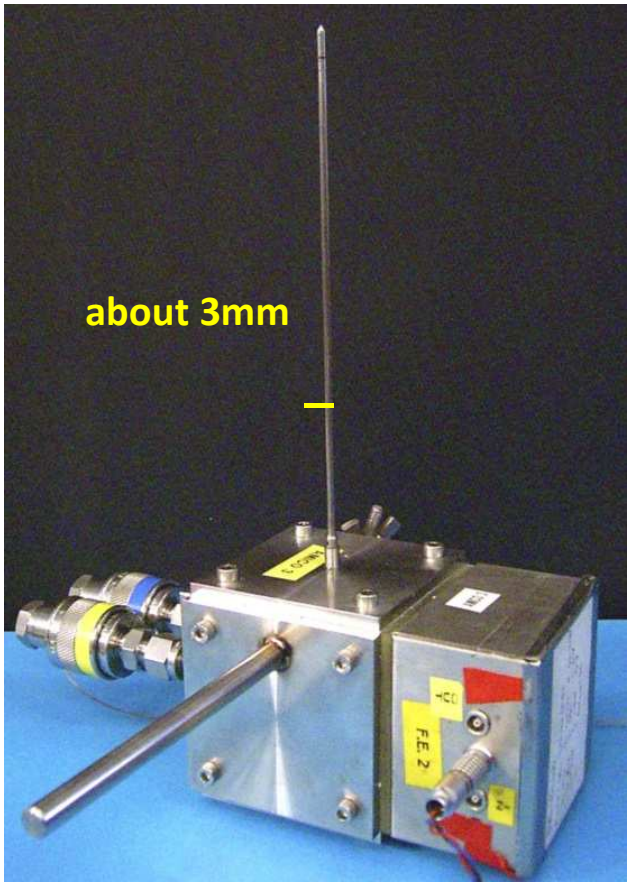
# Towards direct measurement of lineal energy in tissue-equivalent absorbers and corrections for microdosimetric gas counters and silicon detectors

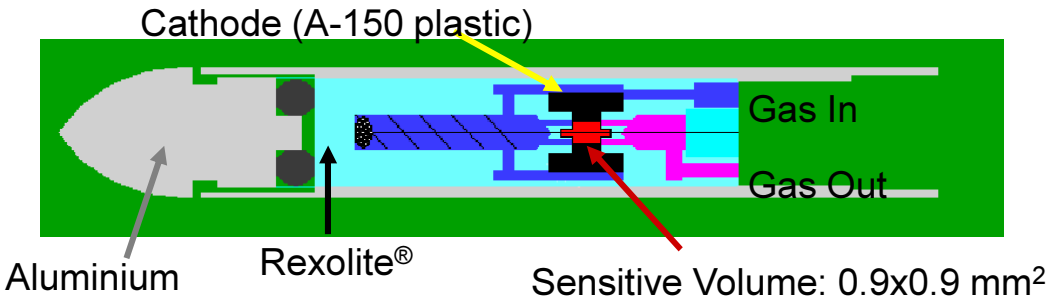
Hugo Palmans, Sebastian Galer, Davide Moro, Andrea Pola, Pedro Teles, Ana Belchior, Carmen Villagrasa, Kamran Fathi, Ling Hao, John Gallop, Andy Nisbet, Karen Kirkby

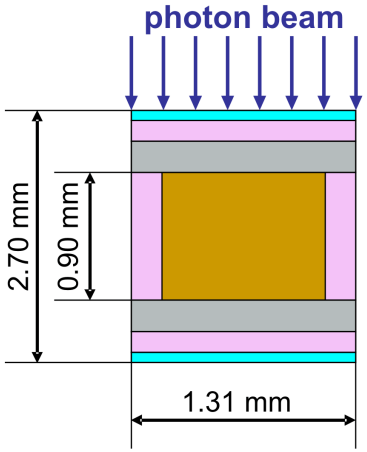
# Overview

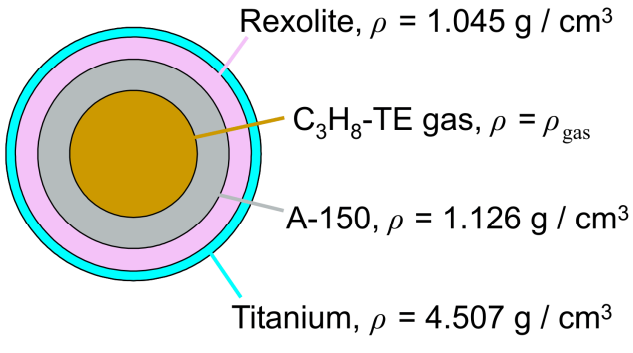
- Existing microdosimeters
  - TEPC -> mini-TEPC
  - Si-based devices -> Si-microtelescope
- New microdosimeter
  - Microcalorimeter
  - Monte Carlo simulations
  - Heat transfer simulation
- Outlook

# Mini-TEPC




Davide Moro, INFN-LNL

# Mini-TEPC example 62 MeV protons

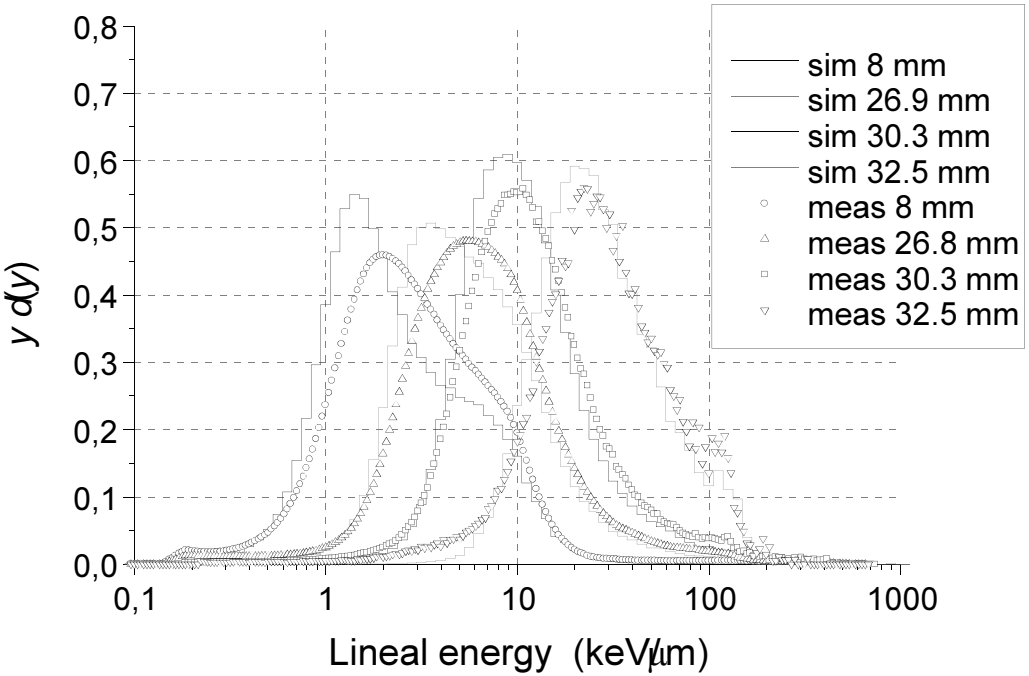



Figure 3 Simulated and measured microdosimetric spectra for the SOBP at different ocular tissue depths.

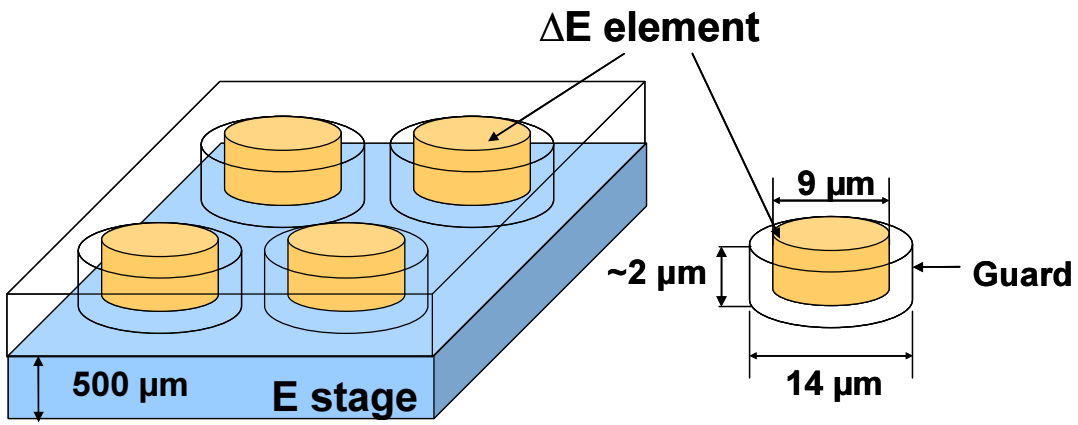
Rollet et al 2010, Rad Prot Dosim (2011) 143:445-9

# Mini-TEPC

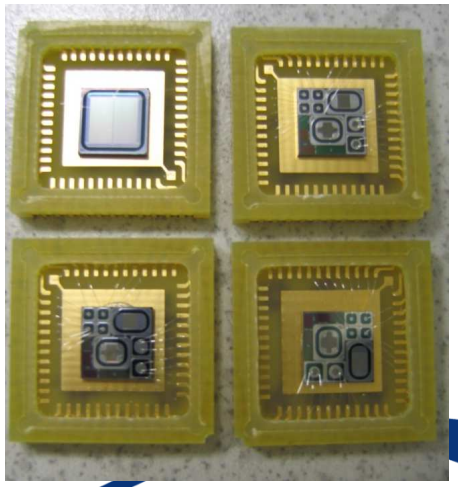
- Advantages
  - Relatively simple readout
  - In-phantom design
  - Reference device: TE, 5 orders of magnitude of lineal energy, high S/N
  - Fast counting (therapeutic dose rates)
  - Variable measurement volume
- Disadvantages
  - Cumbersome
  - Large compared to volume of interest
  - Measures ionization in TE-gas

# Si-microtelescope

Thin ΔE stage (1.9 μm) coupled to a residual energy stage E (500 μm) on the same Si- wafer. The ΔE stage is segmented in a matrix of micrometric cylinders (h= 2 μm , d= 9 μm).

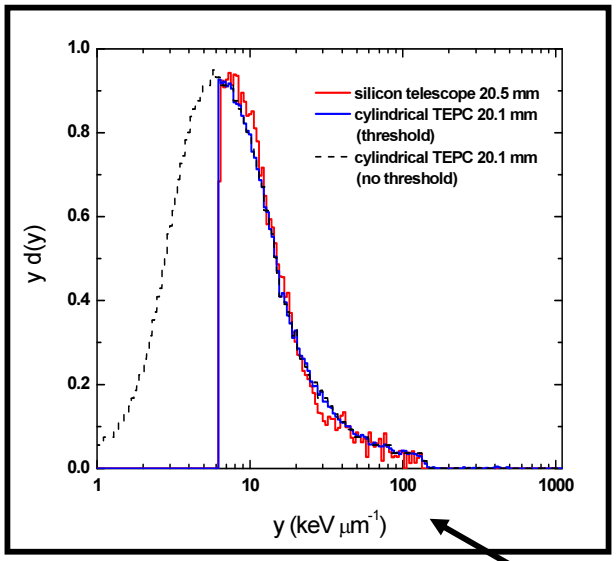


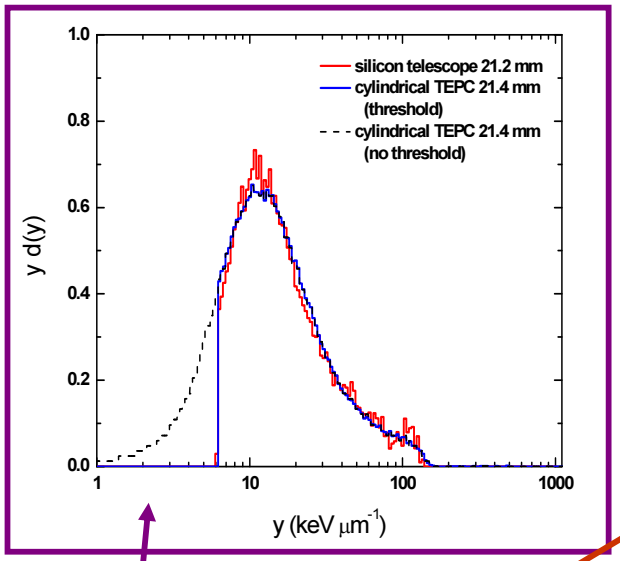

Chip dimensions: about 5x5 mm$^2$

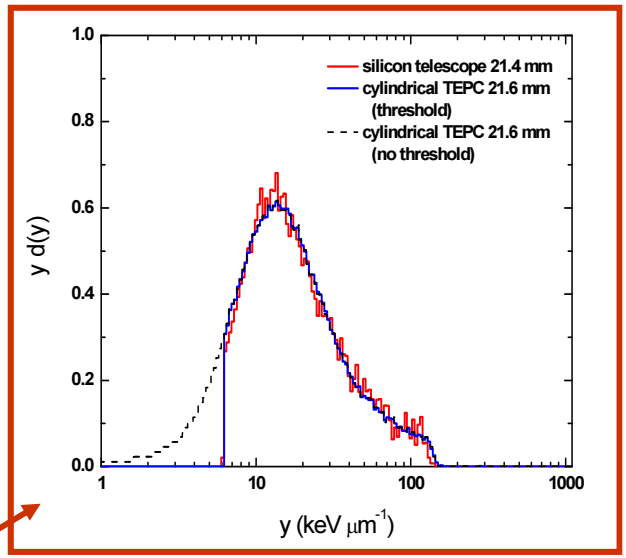


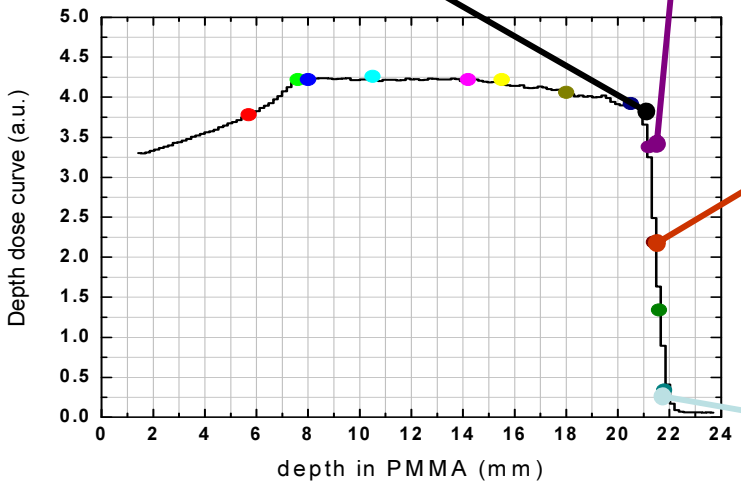
Andrea Pola, Politecnico di Milano

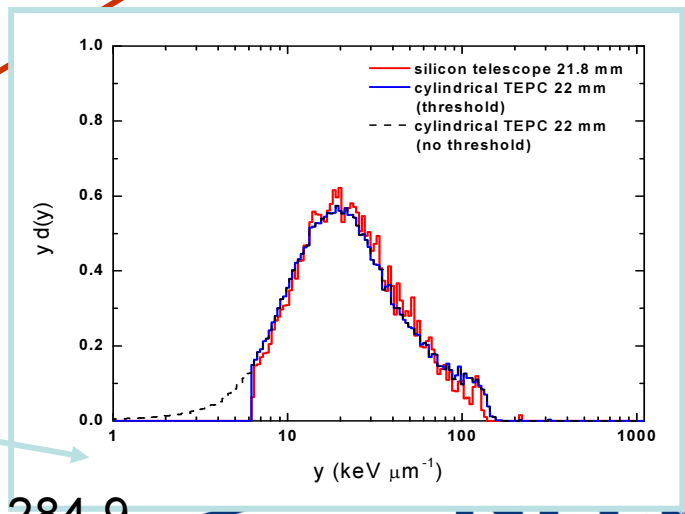
# Si-microtelescope example 62 MeV protons



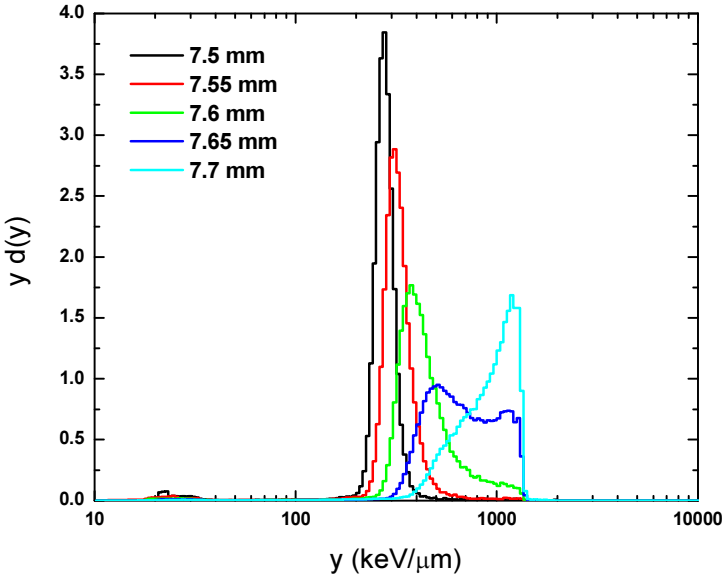



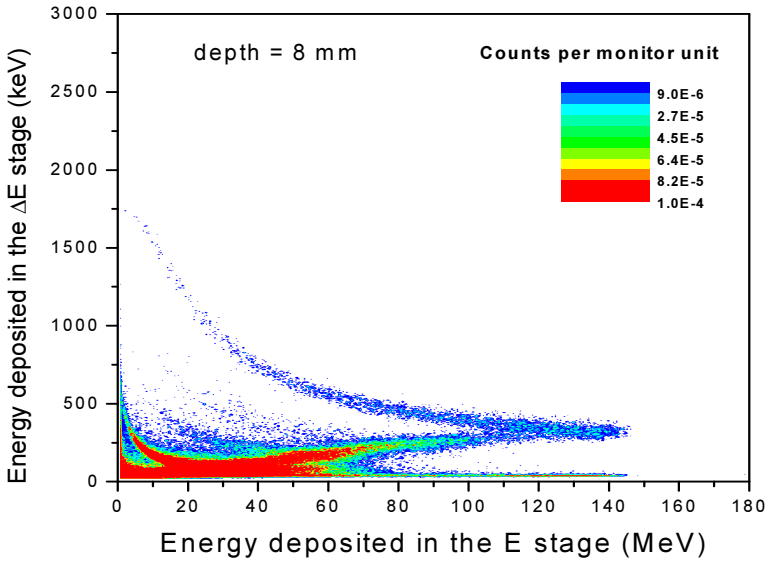




Agosteo et al 2010 Radiation Measurements 45:1284-9

# Si-microtelescope example 62 MeV/u carbon ions




Agosteo et al 2011 Radiation Measurements 46:1534-8

# Si-microtelescope

- Advantages
  - Easy readout
  - Fast counting
  - Differential and integral E in one measurement
    -> event-by-event TE correction
  - Size comparable to volume of interest

- Disadvantages
  - Energy treshold (1 kev/micron)
  - Fixed volume
  - Measures ionization in silicon

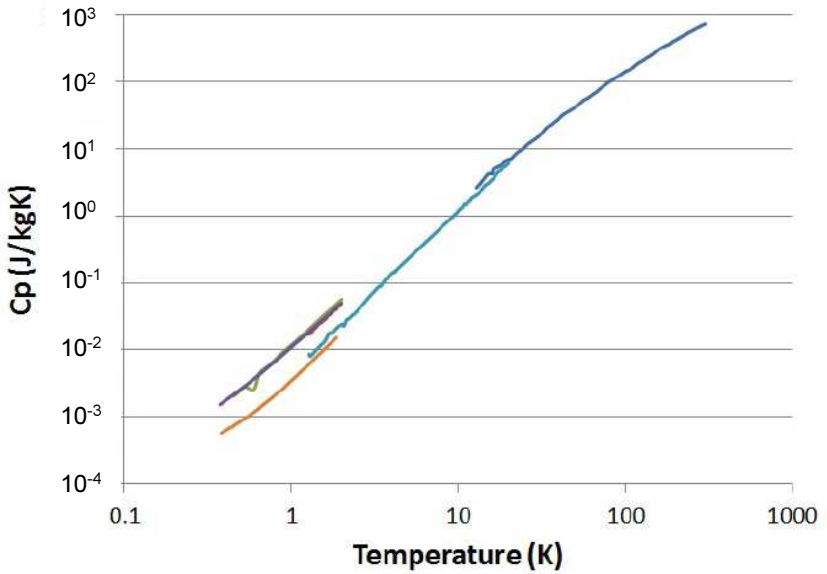
# Calorimetry

- Advantages
  - Measures energy deposition, potentially in liquid water
- Disadvantages
  - Insensitive technique
  - Impurity corrections due to temperature probes limit size

# Microcalorimetry

- Tries to overcome disadvantages by
  - Working at cryogenic temperatures
  - Using non-contacting thermometry methods

Sebastian Galer PhD:




Hao et al 2003 IEEE TAS 13:622-5:

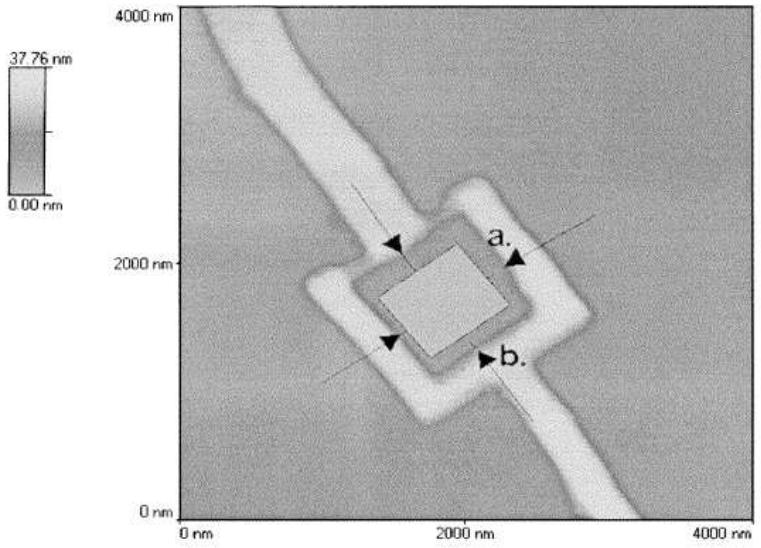
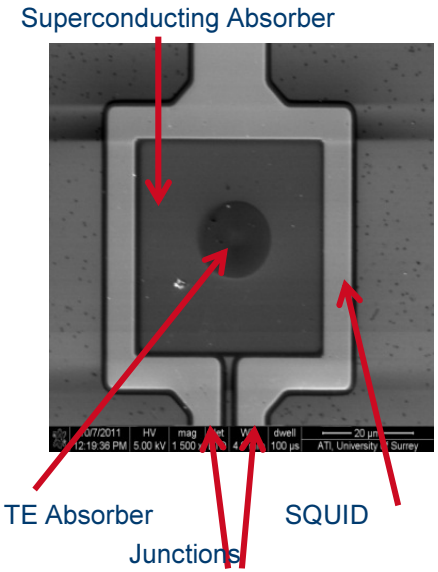
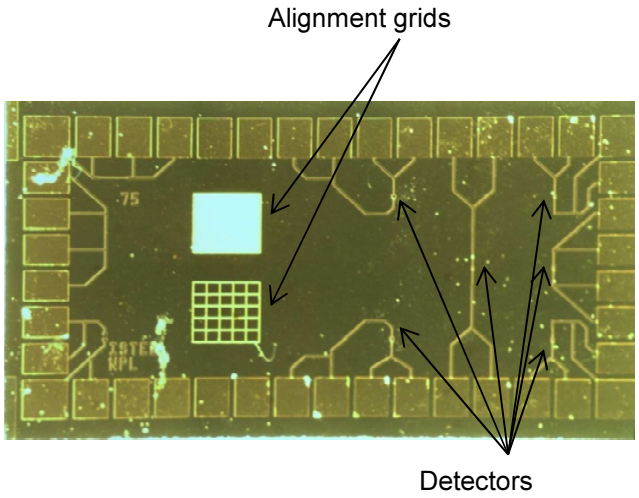


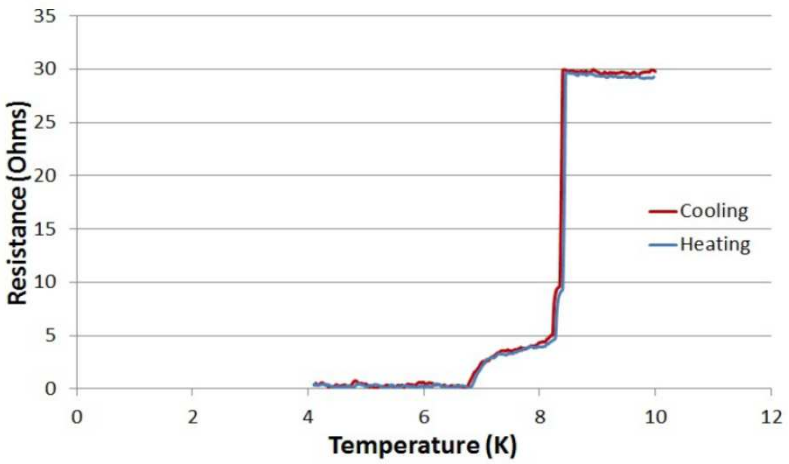

Fig. 1. AFM image of a submicron SQUID loop with schematic indication of a rectangular submicron thin-film absorber deposited in the center (the SQUID

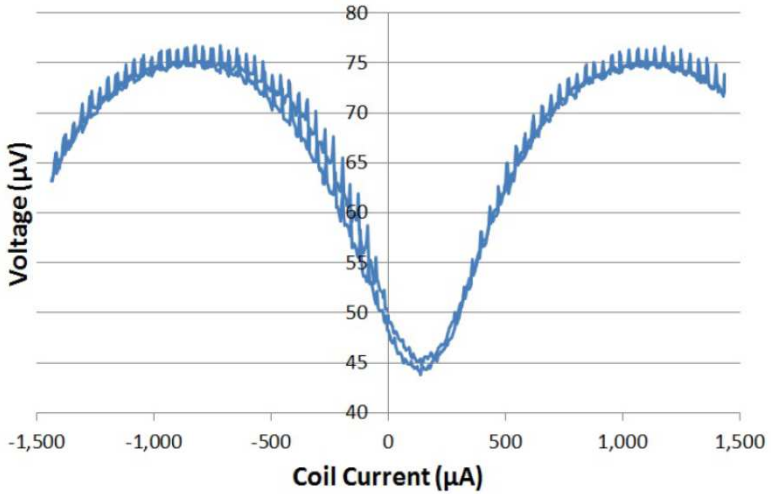
# Progress production/testing microcalorimeters

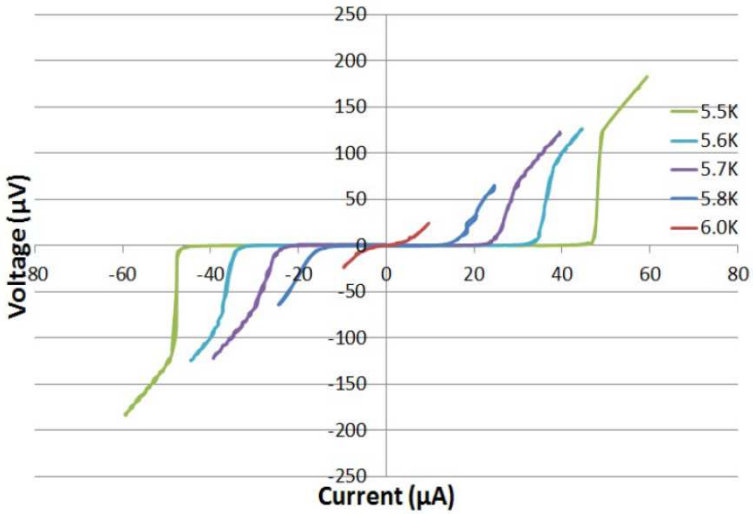


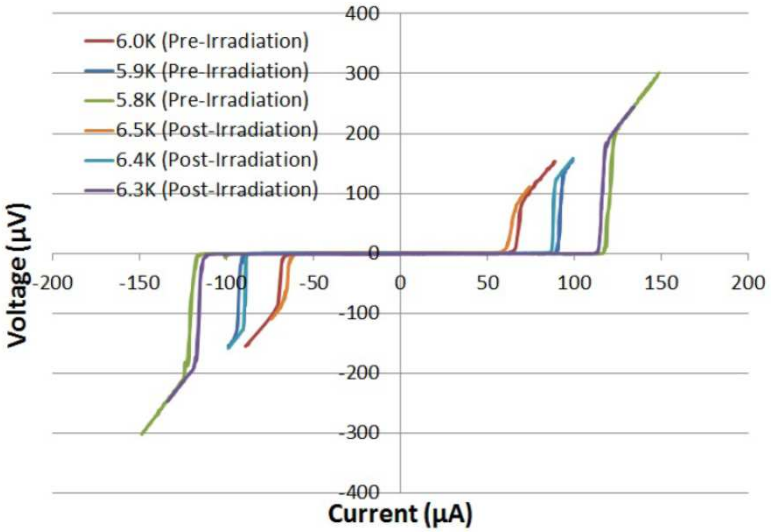




# Progress production/testing microcalorimeters

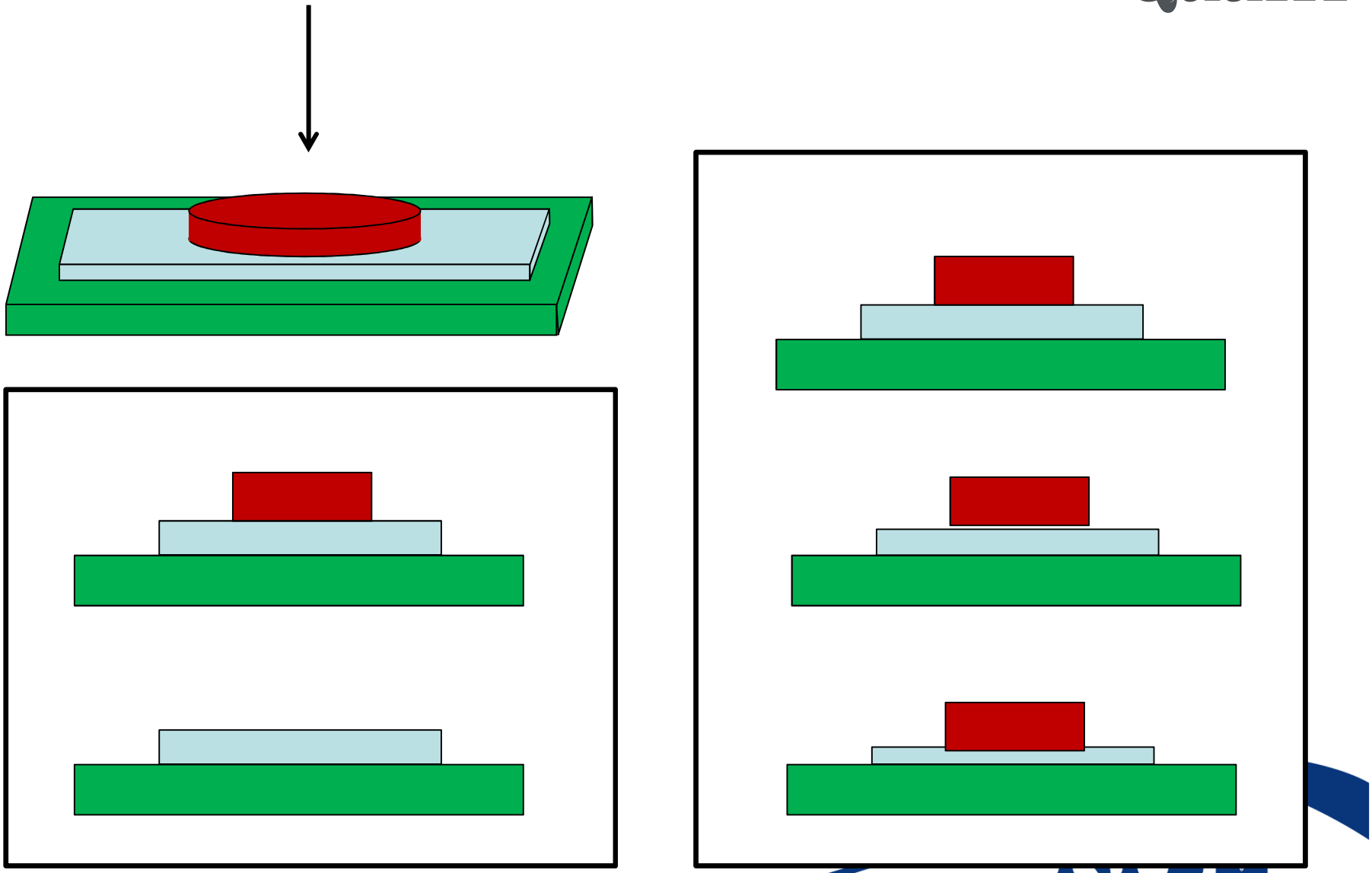


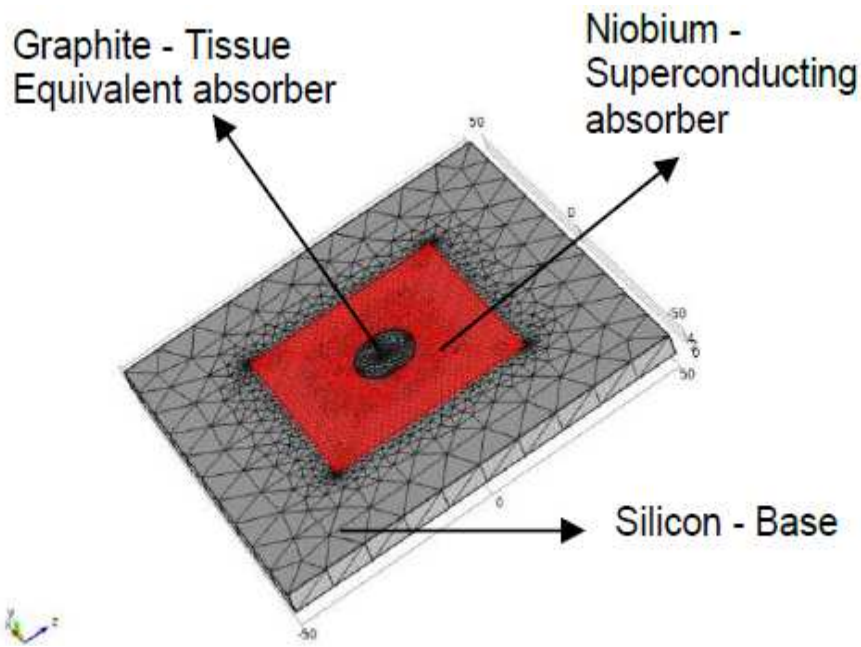



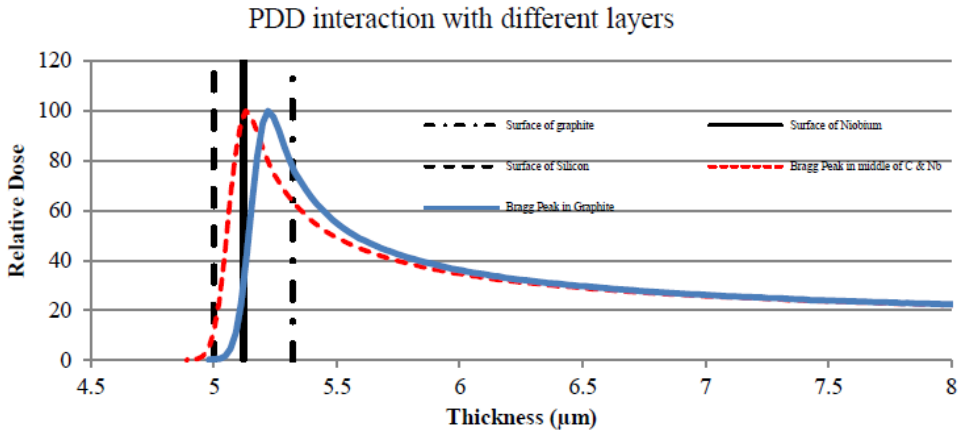



# Correction for Nb absorption – two strategies



# Thermal modelling microcalorimeters / Comsol



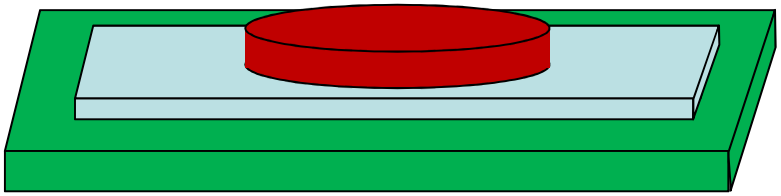



# Thermal modelling microcalorimeters

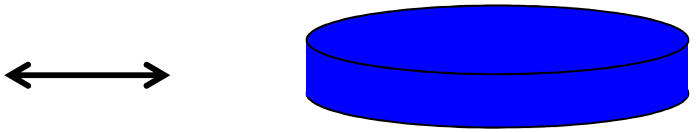
# Unpublished data

# Monte Carlo simulation

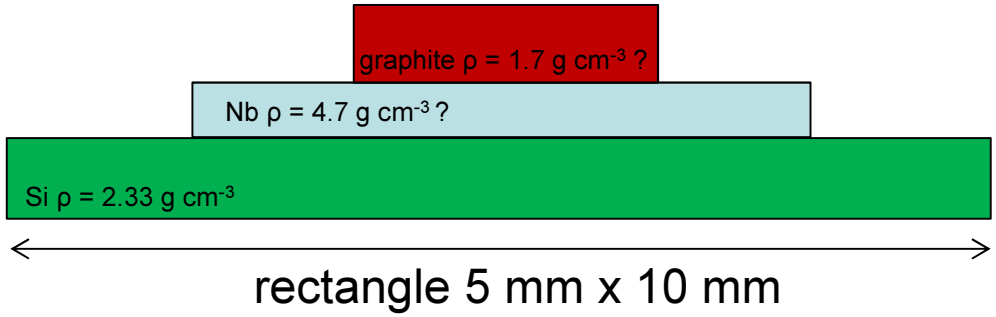
p, He, Li or
C ion



Geant4, FLUKA,
MCNPX



Geant4/DNA




rectangle 5 mm x 10 mm

# MC benchmark

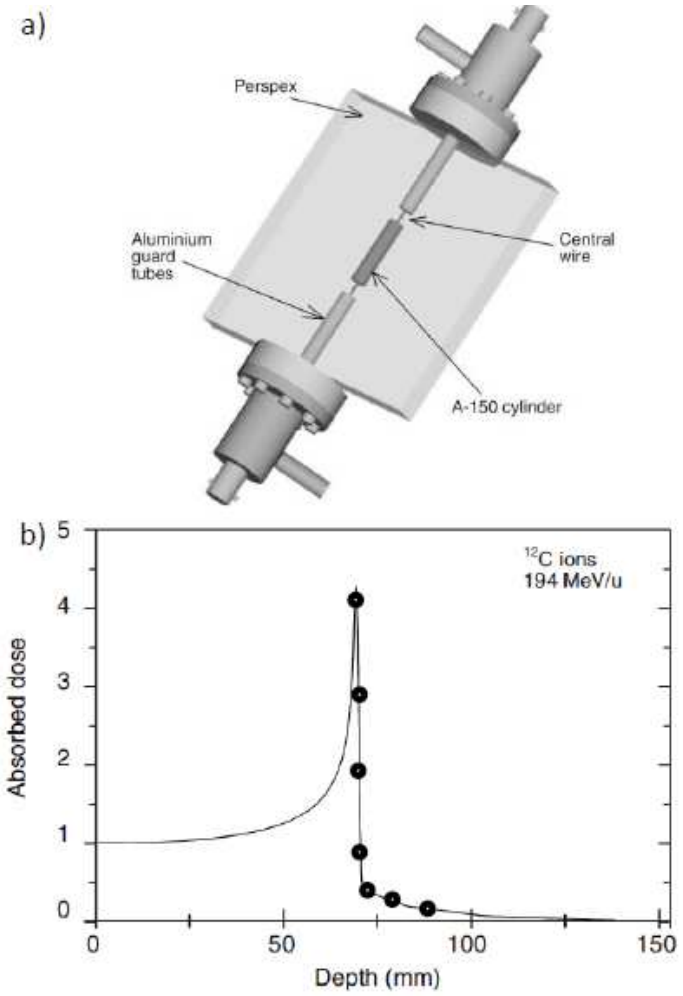



Figure 3 – a) TEPC detector, b) Depth dose profile for the 194 MeV/u $C^{12}$ beam (Gerlach[10])

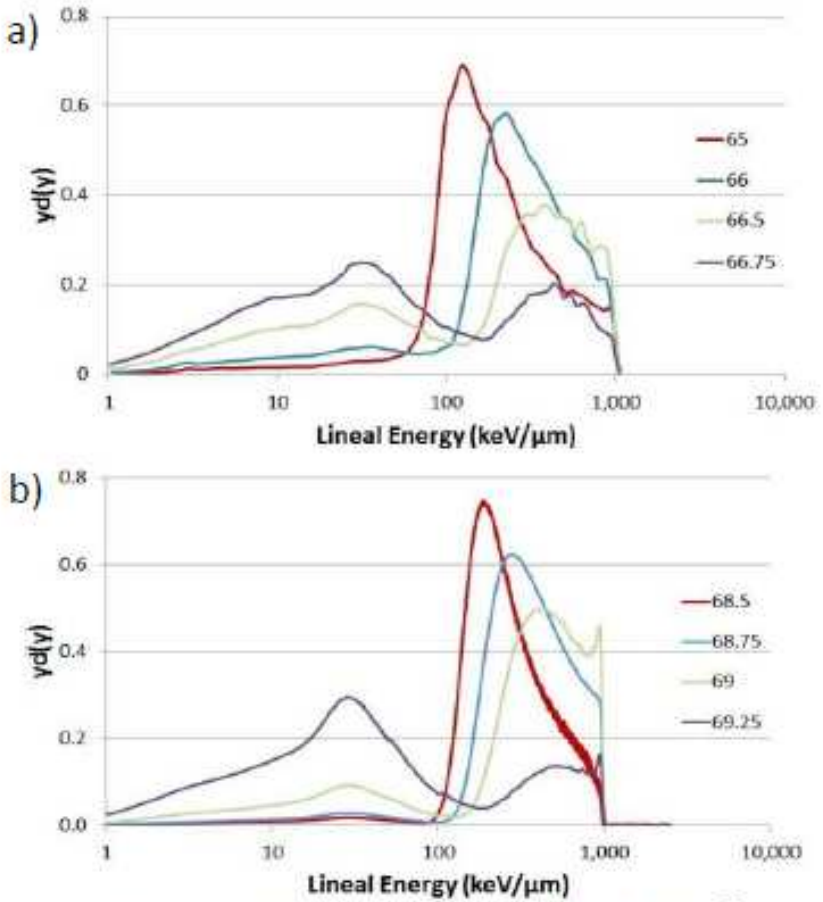
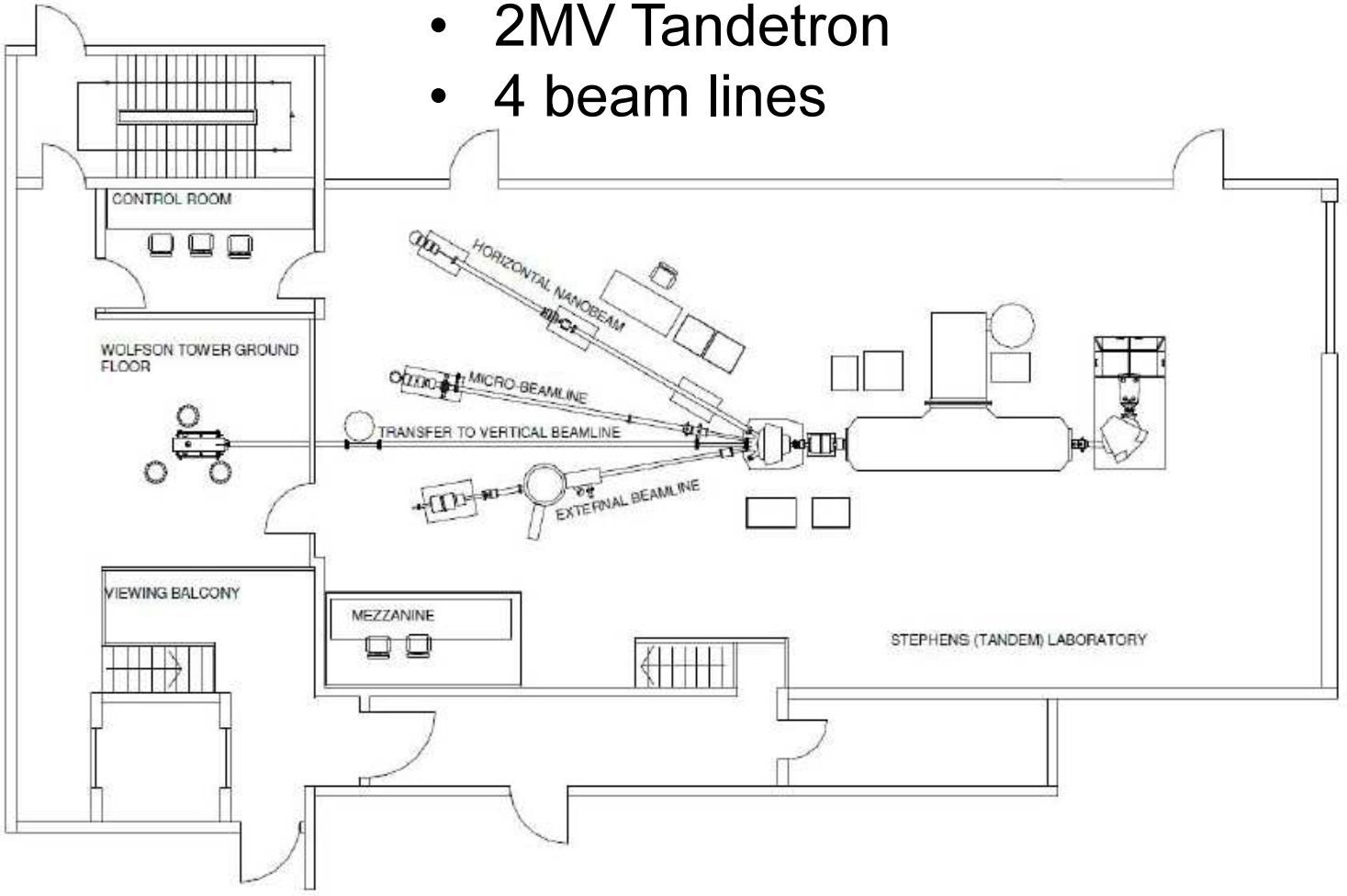



Figure 4 – Microdosimetric spectra of a 194 MeV/u $C^{12}$ beam in Perspex at depths around the Bragg peak, a) experimental [10], b) Monte Carlo

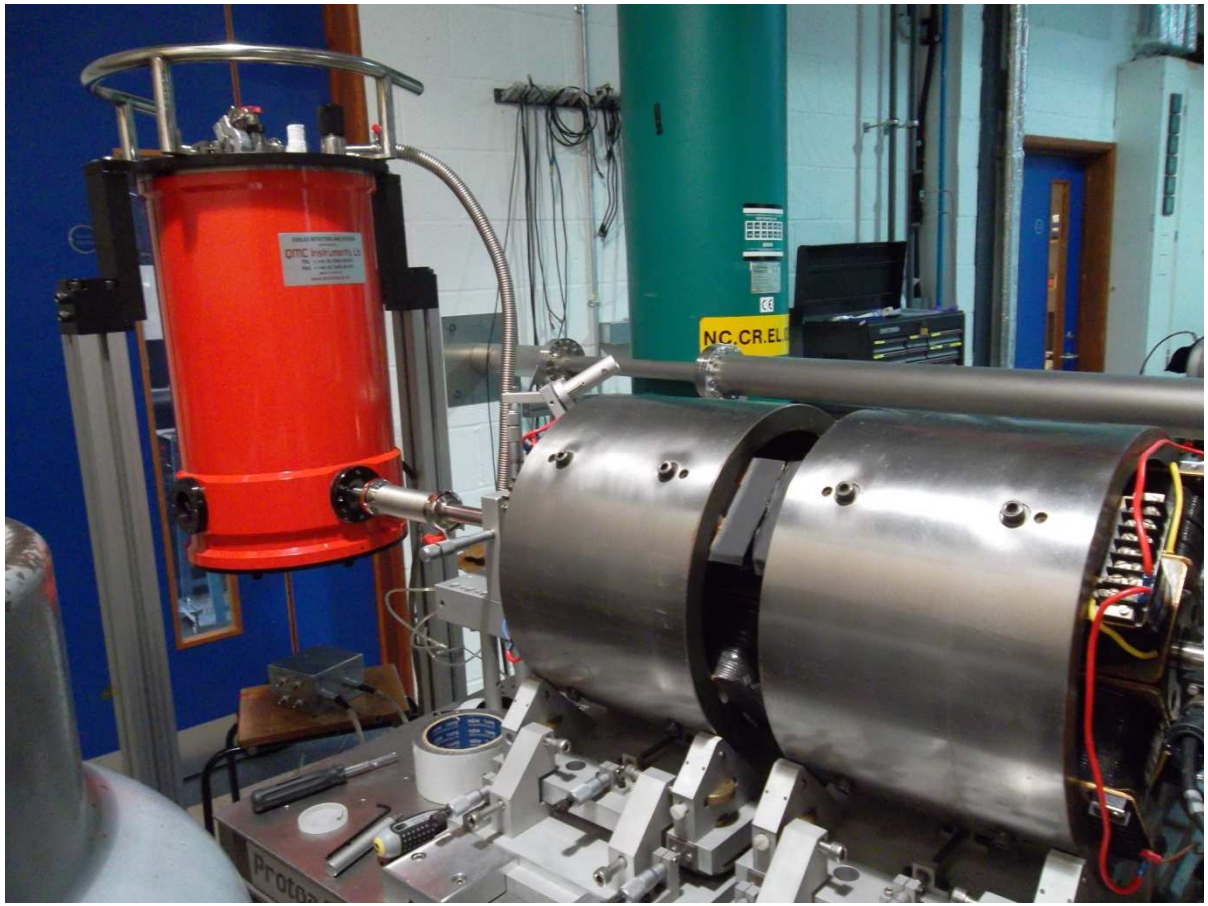
Rad. Prot. Dosim., 99:413-8

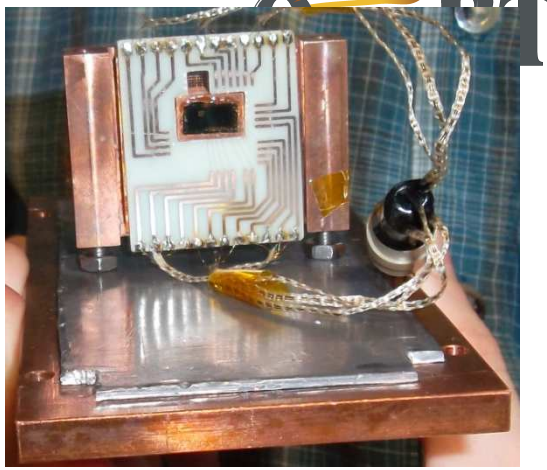
# Planned comparison of microcalorimeter and Si-microtelescope at IBC Surrey

- 2MV Tandetron
- 4 beam lines

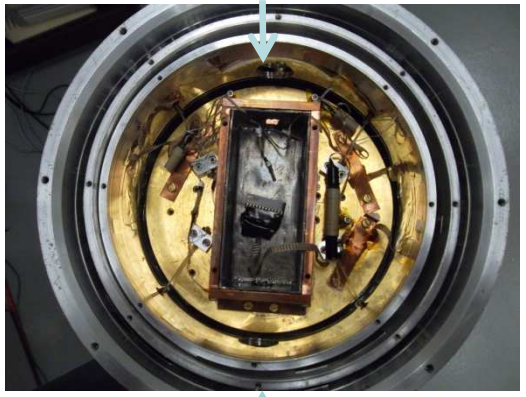


# Experimental set-up IBC/Surrey





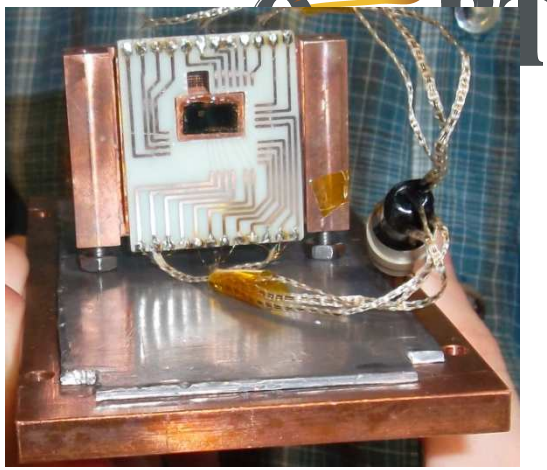
Beam



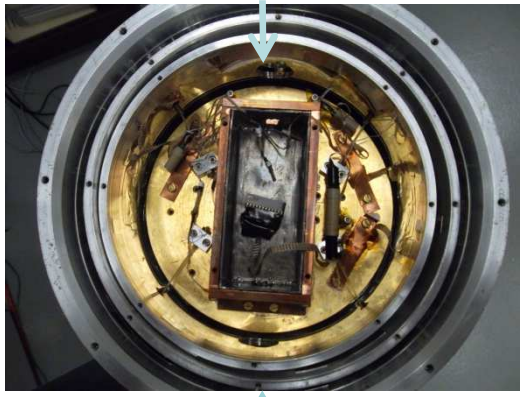
Diode

NPL
National Physical Laboratory

# Experimental set-up IBC/Surrey

Beam



Diode

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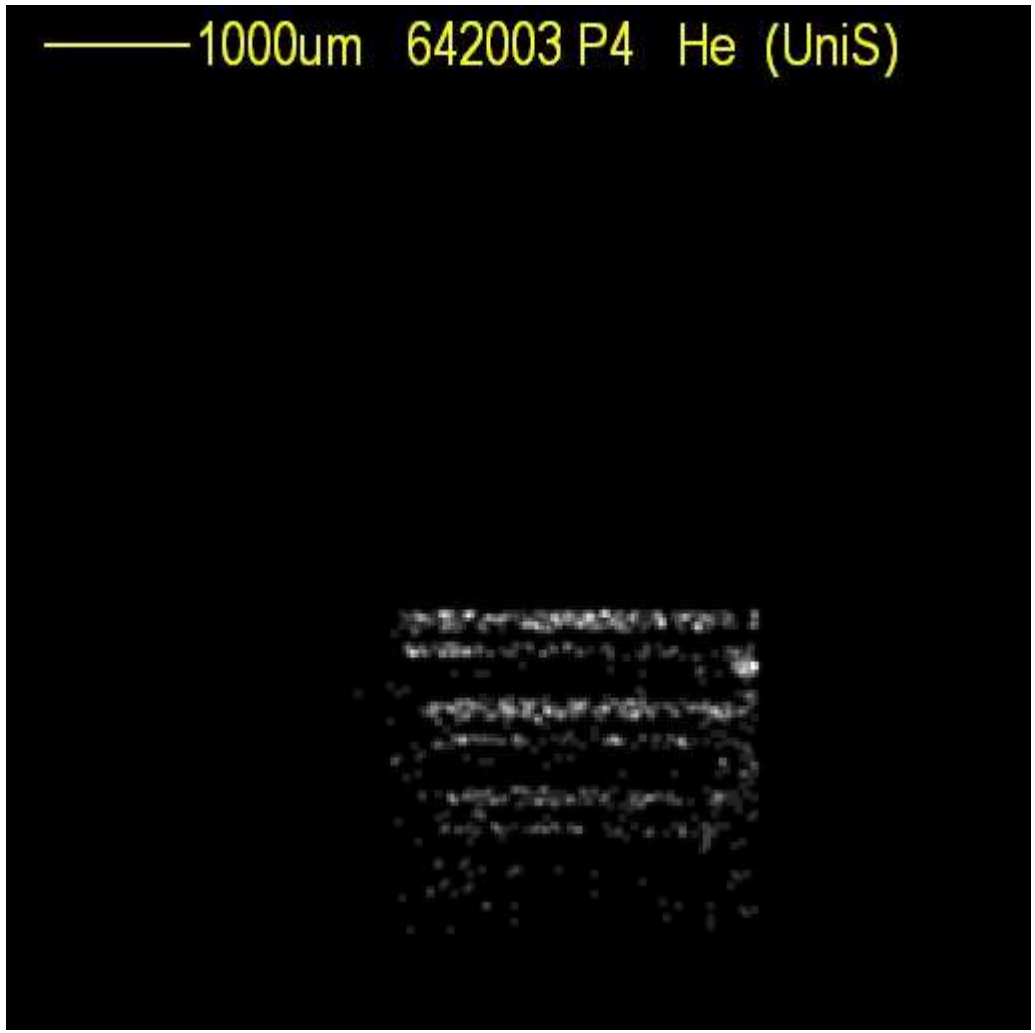


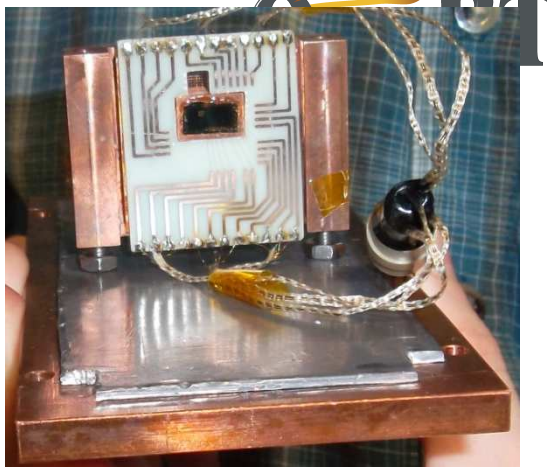

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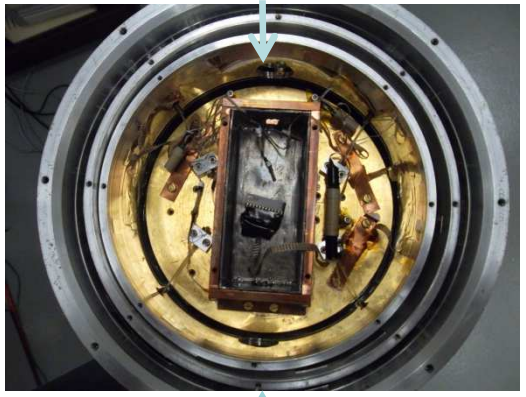

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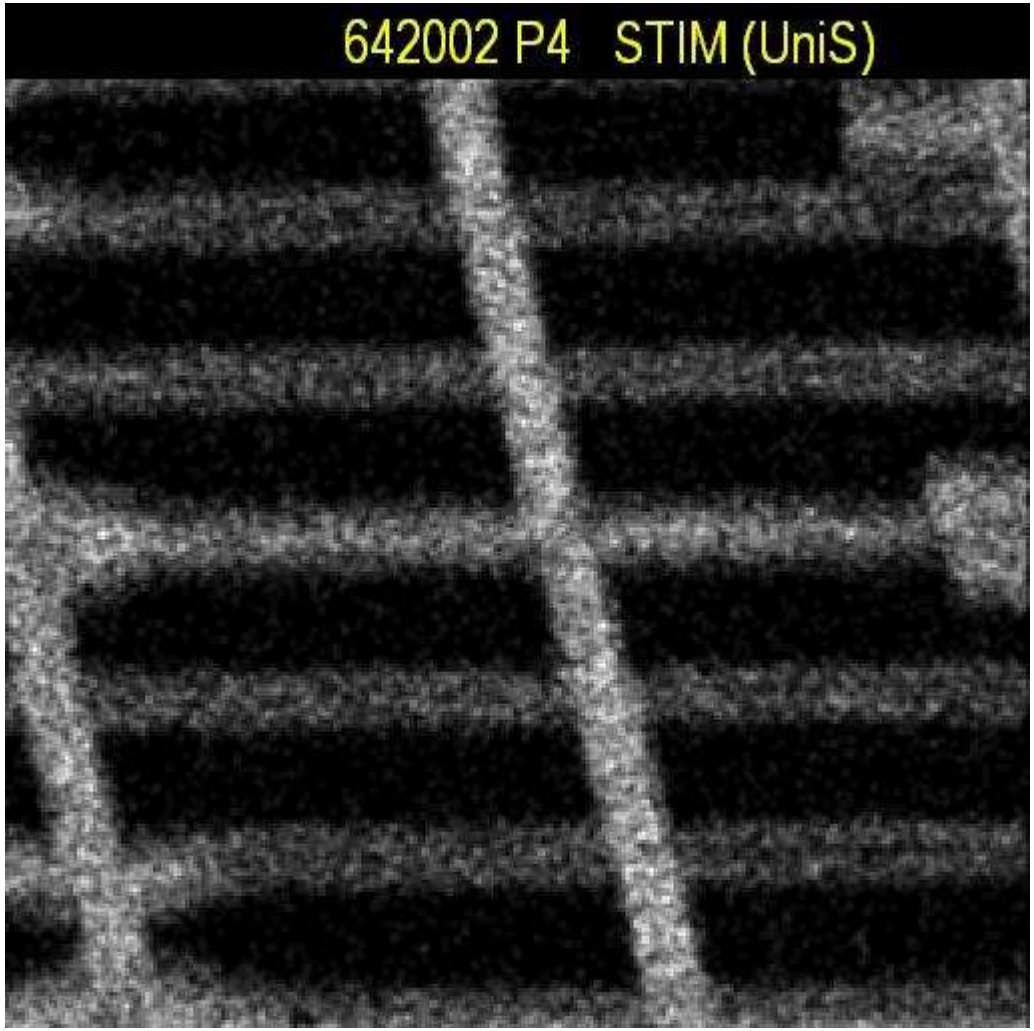


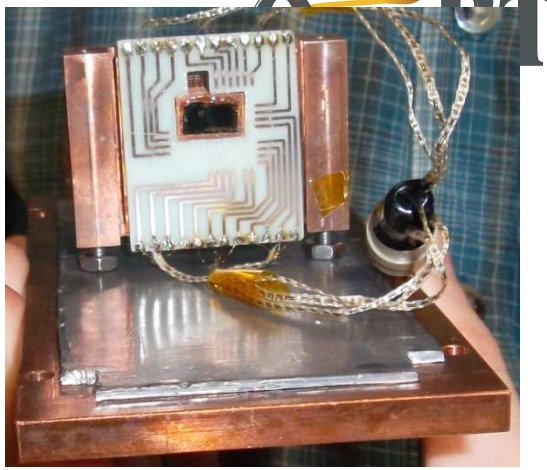

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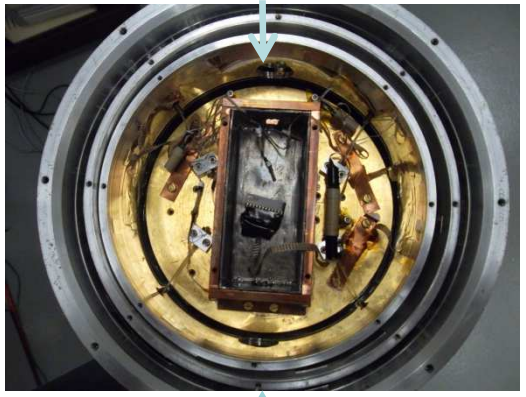
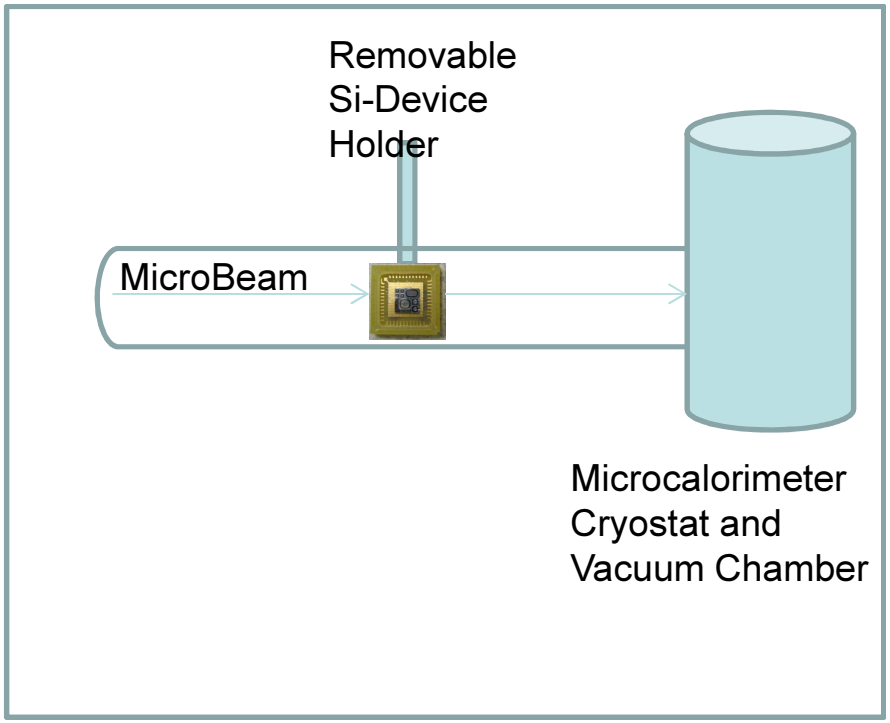


Diode

# Si-microtelescopes at IBC

- External micro beam line chamber arm
- Focussing by different set of coils
- Use of existing co-axial connector feed-throughs (requires modifications to detectors)



# Planned comparison of mini-TEPC, microcalorimeter and Si-microtelescope at INFN-LNS

- WP1-BioQuaRT proposal INFN-LNS submitted / comparison of mini-TEPC, Si-microtelescope and microcalorimeter in:
  - Modulated (ridge filter) and unmodulated 62 MeV/u $^{12}C$-beam
  - Unmmodulated 80 MeV/u $^{12}C$-beam
  - (also RBE/ PC3 and Caco2, clonogenic survival, microarray analyis: γ-H2AX, adhesion and invasion assays: Boyden chamber )

# Conclusions

- Current state-of-the-art micro-dosimeters such as mini-TEPC and Si-microscope measure ionization and are not water-equivalent
- Microcalorimeters are feasible and can potentially measure energy deposition directly in water in condensed phase
- Prototype microcalorimeters have been built
- Monte Carlo radiation transport simulations are needed to correct for non-TE part of absorber
- Heat transfer simulations are needed to correct for heat losses to silicon substrate
- Comparisons will be performed