HELMHOLTZ ZENTRUM
DRESDEN ROSSENDORF

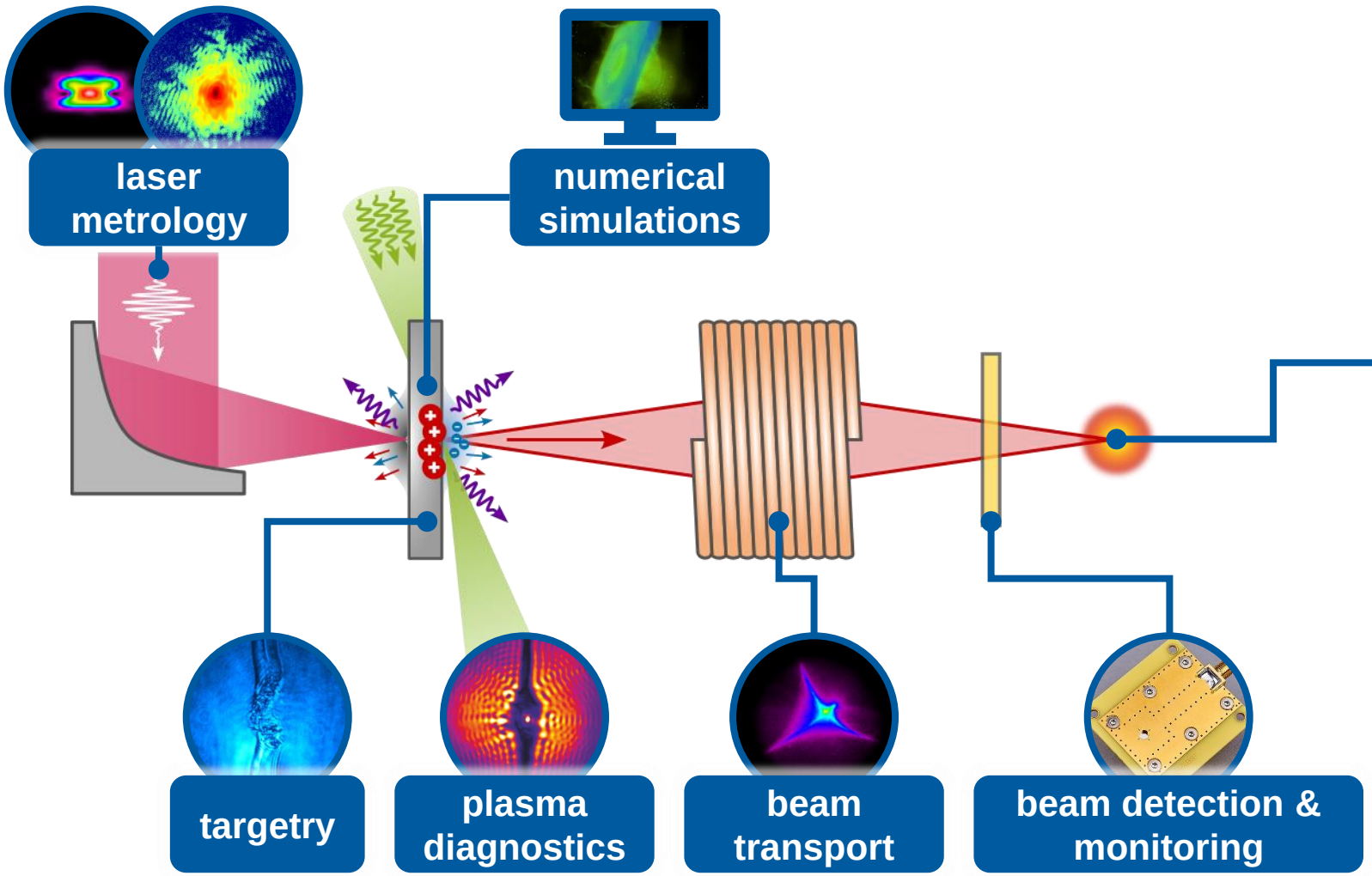
Transforming laser-driven proton beams into application-ready sources

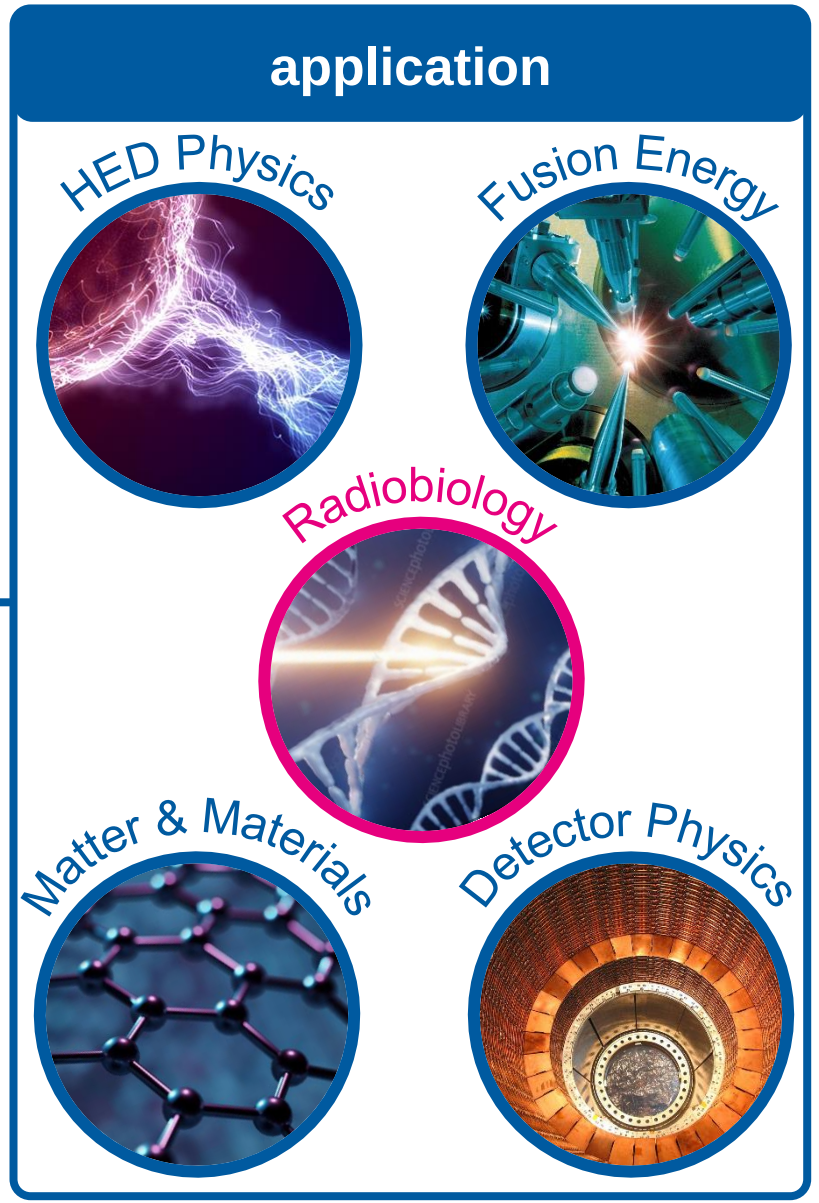
Florian Kroll, J. D. Schilz, S. Assenbaum. M. Rehwald, U. Schramm, K. Zeil, T. Ziegler, and J. Metzkes-Ng

LPAW 2025 – April 13-19, Ischia, Italy

DRESDEN concept

Overview and motivation





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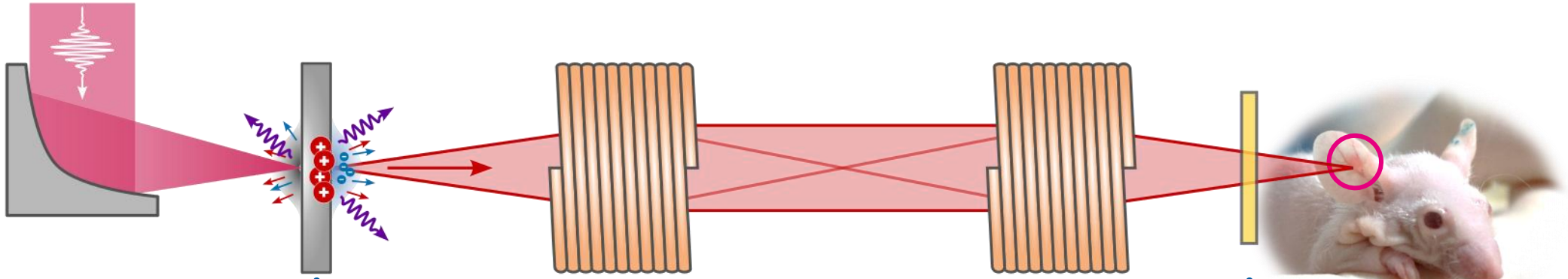
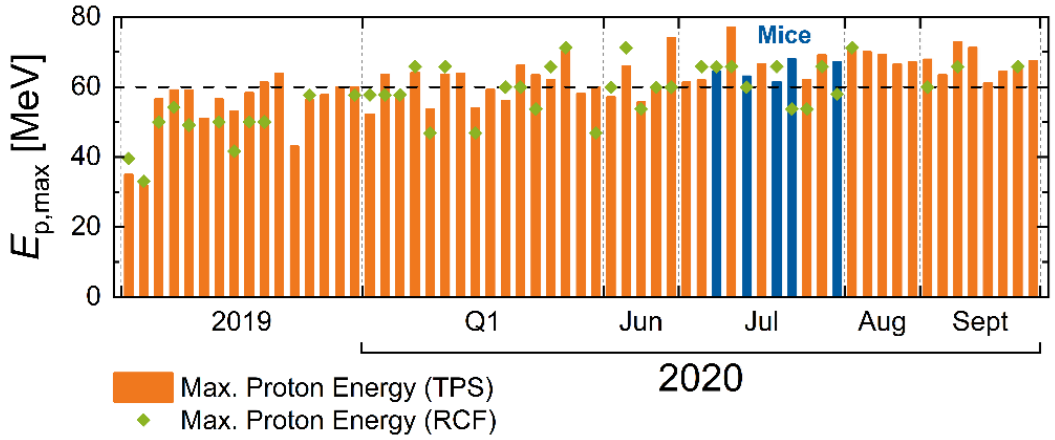
Animal study approval DD24-5131/338/35
Brüchner *et al.*, Radiat. Onc. 9 (2014)
Kroll *et al.*, Nat. Phys. 18 (2022)

In vivo radiobiology with LPA protons

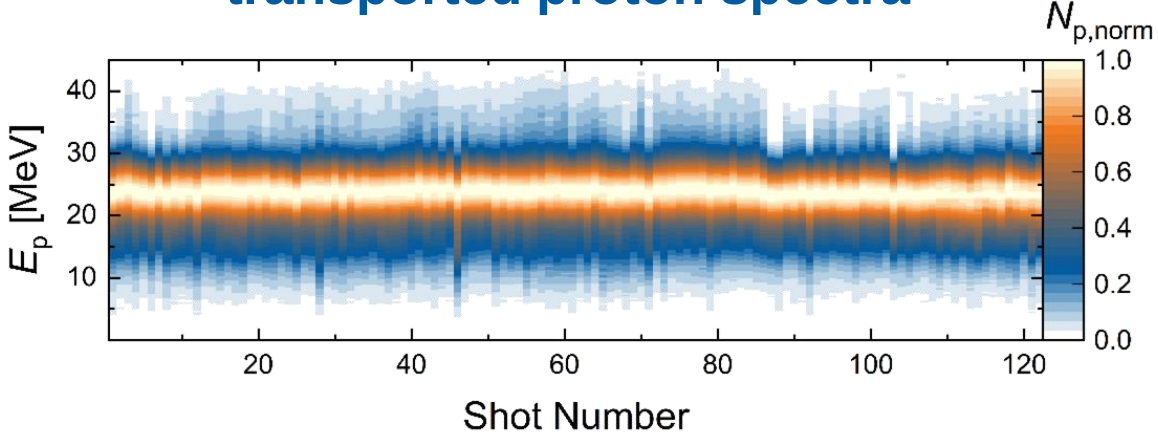
Recap of our results



LPA proton source energies



transported proton spectra



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In vivo radiobiology with LPA protons

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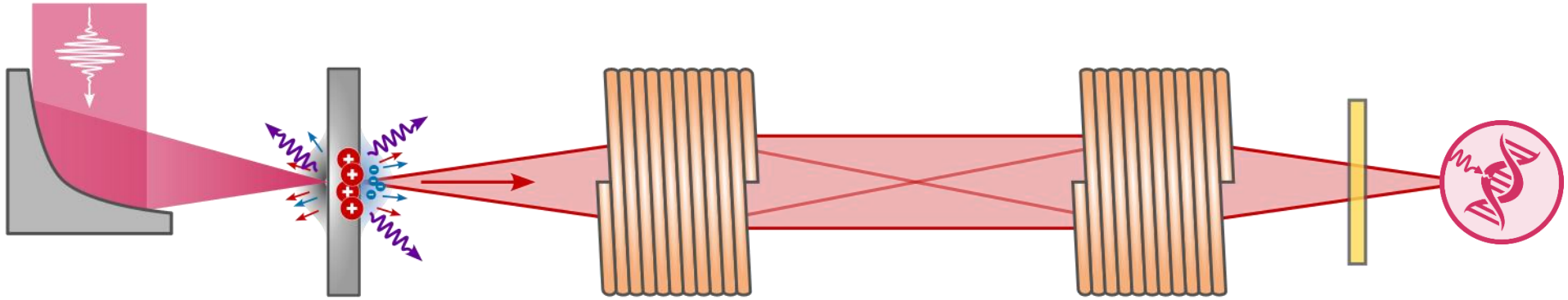
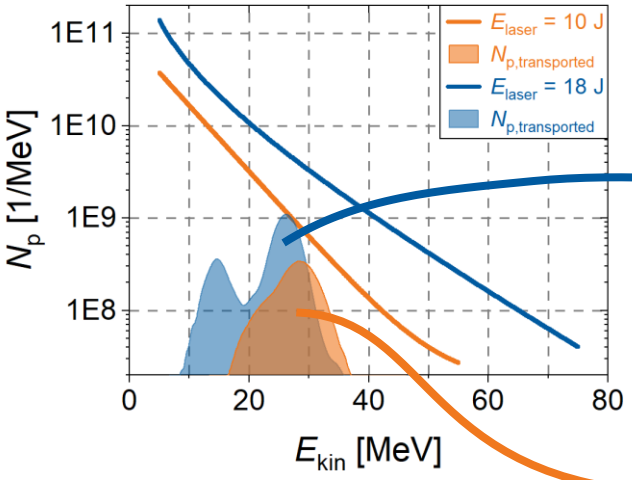
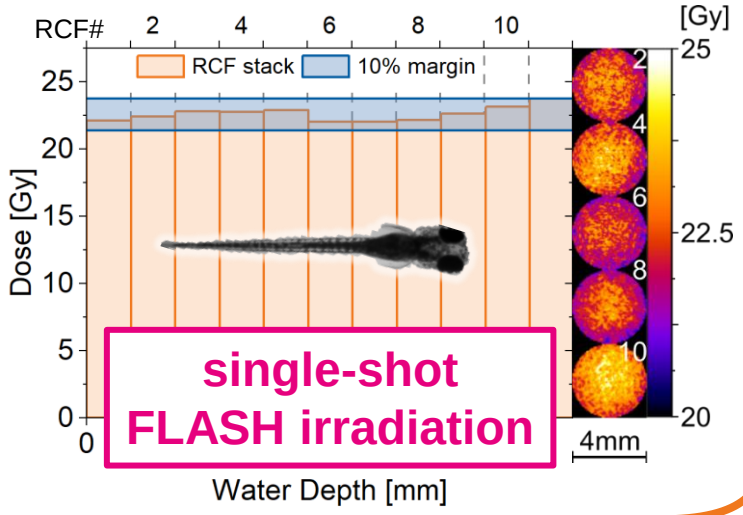
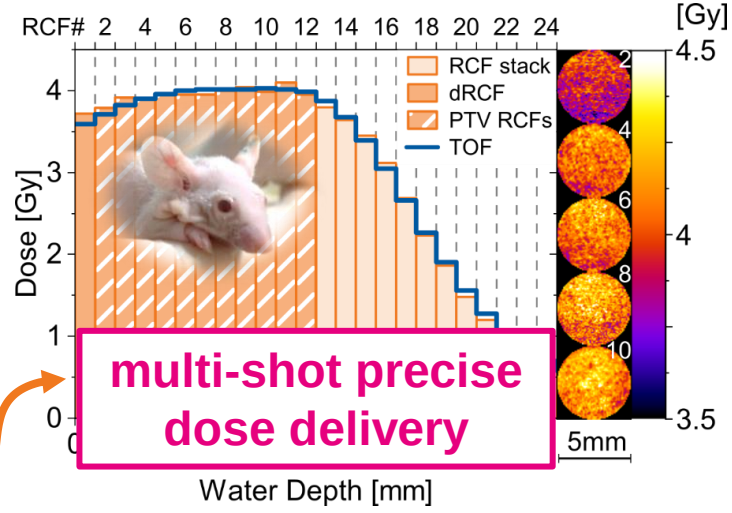


LPA spectra



delivered dose distributions





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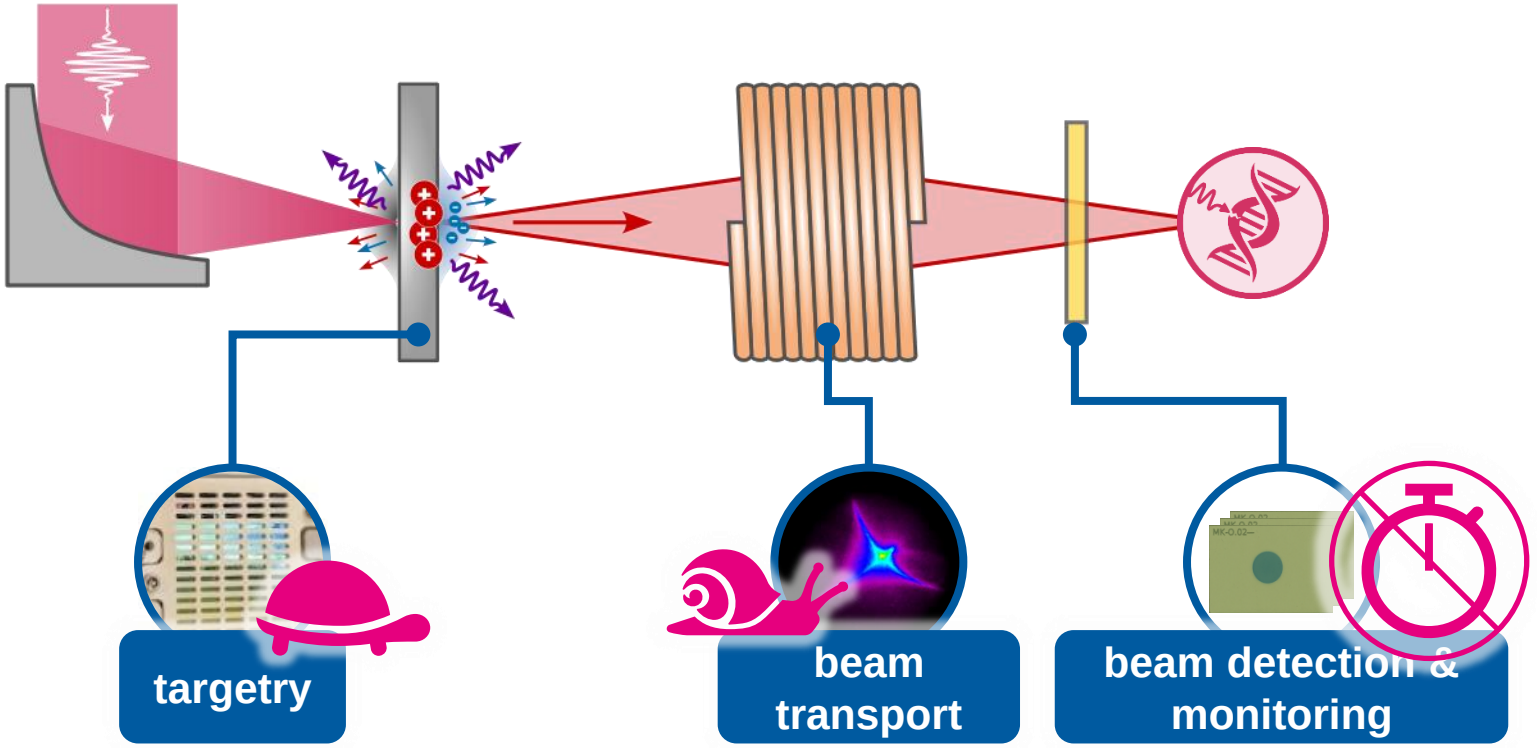
Lessons learned from our radiobiology campaign

Low repetition rate and too laborious offline diagnostics



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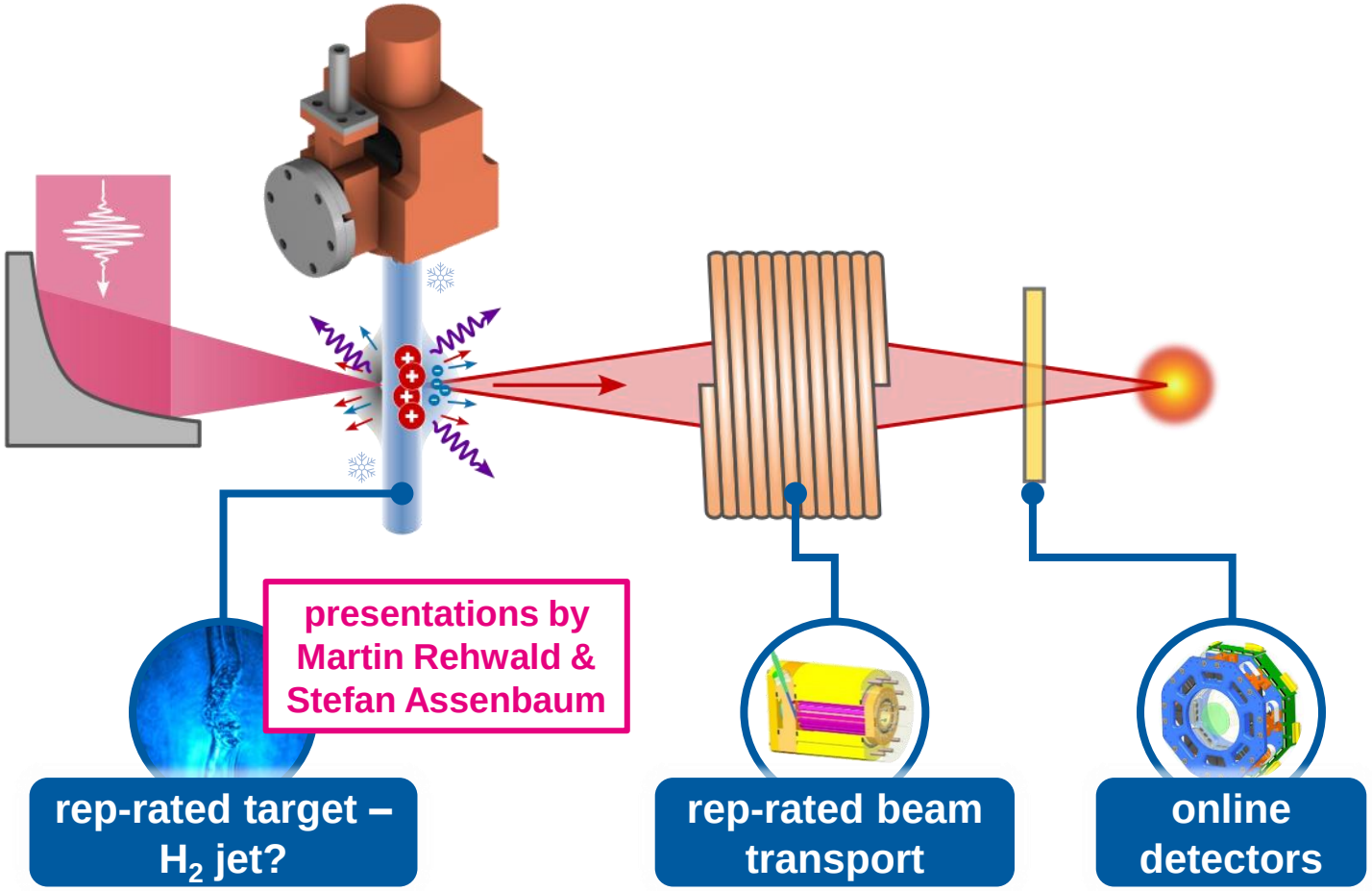
Towards advanced application-ready LPA proton sources

Cryogenic hydrogen + rep-rated pulsed high-field magnets + online detectors w/ active feedback



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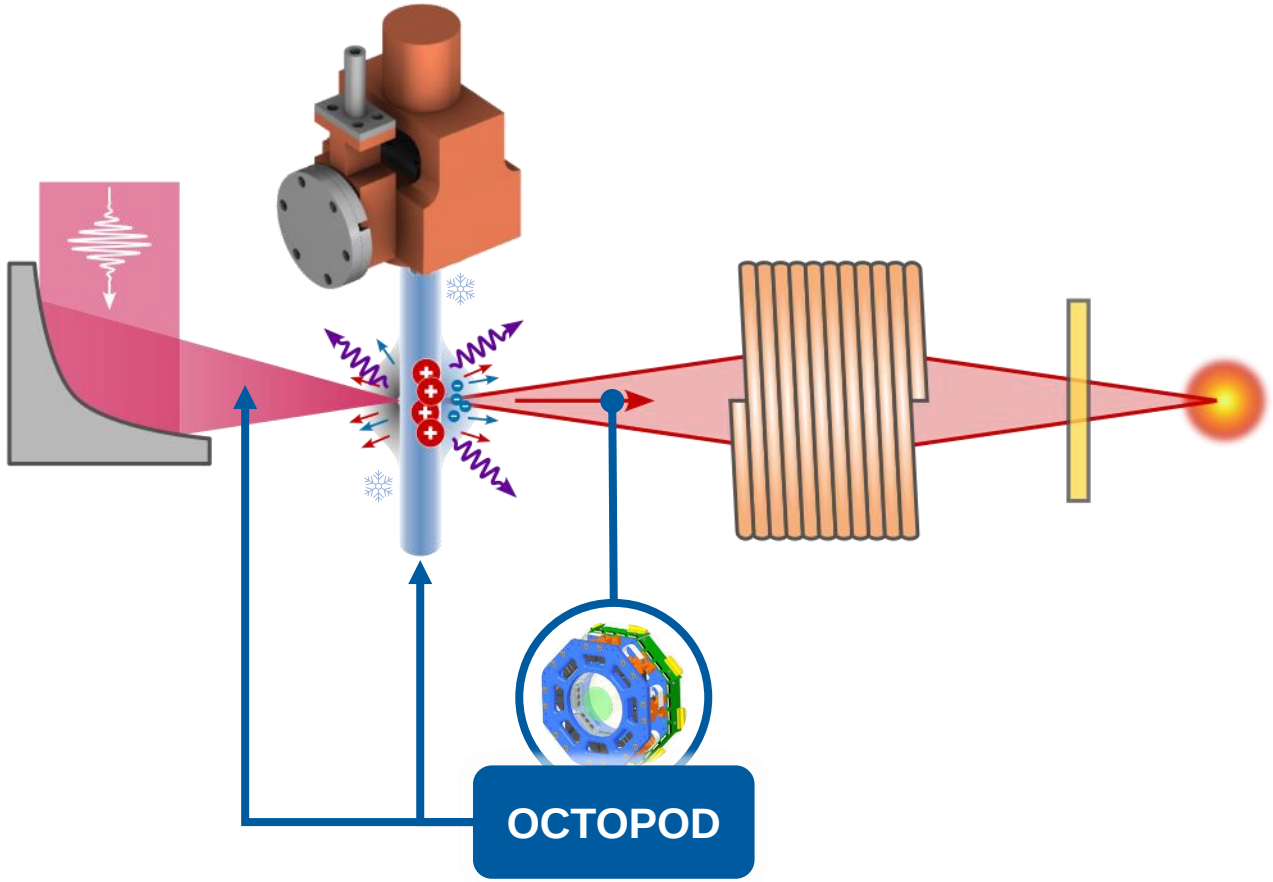
Towards advanced application-ready LPA proton sources

Online detectors w/ active feedback



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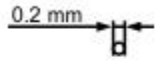
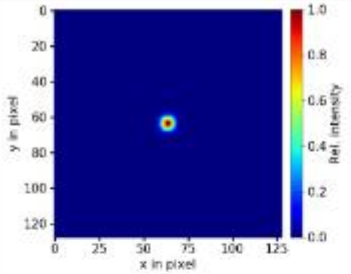
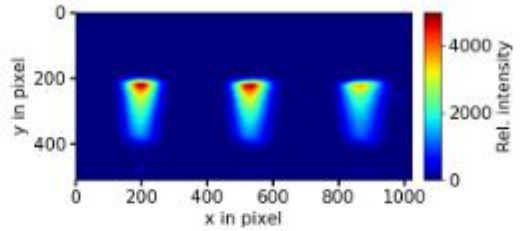
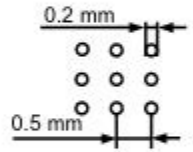
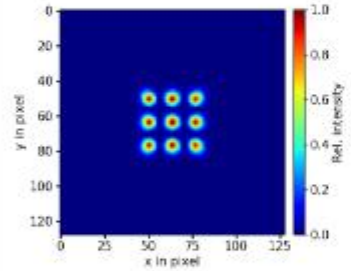
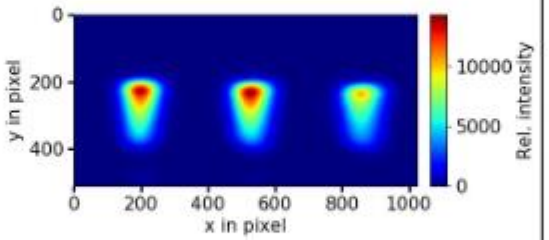
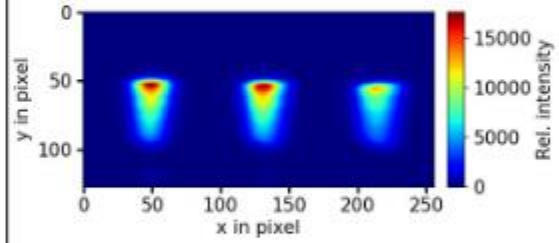
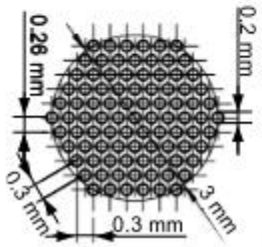
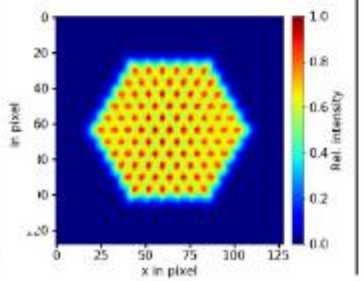
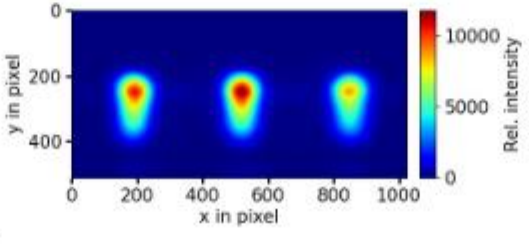
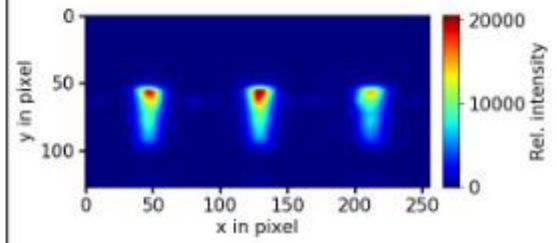
OCTOPOD

Optical Cone-beam TOmograph for Proton Online Dosimetry

- **scintillator-based online detector**
- **3D reconstruction of dose distribution**
- **pinhole(-grid) imaging (RadEye)**

Pinhole grid	LSF	Entrance dose	Measured image	Relative sensitivity	deconvoluted image
		~24 Gy		x1	
		~24 Gy		x2.8	
		~2 Gy		x29	

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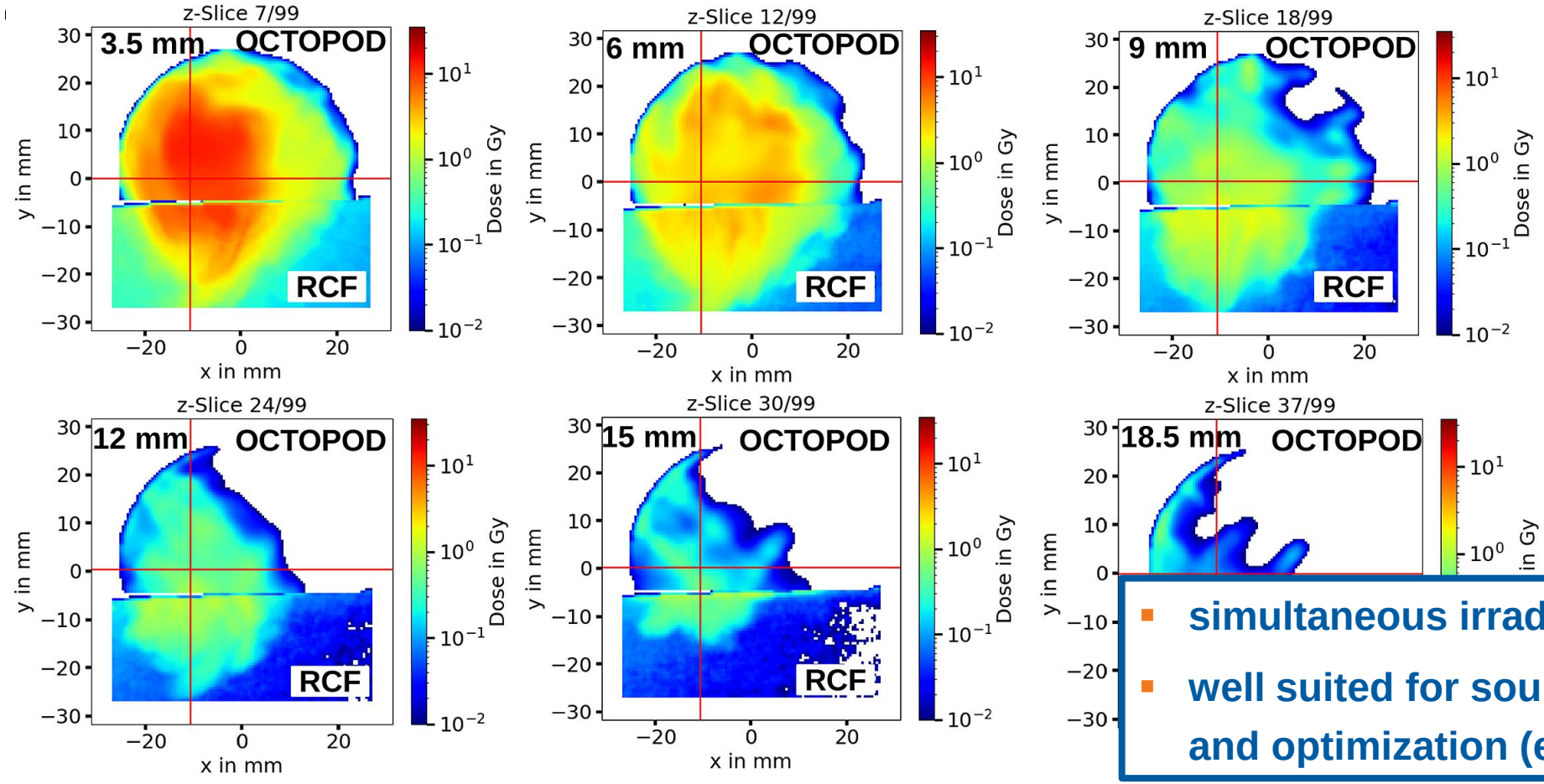
OCTOPOD – Results

OCTOPOD @ Draco PW LPA proton source



- simultaneous irradiation of RCF stack
- well suited for source characterization and optimization (e.g., focus scan)

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OCTOPOD – V2

Optical **C**one-beam **TO**mograph for **P**roton **O**nline **D**osimetry

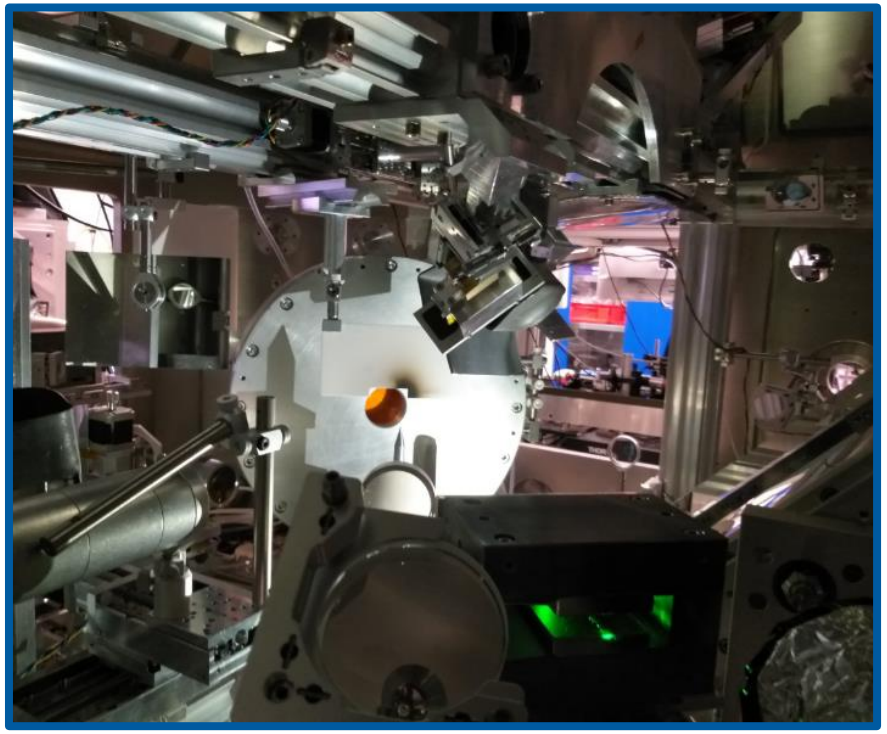
new design

- better vacuum compatibility
- more compact (~ 40% smaller)

deconvolution and reconstruction

- translate hardware intensive calculations to pyTorch and C++ functions

Shot	original code	optimized code	acceleration
LPA bunch	5 min 12 s	57 s	5.5



OCTOPOD V1 inside Target chamber

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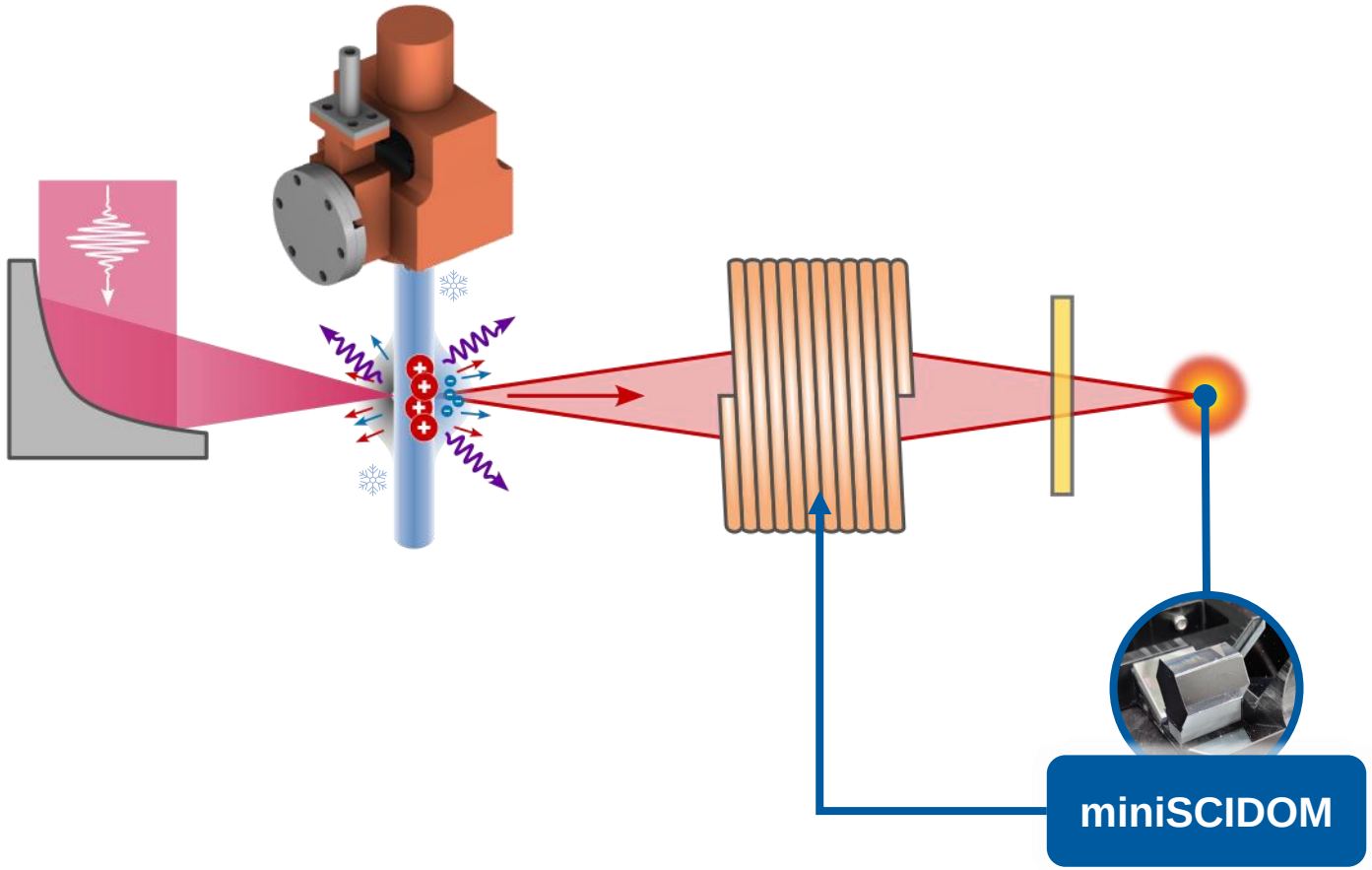
Kroll *et al.*, Med. Phys. 40 (2013)
Corvino *et al.*, HPLSE 12 (2024)

Towards advanced application-ready LPA proton sources

Online detectors w/ active feedback



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Kroll *et al.*, Med. Phys. 40 (2013)
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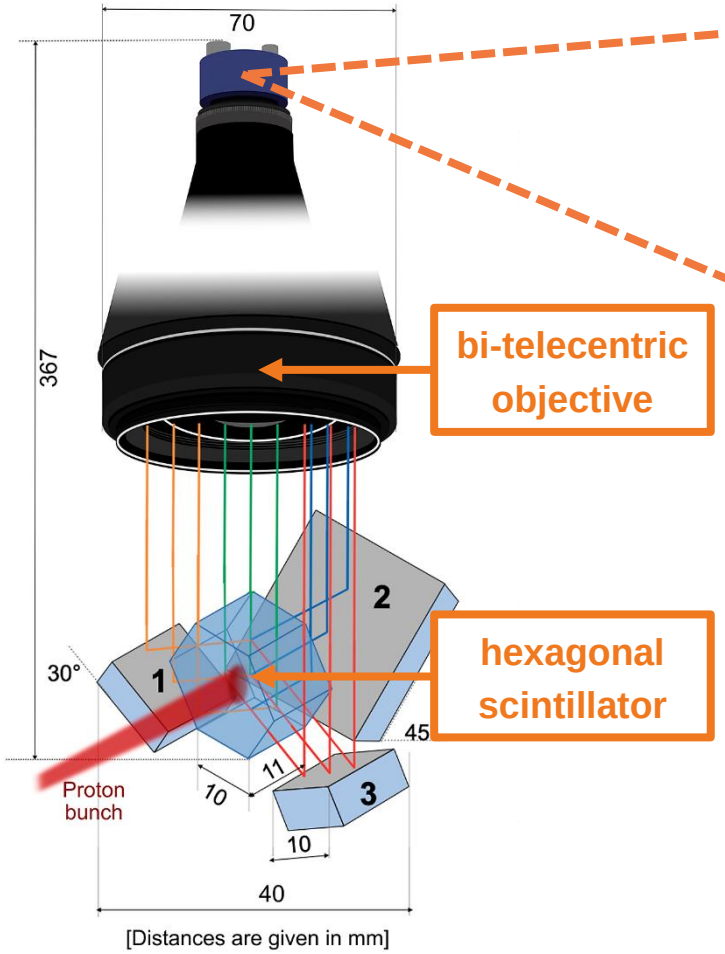
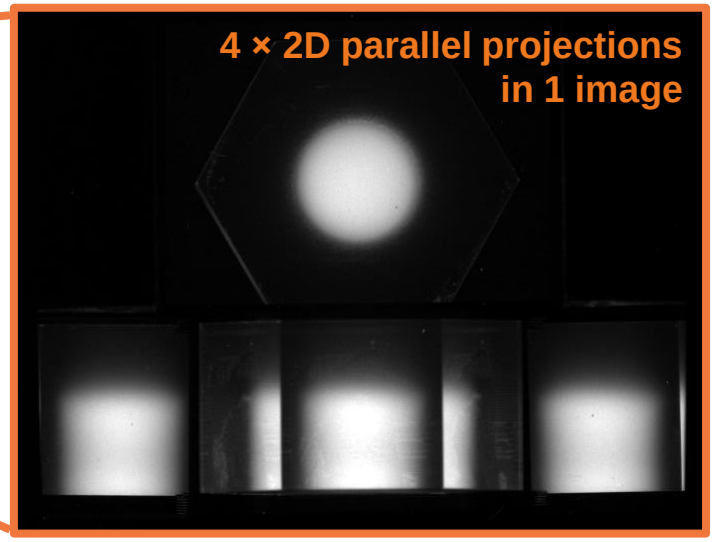
miniSCIDOM

miniature **SCI**ntillator **DO**si**M**eter

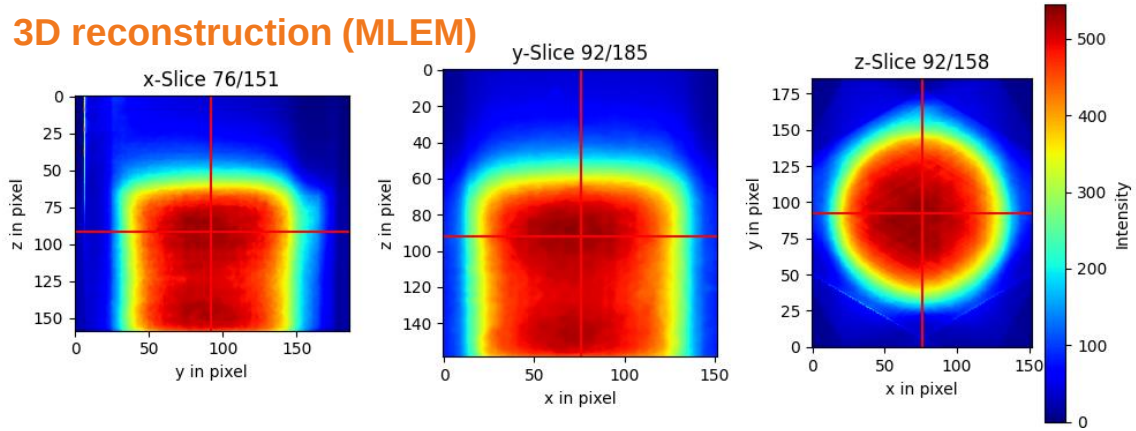


bi-telecentric objective

hexagonal scintillator



3D reconstruction (MLEM)



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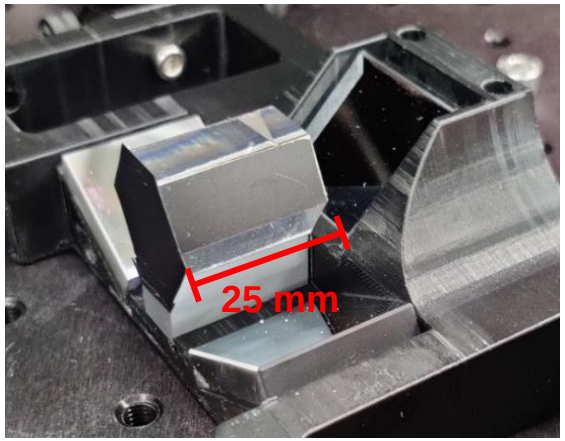
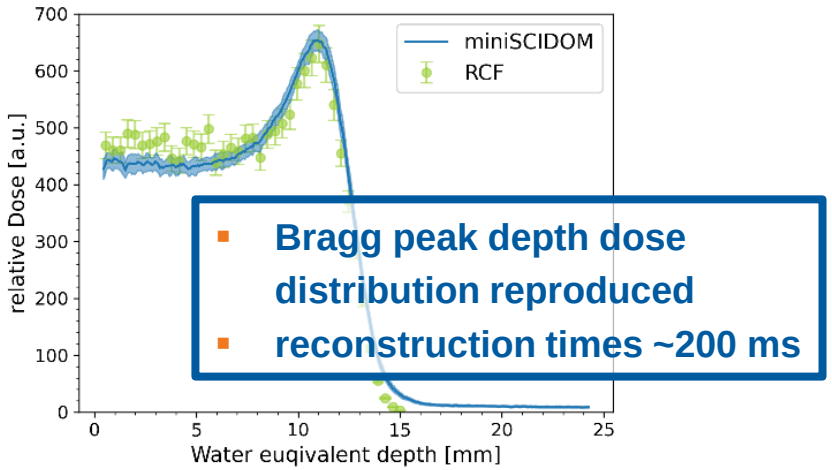
miniSCIDOM – V2

miniature **SCI**ntillator **DO**si**M**eter

larger reconstruction volume

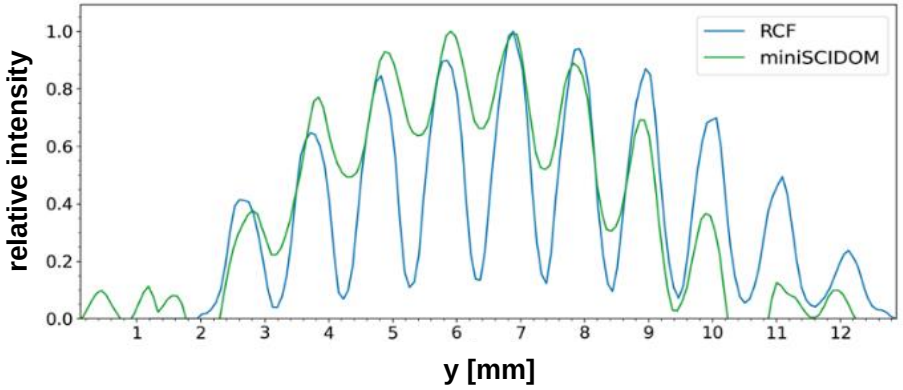


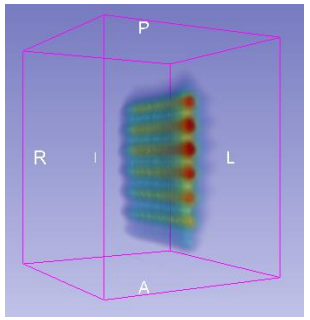


- **Bragg peak depth dose distribution reproduced**
- **reconstruction times ~200 ms**

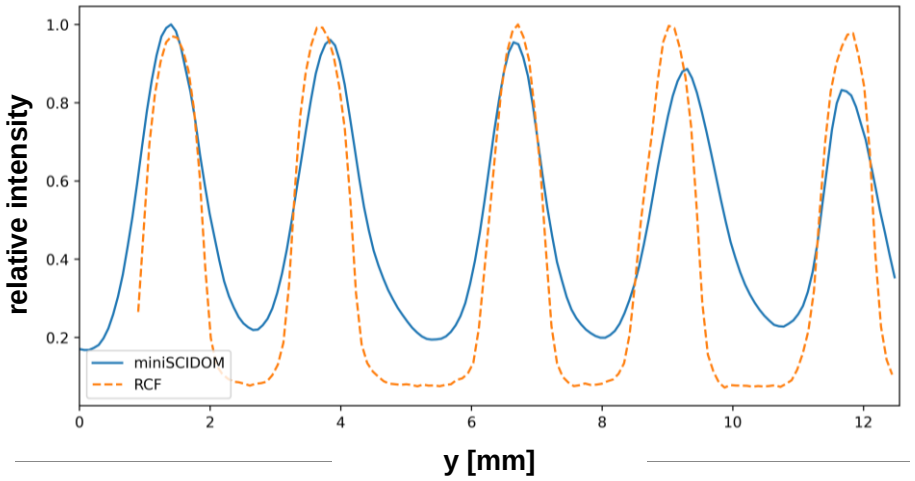
improved signal to background ratio

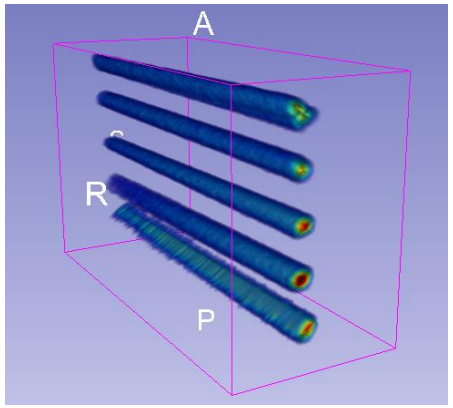
old design





new design





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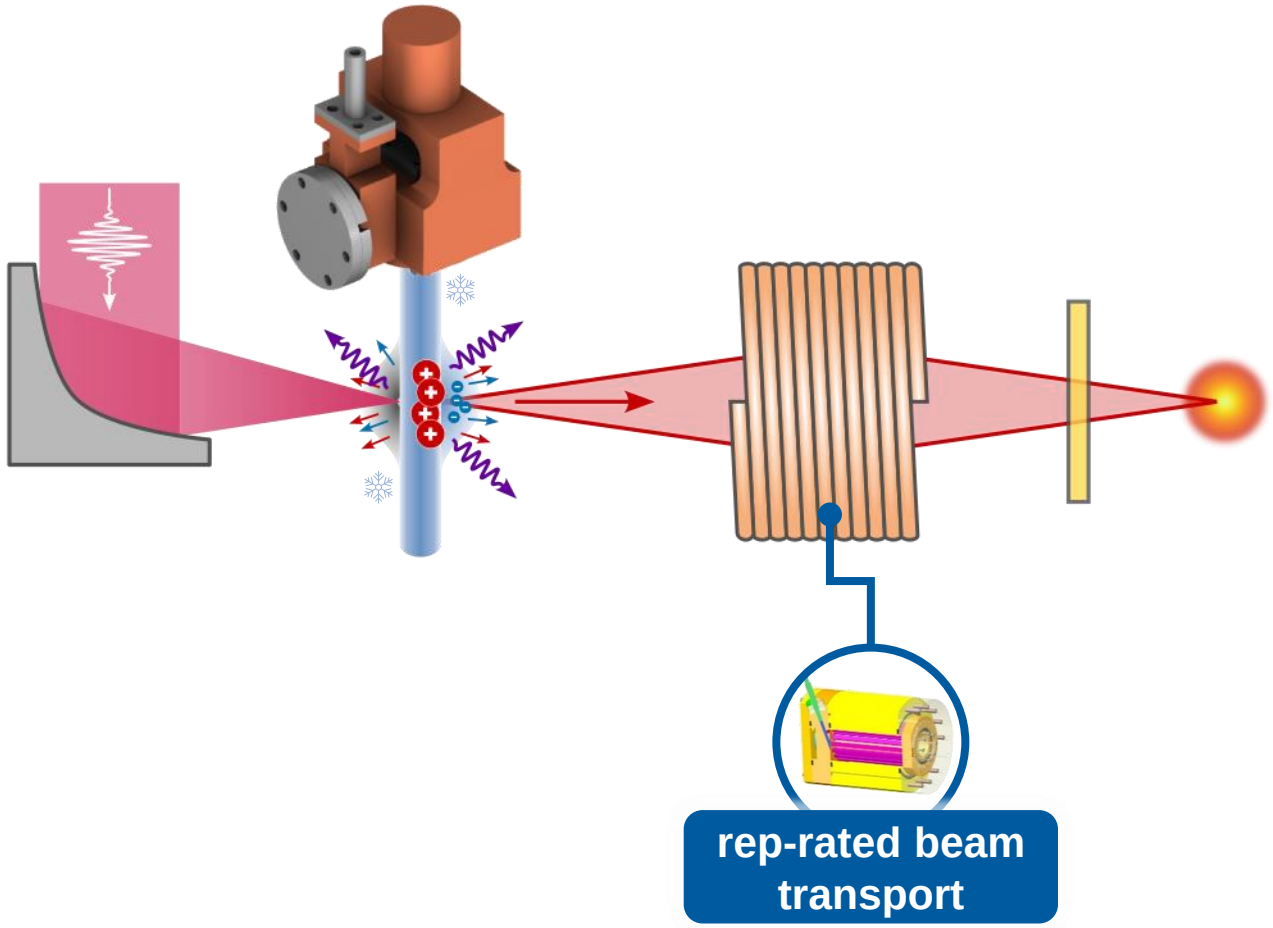
Towards advanced application-ready LPA proton sources

Rep-rated pulsed high-field magnets



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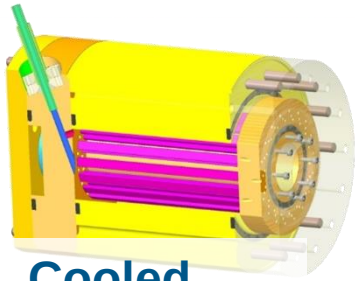
Pulsed power technology platform (ALBUS)

And associated research



Cooled solenoid (20 T)

Dipole sector magnet (10 T)

Quadrupole lens (250 T/m)

Split-pair solenoid (15 T)

Portable current pulse generators (E_{el} ≤ 94 kJ)

Accelerator Physics

Nazary et al., *J. Plasma Phys.* 90 (2024)
Corvino et al., *HPLSE* 12 (2024)
Metzkes-Ng et al., *Sci. Rep.* 13 (2023)
Reimold et al., *PMB* 68 (2023)
Reimold et al., *HPLSE* 11 (2023)
Gerlach et al., *HPLSE* 11 (2023)
Reimold et al., *Sci. Rep.* 12 (2022)
Metternich et al., *PRAB* 25 (2022)
Kroll et al., *Nat. Phys.* 18 (2022)
Brack et al., *Sci. Rep.* 10 (2020)
Haffa et al., *Sci. Rep.* 9 (2019)
Jahn et al., *PRAB* 22 (2019)
Jahn et al., *NIM-A* 909 (2018)
Jahn et al., *RSI* 89 (2018)
Masood et al., *PMB* 62 (2017)
Busold et al., *Sci. Rep.* 5 (2015)
Masood et al., *AP-B* 117 (2014)
Busold et al., *NIM-A* 740 (2014)
Busold et al., *PRAB* 17 (2014)
Busold et al., *PRAB* 16 (2013)

Laboratory Astrophysics

Perez-Martin et al., *HPLSE* 11 (2023)
Bohlin et al., *PPCF* 64 (2022)
Manuel et al., *MRE* 6 (2021)
Mabey et al., *Astrophys. J.* 896 (2020)
Mabey et al., *Sci. Rep.* 9 (2019)
Albertazzi et al., *HPLSE* 6 (2018)
Albertazzi et al., *Science* 346 (2014)
Albertazzi et al., *RSI* 84 (2013)

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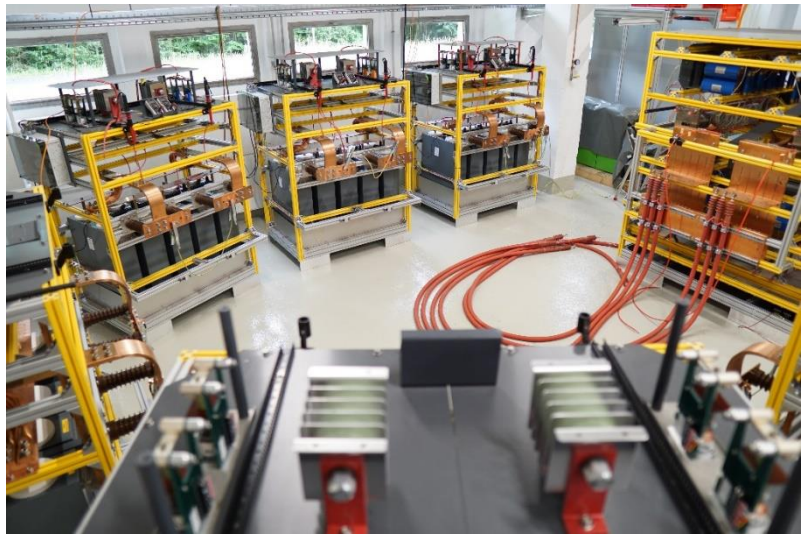
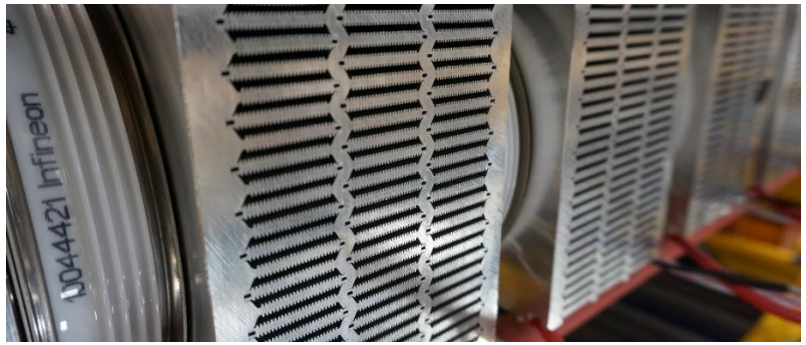
Current pulse generation at 1 Hz

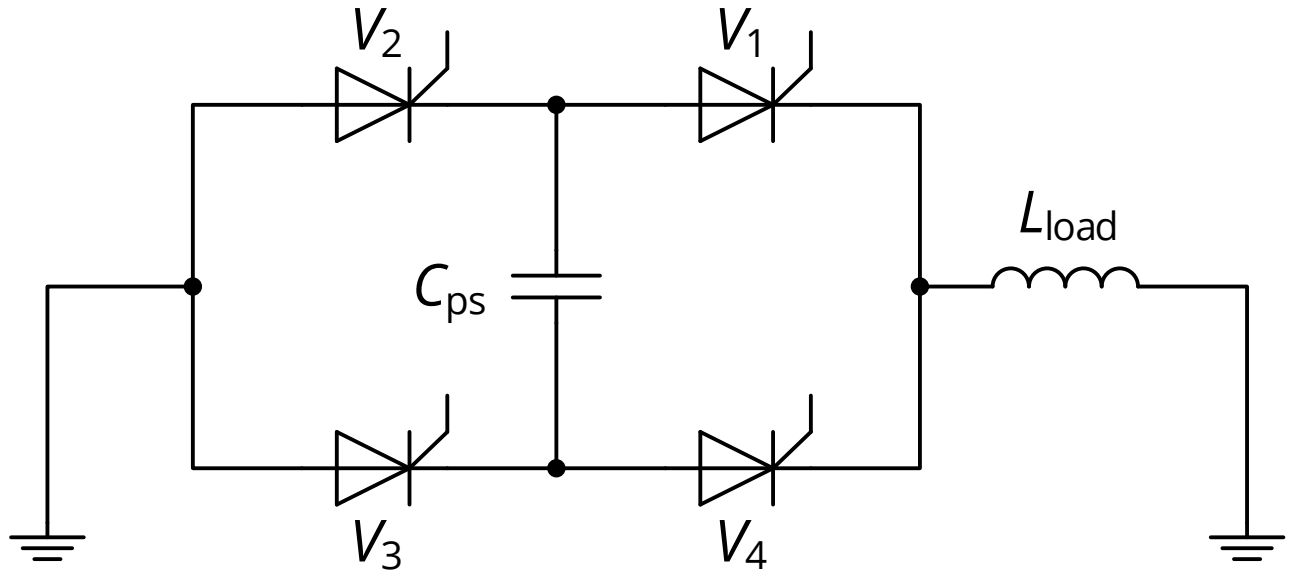
World-wide first 1-Hz-operation of pulsed high-field beam optics





- **collaboration with Institute of Power Electronics, TUD**
- **modular prototype assembled and commissioned**

C = 125 – 750 µF , $E_{el,max}$ = 36 – 216 kJ @ 24 kV



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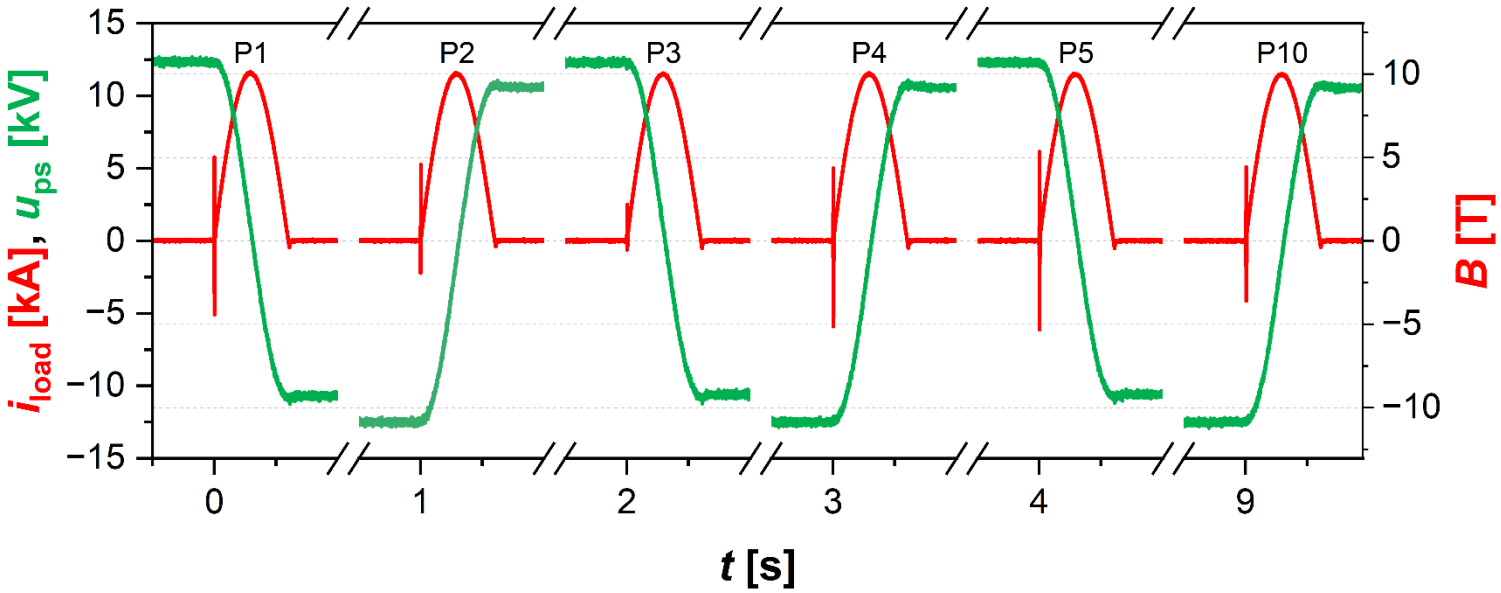
Current pulse generation at 1 Hz

World-wide first 1-Hz-operation of pulsed high-field beam optics

- **Charger commissioning finished last week**
- **functionality proven up to 24 kV**
- **1st pulse trains in beamline solenoid: 10 × 10 T @ 1 Hz**



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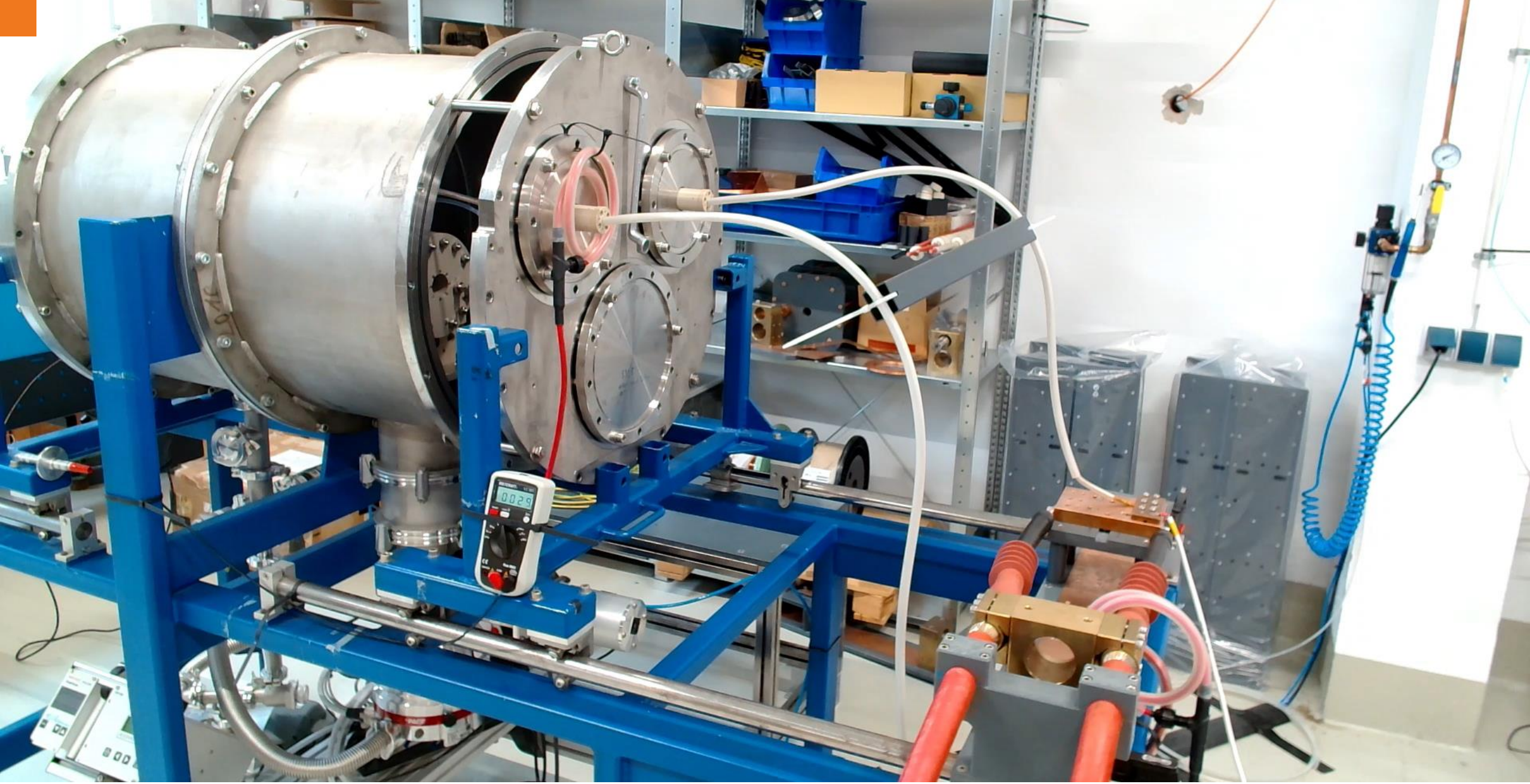

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