Variation in Ion Acceleration Characteristics of the HERMeS Hall Thruster during Magnetic Optimization

IEPC-2019-713

Companion papers:
902, Wed 15:45
841, Thu 15:00

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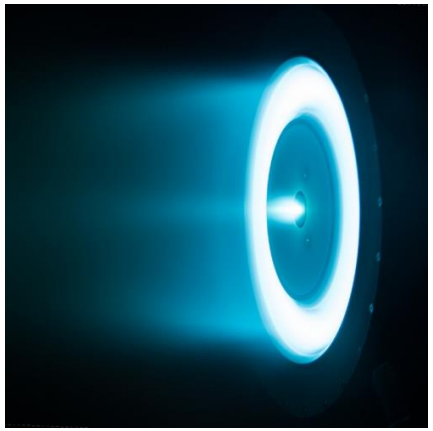
Outline

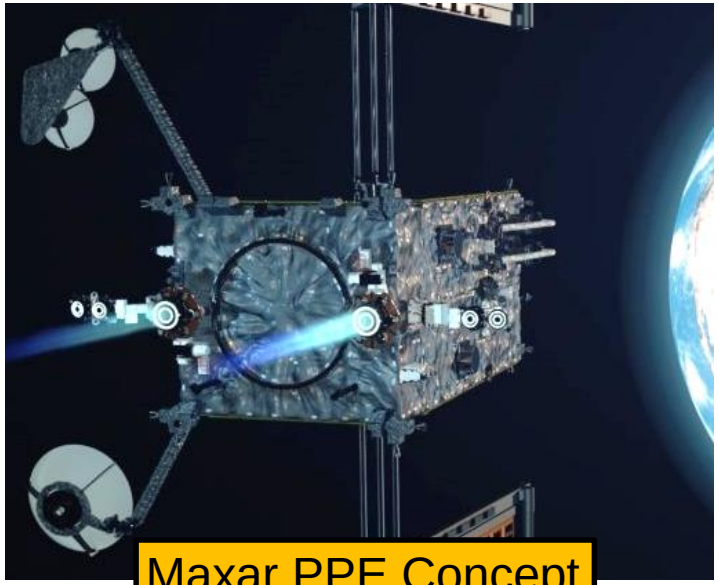
- Introduction
- Magnetic Optimization Test
- Experimental Setup
- Data analysis
- Results
  - Variation in Acceleration Profile
  - Ion Characteristics in Discharge Channel
  - Ion Characteristics near Pole Covers
- Conclusion

Introduction

- A NASA GRC and JPL team developed a 12.5-kW, magnetically-shielded Hall thruster, called Hall Effect Rocket with Magnetic Shielding (HERMeS)
- Flight development continuing in the form of Aerojet Rocketdyne's Advanced Electric Propulsion System (AEPS)
- Propulsion system for the Power and Propulsion Element (PPE), the first element of NASA's Gateway
- Completing risk reduction activities (using HERMeS) and transitioning to Engineering Test Unit (ETU) testing
- Developing a related Plasma Diagnostics Package (PDP)



◀ HERMeS in operation

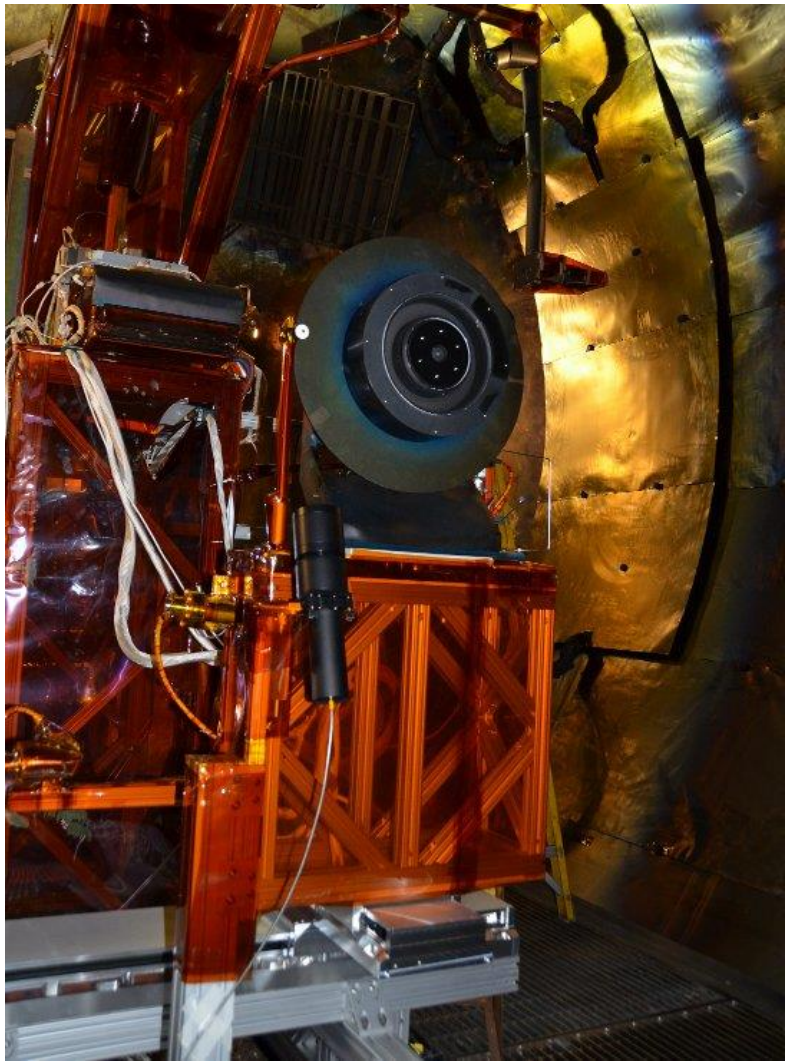


Maxar PPE Concept

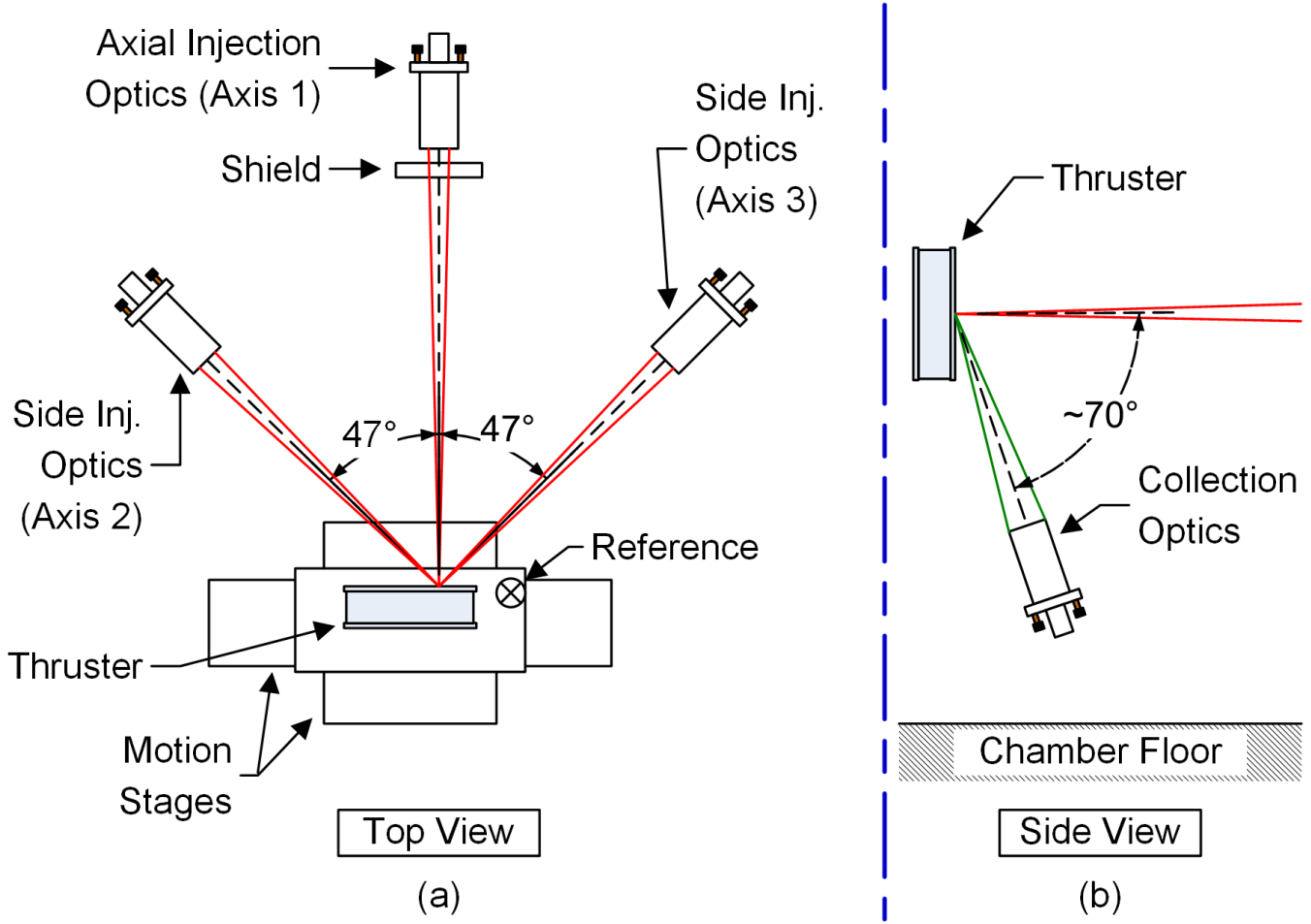
Magnetic Optimization Test

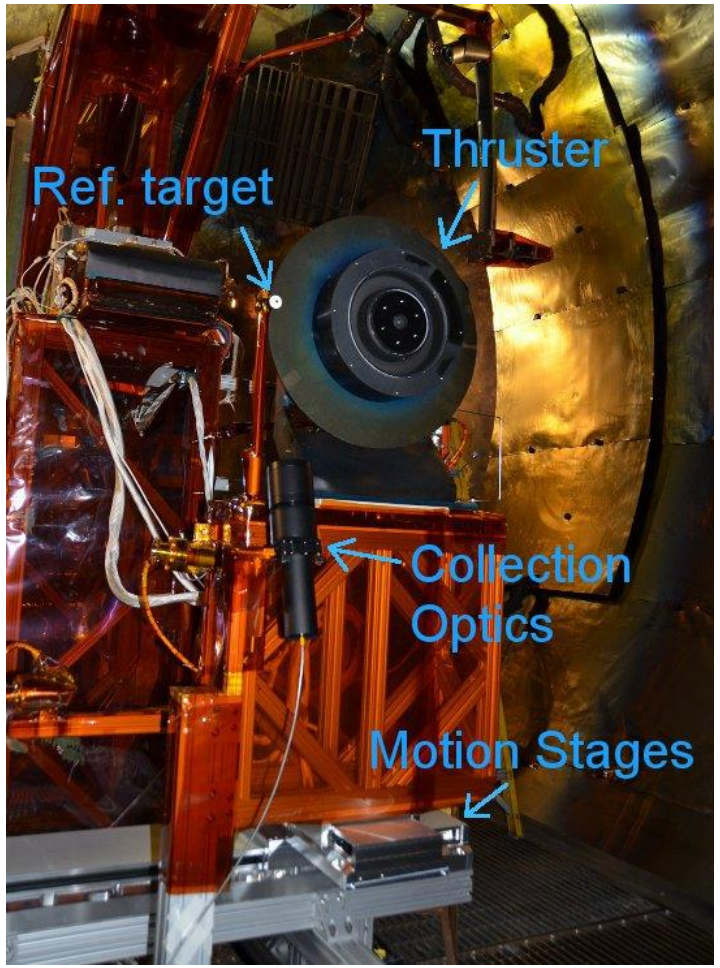
- HERMeS TDU1
  - Throttle range from 0.6 to 12.5 kW, 2000 to 3000 sec
  - Centrally mounted cathode, 7% cathode flow fraction
  - Cathode tied to thruster body
  - Test was in VF6, ~1.2e-5 Torr near thruster
- Four configurations in order of decreasing magnetic shielding: B0, B1, B2, B4
  - B0 is TDU baseline
  - Max radial magnetic field along channel centerline shifted upstream by about the same amount between each configuration in the sequence

Label	Discharge voltage, V	Discharge power, kW
300-6.3	300	6.25
600-12.5	600	12.50



Experimental Setup – Vacuum Side Optics

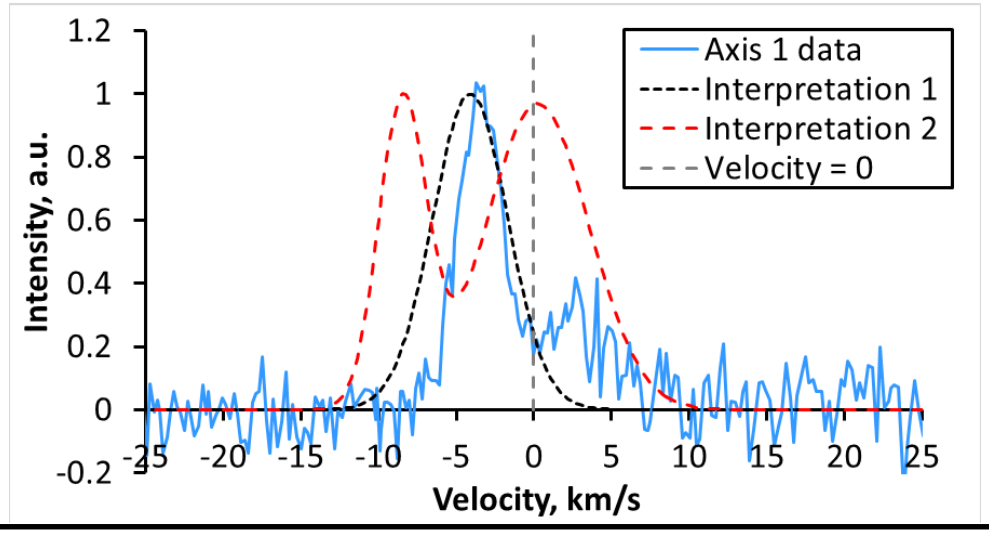


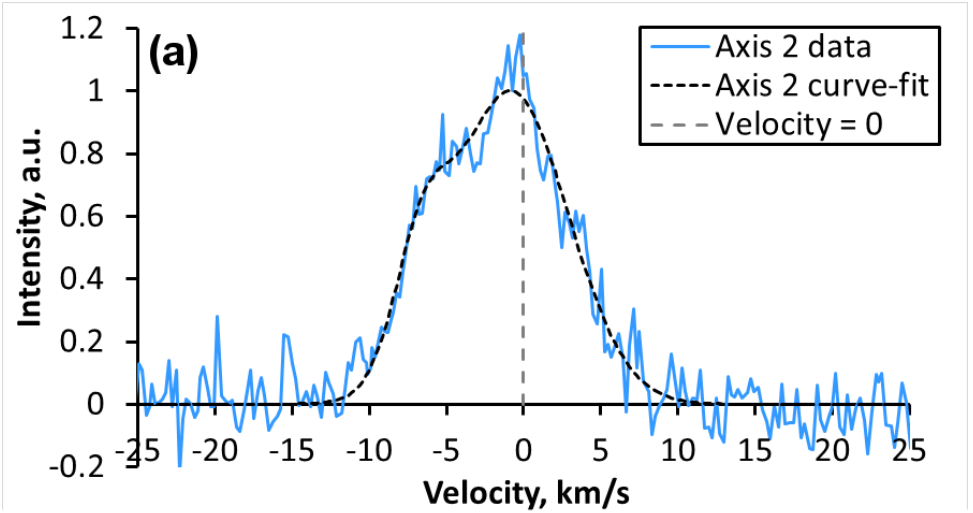


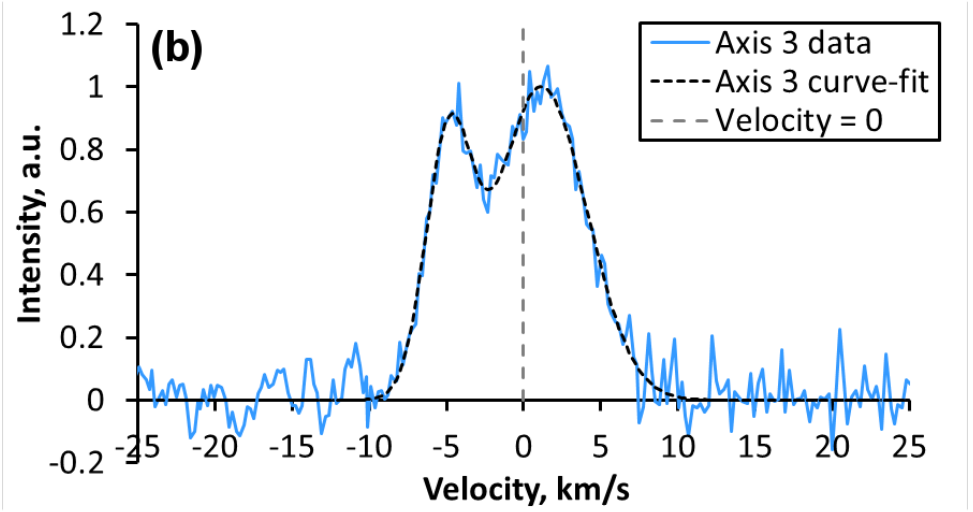
Additional setup info in AIAA-2018-4723

Data Analysis

- Curve fit-based approach accounting for Zeeman Effect (See paper)
- Spatial uncertainty: 0.5 mm
- Velocity uncertainty: ±112 m/s typical (±600 m/s for noisiest scans)
- On Inner Front Pole Cover (IFPC), two peaks found on axes 2 and 3; comparison to axis 1 shows two ion populations pointed into the IFPC
  - One from the discharge channel, one from the cathode
  - See AIAA-2019-3897 for additional details



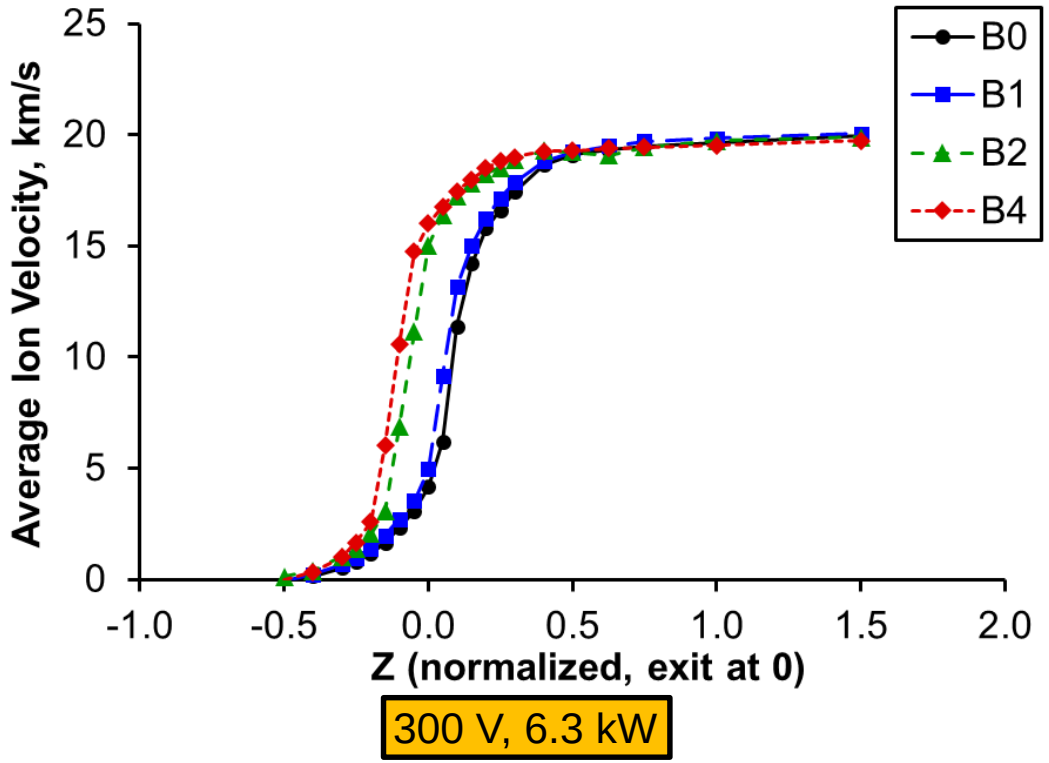




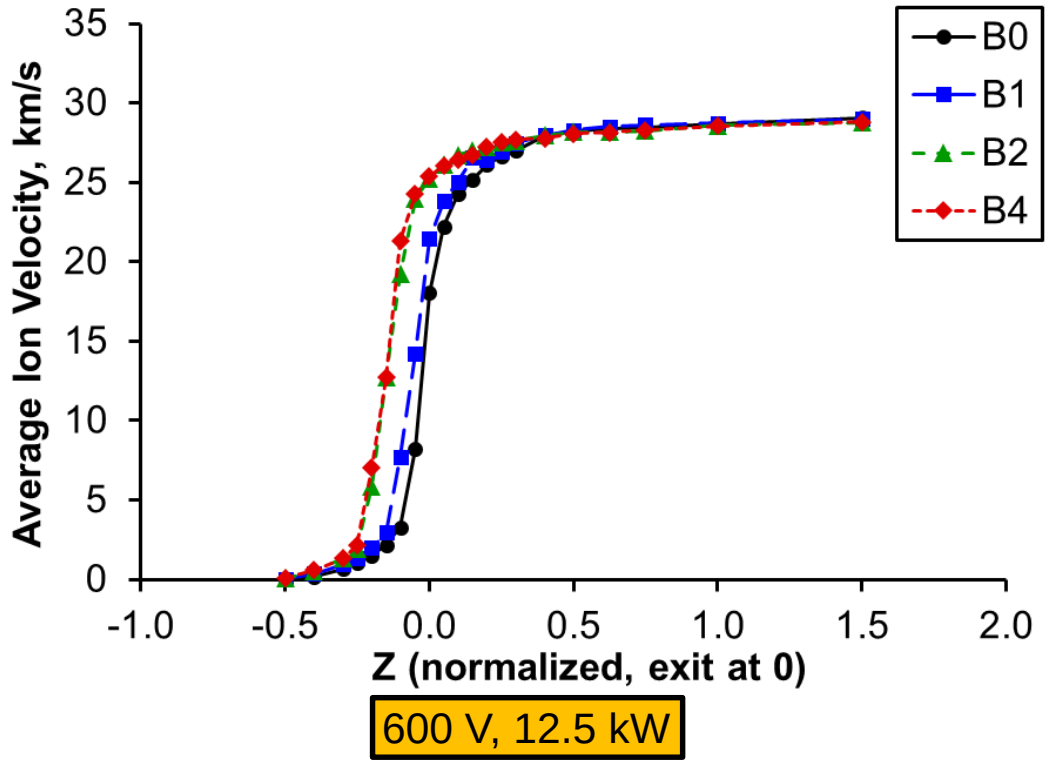
600 V, 12.5 kW, around radial middle of the IFPC

Variation in Acceleration Profile

- Noticeable jump in acceleration zone between B1 and B2



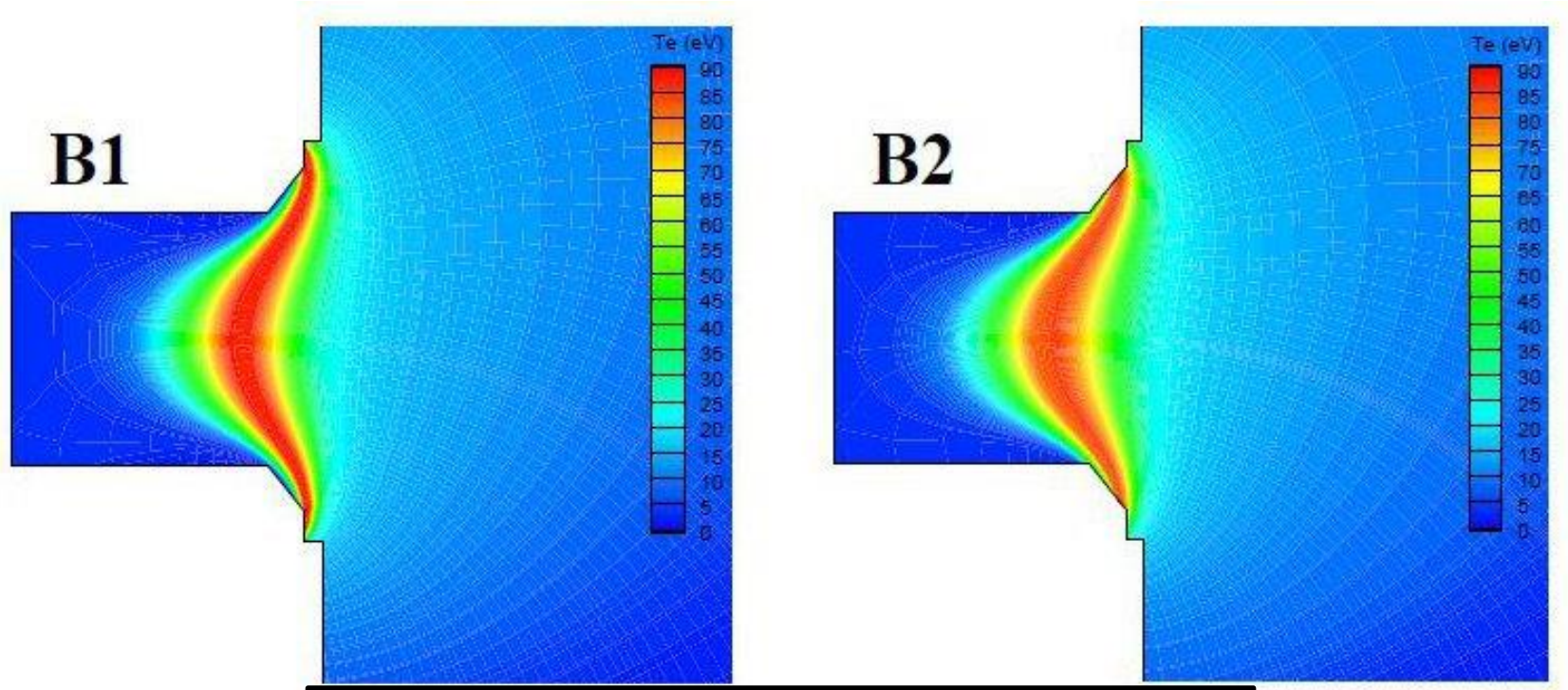
300 V, 6.3 kW



600 V, 12.5 kW

Prior Modeling Work Points to Possible Cause

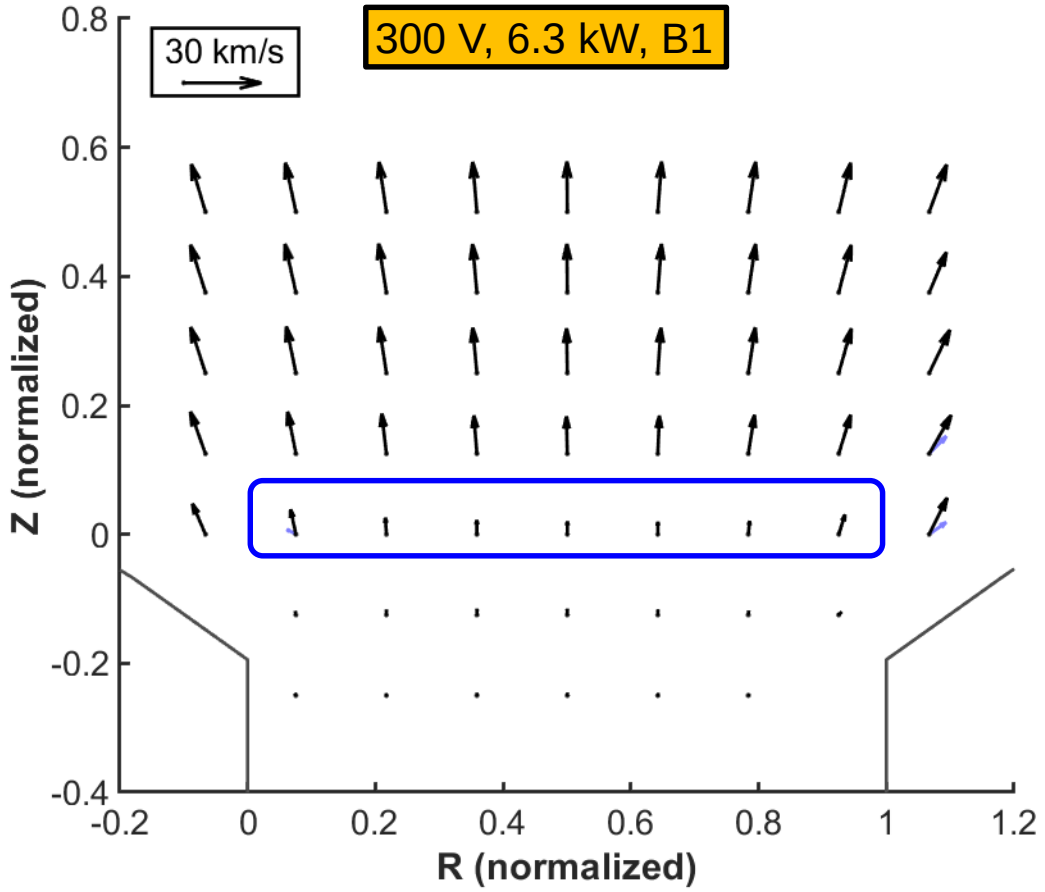
- Hall2De simulation from AIAA-2018-4720 shows a different attachment point for the high-energy plasma (red in plots below) for B1 and B2
- Whereas B0 and B1 were more like magnetically-shielded topology, B2 and B4 were more like reduced / un-shielded topology

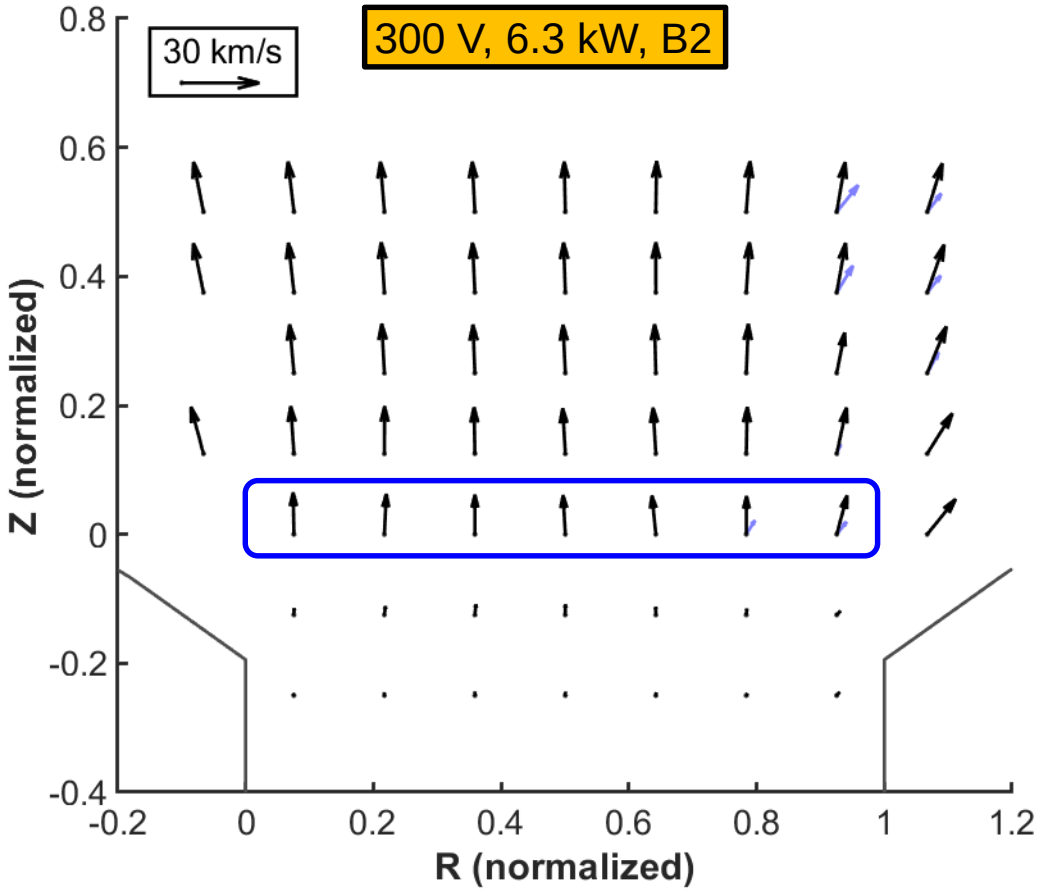


Reproduced from AIAA-2018-4720 for convenience

Ion Characteristics in Discharge Channel

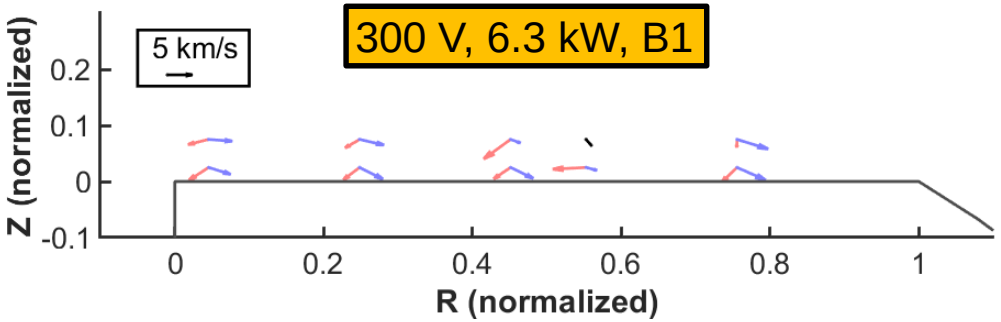
- Going from B1 to B2: Accel zone move upstream, plume becomes less divergent

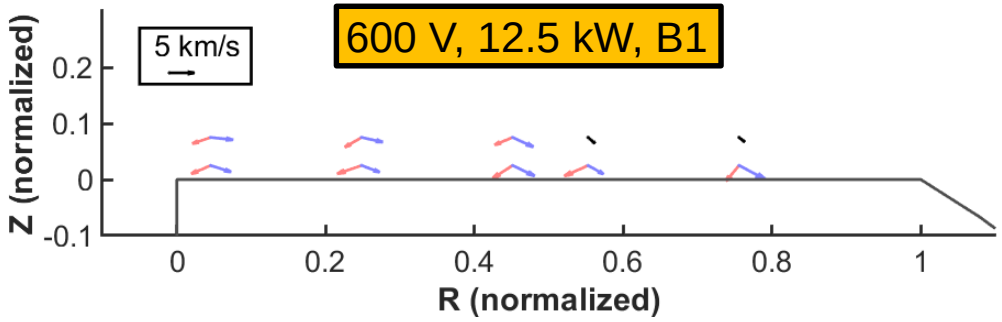


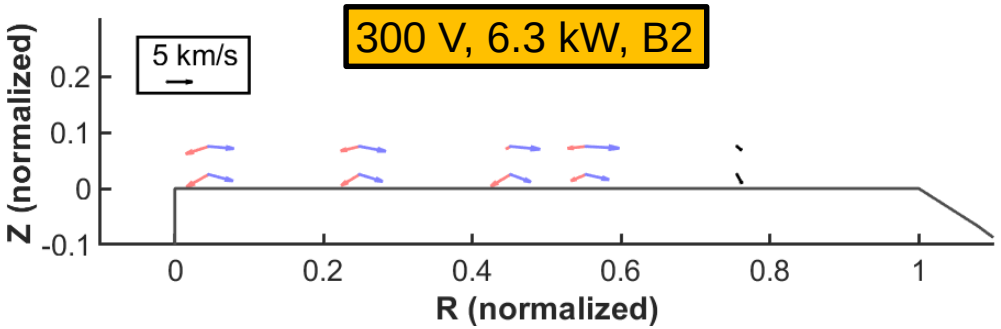


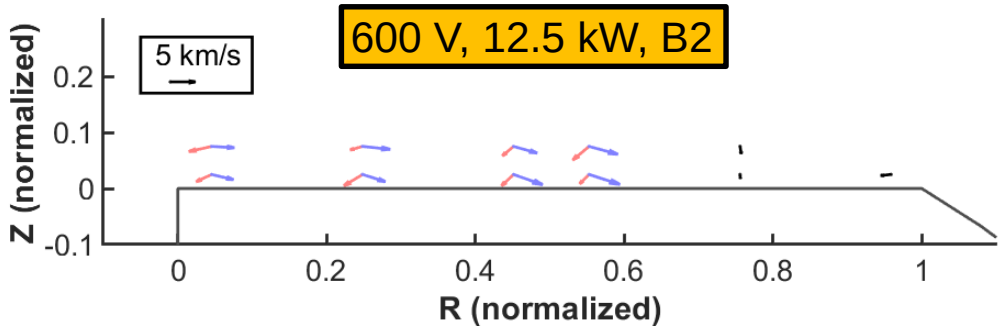
Ion Characteristics near IFPC

- Red vectors represent discharge channel stream, blue vectors represent cathode stream
- Both streams point into the inner pole cover at high oblique angles



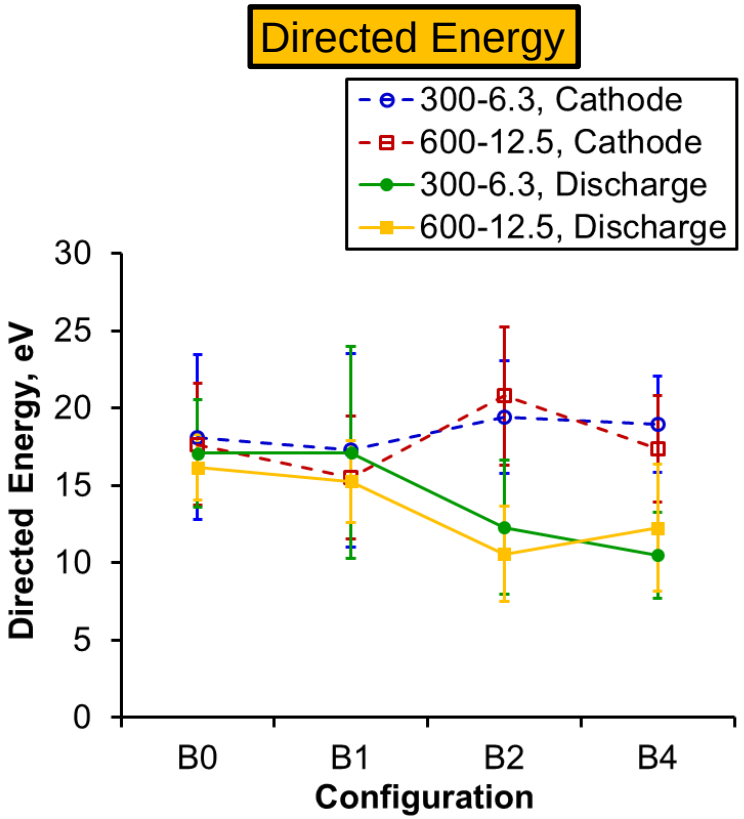


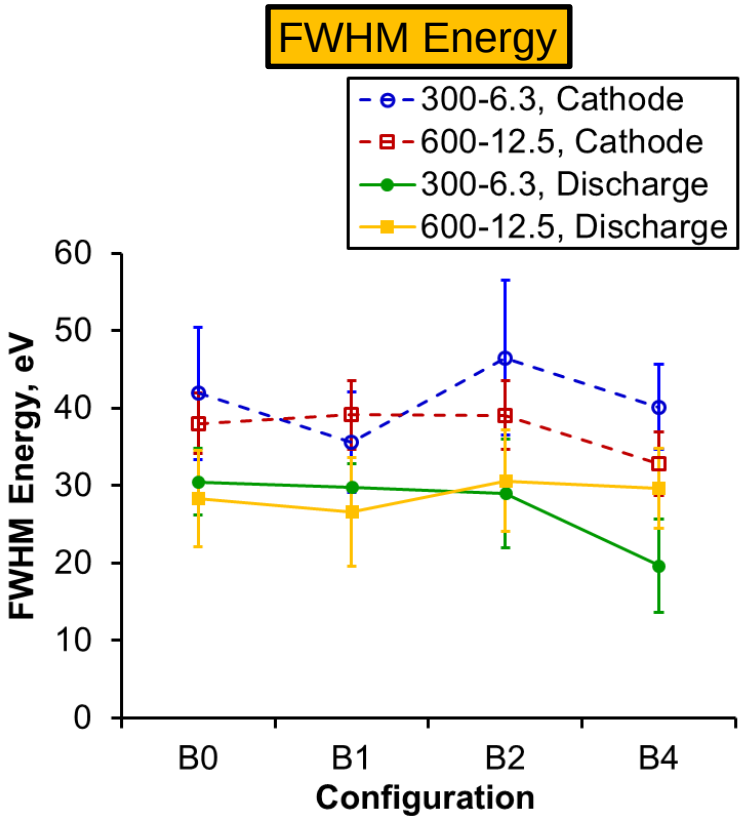


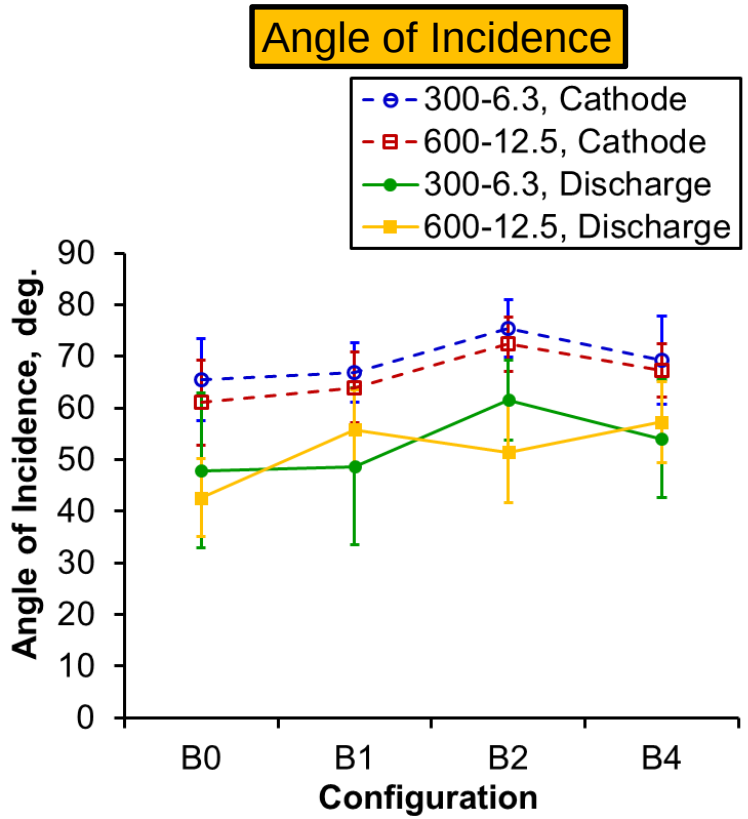


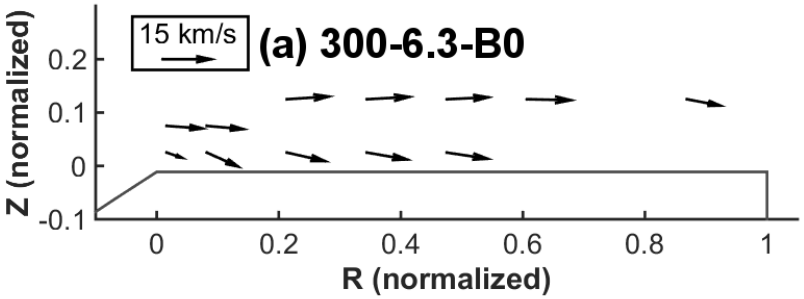
Summary of Ion Energy and Angle near IFPC

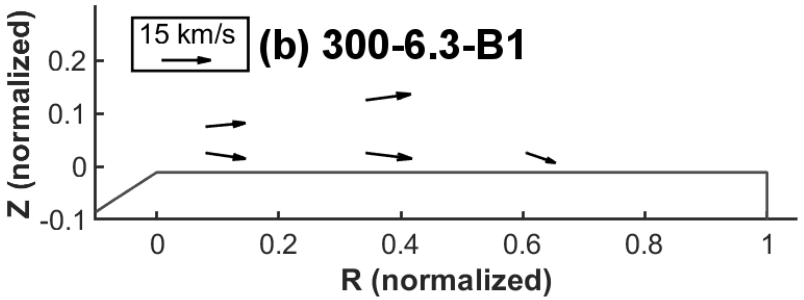
- In the labels of these plots, “Cathode” refers to cathode stream, “Discharge” refers to discharge channel stream
- About the same energy and angles across configurations to within uncertainty

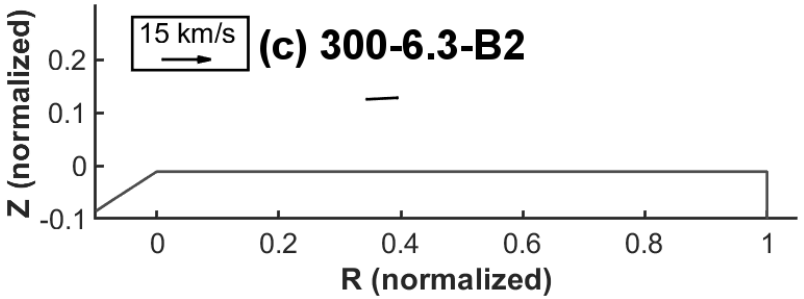


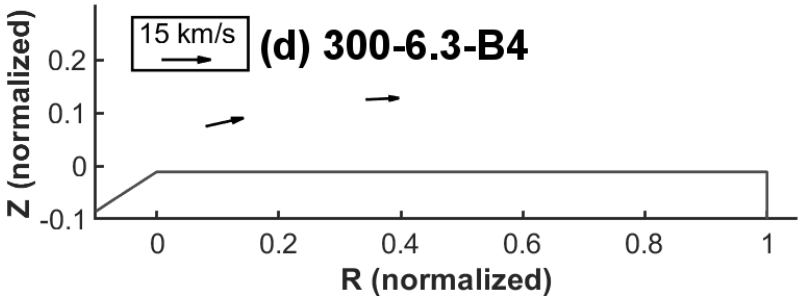


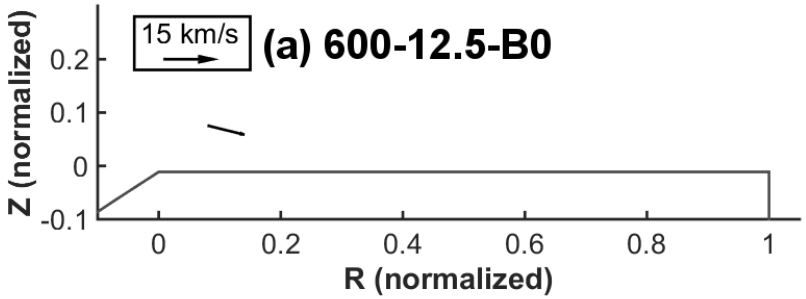


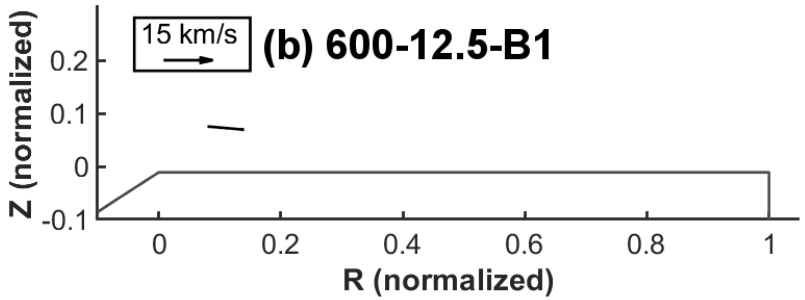


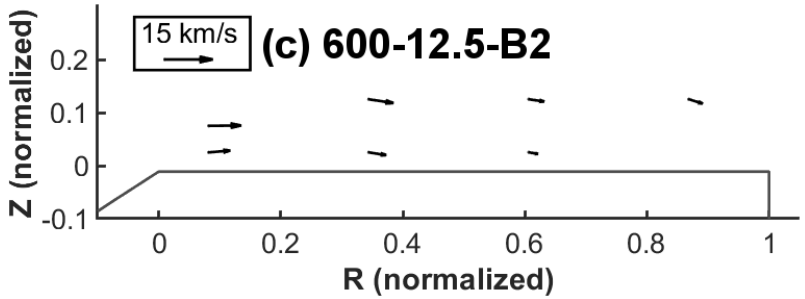


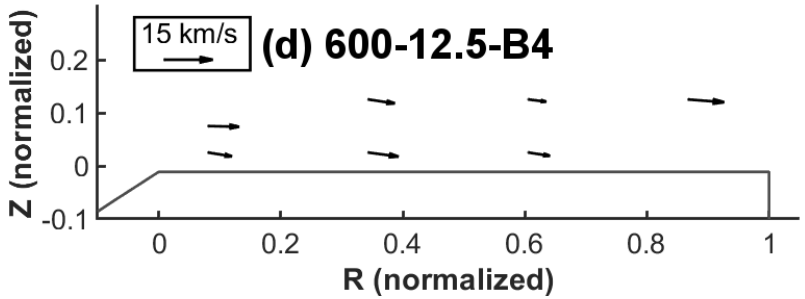










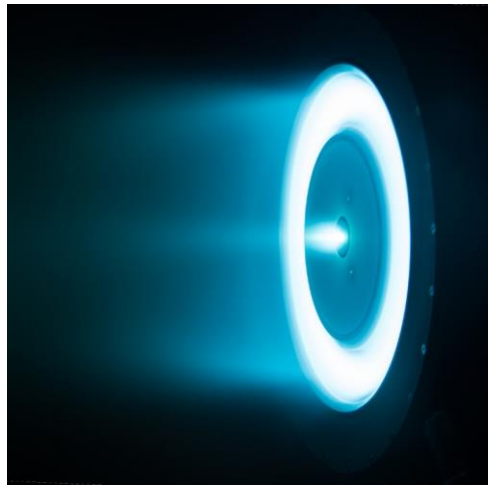


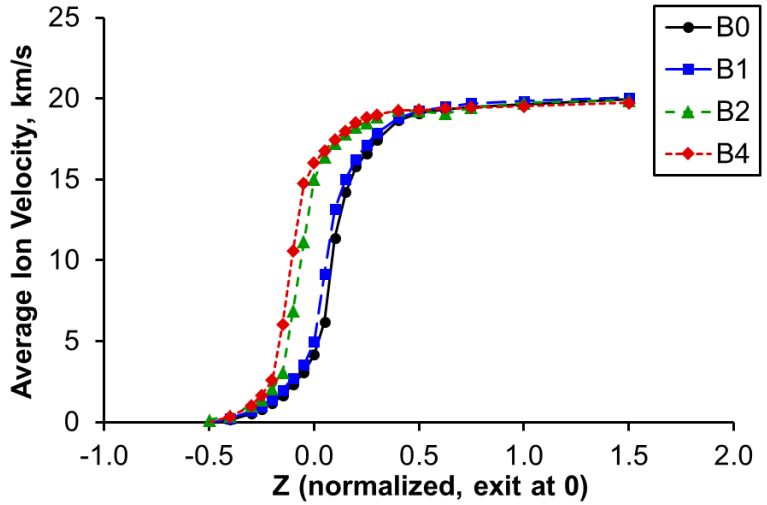
Ion Characteristics near OFPC

- OFPC = Outer Front Pole Cover
- Energy appear to decrease with configuration but limited number of samples
- Signal to noise ratio was low for conditions with limited samples

Conclusion

- Obtained ion velocity data while shifting the magnetic field upstream
- Observed a large jump in ion characteristics between B1 and B2 that suggest a change in how the plasma interacted with the channel walls and poles
- Ion energies near IFPC were constant to within the measurement uncertainty
- Ion energies near OFPC appeared to decrease as magnetic field shift upstream but data set was limited
- Combined with companion papers (902, Wed 15:45 and 841, Thu 15:00), demonstrate that one can trade pole erosion versus channel wall erosion





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