The Feasibility of Energy-Based Dosimetry for Low-Energy, Photon-Emitting Brachytherapy Sources

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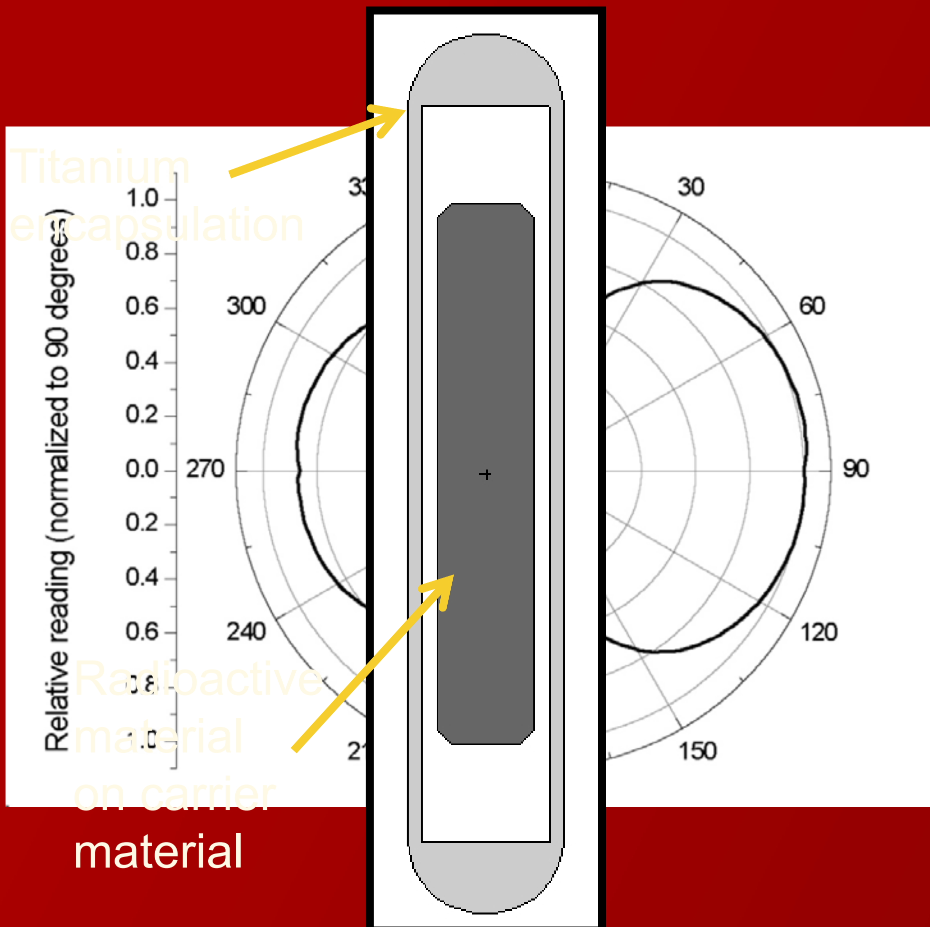
Outline

- **Introduction**
- Source Anisotropy
  - Methods and Materials
  - Results
- Source Strength
  - Methods and Materials
  - Results
- Conclusions

Introduction: Brachytherapy Source Dosimetry



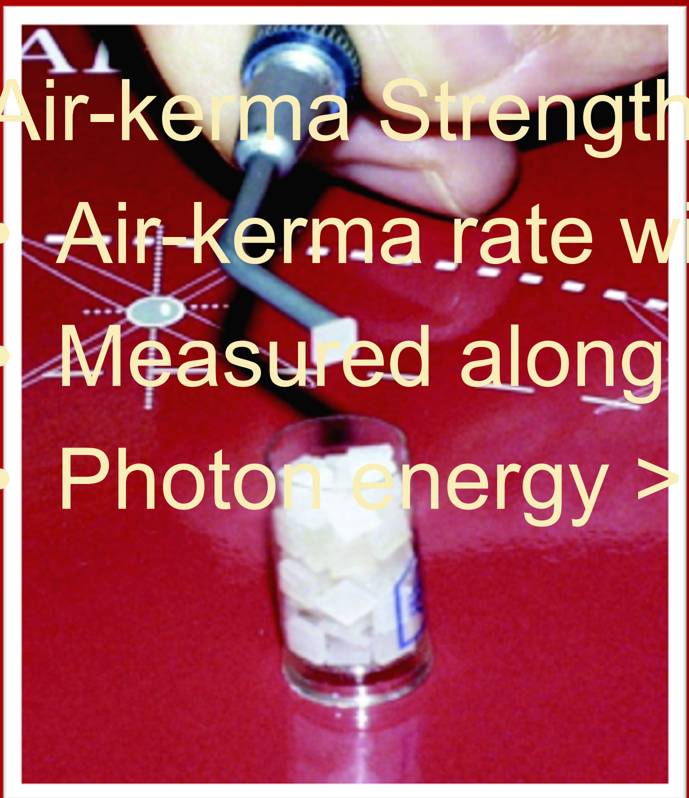
Requires Quantifying:

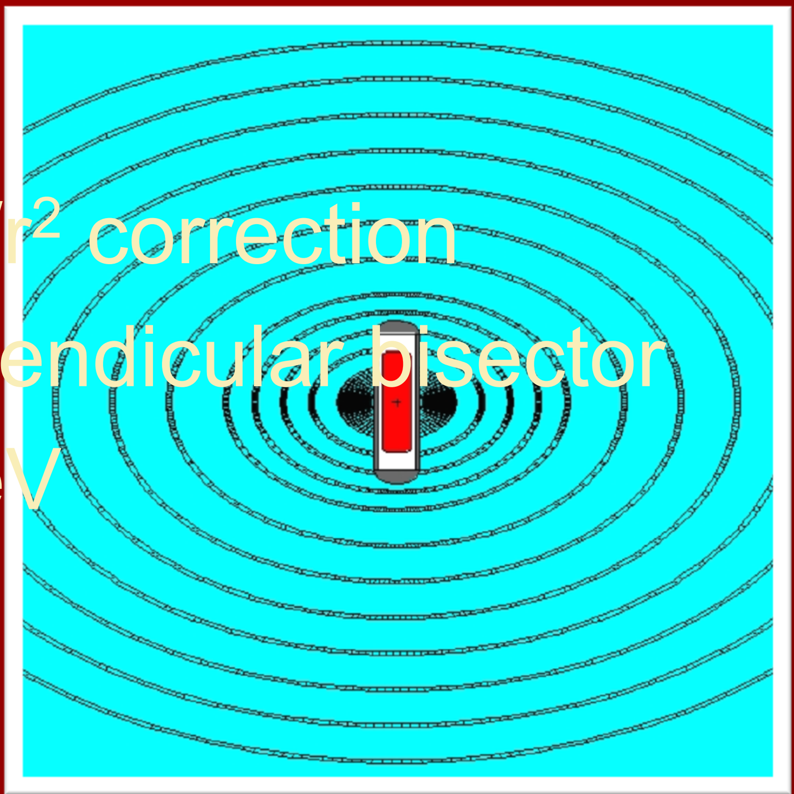
- Source strength
- Anisotropic emission

W. Culberson *Large-Angle Ionization Chambers for Brachytherapy Air-Kerma-Strength Measurements.* PhD Thesis, UW-Madison 2006.

Introduction:
AAPM's Task Group 43 Report

Quantity:	Quantified By:
Source Strength	Air-Kerma Strength (AKS)
Anisotropic Source Output	Dose To Water





Air-kerma Strength:

- Air-kerma rate with $1/r^2$ correction
- Measured along perpendicular bisector
- Photon energy > 5 keV

Introduction: Limitations of TG43 Source Characterization

- AKS is not readily adapted to dosimetry
  - Must be converted to dose to water
  - Conversion introduces uncertainty

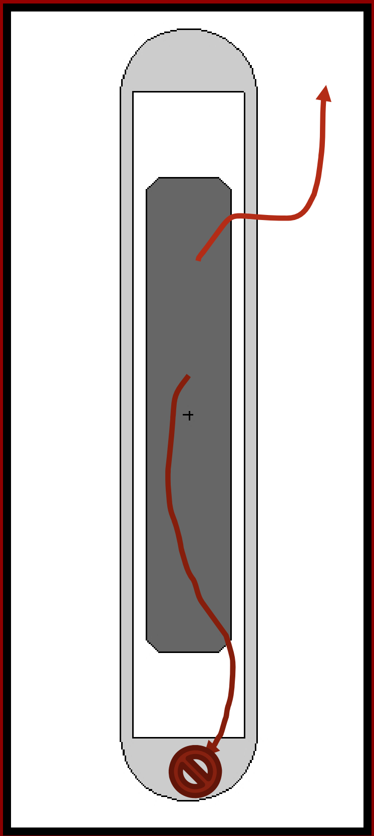
- Constrained to dose to water
  - No heterogeneity corrections
  - Some implant locations have large heterogeneities

Introduction: Proposed Source Characterization

Quantity:	Quantified By:
Source Strength	Emitted Power (EP)
Anisotropic Source Output	Emitted Energy Spectrum

- Emitted Power: Total energy emitted
- Emitted Energy Spectrum: geometric distribution of the emitted energy

- Propagate measured spectrum through Monte Carlo to compute TG43 parameters
- Use as source input for Model-Based Dose Calculation Algorithms



Introduction: Emitted Power

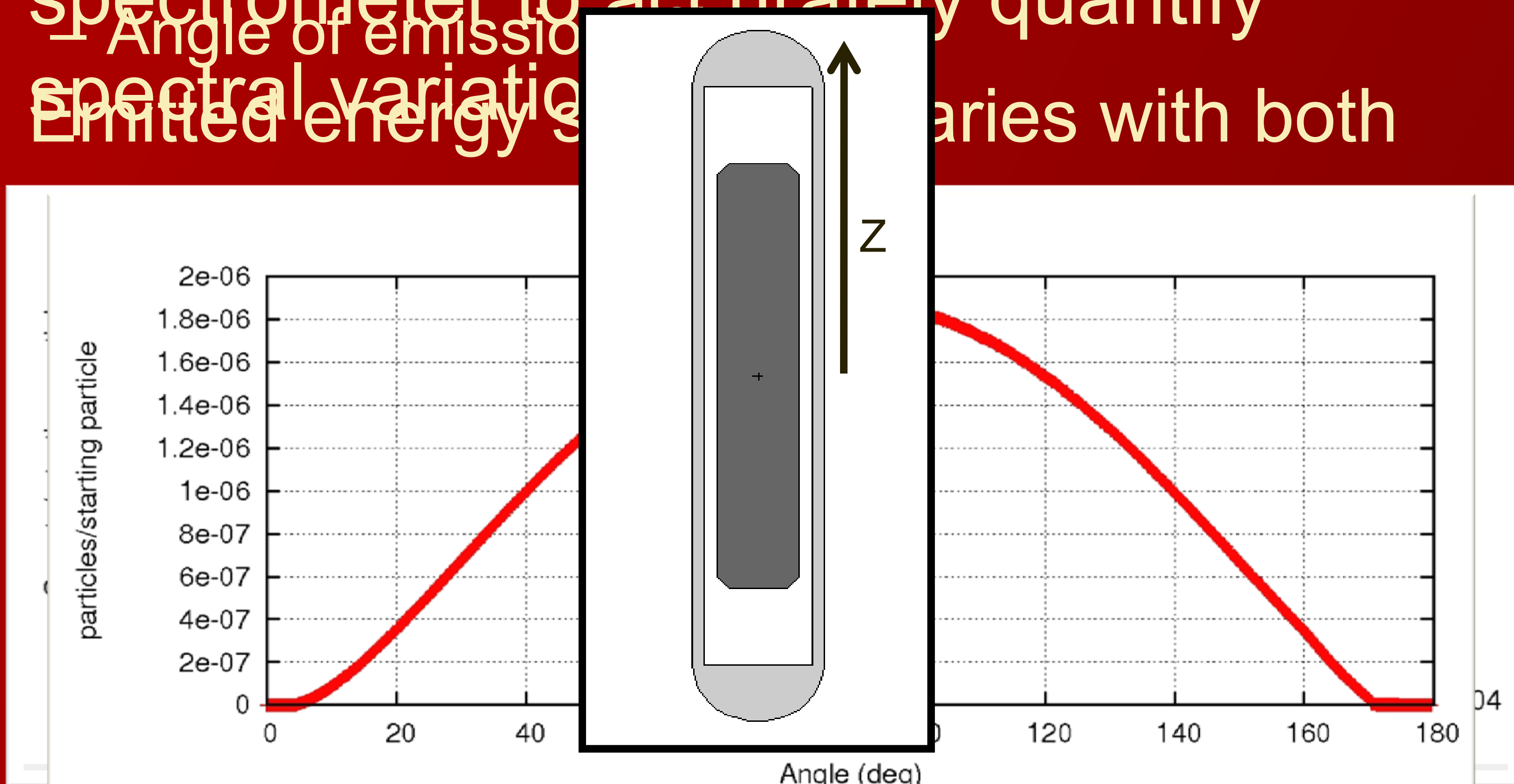
Source Material	AKS [U]	Anticipated EP [μW]
I-125	10	2.5
Pd-103	3	0.7

- Goal of current work: Design for and feasibility of a primary standard for emitted power
- Requires instrument capable of absolute measurement: Calorimeter
- Measurement must differentiate between self-absorbed and emitted powers

Introduction: Emitted Spectrum

- Goal of current work: determine measurement resolution required by a spectrometer to accurately quantify spectral variatio[n]

- Initial work shows fluence varies as a function of:
  – Vertical coordinate (Z)
  – Angle of emissio[n]
- Emitted energy s[...]aries with both



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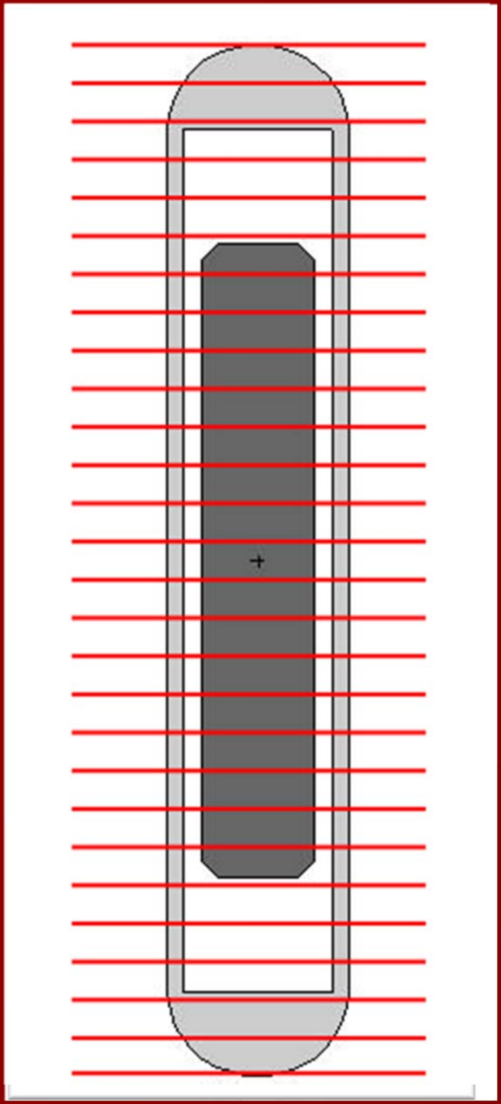
Source Anisotropy: Vertical Resolution Methods

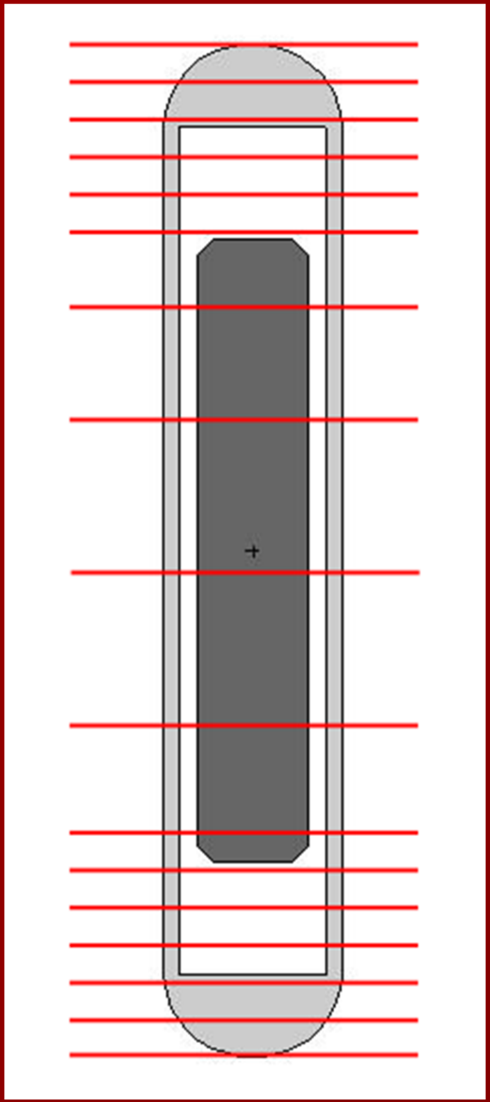
- Oncura 6711 modeled with MCNP5 v1.60
- 5 µm wide segments
- F1 tally of fluence emitted from encapsulation within each segment

- Adjacent segments combined until gradient in fluence across combined segment reached a given tolerance
- Tolerances: 0.1%, 0.5%, 1%, 2%, 5%



Source Anisotropy: Angular Resolution Methods

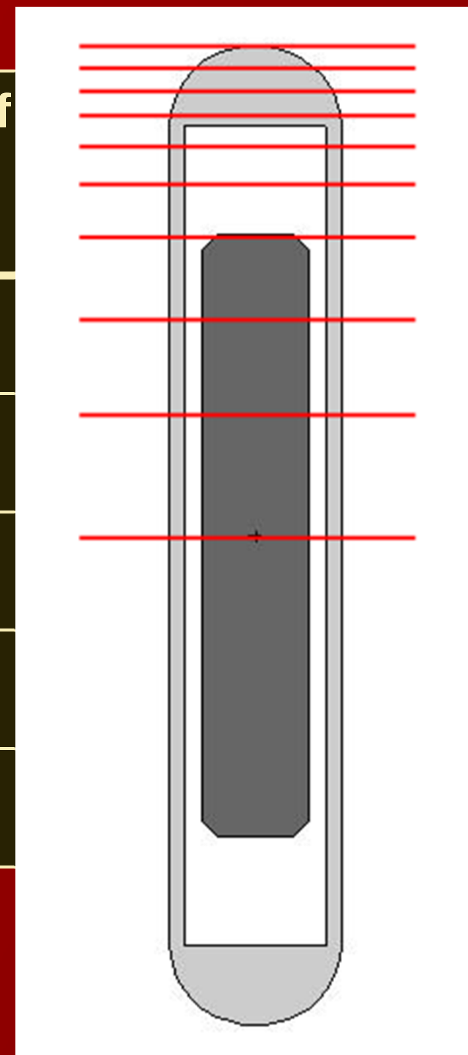
- Utilizing 0.5% vertical tolerance
- Angle of Emission binned in 0.25º segments
- Adjacent angular segments combined until fluence gradient across segments reached a specified tolerance
- Tolerance: 0.5%



Source Anisotropy: Vertical Resolution Results

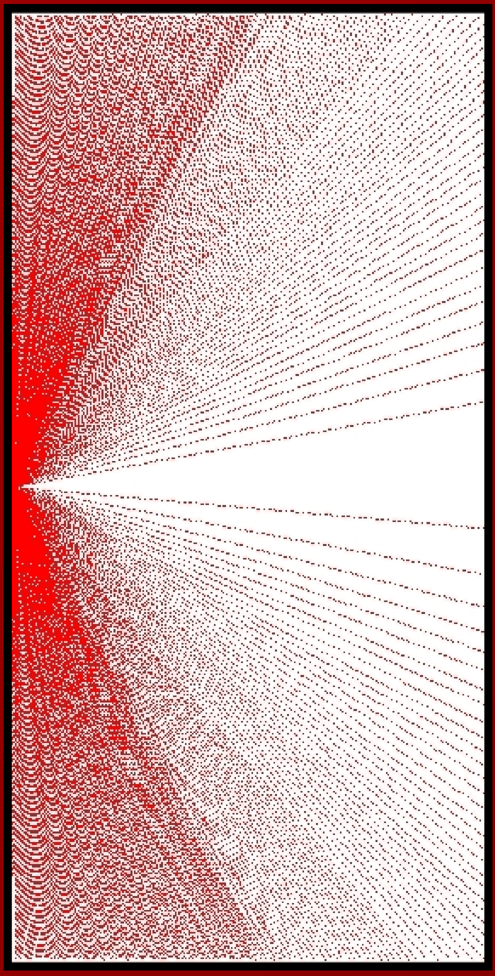
- Segment width varies with Z
- Wit
  - V
  - _

Tolerance on Gradient (%)	Number of
0.1%	424
0.5%	314
1%	278
2%	210
5%	82



Source Anisotropy: Angular Resolution Results

- Varies:
  - Function of Z
  - Function of angle
- Largest bin (15.25º):
  - Near perpendicular bisector
- Smallest bin (0.25º):
  - Along Z axis
  - Near end welds



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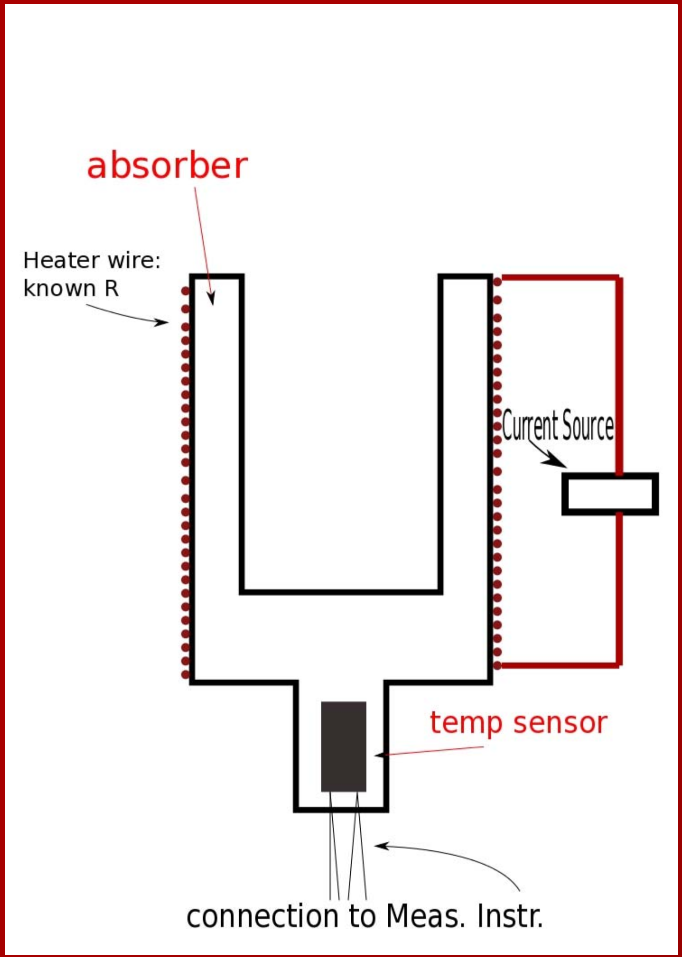
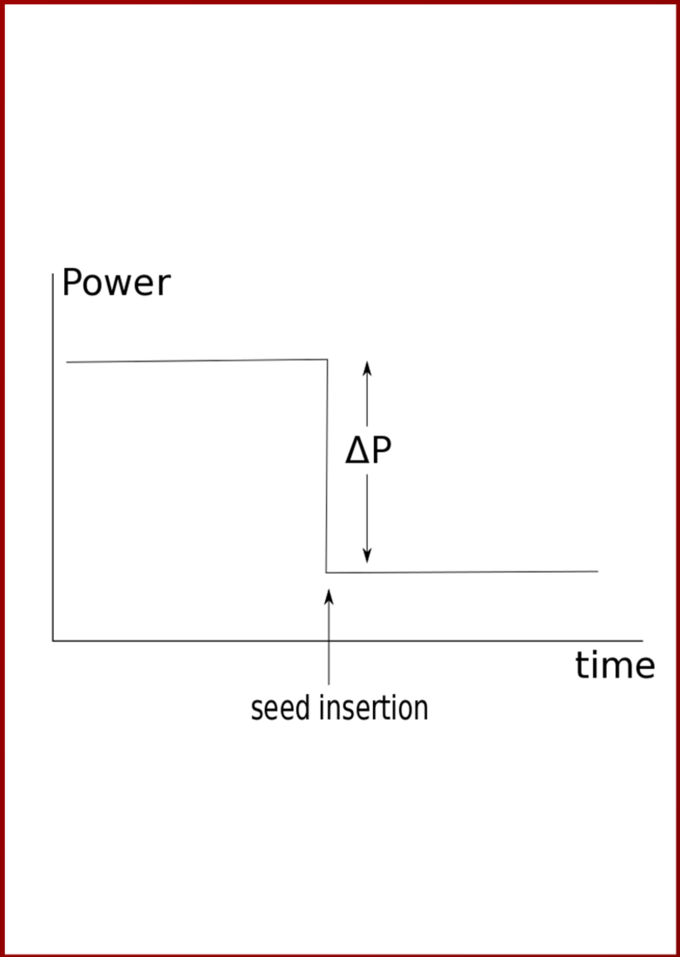
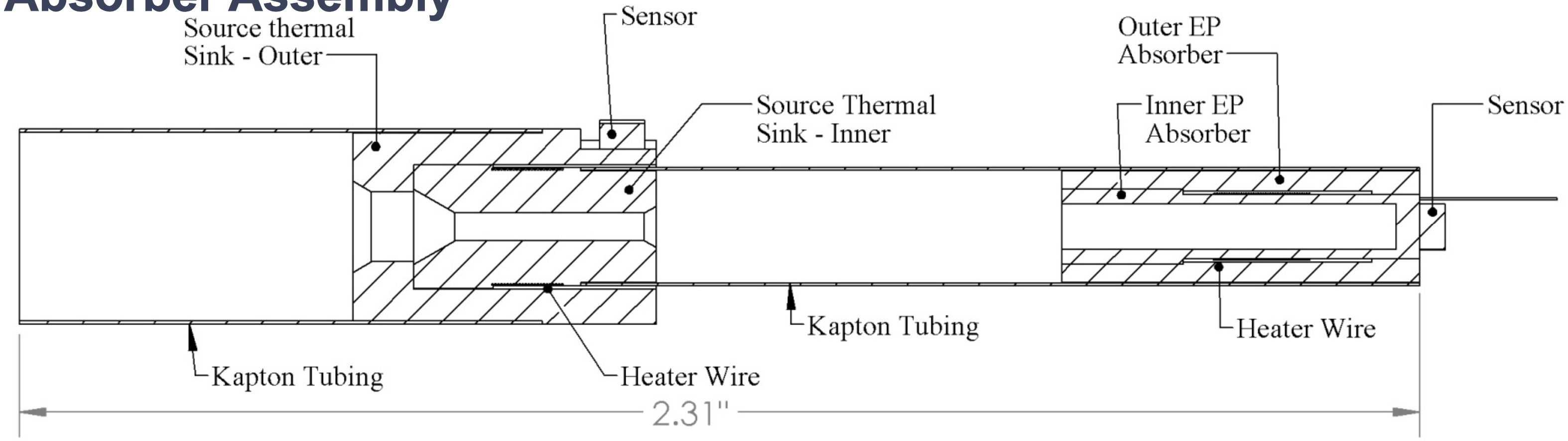
Source Strength: Measurement



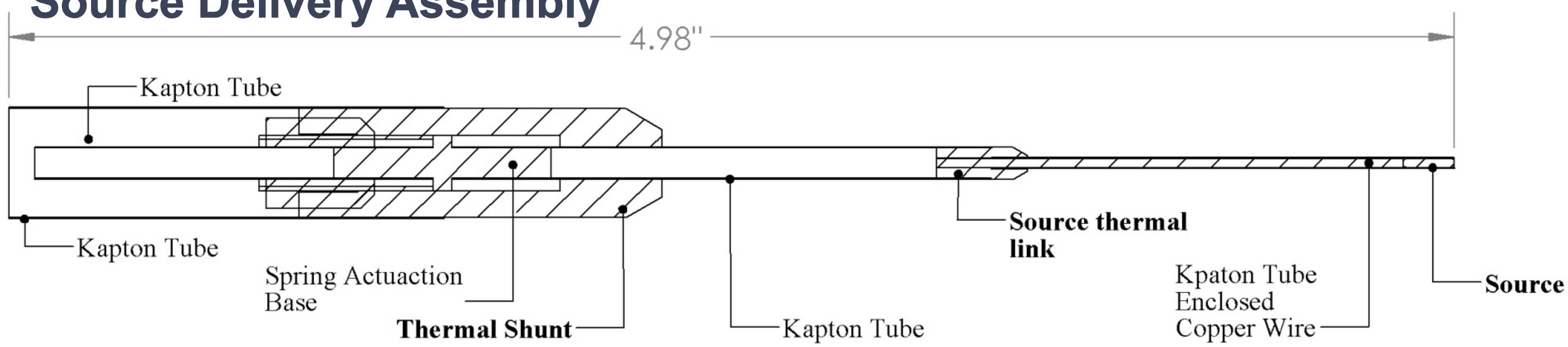


Source Strength: Measurement

Absorber Assembly

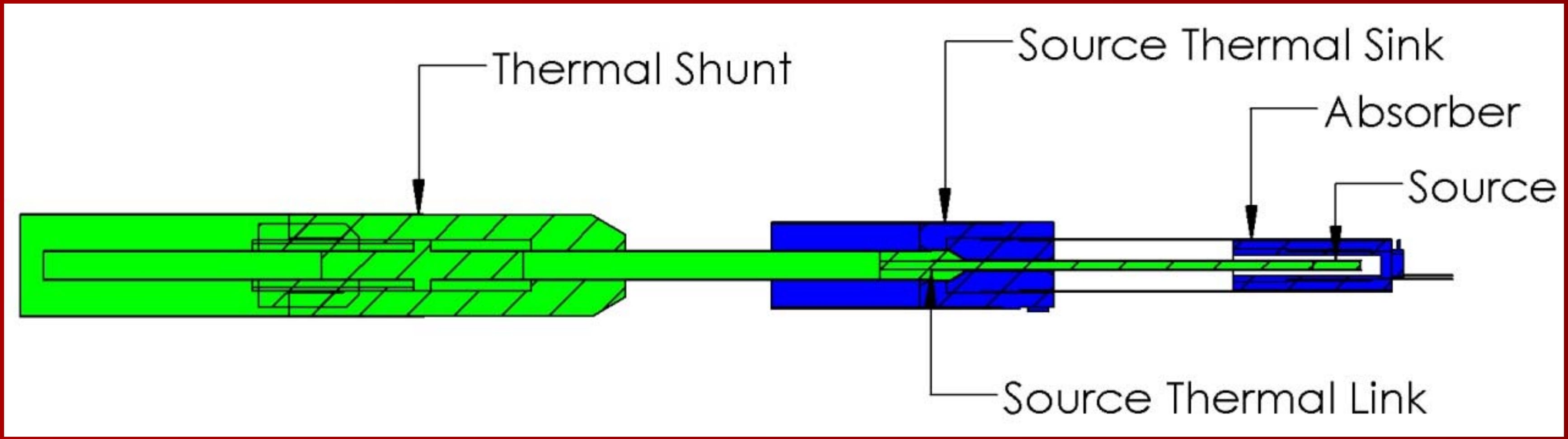


Source Delivery Assembly

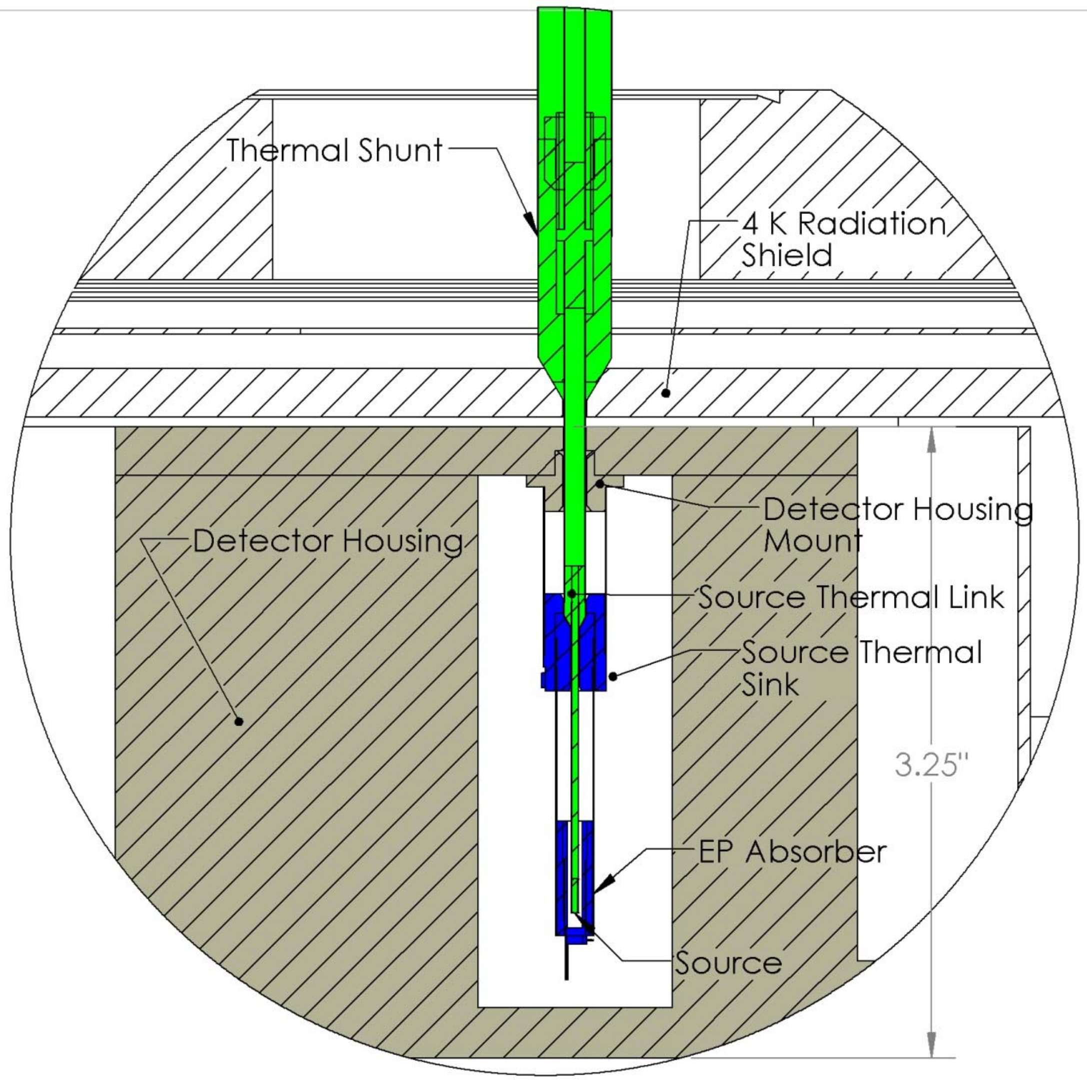


Source Strength: Measurement

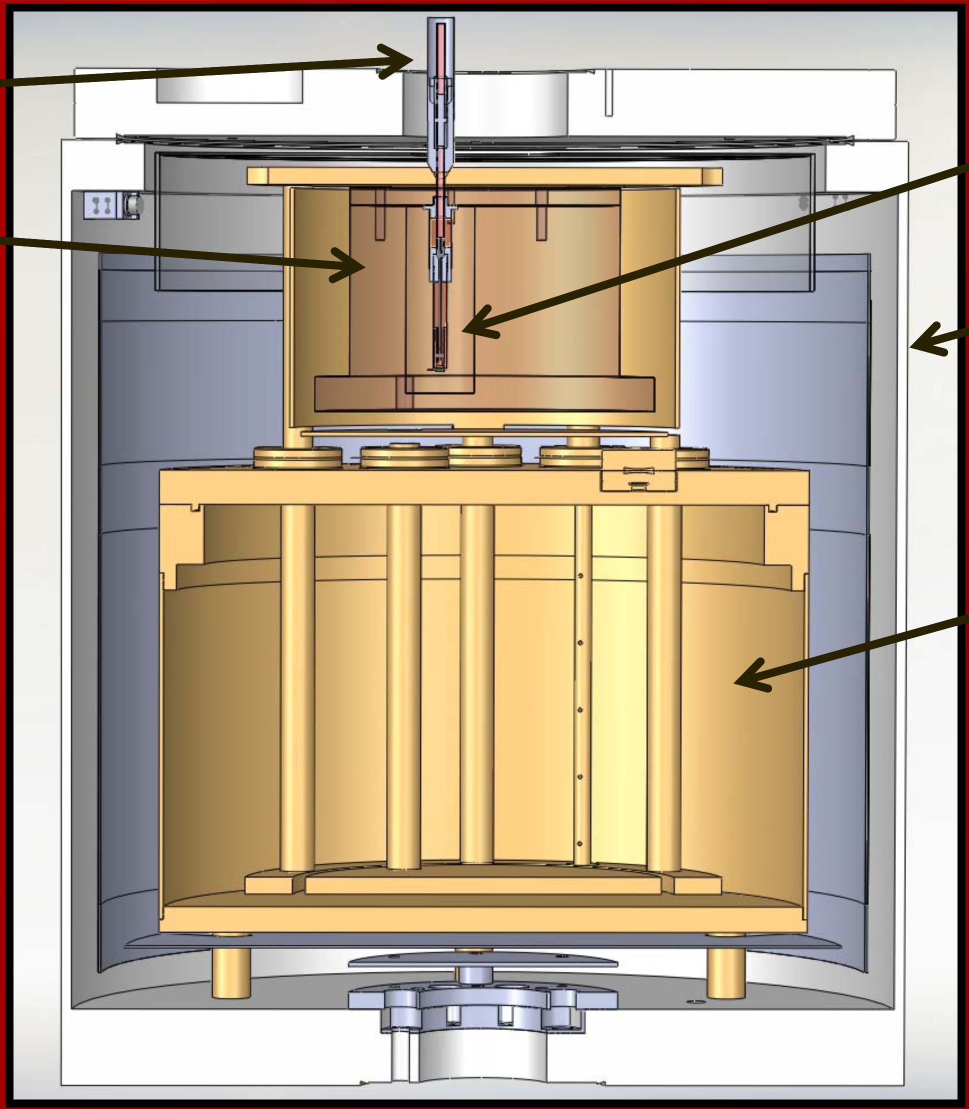
Source Delivery Assembly Interfaced With Absorber Assembly



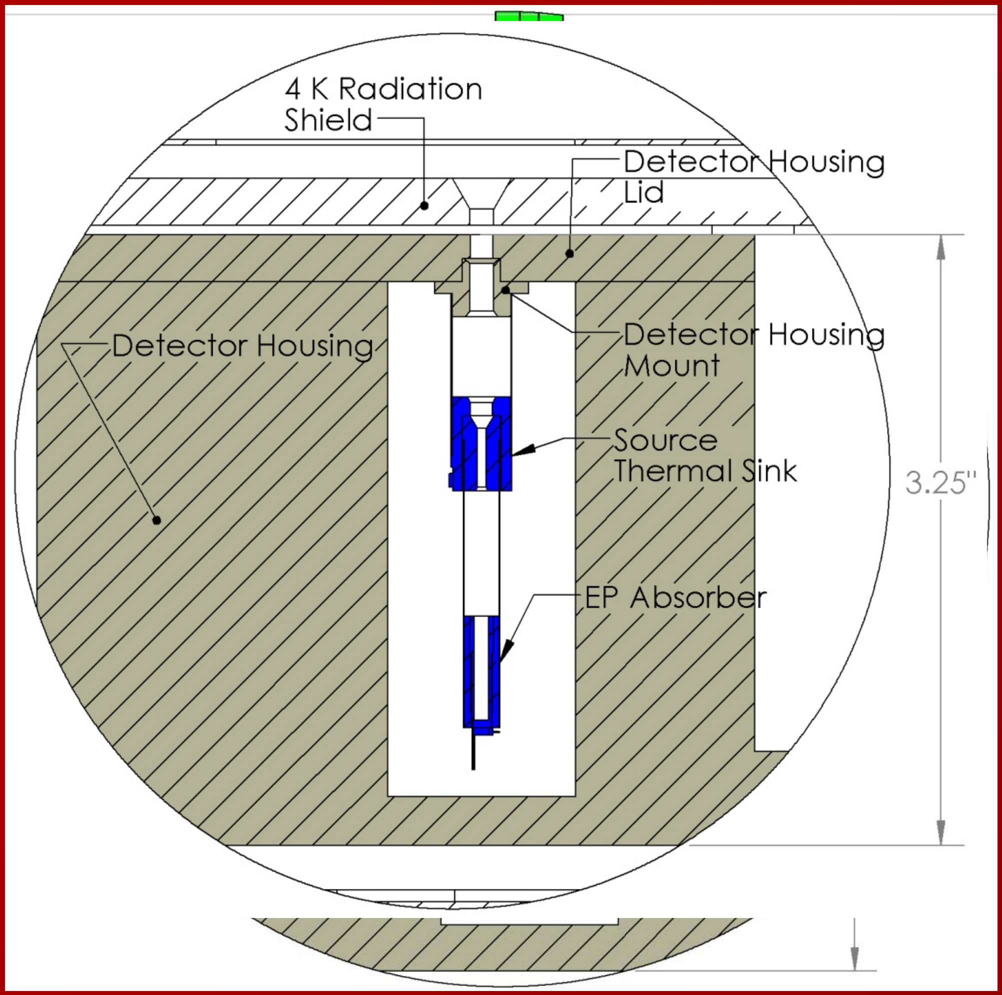
Source Strength: Measurement

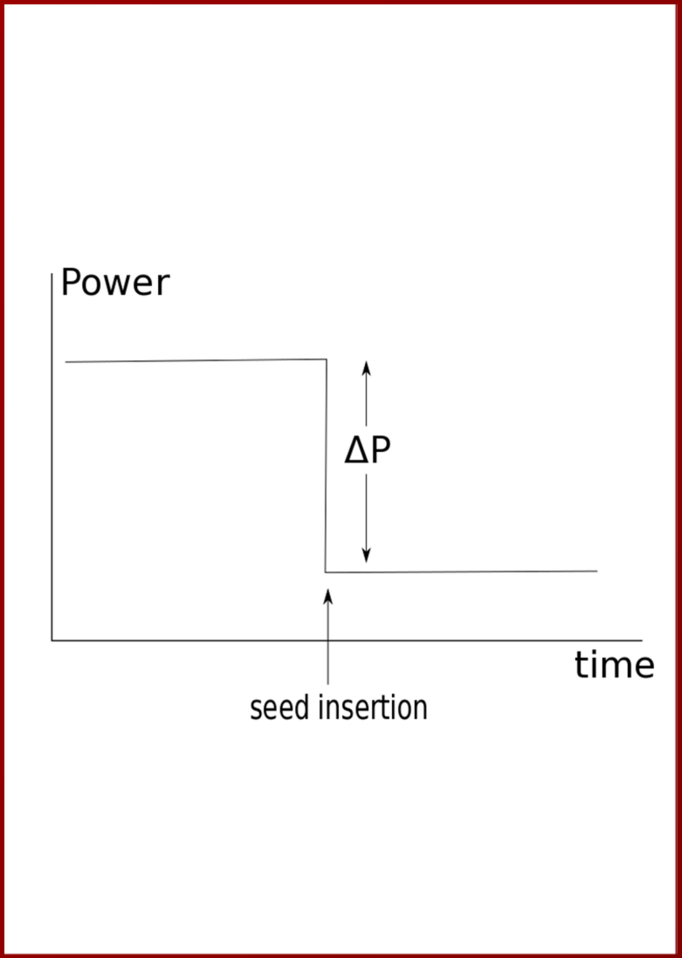


Source Strength: Proposed Calorimeter



Source Strength: Measurement

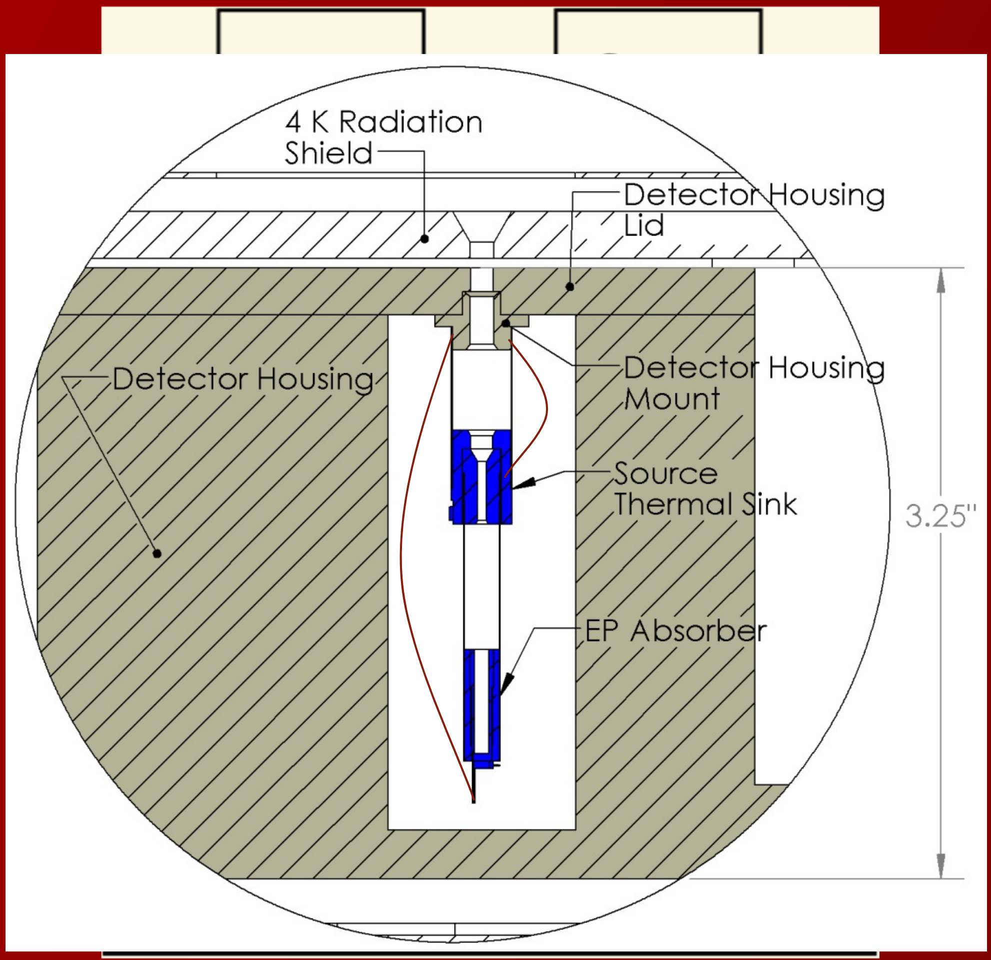




Source Strength: Methods for Thermal Model

Examine:

- Temp control response to source power
- Anticipate thermal noise
- Lumped capacitance model
- MATLAB®



Source Strength: Thermal Model Results

- Temperature measurement resolution = 0.2 mK
- Δtemp /Δpower ~ 200 mK/μW
- Source Strength >= 0.5 μW
- Δtemp ~ 400x measurement resolution

- Assume temp stability of 3 mK
- Power fluctuations to compensate ~4% of source strength

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Conclusions: Feasibility

- Source Anisotropy:
  - Vertical resolution is beyond current measurement techniques
  - Angular resolution might be achieved
- Source Strength:
  - Achievable with the designed system

Conclusion: Future Work

- Sensitivity of dose to water to binning error
- Construction and operation of calorimeter
  - Model-Based Dose Calculation Algorithms could use

Acknowledgements

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