WP5: Adaptive Treatment Planning

ULICE Annual Meeting
Pavia, 15/16-Sep-2012

M. Krämer

M.Kraemer@gsi.de

GSI Darmstadt

co-funded by the European Commission under FP7 Grant Agreement Number 228436.

Collaboration

Table 1: Collaborators

Collaborator	MM	Contact	E-mail
GSI	36	Michael Krämer	m.kraemer@gsi.de
		Emanuele Scifoni	E.Scifoni@gsi.de
UKL-HD	28	Oliver Jäkel	o.jaekel@dkfz-heidelberg.de
		Stefanie Combs	Stephanie.Combs@med.uni-heidelberg.de
MUW	27	Johannes Hopfgartner	johannes.hopfgartner@akhwien.at
		Dietmar Georg	Dietmar.Georg@akhwien.at
UNIMAR	10	Urszula Jelen	jelenu@med.uni-marburg.de
		Uli Weber	u.weber@rhoen-klinikum-ag.com
UOXF	10	Bleddyn Jones	b.jones.1@bham.ac.uk
ETOILE	7	Jacques Balosso	jacques.balosso@centre-etoile.org
		Jean-Michel Moreau	Jean-Michel.Moreau@liris.univ-lyon1.fr
CNAO	7	Piero Fossati	fossati@cnao.it
		Silvia Molinelli	molinelli@cnao.it
ARC	4	Jean Louis Lefaix	lefaix@ganil.fr
		Jean Bourhis	jean.bourhis@igr.fr

Deliverables/Milestones

Table 2: Reports

Deliverable	Due	Contributors
D5.3,D5.4,D5.6/WP5.1,2	Aug 2011/Feb 2012	GSI,UKL-HD,ARC
D5.5/WP5.2	Aug 2011/Feb 2012	UKL-HD,CNAO,Etoile,MUW,GSI
D5.7/WP5.2	Aug 2011/Feb 2012	UKL-HD,GSI
D5.8/WP5.3	Aug 2011/Feb 2012	UOXF,GSI,ARC
D5.9/WP5.4	Aug 2012	UNIMAR,MUW
D5.10/WP5.3	Sep 2012	UOXF,GSI

D5.3/WP5.1,5.2: spatially variable radio-sensitivity (hypoxia)

- TPS tool: TRiP98
- parametrize OER($p_{O_2} \neq 0$,LET), use on top of RBE/Survival
- optimize dose distribution as usual $\rightsquigarrow$ highly non-linear
- $\rightsquigarrow$ requires imaging input from WP3: p_{O_2} distribution

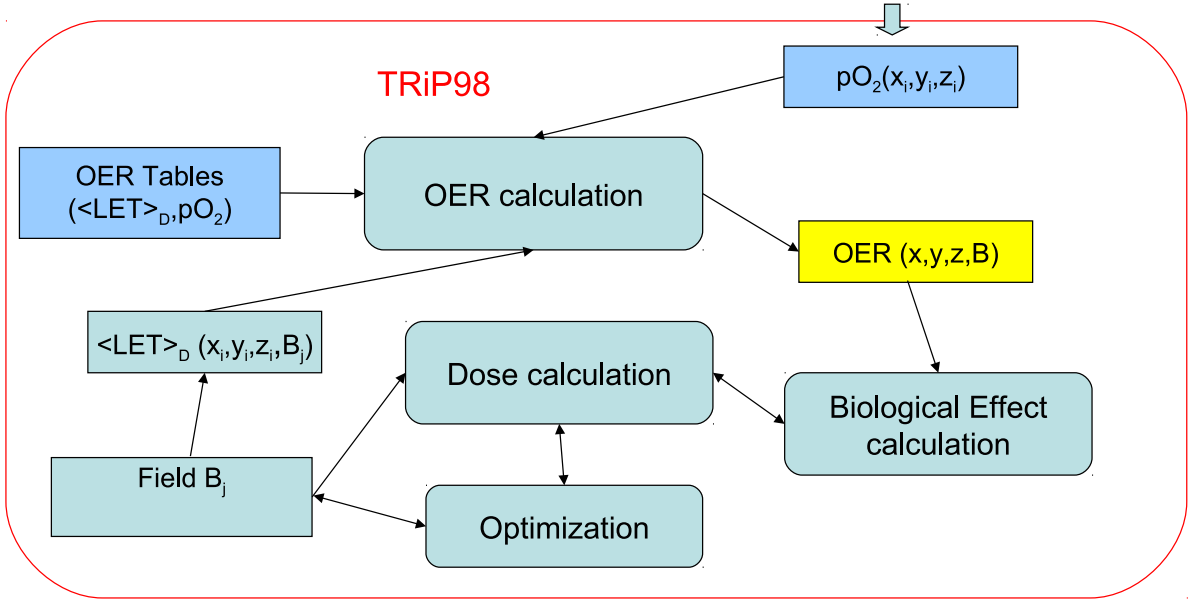

Figure 1: TRiP98-OER implementation scheme

D5.3/WP5.1,5.2

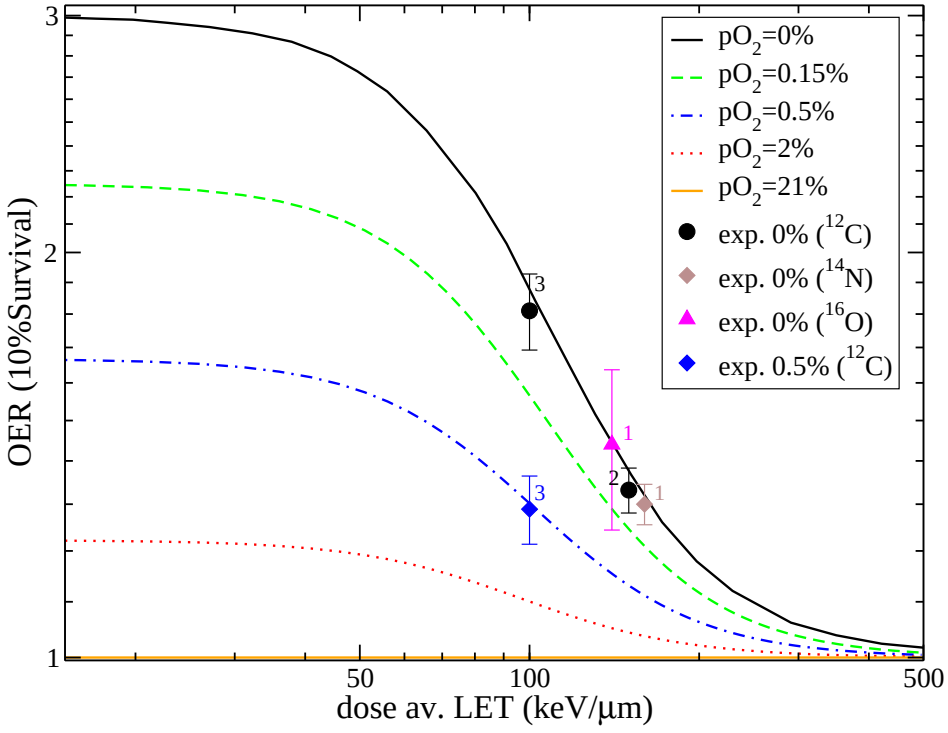

Figure 2: OER dependence on LET and oxygen concentration (Data: Tinganelli et al.). Most important, but few data: $p_{O_2} \neq 0$

D5.6/WP5.2: Table of pre-conditions eligible for multi-ion treatment

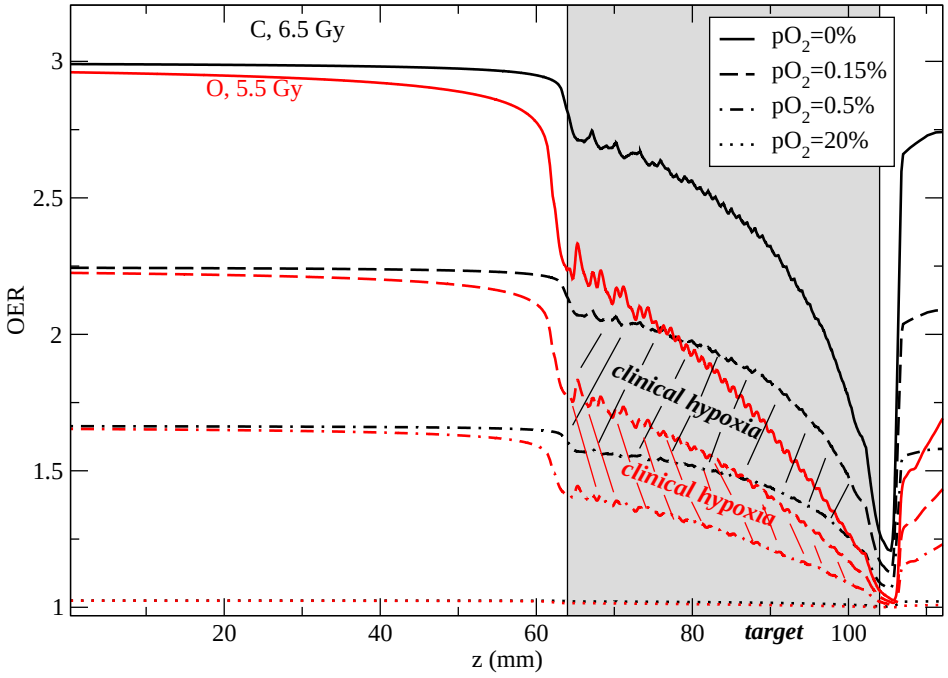

Figure 3: comparison of the computed OER along a SOBP, for Carbon (black curves) and Oxygen (red curves) at different pO2 levels. The hatched areas represent the clinical interesting regions for hypoxia ($0.15\% < p_{O2} < 0.5\%$)

D5.3,5.4: OER compensation

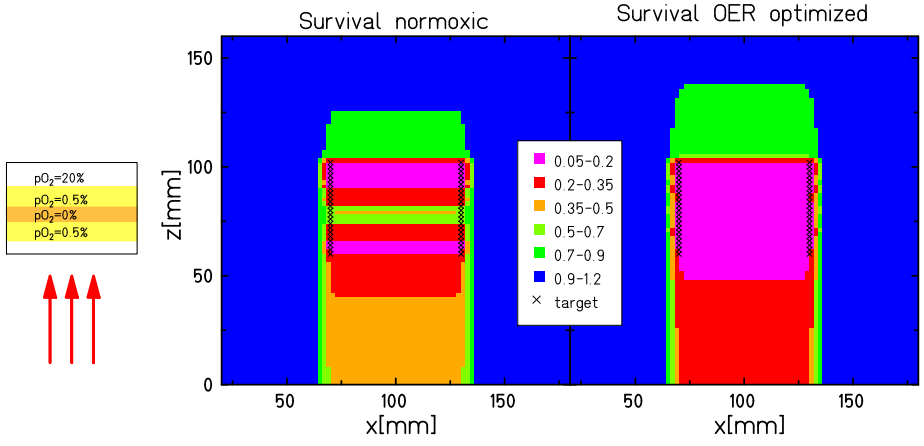

Figure 4: TRiP98 bidimensional computed survival profiles, without (left) and with (right) taking into account the non uniform oxygen concentration of the target tissue into the optimization (E.Scifoni).

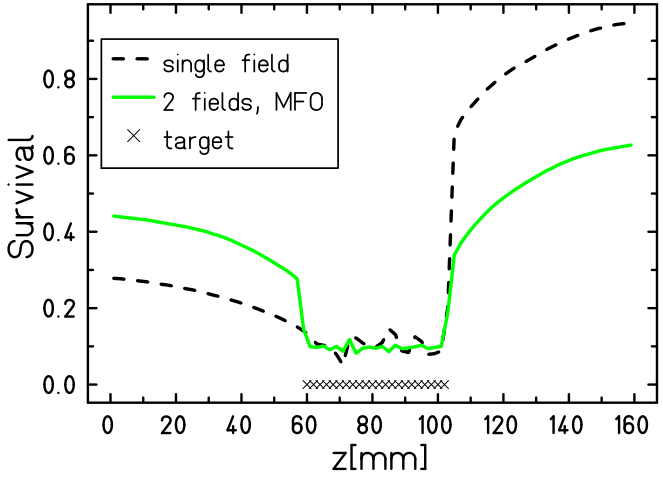

Figure 5: Multiple field optimization as compared to single field

M27/M28: Biological verification of the TPS

OER verification (E.Scifoni, W.Tinganelli, W.K.Weyrather, A.Maier)

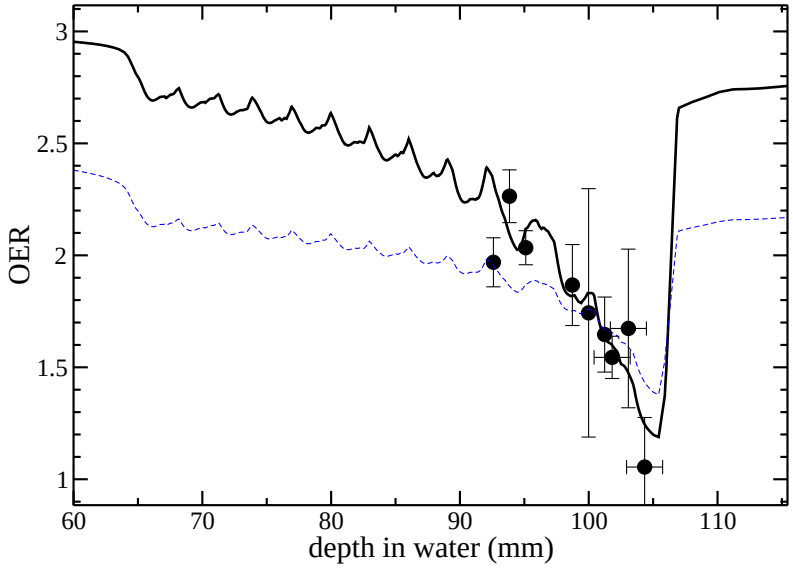

Figure 6: TRiP computed (lines) and measured (points) OER along the extended target irradiation. Black (solid) OER tables from present model, Blue (dashed) from alternative model by Wenzl et al.

D5.4/D3.5: temporal variation

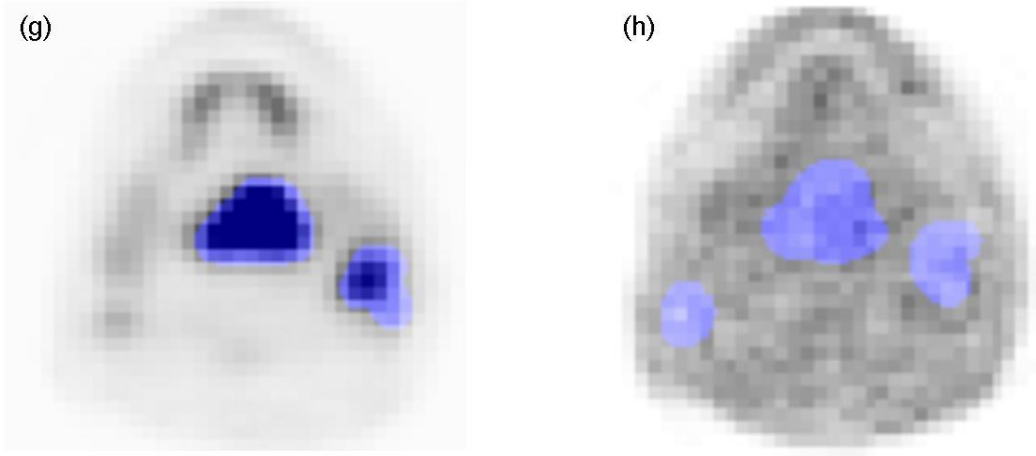

Figure 7: FMISO signal superimposed to the GTV structures, contoured from the FDG signal at the planning moment (g) and after a week (h). See Deliverable report D.JRA 3.5 for details.

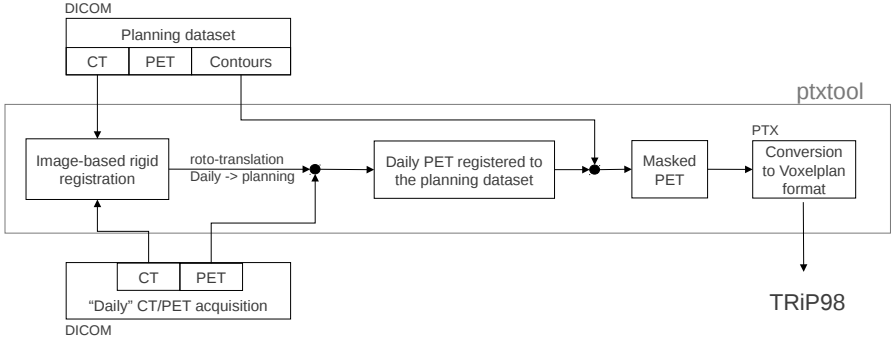

Figure 8: Detail of the conversion tool PTX-TOOL in adjusting the daily acquisitions to the planning CT, before passing the uptake data to TRiP98 (G.Fattori).

D5.5/WP5.2: TPS version for a common photon-ion treatment plan

- import photon plans, optimize ions on top (boost)
- but: RBE-weighted dose $\rightsquigarrow$ consider fractionation
- $\rightsquigarrow$ use fraction "Effect" ("Damage"), not Dose$\times$RBE

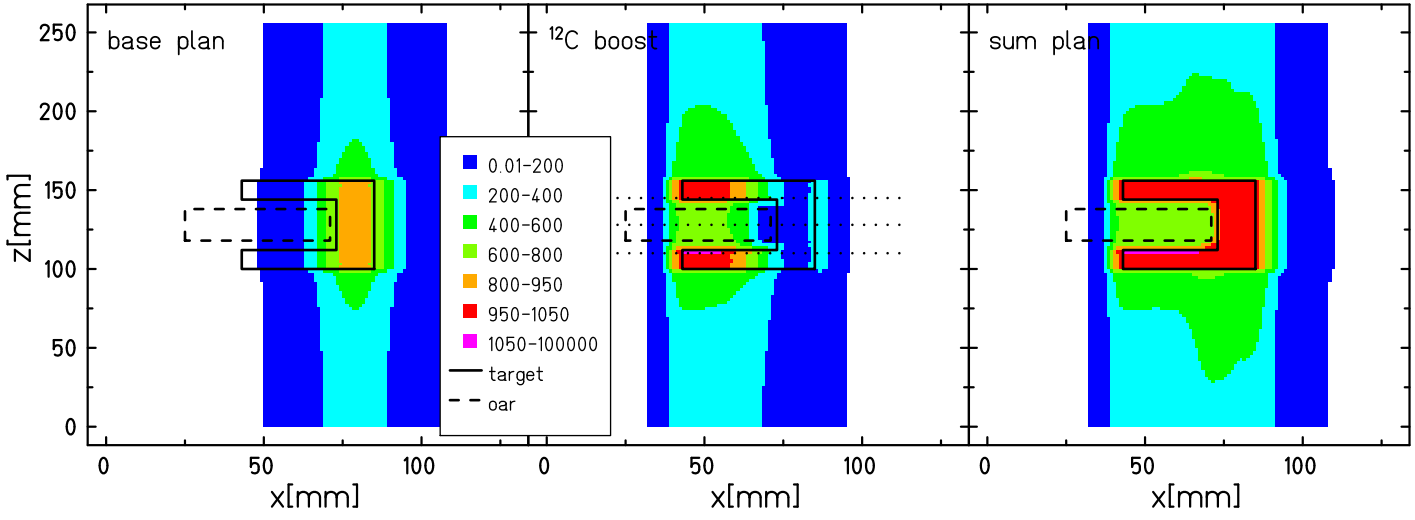

Figure 9: Dose distributions for a carbon ion plan optimized on top of a preirradiated plan with 15mm penumbra. Left: Dose distribution from preirradiation, middle: contribution from carbon ions optimized on top, right: resulting sum dose distribution.

D5.7/WP5.2: TPS version for multi-ion treatment plans

- enhance TRiP89 TPS to handle more than one ion beam modality at once (e.g. ^{12}C+^{16}O, protons+^{12}C)
- $\rightsquigarrow$ proof of principle,

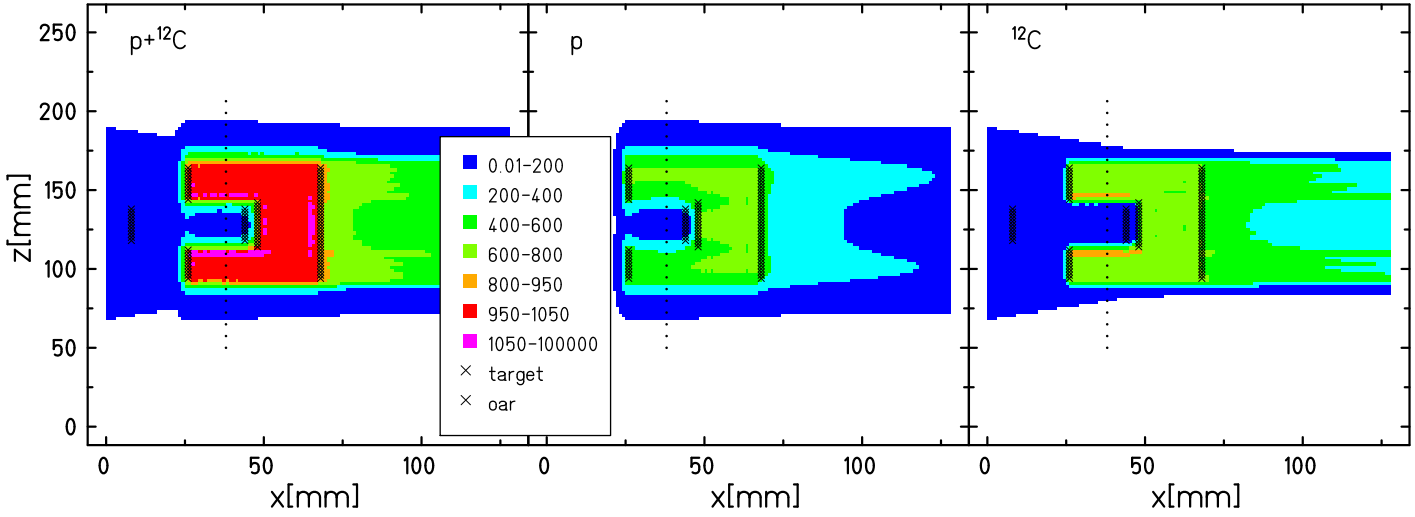

Figure 10: RBE-weighted dose distributions for a multi-ion treatment plan for the combination protons+^{12}C. Left: combined plan, middle: protons, right: carbon ions.

D5.8/WP5.3: Table of alpha/beta values ... (B.Jones)

- Part A: The choice of α/β ratio for particle therapies
  - $\rightsquigarrow$ BED equations
  - $\rightsquigarrow$ ratio tables including ranges
- Part B: Compensation for Unintended Treatment Interruptions
  - $\rightsquigarrow$ calculation examples for BED and fractionation
  - $\rightsquigarrow$ but: experienced person preferred

D5.9/WP5.4 (MUW,UNIMAR)

Protocols to decide in case of inter-fraction motion: replanning or follow inter-fraction organ motion control?

(J.Hopfgartner, Joanna Gora, Urszula Jelen, Filippo Ammazzalorso, Dietmar Georg)

- Three pillars:
  Patient fixation, Margin Application, Image Guidance
- margin/PTV concepts:
  - PTV_{10mm}: uniform expansion, photon experience
  - PTV_{red}: 5mm LR, 8mm IS (Vargas)
  - PTV_{hull}: envelope from CTV_{CT} in first week, 3mm LR,IS, 5mm AP

D5.9/WP5.4: Margins/pelvic treatments (1/3)

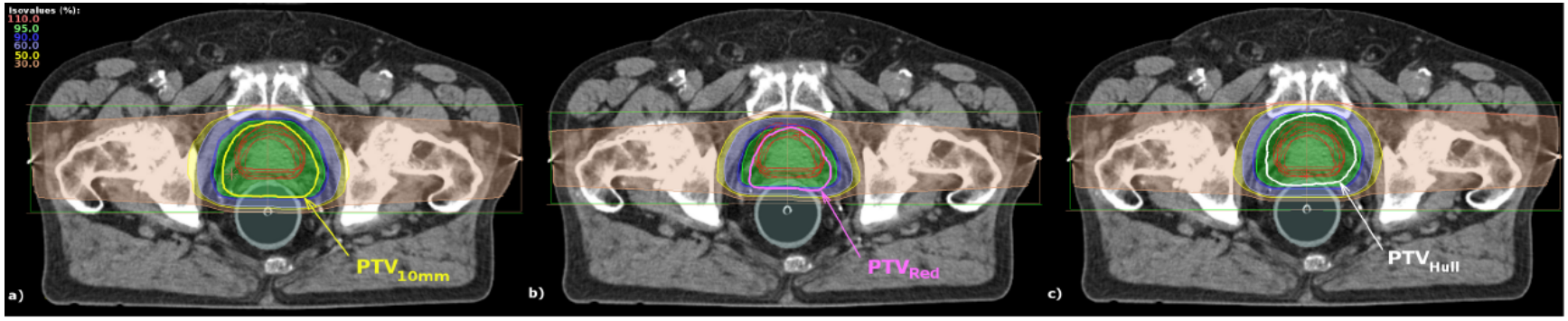

Figure 11: Representative slice of planned proton dose distributions including defined margin strategies. PTV$_{10mm}$ is highlighted in the left part of the figure while PTV$_{Red}$ and PTV$_{Hull}$ are presented in the middle and right part, respectively.

D5.9/WP5.4: Margins/pelvic treatments (2/3)

Example: carbon ions

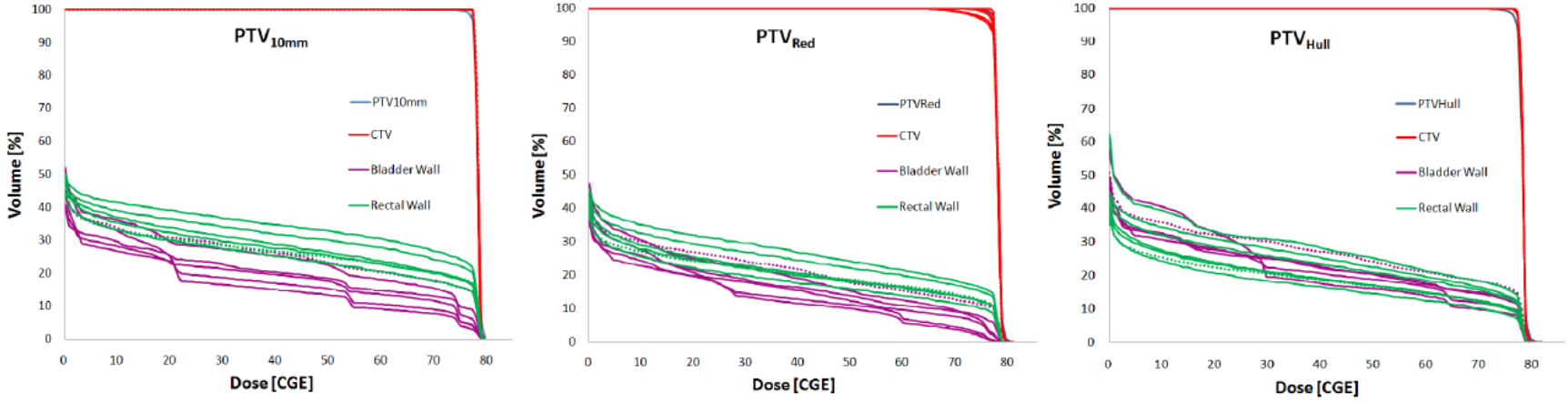

Figure 12: DVHs for one prostate cancer patient showing large inter-fraction motion, planned with the margin strategies explained above

D5.9/WP5.4: Margins/pelvic treatments (3/3)

Conclusion/recommendation for margin concepts (protons, ^{12}C)

- Target coverage:
  only slight differences, PTV$_{Hull}$ approach seemed to be more robust against organ motion.
- OAR sparing (bladder, rectum):
  PTV$_{Red}$ and PTV$_{Hull}$ plans superior over PTV$_{10mm}$ plans.
- extensive analysis: see full report

D5.9/WP5.4: Target based re-alignment (1/2)

Carbon ions (U.Jelen,F.Ammazzalorso)

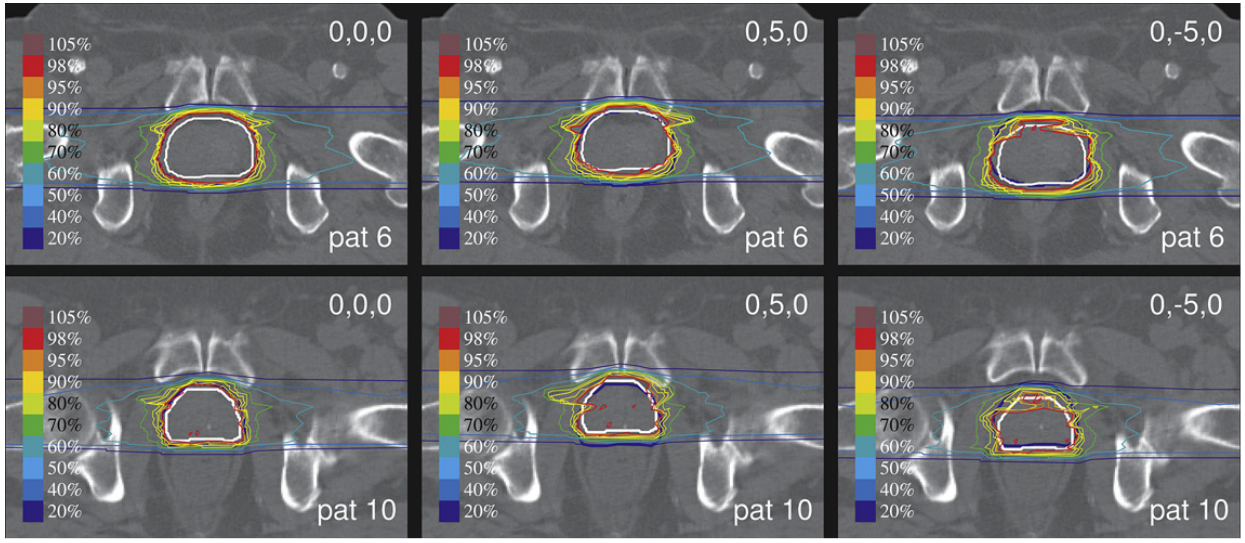

Figure 13: Transversal view of the dose distributions planned with a CTV to PTV margin of 3 mm for 2 patients: The original plan (left), plan with internal target shift of 5 mm and with target-based isocenter realignment in anterior (middle), and posterior (right) direction.

D5.9/WP5.4: Target based re-alignment (2/2)

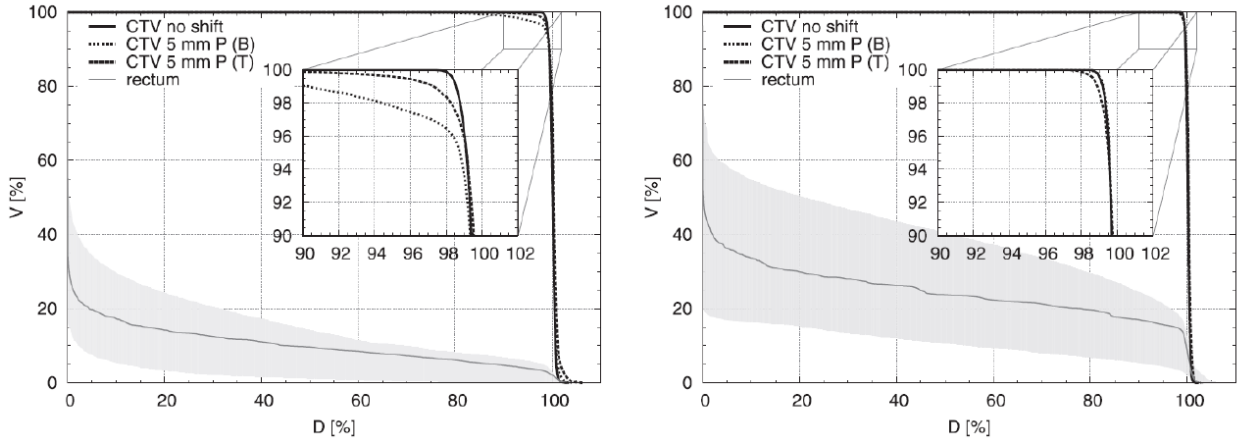

Figure 14: DVHs of the CTV for patient 6 for plans optimized with planning margins of 3 mm (left) and 10 mm (right): for the original plan and for plan recomputed with 5 mm posterior shift simulating bony anatomy based realignment (B) and target based realignment (T). Additionally, to illustrate the benefit of margin reduction, the variability of the DVH for rectum for all the patients is shown in grey.

D5.9/WP5.4: Head and Neck, weight loss

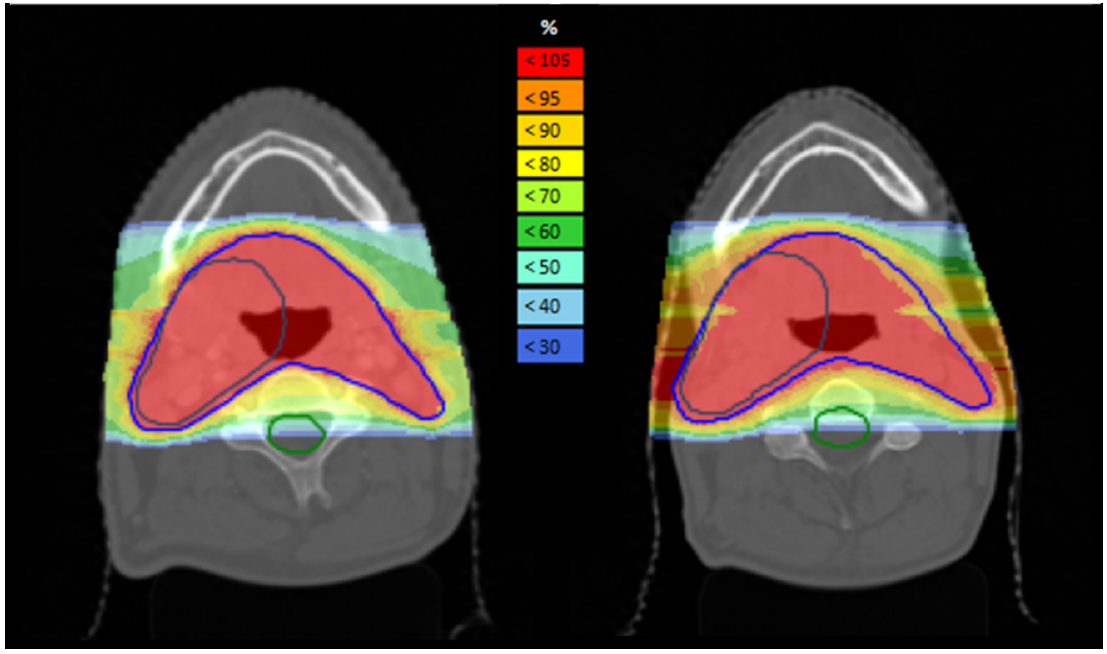

Figure 15: Representative slice of a Carbon ion dose distribution for a Head and Neck cancer patient. Left hand side represents the nominal treatment plan while right hand side shows the nominal treatment plan recalculated on the basis of a CT acquired during the course of fractionated RT exhibiting weight loss of the patient.

D5.9/WP5.4: Head and Neck, tumour shrinkage

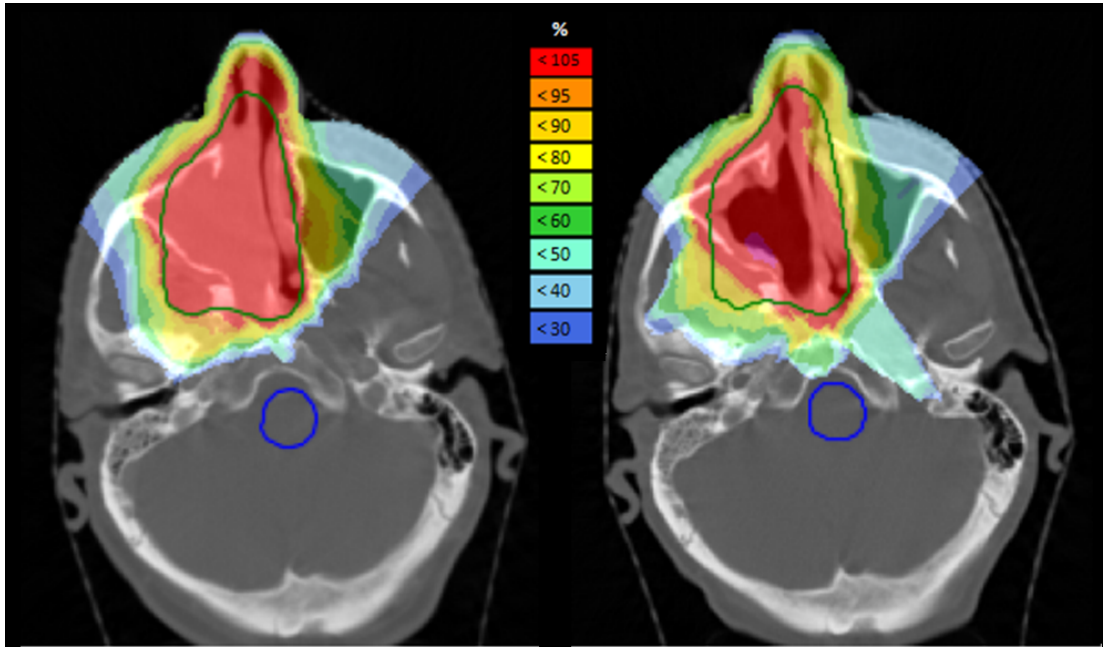

Figure 16: Representative slice of a Carbon ion dose distribution for a Head and Neck cancer patient. Left hand side represents the nominal treatment plan while right hand side shows the nominal treatment plan recalculated on the basis of a CT acquired during the course of fractionated RT exhibiting tumor mass reduction of the patient.

Summary & Outlook

- Publications:

  U. Jelen et al., Robustness against interfraction prostate movement in scanned ion beam radiotherapy, Int J Radiat Oncol Biol Phys 2012

  E. Scifoni et al., Oxygen enhancement ratio in ion beam treatment planning, in preparation

- TRiP98 TPS upgrade:

  WP5 enhancements (OER,multimodality)

  $\rightsquigarrow$ streamlining $\rightsquigarrow$ regular TRiP98 version

Credits:

The ULICE project is co-funded by the European Commission under FP7 Grant Agreement Number 228436.