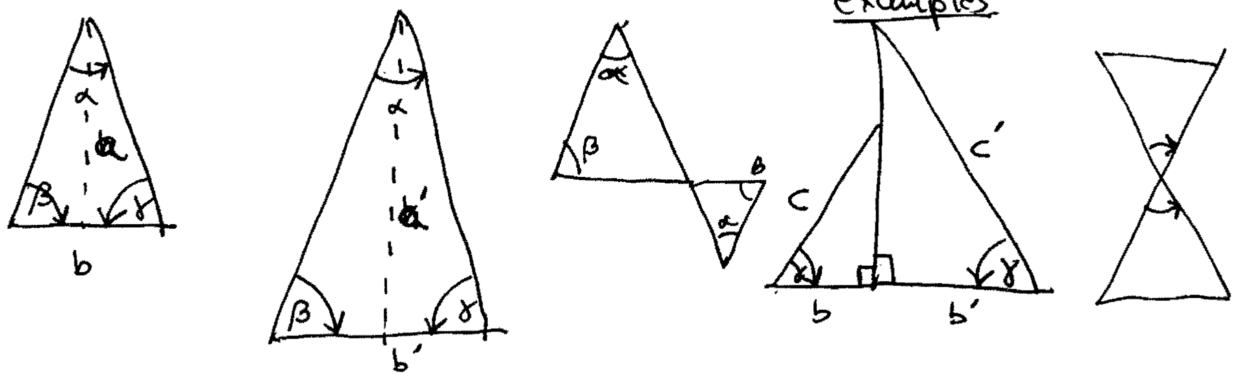
(I) Geometry of Photon Beams (chapter 11) Phys 298

Similar Triangles:

- Similar Triangles are two triangles that have 3 equal angles, but not necessarily equal sides.

examples:



- in similar triangles the following is true:

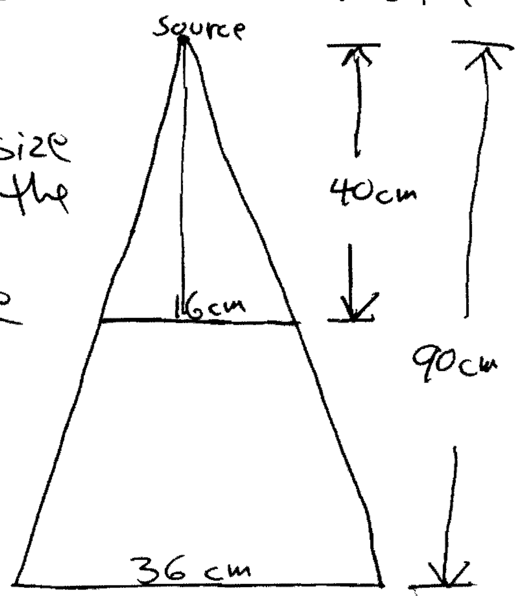
$$\frac{a}{b} = \frac{a'}{b'} \quad \underline{\underline{OR}} \quad \frac{b}{a} = \frac{b'}{a'} \quad \underline{\text{same thing}}$$

that is, similar sides are in proportion to one another.

- Most Geometric aspects of Radiation beams can be dealt with by using similar triangles.

Field Sizes:

- in this example, the field size at a distance of 40 cm from the source is 16 cm.
- To determine the field size at 90 cm, use the equation:



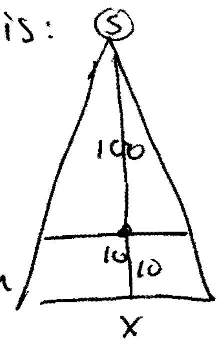
$\frac{a}{b} = \frac{a'}{b'}$

~~$\frac{16}{40} = \frac{X}{90}$, $X = \frac{(16)(90)}{40}$~~

$$\frac{40}{16} = \frac{90}{X} \longrightarrow X = 36 \text{ cm}$$

- Therefore for a given Collimator field size, the Field Size is proportional to the distance from the source.

e.g. - Field Sizes are usually defined at 100cm. By setting a 10×10 field on the console that means that the field size is 10×10 at 100cm. At 110 cm, the Field size is:



$\frac{a}{b}$

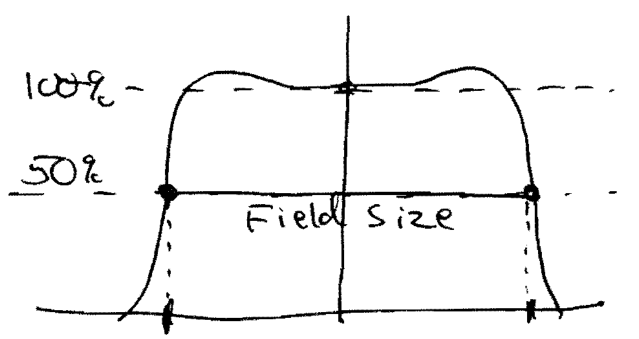
$$\frac{100}{10} = \frac{110}{x} \quad \cancel{\frac{10}{100} = \frac{x}{110}}$$

$$x = \frac{(10)(11.0)}{10} = 11.0\text{cm}$$

- Definition of Field Size.

Field Size is defined as the distance between the Edges of the beam.

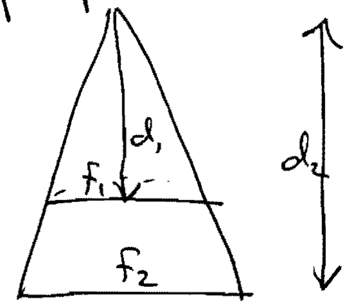
The Beam Edges are defined as the location where the Beam intensity falls to 50% of the central Ray.



Extend Concept to Field Area:

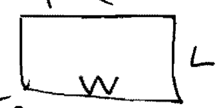
Re~~difining~~ writing the Field Size proportion

$$\frac{f_1}{d_1} = \frac{f_2}{d_2}$$



Area:

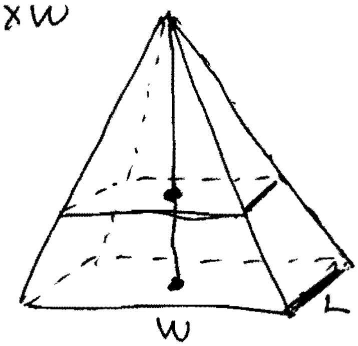
Extending this definition to the area of the Field: $\frac{L_1}{d_1} = \frac{L_2}{d_2}$ and $\frac{W_1}{d_1} = \frac{W_2}{d_2} \Rightarrow \frac{L_1 W_1}{d_1 d_1} = \frac{L_2 W_2}{d_2 d_2}$



Area of a ~~square~~ field ~~f x f~~ $L \times W$ = ~~f^2~~ $\equiv A$

$$\frac{L_1 \times W_1}{d_1 \times d_1} = \frac{L_2 W_2}{d_2 \cdot d_2}$$

$$\frac{A_1}{d_1^2} = \frac{A_2}{d_2^2}$$



Or Area is directly proportional to the square of the distance from the source.

e.g. field size is 10x10 @ 100 cm and ~~11x11 @ 110 cm~~, what is the Area irradiated at 110 cm?

$$\frac{L_1 \times W_1}{d_1^2} = \frac{L_2 \times W_2}{d_2^2}$$

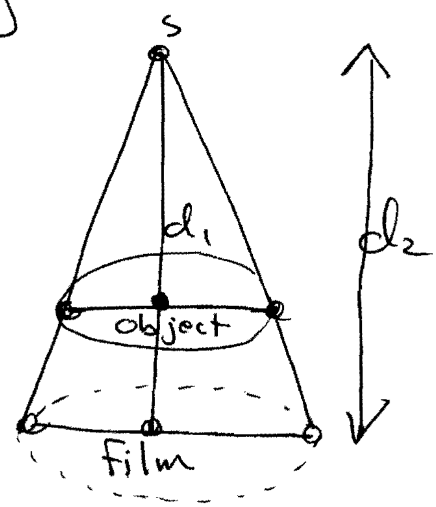
$$\frac{10 \times 10}{100^2} = \frac{A_2}{110^2}$$

$$\frac{110^2}{100} = A_2 = 121 \text{ cm}^2$$

Magnification:

Nearly all Portal films and simulation films are magnified due to the divergence of the x-rays and the distance of ~~the patient~~ the film from the patient.

To accurately measure distances on the films you need to know the Magnification Factor of the film.



Using Similar Triangles again we see that the Object size on the film can be:

$$\frac{Obj_{size}}{d_1} = \frac{\text{Size on Film}}{d_2}$$

re-arranging:

$$\text{Size on Film} = \text{Object Size}\left(\frac{d_2}{d_1}\right)$$

$$\frac{\text{Size on film}}{\text{Object size}} = \frac{d_2}{d_1}$$

The Magnification Factor is the ratio of the object size on the film to the true object size:

$$f_{mag} = \frac{\text{Size on film}}{\text{Object size}}$$

which from above is also:

$$f_{mag} = \frac{\text{Size on Film}}{\text{Object Size}}$$

$$\text{Size on film} = \text{Objectsize}\left(\frac{d_2}{d_1}\right)$$

$$\frac{\text{Size on film}}{\text{Objectsize}} = \left(\frac{d_2}{d_1}\right)$$

$$f_{mag} = \frac{d_2}{d_1} \quad \text{OR} \quad \boxed{f_{mag} = \frac{SFD}{SOD}}$$

Source-Object-dist

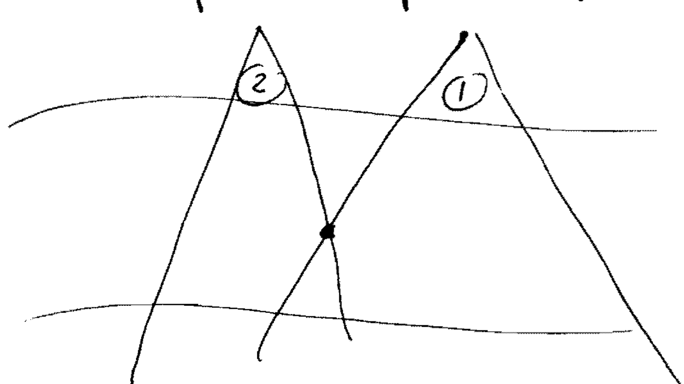
- One can also use Fiducial Plates or Beaded Trays.
  These trays attach to the head of the machine and project beads in a fixed 1 or 2 cm spacing. (pg 148 fig 11.4)

<u>Problem:</u> A simulator has a beaded tray which projects a 7 cm grid ~~onto the~~ at 100 cm. The beaded tray slides into the simulator's block tray at a distance of 40 cm from the source. How far apart are the beads on the tray?

Abutting Fields (Gaps)

- Many times more than one field is used to treat an area.
  - this could be because the area is too large for the maximum field or
  - the area to be treated is adjacent to a previously treated field.

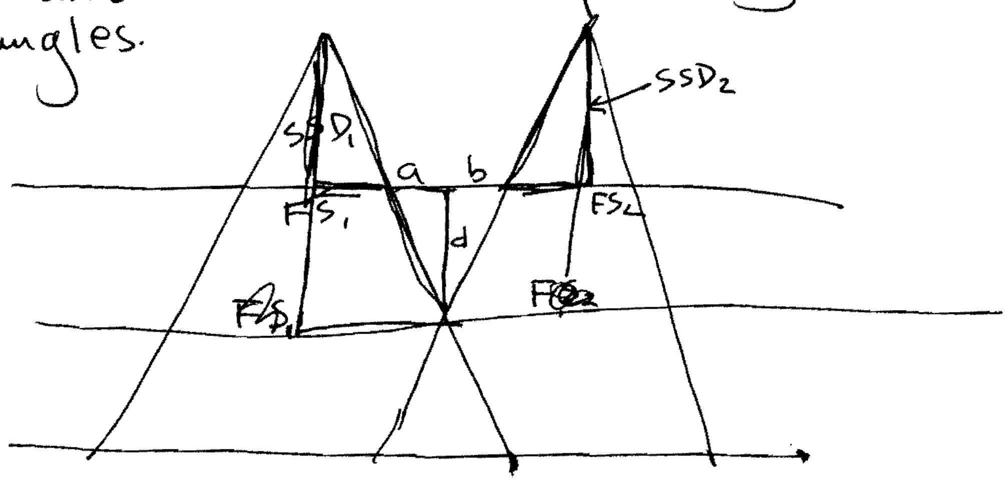
- To properly match the dose in the treated region, the fields should match at some defined depth. (picture pg 149)



- When the fields are matched at some depth, a <u>Gap</u> is created on the skin.

This <u>Gap</u> is used to properly set up the patient.

We can determine the Gap using Similar Triangles.



- from the diagram: Gap = a + b
- from Similar triangles:

$$\frac{a}{d} = \frac{\frac{FS_1}{2}}{SSD_1}$$

$$a = \frac{d}{SSD_1}\left(\frac{FS_1}{2}\right)$$

and

$$b = \frac{d}{SSD_2}\left(\frac{FS_2}{2}\right)$$

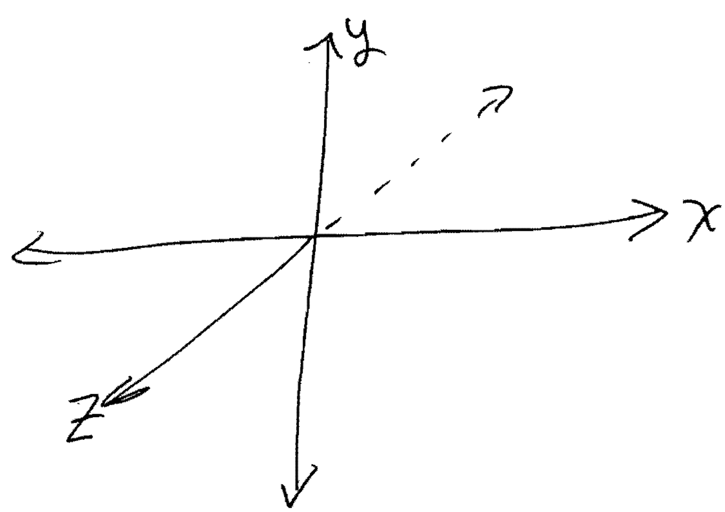
Patient Coordinate System:

- Treatment fields are described in terms of their Lengths & Widths.

- On a patient this usually corresponds to the Cartesian Coordinate system with the X-coordinate representing width and the y-coordinate representing Length

- The X & y axes are perpendicular to each other and are said to be <u>Orthogonal</u> (at right angles)

- Since patients are 3-dimensional, we need to add a third dimension Z which represents the axes from the table to the anterior surface (see pg 154, Fig 11.12)

- 

All three axes are Orthogonal to each other.

Patient Planes:

- The three orthogonal axes are also used to describe 3 orthogonal <u>Planes</u> (slice)
- These planes give different views of the patient anatomy. (see pg 154, fig 11.12)
- The three planes are called:

  1) Coronal - view from above

  2) Sagital - side/lateral view

  3) Transverse - CT slice style

~~Machine Coordinates:~~

- ~~Each Treatment machine has~~

Simple Beam Arrangements:

- There are two main types of set-ups used for patient treatments

  ① SSD setup
  ② SAD or Isocentric setups.

① SSD setups

- The Source-to-Skin distance (SSD) remains the same for all fields
- It is typically 100 cm or 80 cm for some Co-60 & older accelerators.

- Since the skin is at ~~the~~ 100 cm, the Field Size on skin is the same as the collimator setting.

Advantages:

a) All SSD's are the same
b) Good to use for single fields
c) Allows easy calculation using PDD

Disadvantages:

a) For multiple fields, requires moving patient in between fields
b) The Further distance requires slightly more beam time than SAD technique.

② SAD or isocentric Setups

- The SAD is set up within the patient.

- As the Gantry rotates about the patient, the isocenter remains fixed at that point (usually in the Tumor).

Advantages:

a) Easy setups for multiple fields.
b) No patient movement between fields.
c) Can be used for single or multiple fields.

Disadvantages:

a) Need an isocentrically mounted machine.
b) different SSD's for each beam – ~~more calculations~~.

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① SSD Setups:

- Early Treatment machines were fixed gantrys.
- The patient was rolled underneath and turned over if needed.

- To ease set-up, each field was setup with a fixed Source-Skin-Distance (SSD), typically 80 - 100 cm.

- This allowed for rapid + reproducable set-ups.

- But, for complex treatments, the patient had to be moved between fields.

~~Simple Beam~~

(2) SAD or Isocentric Setups

- In the 1950's, the concept of isocentric setups was tried to aid in Rotational treatments

- An isocenter is a point in space that is equally far from the source no matter what the gantry angle. (fig 11.21, pg 159)

- This allows the gantry to rotate to different positions around the patient and have the isocenter always at the same distance.

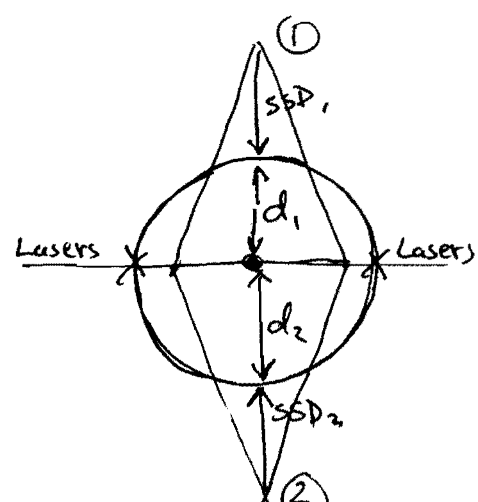
- No moving of the patient between fields.

Isocenter: the intersection of the collimator axis and the gantry axis of rotation.

Example Setups:

(1) Parallel-Opposed-Fields (POF)

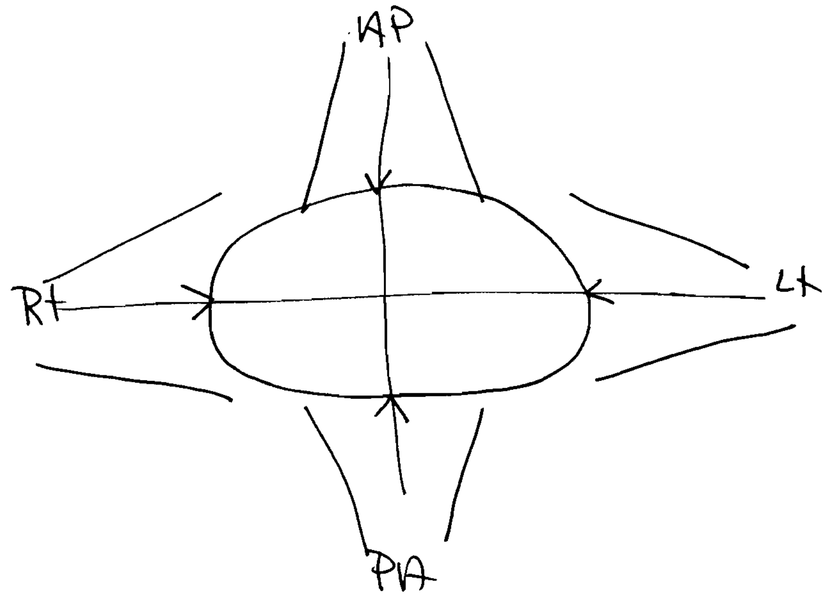
2 fields opposite each other
eg: AP|PA, Rt|Lt Laterals



$SSD_1 + d_1 = SAD$
$SSD_2 + d_2 = SAD$

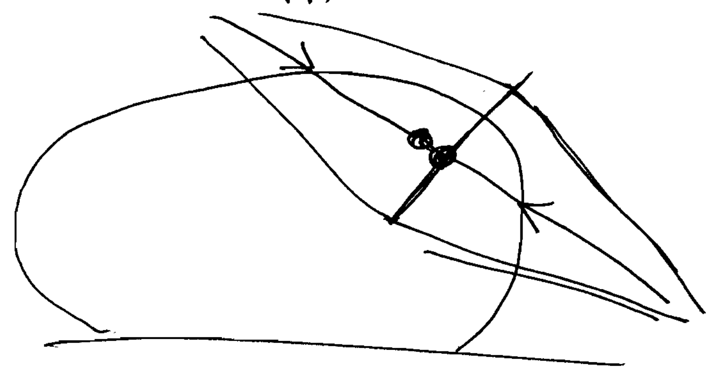
② 4 Field box

eg: Prostate, Cervix



③ Tangential Set-up

eg - Breast, Chestwall



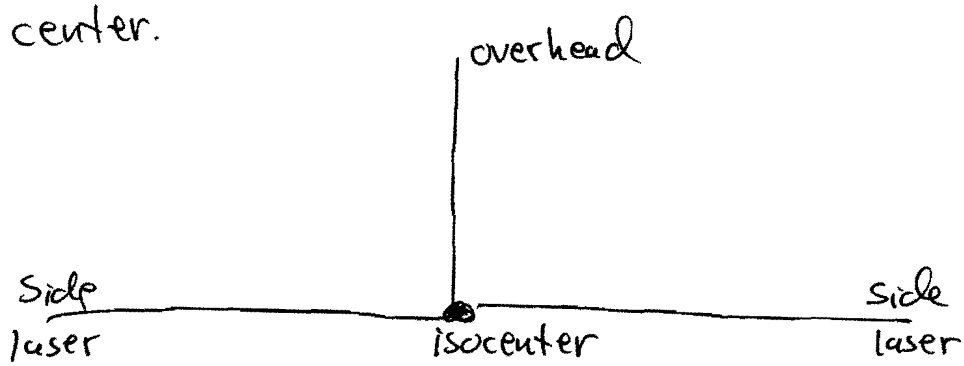
All set-ups can be treated either with the SSD setup or the SAD setup.

- With SSD setup, the patient is moved after each beam so that the SSD is 100 (or 80)

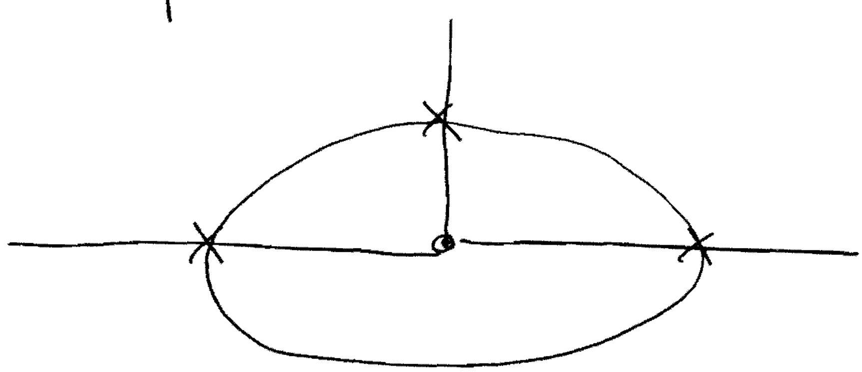
Lasers + 3-pt Setup:

- In isocentric setups, lasers are employed to help set up the patient on a day-to-day basis

- Each Tx machine and Simulator will have a set of at least 3 Lasers which intersect at the isocenter.



- After a patient is simulated, the position where the laser falls on the skin is marked at all three positions



- Each day in the Tx room, the patient is aligned with the laser marks.

- This is called Triangulation or a 3-pt. setup.

- By matching the three points the patient will not be skewed or rotated.

Beam Blocking:

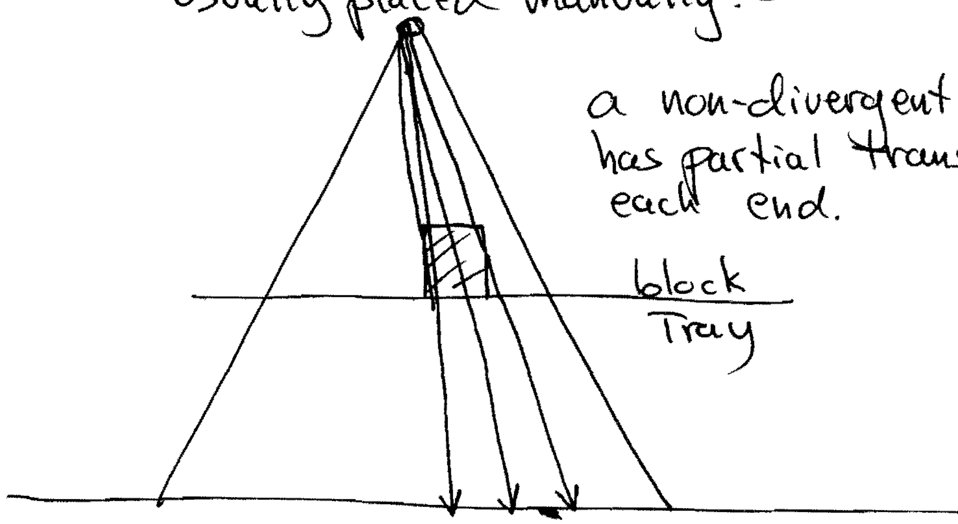
- Most accelerators can only set rectangular fields with the collimator systems.

- Beam blocking is used to block out radiation to critical structures and to conform the radiation to the Tumor shape.

- 3 Main types of Blocking

  ① Simple Rectangular blocks.

  - made of Lead or depleted Uranium
  - non-divergent blocks
  - come in simple shapes (rect, sq., cylinder, etc)
  - usually come in one thickness, so not adequate for all energy beams.
  - usually placed manually.



a non-divergent block has partial transmission on each end.

(2) Custom Beam blocks

- typically made of Cerrobend
- custom made for each patient
- diverging blocks follow divergence of x-ray beam
- mounted to blocking tray.

(3) Multi-Leaf Collimator (MLC)

- built into treatment machine
- easily make custom shielding for each patient.
- no blocks to change for each beam.