

XVII Convegno Regionale
AIRO Piemonte Valle D'Aosta
2008

Asti 18-Ott-

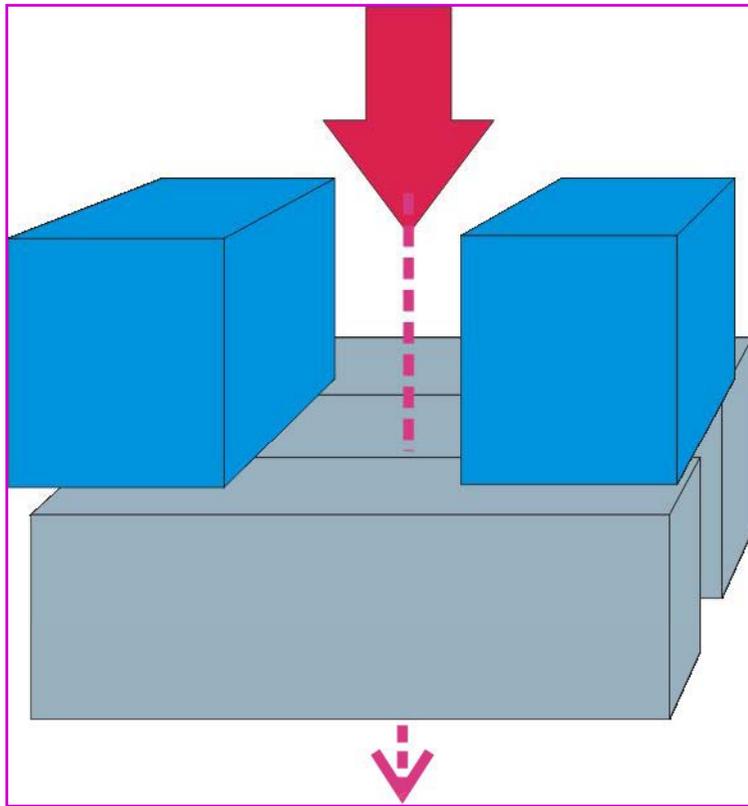
Tecniche innovative “modulate” con LINAC

Riccardo Ragona

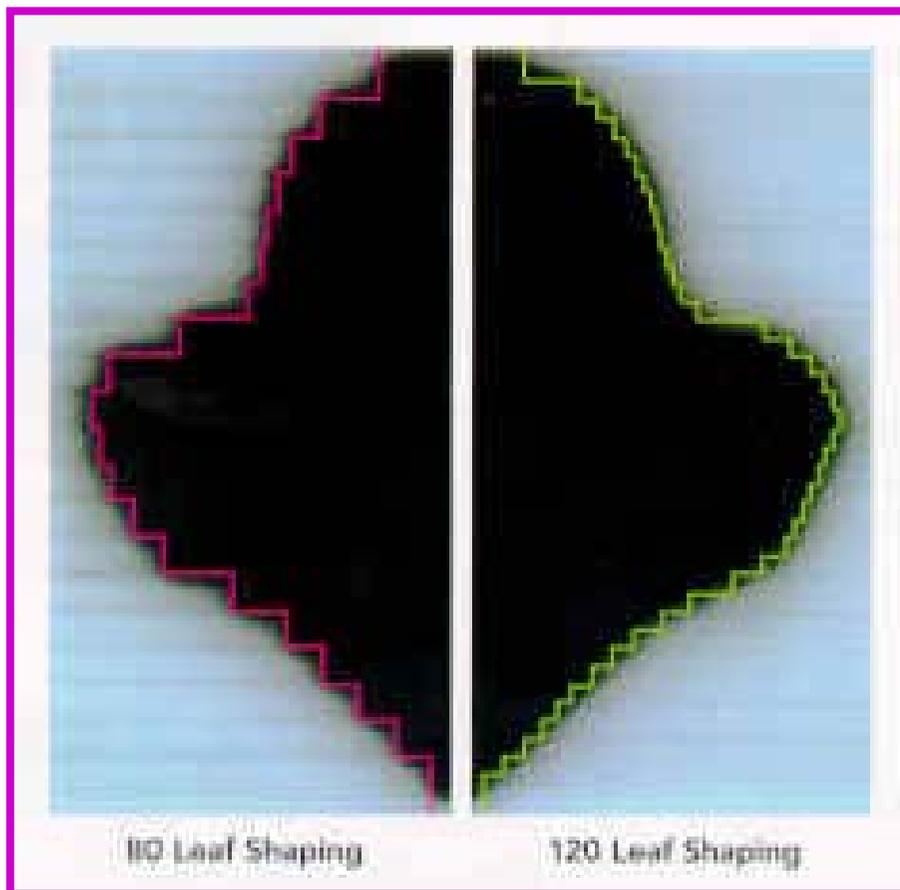
Radioterapia - Università di Torino



Collimatori Multileaf (1995)

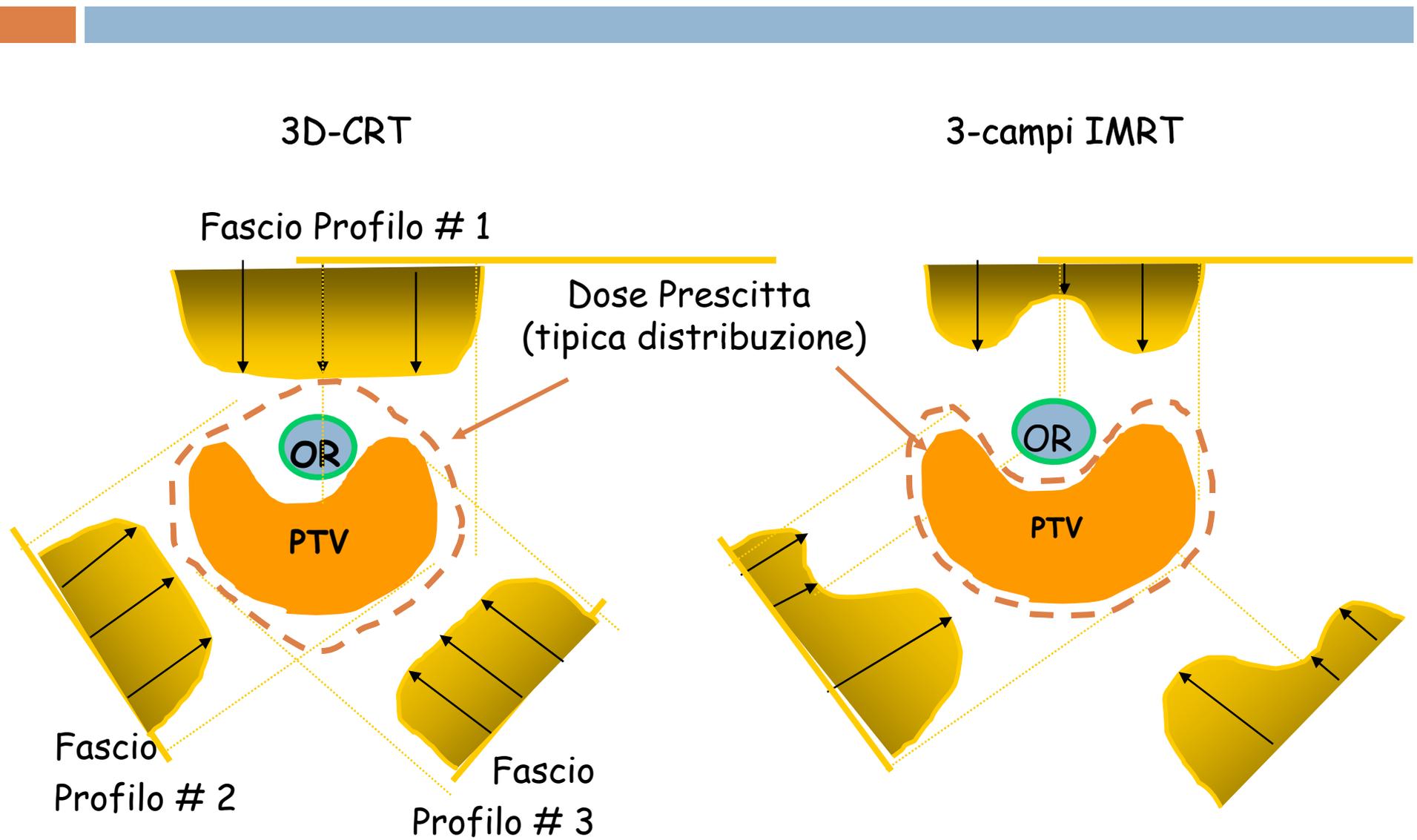


Collimatori Multileaf



- La qualità del campo dipende dalle dimensioni delle lamelle
- Esiste sempre radiazione di fuga fra le lamelle
- La trasmissione del sistema MLC è maggiore rispetto ai collimatori standard

3D CRT versus IMRT



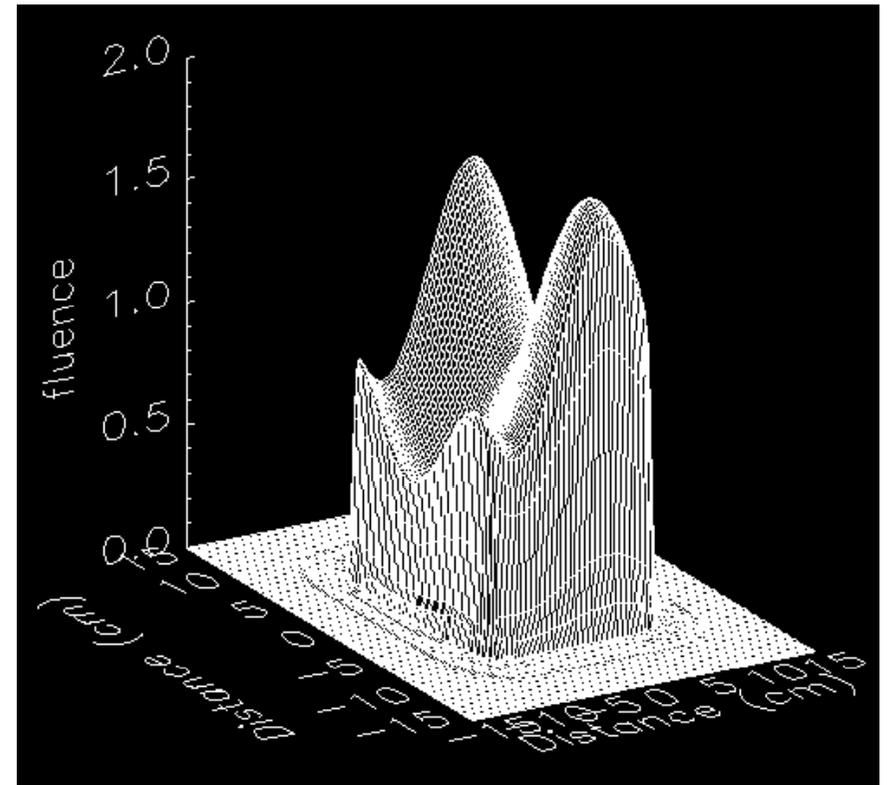
IMRT - Definizione

Intensity Modulated RadioTherapy

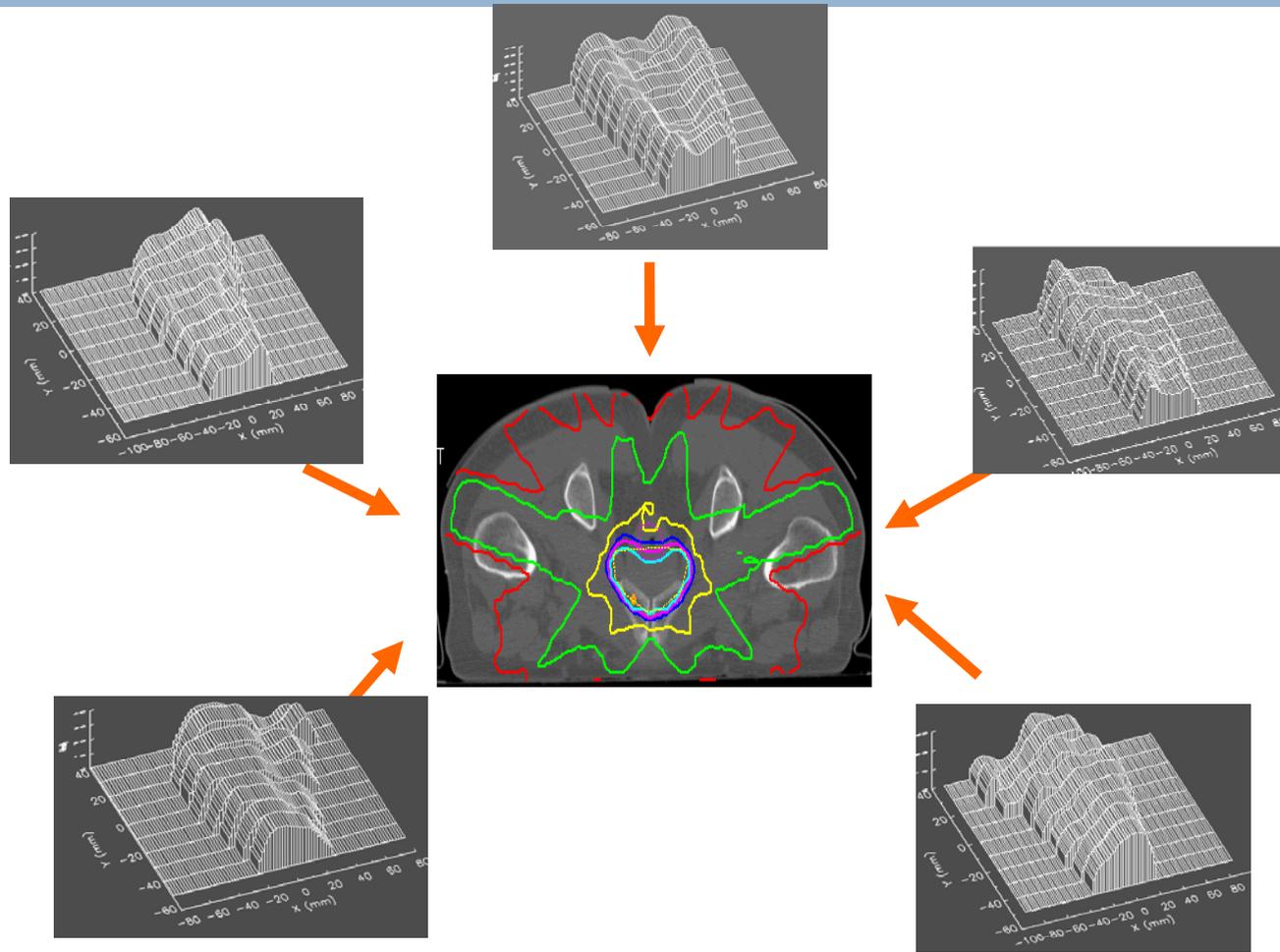
- Geometria a fasci conformati
- Variazione della fluenza lungo il campo
Profilo di dose non uniforme (modulato)

Planning Inverso (Backward)

- Definizione dei constraints per PTV e strutture critiche
- Ottimizzazione della fluenza dei fasci per soddisfare i constraints richiesti



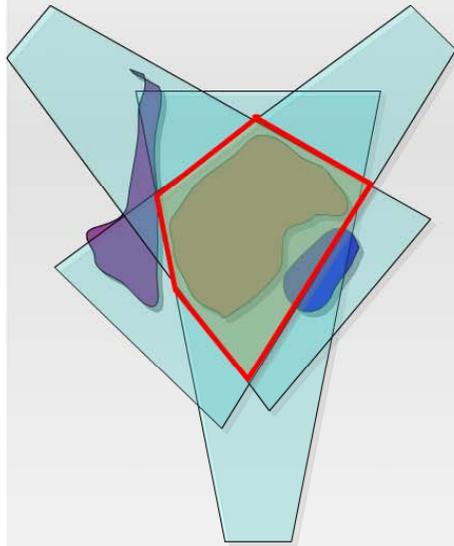
Distribuzione della dose ottimale



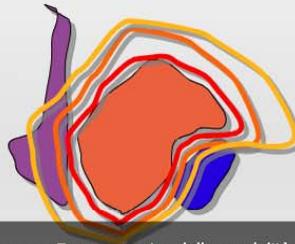
IMRT - Prostata

Forward & Inverse Treatment Planning

“Inverse” Planning

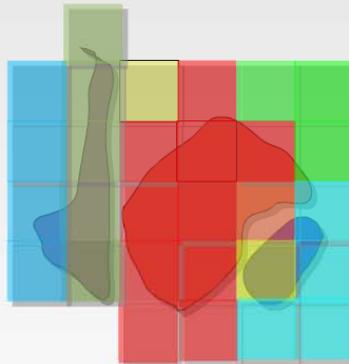


Forward Planning

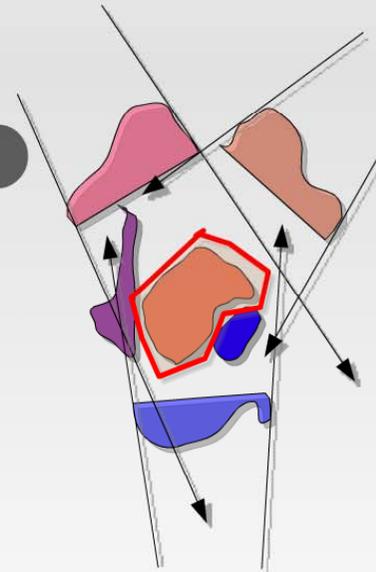


Premere Esc per uscire dalla modalità a schermo intero.

1. Dose distribution specified



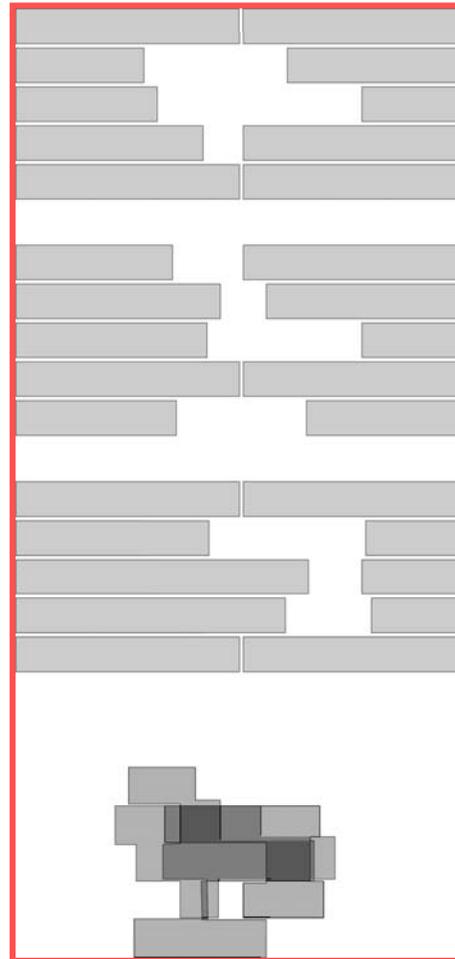
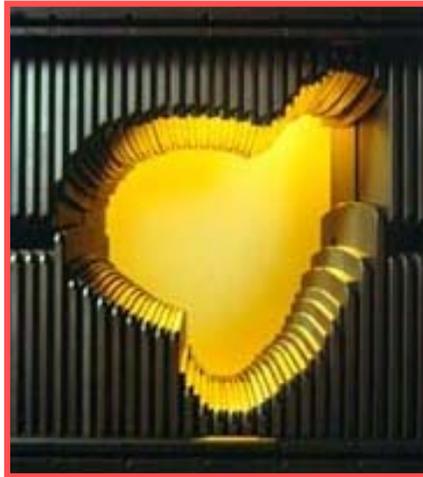
2. Intensity map created



3. Beam Fluence modulated to recreate intensity map

ubuntu

Modulazione della Fluenza (Segmentazione)



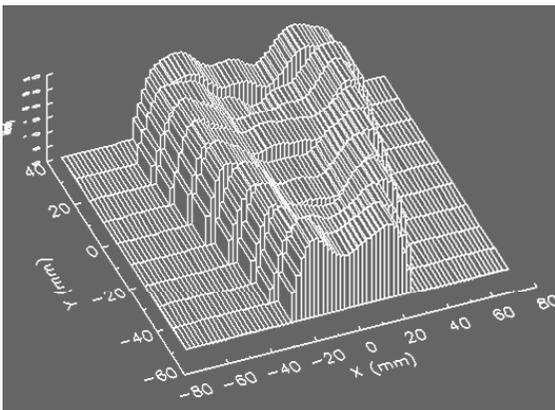
MLC - segmento 1

MLC - segmento 2

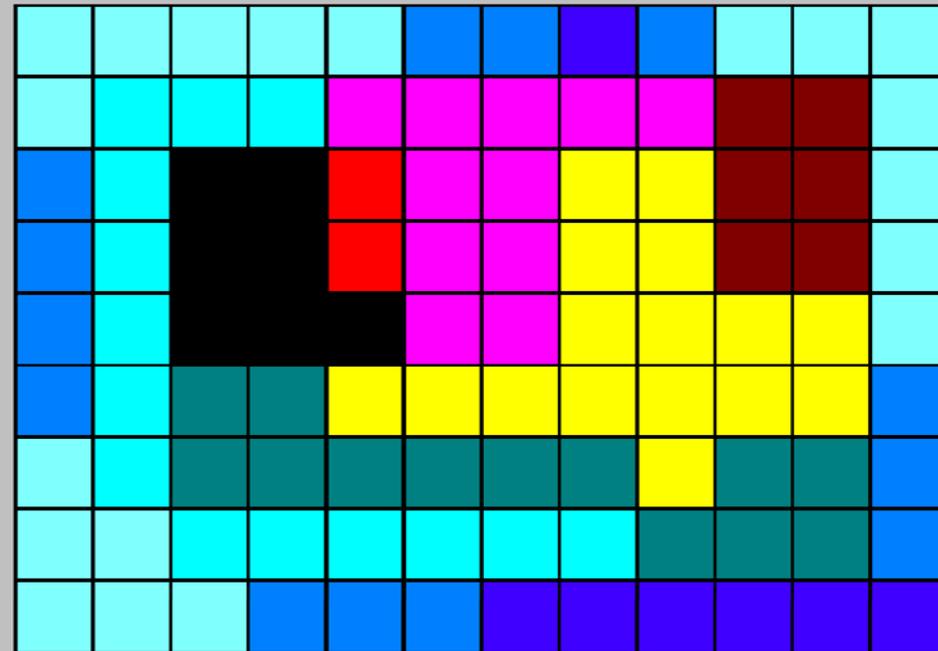
MLC - segmento 3

Mapa di Fluenza
del Campo

Mappa di Fluenza - singolo campo , più segmenti



field width



field length

IMRT a campi statici

Step and Shoot

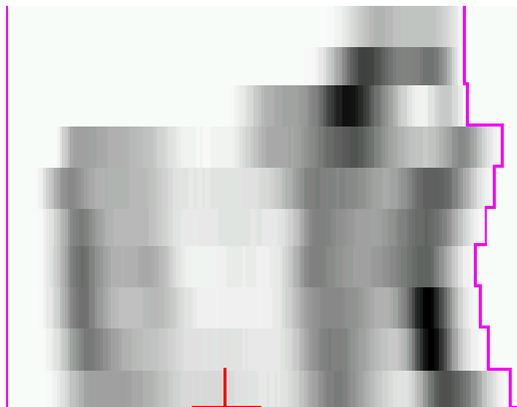
- **1. Modalità**
 - **si muovono le lamelle poi beam ON**
 - **no radiazione durante il movimento lamelle**

Sliding Window (Dinamica)

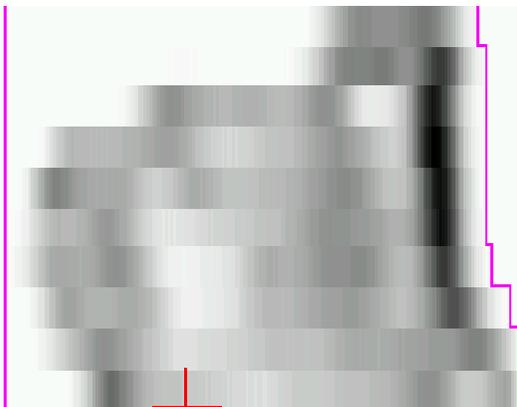
- **2. Modalità**
 - **si muovono le lamelle anche in fase di beam ON**

Mappe di Fluenza di 6 campi statici (Capo-collo)

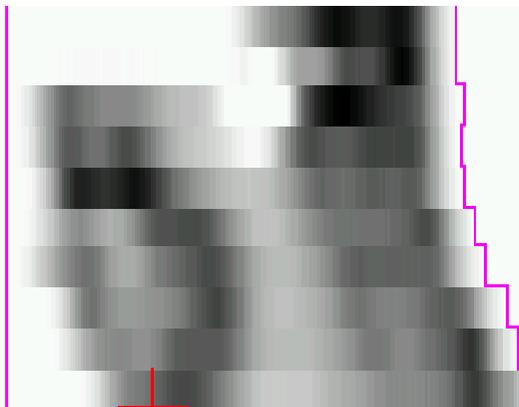
gantry 0



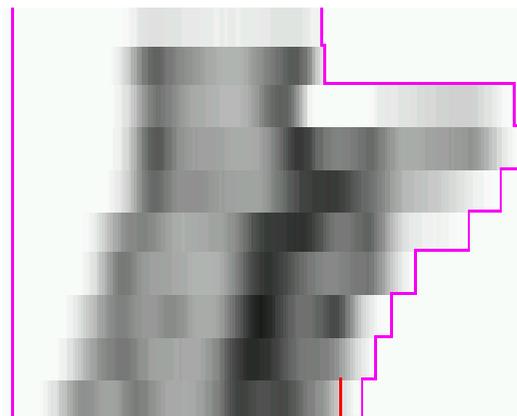
gantry 30



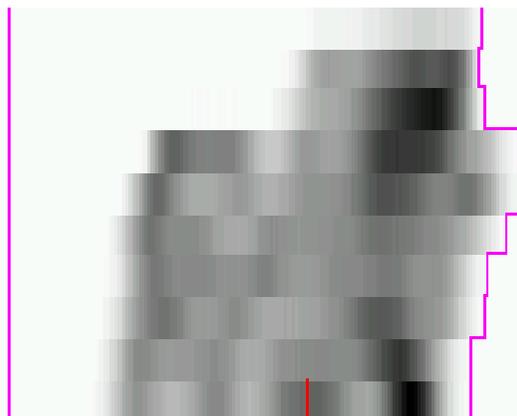
gantry 60



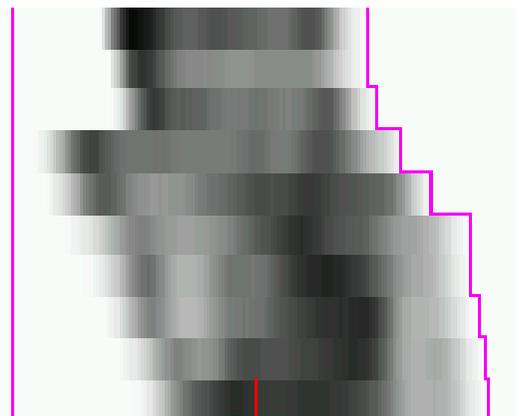
gantry 270



gantry 330



gantry 135



Vantaggi della IMRT

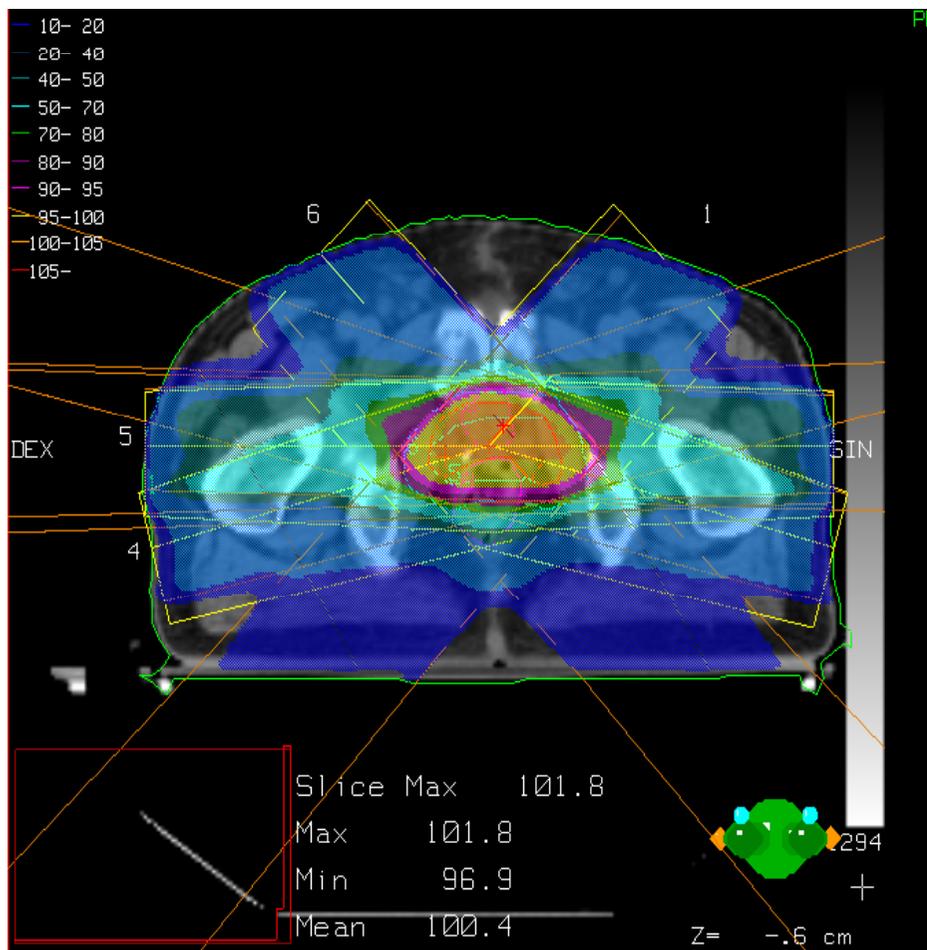


- Migliore conformazione della dose
- Maggiore risparmio dei tessuti critici
- Possibilità di dose-escalation
- Piano di cura basato su obiettivi e constraints

Confronto fra distribuzione di dose

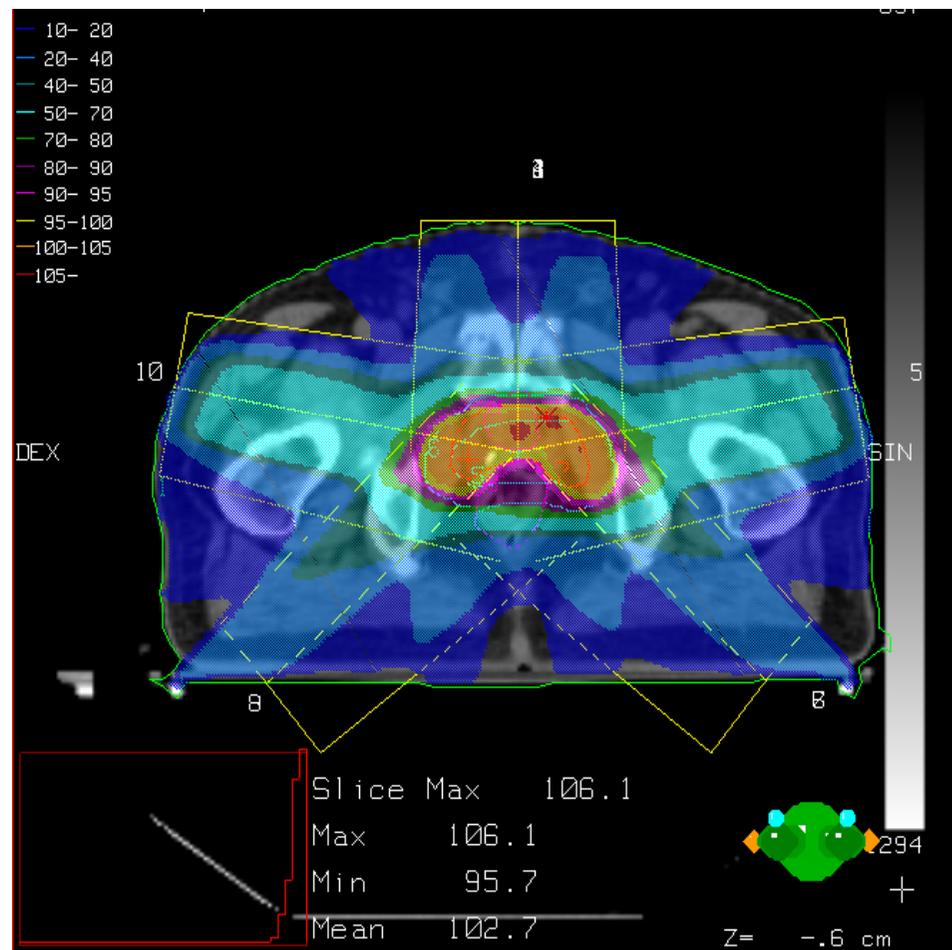
3D-CRT sei campi

HI = 3.5%



vs. IMRT cinque campi

HI = 7.2%



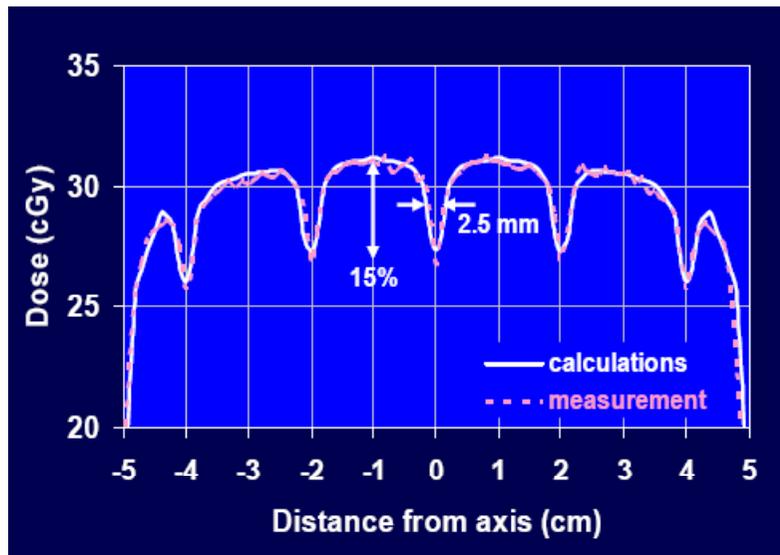
Svantaggi della IMRT



- Maggiore disomogeneità della dose al PTV
- Tongue & Groove
- Aumento delle Unità Monitor erogate
- Aumento dose periferica
- Problemi radioprotezionistici (fattore d'uso)

Tongue & Groove

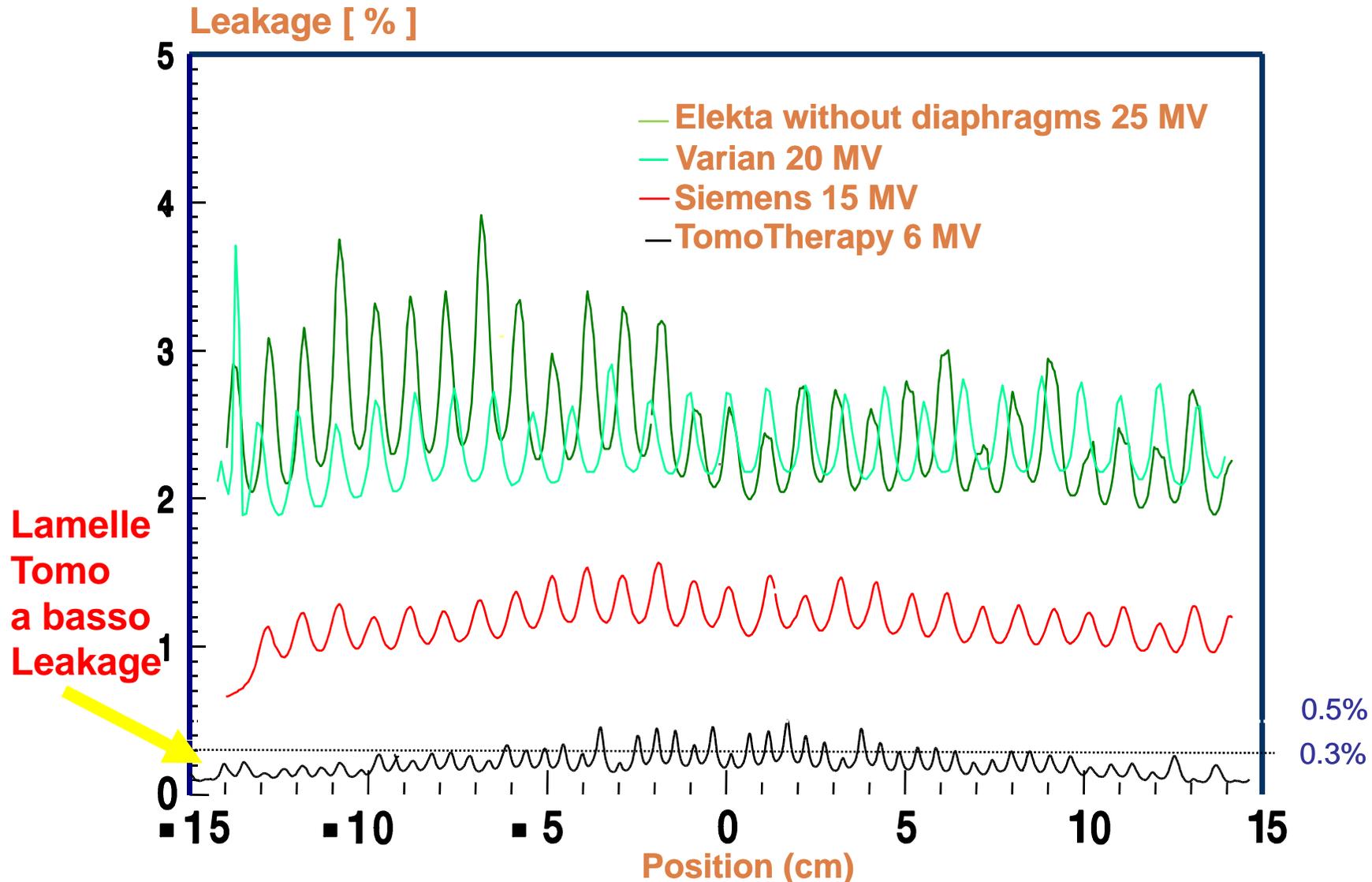
Tongue & Groove



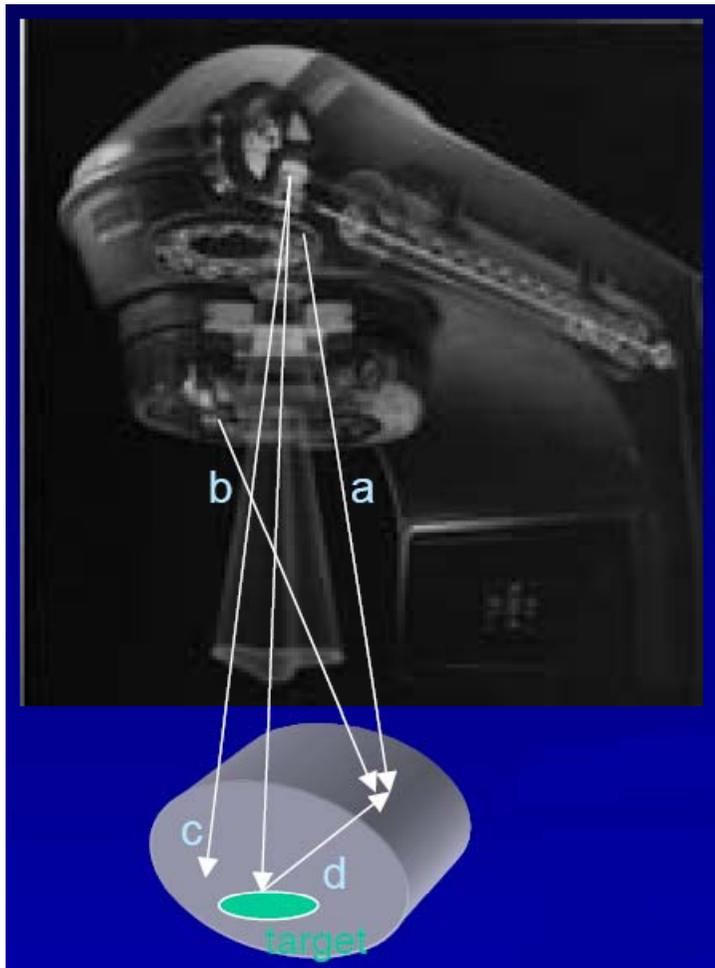
Effetti & Rimedi

- Fenomeni di sottodosaggio all'interno del campo modulato
- E' trascurabile con l'uso di molti campi e ridotta modulazione
- Si può minimizzare con opportune strategie circa la sequenza dei segmenti

Radiazione di fuga attraverso le lamelle



IMRT – Dose periferica



Cause Primarie

- Maggiore trasmissione fra lamelle
- Uso di segmenti per modulare la fluenza

Cause Specifiche

- Aumento della fluenza (UM)
- Protocolli di dose escalation

Dose periferica (Battista J. 2003)

Dose Periferica		RT standard 6 MV	3D CRT con MLC 6 MV	IMRT con DMLC 6 MV
Rx fuga dal collimatore primario		0.1%	0.1%	0.1%
Trasmissione RX collimatori secondari		< 0.5%	< 2.5%	< 2.5%
Fattore di Modulazione		1X 2X (cunei)	2X	> 3X
Fattore di Dose escalation		1.0	1.1	1.3

Dose periferica – rischio di tumore radioindotto

(Followill et al. 1997)

- La dose periferica cresce da 76 mSv a 190 mSv per 70 Gy in IMRT con fasci da 6 MV
- Includendo un fattore di dose escalation di 1.3 diventano $190 \text{ mSv} \times 1.3 = 247 \text{ mSv}$
- Il rischio di tumore radioindotto risulta accresciuto dell' 1%
- 8 volte superiore con fasci di 25 MV (neutroni)

IMRT - Tecniche Cinetiche

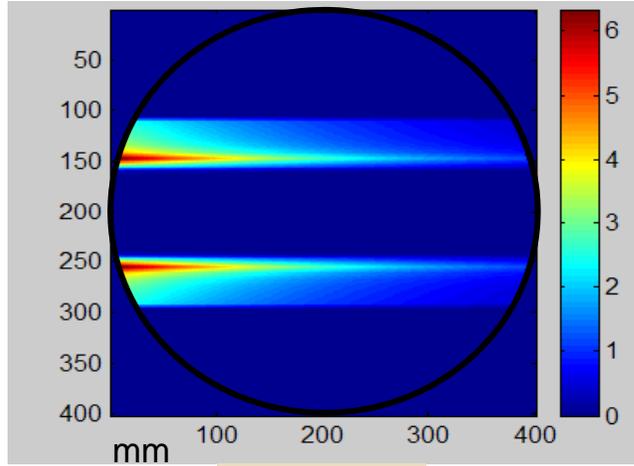
C - Arm



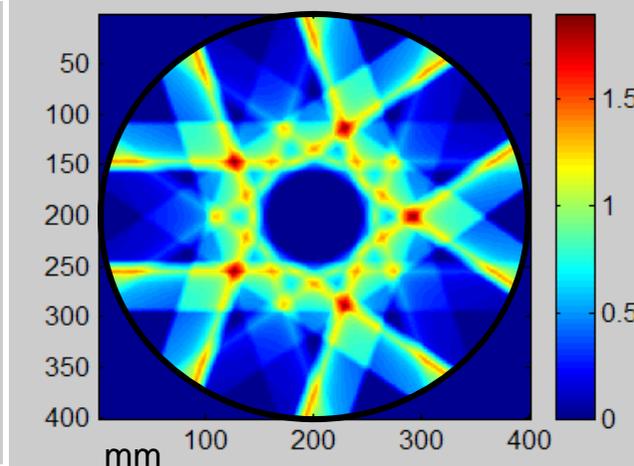
Ring



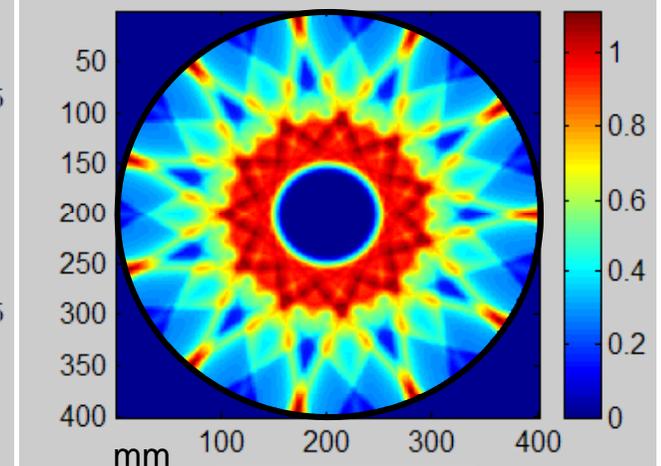
IMRT - Tecniche cinetiche - vantaggi



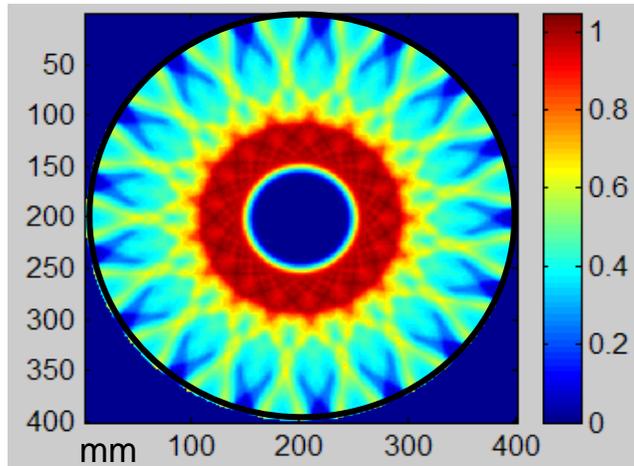
1 Beam



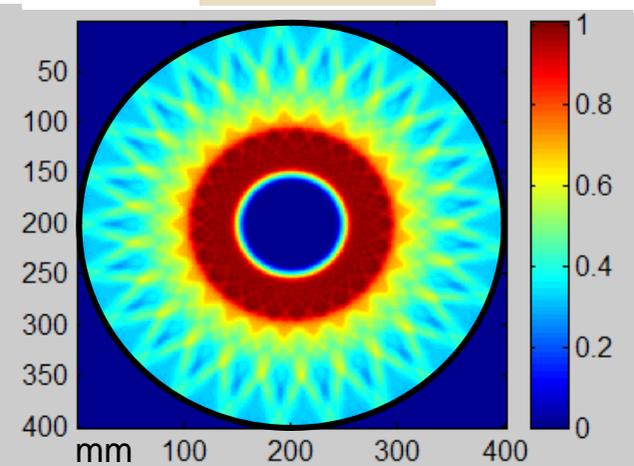
5 Beams



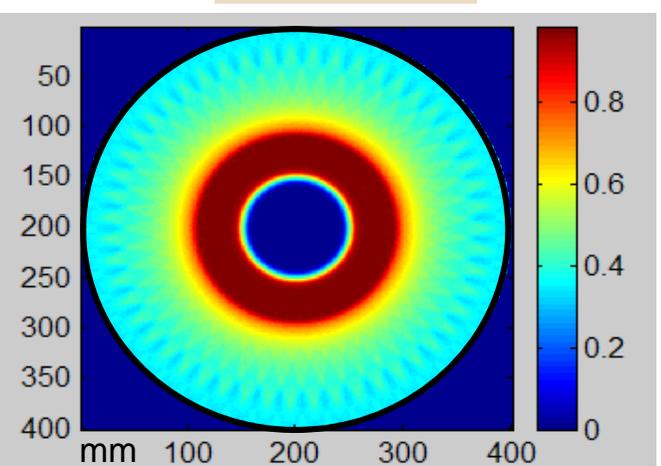
11 Beams



17 Beams



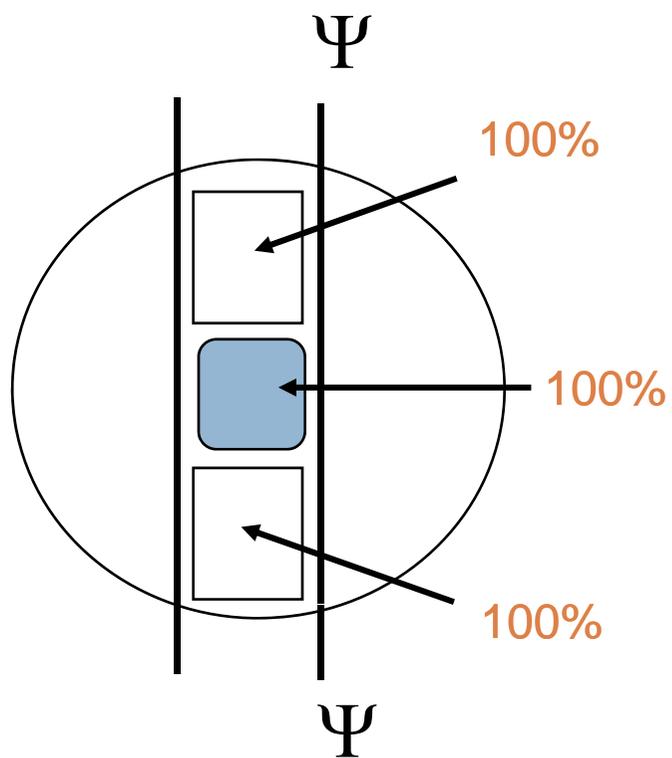
25 Beams



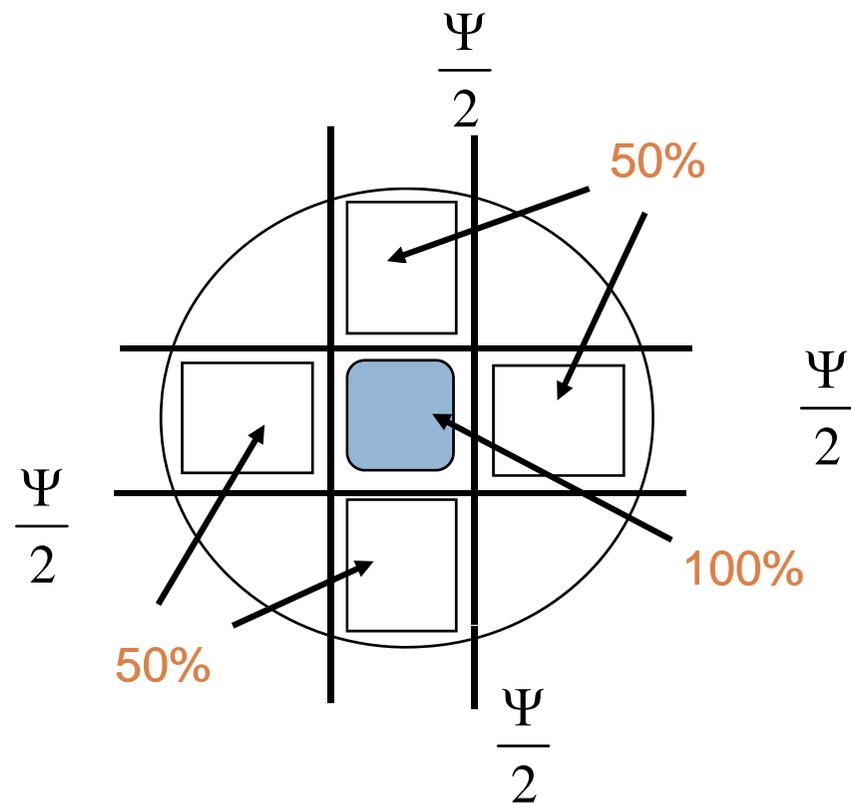
51 Beams

Dose Integrale (Dose * Volume) : Numero dei campi

Opposti Paralleli

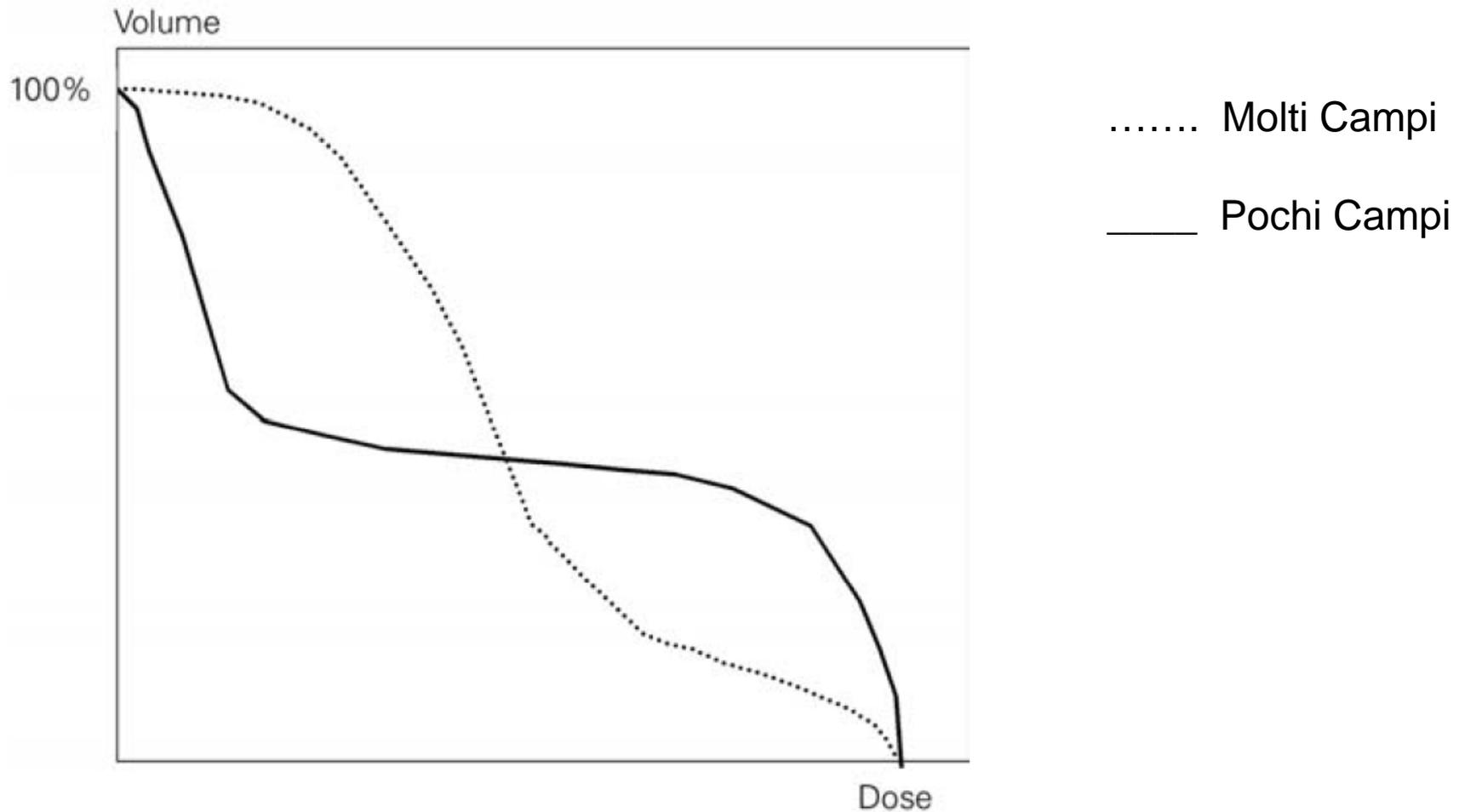


Box a 4 campi



Dose Integrale uguale

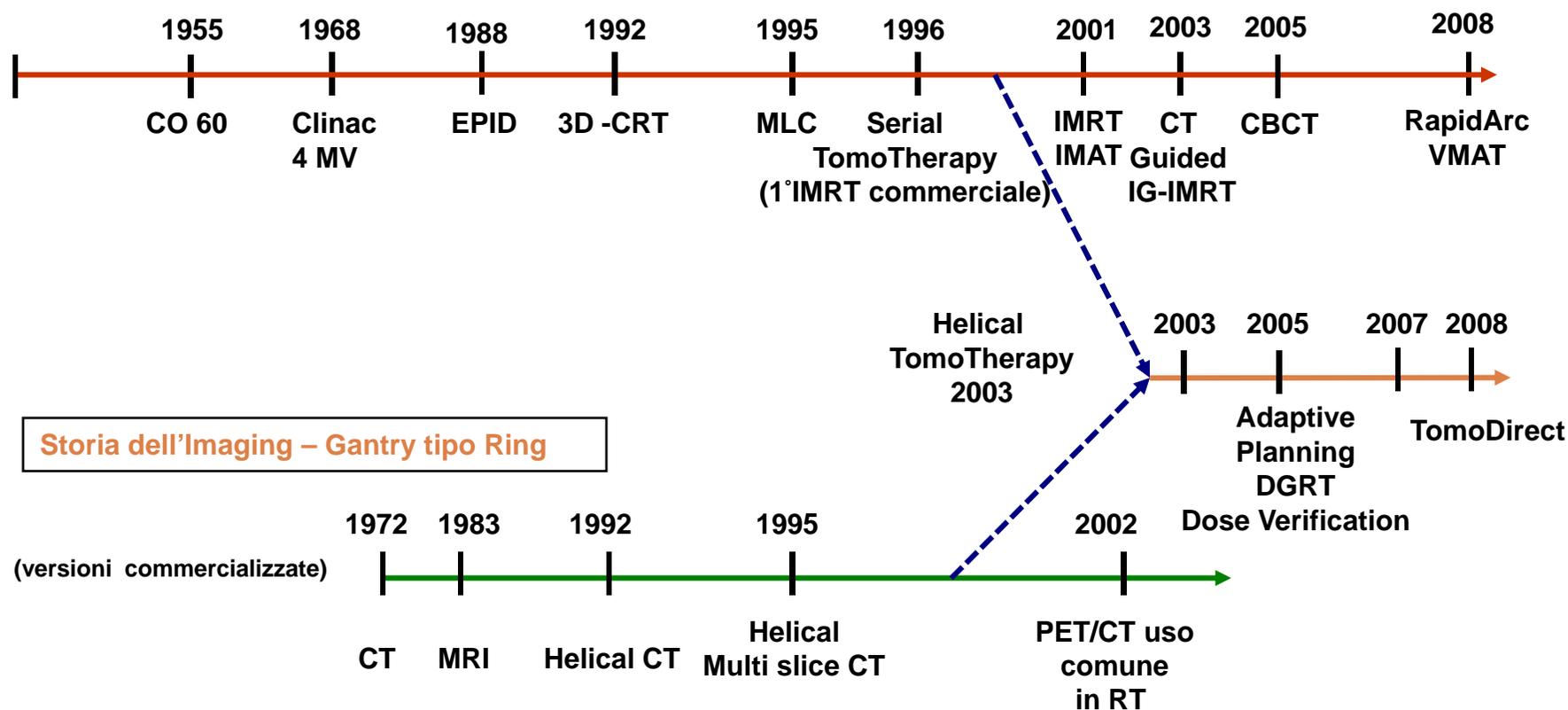
poca dose a grande volume $=$ (?) molta dose a piccolo volume



Storia della Radioterapia a fasci esterni

Storia dei Linac – Gantry tipo C-Arm

Disponibilità commerciale



Storia dell'Imaging – Gantry tipo Ring

(versioni commercializzate)

IMRT - Beam Delivery

Pencil Beam



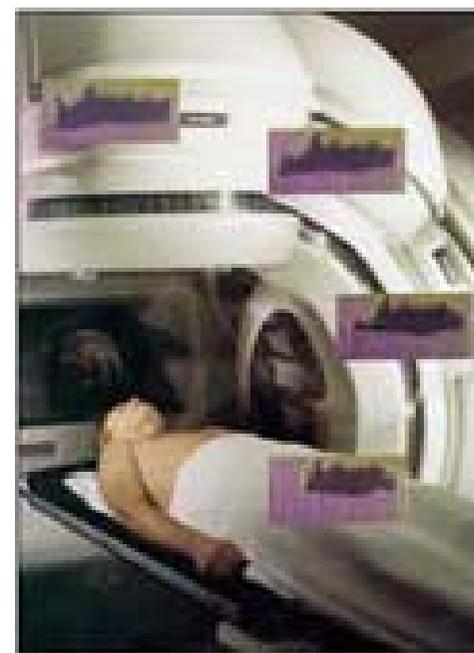
Cyberknife

Fan Beam



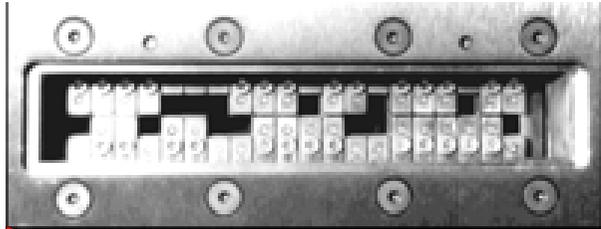
Tomotherapy

Cone Beam

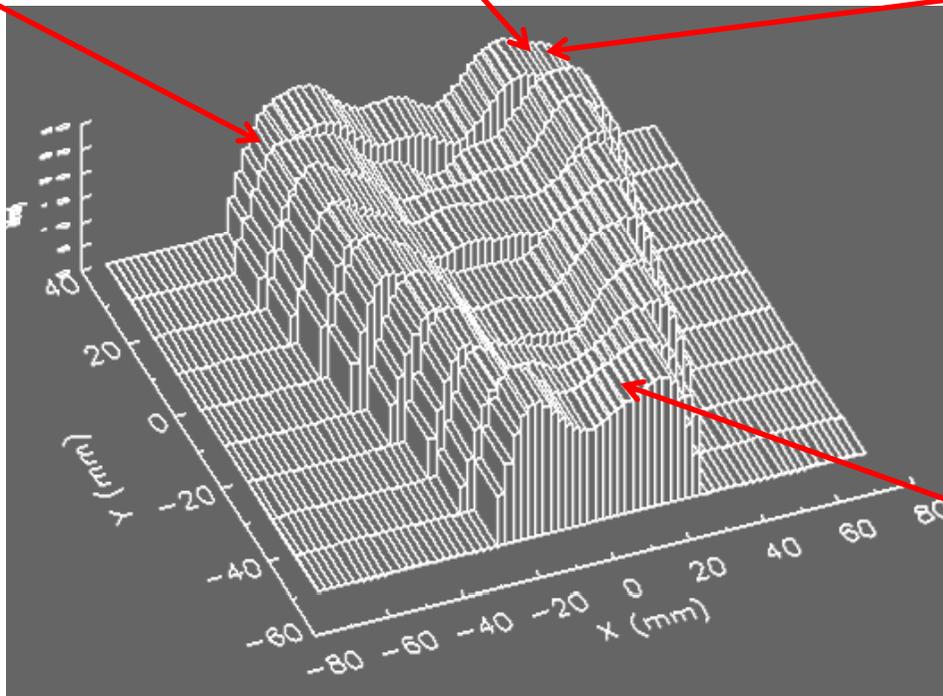


LINAC

IMRT – Fan beam vs. Cone beam



Tomotherapy – Fan Beam
(250 cm/sec)



LINAC – Cone Beam
(2-3 cm/sec)

IMRT - Tecnologie a confronto

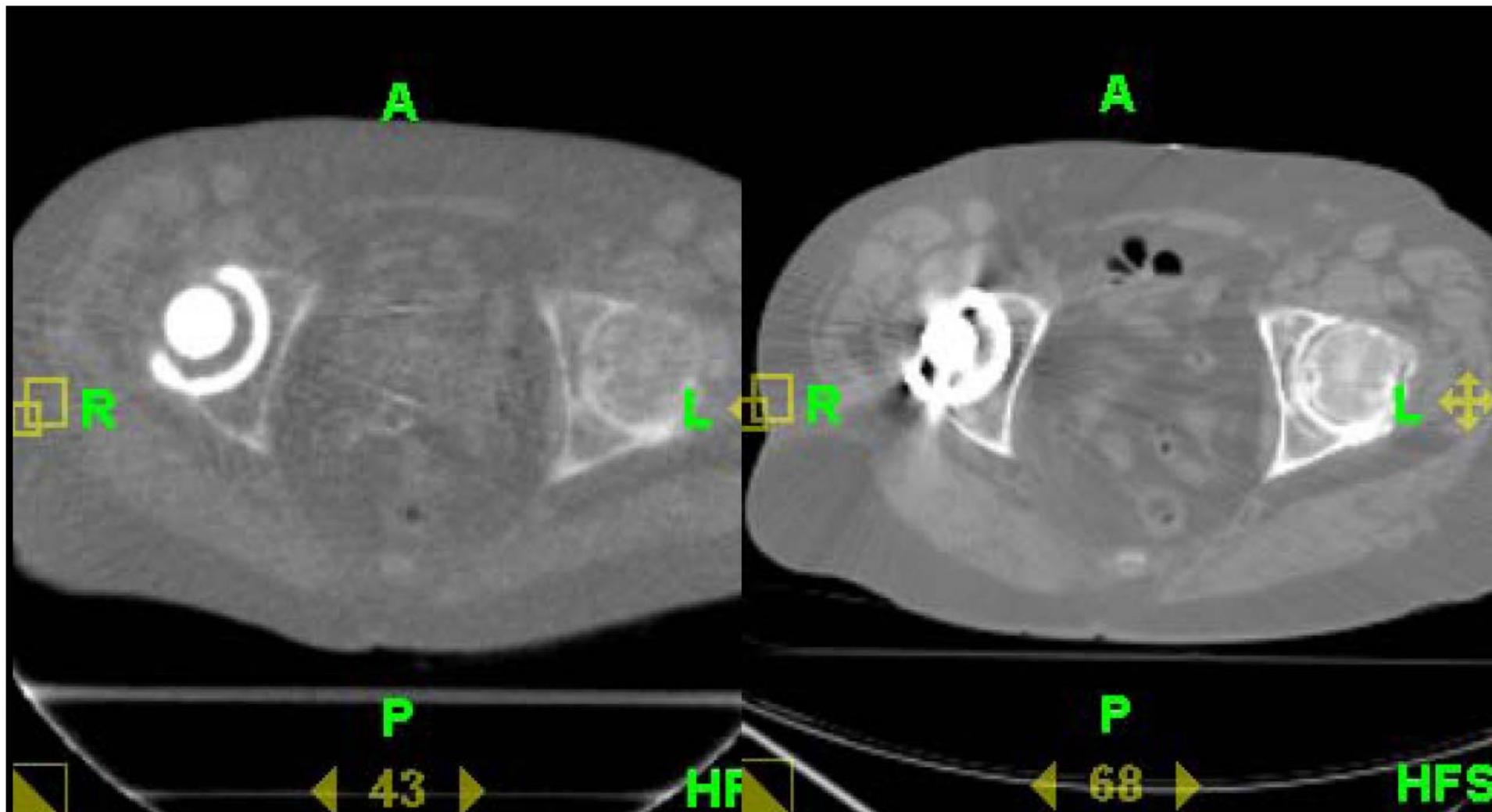
	Geometria Fascio	Design Gantry	Gradi di Libertà	Image Guided
LINAC	Cone Beam	C-Arm	Non Coplanare	Fluoroscopia KV - CT
Tomoterapia Seriale	Fan Beam Sequenziale a step	C-Arm	Coplanare	EPID
Tomoterapia Elicoidale	Fan Beam Elicoidale continuo	Ring	Coplanare	Megavoltage CT
Cyberknife	Pencil Beam	Robotizzato	Non Coplanare	Radiografia Biplanare

IGRT

MV

vs.

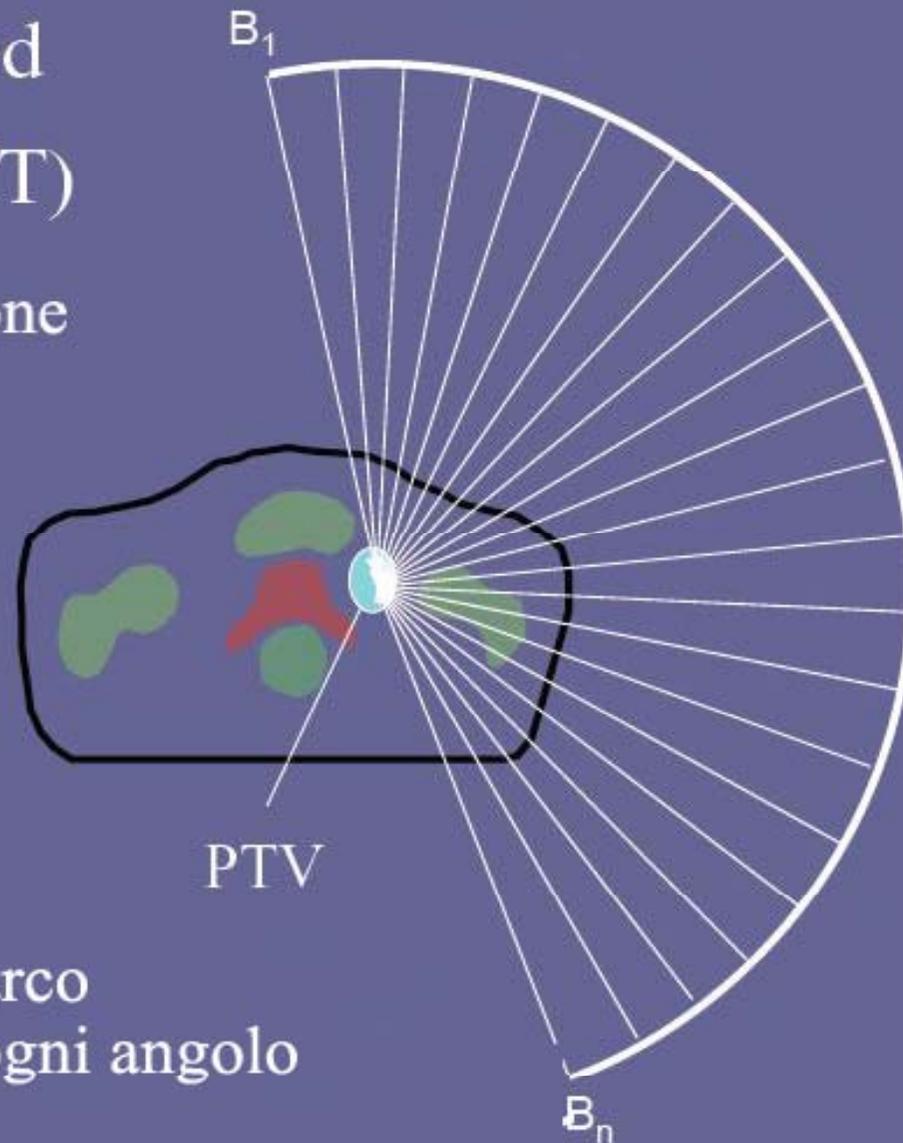
KV



Tecniche cinetiche – LINAC C-Arm Cone beam

Intensity-Modulated Arc Therapy (IMAT)

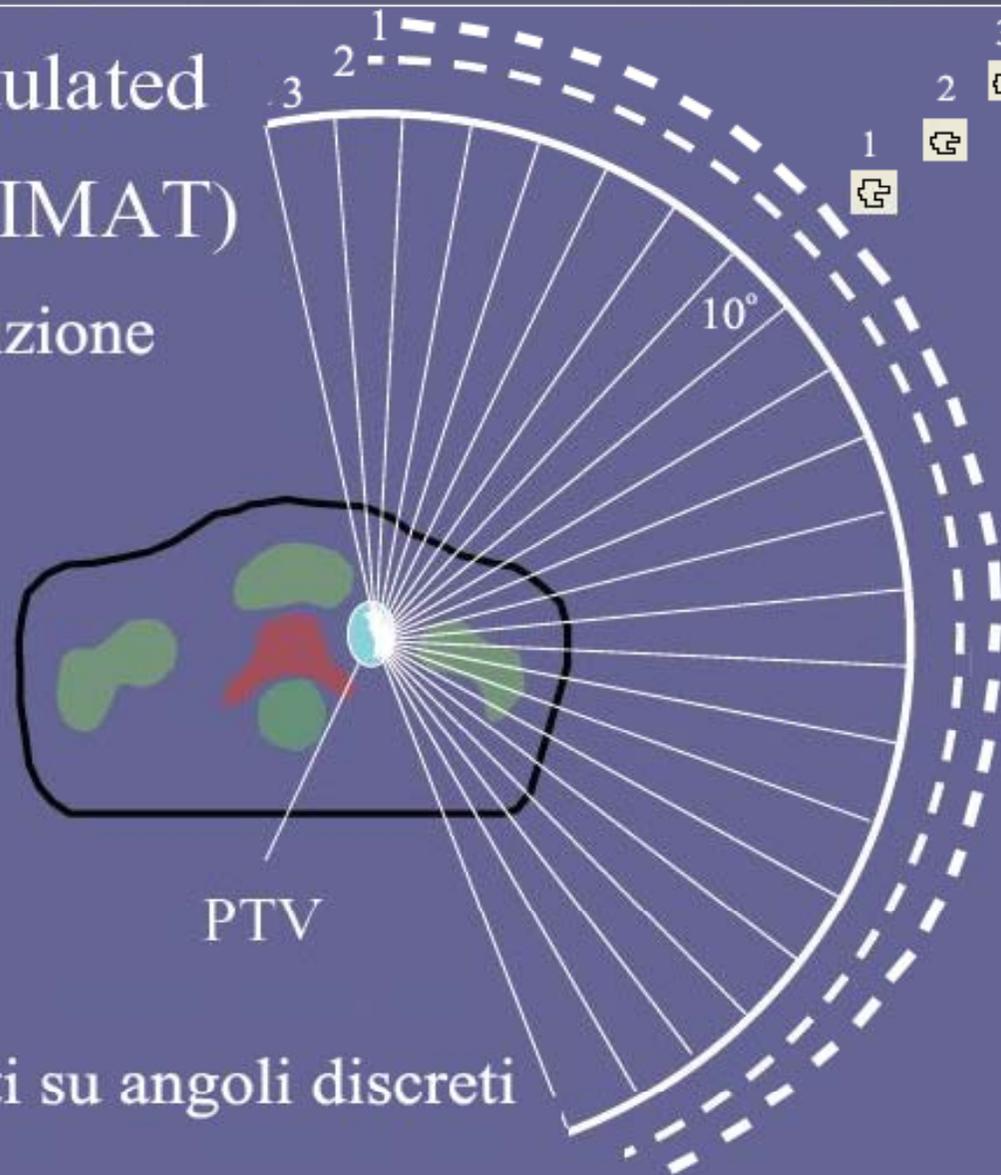
Prima condizione



- Beam ON per tutto l'arco
- MLC conformato su ogni angolo

Tecniche cinetiche – LINAC C-Arm Cone beam

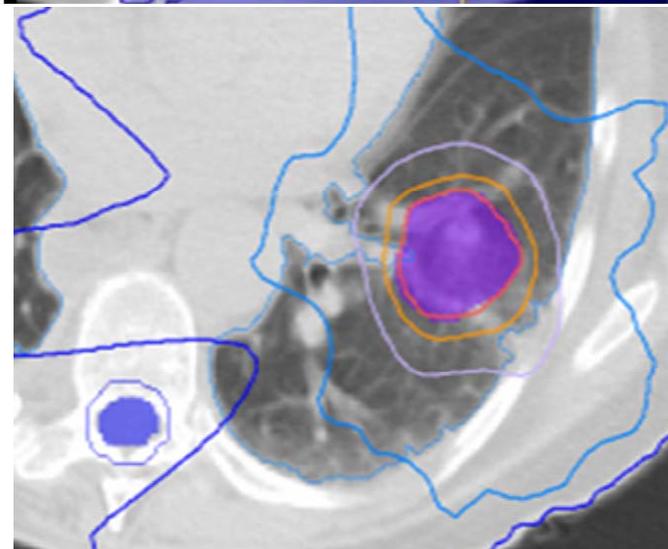
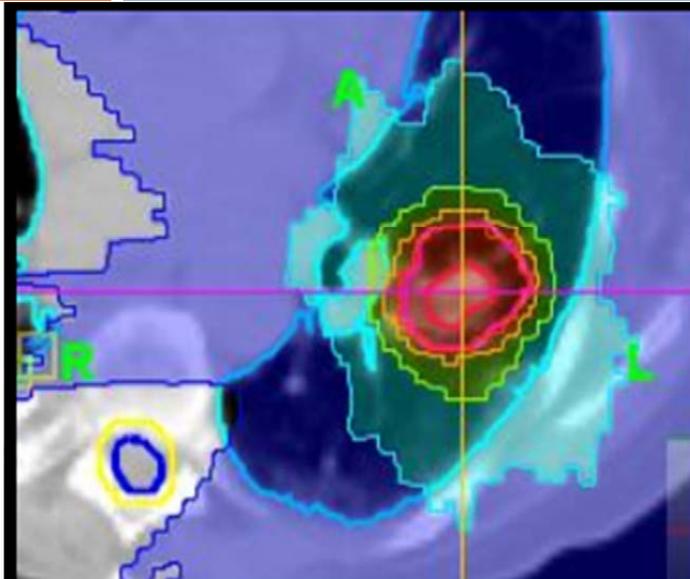
Intensity-Modulated
Arc Therapy (IMAT)
Seconda condizione



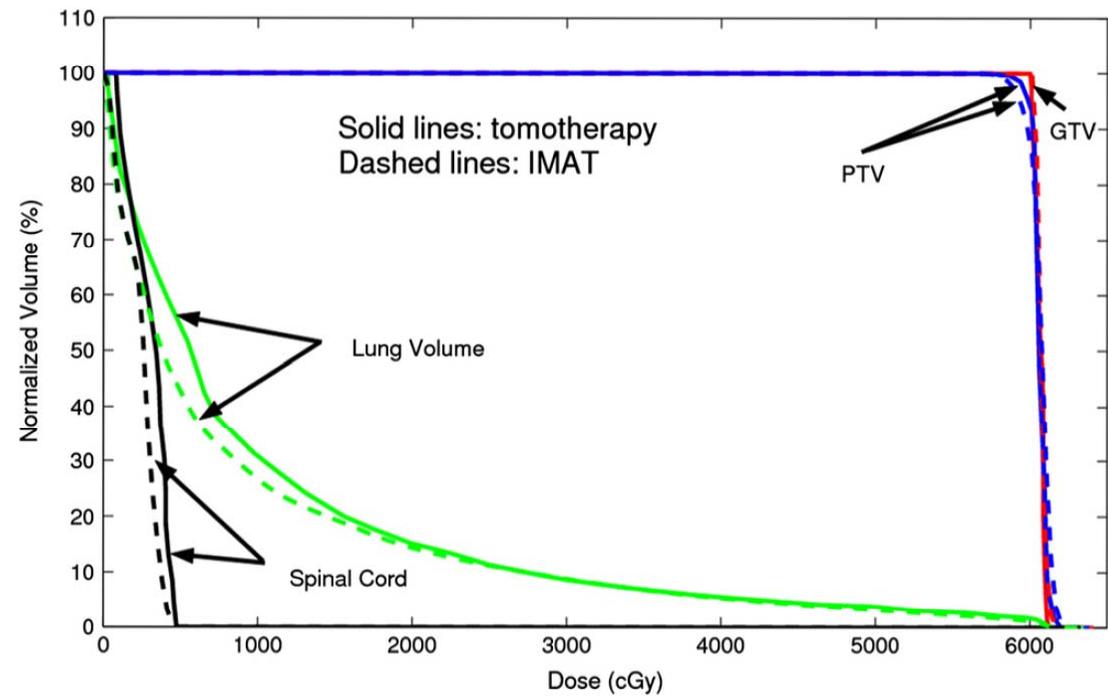
- Due o più archi
- Somma segmenti su angoli discreti

Confronto IMAT-Tomotherapy Caso Polmone

(Cao D. 2007)



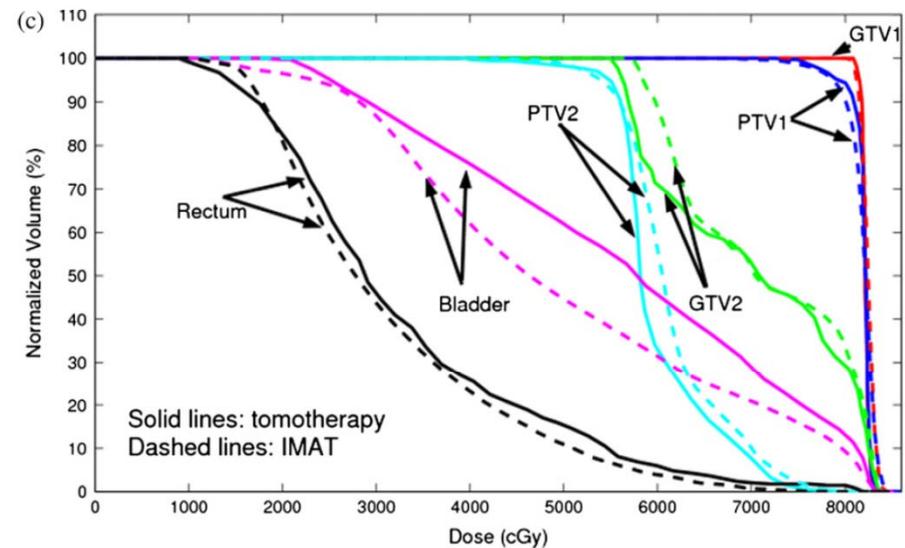
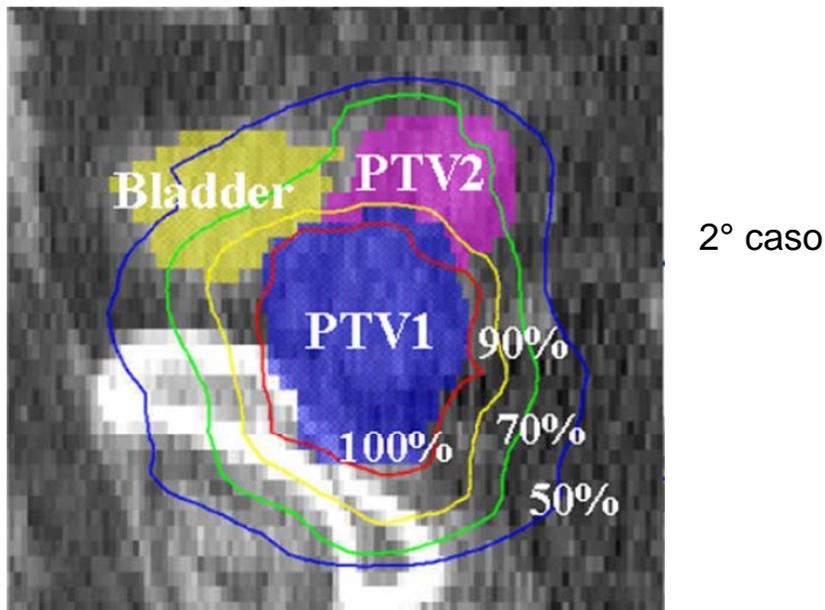
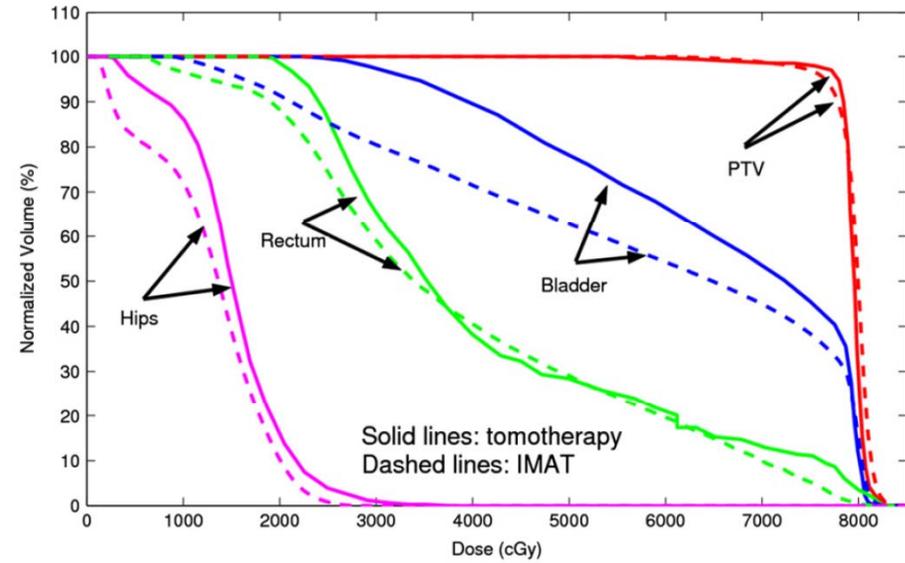
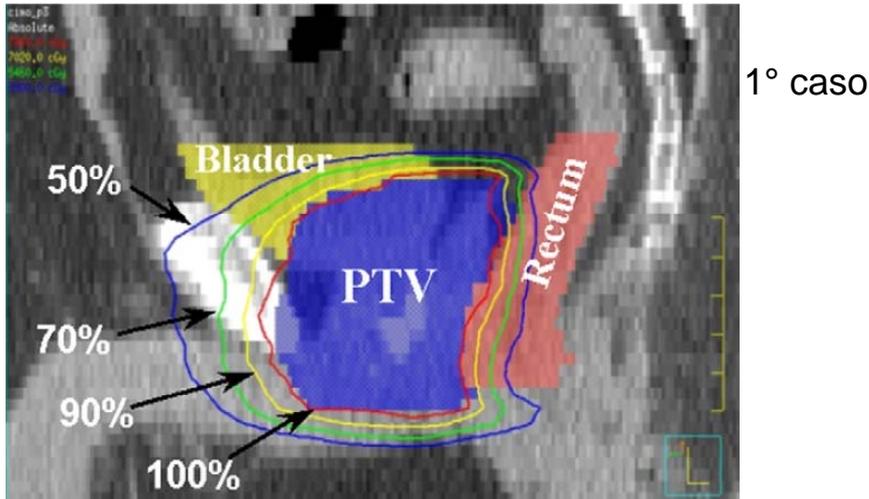
Tomotherapy



IMAT

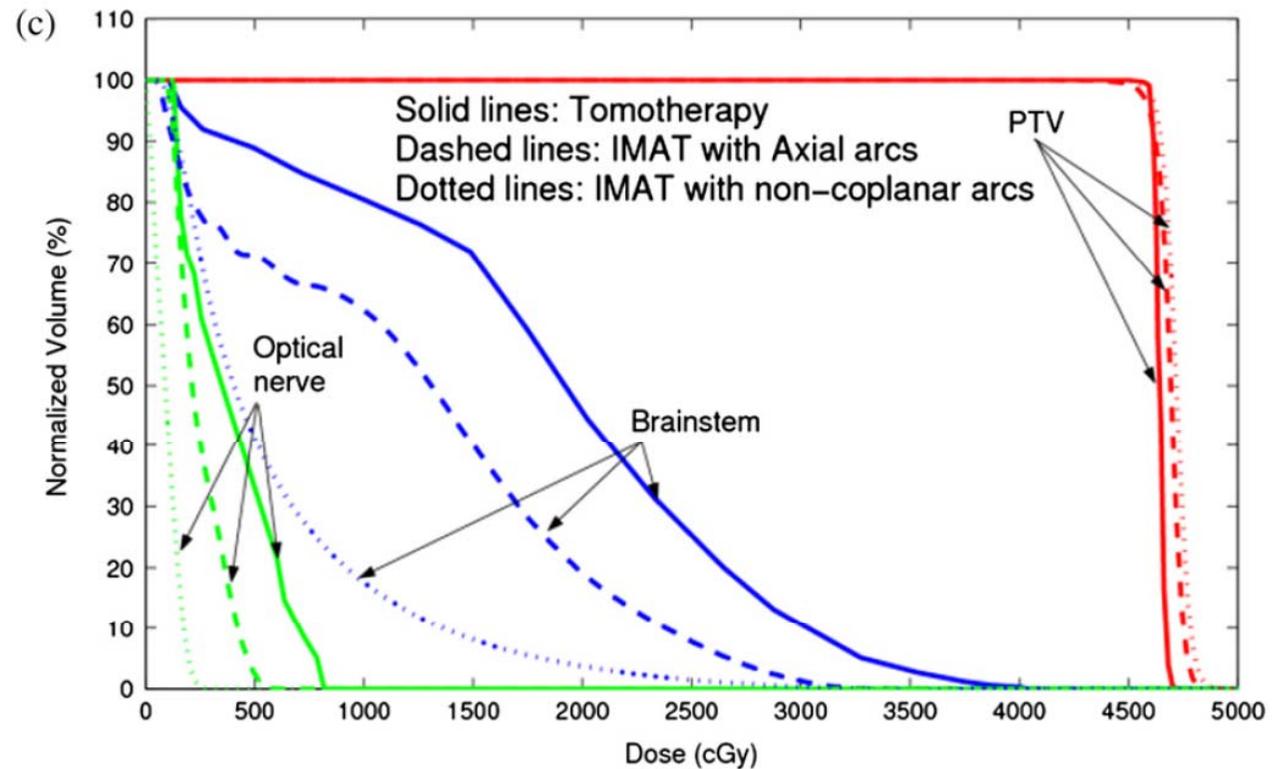
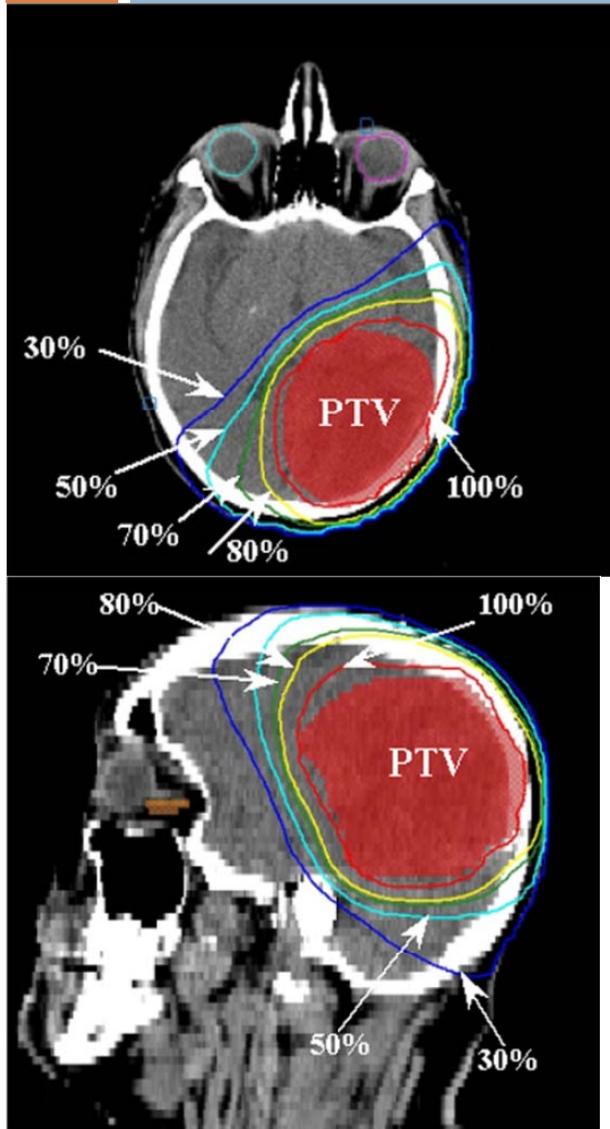
Confronto IMAT-Tomotherapy (Cao D. 2007)

Caso Prostata



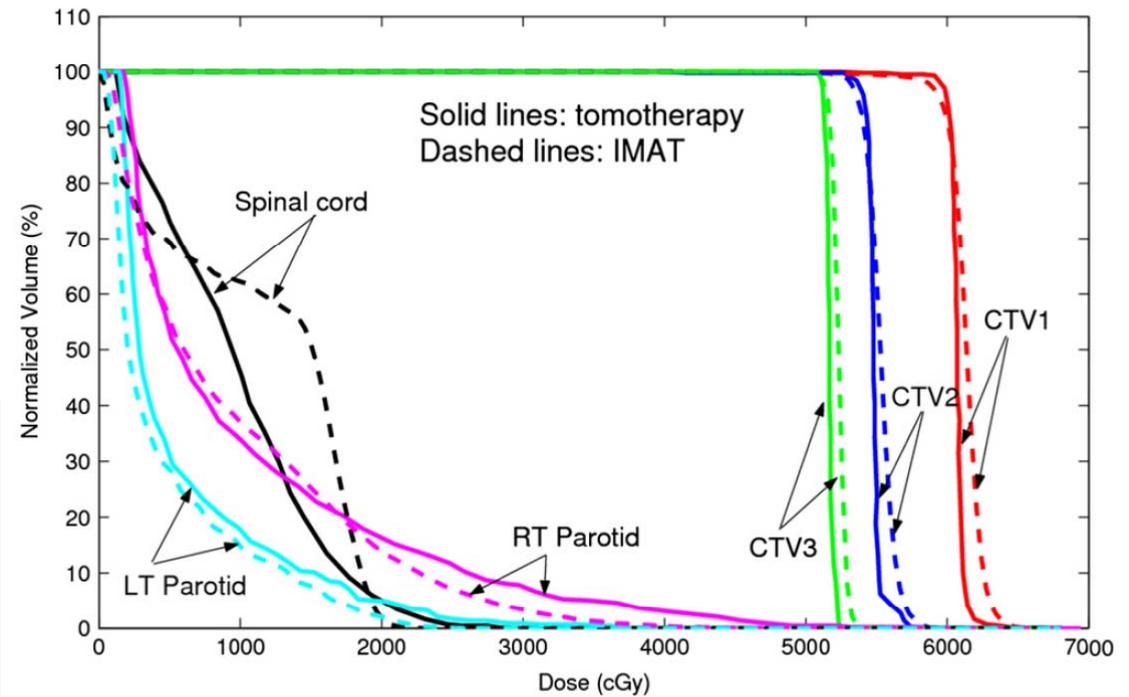
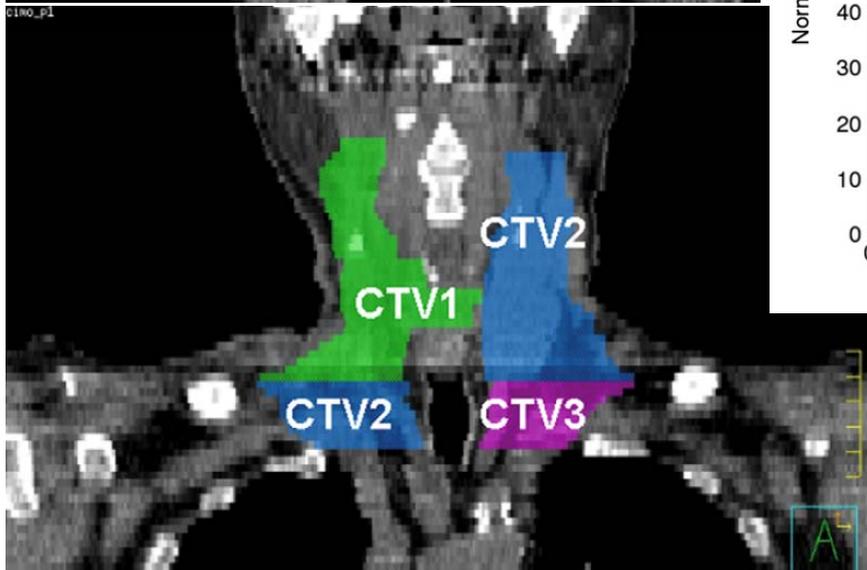
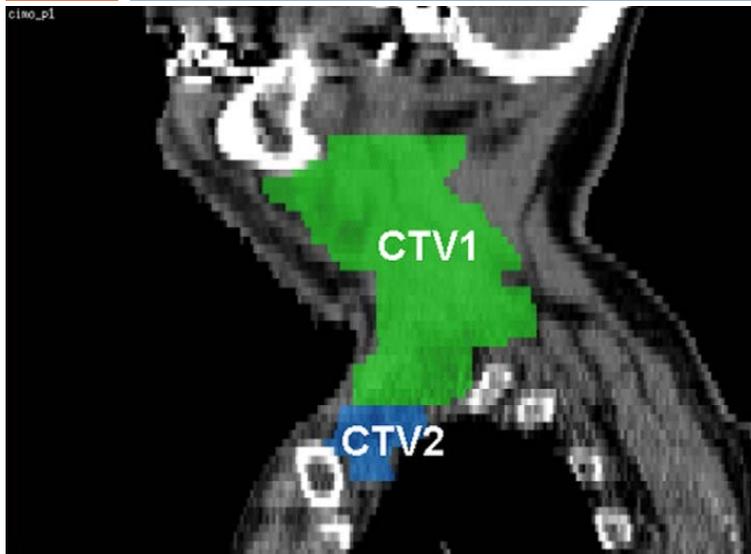
Confronto IMAT-Tomotherapy (Cao D. 2007)

Caso Glioblastoma – fasci non coplanari



Confronto IMAT-Tomotherapy Caso Capo-Collo

(Cao D. 2007)
(11 archi)



Tecniche cinetiche Cone beam di ultima generazione

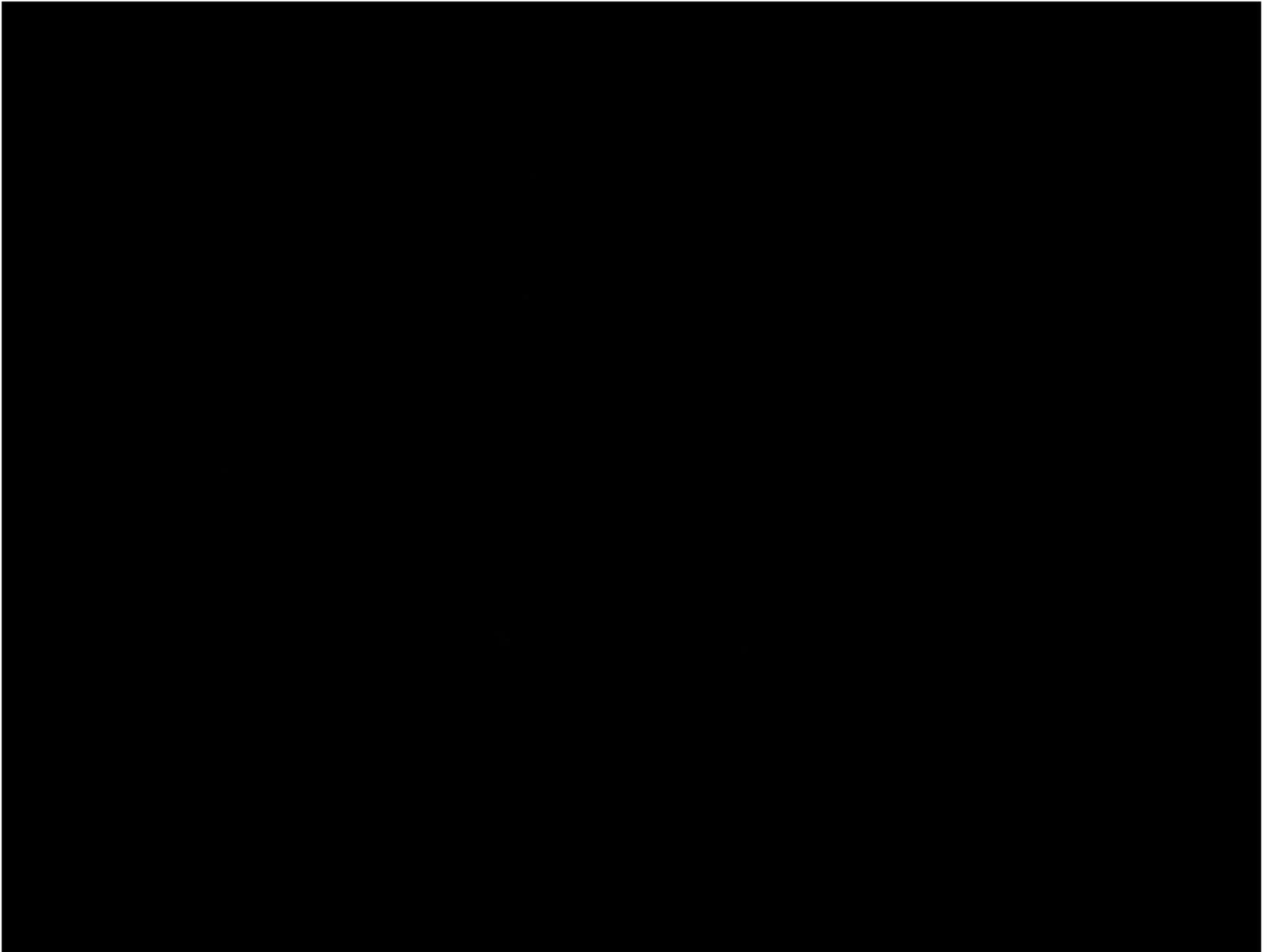
- VMAT Volumetric Modulated Arc Therapy
 - Utilizzo di un solo arco completo o di archi parziali
 - Minore uso di UM
-
1. VMAT (Elekta)
 2. RapidArc (Varian)

VMAT

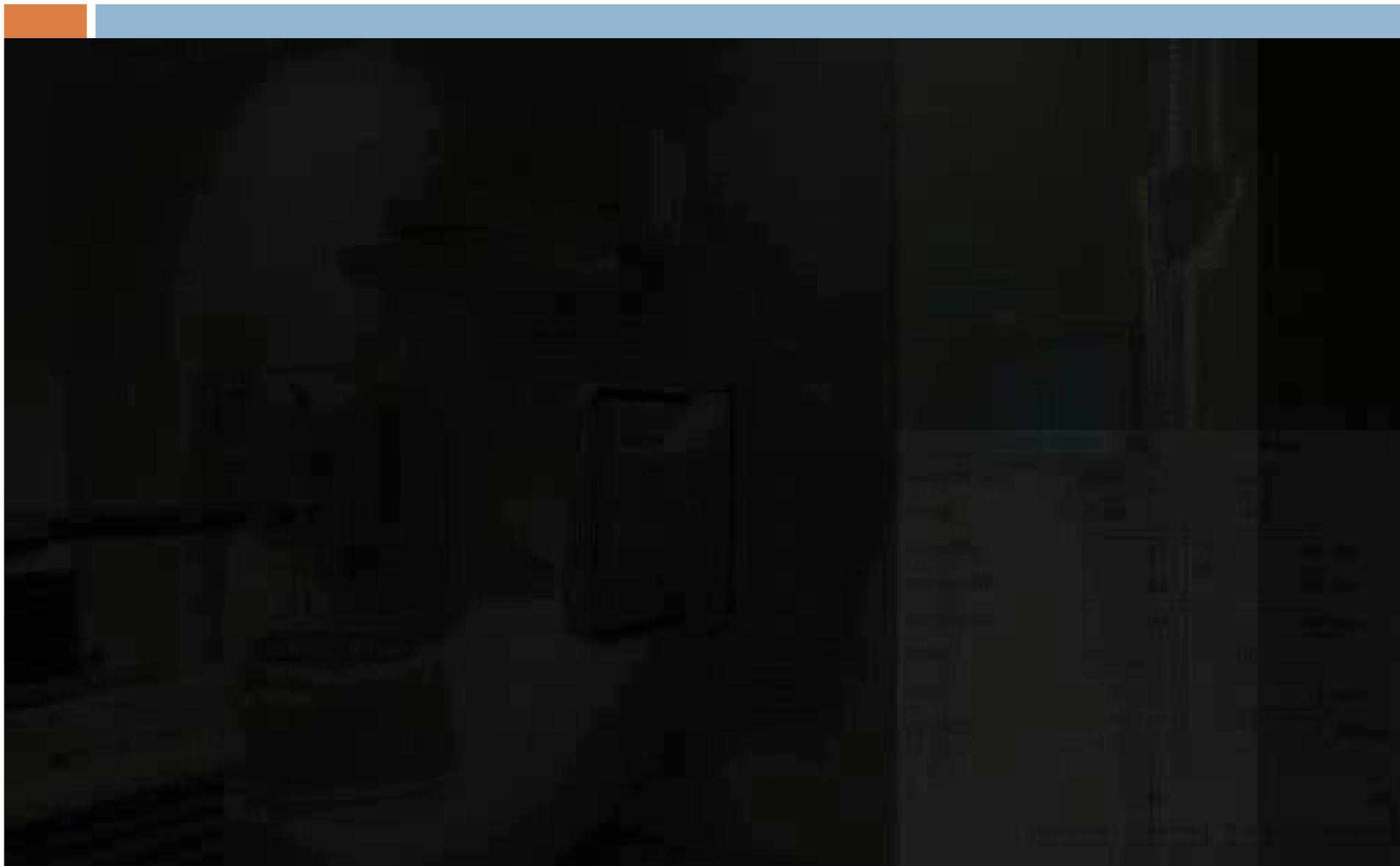
Gradi di libertà durante la fase ON



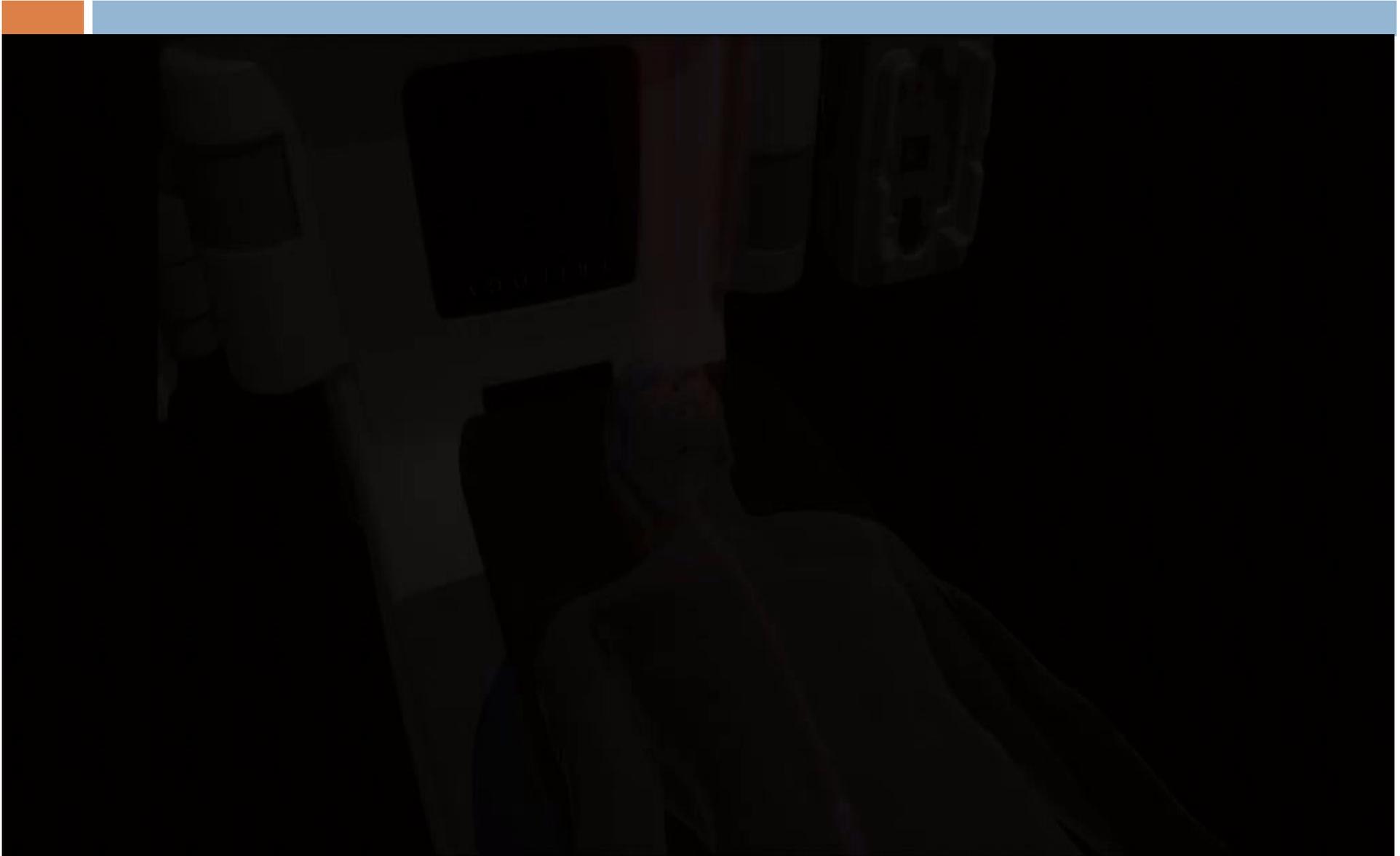
- Movimento delle lamelle
- Rotazione del gantry (velocità variabile)
- Rotazione del collimatore
- Modulazione del dose-rate
- Discreta variazione del dose-rate associata al cambiamento della velocità di rotazione del gantry



VMAT - Elekta



VMAT – Varian (RapidArc)



IMRT vs. VMAT (Elekta)

(M.Stock Vienna Estro 2008)

	Prostate	Anus	H&N
IMRT Beams	7 equidistant , coplanar		
Energy	10 MV		
Technique	Step & Shoot		
Max. Segm	15 per Beam		
Min. MU	2 per Segment		
VMAT Arcs	2x 300°	1x 360°	1x 360°
Energy	10 MV		
Technique	2 Arcs; rectum shielded	Bowel shielded	Parotid gland shielded
Angle Approx.	10°	5°	5°

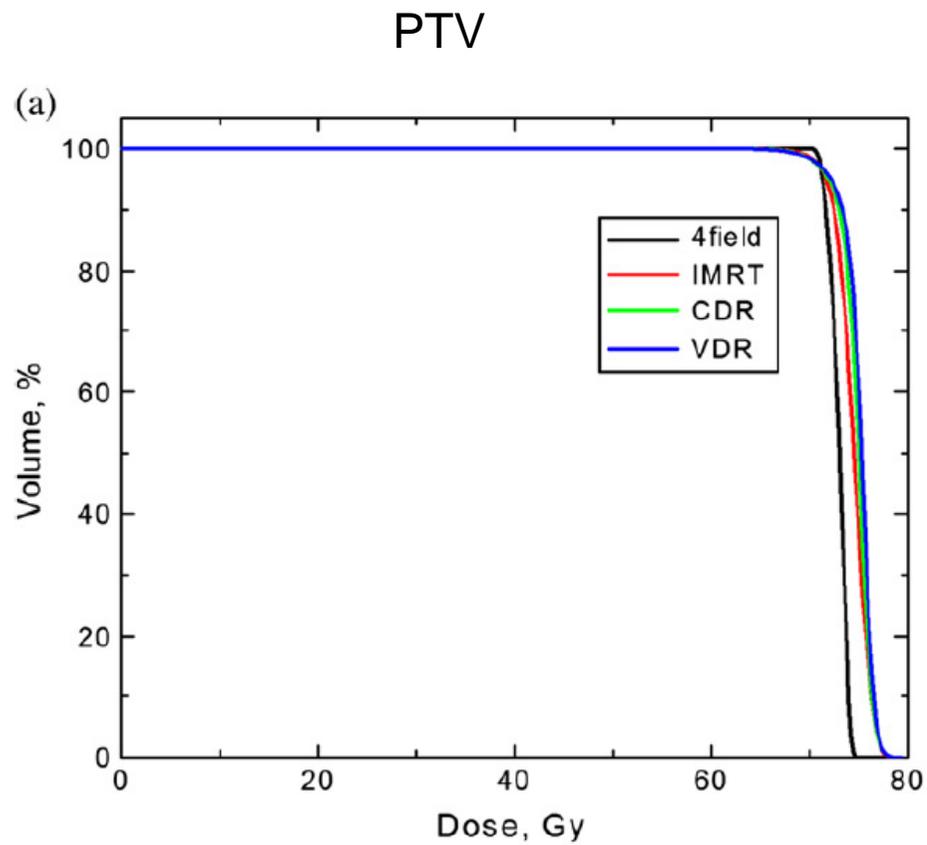
Efficienza del Trattamento

(M.Stock Vienna Estro 2008)

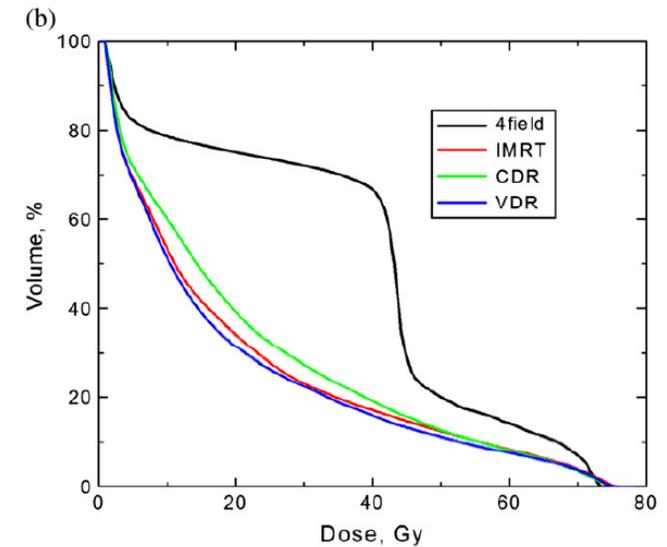
IMRT	Prostate	Anus	H&N
Segments	69	101	75
Beams	7	7	7
Total MU	417	419	419
Treatment Time	11 min	14 min	14 min
VMAT			
Sub Arcs	62	73	73
Arcs	2	1	1
Total MU	293	236	271
Treatment Time	5 min	6 min	8 min

VMAT (RapidArc Varian) – Prostata

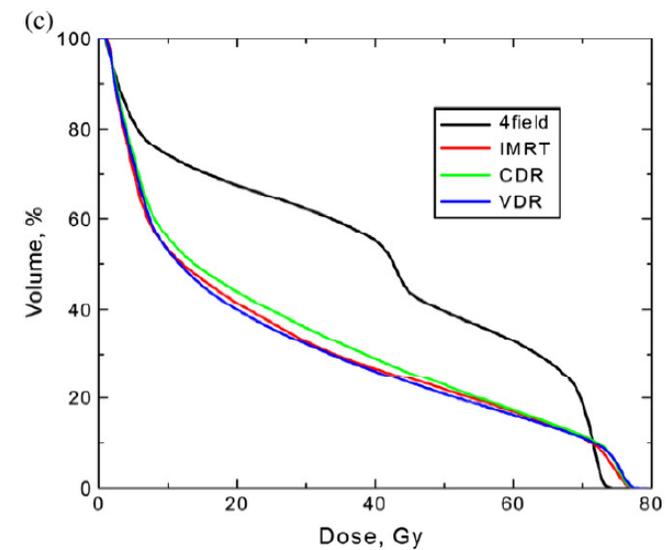
Palma D (Estro 2008)



Retto



Vescica



VMAT-RapidArc – Prostata

Palma D (Estro 2008)

Variable	3D-CRT	IMRT	cdr-VMAT	vdr-VMAT
Monitor units (<i>n</i>)	295.5	788.8	491.6	454.2
Maximal point dose	100.5	106.3	106.8	106.7
Rectum				
V _{70Gy}	7.1	4.1	3.6	3.8
V _{40Gy}	66.8	17.1	19.1	15.9
V _{20Gy}	75.2	34.3	39.3	31.5
Bladder				
V _{40Gy}	55.2	26.7	29.2	26.1
V _{20Gy}	67.6	41.5	44.0	39.6
Femoral head				
Left V _{40Gy}	9.8	3.4	0.4	0.6
Right V _{40Gy}	10.3	3.8	0.2	0.6
PTV mean dose	98.6	100.5	101.0	101.4
Volume of 95% isodose (cm ³)	142.8	116.6	122.3	116.4
Conformality index (volume of 95%/PTV)	1.36	1.12	1.17	1.12
Inhomogeneity index (D _{5%} – D _{95%})/D _{mean}	0.038	0.062	0.063	0.062

Intensity Modulated Radiation Therapy

- La tecnica IMRT non è sostitutiva della radioterapia convenzionale e 3D CRT
- E' utile negli studi di dose escalation
- La tecnica IMRT è considerata necessaria o ragionevole se è essenziale il risparmio dei tessuti sani circostanti al PTV
 - riduzione della morbidity
 - volumi circostanti già irradiati
 - PTV concavi o convessi in prossimità delle strutture critiche
 - Le tecniche cinetiche di ultima generazione offrono ulteriori vantaggi in termini di riduzione della dose



The British Journal of Radiology, 77 (2004), 285–295 © 2004 The British Institute of Radiology
DOI: 10.1259/bjr/22666727

Review article

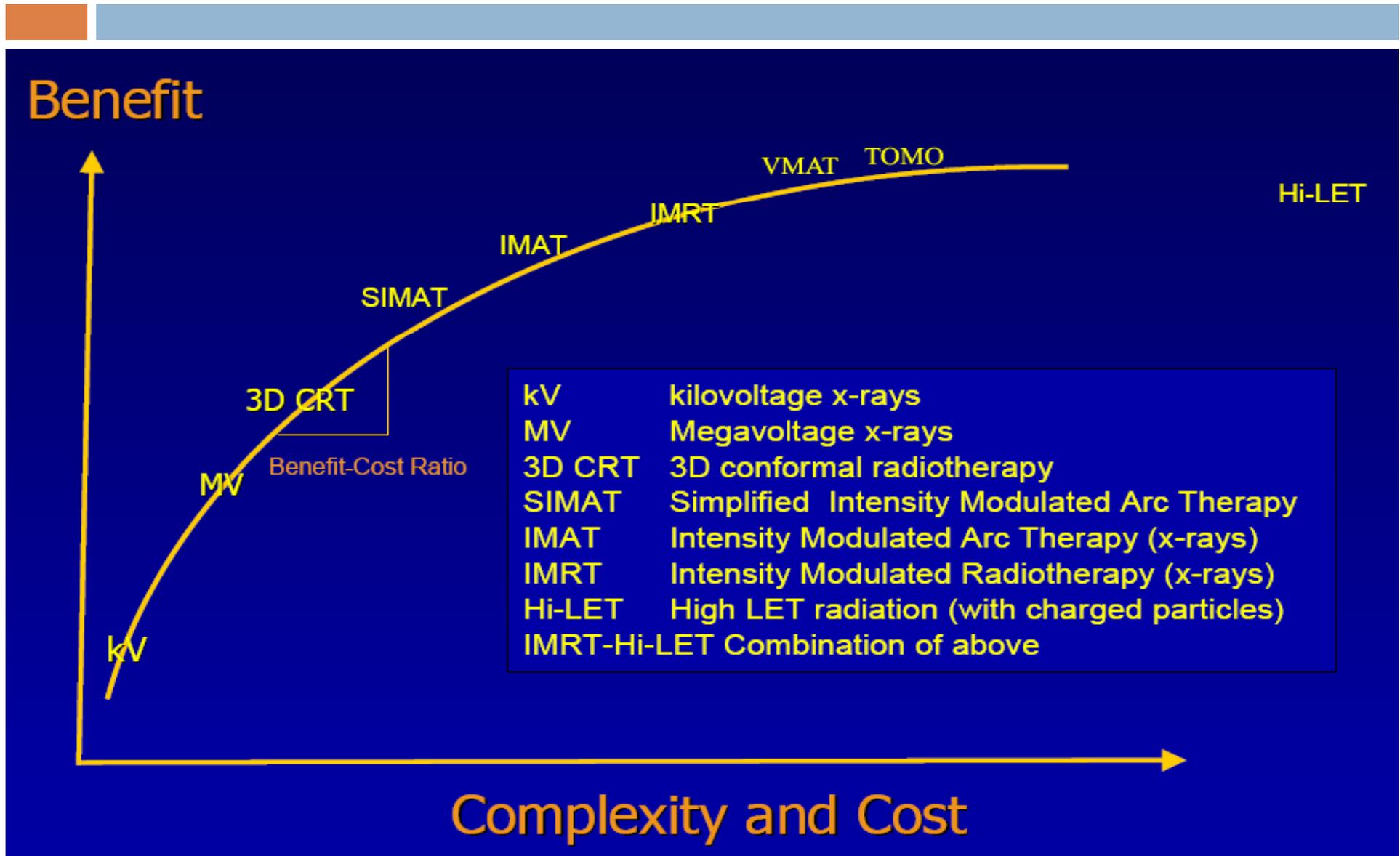
Is tomotherapy the future of IMRT?

A W BEAVIS, PhD, BSc

Department of Medical Physics, Hull and East Yorkshire NHS Trust and Post Graduate Medical Institute, University of Hull and Princess Royal Hospital, Saltshouse Road, Kingston Upon Hull HU8 9HE, UK

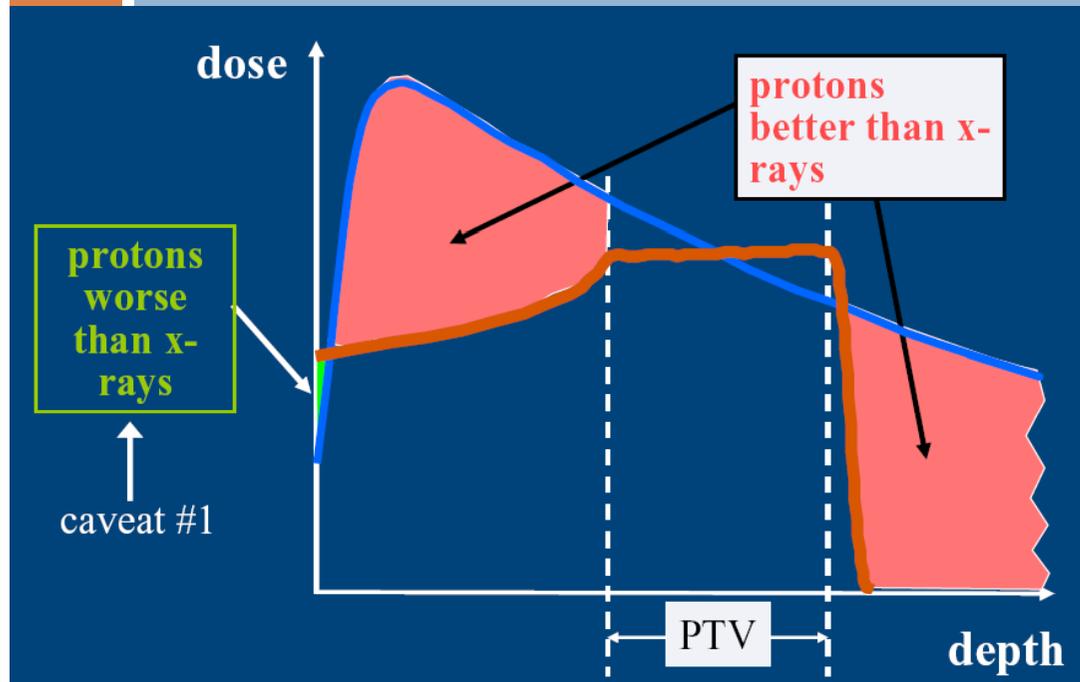
IMRT – Prospective future

(Wong E 200)

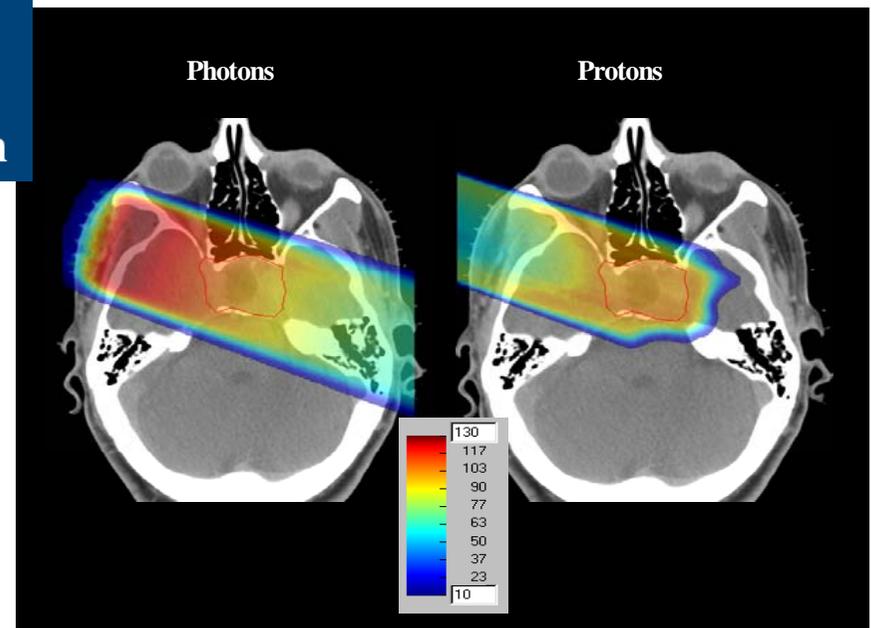


Proton beam radiation therapy

Terapie cinetiche o Tomoterapiche

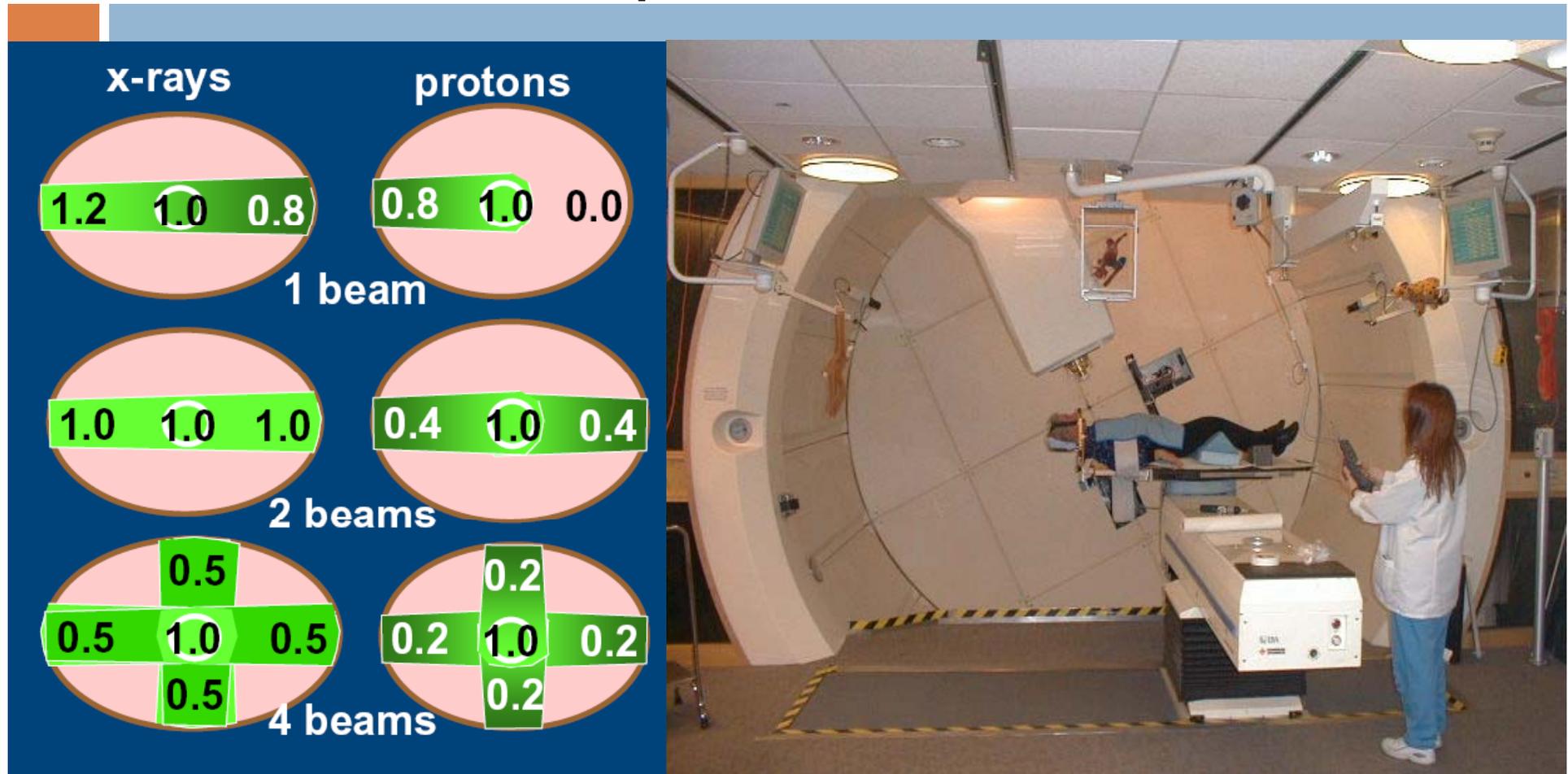


- Maggiore concentrazione della dose al PTV



Proton beam radiation therapy

Terapie cinetiche ?



- Riduzione della dose integrale

Tomo Bicicletta ...?

