

Sources for high dose rate electron and proton irradiation at the ELBE center Dresden

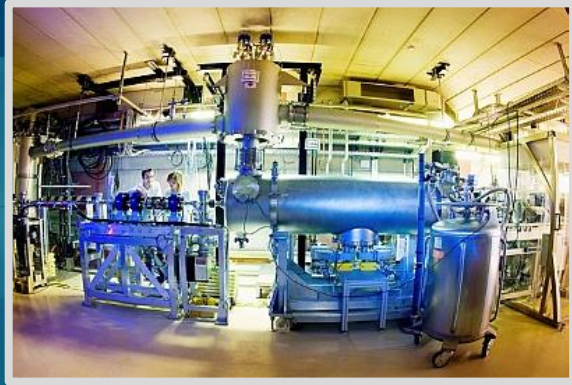
U. Schramm

Helmholtz-Zentrum Dresden-Rossendorf

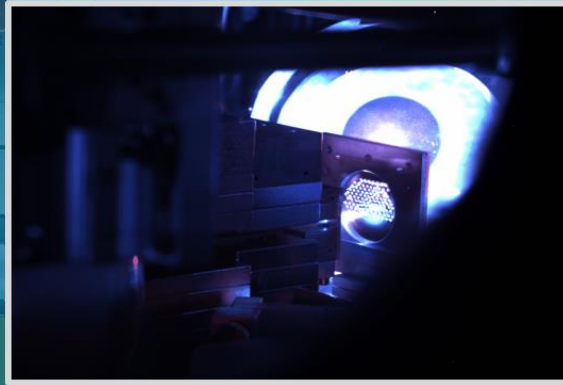


Very High Energy Electron Radiotherapy Workshop (VHEE'2020)

Sources for high dose rate electron and proton irradiation at the ELBE center Dresden



SRF CW electron linac



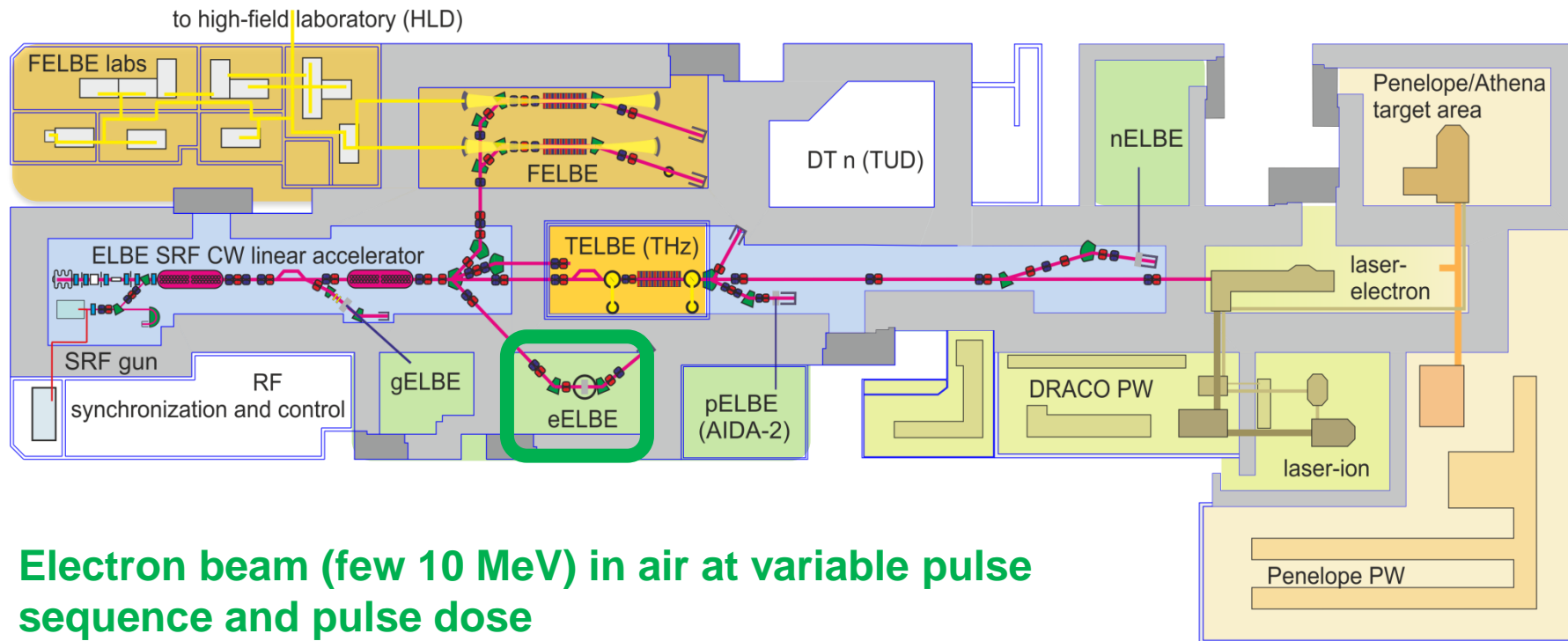
PW laser driven plasma accelerators



Clinical cyclotron and other reference sources

(operated as open user facilities)

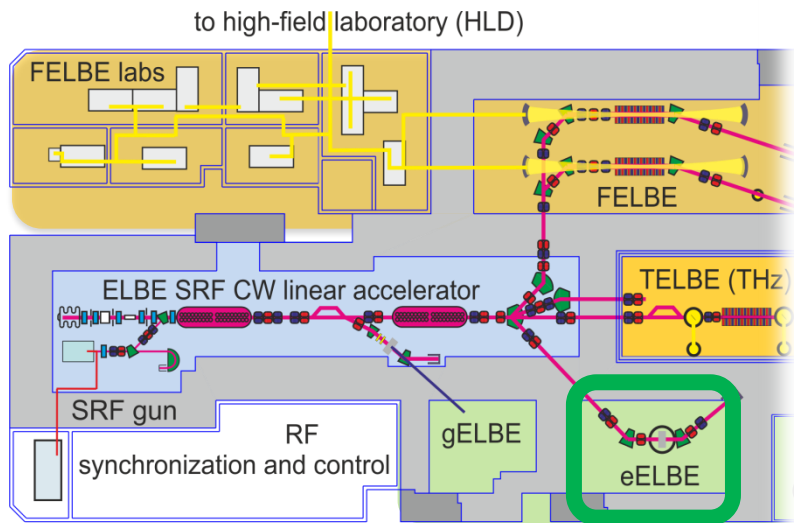
ELBE Center for high power radiation sources



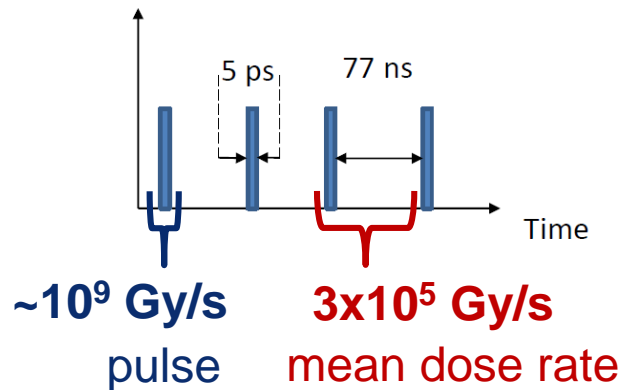
Electron beam (few 10 MeV) in air at variable pulse sequence and pulse dose

Advanced laser plasma accelerator development

ELBE Center for high power radiation sources

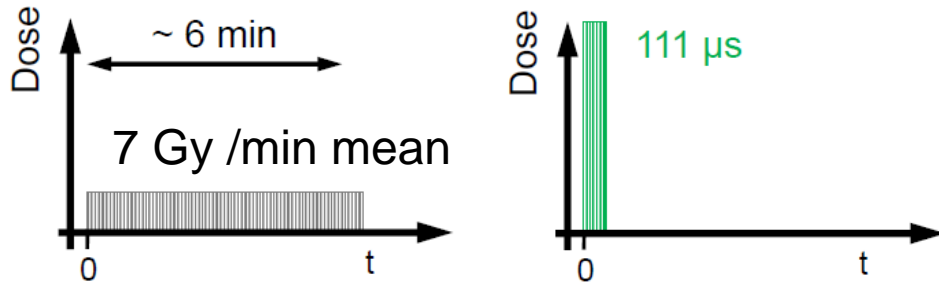


- Linear SRF accelerator with variable pulse sequence (max. rate 13 MHz)
- Short pulses (5ps) → high dose rate



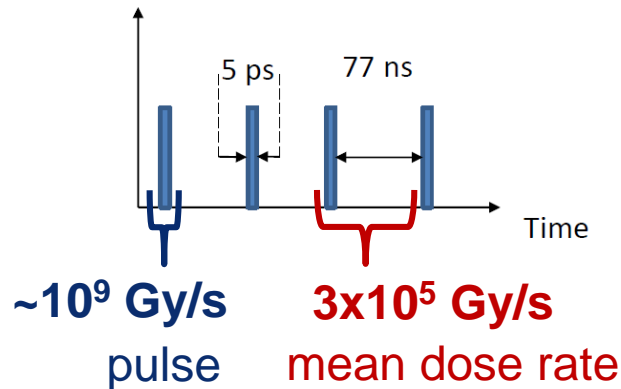
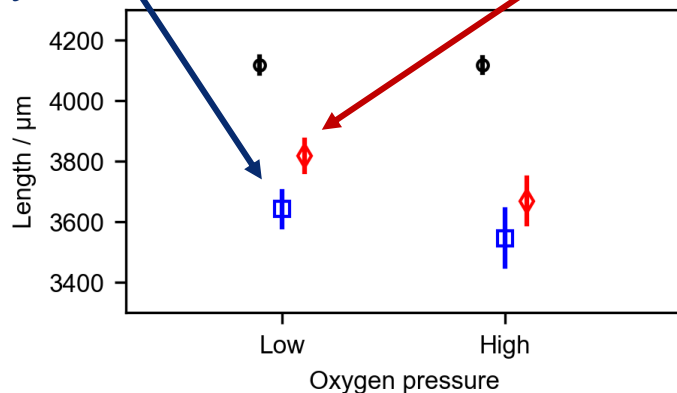
- Total dose determined by:
 - length of pulse train: e.g. 1400 pulses in 0.11ms → 33 Gy
 - bunch charge (between fC and ~ 100 pC)

FLASH Experiments at ELBE (c.f. E. Beyreuther on Monday)



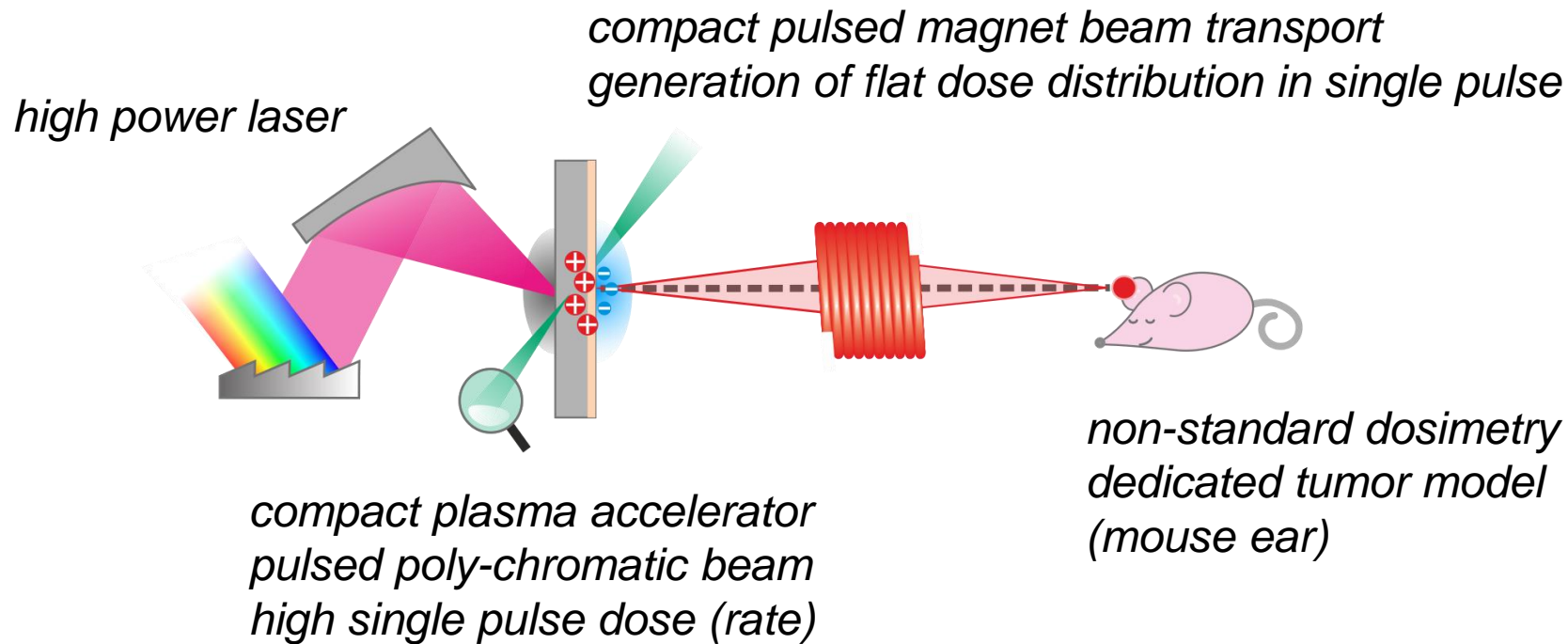
Linear SRF accelerator with variable pulse sequence (max. rate 13 MHz)
Short pulses (5ps) \rightarrow high dose rate

10^3 Gy/s

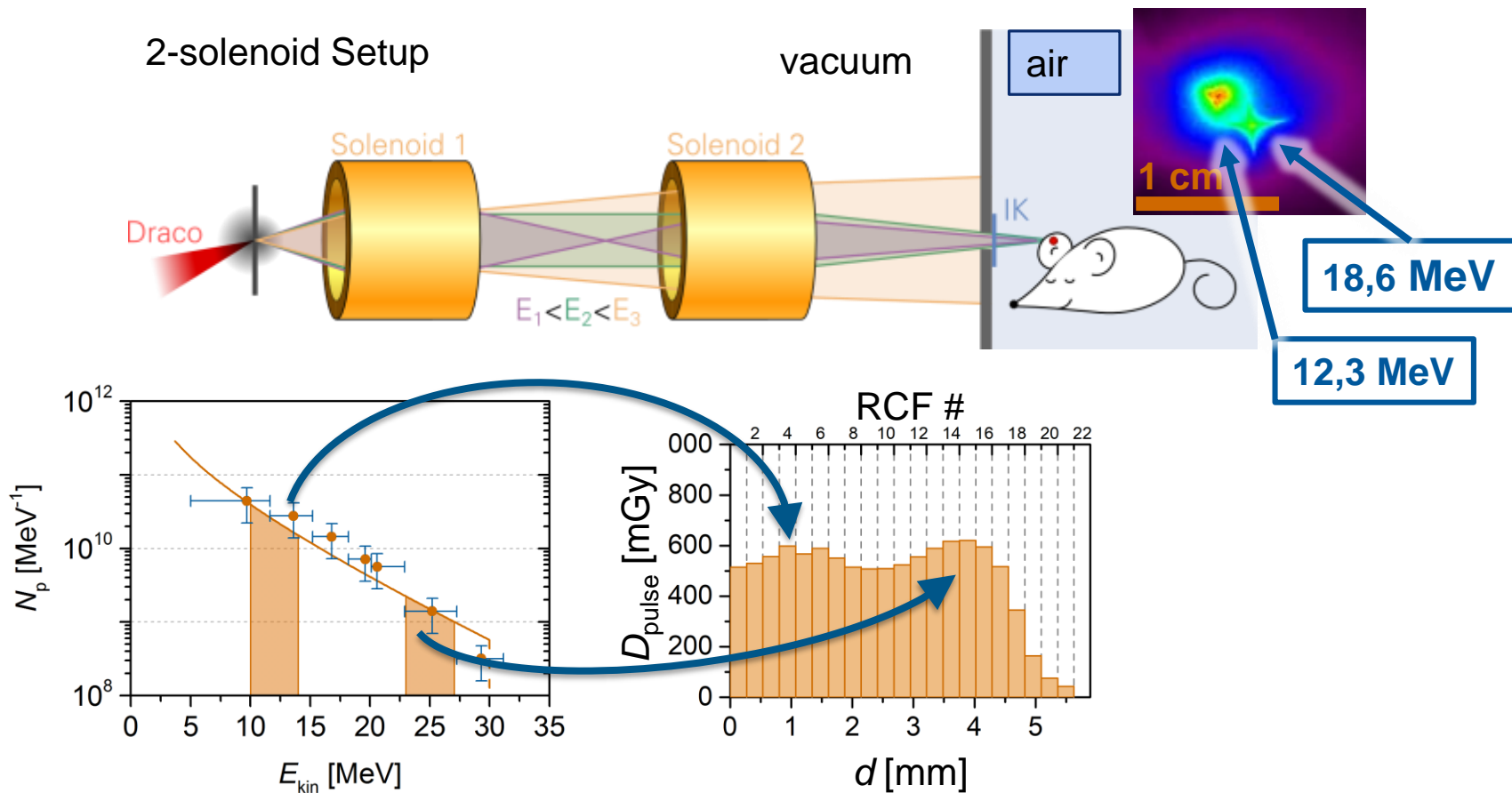


Length of zebra fish embryos (28 hpf) depends on dose rate (and oxygen conc.)

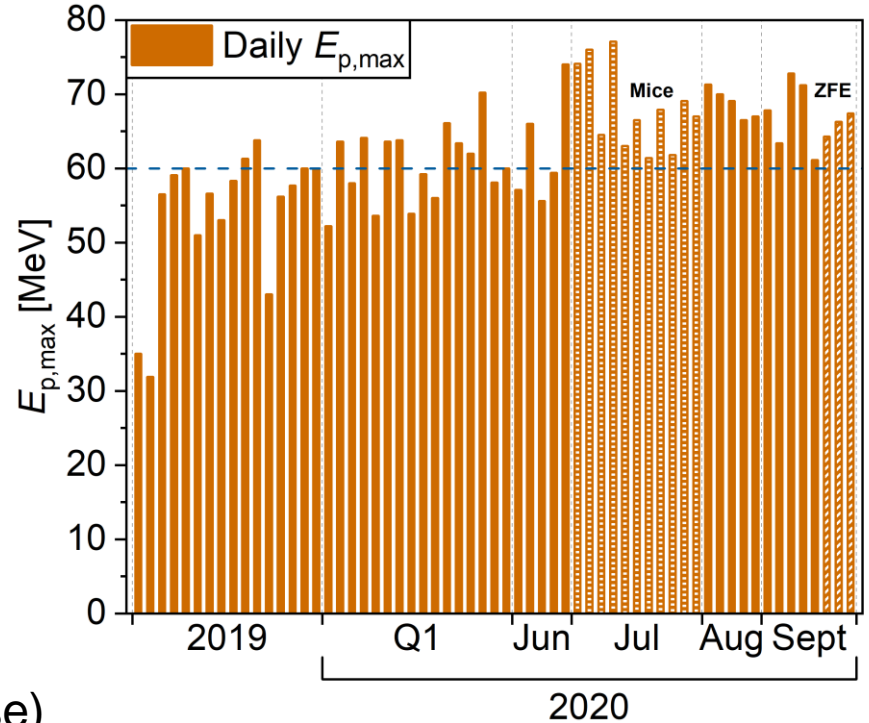
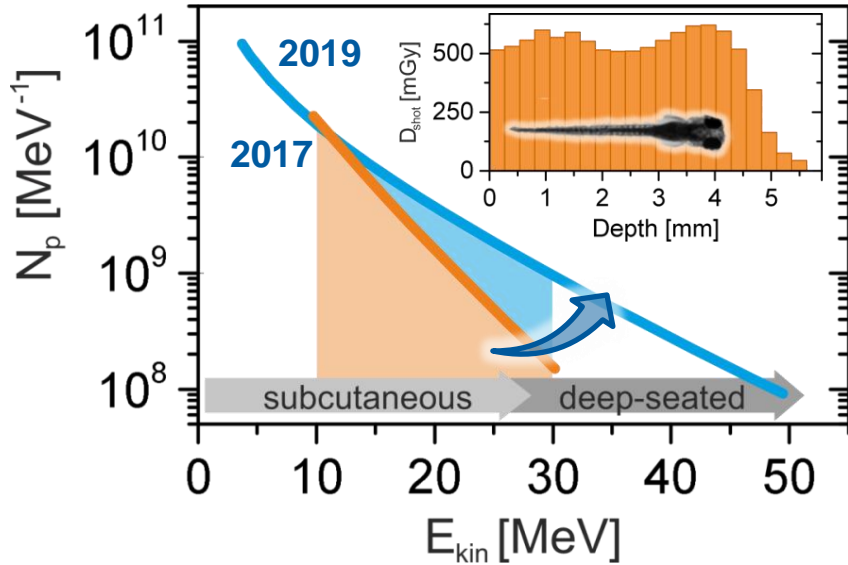
First in-vivo proton irradiation at a compact laser plasma accelerator taking advantage of (and studying the role of) unique beam properties



Proton beam characteristics



Recent progress in proton energies and operational stability

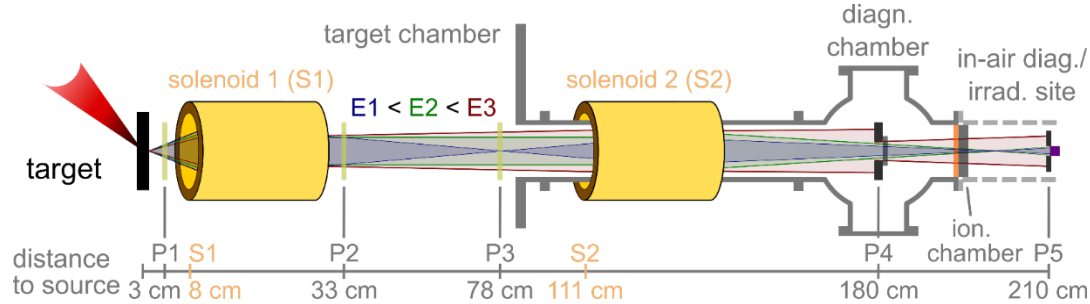


Tailoring the plasma for optimal efficiency
(either directly or via tailoring the laser pulse)

T. Ziegler, et al., arxiv:2007.11499 (2020)

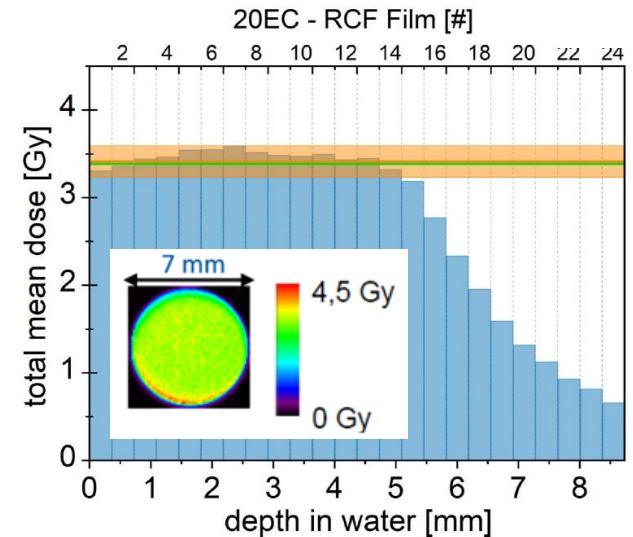
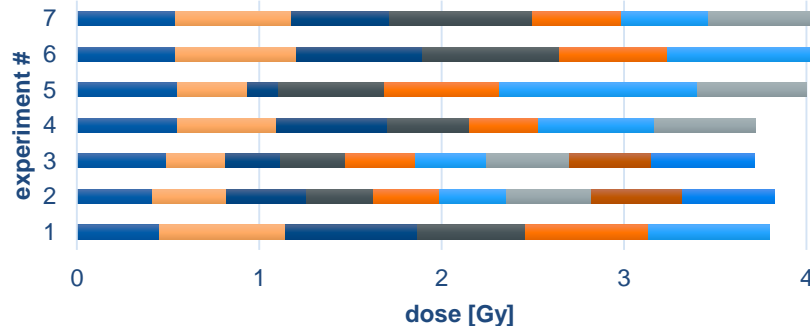
(based on ~15 J laser energy)

First in-vivo proton irradiation at a compact laser plasma accelerator



transferring intense poly-chromatic proton pulse into flat depth-dose

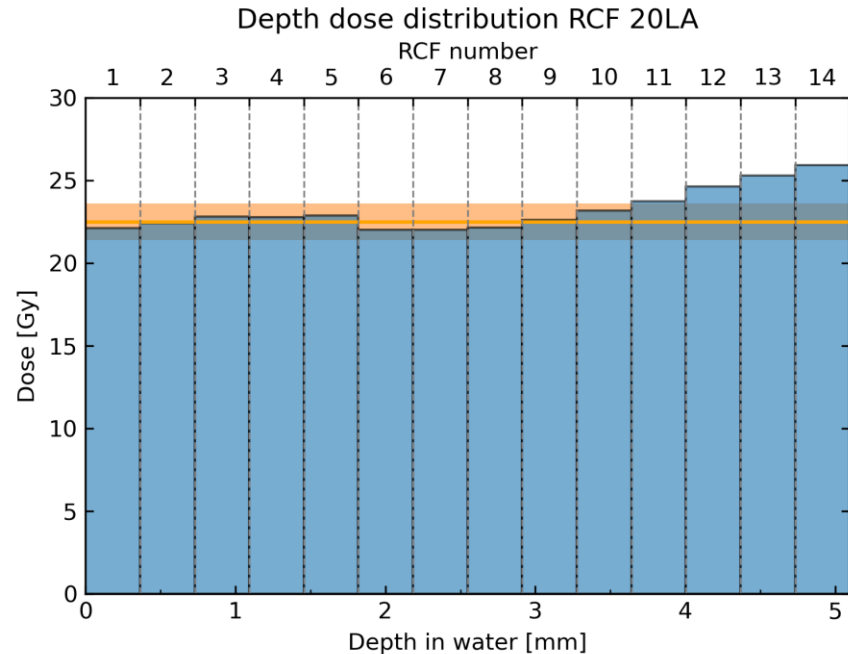
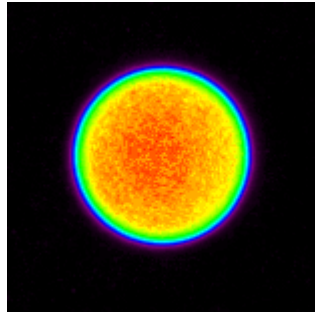
absolute and relative online dosimetry enables monitoring of accumulated prescribed dose



Maximum dose at single pulse for studying dose rate effects

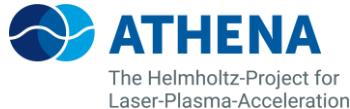
Optimization of transport filter for maximum pulse dose rate of up to 20 Gy in few ns

(reduction of stability and prescribed dose control)

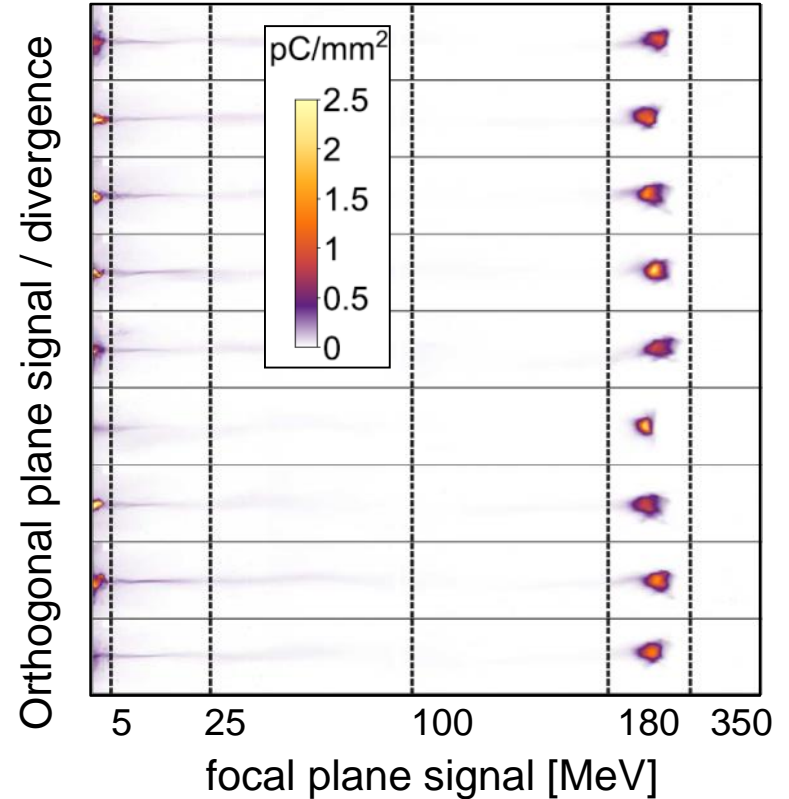
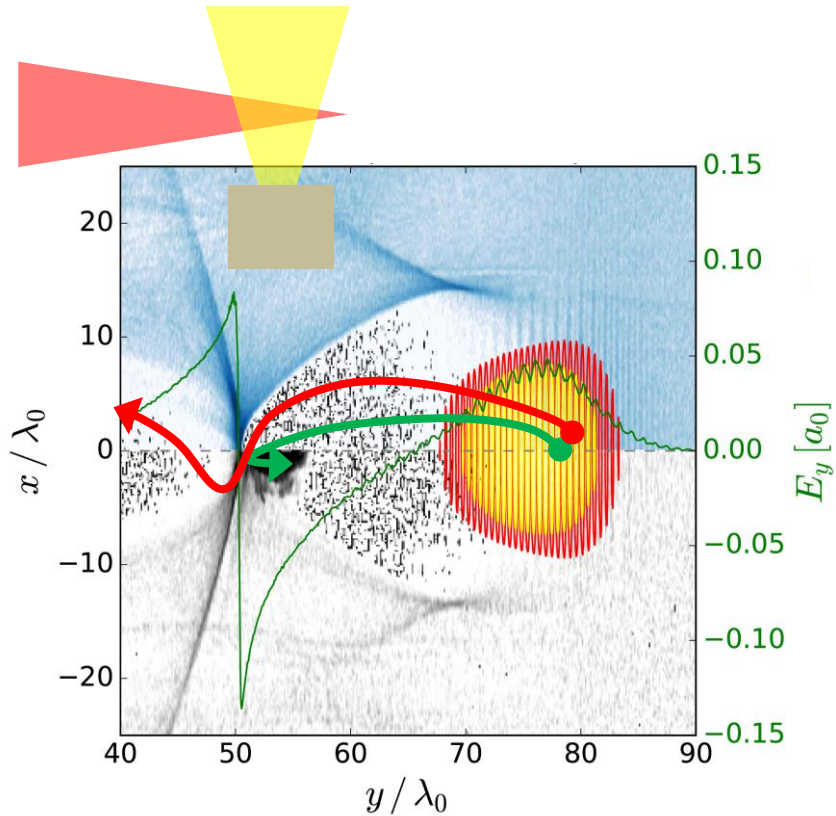


Demonstration of system readiness

- for systematic in-vivo radiobiology studies
(incl. full-scale reference irradiation protocols ...)
- for investigation of high dose rate effects
- for providing a compact platform for reference data generation

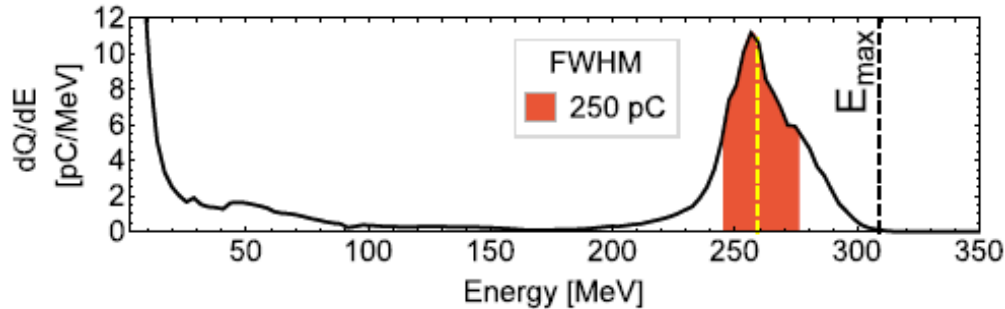


Laser wakefield electron acceleration (VHEE)



J. Couperus, et al., Nat. Commun. 8, 487 (2017)

Laser wakefield electron acceleration (VHEE)



- Stable beam generation in the multi 100 MeV range
- Up to 500 pC charge at up to 10 (1) Hz repetition rate
- Bunch duration only ~ 10 fs (compare ELBE 5 ps)
(thus increasing pulse dose rate by x1000)

Compact source for VHEE but (still) limits in average dose rate

- **K. Zeil, J. Metzkes-Ng, C. Bernert, F. Brack, S. Kraft, F. Kroll, L. Obst-Huebl, M. Rehwald, M. Reimold, H.P. Schlenvoigt, T. Ziegler, et al.**
- **A. Irman, J. Couperus, J. Krämer, A. Köhler, T. Kurz, S. Schöbel, O. Zarini, et al.,**
- **M. Bussmann, A. Debus, R. Pausch, K. Steiniger, A. Hübl, T. Kluge, M. Garten, et al.**
- **J. Pawelke, E. Beyreuther, et al.,**
- M. Siebold, D. Albach, S. Bock, R. Gebhardt, U. Helbig, M. Löser, T. Püschel, et al.

- U. Schramm, T. Cowan, R. Sauerbrey

