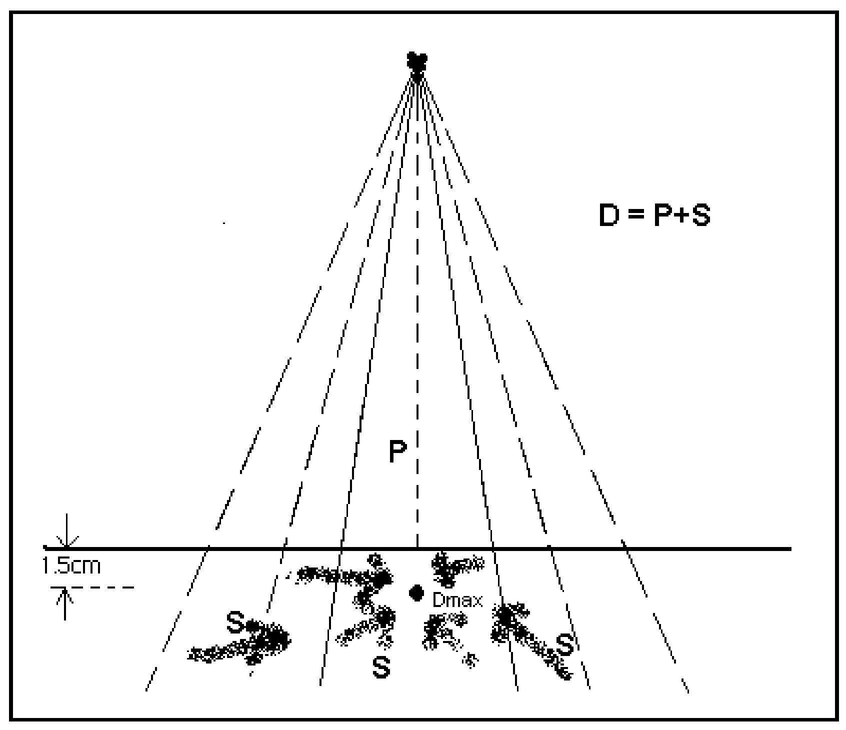
Comparison of Primary Doses Obtained in Three 6 MV Photon Beams Using a Small Attenuator

Christoph Trauernicht
Groote Schuur Hospital &
University of Cape Town

Background

- Method is based on:
  - A method of measuring the primary dose component in high-energy photon beams
    - Paul Nizin & Kenneth Kase
      - Med. Phys. 15(5), Sep/Oct 1988
  - Determination of primary dose in Co-60 gamma beam using a small attenuator
    - Paul Nizin & Kenneth Kase
      - Med. Phys. 17(1), Jan/ Feb 1990

- Total Dose = Primary + Scattered Components



- Primary dose obtained by extrapolation to zero field size – problematic esp. for high energy beams
- Uncertainties in primary dose from 3% - 10%
- This method: no extrapolation necessary

Three Linear Accelerators

Philips SL 75-5

Varian 2300 Clinac

Siemens Mevatron KD2

$$D_T = D_p + D_s \quad (1)\ ; \quad D_T^i = D_p^i + D_s \quad (2)$$

Index i refers to CAX attenuator

Properties of attenuator: (i) Perturbation of scatter dose negligible with attenuator in the beam

(ii) radius of attenuator > lateral electron range


mm
cm
1
2
3
4
5
6
mm

$$D_T = D_p + D_s \quad \textbf{(1)}\ ; \quad D_T^i = D_p^i + D_s \quad \textbf{(2)}$$

Index i refers to CAX attenuator

Properties of attenuator: (i) Perturbation of scatter dose negligible with attenuator in the beam
(ii) radius of attenuator > lateral electron range

For a specified depth d in a phantom, the ratio of the primary components is independent of field size, thus:

$$D_p / D_p^i = \mathbf{constant} = C_D \quad \textbf{(3)}$$

$$D_p\,(d) = [1 - 1/\,C_D(d)]^{-1} \cdot [D_T\,(d,S) - D_T^i\,(d,S)] \quad \textbf{(4)}$$

Determination of $C_D(d)$

$$C_D(d) = \frac{\ln\left[\frac{I(d+\Delta)}{I(d)}\right]}{\ln\left[\frac{I(h+d+\Delta)}{I(h+d)}\right]} \cdot \frac{I(d)}{I(h+d)}$$

where d refers to depth, h refers to the attenuator and Δ is a small thickness of phantom

All these quantities are measurable under narrow-beam conditions

Primary dose can be obtained by four measurements of ionization in narrow beam geometry and two measurements of dose in a large beam in a phantom

$$D_p(d) = [1 - 1/C_D(d)]^{-1} \cdot [D_T(d,S) - D_T^i(d,S)] \qquad (4)$$

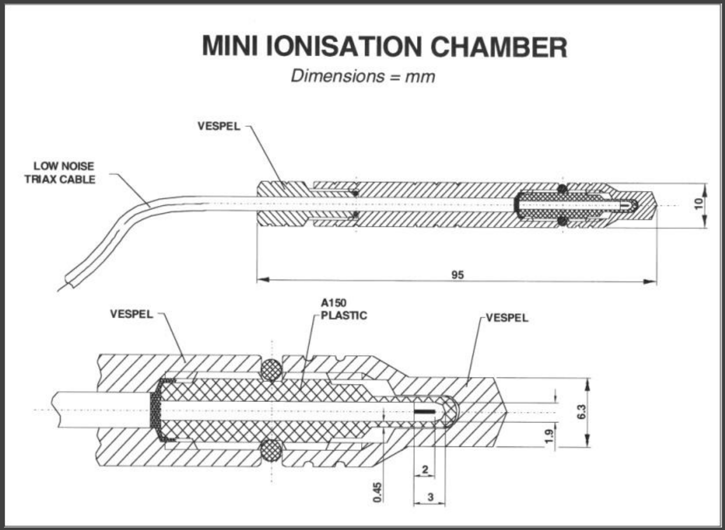
Doses with and without attenuator
in the beam at depth d in water

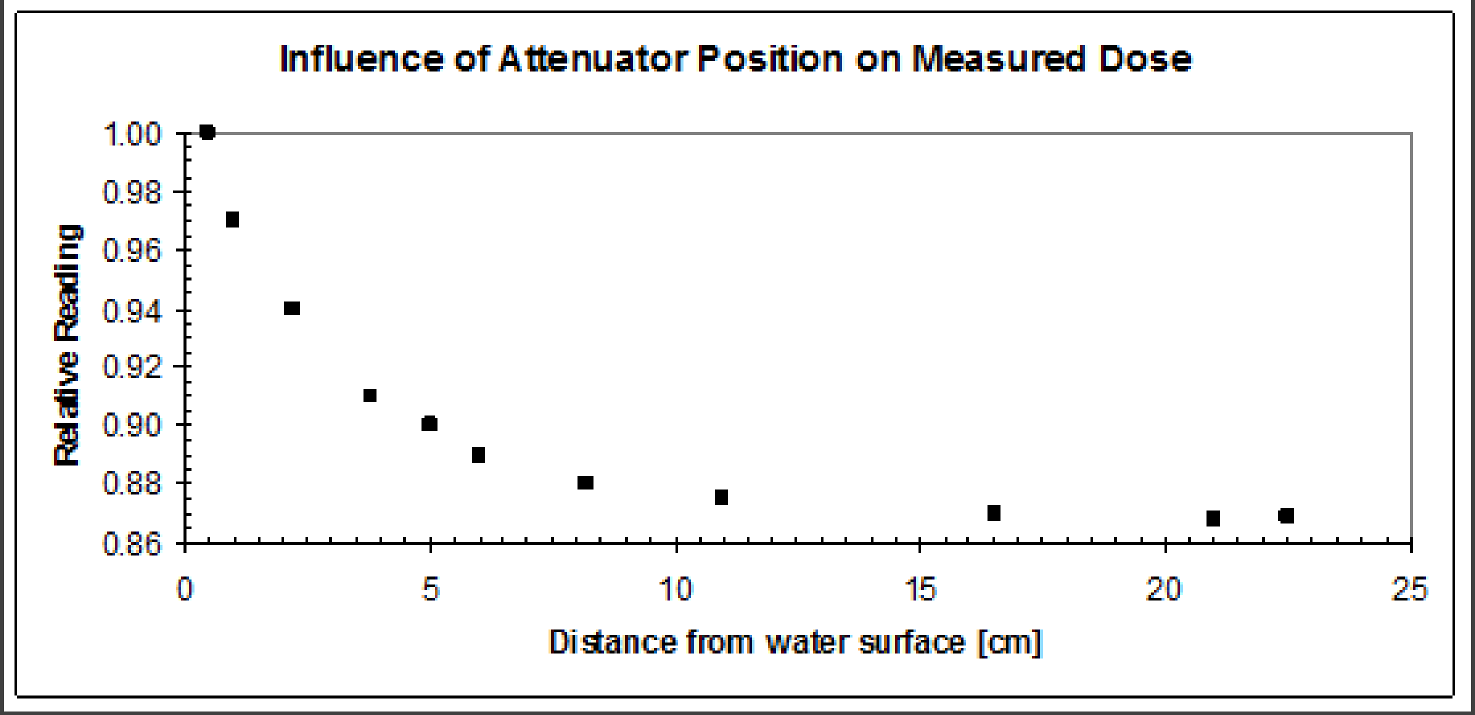
$$C_D(d) = \frac{\ln\left[\dfrac{I(d+\Delta)}{I(d)}\right]}{\ln\left[\dfrac{I(h+d+\Delta)}{I(h+d)}\right]} \cdot \frac{I(d)}{I(h+d)}$$

Measurements at 2 cm intervals up to d = 15 cm

Dose: D_T & D_T^i

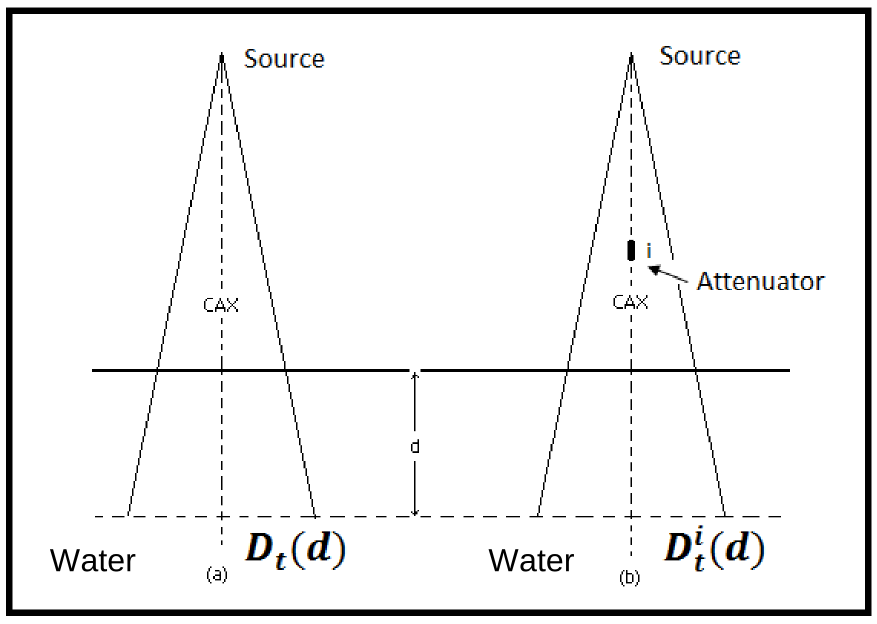
- Measured at different depths in a water tank in a 10 cm X 10 cm field with a 0.016 cc PinPoint chamber or 0.0067cc “mini ionisation chamber”





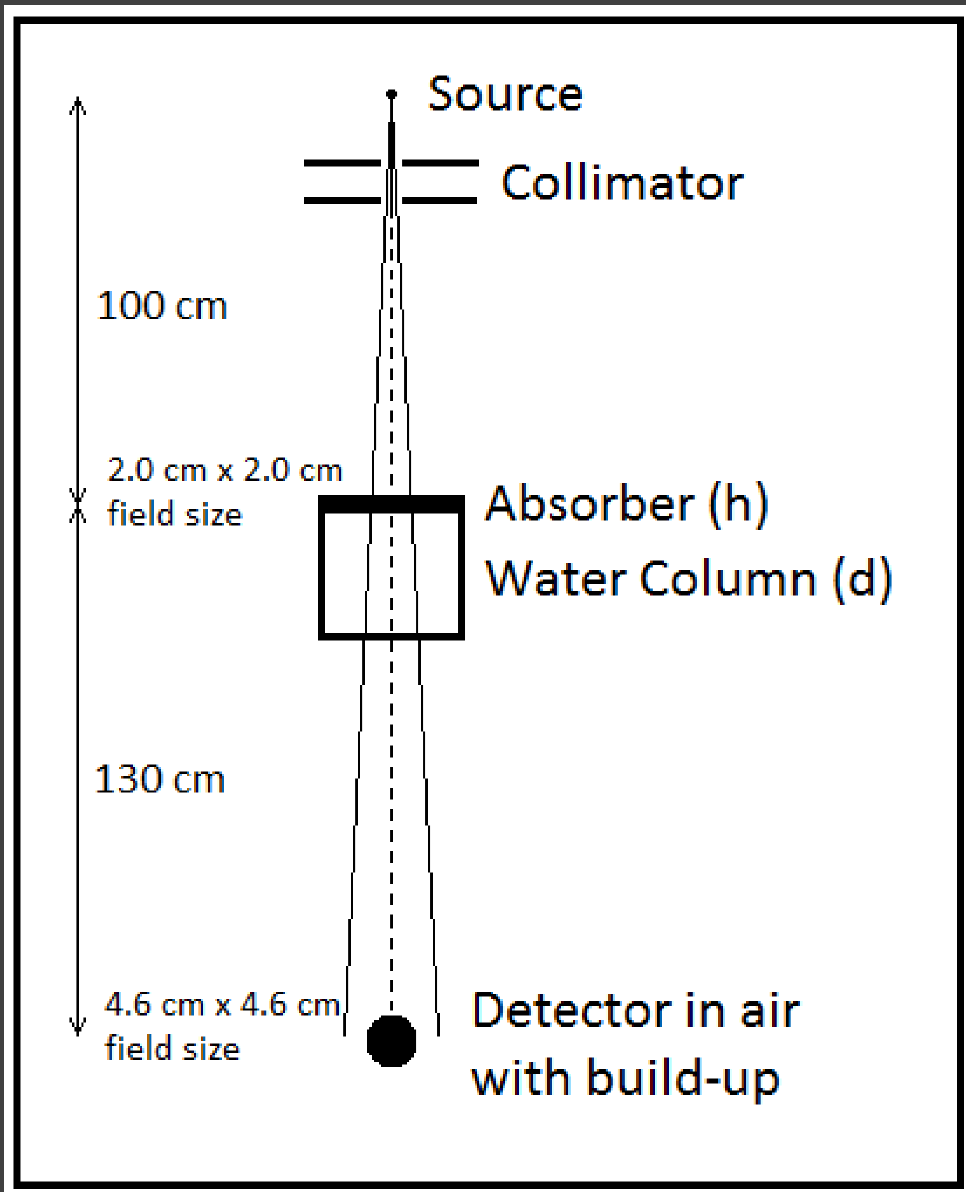
- 1 cm & 2 cm thick lead attenuators
- r = 1 cm each
- Attenuator at least 20 cm above water surface

Measurement Setup

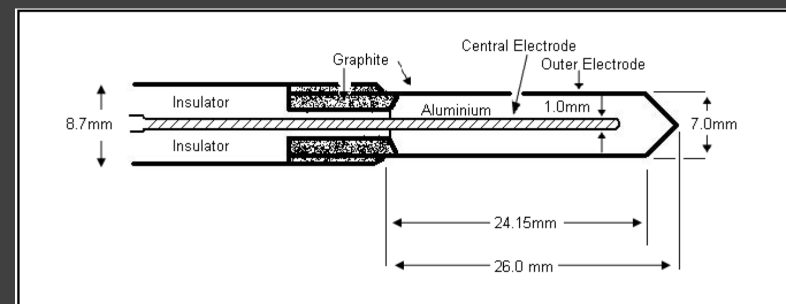


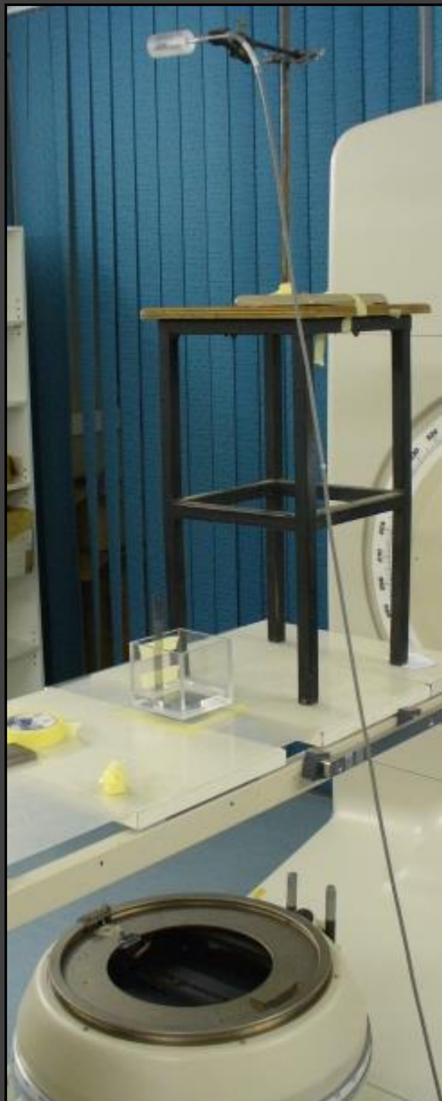
	Philips SL 75-5	Siemens Mevatron KD2	Varian 2300 Clinac
Total Dose [Gy/100 MU]	1.00	1.00	1.00
1 cm Pb attenuator [Gy/100 MU]	0.528	0.528	0.515
2 cm Pb attenuator [Gy/100 MU]	0.309	0.302	0.309

C_D



0.6 cc Farmer chamber



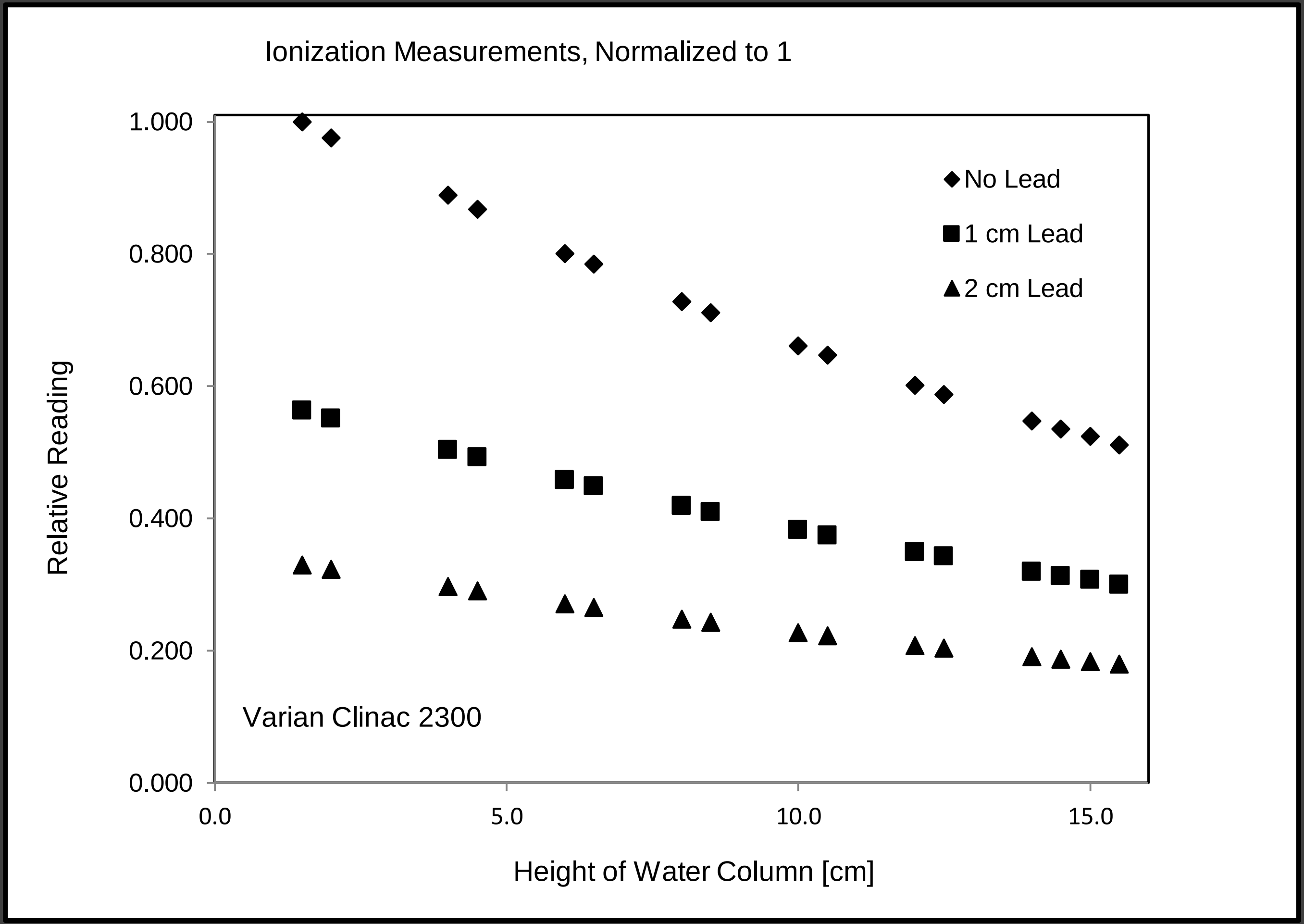


Philips SL75-5

Siemens Mevatron KD2

Varian 2300 Clinac

Results:



- Large uncertainties when using sets of ionization measurements
- Fit an exponential function through the points

$$C_D(d) = \frac{\ln\left[\frac{I(d+\Delta)}{I(d)}\right]}{\ln\left[\frac{I(h+d+\Delta)}{I(h+d)}\right]} \cdot \frac{I(d)}{I(h+d)}$$

Results:

	Philips SL 75-5	Siemens Mevatron KD2	Varian 2300 Clinac
C_D (1 cm Pb), using 1.5 cm and 2 cm depths	2.042	2.014	2.078
C_D (2 cm Pb), using 1.5 cm and 2 cm depths	3.765	3.864	3.951

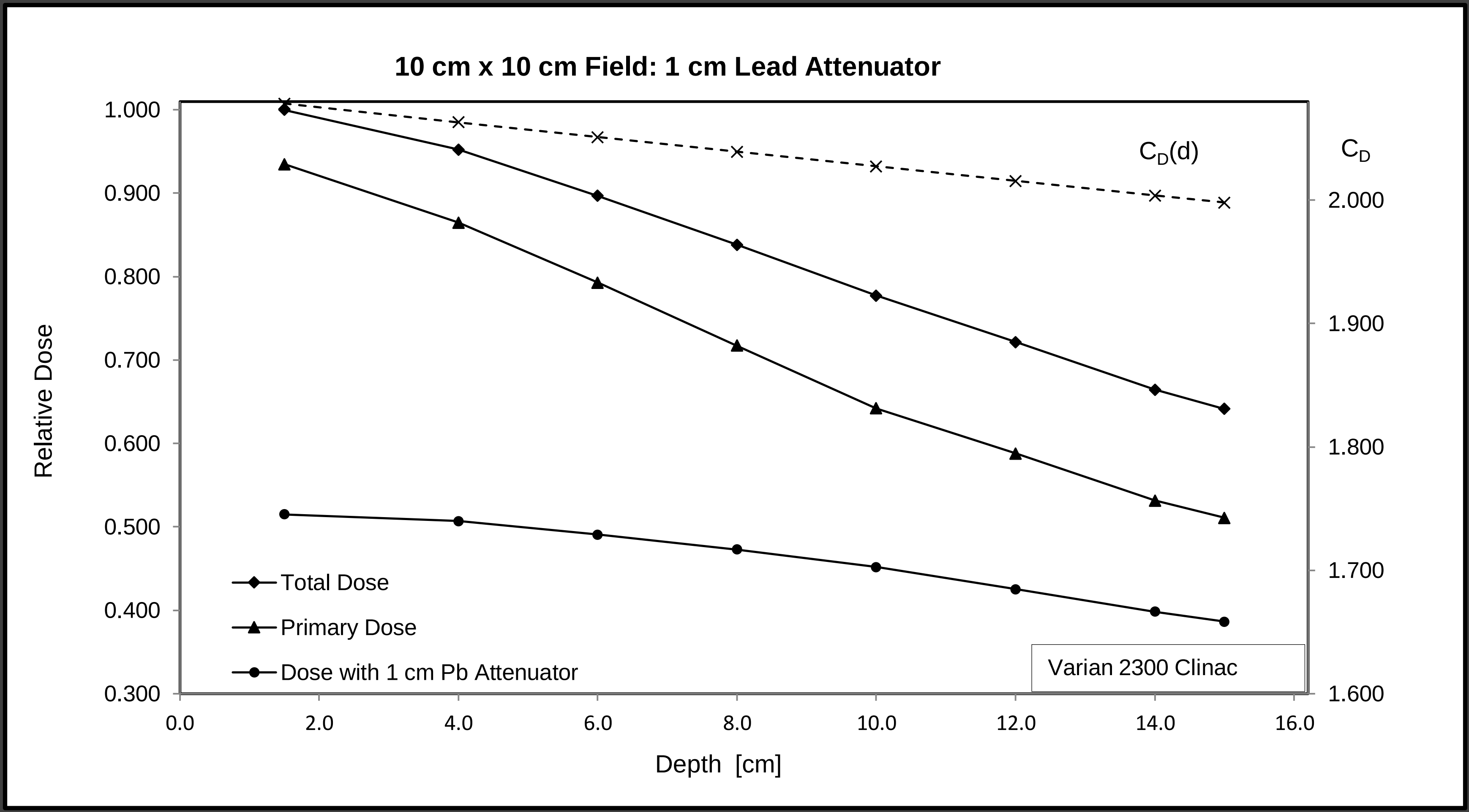
The fractional uncertainty in each measurement was determined by taking 15 consecutive measurements and dividing the standard deviation by the mean.

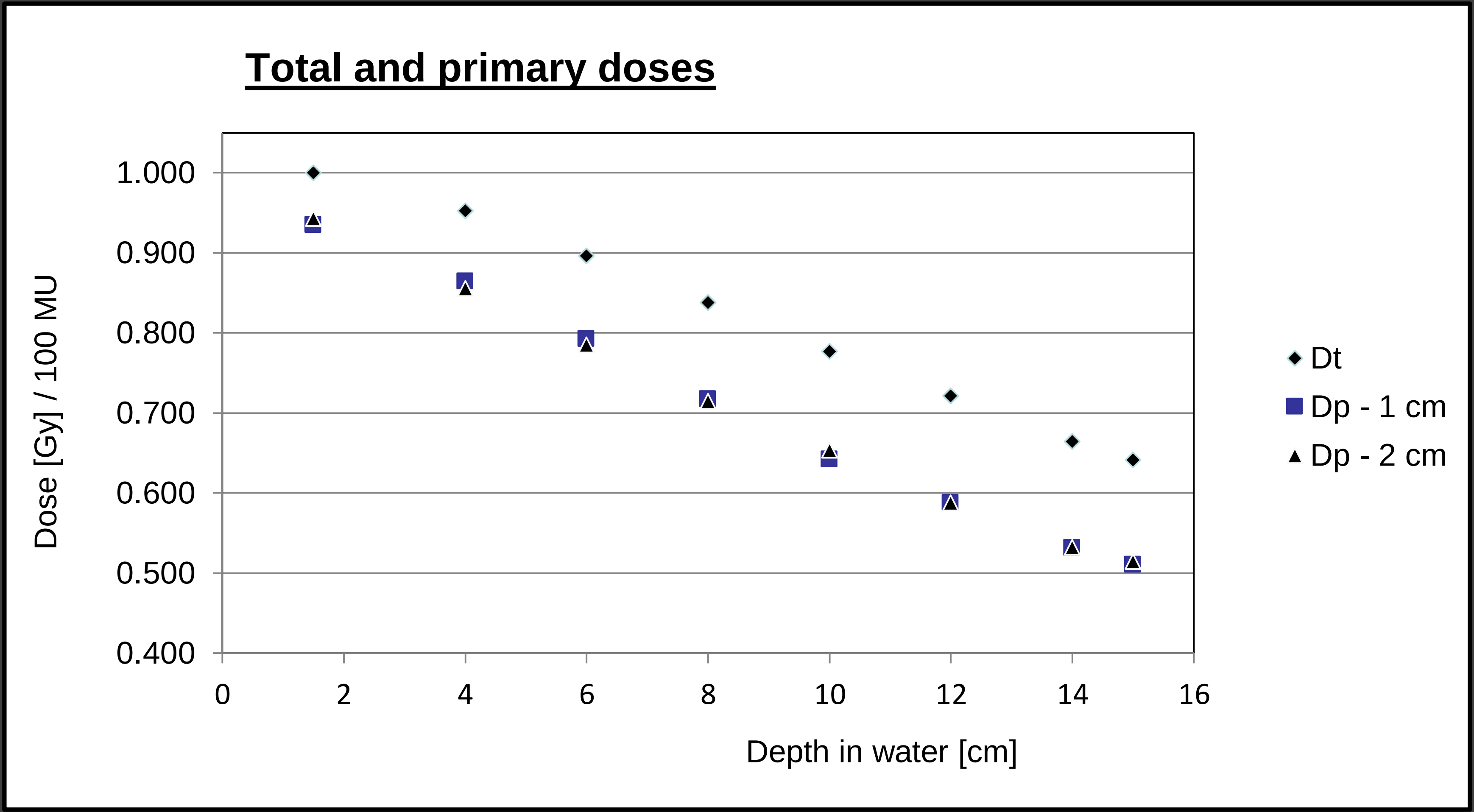
$$D_p(d) = [1 - 1/C_D(d)]^{-1} \cdot [D_T(d,S) - D_T^i(d,S)]$$

Results: Primary Dose

	Philips SL 75-5	Siemens Mevatron KD2	Varian 2300 Clinac
Primary Dose [Gy/100 MU] 1 cm Pb Attenuator	0.925 ± 4.5 %	0.938 ± 4.8 %	0.935 ± 3.3 %
Primary Dose [Gy/100 MU] 2 cm Pb Attenuator	0.941 ± 4.8 %	0.942 ± 5.2 %	0.943 ± 3.5 %

Results for 1 cm Pb Attenuator





Fit an exponential to the primary dose up to 15 cm depth to get the primary linear attenuation coefficient

Primary Linear Attenuation Coefficient

	Philips SL 75-5	Siemens Mevatron KD2	Varian 2300 Clinac
μ (1 cm Pb) [cm^{-1}]	0.0447 ± 0.0007	0.0436 ± 0.0008	0.0458 ± 0.0012
μ (2 cm Pb) [cm^{-1}]	0.0444 ± 0.0006	0.0436 ± 0.0008	0.0458 ± 0.0008

Discussion: Primary Dose

	Philips SL 75-5	Siemens Mevatron KD2	Varian 2300 Clinac
Primary Dose (this work) [Gy/100 MU]	0.925 & 0.941	0.938 & 0.942	0.935 & 0.943
In use [Gy/100 MU]	0.935	0.935	0.926
Monte Carlo (Rice & Chin, 1990) [Gy/100 MU]	0.928 ± 0.013		

Discussion: Primary Linear Attenuation Coefficient

	Philips SL 75-5	Siemens Mevatron KD2	Varian 2300 Clinac
μ (1 cm Pb) [cm^{-1}]	0.0447 ± 0.0007	0.0436 ± 0.0008	0.0458 ± 0.0012
μ (2 cm Pb) [cm^{-1}]	0.0444 ± 0.0006	0.0436 ± 0.0008	0.0458 ± 0.0008
Narrow Beam Attenuation Measurements [cm^{-1}]	0.0460 ± 0.0001	0.0477 ± 0.0003	0.0482 ± 0.0002
Pistorius (1991) CAPDD Kerma Model [cm^{-1}]	0.0445 ± 0.0001	0.0445 ± 0.0001	0.0457 ± 0.0001
TMR extrapolation to zero field size [cm^{-1}]	0.0469 ± 0.0006	0.0465 ± 0.0001	0.0477 ± 0.0002

Conclusion:

- This method suggests a feasible way of measuring the primary dose component of the radiation dose, as well as obtaining a value for the primary linear attenuation coefficient.

References:

-A method of measuring the primary dose component in high-energy photon beams

Paul Nizin & Kenneth Kase, Med. Phys. 15(5), Sep/Oct 1988

-Determination of primary dose in Co-60 gamma beam using a small attenuator

Paul Nizin & Kenneth Kase, Med. Phys. 17(1), Jan/ Feb 1990

-B Bjarngard & P Petti, Phys. Med. Biol. 33, 21 (1988)

-P Kijewski *et al.*, Med. Phys. 13, 74 (1986)

-M Day, Br. J. Radiol. Suppl. 17, 131 (1983)

-R Rice & L Chin, Phys. Med. Biol. 35, 3 (1990)

-JR Taylor: An Introduction to Error Analysis (1982)

- S Pistorius: PhD Thesis (1991)