All-optical GeV electron bunch generation in a laser-plasma accelerator via truncated-channel injection

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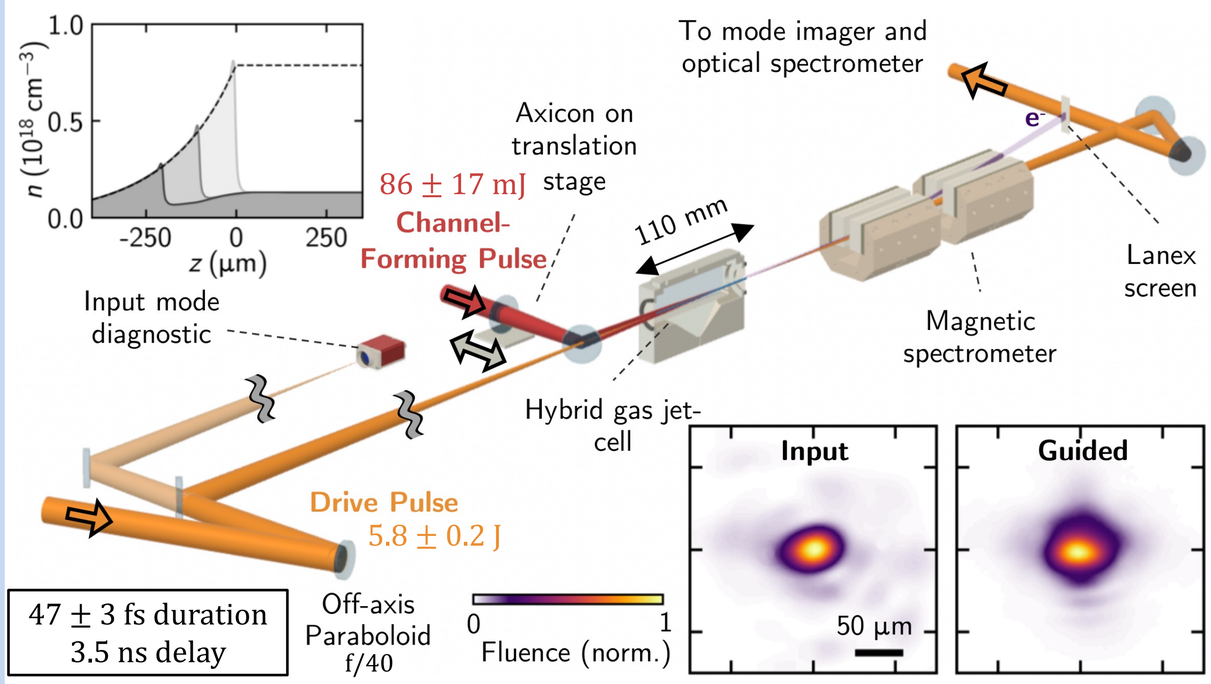
Motivation

- Linear regime LWFA prevents uncontrolled self-injection but requires guiding of drive laser pulse and a mechanism to inject electrons
- Truncated channel injection uses a density downramp at the start of a plasma channel to promote injection of electrons directly into wakefield driven by channel-guided laser pulse

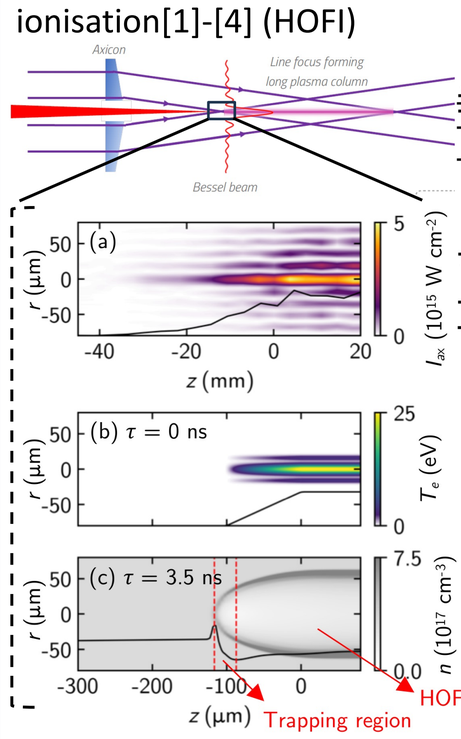
Experimental Layout

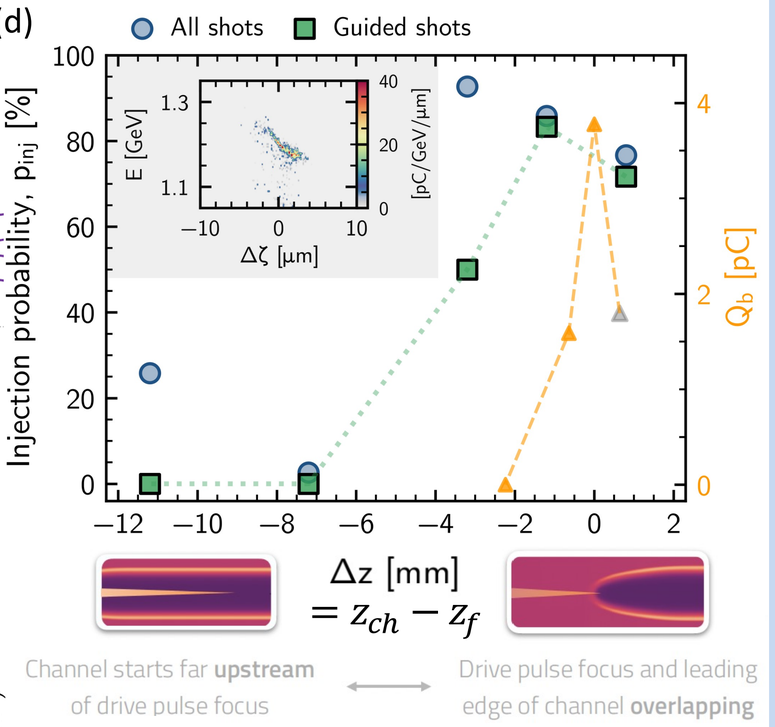


Experiments performed at Astra-Gemini TA3, Central Laser Facility, UK

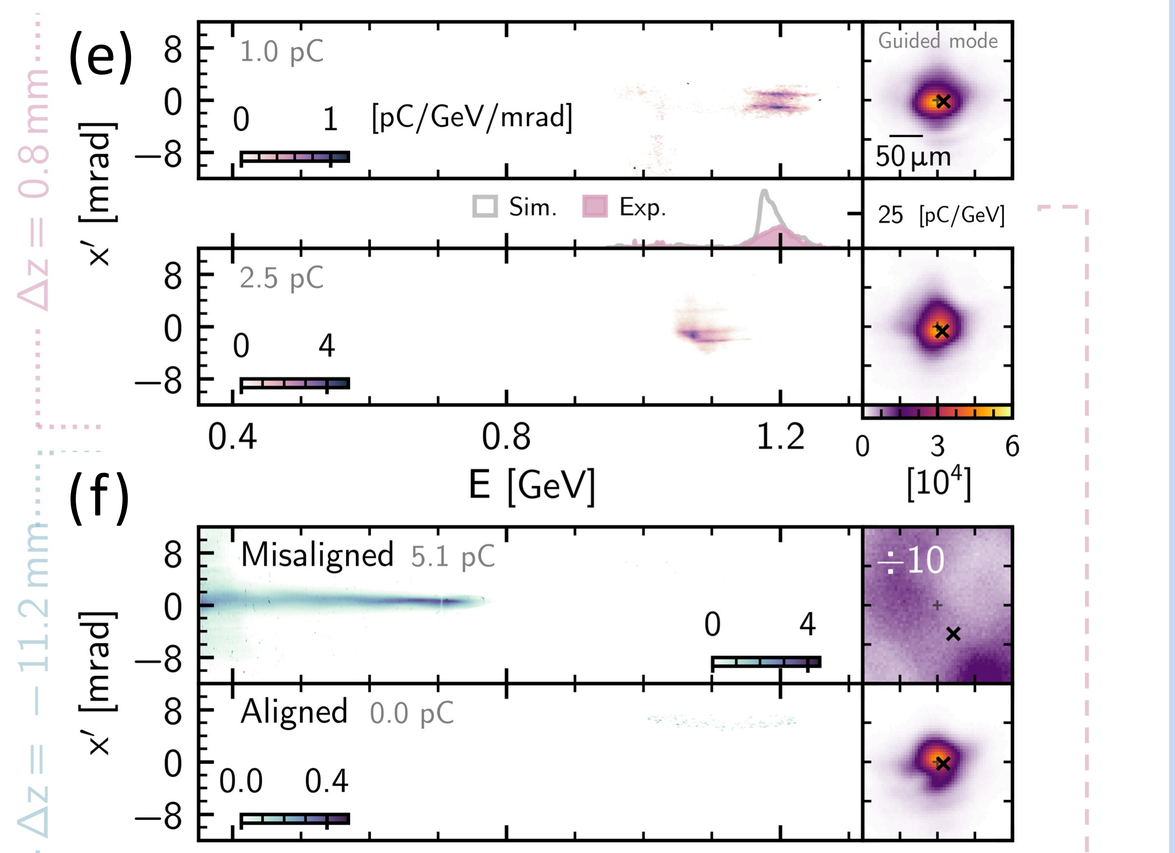
Channel Profile and Position

Axicon used to form low-density plasma channel via hydrodynamic optical field ionisation[1]-[4] (HOFI)



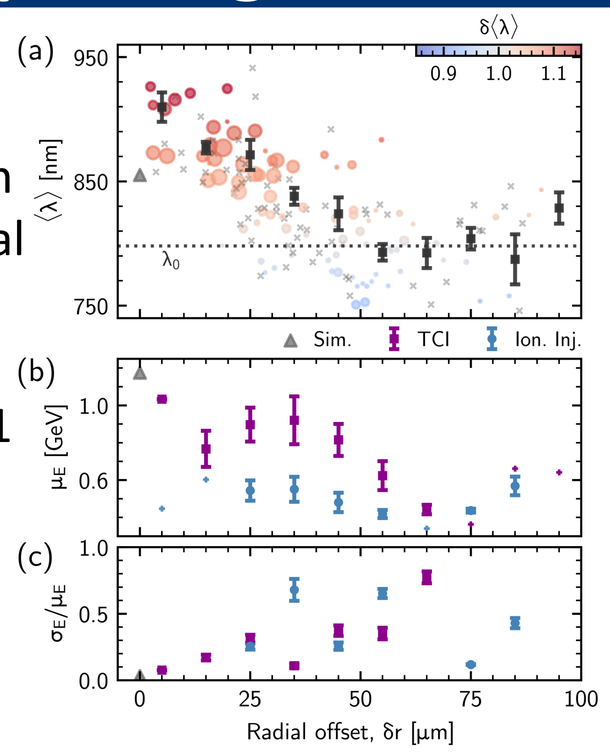


Increased probability of injection when the drive pulse is focused into the leading edge of the channel

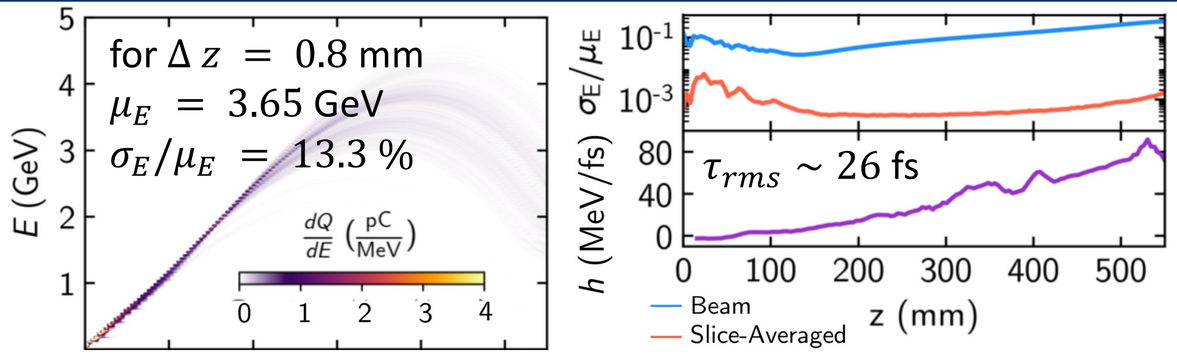


Effect of Input Alignment

a) Red-shifting from wakefield generation and blue-shifting from conditioning of neutral gas
b) Higher energy electrons with TCI (> 1 GeV when aligned)
c) Lower RMS energy spread bunches with TCI compared to ionisation injection



PIC Simulations



- Simulations of optimal TCI with longer interaction length show ~ 4 GeV beams after 400 mm

Outlook

- Generated dark-current-free bunches of energy 1.2 GeV and 4.5 % relative energy spread with 120 TW laser pulses guided in a 110 mm-long HOFI channel
- Increasing channel length to $L_d \approx 410$ mm would yield 3.65 GeV bunches, slice relative energy spread below the per-mille level

[1] S. M. Hooker et al., AAC Workshop (2016)
[2] R. J. Shalloo et al., PRAB 22 (2019)
[3] R. J. Shalloo et al., PRE 97 (2018)
[4] N. Lemos et al., PoP 20 (2013)

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