Supplementary Material A

The Markus ionization chamber, described in Table A1, was calibrated in terms of dose to water, following the dosimetry protocol IAEA TRS398 [1]. A chamber specific dose-to-water correction factor kQ reported for a residual range of 0.25 g/cm^2 in water (corresponding to a proton energy of about 15 MeV) was used. kQ, largely determined by the water-air stopping power ratio, $s_{w,air}$, is in principle dependent on proton energy. Variations in $s_{w,air}$ from 5 MeV to 15 MeV were found to be below 1%, and therefore no further corrections beside the abovementioned factor were included.

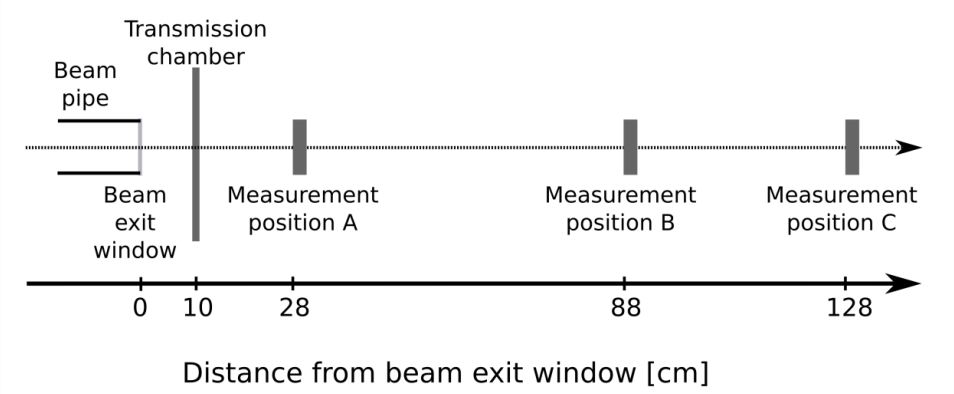

Figure A1: Schematic layout of the irradiation system. The beam was scattered on a tungsten plate (beam exit window) before reaching the beam monitor (transmission chamber) and the candidate cell irradiation positions.

Table A1: Components in the experimental setup.

	Vendor/model	**Material**	**Dimensions in beam direction**
Beam exit window	-	Tungsten	52 ± 1 µm
Transmission chamber	PTW, type 7862	Polyimide Air	2 × 0.1 mm (polyimide) 2.5 mm (air)
Markus ionization chamber	PTW, type 34045	Polyethylene entrance foil Sensitive volume, vented to air	0.03 mm (entrance foil) 1 mm (sensitive volume)
Gafchromic dosimetry film	Gafchromic, EBT3	Polyester film base Active layer	2 × 125 µm (polyester) 30 µm (active layer)

Table A2: Properties of the ionization chamber (IC) entrance foil, absorber sheets and Gafchromic dosimetry films.

	Thickness [mm]	**Density relative to water**	**Stopping power relative to water**	**Water equivalent thickness [mm]**
IC entrance foil	0.030	0.92	1.08	0.030
Paraffin sheet	0.130	0.90	1.09	0.128
Nylon6 sheet	0.500	1.08	1.02	0.551
Gafchromic film	0.280	1.30	1.00	0.364

Table A3: Details of depth dose measurements; measurement position, number and type of absorber sheets present with corresponding water equivalent thickness (WET) and actual measurement (dose). The dose is given in terms of dose to the Advanced Markus chamber (in Gy), relative to the transmission chamber reading (in μC).

Measurement position	**No. of paraffin sheets**	**No. of Nylon6 sheets**	**No. of EBT3 films**	**WET [mm]**	**Dose [Gy/μC]**
A	0	0	1	0.40	10.95
A	0	0	1	0.40	10.86
A	2	1	0	0.84	13.21
A	2	2	0	1.39	21.75
A	0	3	0	1.69	16.88
A	0	3	0	1.69	17.72
A	1	3	0	1.82	0.03
A	2	3	0	1.94	0.03
A	0	4	0	2.24	0.00
B	0	0	0	0.03	1.14
B	0	0	0	0.03	1.14
B	2	0	0	0.29	1.27
B	0	0	1	0.40	1.37
B	0	0	1	0.40	1.40
B	0	1	0	0.58	1.63
B	1	1	0	0.71	1.86
B	2	1	0	0.84	2.22
B	3	1	0	0.97	3.08
B	0	1	1	0.95	2.83
B	4	1	0	1.09	3.50
B	0	2	0	1.14	0.45
B	1	2	0	1.26	0.03
B	2	1	1	1.20	0.05
C	0	0	0	0.03	0.64
C	0	0	1	0.39	0.92
C	0	1	0	0.58	1.63
C	2	1	0	0.84	0.02

Supplementary Material B

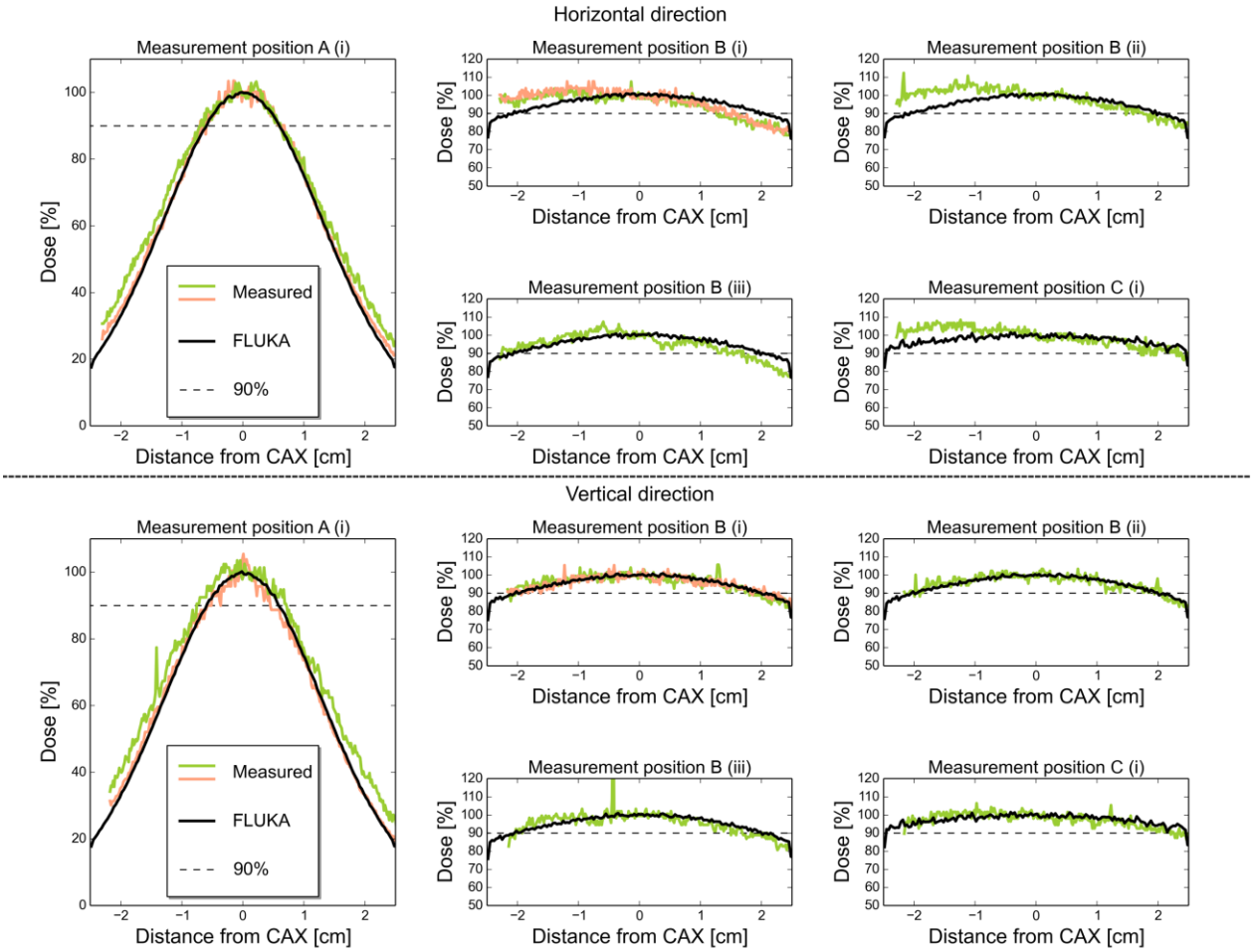

Figure B1: Measured and MC simulated lateral dose profiles, in horizontal (upper panel) and vertical direction (lower panel), as a function of distance from central axis (CAX), at the three measurement positions. The measurements were done at one (position A and C) or three (position B) different water equivalent depths; 0.20 mm (i), 0.76 mm (ii) and 1.01 mm (iii). 100% dose for both measurements and simulations represents the dose at CAX.

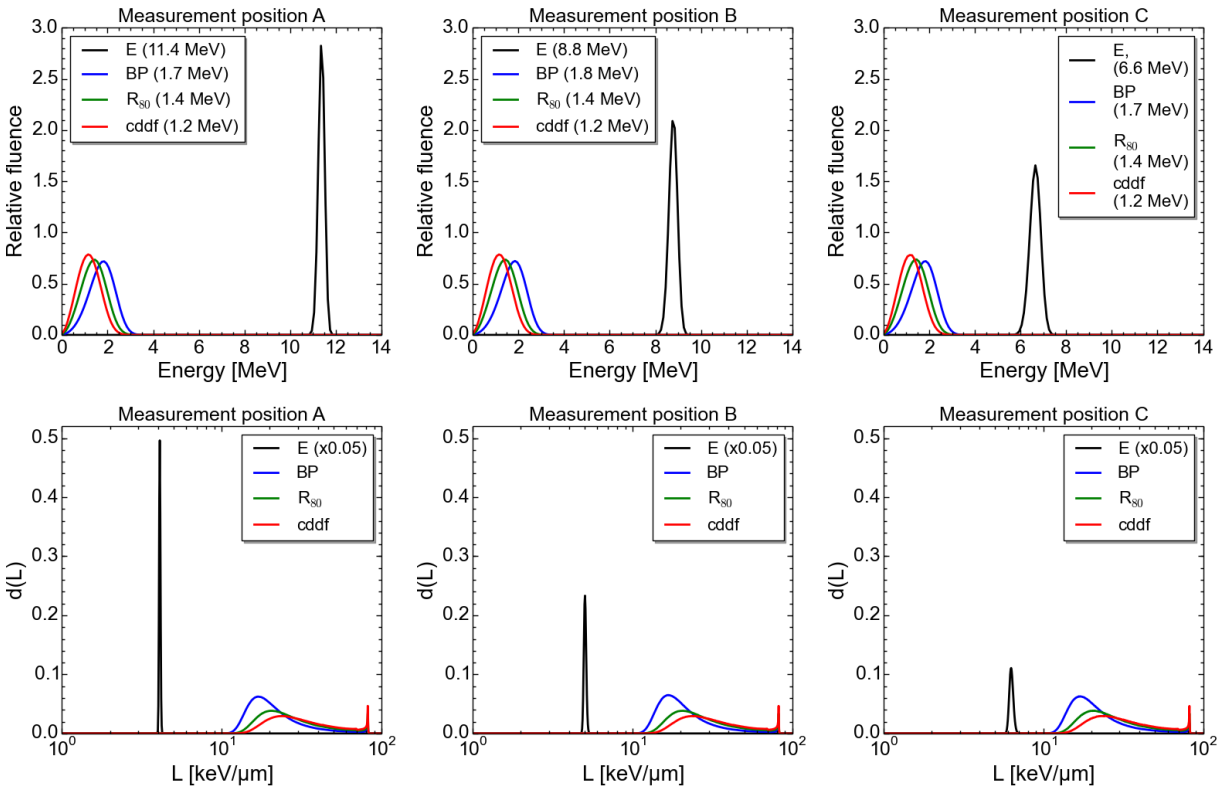

Figure B2: Energy spectra (upper panels) and dose weighted LET spectra (lower panels) at four positions on the depth dose profile; the entrance (E), the Bragg peak (BP), the proton beam range (R_{80}), and the center of the distal dose fall-off (cddf). The LET spectra at the entrance were scaled to make all the spectra visible within the same vertical axis. The mean energies of the spectra, as well as the scaling of the entrance LET spectra, are given in parenthesis in the legends.

List of references (supplementary material)

1. IAEA, TRS. 398. Absorbed dose determination in external beam radiotherapy: An International Code of Practice for Dosimetry based on standards of absorbed dose to water. Vienna International Atomic Energy Agency 2000.