Towards a determination of the absorbed dose to water in water for x-rays below 50 keV

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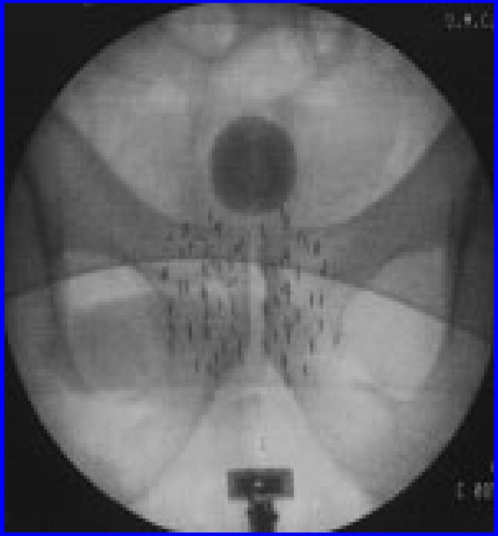
Low-energy photon-emitting brachytherapy seeds

PTB



Permanent seeds e.g. for the treatment of prostate cancer:

^{125}I: 27.20, 27.47 keV

31.00, 31.71 keV

^{103}Pd: 20.07, 20.22 keV

22.72, 23.18 keV

D_w in a water-phantom

Overview

- *Extrapolation chamber Set-up*
- *Problem: Extrapolation from SEE*
- *Extrapolation Method*
- *Comparison to a free air chamber*
- *Uncertainties: Conversion factors*
- *Results*
- *Conclusion*

Graphite Extrapolation Chamber

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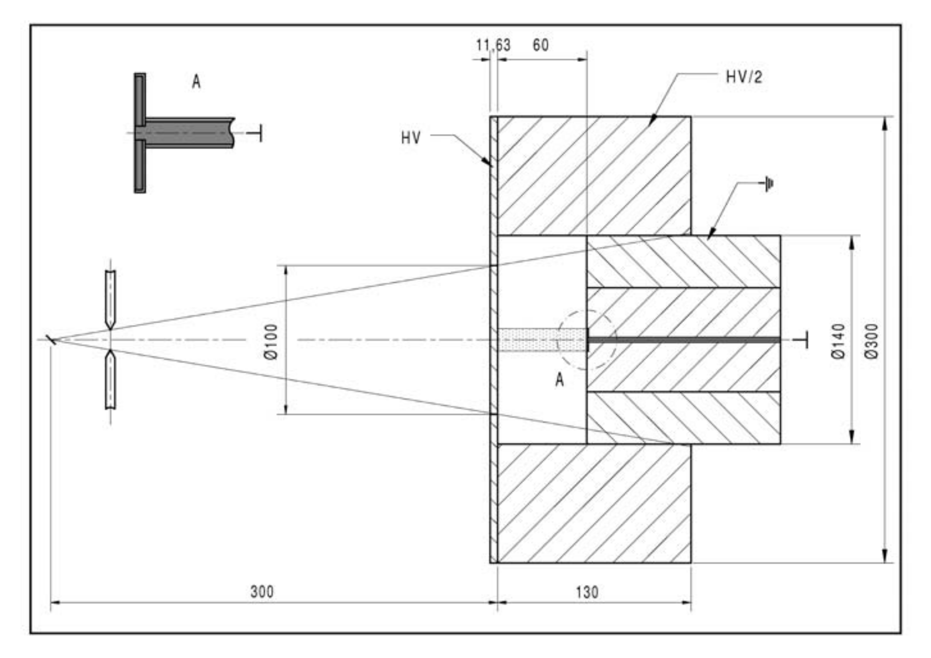
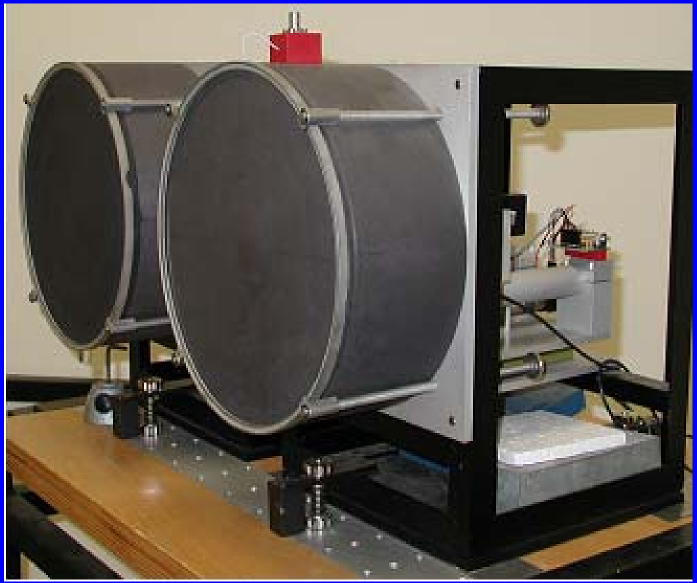
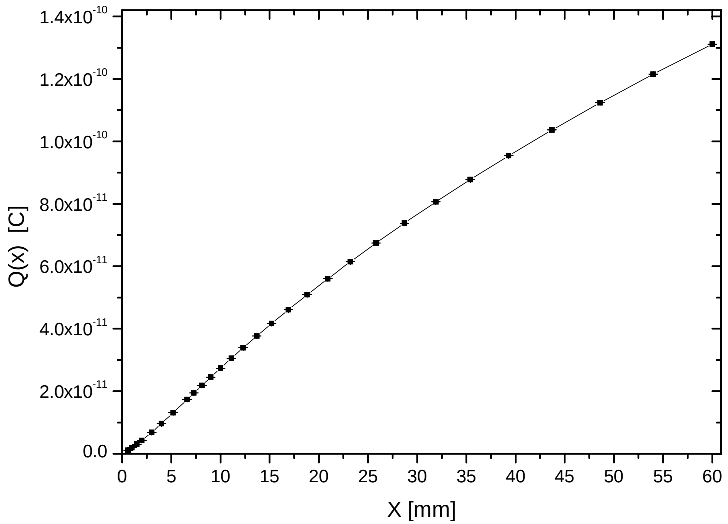


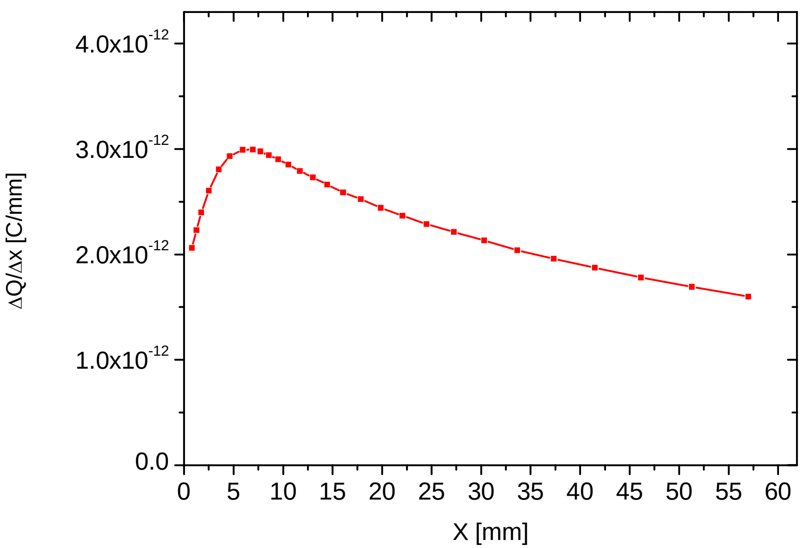


$$K_w^g(0) = K_{air}^g(0) \cdot \frac{\overline{(\mu_{en}/\rho)}^w}{\overline{(\mu_{en}/\rho)}^{air}}$$

Extrapolation from SEE

$$D_{air}(x) = \left(\frac{W}{e}\right) \cdot \frac{1}{\rho_{air} A} \cdot \frac{dQ(x)}{dx}$$





$$Q(x)$$

$$\frac{Q(x_{i+1}) - Q(x_i)}{x_{i+1} - x_i}$$

Effects

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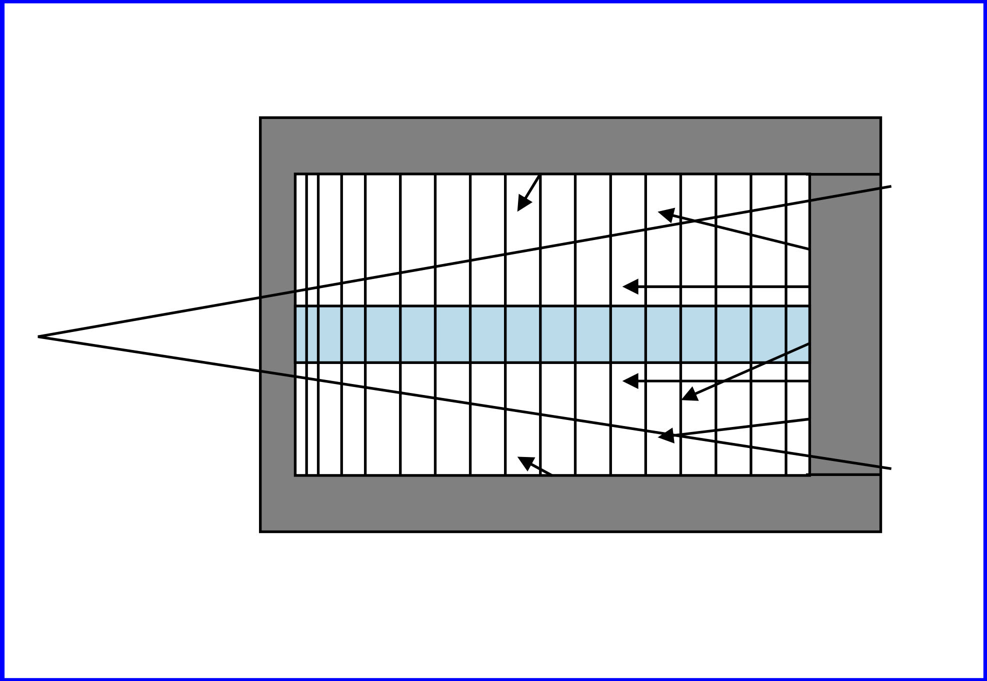

- Beam divergence
- Stray radiation
- Absorption

Photon Fluence Spectra (FluRZnrc)

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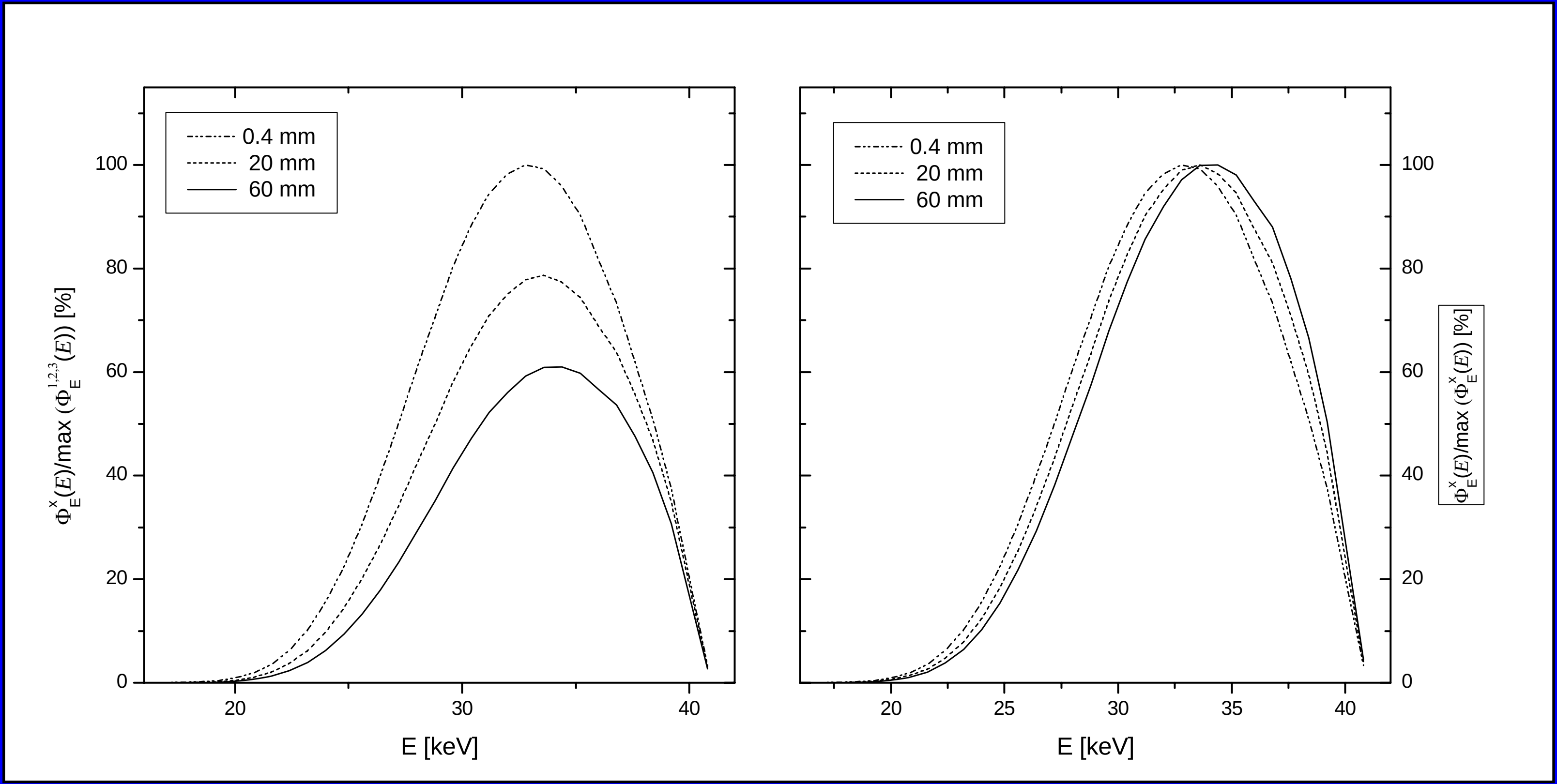

Method I

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SEE: $K_{air}^{g}(x) = D_{air}^{g}(x)$

$$Q(x) = \left(\frac{e}{W}\right)\rho_{air} A \cdot \overline{D}_{air}(x) \cdot x$$

$$k_{KC}^{MC}(x) = \frac{K_{air}^{g}(0)}{\overline{K_{air}^{g}}(x)} = \frac{\int \Psi(E,0)^{MC} \cdot (\mu_{en}(E)/\rho)^{air} \cdot dE}{\int \overline{\Psi(E,x)}^{MC} \cdot (\mu_{en}(E)/\rho)^{air} \cdot dE}$$

Method II

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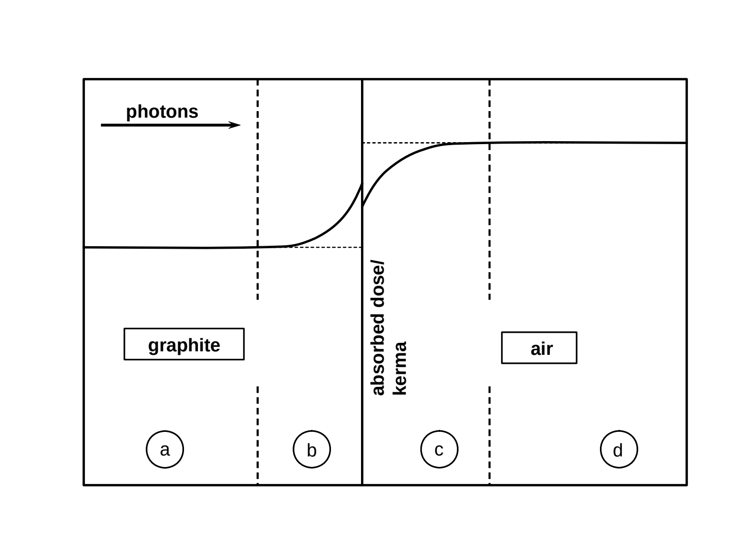
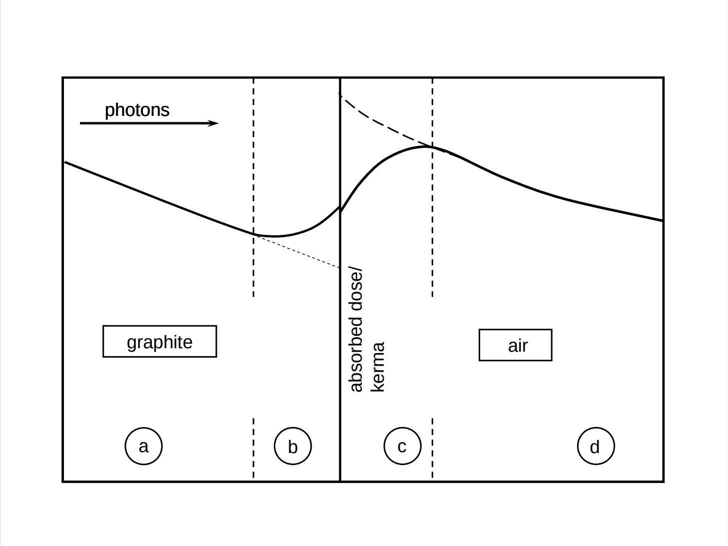
$$k_{KC}^{MC}(x) = \frac{K_{air}^{g}(0)}{\overline{K_{air}^{g}(x)}} = \frac{\int \Psi(E,0)^{MC} \cdot (\mu_{en}/\rho)^{air}(E) \cdot dE}{\int \overline{\Psi(E,x)}^{MC} \cdot (\mu_{en}/\rho)^{air}(E) \cdot dE}$$





Method III

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$$k_{KC}^{MC}(x_{i+1})\cdot Q(x_{i+1})-k_{KC}^{MC}(x)\cdot Q(x)=\left(\frac{e}{W}\right)\rho_{air}A\cdot\Big(k_{KC}^{MC}(x_{i+1})\overline{K}_{air}^{g}(x_{i+1})\cdot x_{i+1}-$$

$$k_{KC}^{MC}(x_i)\cdot\overline{K}_{air}^{g}(x_i)\cdot x_i\Big)=\left(\frac{e}{W}\right)\rho_{air}A\cdot K_{air}^{g}(0)\cdot(x_{i+1}-x_i)$$

$$K_{air}^{g}(0)=\frac{W}{e}\frac{1}{\rho_{air}A}\frac{k_{KC}(x_{i+1})\cdot Q(x_{i+1})-k_{KC}(x_i)\cdot Q(x_i)}{x_{i+1}-x_i}$$

Conversion factor (x , E)

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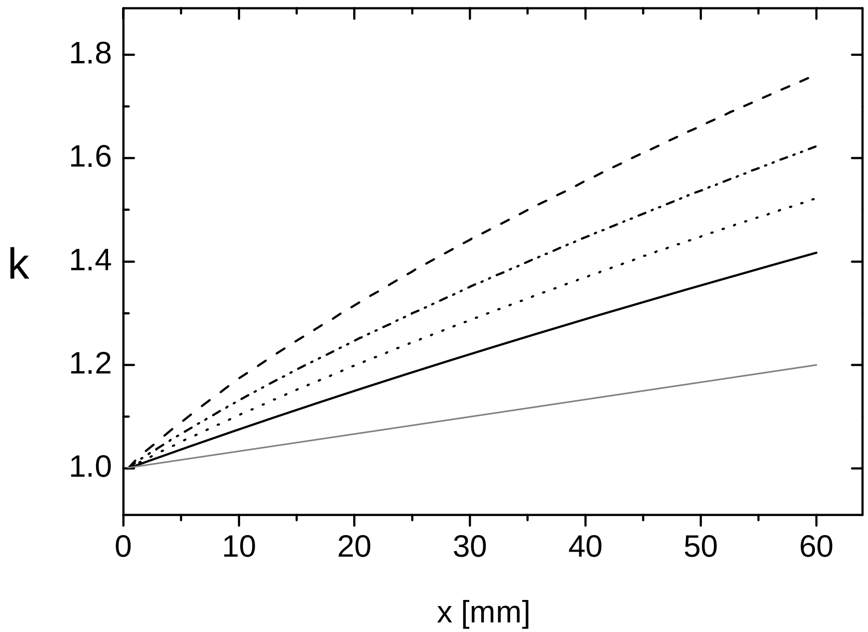
$$k_{KC}(x) = \left(A_1 \exp\left(-x/p_1\right) + A_2 \exp\left(-x/p_2\right) + y_0\right)^{-1}$$



Measured Data (N30)

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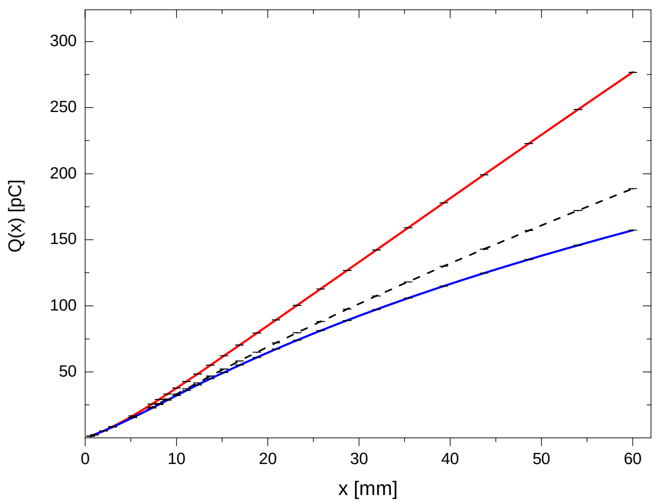

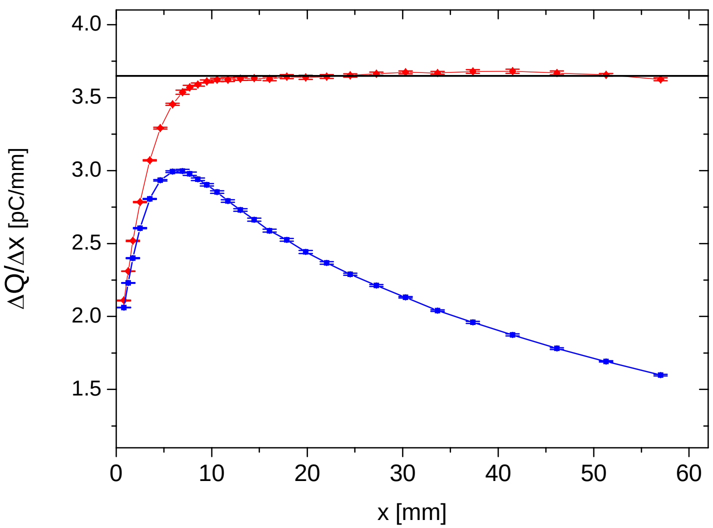

$$Q(x)$$

$$\frac{Q(x_{i+1}) - Q(x_i)}{x_{i+1} - x_i}$$

Linear Extrapolation

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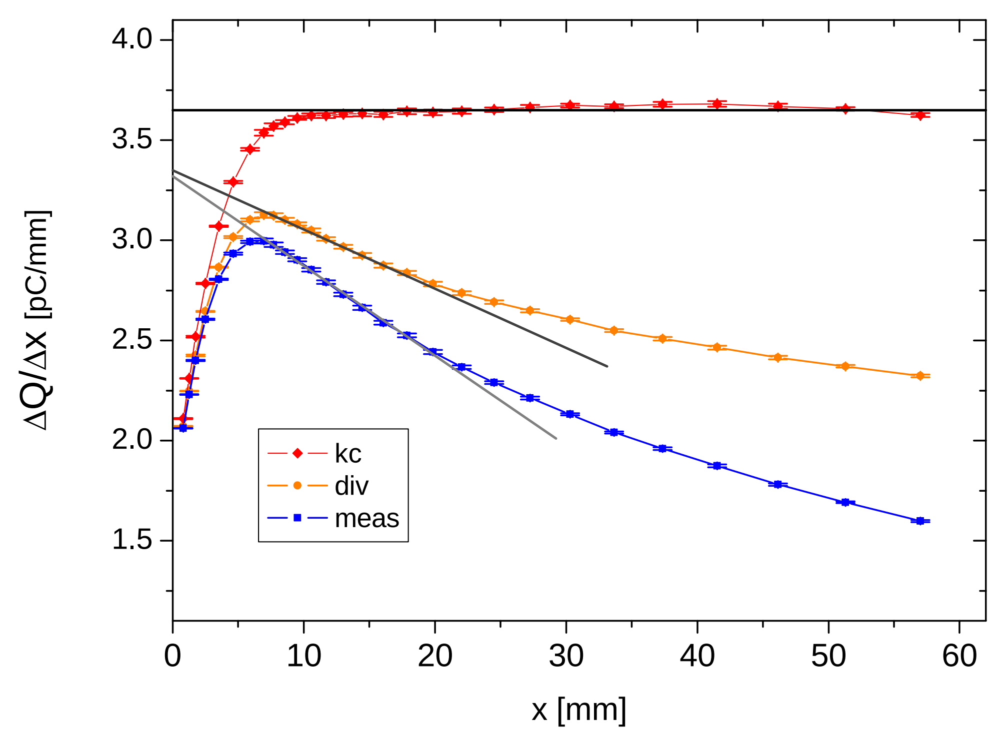
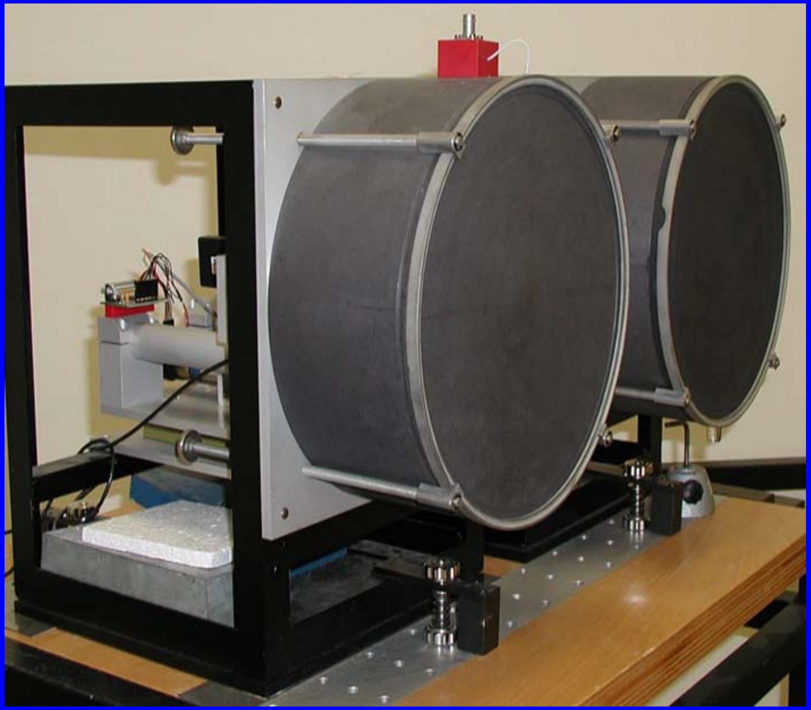


9 %

Comparison with a free air chamber



Conversion factors

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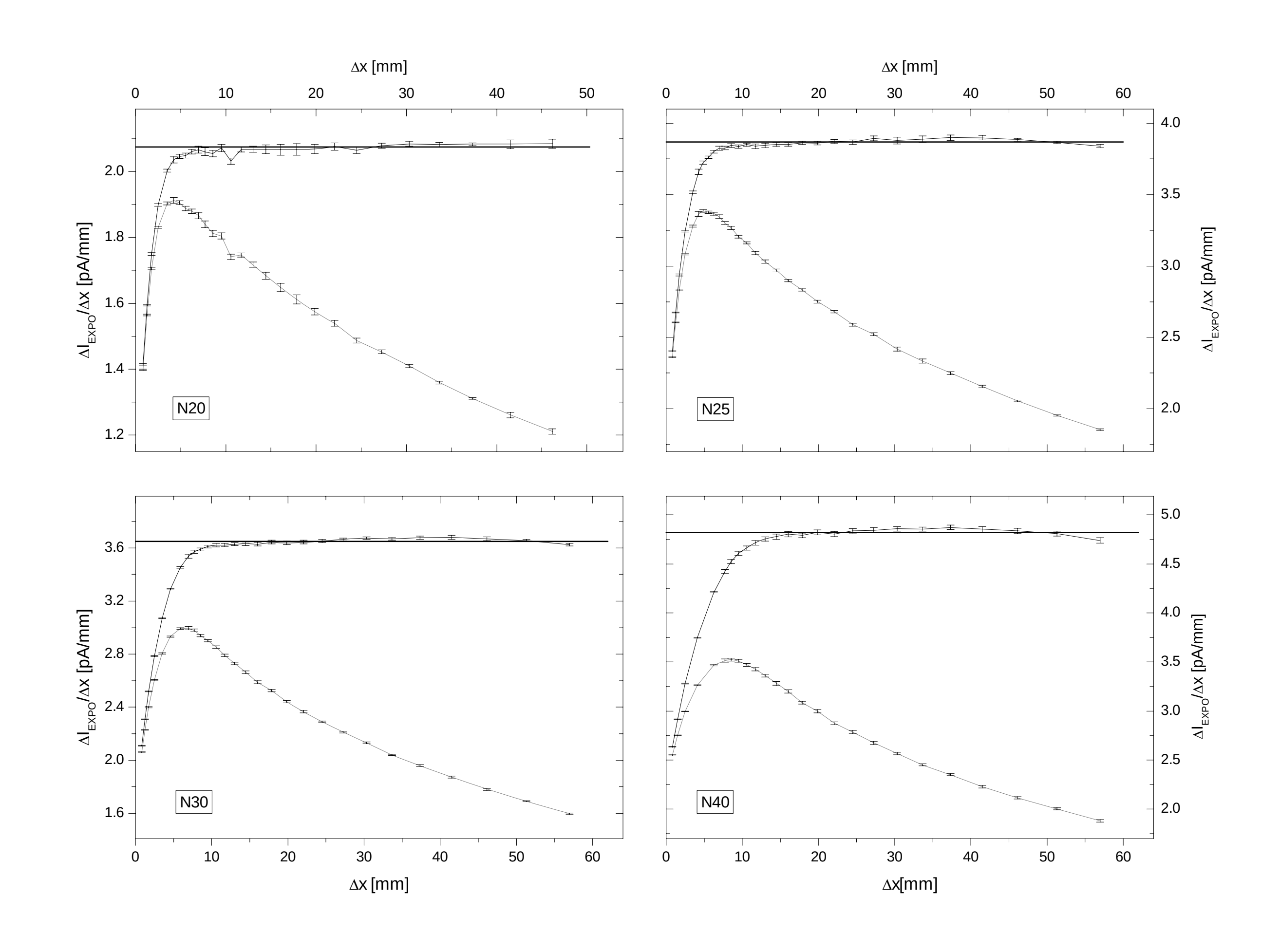
Radiation Quality	$\frac{\overline{(\mu_{en}/\rho)}^{w}}{\overline{(\mu_{en}/\rho)}^{air}}$	$C_{a,a}^{w,g}$
N 20	**1.021 $\pm$ 0.8 %**	**0.4106 $\pm$ 2.1%**
N 25	**1.018 $\pm$ 0.5%**	**0.7399 $\pm$ 1.1%**
N 30	**1.016 $\pm$ 0.5%**	**1.043 $\pm$ 1.1%**
N 40	**1.011 $\pm$ 0.5%**	**1.450 $\pm$ 1.1%**

Quotient folded o. same Spectrum
0.5 % > 10 keV
1 % < 10 keV

μ_{en} folded o. a spectrum
1% > 10 keV
2% < 10 keV
→ not totally independent

Measured Data (N20-N40)



Results

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	$\frac{\Delta Q_{Expo}}{\Delta x}$	$K_w^g\Big\vert^{Expo}$	K_{air}^{air}	$K_w^g\Big\vert^{free-air}$	R
	$(10^{-12}\,C/mm)$	$(10^{-4}\,Gy)$	$(10^{-4}\,Gy)$	$(10^{-4}\,Gy)$	$\pm$
N 20	2.075	3.263	8.083	3.319	1.017
N 25	3.869	6.067	8.275	6.123	1.009
N 30	3.649	5.709	5.446	5.680	0.995
N 40	4.821	7.508	5.135	7.446	0.991
	rel. unc. [%]	rel. unc. [%]	rel. unc. [%]	rel. unc. [%]	rel. unc. [%]
N 20	0.38	0.85	0.38	2.1	2.3
N 25	0.53	0.73	0.38	1.2	1.4
N 30	0.56	0.76	0.38	1.2	1.4
N 40	0.54	0.74	0.38	1.2	1.4

Summary and Conclusion

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- *Method to determine the water-kerma inside a graphite phantom*
- *Conversion factor (MC):* $\overline{K}_{w,g}(x) \rightarrow K_{w,g}(0)$
- *Uncertainty ~ 1 % (k=1)*
- *Phantom of water equivalent material ->* D_w