Double bunch generation for a beam-driven plasma wakefield accelerator at FLASHForward

S. Schröder[1,2], A. Aschikhin[1], R. D´Arcy[1], V. Libov[1,2], K. Ludwig[1], B. Schmidt[1], S. Wesch[1], and J. Osterhoff[1]

[1] *Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany*
[2] *University of Hamburg, Germany*

Beam-driven plasma acceleration at FLASHForward

Plasma-based acceleration is a promising development towards **smaller and cheaper accelerator facilities**.

FF▸▸

FLASHForward (Future oriented wakefield acceleration research and development at FLASH) is a project dedicated to beam-driven plasma acceleration and is situated beside the FLASHII beamline at DESY. Primary objectives are:

- **preservation of beam quality** after plasma based acceleration of ultra-relativistic electrons,
- creation of **high-brightness** electron beams and
- demonstration of **FEL gain** based on plasma acceleration.

Acceleration mechanism (X-2)

Plasma wakefield acceleration (PWFA) via external injection:

1. **Plasma** creation (H_2): electric discharge or laser ionisation
2. Short (100 fs) incoming **electron bunch drives an oscillation** of the plasma electrons

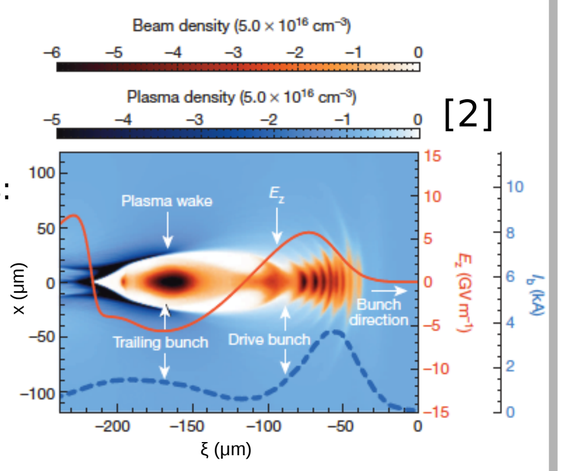
   → Oscillation frequency:

   $$\omega_p = \sqrt{\frac{n_e e^2}{\epsilon_0 m_e}}$$

   → High electric wakefields:

   ~ 100 GV/m [1]

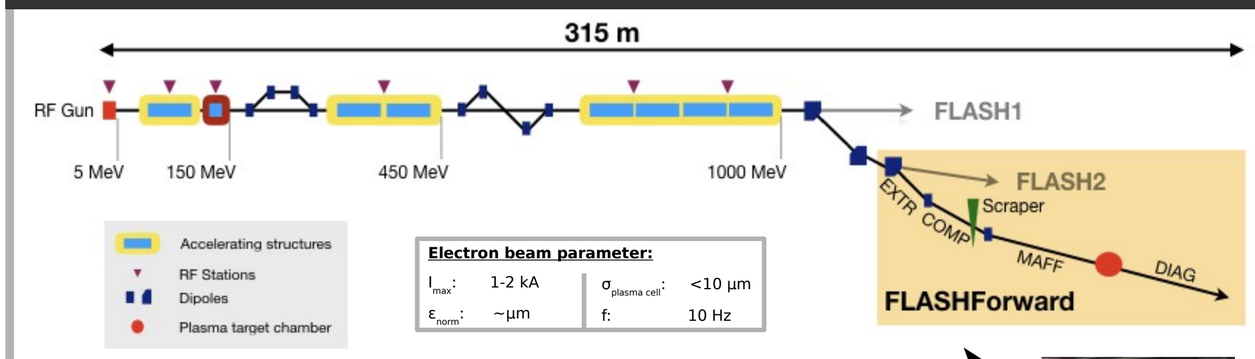
3. Trailing 'witness' bunch **injected** into the **accelerating** wakefield



[2]

Characteristics of the driving and trailing bunches ($\varepsilon, \beta, \alpha, I_{max}$, Q, …) have an crucial impact on the quality of the plasma-accelerated electron bunch.

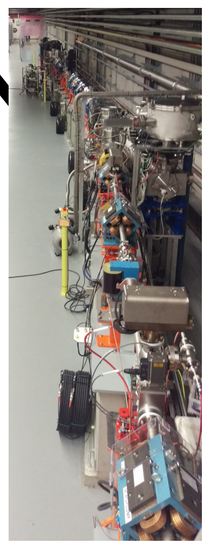
FLASHForward beamline



- Additional beamline to the FLASH X-ray FEL
- Longitudinal bunch profile adjustable by two magnetic chicanes in FLASH beamline
- Separation of single FLASH bunch into two consecutive bunches by a scraping mask
- Final focusing into plasma cell in a quadrupole section

Available electron beam diagnostics:

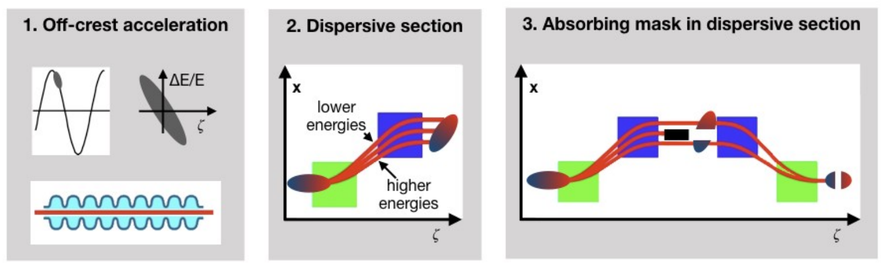
- Beam position monitors
- Screens
- Spectrometer
- Transverse deflecting structure (in 2019)



Production of driver-witness bunches

- **Off-crest** acceleration imposes an energy chirp upon the electron bunch
- **Dispersive section**: long. particle positions correspond to a transvers offset
- **Metallic masks** decelerate parts of the bunch, which then get lost downstream
- After dispersion closure, **two longitudinal seperated bunches** are created

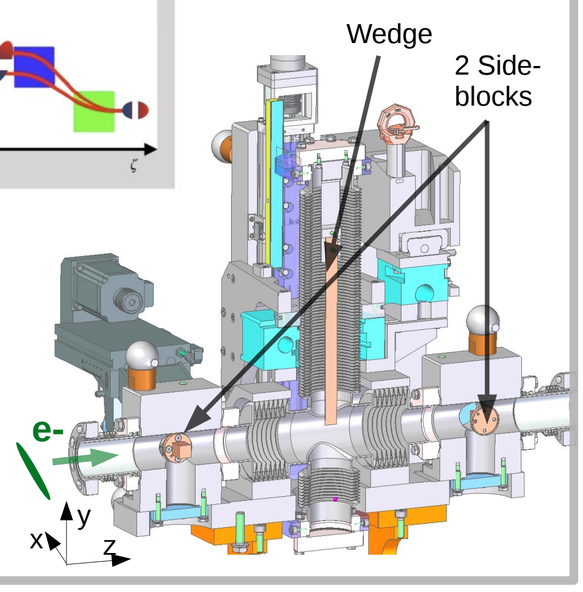
→ Geometry and position of the scraping mask determines the bunch separation



Scraper aperature:

1 wedge 150x15x(0.1-3) mm³
DOF: x-/y-translation; y-/z-rotation
2 blocks 5x10x15 mm³
DOF: x-translation

Material: W-Co alloy for sufficient absorption, less heat production and easy manufacturing

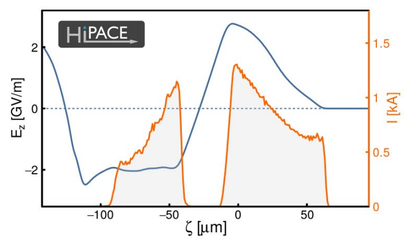


Simulations

ASTRA: Space charge algorithm - tracking at low energies
ELEGANT: Tracking electrons through the beamline
GEANT4: Energy absorption at position of scraping mask
HiPACE: PIC code for beam development in plasma [3] [4]

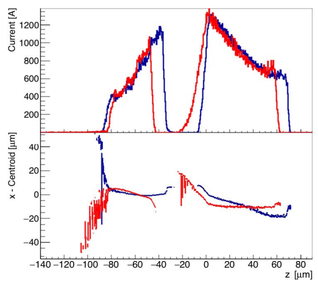
Longitudinal bunch profile optimisation:

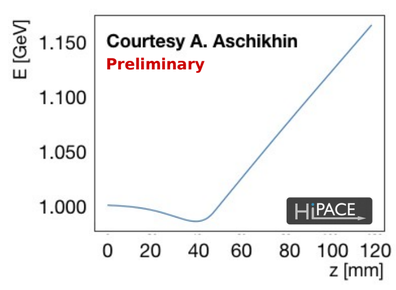
- Triangular shape beneficial for **max. energy transfer** [5] [6]
- Bunch shapes optimized for **beam loading**,
  → Preserving small energy spread of acc. bunch



Transversal bunch profile optimisation:

- **Match** trailing bunch into plasma wakefield
- Position **beam waist** where coherent synchrotron radiation effects (CSR) are the strongest in the LINAC
- Use **phase advance** to let CSR counteract





Summary

- FLASHForward is dedicated for investigations on beam-driven plasma acceleration
- External injection promises fine-tuning of beam parameters and beam quality
- Scraping beamline component was constructed and will be implemented in 2018
- Simulations validated the work of principle

MATTER AND TECHNOLOGIES
ACCELERATOR RESEARCH AND DEVELOPMENT

HELMHOLTZ ASSOCIATION

Sarah Schröder
DESY FLA group
sarah.schroeder@desy.de

References

[1] T. Tajima and J. M. Dawson, Phys. Rev. Letter Vol. 43 No. 4, 1979
[2] M. Litos et al, Nature Vol. 515, 2014
[3] T. Mehrling et al., Plasma Phys. Control. Fusion 56 084012 (2014)
[4] PIC simulations performed by A. Aschikhin
[5] T. Katsouleas, Phys. Rev. A 33, 2056, 1986
[6] M.Tzoufras et al. Pysics of plasma 16, 056705 (2009)