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Development of Graphite Calorimetry at the NPL for Proton Beam Therapy

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Radiation Dosimetry Group

National Measurement Office

Background

- Current protocols based on chambers calibrated in other beam types (electrons, Co60)
- Preferred method of transfer of calibration from primary standard to user is cross calibration in a beam of the same or similar beam quality.
- UK protons are coming, well actually they have already been here since 1989!
- Clatterbridge/NPL collaboration since 1999
- 2001 NPL SR project to examine issues surrounding reference dosimetry for proton beams
- 5th April 2012 UK government announced two NHS “high” energy facilities at Christie and UCLH

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Extract from planning visit 2002

Aim of the original project was to explore the variation of the current recommendations of dosimetry protocols and the feasibility of building a primary standard to routinely operate in the clinical department

Visit and meeting at Clatterbridge 6/11/02

Present: Andrzej Kacperek (AK), Russel Thomas (RAST), Frank Verhaegen (FV), Hugo Palmans (HP)

13:30 Delicious lunch at 400 years old pub

14:30 Visit to workshop and proton treatment room

Inventory of equipment available at Clatterbridge:

- Milling-machine: accuracy 0.005mm, working area 400 mm x 280 mm
  - Plastics, graphite, aluminium, brass,…
  - We could have phantom inserts, etc. made there at no cost for NPL. For parts that need construction, provide drawing + parts that have to be inserted such as ion chamber.
- Computer dedicated to research (we could install MCNPX here!)

ACTION: FV will send AK procedure to obtain MCNPX from NEA database

- Beam line:

Publications resulting directly from work conducted between NPL/CCC plus at least a further 4/5 in preparation

- R Thomas, H Palmans, A Kacperek, S Duane, " Low energy proton beam dosimetry with plane-parallel chambers using NPL electron and ^{60}Co calibrations," Published in proceedings of the ARPANSA workshop on Recent Advances in Absorbed Dose Standards 19-21 August, 2003
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“Of course, our other articles and book chapters (29) we have published on proton or carbon ion dosimetry have also indirectly been enabled by our collaboration with Clatterbridge”

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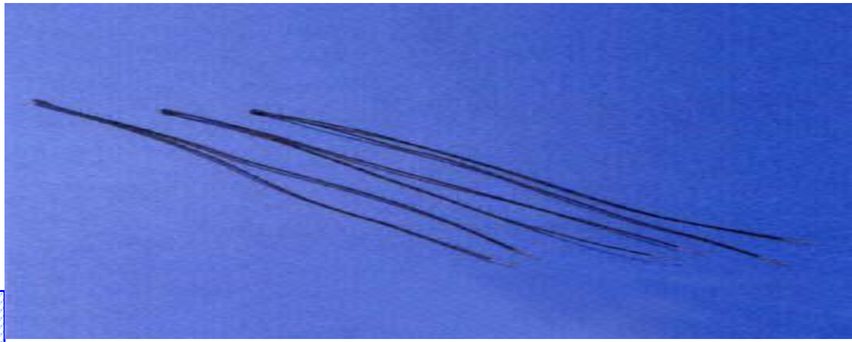
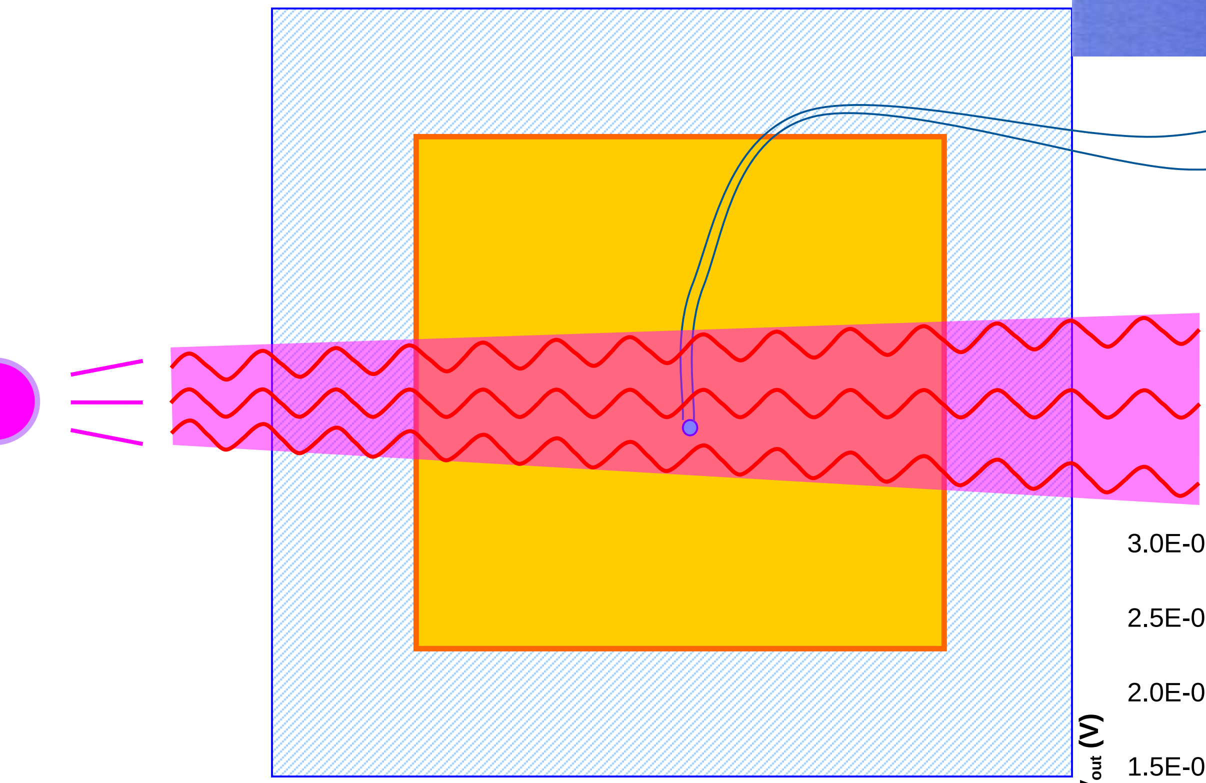
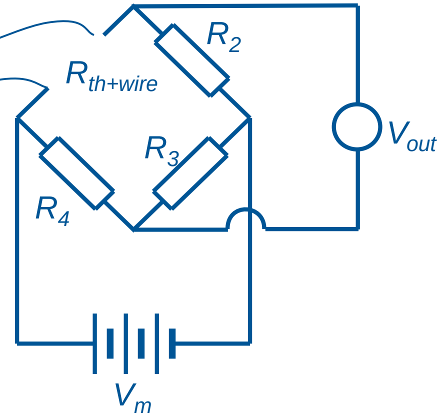
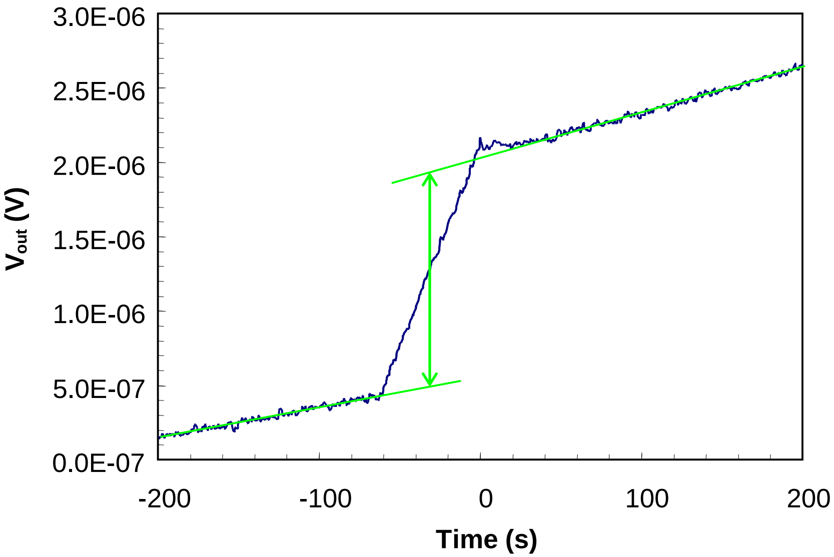
Calorimetry









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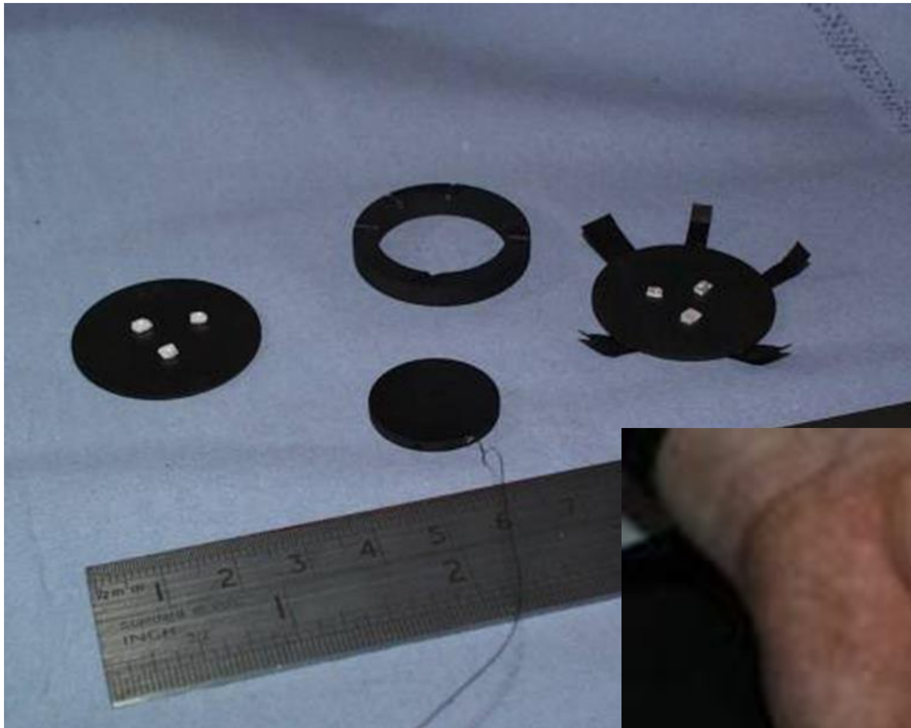

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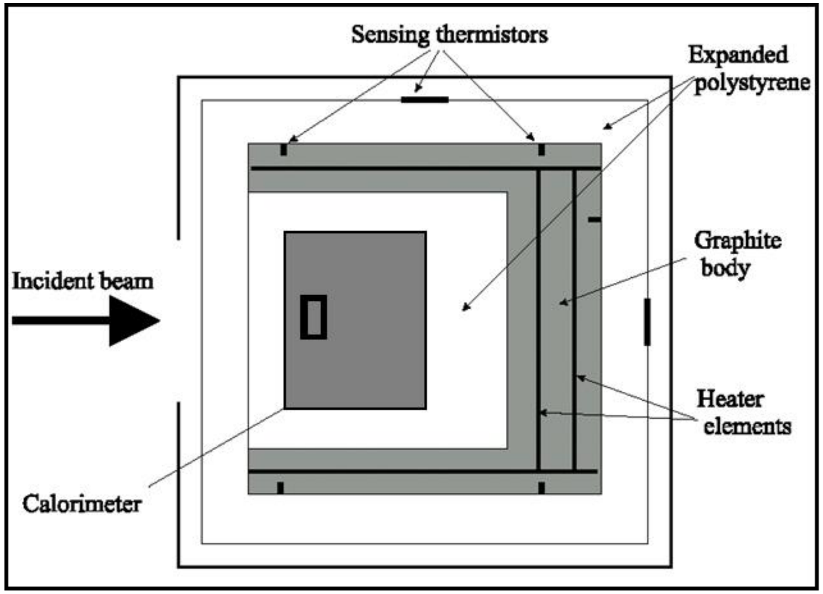
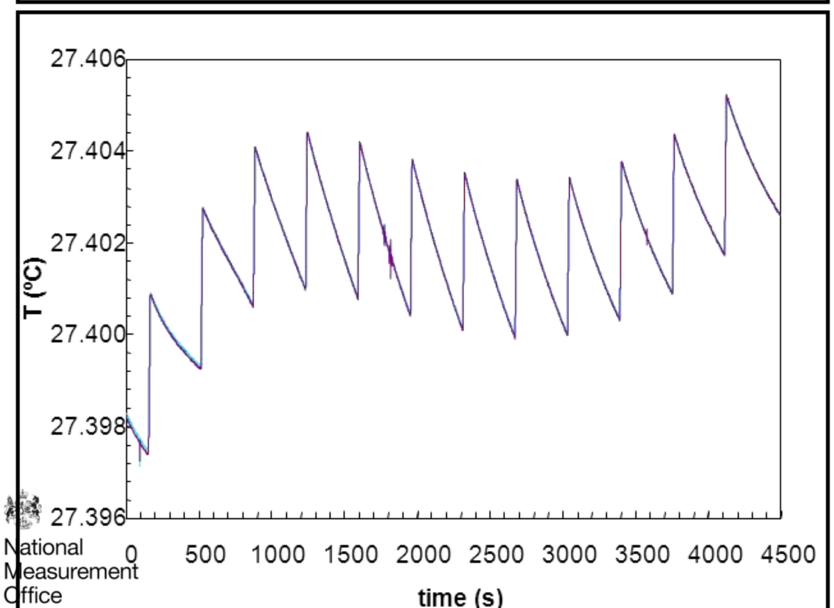
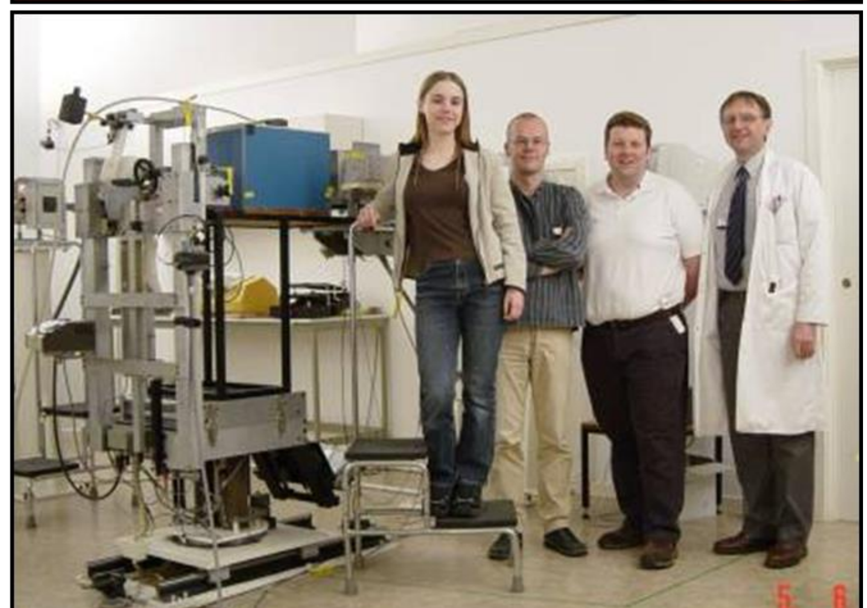
Graphite calorimetry for protons CCO (Palmans et al 2004, Phys Med Biol 49:3737-49)







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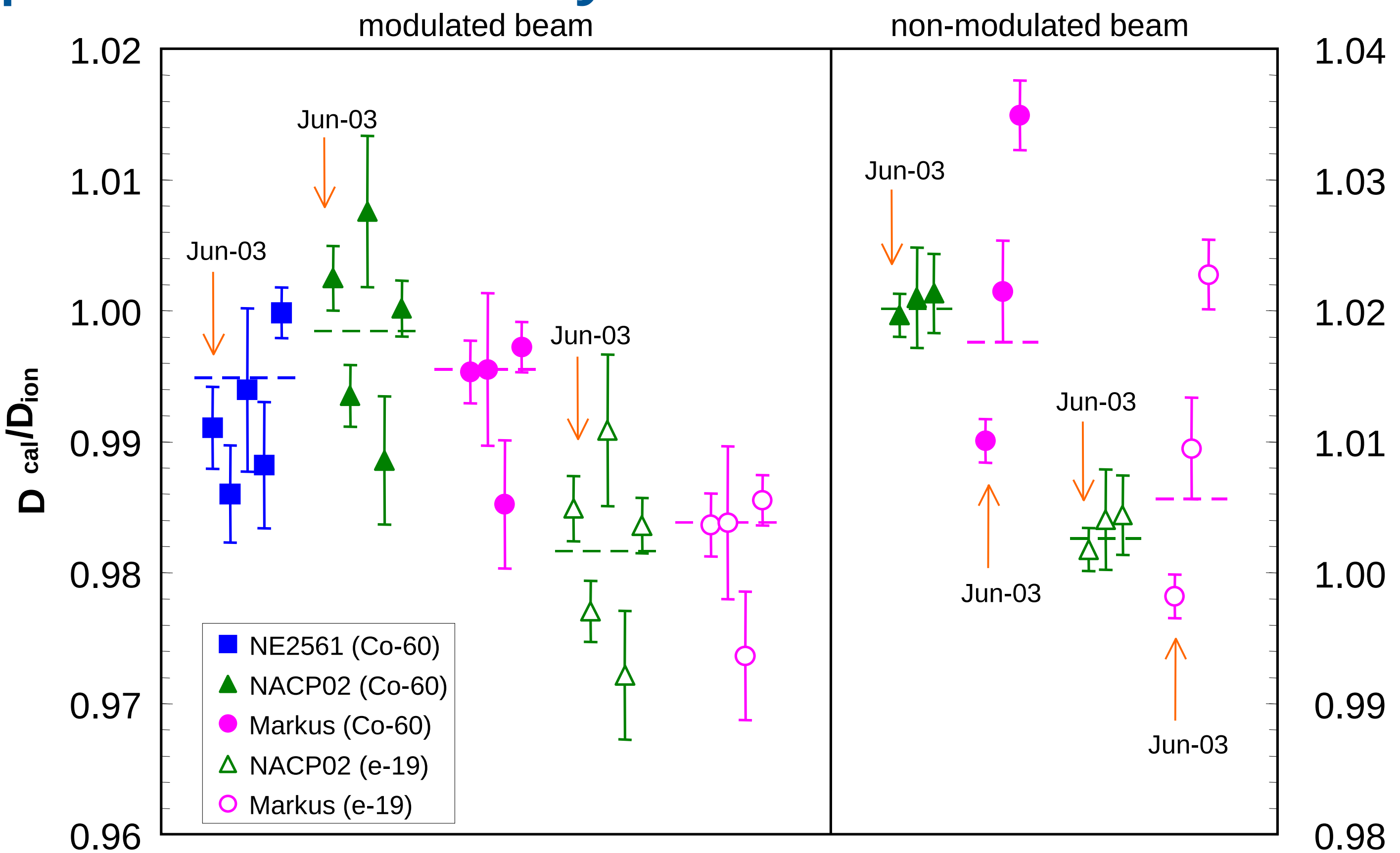
Graphite calorimetry results CCO



	$D_{w,SPGC}/D_{w,IC}$	
Calibration beam quality	modulated	non-modulated
^{60}Co	0.996	1.019
Q_{e19}	0.983	1.004

1925 Triumph 500cc Model P

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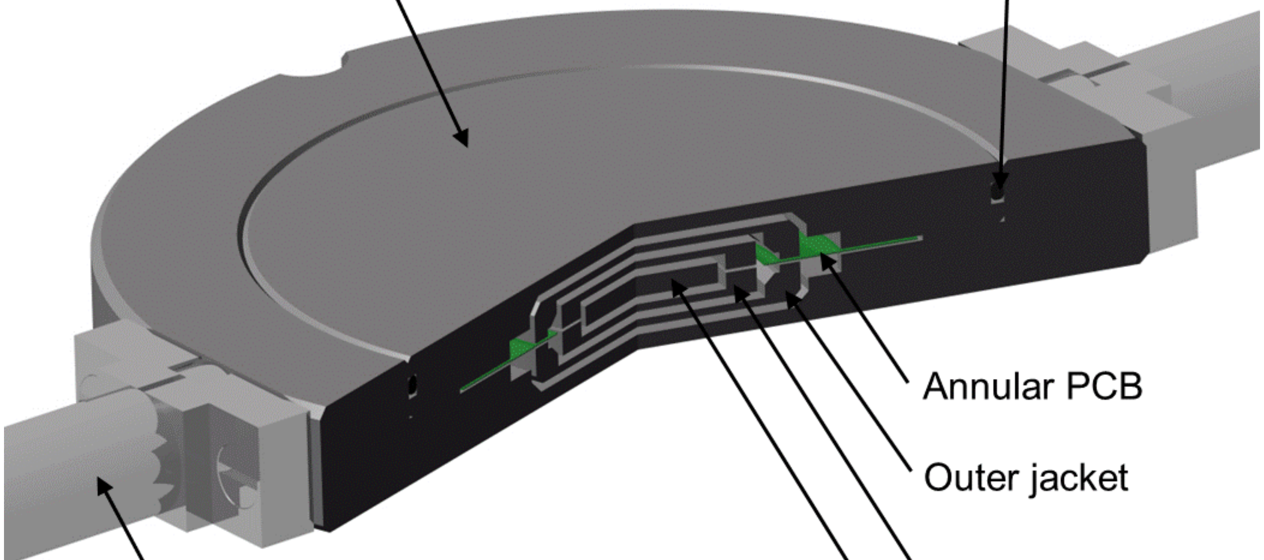
Design of new calorimeter



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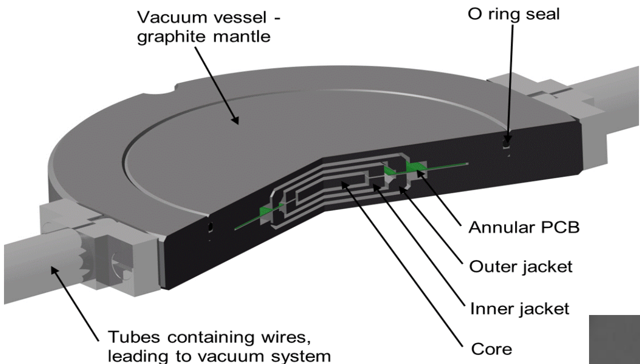
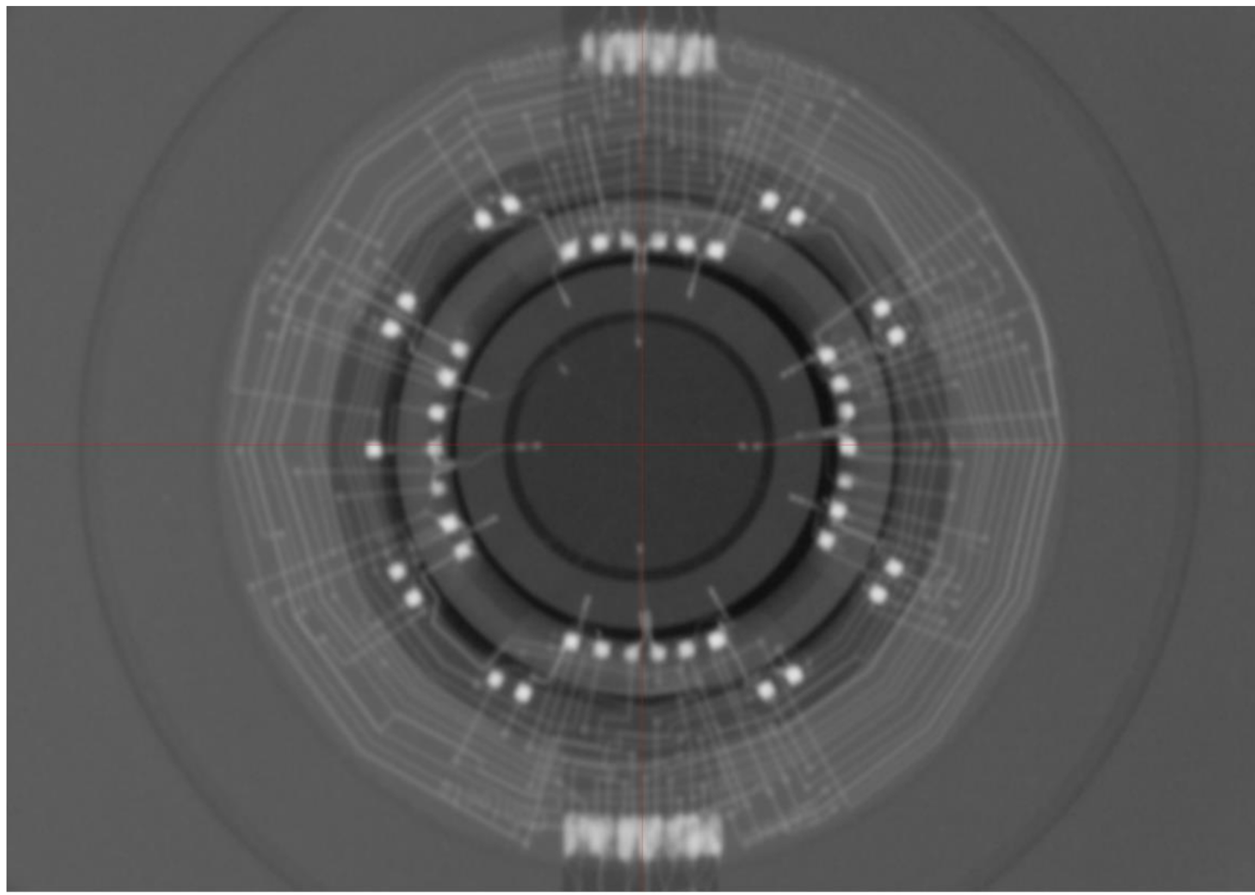

Vacuum vessel -
graphite mantle
O ring seal
Annular PCB
Outer jacket
Inner jacket
Core
Tubes containing wires,
leading to vacuum system



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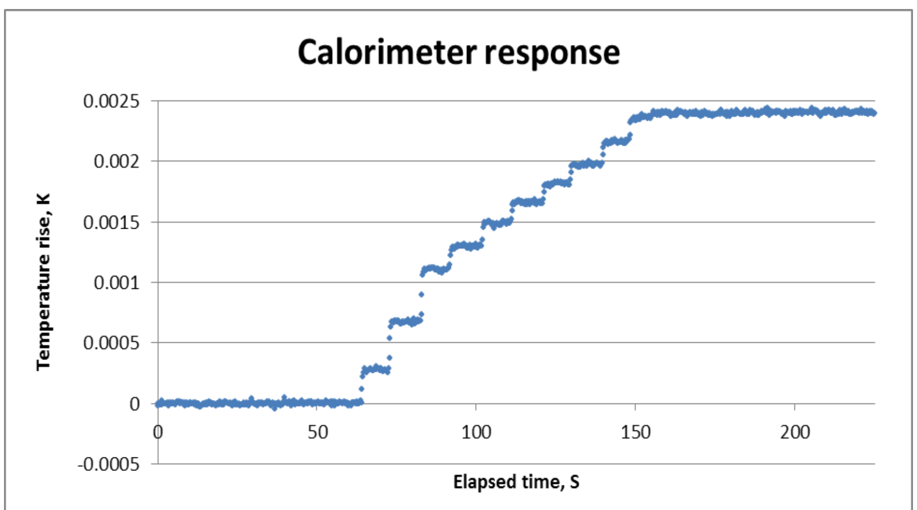
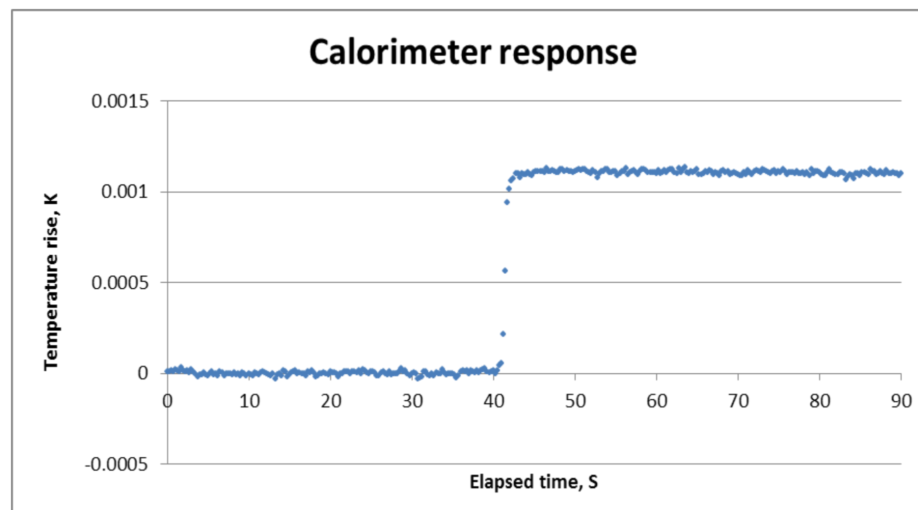
Quasi-adiabatic mode of operation;

Outer jacket of calorimeter is maintained at a constant temperature, usually a few degrees C above the ambient temperature of the room. The core and inner jacket are not controlled and allowed to drift. The absorbed dose, D_g, is obtained by multiplying the temperature rise in the graphite core, ΔT_g, (corrected for heat transfers), by the specific heat capacity, c_p^g of graphite:

$$D_g = c_p^g . \Delta T_g$$





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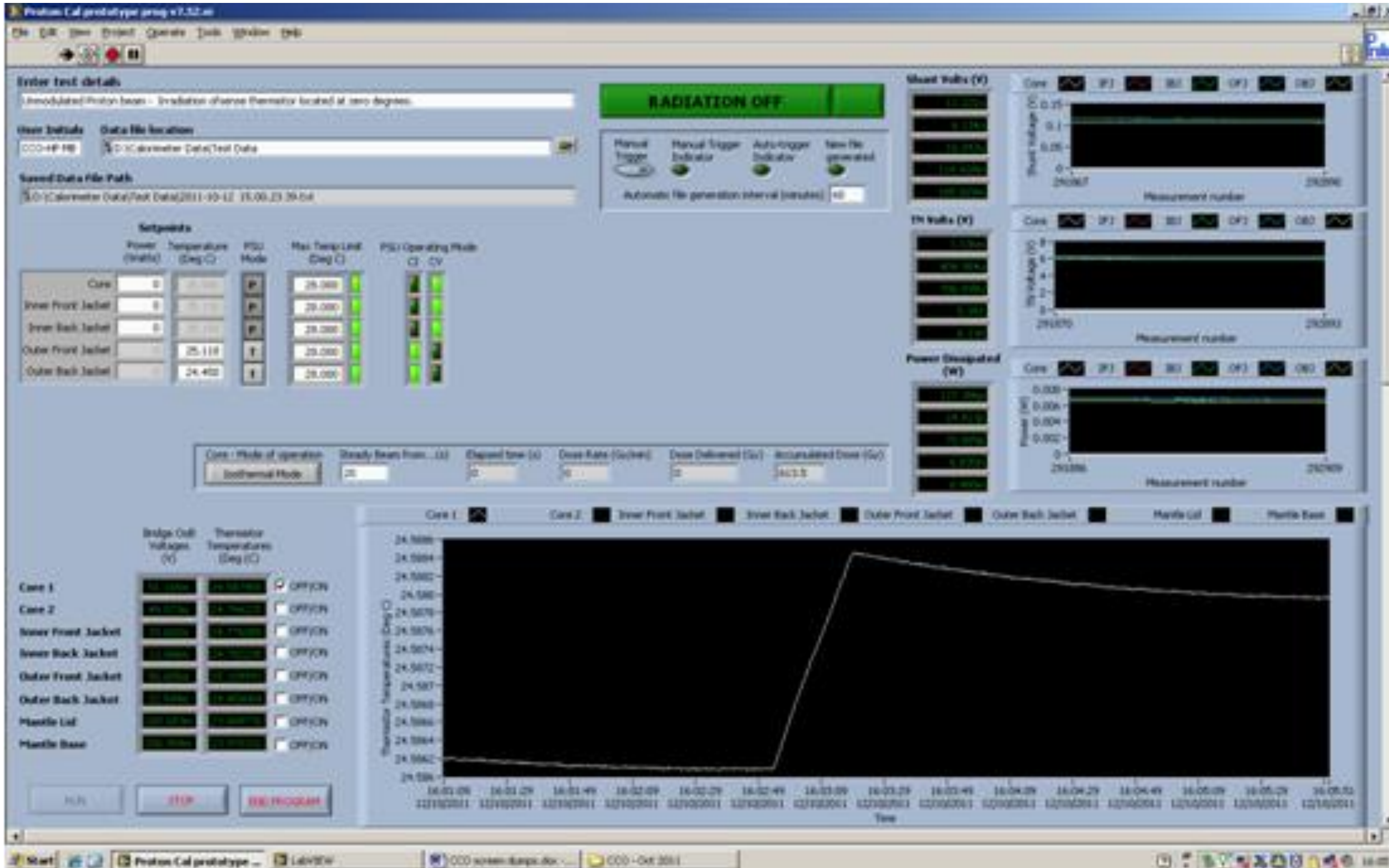

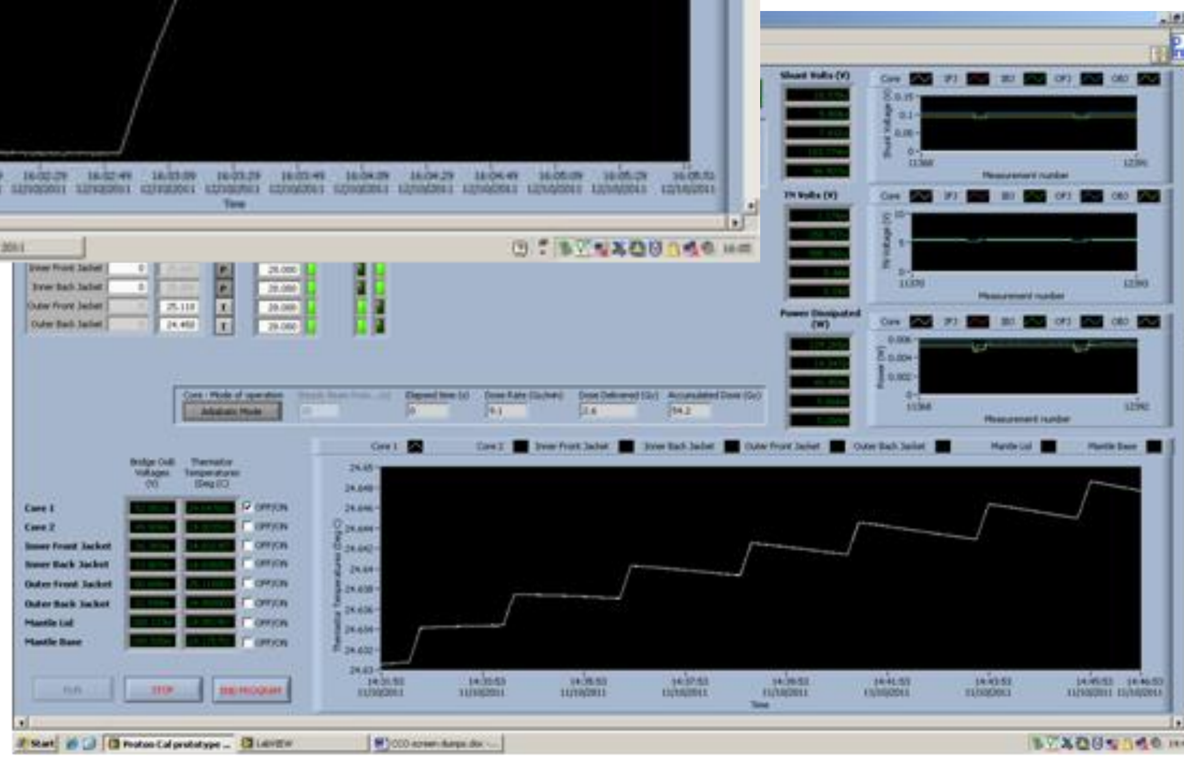

Adiabatic Mode

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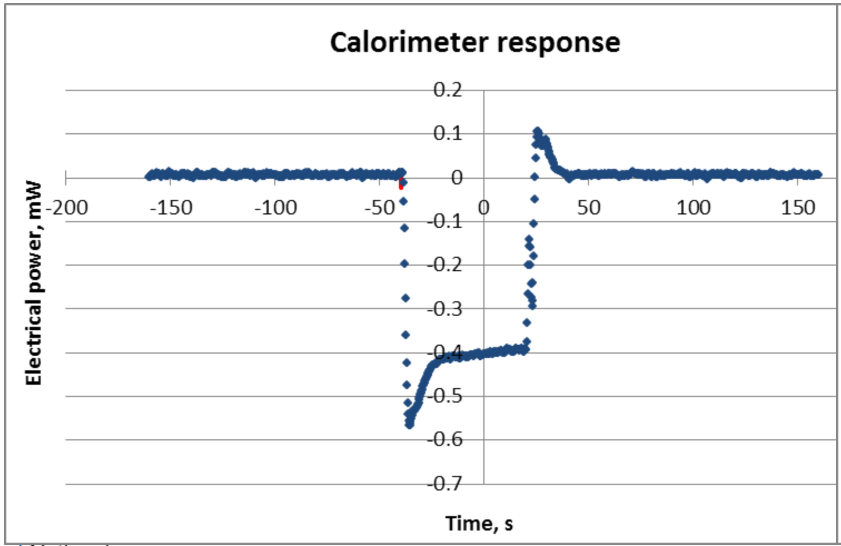
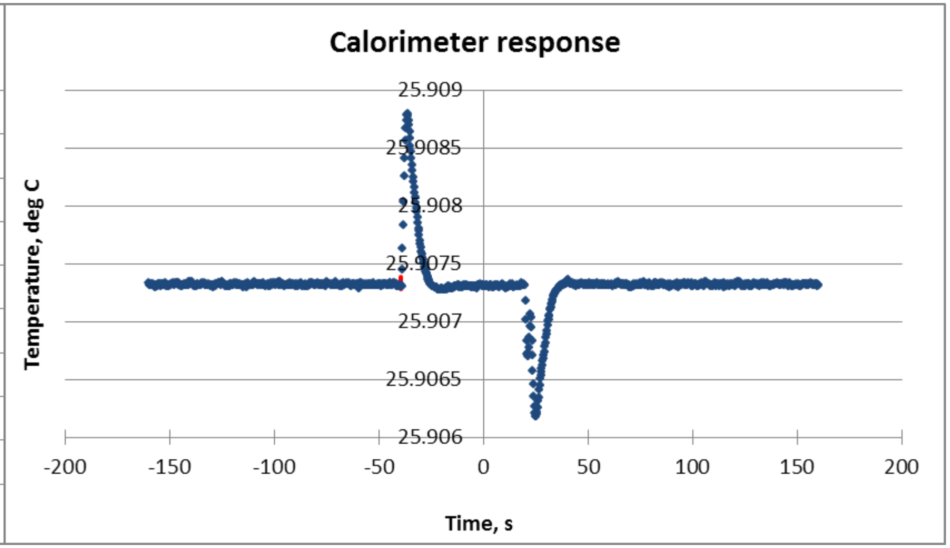
Isothermal mode of operation;

Jackets and core are maintained at constant temperature. The dose delivered to the core by irradiation, D_g, can be calculated from electrical substitution, where ΔE_{elec} is the change in electrical energy supplied to the core during irradiation and m_{core} is the mass of the core.

$$D_g = \frac{\Delta E_{\mathrm{elec}}}{m_{\mathrm{core}}}$$





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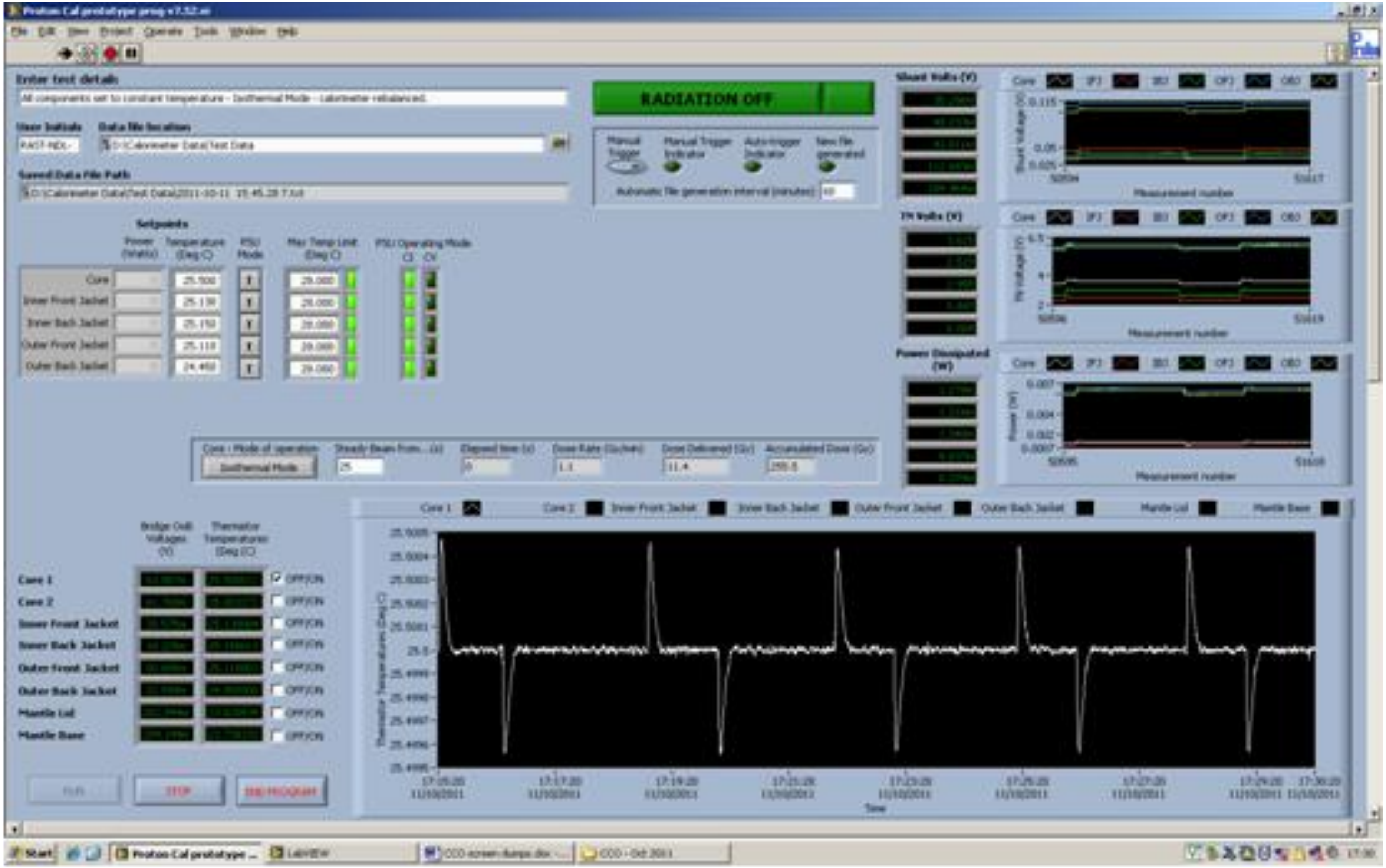
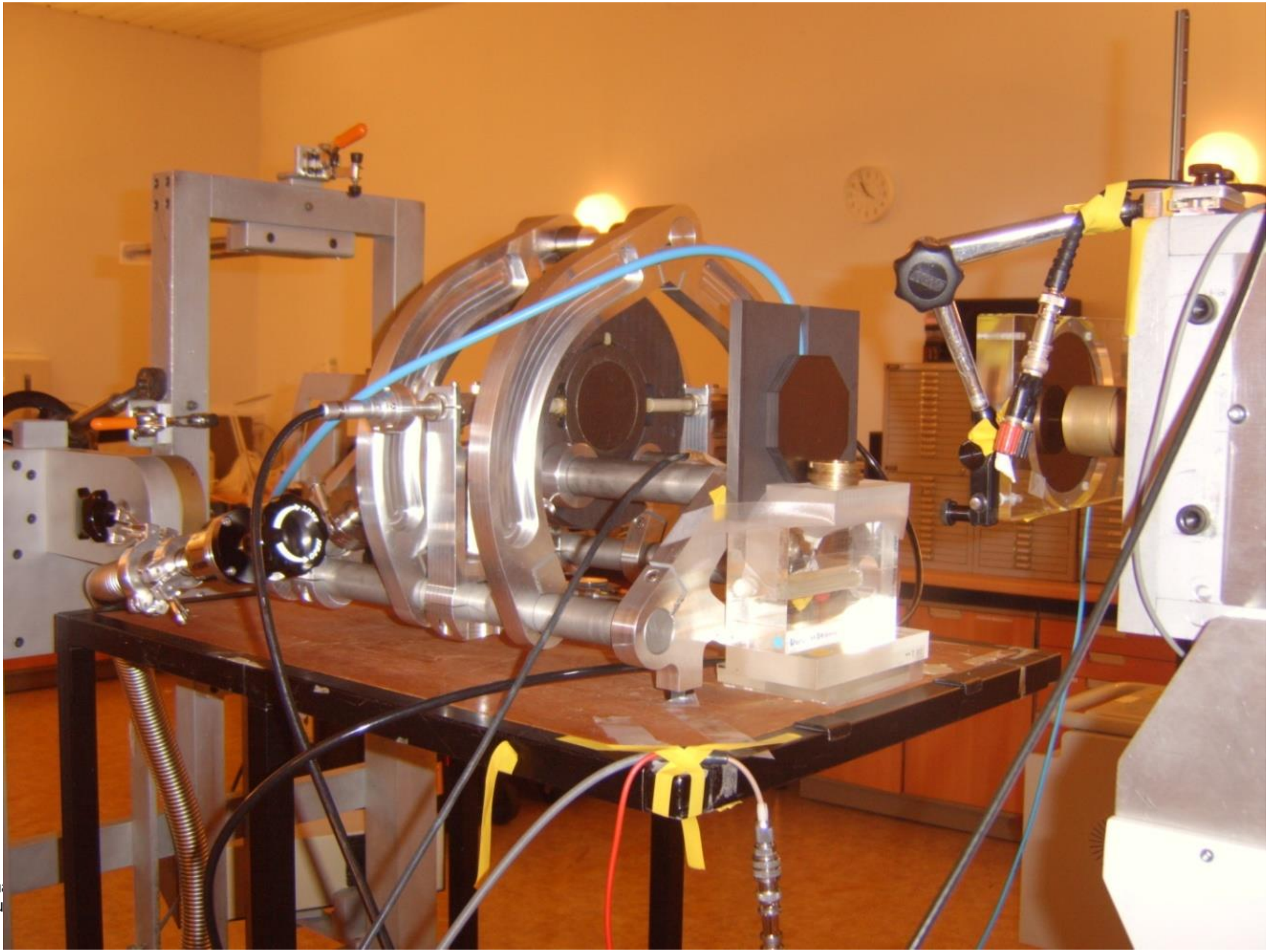
Isothermal Mode



Calorimeter / Ionisation chamber set up at CCO



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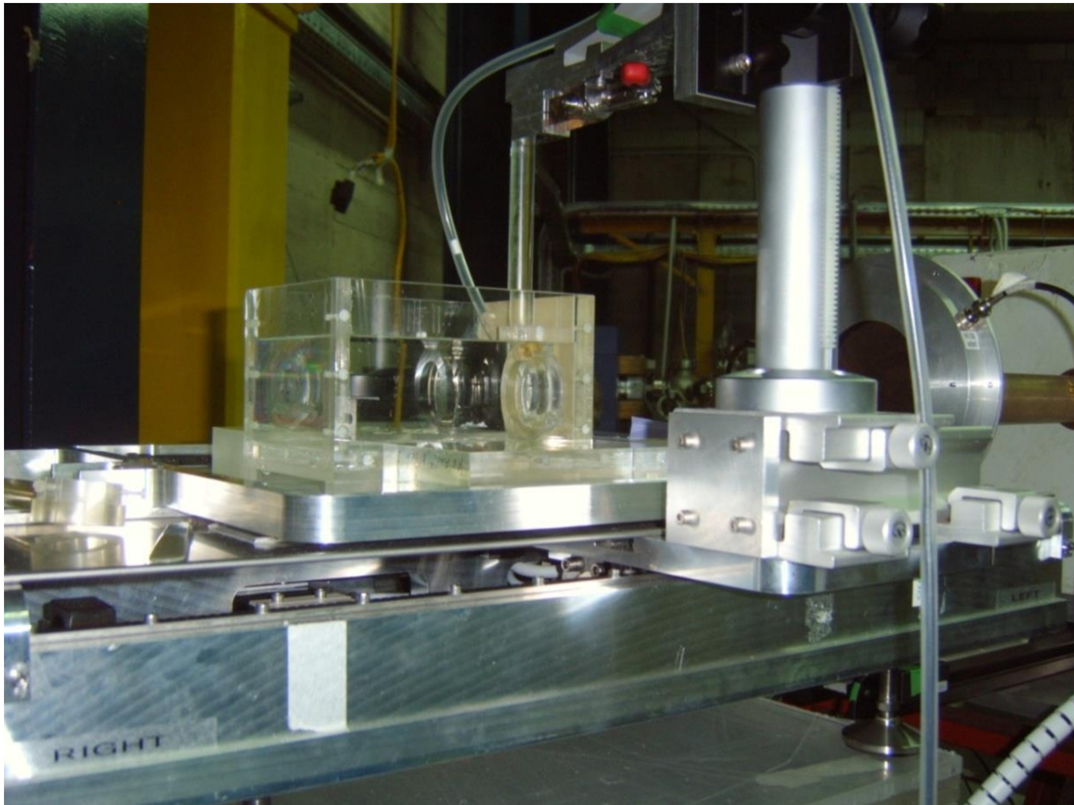

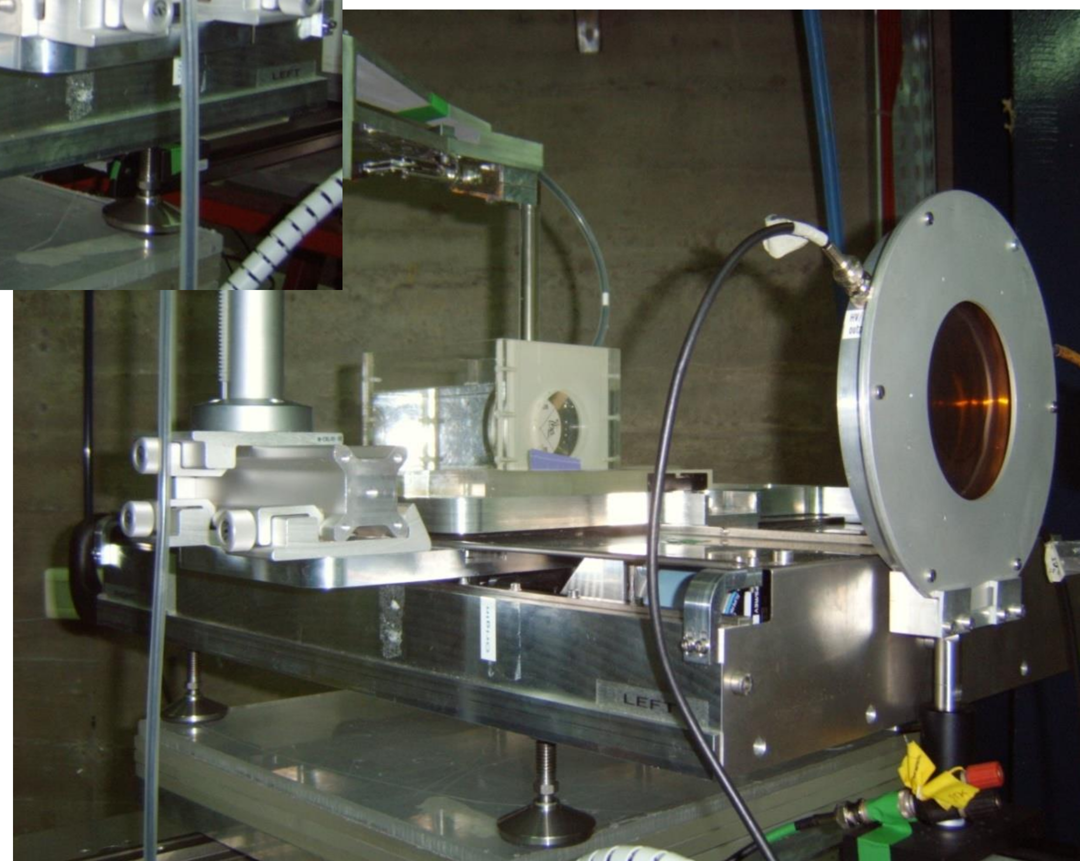

Chamber measurements in Water

Set up at LNS Catania,
for Alpha & Carbon ion beams

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"Portable" Proton Calorimeter

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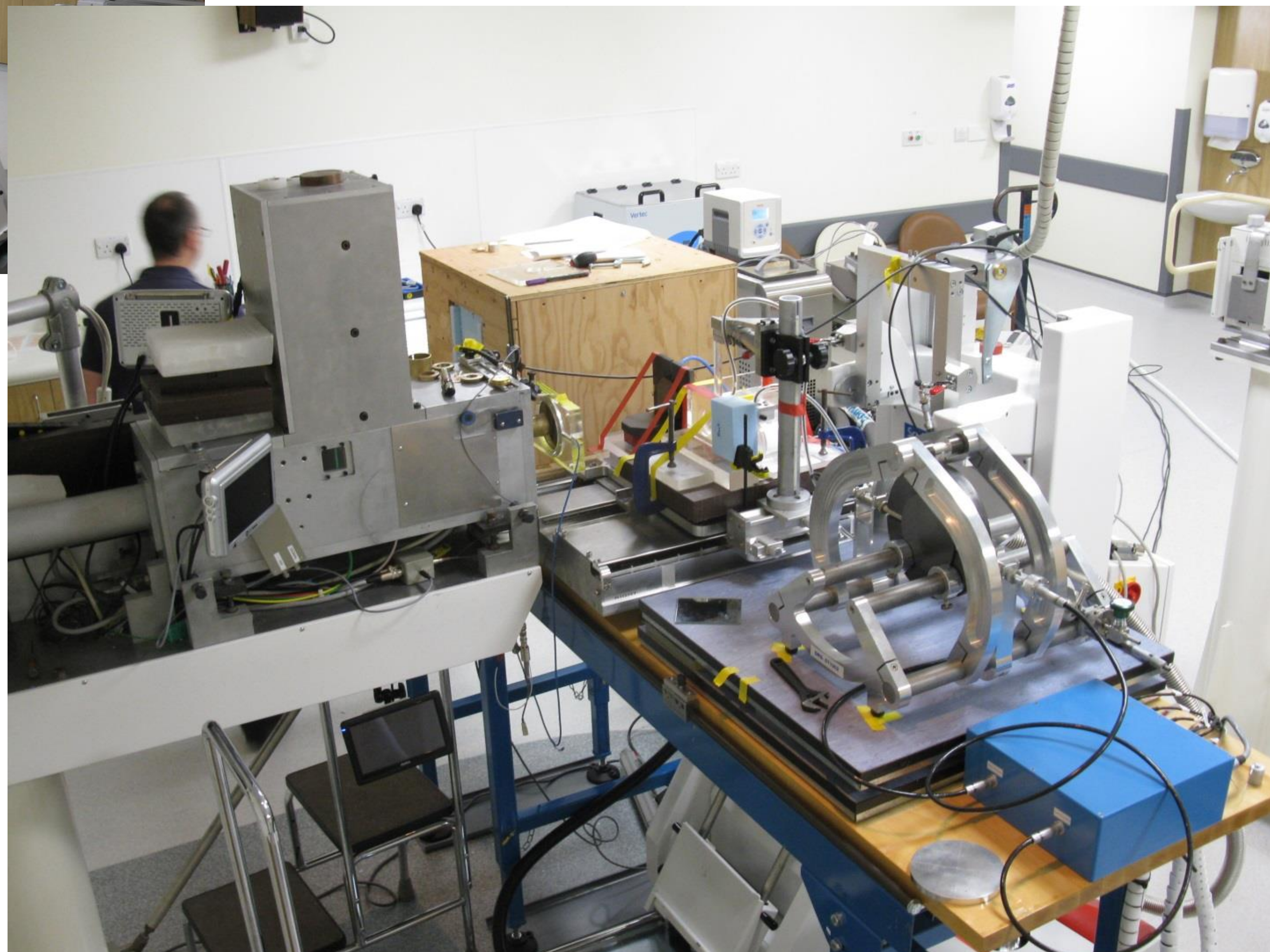

“We need to test this table will hold the weight with something we can afford to loose if it breaks……”

Summary

- Device has been successfully transported by road/sea/air to Sicily, Japan, Prague and Liverpool
- Demonstrated that a robust and portable calorimeter can be built to the level required of a primary standard and operate successfully in the clinical setting
- Initial derivation of the W value shows good agreement with previously derived data and inline with published value
- Traceability & comparability to existing UK dosimetry protocols
- Support clinical trials and biological investigation
- IPEM backing for UK proton reference dosimetry code of practice

Thank you, and over to Stuart….

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Thank You, questions?

National Measurement System

The National Measurement System delivers world-class measurement science & technology through these organisations

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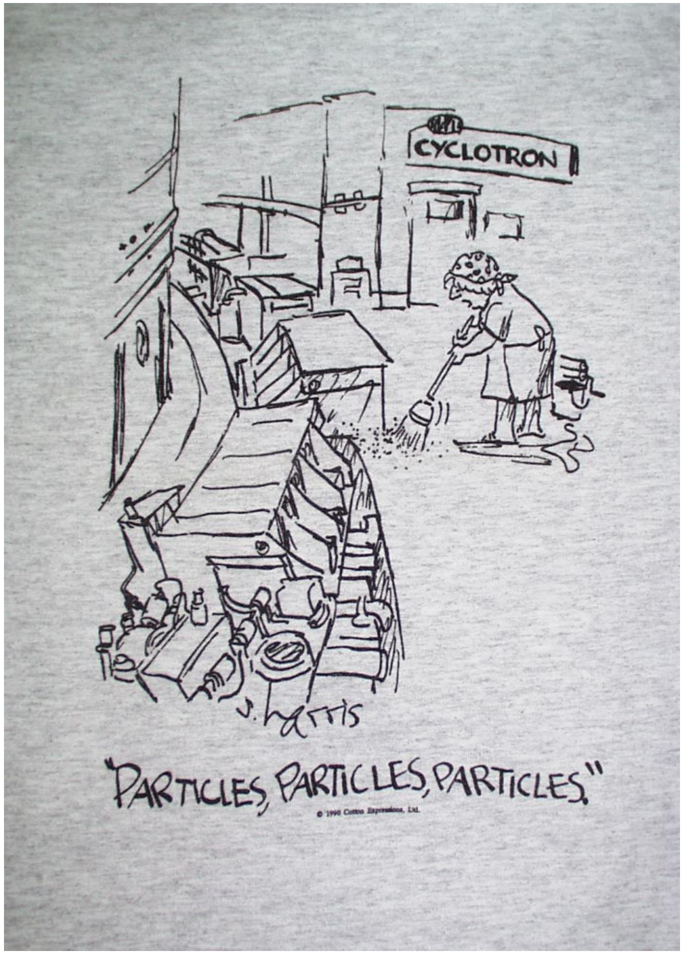
LGC Setting standards in analytical science

nel technology for life



The National Measurement System is the UK's national infrastructure of measurement Laboratories, which deliver world-class measurement science and technology through four National Measurement Institutes (NMIs): LGC, NPL the National Physical Laboratory, TUV NEL The former National Engineering Laboratory, and the National Measurement Office (NMO).

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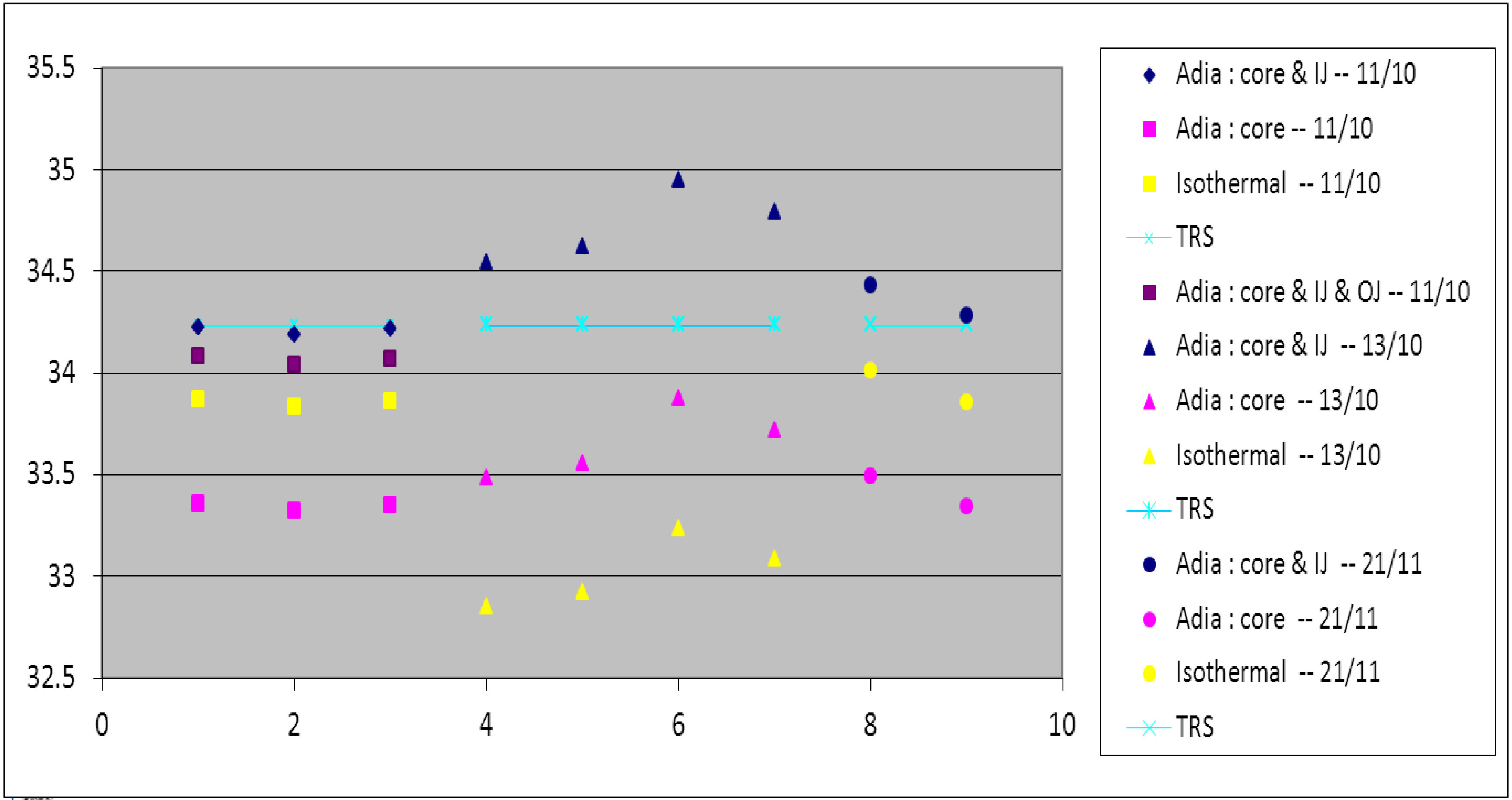
Derivation of $(w_{air})_p$ from calorimeter measurements

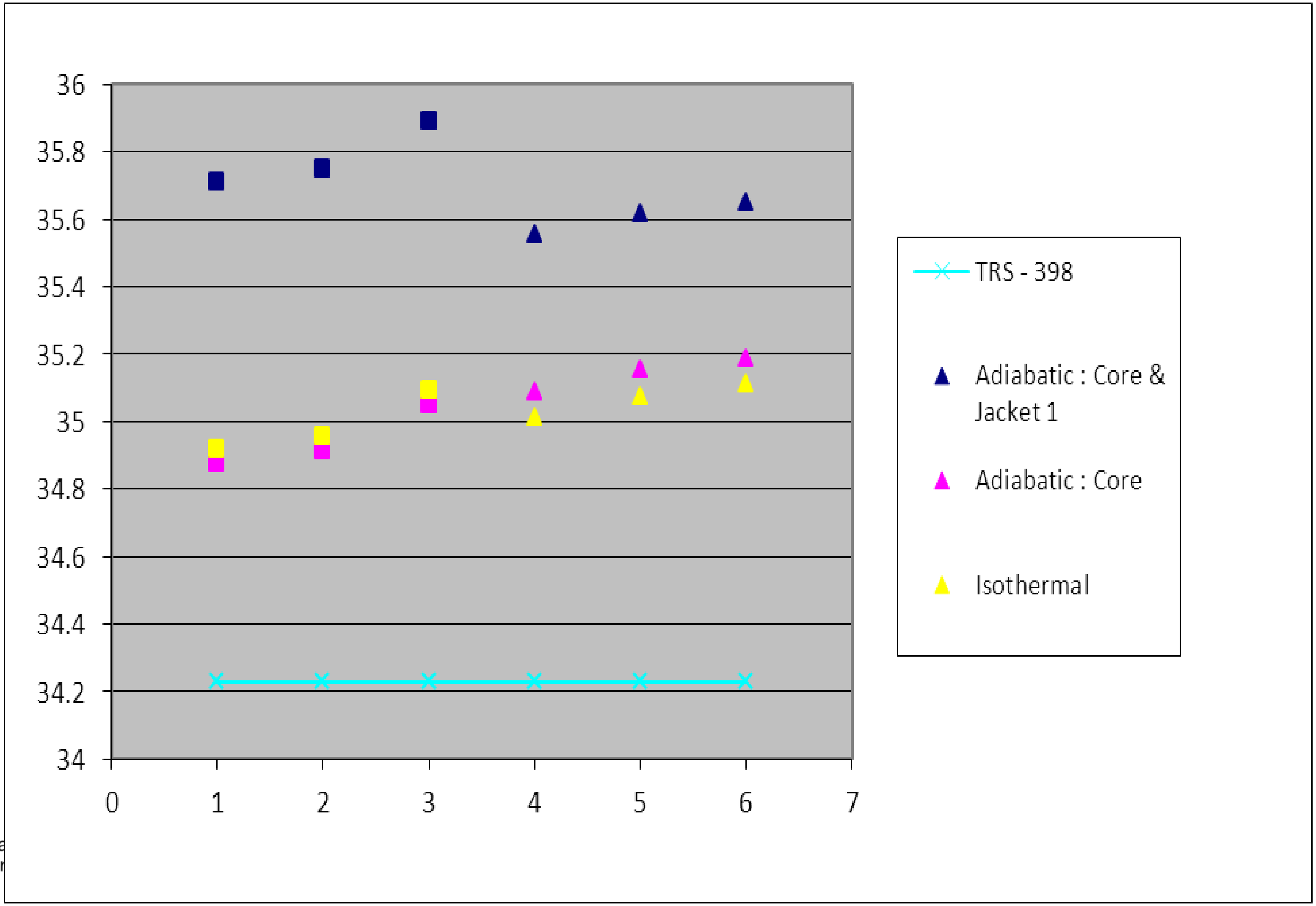
$$k_Q = \frac{N_{D,w,p}}{N_{D,w,c}} = \frac{D_{w,cal,p} / M_p}{N_{D,w,c}} \approx \frac{(w_{air})_p \cdot (s_{w,air})_p \cdot p_p}{(W_{air})_c \cdot (s_{w,air})_c \cdot p_c}$$

$$(w_{air})_p = \frac{D_{w,cal,p} \cdot (W_{air})_c \cdot (s_{w,air})_c \cdot p_c}{M_p \cdot N_{D,w,c} \cdot (s_{w,air})_p \cdot p_p}$$

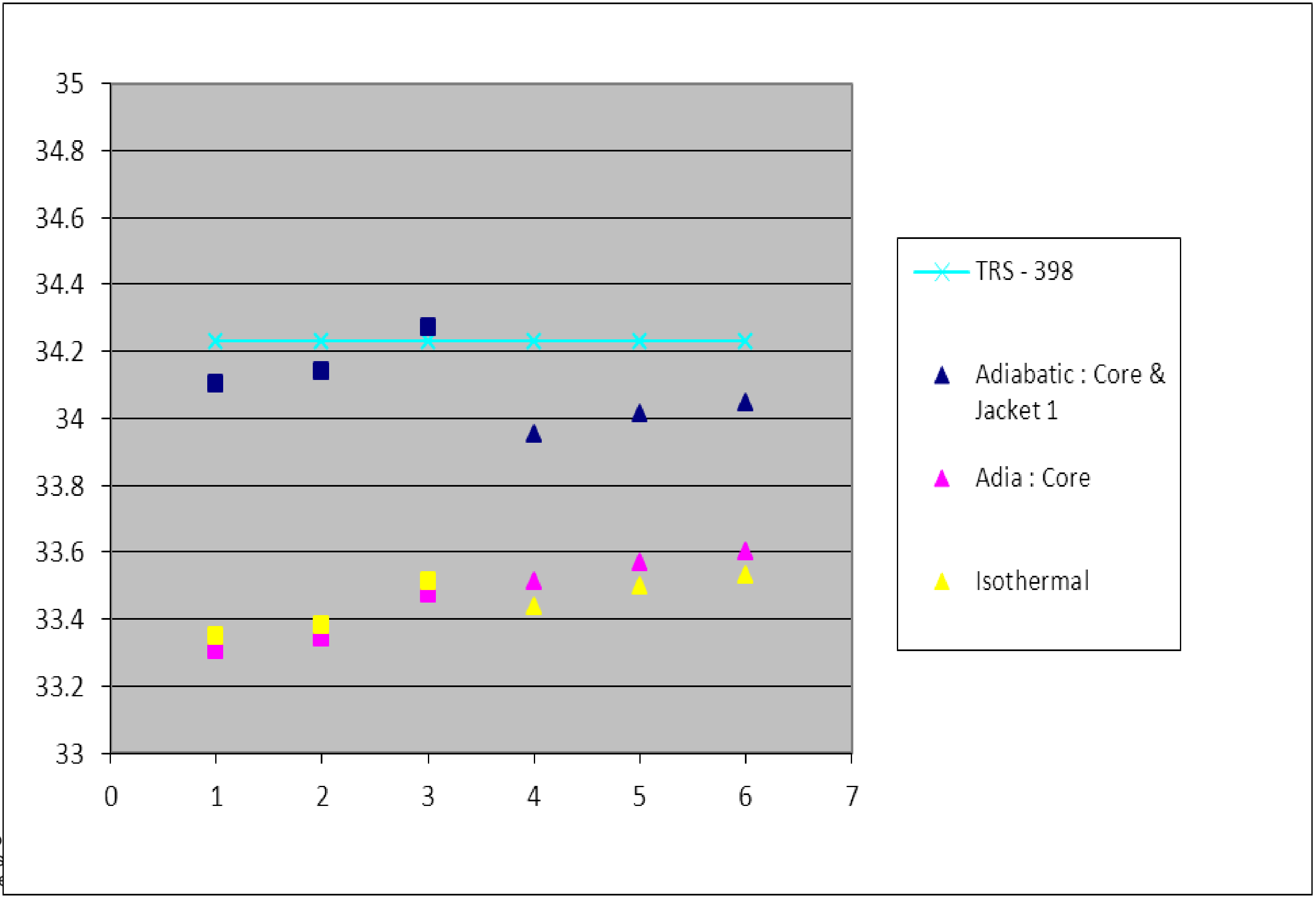
W- value calculated for measurement in modulated beam



W- value calculated for measurement in unmodulated beam



W- value calculated for measurement in modulated beam (corrected!)



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