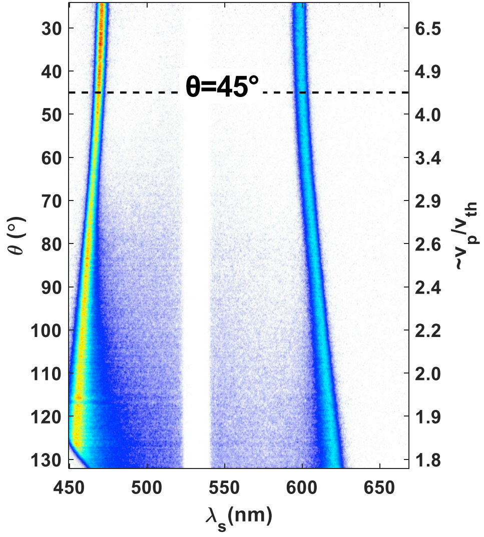
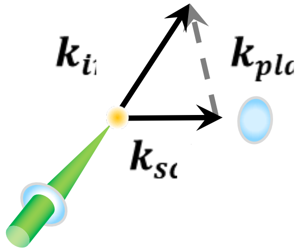
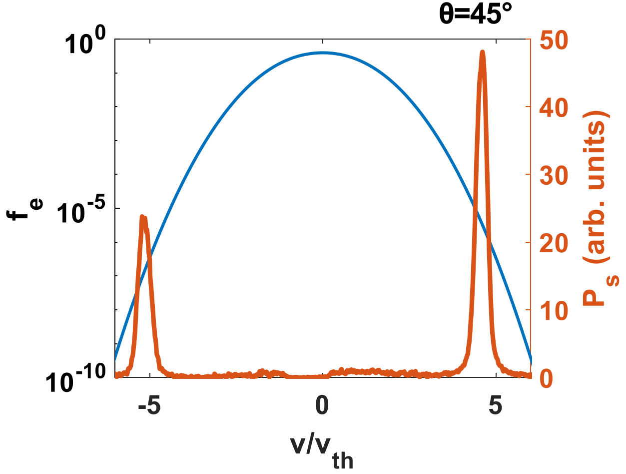
Measurements of arbitrary electron distribution functions using angularly resolved Thomson scattering







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Laboratory for Laser Energetics

61st Annual Meeting of the American Physical Society Division of Plasma Physics
Ft. Lauderdale, FL
21-25 October 2019

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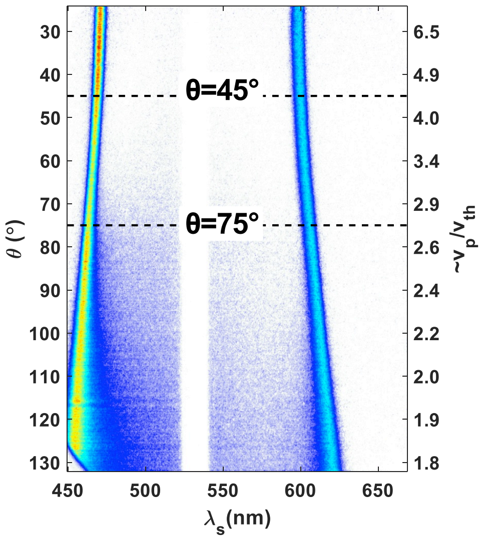

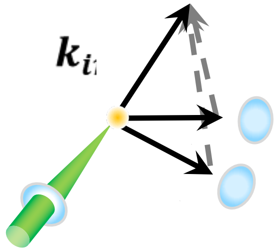

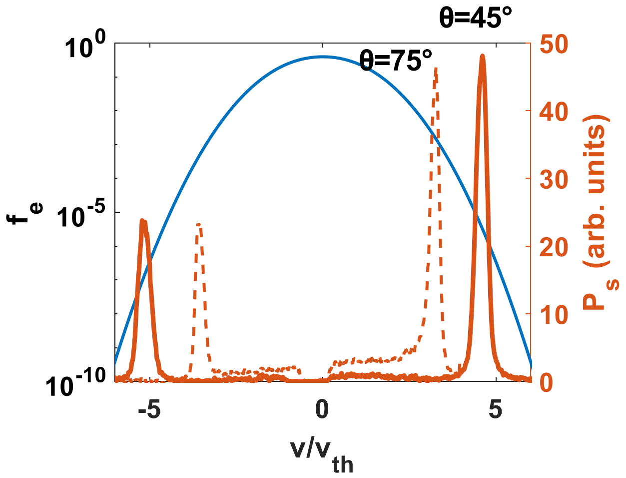

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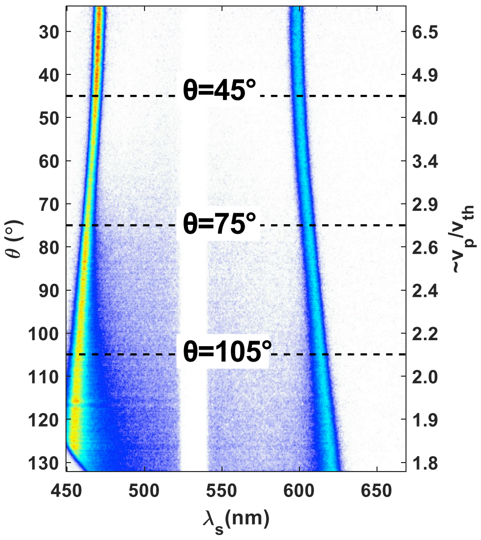

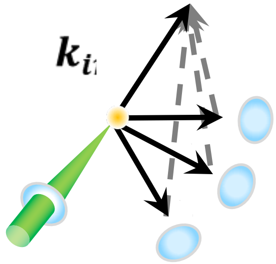

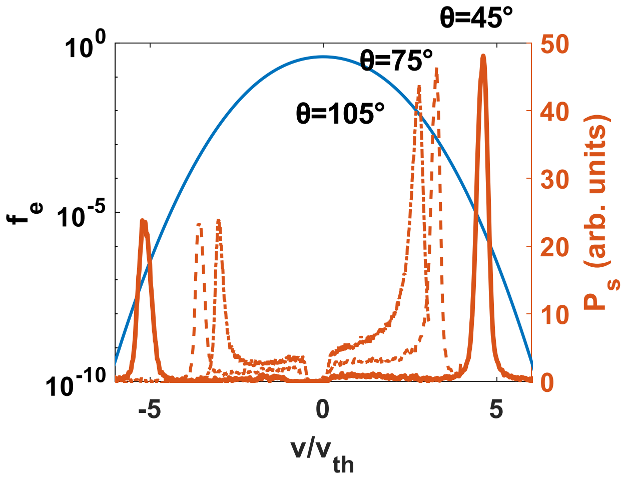

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Summary

Non-Maxwellian electron distribution functions have been measured using angularly resolved Thomson scattering

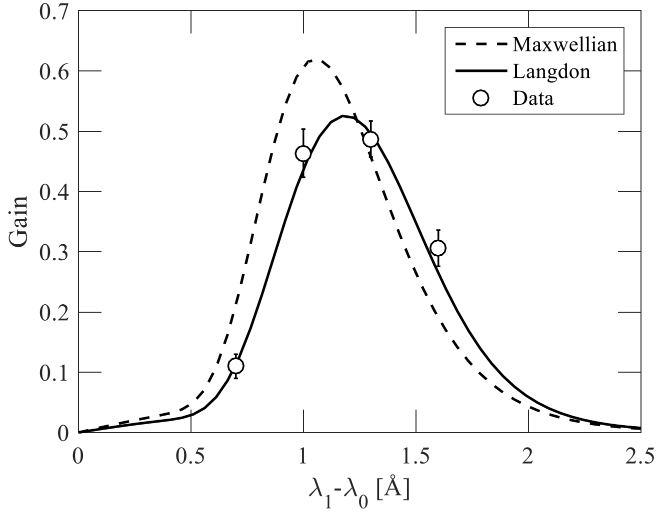
- Collective electron plasma wave Thomson scattering is sensitive to electron velocity distributions
- Angularly resolved Thomson scattering allows direct measurement of the electron velocity distribution
- Measured distributions agree with theoretical predictions for super-Gaussian distributions

Collaborators

J. Katz, R. Boni, D. Nelson, J. P. Palastro, K. Daub, R. Follett, and D. H. Froula
Laboratory for Laser Energetics

The electron velocity distribution function (EDF) is required to accurately model plasmas and laser-plasma instabilities

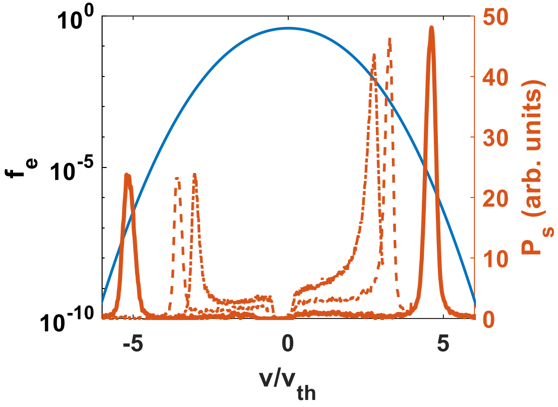
- The gain in instabilities such as cross beam energy transfer, stimulated Raman scattering, and two plasmon decay is dependent on EDF*
- Heat transport is dependent on EDF
- Diagnostic techniques are also influenced by EDF
  - Thomson scattering
  - X-ray spectroscopy

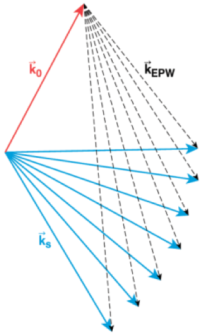


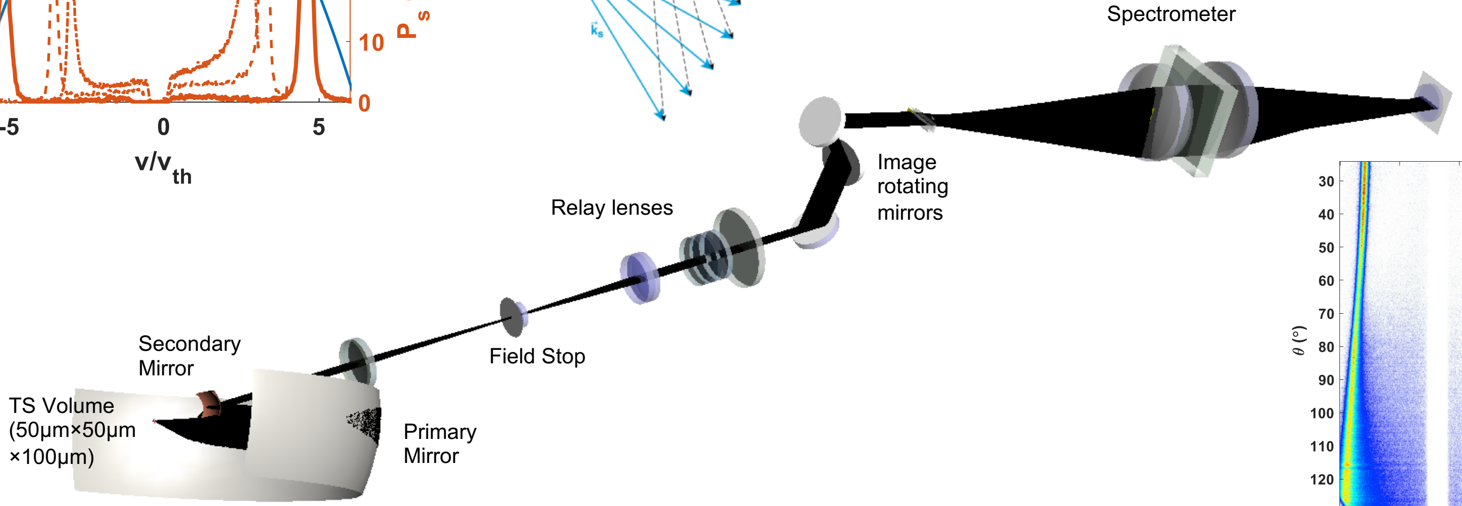
It is often assumed the EDF is Maxwellian but this may not always be the case

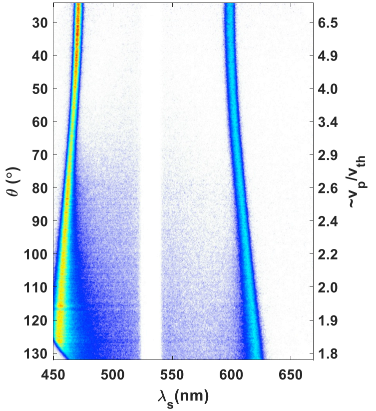
Image: D. Turnbull (invited Monday)
*B. Afeyan *et al.*, PRL 80, 2322 (1998).

Angularly resolved Thomson data allows direct measurement of the electron velocity distribution

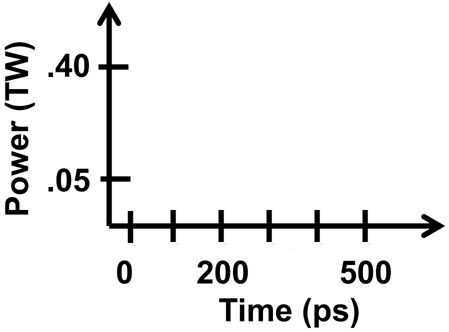


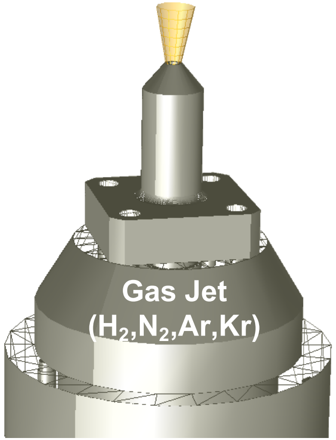






Angularly resolved Thomson scattering experiments were performed on the OMEGA laser system to measure non-Maxwellian distribution functions





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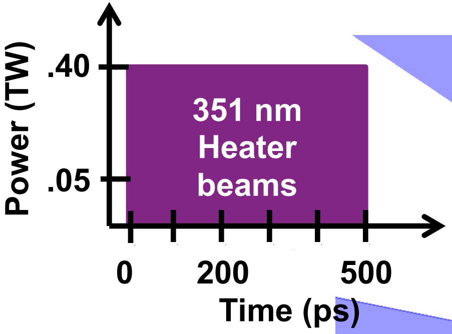

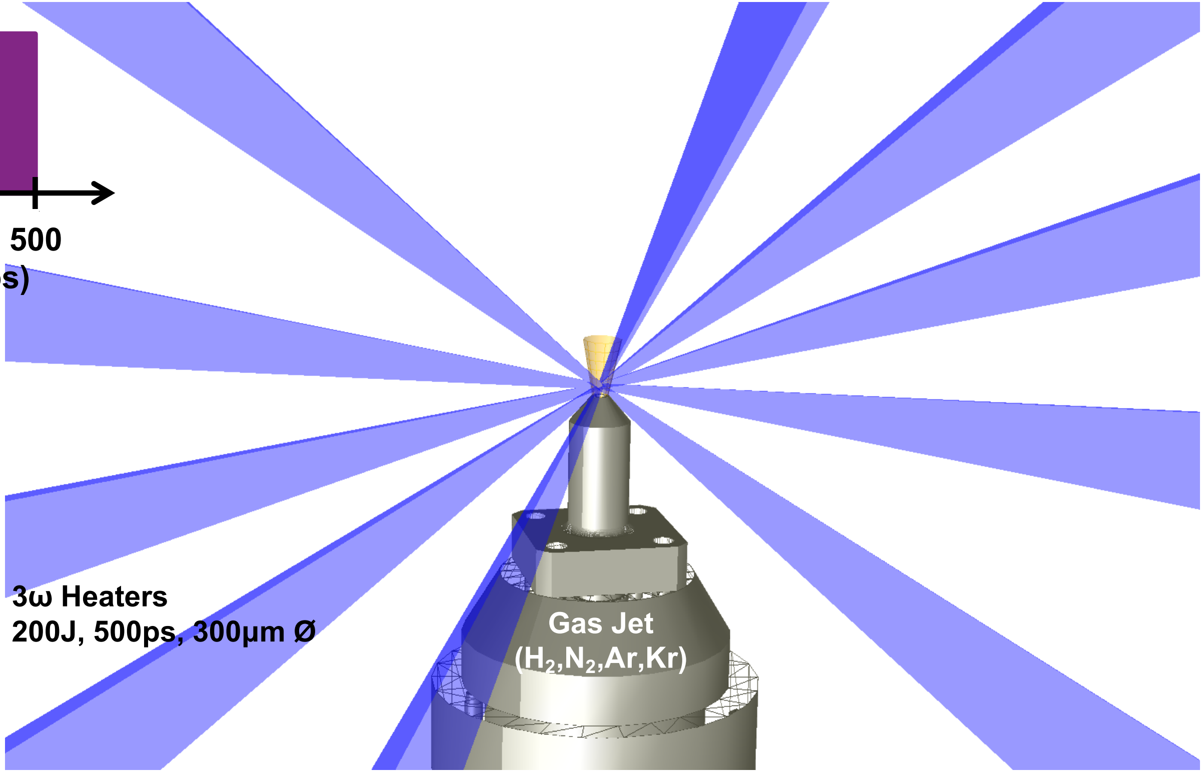

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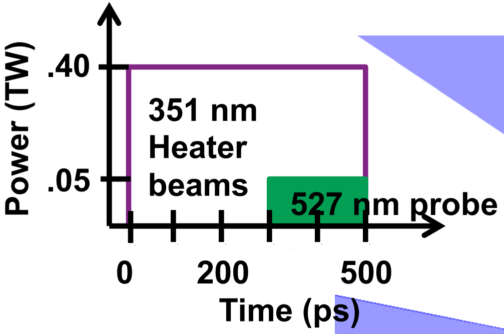
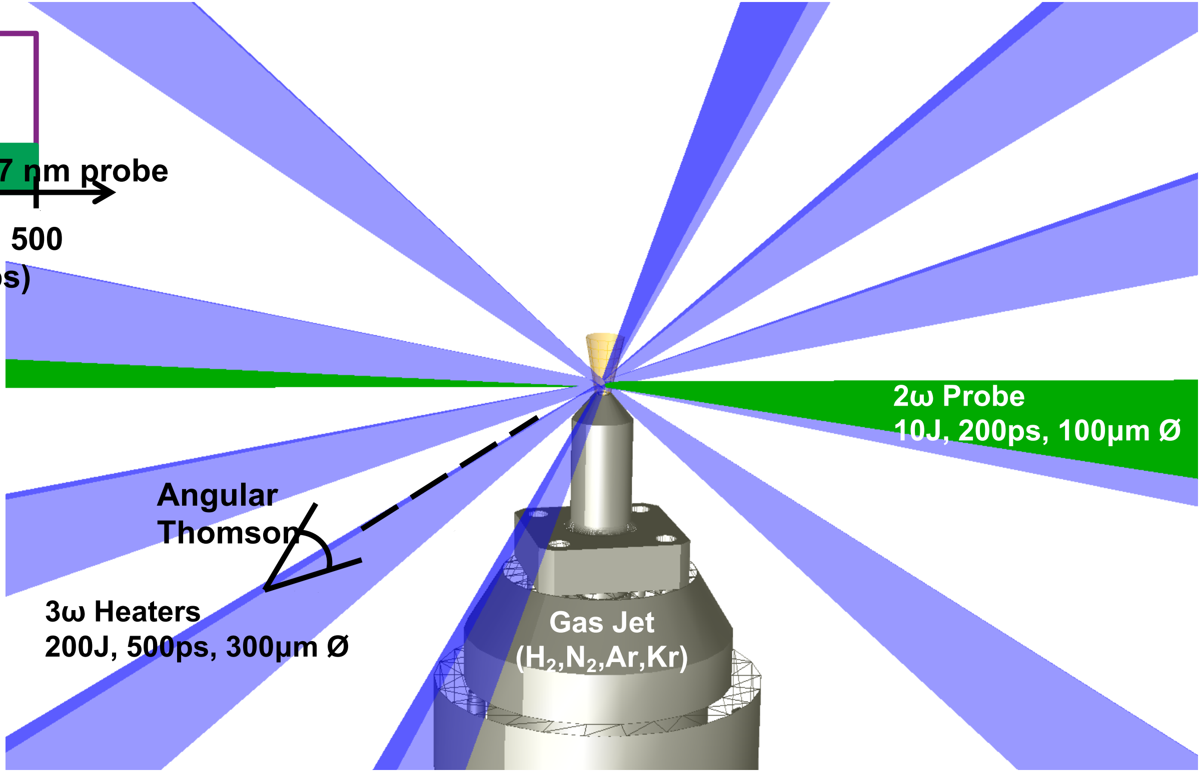




To extract distributions from angularly resolved Thomson data, an iterative fit is performed

Electrons are moved around in the distribution

A susceptibility is calculated numerically

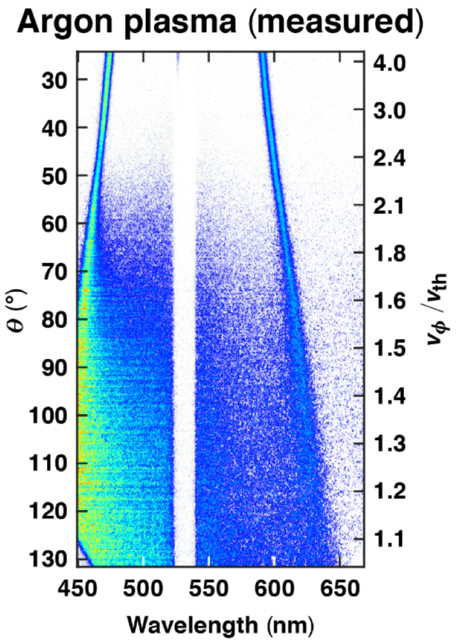
Spectrum is calculated

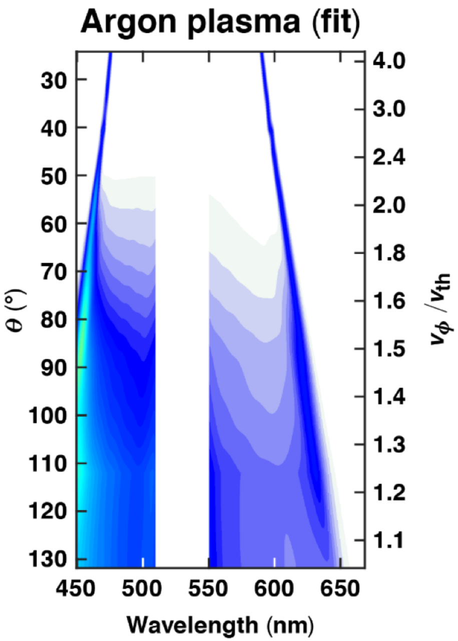
The spectrum is compared to the data over the entire angular range

If the spectrum is an improvement the change is kept

The result is an electron distribution that represents the data without specifying the relevant physics

Angularly resolved Thomson scattering measurements show non-Maxwellian electron distribution functions





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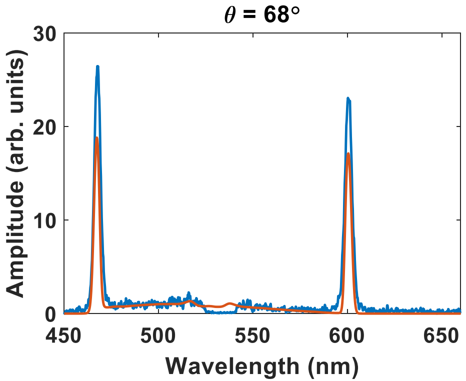

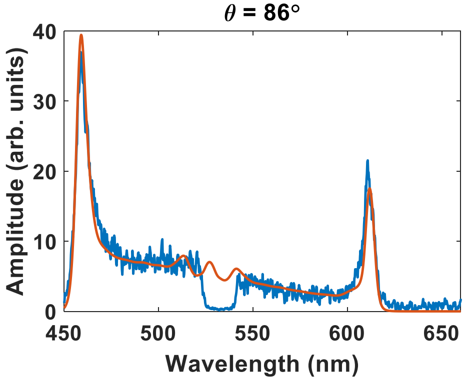

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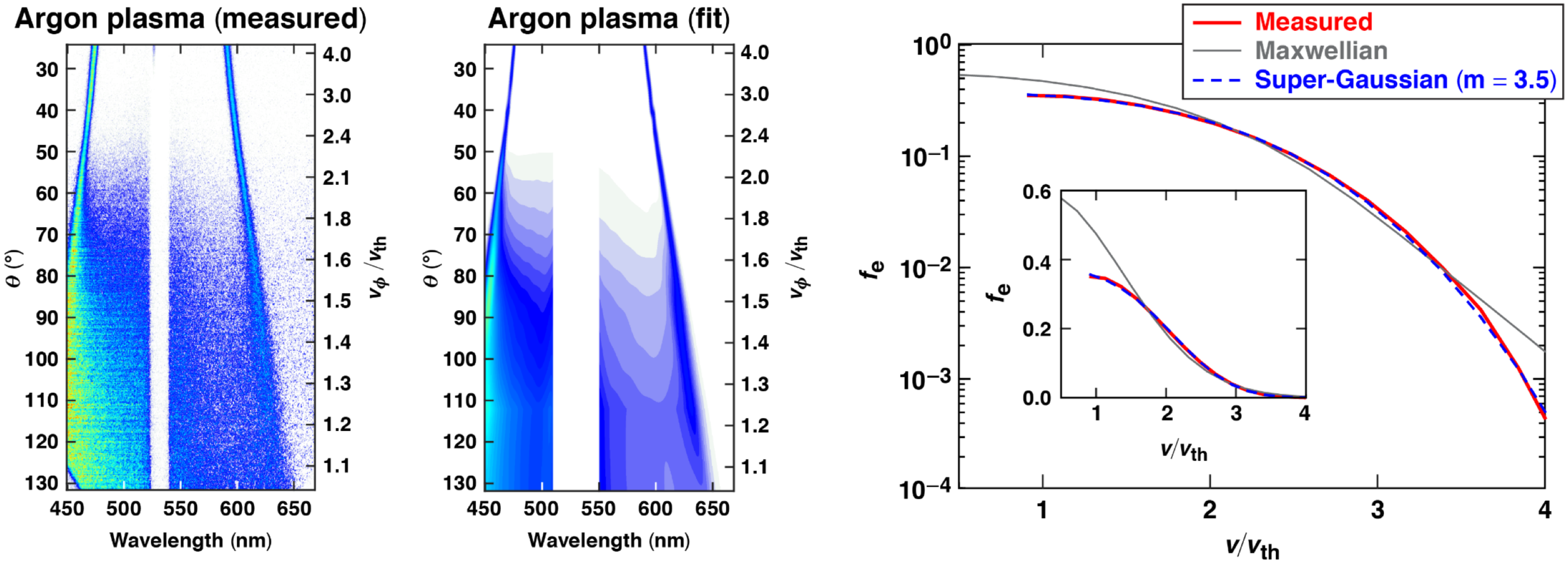

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Super-Gaussian distribution functions result from inverse bremsstrahlung (IB) heating

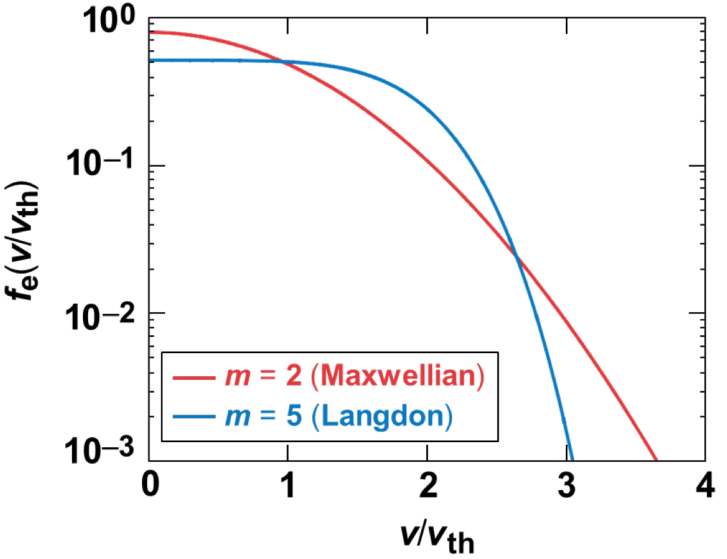
- **Langdon Effect**

$$f_m(x,v,t) = C_m \exp[-(v/v_m)^m]$$

$$v_m^2 = \frac{3k_B T_e}{M_e}\frac{\Gamma(3/m)}{\Gamma(5/m)} \quad \text{and} \quad C_m = \frac{n_e}{4\pi}\frac{m}{\Gamma(3/m)v_m^3}$$

- **Super-Gaussian order varies continuously with the Langdon parameter****

$$\alpha = Z\left(\frac{v_{osc}}{v_{th}}\right)^2 \qquad m = 2 + \frac{3}{1+1.66/\alpha^{0.724}}$$

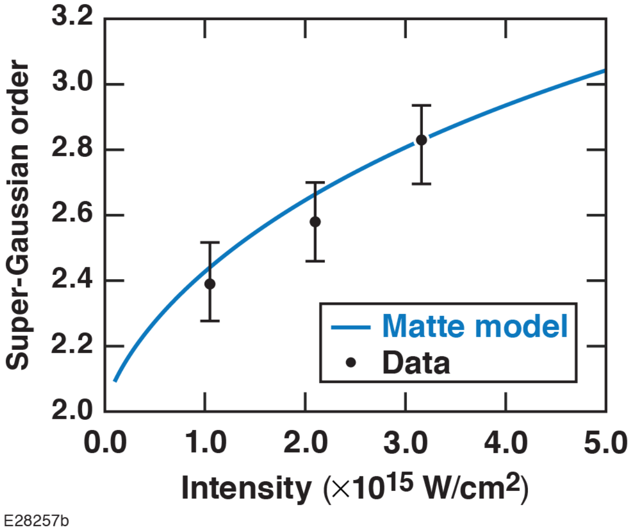


*A. B. Langdon, Phys. Rev. Lett. 44, 575 (1980).
**J. P. Matte *et al.*, Plasma Phys. Controlled Fusion 30, 1665 (1988).

The measured distributions agree well with predictions by Matte *et al.*

$$\alpha = Z\left(\frac{v_{osc}}{v_{th}}\right)^2$$

$$m = 2 + \frac{3}{1 + 1.66/\alpha^{0.724}}$$



Future work will focus on comparing the measured distribution functions to other predictions especially regarding the tails of the distribution function

*J. P. Matte *et al.*, Plasma Phys. Controlled Fusion 30, 1665 (1988).

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