Response of LiF:Mg,Ti TLDs to ^{125}I Low Dose Rate Brachytherapy Sources Relative to ^{60}Co

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Introduction

- **Directly determine the response of LiF:Mg,Ti to ^{125}I relative to ^{60}Co in terms of Dose to Water**
- **Many published works based on air kerma, but few on dose to water**
- **TLD energy response continues to be an active area of research**
- **Novel experimental technique facilitated by University of Wisconsin-Variable Aperture Free Air Chamber**

TLD Applications in LDR Brachytherapy: Dose Rate Constant Determination (TG-43U1)

$$\dot{D}(r,\theta) = S_K \Lambda \frac{G(r,\theta)}{G(r,\pi/2)} g(r) F(r,\theta)$$

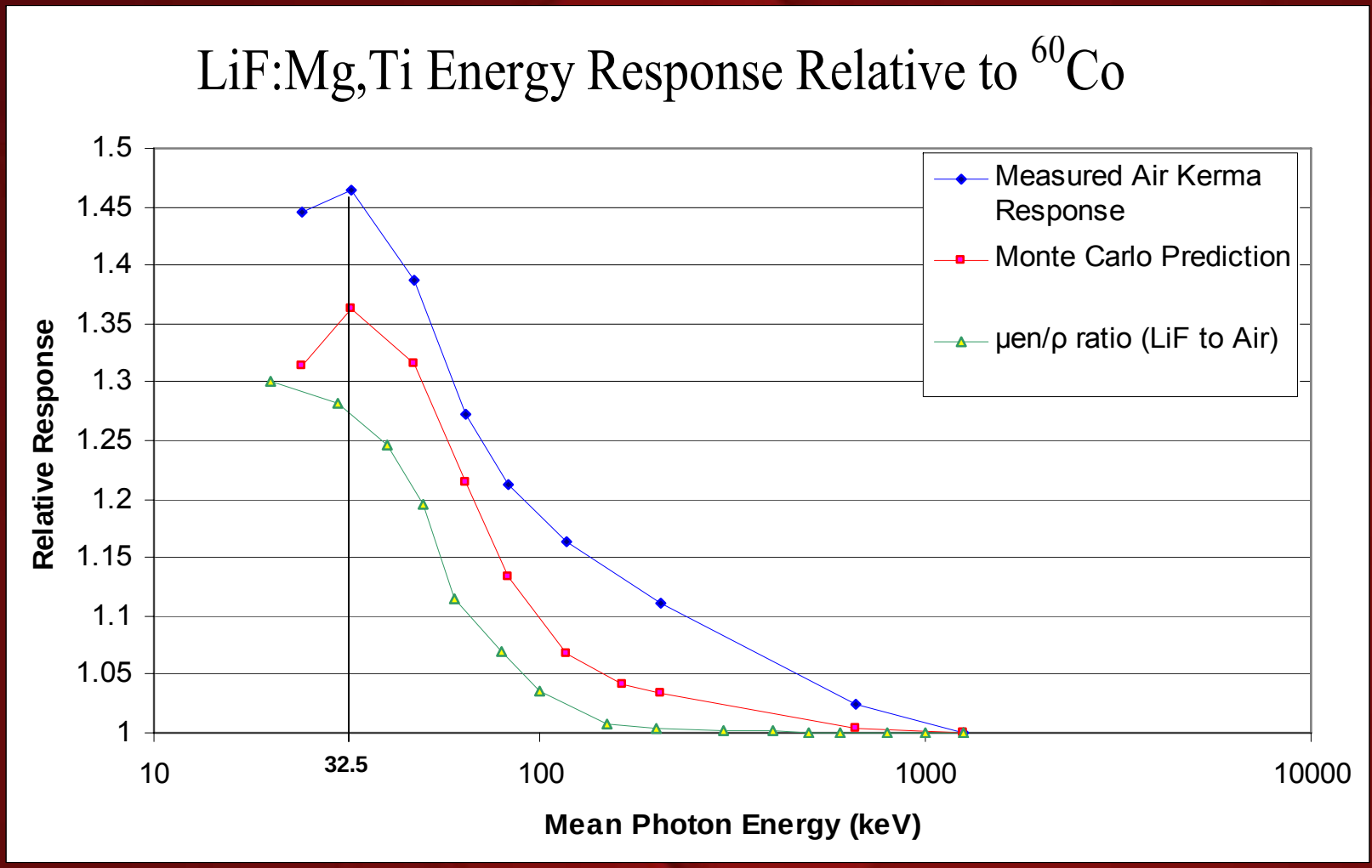
$$\Lambda = \frac{\dot{D}(r = 1\,\text{cm}, \theta = \pi/2)}{S_K} = \frac{R}{S_K \cdot \varepsilon \cdot T \cdot F_{\text{lin}} \cdot E(r)}$$

$$E(r) = \frac{\left[\frac{R}{D_{\text{water}}}\right]_{^{125}\text{I}}}{\left[\frac{R}{D_{\text{water}}}\right]_{^{60}\text{Co}}}$$

TG-43U1 has currently assigned a value of 1.41 to E(r), and is quoted as the largest source of systematic uncertainty in the entire seed characterization formalism (~5%).

M. J. Rivard, B. M. Coursey, L. A. DeWerd, W. F. Hanson, M. S. Huq, G. S. Ibbott, M. G. Mitch, R. Nath, and J. F. Williamson, *Update of AAPM Task Group No. 43 Report: A revised AAPM protocol for brachytherapy dose calculations*, Med. Phys., 31, 633–674 (2004).

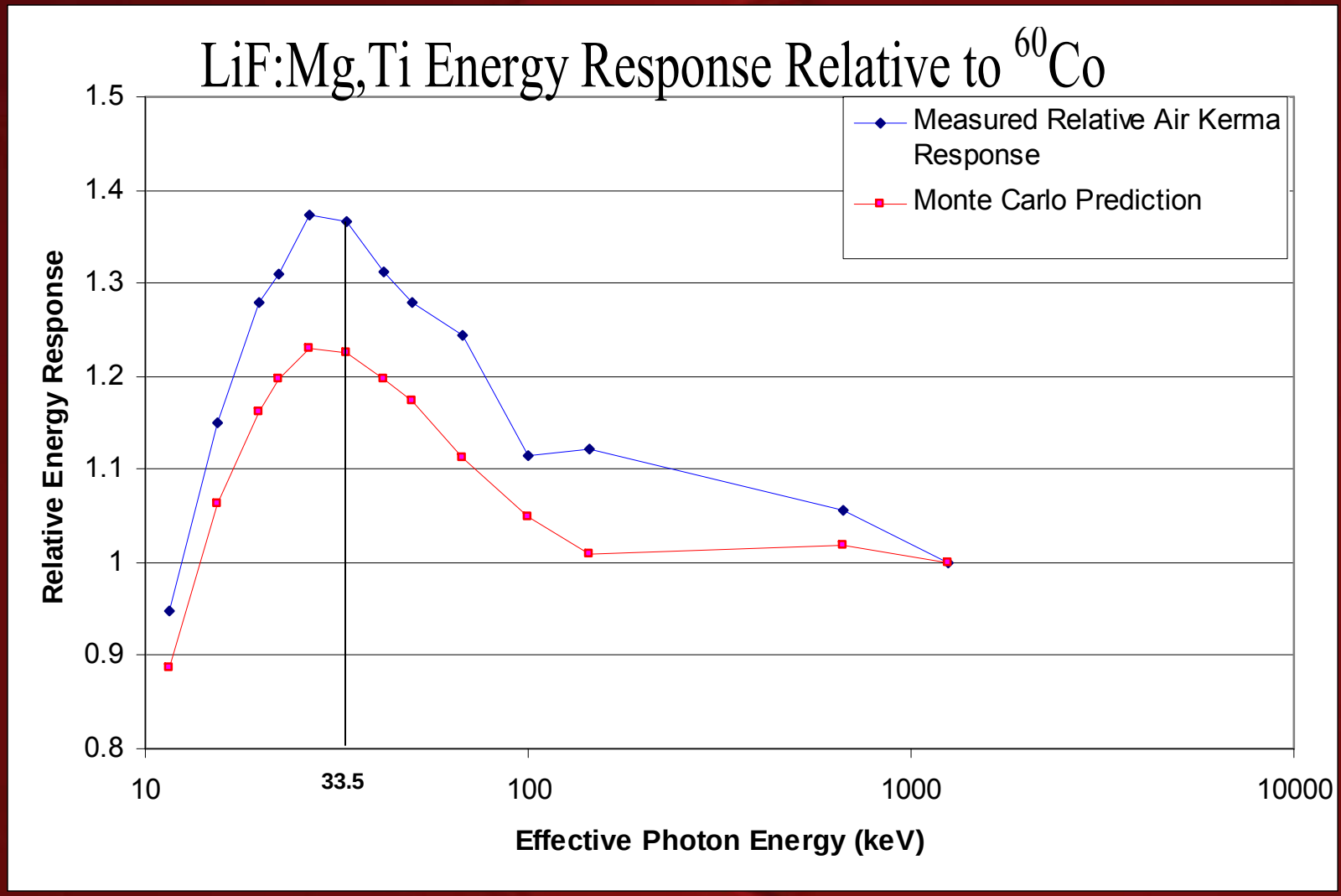
Previous Works: Davis et al. 2003



TG-43U1 estimation of revised E(r) from this work = 1.58

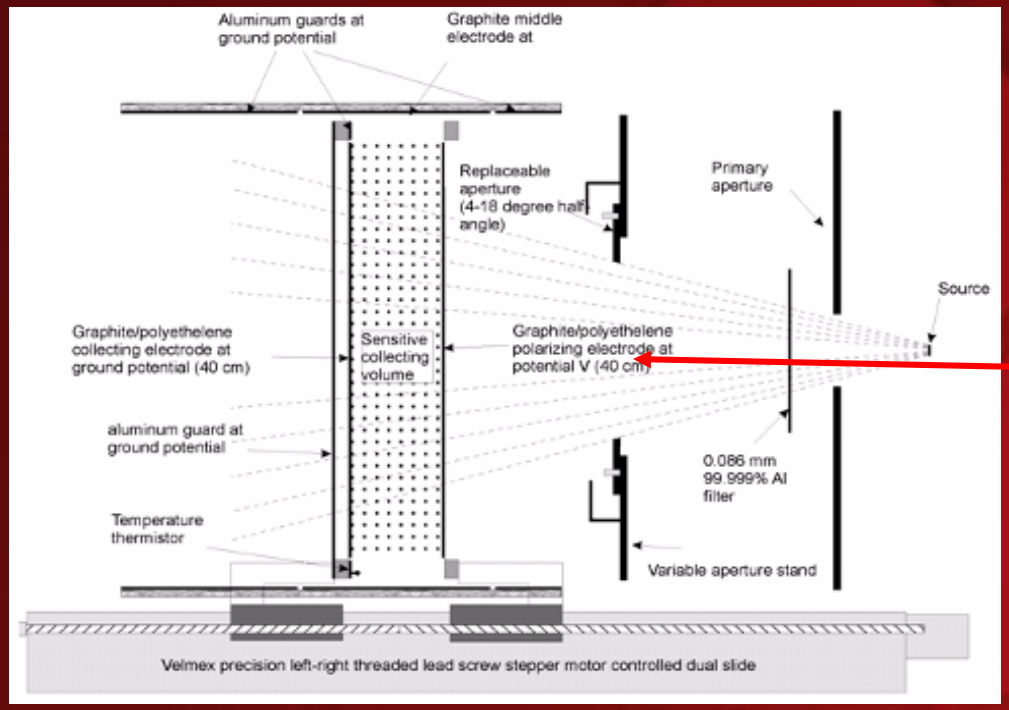
S. D. Davis, C. K. Ross, P. N. Mobit, L. Van der Zwan, W. J. Chase, and K. R. Shortt, *The response of LiF thermoluminescence dosimeters to photon beams in the energy range from 30 kV x rays to ^{60}Co gamma rays*, Radiation Protection Dosimetry, 106, 1, 33–43 (2003).

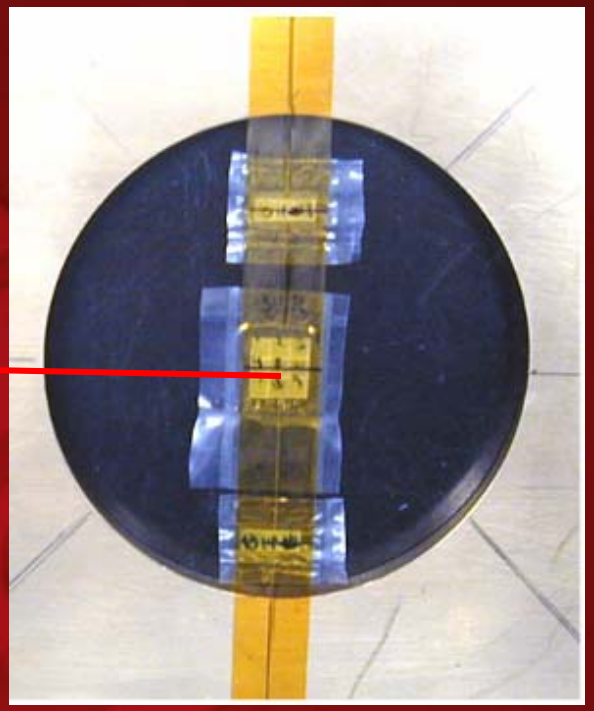
Previous Works: Nunn et al. 2006



A. Nunn, S. Davis, L. DeWerd, and J. Micka. *Energy Response of LiF:Mg,Ti Thermoluminescent Dosimeters to Moderately Filtered X-ray Spectra in the range of 20 to 250 kV Relative to ^{60}Co.* Medical Physics (abstract), 33, 6, 2193-2194 (2006)

TLD Irradiation Using the University of Wisconsin Variable Aperture Free Air Chamber (VAFAC)





W.Culberson, L.A. DeWerd, D.R. Anderson, and J.A. Micka. *Large-volume ionization chamber with variable aperture for air--kerma measurements of low-energy radiation sources Review of Scientific Instruments, 77, 015105, (2006).*

TLD Handling Procedure

LiF:Mg,Ti TLD-100 Chips (3.1x3.1x0.89 mm^3)

-Annealing Cycle:
400 ^oC for 1 hour followed by 80 ^oC for 24 hours

-24 hour waiting period after anneal before irradiation

-24 hour waiting period after irradiation before readout

-Individual chip sensitivity factors determined using ^{60}Co irradiations

- Harshaw Model 5500 automatic reader

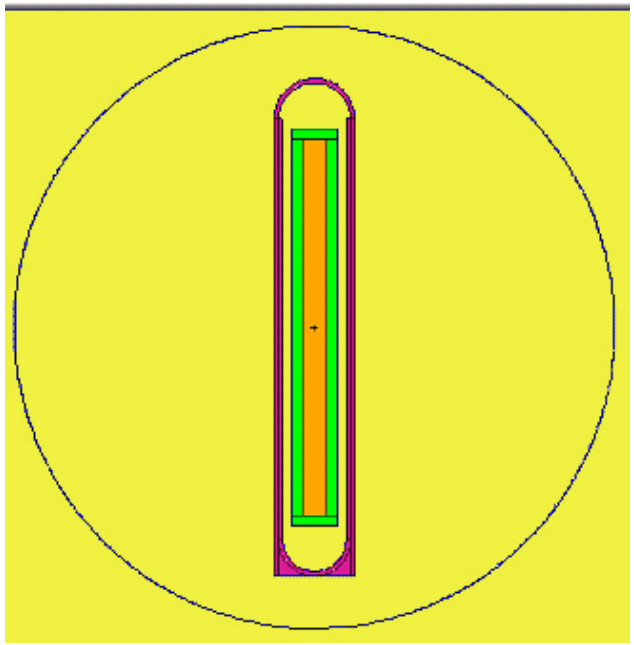
- TLDs are known to be linear with dose and dose rate over a wide dynamic range

^{125}I Dose to Water Calculation Using Monte Carlo Simulation

$$D_{\text{water}} = \frac{\left[\dot{K}_{\text{water}}\right]_{\text{MonteCarlo}}}{\left[\Delta S_{\text{K}}\right]_{\text{MonteCarlo}}} \times \left[S_{\text{K}}\right]_{\text{VAFAC}} \times d^2 \times \frac{1}{\lambda}\left(1 - \text{e}^{-\lambda \Delta t}\right)$$

$$\Delta S_{\text{K}} = \frac{(\Delta E_{\text{Vmax}} - \Delta E_{\text{Vmin}})d^2}{\rho_{\text{air}}(V_{\text{max}} - V_{\text{min}})} k_{\text{inv}} k_{\text{att}} k_{\text{scatter}}$$

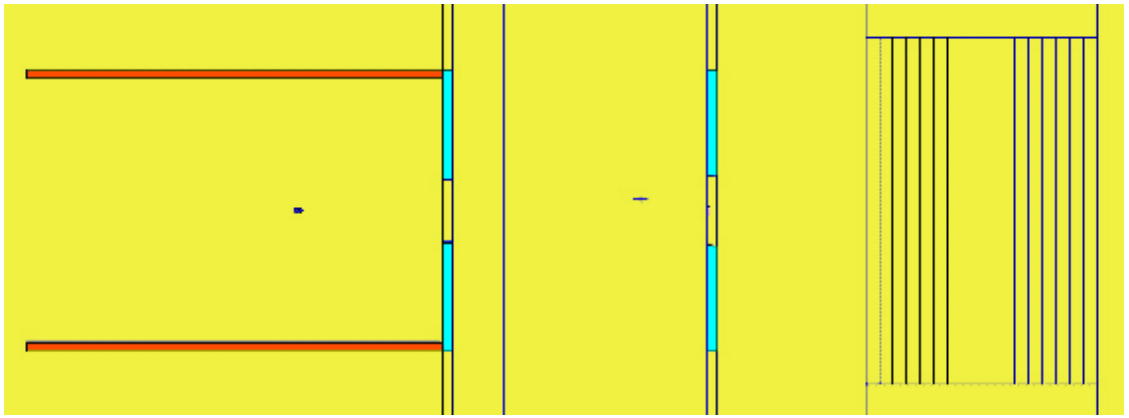
Best Medical Model 2301 ^{125}I Seed



W. Culberson. *Large-angle ionization chambers for brachytherapy air-kerma strength measurements*. Diss. University of Wisconsin, Madison, (2005).

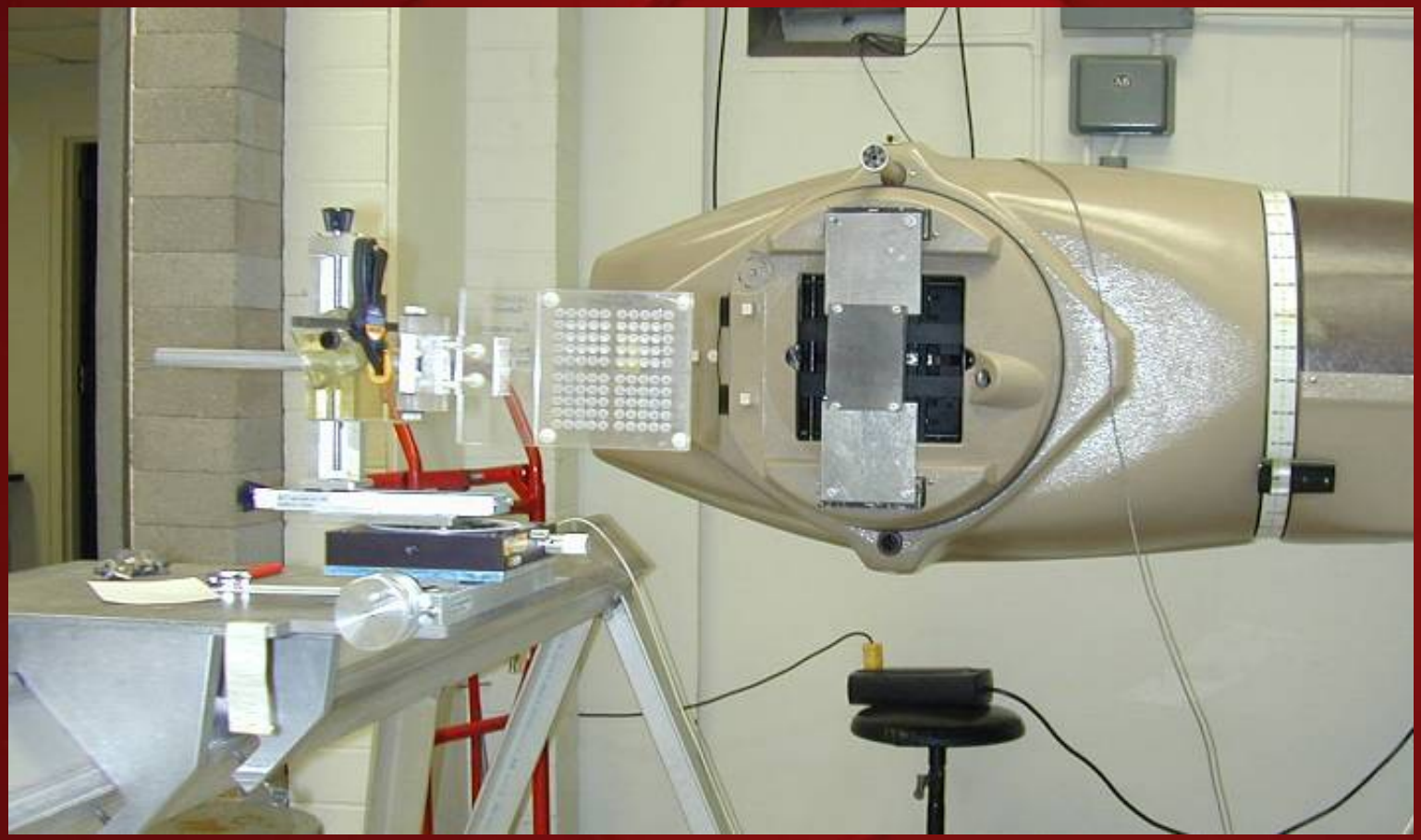
J. Williamson. *Monte Carlo modeling of the transverse-axis dose distribution of the model 200 ^{103}Pd interstitial brachytherapy source*. Medical Physics, 27, 4, 643-654 (2000).

TOP VIEW



^{60}Co Irradiations and Dose to Water Calculation

$$D_{\text{water}} = \frac{\left[\dot{D}_{\text{water}}\right]_{\text{MonteCarlo}}}{\left[\dot{K}_{\text{air}}\right]_{\text{MonteCarlo}}} \times \left[\dot{K}_{\text{air}}\right]_{\text{measured}} \times t$$



Results

Trial Number	Annealing Technique	TL/D_{water} ^{60}Co (nC/cGy)	TL/D_{water} ^{60}Co Uncertainty (nC/cGy)	TL/D_{water} ^{125}I (nC/cGy)	TL/D_{water} ^{125}I Uncertainty (nC/cGy)	E(r)	Type A Uncertainty	Percent Type A Uncertainty
1	Standard	107.7	1.7	167.1	3.7	1.55	± 0.04 3	2.8%
2	Standard	102.0	1.4	156.5	3.1	1.53	± 0.037	2.4%
3	Standard	104.1	1.8	160.9	3.1	1.55	± 0.040	2.6%
Overall	**Standard**	**104.6**		**161.5**		**1.54**	**± 0.023**	**1.5%**
Monte Carlo						1.42	± 0.02	1.4%

	Beam Code	Mean Energy (keV)	Relative Air Kerma Response
This Work	**^{125}I**	**28.4**	**1.369**
Nunn et al.	M-80	33.5	1.365
Davis et al.	N-40	32.5	1.465

Conclusions

- LiF:Mg,Ti does indeed exhibit solid state phenomena that increase the magnitude of the energy response beyond what can be predicted with current Monte Carlo methods.

- The currently applied value of E(r)=1.41 is likely an underestimate and should be revised. This work predicted a value of E(r)=1.54 for ^{125}I spectra.

- Based on these conclusions the current values of experimentally determined dose rate constants are overestimates.

Acknowledgements

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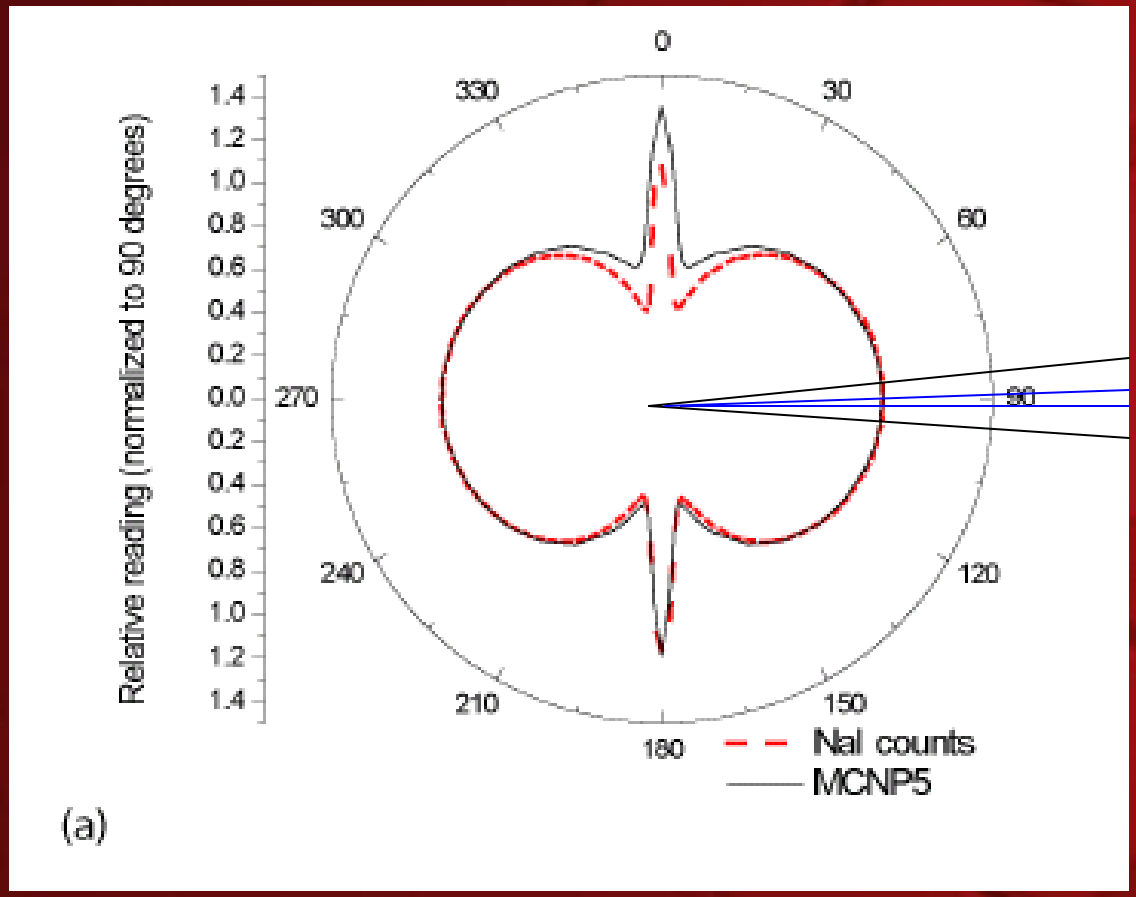
University of Wisconsin ADCL Students

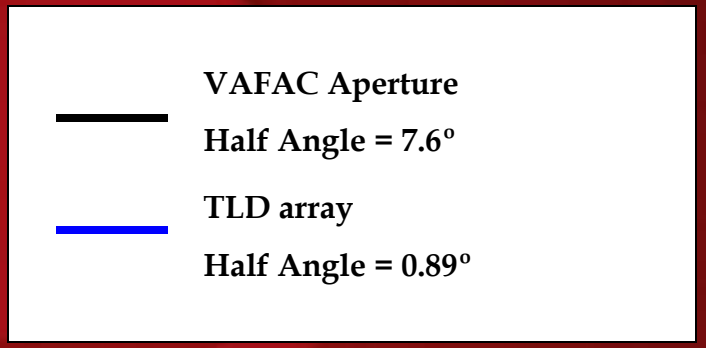
University of Wisconsin ADCL Customers

Which ^{125}I Seed?

Problem: TLDs see small solid angle so they are sensitive to anisotropy.

Best Medical 2301 ^{125}I Seed





W. Culberson. *Large-angle ionization chambers for brachytherapy air-kerma strength measurements*. Diss. University of Wisconsin, Madison, (2006).

Previous Publications

Previous Publications	E(r)
This Work	1.54
Davis et al. TG-43U1 Estimate	1.58
Muench et al. 1991	1.41 or 1.59 ?
Weaver et al. 1989	1.42 - 1.47
Meigooni et al. 1988	1.41
Hartmann et al. 1982	1.40

Keith A. Weaver, Vernaon Smith, David Huang, Colleen Barnett, Michael C. Schell, and Clifton Ling. *Dose parameters of ^{125}I and ^{192}Ir seed sources.* Medical Physics, 16,636 (1989).

A.S. Meigooni, J.A. Meli, and R. Nath. *A comparison of solid water phantoms with water for dosimetry of I-125 brachytherapy sources.* Medical Physics, 15, 5, 695 (1988).

Gunther H. Hartmann, Wolfgang Schlegel, and Harald Scharfenberg, *The three-dimensional dose distribution of ^{125}I seeds in tissue.* Phs. Med. Biol., 28, 6, 693 (1982).

P. J. Muench, A. S. Meigooni, R. Nath, and W. L. McLaughlin, .Photon Energy Dependence of the Sensitivity of Radiochromic Film and Comparison with Silver Halide Film and LiF TLDs Used for Brachytherapy Dosimetry,. Medical Physics, 18, 4, 769 (1991).

Future Work

- More in depth uncertainty calculation will be performed.
- Experiment will be performed with ^{103}Pd Sources.
- The effects of annealing techniques will be further analyzed.
- Effects of TTP in readout will be examined.
- Comparisons will be made with various low energy x-ray beams.