An EGSnrc generated TG-43 dosimetry parameter database

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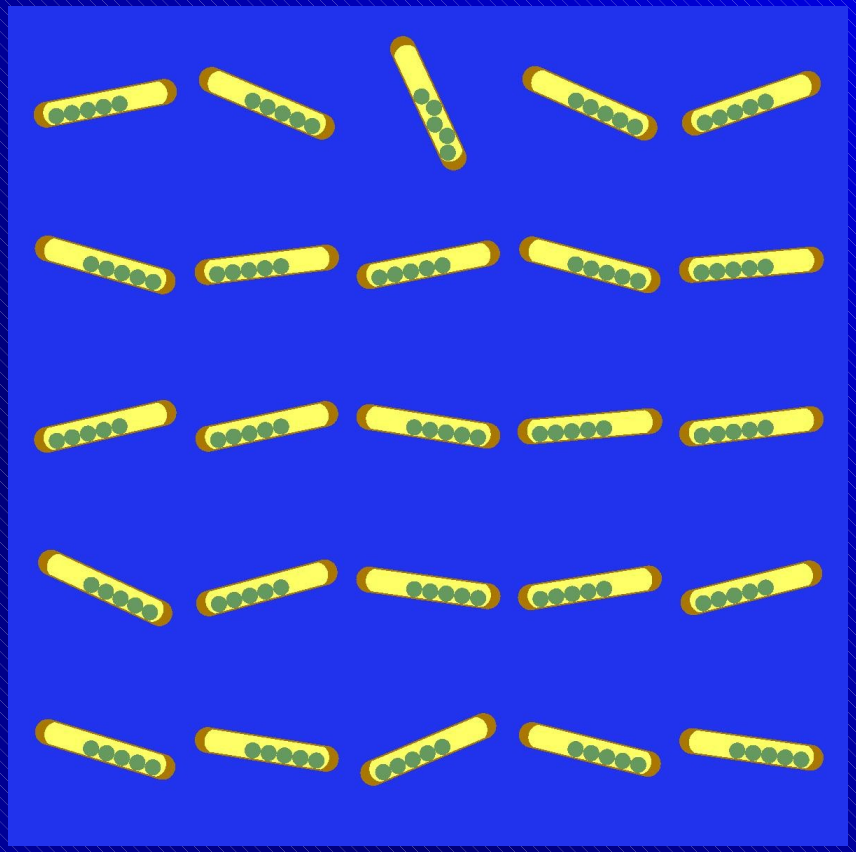
Outline

- Introduction to BrachyDose
  - Rapid M.C. brachytherapy dosimetry
- Benchmarking BrachyDose
  - Voxel size effects
  - X-Ray sources – EGSnrc bugs
- TG-43 Parameter Database
  - Generate data for 16 ^{125}I / ^{103}Pd seeds in RPC/AAPM source registry as well as ^{131}Cs and miniature x-ray sources
  - Make data freely available via the web
- Summary

Introduction to BrachyDose

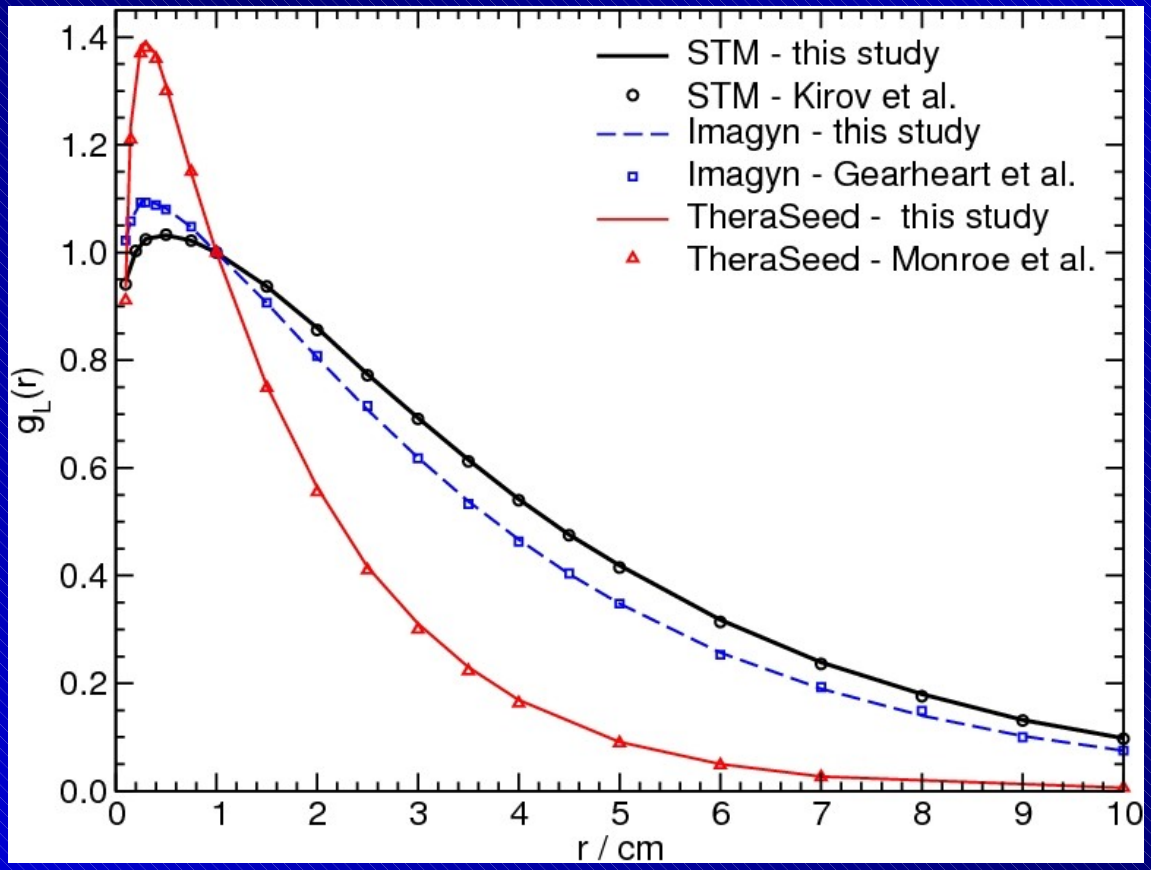
- EGSnrc usercode for rapid brachytherapy dosimetry calculations
  - ~3-4 min to get 2% statistics within implant region using $(1\ mm)^3$ voxels (125 seeds spaced at 5 mm)
  - CT data capable
  - Yegin's geometry package allows detailed modelling of complex seed geometries and seed configurations



Benchmarking BrachyDose

- Brachydose benchmarked by reproducing TG-43 dosimetry parameters for ^{125}I and ^{103}Pd source [1]

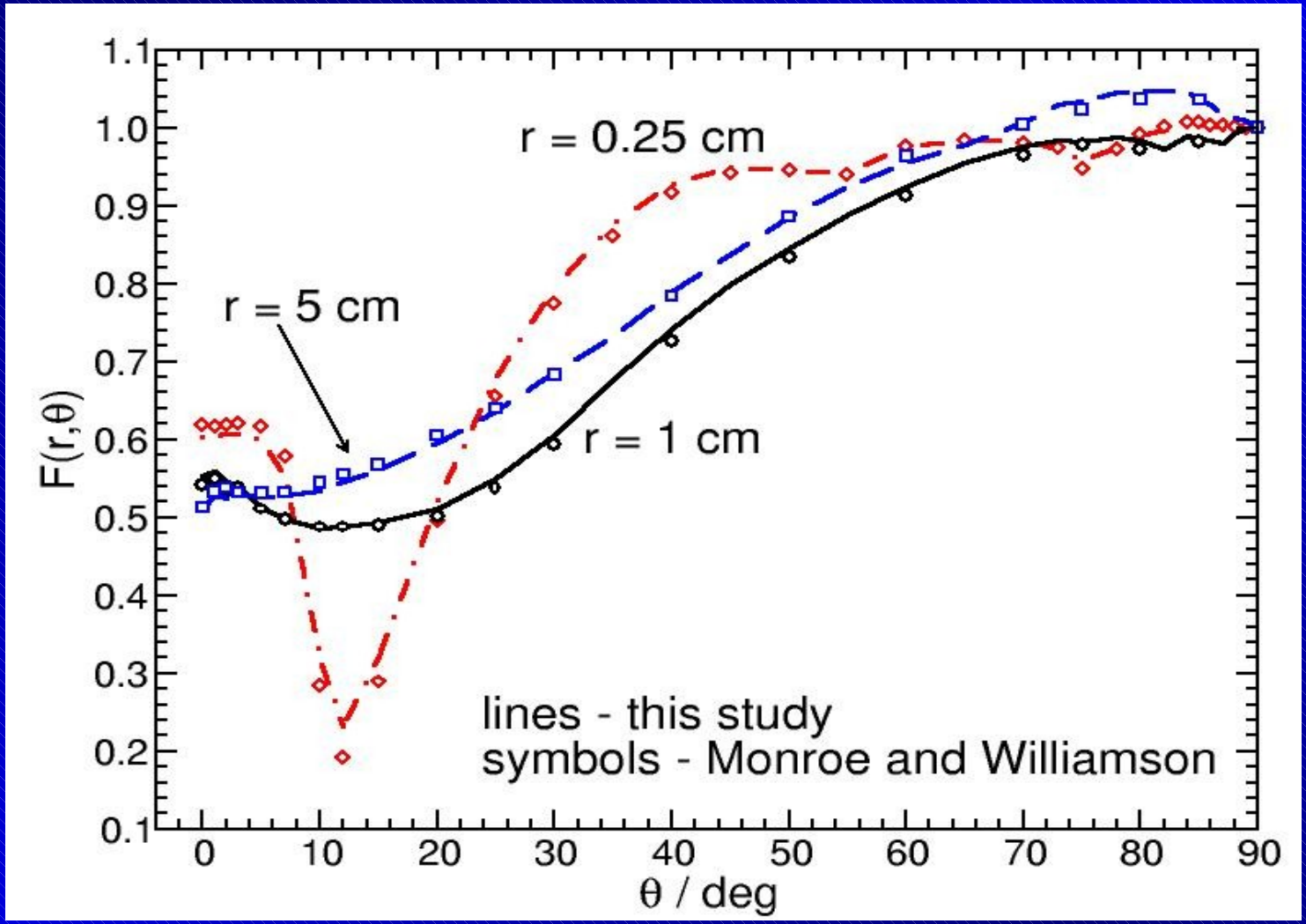
Radial dose function for various seed models



1. Taylor R. E. P., Yegin G. and Rogers D.W.O., 2007, Benchmarking BrachyDose: voxel-based EGSnrc Monte Carlo calculations of TG-43 dosimetry parameters *Med. Phys.* **34** 445 – 457

Benchmarking BrachyDose

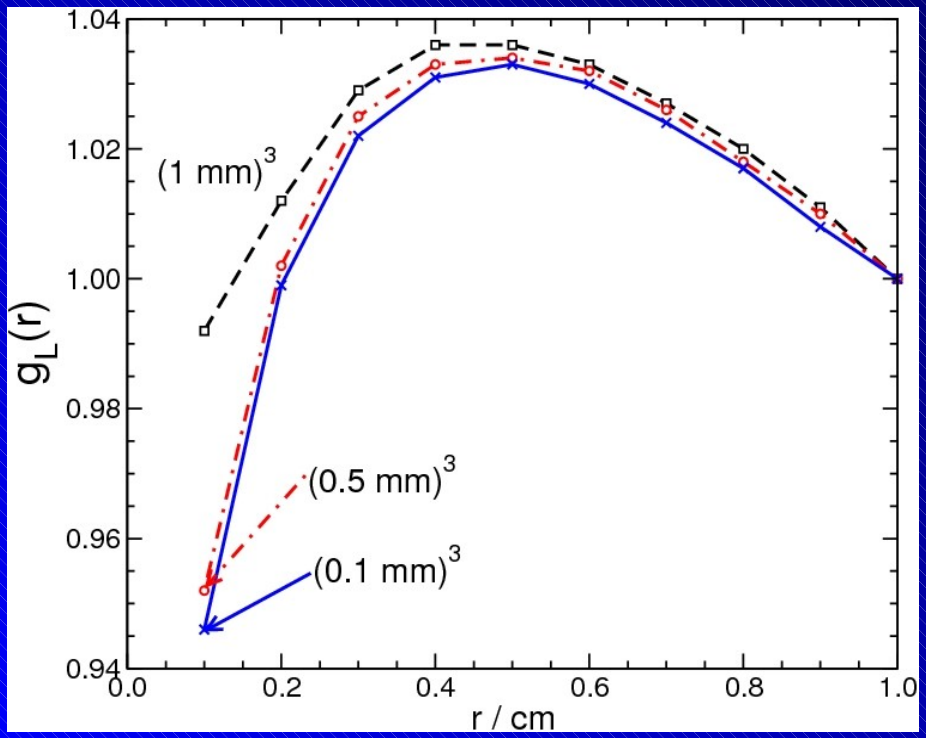
Anisotropy function for STM1251 Model



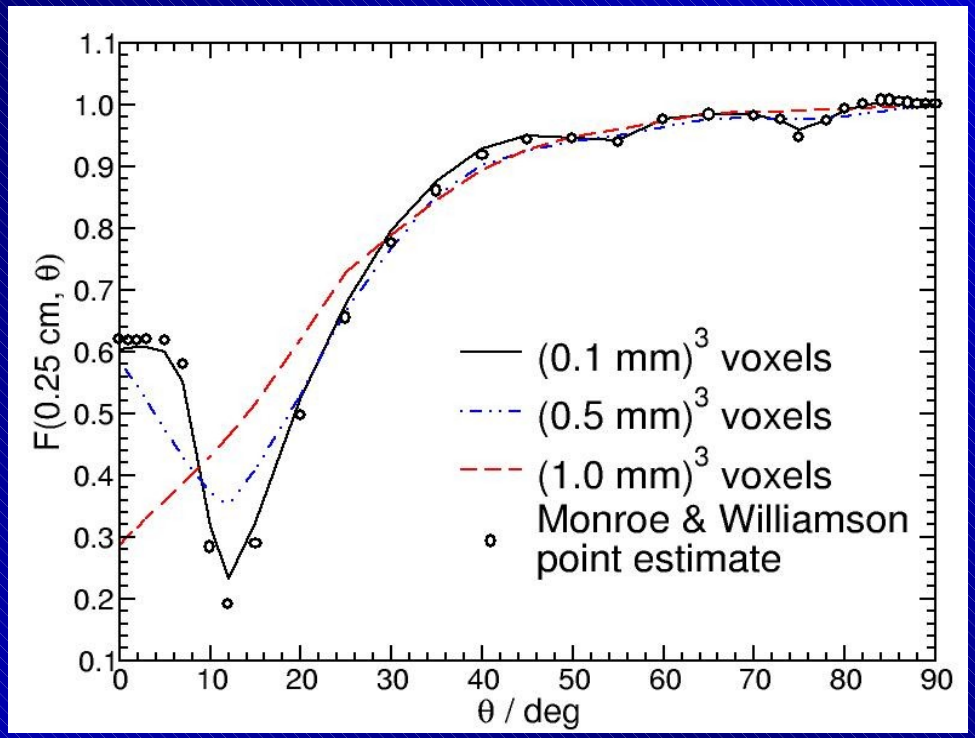
Voxel Size Considerations

- Voxels that are too large can lead to significant errors in calculated dosimetry parameters

Effect of voxel size on radial dose function



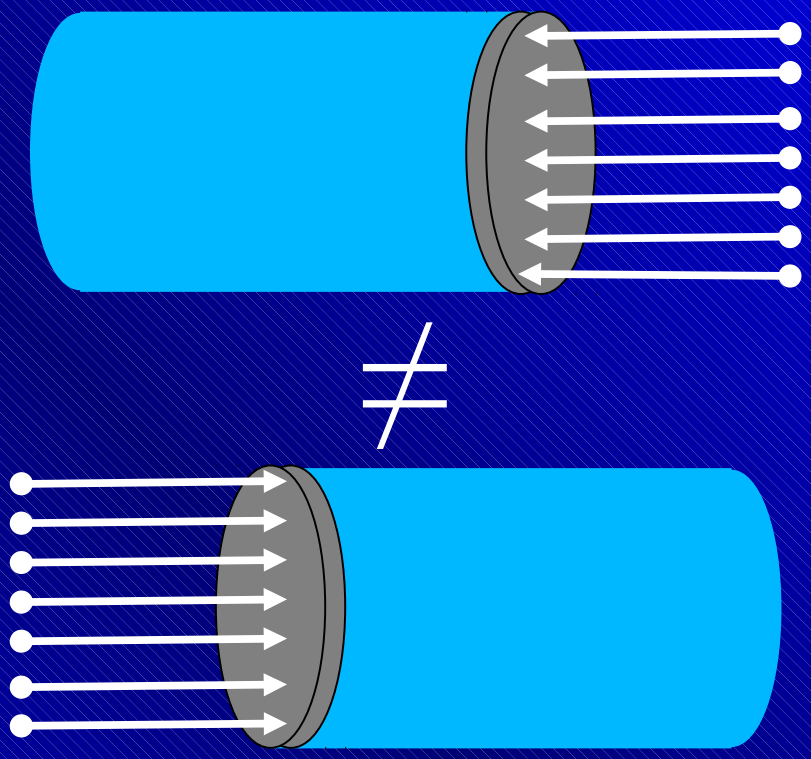
Effect of voxel size on anisotropy function



Benchmarking for x-ray sources

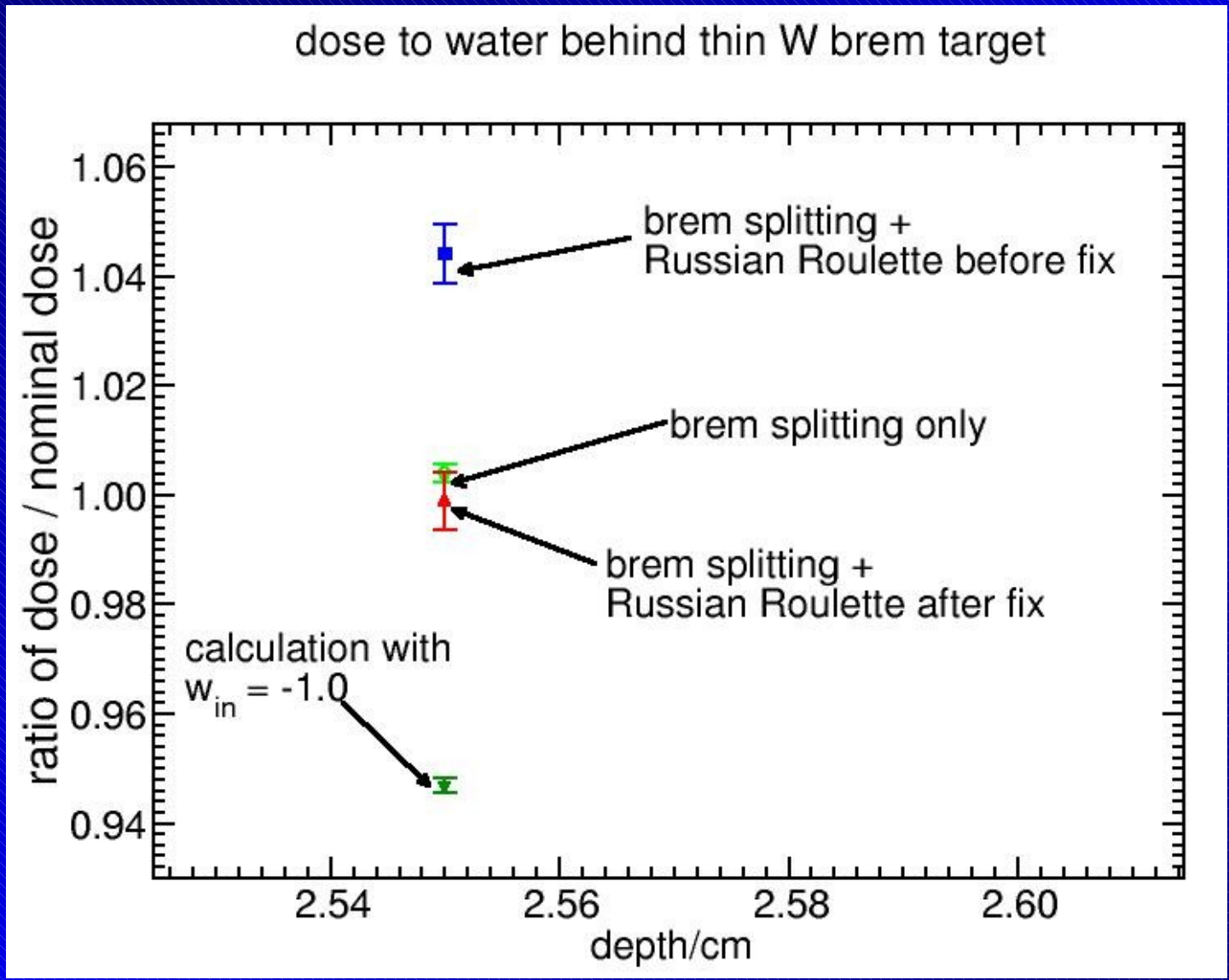
- enabling e^- transport within source allows simulation of x-ray sources -> Xoft x-ray source
- V.R.T improve efficiency by 10^4
- Comparing B.D. and DOSRZnrc revealed two bugs in EGSnrc**
  - e^- travelling exactly in the -ve z direction occassionaly had direction reversed
  - Bug in Russian roulette routines caused 4% overestimate of dose when R.R. turned on.

50 kV e^- on W target



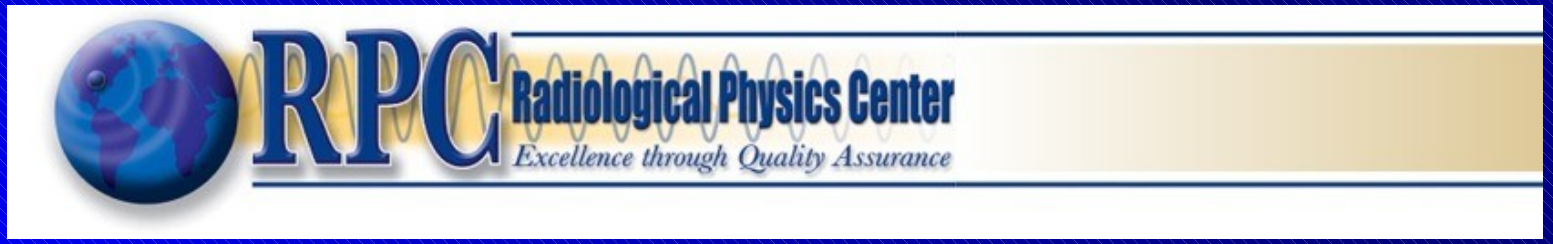
**Patches for bugs provided by I. Kawrakow of NRC

Effect of the two EGSnrc bugs



TG-43 Parameter Database

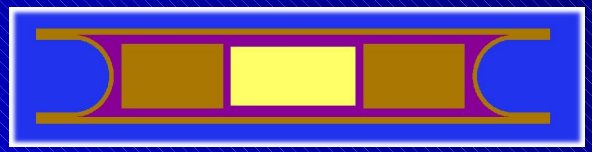
- Currently 16 seeds in the Joint AAPM/RPC Registry of Brachytherapy Sources
  - Sources require at least one M.C. and one measured data set for inclusion in registry
- Dosimetry parameters generated by a variety of authors
  - Most M.C. results from PTRAN and MCNP
  - Different authors use different methodologies
- Useful to have a complete, independent, data set generated using a consistent set of methods



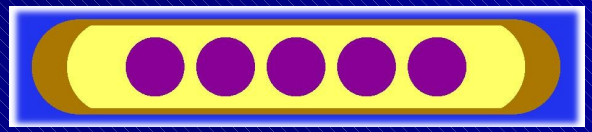
TG-43 Parameter Database

- Use BrachyDose to generate a consistent TG-43 dosimetry parameter database
  - Data for every source generated in a consistent manner at the same set of points in space
  - Provides an independent verification of currently available dosimetry parameters
  - Include dosimetry parameters for ^{131}Cs and miniature x-ray devices such as the Xoft Axxent x-ray source

EchoSeed Model 6733



Theragenics Model 200



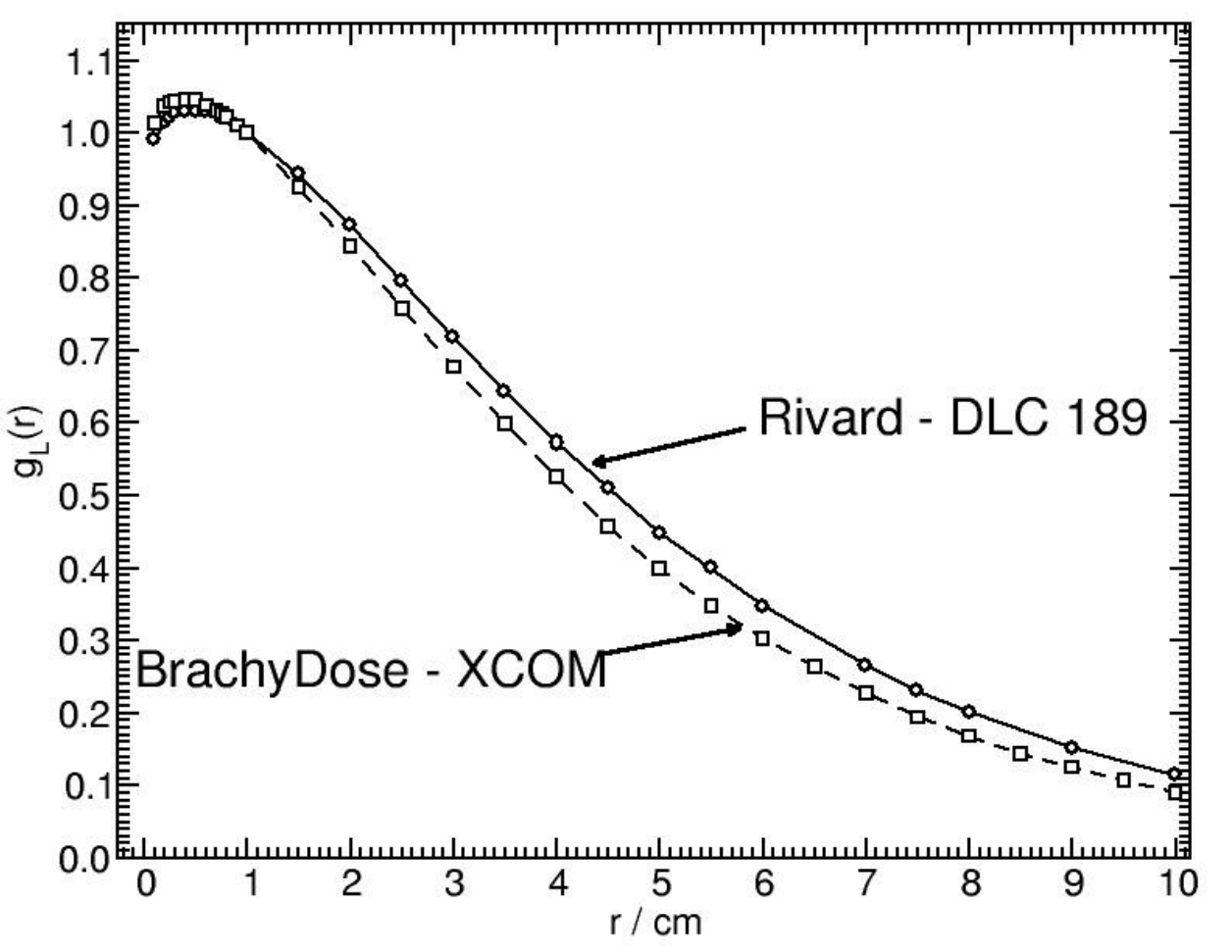
ProstaSeed

Methods & Materials

- Modern cross section data (XCOM)
- Data generated with higher spatial resolution than is currently available for many sources
  - g(r) data from 0.1 cm to 10 cm
  - F(r,theta) data available from 0.25 cm to 10 cm at 32 angles (minimum resolution of 5 deg)
- Voxel size effects minimized
  - $(0.1\ mm)^3$ voxels for $r <= 1$ cm, $(0.5\ mm)^3$ voxels for $r <= 5$ cm, $(1.0\ mm)^3$ voxels for $r <= 10$ cm,
- Air kerma strength data, S_k, calculated at a point on the transverse axis, as well as over a region approximating the aperture size of the WAFAC

Effect of Cross Sections

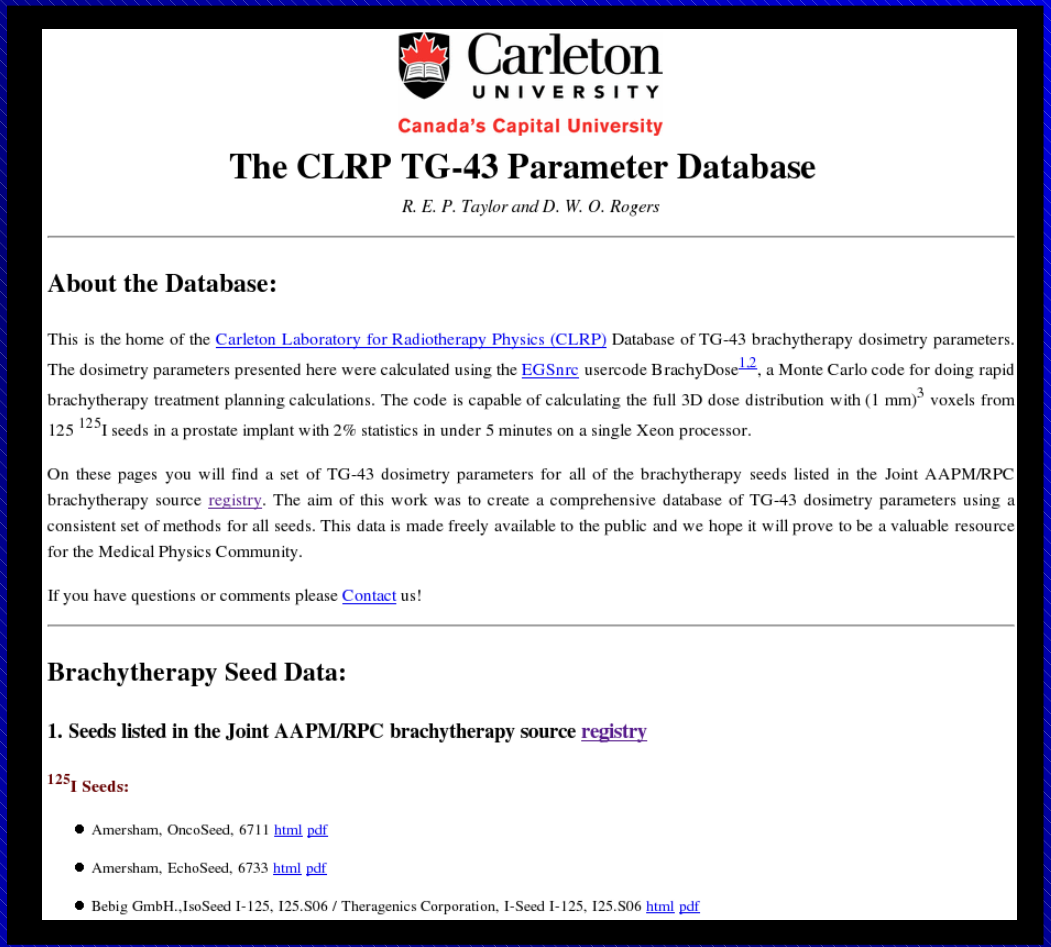
Radial dose function for the Iplant 3500 seed



C.L.R.P TG-43 Web Resource

www.physics.carleton.ca/~drogers/

- Full set of tabulated dosimetry data for each source studied
- Description of calculation methods
- Descriptions & scale drawings of source dimensions and geometry
- Plots comparing values calculated in this study to values calculated by other authors
- Links to relevant papers/websites



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The CLRP TG-43 Parameter Database

R. E. P. Taylor and D. W. O. Rogers

About the Database:

This is the home of the Carleton Laboratory for Radiotherapy Physics (CLRP) Database of TG-43 brachytherapy dosimetry parameters. The dosimetry parameters presented here were calculated using the EGSnrc usercode BrachyDose[1,2], a Monte Carlo code for doing rapid brachytherapy treatment planning calculations. The code is capable of calculating the full 3D dose distribution with $(1\ mm)^3$ voxels from ^{125}I seeds in a prostate implant with 2% statistics in under 5 minutes on a single Xeon processor.

On these pages you will find a set of TG-43 dosimetry parameters for all of the brachytherapy seeds listed in the Joint AAPM/RPC brachytherapy source registry. The aim of this work was to create a comprehensive database of TG-43 dosimetry parameters using a consistent set of methods for all seeds. This data is made freely available to the public and we hope it will prove to be a valuable resource for the Medical Physics Community.

If you have questions or comments please Contact us!

Brachytherapy Seed Data:

1. Seeds listed in the Joint AAPM/RPC brachytherapy source registry

^{125}I Seeds:

- Amersham, OncoSeed, 6711 html pdf
- Amersham, EchoSeed, 6733 html pdf
- Bebig GmbH.,IsoSeed I-125, I25.S06 / Theragenics Corporation, I-Seed I-125, I25.S06 html pdf

C.L.R.P TG-43 Web Resource

Amersham OncoSeed 6711 ^{125}I Source TG-43 data

Source Description:

The 6711 source consists of radioactive AgI and AgBr coated on a 2.8 mm long cy
the silver rod are conical sections beveled at 45^{o} and the end faces of the rod hav
coating is assumed to have a uniform thickness of 1.75 μm on the cylindrical surf
composition as given in ref. 1. The silver rod is encapsulated in a titanium tube w
0.375 mm thick end welds. The inside of the capsule is filled with air. Overall sou
mm.

Dose Rate Constant - Λ :

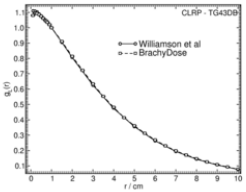
Dose rate constants, Λ , are calculated by dividing the air kerma strength per history
(0.1~mm)^3 voxel centered on the reference position, (1 cm,Π/2), in the 30x30x30
constants are provided for air kerma strenth calculated using voxels of 2.7x2.7x0.0
source. The larger voxel size averages the air kerma per history over a region co
primary collimator of the WAFAC[b,c]. The small voxel serves to estimate the air ker

Author	Λ (cG
this study - 0.1x0.1x0.05 cm^3 voxel at 10 cm	
this study 2.66x2.66x0.05 cm^3 voxel at 10 cm	
Williamson[1] (DLC 146)	
Williamson[1] TLD	

Radial dose function - g(r):

The radial dose function, g(r), is calculated using both line and
less than 1 cm from the source and 0.5 cm intervals from 1 cm

Click image for higher res version



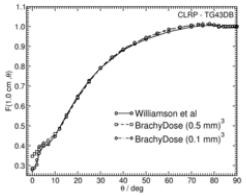
Tabulated g(r) data: html Excel

Anisotropy function - F(r,Θ):

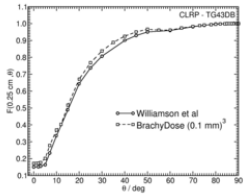
Anisotropy functions are calculated using the line source appro
and 32 unique polar angles with a minimum resolution of 5^{o}. The anisotropy factor, φ_{an}(r), was calculated by integ
weighted dose rate over $0^{o} \le \theta \le 90^{o}$.

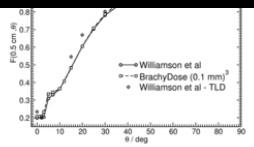
Click images for higher res versions

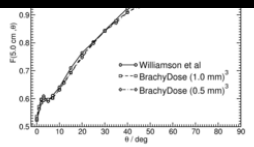
F(01.00,Θ)



F(00.25,Θ)







Tabulated F(r,Θ) data: html Excel

References:

Seed Specific References

1. J. Dolan, Z. Li, and J.F. Williamson, Monte Carlo and experimental dosimtery of an ^{125}I brachytherapy seed, Med. Phys **33** 4675 (2006)

Other References

a. R. E. P. Taylor, G. Yegin, D.W.O. Rogers, Benchmarking BrachyDose: voxel-based EGSnrc Monte Carlo calculations of TG-43 dosimetry parameters, Med. Phys **34**, 445 (2006)

b. R. Loevinger, Wide-angle free-air chamber for calibration of low--energy brachytherapy sources, Med. Phys **20** 907 (1993)

c. S. M Seltzer *et al*, New National Air-Kerma-Strength Standards for ^{125}I and ^{103}Pd Brachytherapy Seeds, J. Res. Natl. Inst. Stand. Technol., **108**, 337 (2003)

d. R. E. P. Taylor, D.W.O. Rogers, An EGSnrc Monte Carlo calculated TG-43 parameter database, *in preparation*

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Carleton Laboratory for Radiotherapy Physics

March 30 2007.

Summary

- BrachyDose is a powerful and *fast* tool for doing accurate brachytherapy dosimetry
  - benchmarked and shown to produce results consistent with other EGSnrc user-codes as well as other M.C. codes
- We have a nearly completed TG-43 parameter database and web resource which includes:
  - A full set of tabulated dosimetry data for each source
  - detailed source descriptions / scale drawings
  - comparisons to previously published data
- We hope BrachyDose will be a useful tool for the Medical Physics community in the future of brachytherapy dosimetry

Acknowledgements

Carleton laboratory for radiotherapy physics (CLRP)

- D. Rogers
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- G. Yegin
- D. La Russa
- E. Ali

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- I. Kawrakow

NSERC
CFI/OIT

Voxel size effects

- Williamson's code uses a point estimator
- when using voxels one must be careful

$$D_{\mathrm{vox}} = \frac{1}{\Delta r}\int_{r_o-\frac{\Delta r}{2}}^{r_o+\frac{\Delta r}{2}} dr\, D(r)$$

i.e., dose is average over voxel

$$D_{\mathrm{vox}} = D(r_o)\left[1+\frac{D''(r_o)}{24D(r_o)}\Delta r^2 + O(\Delta r^4)\right]$$

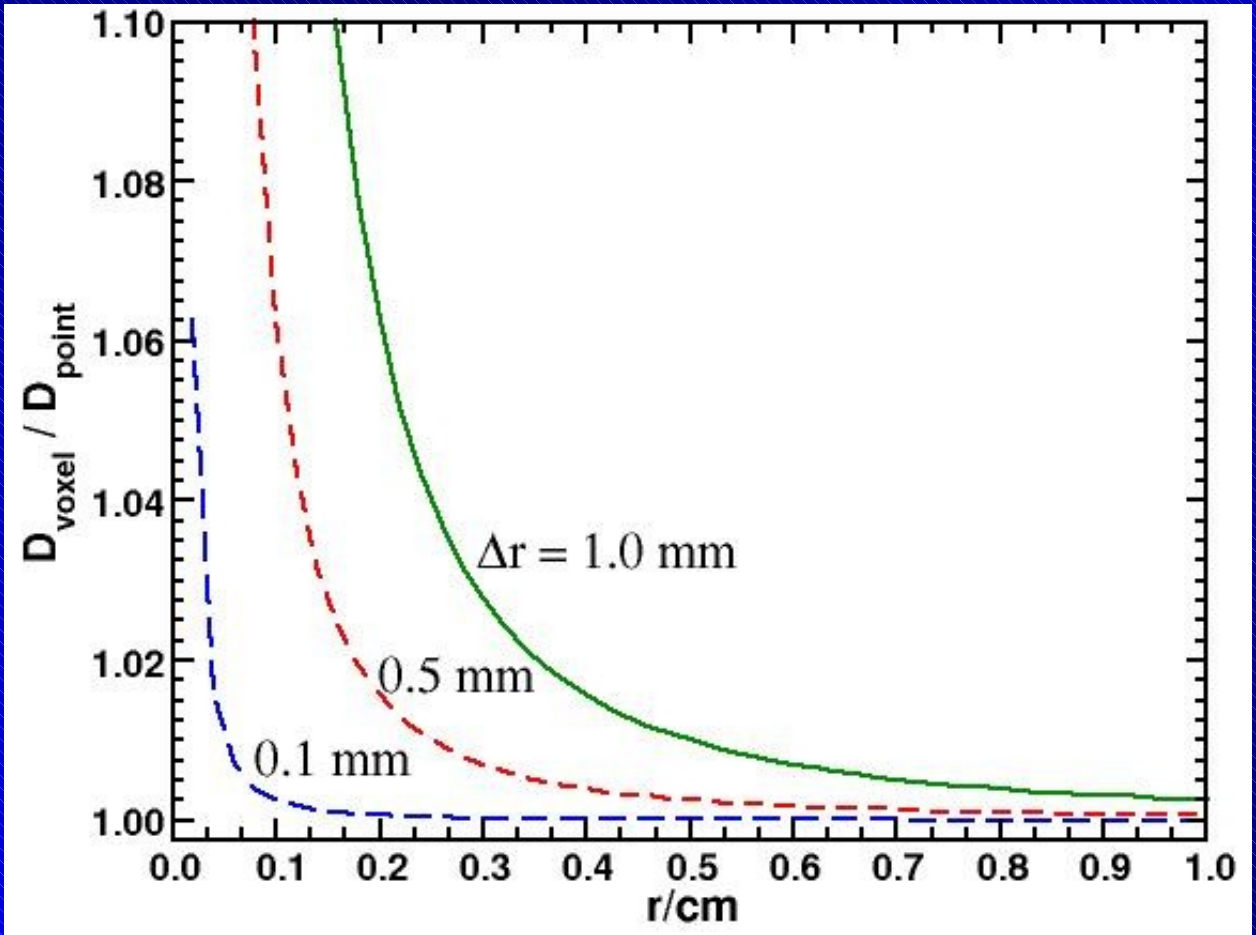
Kawrakow MP 2006 p1829

For $1/r^2$

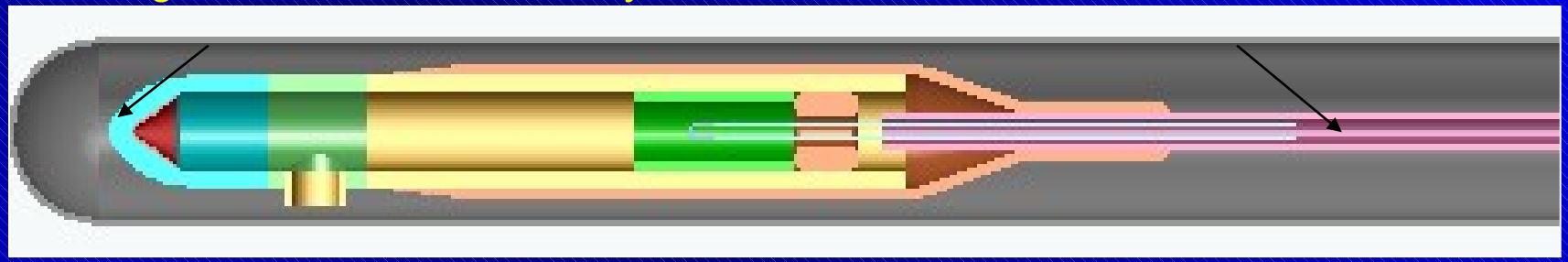
$$D_{\mathrm{vox}} \approx D(r_o)\left[1+\frac{\Delta r^2}{4r_o^2}\right]$$

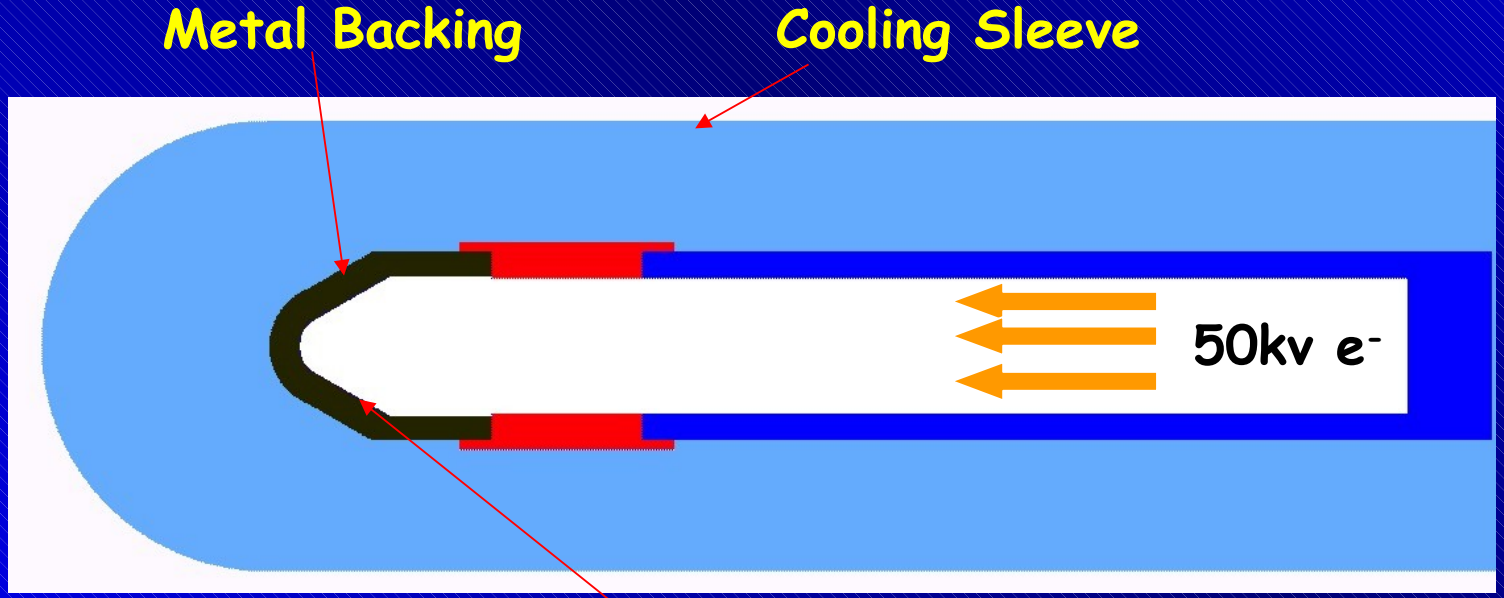
Voxel size effects

Size of error in associating the average dose in the voxel with the dose at the mid-point (near a point source)

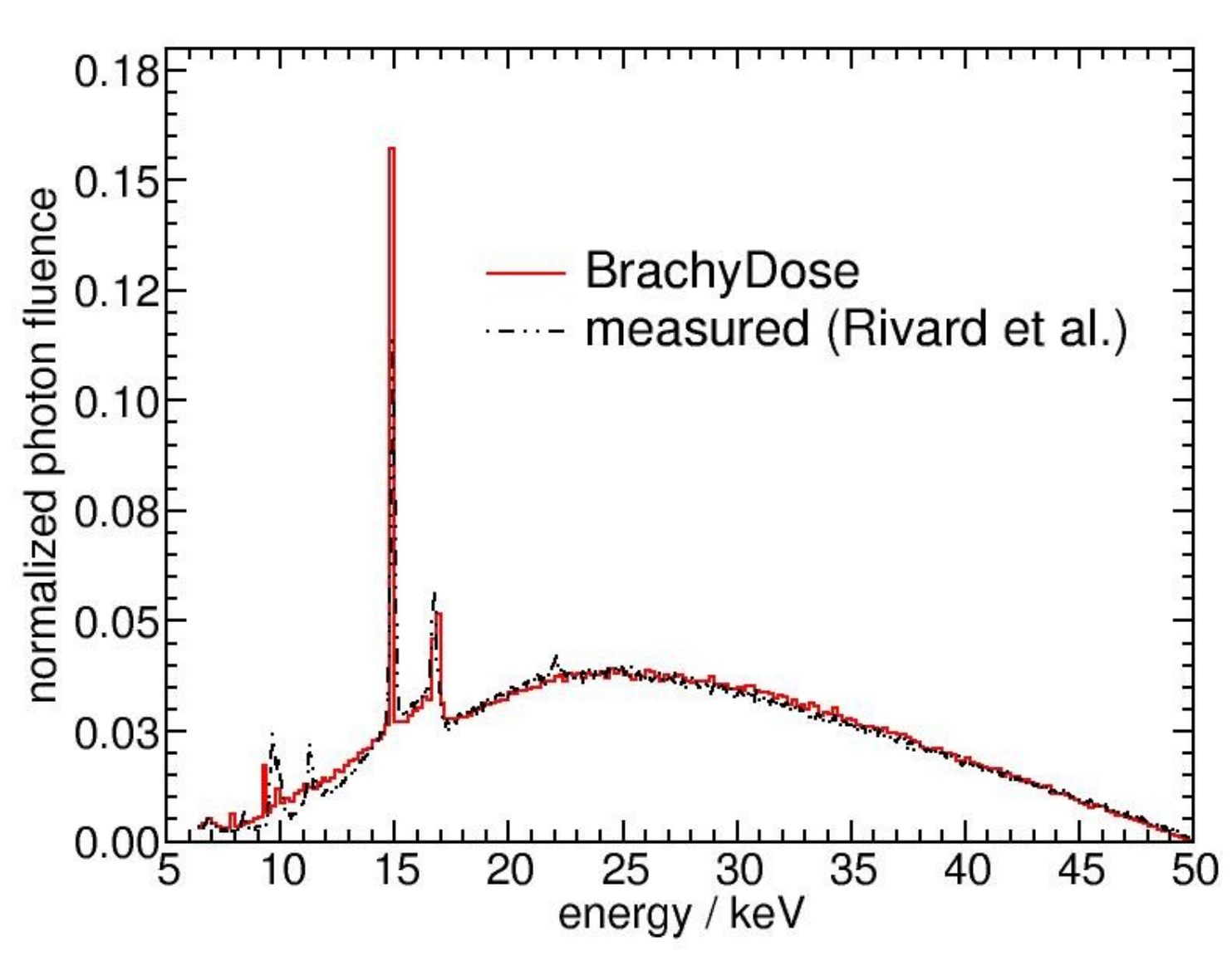


Model for Monte Carlo Simulation

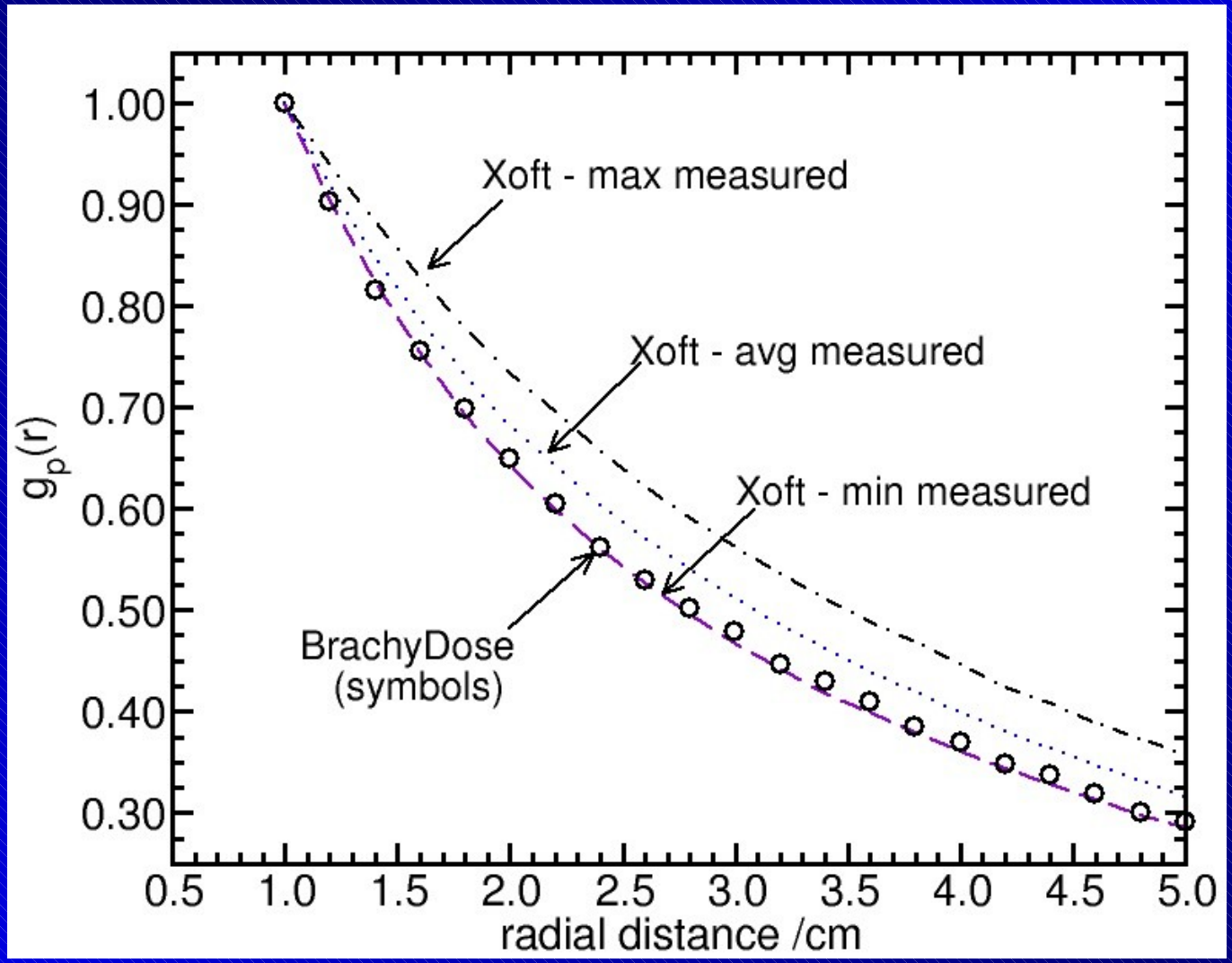




Energy Spectrum Calculations

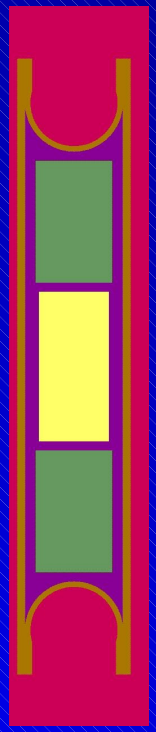


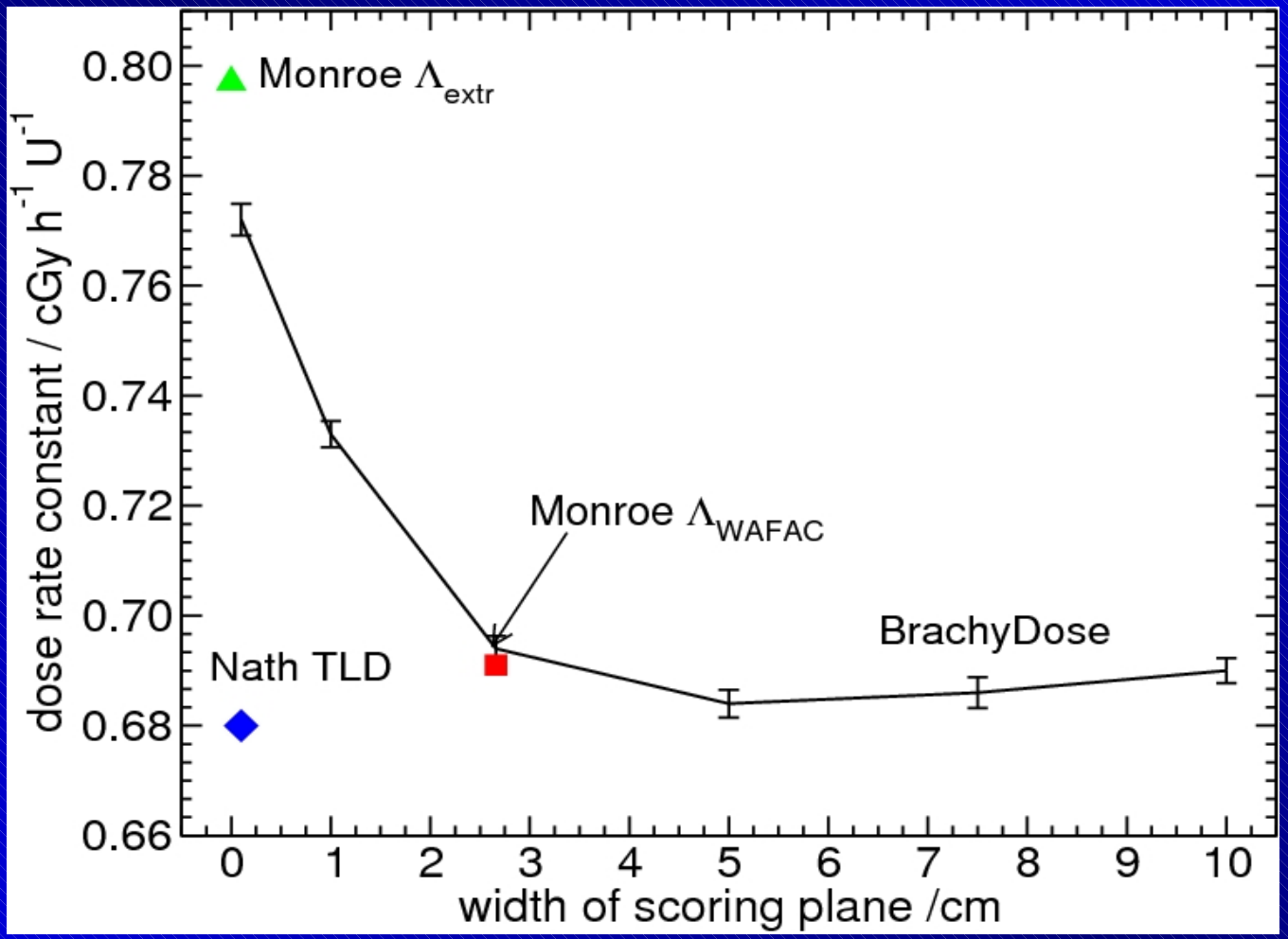
g(r) – Radial Dose Function



Λ - Dose Rate Constant

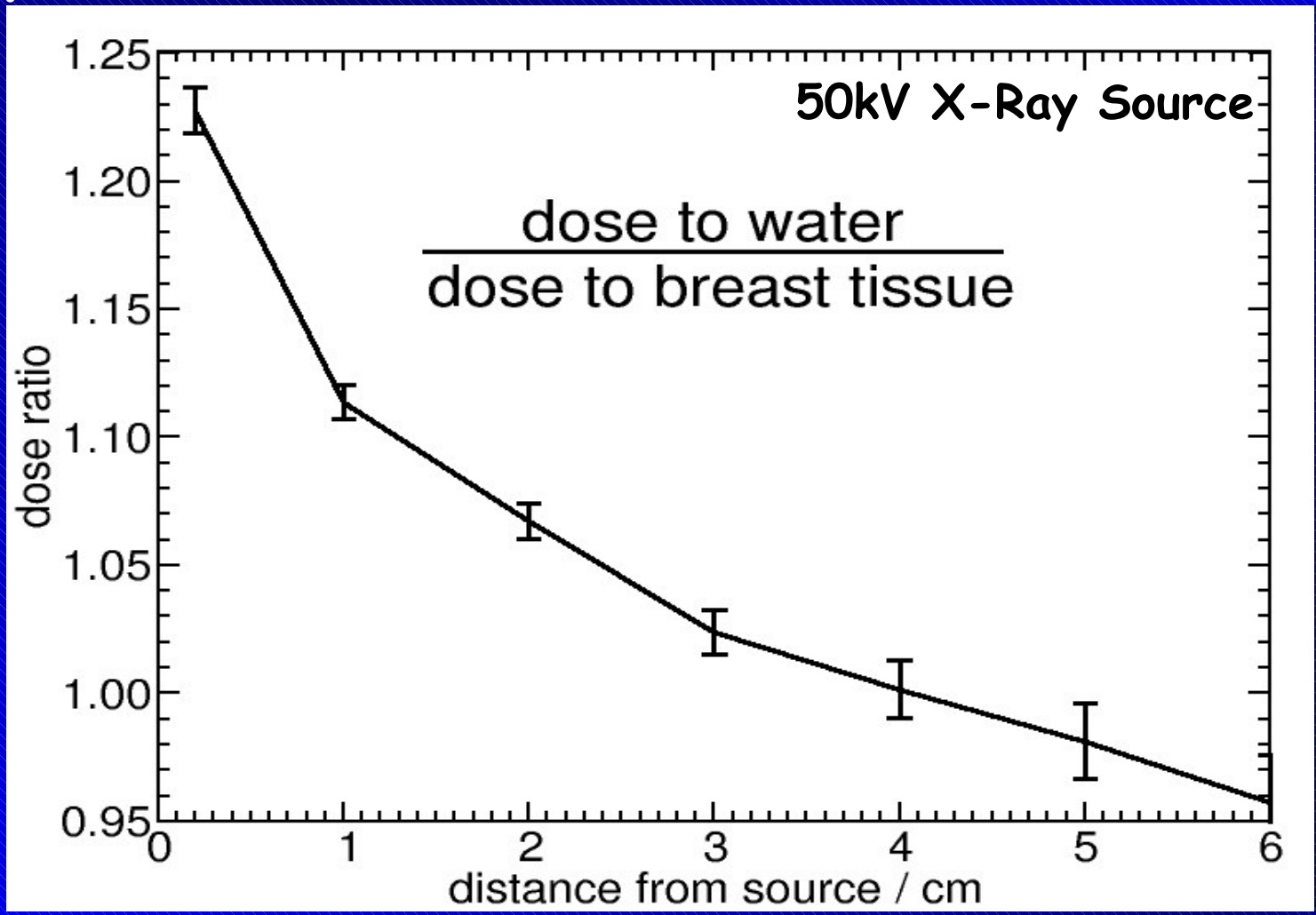
^{103}Pd Source





Effect of Realistic Tissue

Up to 22% difference in dose near source



Tissue Effect