Independent Dose Verification for IMRT Using Monte Carlo

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Outline

- Why Monte Carlo for IMRT QA?
- Experimental verification
- Treatment plan comparison for IMRT
- Monte Carlo as an independent QA tool
- Investigation of new radiotherapy techniques

Why Use Monte Carlo for Radiotherapy Treatment Planning

An accuracy of about 5% in dose delivery is required to effectively treat certain types of cancers and to reduce complications.

ICRU Reports 24 (1976) and 42 (1988)

The Accuracy Requirement for Treatment Planning Dose Calculation

if

$$\sigma^2=\sigma^2_{calib}+\sigma^2_{dose}+\sigma^2_{setup}+\sigma^2_{motion}+\cdots$$

and

$$\sigma \geq 2\sigma_{dose}=5\%$$

then

$\sigma_{dose}=2.5\%$

Why Accurate Dosimetry for IMRT?

Limitations of dose calculation algorithms

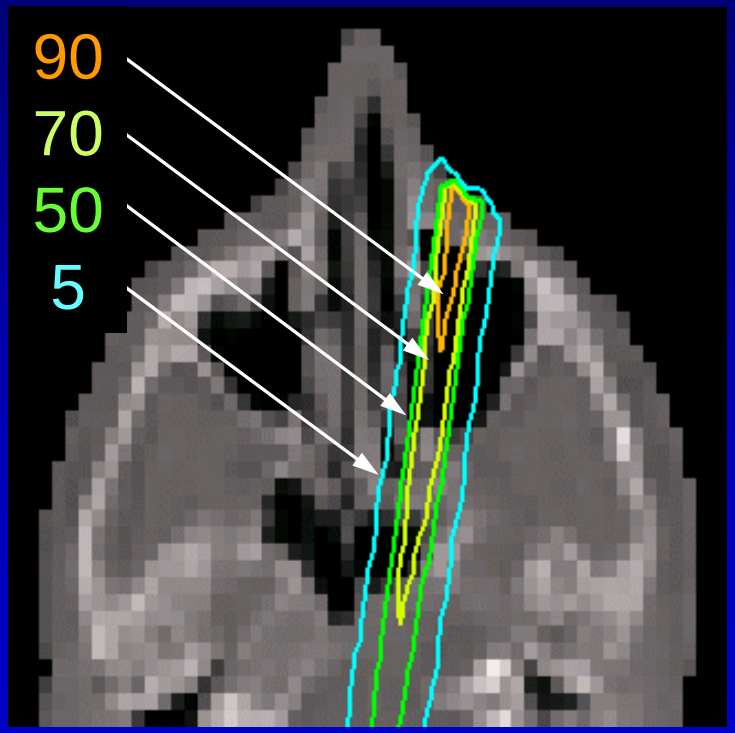
- source models
- narrow beam geometry
- heterogeneous patient anatomy

Limitations of beam delivery systems

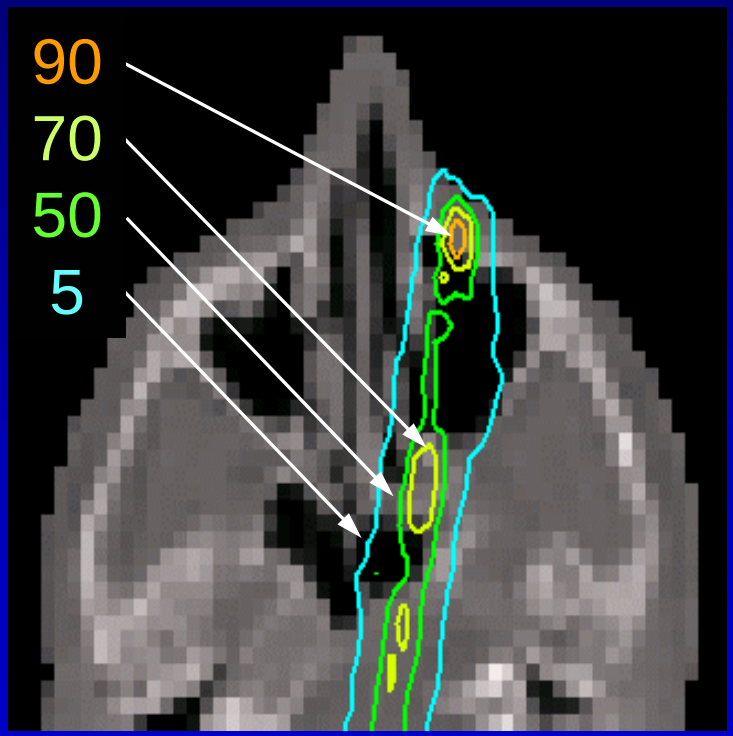
- complex intensity distributions
- complex MLC geometry

Beamlet Dose Distributions

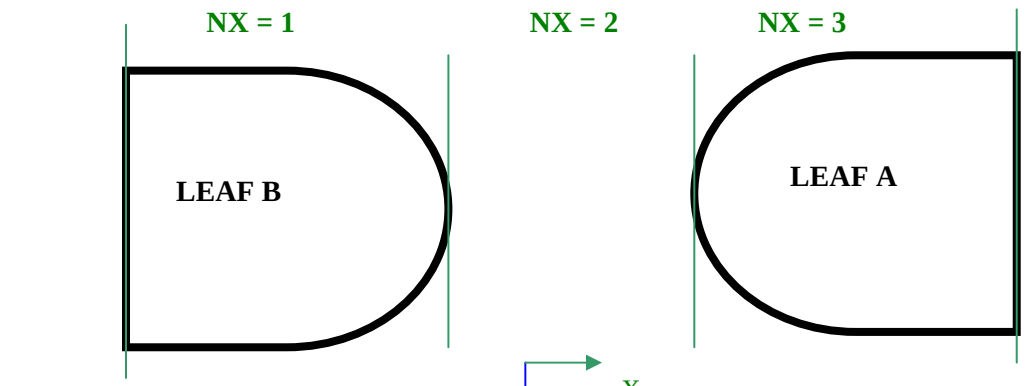
FSPB



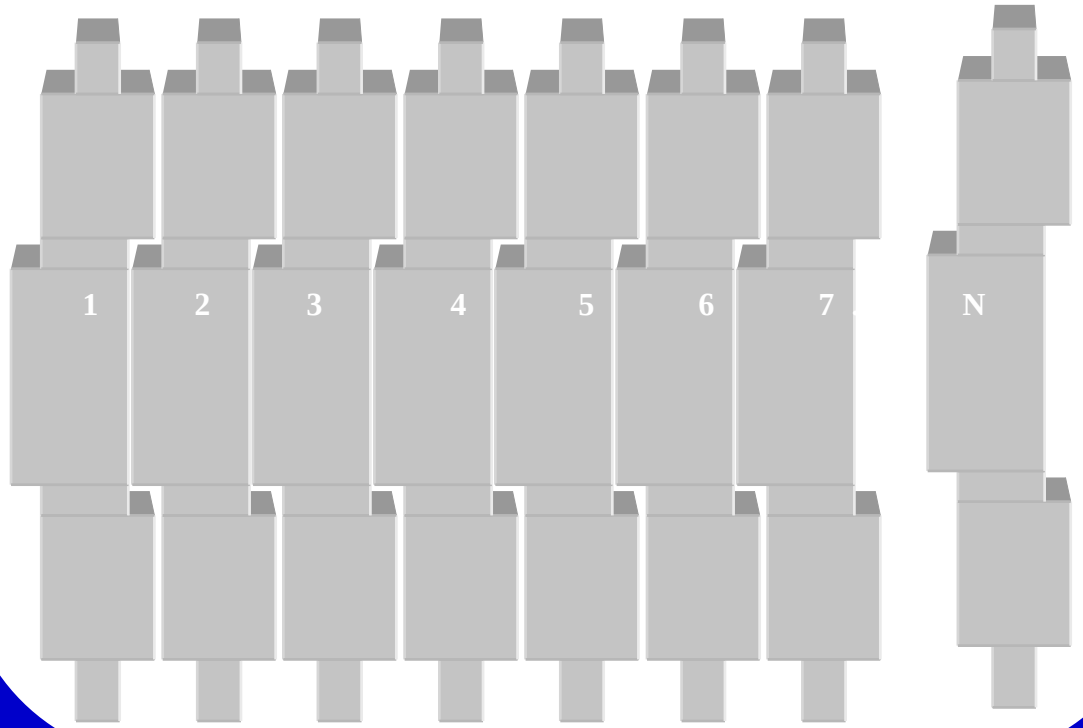
Monte Carlo



MLC LEAVES SIDE VIEW - ROUNDED ENDS

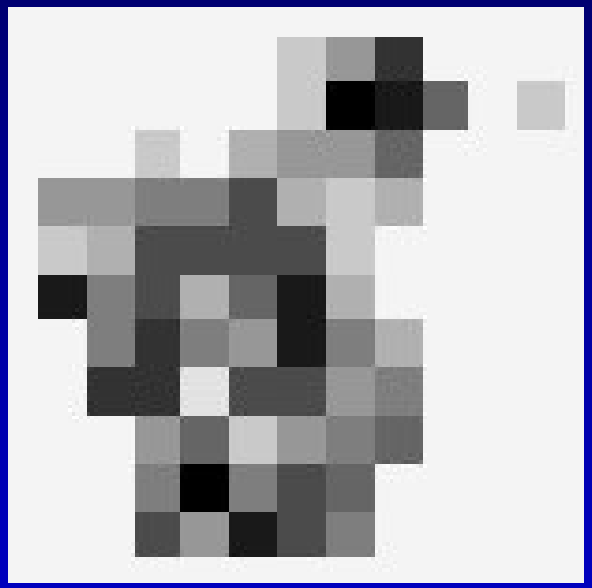


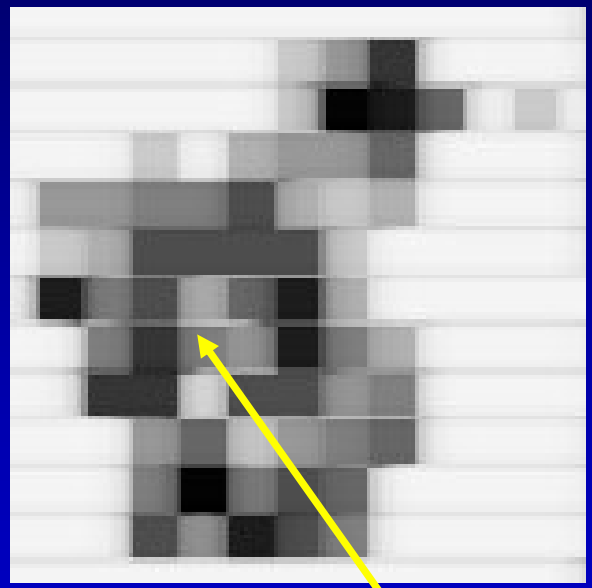
MLC CARRIAGE FRONT VIEW - NON DIVERGENT ENDS



One field intensity map comparison

- Sharp
- No T&G





- Fuzzy
- T&G

T&G

Fluence and Dose Comparison

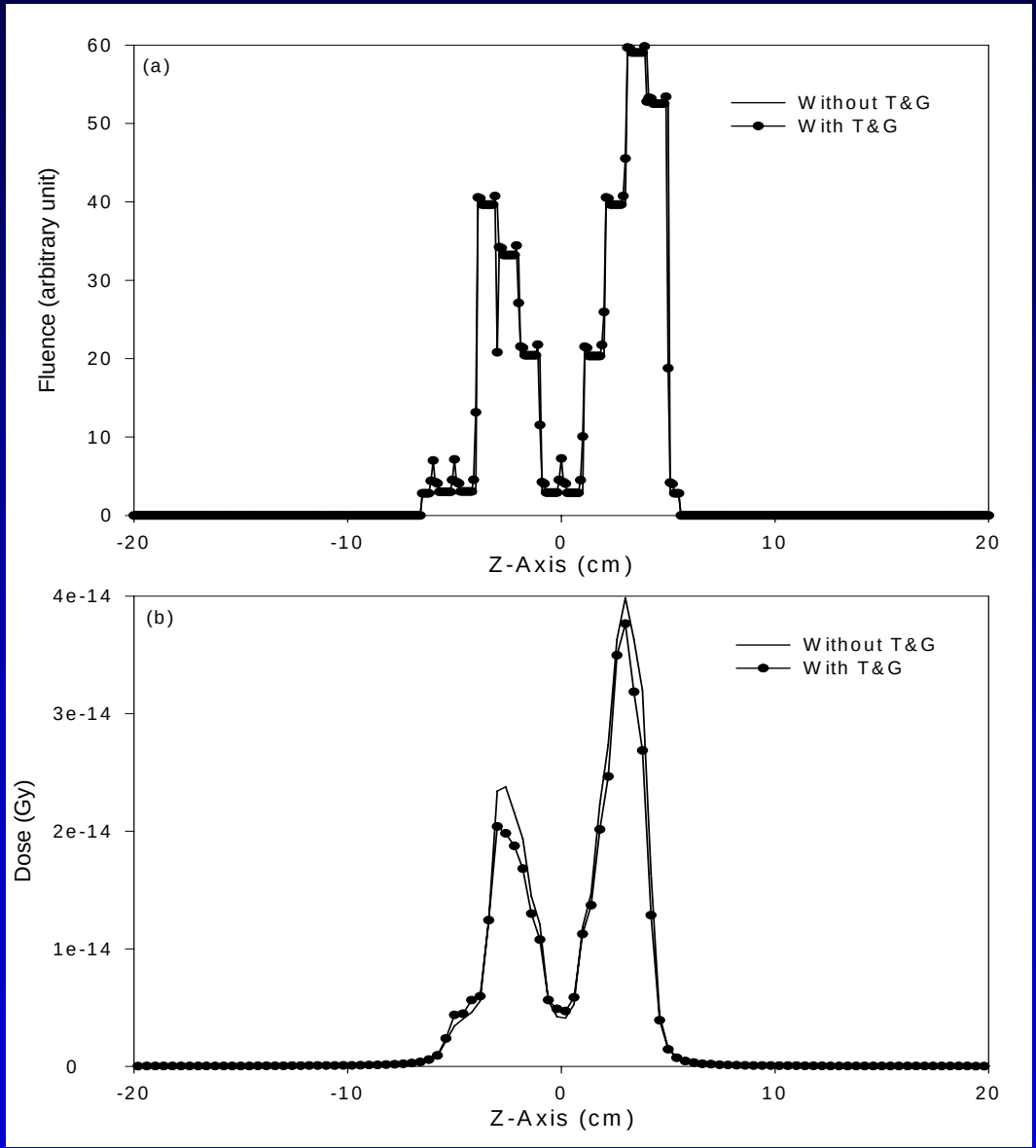
8% underdosage for a single field with 1 mm voxels

6% underdosage for 4 mm voxels

2% underdosage averaged over 1 cm leaf width

T&G causes underdosage in high dose regions

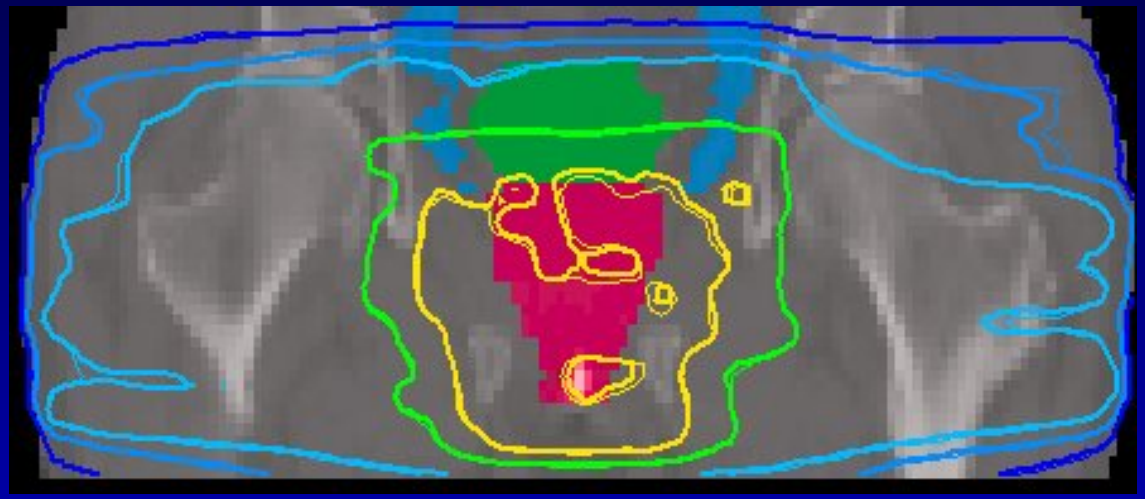
T&G causes overdosage in low dose regions



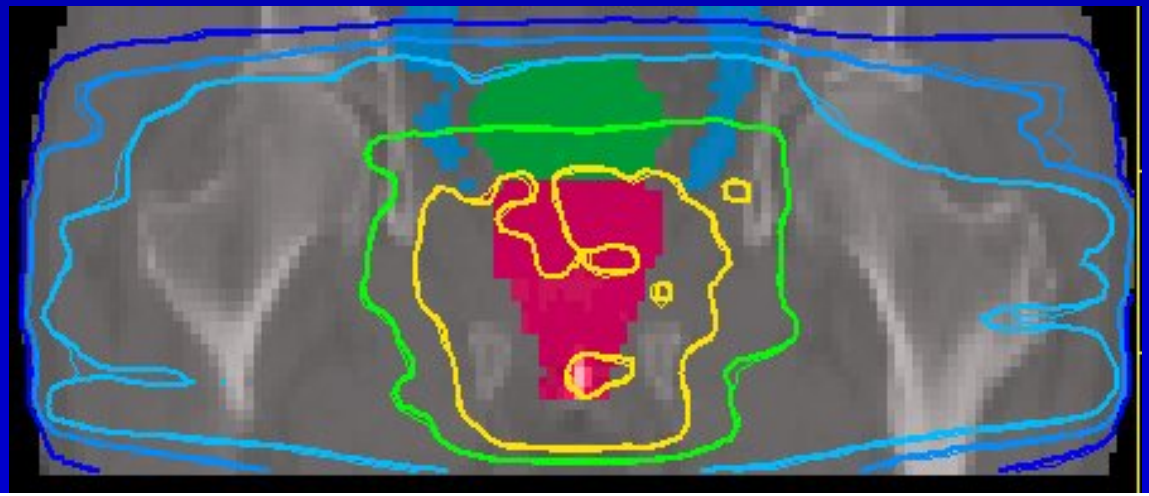
Deng et al 2001

Comparison of IMRT dose distributions (prostate)

With (thin lines) and without (thick lines) T&G effect



Doses with T&G effect increased by 1.6%



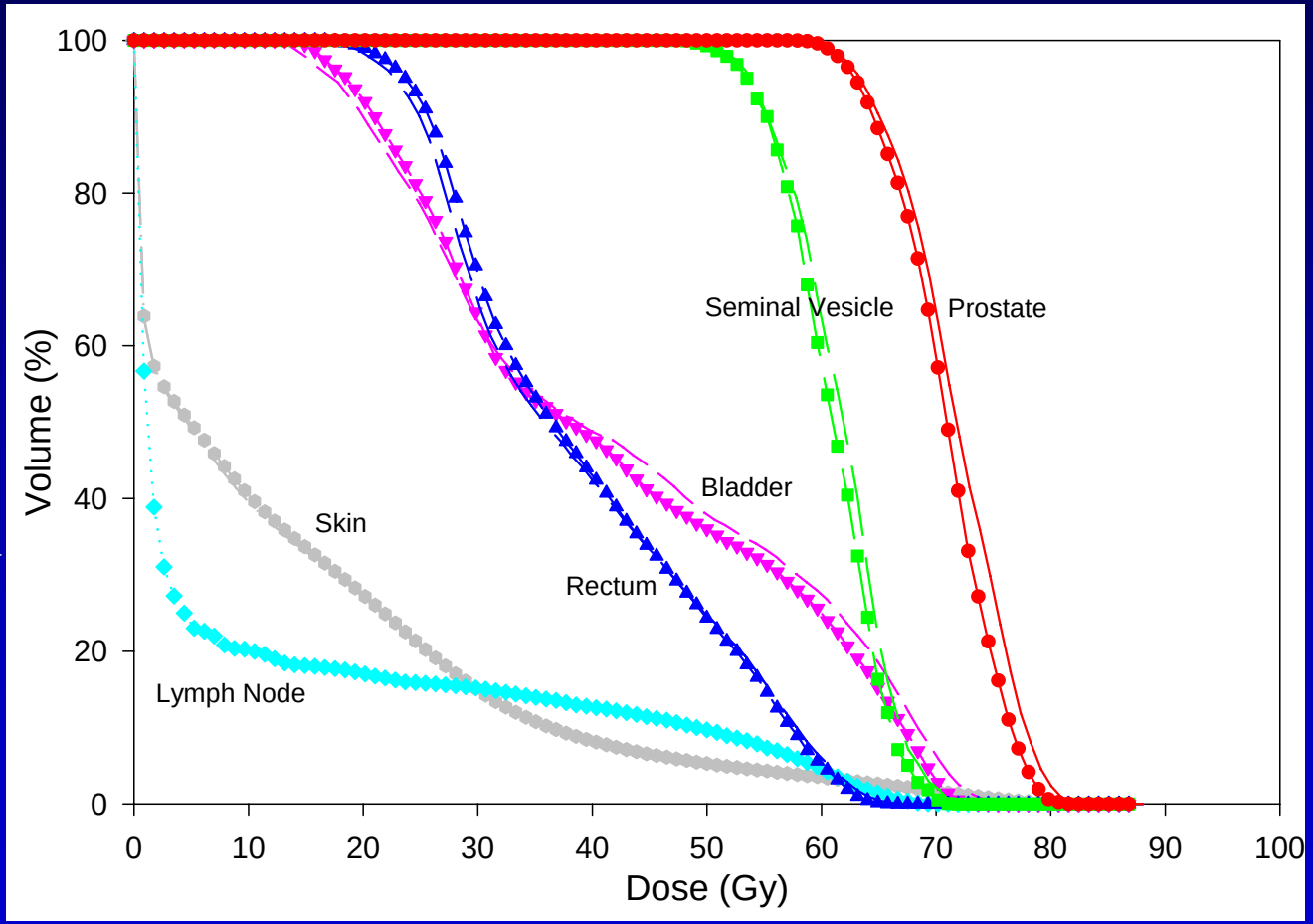
Deng et al 2001

DVH comparison between prostate plans with and without tongue-and-groove effect

Lines:
without T&G

Line-and-symbols:
with T&G

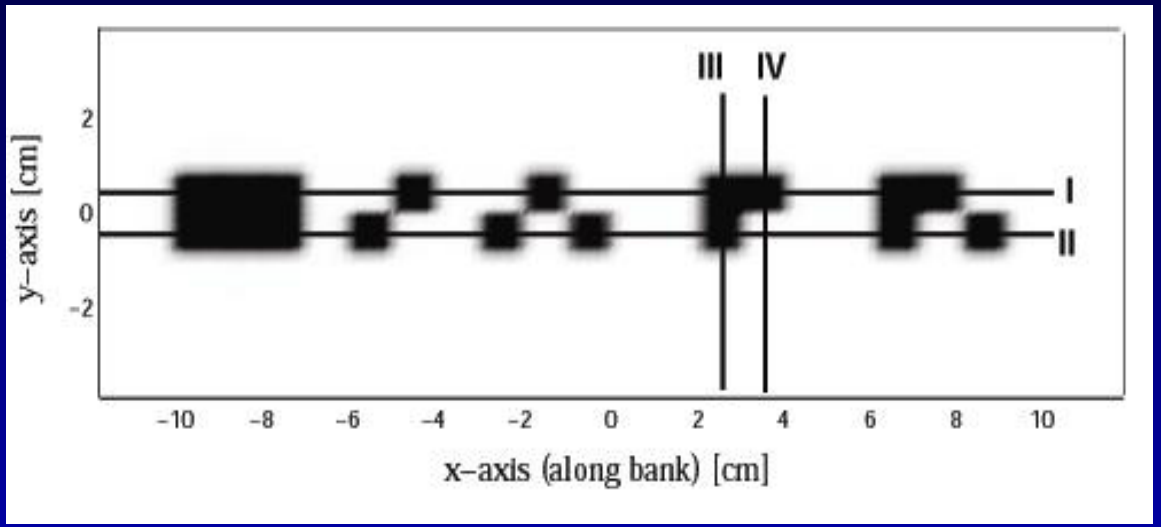
By shifting doses with T&G horizontally by 1.6%, two plans matches

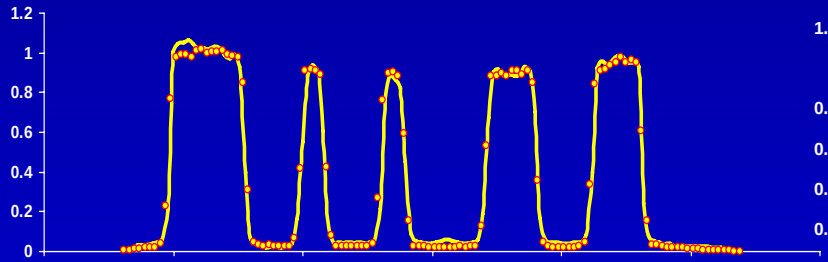


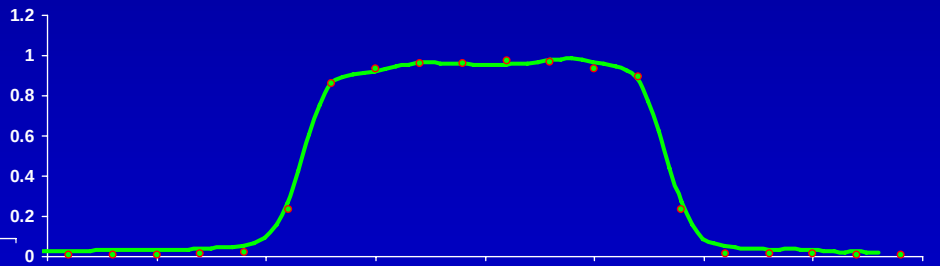
Deng et al 2001

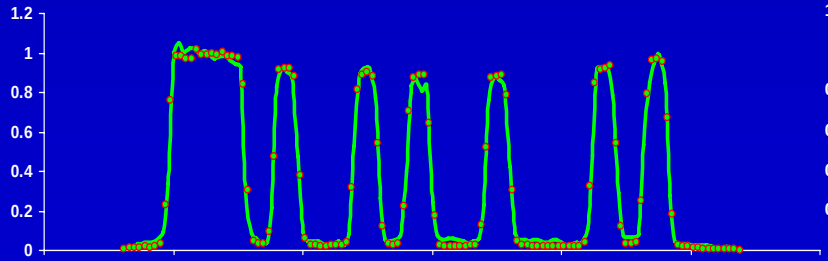
Experimental Verification

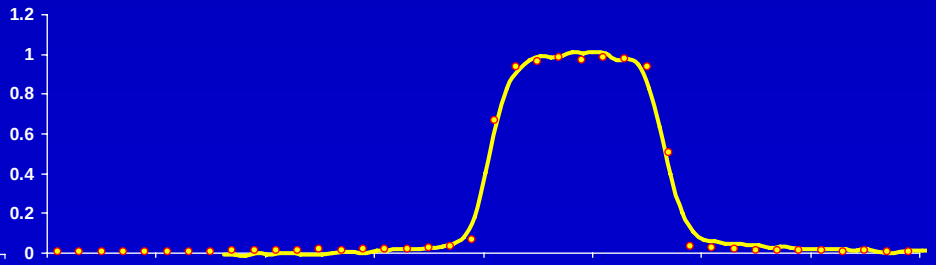
Film vs Monte Carlo











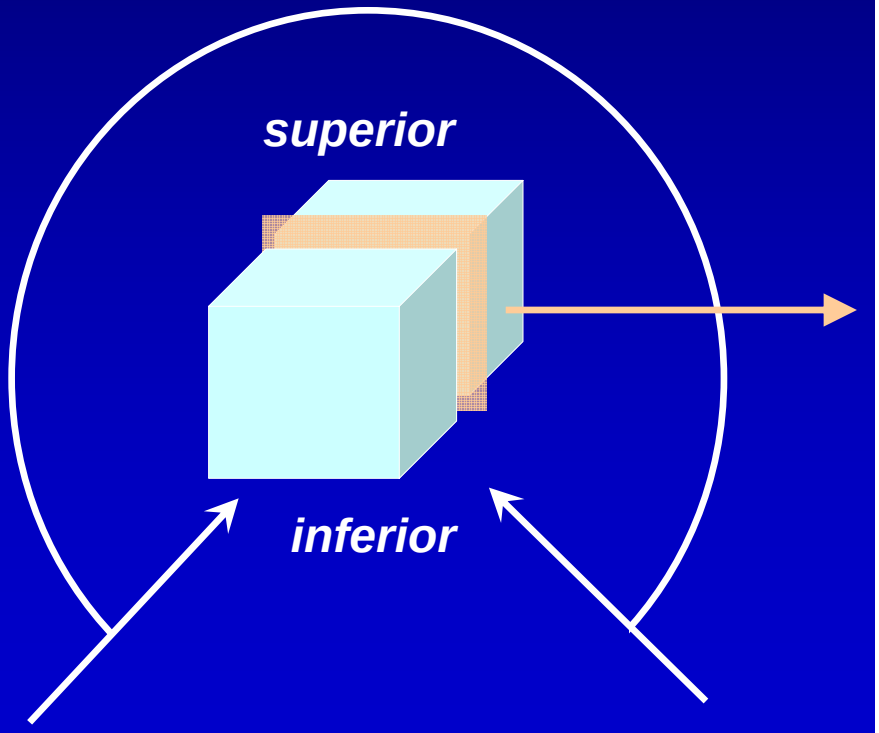
Lee et al 2002

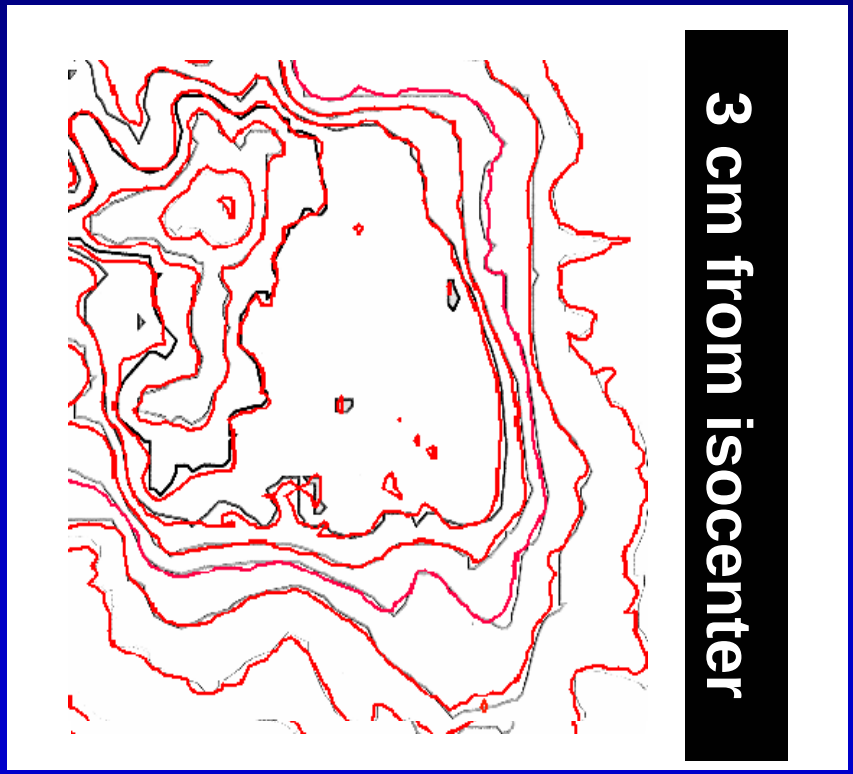
Film vs Monte Carlo

Patient plan (Corvus)

Delivery in film phantom

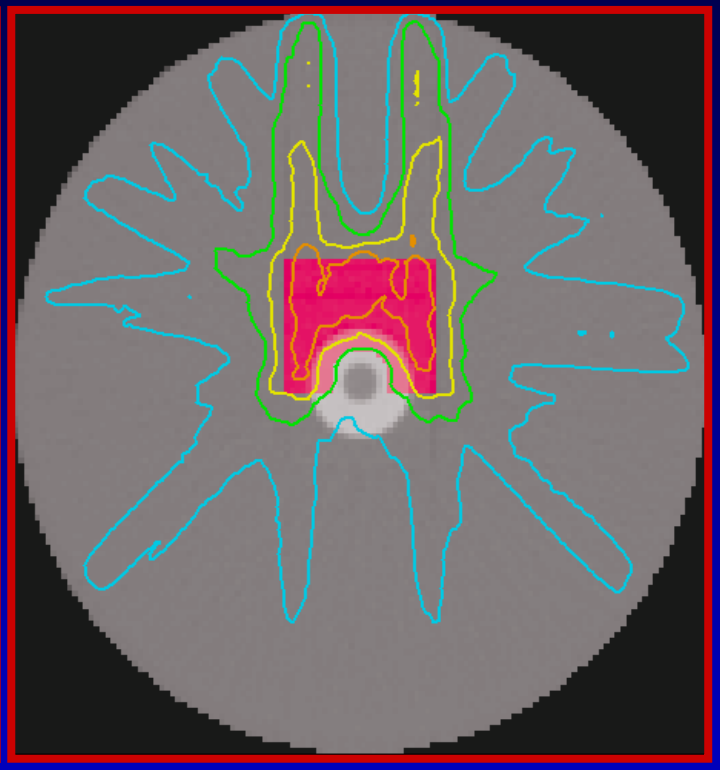
Monte Carlo dose calculation





Lee et al 2001

Calculations vs. Measurements



Energy	M-C	Meas	CORVUS
4 MV	2.177 Gy	2.177 Gy	2.201 Gy
15 MV	2.146 Gy	2.161 Gy	2.276 Gy

Monte Carlo for IMRT QA

Monte Carlo for MU calculation/check

- high accuracy and high efficiency
- independent calculation

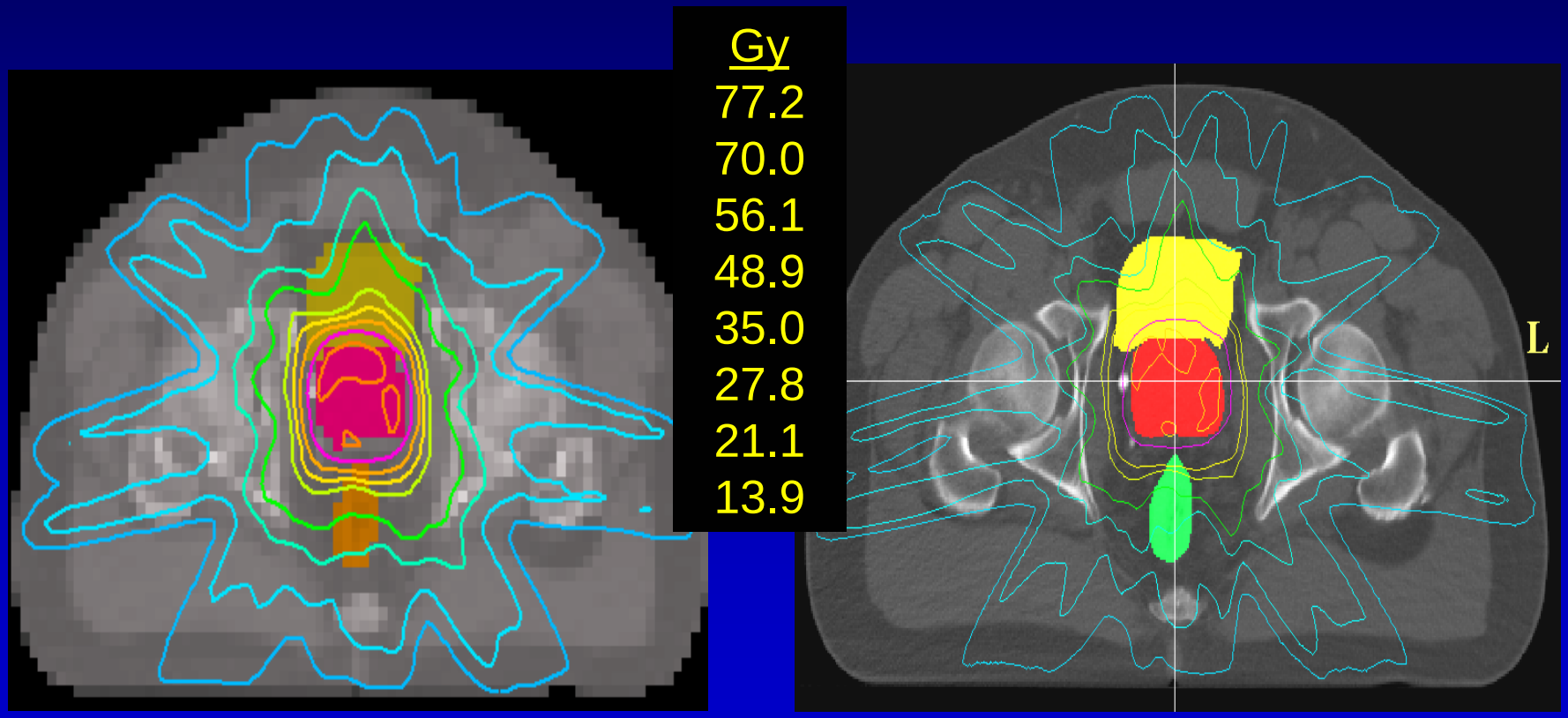
Monte Carlo for patient dose verification

- predict patient dose using leaf sequence
- verify patient dose using MLC log files

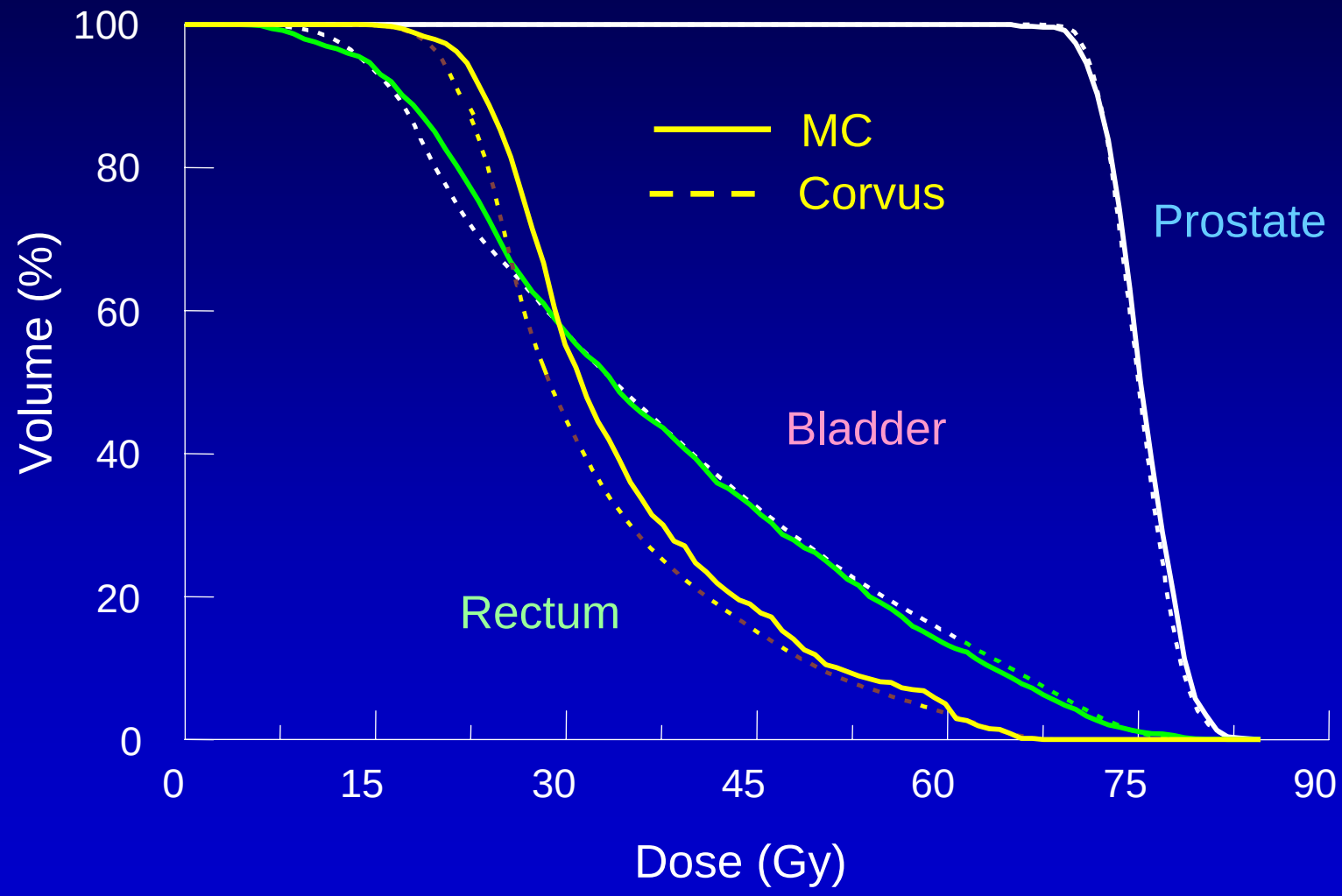
Prostate

Monte Carlo

Corvus

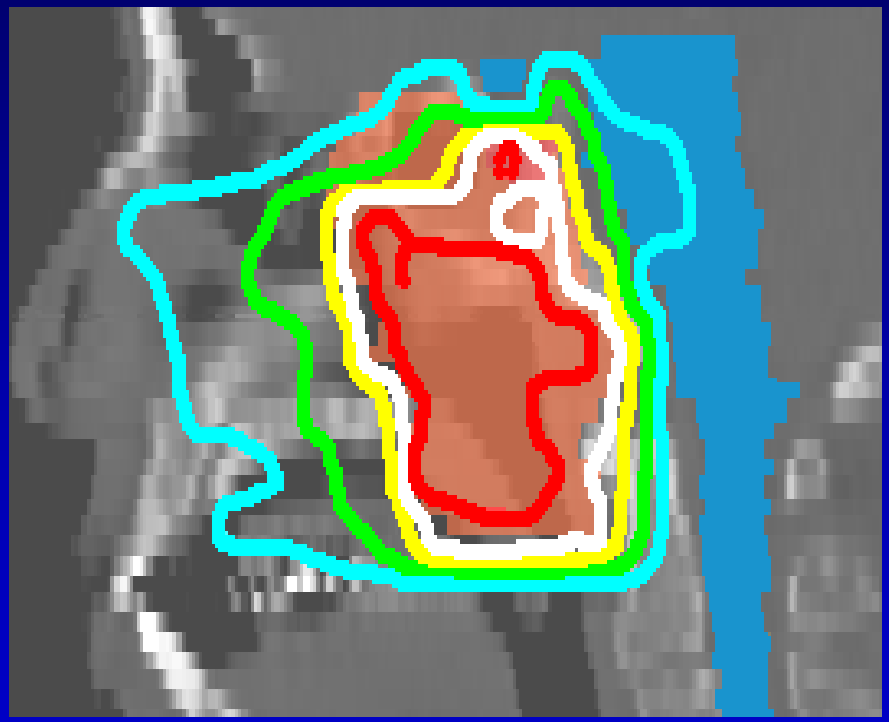


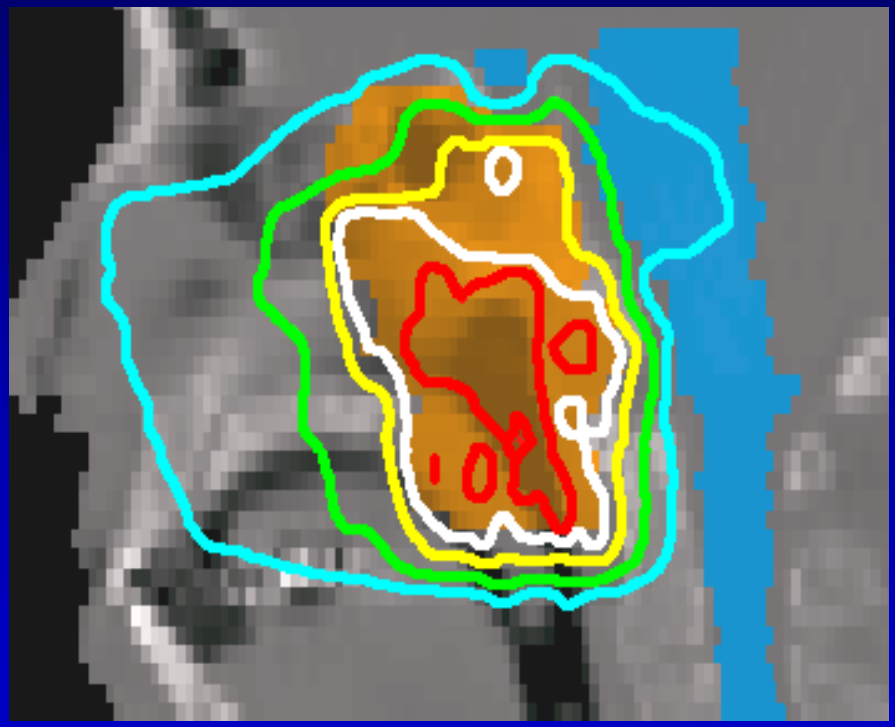
Prostate


100
80
60
40
20
0
Volume (%)
0
15
30
45
60
75
90
Dose (Gy)
MC
Corvus
Prostate
Bladder
Rectum

Pencil Beam

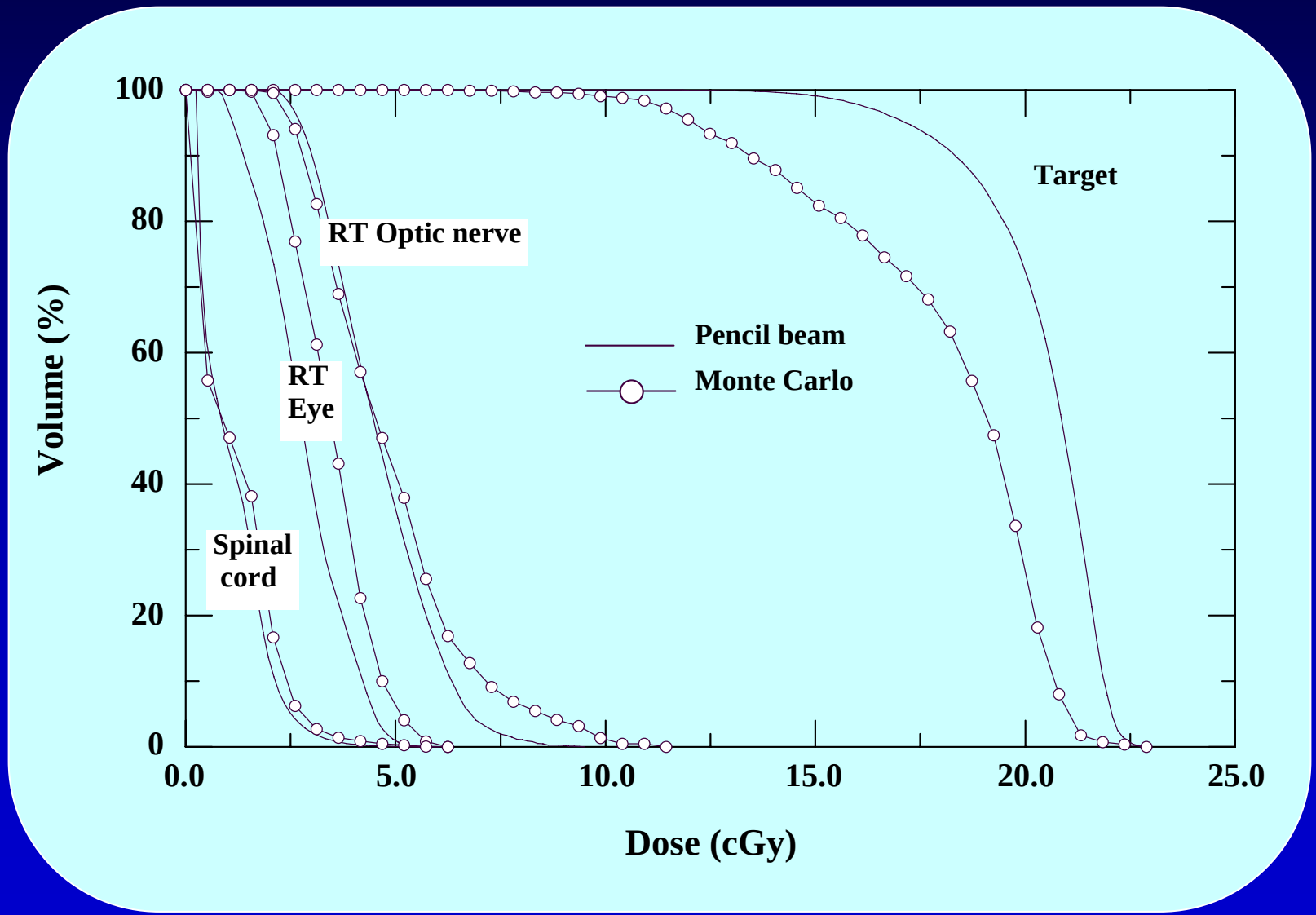
Monte Carlo





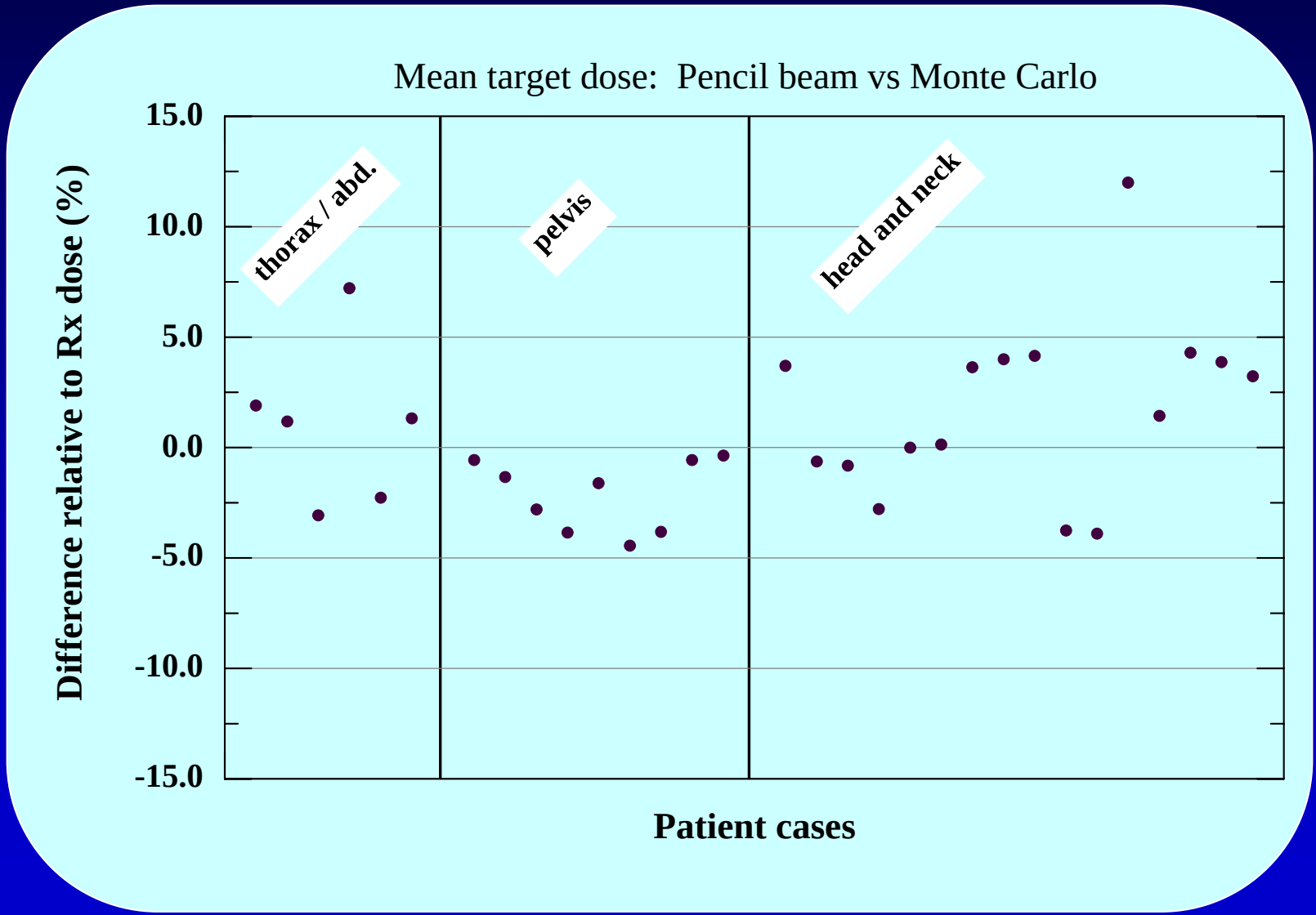
Pawlicki et al 2001

Dose Volume Histogram (H&N)



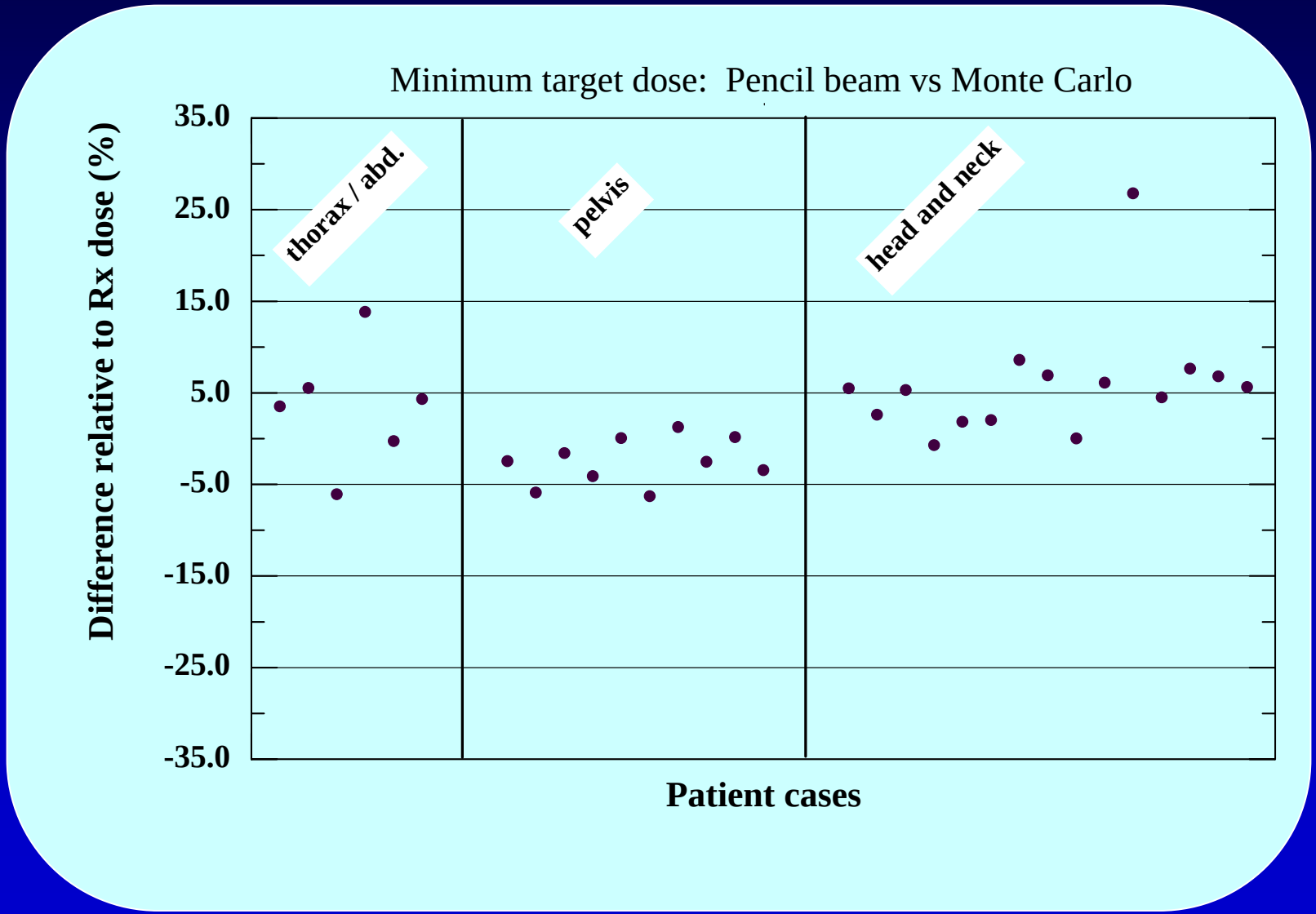
Pawlicki et al 2001

Mean Target Dose (BP vs MC)



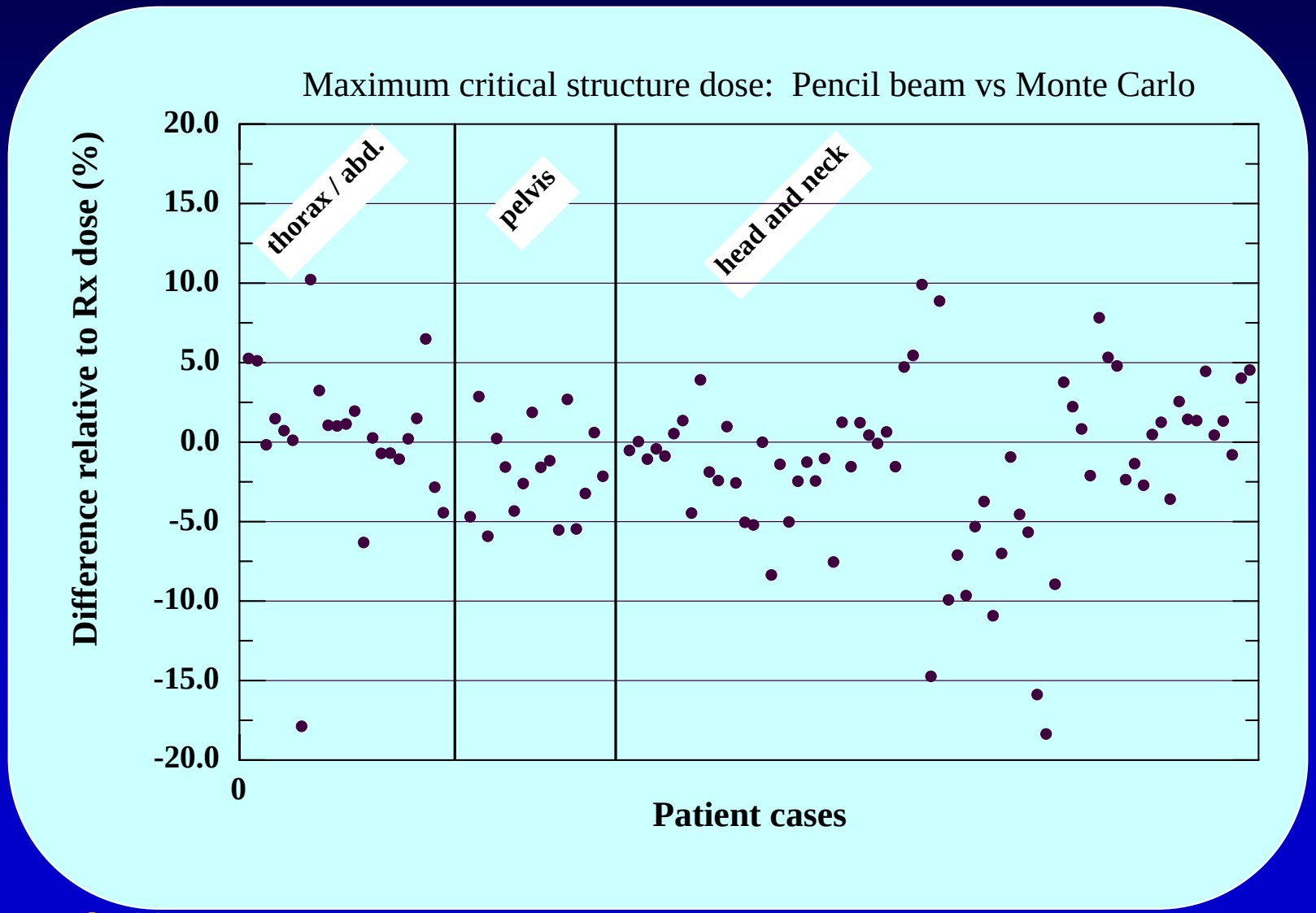
Pawlicki et al 2001

Minimum Target Dose (BP vs MC)



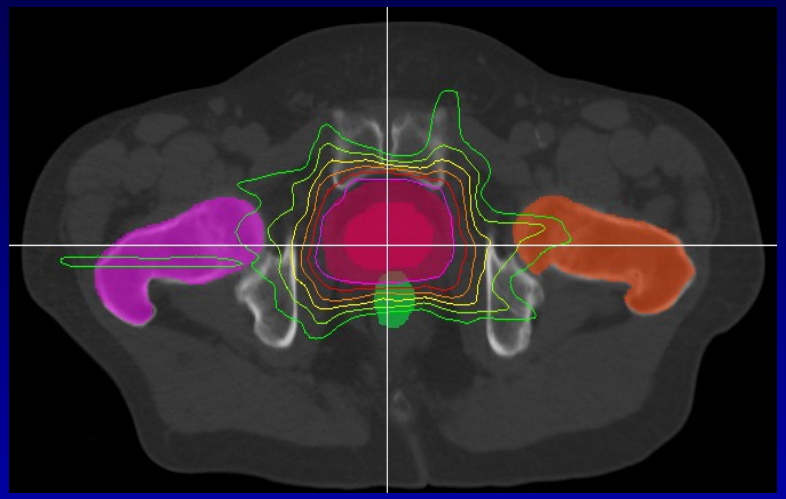
Pawlicki et al 2001

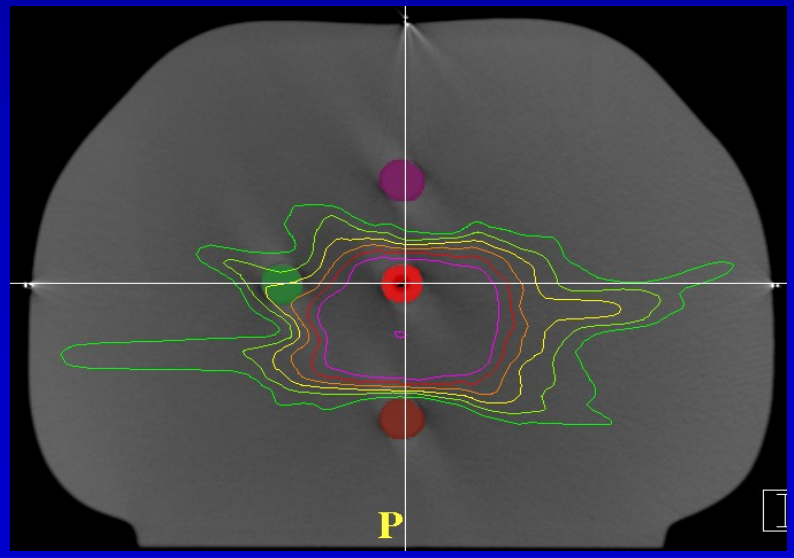
Max. Critical Structure Dose (BP vs MC)



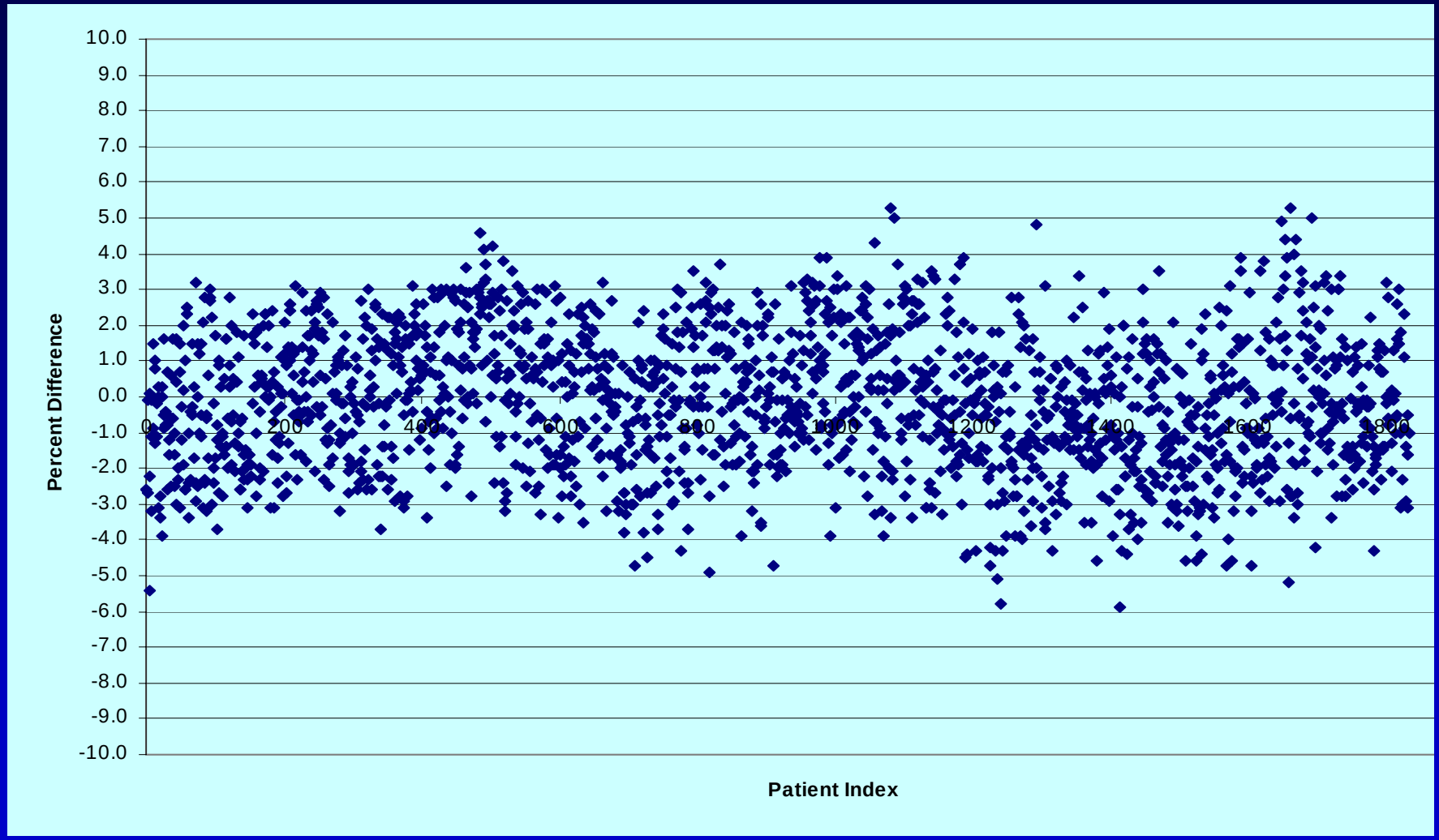
Pawlicki et al 2001

MU Check for IMRT





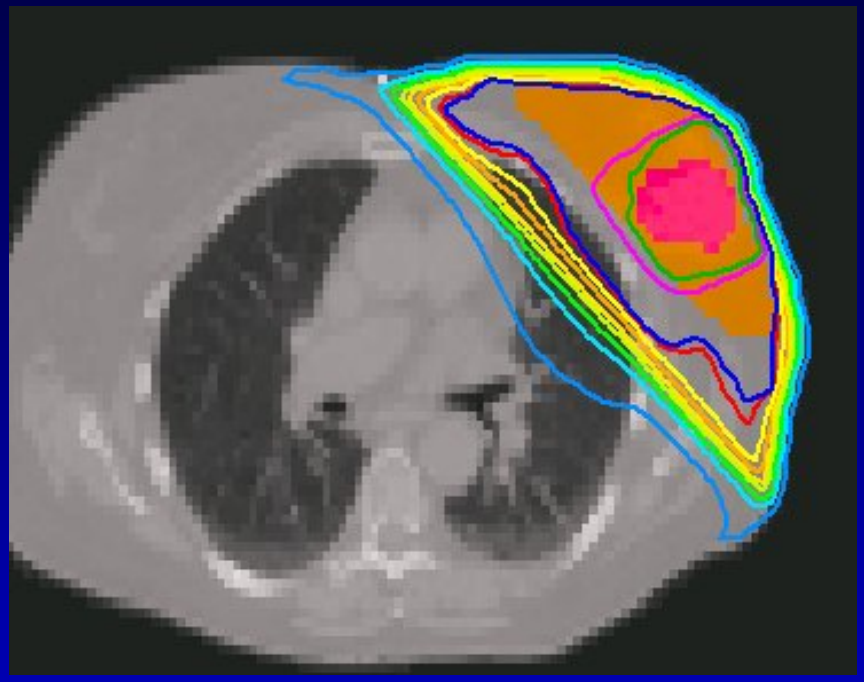
Ion Chamber Point Dose Verification

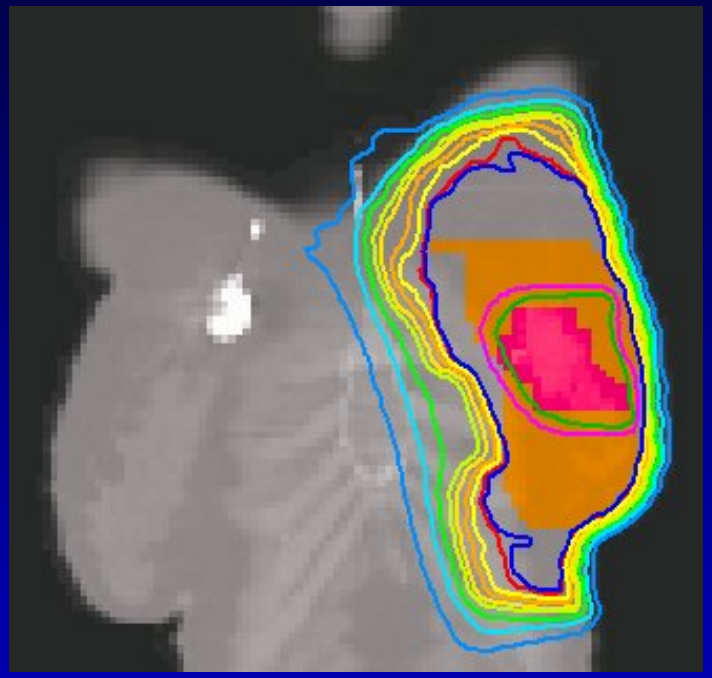


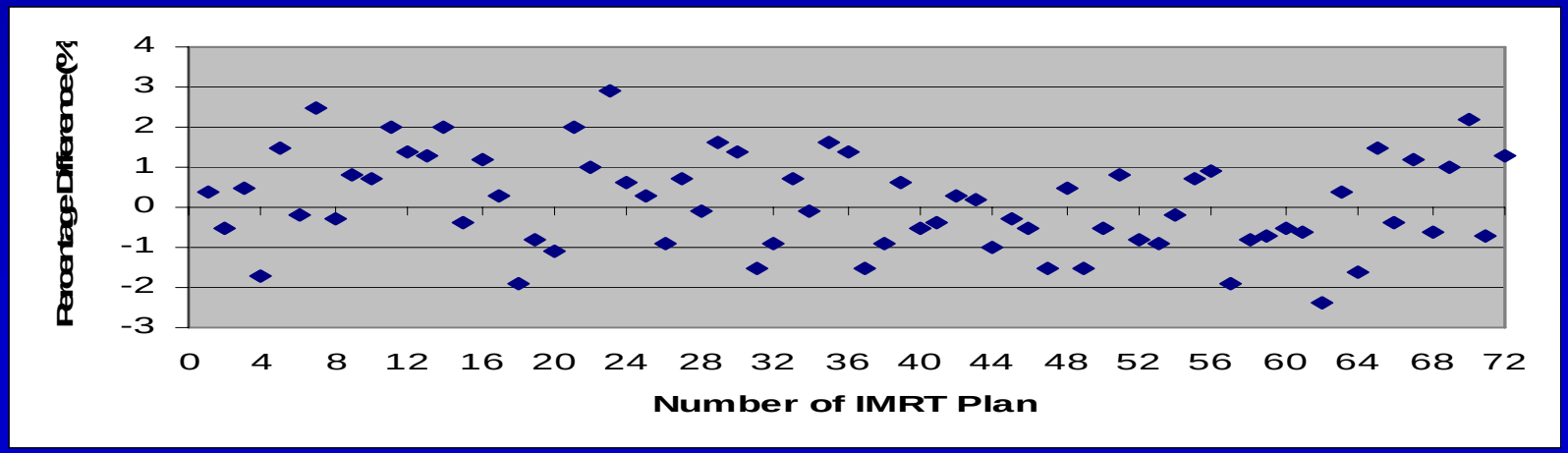
69% are within 2% and 97% within 4% for 2000 patients

Price et al 2005

MU Check for Hypofractionated Breast IMRT

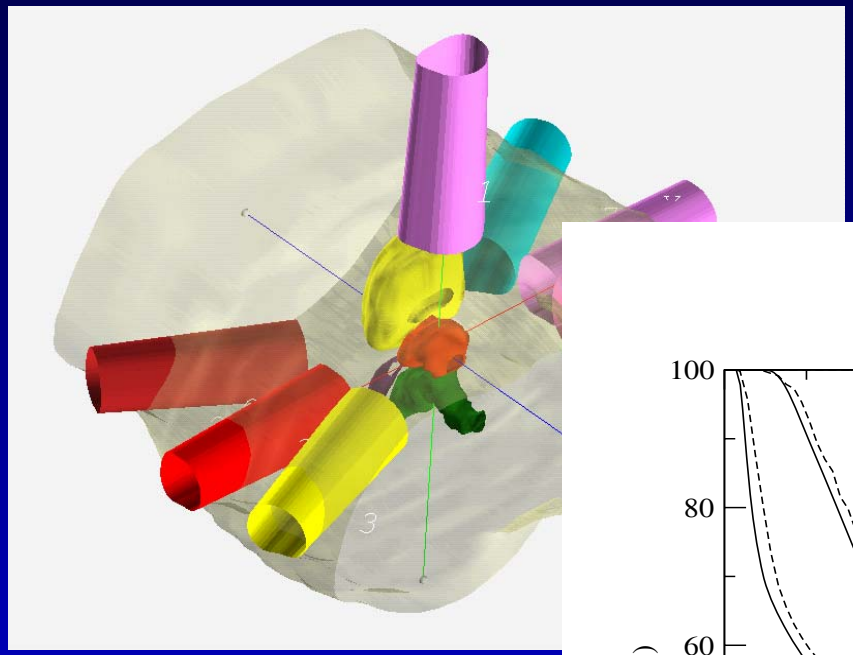


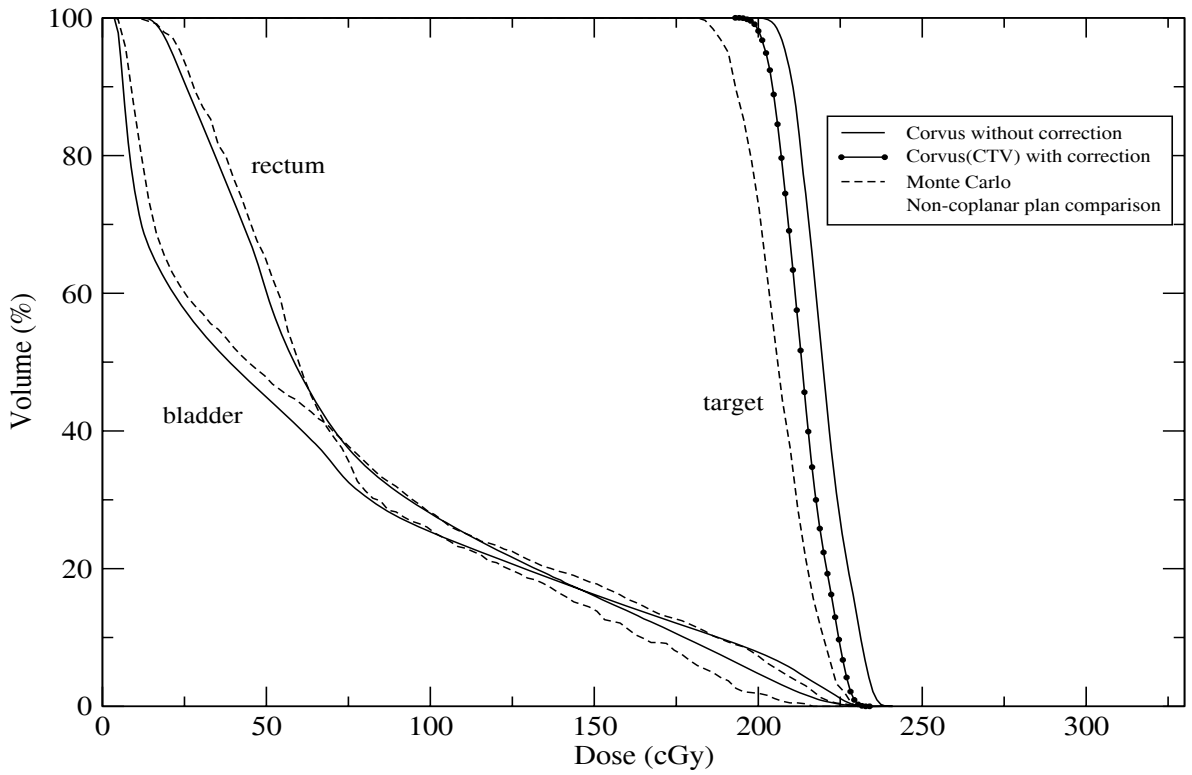




Li et al 2004

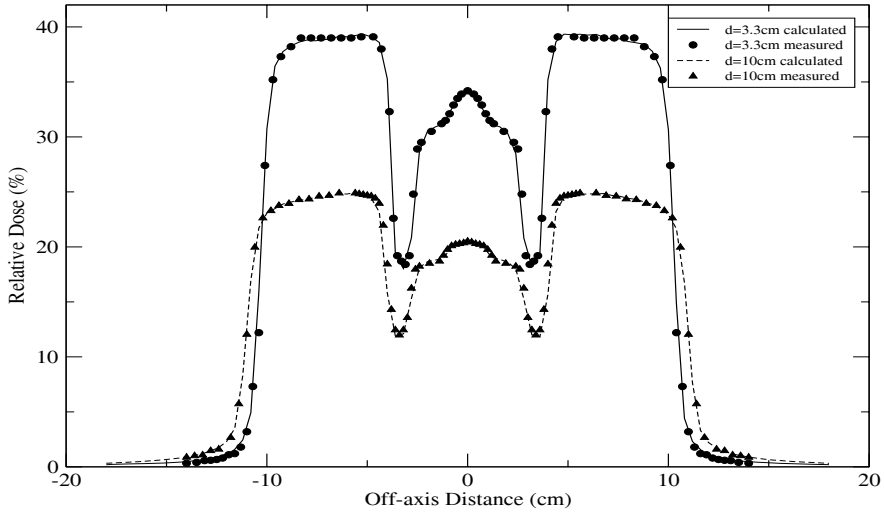
Dose Verification for Non-coplanar Prostate IMRT





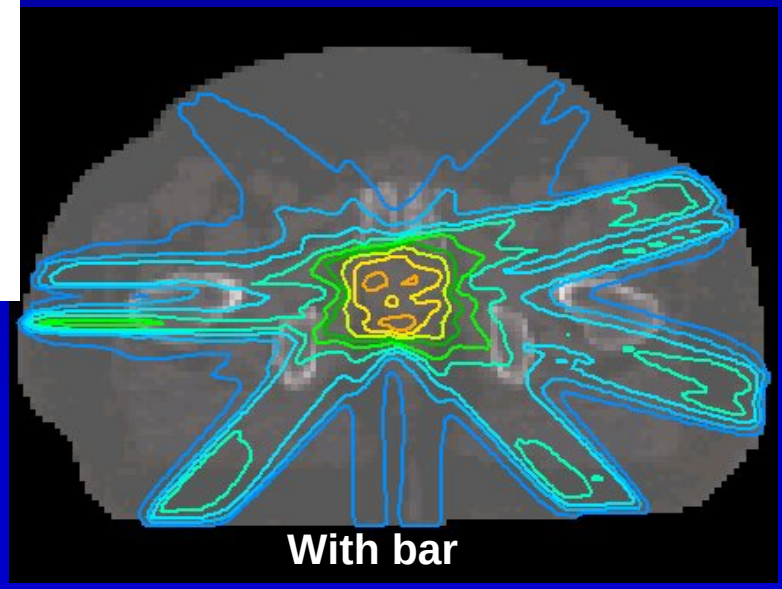
Yang et al 2005

Effect of Couch Bar on IMRT Dose Distribution



MC vs film measurement

Without bar



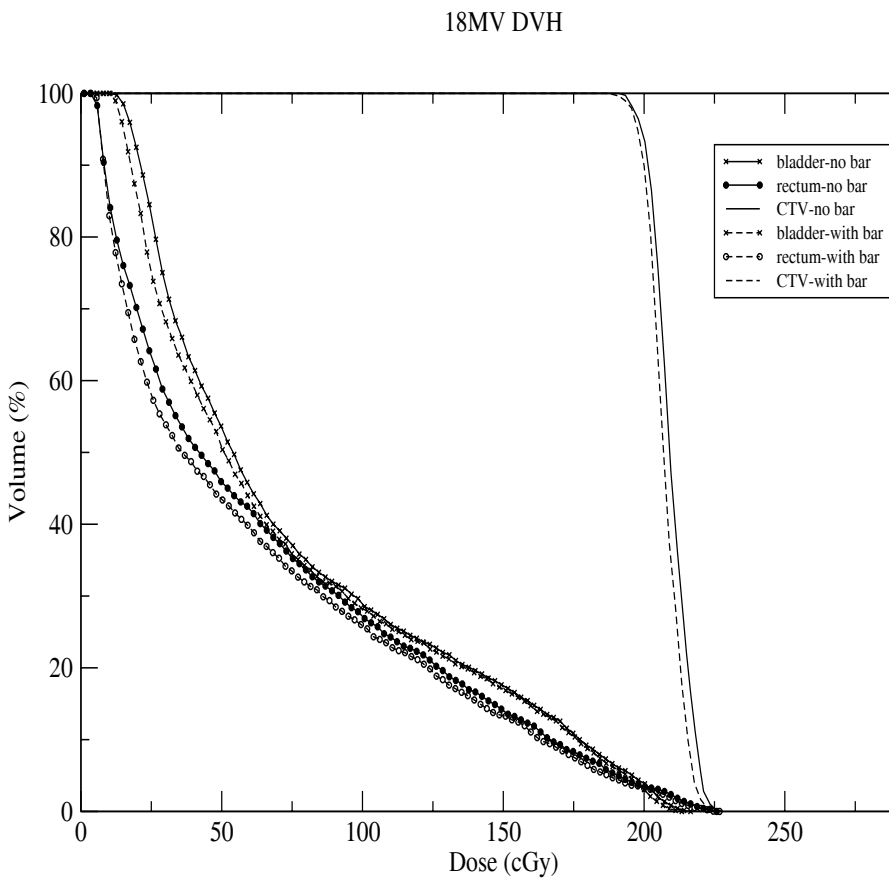
With bar

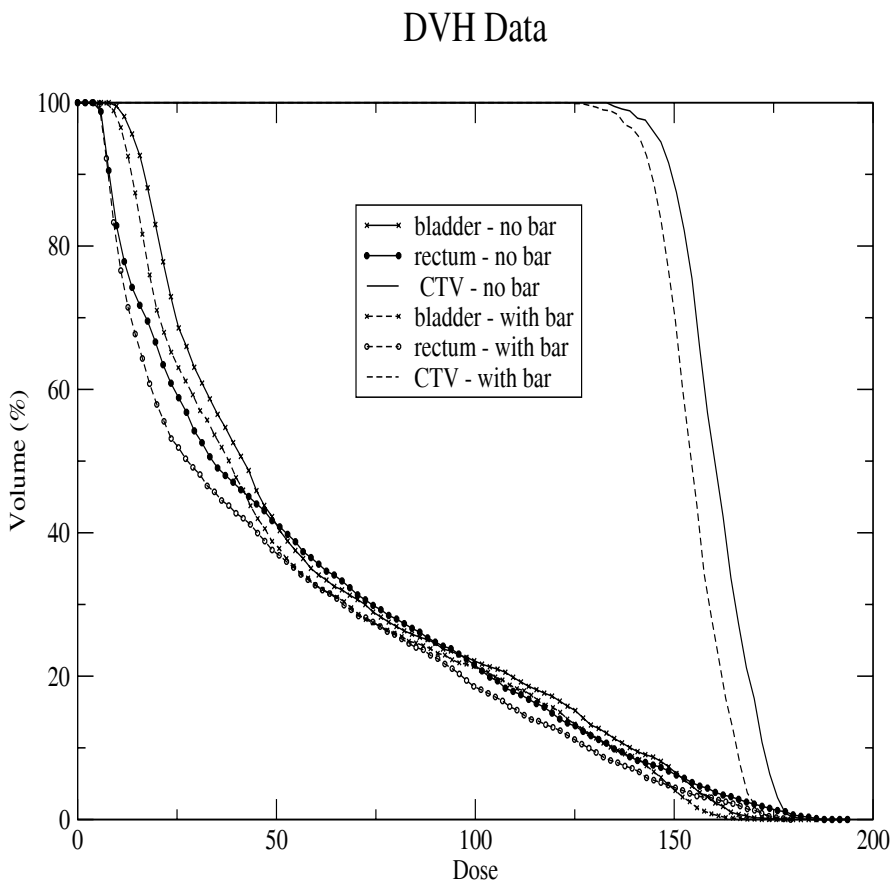
Yang et al 2005

Effect of Couch Bar on IMRT Dose Distribution

IMRT using 18 MV photons

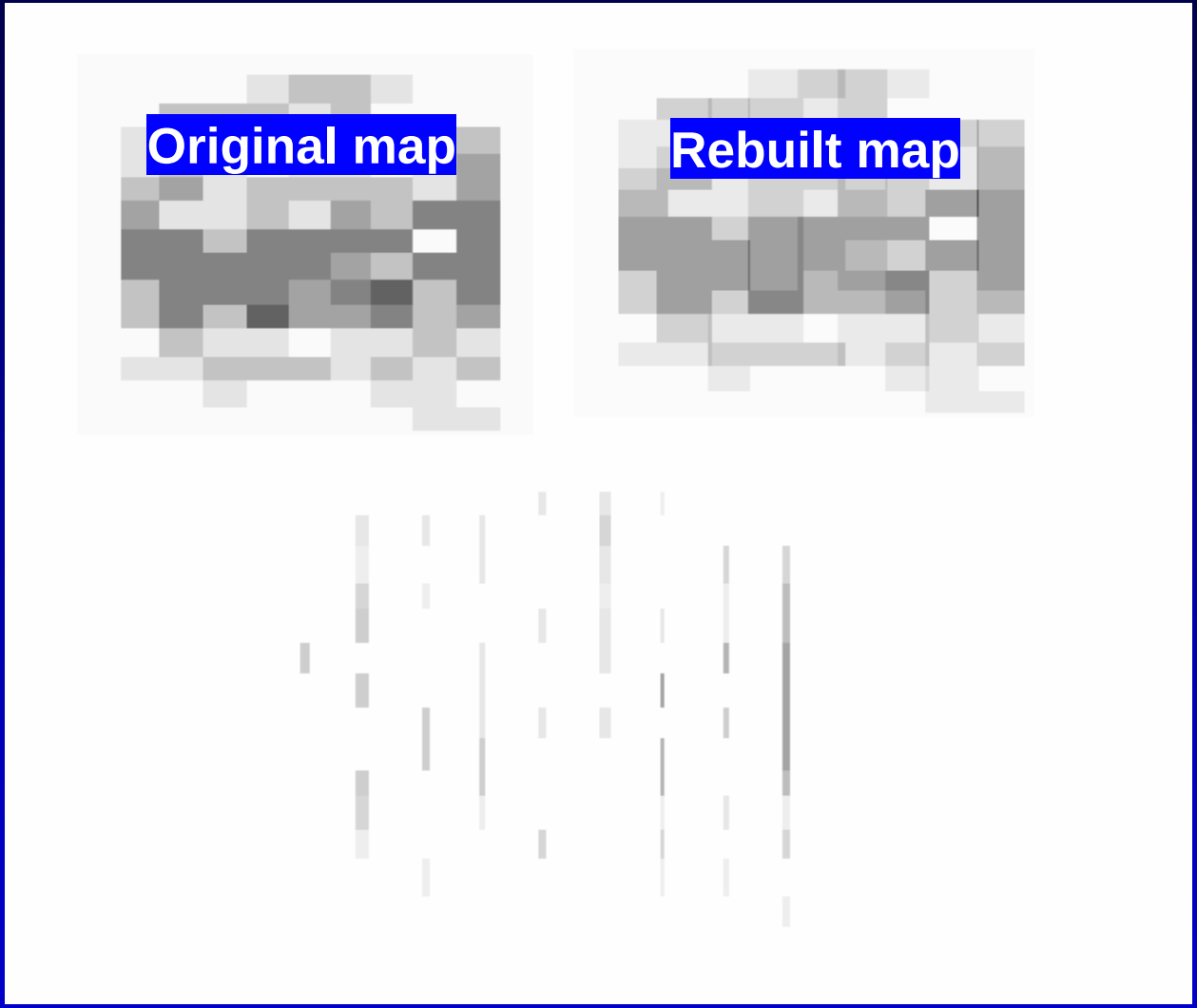
IMRT using 6 MV photons





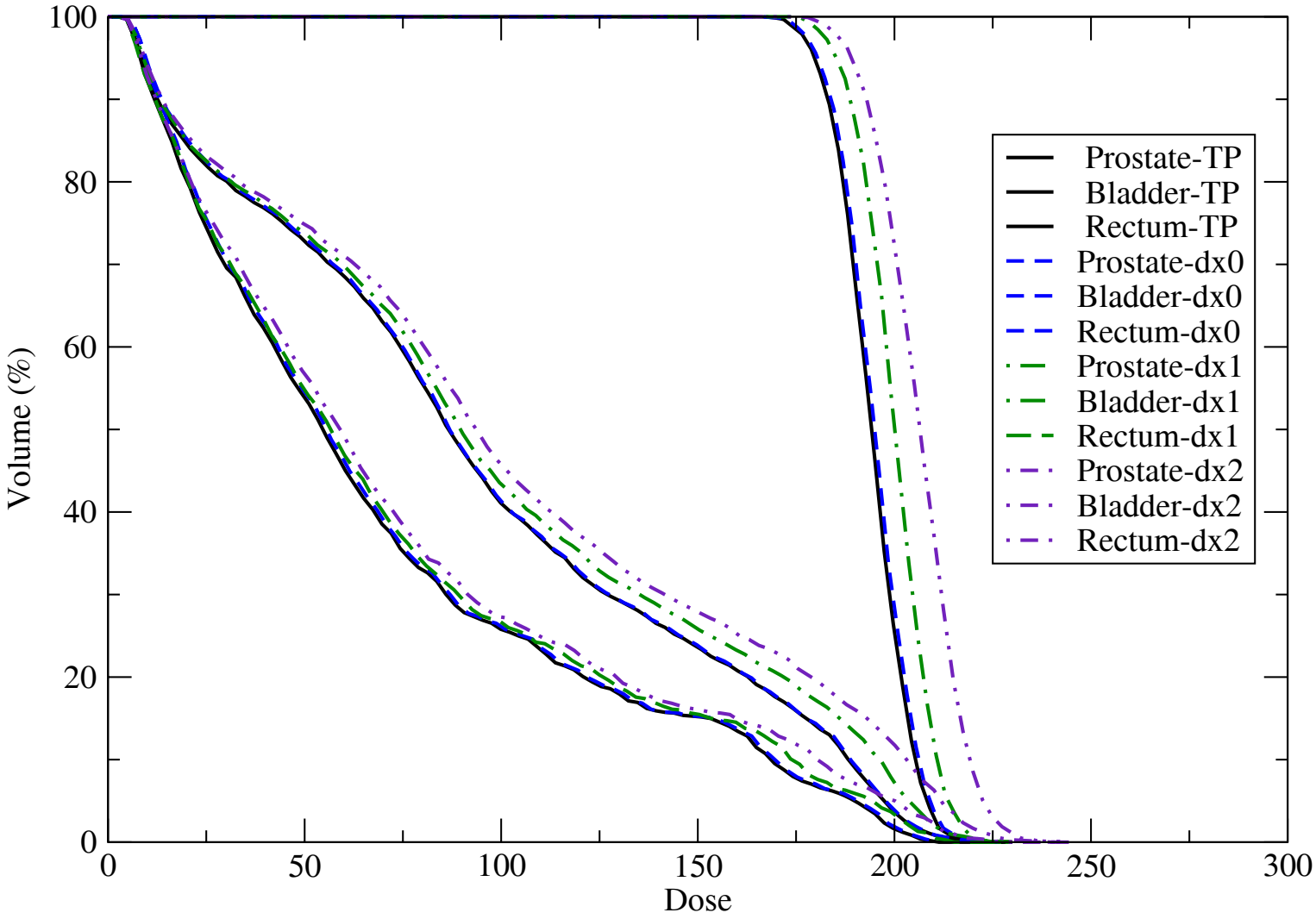
Yang et al 2005

Dose Reconstruction Using MLC Log Files



Error map showing discrepancies between planning and delivery

Luo et al 2006



Luo et al 2006

Monte Carlo for IMRT QA

- **Is calculation-based IMRT dose check sufficient?**

- **Yes if a comprehensive QA system exists**

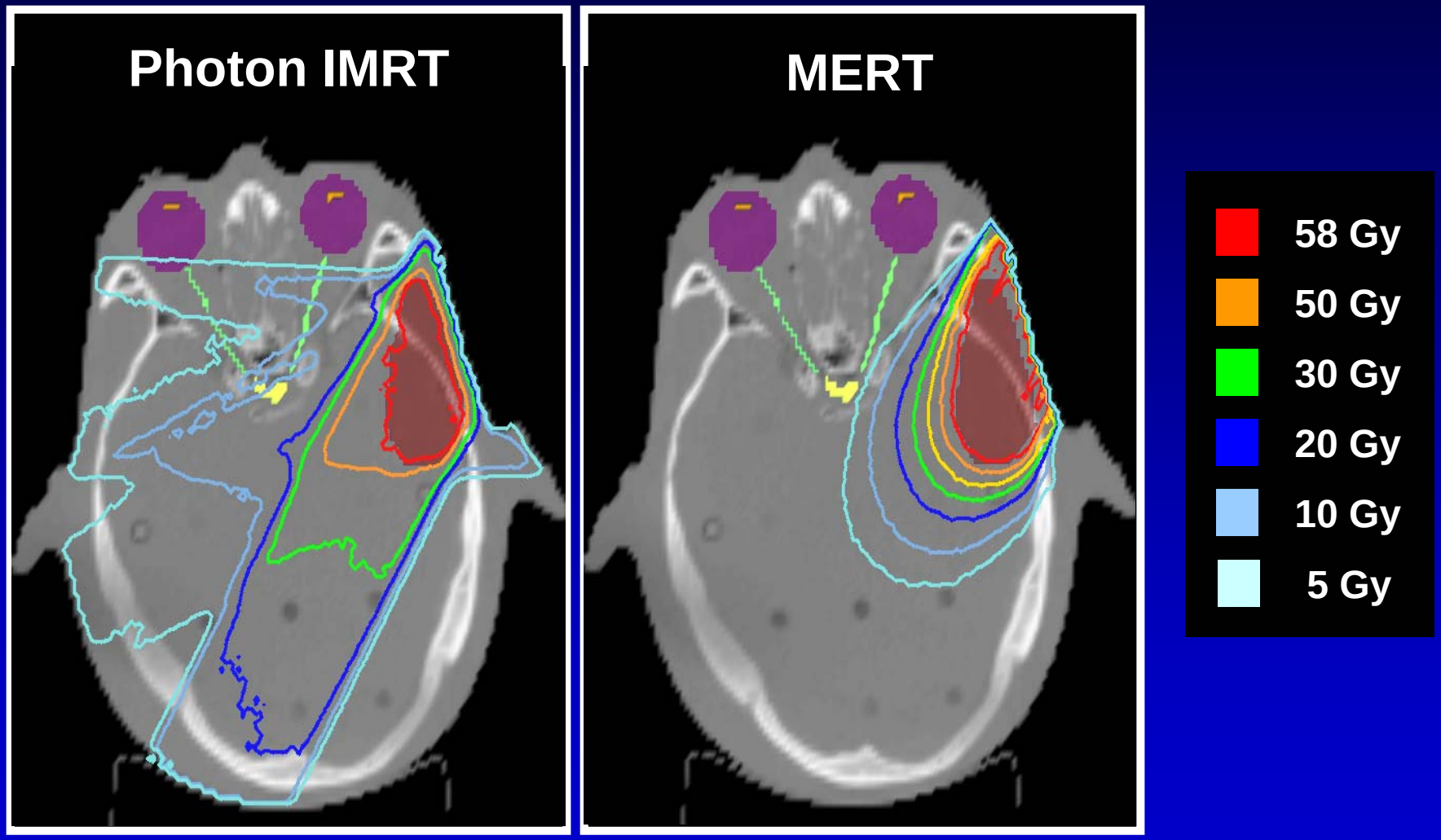
A measurement-based QA procedure is more desirable!

- **Monte Carlo is the way to go!**

Why your own Monte Carlo code?

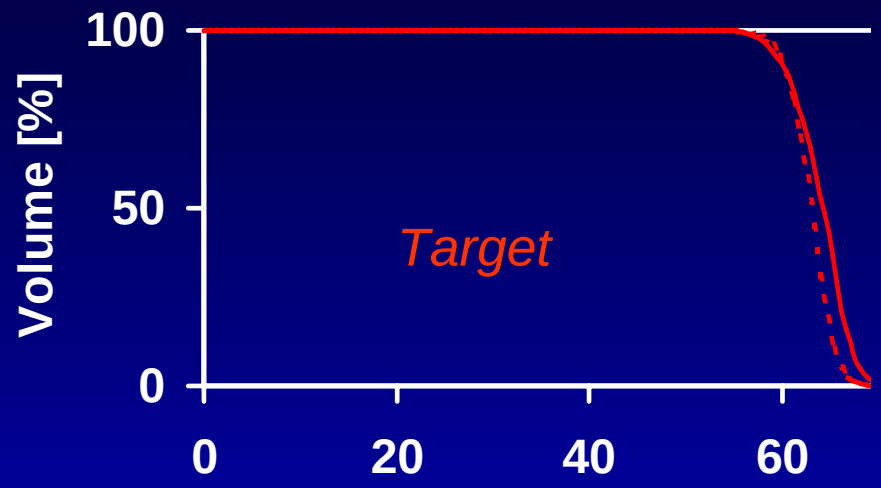
- Ideal for comparing different treatment techniques that use their own TPS (e.g., IMRT vs SRS)
- Ideal as a treatment QA tool (e.g., for IMRT/MU)
- Ideal for investigating new treatment techniques (e.g., for MERT, Cyberknife, laser protons)
- Ideal for clinical research (e.g., customized studies)

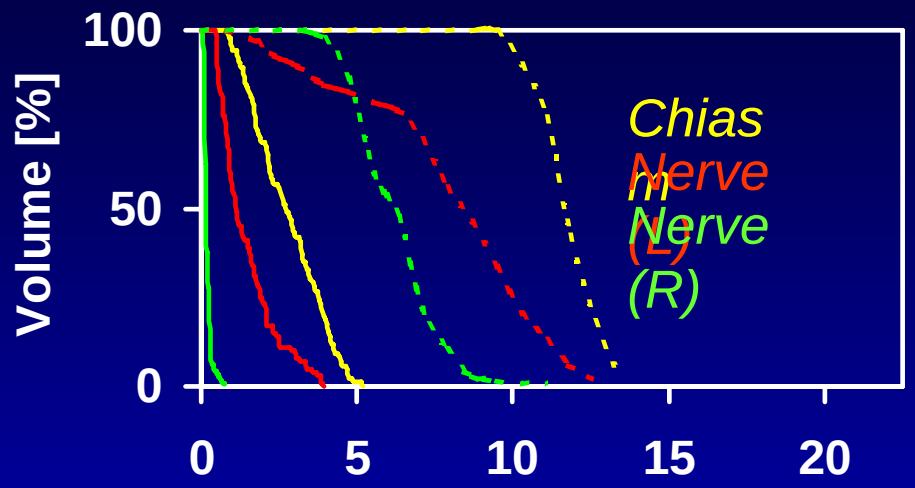
Comparison of MERT and IMRT

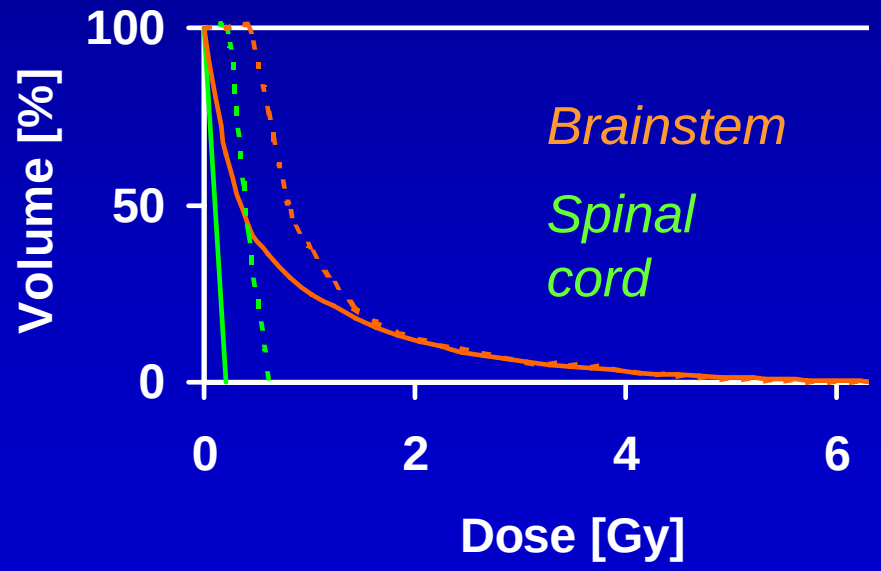


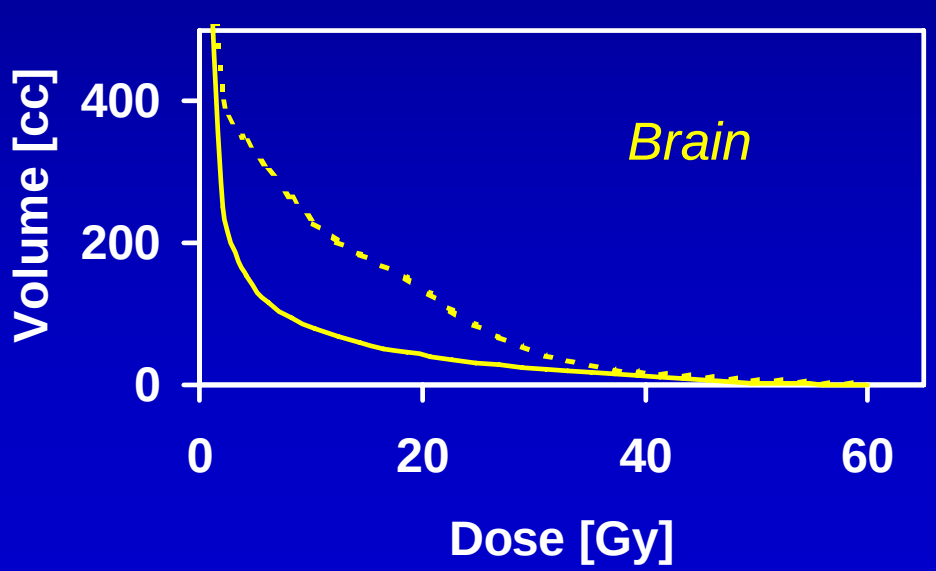
Lee et al 2002

MERT (—) and IMRT (·····)



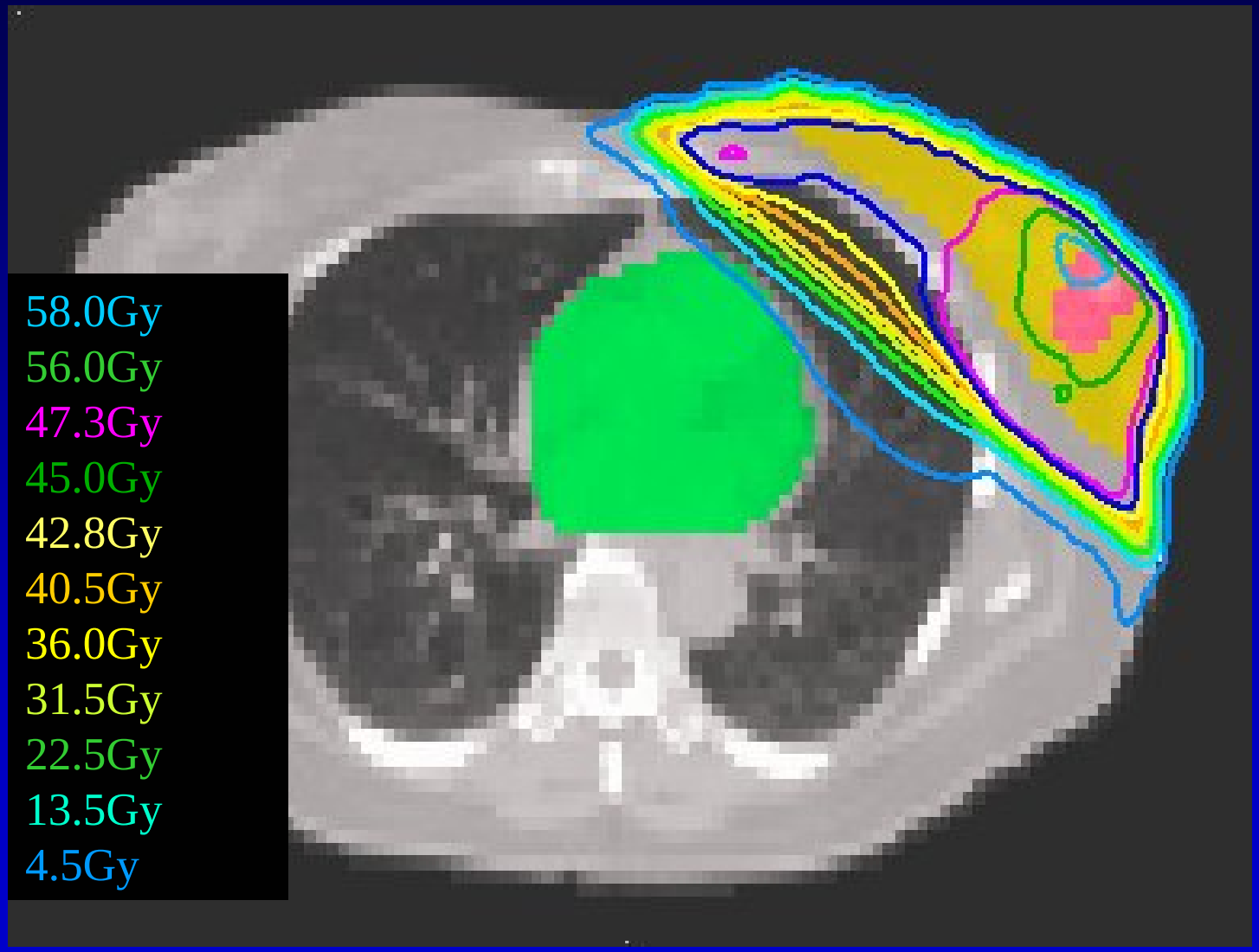






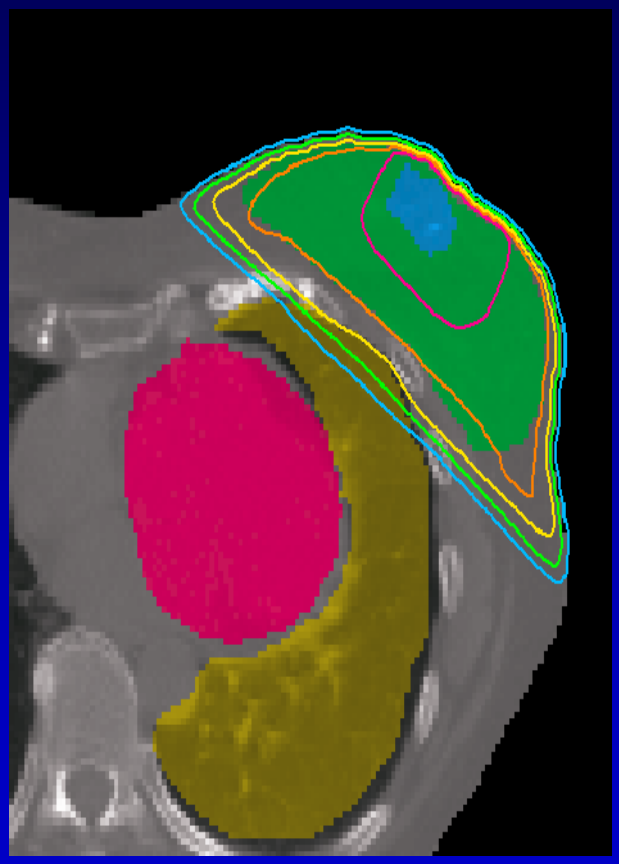
Lee et al 2002

Combined Photon/Electron Plan

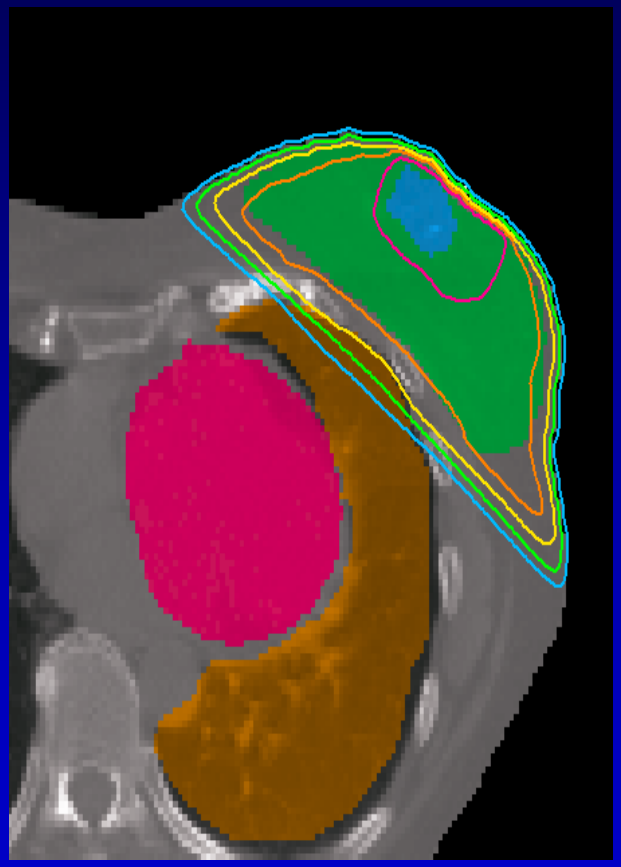


Li et al 2004

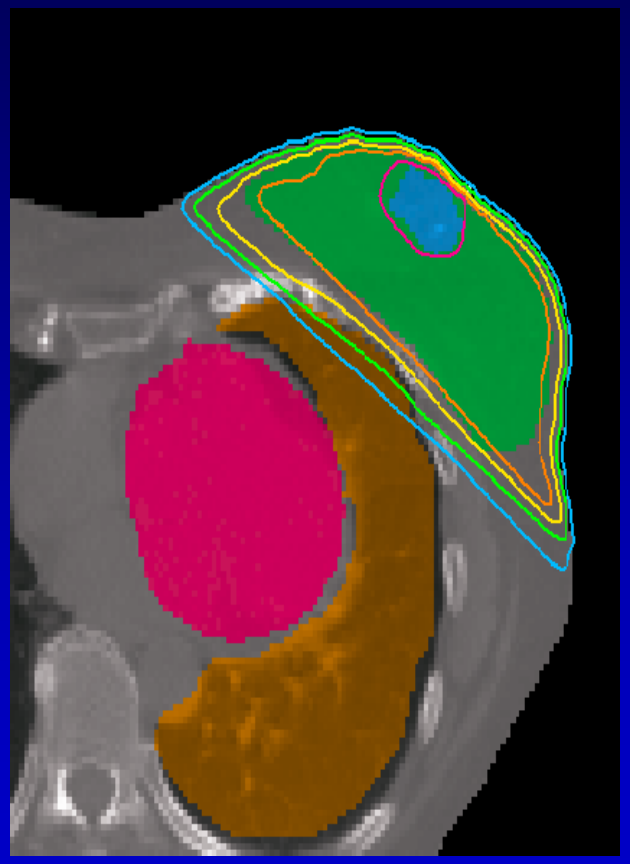
Mixed Beam Breast Plan



Optimize IMRT based on a fixed e- field



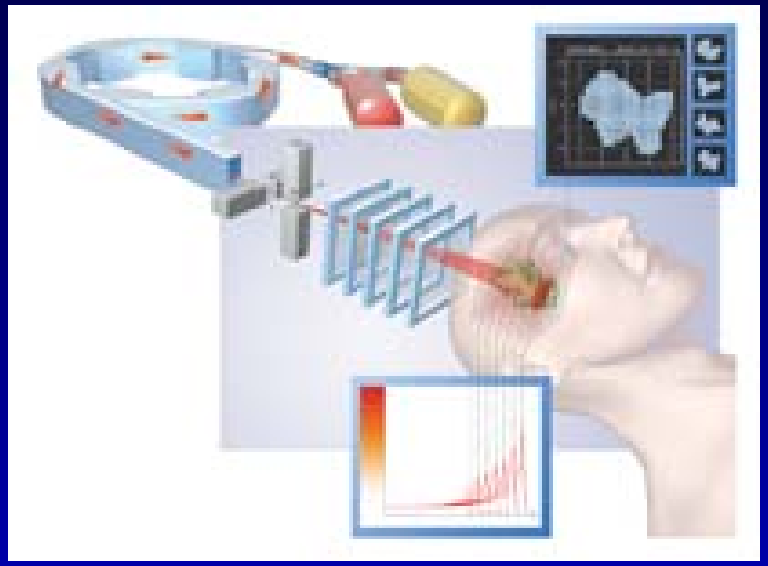
Optimize IMRT and the e- field weight

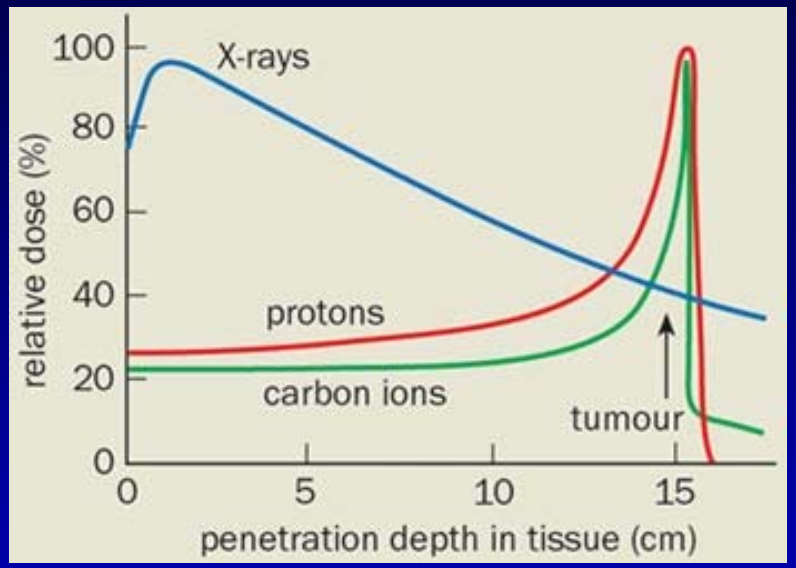


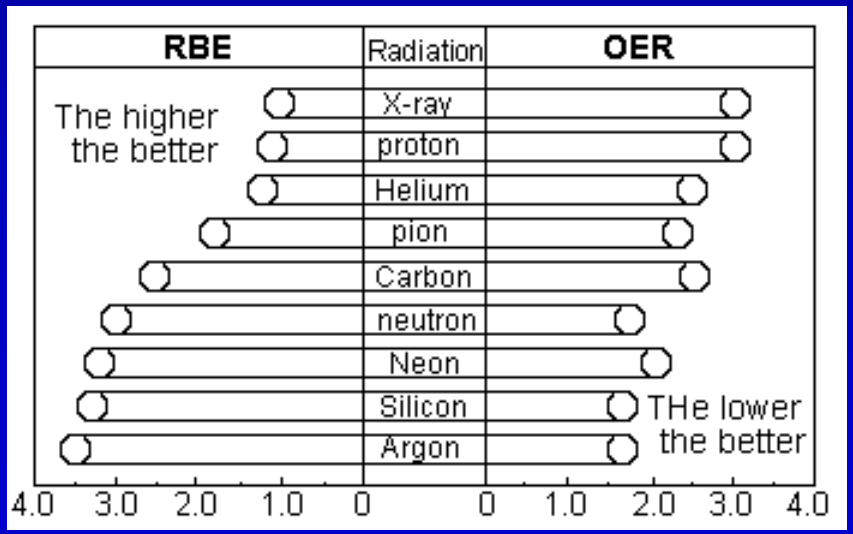
Optimize IMRT and MERT

Xiong et al 2005

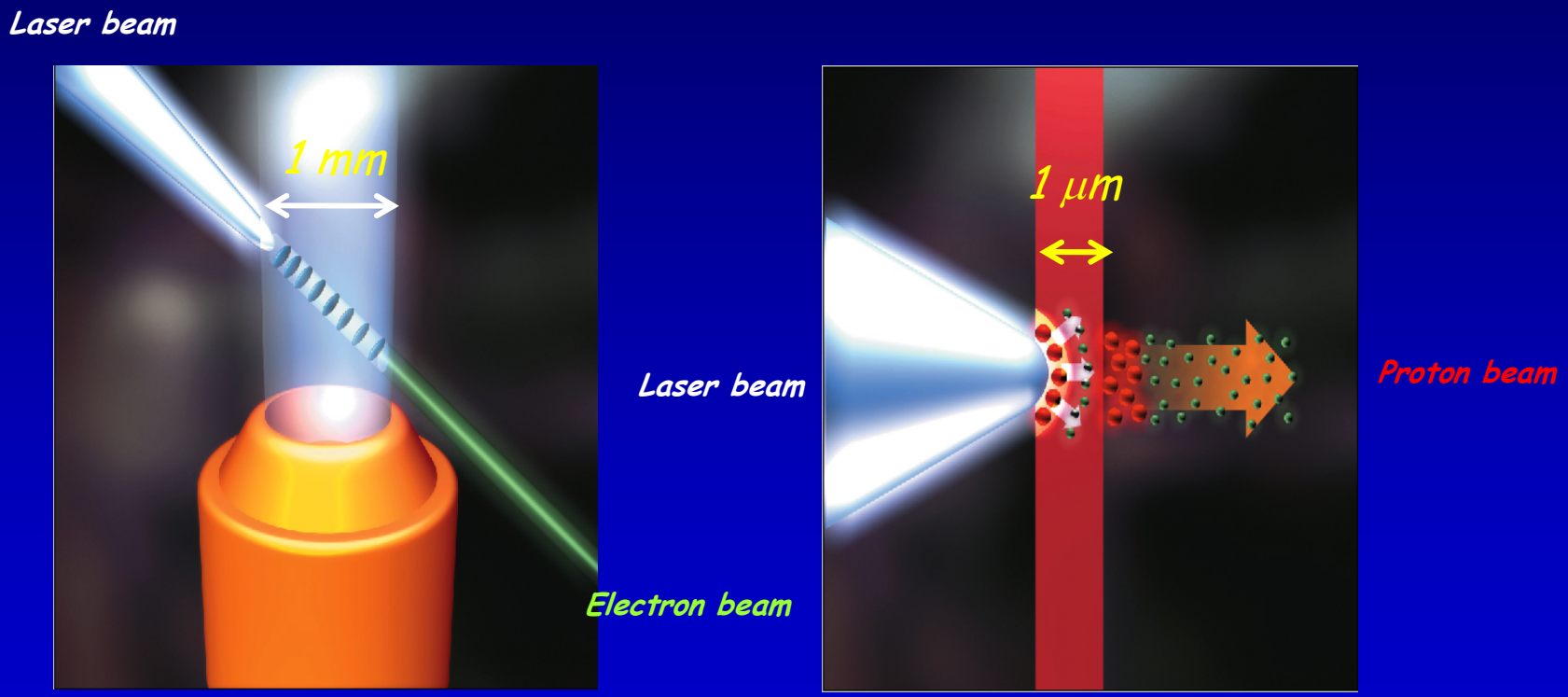
Particle Therapy



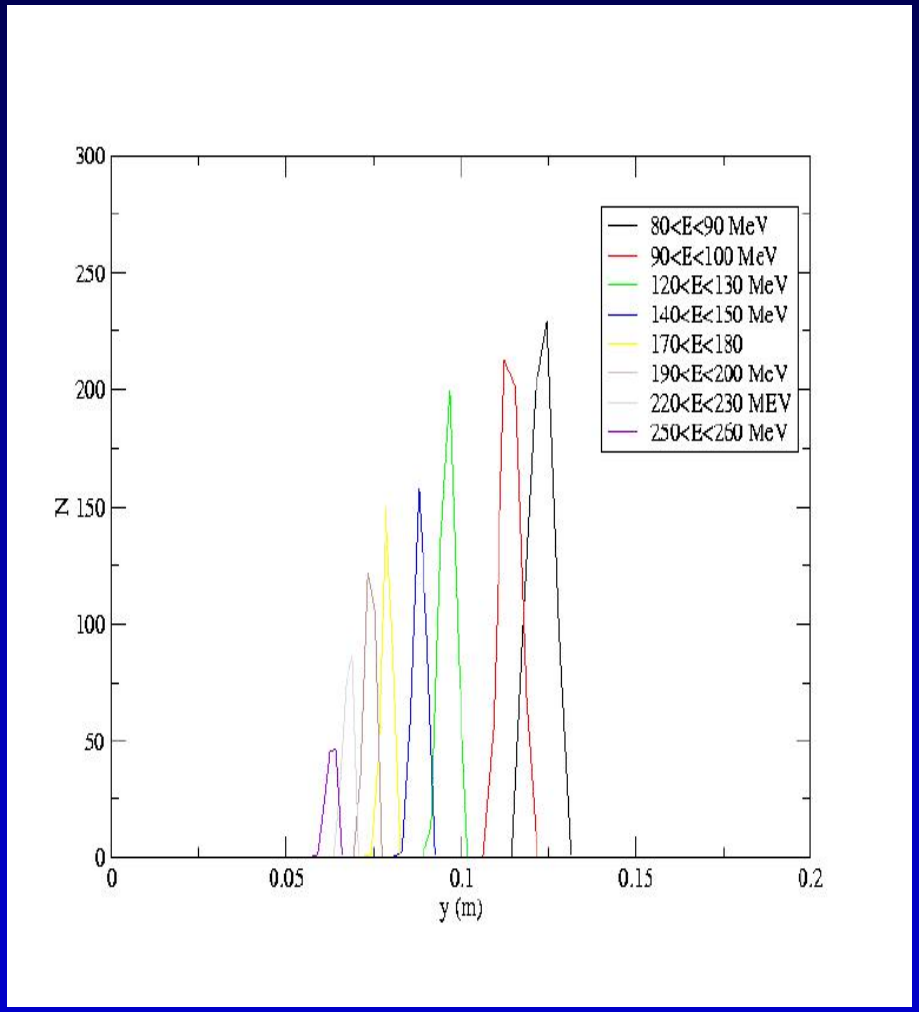




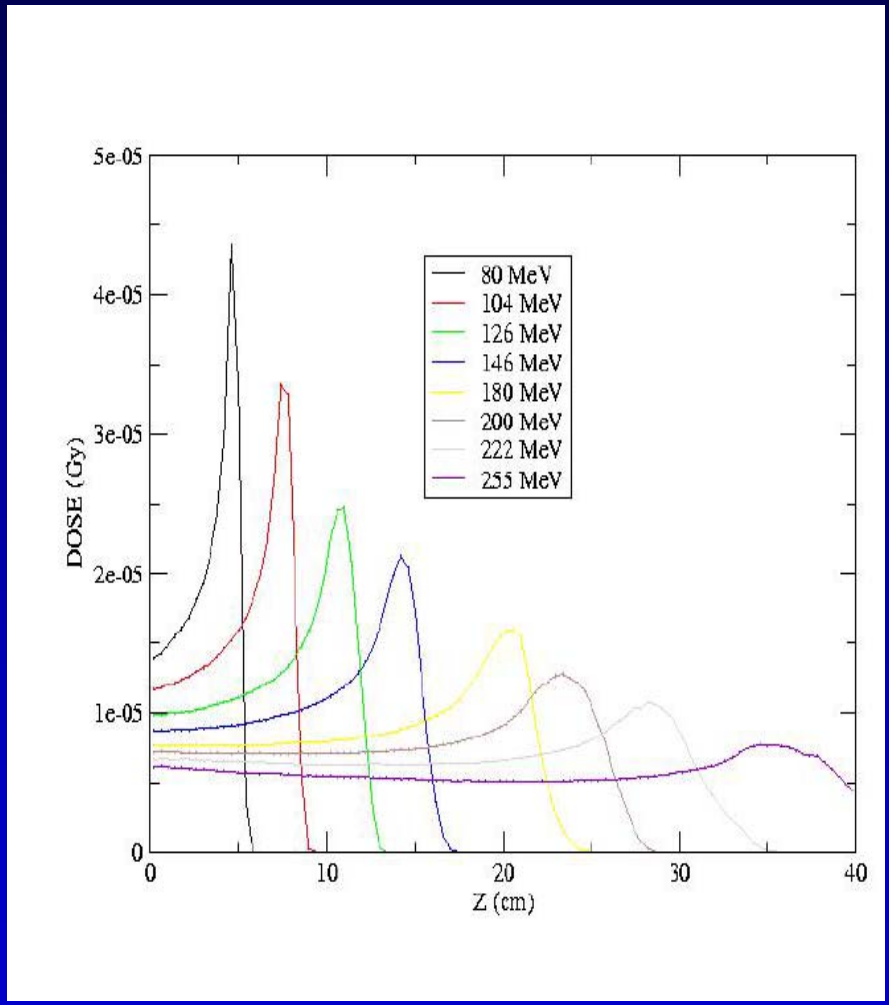
Laser Plasma Acceleration for Electrons and Protons



Proton Spectrum



Beamlet Dose Distribution



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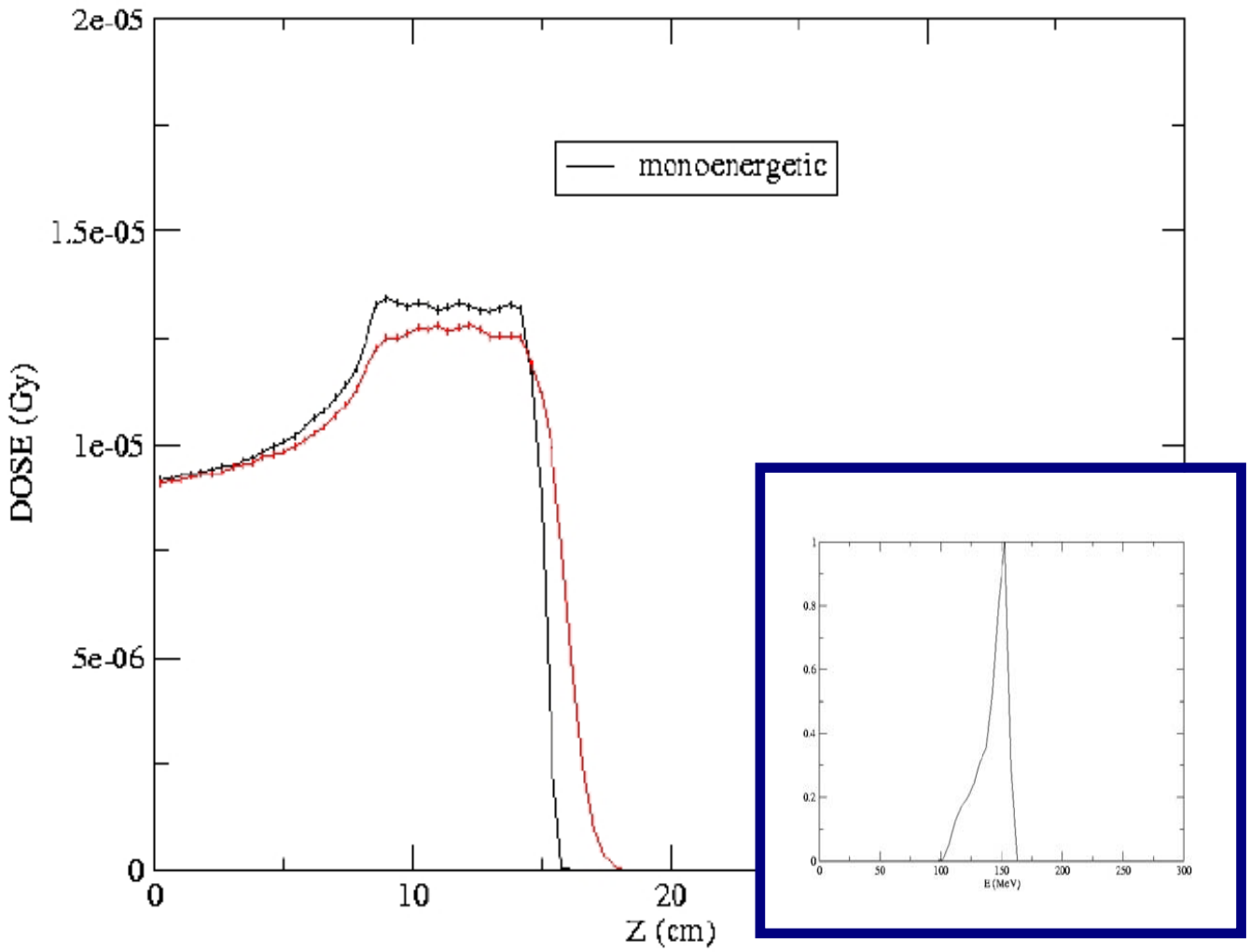
Combined Dose Distribution



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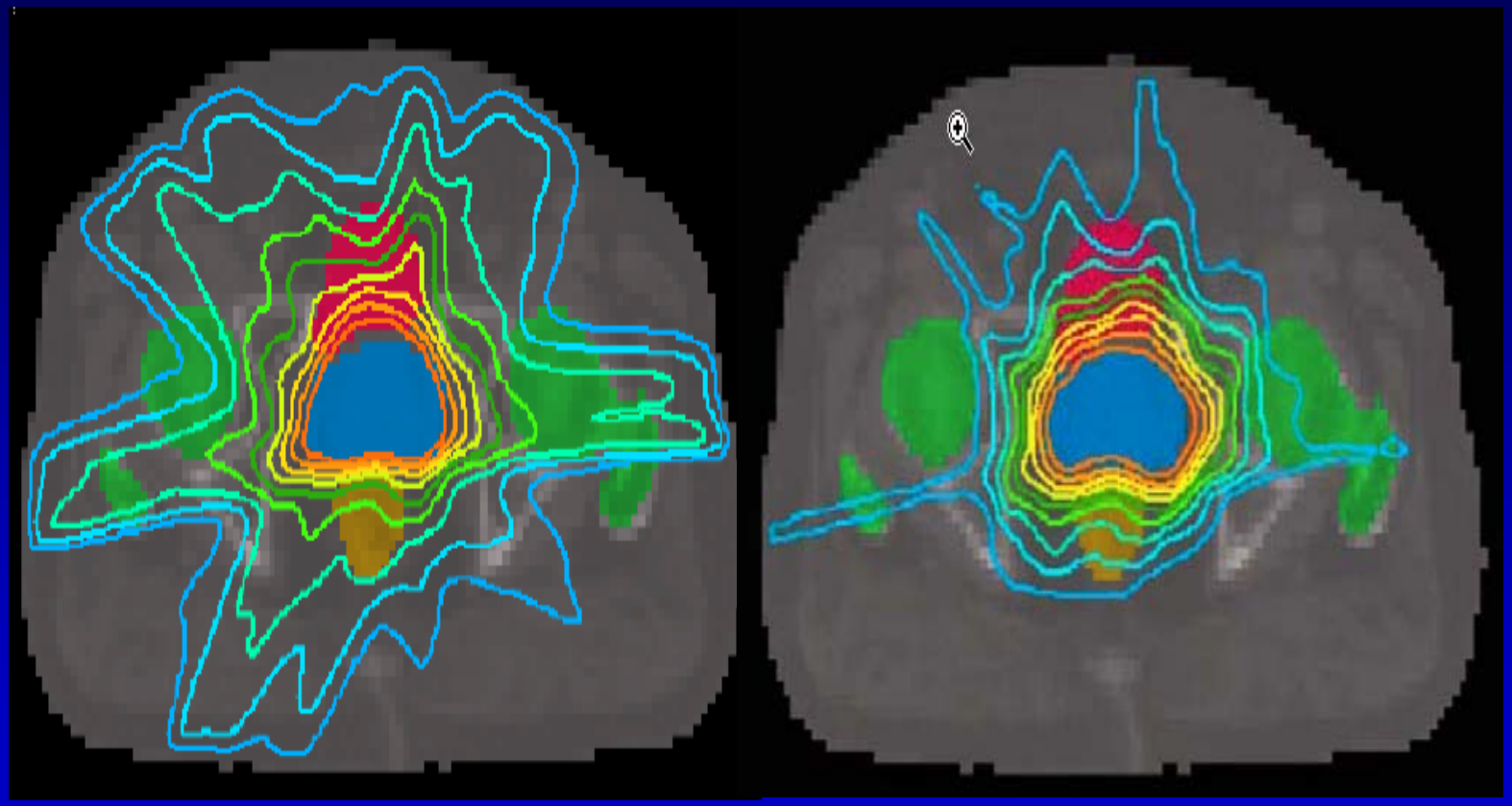
Comparison of Isodose Distribution



7 field IMRT **7 field laser protons**

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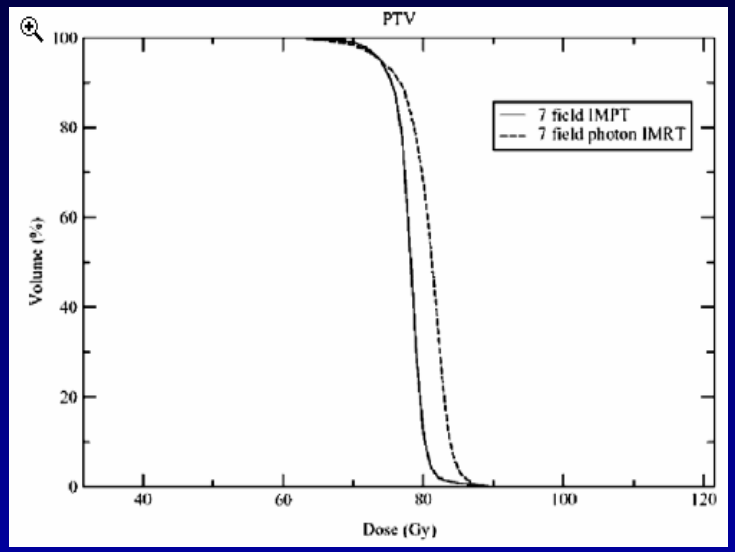
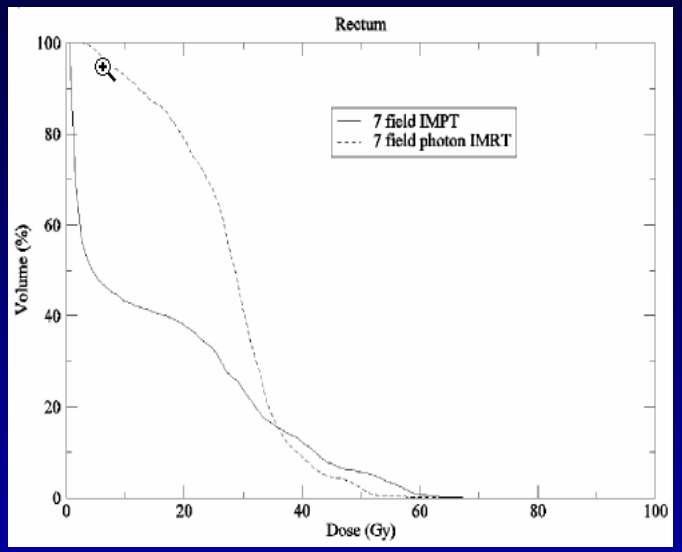
Comparison of DVH

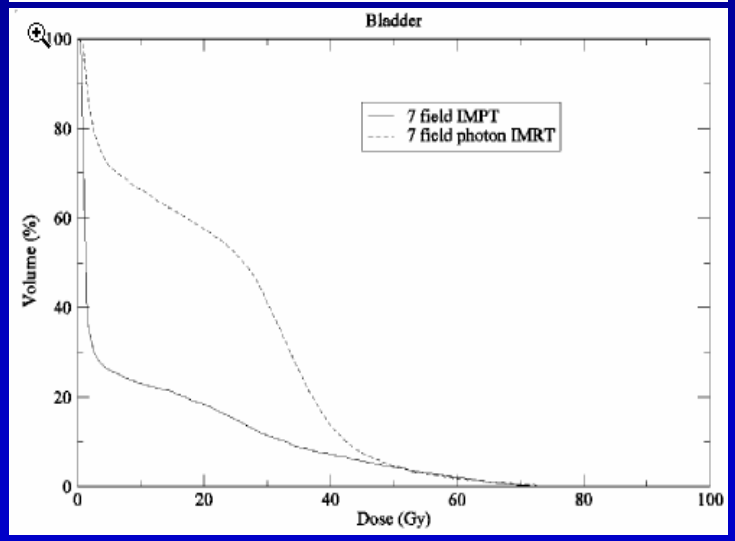
Target

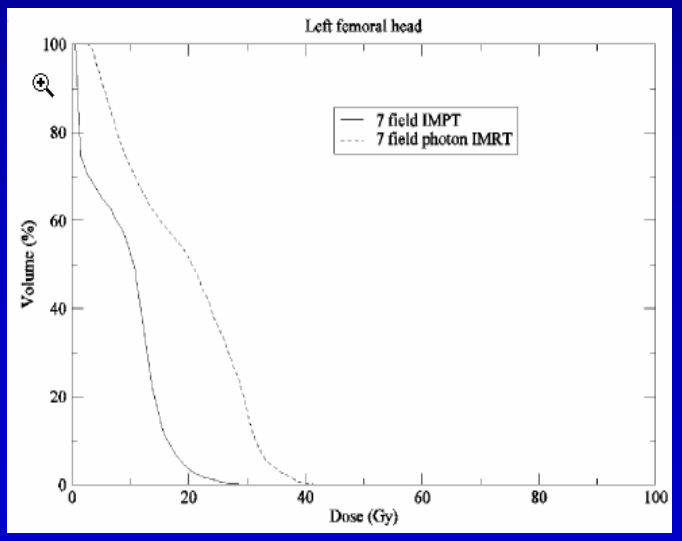




Rectum

Bladder





Femur

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