Multi Leaf Collimator

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Multi Leaf Collimator

- MLC overview
- Conventional Beam Shaping
- Advantage of MLC over Conventional Block
- MLC configuration
- MLC leaf design
- Transmission Specification
- Clinical Application
- Tests on MLC
- Miniature MLCs

Conventional Beam shaping

- Rectangular Field produced by two sets of collimators (or jaws) built into the treatment machine.
- Irregular fields can be produced by using secondary custom blocks attached to the treatment machine beyond the collimator jaws.
- Conventional blocks are
  - Set of lead blocks of different shapes and sizes given by the vendor.
  - Cerrobend blocks fabricated individually for each radiation treatment field.

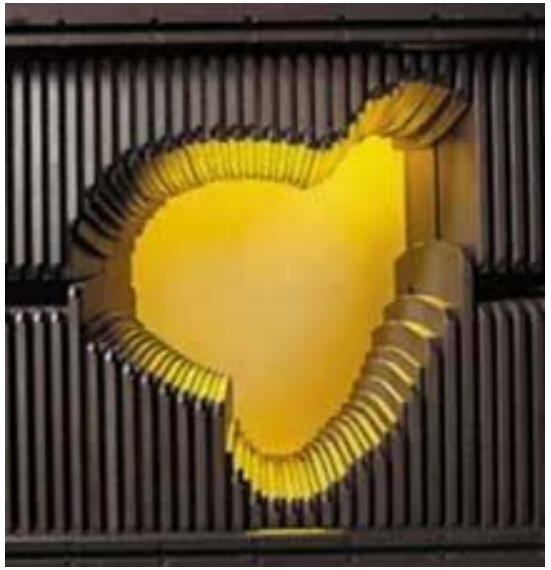
Conventional Beam shaping

Drawbacks of Conventional Block

- Treatment delivery time increases as technologist has to enter the treatment room for each beam to adjust the block set up.
- The fabrication process is lengthy and involves handling of toxic cerrobend material.
- Manual placement of blocks over tray attached to the machine may lead to accidents involving dropping or falling of blocks causing injury to patients and technologists.

Multi leaf collimators

- Multi leaf collimators are introduced into Linacs in the 1980's.
- Multi leaf collimators are a pair of jaws divided into independent movable sections or leaves.
- Computer controlled.
- Shapes fields quickly. (No need of Block set up)
- It can also be used for dynamic treatment. (Intensity Modulation)



Materials and properties

- Tungsten alloy(tungsten,Fe,Cu,Ni) is the material of choice for leaf construction.
- High density
- Hard
- Inexpensive
- low coefficients of thermal expansion
- density of Pure tungsten= 19.3 g/cm3

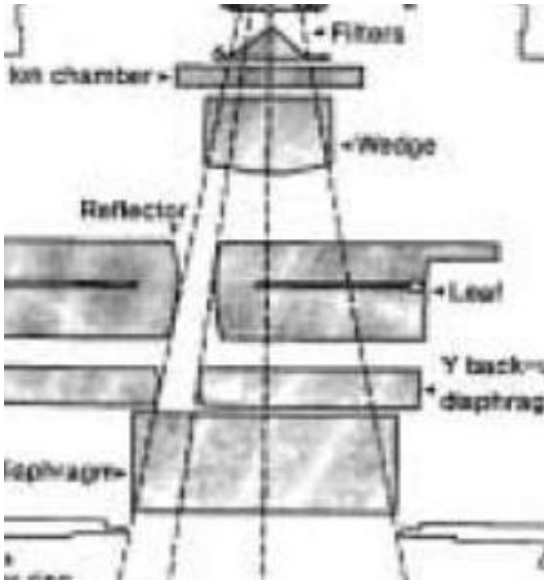
  density of the alloys =17.0- 18.5 g/cm3

Basic Application of MLC

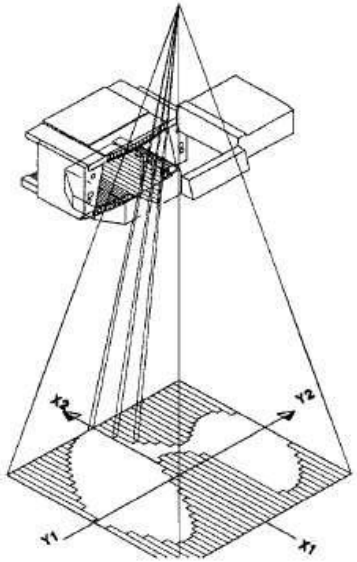
- To replace conventional blocks.
- Matching the BEV to PTV during an Arc rotation of X ray beam.
- Achieve beam intensity modulation.

MLC configuration

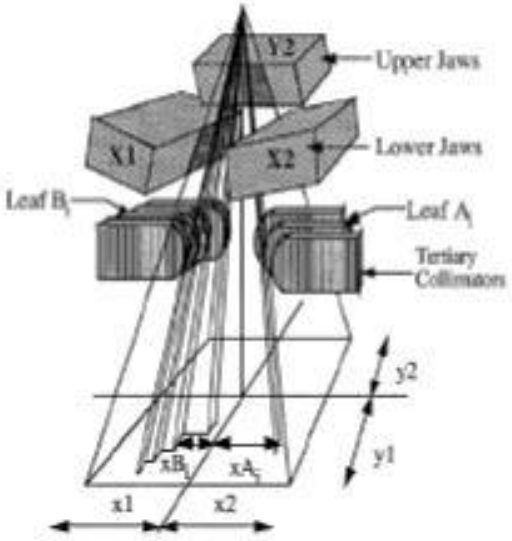
- Upper jaw replacement (Elekta)
- Lower jaw replacement (Siemens)
- Tertiary Collimation (Varian)



Elekta

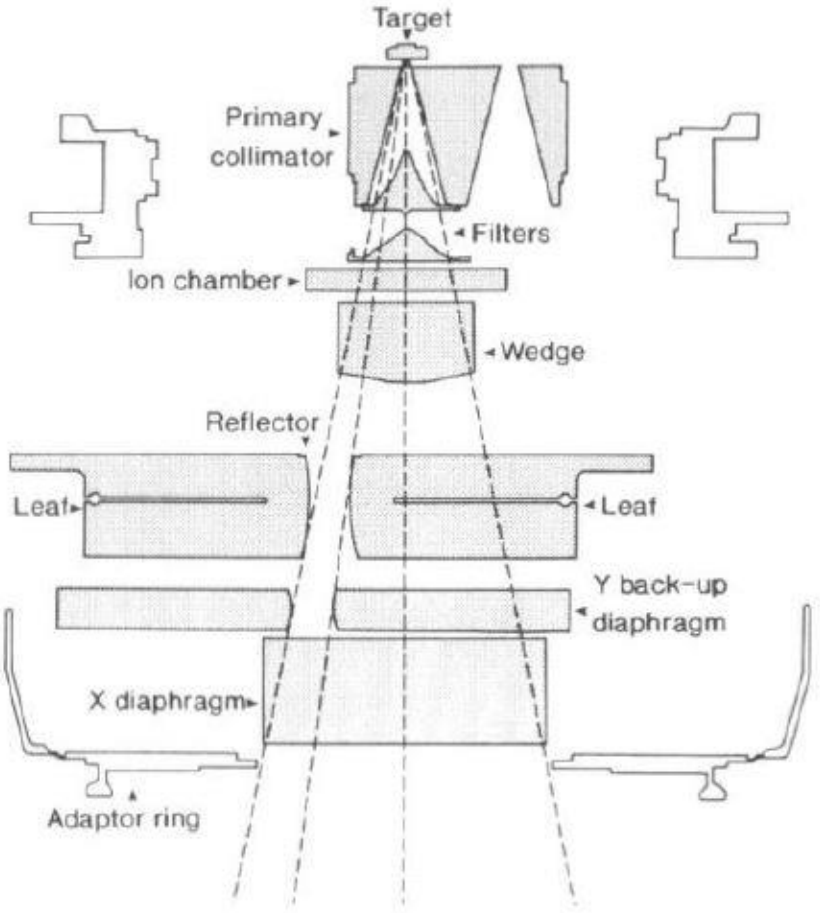


Siemens



Varian

Upper jaw replacement



Upper jaw replacement

- In this configuration the upper jaw is split into a set of leaves. (used by Elekta)
- MLC leaves move in the Y-direction (parallel to the axis of rotation of the gantry)
- A "back-up" collimator located beneath the leaves and above the lower jaws augments the attenuation provided by the individual leaves.
- The back-up diaphragm is essentially a thin upper jaw that can be set to follow the leaves if they are arranged together to form a straight edge, or else, set to the position of the outermost leaf if the leaves form an irregular shape.

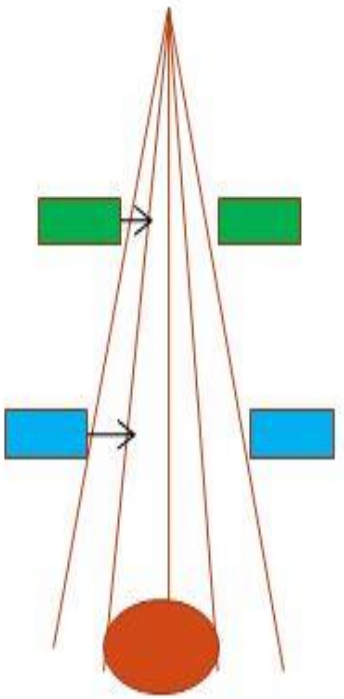
Upper jaw replacement

Advantages

- The range of motion of the leaves required to traverse the collimated field width is smaller.
- It allows for a shorter leaf length and therefore a more compact treatment head diameter

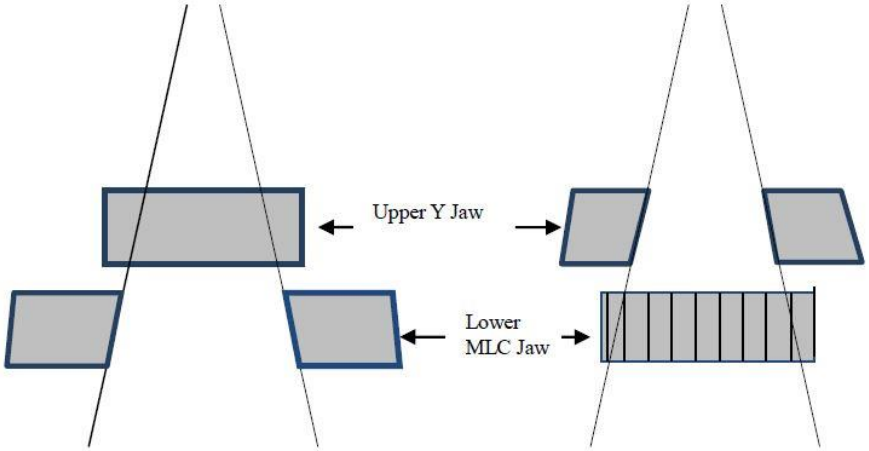
Disadvantages

- Having MLC leaves so far from the accelerator isocenter needs leaf width must be somewhat smaller.
- Tolerances on the dimensions of the leaves as well as the leaf travel must be tighter than for other configurations.



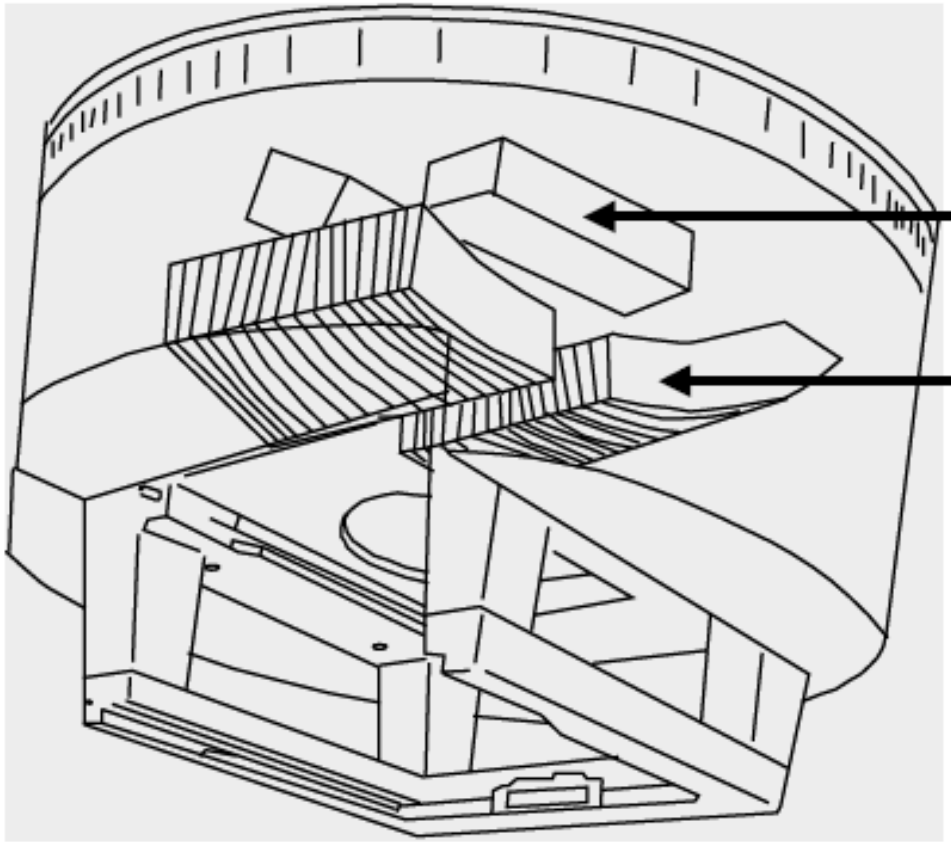
Lower Jaw Replacement

- The lower jaws can be split into a set of leaves as well. (Siemens) and is double focused.
- Both leaf ends and leaf sides match the beam divergence.
- There are no backup jaws.



Lower Jaw Replacement

SIEMENS



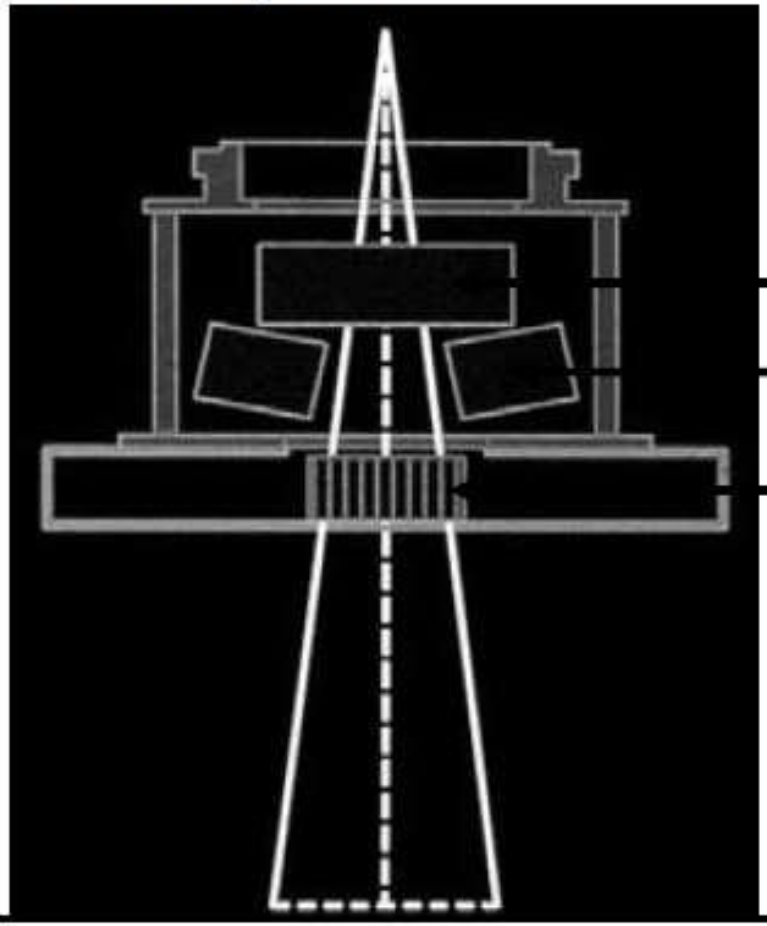
Courtesy Siemens

Tertiary collimation

- MLC are positioned just below the level of the standard upper and lower adjustable jaws(**Varian).**
- This avoids the lengthy downtime in the event of a MLC system malfunction.
- It is possible to move leaves manually out of the field should a failure occur.
- The treatment can be continued by using 'Cerrobend' individual blocks.

Tertiary MLC

VARIAN
medical systems



Upper Diaphragm

Lower Diaphragm

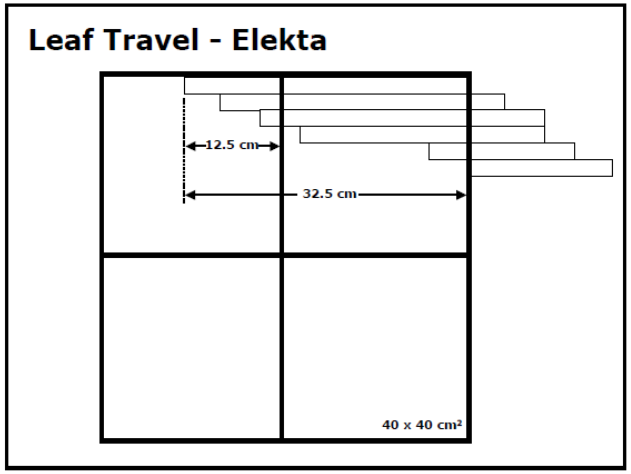
Leaves

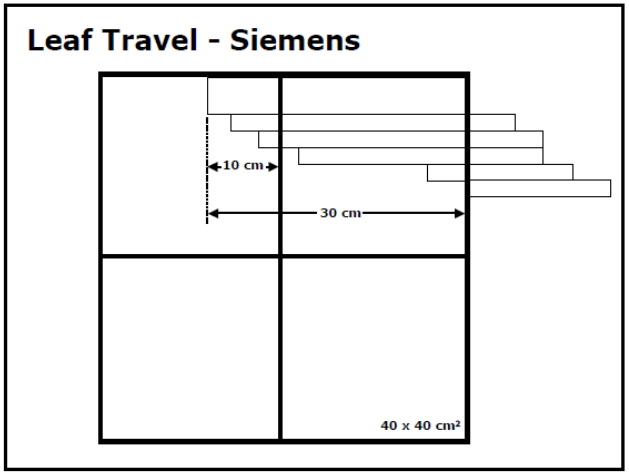
Courtesy Varian

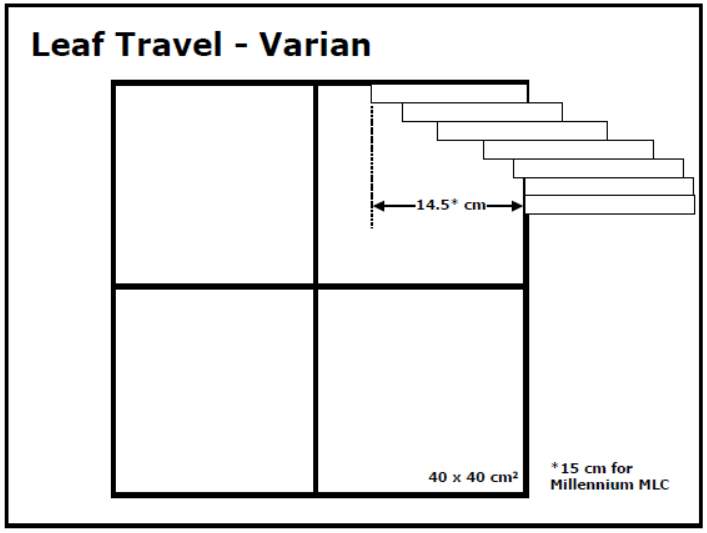
Tertiary Collimation

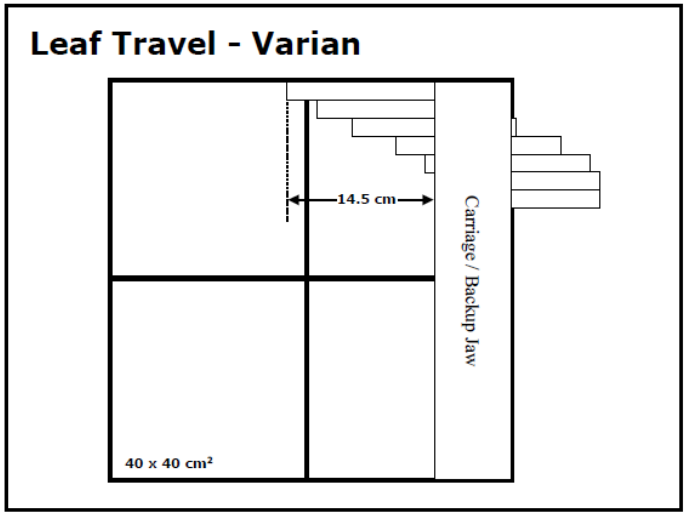
- **Advantages**
  - Allows retro-fitting of MLCs on existing units.
  - Leaves can be manually moved out in case of system malfunction/failure and treatment continued using customized blocks.
  - Allows larger leaf width; easier manufacturing.
  - Easier Leaf positioning / Lesser positional accuracy needed.
- **Disadvantages**
  - Added bulk and clearance to the mechanical isocenter.
  - Moving the MLC further away from the xray target requires increasing the leaves size and a longer travel distance.

Leaf travel distances

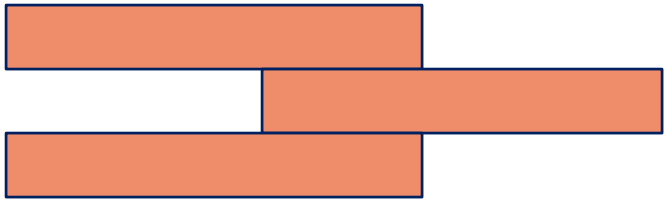




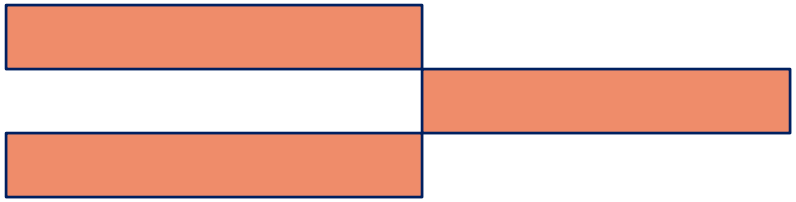




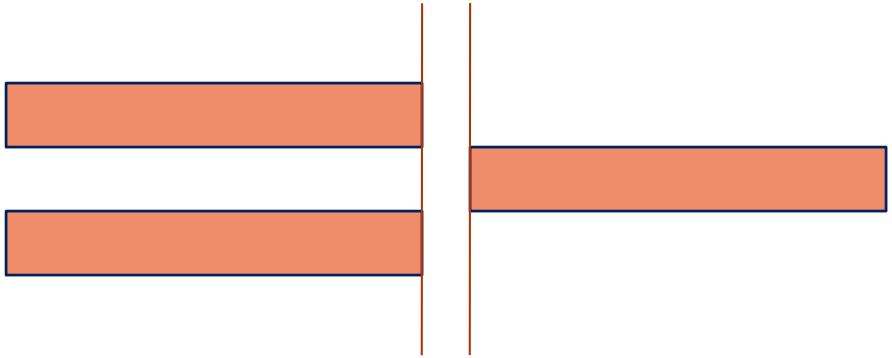
Leaf motion constraints



Interleaf motion
(Varian)

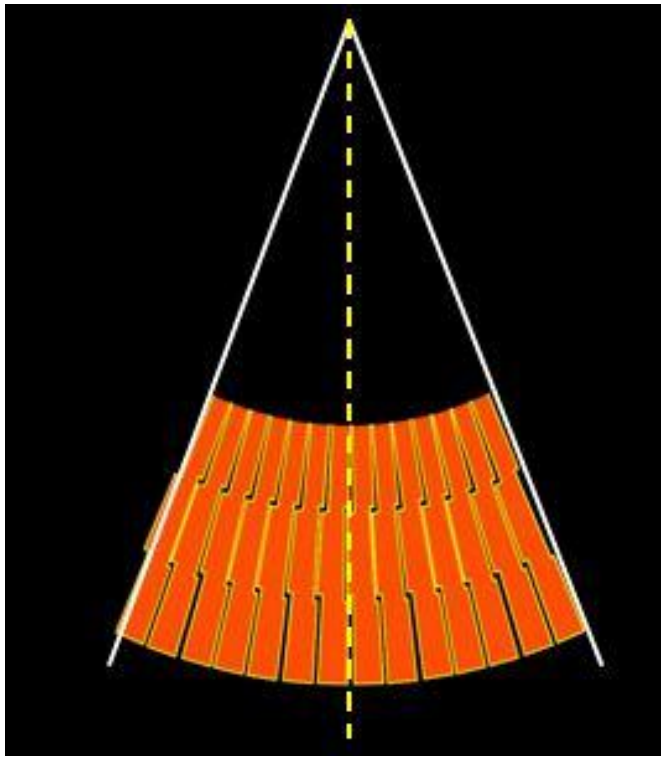


No Interleaf motion
(Siemens)

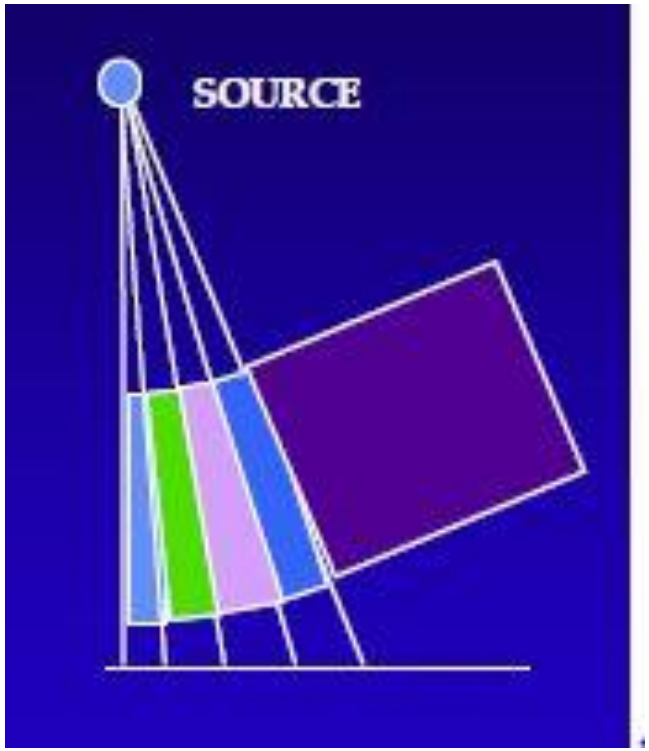


Minimum Gap
(Elekta)

Double Focused MLC

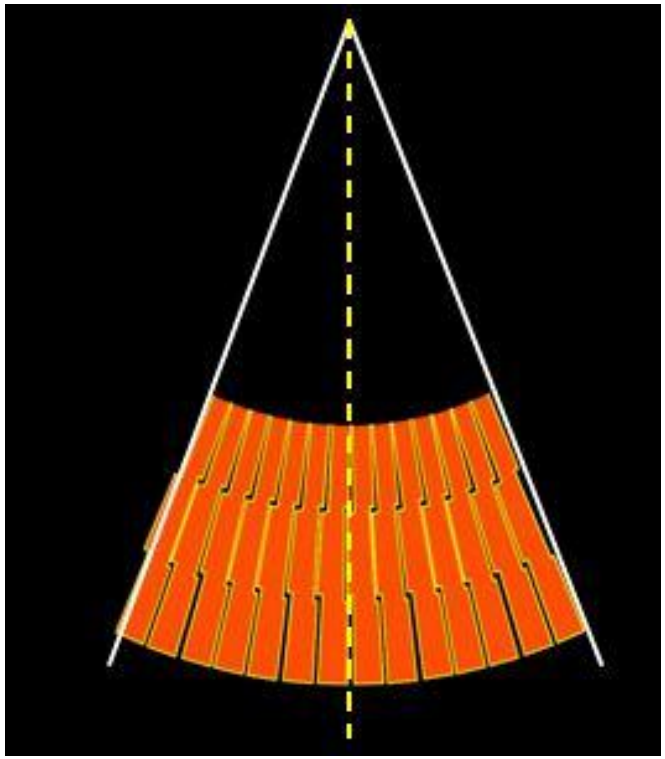


Focused in Y direction

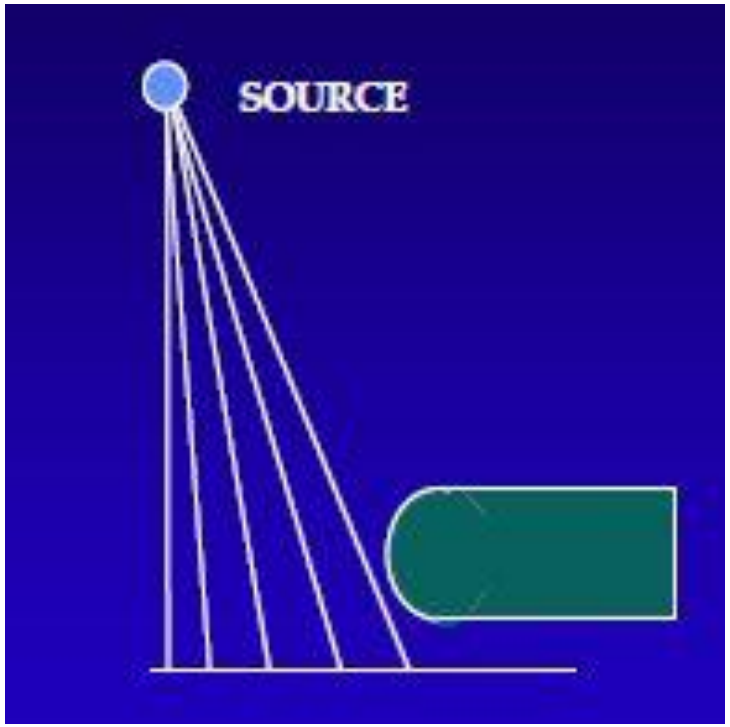


Focused in X direction

Single Focused MLC



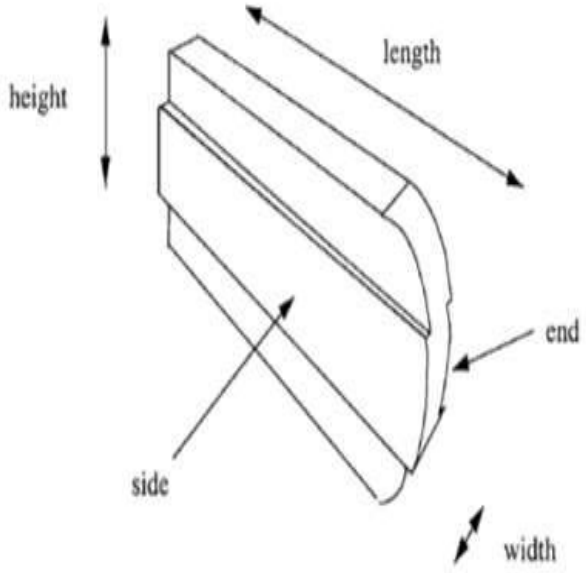
Focused in Y direction



Unfocused in X direction

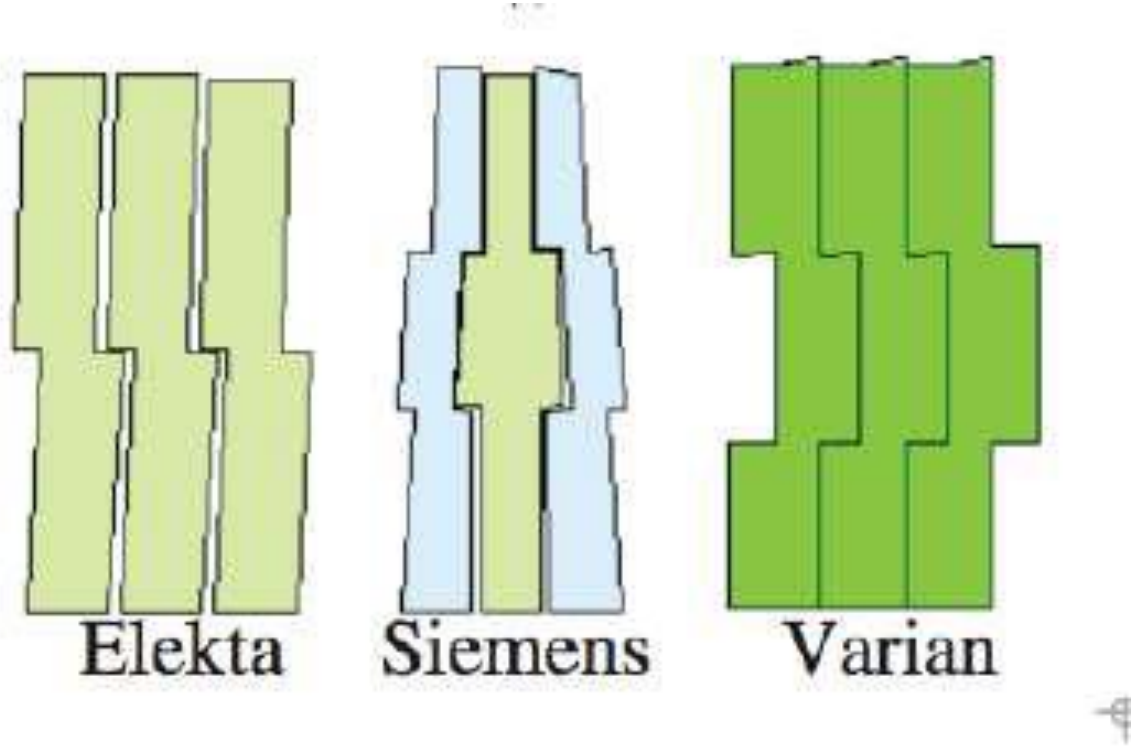
MLC Leaf design

- ***Width of a leaf***-small dimension of the leaf perpendicular to the direction of propagation of the x-ray beam and perpendicular to the direction of motion of the leaf.
- ***Length of the leaf***- leaf dimension parallel to the direction of leaf motion.
- ***Leaf end***-Surface of the leaf inserted into the field.
- ***Leaf sides*** -Surfaces in contact with adjacent leaves
- ***Height of the leaf***-Dimension of the leaf along the direction of propagation of the primary x-ray beam.



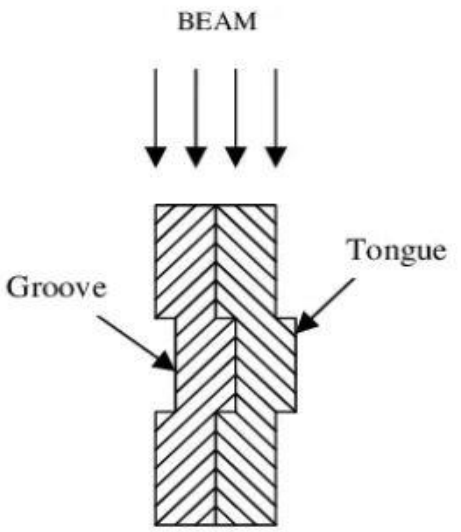
MLC Leaf design- Leaf sides

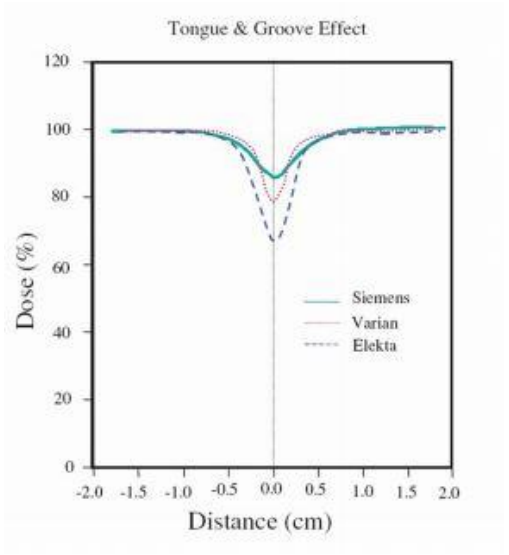
Tongue and Groove Construction



Tongue and groove effect

- The two adjacent leaves are coupled together through the tonge and groove to reduce the radiation leakage.
- When two adjacent leaves have different degrees of extension, the tongue side of the more extended leaf produces an underdose region near the leaf edge.

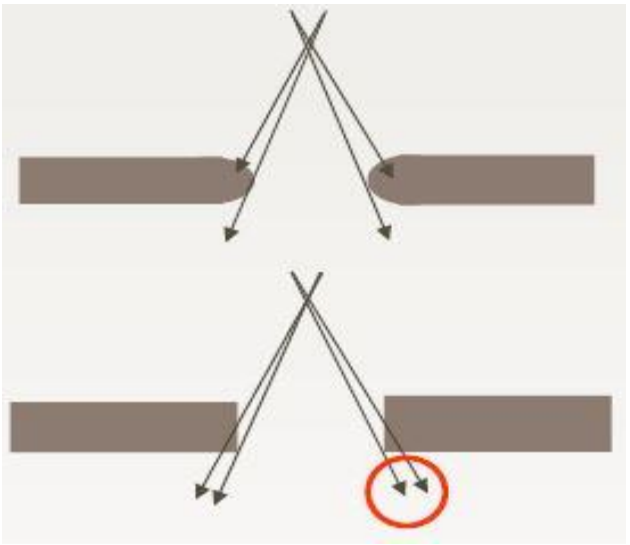




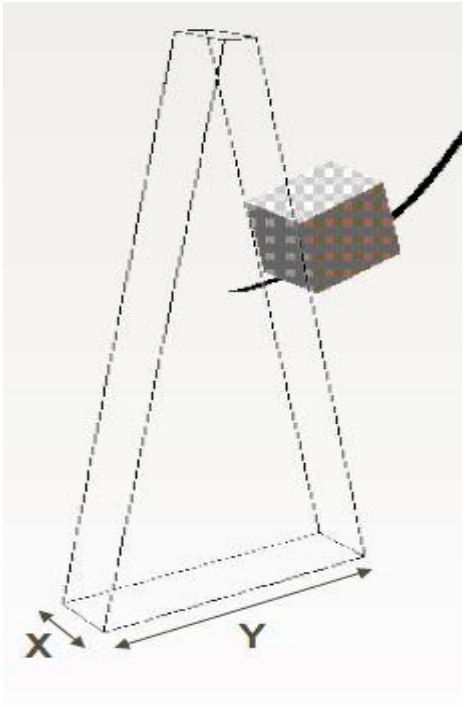
MLC Leaf design – Leaf end

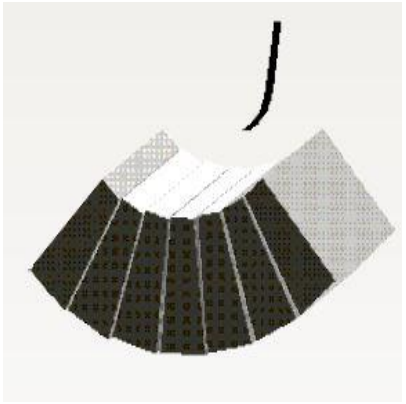
- *Focused Leaf end*
  - the leaf ends are designed to follow the beam divergence as the field opens or closes.
  - Siemens Linac use MLC which move in an arc such that their flat ends are always in the same plane as the radiation focus.
  - Complex design.
  - Penumbra is less.
- *Unfocused Leaf end*
  - The leaf ends are round.
  - Simpler design.
  - Acceptable penumbra.
  - Varian and elekta use this kind of MLC design.

MLC Leaf design – Leaf end



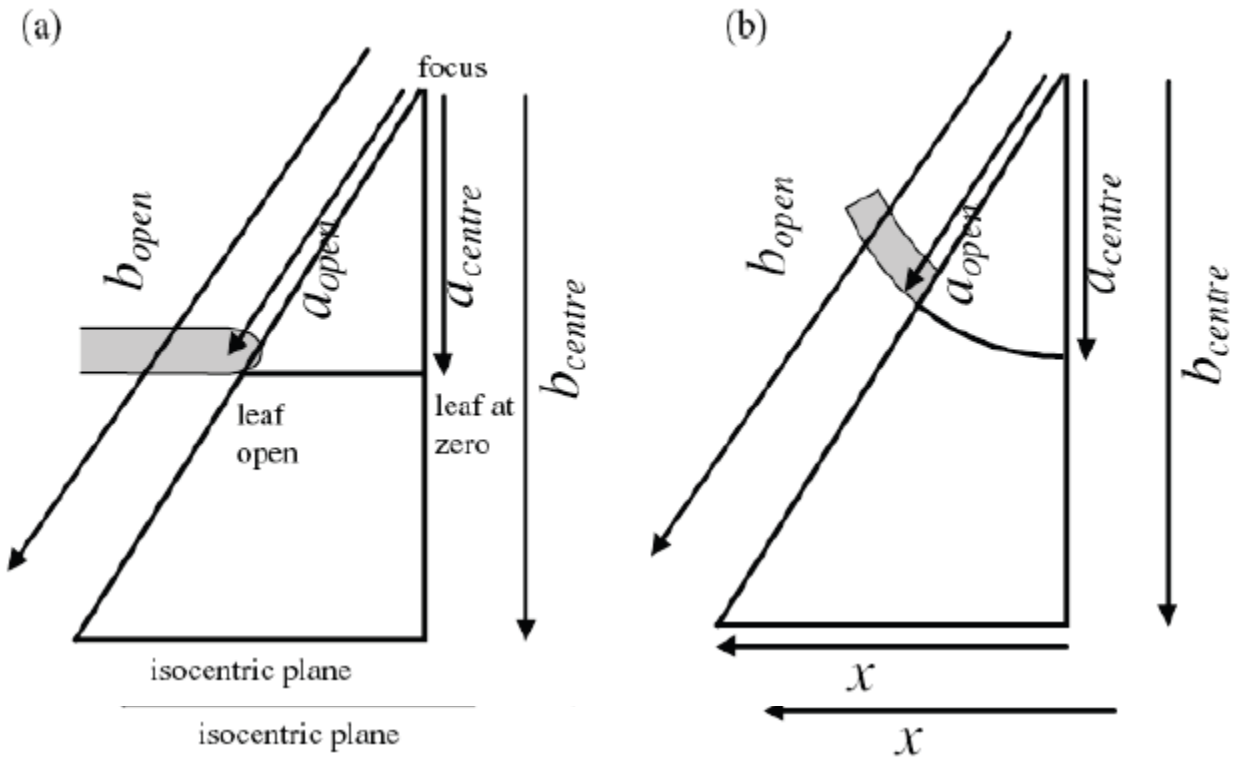
Unfocused





focused

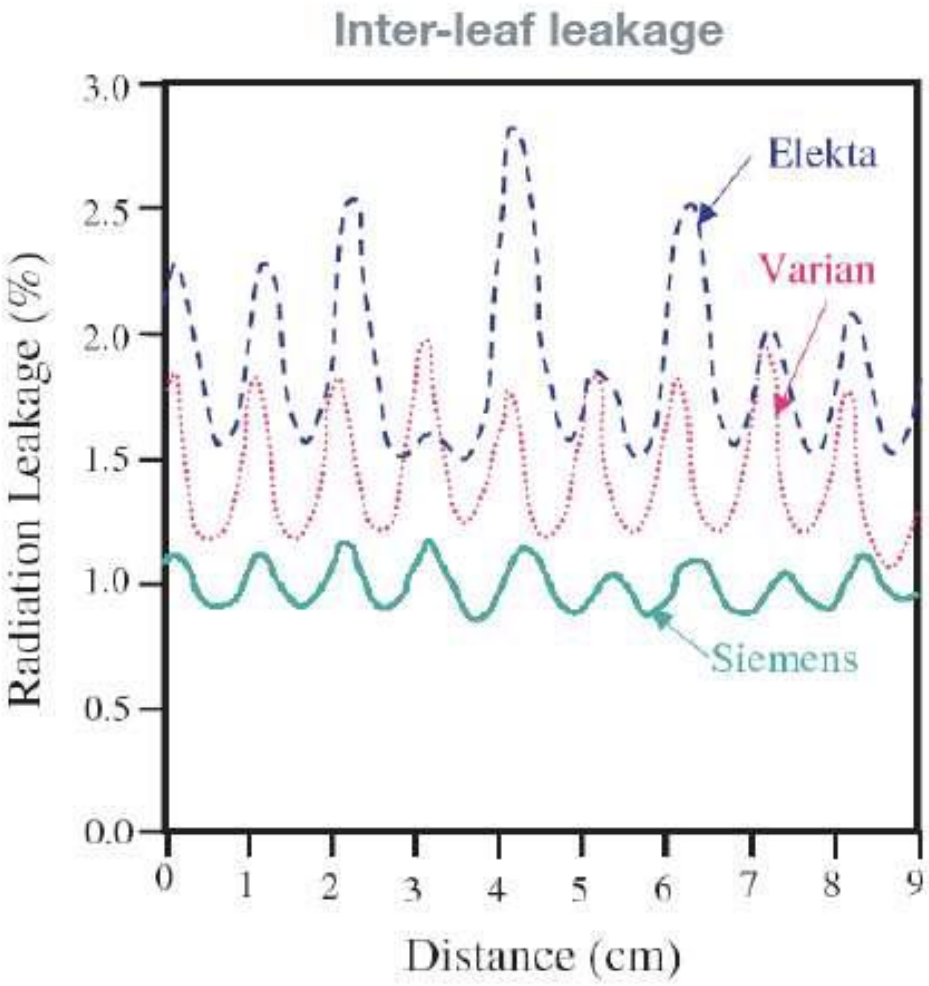
MLC Leaf design – Leaf end



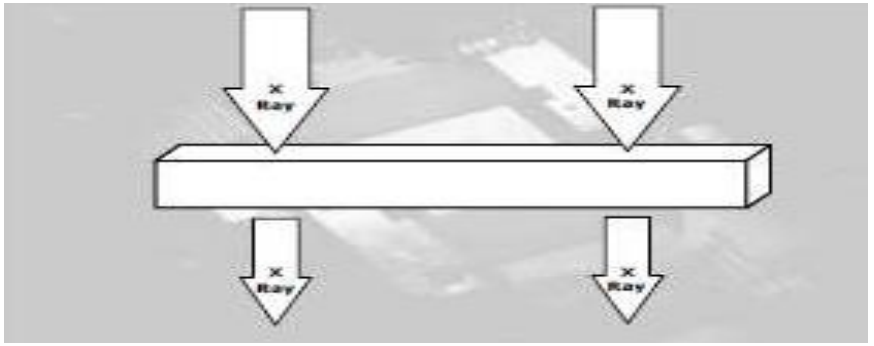
Unfocused **focused**

Transmission Specification

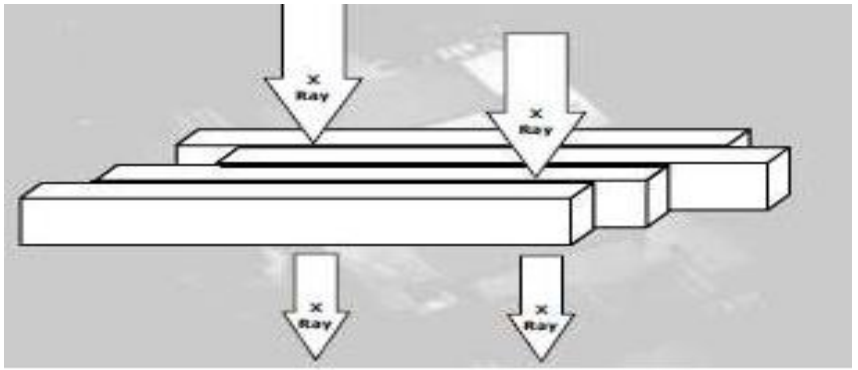
- ***Intra leaf transmission*:** The reduction of dose through the full height of the leaf.
- ***Interleaf transmission*:** The reduction of dose between adjacent leaves.
- ***Leaf end transmission*:** Reduction of dose measured along a ray passing between the ends of opposed leaves in their most closed position.


Inter-leaf leakage
Radiation Leakage (%)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
1
2
3
4
5
6
7
8
9
Distance (cm)
Elekta
Varian
Siemens

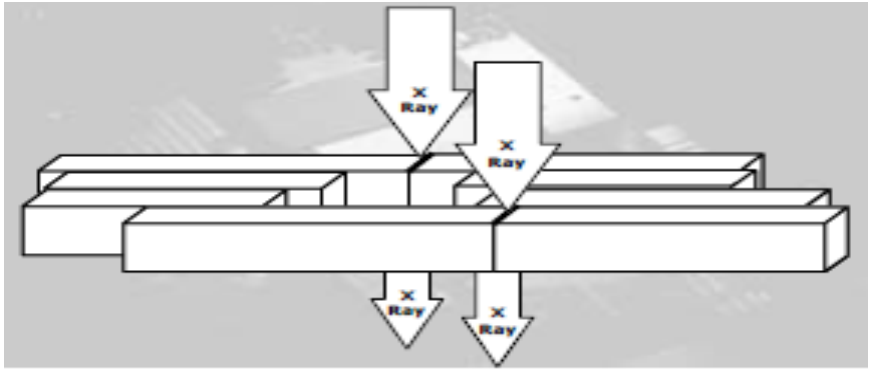
- Intra Leaf Transmission



- Interleaf Transmission



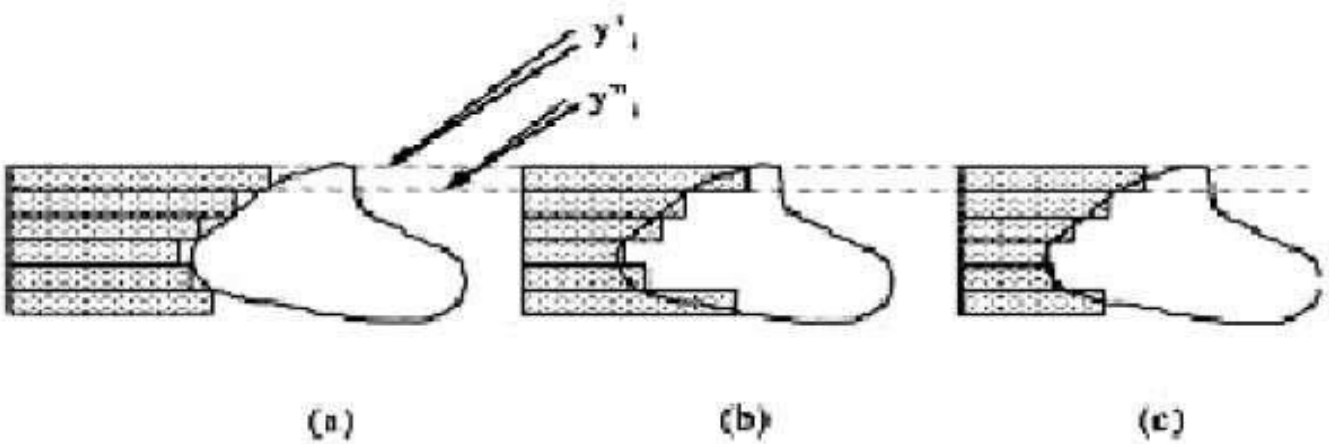
- Leaf end Transmission



Clinical Applications

- ***Leaf placement Strategies***
  - *Definition of Target area* : Treatment planning system facilitates shaping leaves around PTV, as defined by a radiation oncologist.
  - *Optimisation of MLC conformation* : To place automatically the leaves of MLC in conformity with the target contour shape, three leaf coverage strategies can be used.
    - ***Out of field strategy***
    - ***In field strategy***
    - ***Cross boundary technique***

Leaf placement strategies



a. *Out of field strategy* : Avoids shielding any part of PTV which may not be irradiated completely.

b. *In field strategy* : PTV is not irradiated completely, but any part out of PTV is shielded.

c. *Cross boundary technique* : Leaf positions are optimized such that in field area is equal to the out field area.

- ***Optimization of Collimator rotation*** **:**
  - One can optimize matching the leaf shape to target volume by rotating the collimator, and therefore, the direction of leaf travel.
- ***Intensity Modulated Radiotherapy (IMRT) using MLC*** **:**
  - Precise dose delivery on any part of treated area avoiding the surrounding healthy tissue.
  - MLC for IMRT should be very precise, motion of leaves must be fast and constant.
  - Two strategies of IMRT with MLC.
    - ***Step and Shoot*** - leaves moves when radiation is stopped.
    - ***Dynamic*** - Continuous movement of leaves during the treatment

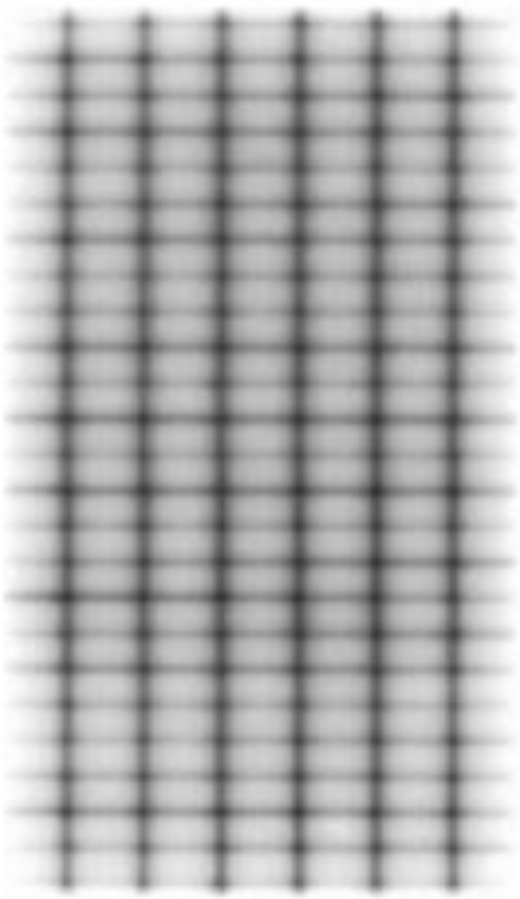
Step and Shoot

Dynamic

Tests on MLC (3DCRT/IMRT)

- Positional accuracy & reproducibility
- Coincidence of MLC, collimator & couch axes
- Leaf width at isocentre
- Inter and intra leaf transmissions
- Leaf end gap - inter leaf collisions
- Over travel accuracy and reproducibility
- Skewness-Misalignment between the MLC leaves and the Primary Jaw or Backup Diaphragm
- Leaf speed
- Leaf end and radiation field edge offset

QA tests on MLC

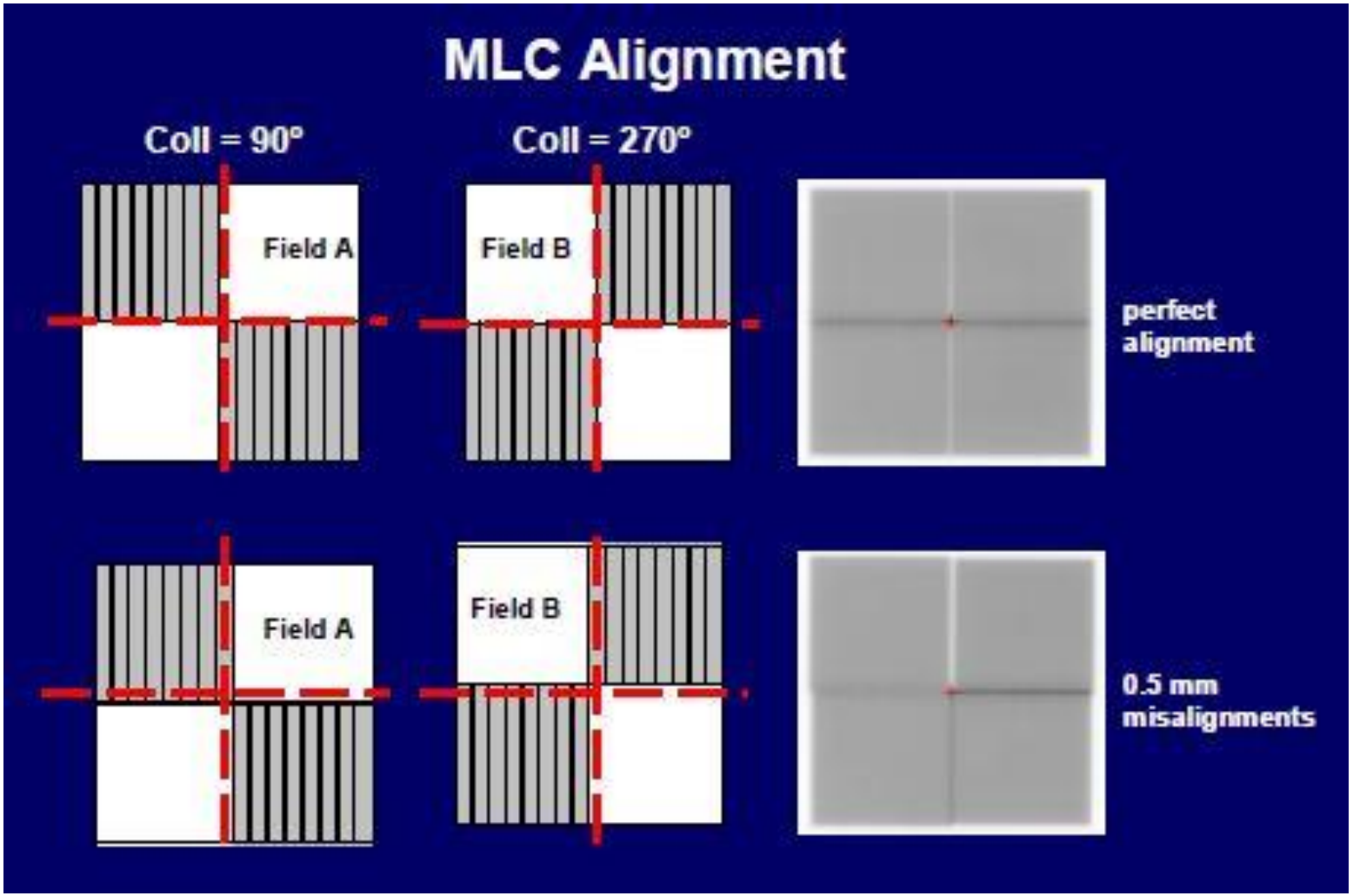


Picket Fence pattern

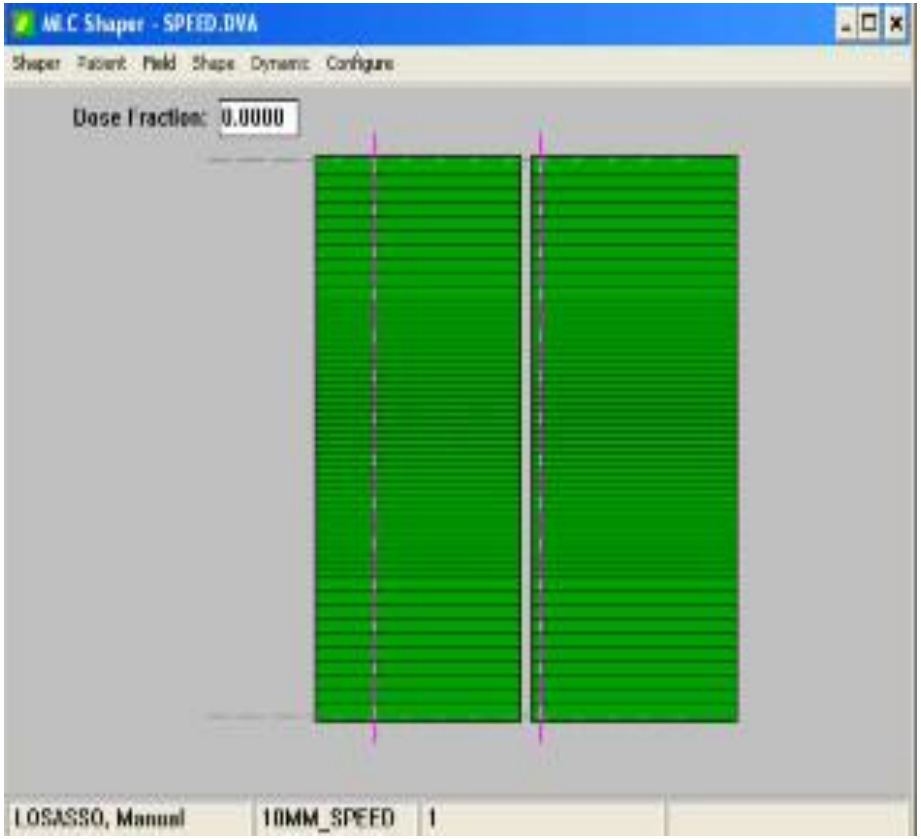
1mm wide strip at 2cm interval.

Provides a quick visual inspection of relative leaf position.

QA tests on MLC



QA tests on MLC



Leaf Speed Test

Alternating pair of MLCs moved at constant speed.

Log file is generated for analysis.

The logged leaf positions are compared with the prescribed leaf position.

QA tests on MLC

Test Parameters	Tolerances
Field overlap	2.0 mm
Positional Accuracy	< 1 mm
Positional Reproducibility	± 1 mm
Light and Radiation field coincidence	± 2 mm
Coincidence of mechanical and radiation isocentre	≤ 2 mm dia
Average of intra and inter leaf transmission	± 0.5 %

Non Conventional MLCs

Mini and Micro MLCs

- Facilitates small field treatments in case of SRS and SBRT.
- Mini MLC- leaf width :2mm to 5mm

  Micro MLC- Leaf width : <2mm
- Built in computer controlled MLC provided by many vendors. e.g. MLC of True beam, Novalis Tx Varian.
- Add on MLC which can be attached to the Linac gantry head. e.g. Elekta Apex, Brainlab etc.

BrainLab

3mm MLC
Max Field
9.8 x 9.8

Elekta Apex

2.5mm MLC
Max Field
12 x 14 cm


THANK YOU
FOR YOUR ATTENTION