Basic Principles of Radiation and Calibration of Therapy Units

Dr. S. D. Sharma

Head, Medical Physics Section

Radiological Physics & Advisory Division
Bhabha Atomic Research Centre
CT&CRS Building, Anushaktinagar
Mumbai - 400094, India

Layout

- **Radiotherapy beams and sources**
- **Basic characteristics of photon and electron beams**
- **Calibration of radiotherapy beams**
- **Calibration of brachytherapy sources**

Radiotherapy

a principal modality of cancer therapy

high and homogenous dose to tumour

Low dose to normal tissue and OAR

Beam therapy

γ-rays
X-rays
Electrons
Protons
Neutrons
Heavy ions

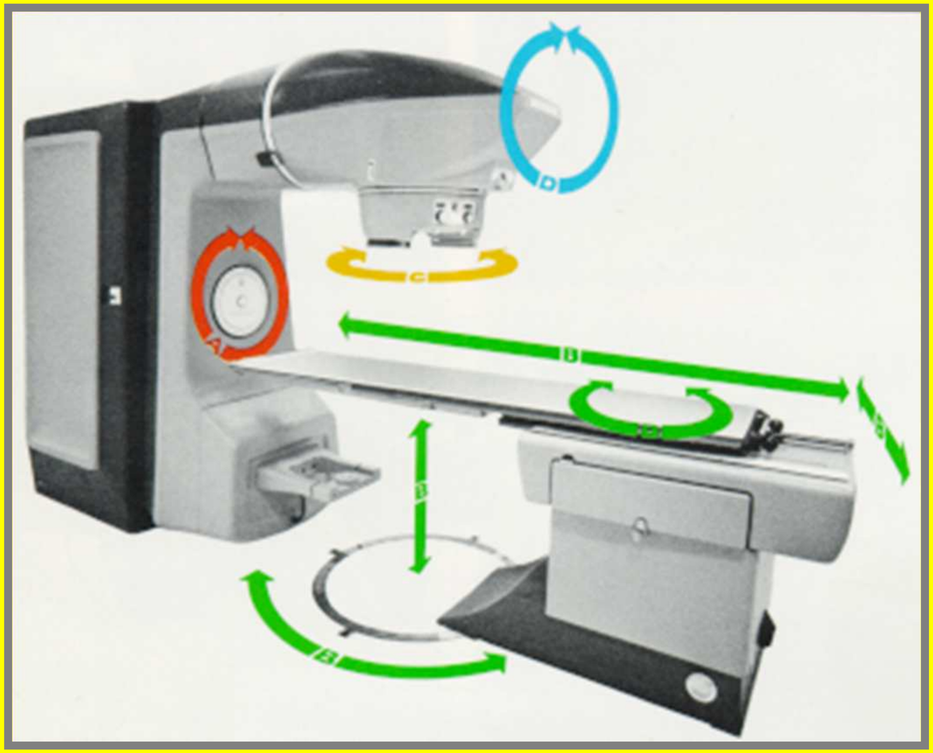
Conventional/conformal/IM

Brachytherapy

HE γ-rays
LE γ/x-rays
β-rays
Neutrons

Single source/multiple source
LDR/MDR/HDR

Telecobalt Units



Bhabhatron-II

- ✓0 X 0 Field size
- ✓ 3 X 3 Treatable Field
- ✓ Fully Computer Controlled
- ✓ Carbon Fiber Table Top
- ✓ Motorized Wedge
- ✓ Asymmetric Collimation
- ✓ Remote diagnosis
- ✓ Battery Backup

Beam Therapy Delivery Devices

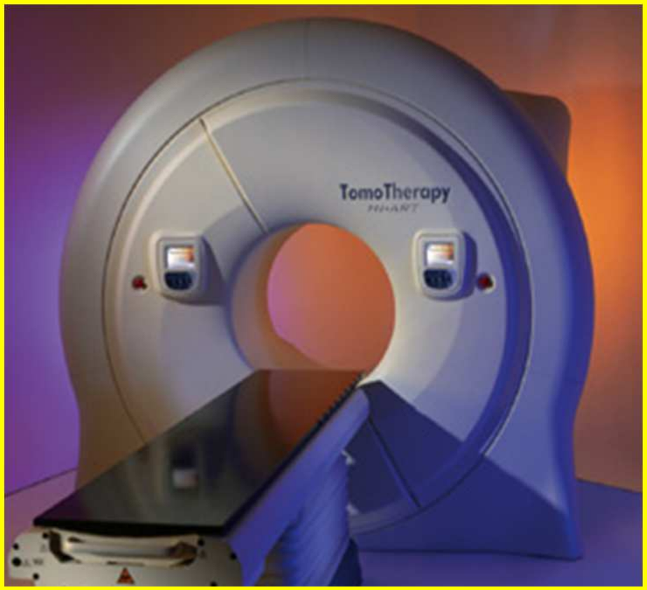

Gamma Knife


Conventional Linac


FFF LINAC


Hi-Tech Linac


Hi-Tech Linac



SRS by Gamma Knife

SRS by X-Knife

BRACHYTHERAPY

- **Clinical use of small encapsulated radioactive sources at a short distance from the target volume for treatment of malignant/benign tumours**
- **It plays an important role in the management of cancers of several anatomical sites**
- **Recently, there is a growing interest in using BT for reducing restenosis after treatment for vascular diseases.**

Brachytherapy Techniques

1

On the basis of <u>source placement</u>

- Interstitial
- Intracavitary
- Surface moulds
- Intraluminal
- Ocular
- Vascular

2

On the basis of <u>dose rate</u>

- LDR
- MDR
- HDR
- PDR

3

On the basis of <u>treatment duration</u>

- Temporary
- Permanent
- Implants

High Dose Rate Brachytherapy

- **HDR brachytherapy refers to a dose rate greater than**

0.2 Gy/min	**(ICRU 38, 1985)**
0.5 Gy/min	**(AAPM TG 56, 1997)**

- **In the past few decades, HDR brachytherapy has been developed as an alternative to LDR brachytherapy.**

BT Sources &Delivery Devices

γ Emitter	β Emitter
^{137}Cs	^{32}P
^{60}Co	$^{90}Sr/^{90}Y$
^{192}Ir	^{186}Re
^{125}I	^{188}Re
^{103}Pd	^{106}Ru

Integrated Brachytherapy Unit

Imaging and planning while the patient remains in the treatment position

Physical characteristics of commonly used γ emitting brachytherapy sources

Sources	$T_{1/2}$	Energy (MeV)		ERC Γ_x $Rcm^2h^{-1}mCi^{-1}$	AKRC Γ_k $\mu Gym^2h^{-1}MBq^{-1}$	HVL in Water (cm)	HVL in Pb (mm)
		Gamma	Beta				
Co-60	5.26 y	1.25	0.31	13.07	0.308	10.8	11.0
Cs-137	30 y	0.662	0.51-1.17	3.26	0.077	8.2	5.5
Ir-192	73.8 d	0.38 (0.14 -1.06)	0.67	4.69	0.111	6.3	2.5
I-125	59.4 d	0.028	-----	1.46	0.034	2.0	0.025
Pd-103	17 d	0.021	-----	1.48	0.035	1.0	0.008

Interaction of Photon & Electron Beams

- **Interaction of x-rays & gamma rays with matter**
  - **- Photoelectric interaction**
  - **- Compton interaction (scattering)**
  - **- Pair production**

- **Interaction of beta rays (electrons) with matter**
  - **- Interaction with atomic electrons**
  - **- Interaction with atomic nuclei**

Photon Beams: General Description

- **All photon beams used for external beam therapy are characterized by the same physical parameters irrespective of their origin, means of production and energy;**

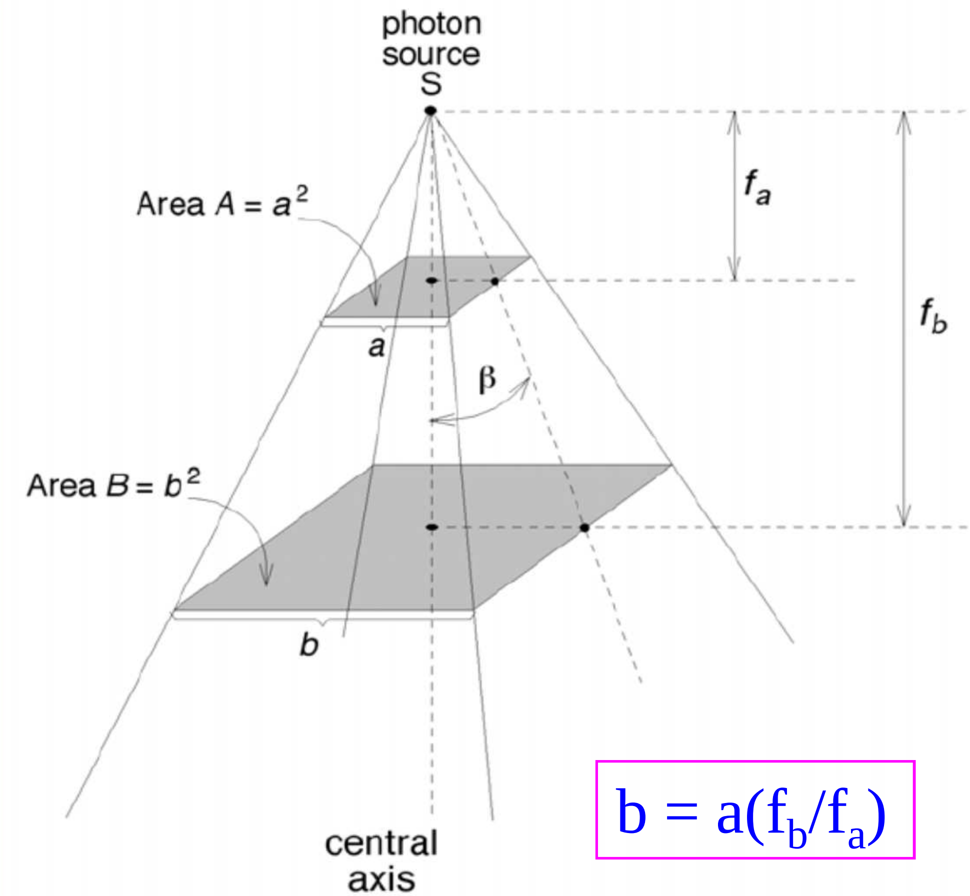
- **Physical parameters used to describe photon beams are:**

  Photon fluence and fluence rate
  Energy fluence and fluence rate
  Dose rate in a given condition, etc.

Inverse Square Law & Beam Divergence

- **Photon beam sources are assumed to be point sources**

- **Beams produced are divergent**



$$b = a(f_b/f_a)$$

Passage of Photon Beam Through a Medium

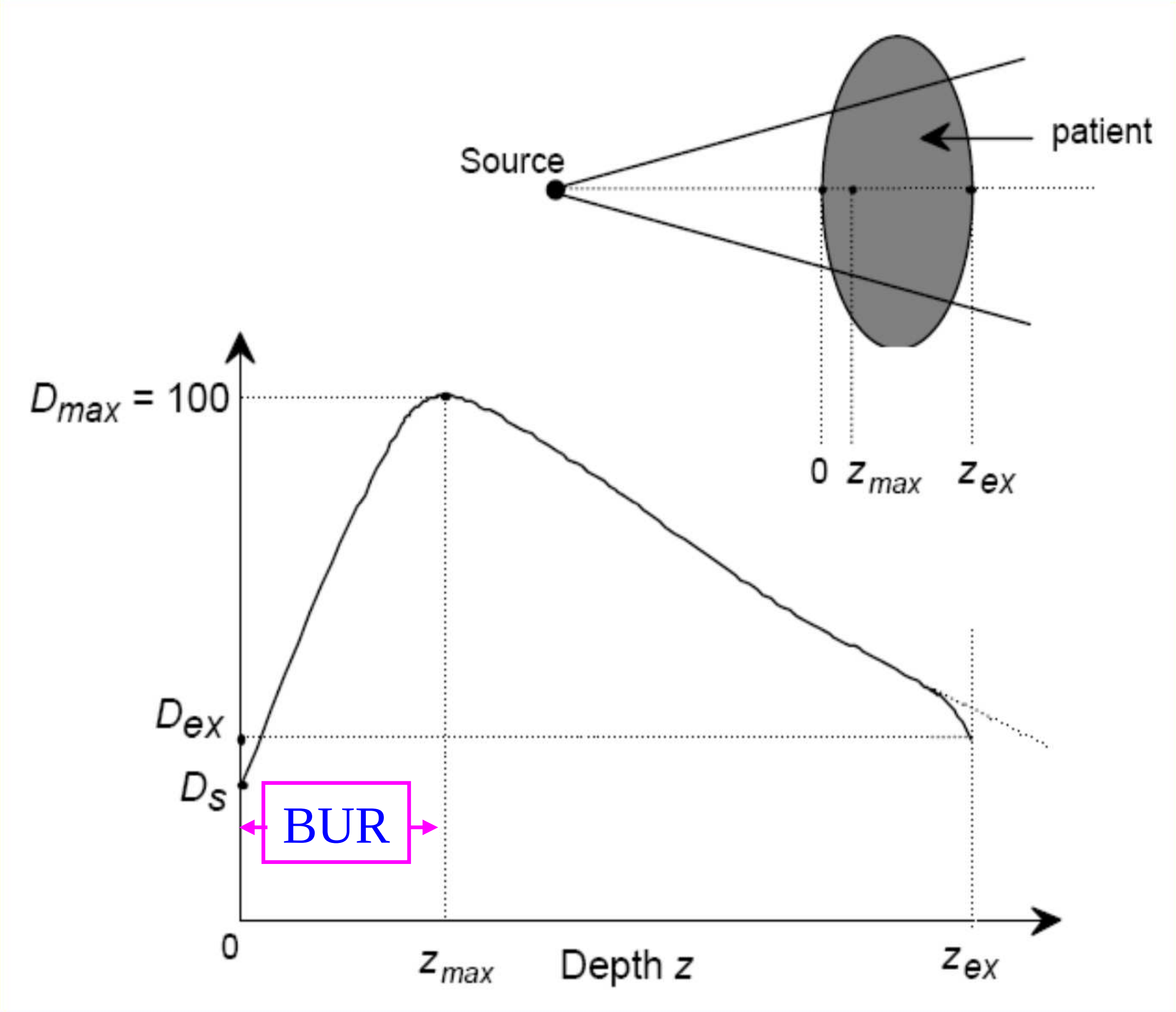
Z_{max} = depth of dose maximum (d_m)

D_{max} = Dose maximum

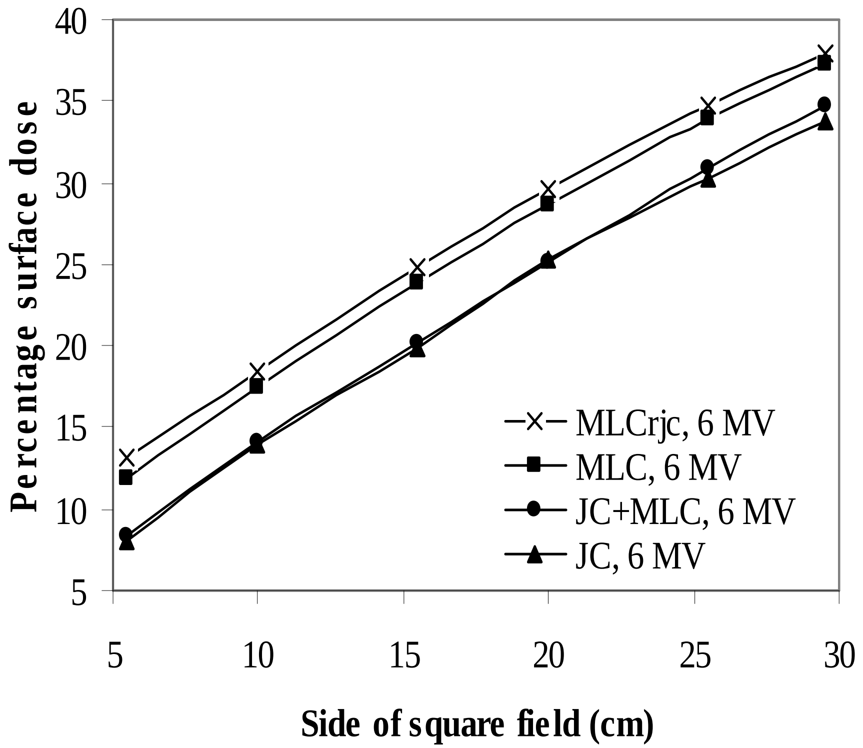
Z_{ex} = depth at exit surface (d_{ex})

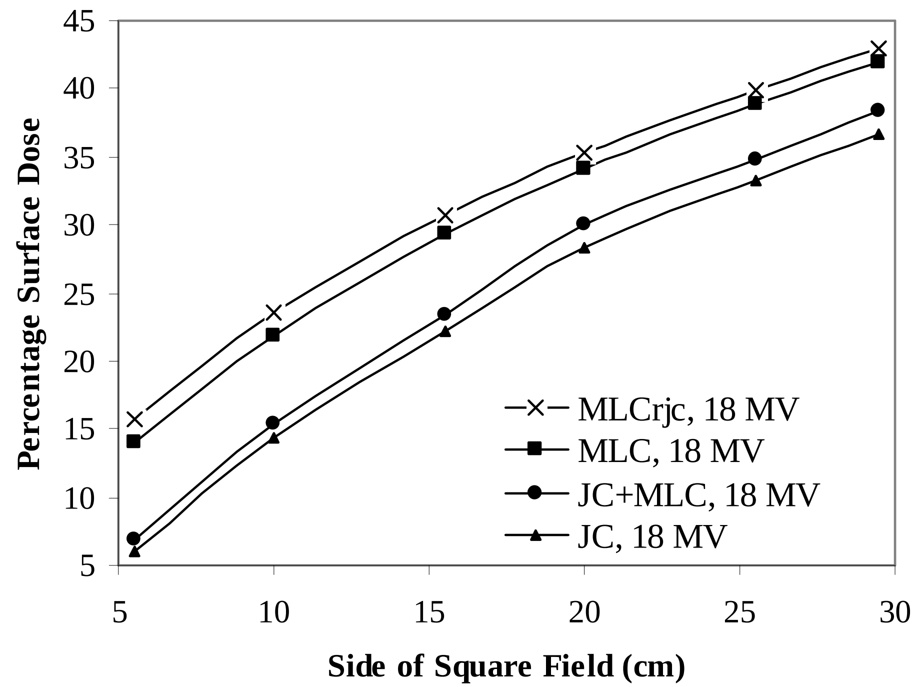
D_{ex} = Exit dose

D_s = Surface dose



Percent Surface Dose of 6 & 18 MV X-rays



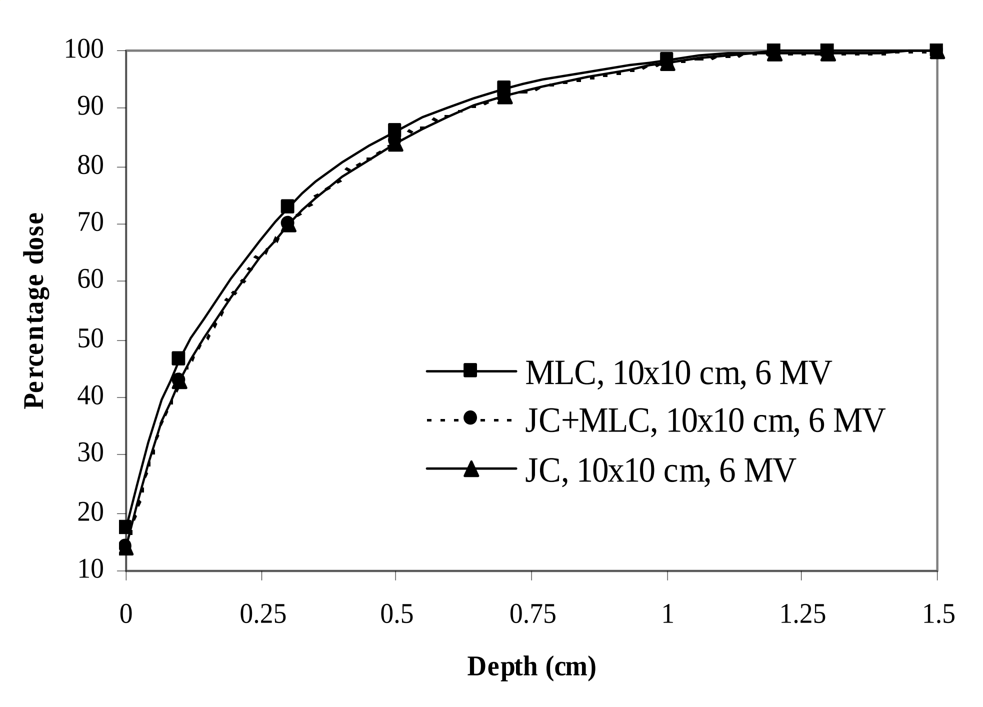


Scattered photons from - collimator, flattening filter and air

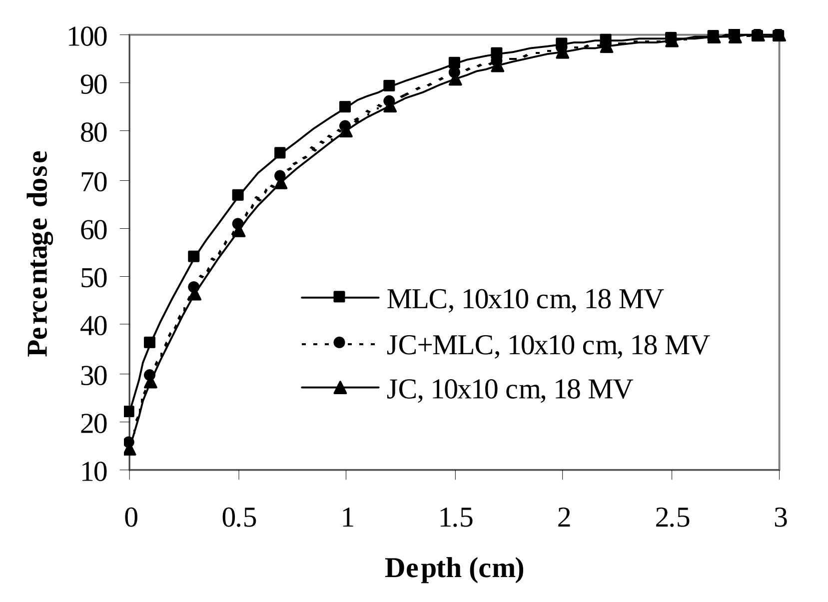
Back scattered photons

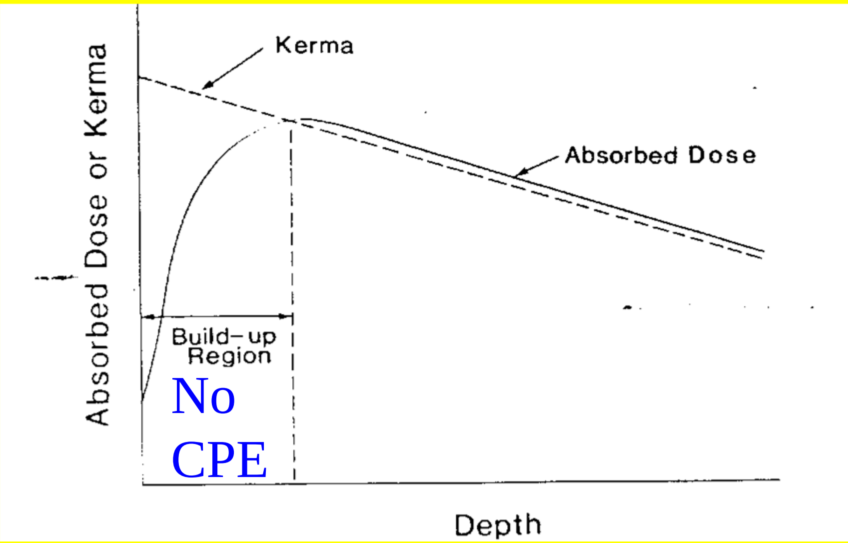
Secondary electrons - collimator, air & phantom/ patient

Build Up Region: 6 & 18 MV X-rays



(Due to long range of secondary electrons produced by photons)





Depth of dose maximum (d_m) and D_{ex}

d_m depends on:

Beam energy & Field size

- dependence on beam energy is more pronounced

D_{ex}

Dose at exit surface

Depends on beam energy

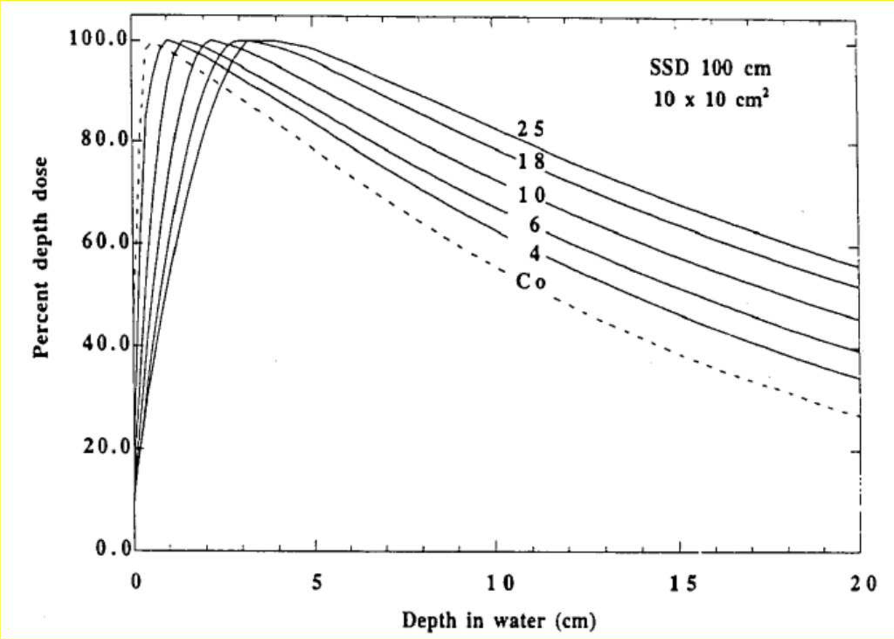
Beam	d_m (cm)
Co-60	0.5
4 MV	1.0
6 MV	1.5
10 MV	2.5
15 MV	3.0
18 MV	3.5

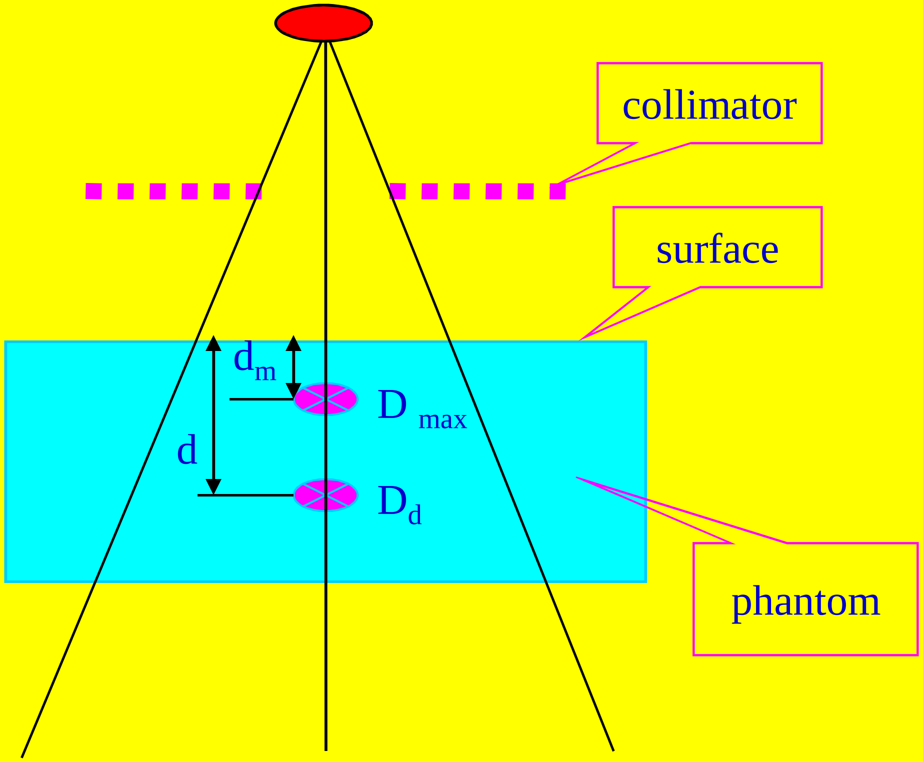
Percentage Depth Dose (PDD)

$$P = \frac{D_d}{D_{d_0}} \times 100$$

$d_0 = d_m$

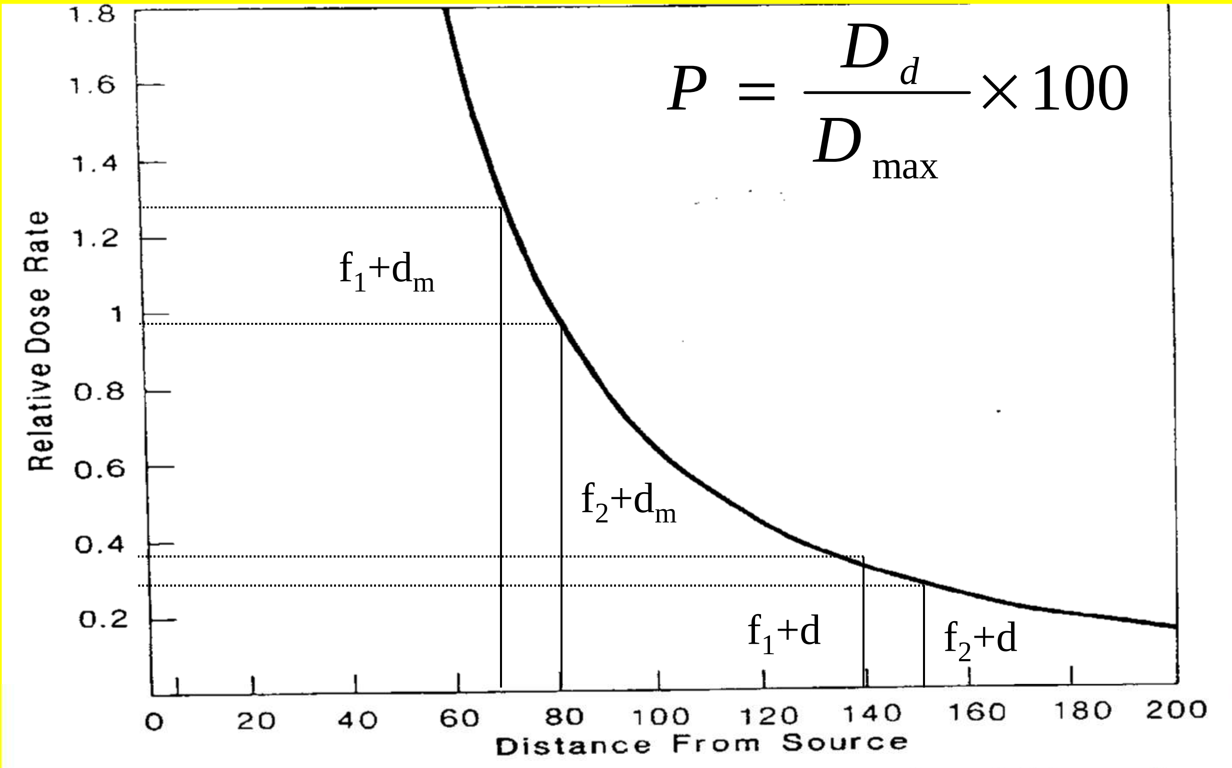
$$P = \frac{D_d}{D_{max}} \times 100$$

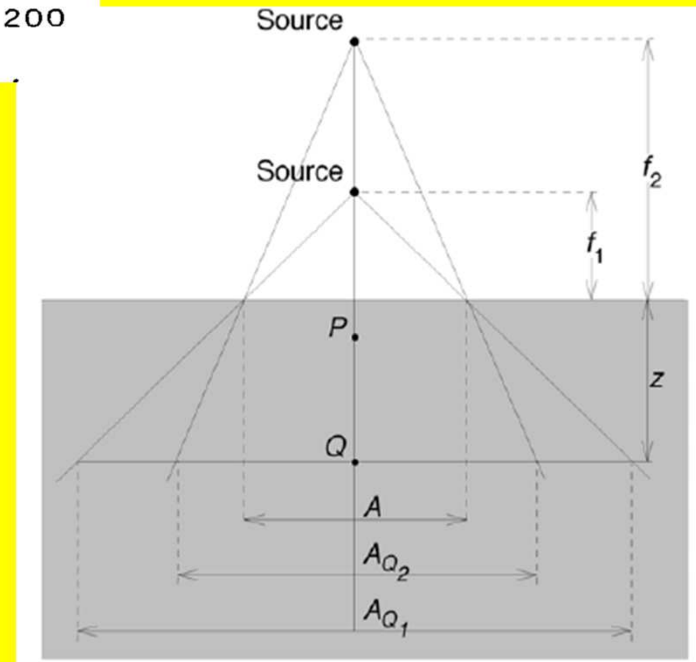




PDD: Dependence on SSD

$$P = \frac{D_d}{D_{max}} \times 100$$





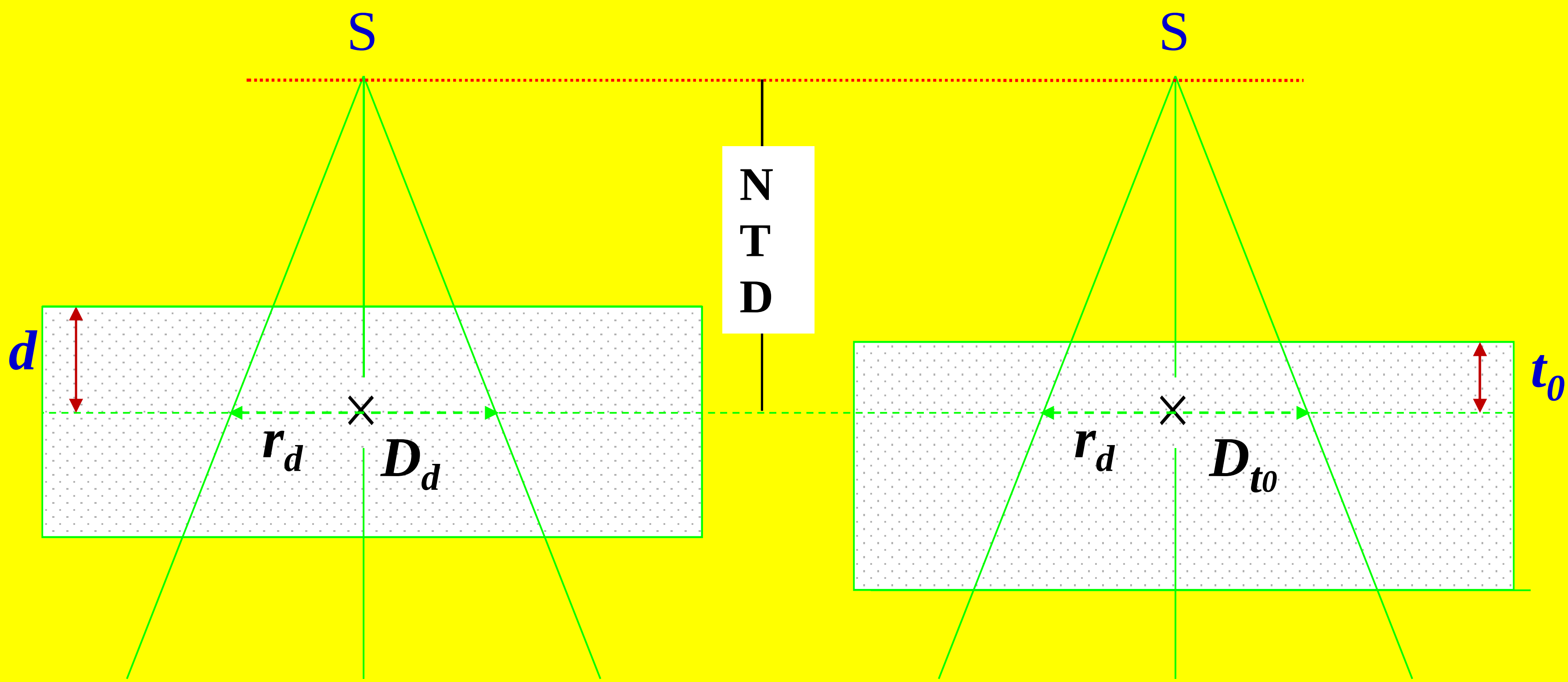
$$F = \left(\frac{f_2 + d_m}{f_1 + d_m}\right)^2 \times \left(\frac{f_1 + d}{f_2 + d}\right)^2$$

TPR and TMR

$$TPR(d, r_d) = \frac{D_d}{D_{t0}}$$

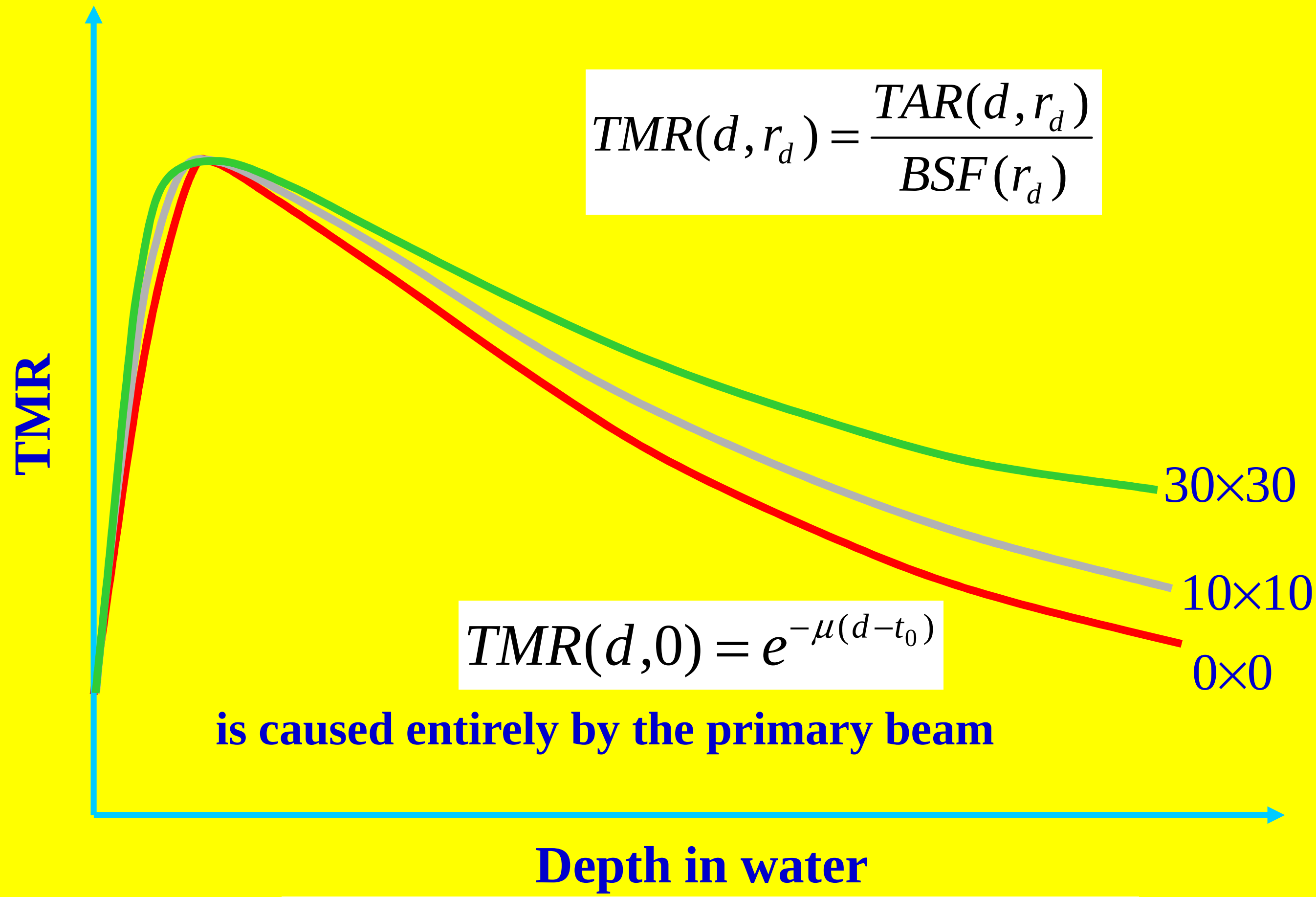
For TPR, $t_0 = d_{10}$

For TMR, $t_0 = dm$



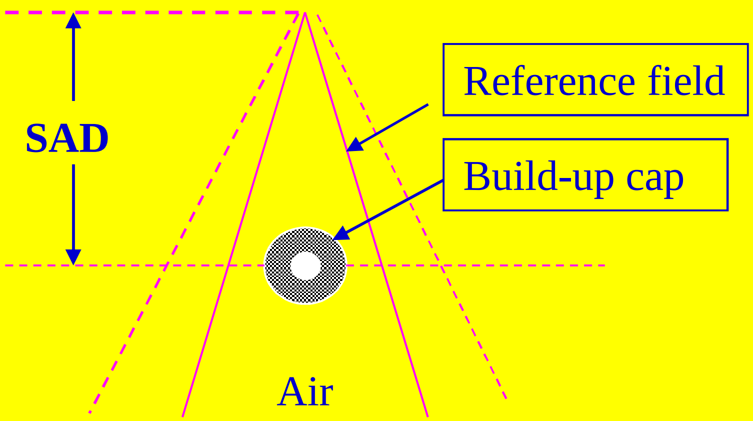
Properties of TMR

TMR is independent of SSD, increases with energy and field size.

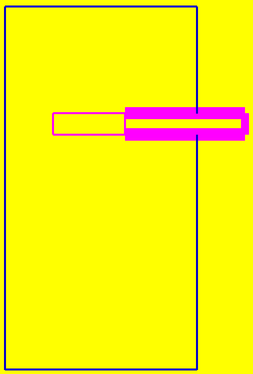


TMR data for 10 MV x-ray beams

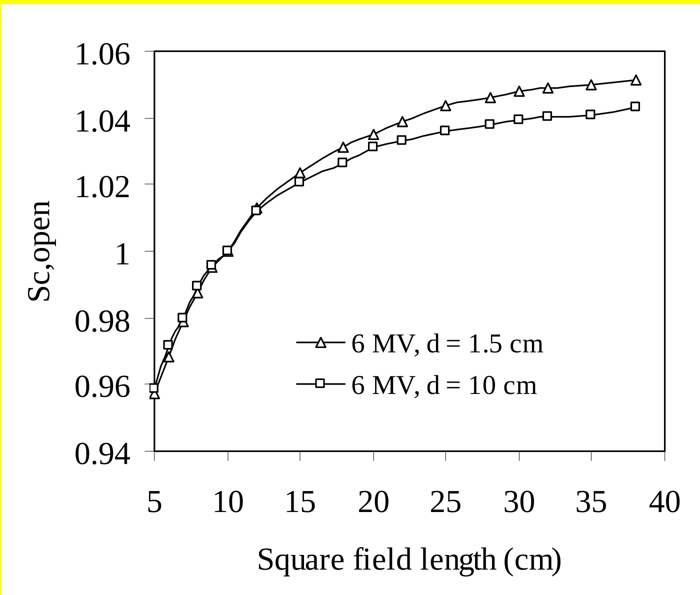
Collimator Scatter Factor (S_c)

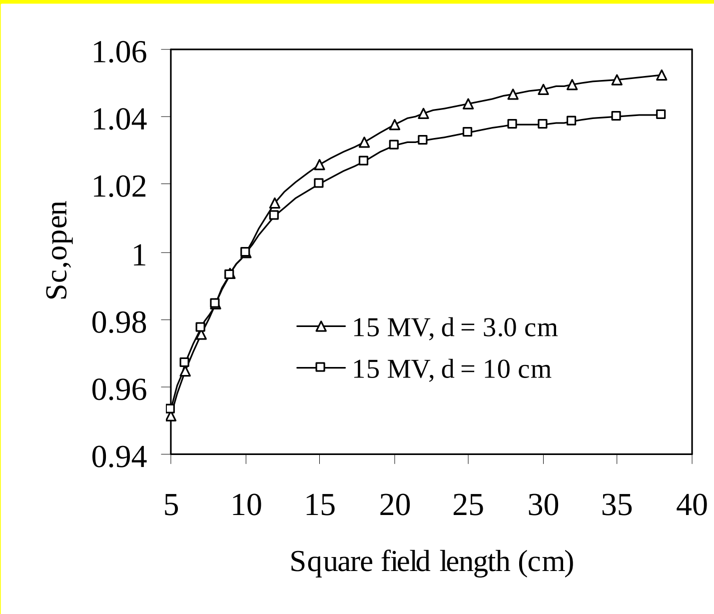


$$S_c = D(r)/ D(10)$$



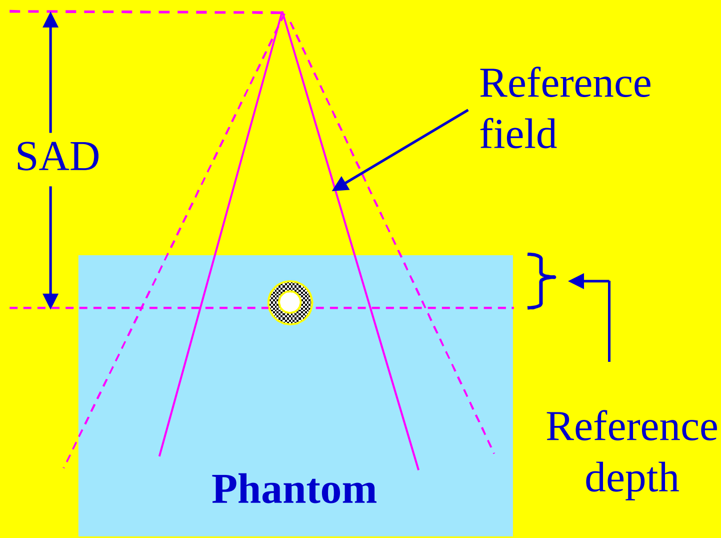
Mini phantom

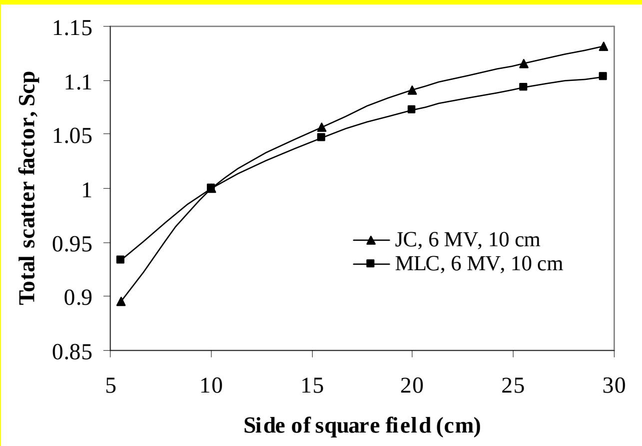


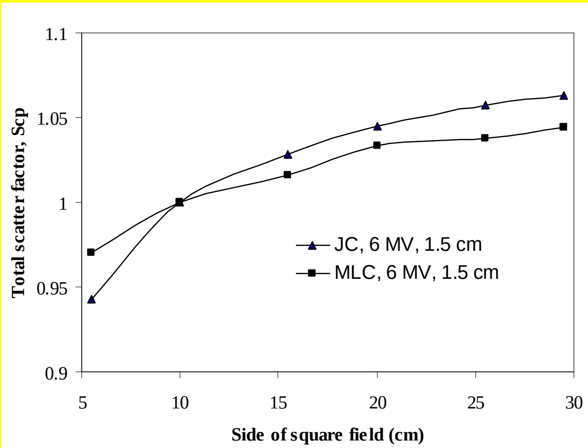


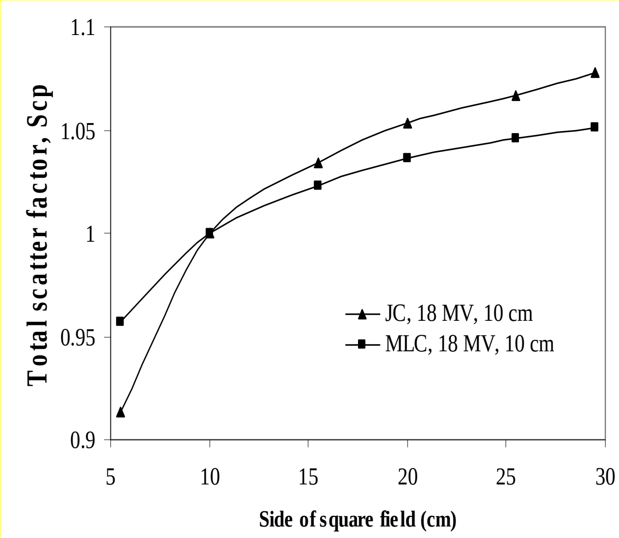
Phantom Scatter Factor (S_p)

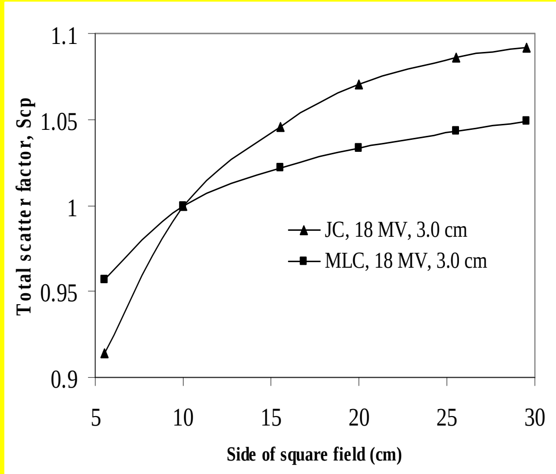
$$S_p = \frac{S_{c,p}(r)}{S_c(r)}$$





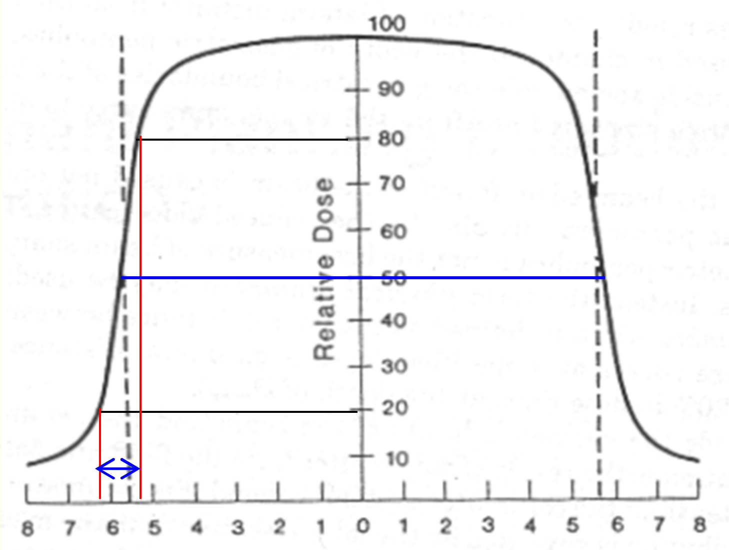


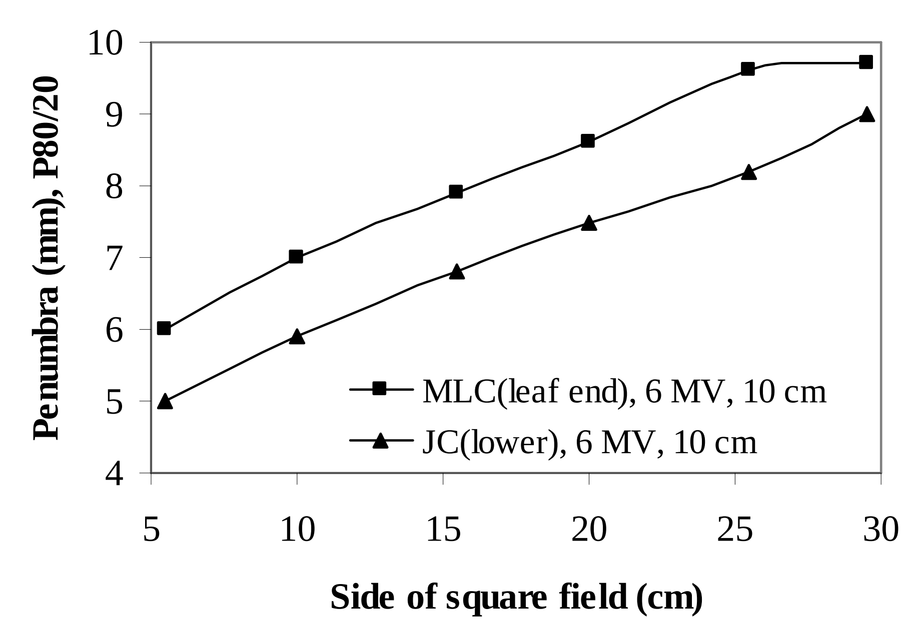


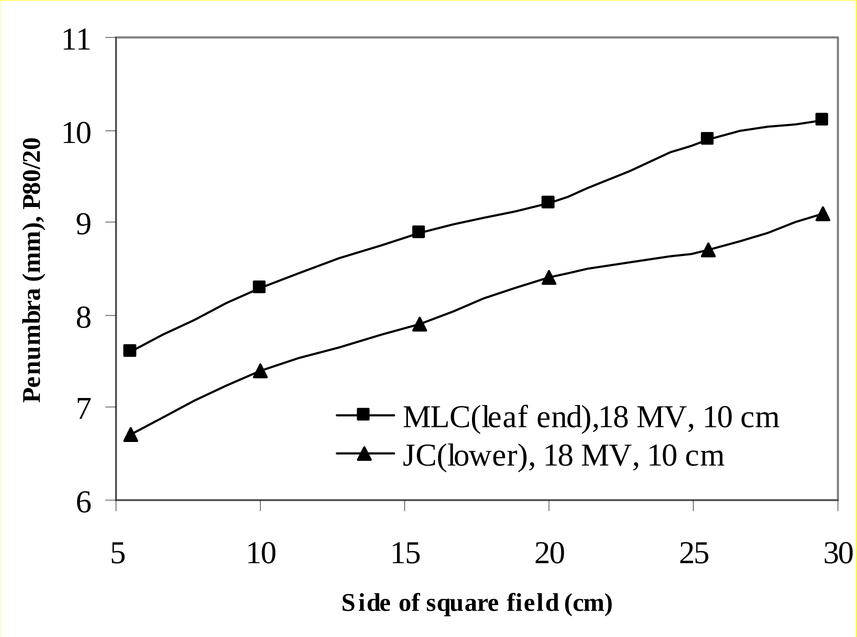


Photon Beam Penumbra

6 & 18 MV X-rays



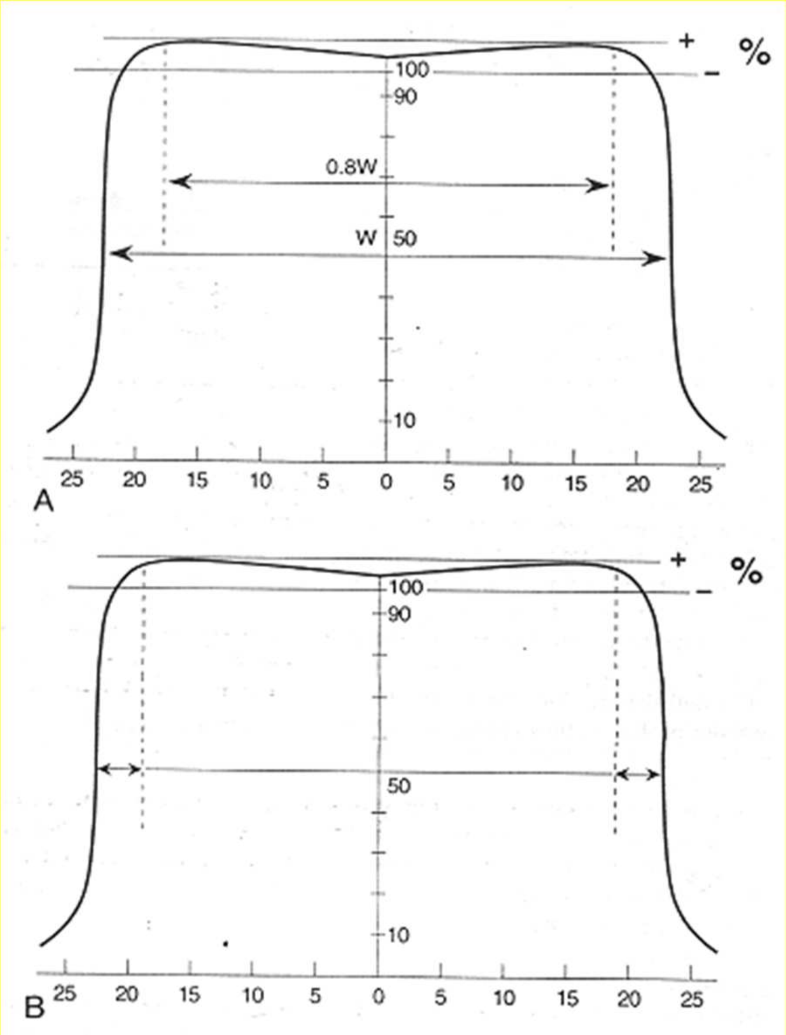




Photon Beam: Flatness and Symmetry

- Flatness
  - within ±3% over 80% of the field
- Symmetry
  - within ± 2% over 80% of the field

$$S = 100 \times \frac{(area_{\text{left}} - area_{\text{right}})}{(area_{\text{left}} + area_{\text{right}})}$$



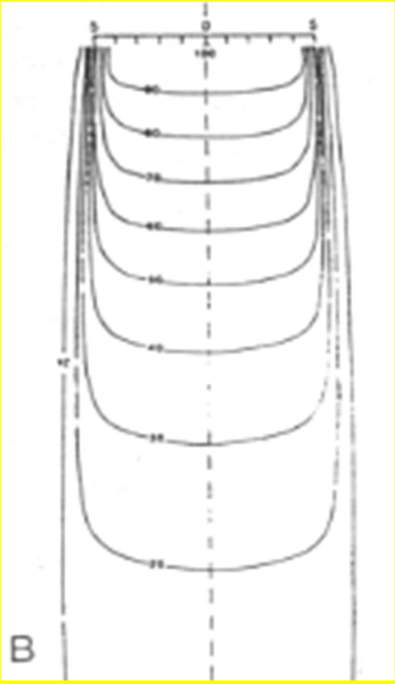
Photon Beam: Isodose Chart

Beam quality

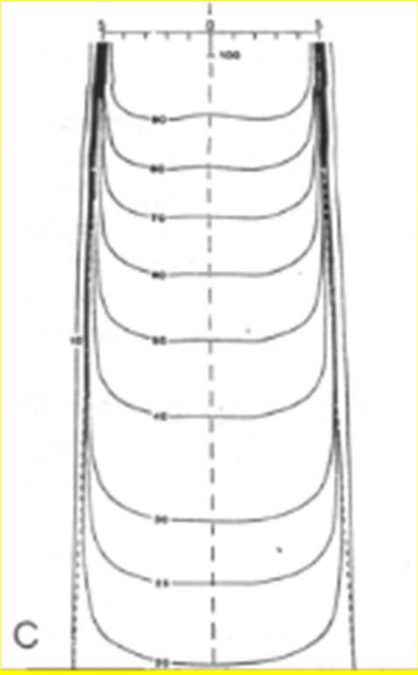
Source size, SSD, and SDD

Collimation and flattening filter

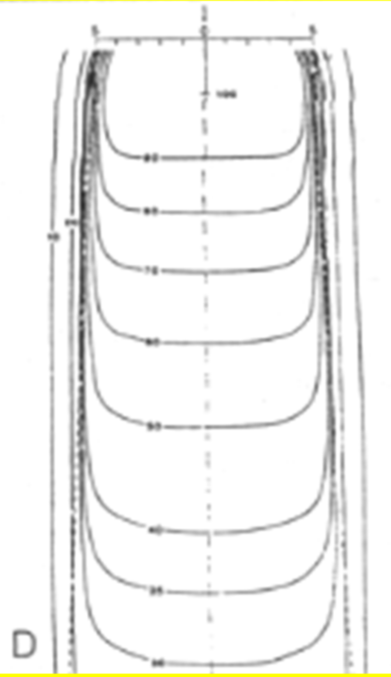
Field size



^{60}Co, SSD = 80 cm



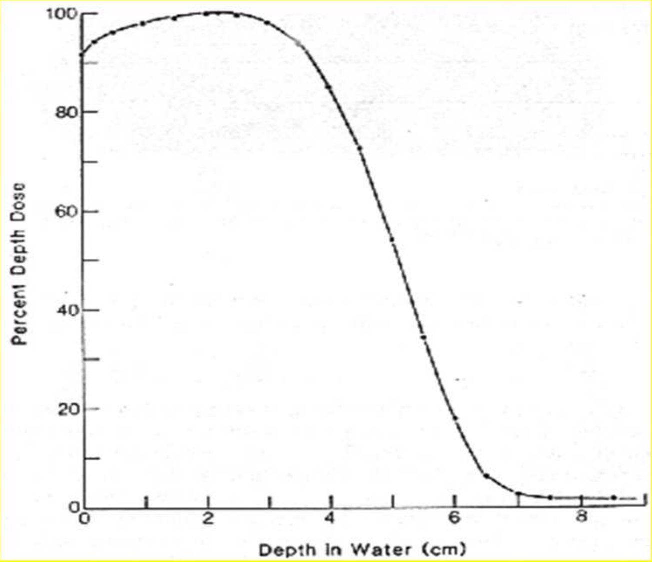
4 MV, SSD =100 cm

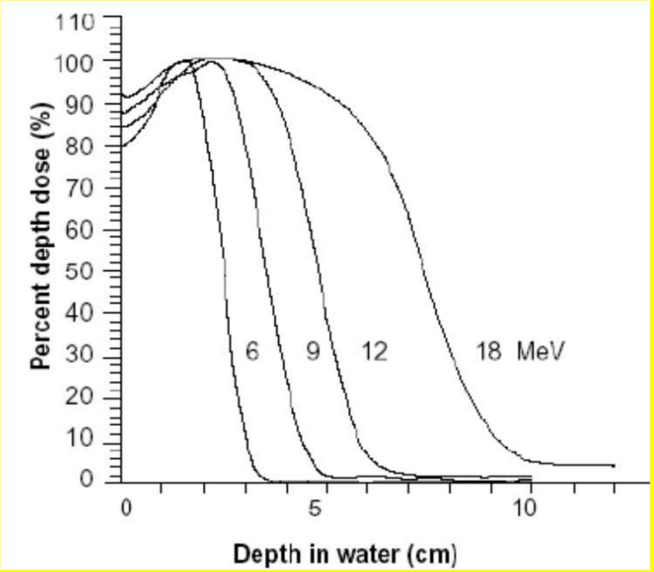


10 MV, SSD =100 cm

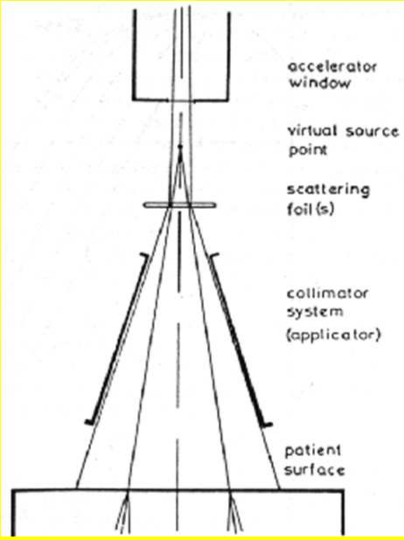
Electron Beam: CADD Curves

- **Rapid dose fall i.e. very high gradient (G)**
- **X-ray contamination (0.5 – 5%)**
- **90% → E/4 cm   80% → E/3 cm**
- **D_{max} does not follow a linear relationship with energy; depends on machine design and accessories**
- **The percent surface dose for electrons increases with energy.**
- **In clinical practice, isodose distributions for an individual machine, cone, and/or field size is required.**



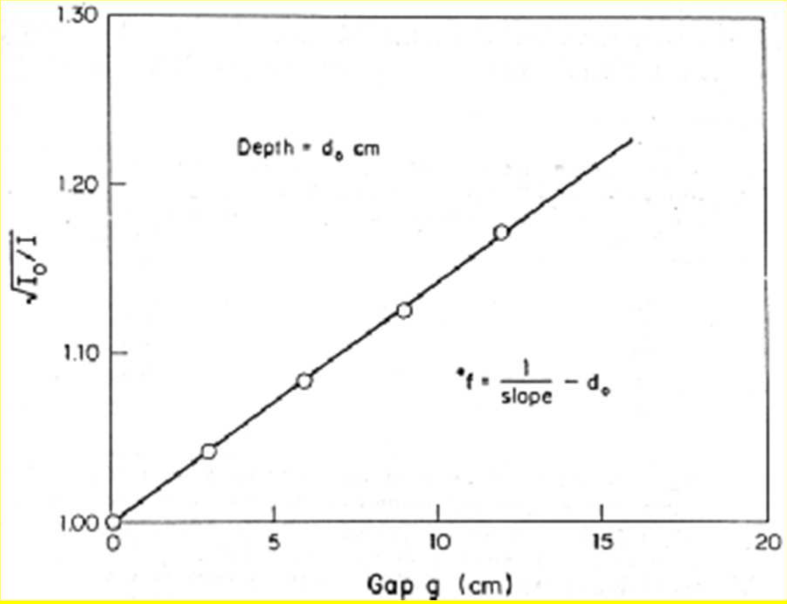


Electron Beam: Inverse Square Law (ISL)
Virtual Source Position - Effective SSD



$$\frac{I_0}{I_g} = \left(\frac{f + d_m + g}{f + d_m}\right)^2$$

$$\sqrt{\frac{I_0}{I_g}} = \frac{g}{f + d_m} + 1$$



SSD_{eff} : distance between virtual source position to isocentre

SSD_{eff} : Function of beam energy and field size

ISL can be used to correct absorbed dose for small variations in air gaps between the patient surface and the applicator

Electron Beam: Range and Energy

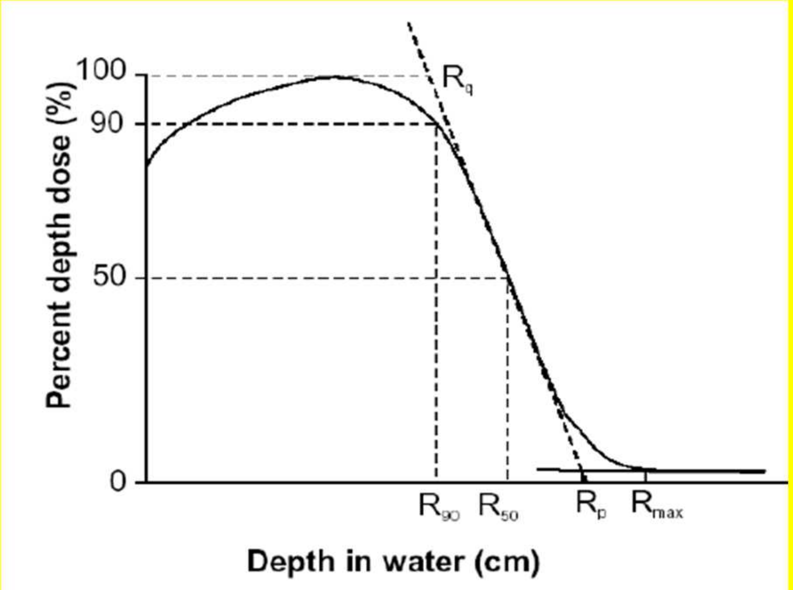
$$G = R_p / (R_p - R_q)$$

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

$$\bar{E}_o = C\, R_{50}$$

C = 2.33 MeV cm^{-1}

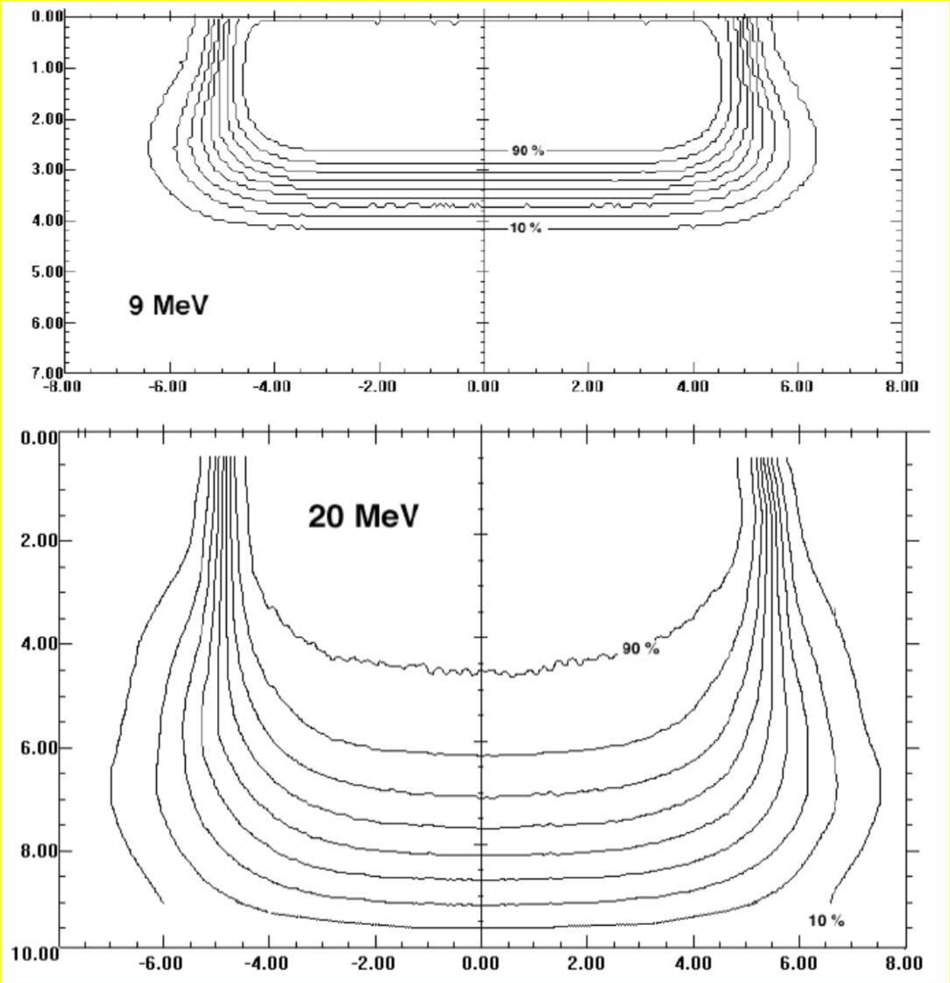
$$\bar{E}_z = \bar{E}_o\, (1 - z / R_p)$$



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

Electron Beam: Isodose Curves

- **Depends on the energy, field size, and collimation**
- **For the low-energy beams**
  - **All the isodose curves show some expansion**
- **For the higher energies**
  - **Only the low dose levels bulge out**
  - **Higher isodose levels tend to lateral constriction, which becomes worse with decreasing field size.**



Calibration of Therapy Beams

Co-60 Gamma rays: 1.25 MeV

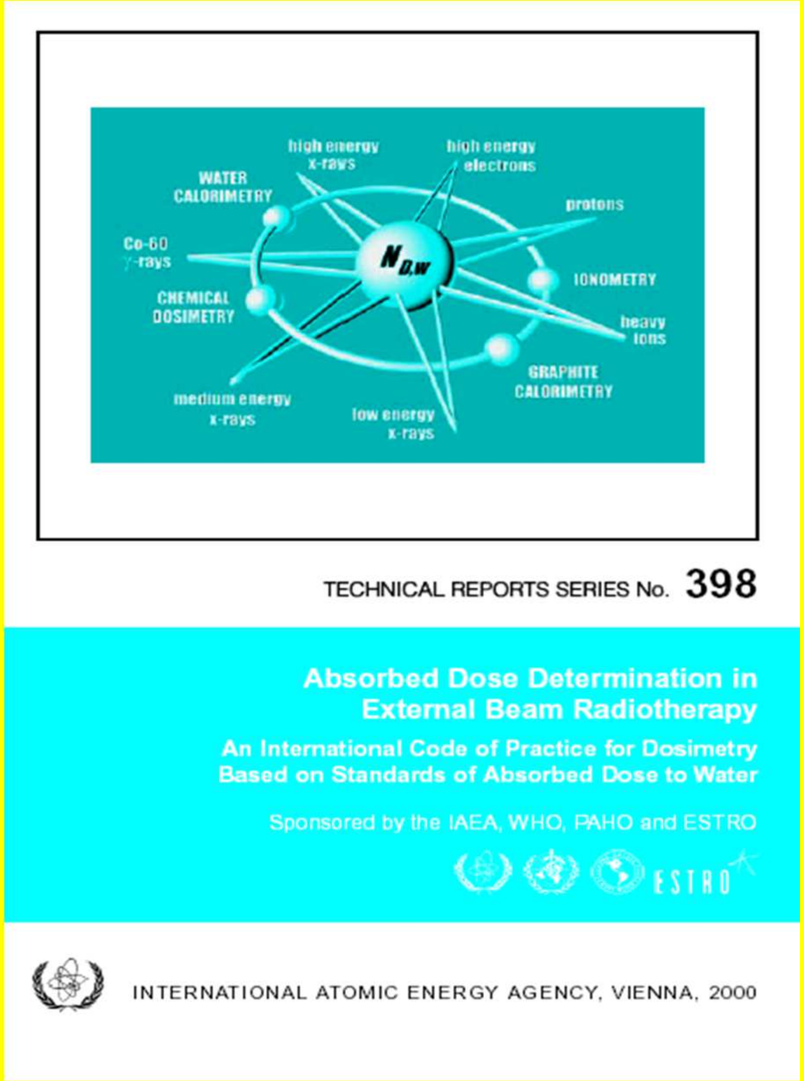
High Energy X-rays: 4, 6, 10, 15, 18 MV

High Energy electrons: 4 - 22 MeV

Proton Beams: All energies

Protocol: IAEA TRS-398

Dosimeter: Ionization chambers



$N_{D,w}$ BASED FORMALISM

The absorbed dose to water at the reference depth z_{ref} in water for a reference beam of quality Q_o and in the absence of the ionisation chamber is given by

$$D_{w,Qo} = M_{Qo} N_{D,w,Qo} \quad (1)$$

where,

M_{Q0} = dosimeter reading under reference conditions (Practical conditions - same as standards lab)

$N_{D,w,Qo}$ = absorbed dose to water calibration factor of the dosimeter obtained from standards laboratory

However, other than reference beam quality

$$D_{w,Q} = M_Q N_{D,w,Qo} k_{Q,Qo} \quad (2)$$

$k_{Q,Qo}$ = beam quality correction factor (BQCF)

General Practical Considerations

- ♠ Chamber sleeve : PMMA, Wall thickness ≤ 1.0 mm; Air gap: 0.1- 0.3 mm
  - ∗ sleeve should not be left in water longer than is necessary to carry out the measurements
  - ∗ The use of a thin rubber sheath is not recommended,
- ♠ Verify stability of the dosimeter system using a check source
- ♠ Enough time should be allowed for the dosimeter to reach thermal equilibrium
- ♠ Mains powered electrometers should be switched on at least two hours before use to allow stabilisation
- ♠ Pre-irradiate the ionisation chamber with 2 - 5 Gy to achieve charge equilibrium in the different materials
- ♠ Operate the measuring system under stable conditions whenever the polarity or polarising voltage are modified
- ♠ Measure the leakage current before and after irradiation(< 0.1%)

Evaluation of Influence Quantities

♠ **Atmospheric variations :**

$$k_{TP} = \frac{(273.2 + T)}{(273.2 + T_o)} \frac{P_o}{P}$$

∗ **No correction for humidity, if $N_{D,w}$ is referred to a relative humidity (RH) of 50% and is used in 20 - 80% of RH**

∗ **If $N_{D,w}$ is referred to dry air, apply k_h = 0. 997 (Q_o = ^{60}Co)**

♠ **Polarity effect (k_{pol}) : true reading is taken to be the mean of the absolute values of readings taken at both polarities**

For routine use of a single potential and polarity

$$k_{pol} = \frac{|M_+| + |M_-|}{2M}$$

Where,

M = electrometer reading obtained with the polarity used routinely (+ or -)

⇒ **For most chamber types, k_{pol} is negligible for photon beams**

Evaluation of Influence Quantities

♠ **Ion Recombination(k_s): (two voltage method)**

For pulsed beams (Linac X-rays and electrons),

(Based on linear dependence of 1/*M* on 1/*V*)

$$k_s = a_o + a_1\left(\frac{M_1}{M_2}\right) + a_2\left(\frac{M_1}{M_2}\right)^2$$

Where,

M_1 = electrometer reading at polarising voltage V_1 (Normal Voltage)

M_2 = electrometer reading at polarising voltage V_2 (Lower Voltage)

(M_1 and M_2 are corrected for k_{pol} at their respective voltages)

a_0, a_1 and a_2 = quadratic fit co-efficients

Ideally, $V_1/V_2 = 3$

Evaluation of Influence Quantities

V_1/V_2	Pulsed			Pulsed–scanned		
	a_o	a_1	a_2	a_o	a_1	a_2
2.0	2.337	–3.636	2.299	4.711	–8.242	4.533
2.5	1.474	–1.587	1.114	2.719	–3.977	2.261
3.0	1.198	–0.875	0.677	2.001	–2.402	1.404
3.5	1.080	–0.542	0.463	1.665	–1.647	0.984
4.0	1.022	–0.363	0.341	1.468	–1.200	0.734
5.0	0.975	–0.188	0.214	1.279	–0.750	0.474

For continuous radiation (^{60}Co gamma rays),

(Based on linear dependence of 1/M on $1/V^2$)

$$k_s = \frac{(V_1/V_2)^2 - 1}{(V_1/V_2)^2 - (M_1/M_2)}$$

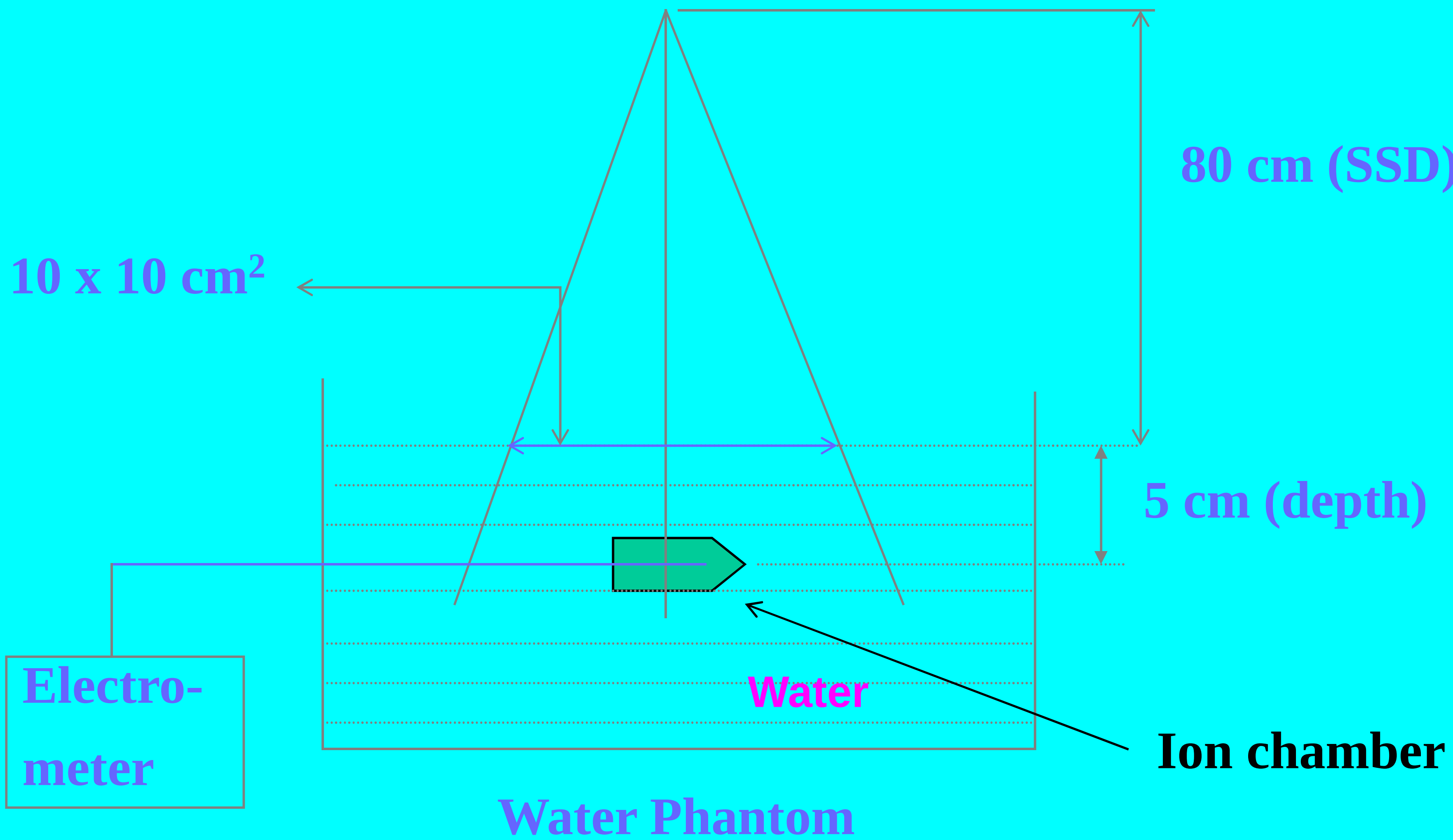
^{60}C0 γ-Rays :Reference Dosimetry

Reference Conditions

Influence quantity	Reference value/characteristics
Phantom material	Water
Chamber type	Cylindrical or plane parallel (PP)
Measurement depth, z_{ref}	5 or 10 g/cm^2
Reference point of the chamber	For cylindrical chambers, on the central axis at the centre of the cavity volume. For pp chambers, on inner surface of the window at its centre
Position of the reference point of the chamber	At the measurement depth z_{ref}
SSD or SCD	80/100 cm
Field size	10 cm × 10 cm

^{60}C0 γ-Rays :Reference Dosimetry

Experimental Set-up : SSD



^{60}C0 γ-Rays :Reference Dosimetry

The absorbed dose to water at z_{ref} in water, in the user ^{60}Co beam and in the absence of the chamber

$$D_w\,(z_{ref}) = MN_{D,w} \quad \text{Gy/min}$$

where,

M = reading of the dosimeter corrected for temperature and pressure, electrometer calibration, polarity effect, ion recombination and timer error

$$= M_{unc}k_{TP}k_{elec}k_{pol}k_s/(t \pm \delta t)$$

t = time of irradiation (min)

Absorbed dose at z_{max} :

For SSD Set-up, $D_w\,(z_{max}) = D_w\,(z_{ref}) \times 100/PDD(z_{ref})$

For SAD Set-up, $D_w\,(z_{max}) = D_w\,(z_{ref})/TMR(z_{ref})$

^{60}C0 γ-Rays : Uncertainty $D_W(z_{ref})$

Physical quantity/ procedure	Rel. Std. uncertainty (%) - typical value	
$N_{D,w}$ calibration of secondary standard at PSDL	0.5	(A1)
Long term stability of secondary standard	0.1	(A2)
$N_{D,w}$ calibration of user dosimeter at SSDL	0.4	(A3)
Combined uncertainty in $N_{D,w}$ calibration of user dosimeter at SSDL (quadrature sum of A1 to A3)	**0.6**	**(A)**
Long term stability of user dosimeter	0.3	(B1)
Establishment of reference conditions	0.5	(B2)
Dosimeter reading relative to timer	0.1	(B3)
Correction for influence quantities	0.3	(B4)
Combined uncertainty in D_w measurement by the user (quadrature sum of B1 to B4)	**0.6**	**(B)**
Combined standard uncertainty in $D_w(z_{ref})$ determination (quadrature sum of A and B)	**0.9**	

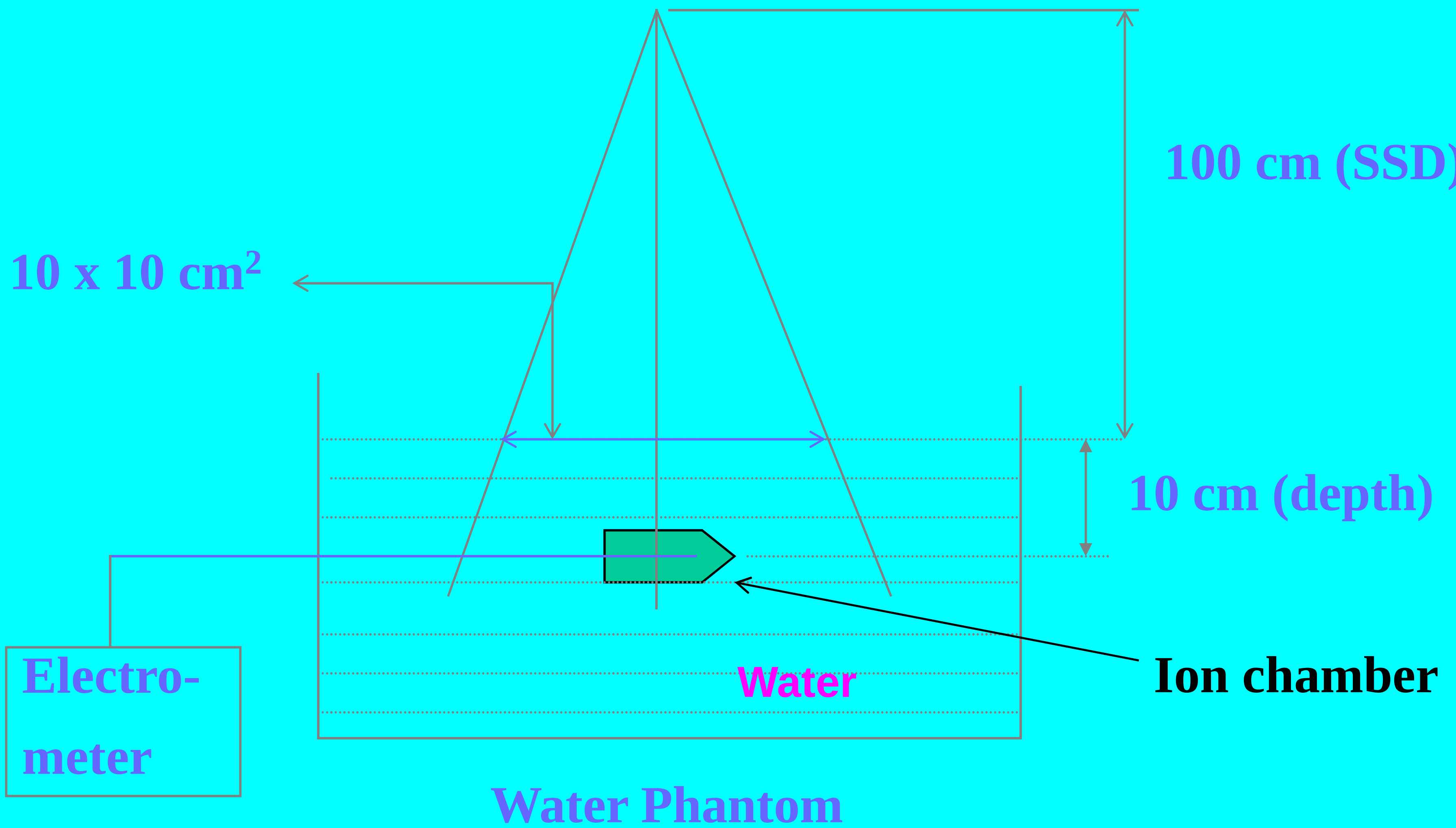
High E X-rays: Reference Dosimetry

Reference Conditions

Influence quantity	Reference value/characteristics
Phantom material	Water
Chamber type	Cylindrical
Measurement depth z_{ref}	For TPR^{20}_{10} < 0. 7, 10 (or 5) g/cm^2 For TPR^{20}_{10} = 0. 7, 10 g/cm^2
Reference point of the chamber	On the central axis at the centre of the cavity volume
Position of the reference point of the chamber	At the measurement depth z_{ref}
SSD/SCD	100 cm
Field size	10 cm × 10 cm

High E X-rays: Reference Dosimetry

Experimental Set-up : SSD

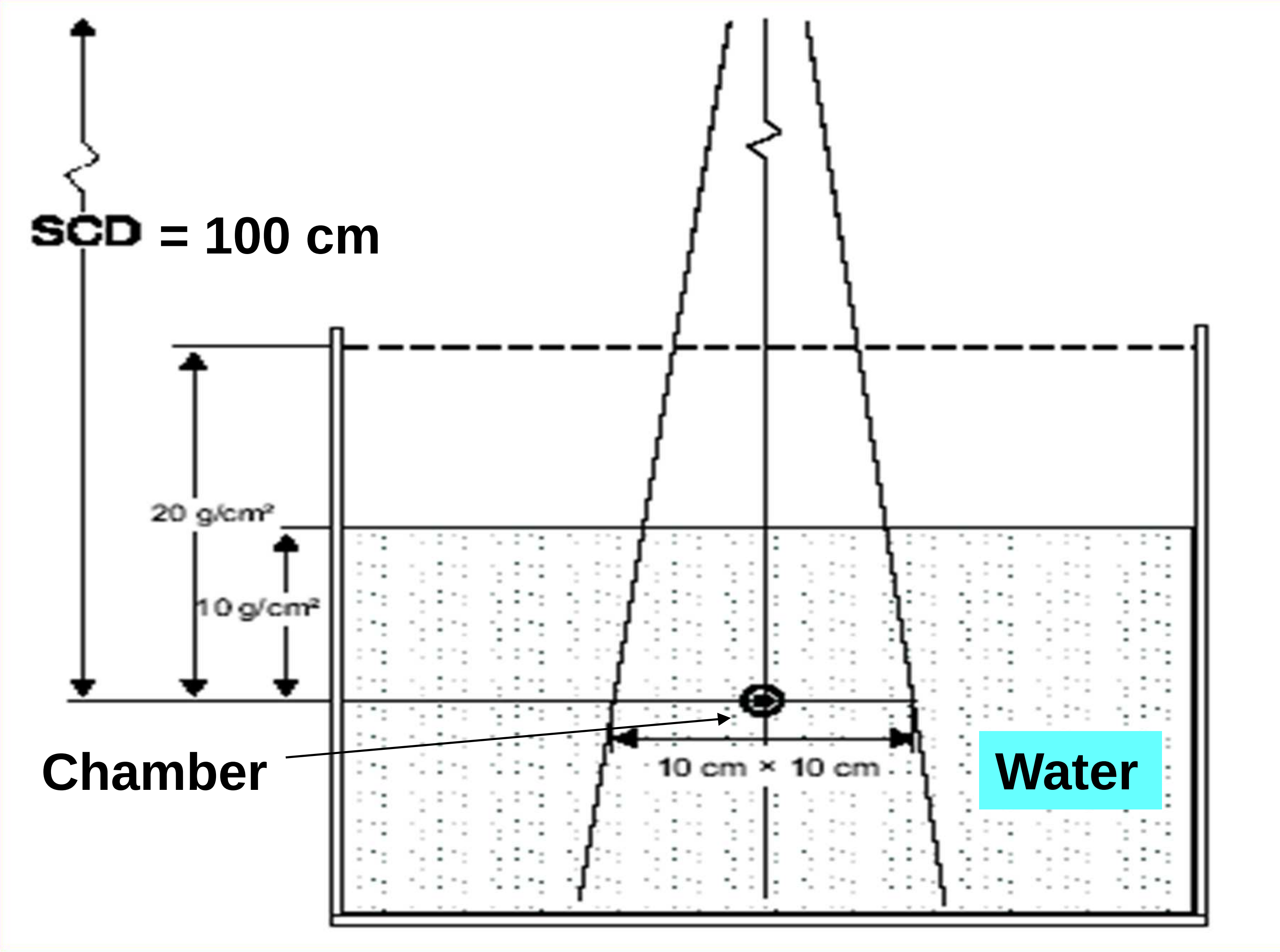


High E X-rays: Measurement of QI (TPR^{20}_{10})

Reference Conditions

Influence quantity	Reference value/characteristics
Phantom material	**Water**
Chamber type	**Cylindrical or plane parallel (PP)**
Measurement depths	**20 and 10 g/cm^2**
Reference point of the chamber	**For cylindrical chambers, on the central axis at the centre of the cavity volume. For PP chambers, on the inner surface of the window at its centre**
Position of the reference point of the chamber	**At the measurement depths**
SCD	**100 cm**
Field size at SCD	**10 cm × 10 cm**

Experimental Set-up for QI



High E X-rays: Reference Dosimetry

Absorbed dose to water at the reference depth z_{ref}

$$D_{w,Q}(z_{ref}) = M_Q\, N_{D,w}\, k_Q \qquad \text{Gy/MU}$$

$M_Q = M_{unc} k_{TP} k_{elec} k_{pol} k_s$ = Corrected Electrometer reading

Absorbed Dose to water at z_{max}

$$D_{w,Q}(z_{max}) = 100\, D_{w,Q}(z_{ref})/PDD\,(z_{ref}) \qquad \text{Gy/MU - SSD}$$

$$D_{w,Q}(z_{max}) = 100\, D_{w,Q}(z_{ref})/TMR\,(z_{ref}) \qquad \text{Gy/MU - SAD}$$

High Energy X-rays : Uncertainty $D_{W,Q}(z_{ref})$

Physical quantity/ procedure	Rel. Std. uncertainty (%) - typical value	
$N_{D,w}$ calibration of user dosimeter at SSDL	**0.6**	**(A)**
Long term stability of user dosimeter	0.3	(B1)
Establishment of reference conditions	0.4	(B2)
Dosimeter reading relative to monitor chamber	0.6	(B3)
Correction for influence quantities	0.4	(B4)
Beam quality correction factor, k_Q (calculated value)	1.0	(B5)
Combined uncertainty in D_w measurement by the user (quadrature sum of B1 to B5)	**1.4**	**(B)**
Combined standard uncertainty of $D_{w,Q}(z_{ref})$ determination (quadrature sum of A and B)	**1.5**	

Uncertainty of $D_{W,Q}(z_{max})$ can be estimated by including uncertainty of PDD/ TMR

Calibration of High Energy Electrons

Reference Conditions

Influence quantity	Reference value/characteristic
Phantom material	water - $R_{50} \geq 4$ g/cm^2 ($E_o \geq 10$ MeV) water or plastic - $R_{50} < 4$ g/cm^2
Chamber type	PP or cylindrical - $R_{50} \geq 4$ g/cm^2 Plane parallel (PP) - $R_{50} < 4$ g/cm^2
Measurement depth z_{ref}	$= (0.6\, R_{50} - 0.1)$ g/cm^2
Reference point of the chamber	PP - on the inner surface of the window at its centre Cylindrical - on the central axis at the centre of the cavity volume
Position of the reference point of the chamber	PP - at z_{ref} Cylindrical : 0.5 r_{cyl} deeper than z_{ref}
SSD	100 cm
Field size at phantom surface	10 cm × 10 cm or that used for normalisation of output factors

HE Electrons: Determination of BQ (R_{50})

Reference Conditions

Influence quantity	Reference value/characteristics
Phantom material	water - $R_{50} \geq 4$ g/cm^2 ($E_o \geq 10$ MeV) water or plastic - $R_{50} < 4$ g/cm^2
Chamber type	PP or cylindrical - $R_{50} \geq 4$ g/cm^2 Plane parallel (PP) - $R_{50} < 4$ g/cm^2
Reference point of the chamber	PP - on the inner surface of the window at its centre Cylindrical - on the central axis at the centre of the cavity volume
Position of the reference point of the chamber	PP - at the point of interest Cylindrical : 0.5 r_{cyl} deeper than the point of interest
SSD	100 cm
Field size at phantom surface	10 cm × 10 cm - $R_{50} \leq 7$ g/cm^2 20 cm × 20 cm - $R_{50} > 7$ g/cm^2

HE Electrons: Determination of BQ (R_{50})

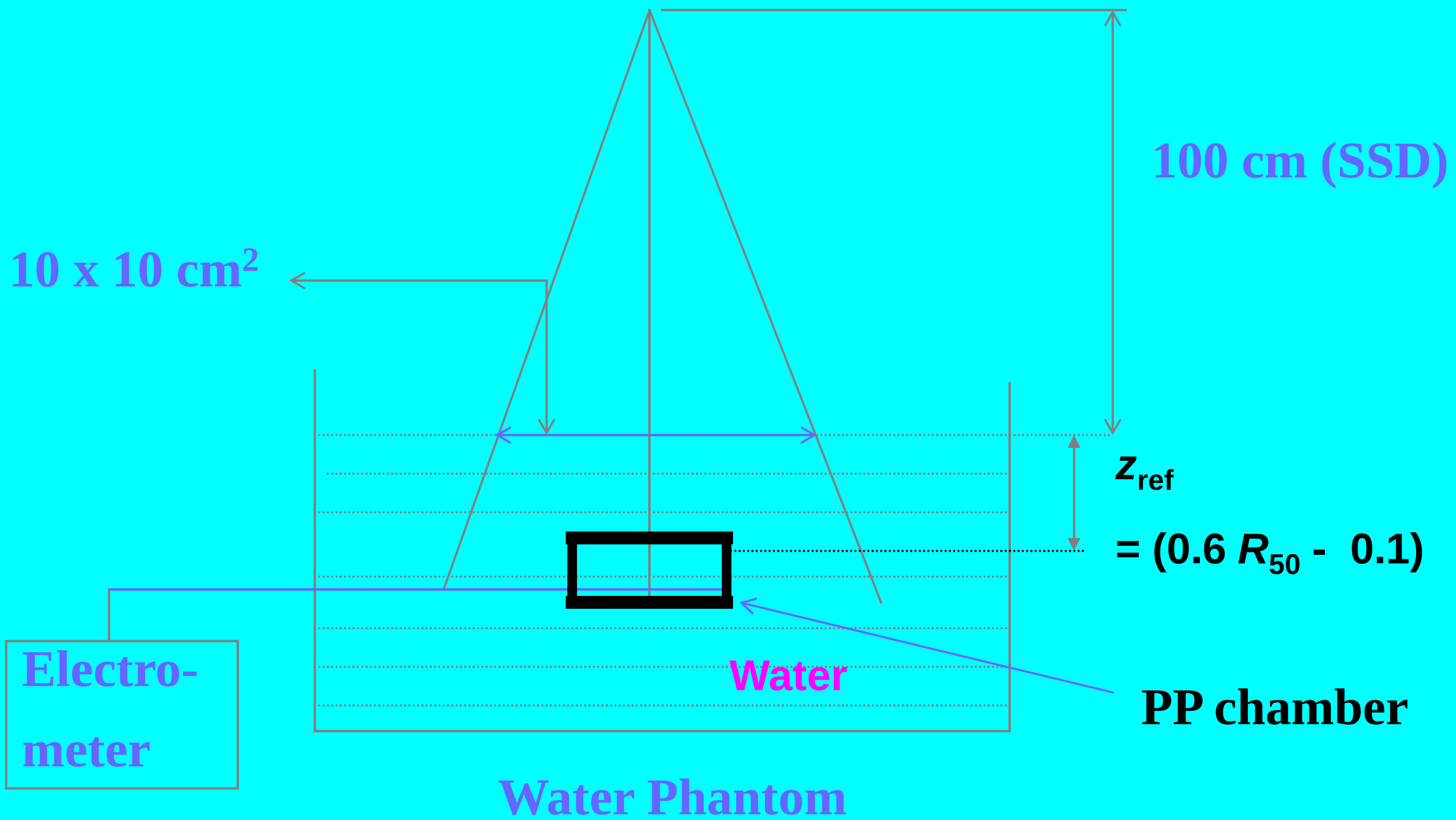
When using an ionisation chamber, the measured quantity is $R_{50,ion}$. The R_{50} is obtained using

$$R_{50} = 1.029\, R_{50,ion} - 0.06\ g/cm^2 \quad (R_{50,ion} \leq 10\ g/cm^2)$$
$$R_{50} = 1.059\, R_{50,ion} - 0.37\ g/cm^2 \quad (R_{50,ion} > 10\ g/cm^2)$$

When using detectors other ion chambers (e. g. diode, diamond, etc.) the measured quantity is R_{50}

HE Electrons: Reference Dosimetry

Experimental Set-up : SSD



HE Electrons: Reference Dosimetry

Absorbed dose to water at the reference depth z_{ref}

$$D_{w,Q}(z_{ref}) = M_Q\, N_{D,w}\, k_Q \qquad \text{Gy/MU}$$

$M_Q = M_{unc} k_{TP} k_{elec} k_{pol} k_s$ = Corrected Electrometer reading

Absorbed Dose to water at z_{max}

$$D_{w,Q}(z_{max}) = 100\, D_{w,Q}(z_{ref})/PDD\,(z_{ref}) \qquad \text{Gy/MU - SSD}$$

HE Electrons: Use of Plastic Phantoms

The use of plastic phantom is strongly discouraged, as in general they are responsible for the largest discrepancies in the determinations of absorbed dose in electron beams.

Nevertheless, when accurate chamber positioning in water is not possible, or when no waterproof chamber is available, their use is permitted.

Plastic phantoms may only be used at beam qualities $R_{50} < 4$ g/cm^2 ($E_0 < 10$ MeV).

Depth scaling	$z_w = z_{pl}\, c_{pl}$ g/cm^2	(z_{pl} in g/cm^2)
BQI	$R_{50,ion} = R_{50,ion,pl}\, c_{pl}$ g/cm^2	($R_{50,ion,pl}$ in g/cm^2)
Reference Depth	$z_{ref,pl} = z_{ref}/c_{pl}$ g/cm^2	(z_{ref} in g/cm^2)
D_w	$M_Q = M_{Q,pl}\, h_{pl}$	

HE Electrons : Uncertainty $D_{W,Q}$ (z_{ref})

Physical quantity/ procedure	Rel. Std. uncertainty (%)	
	Cyl. Chamber	PP Chamber
$N_{D,w}$ calibration of user dosimeter at SSDL (A)	0.6	0.6
Long term stability of user dosimeter (B1)	0.3	0.4
Establishment of reference conditions (B2)	0.4	0.6
Dosimeter reading relative to monitor chamber (B3)	0.6	0.6
Correction for influence quantities (B4)	0.4	0.5
Beam quality correction factor, k_Q (calculated value) (B5)	1.2	1.7
Combined uncertainty in D_w measurement by the user (quadrature sum of B1 to B5)	1.5	2.0
Combined standard uncertainty of $D_{w,Q}(z_{ref})$ determination (quadrature sum of A and B)	1.6	2.1

Uncertainty of $D_{W,Q}(z_{max})$ can be estimated by including uncertainty of PDD

Calibration of Brachytherapy Sources

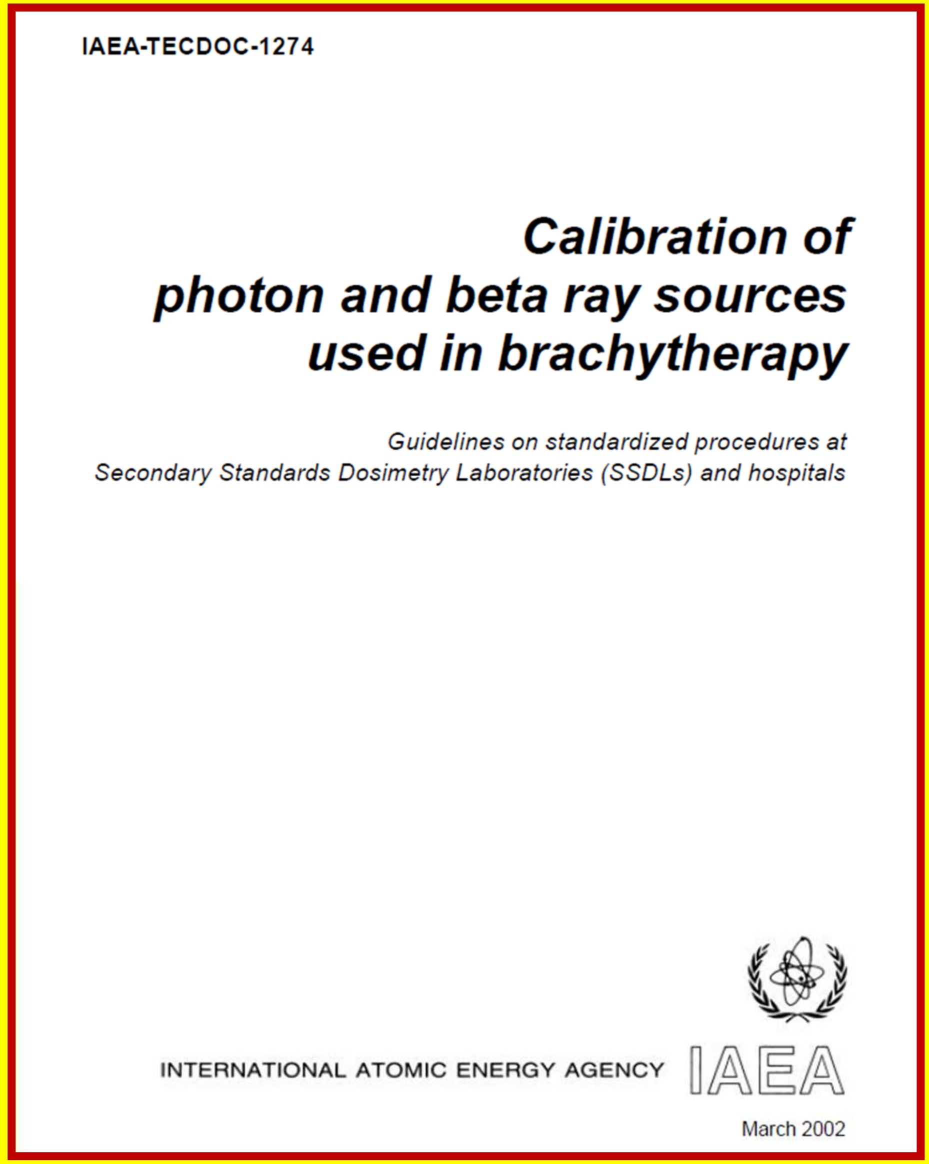
Quantity: RAKR/ AKS

Method: IAEA TECDOC 1274

Detector: Ionization chamber

Well Type Chamber

Cylindrical Chamber



IAEA-TECDOC-1274

Calibration of photon and beta ray sources used in brachytherapy

Guidelines on standardized procedures at Secondary Standards Dosimetry Laboratories (SSDLs) and hospitals

INTERNATIONAL ATOMIC ENERGY AGENCY IAEA

March 2002

Source Strength Specification: ICRU

Reference Air Kerma Rate (RAKR)

Defined as Kerma Rate to air measured in air at a reference distance of 1 meter along the transverse bisector of the source corrected for air attenuation and scattering.

The recommended unit of RAKR is $\mu Gy.h^{-1}$.

Source Strength Specification: AAPM

Air Kerma Strength (AKS)

$$S_k = K_{air}(d)d^2 \quad \mu Gym^2h^{-1}\ (cGycm^2h^{-1}) = 1U$$

- **RAKR does not have the dimensions of a Kerma rate - lead to confusion in teaching and clinical use**
- **Recommendations agree with ICRU in that the source strength is specified directly in terms of AKR in free space at one meter (i.e. RAKR)**

Methods of Source Calibration at Hospitals

(1) Well type ionization chamber

LDR sources (^{137}Cs, ^{192}Ir wires/seeds, ^{125}I seeds),

HDR sources (^{192}Ir, ^{60}Co)

(2) Cylindrical ionization chamber

- in air

- in phantom

HDR sources (^{192}Ir, ^{60}Co)

Calibration using well type chamber

$$\text{RAKR} = M\, K_{t,p}\, K_{recom}\, N_{elec}\, N_{K,RAKR,s}$$

$$\text{AKS} = M\, K_{t,p}\, K_{recom}\, N_{elec}\, N_{K,AKS,s}$$

M = Meter reading = Average current (or charge)

$K_{t,p}$ = Temperature & pressure correction factor

$$K_{t,p} = \frac{(273.15 + t) \times 1013.2}{(273.15 + t_0) \times P}$$

Calibration using well type chamber - contd.

$$1/k_{recom} = 4/3 - [Q_1/(3 - Q_2)]$$

where

Q_1 = charge collected at higher voltage (300 V)

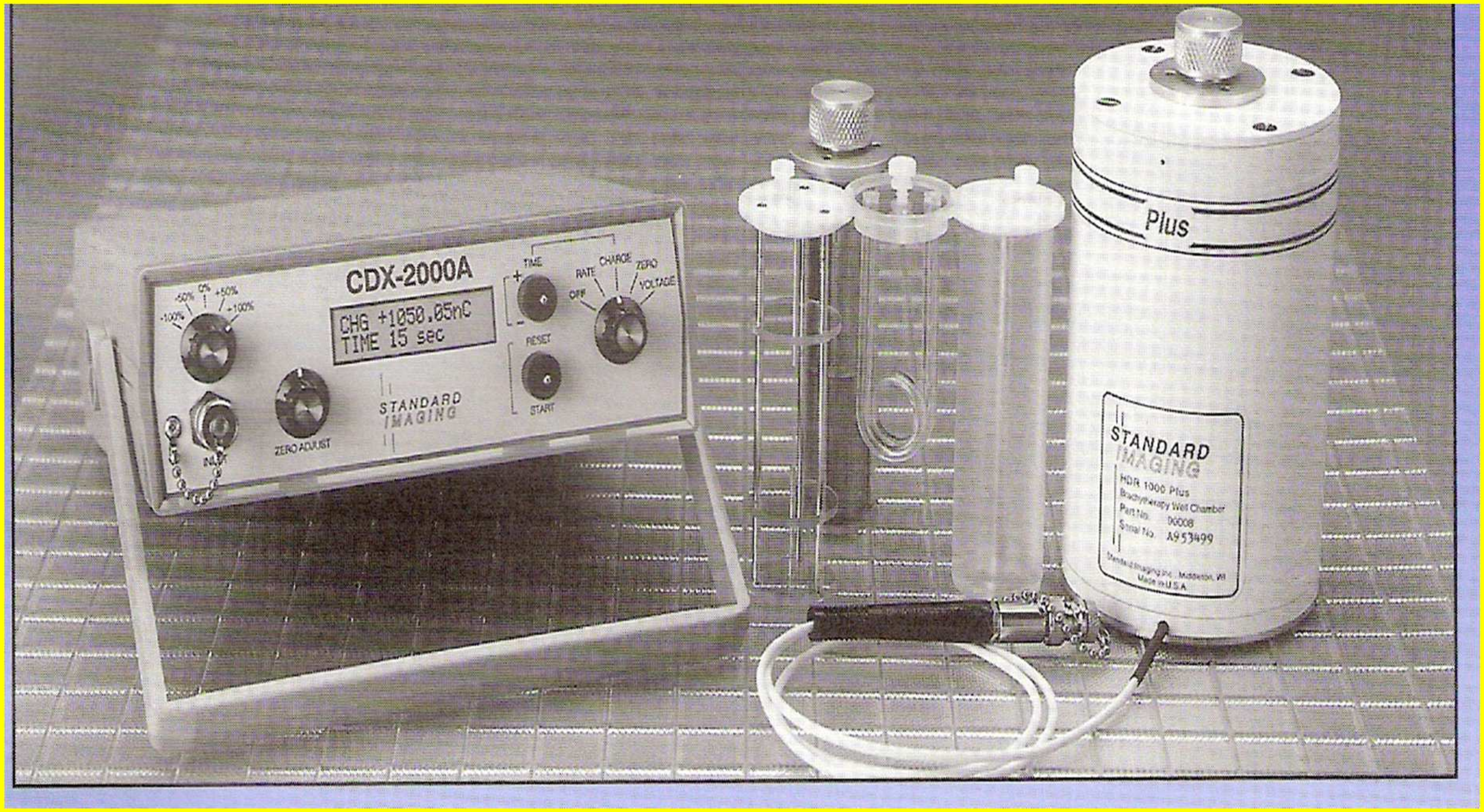
Q_2 = charge collected at lower voltage (150 V)

N_{elec} = electrometer cal. factor

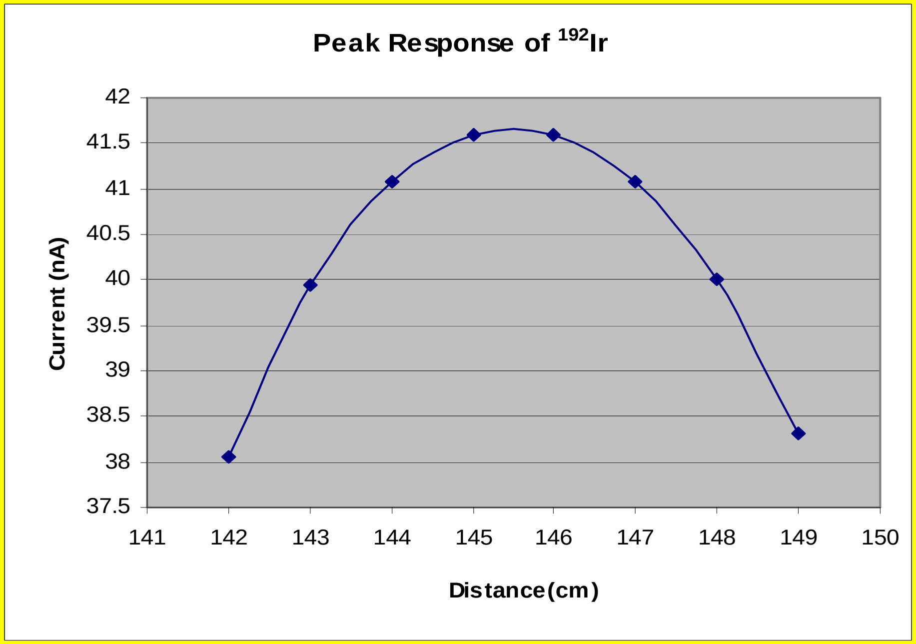
$N_{K,RAKR,s}$ ($N_{K,AKS,s}$) = chamber cal. factor in terms of RAKR (AKS) for the given source s

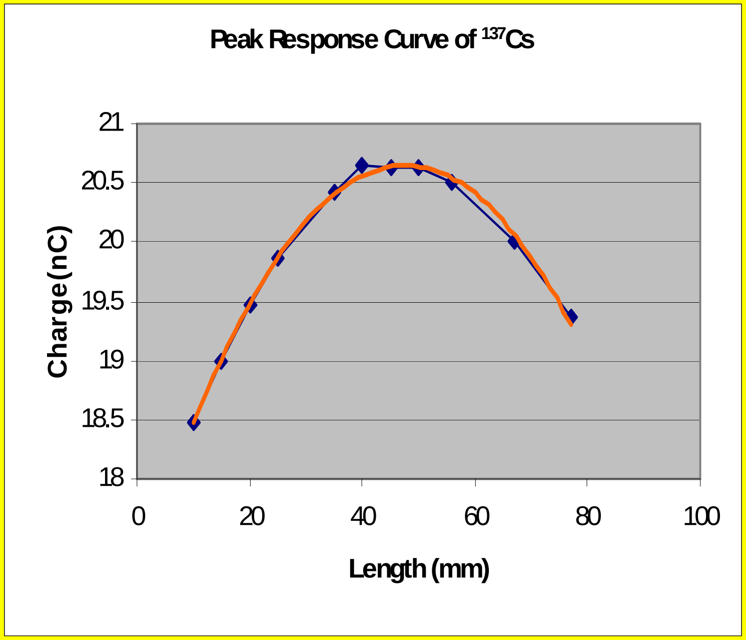
(given by Standard laboratory)

HDR-1000 Well Type Ionization Chamber & Electrometer



Response Graphs: HDR Ir-192 and LDR Cs-137 tube (BARC)





Calibration of HDR ^{192}Ir Source

Thank you