

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

Jan Jansen, Sue Edyvean and Paul Shrimpton



Materials and Methods

- PC-Cluster
- CT scanners
- Anthropomorphic phantoms

Results

- Benchmark
- Data Files
- Phantoms

Conclusions

PHE CT Dosimetry 2013

Future

Acknowledgement









Public Health 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
 - E₁₀₃

- Monte Carlo radiation codes
- Electronic hardware and software



Public Health Introduction (NRPB-SR250) England

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)

Public Health England 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

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				Acquisition	Paramete	ers:		
Manufacturer: Siemens	ufacturer: Siemens 🛛 🚽			Tube current 10.5263		mA	mA	
Scanner: Siemens Som	natom 2, DR1/2	/3 🔽		Rotation tir	ne	1	s	
kV: 125				Spiral pitch 1		1		
Scan Region: Body CTDID.&BOW Tie				mAs / Rota	ation	10.5263	mAs	
Data Set MCSET01	Update	Data Set		Effective n	nAs	10.5263	mAs	
Current Data MCSET01				Collimation			💌 mm	
Scan range			7	Rel. CTDI	Look up	1.00	(assumed)
Start Position 0		om Phantom	17	CTDI (air)	Look up	8.9	mGy/100n	
End Position 0.5	cm [Diagram	4	CTDI (soft	tissue)	9.5	mGy/100n	nAs
			~ 7	_n CTDI _w	Look up	5.1	mGy/100n	nAs
Organ weighting scheme	IC	CRP 107 🔍						
		/ /		CTDIw		0.5	mGy	
				CTDI _{vol}		0.5	mGy	
	// /			DLP		0	mGy.cm	
				0.21		Ŭ	moy.om	
Organ	WT	H _T (mGy)	w _T .H _T] [Remainde	r Organs		H _T (mG
Gonads	0.08	0.0083	0.00067		Adrenals	<u> </u>		0
Bone warrow	0.12	0.0019	0.00023		Small Inte	stine		0.000
Prion	0.12	0.0035	0.00042		Kidney			2.7E-0
Lung	0.12	8.2E-07	9.9E-08		Pancreas			
					i ancreas			2.4E-0
Stomach	0.12	0.000037	4.4E-06		Spleen			
Stomach Bladder	0.12	0.000037 0.005	4.4E-06 0.0002					
				~	Spleen Thymus Uterus / P	rostate (Bl	adder)	1.8E-(0
Bladder	0.04 0.12 0.04	0.005	0.0002	~	Spleen Thymus	rostate (Bl	adder)	1.8E-0 0 0.003
Bladder Breast Liver Oesophagus (Thymus)	0.04 0.12 0.04 0.04	0.005 3.9E-06	0.0002 4.7E-07	~	Spleen Thymus Uterus / P		adder)	1.8E-(0 0.003 0.003 3.3E-(
Bladder Breast Liver Oesophagus (Thymus) Thyroid	0.04 0.12 0.04 0.04	0.005 3.9E-06 0.000015 0	0.0002 4.7E-07 5.9E-07 0 0		Spleen Thymus Uterus / P Muscle Gall Bladd Heart	er	adder)	1.8E-(0 0.003 0.003 3.3E-(
Bladder Breast Liver Oesophagus (Thymus) Thyroid Skin	0.04 0.12 0.04 0.04 0.04 0.01	0.005 3.9E-06 0.000015 0 0 0.0029	0.0002 4.7E-07 5 9E 07 0 2.9E-05		Spleen Thymus Uterus / P Muscle Gall Bladd Heart ET region	er (Thyroid)		1.8E-0 0.003 0.003 3.3E-0 1.6E-0 0
Bladder Breast Liver Oesophagus (Thymus) Thyroid Skin Brine Surfase	0.04 0.12 0.04 0.04 0.14 0.01	0.005 3.9E-06 0.000015 0 0 0.0029 0.0041	0.0002 4.7E-07 5.9E-07 0 0		Spleen Thymus Uterus / P Muscle Gall Bladd Heart ET region Lymph no	er (Thyroid) des (Musc	le)	1.8E-0 0.003 0.003 3.3E-0 1.6E-0 0.003
Bladder Breast Liver Oesophagus (Thymus) Thyroid Skin Brain	0.04 0.12 0.04 0.04 0.04 0.01 0.01	0.005 3.9E-06 0.000015 0 0.0029 0.0041 0	0.0002 4.7E-07 5.9E-07 0 2.9E-05 4.1E-05 0		Spleen Thymus Uterus / P Muscle Gall Bladd Heart ET region Lymph no Oral mucc	er (Thyroid) des (Musc sa (Brain)	le)	1.8E-0 0.003 0.003 3.3E-0 1.6E-0 0.003 0
Bladder Breast Liver Oesophagus (Thymus) Thyroid Skin Brine Surfase	0.04 0.12 0.04 0.04 0.14 0.01	0.005 3.9E-06 0.000015 0 0.0029 0.0029 0.0041 0 0	0.0002 4.7E-07 5 9E 07 0 2.9E-05 4.1E 05 0 0		Spleen Thymus Uterus / P Muscle Gall Bladd Heart ET region Lymph no Oral mucc Other orga	er (Thyroid) des (Musc sa (Brain) ans of inter	le)	1.8E-0 0.003 0.003 3.3E-0 1.6E-0 0.003 0
Bladder Breast Liver Oesophagus (Thymus) Thyroid Skin Brain	0.04 0.12 0.04 0.04 0.04 0.01 0.01	0.005 3.9E-06 0.000015 0 0.0029 0.0041 0	0.0002 4.7E-07 5.9E-07 0 2.9E-05 4.1E-05 0		Spleen Thymus Uterus / P Muscle Gall Bladd Heart ET region Lymph no Oral mucc	er (Thyroid) des (Musc sa (Brain) ans of inter	le)	1.8E- 0 0.003 0.003 3.3E- 1.6E- 0 0.003 0
Bladder Breast Liver Oesophagus (Thymus) Thyroid Skin Bune Surface Brain Salivary Glands (Brain) Remainder Not Applicable	0.04 0.12 0.04 0.04 0.01 0.01 0.01 0.01 0.12 0	0.005 3.9E-06 0.000015 0 0.0029 0.0041 0 0 0.0009 0	0.0002 4.7E-07 5.9E-07 0 2.9E-05 4.1E-05 0 0 0.00011 0		Spleen Thymus Uterus / P Muscle Gall Bladd Heart ET region Lymph no Oral mucc Other orga	er (Thyroid) des (Musc sa (Brain) ans of inter	le)	1.8E-0 0 0.003 0.003 3.3E-0 1.6E-0 0 0.003 0 H _T (m0 0 0.010
Bladder Breast Liver Oesophagus (Thymus) Thyroid Skin Bune Surface Brain Salivary Glands (Brain) Remainder Not Applicable	0.04 0.12 0.04 0.04 0.01 0.01 0.01 0.01 0.12	0.005 3.9E-06 0.000015 0 0.0029 0.0041 0 0 0.0009 0	0.0002 4.7E-07 5 9E 07 0 2.9E-05 4.1E 05 0 0 0.00011		Spleen Thymus Uterus / P Muscle Gall Bladd Heart ET region Lymph no Oral mucc Other orga Eye lense	er (Thyroid) des (Musc sa (Brain) ans of inter	le)	0.003 0.003 3.3E-(1.6E-(0 0.003 0 H _T (mG
Bladder Breast Liver Oesophagus (Thymus) Thyroid Skin Bune Surface Brain Salivary Glands (Brain) Remainder Not Applicable	0.04 0.12 0.04 0.04 0.01 0.01 0.01 0.01 0.12 0	0.005 3.9E-06 0.000015 0 0.0029 0.0041 0 0 0.0009 0	0.0002 4.7E-07 5.9E-07 0 2.9E-05 4.1E-05 0 0 0.00011 0		Spleen Thymus Uterus / P Muscle Gall Bladd Heart ET region Lymph no Oral mucc Other orga Eye lense Testes	er (Thyroid) des (Musc sa (Brain) ans of inter	le)	1.8E-0 0 0.003 0.003 3.3E-0 1.6E-0 0 0.003 0 H _T (mC 0 0.016

ImPACT CT Patient Dosimetry Calculator

Public Health Final and PC Cluster



Linux PC-Cluster

MCNPX 2.7.0

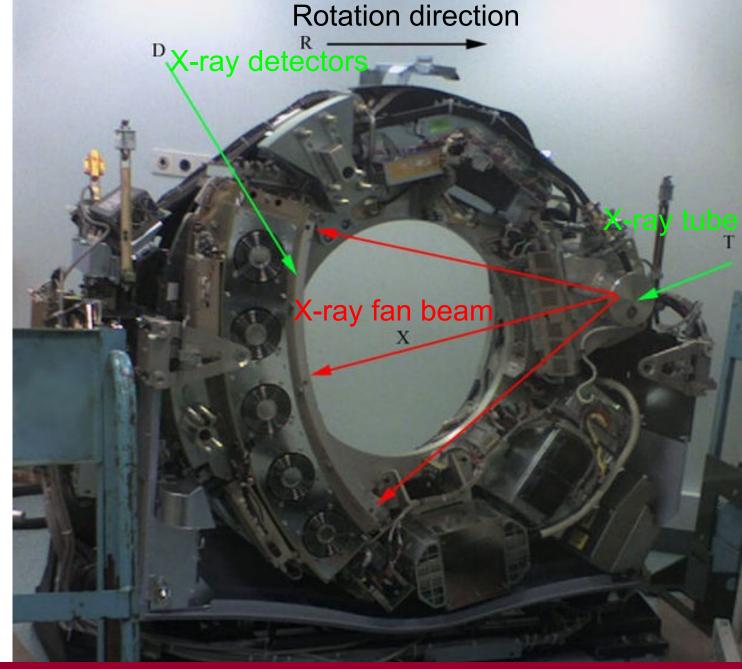




Public Health England

CT scanner models

CT manufacturers provide information





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, S	mall	
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		

Public Health Phantoms England Adult Male (ICRP-110)



Adult Female (ICRP-110)



HPA18+

PhantomCT 1.7.2: Revised NRPB Hermaphrodite Adult

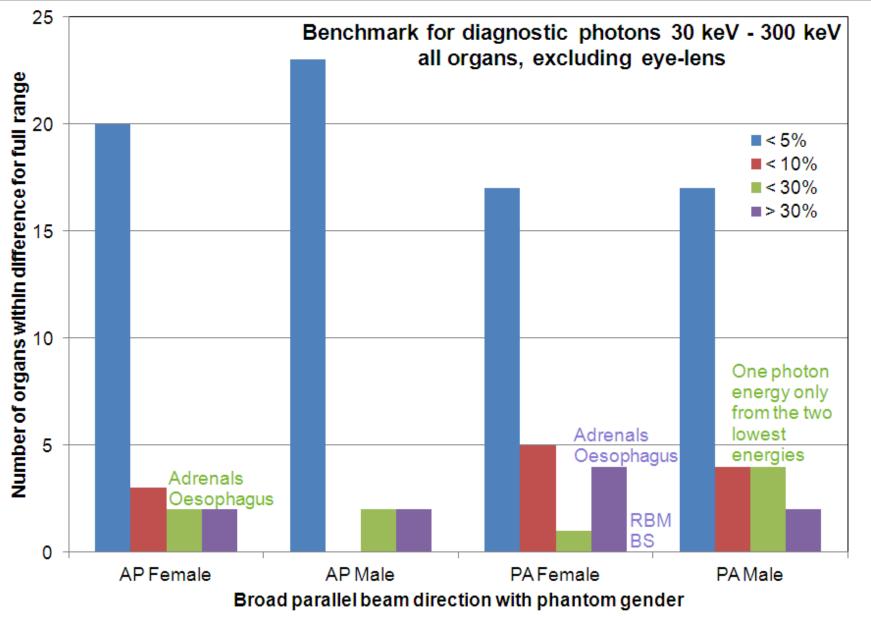
basis: XY		
(1.000000,	0.000000,	0.000000)
(0.000000,	1.000000,	0.000000)
origin:		
(0.00,	0.00,	93.61)
extent = (20.00,	20.00)

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Below CTDI body / head

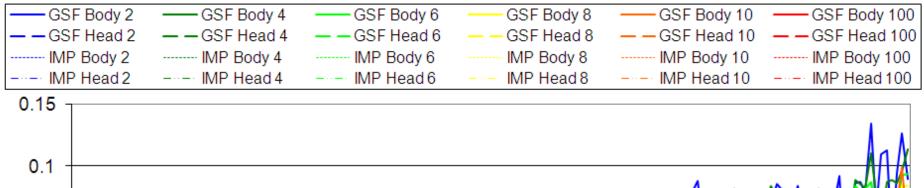


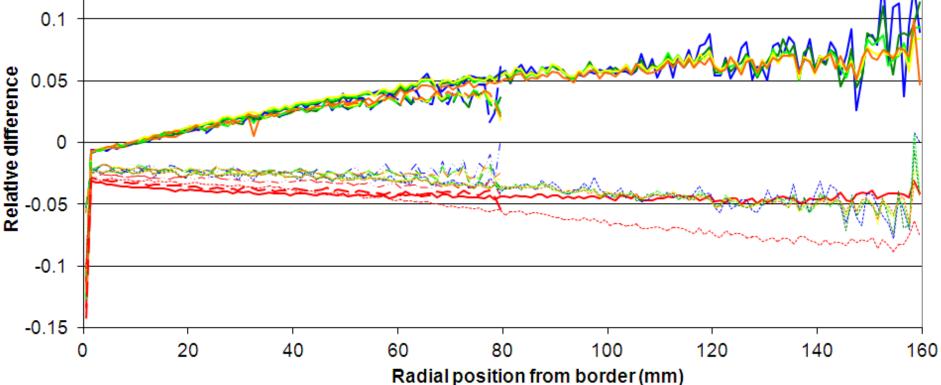
Benchmark against ICRP-116



Public Health England Benchmark for CTDI: GSF and IMP

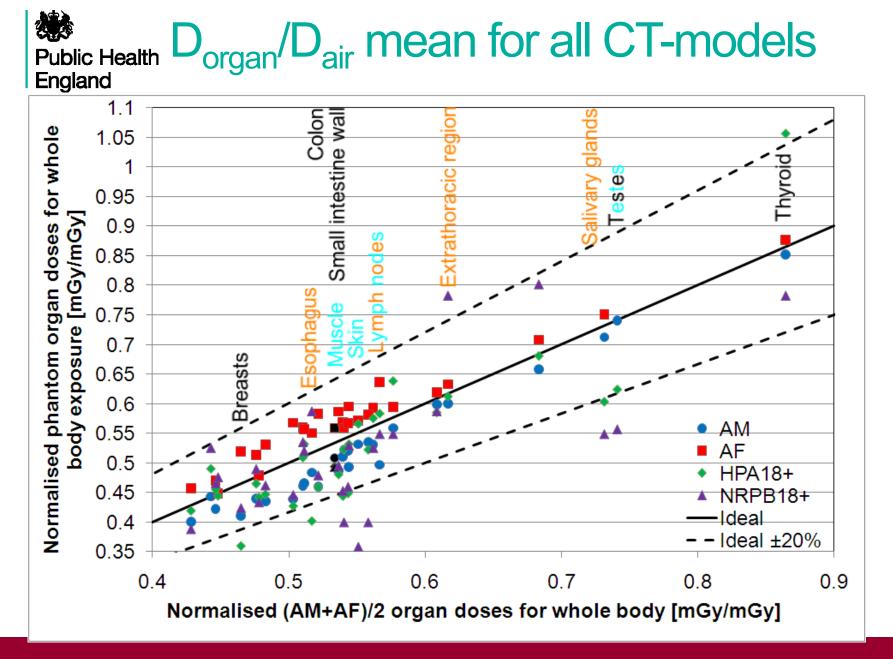
(D_variable/K_variable - D_HPA/K_HPA) / D_HPA/K_HPA

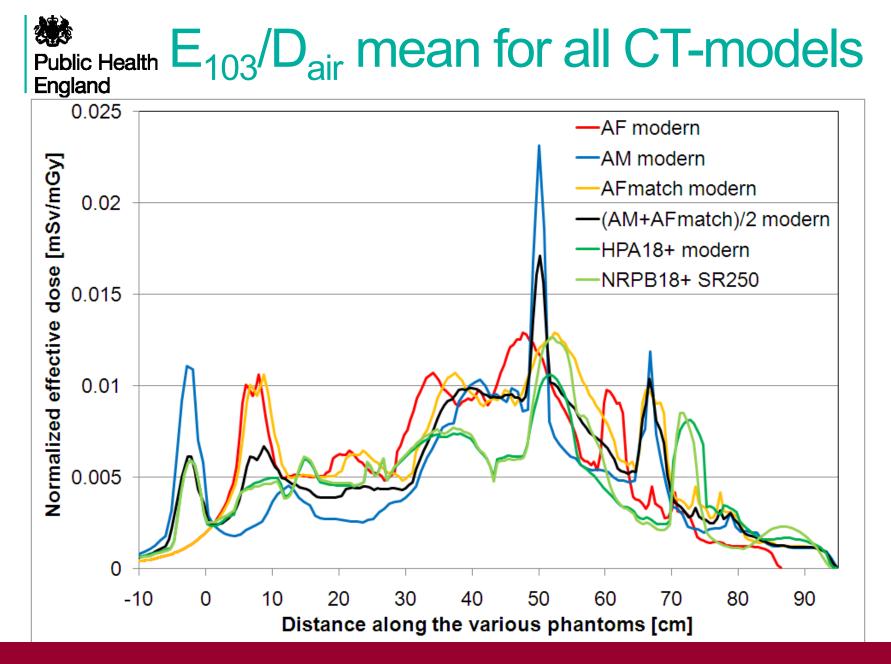




Public Health Current status comparison

Item	NRPB-SR250	Female	Male		
Data files	MCSET23.DAT	MCTAF <i>105</i> .DAT	MCTAM105.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		





CTUG meeting: 7-11-2013 Progress on normalised organ doses by Jan Jansen, Sue Edyvean and Paul Shrimpton

Public Health England	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?			

Public Health Test CTdose13 dataset, new GUI

PHE CT Dosimetry 201	3					
Man <u>u</u> facturer	<u>M</u> odel	Tube <u>V</u> oltage (KV)	<u>B</u> ow-tie filter	F <u>a</u> n beam		
General Electric	Brightspeed 16 Elite 💌	80	▼ Large	Standard 🔻		
Tube current (mA)	<u>R</u> otation Time (s)	Sp <u>i</u> ral Pitch	07016- (0-4000-)	Calculate		
<u></u>	<u></u>	- p <u>1</u>	<u>C</u> TDI fia (mGy/100mAs)			
100	1	1	10			
<u>P</u> hantom	<u>S</u> tart (cm)	<u>F</u> inish (cm)	Organ / Tissue w_T	H_T (mG)	a with	H_T (mSv)
	12.2	67.2		0.12		
Adult Male	43.2 🔷	67.2 🔷	Red marrow	0.12	1.162 0.264	0.139 0.032
	1000	Ā	Colon			
A STATISTICS AND A STAT	A CONTRACTOR OF A CONTRACTOR A		Lungs	0.12 0.12	4.229 2.093	0.508 0.251
ACCESSION NO.	10000		Stomach wall Breast	0.12	4.274	0.251
A REAL PROPERTY AND A REAL	And in the other states of		Ovaries	0.12	4.274	0.513
T INTERNAL PROPERTY.	The second second		Testes	0.08	0.001	0
Property in the Party of the Pa			U-bladder wall	0.08	0.008	0
1000			Oesophagus wall	0.04	2.885	0.115
100 C	and the second se		Liver	0.04	2.255	0.09
			Thyroid	0.04	4.915	0.197
And in case of the local division of the loc	and the state of the state	and the second se	Endosteal region	0.04	0.702	0.007
A REPORT OF THE R.	a de Sanda		Brain	0.01	0.054	0.007
Contraction of the		100703	Salivary glands	0.01	0.297	0.003
Contraction of the local division of the loc	And Address of Concession, Name		Skin	0.01	0.915	0.009
A DESCRIPTION OF THE OWNER OF THE	AND ADD COMPANY AND		Adrenals	0.009	0.993	0.009
CONTRACTOR OF A	Contraction (Contraction of Contraction)		ET region	0.009	0.227	0.003
and the second	and the second	The second se	G-bladder wall	0.009	0.798	0.002
and the second	the second s	Contraction of the local distance of the loc	Heart wall	0.009	4.297	0.007
and the second se	and the second second second	1000	Kidneys	0.009	0.497	0.005
Statement and a second state	A DESCRIPTION OF A DESC		Lymph nodes	0.009	1.364	0.003
and the second	1. T		Muscle	0.009	0.875	0.008
And in case of the local division of the loc	1913 - 1915 - 19		Oral mucosa	0.009	0.176	0.000
and the second	11 12 12 12		Pancreas	0.009	0.666	0.002
and the second	A DESCRIPTION OF TAXABLE PARTY.	100	S-intestine wall	0.009	0.192	0.002
	The second second second second		Spleen	0.009	2.794	0.002
	The second		Thymus	0.009	5.048	0.020
and the second se	A REAL PROPERTY AND A REAL PROPERTY.		Prostate	0.009	0.003	0.047
and the second se		CONTRACT OF CONTRACT.	Uterus/cervix	0	0.005	0
A REAL CONTRACTOR	A Contract of the second s		Tongue	0	0.207	0
And a second sec			Tonsils	0	0.105	0
	and the second se		Lenses of eye	0	0.071	0
	and the second se		Pituitary gland	0	0.061	0
the second s	and the second second		Spinal cord	0	1.537	0
			Ureters	0 0	0.113	Ő
			Adipose tissue	Ű	0.684	Ő
			Whole body	0	1.146	0
			Content	0	0.713	Ő
		The second se	Net body	Ő	1.153	Õ
	,		Psuedo E_103_AM	Ő	0	2.031
				-	_	

Shrimpton



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

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



- 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)