Supplementary material

Monte Carlo calculation geometries

The single volume calculations were performed in three different geometries: a thin water cylinder, an air cylinder, and an air cylinder surrounded by a detailed geometry presenting an IC. The IC was modelled according to Bragg Peak Chamber Type 34073 (PTW.73) manufactured by PTW. A detector with diameter larger than the beams was intentionally chosen due to the uncertainties related to the use of the point detectors in the small-field dosimetry [1]. The IC geometry was built with the information provided by the manufacturer and with the micro computed tomography images of the detector acquired with Siemens Inveon Multimodality PET-CT imaging scanner (Siemens Healthcare GmbH, Erlangen, Germany). The entrance window was modelled as 1.01 mm of polymethyl methacrylate (PMMA), 0.02 mm of graphite, and 0.10 mm of lacquer. In the model, lacquer was replaced by PMMA. The diameters of the air volume and the active air volume were 48.0 mm and 39.6 mm, respectively. The thickness of the air volume was 2.01 mm. The back wall of the IC was composed of 0.10 mm of lacquer (replaced by PMMA), 0.02 mm of graphite, a PMMA isolator with thickness of 0.32 mm, 0.02 mm of graphite, and 1.00 mm of PMMA.

The dose to water was calculated in a thin water cylinder. The diameter of the cylinder was identical to that of the active air volume of IC (39.6 mm). The thickness of the thin water cylinder was set to 0.20 mm. The dimensions of a simple air cylinder in water were chosen similar to that of the air volume of the PTW.73. Dose was scored only in the active air volume. The single volume calculation geometries are illustrated in Supplementary Figure I.

Profiles were scored in 2-mm-thick water rings, which were centred at the depth of 10 cm. The widths of the rings were 1 mm (from 0 to 20 mm off beam central axis), 2.5 mm (from 20 to 50 mm), and 10 mm (from 50 to 100 mm). PDD curves were scored along the central axis of the water phantom in thin cylinders with a radius of 1 mm and a thickness of 1 mm from the entrance surface of the phantom till the depth of 30 mm, and with the thickness of 2 mm onwards.

Parameters for Monte Carlo calculations

The calculations with both user codes were performed with the equal EGSnrc transport parameters, which are listed in Supplementary Table II. To improve the calculation efficiency, the variance reduction techniques were used. The photon cross-section enhancement (only available with the egs_chamber) was turned on with an enhancement factor of 256. Photon splitting was applied with both user codes with a splitting factor of 40.

List of Supplementary Figures

Supplementary Figure I. A schematic presentation of the single volume calculation geometries. In a) the dose is scored in a 0.2-mm-thick water cylinder with a diameter of 39.6 mm, which is centred at the depths of 10 cm and 20 cm in the water phantom at SSD90 and SSD80, respectively. In b) and c) the calculations are performed in an air cylinder, which dimensions are equivalent to the active air volume of PTW.73; a diameter of 39.6 mm and a thickness of 2.01 mm. The entrance surface of the air cylinder was placed at the depths of 10 cm and 20 cm with SSD90 and SSD80, respectively. In b) the air cylinder is surrounded by water, but in c) the detailed PTW.73 is modelled.

Supplementary Figure II. PDD curves for CC7.5 calculated with the DOSRZnrc and the egs_chamber user codes. The global difference is calculated with 1-mm-intervals from the interpolated data. PDD, percentage depth dose; CC, conical collimator.

Supplementary Figure III. Half profiles for CC7.5 calculated with the DOSRZnrc and the egs_chamber user codes. The global difference is calculated with 1-mm-intervals from the interpolated data. Calculated points of the DOSRZnrc and the egs_chamber are presented with circle and cross symbols, respectively. CC, conical collimator.

Supplementary Tables

Supplementary Table I. Differences in Monte Carlo single volume dose calculations between the DOSRZnrc and the egs_chamber user codes with different field sizes (Conical collimators, CC) and at different source-to-surface distances (SSDs).

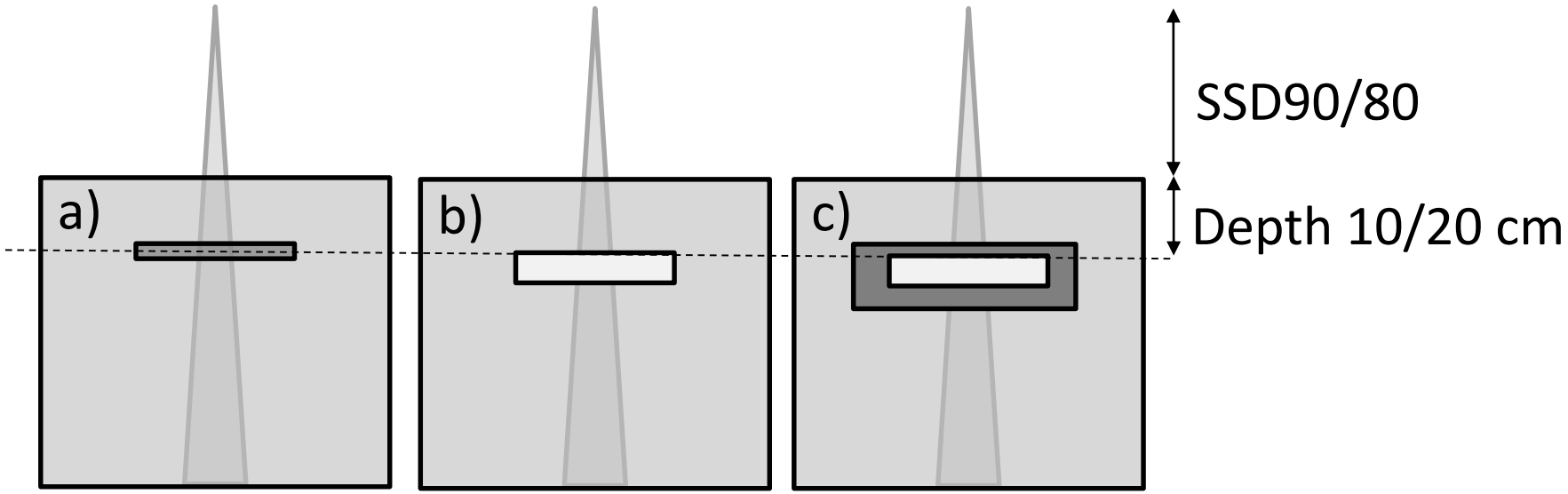
		Difference (%)			
	CC	4 mm	7.5 mm	20 mm	40 mm
Thin water cylinder	SSD80	0.05	0.05	0.05	0.00
	SSD90	0.24	0.03	0.00	0.01
Air cylinder in water	SSD80	0.10	0.03	0.15	0.08
	SSD90	0.20	0.13	0.01	0.10
Air cylinder in IC[a]	SSD80	0.14	0.01	0.01	0.00
	SSD90	0.13	0.00	0.02	0.06
Maximum statistical uncertainty		0.21	0.18	0.11	0.08
Mean statistical uncertainty		0.19	0.13	0.08	0.06

[a]Ionisation chamber

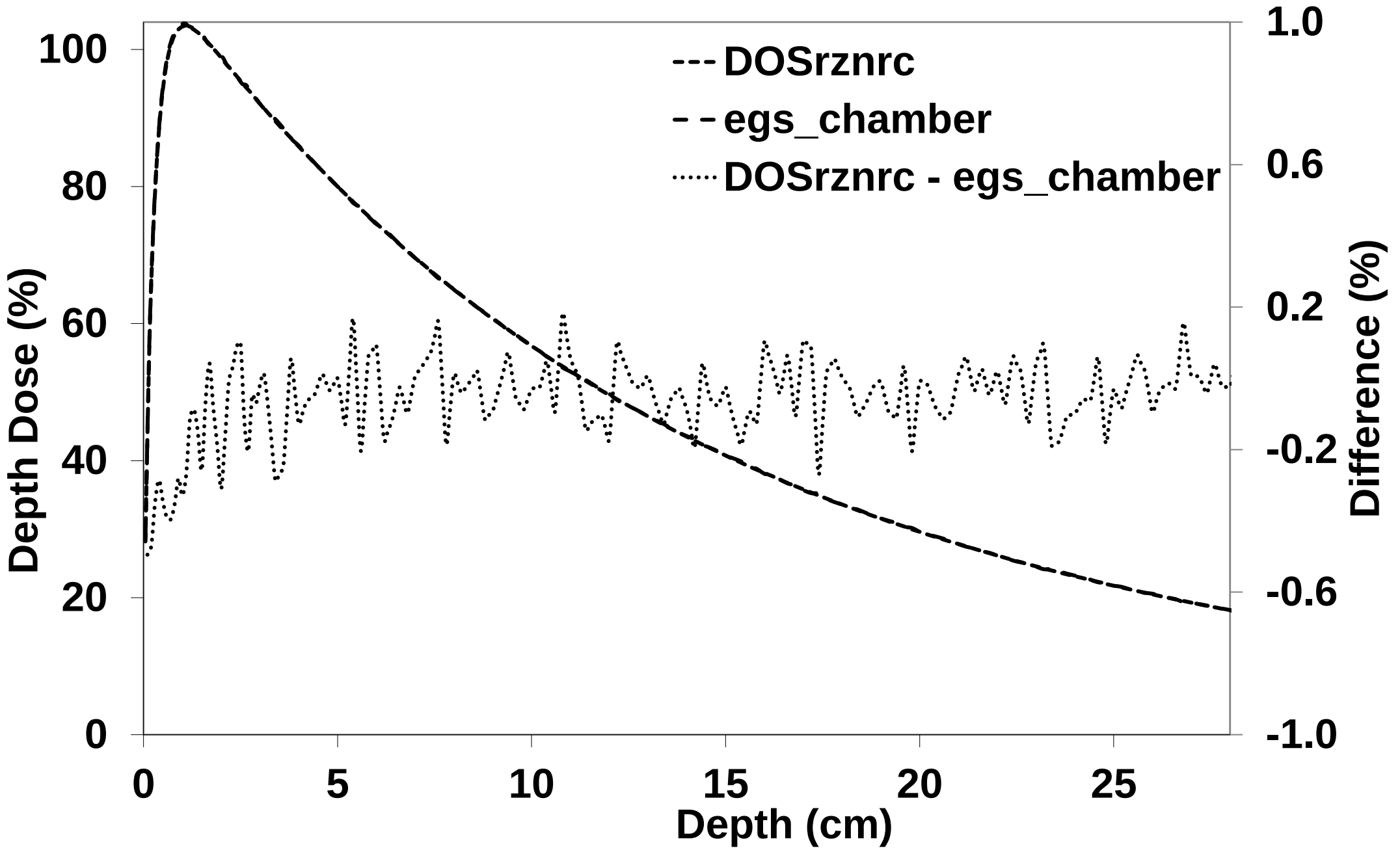
Supplementary Table II. The transport parameters used in Monte Carlo calculations.

ECUT	0.521 MeV
PCUT	0.001 MeV
Global SMAX	1×10^{10}
ESTEPE	0.25
XImax	0.5
Skin depth for BCA	3
Boundary crossing algorithm	EXACT
Electron-step algorithm	PRESTA-II
Spin effects	on
Brems angular sampling	KM
Brems cross sections	NIST
Photon cross sections	xcom
Electron Impact Ionization	On
Triplet production	On
Radiative Compton corrections	On
Bound Compton scattering	On
Pair angular sampling	KM
Pair cross sections	NRC
Photoelectron angular sampling	On
Rayleigh scattering	On
Atomic relaxations	On
Photonuclear attenuation	On

Supplementary Figure I



Supplementary Figure II



Supplementary Figure III