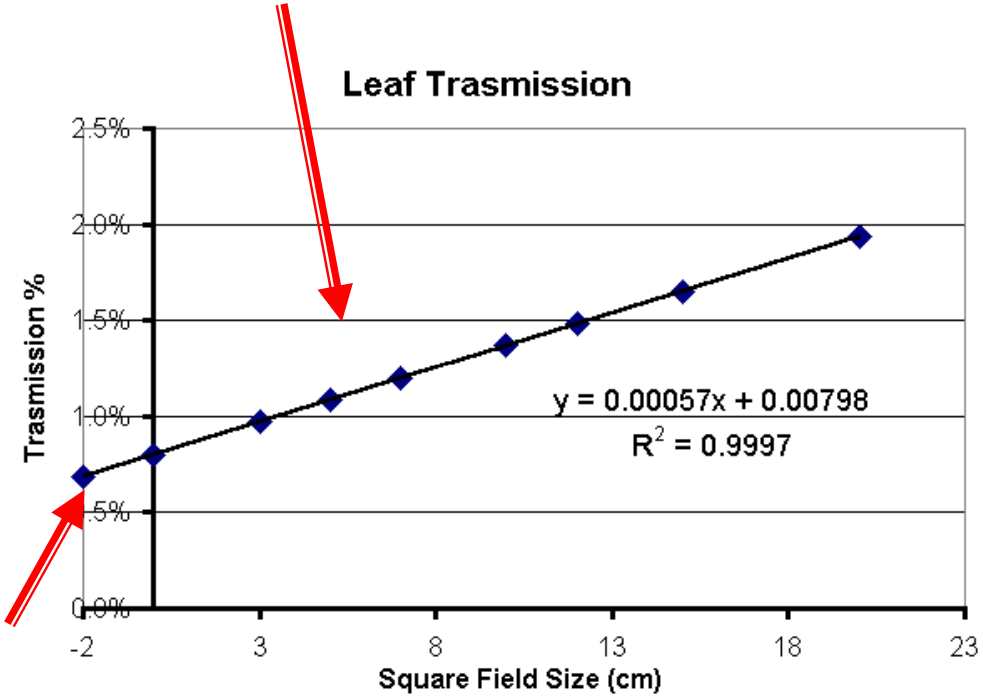
radiazione

scatter ∝

dimensione campo

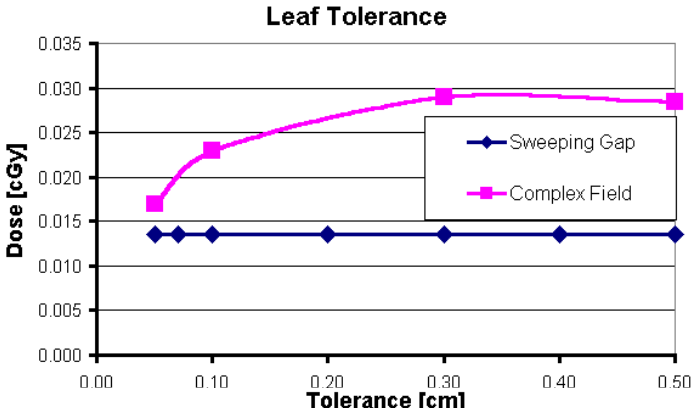


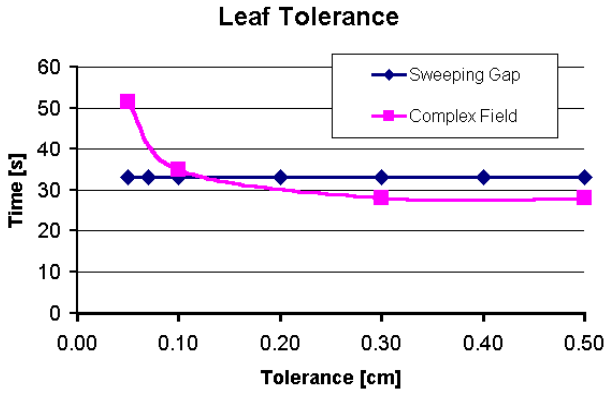
Precisione nel beam delivery?

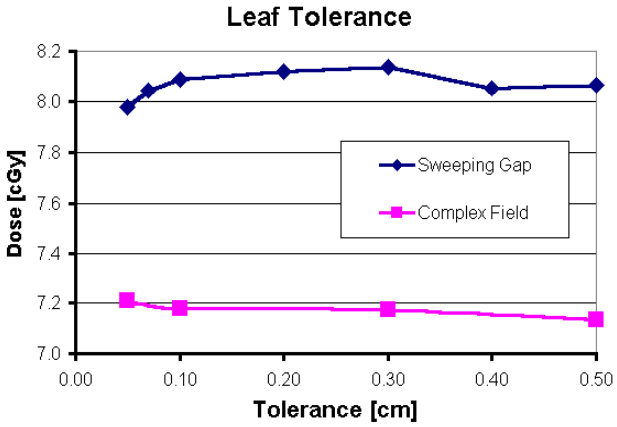


radiazione diretta = costante

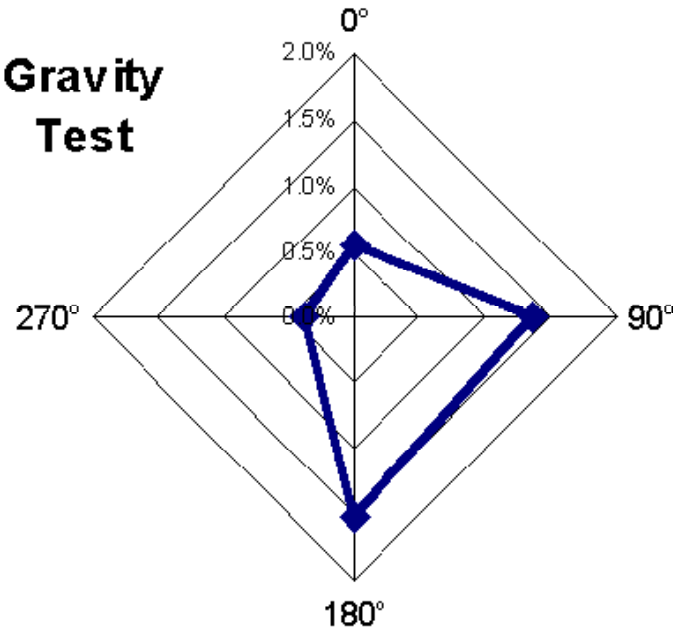
Leaf tolerance







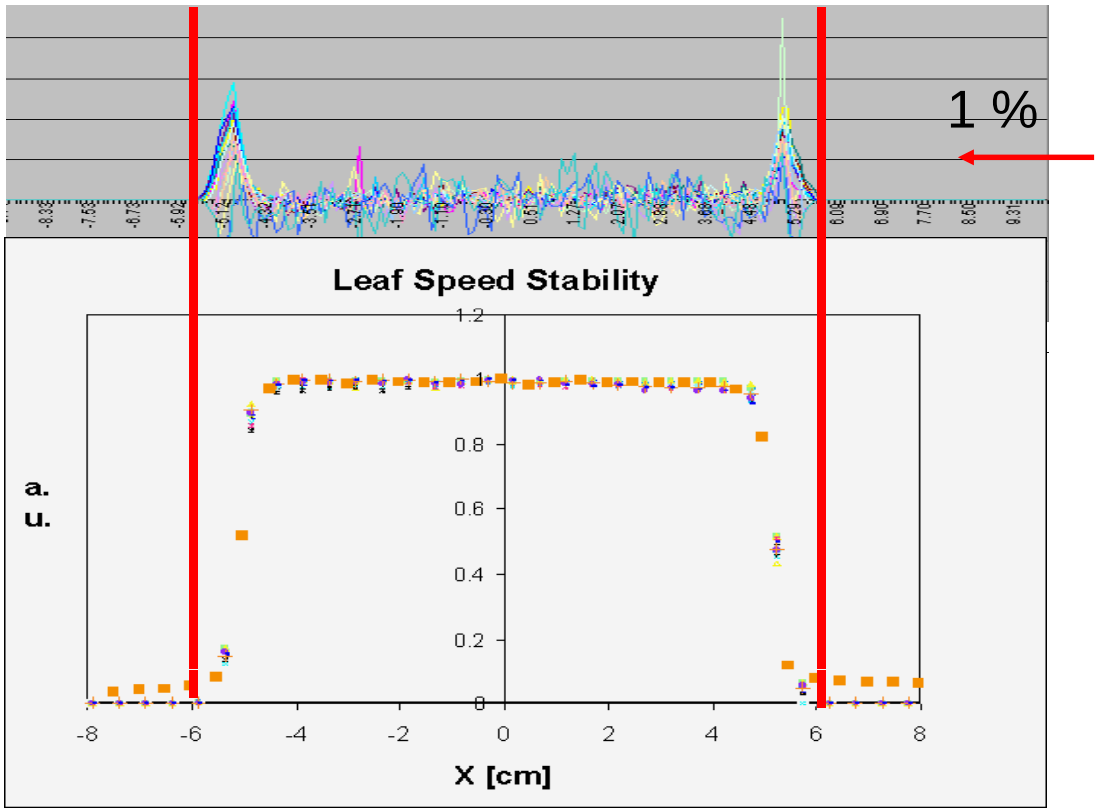
Stability



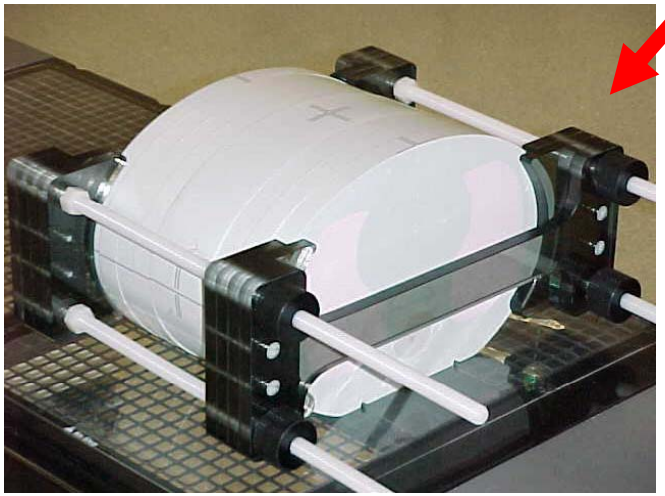
Gantry angle < 1.5 %

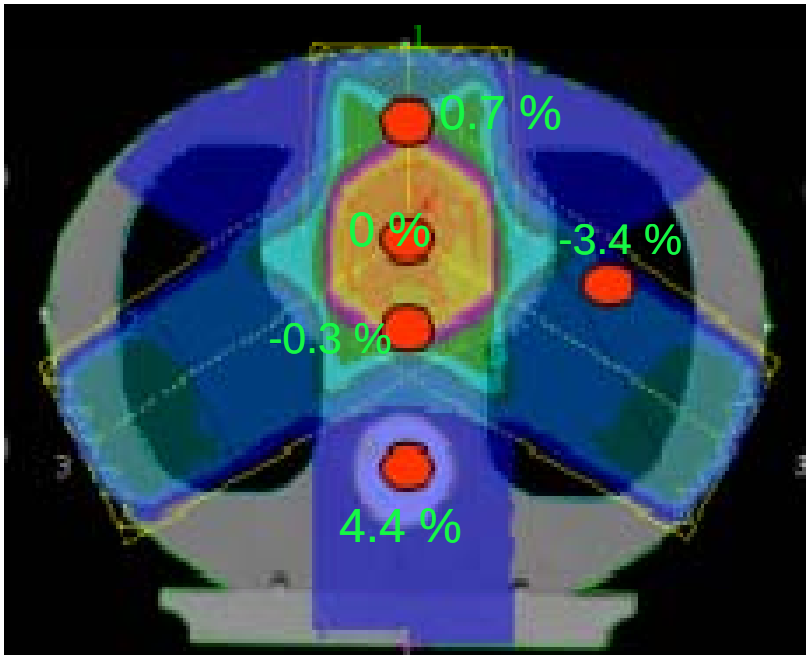
Time < 1 %

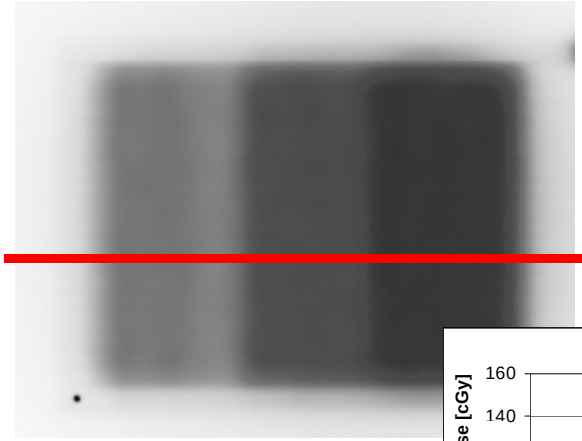
Leaf speed stability



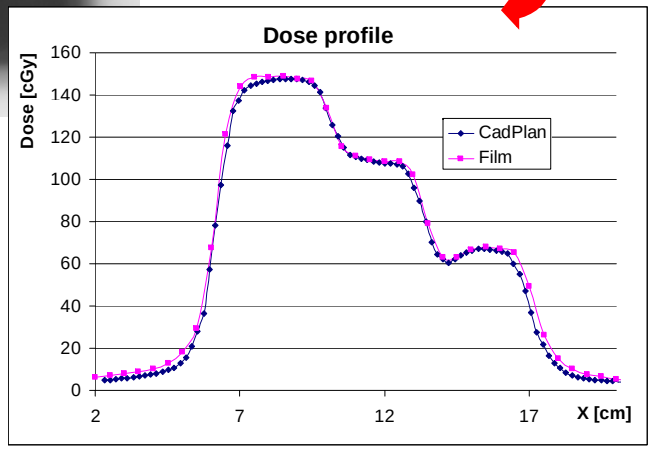
Commissioning TPS: dose assoluta e relativa





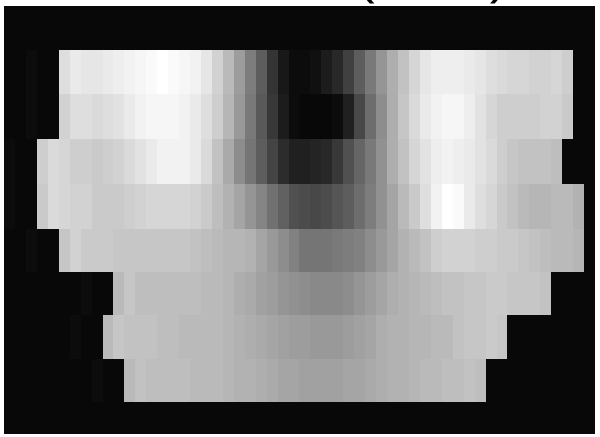


Dose Profile

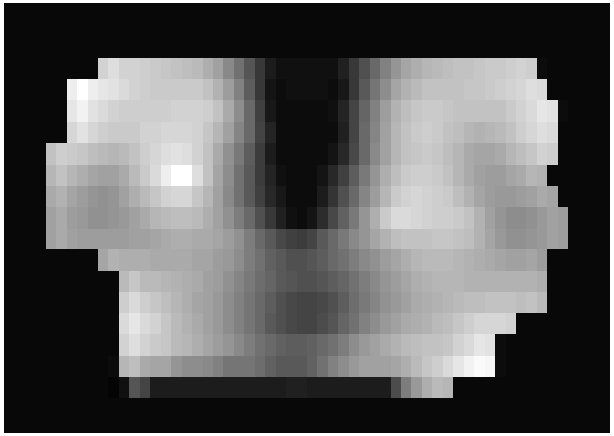


80 o 120 lamelle?

80 lamelle (1 cm)

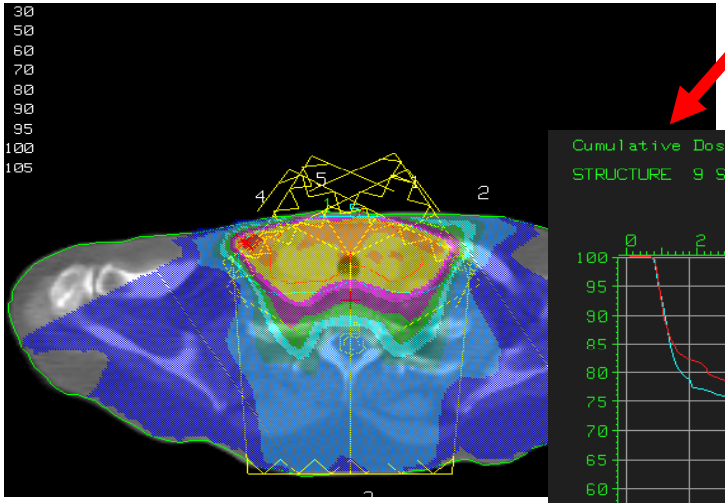


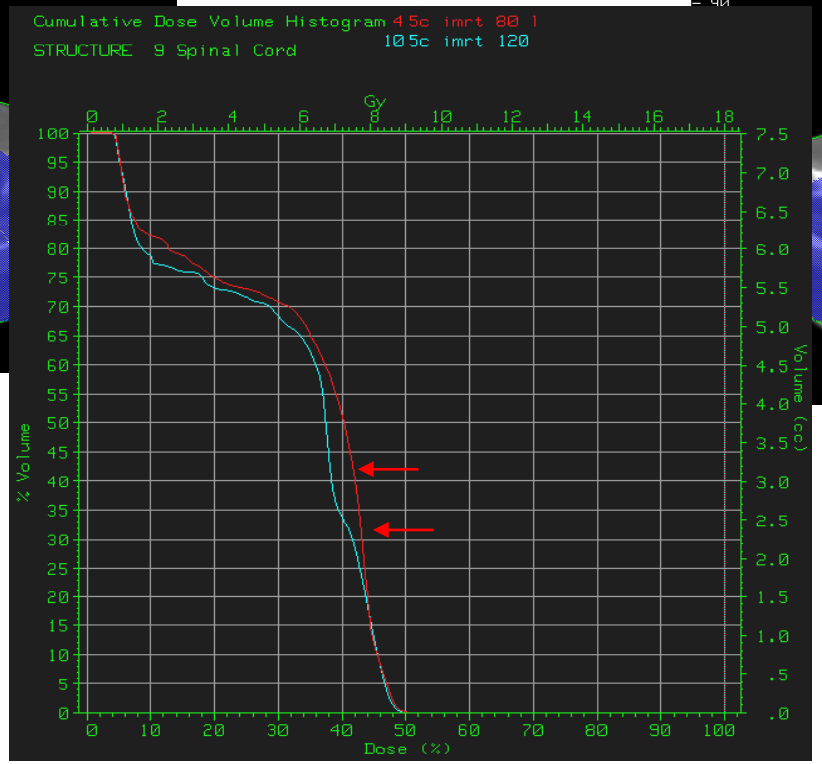
120 lamelle (0.5 cm)

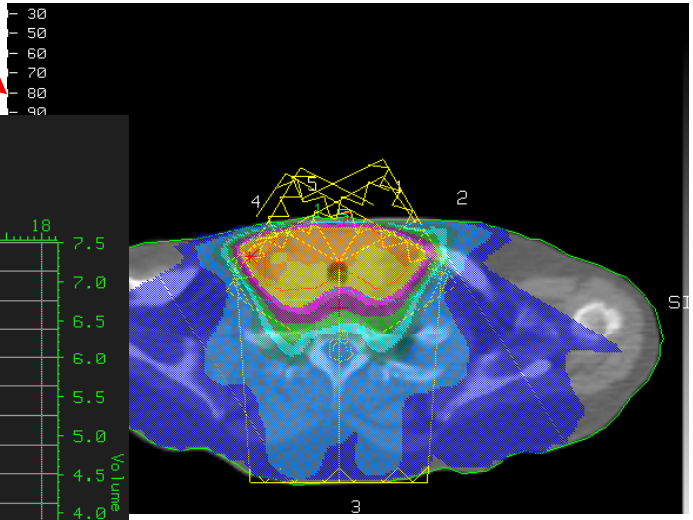


Mappe di fluenza

Piani di trattamento, DVH



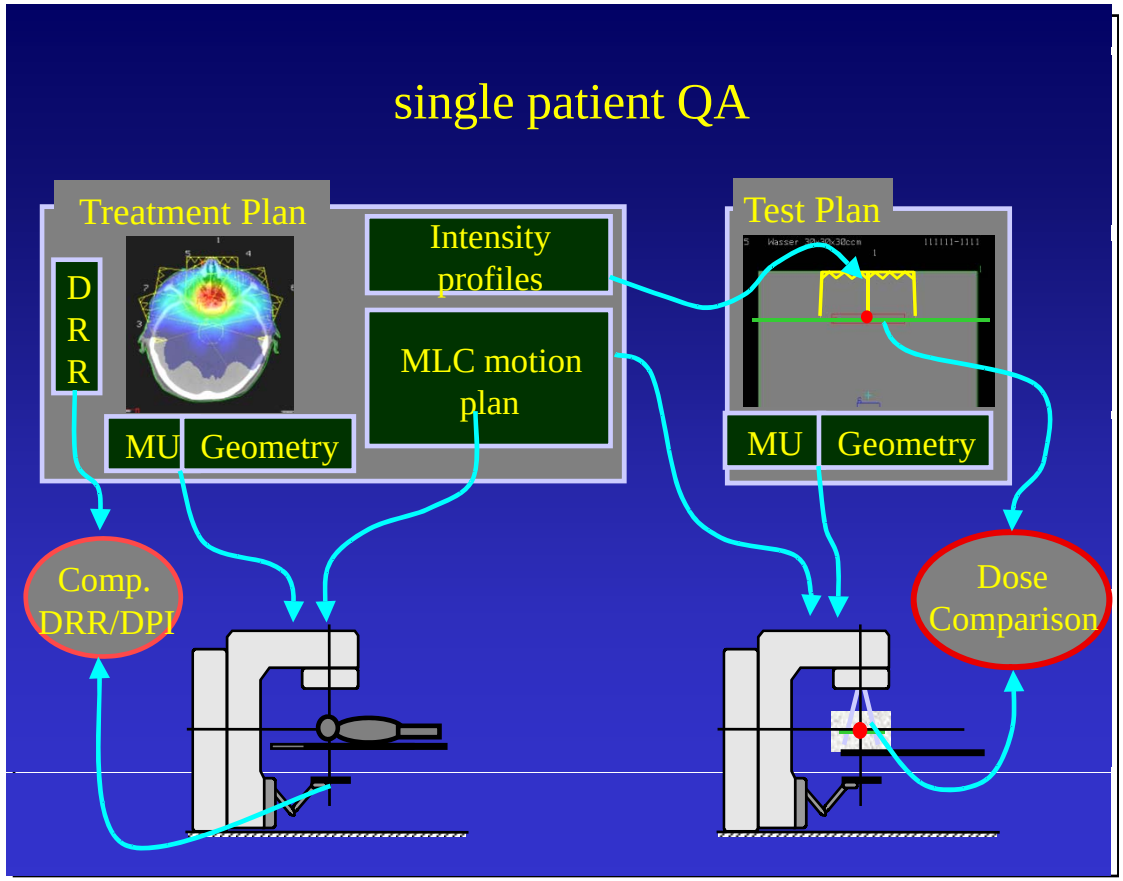




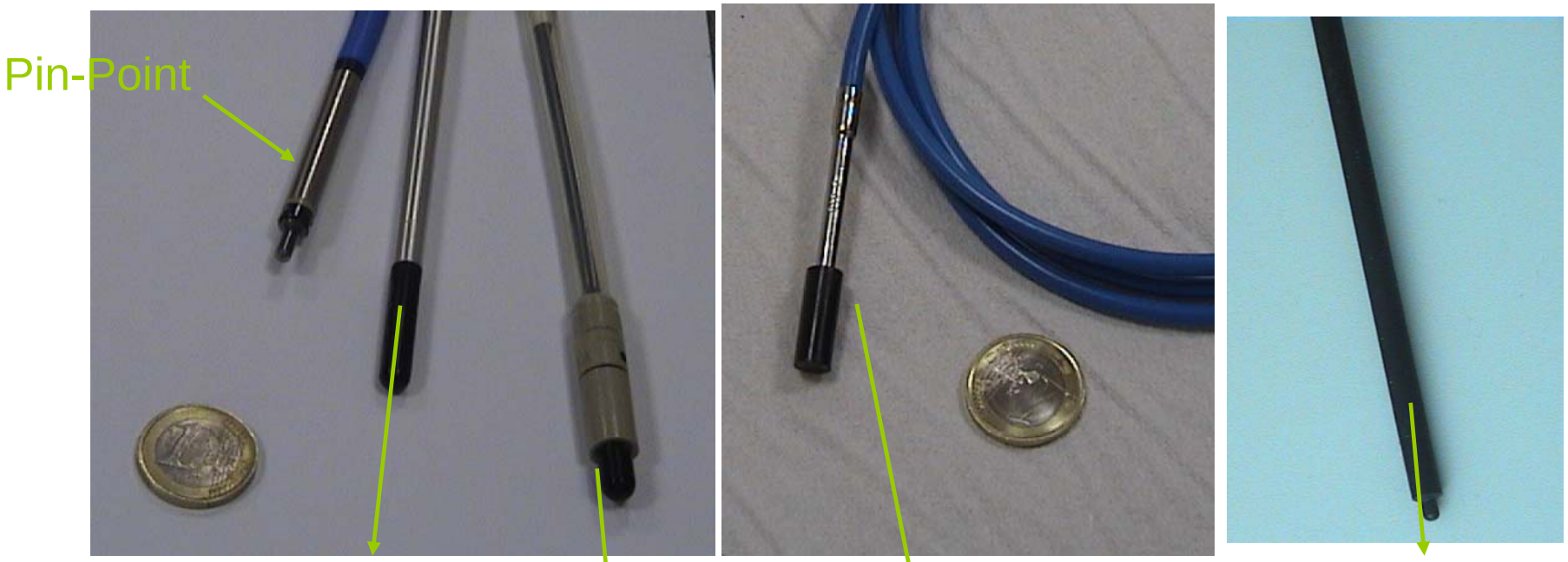
DVH Midollo

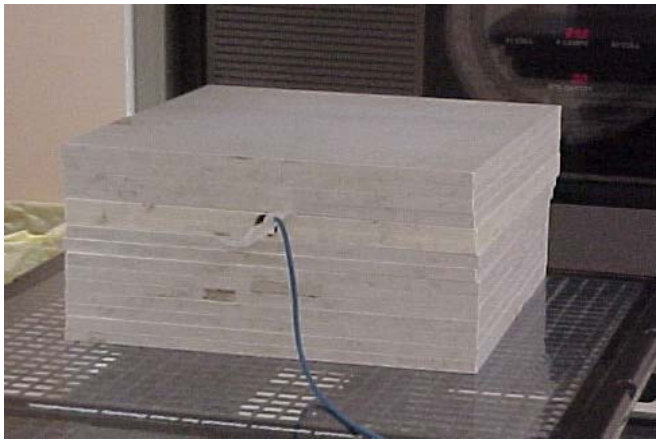
IMRT: *Patient Quality Assurance*

- TPS e R&V (Aria,Varian) integrati
- Verifica di dose pre-trattamento per ogni paziente
  - –Assoluta: microcamera in solid water
  - –Relativa: isodosi misurate vs. calcolate
- Verifica del setup in tempo reale e giornaliera
  - –Campi 0/90 (DRR vs. EPID silicio amorfo → 2 mm in H&N 3 mm in altri): **dose conteggiata nel piano di trattamento!**
  - –Correzione setup *on line* (↓ errore sistematico)



1.M. Stasi, B. Baiotto, G. Barboni, G. Scielzo. The behaviour of several microionization chambers in small intensity modulated radiotherapy fields. **Med Phys 21, 2004:2792-2795.**

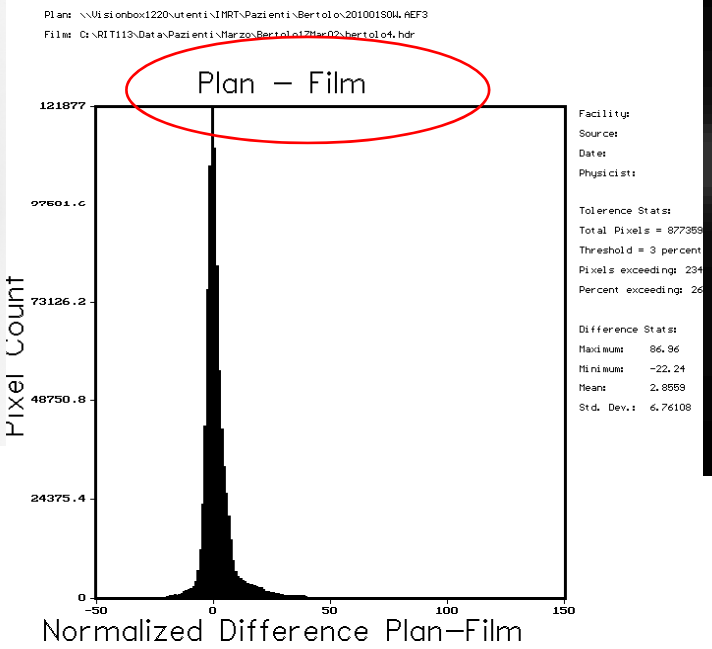


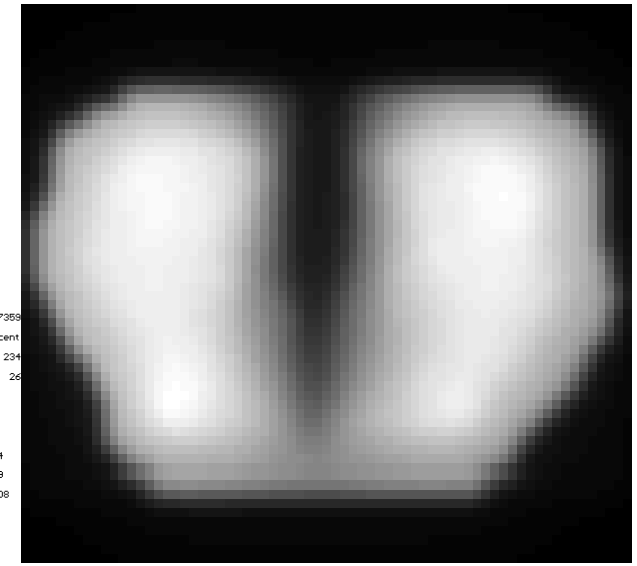


IMRT: pre-treatment patient QA

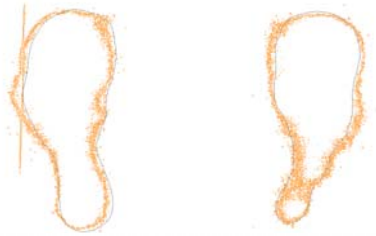
Analisi Matching RIT + VIDAR 12/Scanner
Sottrazione e Differenza Plan-Film

Film in Solid Water



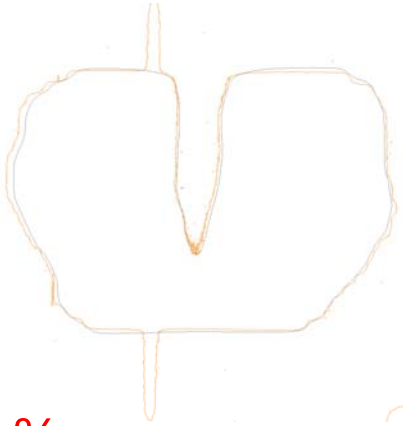


Dose Matrix su TPS

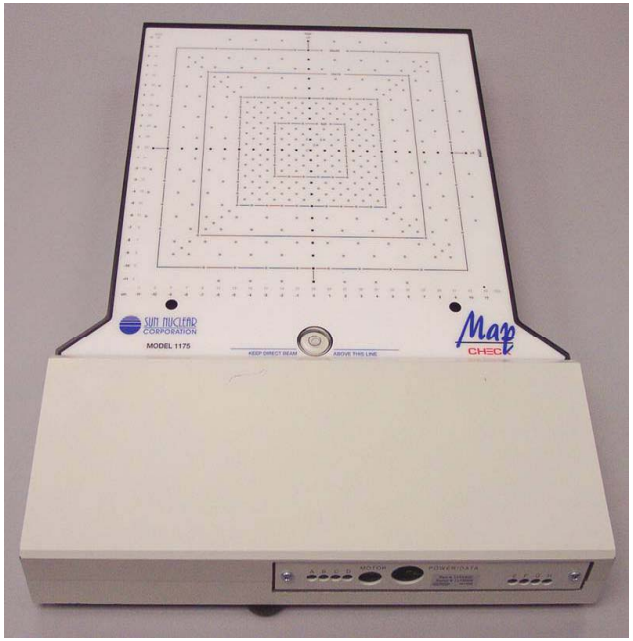


95 %

Dosimetria relativa:
matching isodosi
misurate vs. calcolate

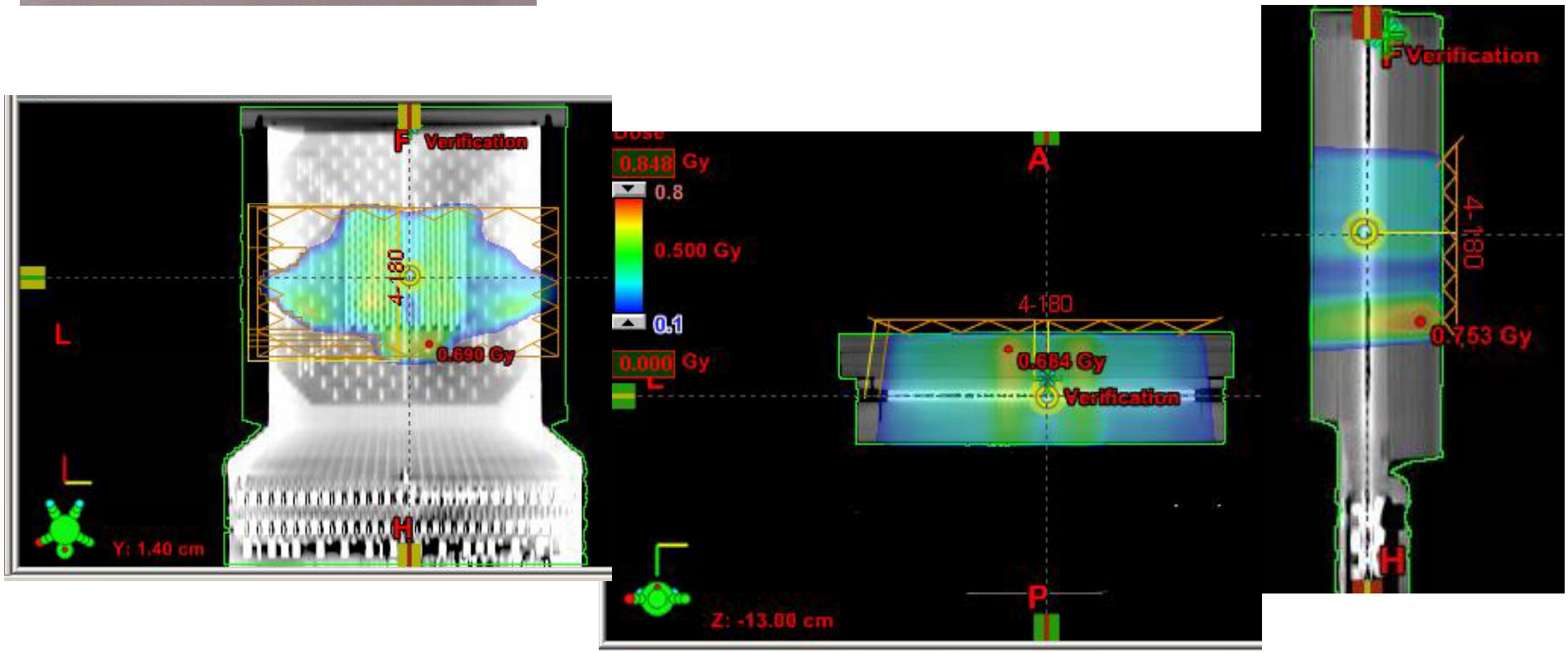


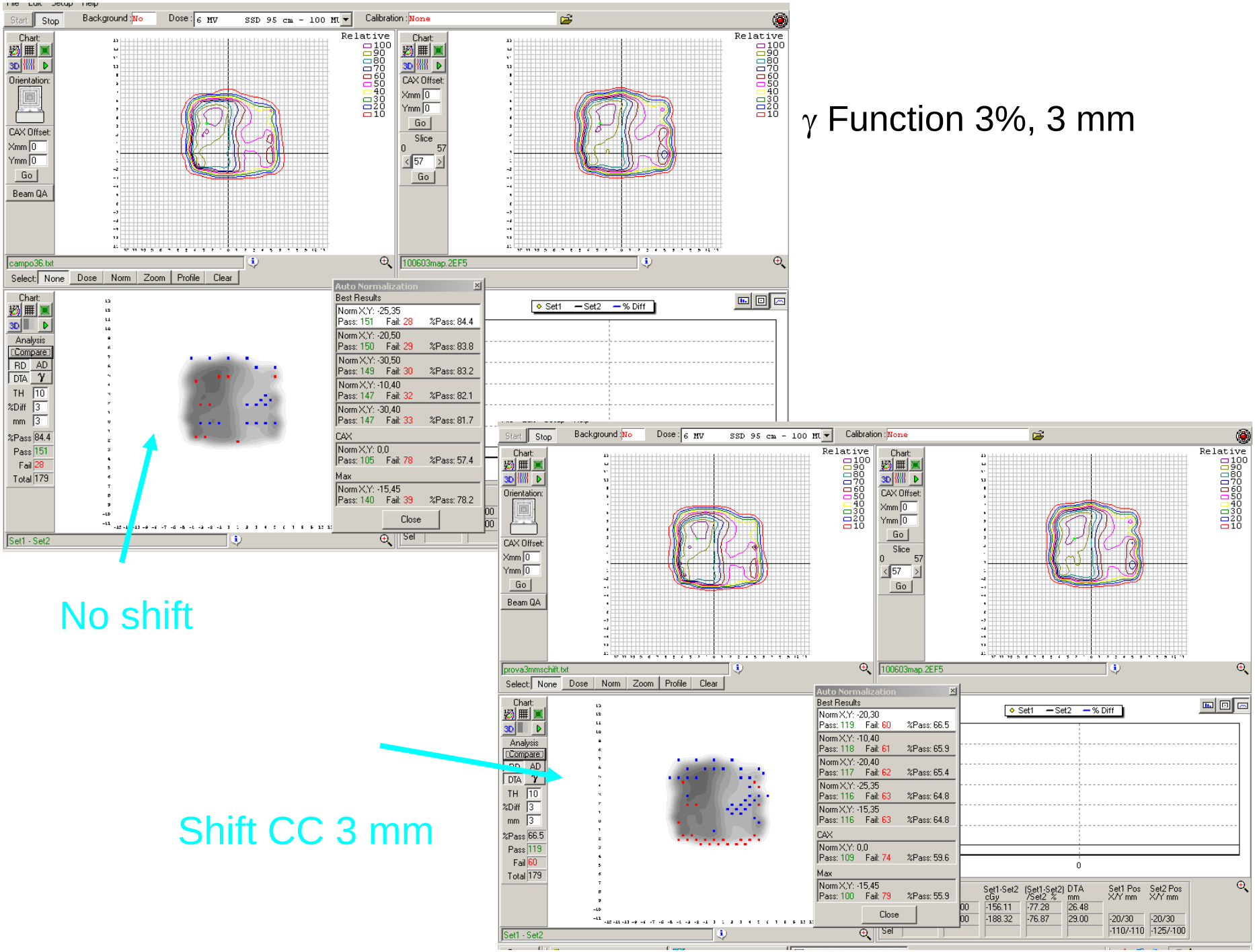
30 %



2D-Array: MapCheck™(Sun Nuclear)

1. 445 rivelatori a stato solido (diodi tipo N) resistenti alla radiazione
2. Spaziatura all'interno del campo 10x10 e sulle diagonali: 6 mm. Esternamente al campo 10x10: 10 mm
3. Limiti sul fascio: 7.7 mGy di dose per impulso, massimo rateo di ripetizione degli impulsi (1000 impulsi/sec)

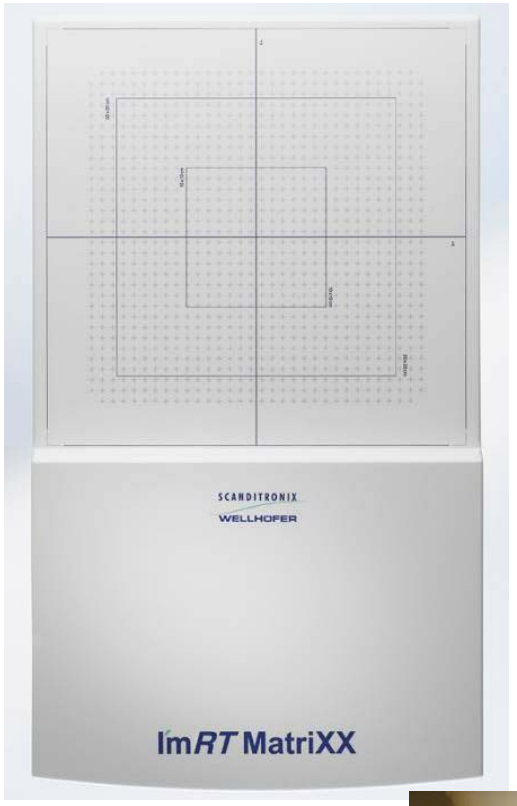



γ Function 3%, 3 mm
No shift
Shift CC 3 mm

Sistema Compass™ (IBA Dosimetry)

Misure di validazione come centro di riferimento internazionale per modalità Sliding Window, Acceleratori Varian

- Ricostruzione on-line dose 3D nella geometria del paziente
- Confronto tra dose attesa e misurata
- Camera a ionizzazione a Trasmissione (T2D), verifica attenuazione
- Verifica durante il trattamento del paziente



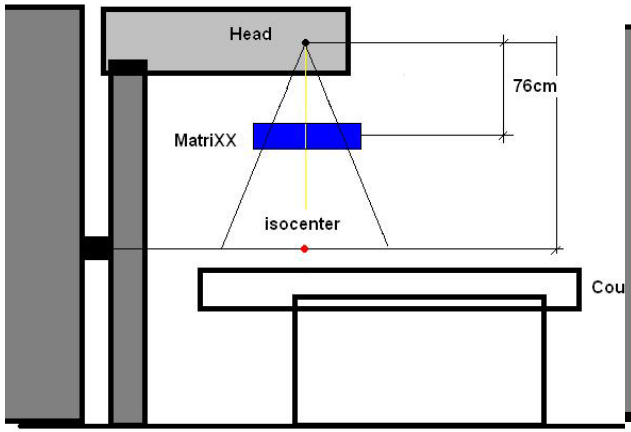
MatriXX™ come Detector

- Accuratezza, precisione, linearità (Stasi et al, PMB 2005)
- Camera a Ionizzazione: 2 cm di build-up
- Quality Assurance pre-trattamento (non “in-vivo”)

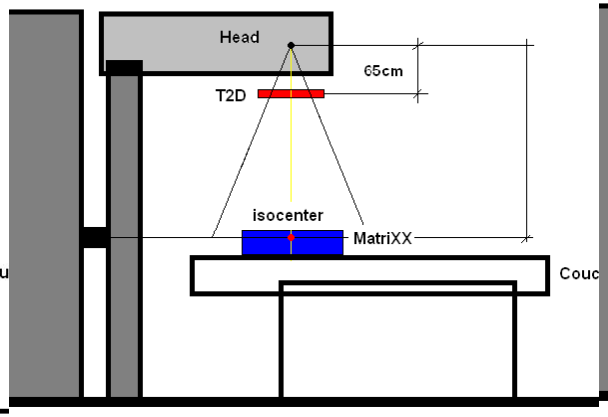
	MatriXX	Transmission Detector T2D
Distance to source	76cm	65cm
Pitch	7.6 mm	6.5mm
Number of Pixels	1024 arranged in a matrix 32x32	1600 (40x40)
Chamber size	4.5 (Ø) x 5 (h) mm, volume 0.08 cm^3	3.8 (Ø) x 2 (h) mm, chamber volume: 0.02 cm^3
Charge Resolution	0.1 pC/count	0.1 pC/count

1.M. Stasi, S.Giordanengo, R. Cirio, A. Boriano, F. Bourhaleb, I Cornelius, M. Donetti, E. Garelli, I. Gomola, F. Marchetto, M. Porzio, C. J. Sanz Freire A. Sardo, C. Peroni. D-IMRT verification with a 2D pixel ionization chamber: dosimetric and clinical results in head and neck cancer.
2.Phys Med Biol 50 (2005)

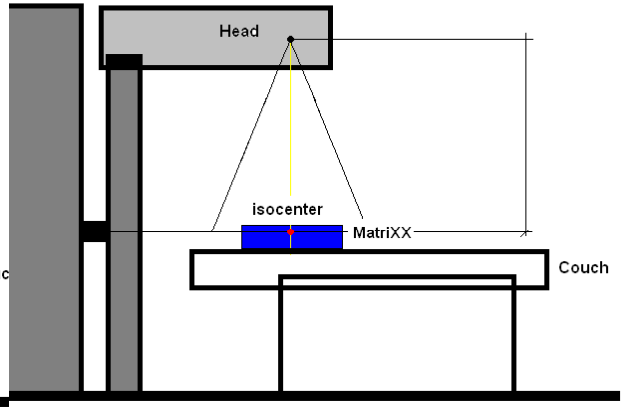
Misure di validazione



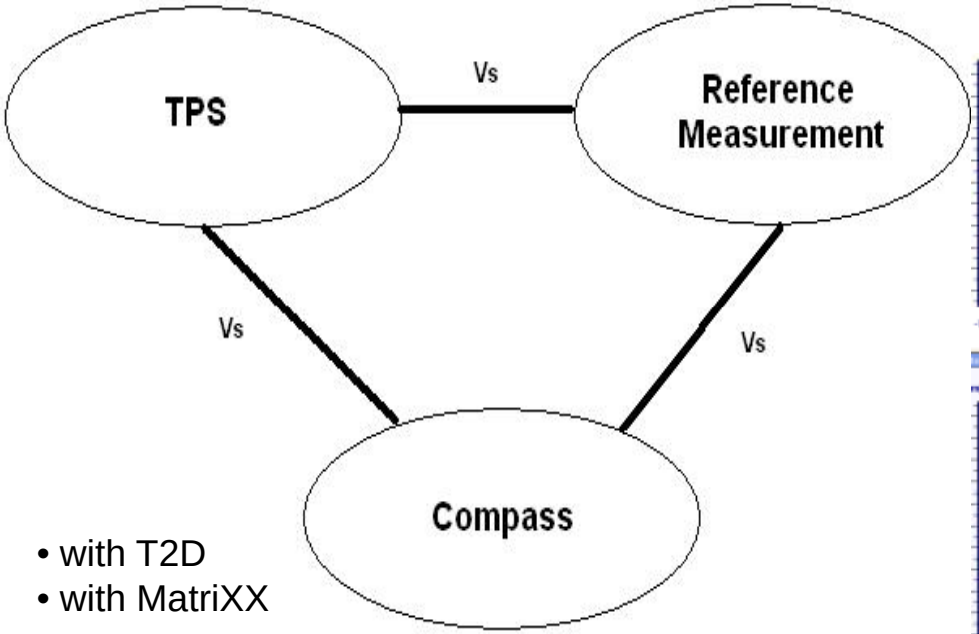
MatriXX a 76 cm come detector di compass



T2D come detector di compass e Misura indipendente sul lettino

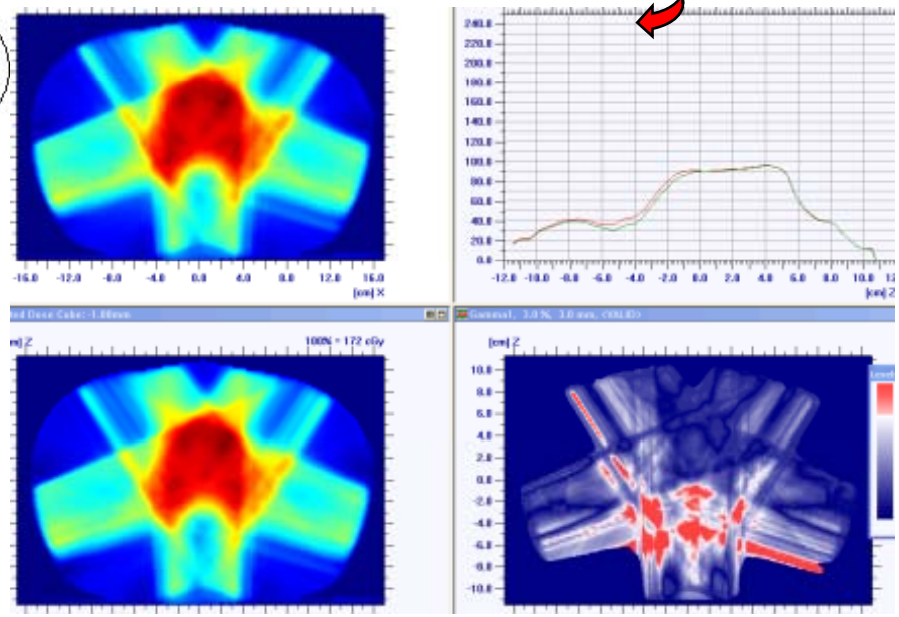


Misura indipendente sul lettino



- with T2D
- with MatriXX

- Campi quadrati e dinamici (QA)
- Piani IMRT in fantoccio



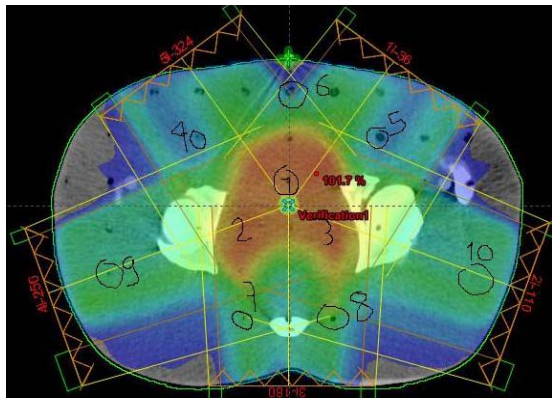
Risultati preliminari

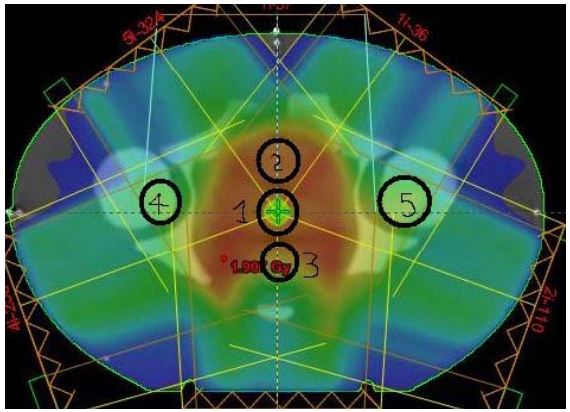
• Il sistema Compass ricostruisce accuratamente campi quadrati e dinamici quando le misure sono acquisite con MatriXX come detector

• La camera a trasmissione misura correttamente la modulazione di fluenza

• L'algoritmo di ricostruzione della distribuzione dose anche in geometrie complesse (fantocci antropomorfi) dà risultati clinicamente accettabili

• L'attenuazione del rivelatore a trasmissione misurata con con micro-camera: (3.1±0.8)%





M.Stasi, B.Baiotto, L.Berta, N.Givehchi, C.Brusasco, M.Donetti, A.Giuliacci, S.Iliescu, L.Mueller, C.Peroni, Clinical validation of Compass System for on-line verification in IMRT, 50th ASTRO Meeting, 21-25 Sept 2008, Boston and ESTRO Meeting Sept 2008, Goteborg

ESTRO EUROPEAN SOCIETY FOR THERAPEUTIC RADIOLOGY AND ONCOLOGY

ASTRO American Society for Therapeutic Radiology and Oncology

IMSure™ QA (v. 3.0 – *STANDARDIMAGING)*

sistema di controllo di qualità per la verifica della dose e delle MU calcolate dal TPS (“Three - Source Model”, Yang et al – Med. Phys. 2002)

Strumento alternativo ⟶ **3D-CRT** - “verifica manuale” delle MU

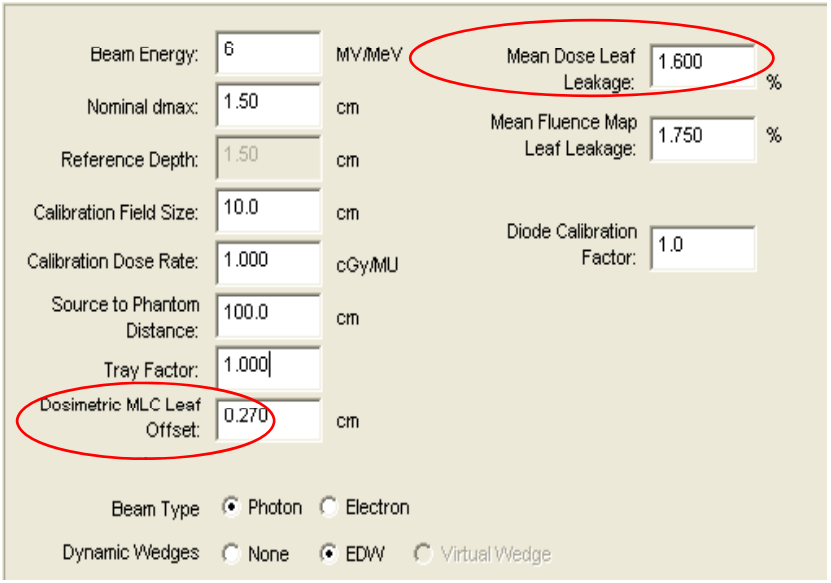
IMRT - verifica della dose assoluta con microcamera
- verifica fluenza con rivelatore 2D

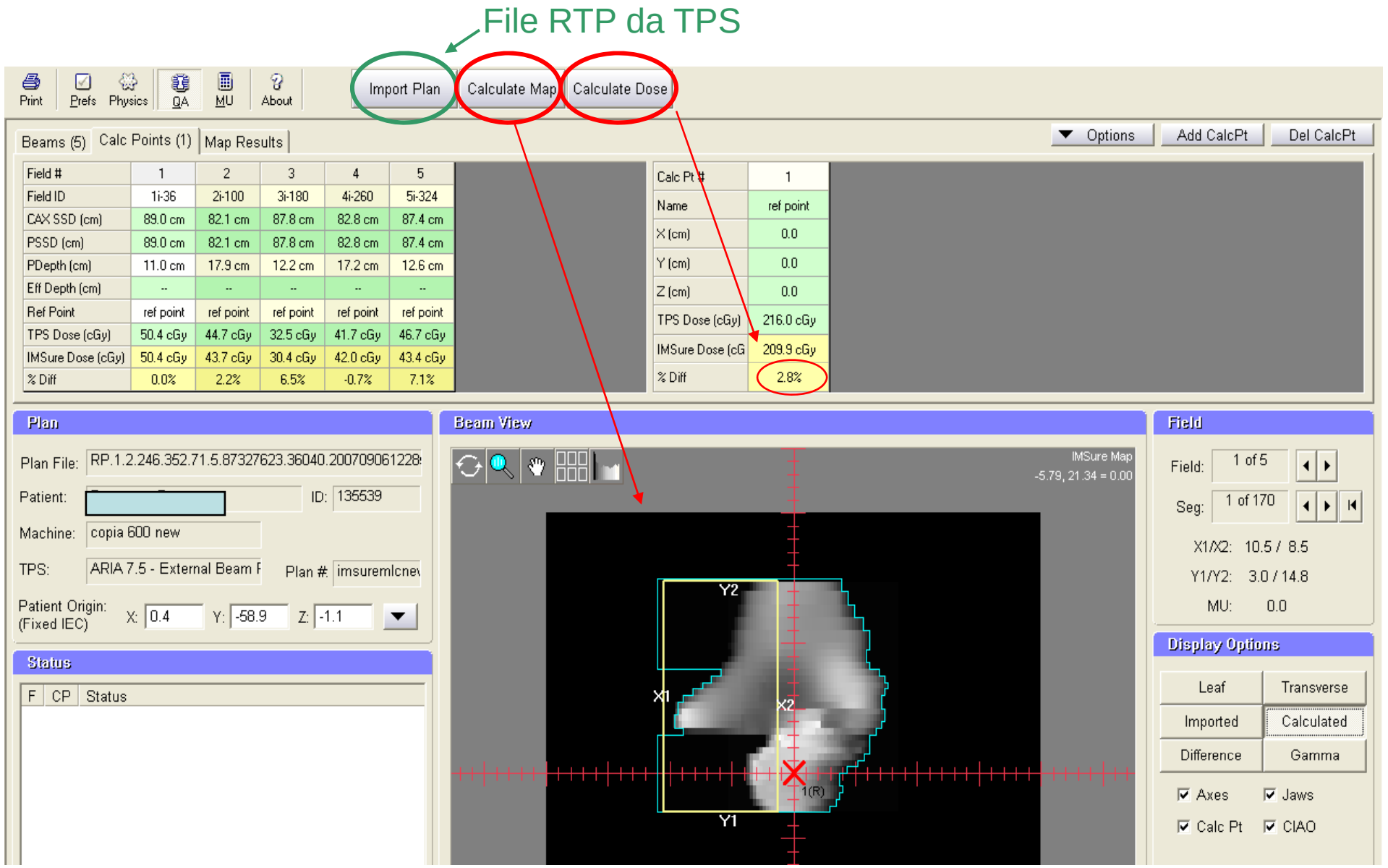
Misure di commissioning (in miniphantom)

Parametri geometrici (jaws, MLC)/dosimetrici (TMR, OCR, OF, Sc)

Fattori di trasmissione per MLC

- Dosimetric MLC offset - *“Distance from true physical leaf edge to dosimetric leaf edge*
- Mean Dose Leaf Leakage – “*Mean leaf leakage through MLC*”

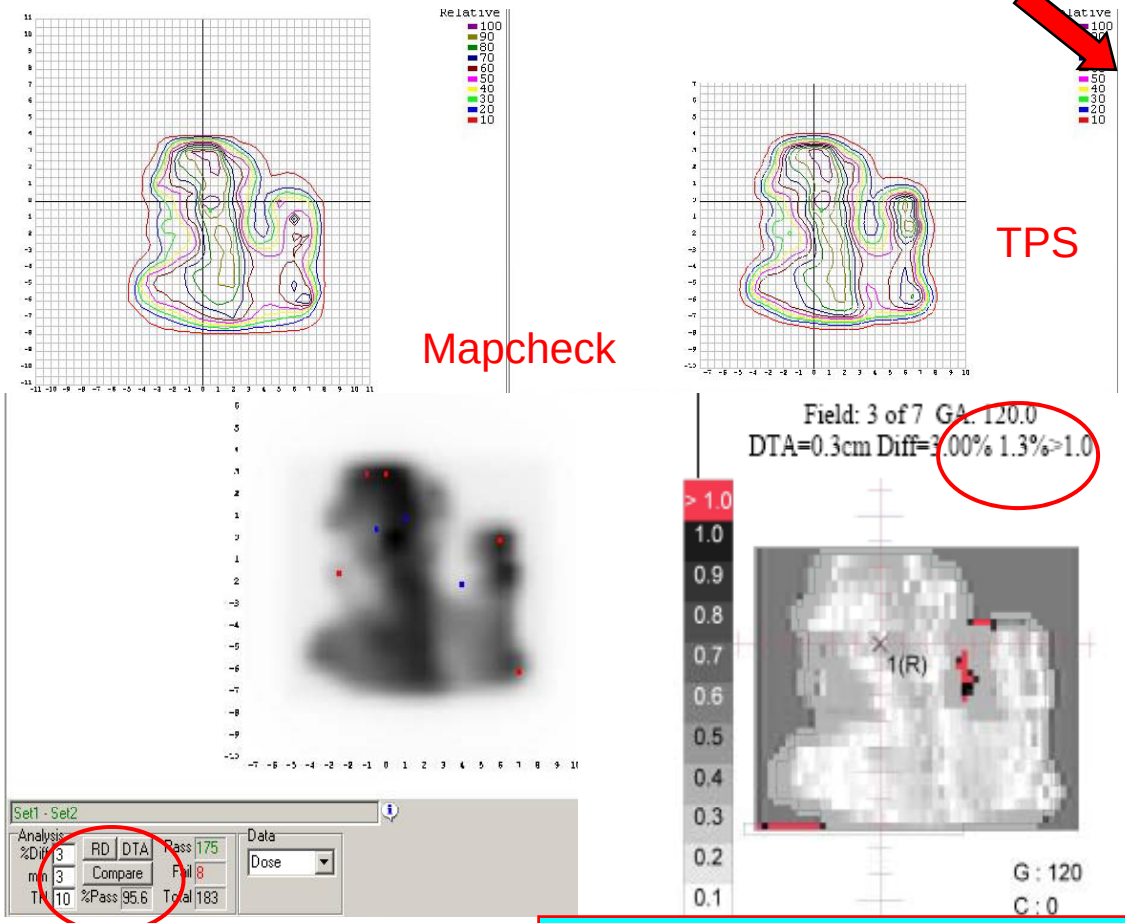



File RTP da TPS
Print
Prefs
Physics
QA
MU
About
Import Plan
Calculate Map
Calculate Dose
Beams (5)
Calc Points (1)
Map Results
Options
Add CalcPt
Del CalcPt
Field #
Field ID
CAX SSD (cm)
PSSD (cm)
PDepth (cm)
Eff Depth (cm)
Ref Point
TPS Dose (cGy)
IMSure Dose (cGy)
% Diff
Calc Pt #
Name
X (cm)
Y (cm)
Z (cm)
TPS Dose (cGy)
IMSure Dose (cG
% Diff
2.8%
Plan
Plan File:
Patient:
ID:
Machine:
copia 600 new
TPS:
ARIA 7.5 - External Beam F
Plan #:
Patient Origin:
(Fixed IEC)
Status
F
CP
Status
Beam View
IMSure Map
-5.79, 21.34 = 0.00
Y2
X1
X2
Y1
1(R)
Field
Field:
1 of 5
Seg:
1 of 170
X1/X2: 10.5 / 8.5
Y1/Y2: 3.0 / 14.8
MU: 0.0
Display Options
Leaf
Transverse
Imported
Calculated
Difference
Gamma
Axes
Jaws
Calc Pt
CIAO

Risultati

Testati 35 piani di trattamento IMRT- SMART Eclipse (Varian, v.8)

Verifica dose con microcamera lungo l'asse: buon accordo IMSure vs. microcamera (-2.7% vs. -1.4%)



Verifica distribuzione di dose con Mapcheck: buon accordo verifica mappe di fluenza

Gamma Index: DTA 3 mm, Diff 3 %

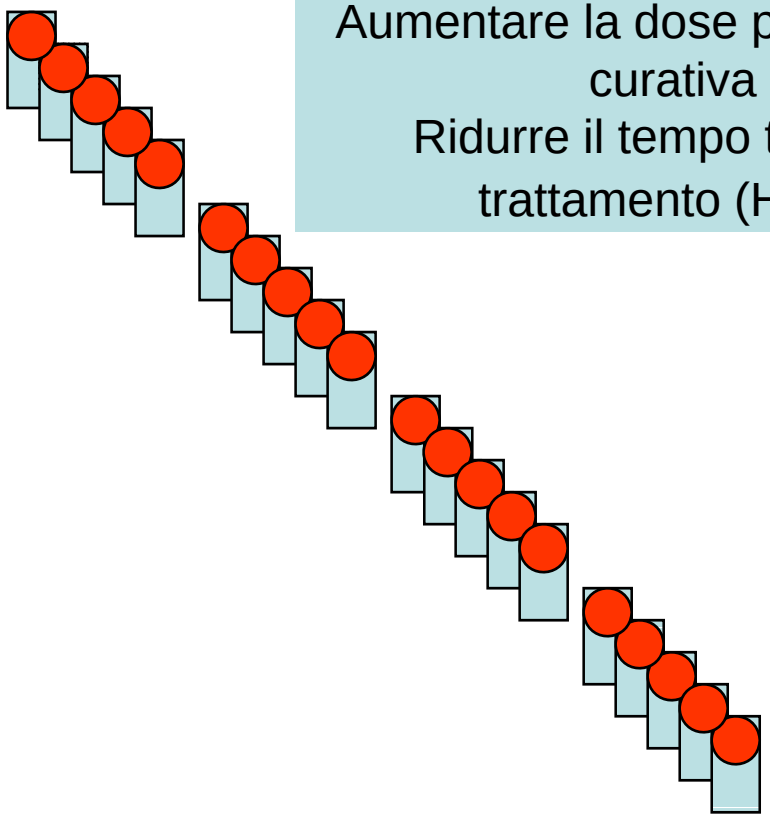
Ulteriori "trigger" del Dosimetric Leaf Offset

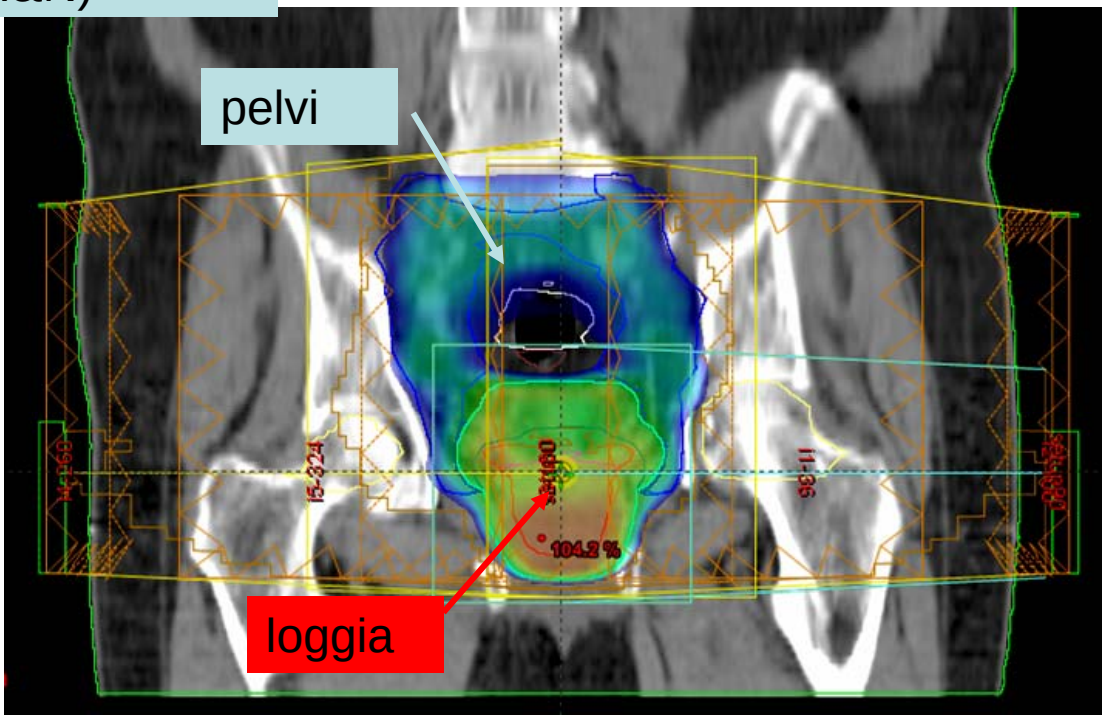
- verifica della validità del sistema nella routine clinica
- strumento integrativo (alternativo ?!..) ai metodi dosimetrici standard di pre-treatment QA in IMRT

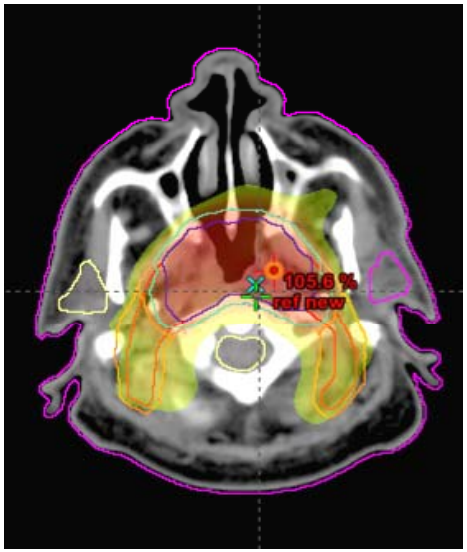
Simultaneous Accelerated Modulated RadioTherapy (SMART)

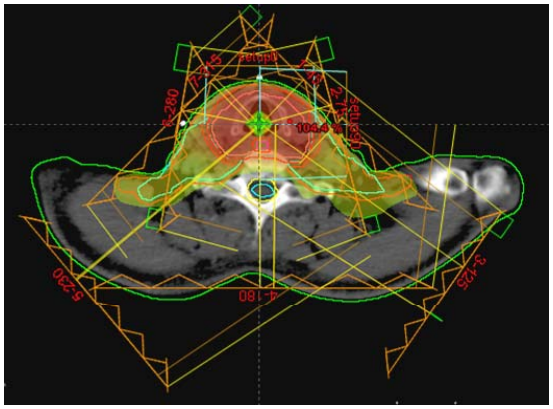
Aumentare la dose profilattica e curativa
Ridurre il tempo totale di trattamento (H&N)

Irradiare volumi differenti con dose totale e dose/fraz differenti all'interno degli stessi campi di trattamento









Casisitica IMRT-SMART:

da gennaio 2005, 43 su 96 pazienti trattati

- 5-7 campi
- 6 MV

Sede trattata	***N. paz.***
Tiroide/esofago	4
Rinofaringe/orofaringe/laringe	13
Seni della faccia	3
Mammella + linfonodi	1
Vescica +linfonodi LA	1
Prostata + pelvi	21

H&N: dose/fraz 1.8 Gy PTV1, 2.2-2.25 Gy PTV2

Dose tot 50.4-54 Gy PTV1, 60-68.2 Gy PTV2 (DE $\geq$ 70 Gy, α/β=10)

Prostata/pelvi: dose/fraz 1.8 Gy PTV1, 2.2 Gy PTV2

Dose tot 50.4-54 Gy PTV1, 61.6-66 Gy PTV2 (DE $\geq$ 79 Gy, α/β=3)

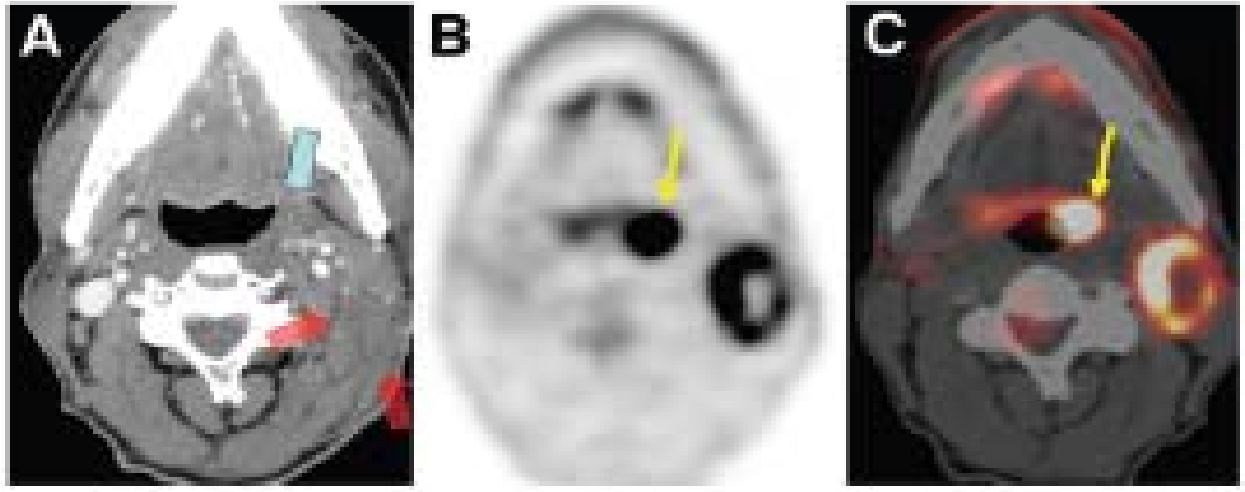
Conclusioni

Elevata complessità tecnica IMRT dinamica

sia in fase di implementazione/commissioning, che in fase di QA

su singolo paziente (time consuming!) $\Rightarrow$ protocolli “standard”di QA

- vantaggi dosimetrici e clinici legati alla tecnica (dose OARs, Conformity Index)
- vantaggi “radiobiologici” SMART-IMRT nella irradiazione simultanea di volumi differenti con dosi differenti



- scelta α/β
- *Biological Target Volume*

?!