

Hybrid LWFA-PWFA: A stability and beam quality booster for laser-generated electron beams

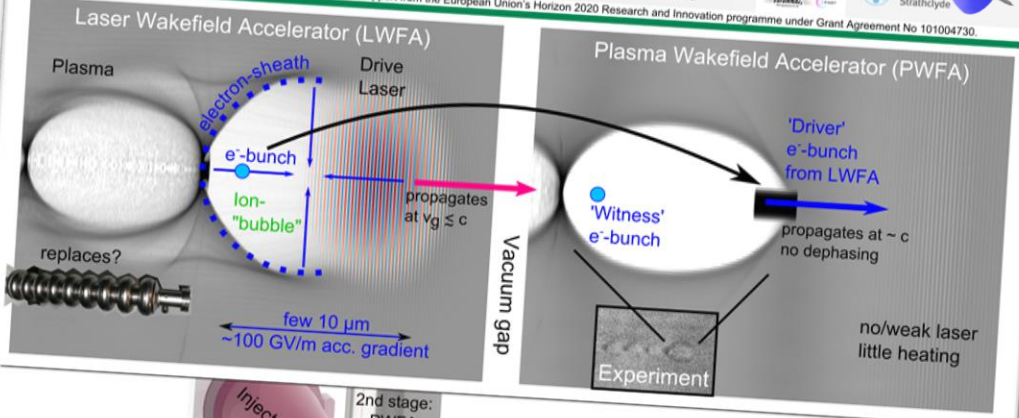
Moritz Foerster¹

Supervisor: Stefan Karsch^{1,2}

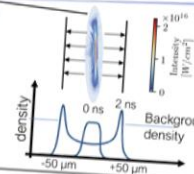
Co-Authors: A. Dügg, F. Haberstroh, K. v. Grafenstein, D. Campbell, Y.-Y. Chang, S. Cordis, J. P. Couperus Cabada, A. Debus, M. F. Gilljohann, A. F. Habib, T. Heinemann, B. Hidding, A. Irman, F. Irshad, A. Kneitsch, O. Kononenko, A. Martinez de la Ossa, A. Nuter, R. Pausch, G. Schlichter, A. Schieller, S. Schöbel, U. Schramm, E. Travac, P. Ufer



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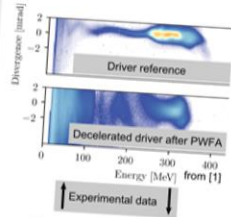


Laser pulses from ATLAS3000 here: 5 J on target, 30 fs (FWHM) f/33 focusing, $a_0 = 2.5$



- Injector beam locally field ionizes and heats plasma
- A hydrodynamic double shock evolves
- Electrons are injected at density downramp

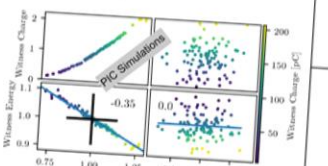
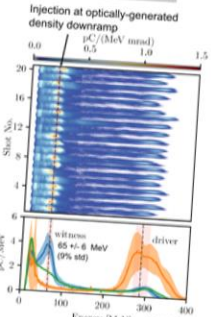
Stable witness generation



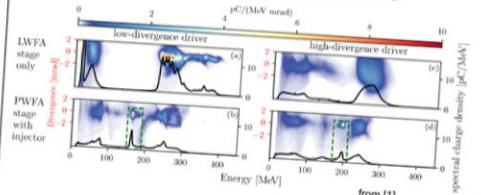
nC-class electron bunches generated in LWFA [2], serve as wakefield driver [3] in a subsequent PWFA stage.

Witness bunches injected in the PWFA stage gain energy from the wakefield [4,5].

Witness energy is insensitive to (relativistic) driver energy. Charge fluctuations of driver are damped.



High quality witness beams



- The witness bunch (optimal beam loading case):
- 3.5% FWHM energy spread (Driver: 18%)
- 0.28 mrad rms divergence (Driver: 0.41 mrad)
- More charge per energy interval and solid angle

Beams could be interesting for FEL-applications. Further characterisation of (slice) emittance and brightness to be done.

References

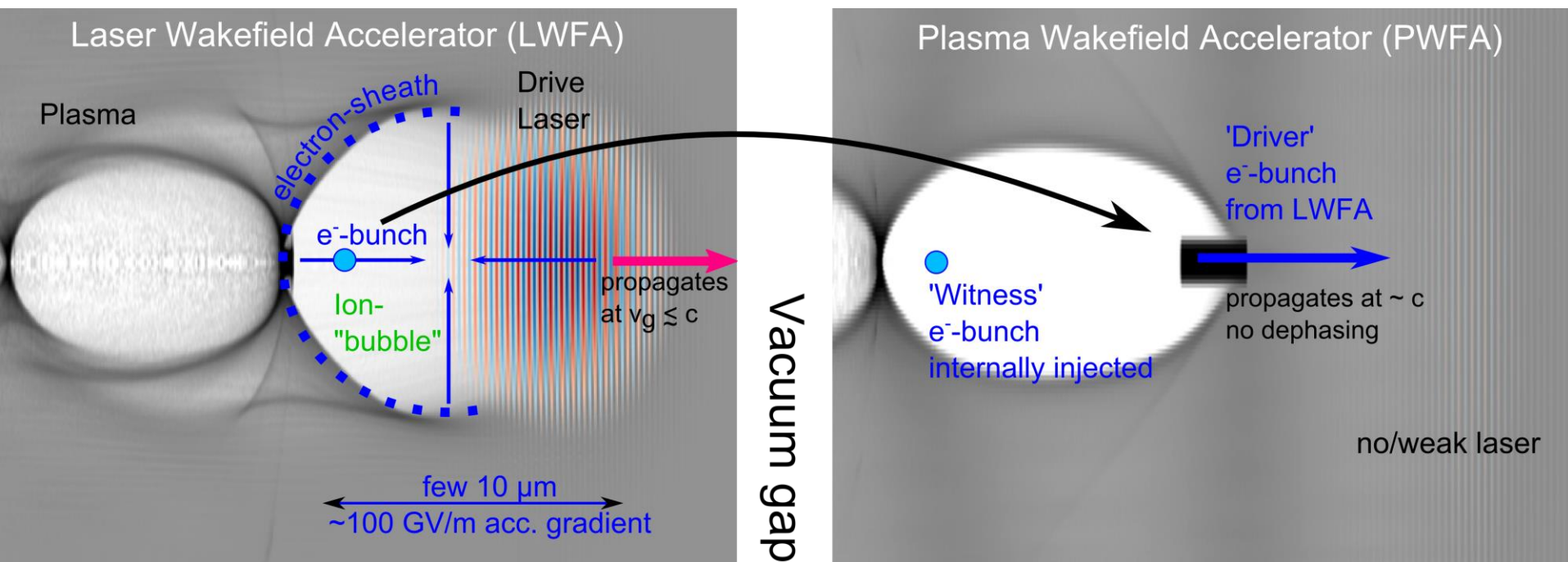
- [1] Foerster et al. under review (2022) and arXiv:2206.00507
- [2] Götzfried et al., Phys. Rev. X, 10, 041015 (2020)
- [3] Gilljohann et al., Phys. Rev. X, 9, 011046 (2019)
- [4] Kurz et al., Nat. Commun. 12, 2895 (2021)
- [5] Couperus Cabada et al., Nat. Commun. 12, 2895 (2021)

Special thanks to:



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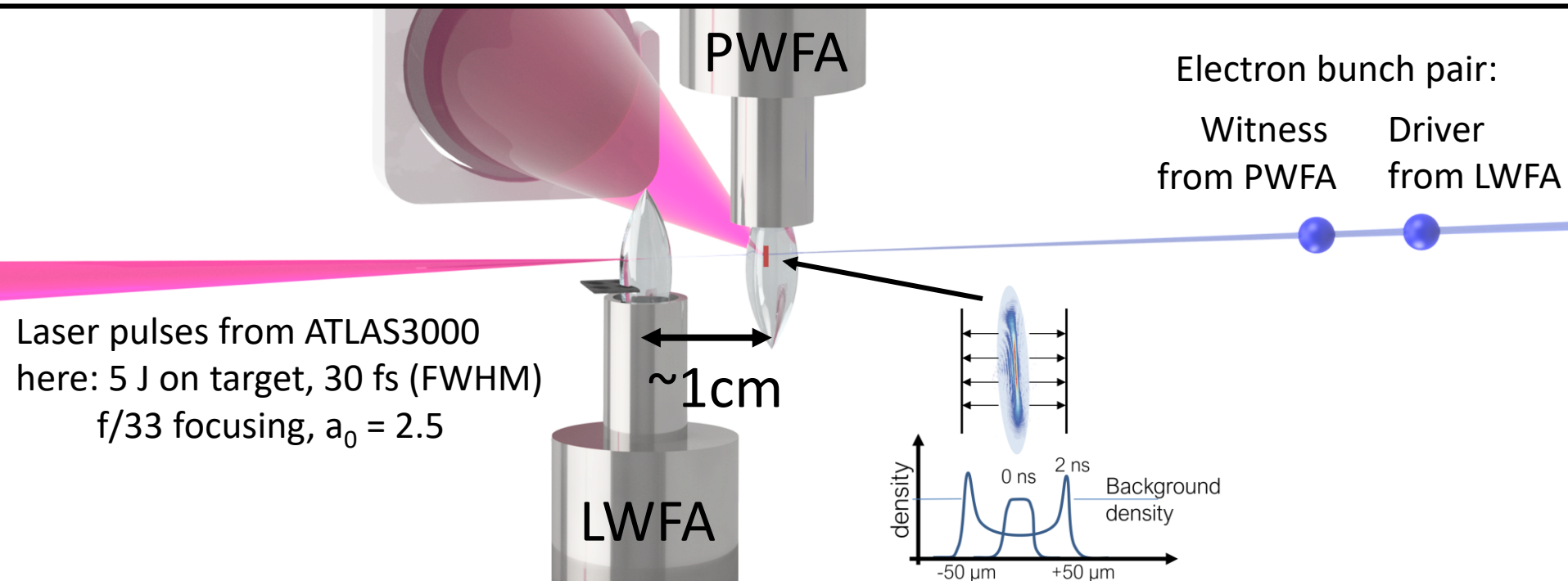
Combine the best of two worlds:



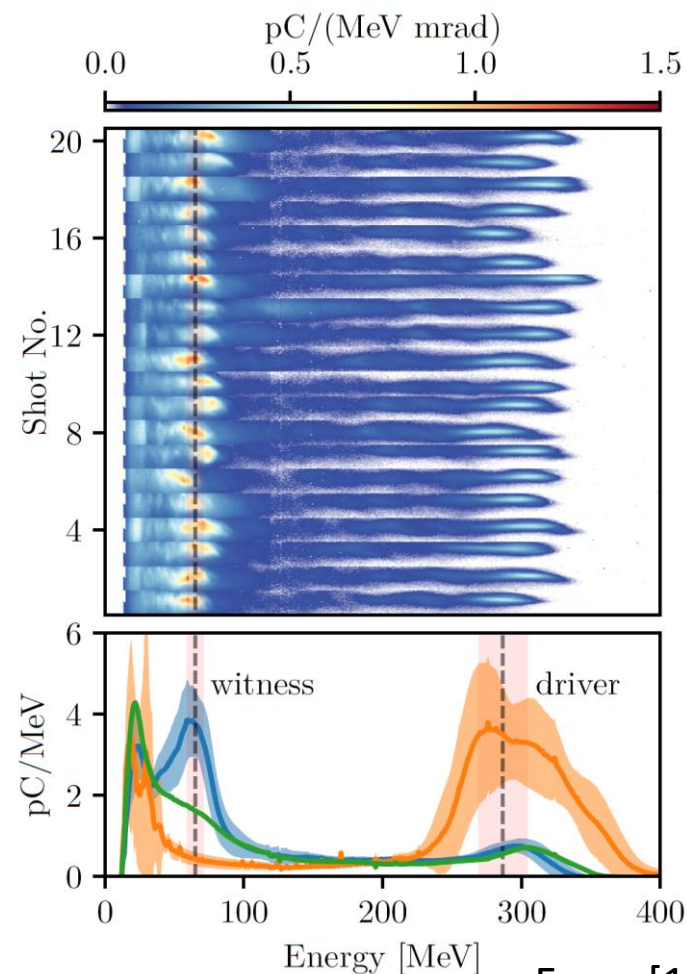
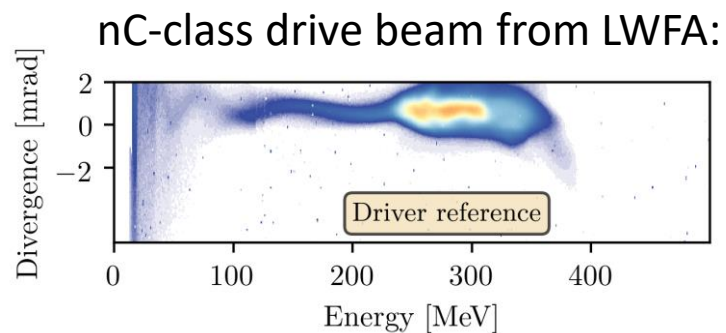
- Aims:**
- improve stability of electron energy
 - enhance quality of electron beam

Setup

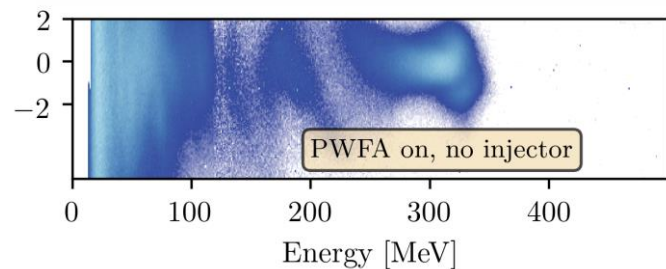
- Two supersonic gas jets
- A strong laser
- A robust injection scheme (in PWFA)



Stability of the PWFA witness



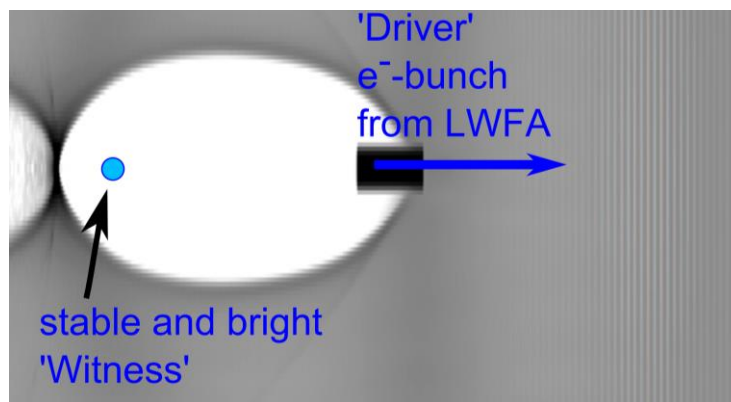
Deceleration of driver in 2nd stage:



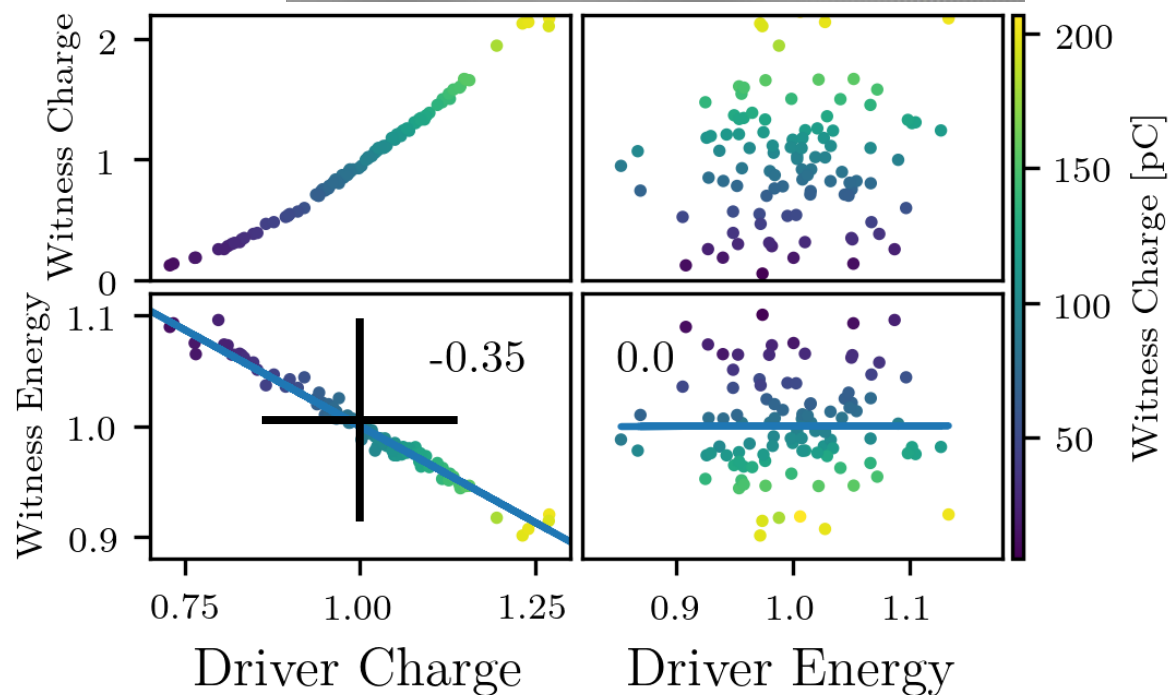
[1] Foerster et al. under review (2022) and arXiv:2206.00507

From [1]

Stability of the PWFA witness

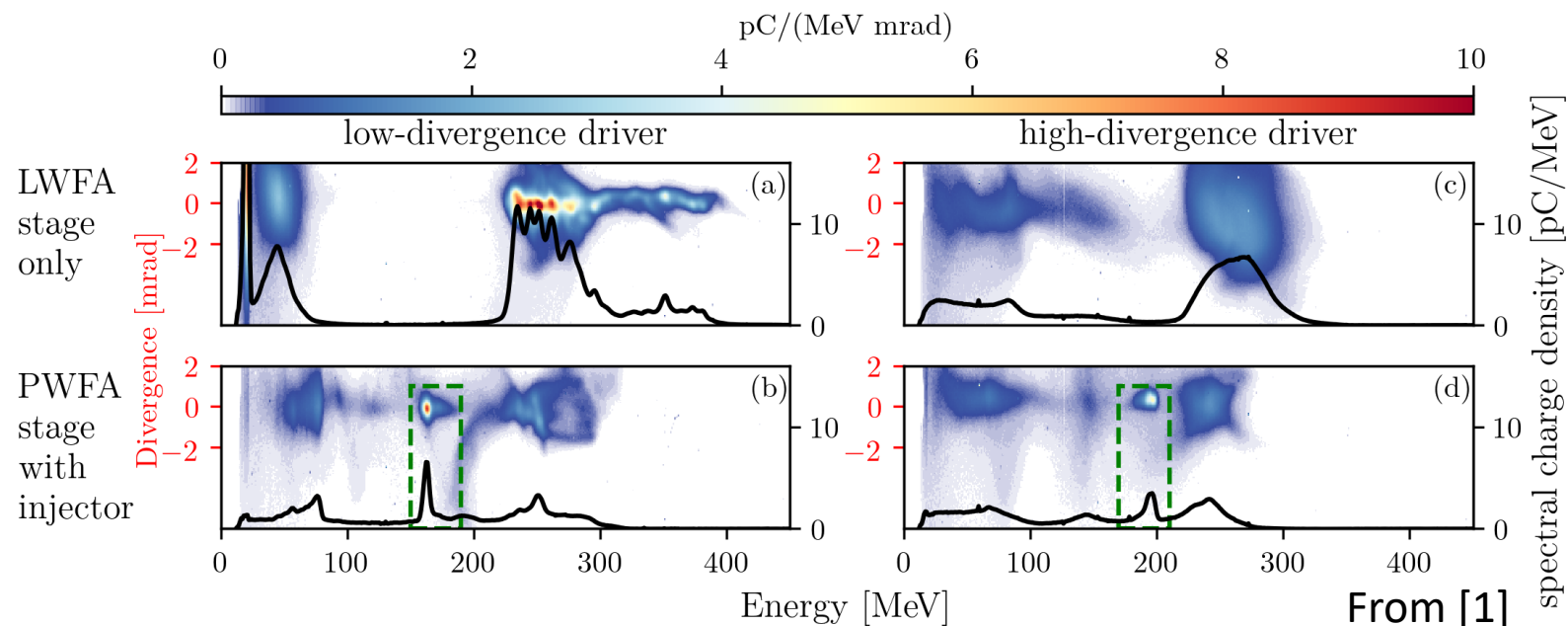


Some PIC simulations:



Beamloading
helps stabilizing
witness energy

Quality of witness beam from PWFA



Decrease:

FWHM energy spread from 18% (Driver) to 3.5% (Witness)

rms divergence from 0.41 mrad (Driver) to 0.28 mrad (Witness)

Thus, more charge per energy interval and solid angle

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Hybrid LWFA-PWFA:
A **stability** and **beam quality**
booster for laser-generated
electron beams

Moritz Foerster
(LMU Munich)



the Hybrid Collaboration

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Moritz Foerster for the Hybrid Collaboration

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Joined experiments of the Hybrid collaboration:
 Special thanks to:
 FEAT/FAIR, Strathclyde

Laser Wakefield Accelerator (LWFA)
 Plasma, Drive Laser, electron sheath, e⁻ bunch, ion- "bubble", propagates at $v_g \leq c$, few 10 μm , ~ 100 GV/m acc. gradient, replaces?, Vacuum gap

Plasma Wakefield Accelerator (PWFA)
 'Witness' e⁻ bunch, 'Driver' e⁻ bunch from LWFA, propagates at $\sim c$ no dephasing, Experiment, no/weak laser little heating

Electron bunch pair:
 Witness Driver from PWFA from LWFA

Laser pulses from ATLAS3000 here: 5 J on target, 30 fs (FWHM) f/33 focusing, $a_0 = 2.5$
 1st stage: LWFA, 2nd stage: PWFA, Injector Beam, -1cm

density, Background density, 0 ns, 2 ns, $\times 10^{18}$ [1/cm³]

- Injector beam locally field ionizes and heats plasma
- A hydrodynamic double shock evolves
- Electrons are injected at density downramp

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