Dosimetry for FLASH Radiotherapy

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Ph.D student
Detector development

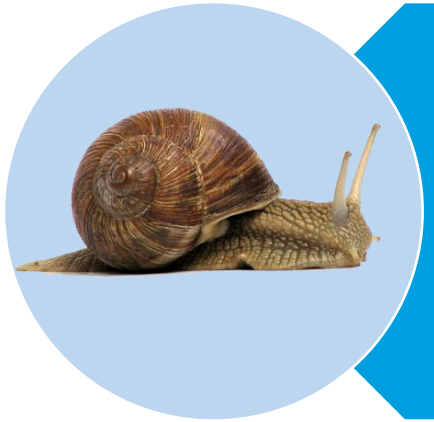
DESY Zeuthen Particle Physics Mini-Retreat, 12 June 2023

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

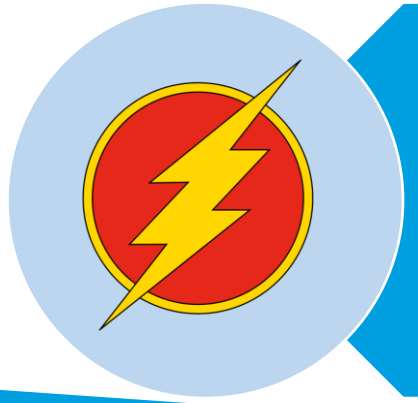
FLASH radiation therapy

The future of cancer treatment?



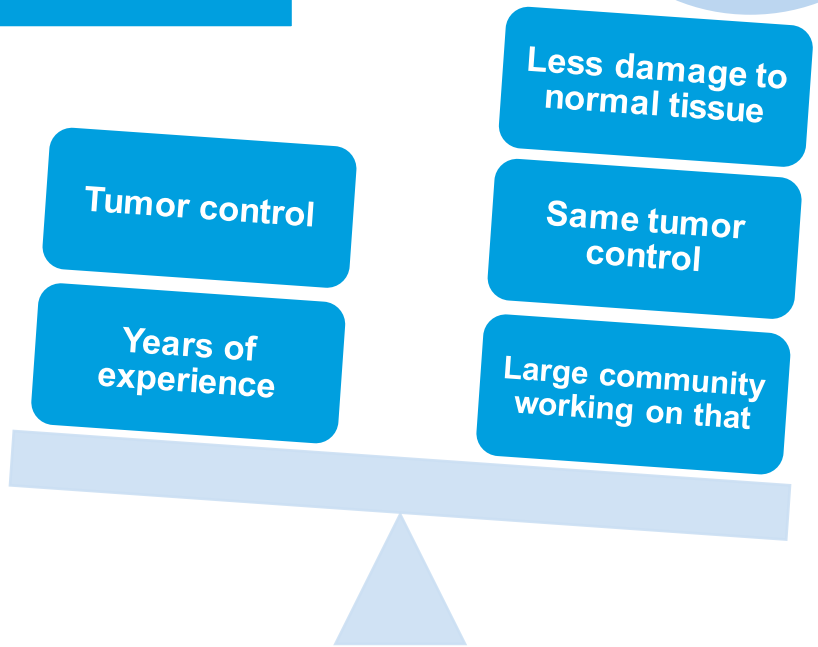
Conventional RT

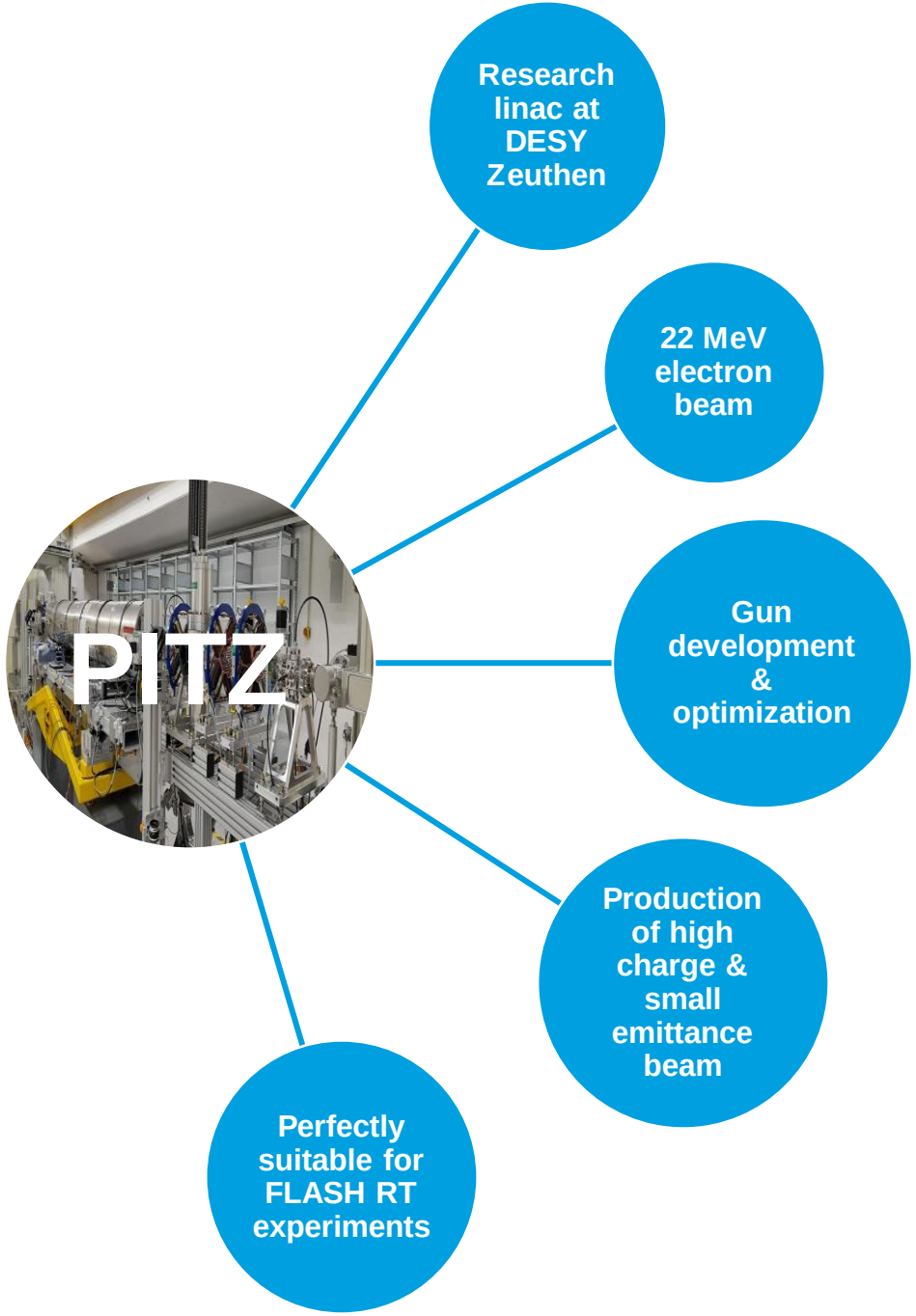
- Dose: 30 – 60 Gy
- Multiple sessions (2 Gy per session)
- Usual dose rate: 2 Gy/min



FLASH RT

- Dose: 30 – 60 Gy
- Less than 200 ms of total irradiation
- Dose rate: > 30 Gy/s

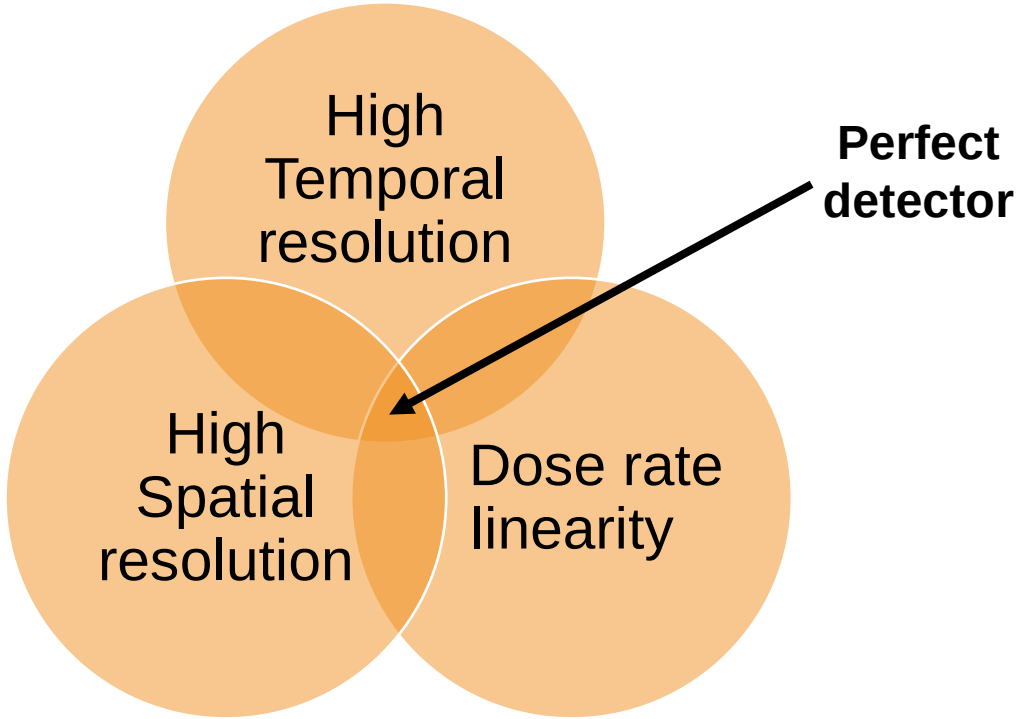




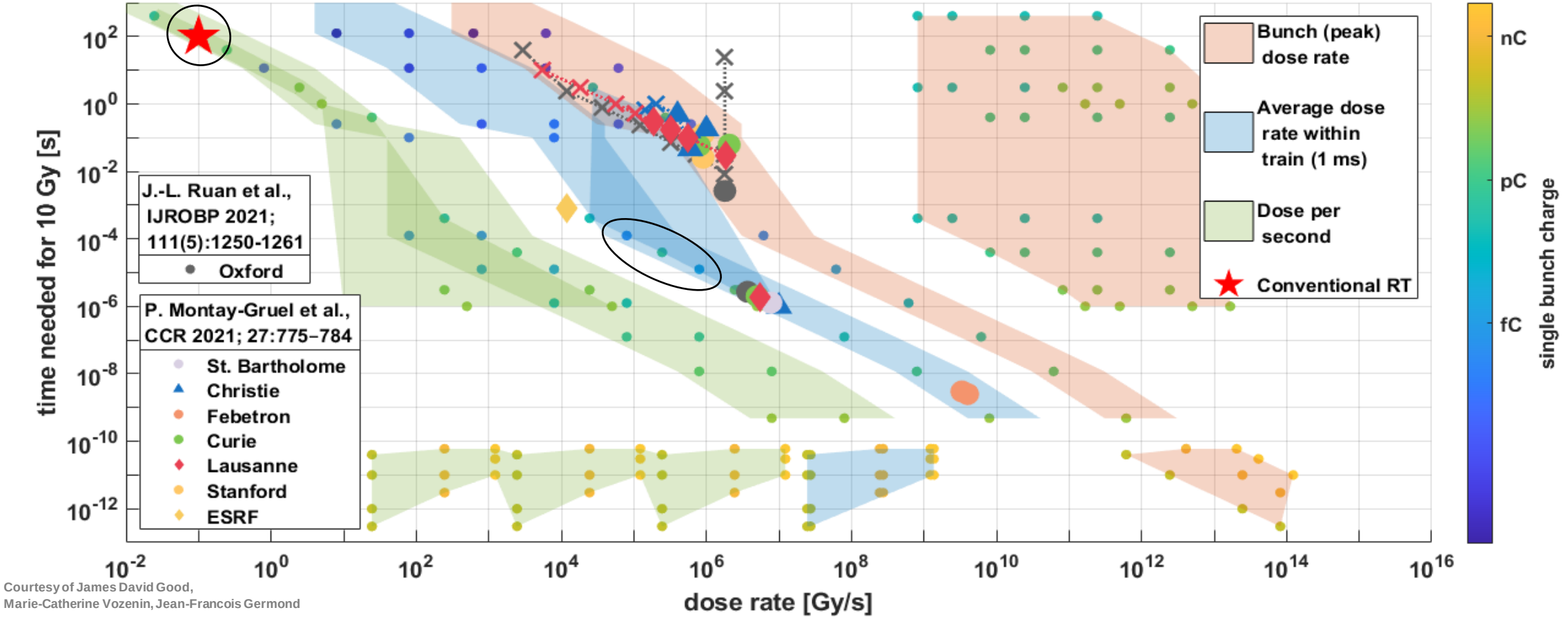
New challenge: Dosimetry

Detection of a huge amount of particles in a very short amount of time

PITZ:
Up to 3×10^{10} particles within 30 ps



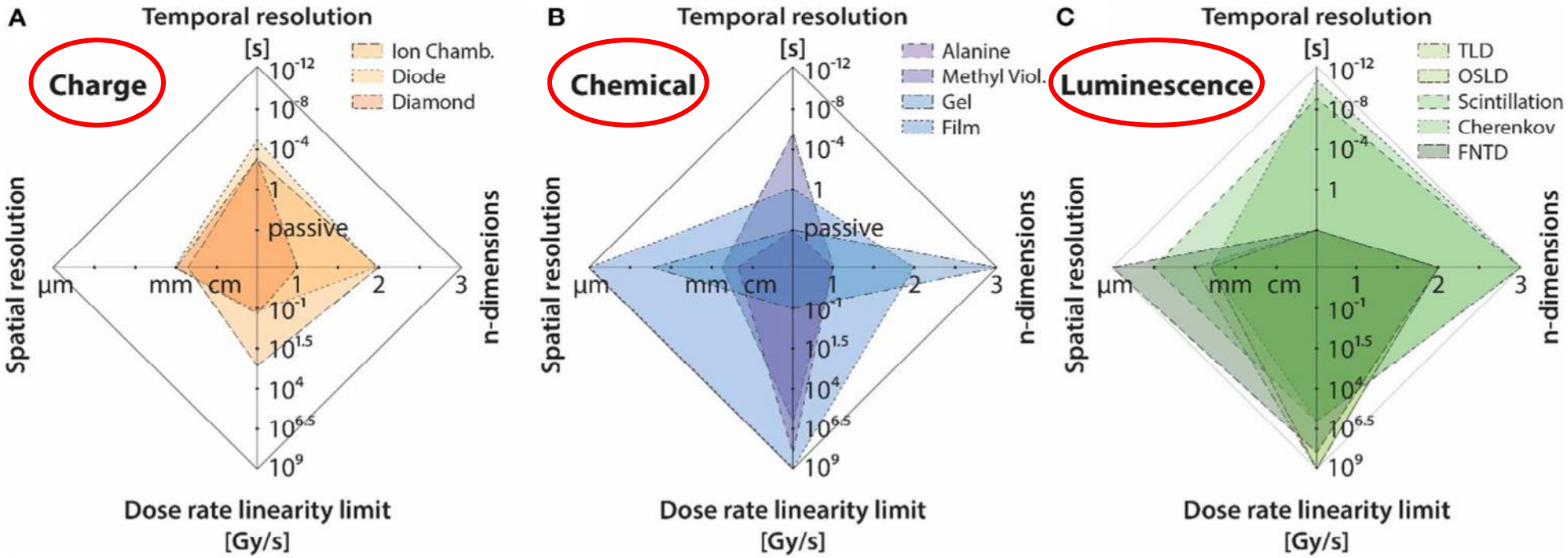
Parameter range available at PITZ



Courtesy of James David Good,
Marie-Catherine Vozenin, Jean-Francois Germond

Challenges of FLASH dosimetry: 3 critical parameters

Three different categories of detectors:

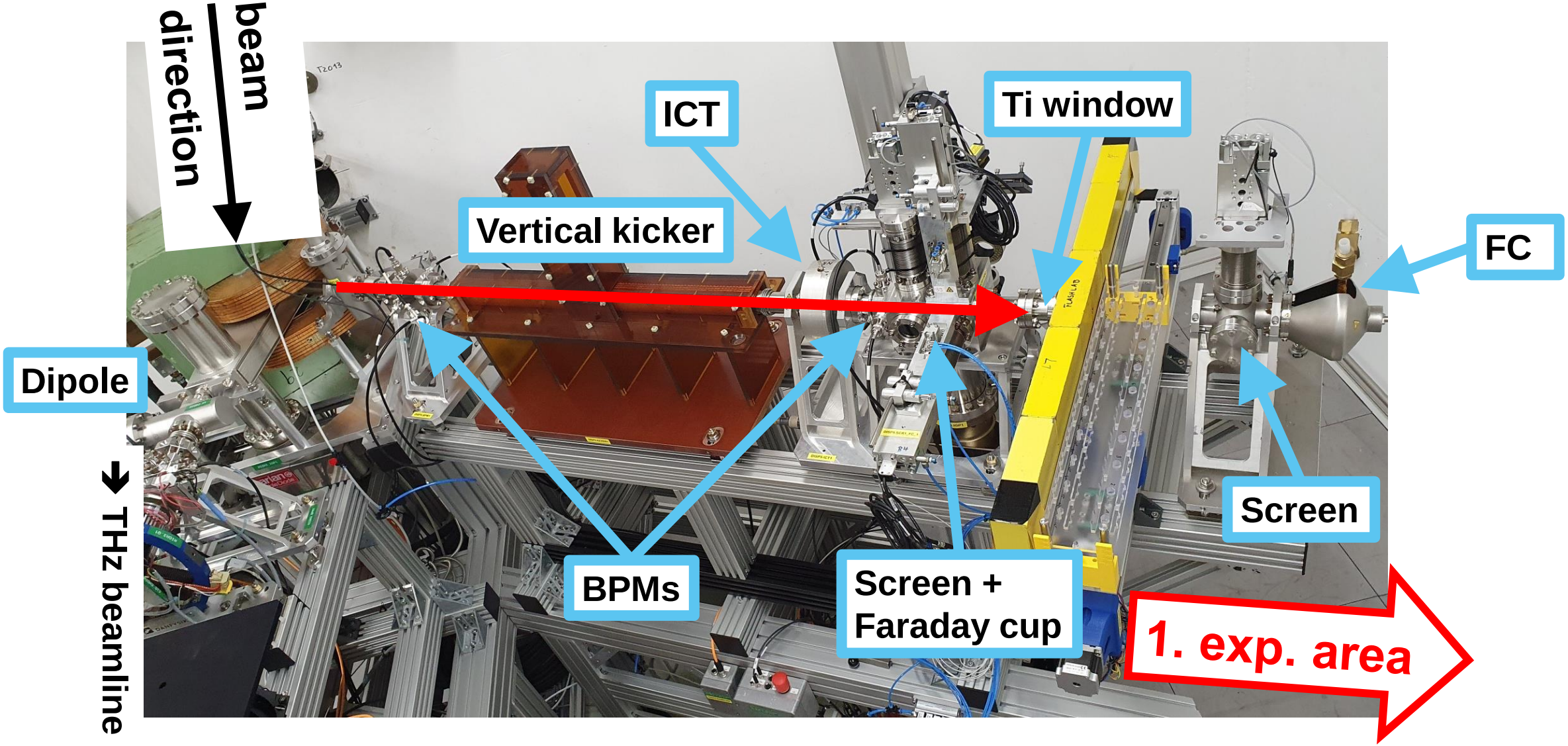


There is no perfect dosimeter for FLASH RT available now.

[arXiv:2006.03755 *Dosimetry for FLASH Radiotherapy]*

Preliminary setup of FLASH*lab*@PITZ

Dipole deflects the beam by 60° to the left

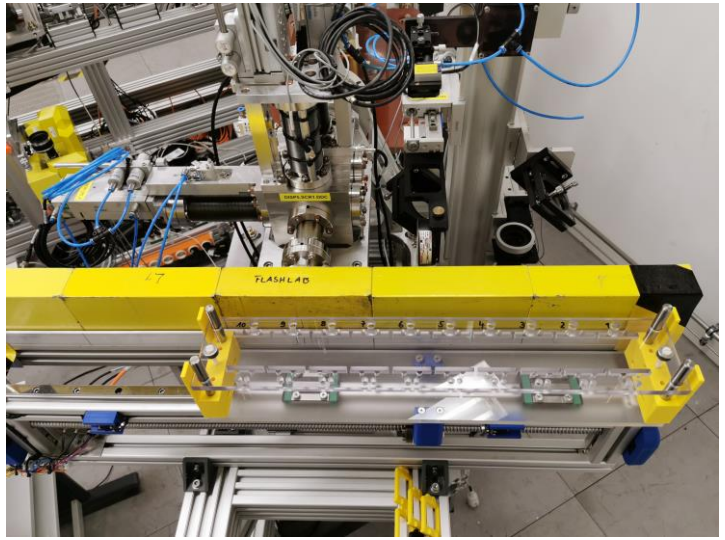


Courtesy of Frank Stephan

Start-up setup for radiation beamline

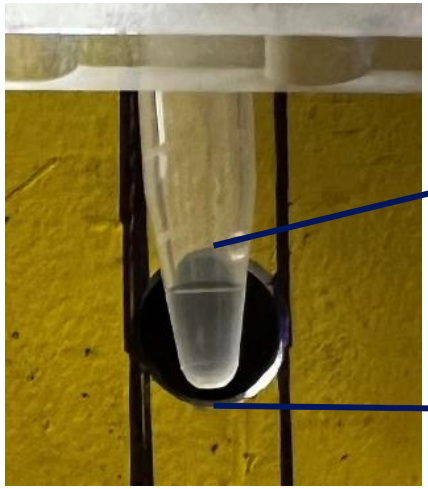
Courtesy of Anna Grebinyk

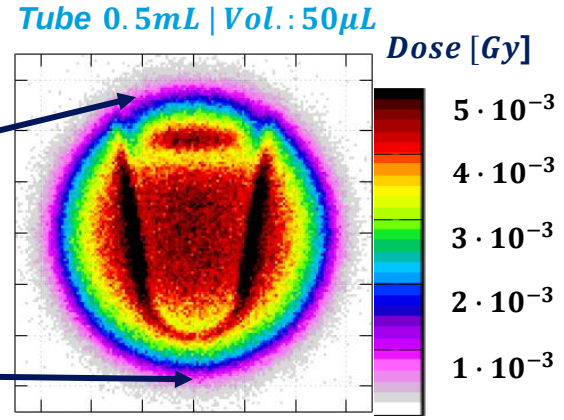
Sample in holder on motorized transverse stage



Courtesy of Frank Stephan

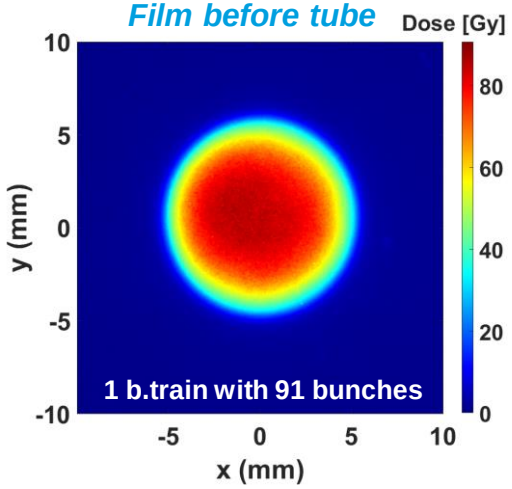
Dose simulation

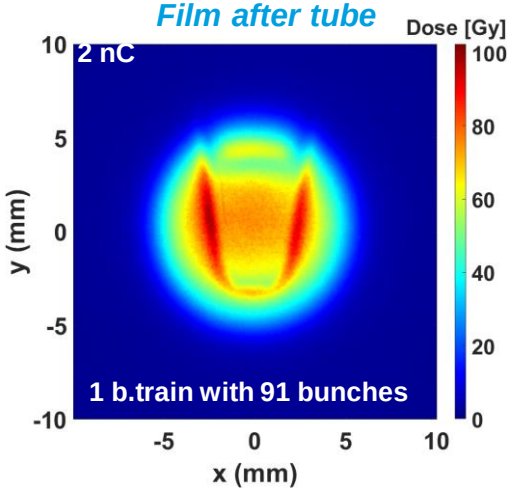




Courtesy of Zohrab Amirkhanyan

Dose measurement with gafchromic films



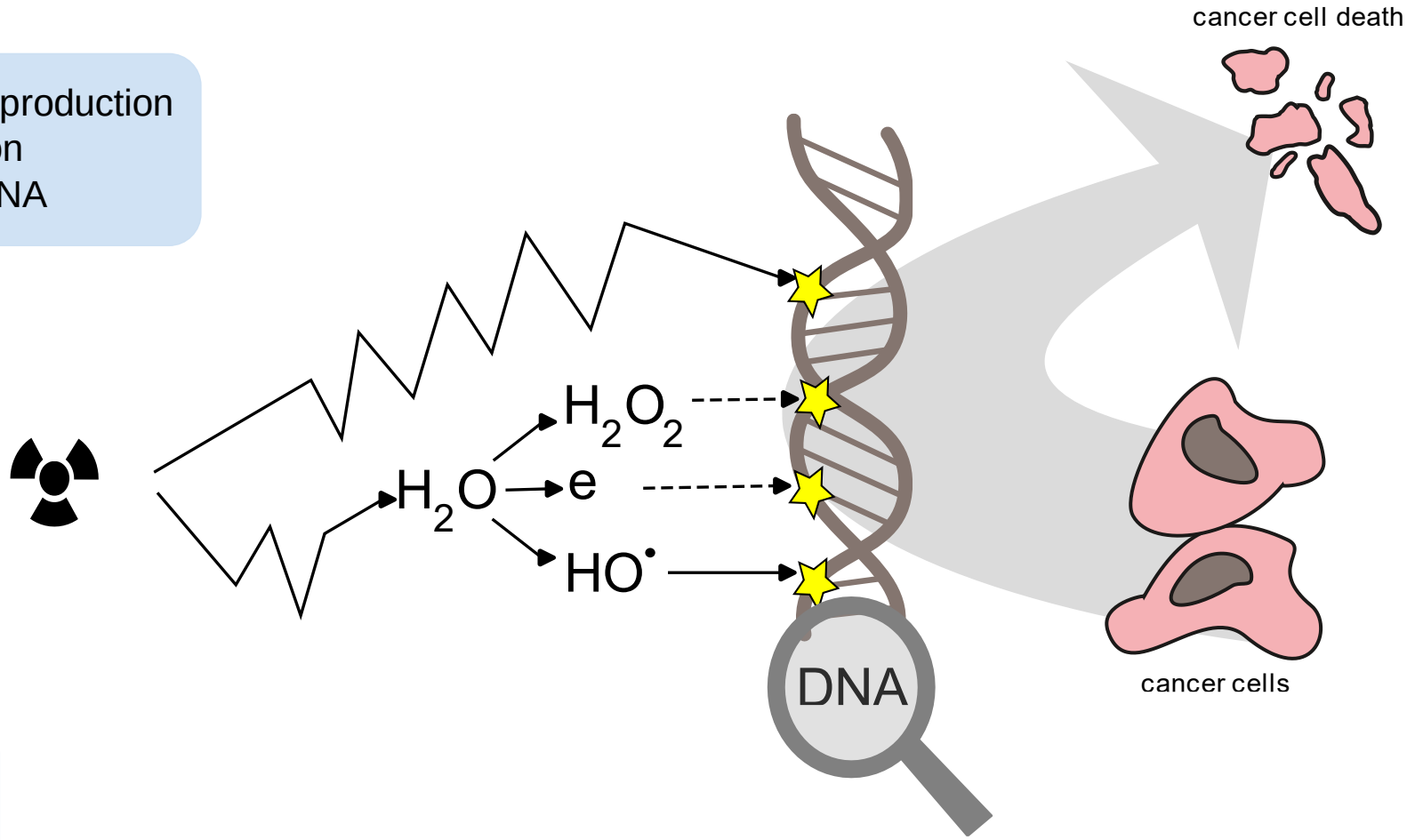


FLASH*lab*@PITZ: first *in vitro* experiments

Courtesy of Anna Grebinyk

Investigation of:

- Hydrogen peroxide production
- Hydroxide production
- Direct damage to DNA

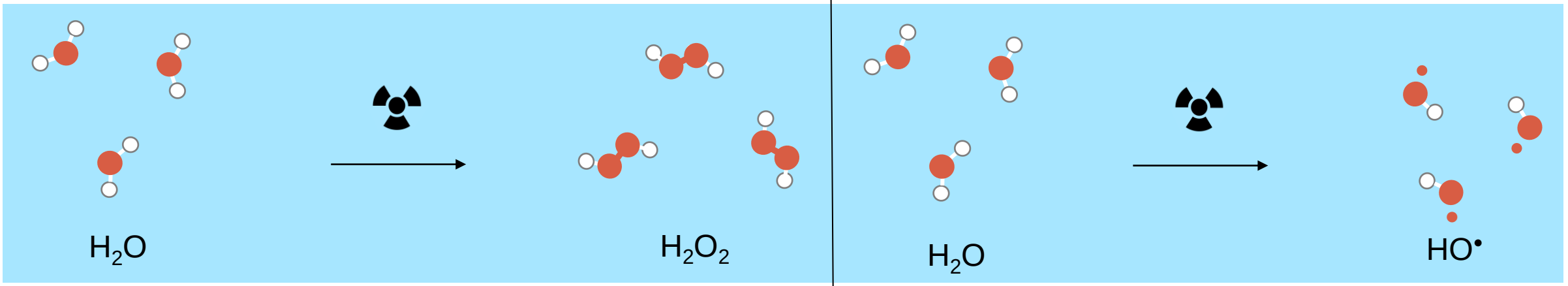


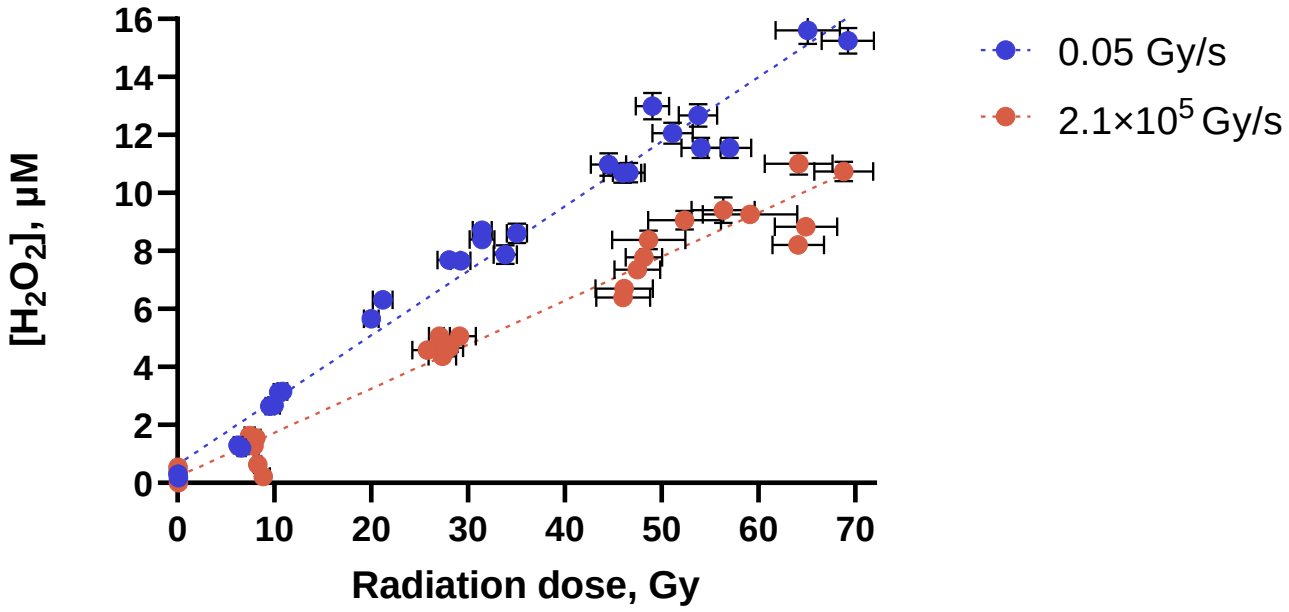
Experiments

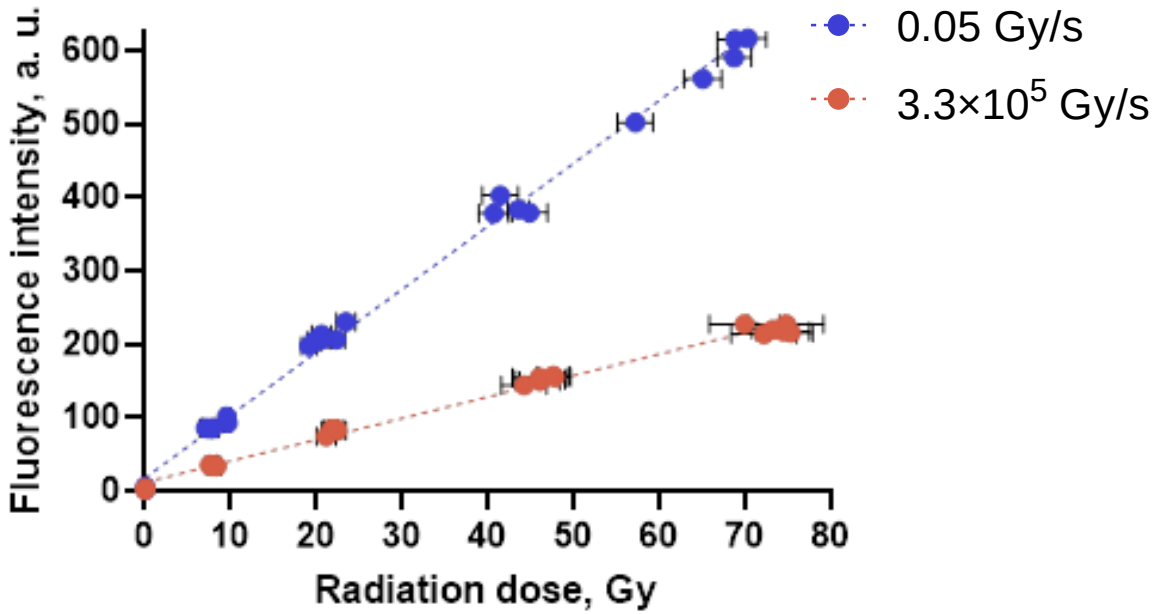
- Irradiation of water
- Irradiation of DNA plasmid
- Irradiation of cancer cells

H_2O_2 & HO generation

Courtesy of Anna Grebinyk



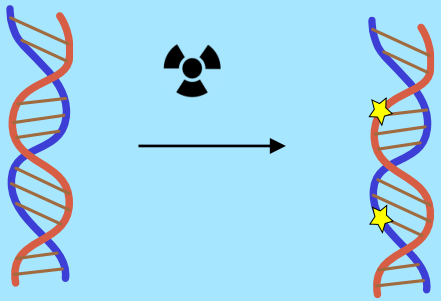




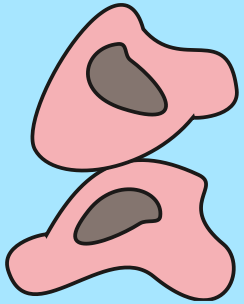
DNA damage & cancer cells

Courtesy of Anna Grebinyk

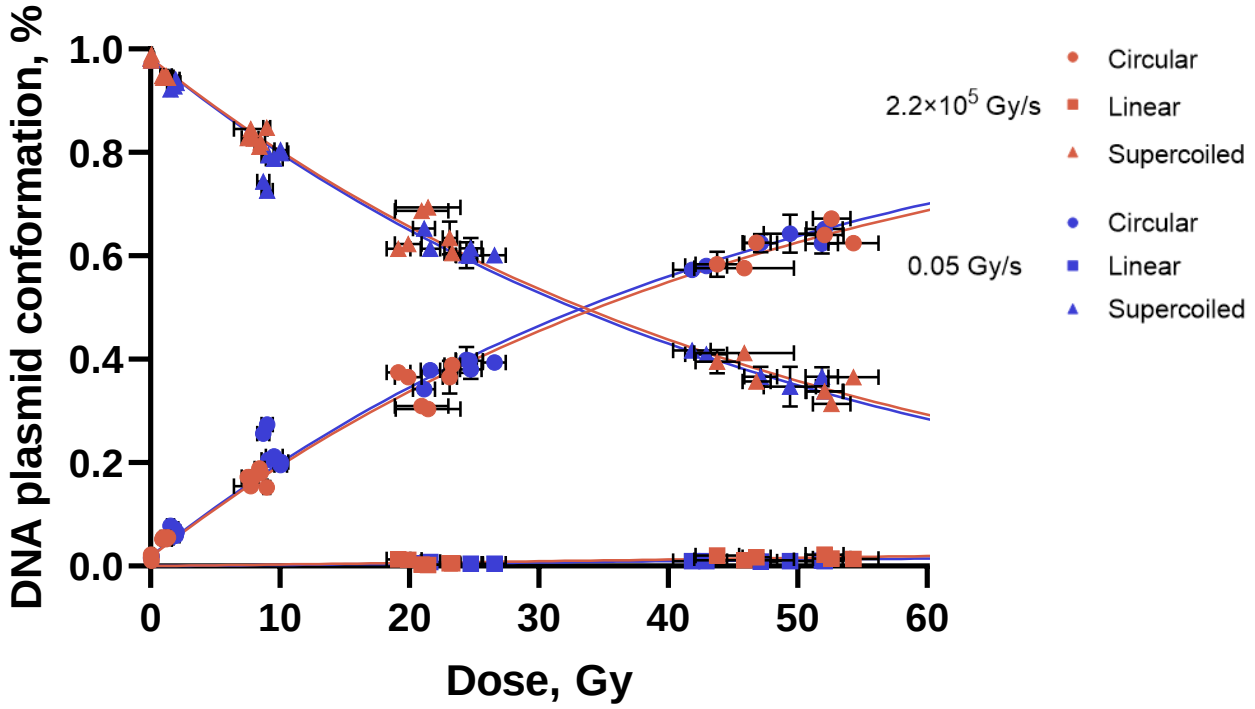
in water

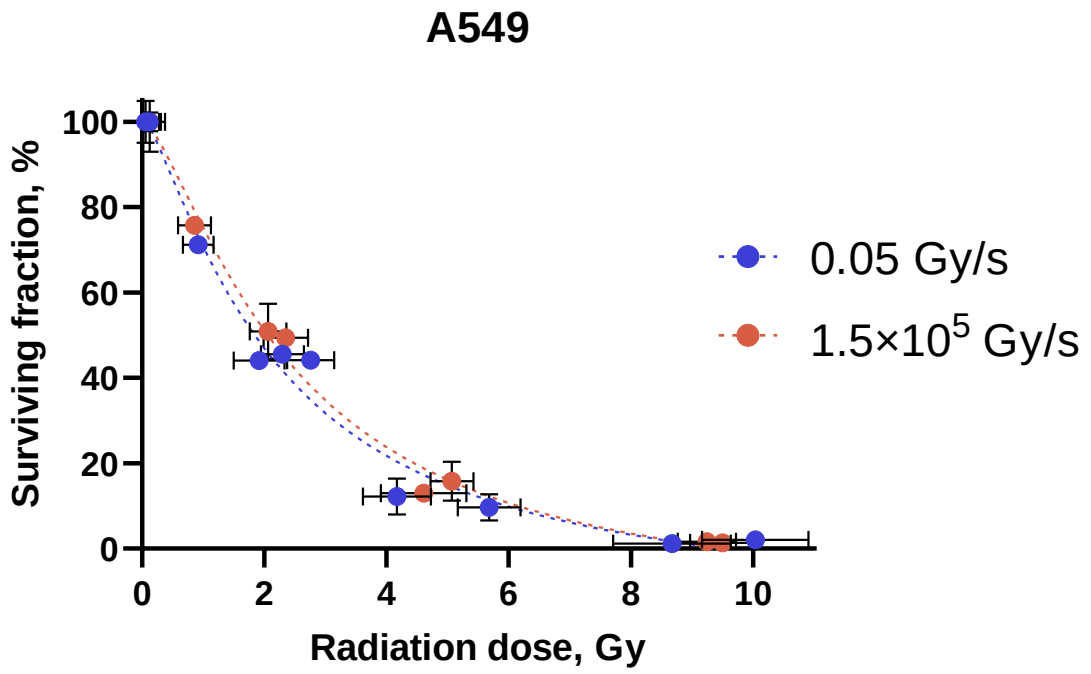


DNA strand breaks



lung carcinoma cells





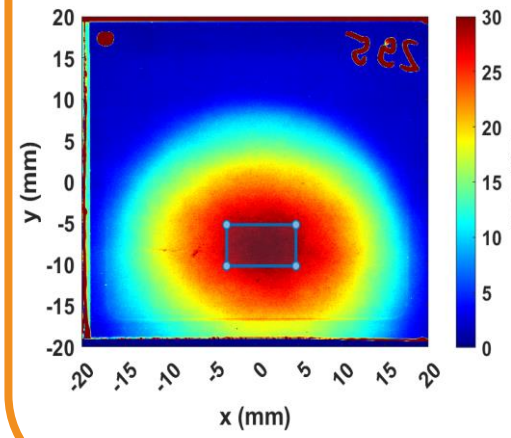
Depth dose profile and dosimetry for HZDR measurements

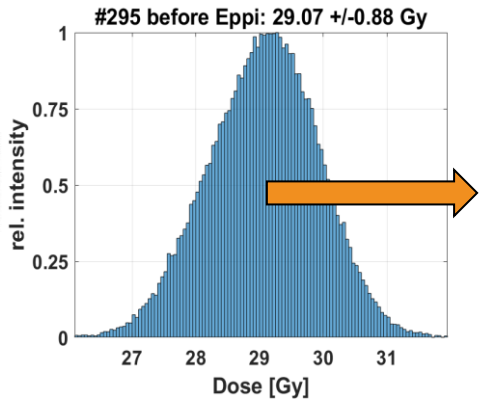
Preparatory dosimetry for later measurement with zebra fish embryos from Helmholtz centrum Dresden-Rossendorf

Uni Manchester/Daresbury provided water tank for depth dose profile measurements

Goal for HZDR: 90% homogeneity in 5x8 mm rectangle, max dose 30 Gy

- Plexiglass plates were introduced to get a more homogeneous beam: 5 & 10 mm were tested.
- **Result:** Homogeneity was achieved with 10mm scattering plate

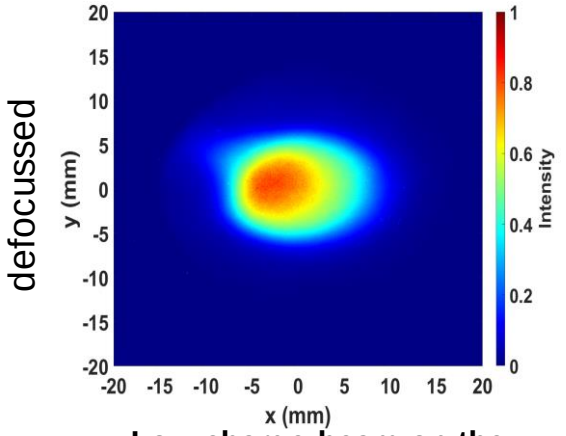


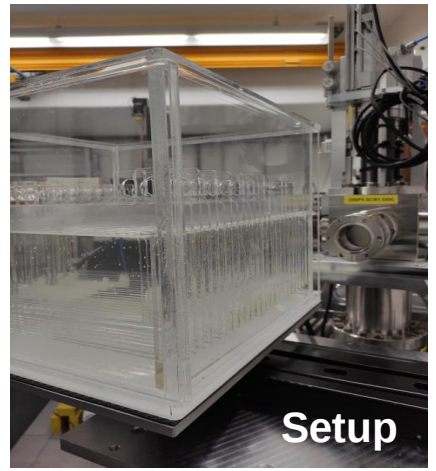


Homogeneity: 90.2 %

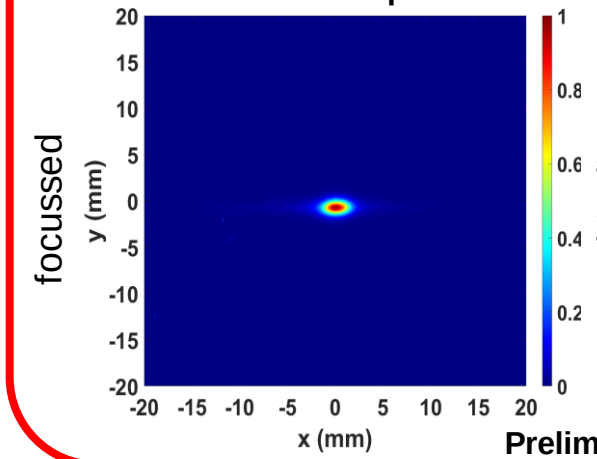
(Definition: Deviation of max/min in ROI from average in ROI)

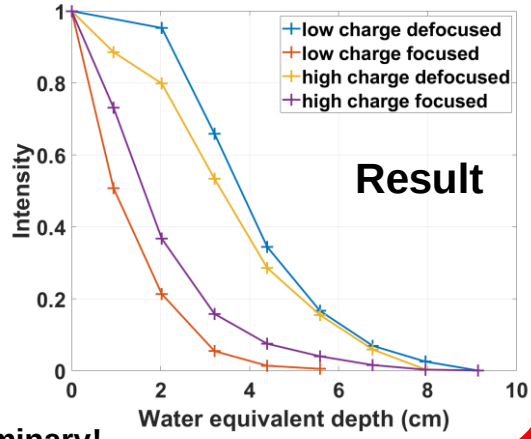
Depth dose profile for 4 different beam parameters





Low charge beam on the outside of the phantom





Preliminary! Analysis ongoing

Conclusion

- **The PITZ accelerator at DESY Zeuthen can provide conv. dose rate up to ultra high dose rate.**
- **Setups: Water phantom & movable stage for irradiation of samples in tubes**
- **Dosimetry: Reference dosimetry was established, more detector tests planned**
- **Biological experiments started**
  - **Irradiation of water: Difference between low and high dose rate**
  - **Irradiation of DNA & cells: No difference**
    Next step: Irradiation under hypoxic (less O_2) conditions

Publications

- **Paper:** F. Stephan et al.: “Progress on the R&D platform FLASHlab@PITZ”, https://doi.org/10.1016/j.ejmp.2022.10.026
- **Poster:** F. Riemer: “First dosimetry tests at PITZ”, FRPT 2022, Barcelona
- **Paper:** Cristina Oancea et al: “Thermal neutron detection and track recognition method in reference and out-of-field radiotherapy FLASH electron fields using Timepix3 detectors”, under review (Physics in Medicine and Biology)
- **Talk:** F. Riemer: “First dosimetry tests at PITZ”, UHDpulse meeting 2023, Prague
- **Talk:** F. Riemer: “Dosimetry tests for FLASH RT at PITZ”, DPG meeting 2023, Dresden
- **Talk:** F. Riemer: “Flashlab@PITZ”, Beam telescopes and test beam workshop 2023, Hamburg
- **Paper & Poster:** Z. Amirkhanyan et al.: “Comparison of measurements and simulation results of dose for the FLASH radiation therapy beamline at PITZ”, submitted for LPR, IPAC 2023, Venice
- **Paper & Poster:** Z. Amirkhanyan et al.: “An alternative beamline setup for FLASH radiation therapy with focused electron beams at the PITZ facility at DESY in Zeuthen: basic concept and dosimetry simulations”, submitted for LPR, IPAC 2023, Venice

Abstracts submitted:

- **Invited talk:** F. Riemer: “Dosimetric experiments at high and low dose rates at FLASHlab@PITZ”, VHEE23, Hamburg
- **Talk:** F. Riemer: “Dosimetrie bei FLASHlab@PITZ”, DGMP meeting 2023, Magdeburg
- **Talk:** F. Riemer: “UHDR Dosimetry at the PITZ accelerator”, FRPT 2023, Toronto

Acknowledgment

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Thank you