DEVELOPMENT AND TEST OF A SMALL PORTABLE GRAPHITE CALORIMETER FOR USE IN ULTRA-HIGH DOSE RATE PARTICLE BEAMS

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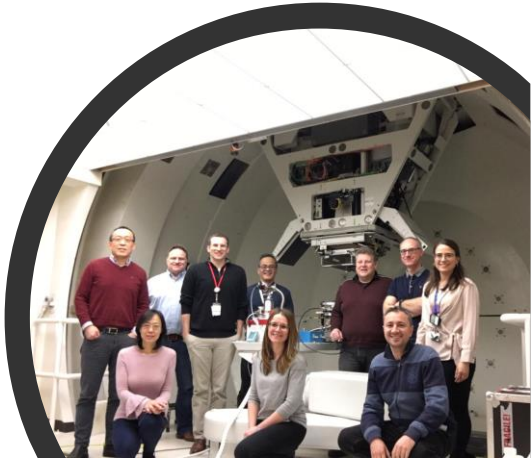
The Visit

Invitation to make measurements with our calorimeter in the research beam line at the Cincinnati Children's Hospital – February 2020

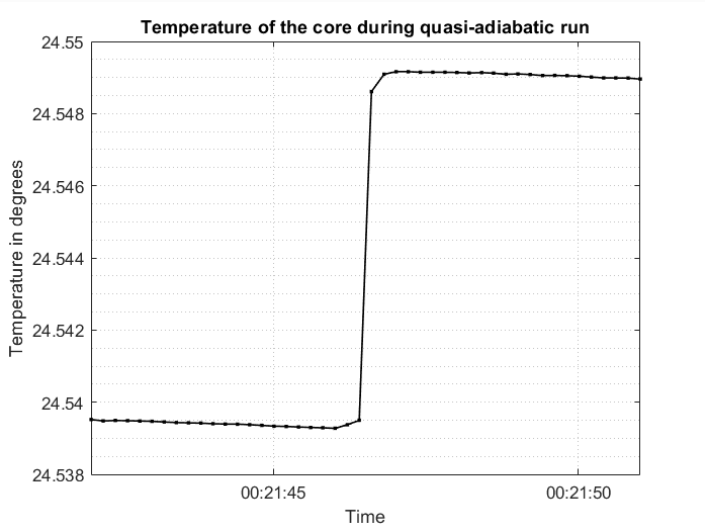
Cincinnati Children's



Methods

- High-dose rate (~65Gy/s)
- 8 rectangular fields of 250 MeV single layer (5x6 – 5x12 cm^2)
  - Treat bone metastasis of extremities using the plateau region
- Five experimental setups:
  - Portable Proton Primary Standard Graphite Calorimeter
  - Gafchromic EBT3 film
  - Alanine
  - Ionisation chambers (PTW Advanced Markus and IBA PPC05)
  - Small Portable Graphite Calorimeter
- Reference points at Isocentre and WET of 5 gcm^{-2}

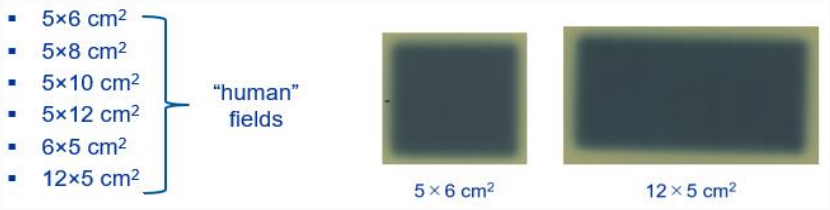
scanning - cyclotron



Eunsin and Lourenço *et al.*, AAPM 2020

Gafchromic EBT3 film

- Films were subjected to 250 MeV FLASH proton beam in a 30 × 30 × 30 cm^3 RW3 solid water phantom at a WET of 5 gcm^{-2}
- Several field sizes in the range 5 × 6 cm^2 up to 5 × 12 cm^2 with 5 mm pencil beam spacing
- Films were digitized in a 48-bit RGB signal with 150 dpi spatial resolution using an Epson Expression 10000XL flatbed scanner operating in the transmission mode without colour corrections



- 1x1 cm^2 ROI at the beam central axis used for analysis
- ** includes only statistical analysis of analysed films

NOTE: Film 5 looks like an outlier. From the log file received from Varian it looks like the dose delivered was approx. 8 Gy. An explanation is not available at this stage but is undergoing investigation

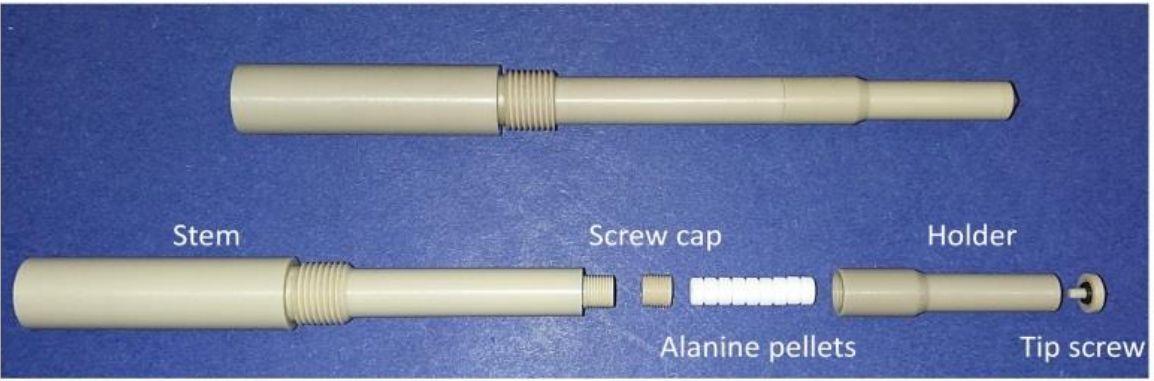
[Publications of these results are in preparation]

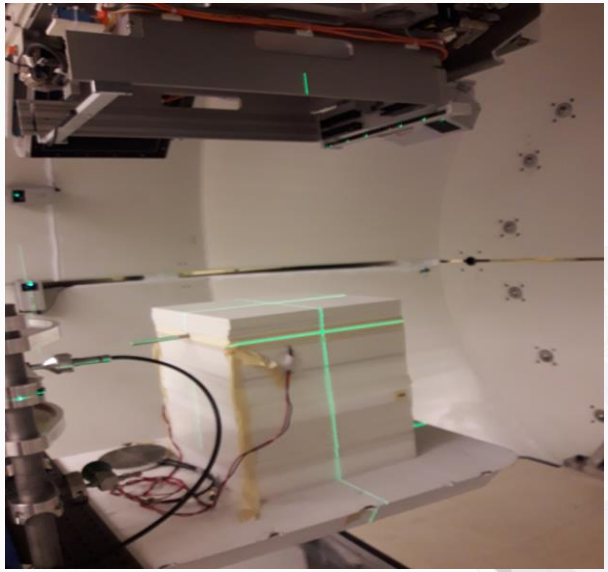
Alanine

- Alanine pellets were arranged in a stack in a Farmer-type holder in an RW3 phantom at a WET of 5 gcm^{-2}.
- Dose delivered was averaged for the 5 independent exposures. No k_Q factor has been applied to alanine readouts as the pellets were positioned in the plateau region of the PDD.

Measured absorbed dose to water with alanine:

[Publications of these results are in preparation]





Ionisation Chamber Data

- Measurement data was acquired from two different types of ionisation chamber, PTW Advanced Markus and IBA PPC-05, following the recommendations of the IAEA TRS 398 Code of Practice
- The chambers were positioned in a 30 × 30 × 30 cm^3 RW3 solid water phantom with the effective point of measurement of each chamber positioned on the beam isocentre at a water equivalent depth of 5 gcm^{-2}

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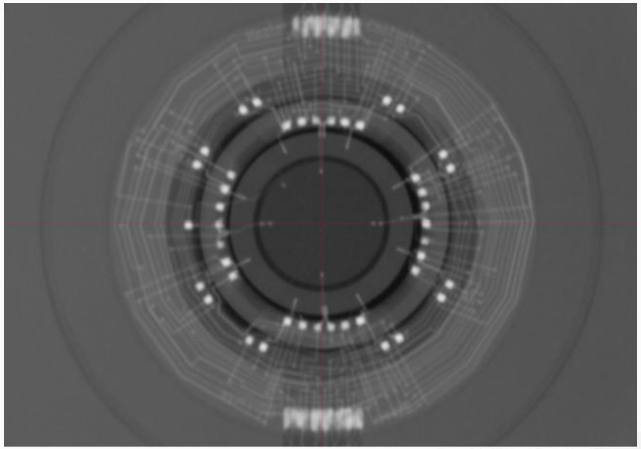
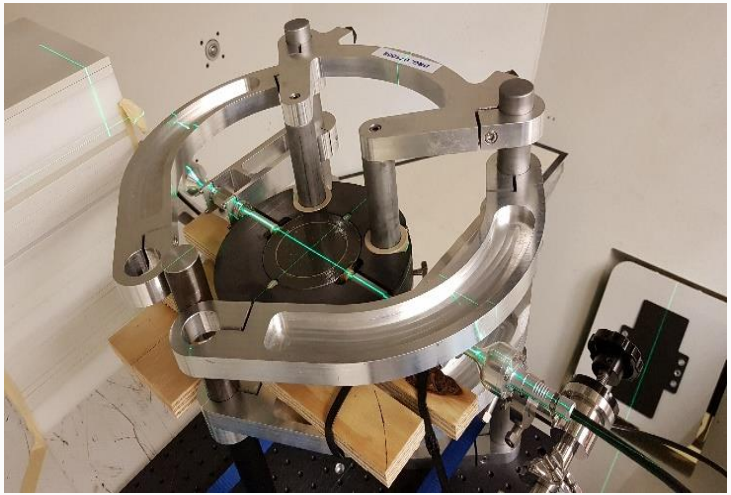
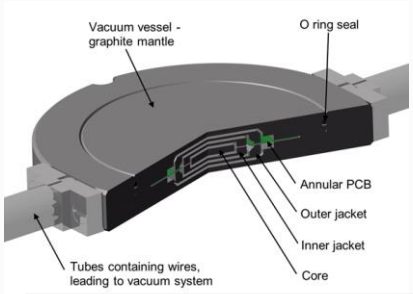
Portable Proton Primary Standard Graphite Calorimeter

- Originally developed for use with conventional proton beams, the control and analysis software was reconfigured to enable it to be used with UHDR particle beams
- Consists of graphite discs arranged in a nested construction, maintained under vacuum
- Operated in quasi-adiabatic mode, thermistors detect changes in temperature of the graphite created by energy absorbed from the radiation beam allowing derivation of absorbed dose
- The core of the calorimeter was positioned at the isocentre with graphite plates placed in front to position the core at a WET of 5 gcm^{-2}

[Publications of these results are in preparation]

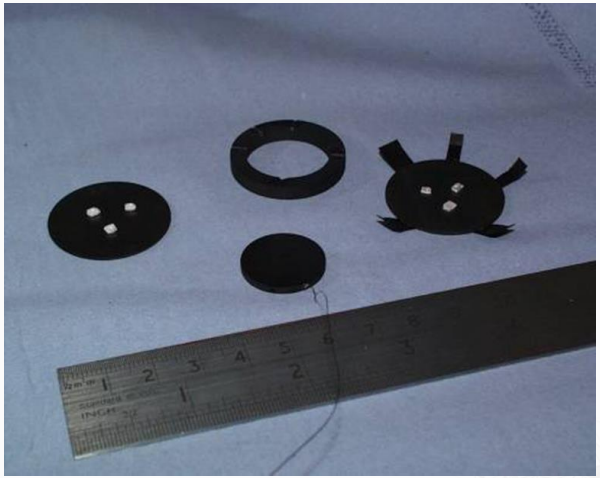


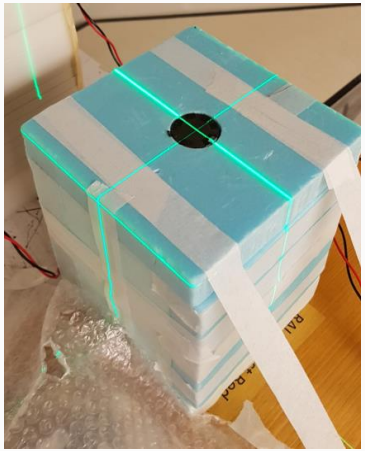


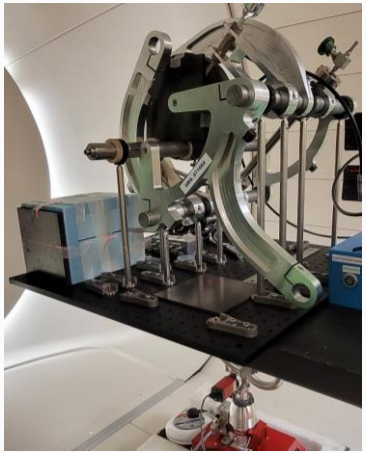


Small Portable Graphite Calorimeter

- Originally developed for use with the Clatterbridge ocular proton beam (Palmans et al. 2002). The device was refurbished and integrated with the current control and analysis software developed for UHDR particle beams
- Thermistors are embedded around the circumference of both graphite components
- Operates only in quasi-adiabatic mode
- The core of the calorimeter was positioned at the isocentre with graphite plates placed in front to position the core at a WET of 5 gcm^{-2}







[Publications of these results are in preparation]

Comparison of results for the 5 cm x 6 cm field

[Publications of these results are in preparation]

Conclusion

- The results presented show agreement between the PPPSGC and the IC, Film and Alanine varies between 0.5% and 3.4%, $k = 1$
- Agreement between the SPGC and PPPSGC is within 0.05%, $k = 1$
- Proof-of-concept of how a simple calorimeter may be an effective tool in the clinic to accurately determine absorbed-dose delivered to the target at a significantly reduced measurement uncertainty compared to other techniques or used to determine correction factors for IC
- This work will support in producing future recommendations for dosimetry protocols for FLASH measurements
- Supported Cincinnati Children's hospital by giving them confidence in their dosimetry to move forward with commencing their clinical trials
- Based on this work a prototype, low cost, secondary standard calorimeter has been developed [publication in preparation]

Thank you for listening