Numerical and Experimental Feasibility Study of HDR ^{192}Ir Brachytherapy Water Calorimetry

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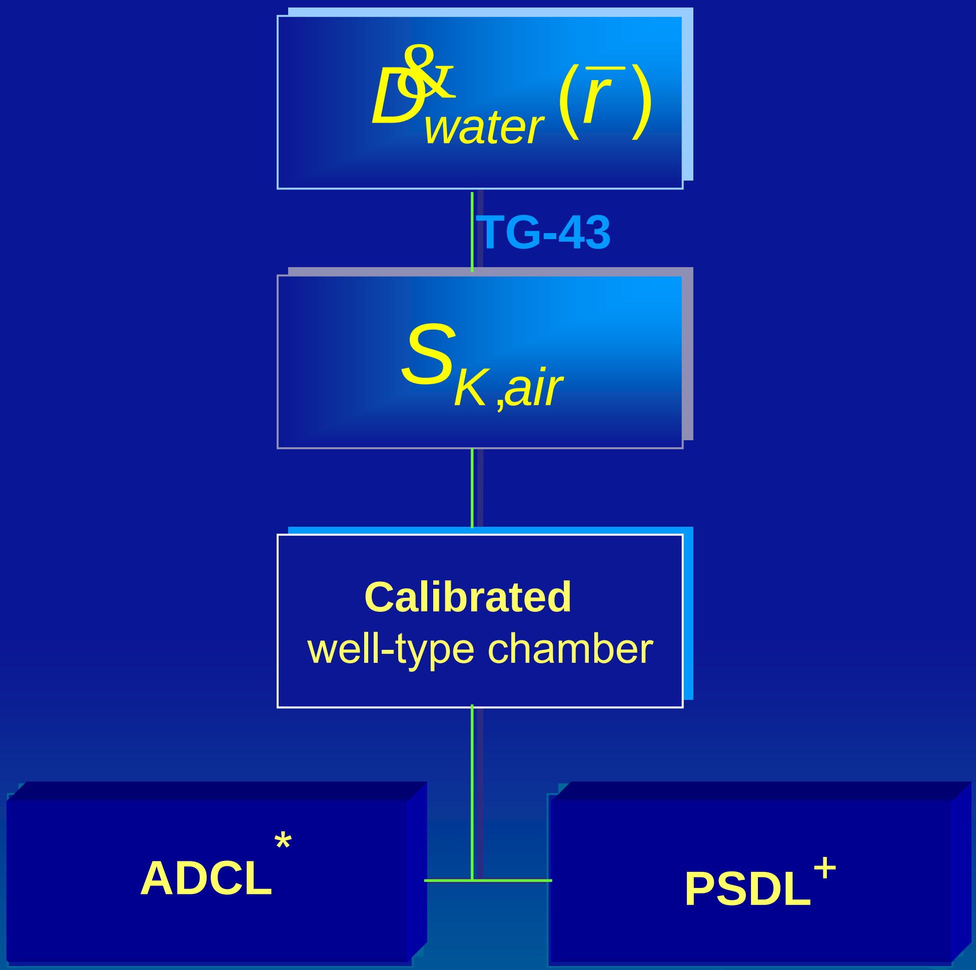
^{192}Ir Brachytherapy Dosimetry



Interpolation of air kerma calibration of a thimble type chamber based on its KV and $^{137}Cs/^{60}Co$ calibration factors.

Cavity ionization chamber with correction for non-validity of Spencer Attix.

*Accredited Dosimetry Calibration Laboratories

+Primary Standard Dosimetry Laboratories

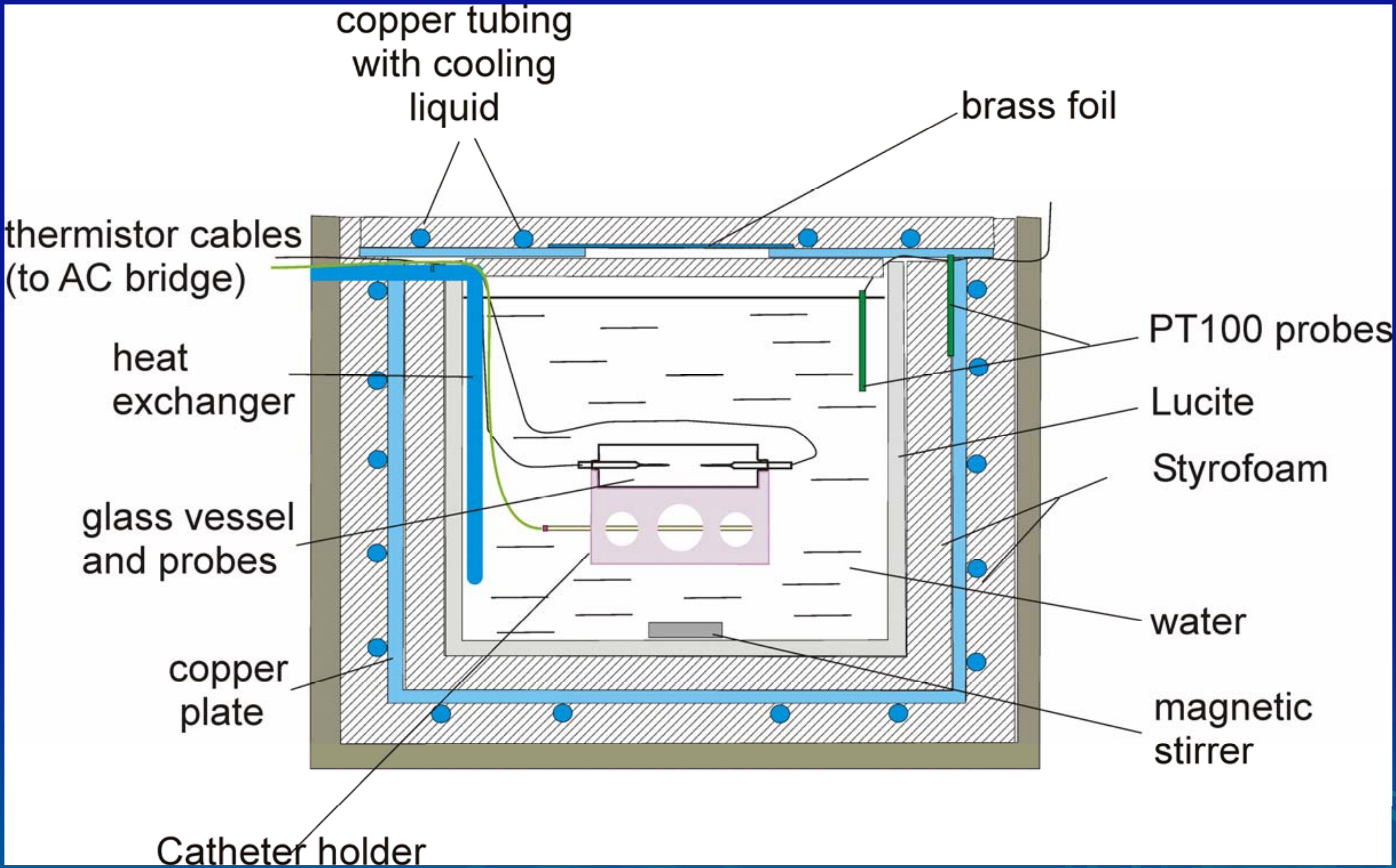
Brachytherapy Water Calorimetry

- Difficulties:

$$D_w(\bar{r}) = c_w \cdot \Delta T(\bar{r}) \cdot \prod k_i$$

  - Sub-mK level temperature rise to be measured with sub-percent precision.
  - Correction factors due to:
    - Heat transport (non-water materials & radiation dose gradient)
    - Heat defect (differences in energy absorbed and measured due to chemical reactions in water)
  - Sharp dose gradient of the source
  - Inherent self-heating of the source
  - Accurate positioning of the source

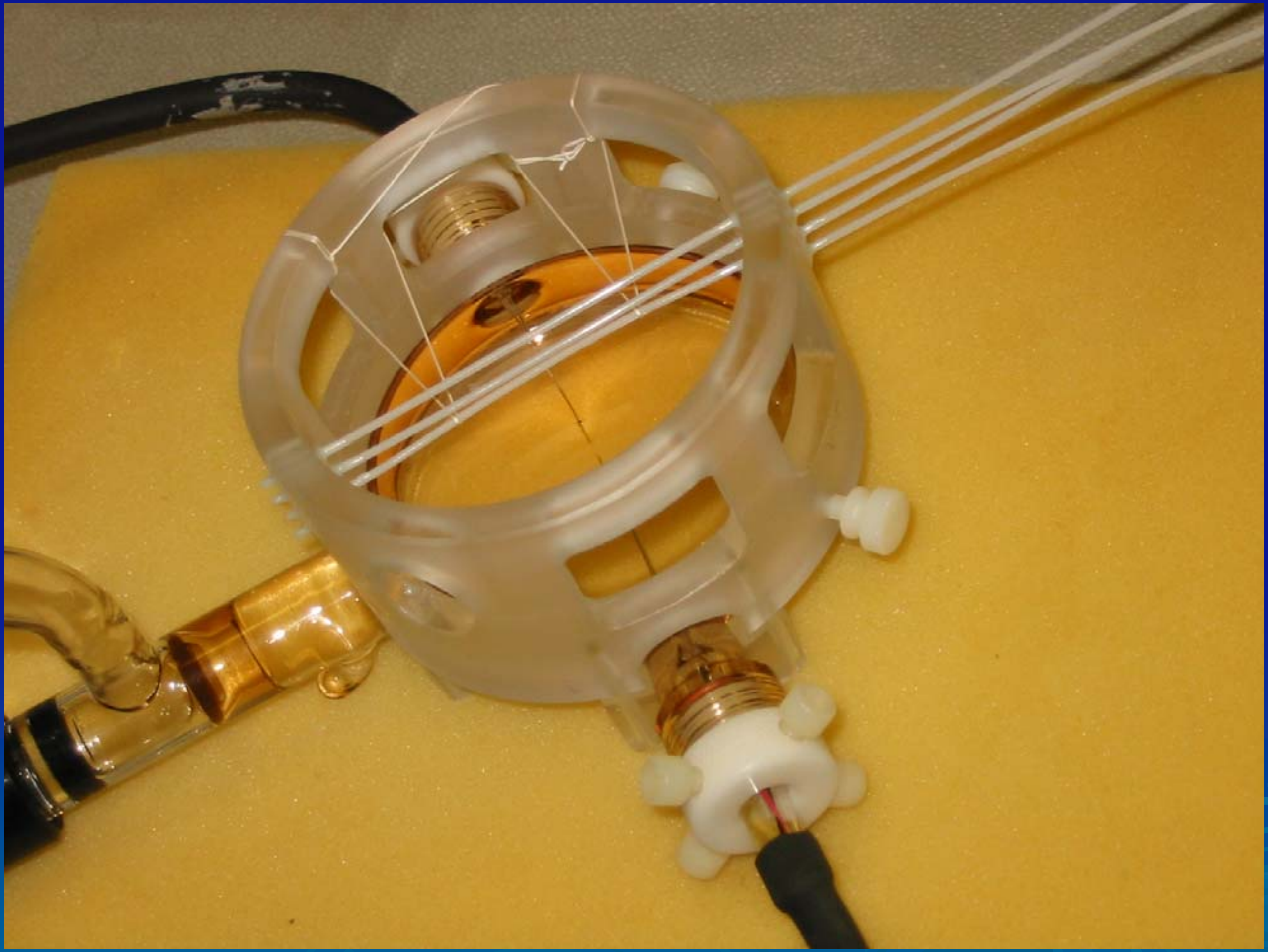
Water Calorimetry



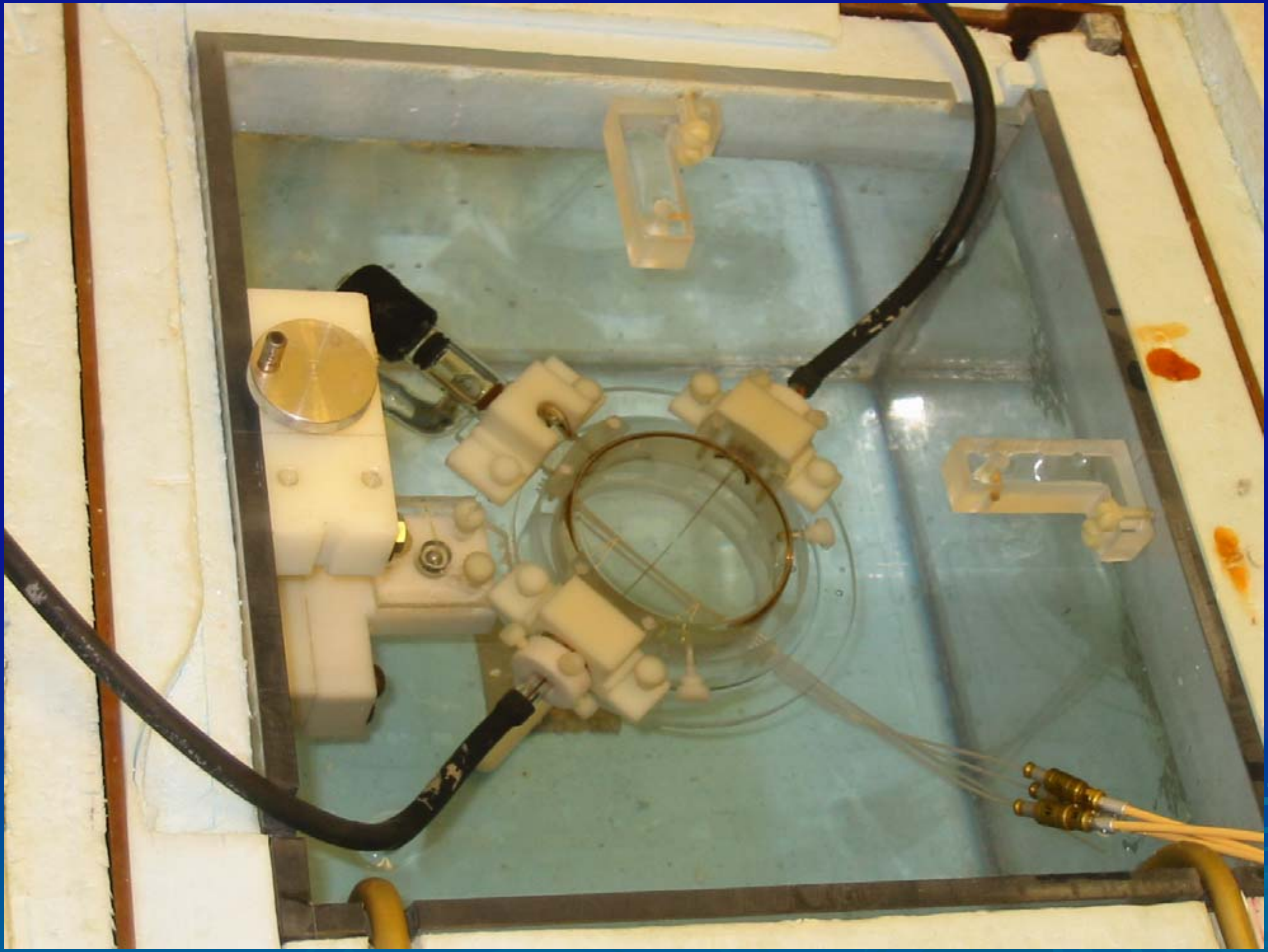
Courtesy of Dr. K. Stewart.

Experimental Setup

Experimental Setup

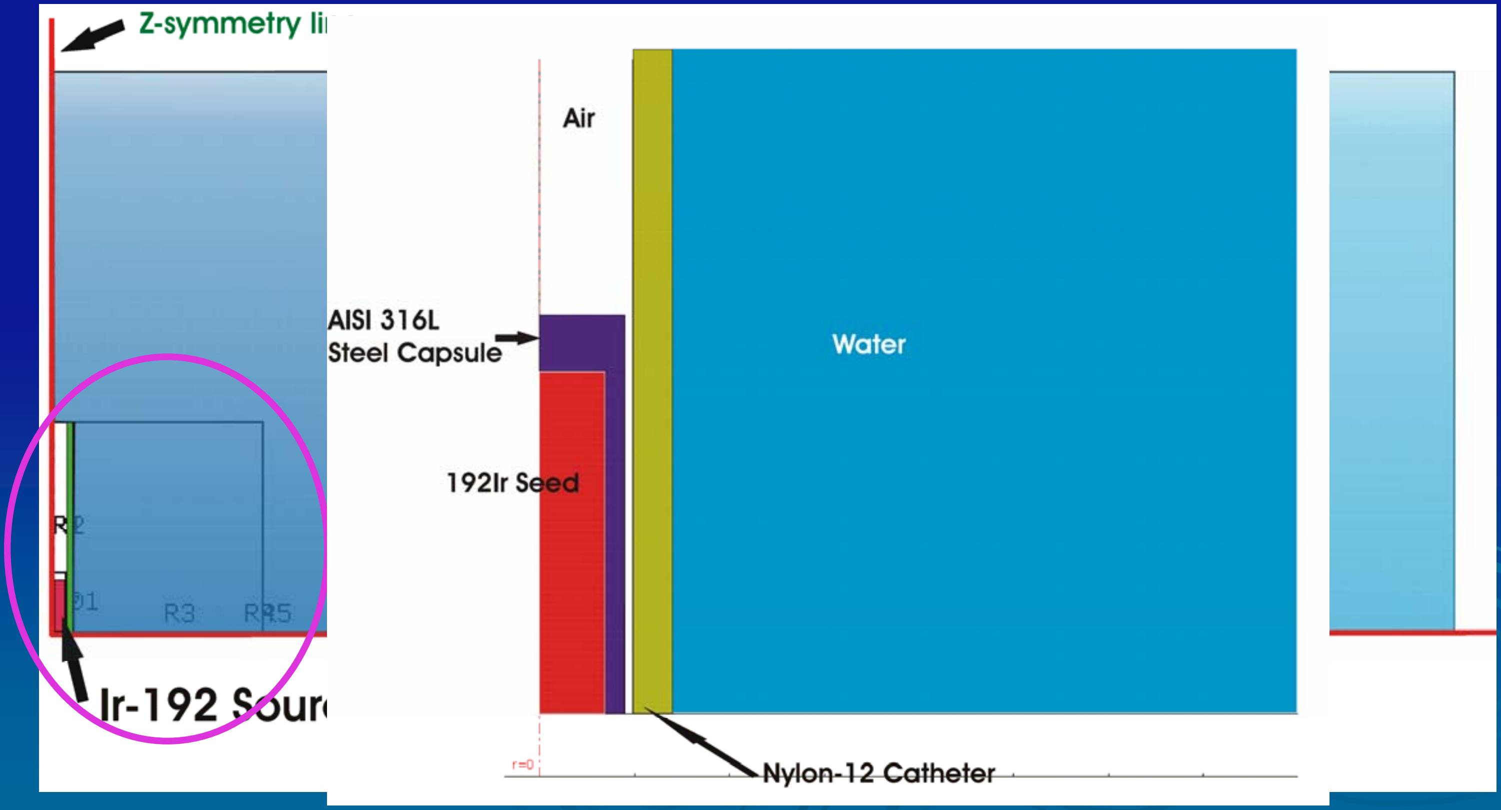


Experimental Setup

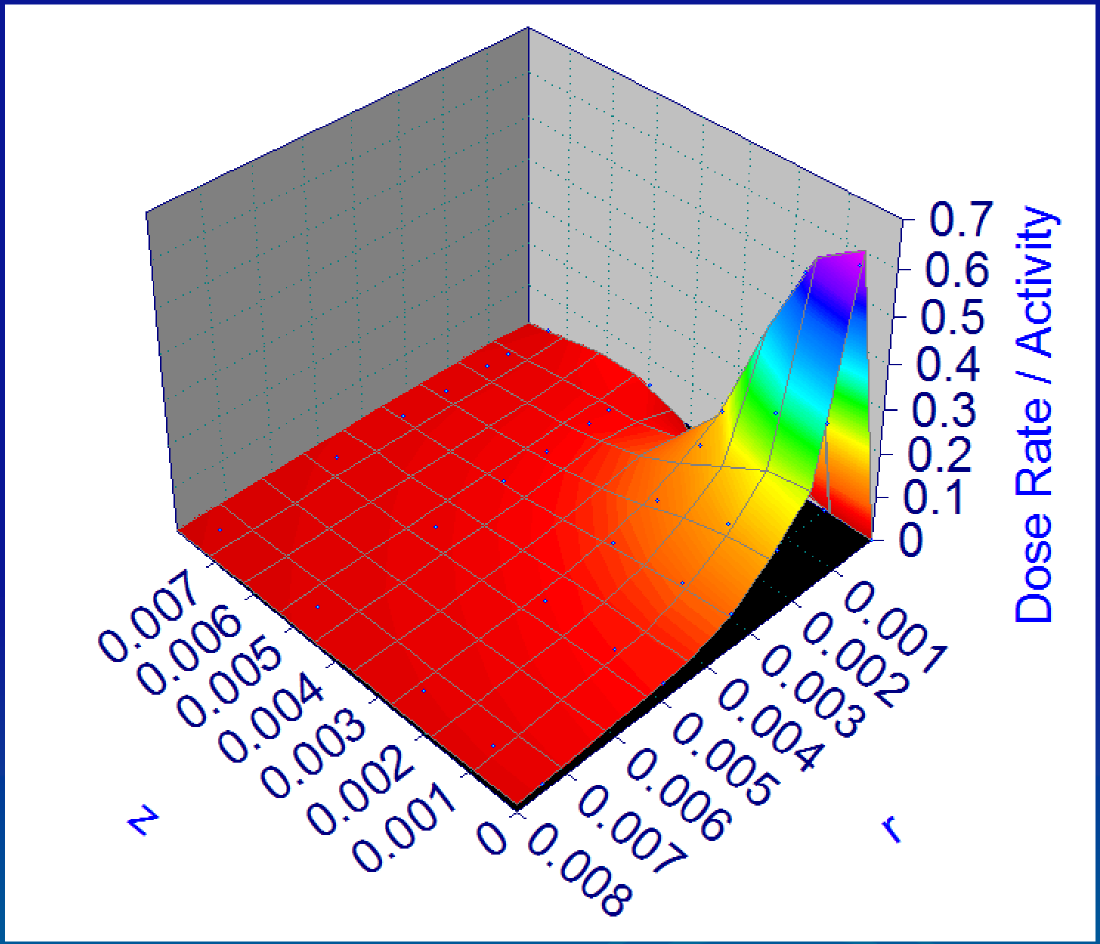


Heat Transport Calculations

- Comsol Multiphysics™ Solves the *heat transport* equation (the partial differential equation) using the *finite element method*.



Dose Distribution

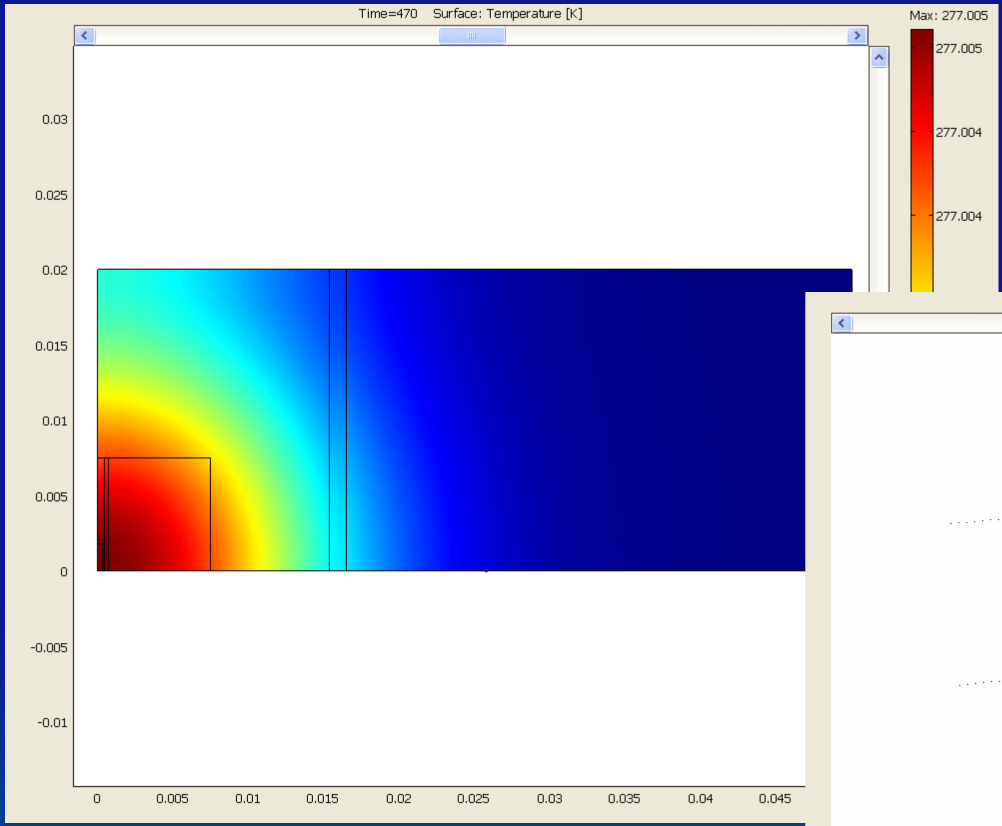


The fractional source self-dissipation due to self-attenuation of ^{192}Ir photons and electrons in the source was calculated using EGSnrcMP code.

D_{core}	1.79×10^{-7} cGy/disintegration
$D_{capsule}$	1.50×10^{-8} cGy/disintegration
$S_{K,air}$	3.80×10^{-11} cGy.cm^2/disintegration

G. M. Daskalov, E. Loffler, and J. F. Wiliamson, "Monte Carlo-aided dosimetry of a new high dose-rate brachytherapy source," Med. Phys. 25, 2200 (1998).

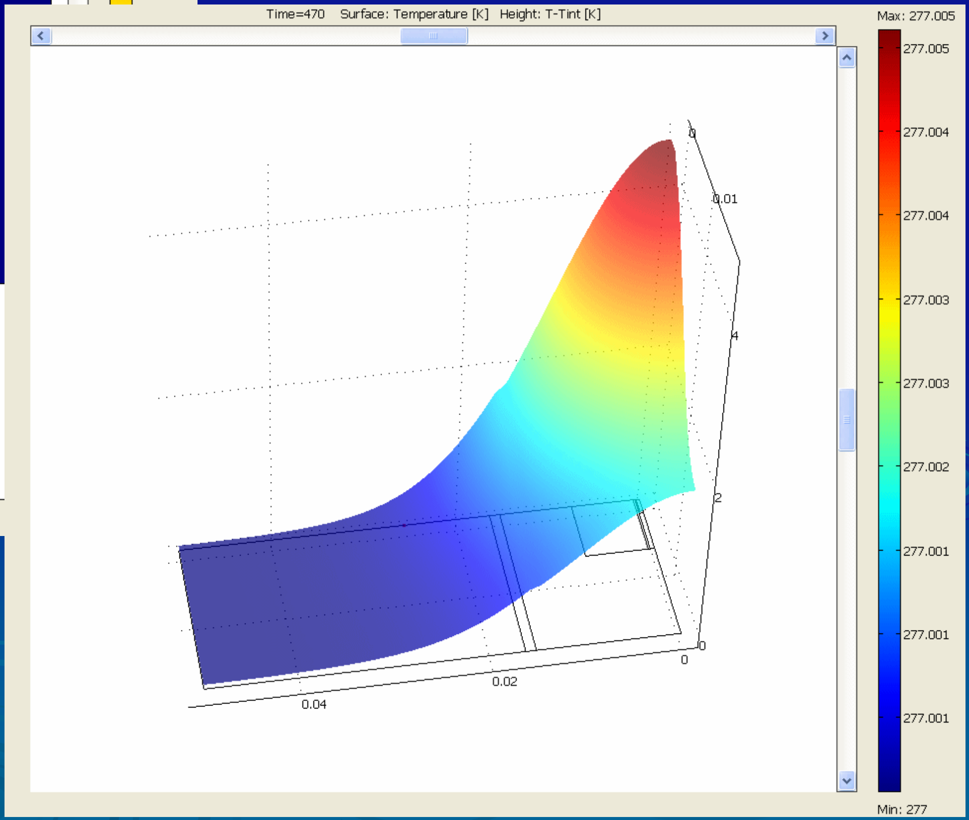
Heat Transport Results



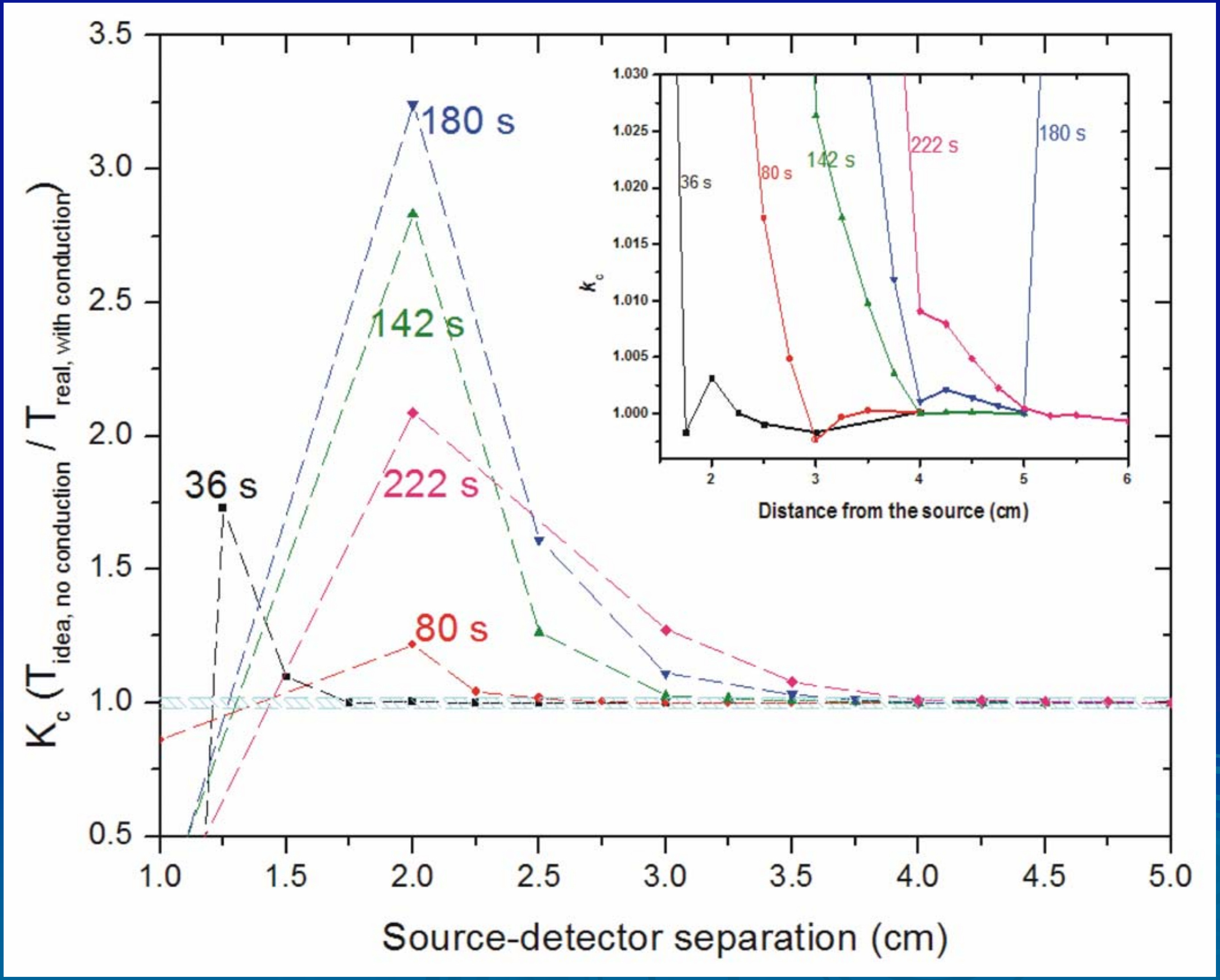
Source Activity: 5.049 Ci

Irradiation time: 70 s

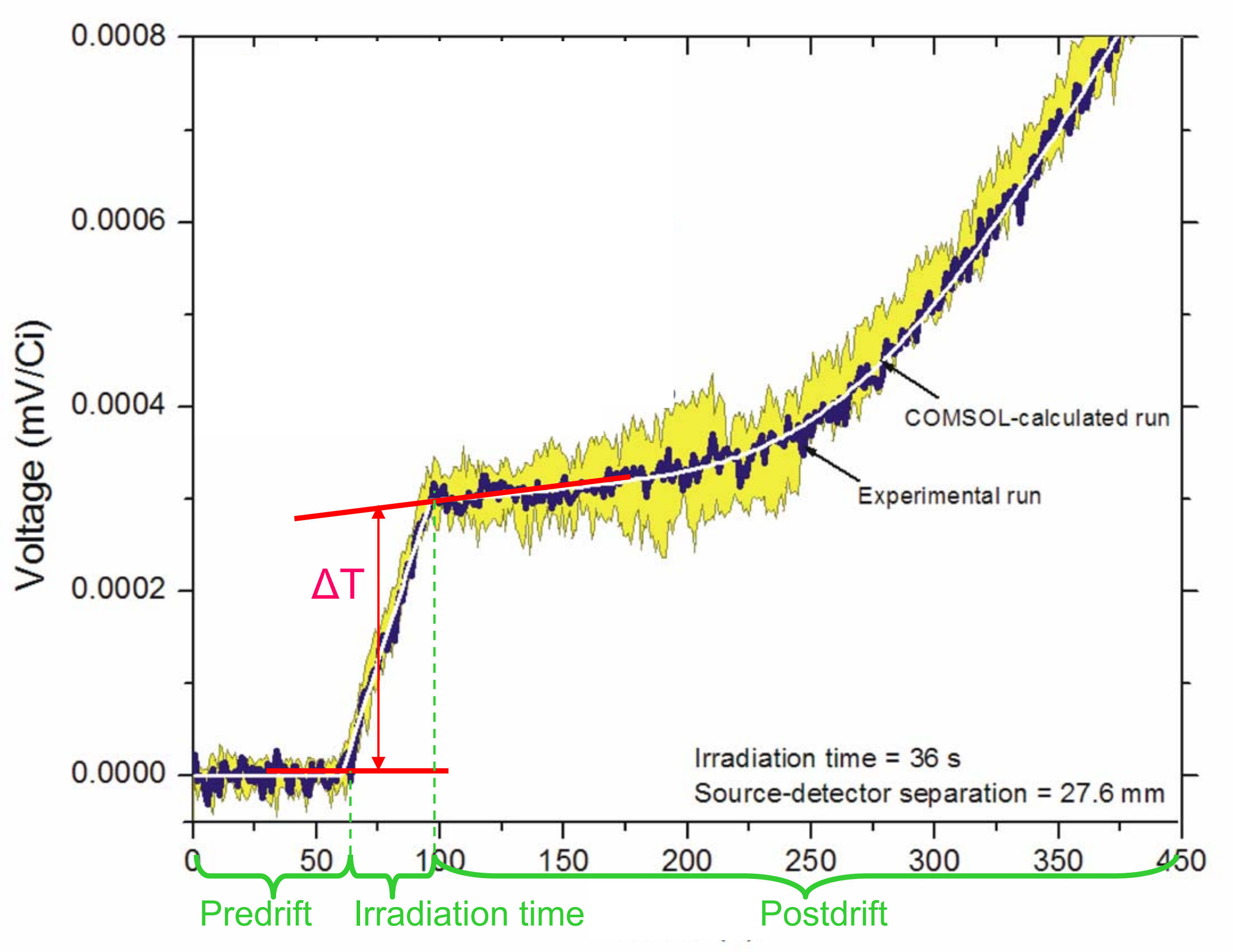
Post-drift: 400 s



Conduction Correction Factor



Measurement vs. Calculation



Summary of Results

Nominal Source activity [Ci]	Source-detector separation [mm]	Irradiation time [s]	Number of calorimetric runs performed	Average dose rate [mGy/(s.Ci)]	TG-43 calculated dose rate [mGy/(s.Ci)]	% diff. exp. & TG-43
9.30	27.6±0.3	36	8	1.79±0.03	1.68	6.5
	26.4±0.4	50	7	1.82±0.03	1.83	0.3
5.05	26.8±0.5	80	3	1.84±0.09	1.83	0.6
	24.7±0.3	75	3	2.02±0.07	2.13	5.0
AVERAGE	**25**		**21**	**2.05±0.03**	**2.06**	**0.5**

Conclusion

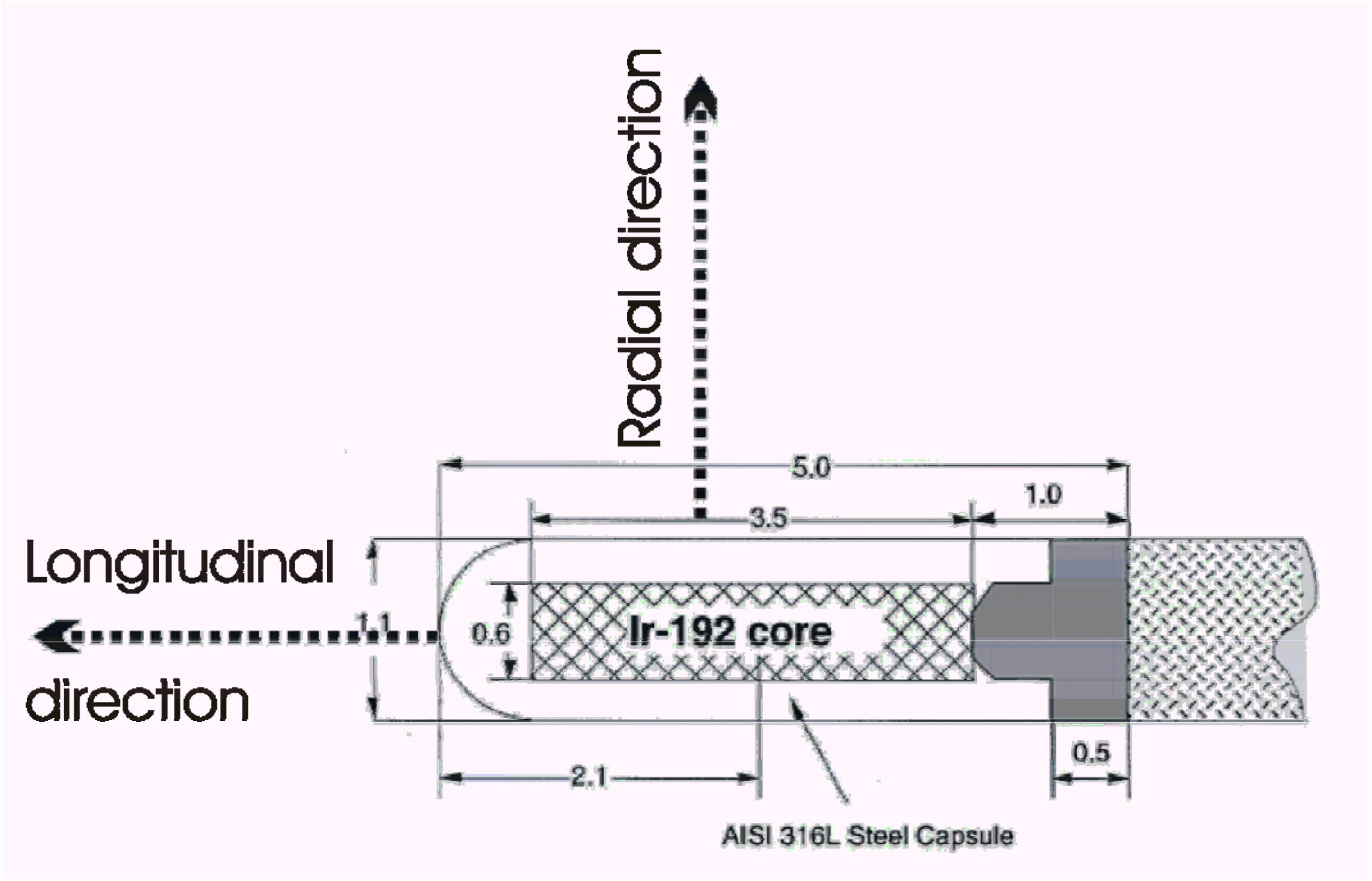
- HDR ^{192}Ir brachytherapy water calorimetry is feasible.
- Absolute dose measurement with an uncertainty much better than 5% is achievable.
- Optimal point of measurement is between 2.5 to 6 cm from the source in the radial direction (on the perpendicular bisector) while ensuring that a minimum dose of 1 Gy is delivered.

Acknowledgements

- Dr. K. Stewart
- Dr. E. Podgorsak
- R. Van Gils
- J. Larkin, B. Siva
- E. Poon

McGill University Health Centre Research Institute

Nucleotron microSelectron-HDR ^{192}Ir



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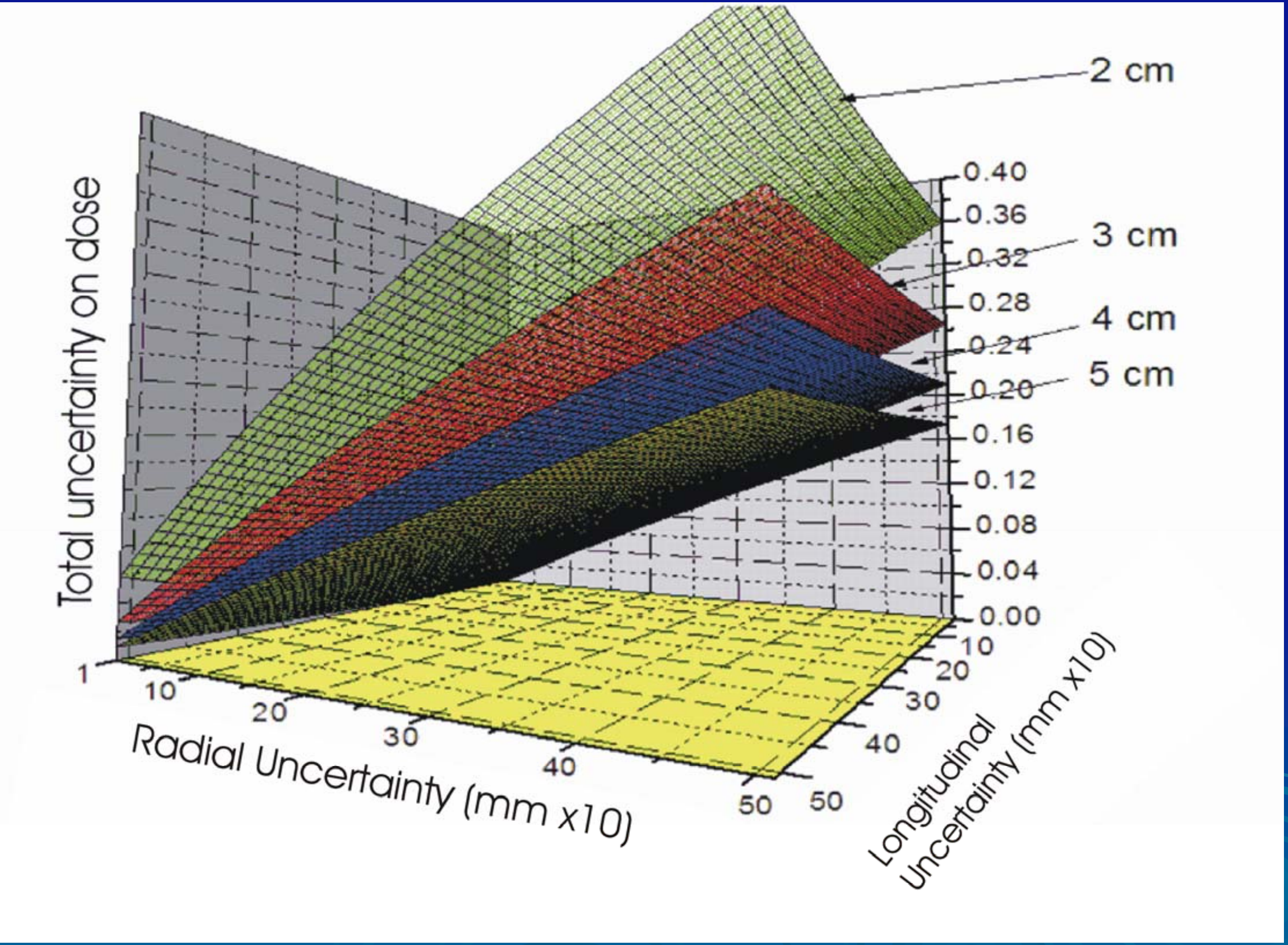
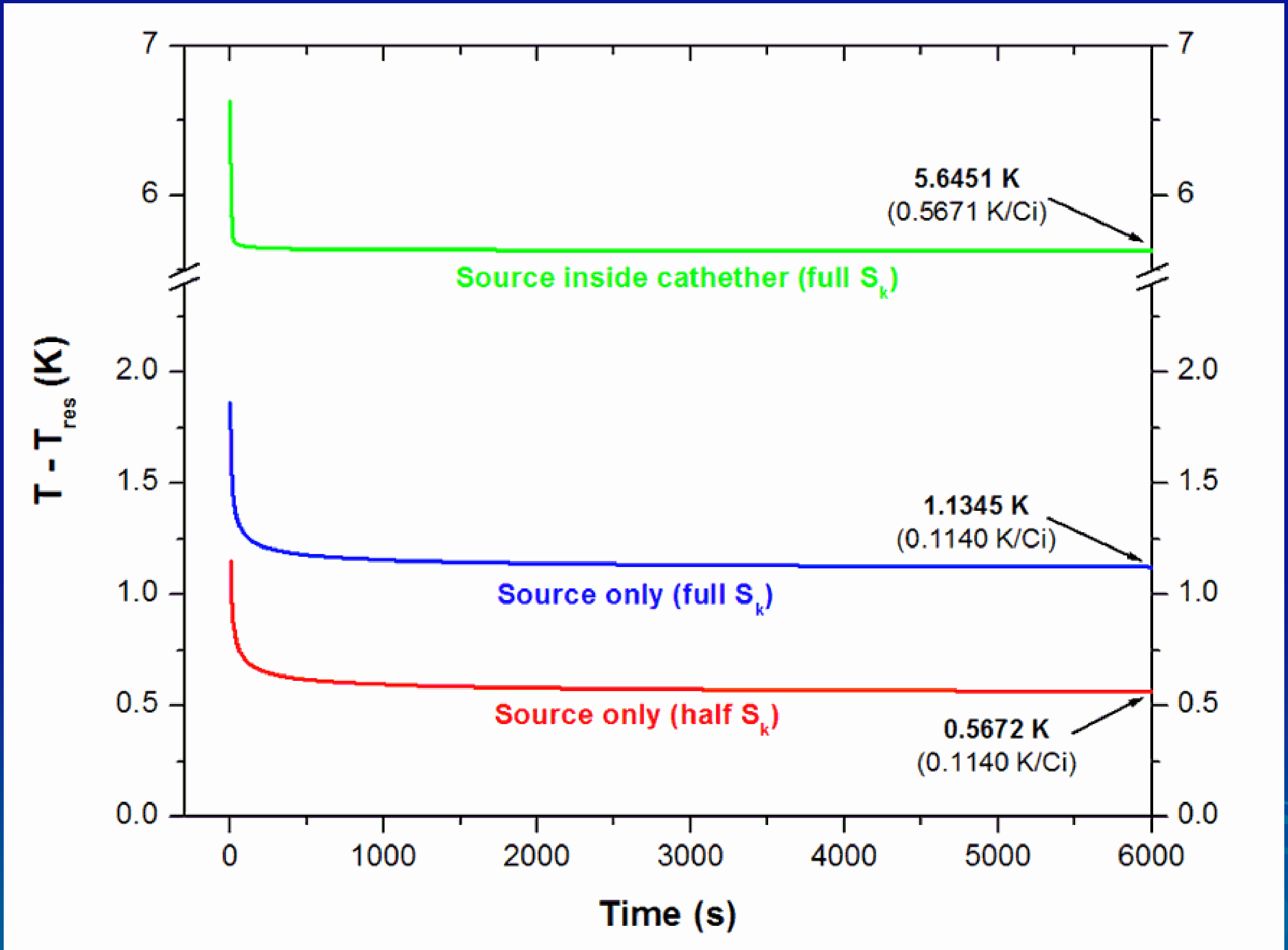
Position Uncertainty



Source Self-Heating



Generic Equation

$$D_w = c_{w,constP} \cdot \Delta T \cdot \prod k$$

k_{hd} = correction for the heat defect (chemical rx in water)

k_{ht} = correction for the heat transfer

k_p = perturbation correction (non-water materials)

k_{dd} = profile correction factor (non-uniformity of dose profile)

k_ρ = density correction factor (difference in density between the calorimeter operation temp and the temp at which another detector, exp. ion chamber, is calibrated