Monte Carlo calculations for the BIPM ionometric standard for absorbed dose to water

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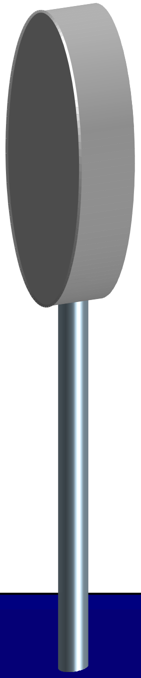
LNE-LNHB / BIPM Workshop on
Absorbed Dose and Air Kerma Primary Standards
May 2007

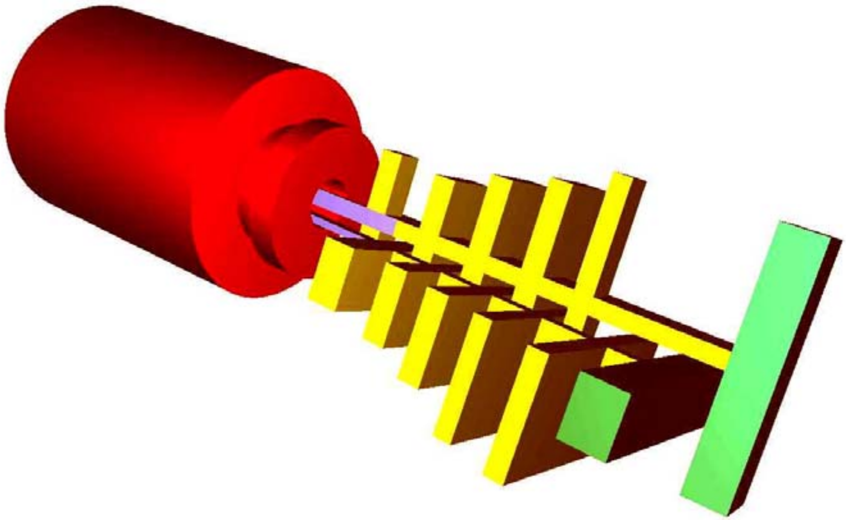
Previous air-kerma calculation

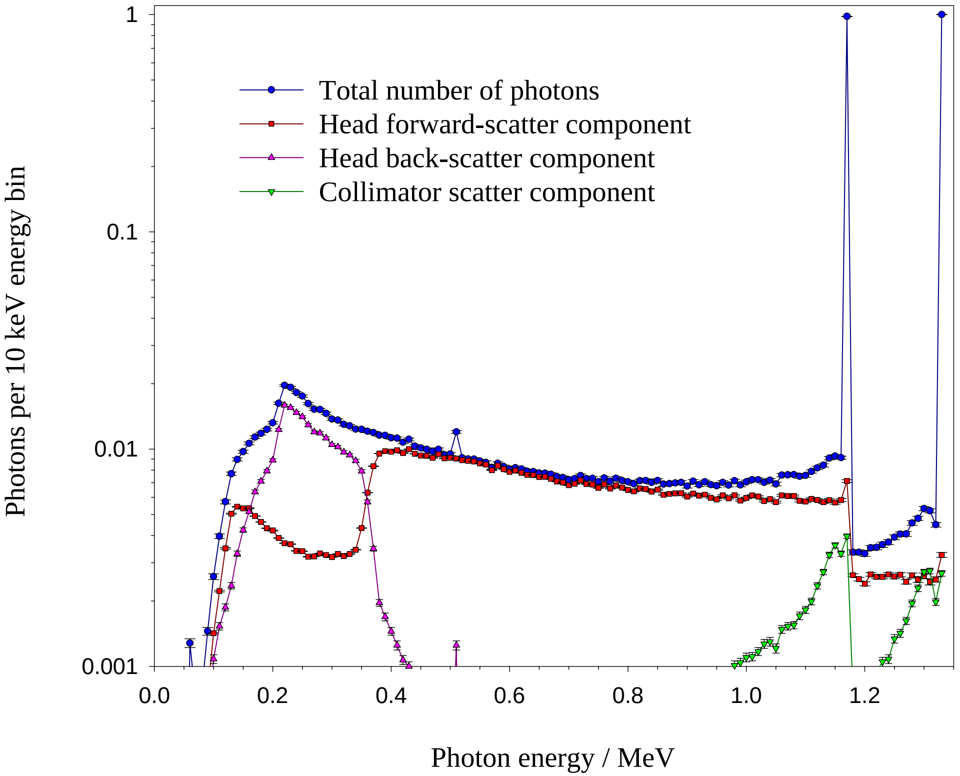
- Follows on from calculation of correction factors for BIPM air-kerma standard using PENELOPE
  - now published as
    Burns D T (2006)
    Phys. Med. Biol. **51** 929–942



Realistic beam simulation

Simulation of BIPM ^{60}Co source using PENELOPE

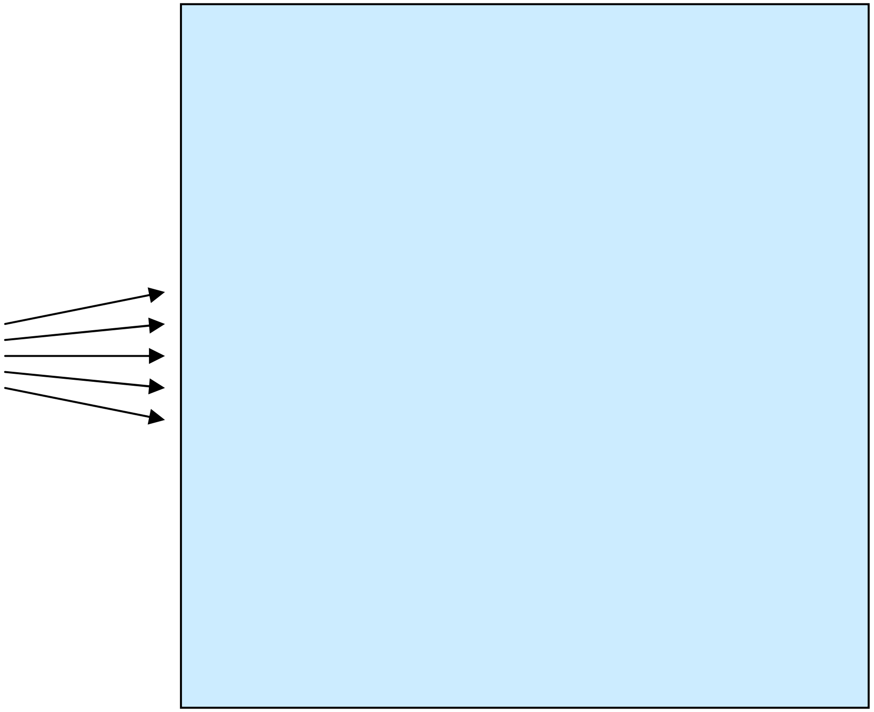




Scatter component:
21 % of energy fluence

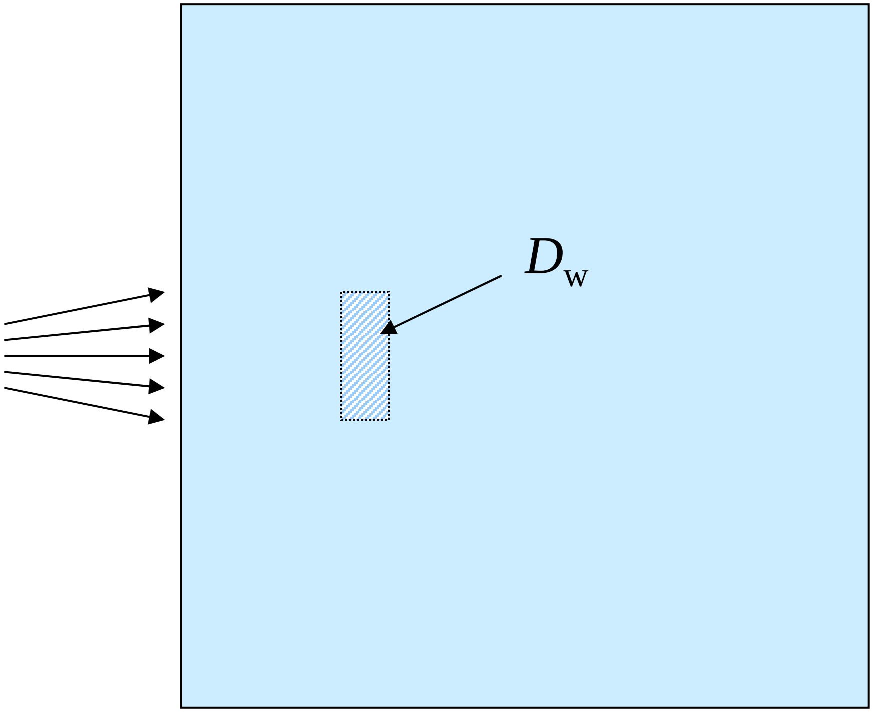
Step-by-step procedure

- Homogeneous water phantom



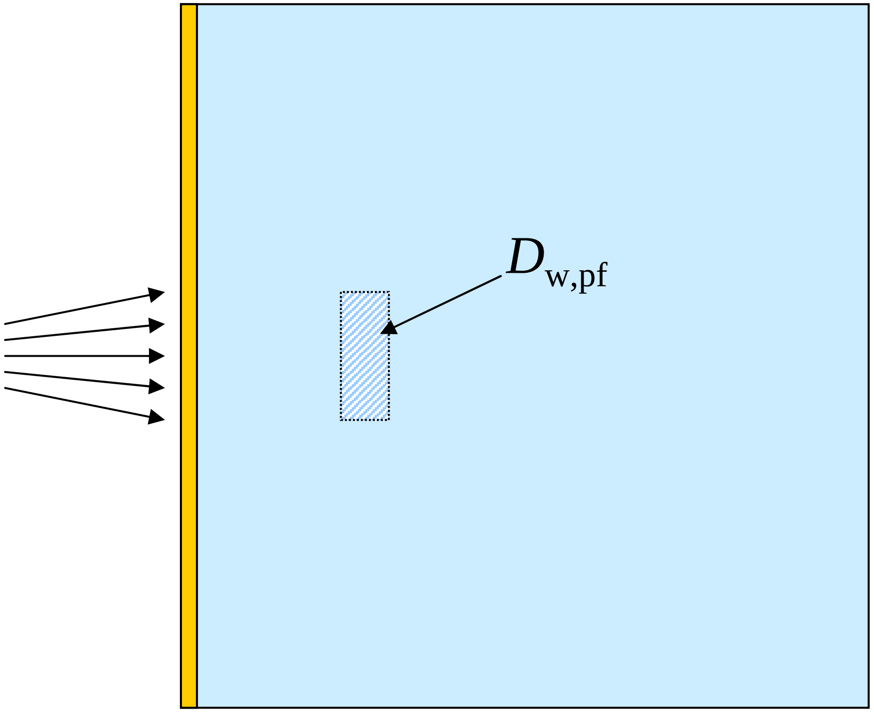
Step-by-step procedure - Step 1

- Homogeneous water phantom
  - calculate D_w in shaded region



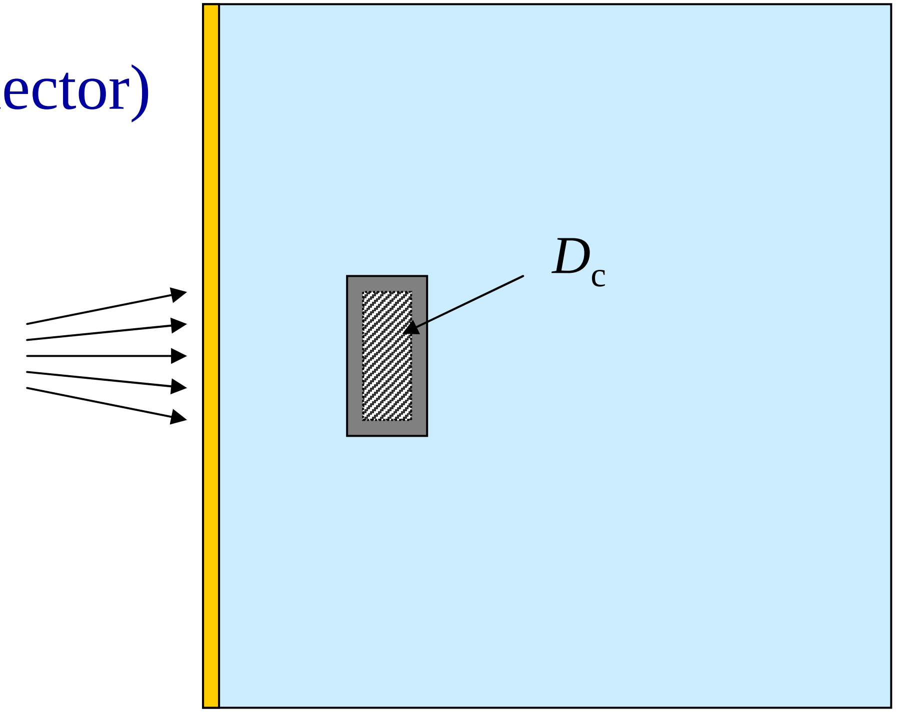
Step-by-step procedure - Step 2

- Homogeneous water phantom
  - calculate D_w in shaded region
- Add PMMA window
  - evaluate $D_w / D_{w,pf} = k_{pf}$



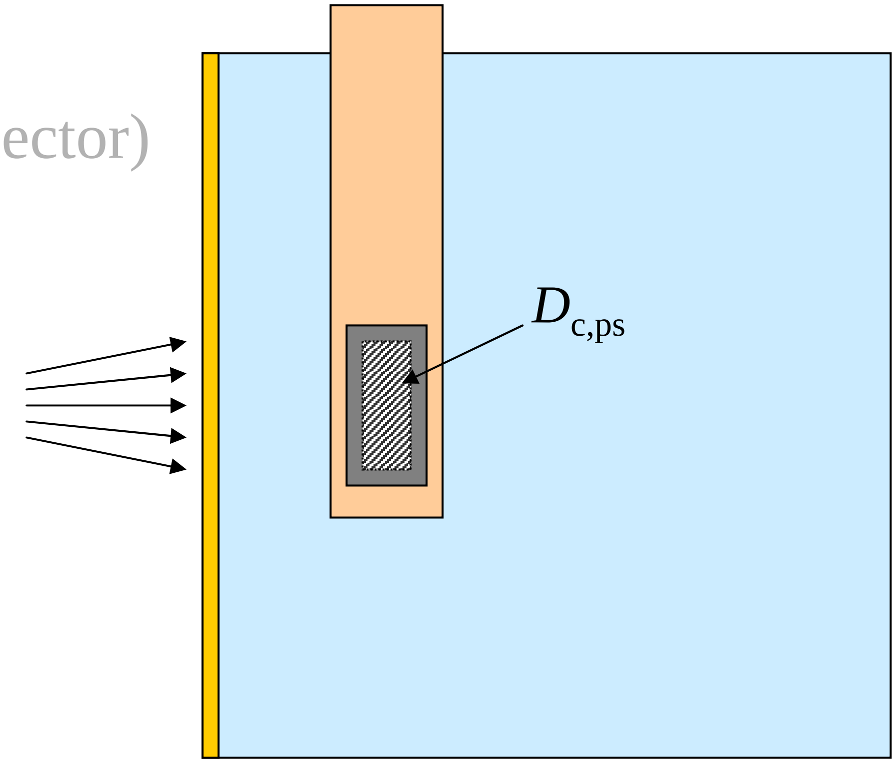
Step-by-step procedure - Step 3

- Homogeneous water phantom
  - calculate D_w in shaded region
- Add PMMA window
  - evaluate D_w / $D_{w,pf} = k_{pf}$
- Add graphite 'chamber' (no collector)
  - evaluate $D_{w,pf}$ / $D_c = K_{col,w,c}\ \beta_{w,c}$



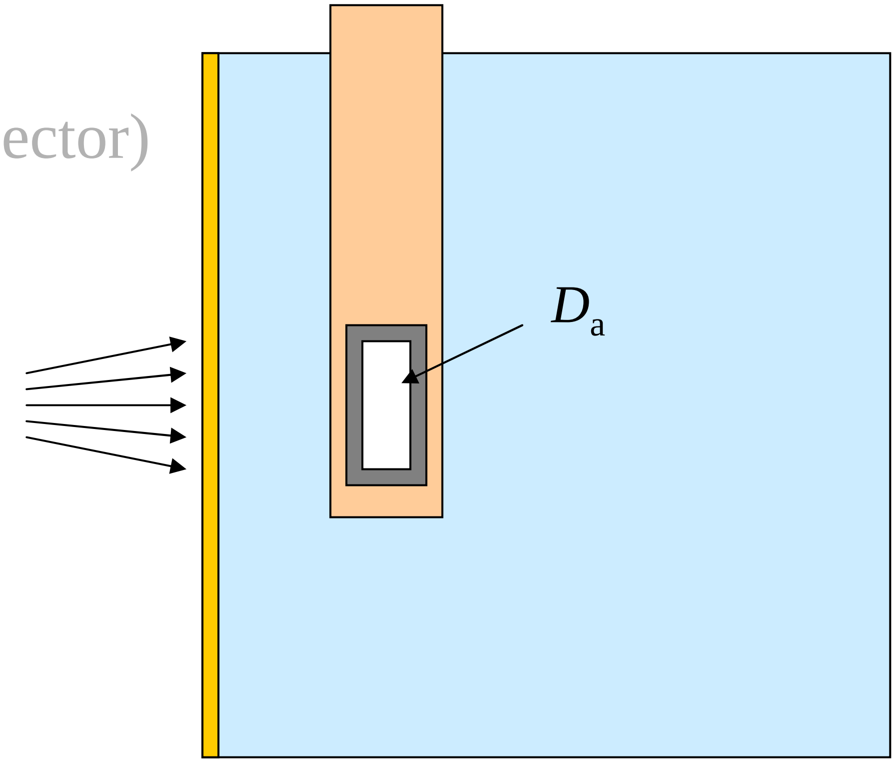
Step-by-step procedure - Step 4

- Homogeneous water phantom
  - calculate D_{w} in shaded region
- Add PMMA window
  - evaluate $D_{w} / D_{w,pf} = k_{pf}$
- Add graphite 'chamber' (no collector)
  - evaluate $D_{w,pf} / D_{c} = K_{col,w,c}\ \beta_{w,c}$
- Add waterproof envelope
  - evaluate $D_{c} / D_{c,ps} = k_{ps}$



Step-by-step procedure - Step 5

- Homogeneous water phantom
  - calculate D_w in shaded region
- Add PMMA window
  - evaluate $D_w / D_{w,pf} = k_{pf}$
- Add graphite 'chamber' (no collector)
  - evaluate $D_{w,pf} / D_c = K_{col,w,c}\ \beta_{w,c}$
- Add waterproof envelope
  - evaluate $D_c / D_{c,ps} = k_{ps}$
- Add 'ideal' air cavity
  - evaluate $D_{c,ps} / D_a = s_{c,a}$



Step-by-step procedure - Step 6

- Homogeneous water phantom
  - calculate D_w in shaded region
- Add PMMA window
  - evaluate $D_w / D_{w,pf} = k_{pf}$
- Add graphite 'chamber' (no collector)
  - evaluate $D_{w,pf} / D_c = K_{col,w,c}\ \beta_{w,c}$
- Add waterproof envelope
  - evaluate $D_c / D_{c,ps} = k_{ps}$
- Add 'ideal' air cavity
  - evaluate $D_{c,ps} / D_a = s_{c,a}$
- Real cavity (with collector)
  - evaluate $D_a / D_{cav} = k_{cav}$

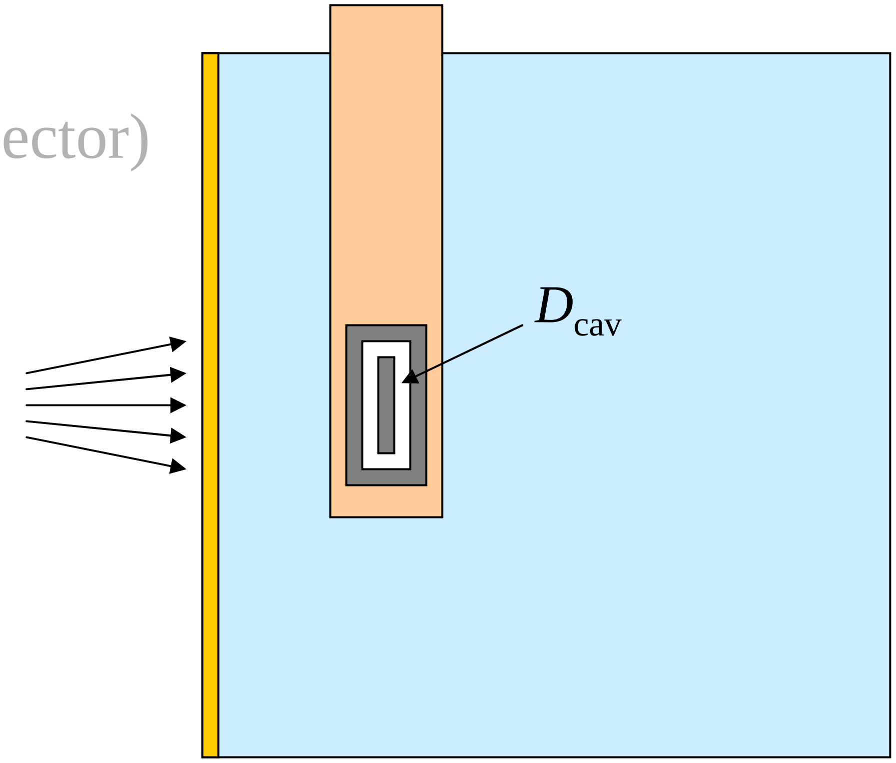


Table of results

Component	New Value*	Existing Value	New / Existing
$\boldsymbol{k_{pf}}$	**0.9996(1)**	**0.9996(1)**	**1.0000**
k_{ps}	0.9993(1)	0.9994(1)	0.9999
$K_{col,w,c}$	1.1172(2)	1.1197(16)	0.9978
$\beta_{w,c}$	0.9998(1)	1.0015(6)	0.9983
$s_{c,a}$	1.0025(3)	1.0030(30)	0.9995
k_{cav}	0.9985(3)	0.9900(5)	1.0086

* statistical uncertainties only

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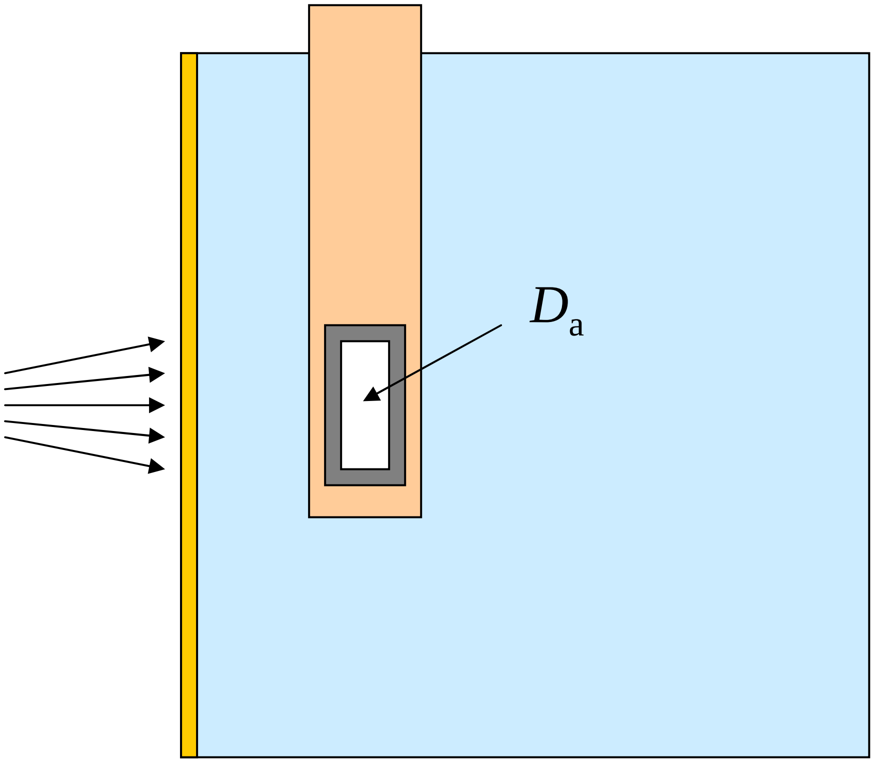
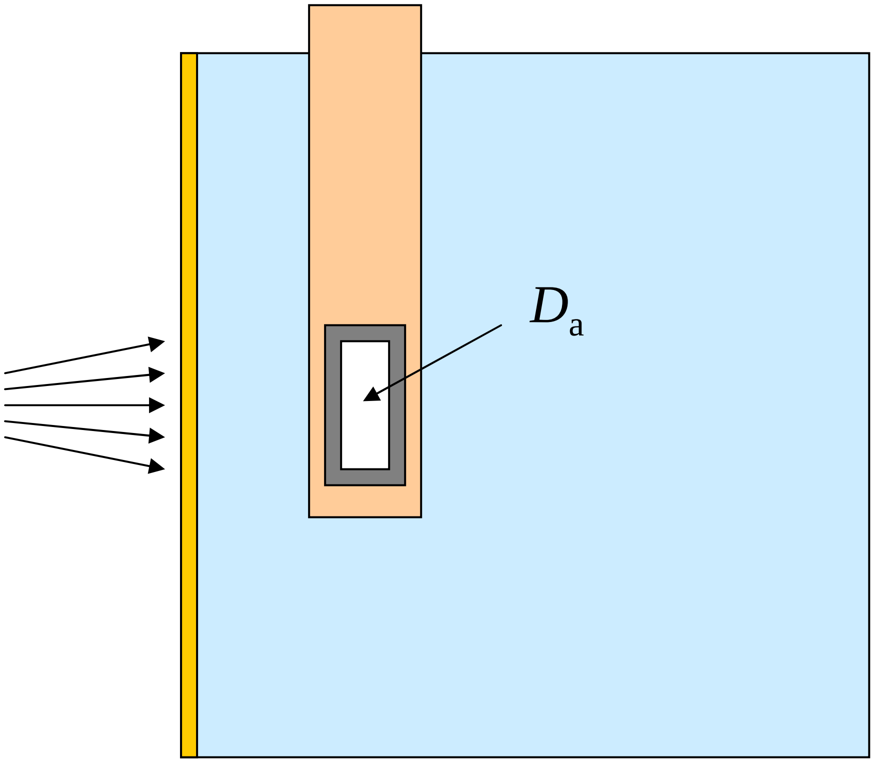
‘Ideal’ cavity

- Verify that D_a does not depend on cavity thickness



‘Ideal’ cavity

- Verify that D_a does not depend on cavity thickness
  - evaluate D_a for different cavities from 1 mm to 5 mm in thickness



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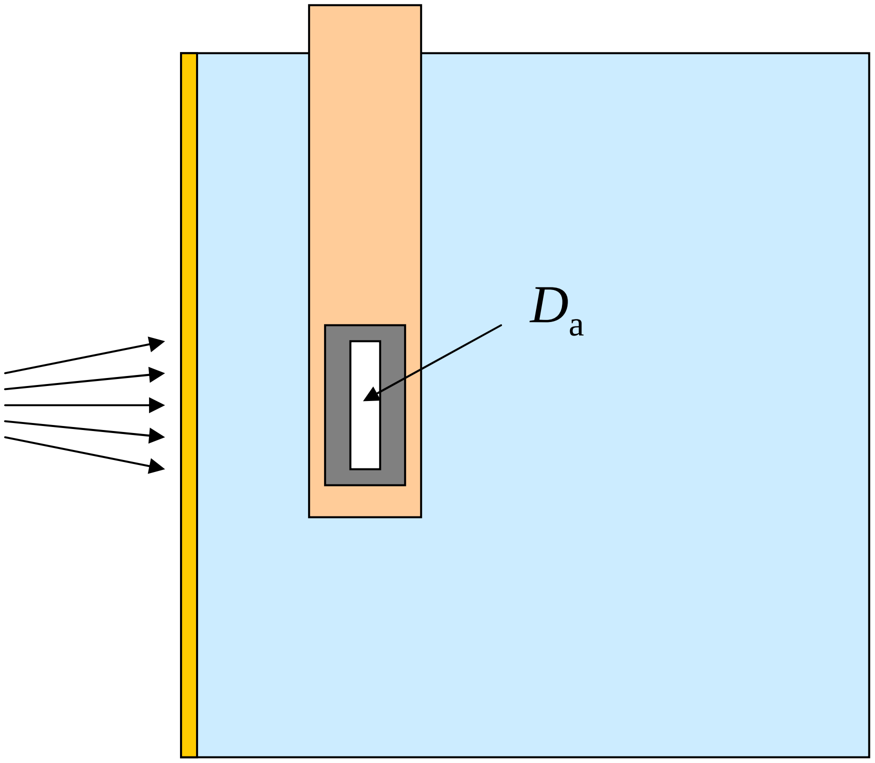

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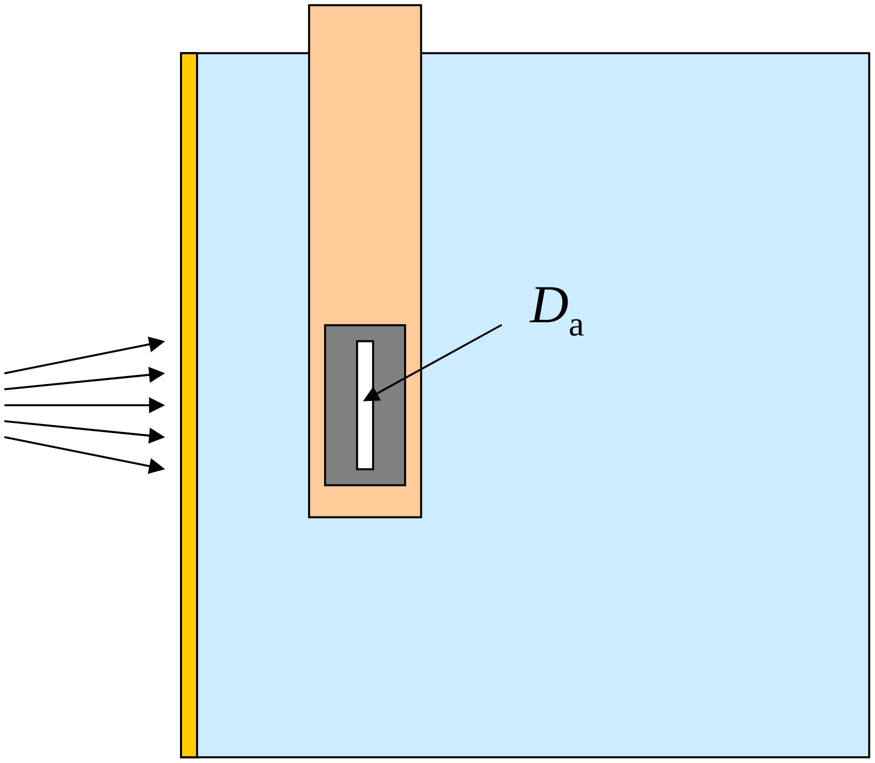

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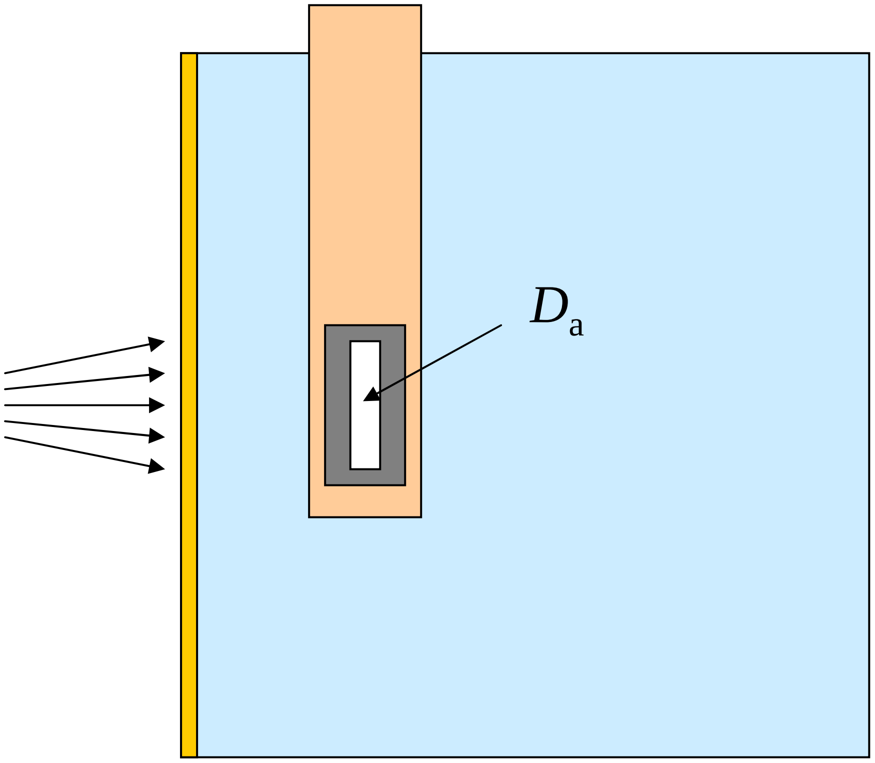

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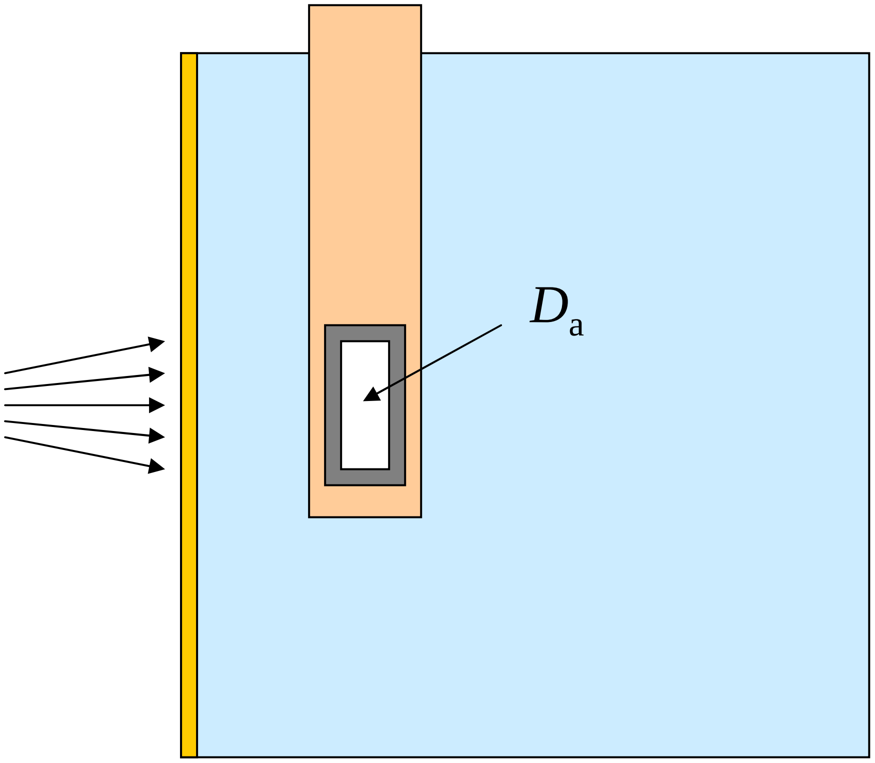
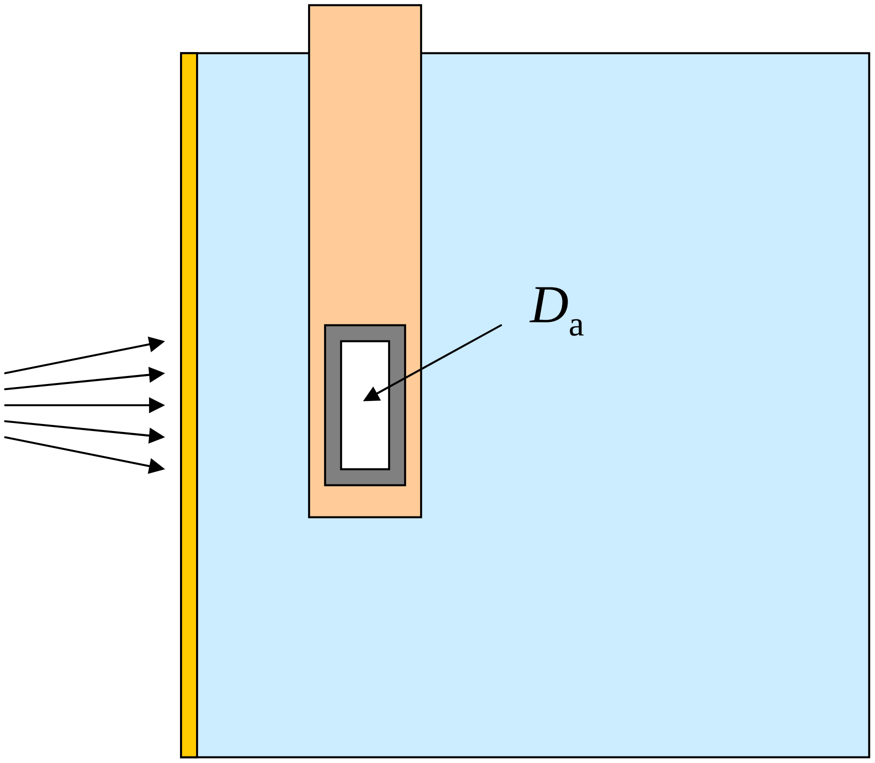
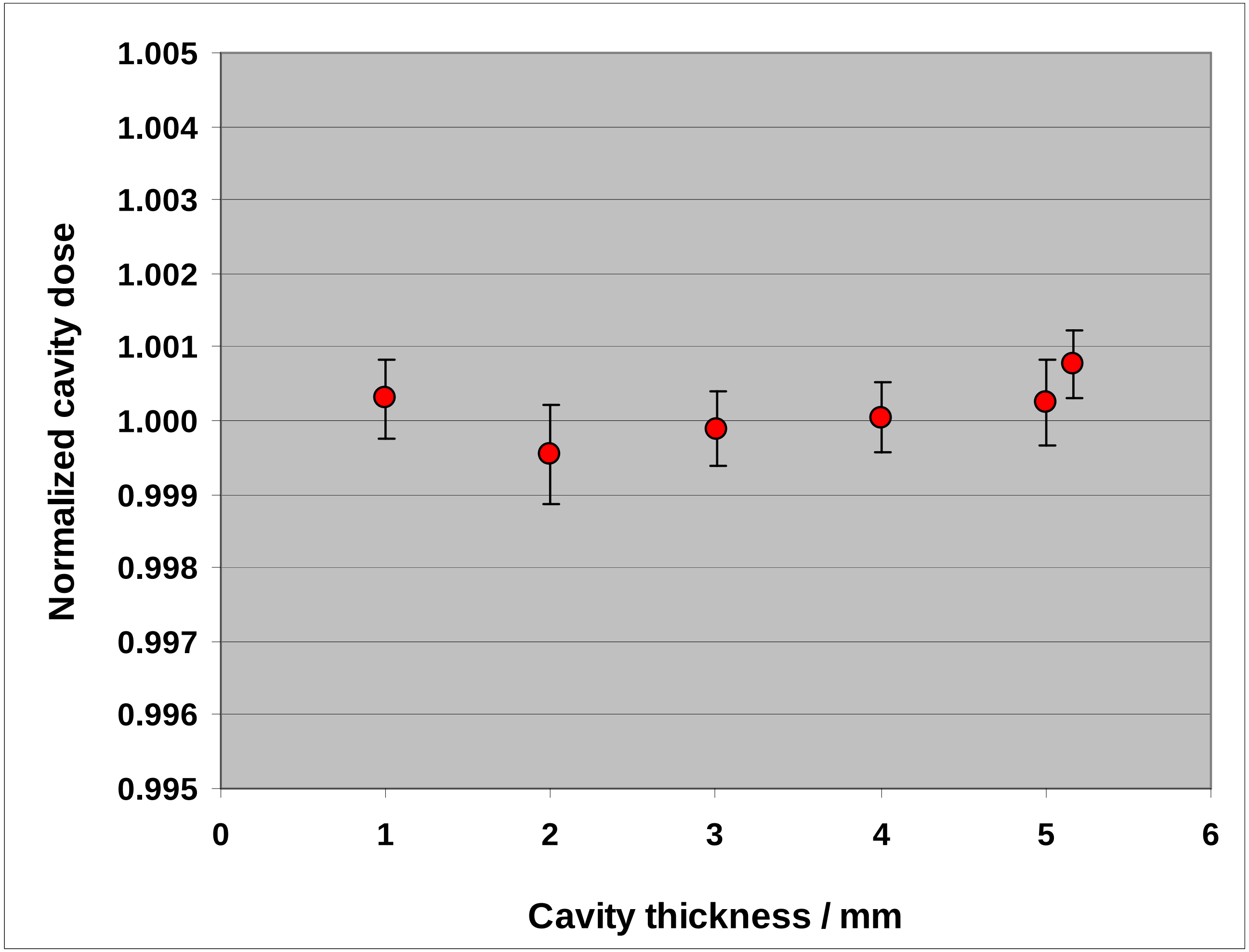


‘Ideal’ cavity

- Verify that D_a does not depend on cavity thickness
  - evaluate D_a for different cavities from 1 mm to 5 mm in thickness
  - total calculation time on 2.5 GHz processor equivalent to 800 days



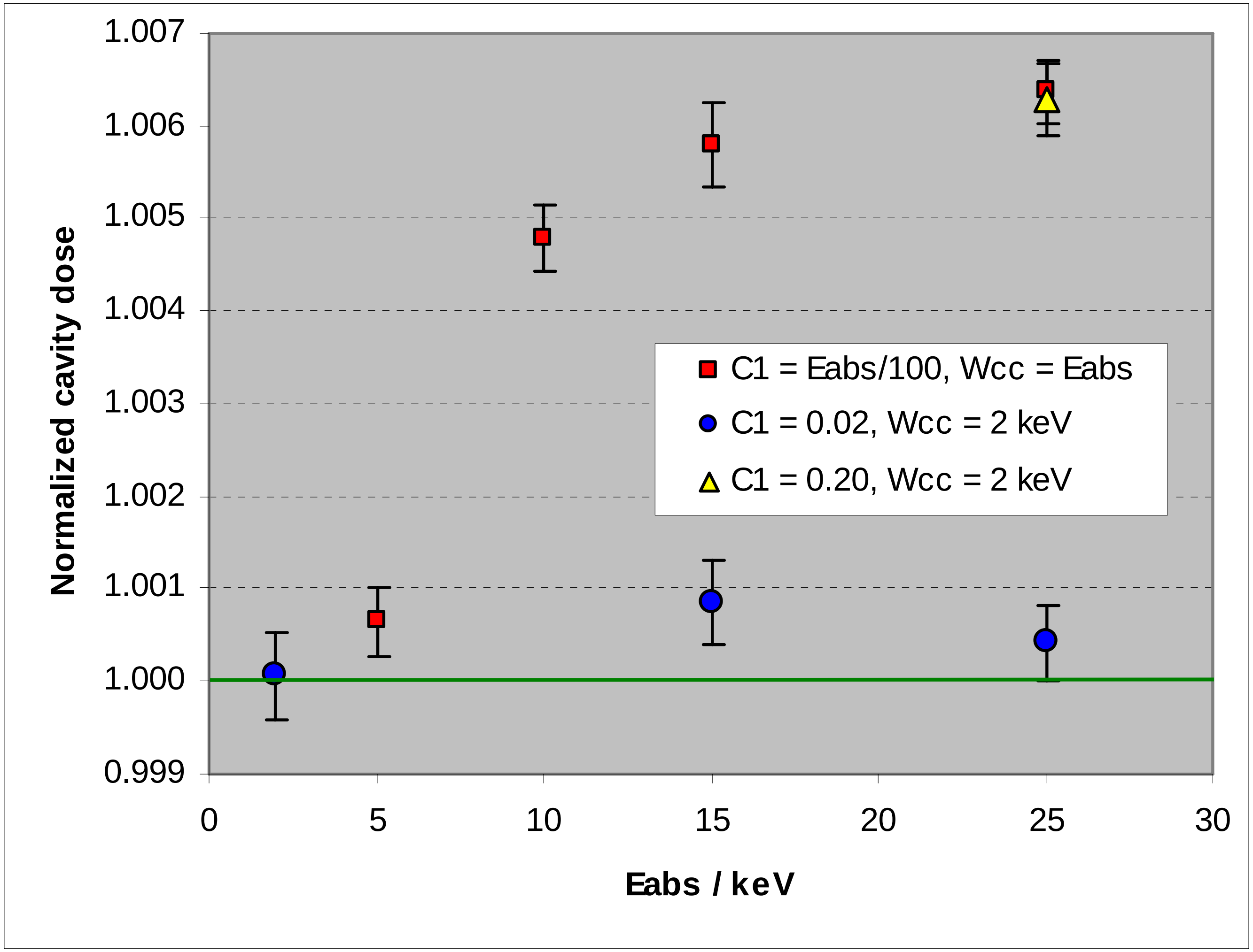
'Ideal' cavity results



Cavity dose in PENELOPE

- Choice of electron transport parameters
  - E_{abs}, C_1, C_2, W_{cc}, W_{cr}
- Modified chamber model
  - thin graphite ‘skin’ on all surfaces in contact with air cavity
  - step-by-step (analogue) electron transport down to E_{abs} = 2 keV ($C_1 = C_2 = 0$, W_{cc} = 2 keV)

Calculation of cavity dose



Results for simple chamber model and different transport parameters

Normalization is to result for 'skin' model

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$\beta_{w,c}$	0.9998(1)	1.0015(6)	0.9983
$s_{c,air}$	1.0025(3)	1.0030(30)	0.9995
k_{cav}	0.9985(3)	0.9900(5)	1.0086
Product	**1.1169**	**1.1124**	**1.0040**

* statistical uncertainties only

Summary of calculation