

Prescribing, Recording, and Reporting Electron Beam Therapy (Report 71)

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- Electron beam radiation is a special type of radiotherapy that consists of very tiny electrically charged particles generated in a linear accelerator and directed towards the skin.
- Electron-beam therapy is advantageous because it delivers a reasonably uniform dose from the surface to a specific depth, after which dose falls off rapidly, eventually to a near-zero value.
- Using electron beams with energies up to 20 MeV allows disease within approximately 6 cm of the surface to be treated effectively, sparing deeper normal tissues.

Electrons are useful in treating

- cancer of the skin and lips, upper-respiratory and digestive tract, head and neck, breast.
- Skin: Eyelids, nose, ear, scalp, limbs.
- Upper-respiratory and digestive tract: Floor of mouth, soft palate, retromolar trigone, and salivary glands.
- Breast: Chest-wall irradiation following mastectomy; Nodal irradiation, Boost to the surgical bed.
- Other sites: Retina, orbit, spine (craniospinal irradiation), Pancreas and other abdominal structures (intraoperative therapy) ,Cervix (intracavitary irradiation)

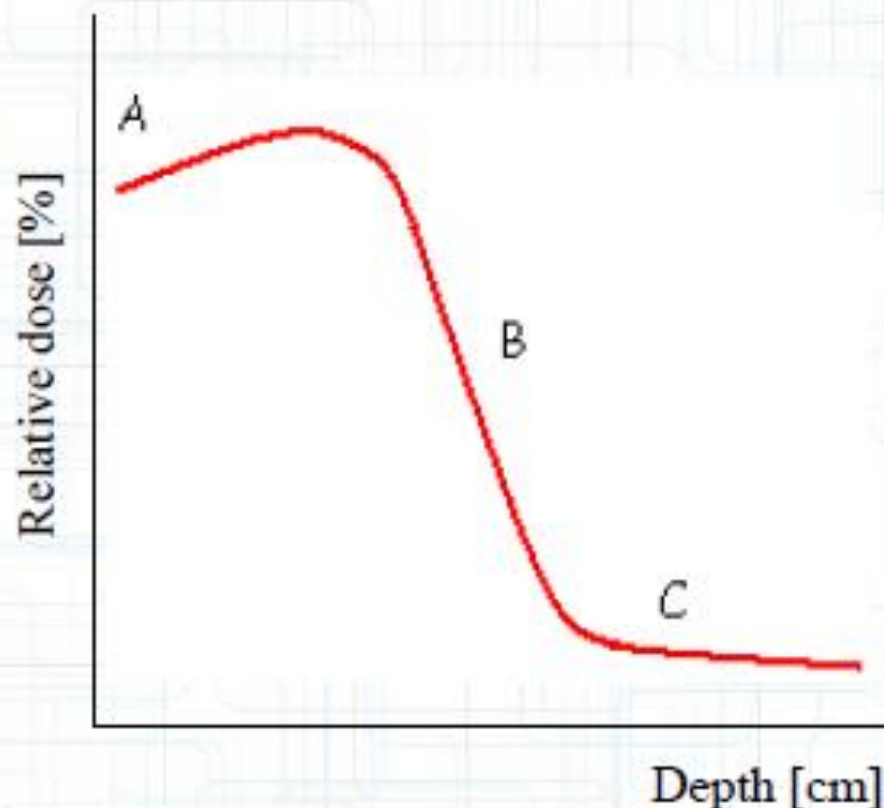
e-Beam Interactions

- **Coulomb force interactions**
 - Inelastic collisions with atomic electrons (ionization and excitation)
 - Inelastic collisions with nuclei (bremsstrahlung)
 - Elastic collisions with atomic electrons
 - Elastic collisions with nuclei
- **Low $Z \Rightarrow$ energy loss by ionization**
High $Z \Rightarrow$ energy loss by bremsstrahlung

- The rate of energy loss for collisional interactions depends on the electron energy and on the electron density of the medium.
- The rate of energy loss per gram per square centimetre, $\text{MeV/g}\cdot\text{cm}^2$ (called the mass stopping power) is greater for low atomic number materials than for high atomic number materials.
- When a beam of electrons passes through a medium the electrons suffer multiple scattering, due to Coulomb force interactions between the incident electrons and predominantly the nuclei of the medium.

- The scattering power of electrons varies approximately as the square of the atomic number and inversely as the square of the kinetic energy.
- For this reason high atomic number materials are used in the construction of scattering foils used for the production of clinical electron beams in a LINAC.
- Electron beam at exit is a narrow pencil beam (2-3mm) and almost monoenergetic. It suffers energy degradation and scattering during exit and when it reaches the surface, there are different levels of electron energy. Clinically, energy is specified by the most probable energy at the surface, kE possessed by most of the electrons.

Percentage Depth Dose - Electrons



High surface dose

Almost constant dose to depth just beyond d_{max}

Sharp fall off with increasing depth

Finite range – sparing of underlying tissues

Range varies with electron energy

A: Build-up region

B: Dose fall-off region

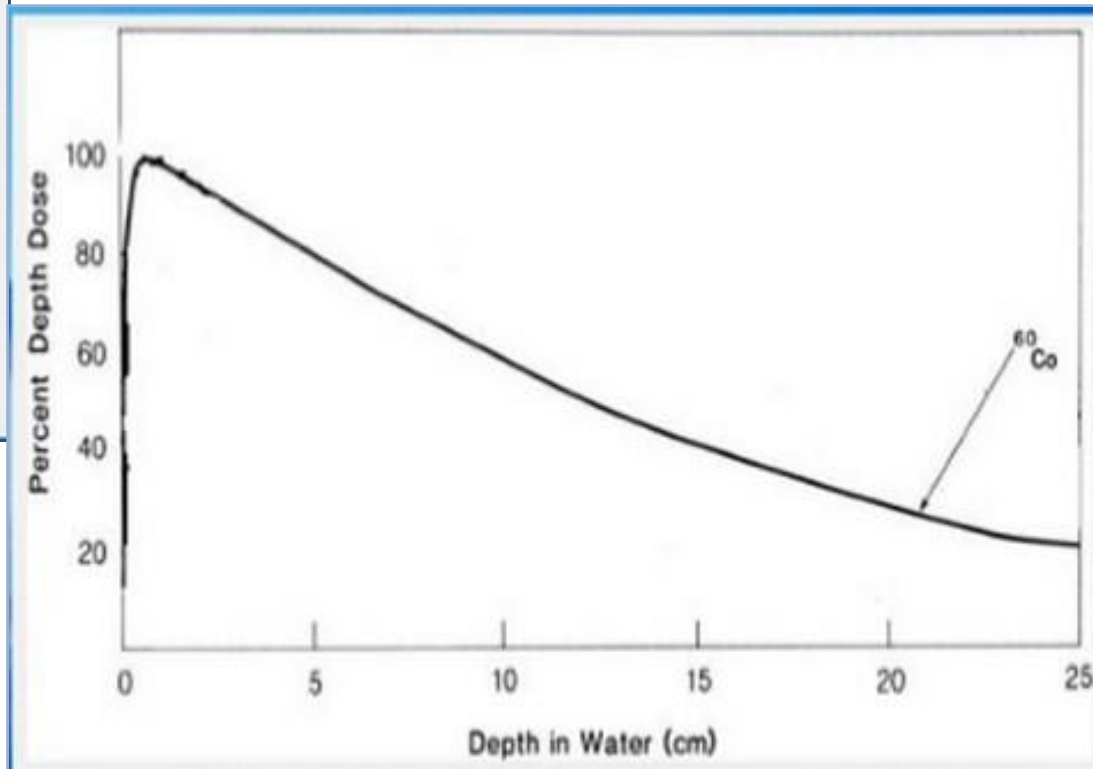
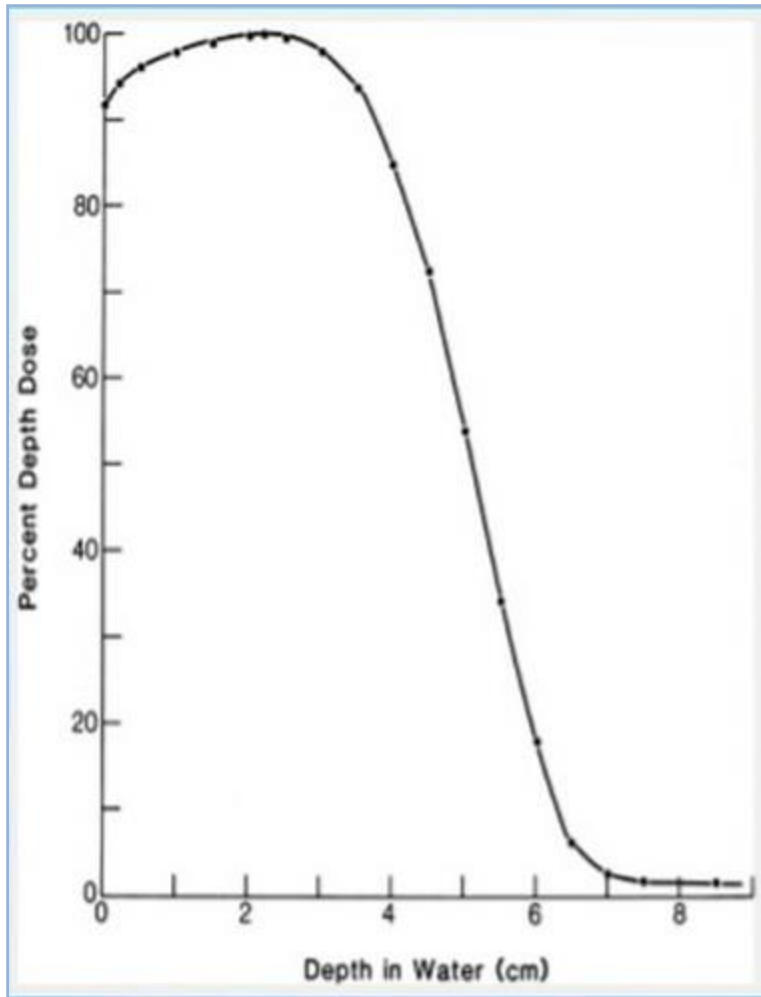
C: depth-dose tail

Typical clinical energies:
5, 7, 9, 12, 15, 18, 20 MeV

ELECTRON

VERSUS

PHOTON



Beam Shaping and Collimation



Target to Applicator end distance = 95 cm

Due to the omnipresence of the scattering effects, the dosimetry of electron beams depends strongly on the energy, collimation, and geometry layout of the medium traversed by the electrons.

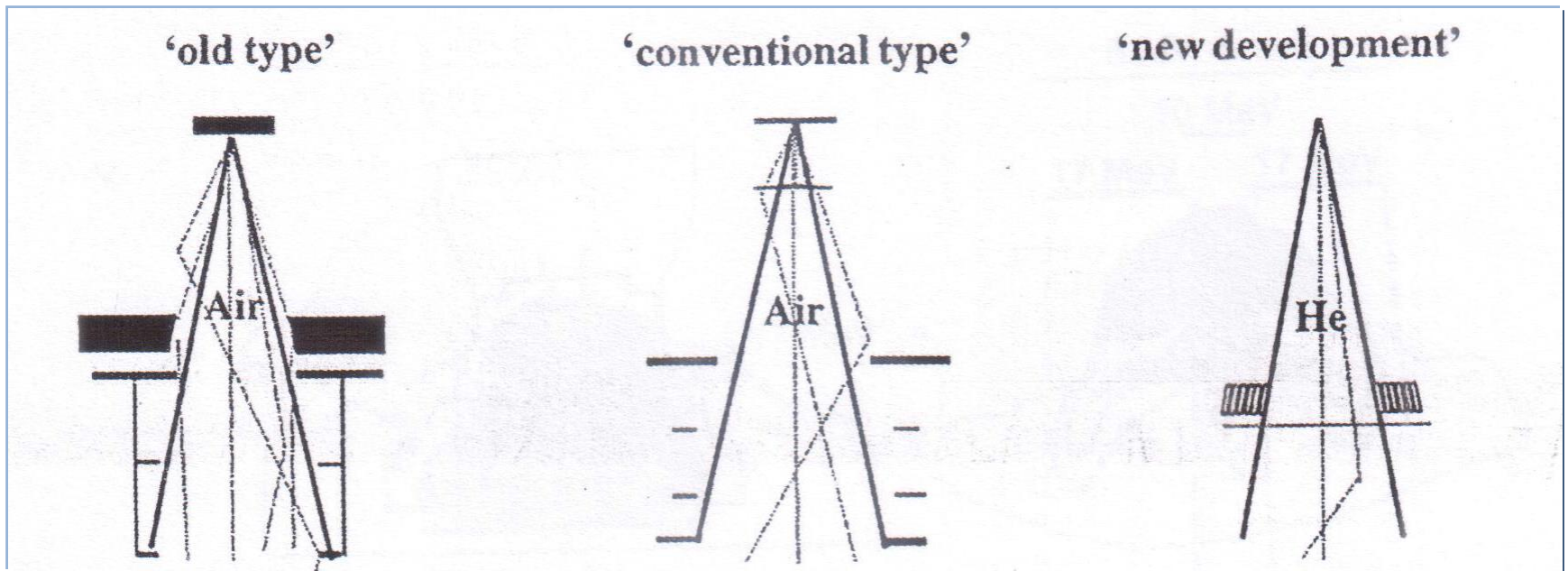


Figure 3.9. Different types of collimating and scattering systems in use for electron beams. The “old type” uses one scattering foil, often of different thickness and material for various energies, and a tube collimator which must be set close to the patient. The “conventional type” uses two scattering foils. Each of them could be changed, and they are optimized for different energies. The applicator close to the patient traps large-angle electrons. The “new development” uses a scanning beam and a leaf collimator for shaping both electron and photon beams. Air is replaced with helium to reduce the scattering material to a minimum. SSD = 100 cm is used both for photon and electron beams, which simplifies patient set-up. (Zackrisson and Karlsson, 1996.)

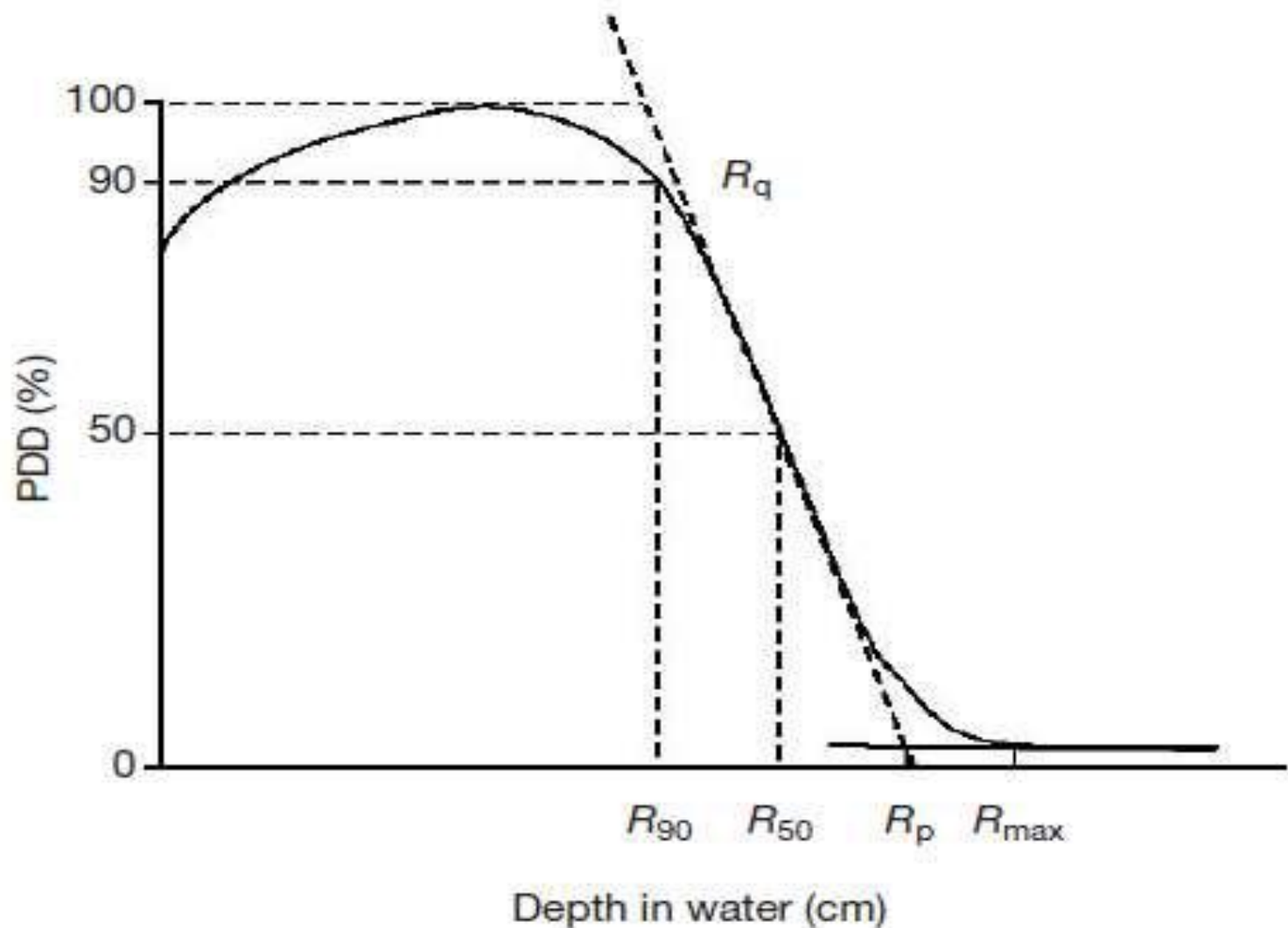
ICRU 71- Prescribing, Recording, and Reporting Electron Beam Therapy

This report is described under following headings:

- Treatment volumes – same as ICRU 50 and 62.
- Characteristics of the clinical electron beams,
- Physical and dosimetric data
- Reporting electron beam therapy; ICRU Reference Point which should always be selected at the centre (or in the central part) of the PTV and clearly indicated.
- Specific recommendations for reporting are provided for non-reference conditions: small and irregularly shaped beams, oblique beam incidence and presence of heterogeneities
- Quality assurance

Basic Characteristics of Clinical Electron Beams

Typical electron beam PDD curve illustrating the definition of R_q , R_p , R_{max} , R_{50}

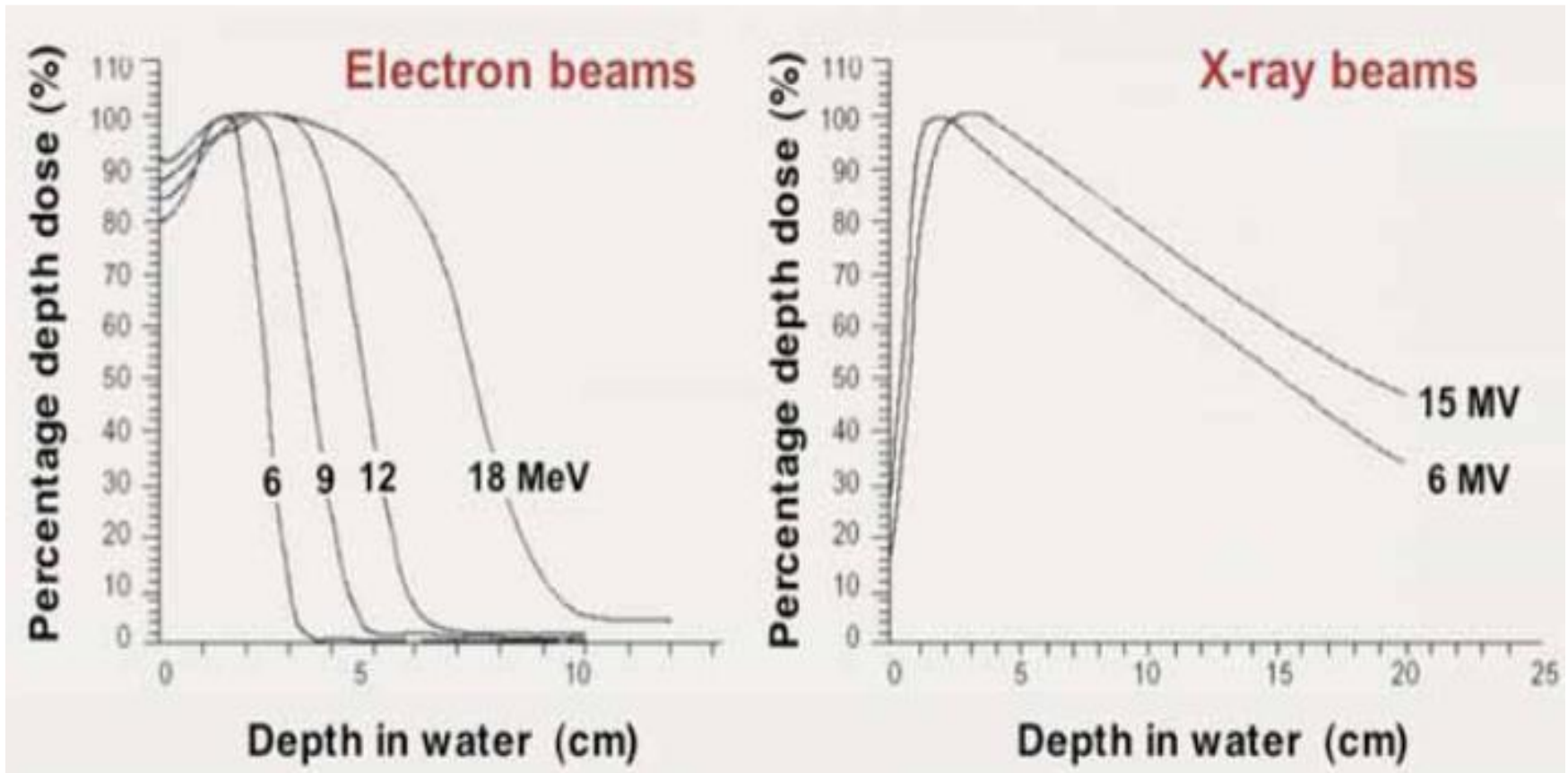


DEFINITIONS

The maximum range R_{max} (cm or g/cm²) is defined as the depth at which extrapolation of the tail of the central axis depth dose curve meets the bremsstrahlung background.

- The practical range R_p (cm or g/cm²) is defined as the depth at which the tangent plotted through the steepest section of the electron depth dose curve intersects with the extrapolation line of the background due to bremsstrahlung.
- R_{50} are defined as, the depth at which the absorbed dose falls to 50% of the maximum dose on the electron PDD curve.

Depth Dose Curve: e & x



Field size = $10 \times 10 \text{ cm}^2$

SSD = 100 cm

Depth Dose Curve

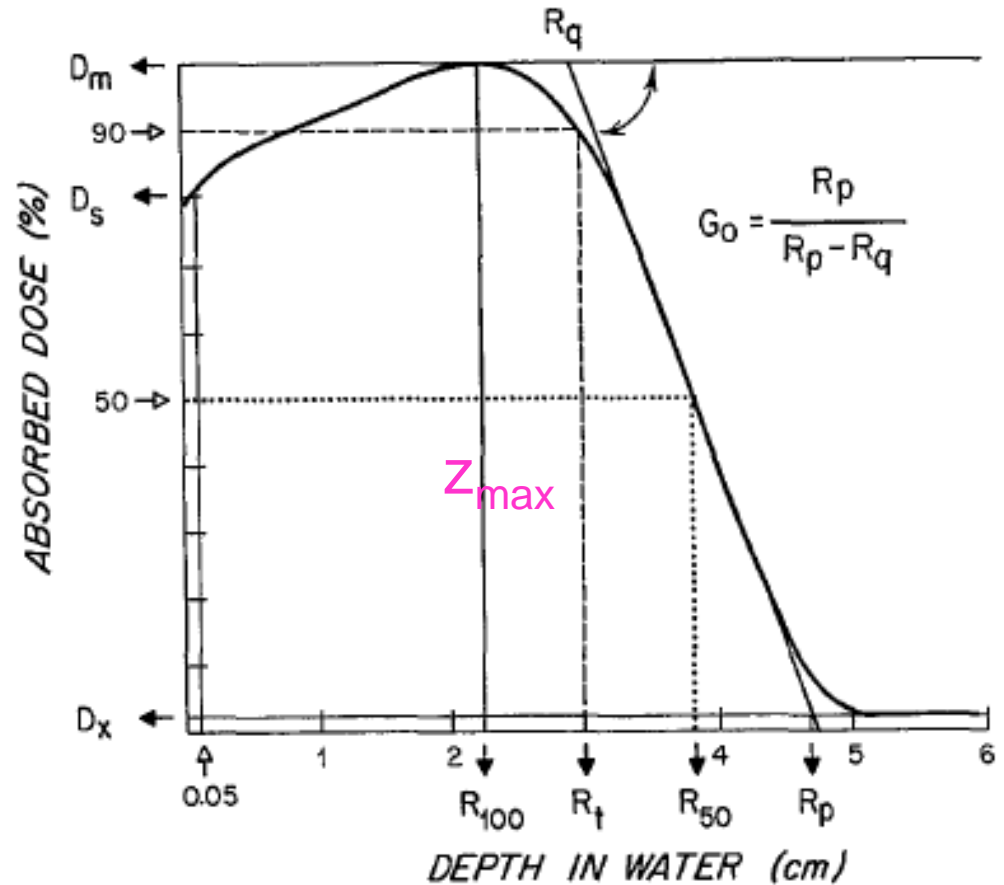
D_s : surface dose
(80 - 100%)

D_m : maximum dose
(depth z_{\max})

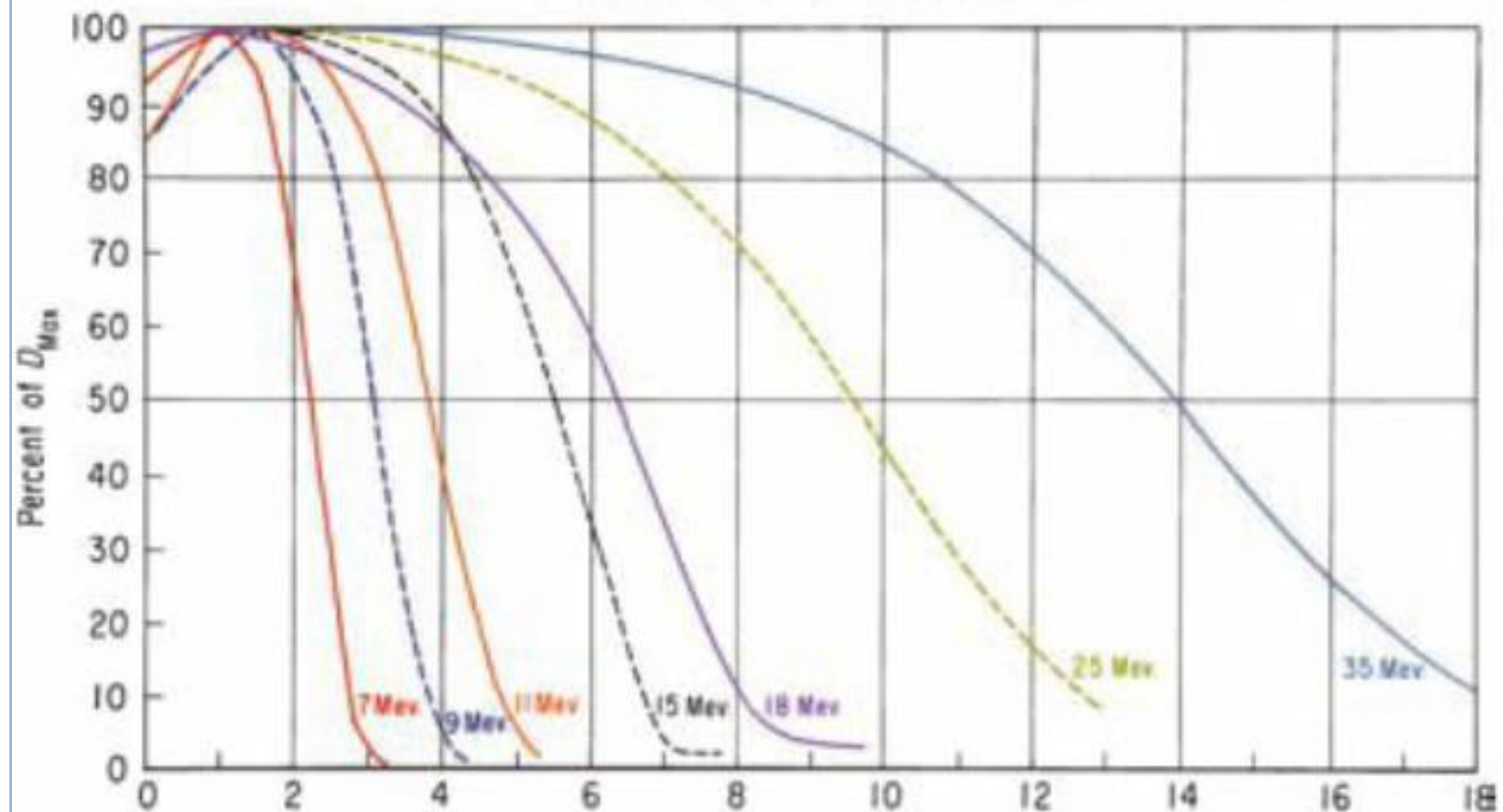
R_t (R_{90}): therapeutic
range

D_x : x-ray tail (1- 4%)

G_0 : dose gradient

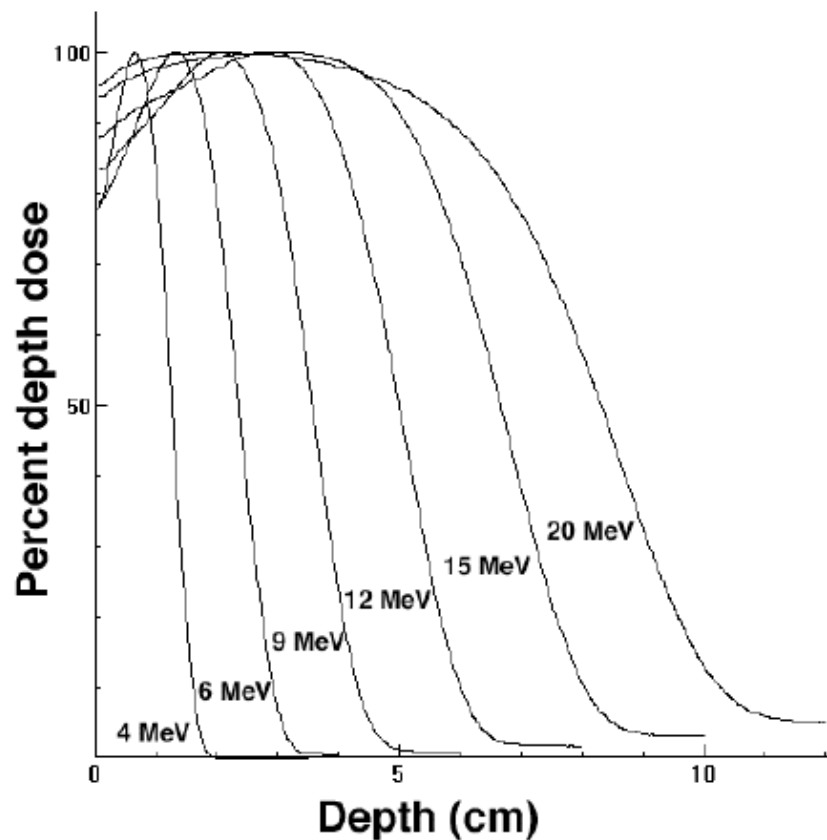


Electron beam central axis depth dose



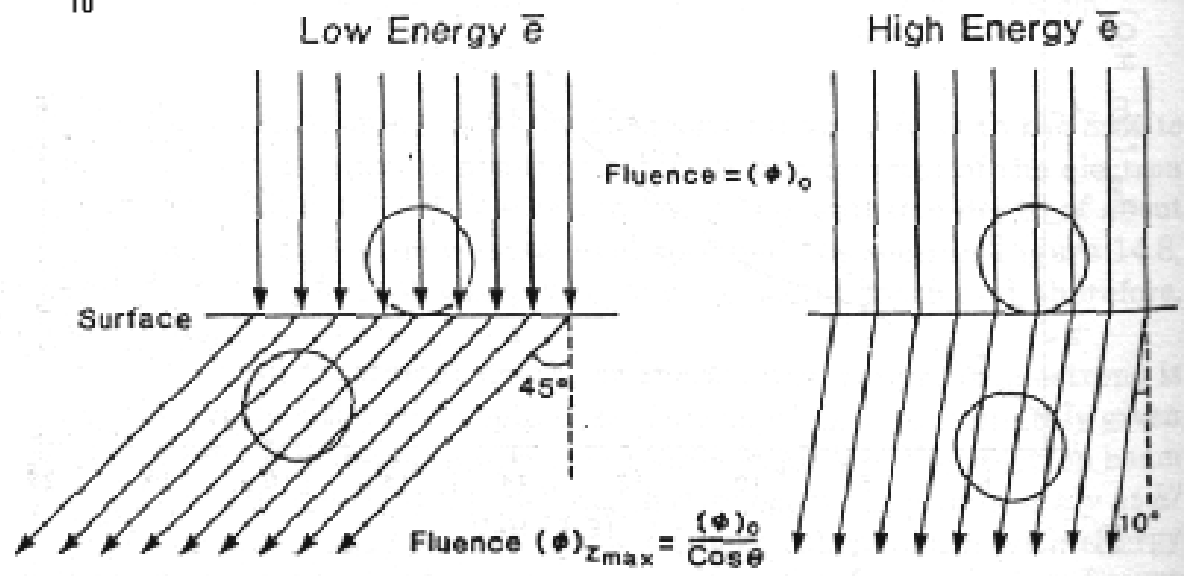
The Percentage Depth dose increases as the energy increases.

However, unlike the photon beams, the percent surface dose for electrons increases with energy.



- Low energy electrons scatter more easily and through larger angles,
- Causes dose to build up more rapidly and over a shorter distance
- Ratio, D_s/D_m , is lower for low energy electrons

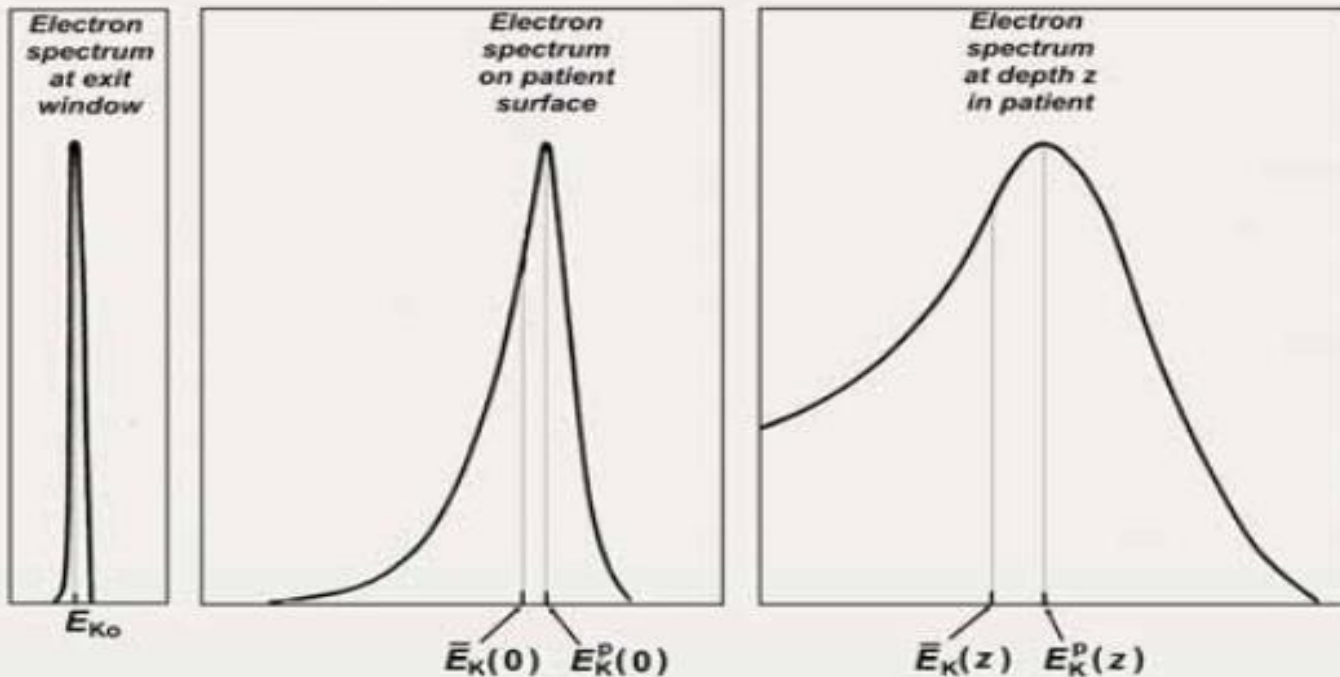
D_s increases with increasing electron energy



Electron Beam Spectrum



The spectrum of the electron beam depends on the point of measurement in the beam.



Energy Specification

- **Almost monoenergetic at exit window of the accelerator**
- **A spectrum of energies at the phantom surface**
- **Usually characterized by the energy at the phantom surface**

Energy Specification - contd.

$$(E_p)_0 = C_1 + C_2 R_p + C_3 R_p^2$$

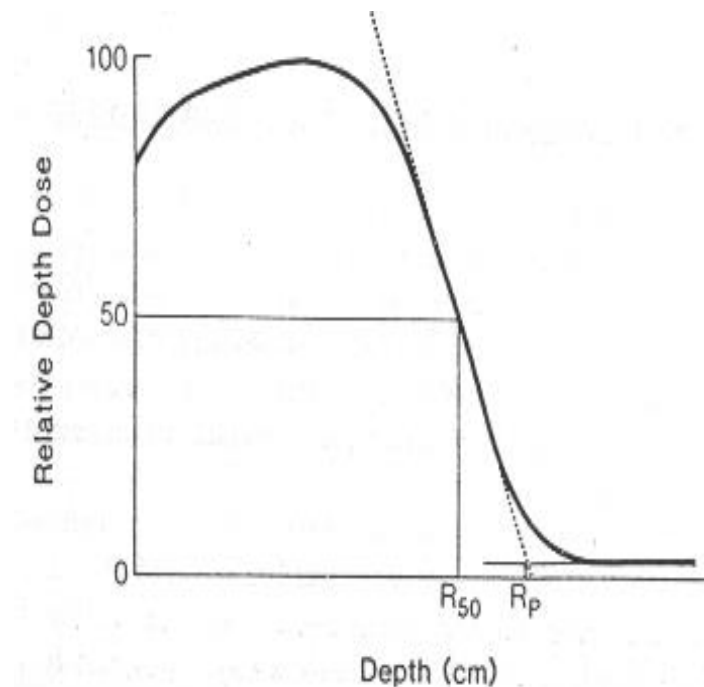
$(E_p)_0$ most probable energy at
the phantom surface (MeV)

R_p the practical range (cm)

For water,

$$C_1 = 0.22 \text{ MeV}, \quad C_2 = 1.98 \text{ MeV cm}^{-1},$$

$$C_3 = 0.0025 \text{ MeV cm}^{-2}$$



Energy Specification - Contd.

$$\overline{E}_0 = C_4 R_{50}$$

for water, $C_4 = 2.33 \text{ MeV}$

$$\overline{E}_z = \overline{E}_0 \left(1 - \frac{z}{R_p}\right)$$

The most probable energy and the mean energy of the spectrum decreases linearly with depth

It is important in dosimetry to know the mean electron energy at the point of interest.

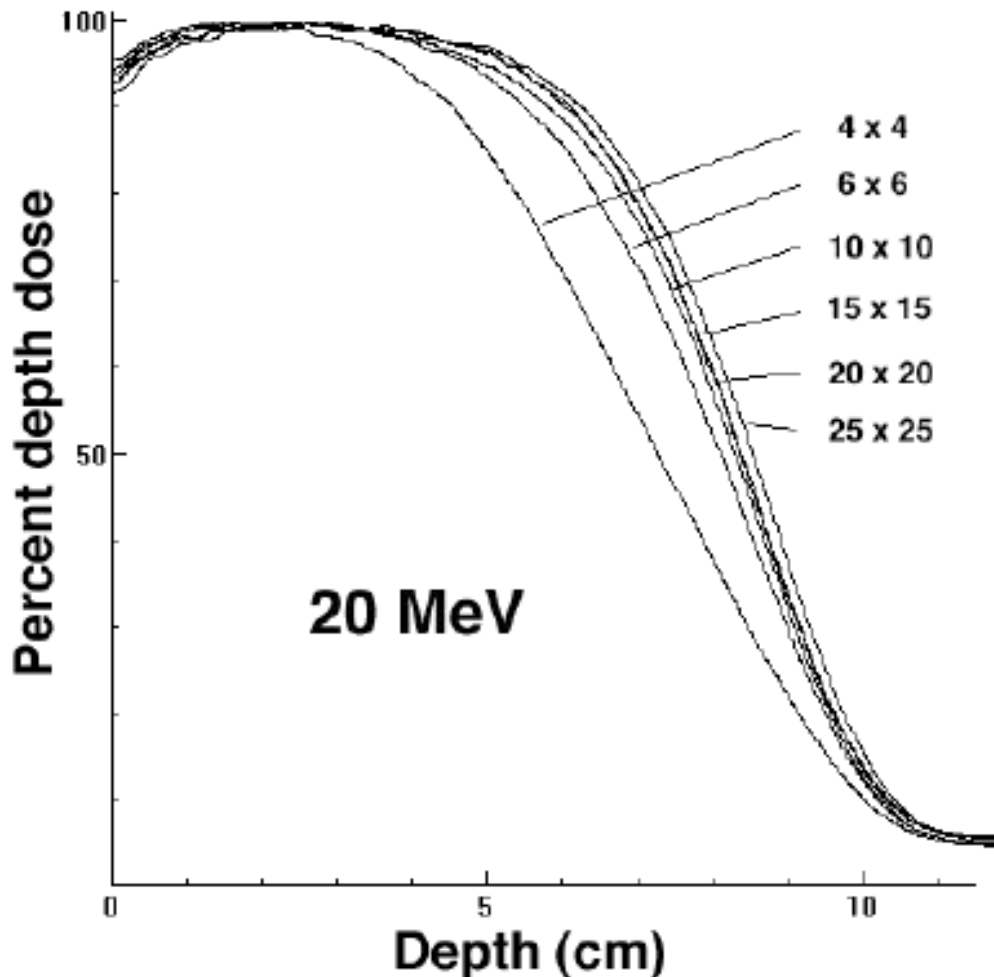
Depth dose Parameters

Typical electron beam depth dose parameters that should be measured for each clinical electron beam

Energy (MeV)	R_{90} (cm)	R_{80} (cm)	R_{50} (cm)	R_p (cm)	$\bar{E}(0)$ (MeV)	Surface dose %
6	1.7	1.8	2.2	2.9	5.6	81
8	2.4	2.6	3.0	4.0	7.2	83
10	3.1	3.3	3.9	4.8	9.2	86
12	3.7	4.1	4.8	6.0	11.3	90
15	4.7	5.2	6.1	7.5	14.0	92
18	5.5	5.9	7.3	9.1	17.4	96

P
D
D
C
U
R
V
E

PDD Vs Field/Applicator Size



For a given energy

- PDD depends on field shape & size
- In case, field length/diameter (FS) $> R_p$, PDD is independent of FS.
- In case of FS $< R_p$, PDD varies with FS
(loss of lateral electron equilibrium at the Central Axis)

Isodose Distribution

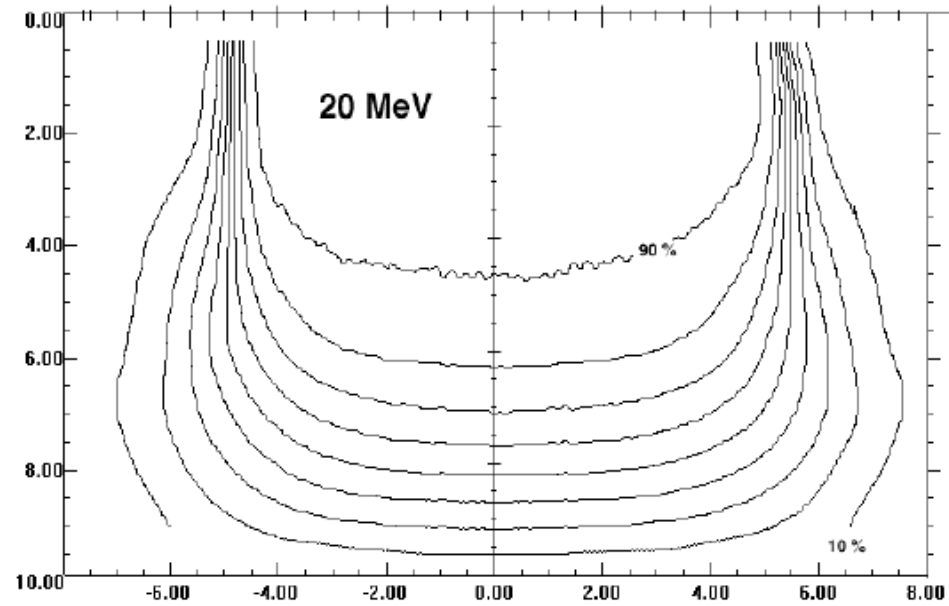
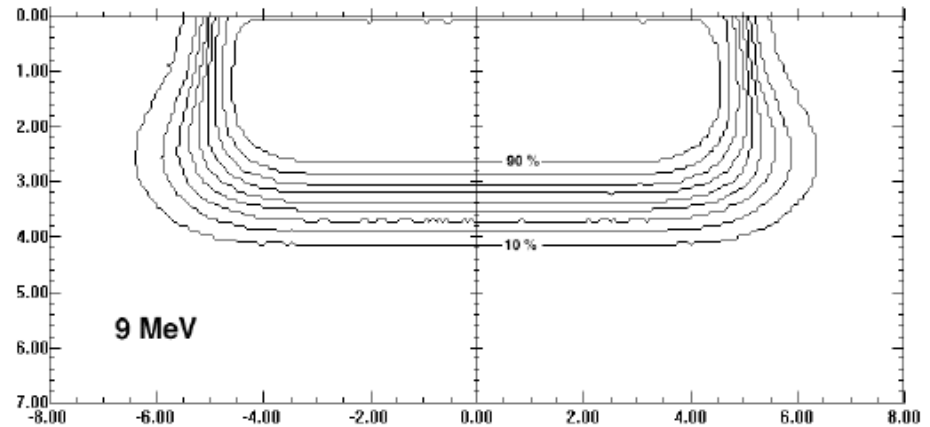
Bulging & Constriction

Spread of isodose line (IDL) below surface depends on

- beam energy, field size and collimation

Bulging out of the low value (<20%) isodose line

Lateral constriction of higher value (>80%) IDL



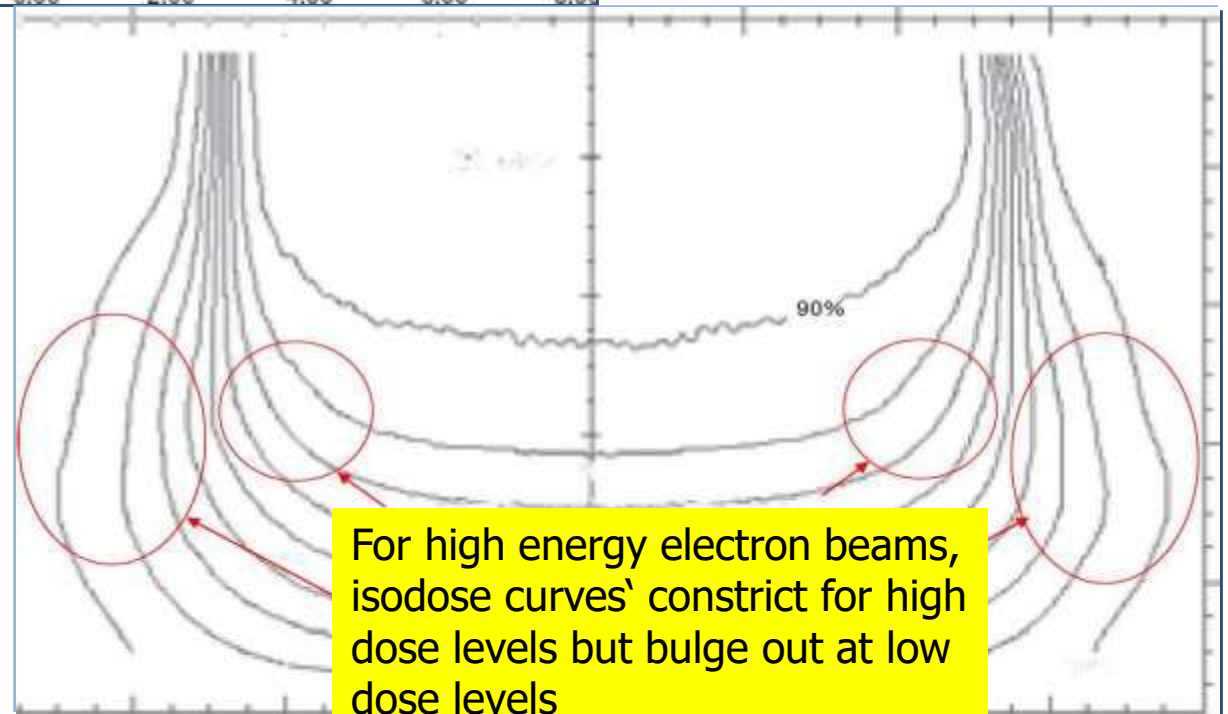
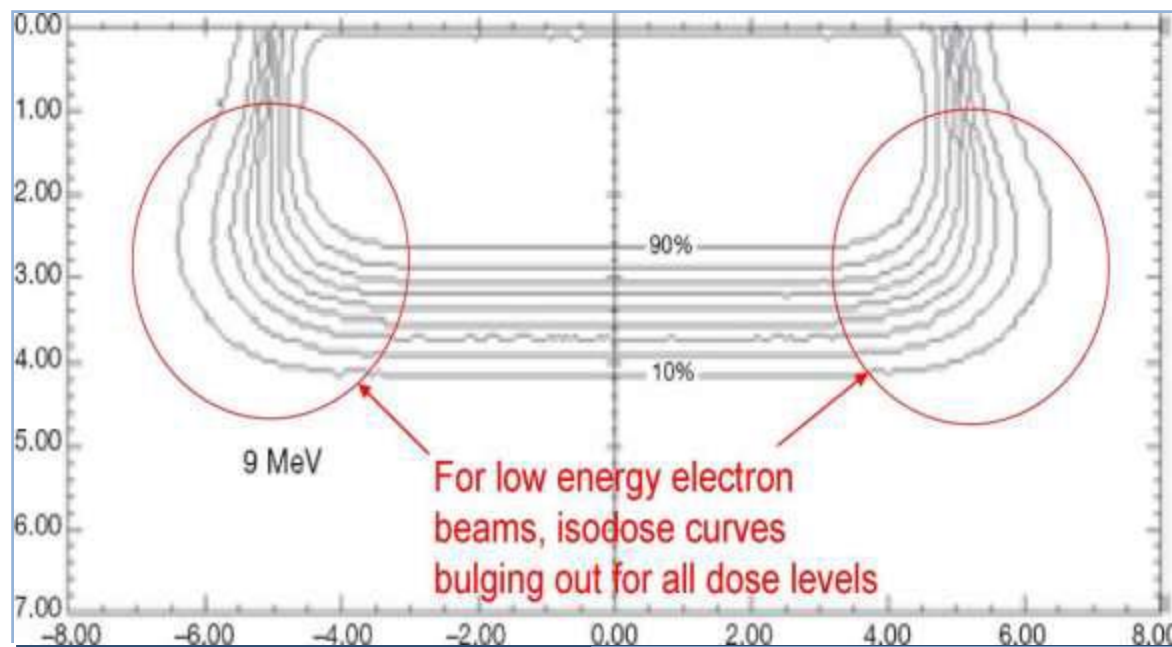
Field size = 10x10 cm²; SSD = 100 cm

Factor Based Dose Calculation Methods

Factors affecting dosimetry

- **Energy of incident electron:** Both PDD & surface dose increases with incident electron energy, but in photon beam therapy surface dose remain unchanged
- **Field size:** By decreasing field size due to loss of side scatter equilibrium the R90 (Therapeutic range) comes closer to surface with relative increase in surface dose
- **SSD:** R90 goes few mm deeper with increase in SSD, but the variation of depth dose is not significant due to poor penetrability of electron beam
- Factors resulting in poor dosimetry are: Beam Obliquity, Internal tissue Inhomogeneity and Surface irregularity.

The ideal irradiation condition for the electron beam is to be incident normal to a flat surface with underlying homogenous soft tissues, which is similar to water phantom.



MU Calculation: Standard Set up

Nominal SSD = 100 cm;
Incidence - perpendicular

Air gap = 5 cm

Dose rate to tumour at depth z along central axis (D_T)

$$D_T = \frac{K(E, 100, 5, z_{\max}, 10 \times 10) * OF(e, 100, 5, C_s) * PDD(e, 100, 5, z, C_s)}{100} \text{ cGy/MU}$$

Where,

$K(E, 100, 5, z_{\max}, 10 \times 10)$ = Reference dose rate/MU

$OF(E, 100, 5, C_s)$ = output factor for the FS C_s

$PDD(E, 100, 5, z, C_s)$ = PDD at the depth z and FS C_s

$$MU = [\text{Dose per fraction (cGy)} / D_T]$$

OUTPUT FACTOR (OF)

OF for the specific electron beam energy E , Applicator size C_s , Insert size I_s and for a given SSD (100 cm)

$$OF(E, C_s, I_s) = \left(\frac{\frac{D_{\max}}{\text{MU}}(E, C_s, I_s)}{\frac{D_{\max}}{\text{MU}}(E, C_0, I_0)} \right)_{\text{SSD}=\text{const}}$$

C_0 = Reference FS = 10x10 cm²

I_0 = reference insert size

$$OF(E, C_s, I_s) = \frac{\frac{D_{\max}}{\text{MU}}(E, C_s, I_0)}{\frac{D_{\max}}{\text{MU}}(E, C_0, I_0)} \times \frac{\frac{D_{\max}}{\text{MU}}(E, C_s, I_s)}{\frac{D_{\max}}{\text{MU}}(E, C_s, I_0)} = \text{CCF} \times \text{ICF}$$

CCF = Applicator OF

ICF = Insert OF

PDD & OF for Rectangular Fields

Hogstrom square root method

$$\text{OF} (x, y) = [\text{OF} (x, x) * \text{OF} (y, y)]^{1/2}$$

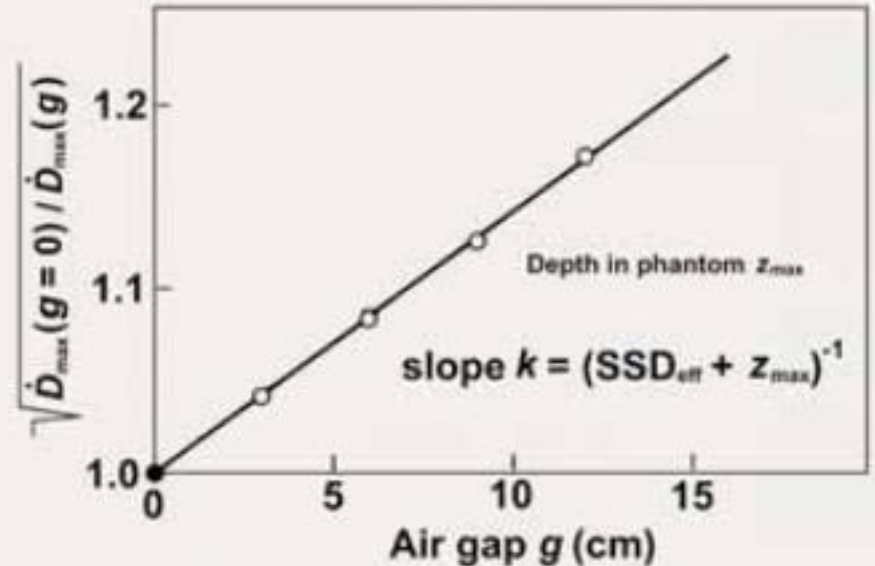
$$\text{PDD} (x, y) = [\text{PDD} (x, x) * \text{PDD} (y, y)]^{1/2}$$

In case of OF it is necessary that photon collimator should have a constant opening i.e. collimator scatter is neglected in this method

Effective SSD (SSD_{eff})

Required to correct dose rate at z_{max} in patients for variations in air gaps (g) between patient surface and nominal SSD

Function of FS and energy



$$\frac{\dot{D}_{\text{max}}(g=0)}{\dot{D}_{\text{max}}(g)} = \left\{ \frac{SSD_{\text{eff}} + z_{\text{max}} + g}{SSD_{\text{eff}} + z_{\text{max}}} \right\}^2$$

The measured slope of the linear plot is:

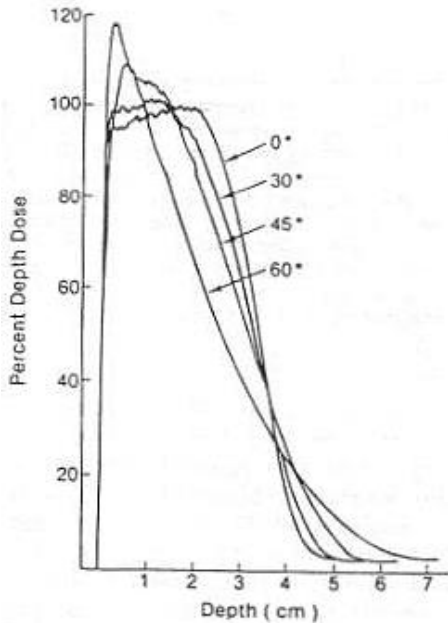
$$k = \frac{1}{SSD_{\text{eff}} + z_{\text{max}}}$$

The effective SSD is then calculated from:

$$SSD_{\text{eff}} = \frac{1}{k} + z_{\text{max}}$$

Surface Irregularity: Air Gap & Obliquity

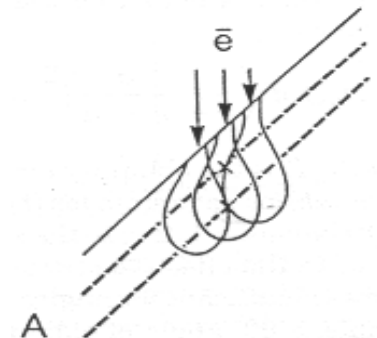
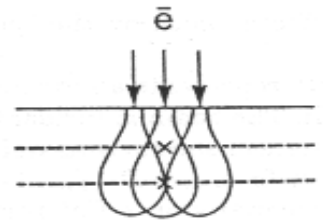
Air Gap: beam divergence -
Decrease in absolute dose at all depths



- Increase in side scatter at z_{\max}
- z_{\max} shifts towards the surface
- Penetration depth decrease

Obliquely incident beam

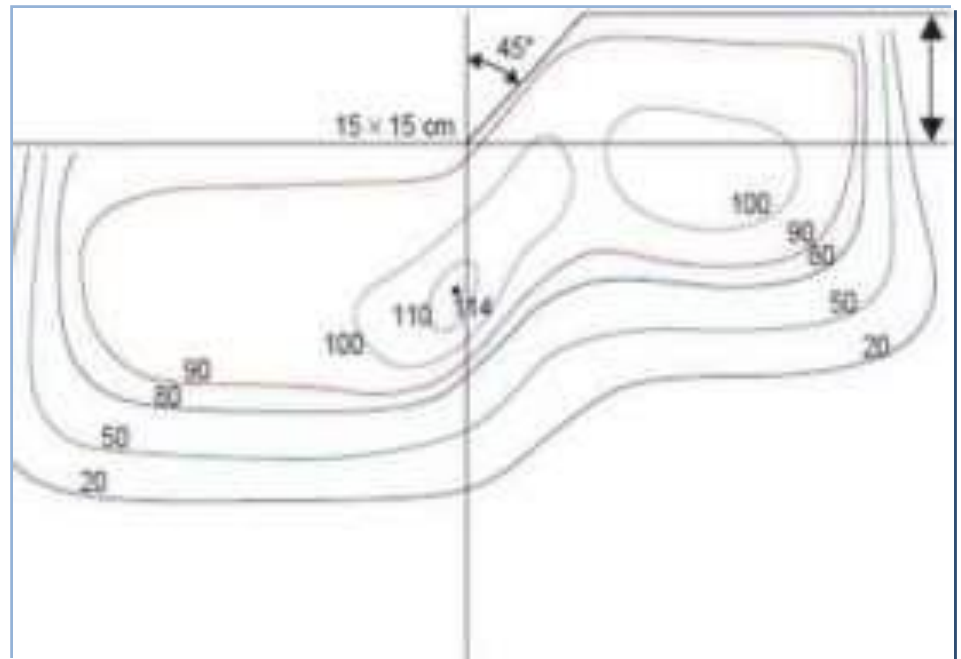
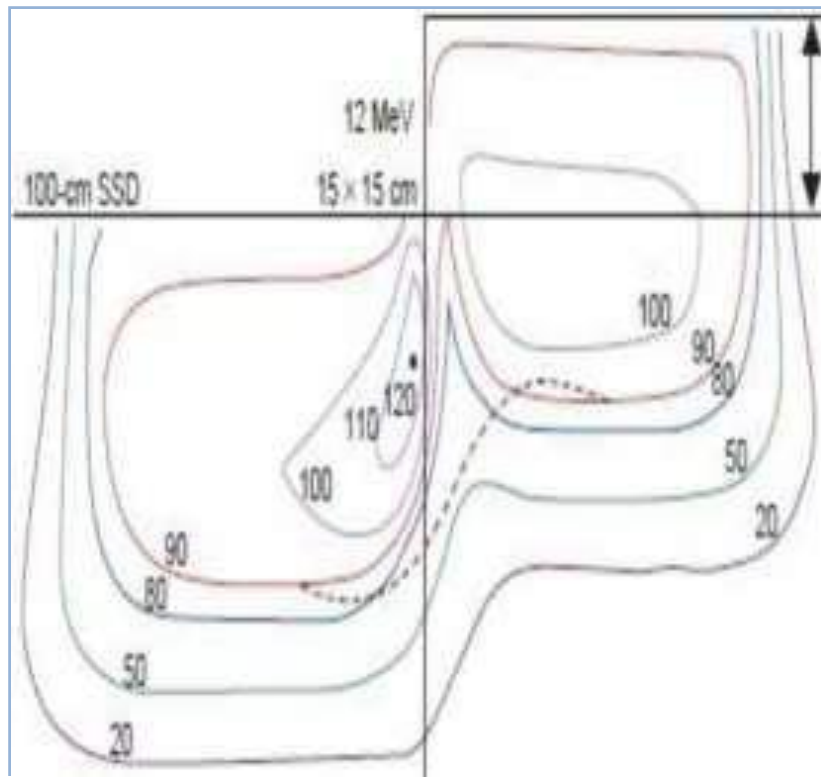
- The point at the greater depth receives less scatter
- The point at the shallow depth receives greater side scatter from the adjacent pencil beam



- The curved contour alters the depth dose distribution.
- Ideal situation would be a flat surface. The more oblique, the more is the surface dose. More x-ray contamination.
- Alteration in the presence of inhomogenous tissues, bone, lung, air cavities.

Effect of Surface Irregularities

- Irregular skin surfaces are encountered primarily during treatment of nose, eye, ear, ear canal and in groin area
- Surgical excision creates treatment area with abrupt changes in surface of the body
- The surface irregularities should be corrected using bolus or tissue compensator with tapered edges

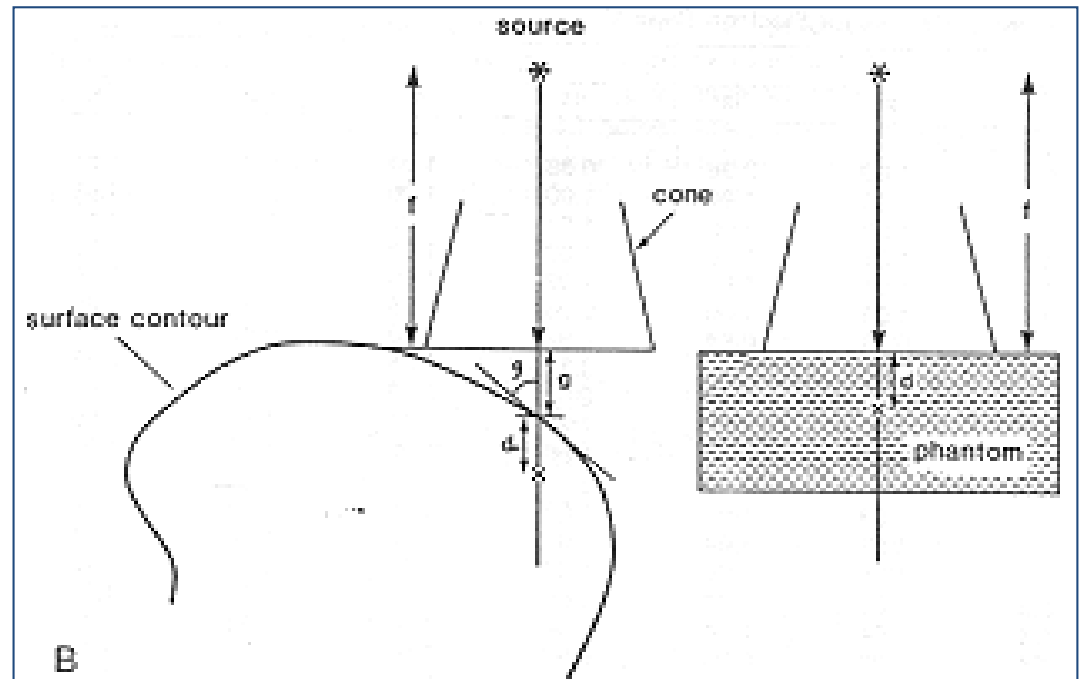


Dose Calculation: Surface Irregularity

Clinical set up for
Chest Wall
irradiation

Uneven air gap

Beam obliquity



$$D(\text{SSD}_{\text{eff}} + g, z) = D_0(\text{SSD}_{\text{eff}}, z) \left[\frac{(\text{SSD}_{\text{eff}} + z)}{(\text{SSD}_{\text{eff}} + g + z)} \right]^2 \text{BOF}(\theta, z)$$

$D_0(\text{SSD}_{\text{eff}}, z)$ = Dose at depth z for a beam incident normally on a flat surface phantom

$\text{BOF}(\theta, z)$ = beam obliquity factor which accounts for change in depth dose at z in phantom for a given angle of obliquity θ but same SSD_{eff} as for $\theta = 0$

Tissue Inhomogeneities

- e-beam dose distribution is significantly altered due to presence of inhomogeneities such as lung bone and air cavities
- It is difficult to determine dose distribution within or around small inhomogeneities because of enhanced scattering effects
- For large and uniform slabs, dose at a point beyond the inhomogeneity is determined by calculating effective depth z_{eff} (*CET Method*)

Tissue Inhomogeneity: Dose calculation

$$z_{eff} = z - t(1 - CET)$$

z = actual depth of the point of interest

t = thickness of the inhomogeneity

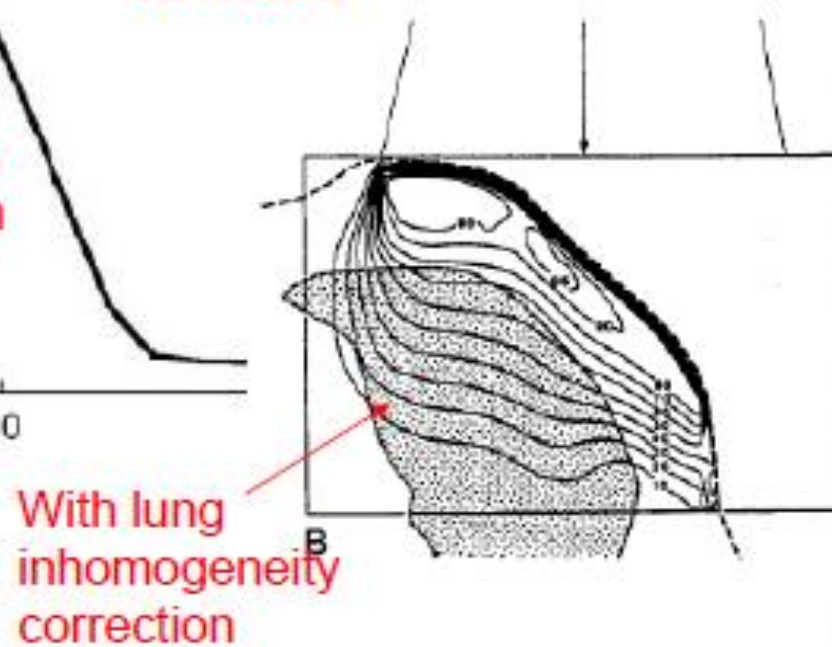
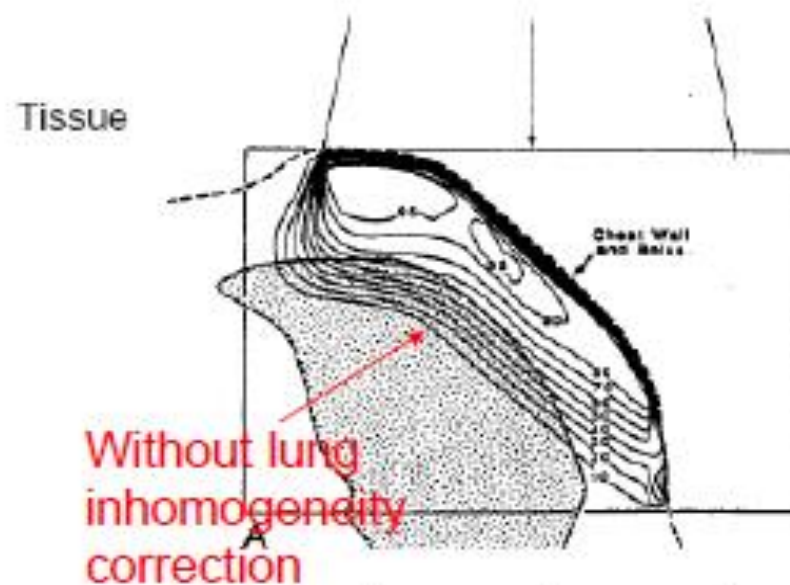
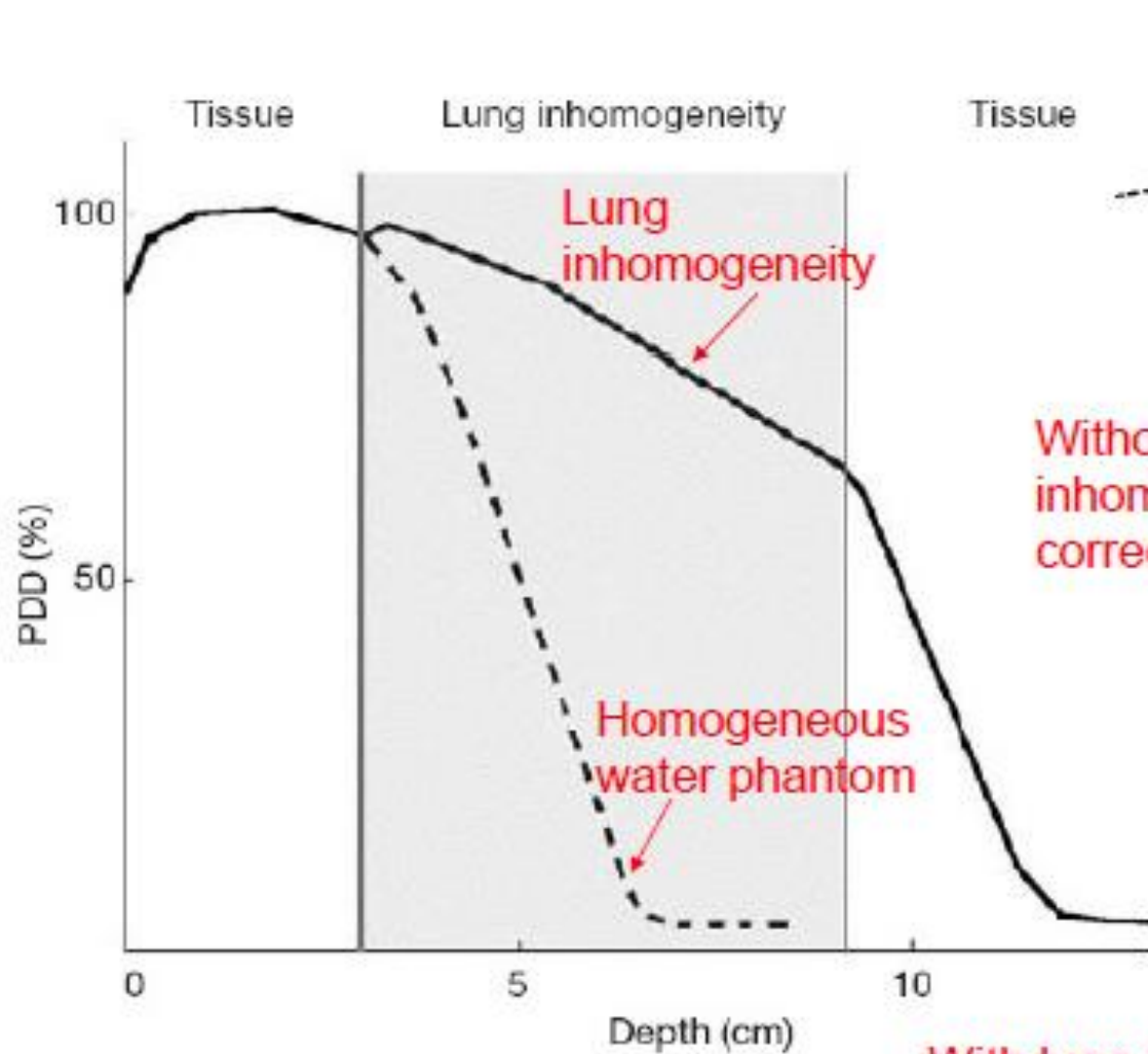
CET = coefficient of equivalent thickness

The electron density (or CET) of an inhomogeneity is essentially equivalent to its mass density

For calculation of dose rate to tumour,

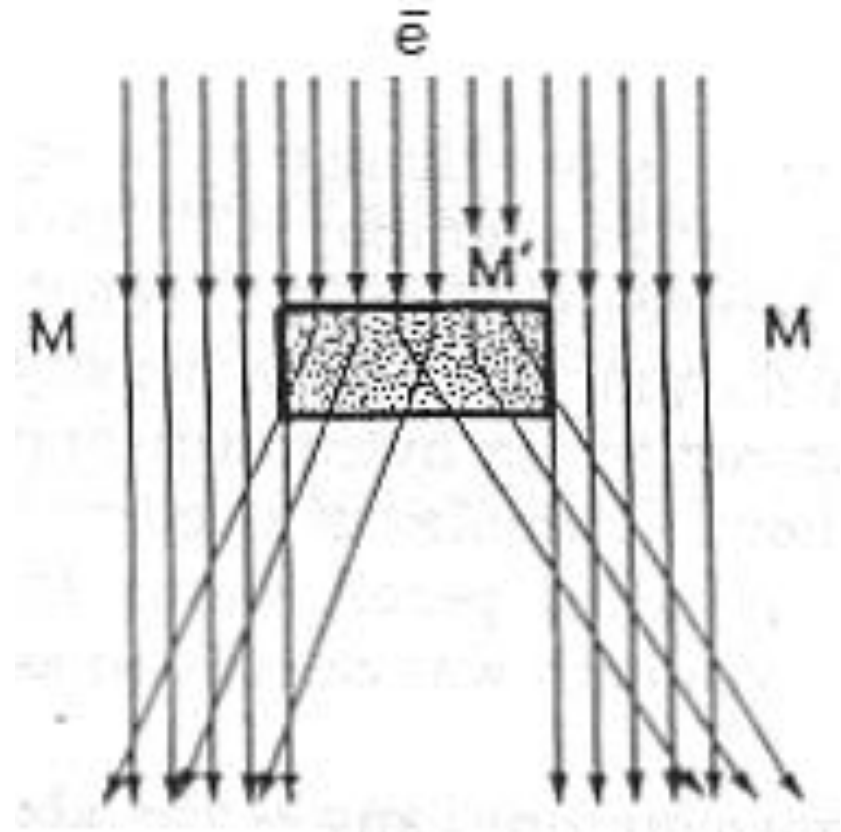
PDD is taken for z_{eff}

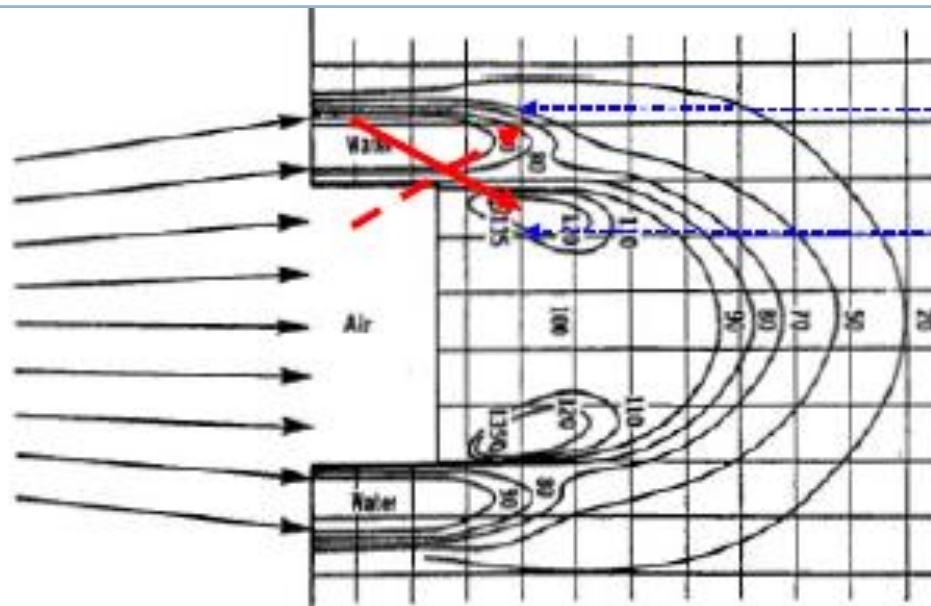
ISL correction $[(SSD_{eff} + z_{eff}) / (SSD_{eff} + z)]^2$ is also applied to account for actual distance of the point from VS.



Small Inhomogeneities

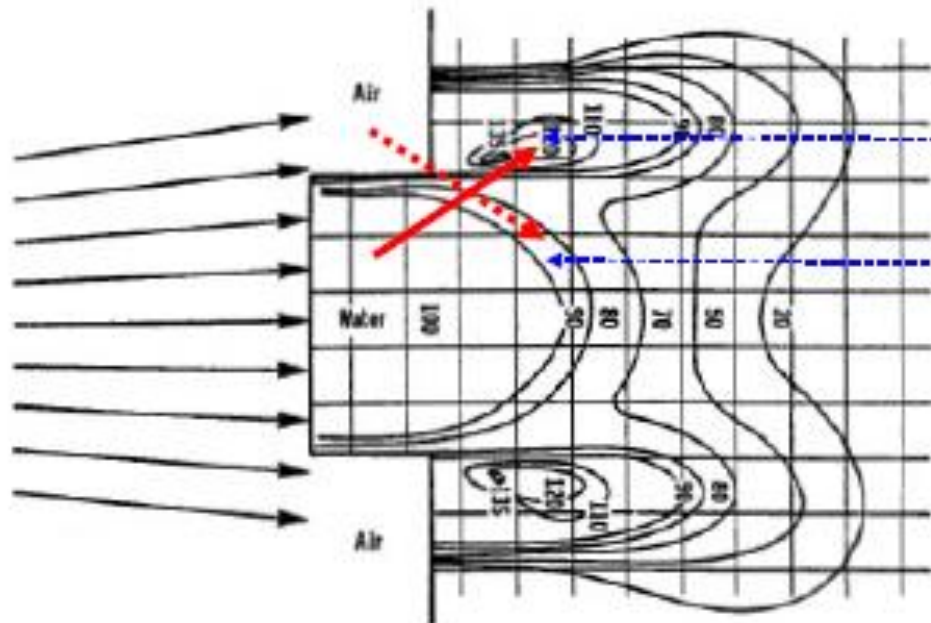
- A decrease in the electron fluence behind the slab
- Increase the dose in the medium M
- Pohlit & Manegold method is used
- A material M' of a higher mass scattering power





Low dose due to
loss of scatter

High dose due to
extra scatter



High dose due to
extra scatter

Low dose due to
loss of scatter

Treatment Planning Calculations

The **early methods in electron treatment planning** accounted for tissue inhomogeneities by scaling the percentage depth doses using the CET approximation which provides useful parametrization of the electron depth dose curve but has nothing to do with the physics of electron transport.

The **Fermi-Eyges multiple scattering theory** considers a broad electron beam as being made up of many individual pencil beams that spread out laterally in tissue following a Gaussian function.

Treatment Planning Calculations

– Pencil Beam Algorithms

The **pencil beam algorithm** can account for tissue inhomogeneities, patient curvature and irregular field shape.

Rudimentary pencil beam algorithms deal with lateral dispersion but ignore angular dispersion and backscattering from tissue interfaces.

Despite applying both the stopping powers and the scattering powers, the modern refined pencil beam, multiple scattering algorithms generally fail to provide accurate dose distributions for most general clinical conditions.

Treatment Planning Calculations – Monte Carlo

The most accurate and reliable way to calculate electron beam dose distributions is through Monte Carlo techniques.

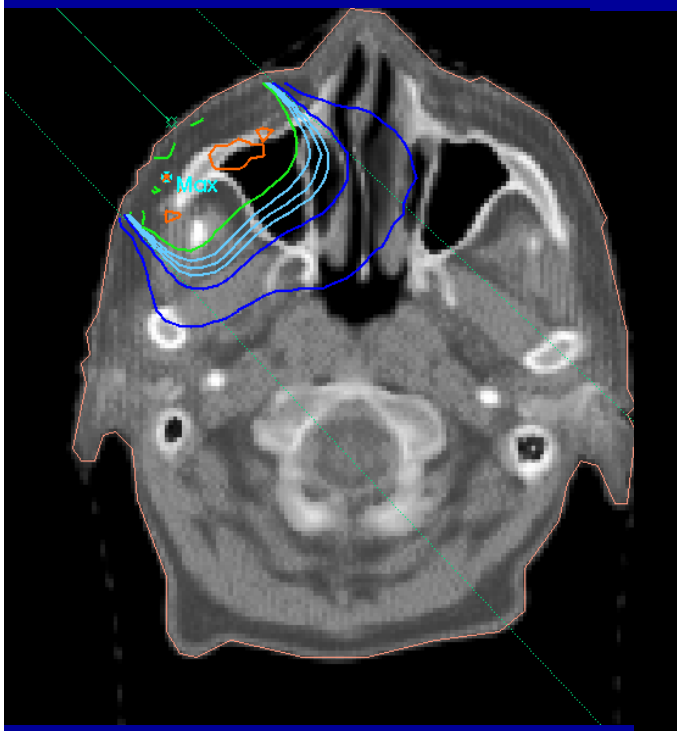
The main drawback of the current Monte Carlo approach to treatment planning is the relatively long computation time.

With increased computing speed and decreasing hardware cost, it is expected that Monte Carlo based electron dose calculation algorithms will soon become available for routine electron beam treatment planning.

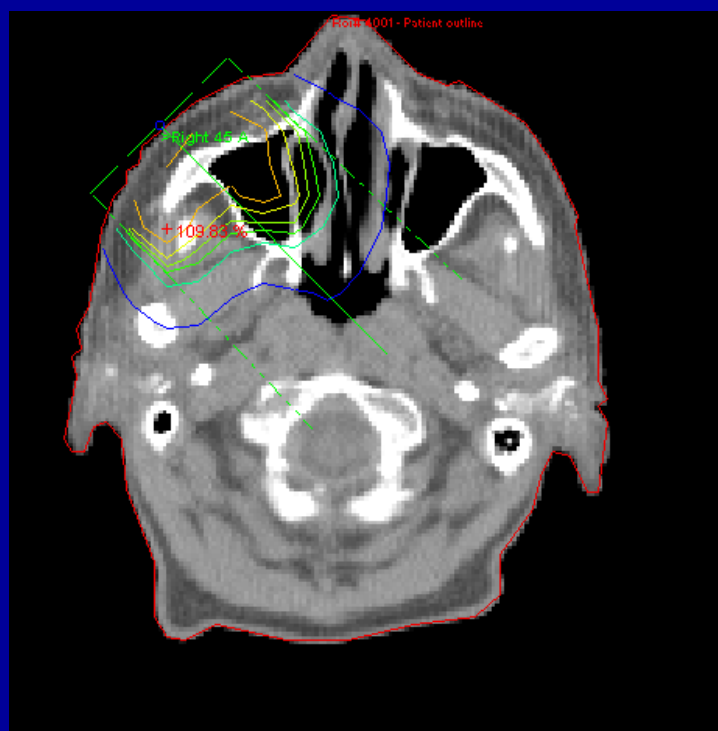
Comparison of PB & MC Calculated Dose Distributions

Comparison 10 MeV electron PB <-> MC

TMS pencil beam



OTP/DM electron MC



Electron Treatment Planning

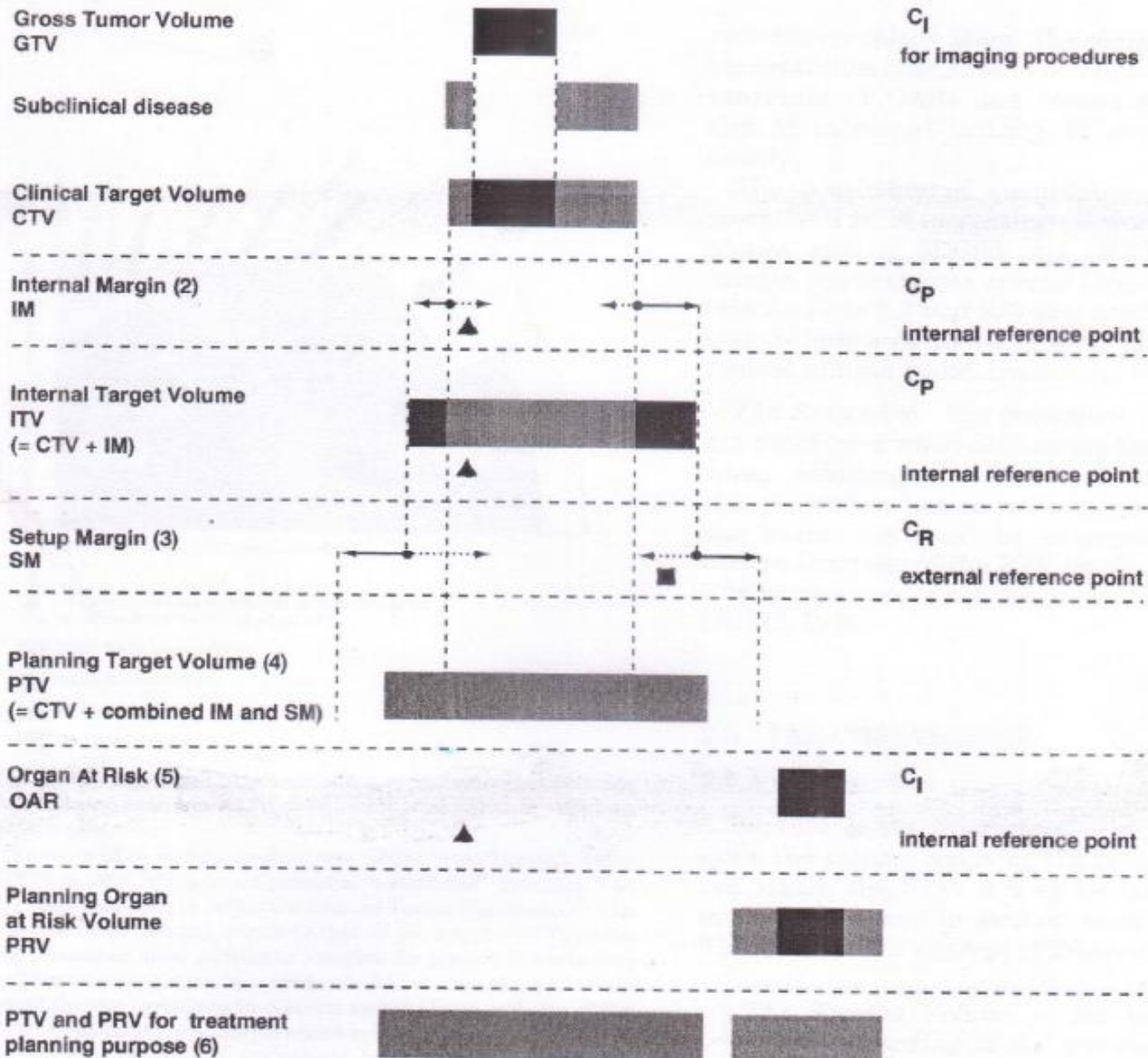
- The first step in the initiation of electron therapy is to determine accurately the target to be treated using diagnostic & operative data.
- Choice of beam energy & field size; Correction of air gap/beam obliquity/ tissue inhomogeneity/ problems of adjacent fields should be taken care of.
- The electron energy for treatment should be selected such that the depth of 90% isodose line covers the deepest portion of the region to be treated in addition to an approximate 5mm additional depth beyond treatment region & considering clinically acceptable dose to the critical organ

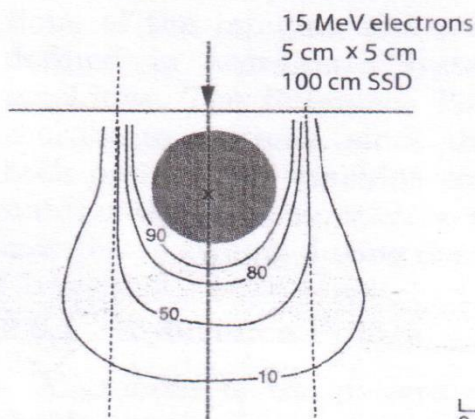
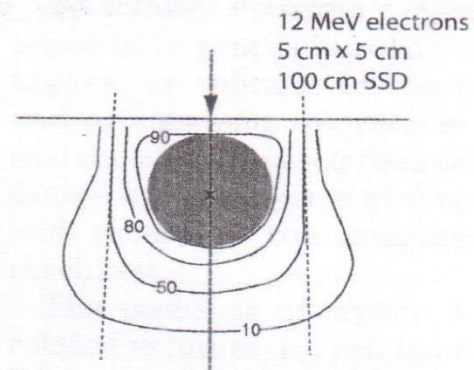
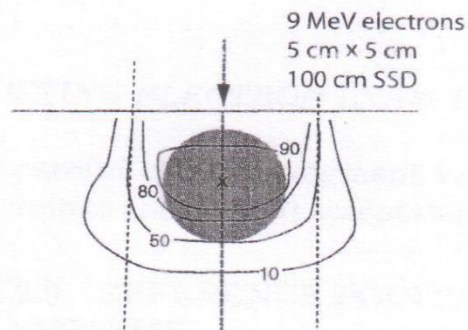
- Electron beam applicators or cones are usually used to collimate the beam, and are attached to the treatment unit head.
- After passing through the scattering foil, the electrons scatter sufficiently with the other components of the accelerator head, and in the air between the exit window and the patient, which create a clinically unacceptable penumbra.
- Electron applicators are used for beam collimation & to avoid penumbra.



ICRU 71 Defined Volumes

- Generally same as for photon beams in ICRU 50 and 62.
- These include GTV, CTV, PTV, Treated Volume (TV), Irradiated Volume, Organ at Risk (OAR) and Planning organ at risk volume (PORV).
- The definitions of each of these is the same as in ICRU 50 and 62.
- Additional feature important here is the penumbra of the beam which may show lateral bulging at lower isodoses. **This penumbra is not considered while marking the PTV.**
- Beam sizes are defined by 50% isodose line.





0 cm 5

(a) 9-MeV electron beam, 5 cm x 5 cm beam size (the beam size is defined on the 50-percent isodose at the depth of the peak dose), ICRU Reference Point (marked "x") at depth 2.1 cm. The energy is too low and the Treated Volume (*i.e.*, the volume encompassed by the 90-percent isodose surface) does not encompass the whole PTV. This irradiation does not comply with the treatment prescription. The CI, in a strict sense as defined in the text, cannot be calculated.

(b) 12-MeV electron beam, 5 cm x 5 cm beam size, ICRU Reference Point (marked "x") at depth 2.6 cm. The Treated Volume totally encompasses and matches as closely as possible the PTV. The CI is 1.2, *i.e.*, close to unity.

(c) 15-MeV electron beam, 5 cm x 5 cm beam size, ICRU Reference Point (marked "x") at depth 2.8 cm. The Treated Volume encompasses the PTV but is much larger, and normal tissues are unnecessarily irradiated. The CI is 1.8.

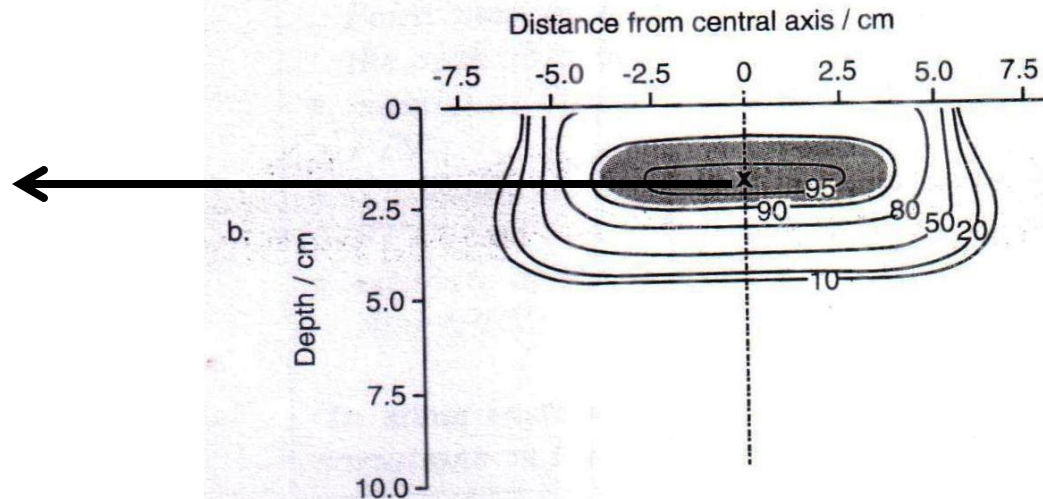
ICRU 71 Defined Volumes

- Conformity Index is defined as the ratio of the treated volume to the PTV (TV/PTV)
- Irradiated volume: that volume getting significant dose w.r.t normal tissue tolerance.
- **ICRU Suggested colour coding during contouring:**
 - GTV – **DARK RED**
 - CTV – **LIGHT RED**
 - PTV – **LIGHT BLUE**
 - OAR – **DARK GREEN**
 - PORV – **LIGHT GREEN**
 - Landmark / Internal or external reference points - **BLACK**

- ICRU Reference Point is selected by following criteria:
- Dose at the point
 1. should be clinically relevant
 2. Accurately measureable
 3. Easy to define in a clear and unambiguous way
 4. No steep dose gradient

Therefore the ICRU Ref Pt. should be in the central part of PTV, on the beam axis at the level of peak dose in case of single beam therapy.

**ICRU
Reference
point**



ICRU Dose Level Reporting criteria

In summary, at Level 1, the following dose values should be reported:

- *peak absorbed dose to water;*
- *location of, and dose value at, the ICRU Reference Point (the ICRU Reference Point may or may not be at the Level of the peak absorbed dose);*
- *maximum dose on the beam axis, in the PTV*;*
- *minimum dose on the beam axis, in the PTV*; and*
- *estimate of the dose(s) to the Organ(s) at Risk (PRV).*

**In some instances, at this level, only dose variations on the beam axis may be available.*

In summary, at Level 2 (or 3), the following dose values should be reported:

- *peak absorbed dose to water;*
- *location of, and dose value at, the ICRU Reference Point (the ICRU Reference Point may or may not be at the Level of the peak absorbed dose; see footnote 1;*
- *maximum dose in the PTV*;*
- *minimum dose in the PTV*; and*
- *dose(s) to Organ(s) at Risk (PRV).**

**Determined from dose distributions and/or dose-volume histograms.*

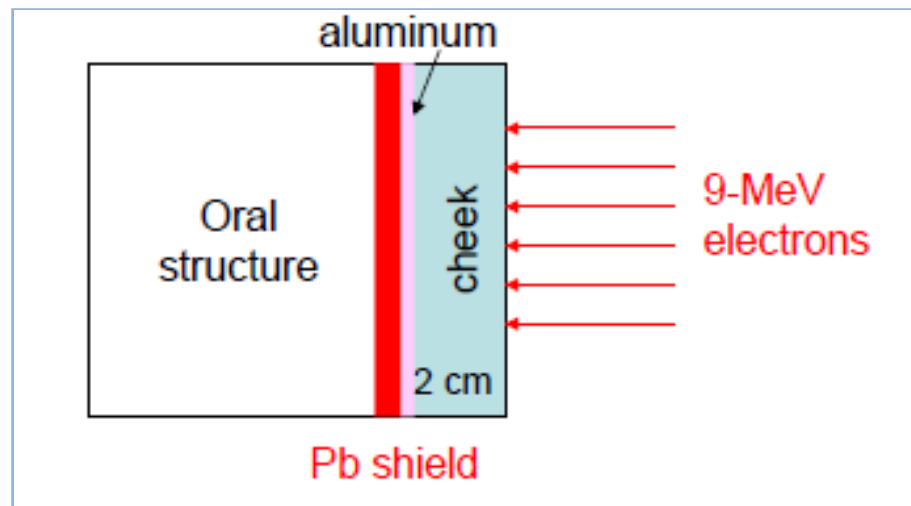
Field Shaping

- For a more customized field shape, a lead or metal alloy cut-out may be constructed and placed on the applicator as close to the patient as possible.
- Custom cut-out shapes may also be designed for patient treatment. Field shapes may be determined from conventional or virtual simulation, but are usually prescribed clinically by the physician before first treatment.
- The minimum diameter of reduced field accepted after field shaping is given by:
$$\text{Electron energy (meV)} / 2.5 \text{ cm in water.}$$



Internal Shielding

- In areas such as lip, buccal mucosa, eyelids or ear lobes, an internal shield may be used to protect normal structures beyond the target volume. Lead is commonly used though Aluminium or acrylic materials have also been used. The required thickness of the shield depends on energy of electron beam.
- Electron decrease in energy by 2mev/cm in muscle & soft tissue, whereas 2mev/mm of lead (so required thickness of lead to shield is proportionate thickness plus extra 1mm for safety)



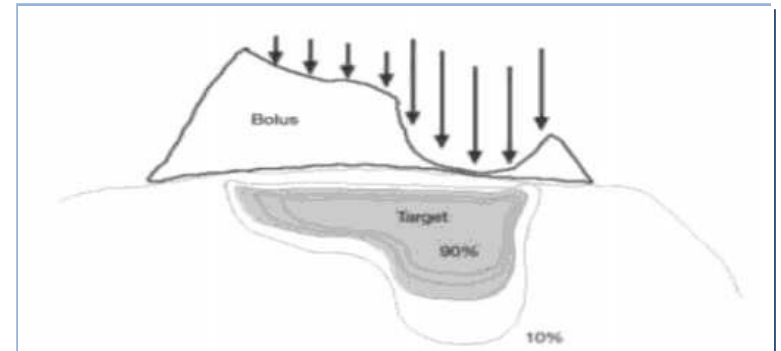
Internal Shielding

- these shields are often dipped in paraffin wax to form a 1 or 2 mm coating around the lead. This not only protects the patient from the toxic effects of the lead, but also absorbs any scattered electrons (back scatters), which are usually low in energy.

Bolus

Is used to

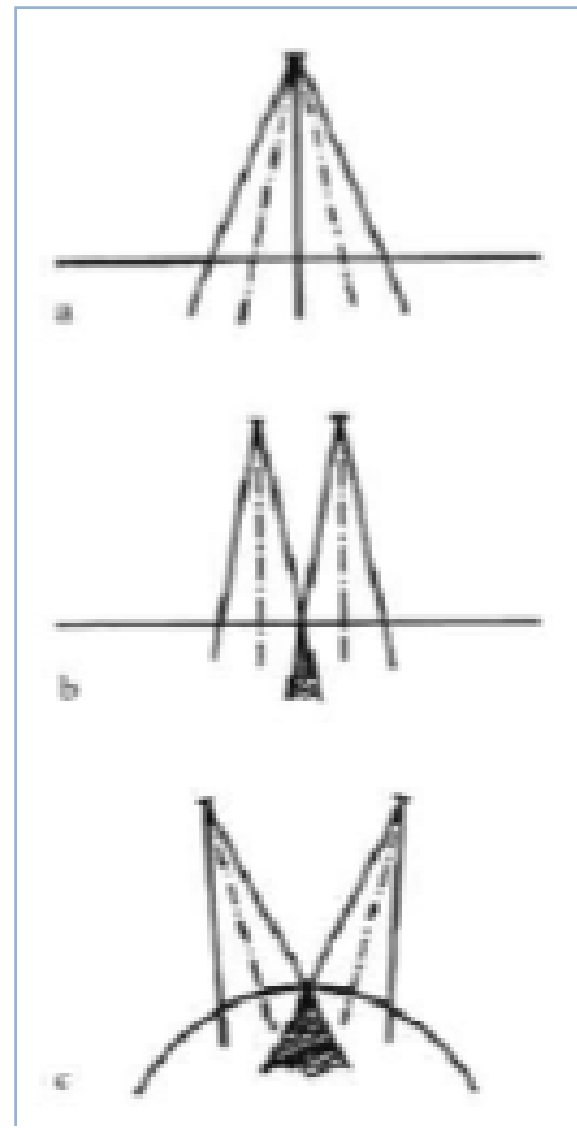
1. To increase the surface dose;
2. To flatten out irregular surfaces
3. Custom bolus conform isodose lines to the shape of the target
4. To reduce penetration of electron in some parts of the treatment field



As a rule of thumb, simply divide the practical range *R_p* by 10 to obtain the *approximate* thickness of lead required for shielding (<5% transmission).

Field abutment

- The purpose of field abutment usually is to enlarge the radiation field or to change the beam energy or modality
- **Fig-a**—the extent and magnitude of the high dose region can be minimised by angling the central axis of each away from each other so that a common beam angle is formed
- **Fig b**—represents overlap that can occur when the central axis of beams are parallel.
- **Fig c**—shows converging beam central axes that result in the greatest amount of overlap with the highest doses and largest high dose regions



DOSE REPORTING

- To maximize healthy tissue sparing beyond the tumor, while at the same time providing relatively homogeneous target coverage, treatments are usually prescribed at either z_{max} , $R90$ or $R80$.
- If the treatment dose is specified at either $R80$ or $R90$, *the skin dose will often be higher than the prescription dose.*
- *The* maximum dose to the patient could be up to 20% higher than the prescribed dose.
- The maximum dose should therefore always be reported for electron beam therapy.

- In general, in electron therapy, the beam energy and the beam delivery system are adjusted so that the maximum of the depth-dose curve on the beam axis (“peak dose”) is reached at the centre (or in the central part) of the PTV.
- The peak dose is always available and directly related to the number of monitor units in reference conditions, i.e., beam incident perpendicularly to a homogeneous medium. This point should be selected as the ICRU Reference Point for reporting.

The following dose values should be reported for reference irradiation conditions:

- the peak absorbed dose to water;
- location of and dose value at the ICRU Reference Point if not located at the level of the peak-absorbed dose;
- the maximum and minimum dose in the PTV, and dose(s) to OAR(s) derived from dose distributions and/or dose-volume histograms.

ELECTRON ARC THERAPY

- Electron arc therapy is a special radio therapeutic technique in which a rotational electron beam is used to treat superficial tumour volumes that follow curved surfaces.
- It is useful in treating postmastectomy chest wall, usually in barrel chested women where tangent beam can irradiate too much lung.
- The beam is collimated at 3 levels: The primary x-ray collimators; Secondary cerrobend insert; Skin collimation.
- The planning sequence is as follows: Patient CT scanning; Delineation of PTV; Selection of isocenter location; Specification of electron arc boundaries; Energy and slab bolus selection; Design of secondary collimator; Calculation of dose

Scanning field width:

Smaller field width →

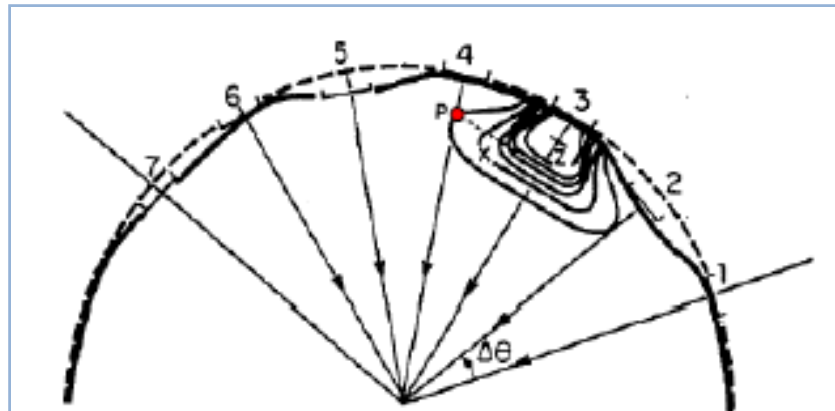
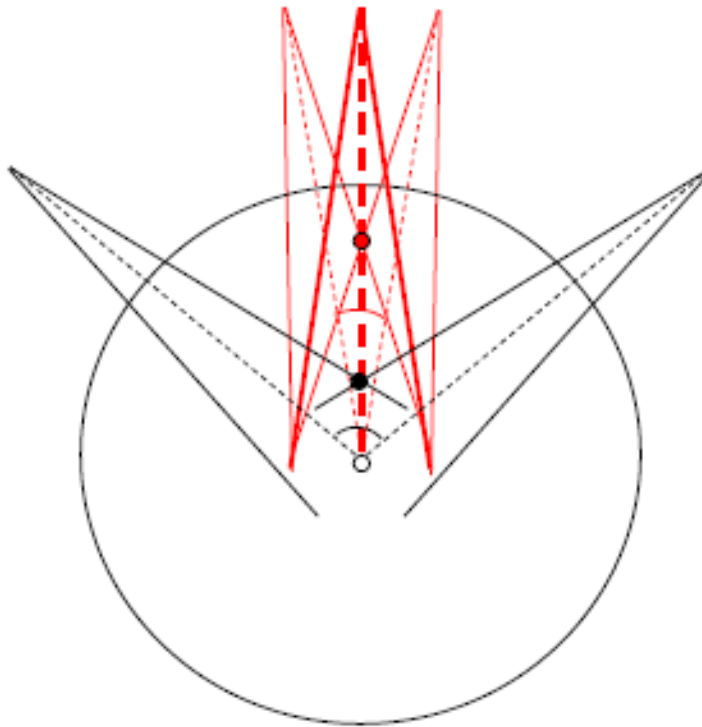
Lower dose rate (greater MU) →

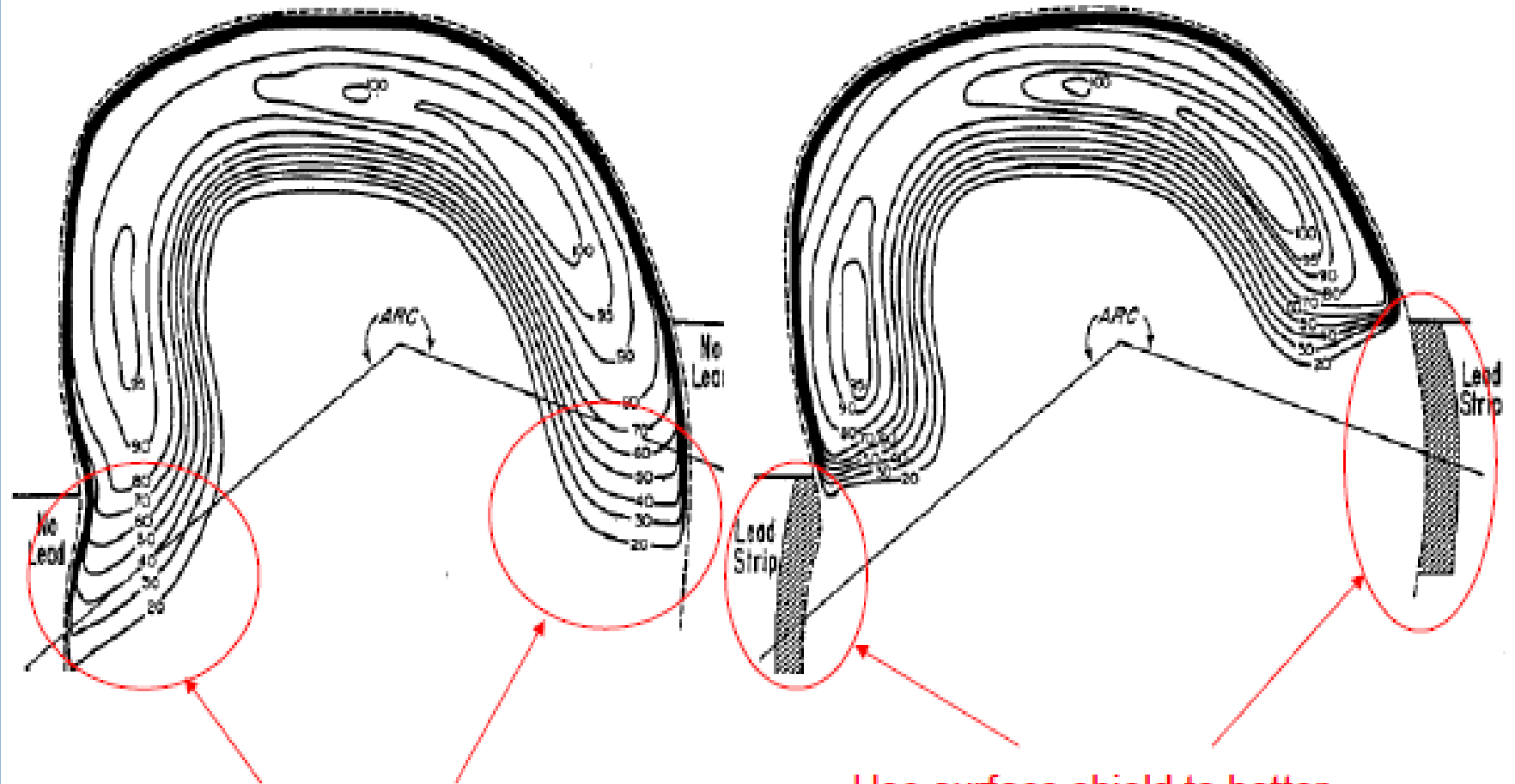
Greater x-ray contamination dose
(at the isocenter)

Smaller field width →

~Normal incidence at all angles
(less surface curvature/obliquity
effect)

Typically, field width 4 – 8 cm at isocenter.



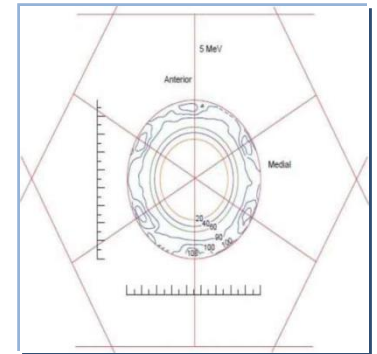


Gradual dose falloff at
both ends of the arc

Use surface shield to better
define the dose distribution

TOTAL-LIMB IRRADIATION

- Six equally spaced 5-MeV electron beams are used to irradiate a 9cm diameter cylinder.
- If the depth beneath the surface is 2 cm or less, electrons offer a uniform dose while sparing deep tissues and structures.

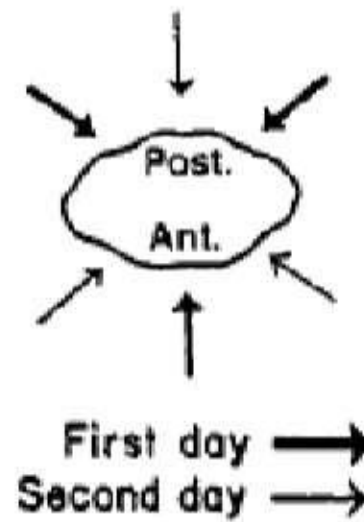
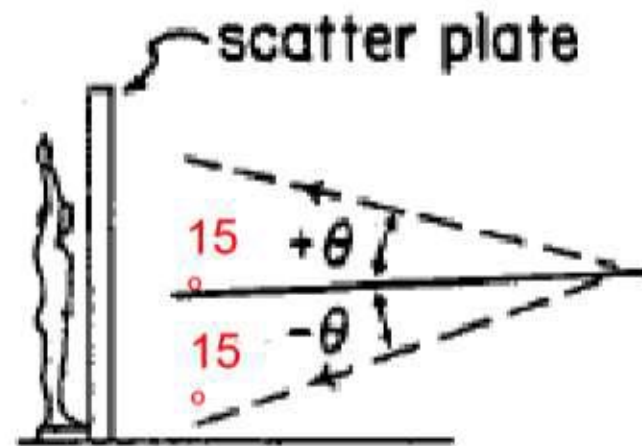
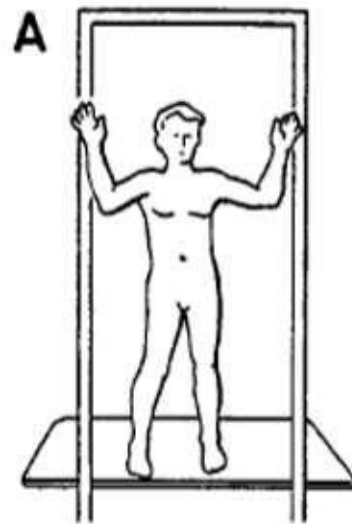


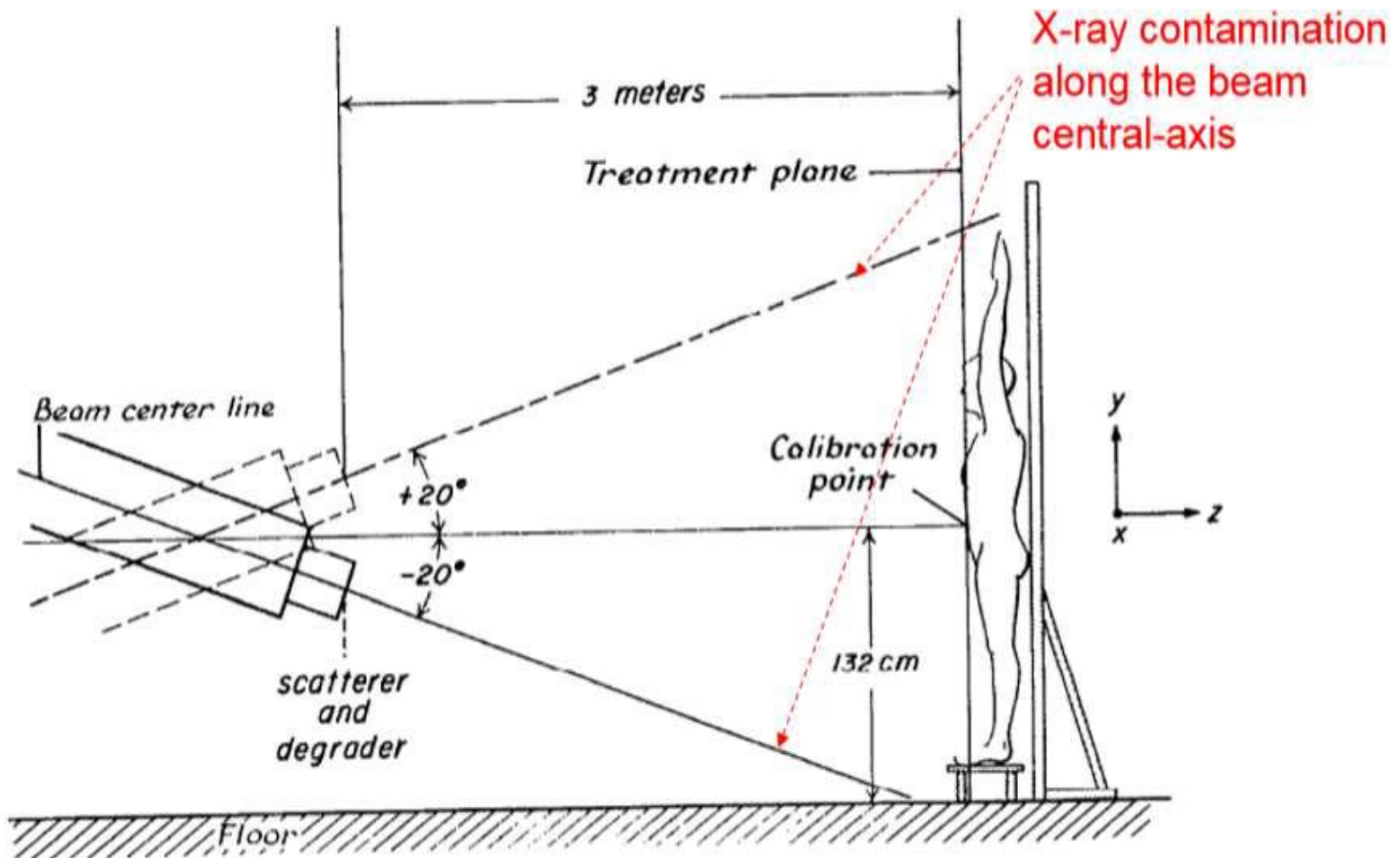
TOTAL-SCALP IRRADIATION

- Used in the management of malignancies (Cutaneous lymphoma, melanoma, and angiosarcoma) that present with widespread involvement of the scalp and forehead.
- Electron-beam therapy is a practical means of achieving the therapeutic goal of delivering uniform dose to the scalp with minimal dose to underlying brain.

TOTAL SKIN IRRADIATION

- Total-skin electron irradiation is a modality designed for management of diseases that require irradiation of the entire skin surface or a significant portion of it using electron beam of energy 2-4mev
- Used most frequently for treatment of mycosis fungoides & Kaposi sarcoma.
- Multiple techniques for total-skin electron therapy have been reviewed. The underlying principles of the various techniques are similar, which are exemplified by the modified Stanford technique.





Reduce x-ray contamination by angling the central axis away from the patient

- The depth-dose curve and d_{max} shift toward the surface, due to oblique incident angles.
- With the 6-field technique, dose uniformity of $\pm 10\%$ can be achieved in general, except in areas with large surface irregularities (e.g. inner thigh) where supplementary irradiation may be needed.
- Bremsstrahlung dose in patient midline is approximately doubled due to the opposed beam arrangement.
- For each anatomical area, an ICRU Reference Point for reporting has to be selected always at or near the center of the PTVs/CTVs.
- The Reference point may be at the level of the peak dose if it is located in the central part of the PTV.
- In addition an ICRU Reference Point, clinically relevant and located within the PTV, can be selected for the whole PTV.

Following dose values should be reported:

- peak absorbed dose in water for each individual electron beam;
- location of, and dose value at the ICRU Reference Point for each anatomical area (the ICRU Reference point may or may not be at the level of the peak dose);
- best estimate of maximum and minimum dose to each anatomical area;
- location and absorbed dose at the ICRU point for the whole PTV, and best estimate of the maximum and minimum dose for the whole PTV;
- any other dose value considered as clinically significant.

Intra-Operative Radiation Therapy (IORT)

- In IORT, electrons are used to deliver a large dose in a single fraction after surgical exposure of a well-defined anatomical area. The CTV is defined as accurately as possible jointly by the surgeon and the radiation oncologist during the procedure.
- The irradiation procedures specific to IORT must be reported: electron energy, IORT applicator system (type, shape, bevel angle, size of the applicator, flattening filter, etc.). The ICRU Reference Point for Reporting is always selected in the centre (or central part) of PTV and, when possible, at the level of the maximum dose on the beam axis.

Following dose values should be reported:

- peak absorbed dose to water, in reference conditions, for each individual beam (if the beam axis is perpendicular to the tissue surface);
- for oblique beam axis, the maximum absorbed dose in water on the “clinical axis” (i.e., the axis perpendicular to the surface of the tissues, at the point of intersection of the central axis of the beam with the tissue surface).
- location of, and dose value at the ICRU reference point (if different from above);
- best estimate of the maximum and minimum dose to the PTV. Usually the irradiation conditions (electron energy, field size, etc.) are selected so that at least 90 percent of the dose at the ICRU Reference Point is expected to be delivered to the entire PTV.

TAKE HOME MESSAGE

- Major attractions: Shape of depth dose curve. (mostly 6 -15 MeV). Rapid drop-off.
- Modest skin sparing effect.
- Percent surface dose increases with energy. (6MeV:70-80% | 25MeV:~95%)
- Dmax depends on the energy, but the relation is not linear. $=0.46E^{0.67}$
- Depth of clinical interest are given by:
D90=E/3.2,
D80=E/2.8

- *“The electron energy should be selected so that the maximum of the depth curve is located at the center of PTV” - ICRU 71.*
- The choice of field size should be based on adequacy of isodose coverage of PTV.
- Ensure that minimum dose to PTV should be adequate to sterilize the tumor and maximum dose doesn't exceed the tolerance of normal tissue.
- Special situations and techniques such as TSET, IORT, Electron arc therapy have their own set of guidelines.

Thank you

