Hybrid LWFA-PWFA staging (LPWFA) as a beam energy and brightness transformer

Arie Irman

Helmholtz-Zentrum Dresden – Rossendorf

Sebastien Corde[1], Andreas Döpp[2], Bernhard Hidding[3], Stefan Karsch[2], Alberto Martinez de la Ossa[5], Ulrich Schramm[6] - *for hybrid LWFA-PWFA collaboration*

[1] *LOA, ENSTA Paris, CNRS, Ecole Polytechnique, Institute Polytechnique de Paris, 91762 Palaiseau, France*

[2] *Ludwid-Maximilians-Universität München, Am Coulombwall 1, 85748 Garching, Germany*

[3] *The Cockcroft Institute, Keckwick Lane, Daresbury, Cheshire WA4 4AD, United Kingdom*

[4] *University of Strathclyde, 107 Rottenrow, Glasgow G4 0NG, United Kingdom*

[5] *Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany*

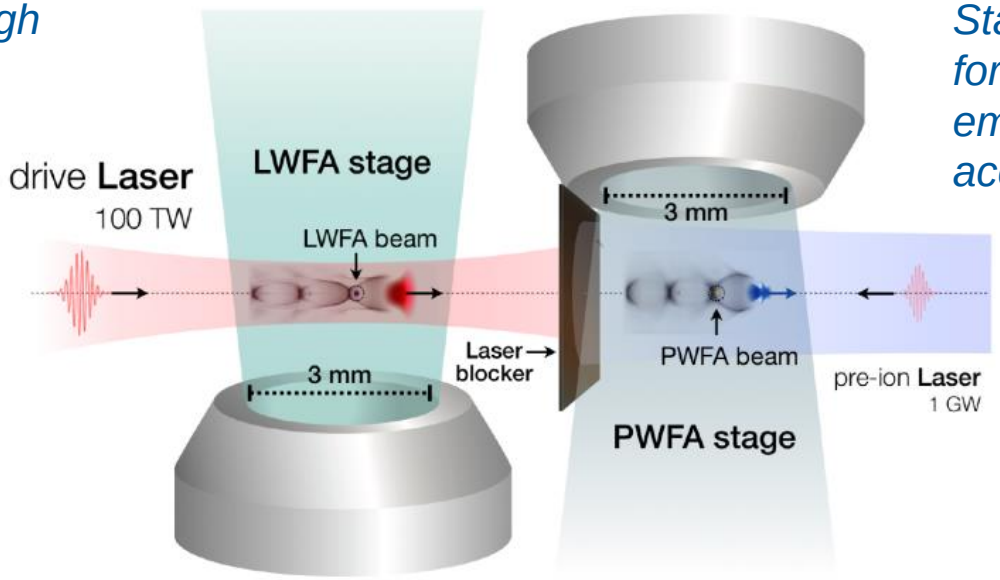
[6] *Helmholtz-Zentrum Dresden – Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany*

SnowMass2021- **AF6** Oral Session 24 September 2010

Concept LPWFA

Laser-driven plasma wakefield acceleration **(LWFA) :**
GeV-class energy, high charge, ultrashort duration, micron-size

Beam-driven plasma wakefield acceleration **(PWFA) :**
Stable wakefield structure for dephasing-free and emittance-preserving acceleration



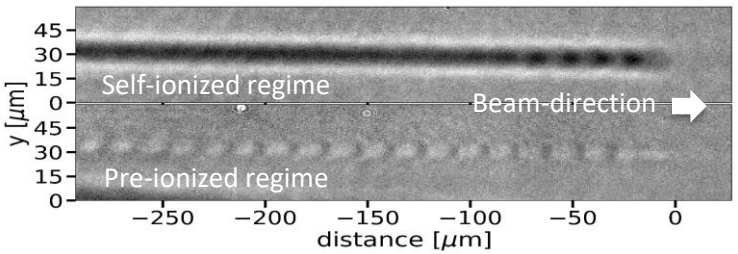
LPWFA : Utilizing high peak-current electron beam from **LWFA** to drive **PWFA**

- High peak-current LWFA drive beam → **PWFA** in **the blowout regime**
- Ultrashort LWFA drive bunch → **PWFA** in **high plasma density regime** (> 10^{18} cm^{-3})
- Sizeable emittance and energy spread → **suppress the driver hosing instability**
- **Inherent** laser-to-beam **synchronization**

Arie Irman • a.irman@hzdr.de
Institute of Radiation Physics

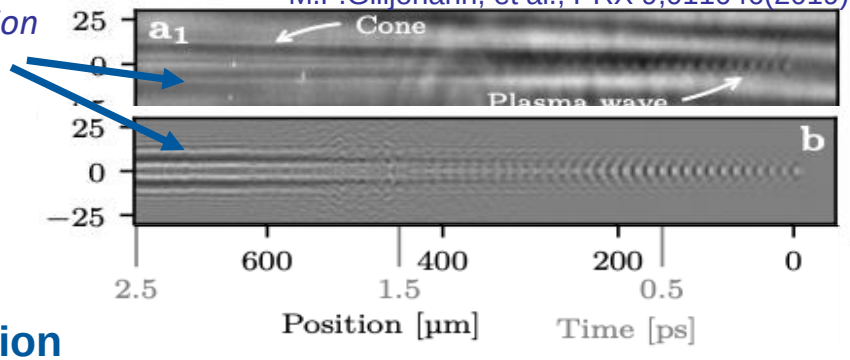
Experimental implementation

Observation of beam-driven plasma wakefields and the associated ion motion



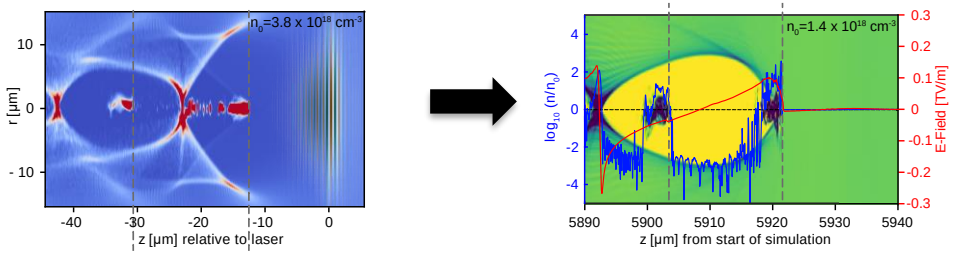
M.F.Gilljohann, et al., PRX 9,011046(2019)

Ion motion



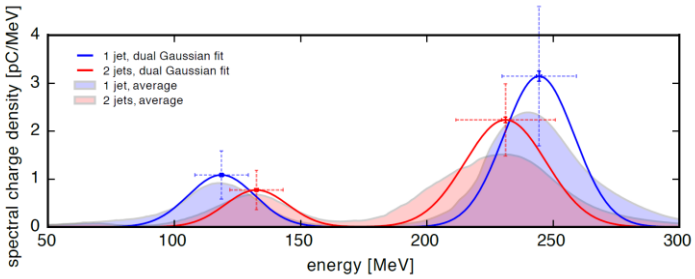
First demonstration of witness bunch acceleration

- Controlled drive-witness bunch pair scenario



LWFA: Optimized shock-front injection

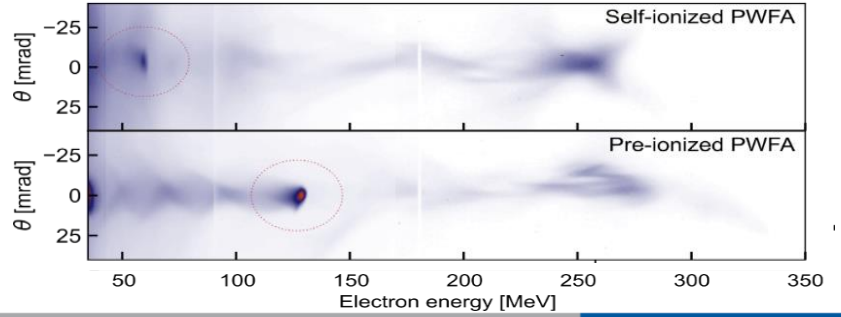
PWFA: Operated at lower density



~70% charge capture efficiency, 20 GV/m acc. gradient

T. Kurz, T. Heinemann, et al. arXiv:1909.06676(2019)

- Witness energy boost @ pre-ionized PWFA

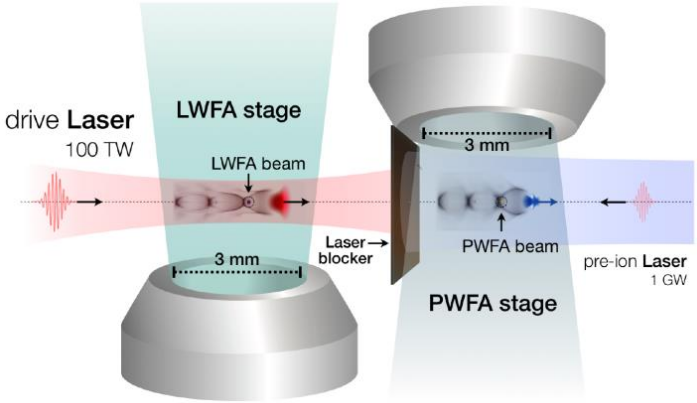


~3.1% total driver-to-witness energy transfer efficiency @ pre-ionized condition

> 50 GV/m acc. gradient

T. Kurz, T. Heinemann, et al. arXiv:1909.06676(2019)

Summary



LPWFA → Exploiting individual advantages of both plasma acceleration schemes in **a truly compact setup** for :

- **Complementary PWFA development platform**
  - *Study driver-witness transfer efficiency*
  - *Explore emittance preservation for extended acceleration distance closer to the driver depletion length*
  - *Explore staging concepts for high-energy physics application*
  - *New insight into plasma wakefields and ion dynamics*

- **Compact sources of high brightness ultralow emittance electron beams**
  - *Implementation of novel cold-injection scheme based on selective ionization or plasma density downramp*
  - *Inherent laser-to-beam for improved injection control*