Range Verification in Proton Therapy

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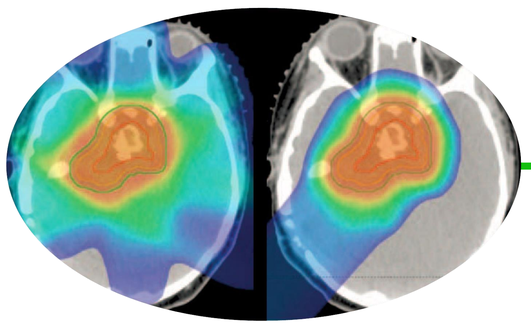
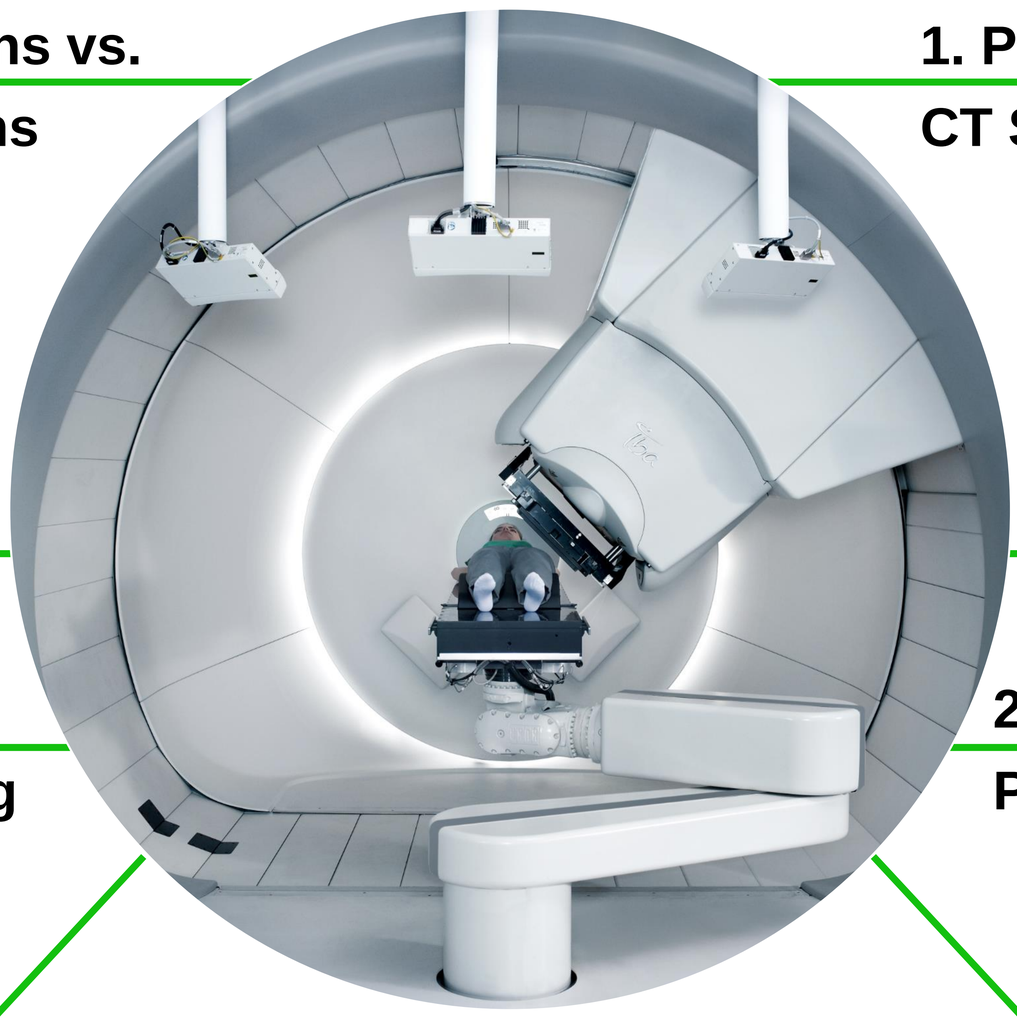
Proton Therapy in a Nutshell



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



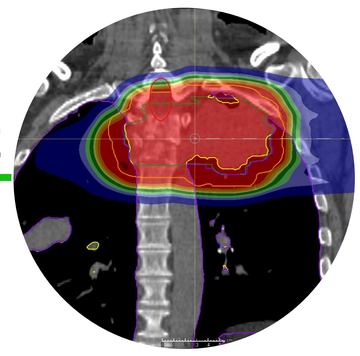
1. Planning CT Scan

- 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



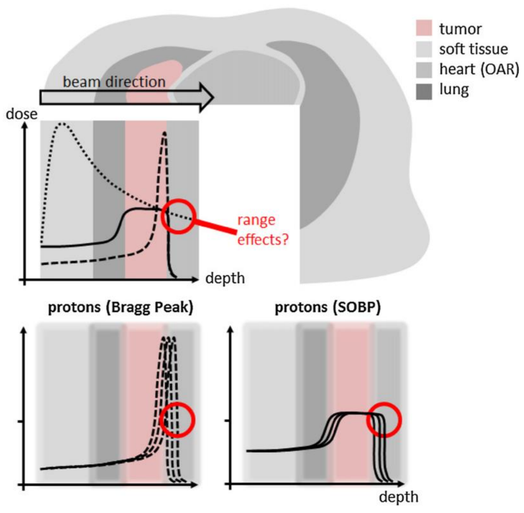
- Physicist plans **proton beams** according to the prescribed dose
- Limit dose to healthy tissue and spare organs at risk

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



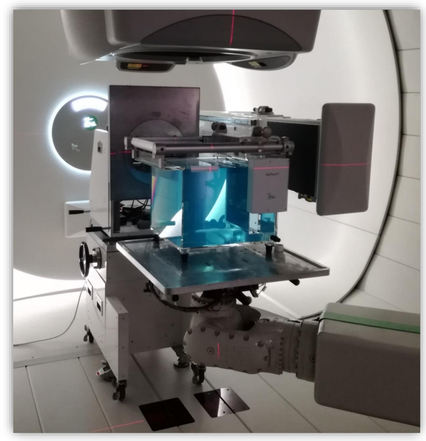
Effect of range uncertainties [1]

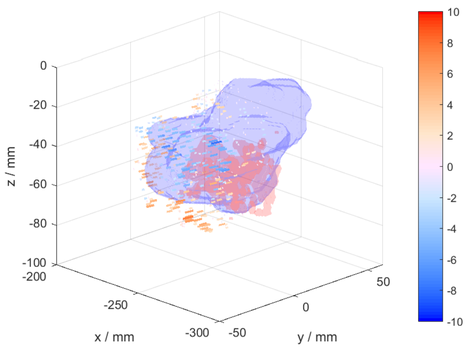
→ **Measure proton range during treatment**

Research within OMA Project

Aim: Improve the prompt gamma camera prototype and its usage for patient treatment

- Benchmark measurements to increase accuracy of camera and fine-tune PG model
  - Development of geometrical correction model [5]
  - Improvement of range-retrieval
- Prototype to position the PG camera under the couch
  - Docking system for **high precision**, **fast** and **reproducible** positioning
  - Position calibration using X-rays
  - Validation in beam measurements
  - Overall accuracy **< 1mm (2σ)**
  - No impact on clinical workflow
  - Successful use within **clinical study**
- 3D visualization of PG data
  - Identify regions of similar range shift behaviour
  - Range shifts overlaid with anatomy

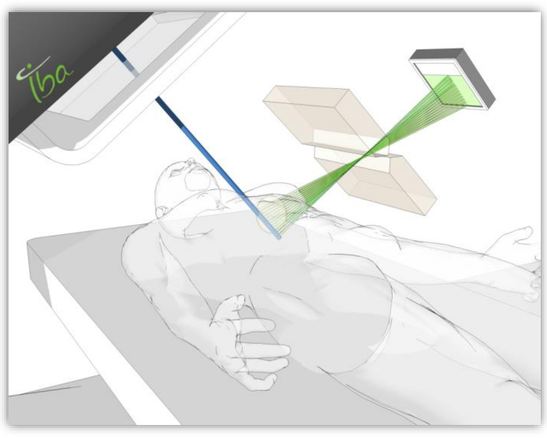




Prompt Gamma Range Verification

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]



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