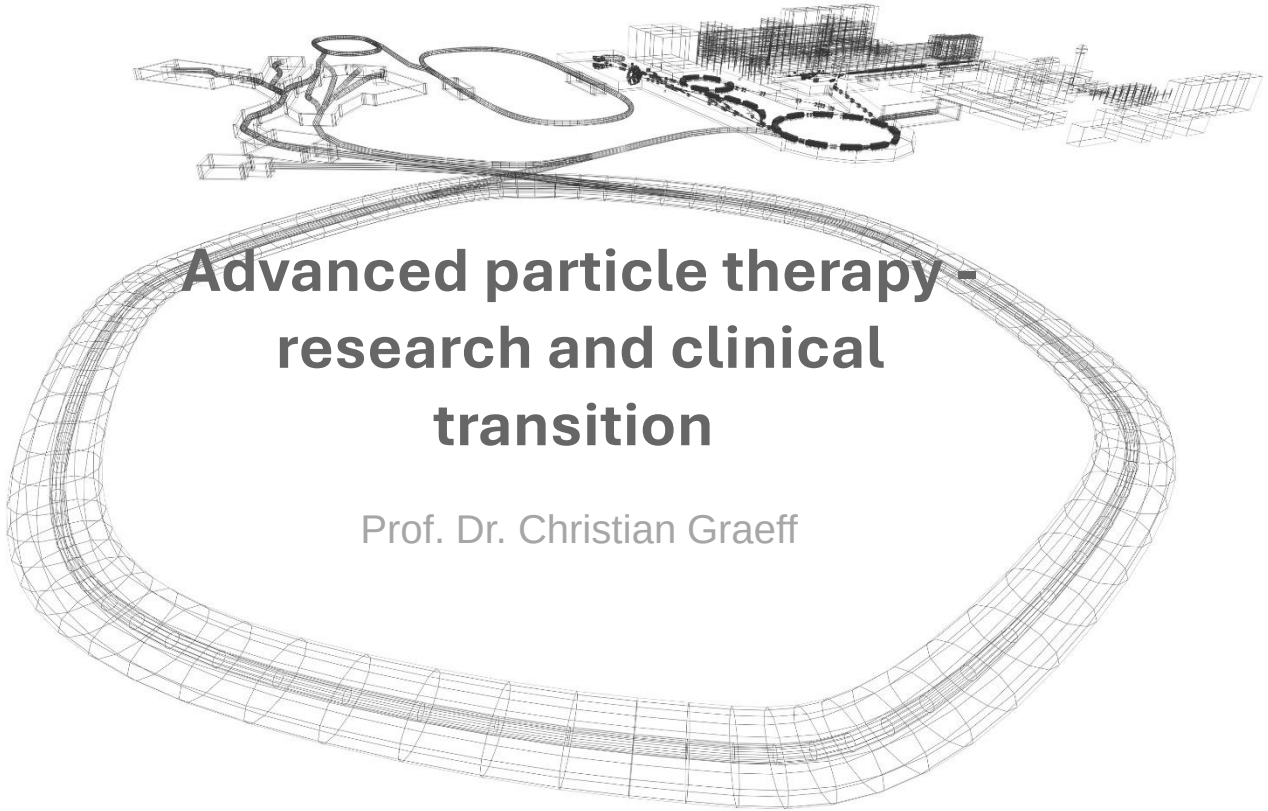
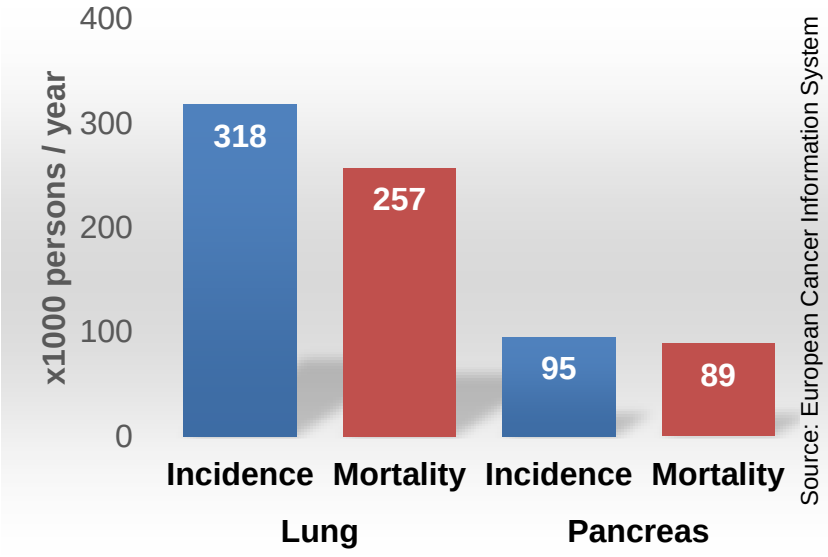


Advanced particle therapy - research and clinical transition

Prof. Dr. Christian Graeff

Current cancer therapy fails for large patient cohorts

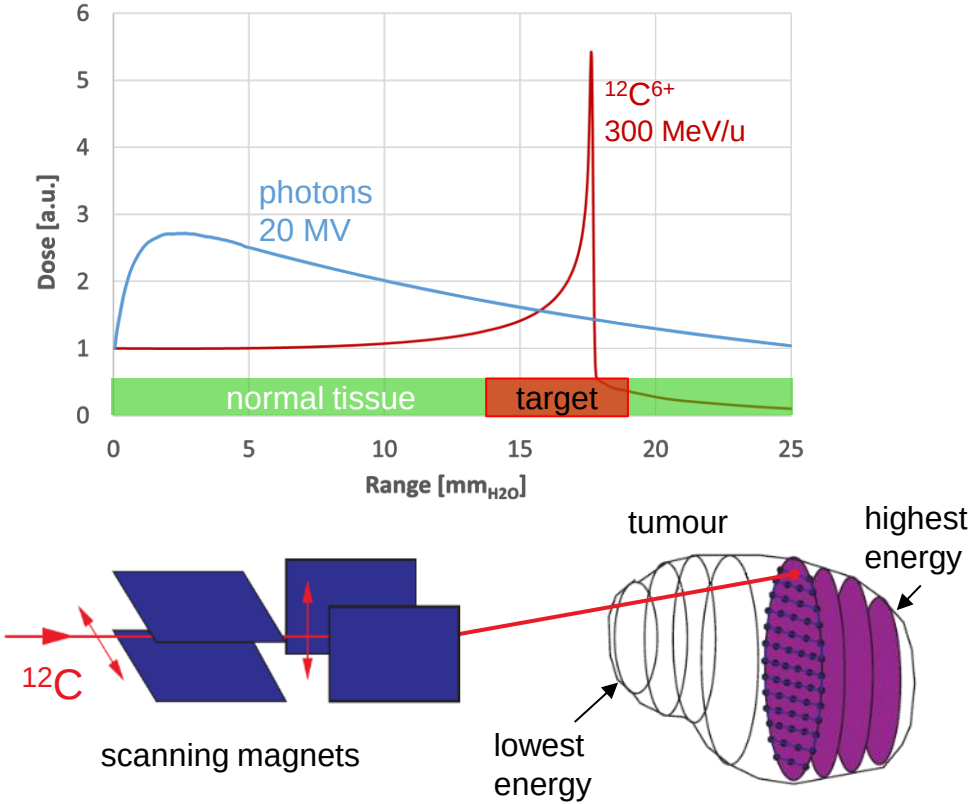


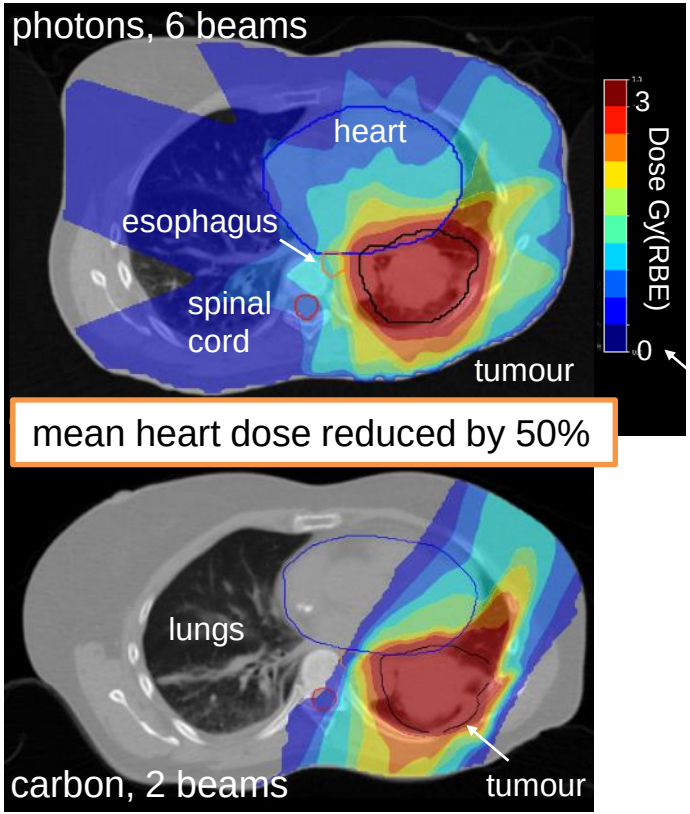
15% of all cases, 27% of all deaths

- Radiotherapy is standard of care for the primary tumor,
  but is currently insufficient
- Abdominal & thoracic tumours are
  - deep inside the patient
  - close to critical structures (heart, colon)
  - moving due to respiration
- Conventional radiotherapy cannot deliver sufficient dose without causing severe side-effects*
- Particle therapy is limited by targt uncertainty in

*Bradley et al. Lancet Oncol 2015

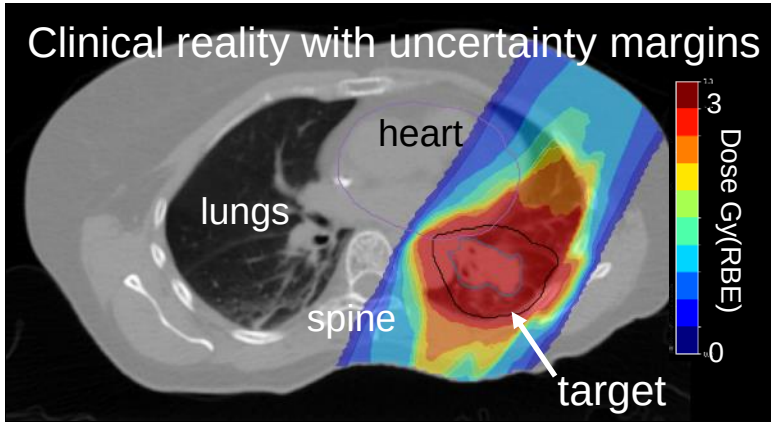
Ion beam therapy advantage

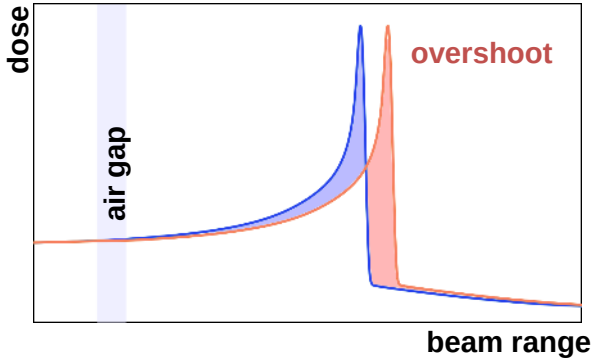


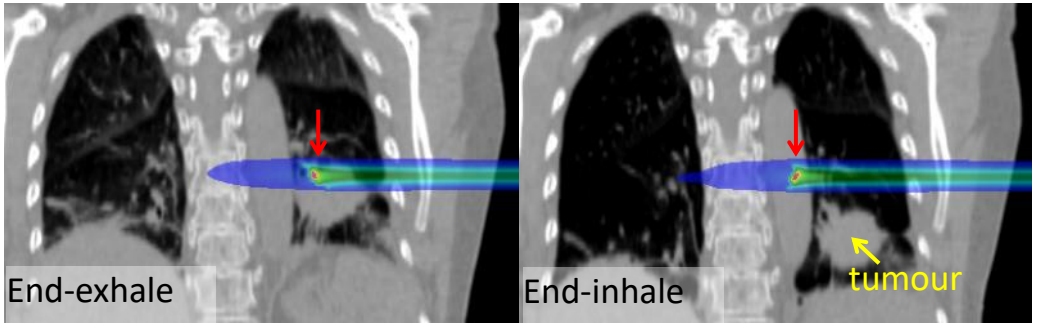


Ion beam therapy challenge: Range uncertainty

- Sharp dose gradients require exact beam range information
  - Hard to obtain inside patients
- Uncertainty drastically increased in the presence of anatomical motion
- ➢ More dose to ensure target coverage







The vision:
Precise and affordable therapy

Funded by the European Union

European Research Council
Established by the European Commission

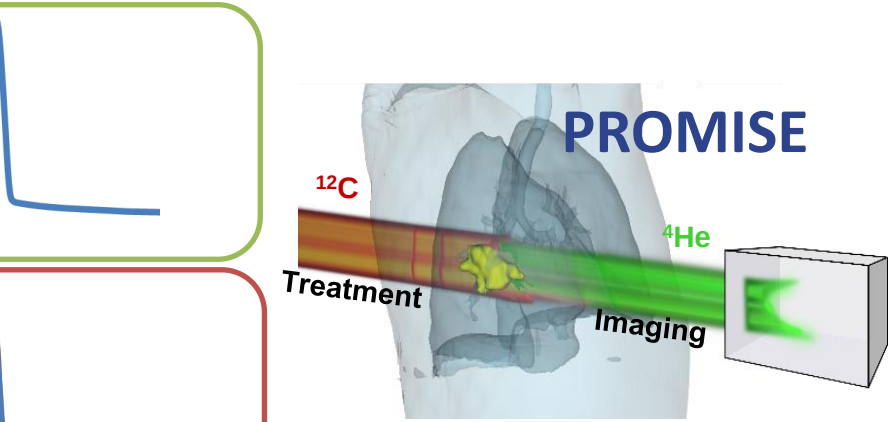
Particle therapy is able to deliver
very precise dose

to deep seated targets

But in clinical reality is still
not fully exploited

Concurrent imaging against **range uncertainty**

Particle therapy is also very expensive,
cost reduction is essential for wider use:
Explore upright patient treatment

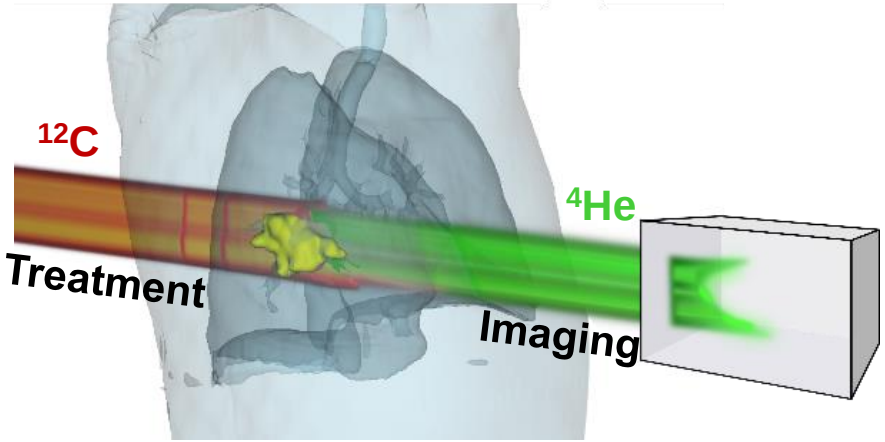


UPLIFT

MSCA DN, Coordinator GSI / Graeff

PROMISE:
Mixed beams for image-guided particle therapy

- He and C have the same behavior in the accelerator, but Helium has triple the range of Carbon: concurrent therapy and imaging beams



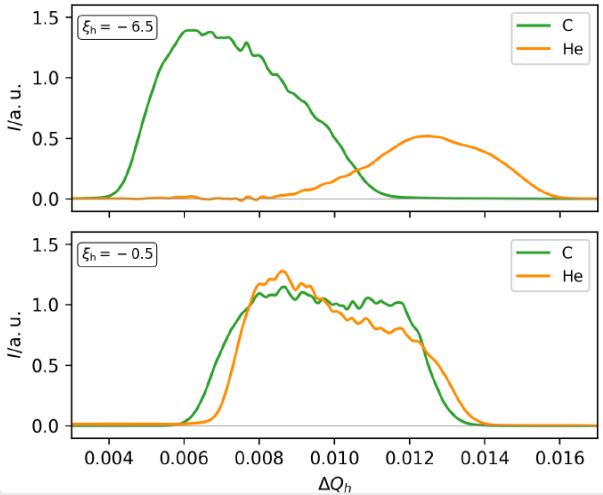
- Control beam delivery through online portal beam range imaging
- Drastic reduction of uncertainty for precise conformal target dose

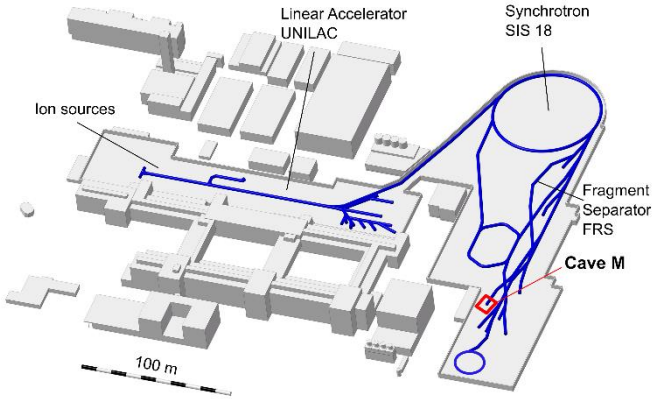
Mixed beam production: 12C3+ and 4He+

- ECR ion source using methane + 4He support gas
  - extraction target: 150 eμA C3+ and 5 eμA He+ (10% particles)
- common acceleration in UNILAC and SIS18: 225 MeV/u, ~5 107 ions / s
- extraction is challenged by 0.065% higher mass:charge of helium
  - horizontal chromaticity adapted for tune-sweep and RF knockout extraction

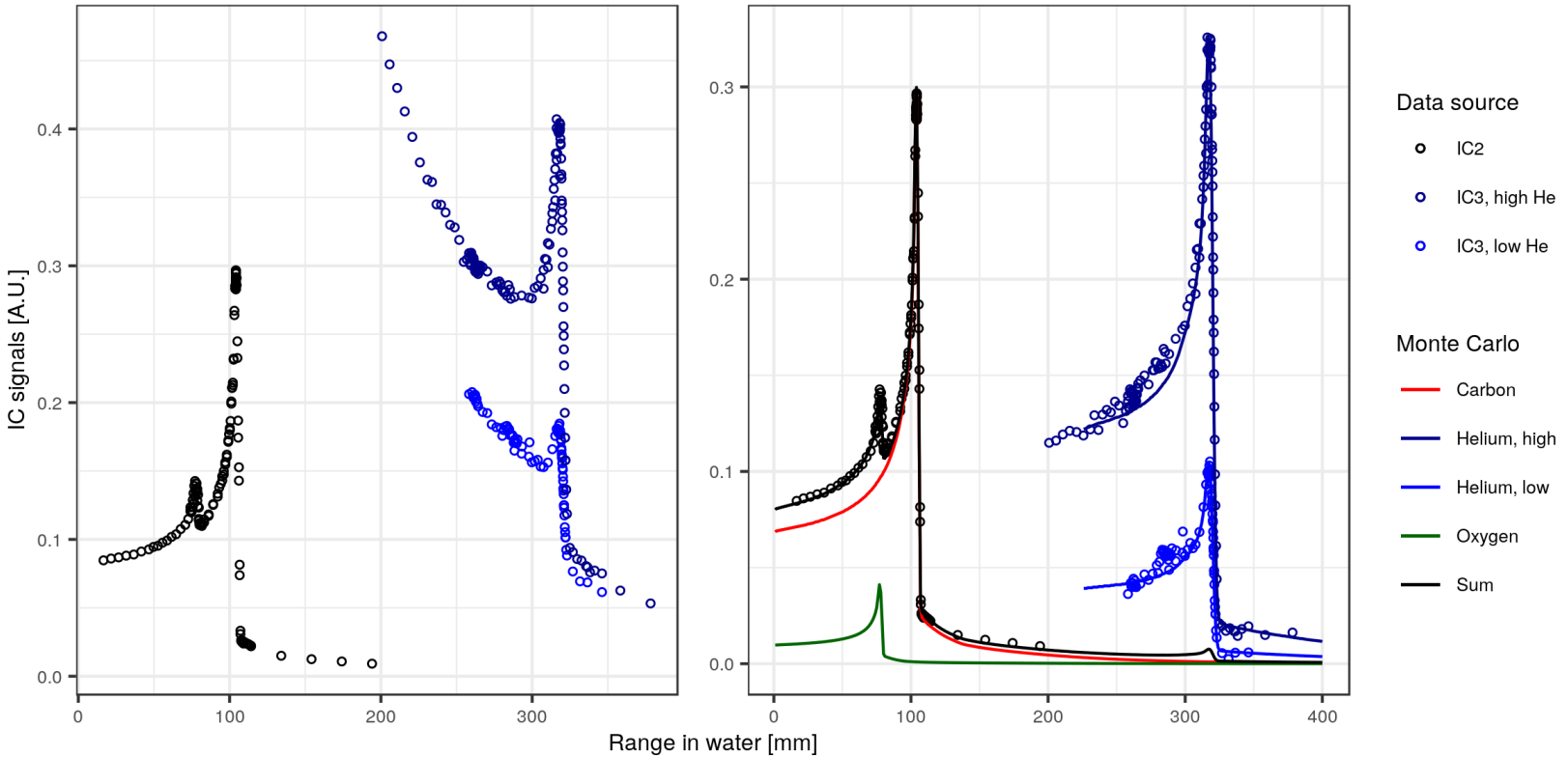
He separated
at natural chromaticity

He and C concurrent
at adapted chromaticity

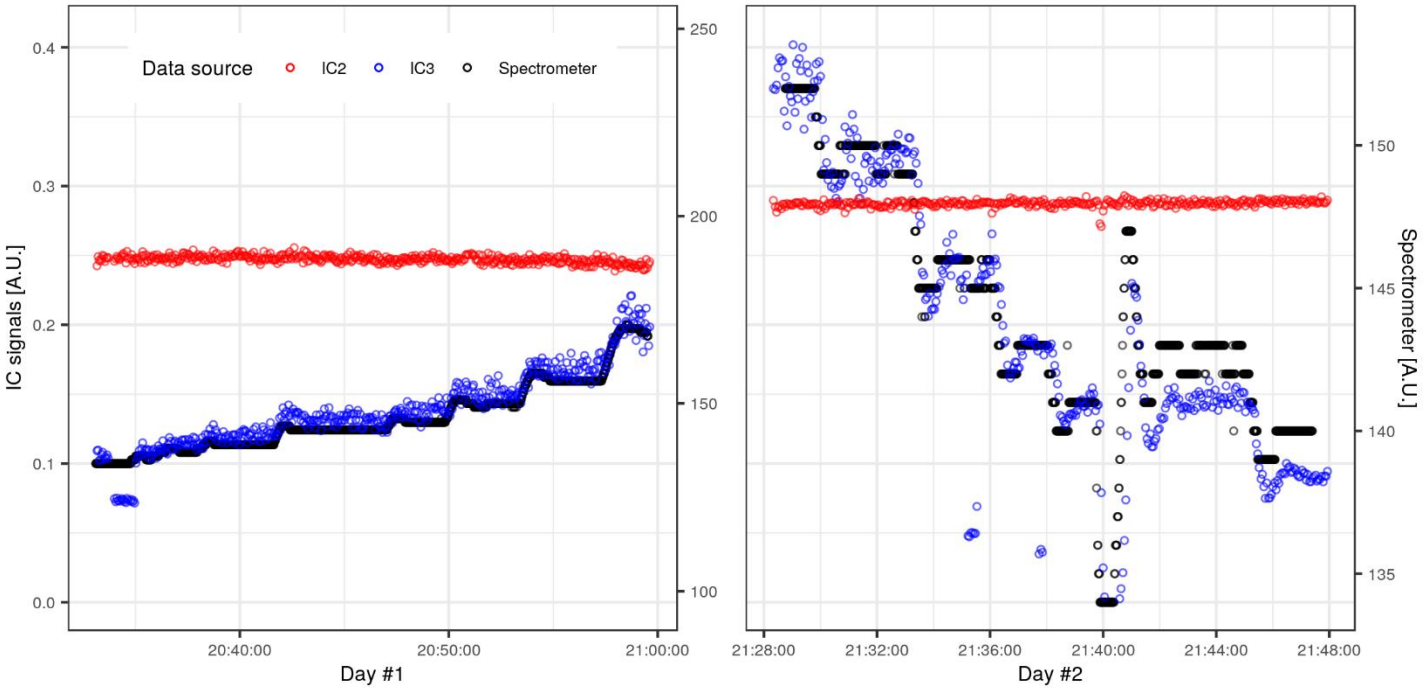




Word-first mixed beam measured in Cave M



Controllable Helium concentration

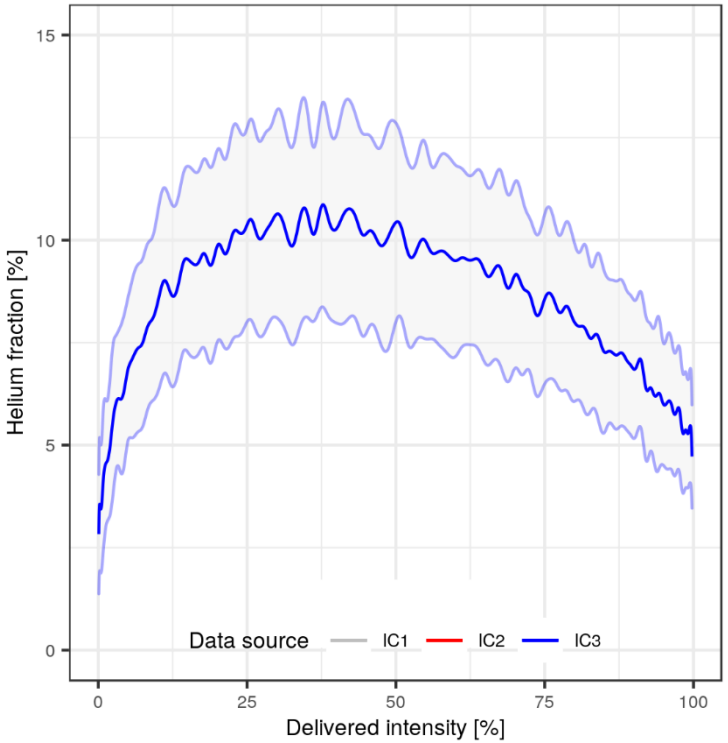


- Variation of Helium injection into the ion source

… stable during extraction

- Helium concentration is >5% for entire spill
- Measurable signal at therapy intensities

- Planned improvement in 2025: intensity-controlled extraction

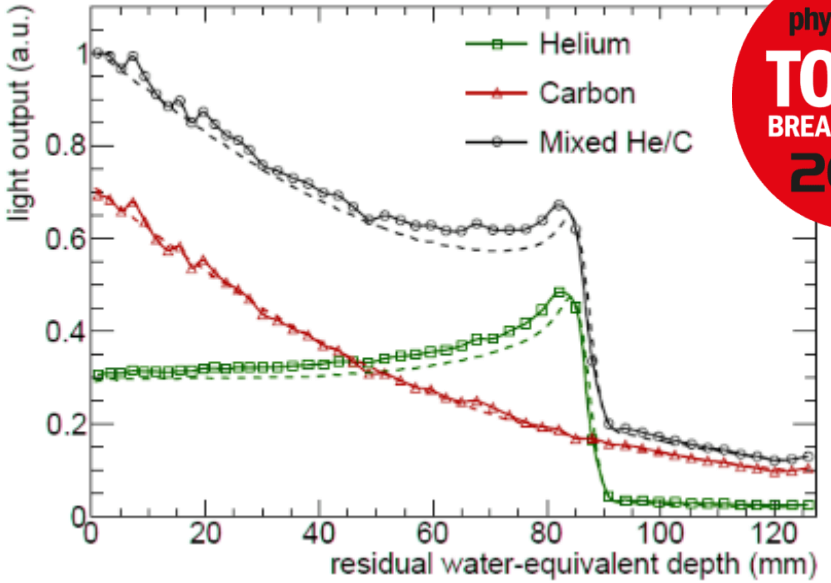


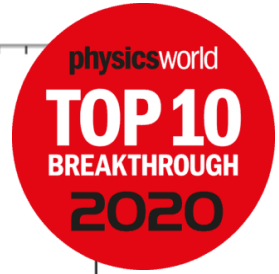
Feasible detection scheme: Scintillators

- Scintillation in plastic blocks is strong enough to resolve helium Peaks
- Usable to detect mm-variations in range

- Long way to go to the clinics, but all essential building blocks are in place!
- PROMISE started in **March 2024**

Scintillator sheets + CMOS





Measured data from separate beams

Volz, …, Graeff et al, PMB 2020

Emerging paradigm shift: Upright radiotherapy

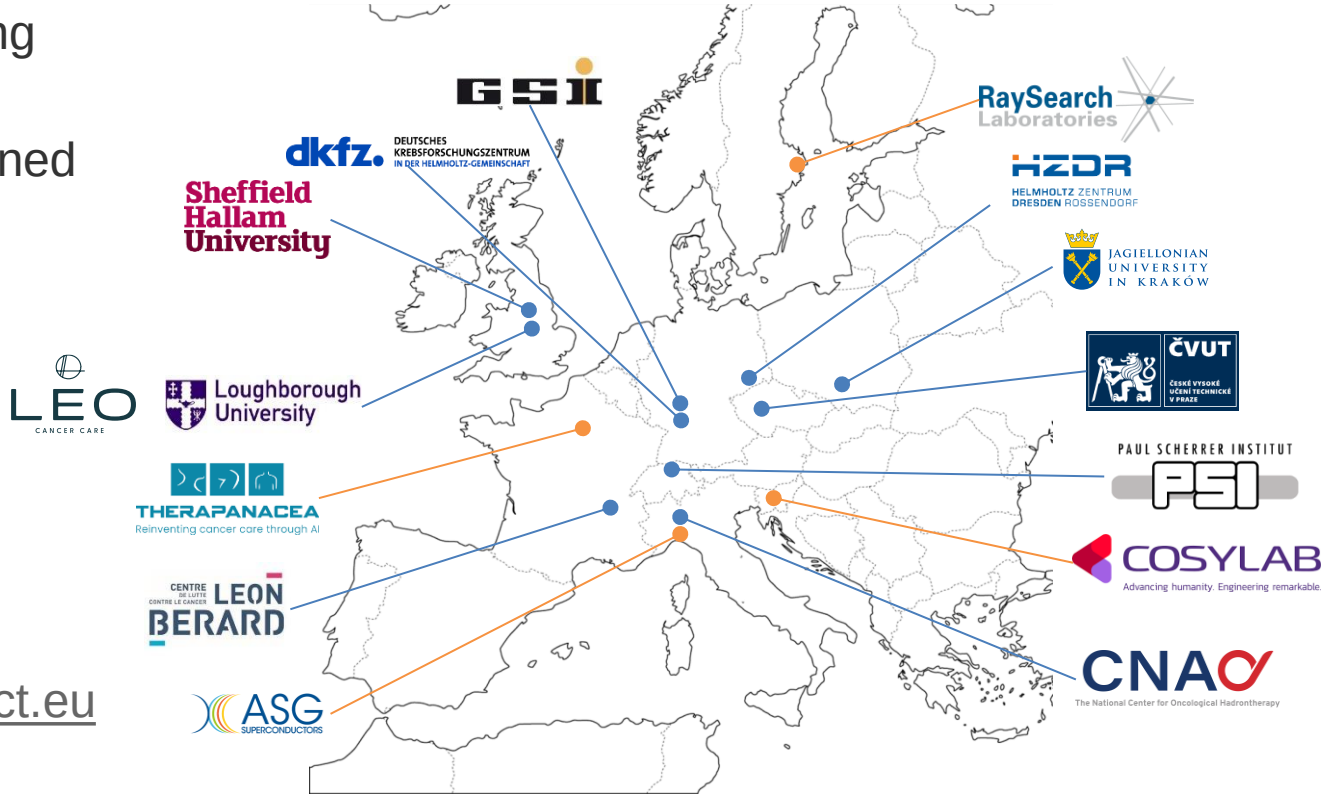
- Turn the patient – not the beam

- Of ~50 installed carbon treatment rooms, only 4 have a gantry!

Two emerging vendors

MSCA Doctoral Network: UPLIFT

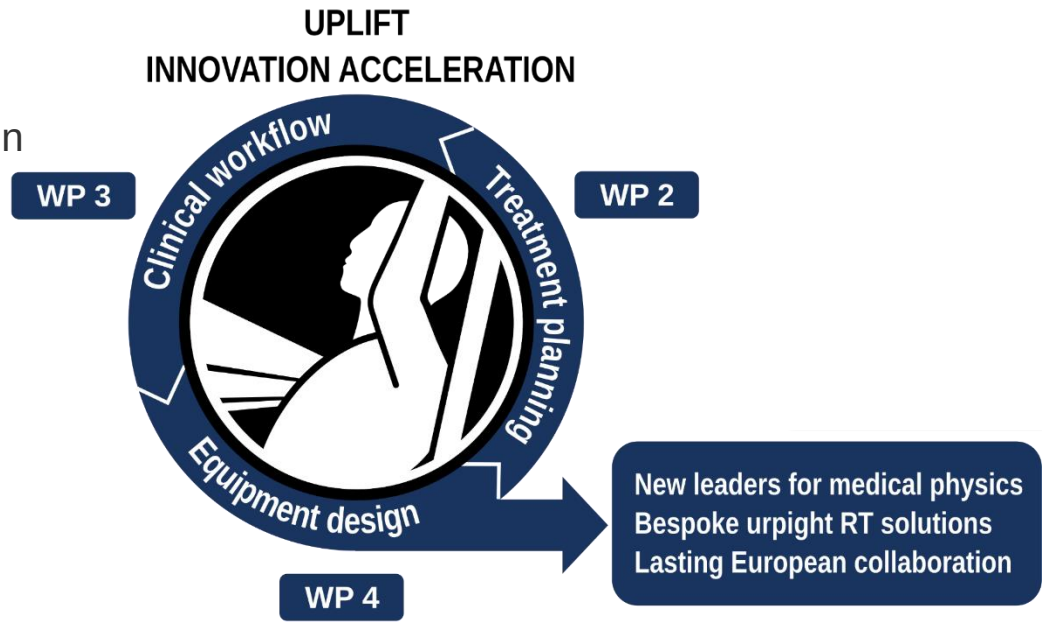
- Kickoff meeting last week
- Positions opened today



www.uplift-project.eu

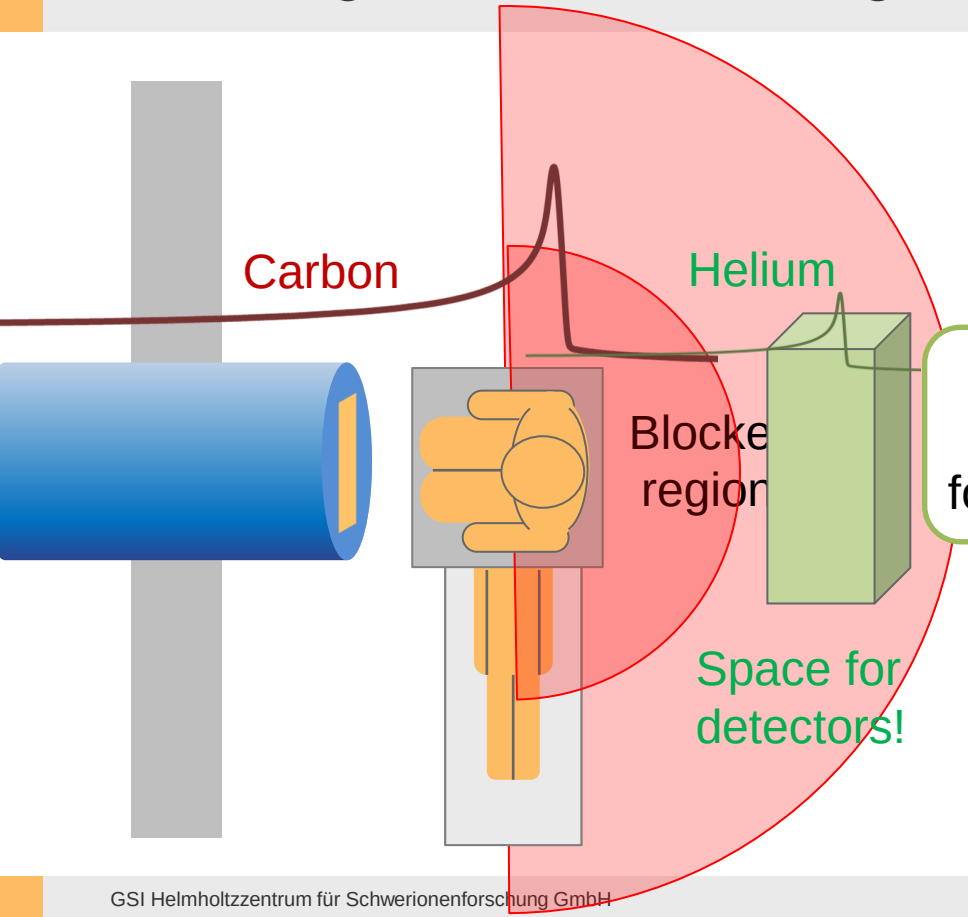
UPLIFT Topics

- EQUIPMENT DESIGN:
  - upright CT, MRI, PET
  - Image segmentation & registration
  - Positioning aides
- TREATMENT PLANNING:
  - robustness
  - motion management
  - particle arc therapy
- CLINICAL WORKFLOW:
  - patient benefit & selection
  - positioning and immobilization
  - patient empowerment
  - cost effectiveness

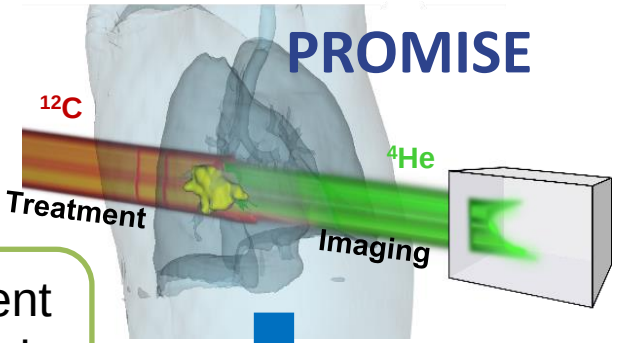


Mix of physics, engineering, medical & social-economics students!

Combining cost reduction & highest precision



Upright treatment is an ideal match for particle imaging



UPLIFT

Funded by the European Union

European Research Council
Established by the European Commission