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Progress on the normalised organ dose Monte Carlo calculations for modern CT scanners with the ICRP-110 Adult phantoms

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Content

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Introduction (Why update?)

Changes since the early 90's

- CT scanners
  - Multi detector rows
  - Spiral
- Anthropomorphic phantoms
  - Mathematical versus Voxel
- Risk estimation (ICRP-103)
  - New risk organs
  - E_{103}
- Monte Carlo radiation codes
- Electronic hardware and software

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Introduction (NRPB-SR250)

NRPB Software Report (SR) 250 contains:

- 23 data files MCSET*i*.DAT where *i* is 01…23
- Each data file contains (expanded):
  - 24 lines of heading text
  - 208 slabs (lines) from -10 cm below base of trunk to top of head
  - Each slab contains 27 organs or regions with normalised dose and uncertainty
- 5 CT manufacturers (Siemens, Picker, GE, CGR, Philips)
  - 13 CT models
  - 3 CT models with a selectable tube voltages (+5)
  - 2 CT models with a selectable bow-tie filter (+2)
  - 1 CT model with Geometric Enlargement setting and Cu filtration (+3)

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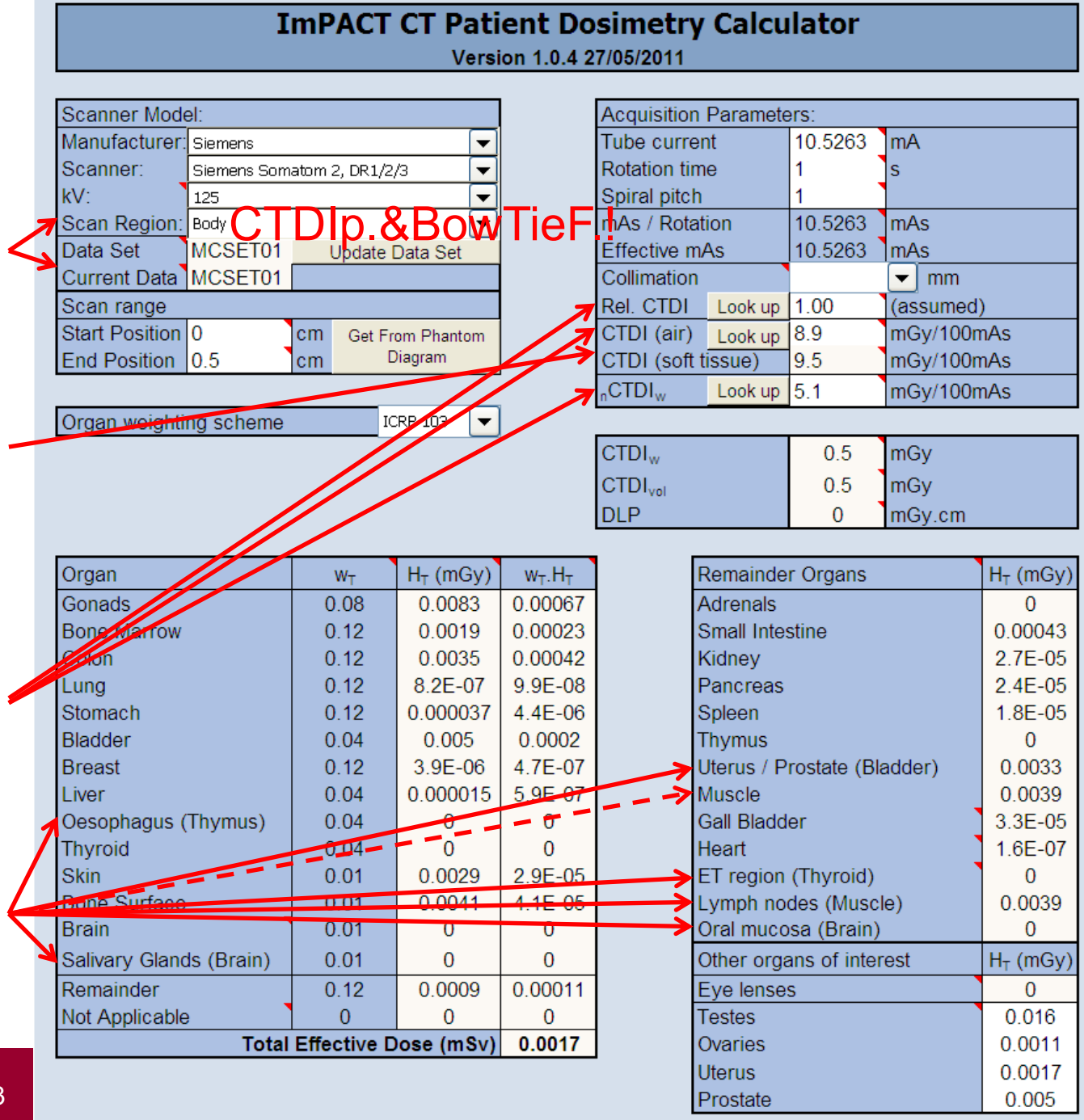
Matches (ImPACT factor) CT scanner to SR250 data sets

Converts air dose to muscle dose in SR250

ImPACT provides a database of measured CTDIs

Uses for new risk organs surrogates



Scanner Model:		
Manufacturer:	Siemens	
Scanner:	Siemens Somatom 2, DR1/2/3	
kV:	125	
Scan Region:	Body	
Data Set	MCSET01	Update Data Set
Current Data	MCSET01	
Scan range		
Start Position	0	cm
End Position	0.5	cm

Get From Phantom Diagram

Acquisition Parameters:			
Tube current		10.5263	mA
Rotation time		1	s
Spiral pitch		1	
mAs / Rotation		10.5263	mAs
Effective mAs		10.5263	mAs
Collimation			mm
Rel. CTDI	Look up	1.00	(assumed)
CTDI (air)	Look up	8.9	mGy/100mAs
CTDI (soft tissue)		9.5	mGy/100mAs
$_nCTDI_w$	Look up	5.1	mGy/100mAs

Organ weighting scheme: ICRP 103

$CTDI_w$	0.5	mGy
$CTDI_{vol}$	0.5	mGy
DLP	0	mGy.cm

Organ	w_T	H_T (mGy)	$w_T.H_T$
Gonads	0.08	0.0083	0.00067
Bone Marrow	0.12	0.0019	0.00023
Colon	0.12	0.0035	0.00042
Lung	0.12	8.2E-07	9.9E-08
Stomach	0.12	0.000037	4.4E-06
Bladder	0.04	0.005	0.0002
Breast	0.12	3.9E-06	4.7E-07
Liver	0.04	0.000015	5.9E-07
Oesophagus (Thymus)	0.04	0	0
Thyroid	0.04	0	0
Skin	0.01	0.0029	2.9E-05
Bone Surface	0.01	0.0041	4.1E-05
Brain	0.01	0	0
Salivary Glands (Brain)	0.01	0	0
Remainder	0.12	0.0009	0.00011
Not Applicable	0	0	0
		Total Effective Dose (mSv)	0.0017

Remainder Organs	H_T (mGy)
Adrenals	0
Small Intestine	0.00043
Kidney	2.7E-05
Pancreas	2.4E-05
Spleen	1.8E-05
Thymus	0
Uterus / Prostate (Bladder)	0.0033
Muscle	0.0039
Gall Bladder	3.3E-05
Heart	1.6E-07
ET region (Thyroid)	0
Lymph nodes (Muscle)	0.0039
Oral mucosa (Brain)	0

Other organs of interest	H_T (mGy)
Eye lenses	0
Testes	0.016
Ovaries	0.0011
Uterus	0.0017
Prostate	0.005

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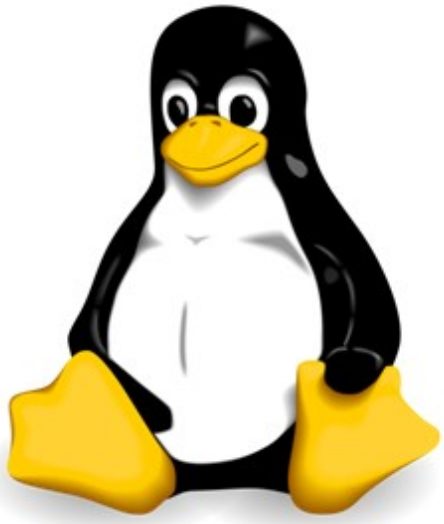
PC Cluster



Linux PC-Cluster

MCNPX 2.7.0

Los Alamos NATIONAL LABORATORY EST.1943

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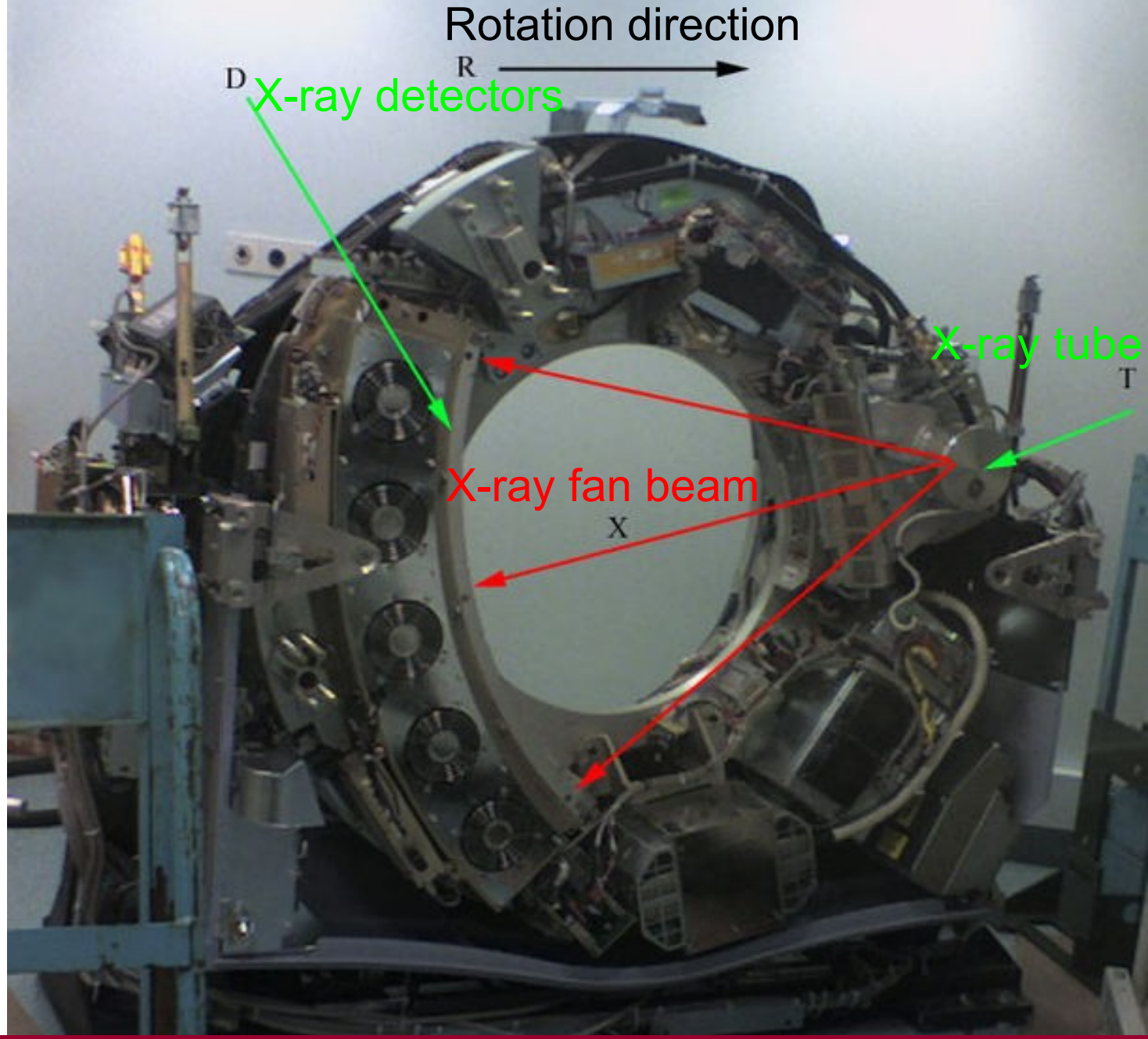
CT scanner models

CT manufacturers provide information



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CT scanners

Models	Tube voltage (kV)	Bow-Tie filter	Fan
Bsp16Elite+Optima660	80, 100, 120, 140	Large, Small	
CT750 HD + VCT	80, 100, 120, 140	Large, Medium, Small	
Brilliance 64	80, 120, 140	Standard	
iCT 256	80,100, 120, 140	Body, Head, Baby	
Definition	80,100, 120, 140	Body, Head	Full, Small
Emotion 6 (ver. 2 + 3)	80, 110, 130	Standard	
Sensation 16	80,100, 120, 140	Body, Head	
Sensation 64 + ” Open	80,100, 120, 140	Standard	
Aquilion 16	80, 100, 120, 135	DR, L, S	

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Phantoms

Adult Male (ICRP-110)

Adult Female (ICRP-110)

HPA18+

```
PhantomCT 1.7.2: Revised NRPB
 Hermaphrodite Adult

basis:    XY
( 1.000000, 0.000000, 0.000000)
( 0.000000, 1.000000, 0.000000)
origin:
(     0.00,      0.00,     93.61)
extent = (    20.00,     20.00)
```

Below CTDI body / head

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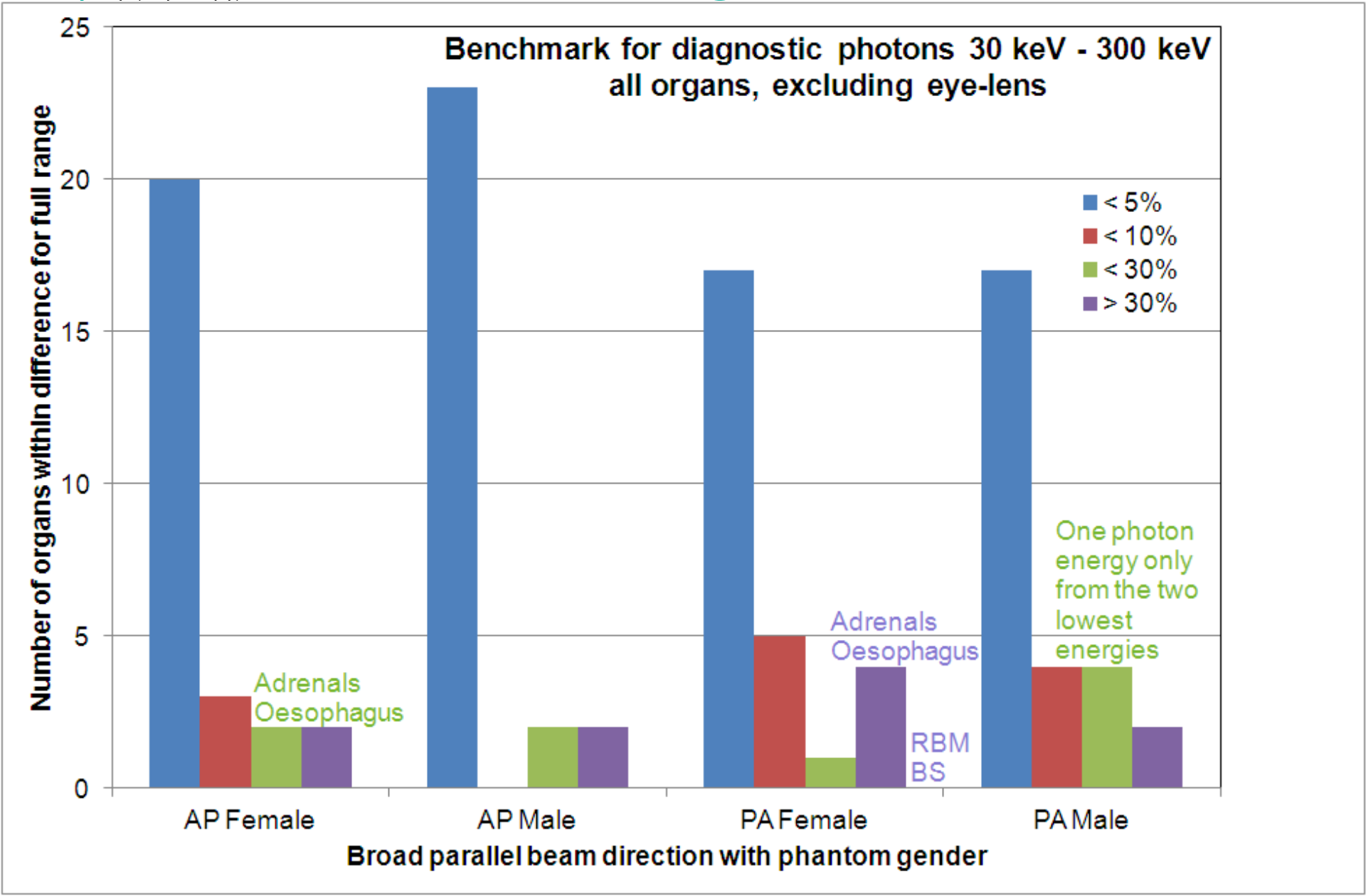
Benchmark against ICRP-116



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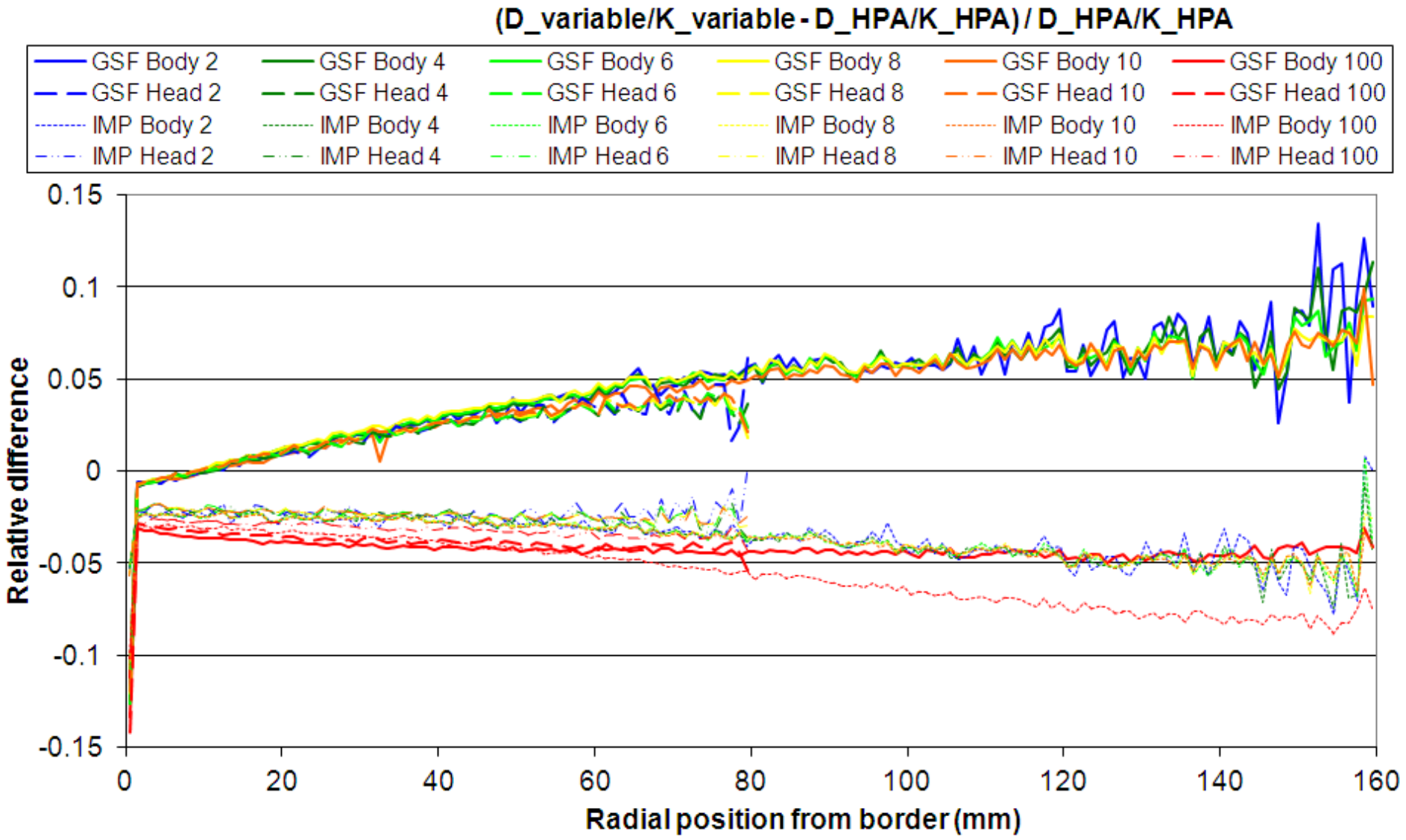
Benchmark for CTDI: GSF and IMP



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Current status comparison

Item	NRPB-SR250	Female	Male
Data files	MCSET*23*.DAT	MCTAF*105*.DAT	MCTAM*105*.DAT
Each data file contains (expanded):			
Heading text	24	21	21
Slab (lines)	208	348	222
Thick (mm)	5	4.84	8
Range	-10 cm to top	Whole body	Whole body
Organs (Rgs)	27	39	39
Manufacturer	5	4	4
Model	13	13	13

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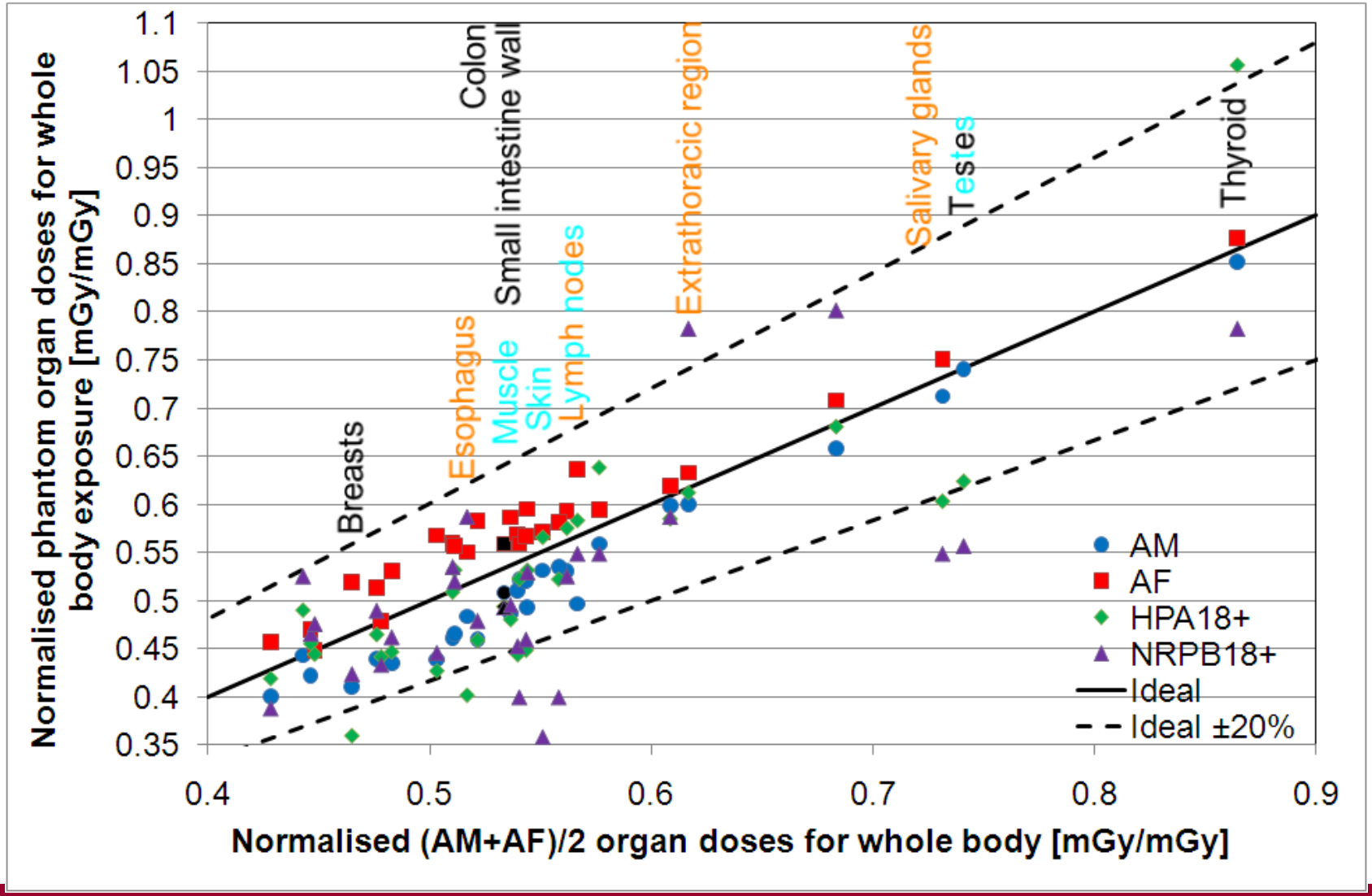
D_{organ}/D_{air} mean for all CT-models



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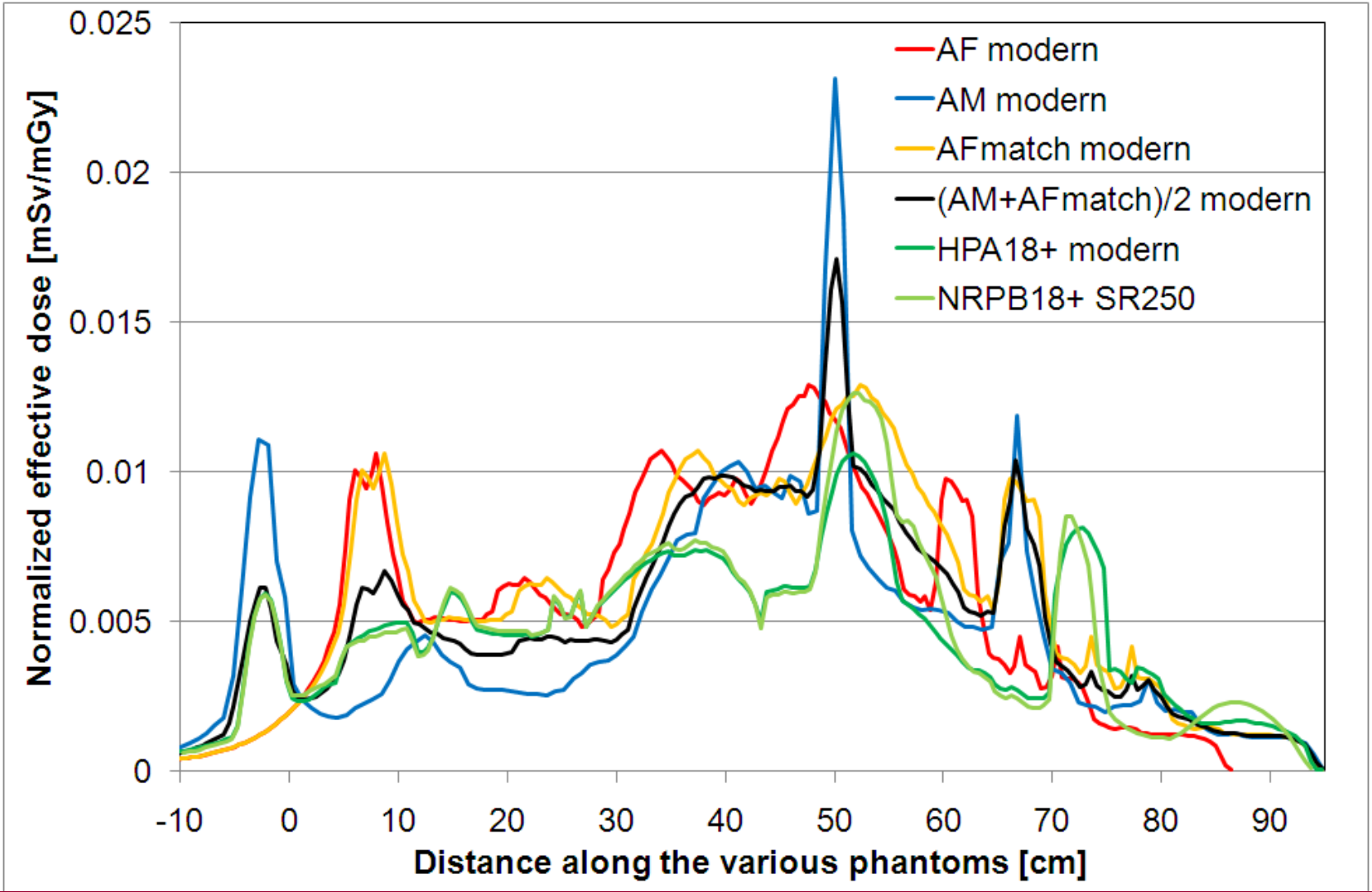
E_{103}/D_{air} mean for all CT-models



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Conclusions

Subject	Status
NRPB-SR250 updated	
• Data files	Done
• Data files checking	In progress
• Report	To be done
PHE CT Dosimetry 2013	
• ImPACT Measurement Database	Skip (Hospital measurements)
• Other CT scanners	In progress, depends on result
• Phantom Images	2D or 3D?
• Software	Java program alike ImageJ?

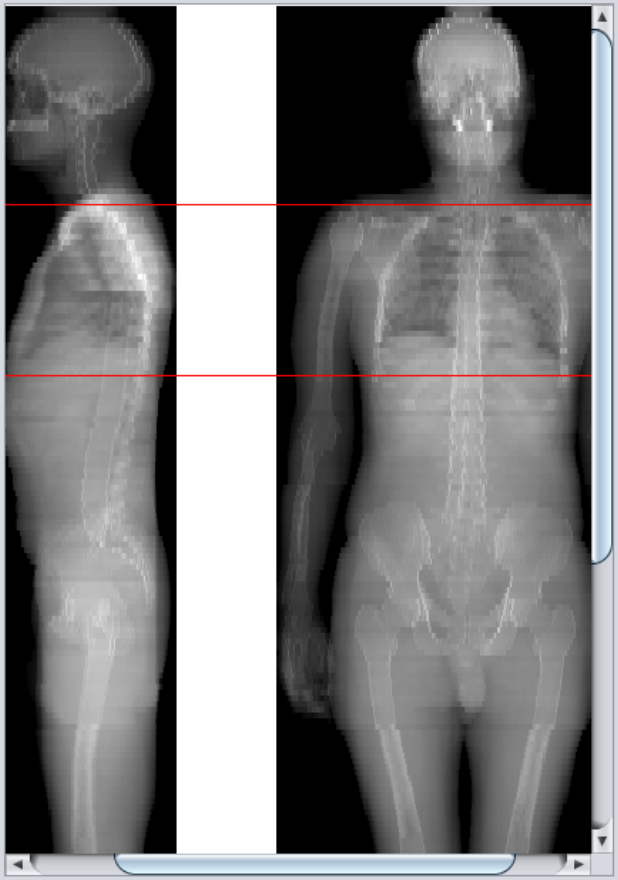
Test CTdose13 dataset, new GUI

PHE CT Dosimetry 2013

Manufacturer: General Electric | Model: Brightspeed 16 Elite | Tube Voltage (kV): 80 | Bow-tie filter: Large | Fan beam: Standard

Tube current (mA): 100 | Rotation Time (s): 1 | Spiral Pitch: 1 | CTDI fia (mGy/100mAs): 10 | Calculate

Phantom: Adult Male | Start (cm): 43.2 | Finish (cm): 67.2



Organ / Tissue	w_T	H_T (mGy)	w_T H_T (mSv)
Red marrow	0.12	1.162	0.139
Colon	0.12	0.264	0.032
Lungs	0.12	4.229	0.508
Stomach wall	0.12	2.093	0.251
Breast	0.12	4.274	0.513
Ovaries	0	0	0
Testes	0.08	0.001	0
U-bladder wall	0.04	0.008	0
Oesophagus wall	0.04	2.885	0.115
Liver	0.04	2.255	0.09
Thyroid	0.04	4.915	0.197
Endosteal region	0.01	0.702	0.007
Brain	0.01	0.054	0.001
Salivary glands	0.01	0.297	0.003
Skin	0.01	0.915	0.009
Adrenals	0.009	0.993	0.009
ET region	0.009	0.227	0.002
G-bladder wall	0.009	0.798	0.007
Heart wall	0.009	4.297	0.04
Kidneys	0.009	0.497	0.005
Lymph nodes	0.009	1.364	0.013
Muscle	0.009	0.875	0.008
Oral mucosa	0.009	0.176	0.002
Pancreas	0.009	0.666	0.006
S-intestine wall	0.009	0.192	0.002
Spleen	0.009	2.794	0.026
Thymus	0.009	5.048	0.047
Prostate	0.009	0.003	0
Uterus/cervix	0	0	0
Tongue	0	0.207	0
Tonsils	0	0.105	0
Lenses of eye	0	0.071	0
Pituitary gland	0	0.061	0
Spinal cord	0	1.537	0
Ureters	0	0.113	0
Adipose tissue	0	0.684	0
Whole body	0	1.146	0
Content	0	0.713	0
Net body	0	1.153	0
Psuedo E_103_AM	0	0	2.031

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Future

Subject	Remark
Age dependent patients	
• Paediatrics	ICRP defined?
• Risks models	Gender and age specific?
	HPA-CRCE-028† broad categ.?
PHE CT Dosimetry 2013	
• Local Hospital Measurement	File support
• Default support	Initialize from file?

† http://www.hpa.org.uk/Publications/Radiation/CRCEScientificAndTechnicalReportSeries/HPACRCE028/

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Acknowledgements

- CT manufacturers for provide details of their scanners and the scanner images
- ImPACT (Details and images of ImPACT CT Dosimetry Calculator and NRPB-SR250)
- Wikipedia (Images of Tux and CT scanner inside)
- Los Alamos National Laboratory (Logo and MCNP(X))
- Physikalisch - Technische Werkstätten (Image PTW equipment of CTDI body, head with pencil ionisation chamber)