Spectral and spatial shaping of laser-driven proton beams using a pulsed high-field magnet beamline

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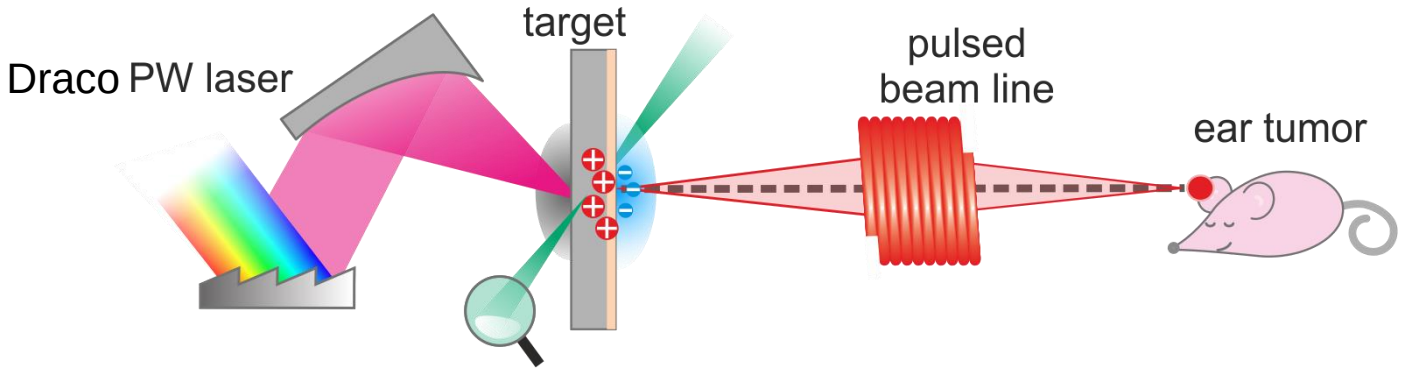
3 OncoRay National Center for Radiation Research in Oncology Dresden

4 eli attosecond

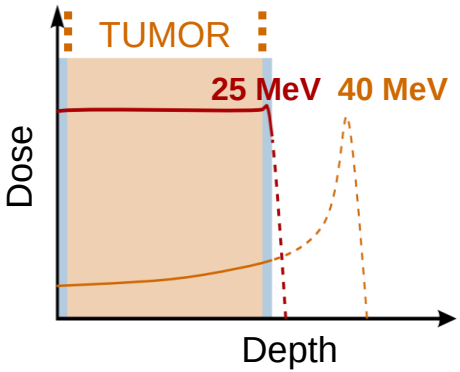
Laser-driven dose delivery for 3D *in vivo* irradiation



Mouse model *Beyreuther et al 2017 PLOS ONE 12*

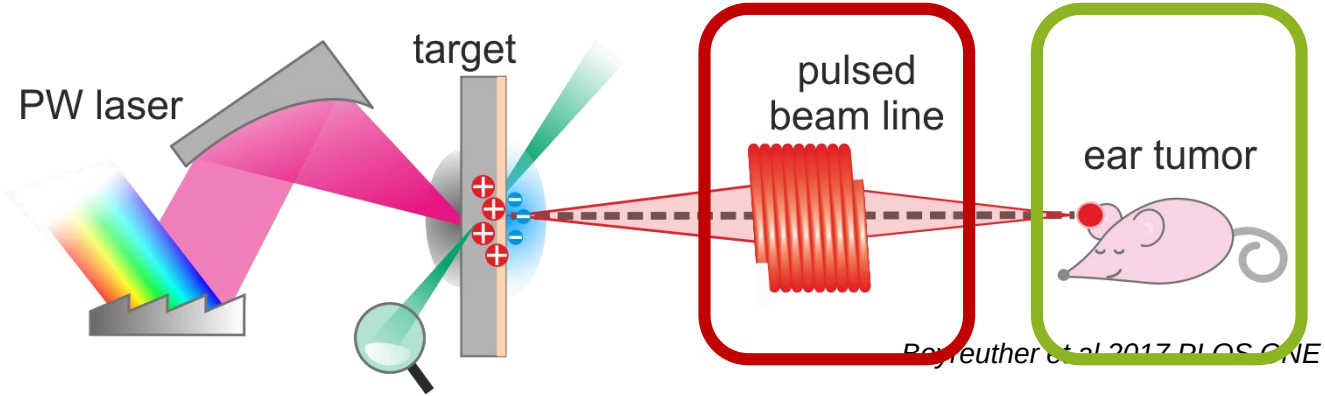
- 4 ± 0.2 Gy homogeneous 3D dose profile (SOBP, 5x5x5 mm³) with mean dose rates in the order of 1 Gy/min
  - proton energy of 25 – 40 MeV
  - < 10% dose homogeneity laterally and in depth
  - < 10% precise total dose value delivery
  - < 10% absolute dosimetry (on- and offline)

- Requested output



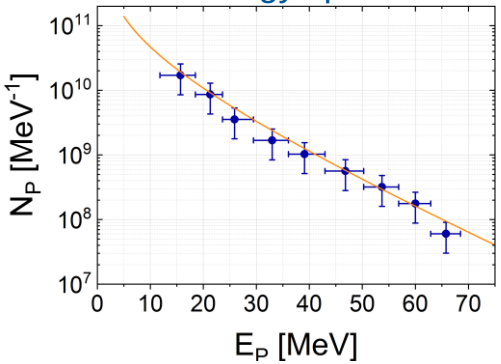
Dose homogeneous within 5×5×5 mm³

Laser-driven dose delivery system



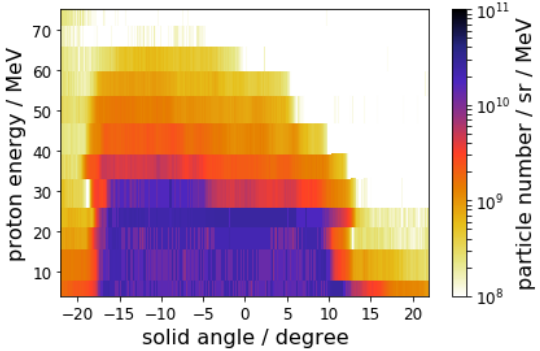
Beyreuther et al. 2017 PLOS ONE 12

- exponentially decaying, broad energy spectrum



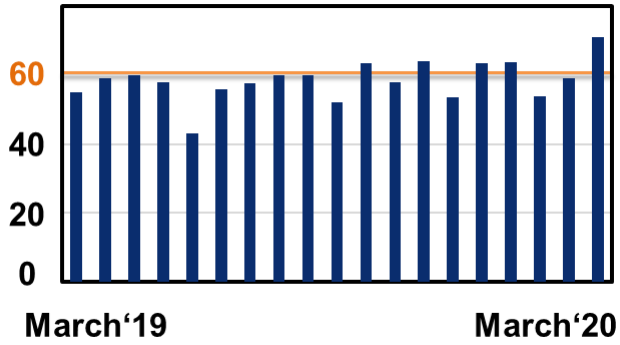
$N_p > 10^{11}$ in ~ps bunch

- angular spectrum



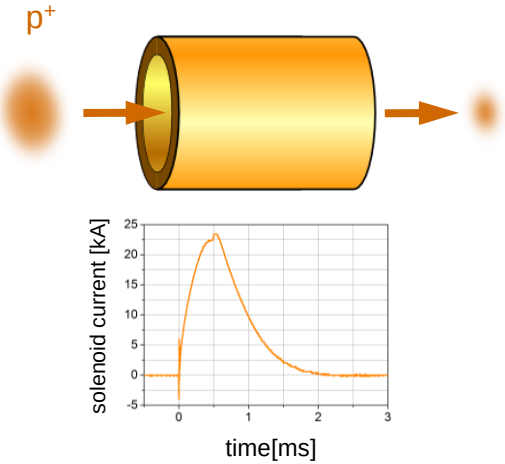
Half-angle divergence ~ 20°

- stable accelerator performance



Pulsed high field magnets

Solenoid



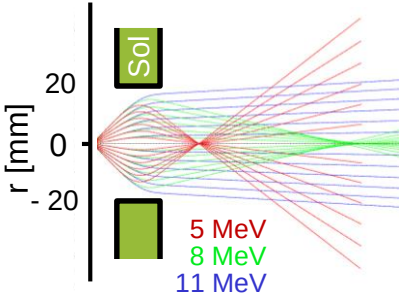
***B*-field: 1 T → 10 T**

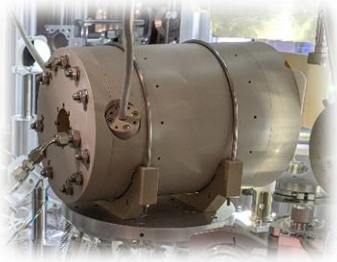
focal length

$$f_S = \frac{4p^2}{q^2 B^2 l}$$

100

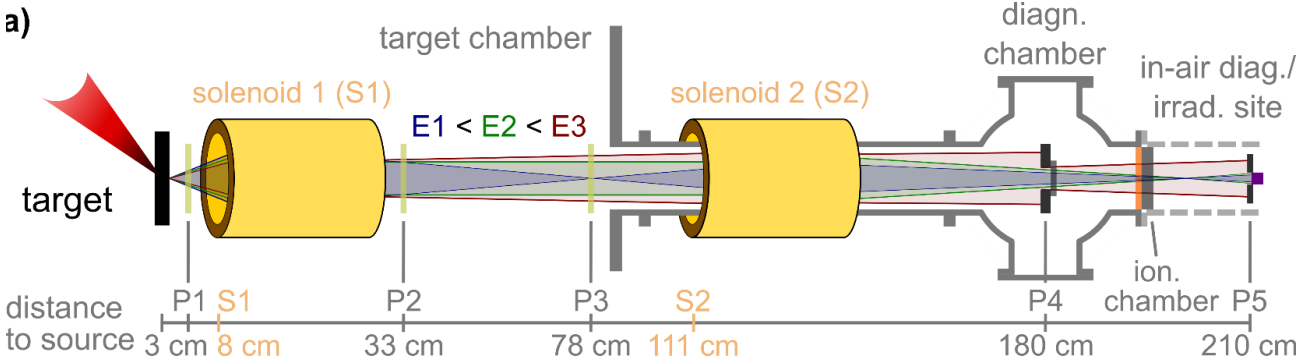
- Chromatic focusing device
  - Energy selection via input current
  - Beam guiding
  - collimation of 70 MeV (scalable)
- 40 mm open aperture
  - high transmission efficiency due to high angular acceptance
- several years operation (1000+ pulses)
- **Cooled solenoid** → higher rep rates possible (1 Hz pulse generator finished soon)



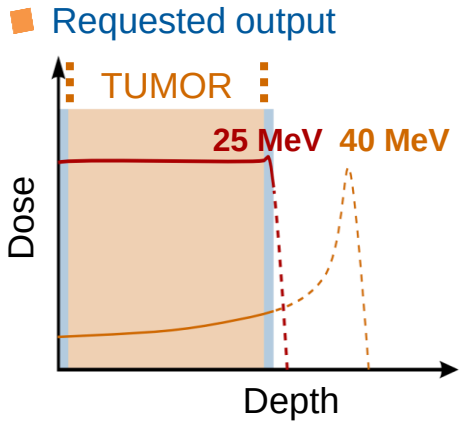


- Solenoids well suitable for broad energy range & large angular distribution of TNSA protons

Beamline setup for 3D *in vivo* irradiation

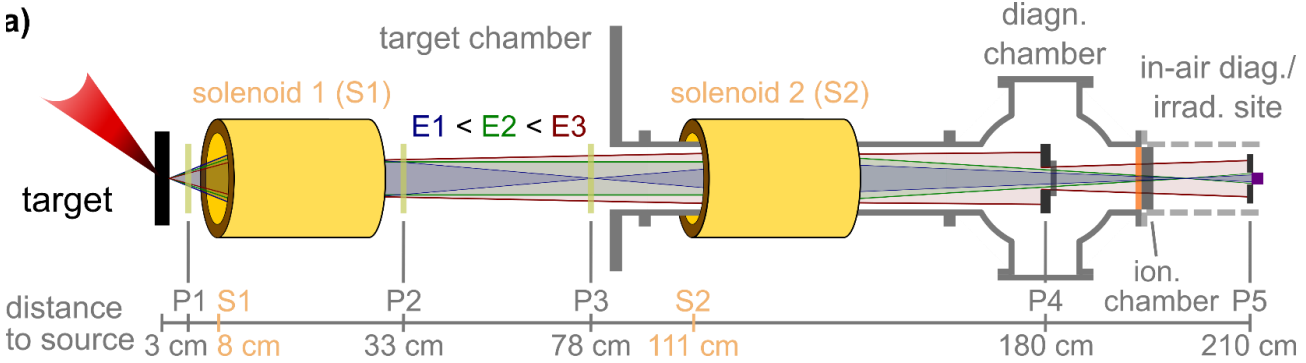


Brack et al., Sci Rep ***10,*** *9118 (2020)*



Dose homogeneous within 5×5×5 mm³

Spectral shaping of laser-driven proton beams



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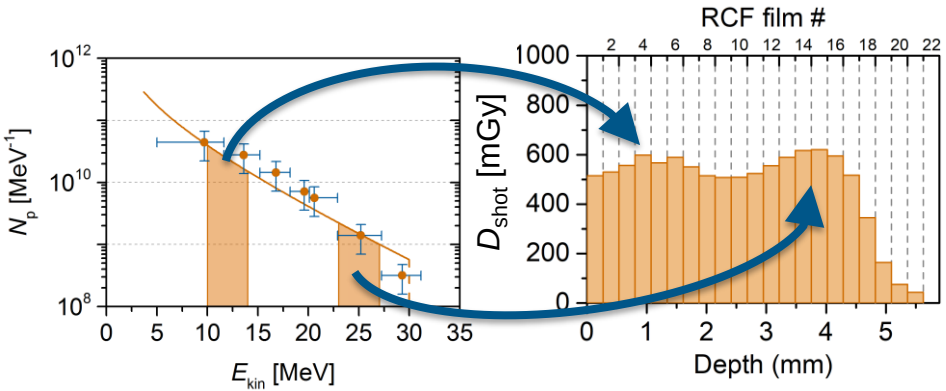
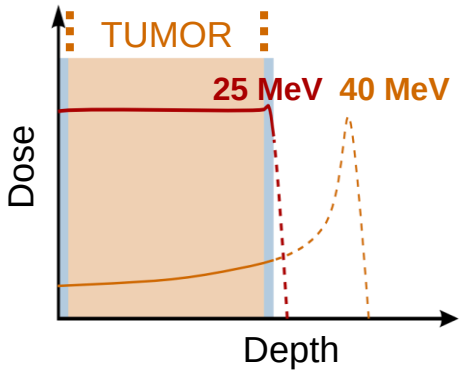
- Dual solenoid setup focuses protons of two independent energies
  - Spectral shaping to homogeneous depth dose distribution via solenoid currents

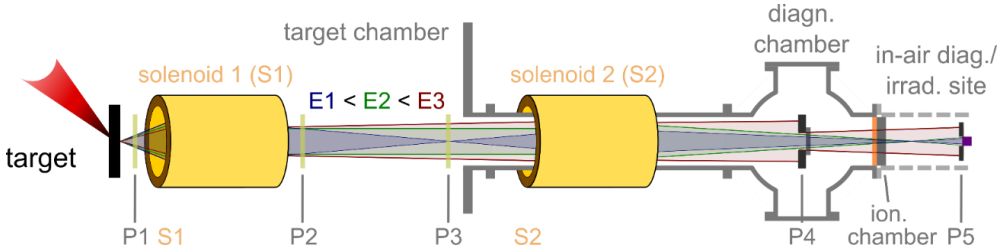


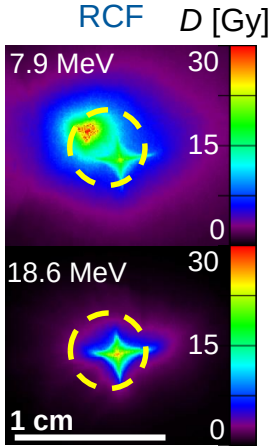
- Requested output



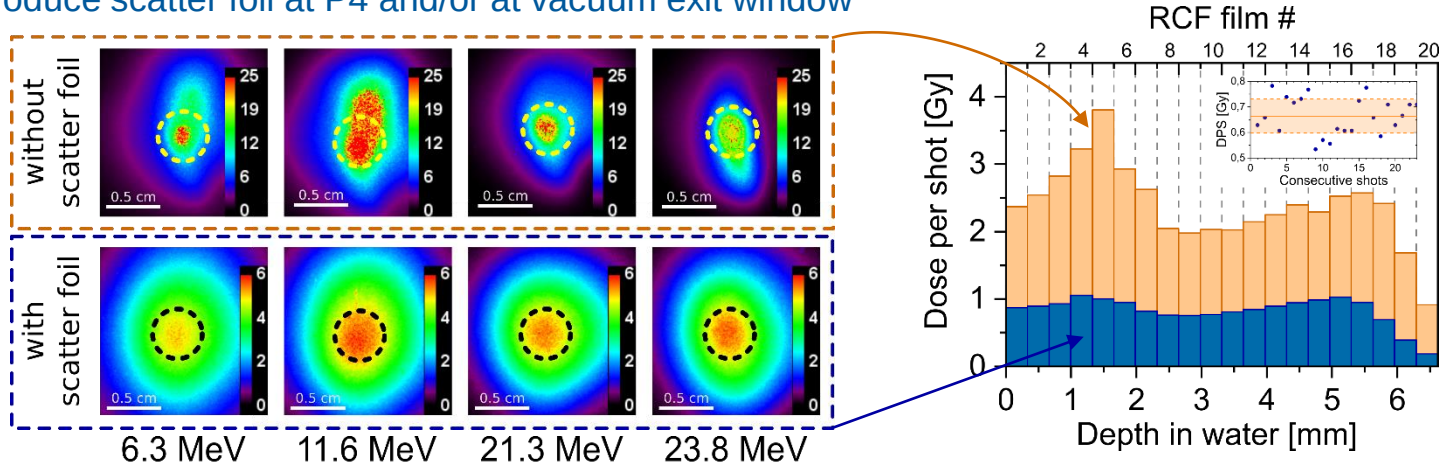
Dose homogeneous within 5×5×5 mm³

Lateral shaping of laser-driven proton beams





- After **spectral** homogenization → **lateral** homogenization
- focus in front of irradiation site and/or aperture at P3 and/or energy selecting aperture at P4
- Introduce scatter foil at P4 and/or at vacuum exit window



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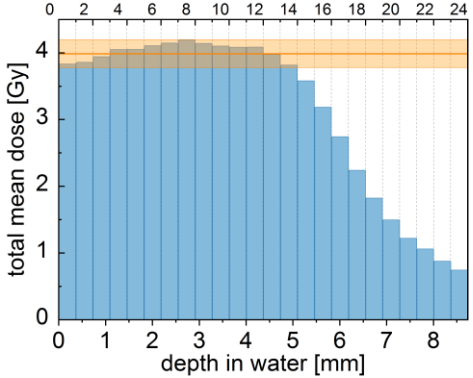
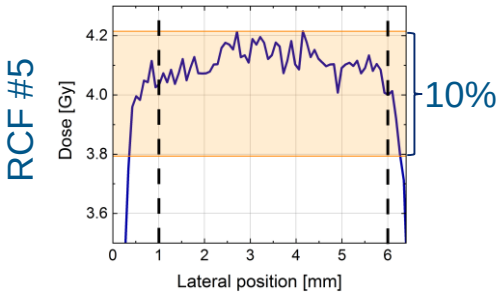
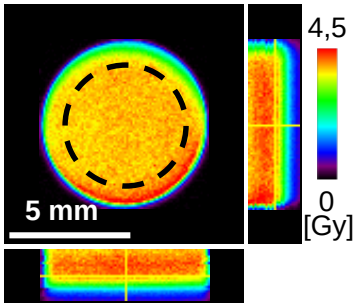
3D dose delivery for radiobiological experiments

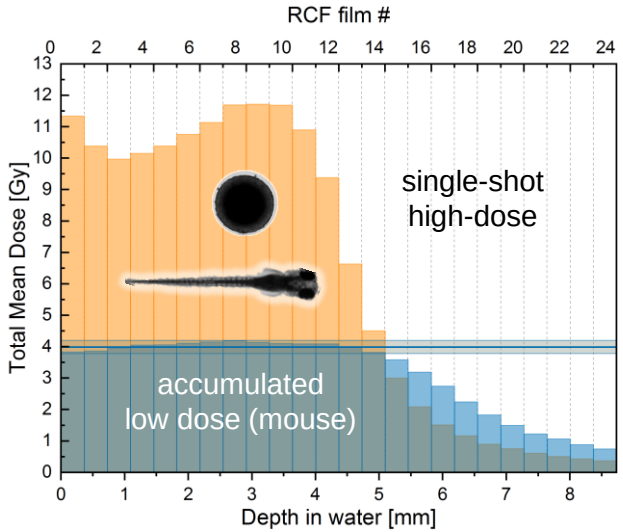
Accumulated low dose

- *in-vivo* studies (**mouse model**) *4 Gy in 5x5x5 mm³ ± 5% accuracy, dose rate > 1Gy/min*





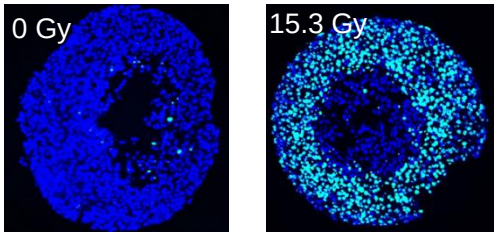




Single shot high dose

- Study high dose (rate) effects e.g. FLASH, ZF embryos, spheroids *> 10 Gy in 3x3x3 mm³*

Tumour spheroids



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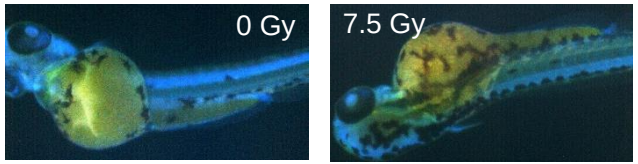
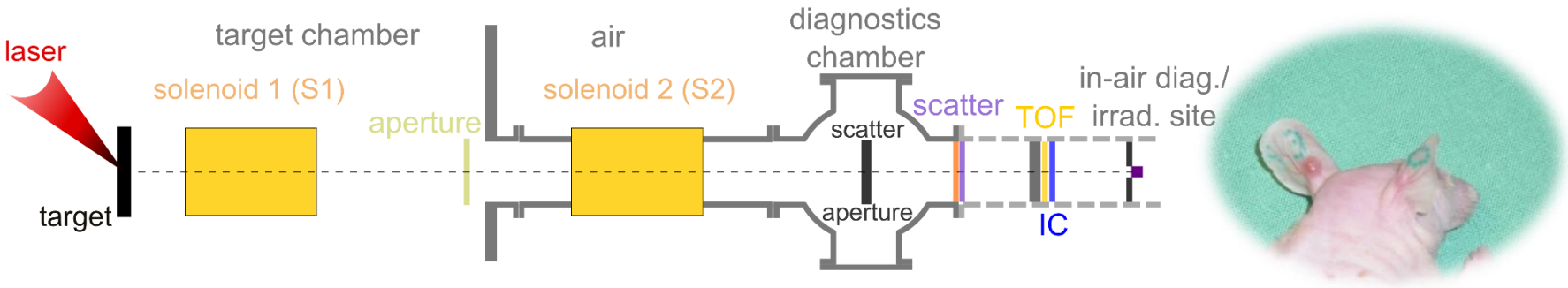
*Z*ebrafish embryo (*in-vivo*)



- First feasability study with too low dose

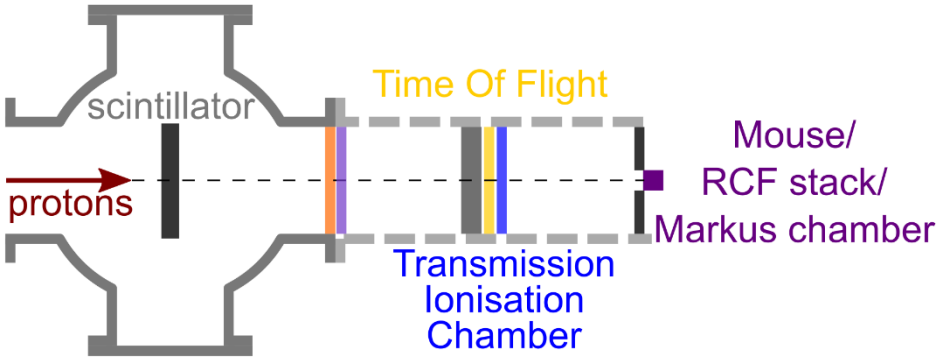
→ new campaign with higher dose planned

Upcoming mouse model irradiation



Mouse irradiation campaign starts this week!

- Fulfilled high demands of mouse model „offline“ → now (online) dosimetry for irradiation needed!



Dosimetry talk by M.Reimold at 17:00

Thanks for your attention!

Feel free to send questions to

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