Effect of driver charge on wakefield characteristics in a plasma accelerator probed by femtosecond shadowgraphy

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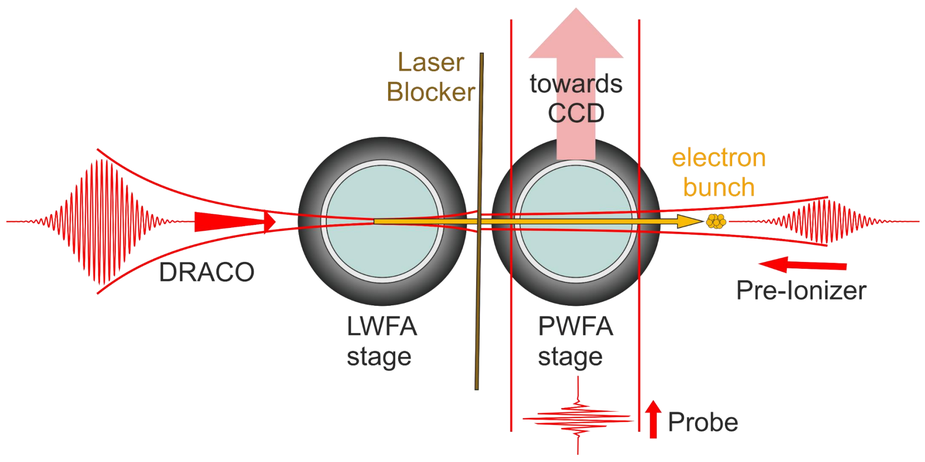
Motivation and Setup

- **PWFA**: promissing acceleration method for the generation and acceleration of **high quality electron beams**
- **LWFA beams** are intrinsically **short** and can reach high peak currents **(>10 kA)**
- **ultrafast** (~ 10 fs FWHM) **optical pulse** for plasma probing
- **inherently synchronized** to LWFA driver laser

Hybrid LWFA driven PWFA



Hybrid Collaboration partners

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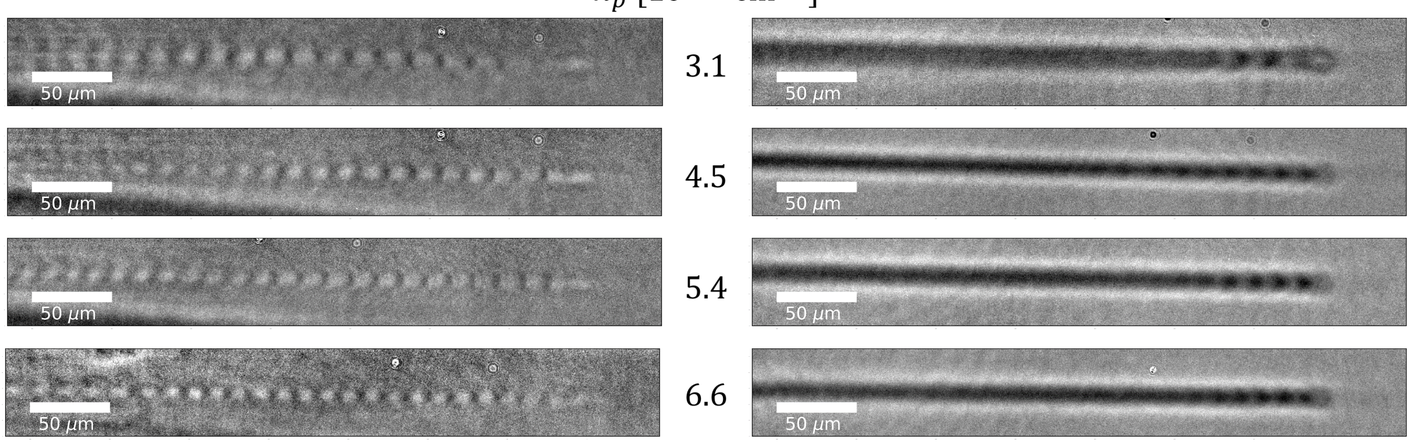
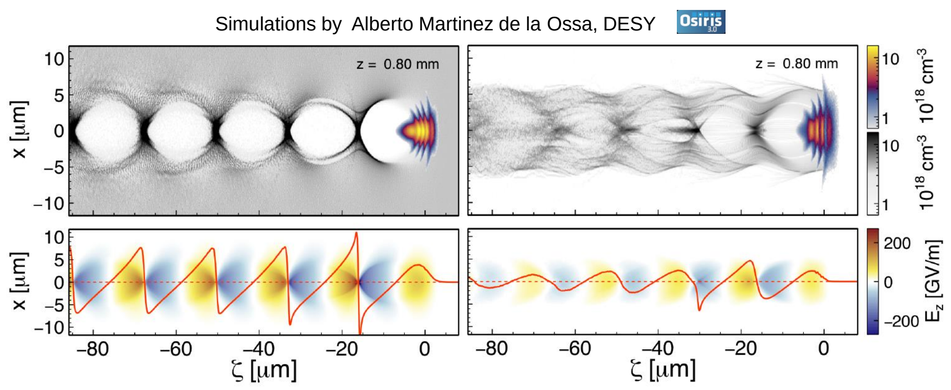
Phil. Trans. R. Soc. A **377**: 20180175 (2019)
New J. Phys. **24** 083034 (2022)

Observation of beam-driven plasma waves



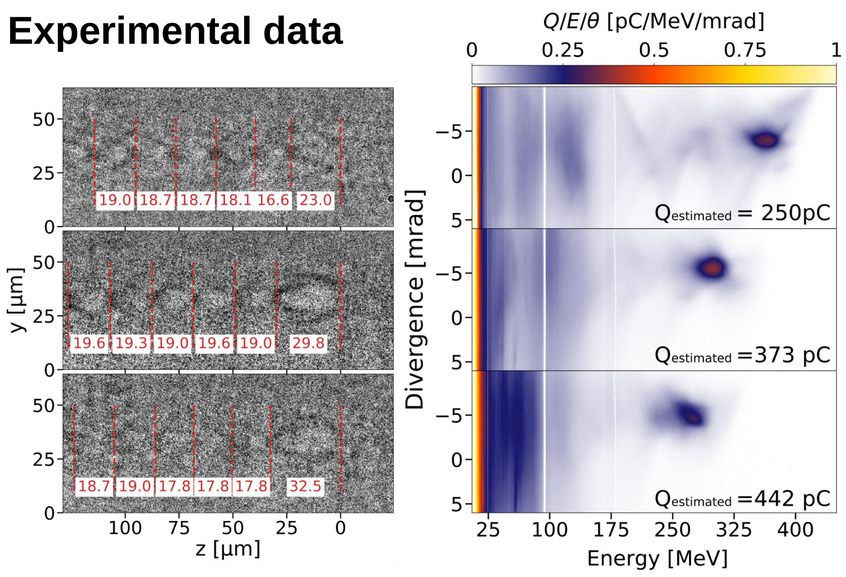
Simulations by Alberto Martinez de la Ossa, DESY



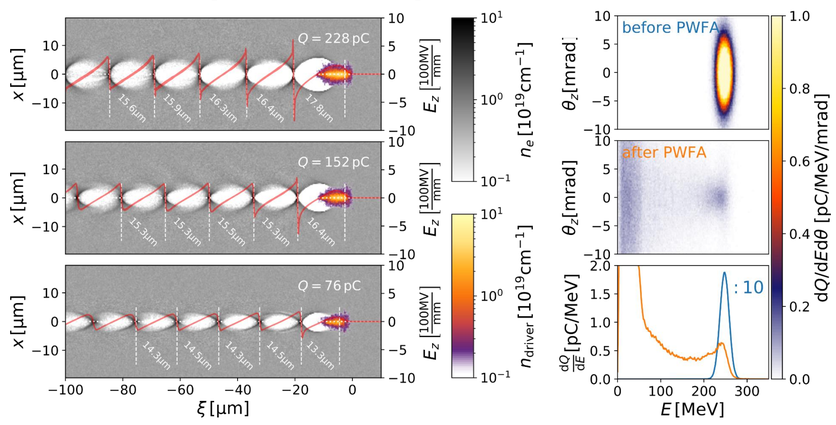
- **pre-ionized**: up to **25 cavities**, stable wakefield
- **self-ionized**: quick **smearing out** of the cavities, maximum **9** cavities visible
- **narrow plasma channel** in self-ionized case
- confirmed by simulations

Driver dependend wakefield formation

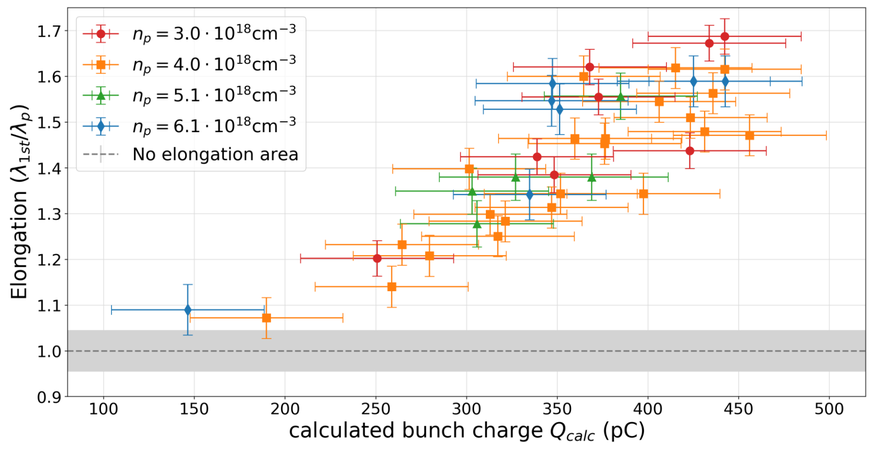
Experimental data



Simulation (PIConGPU)

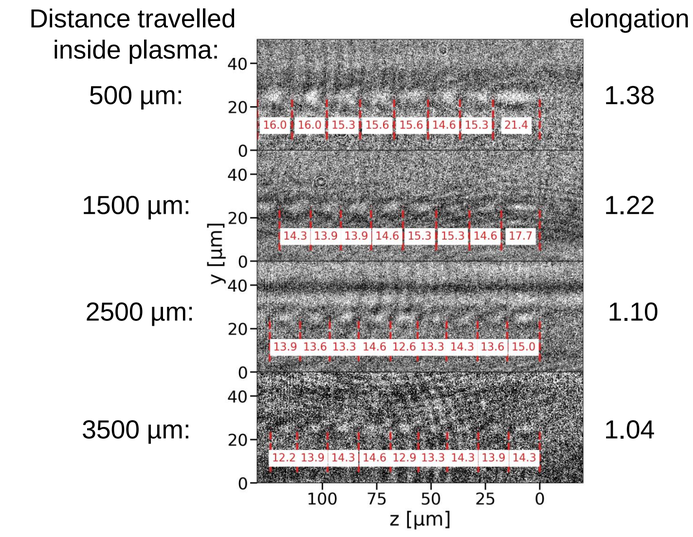


- observation: **first cavity** is **elongated** with respect the nominal plasma wavelength
- **elongation increases** with **decreasing remaining energy** which is coupled to **the initial charge** via **beamloading** in the LWFA stage



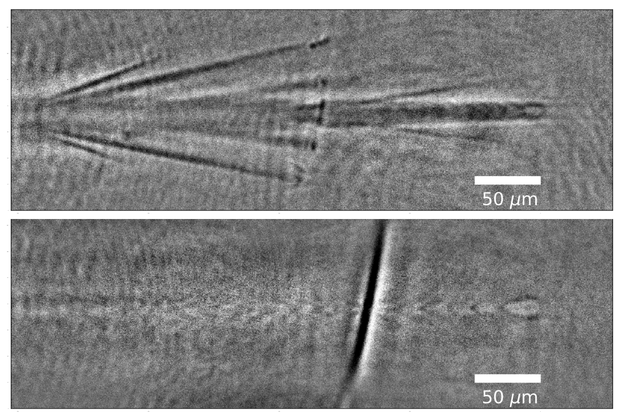
→ **elongation increases with increasing driver charge**

- **consistent** over various plasma densities: clear **correlation** between **elongation** of the first cavity and **initial charge** of the driver beam
- simulations confirm the **charge dependend elongation**
- **Elongation** changes during **propagation** through the target as the **driver charge decreases** (due to deceleration) → **depletion measurement** possible



Conclusions

- **LWFA beam** is strong enough to **fully ionize Hydrogen** and to drive plasma waves.
- **Ultrafast optical probing** technique provides a **new insight revealing subtle details** of the generated plasma wave structure and its dynamics. (e.g. breakups, propagation through shock)
- observation of an **elongation** of the first cavity depending on the **driver charge**
- **Depletion** of the driver beam can potentially **be measured** using this technique
- Plasma probing is **a powerful tool** to assist spatio-temporal problems in advanced injection schemes.



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