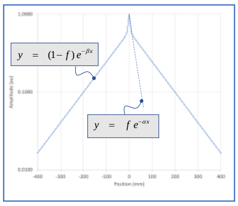
Dose Spread Functions in CT



John M. Boone, Ph.D.
Professor of Radiology and Chief of Medical Physics
Professor of Biomedical Engineering
University of California Davis
Sacramento, California

Dose Spread Functions in CT

Conflicts of Interest:

Board Member (and Treasurer), International Commission on Radiation Units (ICRU)
Board Member and shareholder, Izotropic Imaging (breast CT company)
Board Member, California Radiological Society (local chapter of the ACR)
(in kind) Research Funding, Canon Medical Systems
Travel Funding from:
American Association of Physicists in Medicine (IPC and IEC meetings)
International Commission on Radiation Units and Measurement (ICRU)

Dose Spread Functions in CT

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- Consequences
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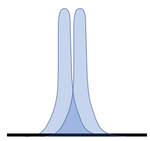
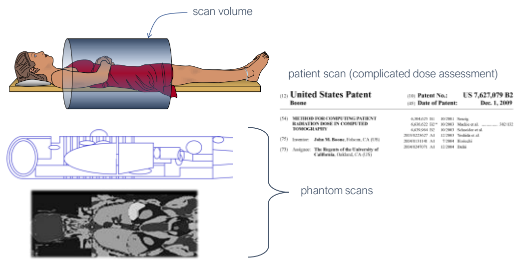


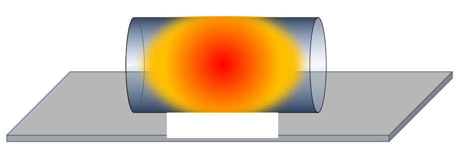
1.5 decades of CT dose in the news…..

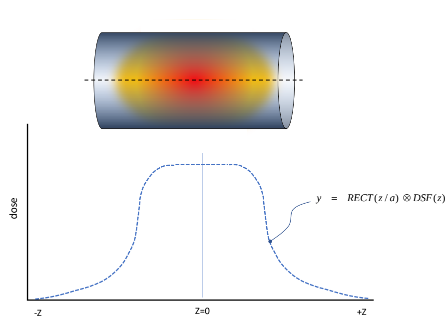
Computed Tomography: patient dosimetry



Computed Tomography: simple phantom imaging

This Work





ICRU / AAPM (TG-200)
Dosimetry Phantom

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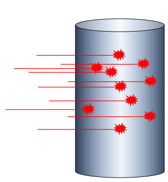
Tu-HI-221CD • San Antonio AAPM • Patient Dose Monitoring in CT with Tube Current Modulation and Multiple Series

This study is a Monte Carlo-based analyses

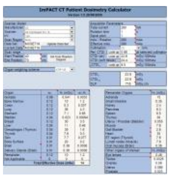
Dose spread functions in computed tomography: A Monte Carlo study

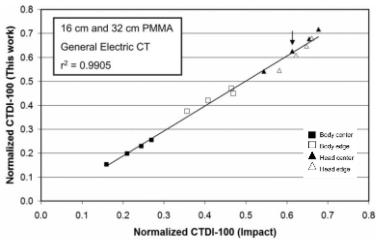
John M. Boone[a]
Department of Radiology and Department of Biomedical Engineering, University of California, Davis Medical Center, 4860 Y Street, Suite 3100 Ellison Building, Sacramento, California 95817

(Received 19 February 2009; revised 3 August 2009; accepted for publication 7 August 2009; published 10 September 2009)



Monte Carlo validation





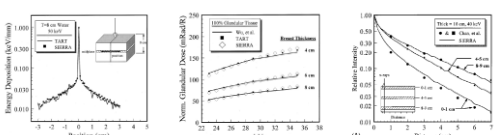
Monte Carlo: SIERRA

Monte Carlo validation in diagnostic radiological imaging

John M. Boone,[a] Michael H. Buonocore, and Virgil N. Cooper III
Department of Radiology, University of California, Davis, Sacramento, California 95817

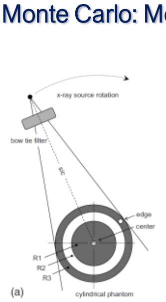
(Received 6 December 1999; accepted for publication 30 March 2000)

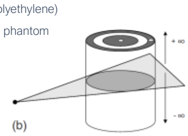
The Sierra Nevada Mountains



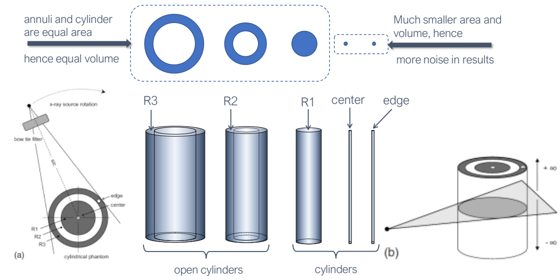
Monte Carlo: Methods

- CT scanner geometry (SIC)
- Accurate spectra using TASMIP Model (kV and HVL)
- Different bow tie filters (GE-VCT, Siemens AS+, none)
- Different diameter cylinders (10-50 cm)
- Cylinders are infinitely long
- Different materials (PMMA, water, polyethylene)
- Different regions of integration in the phantom



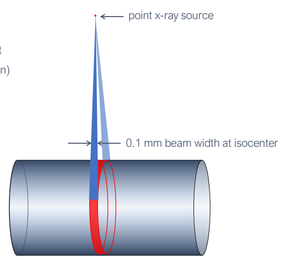


Monte Carlo: quantum noise and collection volume



Beam Geometry

- Complete 2π source rotation around object
- 100 μm beam width at isocenter (δ-function)



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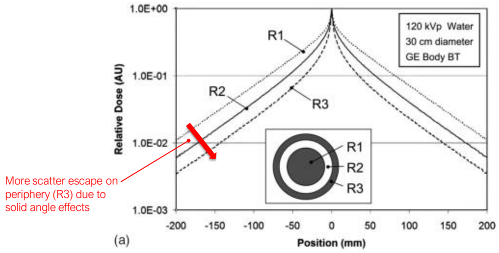
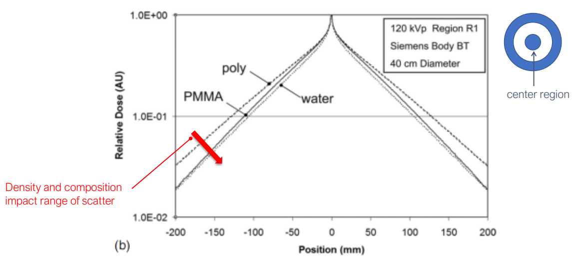
π

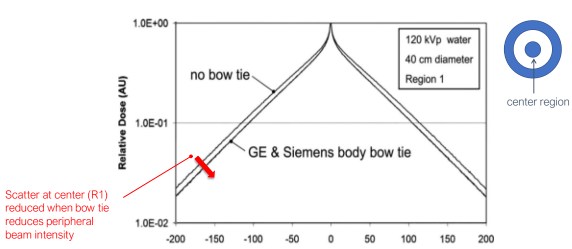
Dose versus position: regional differences



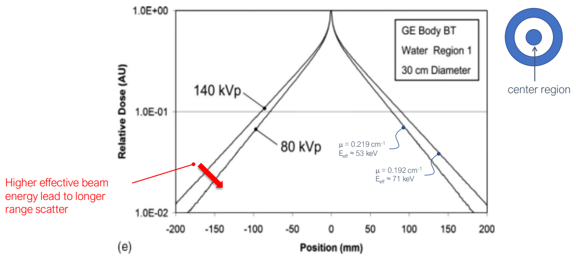
Dose versus position: material differences differences



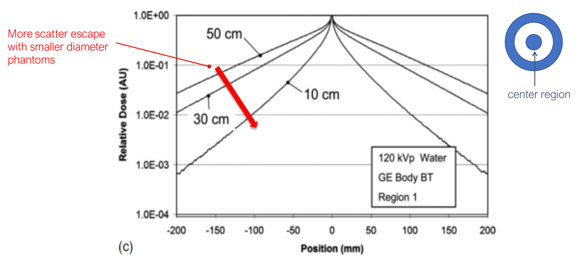
Dose versus position: bow tie differences



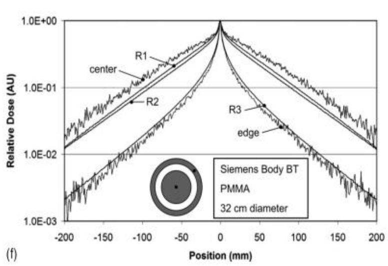
Dose versus position: spectal differences



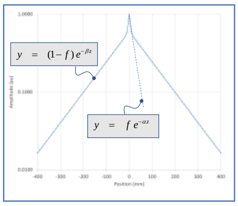
Dose versus position: diameter differences



Dose versus position: smaller volumes noisier

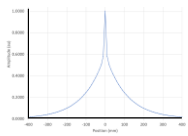


DSF: a classic bi-exponential function



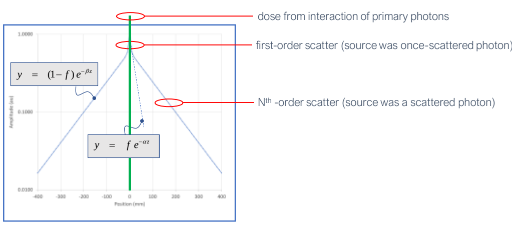
Log vertical axis

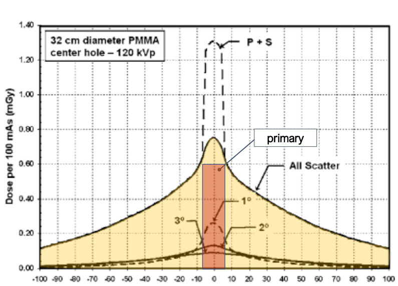
$$DSF(z) = fe^{-\alpha z} + (1-f)e^{-\beta z}$$

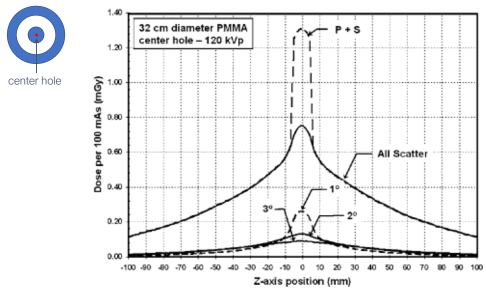


Linear vertical axis

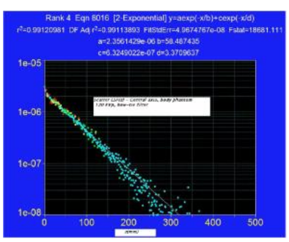
DSF: a classic bi-exponential function





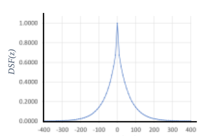


DSF: a classic bi-exponential function

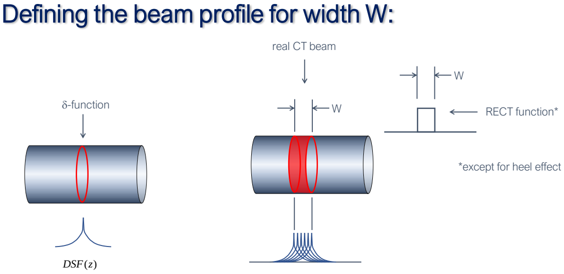


$$DSF(z) = fe^{-\alpha z} + (1-f)e^{-\beta z}$$

α = 0.0171 mm^{-1}
β = 0.2967 mm^{-1}
f = 0.7884

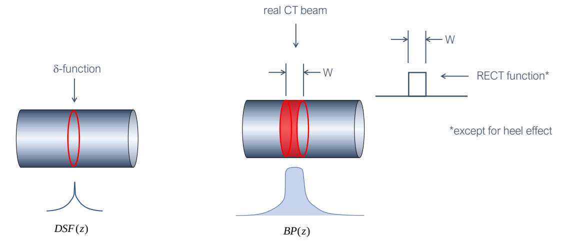


Defining the beam profile for width W:



$$DSF(z) = fe^{-\alpha z} + (1-f)e^{-\beta z}$$

Defining the beam profile (BP) for width W:



$$DSF(z) = fe^{-\alpha z} + (1-f)e^{-\beta z}$$

$$BP(z) = DSF(z) \otimes RECT\left[\frac{z}{w}\right]$$

$$\mathrm{DSF}(z) = P(z) + S(z).$$

$$\mathrm{Dose}(z) = \int_{-\infty}^{+\infty} \mathrm{DSF}(z - z')\Pi(z')dz',$$

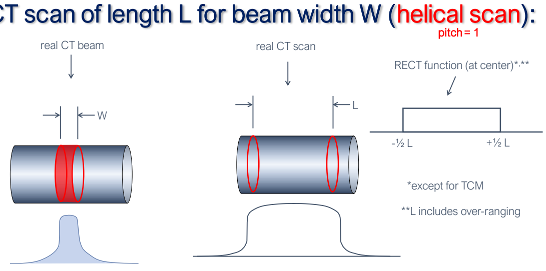
where $\Pi(z)$ is a RECT function of width w defined by

$\Pi(z) = P_0, \quad z = -w/2 \text{ to } +w/2,$

$\Pi(z) = 0, \quad \text{elsewhere}.$

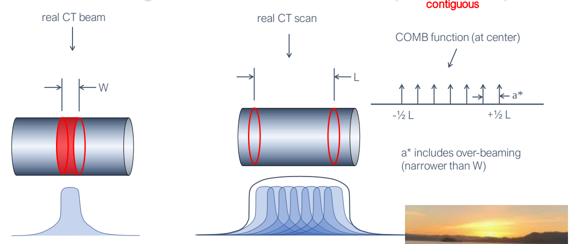
CT scan of length L for beam width W (helical scan):

pitch = 1



$$D(z) = BP(z) \otimes RECT\left[\frac{z}{L}\right]$$

CT scan of length L for beam width W (axial scan):
contiguous



$$D(z) = BP(z) \otimes COMB\left[\frac{z}{a}\right]$$

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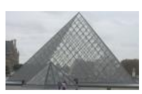

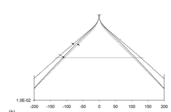

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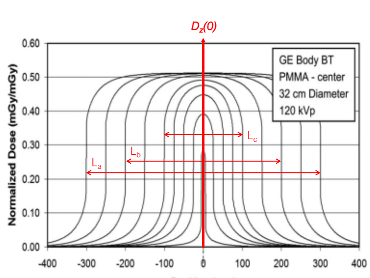
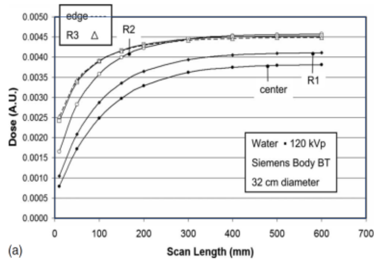
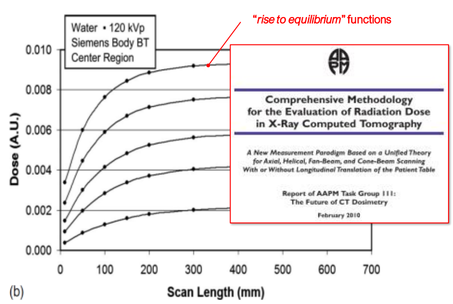
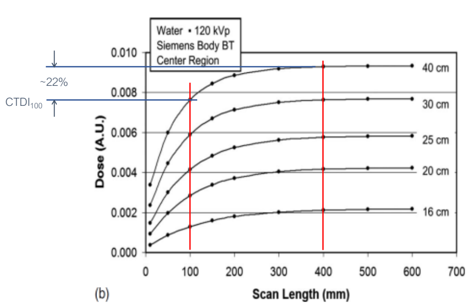



edge
R3 Δ
R2
R1
center
Water • 120 kVp
Siemens Body BT
32 cm diameter
Dose (A.U.)
0.0050
0.0045
0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
0
100
200
300
400
500
600
700
(a)
Scan Length (mm)

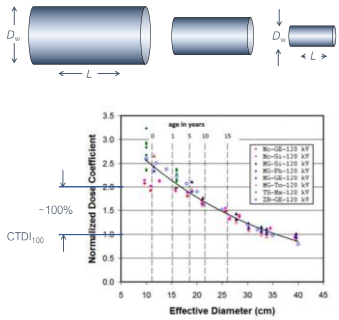

"rise to equilibrium" functions
Water • 120 kVp
Siemens Body BT
Center Region
Comprehensive Methodology
for the Evaluation of Radiation Dose
in X-Ray Computed Tomography
A New Measurement Paradigm Based on a Unified Theory
for Axial, Helical, Fan-Beam, and Cone-Beam Scanning
With or Without Longitudinal Translation of the Patient Table
Report of AAPM Task Group 111:
The Future of CT Dosimetry
February 2010
Dose (A.U.)
0.010
0.008
0.006
0.004
0.002
0.000
0
100
200
300
400
500
600
700
(b)
Scan Length (mm)


Water • 120 kVp
Siemens Body BT
Center Region
~22%
CTDI100
40 cm
30 cm
25 cm
20 cm
16 cm
Dose (A.U.)
0.010
0.008
0.006
0.004
0.002
0.000
0
100
200
300
400
500
600
700
(b)
Scan Length (mm)


AAPM Report No. 204

Size-Specific Dose Estimates (SSDE) in Pediatric and Adult Body CT Examinations

Report of AAPM Task Group 204, developed in collaboration with the International Commission on Radiation Units and Measurements (ICRU) and the Image Gently campaign of the Alliance for Radiation Safety in Pediatric Imaging



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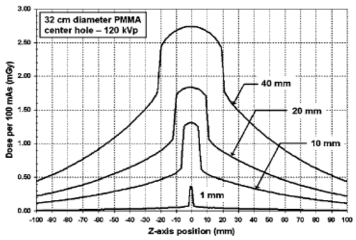
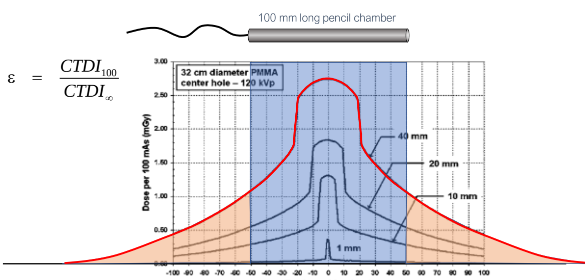
The trouble with $CTDI_{100}$

John M. Boone[a]
Departments of Radiology and Biomedical Engineering, University of California Davis Medical Center, Ellison Building, 4860 Y Street, Suite 3100, Sacramento, California 95817

(Received 1 September 2005; revised 26 October 2006; accepted for publication 6 November 2006; published 20 March 2007)



$$\varepsilon = \frac{CTDI_{100}}{CTDI_{\infty}}$$



The trouble with $CTDI_{100}$

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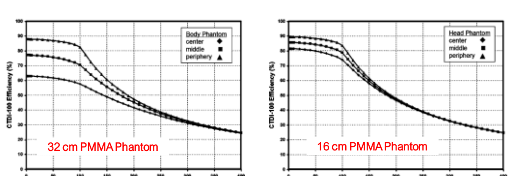

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- Dose Spread Functions (DSFs) are a useful construct for understanding the distribution of radiation dose during a CT scan in a simple, cylindrical object.
- DSFs provide the basis for a mathematical understanding of CT dose under a limited set of geometrical and scan parameters.
- This work has shown – quantitatively – the limitations of the CTDIvol metric and results have guided designs for more accurate – yet large – CT dose phantoms.

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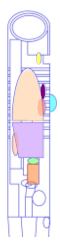
Effective Dose



Organ	Organ Doses OD (mGy)	ICRP 103 values W_t	Organ Effective Doses ED (mSv)
Gonads	0.10	0.08	0.008
Bone marrow	0.10	0.12	0.012
Colon	0.10	0.12	0.012
Lung	1.00	0.12	0.120
Stomach	0.52	0.12	0.062
Bladder	0.48	0.04	0.019
Breast	0.15	0.12	0.018
Liver	1.02	0.04	0.041
Esophagus	0.00	0.04	0.000
Thyroid	0.50	0.04	0.020
Skin	0.10	0.01	0.001
Bone surface	0.25	0.01	0.002
Brain	0.00	0.01	0.000
Salivary Glands	0.00	0.01	0.000
remainder	0.05	0.12	0.006

arbitrary examples

Total ED

0.32 mSv

50