

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

DR. KONRAD LEHMANN



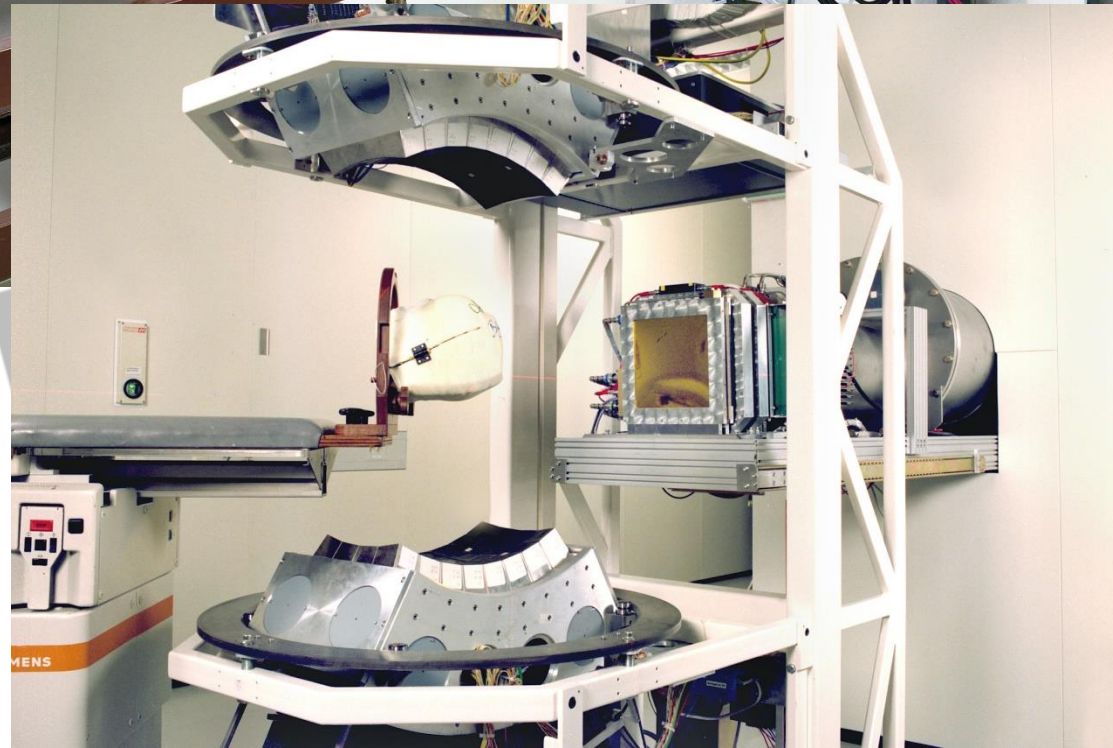
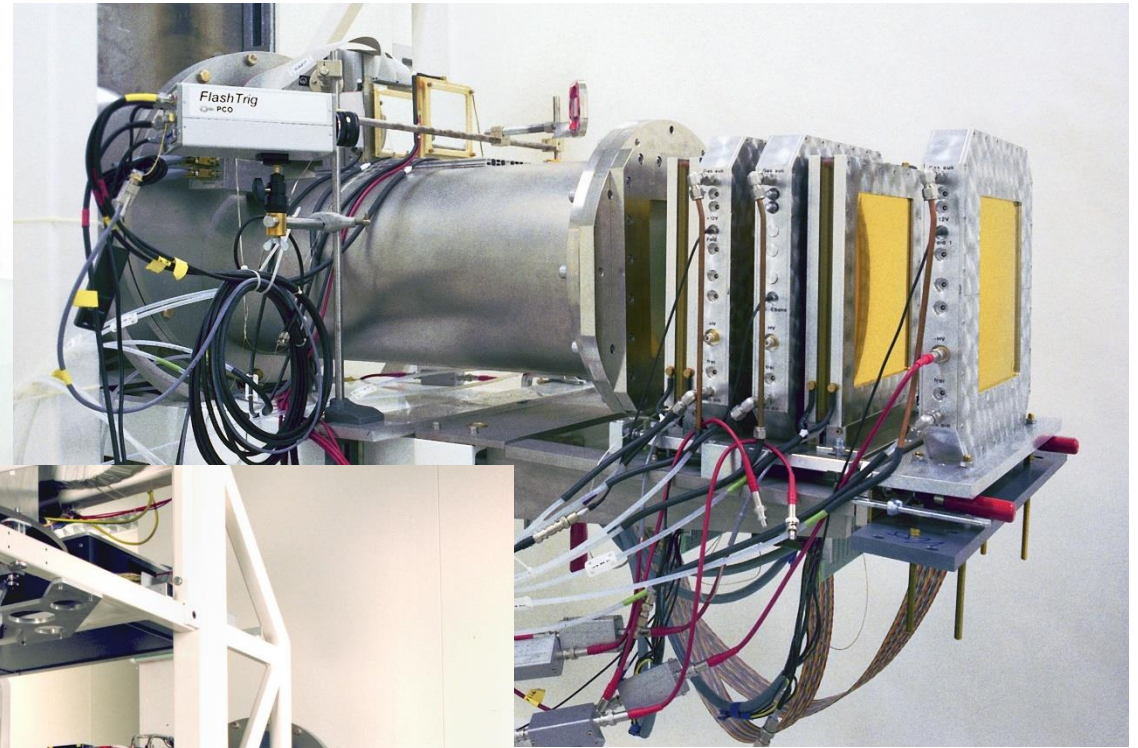
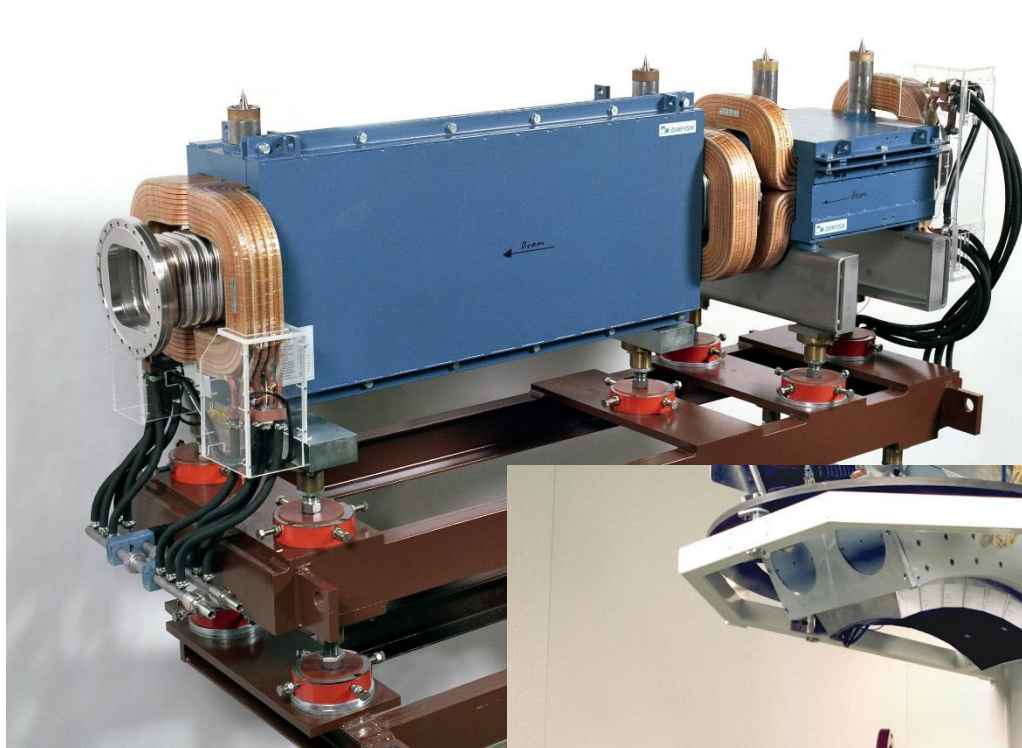
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101008548

# How it all started

Gerhard Kraft

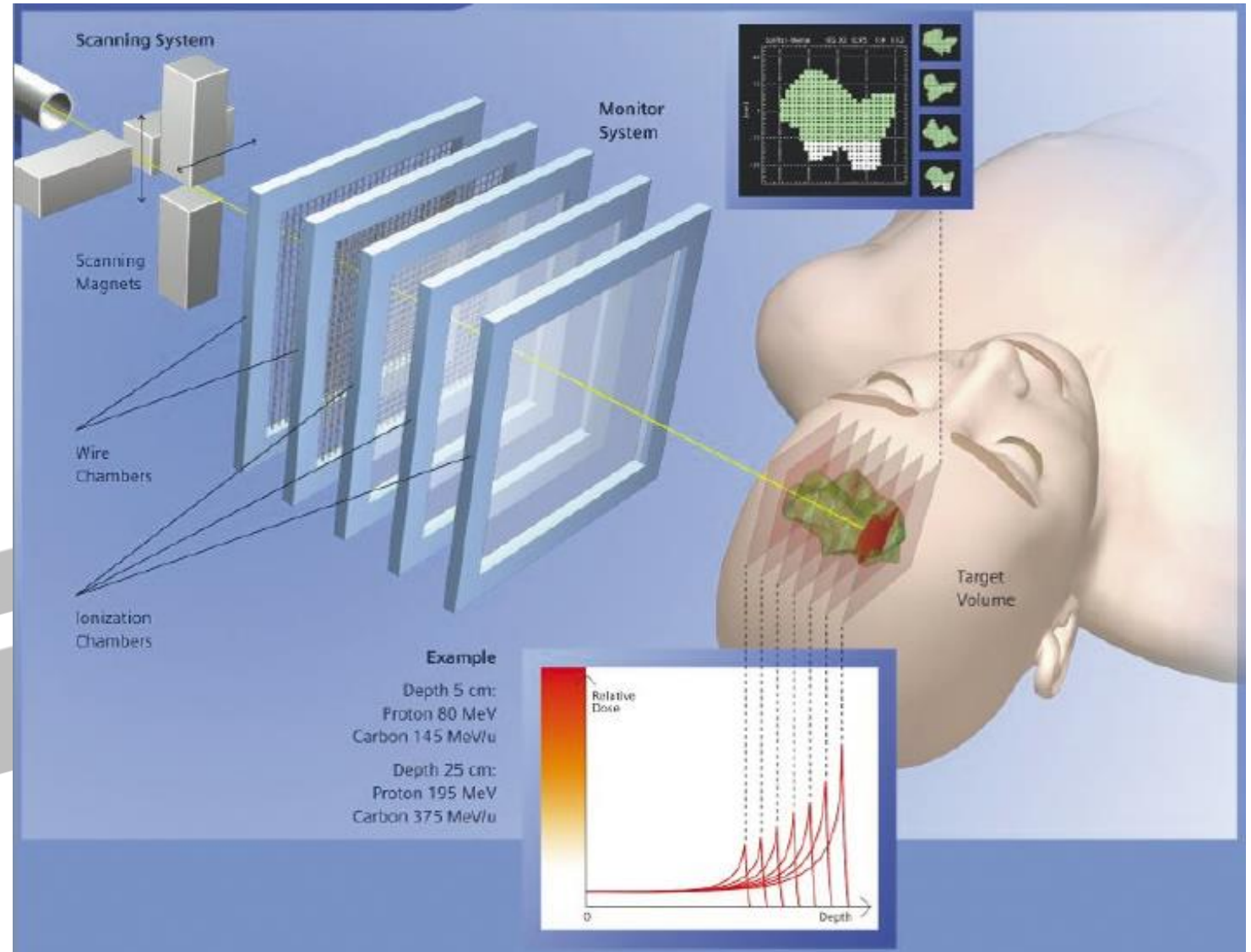
29.10.1941 – 18.3.2023

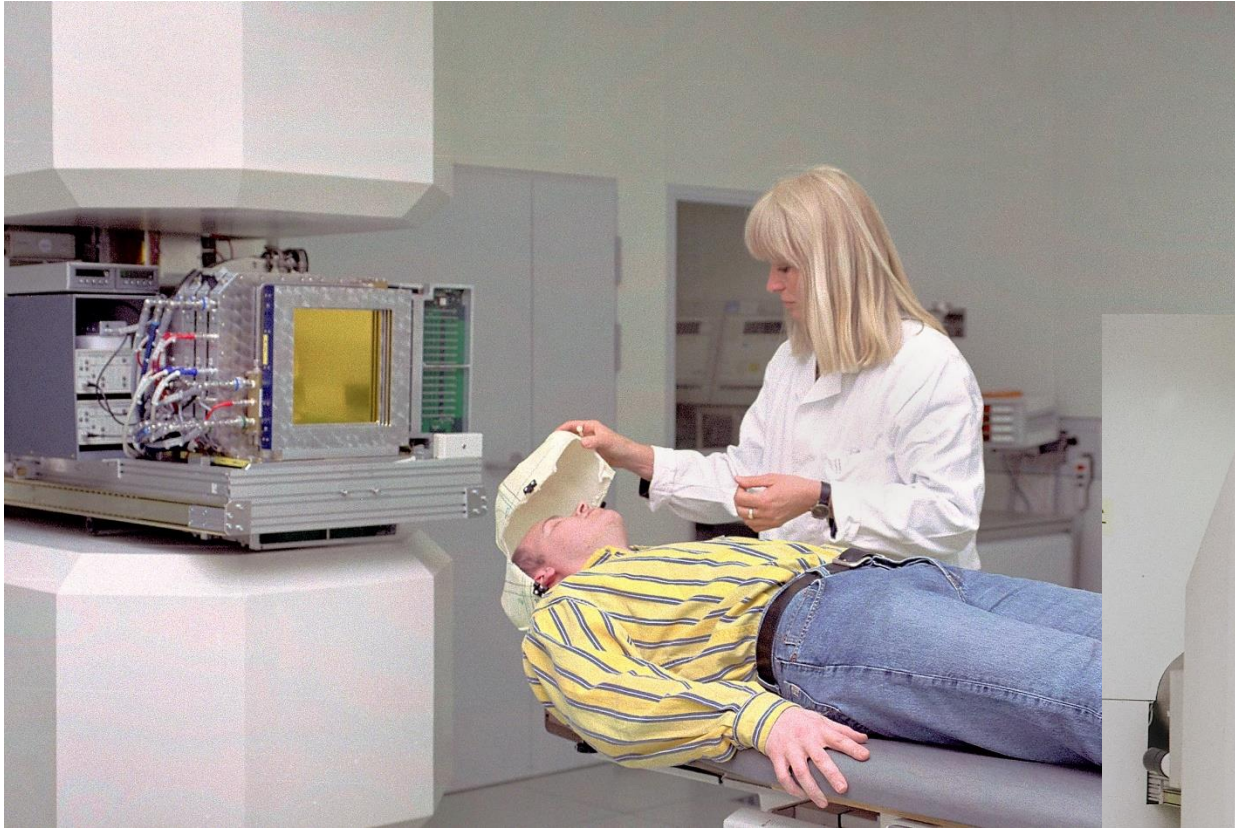




# The Result

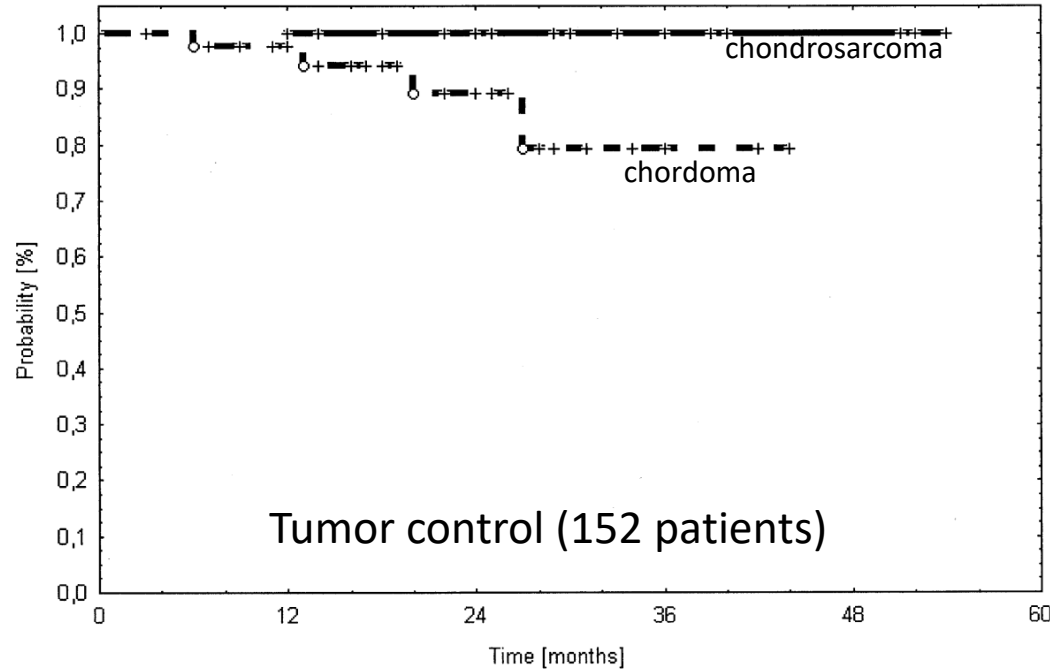
- Tumor scanning in 3D
- Monitoring of both beam and target
- RBE modeling



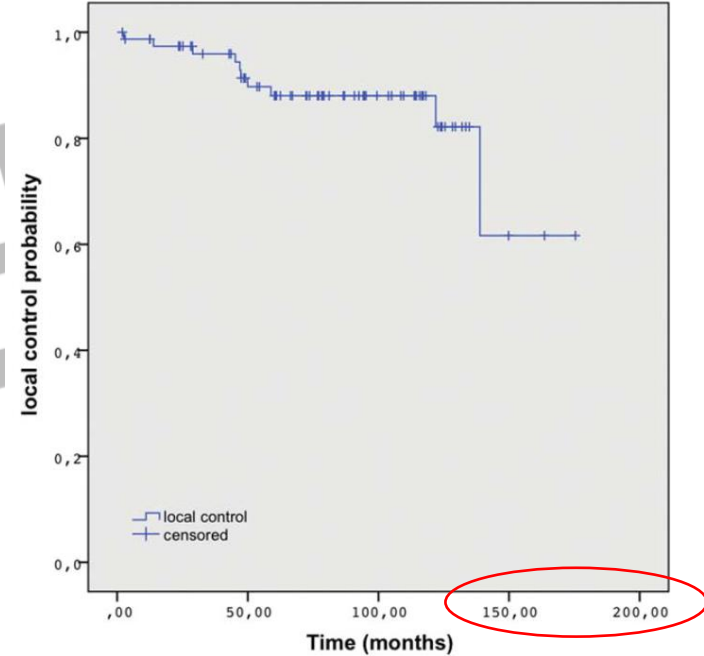


# Pilot project for hadron therapy 1997-2008

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

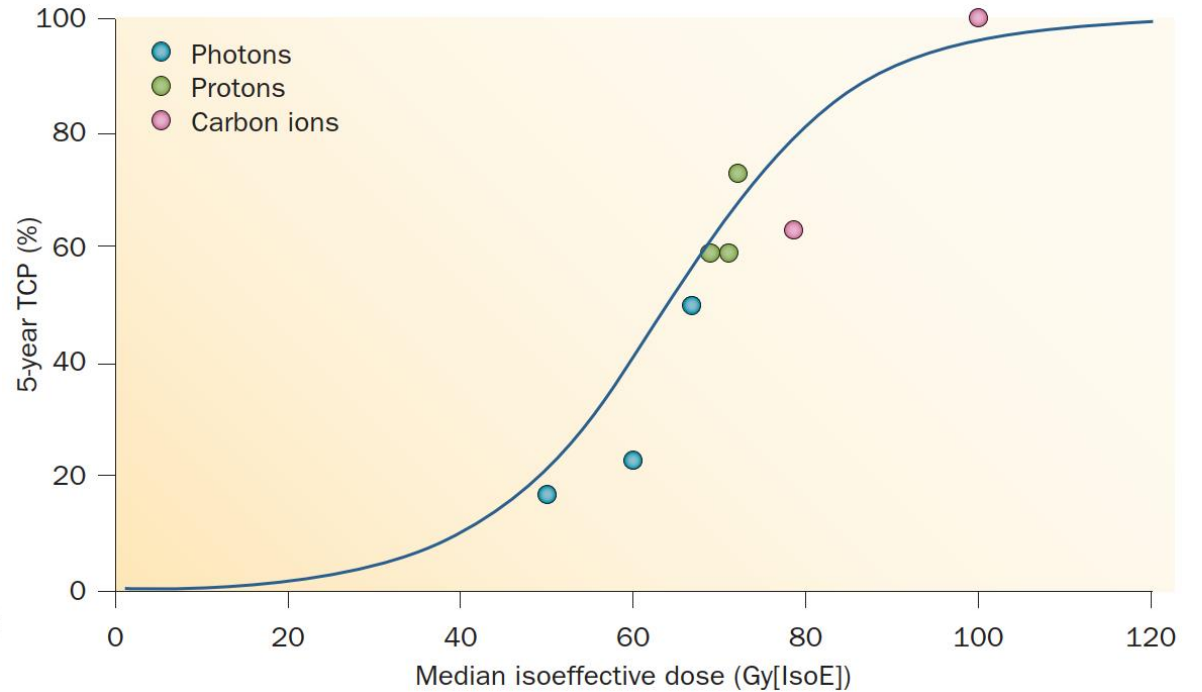
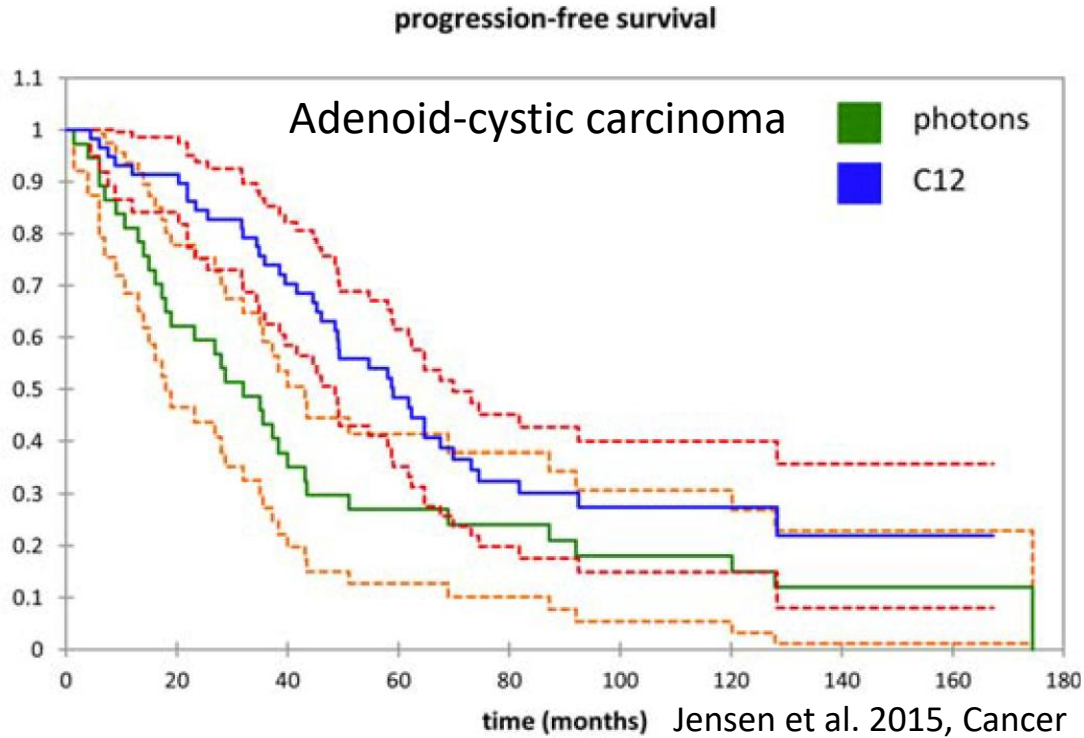


Schulz-Ertner et al. (2004)



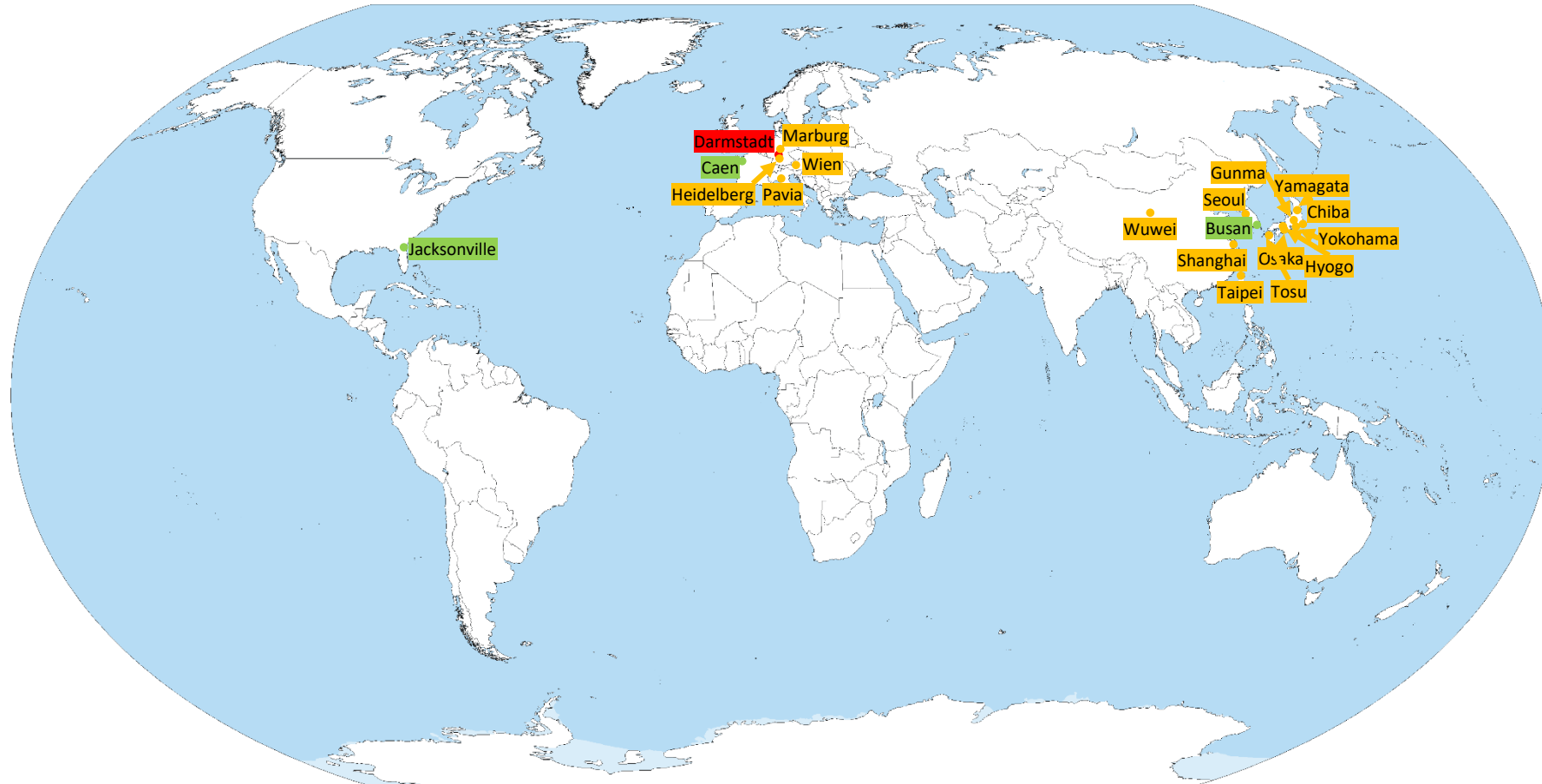
Uhl et al. (2014) Cancer 120: 1579

# 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

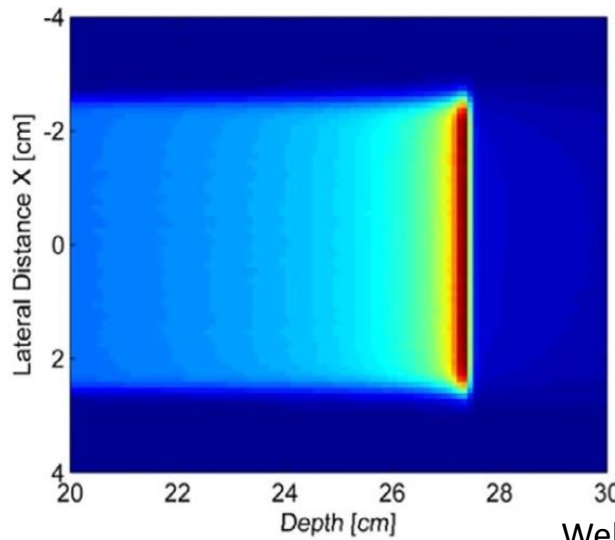


# FLASH / Ultra-High Dose Rate treatment

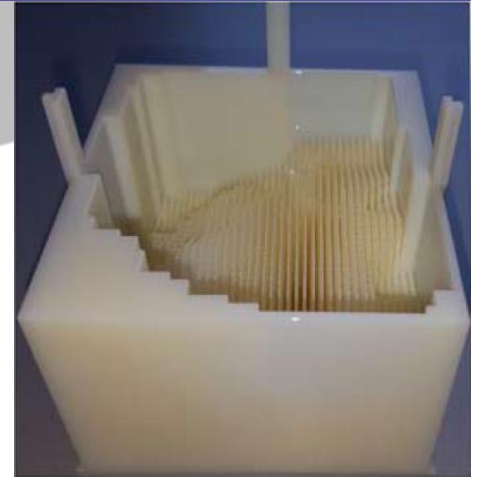
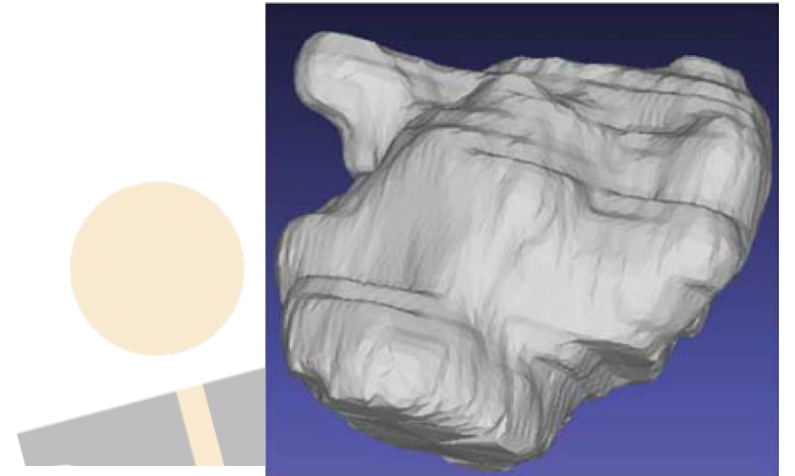
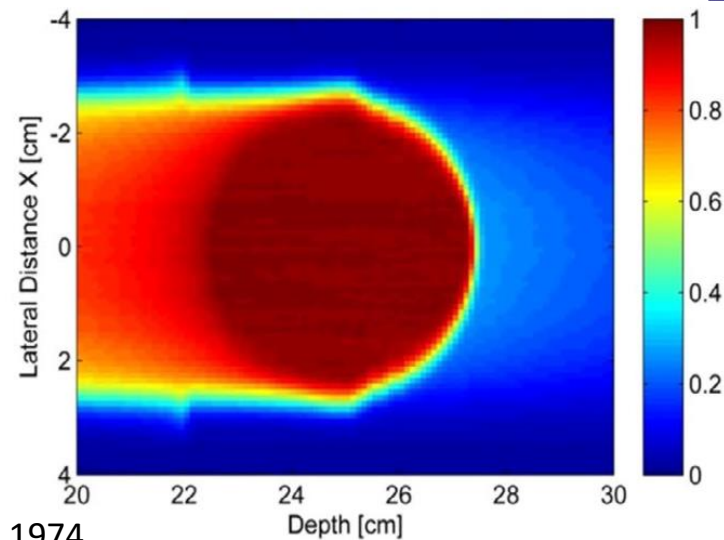
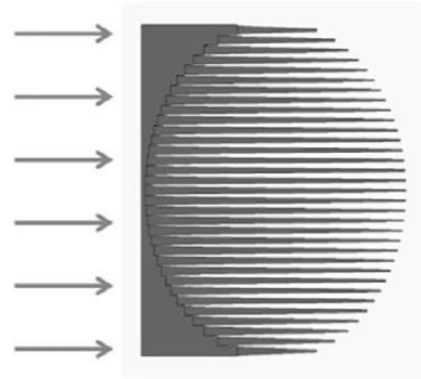
- FLASH effect first discovered in X-ray therapy.
- Sparing of healthy tissue with equal tumor control.
- Easily done with protons in a cyclotron, but more difficult with heavy ions.
- First carbon UHDR by collaboration of GSI / HIT in cell cultures in 2021, and first tumor treatment in experimental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

# Range modulator

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

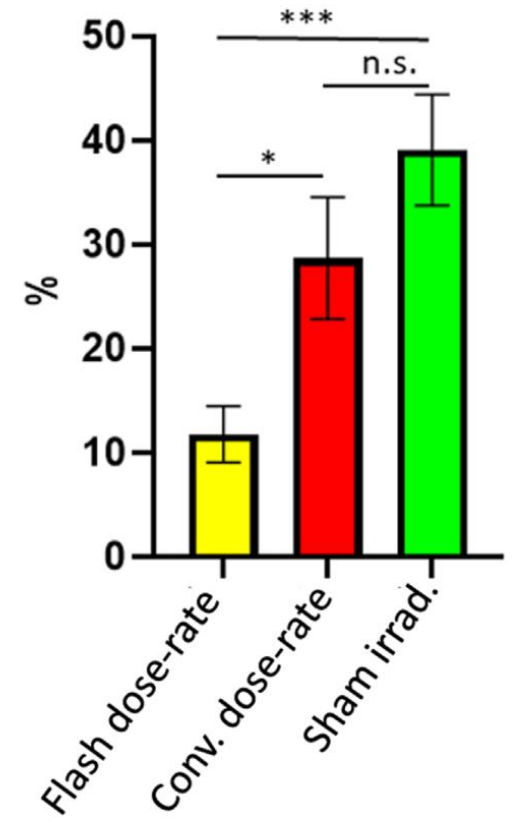
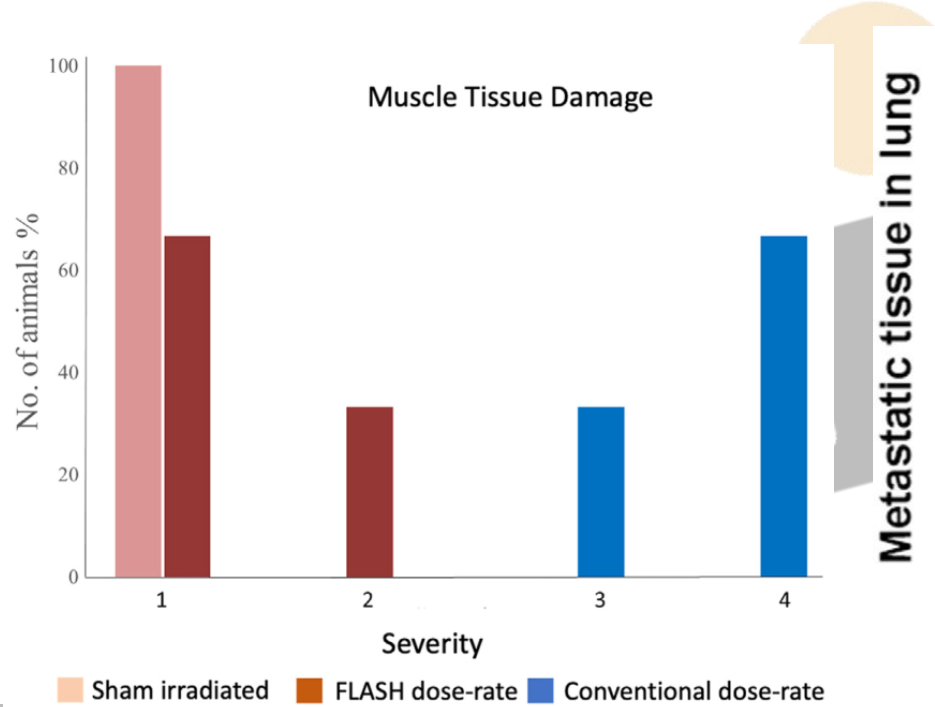
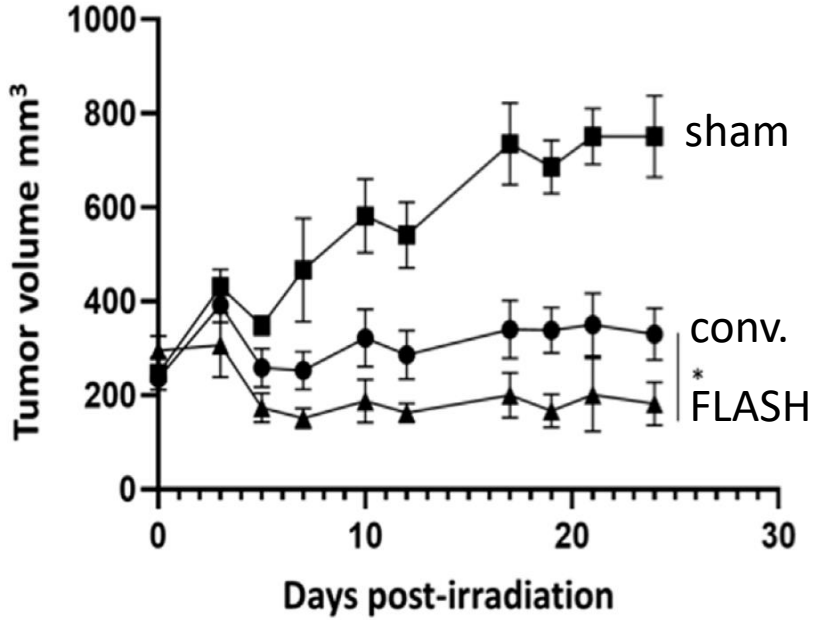


Weber et al. (2021) Med. Phys. 48: 1974



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

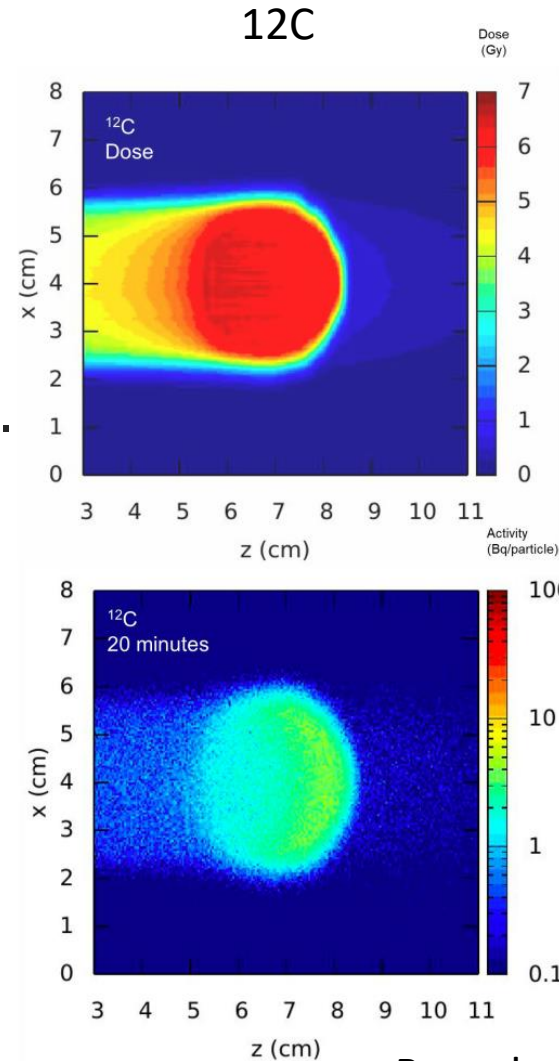
# Carbon FLASH in mice



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



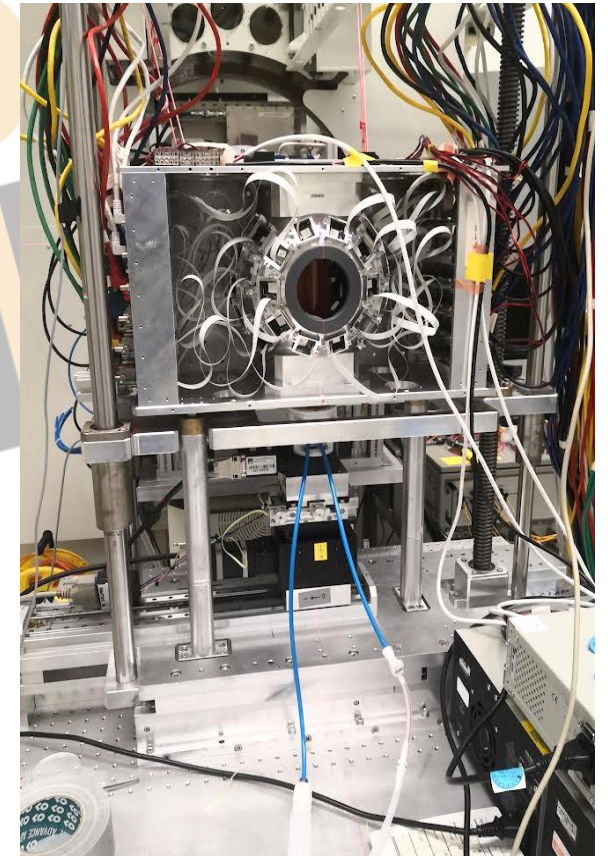
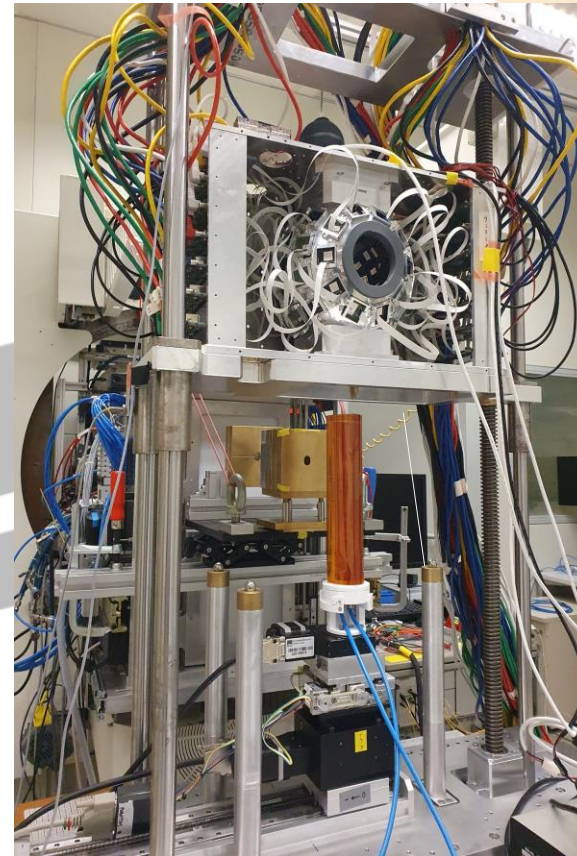
Boscolo et al (2021) Front. Oncol. 11



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# First BARB study in animals

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





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# 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:



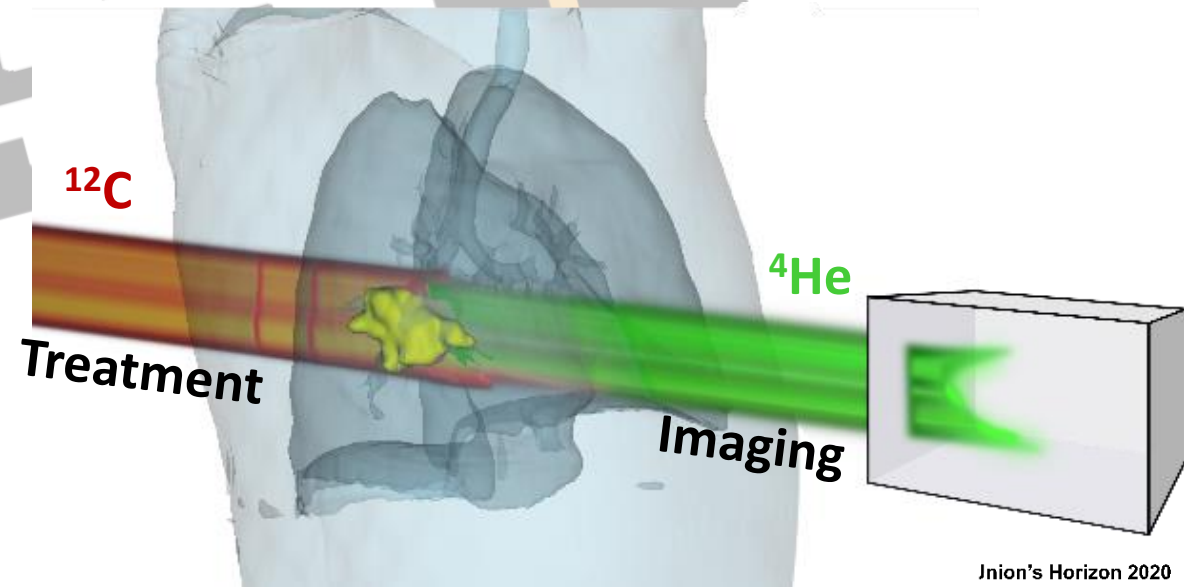
- ~90% carbon for therapy, stops in patient
- ~10% helium for imaging, with 3x higher range, exits patient for online range inference

Several theoretical papers published:

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

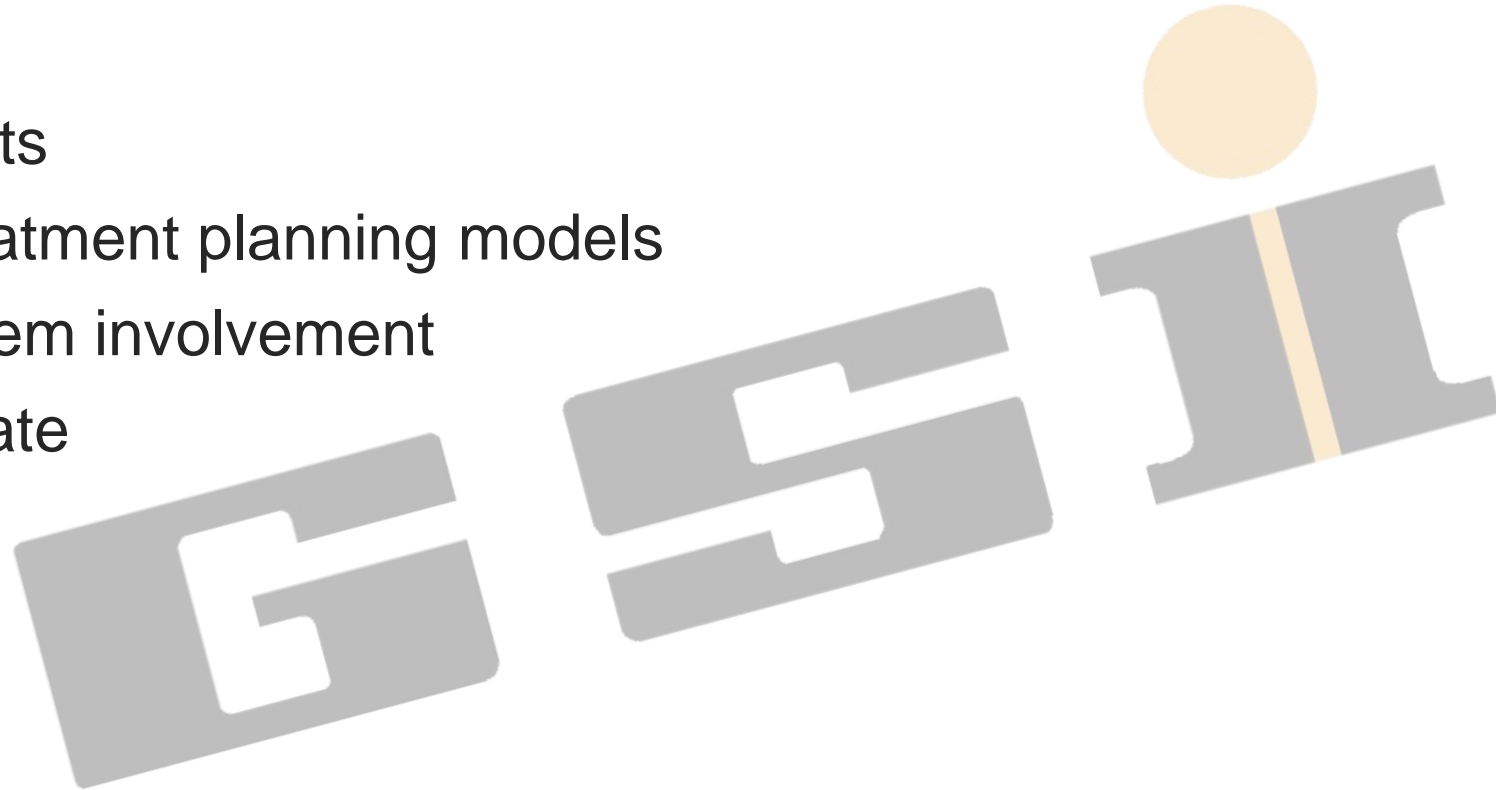
- Minimal additional dose
- Helium should be detectable
- Correlation of He and C range

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



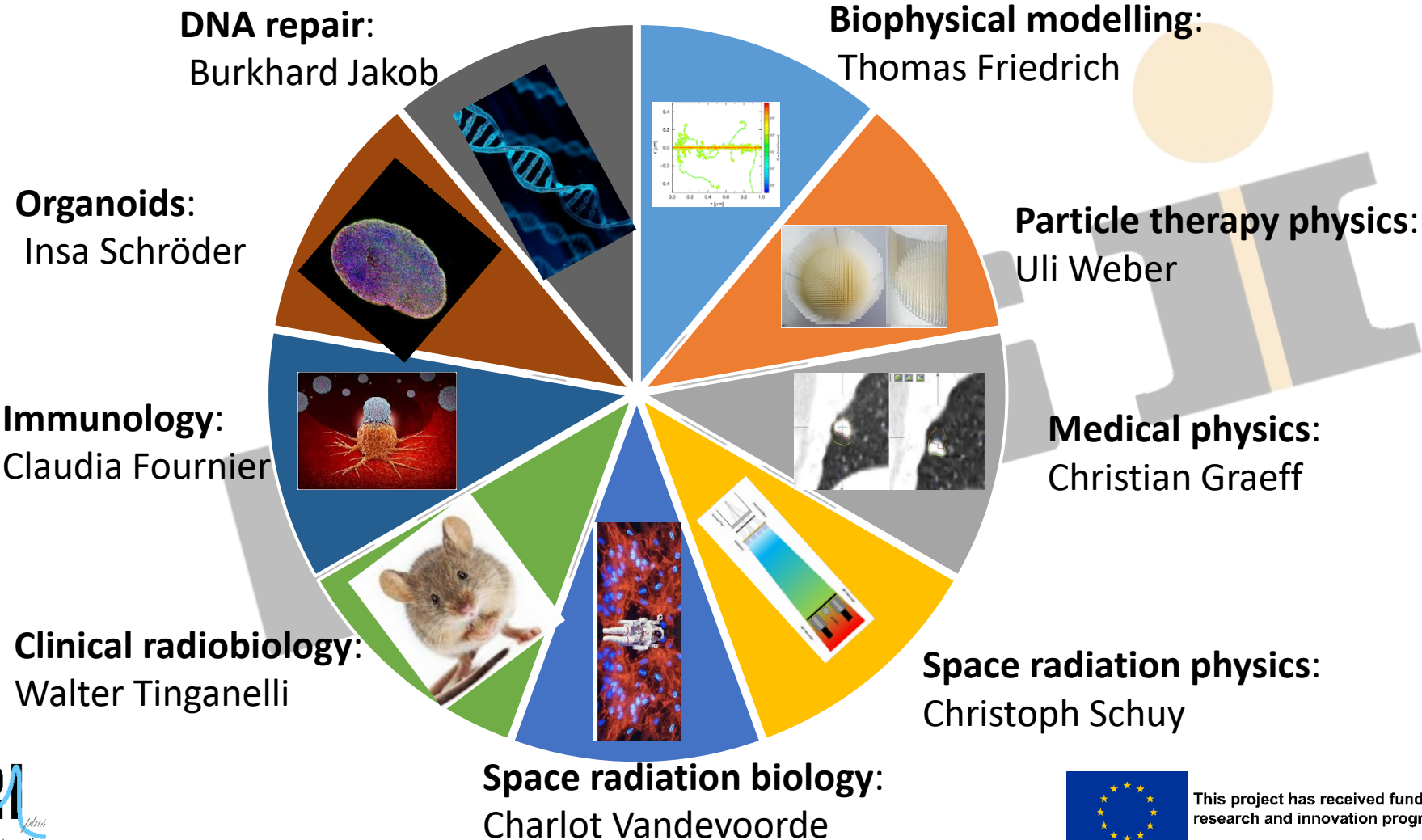


# Biophysics Department today



- 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



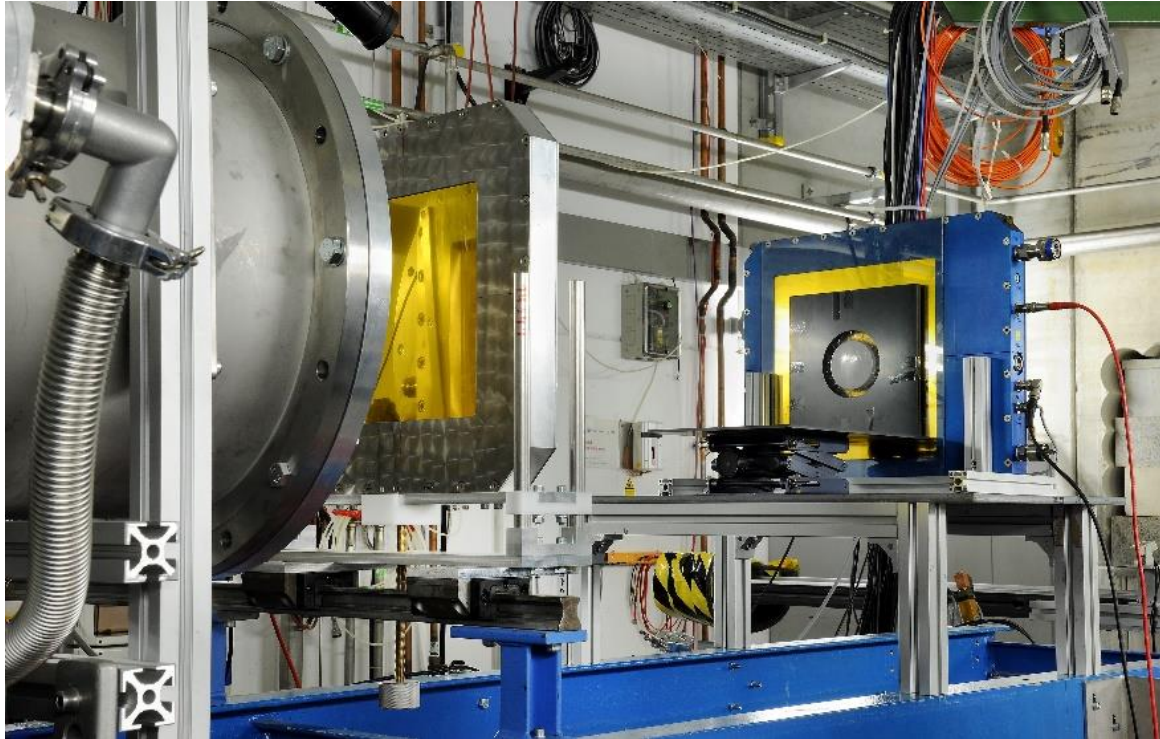
2024

- 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!

