# AERROW: A PROBE FORMAT CALORIMETER

## FOR USE AS A LOCAL ABSORBED DOSE STANDARD FOR HIGH-ENERGY PHOTON BEAMS IN THE CLINICAL ENVIRONMENT


The Aerrow

USA patent granted

PCT/CA2013/000523

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COMP Canadian Organization of Medical Physicists / OCPM Organisation canadienne des physiciens médicaux

EIRR21 Excellence in Radiation Research for the 21st Century

NSERC CRSNG

IRMS Council on Ionizing Radiation Measurements and Standards

Medical Physics RESEARCH TRAINING NETWORK

J.R. acknowledges partial support by the CREATE Medical Physics Research Training Network grant of the Natural Sciences and Engineering Research Council (Grant number: 432290)

CTS Campus des technologies de la santé

CIHR IRSC Canadian Institutes of Health Research / Instituts de recherche en santé du Canada

International Organization for Medical Physics IOMP

McGill DOBSON CUP Start-UP Competition



# Support & Funding

McGill


The Aerrow
USA patent granted
PCT/CA2013/000523

Exradin A12
Standard Imaging Inc.


The Aerrow
USA patent granted
PCT/CA2013/000523

Exradin A12
Standard Imaging Inc.

(1) Develop a graphite calorimeter as a ‘local’, clinical dose standard

(2) Maintain the usability and utility of an ionization chamber

(3) Aim for practicality, user-friendliness, robustness,
and a higher accuracy than achievable using ion chambers



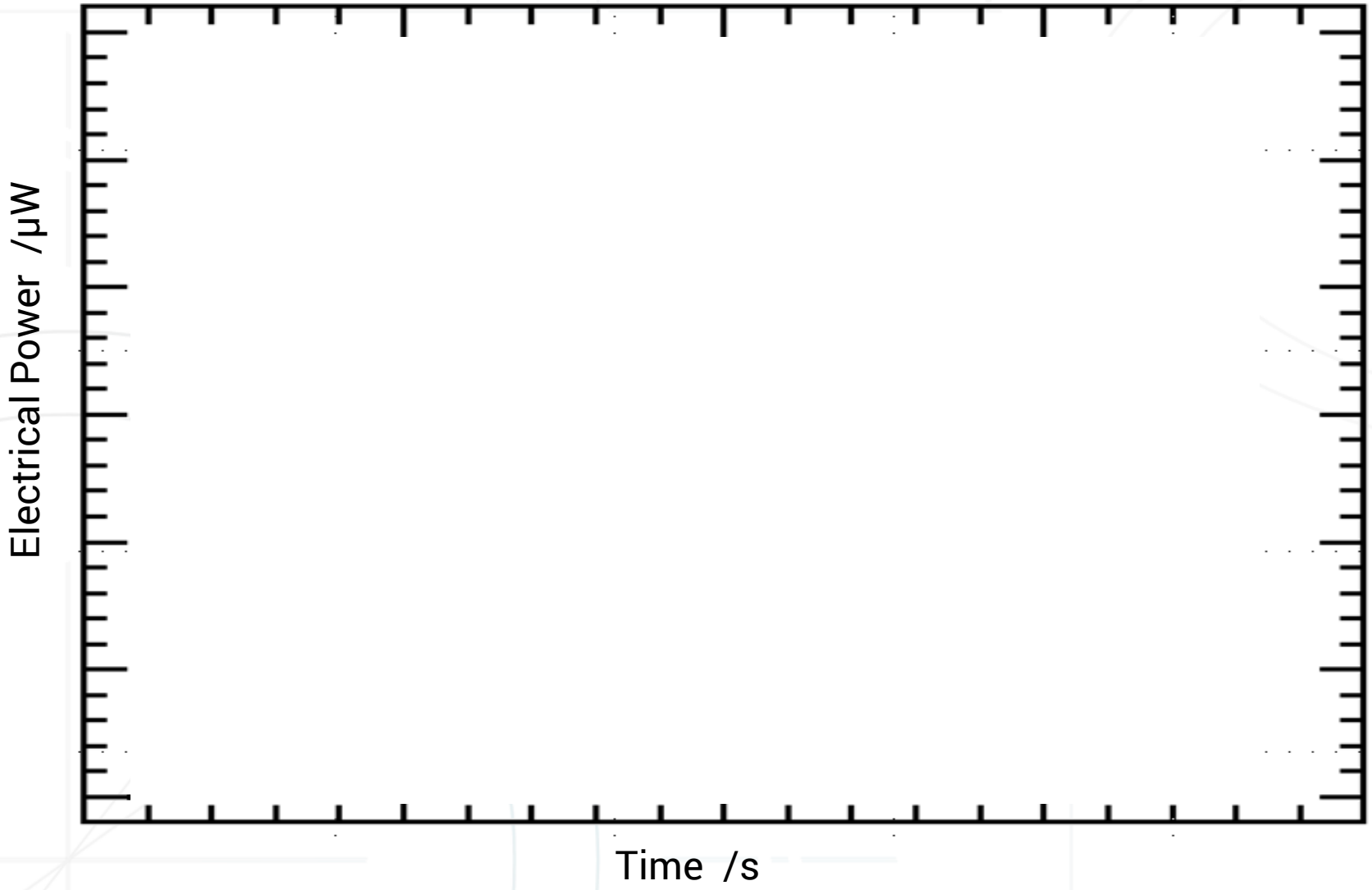
## Project Objectives

$$D_{\mathrm{core}} = \frac{\Delta E_{\mathrm{rad}}}{m_{\mathrm{core}}} = c_{p,\mathrm{core}} \cdot \Delta T$$

| | |
|---|---|
| $\Delta E_{\mathrm{rad}}$ | energy imparted by radiation |
| $m_{\mathrm{core}}$ | mass of core (*i.e.*, sensitive volume) |
| $c_{p,\mathrm{core}}$ | specific heat capacity at constant pressure of core |
| $\Delta T$ | rise in temperature |

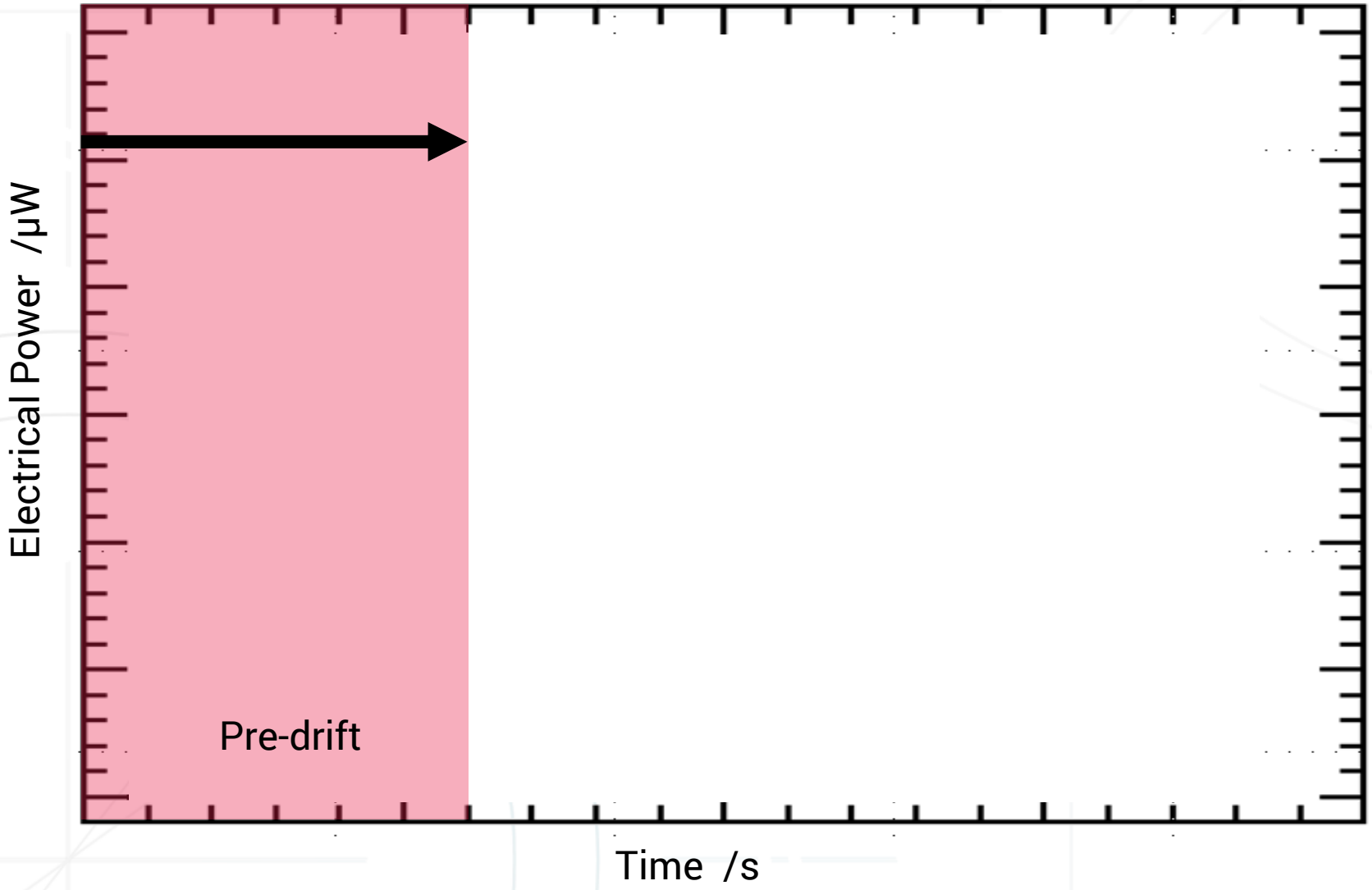


## Fundamental Equation of Absorbed Dose Calorimetry






# Isothermal Mode



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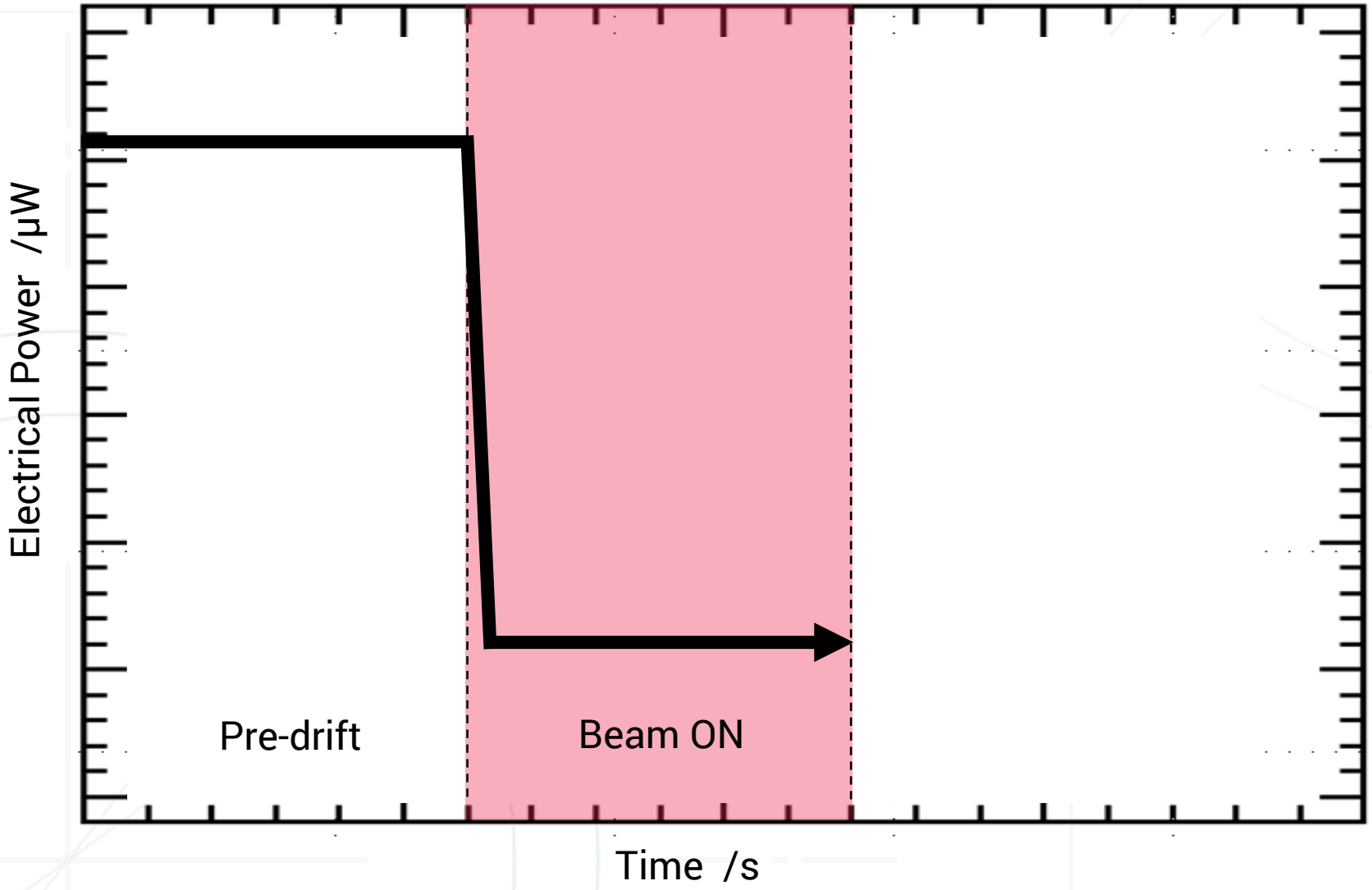




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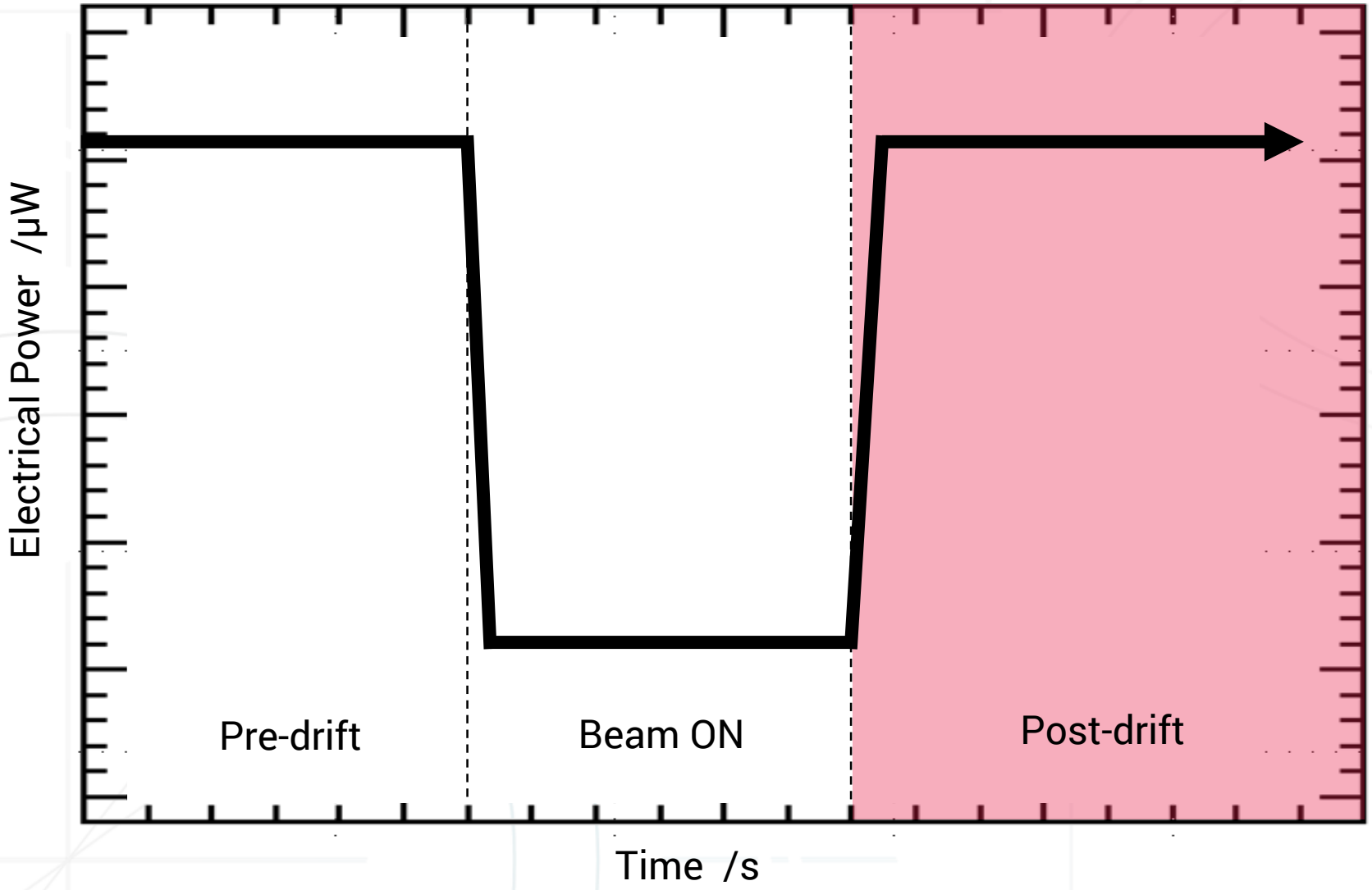




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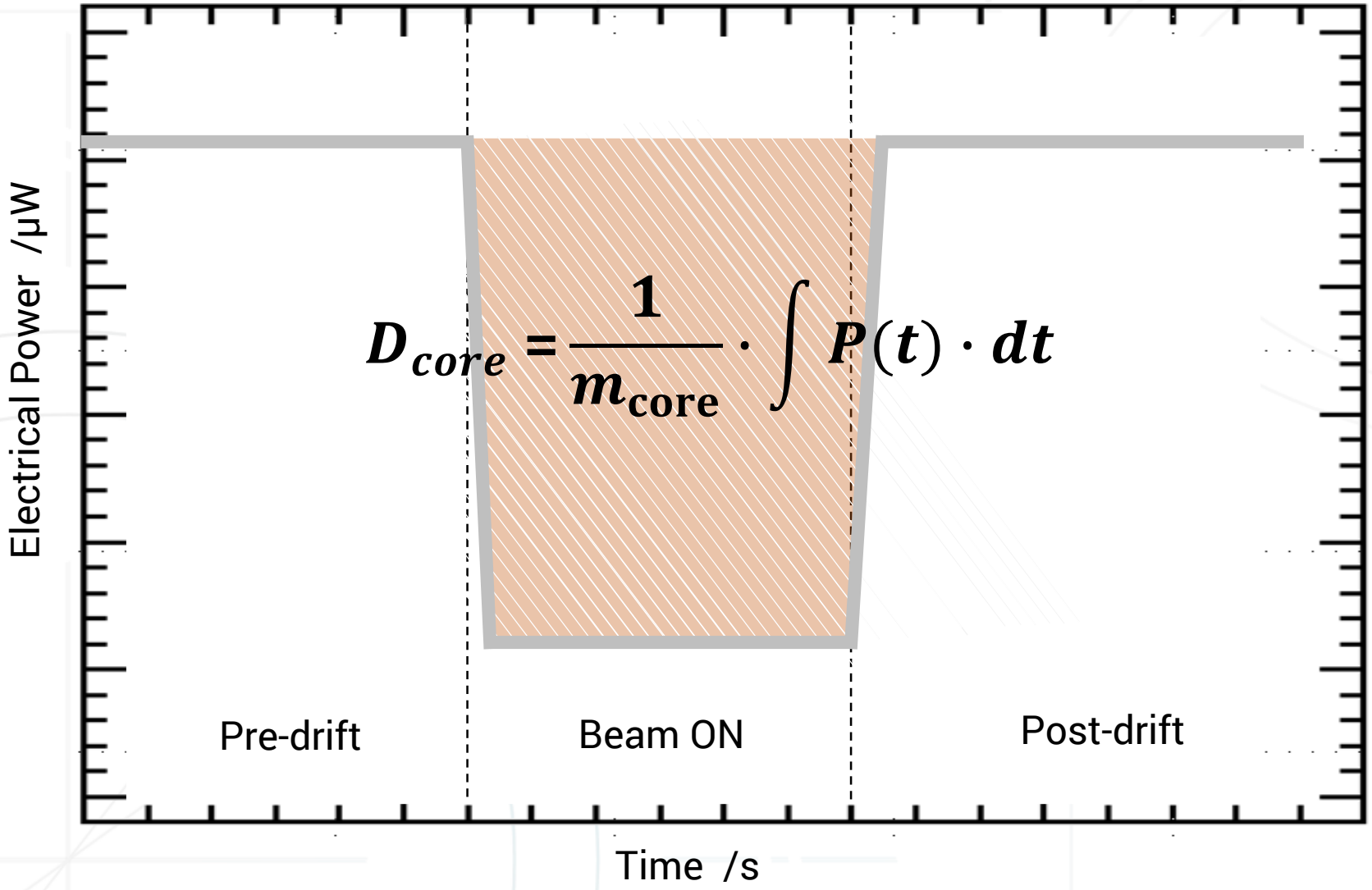
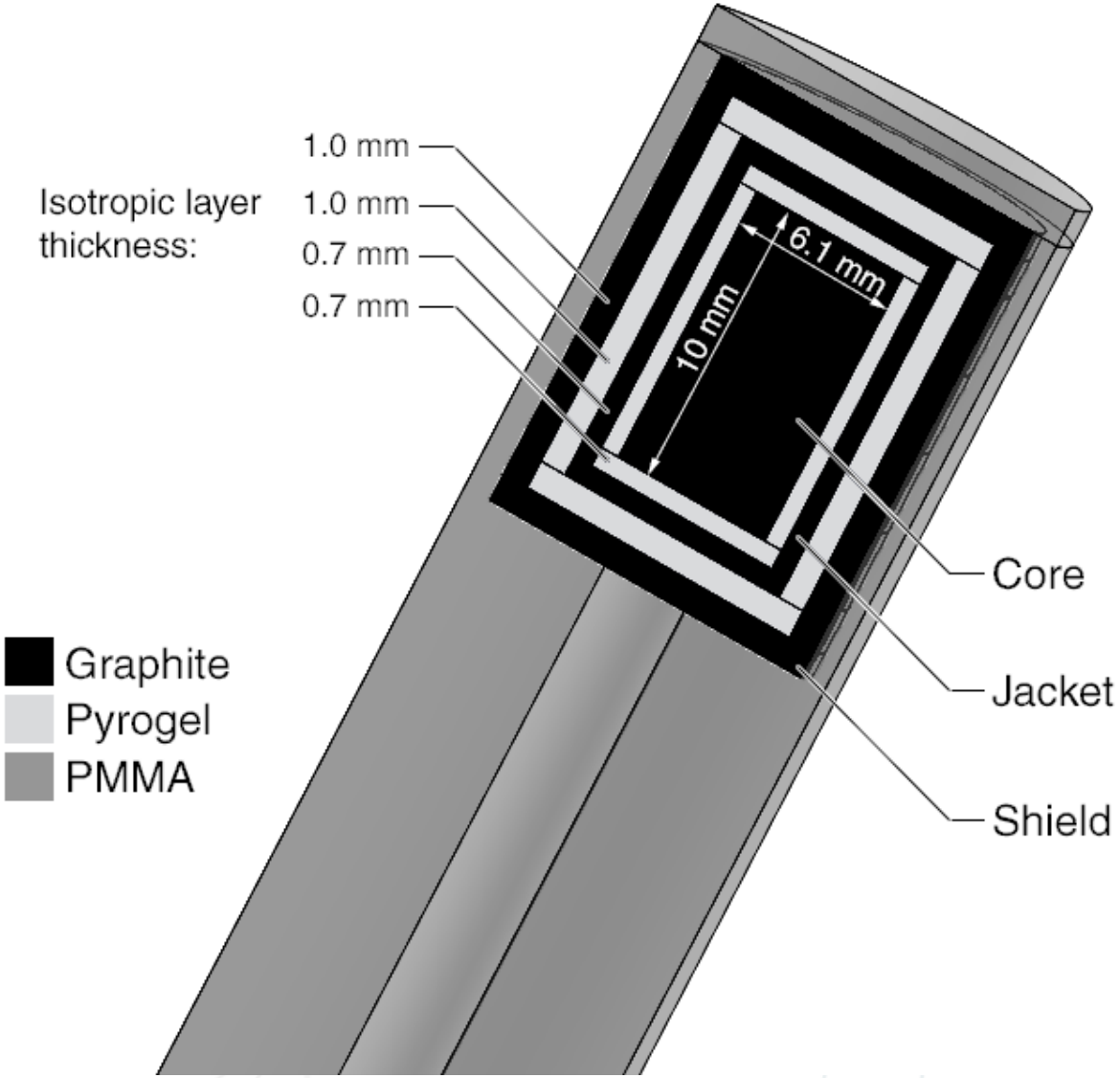
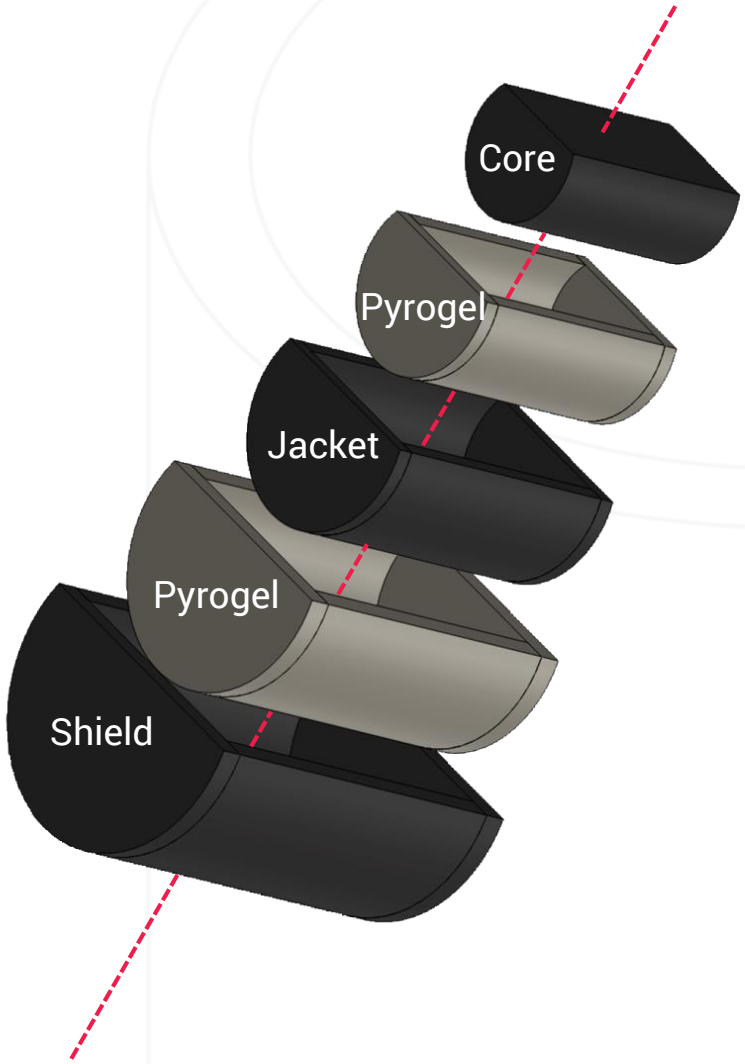



$$D_{core} = \frac{1}{m_{\mathrm{core}}} \cdot \int P(t) \cdot dt$$



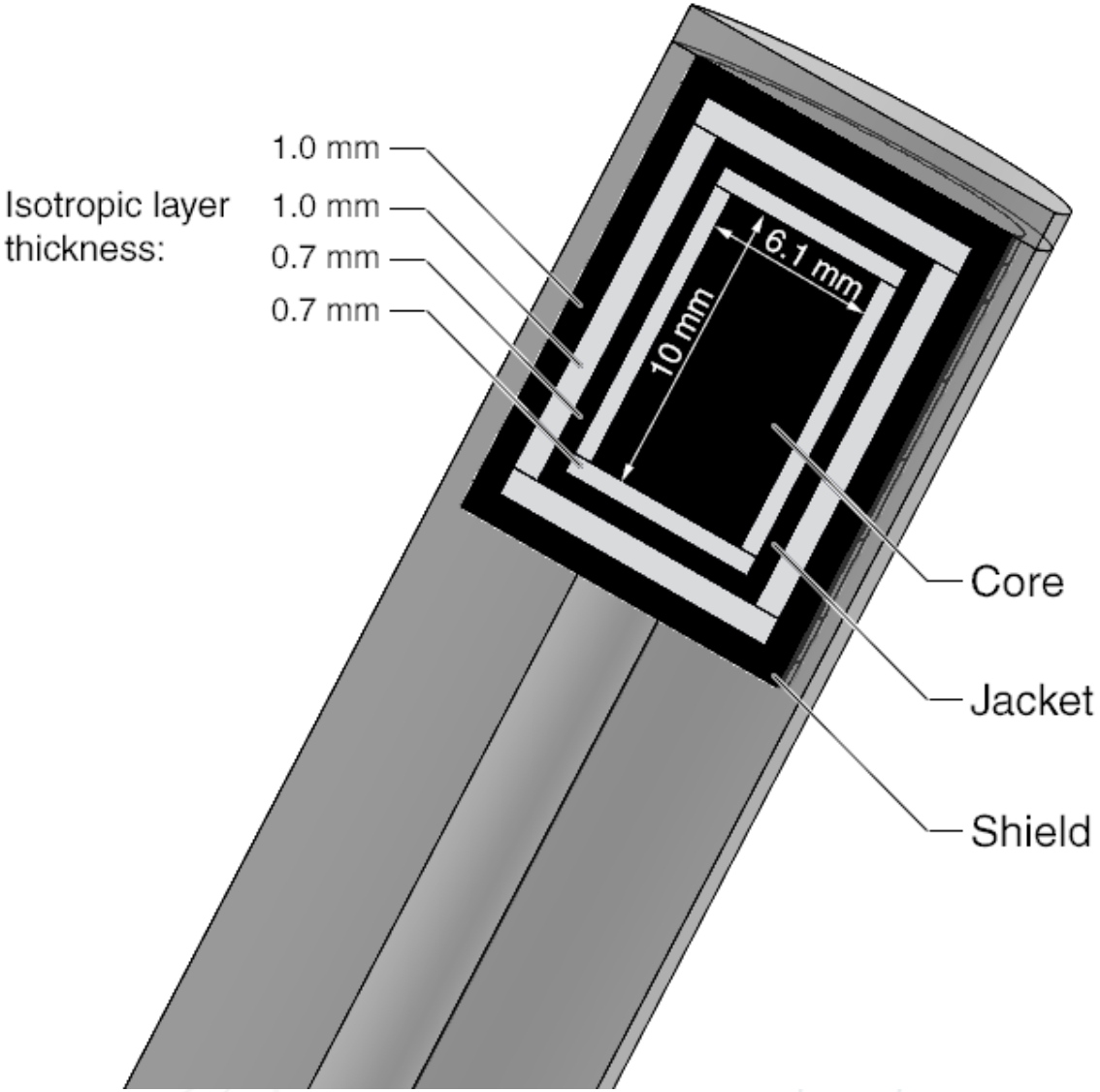
# Isothermal Mode

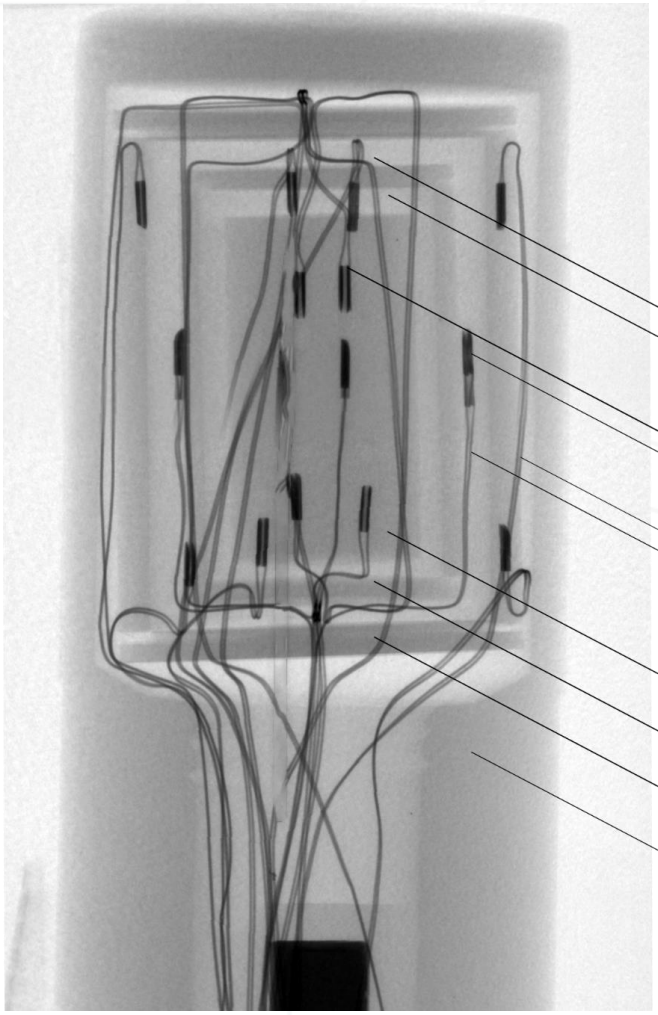





# Prototype Design (Aerrow MKIV)






# Mass Impurity Correction

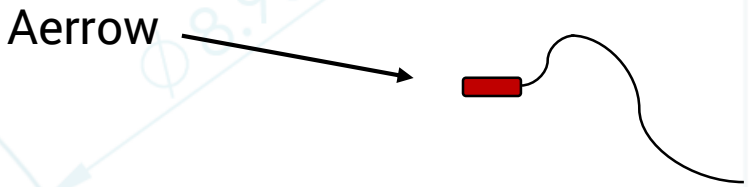
PART I

# DOSIMETRY FORMALISM

FOR HIGH-ENERGY PHOTON BEAMS

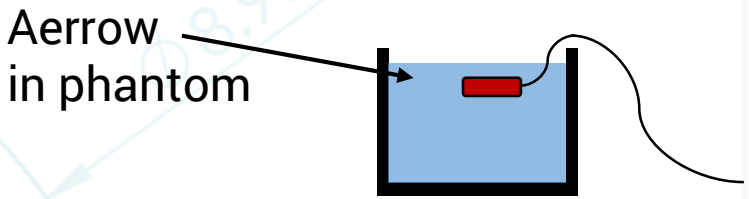


McGill



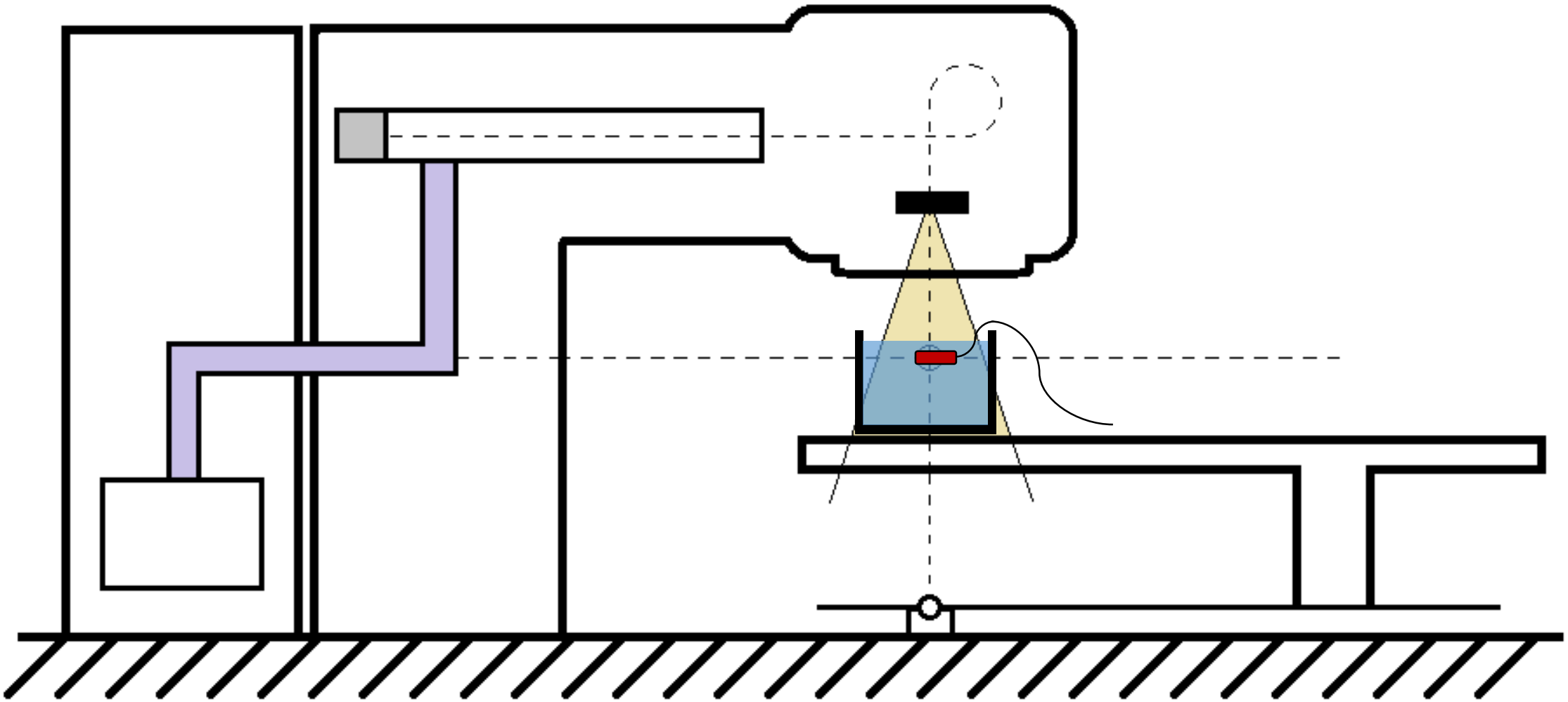



# Dose to Water Analog






# Dose to Water Analog





# Dose to Water Analog

Chamber-based reference dosimetry:

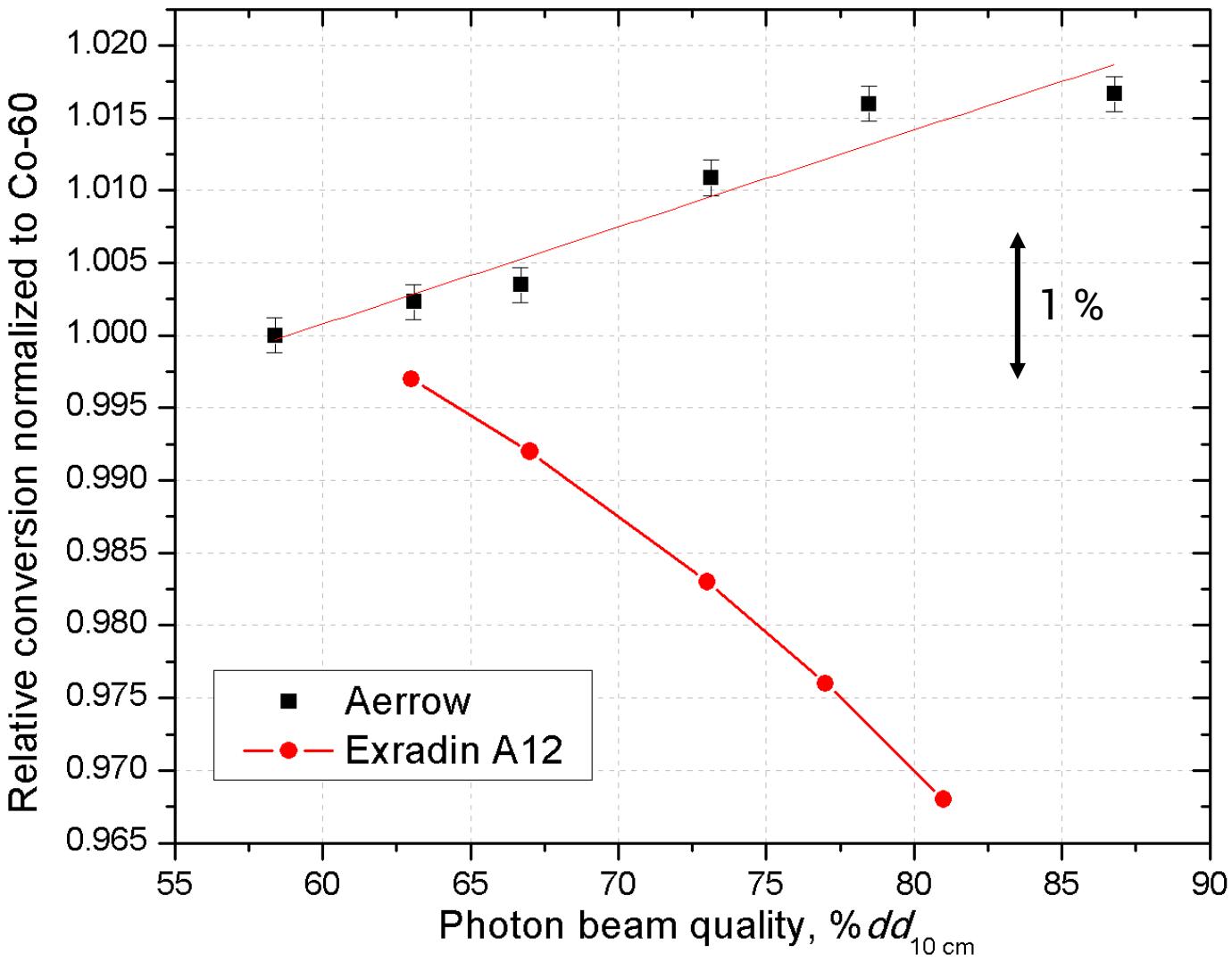
$$D_{w,Q}(z_{\mathrm{ref}}) = M_{w,Q} \cdot N_{D,w,Q_0} \cdot k_{Q,Q_0}$$

Aerrow-based absolute-reference dosimetry:

$$D_{w,Q}(z_{\mathrm{ref}}) = D_{\mathrm{core},Q} \cdot f_{w,\mathrm{core},Q0}^{D_{\mathrm{core}} \rightarrow D_{\mathrm{w}}} \cdot k_{Q,Q_0} = 1.131 \cdot D_{\mathrm{core},Q} \cdot k_{Q,Q_0}$$



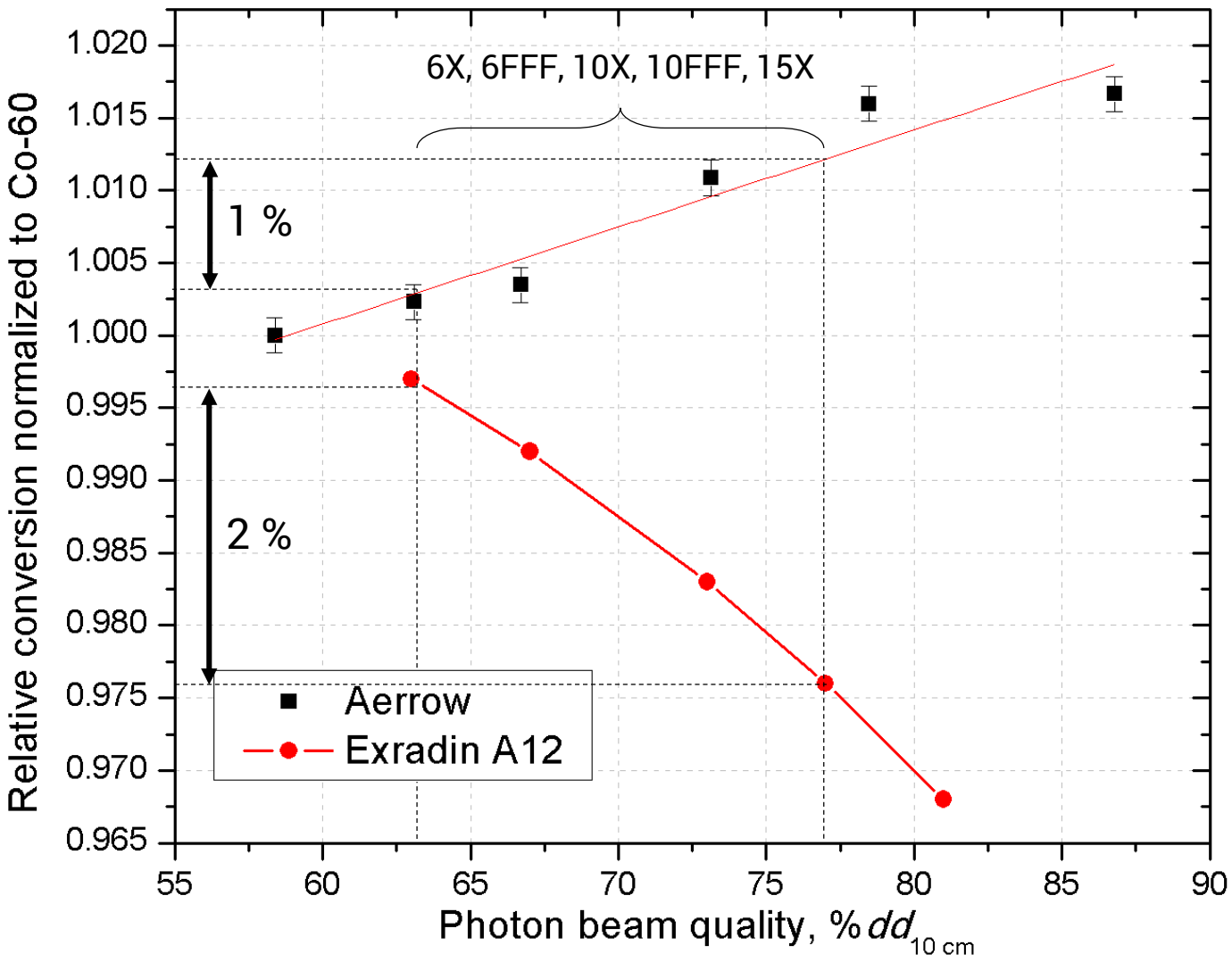
# Dose to Water Analog






# Photon Beam $k_{Q,Q0}$ Comparison

McGill



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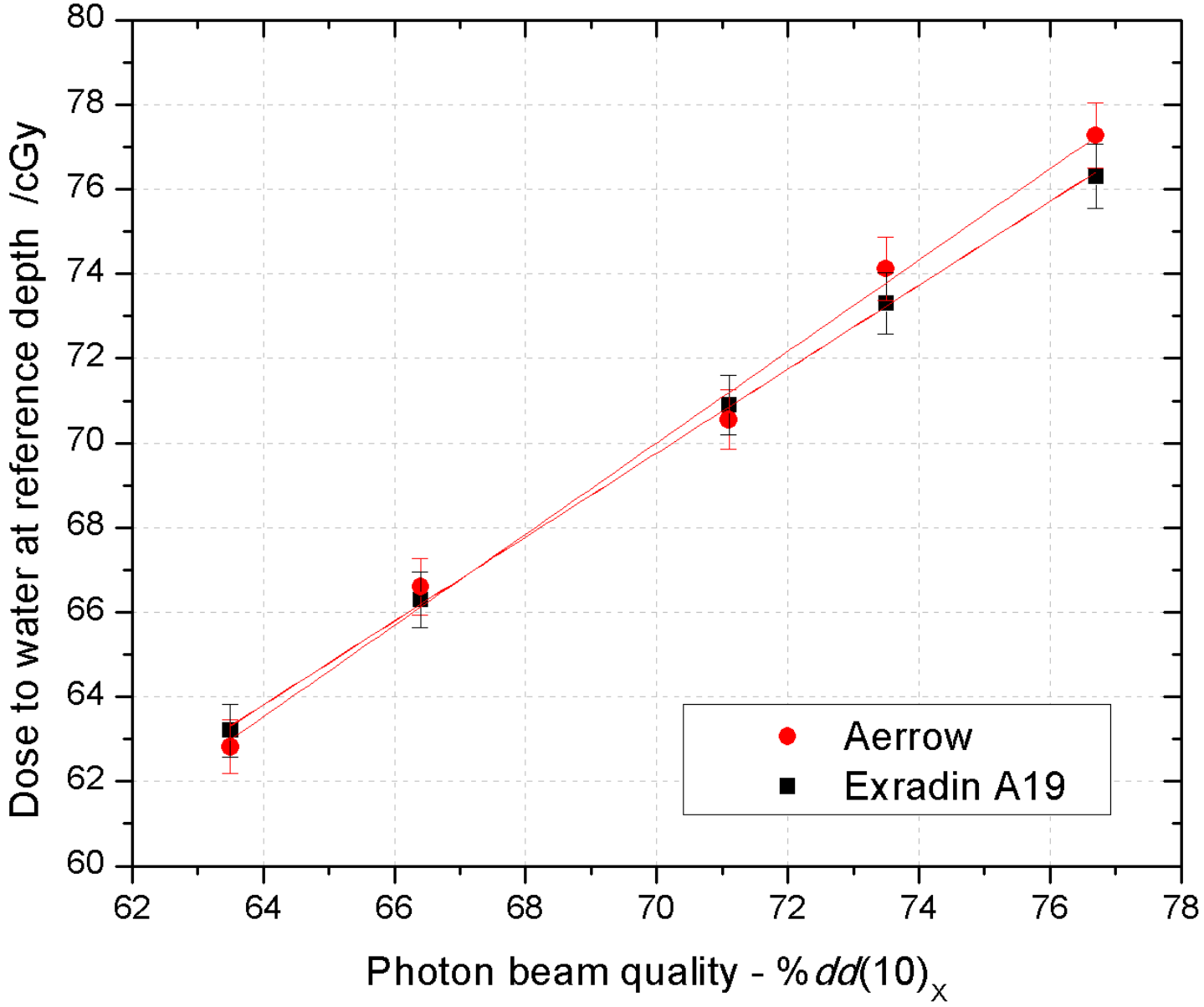





# Mass Impurity Correction

McGill

| Source of uncertainty | Isothermal | |
|---|---|---|
| | Type A [%] | Type B [%] |
| Heat transfer correction | — | 0.1 |
| Reproducibility | 0.6 | — |
| Bridge calibration | — | — |
| Thermistor calibration | — | — |
| Electrical power | — | 0.2 |
| Specific heat capacity | — | — |
| Mass | — | 0.5 |
| Positioning | 0.2 | — |
| Dose perturbation / conversion | — | 0.3 |
| Other sources | — | 0.2 |
| Quadratic summation | 0.6 | 0.6 |
| Combined relative standard uncertainty on $D_w$ | 0.9 | |



# Uncertainty on $D_w$ Determination

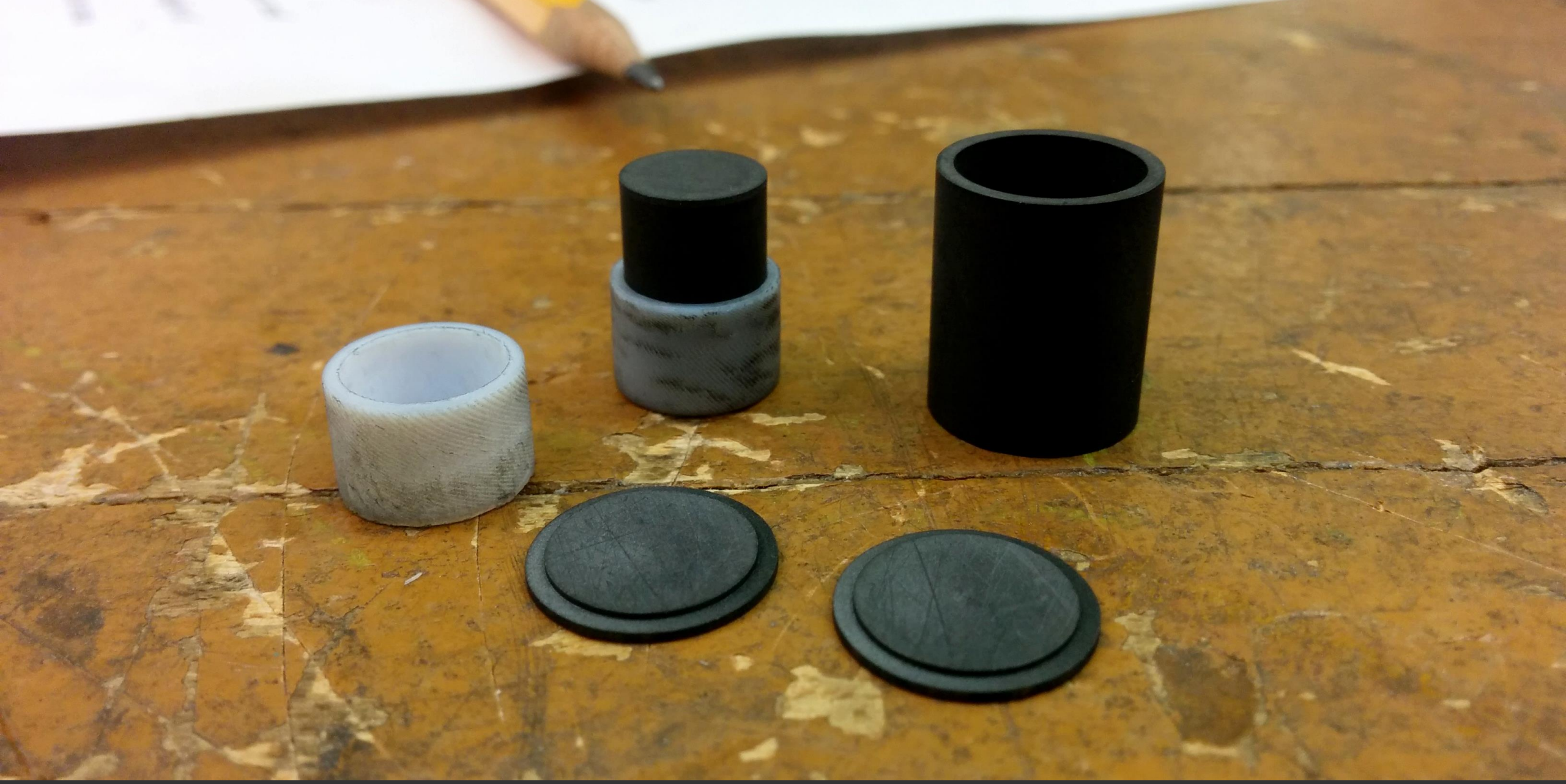
PART II

# MK-V CONSTRUCTION

FROM BENCHTOP TO BUNKER

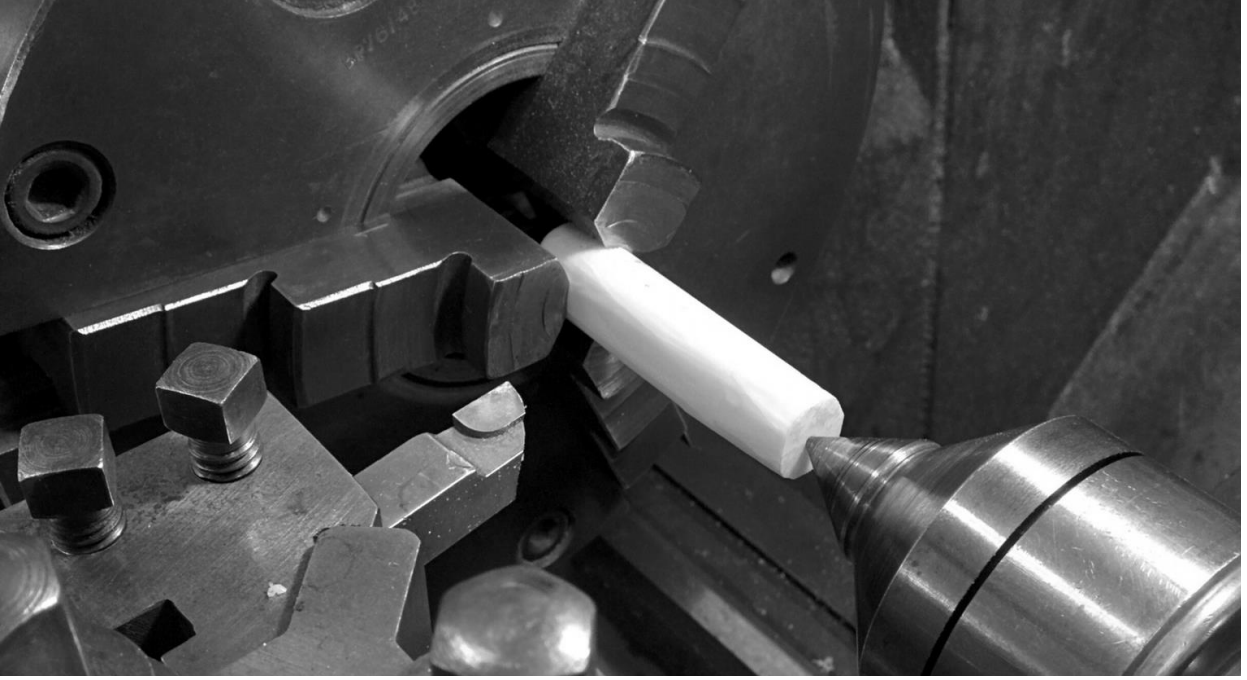


McGill



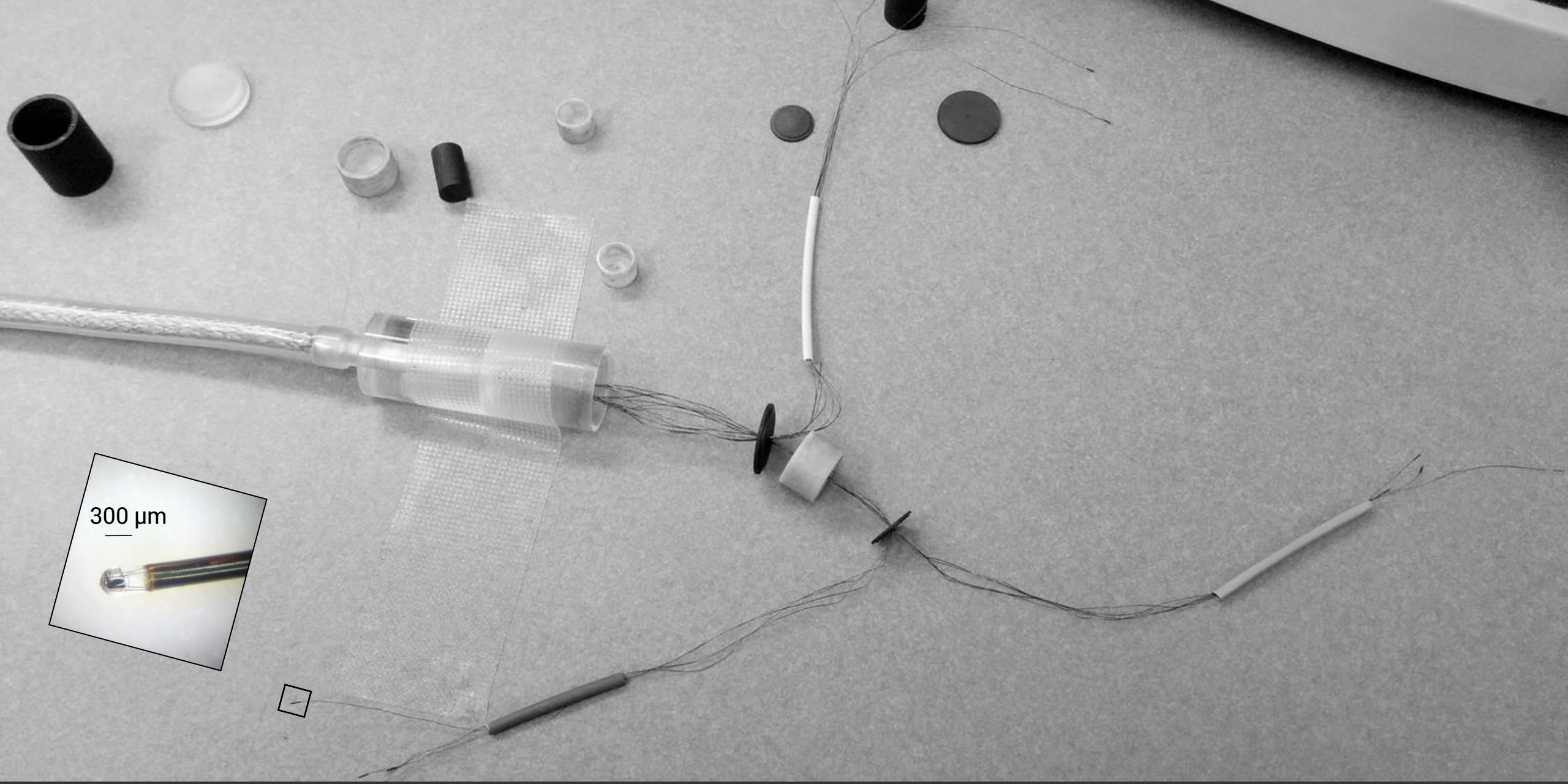


# Aerogel Thermal Insulator





# Early Prototype Construction



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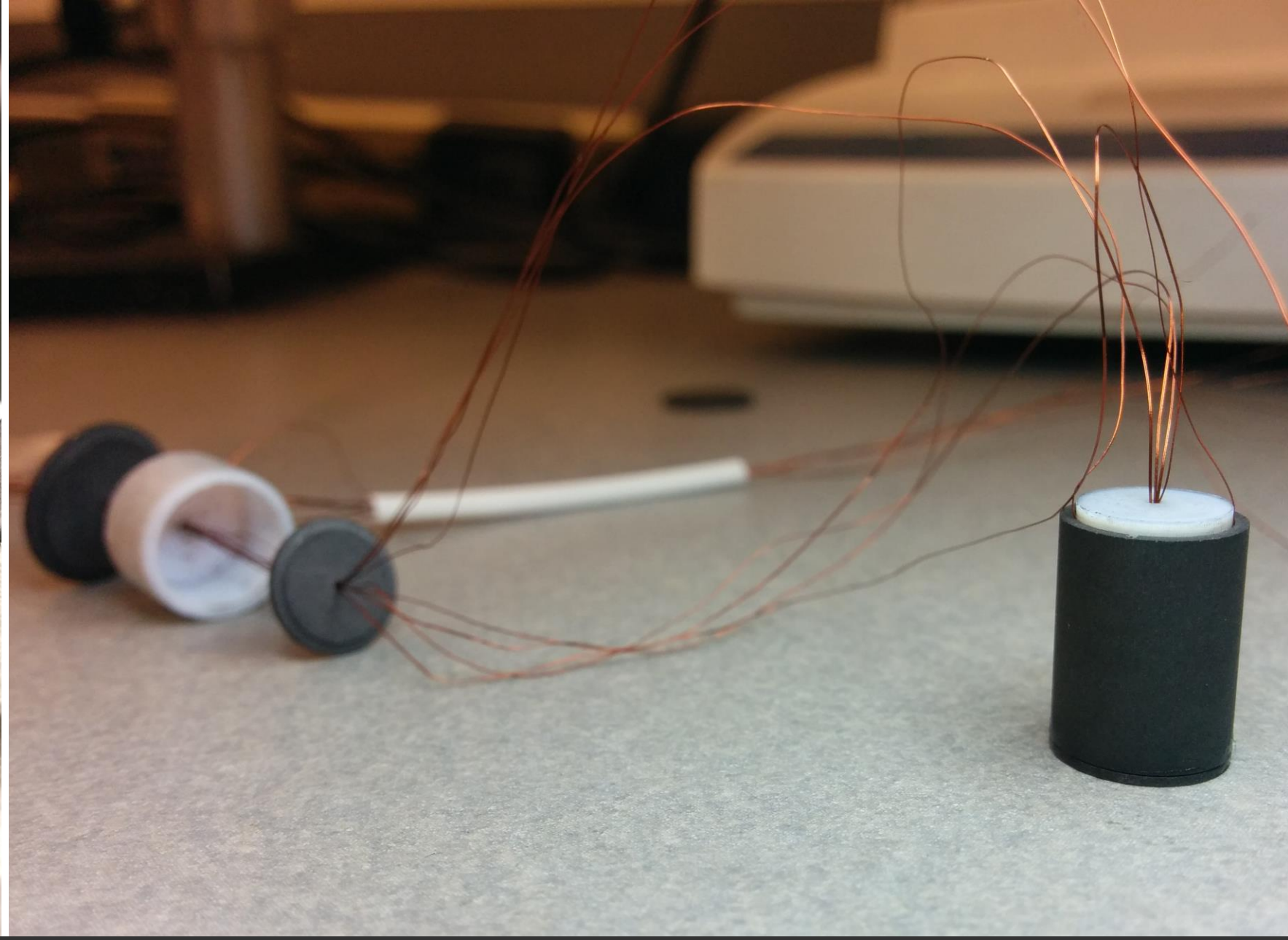



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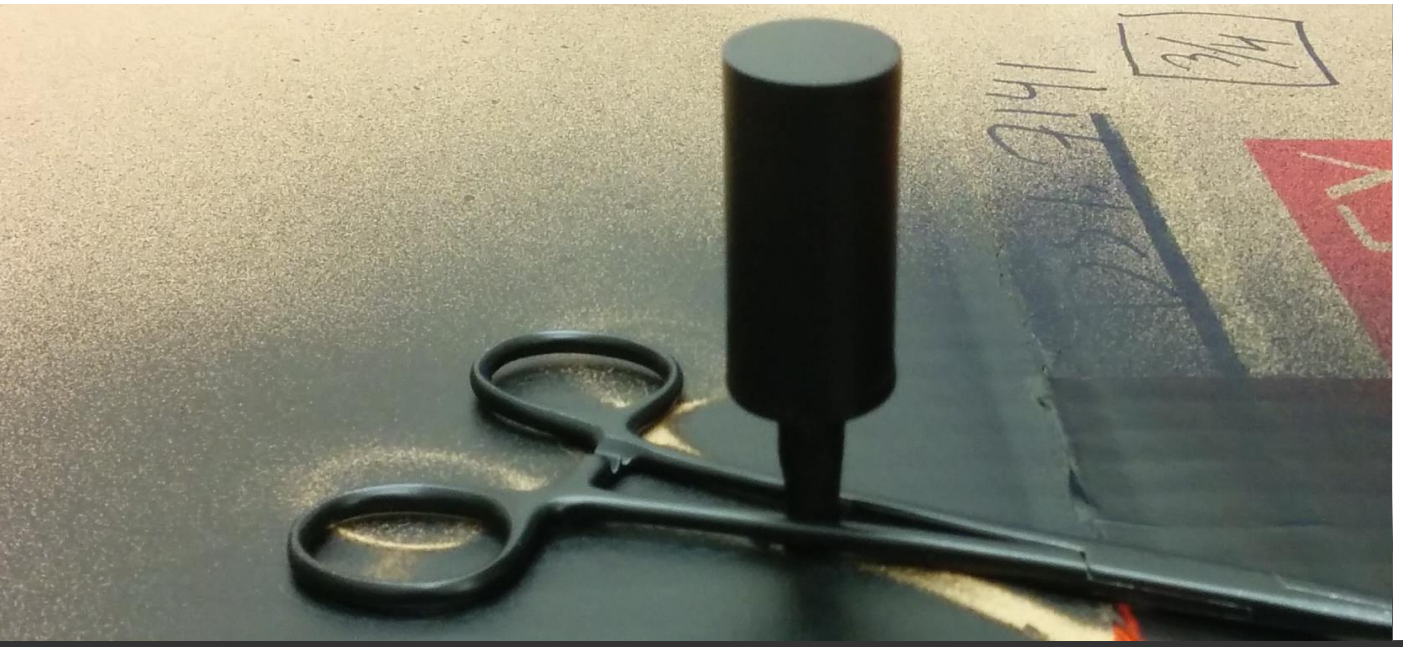
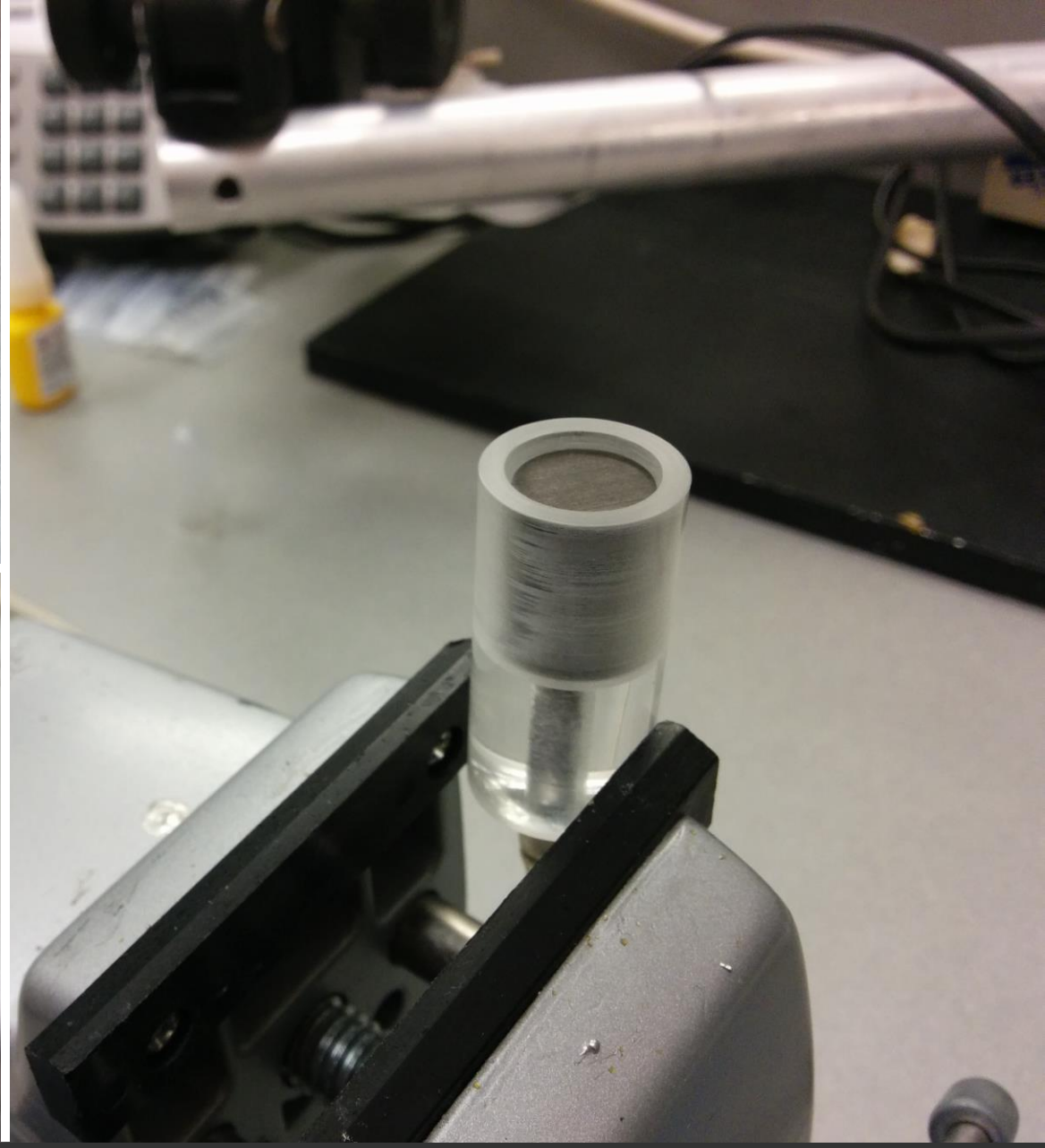
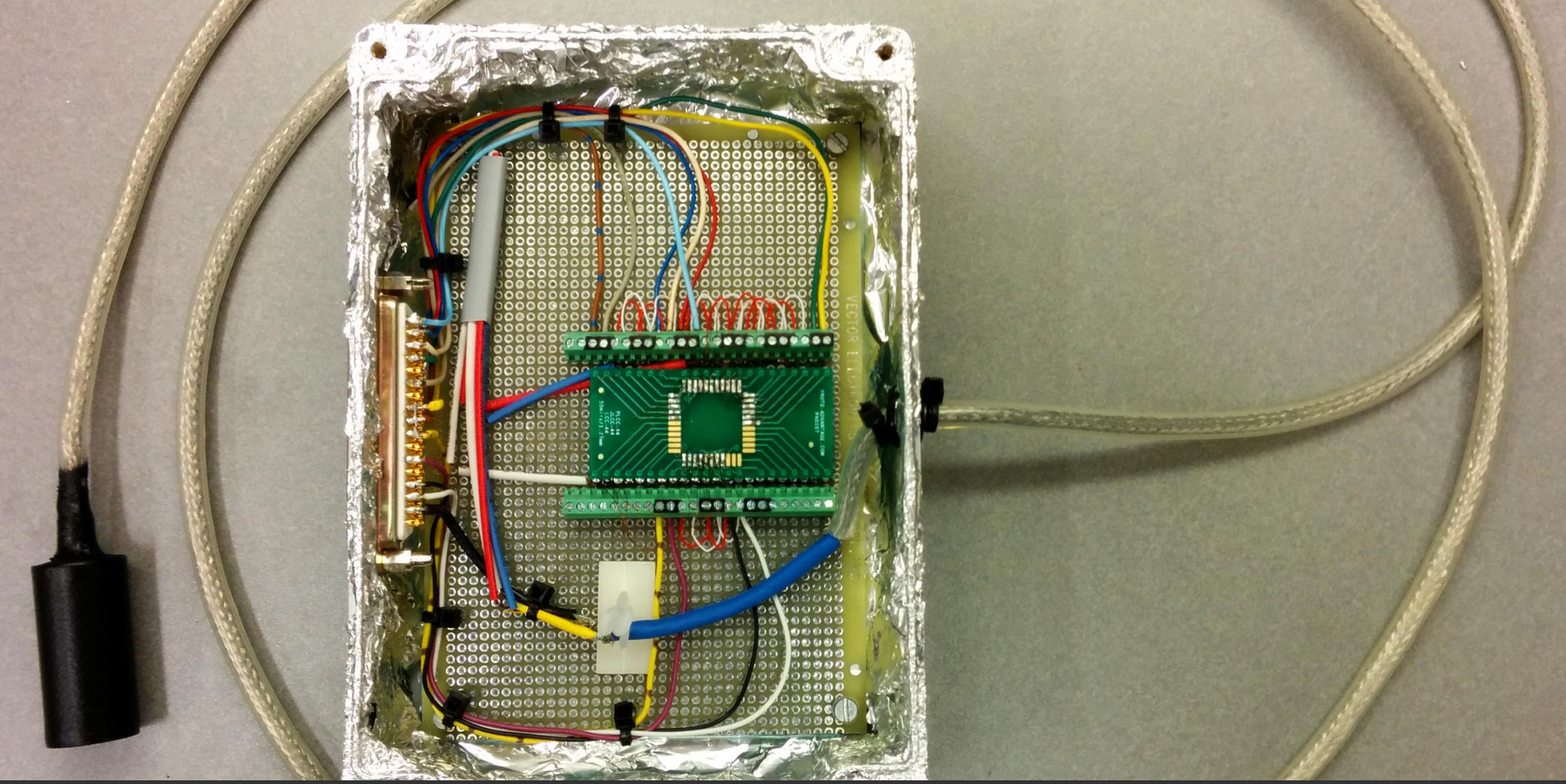






# Early Prototype Construction





# Aerogel Thermal Insulator

PART III

# INITIAL TESTING

EXPERIMENTAL RESULTS



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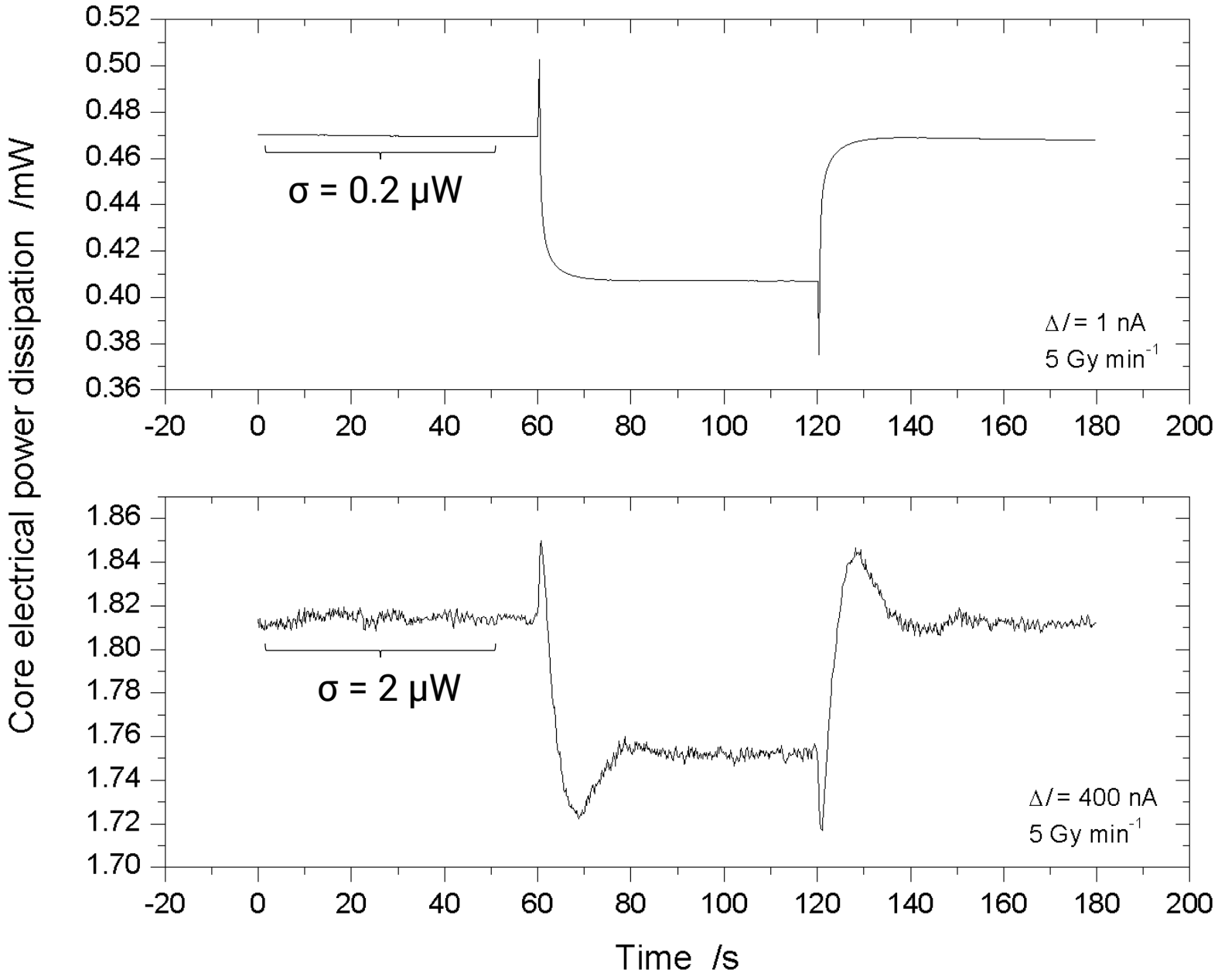
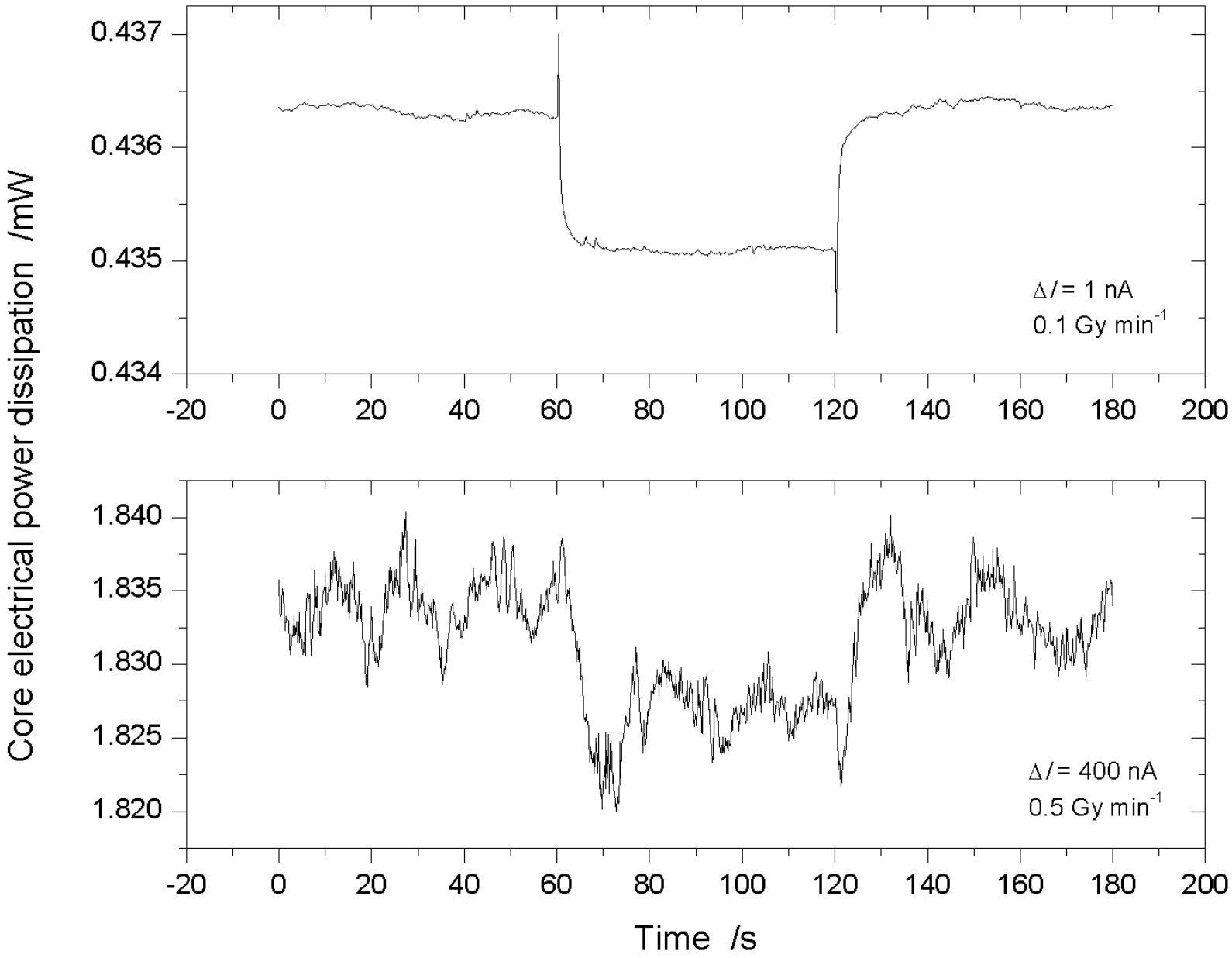





# Aerogel Thermal Insulator






# Aerogel Thermal Insulator

McGill

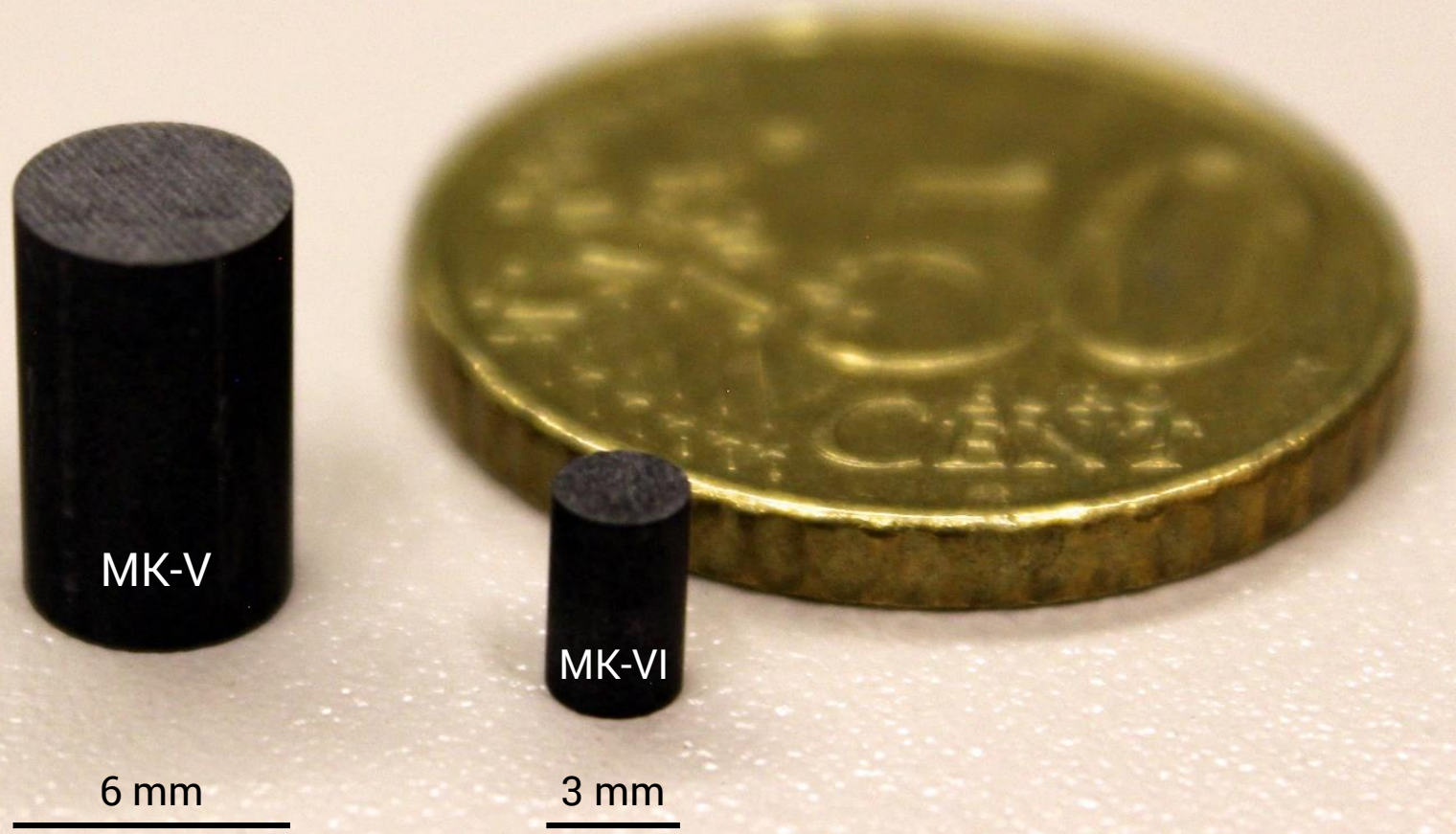
PART IV

# FUTURE DIRECTIONS

VALIDATION AND REFINEMENT

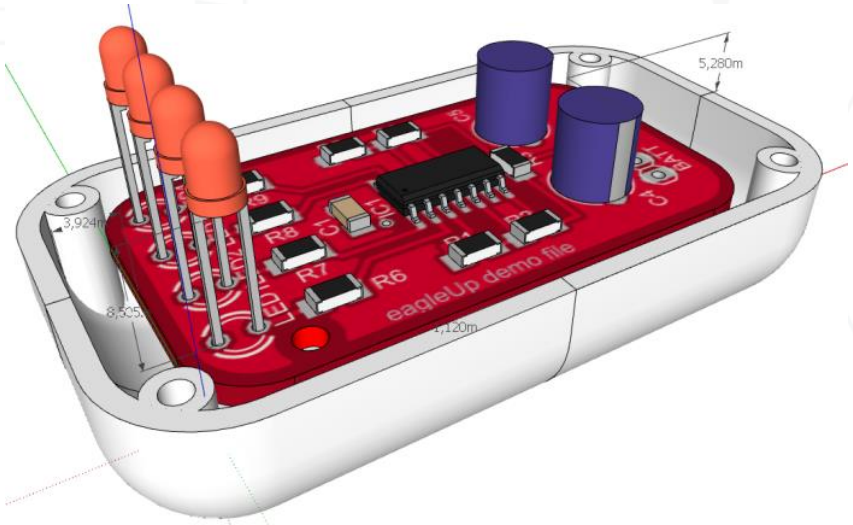


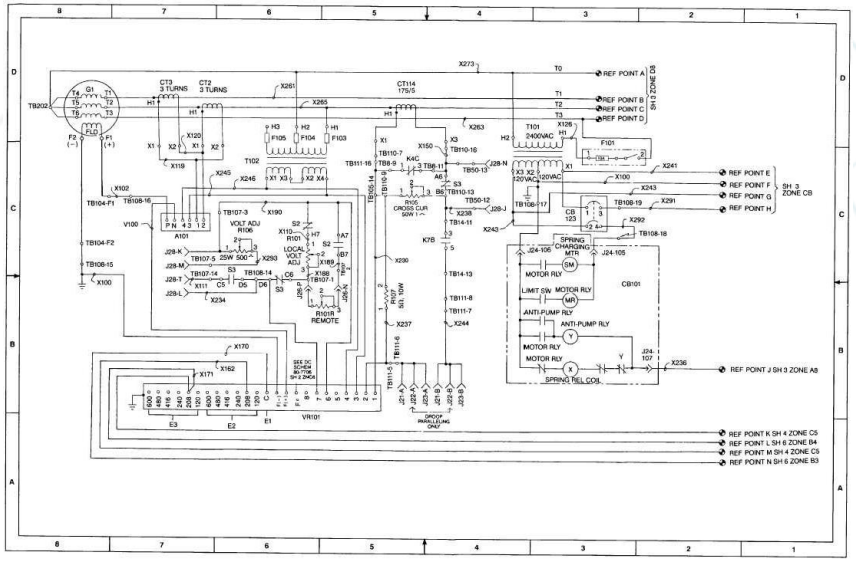
McGill





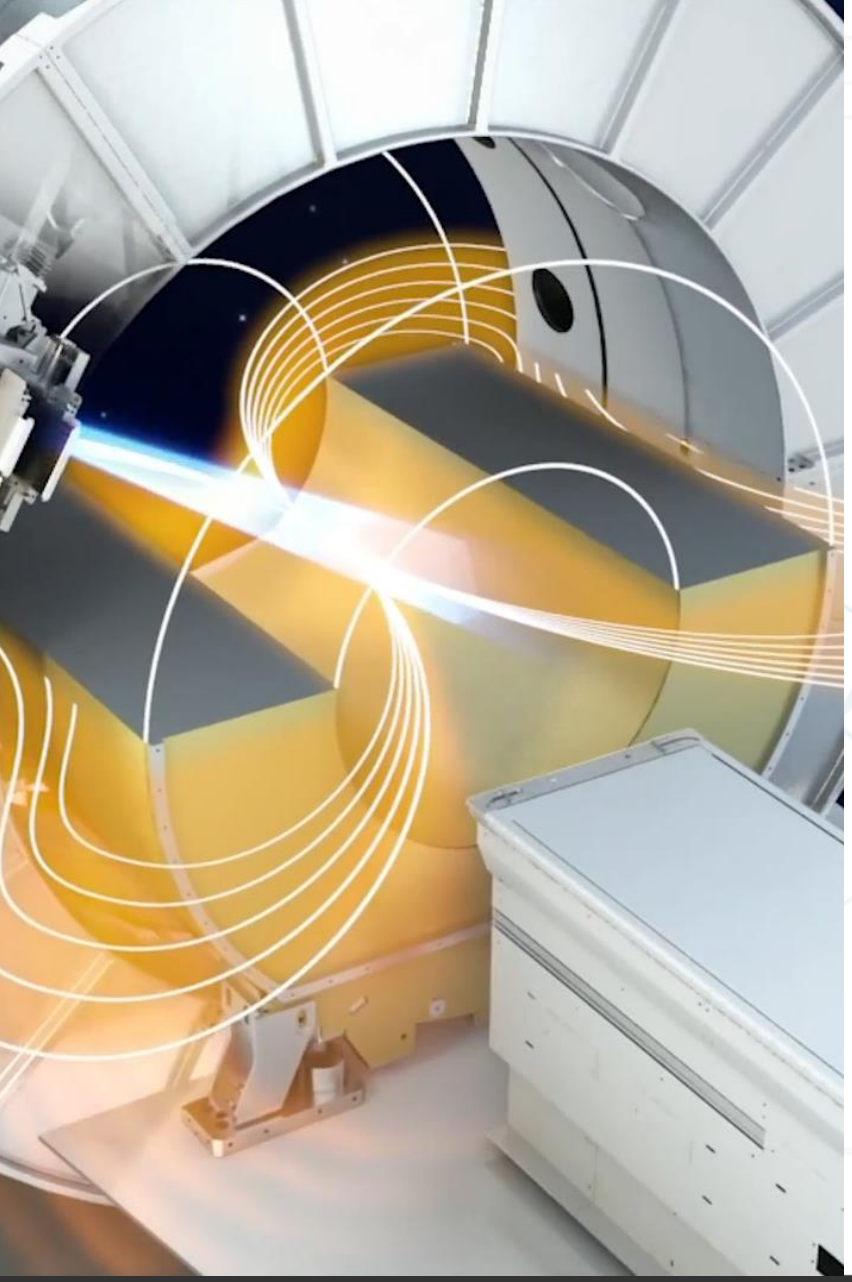

# Device Miniaturization

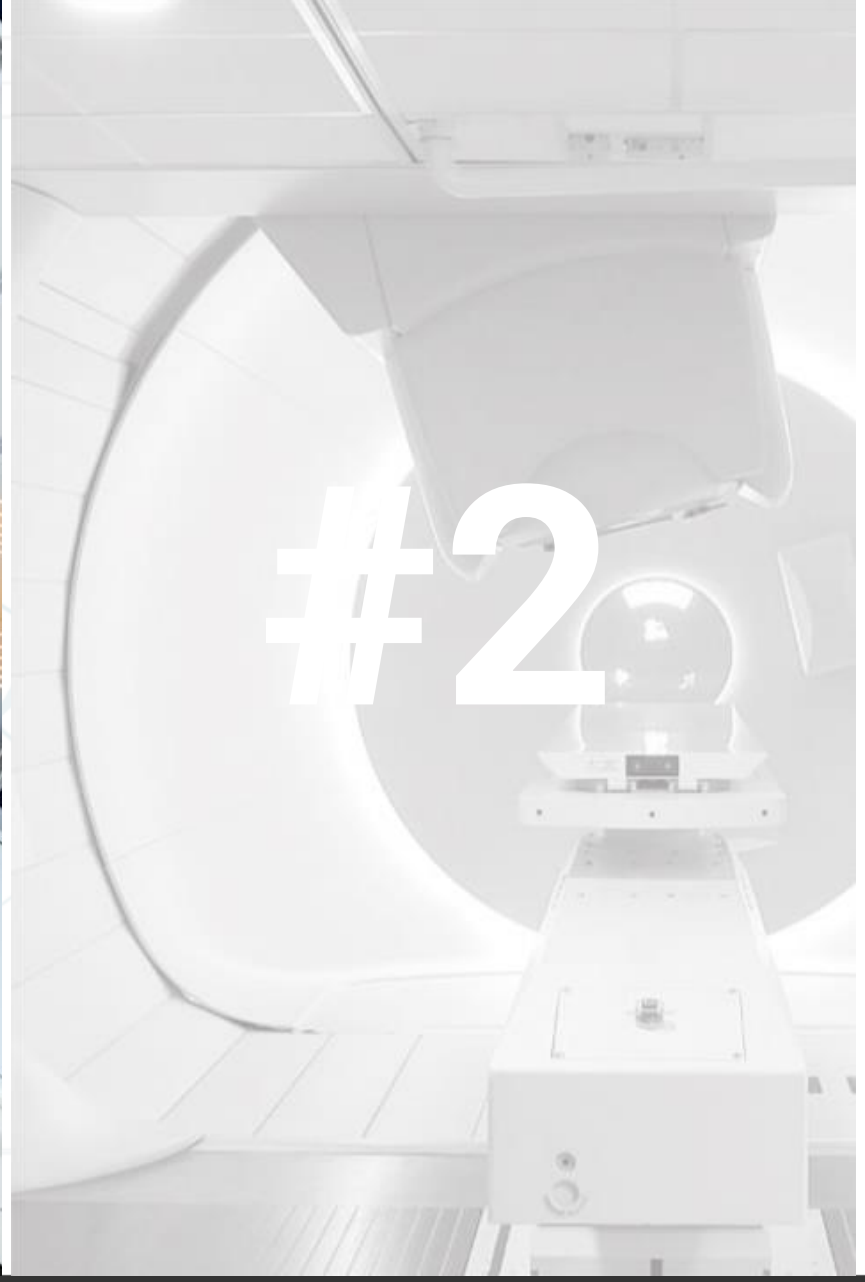




# Electronics Engineering









# New Applications





# New Applications






# New Applications

For more information visit caldose.com

Project portfolio, entirely non-commercial

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[1]McGill University, Montréal, Canada

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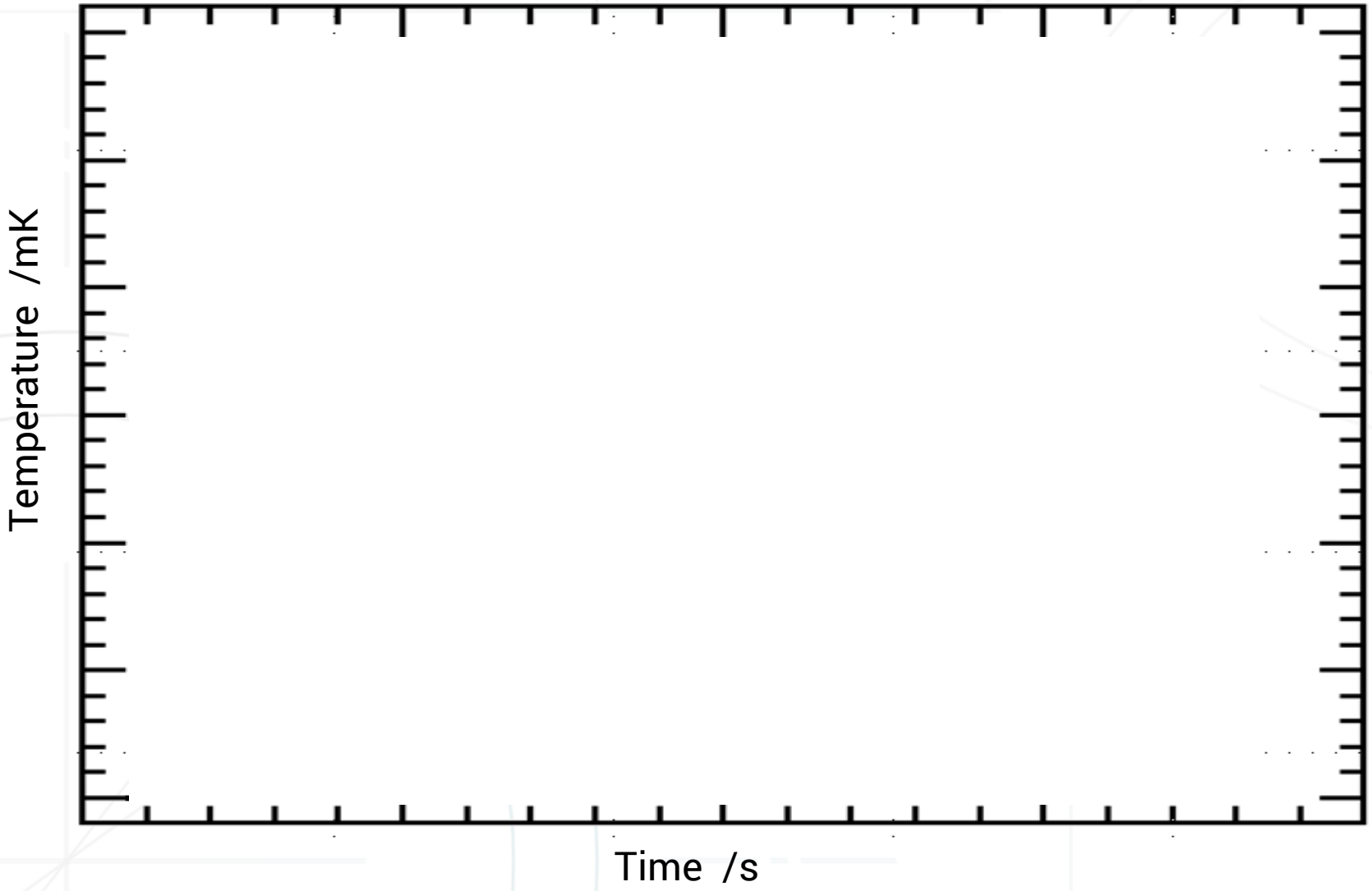
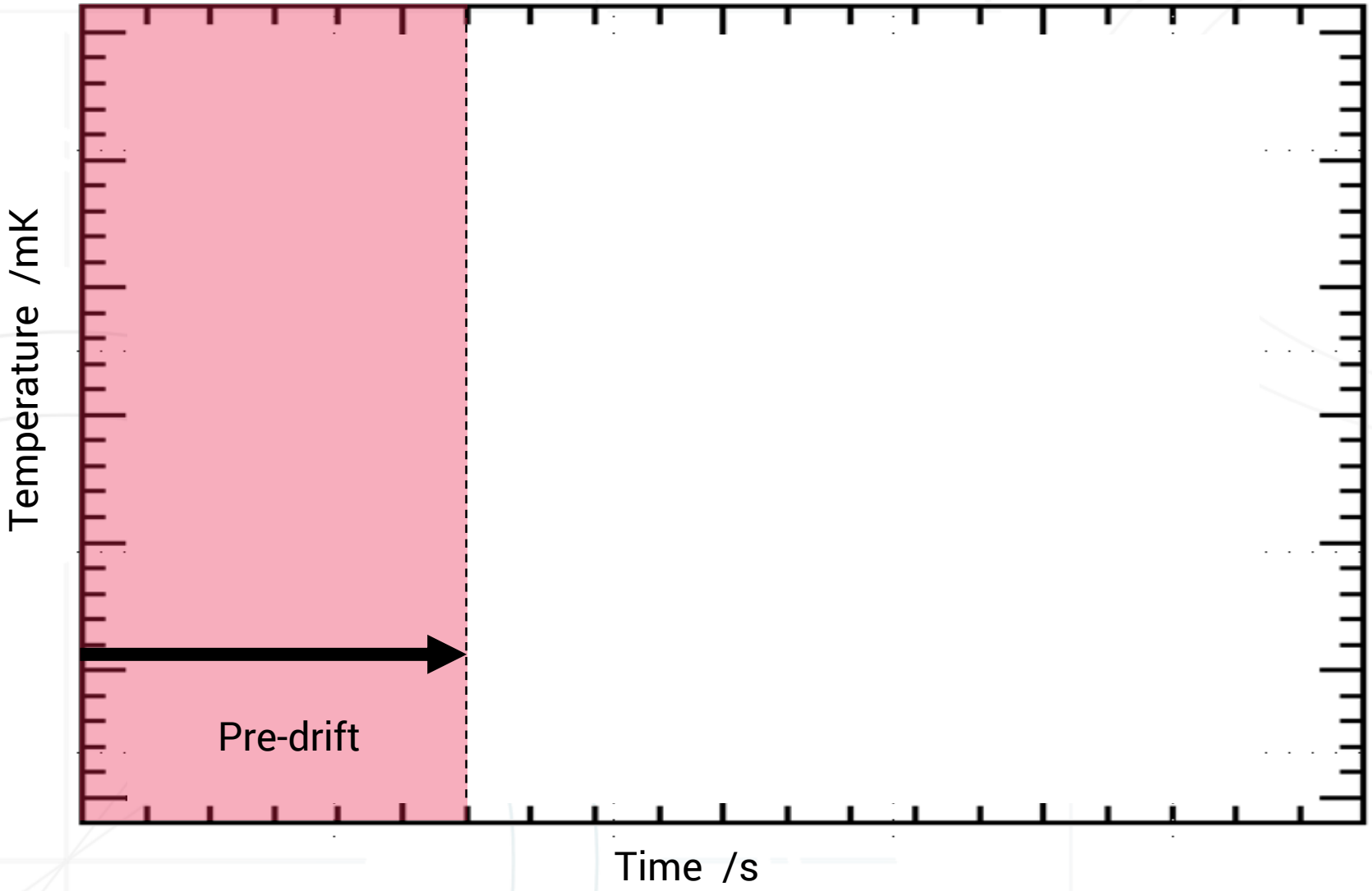


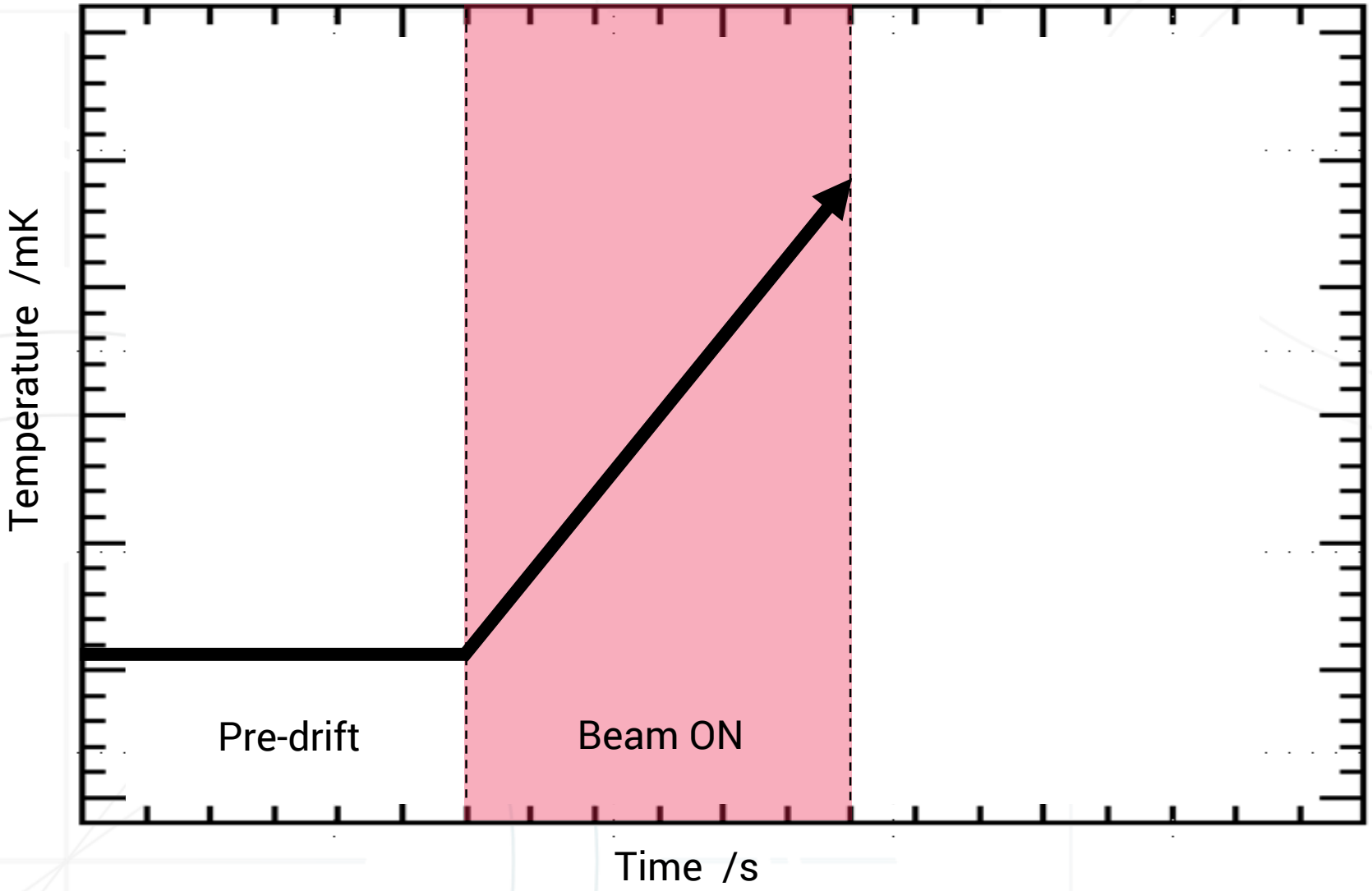



# Adiabatic Mode






# Adiabatic Mode



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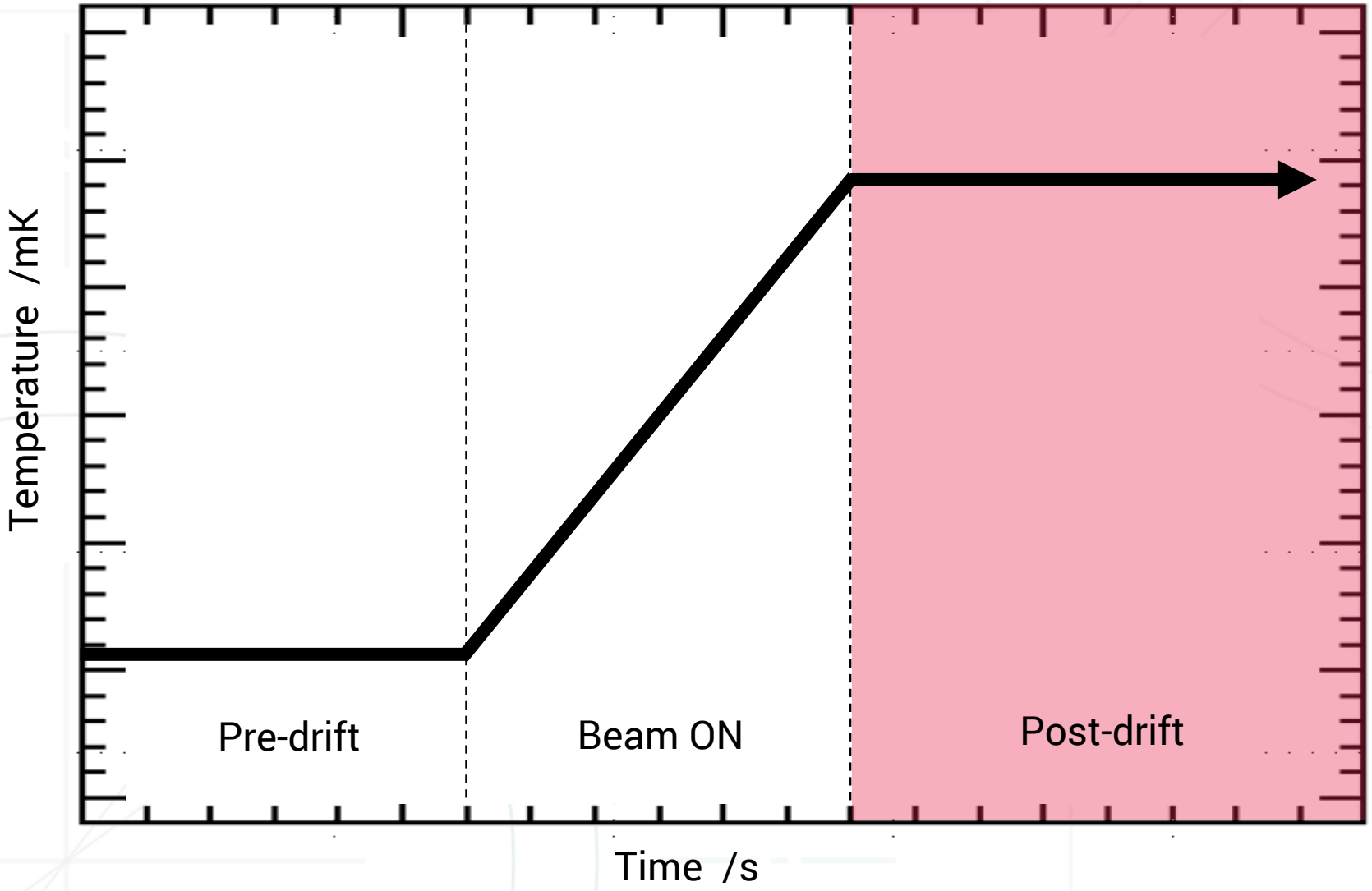
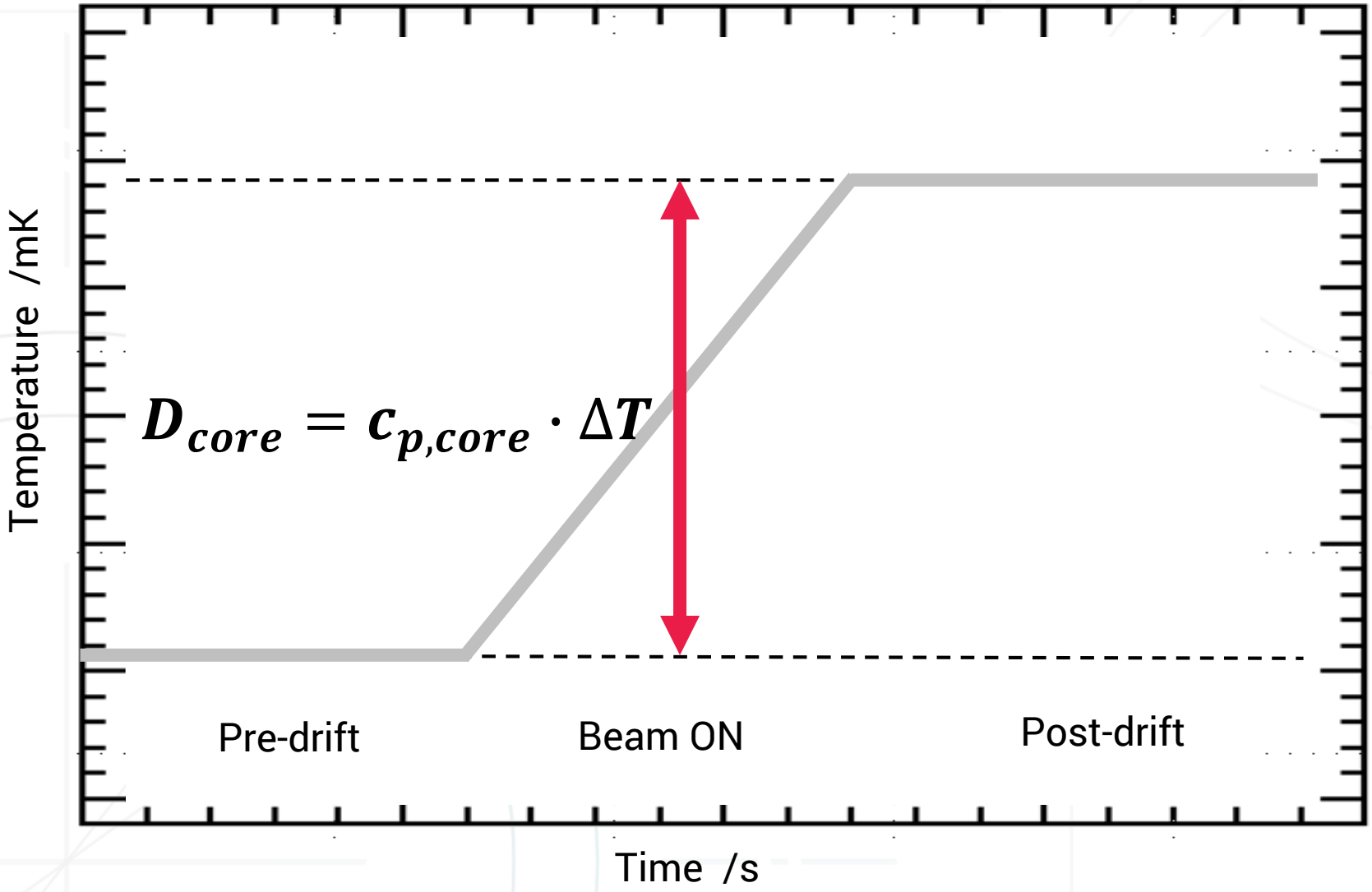




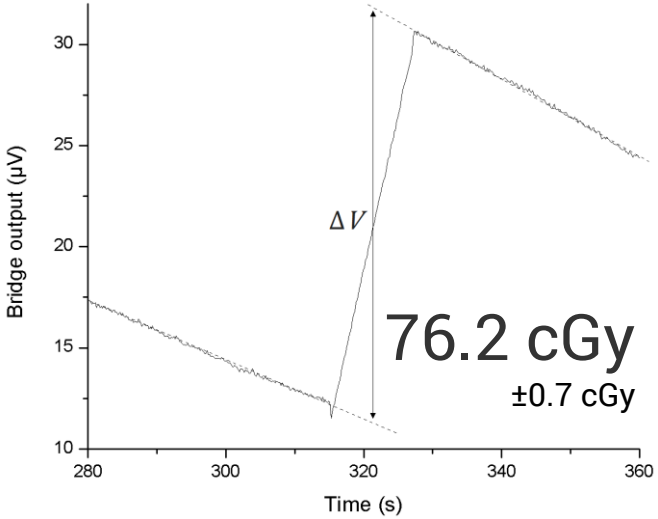

# Adiabatic Mode



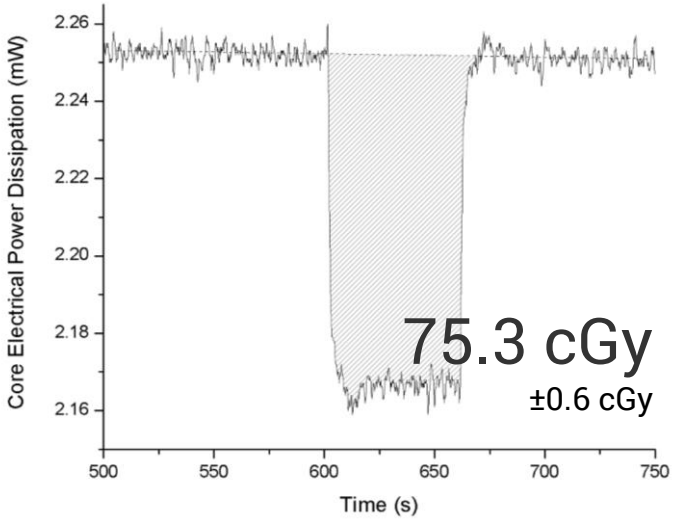



# Adiabatic Mode


Reference-class chamber (TG-51)



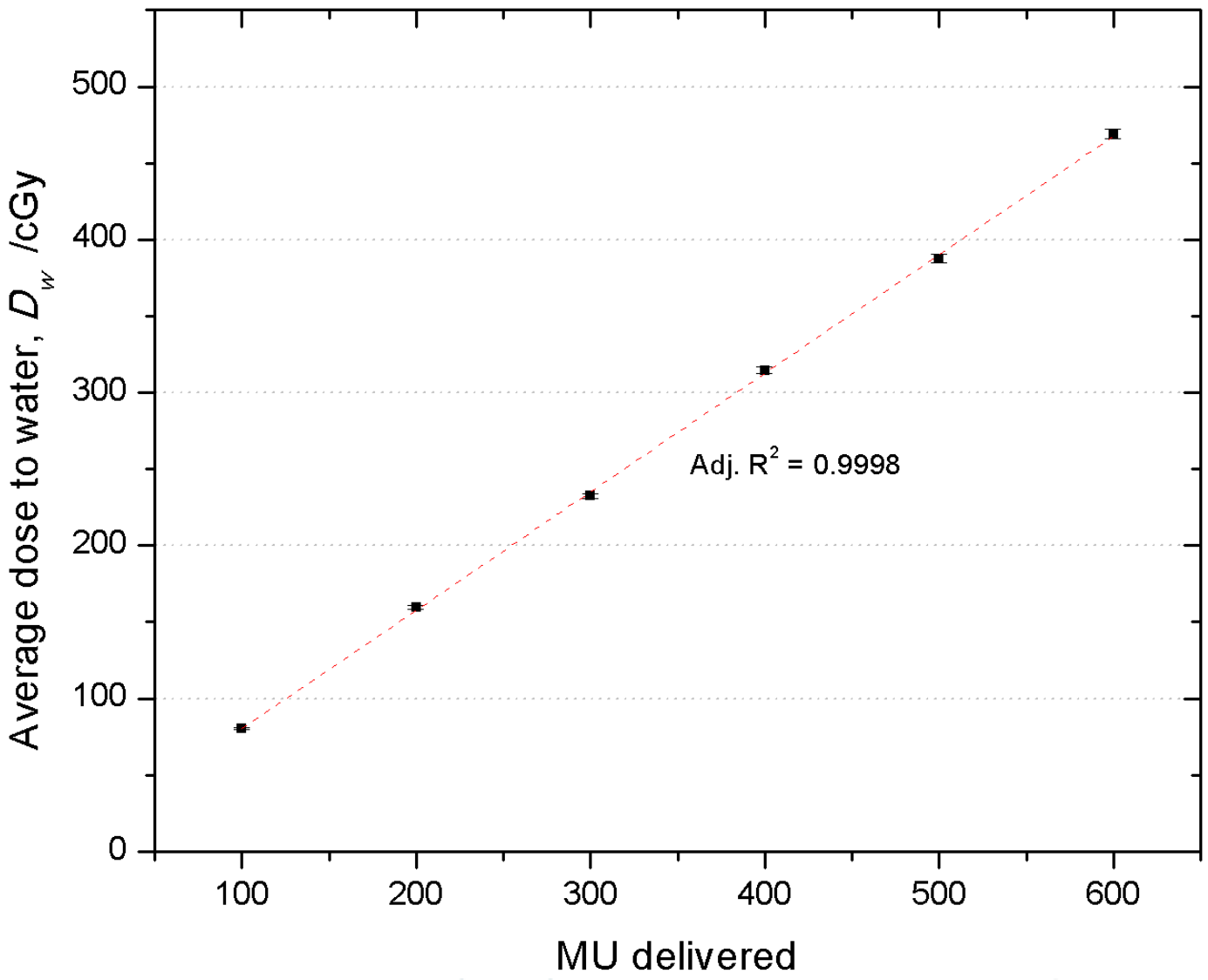

Aerrow: Quasi-adiabatic




Aerrow: Isothermal

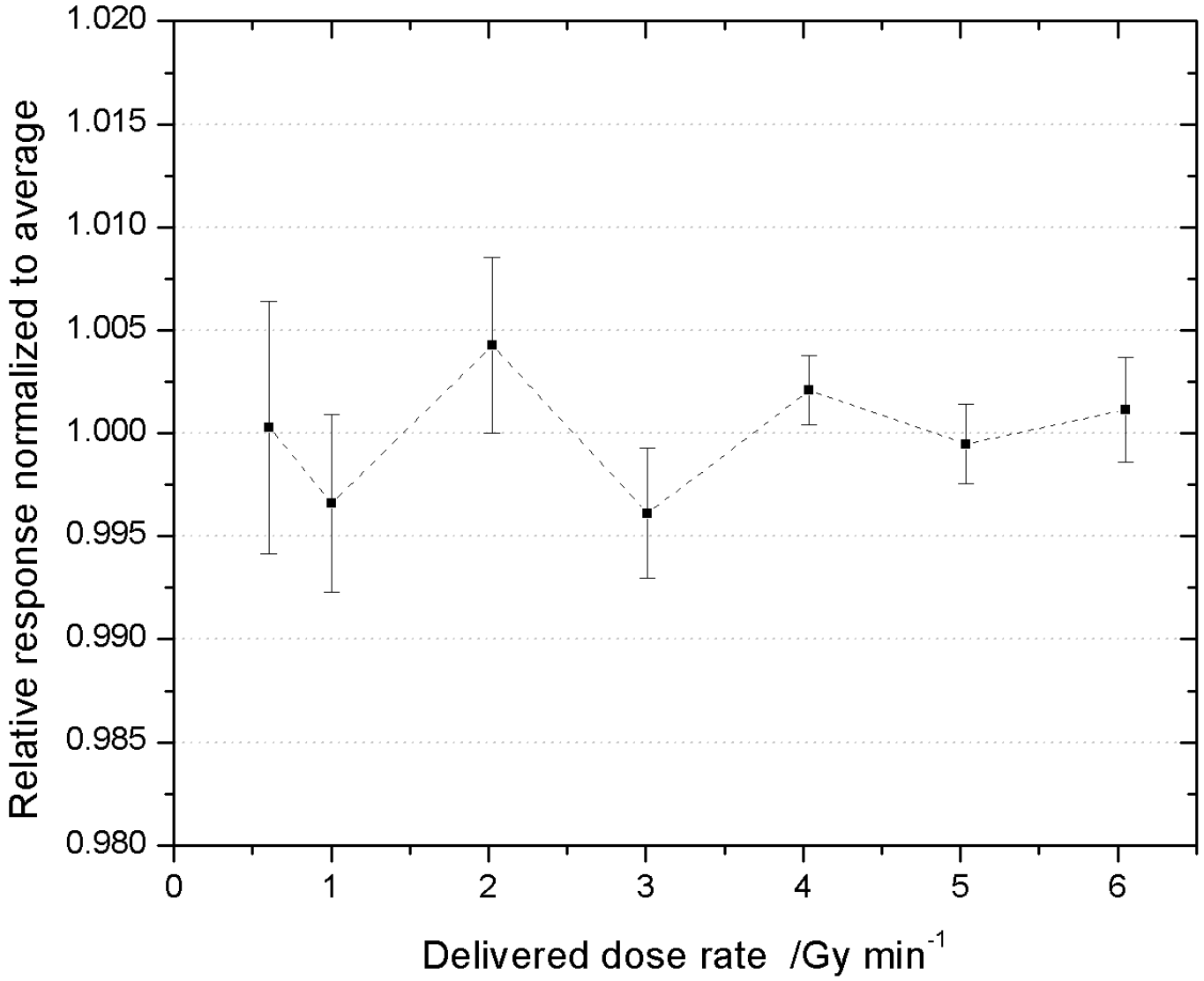


# Reference Dosimetry Comparison


Average dose to water, $D_w$ /cGy
0
100
200
300
400
500
100
200
300
400
500
600
MU delivered
Adj. $R^2$ = 0.9998

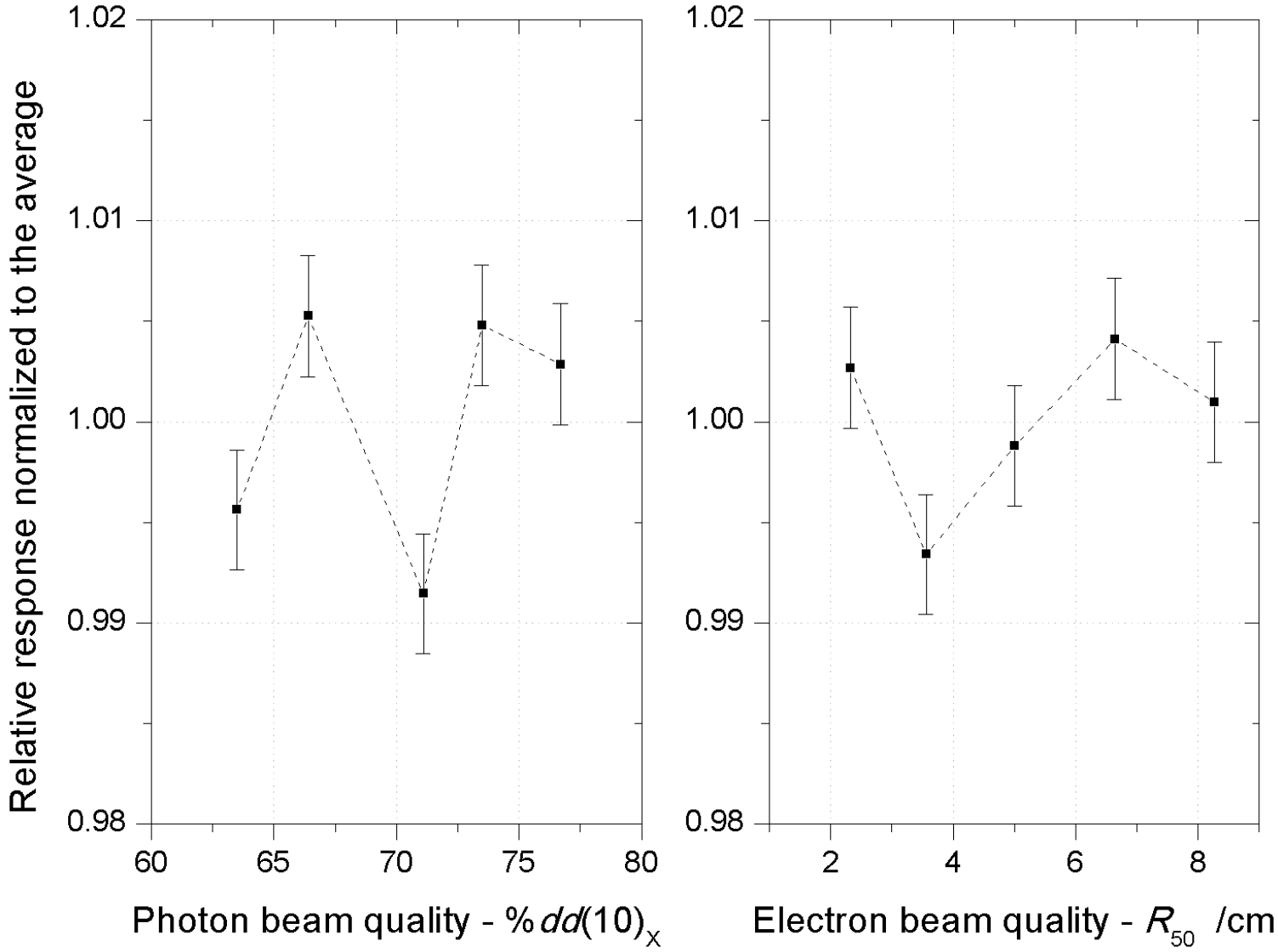


# Linearity



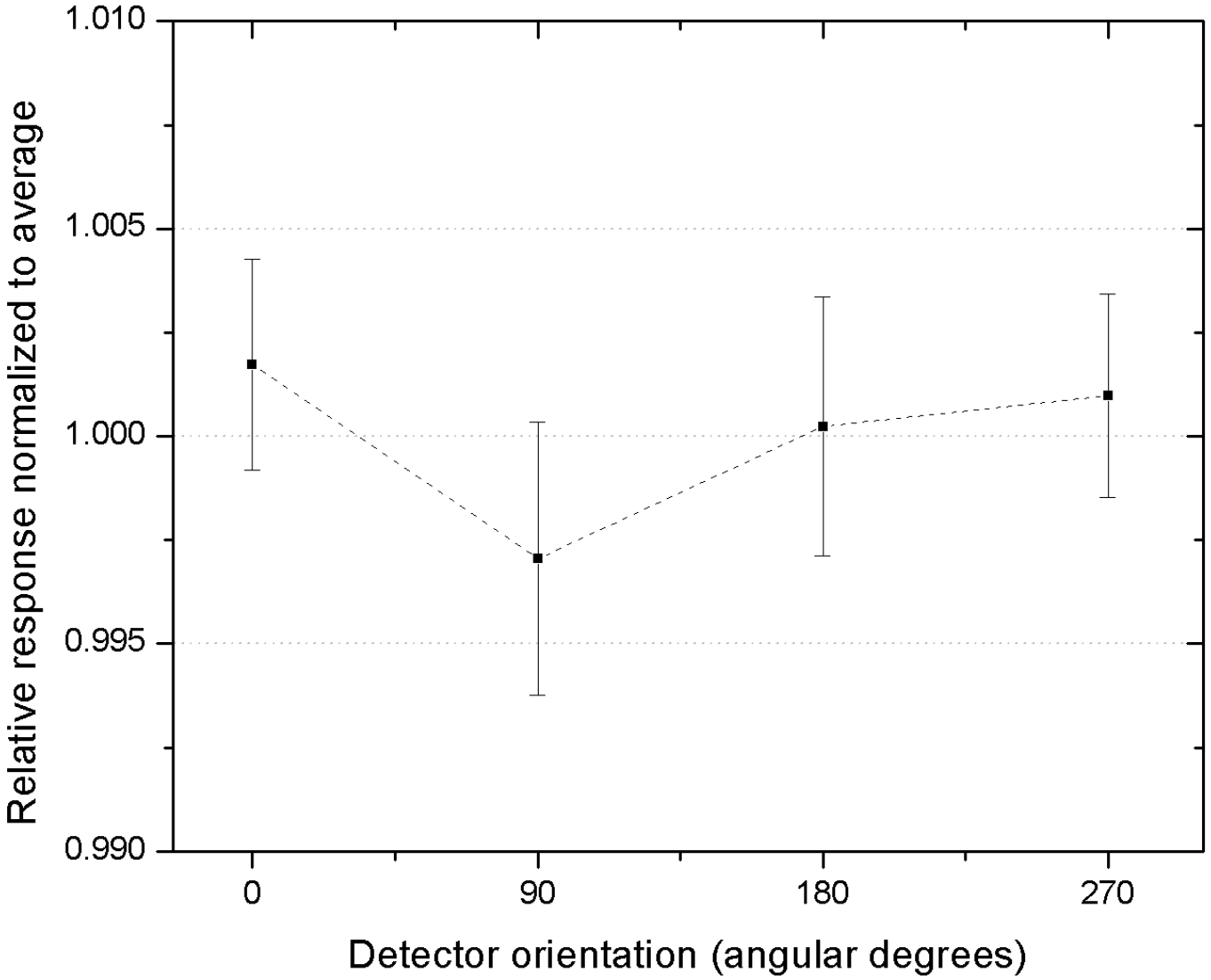



# Dose Rate Dependence



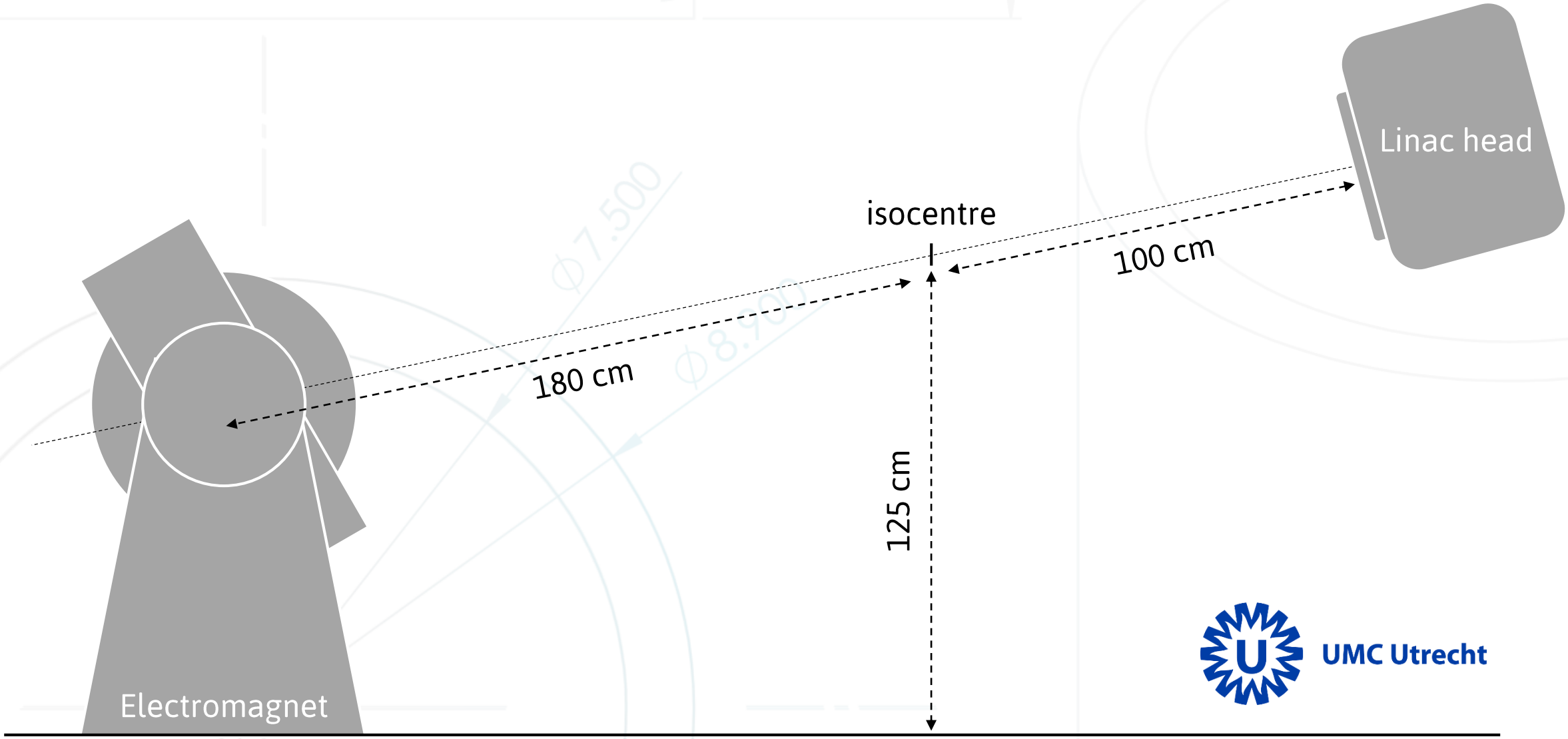



# Relative Calorimeter Response





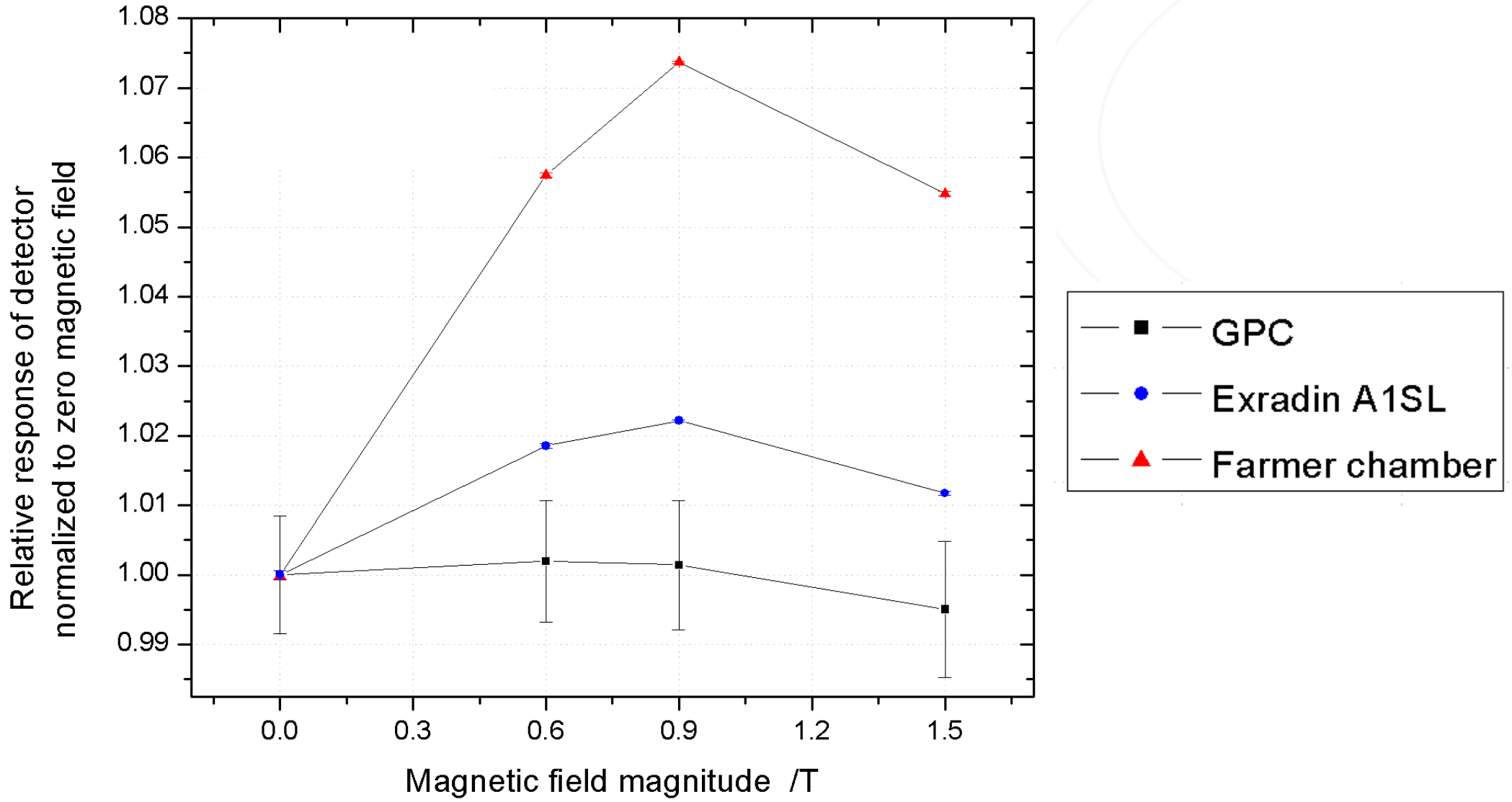

# Orientation Dependence




UMC Utrecht



# Utrecht Research Linac and Electromagnet






# Perpendicular *B*-field Dependence

(1) Routine clinical reference dosimetry with The Aerrow is within reach



The Take Away

(1) Routine clinical reference dosimetry with The Aerrow is within reach

(2) Compared to chambers, The Aerrow is much less energy dependent and requires fewer correction factors



## The Take Away

(1) Routine clinical reference dosimetry with The Aerrow is within reach

(2) Compared to chambers, The Aerrow is much less energy dependent and requires fewer correction factors

(3) The Aerrow's accuracy is currently on par with current TG-51, but has significant room for improvement (~0.5 %)



## The Take Away