UNIVERSITÀ DI PAVIA

INFN

CNAO
Centro Nazionale di Adroterapia Oncologica

International Particle Physics Outreach Group

Particle therapy masterclass

THERAPY PLANNING OF TG119 & LIVER

UNIVERSITY OF PAVIA – PV INFN - CNAO

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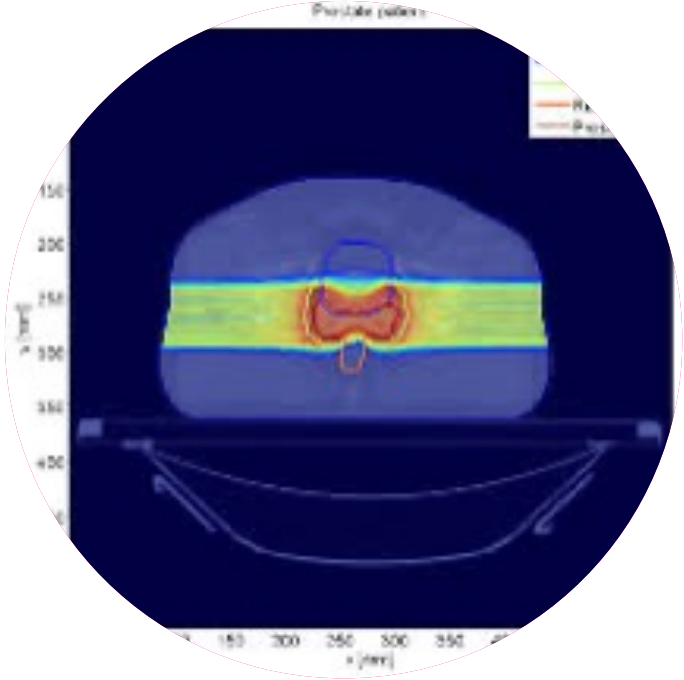
INTERNATIONAL MASTERC
hands on particle

TABLE OF CONTENT

ABSTRACT

We have conducted different simulation modelling several treatment plans taking into account TG119 phantom and one clinical case (liver tumor).

We have planned treatments considering different particle beams made by photons, protons and carbons ions, changing the gantry angles.



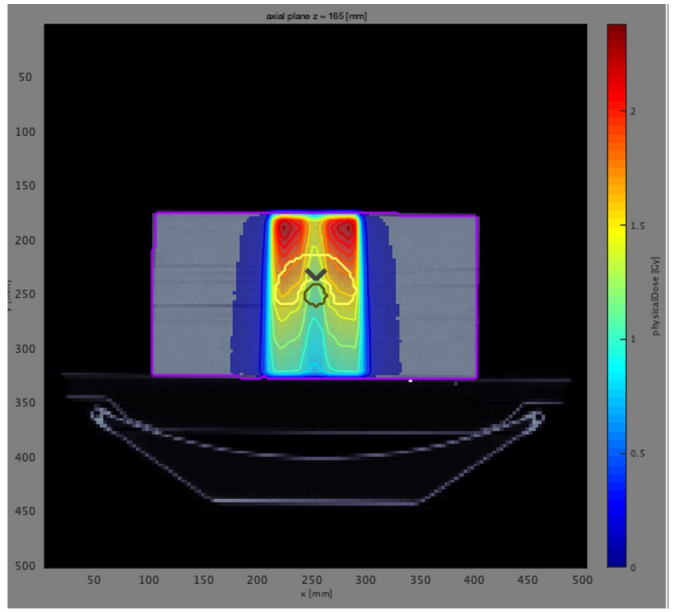
C PHANTOM

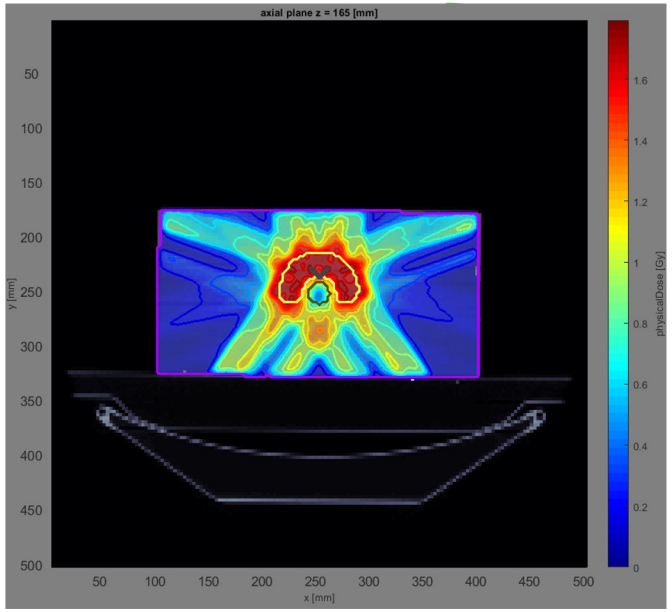
We considered TG119 phantom.

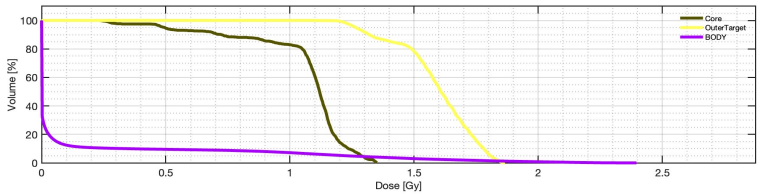
First we planned photon treatments considering:

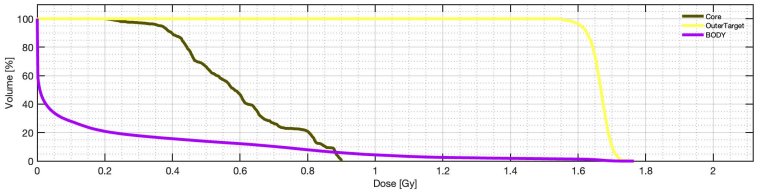
(1) one single beam and

(2) five equispaced beams.









	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.4Gy	V_0.9G
Core	1.0615	0.2183	1.3525	0.2364	1.3359	1.2876	1.1199	0.4966	0.2936	1	0.9750	0.8
OuterTarget	1.5905	0.1581	1.8672	1.0975	1.8349	1.8088	1.6086	1.2669	1.2287	1	1	
BODY	0.1373	0.4068	2.3969	0	1.6934	1.2270	0	0	0	1	0.0980	0.07

	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.3Gy	V_0.7Gy	V_1
Core	0.5966	0.1702	0.9023	0.1969	0.8943	0.8844	0.5836	0.3669	0.2577	1	0.9705	0.2644	
OuterTarget	1.6649	0.0313	1.7654	1.5205	1.7209	1.7103	1.6677	1.6081	1.5819	1	1	1	
BODY	0.1716	0.3434	1.7654	0	1.3643	0.9513	0.0078	0	0	1	0.1779	0.1026	0.

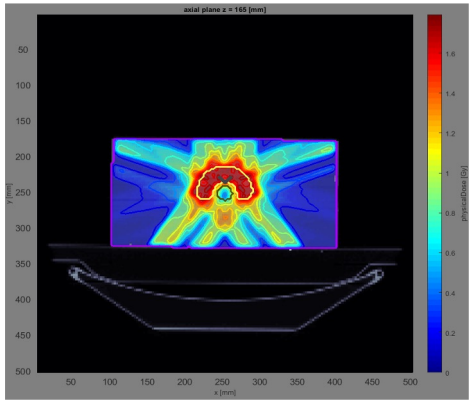
As showed in the dose maps and in the DVHs, the second plan delivers better (more uniformly) the dose in the target plus it spares better (less physical dose) to one of the OAR (core)

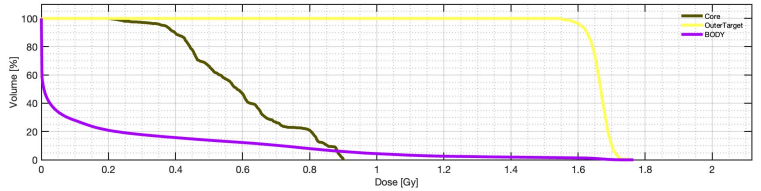
C PHANTOM

We considered TG119 phantom.

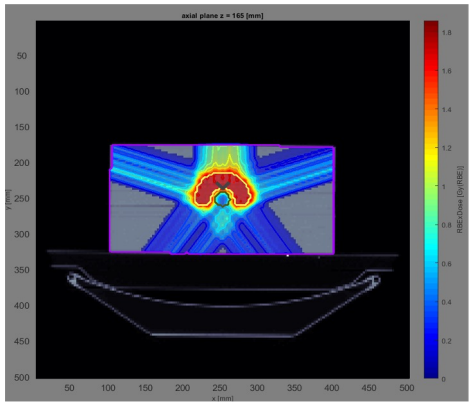
We planned other three different treatment plans considering 5 equispaced beams. We took into account (i) photons, (ii) protons, (iii) carbon ions.

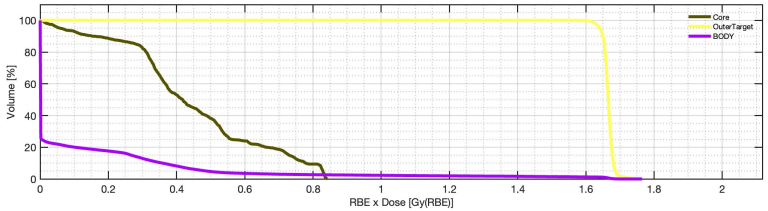
Both dose maps and DVH show an improvement in dose delivery in the target volume… despite it is quite modest (see table after) but…



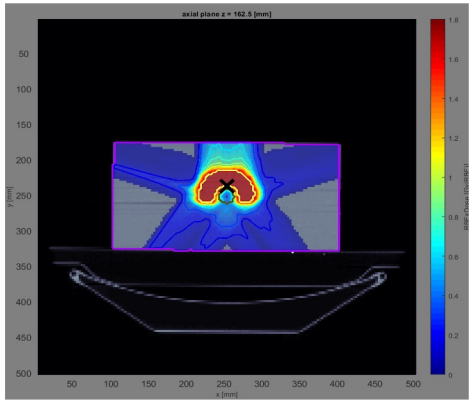


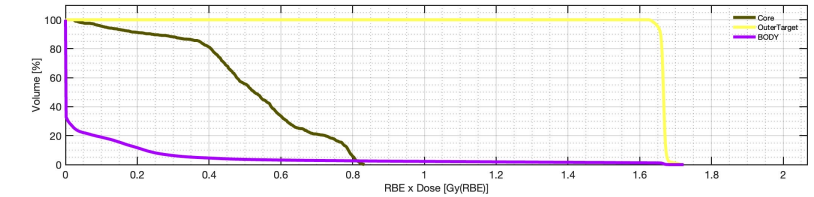
	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.3Gy	V_0.7Gy
Core	0.5966	0.1702	0.9023	0.1969	0.8943	0.8844	0.5836	0.3669	0.2577	1	0.9705	0.2644
OuterTarget	1.6649	0.0313	1.7654	1.5205	1.7209	1.7103	1.6677	1.6081	1.5819	1	1	1
BODY	0.1716	0.3434	1.7654	0	1.3643	0.9513	0.0078	0	0	1	0.1779	0.1026





	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.3Gy	V_0.7Gy
Core	0.4499	0.2147	0.8425	0.0066	0.8339	0.8286	0.4179	0.0601	0.0227	1	0.8258	0.1864
OuterTarget	1.6657	0.0156	1.7654	1.5642	1.6971	1.6869	1.6658	1.6416	1.6284	1	1	1
BODY	0.1000	0.2649	1.7654	0	1.1643	0.4876	0	0	0	1	0.1296	0.0298





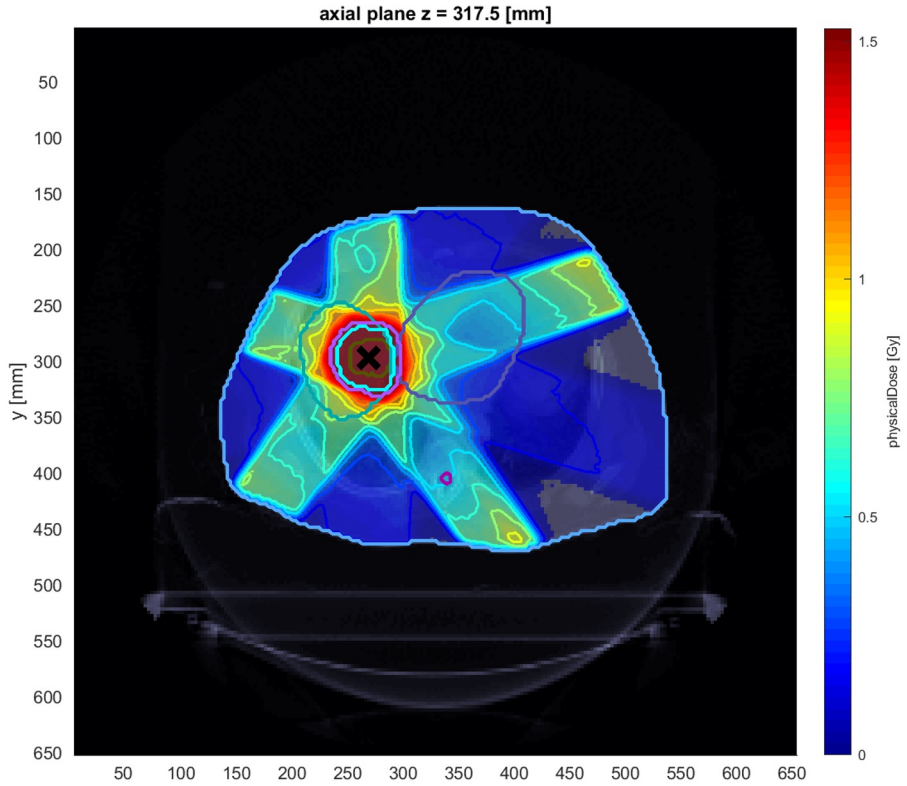
	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.3Gy	V_0.6Gy
Core	0.5226	0.1946	0.8333	0.0213	0.8157	0.8034	0.5265	0.1101	0.0451	1	0.8826	0.3371
OuterTarget	1.6658	0.0093	1.7232	1.5107	1.6823	1.6761	1.6662	1.6511	1.6399	1	1	1
BODY	0.0816	0.2471	1.7232	0	1.1421	0.3622	0	0	0	1	0.0625	0.0317

C PHANTOM

List of all the organs present in the C Phantom classified as organs at risk (OAR) or target and the obtained doses (mean, max, min) for the 3 plans with 5 beams				
Organ	Classification	5 beams photons	5 beams protons	5 beams C-ions
Outer Target	TARGET	1.7, 1.8, 1.5	1.7, 1.8, 1.6	1.7, 1.7, 1.5
Core	OAR	0.6, 0.9, 0.2	0.4, 0.8, 0.0	0.5, 0.8, 0.0
Body	OAR	0.2, 1.8, 0	0.1, 1.8, 0	0.0, 1.7, 0

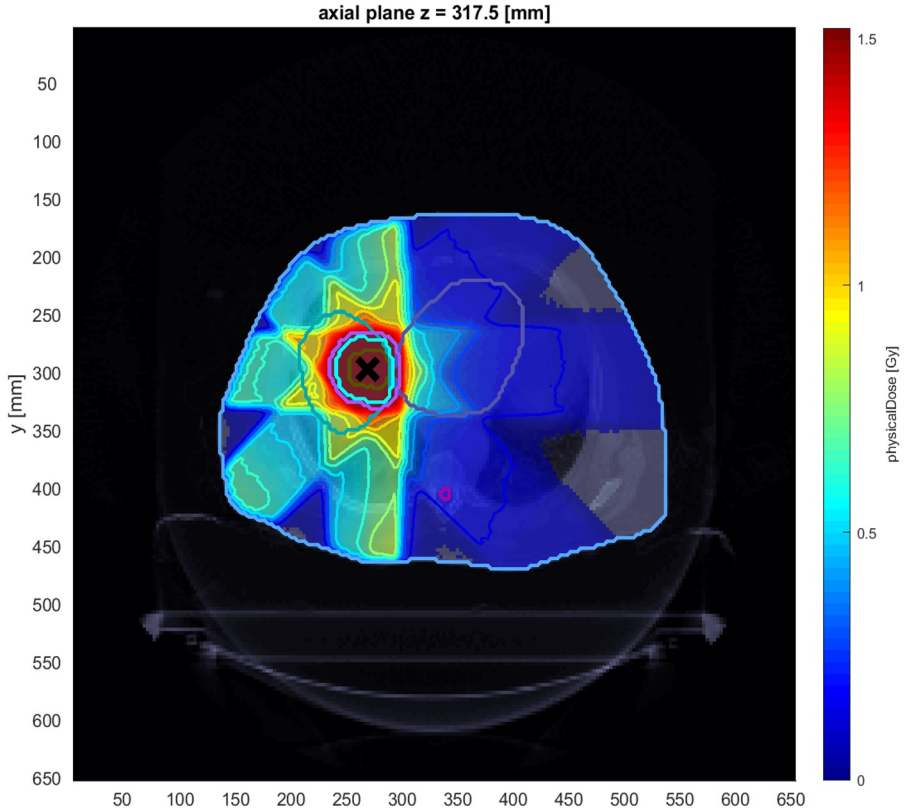
- … protons and C-ions perform better (“less“ doses) than photons in the OARs (core and/or body)

COMPARISON FOR PHOTONS EQUISPACED VERSUS 180°-360° FOR LIVER CASE



Equispaced photons treatment

0° 72° 144° 216° 288°

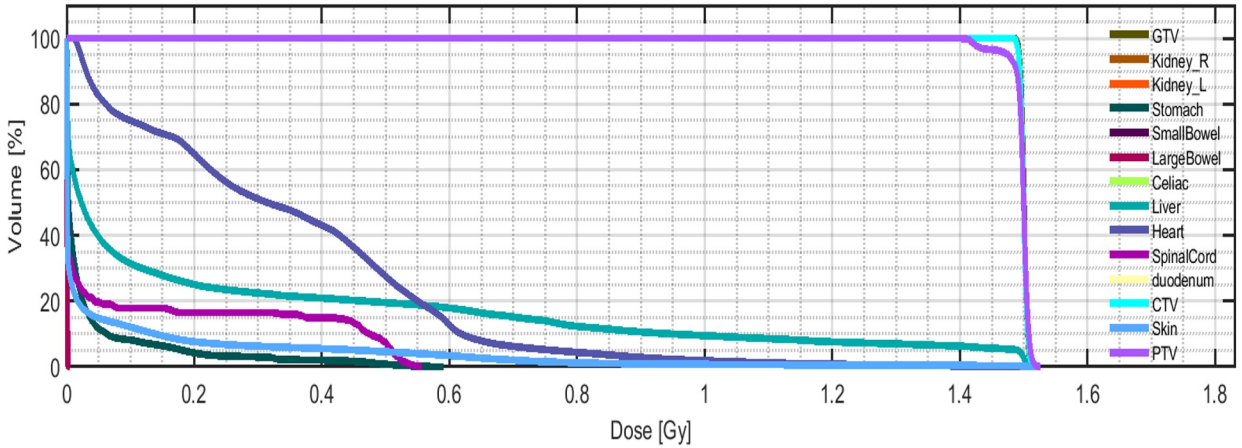


Equispaced (180°-360°) photons treatment

180° 216° 252° 288° 360°

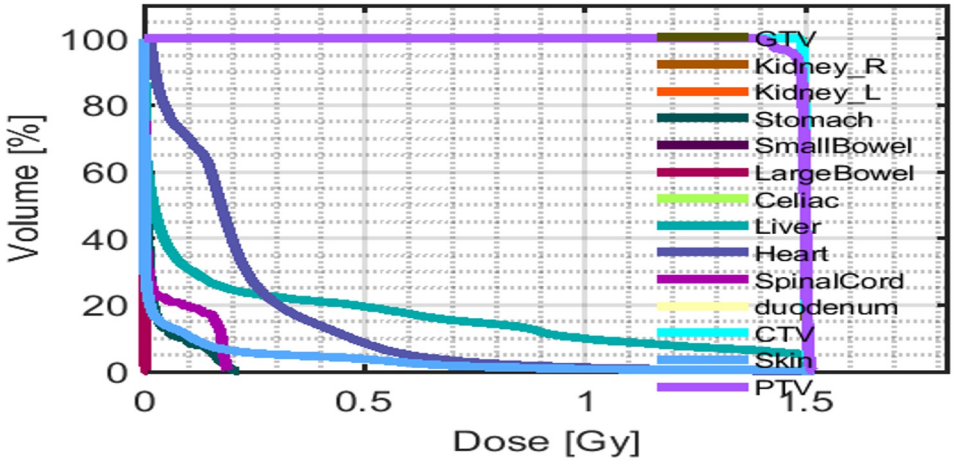
COMPARISON FOR PHOTONS EQUISPACED VERSUS 180°-360° FOR LIVER CASE

Equispaced (0° - 360°) photons treatment



	max	min	mean	std
GTV	1.5172	1.4871	1.5005	0.0044
Kidney_R	0	0	0	0
Kidney_L	0	0	0	0
Stomach	0.5919	0	0.0308	0.0836
SmallBowel	0	0	0	0
LargeBowel	0.0051	0	9.4490e-06	1.5622e-04
Celiac	0	0	0	0
Liver	1.5270	0	0.2438	0.4349
Heart	1.5090	0.0085	0.3399	0.2584
SpinalCord	0.5577	0	0.0851	0.1779
duodenum	0	0	0	0
CTV	1.5198	1.4840	1.5000	0.0049
Skin	1.5270	0	0.0569	0.1822

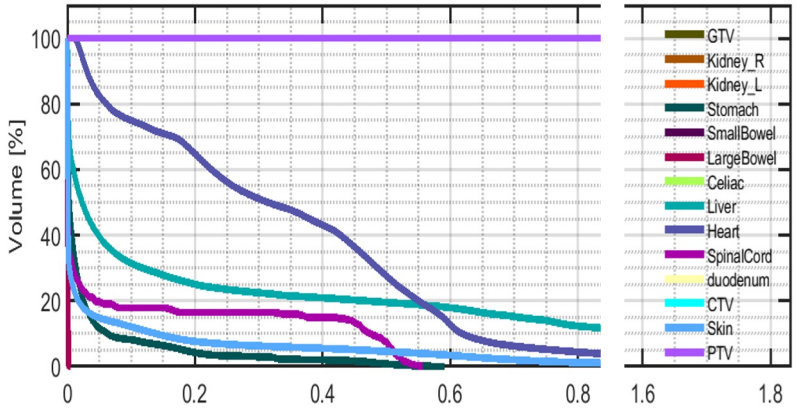
Equispaced (180°-360°) photons treatment



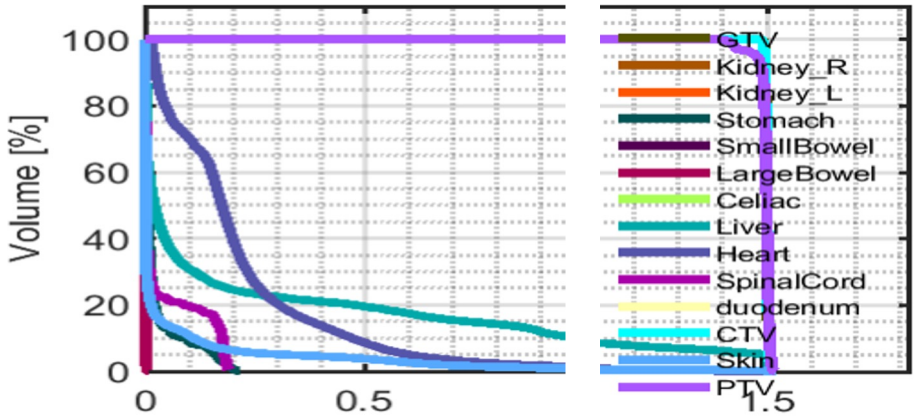
	max	min	mean
GTV	1.5103	1.4874	1.4998
Kidney_R	0	0	0
Kidney_L	0	0	0
Stomach	0.2166	0	0.0232
SmallBowel	0	0	0
LargeBowel	0.0097	0	1.3198e-04
Celiac	0	0	0
Liver	1.5206	0	0.2458
Heart	1.5045	0.0082	0.2159
SpinalCord	0.1910	0	0.0372
duodenum	0	0	0

COMPARISON FOR PHOTONS EQUISPACED VERSUS 180°-360° FOR LIVER CASE

Due to the asimmetric anatomical position of the liver (and thus of the tumour), the second plan (5 beams on the right side of the patient) performs better compared to the first one in some OAR (more than on the TARGETs…) => better preservation of the normal tissues/reduction of the probability of secondary tumours

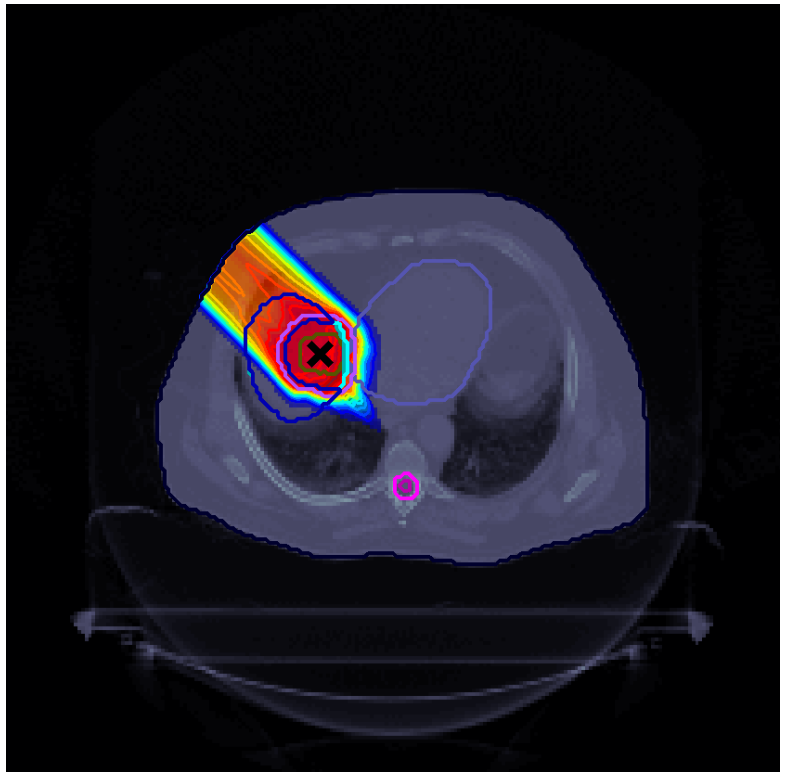


(0° - 360°)

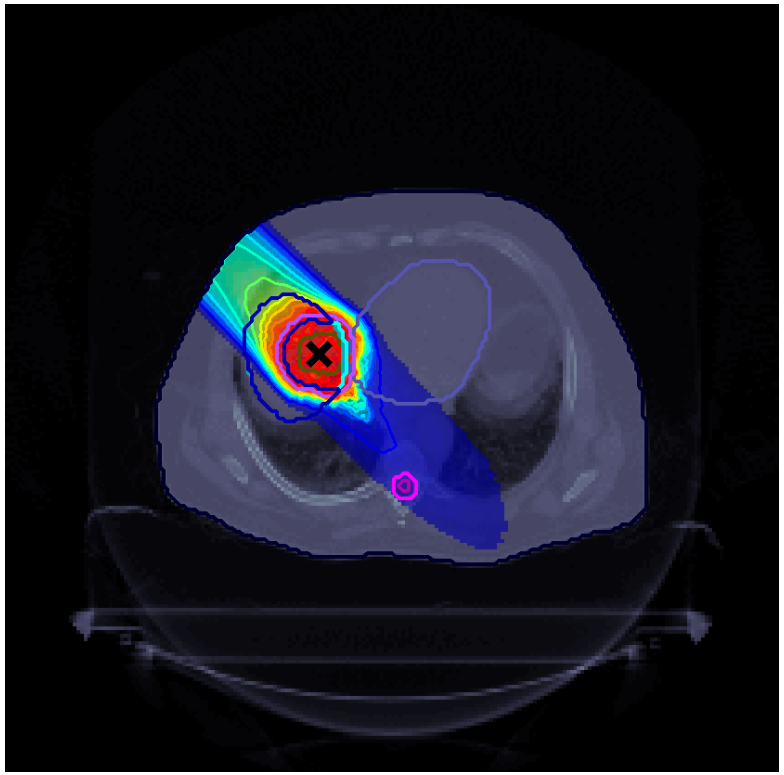


(180° - 360°)

COMPARISON FOR PROTON AND CARBON IONS TREATMENT FOR LIVER CASE



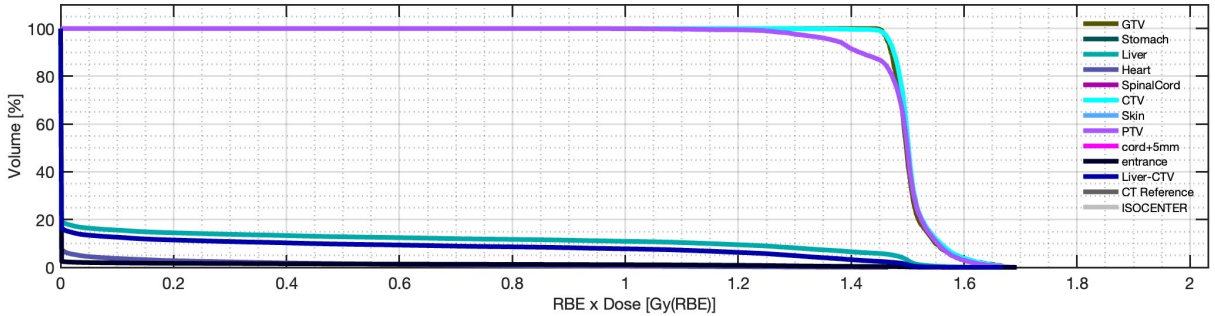
Proton beam at 315°



Carbon-ion beam at 315°

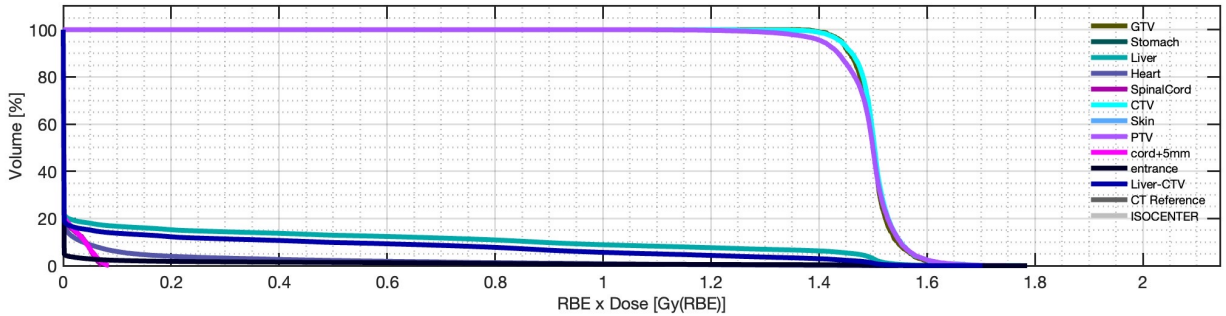
COMPARISON FOR PROTON AND CARBON IONS TREATMENT FOR LIVER CASE

Proton beam at 315°



	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.3Gy	V_0.6Gy
GTV	1.5052	0.0366	1.6905	1.4442	1.6291	1.5803	1.4979	1.4639	1.4580	1	1	1
Stomach	0	0	0	0	0	0	0	0	0	1	0	0
Liver	0.1748	0.4444	1.6941	0	1.5067	1.4763	0	0	0	1	0.1382	0.1243
Heart	0.0199	0.1182	1.4663	0	0.3591	0.0334	0	0	0	1	0.0226	0.0126
SpinalCord	0	0	0	0	0	0	0	0	0	1	0	0
CTV	1.5095	0.0382	1.6941	1.2626	1.6274	1.5884	1.5016	1.4674	1.4581	1	1	1
Skin	0.0184	0.1468	1.6941	0	0.0502	0	0	0	0	1	0.0159	0.0135
PTV	1.4914	0.0674	1.6941	0.8962	1.6164	1.5774	1.4996	1.3702	1.2922	1	1	1
cord+5mm	2.3330e-19	9.8035e-18	5.9013e-16	0	0	0	0	0	0	1	0	0
entrance	0.0184	0.1468	1.6941	0	0.0502	0	0	0	0	1	0.0159	0.0135
Liver-CTV	0.1276	0.3731	1.6685	0	1.4773	1.2943	0	0	0	1	0.1079	0.0934

Carbon-ion beam at 315°

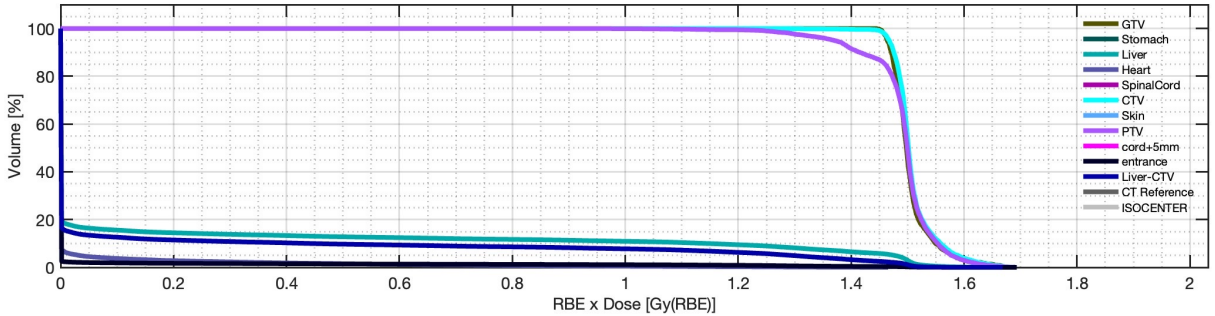


	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.3Gy	V_0.7
GTV	1.5016	0.0395	1.7073	1.3667	1.5976	1.5695	1.5004	1.4424	1.4184	1	1	
Stomach	0	0	0	0	0	0	0	0	0	1	0	
Liver	0.1684	0.4231	1.7864	0	1.5092	1.4675	0	0	0	1	0.1436	0.
Heart	0.0322	0.1467	1.5490	0	0.5593	0.1326	0	0	0	1	0.0324	0.
SpinalCord	0.0076	0.0178	0.0721	0	0.0635	0.0549	0	0	0	1	0	
CTV	1.5049	0.0421	1.7864	1.2166	1.6054	1.5735	1.5027	1.4405	1.4150	1	1	
Skin	0.0173	0.1313	1.7864	0	0.1463	6.4058e-04	0	0	0	1	0.0163	0.
PTV	1.4953	0.0559	1.7864	1.0893	1.6077	1.5738	1.4998	1.4063	1.3479	1	1	
cord+5mm	0.0080	0.0186	0.0862	0	0.0688	0.0568	0	0	0	1	0	
entrance	0.0173	0.1313	1.7864	0	0.1463	6.4058e-04	0	0	0	1	0.0163	0.

Both protons and C-ions deliver a very homogeneous dose in the TARGETs

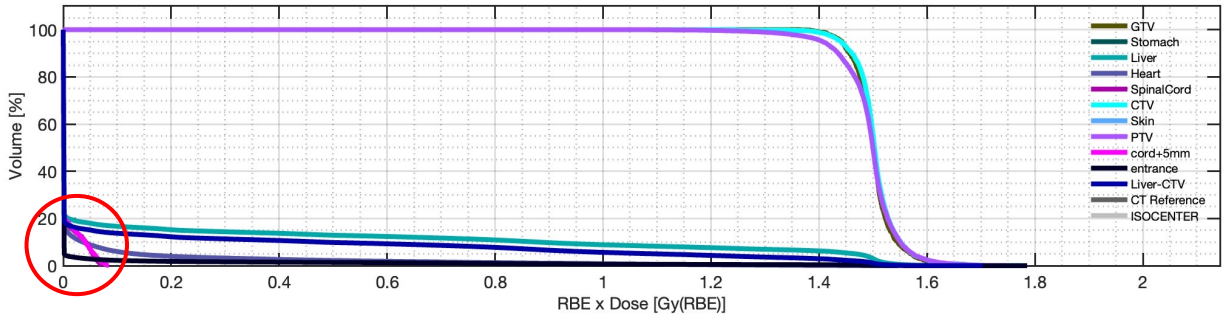
COMPARISON FOR PROTON AND CARBON IONS TREATMENT FOR LIVER CASE

Proton beam at 315°



	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.3Gy	V_0.6Gy
GTV	1.5052	0.0366	1.6905	1.4442	1.6291	1.5803	1.4979	1.4639	1.4580	1	1	1
Stomach	0	0	0	0	0	0	0	0	0	1	0	0
Liver	0.1748	0.4444	1.6941	0	1.5067	1.4763	0	0	0	1	0.1382	0.1243
Heart	0.0199	0.1182	1.4663	0	0.3591	0.0334	0	0	0	1	0.0226	0.0126
SpinalCord	0	0	0	0	0	0	0	0	0	1	0	0
CTV	1.5095	0.0382	1.6941	1.2626	1.6274	1.5884	1.5016	1.4674	1.4581	1	1	1
Skin	0.0184	0.1468	1.6941	0	0.0502	0	0	0	0	1	0.0159	0.0135
PTV	1.4914	0.0674	1.6941	0.8962	1.6164	1.5774	1.4996	1.3702	1.2922	1	1	1
cord+5mm	2.3330e-19	9.8035e-18	5.9013e-16	0	0	0	0	0	0	1	0	0
entrance	0.0184	0.1468	1.6941	0	0.0502	0	0	0	0	1	0.0159	0.0135
Liver-CTV	0.1276	0.3731	1.6685	0	1.4773	1.2943	0	0	0	1	0.1079	0.0934

Carbon-ion beam at 315°

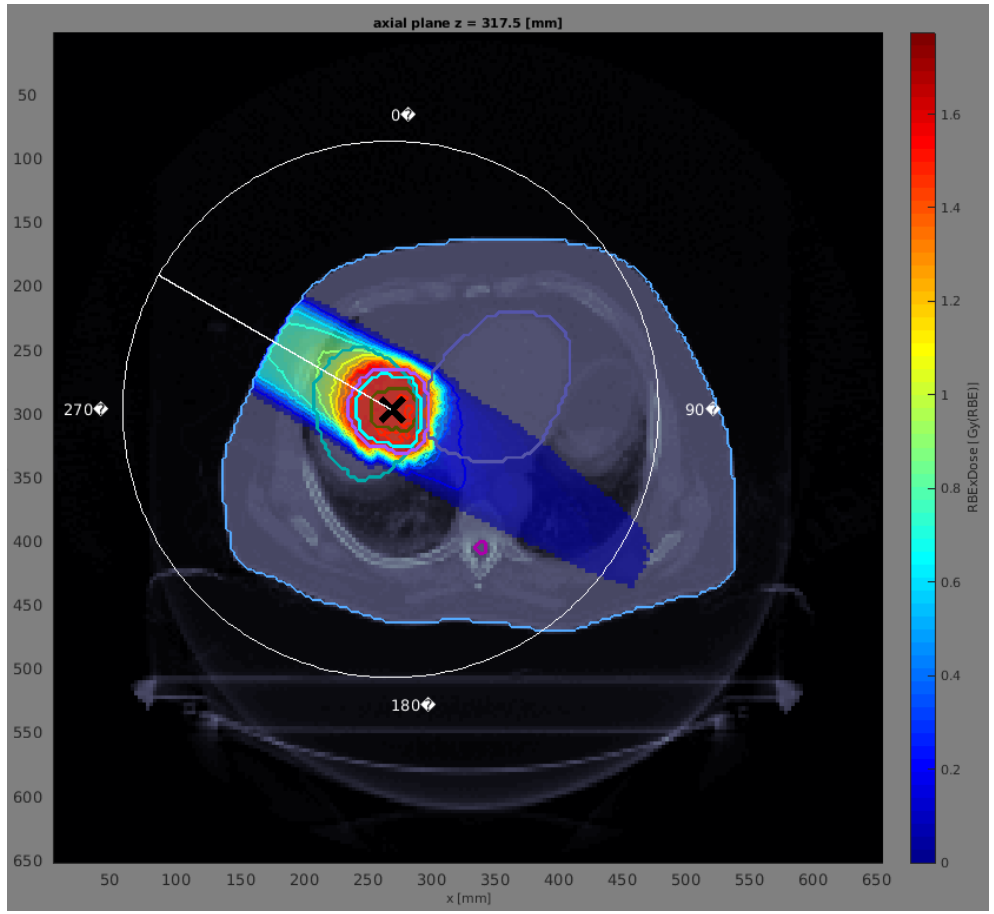


	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.3Gy	V_0.7
GTV	1.5016	0.0395	1.7073	1.3667	1.5976	1.5695	1.5004	1.4424	1.4184	1	1	
Stomach	0	0	0	0	0	0	0	0	0	1	0	
Liver	0.1684	0.4231	1.7864	0	1.5092	1.4675	0	0	0	1	0.1436	0.
Heart	0.0322	0.1467	1.5490	0	0.5593	0.1326	0	0	0	1	0.0324	0.
SpinalCord	0.0076	0.0178	0.0721	0	0.0635	0.0549	0	0	0	1	0	
CTV	1.5049	0.0421	1.7864	1.2166	1.6054	1.5735	1.5027	1.4405	1.4150	1	1	
Skin	0.0173	0.1313	1.7864	0	0.1463	6.4058e-04	0	0	0	1	0.0163	0.
PTV	1.4953	0.0559	1.7864	1.0893	1.6077	1.5738	1.4998	1.4063	1.3479	1	1	
cord+5mm	0.0080	0.0186	0.0862	0	0.0688	0.0568	0	0	0	1	0	
entrance	0.0173	0.1313	1.7864	0	0.1463	6.4058e-04	0	0	0	1	0.0163	0.

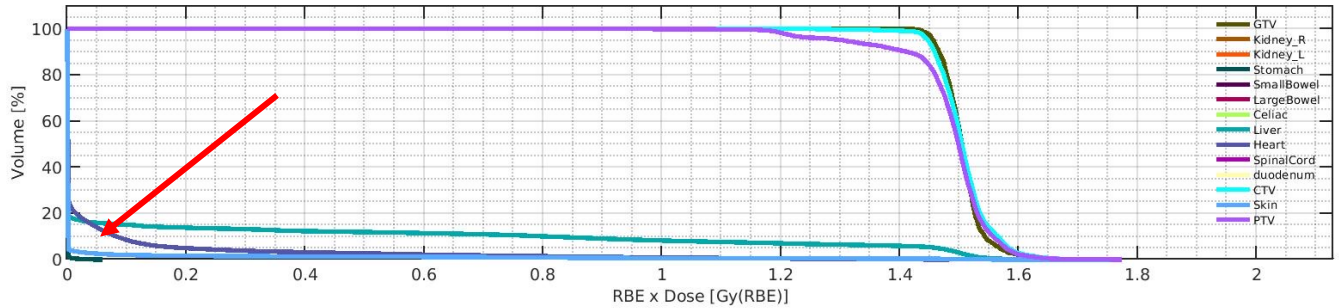
Due to the fragmentation, C-ions leads to a measurable dose to the spinal cord, completely absent in the proton plan

‘‘SOLUTION‘‘ FOR THE C-ION TAILING AFFECTING SPINAL CORD: 300° BEAM

Carbon-ion beam at 300°



Zero dose to spinal cord, but dose increment (nonetheless, absolute values very very low) affecting a bigger volume of the heart (another important OAR, radiosensitive).



	max	min	mean	std
GTV	1.7545	1.4139	1.5064	0.0344
Kidney_R	0	0	0	0
Kidney_L	0	0	0	0
Stomach	0.0597	0	1.6637e...	0.0020
SmallBowel	0	0	0	0
LargeBowel	0	0	0	0
Celiac	0	0	0	0
Liver	1.7545	0	0.1546	0.4107
Heart	1.4842	0	0.0418	0.1559
SpinalCord	0	0	0	0
duodenum	0	0	0	0
CTV	1.7752	1.2432	1.5075	0.0442
Skin	1.7752	0	0.0158	0.1260
PTV	1.7752	0.9625	1.4852	0.0805

Thank you for your attention