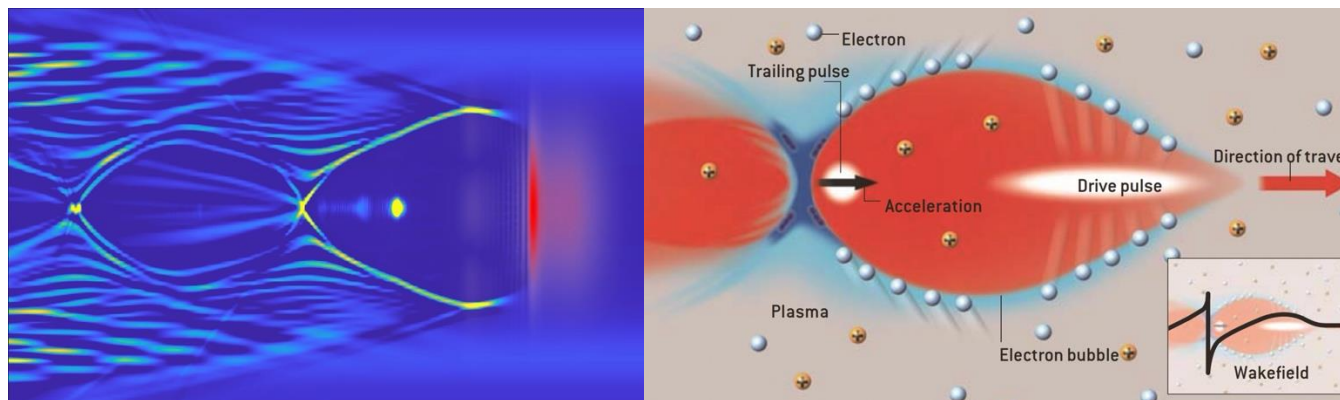


Steps Towards Staging

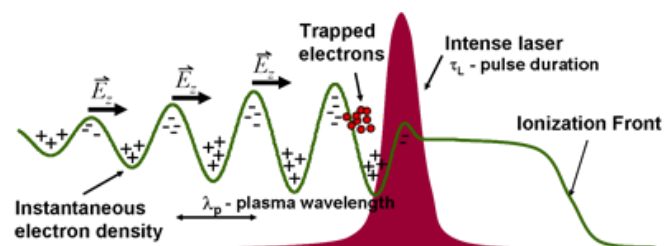
Jasmin Hills

Wakefield Acceleration

$$W_{gain} \propto L_{total} E_z$$



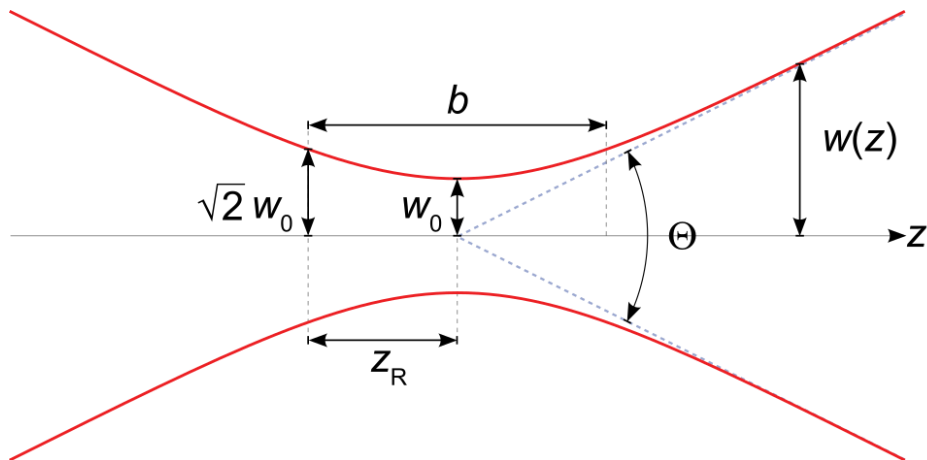
Laser Driven Wakefield Acceleration



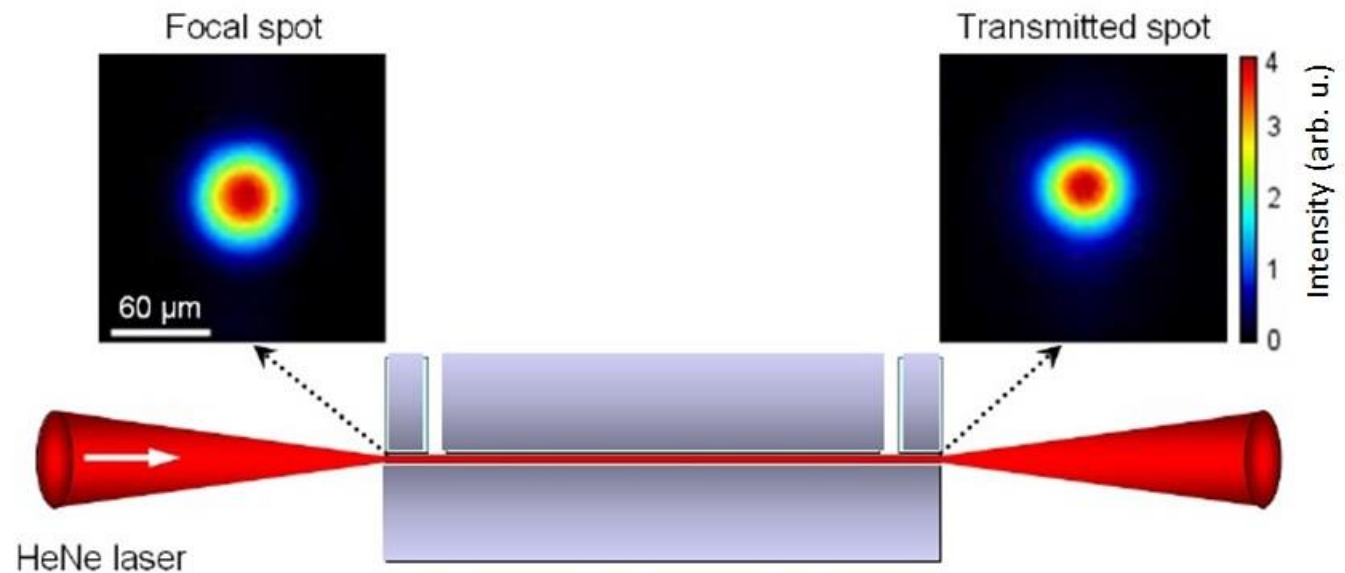
Accelerating gradient is up to 10^3 higher than conventional accelerators

Laser Driven Wakefield Acceleration

$$W_{gain} \propto L_{total} E_z$$



Diffraction limits the distance over which fields can be driven



Guiding occurs when diffraction balances out with self-focussing

Limitations

$$W_{gain} \propto L_{total} E_z$$

Energy gain is limited by the amplitude of the fields and the distance over which they can be driven

$$E_z \propto n_e^{1/2}$$

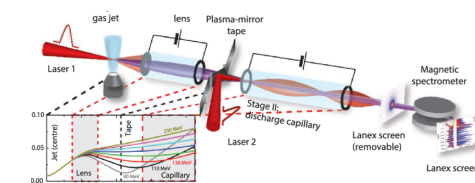
$$L_{dp} \propto n_e^{-3/2}$$

$$W_{gain} \propto n_e^{-1}$$

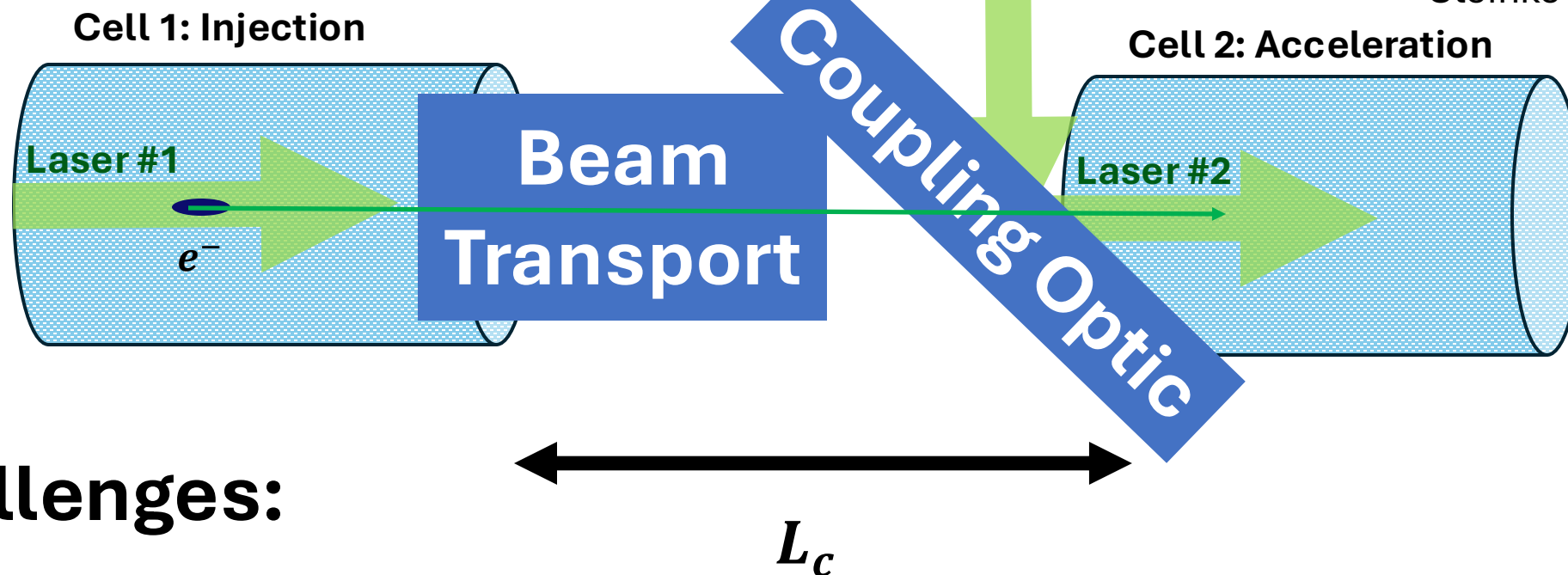
Following this scaling pushes us towards longer, lower gradient accelerators.

We need to find a solution that maximizes the effective gradient, current goal is 1 GV/m.

Potential Solutions: Staging



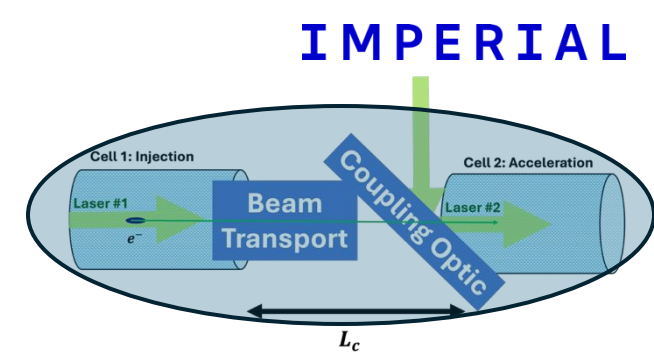
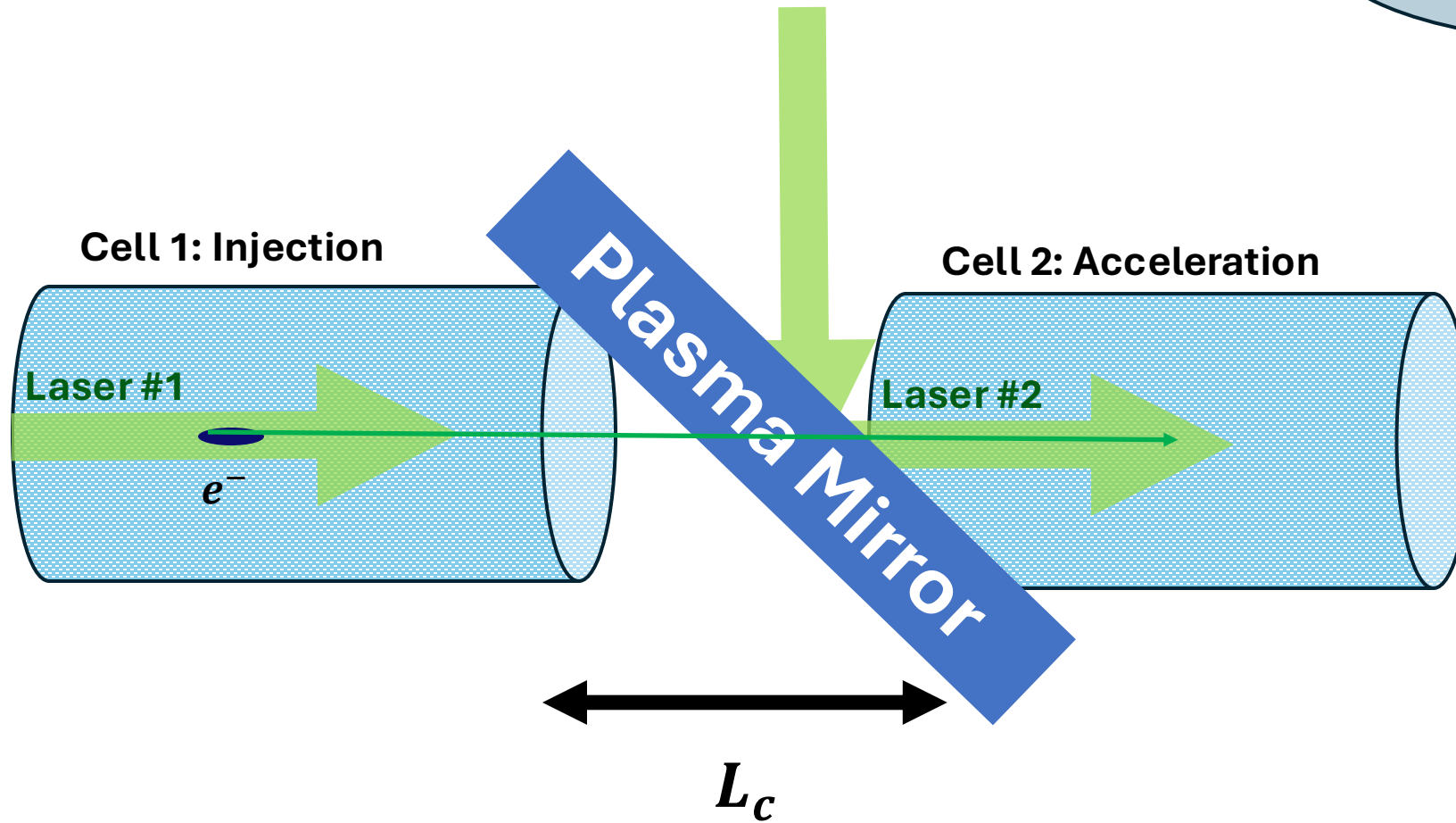
Staging demonstrated by Steinke et al at LBNL



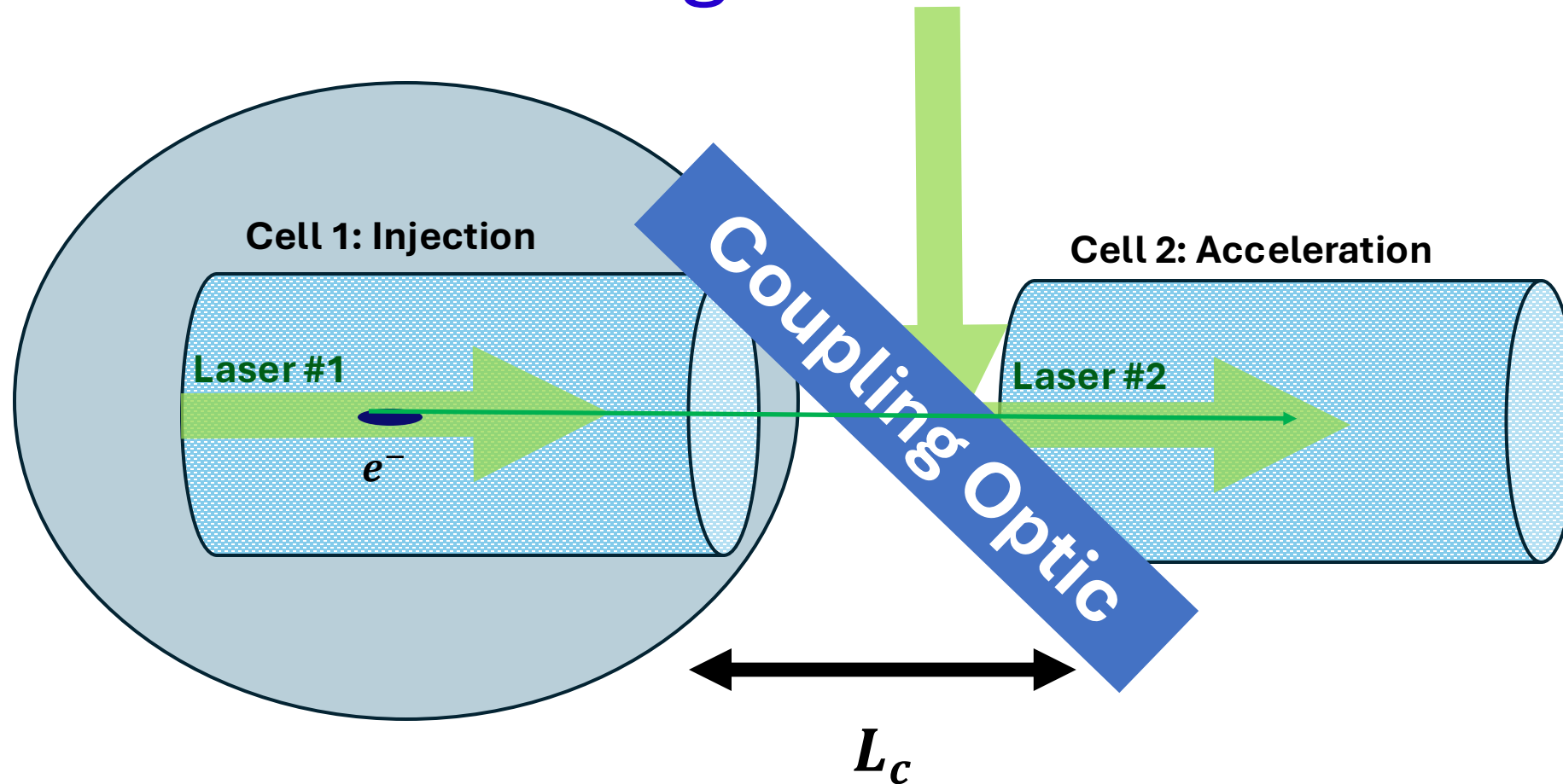
Challenges:

- Beam blow-up between stages
- Coupling in the driving beams (whilst minimizing L_c)

Experimental Design



Cell 1: Low Divergence Beams



Cell 1: Low Divergence Beams

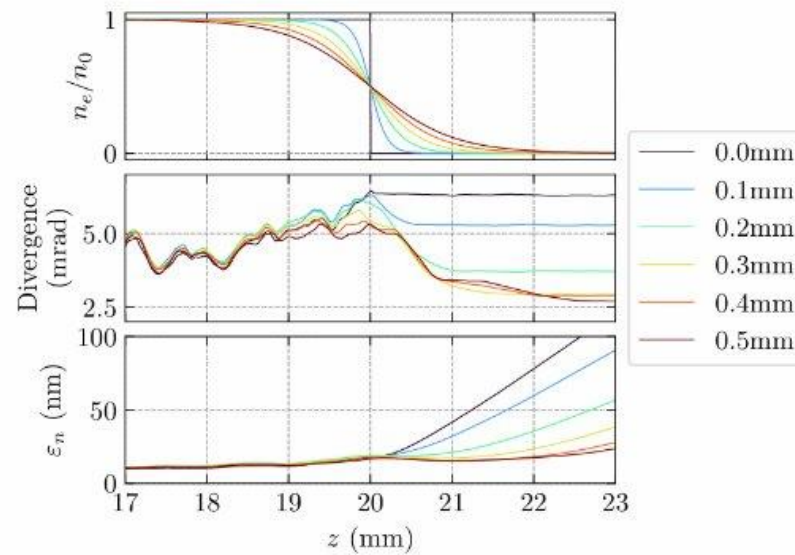
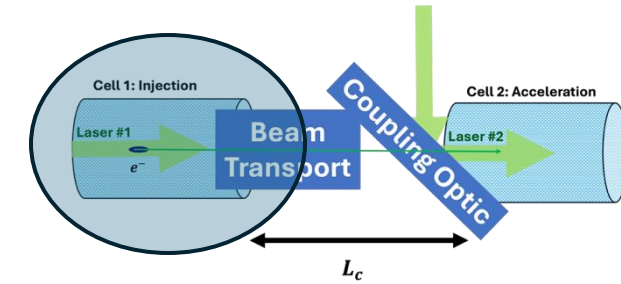
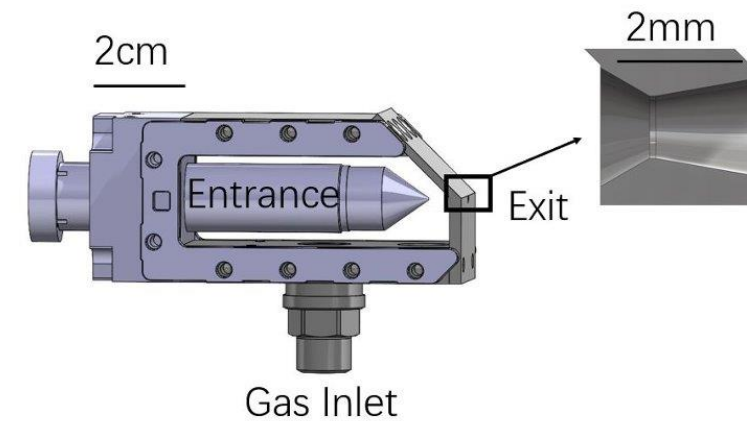
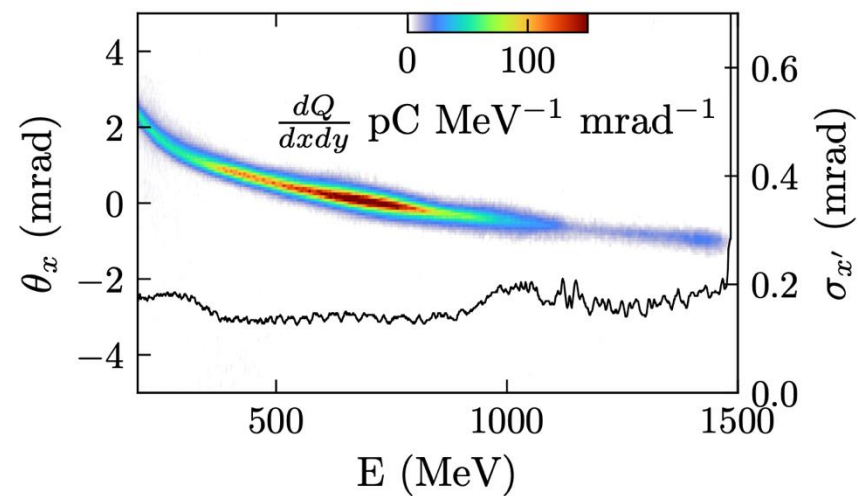
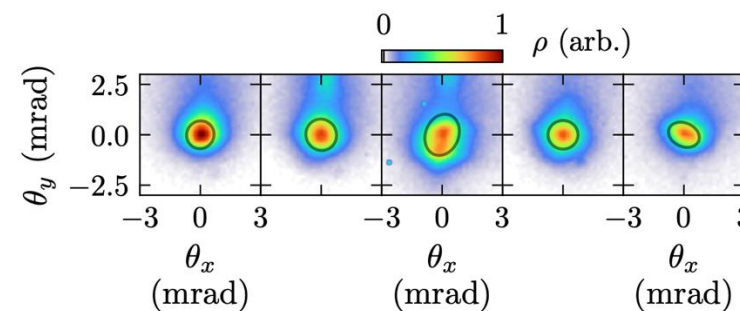
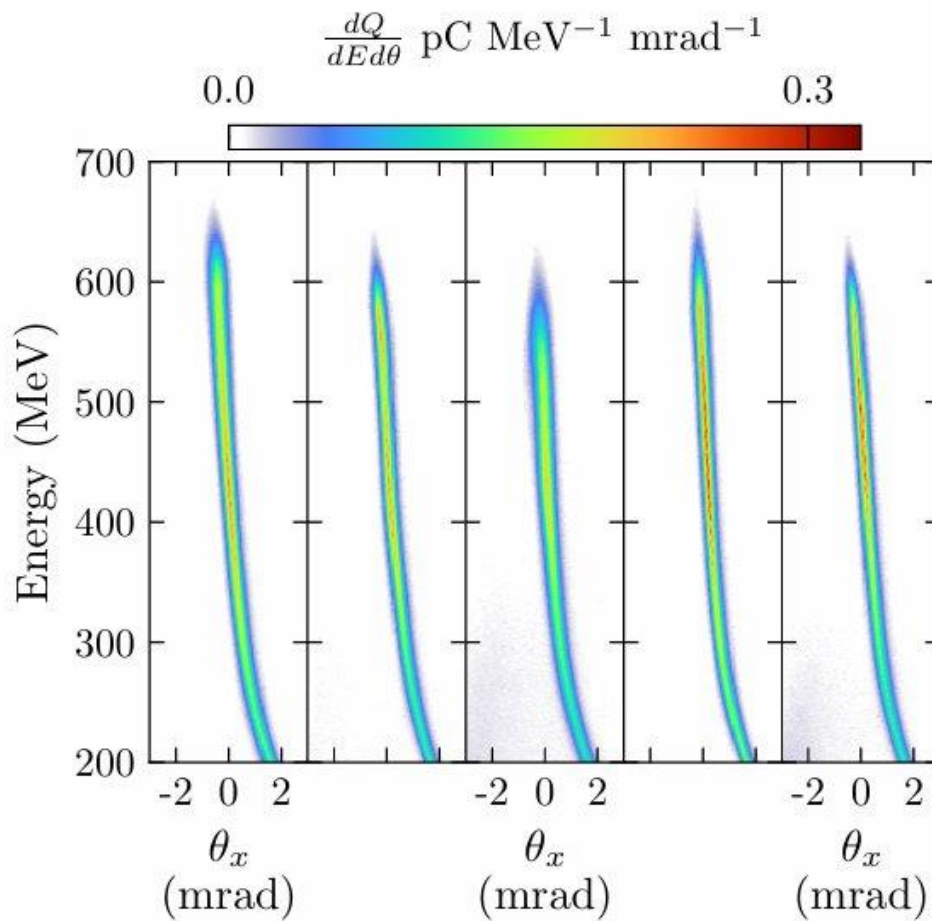
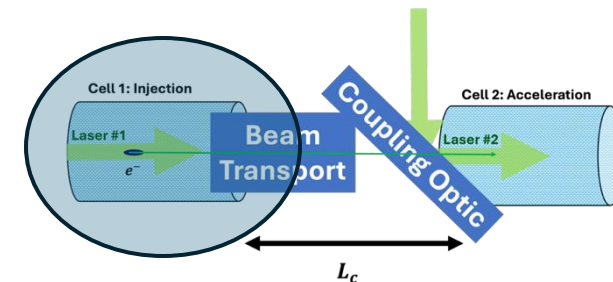


Figure 6.19: Plasma density ramps at the end of the simulations (top), electron beam divergence across all energies (middle), and geometric (phase) normalised emittance (bottom). The divergence and emittance values plotted here are the average of the values projected into the \hat{x} and \hat{y} directions.

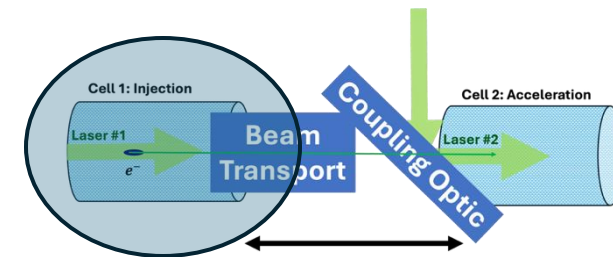


Cell 1: Low Divergence Beams



From M. Backhouse

Cell 1: Low Divergence Beams



Helium Atomic Number Density / m^{-3}



**High Power Laser
Science and
Engineering**

Article contents

Abstract

Accepted manuscript

Modelling of a Variable Length Gas Cell Target for Laser Wakefield Acceleration

Published online by Cambridge University Press: 22 October 2025

R. Luo , G. R. Christian, M. P. Backhouse, N. C. Lopes, S. S. Alatabi, M. S. Bloom, M. Maier and Z. Najmudin

Show author details

Article

Metrics



Abstract

An abstract is not available for this content so a preview has been provided. As you have access to this content, a full PDF is available via the 'Save PDF' action button.

Accepted Manuscript

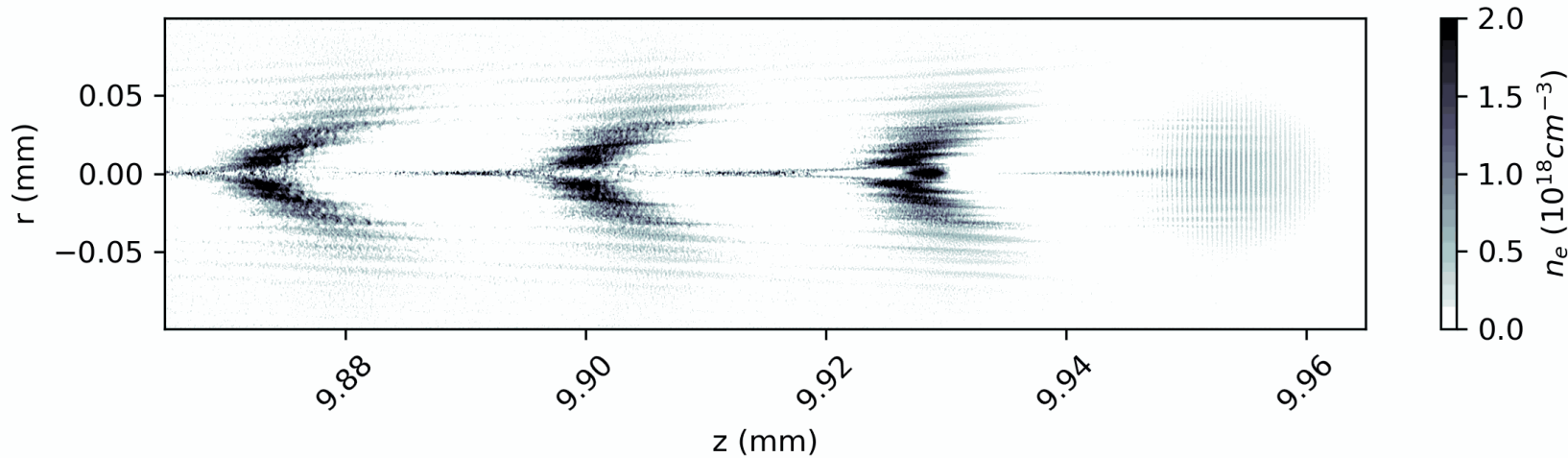
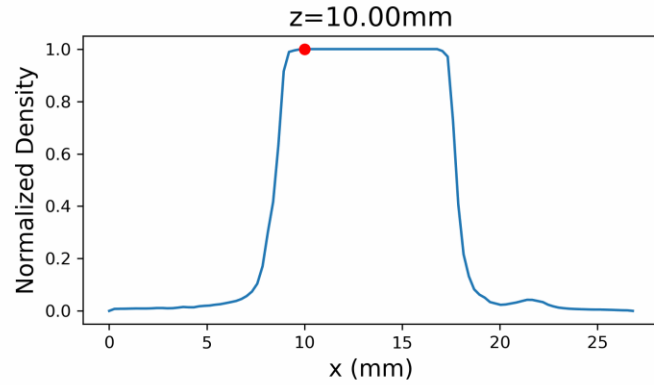
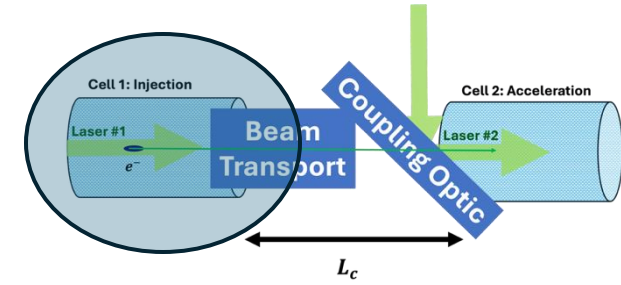


Modelling of a Variable Length Gas Cell Target for Laser Wakefield Acceleration



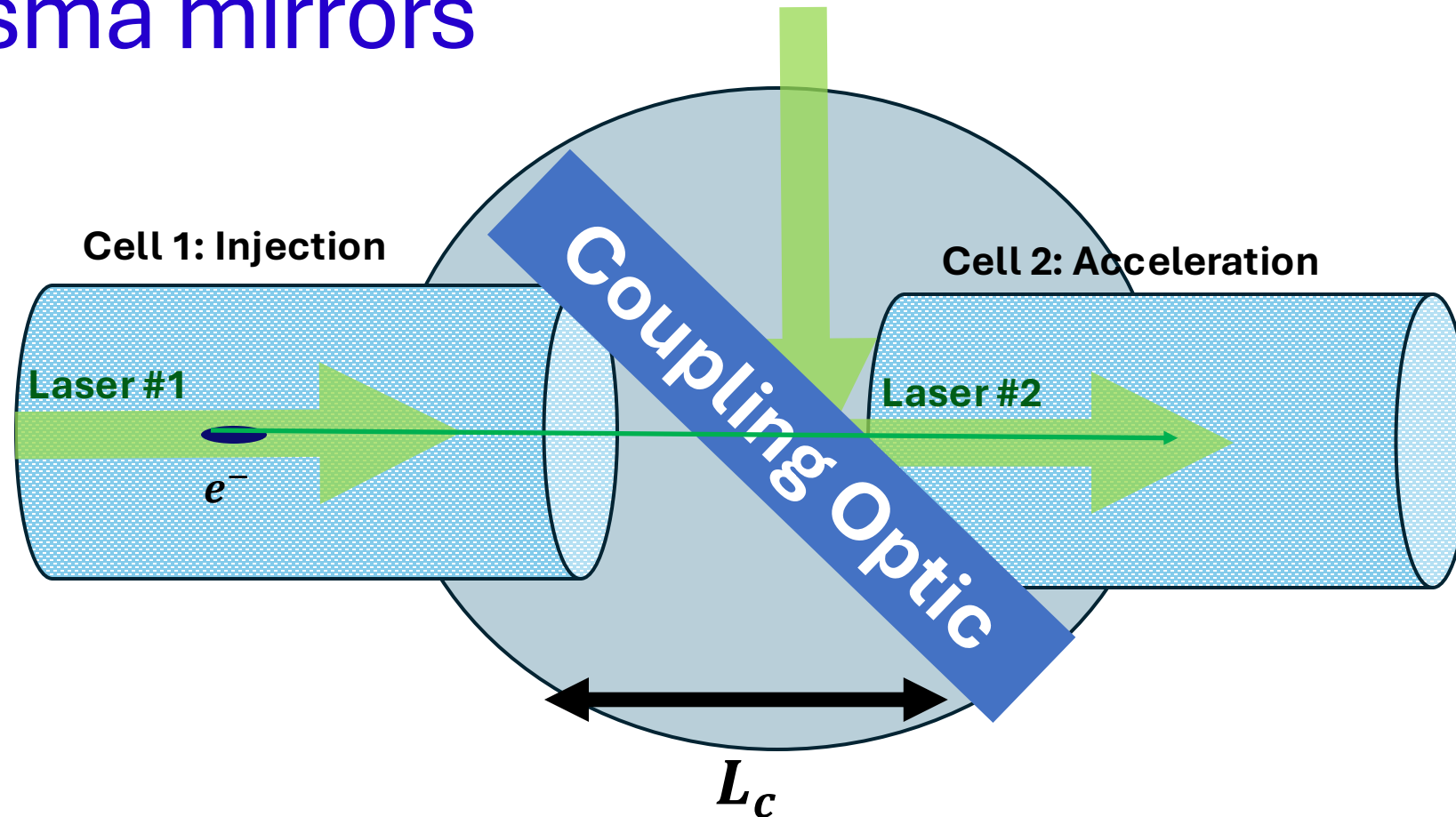
Cell 1: Low Divergence Beams

IMPERIAL

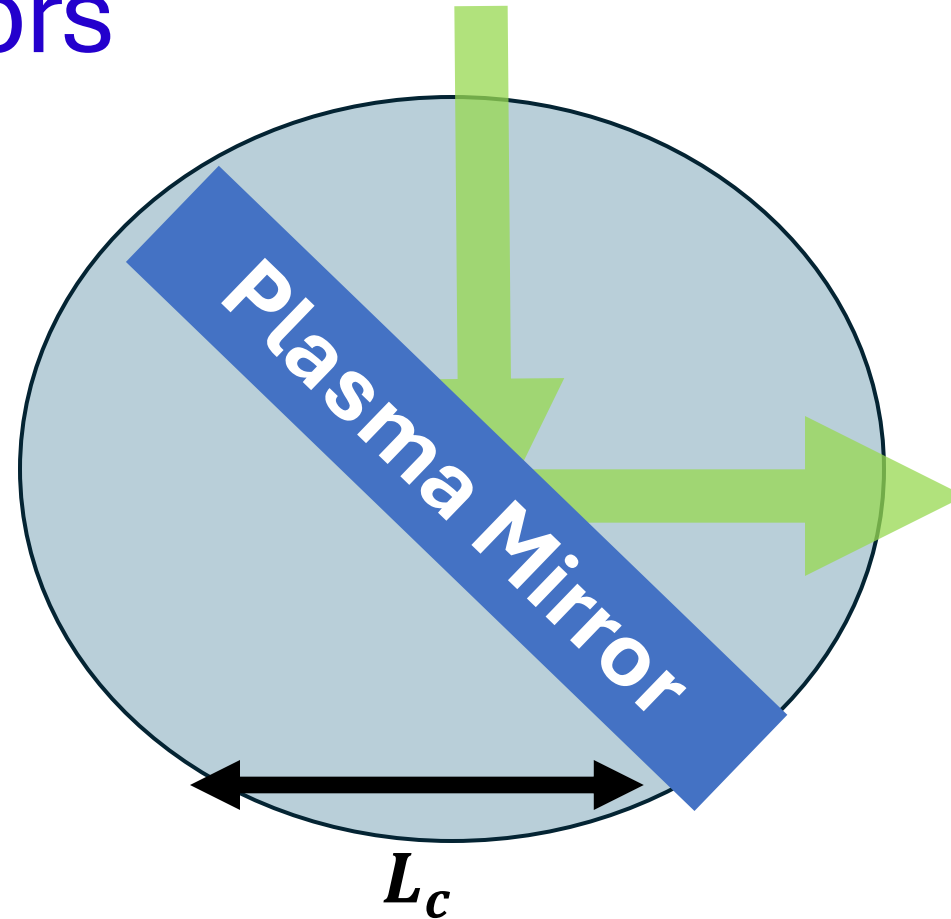


From L. Runfeng

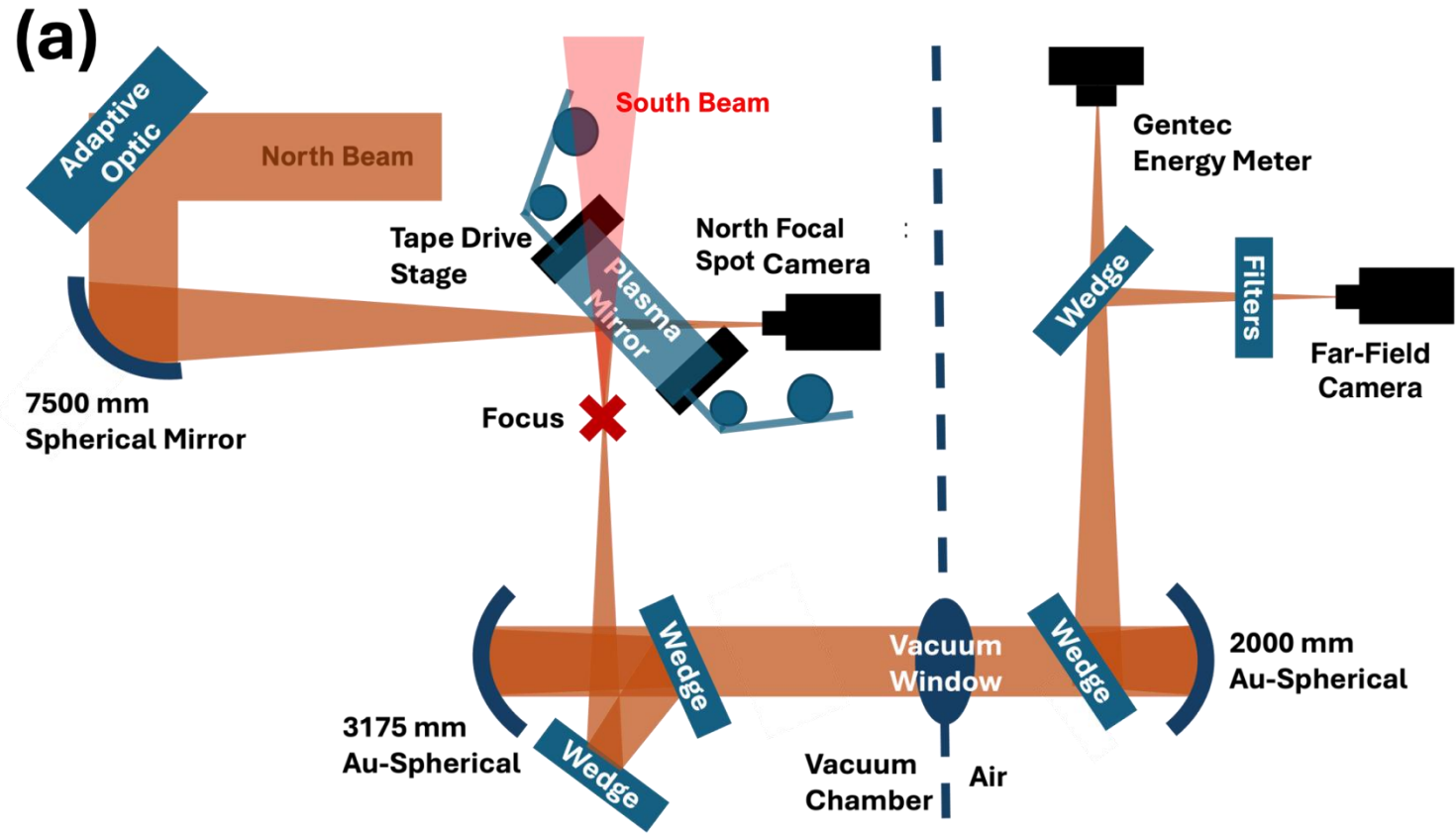
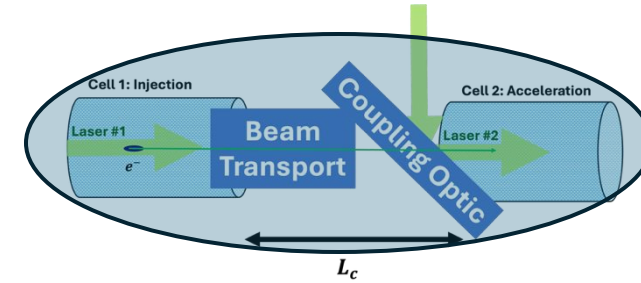
Coupling in a driving beam: Plasma mirrors



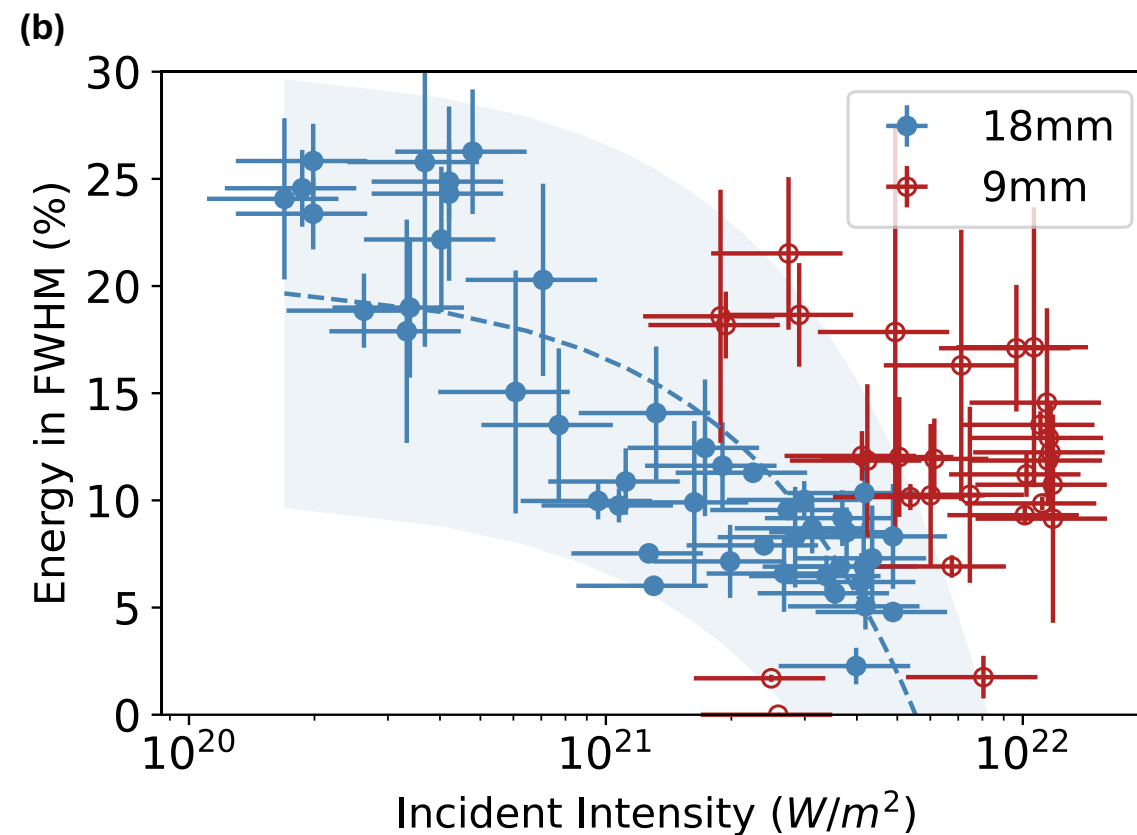
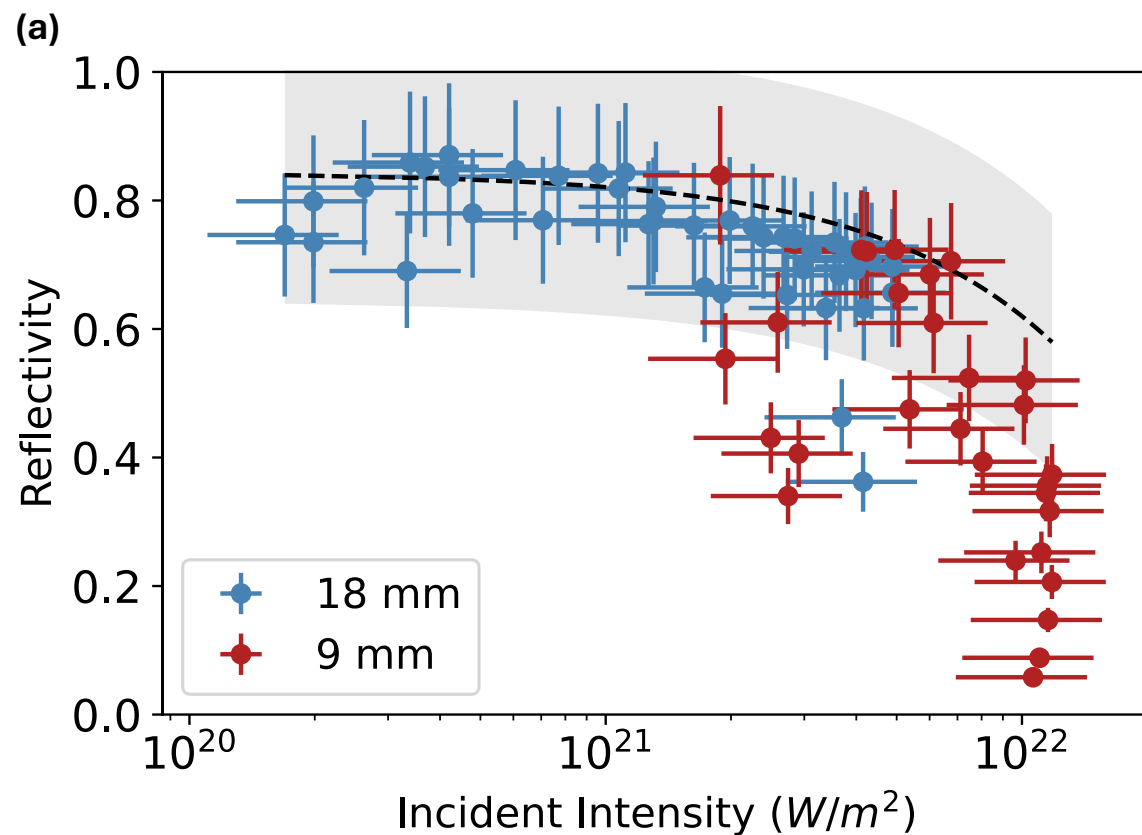
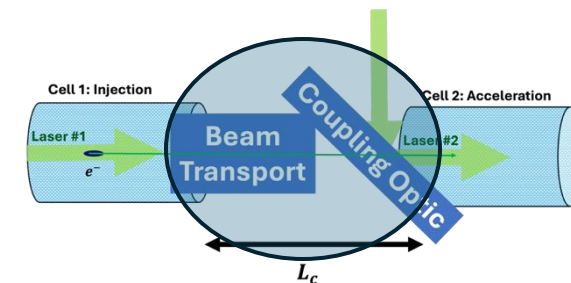
Coupling in a driving beam: Plasma mirrors



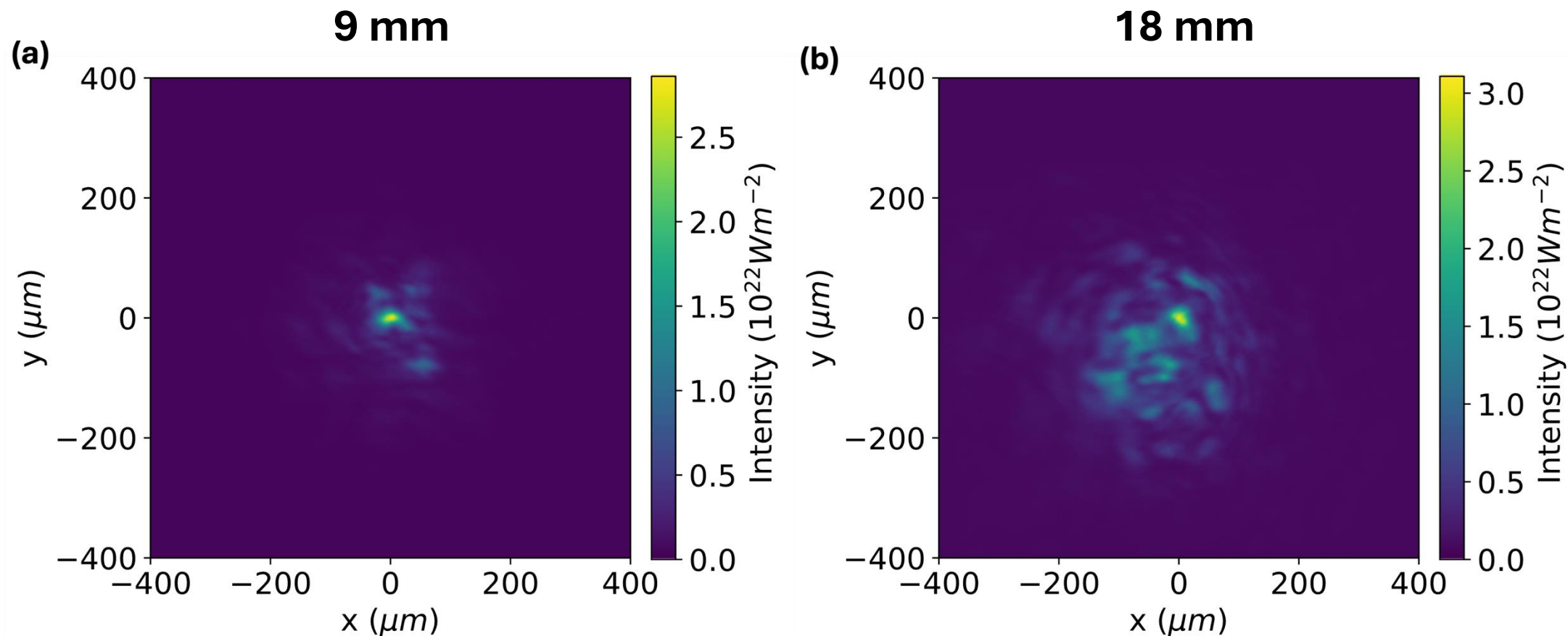
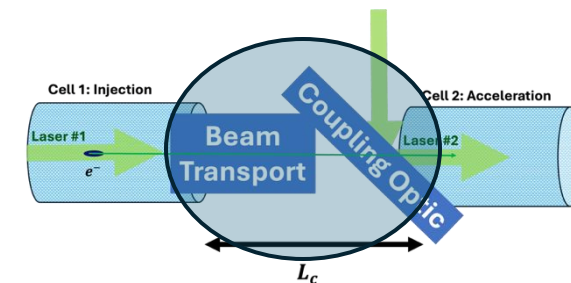
Experimental Design



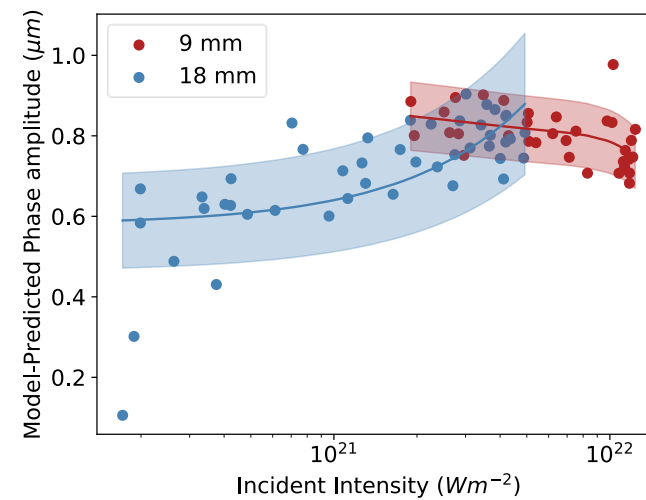
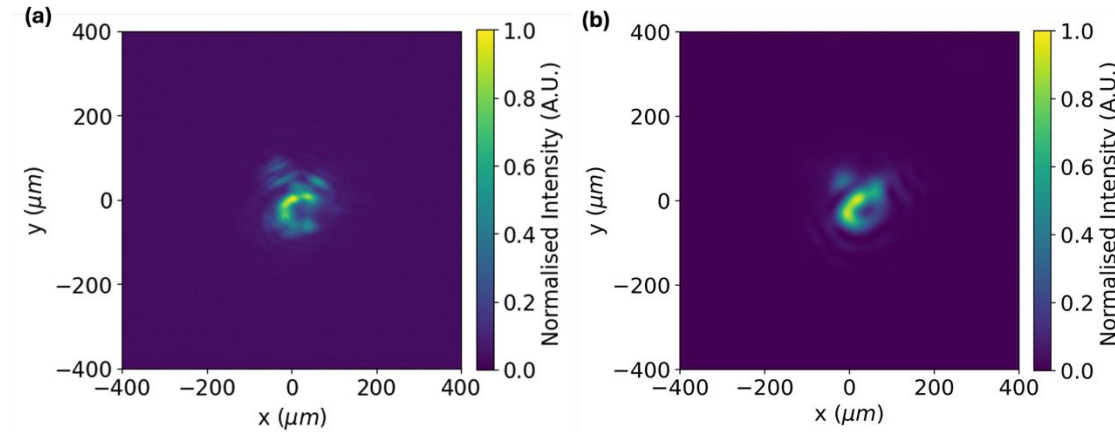
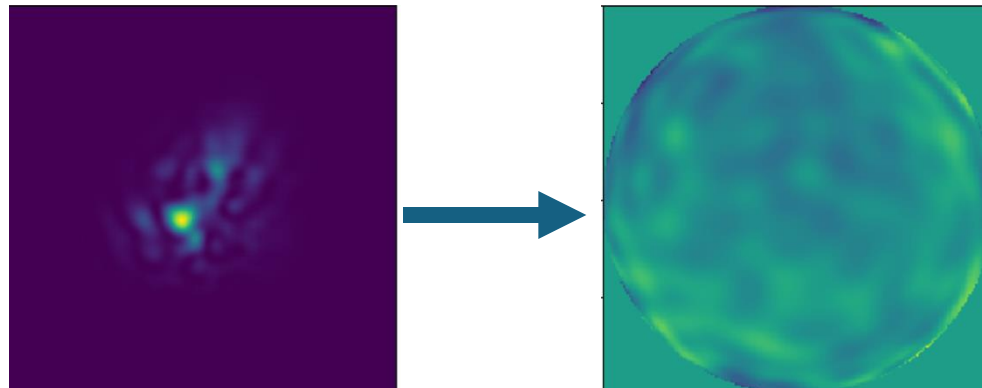
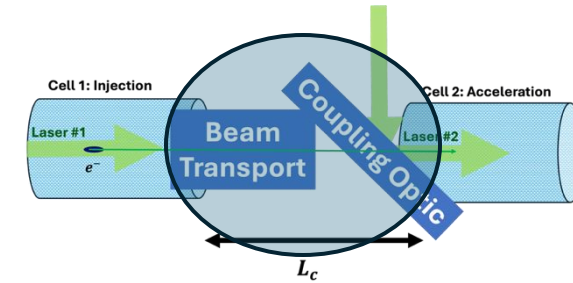
Coupling in a driving beam: Plasma mirrors



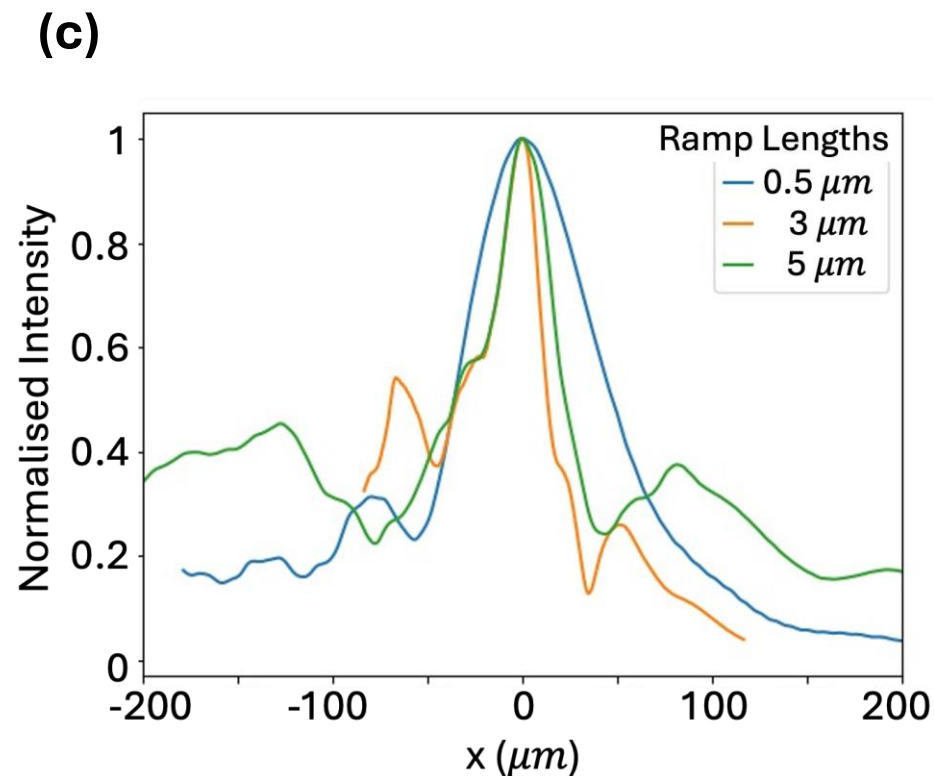
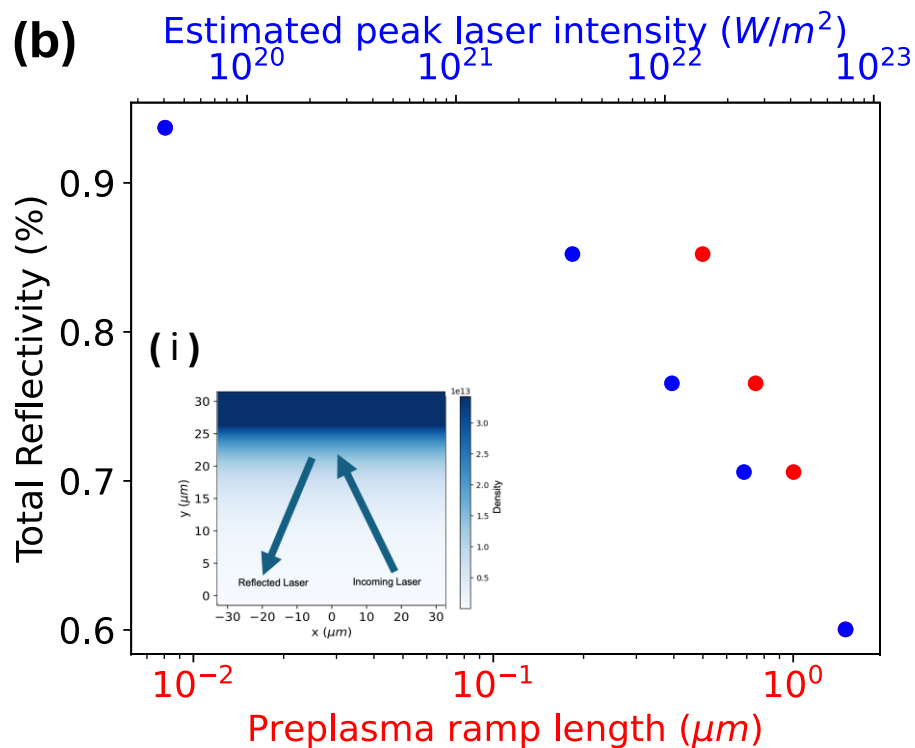
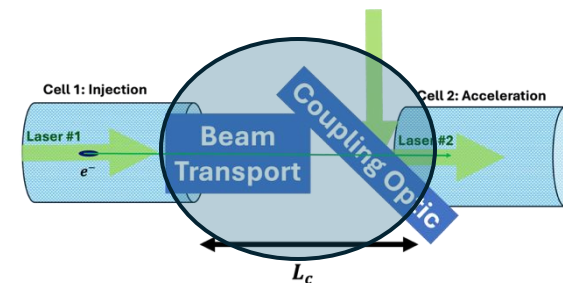
Coupling in a driving beam: Plasma mirrors



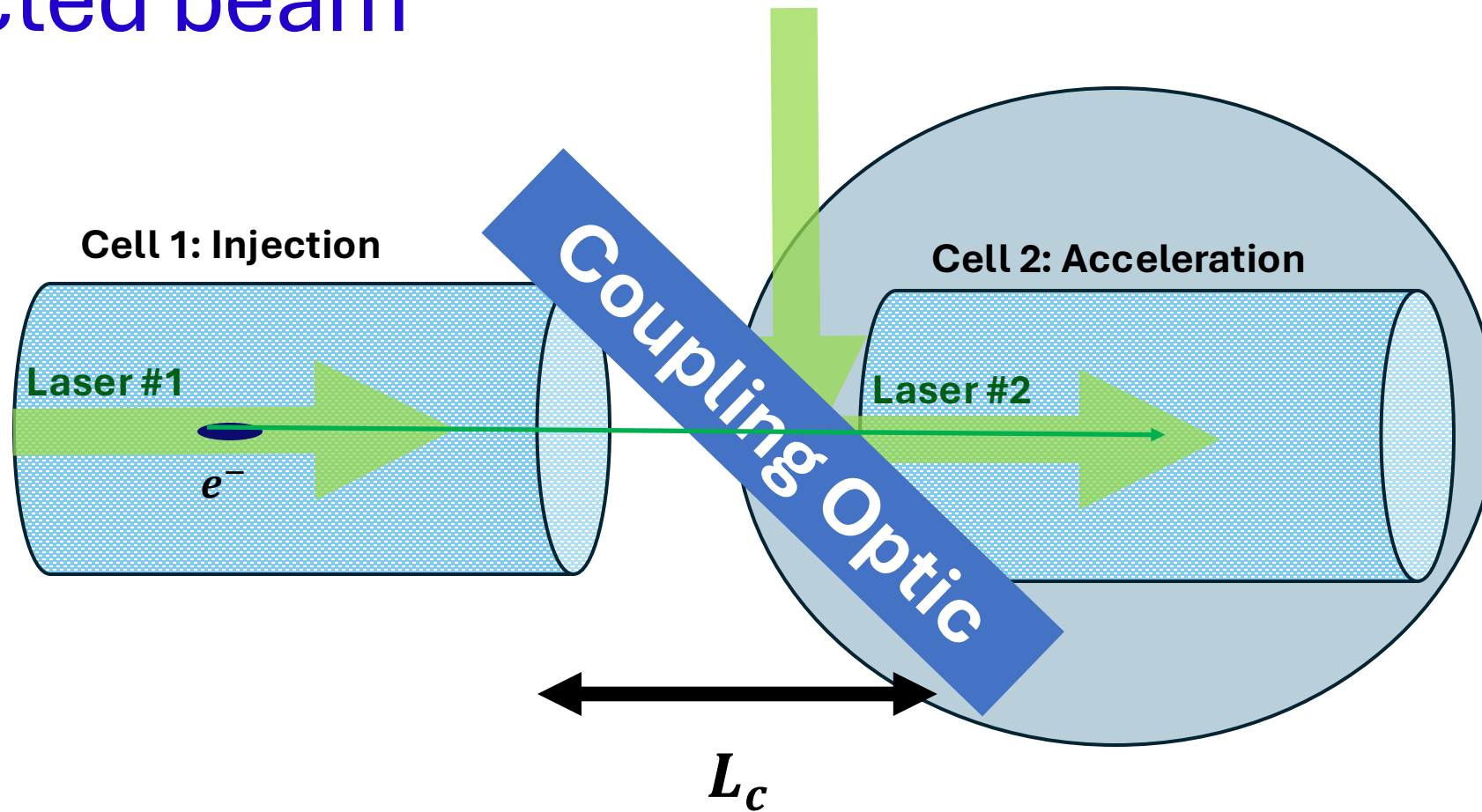
Coupling in a driving beam: Plasma mirrors



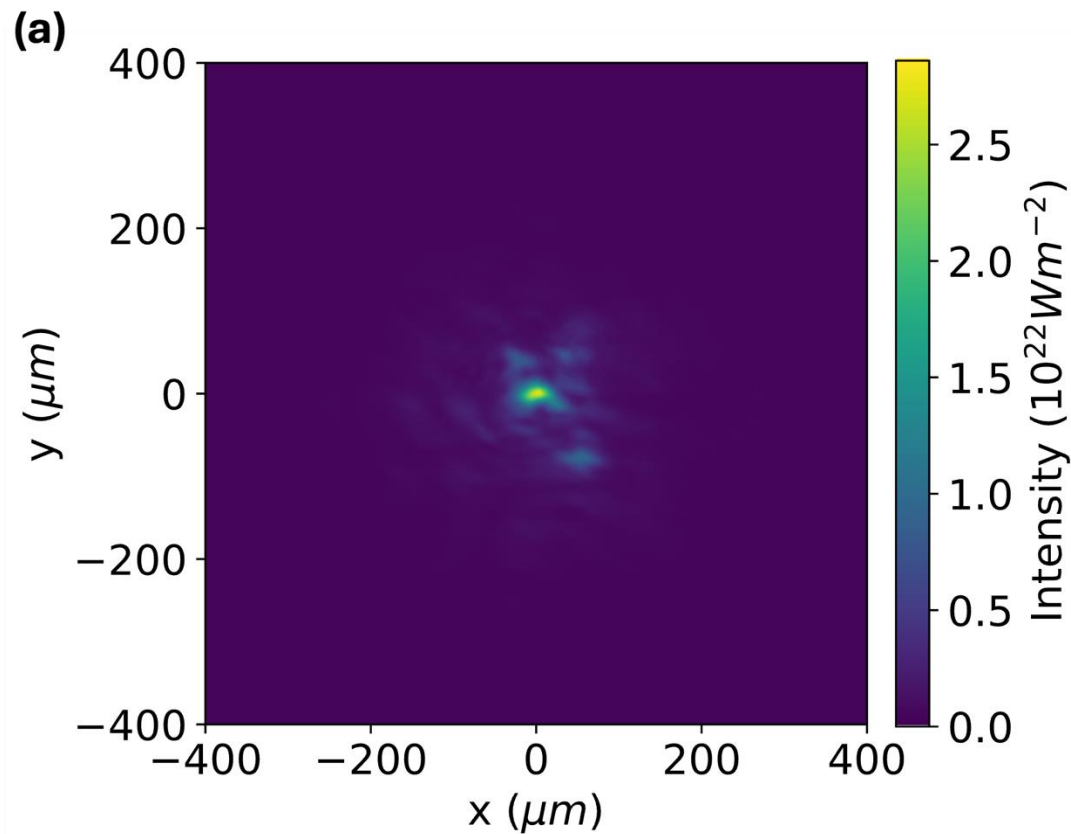
Coupling in a driving beam: Plasma mirrors



Driving a LWFA with a plasma-mirror reflected beam

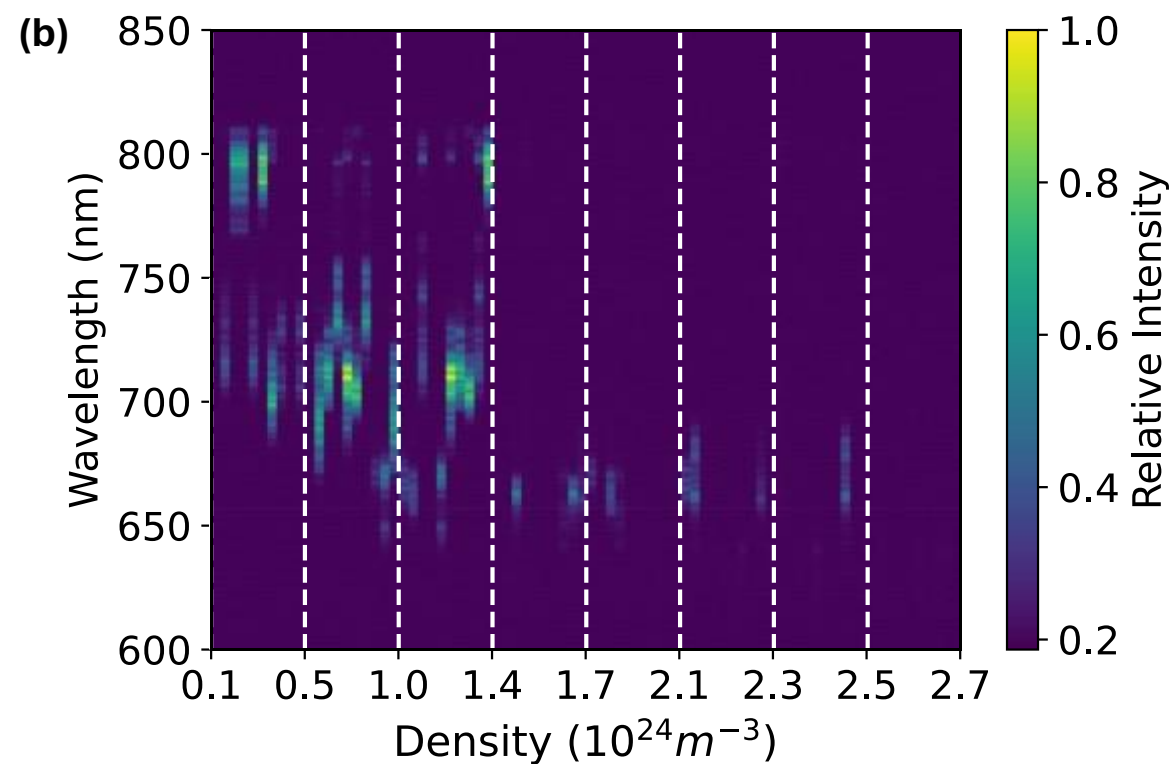
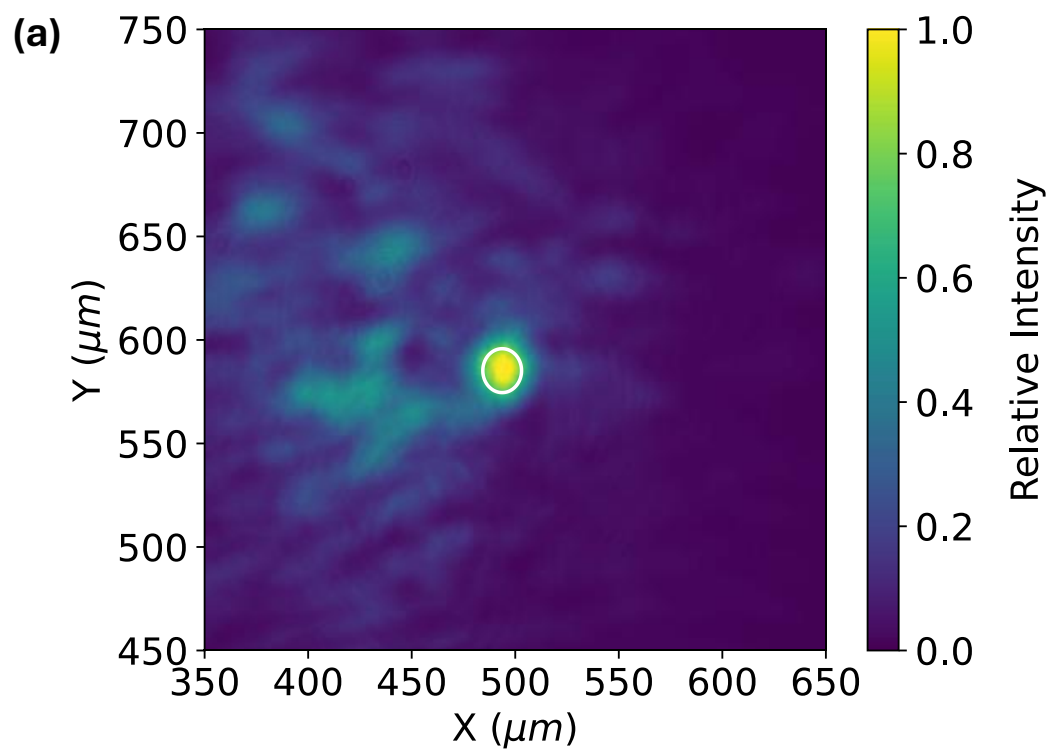
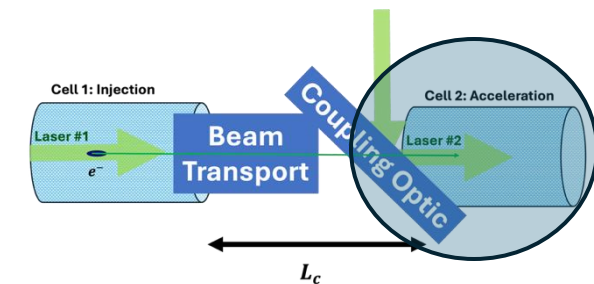


Driving a LWFA with a plasma-mirror reflected beam

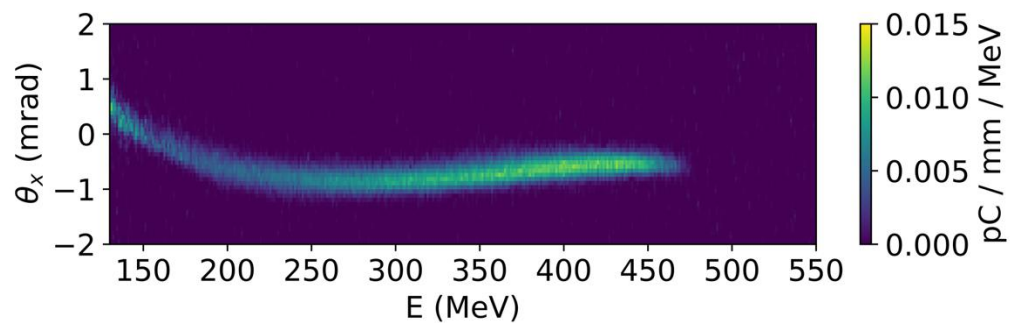
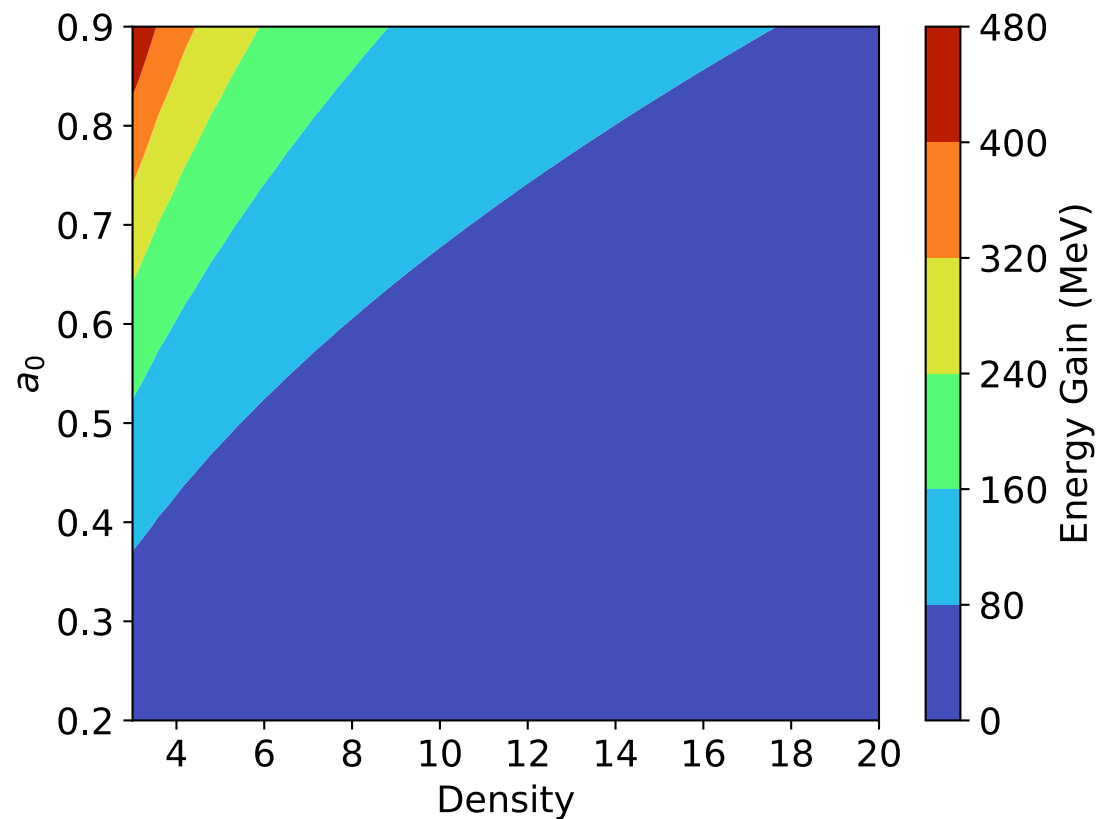
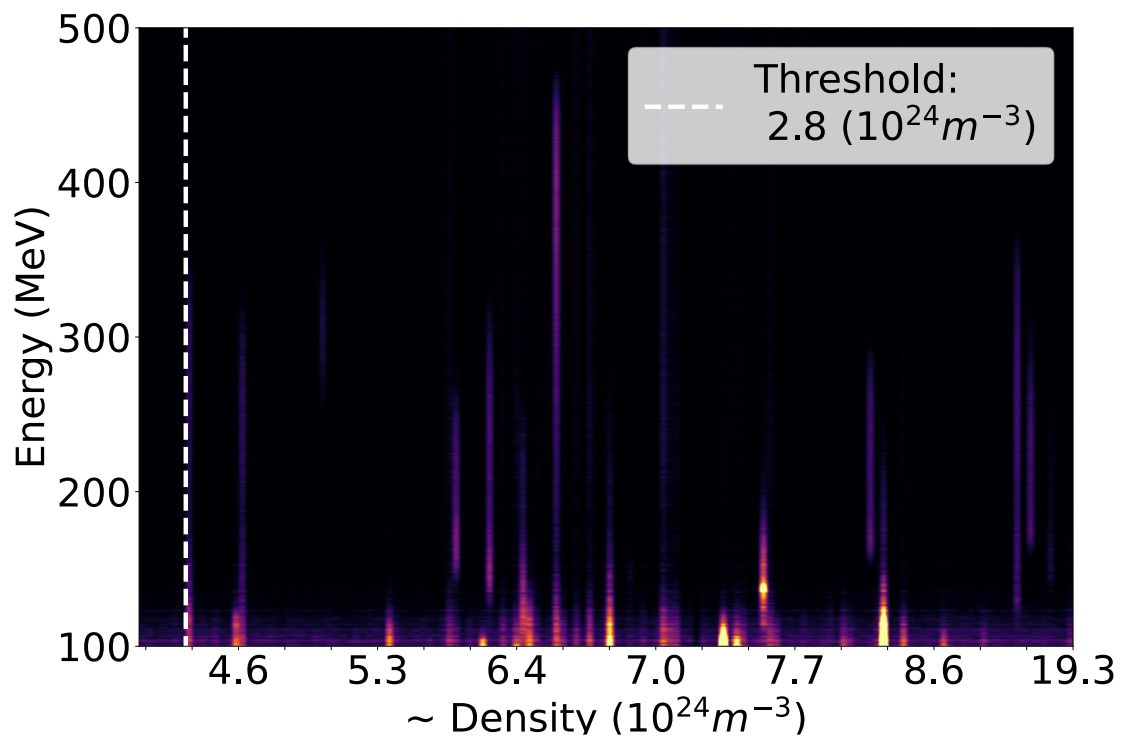
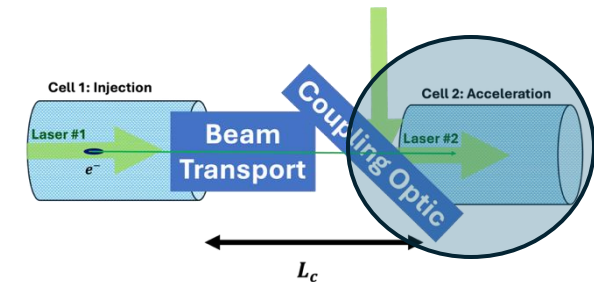


Total Reflected Energy	$\sim 3\text{-}4\text{J}$
Energy in the FWHM	$\sim 0.2\text{-}4\text{J}$
a_0 Values	0.5-0.7

Driving a LWFA with a plasma-mirror reflected beam

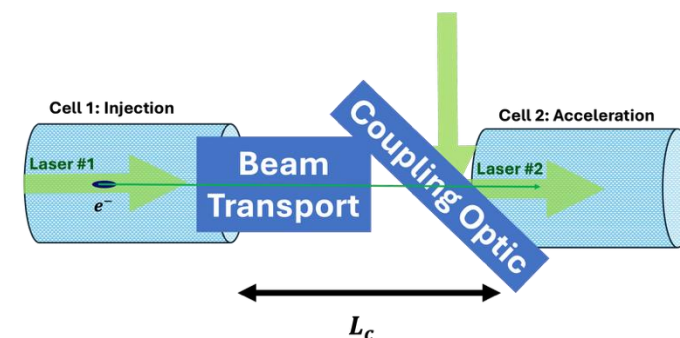


Driving a LWFA with a plasma-mirror reflected beam

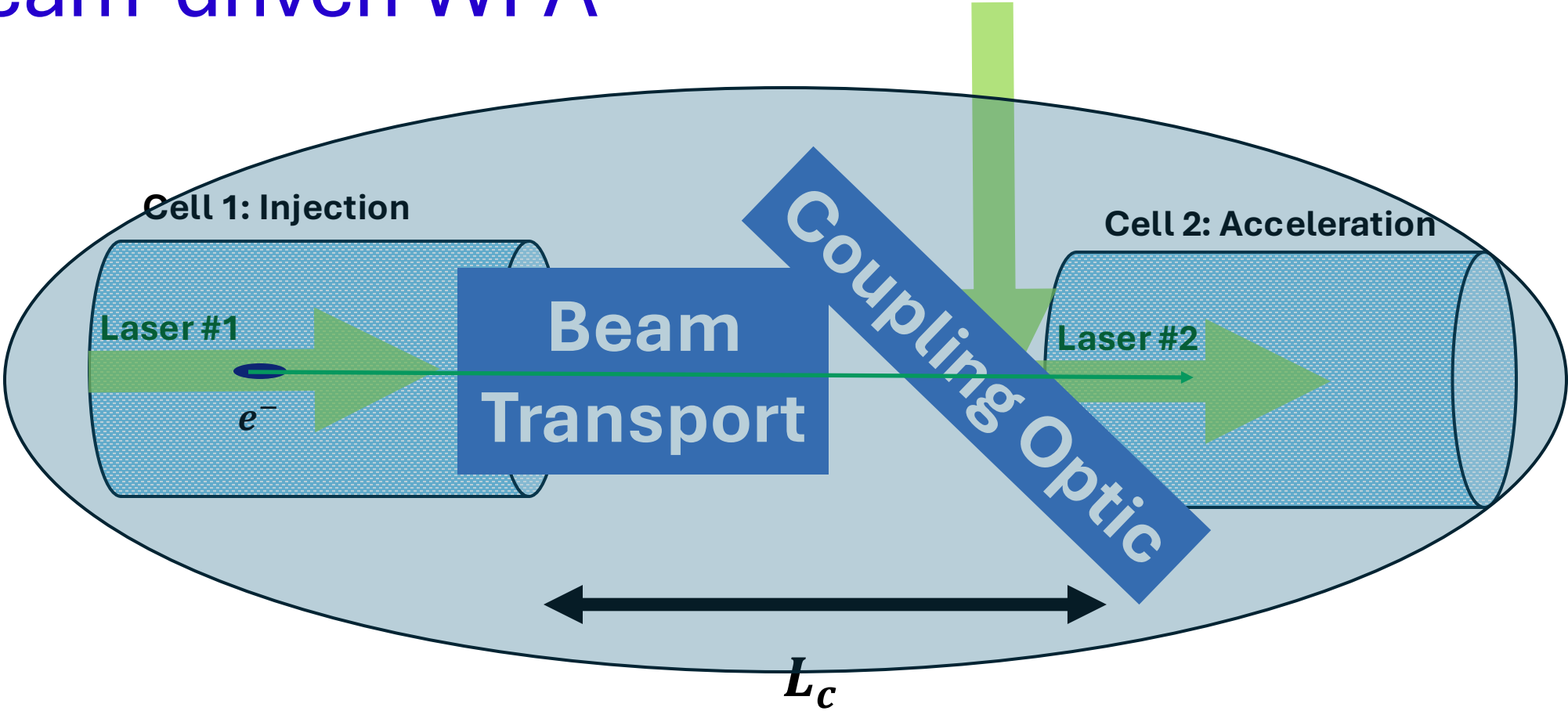


Outline

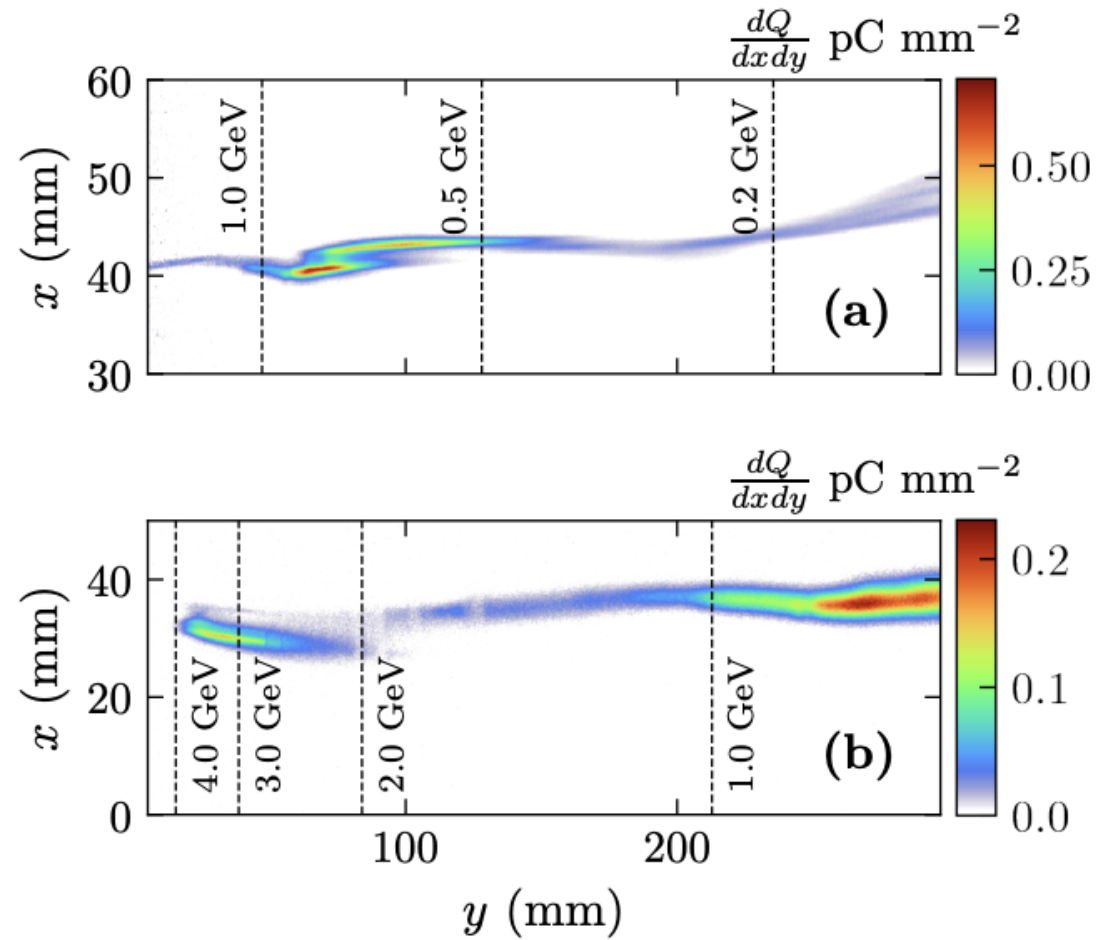
1. Beam Blow up between stages
 - Modelled and implemented experimentally a novel aperture design
 - Demonstrated the production of low divergence (<0.2 mrad) beams
2. Coupling in the driving beam
 - Plasma mirror reflectivity (max 80%) and reflected beam quality highly dependent on pre-plasma
 - Improvements operating at close focus – taking advantage of spatial filtering effects
3. Driving a stable wakefield in the acceleration cell
 - Able to drive a wakefield to injection
 - Injection occurred at a lower than expected threshold, indicating contribution from outside the FWHM
4. Bonus: Beam driven acceleration to 4 GeV



















Bonus: Beam-driven WFA



Bonus: Beam-driven WFA



Many thanks to all the collaborators that made this possible

J. A. Hills^{1,*}, M. P. Backhouse¹, R. Luo¹, P. Blum², N. Bourgeois⁵, C. Cobo¹, E. Gerstmayr⁴, J-N Gruse¹, L. Kennedy¹, N. Lopes³, E. Los¹, G. Sarri⁴, J. Sarma⁴, R. Shalloo², M. Streeter⁴, and Z. Najmudin¹

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Questions?