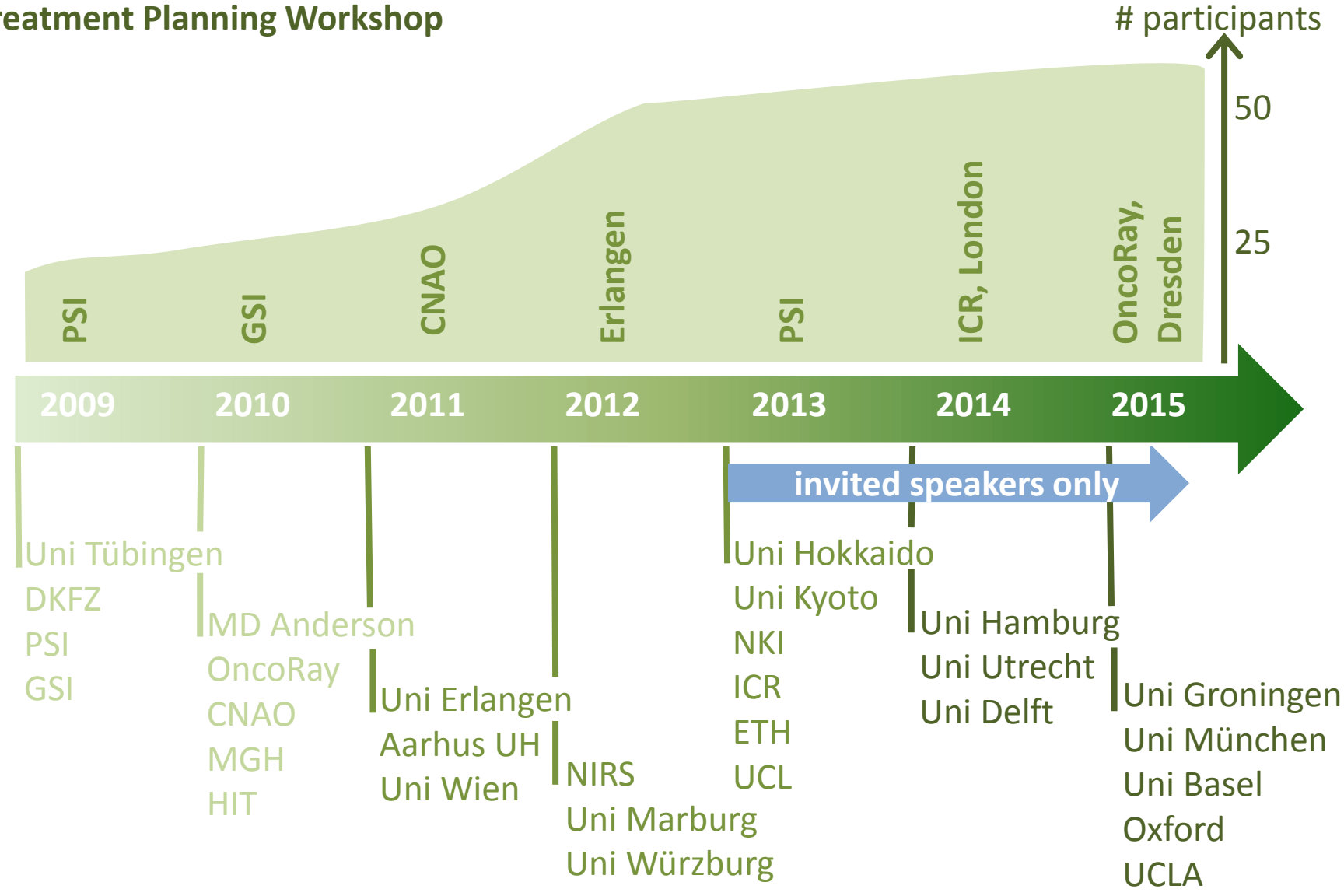
7 years 4D (Treatment Planning) Workshop

→Where we come from?
→Where we are heading to?

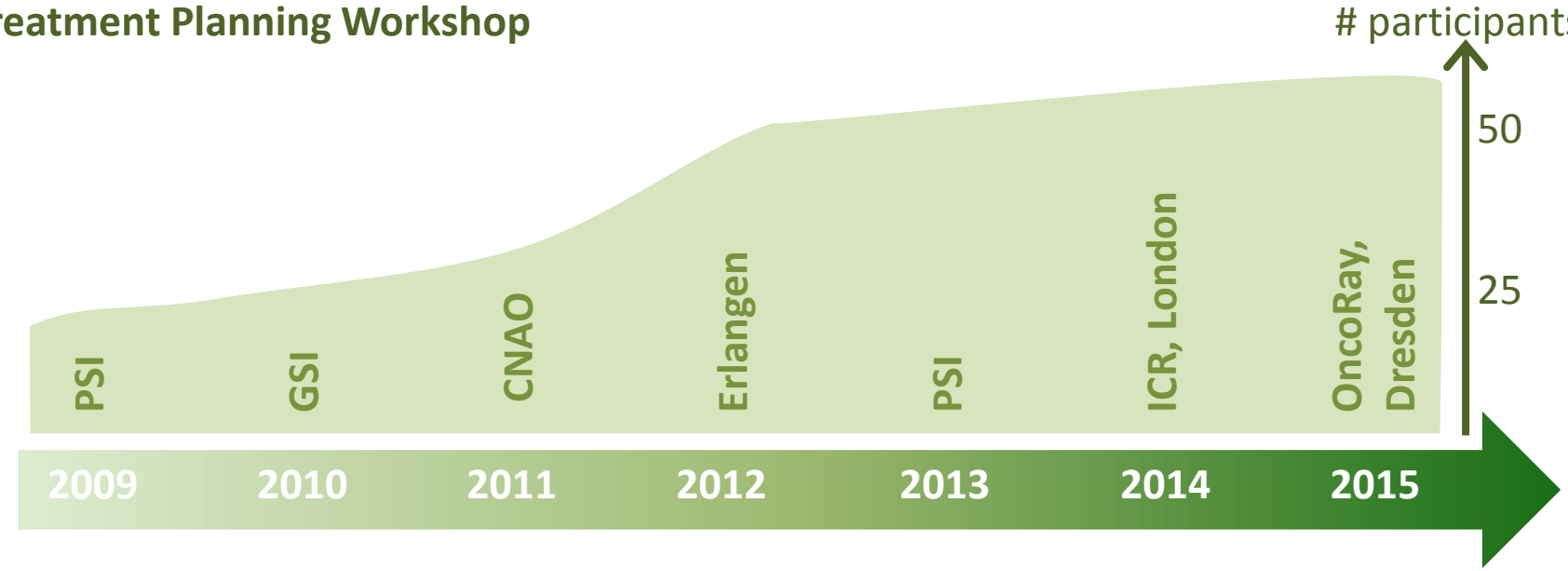
previous organizers:

Antje Knopf, Christoph Bert
Guido Baroni
Jamie McClelland
Christian Richter, Kristin Stützer

4D Treatment Planning Workshop



4D Treatment Planning Workshop



Participants: representatives of ~30 international institutes and ~10 industrial enterprises

Focus: 4D imaging, DIR, motion modelling, 4D treatment planning, motion mitigation techniques, 4D dosimetry, 4D phantoms

Impact: three publications / SGSMP Varian-Recognition-Award 2010

Knopf et al. ***Special Report: Workshop on 4D-treatment planning in actively scanned particle therapy ...*** (2010) Med. Phys.

Bert et al. ***Advances in 4D treatment planning for scanned particle beam therapy - report of dedicated WS*** (2013) Technol Cancer Res Treat.

Knopf et al. ***Challenges of radiotherapy: Report on the 4D TPWS 2013*** (2014) Phys Med.

Knopf et al. **Required transition from research to clinical application: report on the 4D TPWS 2014** (2015) submitted to Phys Med.

4D Treatment Planning Workshop

Where do we want to head to?

Participants: - grow and become professional or remain small and informal ?
- restrict number of participants ?
- allow representatives of industrial enterprises ?

Format: - invited speakers only?

Focus: - particle therapy or radiotherapy in general ?
- specific focus for next year ?

Location: ?

Report on a Survey on 12 Particle Therapy Centres

→How we treat moving targets?
→ How we want to treat moving targets?

Antje Knopf (RMH/ICR, London)

Juliane Daartz (MGH, Boston), Martijn Engelsman (HollandPTC, Delft), Christian Richter (OncoRay, Dresden)

starting point

Scanned particles for moving targets

Promise:

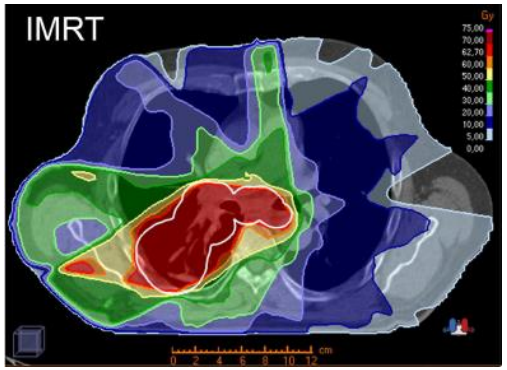
Reduction of toxicity → due to less integral dose

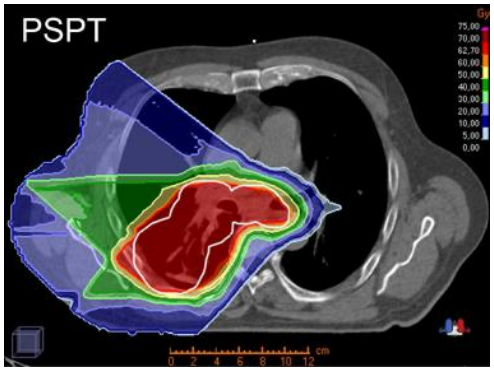
Improvement of local control → by allowing for higher doses

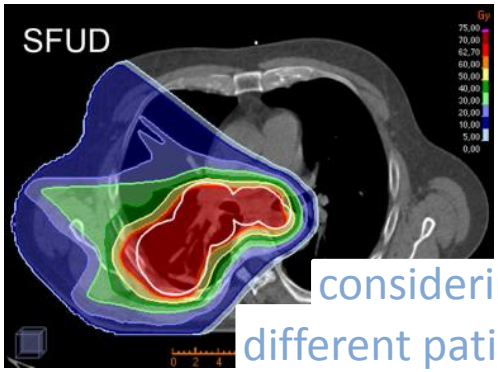
Challenges:

Range uncertainties → less conformal high dose region

Interplay effects → compromises local control







considering dynamics?

different patient / facility?

Current evidence: → based on PSPT – new centers will be scanning facilities

→ neglects dynamics – 4DTP is not commercially available

→ not conclusive – results are patient and facility specific

Philips et al. **Effects of respiratory motion on dose uniformity wit a charged particle scanning method (**1992) Med Phys Biol

Wink et al. **Particle therapy for non-small cell lung tumors: where do we stand? A systematic review…** (2014) Frontiers in Oncology

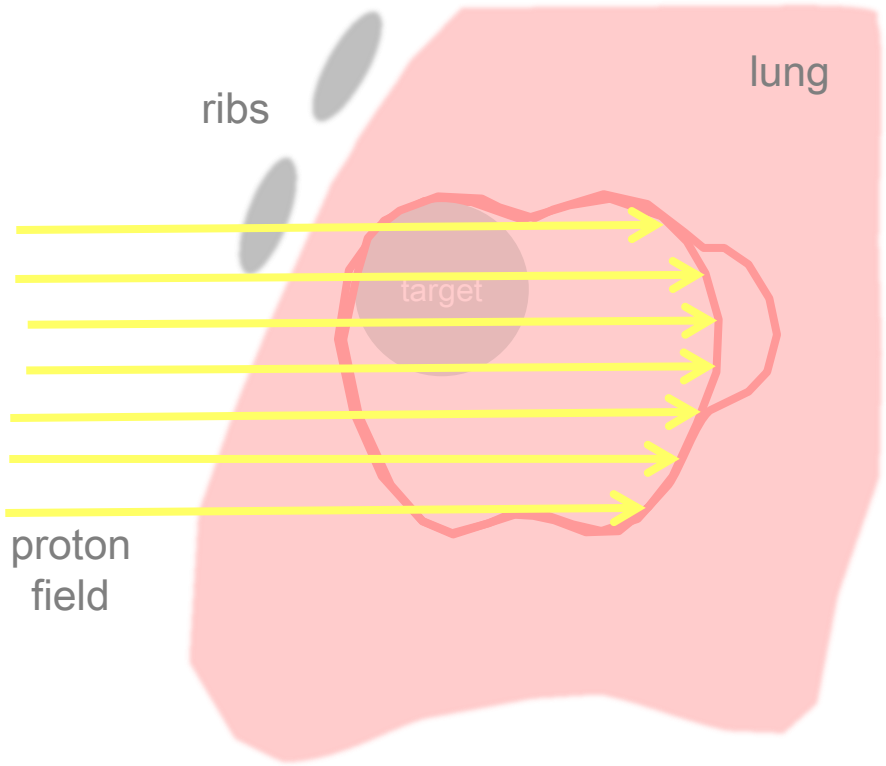
motion effects

target miss

- Treatment planning is usually done on a static representation (reference motion phase) of the patient
- Thus, for mobile targets the «planning situation» differs from the actual «delivery situation»
- If not all possible geometric locations of the target (all motion phases) are considered during treatment planning, target-dose-miss will occur

motion effects

target miss



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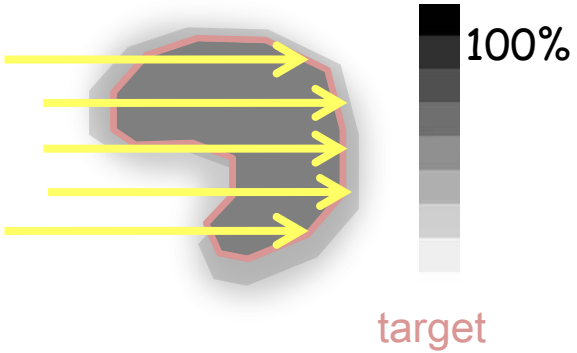
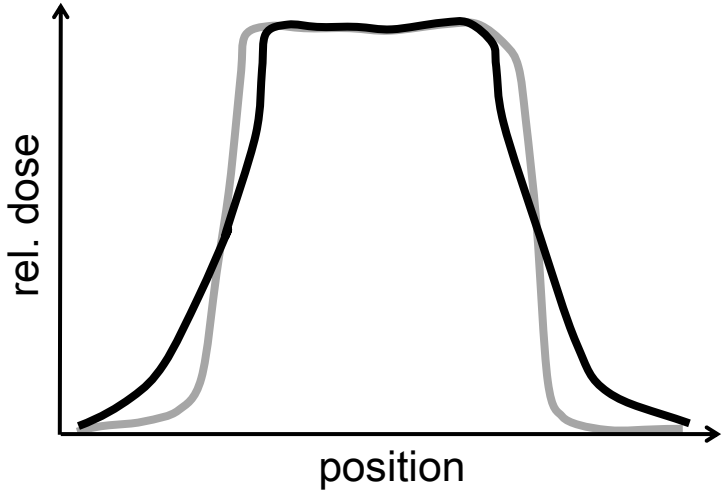
- If not all possible geometric locations of the target (all motion phases) are considered during treatment planning, target-dose-miss will occur
- Non-rigid geometry changes result in density changes within the beam path and will cause dose-miss at the distal edge of the target

motion effects

dose blurring

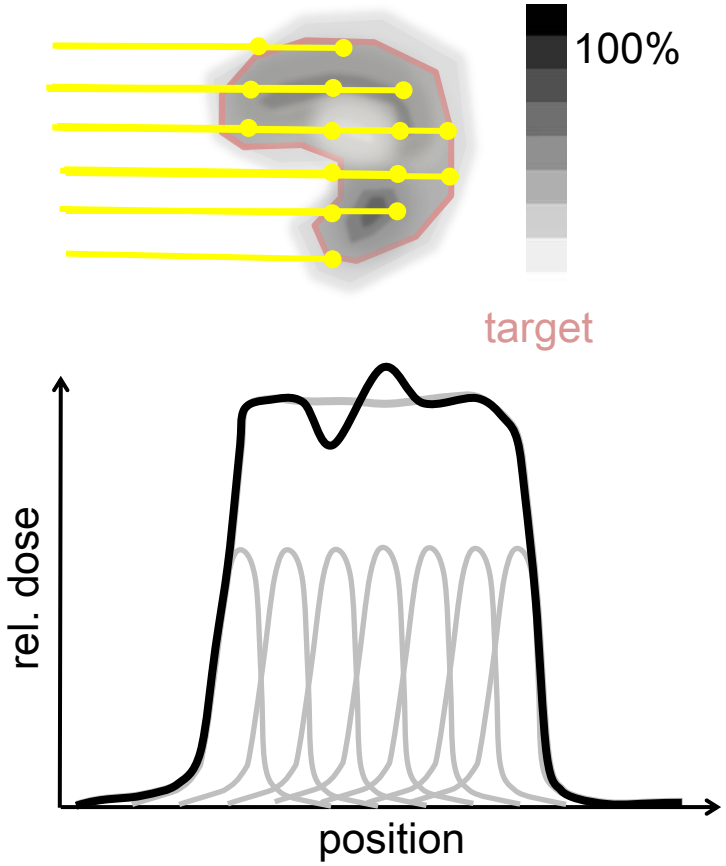




- If the target geometry moves with respect to a static dose delivery setup, the target-dose-distribution will smear out resulting in shallower dose gradients

motion effects

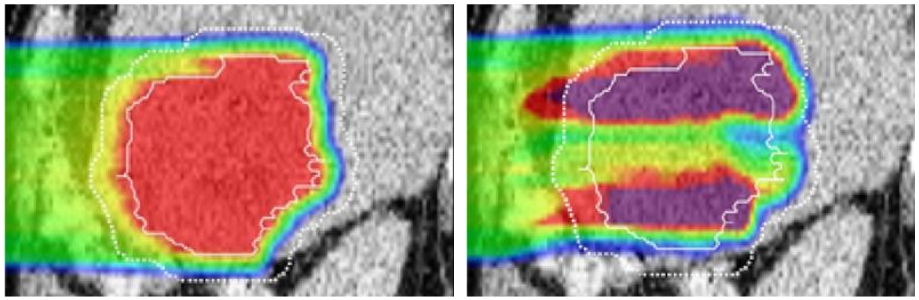
interplay effects



- An additional effect occurs for the treatment of moving targets with scanned particle beams
- Interplay effects happen due to two interfering timelines; the timeline of the patient motion and the treatment delivery timeline
- Dose contributions of single pencil beams are mis-positioned and result in dose inhomogeneities within the target area

motion effects

Motion results in a severe degradation of dose distributions:



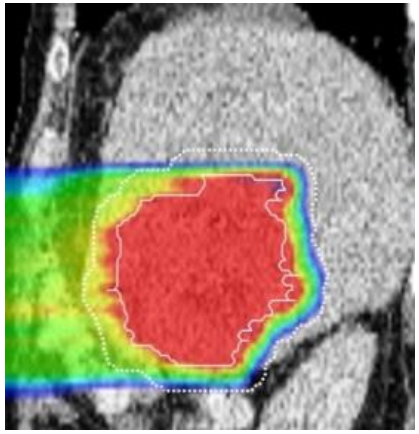
static dose distribution

dynamic dose calculation

Motion mitigation approaches have to be employed to gurantee clinically acceptable treatment plan quality

re-scanning
gating
gating + re-scanning
breath hold
slow tracking
tracking
re-tracking

delivery complexity
implementation effort



Zhang et al. **Online image guided tumour tracking with scanned proton beams: a comprehensive simulation study** (2014) Phys Med Biol
Knopf et al. **Scanned Proton RT for mobile targets - Systematic study on the need and effectiveness of re-scanning…** (2011) Phys Med Biol
Bernatowicz et al. **Comparative study of layered and volumetric rescanning for different scanning speeds…** (2013) Phys Med Biol

treatment approaches

Two ways to approach the motion challenge with scanned particle beams:

Conservative → simulate a quasi static situation

- only apply protons to patients that move little or where motion can be supressed
- account for uncertainty by margins and statistics

→ most robust approach

Progressive → monitor and control the mobile situation

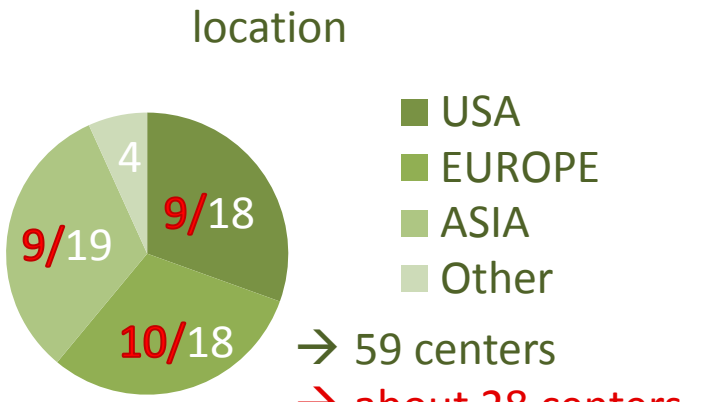
- careful patient selection and motion study prior treatment
- identification of a patient specific treatment protocol using the full potential of PBS
- online motion monitoring to assure a safe treatment delivery

→ approach where patient will maximaly benefit

What do currently treating centers choose to do?

present landscape

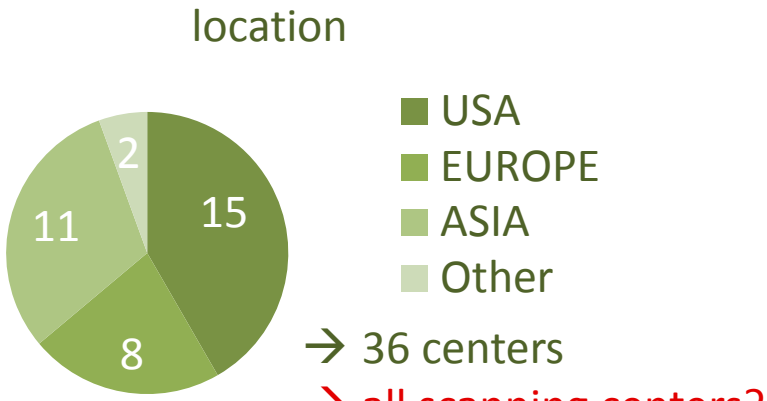
Currently in operation:



→ 59 centers

→ about 28 centers treat with scanned beams

Currently under construction:



→ 36 centers

→ all scanning centers?

Proton therapy vendors

IBA	Pronova
Varian Medical Systems	Mevion
Hitachi	Procure
Sumitomo	ProTom
(Siemens)	Optivus

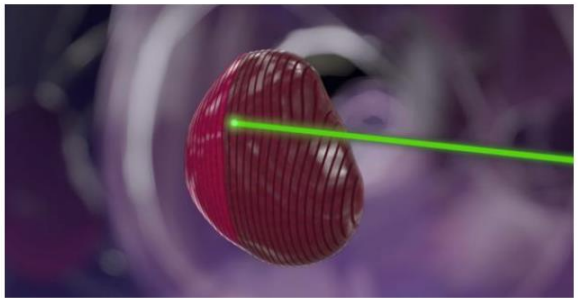
PTCOG webpage

present landscape

iba | Proton Therapy

18th FEBRUARY , 2015 - Clinical Technology

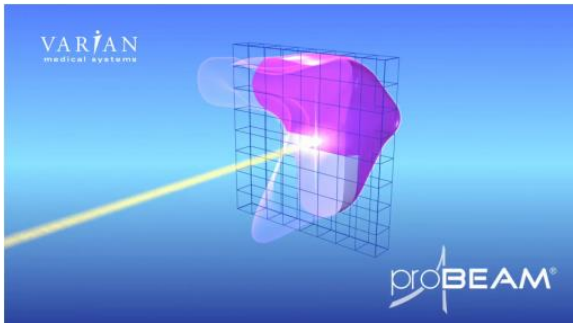
PENCIL BEAM SCANNING (PBS): PROGRESS TO DATE



… **42 PBS rooms accepted** by the end of 2015, and more than 30 are expected to be treating by then.

… Another feature that already has and will further enhance the performance of IBA's PBS installations is the addition of **in-layer and volumetric repainting**. Together with **gating**, this feature addresses the issue of motion management.

VARIAN medical systems



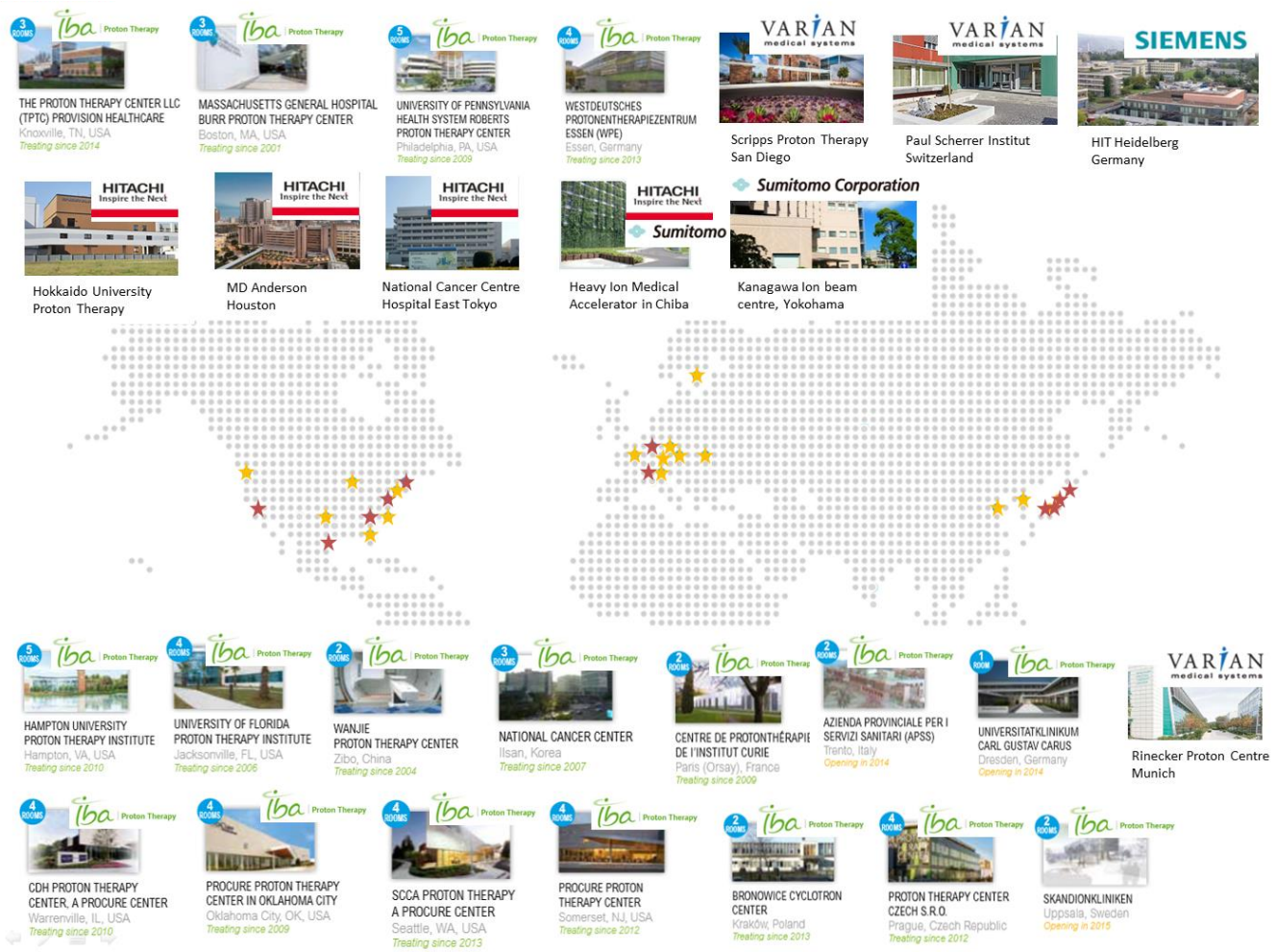
… Varian stands apart from other proton therapy systems in that it uses **pencil beam scanning exclusively**.

… scanning … increases the risk of target misses due to organ motion. This risk can be mitigated by **image-guidance techniques**. Multiple **re-paintings** can also compensate for organ motion by effectively smearing out the dose.

present landscape

Map of 27 scanning particle centers in operation according to the vendors:

★ 12 contacted centers
→ 11 treat (or will treat soon) moving targets



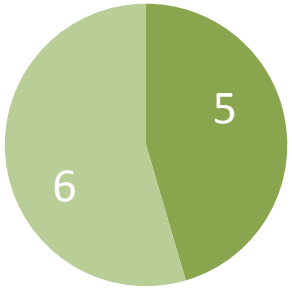
survey

report on 11 centers (9 proton center, 1 carbon center, 1 proton + carbon center):

location

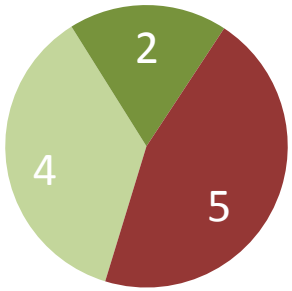
USA
EUROPE
ASIA

delivery technique



scanning only
scanning & scattering

treatment of moving targets



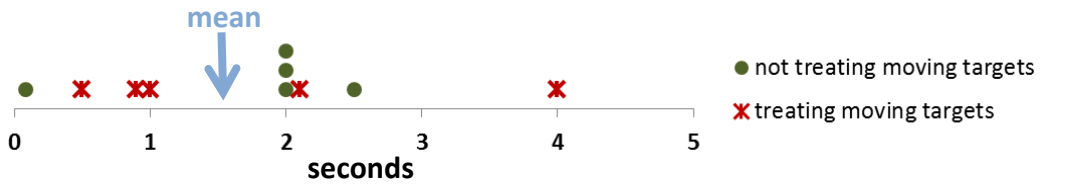
will treat moving targets within the next 1-2 yeras
will only treat moving targets in the far future
treat moving targets currently

survey

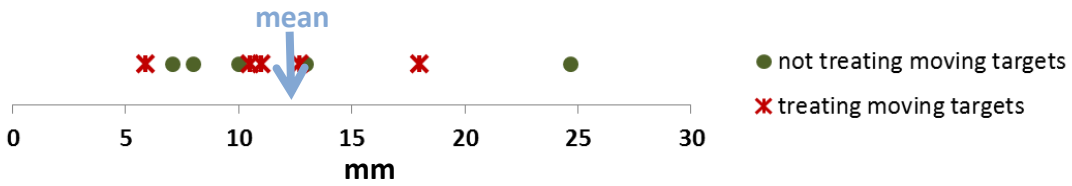
report on 11 centers:

scanning characteristics

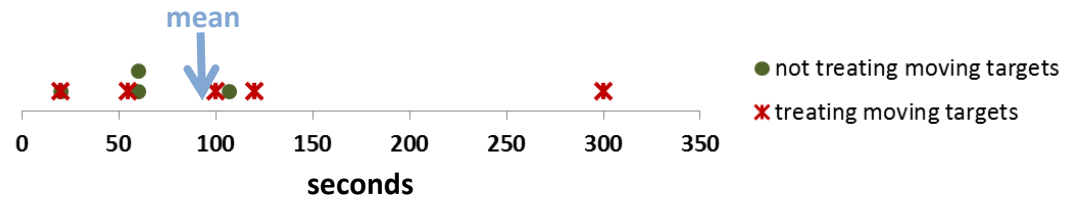
→ **energy switching time**



→ **spot size**
for a 140 MEV beam at iso-centre in air



→ **delivery time**
2Gy to a 10x10x10cm cube at 15 cm depth



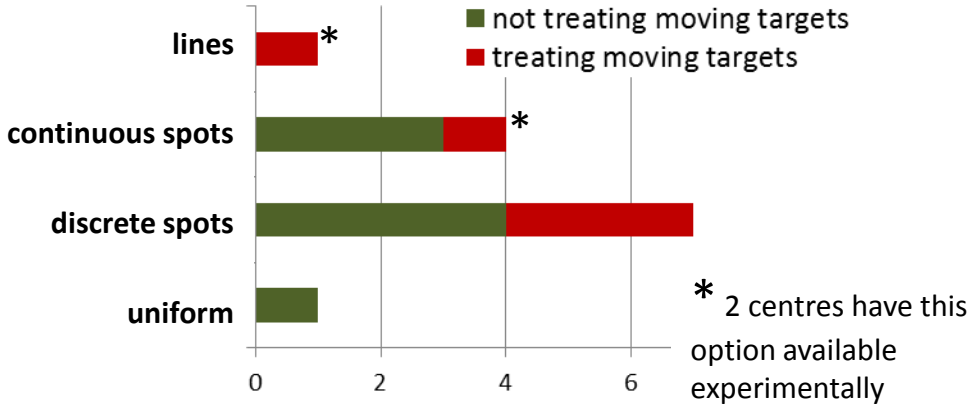
Centres that already treat moving targets don't show any particular characteristics.

survey

report on 11 centers:

scanning characteristics

→ scanning mode



→ rescanning capability

→ Technically most of he centres are able to perform volumetric or layered rescanning in a scaled or iso-layered way.

→ Five centres have a “rescanned delivery” clinically commissioned.

→ Some centres stated they are not sure yet which rescanning mode is most beneficial.

survey

"Scanning seems to be very sensitive to motion. Thus, would it not be more robust and beneficial to treat moving targets with passively scattered particles ?"

General opinion: "No need for passively scattered treatments."

"Scanned beams produce much better treatment plans and are more flexible to perform novel motion mitigation techniques."

"No need for passive techniques if scanning is fast enough and proper monitoring and motion mitigation is available."

"Passive treatments may be an intermediate solution to avoid interplay"

"In some cases passively scattered protons might produce more robust treatments"

survey

We should treat moving targets with scanned particles because it will result in

- plans with better conformity
- less neutron dose
- more possibilities to adapt plans
- higher treatment flexibility

"So what is the best approach?"

- breath hold
- gating
- very fast scanning / rescanning
- (marker less) tracking
- synchronized delivery
- combinations of motion mitigation techniques
- image guided adaptive radiation therapy
- 4D optimization (beam angle selection, spot sequence, spot size)
- robust planning

survey

"All of them or is there a recipe? What does the five centres say that are already treating?"

General answer: "No recipe."

"We only treat if motion is restricted!"

" We use gating, rescanning and/or robust planning."

"We believe there is no "best approach". We are hoping that with experience and careful evaluation, it will be possible to identify groups of patients that are best treated with a certain method."

survey

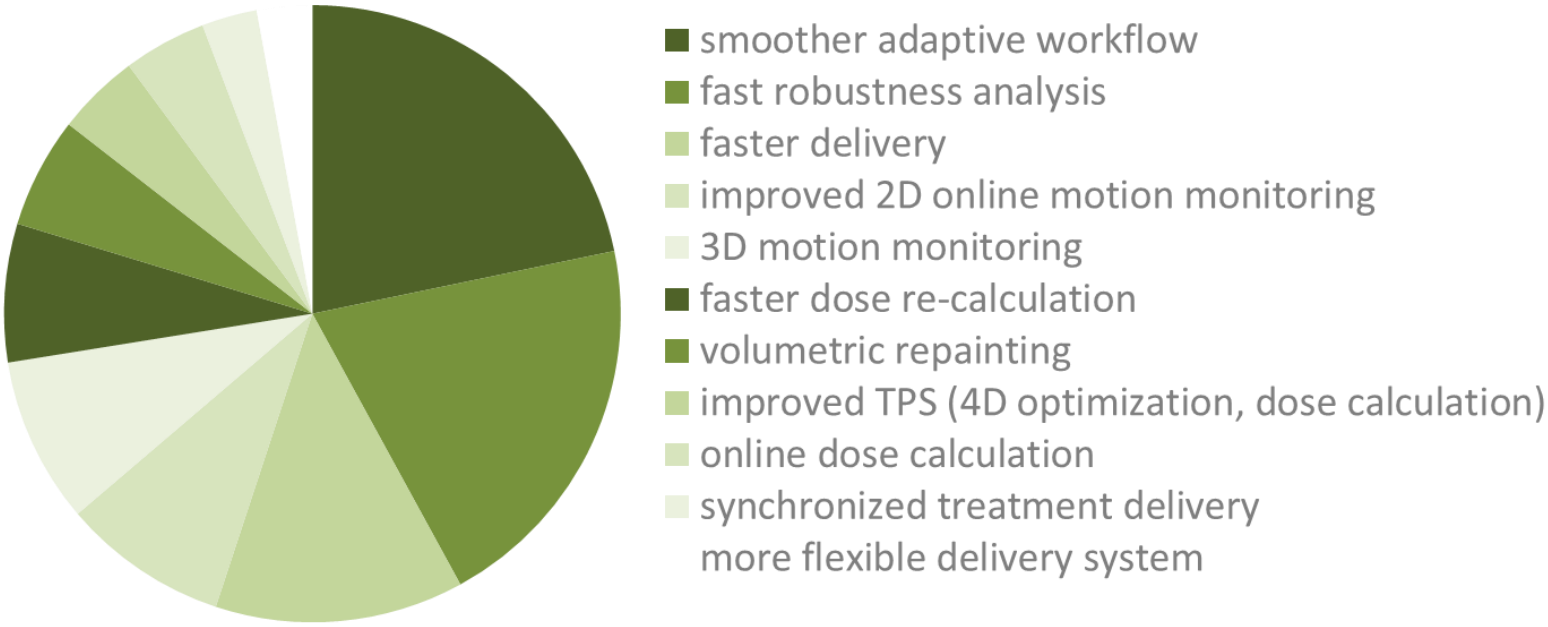
"Hmm, sound complicated? How about treatment planning? How easy is it to perform 4D planning?"

"Easy???"

- There are 8 different treatment planning system used among the 11 centres.
- Most of them miss any 4D capability.
- The possibility to calculate cumulative dose was mentioned as "strongly desired" by most centres.

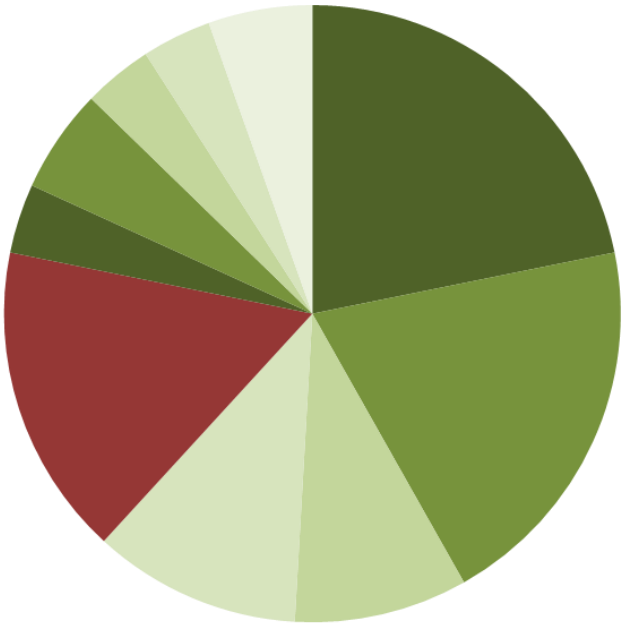
survey

"What are the most needed developments?"



survey

"What are the most needed developments?"



take home message / discussion

"There is still a lot to do!"

Two ways to approach the motion challenge with scanned particle beams:

Conservative → simulate a quasi static situation

→ will not use the full potential of protons

Progressive → monitor and control the mobile situation

→ patient will maximaly benefit

Proton therapy is neither simpler nor less expensive than its photon sibling, thus when used, it should be employed to its optimum!?

take home message / discussion

Points to discuss during the workshop:

- Are we as a community convinced that **patients with moving targets benefit** from a treatment with scanned particle beams?
- Should each new facility continue follow their **own trial an fail error route** when treating moving targets with scanned particle beams?
- Would we be able to establish **guidlines**?
- Would we be able to estabish an **inter-institutional robustness analysis tool** for the treatment of moving targets with scanned particle beams?
- How can we motivate commercial treatment planning system vendors **to implement more 4D capabilities**?

Thanks for your attention and thanks to eveybody helping collecting and sharing the information for the survey!!!