Percentage Depth Dose and Dose Profile of LINAC

Lab report

Pushpraj Bhardwaj

Roll No: 221126006
M.Sc. Medical and Radiological Physics,
Semester: 4th
Centre for Medical and Radiation Physics,
National Institute of Science Education and Research Bhubaneswar

Date of experiment: February 06, 2024
Date of submission: April 11, 2024

April 11, 2024

Aim of the Experiment:

- To determine the percentage depth dose and profile of the Photon and Electron beam from a medical LINAC.
- Write a MatLab code to find various beam parameters from the data obtained during the measurement.

Apparatus Required:

- Medical Linear Accelerator
- 3D Scanner (RFA) with Water Reservoir
- Two Ionization Chamber (Field and reference Ionization chamber)
- Electrometer and Connecting cables.
- Thermometer and Barometer
- Leveling tool (Spirit level)

Theory:

Photon Beam Quality

In radiotherapy, photon beam quality refers to the characteristics of the X-ray or gamma-ray beam used for delivering radiation treatment to patients. This beam quality is crucial because it affects the dose distribution within the patient's body, ultimately influencing treatment efficacy and minimizing damage to surrounding healthy tissues.

Energy Spectrum: Photon beams used in radiotherapy can have a range of energies. The energy spectrum of the beam determines its penetration capability and interaction characteristics with tissues. Higher energy photons penetrate deeper into tissues before depositing their energy.

Beam Production: Photon beams in radiotherapy are typically produced using linear accelerators or radioactive isotopes such as Cobalt-60 . Linacs produce photon beams through the bremsstrahlung process, where high-energy electrons are decelerated by a target material, resulting in the emission of X-rays with a continuous energy spectrum.

Beam Quality Parameters: Beam quality is often characterized by parameters such as the energy spectrum, mean energy, and effective energy of the photon beam. These parameters are important for treatment planning and dose calculations.

Dose Distribution: The energy and quality of the photon beam directly influence the dose distribution within the patient's body. Treatment planners aim to achieve a uniform dose distribution within the target volume while minimizing dose to surrounding healthy tissues. Beam quality plays a significant role in achieving this balance.

Percentage Depth Dose (PDD)

One way of characterizing the central axis dose distribution is to normalize dose at depth with respect to dose at a reference depth. The quantity percentage (or simply percent) depth dose may be defined as the quotient, expressed as a percentage, of the absorbed dose at any depth d to the absorbed dose at a fixed reference depth do, along the central axis of the beam .

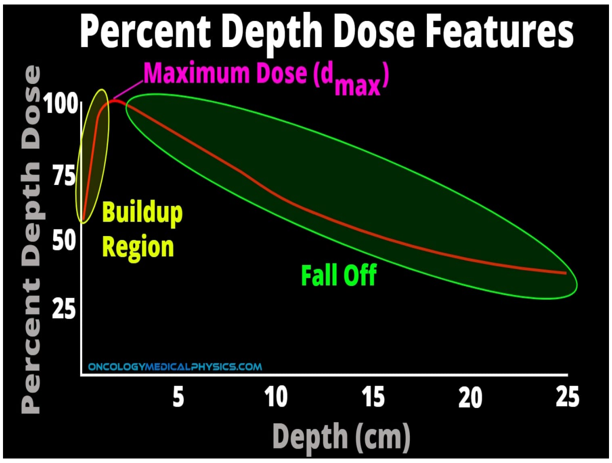

Figure 2: Percentage depth dose illustration

Percentage depth dose (P) is thus:

$$P = \frac{Dose\, at\, any\, depth\, d}{Dose\, at\, reference\, depth\, d_0} = \frac{D_d}{D_{d_0}} \tag{1}$$

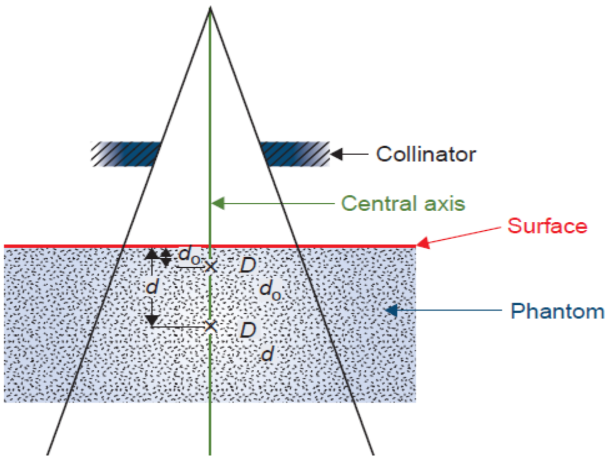

Figure 1: Percentage depth dose illustration

- PDD is SSD dependent.
- Factors influencing PDD is
  - **Inverse square law:** PDD increases slightly as SSD increases
    This is because the ratio of inverse square from depth-of-interest to dmax approaches unity (1) as distance increases.
  - **Attenuation:**Photon attenuation is the process by which photons interact with matter and deposit some or all of their energy. Attenuation is influenced both by the material the beam is passing through and by the energy of the beam.
    KERMA and Dose are related by the relationship between Mass Energy Transfer Coefficient (which relates to energy transferred to charged particles that travel some distance) and Mass Energy Absorption Coefficient (which relates to local energy deposition).
  - **Buildup:**Buildup occurs because much of the energy transferred from the photon beam is initially absorbed by electrons which travel some distance. This energy is eventually deposited as dose at a deeper depth within the phantom.

The buildup region ends when the amount of energy taken downstream by liberated electrons is equal to the energy deposited at that location by electrons liberated upstream. This condition is known as charged particle equilibrium (CPE).

Depth of maximum dose (dmax) is found at the shallowest point where charged particle equilibrium is established. Prior to this point, more energy is carried away by liberated electrons than is deposited locally by electrons liberated upstream. Beyond dmax, attenuation and inverse square law reduce the intensity of the primary photon beam with increasing distance.

Factors on which photon Dose distribution depends

Dependence on beam quality and Depth

- The percentage depth dose (beyond the depth of maximum dose) increases with beam energy. Higher-energy beams have greater penetrating power and thus deliver a higher percentage depth dose
- Increased photon energy increases depth of maximum dose (dmax) because electrons liberated by the primary beam are of higher average energy. This means that the electrons travel farther and require more depth to reach charge particle equilibrium.
- Increased photon energy decreases the slope of the dose fall off. This effect follows directly from the reduction of photon attenuation with increased energies.
- After dmax the percentage depth dose decreases with the distance

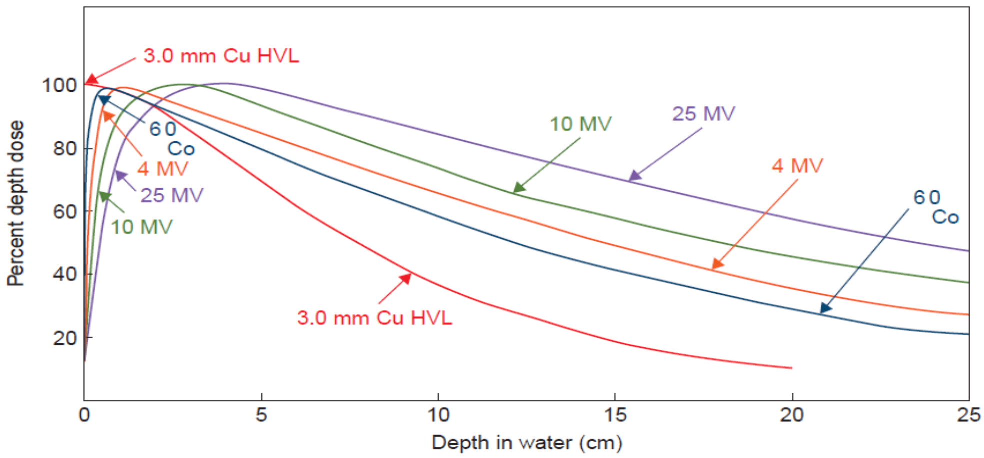

Figure 3: PDD with different beam quality

Effect of Field size and shape:

- As the field size is increased, the contribution of the scattered radiation to the absorbed dose increases. Because this increase in scattered dose is greater at larger depths than at the depth of Dmax the percent depth dose increases with increasing field size.
- The increase in percent depth dose caused by increase in field size depends on beam quality. Since the scattering probability or cross-section decreases with energy increase and the higher-energy photons are scattered more predominantly in the forward direction, the field size dependence of percent depth dose is less pronounced for the higher-energy than for the lower-energy beams.
- With increase in field size the surface dose increases due to scattering contribution.
- with the increase in field size the dmax shift towards the surface

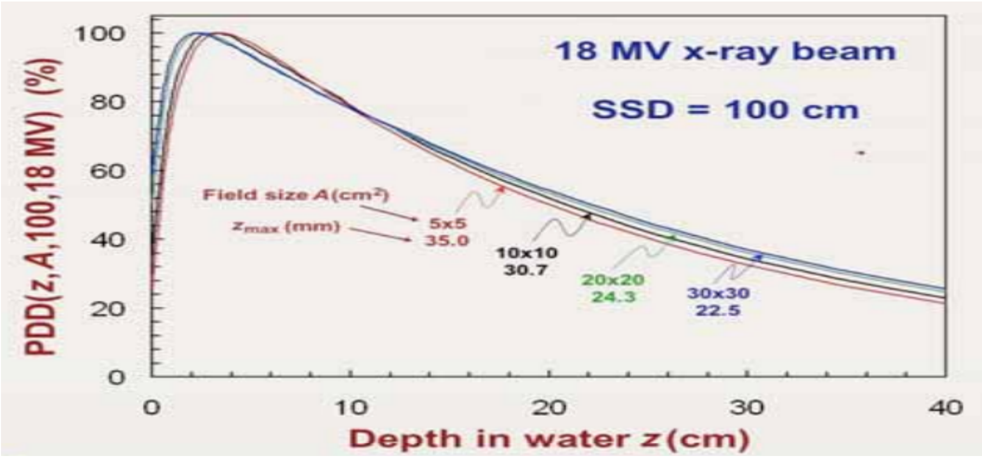

Figure 4: PDD with different field sizes

Dependence on source to surface distance:

- Percent depth dose increases with SSD because of the effects of the inverse square law. Although the actual dose rate at a point decreases with increase in distance from the source, the percent depth dose, which is a relative dose with respect to a reference point, increases with SSD
- Dose rate decreases with distance, the SSD, in practice, is set at a distance which provides a compromise between dose rate and percent depth dose. For the treatment of deep-seated lesions with megavoltage beams, the minimum recommended SSD is 80 cm.
- with the increase in SSD there is no change in surface dose and dmax

Electron Dose Distribution

The behavior of electron depth dose distributions is driven by Coulomb interactions with charged subatomic particles. Clinically, this translates into percent depth dose (PDD) distributions with significantly higher surface dose and more rapid dose fall-off than photon beams. Electrons are used in external beam radiotherapy for treatment of superficial lesions, therefore, accurate knowledge of electron range in water and tissue is important. Since the CSDA range can serve only as a rough guide on the penetration of electron beams into tissue, other more appropriate ranges have been defined for use in radiotherapy, all of them based on measurement of electron depth dose distribution in water.

- Typical electron beam depth dose curve (dose against depth in water normalized to 100 at theb depth of dose maximum z_{max}. Several ranges of interest in radiotherapy and dosimetry, such as $R_{80}, R_{50}, R_p, andR_{max}$, are identified on the curve
- The maximum range Rmax is defined as the depth at which extrapolation of the tail of the depth dose curve meets the bremsstrahlung background. It is the largest penetration depth of electrons in the absorbing medium. The drawback of Rmax is that it does not provide a well defined measurement point.
- The practical range Rp 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 bremsstrahlung background.
- The Bremsstrahlung tail is comprised of photons originating from Bremsstrahlung interactions in the treatment head and the patient/phantom.
  - Bremsstrahlung accounts for around 5-15 % of dose from electron beam.
  - Approximately half of the photons are generated in the treatment head with the other half generated in the phantom.

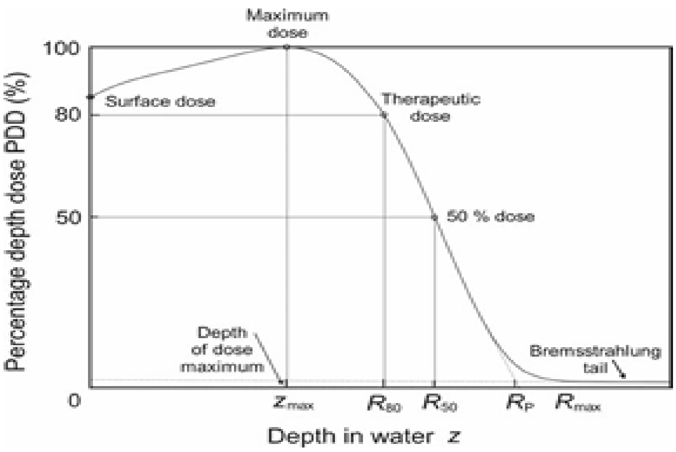

Figure 5: Electron depth dose distribution

- Rx is the depth of x percent of maximum dose.
- RT is the therapeutic range. Therapeutic range is typically taken at either R90 or R80.
- Electrons lose approximately 2MeV per cm in water.
  - $R_{90}\,(\mathrm{cm}) \approx \frac{E_0}{3.2}$
  - $R_{80}\,(\mathrm{cm}) \approx \frac{E_0}{2.8}$
  - $R_{50}\,(\mathrm{cm}) \approx \frac{E_0}{2.33}$
  - $R_p\,(\mathrm{cm}) \approx \frac{E_0}{2}$
- Because of the complexity of the spectrum, there is no single energy parameter that will fully characterize the electron beam. Several parameters are used to describe the electron beam, such as the most probable energy $E_{p,o}$ at the phantom or patient surface, the mean energy E_o on the phantom or patient surface, and R_{50}, the depth at which the absorbed dose falls to 50% of the maximum dose.
  - The most probable energy $E_{p,o}$ on the phantom surface is empirically related to the practical range R_p in water as follows:

    $$E_{p,o} = 0.22 + 1.98R_p + 0.0025R_p^2, \tag{2}$$

    where $E_{p,o}$ is in MeV and R_p is in cm.
  - The mean electron energy E_o at the phantom surface is related to the half-value depth R_{50} as follows:

    $$E_o = C \cdot R_{50}, \tag{3}$$

    where $C = 2.33\,\mathrm{MeV/cm}$ for water.
  - The depth R_{50} is calculated from the measured value of I_{50}, the depth at which the ionization curve falls to 50% of its maximum, by:

    $$R_{50} = \begin{cases} 1.029\,I_{50} - 0.06\,\mathrm{cm} & (\text{for } 2 \le I_{50} \le 10\,\mathrm{cm}) \\ 1.059\,I_{50} - 0.37\,\mathrm{cm} & (\text{for } I_{50} > 10\,\mathrm{cm}) \end{cases} \tag{4}$$

  - E_z, the mean energy at a depth z in a water phantom, is related to the practical range R_p by the Harder equation as follows:

    $$E_z = E_o(1 - \frac{z}{R_p}) \tag{5}$$

Factors on which Electron Dose distribution depends

- **Electron Energy** Increased electron energy has the following impacts on a percent depth dose distribution.
  - Increases skin dose
  - Increases depth of maximum dose
  - Increases range straggling
  - Decreases sharpness of dose fall-off
  - Increases Bremsstrahlung X-ray tail
  - High dose isodose lines contract slightly
  - Low dose isodose lines expand laterally due to range straggling

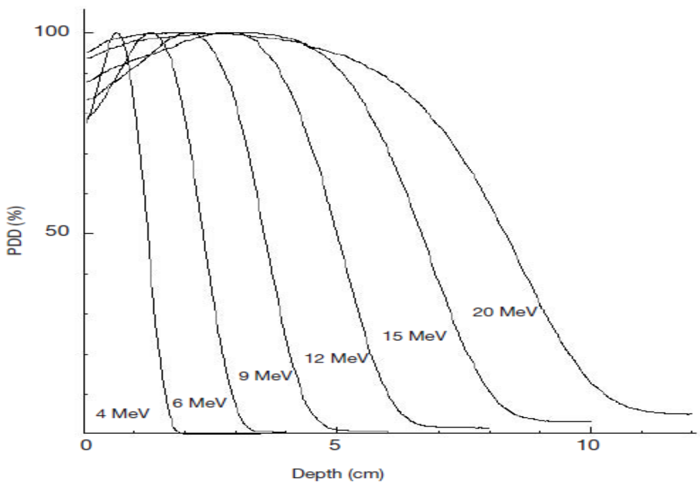

Figure 6: Electron energy impact on PDD

- **Field Size:** For field sizes smaller than the practical range of incident electrons, lateral charged particle equilibrium is lost and the following trends are observed.
  - Decreased field size reduces depth of maximum dose.
  - Decreased field size increases relative skin dose.
  - Decreased field size increases range straggling and decreases sharpness of dose fall off.

  For field sizes larger than the practical range of incident electrons, lateral charged particle equilibrium is preserved and there is little change in depth dose with field size.

- **Angle of Incidence:** Increased angle of obliquity has the following effects on depth dose distributions:
  - Shift the depth of maximum dose, and R_{80}, toward the surface.
  - Increase $D_{\max}$ (maximum dose).
  - Increase surface dose.
  - Increase the practical electron range.

  This is because of the contribution of high scatter angle electrons, which do not pass through as much tissue.

Beam Profile:

- Combining a central axis dose distribution with off-axis data results in a volume dose matrix that provides 2-D and 3-D information on the dose distribution in the patient.

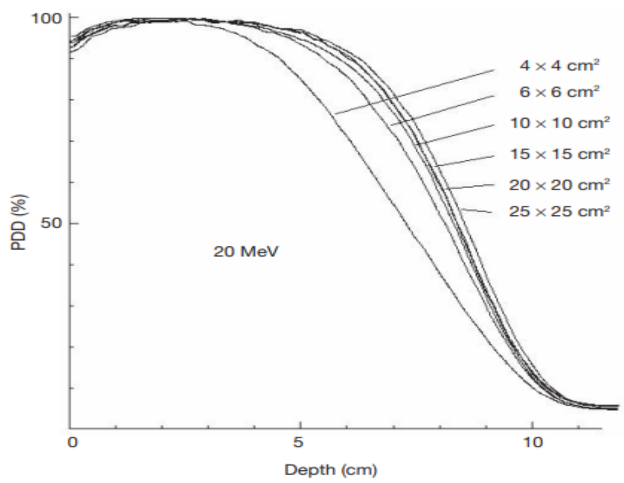

Figure 7: Field size impact on PDD for 20 Mev electron Energy

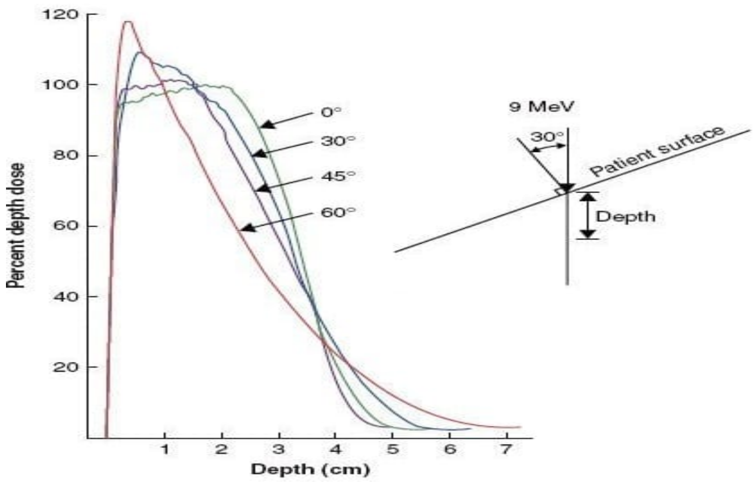

Figure 8: Angle of Incidence impact on PDD for 12 Mev electron Energy

- To represent volumetric or planar variations in absorbed dose, distributions are depicted using **isodose curves**, which are lines passing through points of equal dose.
- The dose variation across the center of the field at a specified depth. Such a representation of the beam is known as the **beam profile**.
- **Field Size** is defined as the lateral distance between the nthe 50 % isodose lines at a reference depth.
- Another way of depicting the dose variation across the field is to plot isodose curves in a plane perpendicular to the central axis of the beam (Fig. 11). Such a representation is useful for treatment planning in which the field sizes are planned based on an isodose curve.
- Megavoltage beam profiles consist of three regions:
  - Central region represents the central portion of the profile extending from the central axis to within 1 to 1.5 cm of the geometric field edges of the beam. **Profile flat in 80 % of the central portion of the field.**
  - Penumbra is the region close to geometric field edges where the dose changes rapidly and depends on field-defining collimators, the finite size of the focal spot (source size) and the lateral electronic disequilibrium dose on the beam profile normalized to 100 % at the central axis. **Penumbra is typically defined as the distance between 80 % and 20 % dose on the beam profile normalized to 100 % at the central axis.**

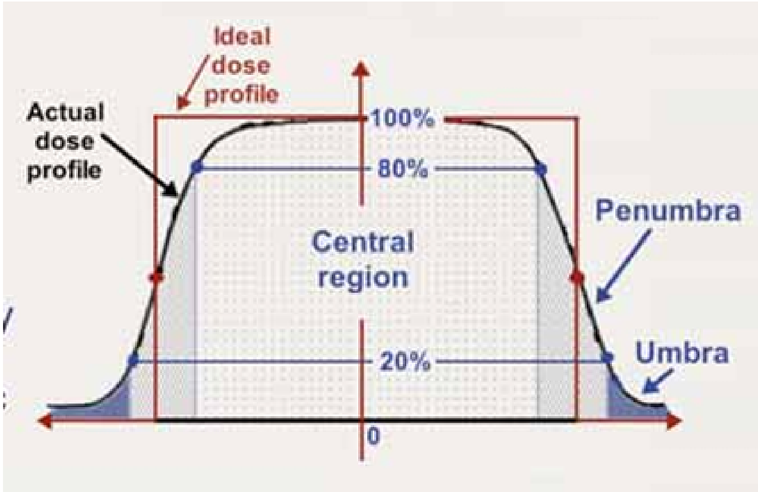

Figure 9: Dose profile at depth showing the variation of dose across the field

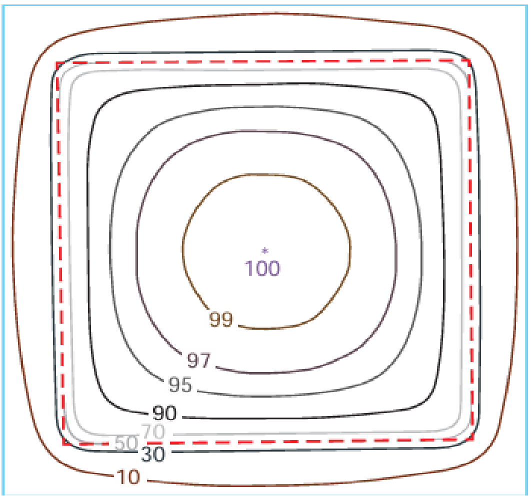

Figure 10: Cross-sectional isodose distribution in a plane perpendicular to the central axis of the beam. Isodose values are normalized to 100 % at the center of the field. the dashed line shows the boundary of the geometric field.

  - Umbra is the region outside of the radiation field, far removed from the field edges. The dose in this region is low and results from radiation transmitted through the collimator and head shielding.**Umbra is typically less than 1 % of the dose on the central axis.**

- **Isodose Charts** Isodose charts provide a 2D map of a dose distribution. Isodose charts are typically normalized to maximum dose but, especially in treatment planning, may be normalized to prescription dose.

- Isodose charts illustrate several important aspects of MV photon dose distributions:

  - **Central Axis**

    Dose is highest along the central axis of the beam.

    Exception: For beams generated with a flattening filter there are often "horns" in the superficial isodose lines. The flattening filter overcompensates in this superficial region to produce a flatter dose distribution at treatment depths.

  - **Field Edge**

    The dose near the field edge falls off rapidly. This is caused both by geometric penumbra and also loss of lateral scatter equilibrium.

    Isodose chart with dose horns, penumbra, flat region, and forward peak.

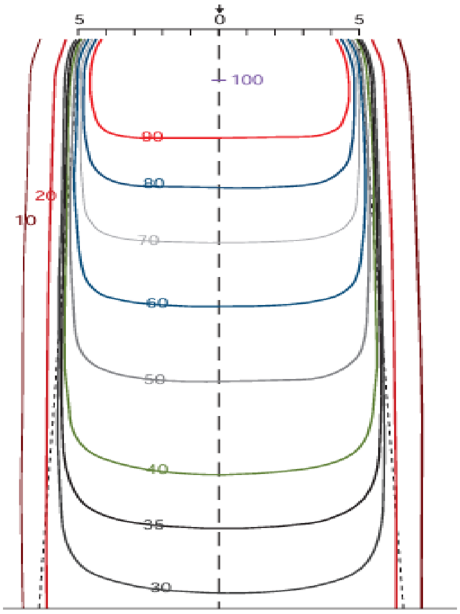

Figure 11: Isodose distributions for 10-MV x-rays, SSD = 100 cm, field size = 10 × 10 cm^2

- **Flattened field "horns"** The horns found in shallow depths of flattened fields are caused by differential attenuation within the flattening filter. Horns are most pronounced for lower MV fields and larger field sizes where the lateral photon energy is much lower (softer) than along the central axis.

Flatness and Symmetry:

An unflattened MV photon beam will have its highest dose rate along the central axis of the beam. Dose rate falls off laterally resulting in a peaked isodose distribution.

Flattening Filters are cone-shaped pieces of metal commonly used to normalize the dose distribution laterally. These filters are designed to attenuate the central axis of the beam leaving a very uniform dose distribution at a given depth, usually 10cm. Shallower than this depth, the lateral region will have the highest dose rate which appear as "horns" on the dose distribution. Beyond 10cm depth, the dose distribution again becomes forward peaked.

Flatness:

Flatness is defined in AAPM TG-45 as the ratio of the maximum to the minimum dose inside the central 80 % of the field width at a given depth. Field width is defined here as full width at half maximum (FWHM).

$$Flatness = \frac{(Dose)_{max} - (Dose)_{min}}{(Dose)_{max} + (Dose)_{min}} \times 100\% \tag{6}$$

A flatness of ±3 % is acceptable.

- Standard linac specifications generally require that F be less than 3 % when measured in a water phantom at a depth of 10 cm and an SSD of 100 cm for the largest field size available (usually 40 × 40 cm^2)
- Flatness for electron beam along major axes at the depth of dose maximum as the separation between 90 % and 50% dose points on either side of the beam profile for:
  - 10x10 cm^2 applicator
  - Maximum applicator size

The tolerance value is 10 mm.

Symmetry:

Symmetry is defined in AAPM TG-45 as a maximum deviation of the left side dose from the right side dose of a beam over the central 80 % of FWHM.

The beam symmetry for the photon is usually determined at , which represents the most sensitive depth for assessment of this beam uniformity parameter. A typical symmetry specification is that any two dose points on a beam profile, equidistant from the central axis point, are within 2 % of each other. Alternately, areas under the z_{max} beam profile on each side (left and right) of the central axis extending to the 50% dose level (normalized to 100% at the central axis point) are determined, and symmetry is then calculated from

$$symmetry = \frac{(area)_{left} - (area)_{right}}{(area)_{left} + (area)_{right}} \times 100\% \tag{7}$$

A symmetry value of ±2% is acceptable.
Symmetry for electron beam along major axes at depth of dose maxima in SSD setup (maximum ratio of absorbed doses at symmetrical points from central beam axis and more than 1 cm inside the 90% isodose contour)

Observation:

Photon PDD

We have developed a MATLAB code to generate a depth dose curve based on the provided data for 6 MV photon energy. The code allows us to calculate essential parameters such as surface dose, depth of maximum dose, percentage dose at 10 and 20 cm depths, and the dose fall-off slope beyond 10 cm. **MatLab code**

```
data = xlsread("/MATLAB Drive/6 MV photon.xlsx");
depth = data(:, 1);
dose = data(:, 2);

surfacedose = dose(depth == 0);
maxdose = max(dose);
maxdepth = depth(dose == maxdose);

dose_at_10cm = dose(depth == 100);
dose_at_20cm = dose(depth == 200);
%finding the index in the n*2 matrix corresponding to 10cm depth
index10 = find(depth == 100);
%defining a saperate depth matrix of n*1 starting from the index
   corresponding to 10cm depth
dx = depth(index10 : end);
%defining a saperate dose matrix of n*1 starting from the dose index
    corresponding to 10cm depth
dy = dose(index10: end);
slope = diff(dy) ./ diff(dx);
slope(5)
%finding element wise slope in the dose falloff region after the
   dmax
%Y = diff(X) calculates differences between adjacent elements of X.
%If X is a vector of length m, then Y = diff(X) returns a vector of
   length m-1.
%The elements of Y are the differences between adjacent elements of
   X.
%Y = [X(2)-X(1) X(3)-X(2) ... X(m)-X(m-1)]
plot(depth, dose, 'k', 'linewidth', 2)

hold on;
```

```
plot(0, surfacedose,"c*", "Markersize", 15)
plot(maxdepth, maxdose, "r-o", "Markersize", 15)
plot(100, dose_at_10cm, "b*", "Markersize", 15)
plot(200, dose_at_20cm, "m*", "Markersize", 15)
%These lines plot markers at specific points on the graph:
%surface dose (surfacedose), maximum dose depth (maximumdepth),
%doses at 10 cm and 20 cm (Doseat10cm and Doseat20cm, respectively).


plot([maxdepth maxdepth], [0 maxdose], "k--")
plot([0 maxdepth], [maxdose maxdose], "k--")

plot([100 100], [0 dose_at_10cm], "k--")
plot([0 100], [dose_at_10cm dose_at_10cm], "k--")

plot([200 200], [0 dose_at_20cm], 'k--')
plot([0 200], [dose_at_20cm dose_at_20cm], "k--")

xlabel("Depth (in mm)")
ylabel("PDD (%)")
title("Depth vs PDD")
grid()
grid minor

legend("PDD", "Surface Dose", "d_m_a_x", "Dose at 10cm", "Dose at 20
    cm")

disp(['Surface Dose: ', num2str(surfacedose), '%'])
disp(['d_max: ', num2str(maxdepth), ' mm'])
disp(['Dose at 10 cm: ', num2str(dose_at_10cm), ' %'])
disp(['Dose at 20 cm: ', num2str(dose_at_20cm), ' %'])
```

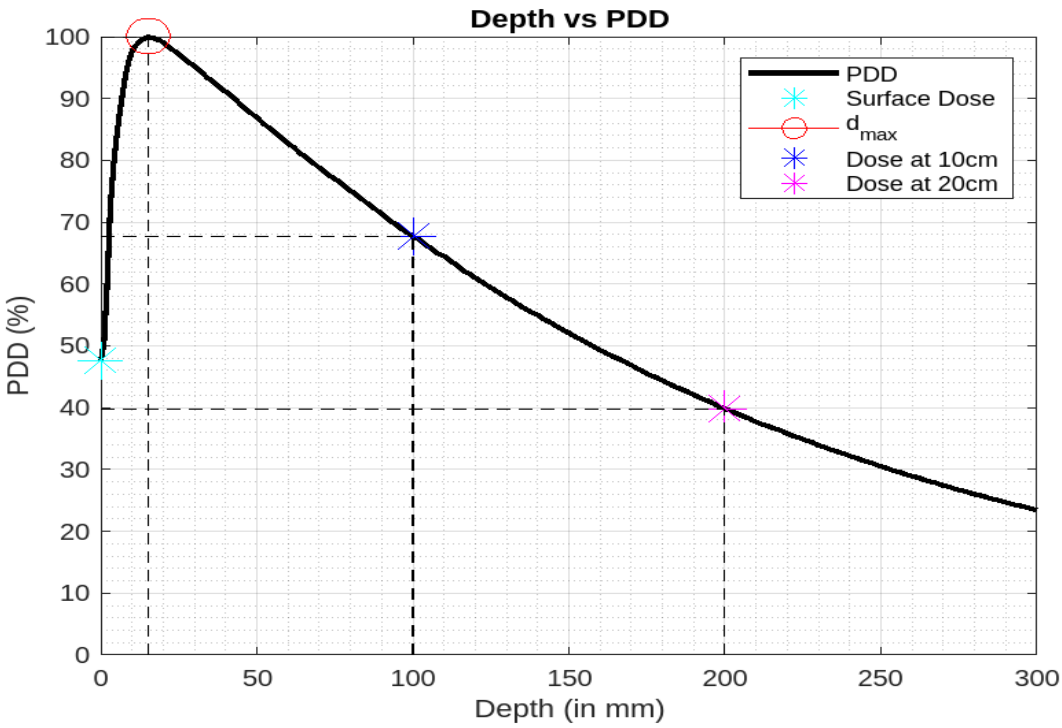

Figure 12: Photon Dose Distribution(6MV)

Photon Beam Profile

We have developed a MATLAB code to generate a Beam profile based on the provided data for 6 MV photon energy. The code allows us to calculate essential parameters such as MAXIMUM and Minimum dose ,Flatness and symmetry within 80 % of field width.Also the penumbra whiCh is the lateral distance between the 20 % and 80 % of isodose curve. **MatLab code**

```
data=xlsread(" C:\Users\USER-118\Downloads\beam photon profile.xls")
    ;

depth=data(:,1);
dose=data(:,2);
maxdose=max(dose);
normalizedose=(dose/maxdose) *100;

doseatcenter=normalizedose(depth==0);
doseat50=0.5*doseatcenter;
[~,idx]=min(abs(dose-doseat50));

fwhm_fieldsize=depth(idx);

% Find maximum and minimum dose within 80% of the line plotted
depth1=0.8*fwhm_fieldsize;
b1=depth(depth <=round(depth1) & depth >= 0 | depth<=0 & depth>=-
    round(depth1) );
b2=normalizedose(depth <=round(depth1) & depth >= 0 | depth<=0 &
    depth>=-round(depth1) );
max1=max(b2);
min1=min(b2);
Flatness=((max1-min1)/(max1+min1))*100;
b3=normalizedose(depth >=0);
arearight=sum(b3);
b4=normalizedose(depth<=0);
arealeft=sum(b4);

symmetry=abs(((arealeft-arearight)/(arealeft+arearight))*100);

dose80=0.80*max1;
dose20=0.20*max1;
[~,idx1]=min(abs(dose(fwhm_fieldsize:end)-dose80));
depth_80=depth(idx1);
[~,idx2]=min(abs(dose-dose20));
depth_20=depth(idx2);
penumbra=abs(depth_80)-depth_20;

k1 =normalizedose(depth==round(depth1));
plot(depth,normalizedose,"linewidth",2);
hold on;
verticalline1=plot([fwhm_fieldsize+2 ,fwhm_fieldsize+2],[0 50],'--',
     'Color',
'red', 'LineWidth', 1.5);
%verticalline2=plot([-48 ,-48],[0 50],'--', 'Color', 'red',
%'LineWidth', 1.5);
%horizontalLine = plot([-fwhm_fieldsize-3, fwhm_fieldsize+3], [50,
    50],
%'--', 'Color', 'red', 'LineWidth', 1.5);
%vert3=plot([round(depth1) round(depth1)],[0 k1],'--', 'Color', '
    black', %'LineWidth', 1.5);
vert4=plot([-round(depth1) -round(depth1)],[0 k1],'--', 'Color', '
    black', 'LineWidth', 1.5);
```

```
plot(depth(normalizedose==max1(1)),max1,'k*','Markersize',12);
plot(depth(normalizedose==min1),min1,'m+','Markersize',12);
%plot(fwhm_fieldsize+2,dose(idx),'k*',"Markersize",10);
title('Depth Dose curve for 6MV');
xlabel('Distance from the Central axis(mm)');
ylabel('Relative dose');
grid();
grid  minor;

legend('Beam Profile (6MV)','Field size width','80 % of field size
width','Maximum dose',' ','Minimum dose');

disp(['Maximum Dose: ',num2str(max1),'%']);
disp(['Minimum Dose(within 80 % of field width): ', num2str(min1),'%
   ']);
disp(['Flatness (within 80% of field width )',num2str(Flatness),' ',
   '%']);

disp(['Symmetry  ',num2str(symmetry),' ','%']);
disp(['Penumbra  ',num2str(penumbra/2),' ','cm']);
verticalline2=plot([-48 ,-48],[0 50],'--', 'Color', 'red', '
   LineWidth', 1.5);
horizontalLine = plot([-fwhm_fieldsize-3, fwhm_fieldsize+3], [50,
   50],
'--', 'Color', 'red', 'LineWidth', 1.5);
vert3=plot([round(depth1) round(depth1)],[0 k1],'--', 'Color', '
   black', 'LineWidth', 1.5);
```

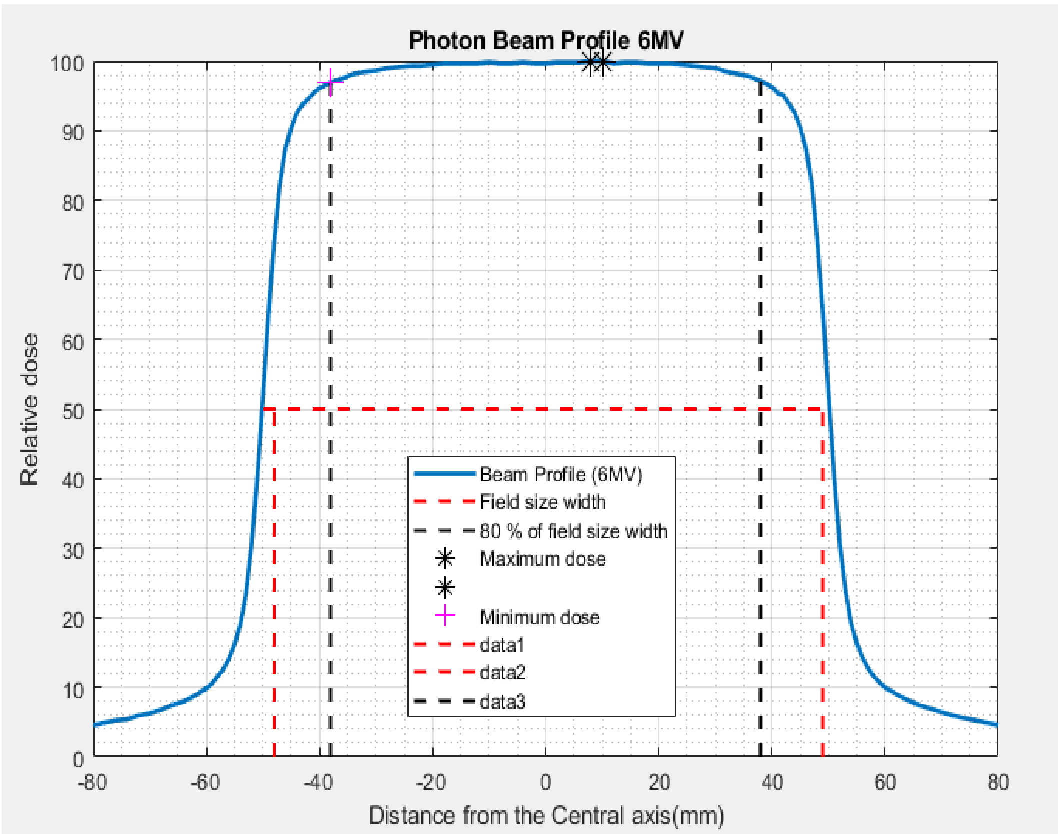

Figure 13: Photon Beam profile Distribution(6MV)

Electron Depth Dose Distribution (6 MeV)

We have developed a MATLAB code to generate a depth dose curve based on the provided data for 6 MeV electron energy. The code allows us to calculate essential parameters such as surface dose, depth of maximum dose, R_{90}, R_{80},R_{50}, Practical range, mean and most probable energy. **MatLab code**

```
data = xlsread("/MATLAB Drive/6 MeV electron.xlsx");
depth = data(:, 1);
dose = data(:, 2);
plot(depth, dose, "k-", "LineWidth", 2)
hold on;


surfacedose = dose(depth == 0);
maxdose = max(dose);
maxdepth = depth(dose == maxdose);

plot(0, surfacedose,"c*", "Markersize", 12)
plot([maxdepth maxdepth], [0 maxdose], "b--o")
hold on;


for y = 50
    dx = y./100 * maxdose;
    [~,idx] = min(abs(dose-dx));
    R_50 = depth(idx);
    dose_at_R_50 = dose(idx);
end

for y = 80
    dx = y./100 * maxdose;
    [~,idx] = min(abs(dose-dx));
    R_80 = depth(idx);
    dose_at_R_80 = dose(idx);
end


dose_at_R_90 = 91.9;
R_90 = depth(dose == dose_at_R_90);

%Plotting
plot([R_50 R_50], [0 dose_at_R_50],"black--o")
plot([R_80 R_80], [0 dose_at_R_80],"magenta--o")
plot([R_90 R_90], [0 dose_at_R_90],"red--o")
hold on;

line1_coef = polyfit(depth(20:30), dose(20:30), 1);
y1 = line1_coef(1) * depth + line1_coef(2);
plot(depth(20:34), y1(20:34),'linewidth',2)

hold on;
line2_coef = polyfit(depth(39:46), dose(39:46), 1);
y2 = line2_coef(1) * depth + line2_coef(2);
plot(depth, y2, "linewidth", 2)

%putting the value of the dose of the intersection point of the two
    lines
%into the first line defined
R_p = (line2_coef(2) - line1_coef(2)) / line1_coef(1);
plot(R_p, line2_coef(2),"y*", "MarkerSize", 12)
```

```
E_p = 0.22 + 1.98 * R_p + 0.0025 * (R_p)^2;
E_mean = 2.33 * R_50;

xlabel("Depth (in mm)")
ylabel("PDD (%)")
title("Depth vs PDD")
grid()
grid minor

legend("PDD", "Surface Dose", "d_m_a_x", "", "R_5_0", "R_8_0", "
    R_9_0", "extrapolated dose falloff", "Bremmstrahlung tail", "R_p
    ")

disp(['Surface Dose: ', num2str(surfacedose), '%'])
disp(['dmax: ', num2str(max(maxdepth)), 'mm'])
disp(['R_50: ', num2str(dose_at_R_50), 'mm'])
disp(['R_80: ', num2str(dose_at_R_80), 'mm'])
disp(['R_90: ', num2str(dose_at_R_90), 'mm'])
disp(['Practical range (R_p): ', num2str(R_p), 'mm'])
disp(['Most probable energy (E_p): ', num2str(E_p), 'MeV'])
disp(['Mean kinetic energy (E_mean): ', num2str(E_mean), "MeV"])
```

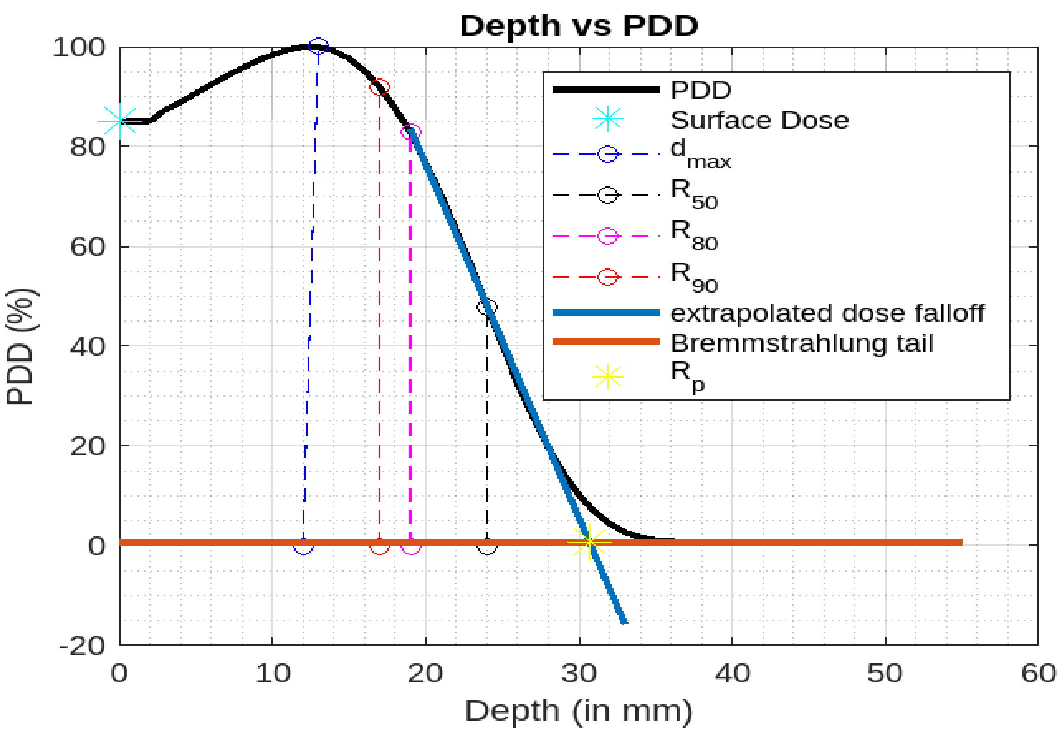

Figure 14: Electron Depth Dose Distribution(6MeV)

Result:

The result of three parts of experiment are as follows:

PDD (6 MV):

```
>> PDD_6MV_photon_25_03_24

ans =

    −0.2000

Surface Dose: 47.6%
```

```
d_max: 15 mm
Dose at 10 cm: 67.7 %
Dose at 20 cm: 39.8 %
>>
```

Beam Profile (6 MV):

```
 >> BeamProfile(6MV)
Maximum Dose: 100%
Minimum Dose(within 80 % of field width): 96.944%
Flatness (within 80% of field width ): 0.15517 %
Symmetry:  0.013437 %
Penumbra:  1.2 cm
```

Flatness and Symmetry are within the tolerence limit defined by AAPM TG-45.
A flatness of ±3 is acceptable.
A symmetry value of ±2 is acceptable.

PDD (6 MeV):

```
>> PDD_6MeV_electron_29_03_24
Surface Dose: 85%
dmax: 13mm
R_50: 47.9mm
R_80: 82.9mm
R_90: 91.9mm
Practical range (R_p): 30.6919mm
Most probable energy (E_p): 63.3449MeV
    "Mean kinetic energy (E_mean): "    "55.92"    "MeV"
>>
```

Conclusion:

In conclusion, the experiment successfully demonstrated the capability to generate MATLAB code from provided Excel data for plotting the percentage depth dose (PDD) of photon (6 MV) and electron beam (6 MeV), as well as the beam profile (6 MV). The generated plots allowed for the visualization and analysis of the dosimetric characteristics of the radiation beams.
Furthermore, various parameters were calculated from the graphs, and it was confirmed that they fell within the predetermined tolerance limits
Overall, the experiment not only showcased the effectiveness of MATLAB in processing and visualizing dosimetric data but also ensured that the dosimetric parameters derived from the plots met the necessary quality assurance criteria.

Reference:

- FM Khan BOOK
- https://oncologymedicalphysics.com/dose-calculation-algorithms