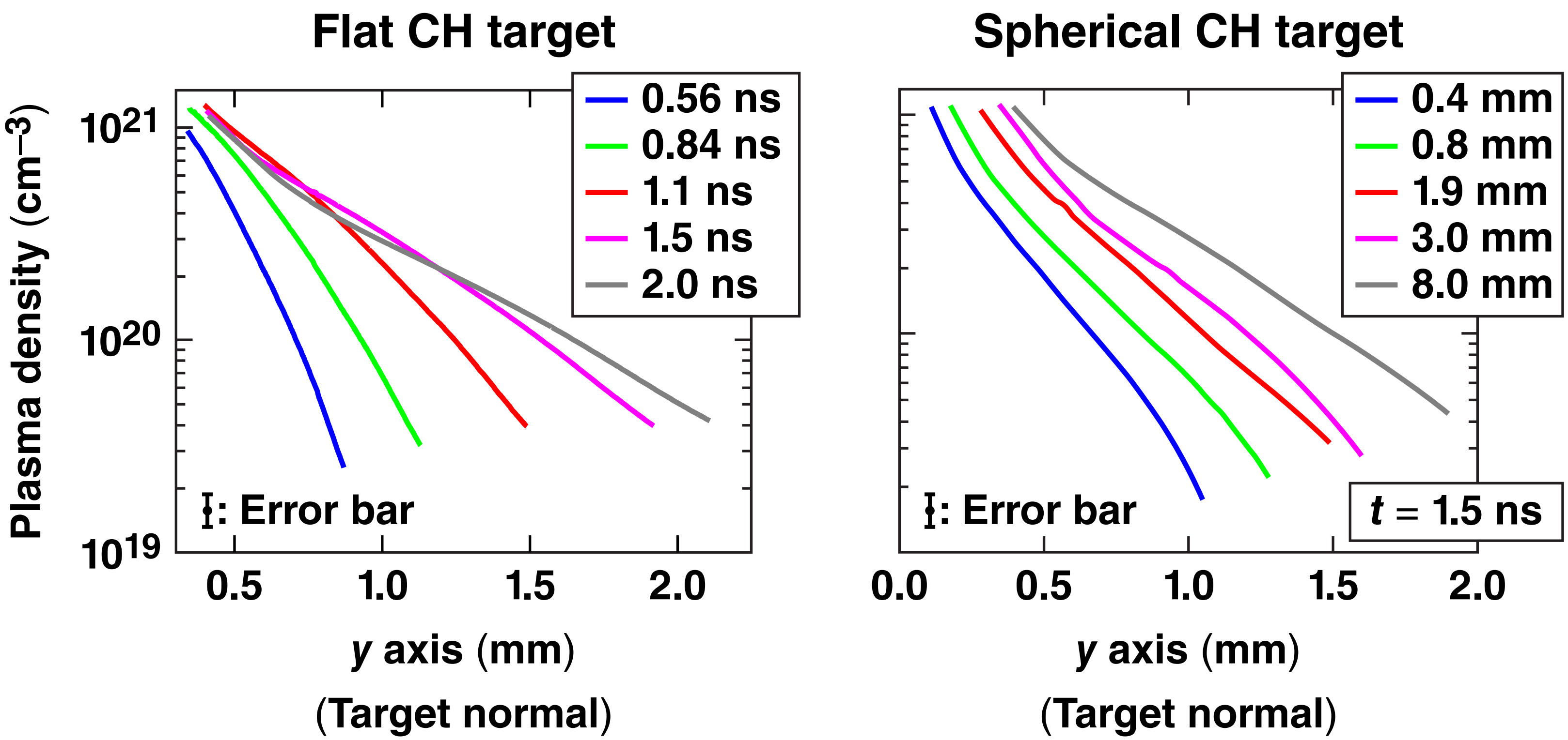
Coronal Plasma Density Characterization in Long-Scale-Length High-Energy-Density Plasmas



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American Physical Society
Division of Plasma Physics
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Summary

Measurements of the coronal plasma density profile deviate from hydrodynamic simulations at large density scale lengths

UR LLE

- Coronal plasma density profiles are measured up to 10^{21} cm^{-3} using a novel diagnostic—angular filter refractometry (AFR)
- Hydrodynamic simulations predict larger densities and longer scale lengths (L_n) late in time for flat targets and for larger-diameter spherical targets
- The discrepancies in the plasma density profiles appear to be correlated to the presence of significant two-plasmon–decay (TPD) generated hot electrons

E22503

Collaborators

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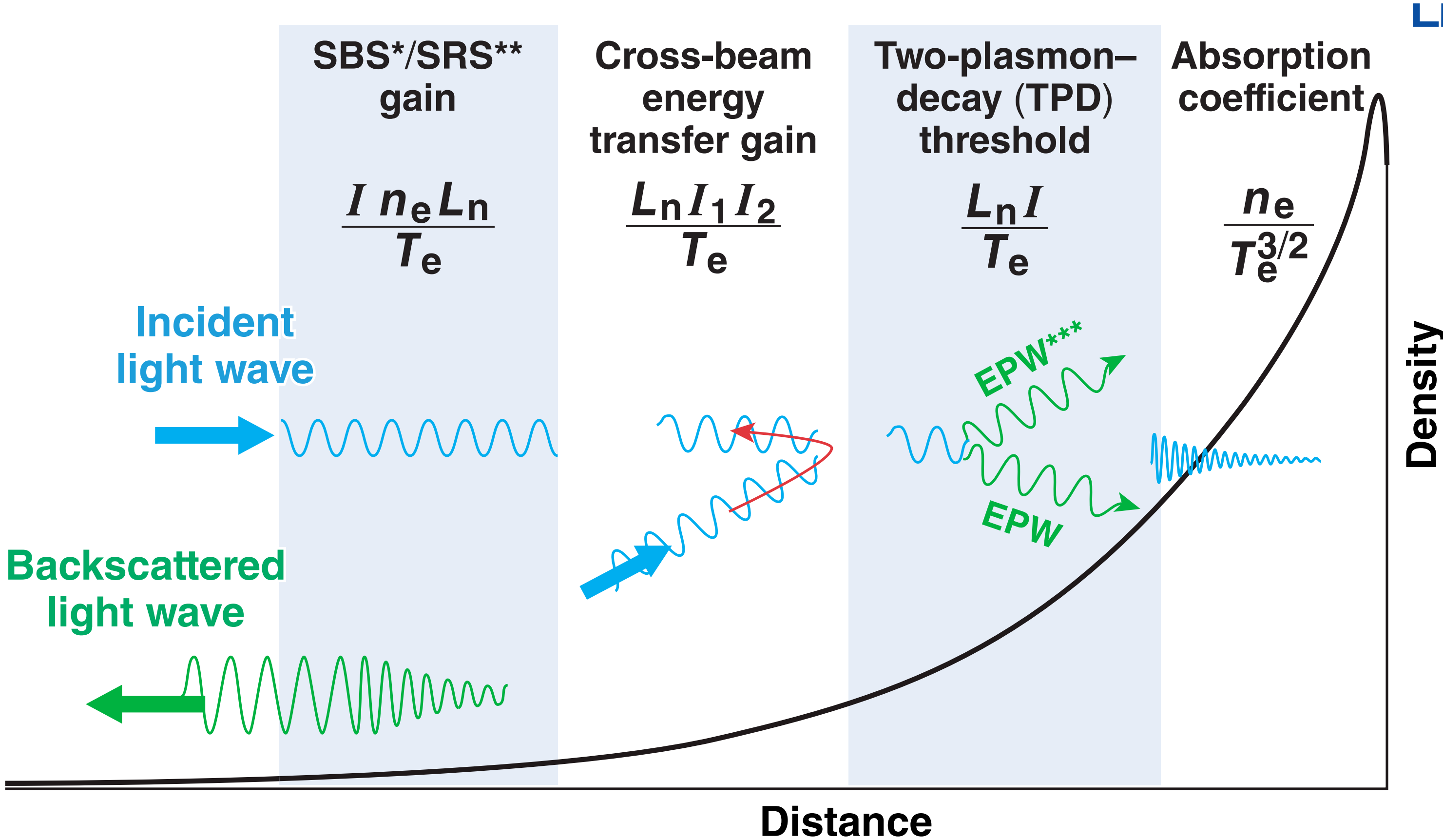
Coronal plasma density measurements are important to accurately predict the laser–plasma interaction

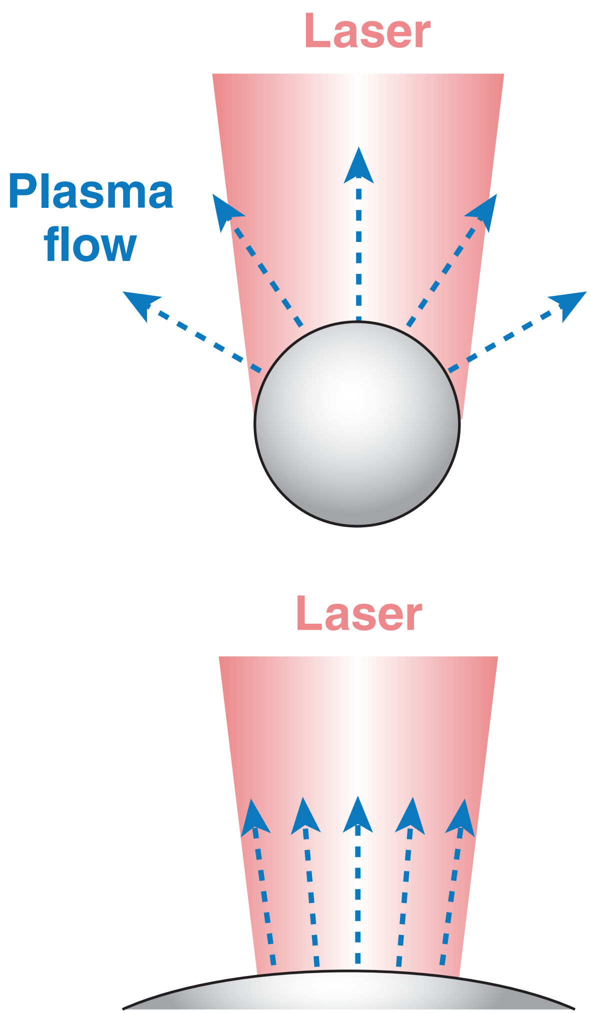


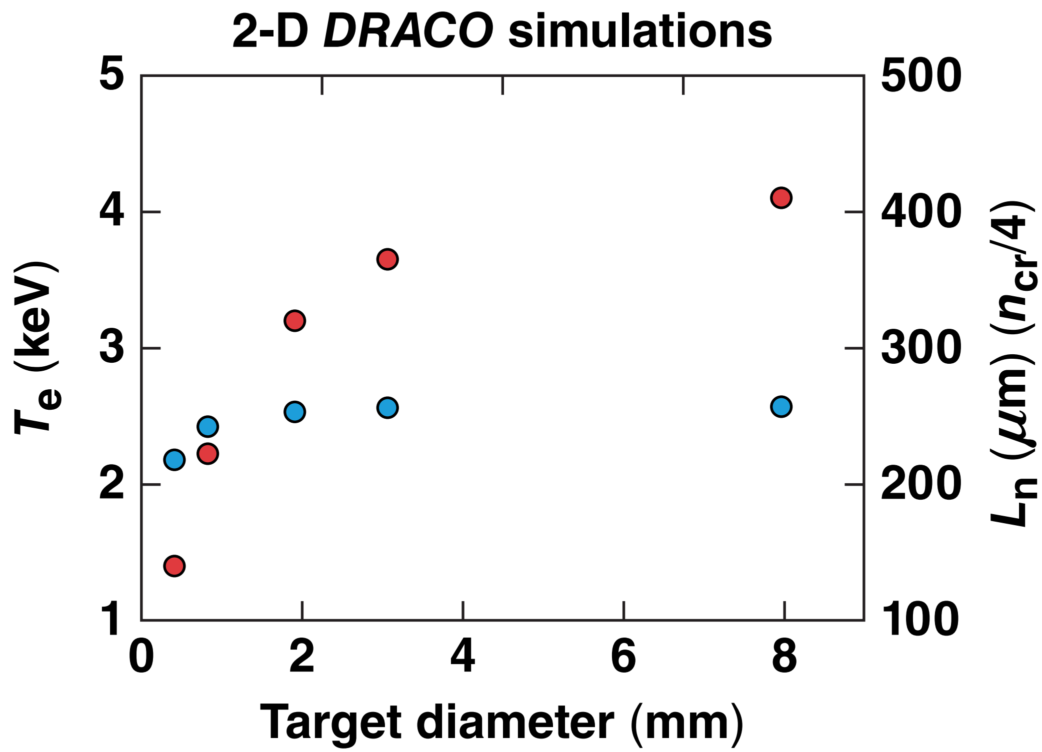
Laser–plasma instabilities can change the absorption profile and therefore hydrodynamic profile; this is a feedback process that requires experimental measurement of the density profile.

*Stimulated Brillouin scattering
**Stimulated Raman scattering
***Electron plasma wave

E19964d

The dependence of laser–plasma instabilities on the plasma scale length is isolated by using targets of varying radii



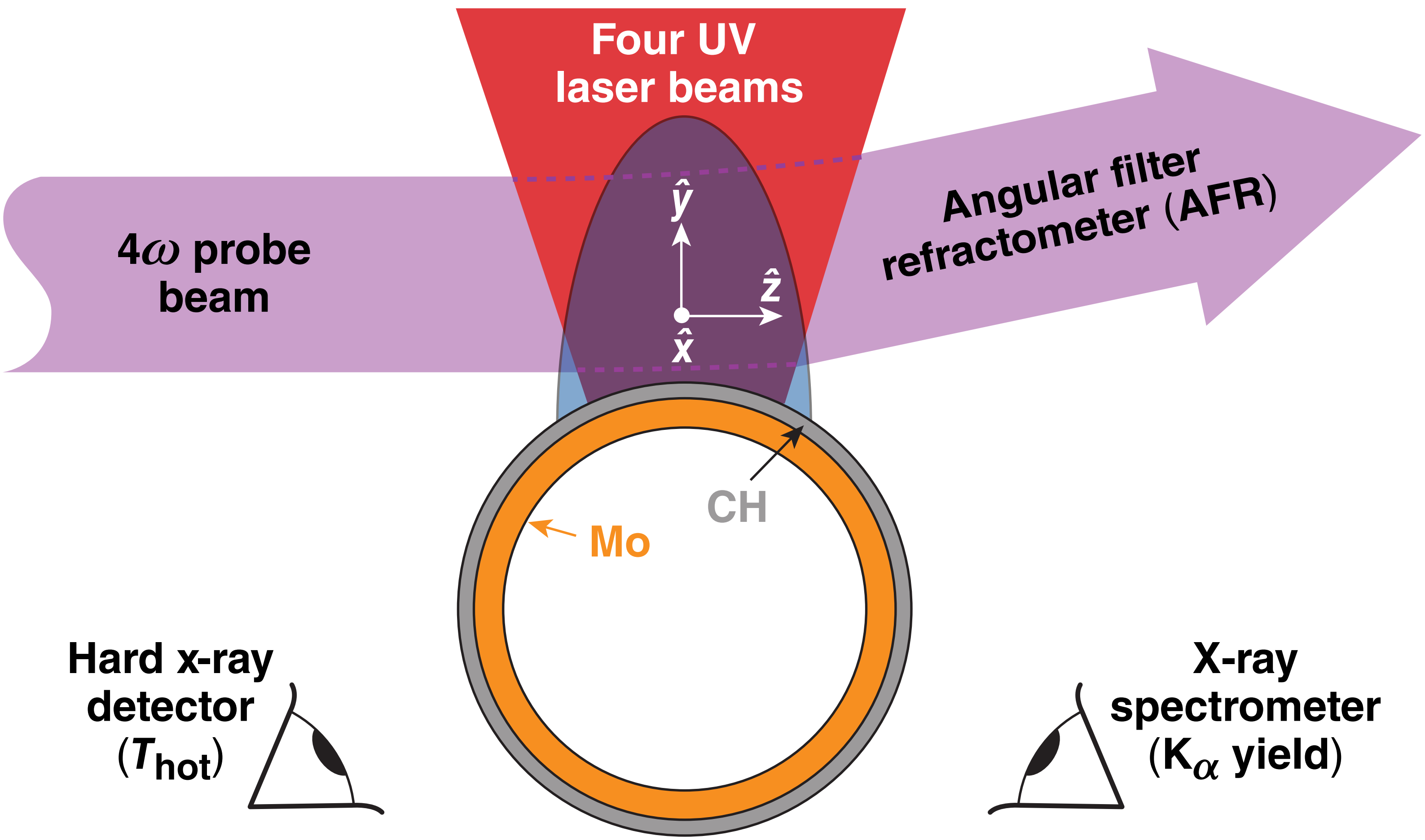


Over the range of experiments, the quarter-critical density scale length was varied by more than a factor of 3.

E22505

OMEGA EP experiments were designed to measure the plasma density scale length and the hot-electron production

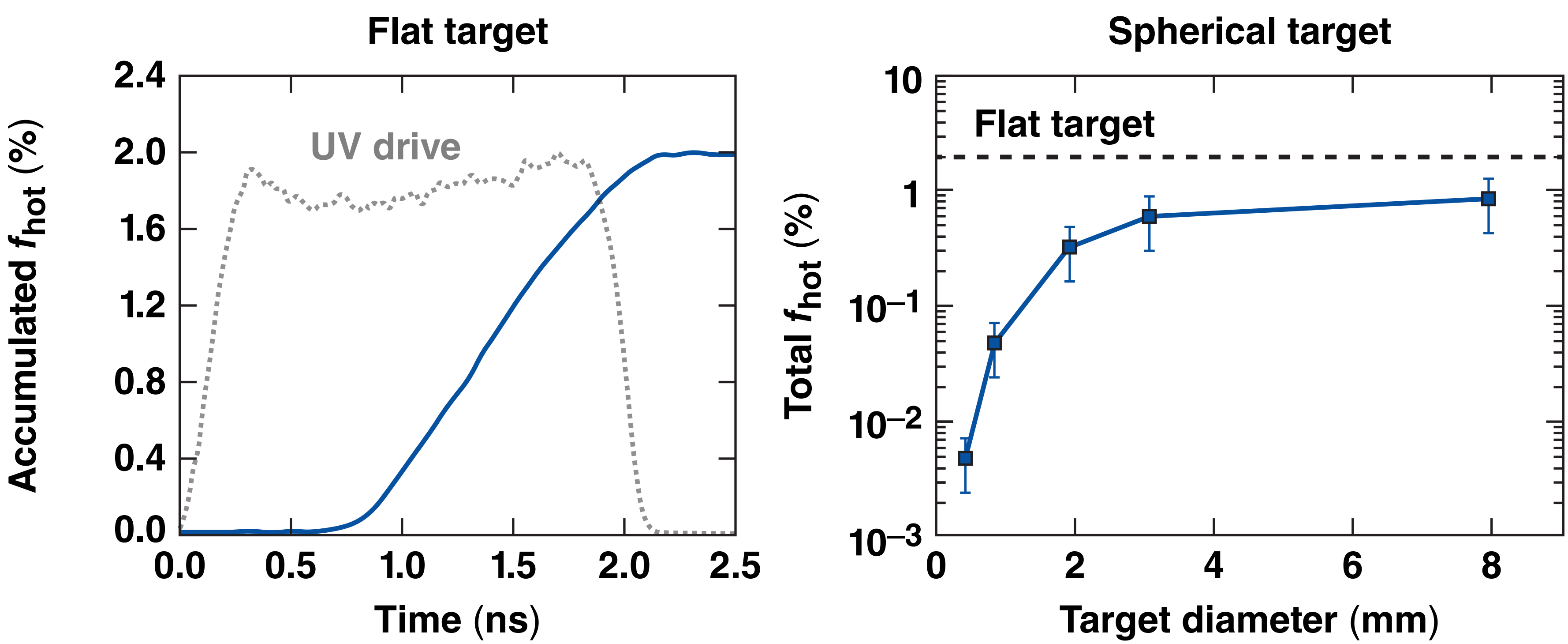
351-nm, 2-ns square, 9-kJ, 1-mm spot (DPP*)



*Distributed phase plate

E22055b

The presence of two-plasmon decay (TPD) is observed through measuring the fraction of laser energy converted to hot electrons (f_{hot})



E22554

The OMEGA EP 4ω probe laser system was used to measure the plasma density profiles

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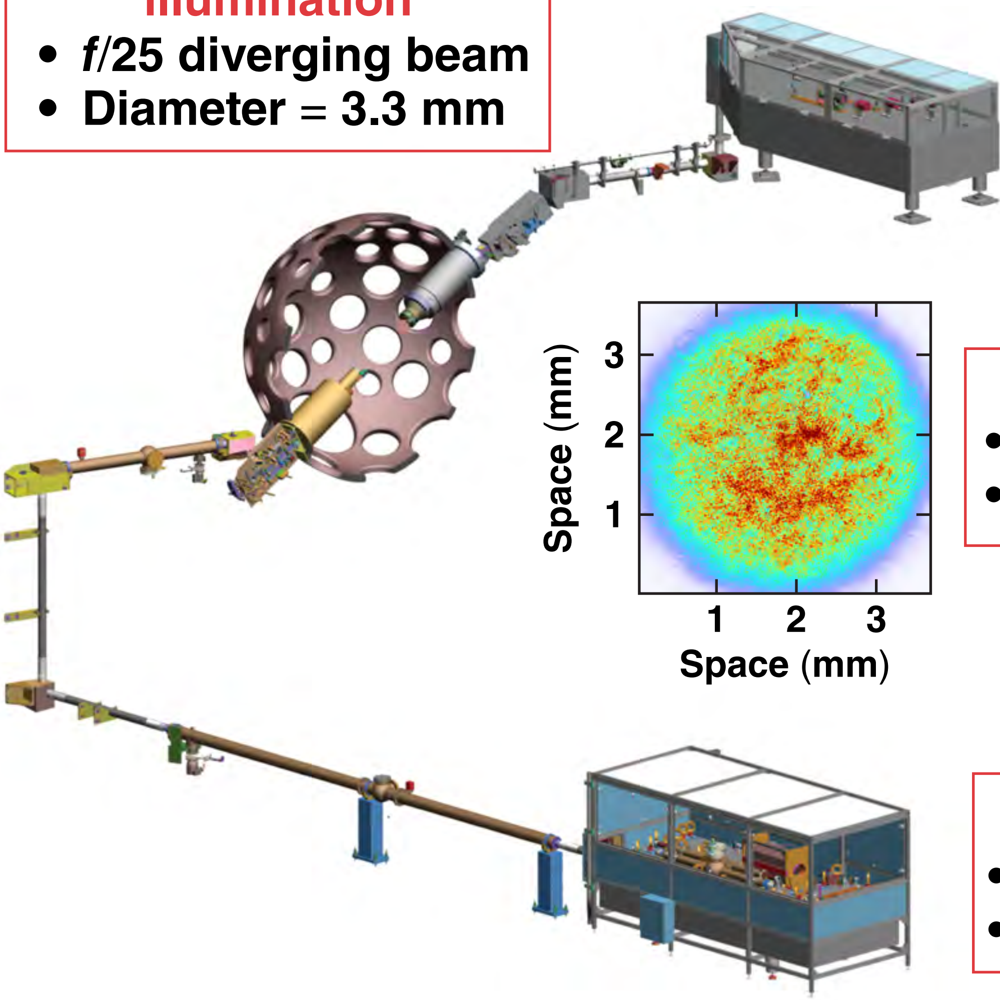
Target chamber center illumination
- *f*/25 diverging beam
- Diameter = 3.3 mm

Diagnostic table
- 5-μm resolution
- 3.7 × 3.7-mm field of view

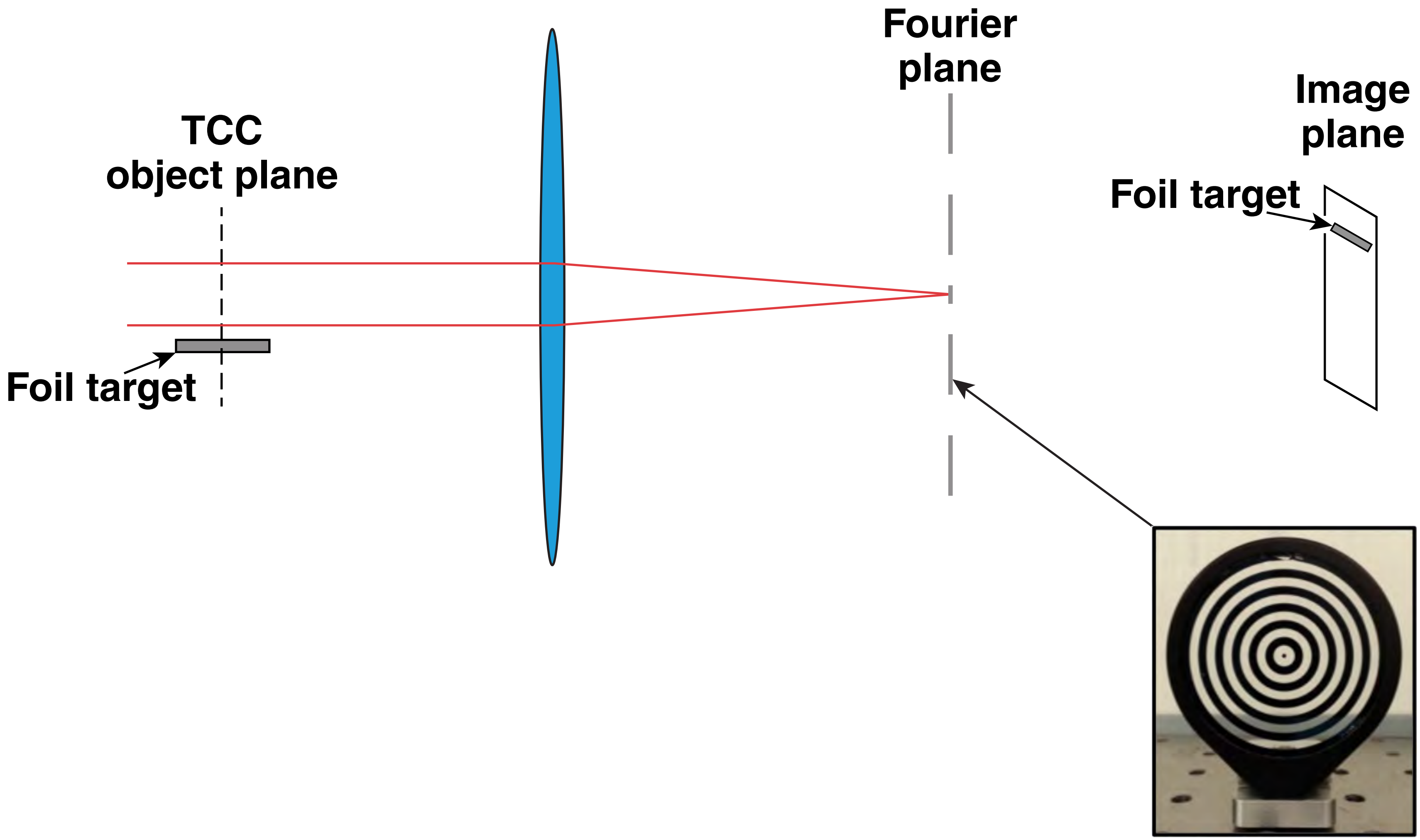


Timing
- ±50-ps accuracy
- ±20-ps post-shot measurement

Nd:glass laser
- 4ω (263 nm) ~ 20 mJ
- Pulse width = 10 ps

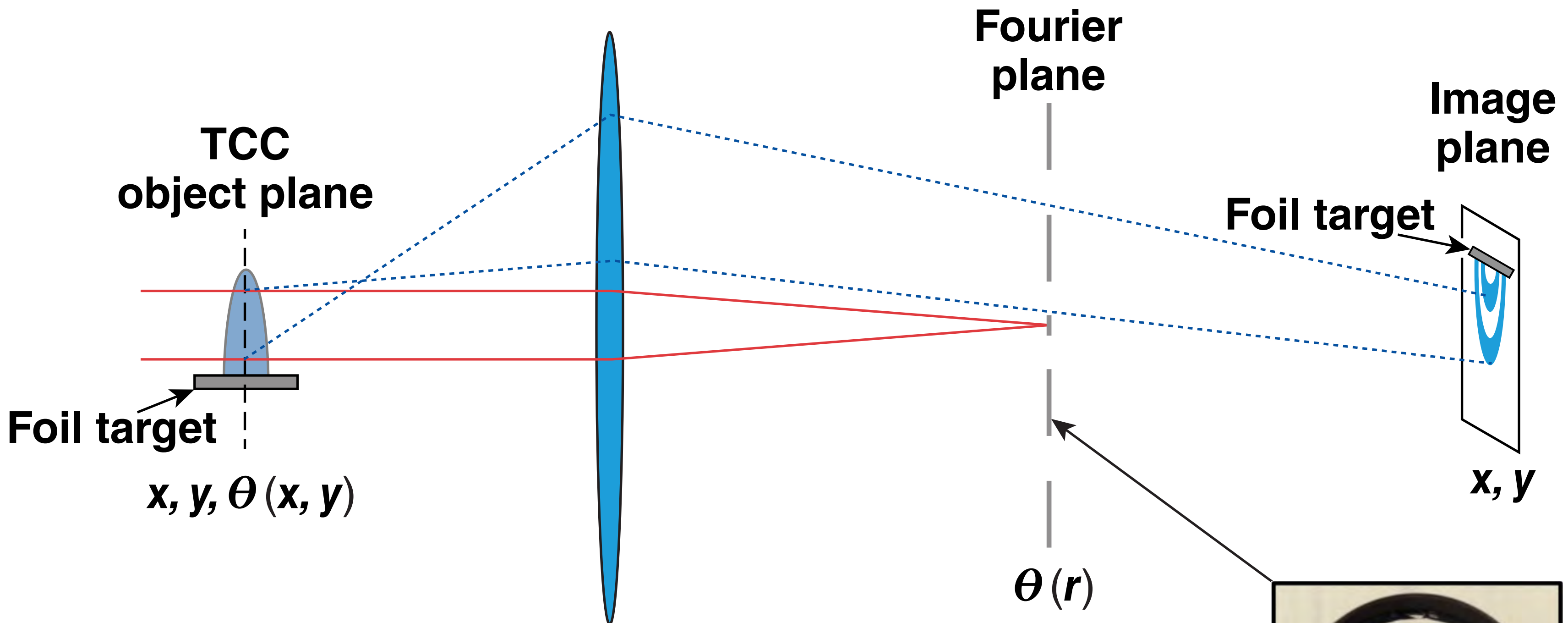
E22054b

Angular filter refractometry (AFR) maps the refraction of the probe beam at target chamber center (TCC) to contours in the image plane



E22129f

Angular filter refractometry (AFR) maps the refraction of the probe beam at target chamber center (TCC) to contours in the image plane

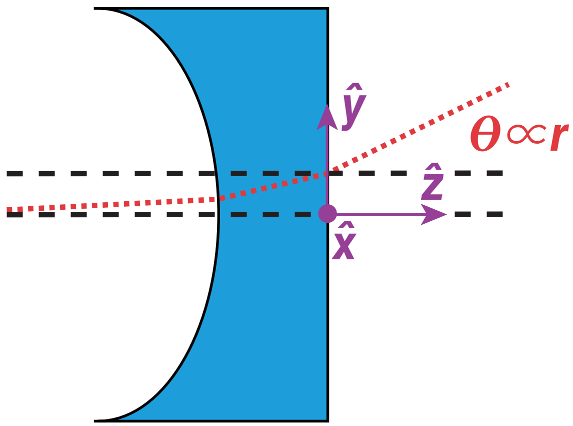


The edges of the rings map a certain refraction angle to the spatial location in the object plane.

E22129g

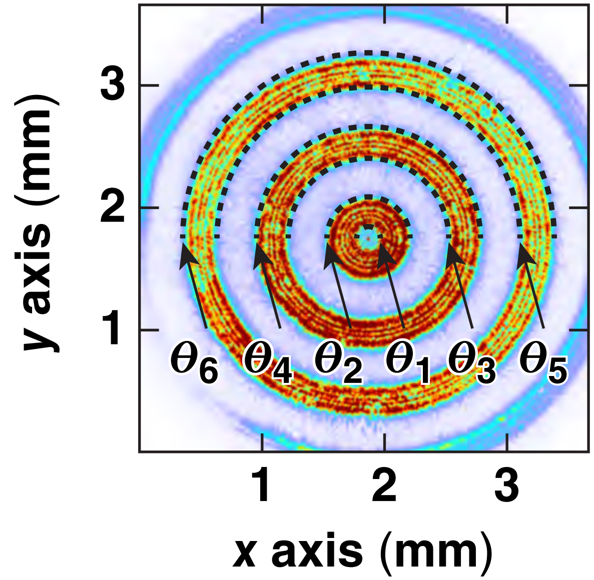
The diagnostic is calibrated using a negative lens that has a well-defined $\theta(x,y)$

Negative spherical lens at TCC



Round beam shape at Fourier plane

Image using a spherical lens

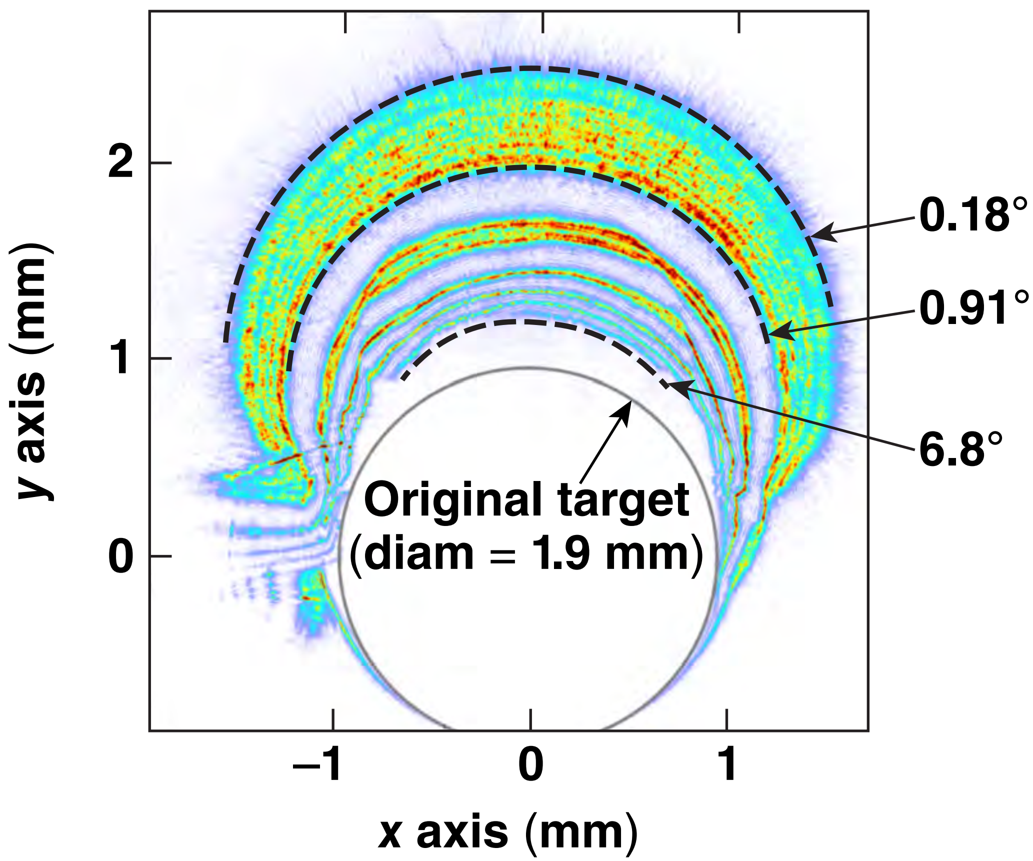


The association of these angles with the specific angular filter bands can be applied to a plasma to measure its refraction profile.

The experimental angular filter refractometry images are analyzed using the calibration angles

UR LLE

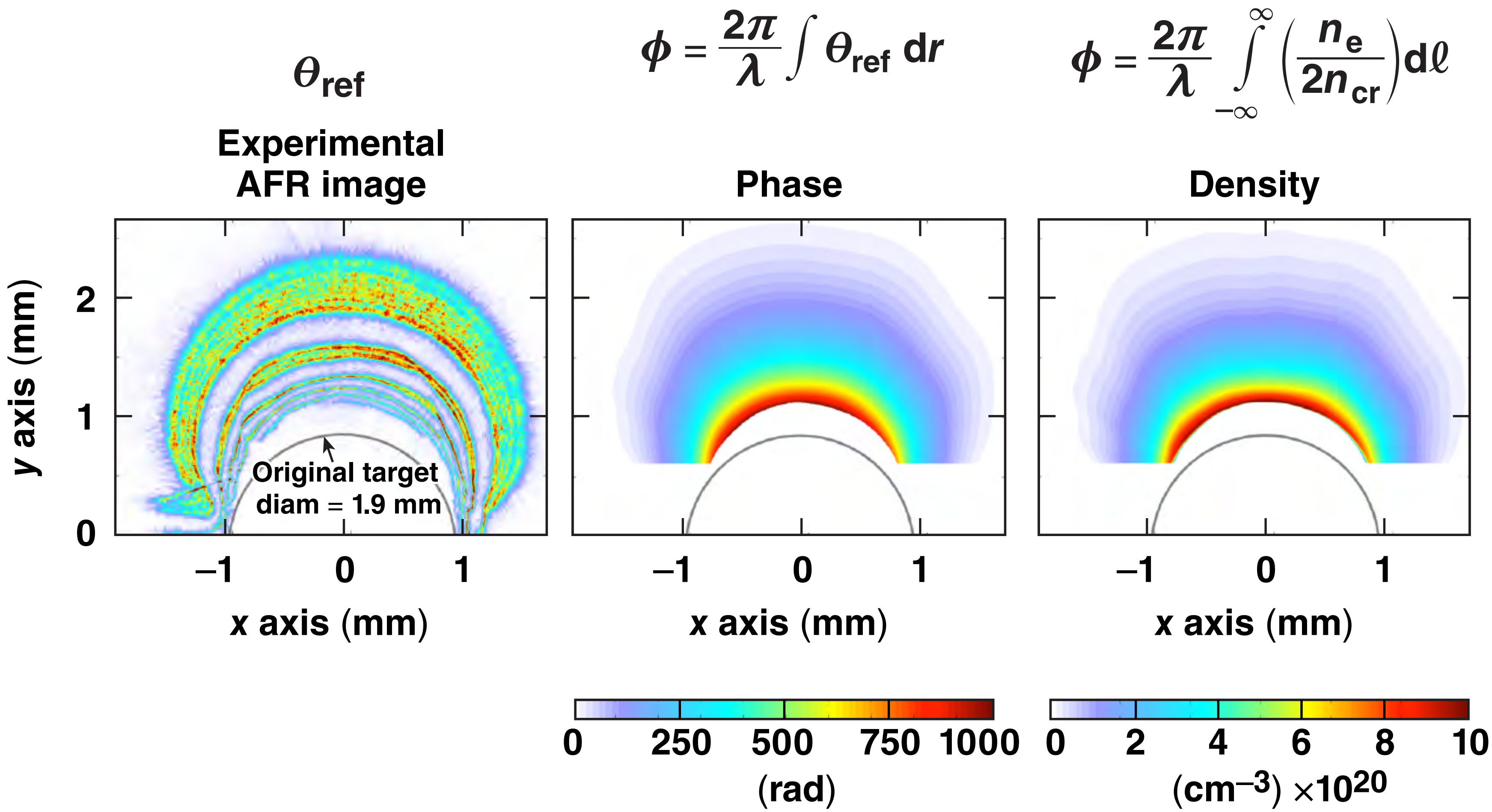
Experimental AFR image



Processing the experimental angular refactometry images creates a contour map of the refraction angle.

E22187a

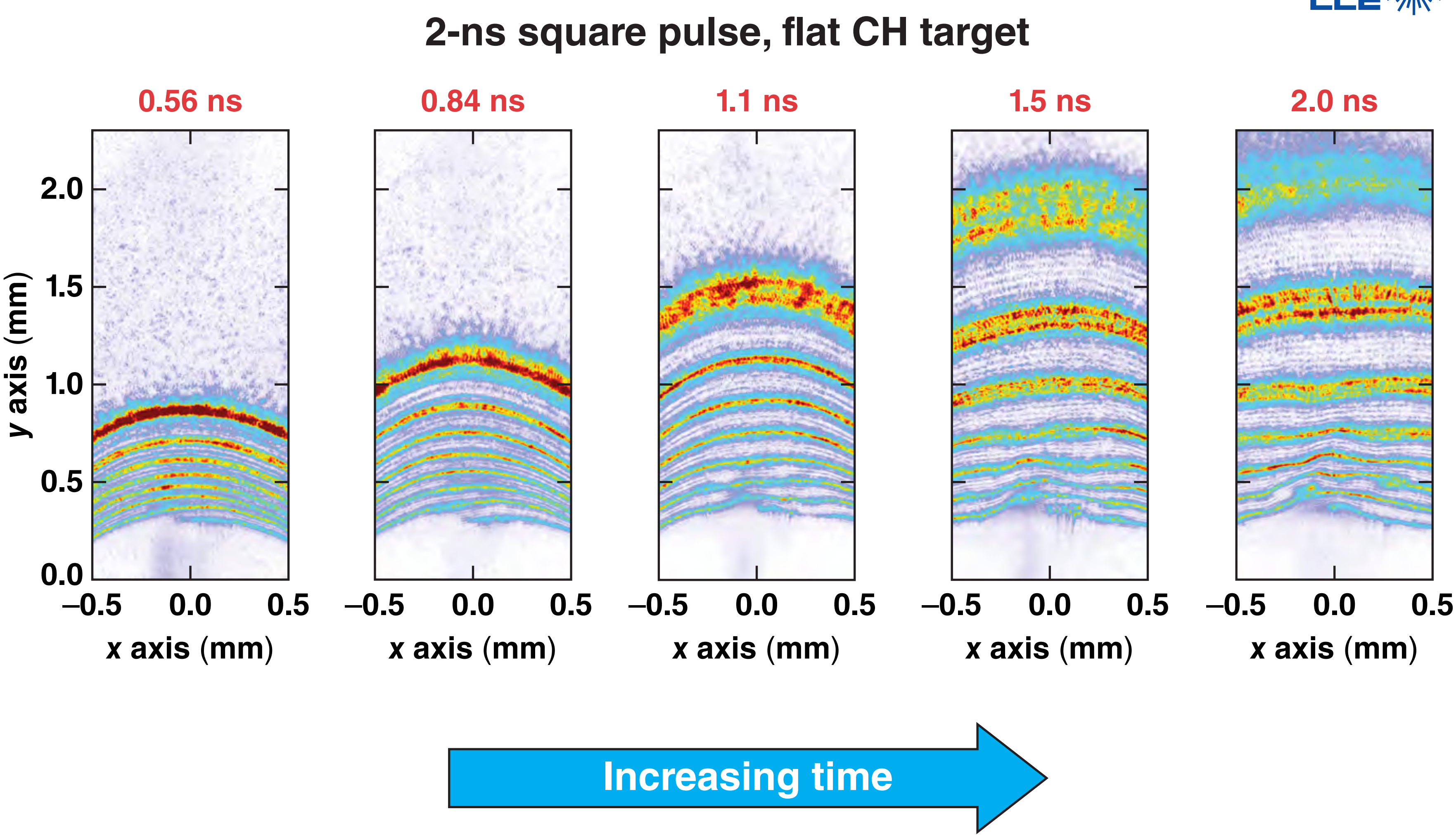
The plasma density profile can be determined from the refractive contour map



The density has an error of ±15%.

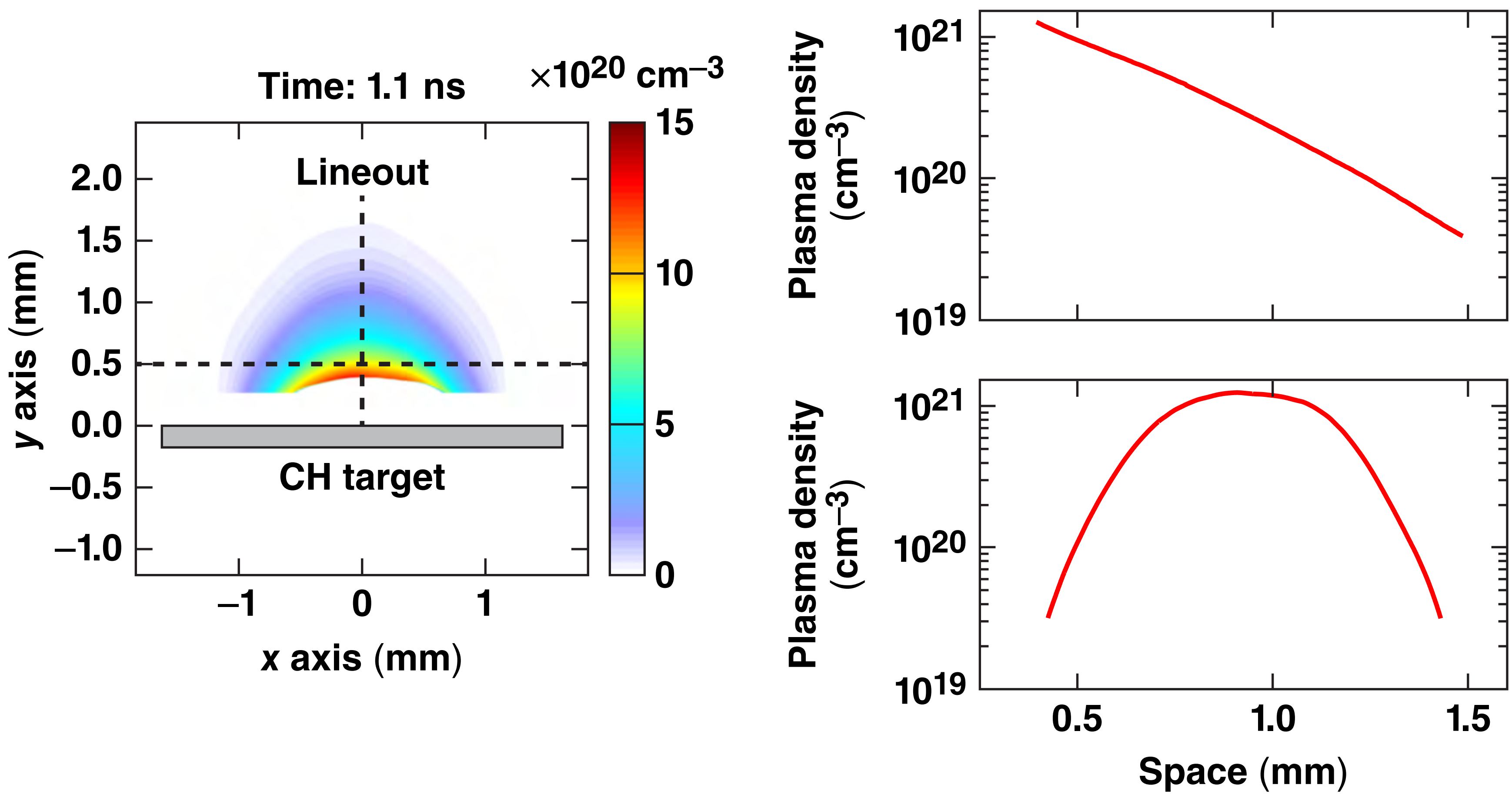
E22188a

The temporal evolution of the plasma density profile of UV-irradiated planar targets is illustrated using the angular filter refractometer

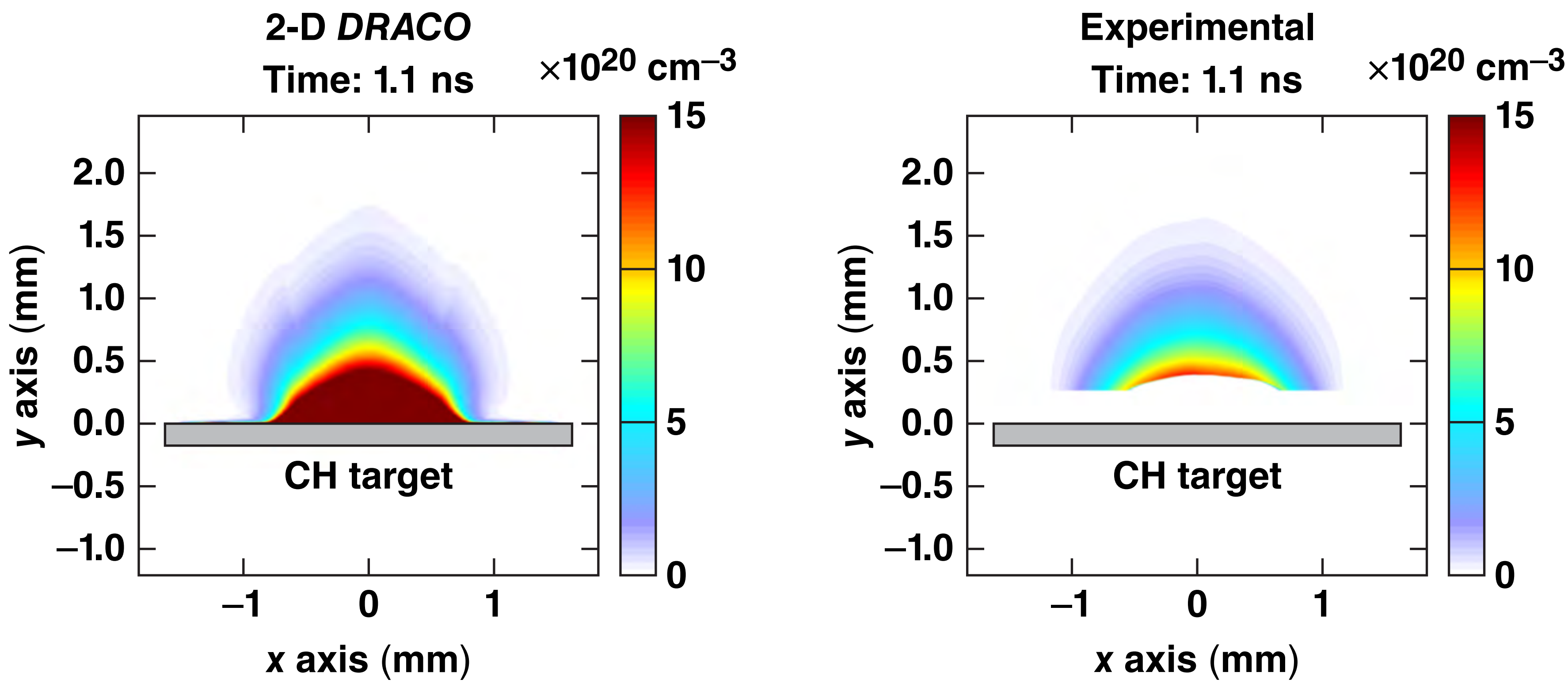


E22081b

Analysis of the AFR images produces a 2-D density profile

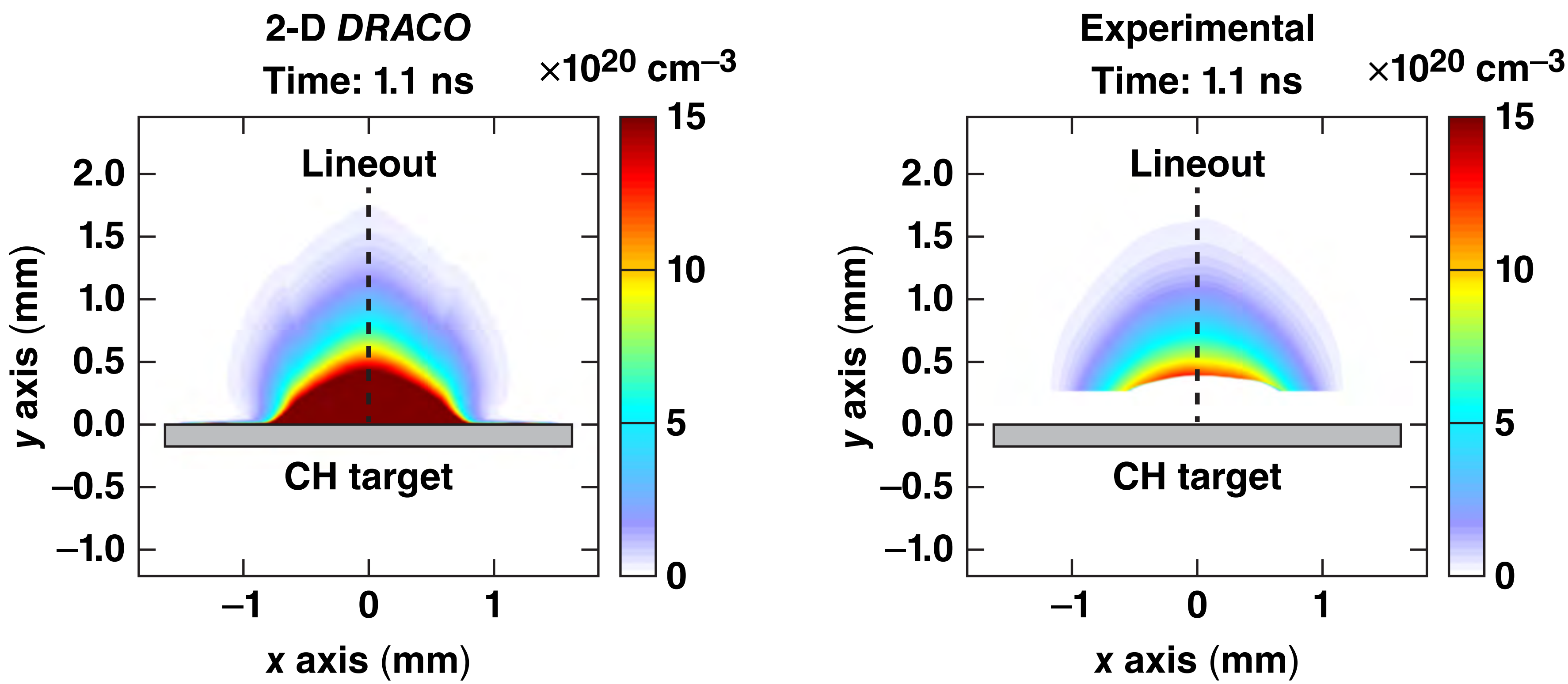


DRACO 2-D hydrodynamic simulations were run with a flux limiter of 0.06



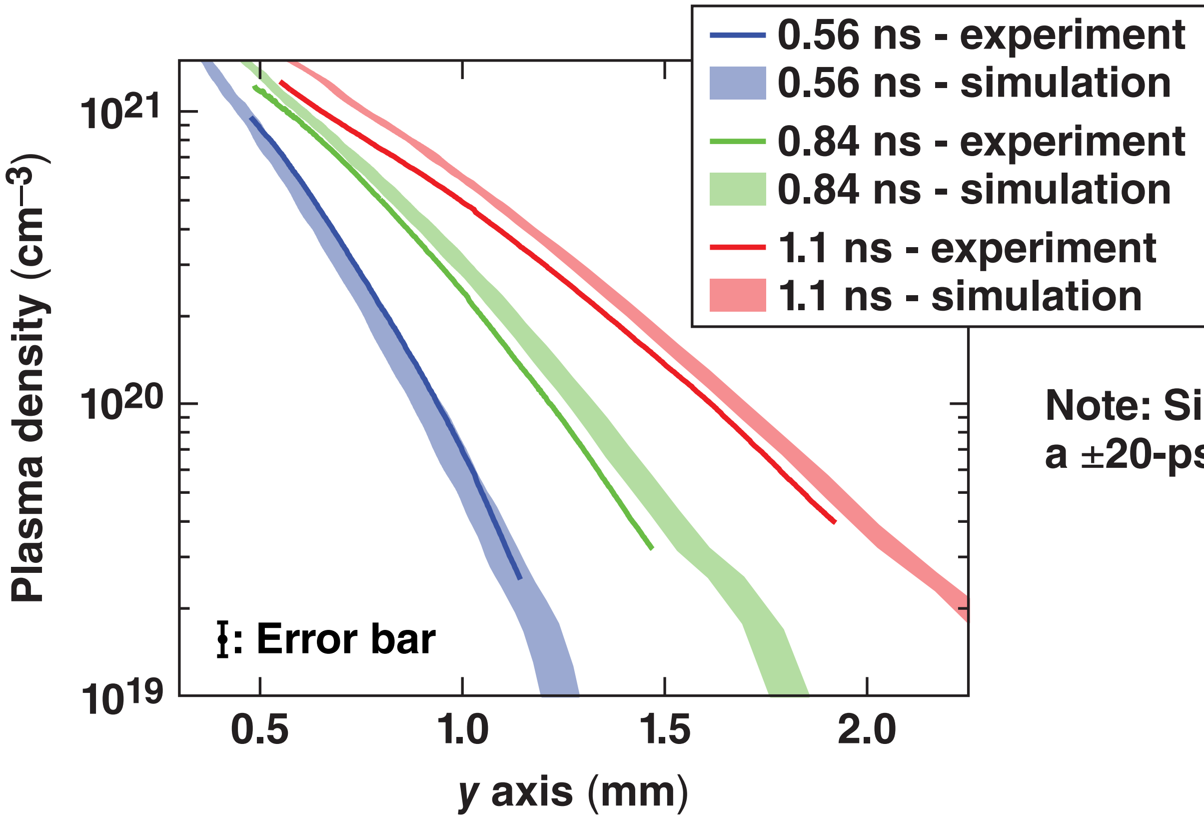
E22184c

DRACO 2-D hydrodynamic simulations were run with a flux limiter of 0.06



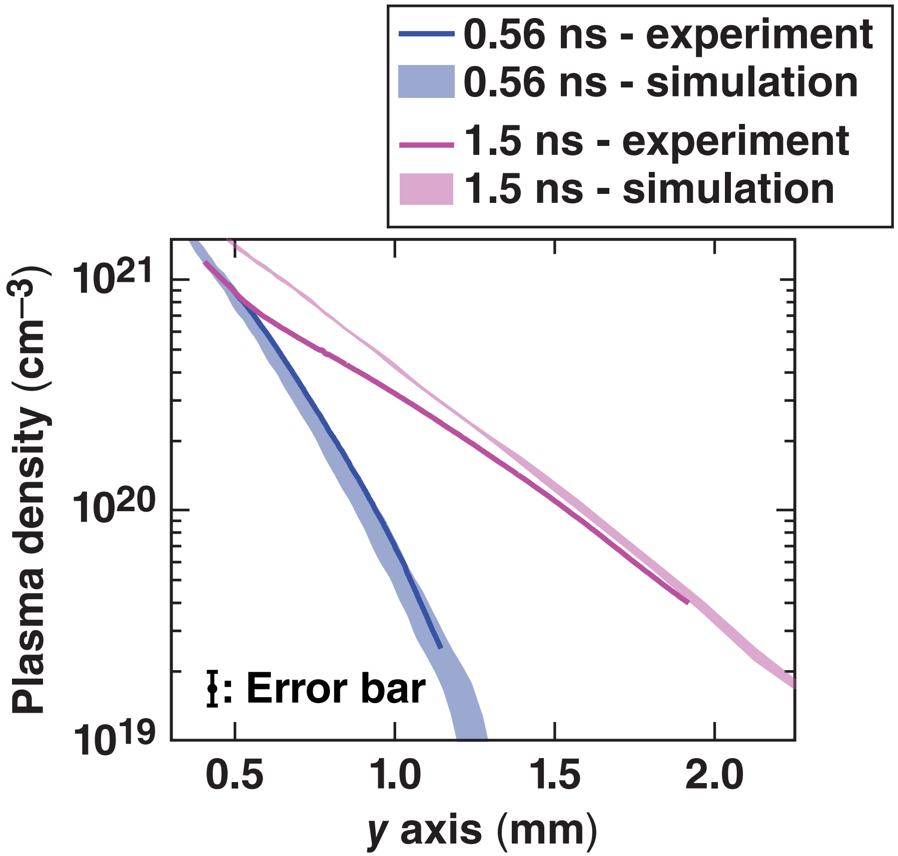
E22609

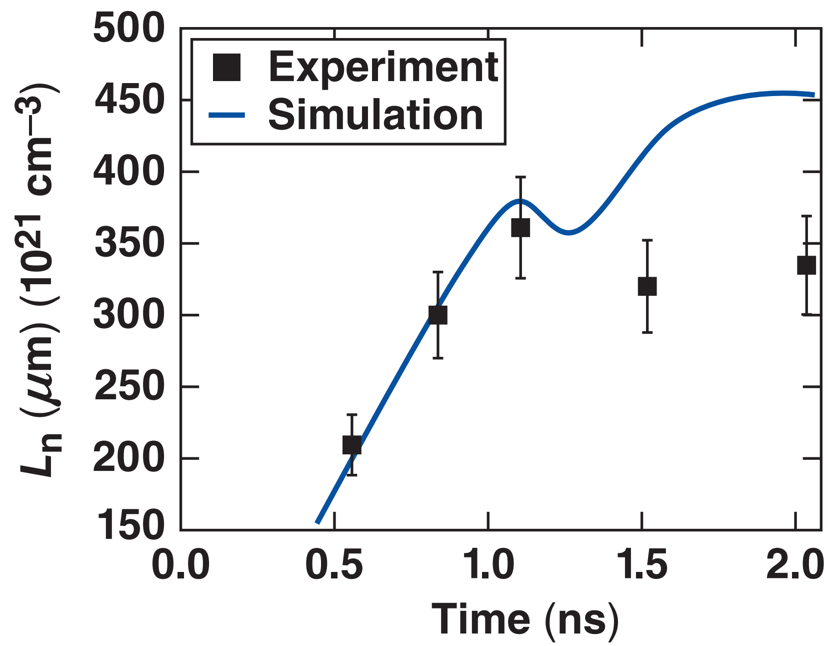
The simulated density profiles show good agreement with the measured profiles at early times



Note: Simulations cover a ±20-ps range

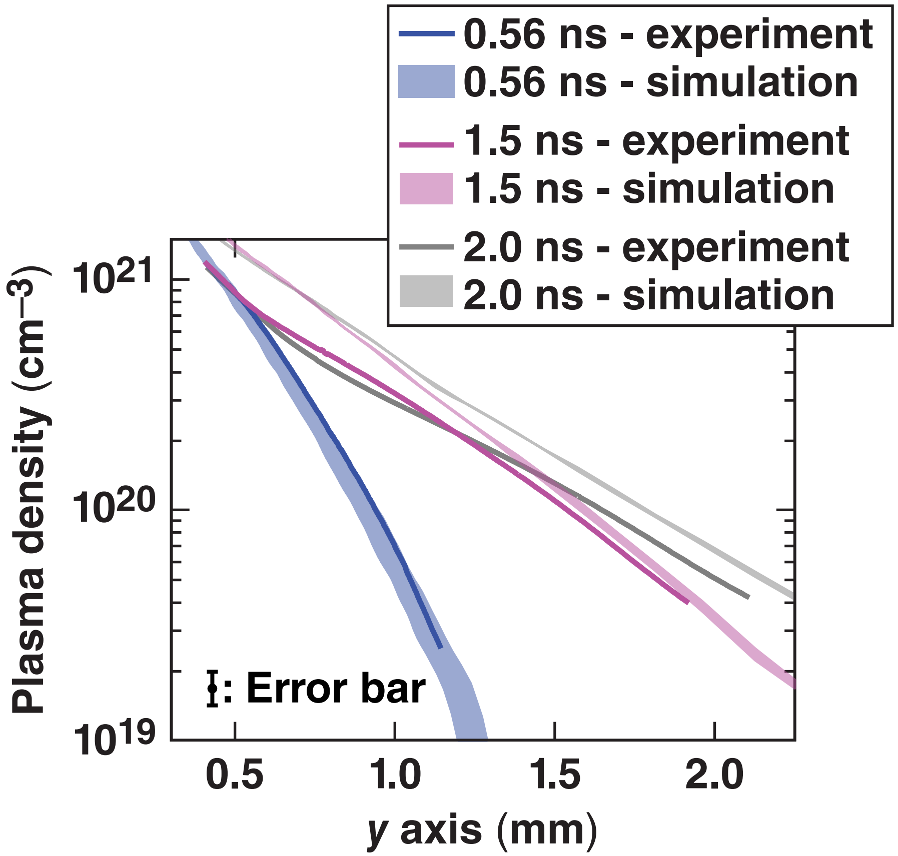
At later times, the simulations predict larger densities and scale lengths as compared to the measurements

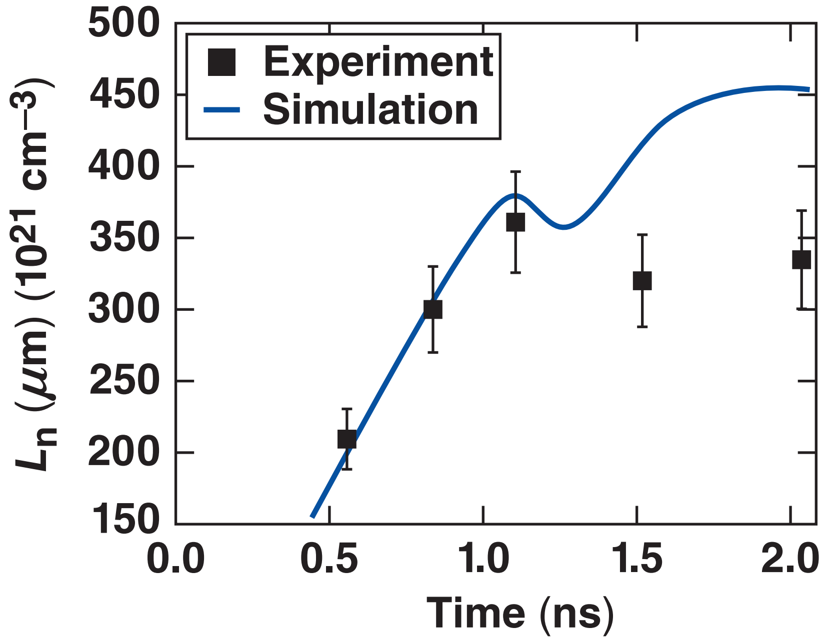




E22568

At later times, the simulations predict larger densities and scale lengths as compared to the measurements



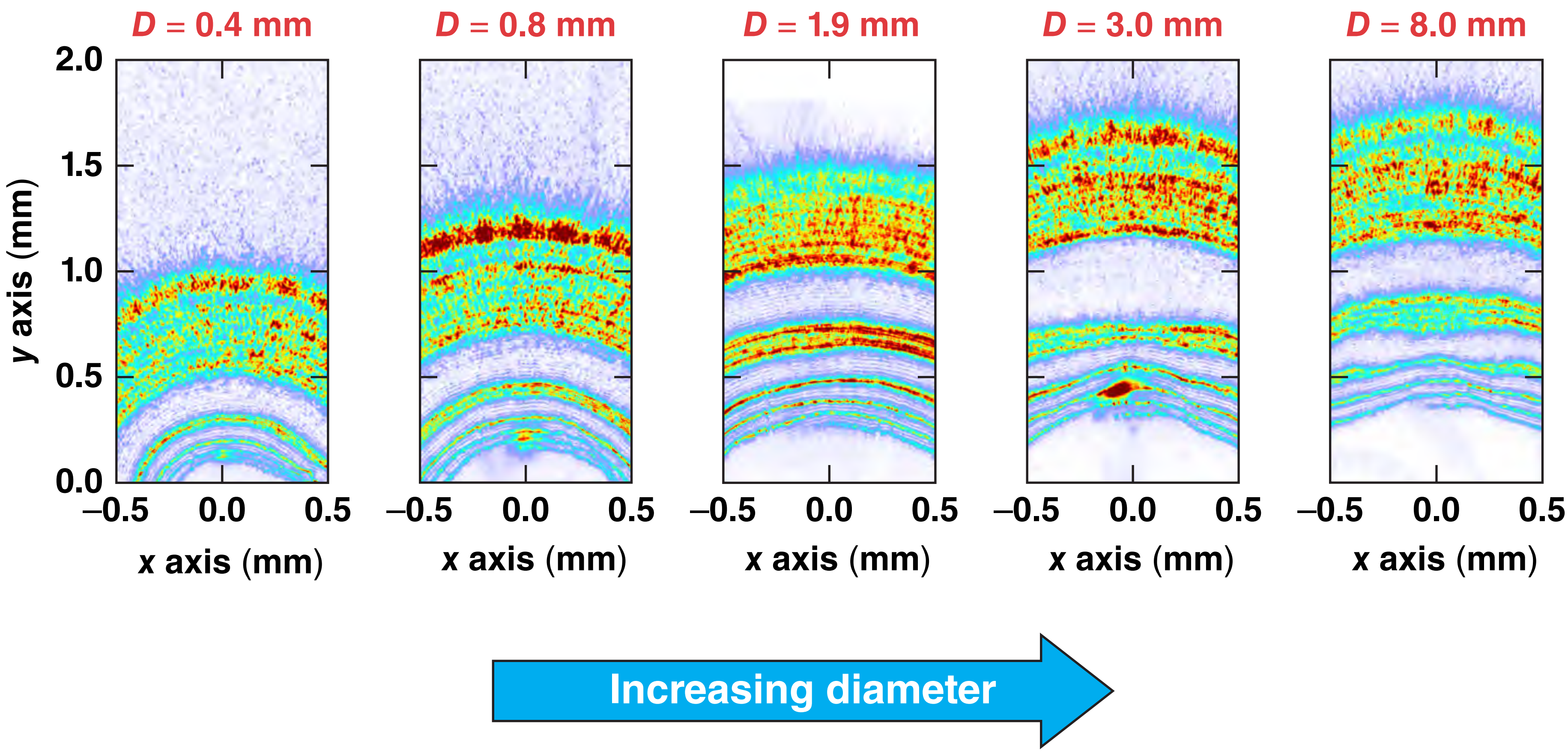


E22635

The plasma expansion from UV-irradiated spheres of varying radii was studied using the AFR diagnostic

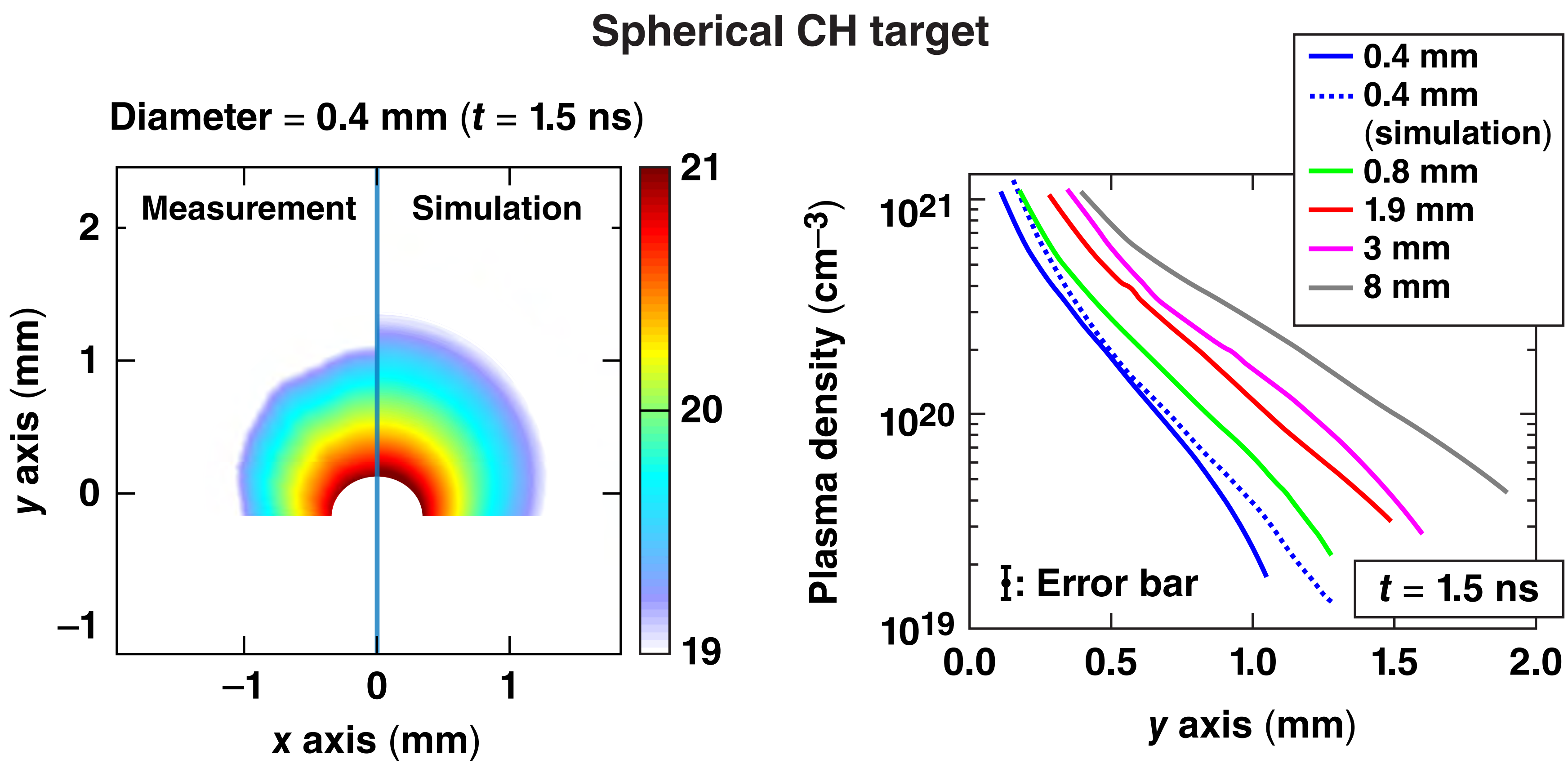
UR LLE

Laser: 2-ns square pulse, probe timing: 1.5 ns



E22183b

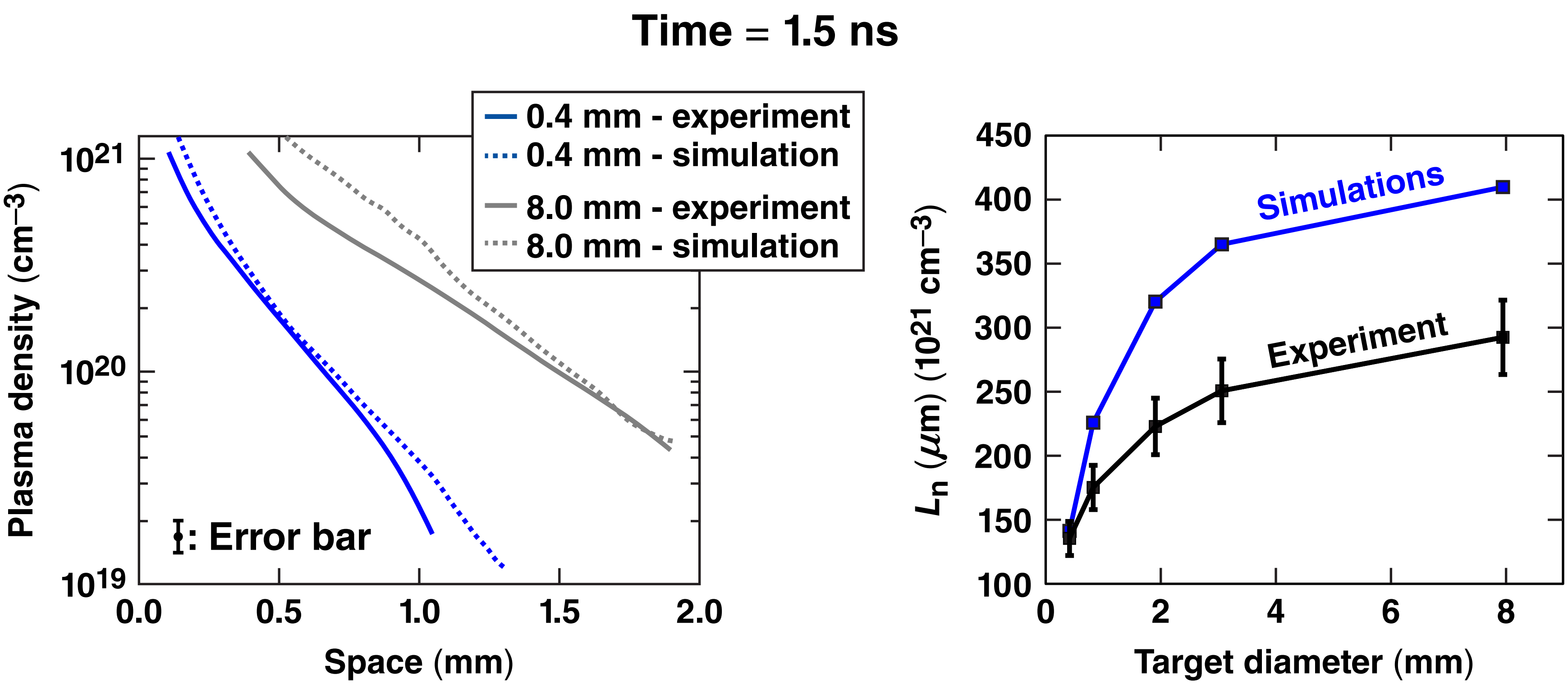
The plasma expansion is more planar as the target diameter is increased



For small spheres (short scale lengths) and late times (1.5 ns), hydrodynamic simulations are in good agreement with the measurements.

E22571

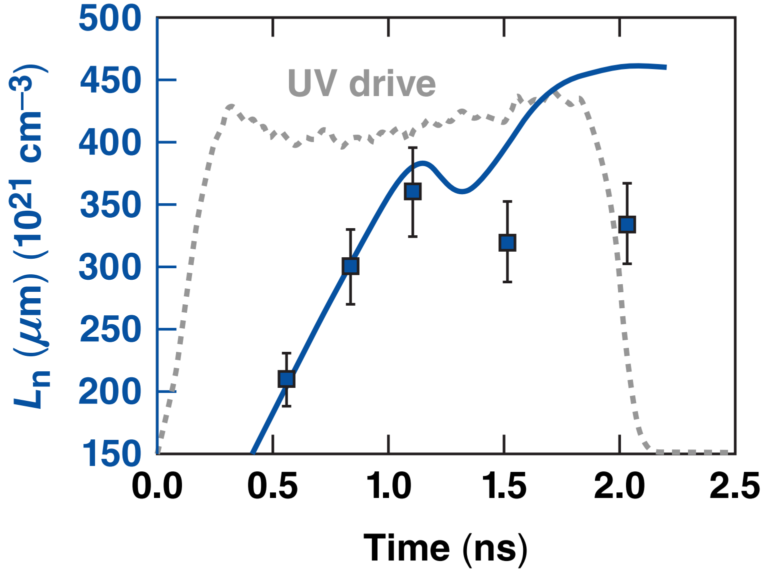
As the target diameter is increased, the hydrodynamic simulations predict higher densities and longer scale lengths compared to measurements



Both experimental configurations (time and radial series) show discrepancies with simulations as the scale length increases.

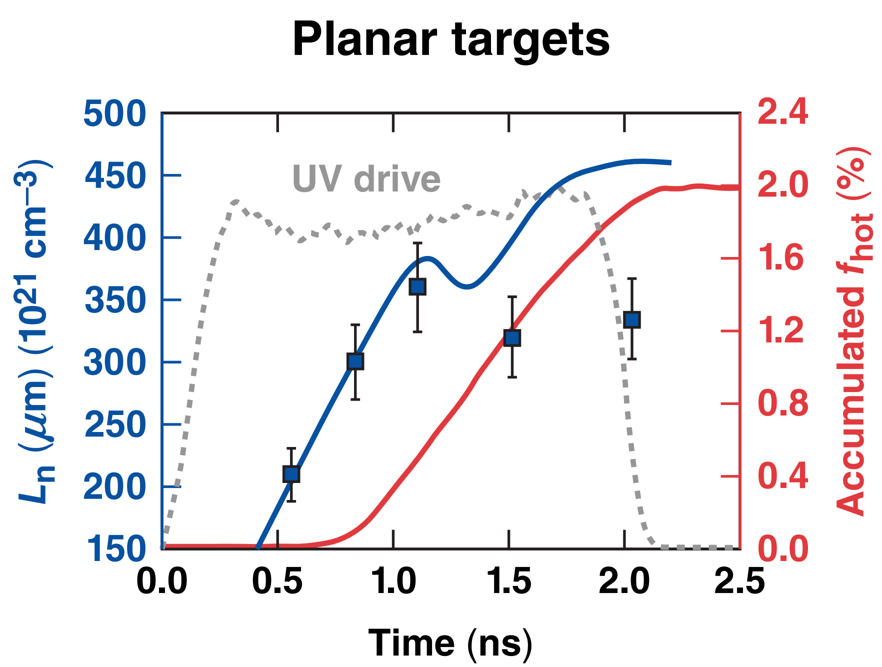
In both configurations, these discrepancies arise when hot electrons are prevalent

Planar targets



E22572

In both configurations, these discrepancies arise when hot electrons are prevalent

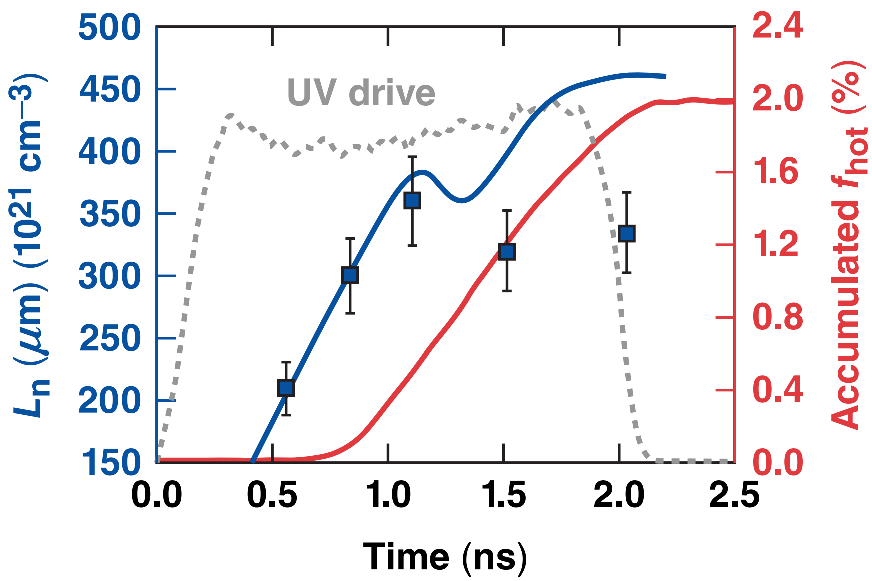


E22572a

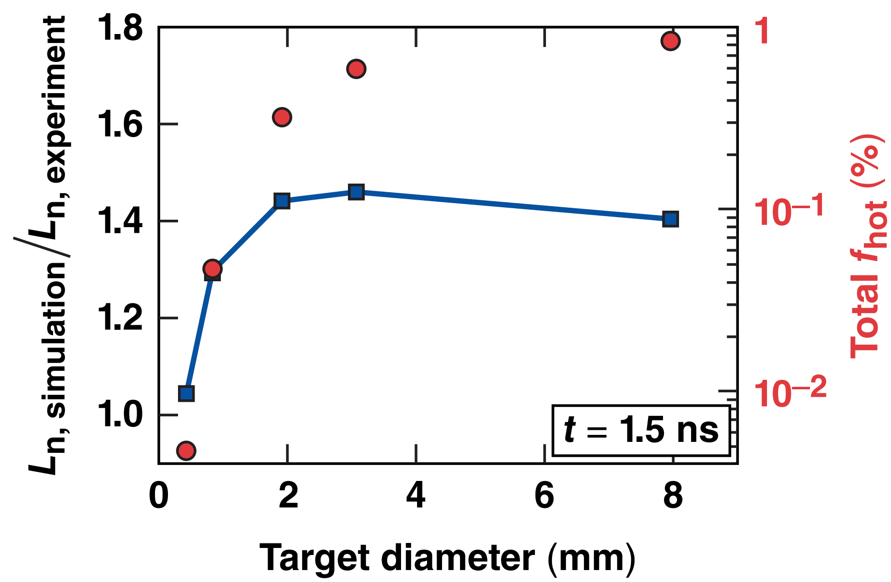
In both configurations, these discrepancies arise when hot electrons are prevalent

UR LLE

Planar targets



Spherical targets



E22572b

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E22503