A treatment planning system for manifold multi-ion particle therapy - supplementary material

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1 Per-ion dose-volume contributions

The breakdown of the percentage contribution of each individual ion species to the overall dose-volume in the target region for three different target depths is shown in Tables 1 and 2 for the no hypoxia / OAR case and the hypoxia/no OAR case, respectively.

For the case with a hypoxic tumour sub-volume and no OAR, there tends to be quite a large contribution from heavier ions compared with the other cases. Two or three-ion combinations show a relatively equal split between the different ions in the shallow and central tumour position, while at greater depths, helium or lithium tend to dominate where available. A notably large contribution from iron may be observed for the shallow tumour location for the lithium/carbon/iron plan.

For the deepest tumour location with a hypoxic region (Figure 3), the dose remains dominated by helium ions; however, now there is a non-trivial contribution from protons, lithium, carbon and neon. As expected, the exclusion of light ions with low LET from the hypoxic region results in an increased contribution from carbon; consequently a 'hole' structure can be seen in the entrance through the skull in the total dose distribution (in front of the hypoxic region), since for a given depth, carbon ions deposit a lower entrance dose relative to the Bragg peak.

When an OAR is present, but no hypoxia, the 8-ion plan only uses protons and helium when the tumour is in the central and deep locations, while at the shallow location only minor contributions from ions heavier than helium are used. Again, the lightest available ion tends to dominate in most cases. Notably, the lithium/carbon/iron plan uses a significant proportion of iron in the shallow and central tumour locations, but very little in the deepest location.

The presence of a distal OAR with no hypoxic region (Figure 6) is also dominated by helium, with the majority of the remaining dose contributed by protons - especially for the region of the tumour in front of the OAR. This is due to the need to avoid dose deposition by the fragmentation tail at the distal edge of the tumour, since proton irradiation dose not produce a fragmentation tail.

2 Dose uniformity

For the case with a hypoxic volume and no OAR (Table 3), the 8-ion plan again produces the lowest target and distal boundary RMSE for all tumour positions, and no plan produces consistently lower RMSE in the other defined regions.

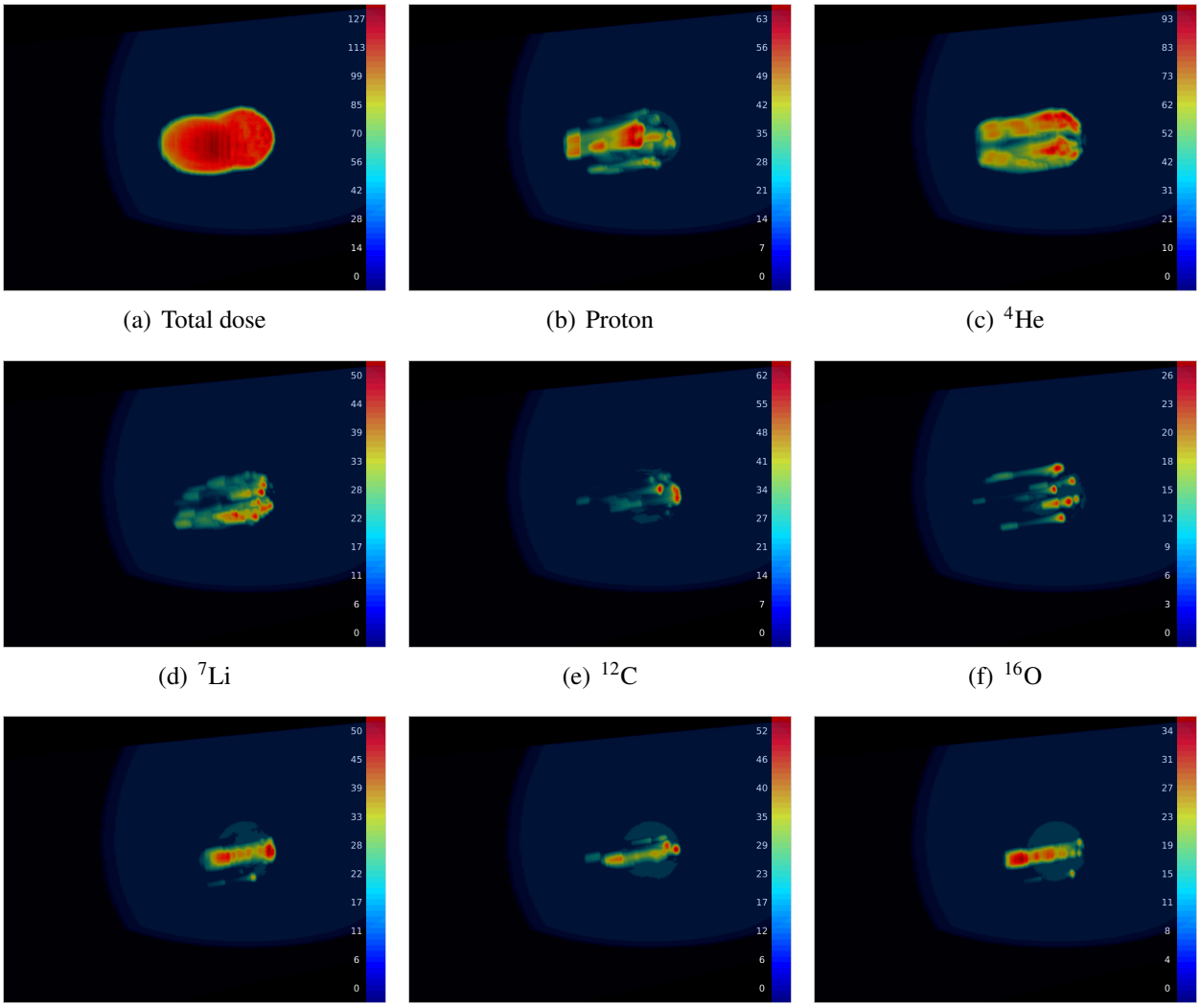
In the absence of hypoxic regions, but with a distal OAR present, the 8-ion plan again performs well in terms of tumour RMSE - however, in the central and deep tumour locations, it is outperformed by the three-ion combination of proton, helium and oxygen. In the distal boundary region, several single-ion plans perform better than the 8-ion plans (in particular, carbon, oxygen and neon perform well for the shallow and

Table 1. The percentage contribution of individual ions in each multi-ion treatment plan. A hypoxic region is located inside the tumour.

Tumour position	Ion combination	H%	He%	Li%	C%	O%	Ne%	Si%	Fe%
Shallow	^{1}H, ^{12}C	57.99	-	-	42.01	-	-	-	-
	^{4}He, ^{16}O	-	64.42	-	-	35.58	-	-	-
	^{7}Li,^{20}Ne	-	-	50.41	-	-	49.59	-	-
	^{1}H, ^{4}He, ^{16}O	21.61	48.42	-	-	29.97	-	-	-
	^{7}Li, ^{12}C, ^{56}Fe	-	-	44.98	26.29	-	-	-	28.73
	^{12}C, ^{16}O, ^{20}Ne	-	-	-	32.35	23.39	44.27	-	-
	All ions	15.73	41.79	12.45	9.06	3.01	7.17	6.53	4.27
Central	^{1}H, ^{12}C	50.28	-	-	49.72	-	-	-	-
	^{4}He, ^{16}O	-	85.09	-	-	14.91	-	-	-
	^{7}Li,^{20}Ne	-	-	76.66	-	-	23.34	-	-
	^{1}H, ^{4}He, ^{16}O	24.41	61.56	-	-	14.03	-	-	-
	^{7}Li, ^{12}C, ^{56}Fe	-	-	68.73	22.33	-	-	-	8.94
	^{12}C, ^{16}O, ^{20}Ne	-	-	-	63.29	21.47	15.24	-	-
	All ions	22.67	46.20	13.02	9.56	0.95	2.75	4.06	0.80
Deep	^{1}H, ^{12}C	43.51	-	-	56.49	-	-	-	-
	^{4}He, ^{16}O	-	86.38	-	-	13.62	-	-	-
	^{7}Li,^{20}Ne	-	-	81.59	-	-	18.41	-	-
	^{1}H, ^{4}He, ^{16}O	13.81	73.65	-	-	12.54	-	-	-
	^{7}Li, ^{12}C, ^{56}Fe	-	-	72.11	27.67	-	-	-	0.23
	^{12}C, ^{16}O, ^{20}Ne	-	-	-	86.84	10.99	2.17	-	-
	All ions	13.96	56.79	14.26	12.80	0.88	1.30	0.01	0.00

Table 2. The percentage contribution of individual ions in each multi-ion treatment plan. An OAR is located distal (and adjacent) to the tumour.

Tumour position	Ion combination	H%	He%	Li%	C%	O%	Ne%	Si%	Fe%
Shallow	^{1}H, ^{12}C	91.60	-	-	8.40	-	-	-	-
	^{4}He, ^{16}O	-	95.75	-	-	4.25	-	-	-
	^{7}Li,^{20}Ne	-	-	86.05	-	-	13.95	-	-
	^{1}H, ^{4}He, ^{16}O	56.28	39.89	-	-	3.83	-	-	-
	^{7}Li, ^{12}C, ^{56}Fe	-	-	63.76	0.00	-	-	-	36.24
	^{12}C, ^{16}O, ^{20}Ne	-	-	5.77	53.33	40.90	-	-	
	All ions	54.89	36.94	5.25	0.16	0.71	0.93	0.35	0.78
Central	^{1}H, ^{12}C	94.93	-	-	5.07	-	-	-	-
	^{4}He, ^{16}O	-	100.00	-	-	0.00	-	-	-
	^{7}Li,^{20}Ne	-	-	99.67	-	-	0.33	-	-
	^{1}H, ^{4}He, ^{16}O	53.70	46.30	-	-	0.00	-	-	-
	^{7}Li, ^{12}C, ^{56}Fe	-	-	87.92	0.00	-	-	-	12.08
	^{12}C, ^{16}O, ^{20}Ne	-	-	-	33.08	58.23	8.70	-	-
	All ions	53.81	45.76	0.27	0.16	0.00	0.00	0.00	0.00
Deep	^{1}H, ^{12}C	95.57	-	-	4.43	-	-	-	-
	^{4}He, ^{16}O	-	100.00	-	-	0.00	-	-	-
	^{7}Li,^{20}Ne	-	-	100.00	-	-	0.00	-	-
	^{1}H, ^{4}He, ^{16}O	44.25	55.75	-	-	0.00	-	-	-
	^{7}Li, ^{12}C, ^{56}Fe	-	-	98.78	0.00	-	-	-	1.22
	^{12}C, ^{16}O, ^{20}Ne	-	-	-	54.36	40.38	5.26	-	-
	All ions	44.25	55.75	0.00	0.00	0.00	0.00	0.00	0.00

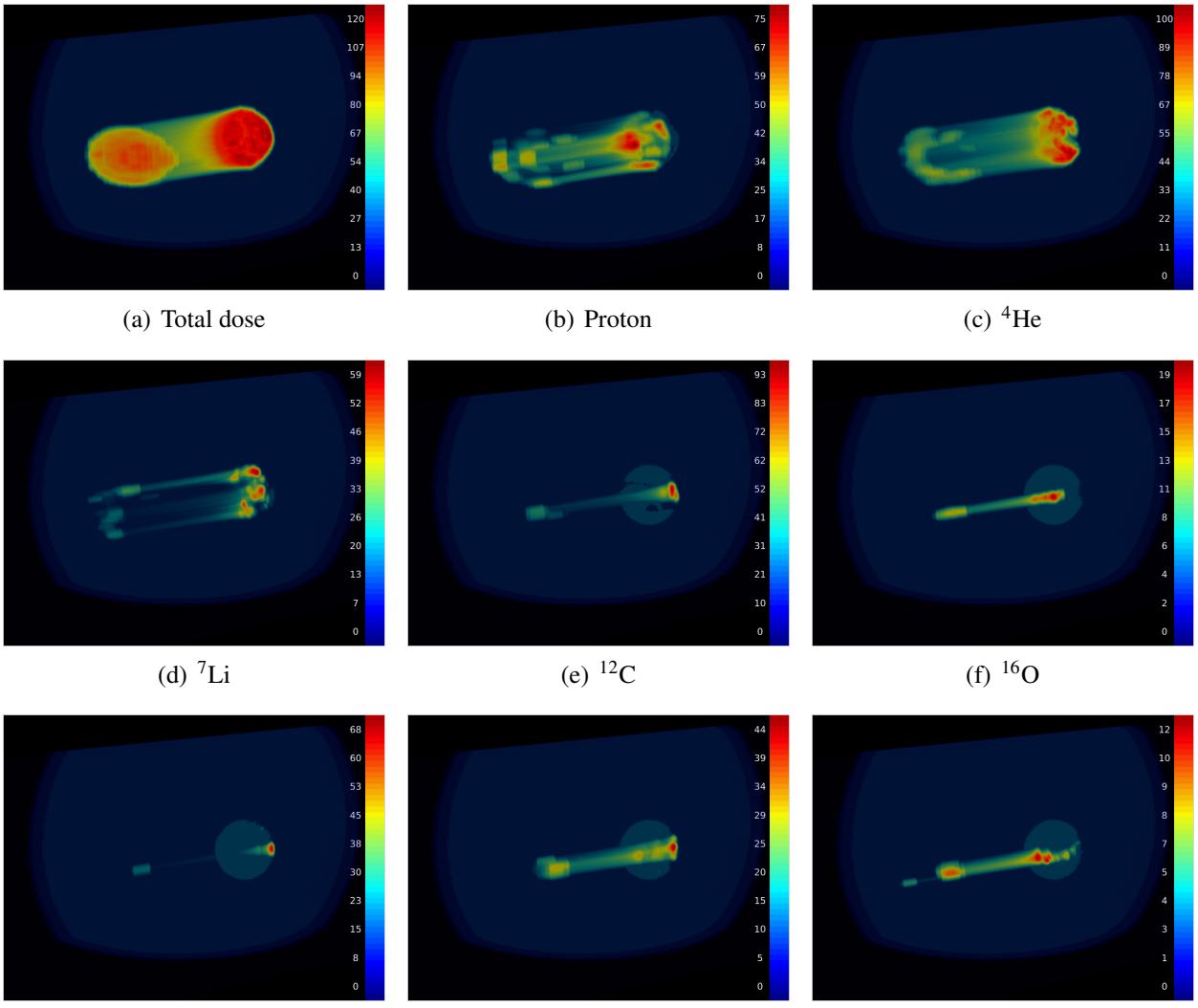


(a) Total dose (b) Proton (c) ^{4}He

(d) ^{7}Li (e) ^{12}C (f) ^{16}O

(g) ^{20}Ne (h) ^{28}Si (i) ^{56}Fe

Figure 1. 3D volumetric visualisations of total dose and contributions from each individual ion species, for an 8-ion treatment plan. The tumour is located at the 'shallow' position, a hypoxic region is located inside the tumour, no OAR is defined.

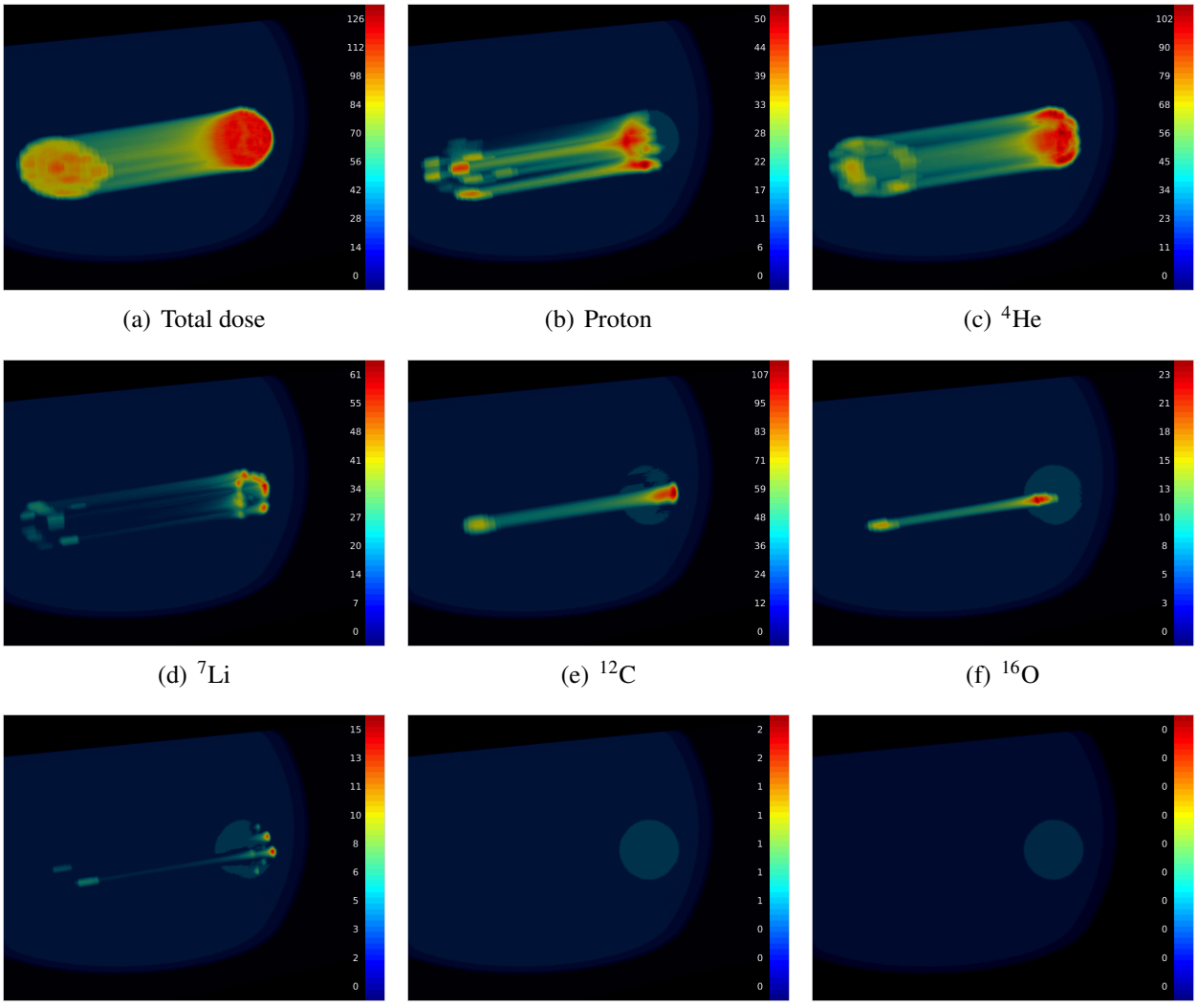


(a) Total dose (b) Proton (c) ^{4}He

(d) ^{7}Li (e) ^{12}C (f) ^{16}O

(g) ^{20}Ne (h) ^{28}Si (i) ^{56}Fe

Figure 2. 3D volumetric visualisations of total dose and contributions from each individual ion species, for an 8-ion treatment plan. The tumour is located at the 'central' position, a hypoxic region is located inside the tumour, no OAR is defined.

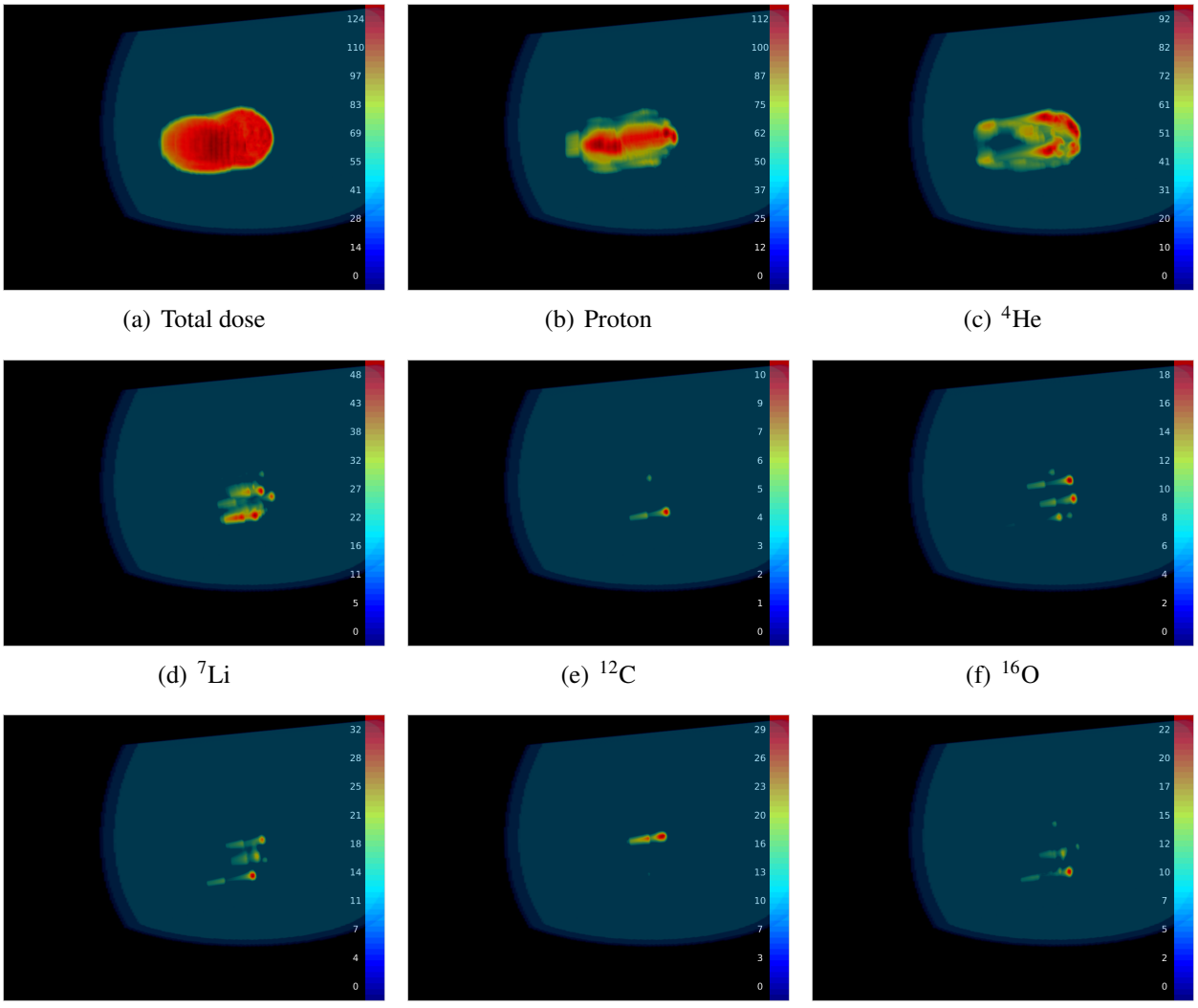


(a) Total dose (b) Proton (c) ^{4}He

(d) ^{7}Li (e) ^{12}C (f) ^{16}O

(g) ^{20}Ne (h) ^{28}Si (i) ^{56}Fe

Figure 3. 3D volumetric visualisations of total dose and contributions from each individual ion species, for an 8-ion treatment plan. The tumour is located at the 'deep' position, a hypoxic region is located inside the tumour, no OAR defined.

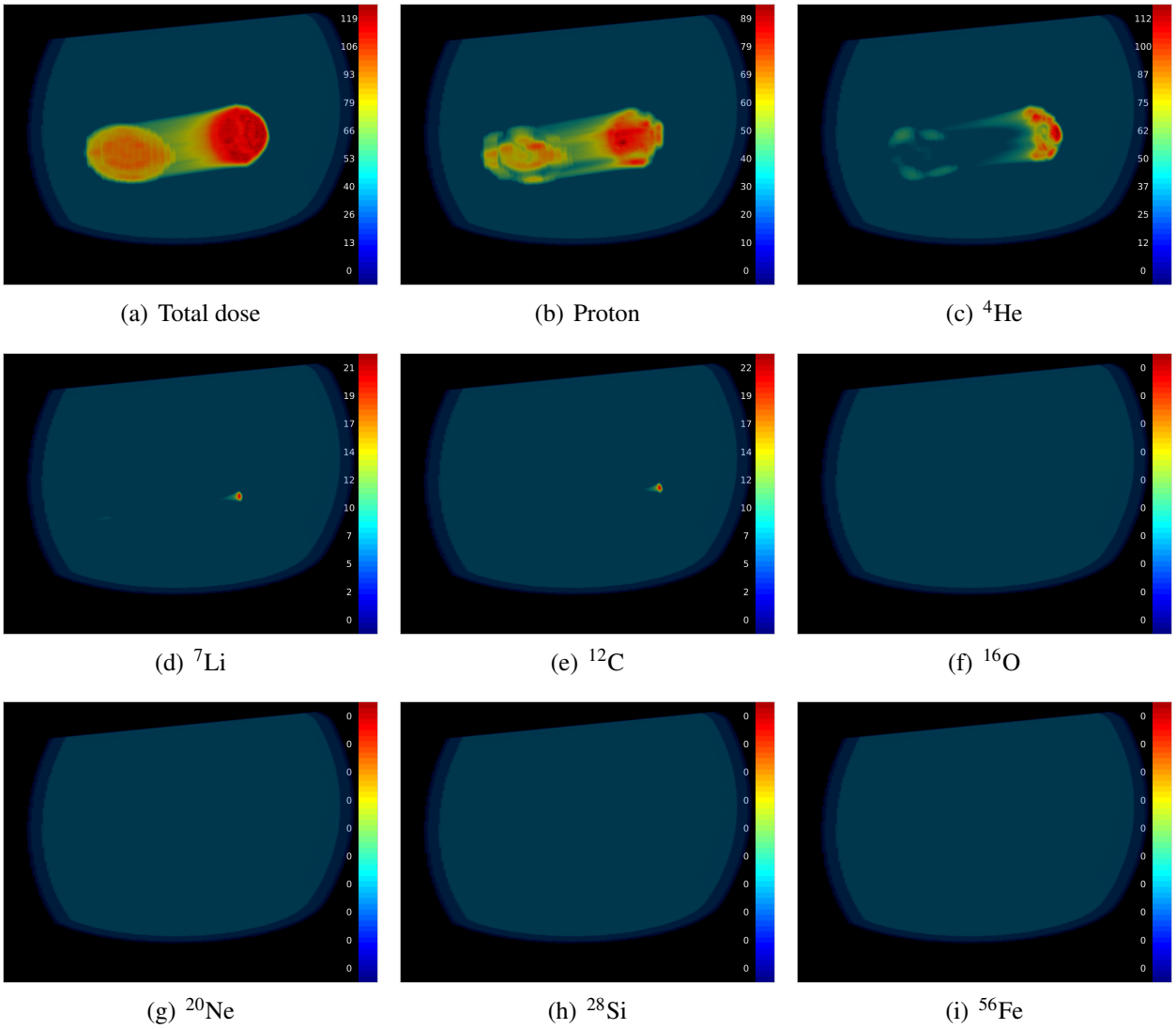


(a) Total dose (b) Proton (c) ^{4}He

(d) ^{7}Li (e) ^{12}C (f) ^{16}O

(g) ^{20}Ne (h) ^{28}Si (i) ^{56}Fe

Figure 4. 3D volumetric visualisations of total dose and contributions from each individual ion species, for an 8-ion treatment plan. The tumour is located at the 'shallow' position, no hypoxic regions are present, and an OAR is positioned distal to the tumour.

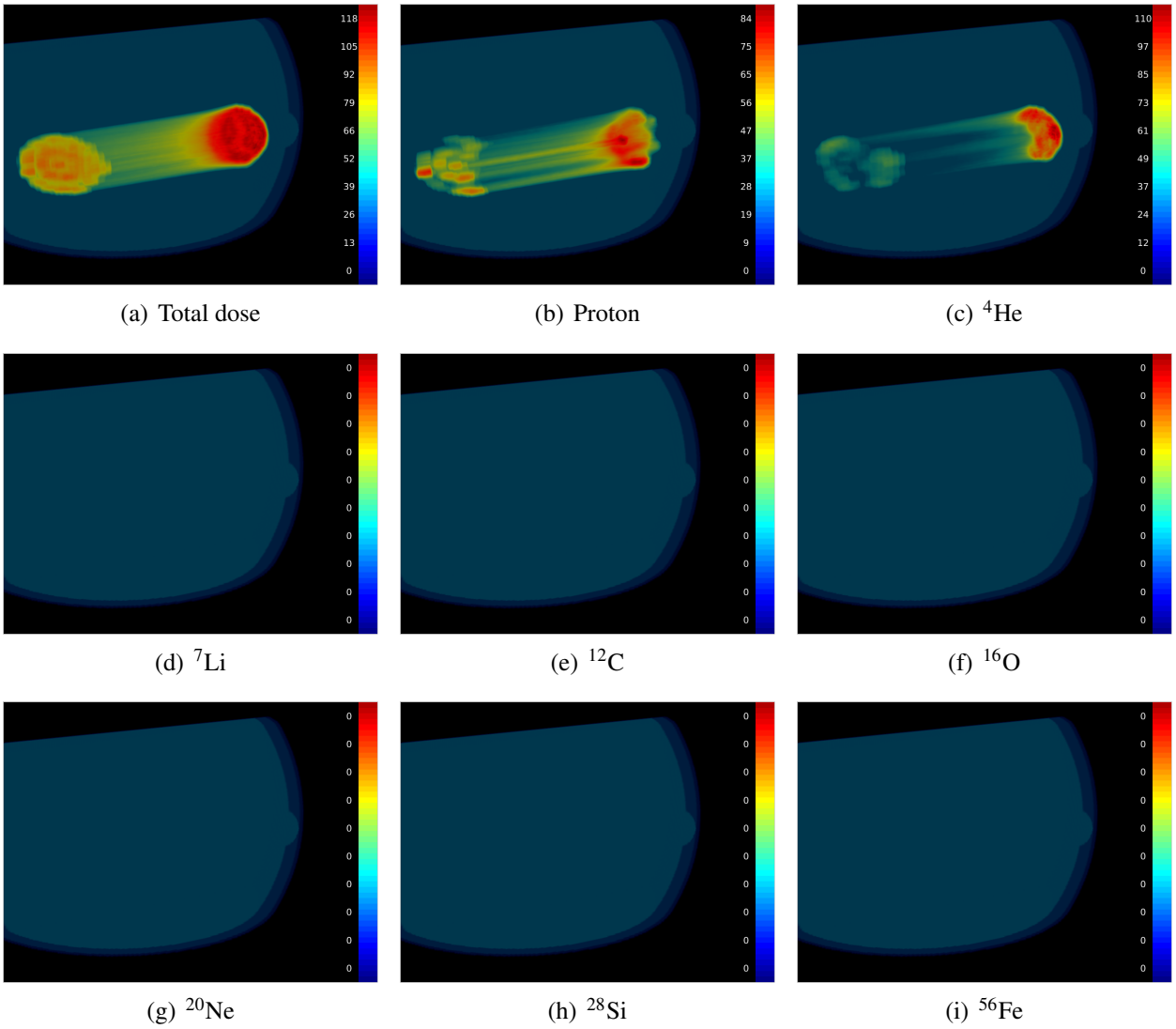


(a) Total dose (b) Proton (c) ^{4}He

(d) ^{7}Li (e) ^{12}C (f) ^{16}O

(g) ^{20}Ne (h) ^{28}Si (i) ^{56}Fe

Figure 5. 3D volumetric visualisations of total dose and contributions from each individual ion species, for an 8-ion treatment plan. The tumour is located at the 'central' position, no hypoxic regions are present, and an OAR is positioned distal to the tumour.



(a) Total dose (b) Proton (c) ^{4}He

(d) ^{7}Li (e) ^{12}C (f) ^{16}O

(g) ^{20}Ne (h) ^{28}Si (i) ^{56}Fe

Figure 6. 3D volumetric visualisations of total dose and contributions from each individual ion species, for an 8-ion treatment plan. The tumour is located at the 'deep' position, no hypoxic regions are present, and an OAR is positioned distal to the tumour.

Table 3. RMS error (Gy) for dose distributions within the target and the surrounding regions; hypoxic sub-volume within the tumour, no organs at risk.

Tumour position	Ion combination	Target	Distal boundary	Distal	Peripheral	Proximal
Shallow	^{1}H, ^{12}C	11.46	15.79	0.42	1.90	33.99
	^{4}He, ^{16}O	11.47	15.46	0.35	1.85	34.07
	^{7}Li, ^{20}Ne	11.73	15.87	0.55	1.86	34.37
	^{1}H, ^{4}He, ^{16}O	11.22	15.52	0.28	1.88	34.03
	^{7}Li, ^{12}C, ^{56}Fe	11.88	15.89	0.58	1.85	34.72
	^{12}C, ^{16}O, ^{20}Ne	11.62	15.95	0.77	1.85	34.28
	All ions	10.88	15.54	0.36	1.87	34.20
Central	^{1}H, ^{12}C	11.41	16.81	1.00	2.42	44.69
	^{4}He, ^{16}O	11.55	16.37	0.55	2.21	44.83
	^{7}Li, ^{20}Ne	11.41	17.36	1.09	2.22	45.76
	^{1}H, ^{4}He, ^{16}O	11.37	16.31	0.46	2.32	44.60
	^{7}Li, ^{12}C, ^{56}Fe	11.37	17.24	1.17	2.22	45.75
	^{12}C, ^{16}O, ^{20}Ne	11.65	17.96	1.79	2.15	45.31
	All ions	11.14	16.34	0.65	2.32	44.89
Deep	^{1}H, ^{12}C	11.62	17.61	1.51	2.86	52.03
	^{4}He, ^{16}O	11.72	16.87	0.72	2.48	52.00
	^{7}Li, ^{20}Ne	11.68	18.16	1.54	2.51	53.60
	^{1}H, ^{4}He, ^{16}O	11.65	16.83	0.65	2.58	51.89
	^{7}Li, ^{12}C, ^{56}Fe	11.45	17.96	1.60	2.51	53.57
	^{12}C, ^{16}O, ^{20}Ne	11.70	19.18	2.51	2.37	52.93
	All ions	11.37	16.76	0.82	2.58	52.20

central positions). In the OAR region, proton-only plans perform the best - however, several light-heavy ion combinations also perform well (notably proton/carbon, helium/oxygen and proton/helium/oxygen).

3 Dose coverage

For the hypoxia, no-oar case, the 8-ion plan provided the best D_{90} coverage except for the deepest case, where it was outperformed by several 2-ion and 3-ion combinations (in particular lithium/carbon/iron).

Dose isosurfaces at 50% (Figure 7) and 90% (Figure 8) of nominal target dose demonstrate excellent dose conformance in the target in all cases. The 50% isodose surface shows the extent of the entrance dose distribution, while the 90% surface shows that peak dose is largely concentrated in the target and some parts of the entrance bone tissue (moreso for the shallowest tumour position, where the entrance dose gradient is steeper compared to the other tumour positions).

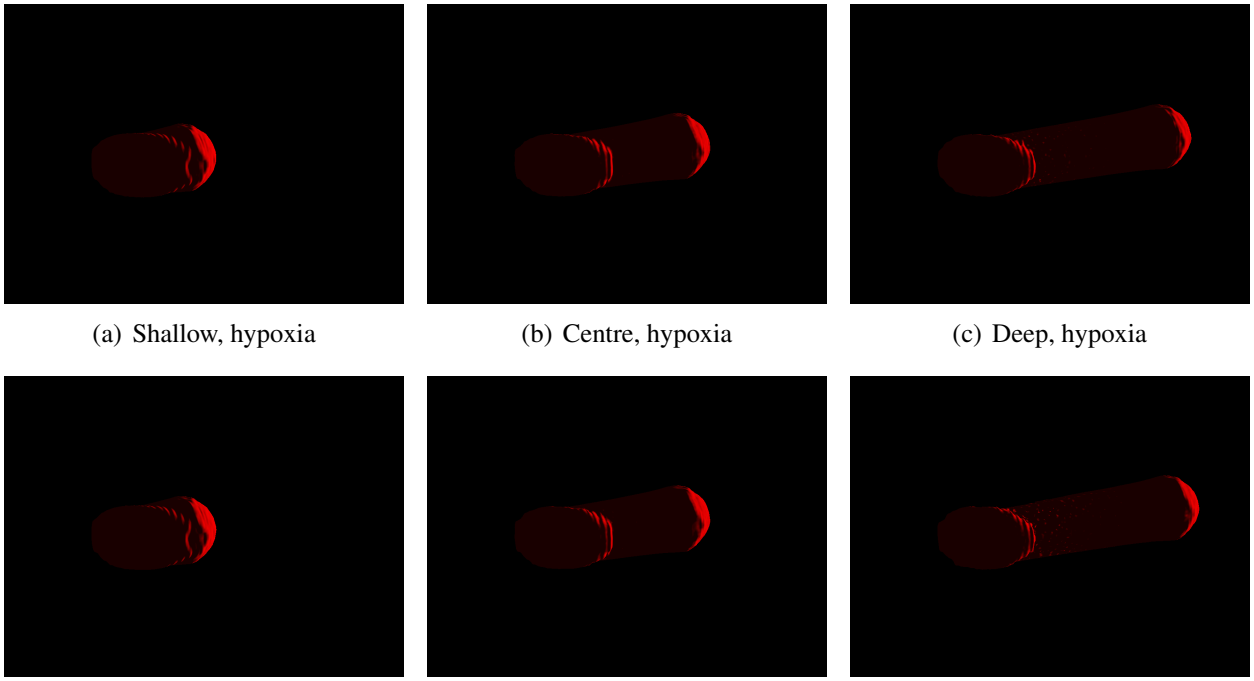
4 Normal tissue dose

Table 4. RMS error (Gy) for dose distributions within the target and the surrounding regions; no hypoxic sub-volume within the tumour, OAR region distal (adjacent) to tumour

Tumour position	Ion combination	Target	Distal boundary	Distal	Peripheral	Proximal	OAR
Shallow	^{1}H	11.46	18.34	0.01	1.92	33.68	0.19
	^{4}He	11.85	17.59	0.14	1.84	33.89	0.73
	^{7}Li	12.73	17.39	0.32	1.85	34.05	2.19
	^{12}C	14.28	17.20	0.74	1.79	32.94	3.54
	^{16}O	13.93	17.32	0.53	1.82	33.29	2.97
	^{20}Ne	14.14	17.37	0.55	1.82	33.31	3.09
	^{28}Si	15.10	17.72	0.53	1.83	33.88	3.01
	^{56}Fe	14.81	17.82	0.44	1.83	34.70	2.75
	^{1}H, ^{12}C	11.39	18.12	0.08	1.91	33.73	0.29
	^{4}He, ^{16}O	11.70	17.53	0.16	1.84	33.90	0.79
	^{7}Li, ^{20}Ne	12.42	17.40	0.36	1.85	34.04	2.21
	^{1}H, ^{4}He, ^{16}O	11.13	17.68	0.08	1.88	33.81	0.37
	^{7}Li, ^{12}C, ^{56}Fe	12.57	17.76	0.39	1.84	34.41	2.10
	^{12}C, ^{16}O, ^{20}Ne	13.41	17.32	0.55	1.82	33.38	2.93
	All,ions	11.10	17.64	0.09	1.88	33.85	0.39
Central	^{1}H	12.27	19.69	0.04	2.45	43.70	0.47
	^{4}He	11.61	18.11	0.28	2.19	44.18	1.18
	^{7}Li	14.36	17.94	0.67	2.16	43.79	3.72
	^{12}C	20.57	17.56	1.43	1.99	39.72	5.53
	^{16}O	22.85	17.50	1.16	2.03	40.72	5.12
	^{20}Ne	23.43	17.65	1.32	2.03	40.33	5.50
	^{28}Si	27.81	18.45	1.40	2.04	41.18	5.34
	^{56}Fe	26.81	19.11	1.39	2.12	43.31	5.14
	^{1}H, ^{12}C	12.09	19.51	0.10	2.44	43.77	0.54
	^{4}He, ^{16}O	11.61	18.11	0.28	2.19	44.18	1.18
	^{7}Li, ^{20}Ne	14.36	17.92	0.67	2.15	43.79	3.72
	^{1}H, ^{4}He, ^{16}O	11.45	18.37	0.13	2.37	44.12	0.59
	^{7}Li, ^{12}C, ^{56}Fe	14.26	18.47	0.82	2.16	44.10	3.67
	^{12}C, ^{16}O, ^{20}Ne	19.93	17.76	1.26	2.05	40.88	5.16
	All ions	11.44	18.36	0.14	2.37	44.12	0.60
Deep	^{1}H	13.21	20.88	0.06	2.98	50.26	0.53
	^{4}He	11.94	18.40	0.28	2.47	50.80	1.48
	^{7}Li	17.15	17.77	0.87	2.40	49.50	4.69
	^{12}C	27.39	17.25	1.59	2.13	42.75	6.79
	^{16}O	31.87	17.71	1.51	2.24	44.04	6.46
	^{20}Ne	33.40	17.88	1.71	2.20	42.53	6.73
	^{28}Si	39.48	19.72	1.96	2.25	43.66	6.65
	^{56}Fe	39.55	21.47	2.23	2.35	45.84	6.51
	^{1}H, ^{12}C	13.07	20.62	0.13	2.97	50.36	0.63
	^{4}He, ^{16}O	11.94	18.40	0.28	2.47	50.80	1.48
	^{7}Li, ^{20}Ne	17.15	17.77	0.87	2.40	49.50	4.69
	^{1}H, ^{4}He, ^{16}O	11.88	18.92	0.16	2.73	51.05	0.88
	^{7}Li, ^{12}C, ^{56}Fe	17.13	17.89	0.92	2.41	49.57	4.68
	^{12}C, ^{16}O, ^{20}Ne	26.77	17.82	1.55	2.20	44.18	6.56
	All ions	11.88	18.92	0.16	2.73	51.05	0.88

Table 5. Percentages of the target volume that received at least 50%, and 90% of the dose volume; hypoxic sub-volume within the tumour, no organs at risk.

Tumour position	Ion combination	D_{50}	D_{90}
Shallow	^{1}H, ^{12}C	99.38	87.68
	^{4}He, ^{16}O	99.45	87.75
	^{7}Li, ^{20}Ne	99.26	87.58
	^{1}H, ^{4}He, ^{16}O	99.52	87.93
	^{7}Li, ^{12}C, ^{56}Fe	99.07	87.55
	^{12}C, ^{16}O, ^{20}Ne	99.34	87.64
	All ions	99.69	88.15
Central	^{1}H, ^{12}C	99.46	86.84
	^{4}He, ^{16}O	99.44	87.27
	^{7}Li, ^{20}Ne	99.56	87.13
	^{1}H, ^{4}He, ^{16}O	99.50	87.21
	^{7}Li, ^{12}C, ^{56}Fe	99.53	87.18
	^{12}C, ^{16}O, ^{20}Ne	99.39	87.18
	All ions	99.63	87.40
Deep	^{1}H, ^{12}C	99.44	86.00
	^{4}He, ^{16}O	99.48	86.70
	^{7}Li, ^{20}Ne	99.40	86.60
	^{1}H, ^{4}He, ^{16}O	99.50	86.71
	^{7}Li, ^{12}C, ^{56}Fe	99.51	86.68
	^{12}C, ^{16}O, ^{20}Ne	99.48	86.49
	All ions	99.58	86.85



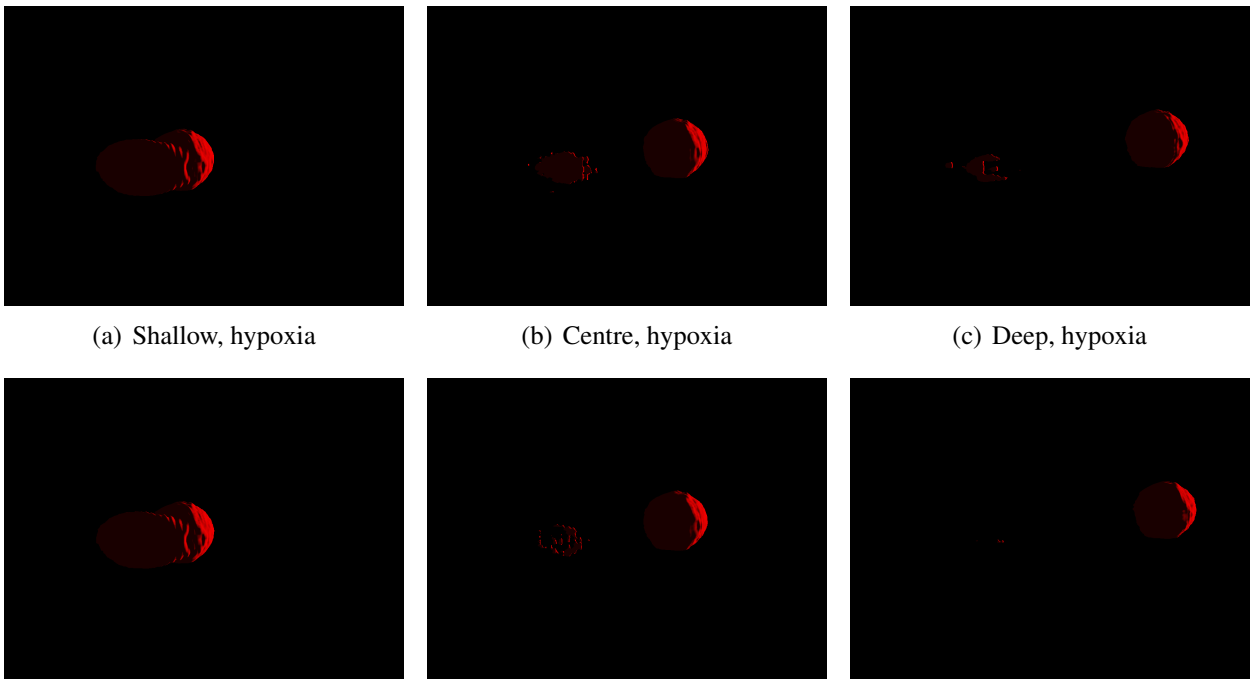
(a) Shallow, hypoxia (b) Centre, hypoxia (c) Deep, hypoxia

(d) Shallow, OAR (e) Central, OAR (f) Deep, OAR

Figure 7. 50% isodose surfaces for 8-ion treatment plans for 3 tumour positions, with hypoxic regions / no OAR and no hypoxia / OAR cases

Table 6. Percentages of the target volume that received at least 50%, and 90% of the dose volume; no hypoxic sub-volume within the tumour, OAR region distal (adjacent) to tumour.

Tumour position	Ion combination	D_{50}	D_{90}
Shallow	^{1}H	99.51	87.13
	^{4}He	99.17	87.28
	^{7}Li	98.71	84.77
	^{12}C	98.16	78.57
	^{16}O	98.18	81.64
	^{20}Ne	98.28	80.13
	^{28}Si	97.50	80.89
	^{56}Fe	98.01	81.39
	^{1}H, ^{12}C	99.55	87.33
	^{4}He, ^{16}O	99.29	87.29
	^{7}Li, ^{20}Ne	98.93	84.89
	^{1}H, ^{4}He, ^{16}O	99.62	87.66
	^{7}Li, ^{12}C, ^{56}Fe	98.81	85.13
	^{12}C, ^{16}O, ^{20}Ne	98.52	81.97
	All ions	99.63	87.71
Central	^{1}H	99.17	85.34
	^{4}He	99.42	87.10
	^{7}Li	98.28	76.49
	^{12}C	96.62	44.14
	^{16}O	93.67	55.42
	^{20}Ne	93.87	45.95
	^{28}Si	90.29	49.50
	^{56}Fe	91.55	50.92
	^{1}H, ^{12}C	99.39	85.57
	^{4}He, ^{16}O	99.42	87.10
	^{7}Li, ^{20}Ne	98.28	76.51
	^{1}H, ^{4}He, ^{16}O	99.51	86.76
	^{7}Li, ^{12}C, ^{56}Fe	98.33	76.91
	^{12}C, ^{16}O, ^{20}Ne	96.70	55.25
	All ions	99.51	86.75
Deep	^{1}H	98.79	83.68
	^{4}He	99.38	86.31
	^{7}Li	97.20	63.95
	^{12}C	94.39	21.56
	^{16}O	87.38	26.18
	^{20}Ne	86.56	21.46
	^{28}Si	79.45	19.57
	^{56}Fe	80.19	21.49
	^{1}H, ^{12}C	98.91	83.83
	^{4}He, ^{16}O	99.38	86.31
	^{7}Li, ^{20}Ne	97.20	63.95
	^{1}H, ^{4}He, ^{16}O	99.43	85.87
	^{7}Li, ^{12}C, ^{56}Fe	97.20	64.06
	^{12}C, ^{16}O, ^{20}Ne	94.17	25.48
	All ions	99.43	85.87



(a) Shallow, hypoxia (b) Centre, hypoxia (c) Deep, hypoxia

(d) Shallow, OAR (e) Central, OAR (f) Deep, OAR

Figure 8. 90% isodose surfaces for 8-ion treatment plans for 3 tumour positions, with hypoxic regions / no OAR and no hypoxia / OAR cases.

Table 7. Total volumes outside the tumour which received at least 5%, 10% and 50% of the target dose volume in mm^3; hypoxic sub-volume defined within the tumour, no organs at risk. Planning target volume (PTV) is 14147 mm^3.

Tumour position	Ion combination	V_5 mm^3	V_{10} mm^3	V_{50} mm^3
	^{1}H,^{12}C	30589	27140	15905
	^{4}He,^{16}O	30075	26660	15791
	^{7}Li,^{20}Ne	30950	26805	15924
Shallow	^{1}H,^{4}He,^{16}O	30309	26883	15839
	^{7}Li,^{12}C,^{56}Fe	30750	26790	15995
	^{12}C,^{16}O,^{20}Ne	31425	26726	15903
	All ions	30347	26837	15858
	^{1}H,^{12}C	74188	65421	40127
	^{4}He,^{16}O	70767	63094	39049
Shallow	^{7}Li,^{20}Ne	74384	63849	39714
	^{1}H,^{4}He,^{16}O	72065	64383	39694
	^{7}Li,^{12}C,^{56}Fe	74389	63670	39740
	^{12}C,^{16}O,^{20}Ne	77583	63744	39255
	All ions	72310	64367	39799.00
	^{1}H,^{12}C	117478	99899	59235
	^{4}He,^{16}O	107053	95248	57637
Shallow	^{7}Li,^{20}Ne	113884	97061	59708
	^{1}H,^{4}He,^{16}O	108360	96486	57905
	^{7}Li,^{12}C,^{56}Fe	114193.	96605	59680
	^{12}C,^{16}O,^{20}Ne	118919	98125	58536
	All ions	108699	96455	58634

Table 8. Total volumes outside the tumour which received at least 5%, 10% and 50% of the target dose volume in mm^3; no hypoxic sub-volume within the tumour, OAR region defined distal (adjacent) to the tumour. Planning target volume (PTV) is 14147 mm^3.

Tumour position	Ion combination	V_5 mm^3	V_{10} mm^3	V_{50} mm^3
Shallow	^{1}H	30786	27388	15866
	^{4}He	29803	26653	15758
	^{7}Li	30275	26719	15863
	^{12}C	31070	26493	15550
	^{16}O	31055	26608	15628
	^{20}Ne	31140	26597	15661
	^{28}Si	31330	26799	15773
	^{56}Fe	30927	26825	15947
	^{1}H,^{12}C	30700	27291	15850
	^{4}He,^{16}O	29821	26664	15761
	^{7}Li,^{20}Ne	30322	26698	15871
	^{1}H,^{4}He,^{16}O	30321	26990	15807
	^{7}Li,^{12}C,^{56}Fe	30277	26725	15931
	^{12}C,^{16}O,^{20}Ne	31024	26609	15653
	All ions	30298	26977	15814
Central	^{1}H	73639	65979	39601
	^{4}He	70084	62947	38814
	^{7}Li	72332	63227	39003
	^{12}C	74880	62100	36282
	^{16}O	75054	62702	37378
	^{20}Ne	75612	62561	36744
	^{28}Si	76242	63762	38084
	^{56}Fe	75916	64043	39708
	^{1}H,^{12}C	73464	65843	39577
	^{4}He,^{16}O	70084	62947	38814
	^{7}Li,^{20}Ne	72334	63227	39003
	^{1}H,^{4}He,^{16}O	72255	64909	39618
	^{7}Li,^{12}C,^{56}Fe	72720	63199	39355
	^{12}C,^{16}O,^{20}Ne	75044	62651	37631
	All ions	72267	64917	39628
Deep	^{1}H	113550	101625	54979
	^{4}He	105753	95071	56281
	^{7}Li	109710	95021	56546
	^{12}C	113657	92352	30249
	^{16}O	113974	95011	34891
	^{20}Ne	115534	94531	29672
	^{28}Si	117407	97110	34726
	^{56}Fe	118142	97777	42679
	^{1}H,^{12}C	113458	101513	55212
	^{4}He,^{16}O	105753	95071	56281
	^{7}Li,^{20}Ne	109710	95021	56546
	^{1}H,^{4}He,^{16}O	109408	98275	56450
	^{7}Li,^{12}C,^{56}Fe	110088	95166	56774
	^{12}C,^{16}O,^{20}Ne	114367	93466	35172
	All ions	109408	98275	56450