Monte Carlo for Reference Dosimetry of Light-ion Beams

Hugo Palmans

MedAustron, Wiener Neustadt, Austria
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Reference dosimetry

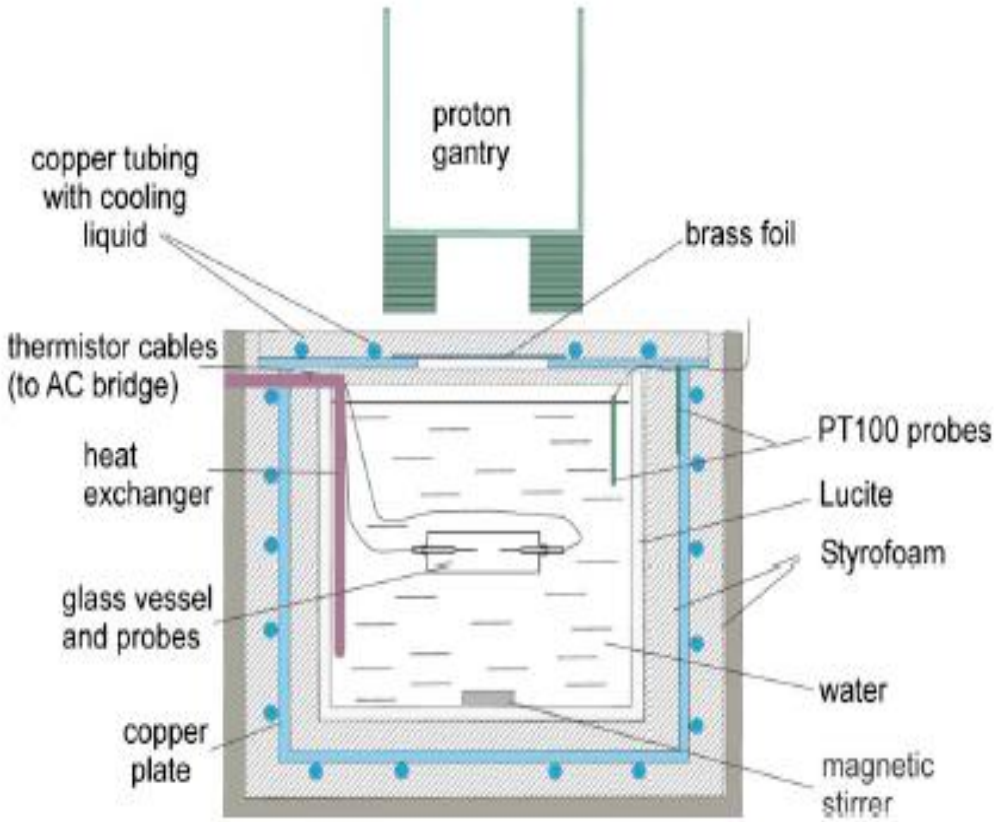
Primary standards

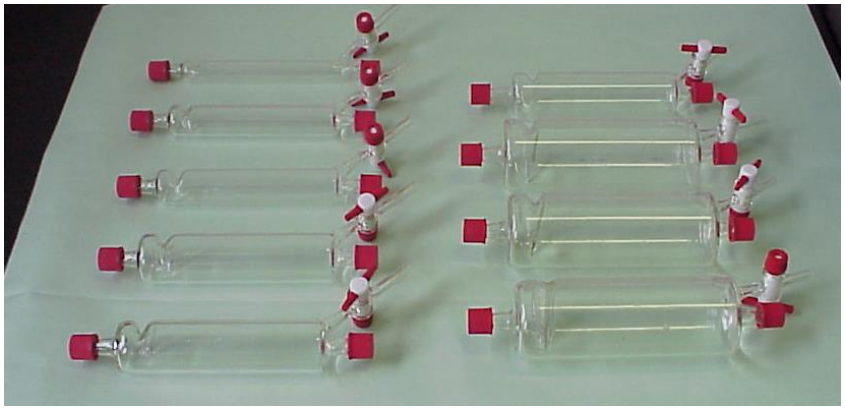
Dissemination

Clinical reference dosimetry using ionization chambers

Verification of dosimetry chain using independent dosimeters

Primary standards – water calorimeters: scatter and attenuation





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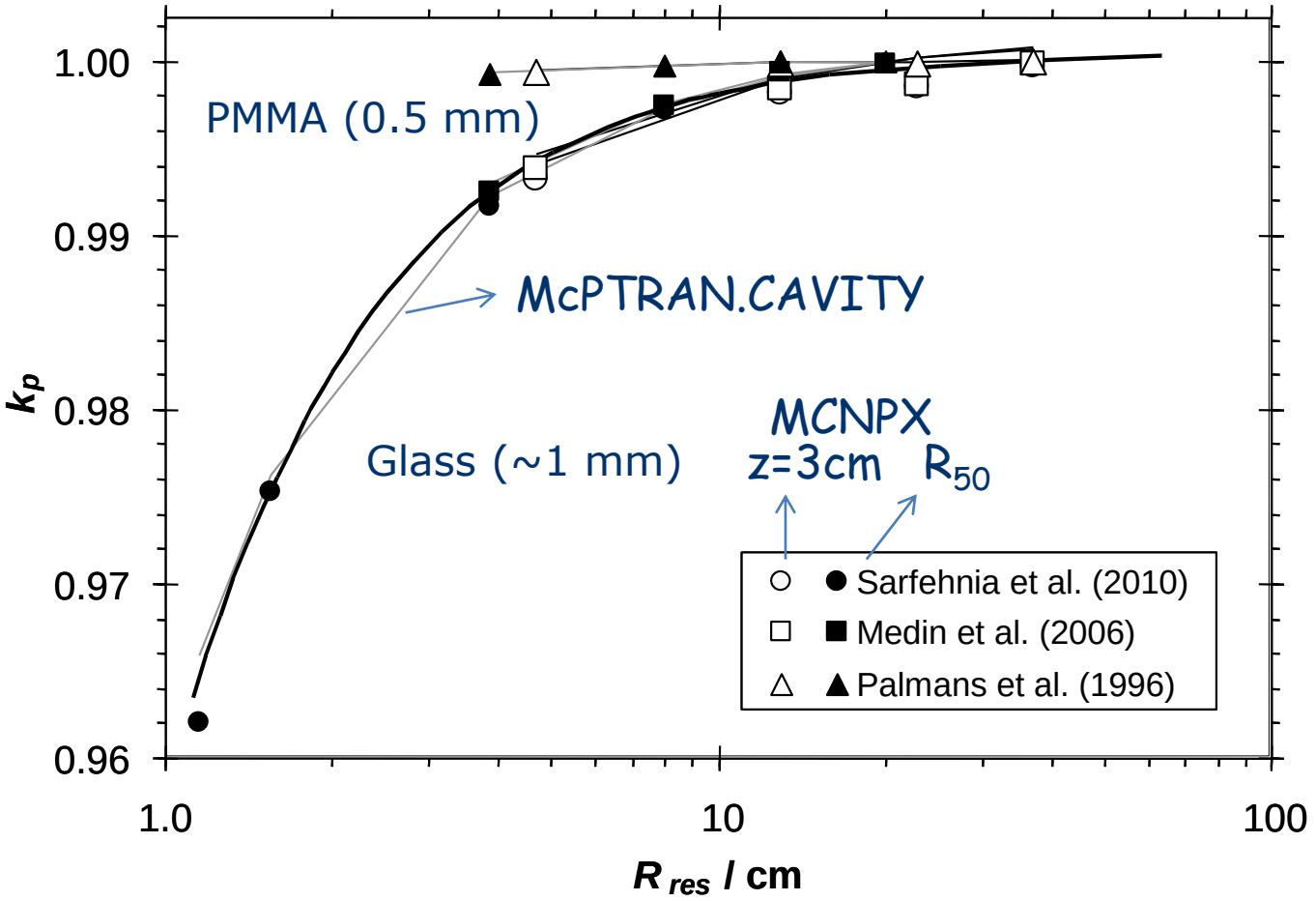
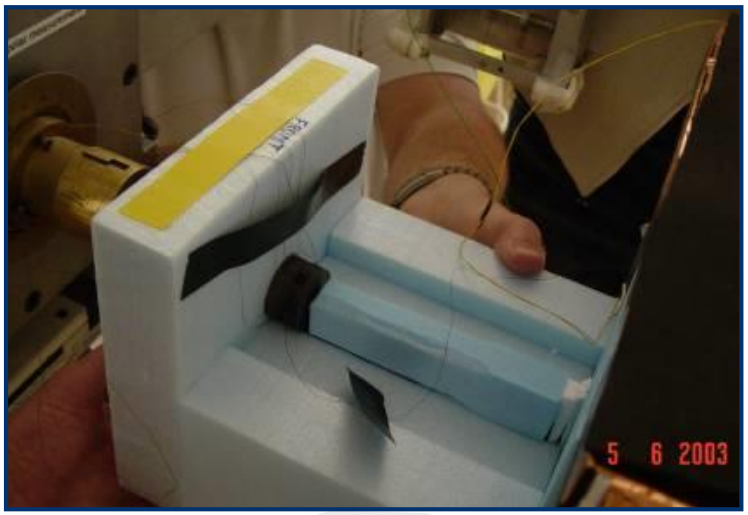
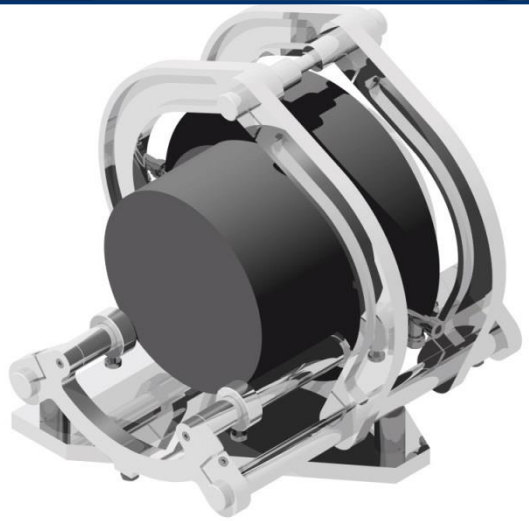
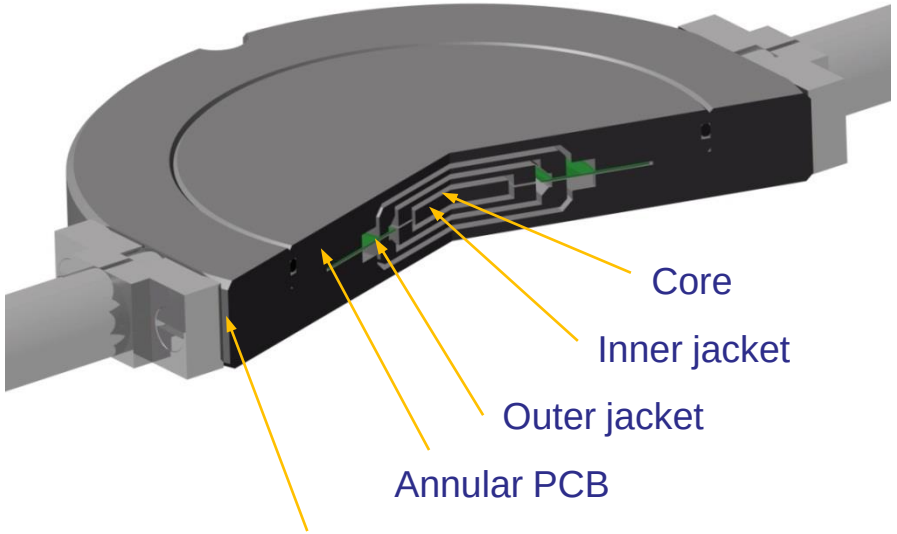


Primary standards – graphite calorimeters

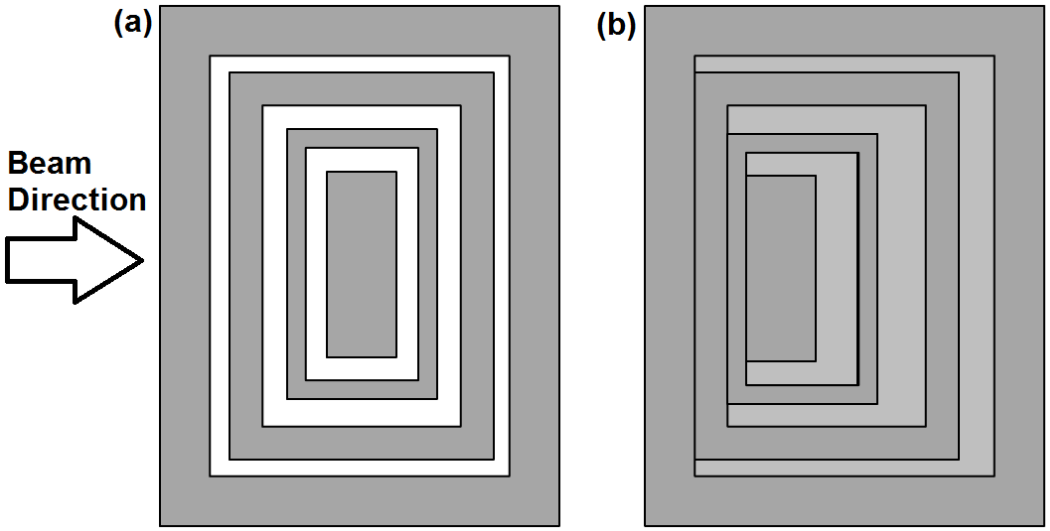


Palmans et al 2004
Phys Med Biol 49:3737





Primary standards – graphite calorimeters: gap corrections (PhD Lauren Petrie, see also presentation Francesco Romano)



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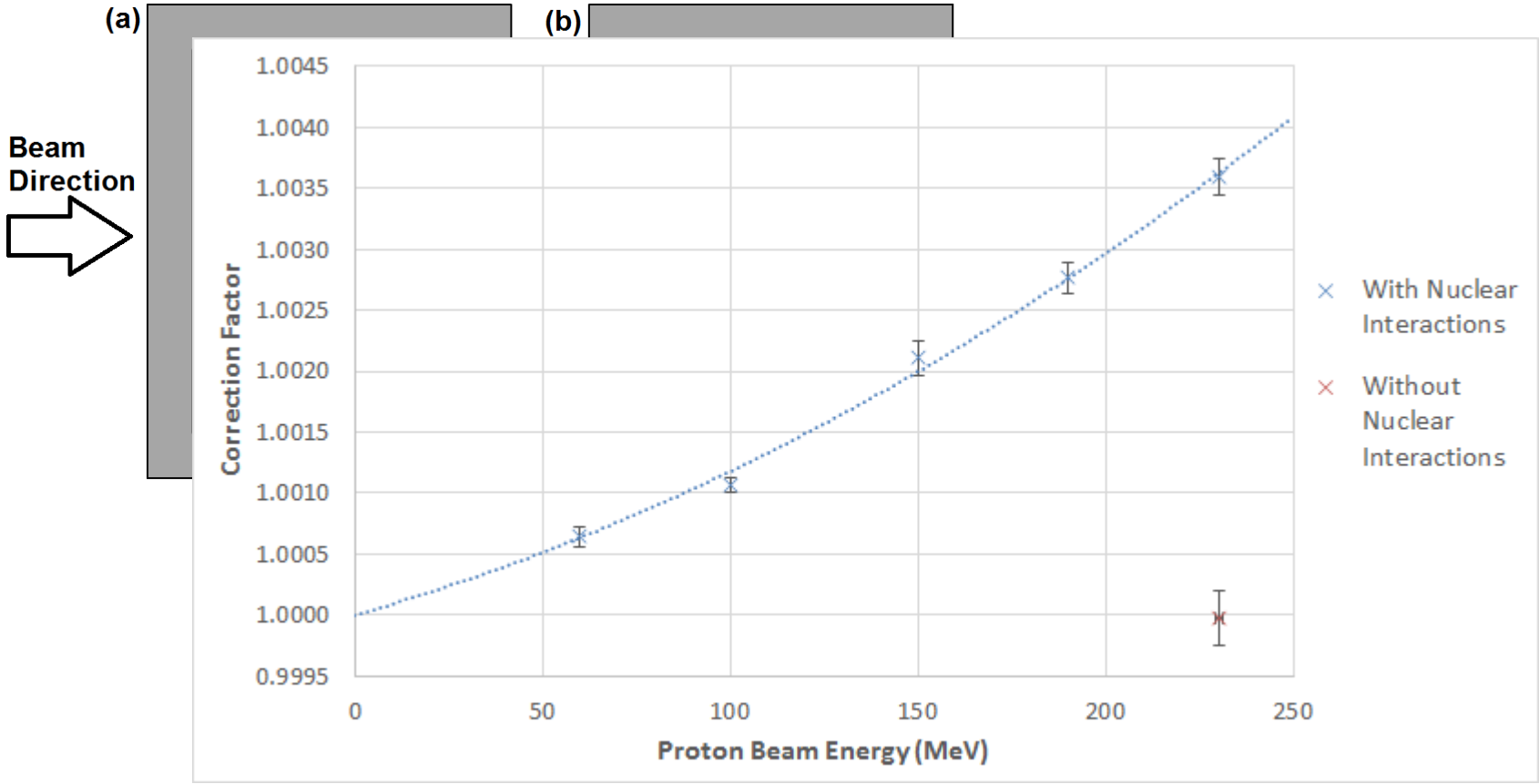

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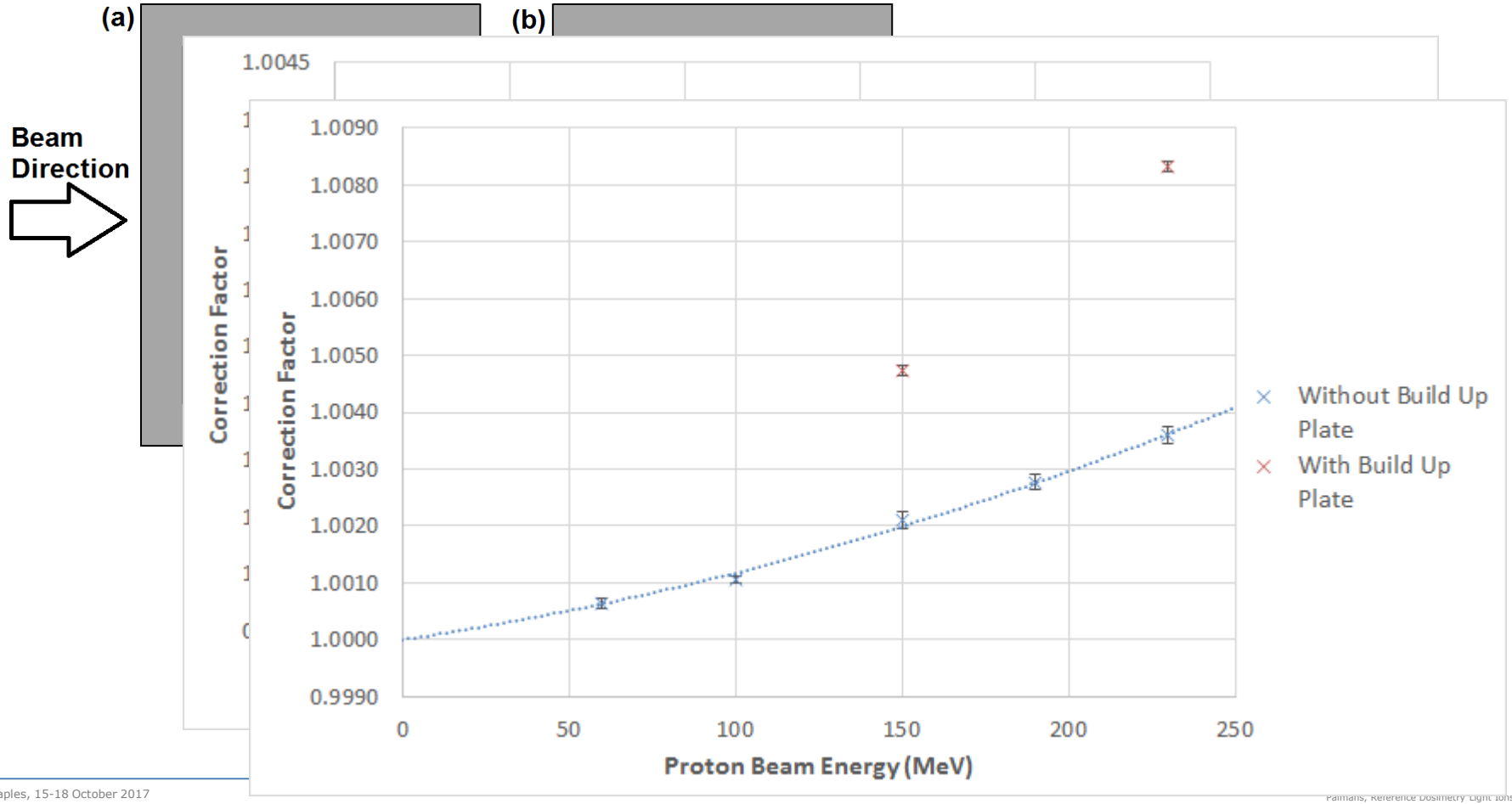
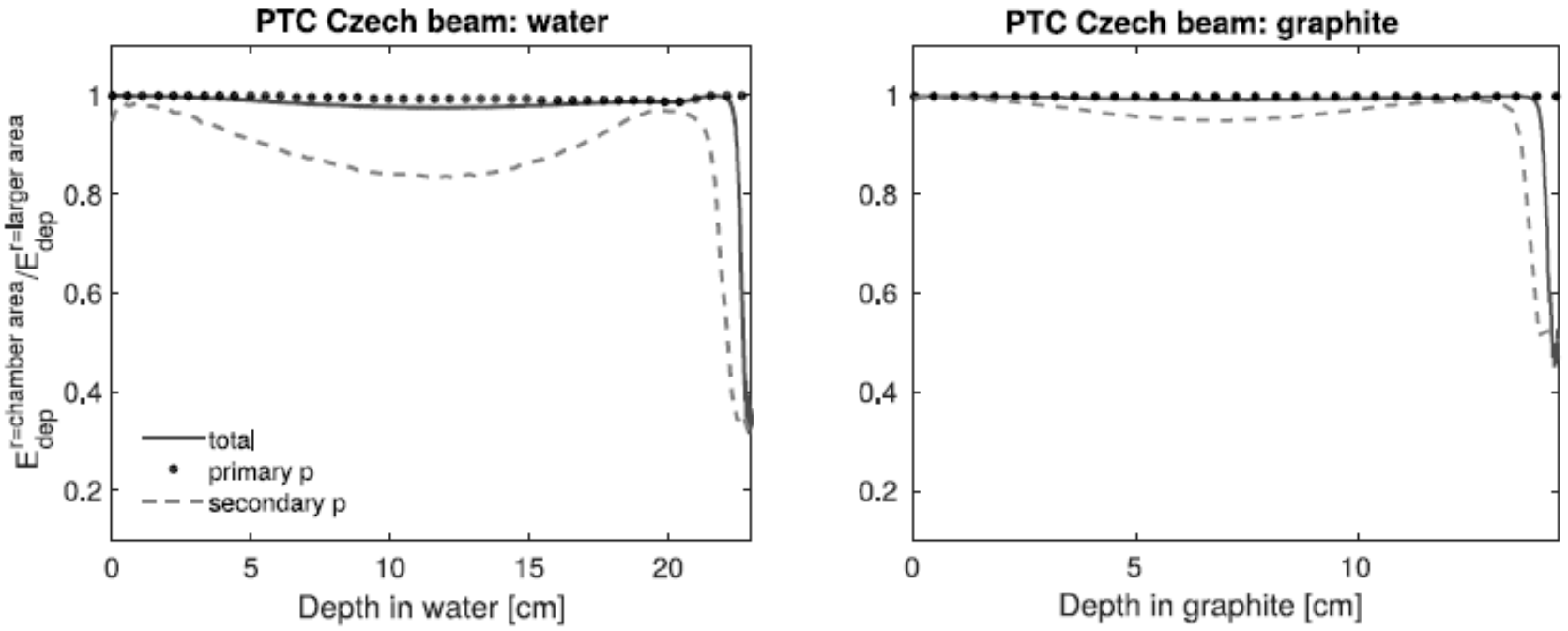


Primary standards – graphite calorimeters: D_g to D_w conversion (PhD Ana Lourenço)



Lourenço et al 2016 Med Phys 43:4122

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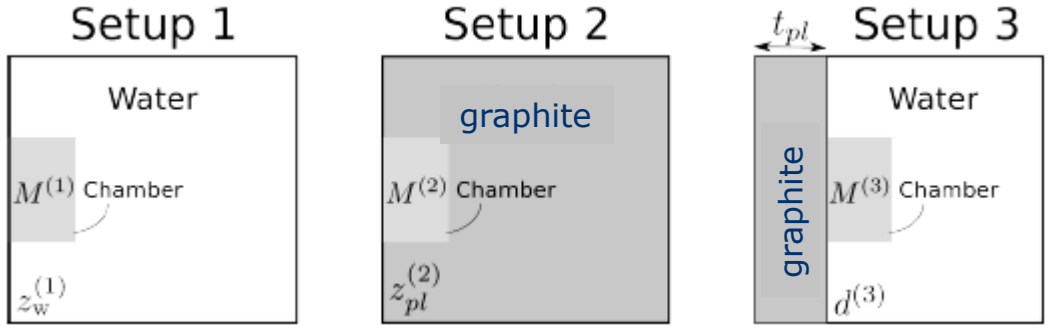
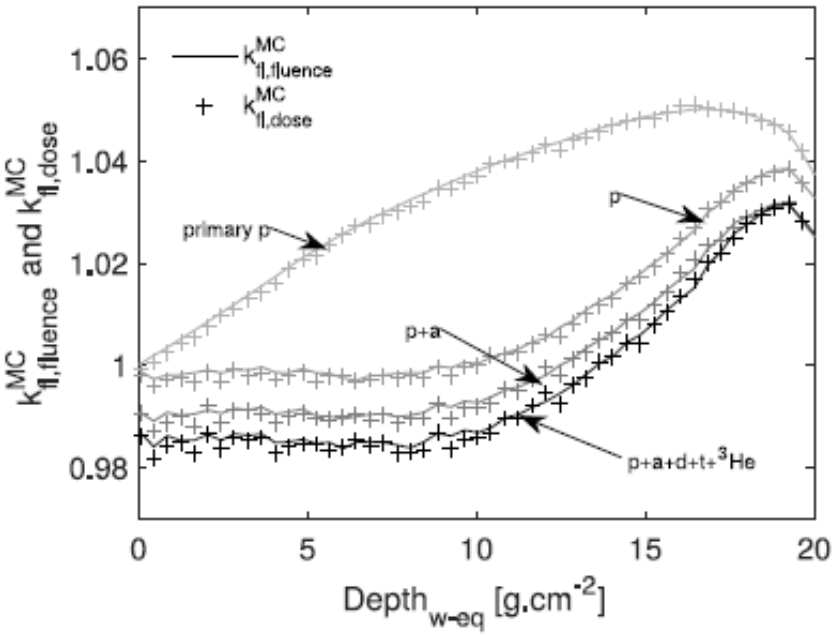
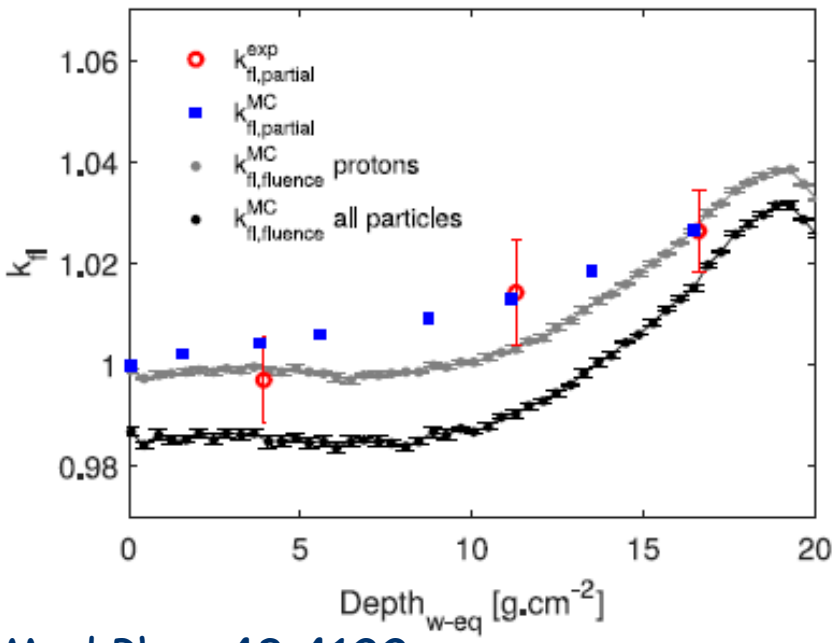
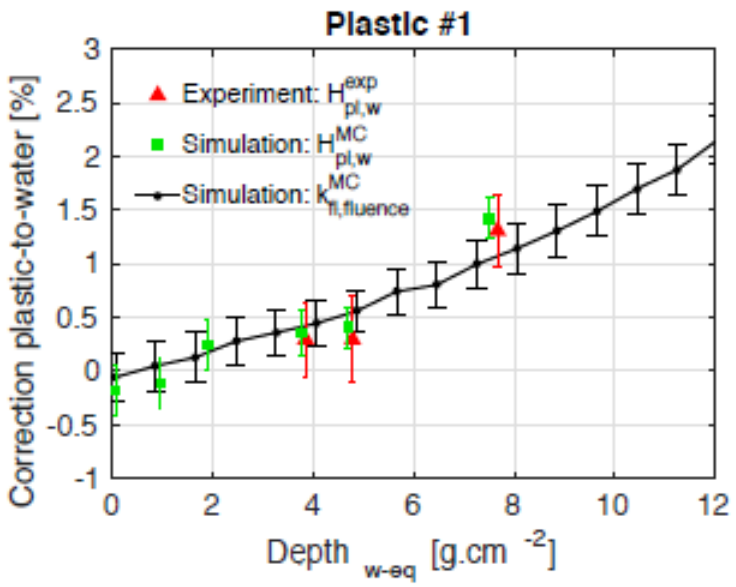


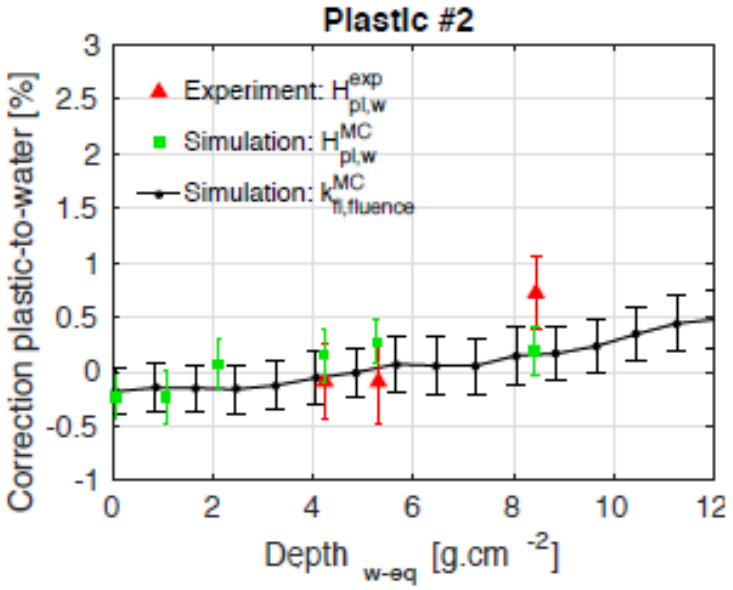




Lourenço et al 2016 Med Phys 43:4122

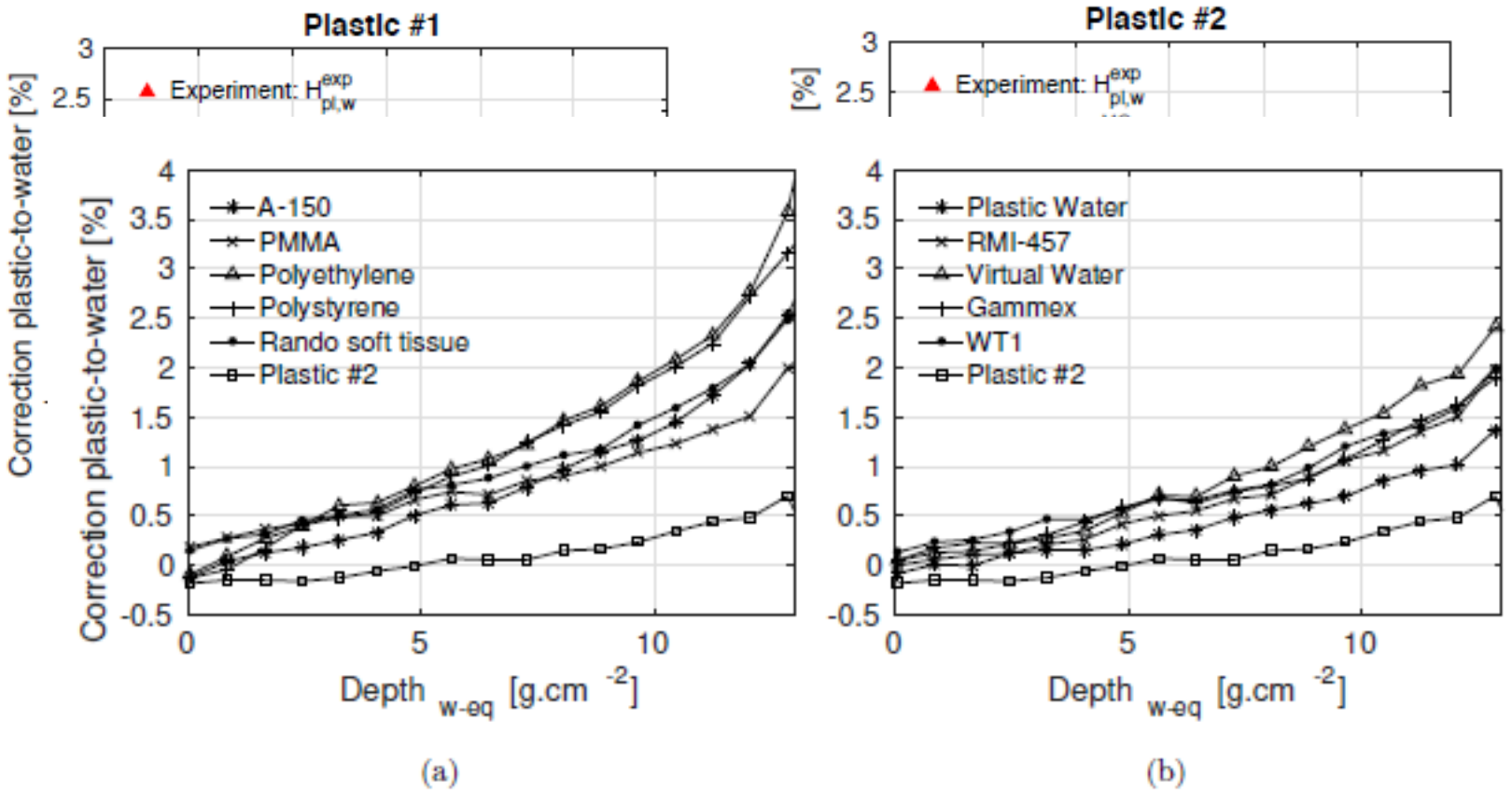
Dissemination – phantom materials: water-equivalence (PhD Ana Lourenço)





Lourenço et al 2017 Phys Med Biol 62:3883

Dissemination – phantom materials: water-equivalence (PhD Ana Lourenço)



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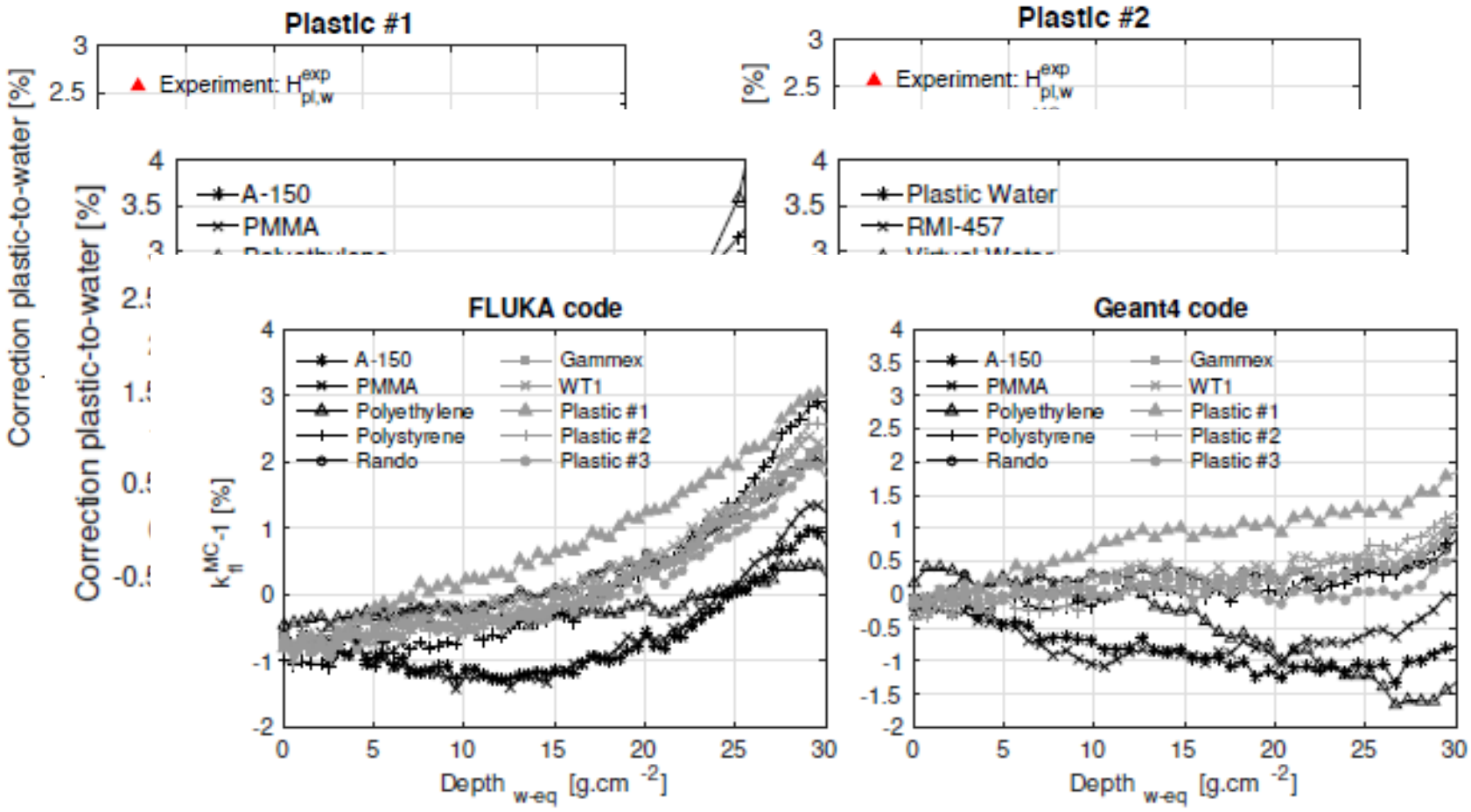
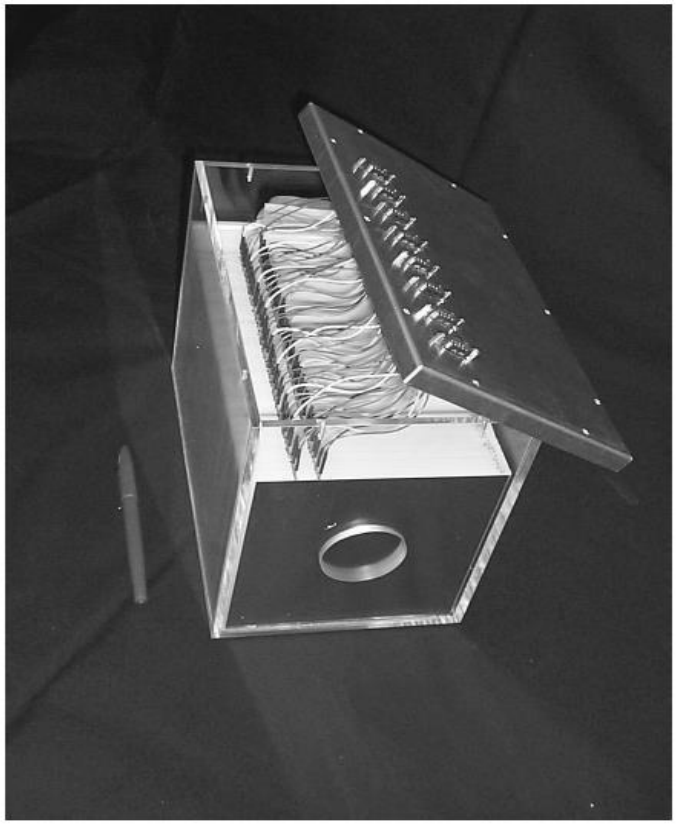
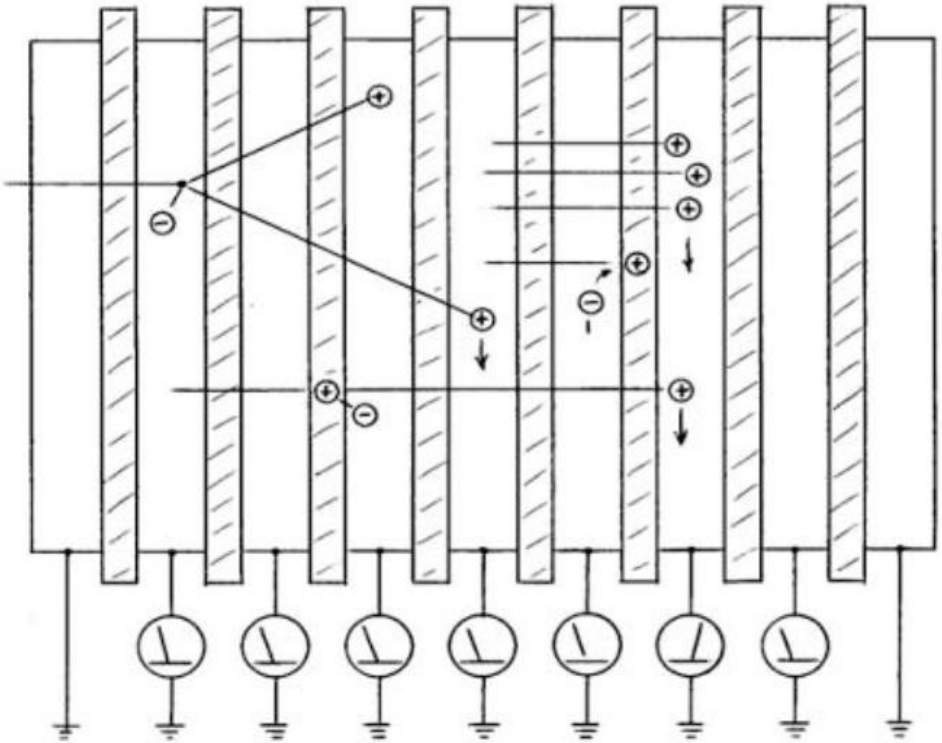


Lourenço et al 2017 Phys Med Biol 62:3883

Dissemination - phantom materials: nuclear interactions - MLFC experiment



Paganetti and Gottschalk 2003 Med Phys 30:1926



Kunert et al. 2013 Proc Cyclotrons 2013 Vancouver

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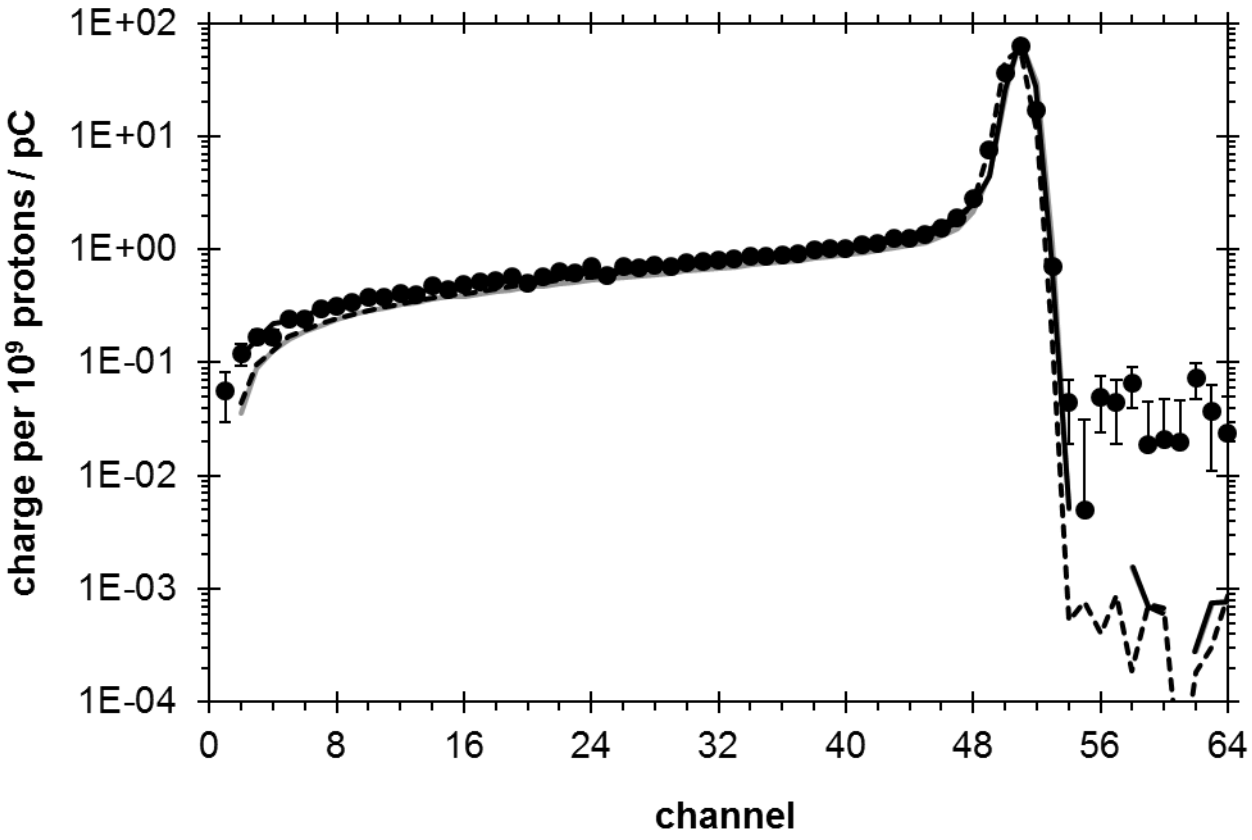

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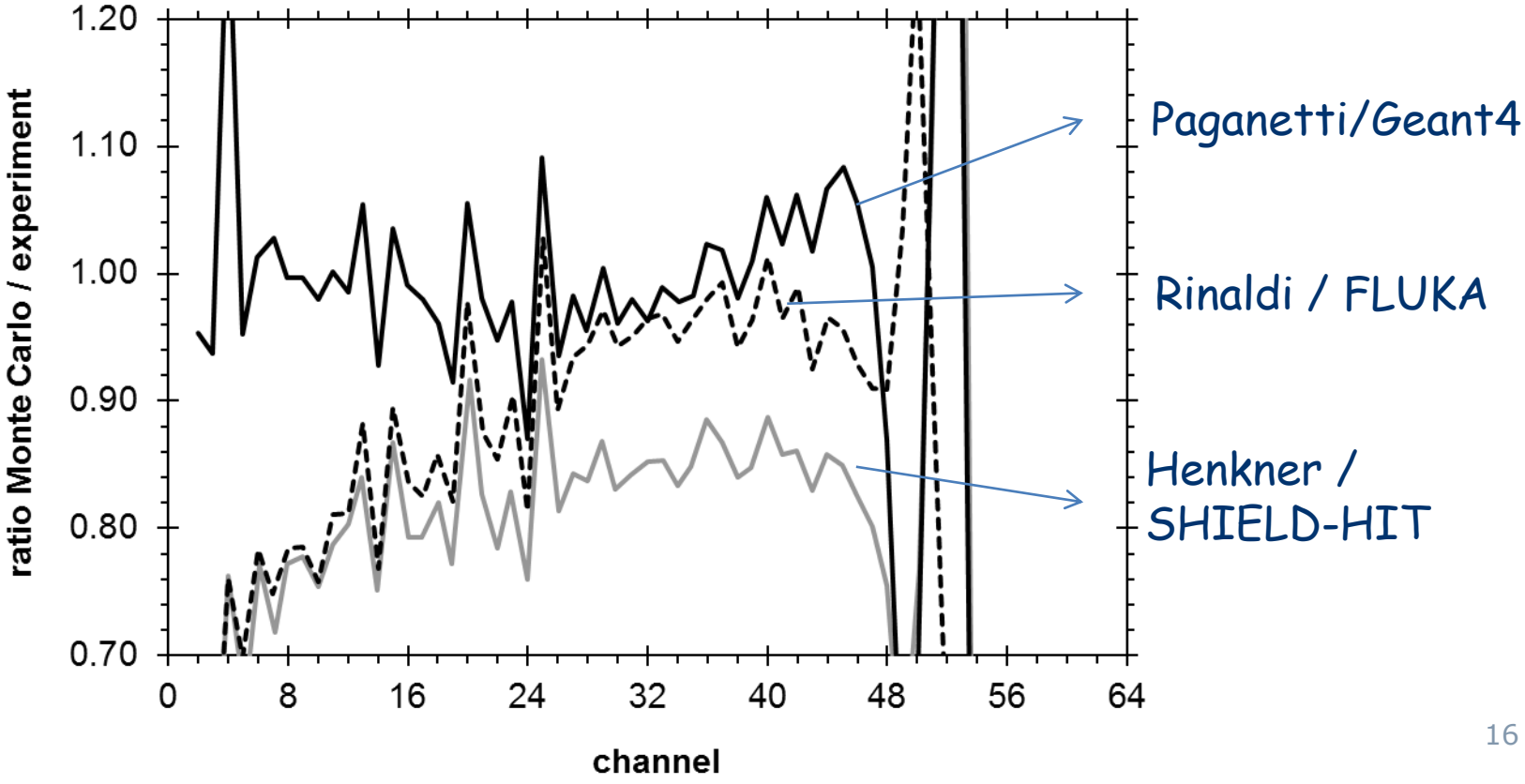


Clinical reference dosimetry using IC

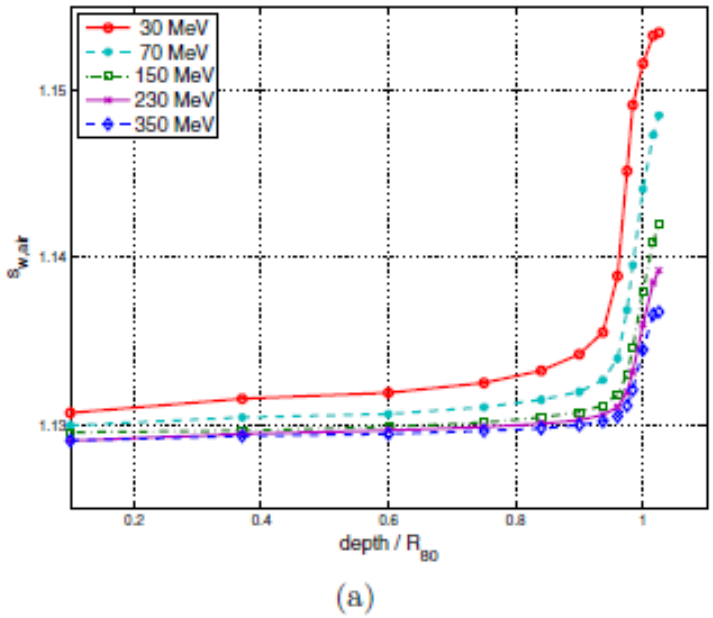
IAEA TRS-398:

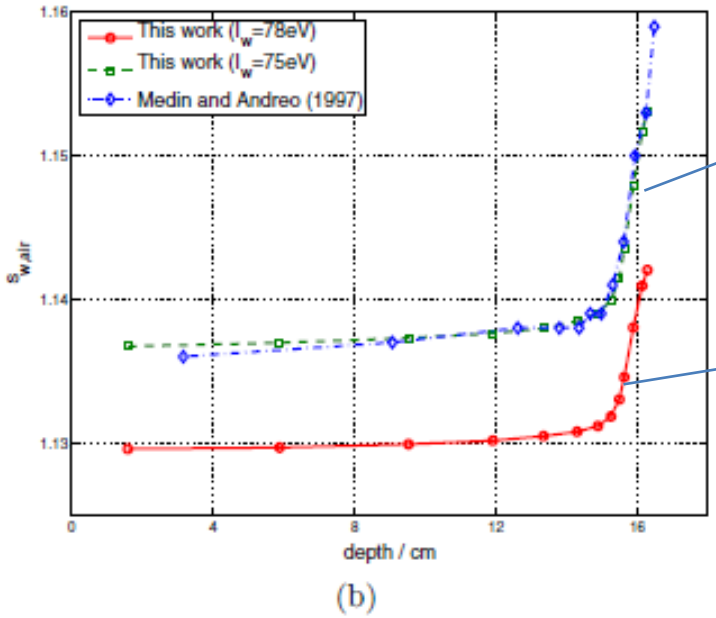
$$D_{w,Q} = M_Q N_{D,w,Q_0} k_{Q,Q_0}$$

Calculated beam quality correction factor:

$$k_{Q,Q_0} = \frac{(W_{air})_Q (s_{w,air})_Q p_Q}{(W_{air})_{Q_0} (s_{w,air})_{Q_0} p_{Q_0}}$$

Clinical reference dosimetry using IC: water-to-air stopping power ratios



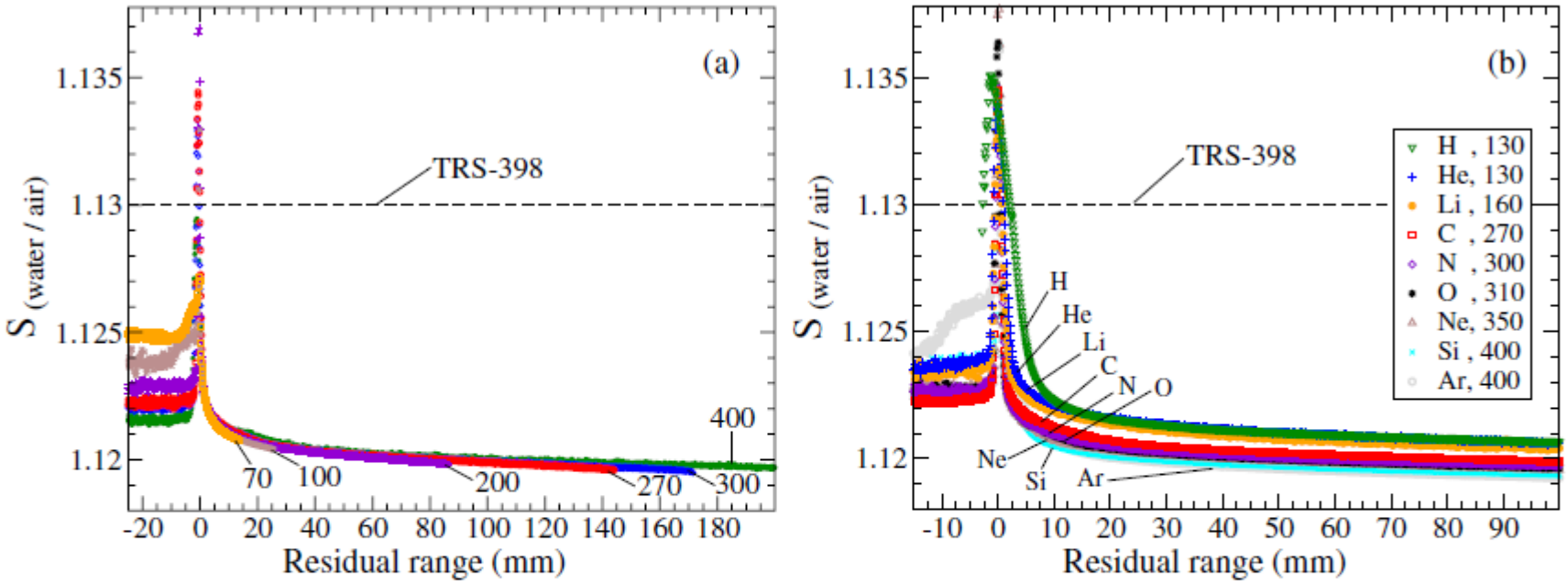


ICRU 49

ICRU 90

Goma et al 2013 Phys Med Biol 58:2509 / Geant4

Clinical reference dosimetry using IC: water-to-air stopping power ratios

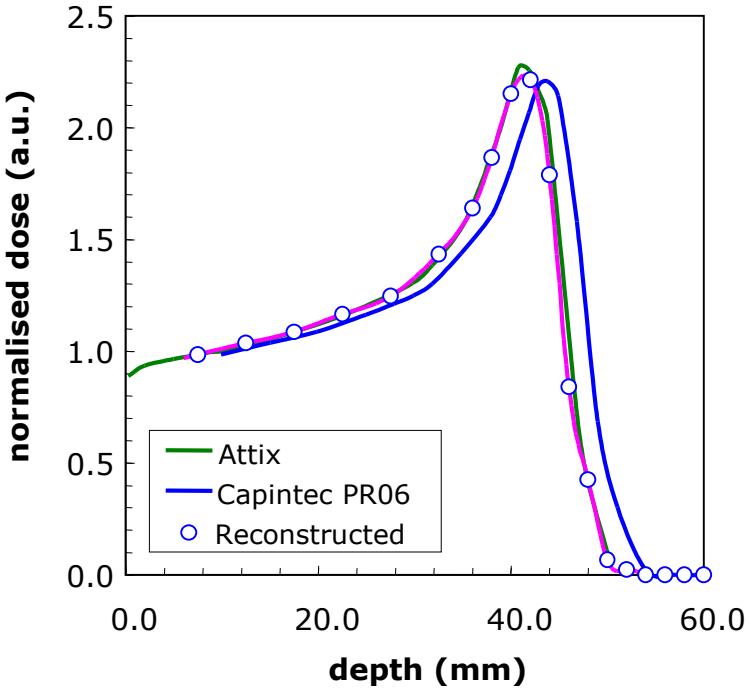


Luhr et al 2011 Phys Med Biol 56:2515 / SHIELD-HIT

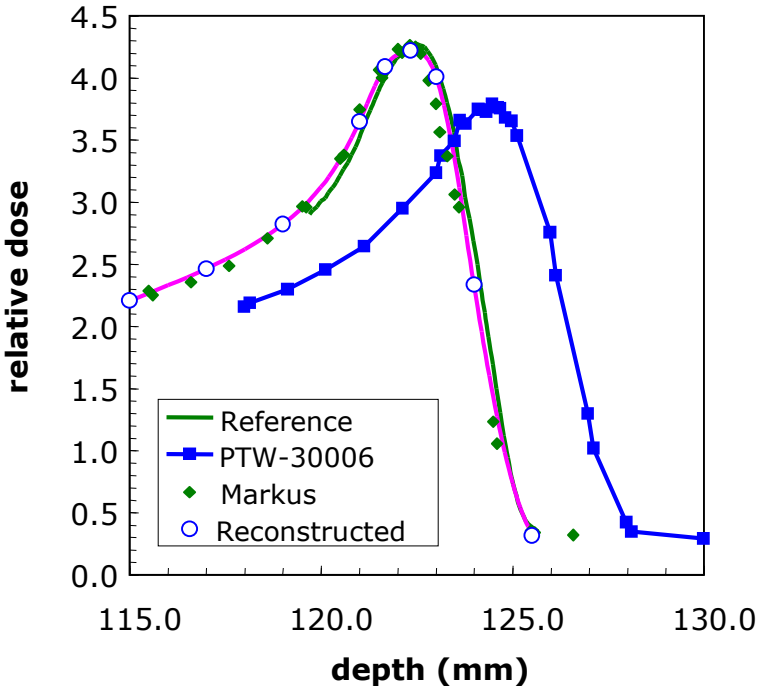
Clinical reference dosimetry using IC: displacement correction factors

Mobit et al. 2000 *Med. Phys.* 27:2780-2787 Jäkel et al. 2000 *Phys. Med. Biol.* 45:599-607

exp. data for 78 MeV protons

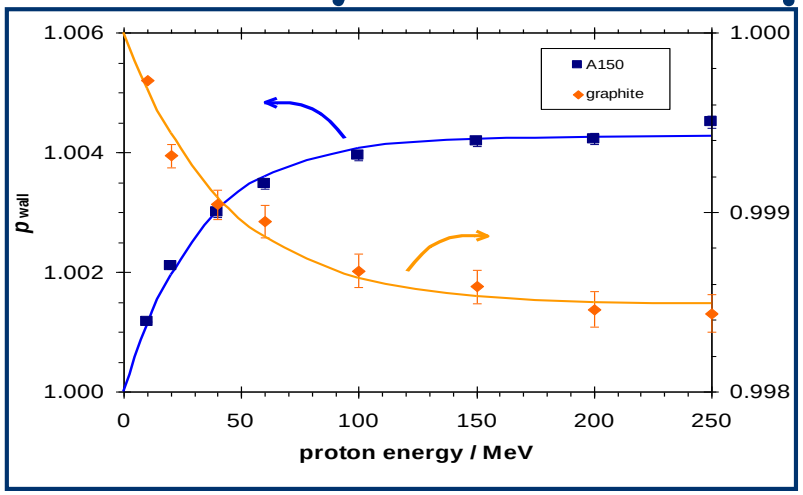


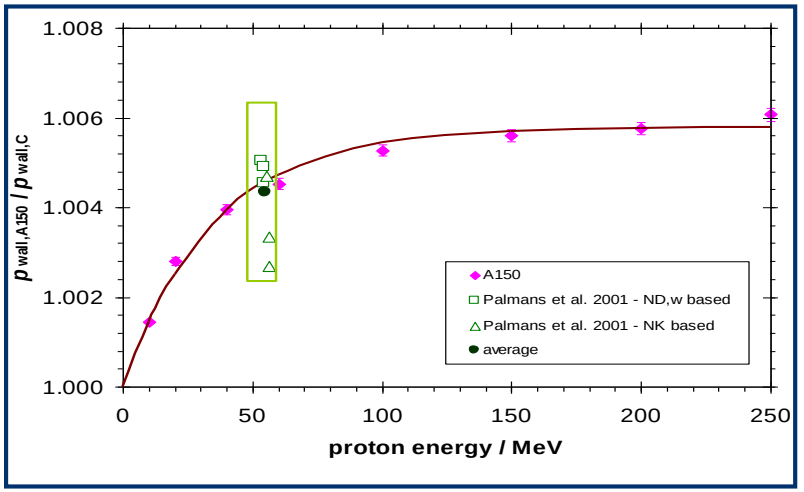
exp. data for 3 GeV ^{12}C

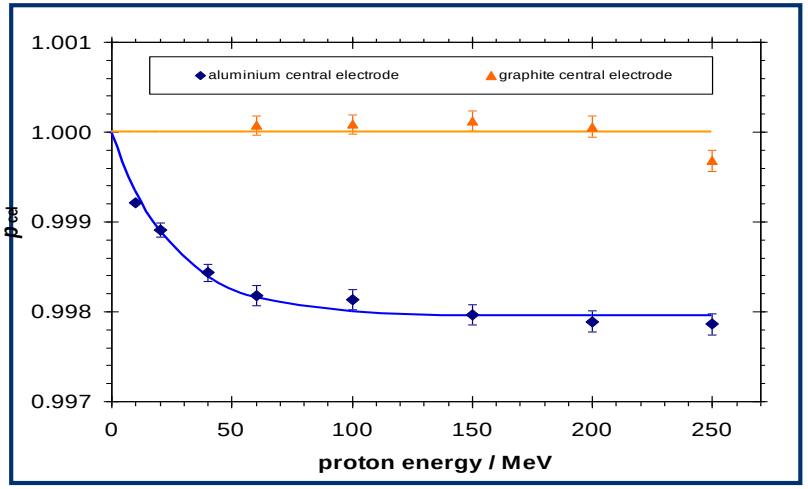


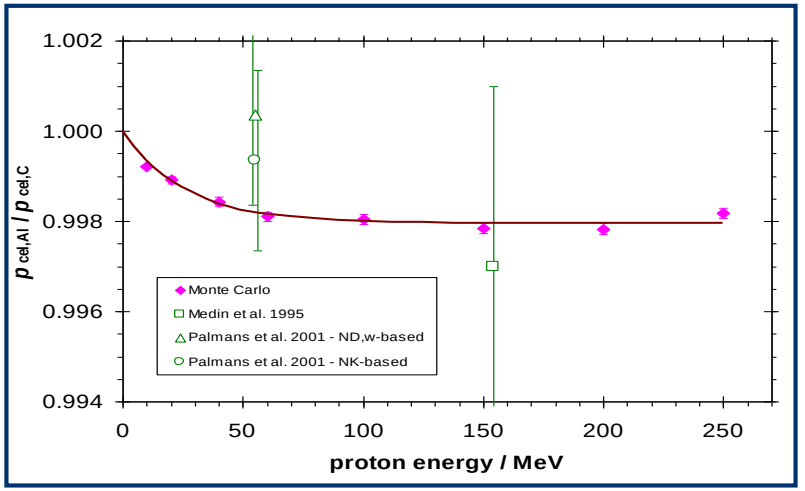
Palmans 2006 Phys Med Biol 51:3483 / McPTRAN.CAVITY

Clinical reference dosimetry using IC: secondary electron perturbation factors



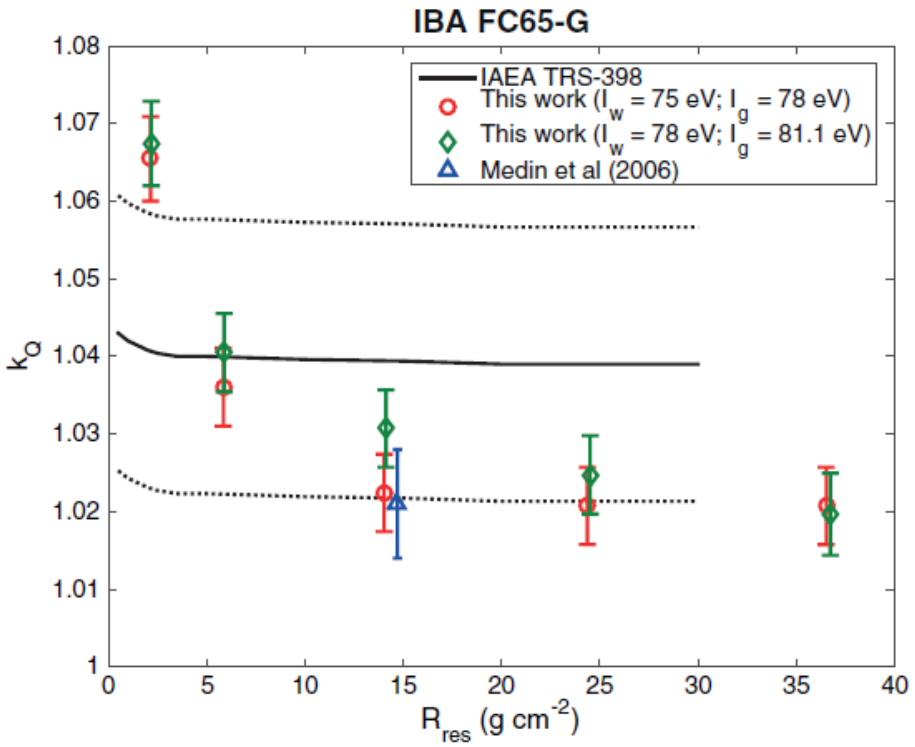


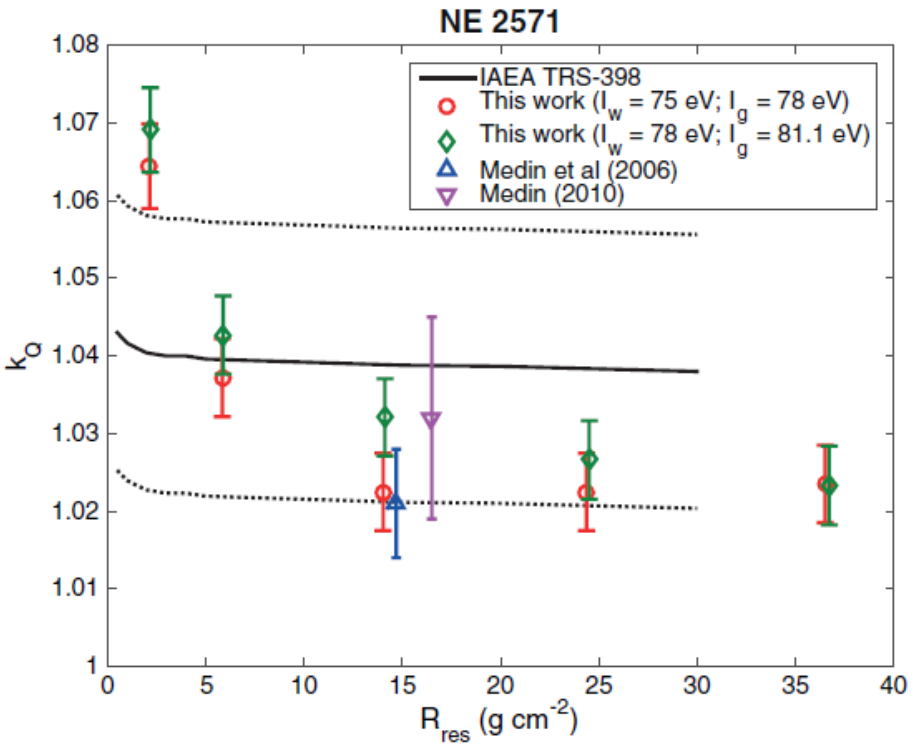




Palmans et al 2011 Proc IDOS, IAEA-CN182-230 / PTRAN + egsnrc

Clinical reference dosimetry using IC: k_{Q,Q_0} factors





Goma et al 2016 Phys Med Biol 61:2389 / GAMOS + PENH

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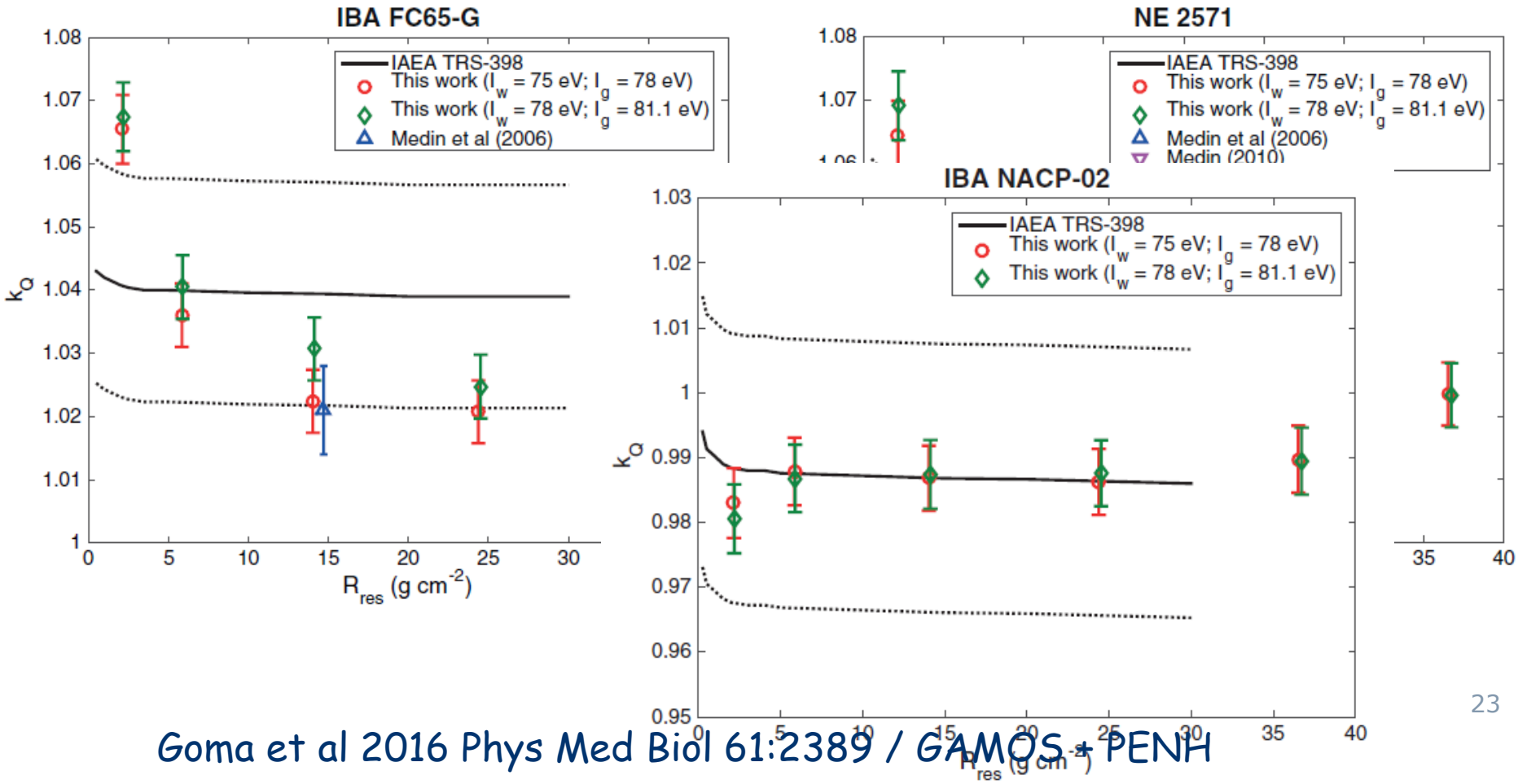
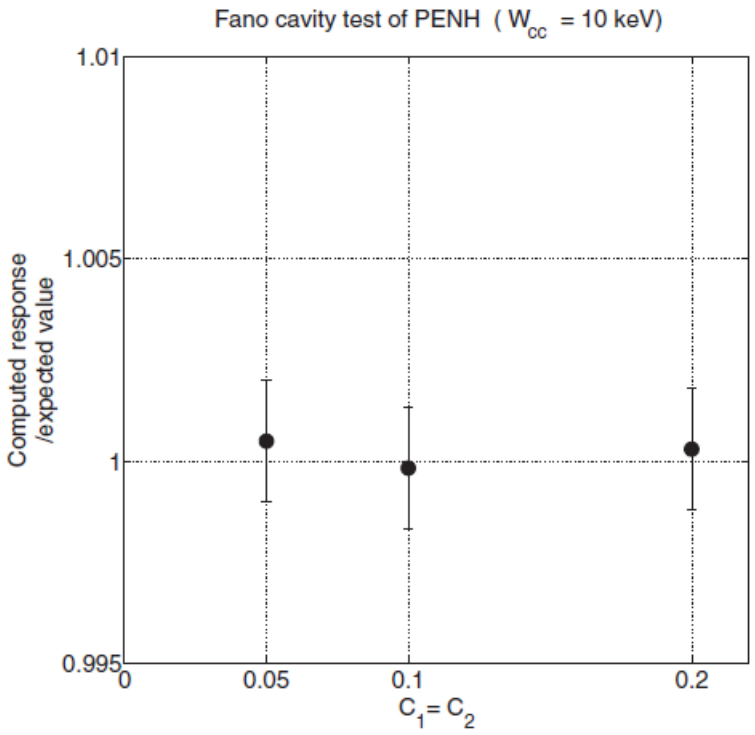


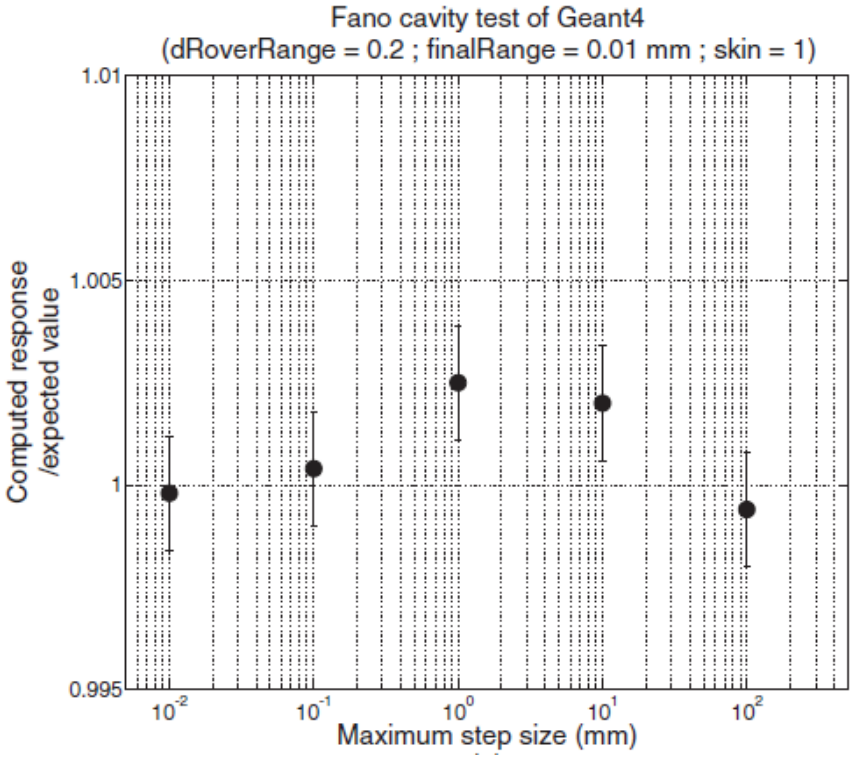
Goma et al 2016 Phys Med Biol 61:2389 / GAMOS + PENH

Clinical reference dosimetry using IC: Fano test for protons

PENH



Geant4



Sterpin et al 2014 Med Phys 41:011706

Clinical reference dosimetry using IC: Fano test for protons - FLUKA

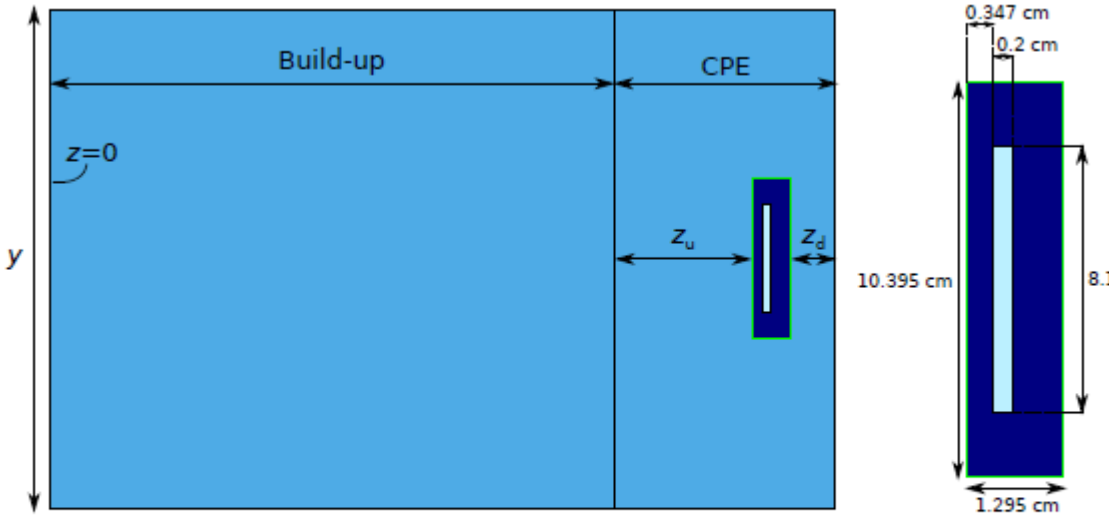


Figure 6.1: *(a) Simulation geometry of the Fano cavity test. (b) Dimensions of the cahmber consi in this study. Adapted from Poon et al. [89] and Sterpin et al. [81].*

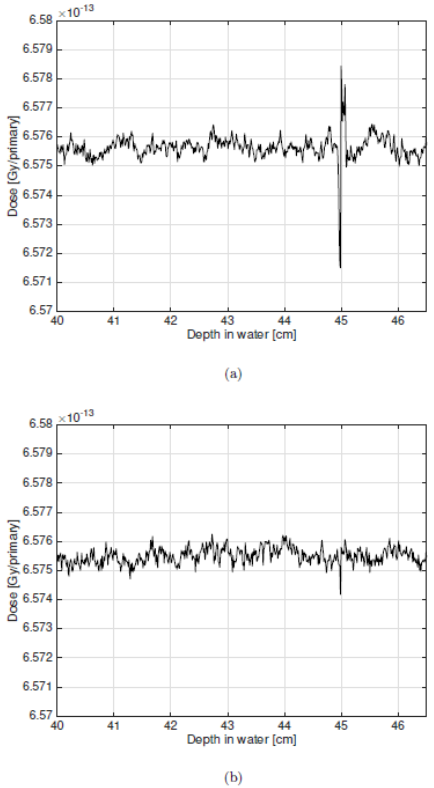


Figure 6.4: *Detail of CPE regions using a (a) large and (b) small step sizes. The geometry consists of two identical regions of water at a depth of 45 cm.*

Lourenço 2016 PhD

Verification of dosimetry chain using independent dosimeters: alanine (similar for most solid detectors)

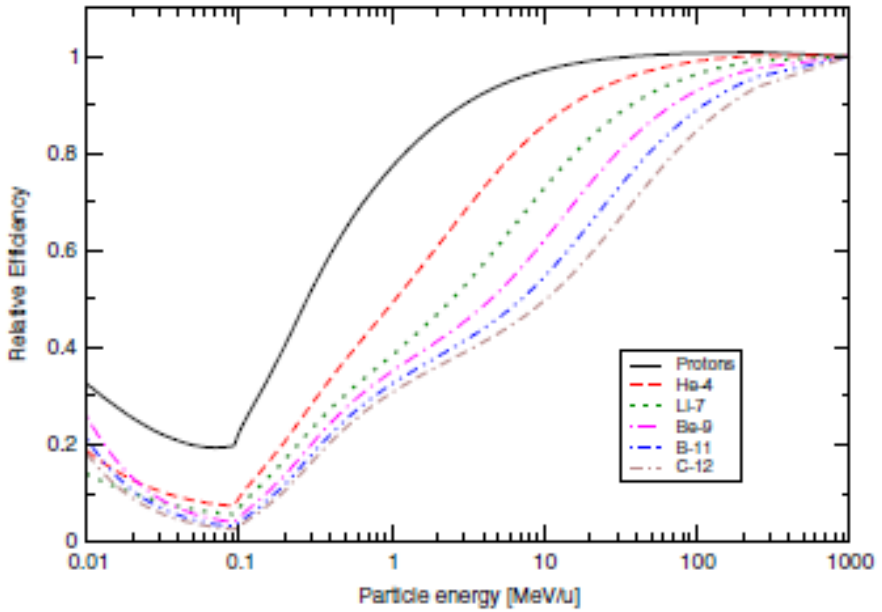


Fig. 1. Calculated relative efficiencies for infinitesimal thin detectors, without fading effects.

Convolving response functions inline

$$\overline{\eta}_{\mathrm{Al}} = \frac{\sum_{i=1}^{n_{\mathrm{hist}}} \sum_{j=1}^{n_i} \left[s_{ij} \times \left(\frac{S_{\mathrm{el}}}{\rho} \right)_{\mathrm{ala}} (E,Z) \times \eta_{\mathrm{Al}}(E,Z) + \eta \mathrm{TE}_{ij} \right]}{\sum_{i=1}^{n_{\mathrm{hist}}} \sum_{j=1}^{n_i} \left[s_{ij} \times \left(\frac{S_{\mathrm{el}}}{\rho} \right)_{\mathrm{ala}} (E,Z) + \mathrm{TE}_{ij} \right]}$$

$$\mathrm{TE}_{ij} = \frac{E_{\mathrm{cut}}}{\rho V_{voxel}} \quad \text{en} \quad \eta \mathrm{TE}_{ij} = \frac{\int_0^{E_{\mathrm{cut}}} \eta_{\mathrm{Al}}(E,Z) dE}{\rho V_{voxel}}$$

Bassler et al 2008 NIMB 266:929

Carlino 2017 PhD thesis

Verification of dosimetry chain using independent dosimeters: alanine

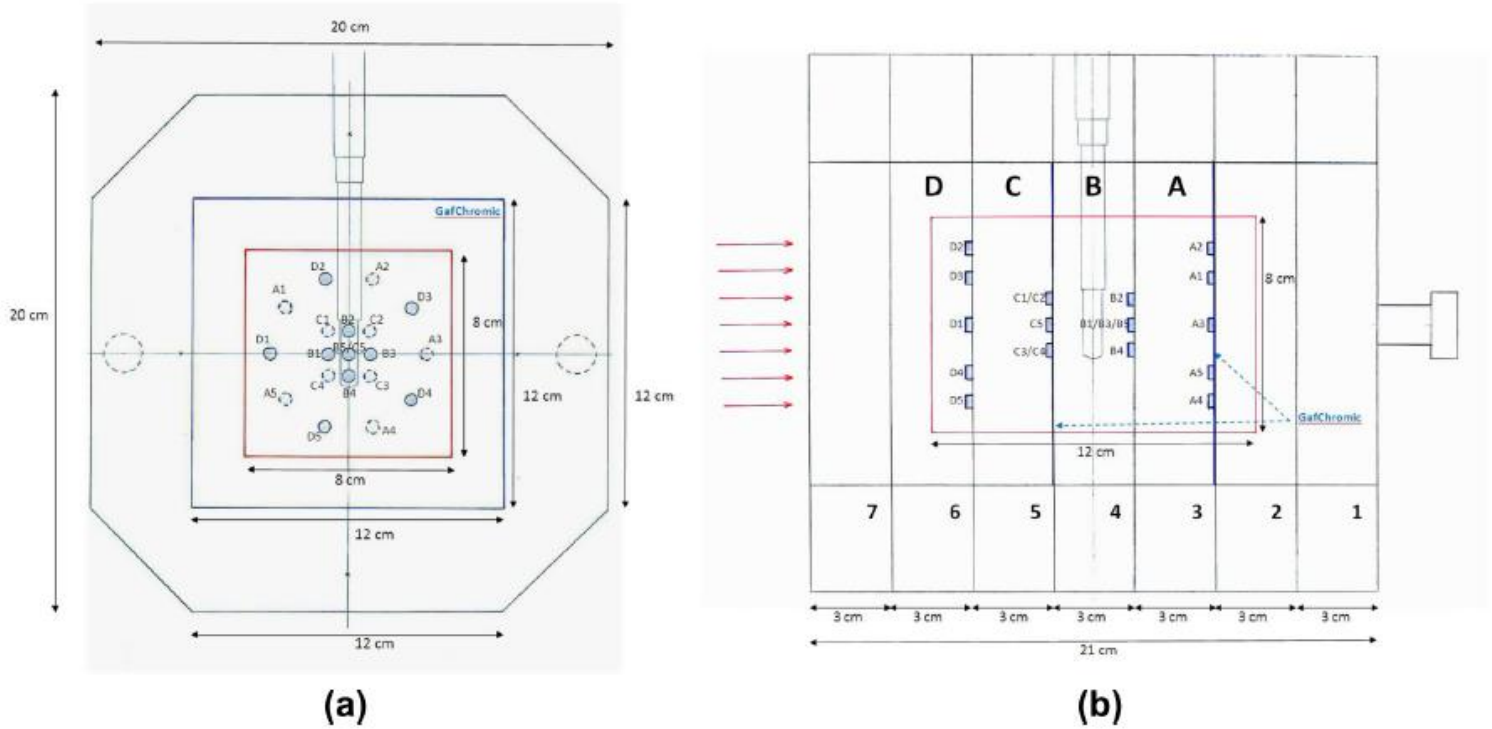


Fig. 1. Drawings of the phantom design in axial and sagittal view are given in (a) and (b). Red lines inside the phantom represent the target volume and the arrows outside in (b) show the beam direction. A Farmer chamber indicates here the additional plate which can be placed in the centre of the phantom (instead of plate B holding 5 alanine detectors).

Ableitinger et al 2013 Radiother Oncol 108:99 / FLUKA

Verification of dosimetry chain using independent dosimeters: alanine

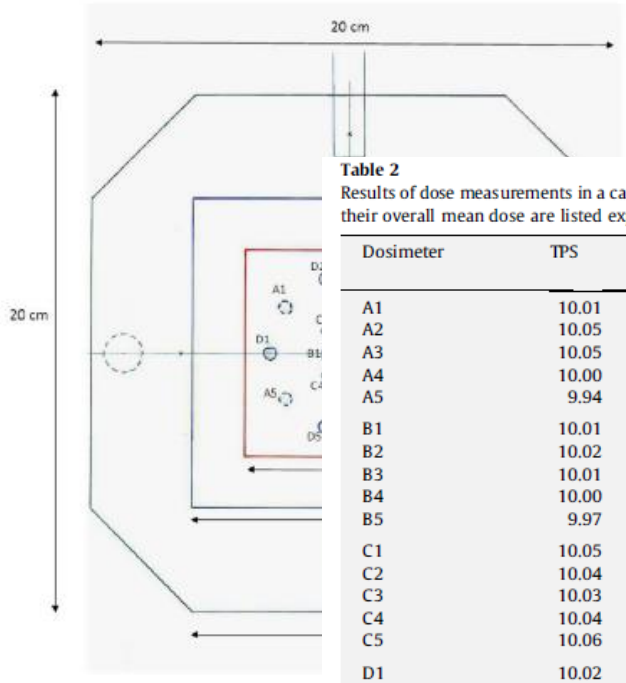


Fig. 1. Drawings of the phantom design (b) show the beam direction. A Farmer detectors).

Carbon ions SOBP / FLUKA

Table 2
Results of dose measurements in a carbon ion beam with 20 alanine dosimeters and with a Farmer chamber. The different conversion factors for each alanine pellet (A1–D5) and their overall mean dose are listed explicitly.

Dosimeter	TPS	TPS corrected for daily output	$D_{w,^{60}Co}$ [Gy]	Relative effectiveness	$(\mu_{en}^{^{60}Co}/\rho)_w^{al}$	$(S^{^{12}C}/\rho)_{al}^{w}$	$D_{w,^{12}C}$ (Gy)	Deviation (%)
A1	10.01	9.89	7.42	0.747	0.970	1.016	9.80	−0.9
A2	10.05	9.93	7.41	0.748	0.970	1.016	9.76	−1.6
A3	10.05	9.93	7.30	0.744	0.970	1.016	9.67	−2.6
A4	10.00	9.88	7.35	0.745	0.970	1.016	9.73	−1.4
A5	9.94	9.82	7.36	0.748	0.970	1.016	9.69	−1.2
B1	10.01	9.89	8.27	0.840	0.970	1.017	9.73	−1.6
B2	10.02	9.90	8.22	0.839	0.970	1.017	9.67	−2.3
B3	10.01	9.89	8.23	0.840	0.970	1.017	9.67	−2.2
B4	10.00	9.88	8.24	0.840	0.970	1.017	9.68	−2.0
B5	9.97	9.85	8.28	0.839	0.970	1.017	9.73	−1.1
C1	10.05	9.93	8.55	0.876	0.970	1.018	9.63	−3.0
C2	10.04	9.92	8.56	0.877	0.970	1.018	9.64	−2.8
C3	10.03	9.91	8.40	0.877	0.970	1.018	9.46	−4.5
C4	10.04	9.92	8.62	0.878	0.970	1.018	9.69	−2.2
C5	10.06	9.93	8.60	0.877	0.970	1.018	9.68	−2.5
D1	10.02	9.90	8.59	0.900	0.970	1.018	9.43	−4.7
D2	10.02	9.90	8.86	0.900	0.970	1.018	9.72	−1.7
D3	10.01	9.89	9.00	0.898	0.970	1.018	9.90	0.1
D4	9.99	9.87	8.79	0.897	0.970	1.018	9.67	−1.9
D5	10.05	9.93	8.76	0.898	0.970	1.018	9.63	−2.9
Mean dose	10.02	9.89	–	–	–	–	9.68	**−2.2**
Std. dev.	0.03	0.03	–		–	–	0.10	1.1
Farmer chamber	10.00	9.88	–	–	–	–	9.78	**−1.0**

Ableitinger et al 2013 Radiother Oncol 108:99 / FLUKA