Dosimetry of light-ion beams

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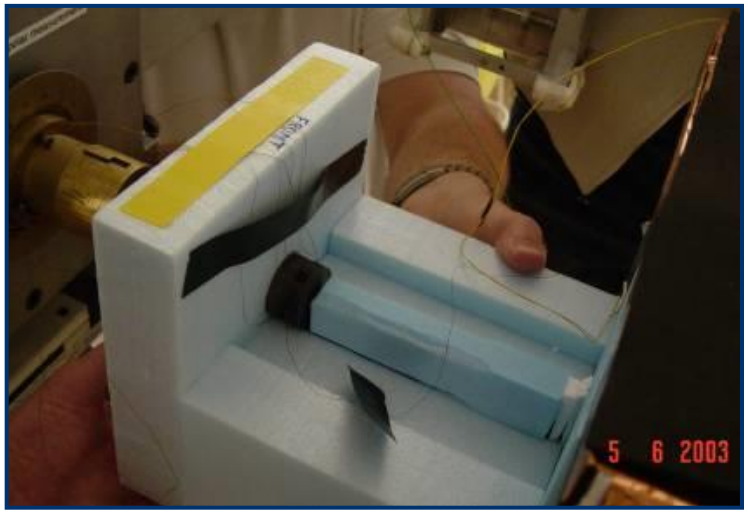
Overview

- Primary standards – calorimeters
- Reference dosimetry - ionization chambers
- Relative dosimetry – LET dependence of detectors
- Particular issue with scanned beams

Calorimetry

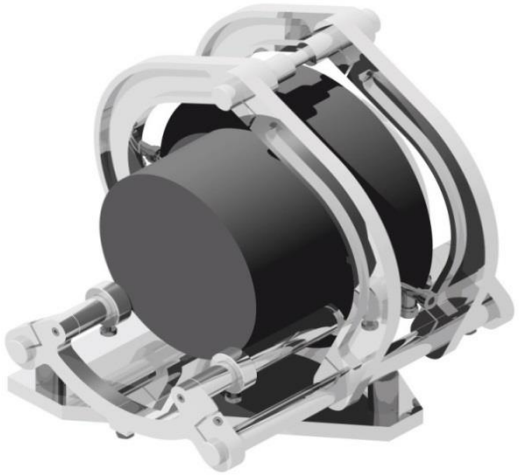
$$D_{med} = c_{med} \Delta T \frac{1}{1-h} \Pi k_i$$

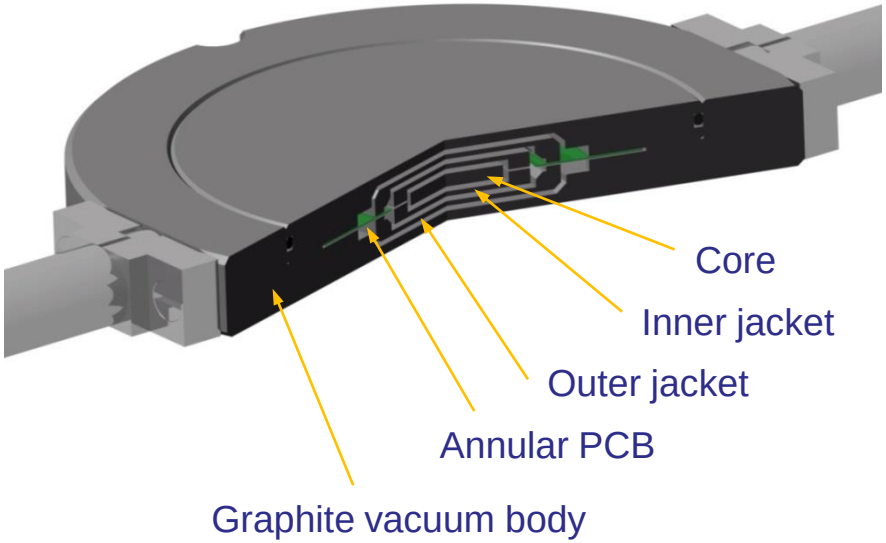


Palmans et al (2004)
Phys Med Biol 49:3737

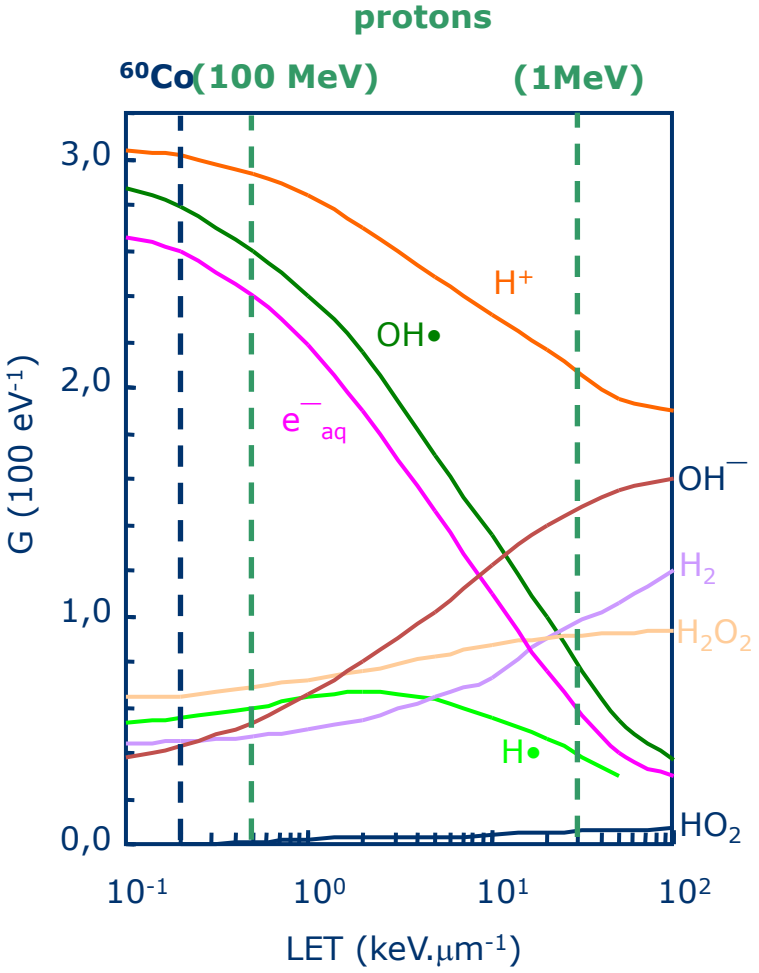
Calorimetry

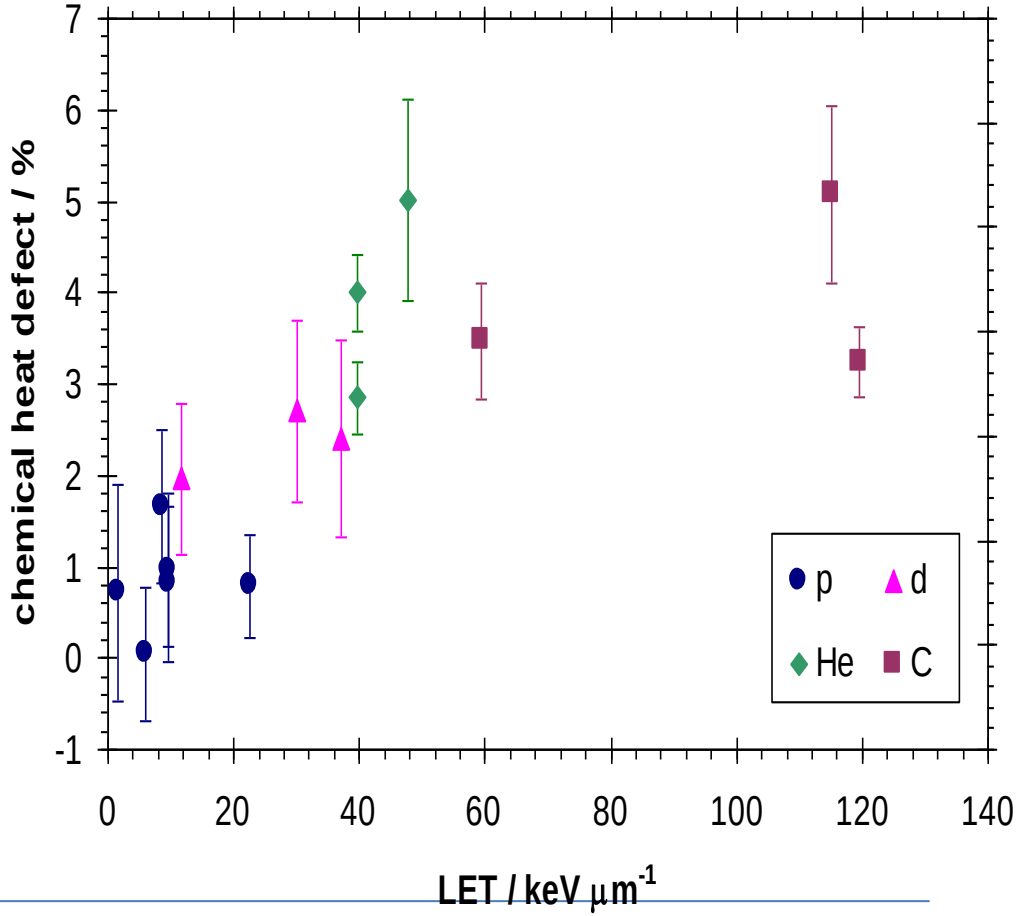
$$D_{med} = c_{med} \Delta T \frac{1}{1-h} \Pi k_i$$





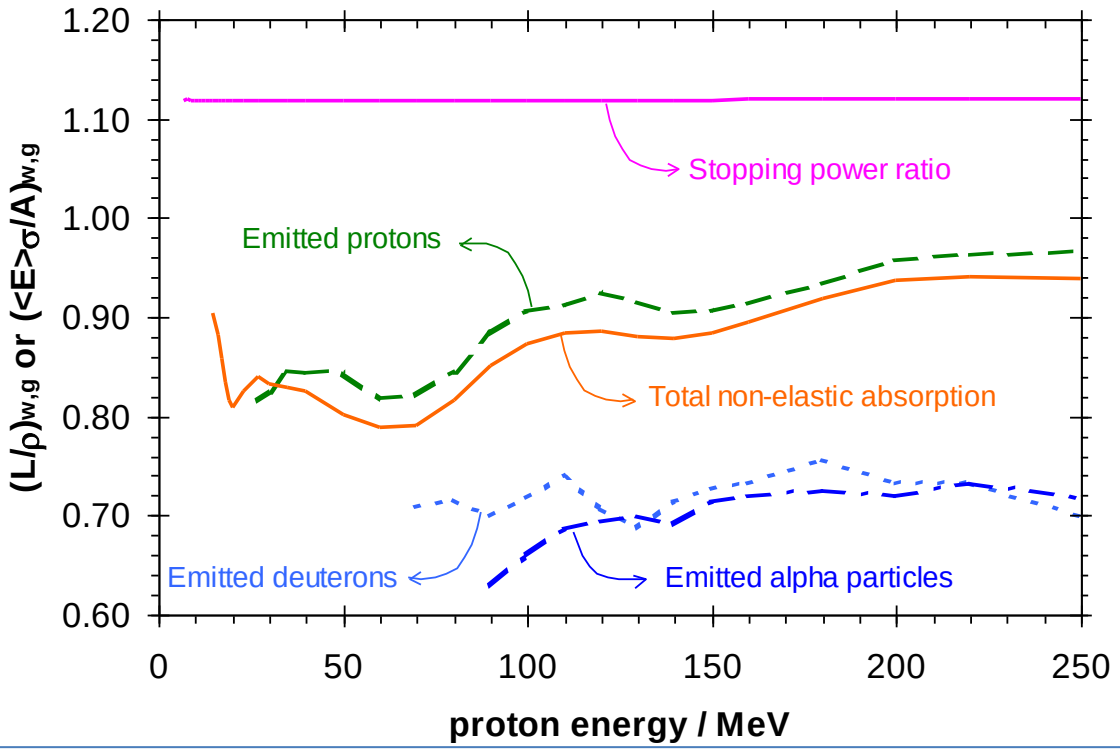
Water calorimetry – heat defect





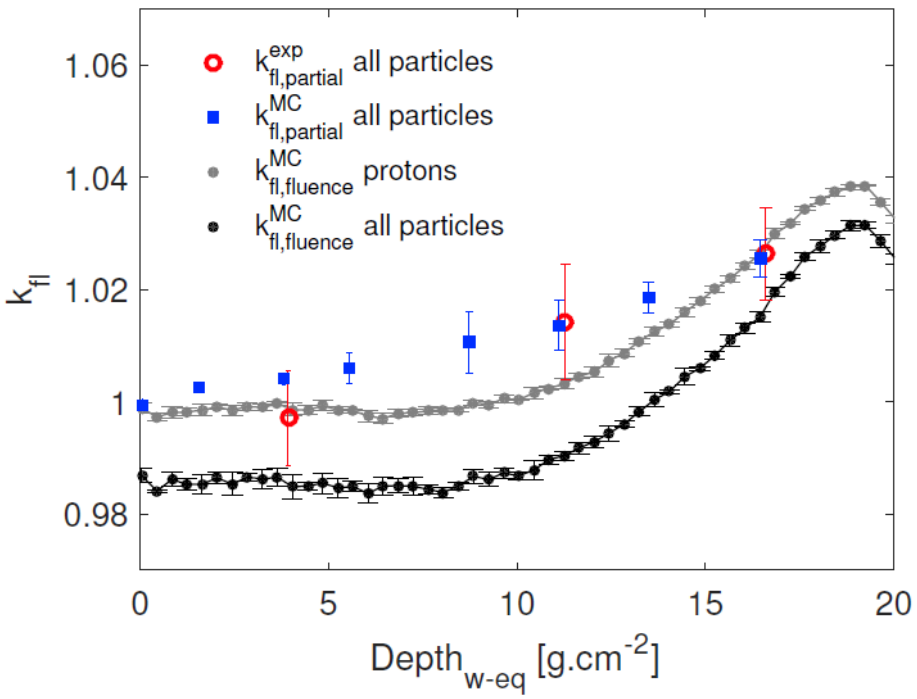
Graphite calorimetry: D_g to D_w

$$D_w(z_w) = D_g(z_g) \cdot \left(\frac{S}{\rho}\right)_g^w k_{fl}$$



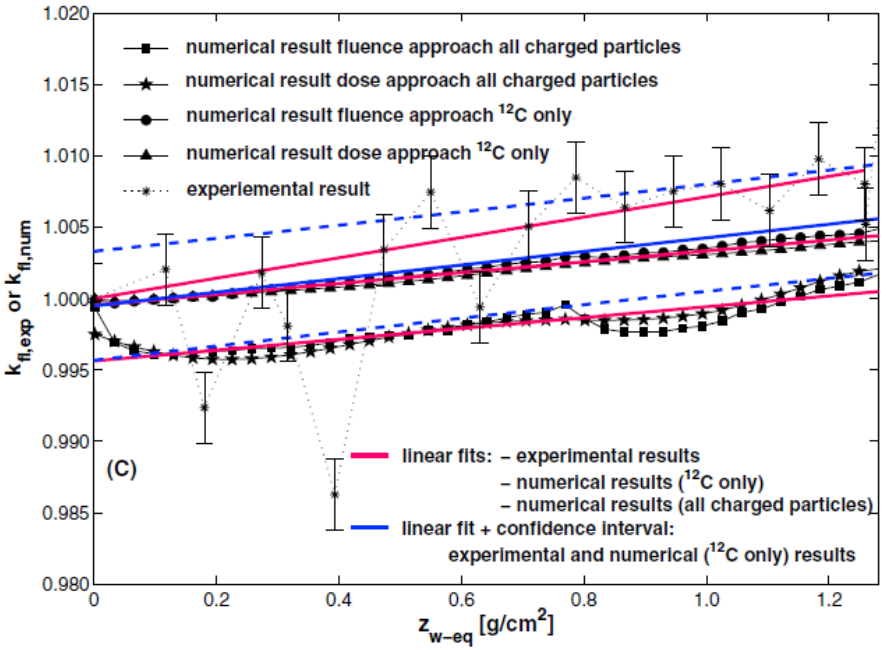
Graphite calorimetry: D_g to D_w

Protons



Lourenço et al (2016)
Med. Phys. *submitted*

Carbon ions



Rossomme et al (2013)
Phys. Med. Biol. 58:5363

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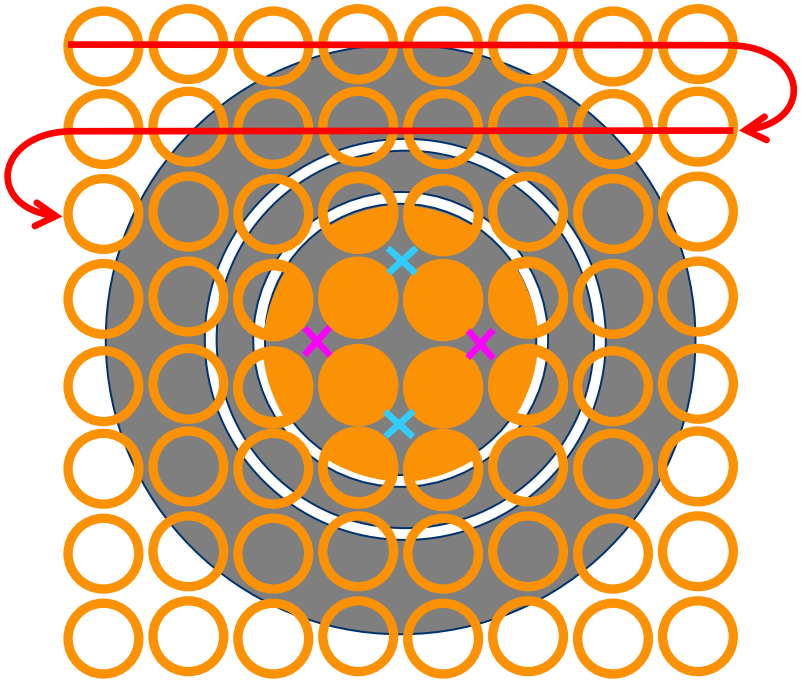
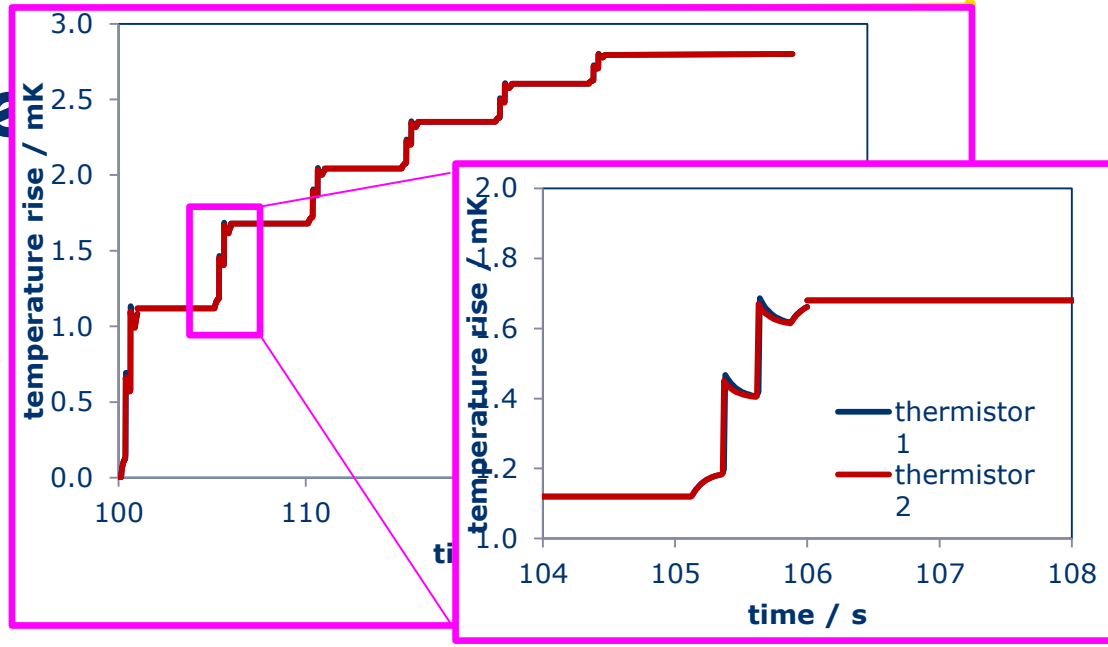
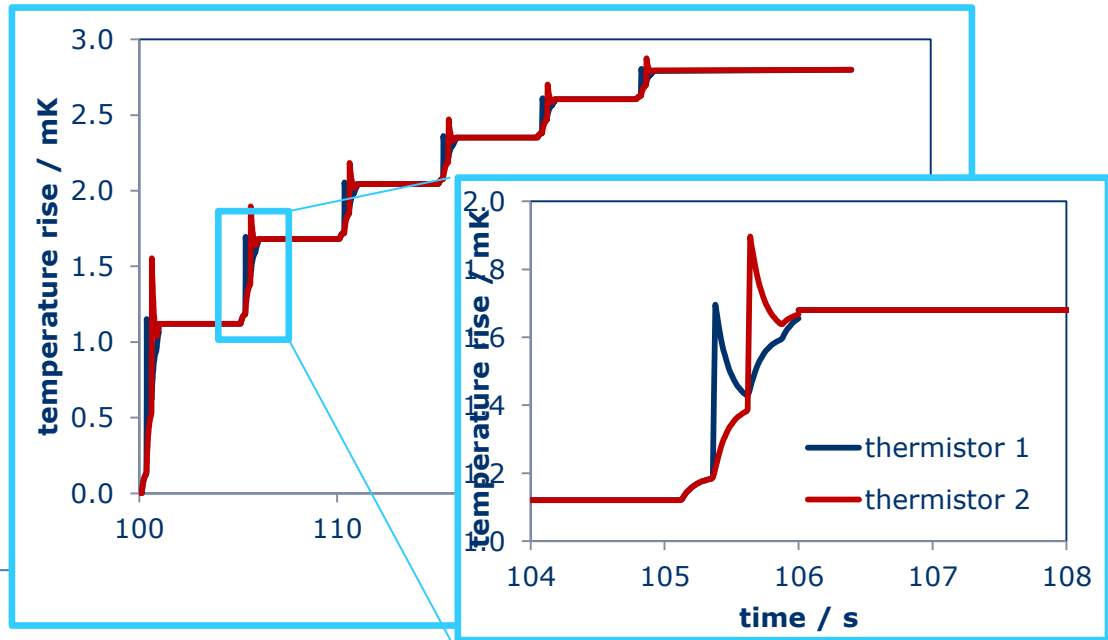
Graphite calorime within core







Reference dosimetry with ionization chambers

Ideally:

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

Present-day reality:

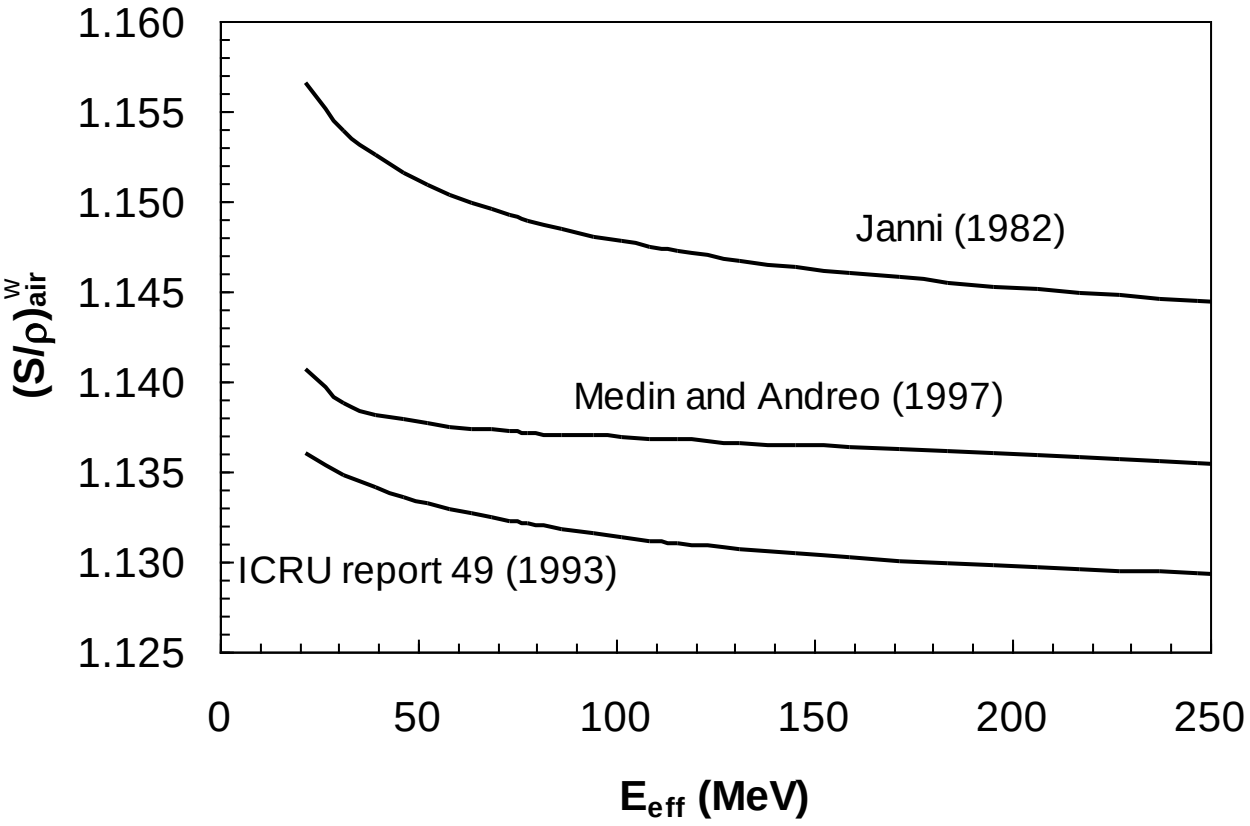
$$D_{w,Q} = M_Q N_{D,w,Q_0} k_{Q,Q_0}$$

with

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

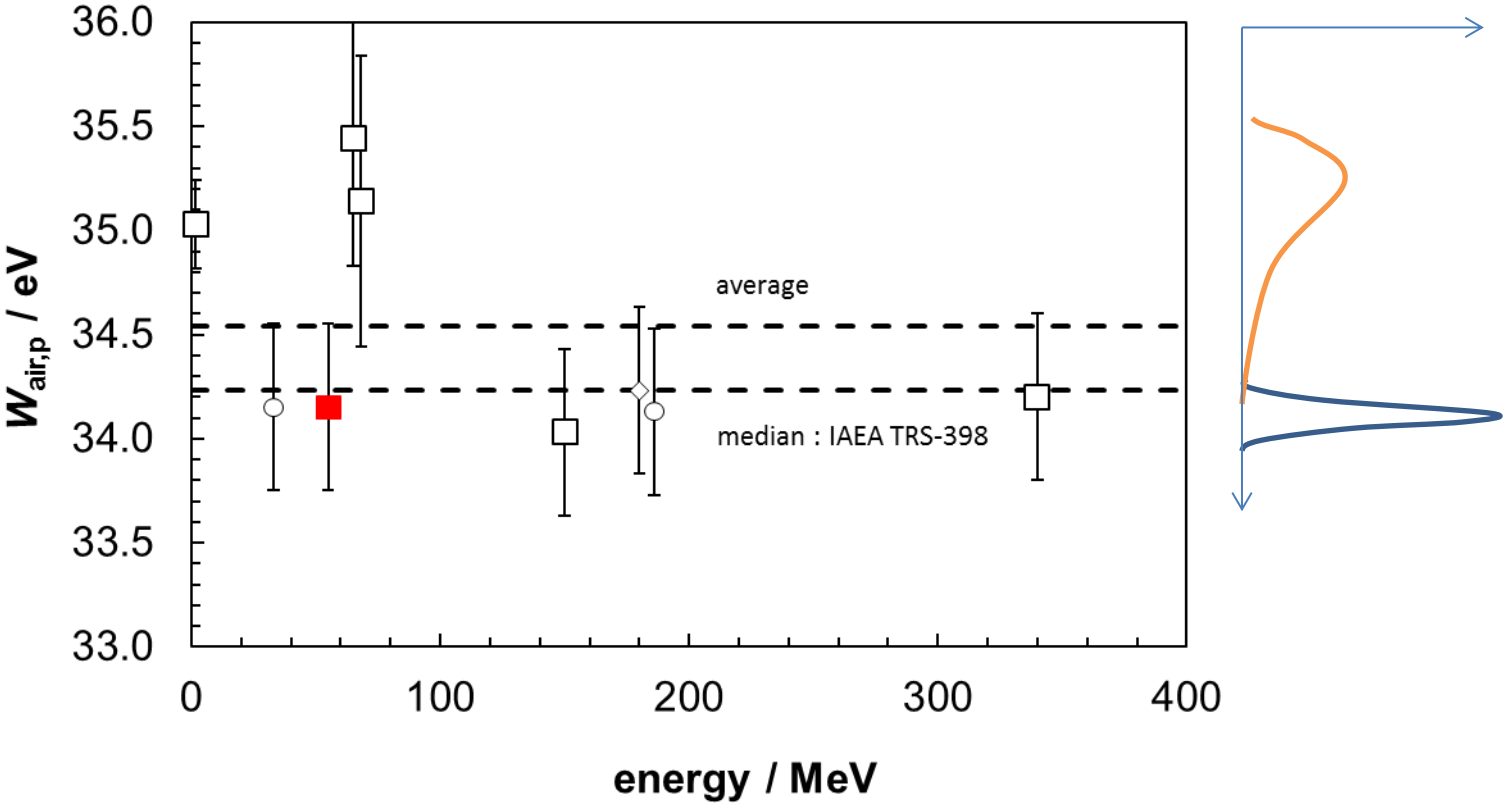
This is the formalism of IAEA TRS-398 and ICRU Report 78

Ionization chambers: $s_{w,air}$



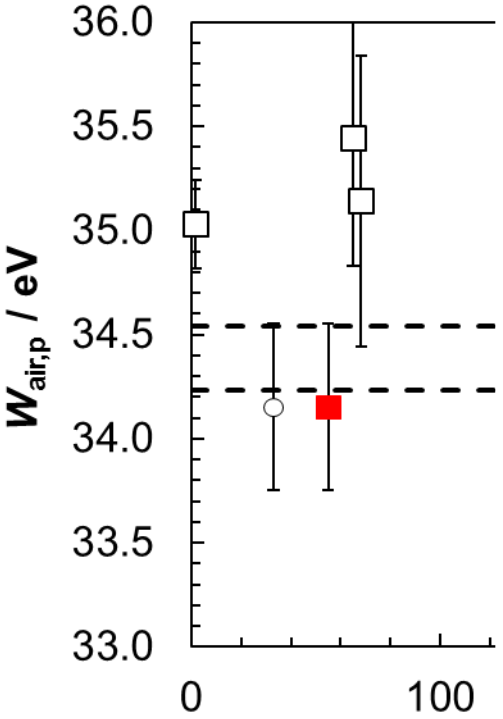
Ionization chambers: W_{air} / protons

TRS-398

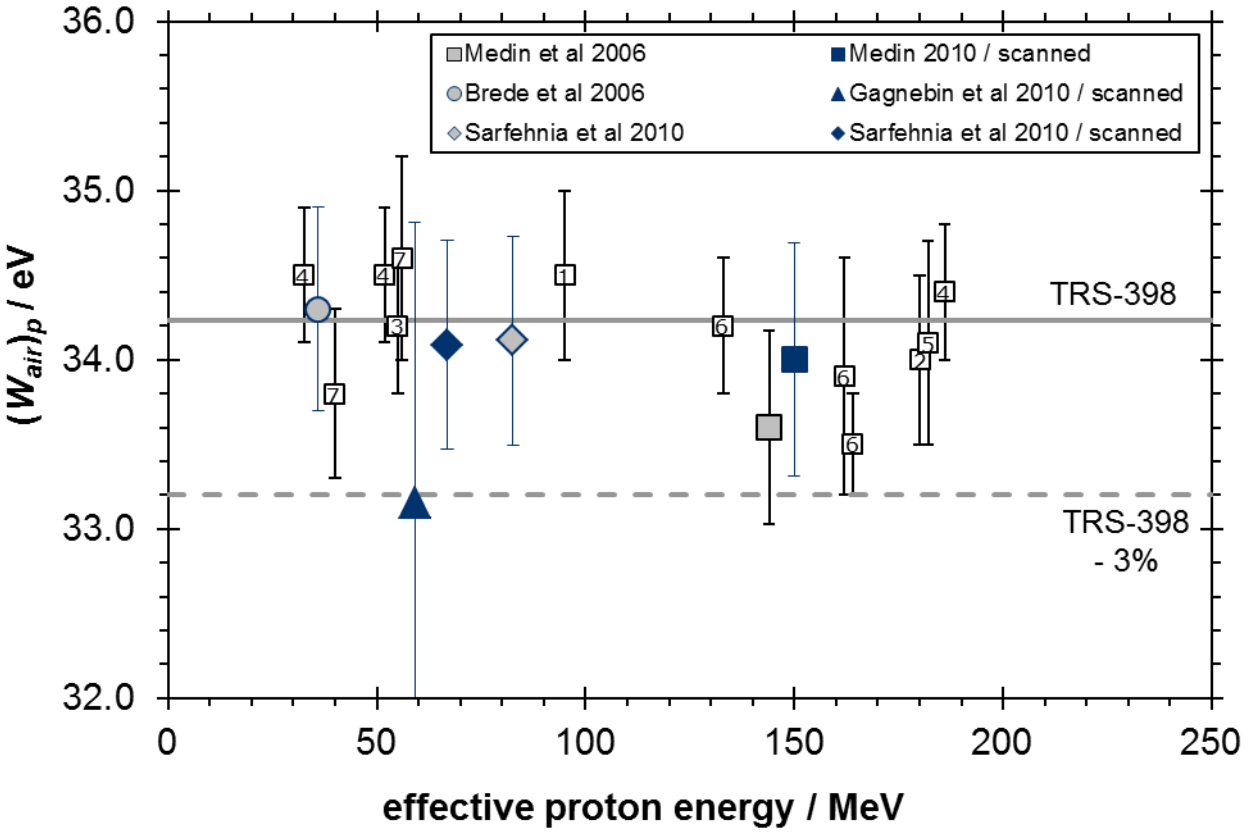


Ionization chambers: W_{air} / protons

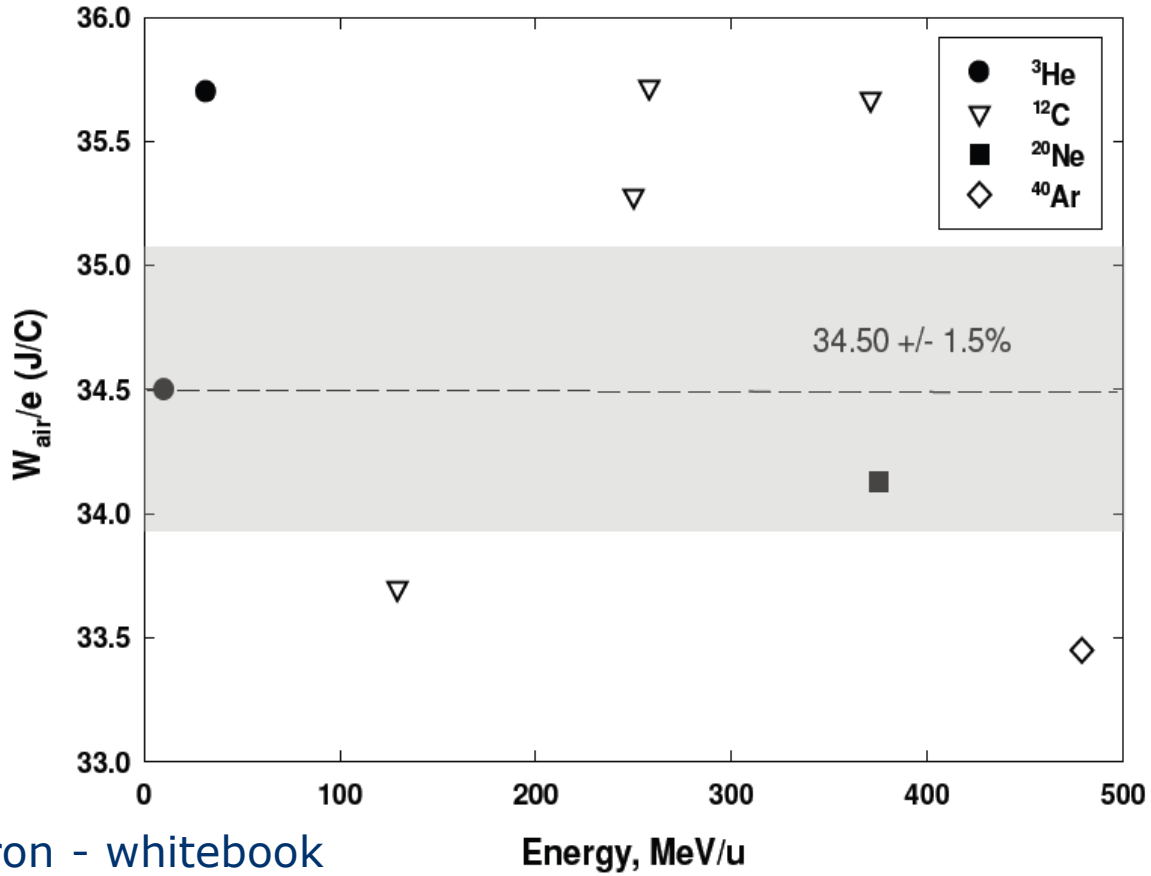
TRS-398



Calorimetry data Jones 2006 Rad Phys Chem 75:541 + more recent



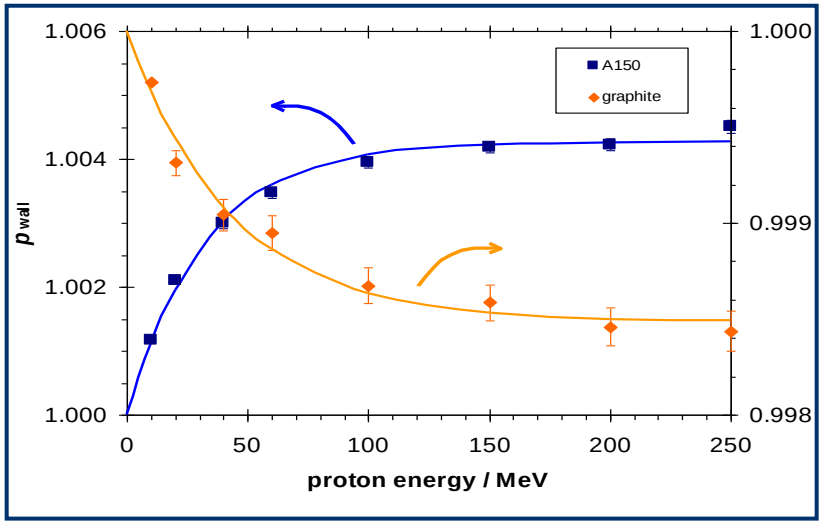
Ionization chambers: W_{air} / ions

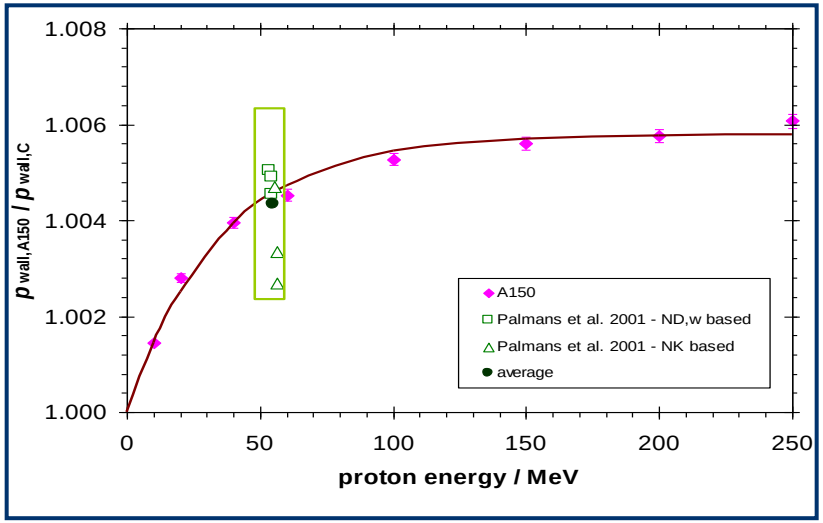


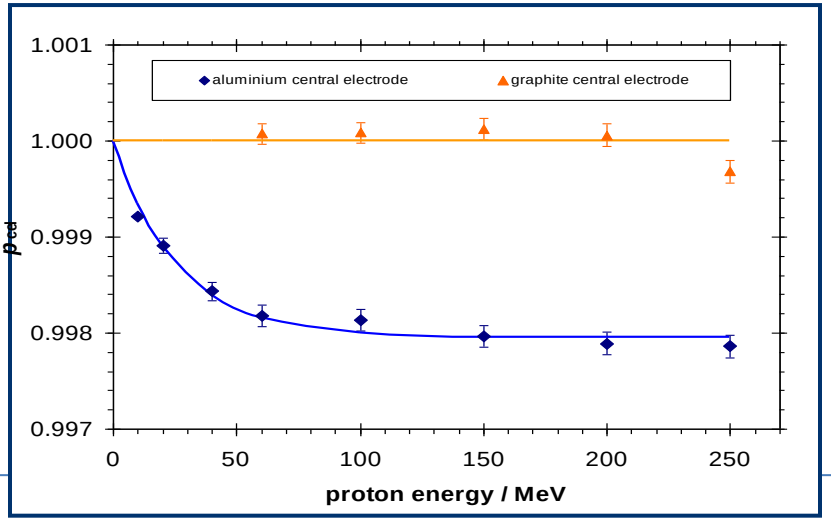
MedAustron - whitebook

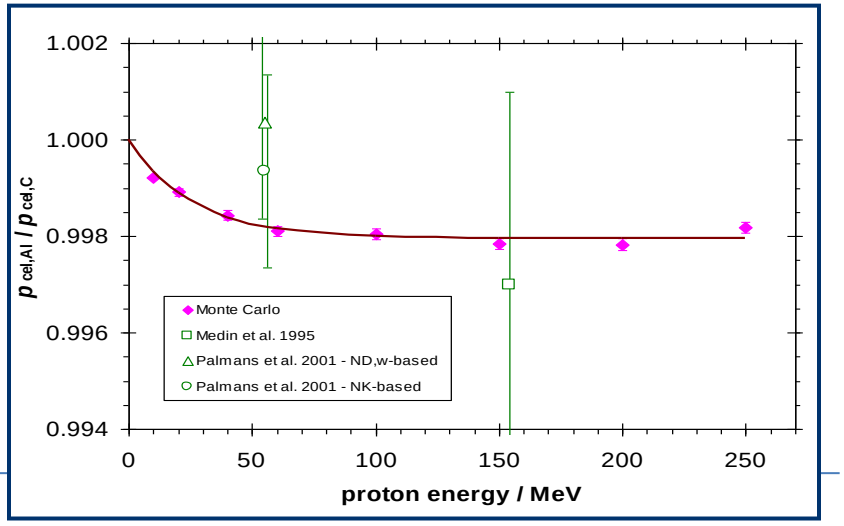
Ionization chambers – perturbations

Palmans et al. (2011) Proc IDOS, IAEA-CN182-230

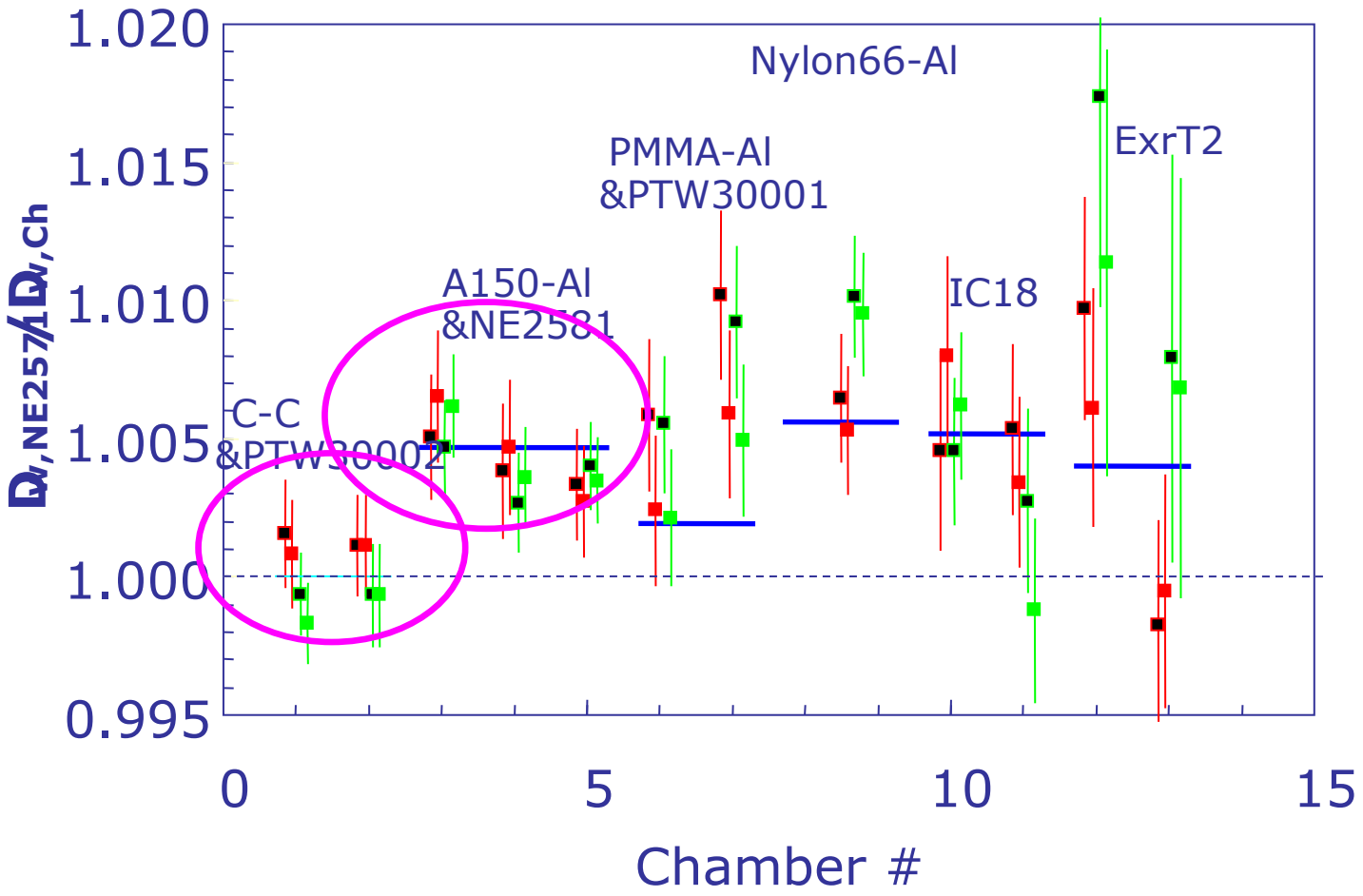




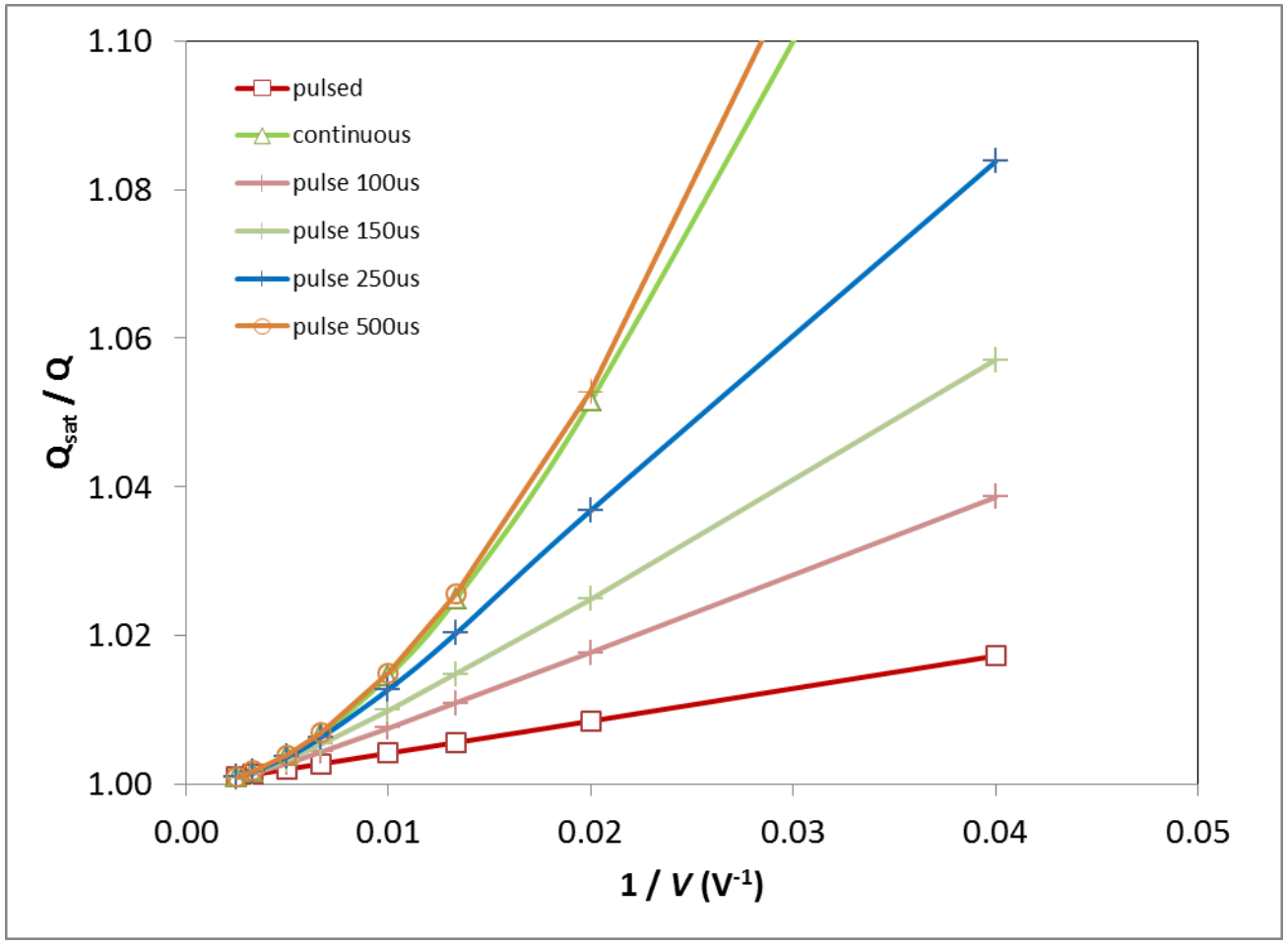




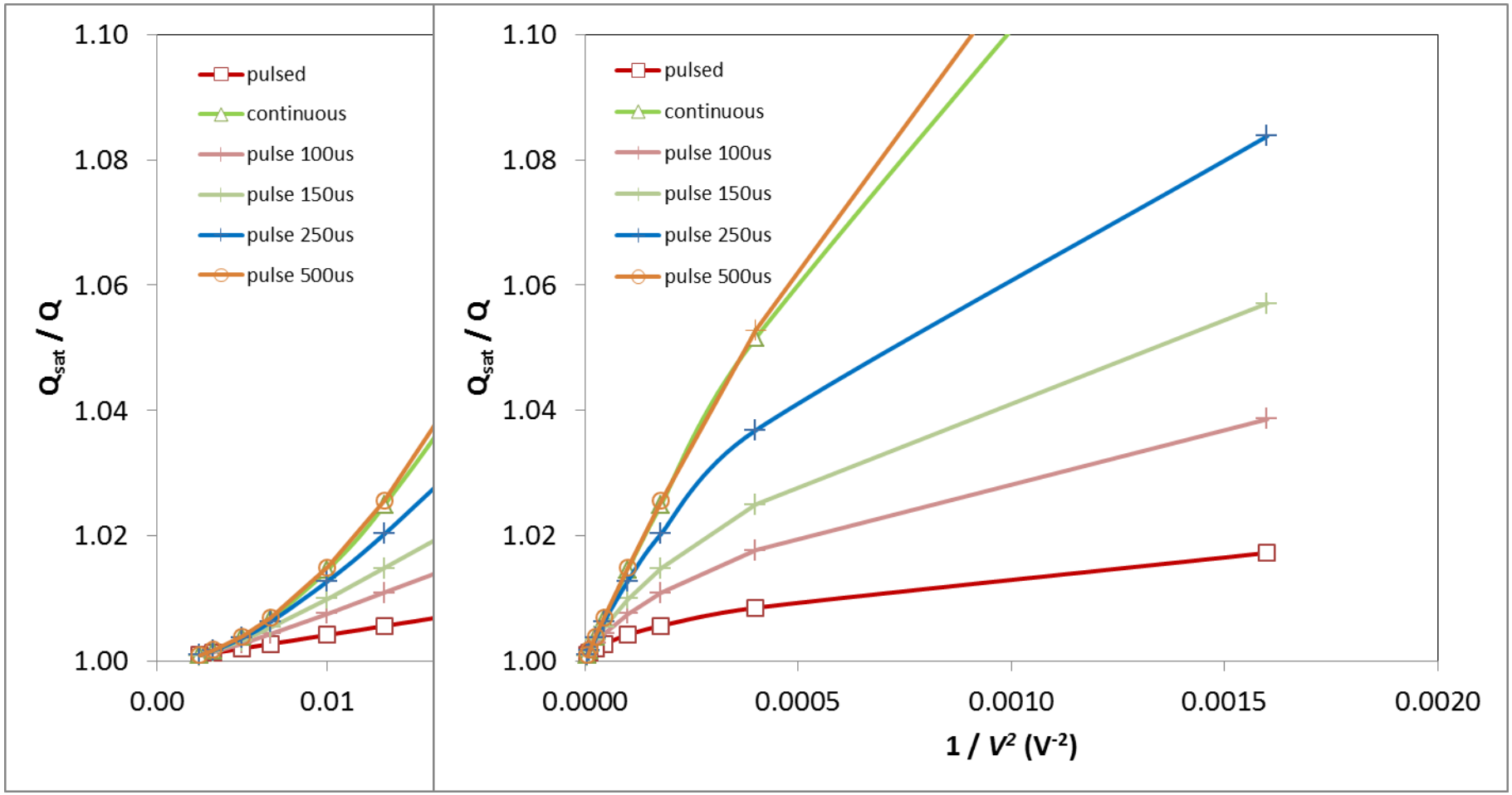
Ionization chamber perturbations



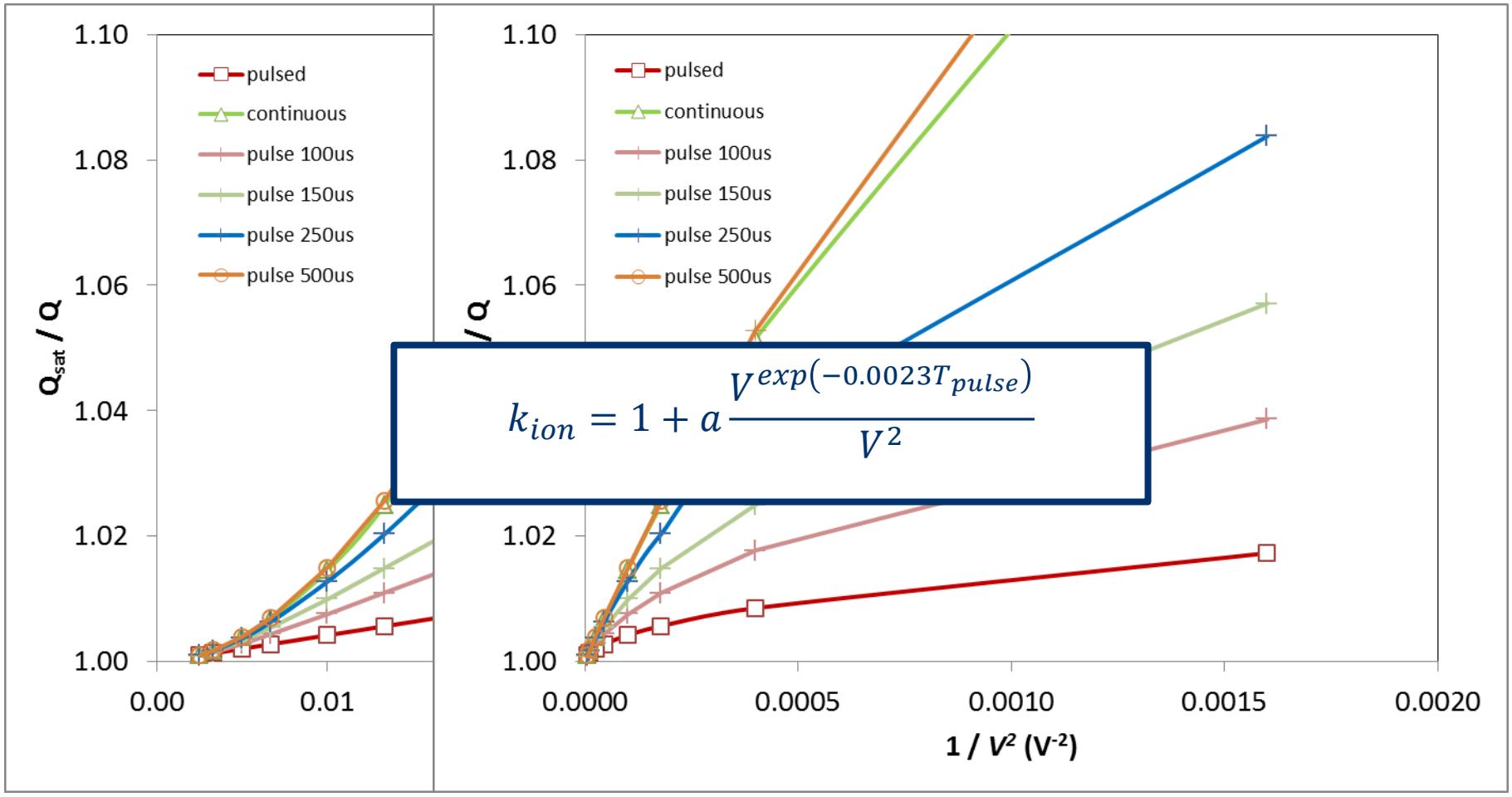
Volume recombination vs pulse length



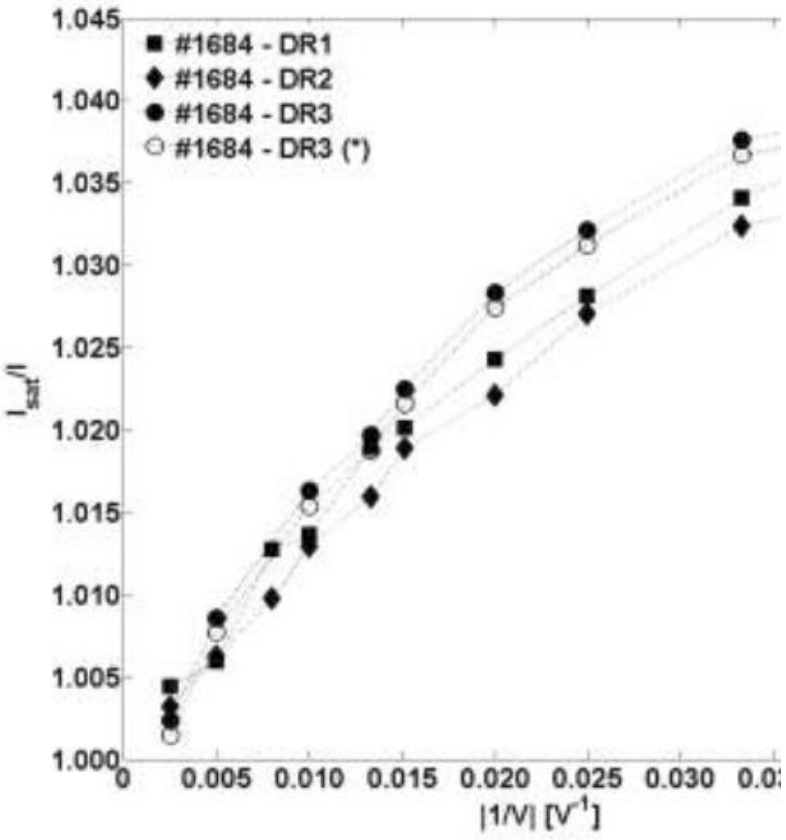
Volume recombination vs pulse length

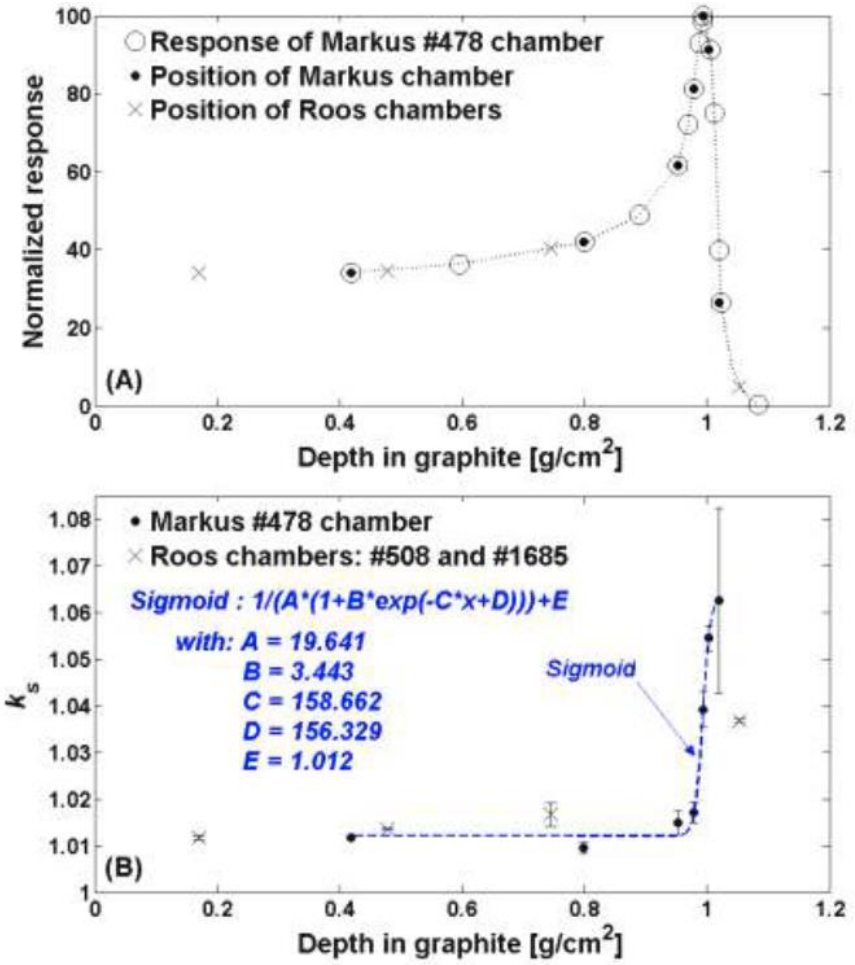


Volume recombination vs pulse length



Initial recombination in carbon ions

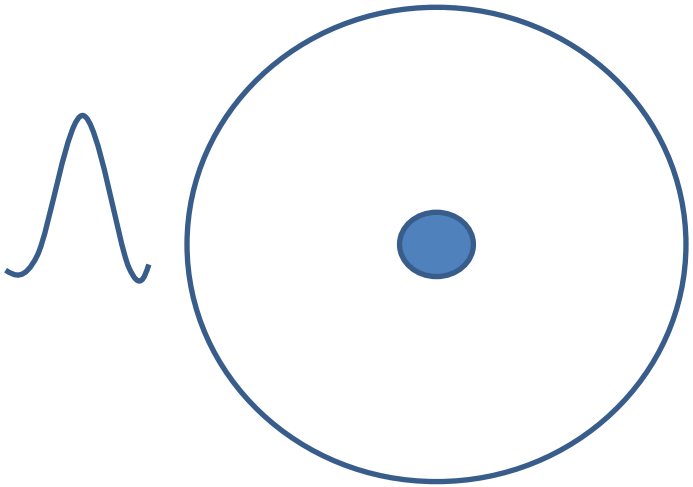




Rossomme et al (2016)
Med. Phys. *submitted*

Reference dosimetry scanned beams

Gillin et al 2010
Med Phys 37:154



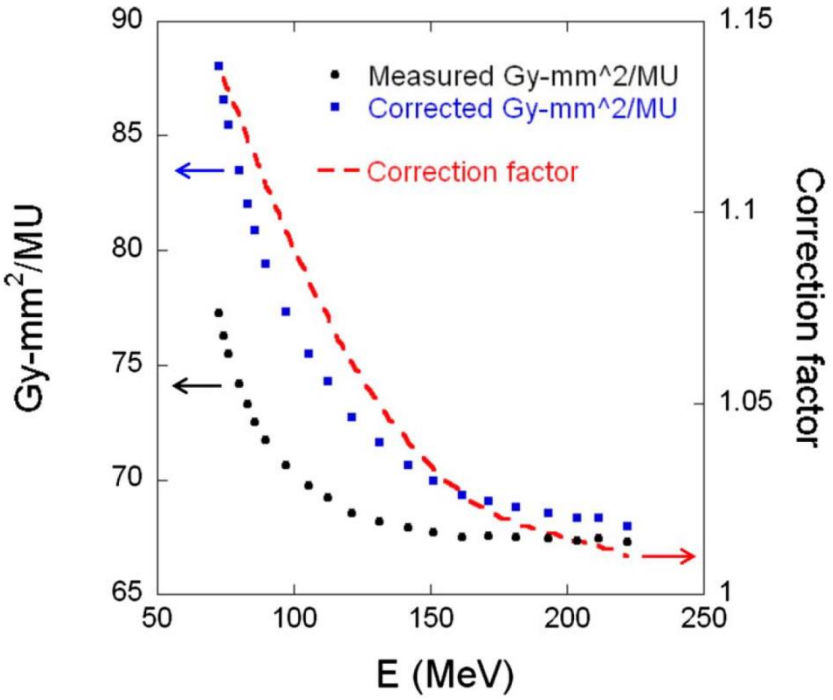
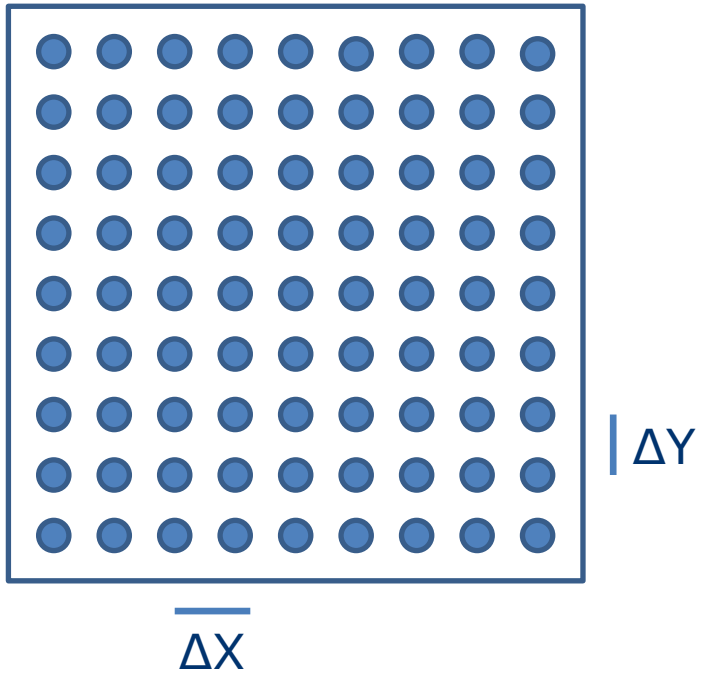


FIG. 5. Integral doses in Gy mm^2/MU at the depth of 2 cm as a function of energy. Circles are measured integral doses; squares are corrected integral doses; and dashed line is the correction factors.

Reference dosimetry scanned beams

Jaekel et al Phys Med Biol2004



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

$$n = \frac{D_{w,Q}^{cyl} \Delta X \Delta Y}{(S/\rho)_w}$$

Relative dosimetry – LET dependence alanine

Bassler et al. 2008

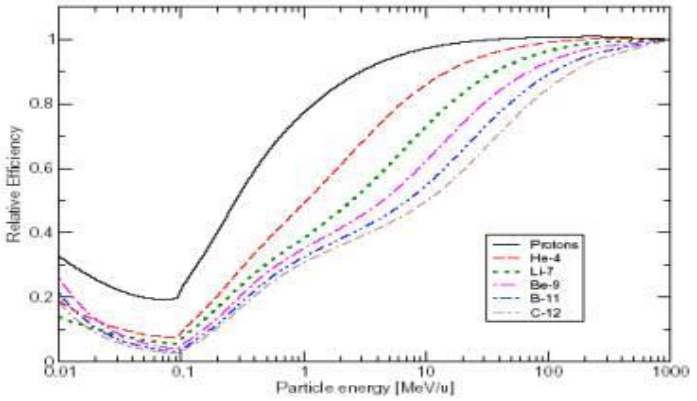
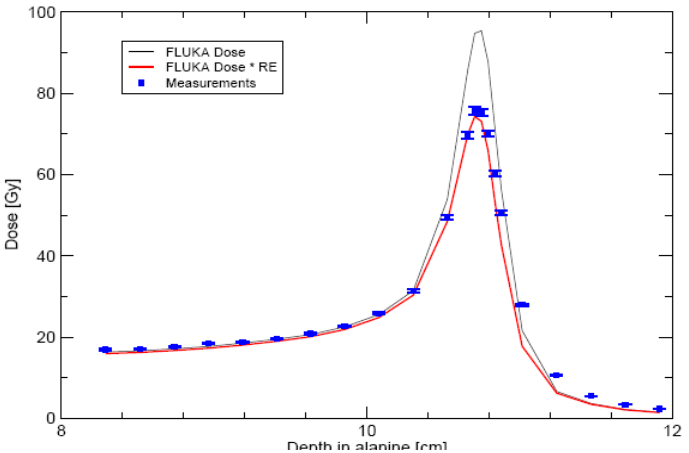
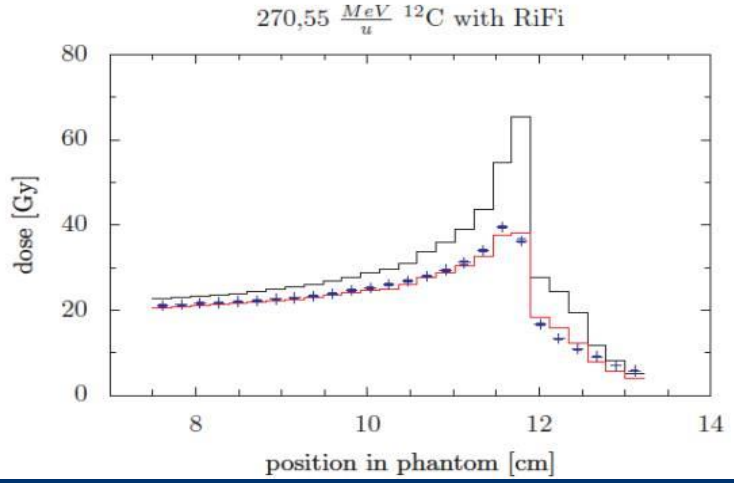


Fig. 1. Calculated relative efficiencies for infinitesimal thin detectors, without fading effects.

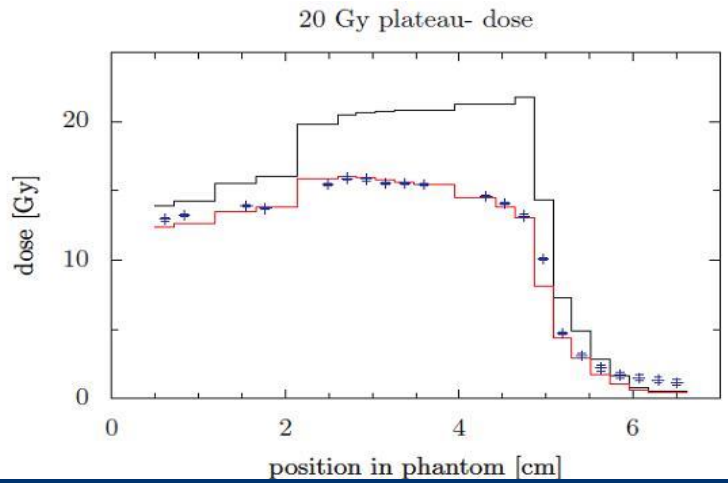
CERN anti-proton beam



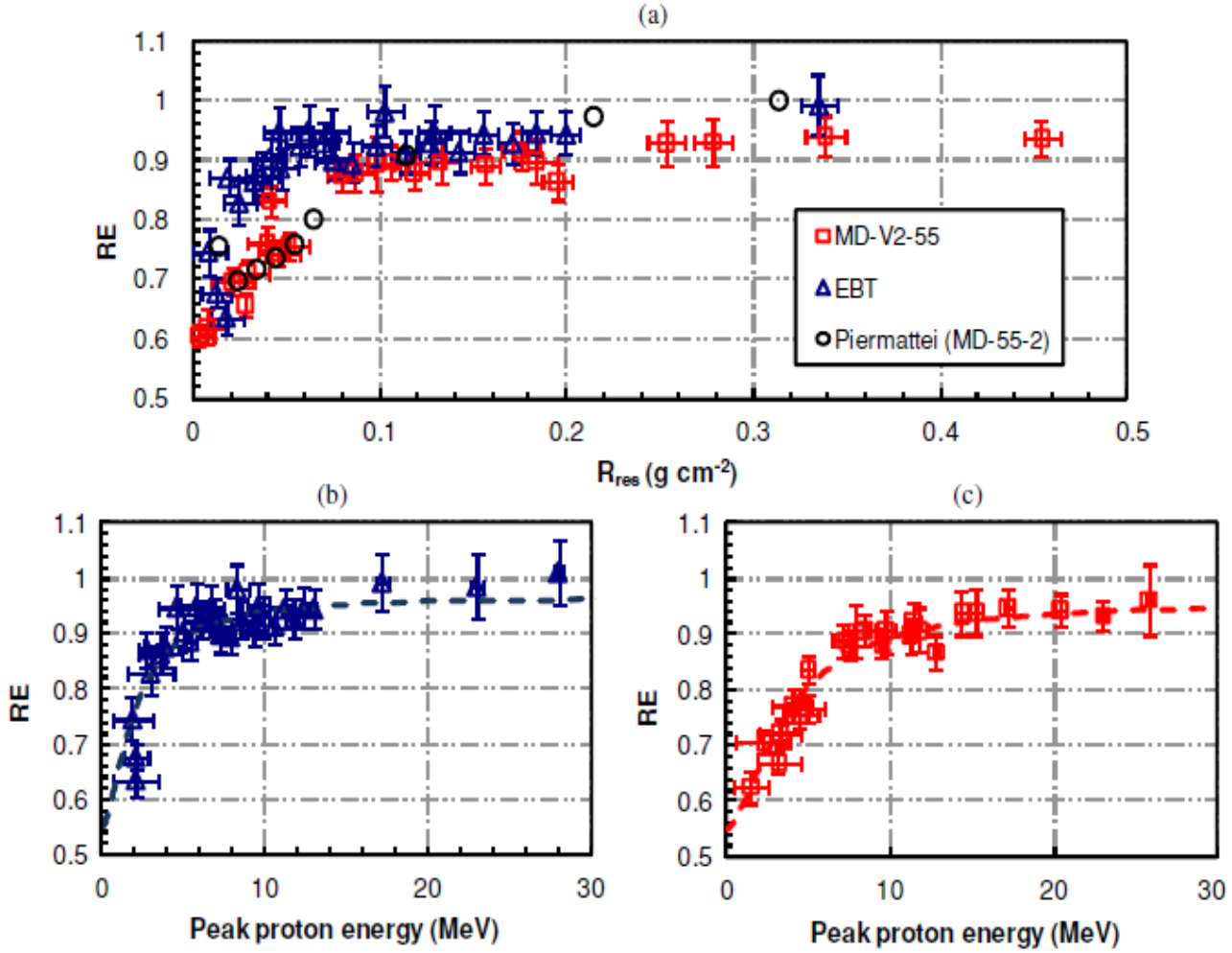
Herrmann et al. 2011



GSI ^{12}C ion beam

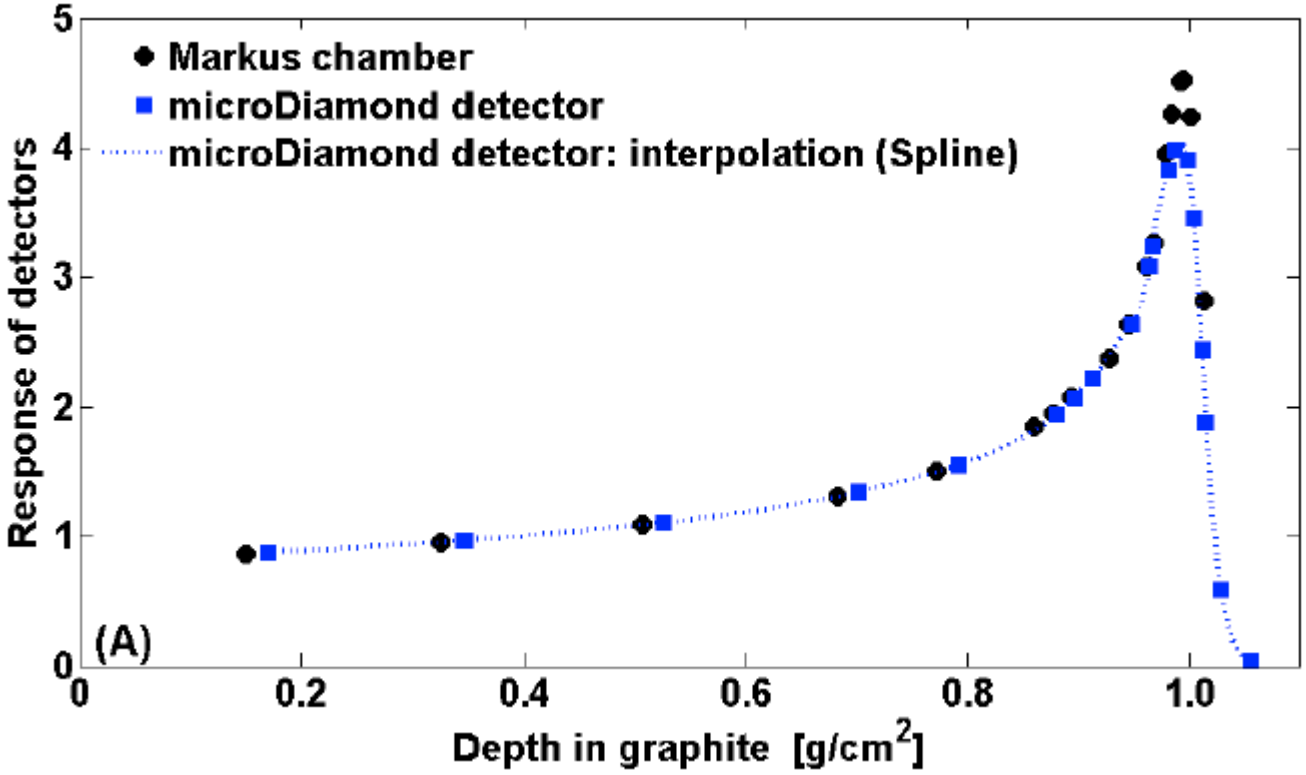


Relative dosimetry – LET dependence RCfilm



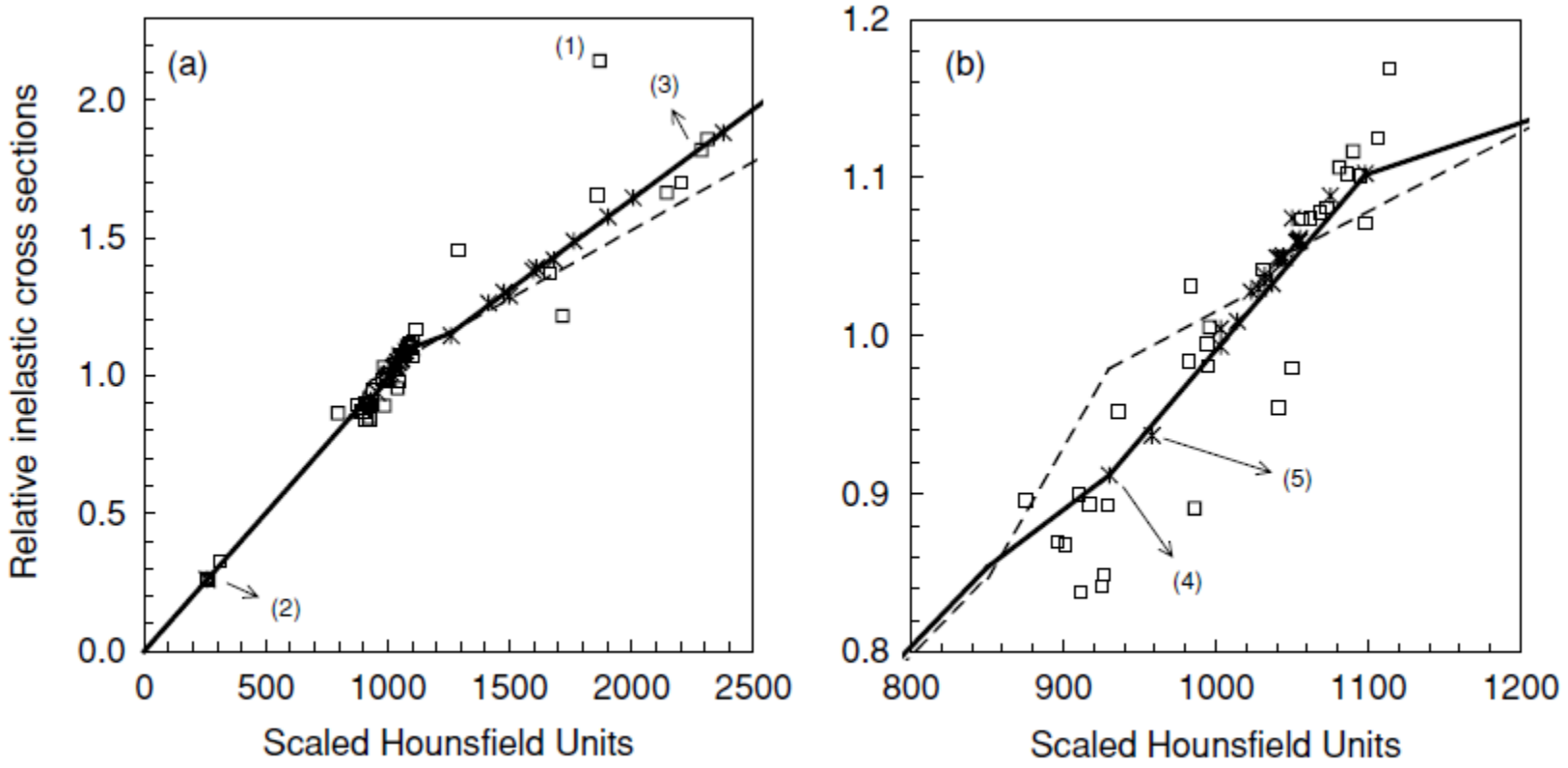
Kirby et al (2010) Phys. Med. Biol. 58:417

PTW microDiamond



Rossomme et al (2016)
Phys. Med. Biol. *submitted*

Tissue-equivalence



Palmans et al. (2005) *Phys. Med. Biol. 50*:991-1000

Other issues not discussed

Partial irradiation detectors

Detector arrays

Resolution requirements

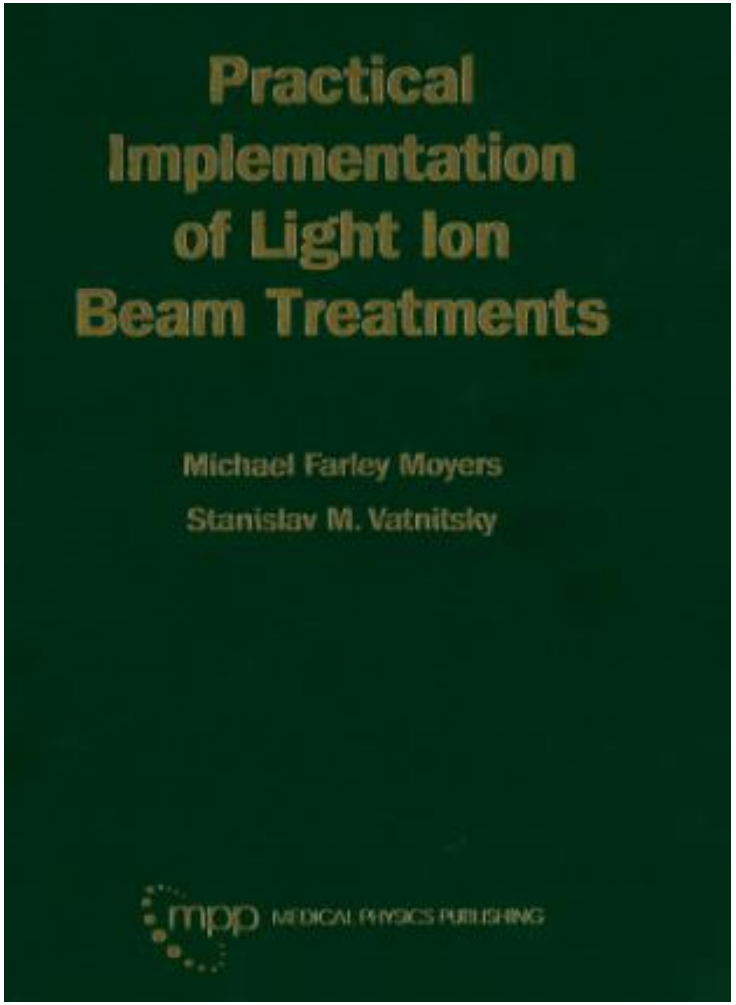
Audit and dose verification

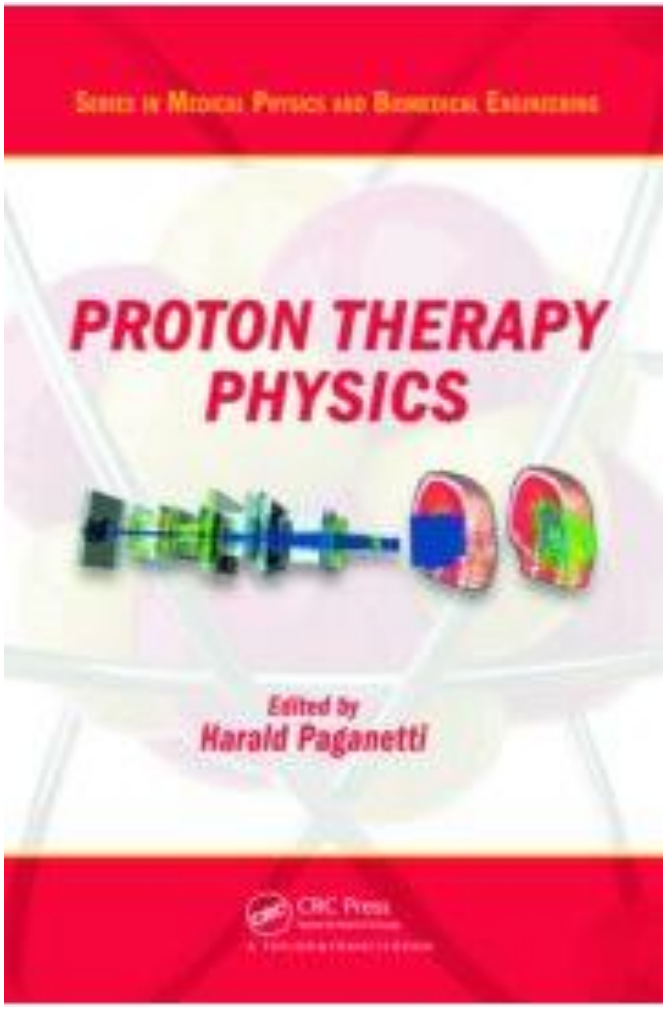
Alternative quantities for absorbed dose (microdosimetry and nanodosimetry based)

Track structure approaches

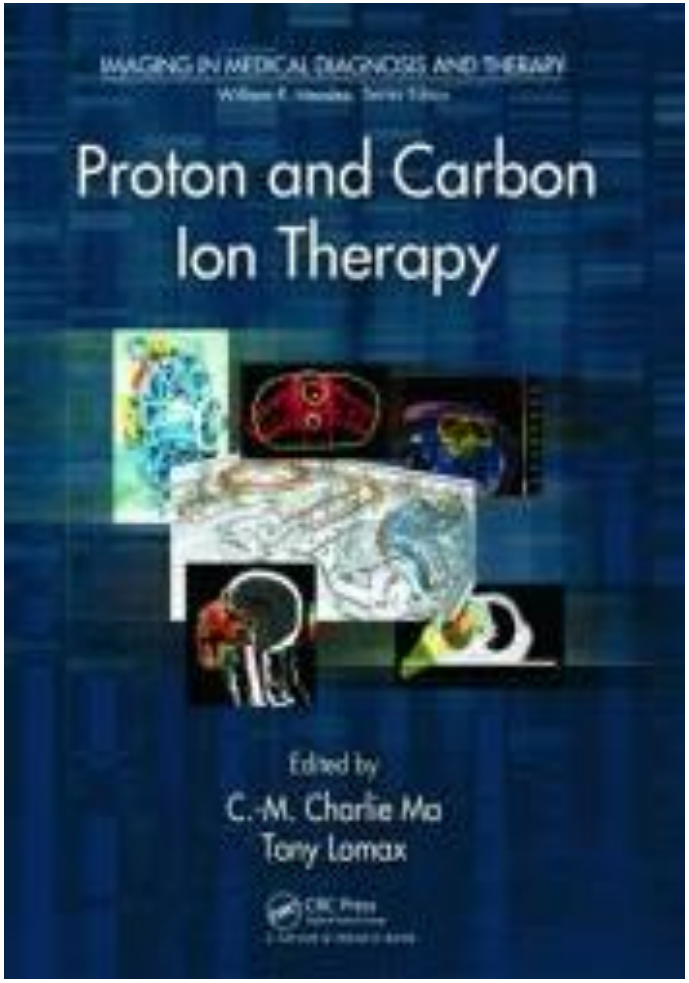
Biological dosimetry

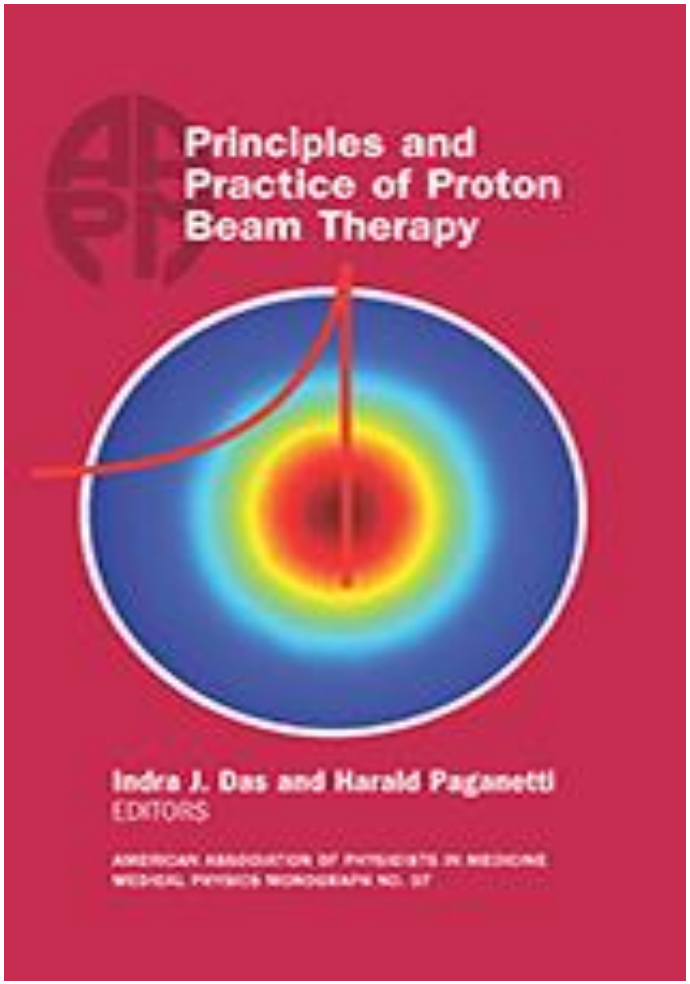
Additional reading





Additional reading



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Thank you for your attention!