First dosimetry tests at PITZ

UHDpulse 2nd Stakeholder Meeting
Prague, January 26 – 27

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PhD student

In behalf of the PITZ team

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

DESY

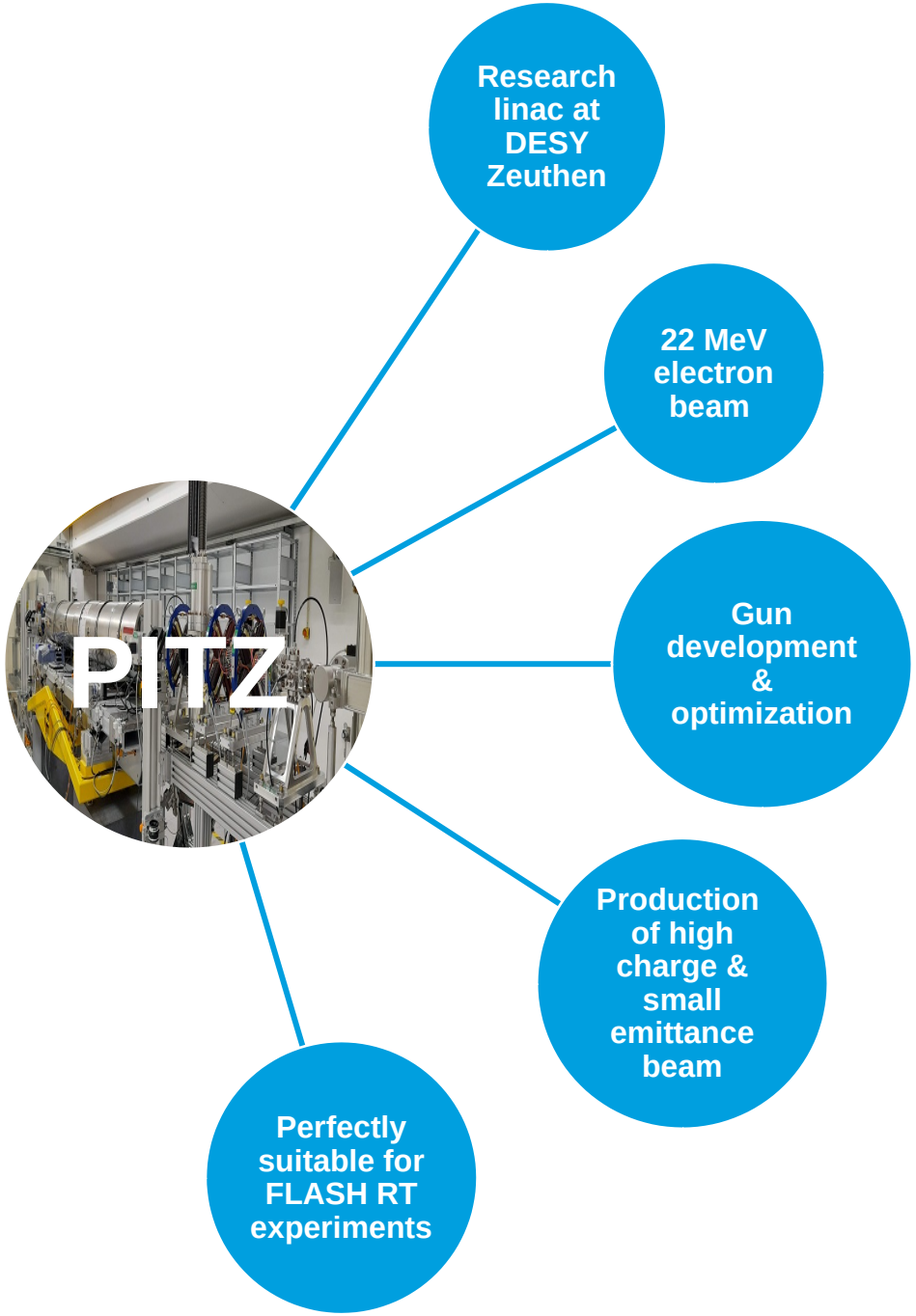
Largest accelerator center in Germany, one lab - two locations: Hamburg + Zeuthen (near Berlin)

(ARES: single e^- bunches, 50Hz, **160 MeV)**

Facts and Figures

- publicly funded national research centre of the Helmholtz Association
- **Employees** at DESY
  - approximately **2700**, including 1180 scientists
- Interdisciplinary research, international cooperation
- Research at DESY in 4 areas:
  - **Accelerators**
  - Photon Science (focus in Hamburg)
  - Particle Physics
  - Astroparticle Physics (focus in Zeuthen)

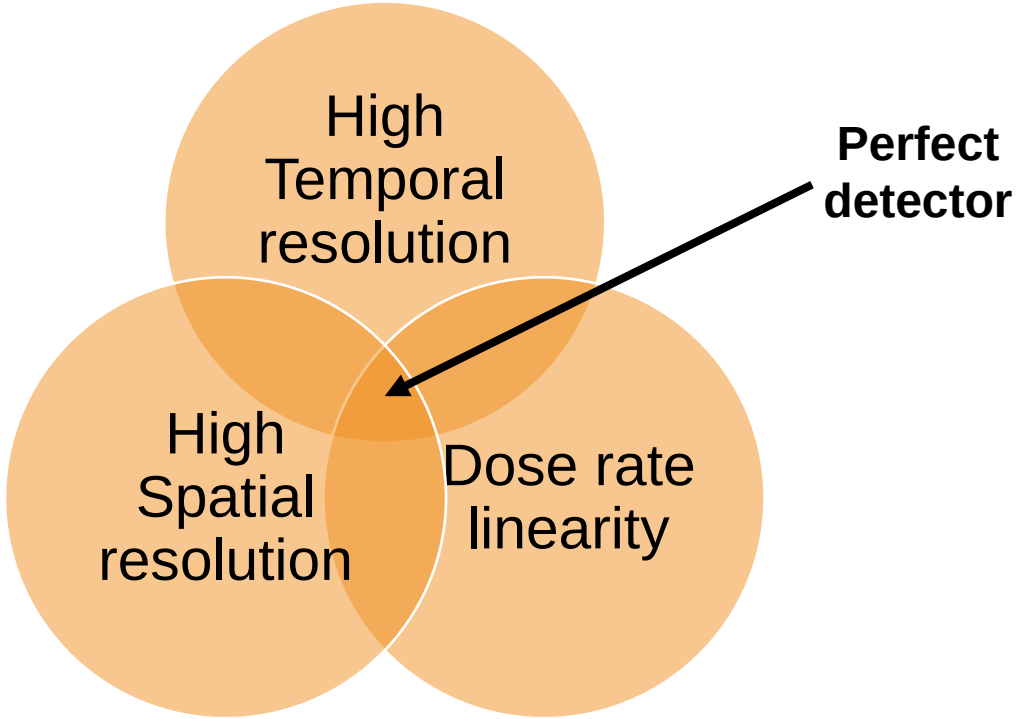
Courtesy of Ulrike Behrens & Frank Stephan



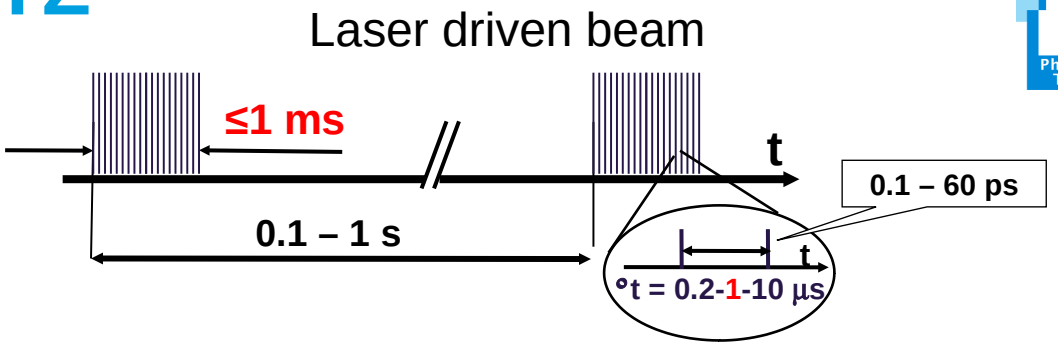
New challenge: Dosimetry

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

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



Beam parameters available at PITZ



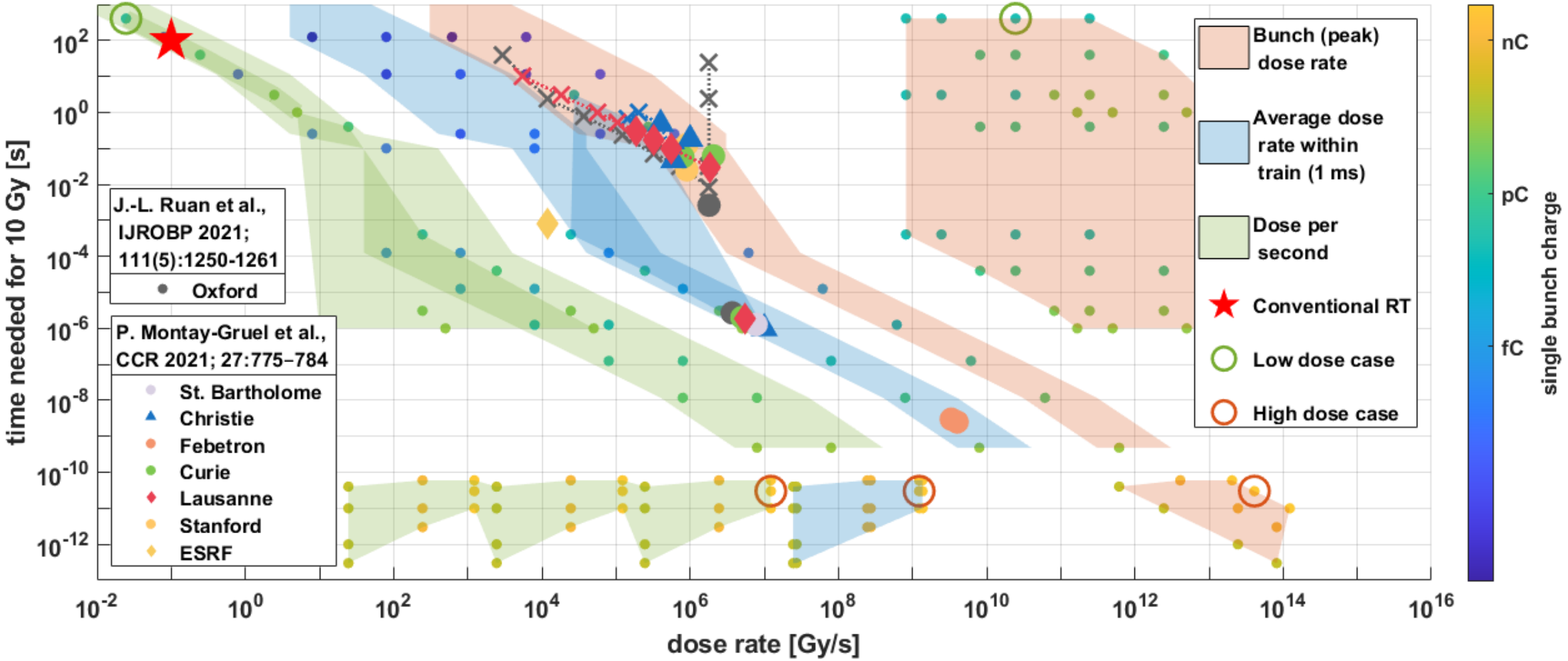
Options @PITZ:	low dose case	high dose case
Bunch charge	**0.1 pC**	**5 000 pC**
Single bunch OR train	single bunch	1ms train (1MHz)
RF pulse rep. rate	1 Hz	10 Hz
Bunch length	<1 ps	~30 ps
Dose per bunch	0.02 Gy	1000 Gy
Dose rate per bunch	$2x10^{10}$ Gy/s	$4x10^{13}$ Gy/s
Dose per train (ms)	**0.02 Gy**	**$1x10^{6}$ Gy**
Dose rate per train (ms)	20 Gy/s	$1x10^{9}$ Gy/s
Dose per second	**0.02 Gy/s**	**$1x10^{7}$ Gy/s**

Bunch/micropulse charge is tunable from 0.1 pC up to 5 nC

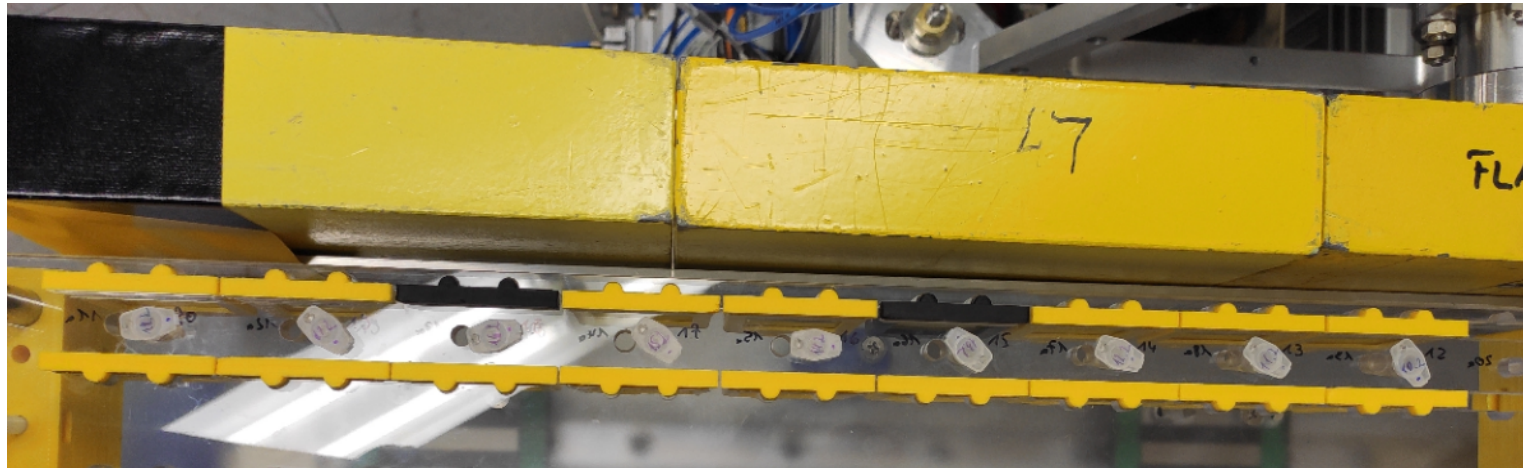
 # bunches/micropulses per pulse can be tuned from 1 up to 1000

Dose rate can be tuned from conv. DR up to UHDR

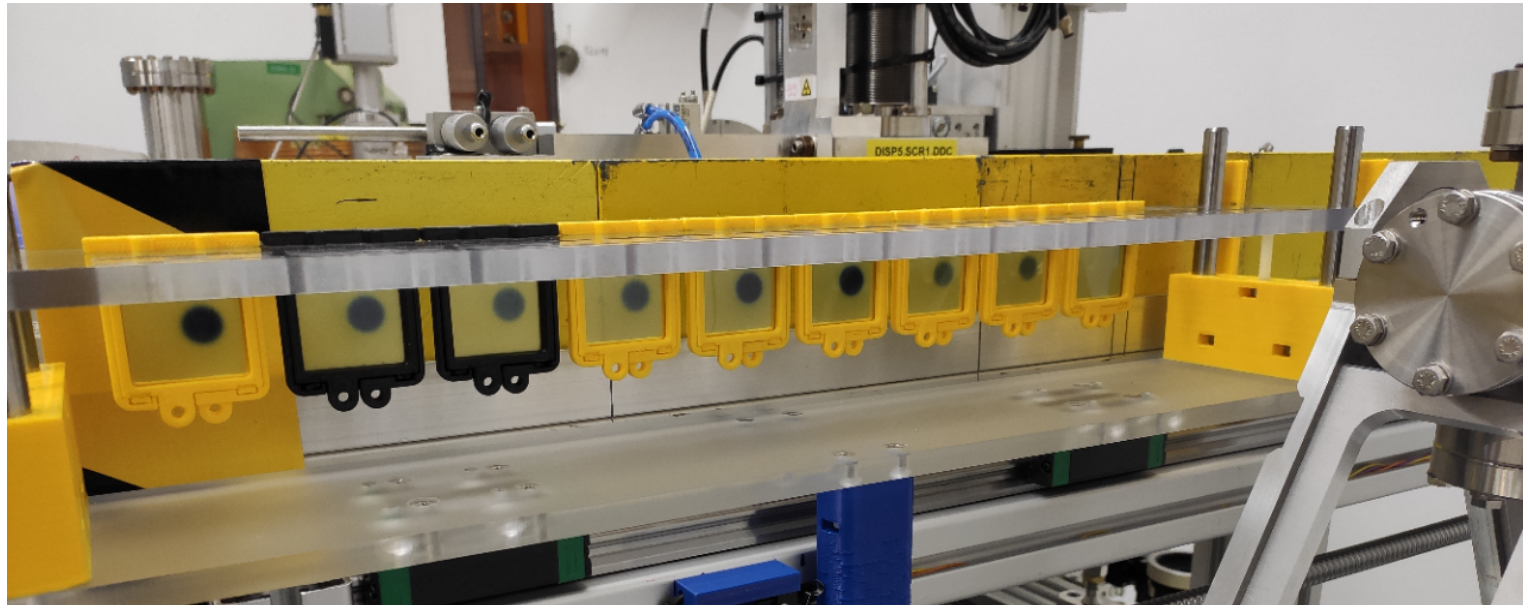
Time needed for 10 Gy vs. Dose rate at PITZ

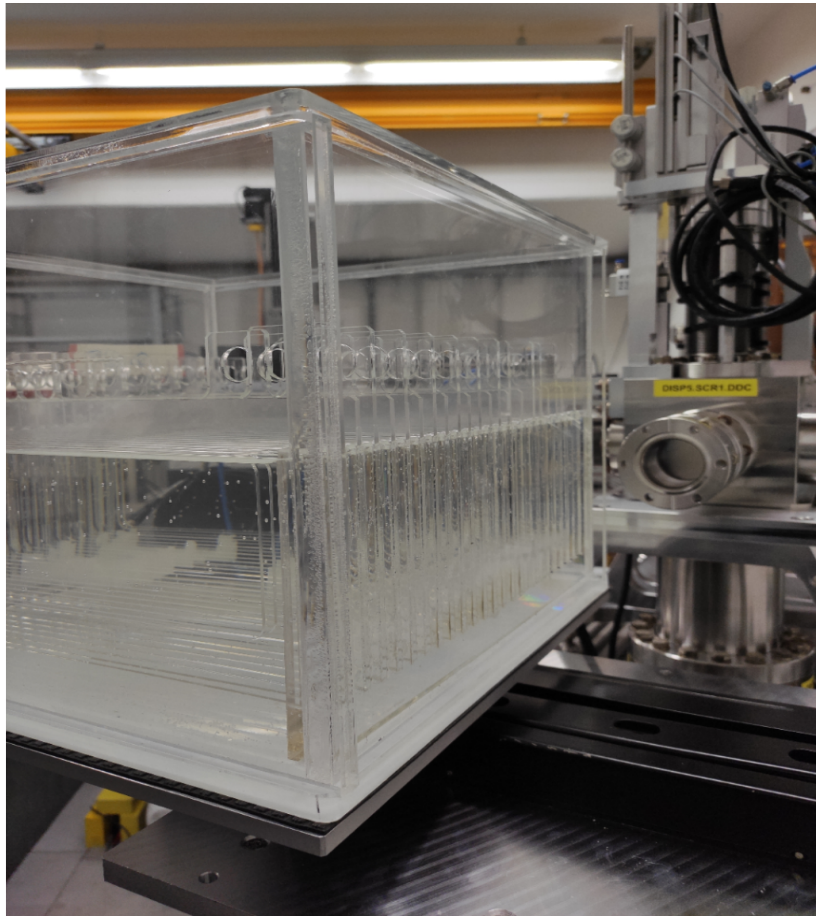


Courtesy of James David Good,
Marie-Catherine Vozenin, Jean-Francois Germond



Preliminary setup of FLASH*lab*@PITZ





Characterization of EBT-XD films & experiments done/planned

Limit test:

- Calibration was done up to 200 Gy
- Irradiation up to 370 Gy -> Extrapolation of calibration
- Deviation of 20% beyond 250 Gy
- Next batch of films: Calibration up to 300 Gy -> Experiments ongoing.

Dose rate linearity

- Dose rate linearity was confirmed up to 10^8 Gy/s as in literature
- Irradiation to dose rates up to $8x10^{10}$ Gy/s were done
- High background due to dark current (Background 3 times higher than signal)
- Dark current was decreased in the mean time: Experiment will be redone

Experiments at PITZ

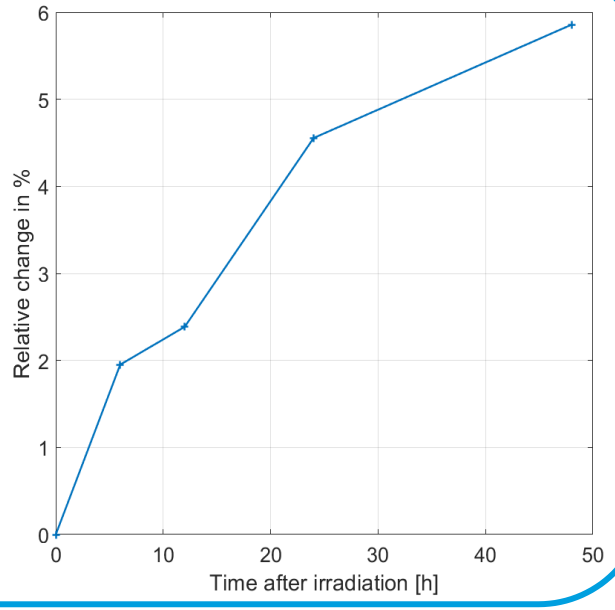
- We just started in November 2022
- Hydrogen peroxide production, irradiation of DNA plasmid & cells (cooperation with TH Wildau)
- Irradiation of sarcoma cancer cells (cooperation with Charité)

Planned experiments

- Irradiation of zebrafish embryos (cooperation with HZDR)
- Alanine calibration (cooperation with PTB)

Readout of films:

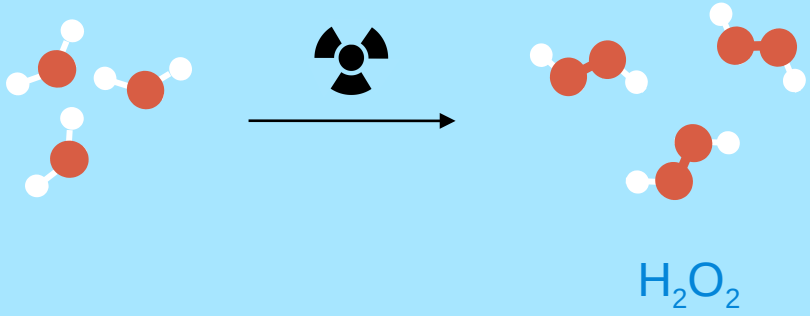
- Relative Change of about 5%, 24h after irradiation
- Standard readout after 24h was used for all experiments

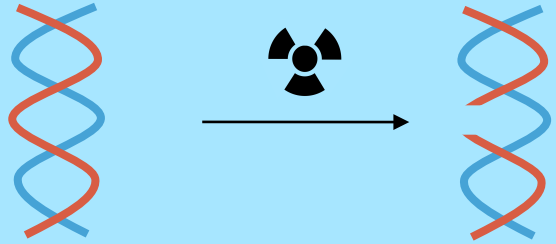


First chemical / biochemical experiments at FLASH*lab*@PITZ

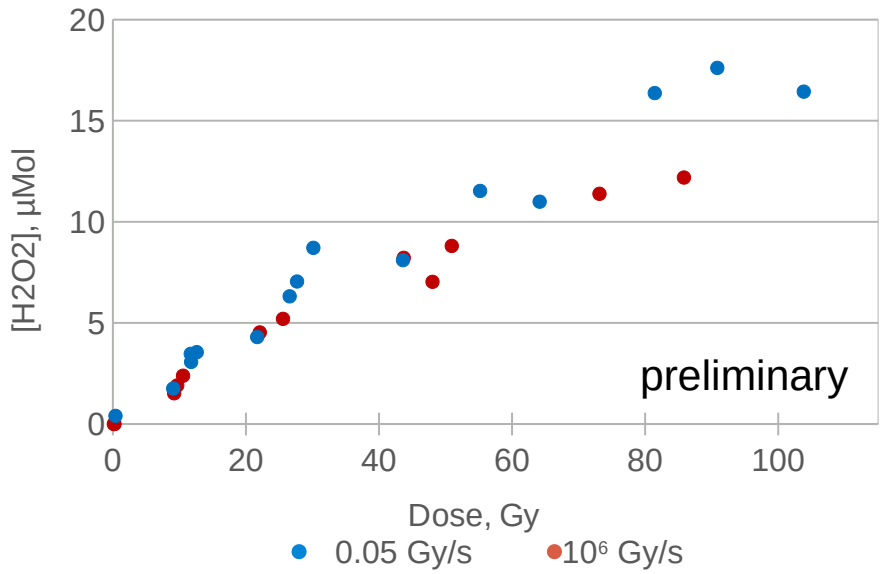
First proof-of-concept for doing chemical and biological research at PITZ

in water

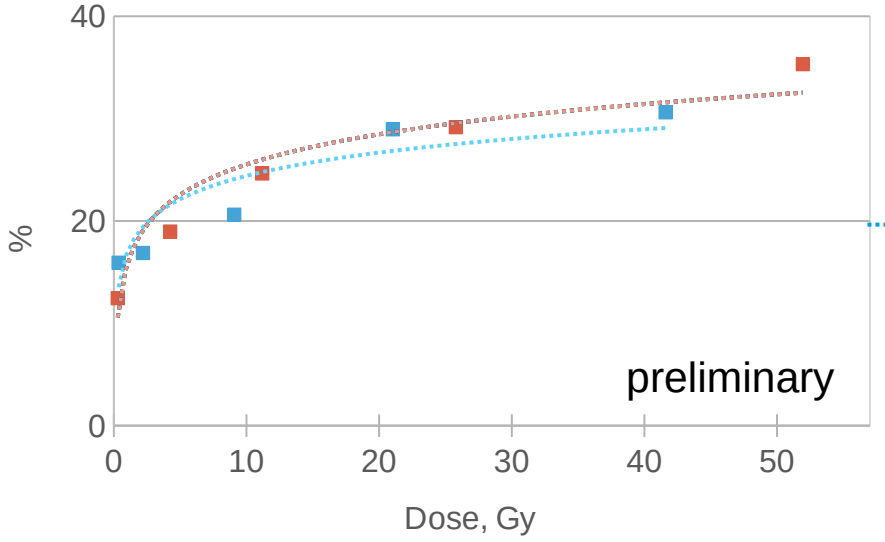




H_2O_2 generation



DNA plasmid conformation



Supercoiled, **10^6 Gy/s**

Supercoiled, **0.05 Gy/s**

Circular, **10^6 Gy/s**

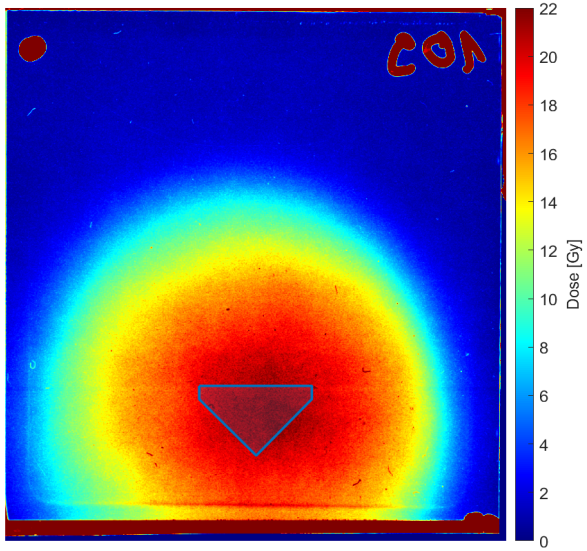
Circular, **0.05 Gy/s**

 comparable for both dose rates

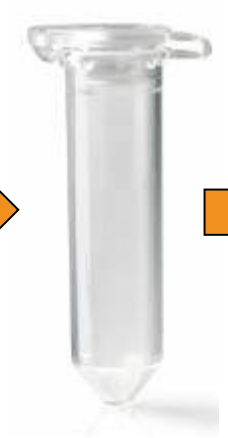
Courtesy of Anna Grebinyk

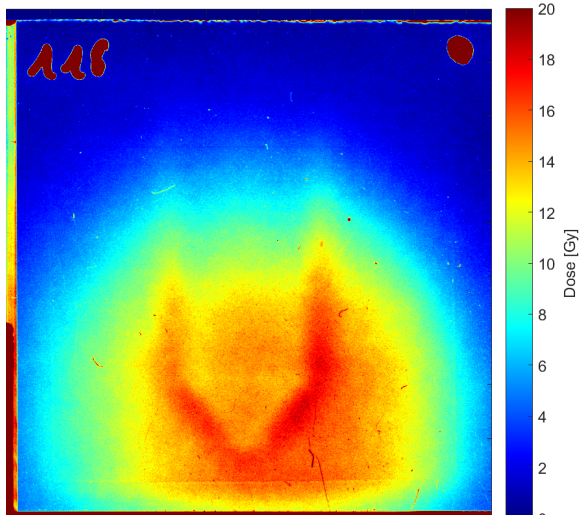
Irradiation of samples -> Homogeneity

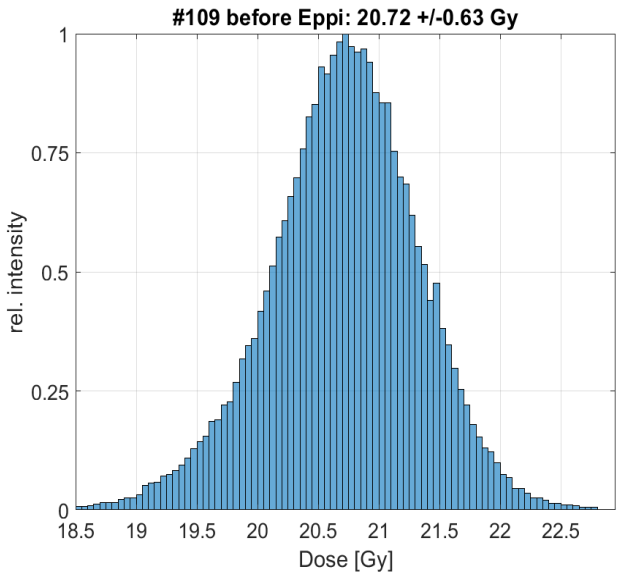
1.4x10⁵ Gy/s @ 700 pC



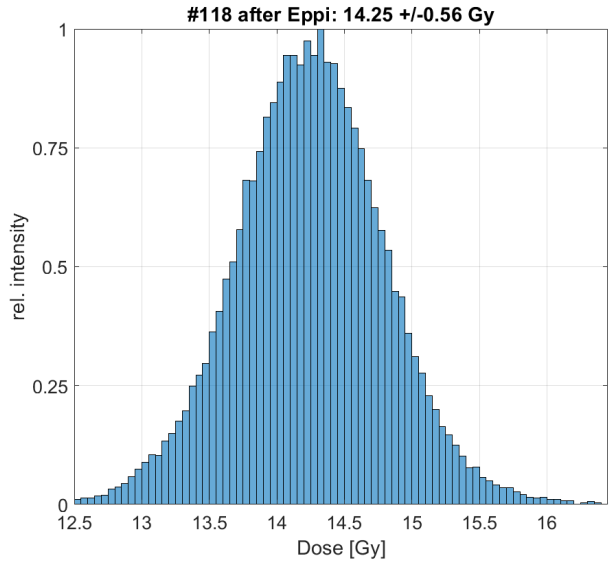
Sample







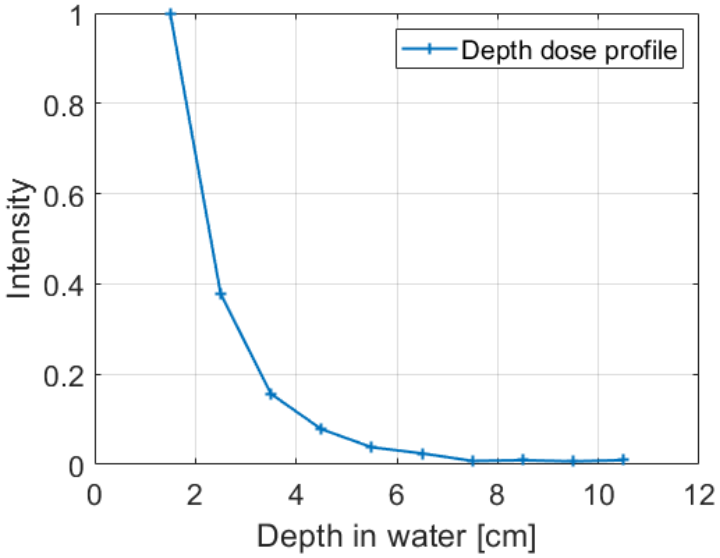
Dose distribution of irradiated volume / surface



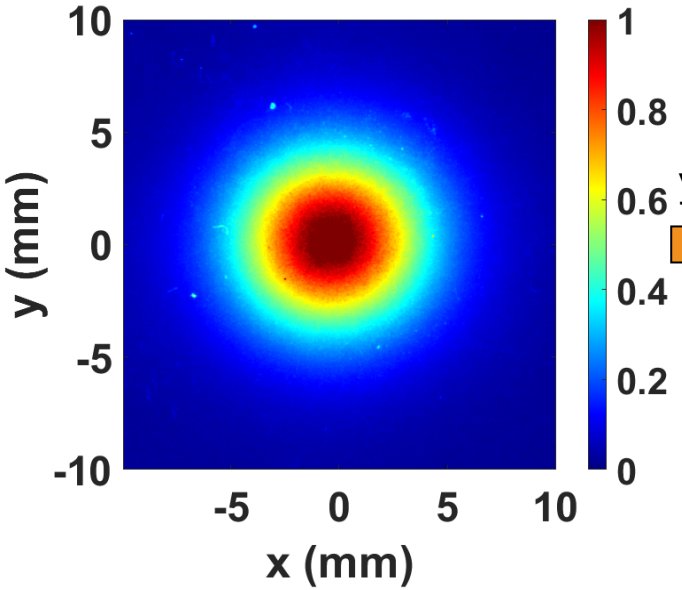
First irradiation of cancer cells were done last week

Water phantom: Depth dose curve & beam profile

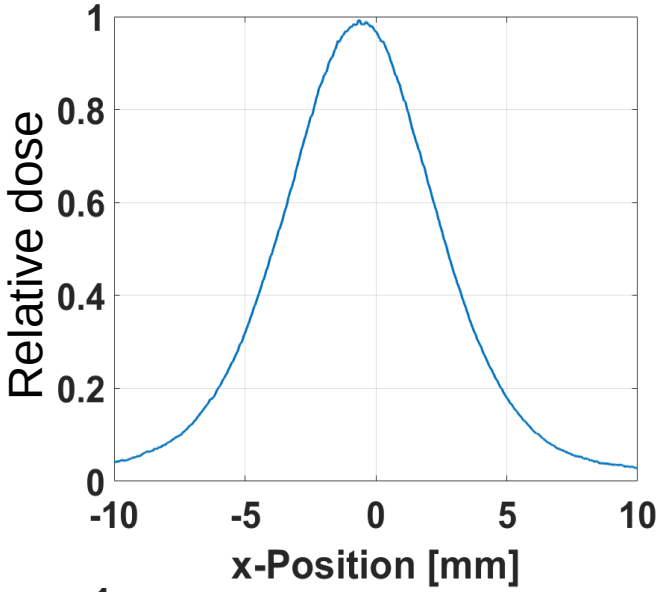
$\sigma_x = \sigma_y = 1$ mm



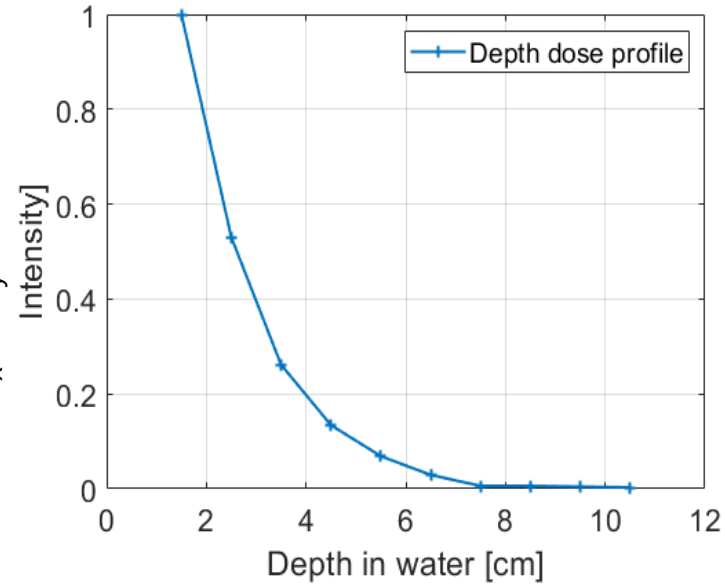
1.5 cm



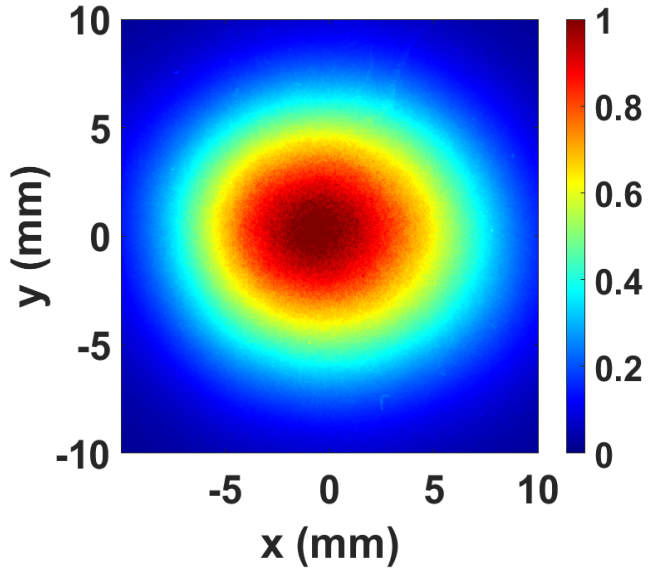
y = 0



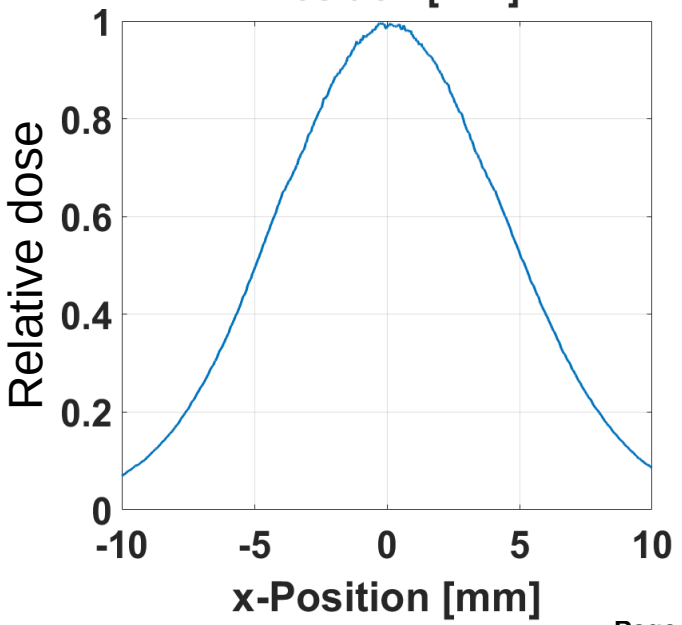
$\sigma_x = \sigma_y = 3$ mm



1.5 cm

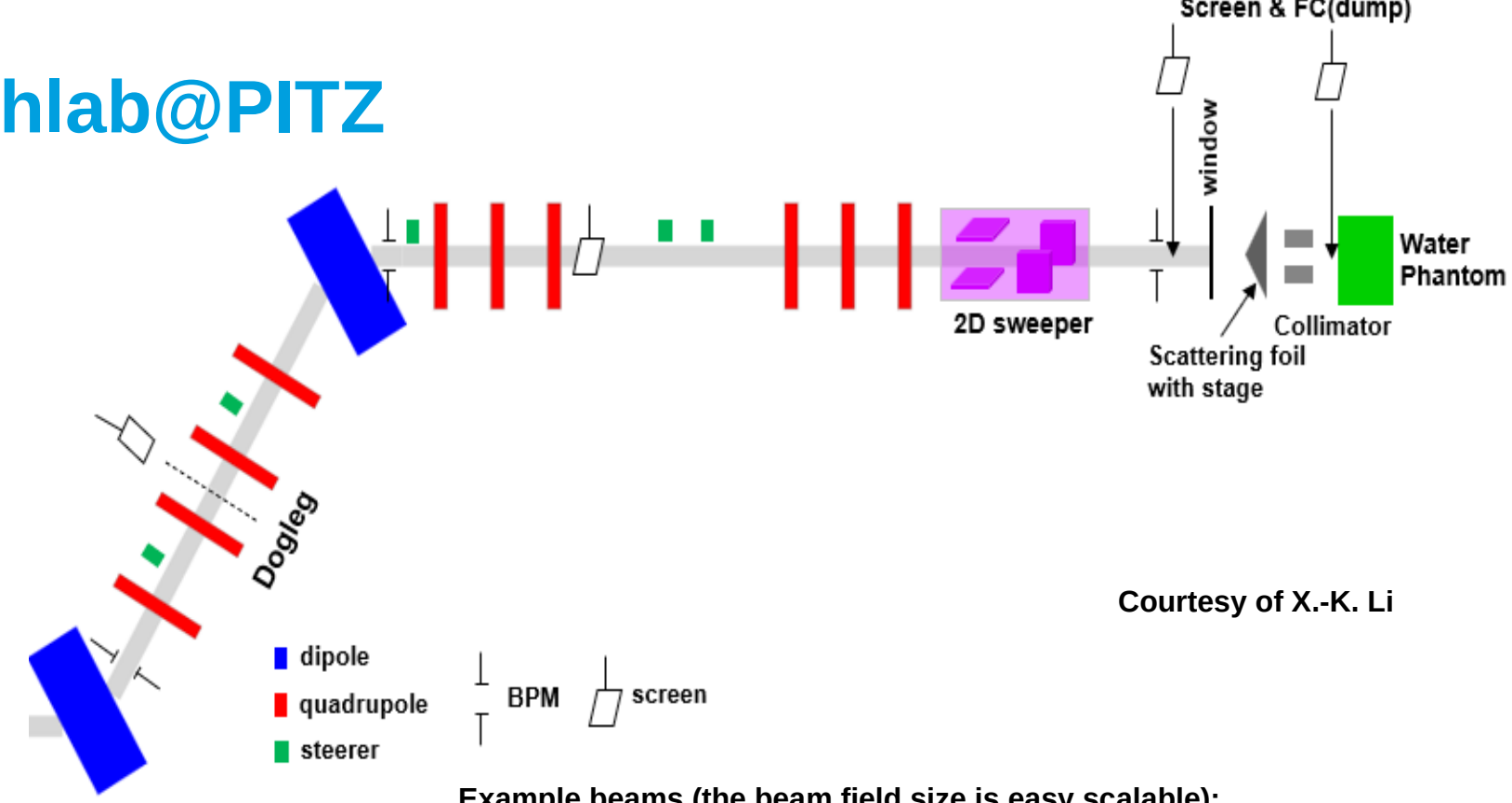


y = 0



Upgrade plan for Flashlab@PITZ

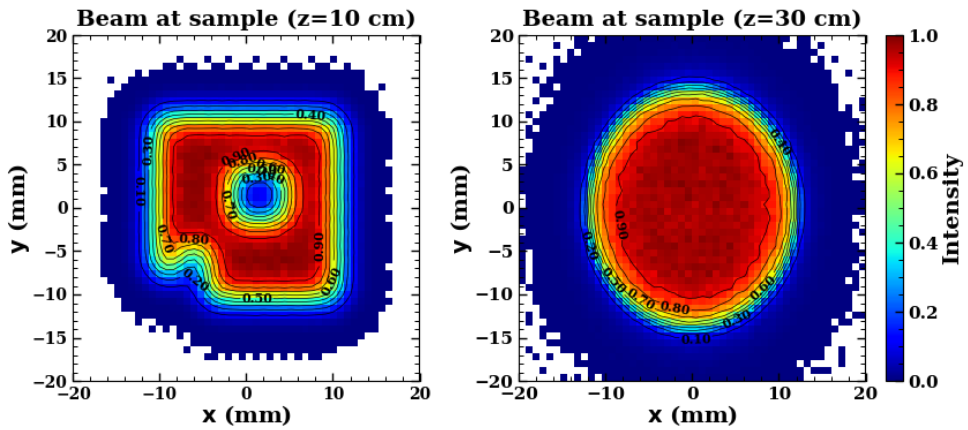
- Upgrade of existing setup is planned to be finished 2023/24
- More than 10 magnets for beam focusing are already ordered
- Beam diagnostics (BPM, screen, Faraday cup)
- 2D sweeper to scan the beam over surface



Courtesy of X.-K. Li

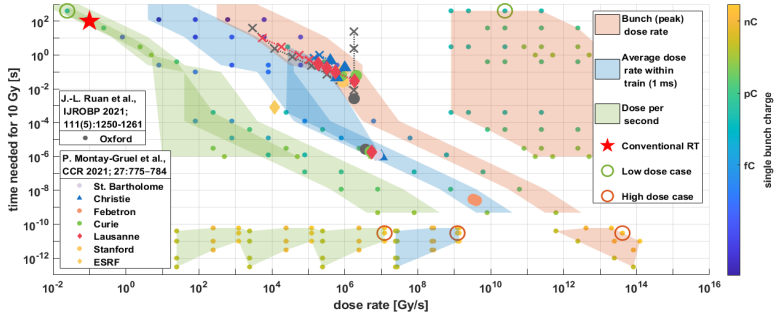
Example beams (the beam field size is easy scalable):

a) From 2D sweeper **b) from scattering foil**

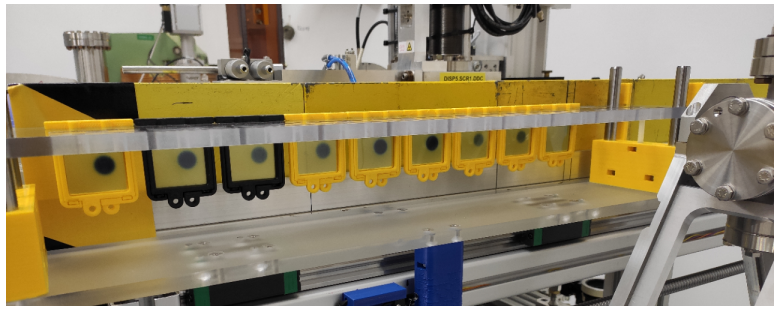


Conclusion

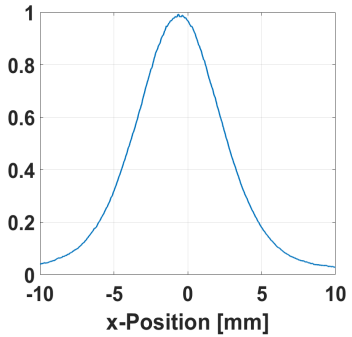
- **The PITZ accelerator at DESY Zeuthen can provide conv. DR up to UHDR. BUT: We just started.**

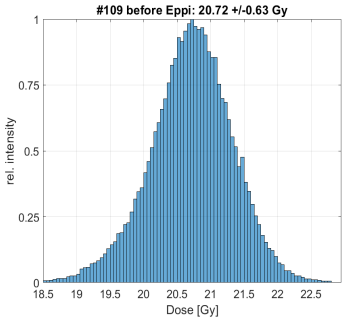


- **Setups: Water phantom & movable stage for irradiation of samples in Eppendorf tubes**

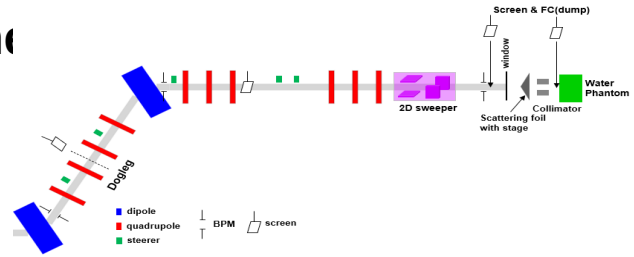


- **Dosimetry: Gafchromic films**
  - **Limit test, dose rate linearity, time dependence**
  - **Water phantom: Depth dose profile, lateral profile**
    → **more measurements will be done soon**





- **Experiments done and planne**
- **Upgrade plan for PITZ**



Acknowledgment

DESY & PITZ team:
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R. Jones (University of Manchester),

D. Angal-Kalinin (ASTeC/STFC), J. Jones (ASTeC/STFC)

You are invited to come to us and do joint experiments!
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