Important notice!

The work presented here had excellent results on simple sites with few objectives.

Unfortunately, when generalizing to complex cases with more objectives, the method of fast re-planning using Lagrangian multipliers behaved unpredictably. Not too bad, but also not good enough for clinical application.

As such, this presentation is useful to learn about what does not work.

Sorry!

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A fast and accurate automated method for online re-planning in adaptive radiotherapy

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Thanks to Theodore Mutanga, Peter Voet and Suzanne Leinders

ICCR 2010 Amsterdam

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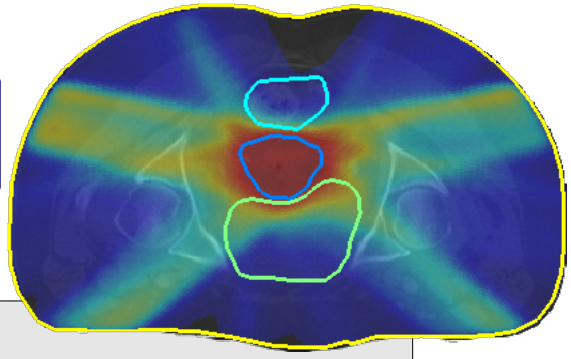
Workflow



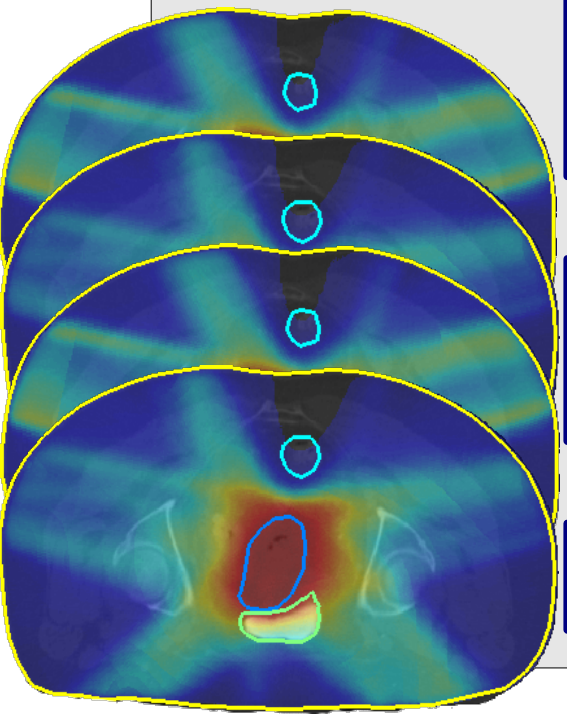
plan on planning CT

make daily
in-room CT scan

use Fast optimization
on daily CT

check and apply plan

each
fraction



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Fast optimization

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Reduce human interaction

Automate treatment planning

Multi-criteria optimization

- Use a wish-list, a prescription list with constraints and goals.
- Automates decision making.
- Gives a single Pareto-optimal plan.
- 2 phase [illegible] strategy.
- Wish-list used as a template.
- Plans are clinically relevant.

Full optimization

- The equivalence of multi-criteria methods for radiotherapy plan optimization, Breedveld *et al* 2009, *Phys. Med. Biol.* 54
- A novel approach to multi-criteria inverse planning for IMRT, Breedveld *et al* 2007, *Phys. Med. Biol.* 52

Wish-list: cervix-uterus boost

Constraints

Nr	Volume	Type	Limit
1	Cervix-uterus (CTV)	maximum	80 Gy
2	CTV Conformity Ring	maximum	62.9 Gy
3	Bladder - CTV+10mm	maximum	70 Gy
4	External - 50mm Ring	maximum	50 Gy

Objectives

Priority	Volume	Type
1	Cervix-uterus (CTV) (74 Gy)	minimize LTCP
2	Rectum	minimize mean
3	Bladder	minimize mean
4	Unspecified Tissue	minimize mean

- The equivalence of multi-criteria methods for radiotherapy plan optimization, Breedveld *et al* 2009, *Phys. Med. Biol.* 54
- A novel approach to multi-criteria inverse planning for IMRT, Breedveld *et al* 2007, *Phys. Med. Biol.* 52

Wish-list: cervix-uterus boost

Constraints

Nr	Volume	Type	Limit
1	Cervix-uterus (CTV)	maximum	80 *Gy*
2	CTV Conformity Ring	maximum	62.9 *Gy*
3	Bladder - CTV+10mm	maximum	70 *Gy*
4	External - Sigmoid Rectum	maximum	50 *Gy*

Objectives

Priority	Volume	Type
1	Cervix-uterus (CTV) (74 *Gy*)	minimize LTCP
2	Rectum	minimize mean
3	Bladder	minimize mean
4	Rest-of-Artificial Tissue	minimize mean

List for complicated sites much longer many optimizations

- The equivalence of multi-criteria methods for radiotherapy plan optimization, Breedveld *et al* 2009, *Phys. Med. Biol.* 54
- A novel approach to multi-criteria inverse planning for IMRT, Breedveld *et al* 2007, *Phys. Med. Biol.* 52

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How to avoid iterative optimizations while maintaining benefits of this method?

Novel Fast online method

- use Lagrange multipliers from Full automated multi-criteria optimization
- use weighted-sum method to optimise all objectives at once

$$\boxed{w_1} f_1(x) + \boxed{w_2} f_2(x) + \ldots + \boxed{w_n} f_n(x)$$

known from planning CT plan!

Constraints

Nr	Volume	Type	Limit
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Properties

- Fast method uses only 1 optimization where the Full method uses many.
- On the same CT, both methods give identical result.
- Fast method is robust to small changes.
- On a different CT, the Fast method returns a similar plan compared to the Full method.

Properties

PERFECT FOR ONLINE

ADAPTIVE PLANNING

- On a different CT, the Fast method returns a similar plan compared to the Full method.

Optimization

- Optimizations done in YARTOS (Yet Another Radiation Therapy Optimization Suite), in-house developed.
- Based on interior-point method.
- Multi-threaded (modern 8-core server).
- Single, multi-criteria, beam angle optimization, non-rigid transformation, etc.
- No leaf-sequencing → dose attainable by clinical TPS.

Results

3 strategies:

- Best plan of the day
- Additional planning
- Today's PTV

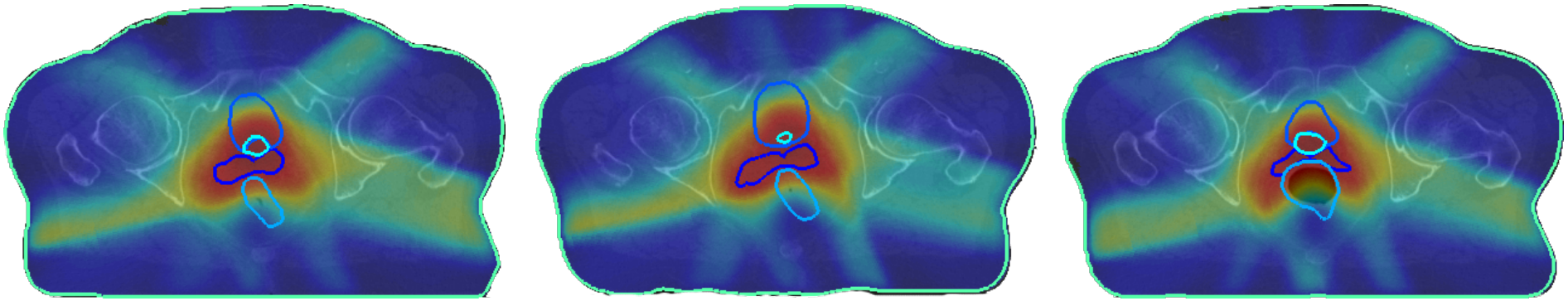
3 sites:

- Cervix-uterus boost (2)
- Prostate (10)
- Liver (2)

Full method is used as golden reference!

Strategy 1: Best plan approach

- *Best-plan-of-the-day*: make a best plan regardless of previous fractions



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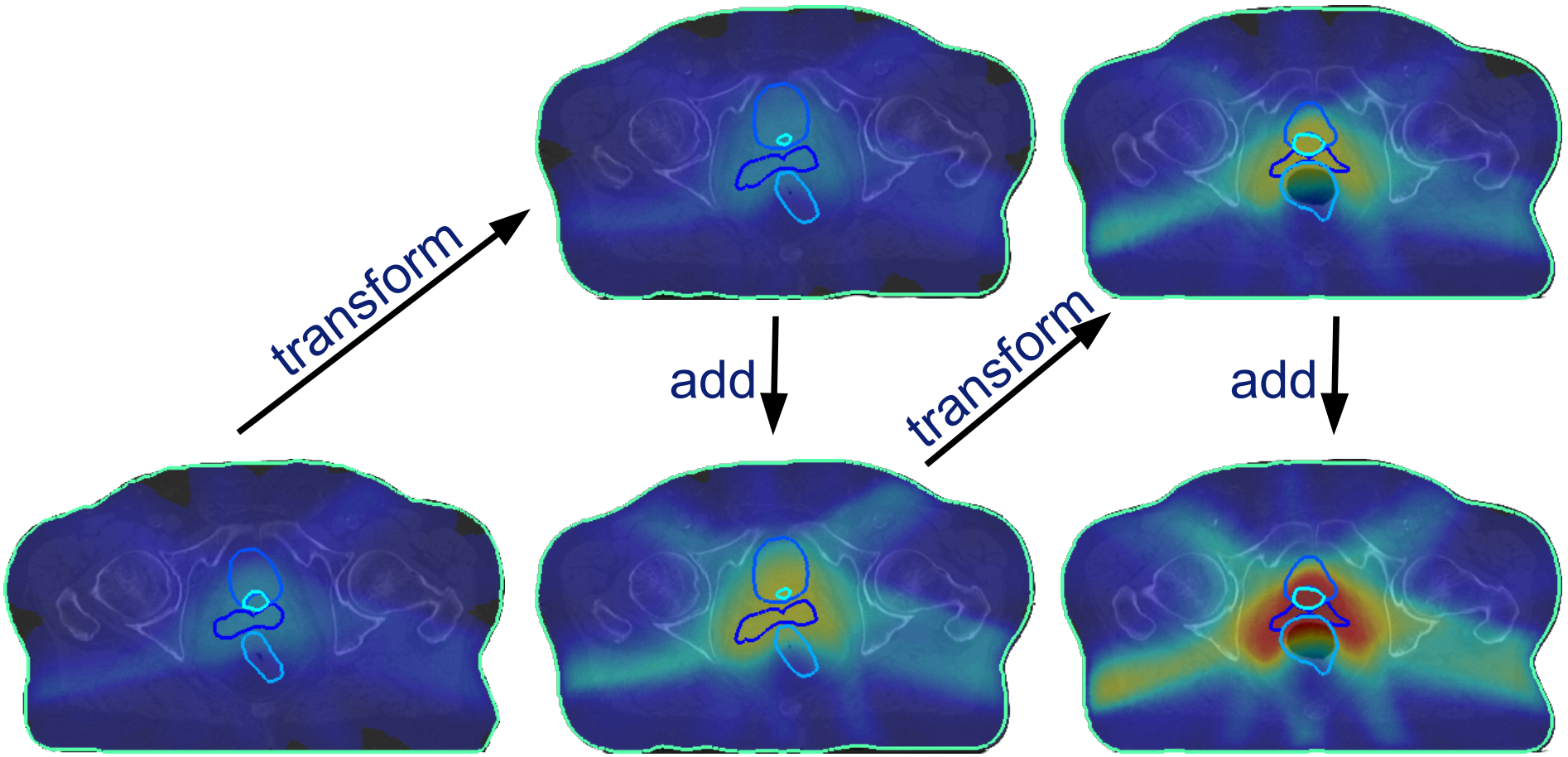
Strategy 2: Additional plan approach

- *Additional plan*: take dose of previous fractions into account



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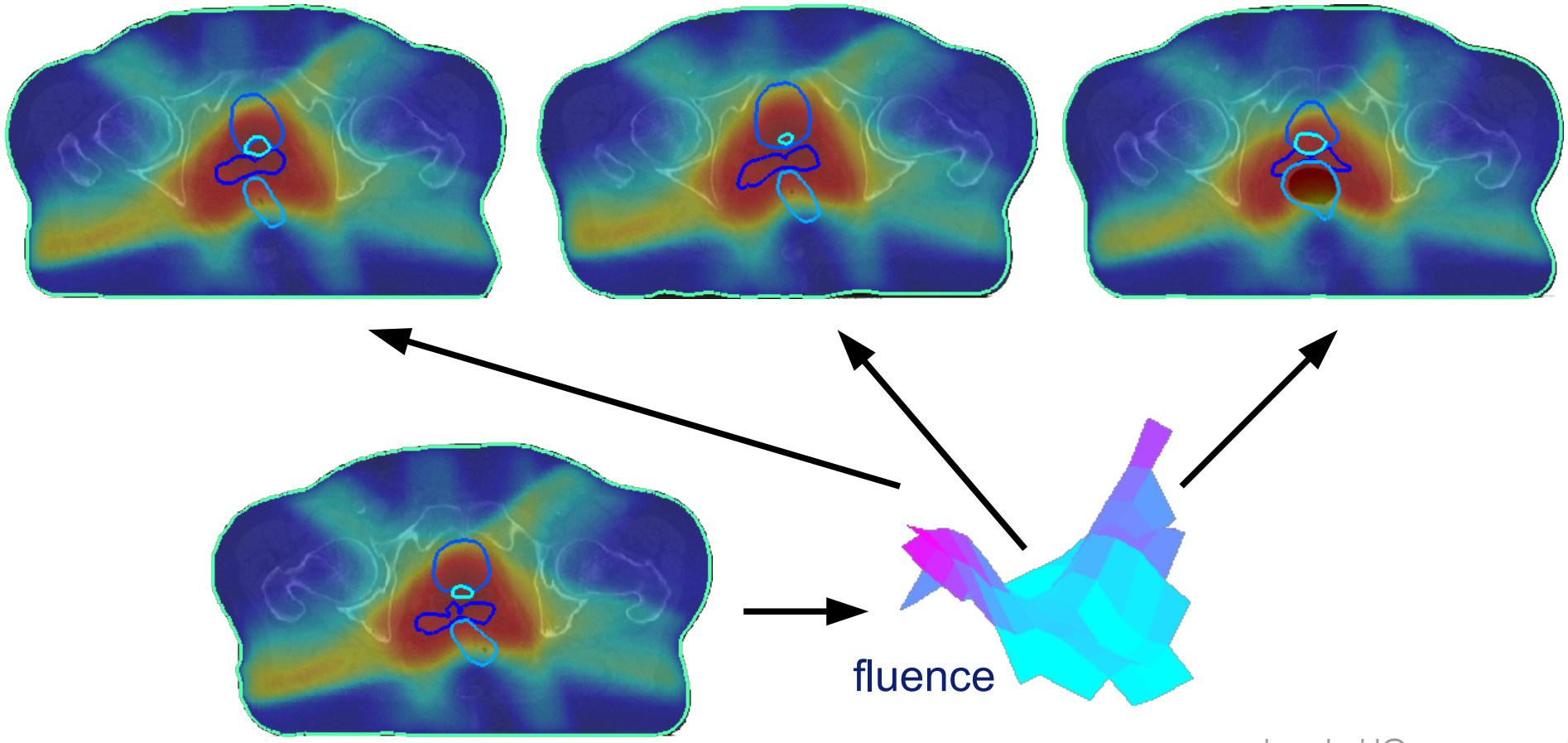
Strategy 3: Today's PTV

- *PTV*: make a single PTV plan and apply every fraction (marker based translations)



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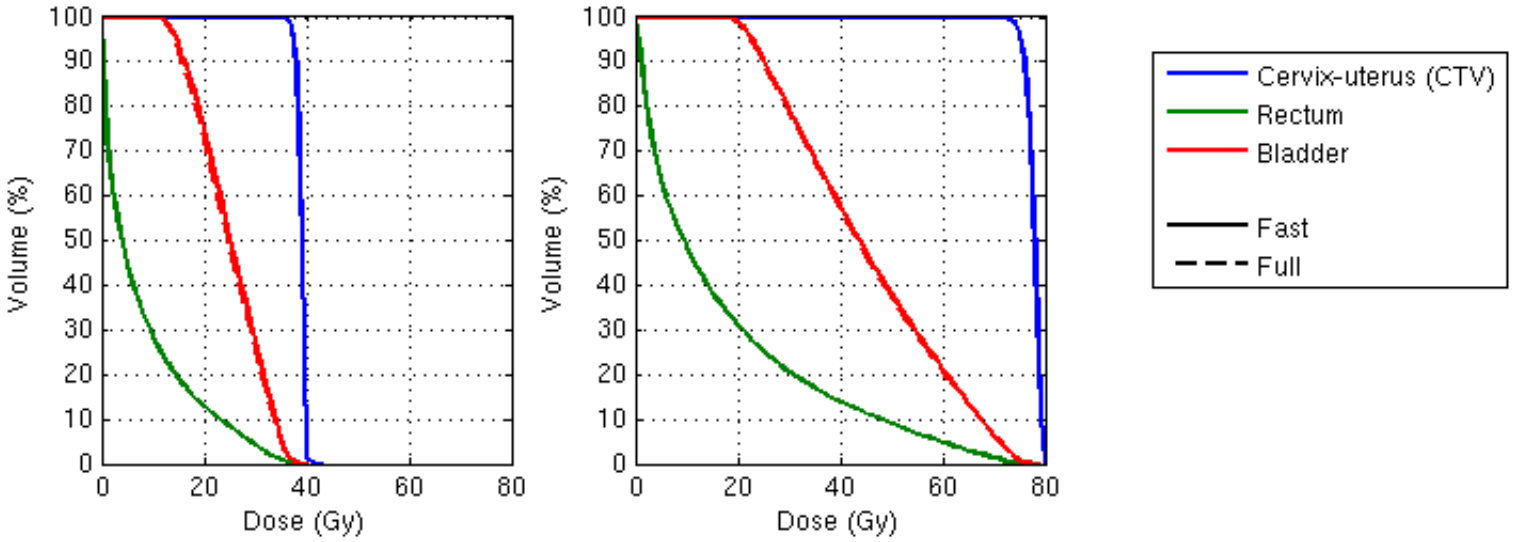
Cervix-uterus: Best plan of the day
Fast vs. Full

Planning done on full bladder (234 cc)

Empty bladder (31 cc)

Intermediary bladder (78 cc)



Full: 53 seconds

Fast: 11 seconds

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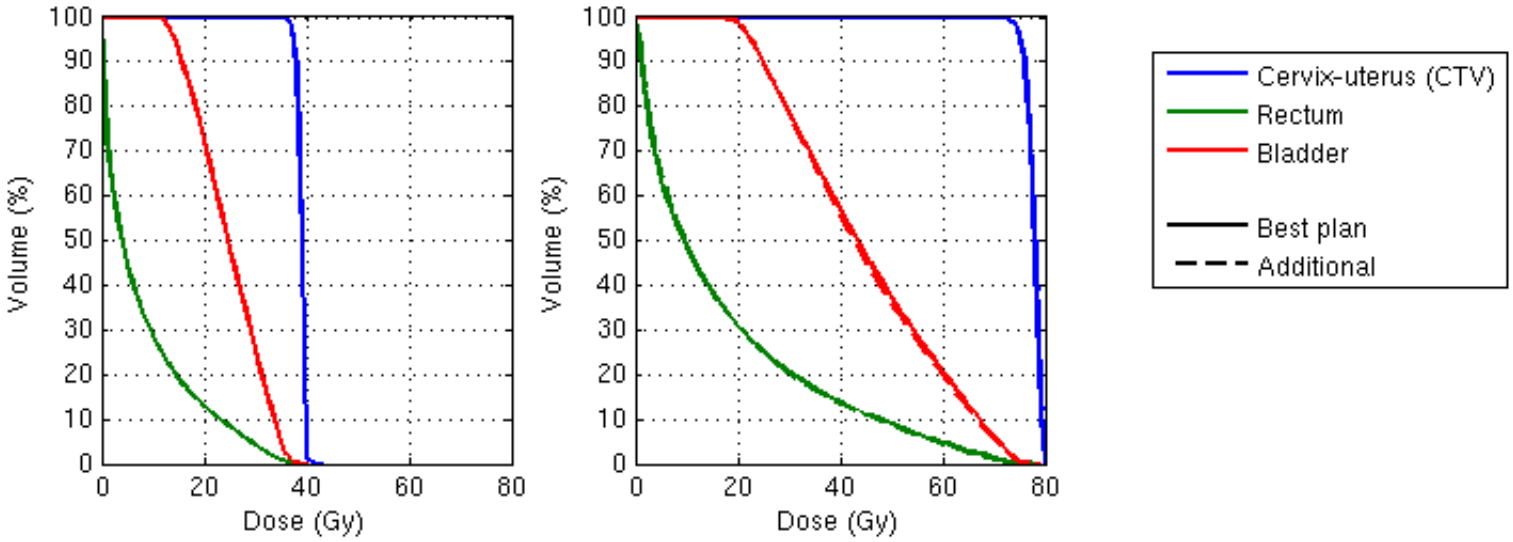
Cervix-uterus: Additional planning vs. Best plan

Planning done on full bladder (234 cc)



Empty bladder (31 cc)

Intermediary bladder (78 cc)

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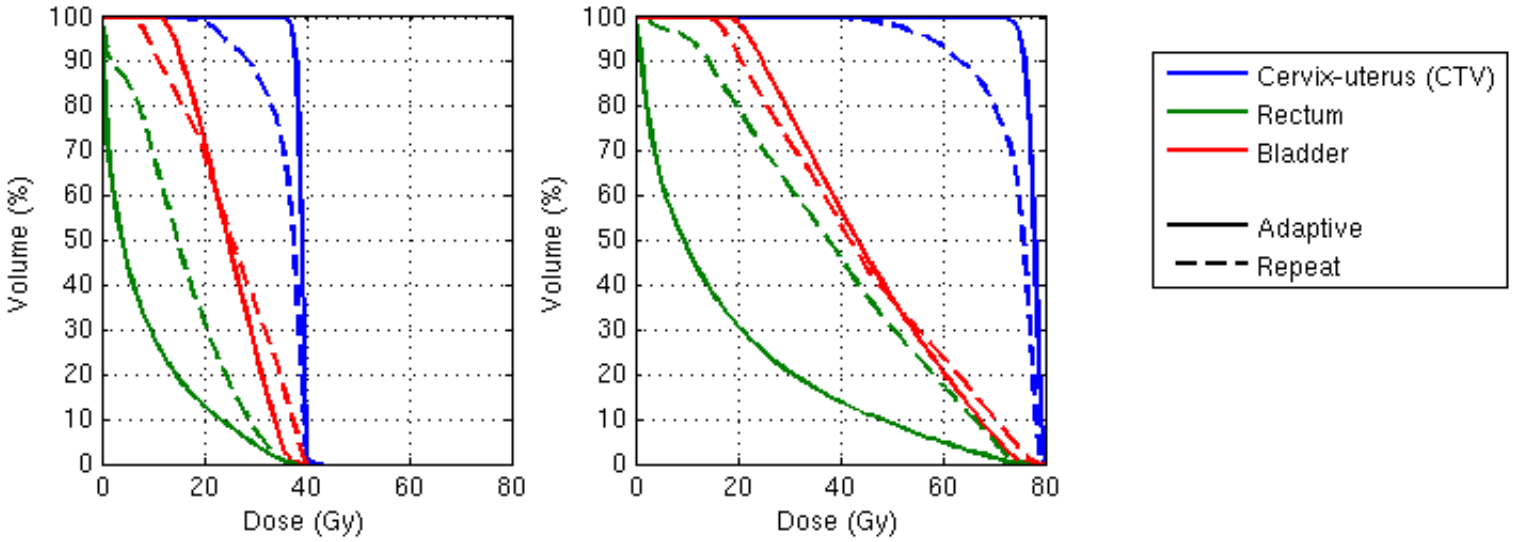
Cervix-uterus: Today vs. Adaptive

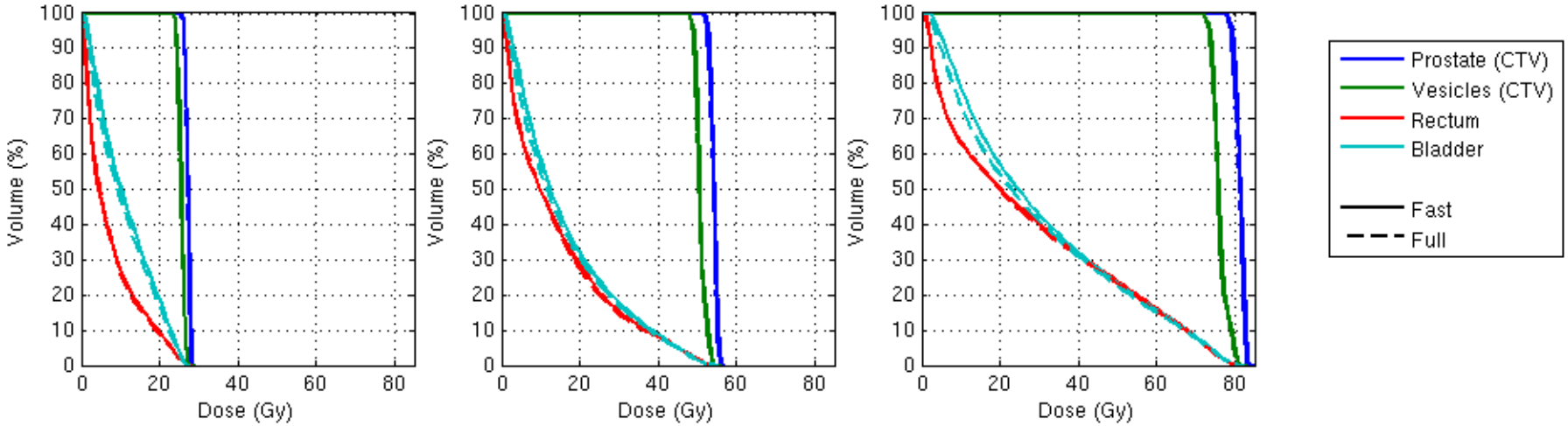
Planning done on full bladder (234 cc), and on PTV



Empty bladder (31 cc)

Intermediary bladder (78 cc)

Prostate: Best plan of the day
Fast vs. Full



Full: 72 seconds
Fast: 13 seconds

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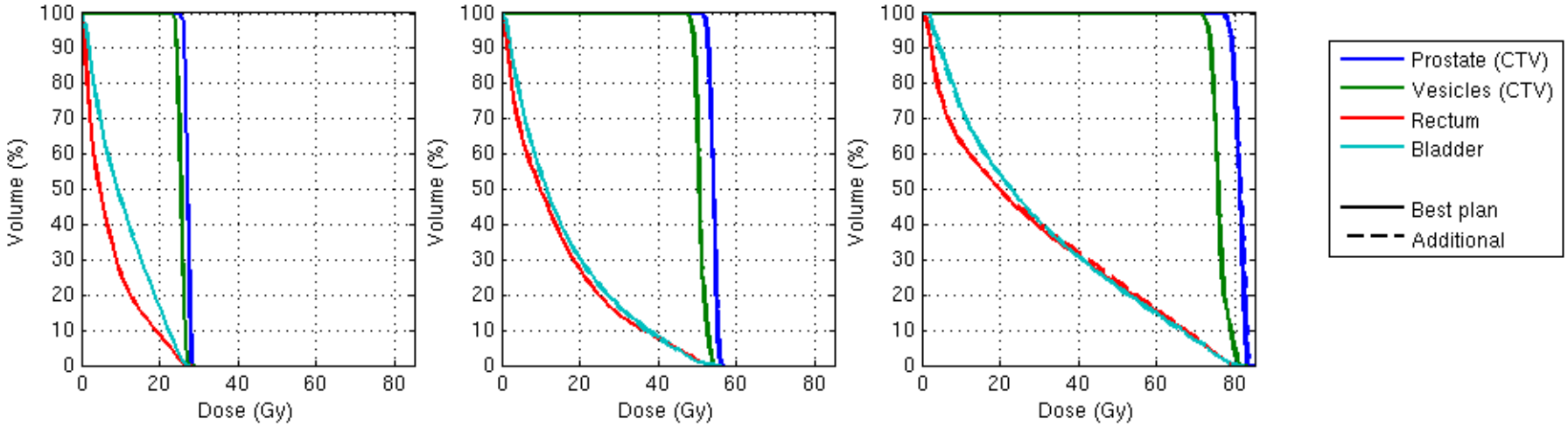
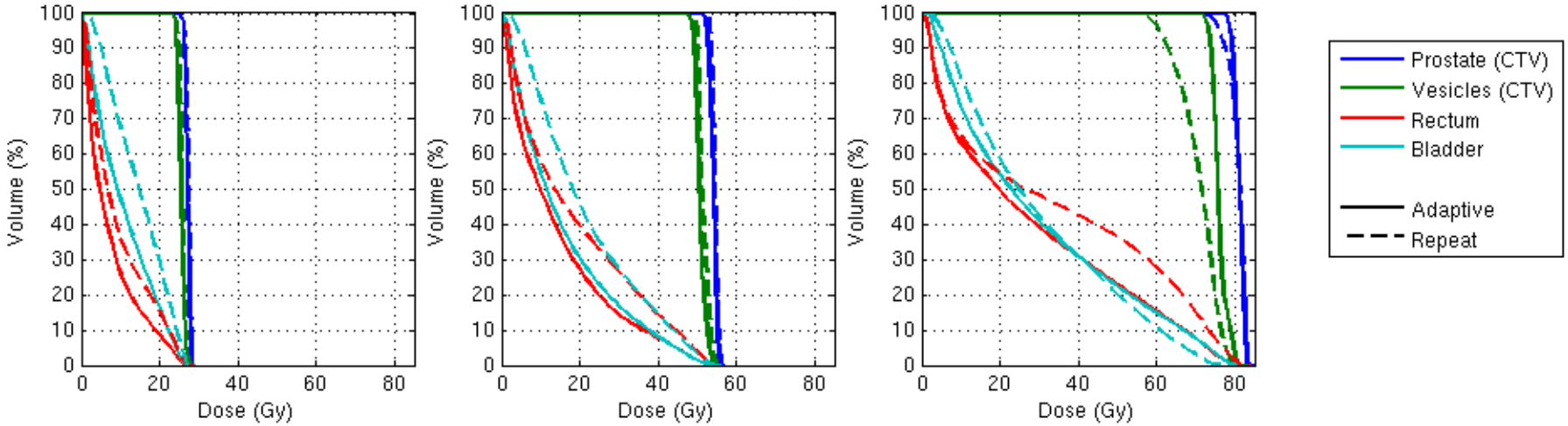
Prostate: Additional planning vs. Best plan



Prostate: Today vs. Adaptive



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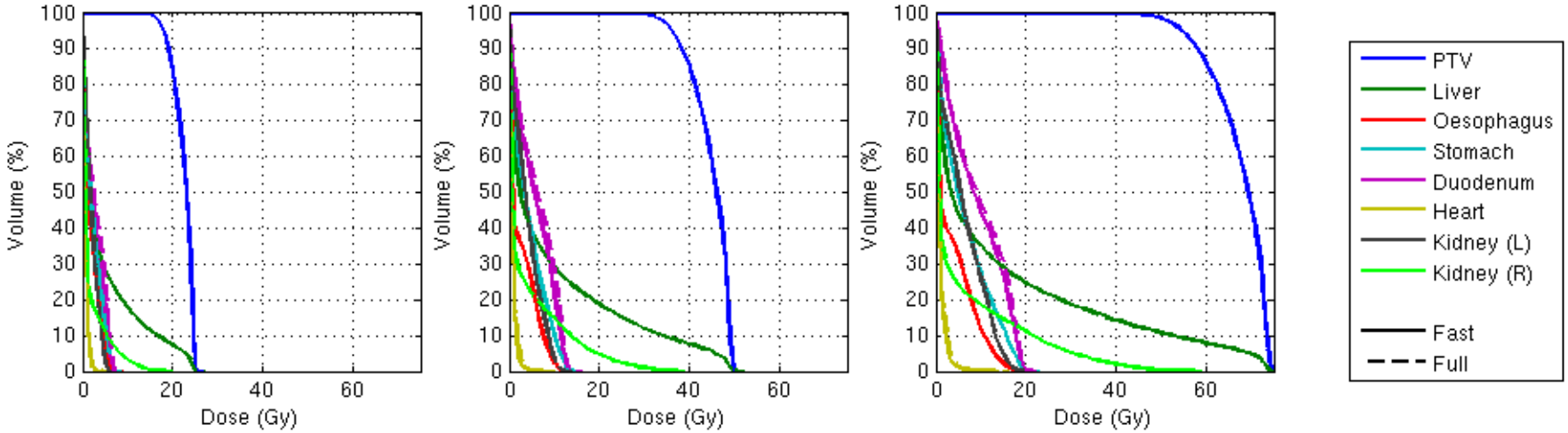
Liver: Best plan of the day
Fast vs. Full



Full: 363 seconds
Fast: 51 seconds

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Conclusions

The Fast method is a valid online alternative to a Full automated optimization.

For cervix-uterus and prostate cases, we have not detected an advantage for online non-rigid transformation of dose.

Adaptive treatment planning:

- gives expected target coverage
- reduces dose to OAR

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