

ARD ST 4 - Highlights

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Ulrich Schramm, HZDR

February 2nd, 2021
7th Annual MT Meeting
Online

Software Development & Theory Support

The foundation of many of our activities



Naturally links ATD/ST4 to DMA

New theory & simulation group for plasma acceleration at DESY

Lead by M. Thévenet (former LBNL)

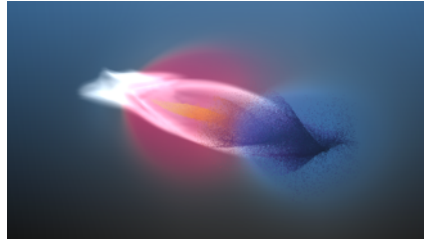
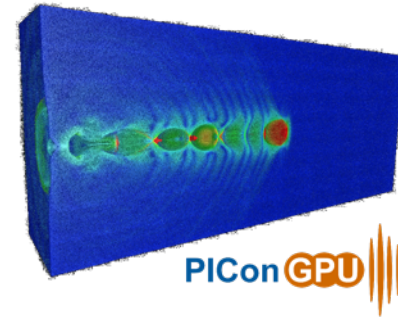


Image: Angel Ferran Pouso



<https://github.com/ComputationalRadiationPhysics/picongpu>

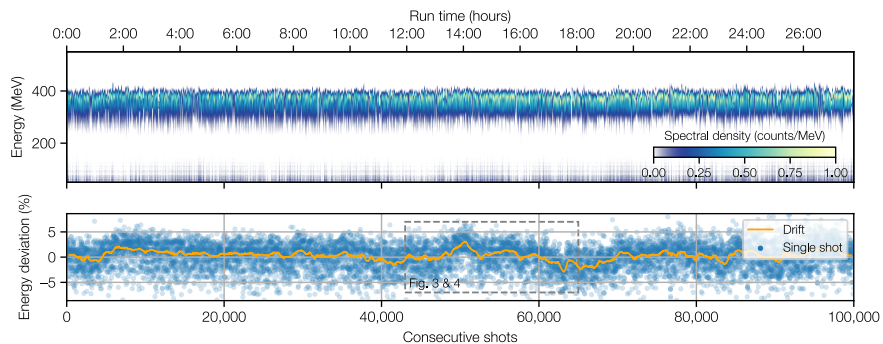
Portfolio includes

- Prioritizing accelerated computing and Start2End workflow
- AI methods to improve plasma accelerators
- Conceptual design of a plasma injector for Petra IV
- Strong ties to experimental programs

HZDR engages in high-profile early-access projects for driving predictive capabilities on world-leading supercomputing architectures. Including JSC (Jülich, Juwels Booster / NVIDIA GPUs) and CAAR (Oak Ridge, Frontier/AMD GPUs)

Increasing Reliability

Extended run times for laser-accelerated electrons and protons



Phys. Rev. X 10, 031039 (2020)

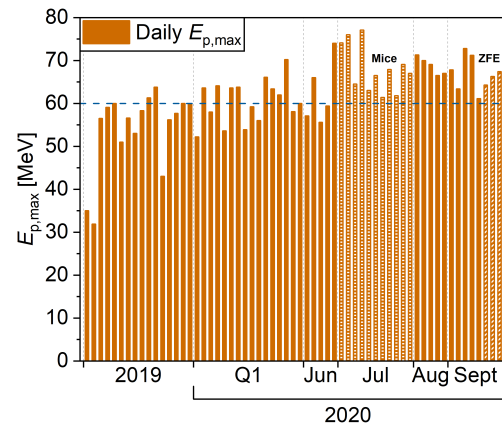


Figure: F. Kroll

Electrons

- Repeated 24-hour operation of a laser-plasma accelerator demonstrated at the LUX beamline (UHH, DESY)
- High statistics enables decoding the sources of energy variability

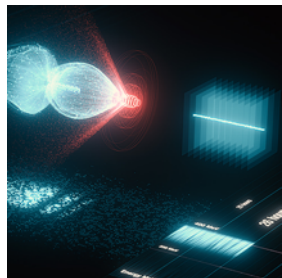


Image: Science Communication Lab (DESY)

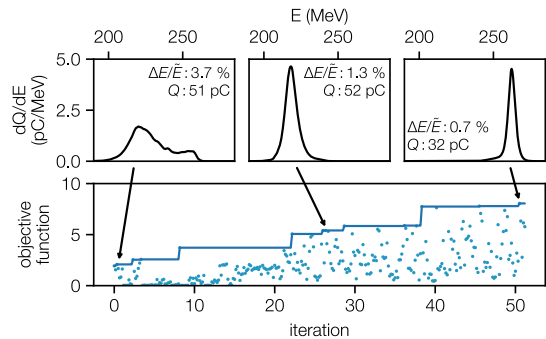
Protons

- Reproducible performance over months enabled first in-vivo irradiation studies at highest dose rate at HZDR
- See *highlight talk by F. Kroll, Wed. 03.02.21, 11.15*
- *T. Ziegler, et al., arxiv:2007.11499 (2020)*

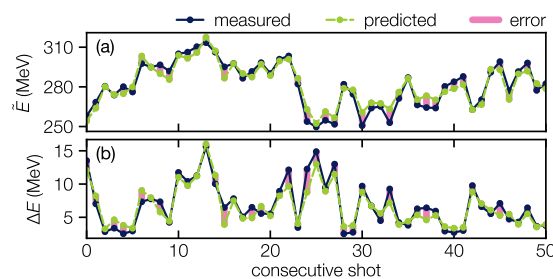


Machine Learning to Improve LPA Electrons

Auto-tuning the accelerator and predictive modeling



S. Jalas et al., submitted (2020)



M. Kirchen et al., submitted (2020)

ML-based optimization of LPA experiment

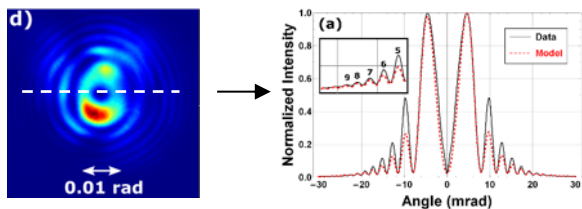
- LUX laser-plasma accelerator tunes to sub-percent energy spread beams using bayesian optimization
- S. Jalas et al., submitted (2020)
- See highlight talk by S. Jalas, Wed. 03.02.21, 14.45

ML-based surrogate model of LPA experiment

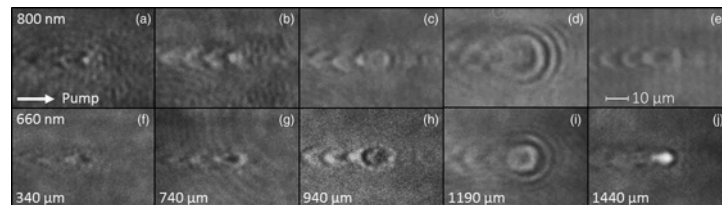
- Data from LUX laser-plasma accelerator trains a surrogate model and enables single-shot predictive modeling of the plasma electron properties
- Paves the way for active feedback & stabilization and analysis mechanisms of residual parameter variations
- M. Kirchen et al., submitted (2020)

Advanced Diagnostics

Accessing ultrashort time and length scales



Phys. Rev. Lett. 125, 014801 (2020)



Phys. Rev. Accel. Beams 23, 032801 (2020)

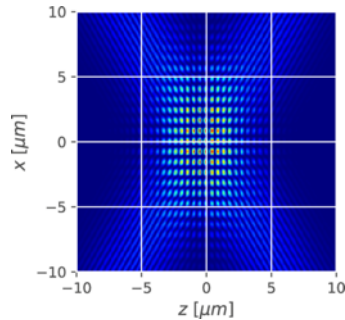
Coherent OTR Interferometry at HZDR

- Simultaneous single-shot measurement of beam size and divergence at LPA exit
- LPA bunches show 1% level microbunching at the LPA exit
- *Phys. Rev. Lett.* 125, 014801 (2020)

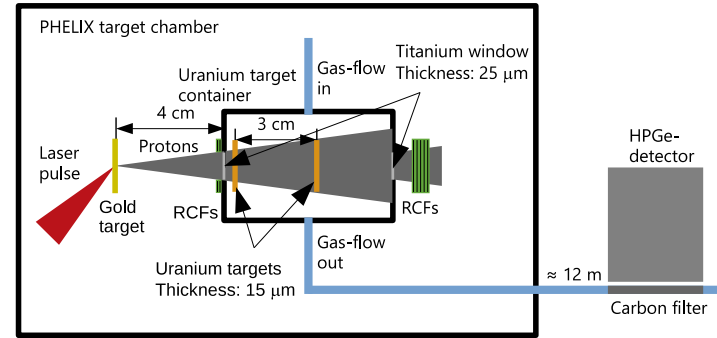
Visualization of relativistic laser pulses in underdense plasma at HI-Jena

- Optical probing of the LPA plasma
- Wavelength dependent probe transmission due to relativistic electron cyclotron resonances in the plasma
- In-situ diagnostics for the pump laser
- *Phys. Rev. Accel. Beams* 23, 032801 (2020)

Advanced Diagnostics & Targets



Phys. Rev. Accel. Beams 24, 012804 (2021)



Sci. Reports 10, 17183 (2020)

Novel concept to measure small emittances

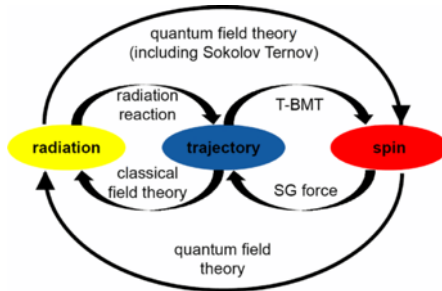
- Laser interference pattern modulates momentum space
- Sensitive to nm.rad emittances
- *Phys. Rev. Accel. Beams 24, 012803 (2021)*

Radioactive fission isotopes from laser-driven protons

- PHELIX generates high proton fluxes
- Creates laser-induced nuclear physics
- Identified short-lived nuclides (^{134}I , ^{136}I , ^{137}Xe , ^{138}Xe , ^{139}Xe and ^{140}Cs)
- *Sci. Reports 10, 17183 (2020)*

Advanced Targetry

Polarized Beams



Phys. Rev. Accel. Beams 23, 064401 (2020)

Scaling laws for the time-scales of depolarization in strong fields

- Investigate the feasibility of particle acceleration in strong fields without destroying an initial polarization
- *Phys. Rev. Accel. Beams 23, 064401 (2020)*

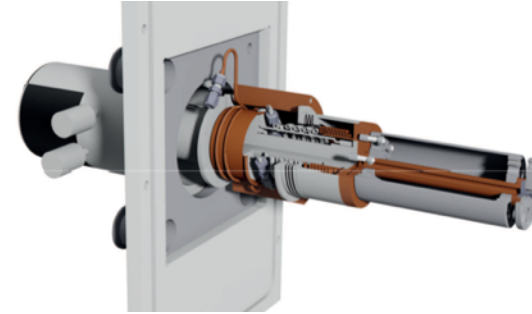


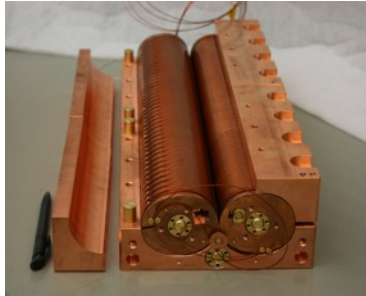
Image: JuSPARC

Development of cluster target

- Concept: inject attosecond electron bunches from nm-scale solid target into LPA
- Based on kHz@40mJ drive laser

Plasma-Based Free-Electron Lasers

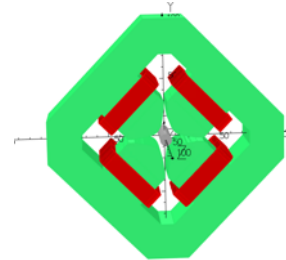
Superconductor-based beam optical elements



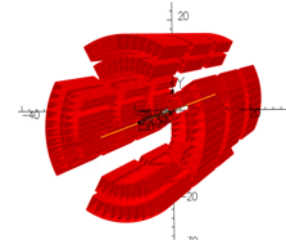
V. Afonso Rodriguez, PhD thesis KIT (2015)

Nb-Ti SC transverse-gradient undulator

- 40 periods, $\lambda_u=10.5$ mm, $K=1.1$
- Operating temperature reached
- Both TGU coils reached SC state
- Investigating temperature behavior during cool-down, powering and quenches
- Preparatory work: BMBF Verbundforschung



Samira Fatehi (KIT)



Samira Fatehi (KIT)

HTS quadropoles

- Design high-field and combined function magnets for compact LPA beam transport
- Few-mm bore radius and up to 600 T/m gradients
- Preparatory work: BMBF Verbundforschung

Plasma-Based Free-Electron Lasers

Towards Applications

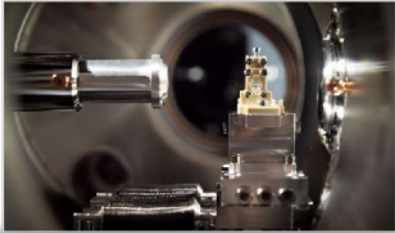


Image: Niels Delbos (UHH)

Upgrade of the LUX plasma accelerator

- Goal: demonstrate gain using the decompression scheme proposed in *Phys. Rev. X 2, 031019 (2012)*
- Beamline upgrade ongoing
- Preparatory work: BMBF Verbundforschung



Image: Max Trunk (UHH)

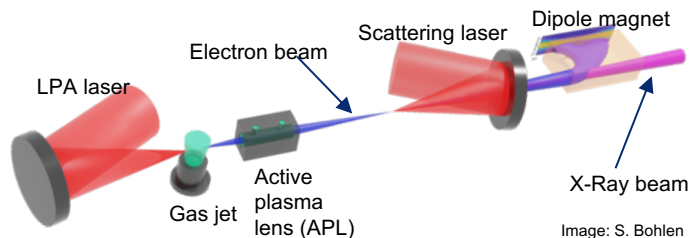
CAD model

Development of Cryogenic Undulator

- 130 periods, $\lambda_u=15$ mm, $K=3$
- Tailored design for demoFEL Experiment
- Jointly developed by Hamburg University, HZB and DESY (initially incl. LMU)
- In final stage of commissioning (field tuning)

ARD Plenary Talks

All-optical x-ray source for XFEL
 This morning, K. Poder, 11.45



- Demonstrated bandwidth narrowing and tunability using an active plasma lens
- Mouse phantom imaging in 2021
- Custom-design x-ray detectors (KIT) to be tested in 2021



Innovationpool Project PLASMED-X (2019-2020)

Highlights From FLASHForward
 Tomorrow, J. Osterhoff, 16.00

