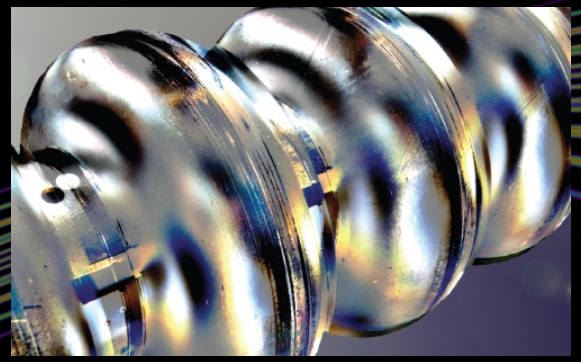
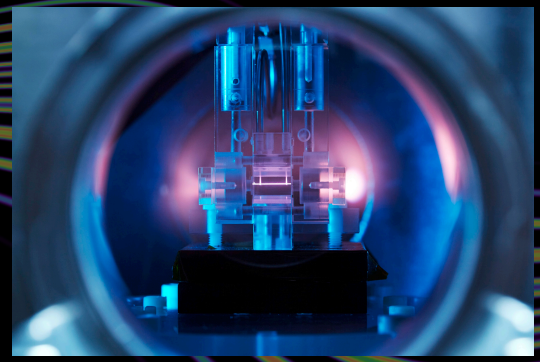
Laser-Plasma Acceleration

Results and Plans


Helmholtz Program: Matter & Technology (MT)

PoF III Topic: Accelerator Research & Development (ARD)

DESY Research Unit: ARD/ST4

Andreas R. Maier

Center Evaluation DESY, 5 – 9 February 2018

HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

MT
MATTER AND TECHNOLOGIES

DESY

Laser- and Beam-Driven Plasma Acceleration

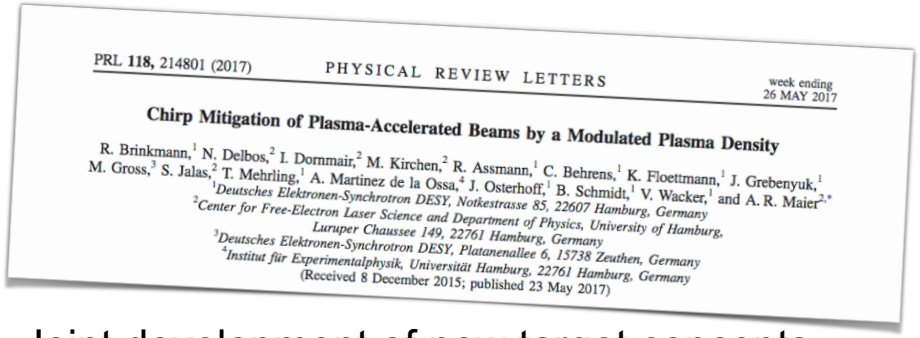
A Closely Coordinated Approach

A complementary approach

- We study laser- and beam-driven plasma acceleration on campus
- Two technologies with complementary strengths:
  - Rep-rate and average power
  - Timing- and synchronization capabilities
  - Footprint and costs

Benefits

- Both technologies share challenges that we address in a close and campus-wide collaborative effort
  - Plasma lenses
  - Plasma diagnostics
  - PIC code development
  - Laser development



PRL 118, 214801 (2017) PHYSICAL REVIEW LETTERS week ending 26 MAY 2017

Chirp Mitigation of Plasma-Accelerated Beams by a Modulated Plasma Density

R. Brinkmann,[1] N. Delbos,[2] I. Dornmair,[2] M. Kirchen,[2] R. Assmann,[1] C. Behrens,[1] K. Floettmann,[1] J. Grebenyuk,[1] M. Gross,[3] S. Jalas,[2] T. Mehrling,[1] A. Martinez de la Ossa,[4] J. Osterhoff,[1] B. Schmidt,[1] V. Wacker,[1] and A. R. Maier[2,*]

[1]*Deutsches Elektronen-Synchrotron DESY, Notkestrasse 85, 22607 Hamburg, Germany*
[2]*Center for Free-Electron Laser Science and Department of Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany*
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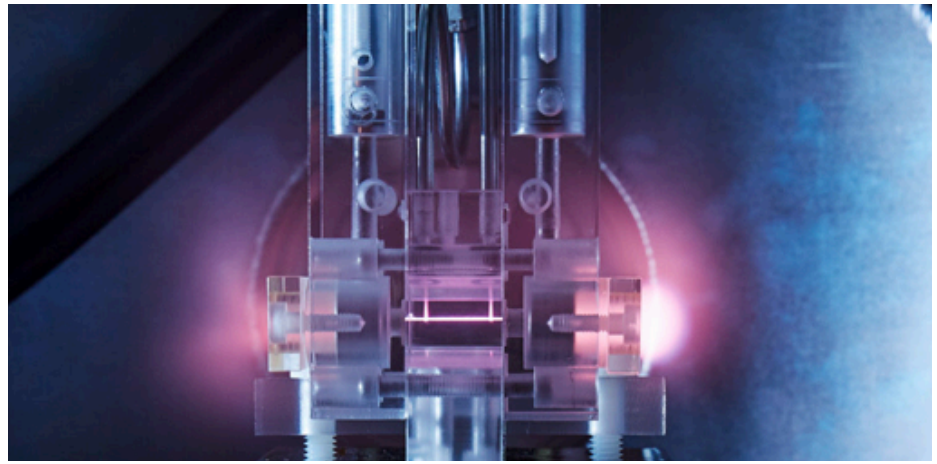
[4]*Institut für Experimentalphysik, Universität Hamburg, 22761 Hamburg, Germany*
(Received 8 December 2015; published 23 May 2017)

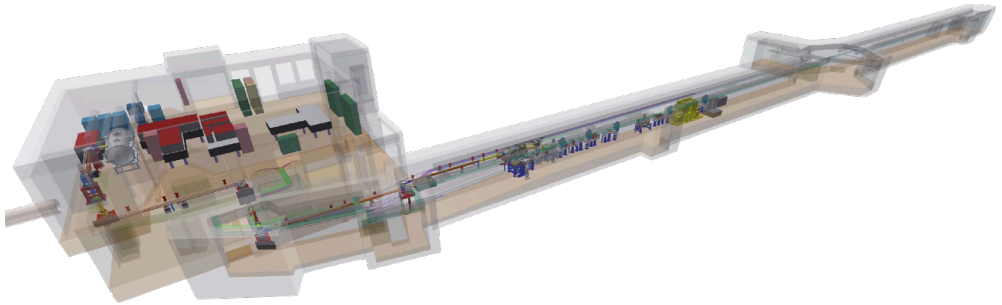
Joint development of new target concepts



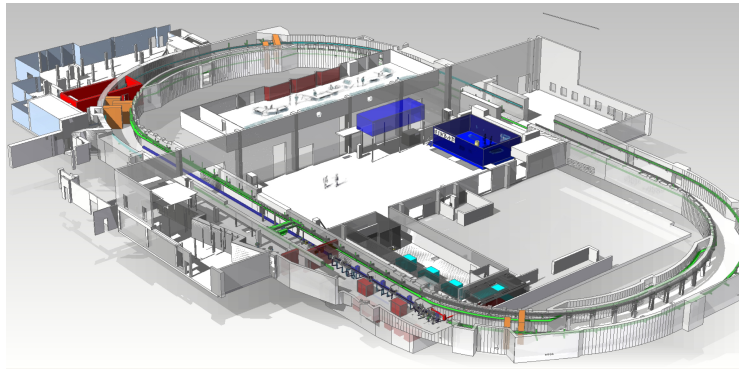
Joint beamtimes to develop plasma lens

Laser-Plasma Acceleration on Campus

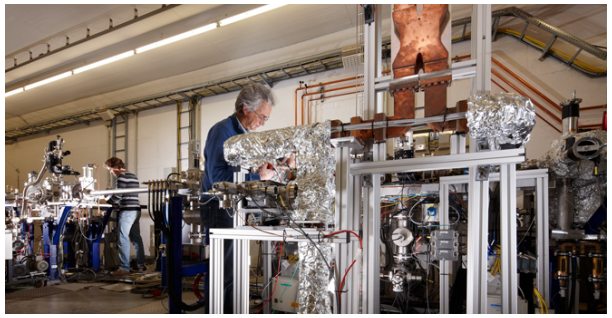
A Closely Coordinated Approach



LUX – Plasma-Driven Undulator



SINBAD – ARD Facility



REGAE – External Injection

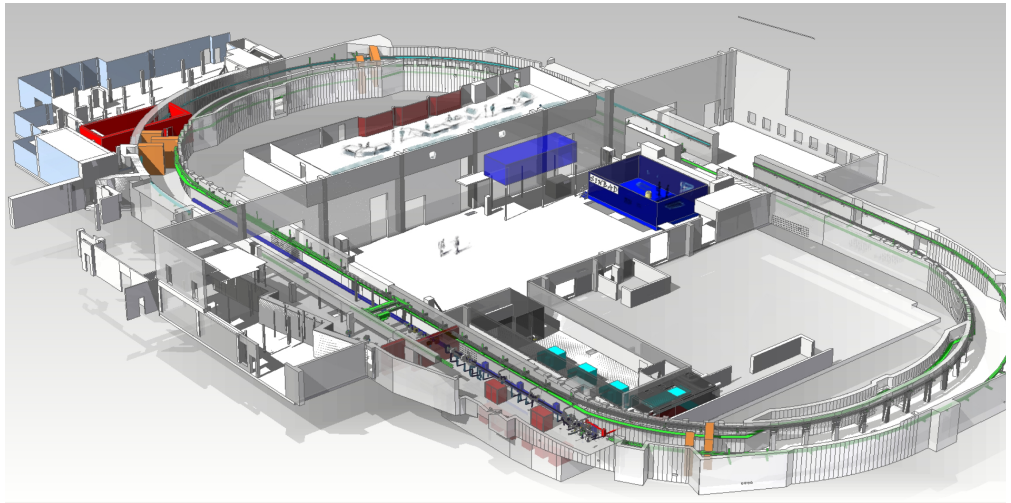
FLASHForward TestLab – Med. Imaging

SINBAD

Dedicated, Long-Term Accelerator R&D Facility

SINBAD - a dedicated, long-term accelerator R&D facility

- Will integrate laser-plasma activities on campus as part of ATHENA
- Collaborative effort of DESY, UHH and Helmholtz-Athena collaborators
- Currently entering commissioning stage
- Will host:
    - External injection using ARES linac into laser-driven wake
    - Optical injection beamline LUX
    - Pilot FEL experiment
    - Medical imaging pilot studies



See talks by B. Marchetti and U. Dorda

REGAE – External Injection

Technology Development and Pilot Studies for SINBAD

REGAE is a 5 MeV electron gun for ultra-fast electron diffraction and provides unique capablities to test external injection into a laser-plasma driven wake using the 200 TW laser available on campus.

Two motivations for external injection:

- Improved beam quality using conventional injectors
- Necessary to control staged acceleration schemes

Develop core technologies

- Synchronization of laser and RF oscillators
- Create sub-fs bunches for injection: linearization scheme
- Adiabatic matching


PHYSICAL REVIEW SPECIAL TOPICS—ACCELERATORS AND BEAMS 18, 120102 (2015)

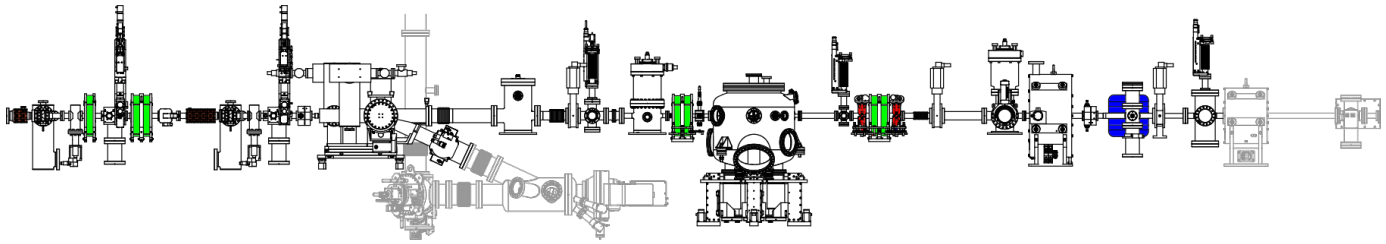
Linearization of the longitudinal phase space without higher harmonic field

Benno Zeitler,[1,*] Klaus Floettmann,[2] and Florian Grüner[1]

[1]Center for Free-Electron Laser Science and Department of Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany
[2]Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22603 Hamburg, Germany
(Received 20 July 2015; published 30 December 2015)

Current status

- Beamline upgrade complete
- First beam expected for spring 2018

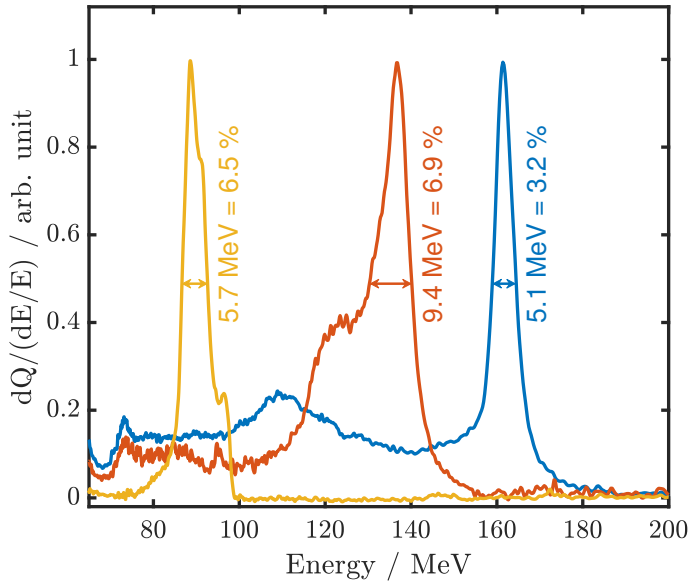


FLASHForward▸▸ Laser-Wakefield Laboratory

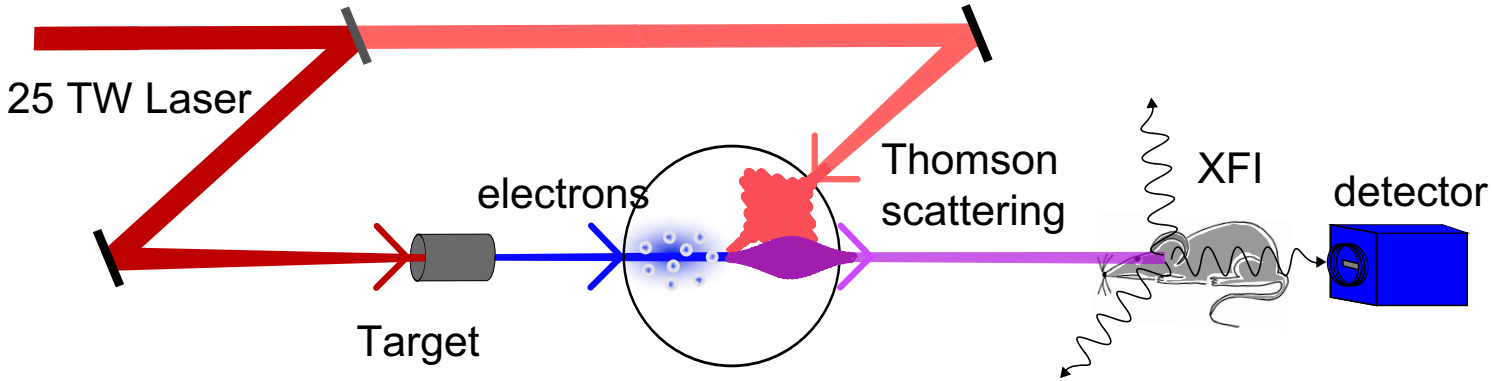
Beam Diagnostics Development & Medical Imaging Prototyping

Plasma accelerator:
- 25 TW Ti:sapphire laser
- ionization injection with tunable electron energies:
  1 mrad divergence, 5 mrad pointing, 50 pC ± 10%

e⁻-beam diagnostics R&D:
- fC to nC charge benchmarking (DaMon cavity, ICT)
- transition radiation spectroscopy with CdHgTe detector (in 2018)



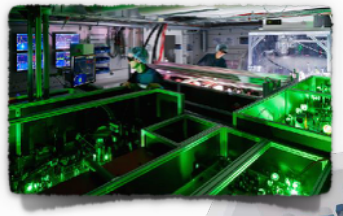
LWFA-based medical scanning X-ray fluorescence imaging (XFI)
- imaging of gold-nanoclusters bound to anti-bodies
- supported by DESY Strategy Fund



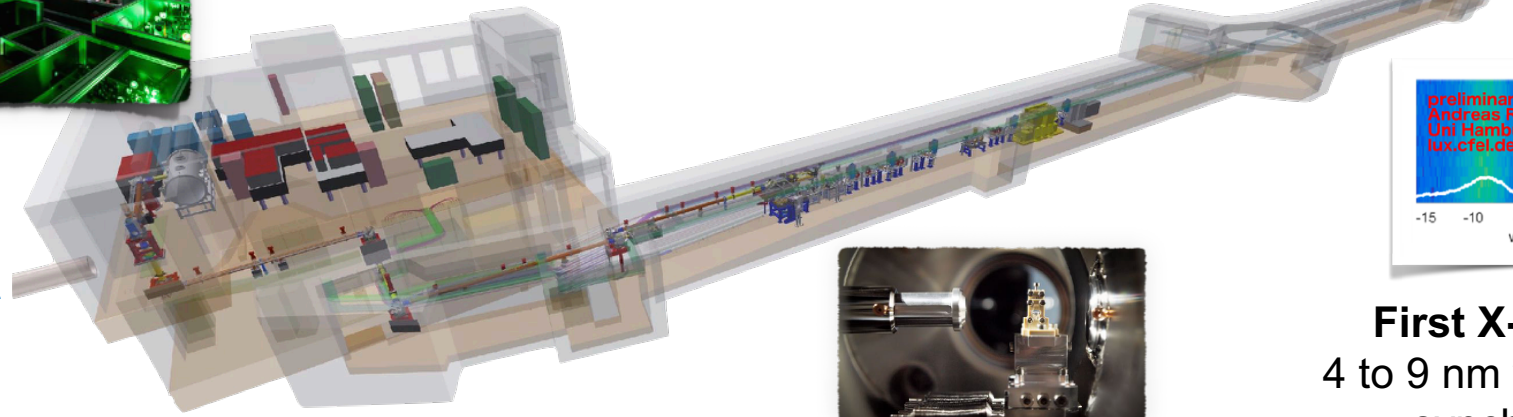
LUX – Plasma-Driven Undulator Beamline

Dedicated Plasma-Accelerator Beamline for Undulator Radiation

ANGUS
200 TW laser

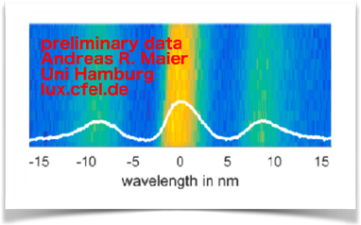


LUX Beamline
60 m accelerator tunnel



laser transport
to REAGE ext. inj.

plasma target
@ 1- 5 Hz, 300 – 800 MeV



First X-Rays 2017
4 to 9 nm wavelength
synchrotron type

- Merge plasma and accelerator technology
- LUX is a 15 m long beamline with BPMs, quads, kickers, profile monitors, …
- Master beam optics and diagnostics

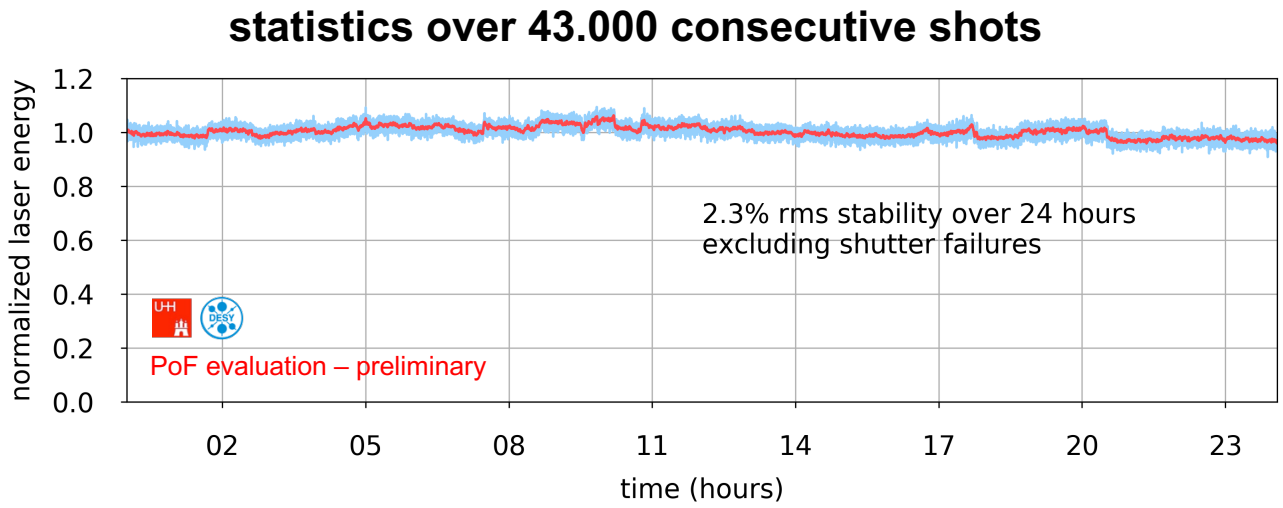
- Focus on stability and reproducibility
- Fully integrated into controls system
- High rep-rate and high statistics
- Immediate step before FEL

LUX – Highlight Results

Recent Results From Late 2017 Campaign

Laser stability

- 2% rms over 24 hours (energy of final amplifier)



LUX – Highlight Results

Recent Results From Late 2017 Campaign

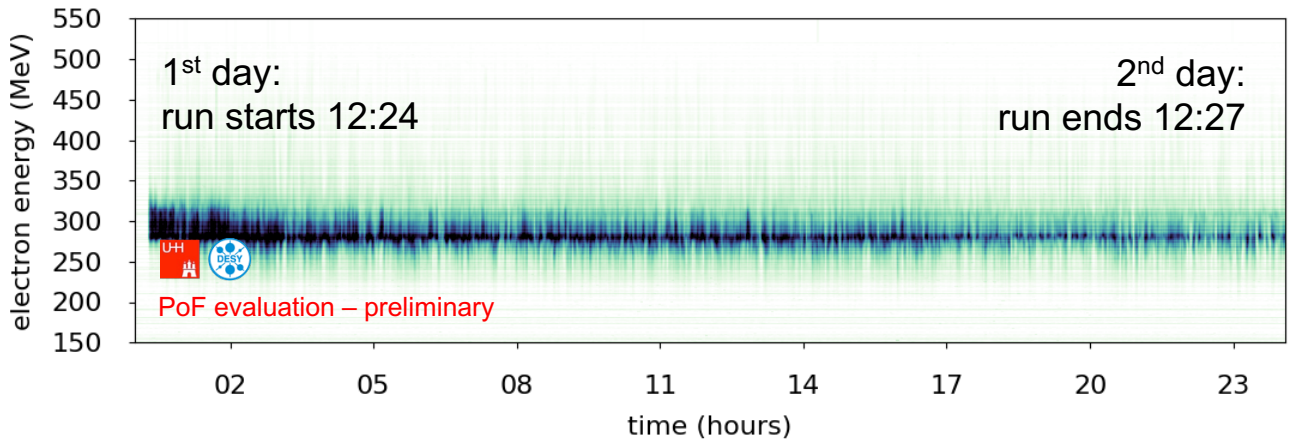
Laser stability

- 2% rms over 24 hours (energy of final amplifier)

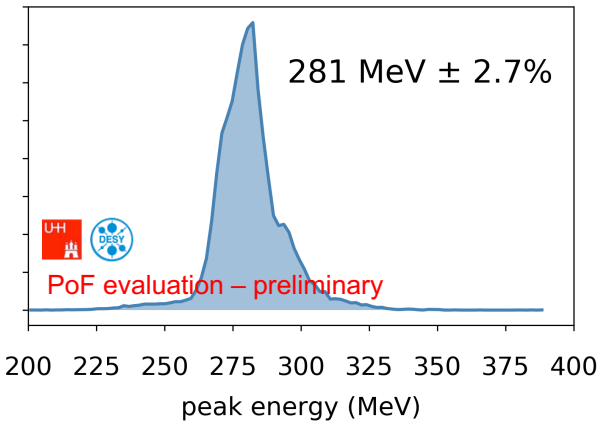
First 24 hr run

- 24 hours run of a plasma accelerator
- 43.000 consecutive shots
- 98% beam

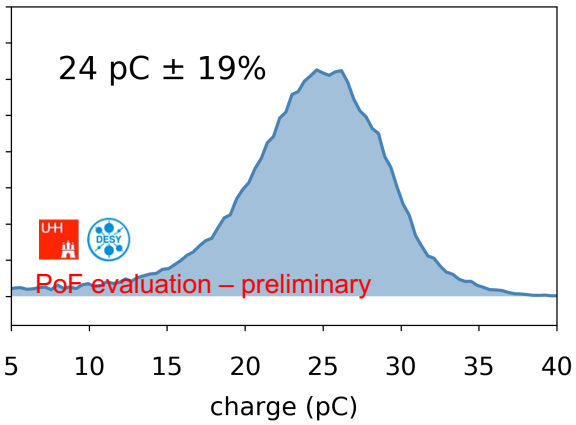
statistics over 43.000 consecutive shots



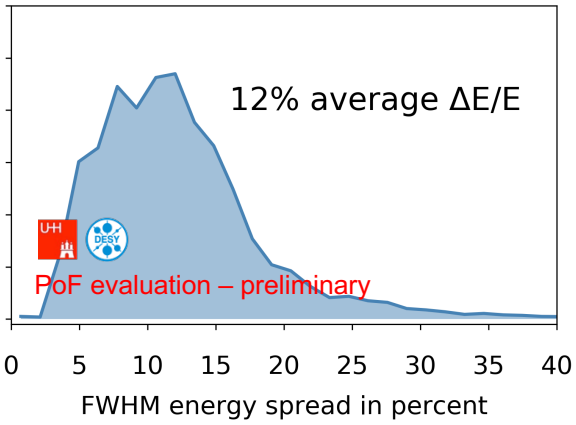
energy stability



charge stability



energy spread stability



LUX – Highlight Results

Recent Results From Late 2017 Campaign

Laser stability

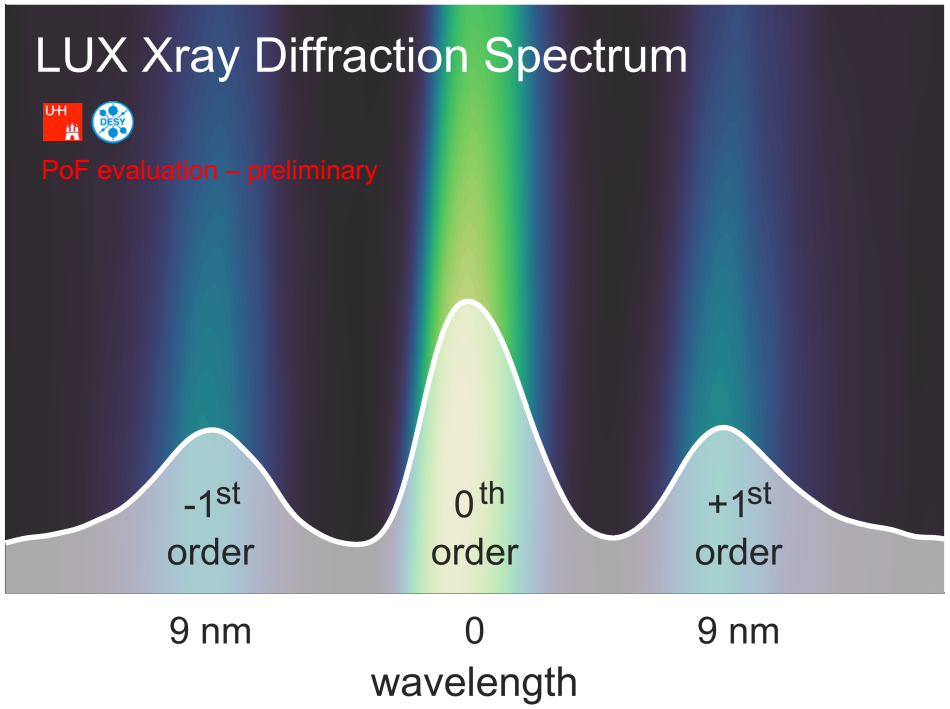
- 2% rms over 24 hours (energy of final amplifier)

First 24 hr run

- 24 hours run of a plasma accelerator
- 43.000 consecutive shots
- 98% beam

First undulator radiation

- Miniature undulator
- Synchrotron type
- Demonstrated 4 – 9 nm



Conclusion

- We fulfilled all major milestones of the PoF3 proposal
- Mission: ”from acceleration to accelerators”

- Close collaboration of national lab and university
- Approach: Merge laser-plasma with state-of-the-art accelerator technology
- Our facilities are just getting online with first highlight results demonstrated
- We want to catch up with international leading labs (Berkeley, …)