Computed tomography phase-space source model using the PENELOPE/PenEasy Monte Carlo code: implementation and validation

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Introduction

Computed tomography phase-space source model based on the GE Lightspeed 8 Ultra characteristics was implemented using PENELOPE/PenEasy Monte Carlo code. The model implements the anode tilt and the target self-attenuation. Validation based on the dose profile (total and primary component) using analytical equations published Dixon and Boone was performed (1), (2). Position of bowtie filter was defined attending the detector response and the ratio $CTDI_{100,c}/CTDI_{100,p}$ was compared with experimental and simulated data (3) to validate the source model.

Materials and Methods

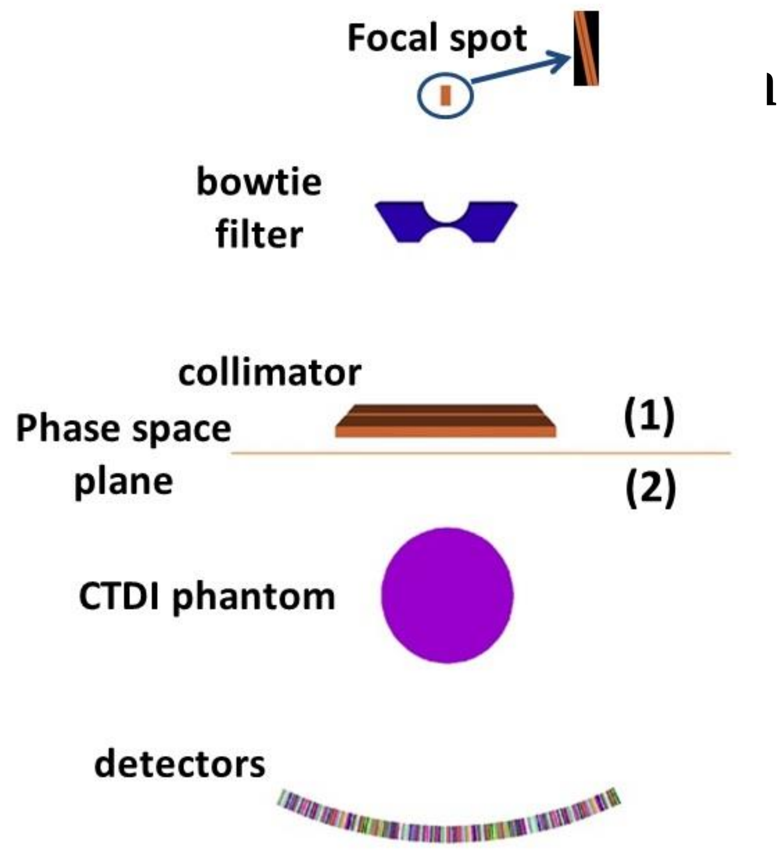

Fig. 1 Schematic representation of the simulation geometry used to create the phase space file, PSF, (stage 1) and for the computation of the detector responses to define the bowtie filter position (stage 2). Cylindrical phantom with 32cm and 16cm diameters were used.

a) Dose profile computation

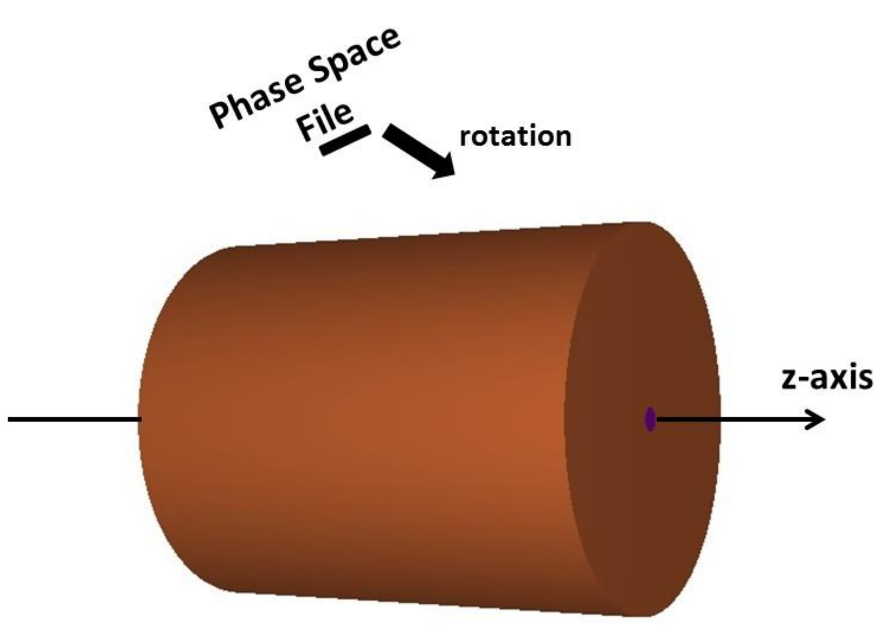

Fig. 2 Geometrical setup used to compute the dose profile along the central axis (z-axis). This geometry without the phantom was used to compute the primary profile.

Analytical equations used to validate the simulated dose profile and its primary component (1), (2).

$$f_p(z) = \rho(z)A_0\left\{\frac{1}{2}erf\left[\frac{\sqrt{\pi}}{c_L}\left(\frac{a}{2}+z\right)\right]+\frac{1}{2}erf\left[\frac{\sqrt{\pi}}{c_R}\left(\frac{a}{2}-z\right)\right]\right\}$$

$$\left.\begin{aligned} f_{si}(z) &= A_0\eta\left[1-e^{-a/d}\cosh\left(\frac{2z}{d}\right)\right] \\ f_{so}(z) &= A_0\eta\,\sinh\left(\frac{a}{d}\right)\exp(-2|z|/d)\end{aligned}\right\} f_s(z)$$

b) CTDI computation

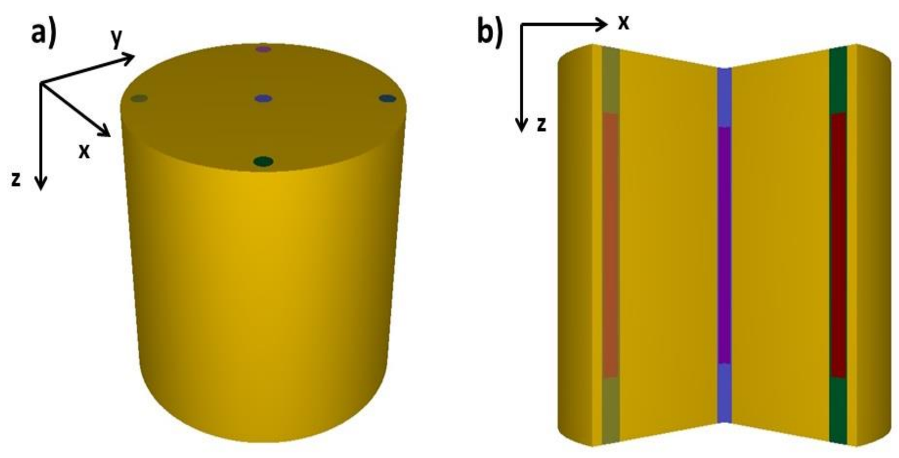

Fig. 3 a) CTDI cylindrical phantom used to compute the $CTDI_{100,c}$ (center) and $CTDI_{100,p}$ (4 peripheral position), b) 3D view showing the cylindrical bodies with 10 cm length and 8 mm of diameters used to compute the $CTDI_{100}$.

Results and Discussions

Validation based on dose profile

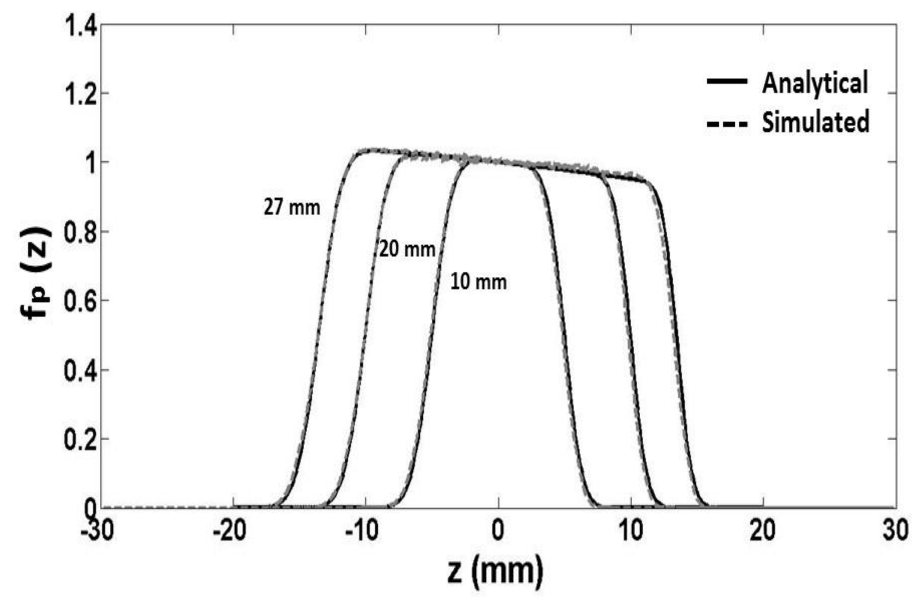

Fig. 4 Analytical (continuous line) and simulated (dashed line) primary beam profile in air for 27, 20 and 10 mm collimation (projection on the axis of rotation).

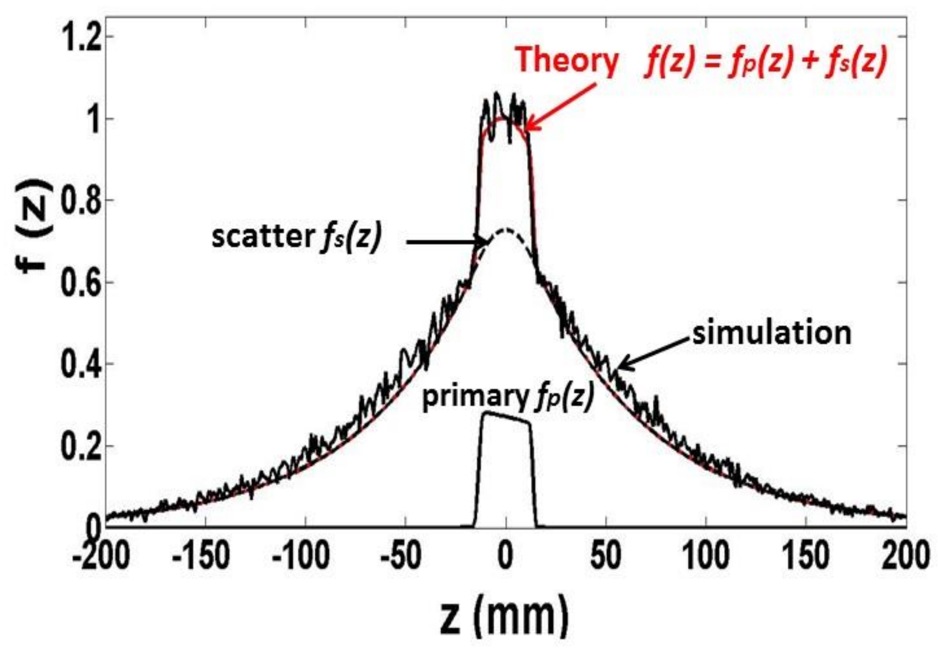

Fig. 5 Analytical and simulated dose profile for 27mm collimation (on AOR). Contribution of the dose profile scatter and primary component.

Validation based on $CTDI_{100}$

Table. 1 $CTDI_{100,c}/CTDI_{100,p}$ for head and body phantom

kV	Scanner	$CTDI_{100,c}/CTDI_{100,p}$ (Head)		$CTDI_{100,c}/CTDI_{100,p}$ (Body)	
		C/P	C/P	C/P	C/P
80	GE Lightspeed Ultra	1.14(2)	0.94	0.38(1)	0.40
100		1.16(2)	0.99	0.47(1)	0.46
120		1.16(2)	1.01	0.43(1)	0.50
140		1.14(2)	1.02	0.47(1)	0.52

References

(1) DIXON, R. L., MUNLEY, M. T. & BAYRAM, E. 2005. An improved analytical model for CT dose simulation with a new look at the theory of CT dose. *Medical Physics,* 32, 3712-3728.

(2) DIXON, R. L. & BOONE, J. M. 2011. Analytical equations for CT dose profiles derived using a scatter kernel of Monte Carlo parentage with broad applicability to CT dosimetry problems. *Med Phys,* 38, 4251-64.

(3) KRAMER, R., CASSOLA, V. F., ANDRADE, M. E. A., ARAÚJO, M. W. C. D., BRENNER, D. J. & KHOURY, H. J. 2017. Mathematical modelling of scanner-specific bowtie filters for Monte Carlo CT dosimetry. *Physics in Medicine and Biology,* 62, 781.

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