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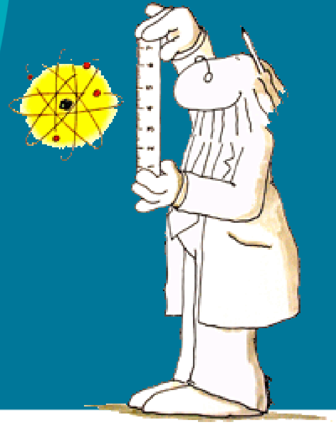
Development of a hybrid alanine-calorimetry absorbed dose standard for linac electron beams

Rodi Surensoy and Bryan Muir

NRC Metrology Research Centre, Ottawa, Canada

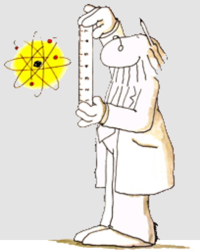


National Research Council Canada

Conseil national de recherches Canada

Canada

External beam calibration for cancer treatments

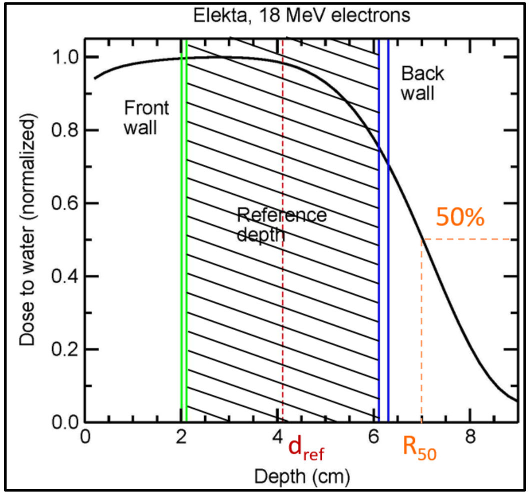


$$D_w = M N_{D,w}^{Q} = k_Q M N_{D,w}^{\mathrm{Co}}$$

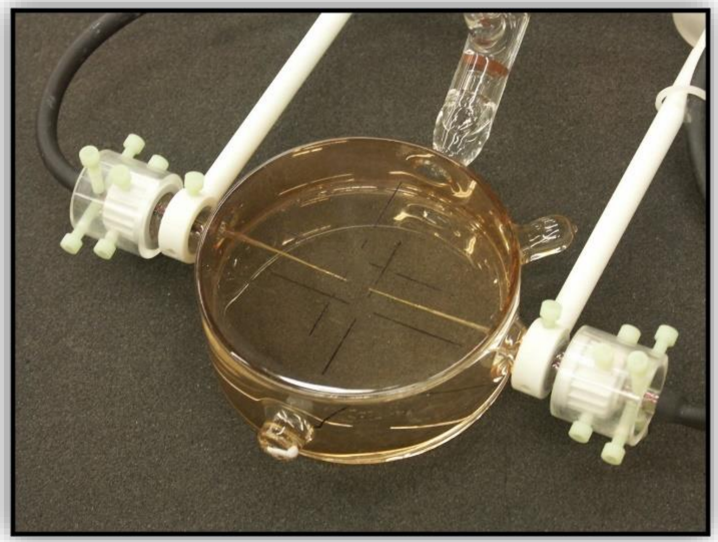
$\boldsymbol{D_w}$: relevant quantity for calibrating all linac beams

Almond et al. Medical physics 26.9 (1999): 1847-1870.

Water calorimetry for high-energy e⁻ beams



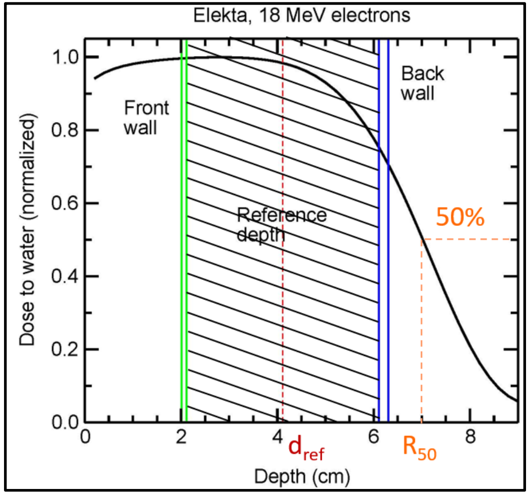
$$d_{ref} = 0.6R_{50} - 0.1\ (cm)$$



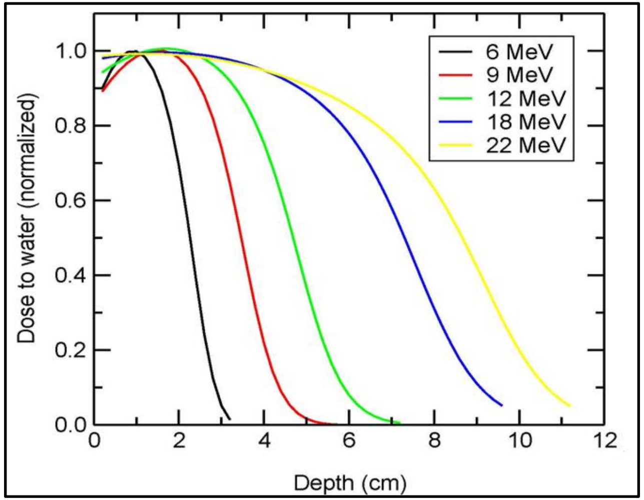
Parallel-plate calorimetry vessel

Muir, et al. Medical physics 44.10 (2017): 5433-5444.

Cannot measure D_w for lower-energy e⁻ beams



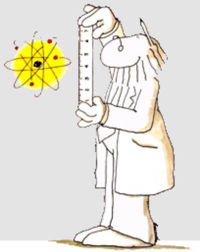
$$d_{ref} = 0.6R_{50} - 0.1\ (cm)$$

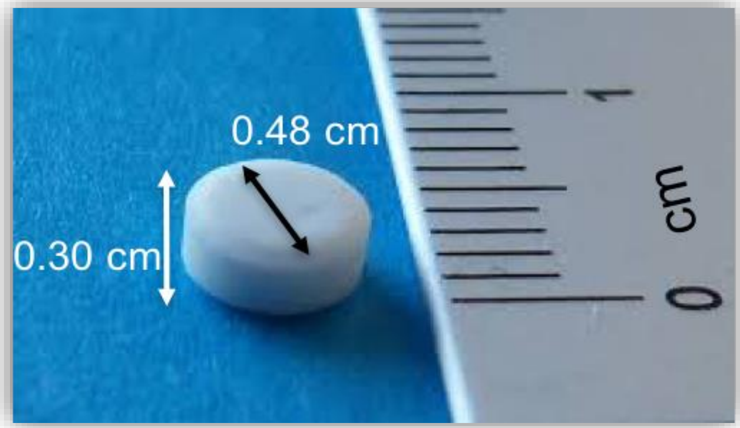


Only possible to measure in 18 and 22 MeV

Muir, et al. Medical physics 44.10 (2017): 5433-5444.

Alanine dosimetry and measurement accuracy





Usually formed into pellets which makes handling and readout simpler

Alanine is a good candidate due to:

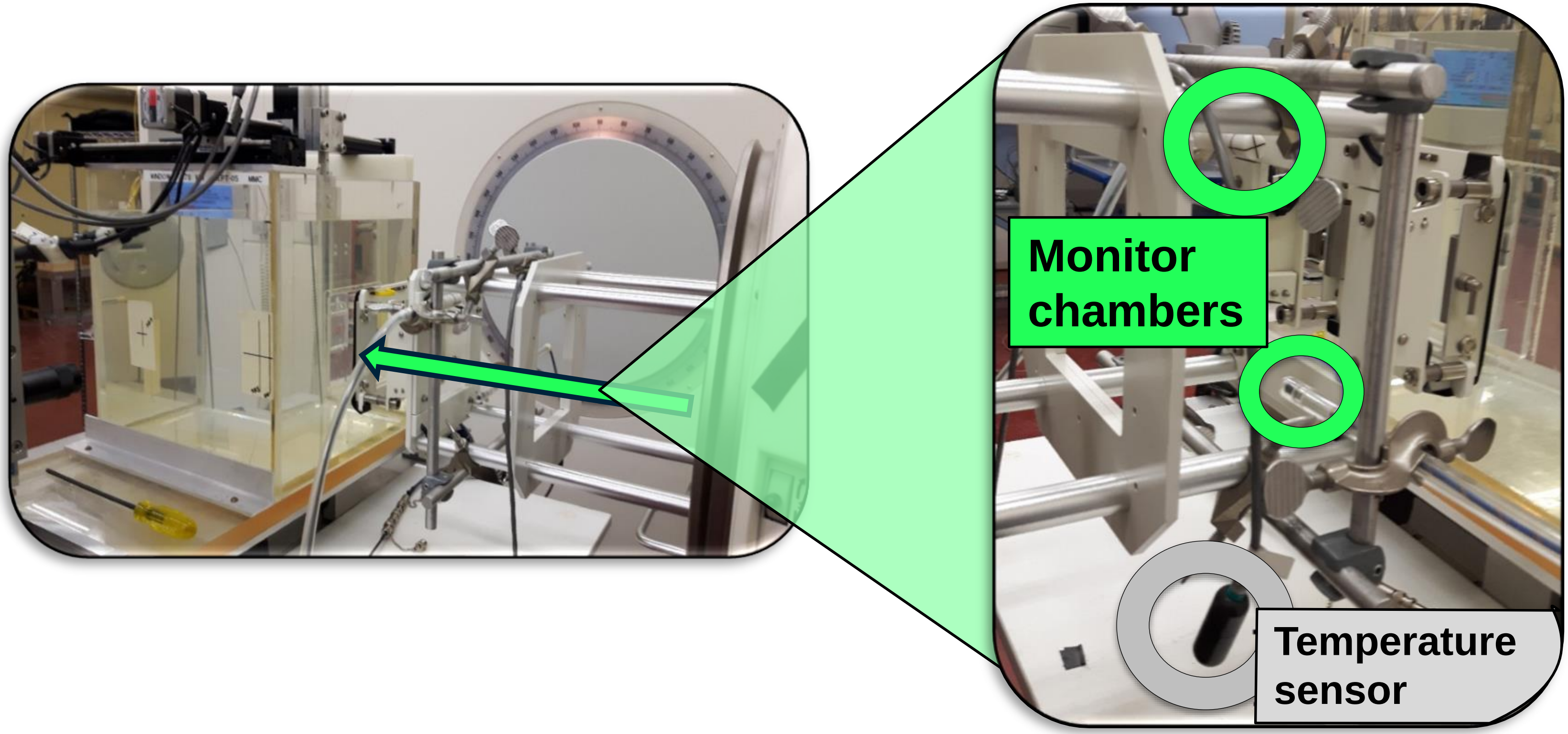
- Small size
- Lack of dependence on:
  - Dose rate
  - Temperature

Accurate measurement with precision

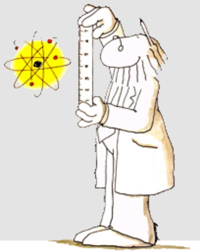
EPR spectrometers

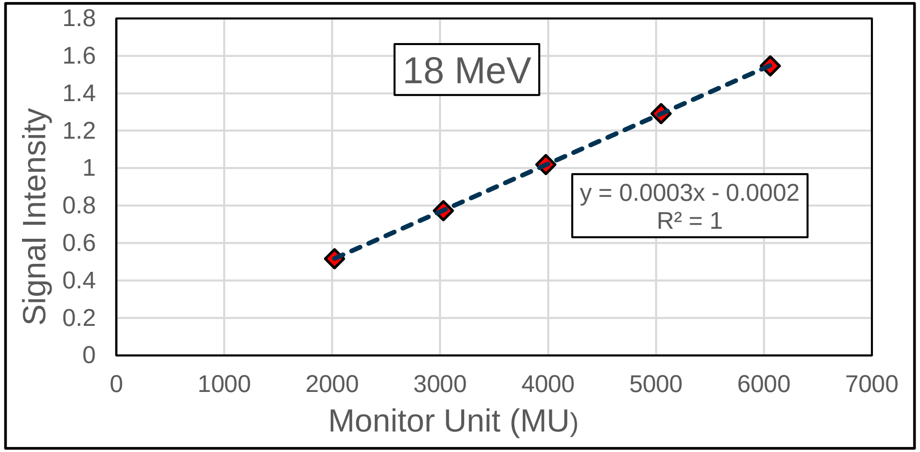
Mansour, Iymad. "Development of mailed dosimetric audit for external beam radiation therapy using alanine dosimeters.", 2018.

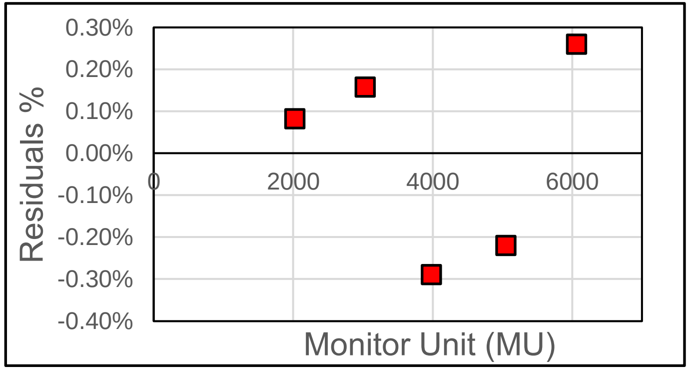
The irradiation set-up



The calibration curve is linear







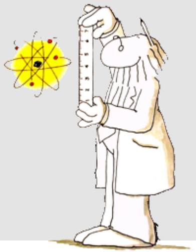
5 doses, 20 Gy to 60 Gy, 4 MeV to 22 MeV

$$I_{Al} = k_l \, G(Al) \, D_{Al}$$

Average RMSD = 0.2 %

Type A uncertainty ~ 0.2%

Derivation of $N_{D,w}$ from alanine



$$I_{Al} = k_l\, G(Al)\, D_{Al}$$

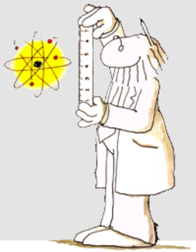
$$D_w = f(Q) k_{bq}(Q) D_{Al}$$

$$D_w = \underbrace{[k_l\, G(Al)]^{-1} f(Q) k_{bq}(Q)}_{\textbf{Slope}} I_{Al}$$

$$D_w = M N_{D,w}$$

$N_{D,w}$ → ***Calorimetry***

$N_{D,w}^{Q*}$ from alanine (* indicates derived)

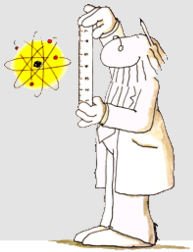


$$N_{D,w}^{Q*} = N_{D,w}^{Qecal} \frac{\left[\frac{M}{MU}\right]^{Qecal} \left[\frac{S}{MU}\right]^{Q*}}{\left[\frac{S}{MU}\right]^{Qecal} \left[\frac{M}{MU}\right]^{Q*}} \frac{\left[f(Q)k_{bq}(Q)P_{wall}\right]^{Q*}}{\left[f(Q)k_{bq}(Q)P_{wall}\right]^{Qecal}}$$

$D_w^{Q} = M N_{D,w}^{Qecal}$ (Gy) **18, 22 MeV from calorimetry**

$D_w^{Q} = M N_{D,w}^{Q*}$ (Gy) **4, 6, 8, 12, 15, 18 MeV from alanine**

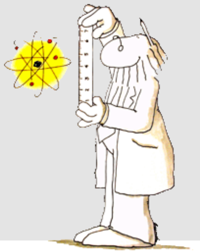
What you need to know

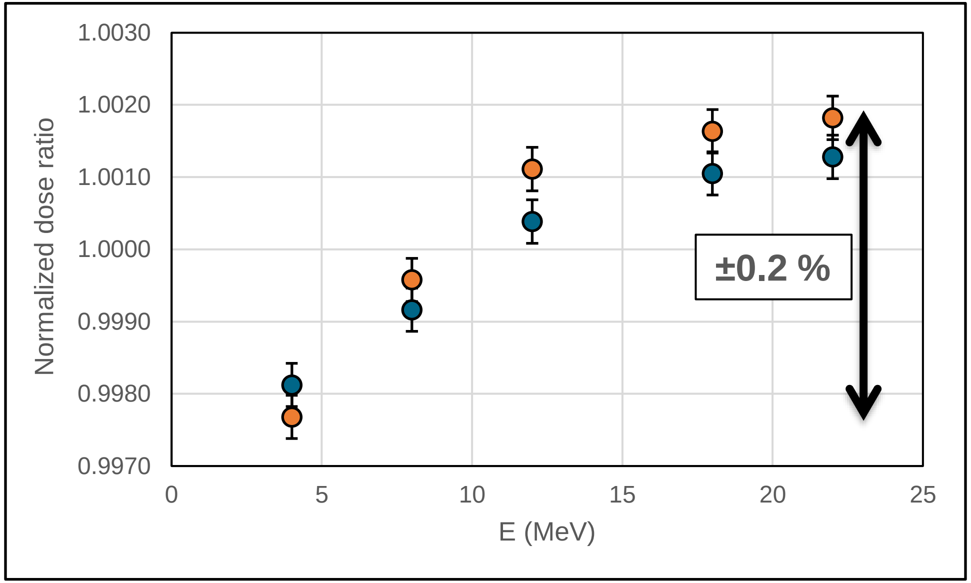


The analysis is complicated!

If alanine is independent of electron beam energy, $N_{D,w}$ can be derived for low-energy electron beams.

Monte Carlo results: normalized $\frac{D_{Al}}{D_w}$

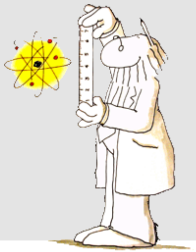




Single alanine pellet in phantom

Independent calculation with holder modelled in phantom

The beam quality conversion factor, k_Q

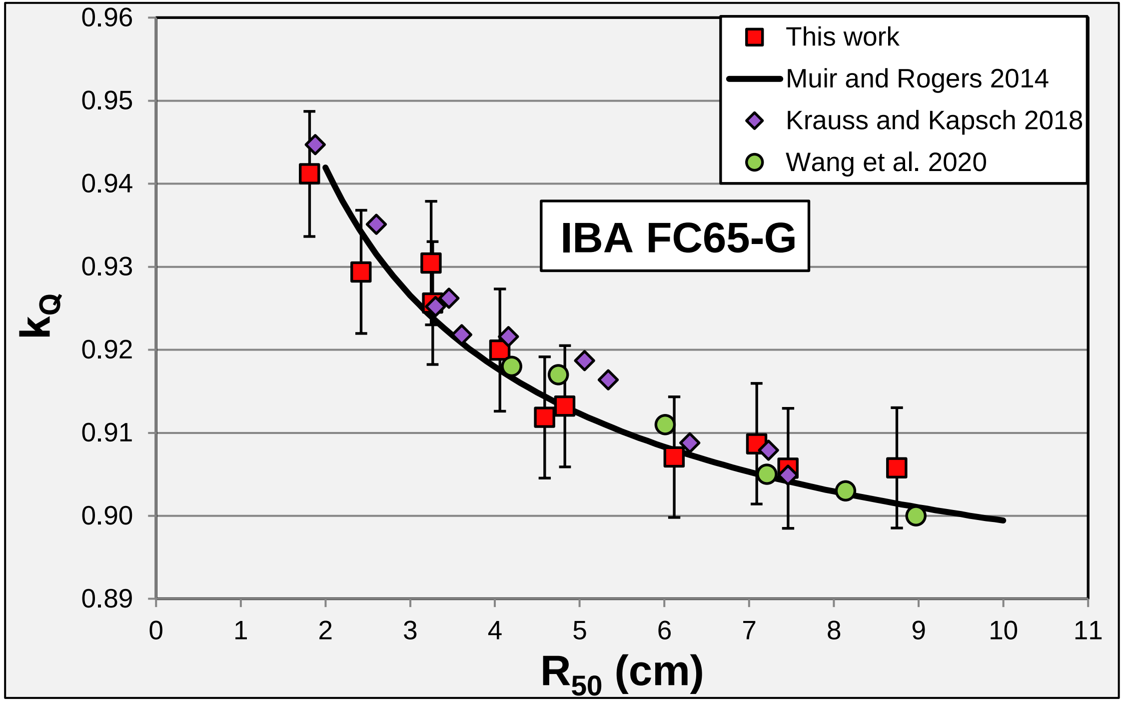


$$D_w = M N_{D,w}^{Q} = k_Q M N_{D,w}^{\mathrm{Co}}$$

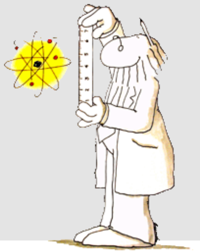
$$\Longrightarrow$$

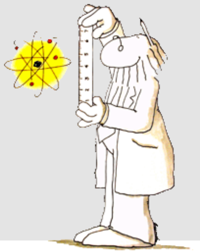
$$k_Q = \frac{N_{\mathrm{D,w}}^{Q}}{N_{\mathrm{D,w}}^{\mathrm{Co}}}$$

The beam quality conversion factor, k_Q



Error bars represent combined type A and B uncertainties (0.8%, k=1)





Conclusions

- ✓ Developed a hybrid-alanine standard for low-energy electron beams
- ✓ Demonstrated that absorbed-dose energy-dependence is ±0.2 %
- ✓ Demonstrated agreement within ~1 % with published data

Applications:

- ion chamber calibration service
- postal audit service for dose verification
- FLASH electron studies

THANK YOU

Rodi Surensoy • Graduate Student • Rodi.Surensoy@nrc-cnrc.gc.ca