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SHEATH EXPANSION AROUND LANGMUIR PROBES IN FLOWING PLASMAS

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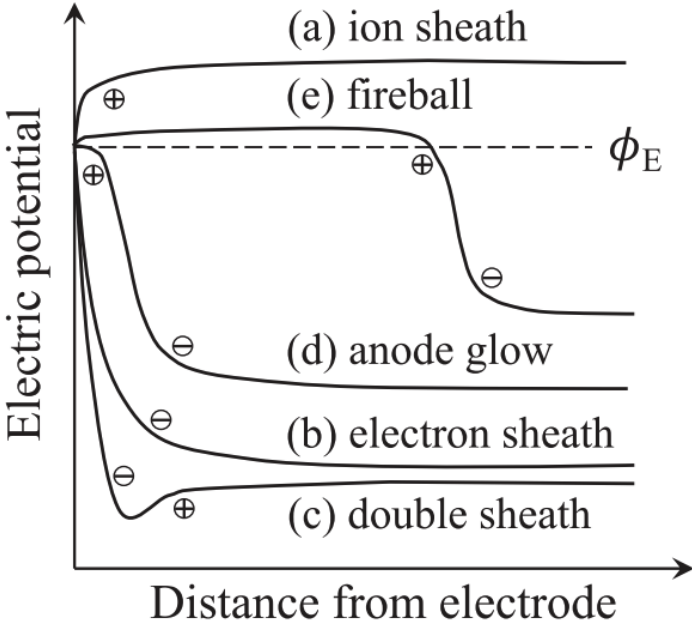
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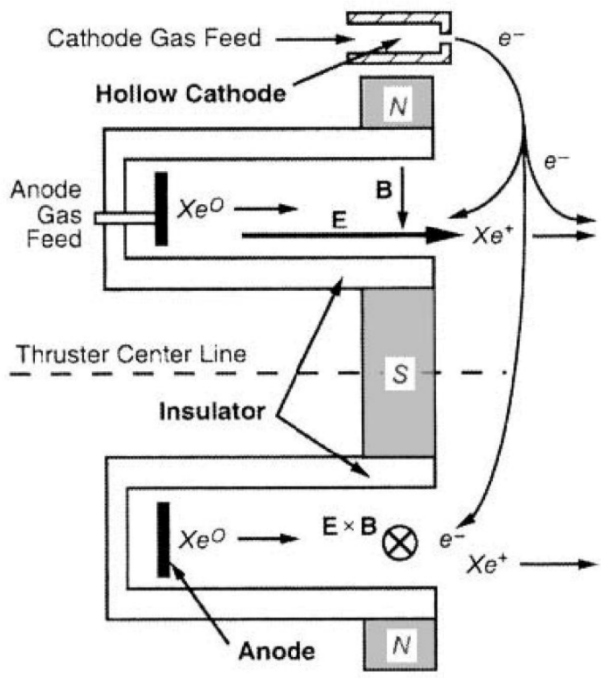
ESCAMPIG XXVI, Brno, Czech Republic, July 9–13, 2024



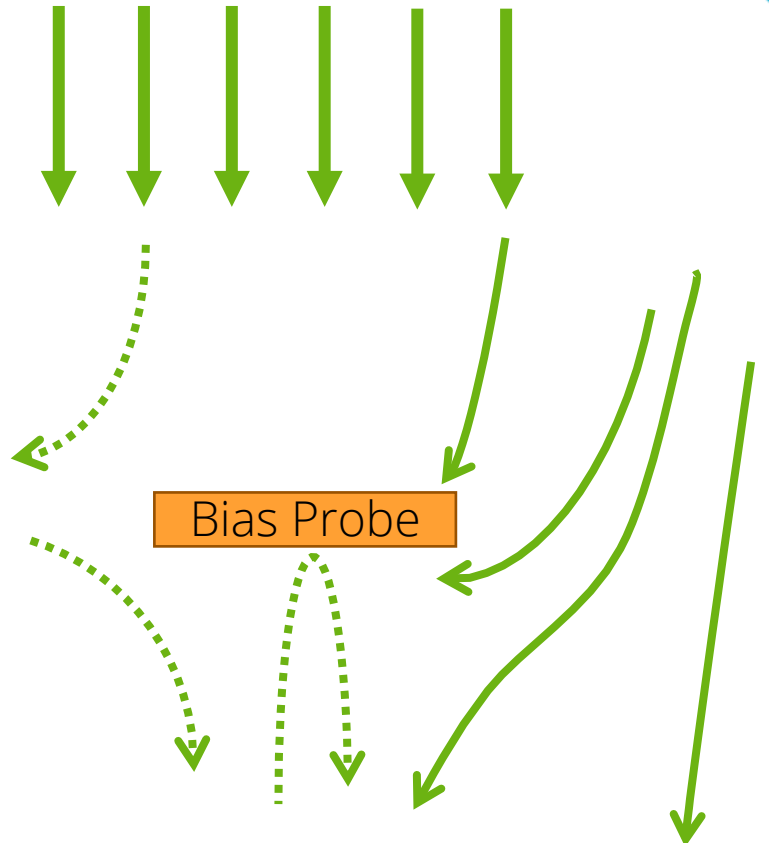
PLASMA FLOWS ARE A STAPLE OF MANY IMPORTANT PLASMAS



Baalrud et al., PSST 29 (2020)

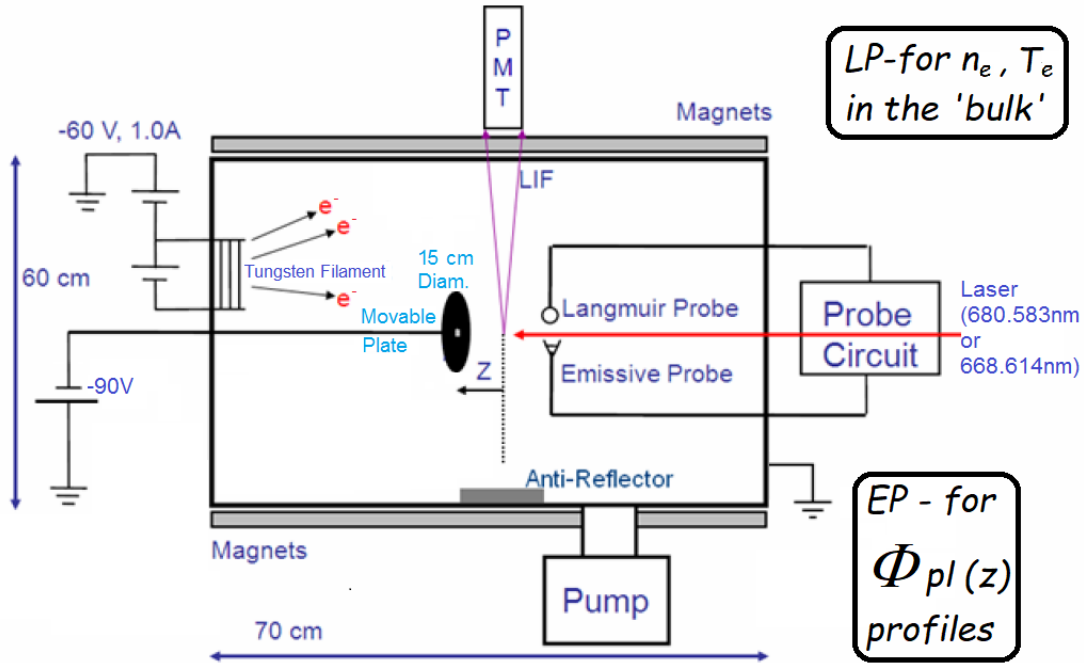


Goebel and Katz., John Wiley & Sons, Incorporated, 2008.



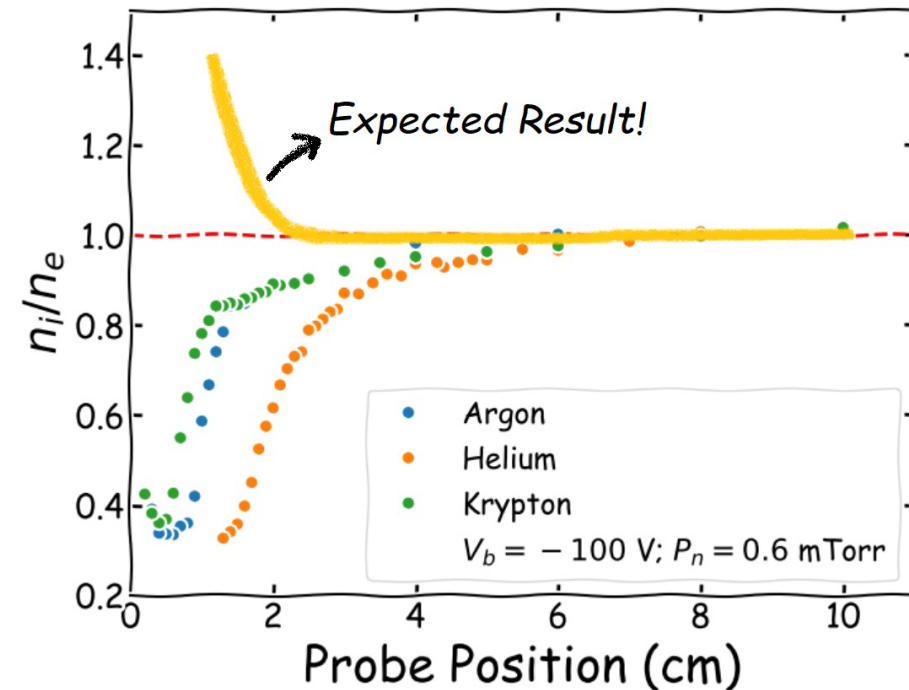
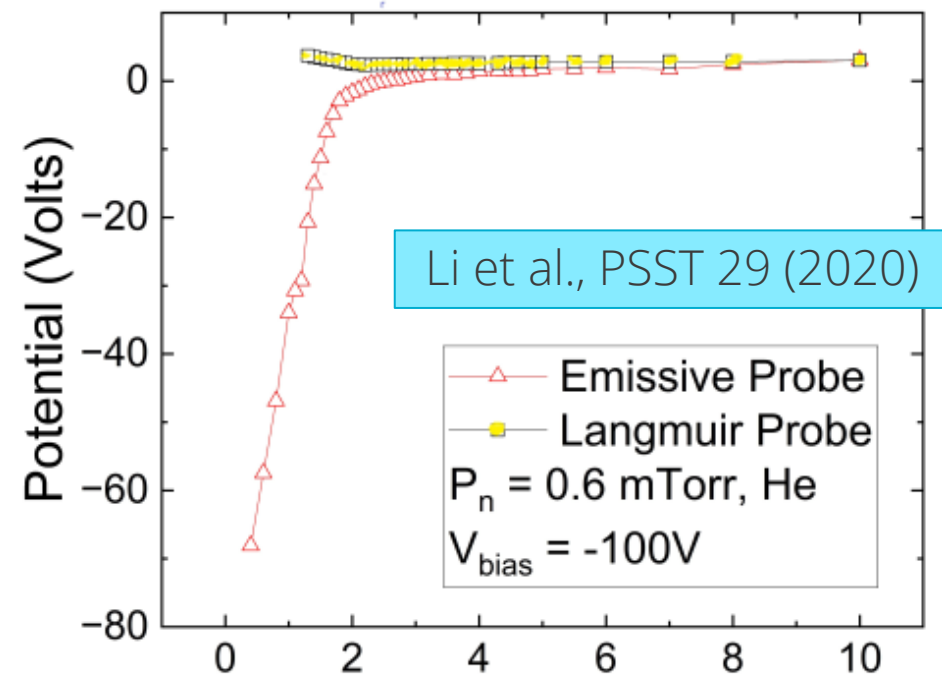
How does a flow affect the current collected by a biased probe?

OBSERVATIONS INDICATE THEY DO AFFECT PROBE MEASUREMENTS



- Incorrect increase in Φ_{pl} observed for cylindrical, two-sided, and one-sided probes

Hypothesis: ion flow changes sheath expansion

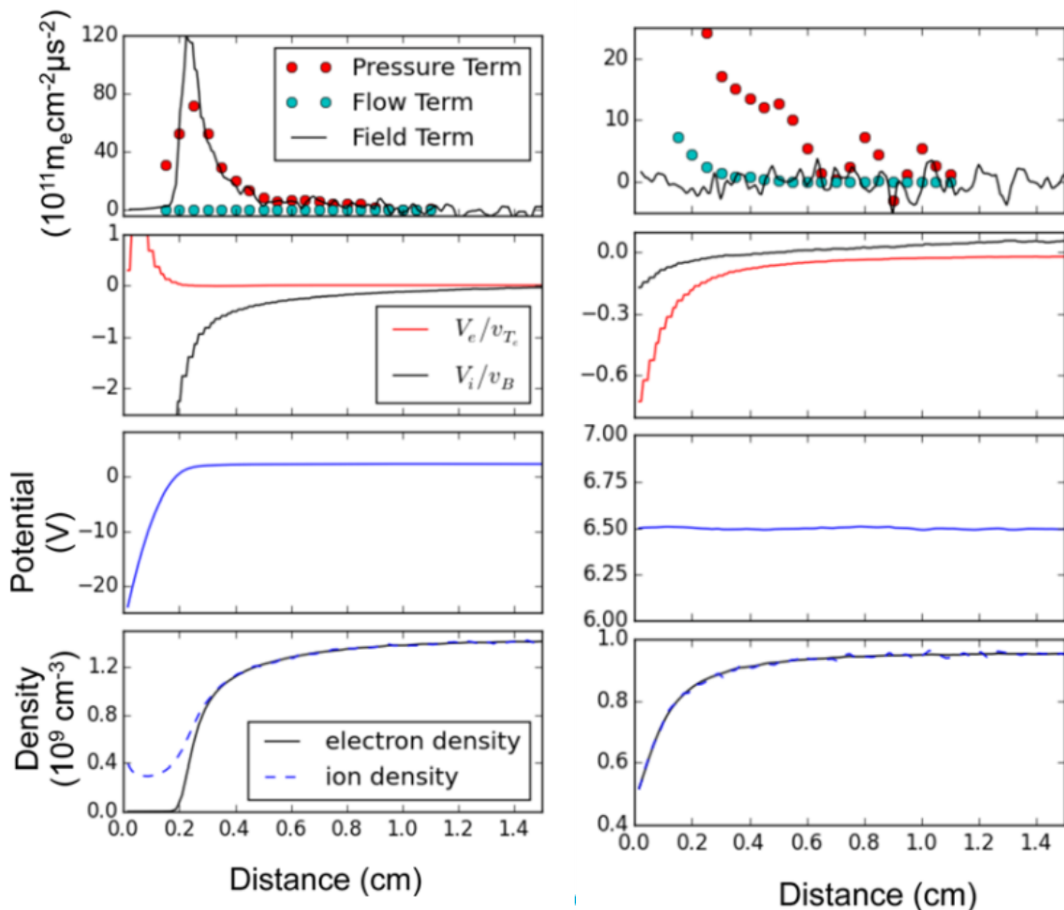


PRIOR SHEATH PHYSICS STUDIES USING ALEPH

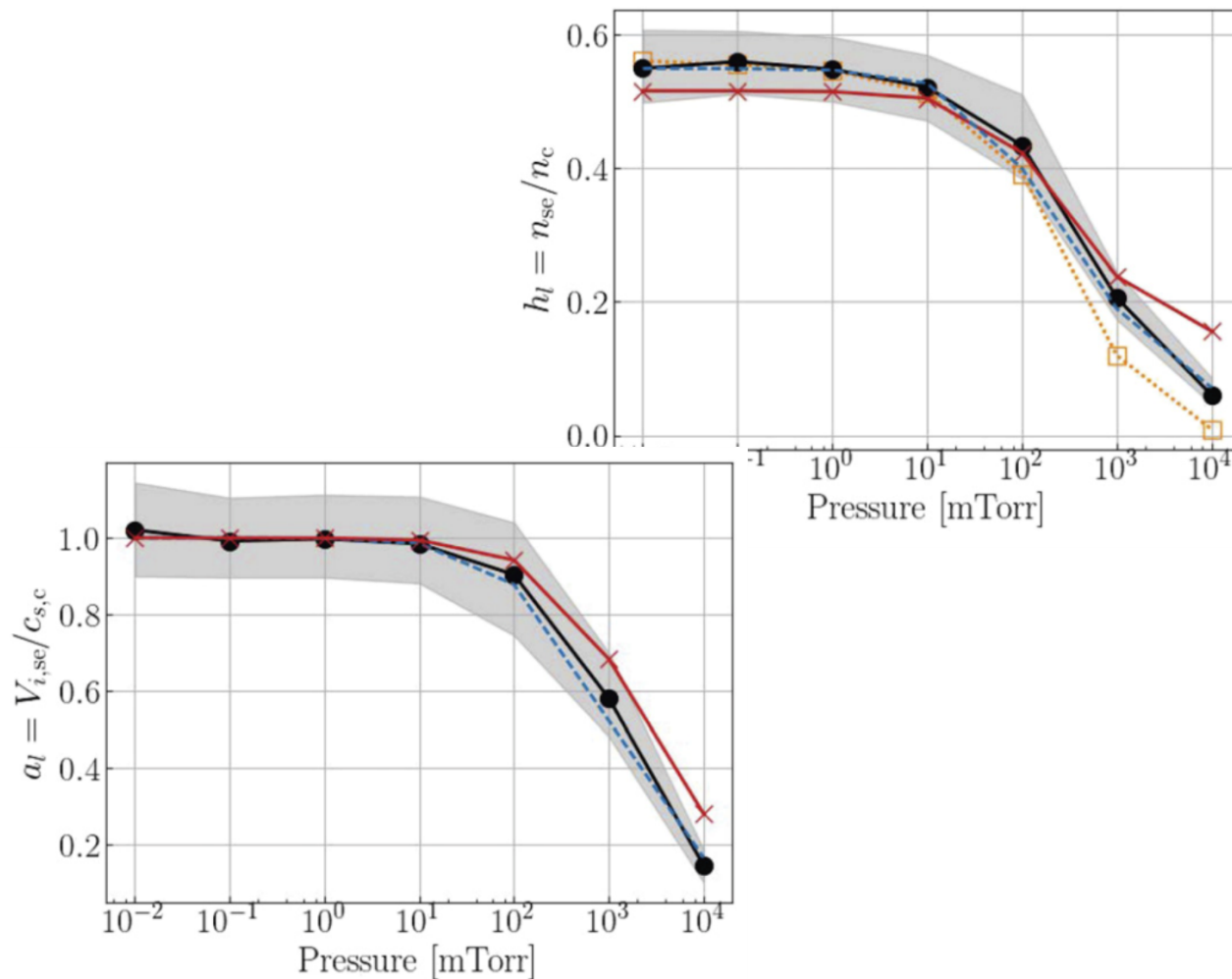
Scheiner et al., Phys. Plasmas
23 (2016)

$\phi_E = -25V$
 $\phi_p = 2.2V$

$\phi_E = 6.5V$
 $\phi_p = 6.5V$



Beving et al., PSST 31 (2022)



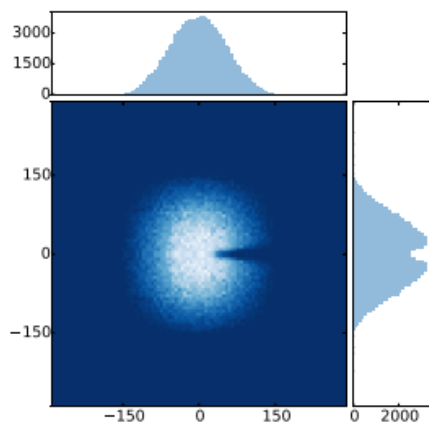
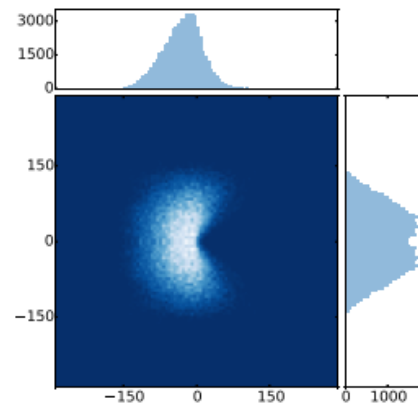
ALEPH CAN EXTRACT DETAILS THE PARTICLE DATA



Scheiner et al., Phys. Plasmas
23 (2016)

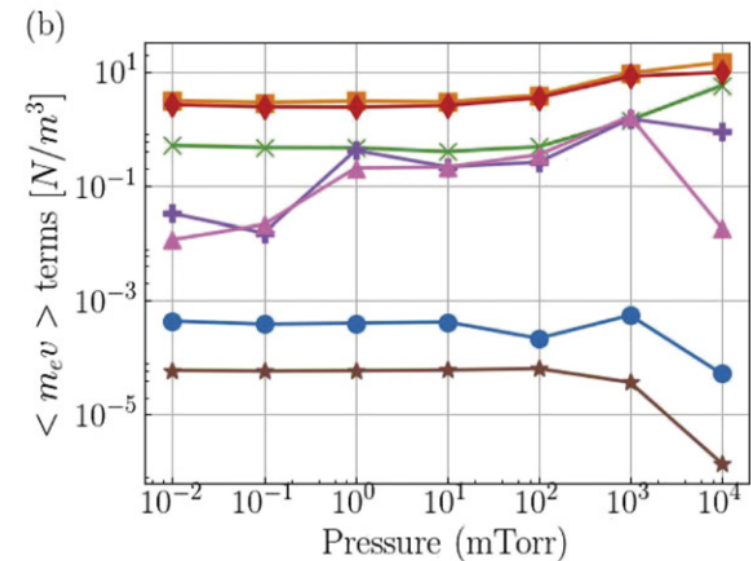
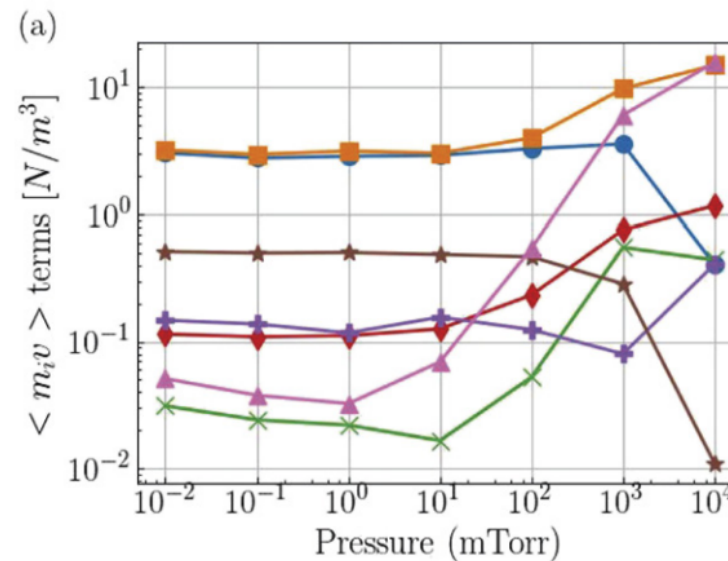
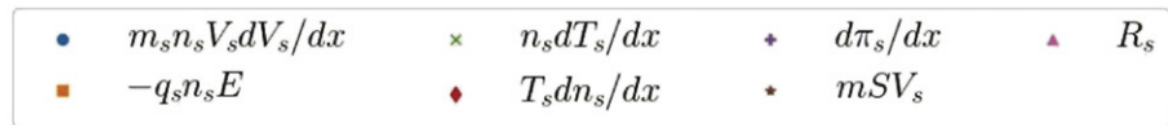
$$\phi_E = 6.5V$$

$$\phi_p = 6.5V$$



V_x (cm/ μ s) Particles

Beving et al., PSST 31 (2022)

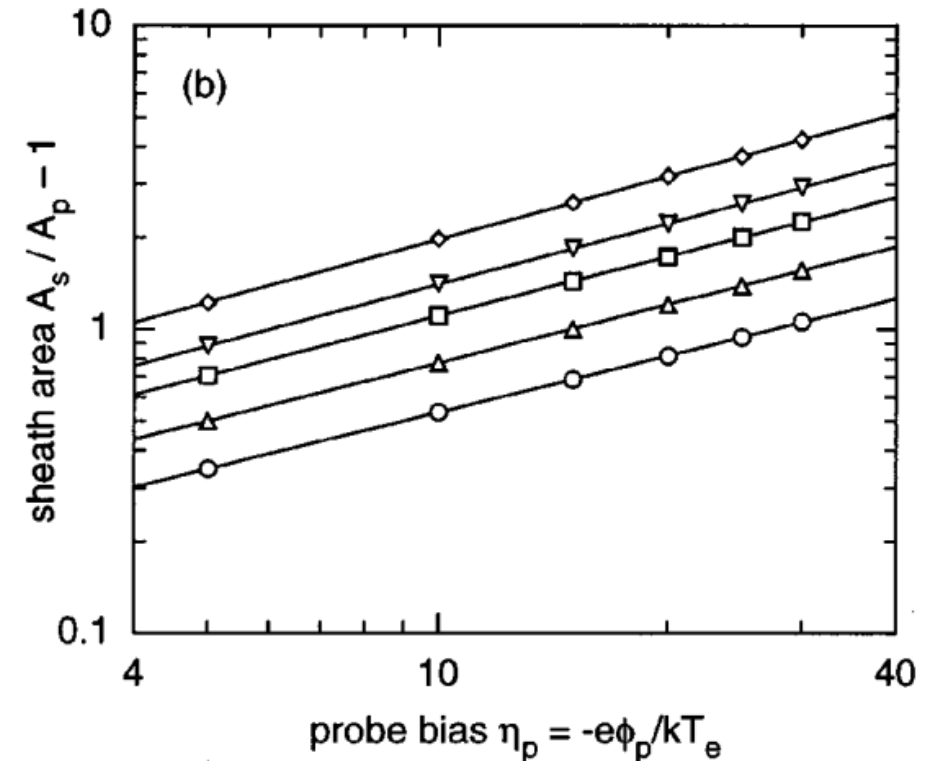
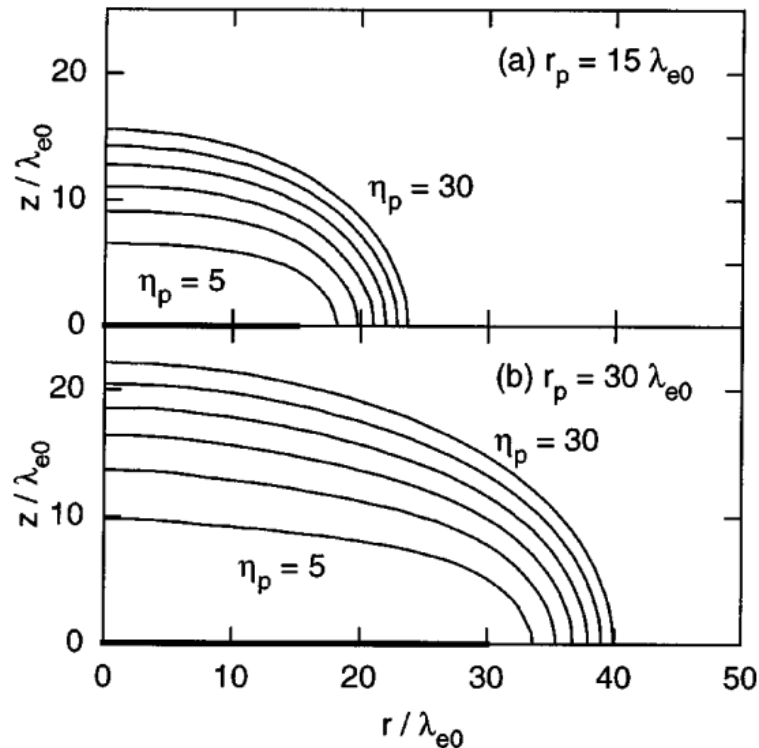


USING SIMULATIONS TO MODEL SHEATH EXPANSION IS NOT NEW: SHERIDAN'S SHEATH EXPANSION MODEL

- Simulations used Boltzmann electrons and particle ions with a flux condition at distant boundary
- Sheath edge \rightarrow where ions reached sound speed

$$I_+ = en_0 \kappa A_s v_B$$

$$A_s / A_p = 1 + a \eta_p^b$$



Sheridan et al., Phys. Plasmas 7 (2000)

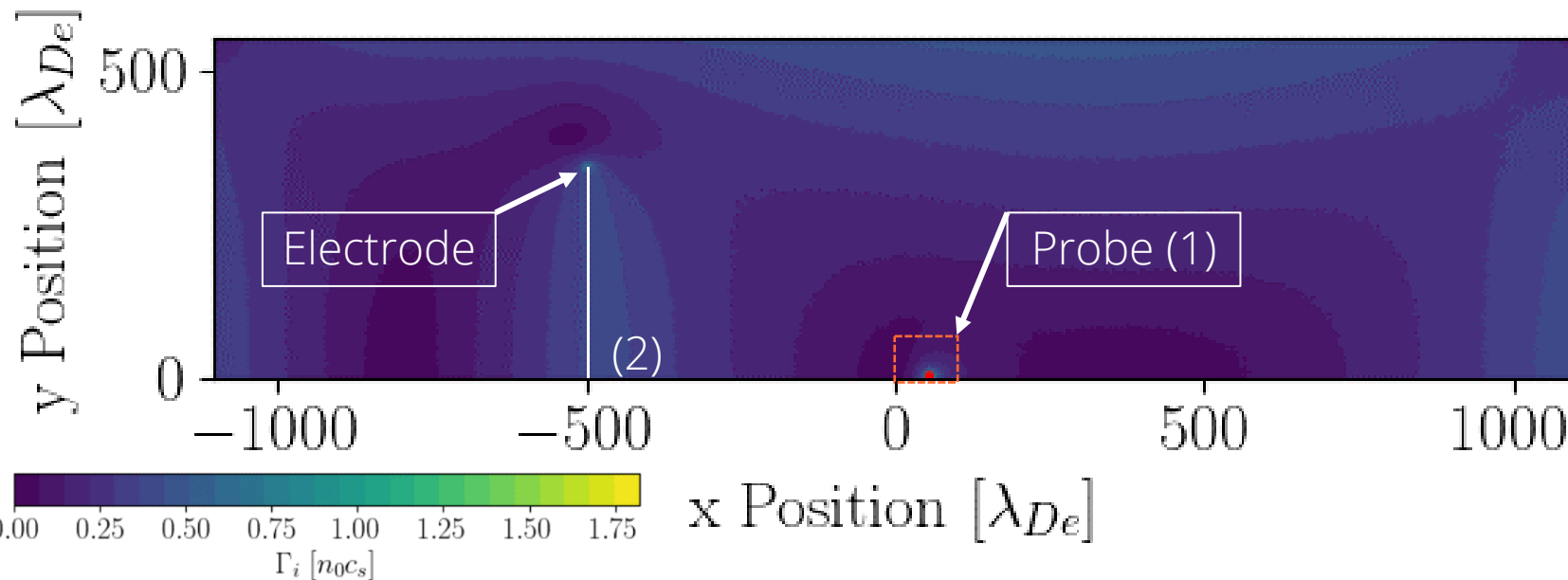
What we will add to the bigger picture:
how plasma flows affect these results



TO STUDY HOW AN ION FLOW AFFECTS SHEATH EXPANSION WE WILL:

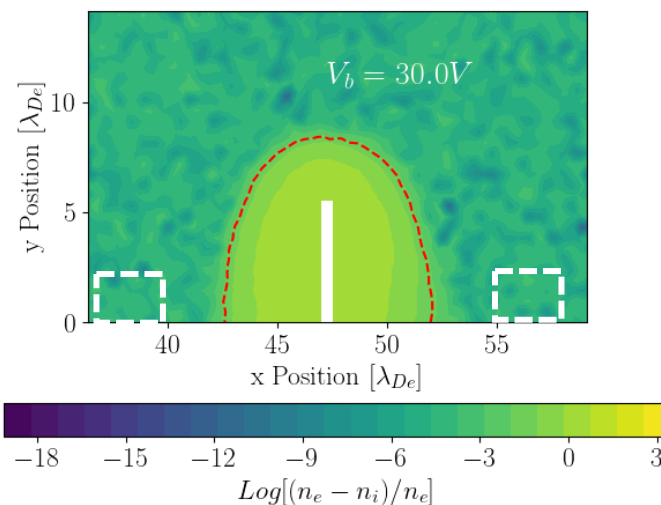
- (1) SIMULATE AN I-V SWEEP IN A NON-FLOWING PLASMA FOR COMPARISON WITH MODELS**
- (2) SIMULATE AN I-V SWEEP IN A FLOWING PLASMA ($V_i \approx 0.8c_s$) FOR COMPARISON WITH (1)**
 - (2A) INCLUDING COMPARISONS OF SHEATH EXPANSION AT DIFFERENT VOLTAGES**
 - (2B) AND COMPARISONS OF THE VDFS UP/DOWNSTREAM OF THE PROBE**

2D SYMMETRIC DOMAIN WITH ABSORBING WALLS AND A SPATIALLY UNIFORM SOURCE MODELS A MULTIDIPOLE CHAMBER



- Top wall is reflecting and a line of symmetry for particles and the electric field
- All other boundaries are perfectly

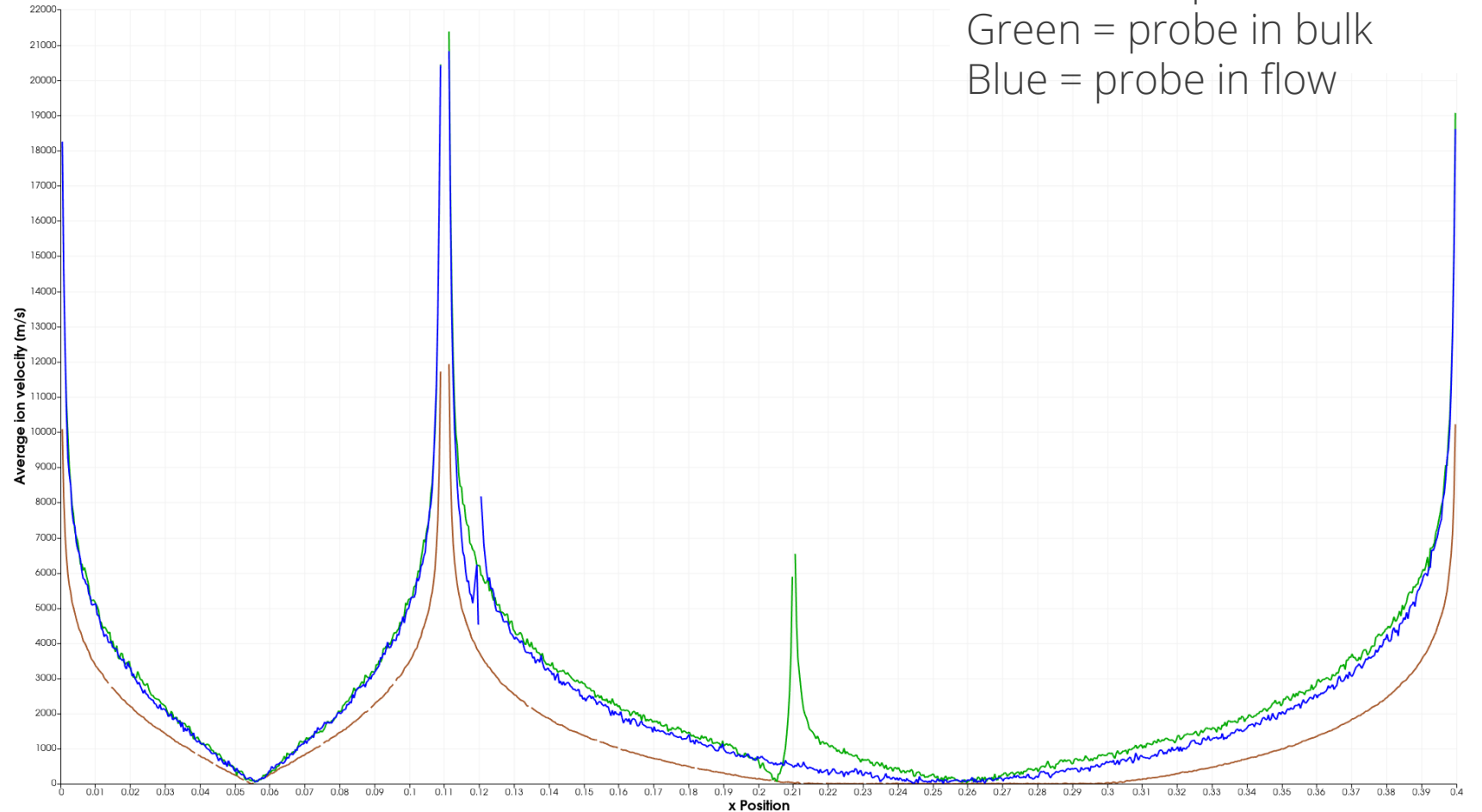
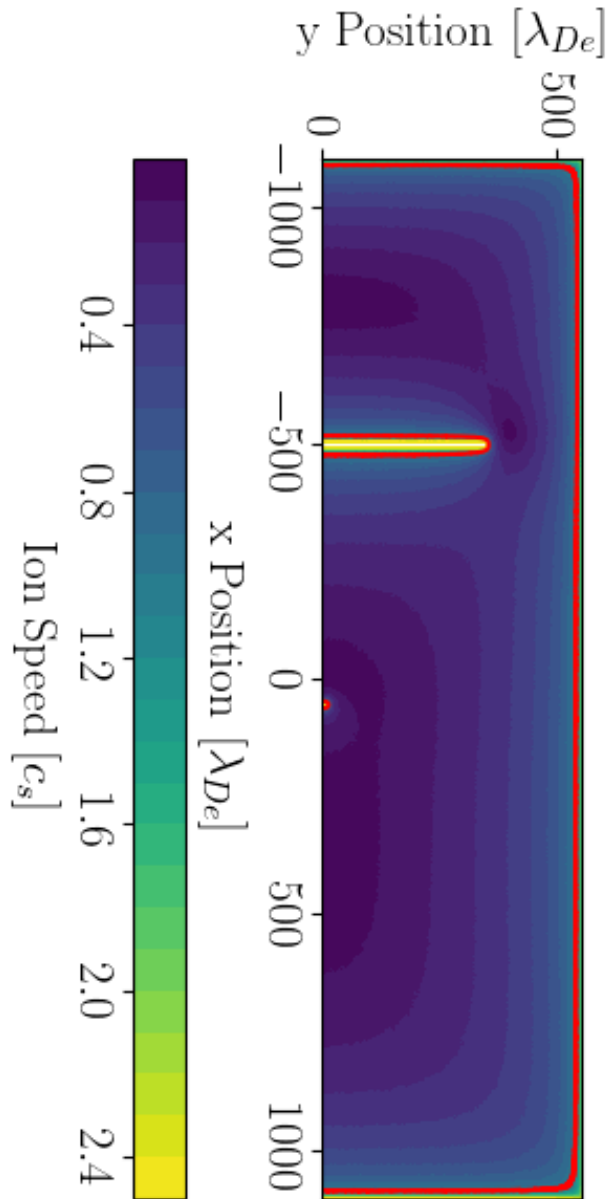
- Sheath perimeters (red dashed line), fluxes, and VDFs are measured within a small region near the probe.
- VDFs are measured upstream (right side of lower plot) and downstream (left side) of the probe, indicated by the white dashed boxes



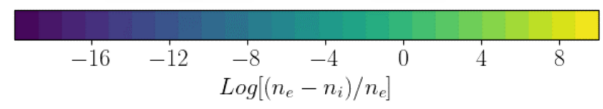
Two sets of simulations were done, (1) with the probe situated as above and (2) with the probe situated at (2).



WE CAN MOVE THE PROBE RELATIVE TO THE ELECTRODE IN OUR SIMULATIONS TO STUDY THE EFFECTS OF AN ION FLOW

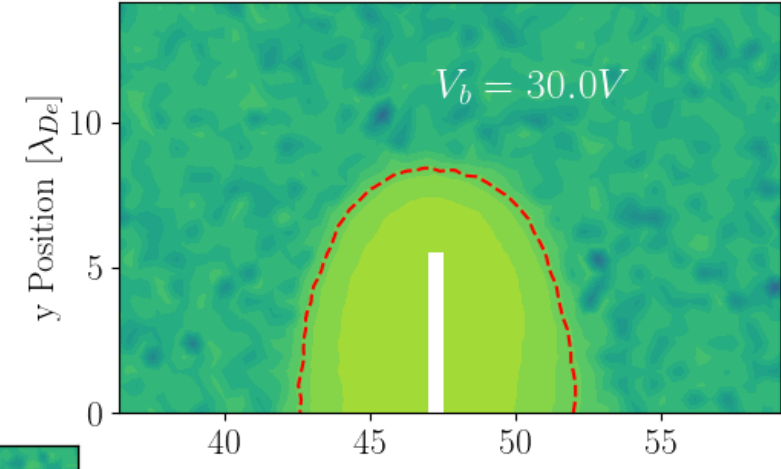
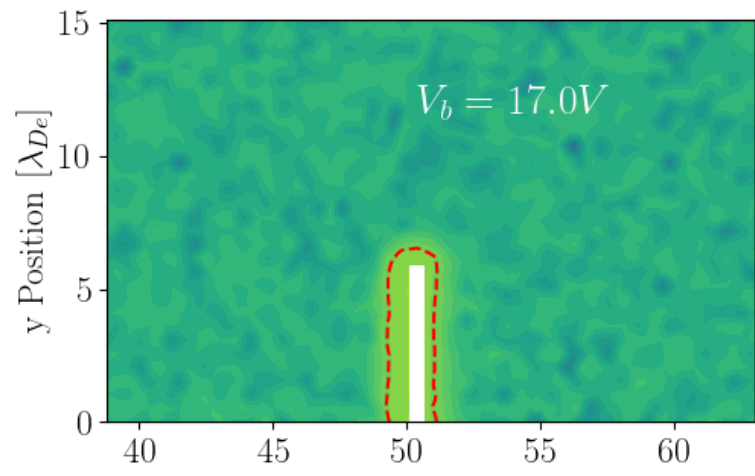
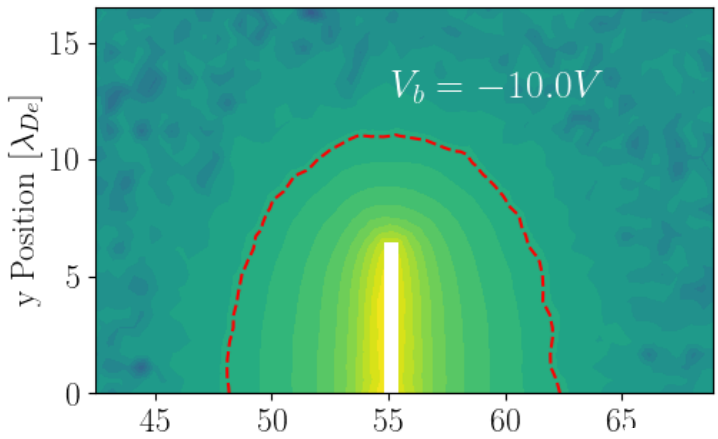


Brown = no probe
Green = probe in bulk
Blue = probe in flow



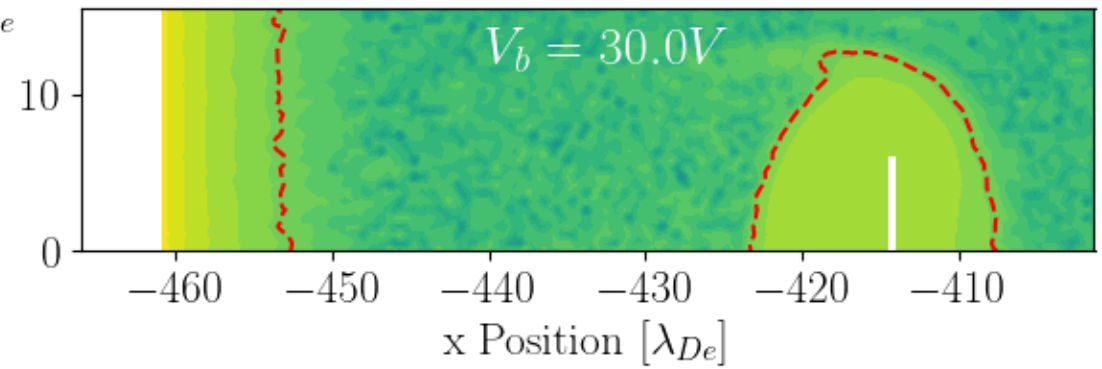
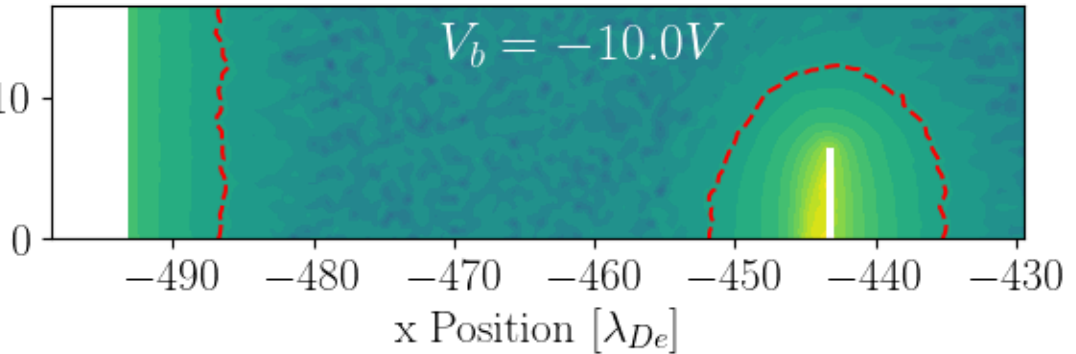
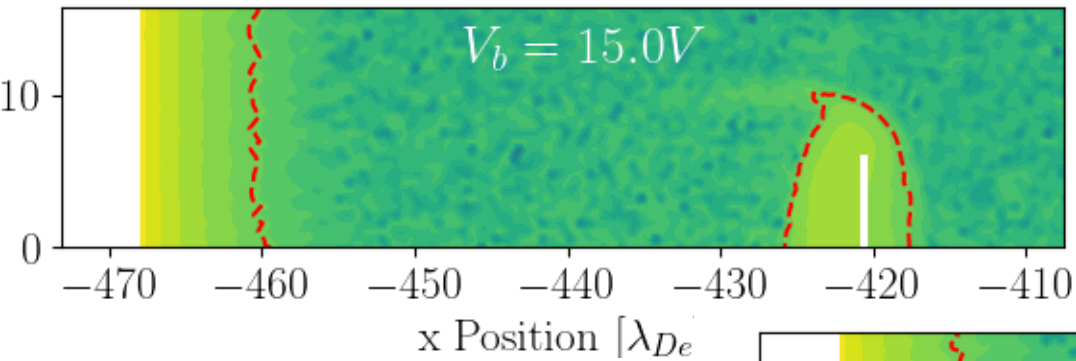
SHEATH EXPANDS FOR ANY BIAS AWAY FROM THE PLASMA POTENTIAL, BUT DEFORMS MORE IN A FLOWING PLASMA

bulk

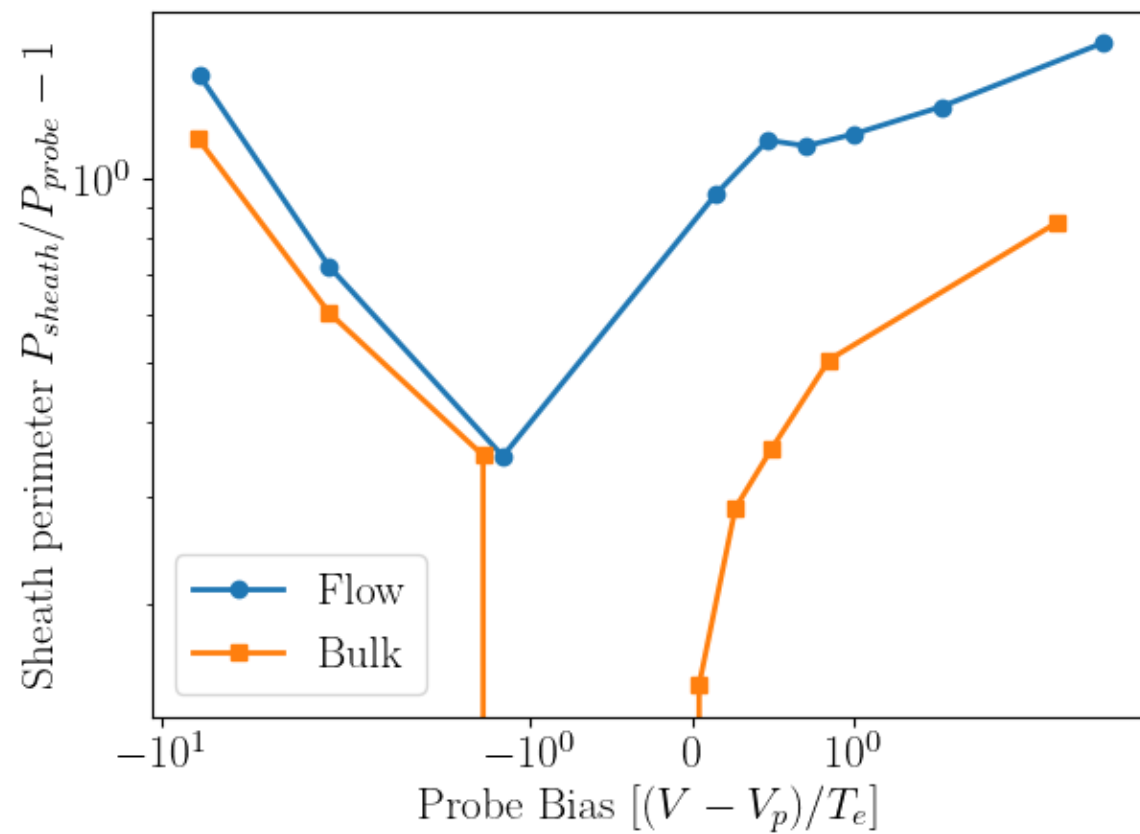
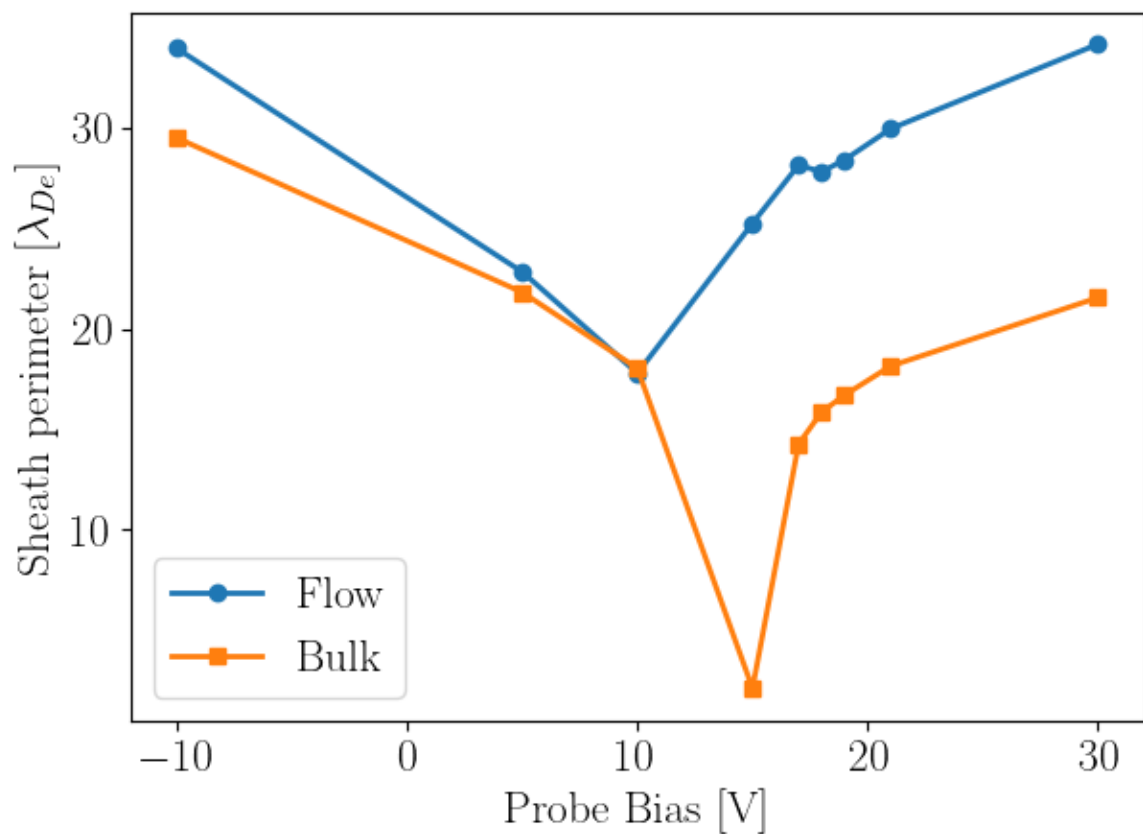


flow

Here, the sheath edge is defined as the location where $(n_i - n_e)/n_e = 0.175$. The red dashed line is the sheath edge.

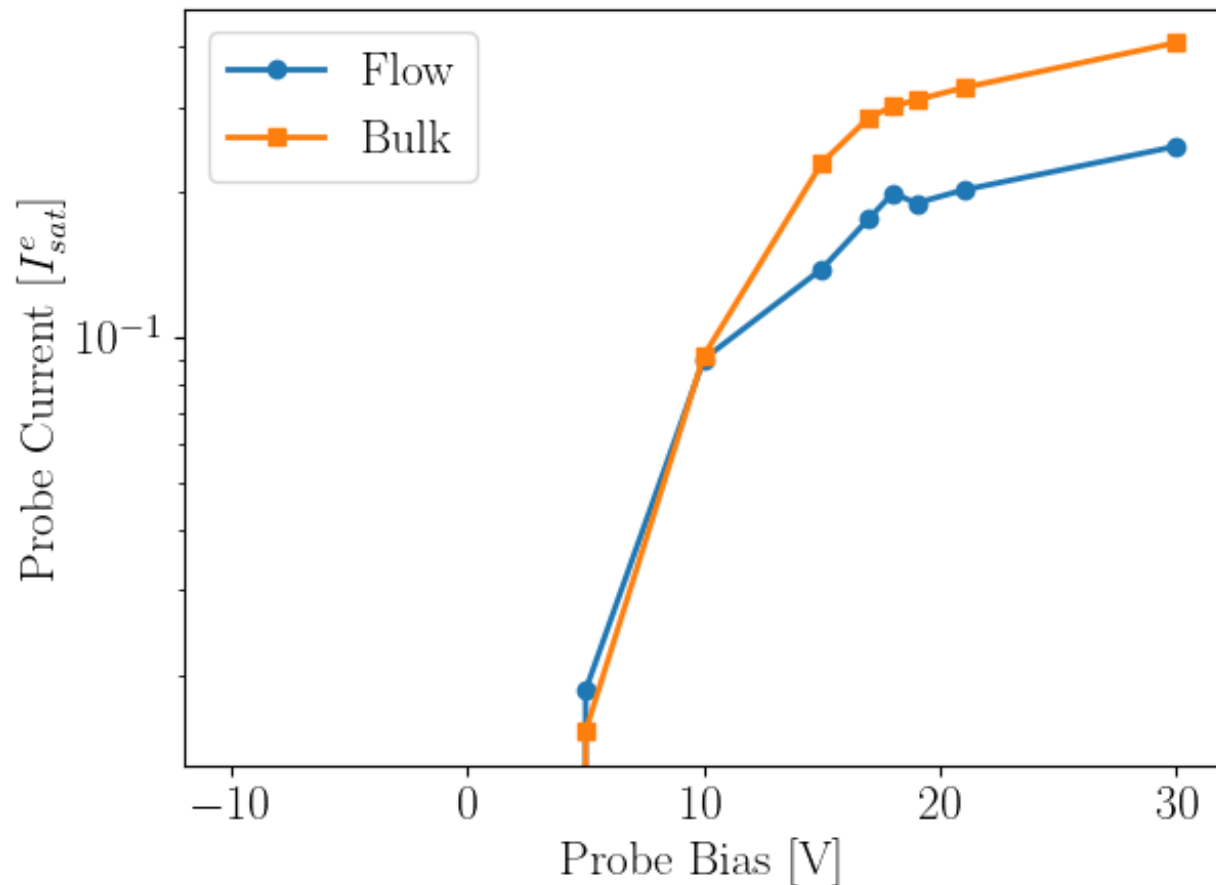
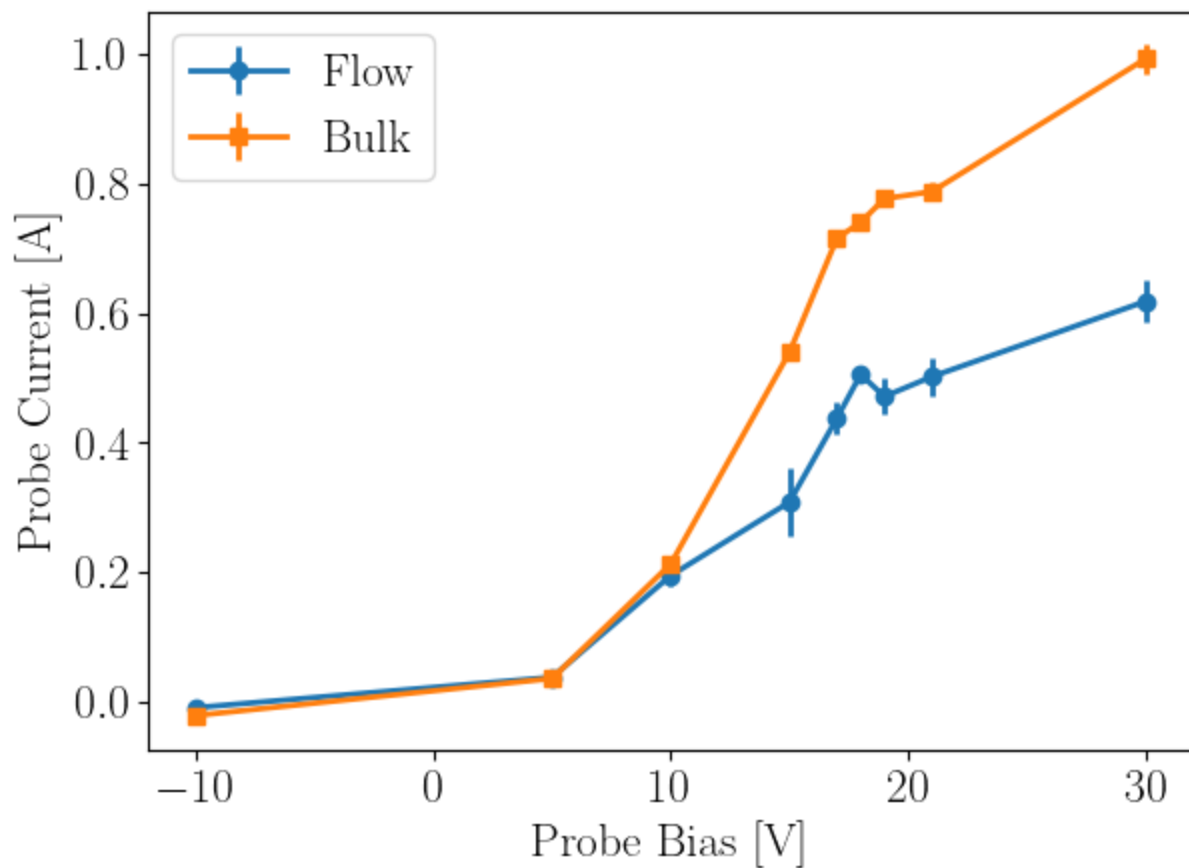


SHEATH EXPANSION LOG PLOT WITH EXPONENTS ON ION SHEATH AND ELECTRON SHEATH VALUES





IV TRACE SHOWS SIGNIFICANT DIFFERENCE BETWEEN BULK AND FLOWING PLASMAS



The flow data current is lower since it is placed in the presheath of the electrode, where the density is ≈ 0.5 of the bulk value. In addition, the slope of the IV curve near the plasma potential is slightly lower in the flow data.

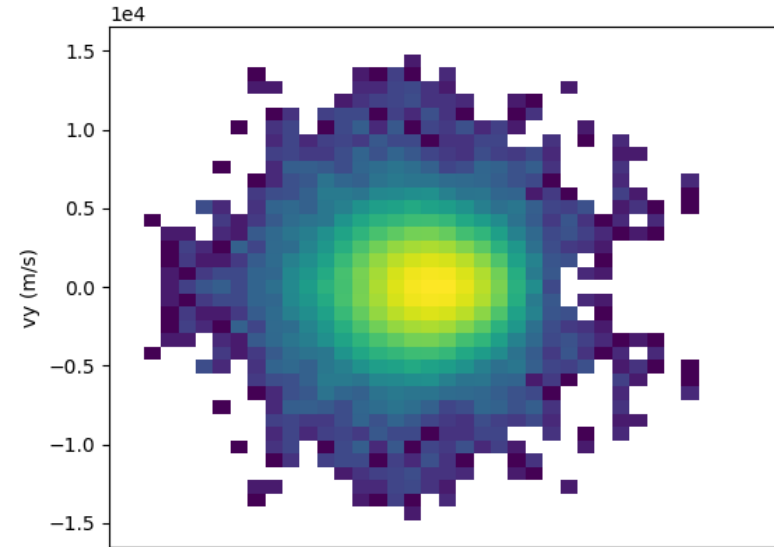
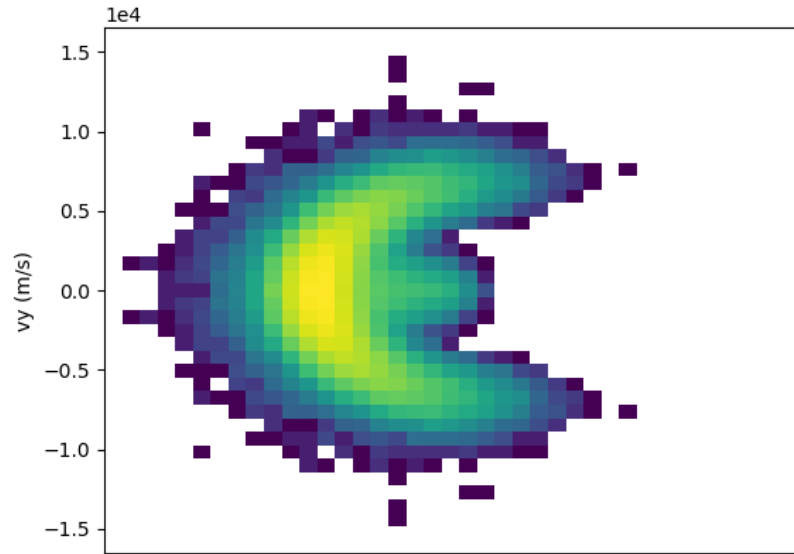


IVDFS IN A BULK PLASMA

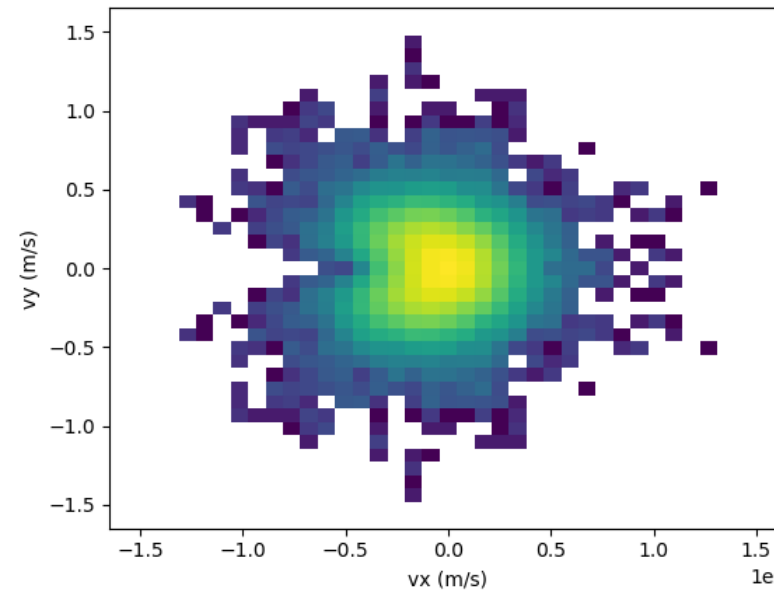
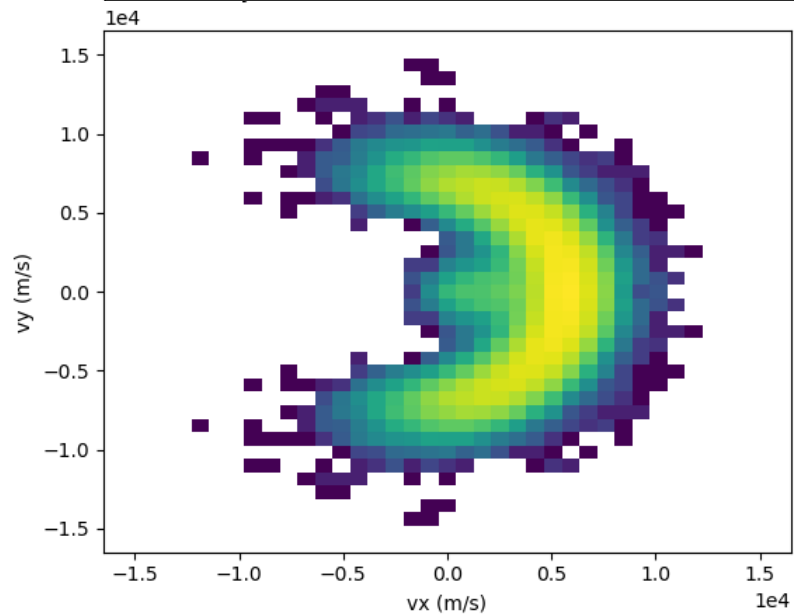
-10V Bias (12.8V PP)

17V Bias (16.8V PP)

upstream



downstream



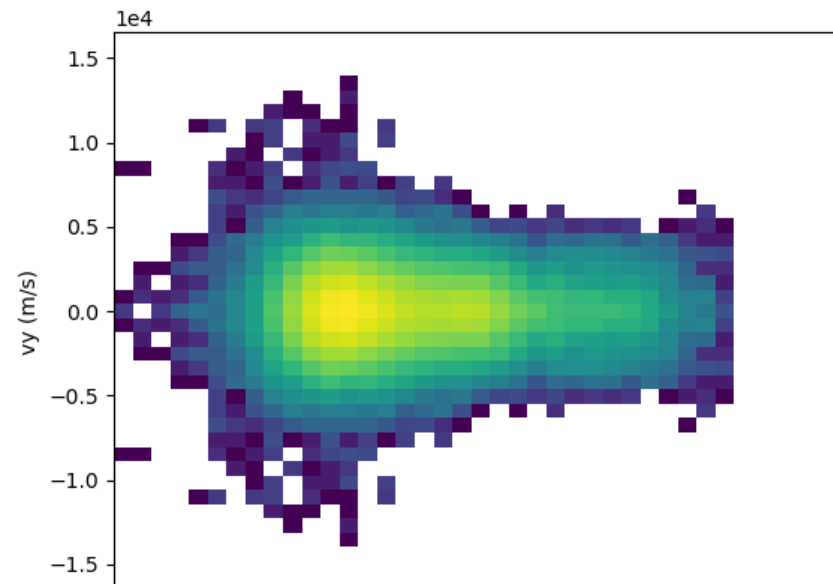
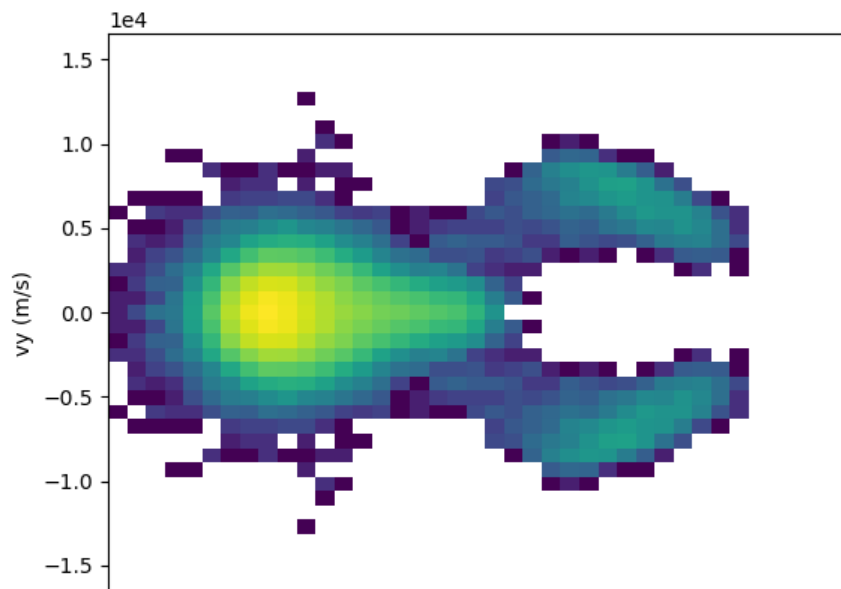
IVDFS IN A FLOWING PLASMA



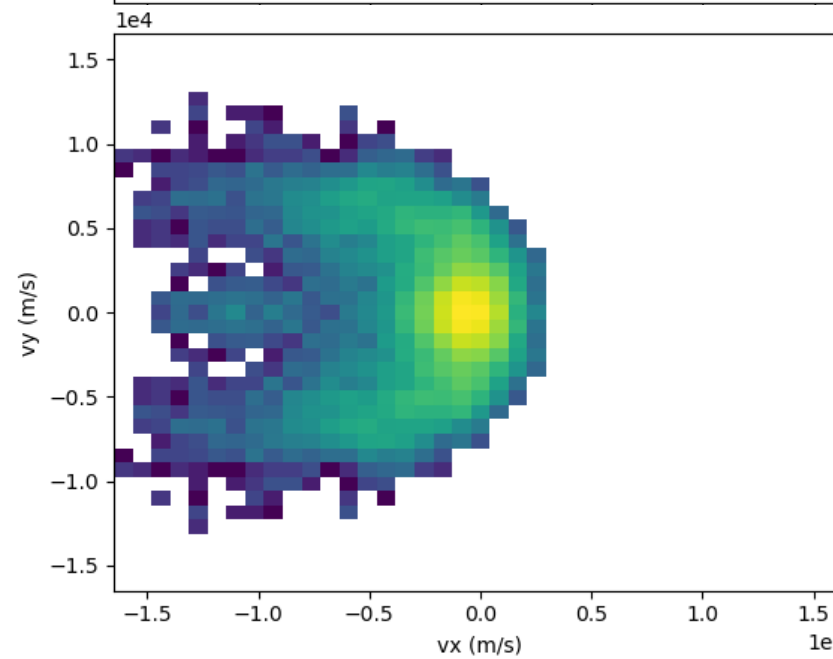
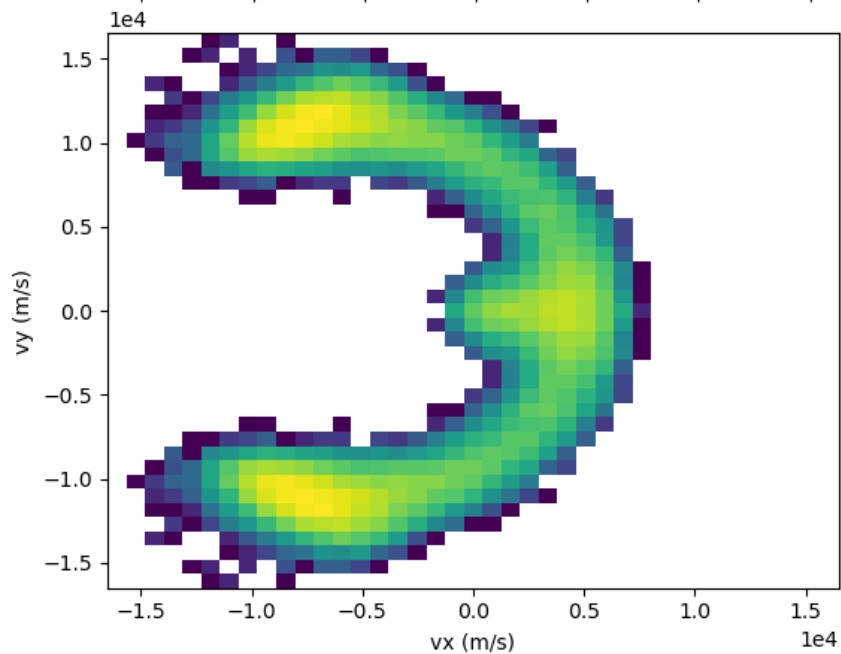
-10V Bias (13.6V PP)

15V Bias (14.5V PP)

upstream



downstream



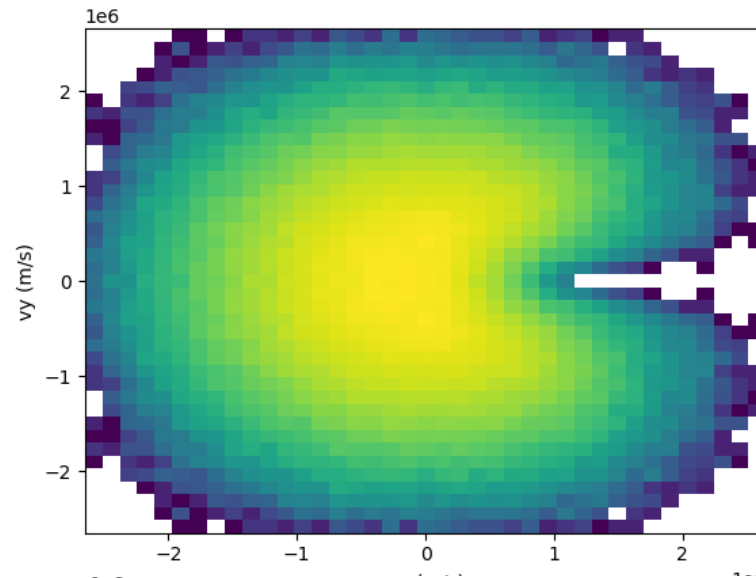
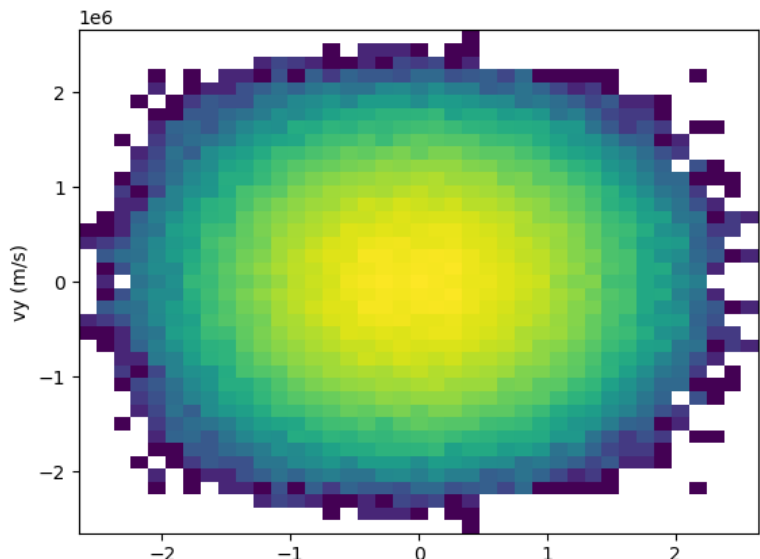


EVDFS IN A BULK PLASMA

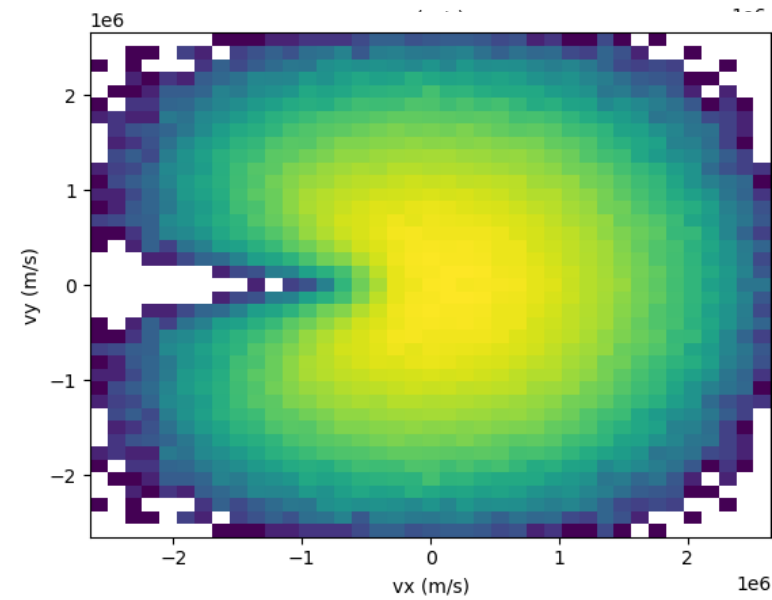
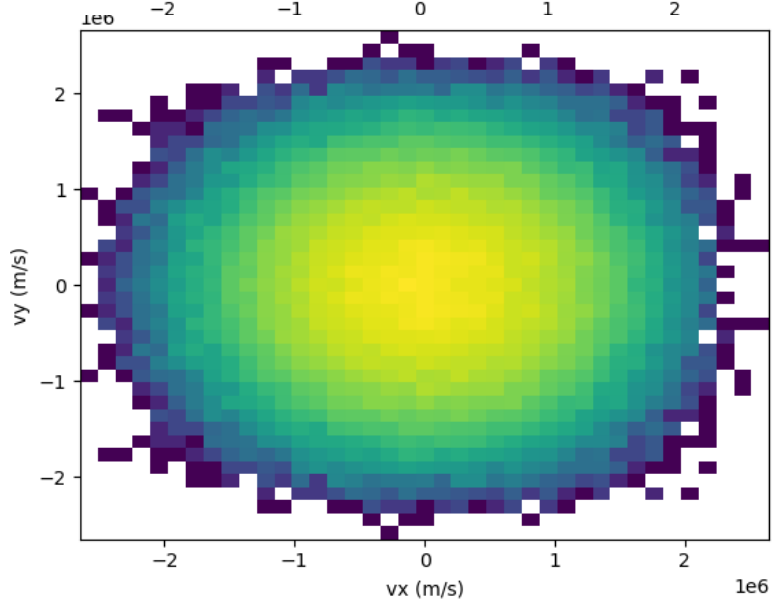
-10V Bias (12.8V PP)

17V Bias (16.8V PP)

upstream



downstream



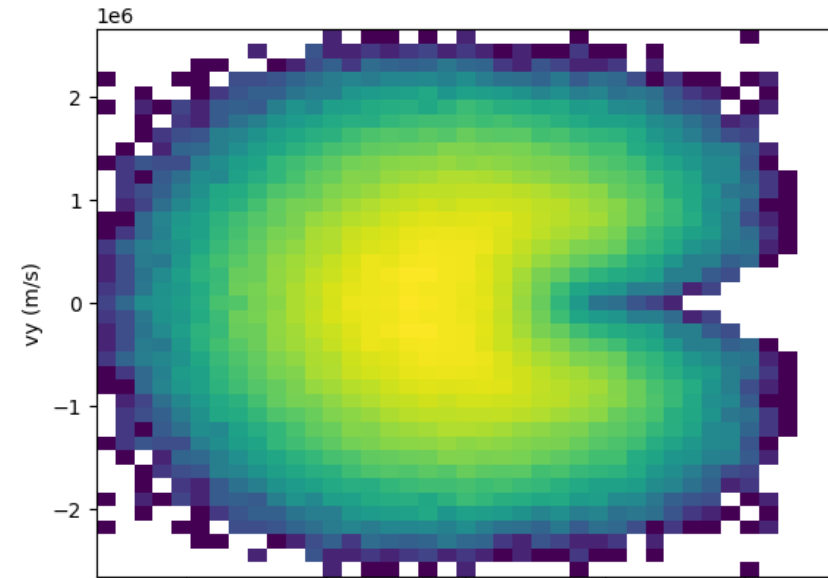
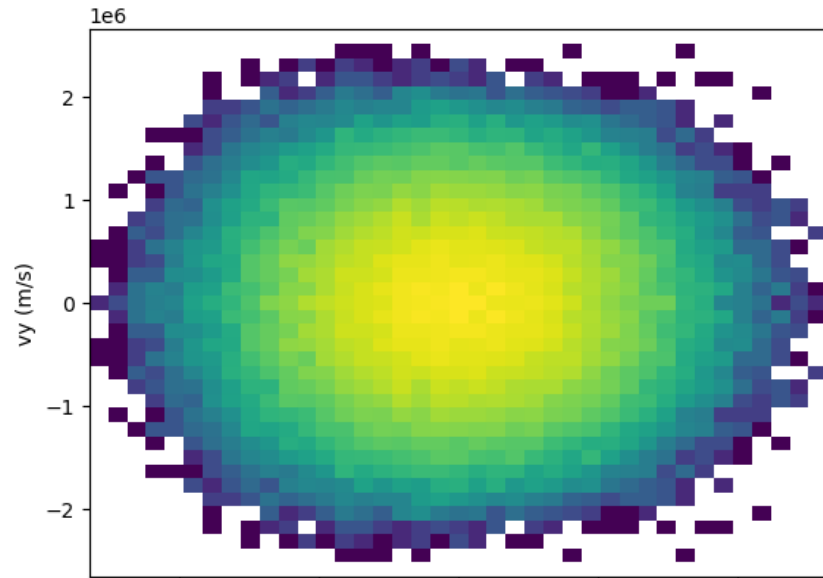
EVDFS IN A FLOWING PLASMA



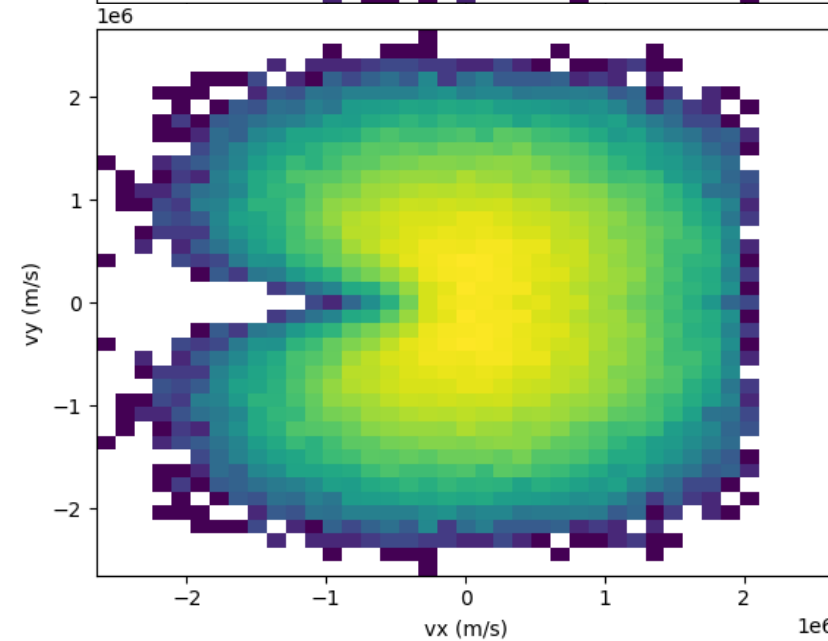
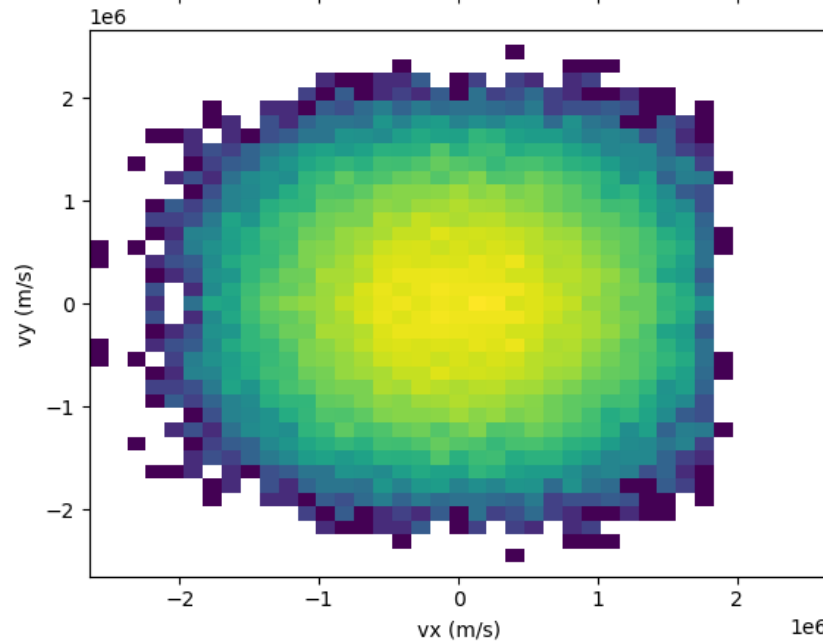
-10V Bias (13.6V PP)

15V Bias (14.5V PP)

upstream



downstream





Acknowledgements

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