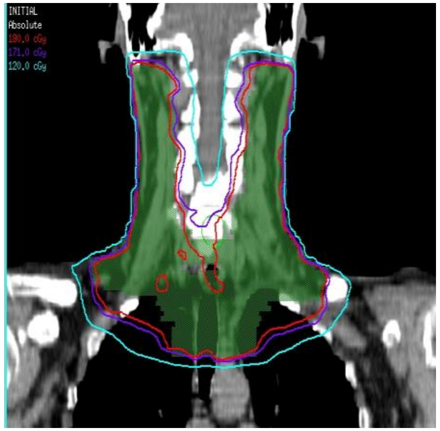
Treatment Planning: Simulation, Beam Arrangements, Modifiers



Resident Physics Board Exam Review 2012
University of Maryland School of Medicine
Department of Radiation Oncology

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Outline

I. Simulation

II. Single field isodose

II. Parallel opposed

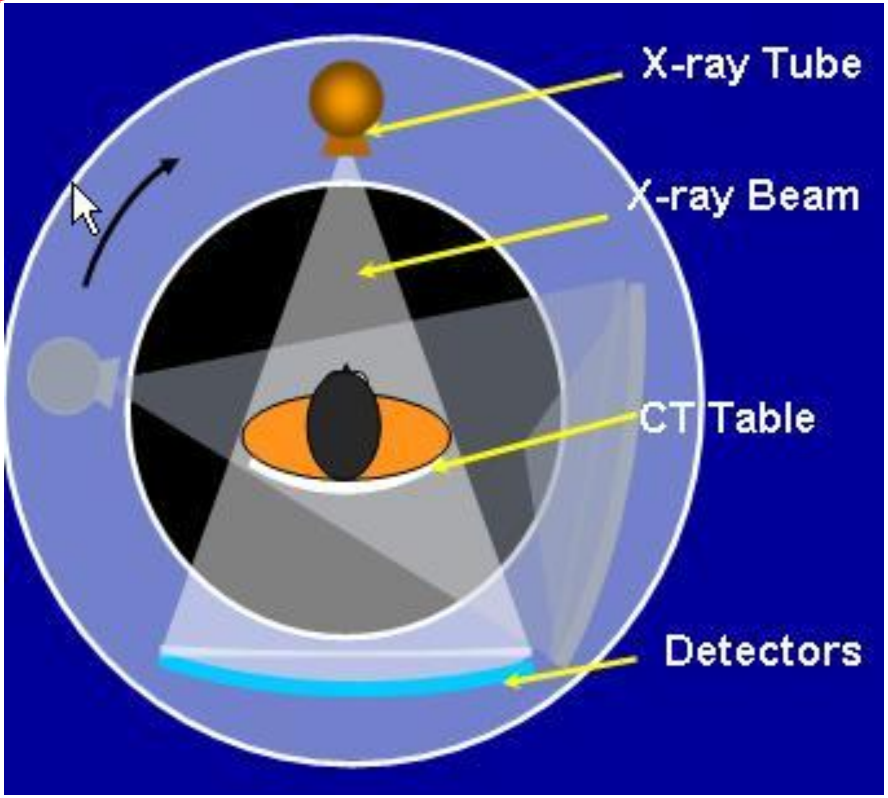
III. Multiple beams (isocentric)

IV. Modifiers

V. Field matching

VI. Other

CT in 3D planning



Measures the linear attenuation coefficient using x-rays and backprojection algorithms to acquire a 3D representation of the patient to use for treatment planning

Two main purposes

1) Treatment simulation (positioning, organ delineation, beam placement)
2) Density information for dose calculation

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CT Simulator Components

- CT scanner
- Localization system (eg lasers)
- Virtual simulation software package

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CT Simulator: CT Scanner

Specifications:

- Flat tabletop
- Larger bore to accommodate immobilization devices
- Patient must be scanned in treatment position

Uses:

- Target volume and organ delineation
- Quantitative data for tissue heterogeneity correction in dose calculation

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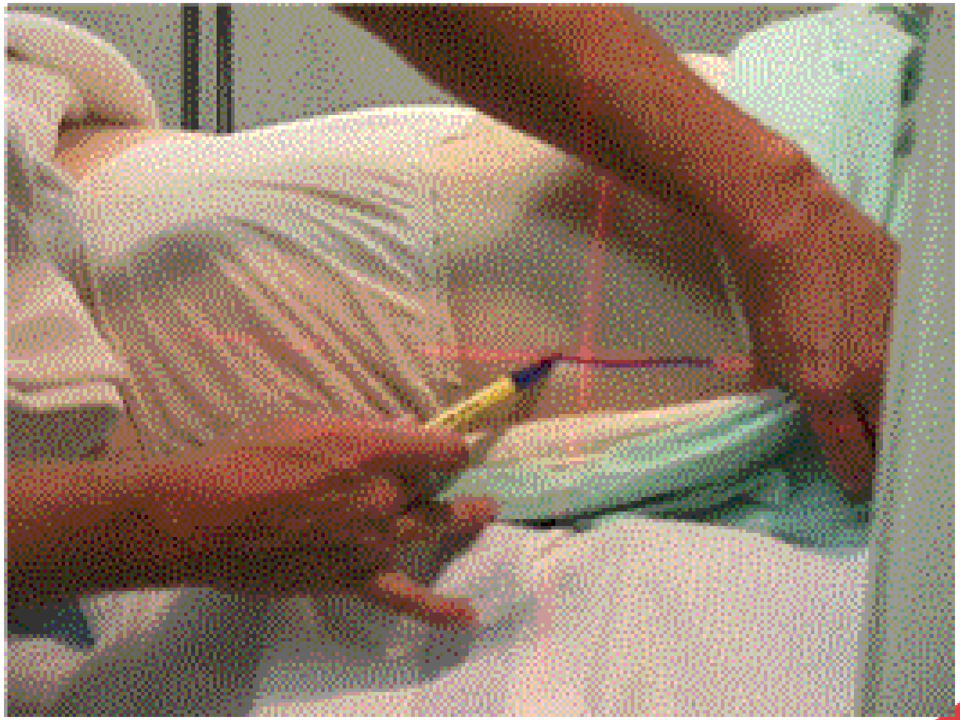
CT Simulator: Localization

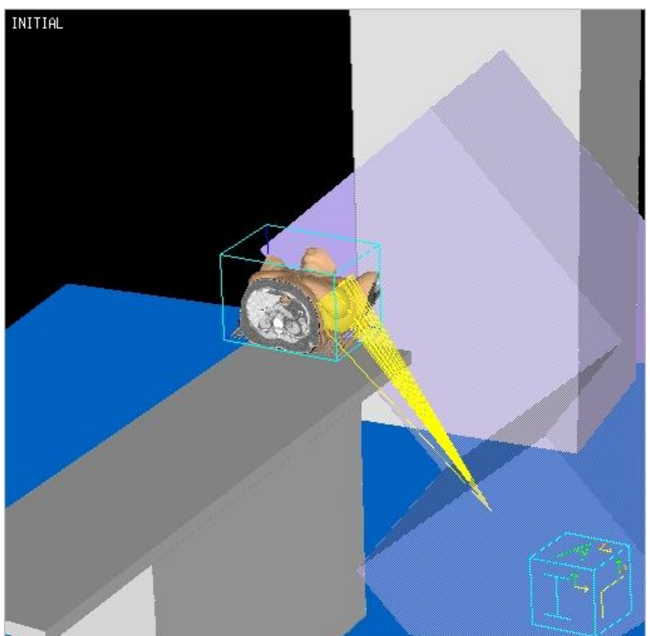
- Laser system
- Coordinate of localization transferred to Virtual simulation computer
- Mark patient for localization and straightening

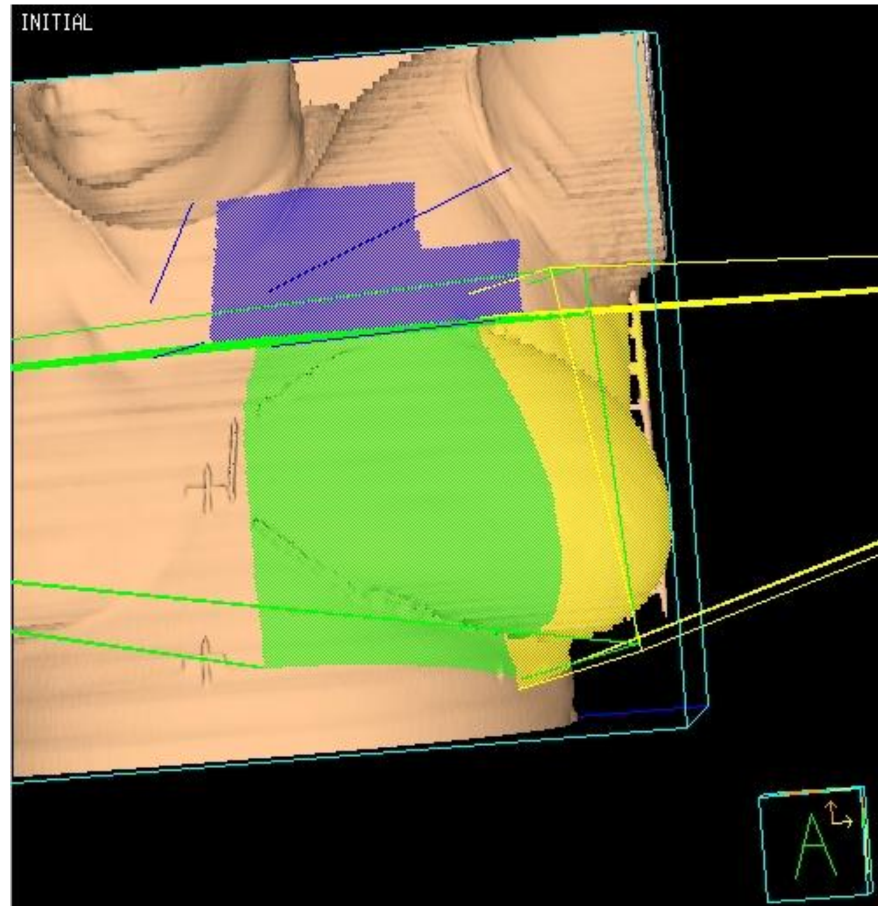


CT Simulator: Virtual Simulation

In a “virtual” environment (on the computer), we can:

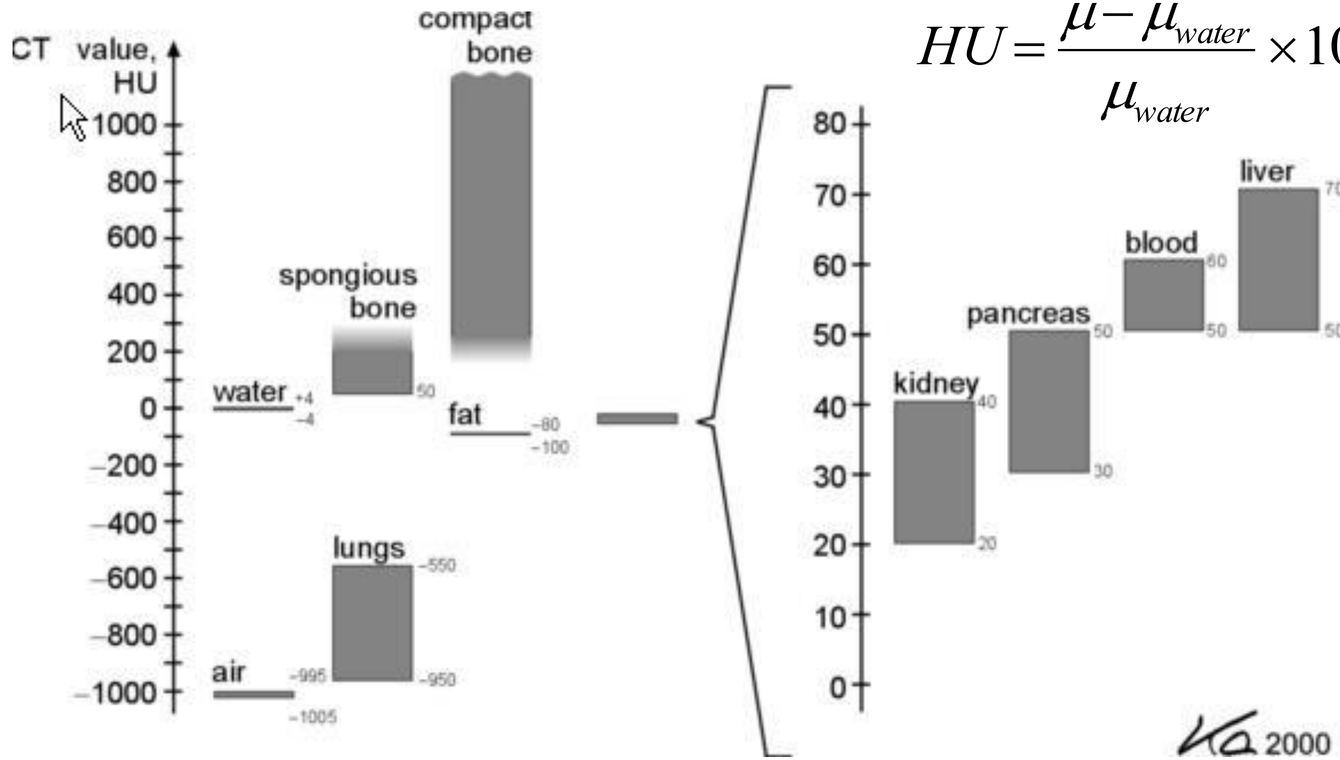
- Determine field arrangement
- Design field shapes
- Outline target and critical structures





Hounsfield Units

$$HU = \frac{\mu - \mu_{water}}{\mu_{water}} \times 1000$$



- Water: 0 HU
- Fat: ~-100 HU
- Bone: 400 to 2000 HU
- Air: ~-1000 HU
- Lung: -900 to -550 HU

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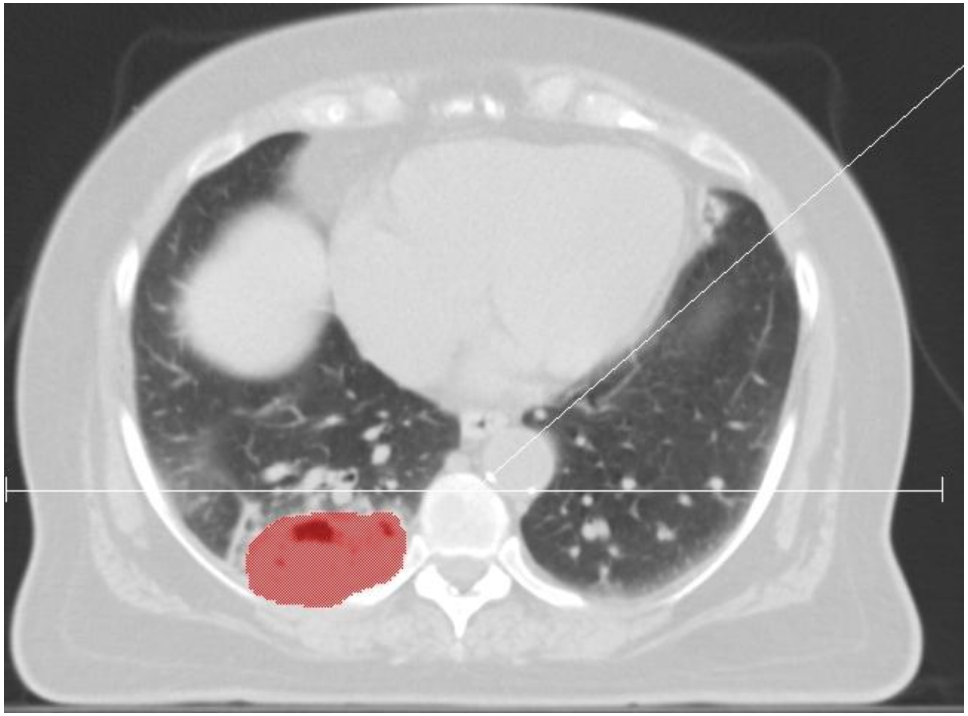
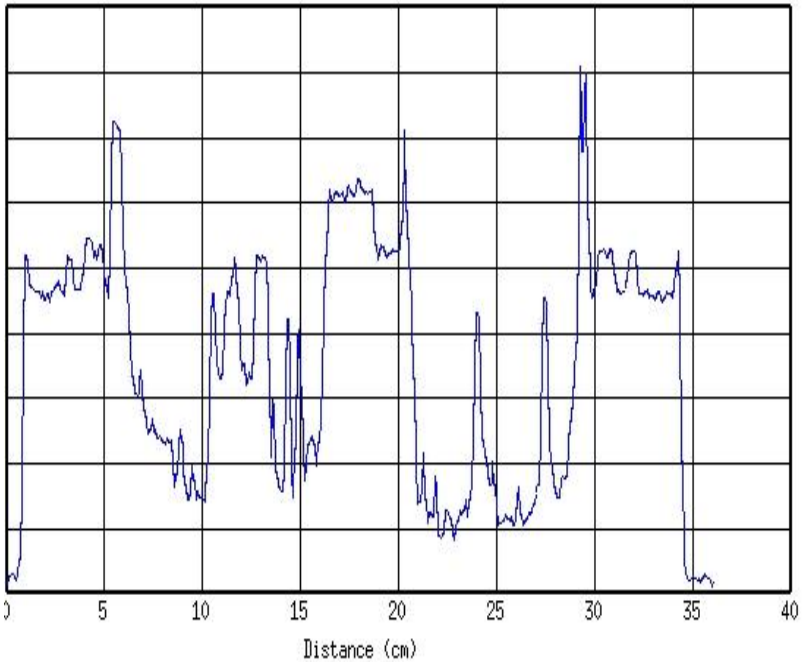
HU example: Lung



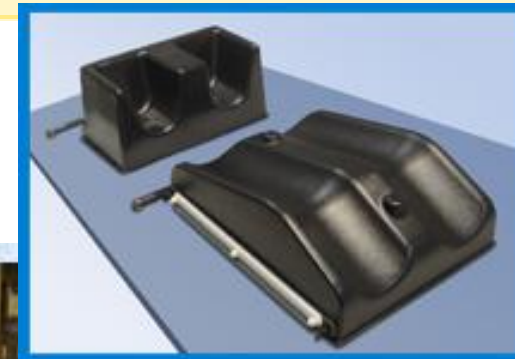


Scan across this line and plot HU as we go along

Rectum: Immobilization

“Belly board” used for patient setup reproducibility and to dislocate the bowel away from the radiation field.

Prostate: Immobilization



Thorax: Immobilization

Arms are generally up

Vac-lok bags

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Breast: Immobilization

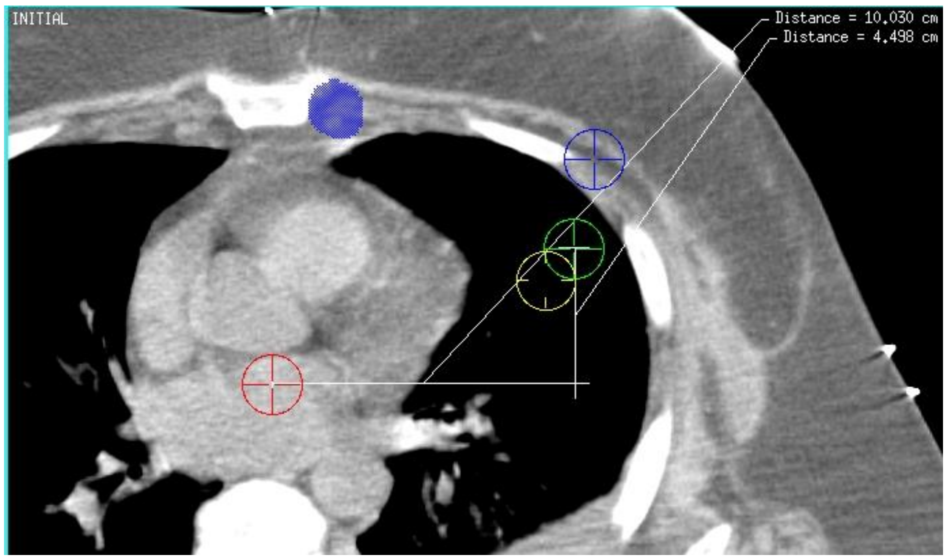
Breast board tilts patient's thorax to an angle:

1) Sternum closer to parallel
2) Not enough angle: breast may fall toward chin
3) Too much angle: breast may fall toward abdomen

Breast board also assists in reproducibility of setup.

Breast: Setup

Tangent isocenter from tattoos



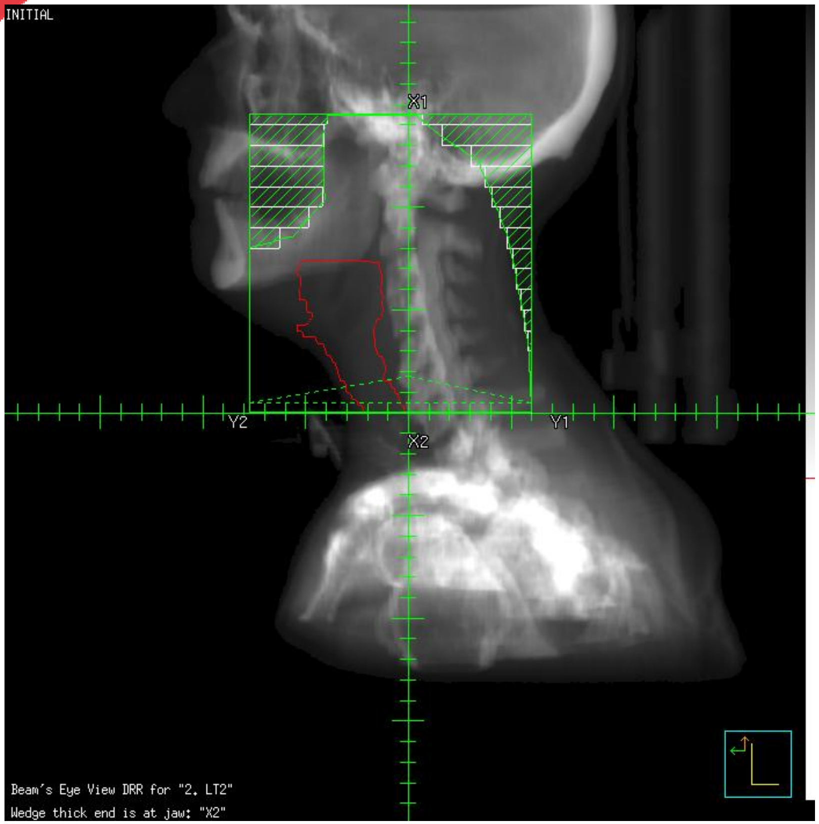
1) Line up to tattoos (sternal setup)
2) Drop table prescribed distance (SSD check)
3) Shift table prescribed distance

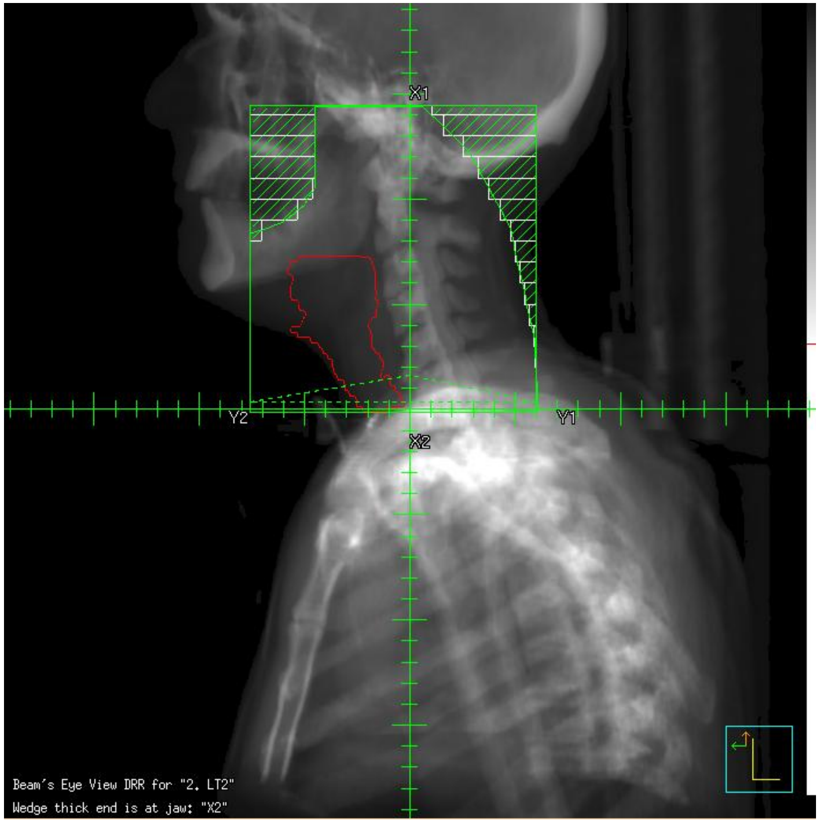
SC isocenter from tangents

Move table out prescribed distance

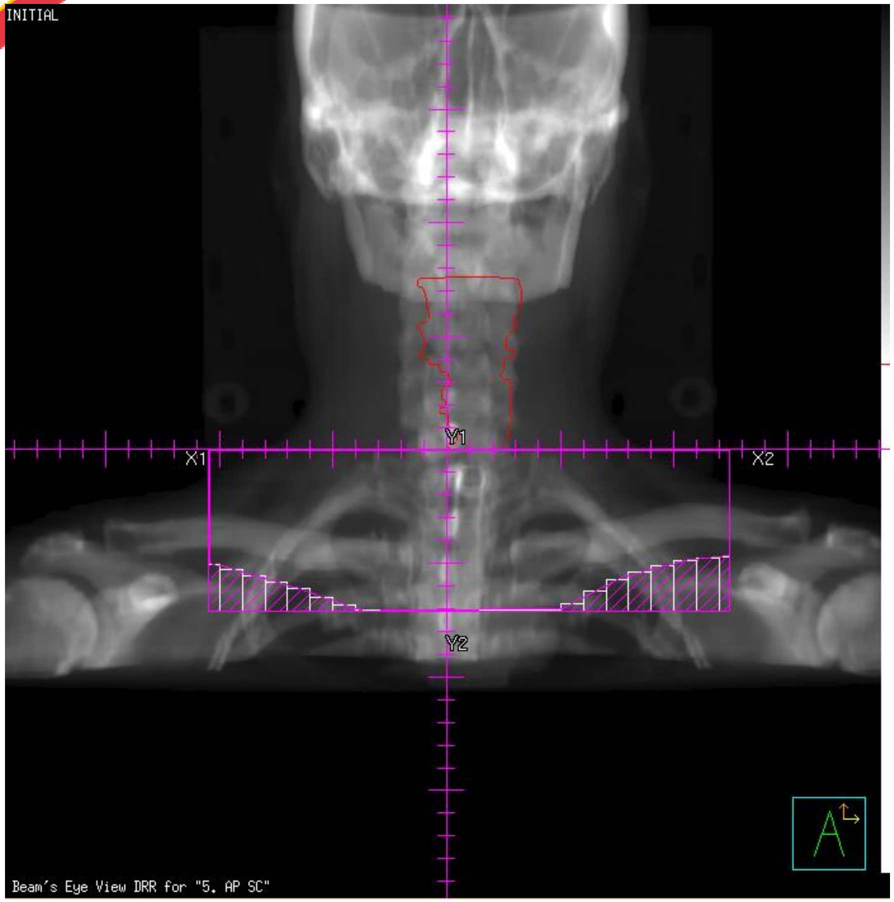
HN: Immobilization

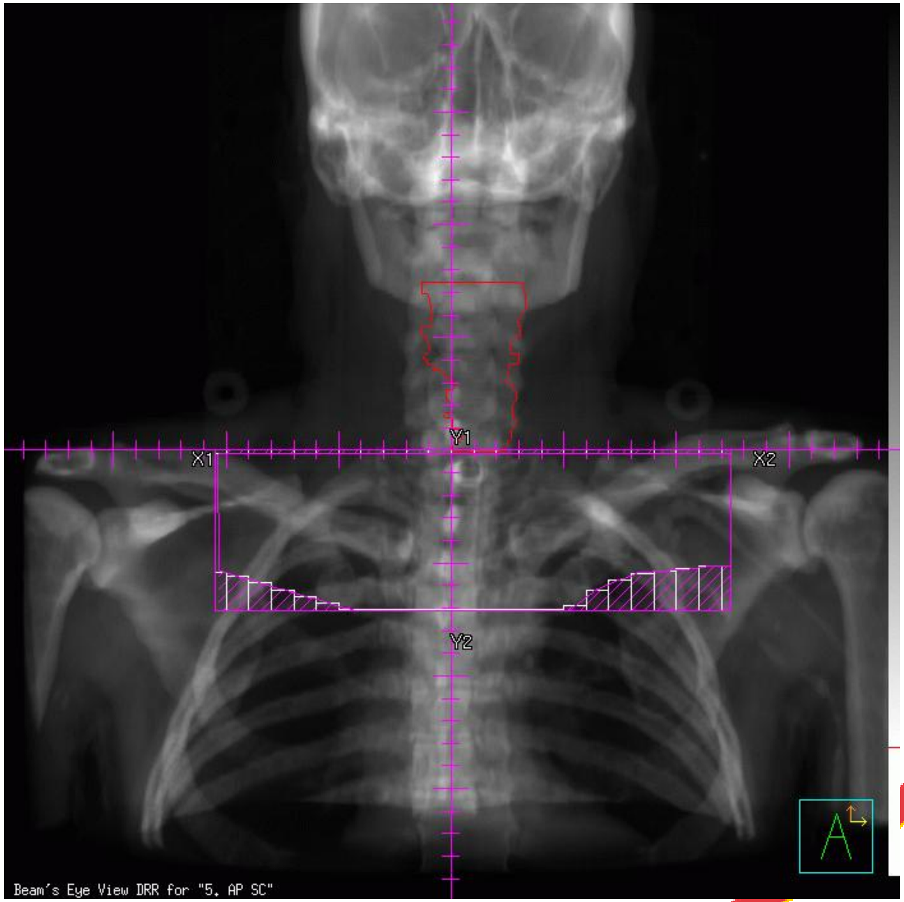
Shoulder Immobilization



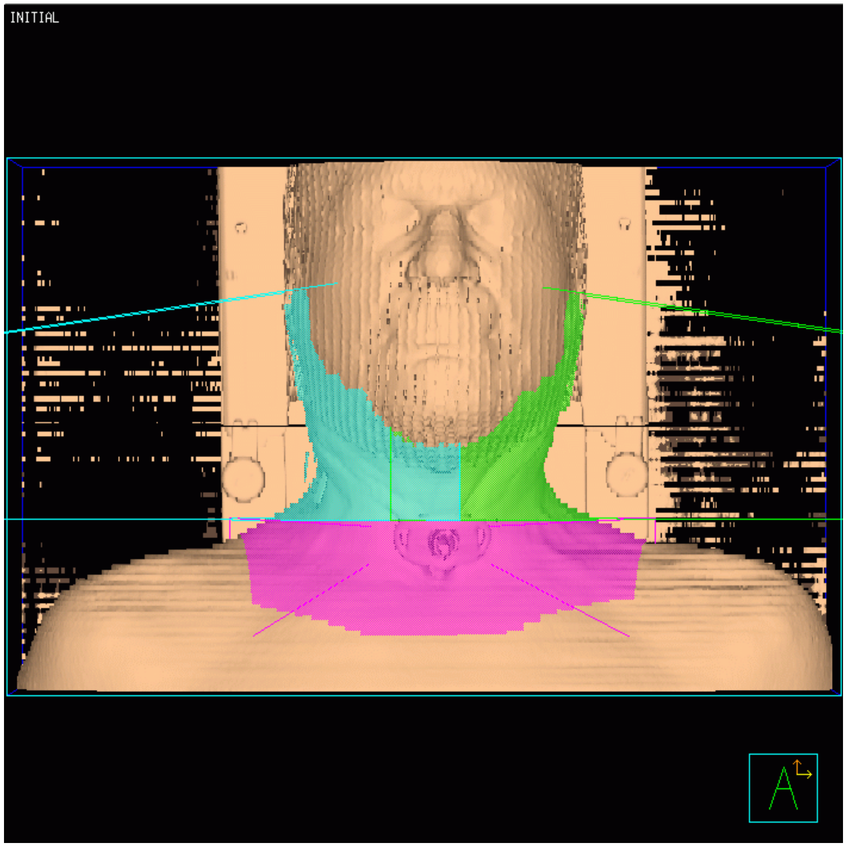


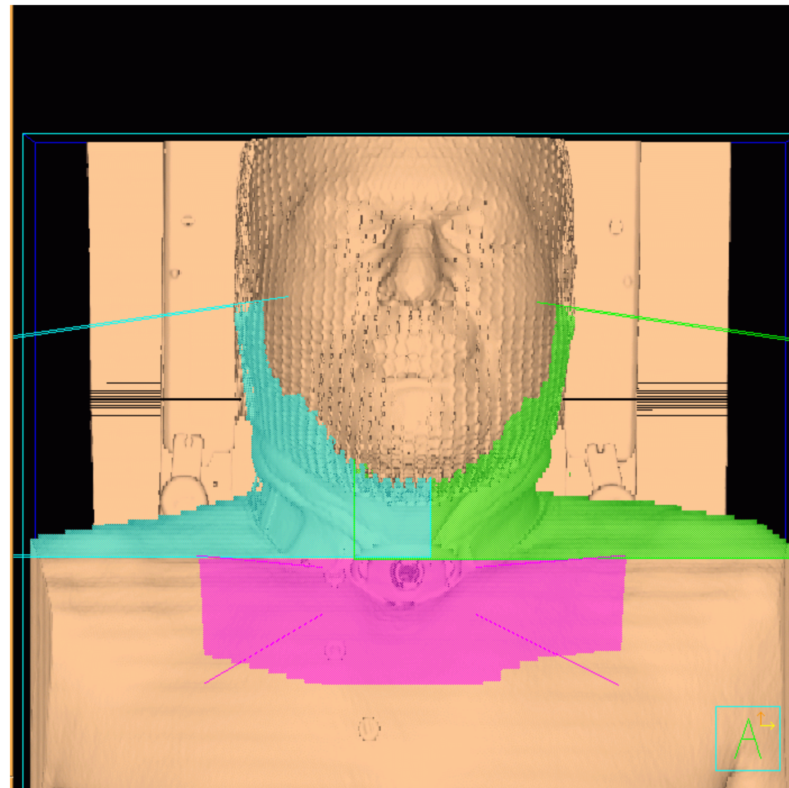
Shoulder Immobilization





Shoulder Immobilization





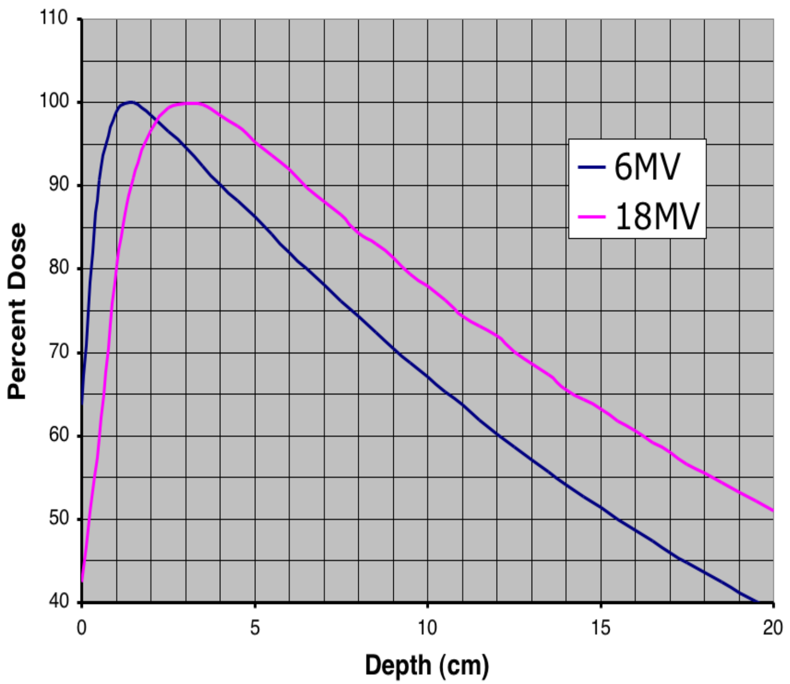
Dose Calculation/Planning

And now we switch gears…..

I. Simple field properties
II. Parallel opposed, Multiple fields
III. Modifiers: wedges, blocking, bolus
IV. Inhomogeneities
V. Field Matching
VI. ICRU 50 and 62

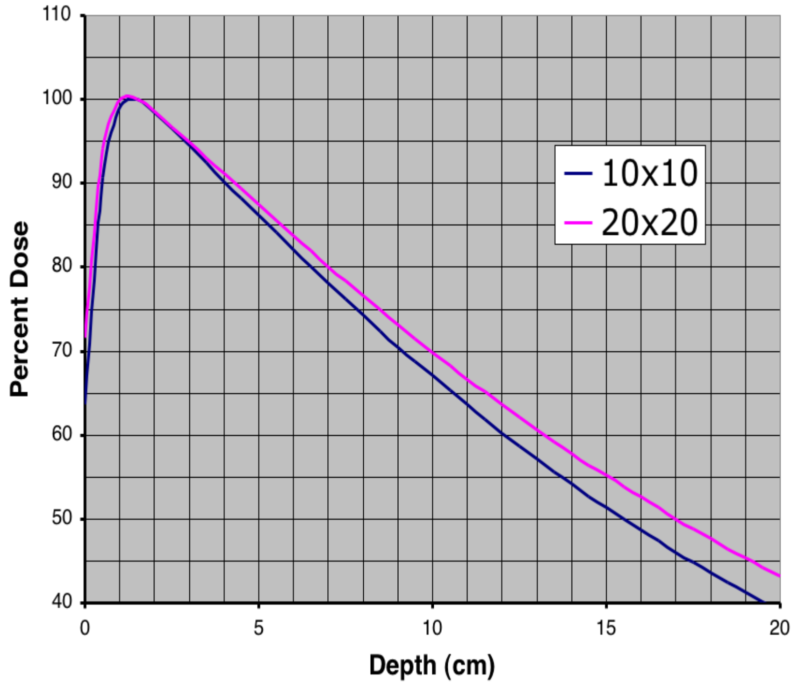
Single Field PDD

6 MV vs 18 MV Percent Depth Dose



1) Higher energy penetrates deeper
2) Less superficial dose for higher energy (improved skin sparing)

10x10 vs 20x20 PDD (6 MV)



1) Larger field size penetrates deeper
2) More superficial dose for larger field size

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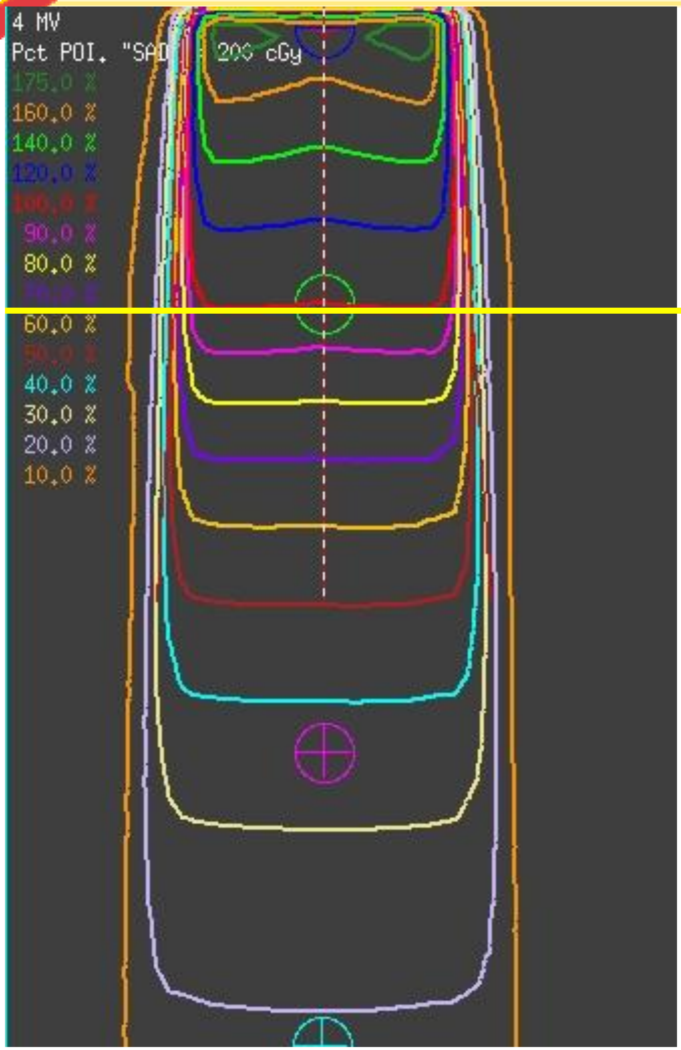
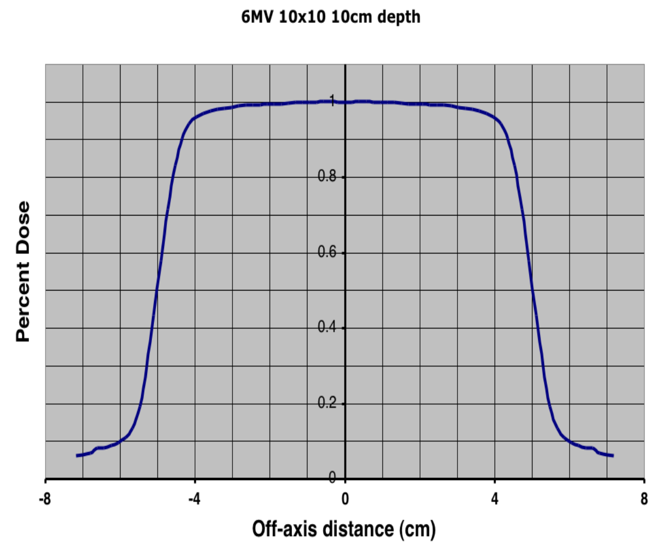
Single Field Profile



Scan across this line and plot dose values as a function of distance across the line



1) Geometric penumbra depends on source size, SAD, SCD
2) Physical penumbra includes geometric and scatter. Eg. "80-20" is the distance between the 80% and 20% levels in the profile

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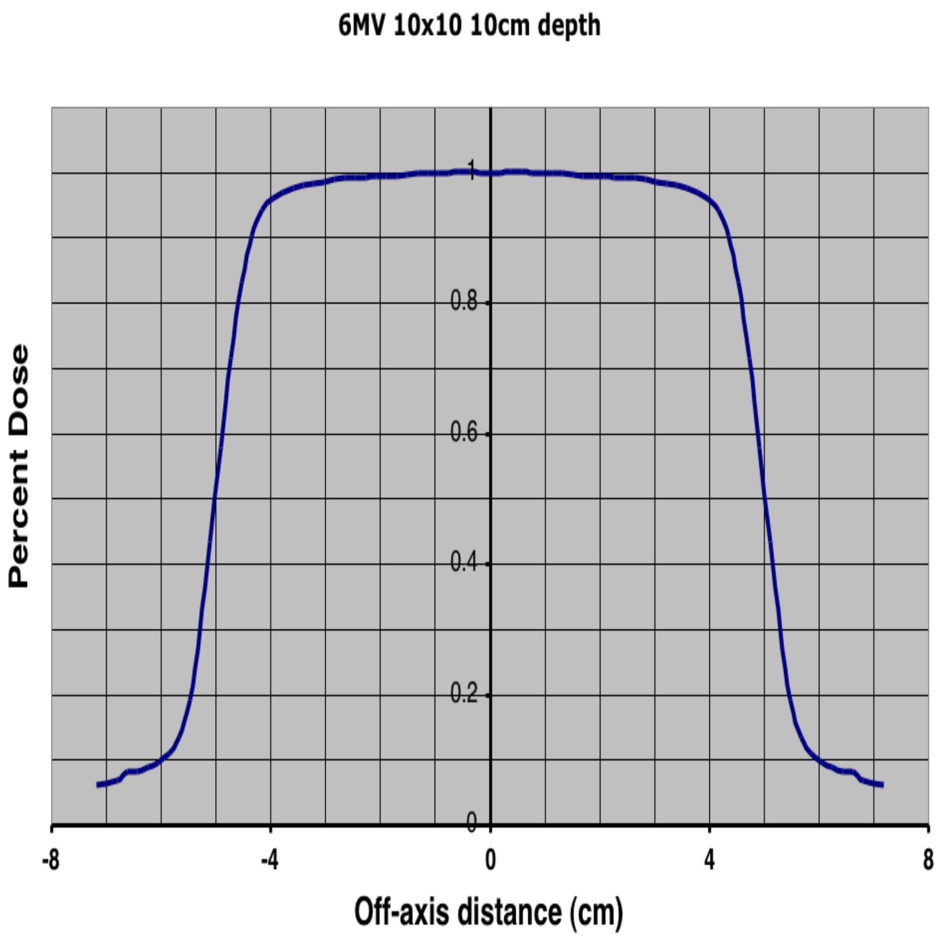
Single Field Profile



Central region: Flatness

Edge of field: Penumbra

Geometric penumbra depends on source size (*SS*), *SPD* (source to measurement plane), and source to collimator distance (*SCD*)

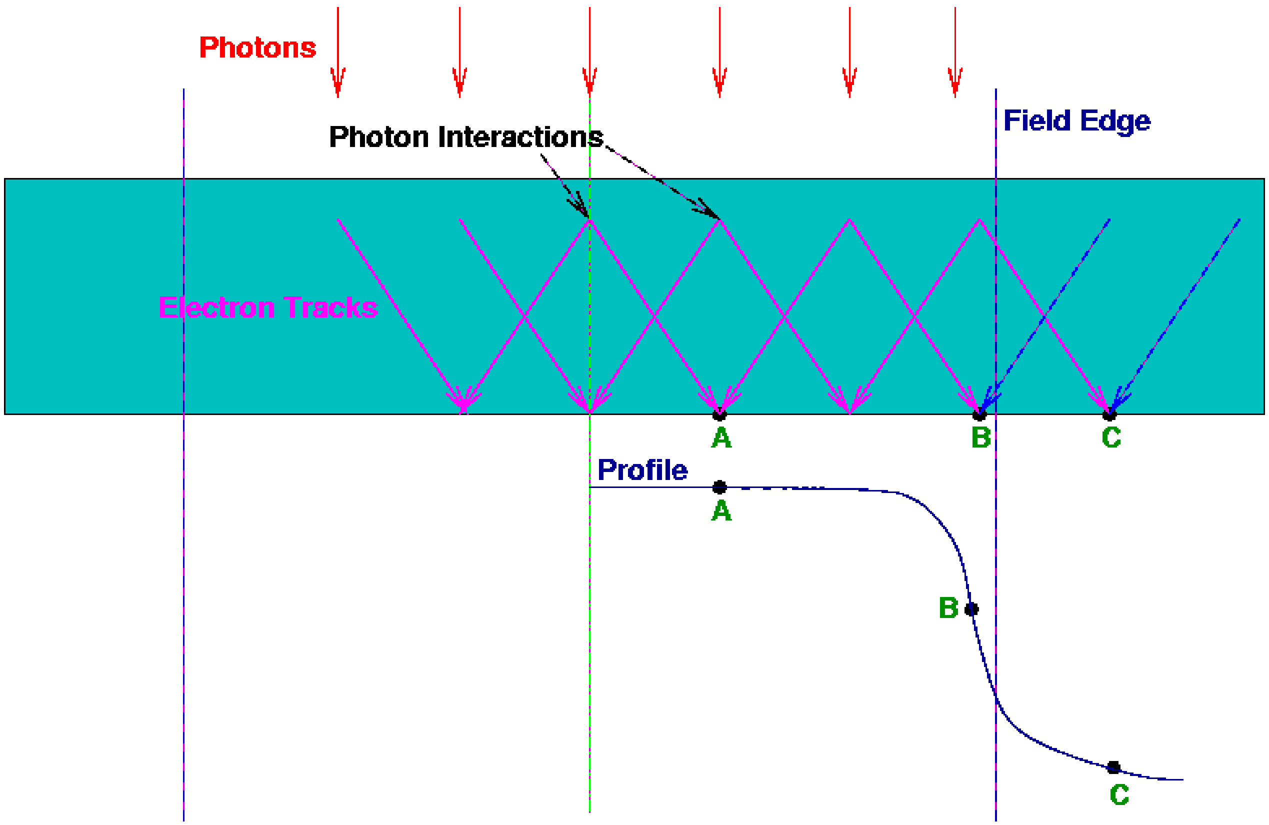
$$p = \frac{SS(SPD - SCD)}{SCD}$$

1) *SS* increase…. *p* increase
2) *SPD* increase…. *p* increase
3) *SCD* increase…. *p* decrease

Physical penumbra depends on both geometric and radiation effects (scatter)

Physical Penumbra

Lateral electronic equilibrium

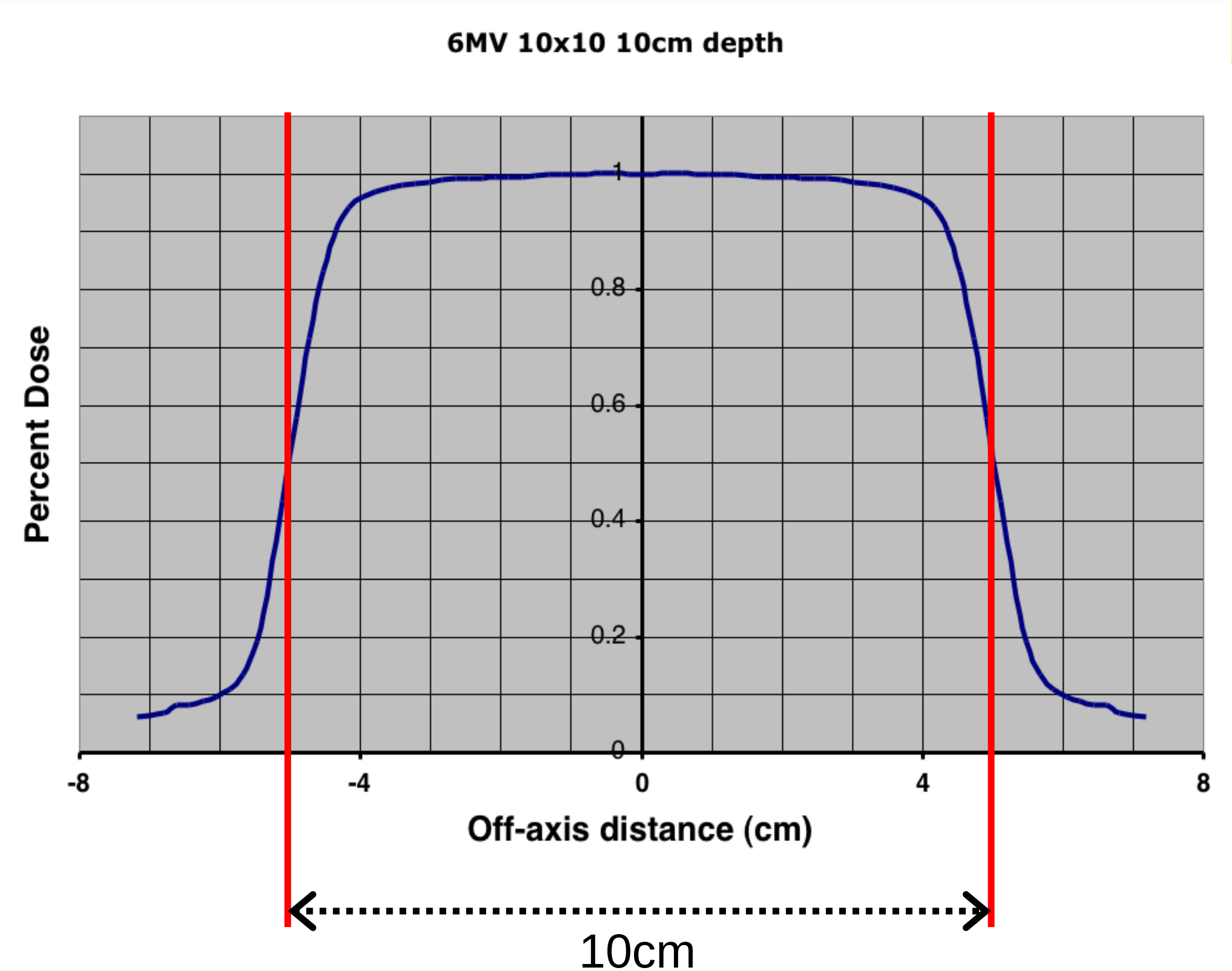


Point A: Receives electron tracks from all directions

Point B: Inside field, but receives fewer electron tracks

Point C: Outside field, but still receives some electron tracks

Field size definition

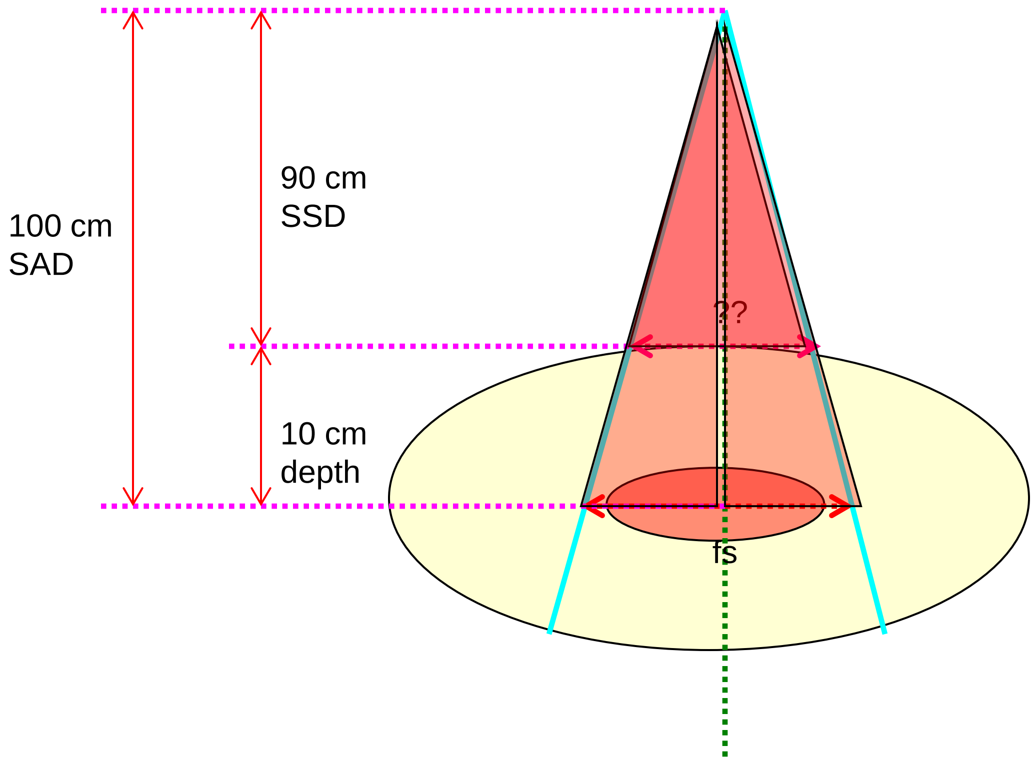


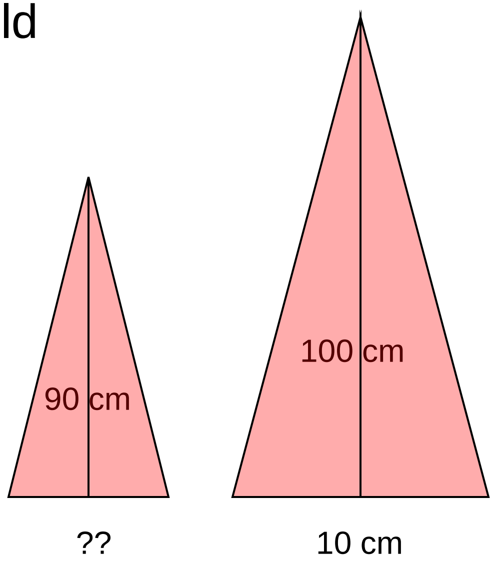
Field size is defined as the lateral distance between the 50% isodose line at a reference depth (eg. 10 cm) at SAD.

The light field projects the field size at SAD

A field size question

A 10x10 field is used to cover a tumor at 10 cm depth. If the center of the tumor is placed at the isocenter (100 cm SAD), what is the approximate size of the light field projection on the patient's skin?





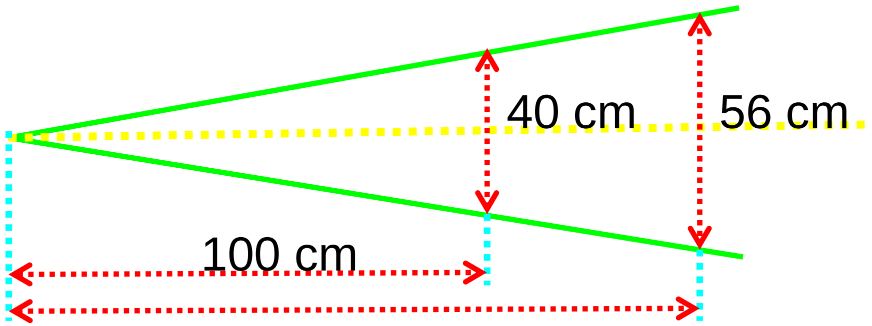
Similar triangles:

$$\frac{??}{90} = \frac{10}{100} \qquad ?? = \frac{10 \times 90}{100} = 90$$

Projects to 9x9 on skin

Similar triangles

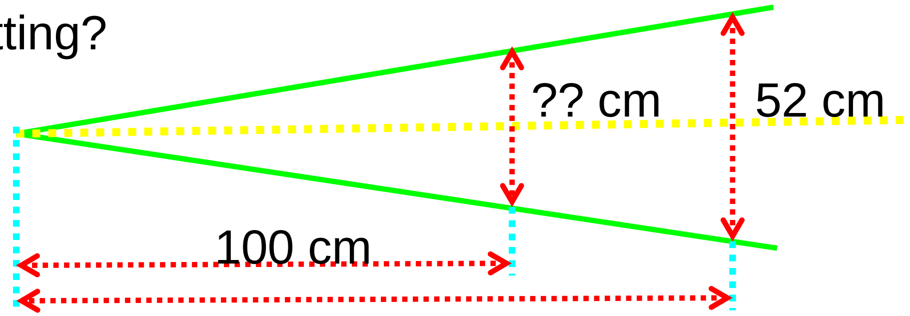
At what SSD will a field size of 40x40 (on a 100 SAD machine) diverge to 56x56?



$$\frac{??}{56} = \frac{100}{40}$$

$$?? = \frac{56 \times 100}{40} = 140$$

A patient's spine is treated at extended distance in order to obtain a large enough field. The total length is 52 cm on the skin and the SSD is 135 cm. What is the collimator setting?



$$?? = \frac{100 \times 52}{135} = 38.5$$

Single Field: Treatment

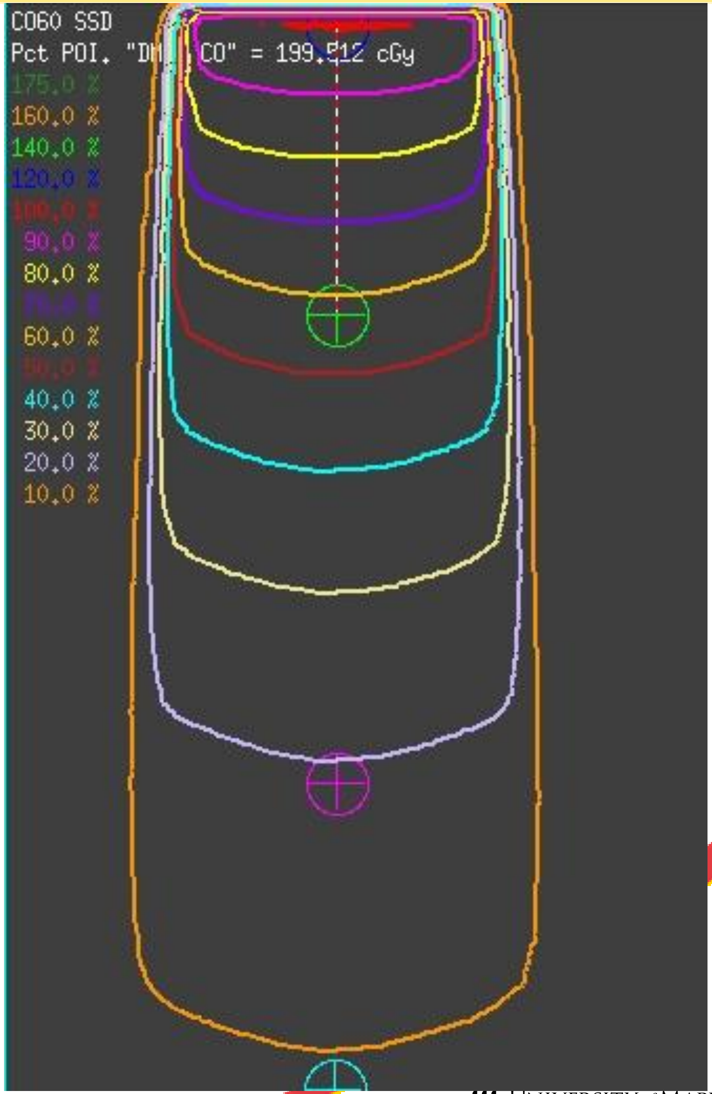
Criteria:

1) Uniformity within +/-5%
2) Max dose <110%
3) Normal critical structures don't receive doses beyond tolerance

Types of beams:

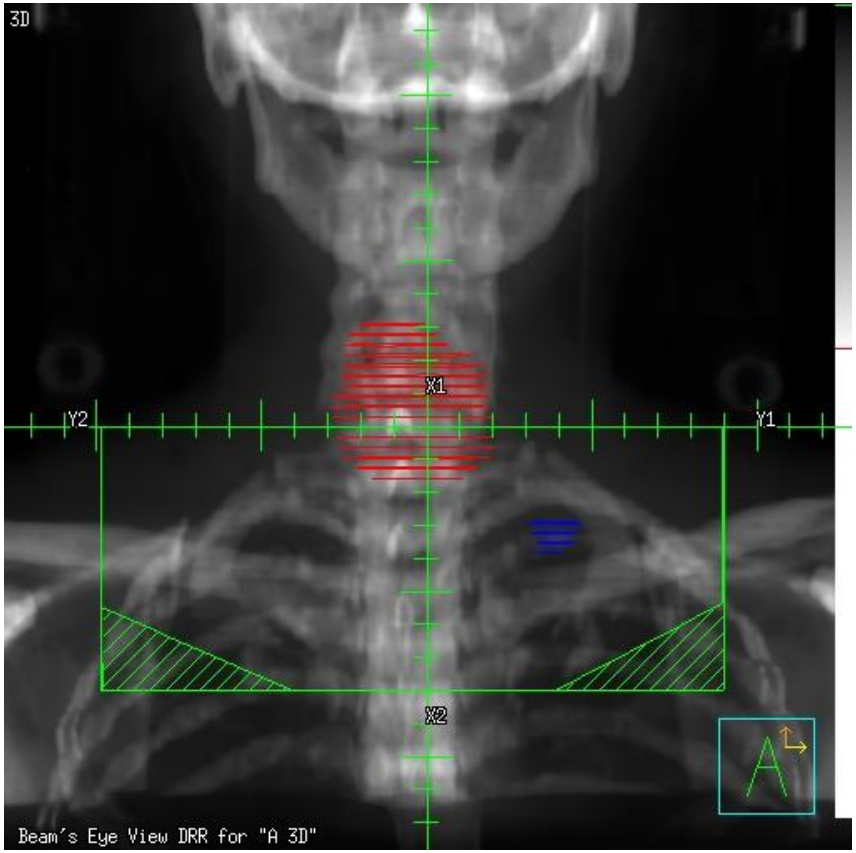
1) Superficial: a few millimeters (skin cancer, etc)
2) MV beams not usually used for single beam treatments. What types of treatments are they used?

Any benefits???

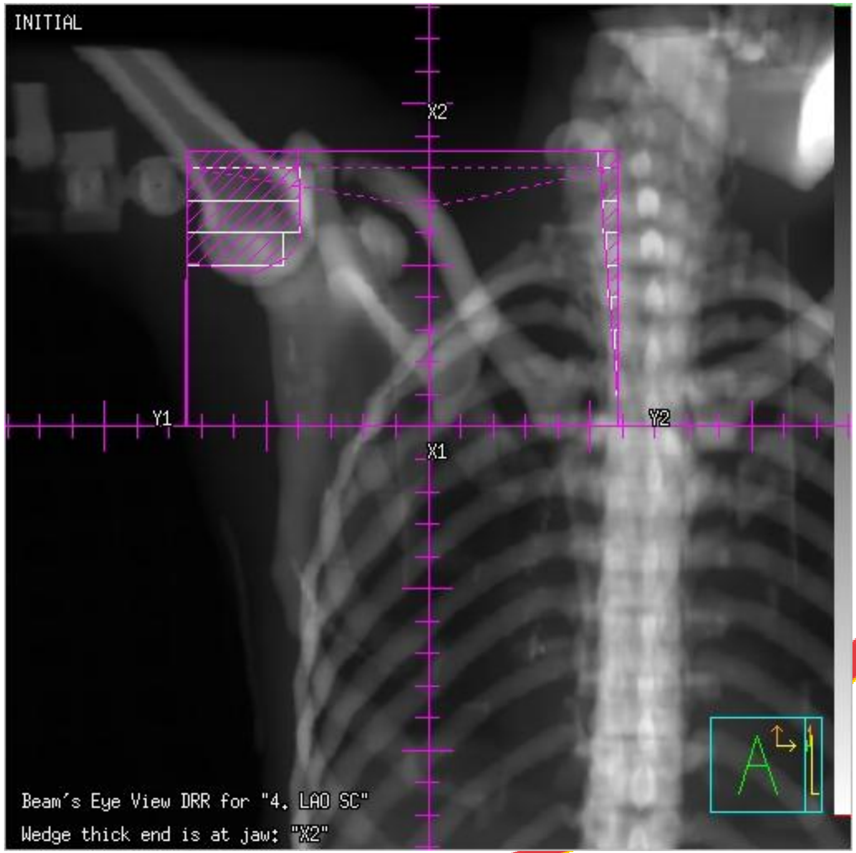


Megavoltage single beam treatments

Supraclavicular for head and neck

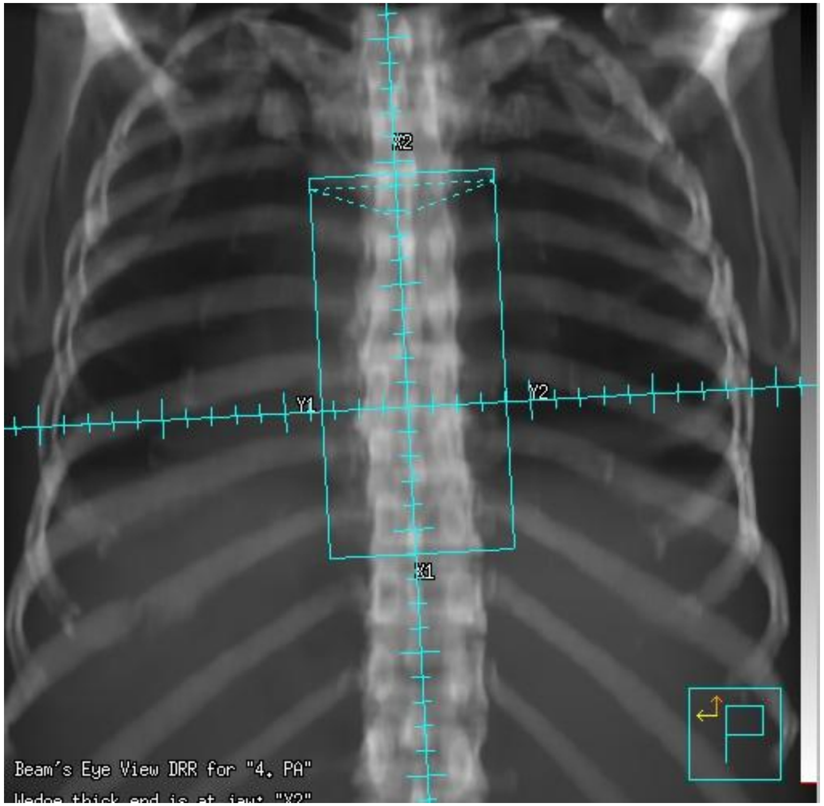


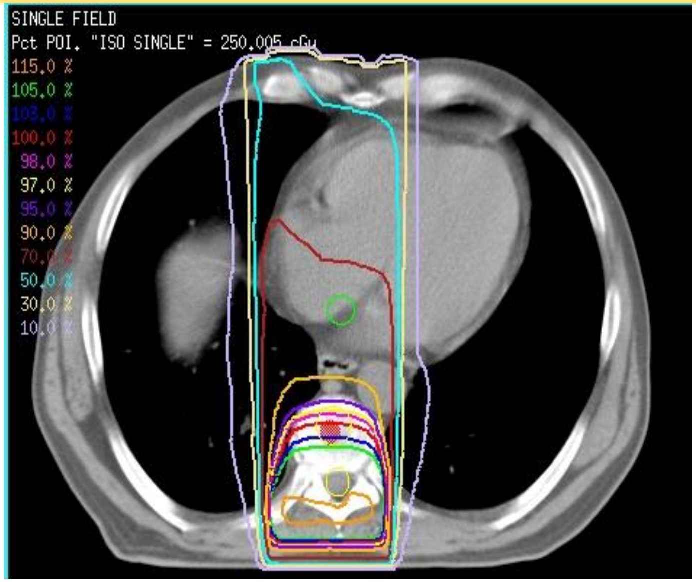
Supraclavicular for breast

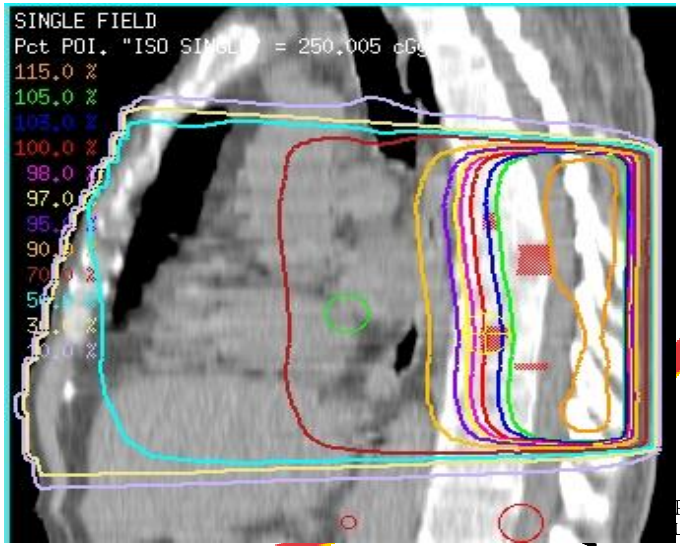


Megavoltage single beam treatments

Single field spine treatment







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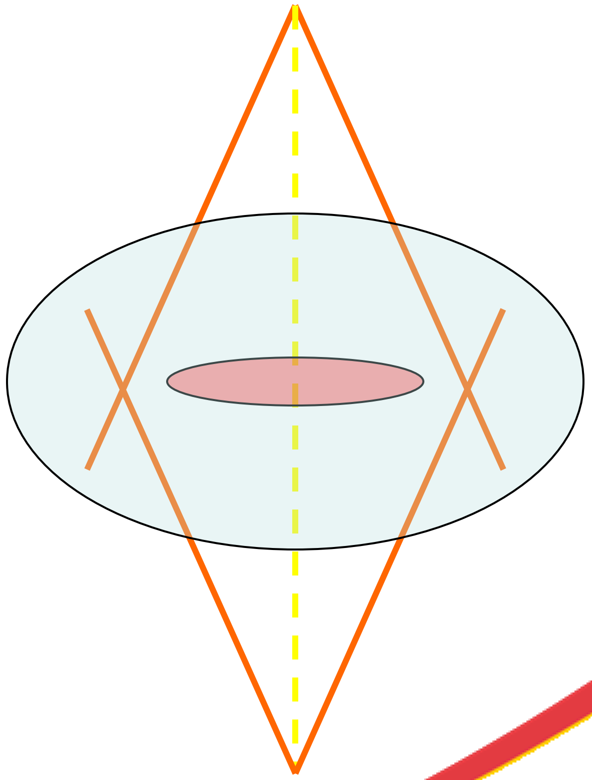
Parallel Opposed Beams

Two beams directed along the same axis from opposite sides

Advantages:

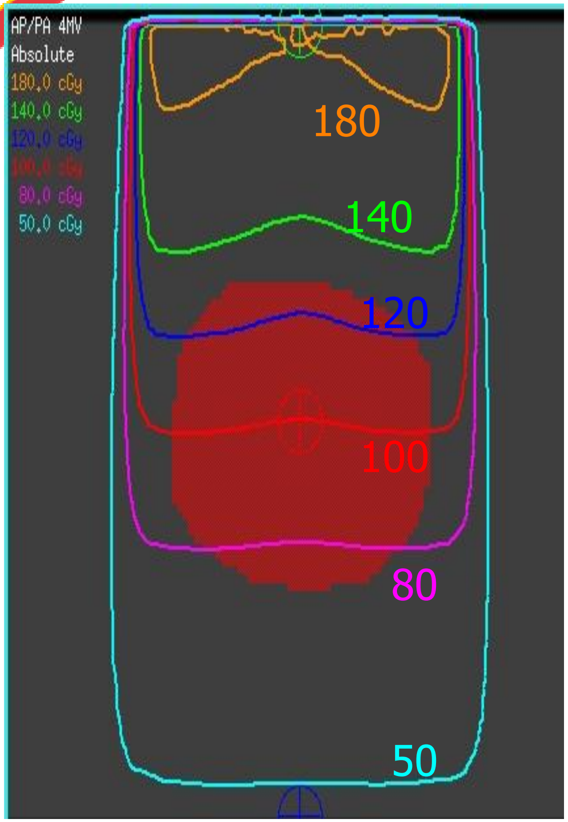
1) Simple, reproducible
2) Tumor dose homogeneity
3) Less chance of geometrical miss

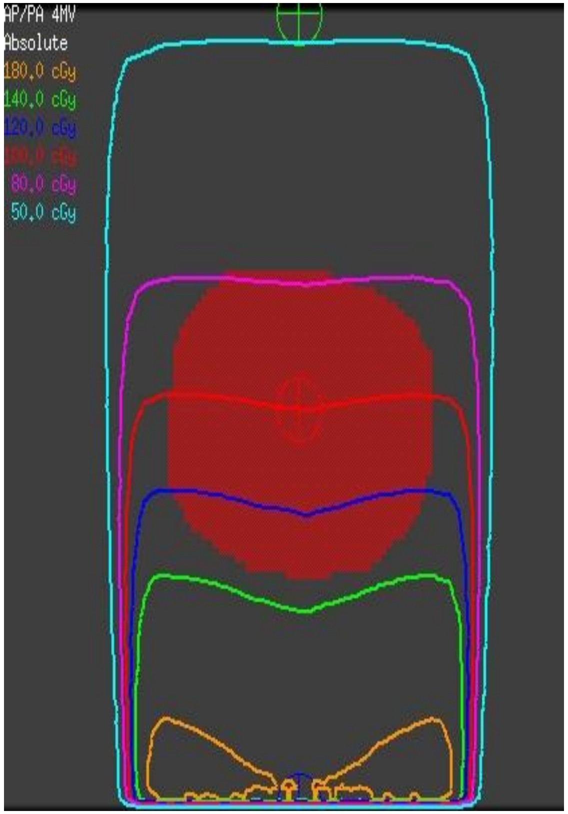


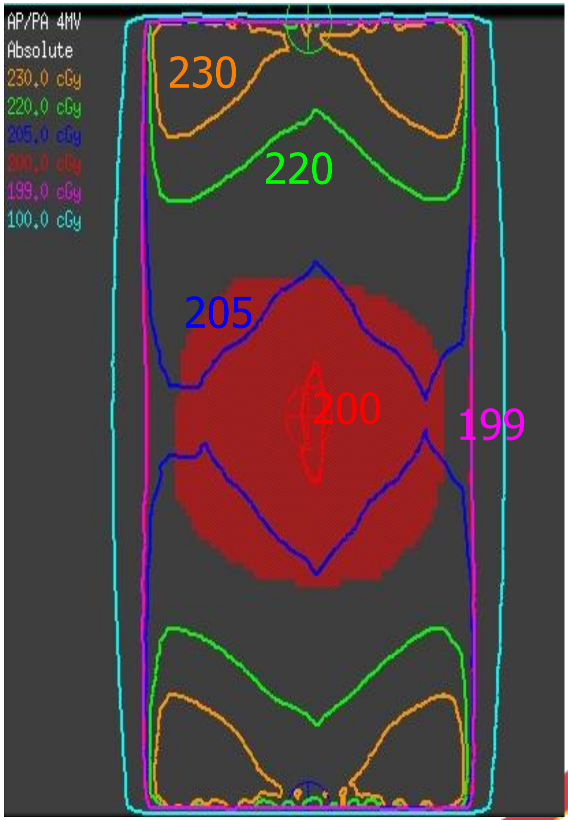
Main disadvantage:

Excessive dose to normal tissue

Parallel Opposed Beams







Combine the AP

With the PA

To get this

230/200 = 1.15 Hot spot
(25cm separation)

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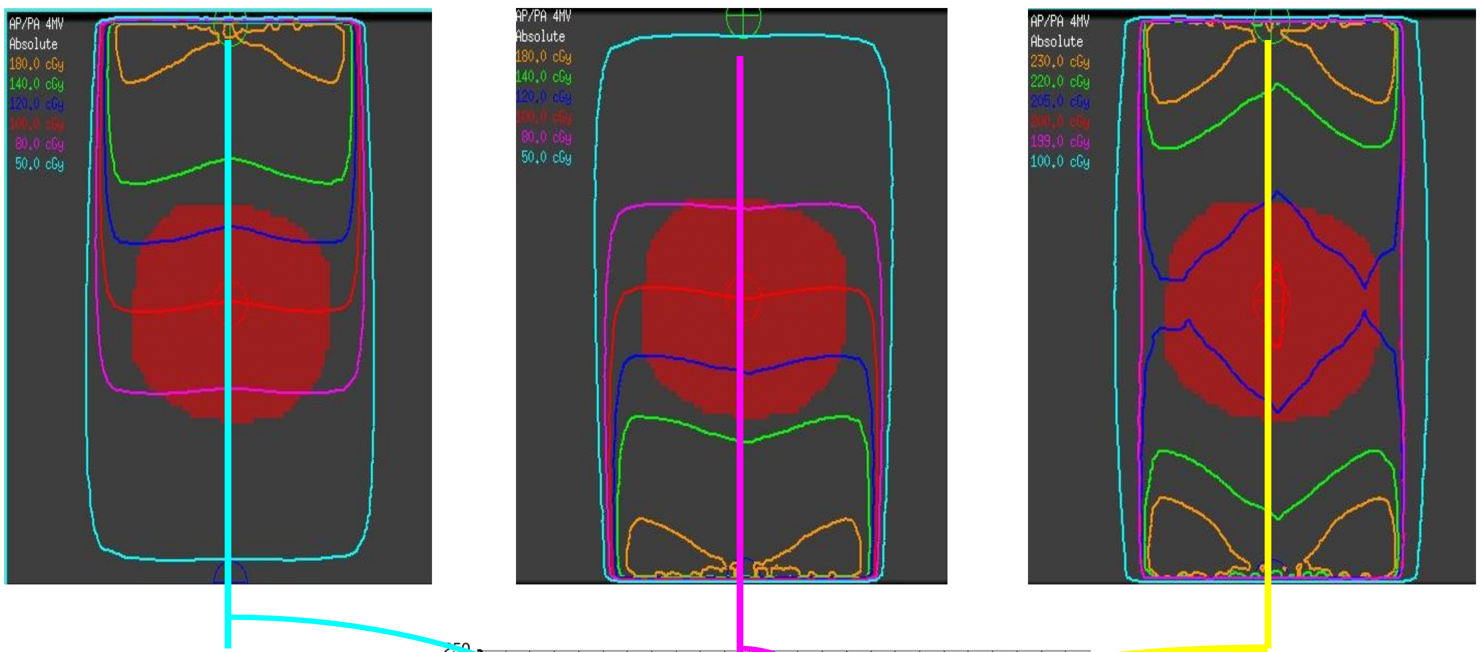
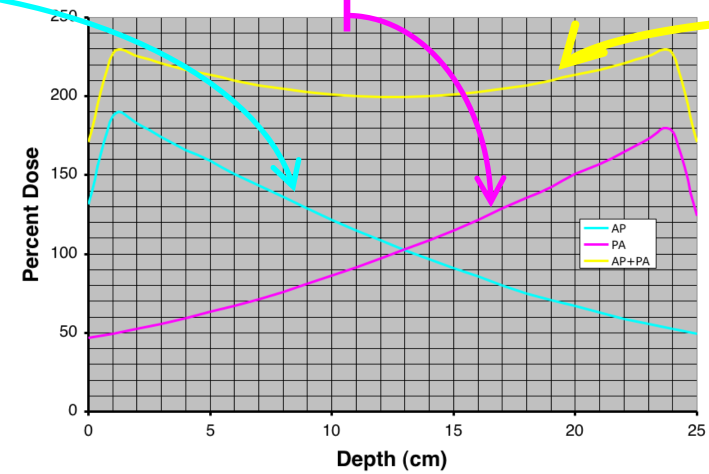
Hot Spots: Thickness and Energy



Scan across these lines and plot dose as a function of distance from the top



Maximum dose occurs at d_{max}

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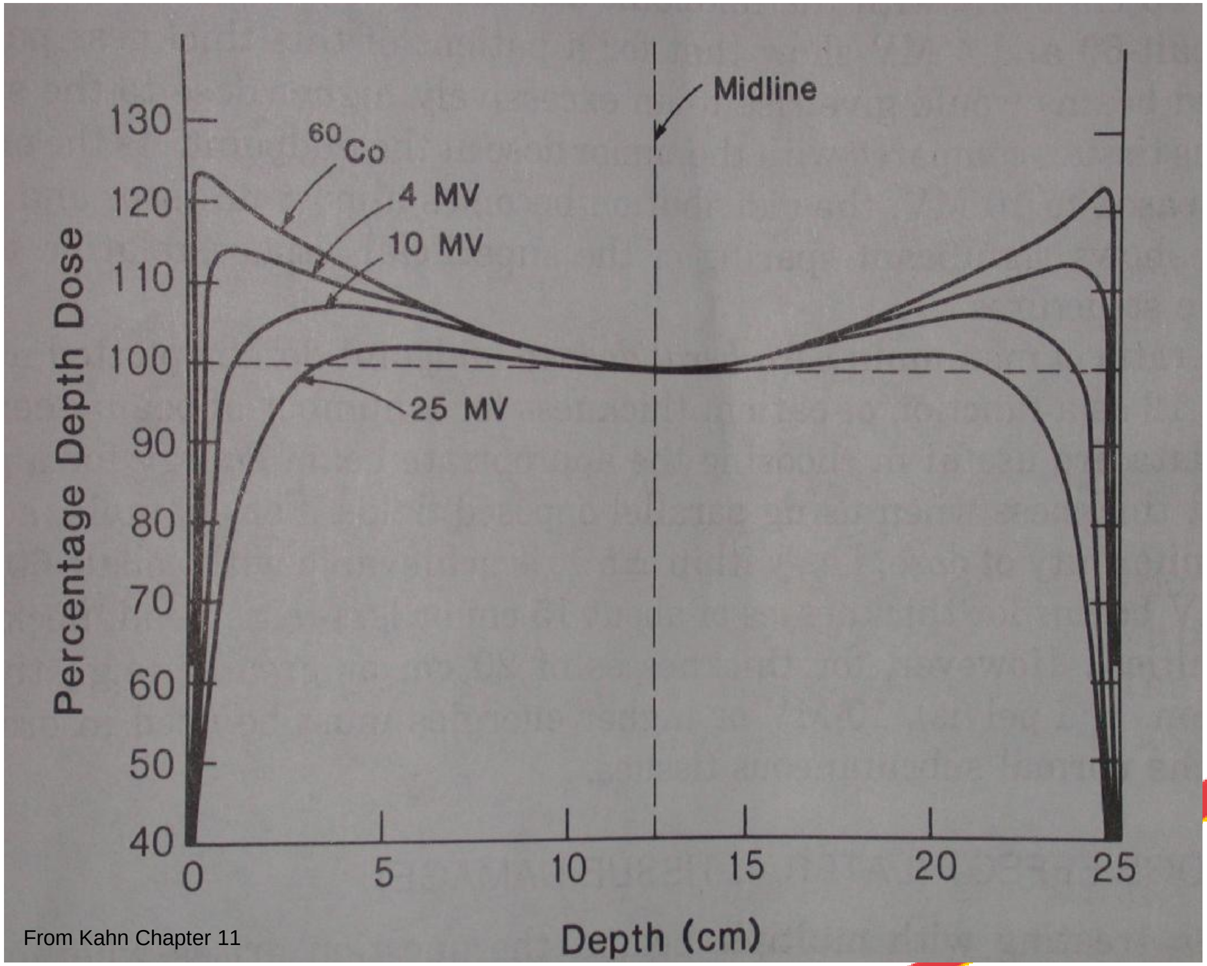
Tissue Lateral Effect

When prescribing to midline for parallel opposed beams, increasing the beam energy results in:

1) Less dose at d_{max}
2) Reduced skin dose
3) Improved uniformity

Q: When would we ***NOT*** want to use parallel opposed higher energy?

A: When you ***DO*** want to treat close to the surface. E.g. Traditional H&N lateral fields.

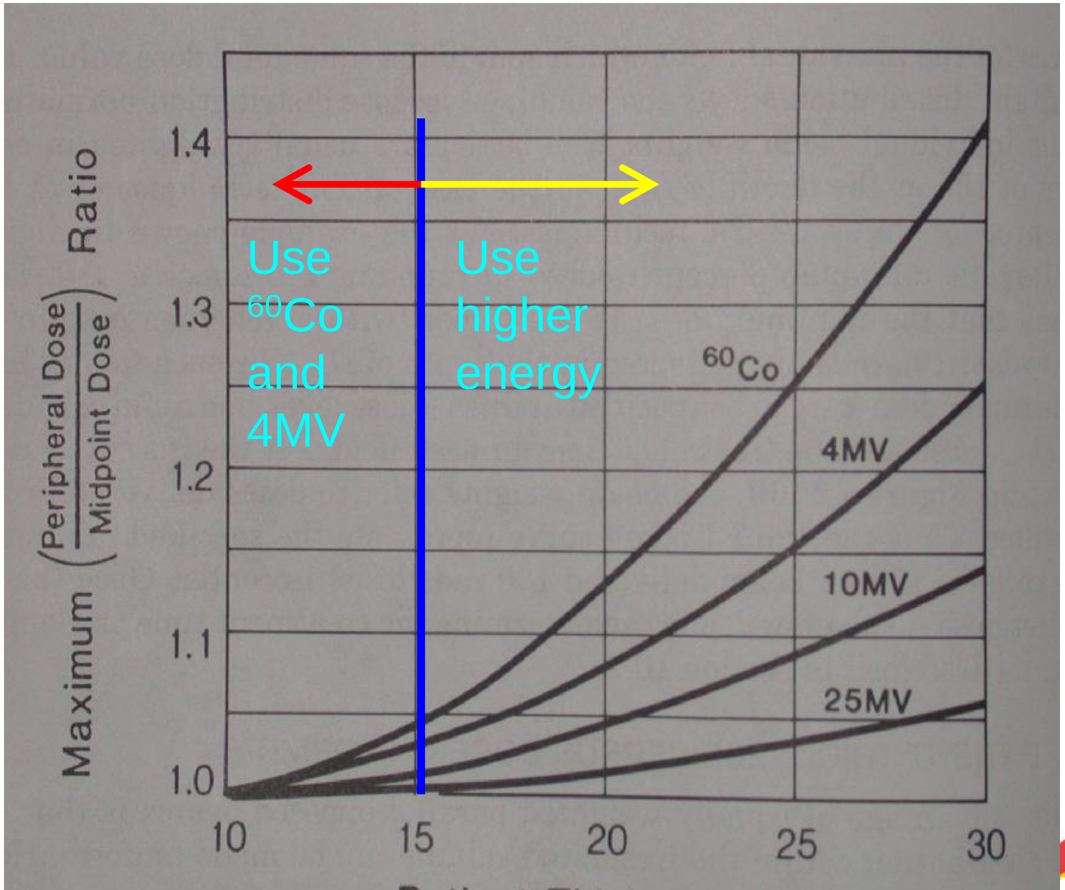


From Kahn Chapter 11

What Energy to Use?

The ratio of maximum peripheral dose to midpoint dose guides our energy selection for parallel opposed beams

Hope to achieve +/-5% uniformity



From Kahn Chapter 11

A question (straight out of RAPHEX 05)

The total dose delivered at d_{max} from a pair of parallel opposed fields, expressed as a percentage of the total dose at midplane:

A. Decreases as photon energy increases

B. Decreases as field size increases

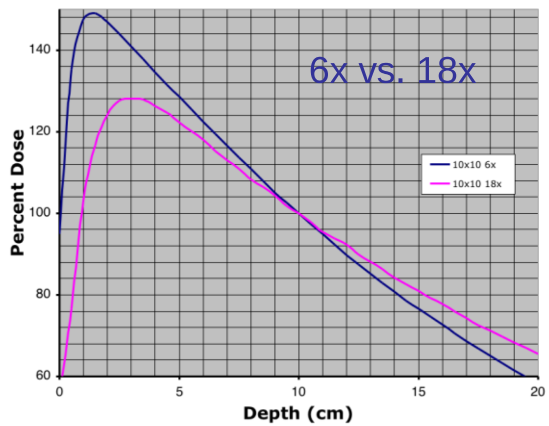
C. Increases as patient thickness increases

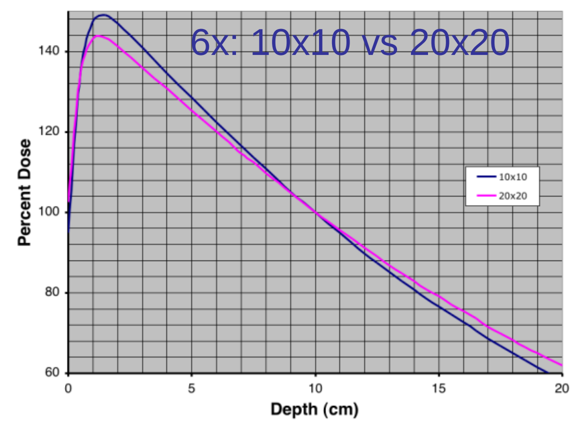
D. Is slightly less for an SSD setup than for an SAD setup

E. All of the above

Remember: Higher PDD at depth means lower dose at d_{max} for parallel opposed beams

We can also think about it this way: If we normalize the PDD curves at depth, we can compare the relative dose at d_{max}.





The answer

A) Decreases as photon energy increases?

Yes, PDD increases with increasing energy.

B) Decreases as field size increases?

Yes, PDD increases with increasing field size.

C) Increases as patient thickness increases?

Yes, PDD decreases with increasing depth.

D) Is slightly less for an SSD setup than for an SAD setup?

Yes, PDD increases with increasing SSD. SSD is greater for an SSD setup.

Treatment Planning Objectives

One of the most fundamental goals in our business is to maximize dose to the target volume while minimizing dose to surrounding normal tissue and organs.

- Number of beams and orientation
- Beam weighting
- Blocking
- Beam modifiers

SSD vs. SAD Technique

SSD

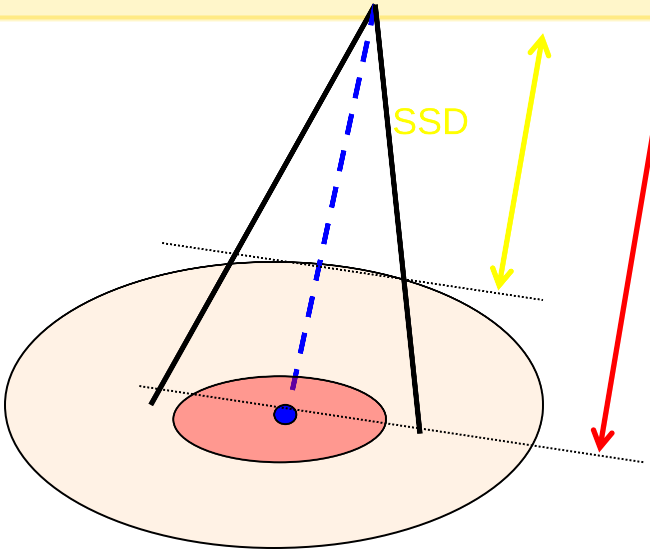
- Set patient up to source to skin distance
- Normalize each field to d_{max}
- Patient moved for each field
- Sometimes necessary to achieve desired field length

SAD

- Set patient up to isocenter (SAD)
- Normalize to isocenter
- Gantry moved for each field
- Easier patient setup
- Improved accuracy over SSD technique

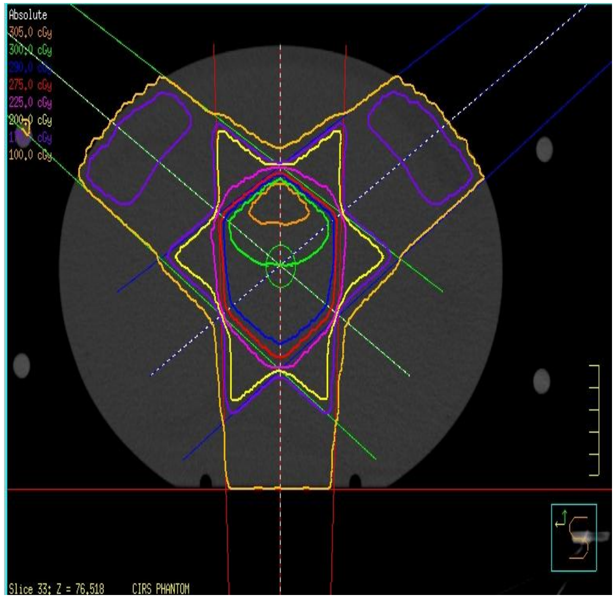
Isocentric (SAD) technique

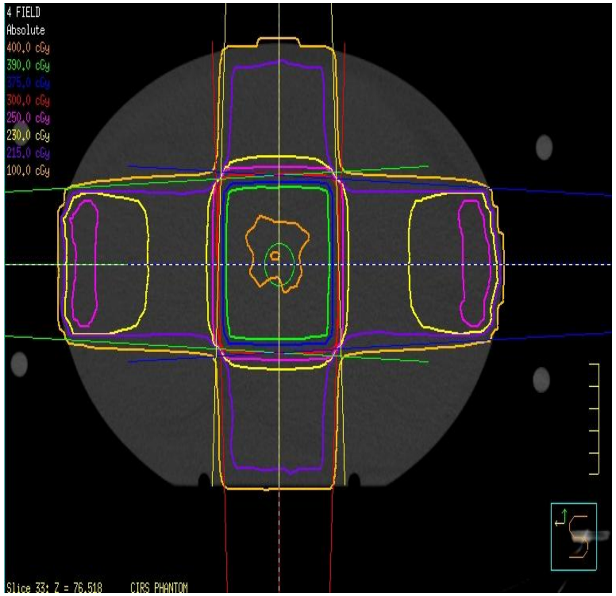
Gantry rotates through 360º with the isocenter defined as the point of intersection of the collimator axis and the gantry axis of rotation.

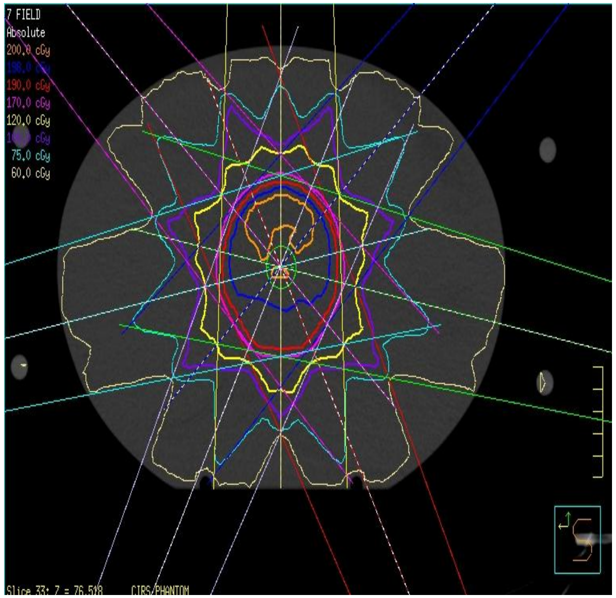


1) Place isocenter somewhere in the patient
2) Direct beams from different directions
3) SAD constant
4) SSD = SAD - d (d is depth of the isocenter)
5) Position patient once, then move gantry for subsequent beams
6) Relies primarily on the machine isocentricity

Field Arrangements







3 field: e.g. esophagus

4 field: e.g. pelvis

7 field: semi-typical IMRT

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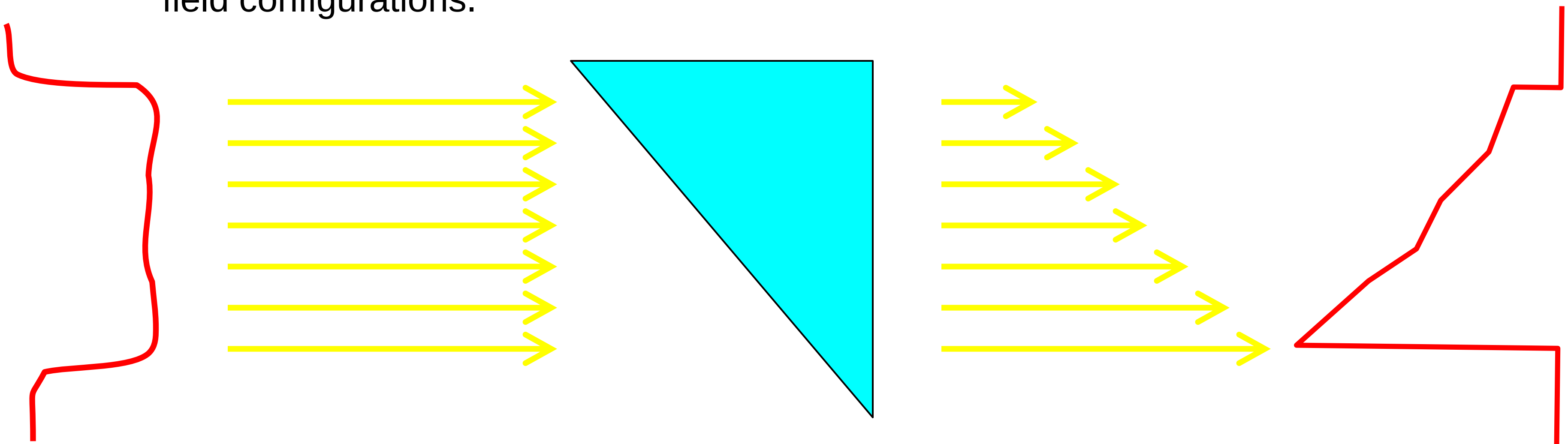
Wedge Filters

A wedge filter compensates for tissue irregularities and also “asymmetric” field configurations.

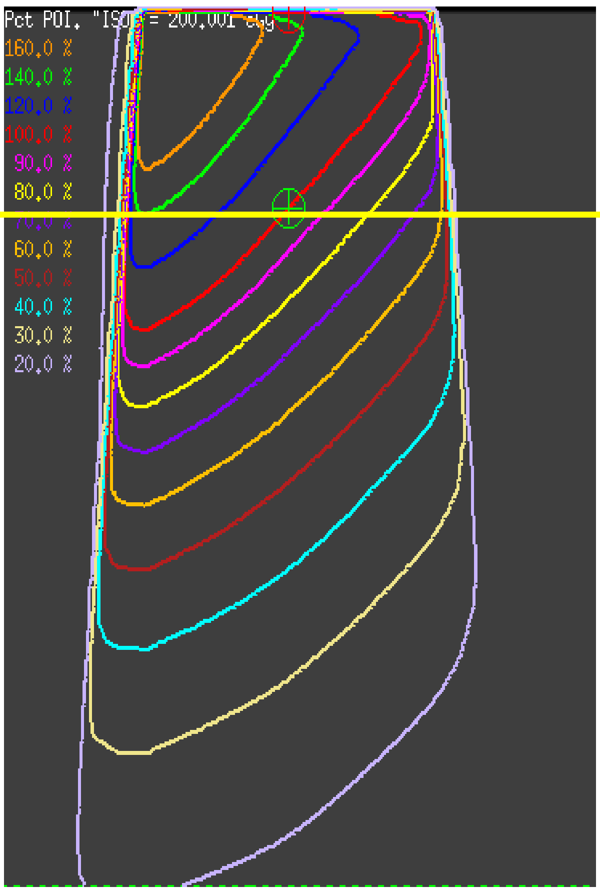


Open Field Uniform intensity

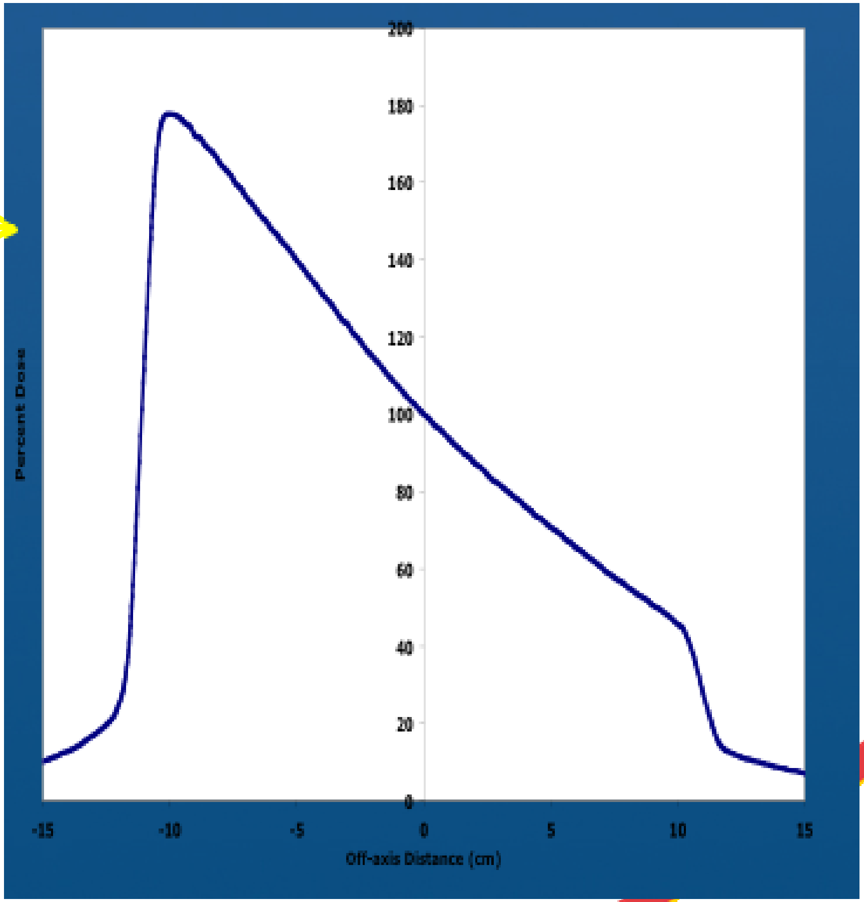
Wedge Filter

Wedged Field Varying Intensity

Wedge Filter: Isodose distribution

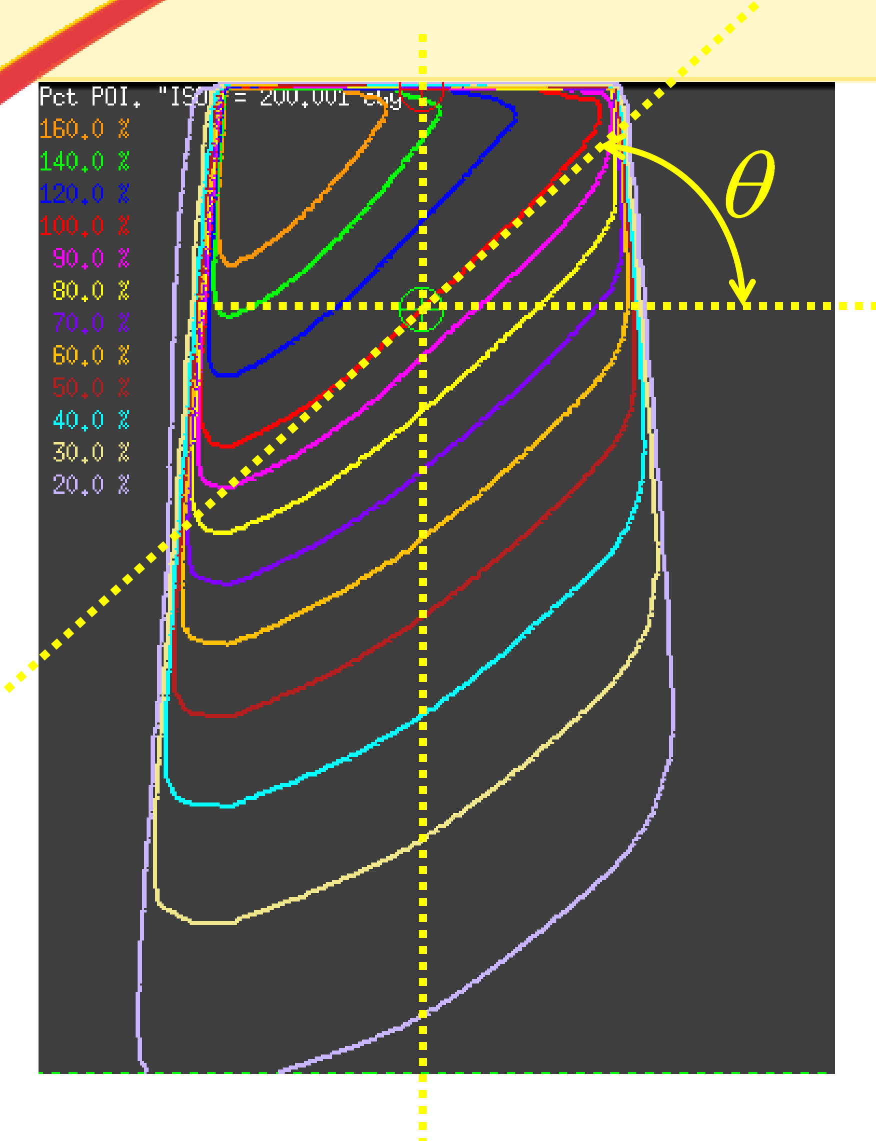


Scan across this line and plot dose values as a function of distance across the line



1D Profile

Wedge angle definition



The wedge angle is the angle through which an isodose curve is tilted at the central ray of a beam at a specified depth.

Reference depth possibilities

- Function of field size
- 50% isodose curve and CAX
- **Standard depth. Current recommendation is 10 cm**

Wedge Factor and Beam Quality

The wedge factor (WF) is the ratio of the dose with the wedge in the field (D_w) to that without the wedge in the field (D_o) at a specified depth

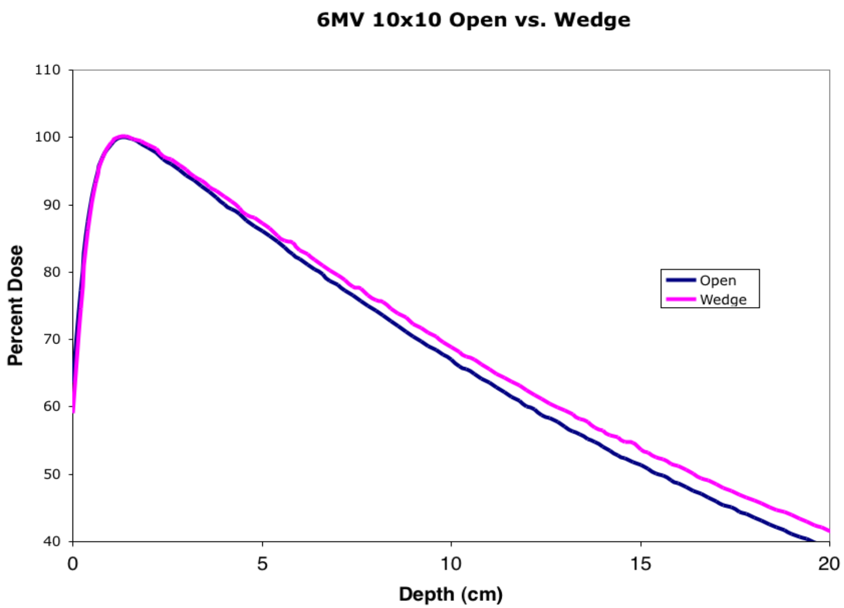
$$WF(fs,d,E) = \frac{D_w(fs,d,E)}{D_o(fs,d,E)}$$

Where fs is the field size, d is the depth, and E is the beam energy

For x-rays the presence of a wedge

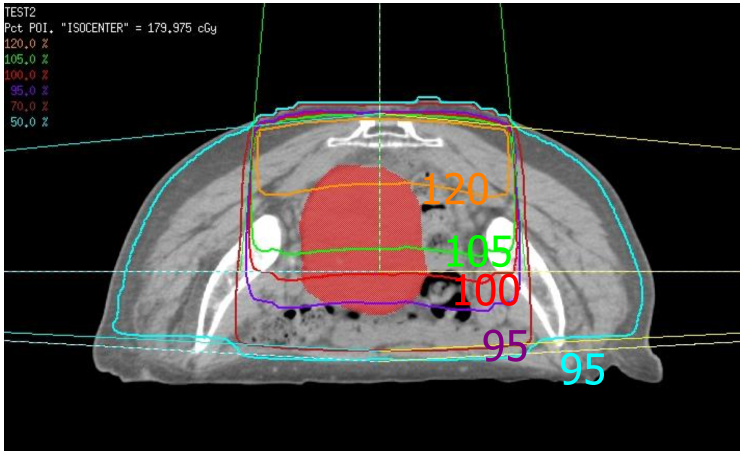
- Preferentially attenuates lower energy photons
- Compton scattering (to a lesser extent)
- Overall effect is a harder beam

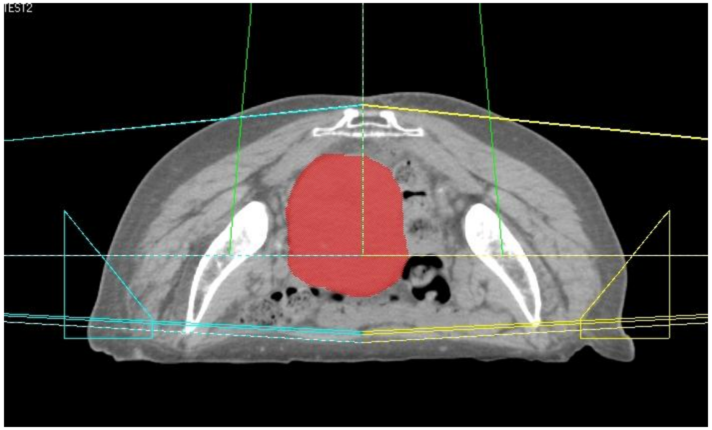
(most prominent for lower energy and smaller fields)



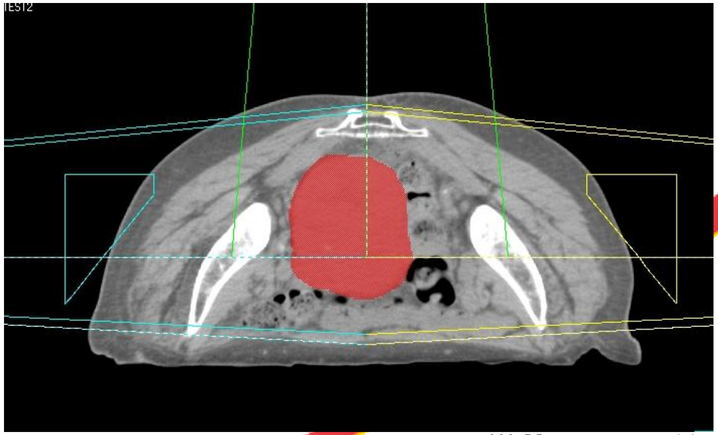
Example: 3 Field

Which wedge orientation will fix the distribution on this 3-field pelvis (AP+Laterals)?

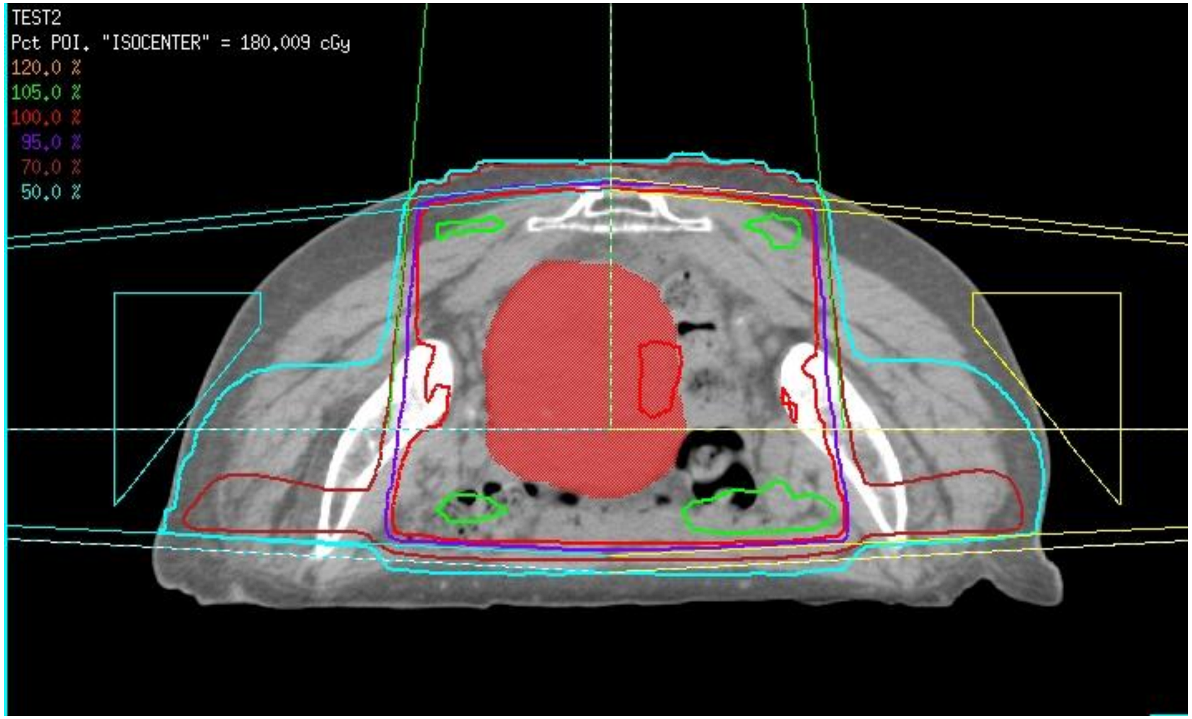




OR



Example: 3 Field Pelvis

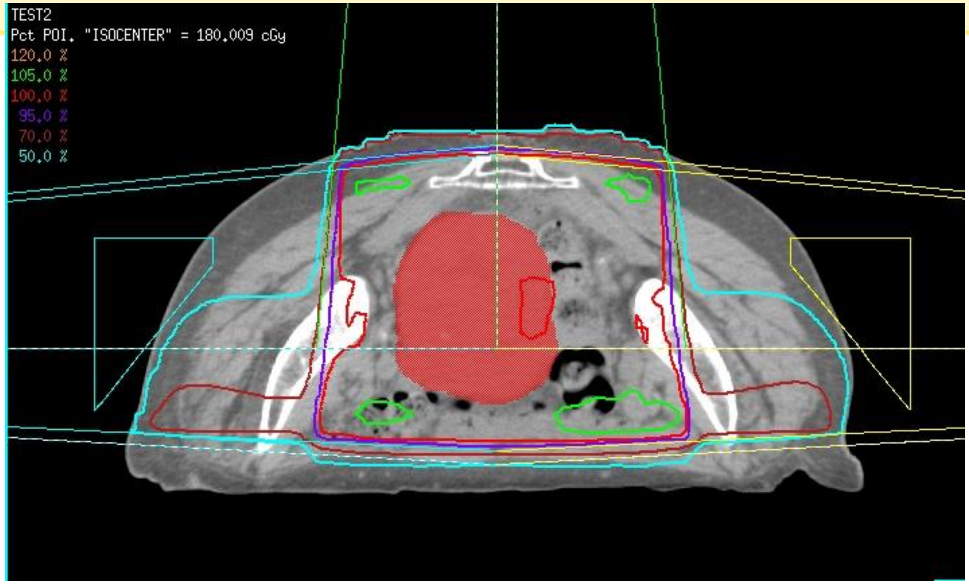


With 60º wedges, what would the relative weight of the open field be compared to that in a plan which utilizes 45º wedges? Greater, less, or the same?

Answer: Greater

More open means more dose posterior from open. Need more wedge to compensate

Example: 3 Field Pelvis



In this 3 field pelvis plan, the wedged lateral 18MV beams each contribute 40 cGy per fraction to the isocenter. The wedge factor for this field is 0.305 and the TMR is 0.752. The output factor (includes S_c and S_p) is 1.03. The machine is calibrated to give 1cGy/MU at dmax 100 SAD. What is the MU setting?

$$MU = \frac{D}{CF \times OF \times WF \times TMR}$$

$$MU = \frac{40cGy}{1cGy/MU \times 1.03 \times 0.305 \times 0.752} = 169\,MU$$

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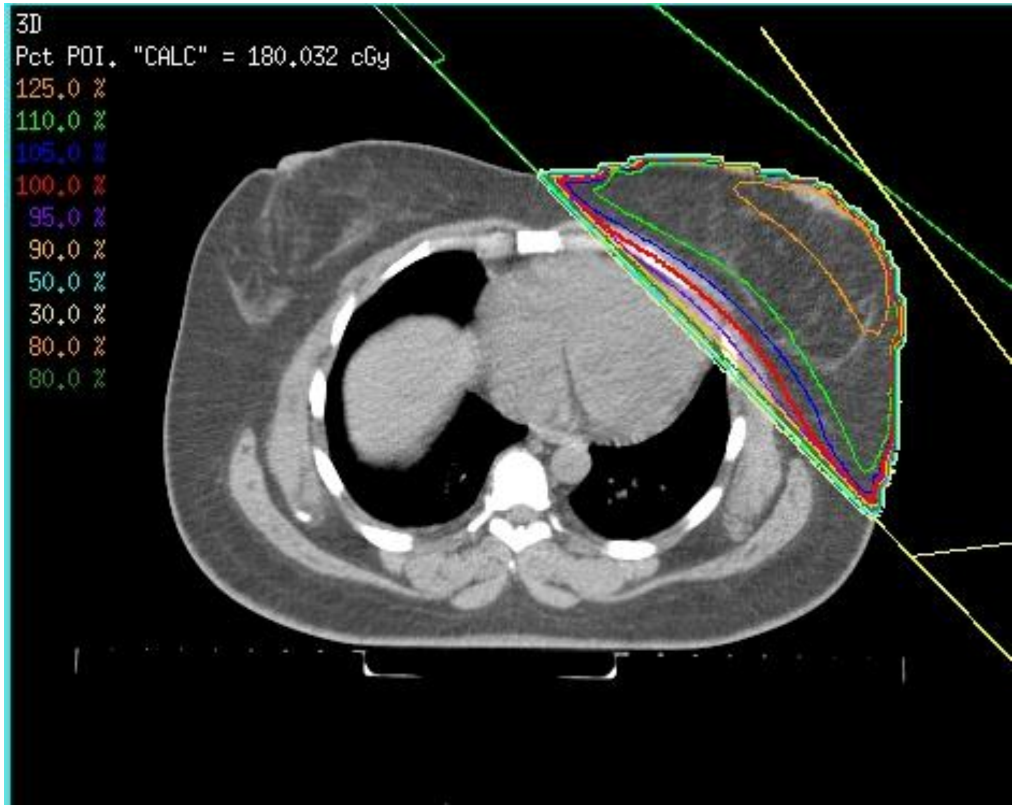
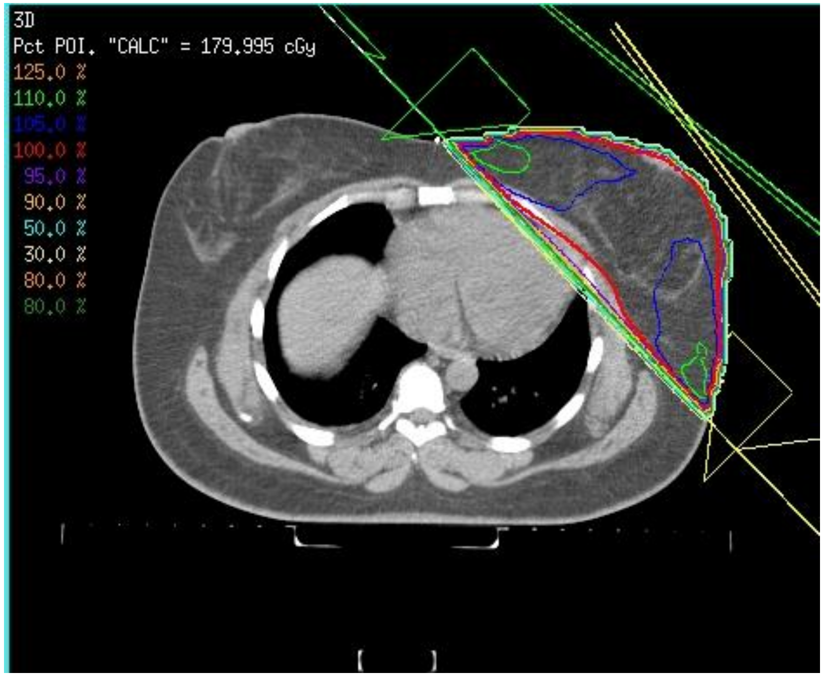
Example: Breast

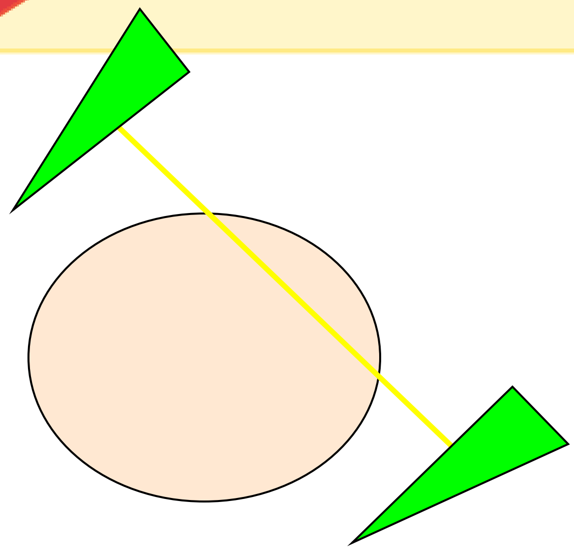
Which wedge orientation will fix the distribution on this breast case (tangents)?



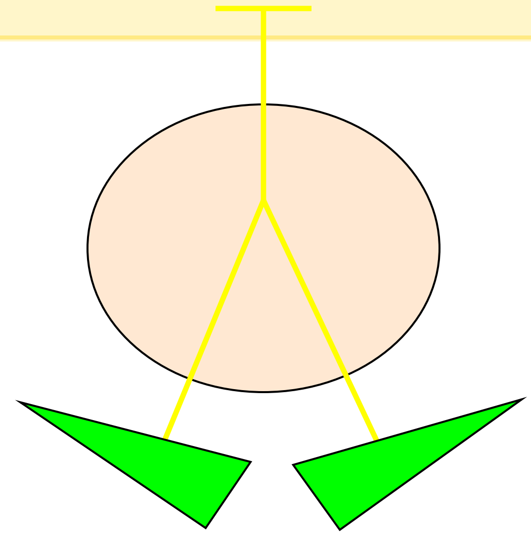
Example: Breast



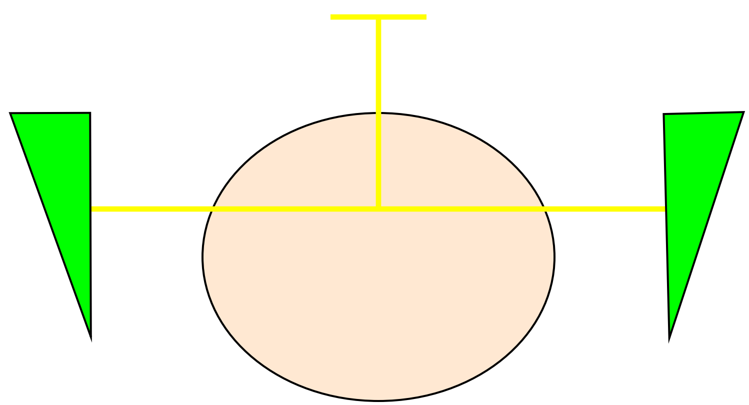
Some wedge examples



Tissue compensation



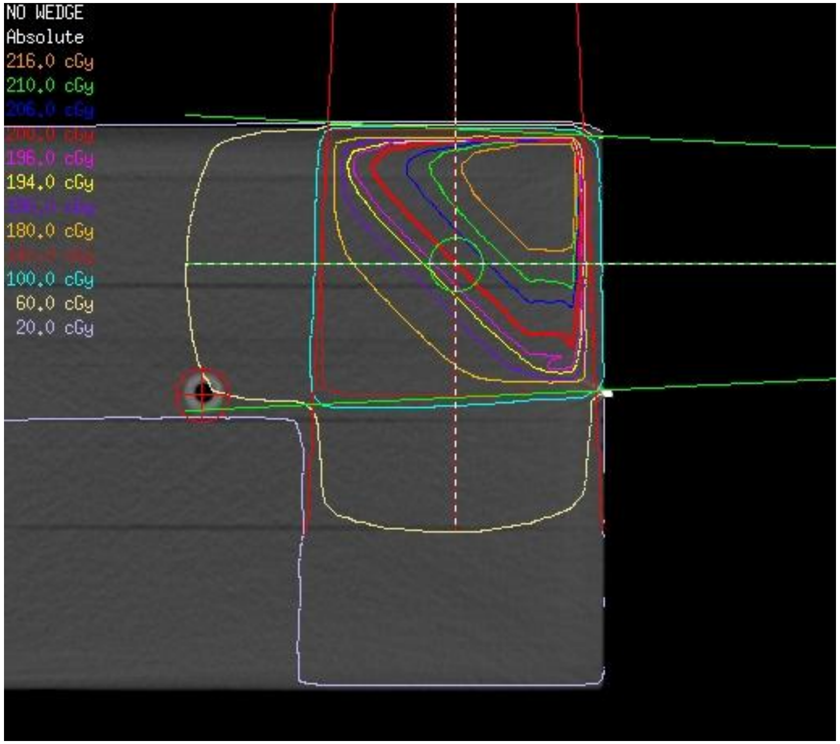
Dose compensation



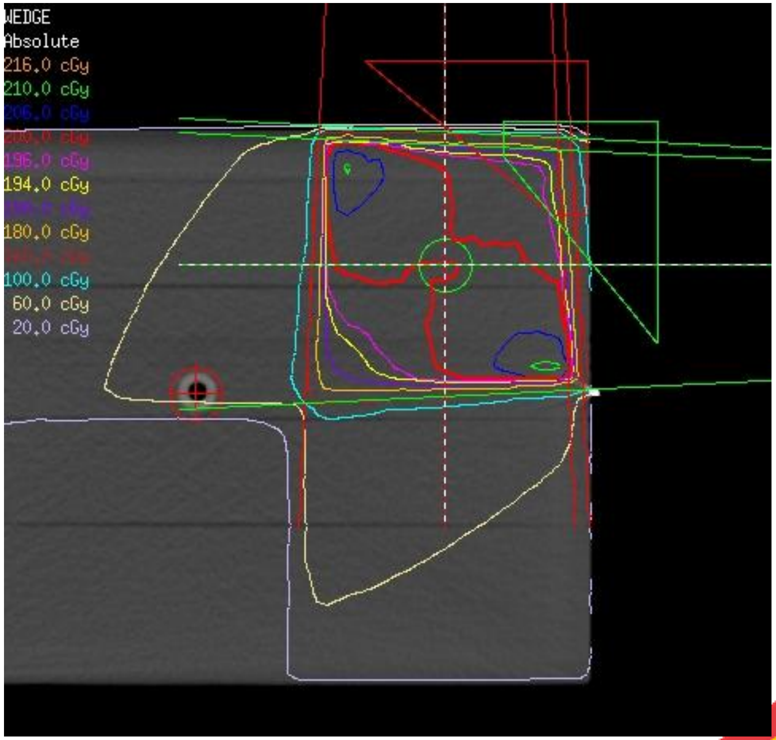
Dose+tissue compensation

Wedge Pairs

Relatively superficial targets can be treated with two wedged beams directed from the same side of the patient



No wedges



With wedges

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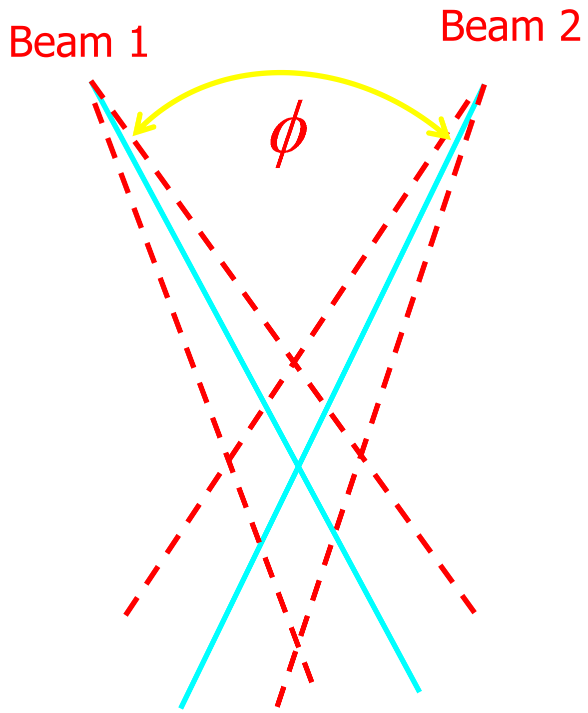
Wedge Pairs: Hinge Angle

The required wedge angle θ can be estimated by:

$$\theta = 90^o - \phi/2$$



This relationship assumes a flat surface. In practice, patient surfaces are curved and/or irregular. You need to adjust wedge angles for this

Blocking: Lead and Cerrobend

Lead

- density of 11.3 g/cm^3
- 6MV HVL = 13.6 mm
- 18MV HVL = 14.0 mm
- Standard shielding: 70 mm (5 HVL or about 2% transmission)

Cerrobend

- low melting point
- density of 9.4 g/cm^3 (83% of lead density)
- 6MV HVL = 15.9 mm
- 18MV HVL = 16.1 mm
- Standard shielding: 76 mm (4.8 HVL or about 3.5% transmission)

Blocking: MLC

Multi-leaf collimator

- Tungsten alloy
- density range 17.0 to 18.5 g/cm^3
- about 2% primary transmission
- "traditional" 1 cm leaf width (SAD)
- "newer" 5 mm leaf width near center

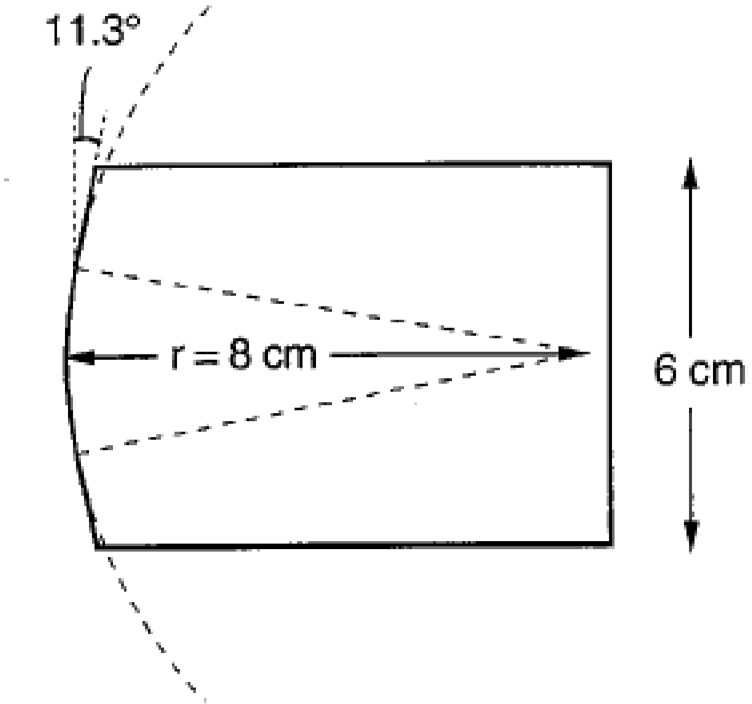
Advantages

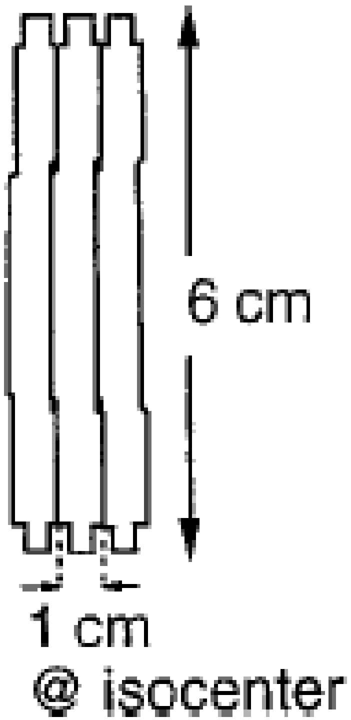
- Eliminate cutting blocks
- Faster set-up
- Transmission slightly smaller

Disadvantages

- "Island blocks" (eg larynx) not possible
- Smaller precise conformal fields
- Leaf direction conflicts w/wedge direction
- Leaf length sometimes imposes field limits

MLC: leaf design





Rounded leaf edge: maintain geometric penumbra at any leaf position in the beam

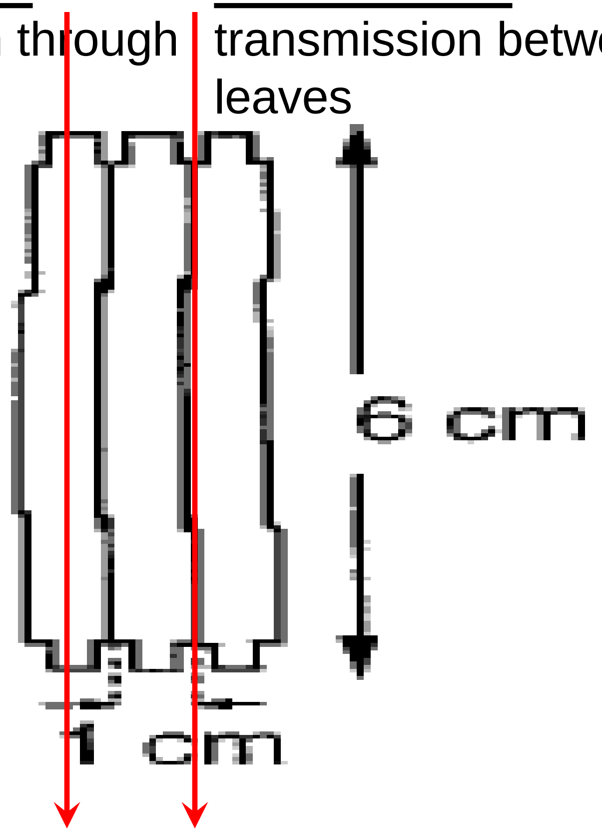
"Tongue and groove": reduce interleaf transmission

Pictures from LoSasso *et al*. Med. Phys. **25**(10) p. 1919 (1998).

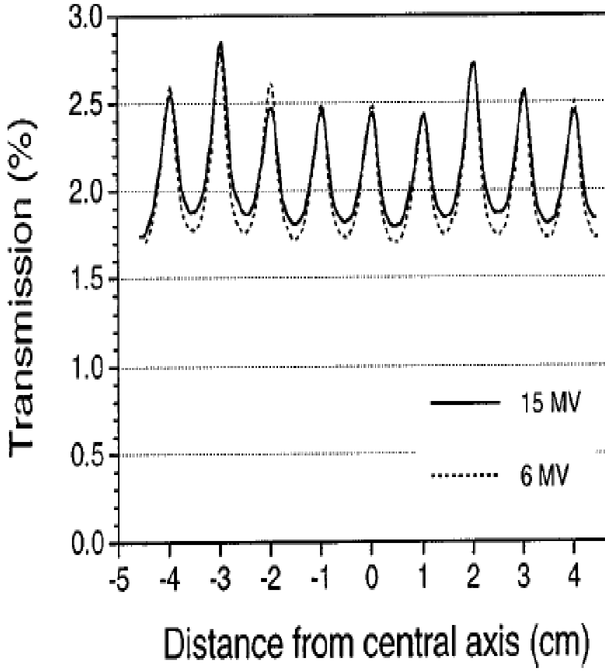
MLC: intra and inter-leaf transmission

Intra-leaf transmission: transmission through "body" o

Inter-leaf transmission: transmission between leaves



"Tongue-and-Groove" effect



Diagrams from LoSasso *et al*. Med. Phys. **25**(10) p. 1919 (1998).

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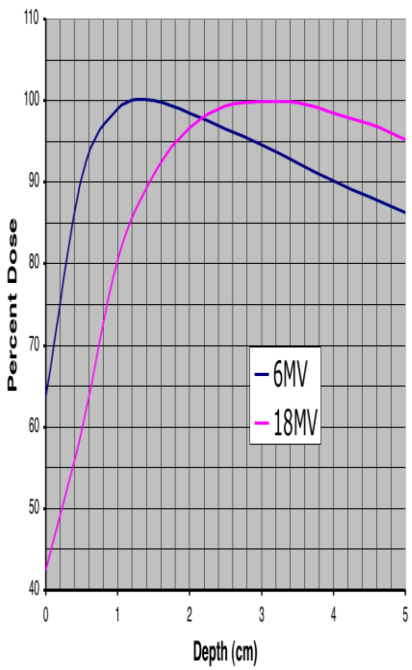
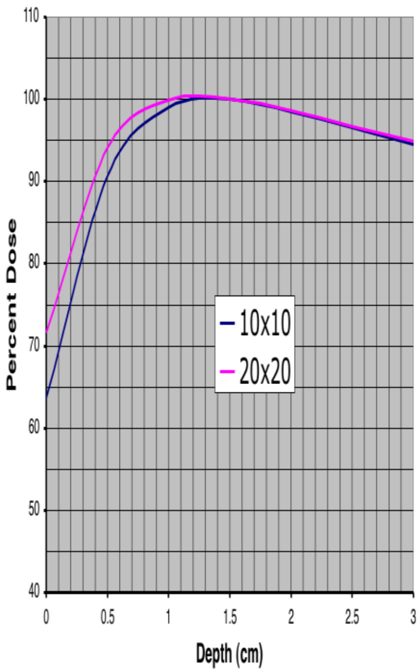
Skin Dose

Surface dose from photon beam increases with:

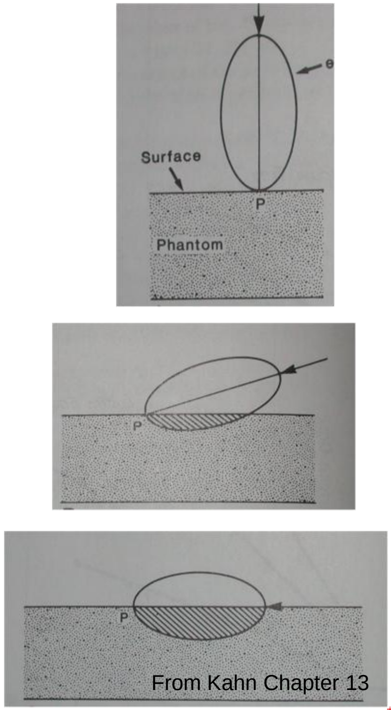


Decreased energy



Increased field size

Blocking tray (or spoiler) Increses with increased field size and decreasing tray to skin distance



From Kahn Chapter 13

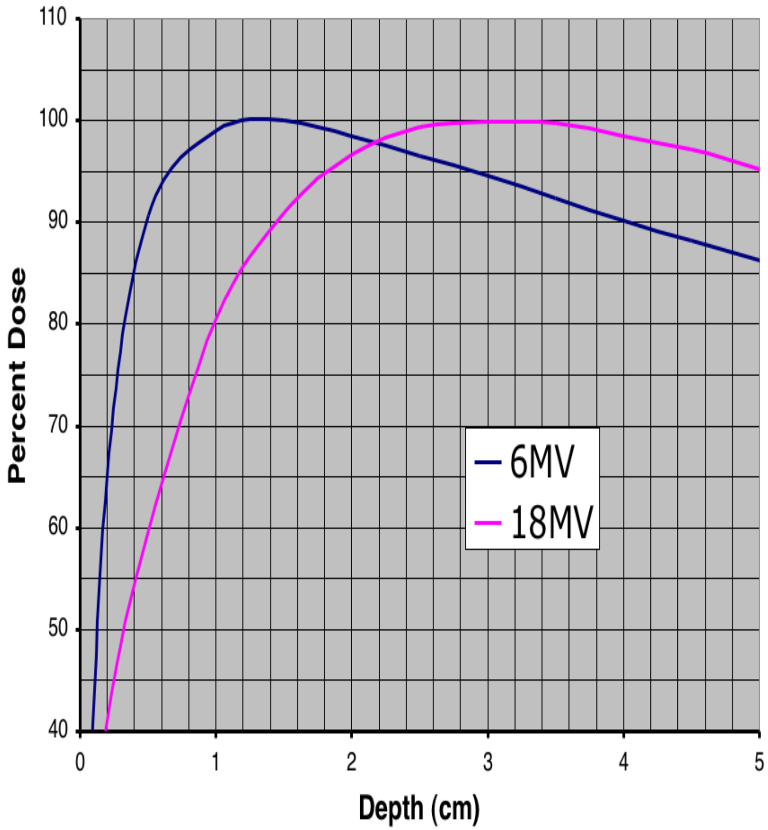
Increased beam obliquity

Skin Dose: Energy

Surface dose increases with decreasing energy

For a 10x10 field

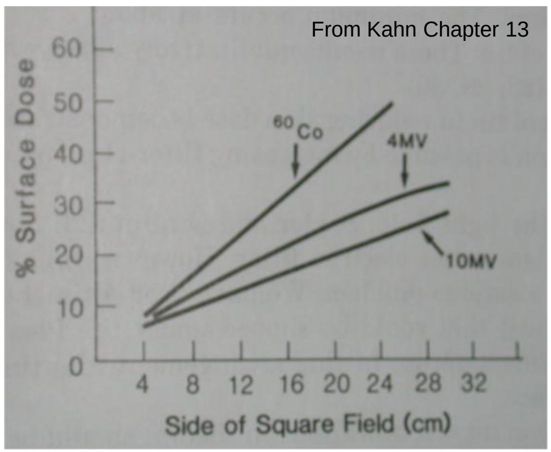
Depth (mm)	^{60}Co	4 MV	10 MV	25 MV
0	18.0	14.0	12.0	17.0
1	70.5	57.0	30.0	28.0
2	90.0	74.0	46.0	39.5
3	98.0	84.0	55.0	47.0
4	100	90.0	63.0	54.5
5	100	94.0	72.0	60.5
6		96.5	76.0	66.0
8		99.5	84.0	73.0
10		100	91.0	79.0
15			97.0	88.5
20			98.0	95.0
25			100	99.0
30				100

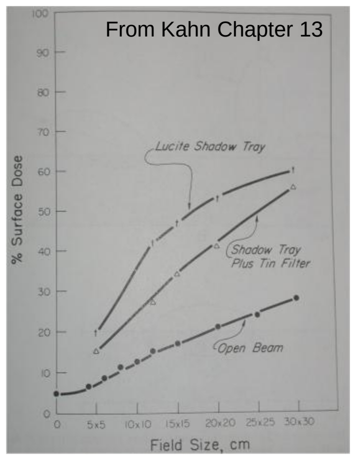


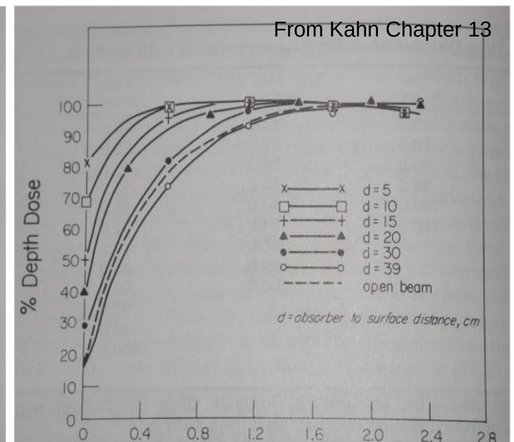
^{60}Co and 4MV: Velkley et al Med Phys 2 (1975)
10 and 25MV: Khan et al Radiology 109 (1973)

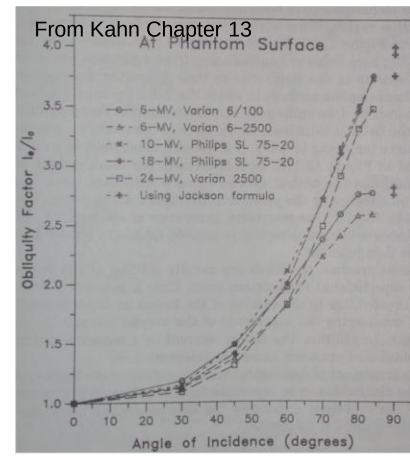
Skin Dose (more detail)

Surface dose from photon beam increases with:









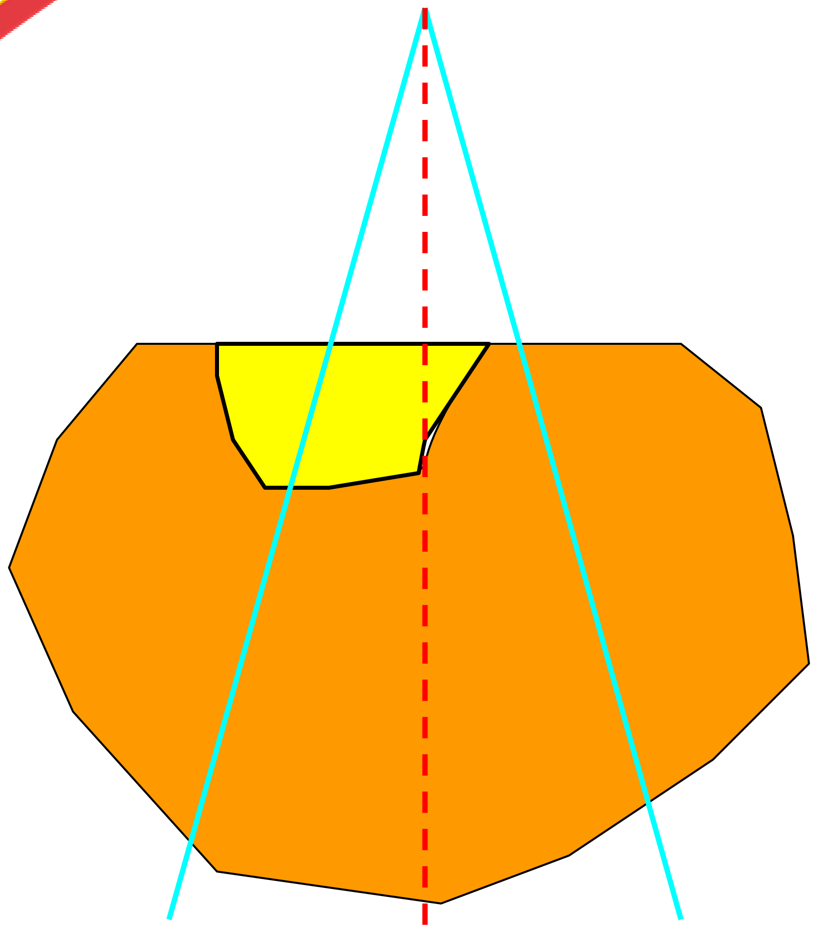
Increased field size

Blocking tray (or spoiler) Increses with increased field size and decreasing tray to skin distance

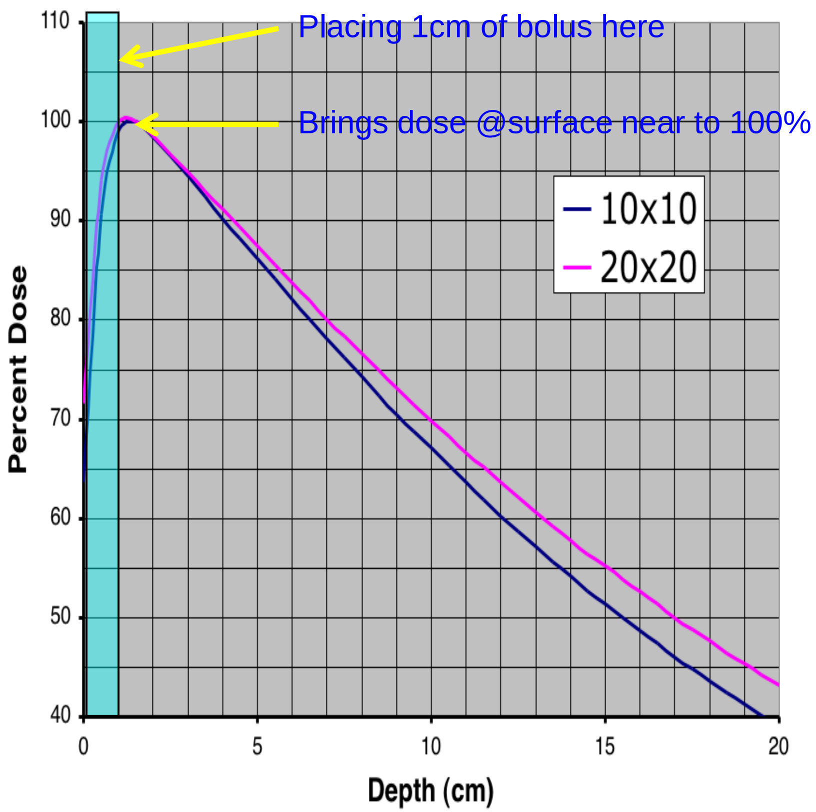
Increased beam obliquity

Bolus

Material with density similar to water that can account for tissue irregularities or to enable treatment at or near the skin surface.



Tissue compensation to create a flat surface



Bolus to account for lower dose in build-up region if we need to treat close to the surface

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Inhomogeneiteies: General rules of thumb

Increase in dose to tissues beyond lung:

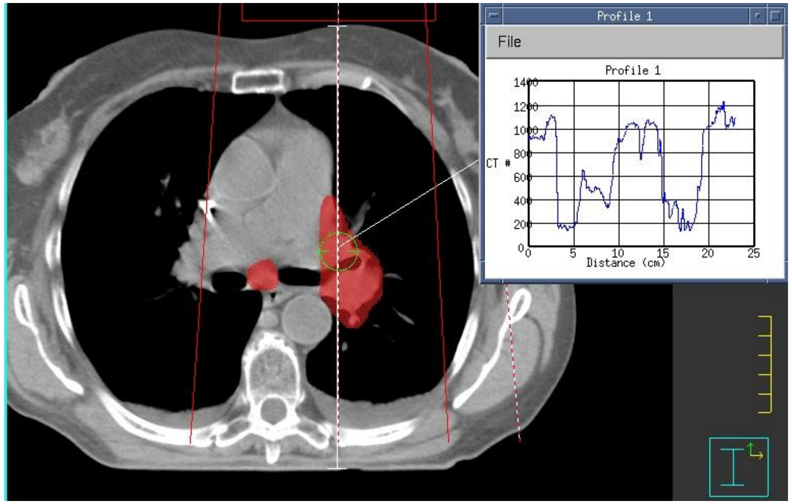
^{60}Co:	+4% per cm
4 MV:	+3% per cm
10 MV:	+2% per cm
20 MV:	+1% per cm

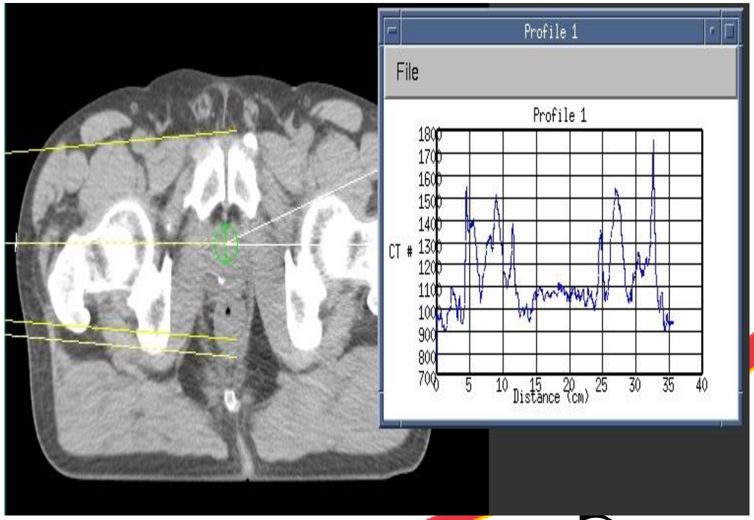
From Kahn table 12.3

Decrease in dose to tissues beyond 1 cm of bone (with ρ_e = 1.65):

^{60}Co:	-3.5%
4 MV:	-3%
10 MV:	-2%

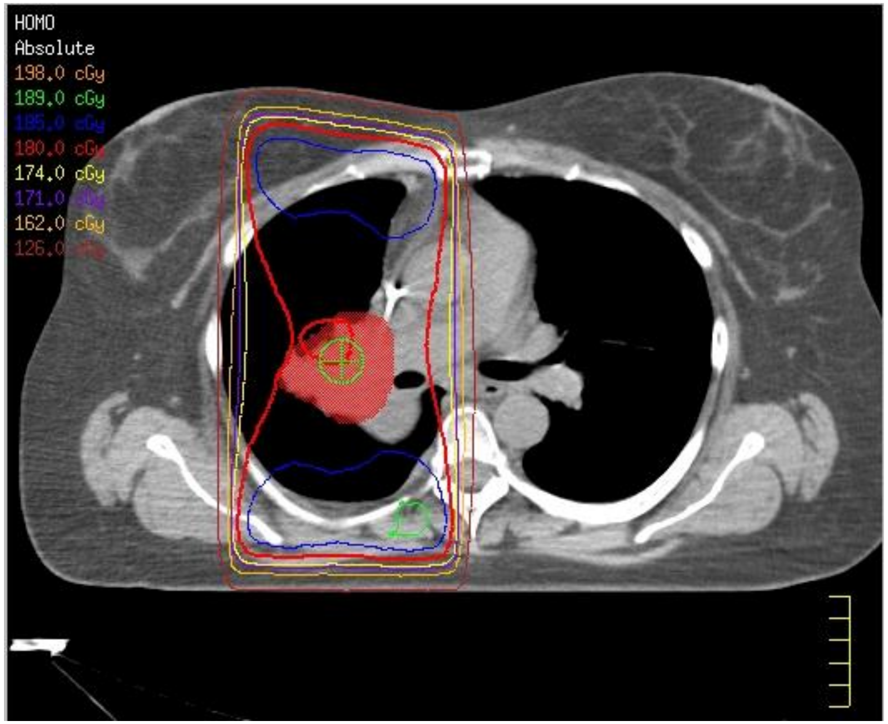
From Kahn table 12.4



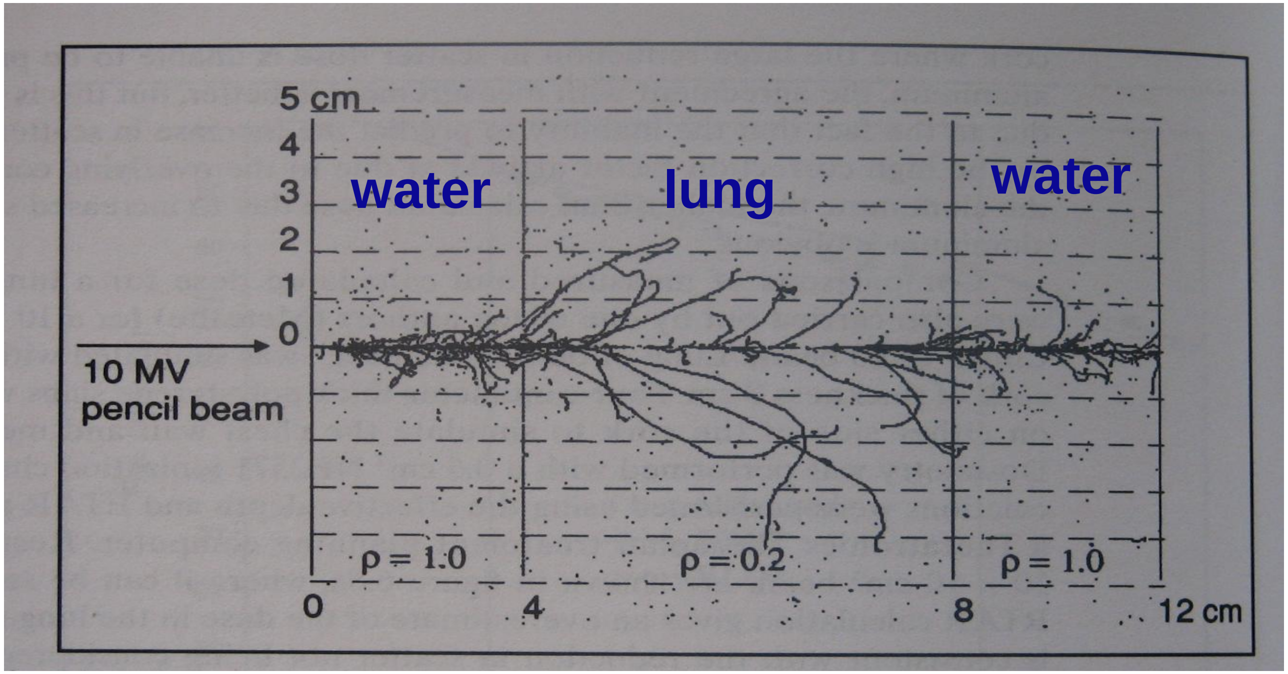


An example

- For this patient, we planned with a homogeneous dose calculation
- We took the MU's from the homogeneous plan and then plugged them into a heterogeneous plan



Inside Lung tissue



From "The Physics of Radiotherapy x-rays from linear accelerators" (p.390) Metcalfe et al Medical Physics Publishing, Madison, WI 1997

An EGS4 Monte Carlo simulation of a 10MV pencil beam striking a water-lung-water phantom

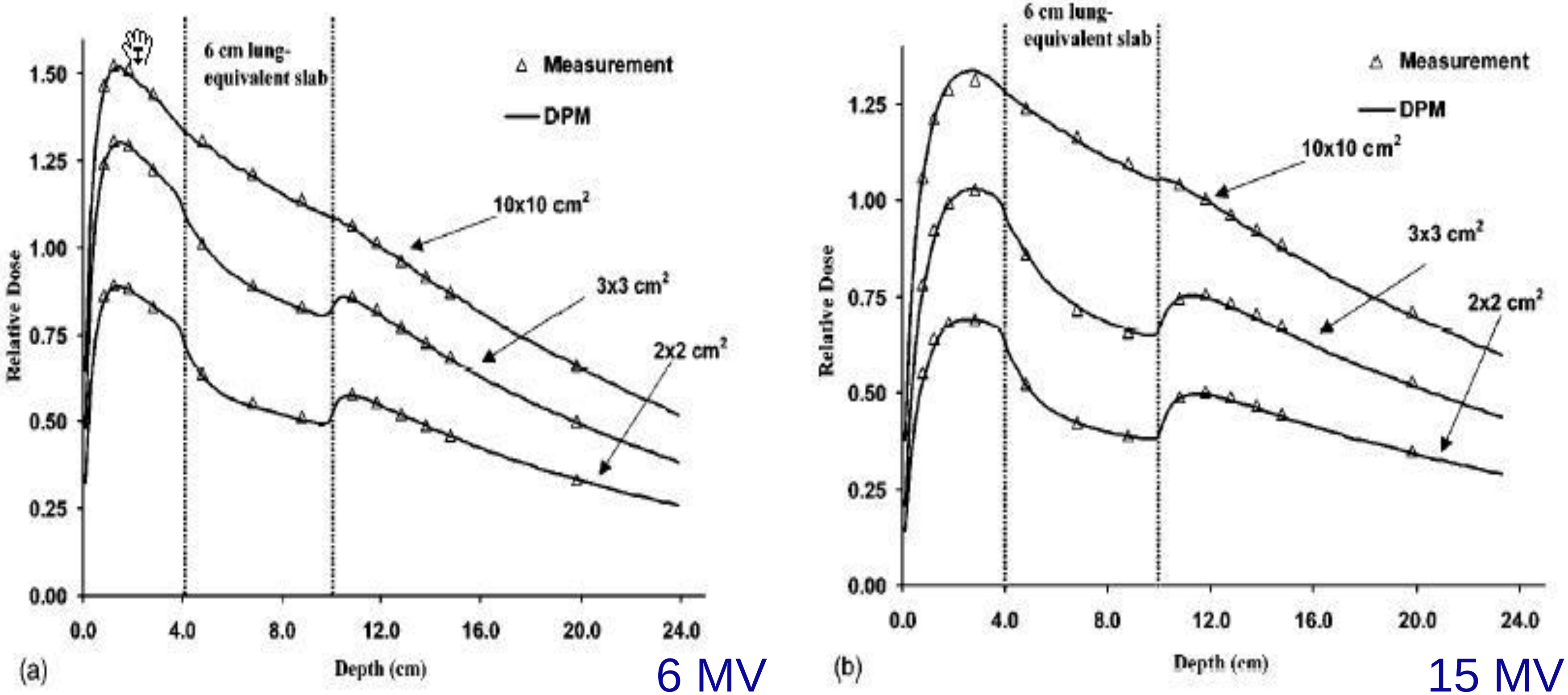
Inside lung tissue, the lower density allows more electrons to stray outside the geometric limits of the beam.

1) Less dose inside the lung

2) More "bulging" of the lower isodose lines outside the geometrical limits

This is the concept of "loss of lateral electronic equilibrium"

Inside Lung tissue

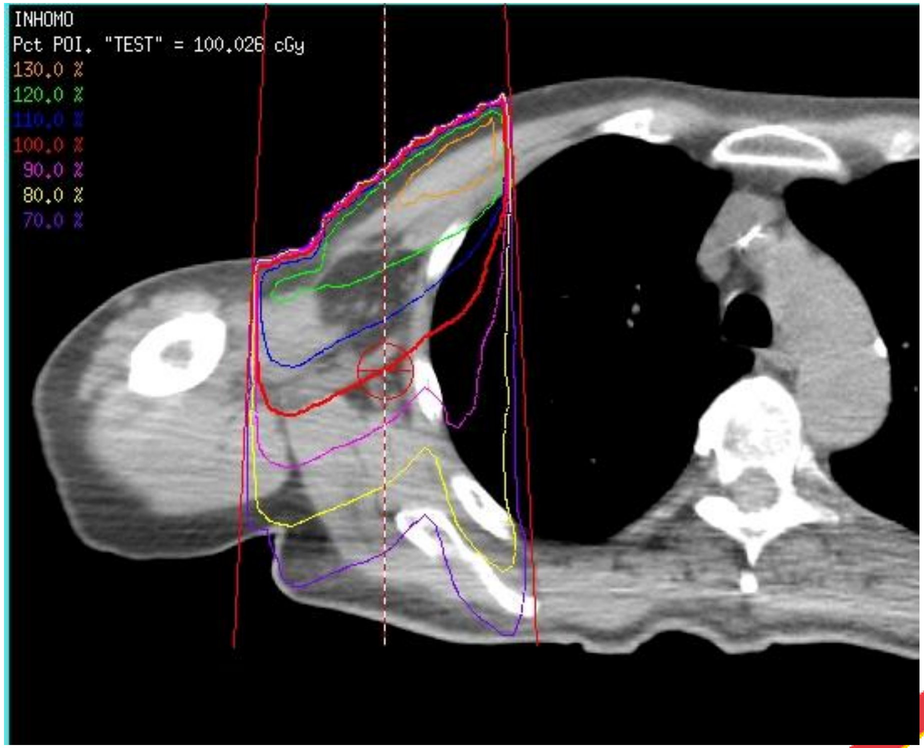


Chetty et al. *Med Phys* **30**(4) p.563 (2003)

The effect is more pronounced for

1) Small field sizes
2) Higher energy

With and without corrections



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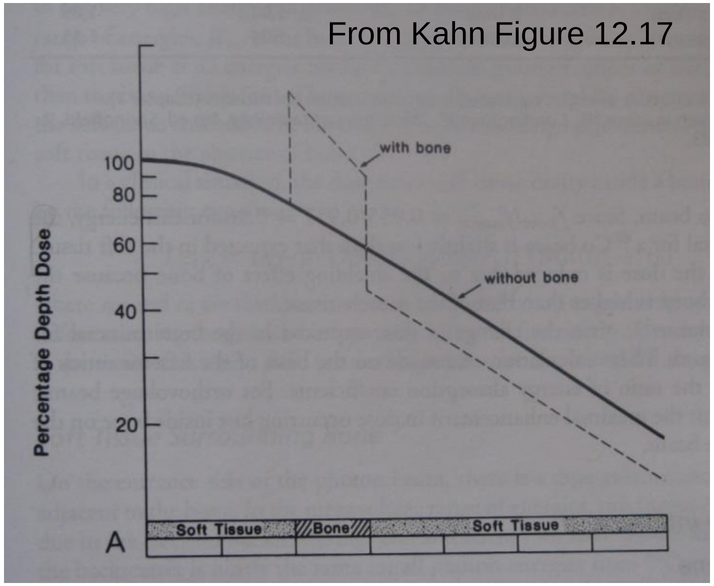
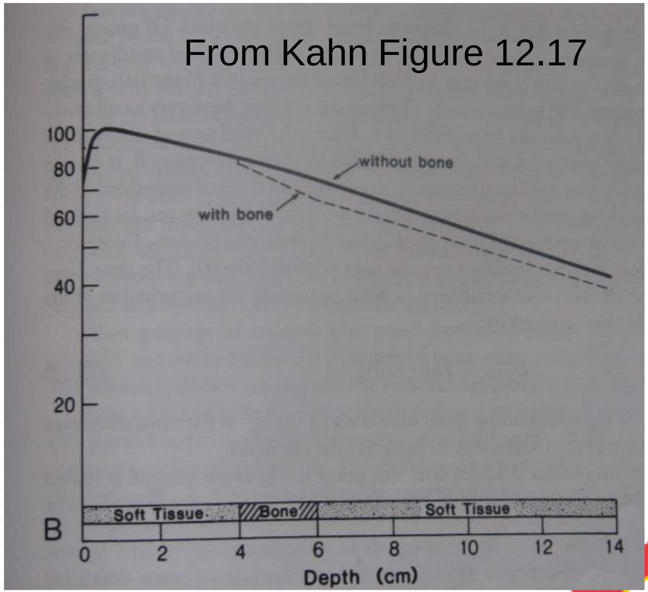
Absorbed Dose in Bone

The absorbed dose in bone relative to that in tissue is given by the ratio of energy absorption coefficients for bone and tissue:

$$\frac{f_{bone}}{f_{tissue}} \quad \text{OR} \quad \left(\frac{\mu_{en}}{\rho}\right)_{tissue}^{bone}$$



Superficial (~80 kV) beams:
f_{bone}/f_{muscle} = 1.9/0.94 ~ 2.0

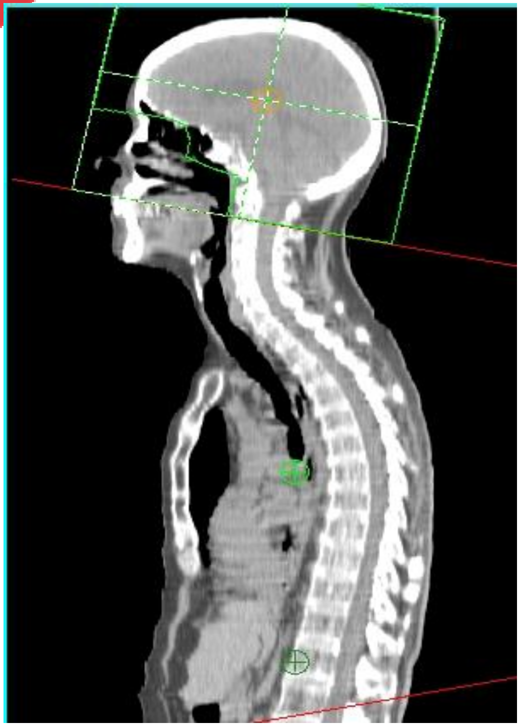


For megavoltage beams
f_{bone}/f_{muscle} = 0.927/0.962 ~ 0.96

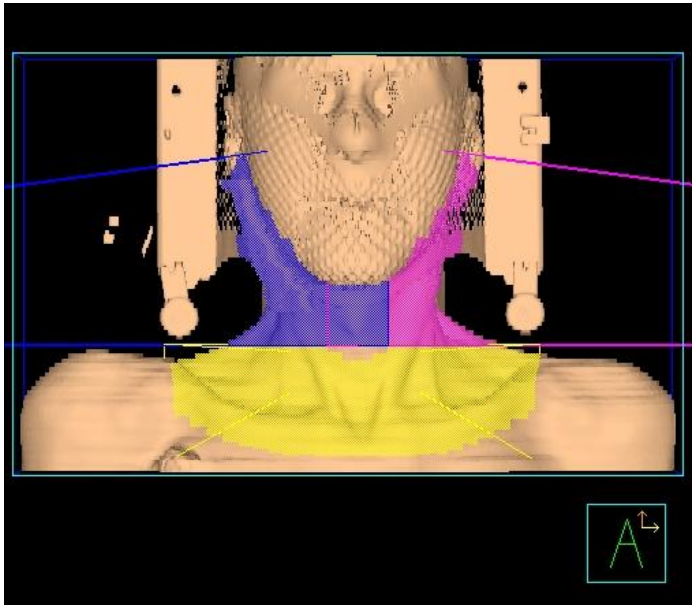
(See table 8.1 in Kahn)

Adjacent Fields

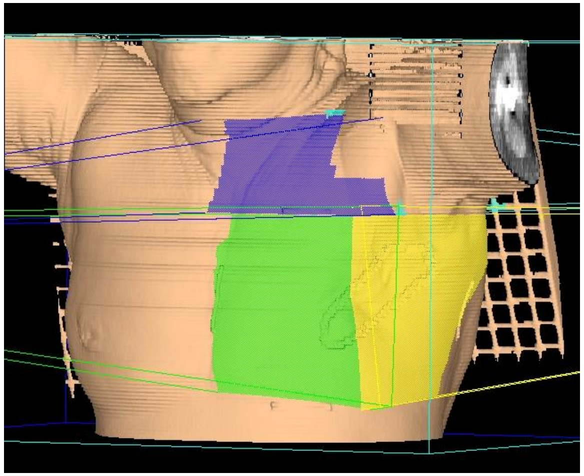
Some scenarios where we encounter adjacent fields



Craniospinal: brain matched to spine



Head and neck: opposed laterals for upper neck matched to anterior supraclavicular field

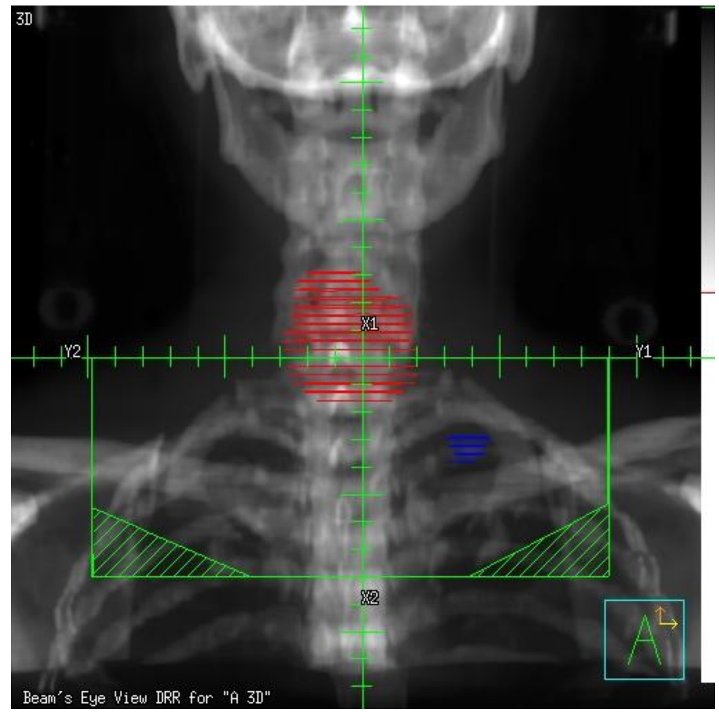


Breast: Tangent breast fields matched to SC field

The Problem with Adjacent Fields

Care must be taken when fields are close to one another or abut one another due to potential for dosage errors across the junction.

Overdosing can lead to complications (eg spinal cord)

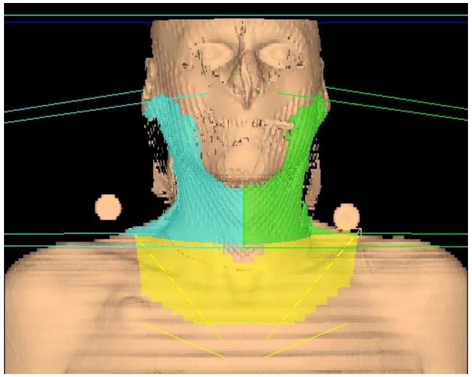


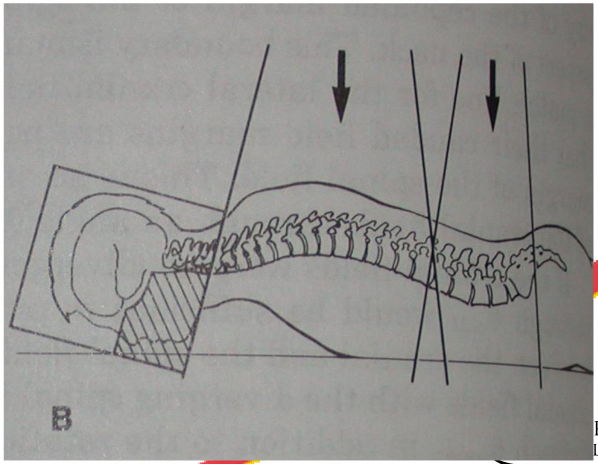
Underdosing can lead to recurrence

Orthogonal field juctions

We can match field edges by either (or sometimes both):

1. Half beam block to remove divergence (eg Head and neck)
2. Rotating collimator, gantry, and/or couch to match diverging field edge (eg craniospinal)

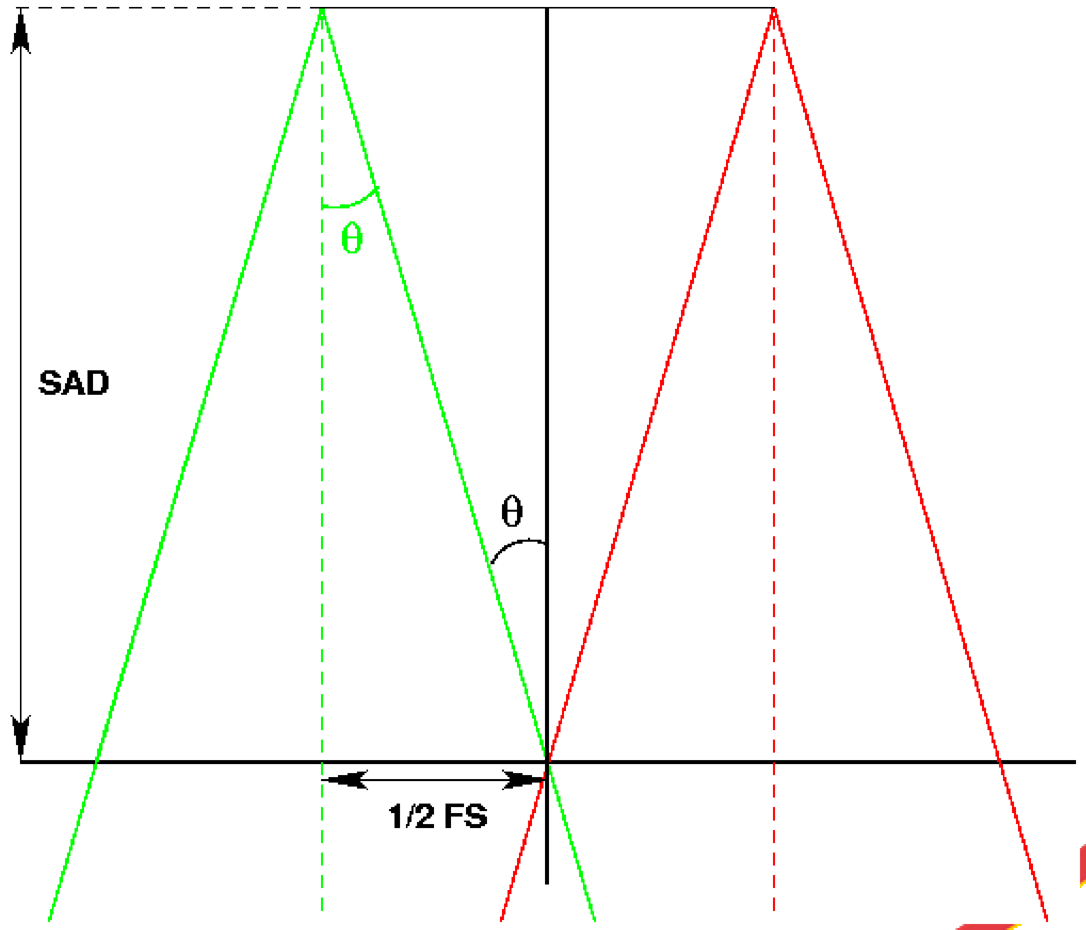




Angling the fields

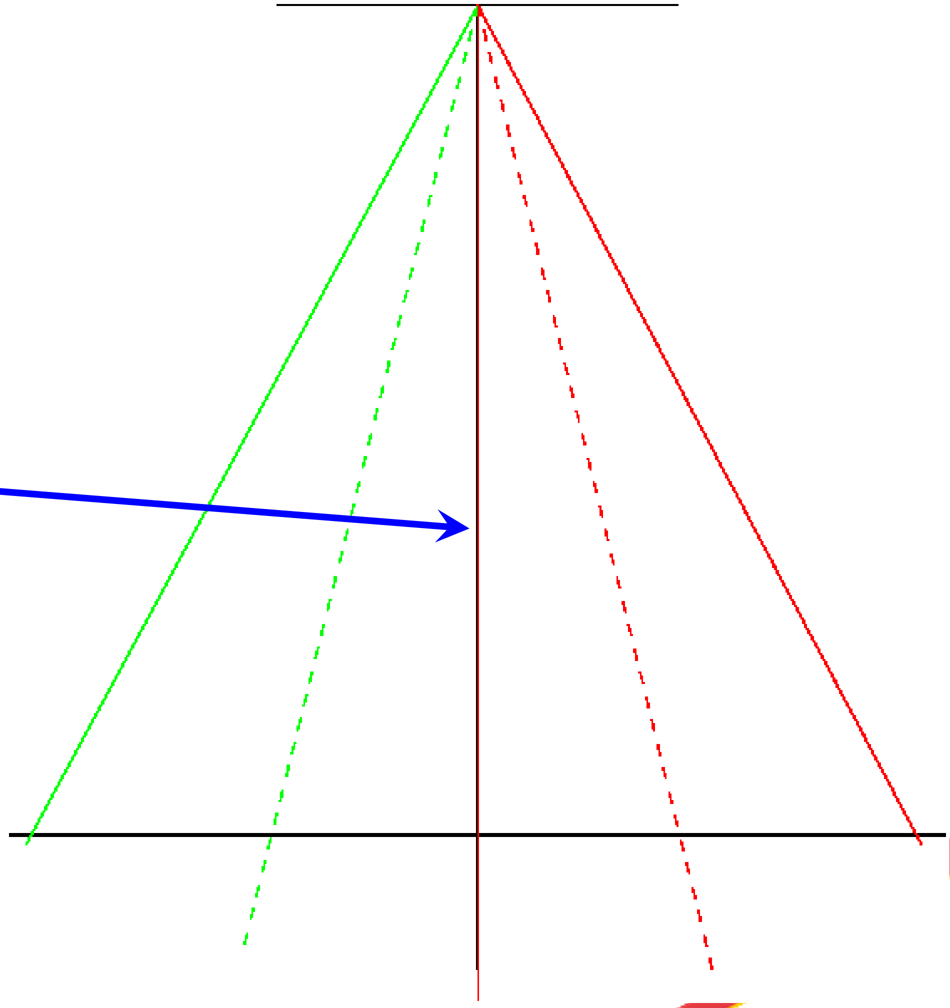
$$\tan\theta = \frac{\frac{1}{2}FS}{SAD}$$

$$\theta = \arctan\frac{1}{2}\frac{FS}{SAD}$$



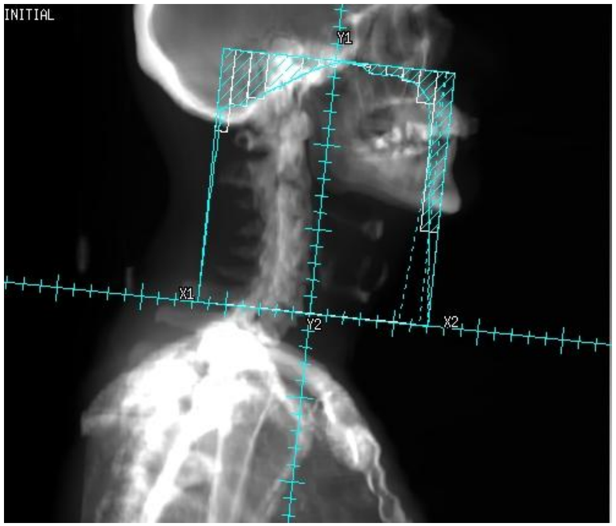
Divergence matches

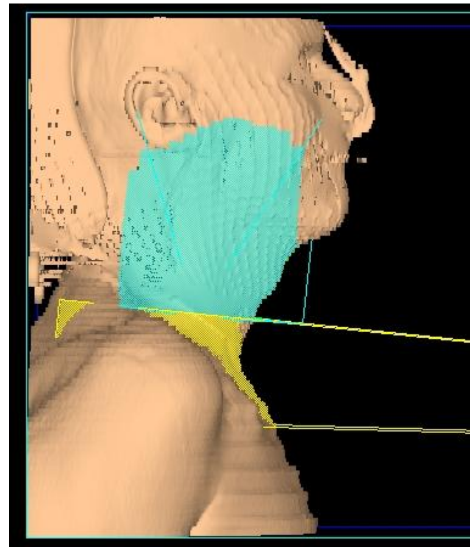
Divergence of both beams now coincide so that 50% + 50% is 100% at the match



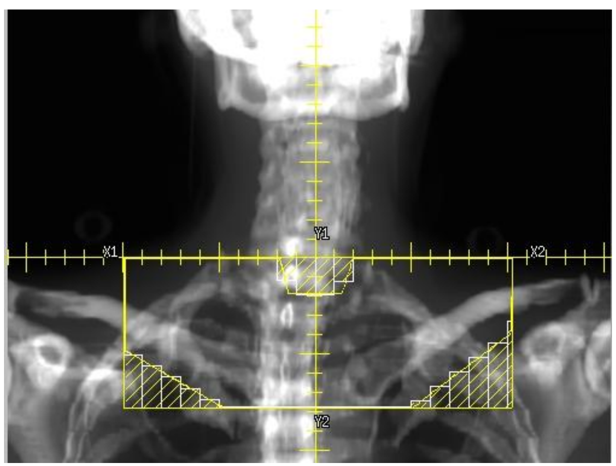
Half-beam block: Sample H&N Case

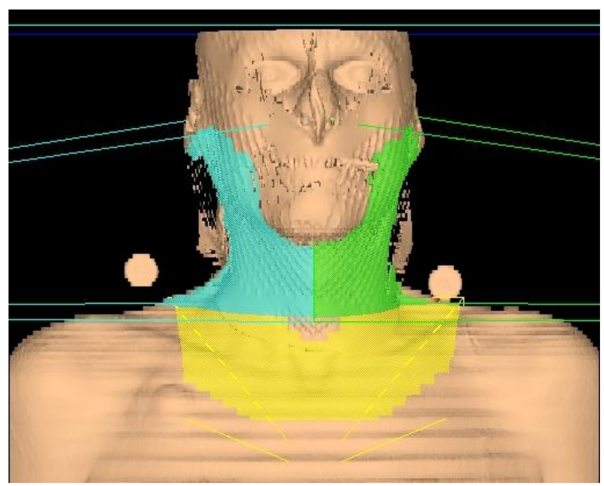
With asymmetric jaws, we can align one jaw with the central axis to remove beam divergence

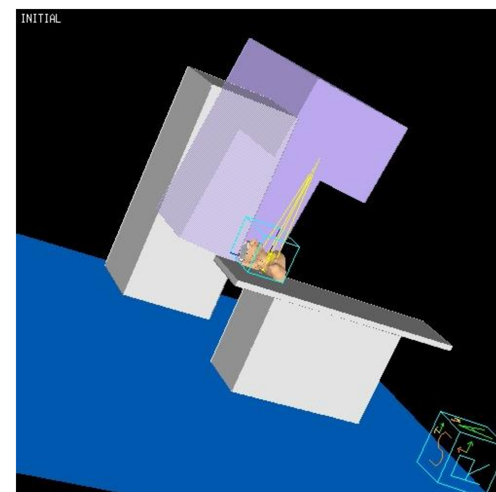




For the AP Supraclavicular field, we need to rotate the couch to 90º and the gantry to the same angle as the lateral field collimator angle in order to match the half beam







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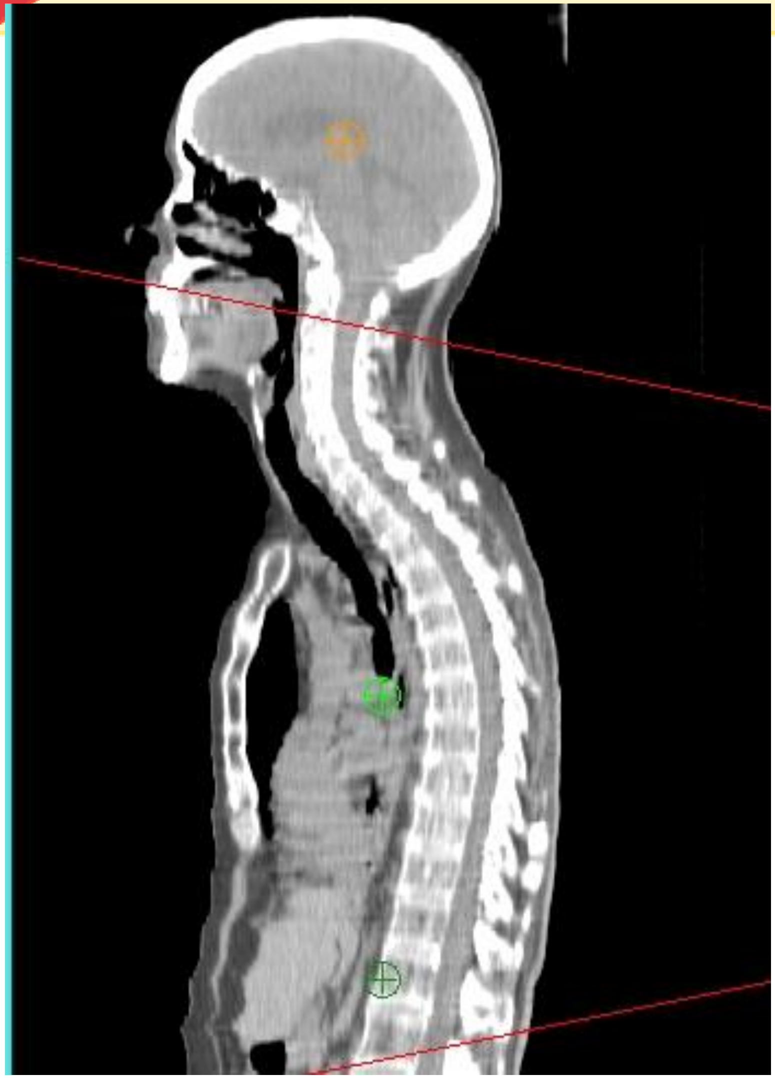
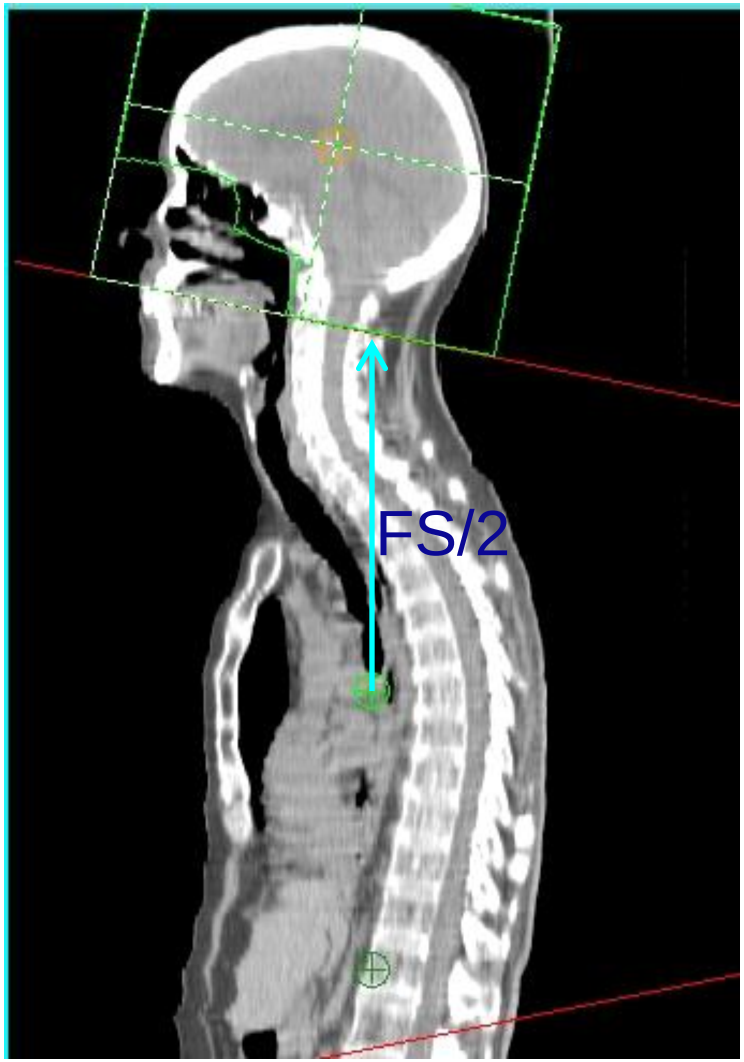
Craniospinal



How do we match the brain field to this diverging spine field?

Craniospinal: Brain field

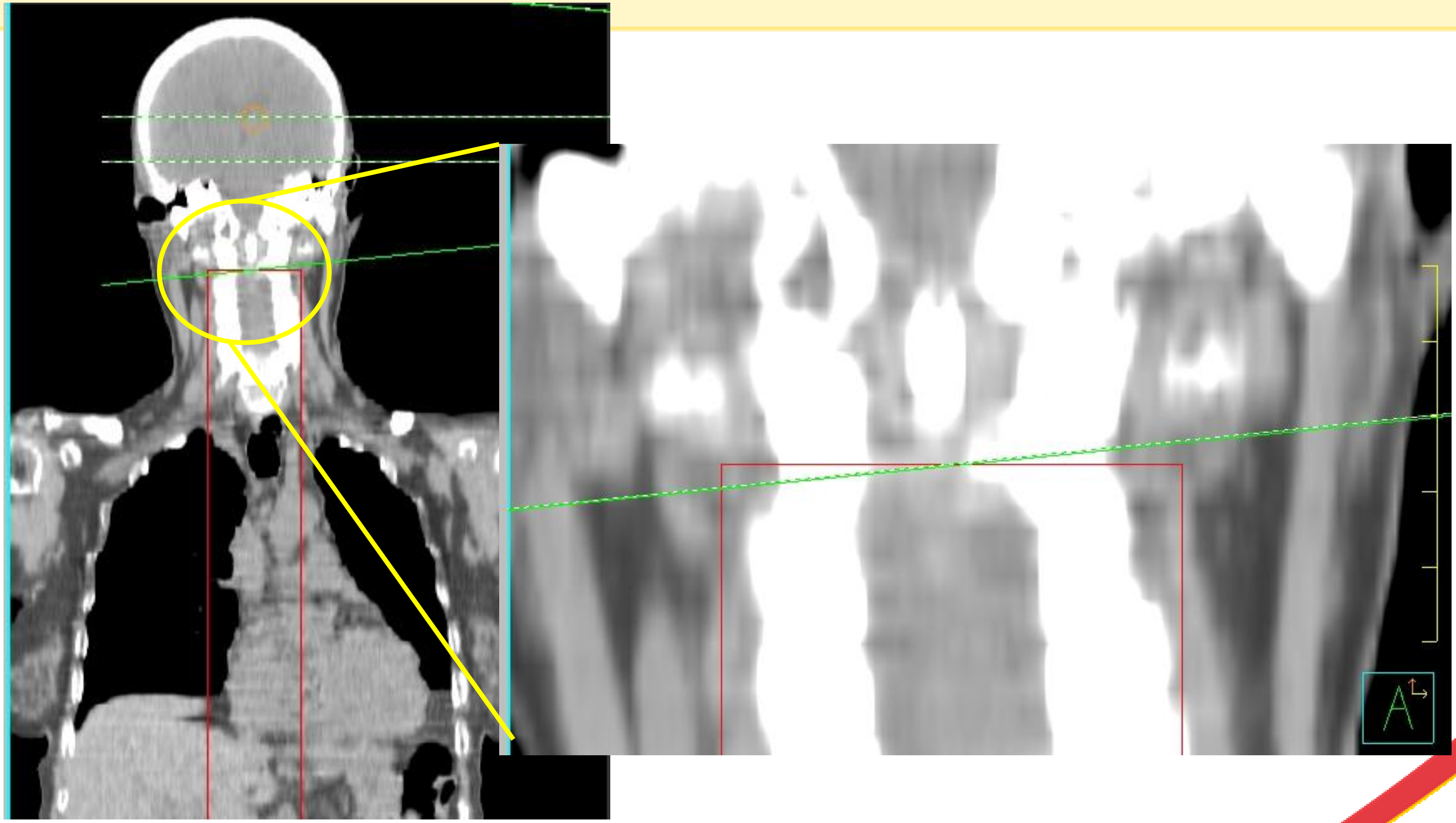


We rotate the collimator by:

$$\theta = \arctan \frac{FS/2}{SAD}$$

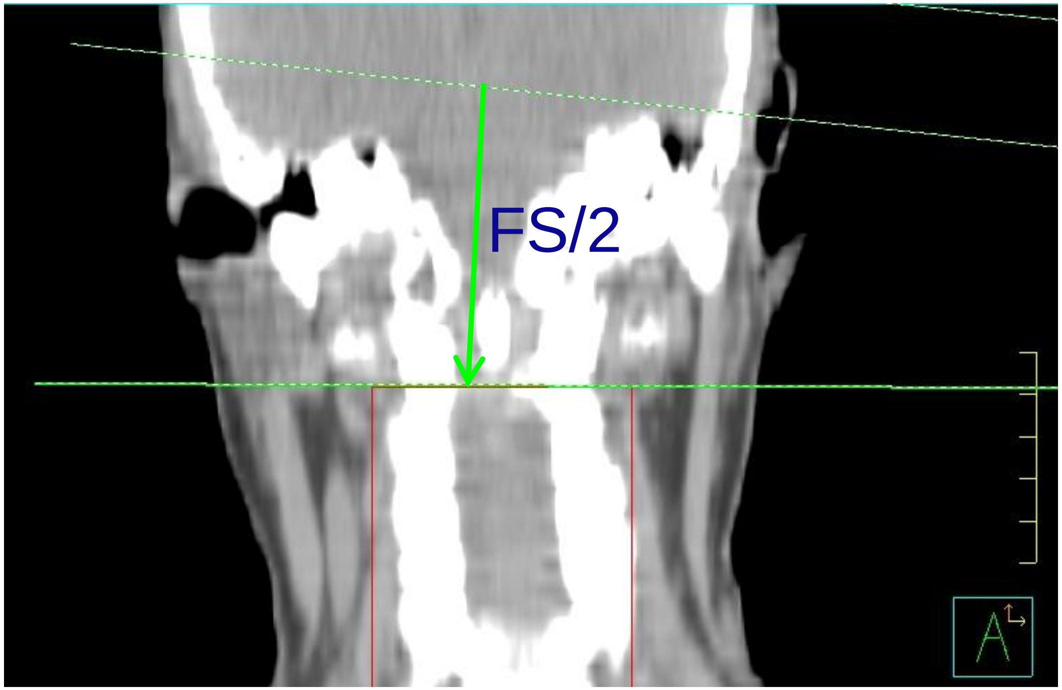
But we still have a problem.
What is it?

Craniospinal: Couch kick



The brain fields are still diverging into the edge of the spine field

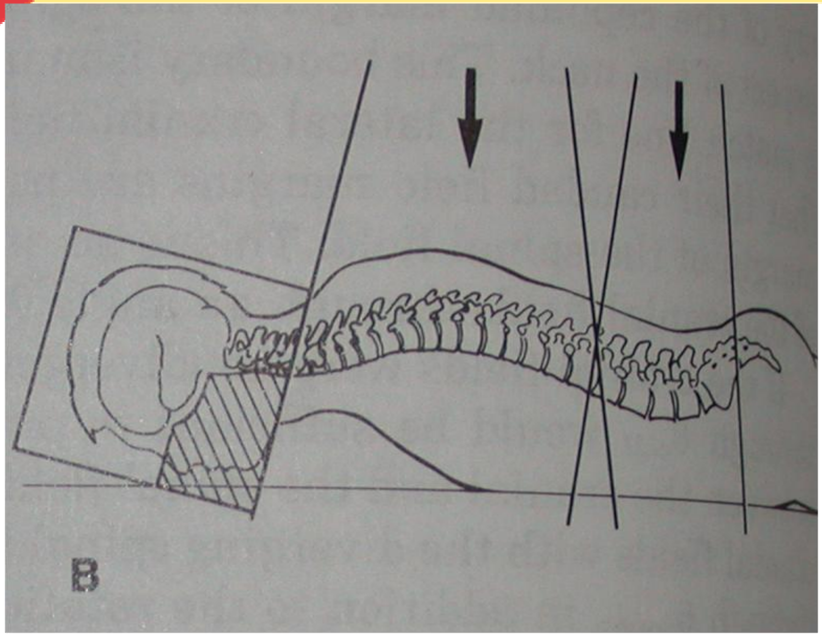
Craniospinal: Couch kick

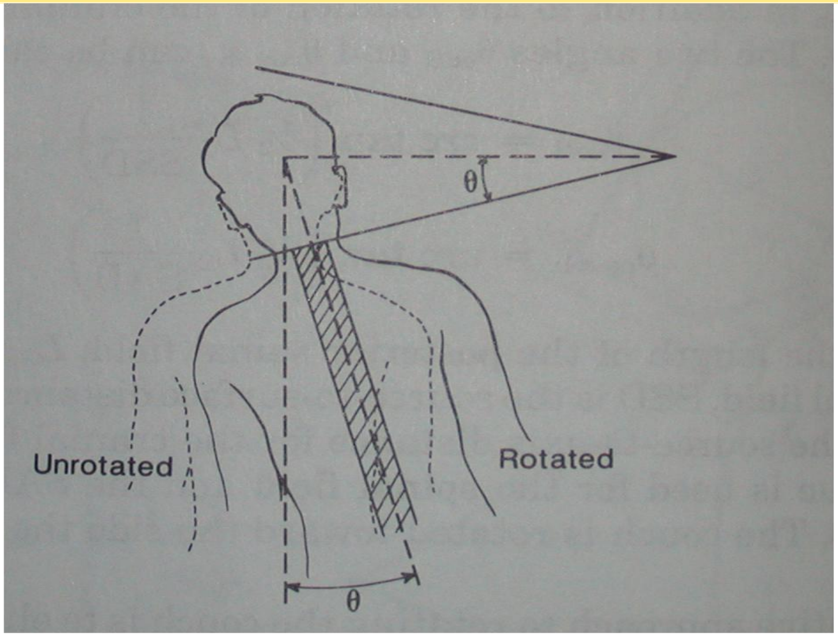


We need to have a table rotation of:

$$\theta = \arctan \frac{FS/2}{SAD}$$

Craniospinal: Summary



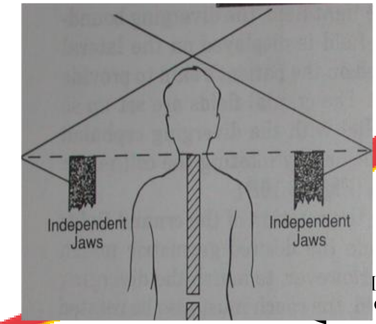


1. May need to abut spine fields
2. Collimator rotation for cranial field

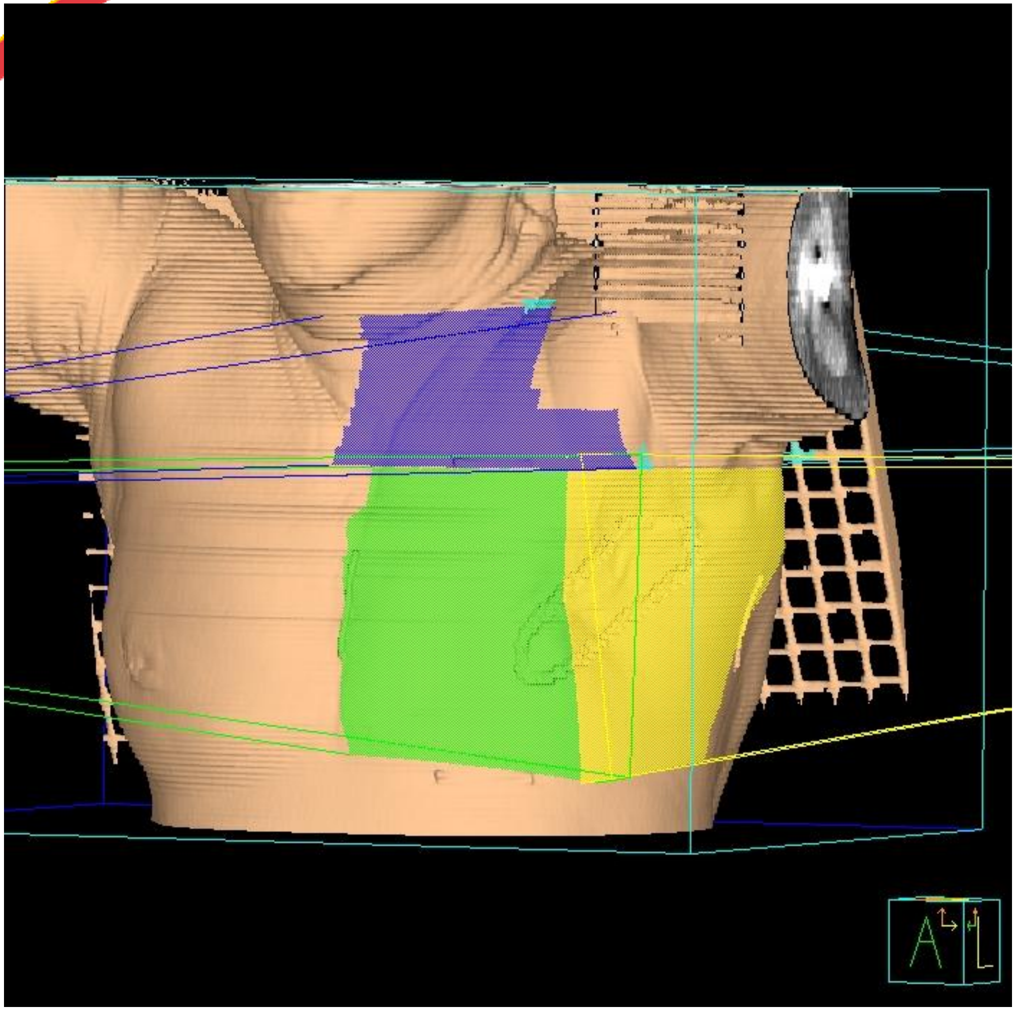
Table rotation for cranial field to match divergences

$$\theta = \arctan(\tfrac{1}{2} L \frac{1}{SAD})$$

Could also half beam block the cranial fields to remove divergence



Breast planning



Treating:

1) Breast tissue
2) Sometimes supraclavicular and axillary nodes
3) Sometimes internal mammary nodes

Avoiding:

1) Lung
2) Heart (for left breast)
3) Liver (for right breast)
4) Spinal cord, trachea, etc (SC field)

Issues:

1) Beam angles
2) Blocking
3) Matching
4) Immobilization and reproducibility

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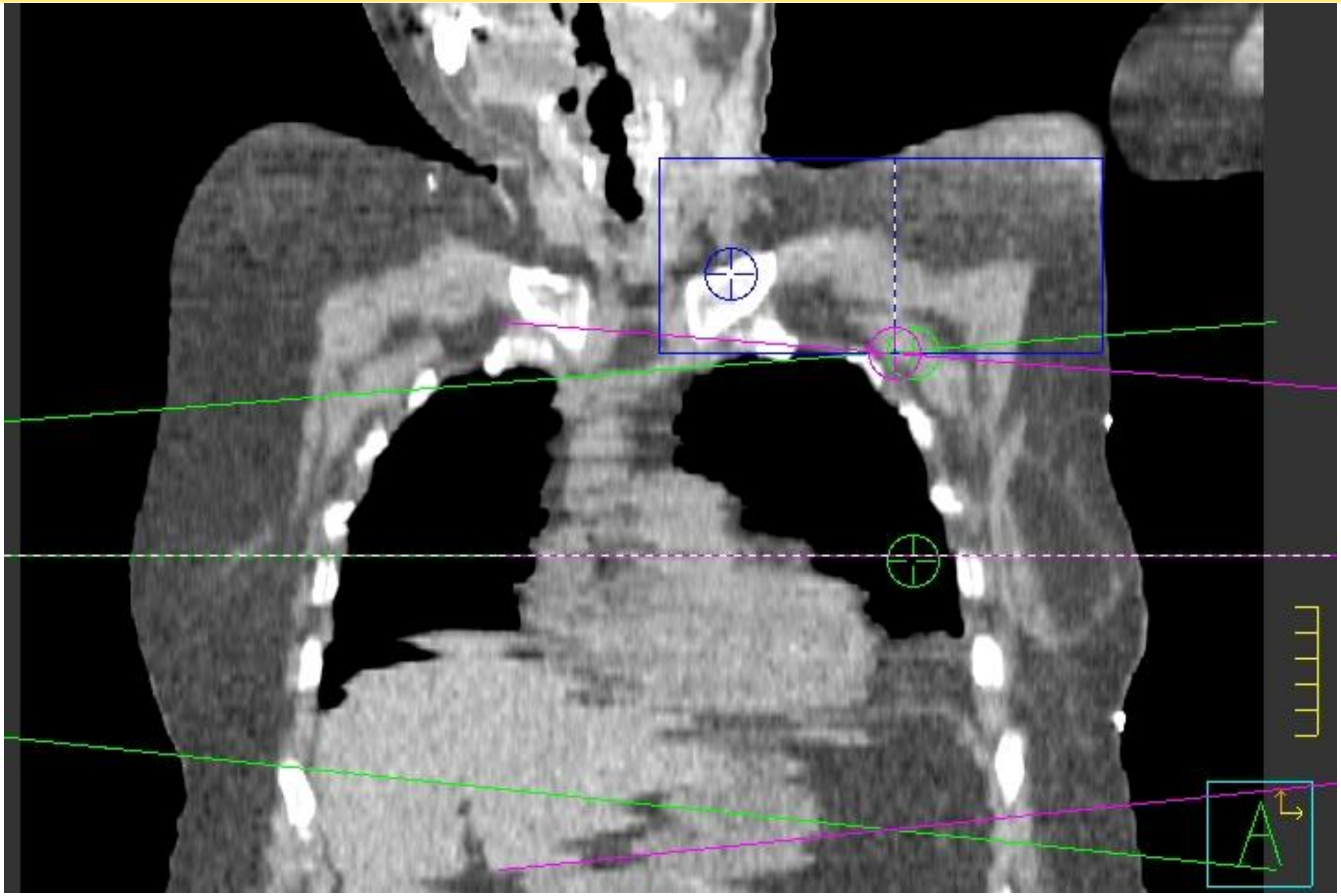
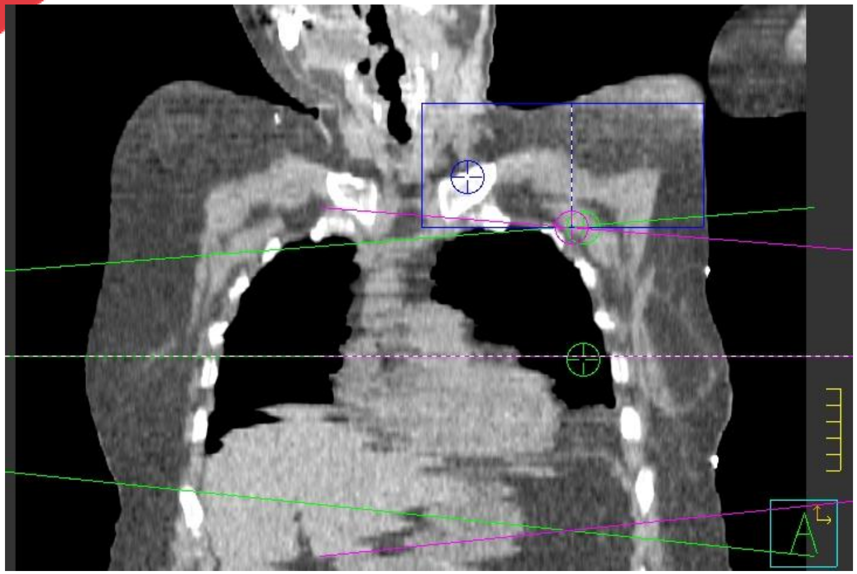
Breast: Matching tangents to SC



Supraclavicular field is half beam blocked. Consider direct laterals. How do we take care of the divergence of the laterals into the SC field?

Breast: Matching tangents to SC

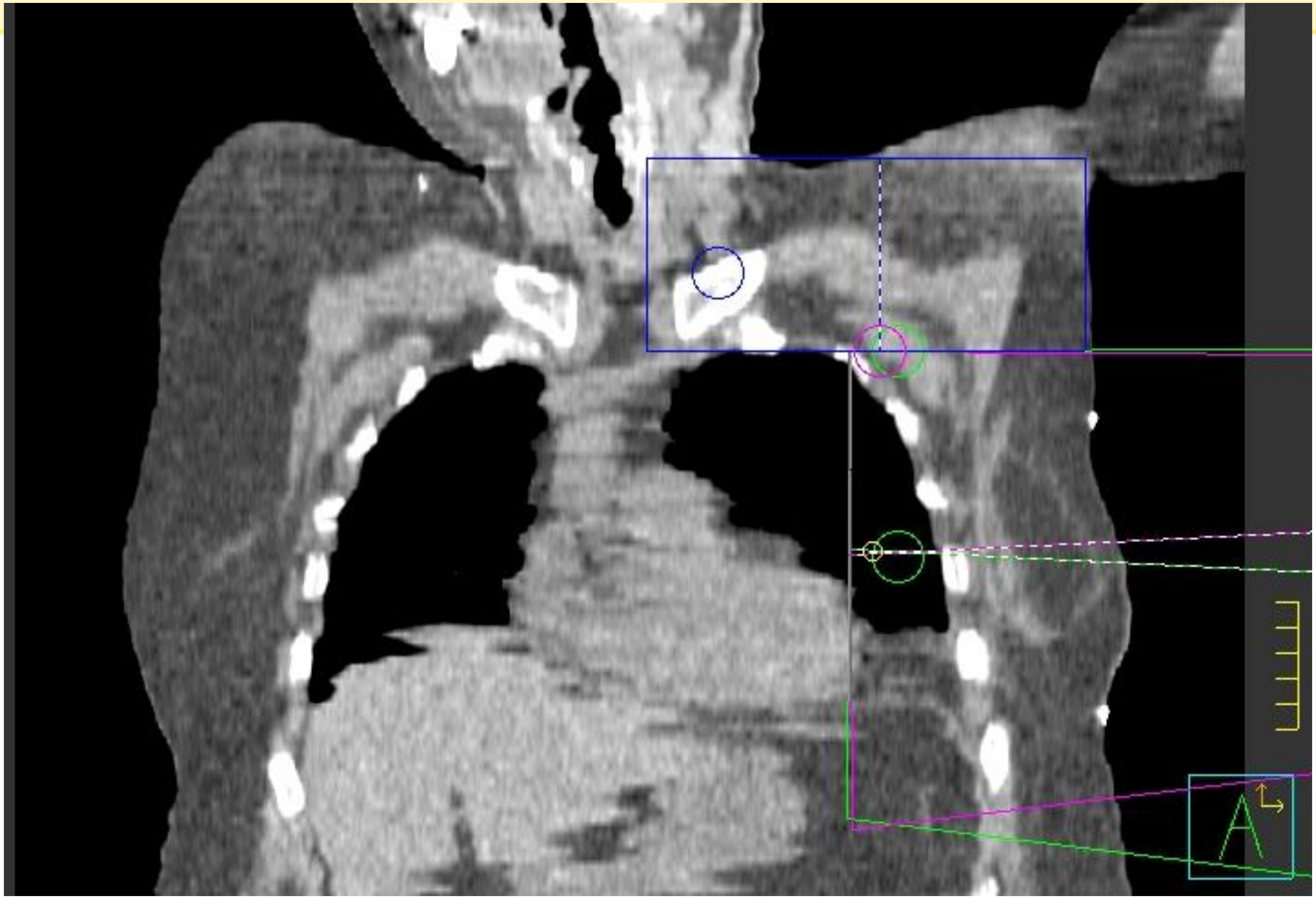


By rotating the couch, we can remove this divergence. By what angle do we rotate the couch?

Breast: Matching tangents to SC

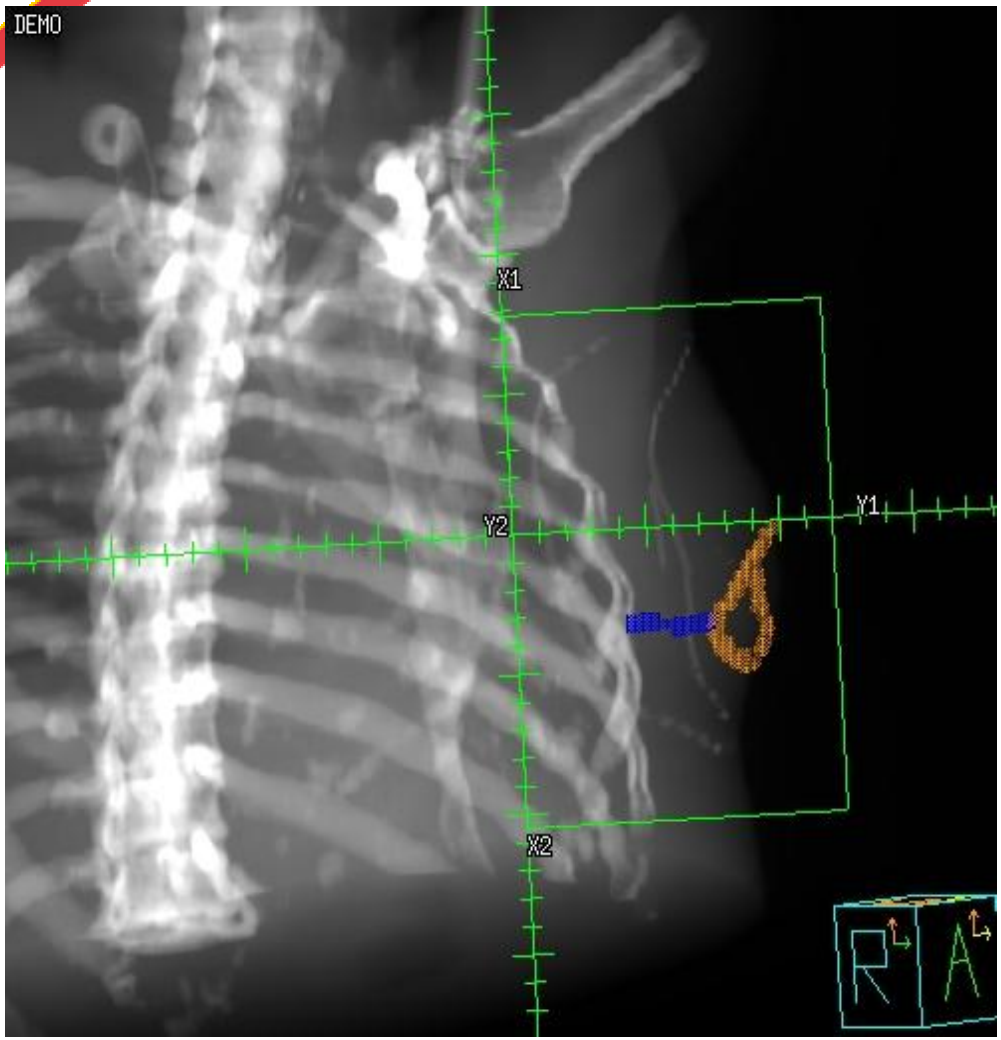
Now if we rotate the laterals to an appropriate angle for tangent breast treatment (say 45º), they no longer match the SC field. How can we fix this?

Breast: Matching tangents to SC



Rotate the collimator

Breast: Tangent field

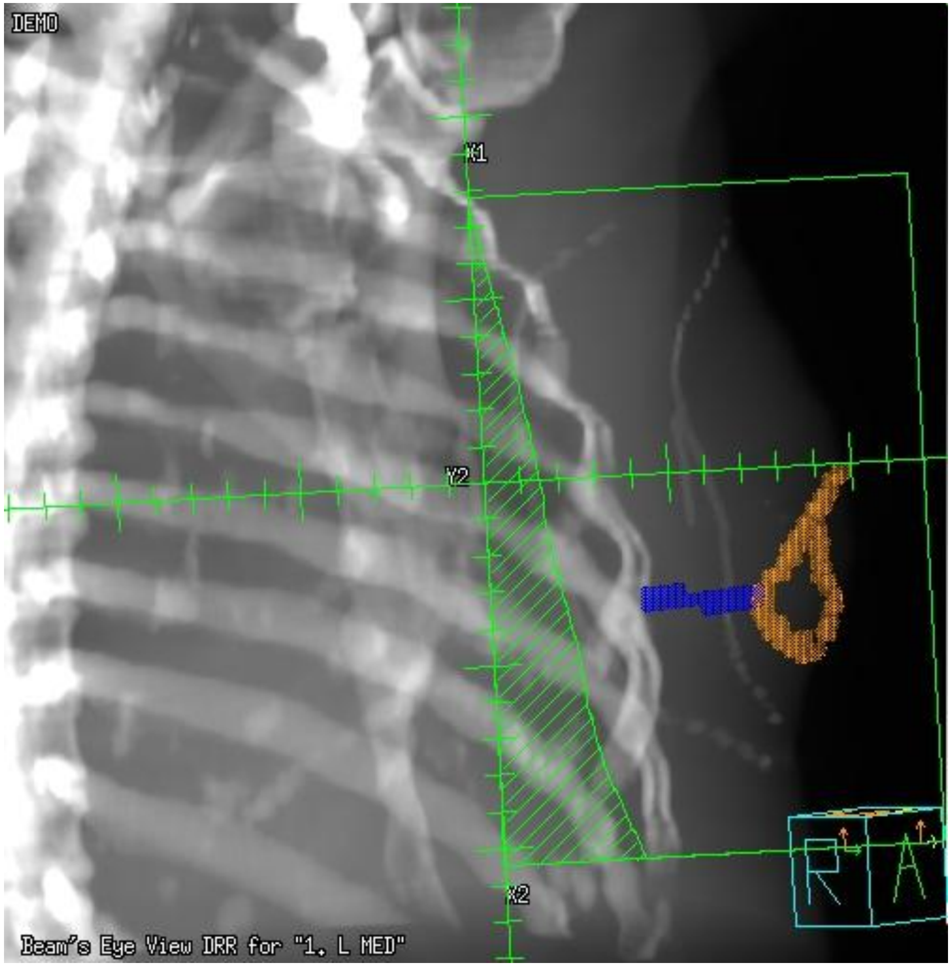


Here is the medial tangent field that matches the anterior SC field. Matching was achieved by:

1) Rotating table to align beam divergence to half beam of SC field
2) Rotating collimator to account for table and gantry rotation causing divergence into SC field

What do we need now?

Breast: Tangent Block

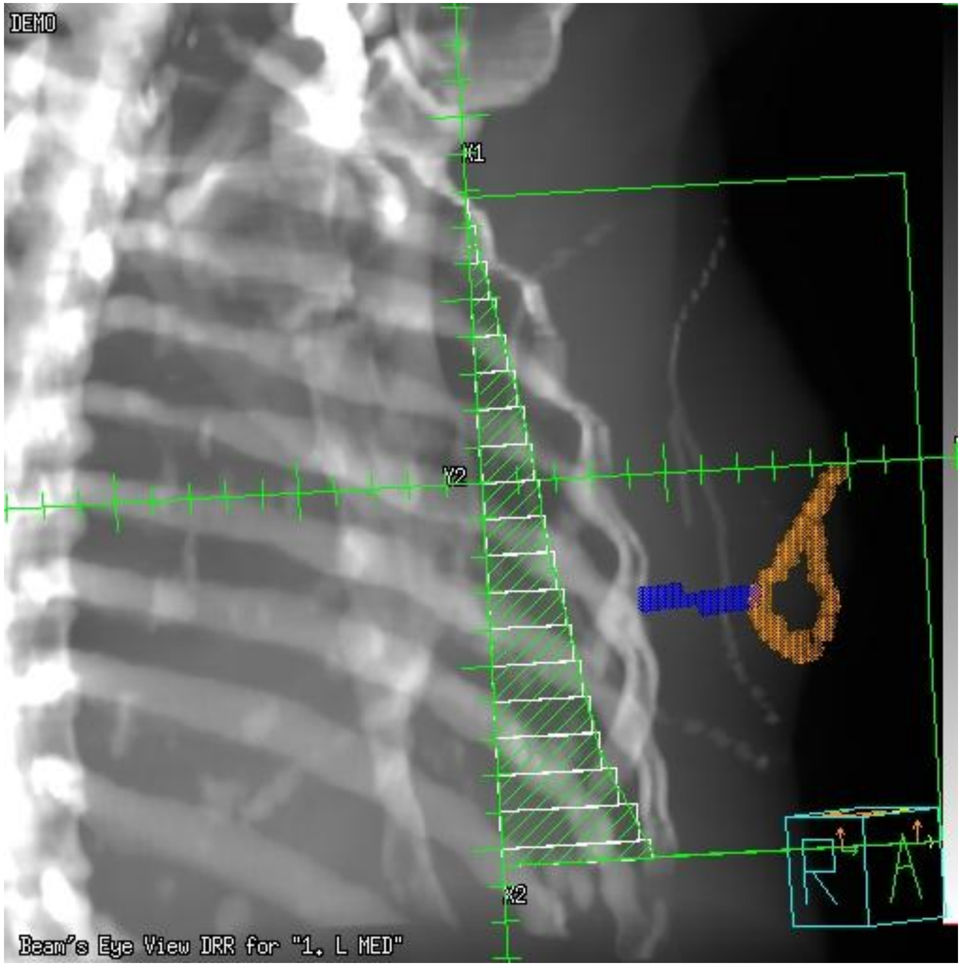


We need to put in a block to protect the lung.

Some Questions:

1) If the gantry of this medial beam is 315º, what is the gantry of the lateral beam?
2) This example has half-beam blocked tangents. What would change if we put the isocenter in the breast?

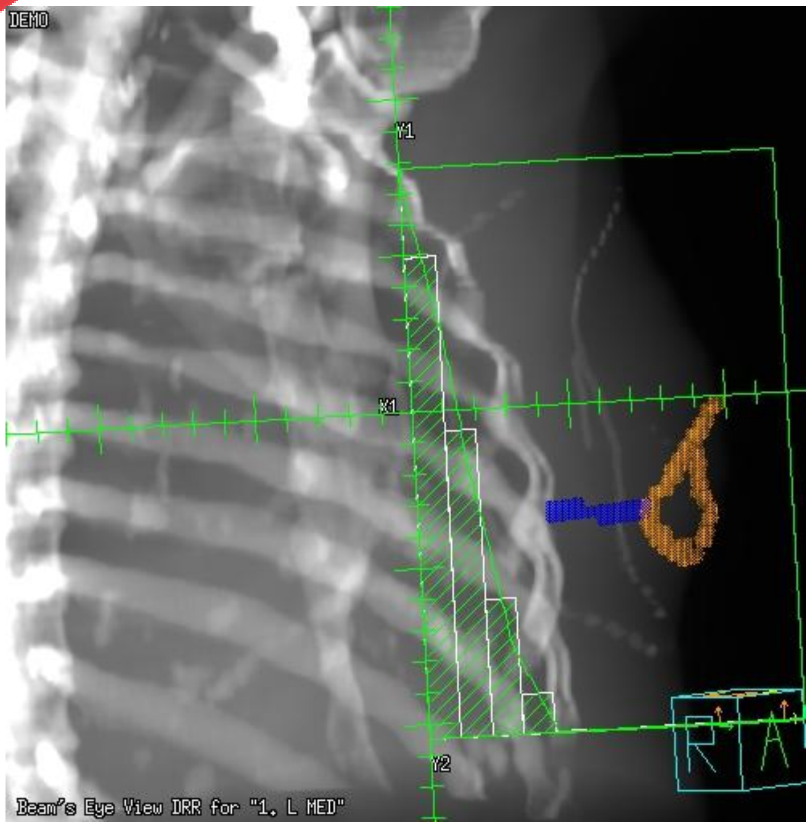
Breast: MLC on tangents

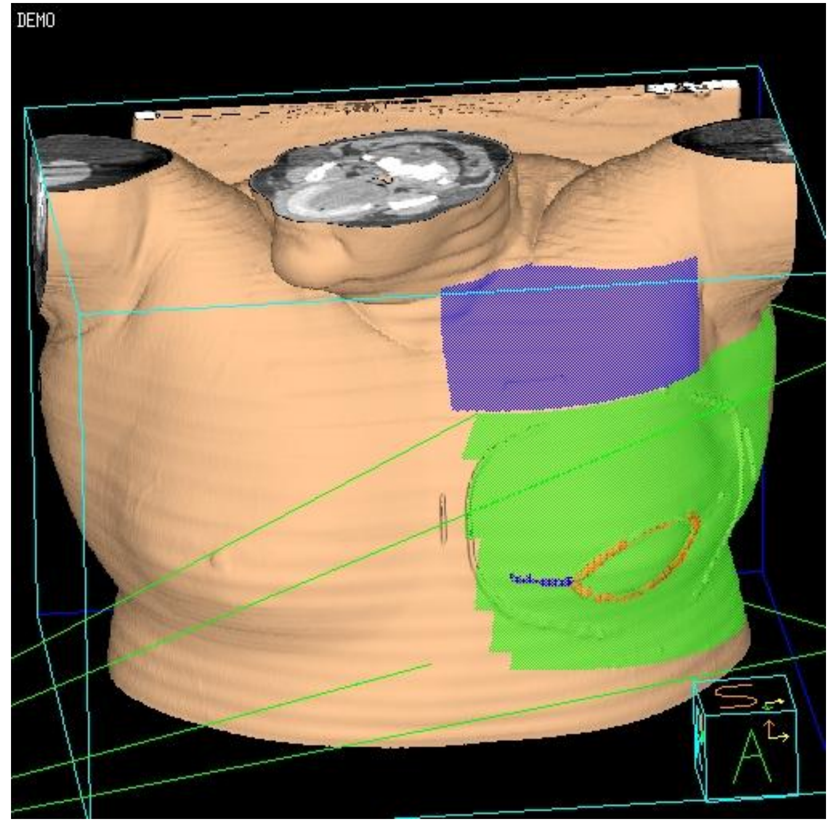


We can possibly achieve this blocking with our multi-leaf collimator.

However, what is a potential issue for the Elekta machine?

Breast: Elekta wedge

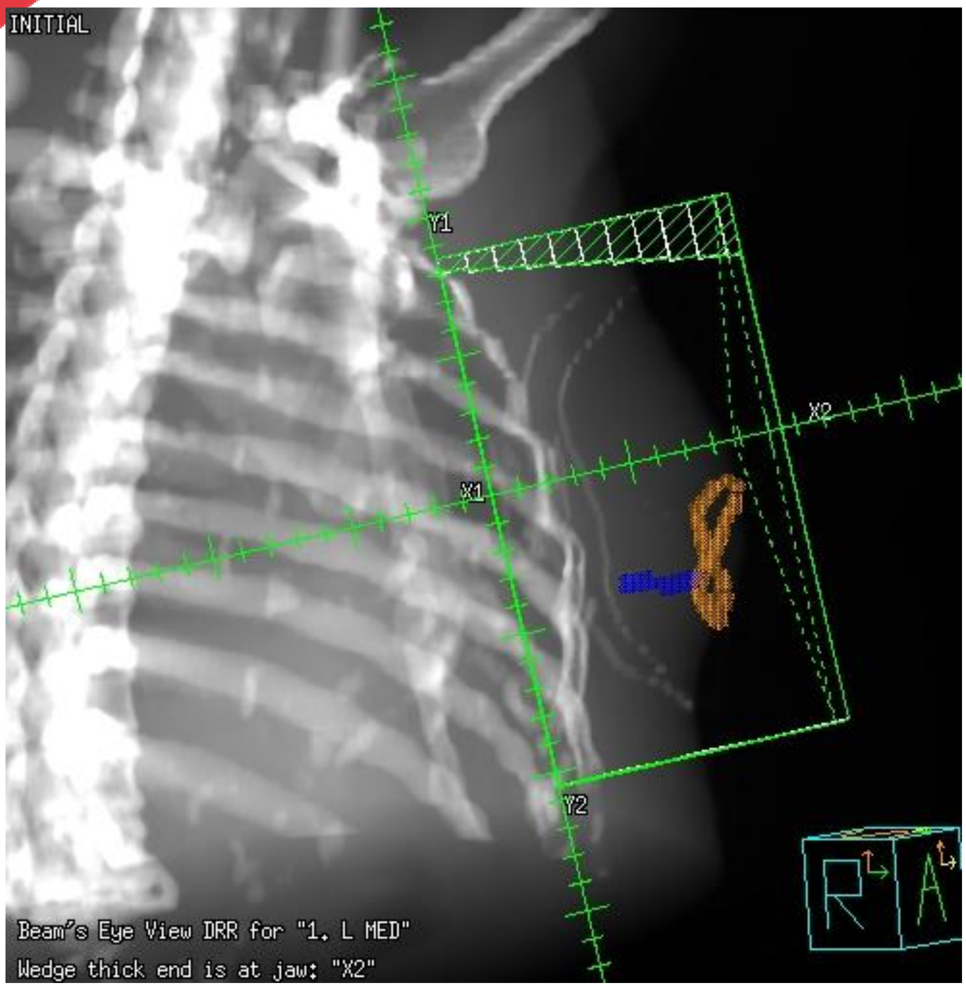




With breast cases, we want our wedge direction to be ant-post, so this requires us to rotate the collimator, causing a jagged edge...

… not only on the block, but on the skin.

Breast: Another way to do it



Instead of the lung block, we can rotate our collimator so that the field edge aligns with the chestwall.

What is different about this configuration?

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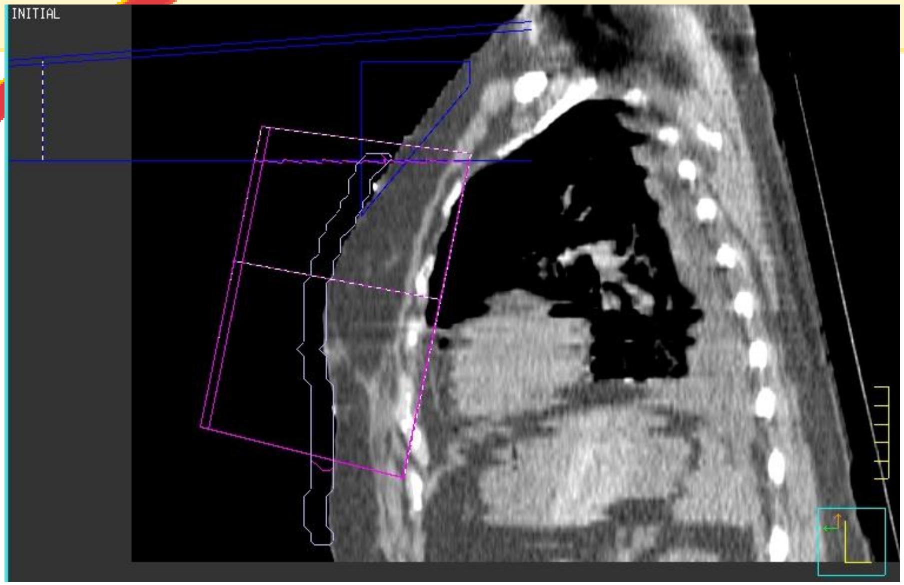
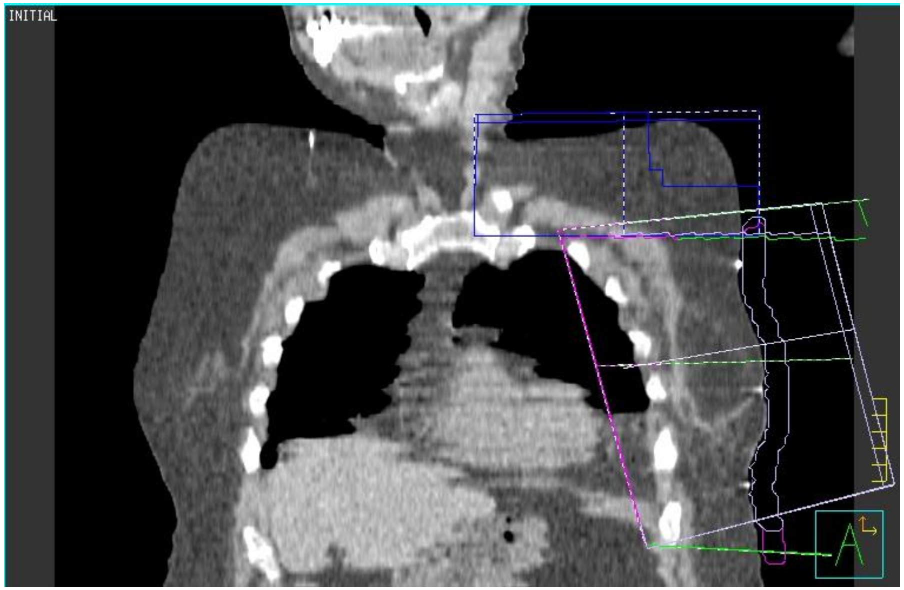
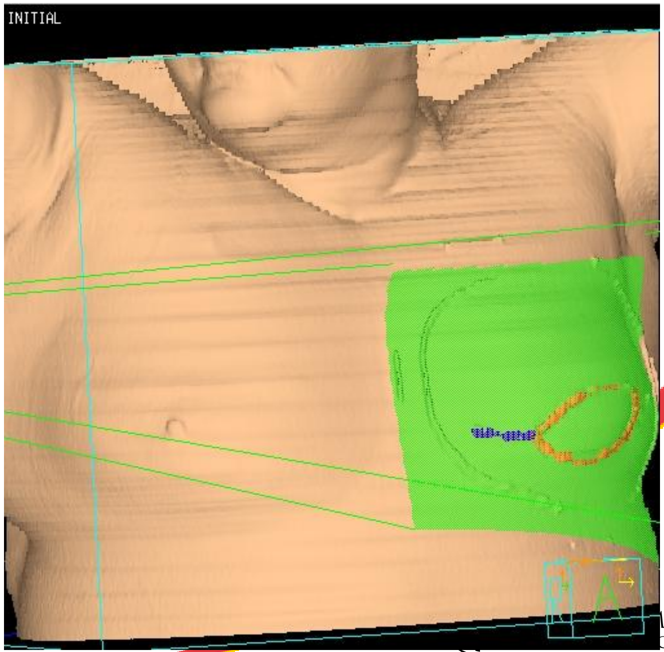
Breast: Corner block



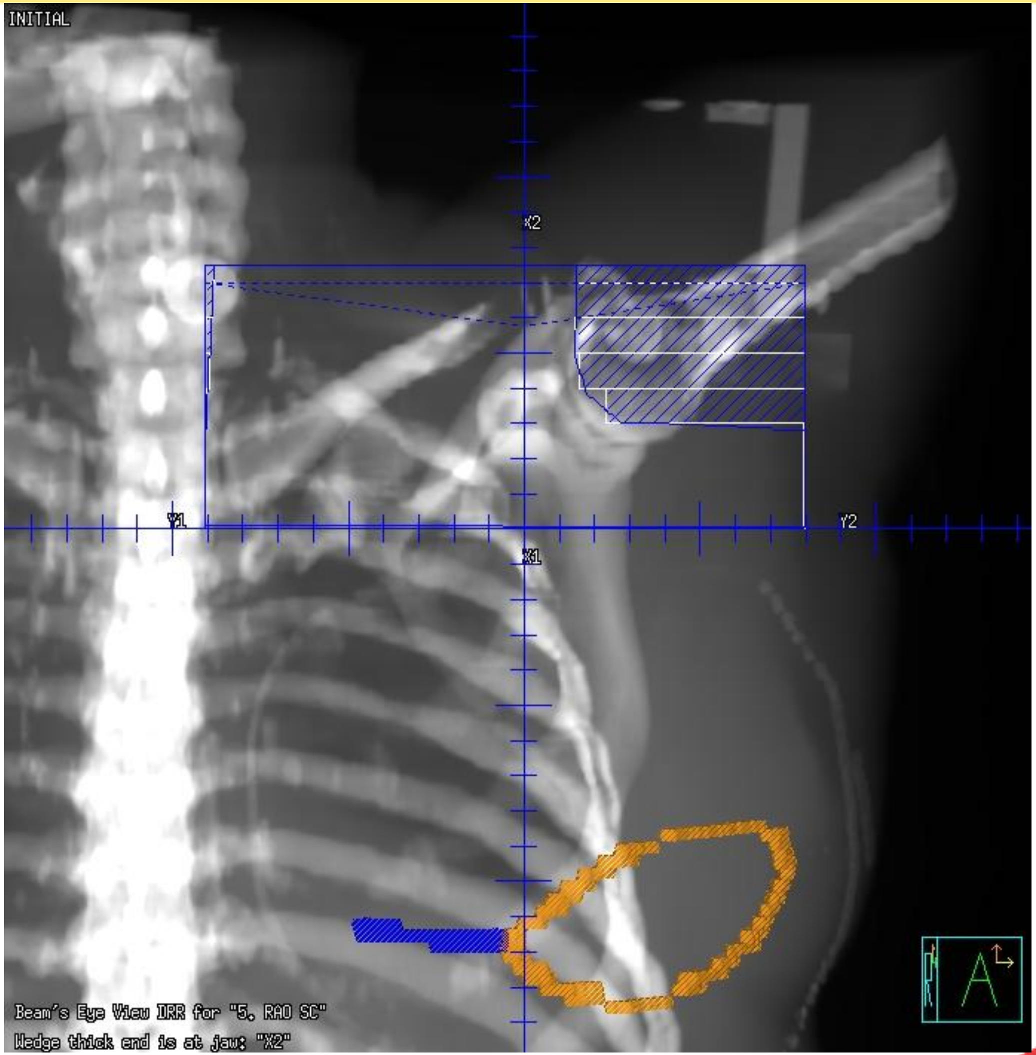


The match is achieved now with a corner block on the tangent fields.

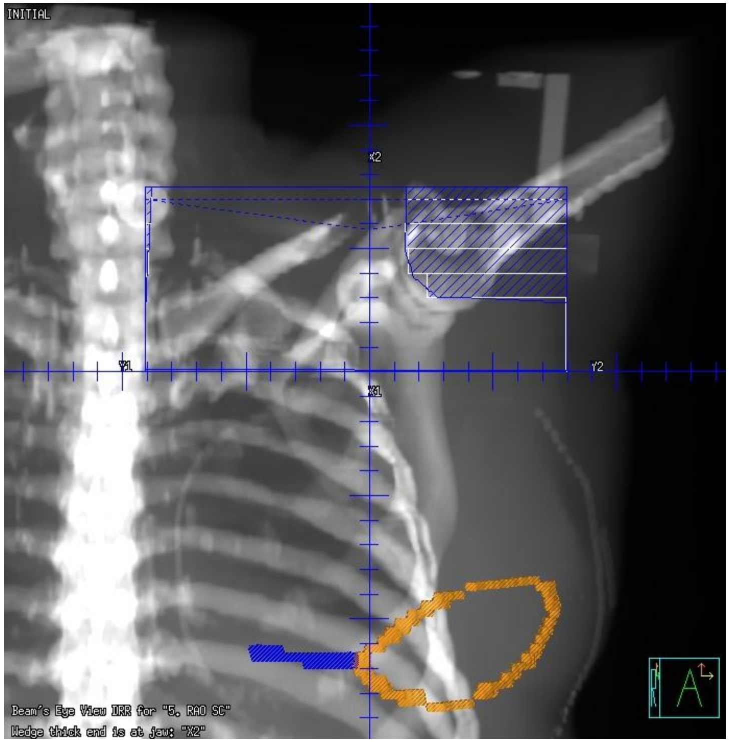
Also, there is a smooth edge field projection medially

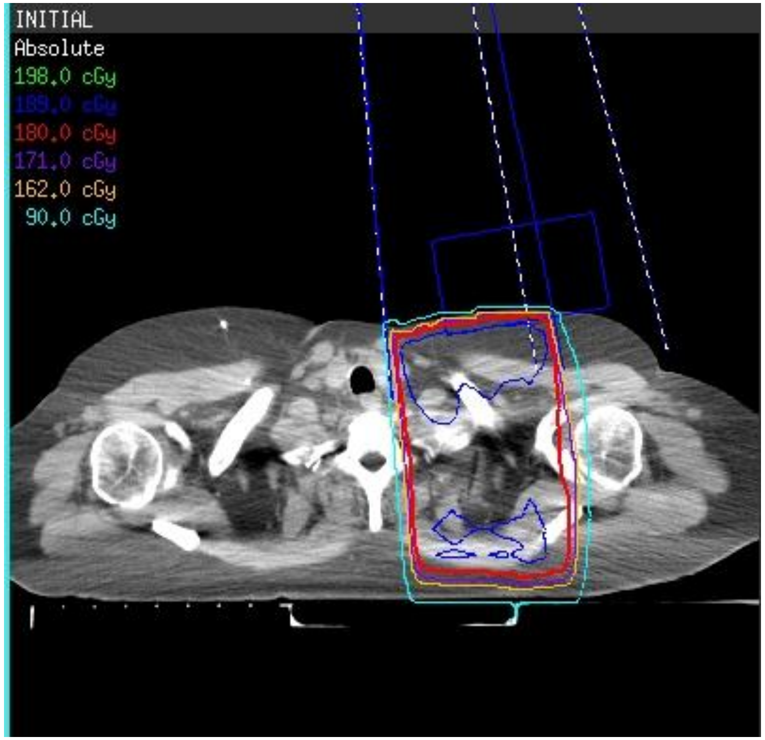


Breast: Supraclavicular field



Breast: Supraclavicular field



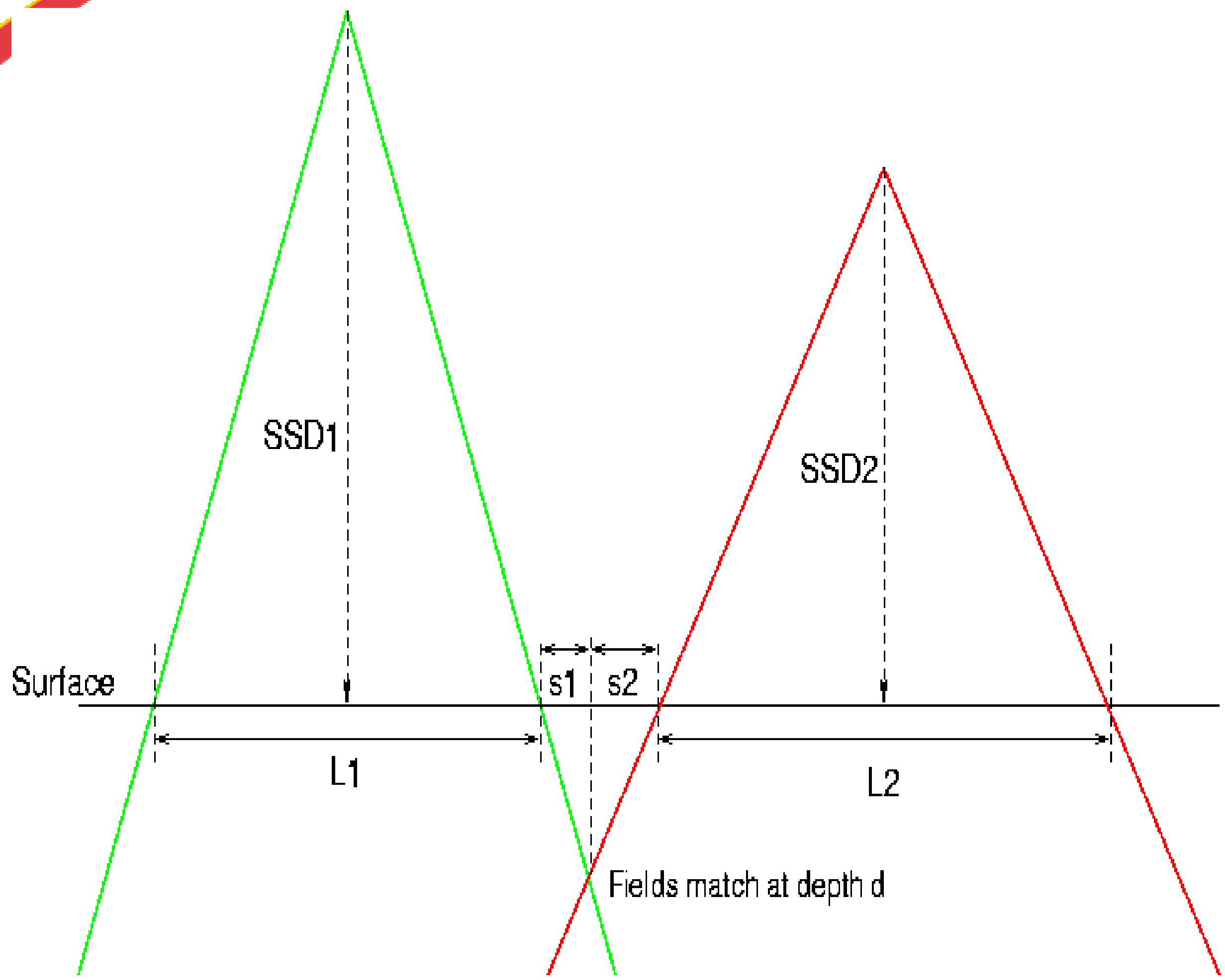


With this case, how do you think the SC nodes were treated (field configuration)?

Breast: Isodose Distribution

We can now compute the dose distribution within the patient. (In this case, we used Pinnacle's Convolution Superposition dose engine).

Gap calculations



$$\frac{s1}{d} = \frac{\frac{1}{2}L1}{SSD1}$$

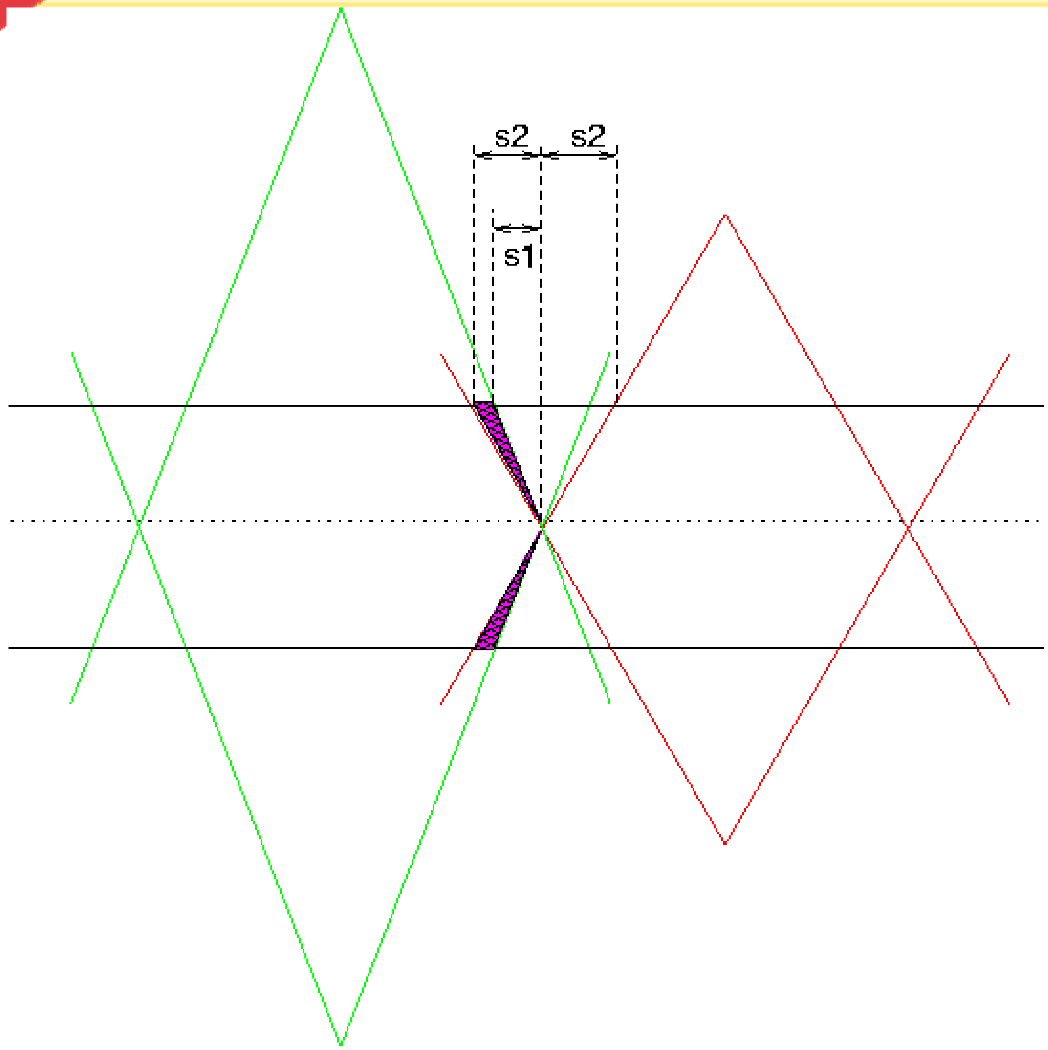
$$\frac{s2}{d} = \frac{\frac{1}{2}L2}{SSD2}$$

$$s = s1 + s2$$

$$s = \frac{d}{2}\left(\frac{L1}{SSD1} + \frac{L2}{SSD2}\right)$$

Matching fields at a depth d: What is the gap on the skin? Again, it is all about geometry and similar triangles

Gap: Parallel opposed



But what if the divergences don't align (ie s1 does not equal s2)?

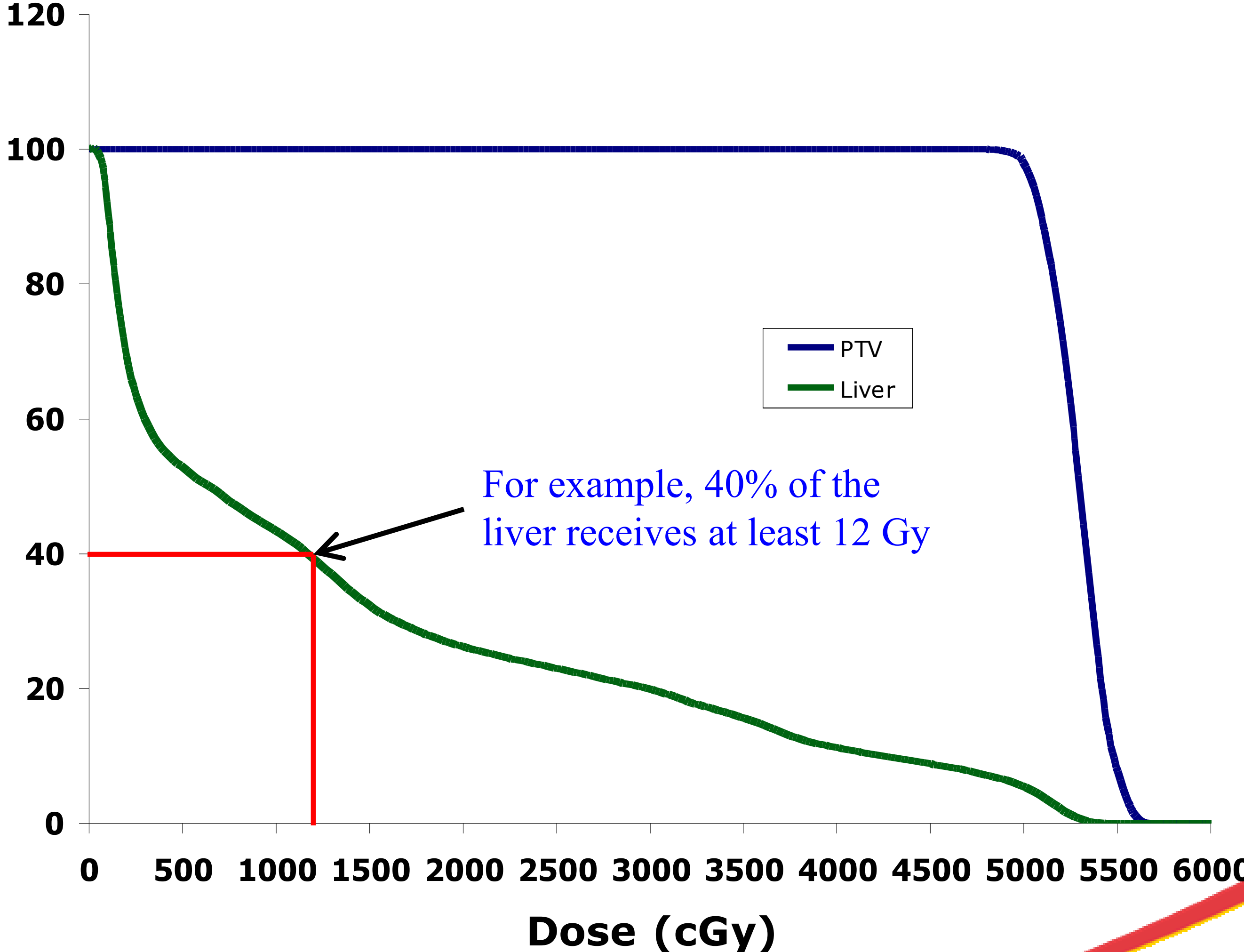
This is the concept of "3 field overlap"

By making s1 = s2, we align divergences and remove "3 field overlap"

OR, we can increase the gap by s2-s1 (to make it 2xs2). What is the potential problem here?

Dose Volume Histograms

X% of the volume receives at least a dose of ***Y***



Question: How much of the liver receives 12 Gy or less?

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ICRU-50 and 62 Target delineation

GTV (Gross Tumor Volume): clinically "visible" disease

Subclinical (microscopic disease)

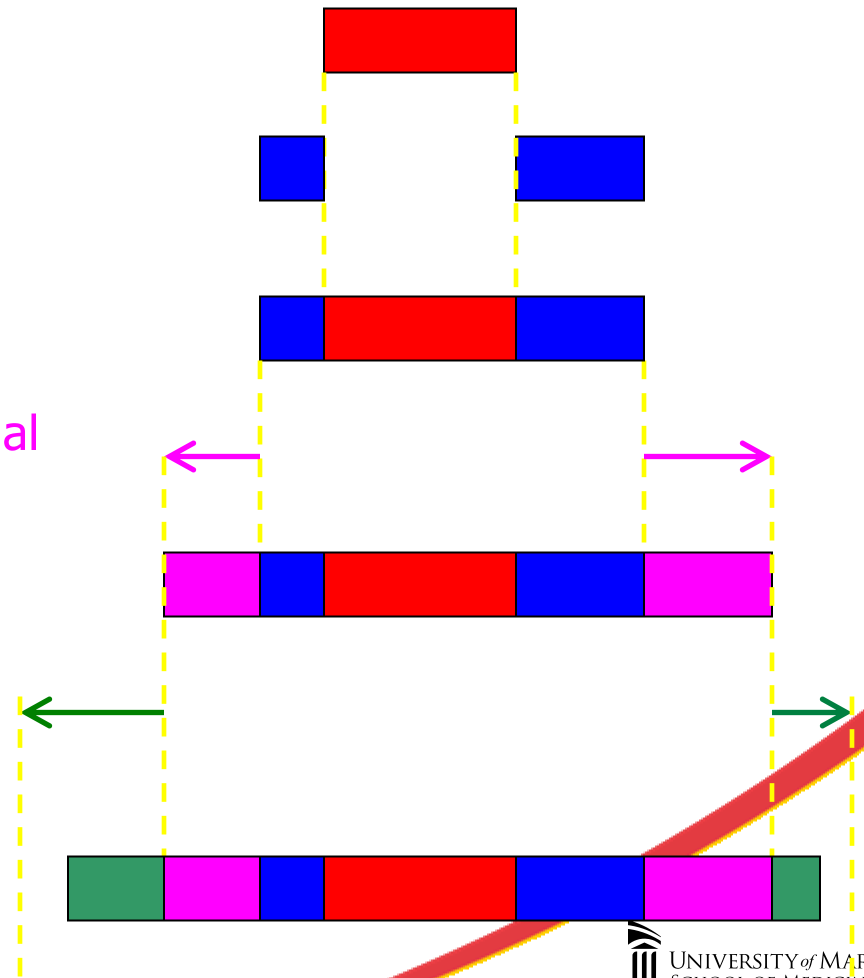
CTV (Clinical Target Volume): GTV + subclinical

IM (Internal Margin): accounts for internal motion

ITV (Internal Target Volume)

SM (Setup Margin): accounts for daily setup error, patient movement

PTV (Planning target volume): SM and IM not added linearly, but subjectively



ICRU-50 and 62 Margins

When deciding upon margin determination, we must balance the risk of missing part of the cancer cell population with the risk of severe and serious complications.

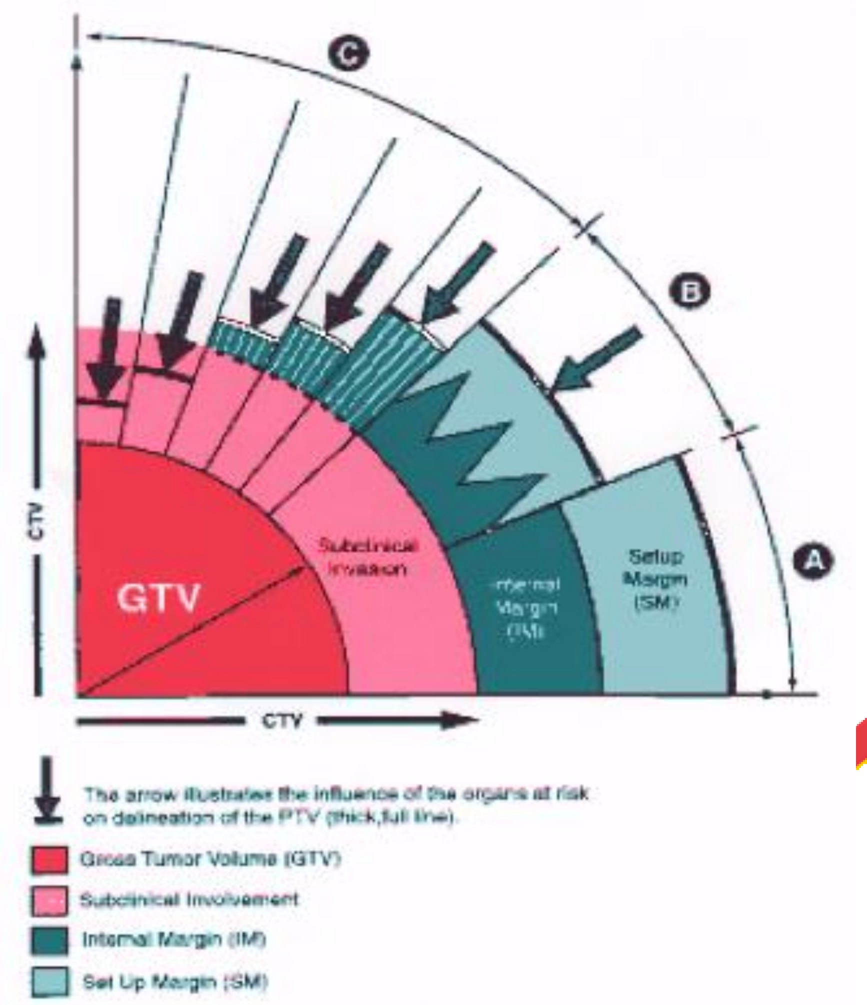
Region A: PTV = CTV+IM+SM. We simply add internal margin and setup margin.

Region B: Instead of linearly adding, we might use a quantitative approach like

$$\sigma_{total} = \sqrt{\sum \sigma_i^2}$$

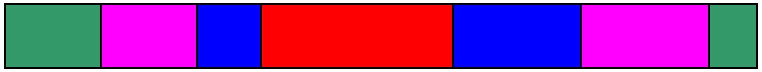
However, we must have a good knowledge of what σ_i are.

Region C: Safety margins depend on a number of factors.



ICRU-50 Organ at risk delineation

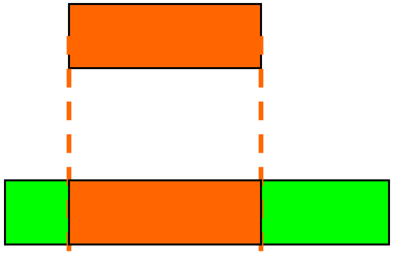
PTV (Planning target volume): Includes all margins (subclinical, internal, setup, patient movement)



Similar, less complicated scenario with organs at risk (OARs)

OAR (Organ at risk)

PRV (Planning Organ at risk volume): Includes all margins (internal, setup, patient movement) to consider for treatment planning



The End!!!

Please contact me for questions, etc.

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