Calculation of dose coefficients and the dose coefficient library

Chapter 3+4: Calculation of dose coefficients

Chapter 5+Annex D: The dose coefficient library

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Calculation of dose coefficients and the dose coefficient library

- **Calculation of doses**
  - Overview of Monte Carlo calculations
  - Example Monte Carlo calculation for adult phantoms
  - Monte Carlo radiation transport codes used

- **Dose coefficient library**
  - Organ and $E_{103,\#\#M}$ and $E_{103,\#\#F}$ dose coefficient files
  - $CTDI_w/CTDI_{free\text{-}in\text{-}air}$ conversion files
  - Attenuation A^{AP} and A^{RLAT} files
  - Figures of organ and $E_{103,\#\#M}$ and $E_{103,\#\#F}$ dose coefficients, comparison of the ICRP Reference scanner and the CT database scanners.

Overview of Monte Carlo calculations

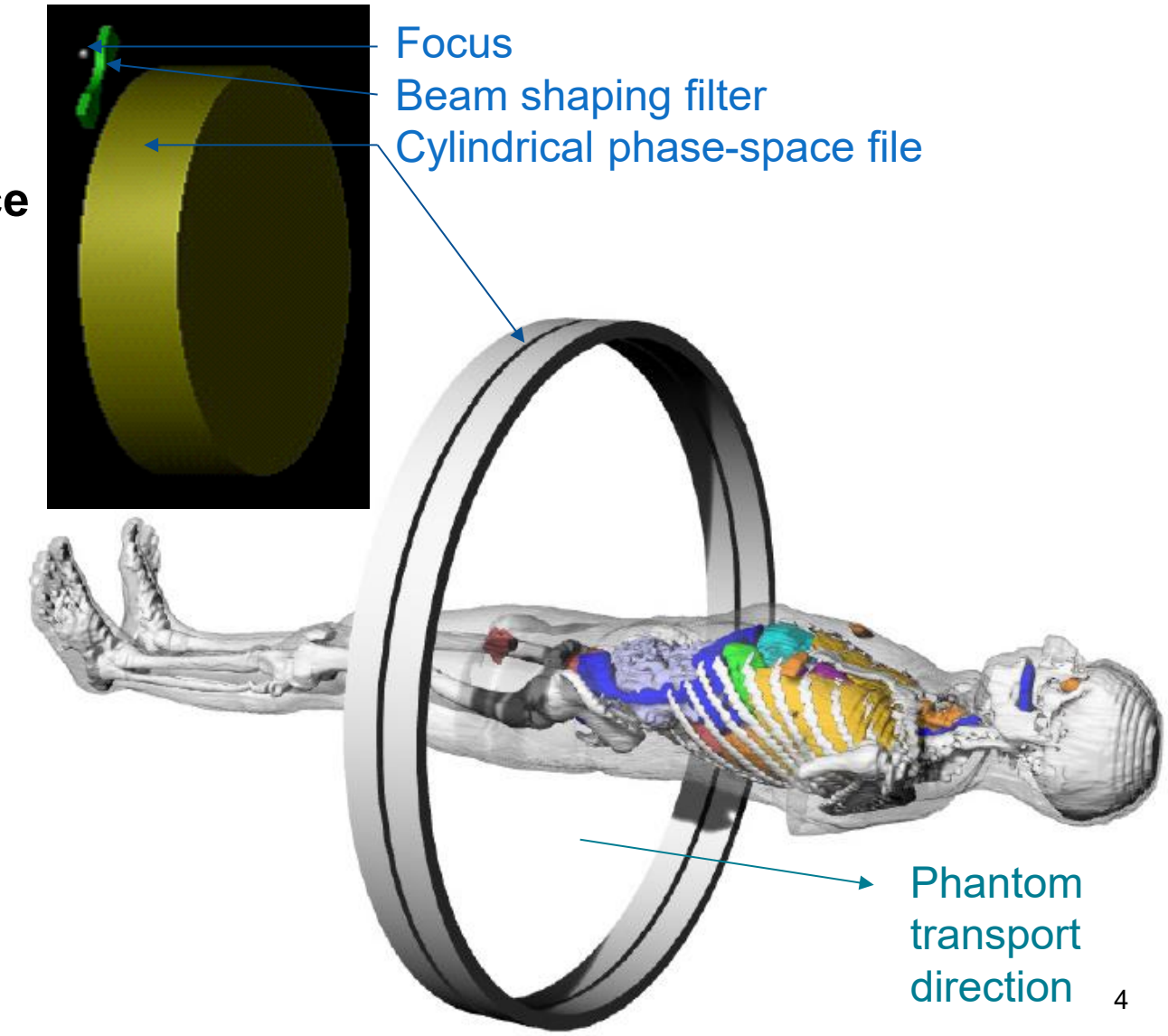
Free-in-air and CT Dosimetry phantom diameter 16 cm and 32 cm, in centre and 4 periphery positions, for 4 tube voltages and 2 beam shaping filters.

Organ and $E_{103,\#\#M}$ and $E_{103,\#\#F}$ dose coefficients					
ICRP Adult and Paediatric Computational Reference voxel Phantoms			ICRP Reference CT scanner		
Phantom		# of slices	Tube Voltage (kV)	Beam Shaping Filter	ATCM
Adult	AF	348	80, 100, 120, 140	Body, Head	None, Cosine
	AM	222			
Paediatric	15F	571	80, 100, 120		
	15M	586			
	10F	576			
	10M	576			
	05F	572			
	05M	572			
	01F	546			
	01M	546			
	00F	358			
	00M	358			

Localiser Radiograph Attenuation		
ICRP Adult and Paediatric Computational Reference voxel Phantoms		ICRP Reference CT scanner
Phantom	# of slices	Tube Voltage (kV)
AF	348	80,100, 120, 140
AM	222	
15F	571	80,100, 120
15M	586	
10M	576	
05M	572	
01M	546	
00M	358	

Monte Carlo calculation for adult phantoms

- **First, Monte Carlo simulation with the CT scanner in a fixed position and writing the photons hitting the cylinder to a phase space file**
- **Rotate these photons by an arbitrary angle**
- **Transport these photons through the reference voxel phantom, or free-in-air, or through a 16 cm or 32 cm CT dosimetry phantom**
- **Tally the organ absorbed dose and the CTDI dose**
- **Normalize the organ absorbed doses by dividing to the $CTDI_{free\text{-}in\text{-}air}$**
- **Transfer the phantom through the gantry assuming steps equal to voxel size**



Monte Carlo radiation transport

Various Monte Carlo radiation transport codes used by different groups and with good agreement.

Monte Carlo code	MCNP6.1	MCNPX2.7	GEANT4	EGSnrc
Adult	Primary	Spot check	Spot check	CT Localizer Radiograph
Paediatric	Spot check	Primary	Spot check	CT Localizer Radiograph
Transport particle	Photon	Photon	Photon + Electron	Photon
Cross section libraries	MCPLIB84, EL03	MCPLIB04 / MCPLIB84	EPDL97, EEDL, EADL	XCOM
Source	Phase-Space file	Own Source subroutine	Phase-Space file	Point source
Surrounding material	Air	Air	Vacuum	Vacuum

Dose coefficient library (1)

Data files included with the final publication

All data files are provided as Excel and open-source spreadsheets.

- **Organ and $E_{103,\#\#M}$ or $E_{103,\#\#F}$ dose coefficient files**
  - Folders: Constant (no TCM), Cosine (with TCM: ~(1+cos(2φ)))
  - Files for each Phantom

Example 15F:
Draft version

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	slab no.	z	R-marrow	Colon	Lungs	St-wall	Breast		SI-wall	Spleen	Thymus	Lens	Effective dose
2	1	0.1414	3.50E-06	1.35E-06	4.32E-06	1.77E-06	3.31E-06		9.56E-07	1.36E-06	5.41E-06	1.40E-05	2.86E-06
3	2	0.4242	1.43E-04	1.32E-06	5.01E-06	1.57E-06	4.02E-06		9.67E-07	1.88E-06	5.59E-06	4.85E-05	3.24E-05
4	3	0.707	3.76E-04	1.17E-06	5.27E-06	1.58E-06	3.79E-06		9.23E-07	1.71E-06	8.00E-06	9.85E-05	6.87E-05
5	4	0.9898	7.88E-04	1.06E-06	5.64E-06	1.80E-06	4.12E-06		7.92E-07	1.87E-06	1.28E-05	1.24E-04	1.29E-04
6	5	1.2726	1.19E-03	1.08E-06	5.96E-06	1.65E-06	4.57E-06		8.93E-07	1.76E-06	1.13E-05	1.83E-04	1.90E-04
7	.....	.....	.....	.....	.....	.....	.....		.....	.....	.....	.....	.....
8	567	160.2062	9.11E-07	2.42E-06	5.18E-07	9.29E-07	2.92E-06		1.82E-06	7.42E-07	6.58E-08	0.00E+00	1.39E-05
9	568	160.489	6.97E-07	1.99E-06	4.09E-07	4.60E-07	2.21E-06		1.33E-06	6.49E-07	9.85E-08	0.00E+00	9.85E-06
10	569	160.7718	5.40E-07	1.44E-06	4.47E-07	4.58E-07	1.23E-06		9.45E-07	7.77E-07	1.58E-07	0.00E+00	5.85E-06
11	570	161.0546	4.31E-07	8.88E-07	3.67E-07	3.69E-07	8.09E-07		6.36E-07	5.14E-07	5.61E-08	6.59E-08	2.25E-06
12	571	161.3374	3.35E-07	8.79E-07	4.42E-07	3.84E-07	7.33E-07		5.83E-07	3.95E-07	2.58E-07	4.02E-06	6.38E-07

80head | 80body | 100head | 100body | 120head | 120body

Z (cm), Organ (mGy/mGy), Effective dose (mSv/mGy)

Dose coefficient library (2)

- **$CTDI_w/CTDI_{free\text{-}in\text{-}air}$ conversion files**
  - Folder: CTDIw
  - 1 data file with $CTDI_{w,32}/CTDI_{free\text{-}in\text{-}air}$ and $CTDI_{w,16}/CTDI_{free\text{-}in\text{-}air}$ in Gy/Gy

Draft version of CTDIw

	A	B	C
1	CTDIw per CTDI free-in-air (Gy/Gy)		
2			
3	x-ray spectrum	$CTDI_{w,32cm}$	$CTDI_{w,16cm}$
4	80 kV head filter	0.262	0.637
5	80 kV body filter	0.309	0.705
6	100 kV head filter	0.302	0.693
7	100 kV body filter	0.352	0.752
8	120 kV head filter	0.327	0.722
9	120 kV body filter	0.377	0.778
10	140 kV head filter	0.345	0.737
11	140 kV body filter	0.394	0.791
12			

- **Attenuation A^{AP} and A^{RLAT} files**
  - Folder: Attenuation Data
  - 4 data files are provided, for each tube voltage
  - Sheets are provided, for all male phantoms, and female adult and 15 year

Draft version for Attenuation (Example 80 kV)

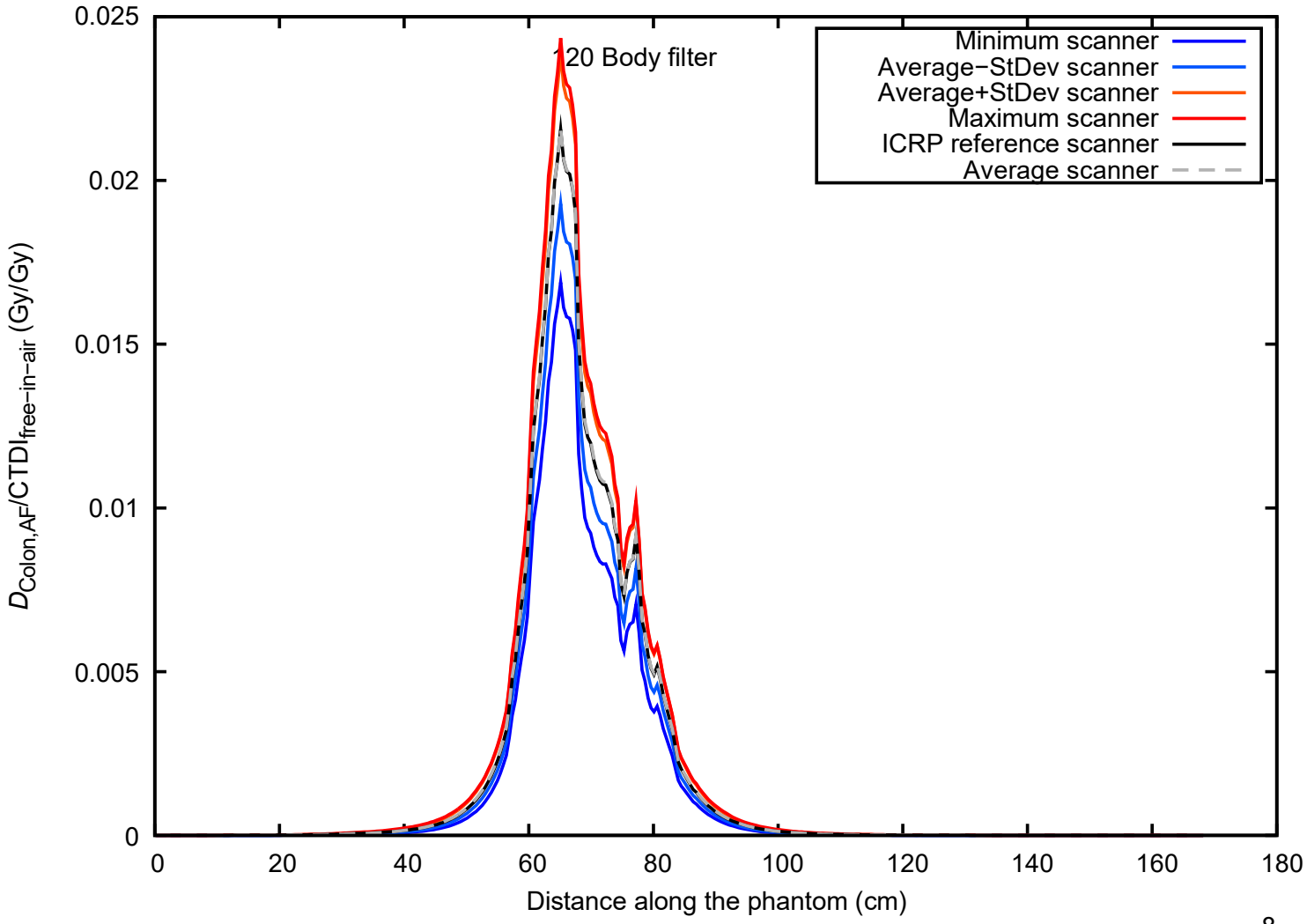
	A	B	C	D	E	F	G	H
1	#slab no.	z	A(ap)	A(lat)		τ (longitud.)	ζ (angul.)	η (z-modul)
2	1	0.141	2.62E-04	2.63E-04		2.06E-03	1.43E-03	2.07E-03
3	2	0.424	3.74E-04	4.34E-04		2.69E-03	5.90E-02	3.01E-03
4	3	0.707	5.17E-04	1.08E-03		3.43E-03	3.69E-01	5.96E-03
5	4	0.990	6.95E-04	2.90E-03		4.28E-03	9.60E-01	1.25E-02
6	5	1.273	1.13E-03	5.08E-03		6.16E-03	1.04E+00	1.90E-02
7	.....	.....	.....	.....	.....	.....	.....	.....
8	567	160.206	7.94E-03	4.00E-03		2.66E-02	-2.01E-01	2.66E-02
9	568	160.489	5.99E-03	3.06E-03		2.15E-02	-1.98E-01	2.15E-02
10	569	160.772	9.99E-04	8.41E-04		5.62E-03	-6.06E-02	5.62E-03
11	570	161.055	6.39E-04	5.87E-04		4.02E-03	-3.08E-02	4.02E-03
12	571	161.337	3.23E-04	3.24E-04		2.41E-03	1.16E-03	2.41E-03

15F | 15M | ADF

Comparing ICRP Reference scanner with DB

- **Set of figures comparing calculations using ICRP Reference scanner versus physical CT scanners**
  - Folder: CT scanner-specific dose coefficients
  - Files for: all ICRP risk and remainder organs, eye lens; and $E_{103,ADM}$ or $E_{103,ADF}$
  - For each combination of
    - 2 Adult phantoms
    - 4 Tube voltages
    - 2 Beam shaping filters

Example draft figure for Colon AF 120 kV Body



Summary

- **Monte Carlo calculations**
  - Monte Carlo calculations to derive organ absorbed doses, $CTDI_{free\text{-}in\text{-}air}$, and $CTDI_{w}$ for 2 CT dosimetry phantoms, attenuation factors
  - Monte Carlo Adult phantom calculation method example
  - Overview of Monte Carlo codes

- **Dose coefficient libraries**
  - $D_{T,i}$ / $CTDI_{free\text{-}in\text{-}air}$, $E_{103,\#\#M,\,i}$ / $CTDI_{free\text{-}in\text{-}air}$, and $E_{103,\#\#F,\,i}$ / $CTDI_{free\text{-}in\text{-}air}$
  - $CTDI_{w}$ / $CTDI_{free\text{-}in\text{-}air}$
  - A^{AP}_{i}, A^{RLAT}_{i}, ζ_i, τ_i, and η_i
  - Set of figures to compare the ICRP Reference CT scanner with the database CT scanners



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