TREATMENT PLANNING

Diana Baacke BS, CMD

School of Dosimetry
Cancer Therapy & Research Center

CANCER THERAPY & RESEARCH CENTER
UT HEALTH SCIENCE CENTER
SAN ANTONIO

Treatment Planning Considerations

- What constitutes a good plan
- What tools are available to produce a good plan
- Have all the constraints been met
- Is the plan treatable

Topics for Review

- Modality selection
- Energy selection
- Field size determination
- Beam arrangements
- Beam weighting
- Use of beam modifiers
- Normalization
- DVH

Topics for Review

- Aperture design
- Hand calculations
- Gap calculations
- The treatment planning process involves the determination of treatment parameters considered optimal in the management of the patient's disease.

Topics for Review

- Parameters include:
  Target Volume
  Dose-Limiting Structures
  Treatment Volume
  Dose Prescription
  Dose/Fraction
  Dose Distribution
  Positioning of Patient – immobilization

Topics for Review

- Modality selection
- Energy selection
- Field size determination
- Beam arrangements
- Beam weighting
- Use of beam modifiers
- Normalization
- DVH

MODALITY SELECTION

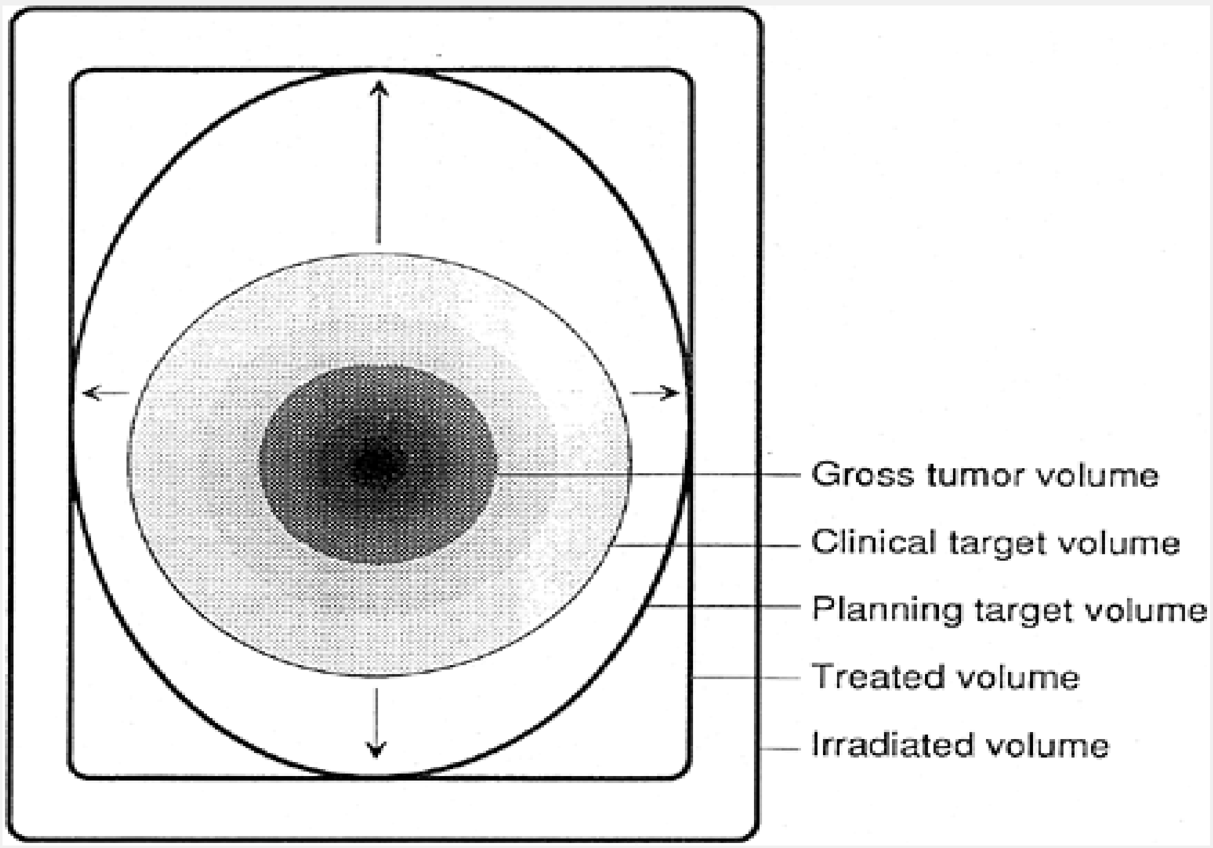
- Modality selection is based on anatomy, tumor location, tumor size, and organs at risk.
- Definition: Treatment Volume: includes tumor (demonstrated by imaging) and its occult spread to surrounding tissues or lymphatics.

MODALITY SELECTION

- Errors in the target volume/localization result in radiotherapy failures.
- Radiation Oncologist uses CT, MRI, ultrasound, single photon emission CT (spect), PET, to localize disease.
- GTV – Defn: Disease that is seen using imaging.
- CTV – Defn: volume that includes GTV plus invisible microscopic tumor. It is estimated clinically; GTV plus margin that includes occult disease. SUBJECTIVE.

MODALITY SELECTION

ICRU 50 Definitions



MODALITY SELECTION

- Treatment failures result in the misjudgment of CTV.
- The CTV is not static. It changes with time variations in set up, motion of internal organs, breathing and positioning instability.
- PTV = CTV + Margin; the ultimate target volume which is the primary focus of treatment planning and delivery.

MODALITY SELECTION

- Treatment modality selection may include: photons, electrons, protons, IMRT, stereotactic radiotherapy, Brachytherapy, and any combination thereof.
- There are further selections to be made in each of the mentioned modalities.

Topics for Review

- Modality selection
- Energy selection
- Field size determination
- Beam arrangements
- Beam Weighting
- Use of beam modifiers
- Normalization
- DVH

Energy Selection

- When choosing an energy the following items are considered

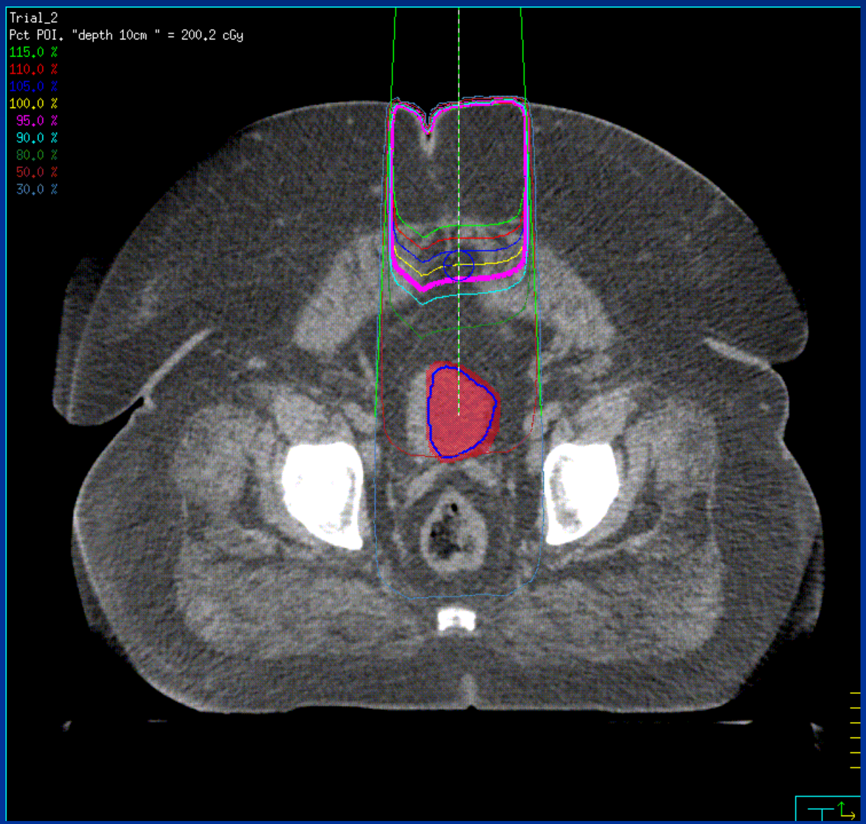
  1. Tumor location
  2. Tumor size
  3. Surrounding tissues
  4. Skin sparing
  5. Exit dose

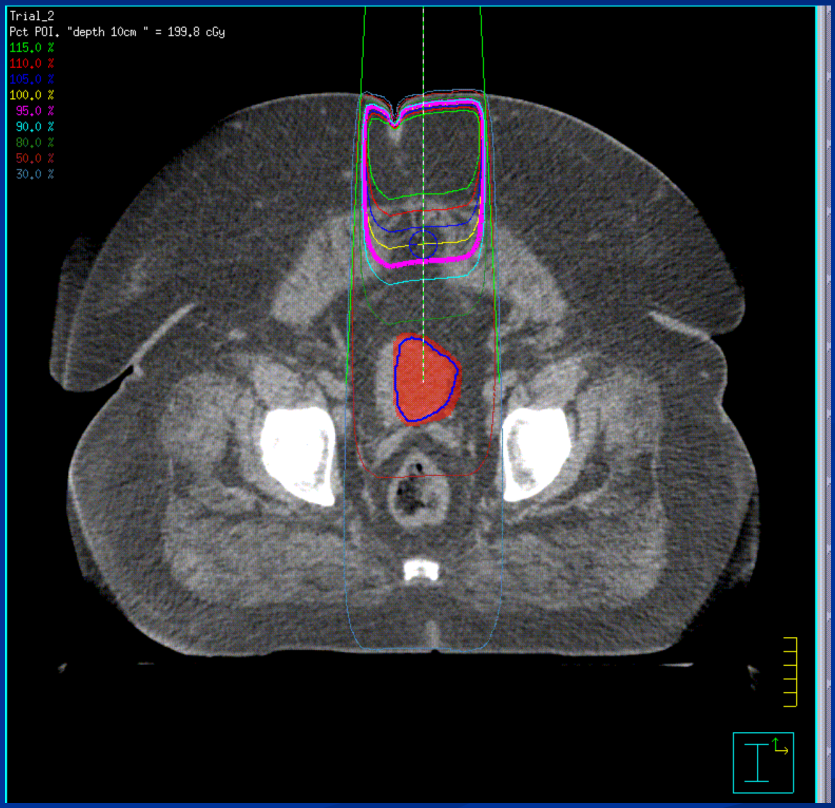
Energy Selection

- Question:

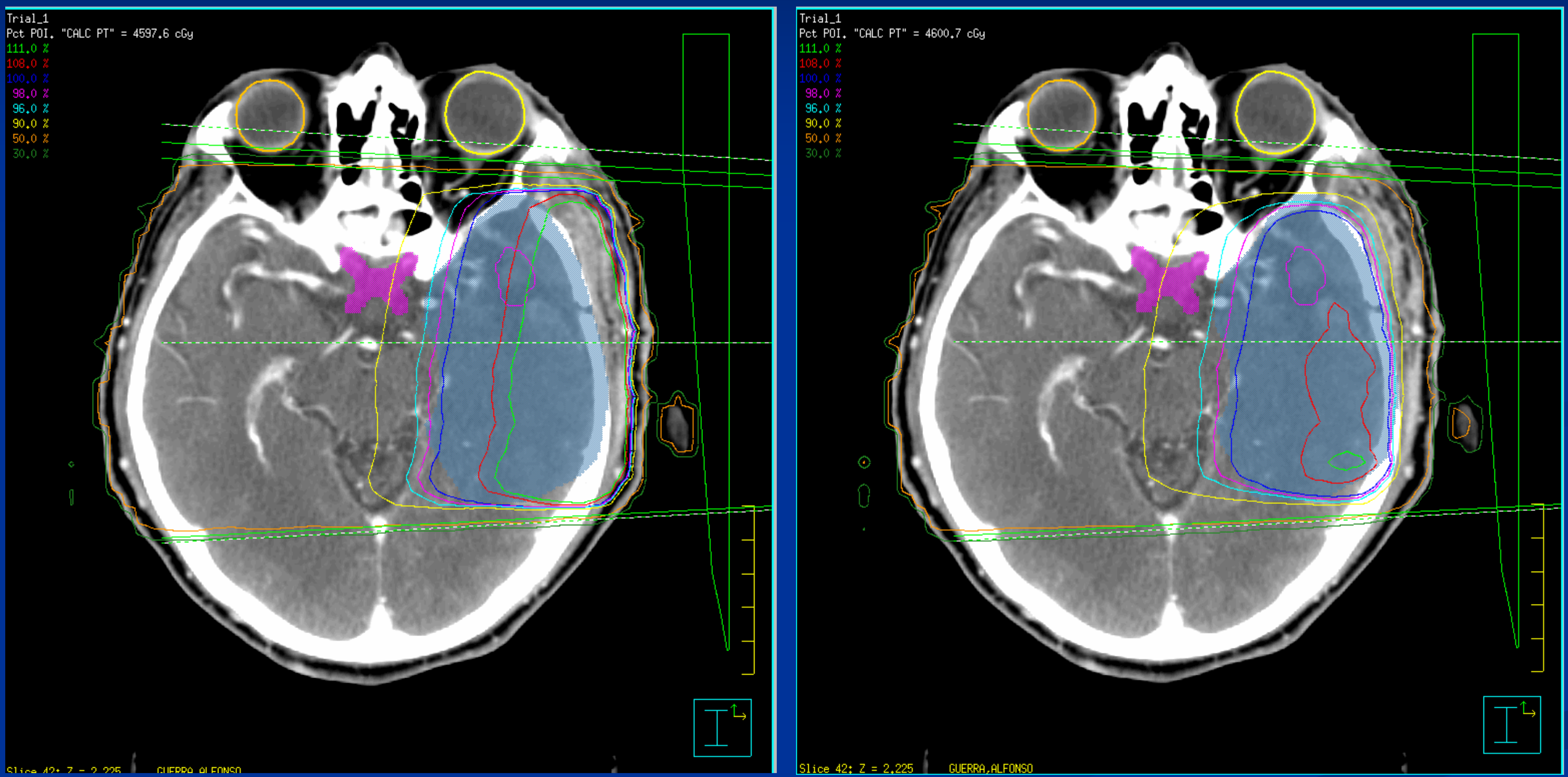
  In the following examples what differences do you notice in the plans?

Energy Selection





Energy Selection



Topics for Review

- Modality selection
- Energy selection
- Field size determination
- Beam arrangements
- Beam Weighting
- Use of beam modifiers
- Normalization
- DVH

Field Size Determination

- Field size is based on two different definitions
- Dosimetric field size

  Isodose curve (i.e. 90%) encompasses the treatment volume

- Geometric field size

  The field size is defined as the intersection of the 50% isodose line and the surface

Field Size Determination

- Of the two methods for determining field size the geometric field size is the preferred method
- Field boundaries must include physical penumbra (lateral distribution between field edge and 90% or 95% ISO line). Sometimes field adjustments, i.e. field size must be increased once distribution is seen.

Field Size Determination

- Penumbra

  Region, at the edge of a radiation beam, over which the dose rate changes rapidly as a function of distance from the beam axis.

- Geometric penumbra

  Penumbra due to the source geometry.

Field Size Determination

- Penumbra facts
  - SDD can be increased by extendable penumbra trimmers. The trimmers attenuate the beam in the penumbra region.
  - Secondary blocking can also be used to reduce the penumbra
  - Physical penumbra width: lateral distance between two specified isodose curves at a specified depth,10cm

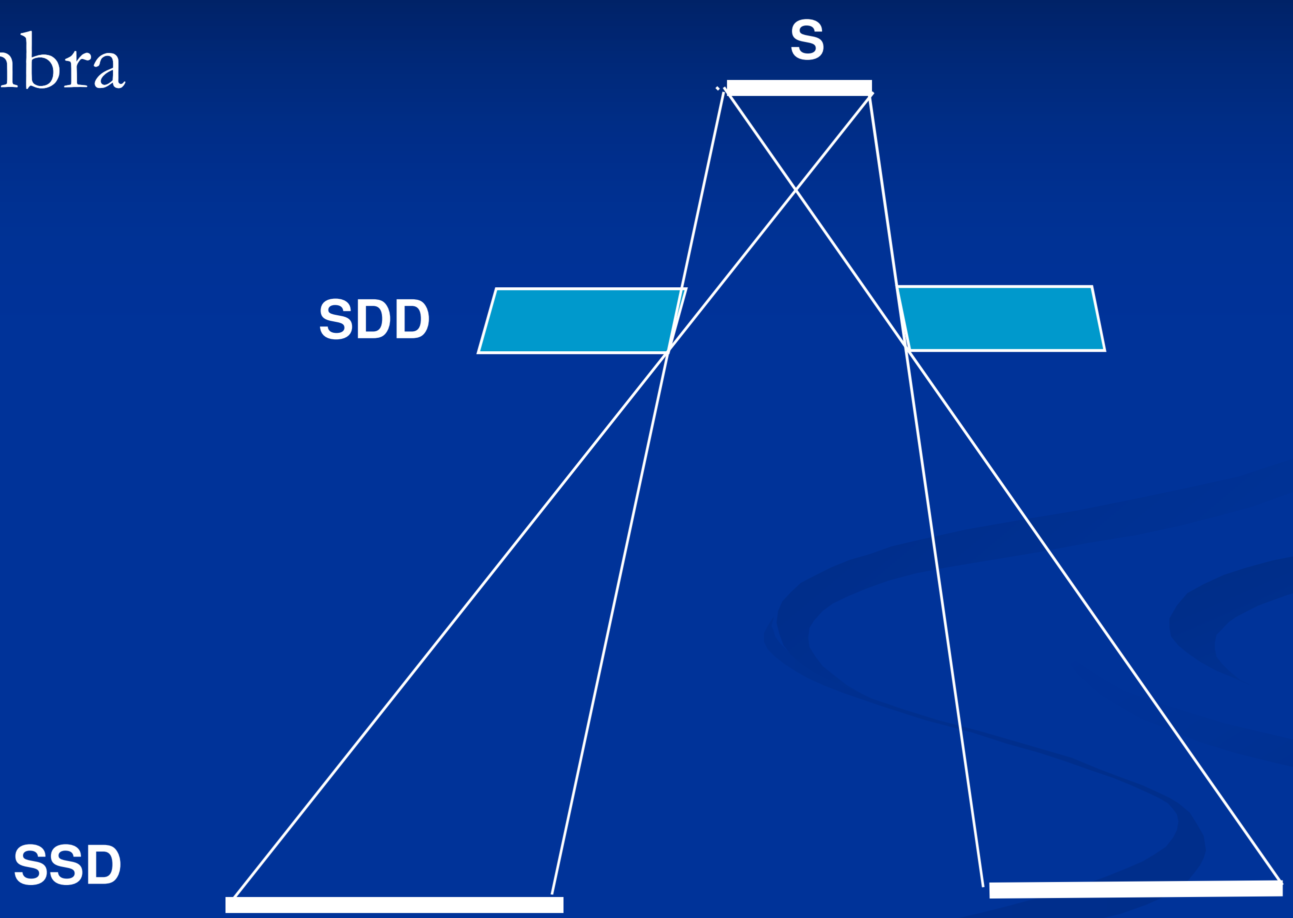
Field Size Determination

Penumbra facts

- Geometric Penumbra: $P = S\frac{(SSD + d - SDD)}{SDD}$
- As S ↑, Geometric Penumbra ↑
- As SSD ↑, Geometric Penumbra ↑
- As d ↑, Geometric Penumbra ↑
- As SDD↑, Geometric Penumbra ↓
- Other sources of penumbra:
  - Absorption sharpness
  - Motion unsharpness

Field Size Determination

Penumbra



Field Size Determination

- Question #1:

  What is the SSD if P = 0.41 cm on the surface of a patient where the SDD of the unit being used is 55 cm AND THE SOURCE SIZE = 0.5 cm?
- Question #2: In the above question what is P if SSD = 110 cm?
- Question #3: What is the third type of penumbra?

Field Size Determination

- Ans 1: P=S(SSD+d-SDD)/SDD

  S= 0.5 cm, d=0, SDD=55 cm, P=0.41

  (PxSDD)/S +SDD-d = SSD

  (0.41x55)/0.5 + 55 -0 = 100cm

- Ans 2: P = 0.5(110+0-55)/55 =0.5 cm

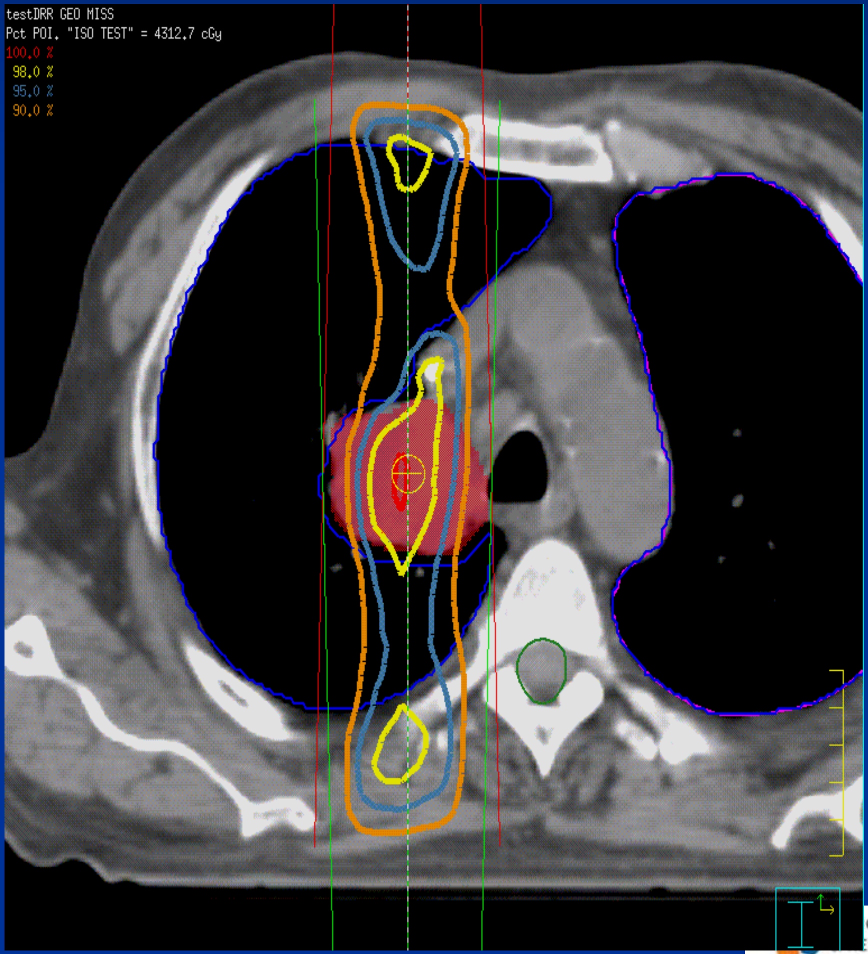
- Ans 3: Transmission penumbra

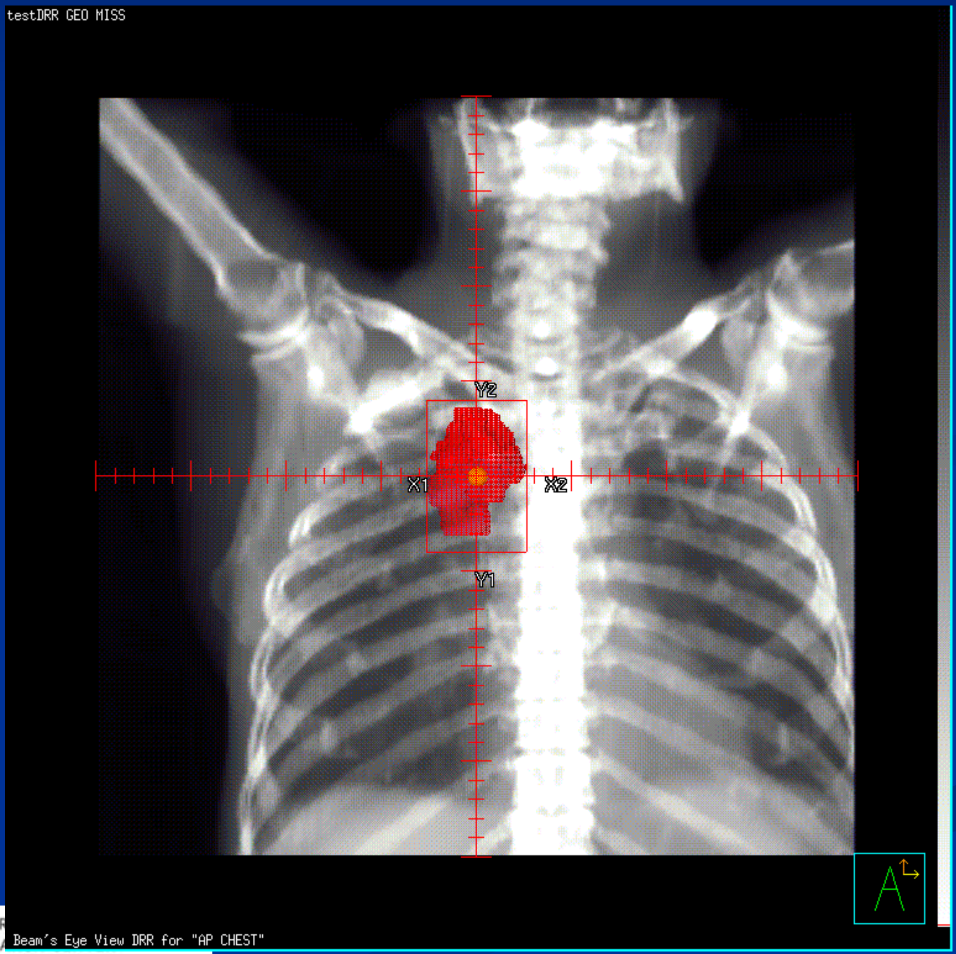
Field Size Determination

- When considering the following slides take note of the following:
  1. Field size considerations
  2. Energy chosen
- What issues in regards to penumbra and energy must be considered when choosing energy?

Field Size Determination

F/S= 5.2 x 8



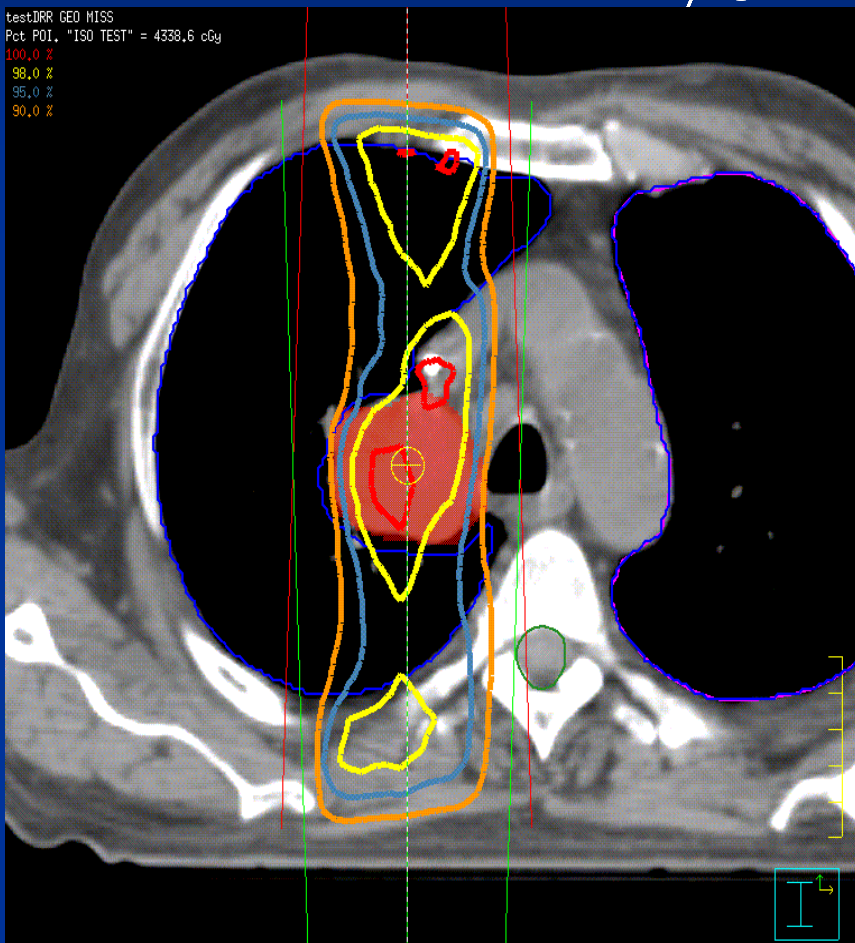


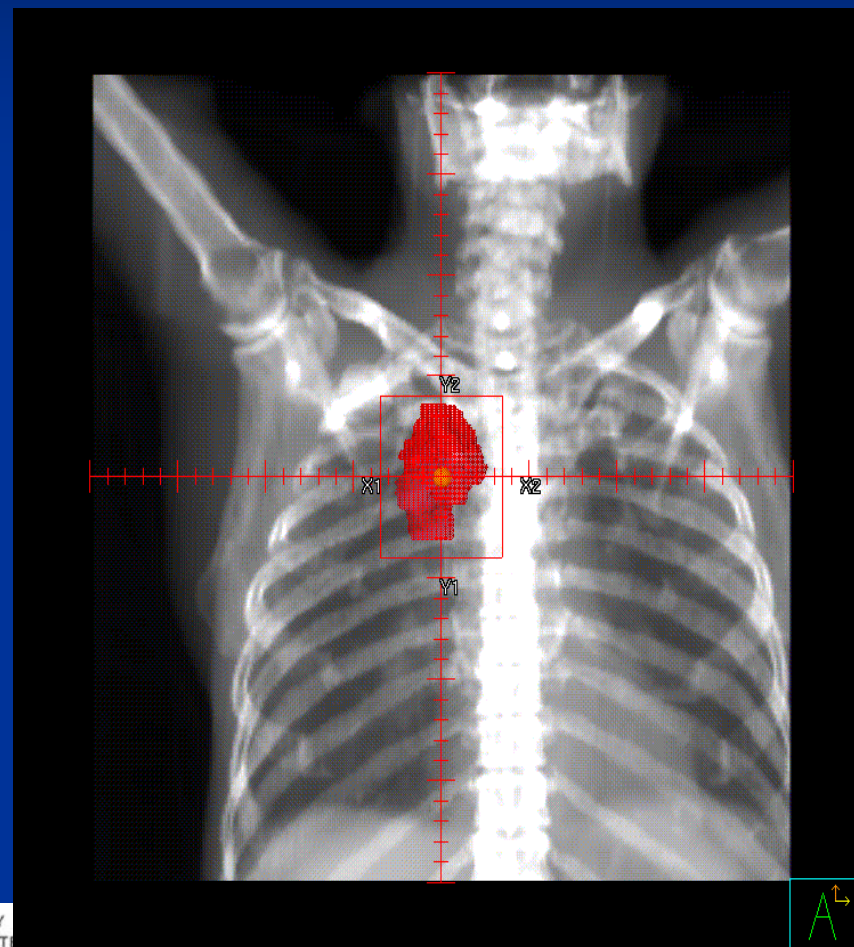
School of Dosimetry
Cancer Therapy & Research Center

UT Health Science Center San Antonio

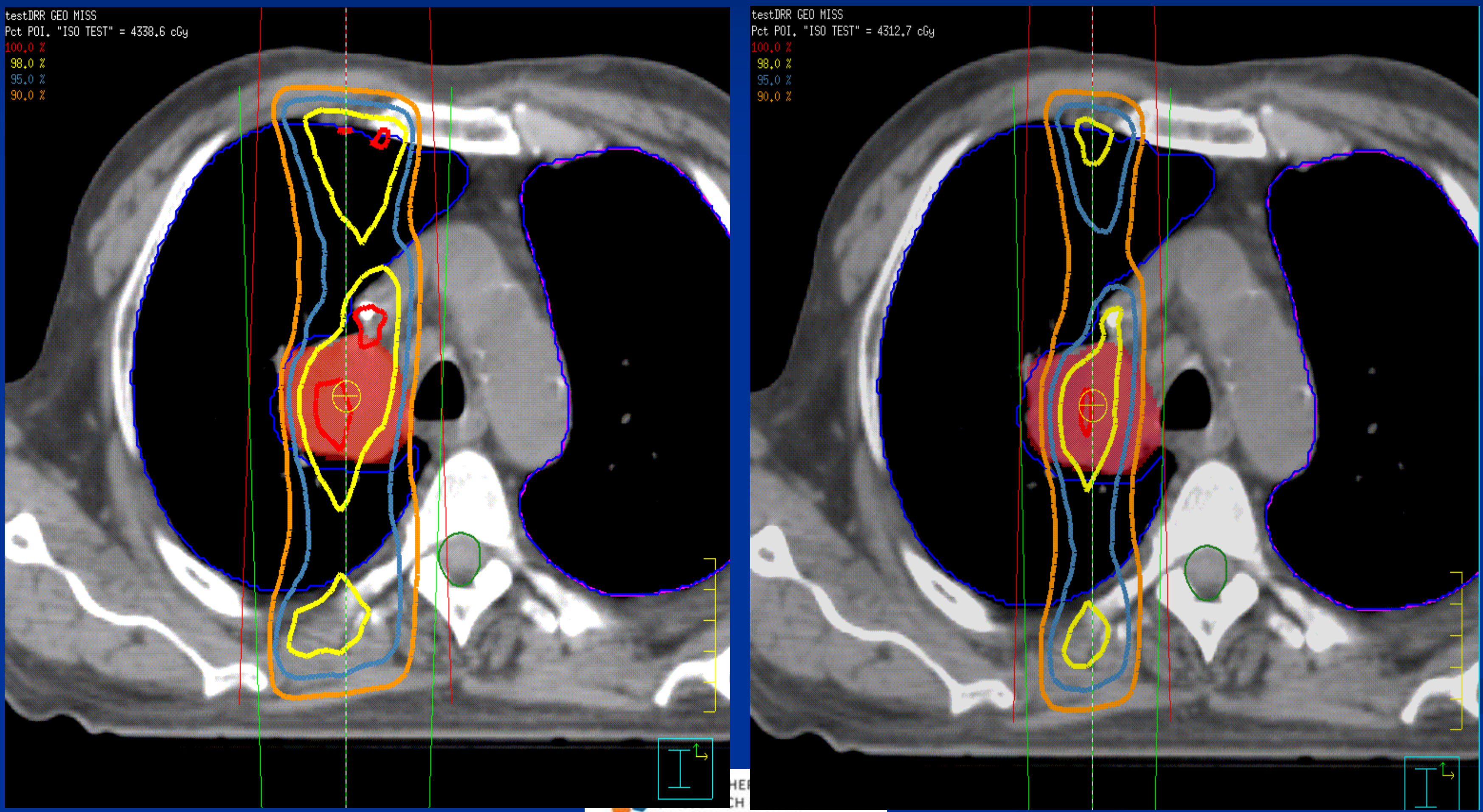
Field Size Determination

F/S= 7 x 8





Field Size Determination



Field Size Determination

- Geometric misses due to either incorrect portal design or incorrect tumor delineation are very difficult to correct
- The responsibility of judgment in an accurate treatment plan rests on the physician

Topics for Review

- Modality selection
- Energy selection
- Field size determination
- Beam arrangements
- Beam Weighting
- Use of beam modifiers
- Normalization
- DVH

Beam Arrangements

- Single field
- Parallel opposed fields
- Multiple fields

  1. Four field technique
  2. Three field coplanar or noncoplanar beams
  3. More than four fields
  4. Rotational therapy
- Split beam technique

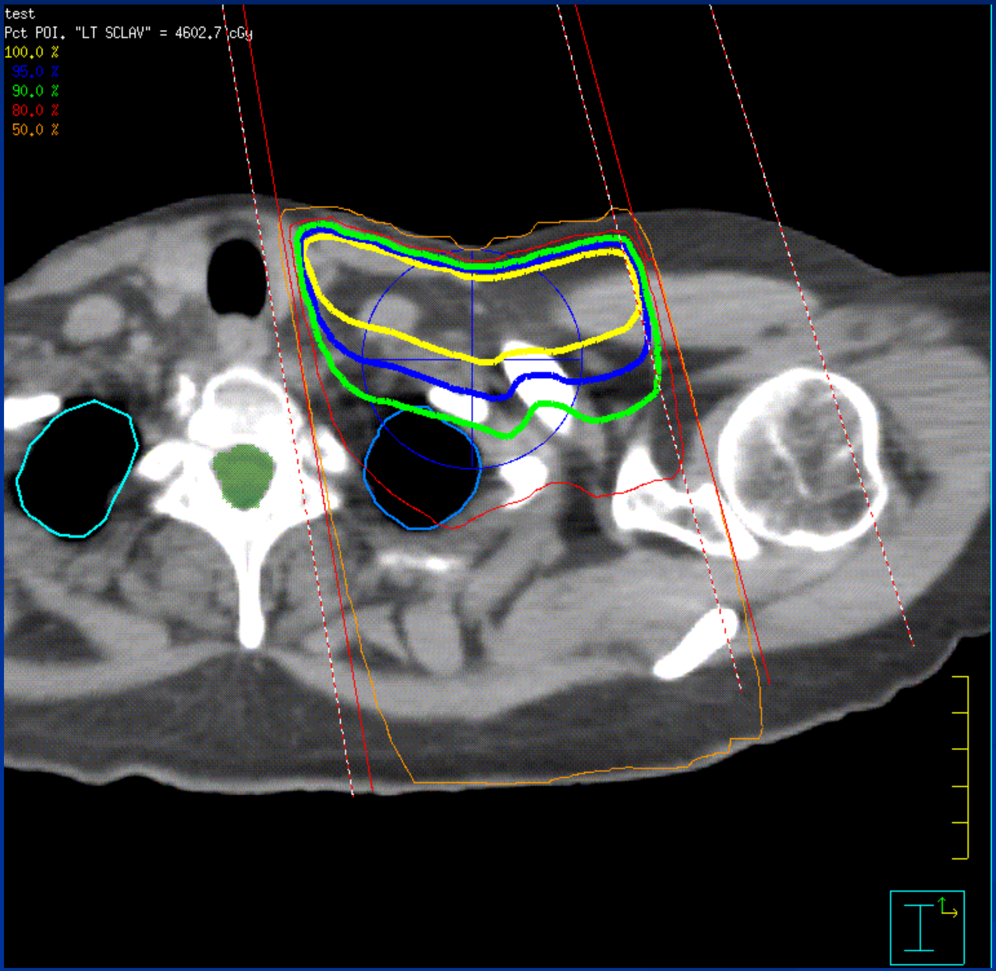
Single Field

- A single field approach is simplistic but not often used
- Dose uniformity across the tumor is uniform (± 5%)
- Hotspots ≤ 110%
- Dose to normal structures do not exceed tolerance
- Used to treat superficial tumors or to restrict dose to the opposite side of the body

Single Field

- Examples of a single field technique:
  1. Supraclaviclular field
  2. Spine field
  3. Electron fields

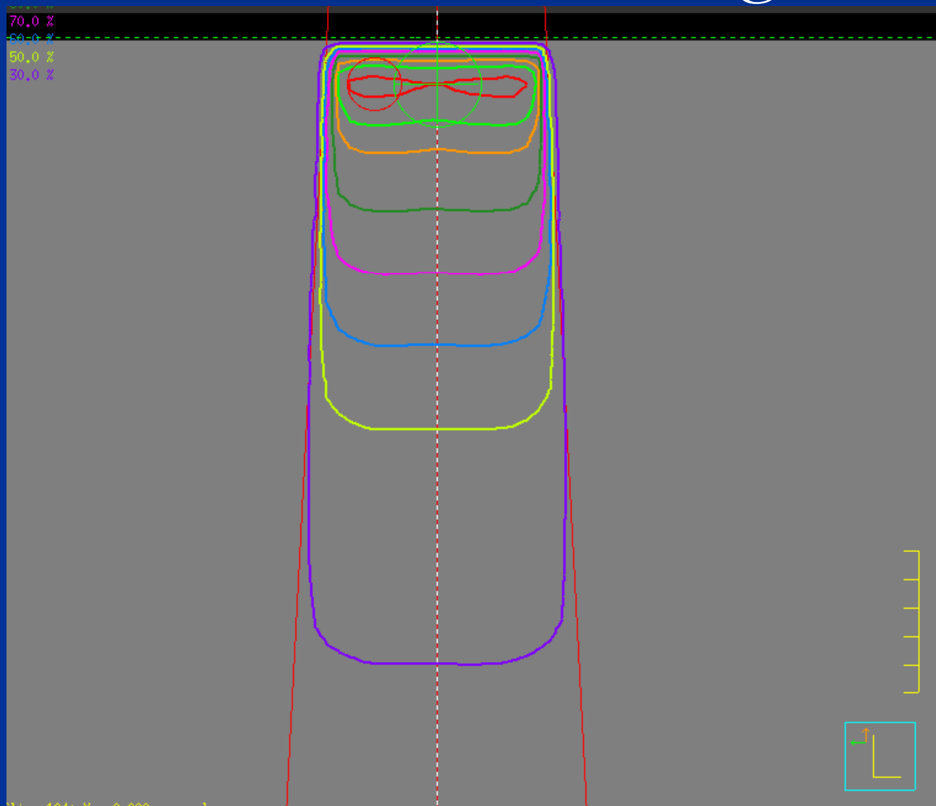
Single Field

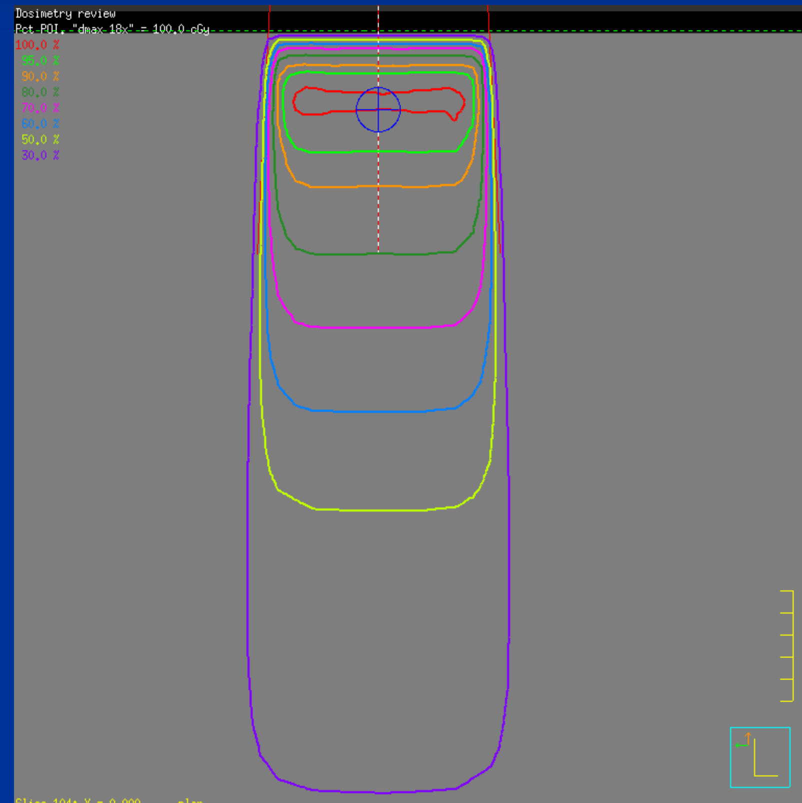


CANCER THERAPY & RESEARCH CENTER
UT HEALTH SCIENCE CENTER™
SAN ANTONIO

Single Field

- What is the difference between these single beams?





Parallel Opposed Fields

- Use when the dose gradient across the tumor is >5% with just a single field
- Advantages include: simplicity and reproducibility of set up, homogeneous dose across the tumor, and decreased chance of a geometric miss
- Disadvantage: large doses to structures above and below tumor

Parallel Opposed Fields

- For parallel opposed fields dose uniformity is dependent on energy, beam flatness, and patient separation
- Tissue lateral effect - Increased separation or a decrease in energy will increase the superficial dose along the CAX relative to the midpoint dose
- For parallel opposed fields, what factors affect dose at dmax versus dose at depth? Ans: E, separation

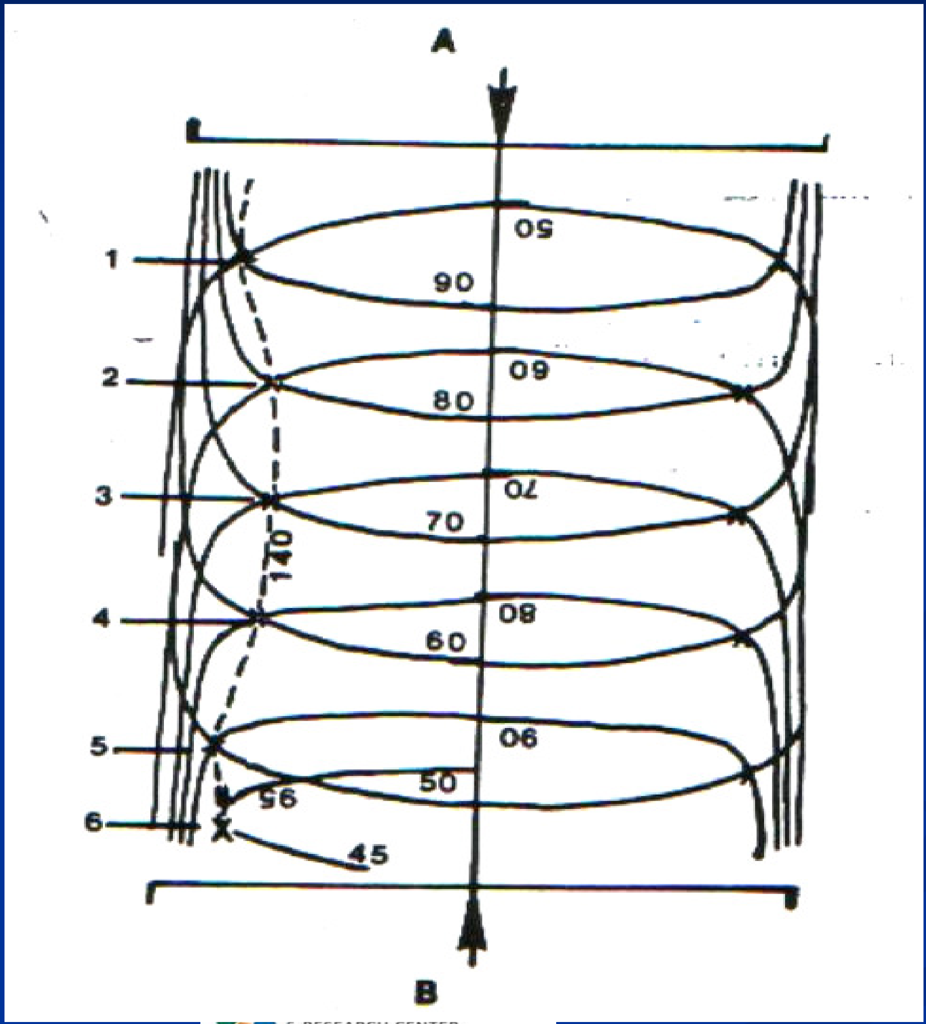
Parallel Opposed Fields

- Edge effect (Lateral tissue damage) When using parallel opposed fields, treating only one field per day produces greater biologic damage to normal subcutaneous tissue
- Normal tissues will receive alternating high and low doses altering the biological effect
- Maximum edge effect occurs with large (≥20 cm) separations, treating only one field per day, and a lower energy beam

Parallel Opposed Fields

- Integral dose – Measurement of total energy absorbed in the volume treated
- The higher the photon energy the lower the integral dose
- Seldom used clinically yet can aid in the selection of beam energy, field sizes, and number of beams to use
- General rule: keep integral dose to a minimum

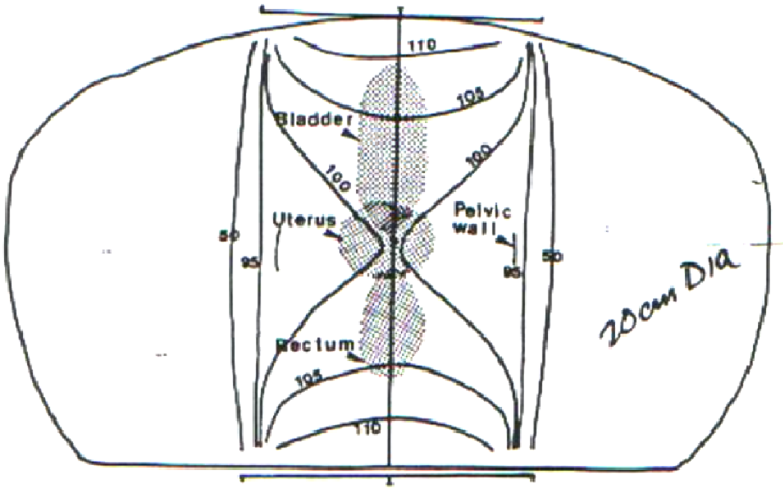
Parallel Opposed Fields

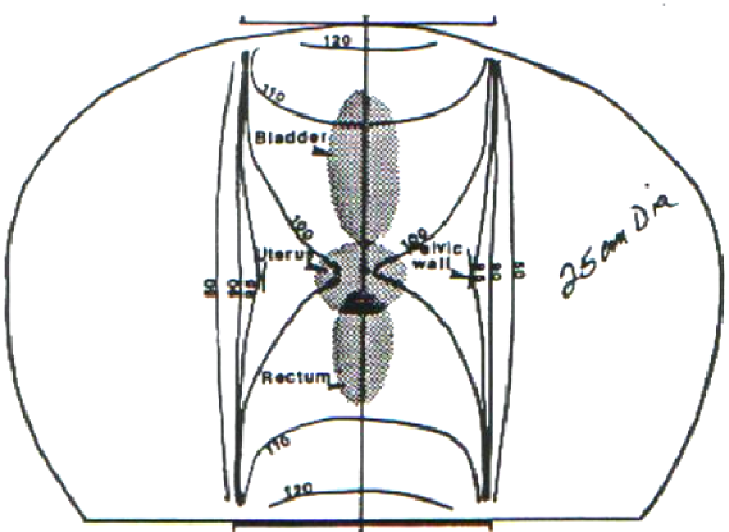


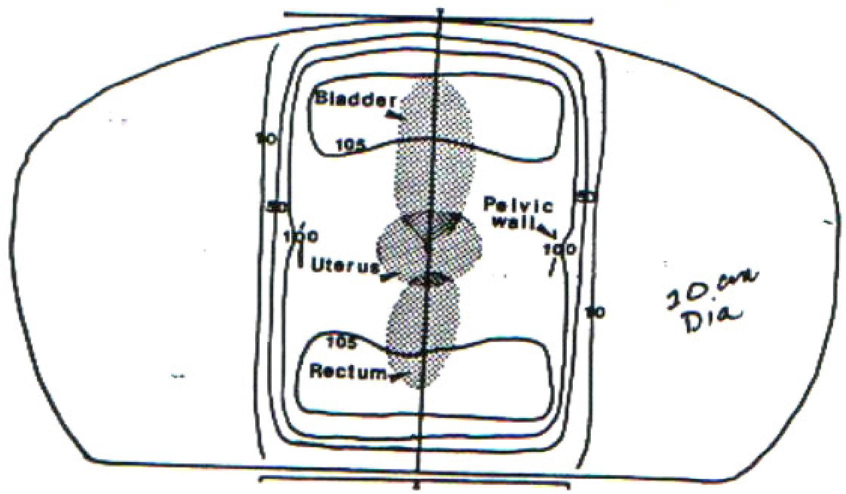
& RESEARCH CENTER
UT HEALTH SCIENCE CENTER
SAN ANTONIO

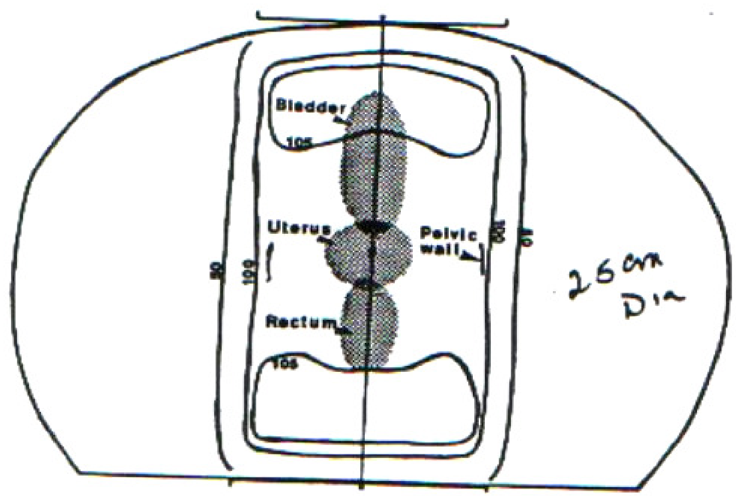
Parallel Opposed Fields

vs. 16



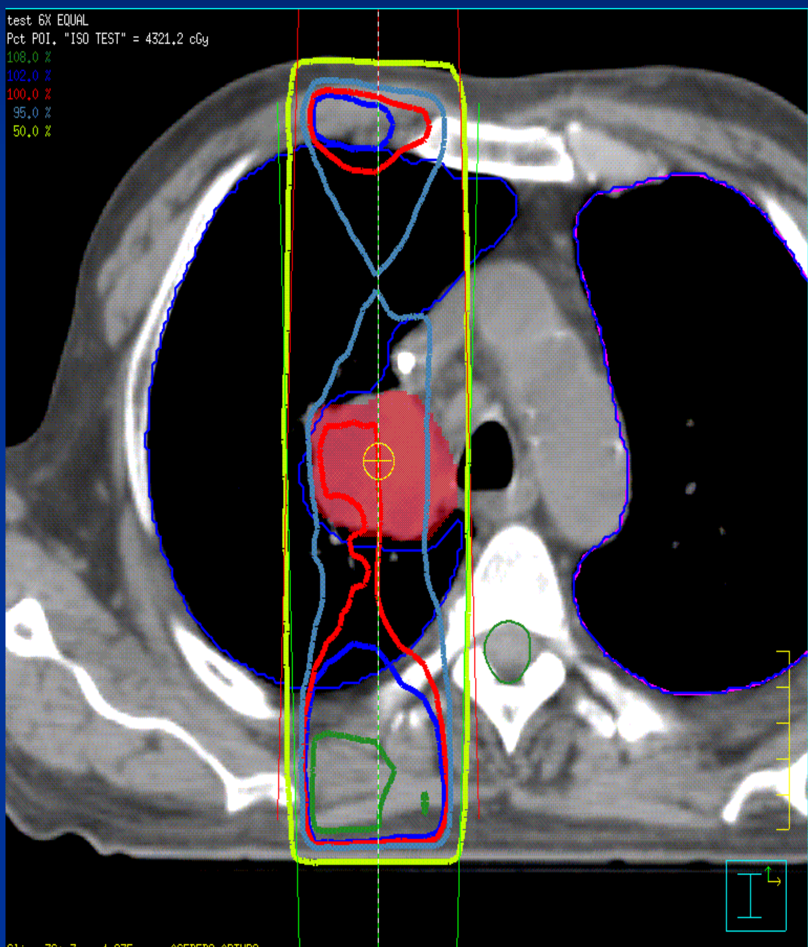


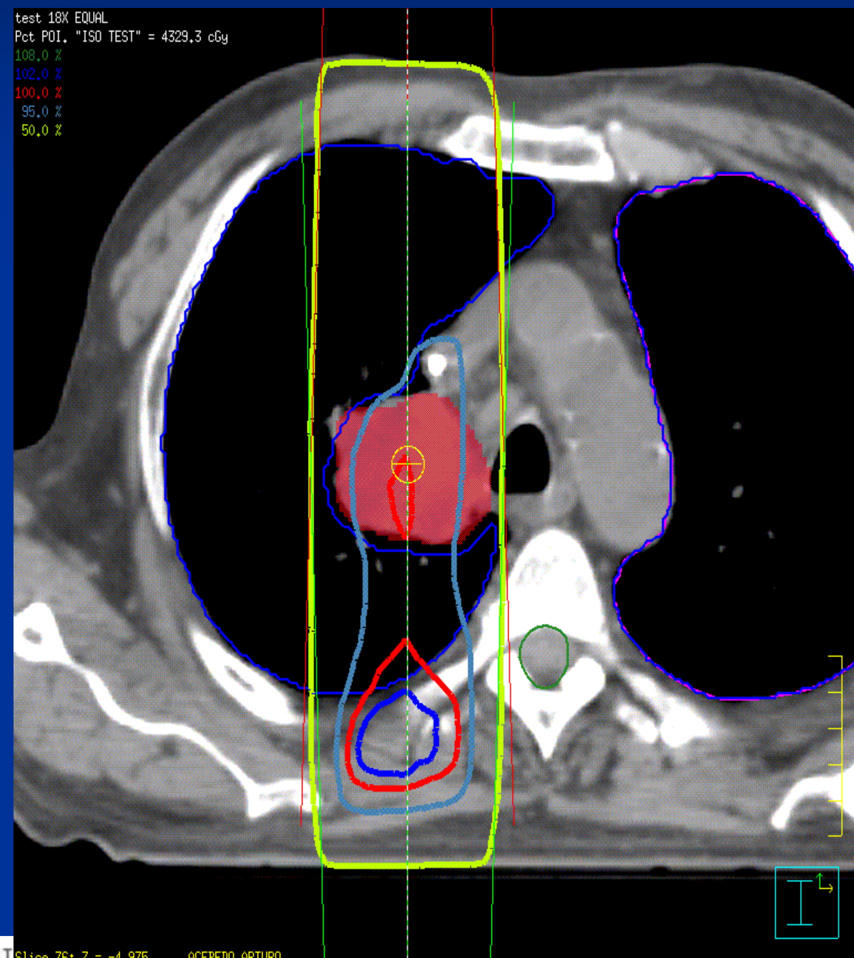




Parallel Opposed Fields

6MV vs. 18MV



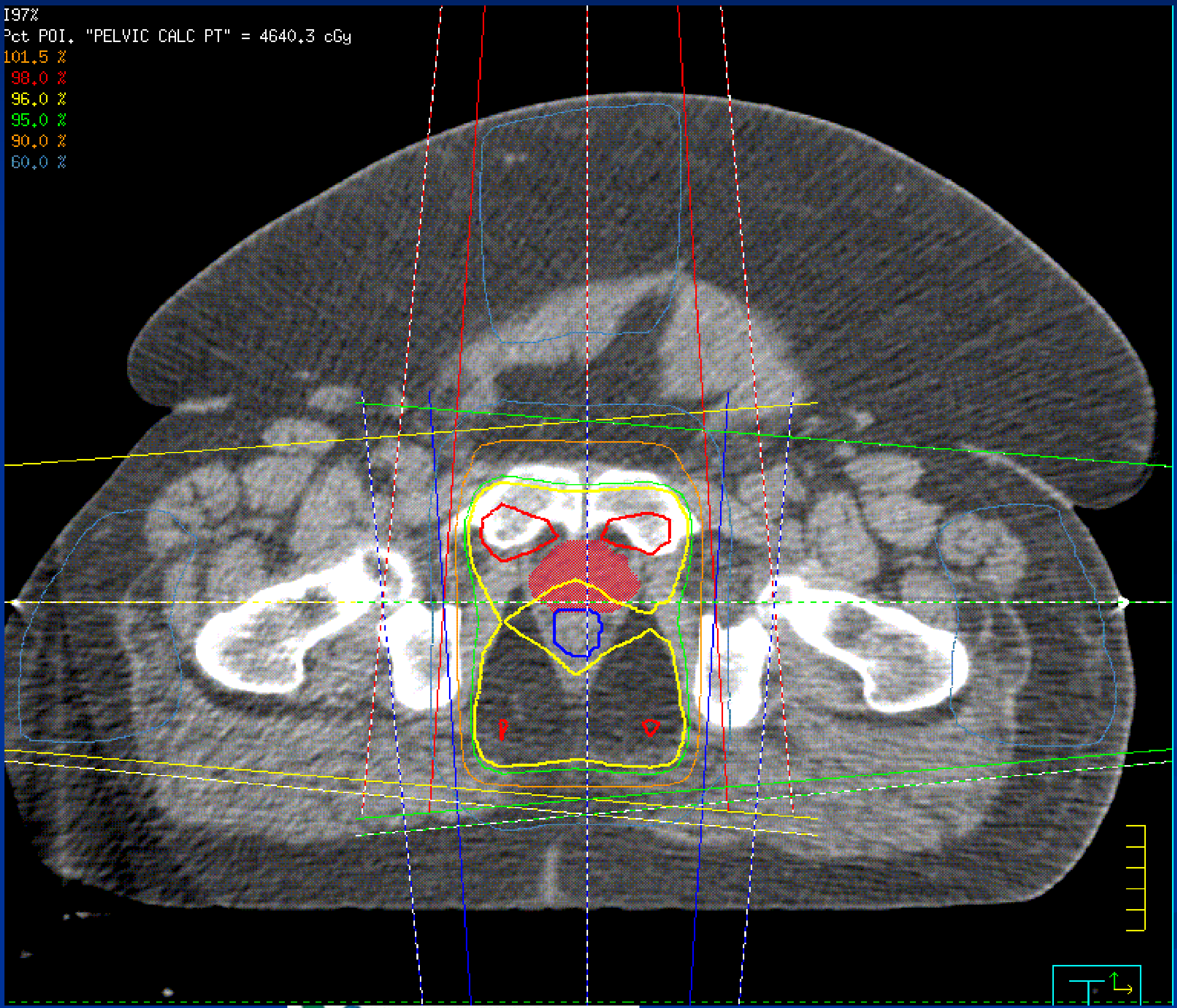


Multiple fields

- Increases the ratio of the tumor dose to the normal tissue dose
- Limitations of multiple fields
  - 1. Clinical limitation: critical organ in its path
  - 2. Technical limitation: set up accuracy (SSD beams)
- Multiple fields (> 2) yields a reduction in dose to normal tissues surrounding tumor

Multiple fields

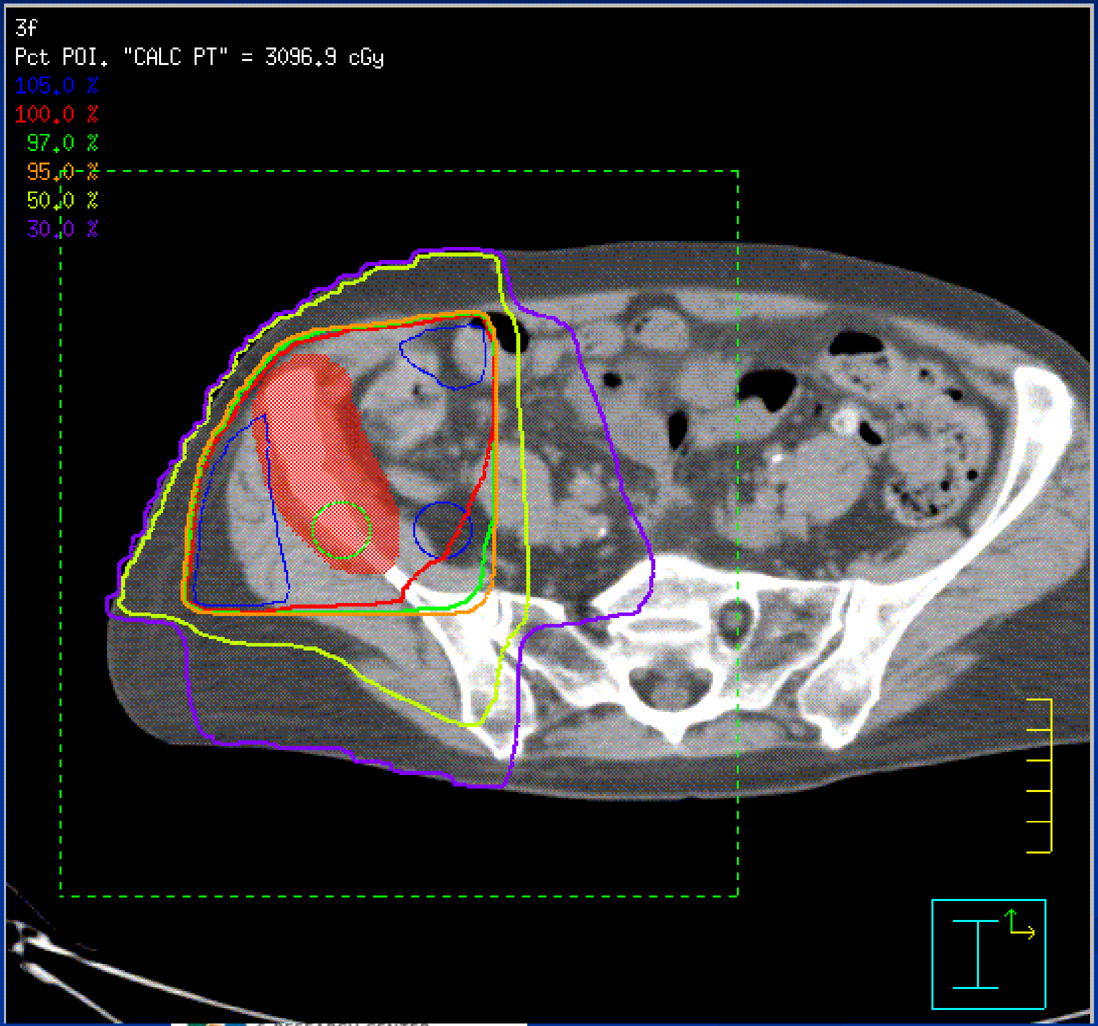
- 4field box



& RESEARCH CENTER
UT HEALTH SCIENCE CENTER
SAN ANTONIO

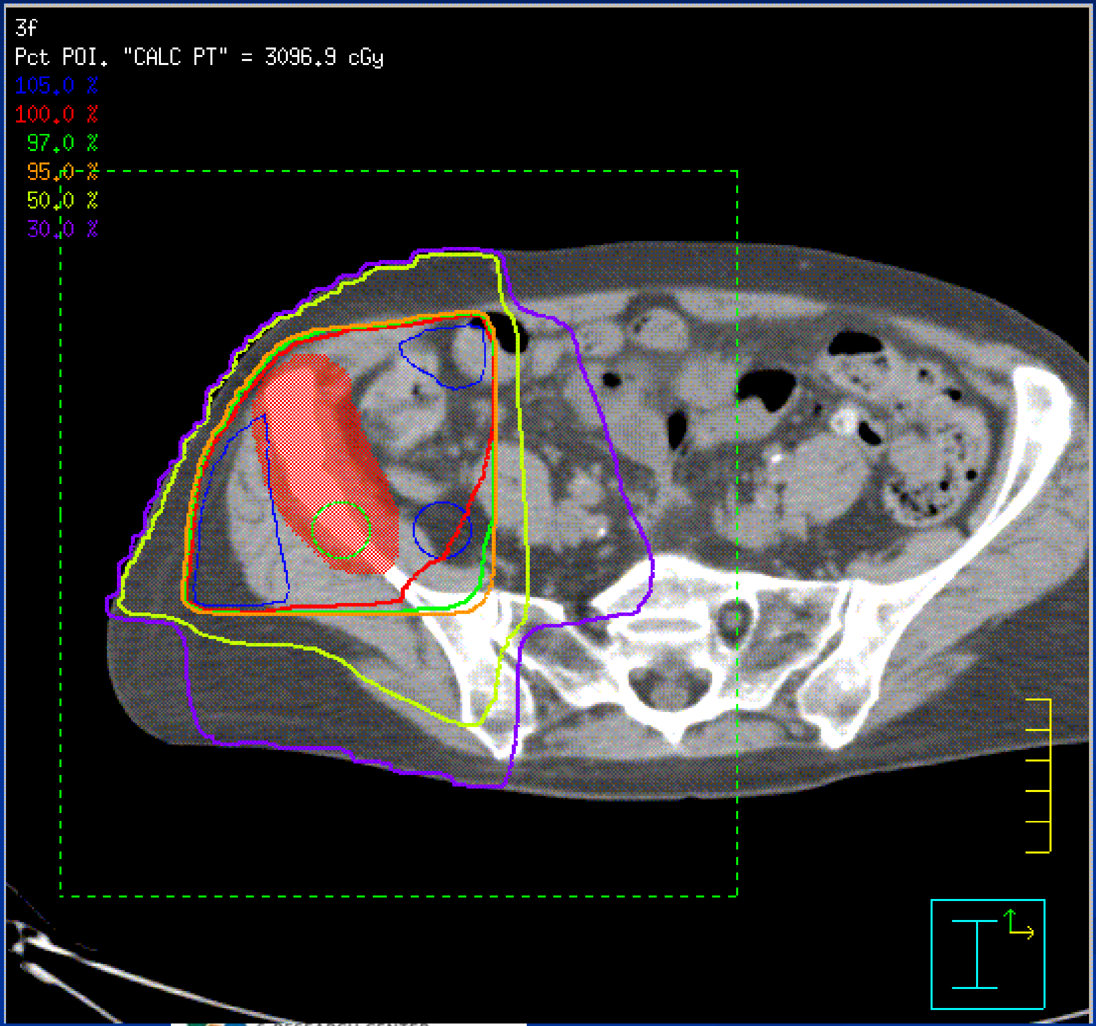
Multiple fields

- How many beams?



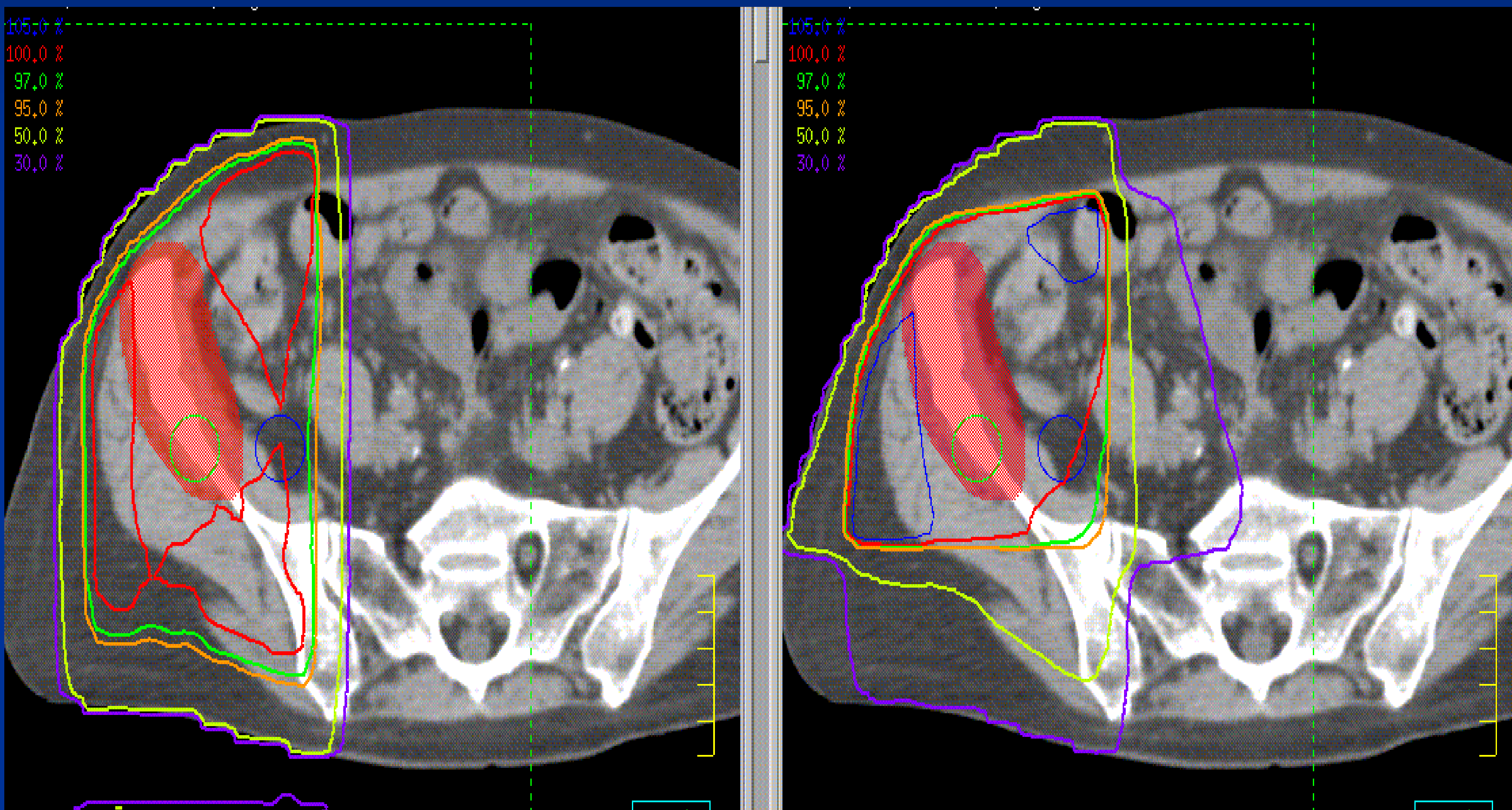
Multiple fields

- Three field coplanar

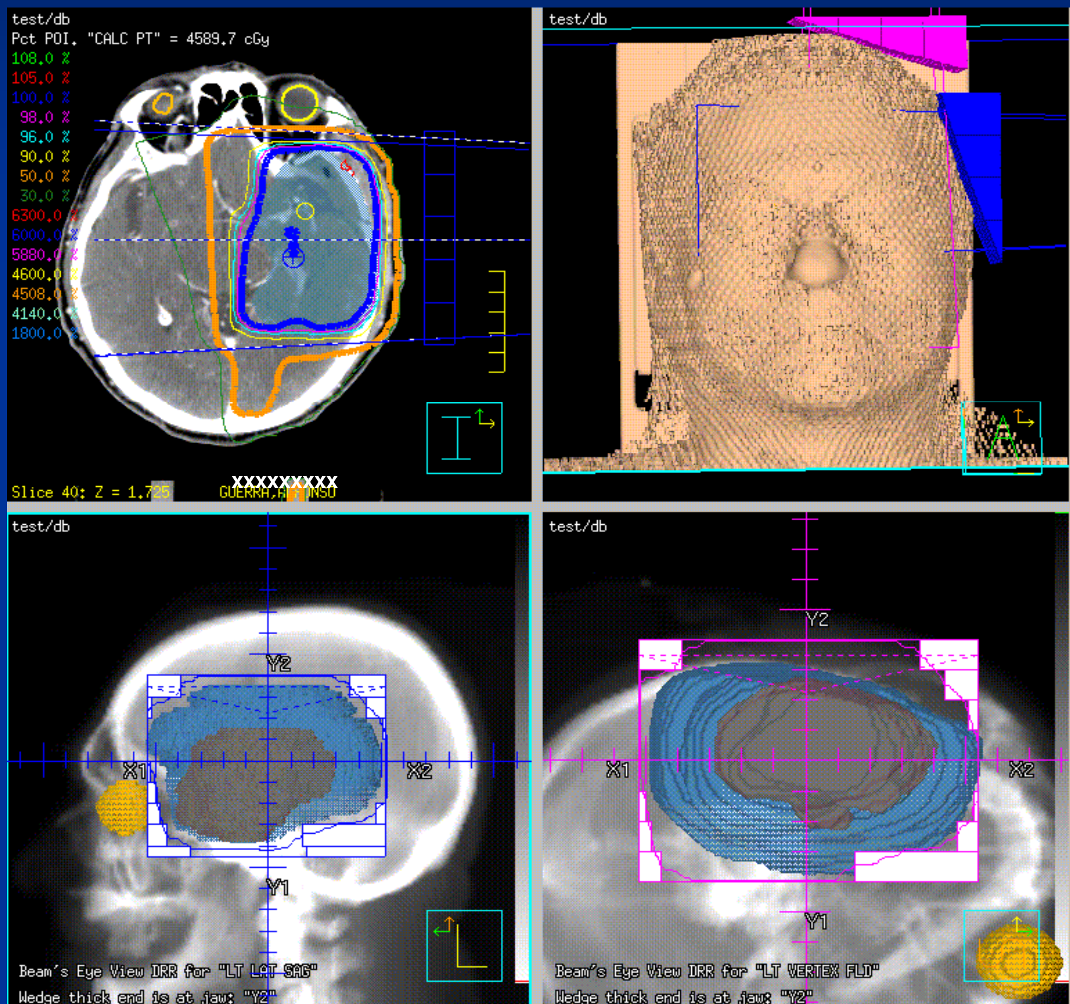


Multiple fields

- 2F vs. 3F



Multiple fields



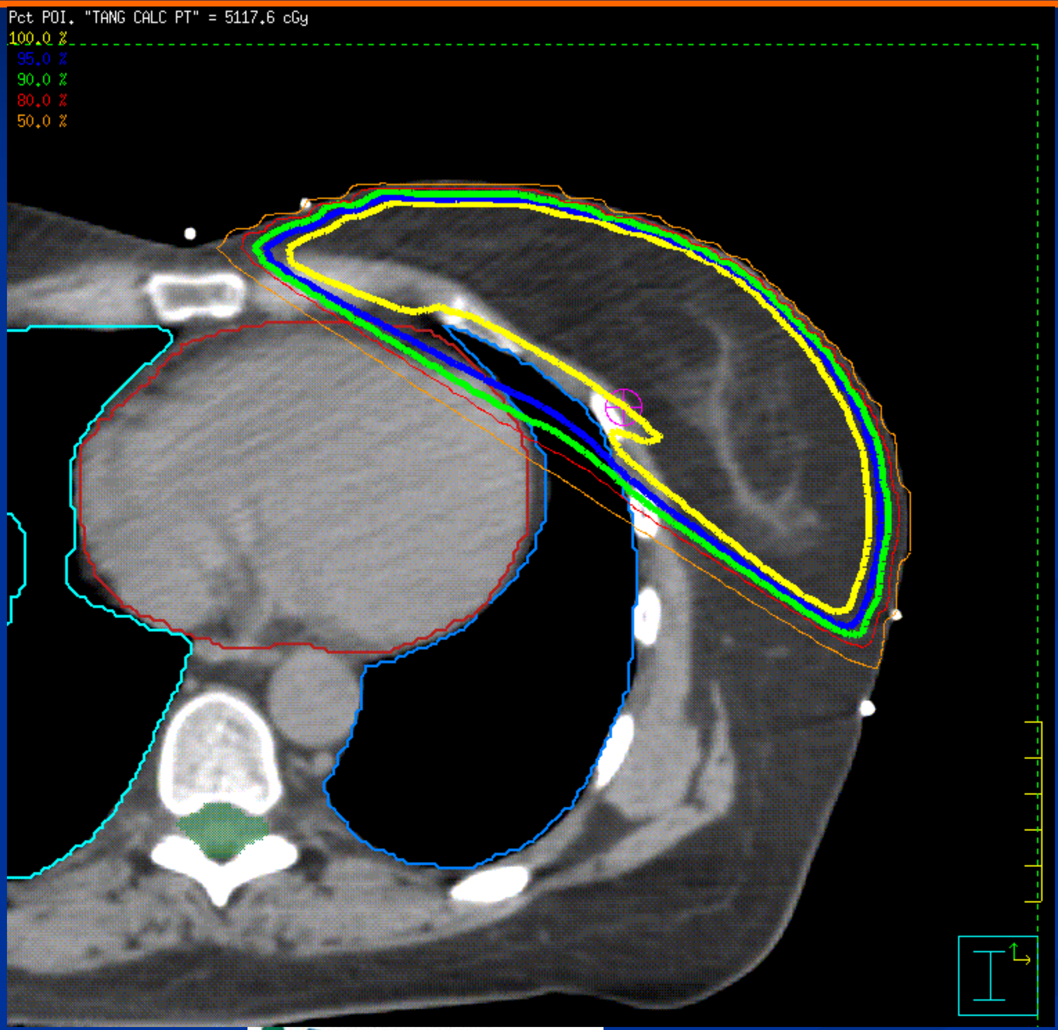
Three field non-coplanar

Where is the third beam?

Multiple fields

- More than four fields
- In conventional planning an increase in the number of fields yields an increase in conformality
- An example of 5 or more fields: 6F prostate
- Field in field plans can be considered multiple fields with 5 or more segments

Multiple fields



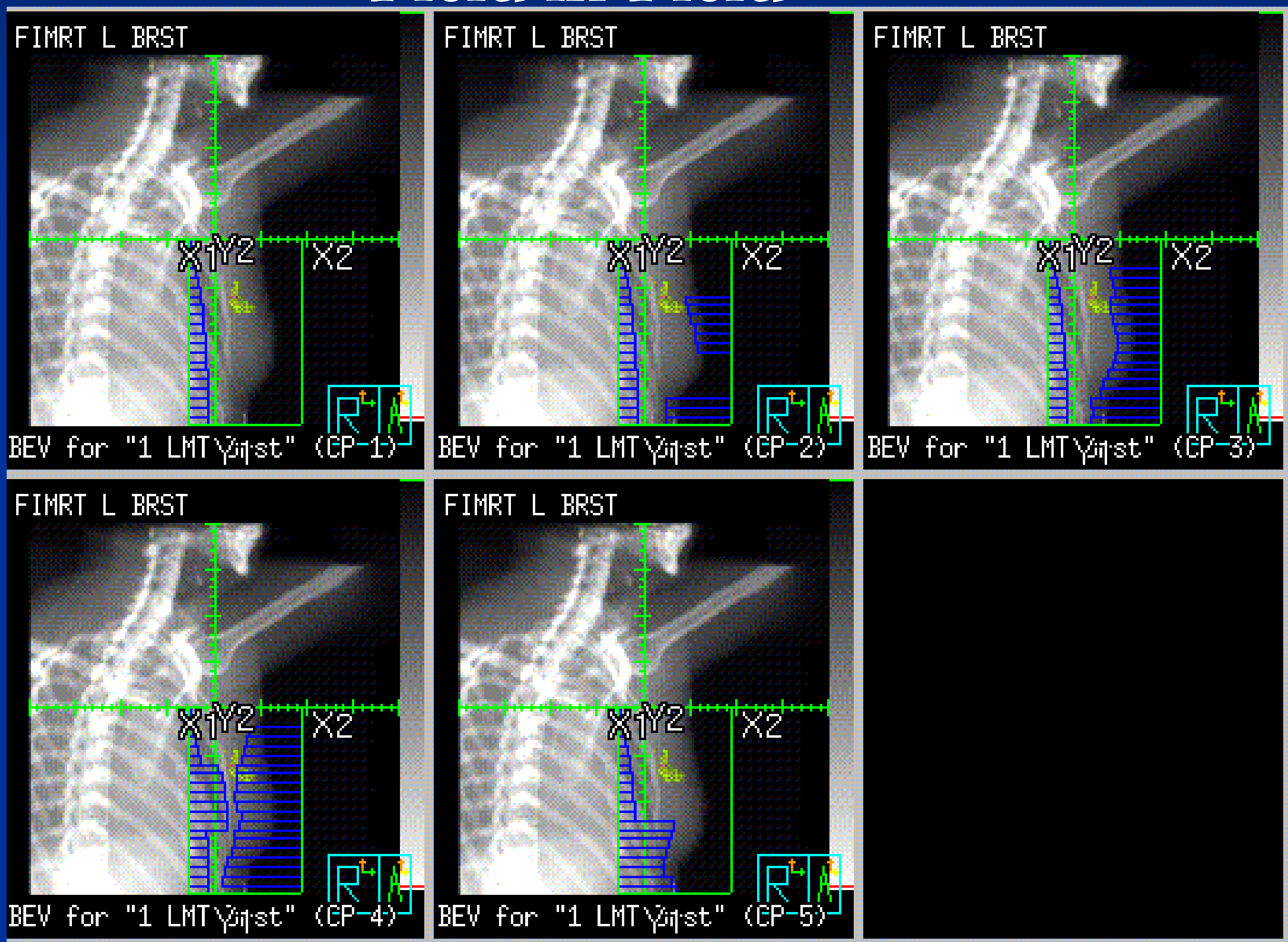
- Field in Field

Multiple fields

- Aside: Speaking of breast plans; How would you increase homogeniety within your plan?
  1. Add bolus?
  2. Use a compensator?
  3. Use a split beam?

Multiple fields

- Field in Field



Multiple fields

- Rotational or Arc Therapy
- An isocentric technique with the gantry rotating about the patient while beam is on
- Best suited for small deep- seated tumors
- The number of degrees in the treated area alters the shape of the distribution
- Pastpointing: For arc therapy, the isocenter is placed on the opposite side of the tumor relative to beam entrance

Multiple fields

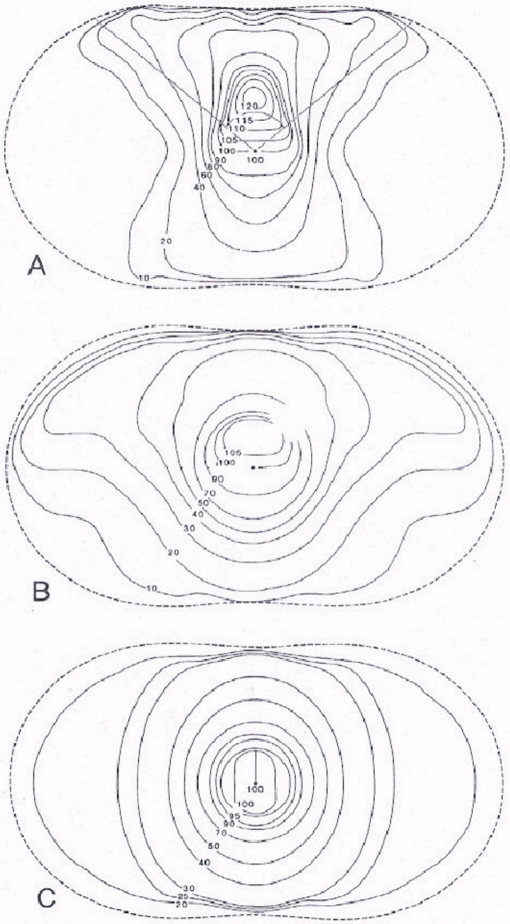


Figure 11.16. Examples of isodose distribution for rotation therapy. **A,** Arc angle = 100°; **B,** arc angle = 180°; **C,** full 360° rotation; 4 MV, field size = 7 × 12 cm at isocenter, SAD = 100 cm.

Rotaional Therapy

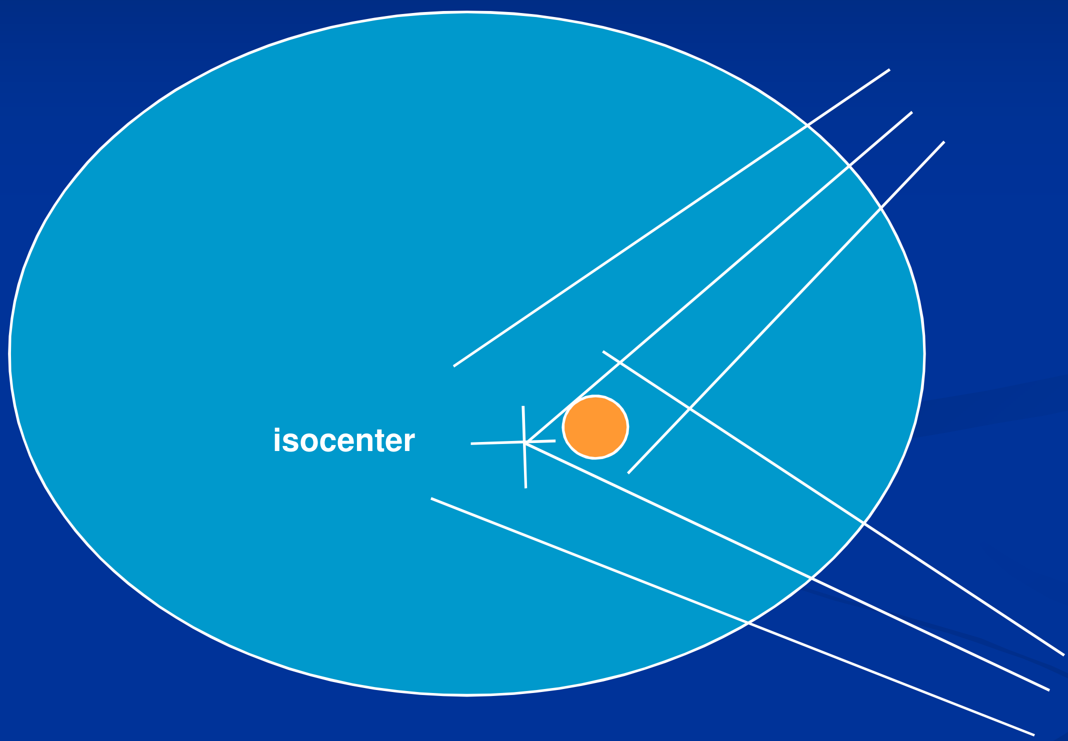
Khan pp 249

ion

CANCER THERAPY & RESEARCH CENTER
UT HEALTH SCIENCE CENTER
SAN ANTONIO

Multiple fields

Pastpointing

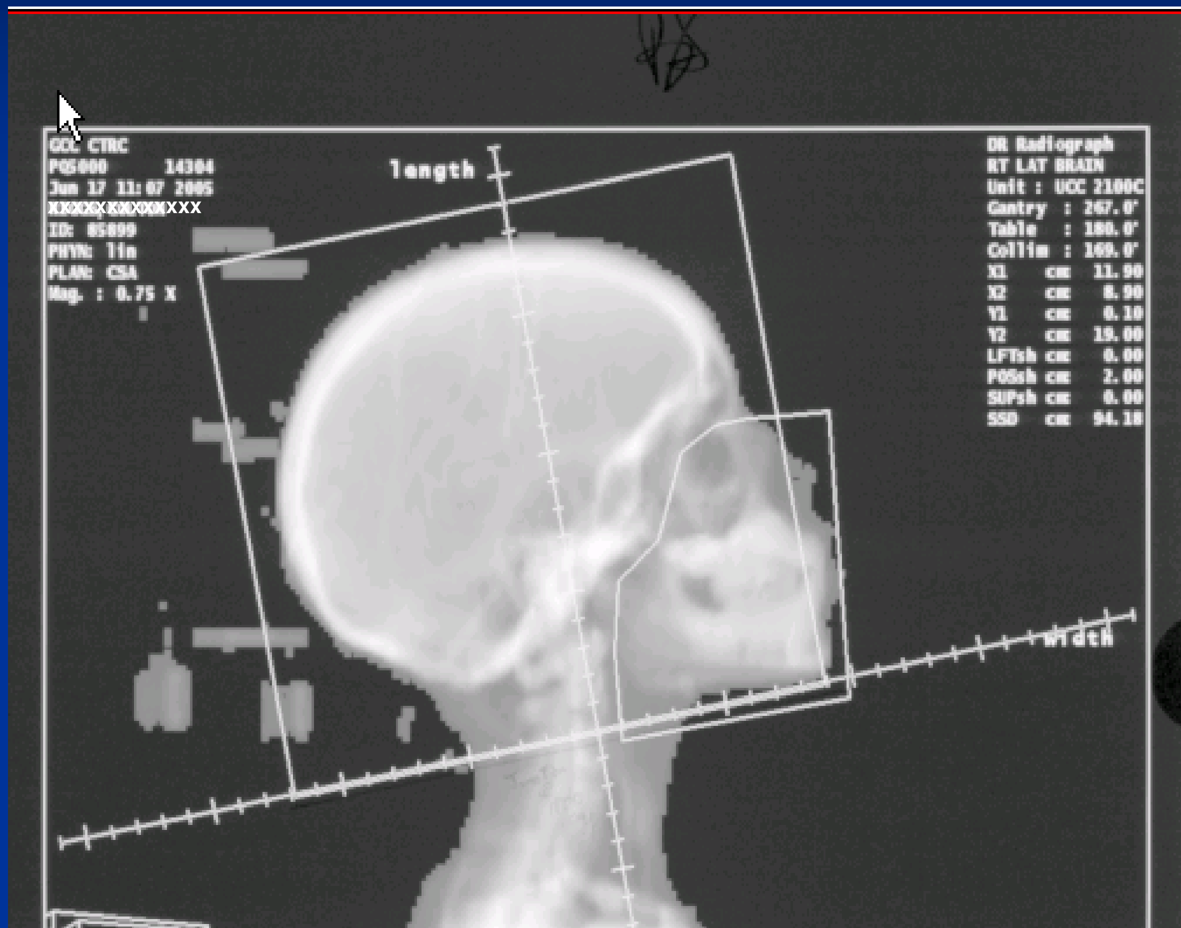


CANCER THERAPY & RESEARCH CENTER UT HEALTH SCIENCE CENTER SAN ANTONIO

Split Beam

- Used when abutting fields are needed
- Used when treating an area adjacent to a previously treated area
- Used to eliminate divergence to a critical structure
- Limiting factor: field size

Split Beam



Split Beam

- How would you eliminate the divergence to the opposite eye?
- $\tan \theta$ = half field length/SSD
- $\tan \theta = 6/100$
- $\theta = \tan^{-1} 6/100 = 3.4°$
- Where else do you use this equation?

Split Beam

Topics for Review

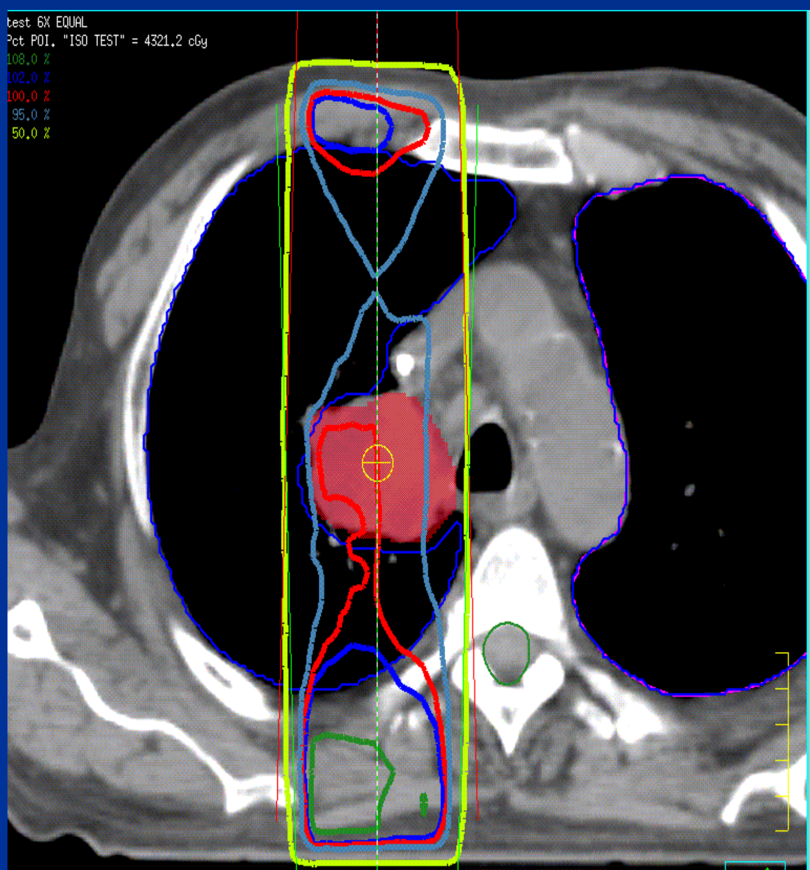
- Modality selection
- Energy selection
- Field size determination
- Beam arrangements
- Beam Weighting
- Use of beam modifiers
- Normalization
- DVH

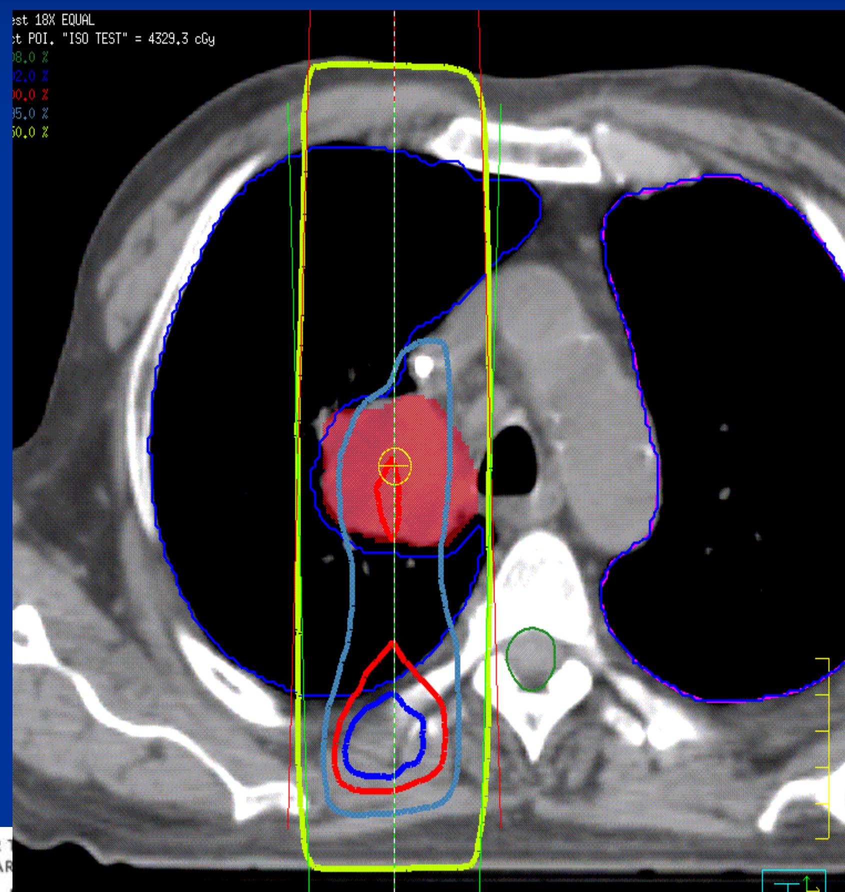
Beam Weighting

- Beam weighting alters the distribution and can be adjusted to produce a favorable plan
- Equal weighting - Achieved by assigning equal amount of dose to all beams
- Equal distribution – Achieved by unequal weighting to reduce hot spots

Parallel Opposed Fields

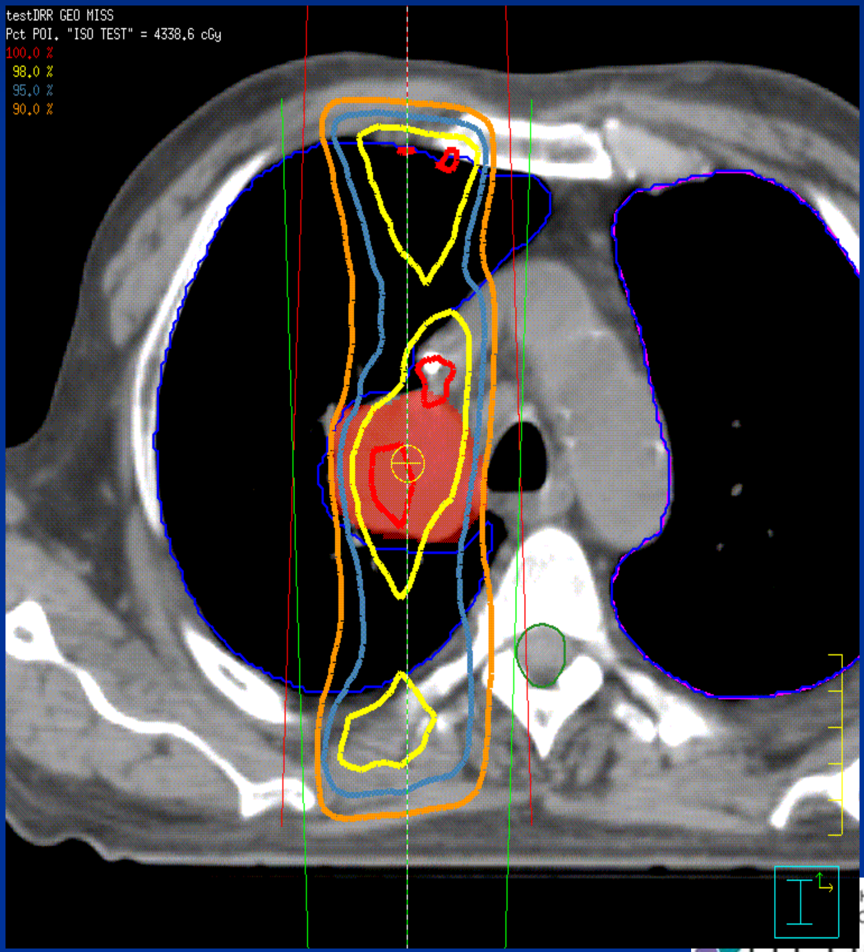
Equally weighted plans

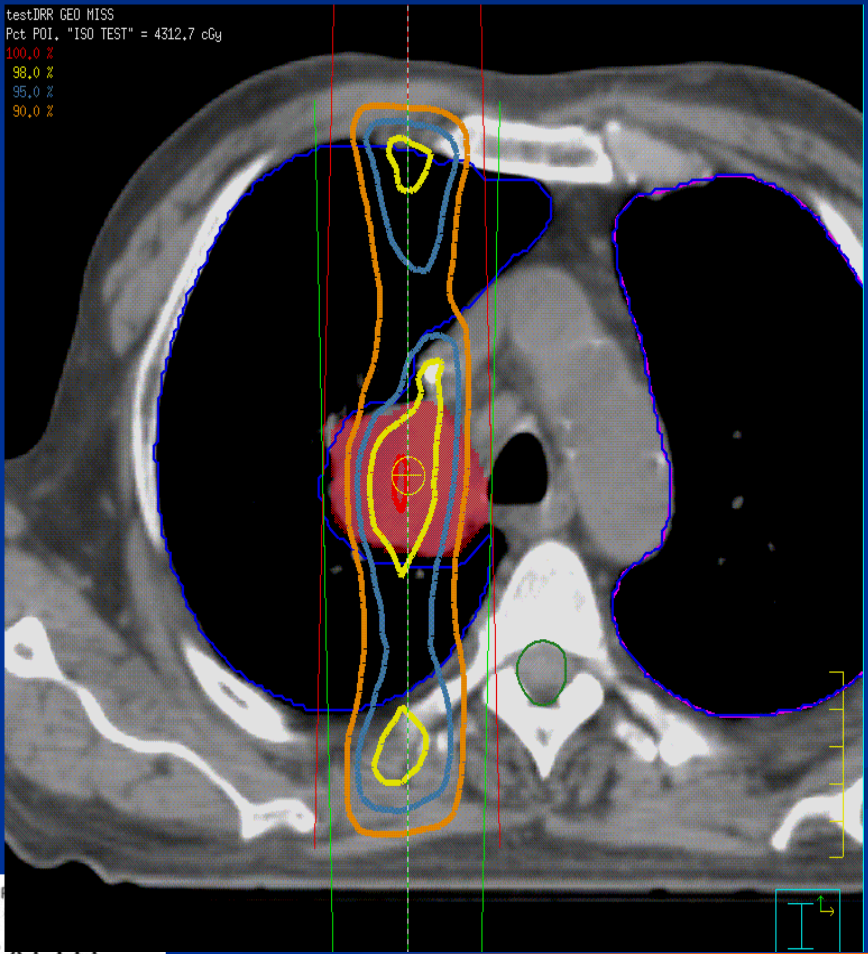




Beam Weighting

Unequal weighting/ Equal distribution





Beam Weighting

- Unequal weighting i.e. 2:1, 3:2

  Used for one sided tumors or to restrict dose to the unaffected side

  Example: 180cGy per fraction weighted 2/1, AP/PA, results in a dose of 120cGy to the AP field and 60cGy to the PA field
- Optimized weighting – Demonstrated in IMRT to shape distribution conformably around the tumor

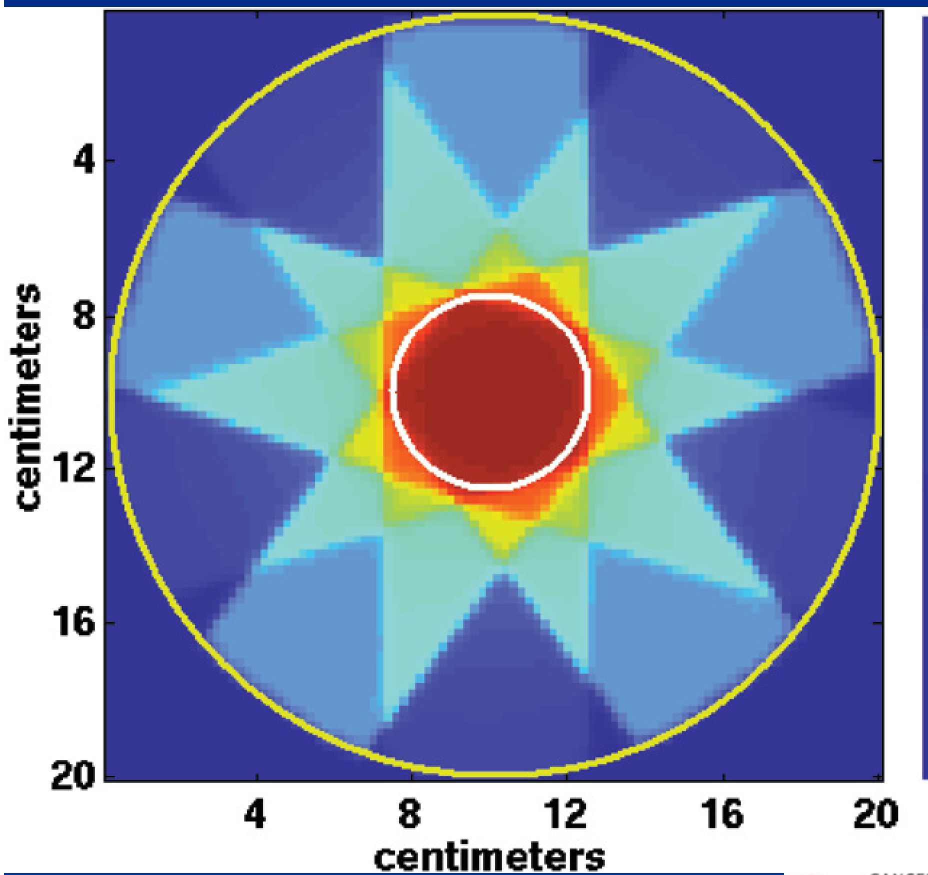
Beam Weighting

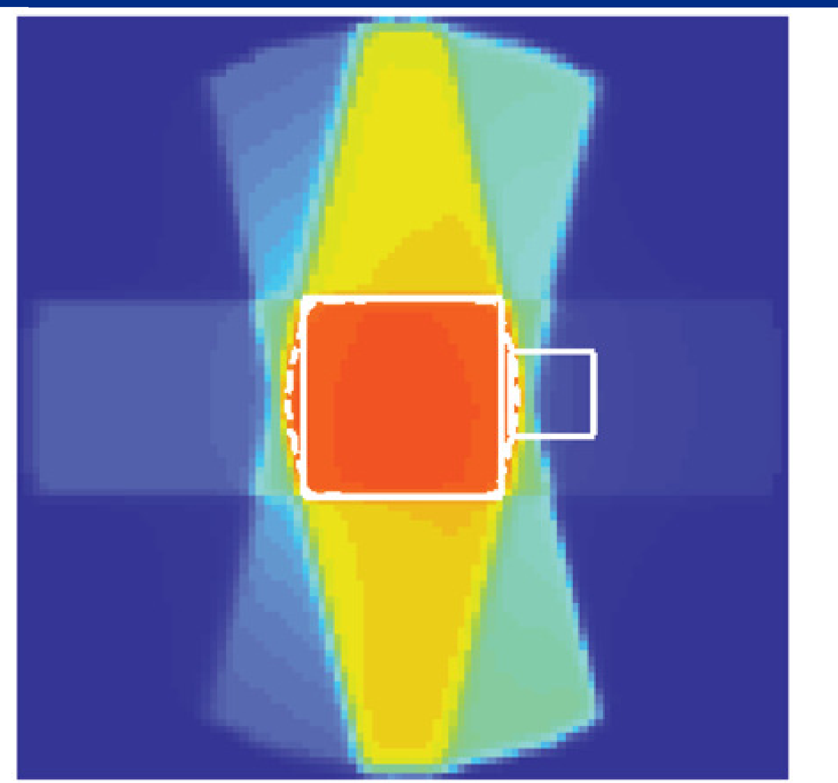
- Optimized weighting – The following slides

  Taken from "Optimizing the Delivery of Radiation Therapy to Cancer Patients" by D Shepard, M Ferris, G H Olivera, and T R Mackie. Siam Review Vol.41, No.4, pp 721-744

Beam Weighting

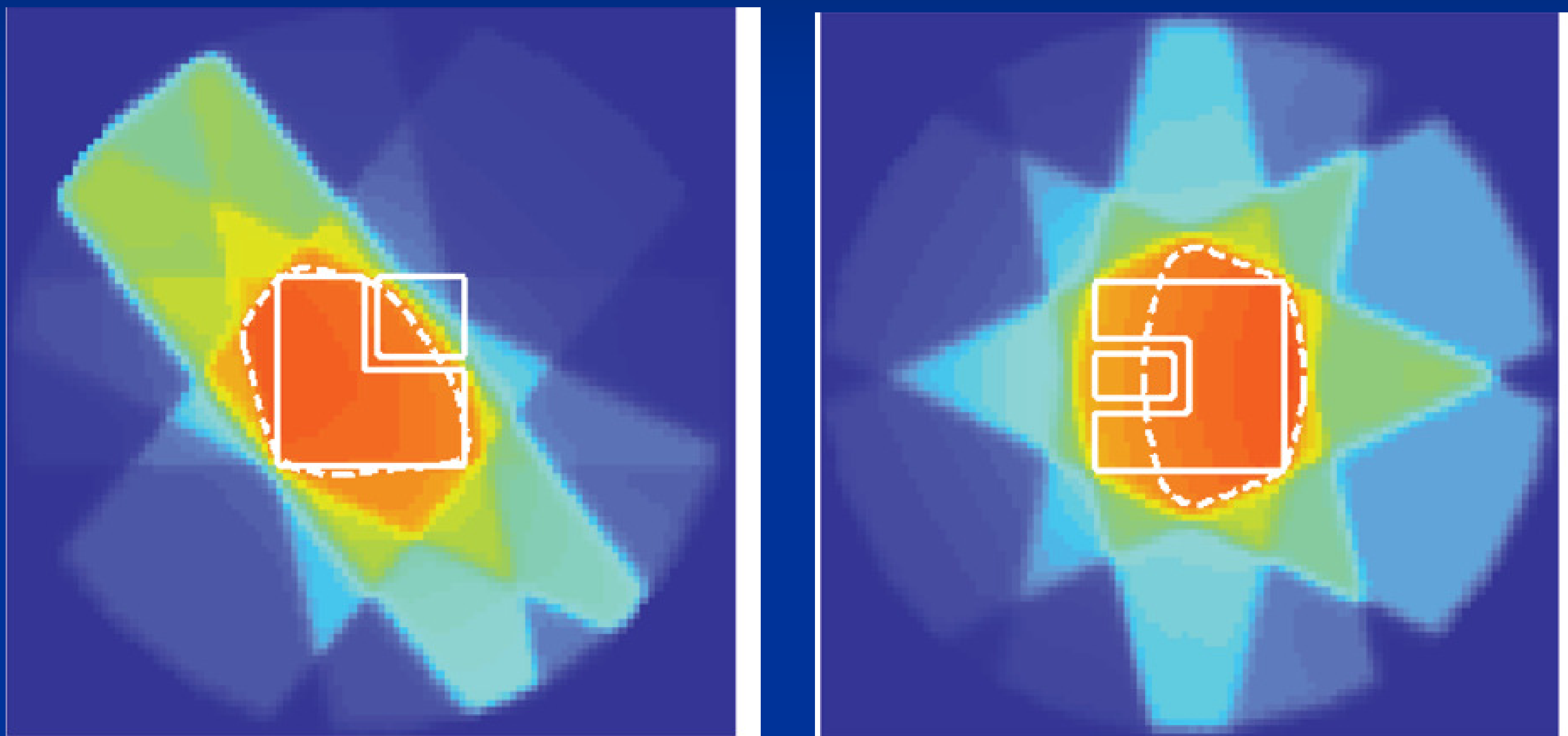
Optimized weighting





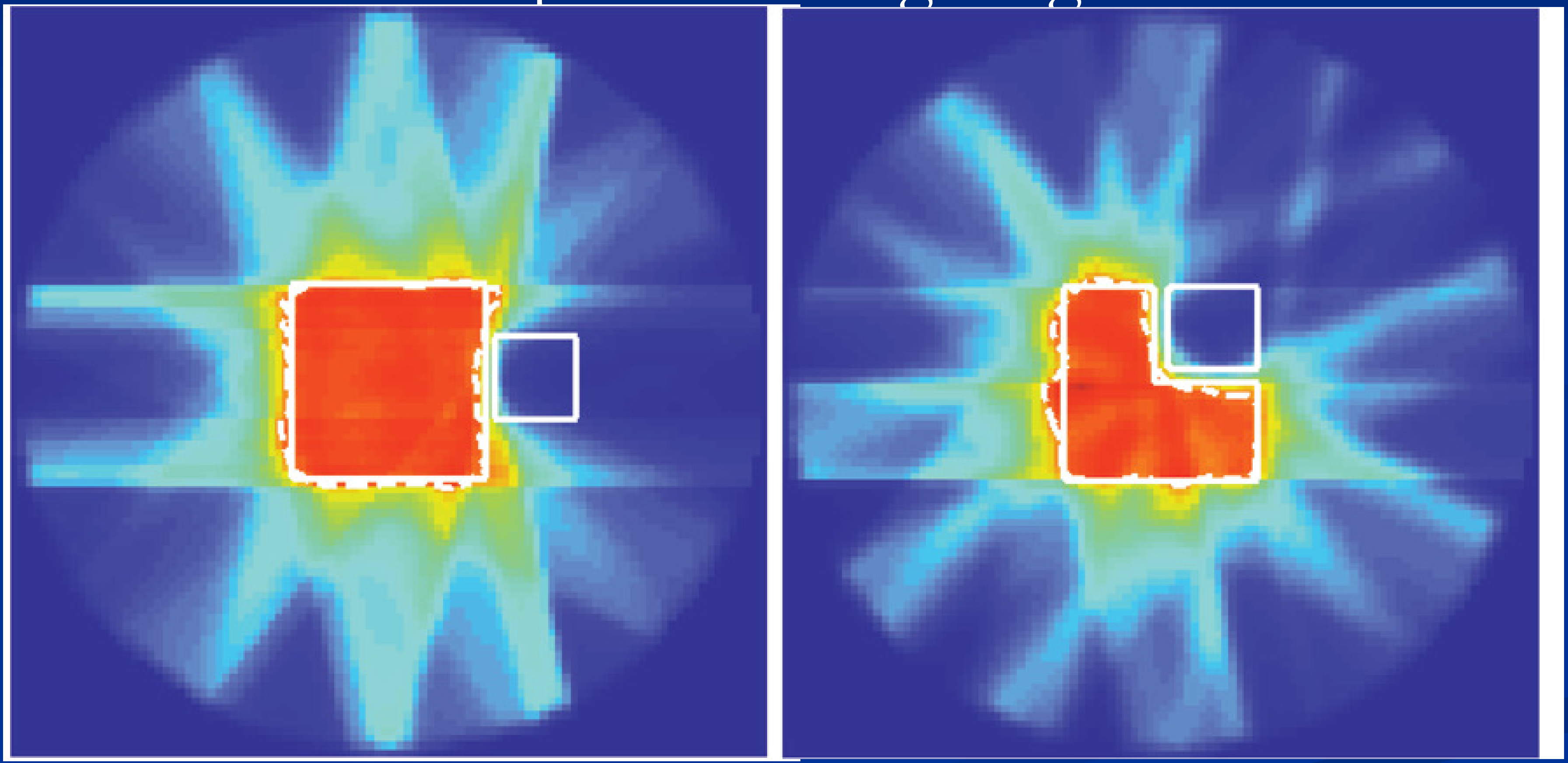
Beam Weighting

Optimized weighting



Beam Weighting

Optimized weighting



Topics for Review

- Modality selection
- Energy selection
- Field size determination
- Beam arrangements
- Beam Weighting
- Use of beam modifiers
- Normalization
- DVH

Use of Beam Modifiers

- What is a wedge filter?
- A wedge filter is a wedged shape absorbing block placed in the path of the beam used to alter the isodose distribution by decreasing the intensity across the beam
- Made of various dense materials
- It decreases the intensity of the beam

Use of Beam Modifiers

- Wedge angle: the angle of the tilt of the isodose curve and the normal to the central axis at a specified depth (10cm)
- The amount of scatter in the beam causes the tilt of the isodose line to decrease with increased depth making depth a crucial issue

Use of Beam Modifiers

- Wedge factor: the ratio of the doses with and without a wedge measured in a phantom along the CAX of the beam
- Hardens the beam
- Results in changed percent depth dose
- Produces scatter to the field caused by the wedge
- Require more MU's to deliver the same dose as without a wedge

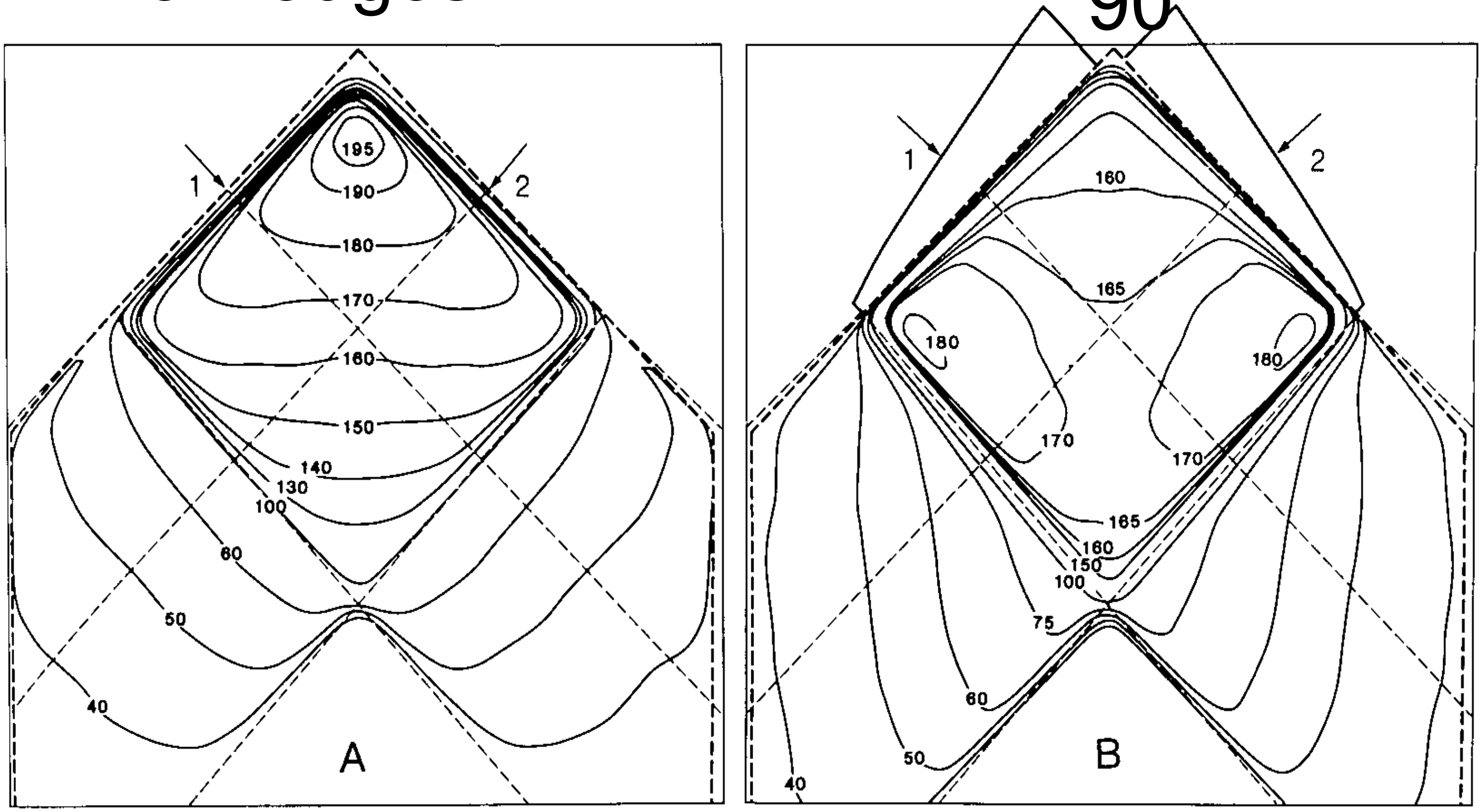
Use of Beam Modifiers

- Wedge factor: Can be incorporated in the isodose curves
  - The dose distribution is normalized to Dmax without the wedge
  - Look for the isodose value at Dmax; if the value is not 100% the isodose curve includes the wedge factor (Don't use a wedge factor in the hand calc!)

Use of Beam Modifiers

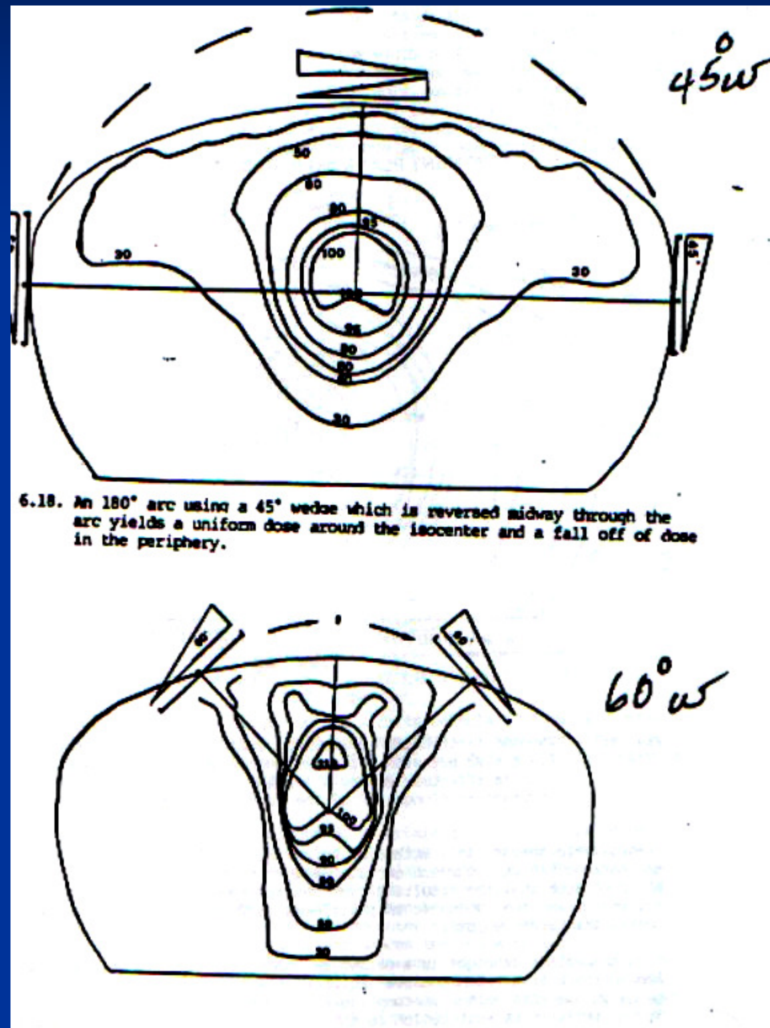
No wedges

45° wedges, hinge angle 90°



Use of Beam Modifiers

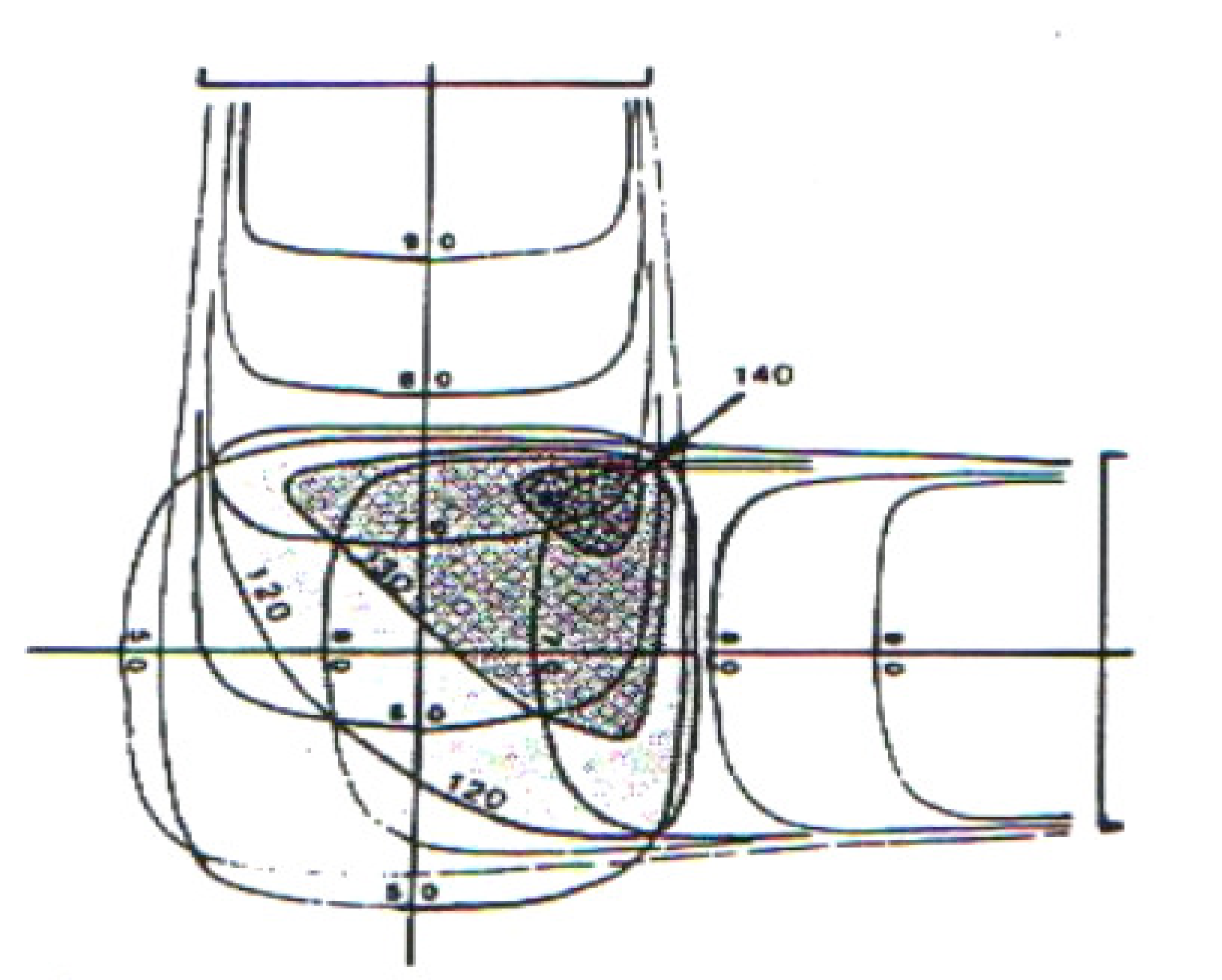
Flying Wedge Technique



6.18. An 180° arc using a 45° wedge which is reversed midway through the arc yields a uniform dose around the isocenter and a fall off of dose in the periphery.

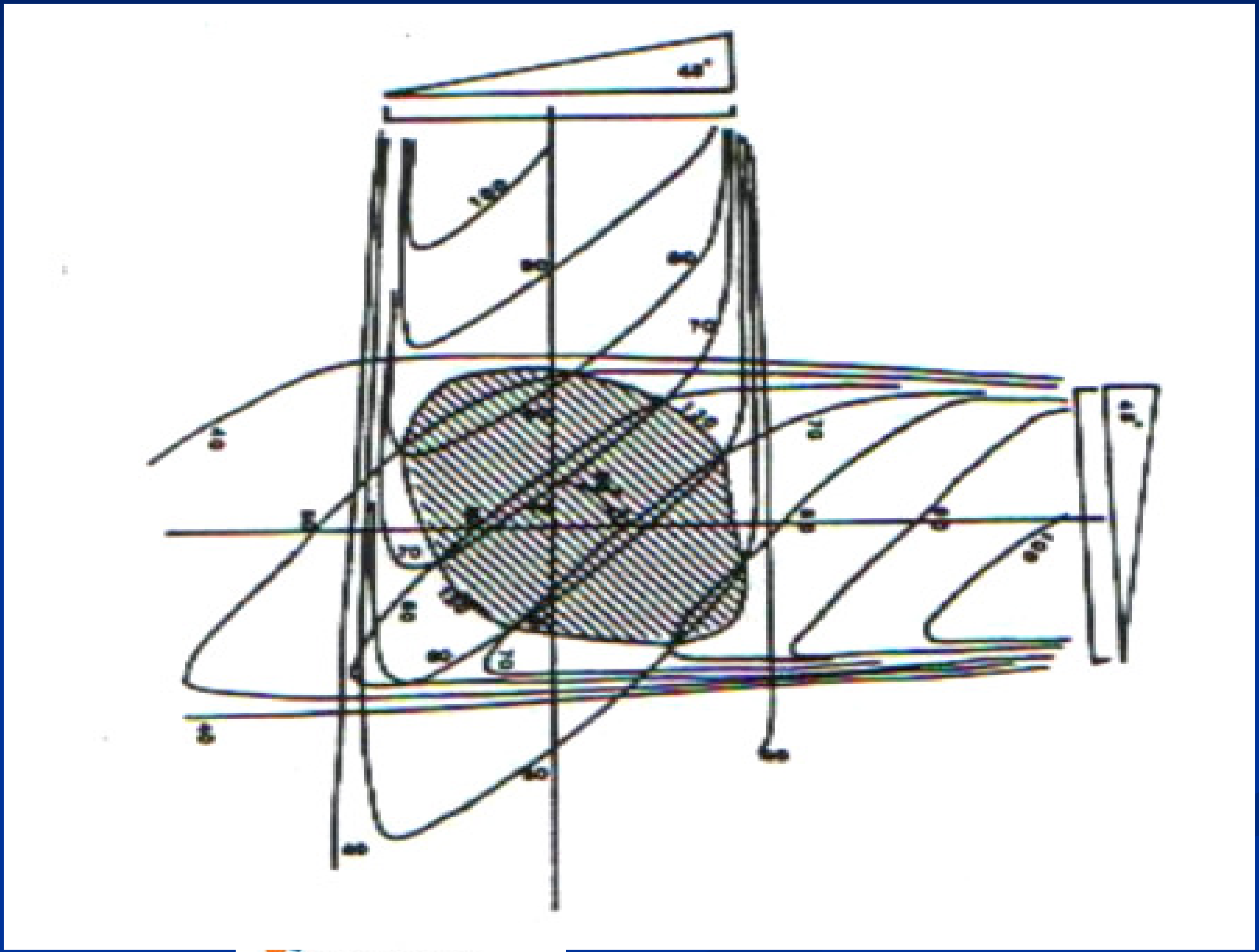
Use of Beam Modifiers

Beams @ 90^0 with No Wedges



Use of Beam Modifiers

Beams @ 90° with Wedges



UT Health Science Center San Antonio

Use of Beam Modifiers

- Wedge systems

  Individualized wedge system

  - Separate wedge for each beam width
  - Align thin edge of wedge with beam edge to minimize loss of beam output

  Universal wedge

  - Single wedge for all beam widths
  - Fixed centrally

Use of Beam Modifiers

Dynamic wedge

- Jaws move during treatment to modify dose distribution
- One 60° wedge moves in/out of beam

Enhanced Dynamic Wedges

- Produces any beam angle
- Jaws/MLC's move during treatment - modifies dose distribution

Use of Beam Modifiers

Jaws or MLC's move during treatment to modify dose distribution

Enhanced Dynamic wedges

- Produce a sharper penumbra
- Wedge factors are a function of field size

Control point plans (Field in Field)

- Eliminates the need for wedges
- Three dimensional compensation

Topics for Review

- Modality selection
- Energy selection
- Field size determination
- Beam arrangements
- Beam Weighting
- Use of beam modifiers
- Normalization
- DVH

Normalization

- The method by which a treatment plan meets the volume coverage goal
- Compensates for the inability to further adjust machine characteristics to improve a plan by altering the prescription
- Pros – the volume coverage goals are met
- Cons – Results in a dose change to the normal tissues

Normalization

- Normalizing to a single specific point
  - Plan can be viewed in relative terms i.e. percentage of the dose point
- Normalizing to an isodose line
  - Adjusts the dose by a factor equal to the isodose line value. i.e. normalize to the 97% isodose line alters all doses by an increase of 3 %

Normalization

- Normalizing to a specific value
  - All doses will be displayed relative to the desired value
- Absolute dose
  - Used with multiple prescription points
- Normalizing to a maximum dose
  - All doses will be displayed relative to the maximum value

Topics for Review

- Modality selection
- Energy selection
- Field size determination
- Beam arrangements
- Beam Weighting
- Use of beam modifiers
- Normalization
- DVH

DVH

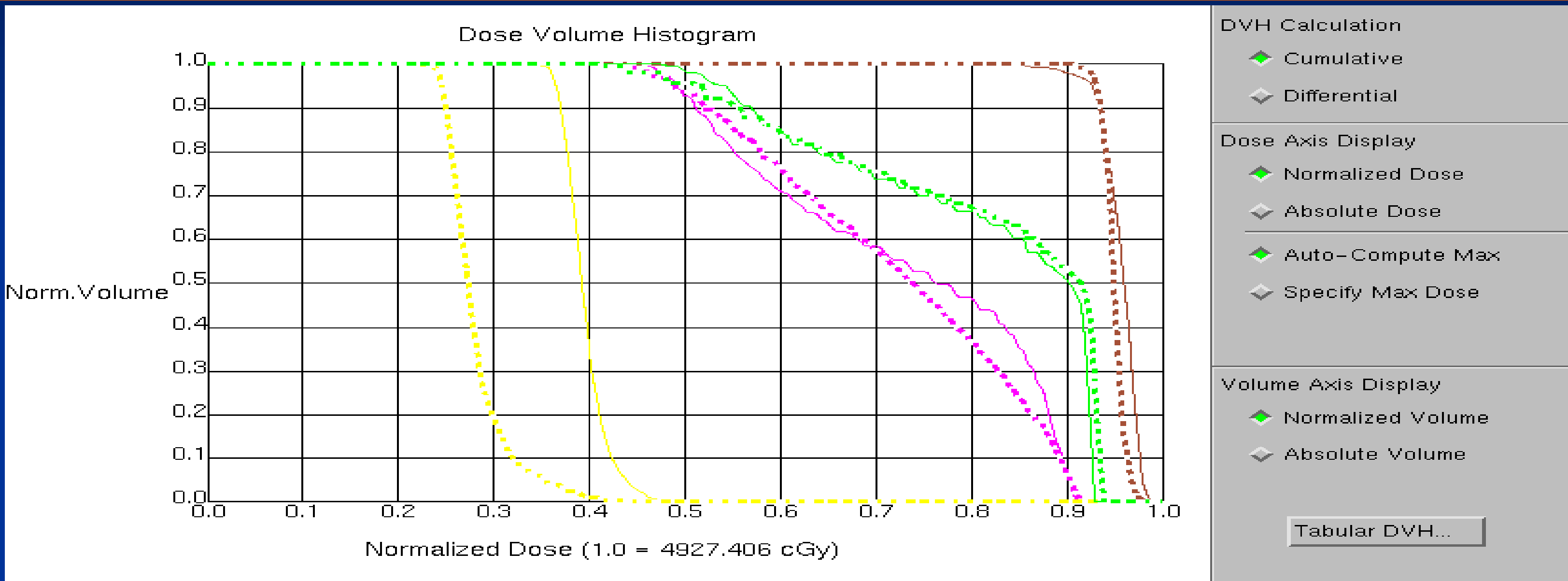
- Dose Volume Histograms
  - A quantitative graph to analyze and compare plans
- A DVH not only provides quantitative information with regard to how much dose is absorbed in how much volume but also summarizes the entire dose distribution into a single curve for each anatomic structure of interest
- The DVH may be represented in two forms: the cumulative integral DVH and the differential DVH.

CANCER THERAPY & RESEARCH CENTER UT HEALTH SCIENCE CENTER SAN ANTONIO

DVH

- Any point on the cumulative DVH curve shows the volume that receives the indicated dose or higher
- The cumulative DVH has been found to be more useful and is more commonly used than the differential form.

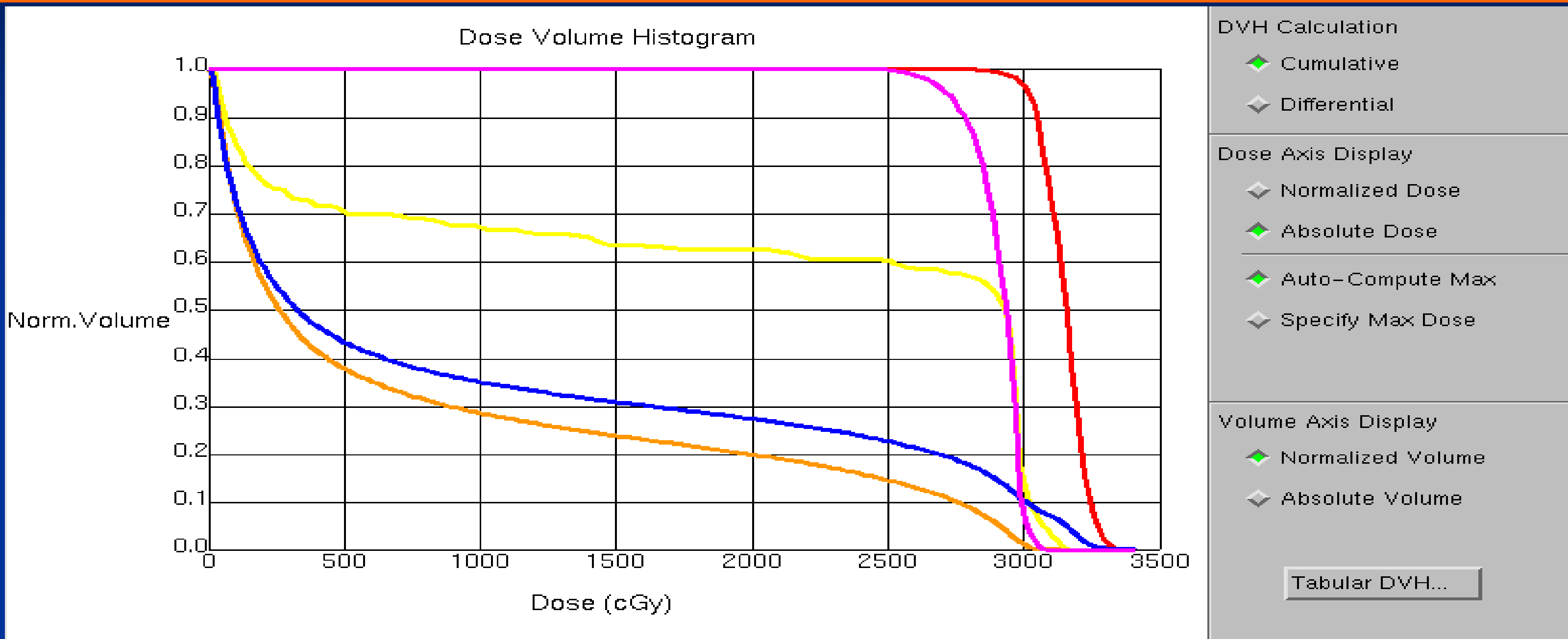
DVH



ROI Statistics

Line Type	ROI	Trial	Min.	Max.	Mean	Std. Dev.	% Outside Grid	% > Max	Generalized EUD
	CHIASM	BRAIN	2230.1	4489.6	3585.9	742.5	0.00 %	0.00 %	3587.29
	CHIASM	test/db	2129.2	4519.0	3550.2	674.2	0.00 %	0.00 %	3551.33
	Eye_L	BRAIN	1368.1	2415.2	1942.8	109.7	0.00 %	0.00 %	1943.3
	Eye_L	test/db	918.3	2179.6	1380.2	160.5	0.00 %	0.00 %	1379.14
	GTV	BRAIN	4115.2	4884.9	4712.4	99.3	0.00 %	0.00 %	4713.03
	GTV	test/db	4326.0	4833.1	4677.9	54.7	0.00 %	0.00 %	4678.18
	LT OPTIC NERVE	BRAIN	2333.0	4579.3	3995.7	709.8	0.00 %	0.00 %	4004.49

DVH



ROI Statistics

Line Type	ROI	Trial	Min.	Max.	Mean	Std. Dev.	% Outside Grid	% > Max	Generalized EUD
yellow	CORD	Trial_2	19.7	3162.7	1931.3	1303.2	1.39 %	0.00 %	1948.06
red	GTV	Trial_2	2548.2	3390.6	3147.4	81.2	0.00 %	0.00 %	3147.8
orange	RT LUNG	Trial_2	5.6	3130.4	701.8	982.3	14.03 %	0.00 %	811.548
blue	TOTAL LUNG	Trial_2	5.6	3410.4	890.0	1158.8	13.55 %	0.00 %	1023.45
magenta	carina	Trial_2	2362.1	3072.8	2907.3	95.3	0.00 %	0.00 %	2907.49

DVH

- The differential DVH is a plot of volume receiving a dose within a specified dose interval (or a dose bin) as a function of dose
- The differential form of DVH shows the extent of dose variation within a given structure
- An example the differential DVH of a uniformly irradiated structure is a single bar of 100% volume at the stated dose
- A DVH is not a stand alone evaluator of a plan

Topics for Review

- Aperture design
- Hand calculations
- Gap calculations

Aperture design

- Multileaf collimators
- Cerrobend blocks

Aperture design

- Multileaf collimators
  - Automated beam shaping
  - Penumbra considerations
  - Calculation considerations
  - Intensity modulated radiotherapy Multileaf collimators

Aperture design

- Multileaf collimators
  - Large number of collimating blocks or leaves driven automatically, independent of each other, to generate a field of any shape.
  - Thickness of leaves provides low beam transmission

Aperture design

- A multi-leaf collimator (MLC) allows automatic reshaping of the treatment field from outside the room while the patient is being treated.
- The ease and speed of automatic field shaping makes the delivery of complex multiple field arrangements more efficient.
- MLC provides a logistic solution to the problem of designing, carrying, and storing a large number of heavy blocks

Aperture design

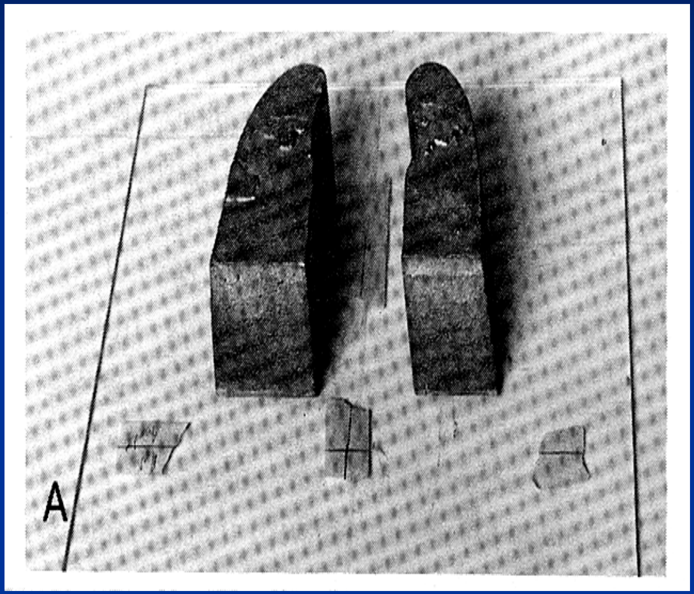
- Consideration: planned field boundary is continuous and actual boundary is jagged stepwise
- Applications: replace cerrobend blocking, automatic beam shaping for multiple fields, dynamic conformal therapy, modifying dose distributions within field by computer controlled dwell time of leaves

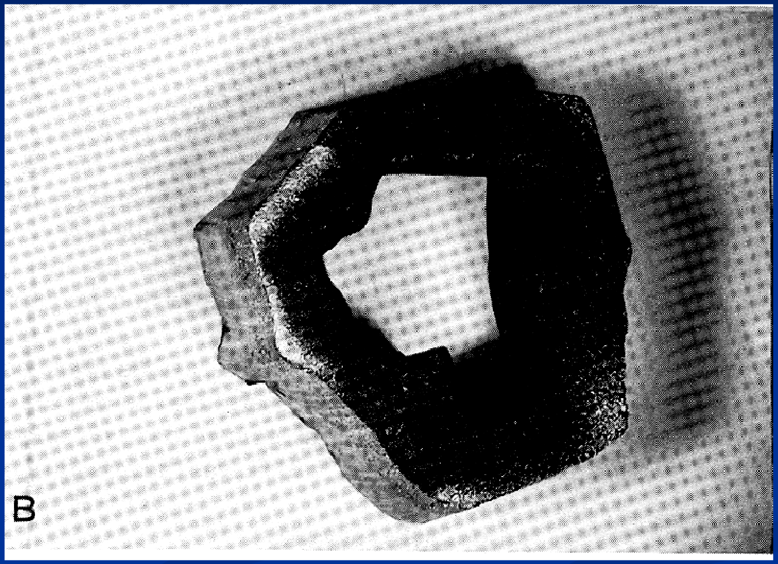
Aperture design

Cerrobend

1. Alloy composed of bismuth, lead, tin, and cadmium.
2. Relatively low melting point of 158^0 F.
3. Easily machined, can be poured into a styrofoam mold.
4. Can be remelted and reused.
5. Foreign matter (Screws and bolts) floats to the top after cerrobend is recycled and can be easily removed.
6. Floating vs. mounted blocks.

Aperture design





Positive blocks: lungs

Negative blocks

Topics for Review

- Aperture design
- Hand calculations
- Gap calculations

Hand Calculations

- Questions to ask yourself when doing hand calculations Is the set up SSD or SAD?
  - What Inverse square factor is required?
  - Are blocks or MLC's used?
  - Is the calculation point the isocenter?
  - Is the point off axis?
- All these factors will impact the calculation

Hand Calculations

- If the set up is SSD use a percent depth dose calculation or a TxR calculation
- If the set up is isocentric use a TxR calculation
- Based on the method of calculation the inverse square will be as follows:

SSD calculation: Inverse Square =

$$(\text{Reference distance}/\text{SSD}_{\text{calc pt}} + \text{dmax})^2$$

Hand Calculations

SAD calculation: Inverse Square =

(Reference distance/SSD $_{\text{calc pt}}$ + depth)^2

NOTE: Know the reference distance; distance where output is defined

- If using blocks use a tray factor
- If the calculation point is not the isocenter, know the distance in depth away from the isocenter

Hand Calculations

- If the calculation point is not the isocenter, what is the distance off axis and is it out of the penumra region?
- Consider the following example
  - Calculate the MU's required to deliver 200 cGy to a depth of 5cm with a field size of a 12 x 12 using 6 MV x-rays. The output is 1cGy = 1 MU at 100cm.

Hand Calculations

- Using the TAR_{avg} determined previously, determine the treatment time to deliver 200cGy at the center of rotation, given data: dose rate free space for 6x6 cm^2 ^{60}Co at SAD is 86.5 cGy/min

Hand Calculations

Mayneord's F factor:

- Mayneord's F factor: PPD varies with SSD.
- Based on strict application of inverse square without considering changes in scattering as the SSD changes
- Do not use for large fields due to increased amount of scatter
- For lower energies use: (1+MF factor)/2
- Tables are made with data collected at a known
- SSD.

Hand Calculations

Mayneord's F factor:

- If a calculation is to be done at a different SSD than the standard, then an additional factor must applied to the percent depth dose
- The Mayneord's F-factor is that correction and is defined as:

Hand Calculations

- Mayneord's F factor:

$$F = \left(\frac{SSD_2 + d_m}{SSD_1 + d_m}\right)^2 \left(\frac{SSD_1 + d}{SSD_2 + d}\right)^2$$

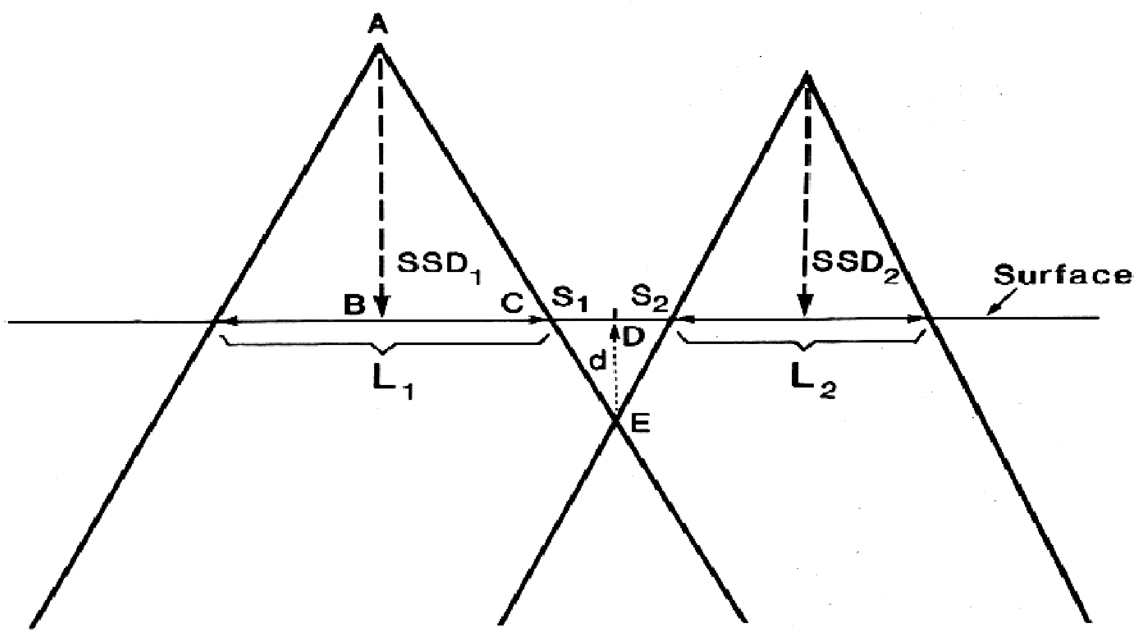
Topics for Review

- Aperture design
- Hand calculations
- Gap calculations

Gap Calculations

$$\frac{CD}{DE} = \frac{BC}{AB}$$

$$\frac{S_1}{d} = \frac{L_1}{2} \cdot \frac{1}{\mathrm{SSD}_1}$$



Gap Calculations

- Gaps and Abutting Fields
- Used when two treatment fields are adjacent to each other.
- The gap calculation determines the separation on the skin that will abut the fields at depth
- Gap = d/2 (fld1/SAD) + (fld2/SAD)

where d is the depth to the abutment

Khan's Treatment Planning

- Minimizing The Impact Of Setup Variations On Treatment
  - Set up margin, SM, is included in the PTV
  - Reducing SM results in a reduced PTV and therefore less toxicity to normal structures
  - Efforts are made to reduce set up errors reducing their impact on treatment delivery

Khan's Treatment Planning

- Strategies for Position Correction
  - Three methods
    - On-line
    - Off-line
    - Adaptive

Khan's Treatment Planning

- On-line
  - Corrections for set up are done in the room prior to the treatment delivery. They involve measurement, decision, adjustment, and sometimes verification
  - Measurement devices include: imagine equipment, markers such as electromagnetic or fiducial

Khan's Treatment Planning

- On Line
  - Analysis is the comparison of the reference information to the information gathered at treatment
  - The decision to adjust must take into account errors in the measurement and correction technologies.
  - The use of thresholds for corrections allows a trade-off B/T frequency of adjustment and actual reduction of errors On Line.

Khan's Treatment Planning

- SAL – Shrinking action level
  - Verify setup and adjust daily for the first few fractions using a tolerance that reduces in magnitude as the fractions progress

Khan's Treatment Planning

- NAL – No action level
  - Acquire images for first 3-5 fractions and evaluate off line then make the adjustment at next fraction

Khan's Treatment Planning

- Adaptive
  - Uses off-line and on-line strategies
    - Follows a population model before patient specific measurements
    - As information on a particular patient is gathered the model is refined to adjust position and margins
    - Basis for plan modification

Khan's Treatment Planning

- Geometric variations increase the significance of conformality of the planned treatment
- The most significant geometric variation is systemic positioning error
- Knowing the limitations of the organ movement tracking system, as well as the uncertainties of target delineation versus dose, will yield efficient strategies to limit the impact of movement on the treatment outcome

Let's Calculate!