FLASHForward X-1: High quality electron beams from internal injection in a plasma-wakefield accelerator.

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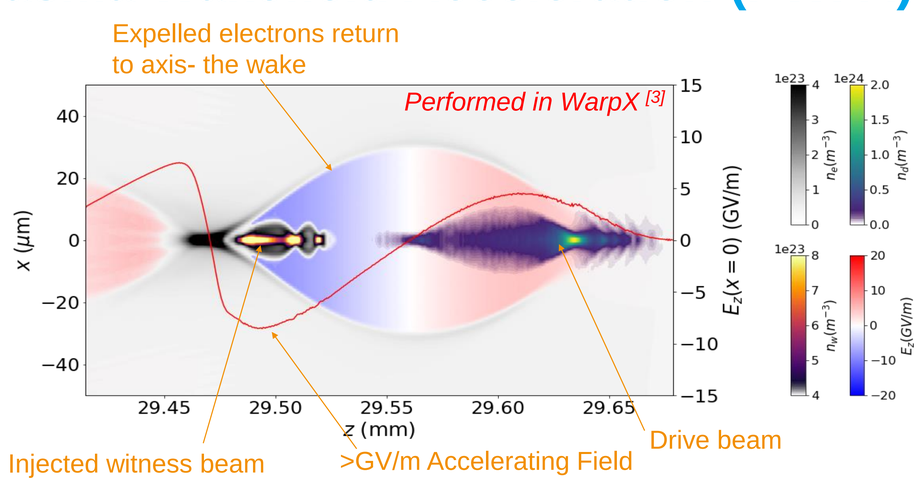
Plasma Wakefield Acceleration (PWFA)



> Strong drive beam (laser or particle) excites plasma oscillations [1]

> High accelerating gradients (~> GV/m) in the wake of the driver (wakefields)

> Beam drivers: wakefield structures propagate at ~c (dephasing-free) [2]

> Inject 'witness' bunch at correct phase → very high energies over short distances

> Two main injection categories: **external** and **internal** injection.

Internal Injection via a Density Downramp

> Completely new beam generated → different properties to drive beam (e.g lower emittance)

> Low emittance, high current beams from PWFA stages → **beam brightness transformer:**

$$B_{5D} \propto \frac{I_p}{\varepsilon_x \varepsilon_y}$$

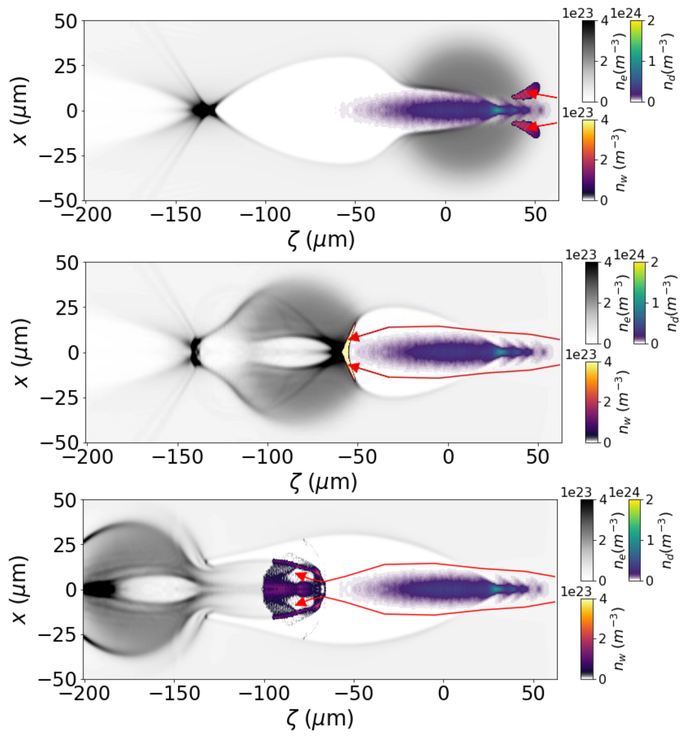
> **Density Downramp** Injection [4]:

> Reduce wake phase velocity → rephase plasma electrons → accelerate

> Robust: moderate synchronization levels (~ps) and drive beam currents (~>1.5 kA) required

> Ramp generation: hydrodynamically or with **selective laser ionization of gas species [5]**

> First beam-driven downramp injection achieved experimentally in 2016 [6]

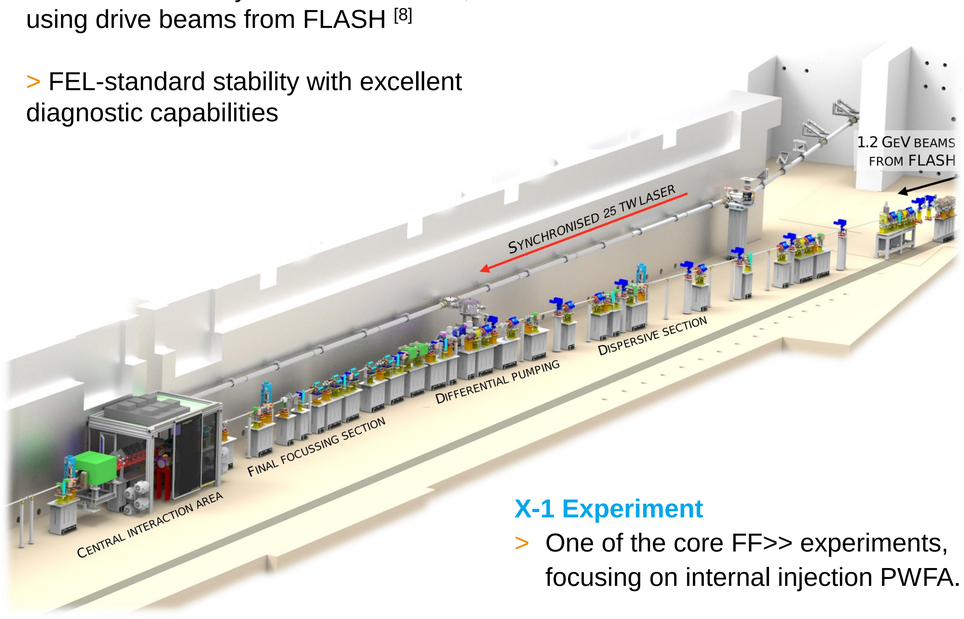


Performed in WarpX

FLASHForward [7] @ DESY

> Dedicated mainly to PWFA research, using drive beams from FLASH [8]

> FEL-standard stability with excellent diagnostic capabilities

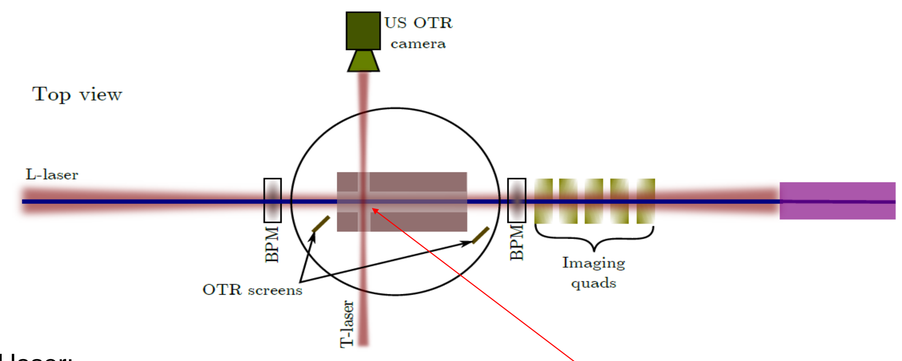


X-1 Experiment

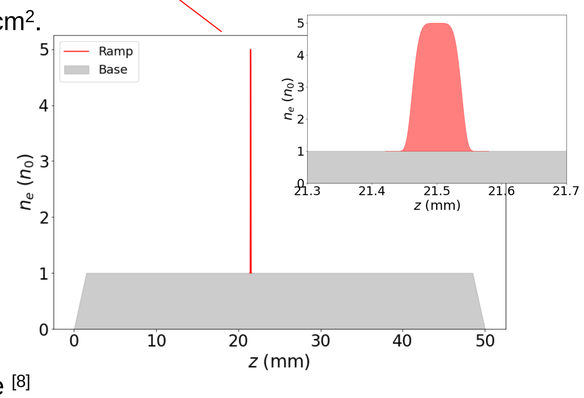
> One of the core FF>> experiments, focusing on internal injection PWFA.

> Goal: (<)< 1 mm mrad norm. emittance witness beams → **beam brightness converter for FLASH**

X-1 Experiment



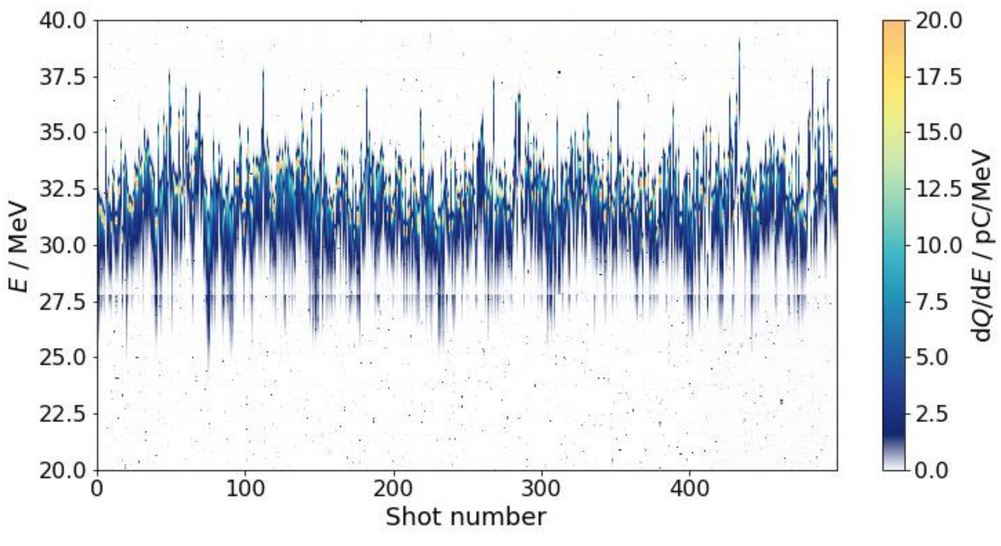
> Longitudinal laser:
  > (460 x 330) μm FWHM, 40 fs, I>4.6 x 10^{14} W/cm^2.
  > Background plasma creation (Ar^{1+}).
> Transverse laser:
  > ~50 μm FWHM, 40 fs , I>10^{15} W/cm^2
  > Density spike creation (Ar^{2+} + optional dopant gases)
> FLASH electron beam:
  > Peak currents ~ 2 kA after compression
  > RMS focal size (5 x 5) μm at capillary entrance [8]



Witness beam injection and characterisation

> **2019**: first demonstration of **stable** and **controlled (**5 MeV rms energy jitter, ~95% injection probability) Density Downramp Injection @FF>>. [9]

> **Present:** identified further stable working points (1.3 MeV rms energy jitter , >99% injection probability) to perform e.g witness **emittance** measurements.



Summary and Outlook

> The X-1 experiment @ FLASHForward aims to demonstrate internal injection of high-quality electron beams into a PWFA stage via a density downramp → **beam brightness converter**

> Stable and controllable injection has been demonstrated and working points identified for witness beam characterization

> Next steps:
  > Attempt transportation of injected beams to Transverse Deflecting Structure (XTDS) for **longitudinal phase space measurements**
  > Experiment with different gases (e.g H_2 , Ne etc.) and preionization methods (i.e discharge) as a means of further controlling the injection and acceleration processes.

References

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