

Plasma Wakefield Acceleration for Leptons

Activities at DESY

Jens Osterhoff

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DESY. Accelerator Division

DMLab Scientific Kickoff

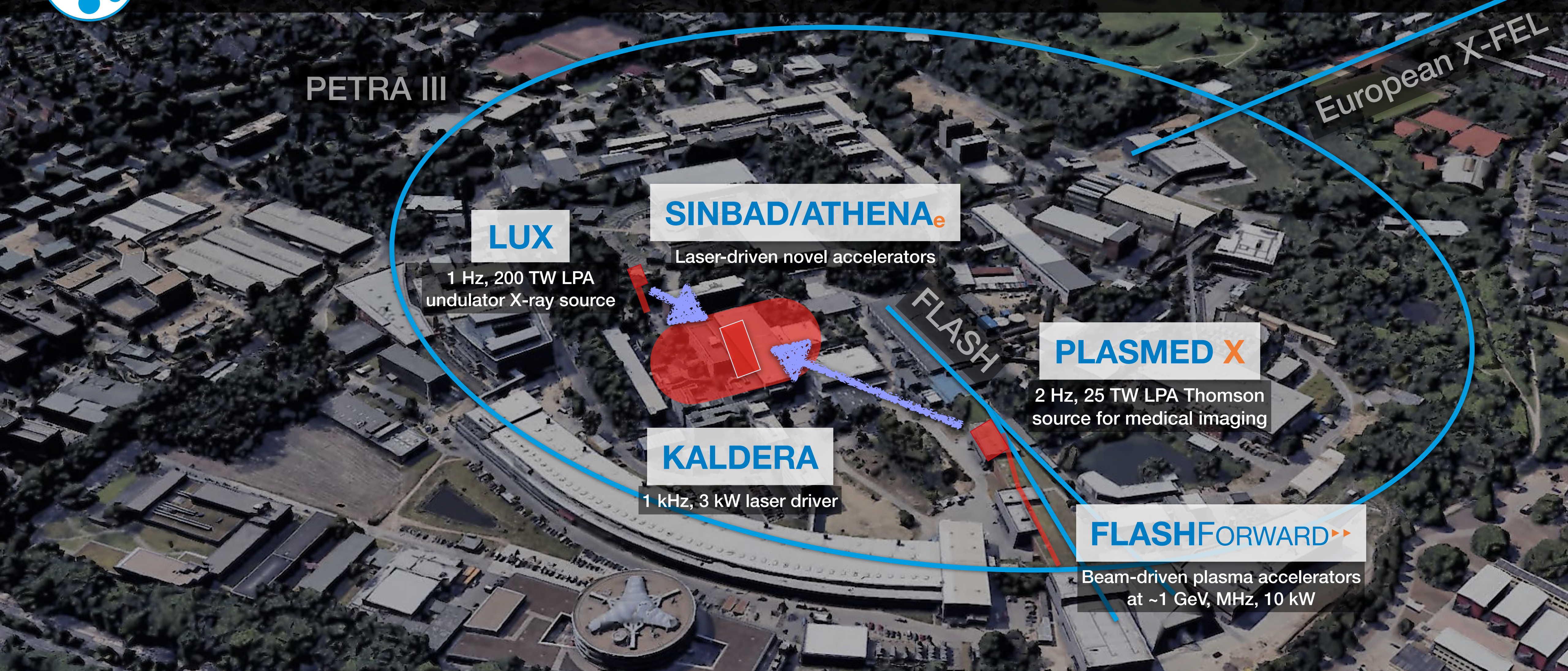
December 9th, 2021

HELMHOLTZ RESEARCH FOR
GRAND CHALLENGES





plasma accelerators focus on average power and applicability



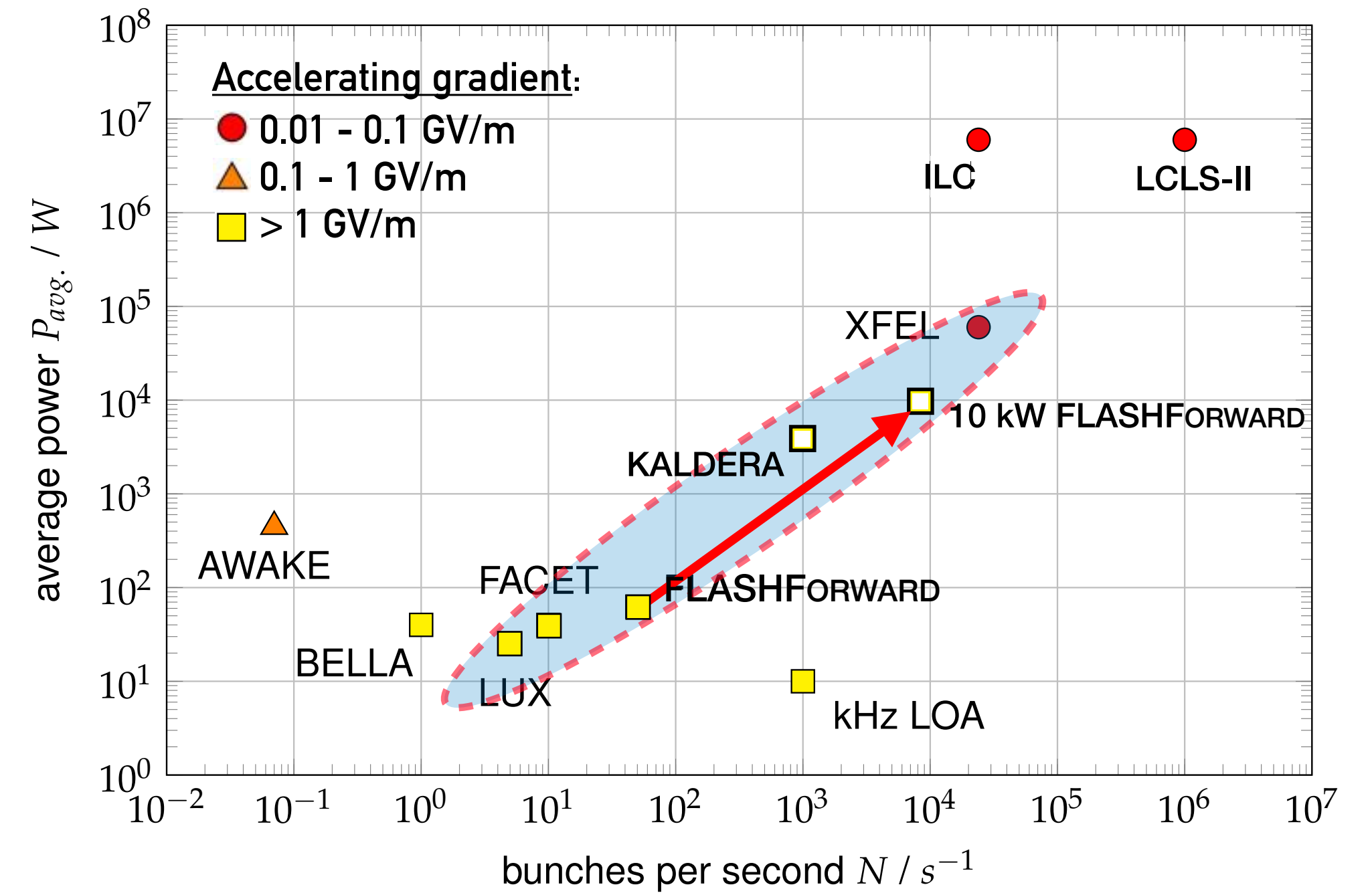
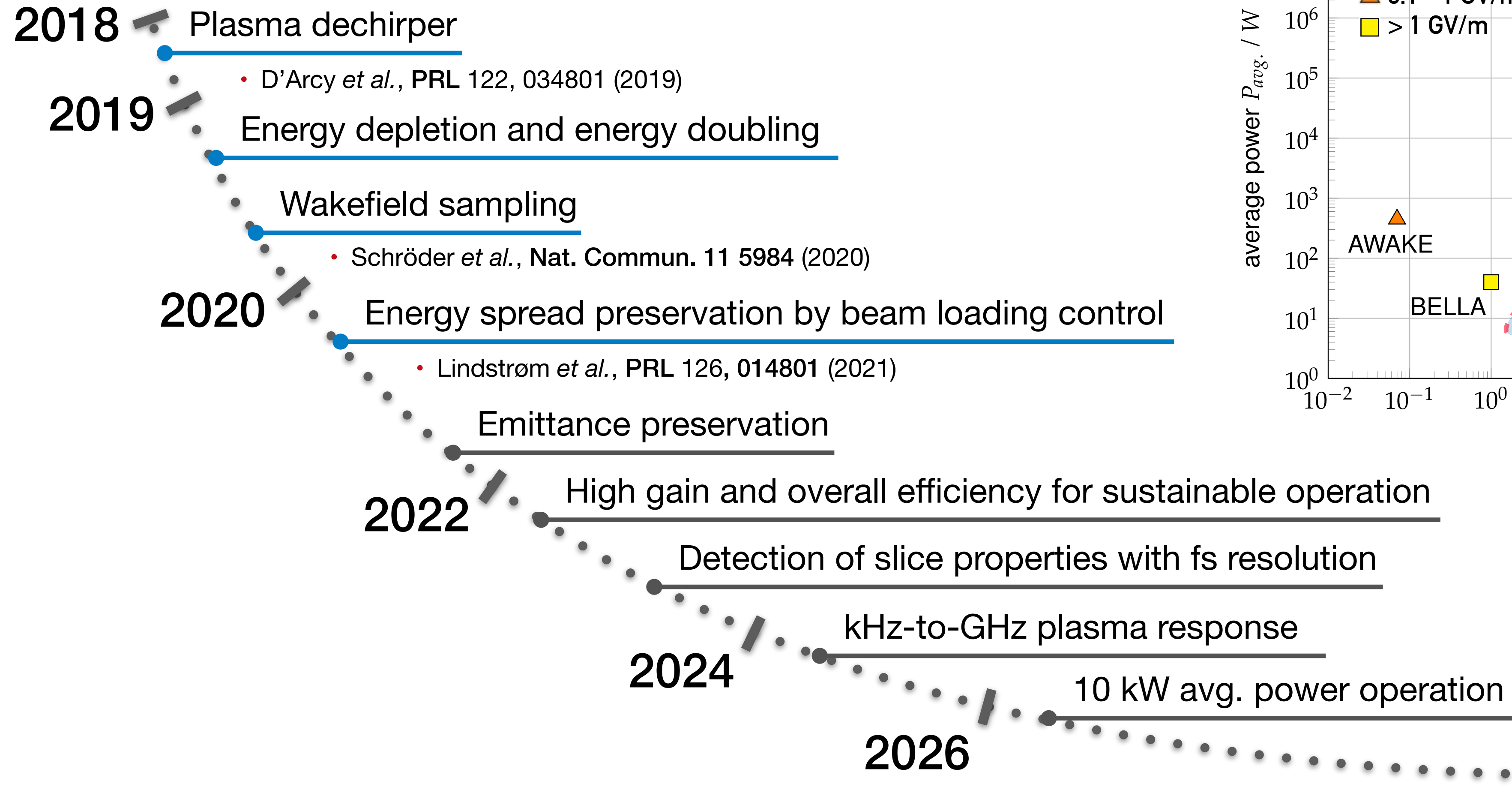
Leverage the system competence in engineering, operations, and accelerator R&D

Image: Copernicus

Google Earth

FLASHFORWARD ▶▶ roadmap aims at 10 kW with high beam quality

Plan covers major plasma accelerator challenges

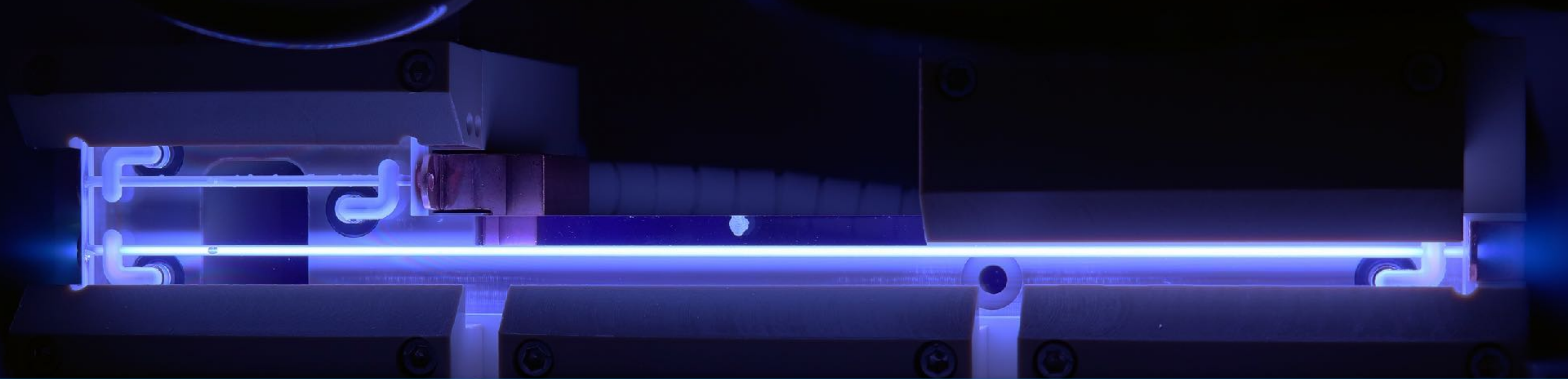


10 kW stage with 50% efficiency & beam quality conservation

→ **FLASH:** increase FEL energies, access oxygen K-edge at 2.33 nm wavelength

FLASHFORWARD develops the ultimate plasma booster module

Objective is to double the FLASH beam energy with high efficiency and power while maintaining FEL beam quality



First plasma accelerator recovery

- D'Arcy *et al.*, under review at Nature (2021)

First energy spread preservation at 0.1% and record efficiency

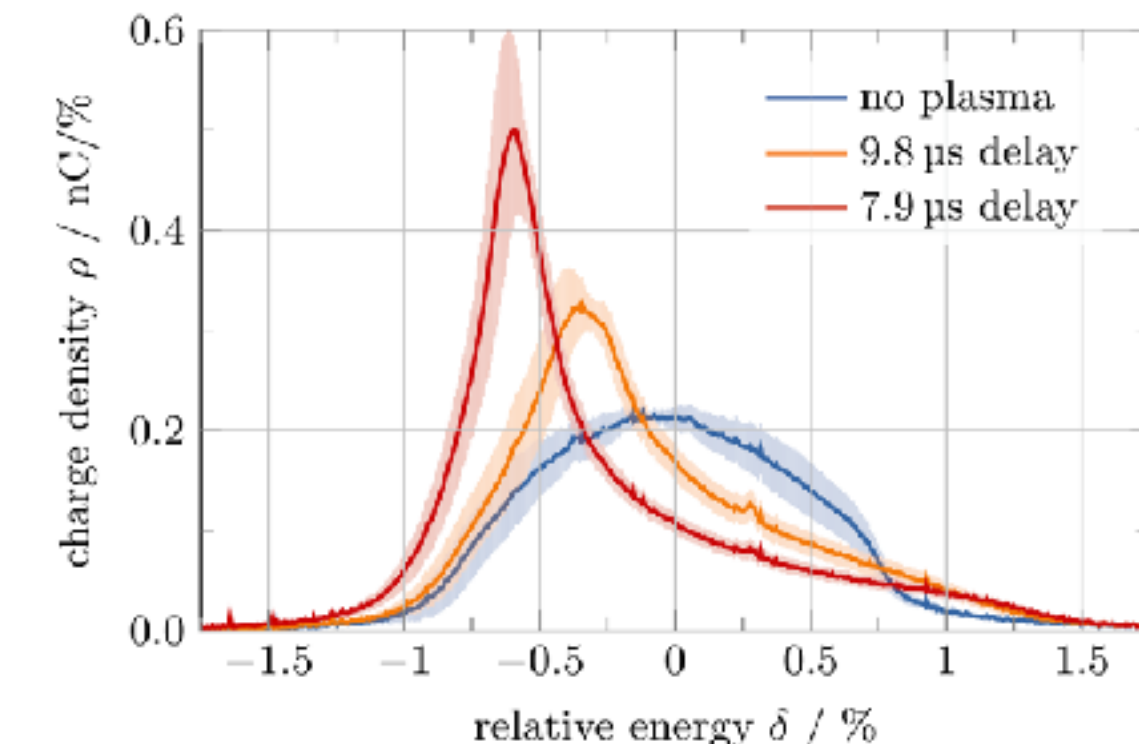
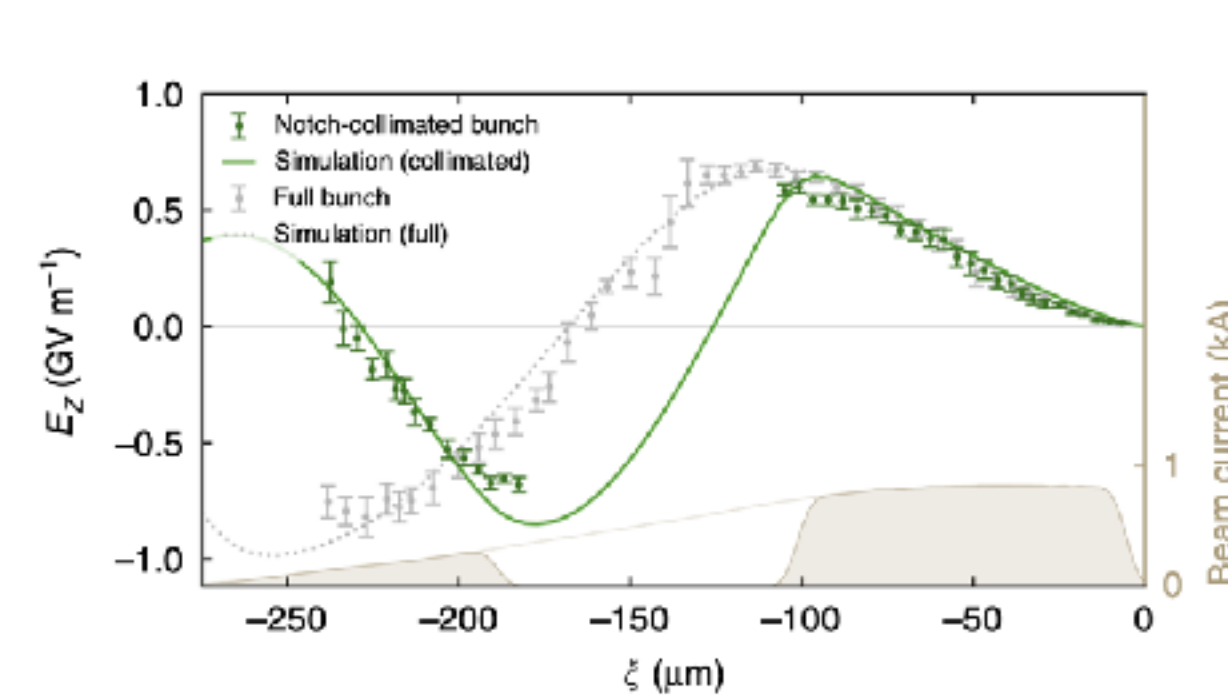
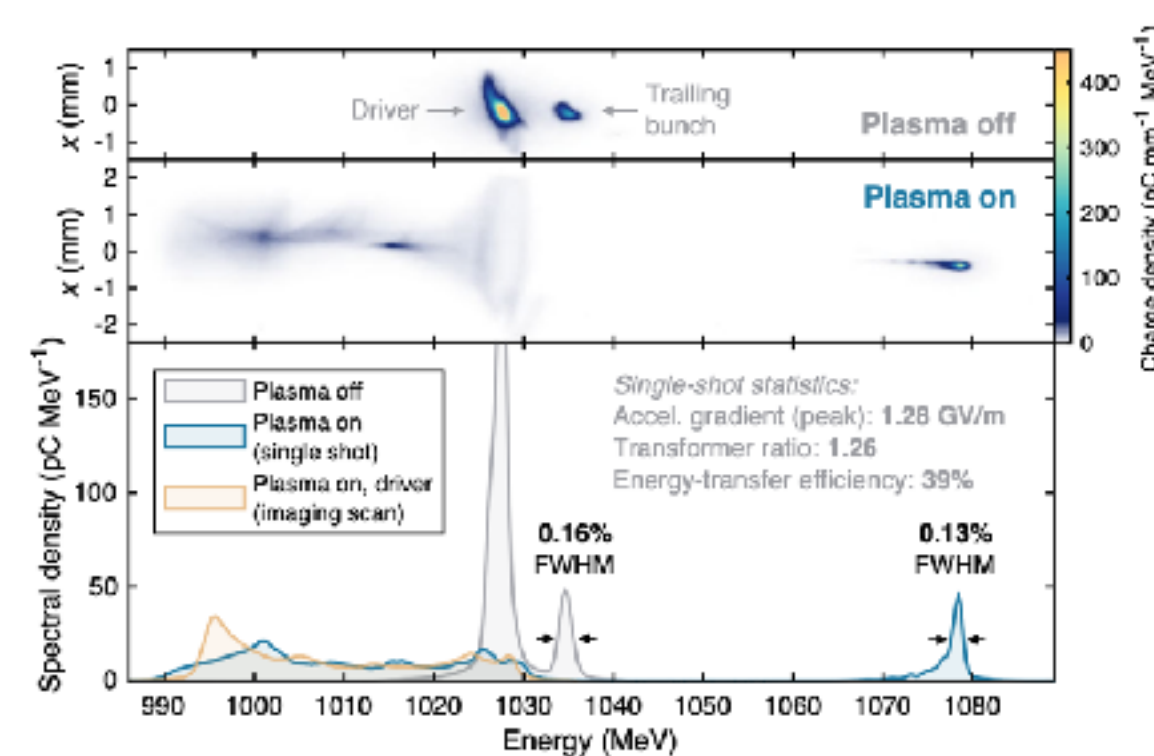
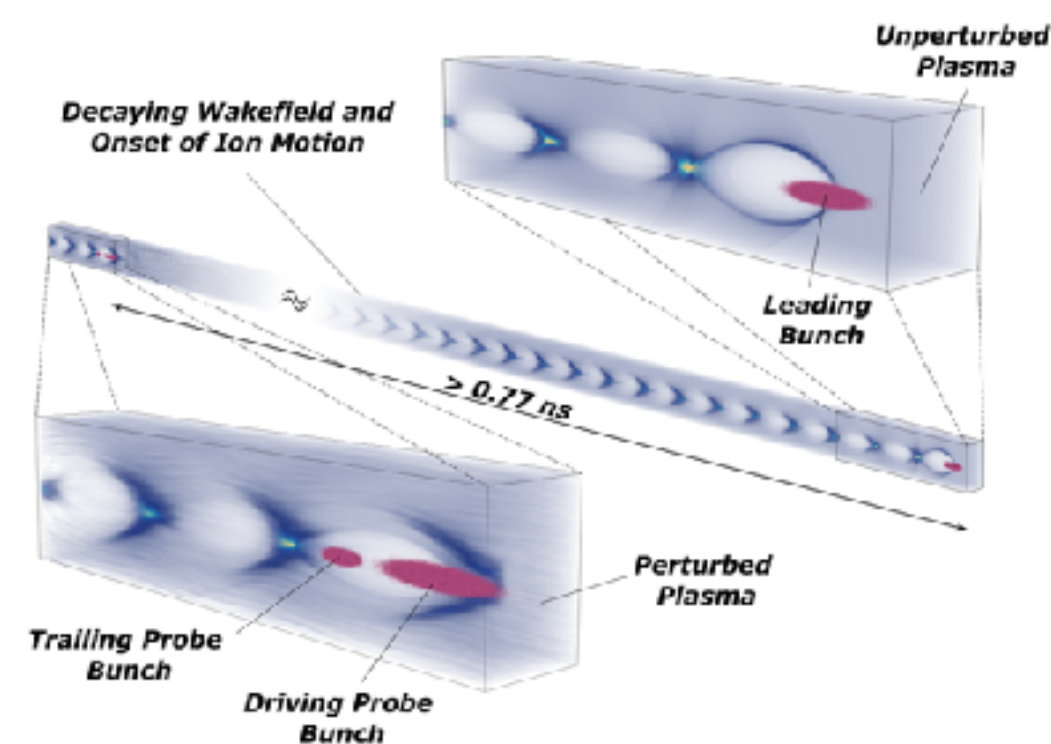
- Lindstrøm *et al.*, PRL 126, 014801 (2021)

First direct wakefield sampling

- Schröder *et al.*, Nature Com. 11, 5984 (2020)

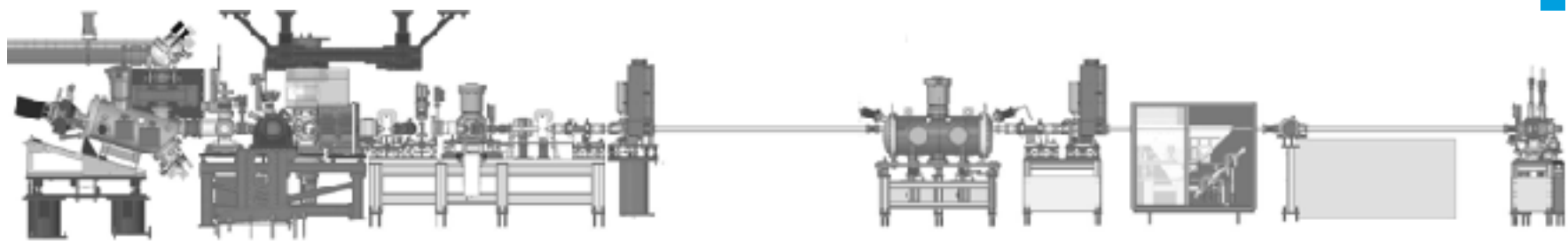
First plasma dechirper

- D'Arcy *et al.*, PRL 122, 034801 (2019)



Powering an FEL, injection into state-of-the-art storage ring, novel end-station modalities and 10+ GeV laser-plasma accelerator are goals at DESY

Stable, reliable generation of high-quality beams to ensure machine tunability and availability



Demo-FEL operational at LUX

- Demonstrate LPA powering an FEL
- Long term runs (week or more)

Medical initiatives

- PLASMED X
- Radiation biology with ARES/PITZ and LPAs

2019

Laser plasma accelerators

- Up to 8 GeV
- Dechirper, plasma lenses, low emittance
- 29h stability run

2021

CDR for PETRA-IV injection

- Phase-space tailoring, avg. current

2023

KALDERA operational

- Multi-kW laser
- kHz operation of LPA

2023

kHz X-ray source and kHz FEL

- KALDERA drives novel sources

2025+



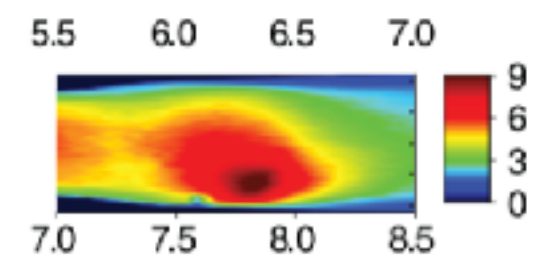
Moon shot

2nd injection system R&D for PETRA-IV: LPA based



Mars shot

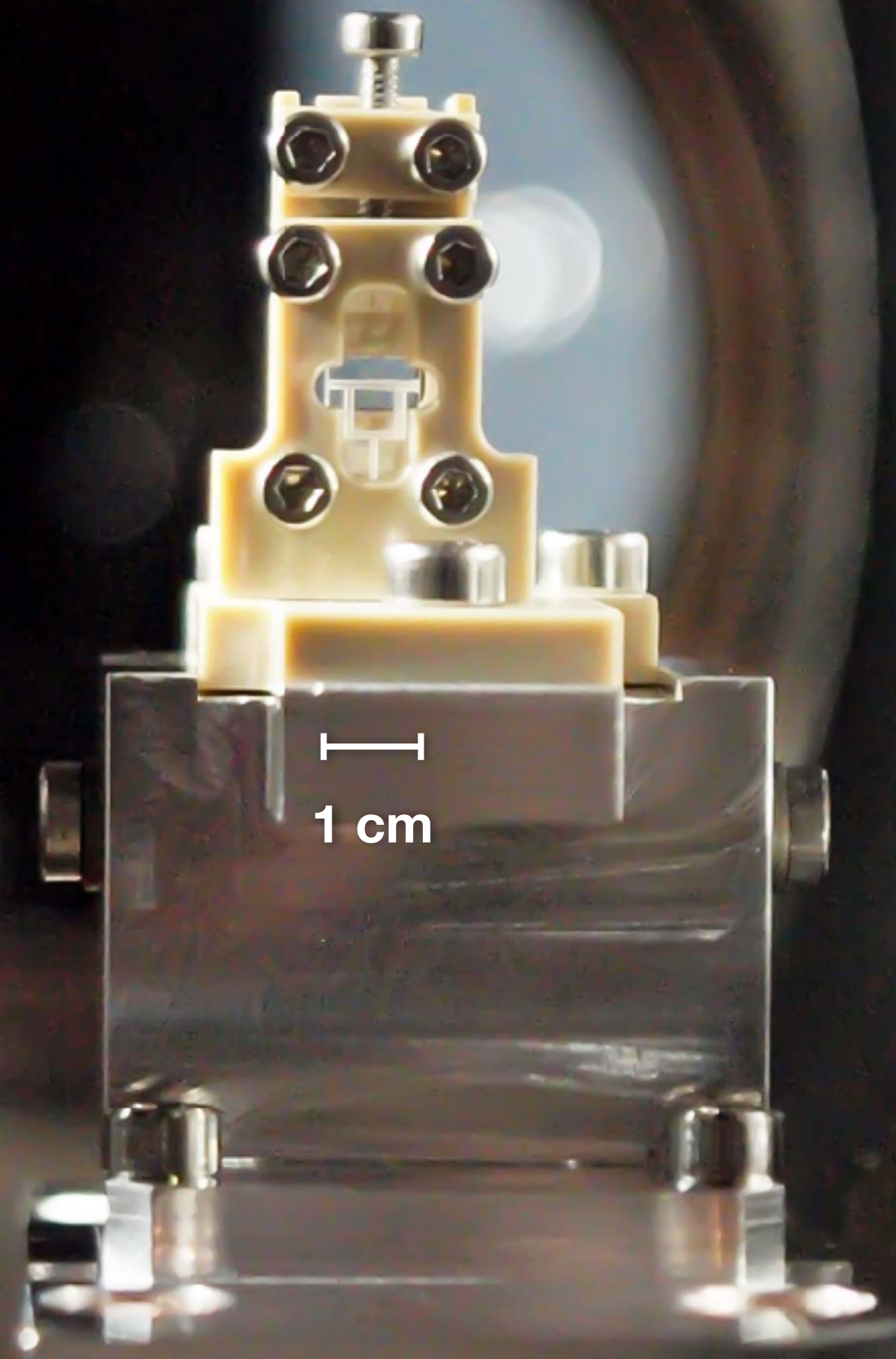
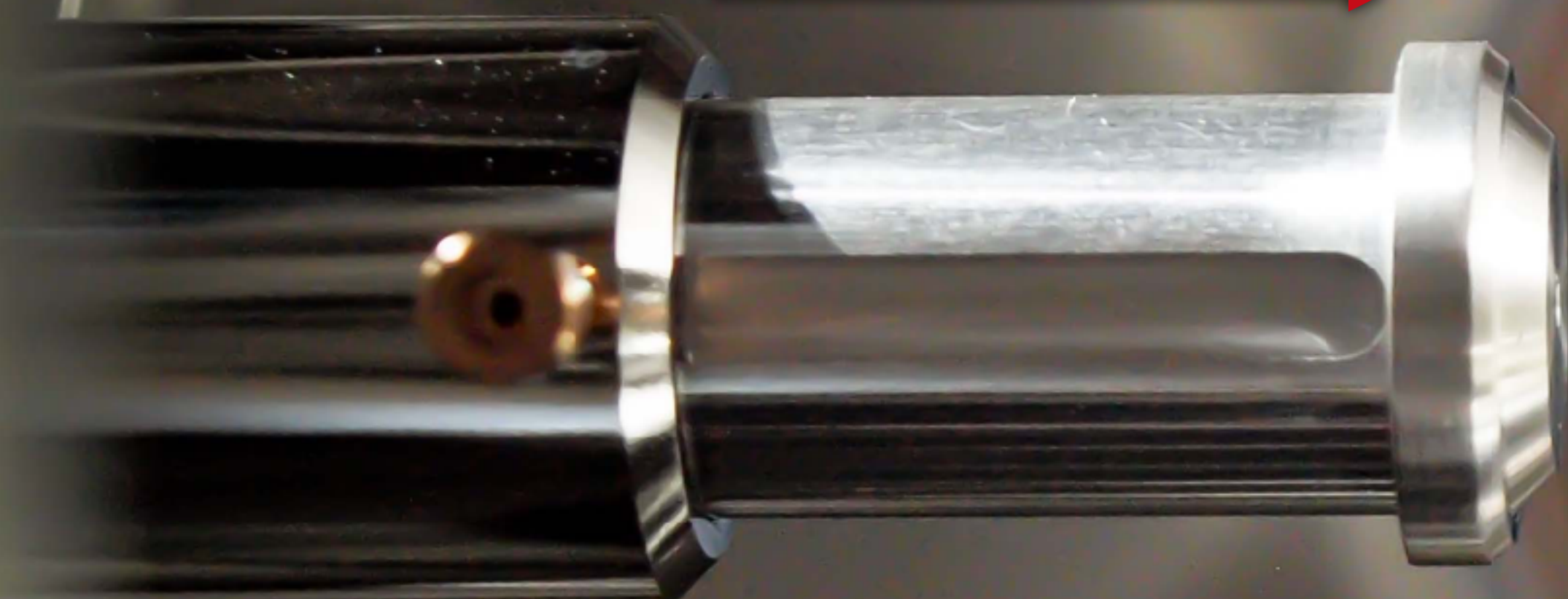
Non-linear QED plasma building block for collider



Energy/MeV
A. F. Maier et al., in preparation

LUX — Laser-plasma accelerator for photon science

ANGUS 200 TW Laser

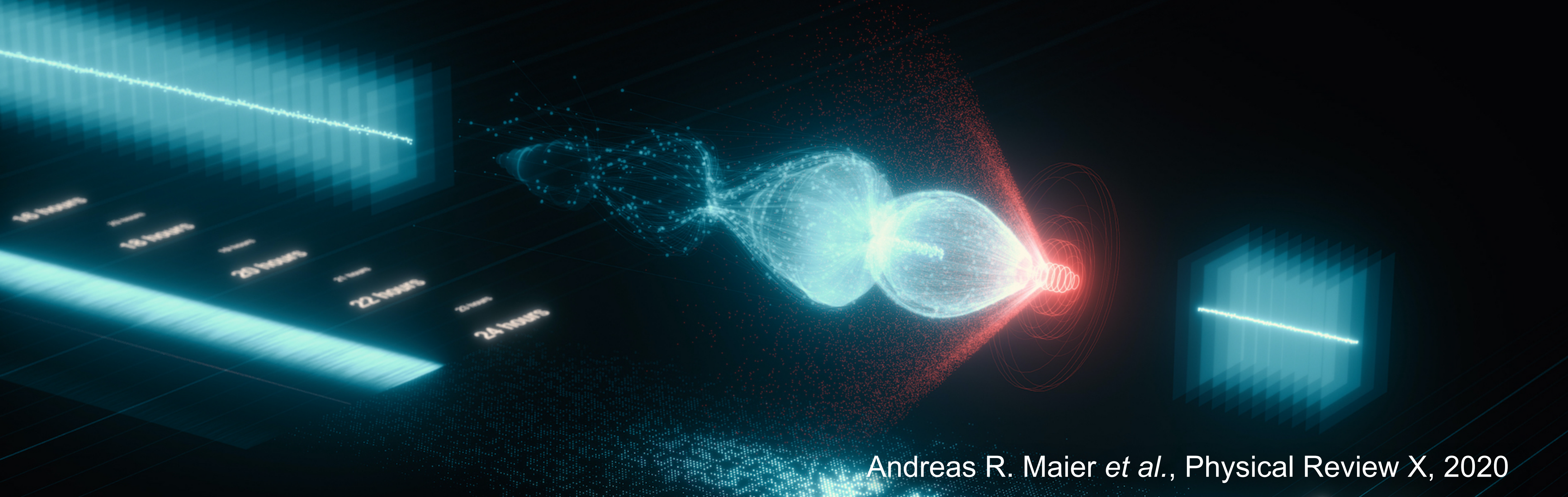


Project coordinator:
Andreas R. Maier (DESY)

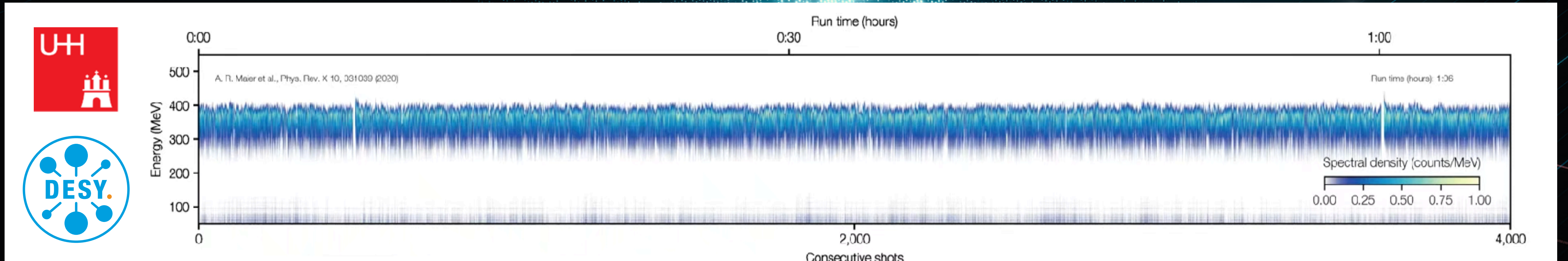
→ <http://lux.cfel.de/>

Technological breakthrough: previously unattained stability

Plasma accelerator LUX performs for 28 hours straight

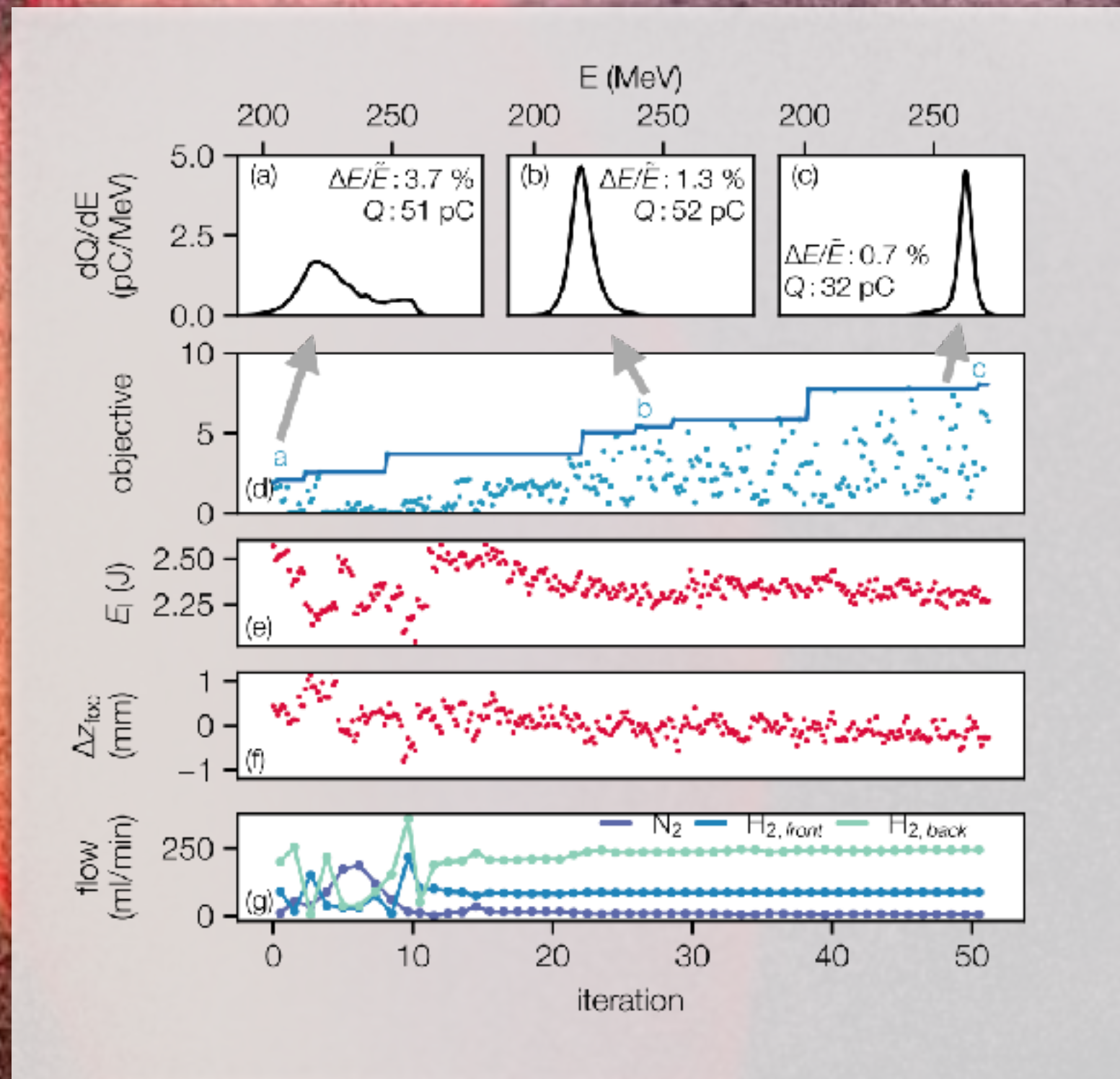


Andreas R. Maier *et al.*, Physical Review X, 2020



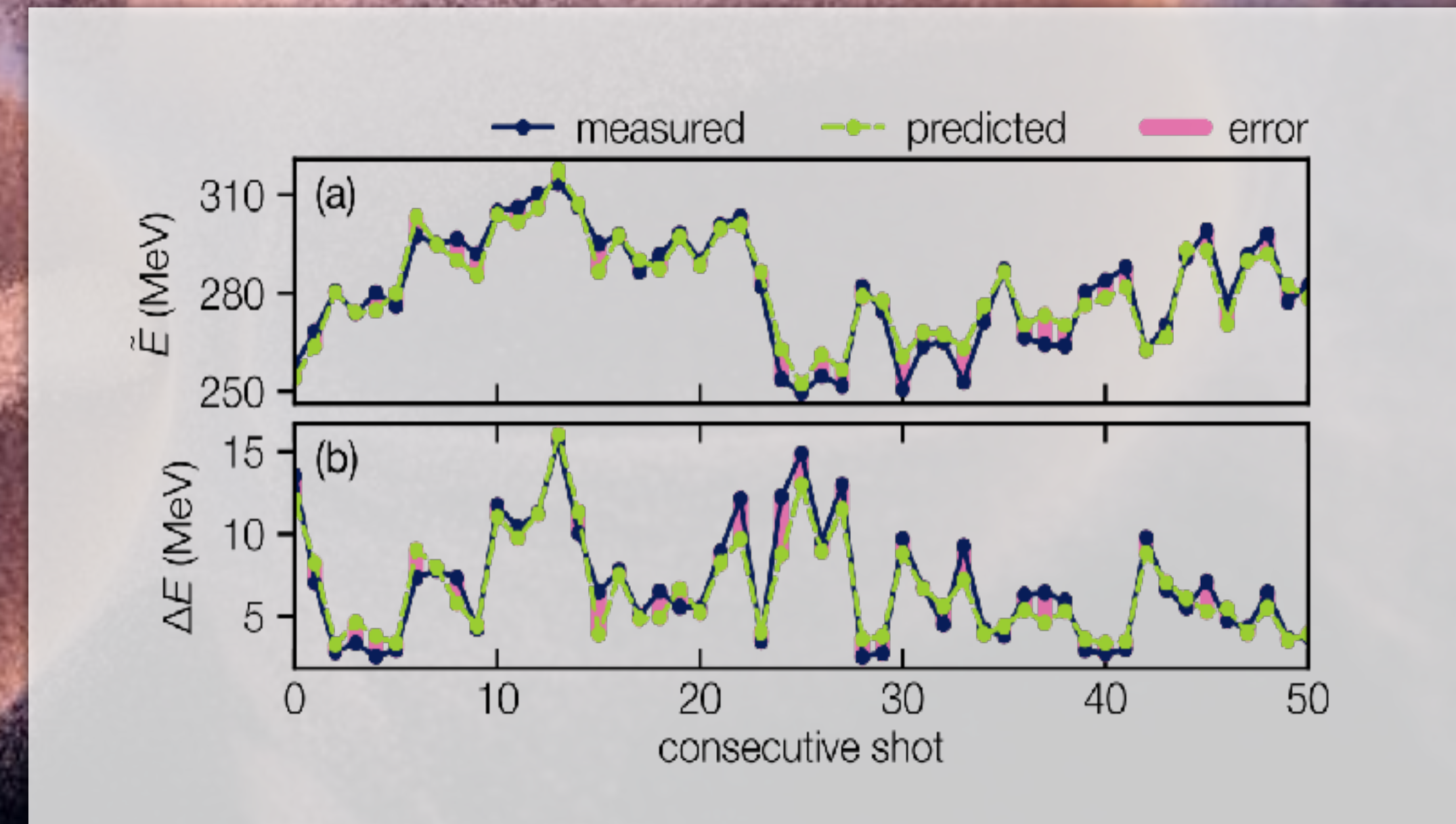
Artificial intelligence for laser-plasma accelerator optimization

LUX plasma accelerator auto-tunes to high-quality electron beams



Plasma accelerator autonomously tunes to sub-percent energy spread beams.

S. Jalas et al., PRL 126, 104801 (2021)



We know how to get high-quality sub-percent energy spread few-kA peak current beams → we need active stabilization to get them more often

M. Kirchen et al., PRL 126, 174801 (2021)



DESY/UHH develop a portfolio of open-source, high-performance codes for plasma accelerator emulation

Quasistatic

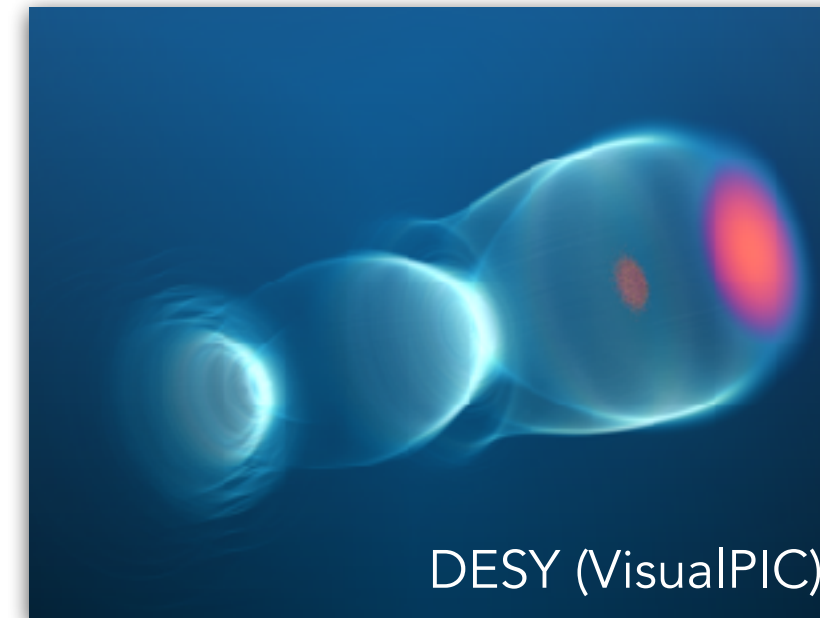
Fully electromagnetic

Quasi-cylindrical

Wake-T (DESY)

→ Conceptual designs (sec-min)

Open-source

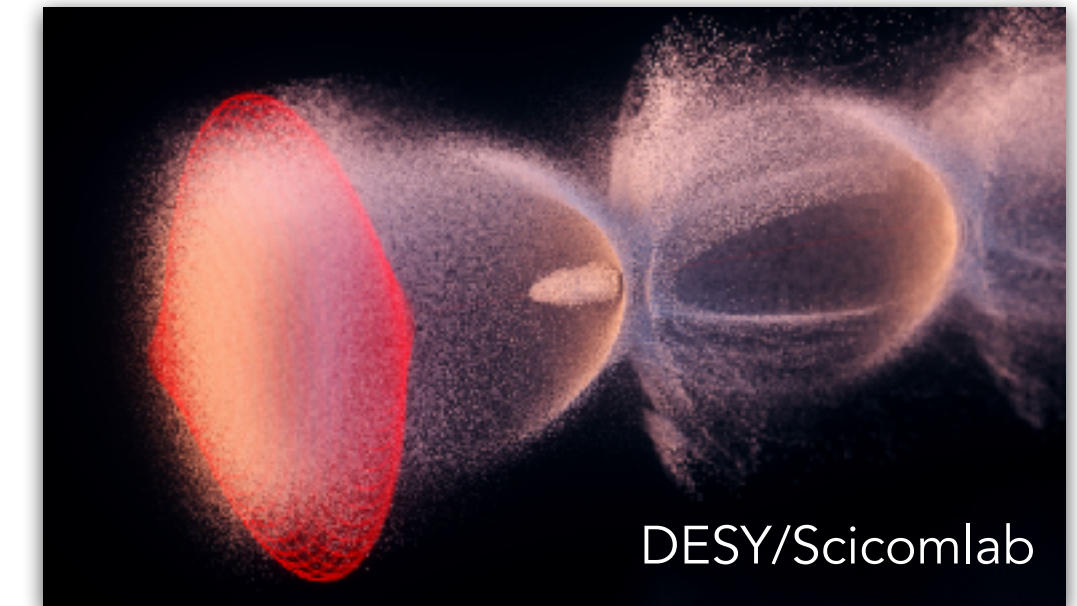


<https://github.com/AngelFP/Wake-T>

FBPIC (LBNL + UHH)

→ LPA with injection

Open-source GPU



<https://github.com/fbpic/fbpic>



3D

HiPACE++ (DESY + LBNL)

→ 3D external injection

Open-source GPU

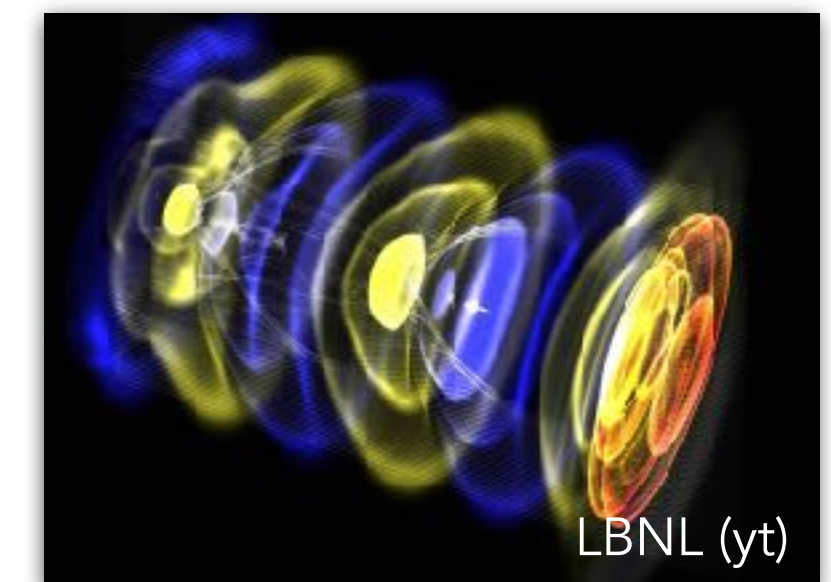


<https://github.com/Hi-PACE/hipace>

WarpX (LBNL + many incl. DESY)

→ LPA with injection

Open-source GPU



<https://github.com/ECP-WarpX/WarpX>

Multiple options: **PIConGPU**, **OSIRIS**

Plasma wakefield acceleration for leptons

Conclusion

- > Plasma acceleration is a high potential technology for compact particle accelerators
- > It is developing at a rapid pace and will mature in the next years to enable applications
- > DESY is one of the driving forces in this field,
Research programs in German partner centers FZJ and KIT have started or are being launched
- > We are happy to discuss and engage in collaborations within the DMLab framework