



umcg



Multi-Modal-In-Room Imaging and Adaptation

Image Guided and Adaptive Proton Therapy for Moving Targets

Antje-Christin Knopf

ENLIGHT Proton Meeting
15/09/2016

Motivation

What if something changes?

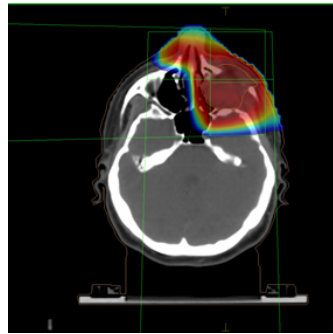


image

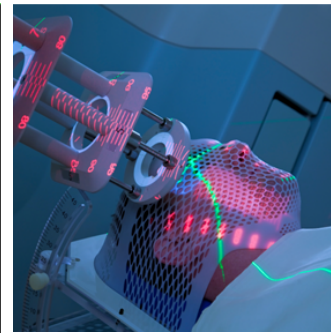


- identify target volume
- identify organs at risk

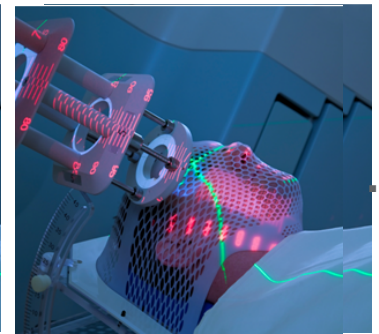
plan



treat



~~treat~~



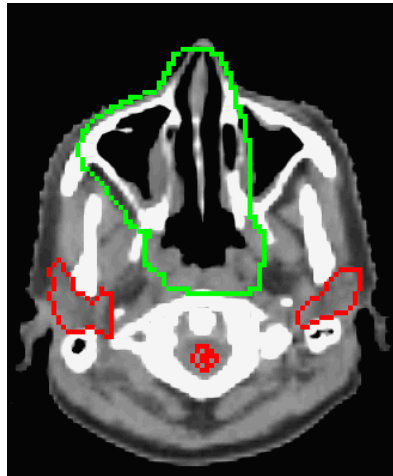
anatomical changes
treatment response
setup errors

Motivation

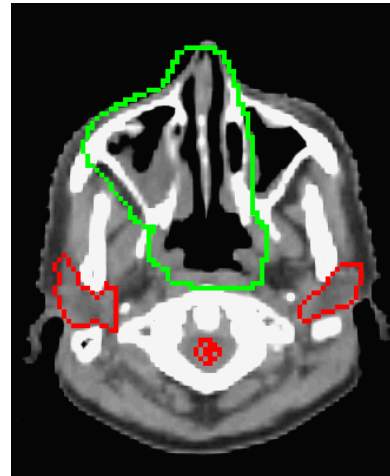
Anatomical changes



planning CT



first treatment day

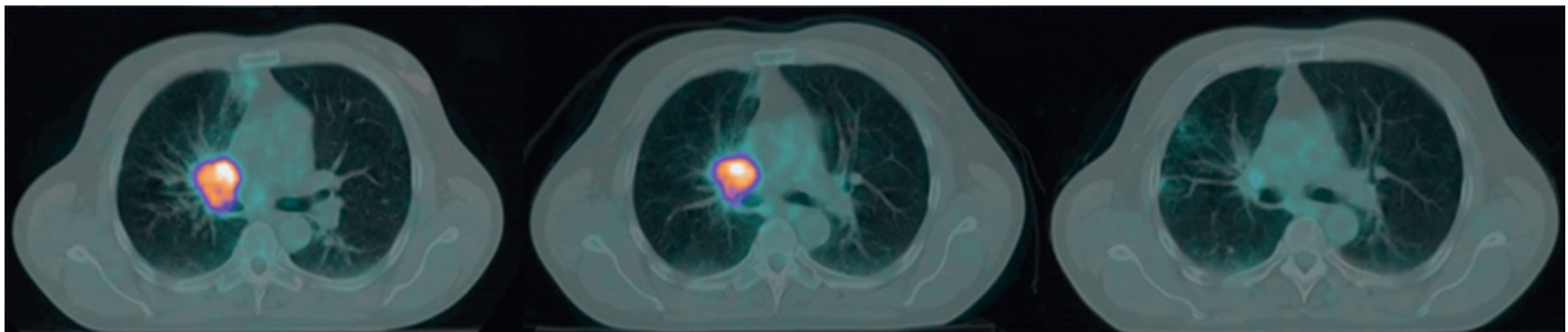


fourth treatment day

**Francesca Albertini, PSI*

Treatment response

**Grootjans et al, Nature Reviews Clinical Oncology 2015*



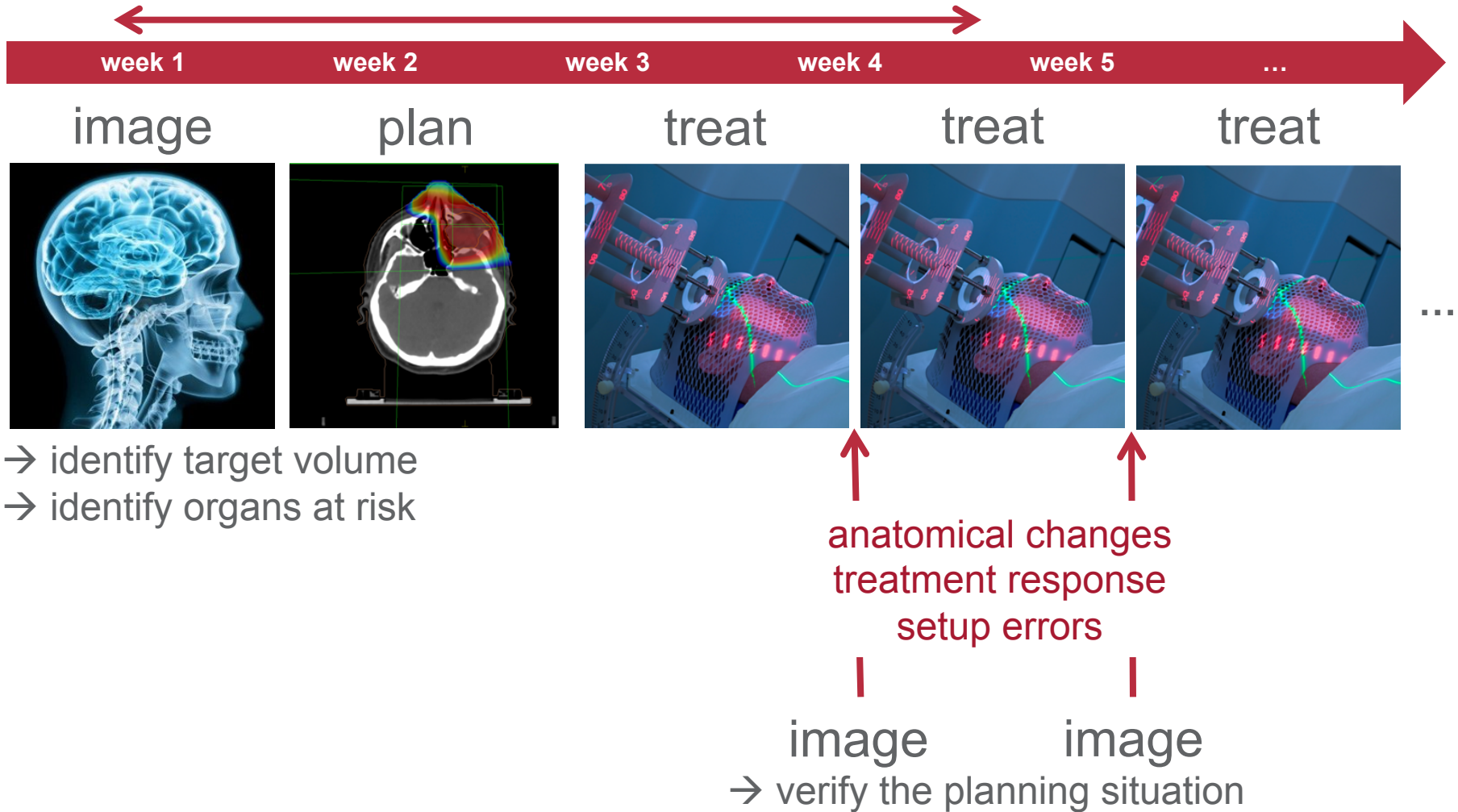
pre-treatment

in-treatment

end-of-treatment

Motivation

What if something changes?



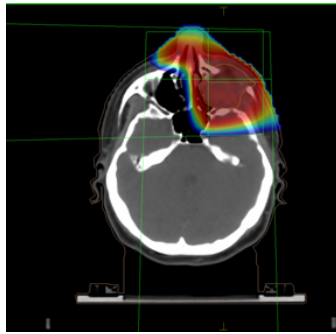
Motivation

What if something changes?

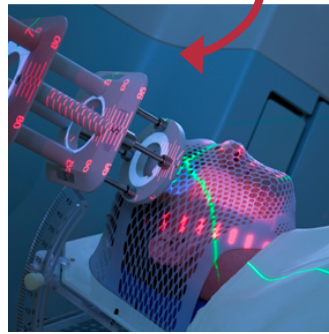
image



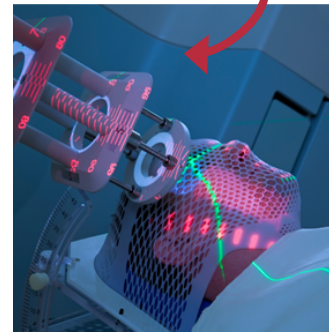
plan



treat



treat



treat

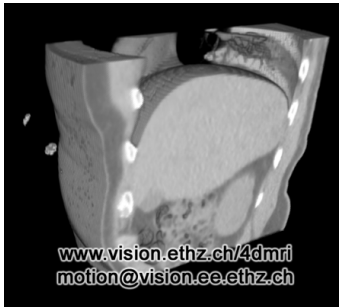


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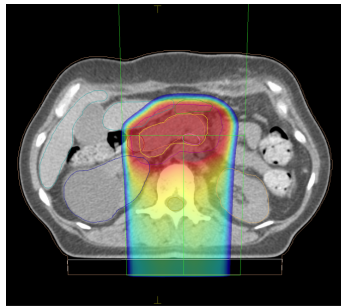
Motivation

What if something changes?

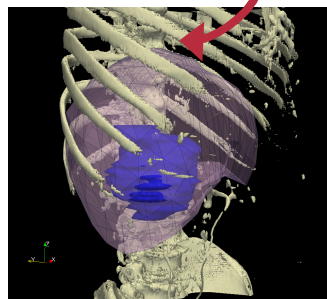
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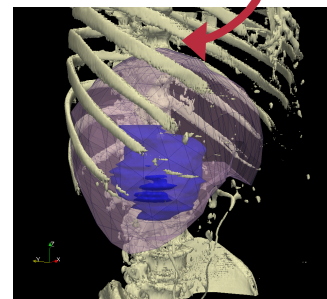
plan



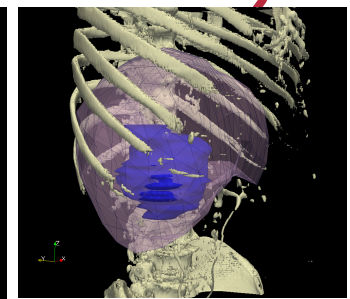
treat



treat



treat



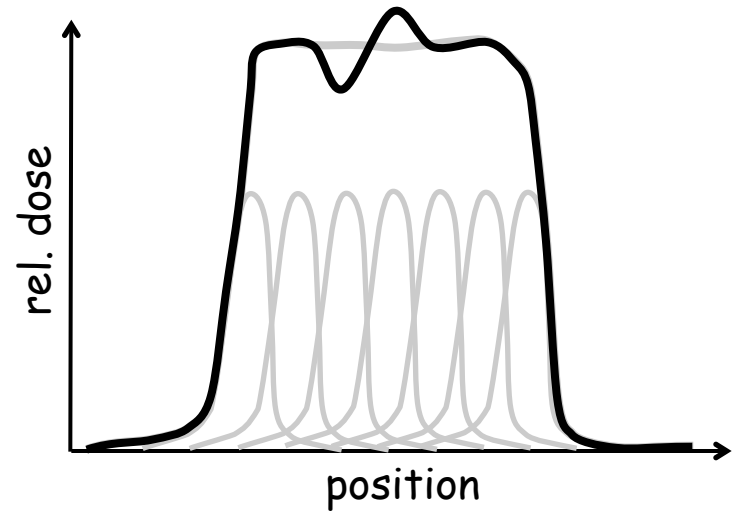
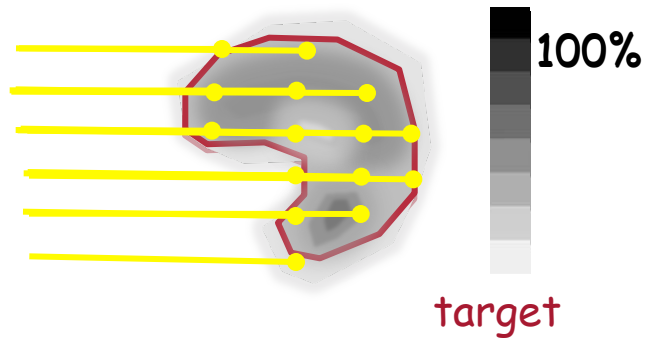
...

motion

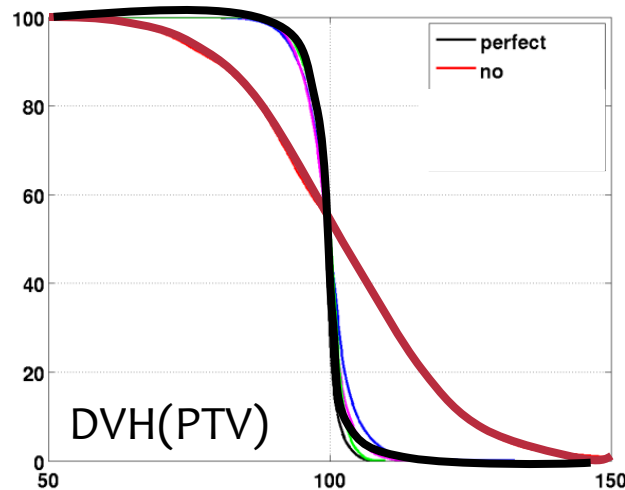
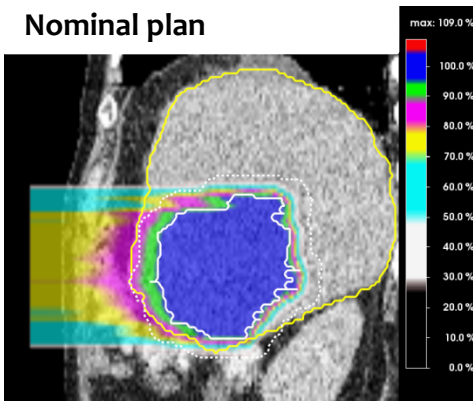
- target miss
- blurring
- interplay effects

Motivation

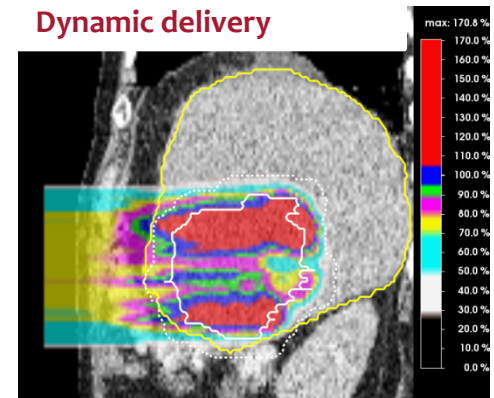
Interplay effects



Nominal plan

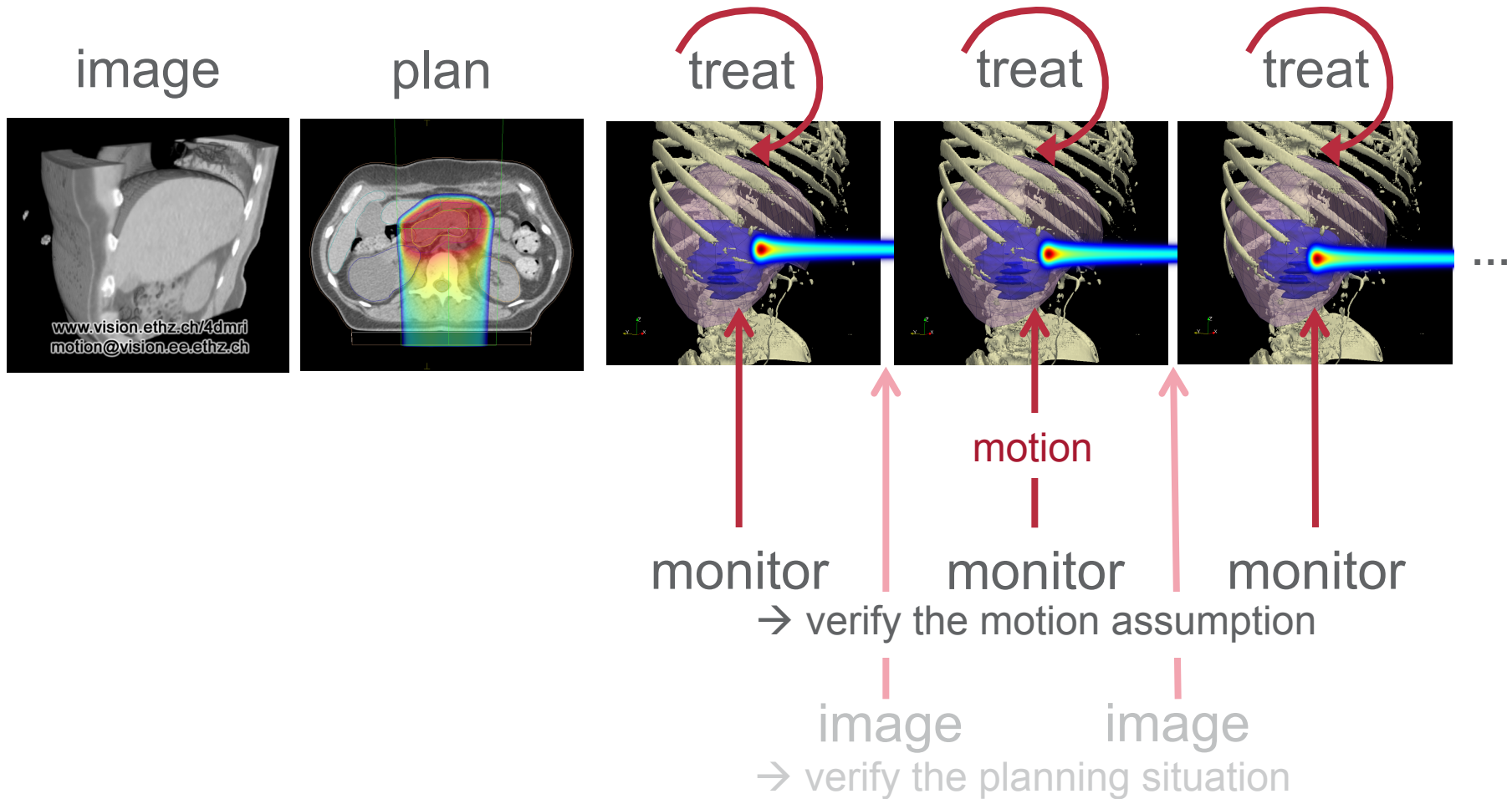


Dynamic delivery



Motivation

What if something changes?



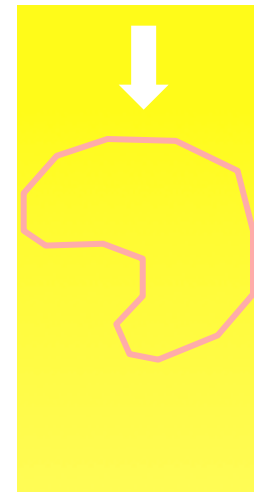
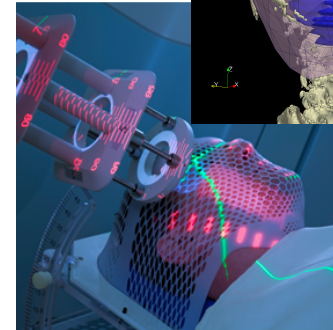
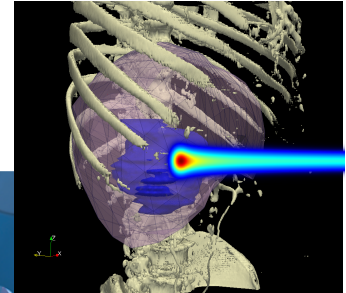
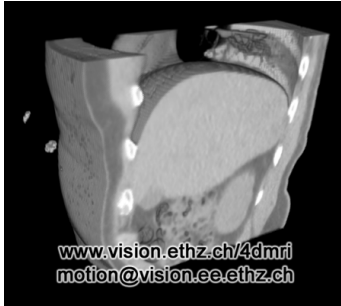
Motivation

image



treat

high-precision dose delivery
requires
high-precision imaging



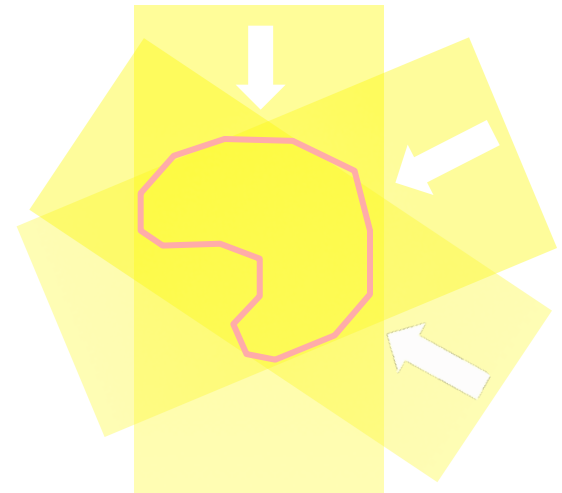
Motivation

image



treat

high-precision dose delivery
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Motivation

image

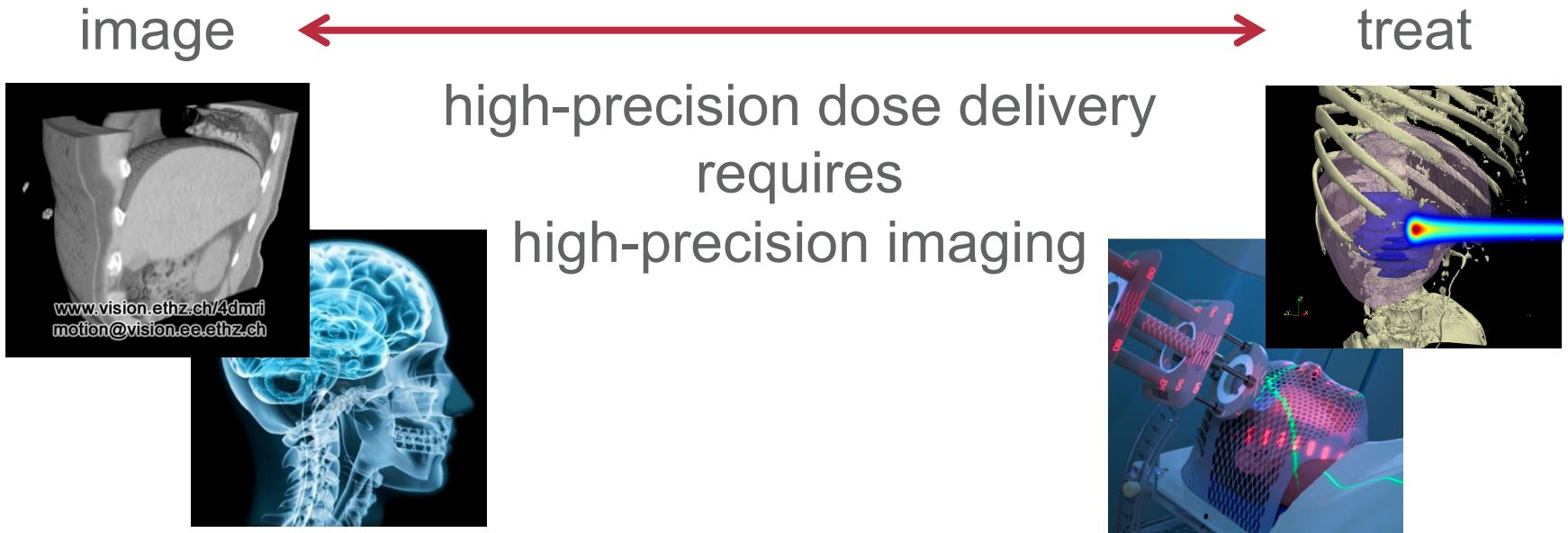


treat

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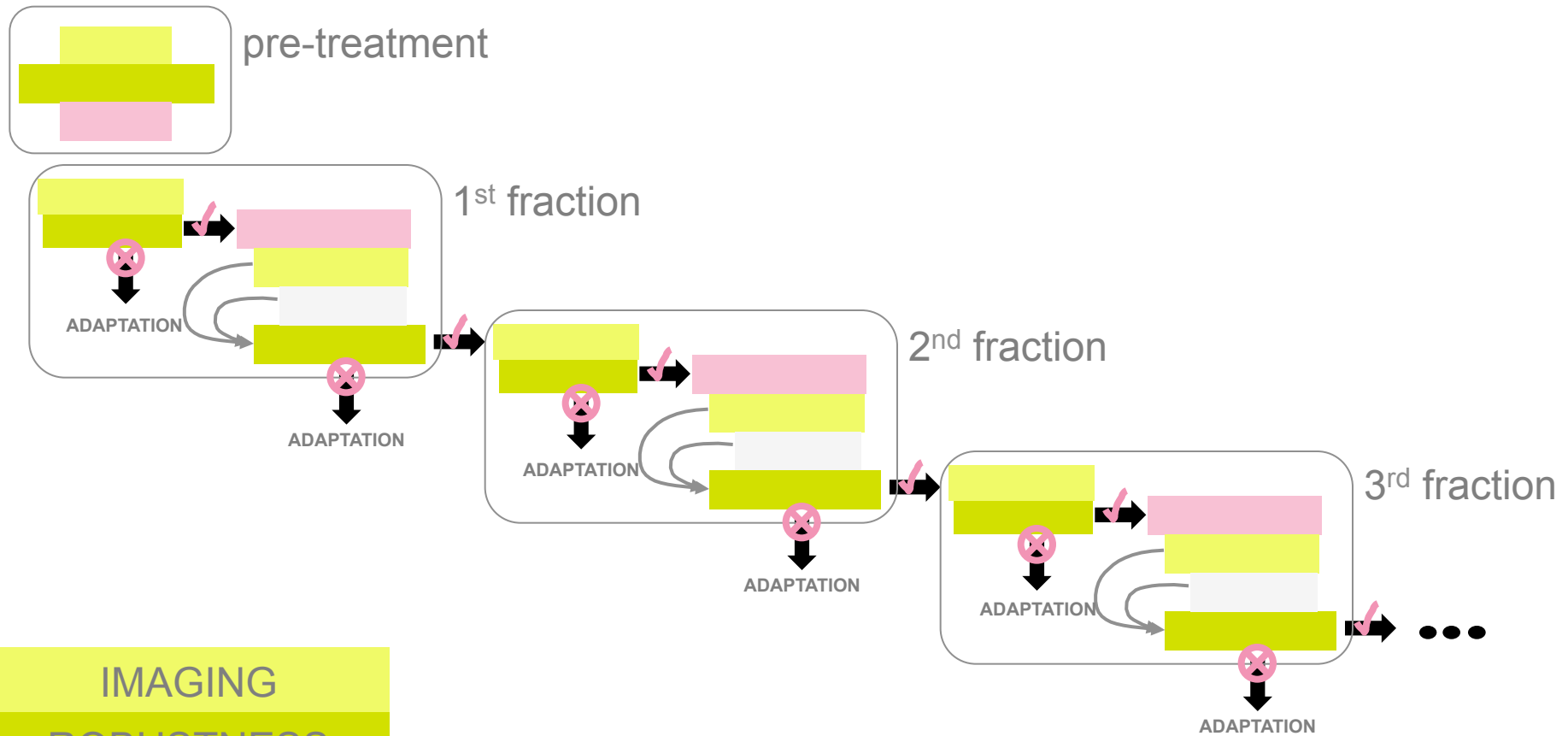
Motivation



In-room imaging enables adaptive workflows for moving targets.

Imaging information needs to be processed in time to take adaptive decisions.

An **adaptive** workflow for moving targets based on **multi-modal - in-room imaging**:

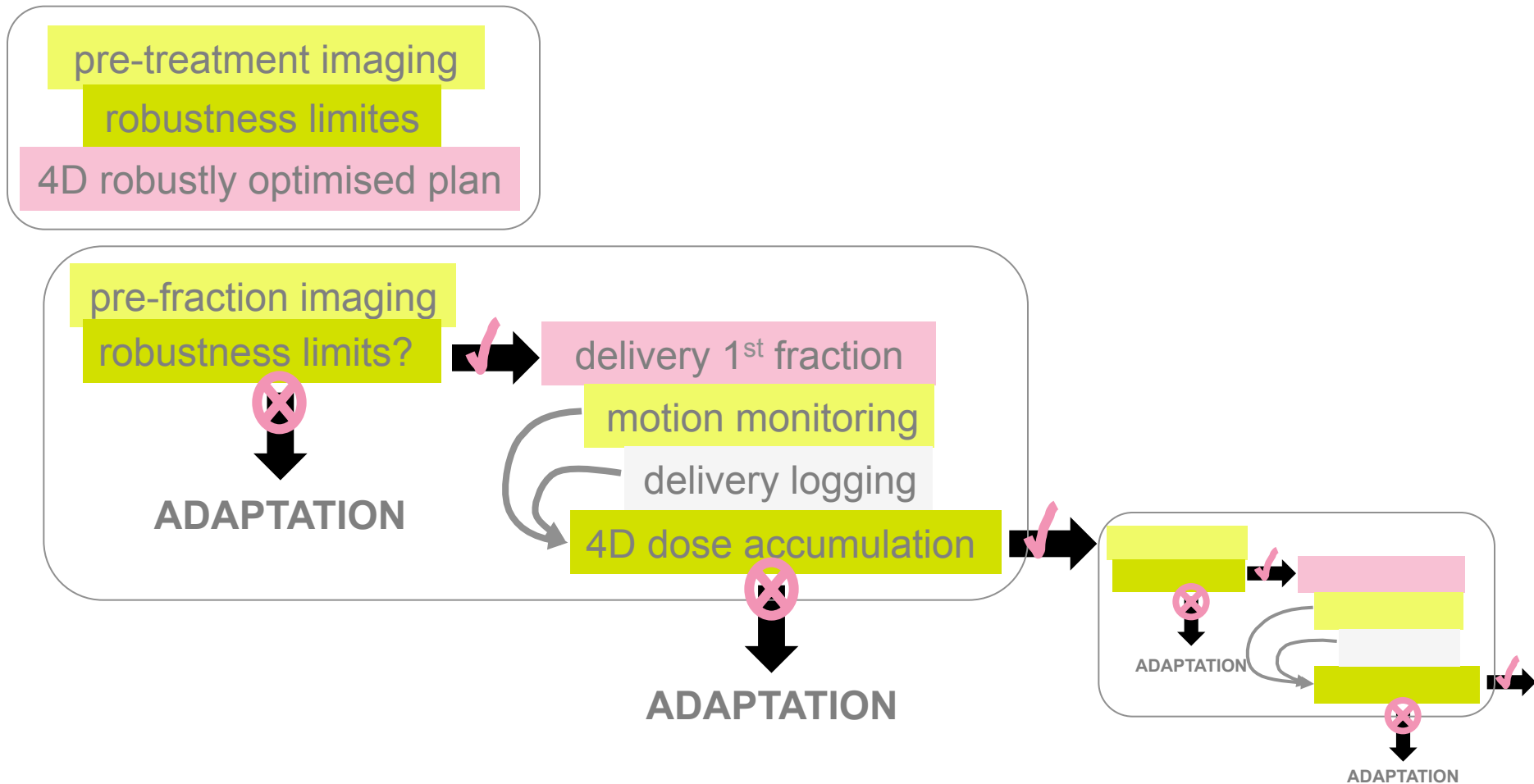


IMAGING

ROBUSTNESS

TREATMENT PLAN

An **adaptive** workflow for moving targets based on **multi-modal - in-room imaging**:



An **adaptive** workflow for moving targets based on **multi-modal - in-room imaging**:

IMAGING

pre-treatment imaging

pre-fraction imaging

motion monitoring

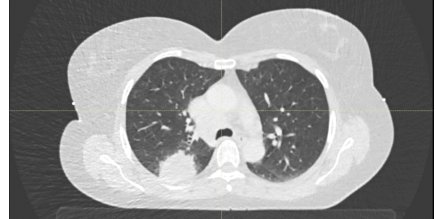
An **adaptive** workflow for moving targets based on **multi-modal - in-room imaging**:

IMAGING

pre-treatment imaging

- target definition
- delineation of relevant structures
- base for treatment planning
- motion analysis

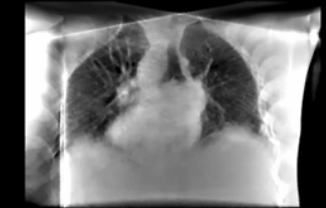
4DCT



pre-fraction imaging

- setup verification
- anatomical verification
- motion verification

4DCBCT



motion monitoring

- real-time online monitoring



An **adaptive** workflow for moving targets based on **multi-modal - in-room imaging**:

ROBUSTNESS



robust 4D plan
→ 5mm motion amplitude limit

An **adaptive** workflow for moving targets based on **multi-modal - in-room imaging**:

ROBUSTNESS



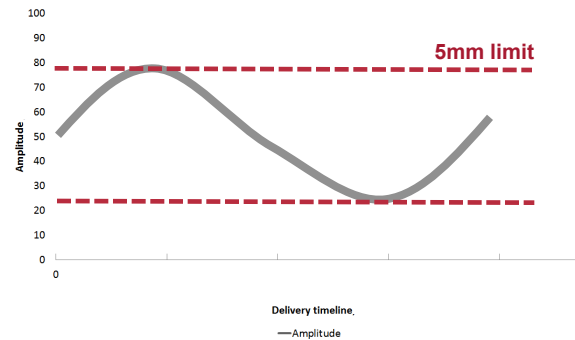
robust 4D plan
→ 5mm motion amplitude limit

robustness limites

4DCBCT

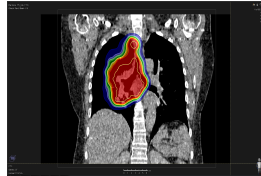


pre-fraction imaging



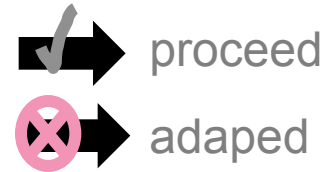
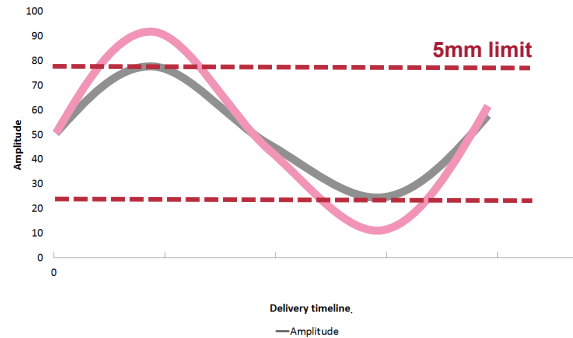
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robustness limites



4DCBCT



pre-fraction imaging

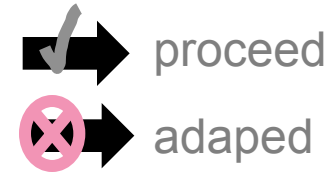
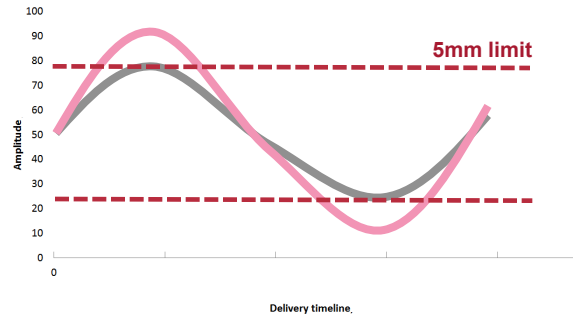
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ROBUSTNESS



robust 4D plan
→ 5mm motion amplitude limit

robustness limites

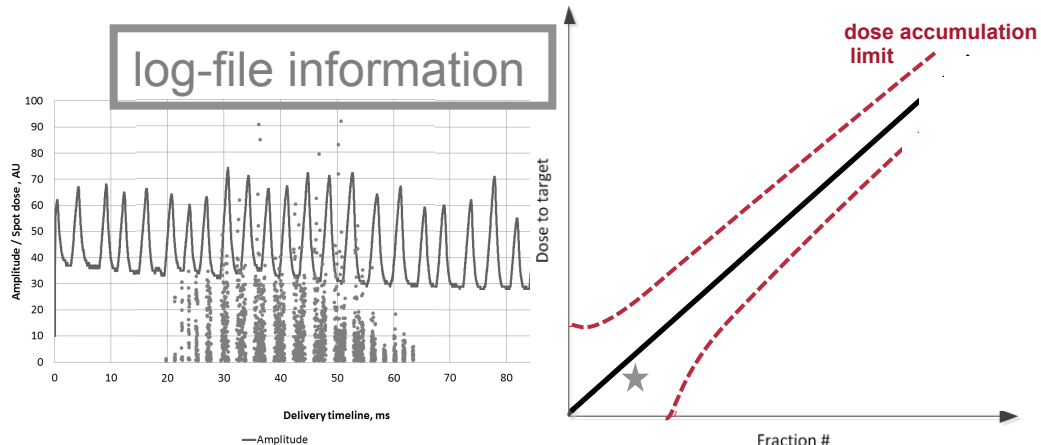


4DCBCT



pre-fraction imaging

4D dose accumulation



motion monitoring

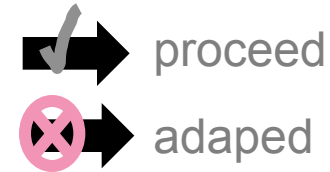
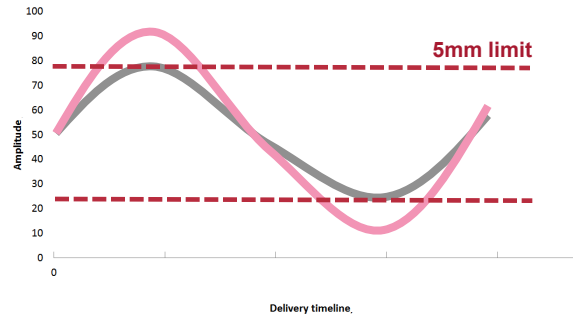
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ROBUSTNESS



robust 4D plan
→ 5mm motion amplitude limit

robustness limites

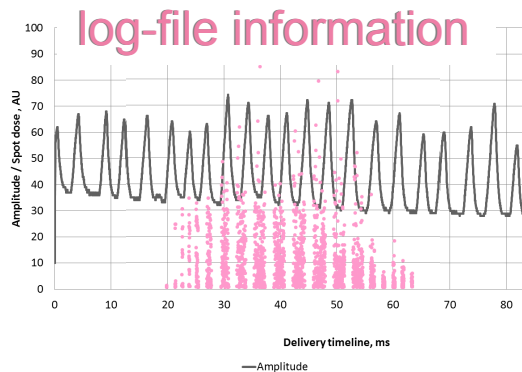


4DCBCT

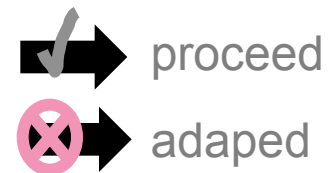
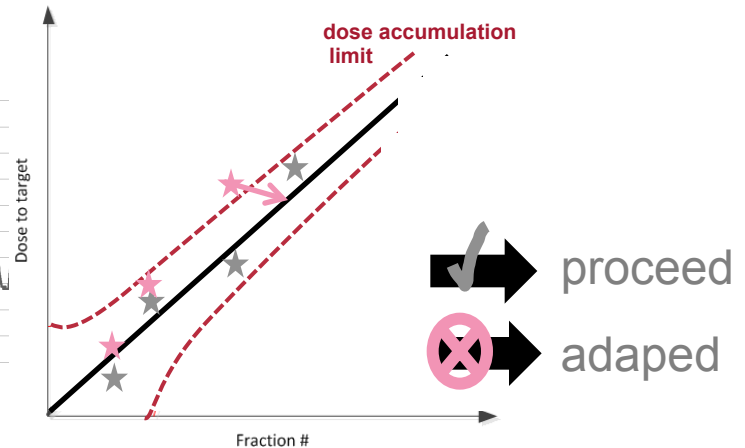


pre-fraction imaging

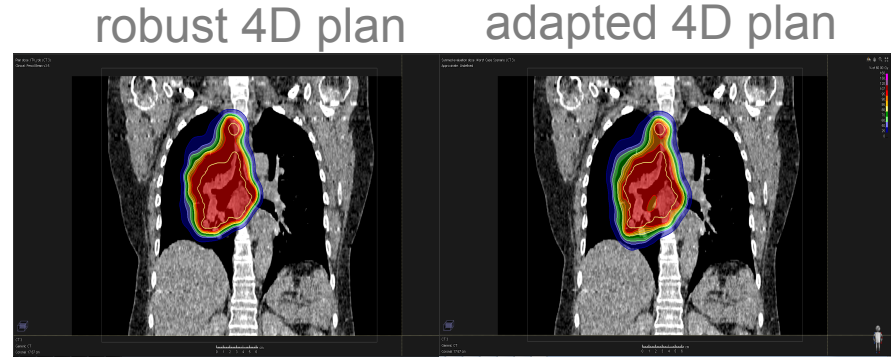
4D dose accumulation



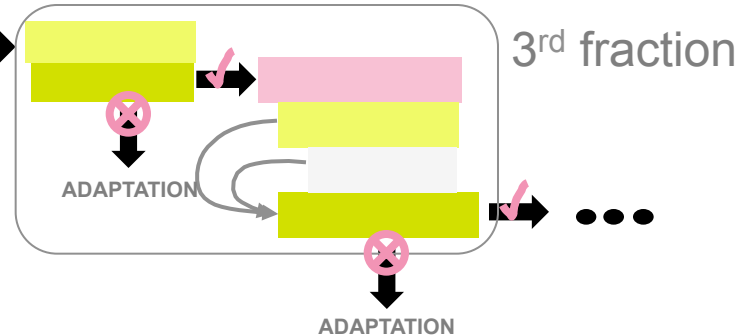
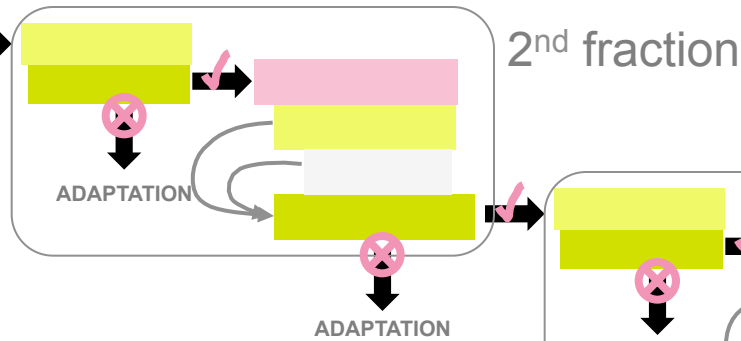
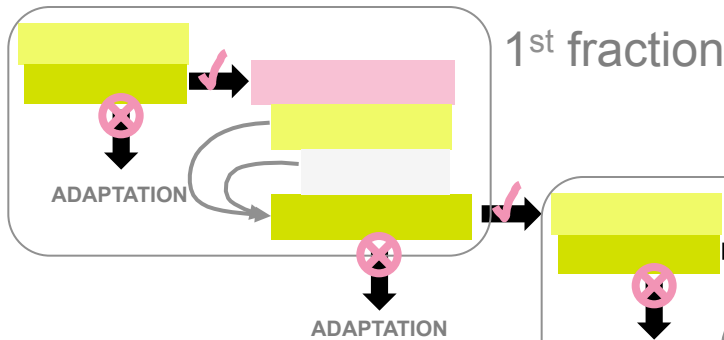
motion monitoring



An **adaptive** workflow for moving targets based on **multi-modal - in-room imaging**:



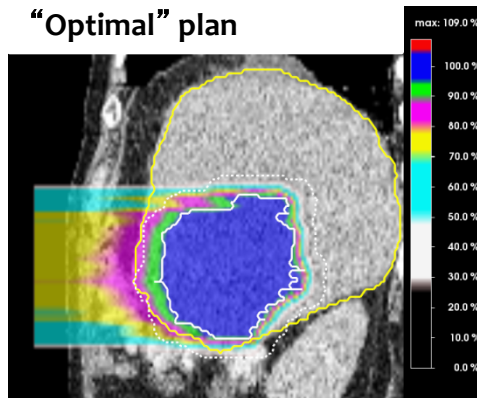
Is that the best we can achieve?



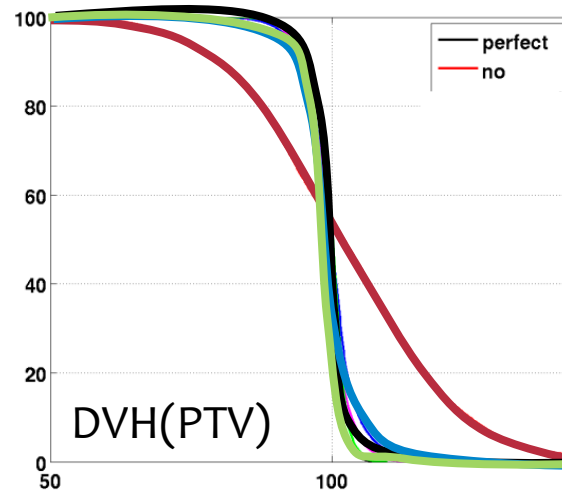
The future: MR-guided proton therapy?

A robust plan is in some way always a compromised plan.

However, a non-robust “optimal” plan will be significantly degraded by motion.



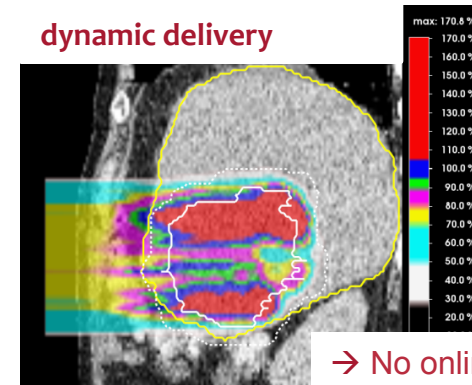
*Ye Zhang, PSI



Theoretically, **tracking** has been proposed as ideal solution.

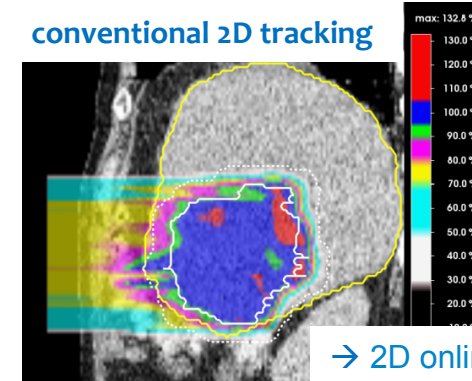
To perform tracking and achieve “optimal” plan quality, **online, real-time 3D information** is required.

dynamic delivery



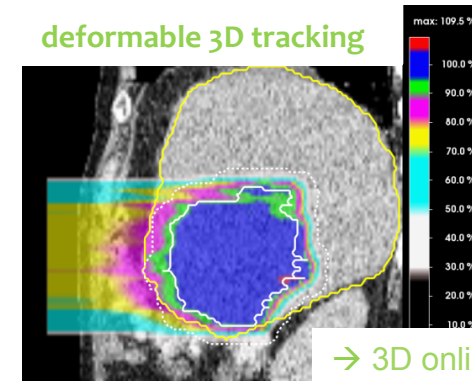
→ No online information

conventional 2D tracking



→ 2D online information

deformable 3D tracking

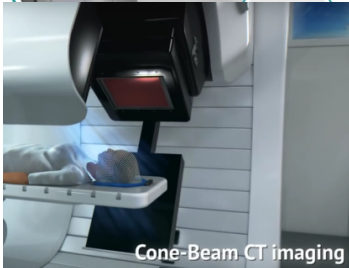
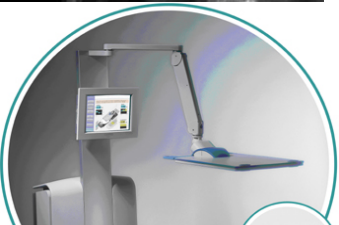
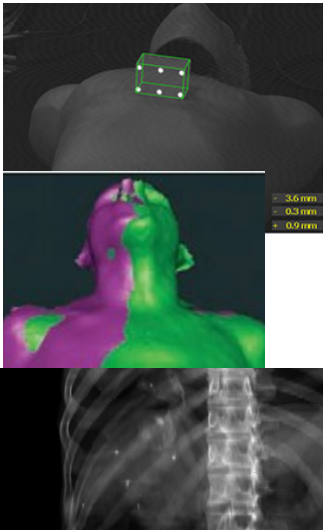


→ 3D online information

The future: MR-guided proton therapy?

Image information:

online real-time 1D 2D 3D

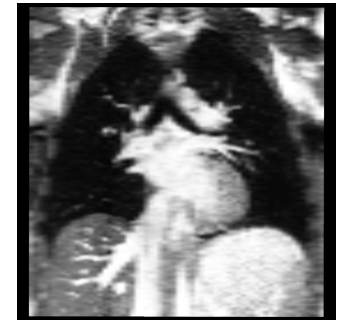
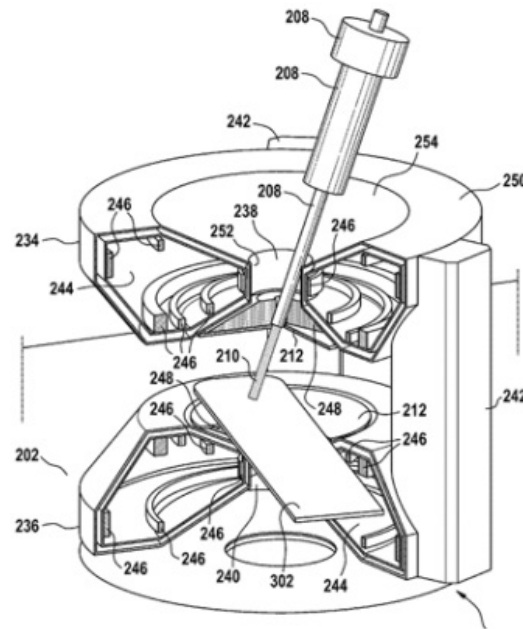


No online, real-time 3D information available!

The future: MR-guided proton therapy?

A combined MR-PT machine could enable online, real-time 3D imaging and thus 3D proton beam tracking.

*Bas Raaymakers, UMCU:
"We should go for a MR-
proton hybrid system. It's
simply too cool not to do it."*



patent application 20110230754 by Johan Overweg, Philips Hamburg, Germany

Real-time knowledge of the target volume location in combination with high-precision dose delivery will make a real difference!

Summary

Imaging has always been the basis for radiotherapy treatments.

Technology has evolved from pre-treatment imaging via inter-fractional imaging towards online imaging.

Eventually, a combined PT-MR hybrid machine could provide optimal imaging information and would substitute multi-modal imaging.

Combining online MR imaging and high-precision proton dose delivery would enable optimal IGRT/ART treatments for moving targets.



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Thank you very much to my colleagues at

PSI:

Toni Lomax

Francesca Albertini

Ye Zhang

UMCG:

Arturs Meijers

Cassia Oraboni

for helping preparing these slides.

Thank you very much for your attention !
