# FACET-II

Facility for Advanced
Accelerator Experimental Tests

# E-301 Plans for 2024

## 2023 FACET-II User Meeting

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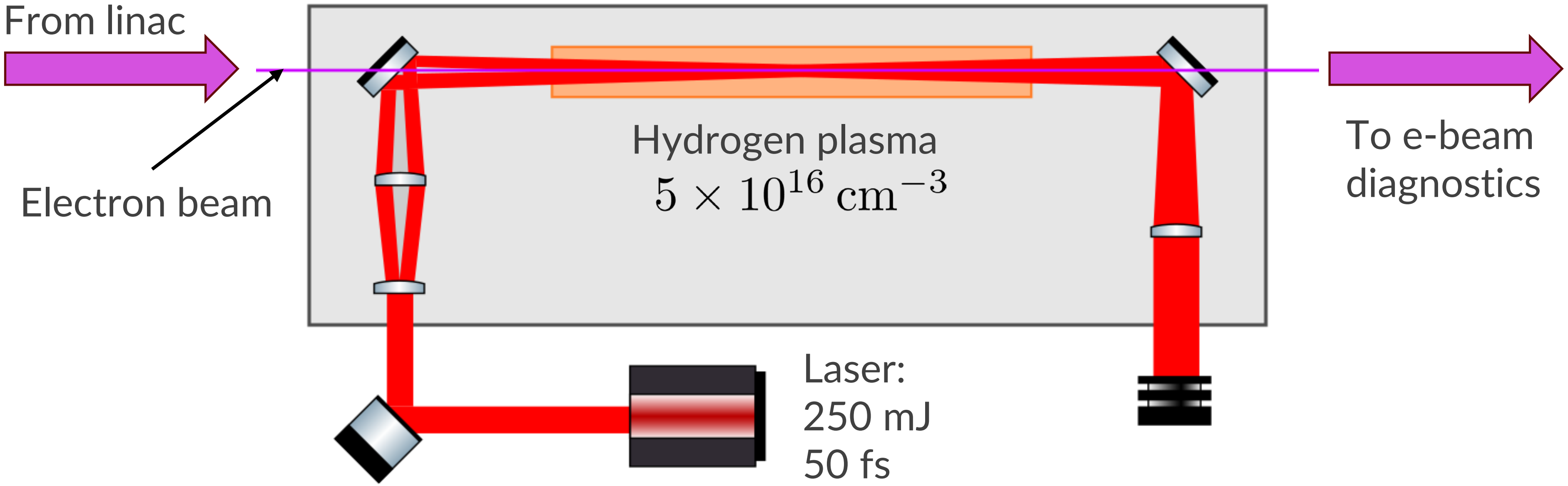
October 17-19, 2023

SLAC NATIONAL ACCELERATOR LABORATORY

Stanford University | U.S. DEPARTMENT OF ENERGY

# E-301 Overview

- Laser ionized plasma source in a filled chamber
- Semi-arbitrary longitudinal density profile
- Optically accessible
- Permits the use of gas jets along the plasma




**PWFA capabilities in a tunable plasma that is physically and optically accessible.**

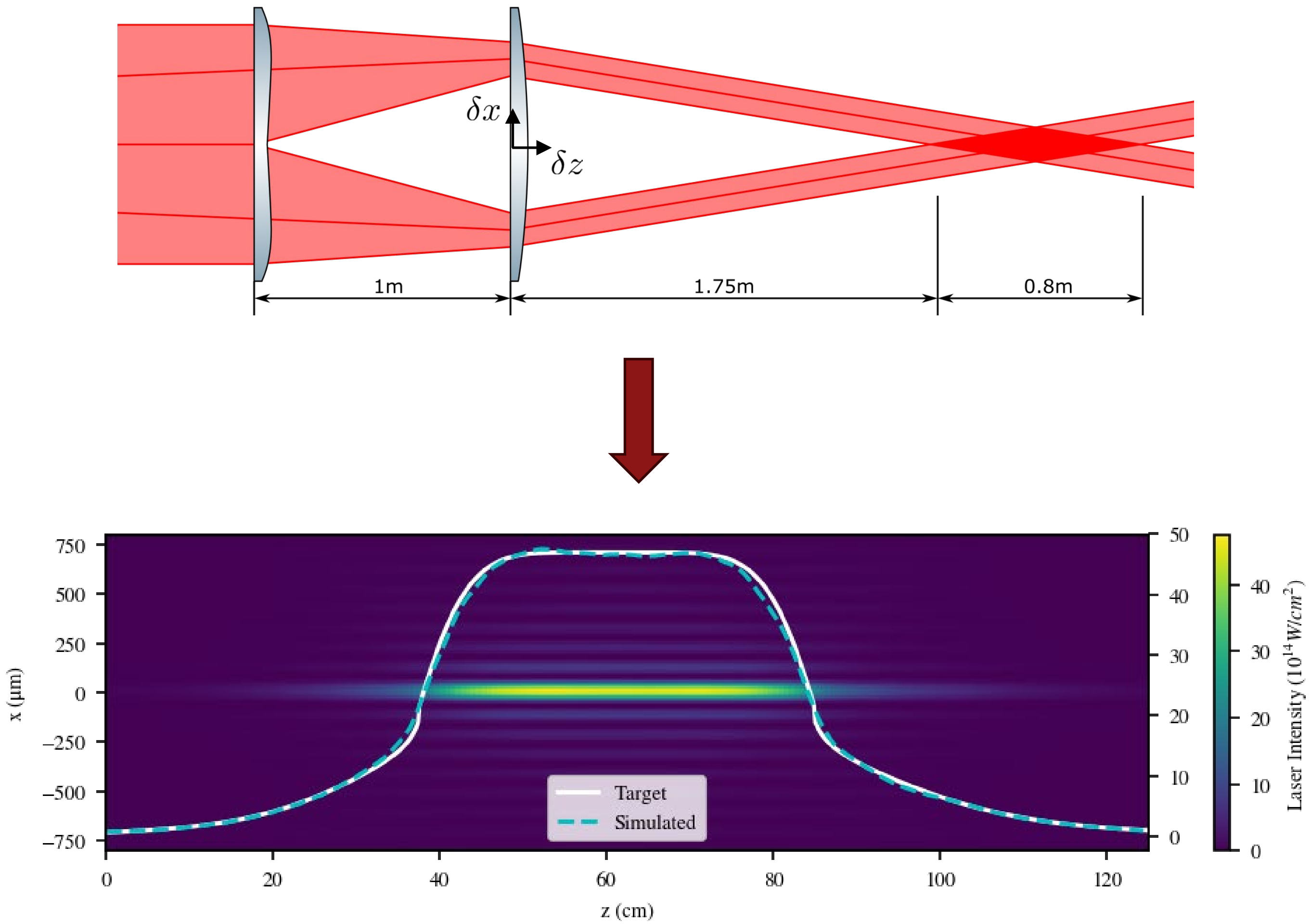
# E-301 Science goals

- 10 GeV scale PWFA stage (2-3 years)
  - High energy gain
  - High driver-witness efficiency
  - Low energy spread
  - Full charge transmission
  - Emittance preservation
- Detailed PWFA physics studies (2-3 years)
  - Longitudinal beam dynamics: loading, transformer ratio, efficiency
  - Transverse beam dynamics: chromatic phase mixing, hosing (E-302)
- Platform for other experiments (2-5 years)
  - High brightness beam injection (E304, E307, E31X)
  - Narrow channel electron and positron PWFA (E333)
  - Ion channel laser (E306)

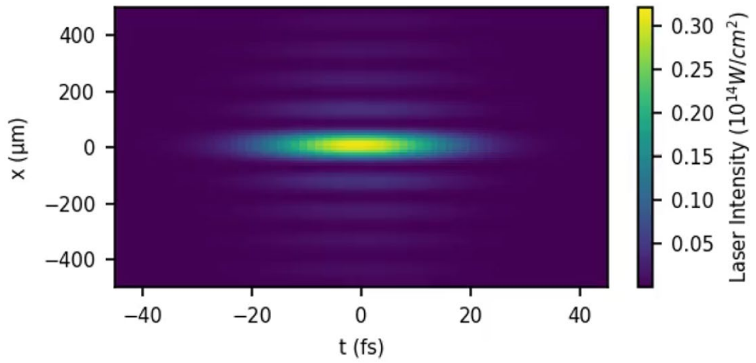
**Achieving E-301 science goals enables many other experiments.**

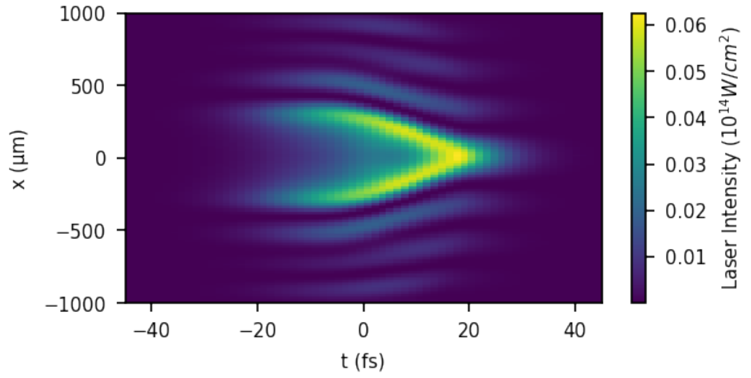
# E-301 Optical setup

**Tandem lens can produce a near arbitrary on axis intensity profile (also have a 0.7° axicon)**

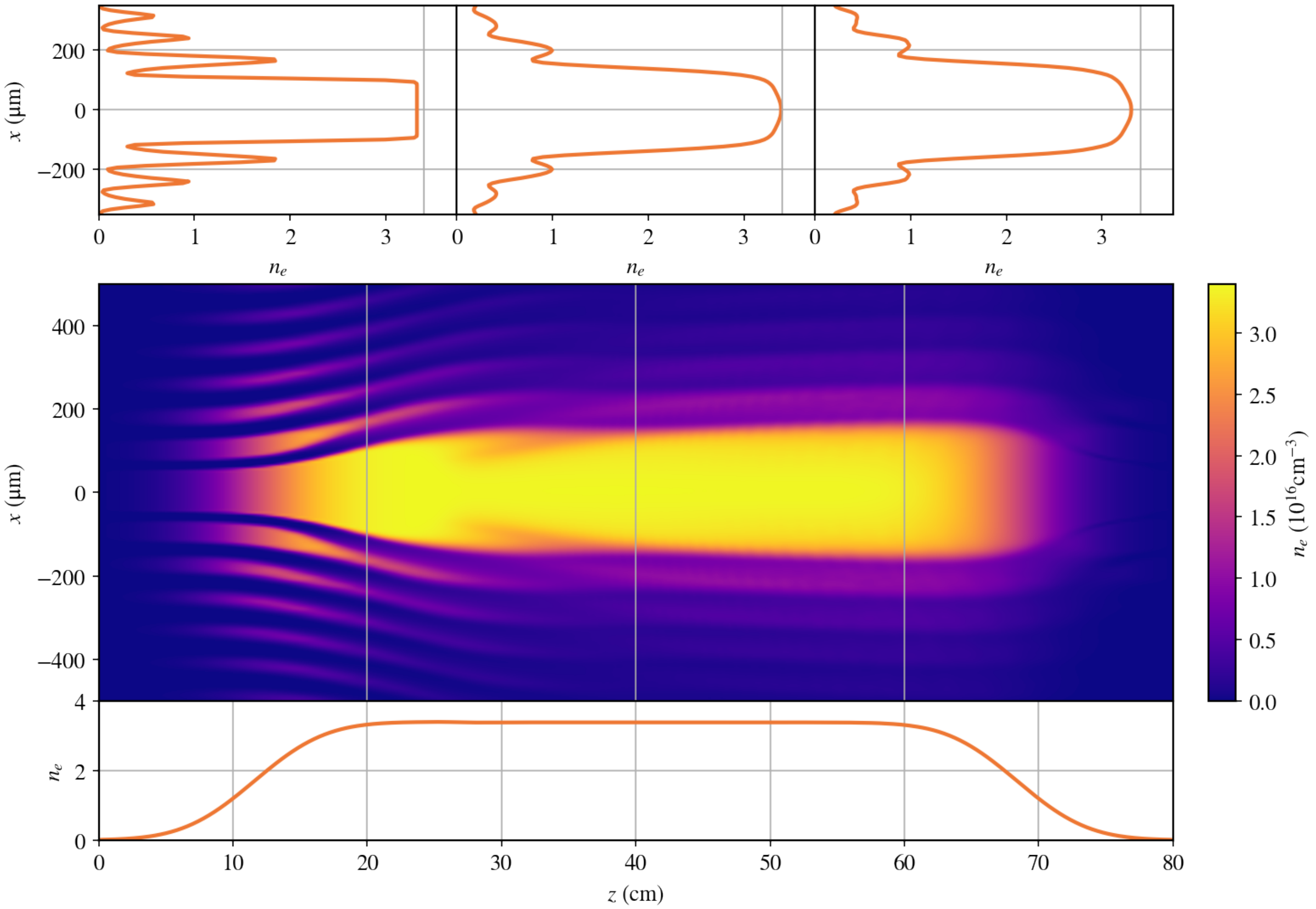



Broadening due to plasma index



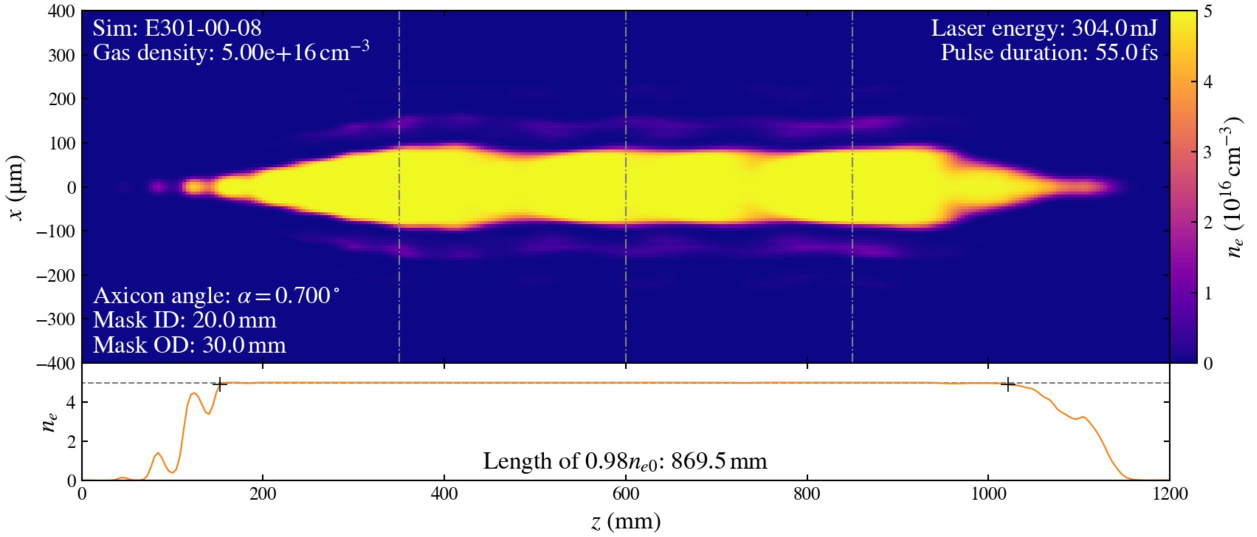
# Expected plasma – pre-ionized lithium

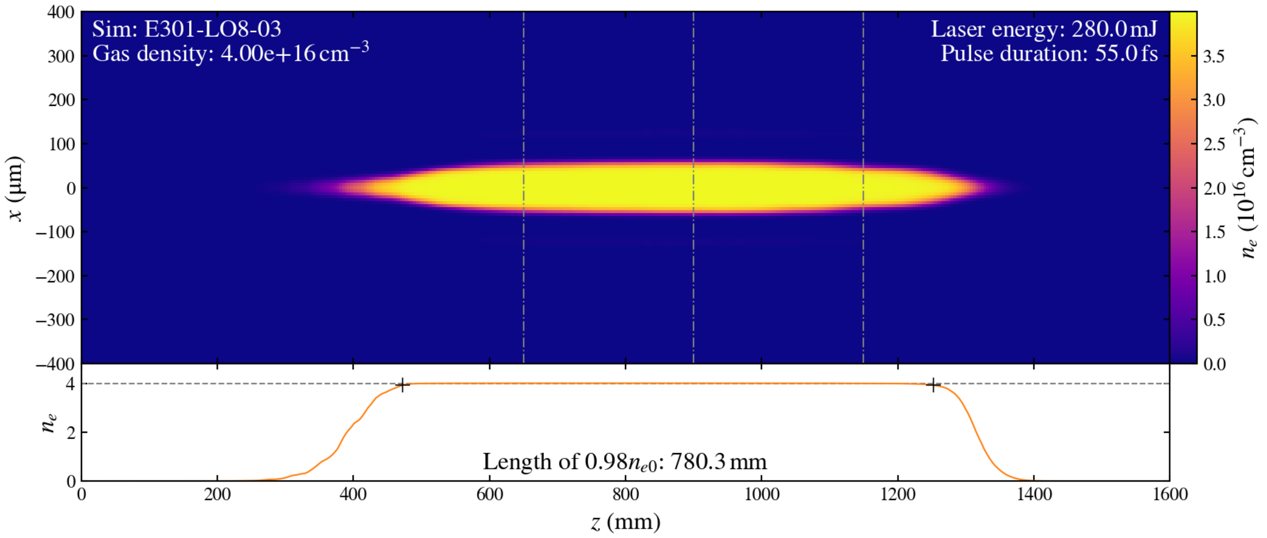


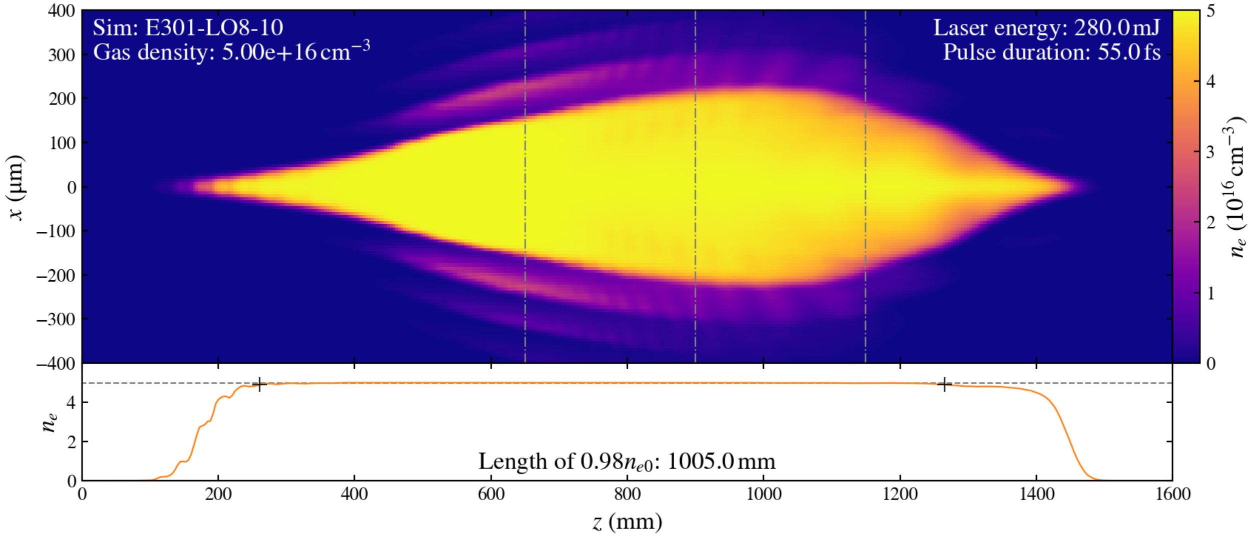
# E-301 Expected plasmas

**Goal is a fully ionized plasma, as wide as possible.**

- Not enough laser energy to get a wide plasma in He.
- Either axicon or tandem lens produces a good H2 plasma.
- The tandem lens delivers almost three times the energy to the target – leads to a wider plasma.
- Bubble size about $\lambda_p = 150\,\mu m$ (target width $195\,\mu m$)

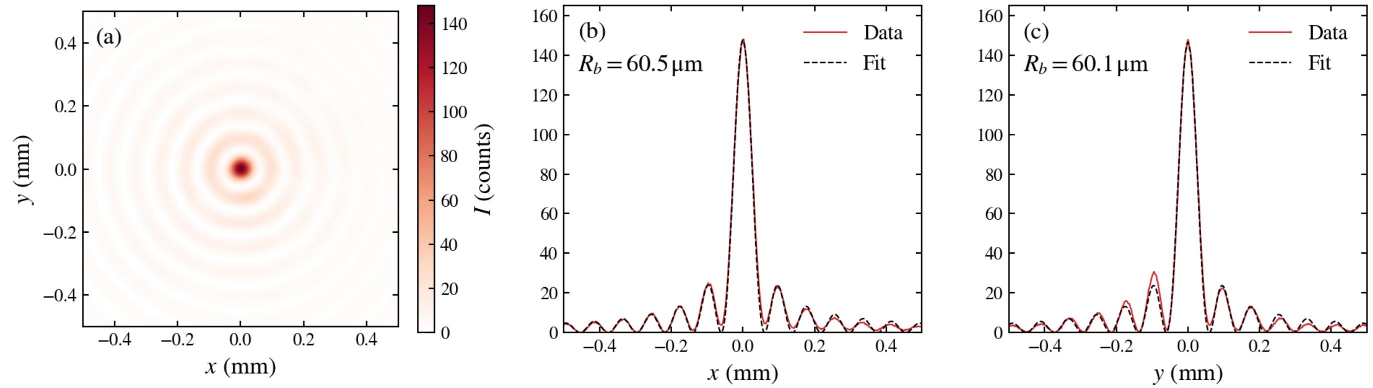


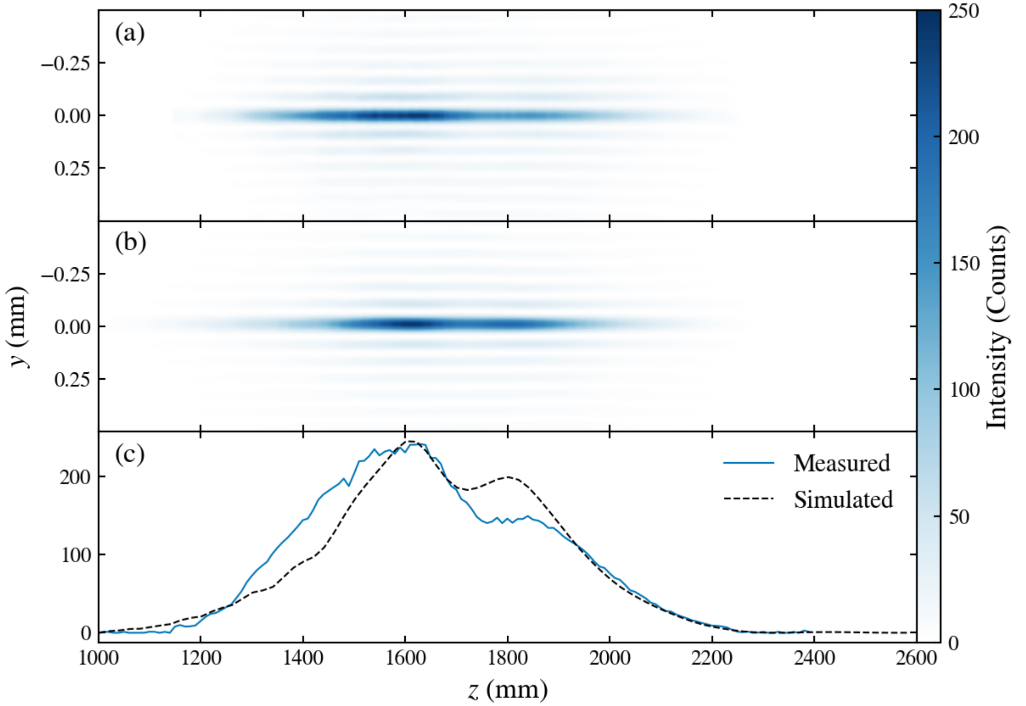



# E-301 Current state - optics

- One set of tandem lens has been made
  - Tested at University of Colorado
  - Performs as expected from simulation
  - Designed for the lithium oven

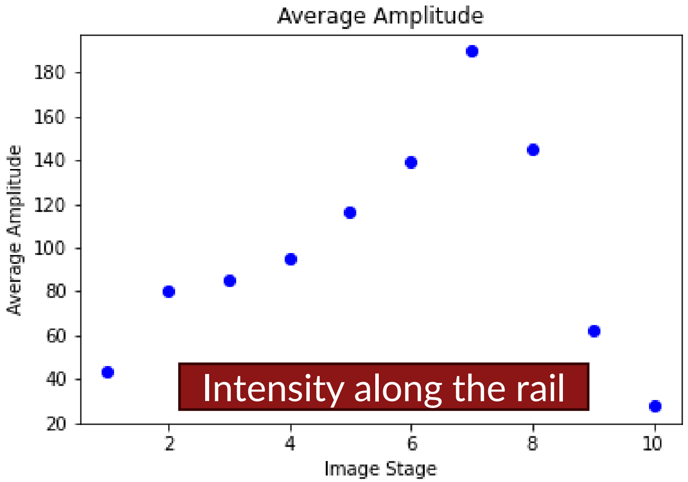


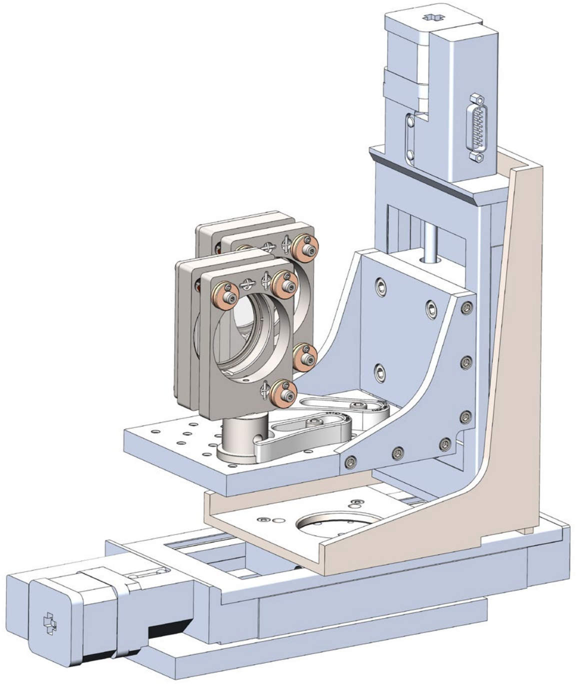

**Optical technique/design software validated**

# E-301 Recent upgrades

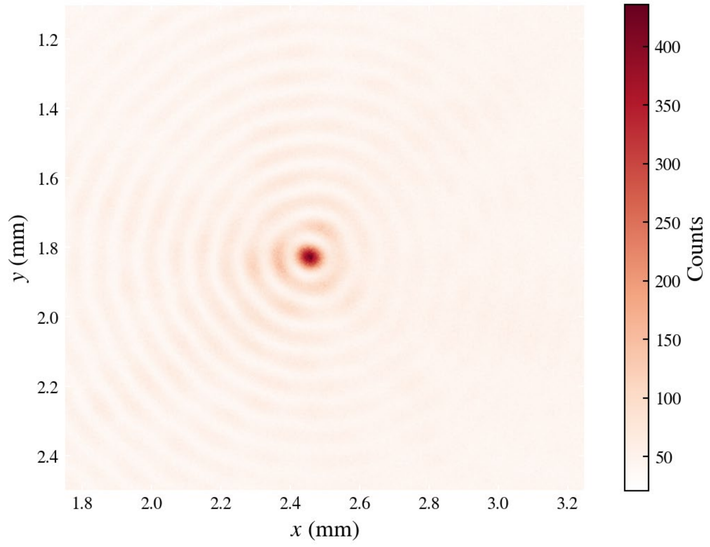
- Two axis mover in the compressor
  - 2D raster scan tandem lens
- Motorized rail camera
- DSHM Near and Far setup
  - Observe broadening due to refraction



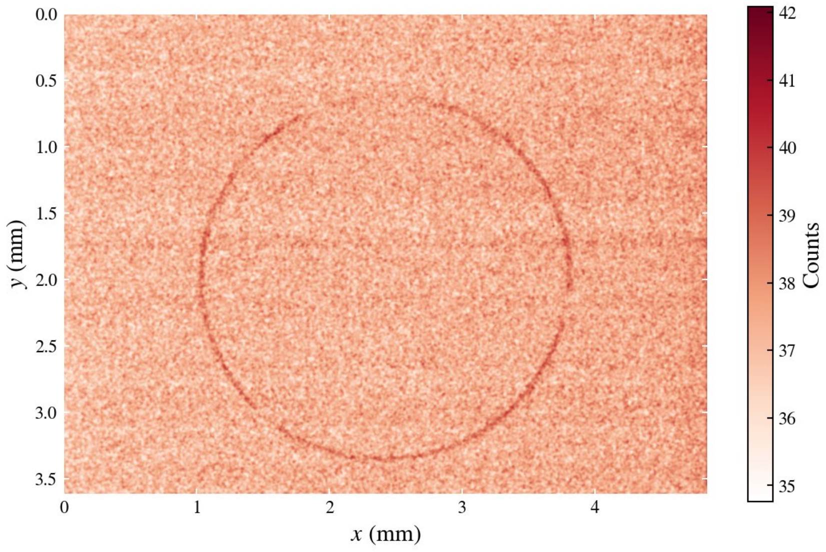

Intensity along the rail



Lens mover in the compressor



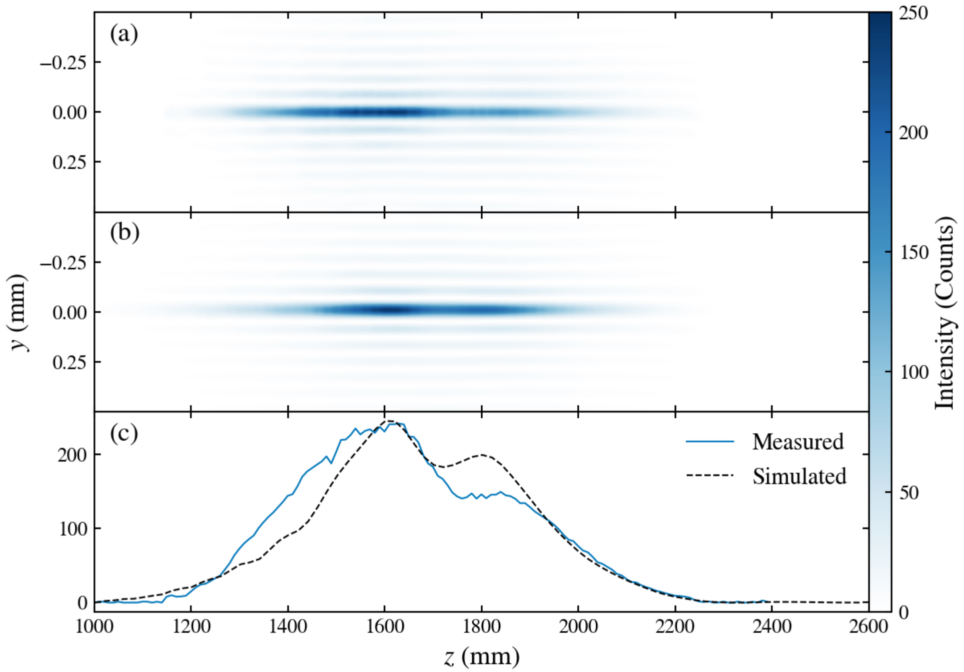

DSHM Near

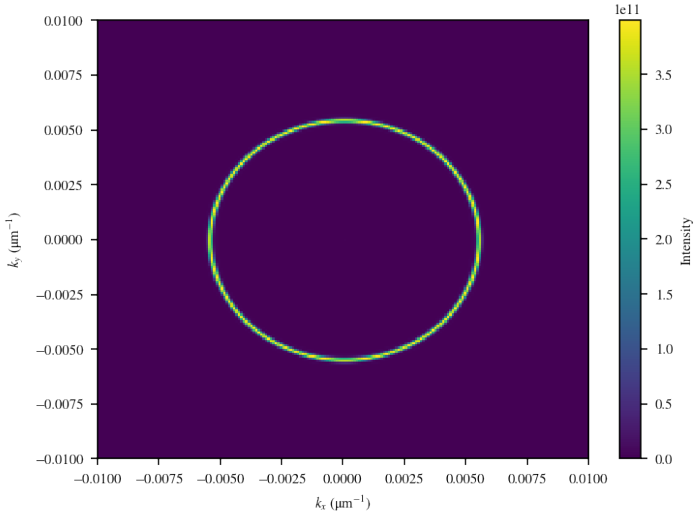


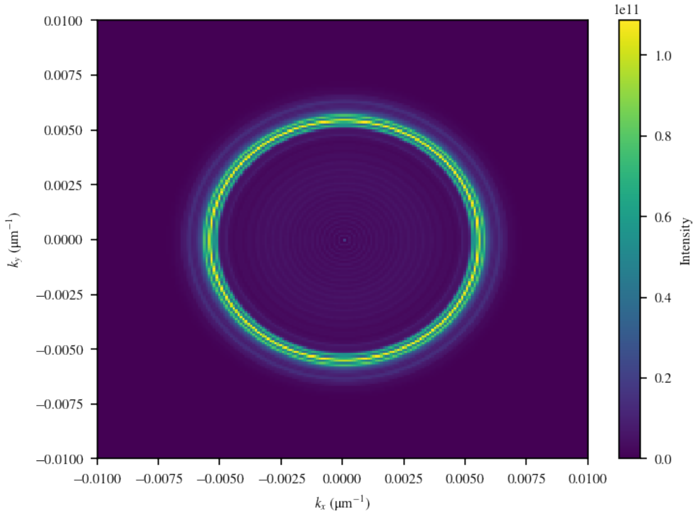

DSHM Far

# E301 Plans for 2023 – Axicon only

- Measure intensity along the focus in-situ
- Ionize H2 and observe broadening of the spot
- Send single bunch through laser-ionized plasma
  - Raster scan the plasma across the electron beam
- Interested in beam ionization in H2 with laser heater



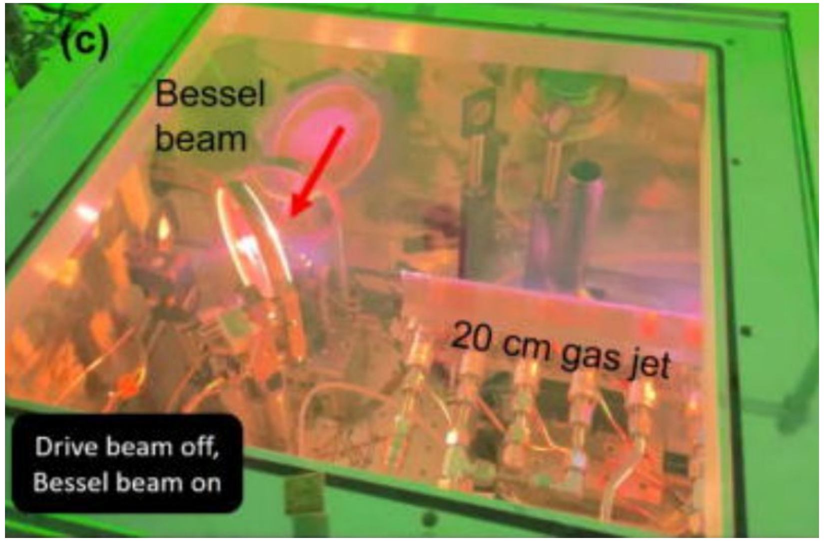
# E301 Plans for 2024

- Repeat intensity/ionization measurements with the tandem lens
- Single bunch PWFA studies
  - Drive bunch depletion
  - Beam matching of the tail
- Two bunch (when available) PWFA studies
  - Clean acceleration of the witness

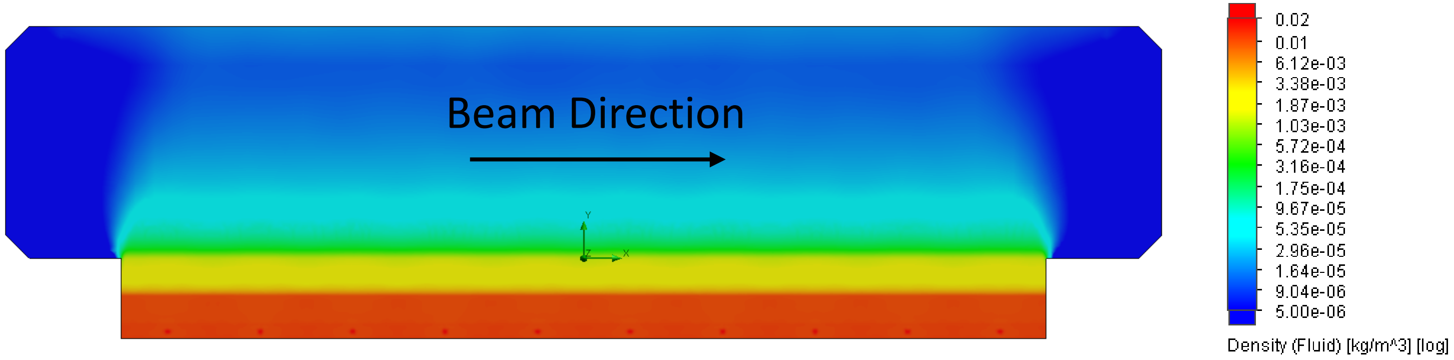
**Understand the optical system and electron beam in order to design an optimized lens(es).**

# E-301 Future evolution

- Extreme beams will ionize the partially ionized plasma ramps
  - Increases emittance growth
- PWFA applications will require a high rep rate plasma source
- Elongated gas jet one potential solution




J.E. Shrock, *Phys. Plasmas* **29**, 073101 (2022)




# Summary

Everything is ready for initial experiments with/without beam

2023:

- Characterize optics with the S20 laser in the tunnel
- Measure plasma refraction effect
- Measure plasma width – raster scan

2024:

- Single bunch PWFA experiments
- Drive beam depletion
- Energy matching of the tail
- Two bunch PWFA – clean acceleration of the witness

**E-301 collaboration:**

**UCLA:** C. Joshi's group
**SLAC:** FACET-II group
**Stony Brook:** N. Vafaei-Najafabadi's group
**Ecole Polytechnique:** S. Corde's group
**University of Oslo:** E. Adli's group
**University of Colorado Boulder:** M. Litos group

Ready for e-beam for initial studies

# Questions?

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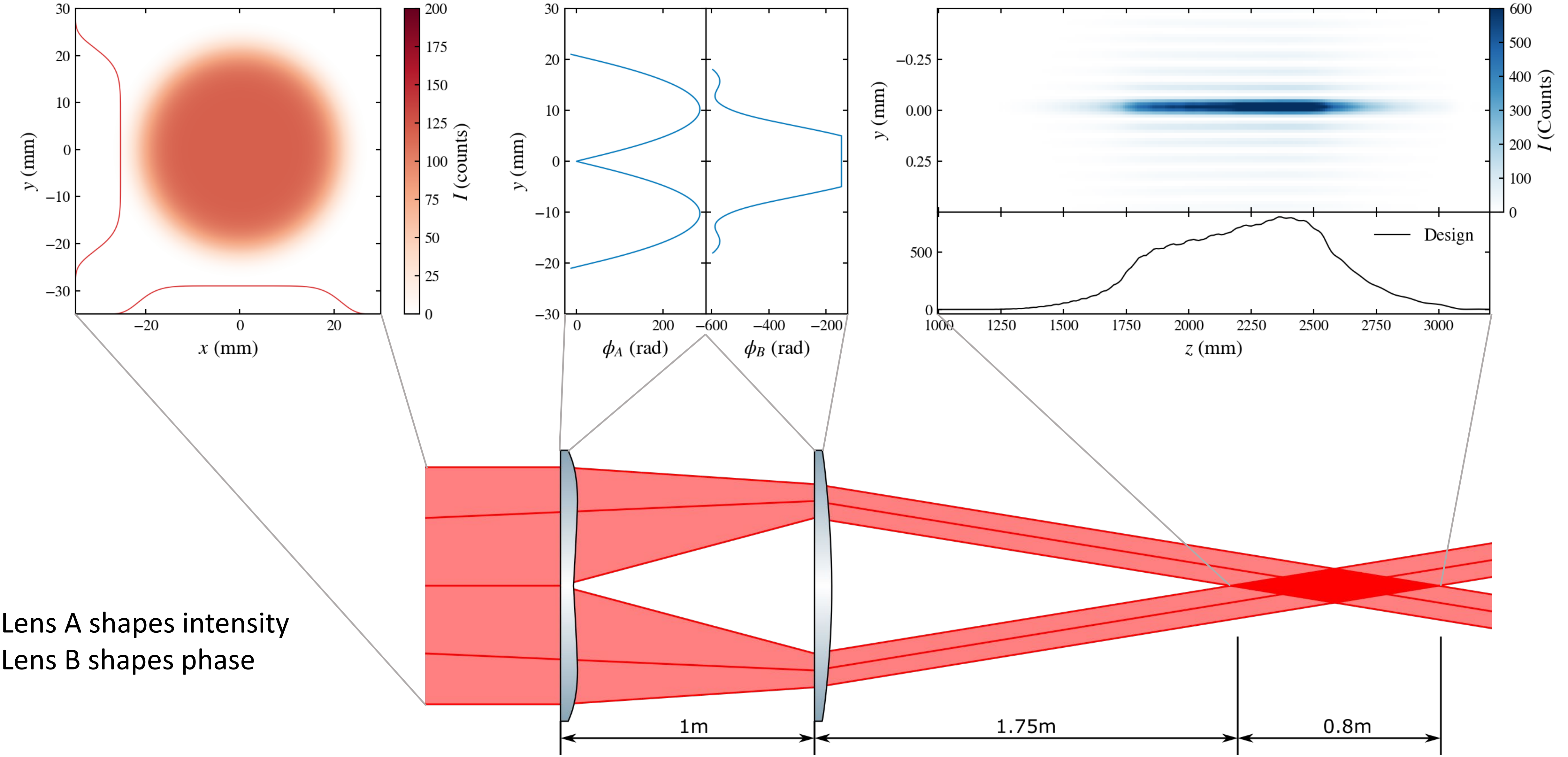
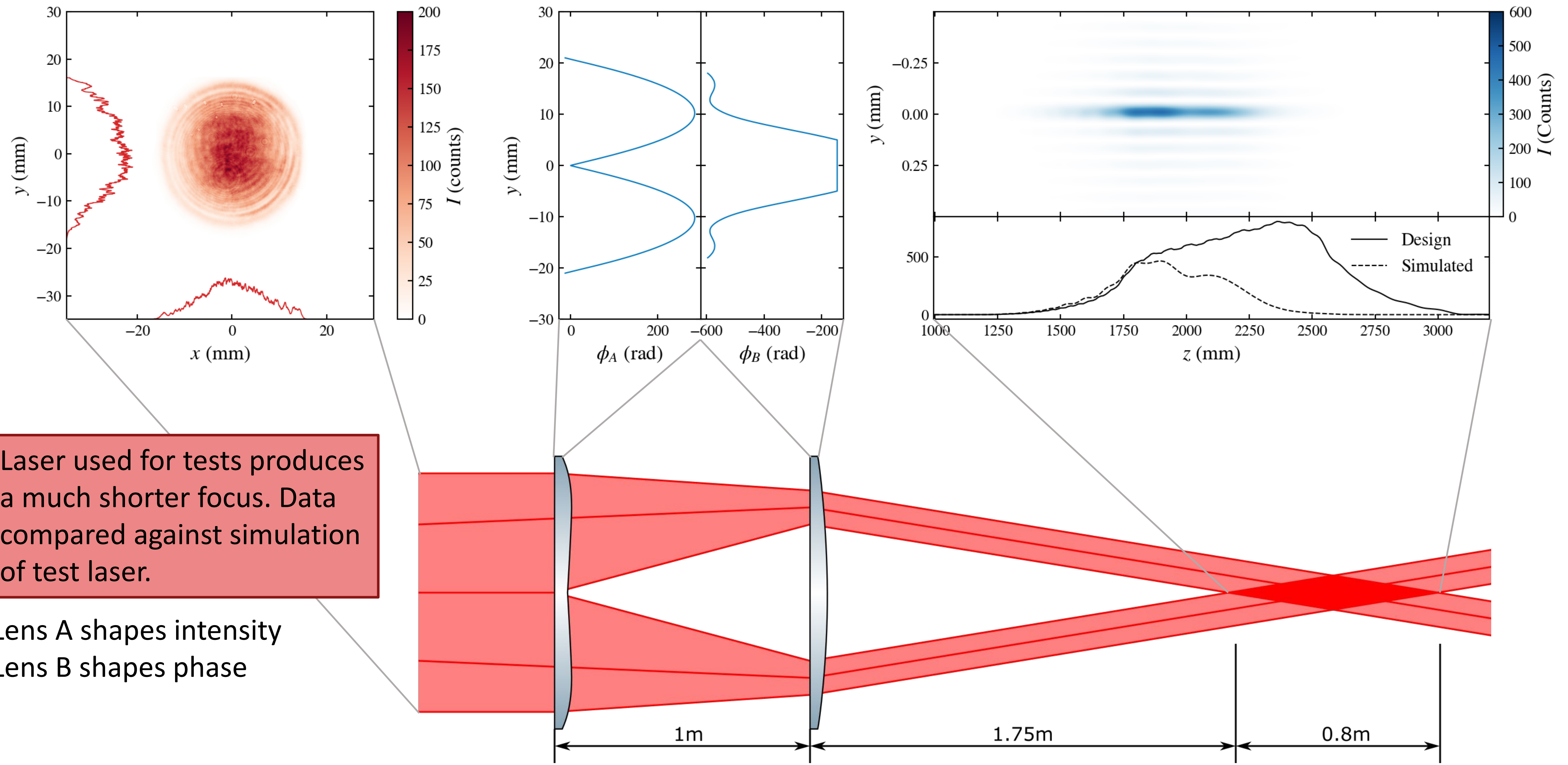
# Designed for the FACET laser




Lens A shapes intensity
Lens B shapes phase

# Tested with the CU laser




Laser used for tests produces a much shorter focus. Data compared against simulation of test laser.

Lens A shapes intensity
Lens B shapes phase

# 0.7 deg axicon, energy scan H2

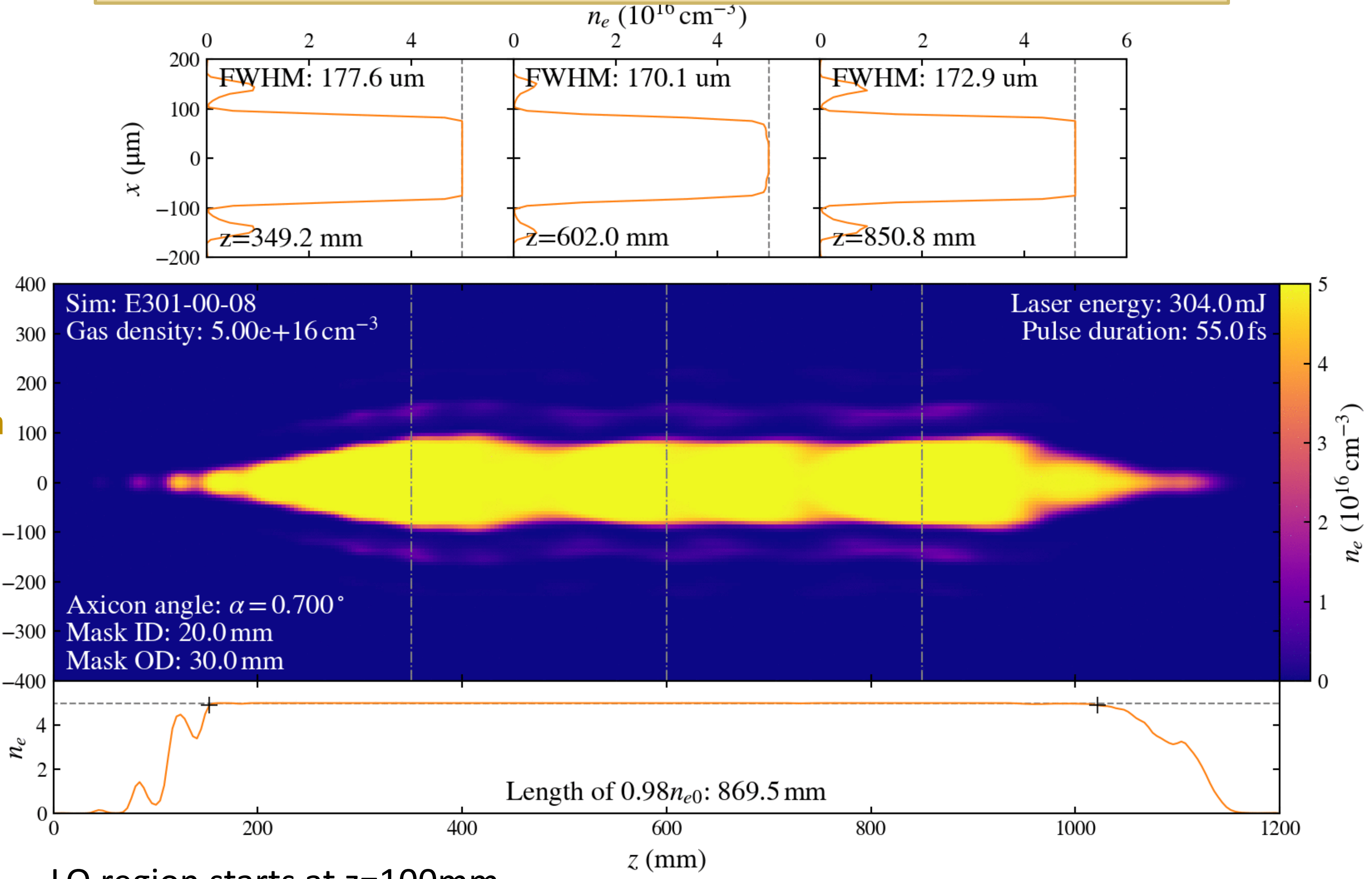
**Gas Parameters**
Gas species: H2
Gas density: 5.00e16 $cm^{-3}$
Gas profile: Filled chamber
Gas pressure: 1.52 Torr

**Laser Parameters**
Main-amp output: 800-500mJ
Pulse duration: 55fs FWHM
Wavelength: 800nm
Beam size (w0): 20.24mm
Beam profile: Super-Gaussian

**Laser Energy**
Energy to mask: 304-190mJ
Energy after mask: 114-71mJ
Energy to ionize: 2.30-1.04mJ

**Laser refraction simulation**
Split step Fourier based code.
Energy loss due to ionization.
No dispersion, no self-focusing.

Can still get something even if the laser energy is a bit on the low side.




LO region starts at z=100mm

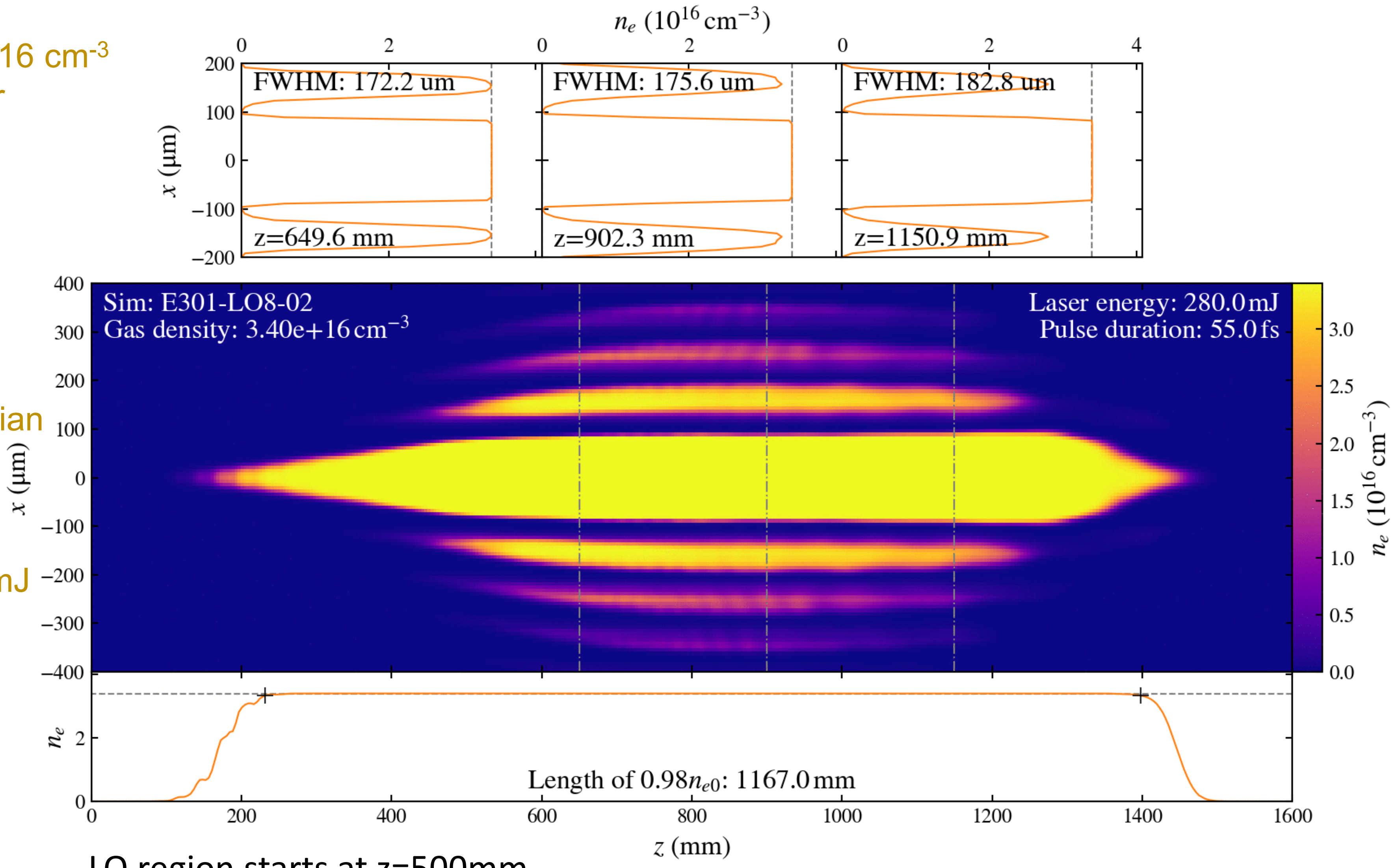
# LO8 tandem lens, density scan H2

**Gas Parameters**
Gas species: H2
Gas density: 1.70e16-4.50e16 $cm^{-3}$
Gas profile: Filled chamber
Gas pressure: 0.52-1.37 Torr

**Laser Parameters**
Main-amp output: 800mJ
Pulse duration: 55fs FWHM
Wavelength: 800nm
Beam size (w0): 20.24mm
Beam profile: Super-Gaussian

**Laser Energy**
Energy after optics: 276mJ
Energy to ionize: 6.96-20.12mJ

**Laser refraction simulation**
Split step Fourier based code.
Energy loss due to ionization.
No dispersion, no self-focusing.




LO region starts at z=500mm