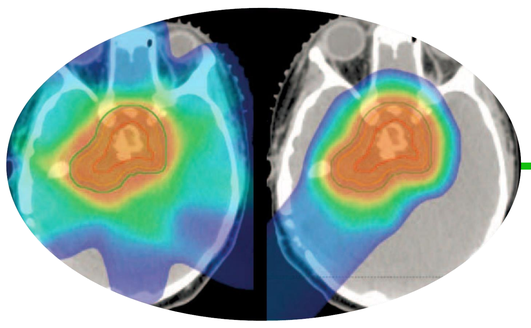
Range Verification in Proton Therapy

J. Petzoldt[1], Y. Xie[2], G. Janssens[1], L. Hotoiu[1], J. Smeets[1], F. Vander Stappen[1], K. Teo[2], D. Prieels[1]

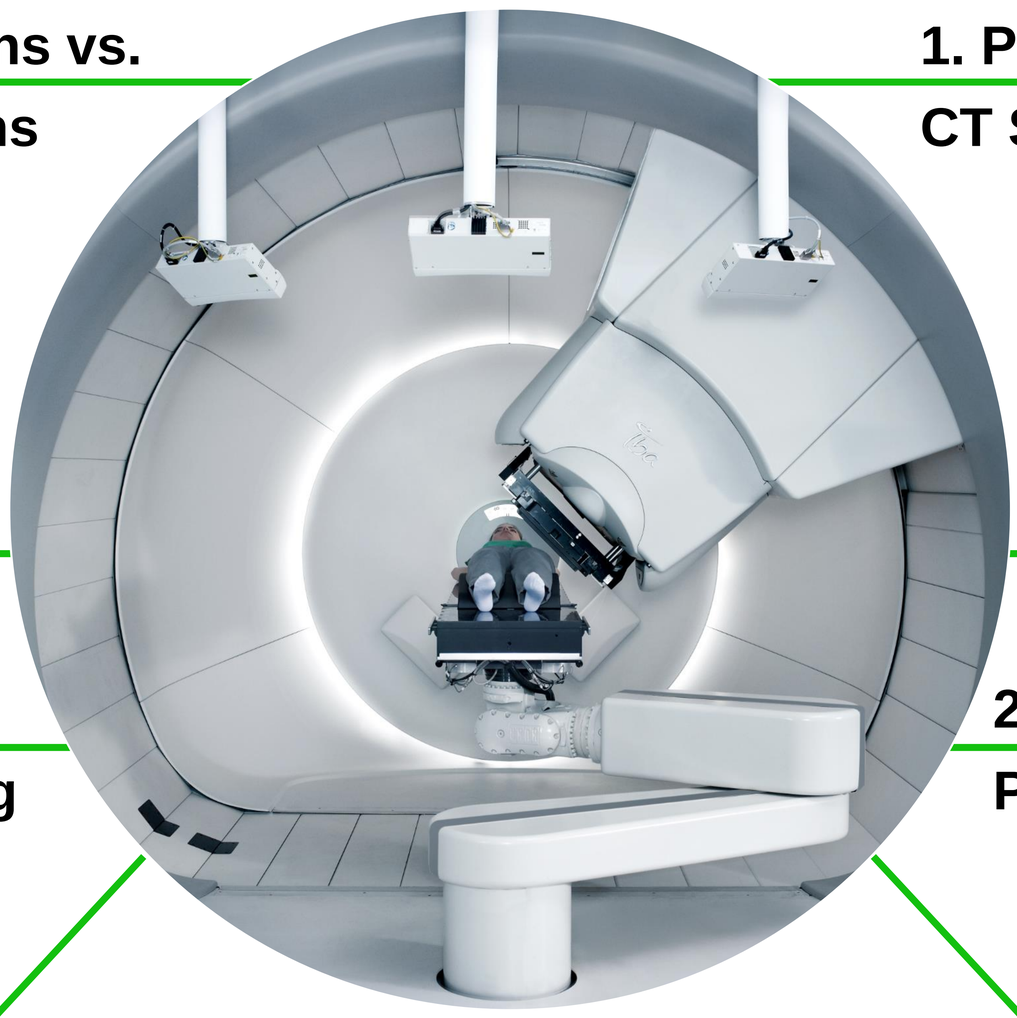
[1]*Ion Beam Applications SA, Louvain-la-Neuve, Belgium,* [2]*University of Pennsylvania, Philadelphia, USA*

Proton Therapy in a Nutshell



Photons vs. Protons

- Photons have exponential decrease of dose deposition
- **Protons** have a **limited range** and **stop inside** the patient
- Highest dose in Bragg peak



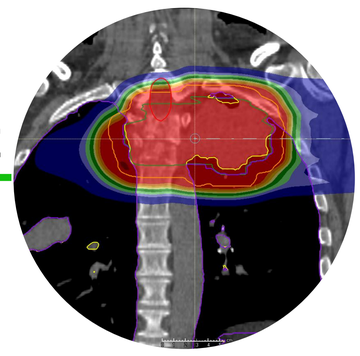
1. Planning CT Scan

- Computed Tomography (CT) X-ray scan of the patient
- Physician marks tumor area and prescribes treatment / dose

3. Patient Positioning

- Patient is positioned using a laser system
- Individual molds or masks for optimal patient position
- Treatment position is verified using X-rays

2. Treatment Planning



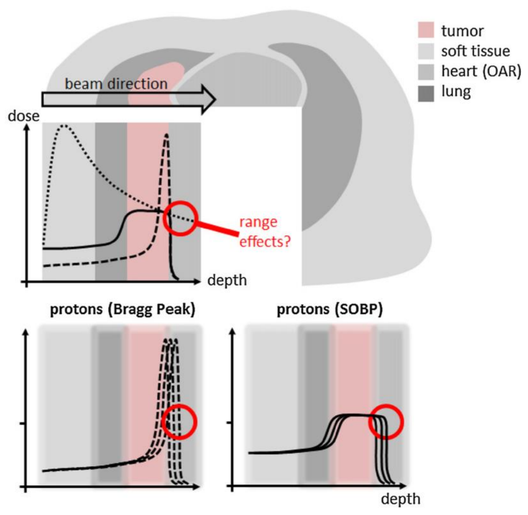
- Physicist plans **proton beams** according to the prescribed dose
- Limit dose to healthy tissue and spare organs at risk

4. Patient Irradiation

- Proton pencil beam scans the tumor volume in 3D
- Actual irradiation time of few minutes
- Around 30 treatment days to deliver the prescribed dose

Range Uncertainties

- Range uncertainties have a strong effect on protons
- Uncertainties occur in the treatment course:
  - Conversion from CT image to treatment plan
  - Organ motion
  - Breathing
  - Anatomy change



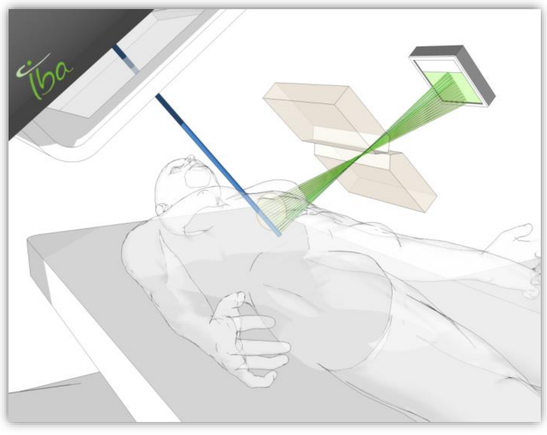
Effect of range uncertainties [1]

→ **Measure proton range during treatment!**

Prompt Gamma Range Verification

As protons stop in the patient, other signatures have to be used!

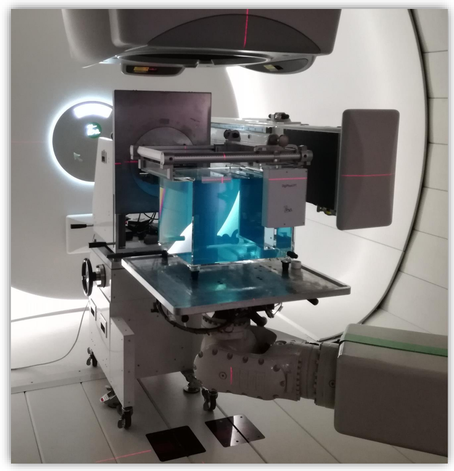
- **Prompt Gamma Rays** are produced during the treatment, have a strong correlation to the dose, and leave the patient
- The **prompt gamma camera** prototype measures the spatial emission and detects range variations [2]
- **First patient** data [3,4]

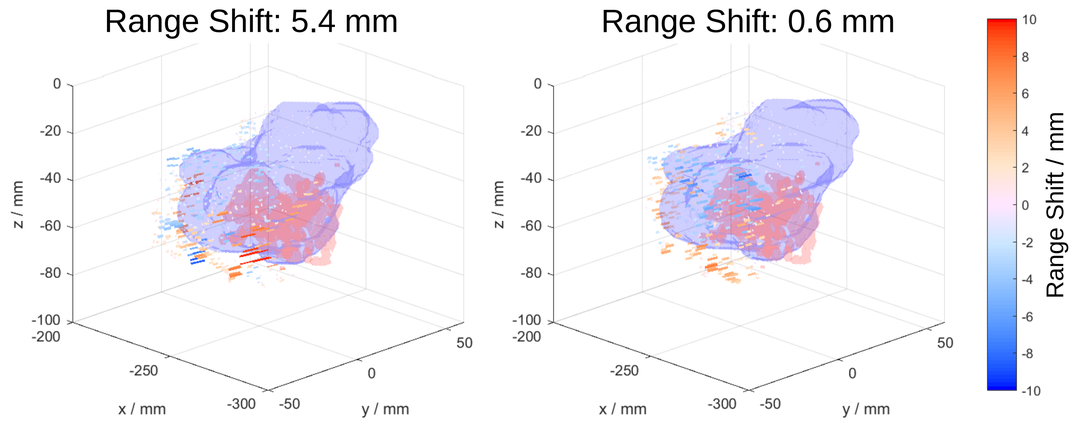


Research within OMA Project

Aim: Improve the prompt gamma camera and make it more accessible for patient treatment!

- Calibration measurements to increase accuracy of camera
- Better mechanical integration into treatment room → more patient data can be acquired
- Develop algorithms and software tools for patient data analysis
- Develop algorithms to identify the error scenario





Range shift for individual spots based on prompt gamma measurements for a brain tumor treatment. Left: Over-range visible due to an anatomy change. Right: No over-range visible due to updated treatment plan based on new CT image. Unpublished data.

[1] A. Knopf et al. Phys Med Biol, 58(15):R131, 2013.
[2] J. Smeets et al. Phys Med Biol, 57(11):3371, 2012.
[3] C. Richter et al. Radiother Oncol, 118(2):232, 2016.
[4] Y. Xie et al. Int J Radiat Oncol Biol Phys, 99(1):210, 2017.

Contact: johannes.petzoldt@iba-group.com

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