Dosimetric Characterization of the CivaString ^{103}Pd Brachytherapy Source

Joshua Reed, M.S.

Under the supervision of Professor Larry DeWerd

University of Wisconsin – Madison, Department of Medical Physics
Medical Radiation Research Center

2012 CIRMS Annual Meeting

Outline

- Introduction
- Project Motivations
- Methods
- Results
- Conclusions

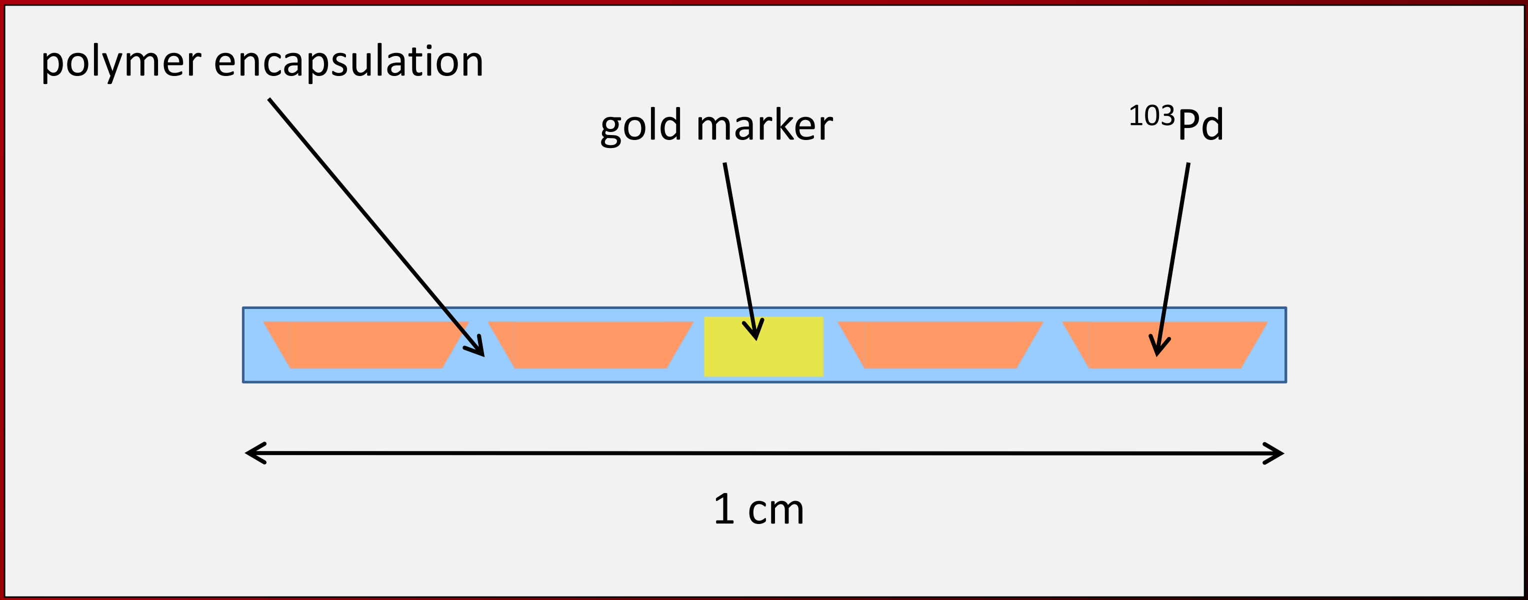
Introduction

- Permanent prostate low-dose rate brachytherapy:
  - Typical radioisotopes: ^{125}I and ^{103}Pd
  - Sources are typically encapsulated in titanium and have a physical length of ≈ 0.5 cm (active length is even shorter)

- Drawbacks:
  - Combination of titanium encapsulation and low-E photons:
    - Anisotropic dose distribution
    - Intersource attenuation
  - Short physical and active lengths:
    - Point-like dose distributions → reduced dose distribution uniformity in target volume

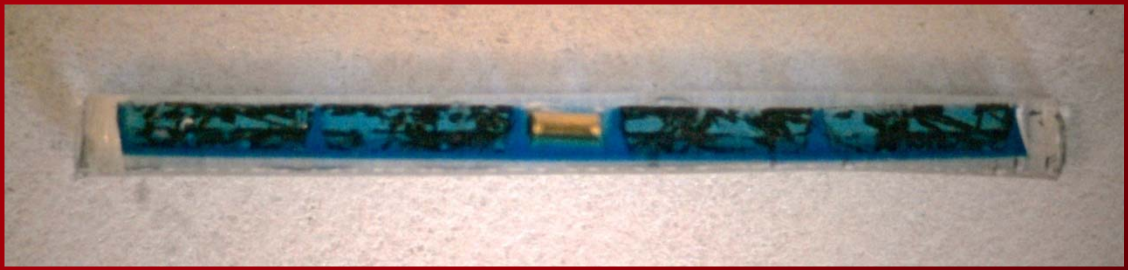
Introduction

- CivaString ^{103}Pd brachytherapy source:
  - Polymer-encapsulated
  - Physical lengths from 1 cm to 6 cm, integral lengths of 1 cm
  - Active length ≈ 1 cm for the 1 cm source



Introduction

- CivaString ^{103}Pd brachytherapy source:



Introduction

- CivaString → Advantages over conventional titanium encapsulated sources:

  - Low-Z polymer encapsulation:
    - Homogeneous dose distribution around a single source
    - Reduced intersource attenuation

  - Elongated physical and active lengths:
    - More continuous distribution of radioactive material
    - Improved dose distribution uniformity throughout target volume

Project Motivations

- CivaString ^{103}Pd brachytherapy source must be accurately characterized prior to use in a clinical setting:
  - Calibration at NIST
  - Characterization of azimuthal anisotropy
  - Determination of AAPM TG-43 dosimetry parameters: [1]
    - Experimental measurements
    - Monte Carlo calculations
  - Comparison of measured and Monte Carlo-calculated dosimetry parameters

- This work serves as an experimental and Monte Carlo characterization of the 1 cm CivaString source

1. Rivard *et al.*, "Update of AAPM Task Group No. 43 Report: A revised AAPM protocol for brachytherapy dose calculations," Med. Phys. **31** 633-674 (2004).

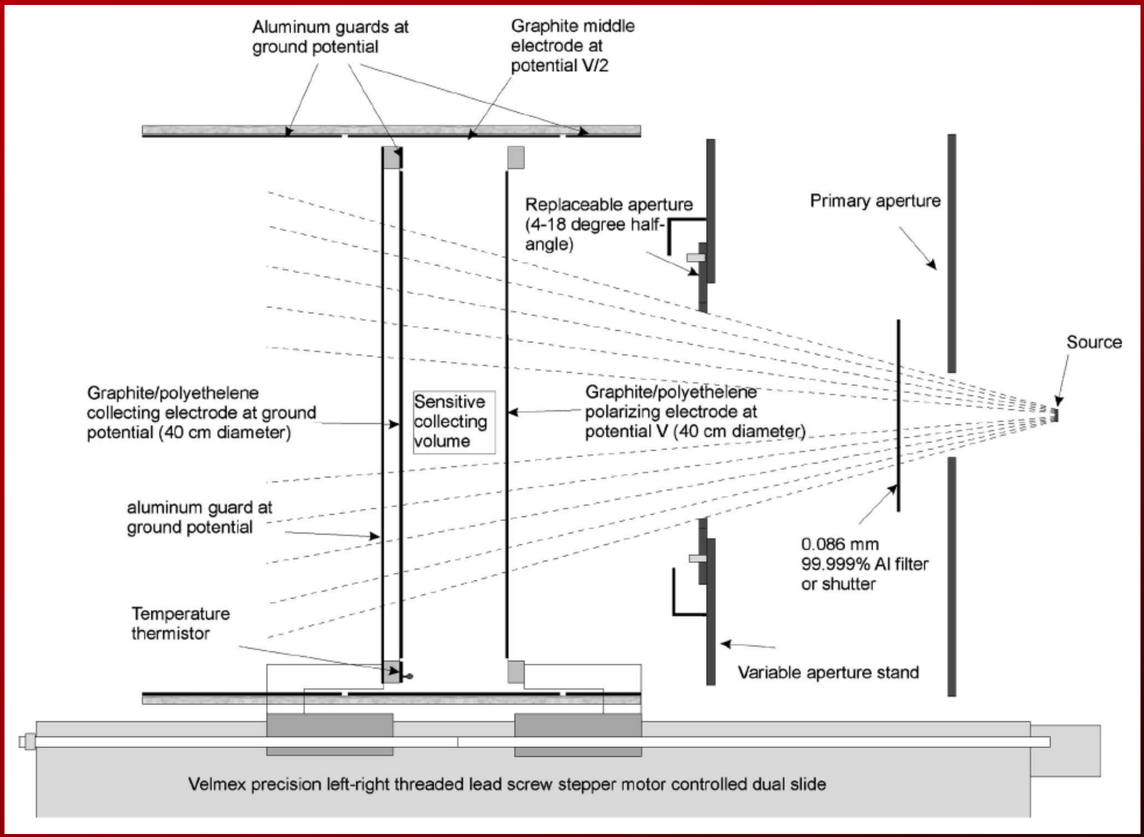
Methods

- Measurements:
  - Source strength
  - Azimuthal anisotropy
  - In-phantom dose distribution

- Monte Carlo simulations:
  - Azimuthal anisotropy
  - In-phantom dose distribution
  - In-water dose distribution

Methods (Source Strength)

- Source strength measurements with Variable-Aperture Free-Air Chamber (VAFAC):[1]



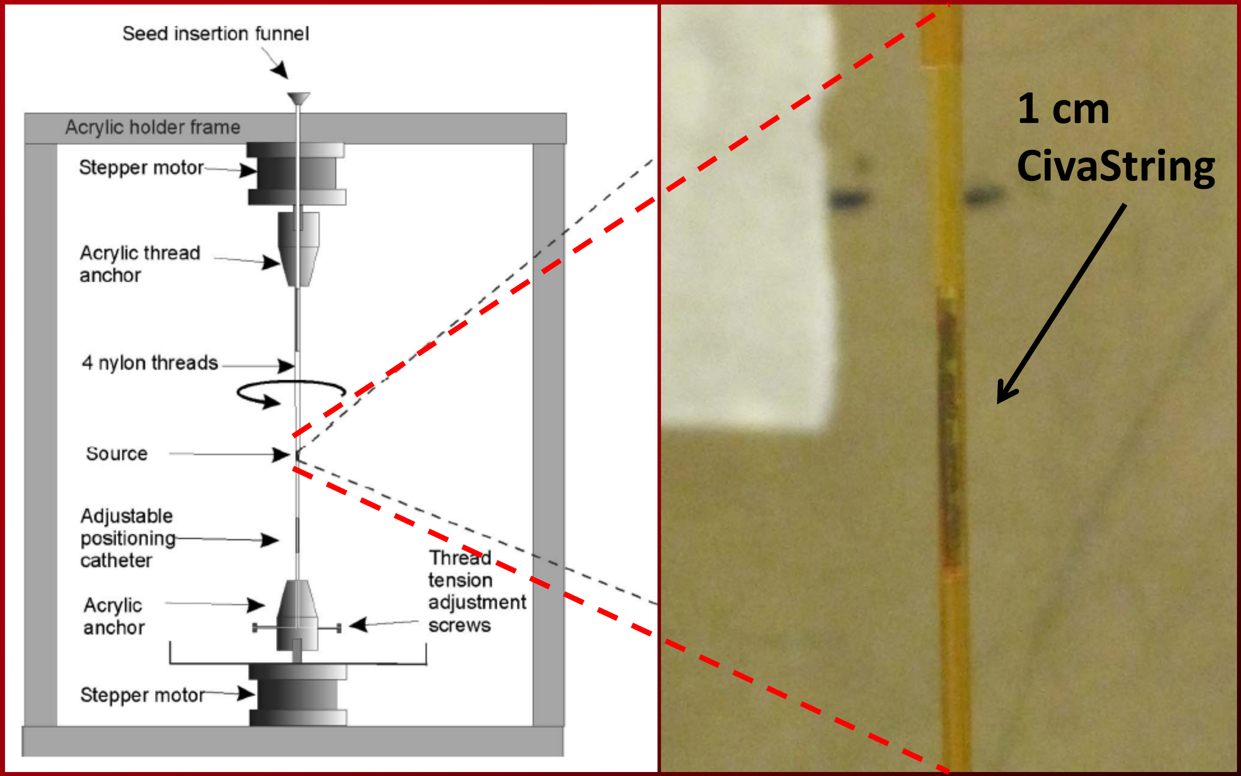
1. Culberson *et al.*, "Large-volume ionization chamber with variable apertures for air-kerma measurements of low-energy radiation sources," Rev. Sci. Instrum. **77**, 015105:1-9 (2006).

Methods
(Source Strength)

- Source strength measurements with VAFAC:

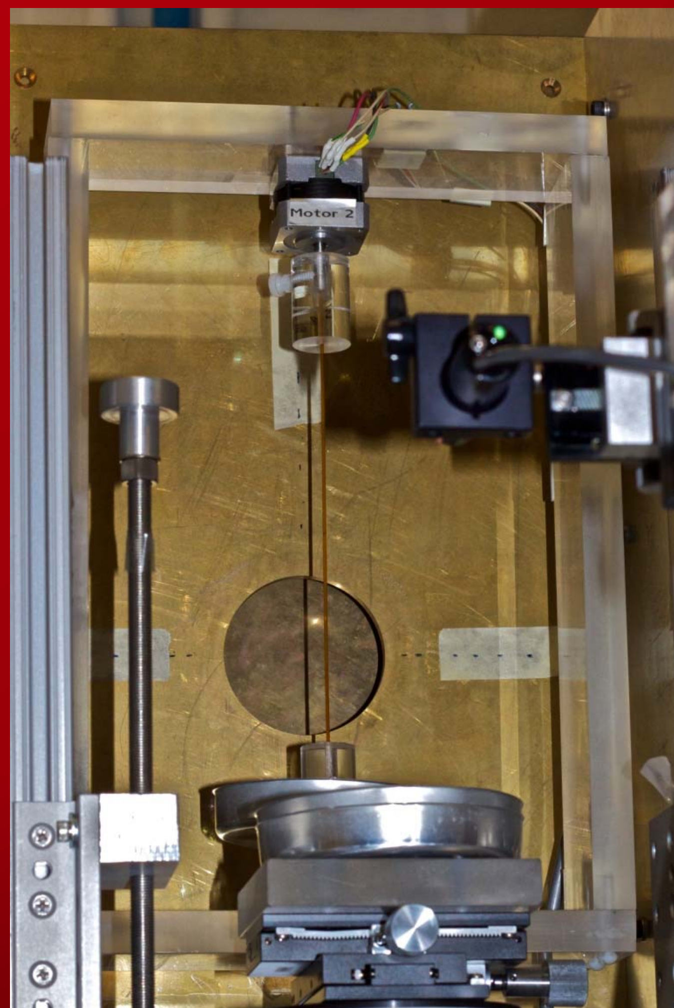
Methods
(Source Strength)

- Source strength measurements with VAFAC:[1]



1. Culberson *et al*., "Large-volume ionization chamber with variable apertures for air-kerma measurements of low-energy radiation sources," Rev. Sci. Instrum. **77**, 015105:1-9 (2006).

Methods
(Source Strength)



Methods
(Source Strength)

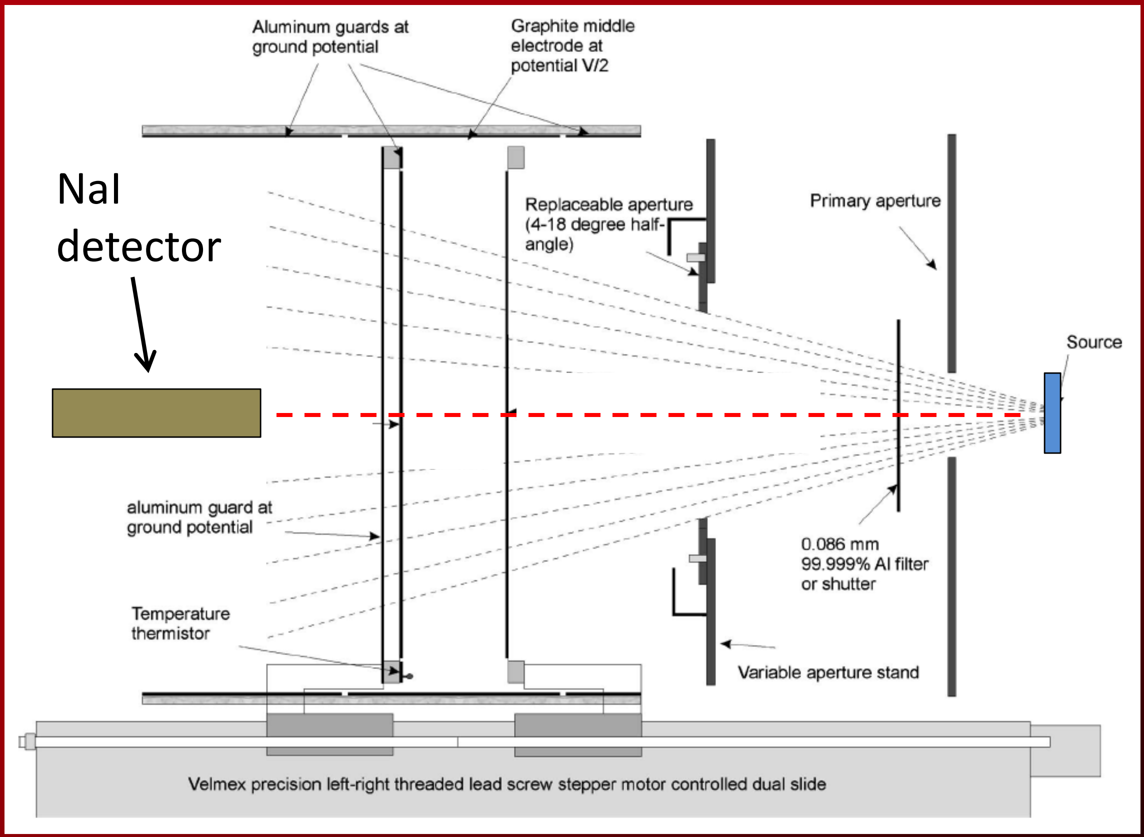
- Source strength measurements with PRM WC-2 and SI IVB1000 well chambers:

Results
(Source Strength)

- Two separate 1 cm CivaString sources measured with the VAFAC and with the WC-2 and IVB1000 well chambers
- Well chamber calibration coefficient = ratio of the air-kerma strength (VAFAC) and the fully-corrected ionization current (well chamber)
- <u>WC-2 chamber:</u>
  - Calibration coefficients calculated using two separate sources agreed to within 1.3%
- <u>IVB1000 chamber:</u>
  - Calibration coefficients calculated using two separate sources agreed to within 0.9%

Methods (Azimuthal Anisotropy)

- Azimuthal anisotropy measurements with NaI scintillator detector mounted on the VAFAC:[1]



1. Culberson *et al.* "Large-volume ionization chamber with variable apertures for air-kerma measurements of low-energy radiation sources," Rev. Sci. Instrum. **77**, 015105:1-9 (2006).

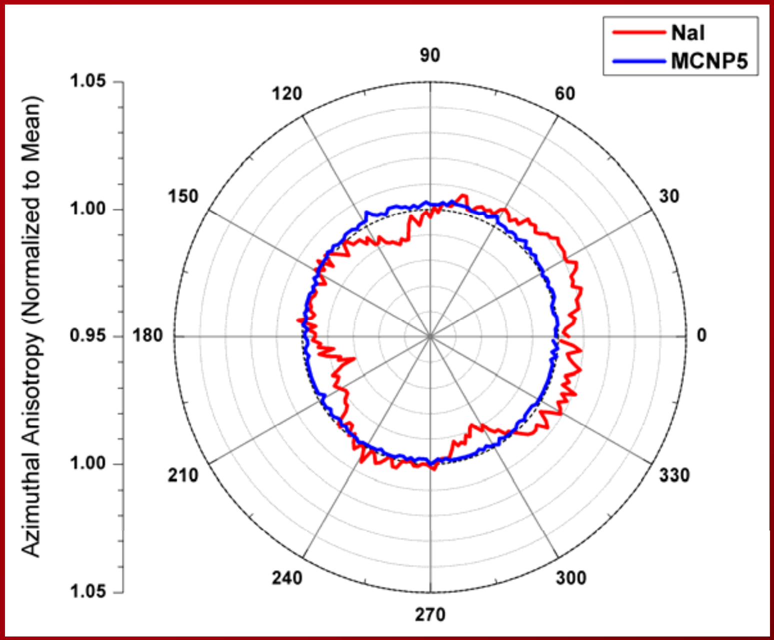
Methods
(Azimuthal Anisotropy)

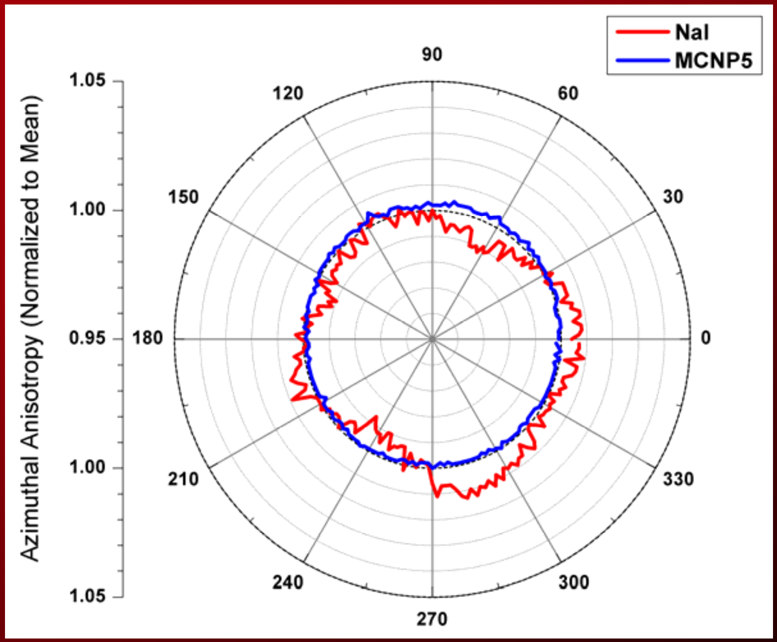
Methods
(Azimuthal Anisotropy)

- Azimuthal anisotropy calculated using Monte Carlo simulations
- 1 cm CivaString source in air was fully modeled in the MCNP5 Monte Carlo radiation transport code
- Calculated dose to air in a thin cylindrical mesh with a radius of 70 cm centered on the source and subdivided into 1.8 angular bins (geometry similar to that of the NaI measurements)

Results
(Azimuthal Anisotropy)

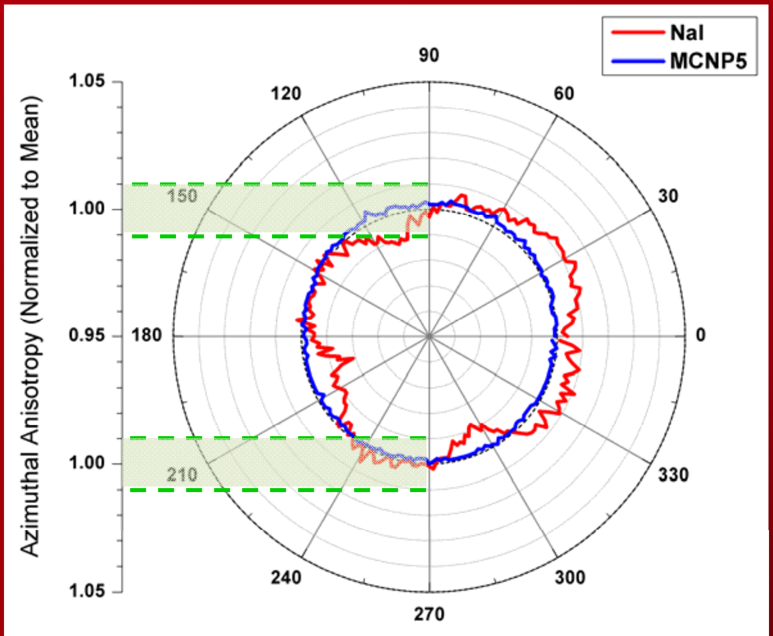
- Azimuthal anisotropy for two 1 cm CivaString sources:

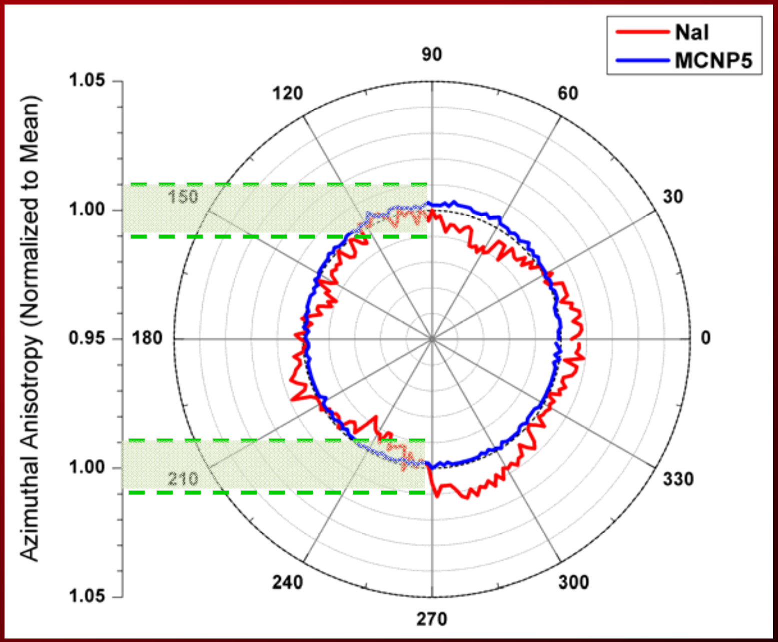




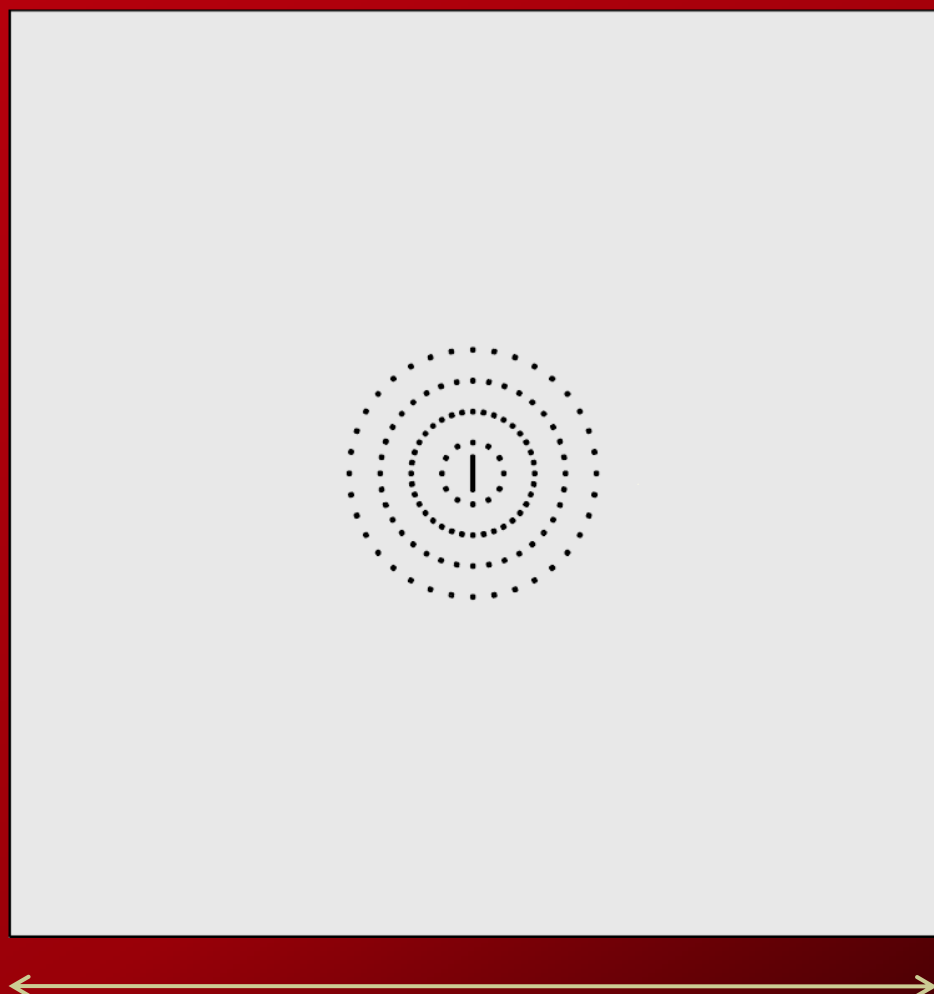
Results
(Azimuthal Anisotropy)

- Azimuthal anisotropy – variations within 1%:





Methods
(Anisotropy Phantom Template)



1 mm thick PMMA template

30 cm x 30 cm area

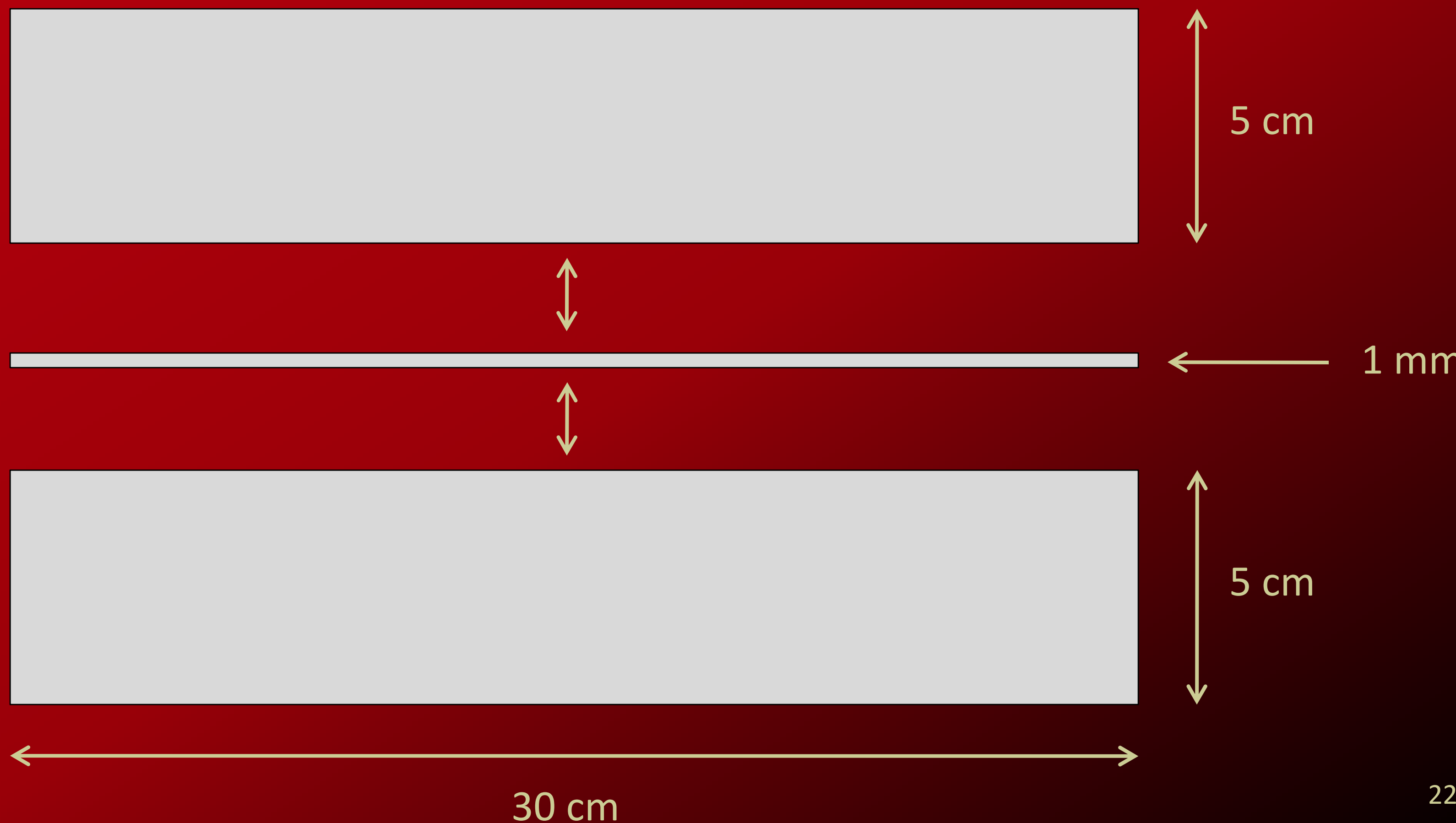
TLDs held in precision laser cut square holes

CivaString source lies in plane of template

Methods
(Anisotropy Phantom Template)

Methods
(Anisotropy Phantom Full Setup)

- Side view of 1 mm thick PMMA template sandwiched between two PMMA slabs:

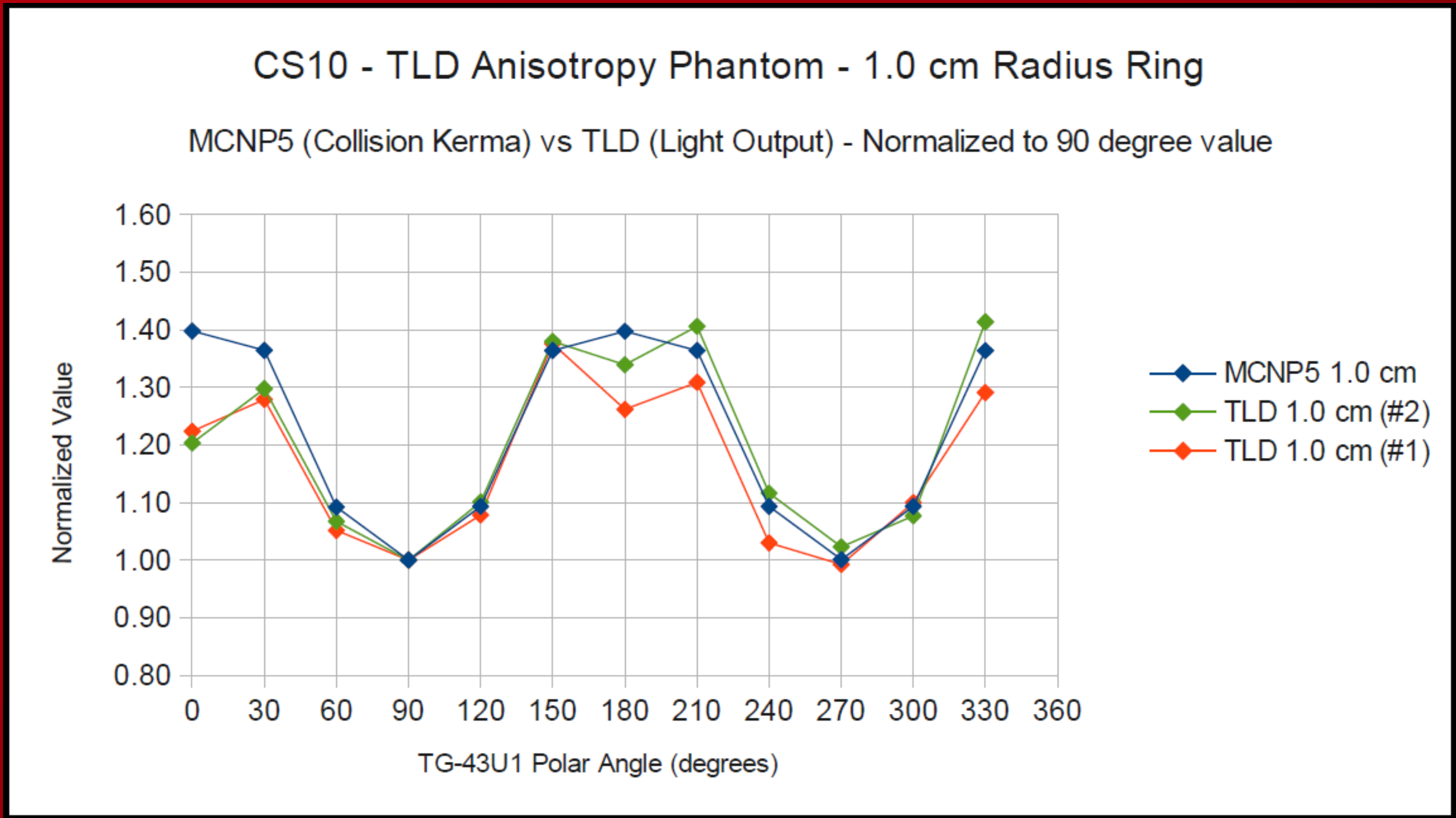


Methods (Anisotropy Phantom)

- Dose to the TLDs in the anisotropy phantom calculated using Monte Carlo simulations
- 1 cm CivaString source and TLDs in the anisotropy phantom were fully modeled in MCNP5 code
- Calculated dose to LiF TLDs in the individual TLDs in each of the four concentric rings surrounding the source

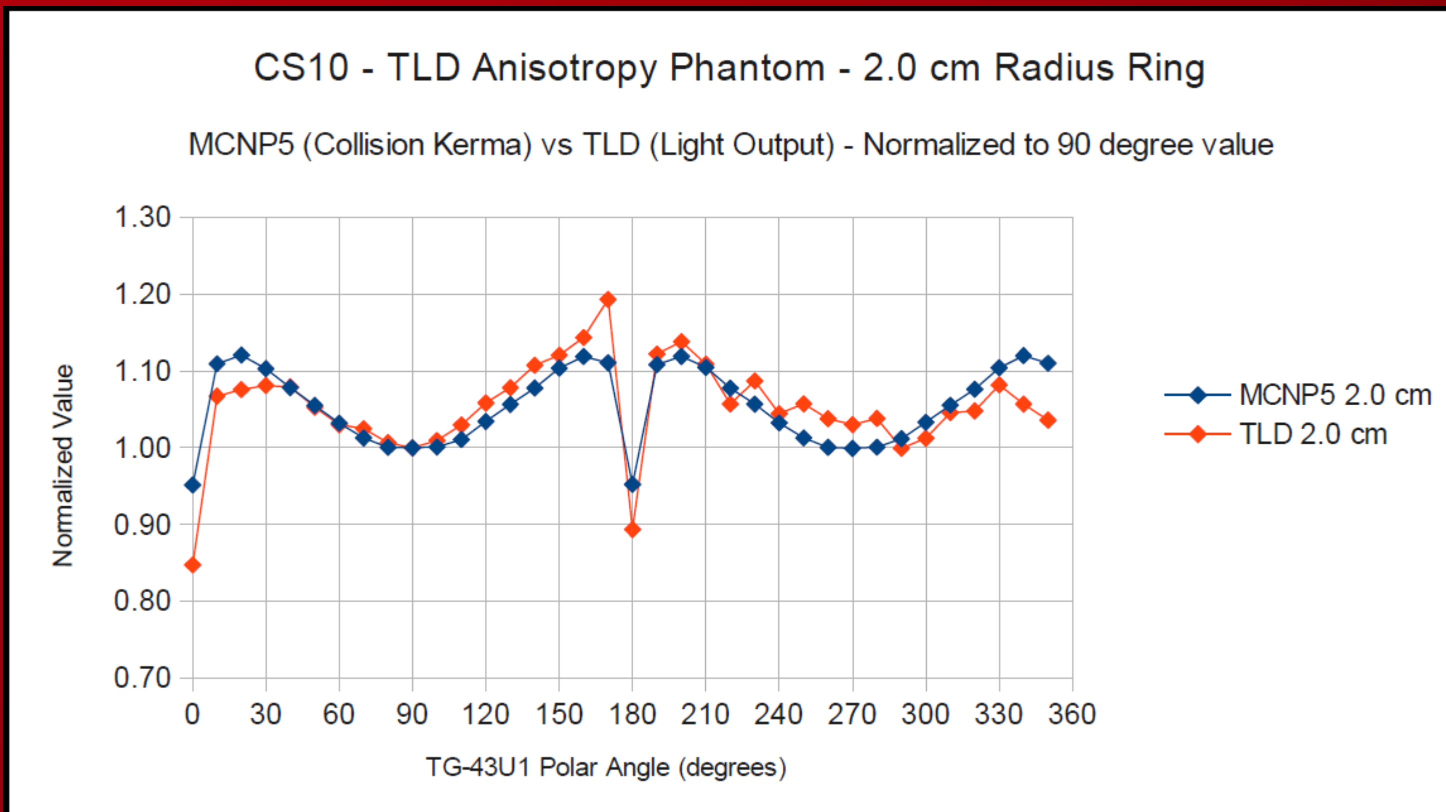
Results (Anisotropy Phantom)

- TLD measurements (2 trials) in PMMA phantom versus MCNP5-calculated dose to TLD in PMMA phantom
- No corrections for geometric falloff were applied; collision kerma ≈ dose



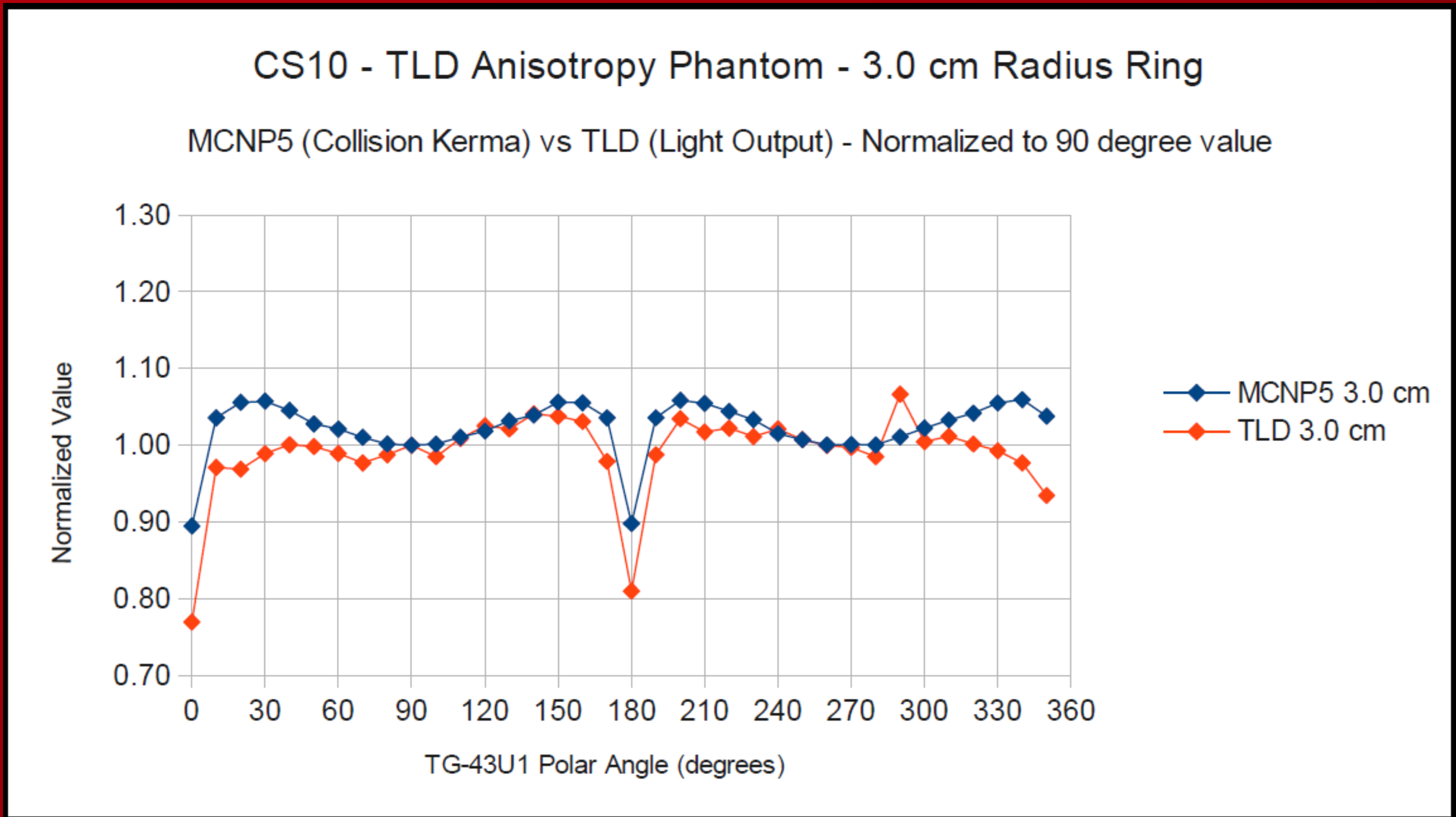
Results (Anisotropy Phantom)

- TLD measurements (1 trial) in PMMA phantom versus MCNP5-calculated dose to TLD in PMMA phantom
- No corrections for geometric falloff were applied; collision kerma ≈ dose



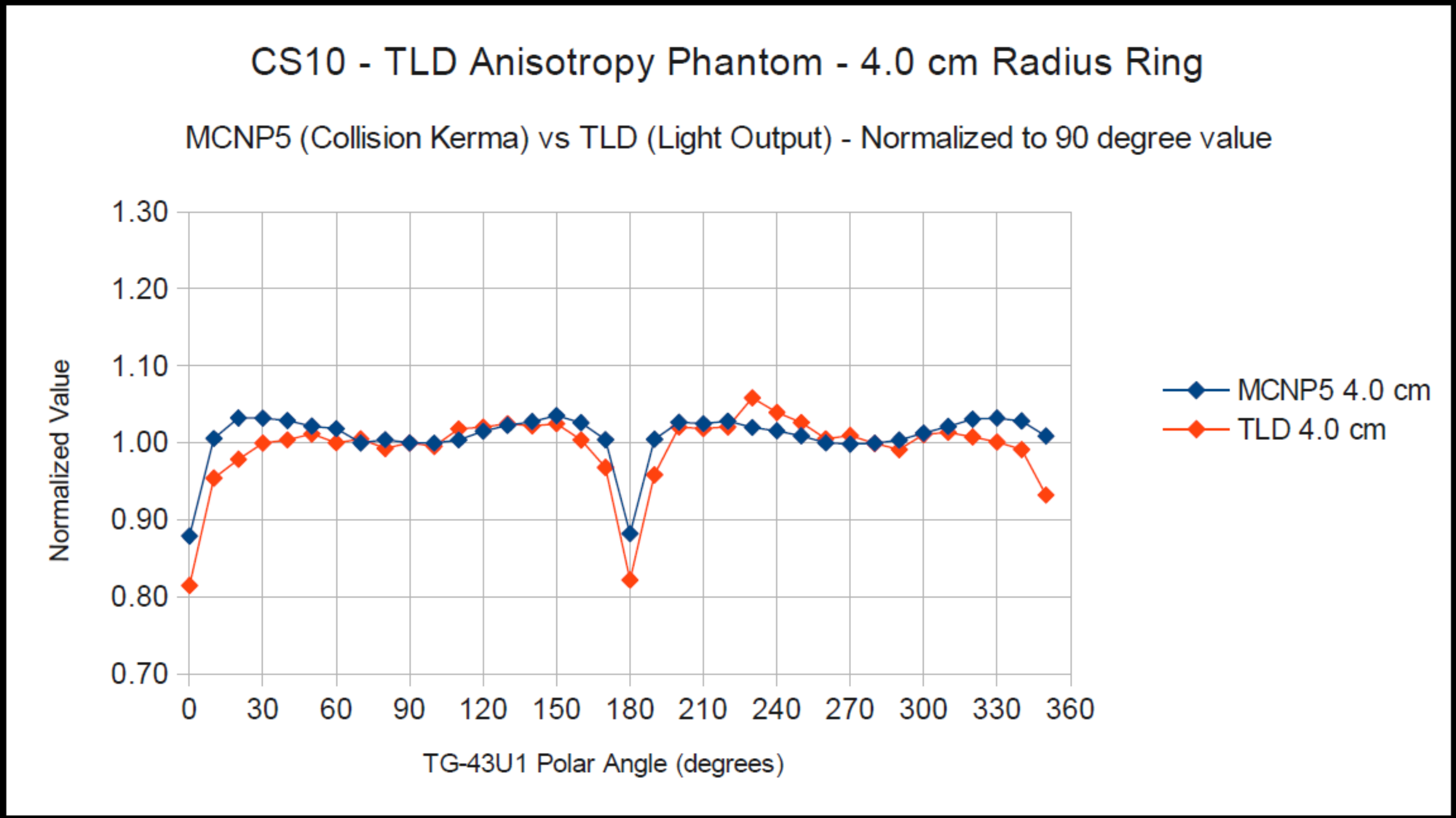
Results
(Anisotropy Phantom)

- TLD measurements (1 trial) in PMMA phantom versus MCNP5-calculated dose to TLD in PMMA phantom
- No corrections for geometric falloff were applied; collision kerma ≈ dose

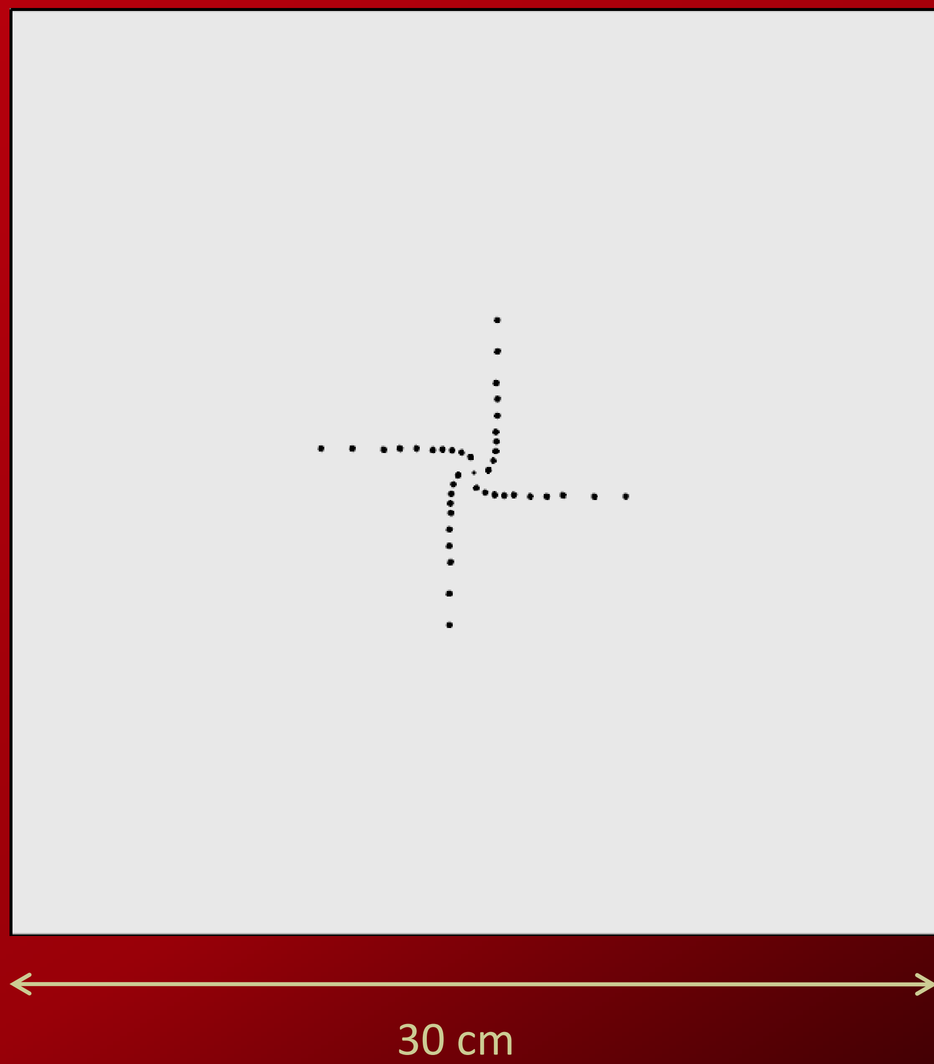


Results (Anisotropy Phantom)

- TLD measurements (1 trial) in PMMA phantom versus MCNP5-calculated dose to TLD in PMMA phantom
- No corrections for geometric falloff were applied; collision kerma ≈ dose



Methods
(Radial Dose Phantom Template)



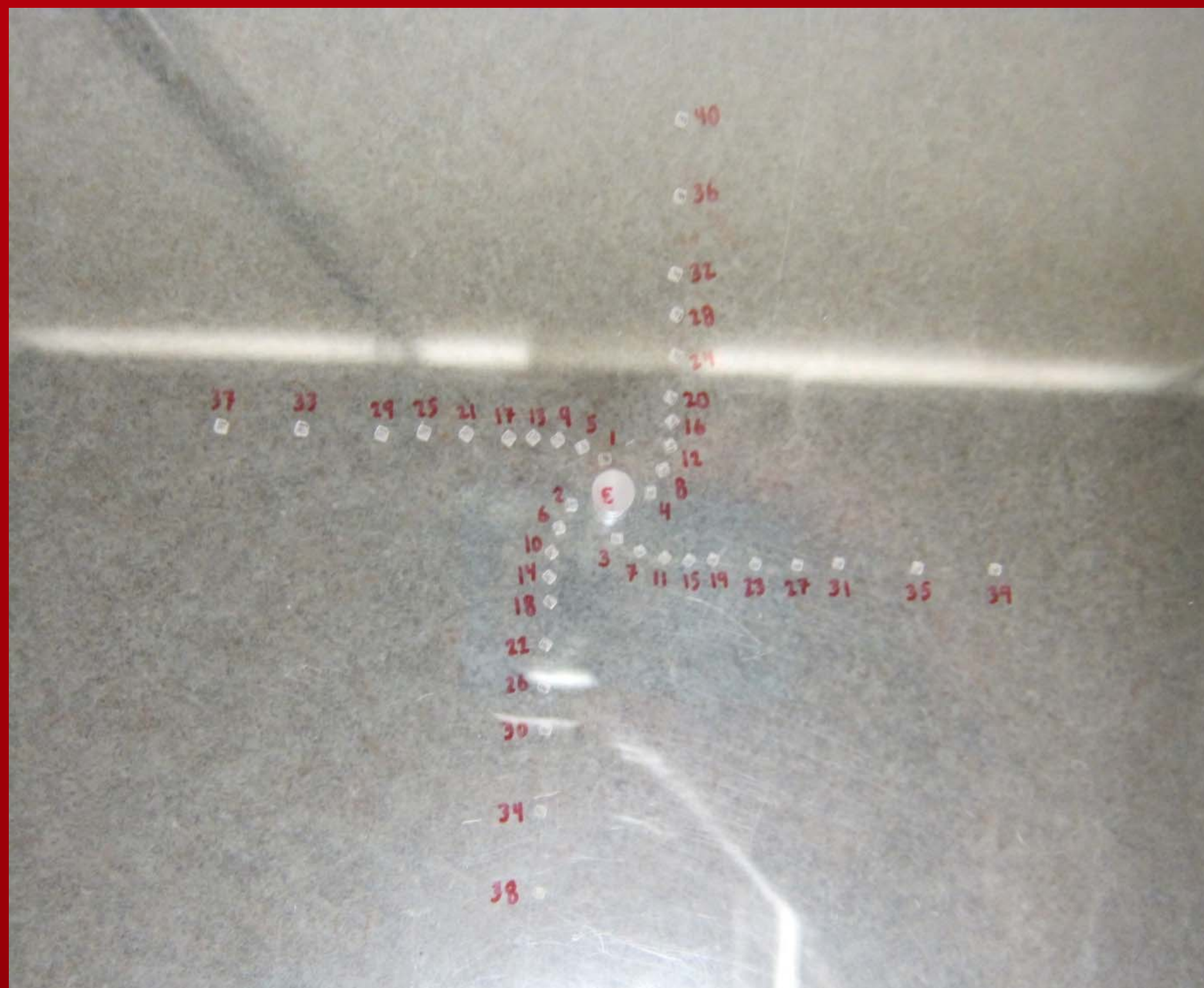
1 mm thick PMMA template

30 cm x 30 cm area

TLDs held in precision laser cut square holes

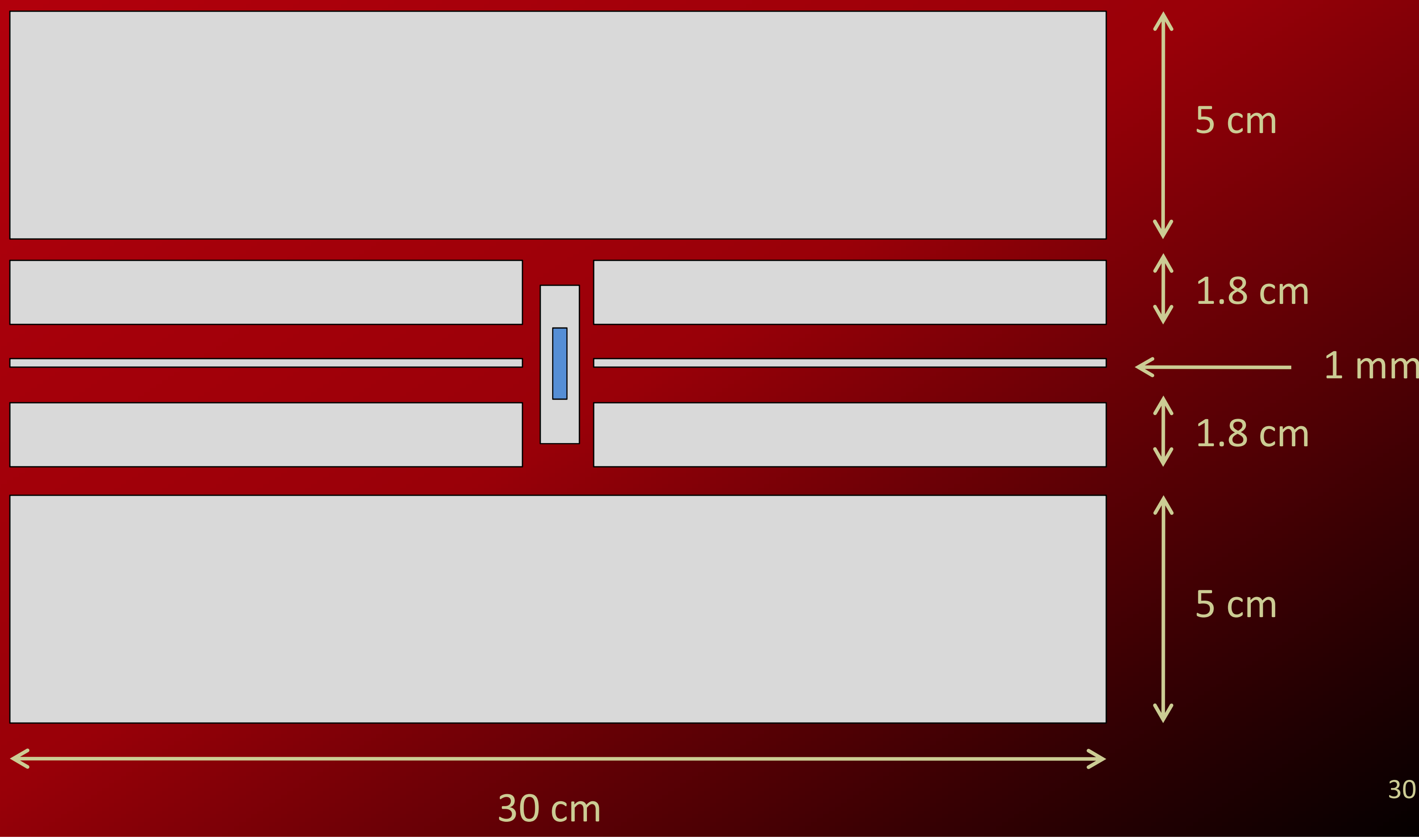
CivaString source inserted through template via a source insert machined in house

Methods
(Radial Dose Phantom Template)



Methods
(Radial Dose Phantom Full Setup)

- Side view of 1 mm thick PMMA template sandwiched between four PMMA slabs:

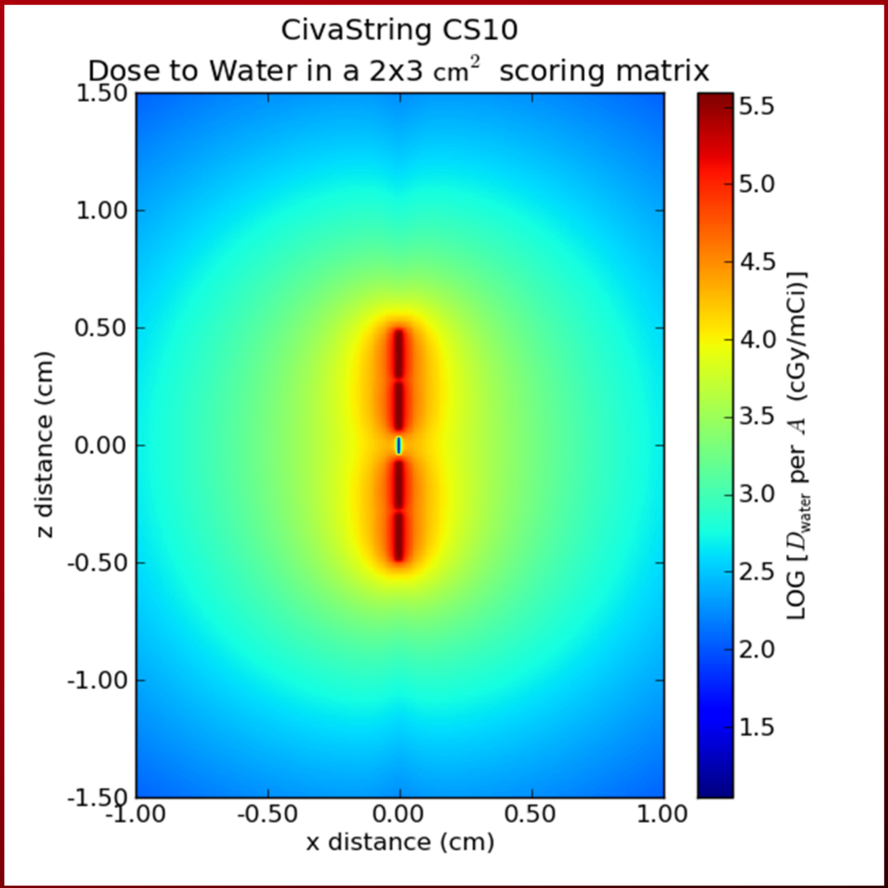


Methods
(In-Water Dose Distribution)

- In-water dose distribution calculated using Monte Carlo simulations
- 1 cm CivaString source in a large water medium was fully modeled in MCNP5 code
- Calculated dose to water in a thin rectangular mesh centered on the source

Results (In-Water Dose Distribution)

- MCNP5-calculated dose distribution in water
- Dose to water calculated in thin rectangular mesh centered on source



Conclusions

- NIST-traceable WC-2 and IVB1000 well chambers can be used to accurately calibrate 1 cm CivaString sources
- Azimuthally-asymmetric distribution of radioactive material within the source → negligible variations in azimuthal anisotropy (< 1%)
- Measured and MCNP5 results are in good agreement both in-air and in-phantom, which indicates that MCNP5 can be used to accurately calculate the dose distribution around the CivaString in water
- MCNP5 simulations in water → demonstrate the homogeneous dose distribution around the 1 cm CivaString source
- Future work → measurements of additional CivaString sources and determination of TG-43 dosimetry parameters

Acknowledgements

- Thanks for your attention!
  - Professor Larry DeWerd, Ph.D.
  - UWMRRC students and staff
  - Customers of the UW-ADCL
  - Seth Hoedl, Ph.D. and Mark Rivard, Ph.D.
  - CivaTech Oncology, Inc.