

# Hadron Therapy at GSI - where we come from, where we go

DR. KONRAD LEHMANN



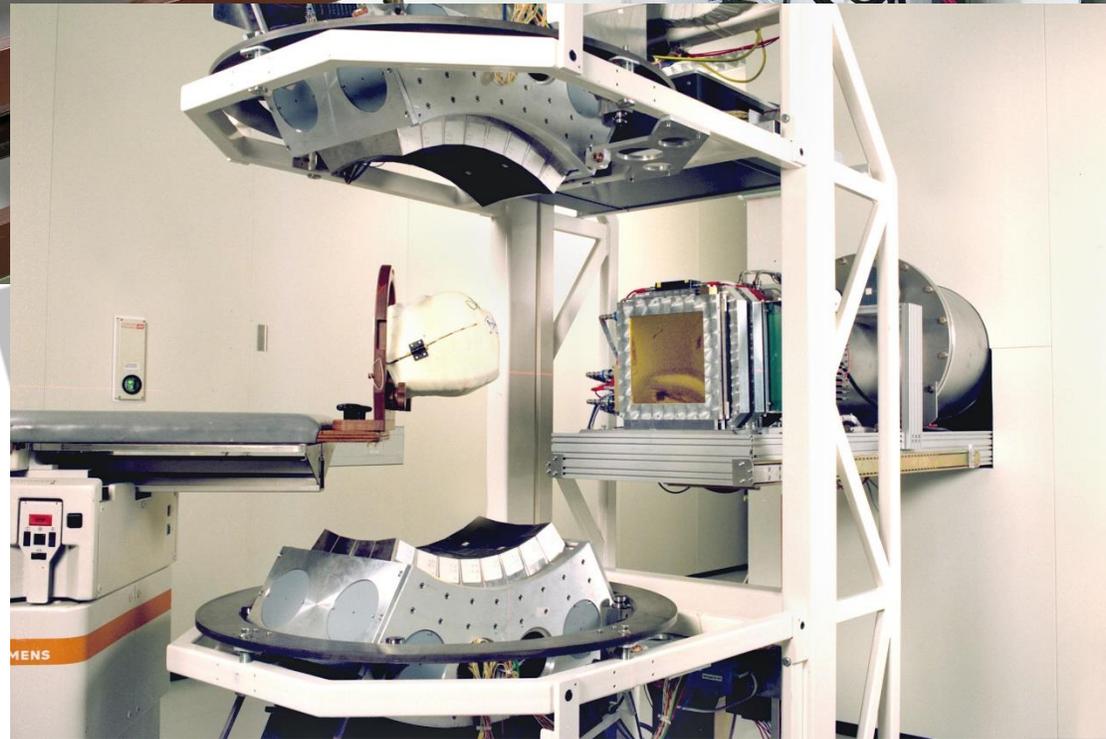
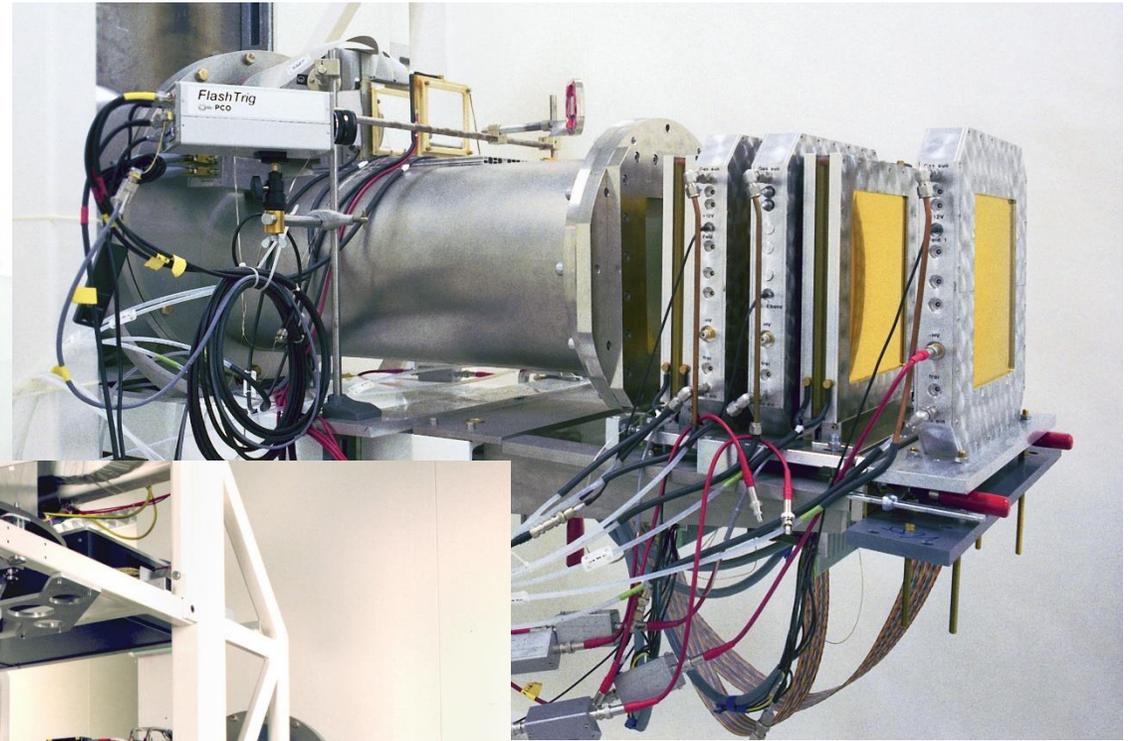
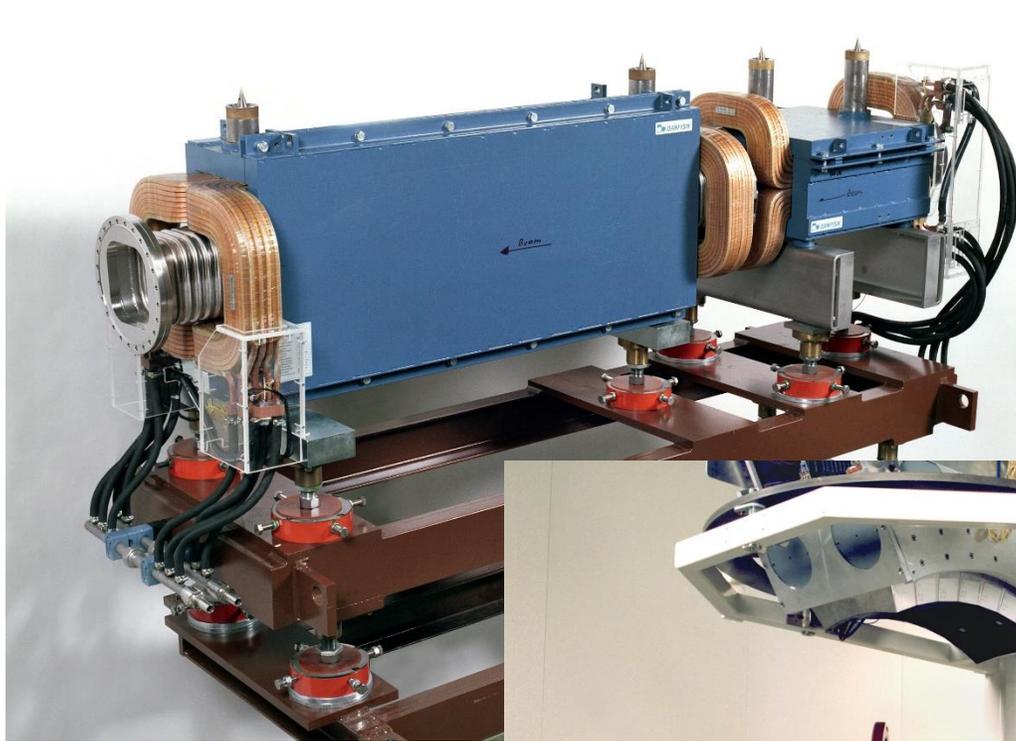
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101008548

# How it all started

Gerhard Kraft

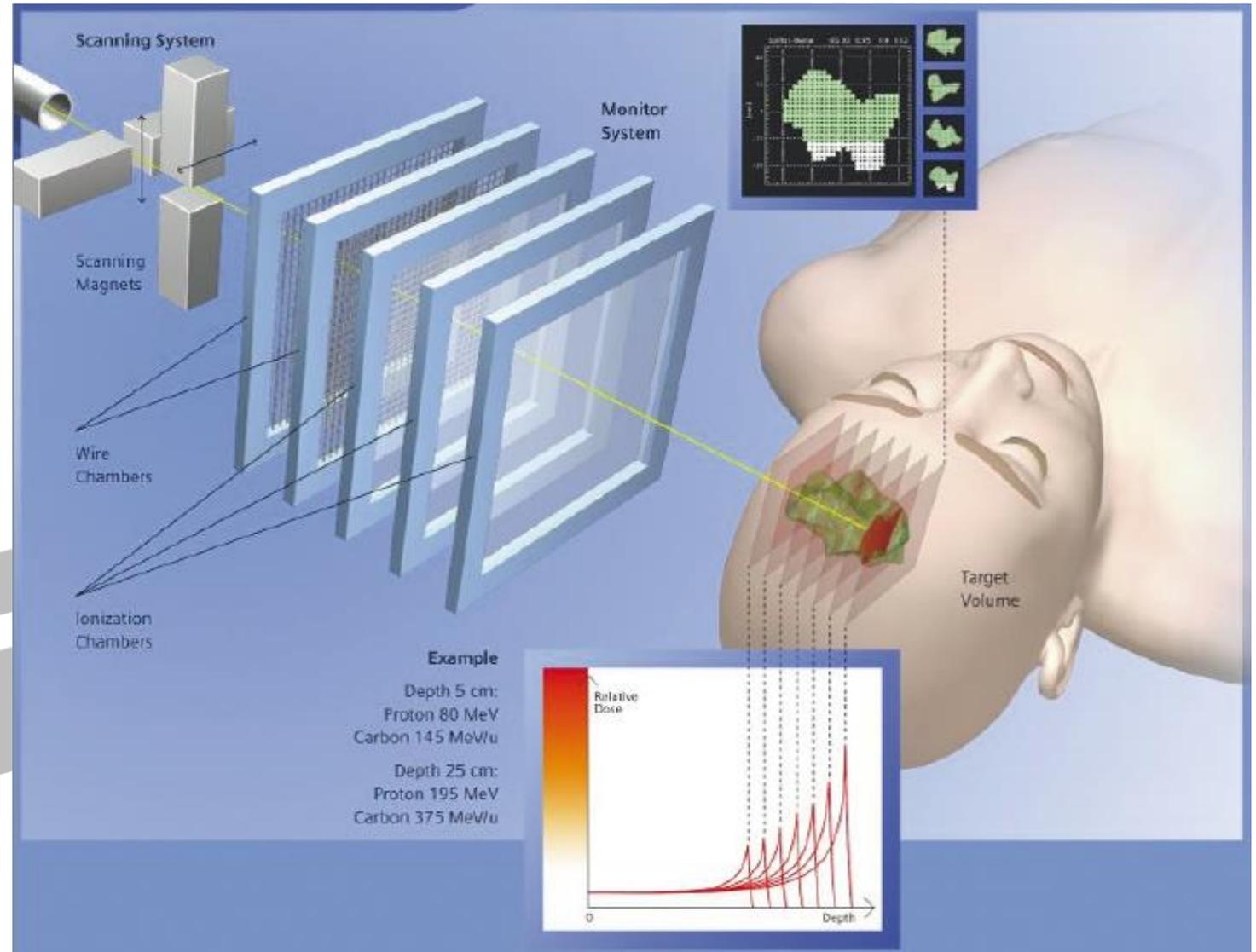
29.10.1941 – 18.3.2023

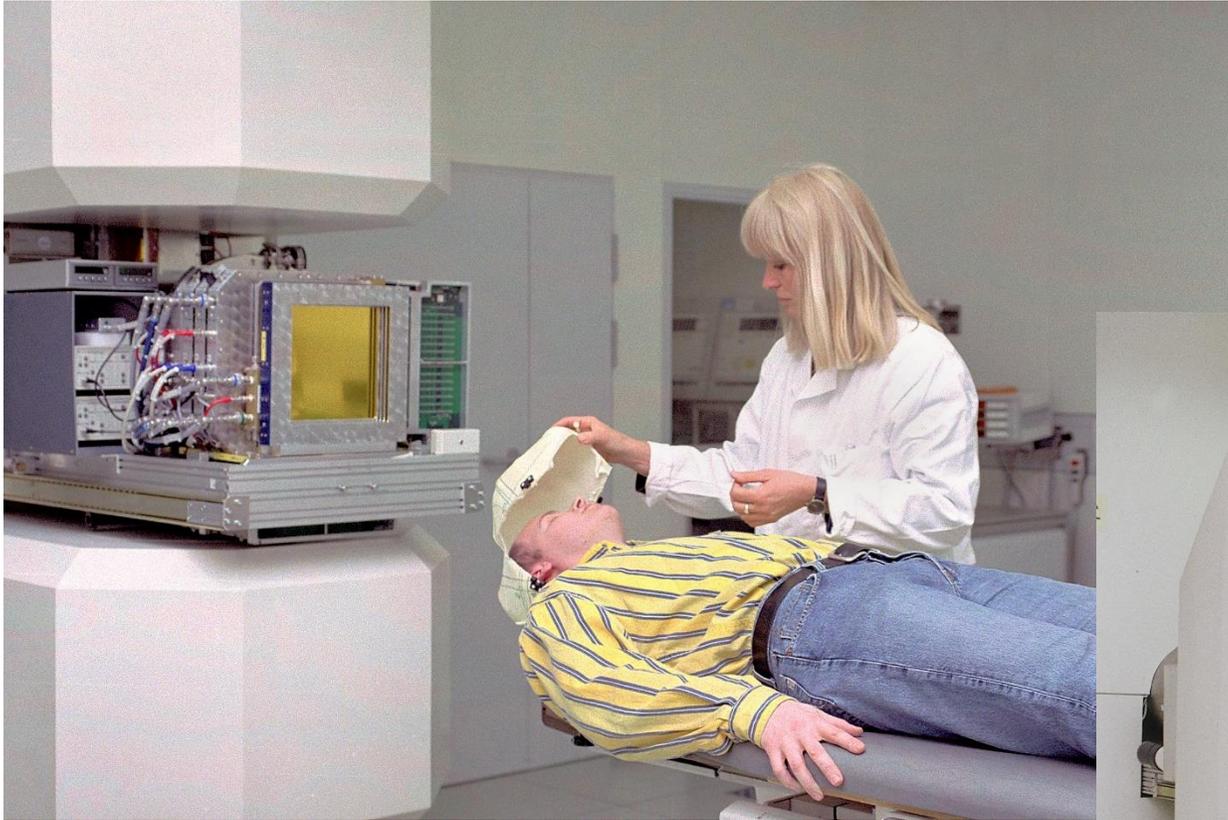




# The Result

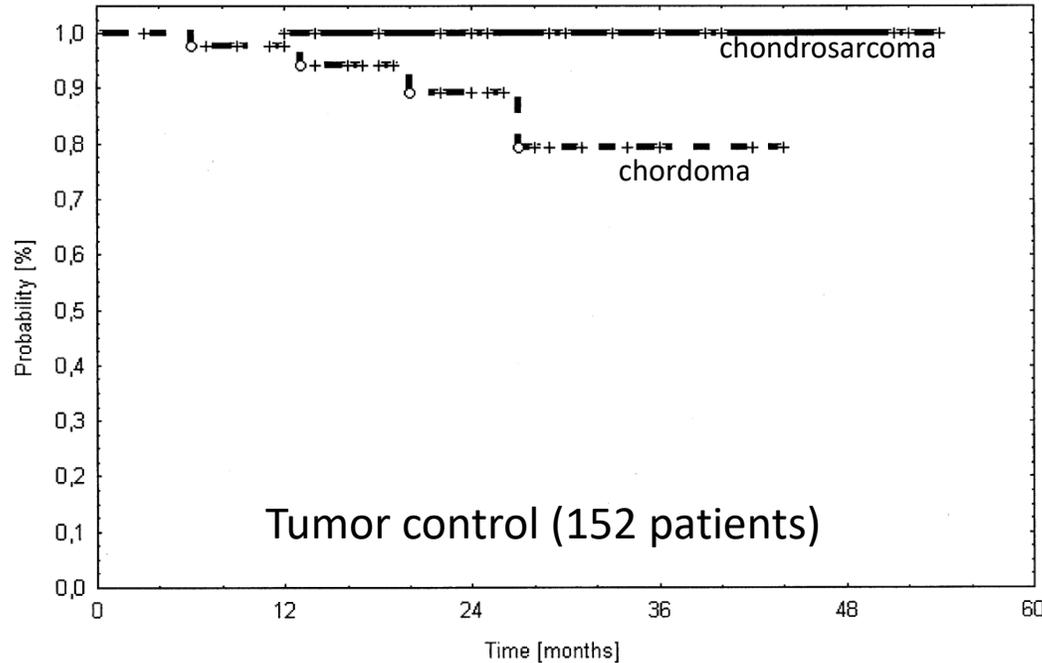
- Tumor scanning in 3D
- Monitoring of both beam and target
- RBE modeling





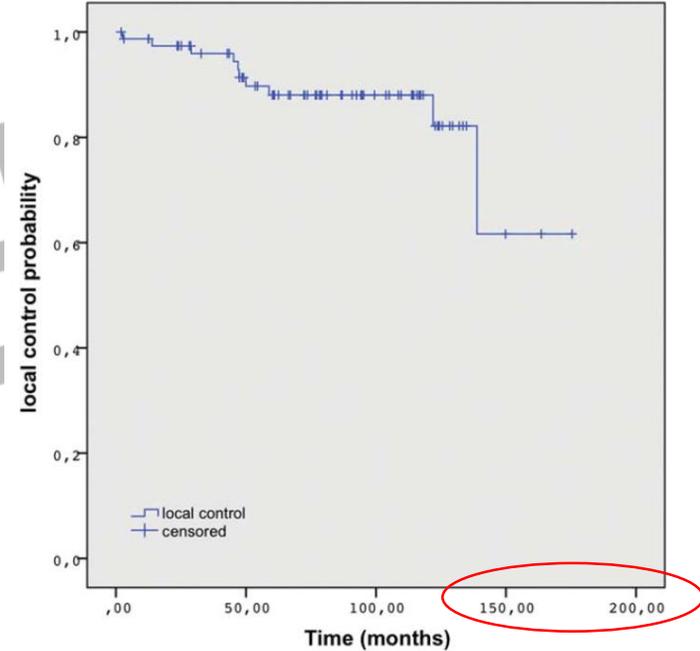
# Pilot project for hadron therapy 1997-2008

## Treatment of 434 patients with head-and-neck tumors



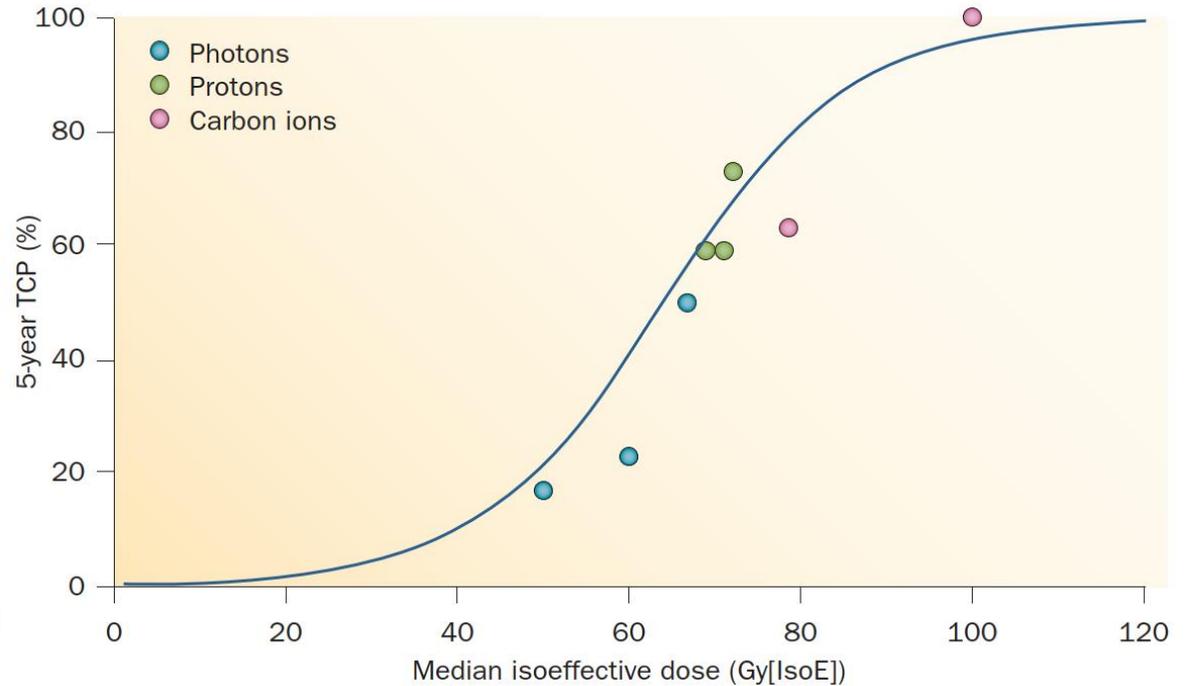
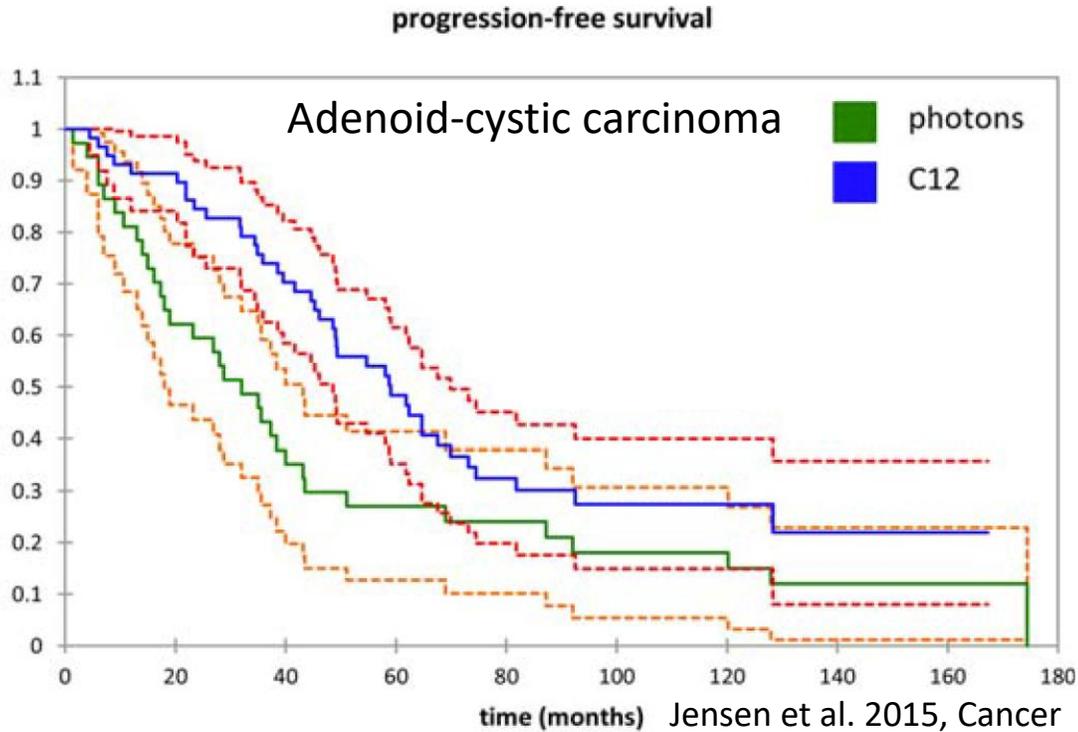
Tumor control (152 patients)

Schulz-Ertner et al. (2004)



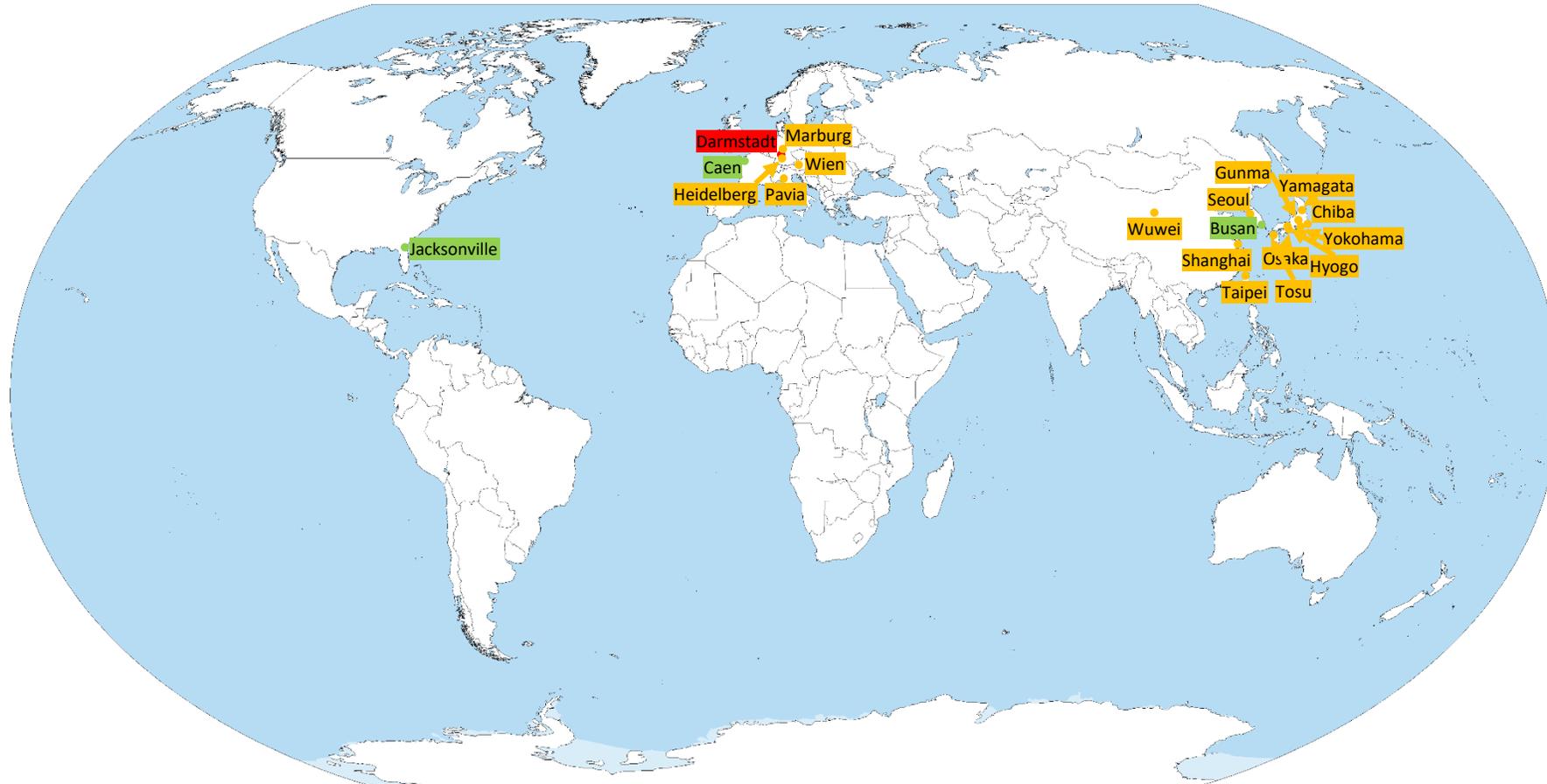
Uhl et al. (2014) Cancer 120: 1579

# Better than x-ray



Loeffler & Durante (2013) Nat. Rev. Clin. Oncol. 10: 411

# We metastasize



# But science never ends

- FLASH / Ultra-High Dose Rate
- BARB
- Mixed beam

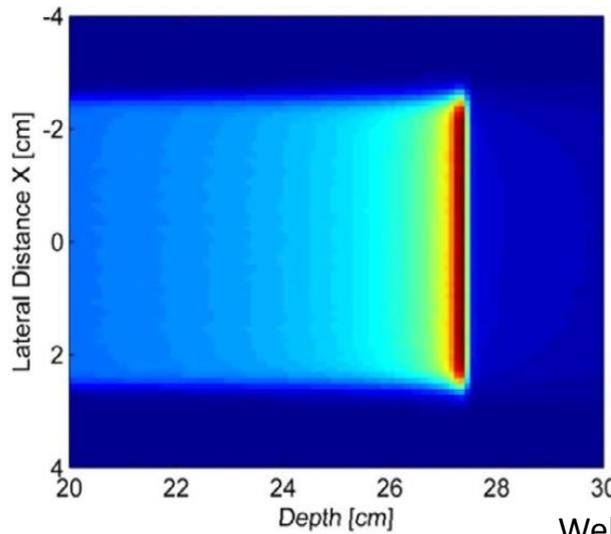


# FLASH / Ultra-High Dose Rate treatment

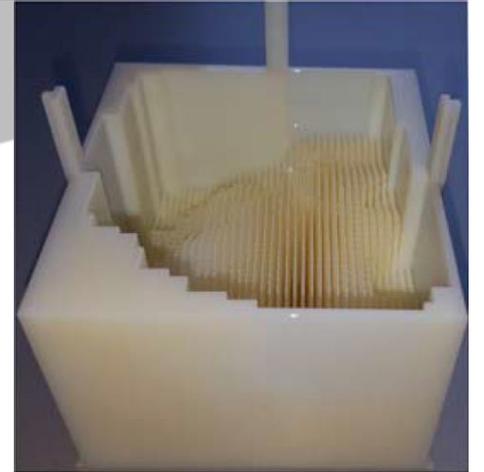
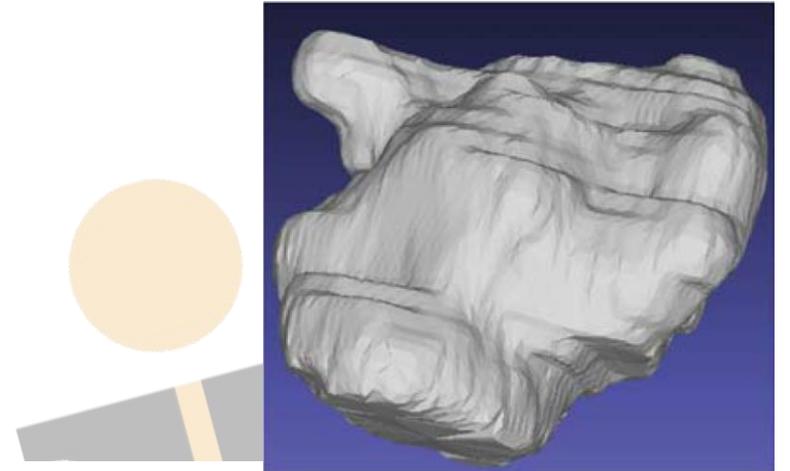
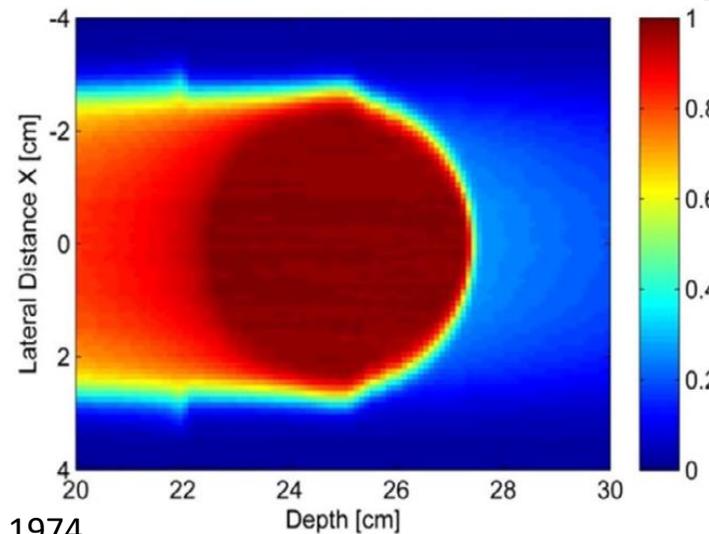
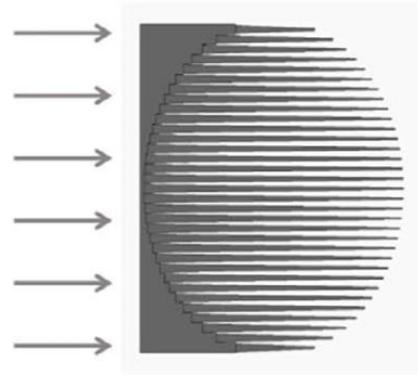
- FLASH effect first discovered in X-ray therapy.
- Sparing of healthy tissue with equal tumor control.
- Easily done with protons in a cyclotron, but more difficult with heavy ions.
- First carbon UHDR by collaboration of GSI / HIT in cell cultures in 2021, and first tumor treatment in experimental animals at GSI in 2021.

# Range modulator

Problem: UHDR too fast for scanning.  
⇒ development of the range modulator

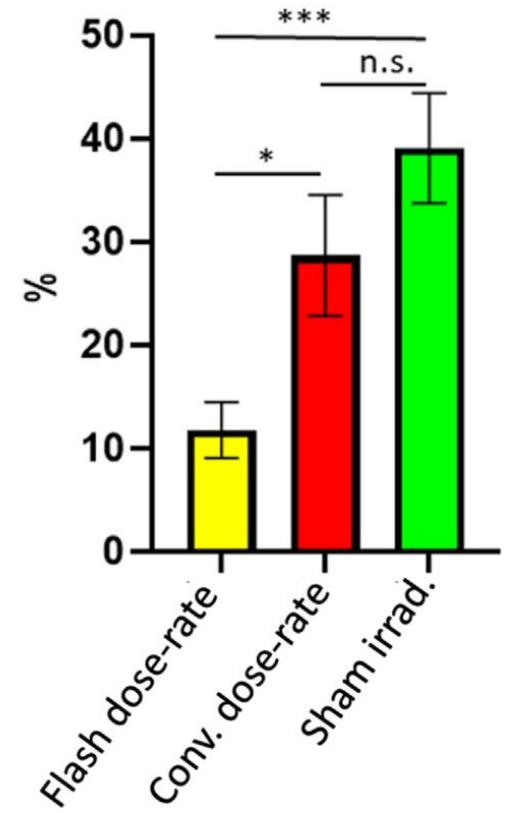
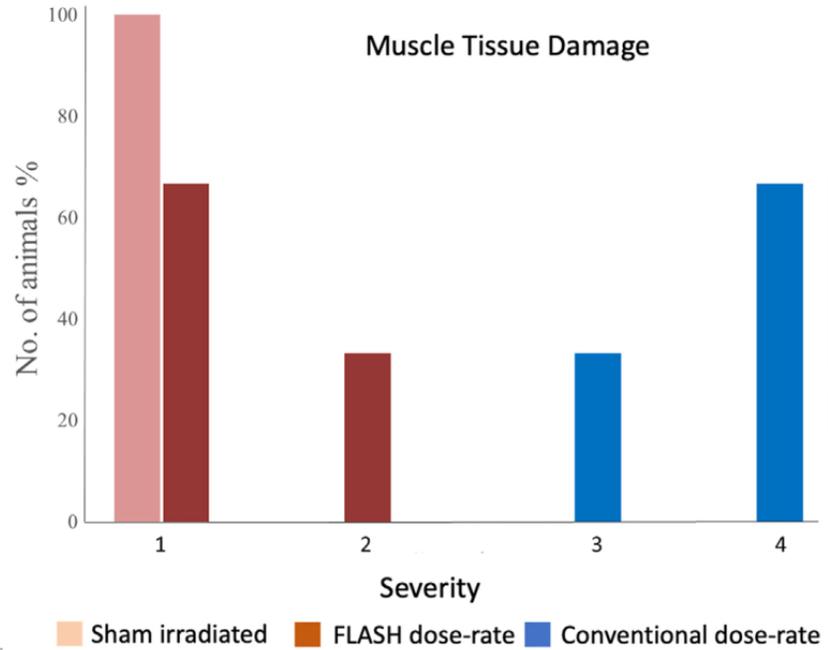
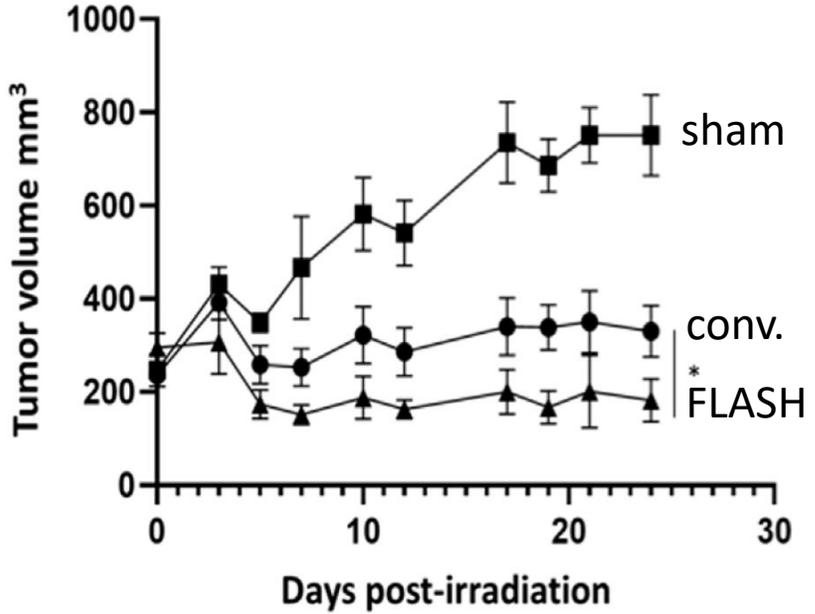


Weber et al. (2021) Med. Phys. 48: 1974



Simeonov et al. (2022) Biomed. Phys. Eng. Express 8: 035006

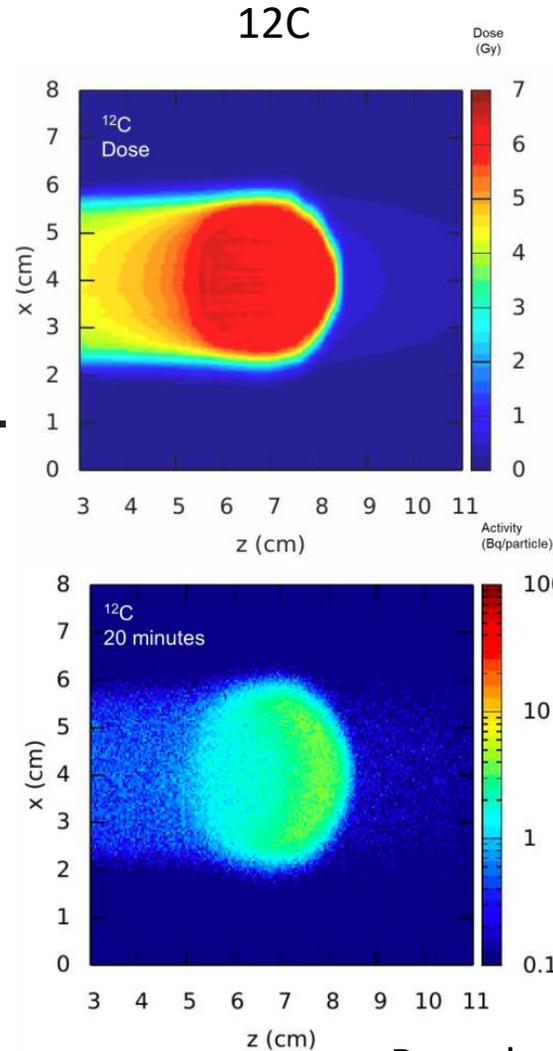
# Carbon FLASH in mice



Tinganelli et al (2022) Radiother. Oncol. 175: 185-190

# BARB

Problem: Do we hit the tumor?  
PET too weak for an online image.  
Solution: radioactive beam



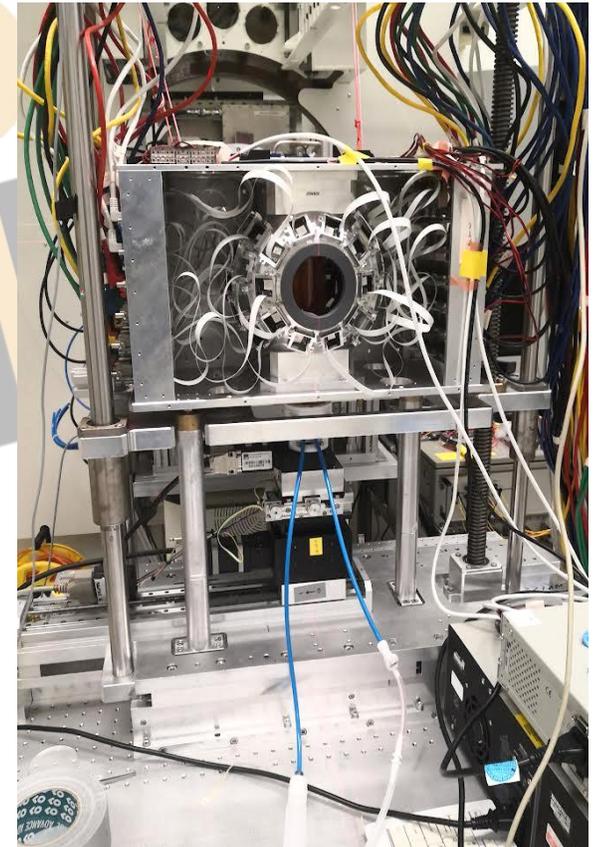
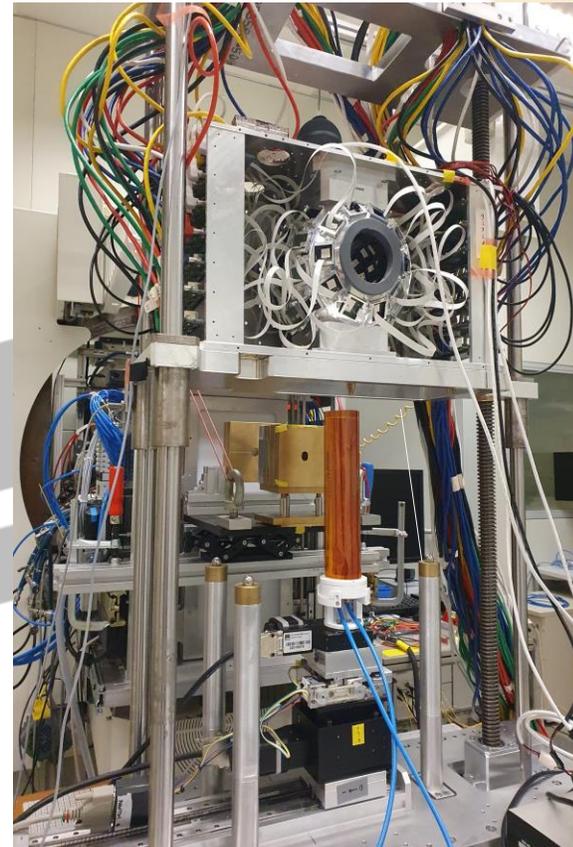
Boscolo et al (2021) Front. Oncol. 11



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# First BARB study in animals

- tumor-bearing mice
- SIRMIO PET scanner by Katia Parodi
- range determination
- washout





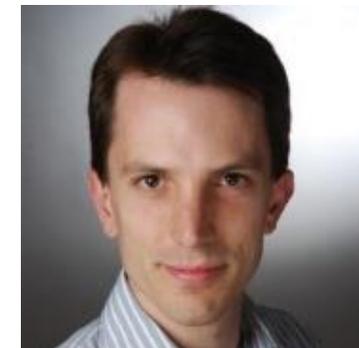
Funded by the European Union (ERC CoG PROMISE, 101124273). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Council Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

# Mixed He C ion beams for range monitoring

Range uncertainty is a major challenge, especially for moving targets

Mixed carbon and helium ions for concurrent therapy and monitoring:

- ~90% carbon for therapy, stops in patient
- ~10% helium for imaging, with 3x higher range, exits patient for online range inference

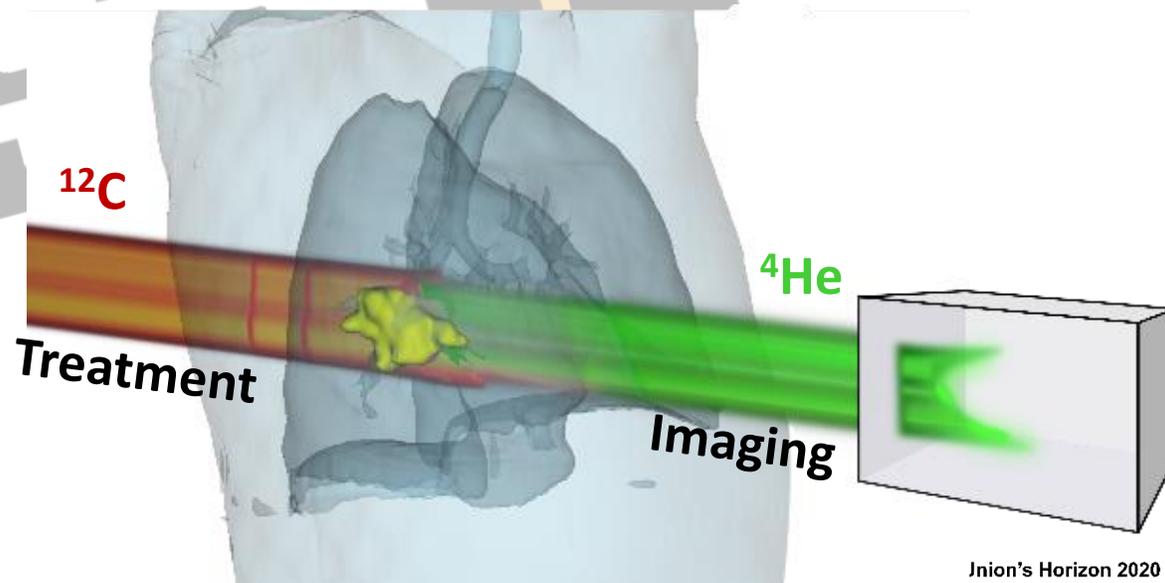


Several theoretical papers published:

[Graeff et al 2018, Volz et al 2020, Hardt et al 2024]

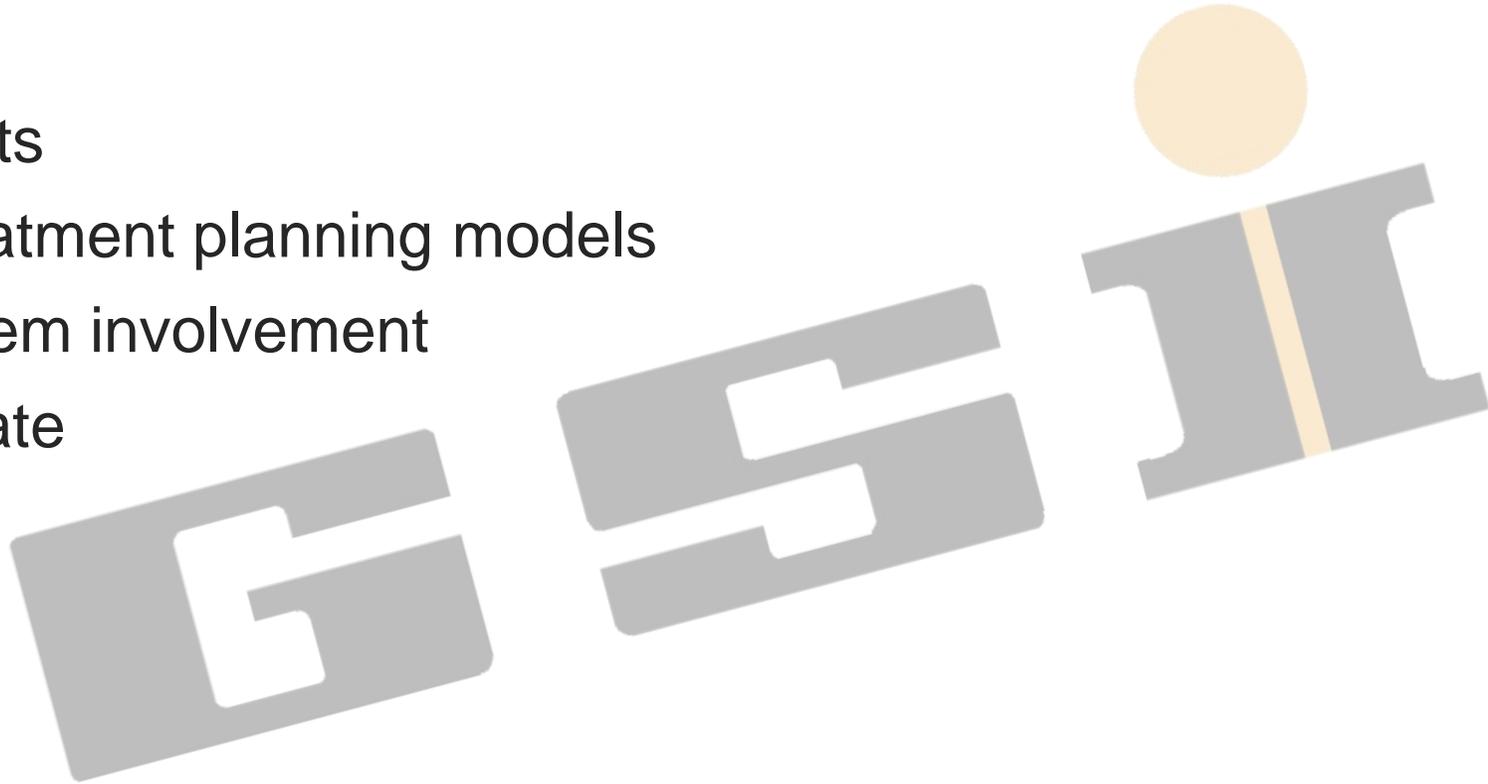
- Minimal additional dose
- Helium should be detectable
- Correlation of He and C range

This is the first experimental proof of concurrent mixed ion beam production



# Further projects

- moving targets
- improved treatment planning models
- immune system involvement
- torpor-like state
- microbiome

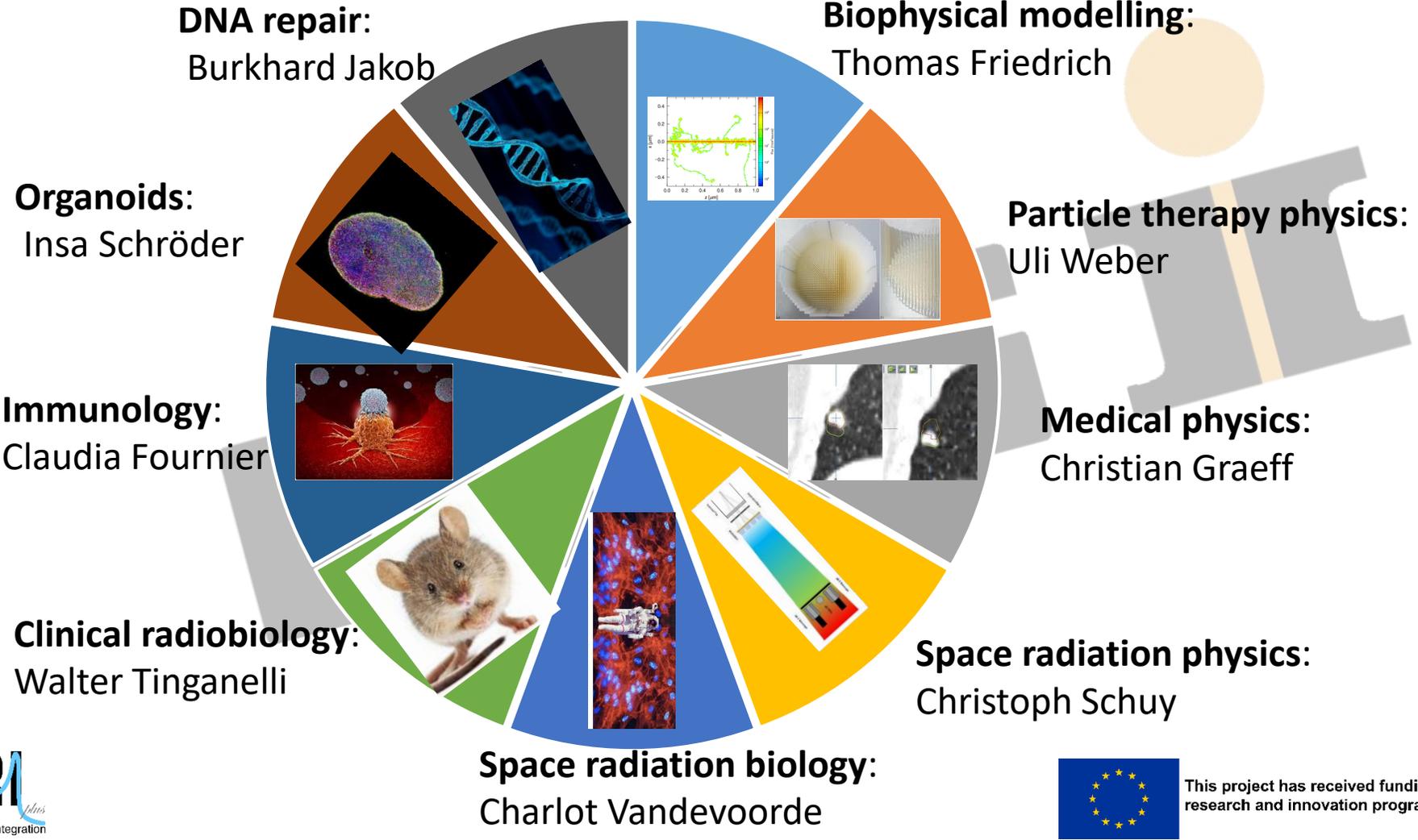


# Biophysics Department today



- 86 members
- 26 staff
- 52% women
- 44% foreign citizens
- 18 nationalities
- Median age 34 years

# The Biophysics Department



# Biophysics at GSI – science with existing facilities

## Space radiation protection



- ESA reference facility for ground-based space radiation protection studies
- Current ESA-supported programs ongoing: IBER/IRES/ROSSINI/GCRsim
- ESA/FAIR Summer School in Darmstadt
- EU programs: RADNEXT-HEARTS
- Target station: Cave A (SIS18)

## Particle therapy



1997



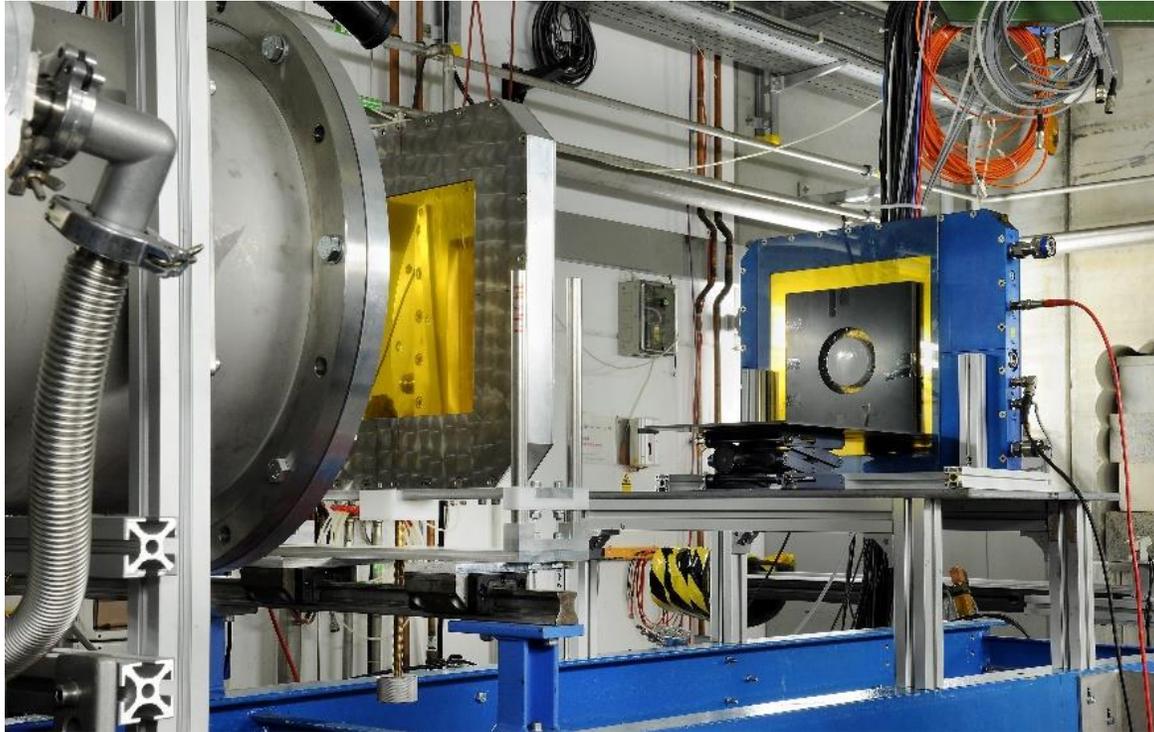
2024

- First European center to treat patients with high energy  $^{12}\text{C}$ -ions (434 patients treated on site)
- Now extensive research program in particle therapy covering from nuclear physics to molecular biology
- Work supported by BMBF, EU, NIH
- Target station: Cave M (SIS18)



# Biophysics at present facilities

## Cave A



## Cave M



# A FAIR future



# A FAIR future



# A few words on HITRI+ TNA

- Consortium of all carbon centres in Europe:
  - GSI
  - HIT
  - MIT
  - MEDAUSTRON
  - CNAO
- Clinical & research TNA
- Application via website: <https://www.hitriplus.eu/>



# Thank you!

