Quality Assurance beam tracking

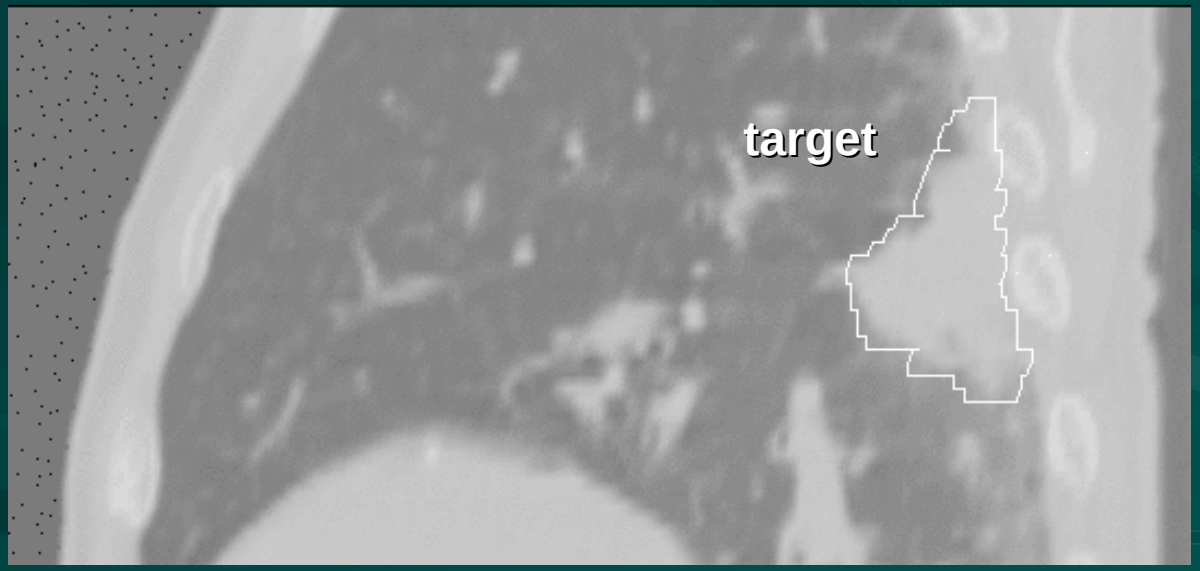
Nami Saito
GSI, Darmstadt, Germany
biophysics department

Outline

- Introduction
  - Beam tracking
  - GSI beam tracking system
- Beam tracking QA
  - Function QA
  - Dosimetric QA
    - example
    - cross check method
- Summary

Introduction - beam tracking

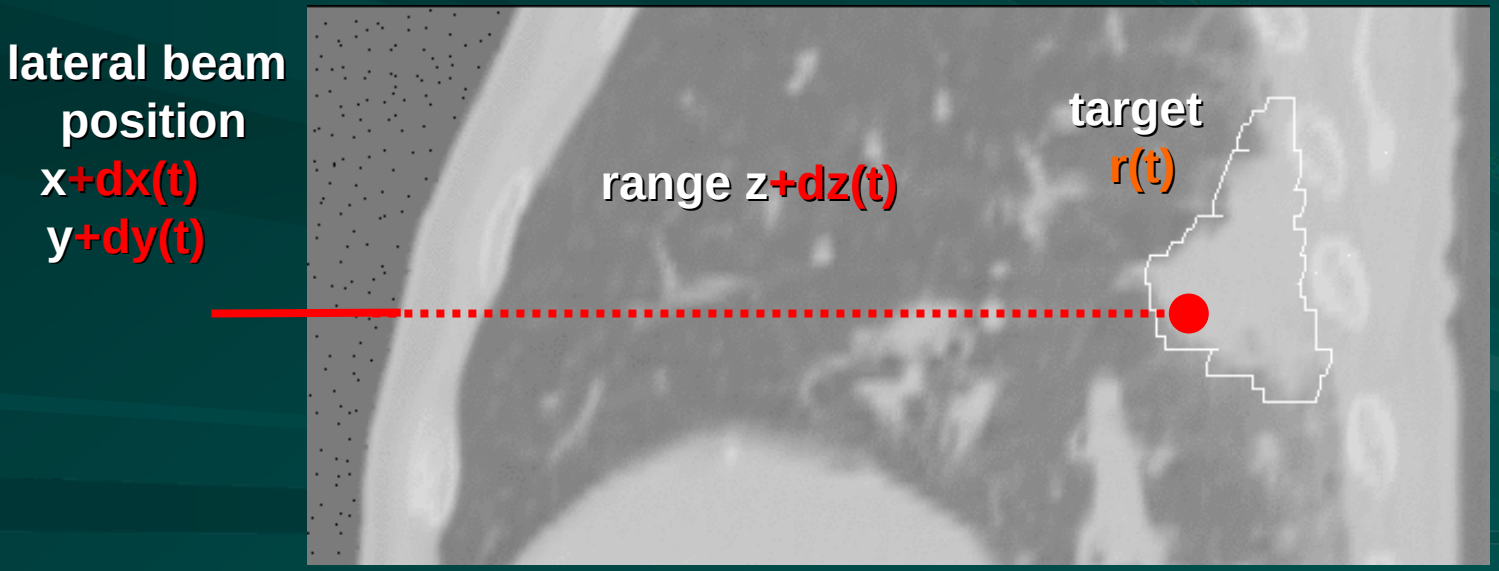
- Irradiation technique for moving target :
  Ion beam tracking → continuous beam adaptation in 3D
- Dynamic beam delivery QA
  → need careful QA of motion-dependent beam controlling



Lung cancer
4DCT data
(10 motion phases)
courtesy E. Rietzel

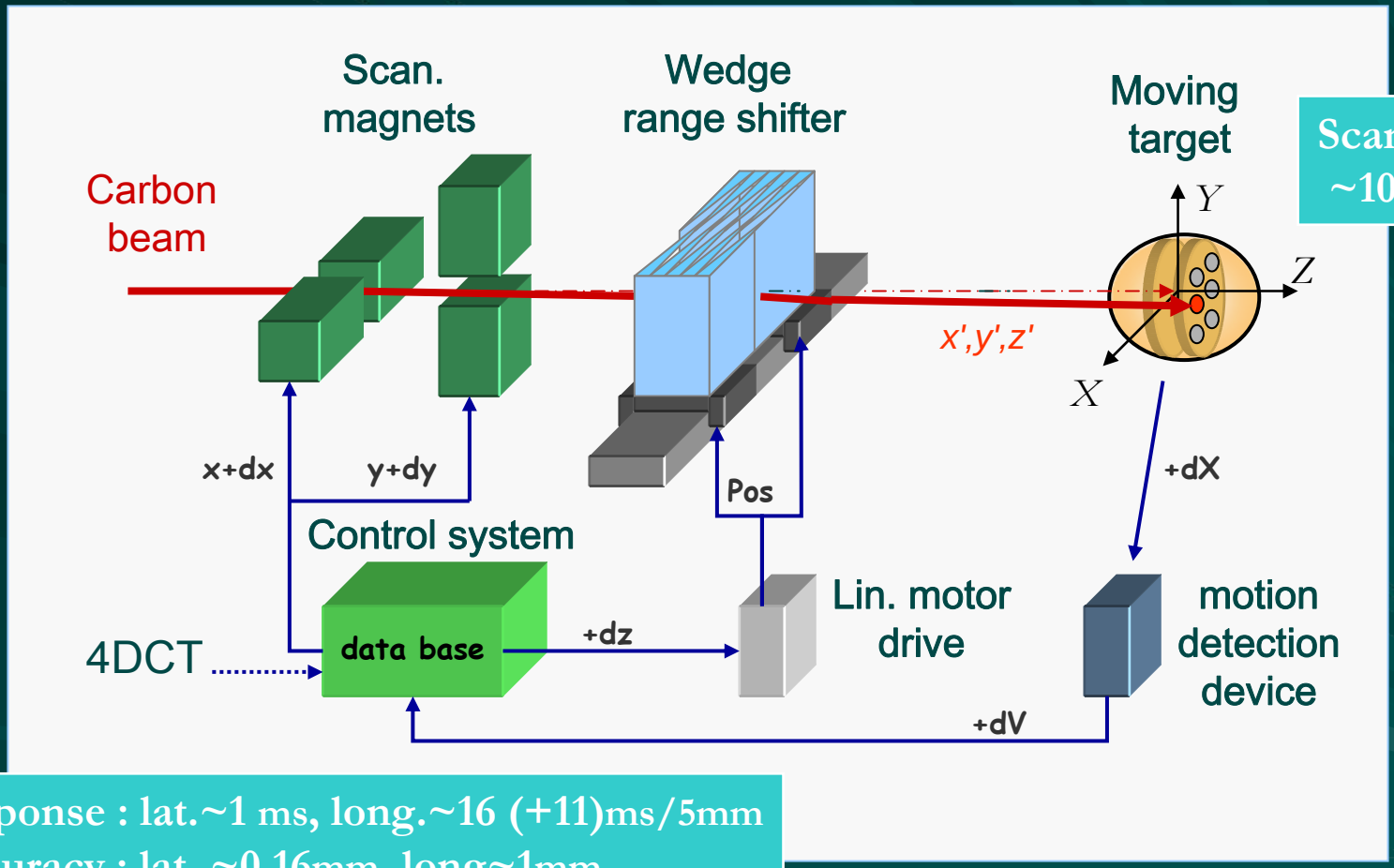
Introduction - beam tracking

- Irradiation technique for moving target :
  Ion beam tracking → continuous beam adaptation in 3D
- Dynamic beam delivery QA
  → need careful QA of motion-dependent beam controlling



Lung cancer
4DCT data
(10 motion phases)
courtesy E. Rietzel

Introduction – GSI beam tracking



response : lat.~1 ms, long.~16 (+11)ms/5mm
accuracy : lat. ~0.16mm, long~1mm

Saito et al, Phys. Med. Biol. 54 (2009) 4849

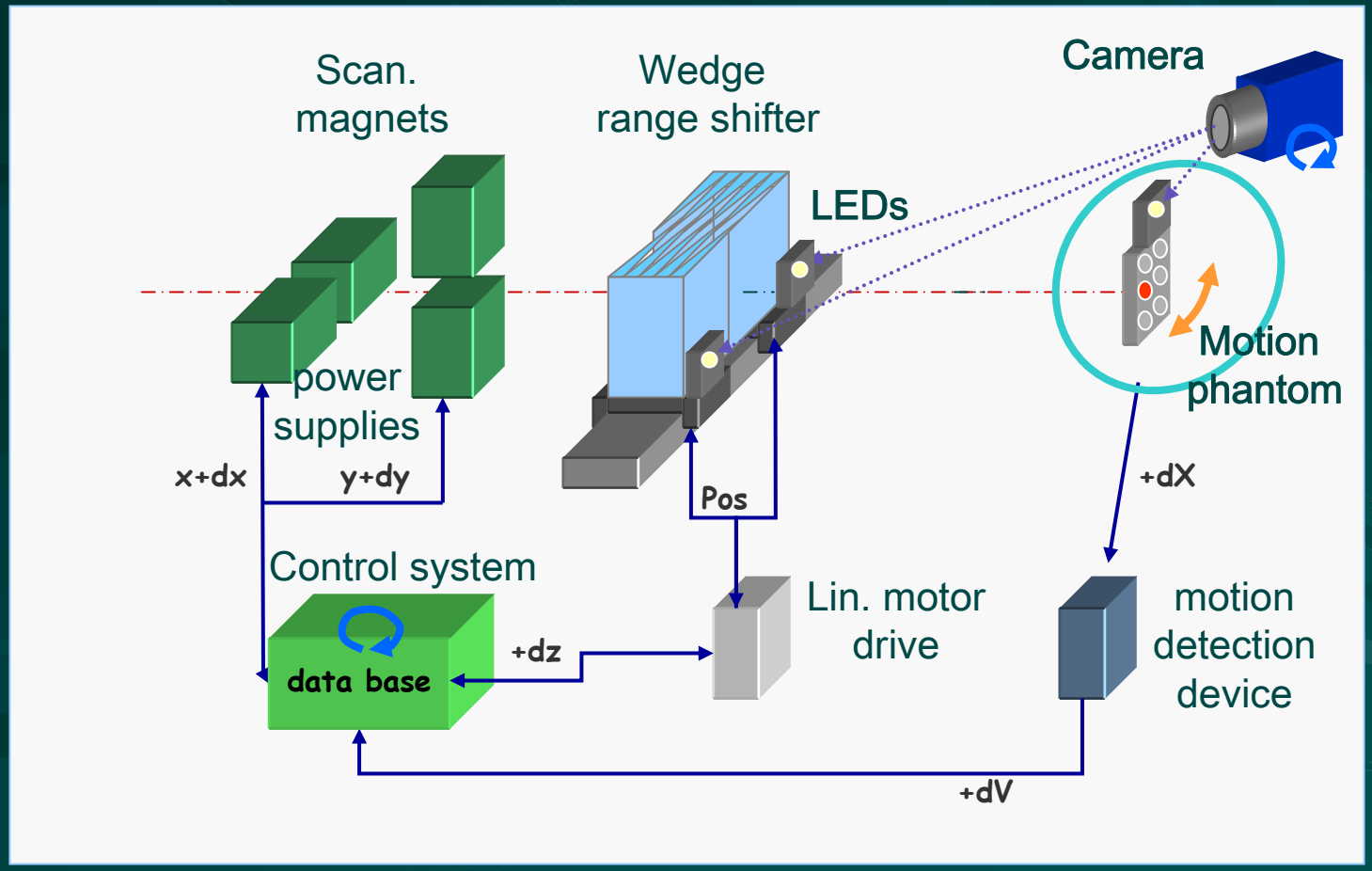
Beam tracking specific QA

- Consideration of dynamics
  - Function QA (status, response in **motion**, interlock, etc.)
  - Dosimery QA (beam tracking with **motion** signal)
- QA frequency
  - Daily/Monthly/Quarterly/Yearly
  - Installation/Commissioning

GSI beam tracking is at experimental stage, BT QA is still under investigation …

Function QA

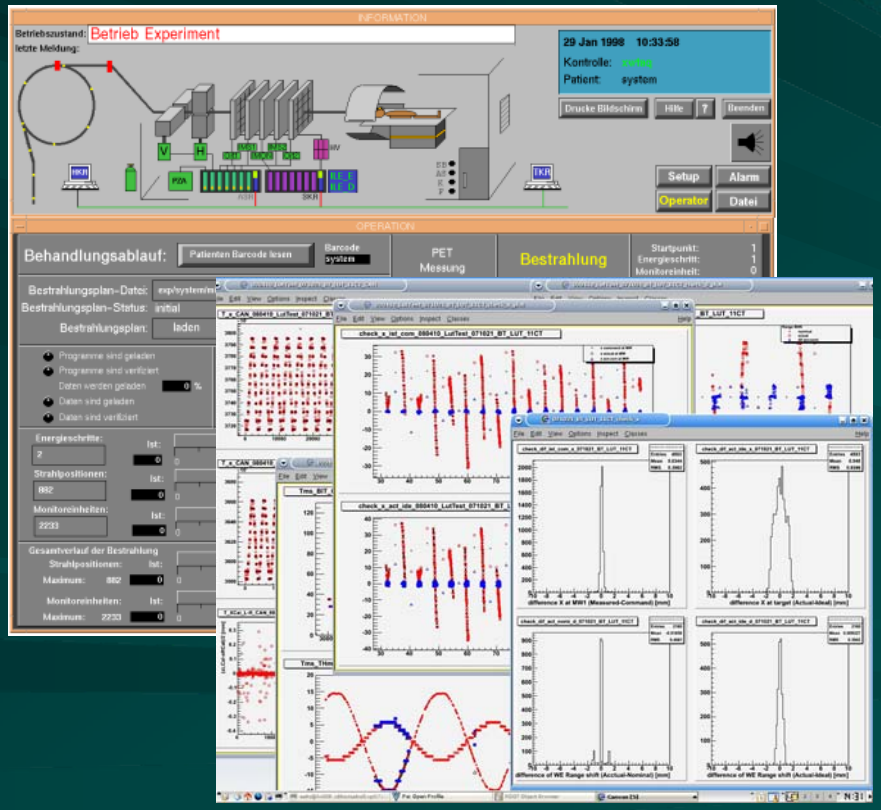
- Response for a standard **motion** without beams



Function QA

QA Interface :

- indicators/data plot/histogram → OK/warning/error
- **time resolved data** → find synchronization error/slow response



Device check list

Static

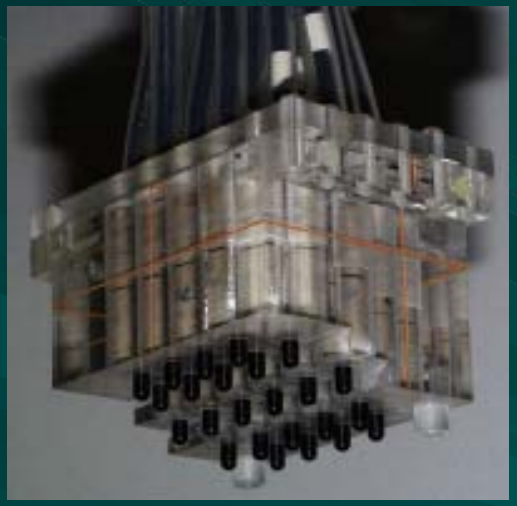
- ✓ sensor
- ✓ power
- ✓ communication
- ✓ ..

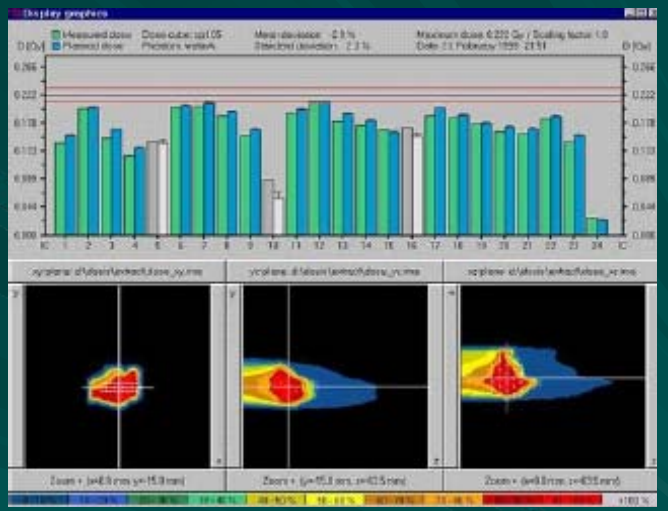
Motion

- ✓ motion detector
- ✓ scanner current
- ✓ range shifter
- ✓ ..

Dosimetric QA

- Similar to plan verification method at GSI therapy
  - 3D dose measurement in water phantom





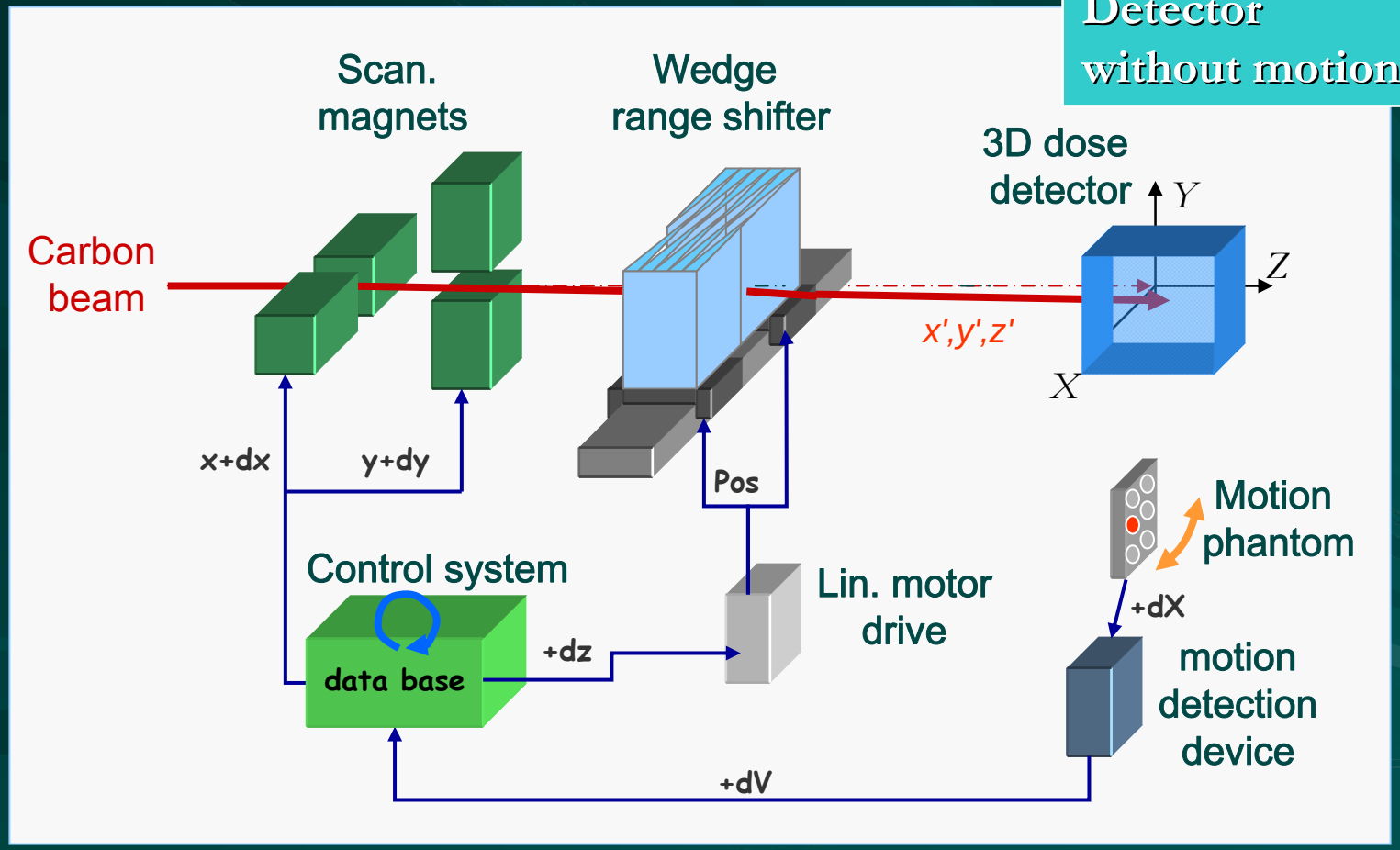
C. Karger et al. Med. phys. 26 (10) 1999

- For beam tracking
  - 4D treatment planning* (reference plan+adaptation)
  - motion signal

* Bert and Rietzel, Radiat. Oncol. 2 (24) 2007

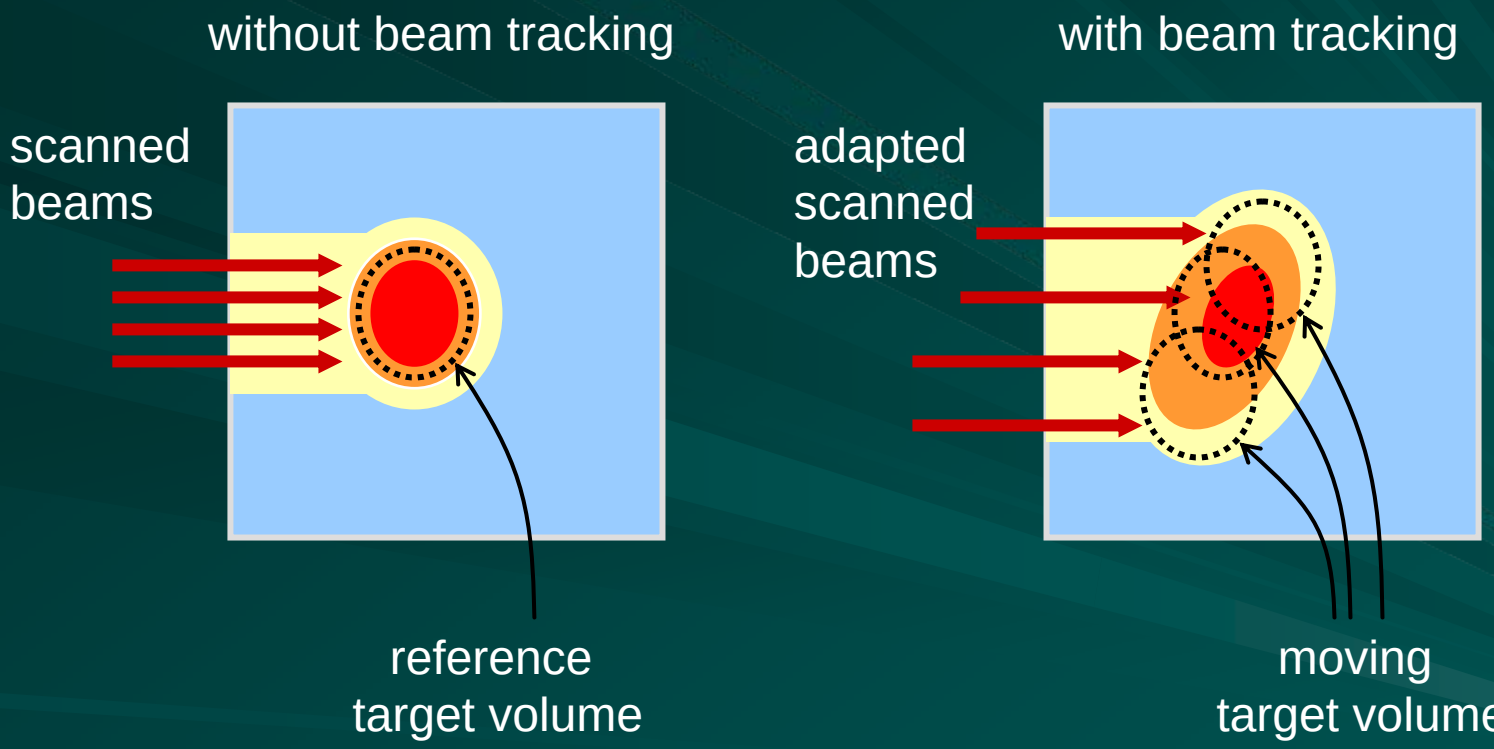
Dosimetric QA

- Dose measurement with a motion signal



Dosimetric QA

- Dose on **static** detectors



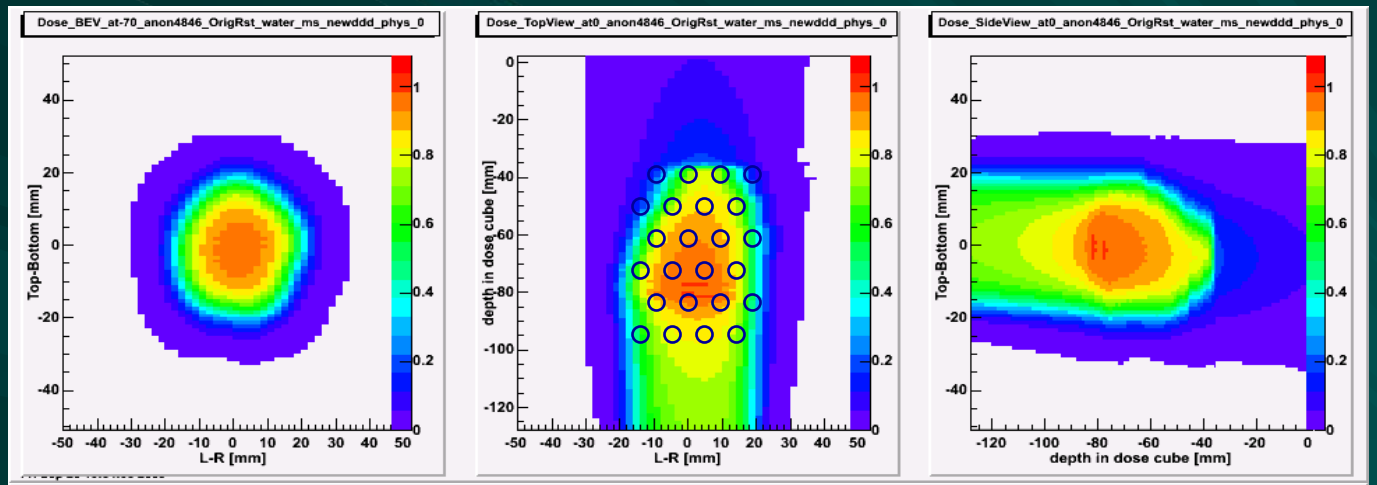
Beam tracking sequence → unique dose pattern → find mis-tracking

Dosimetric QA

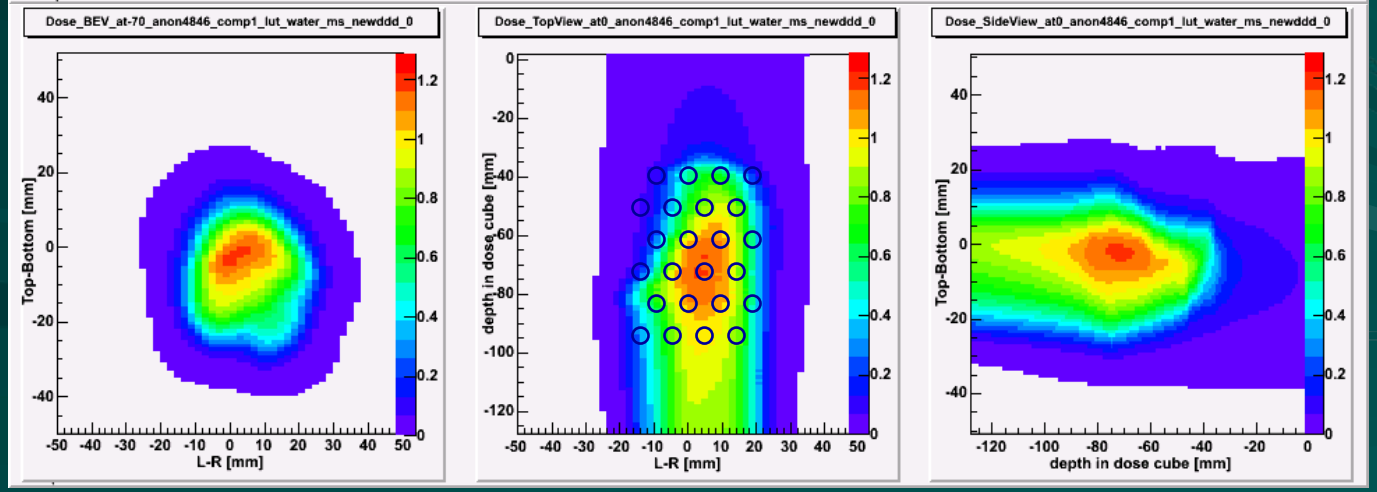
- Calculation : Dose pattern in water (a lung patient plan)

Beam's eye view | Top view | Side view

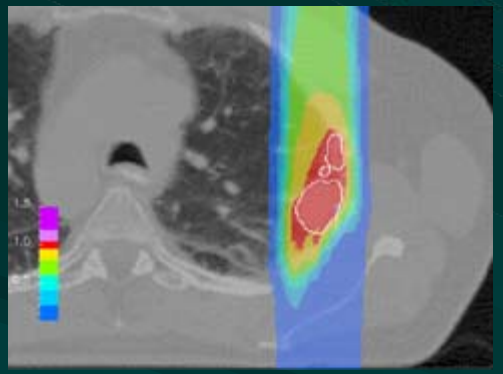
No tracking

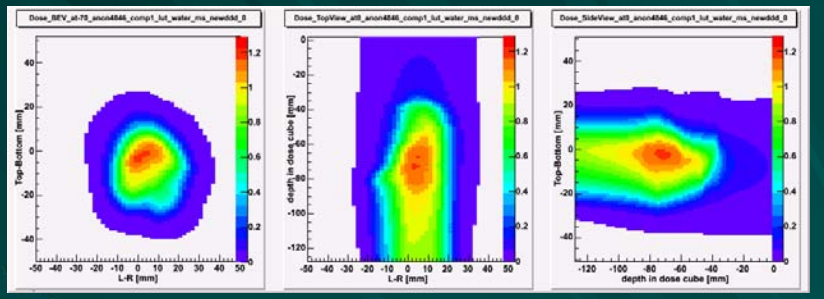


Tracking



Dosimetric QA - process

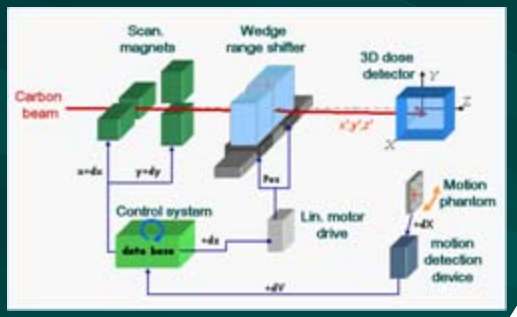




4D Treatment planning*

nominal dx, dy, dz

Dose calc. in water (with recorded motion signal)



Beam tracking (record motion signal) Dose measu. in water

Dose comparison

* Bert and Rietzel, Radiat. Oncol. 2 24 (2007)

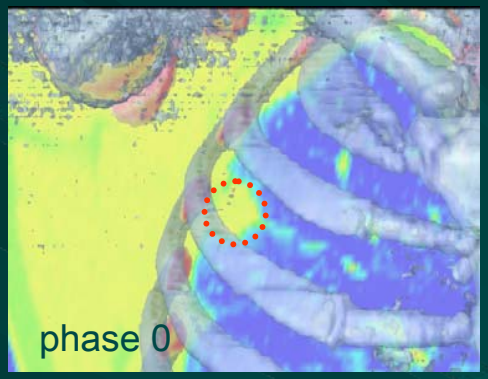
Dosimetric QA example

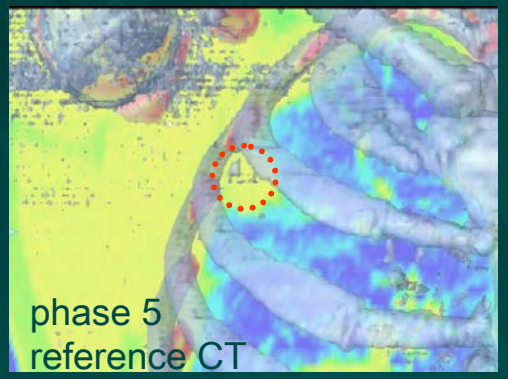
Treatment plan

4D-CT data
- lung tumor (6.5cm^3)
- 10 motion phases

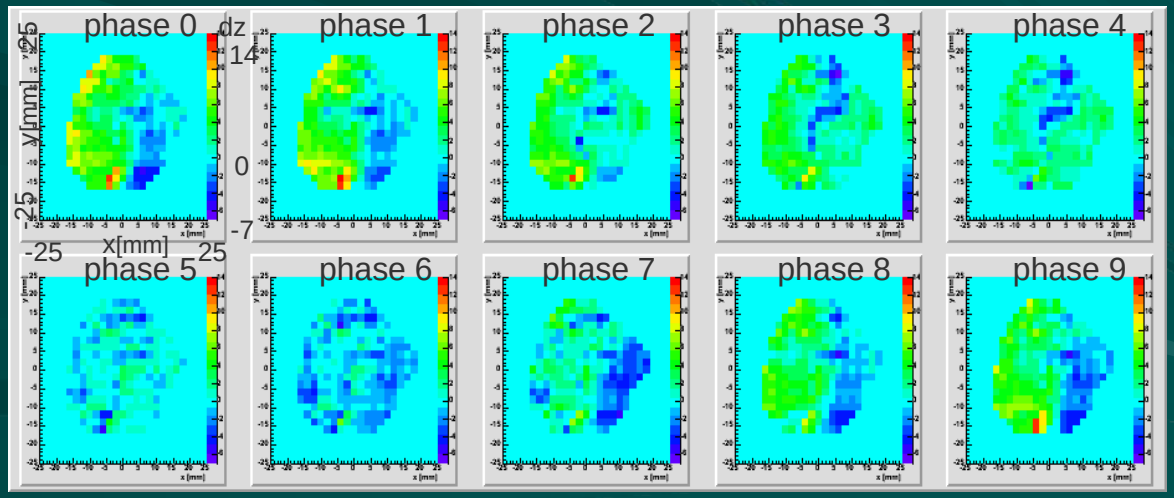
4D treatment plan*
- 48 slices
- 7389 scan spots
- target vol. as rigid
- 1 Gy
- dx,dy,dz in LUT
  dx: 0~ 5 mm
  dy: -10~0 mm
  dz: -8~19 mm

* Bert and Rietzel, Radiat. Oncol. 2 24 (2007)





Depth correction dz [mm] of a slice for 10 CT phases



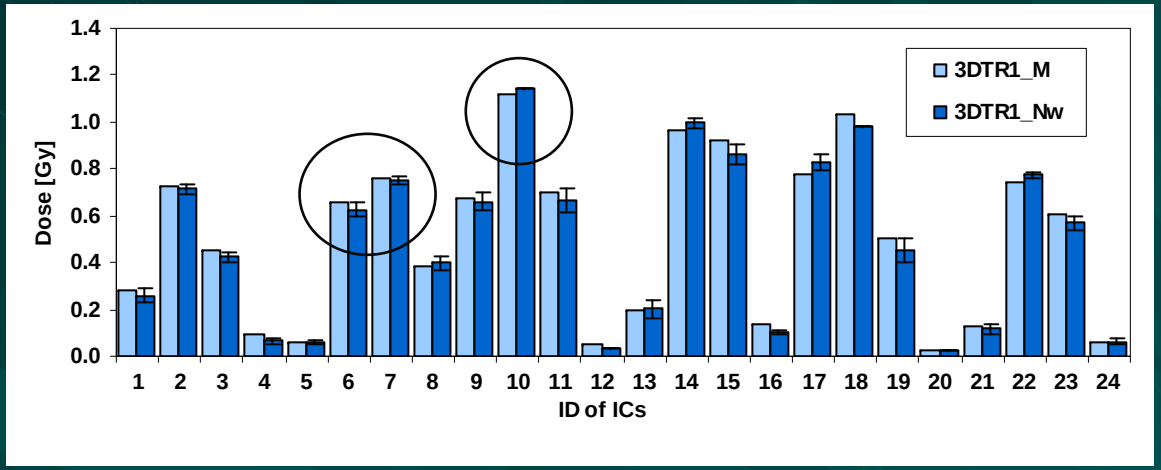
Dosimetric QA example

- Dose comparison (norm. by prescribed dose 1 Gy)

3D beam tracking

M : 3D TR measured
Nw: 3D TR calc.

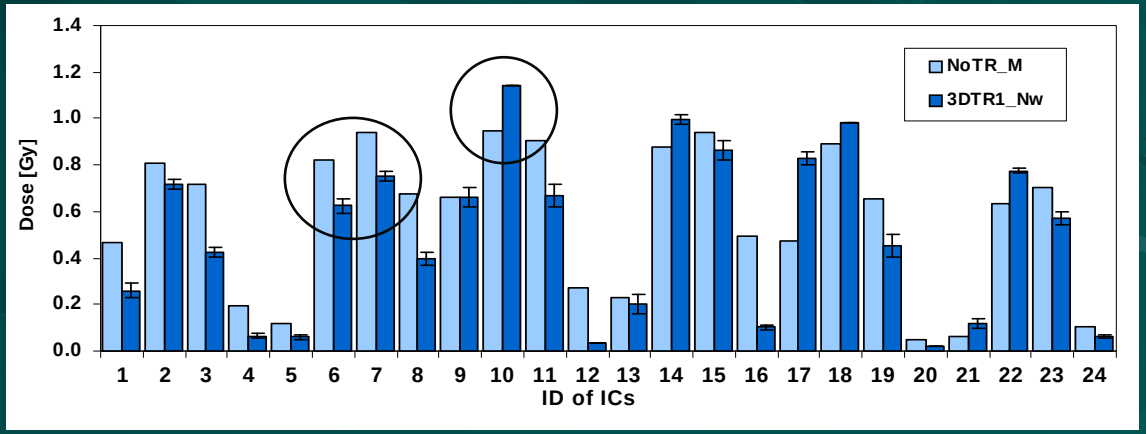
Dose dif. 1.2 ±2.8 %



Failure case

M : no beam tracking
Nw: 3D TR calc.

Dose dif. 7.8 ±17.5 %

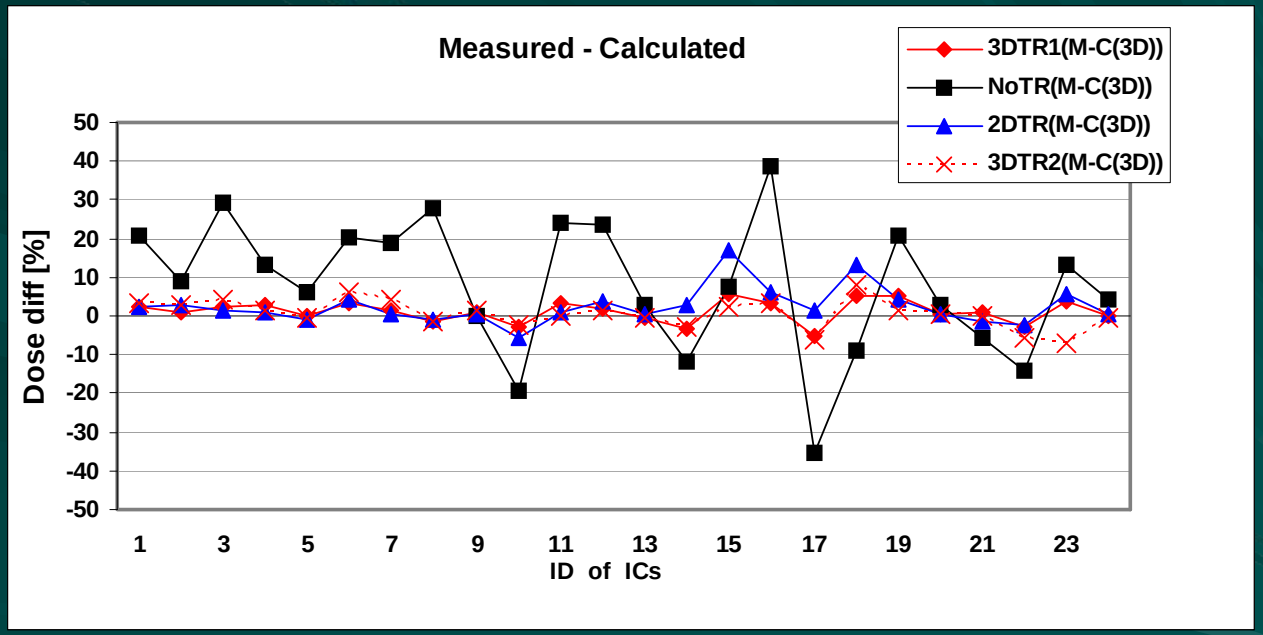


Dosimetric QA example

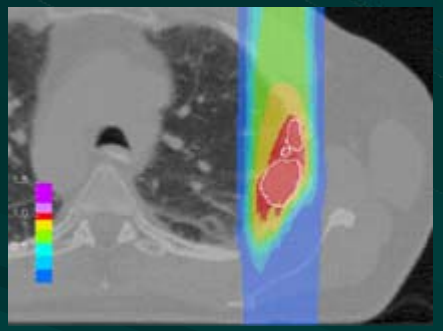
- Dose difference : Measured – Calc.

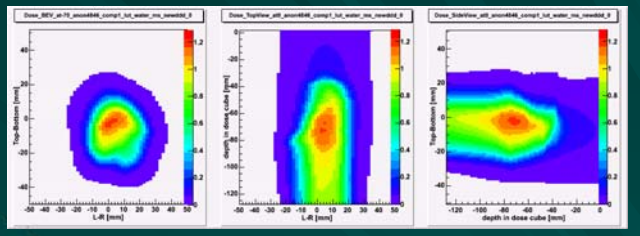
Beam TR: dose dif./1Gy

3D TR1 : **1.2 ± 2.8** %
No TR : 7.8 ±17.5 %
2D TR : 2.4 ± 4.7 %
3D TR2: 0.6 ± 3.7 %



Dosimetric QA - cross check

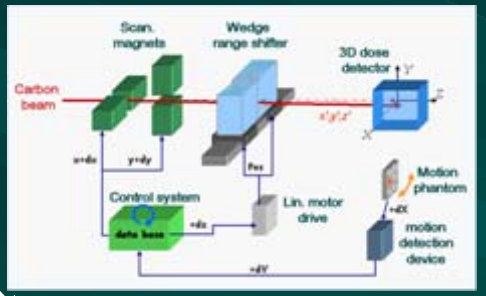




4D Treatment planning

nominal dx, dy, dz

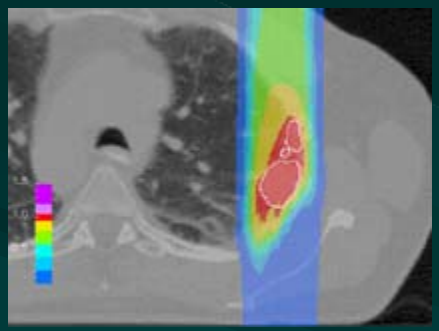
Dose calc. in water (with recorded motion signal)

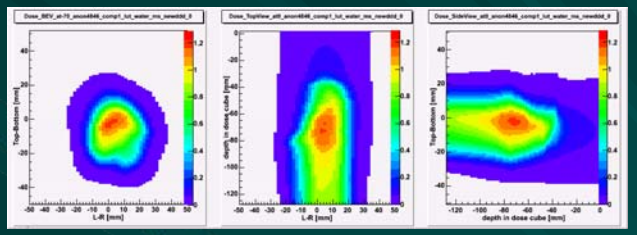


Beam tracking
(record motion signal)
dose measurement

Dose comparison

Dosimetric QA - cross check

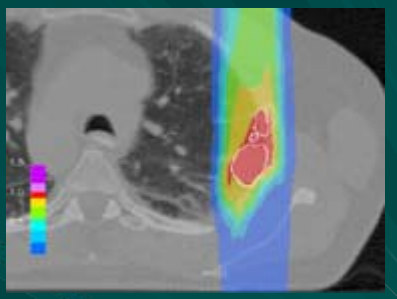


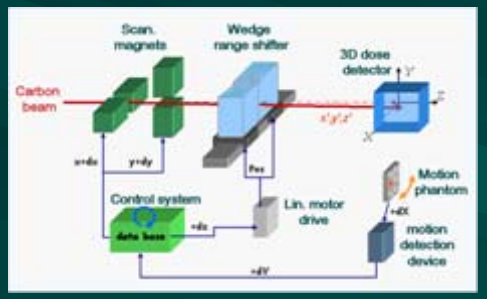


4D Treatment planning

nominal dx, dy, dz

Dose calc. in water (with recorded motion signal)





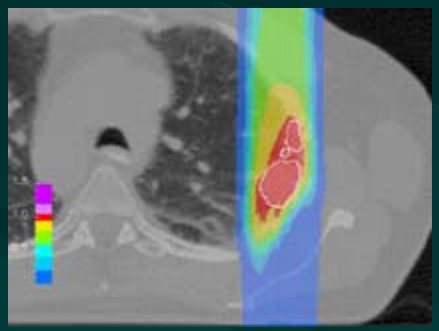
Beam tracking x' y' z'
(record motion signal)
dose measurement

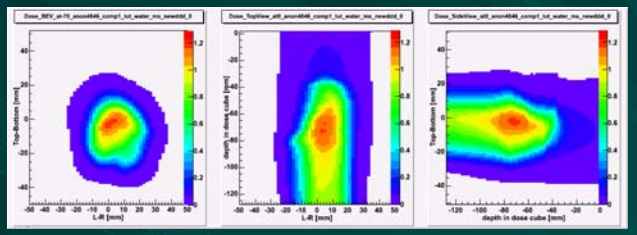
Dose comparison

Dose calc. in CT (with recorded motion signal & beam tracking)

DVH

Dosimetric QA - cross check

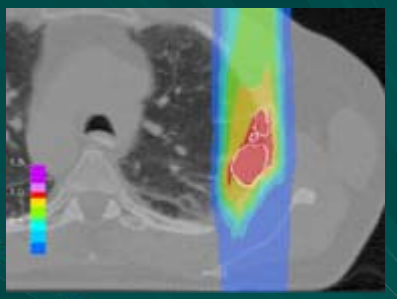


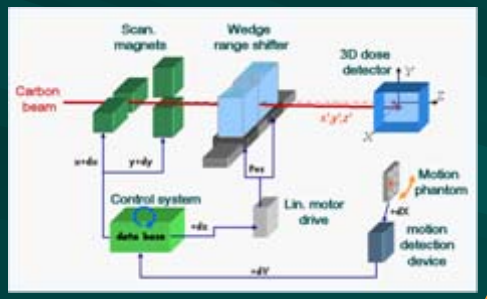


nominal dx, dy, dz

4D Treatment planning

Dose calc. in water (with recorded motion signal)





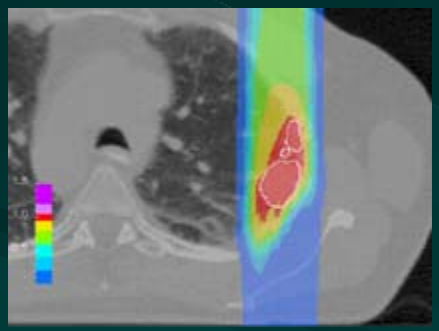
Beam tracking x' y' z'
(record motion signal)
dose measurement

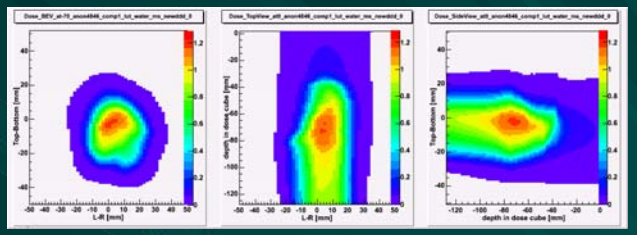
Dose comparison

Dose calc. in CT (with recorded motion signal & beam tracking)

DVH

Dosimetric QA - cross check

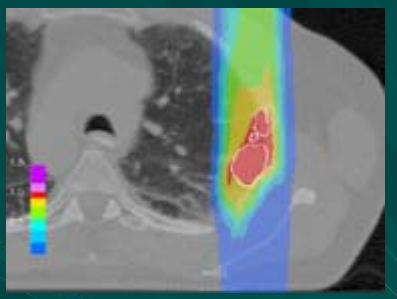


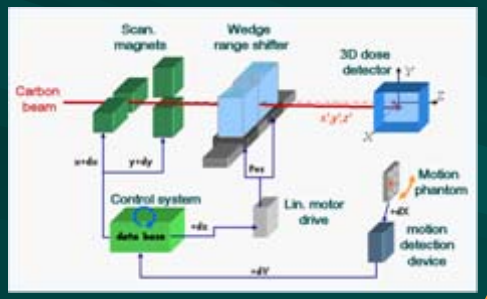


nominal dx, dy, dz

4D Treatment planning

Dose calc. in water (with recorded motion signal)





Beam tracking x' y' z'
(record motion signal)
dose measurement

Dose comparison

Dose calc. in CT (with recorded motion signal & beam tracking)

DVH

Summary

- From experience of beam tracking validation, possible beam tracking QA was presented
- Importance of time resolved data check system was pointed out for dynamic beam delivery QA
- Dosimetrical QA method :
  - dose measurement with beam tracking
  - dose calculation for the recorded motion
  - dose comparison
- Further cross check method to see actual beam tracking effect on CT was presented

Acknowledgement

Christoph Bert
Alexander Gemmel
Naved Chaudhri
Robert Lüchtenborg
Peter Steidl
Jan Trautmann
Daniel Richter
Sebastian Hild
Dirk Müssig
Anna Constantinescu

Gerhard Kraft
Eike Rietzel
Marco Durante
Michael Krämer
Dieter Schardt
and
Colleagues
at GSI & HIT

This work is in part funded by Siemens Healthcare.

Thank you
for your attention