INDUCTIVELY COUPLED PLASMAS: ONE BIG PRESHEATH?

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AGENDA

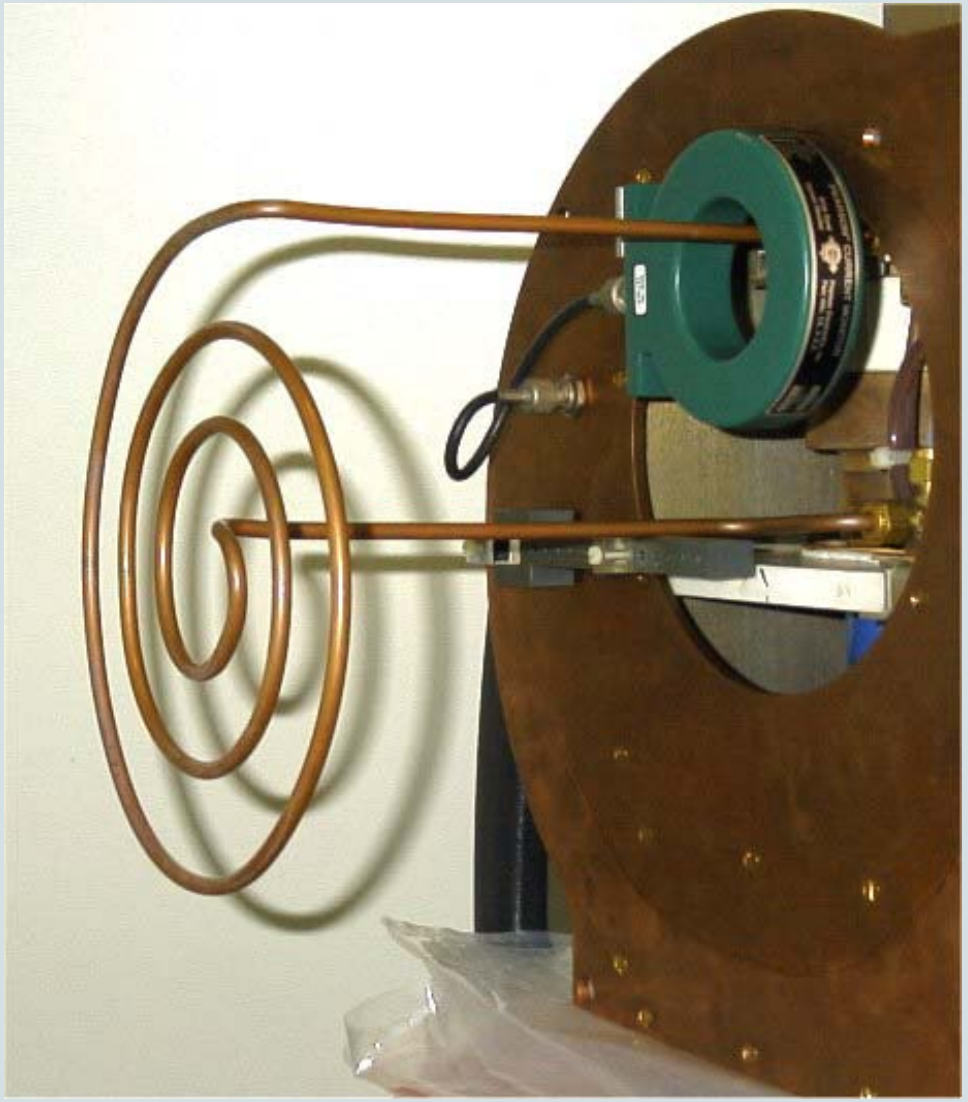
- Introduction
- Reactor Geometry
- Diagnostics
- Experimental and Modeling: Ion Velocity Distributions
- Conclusions

INTRODUCTION

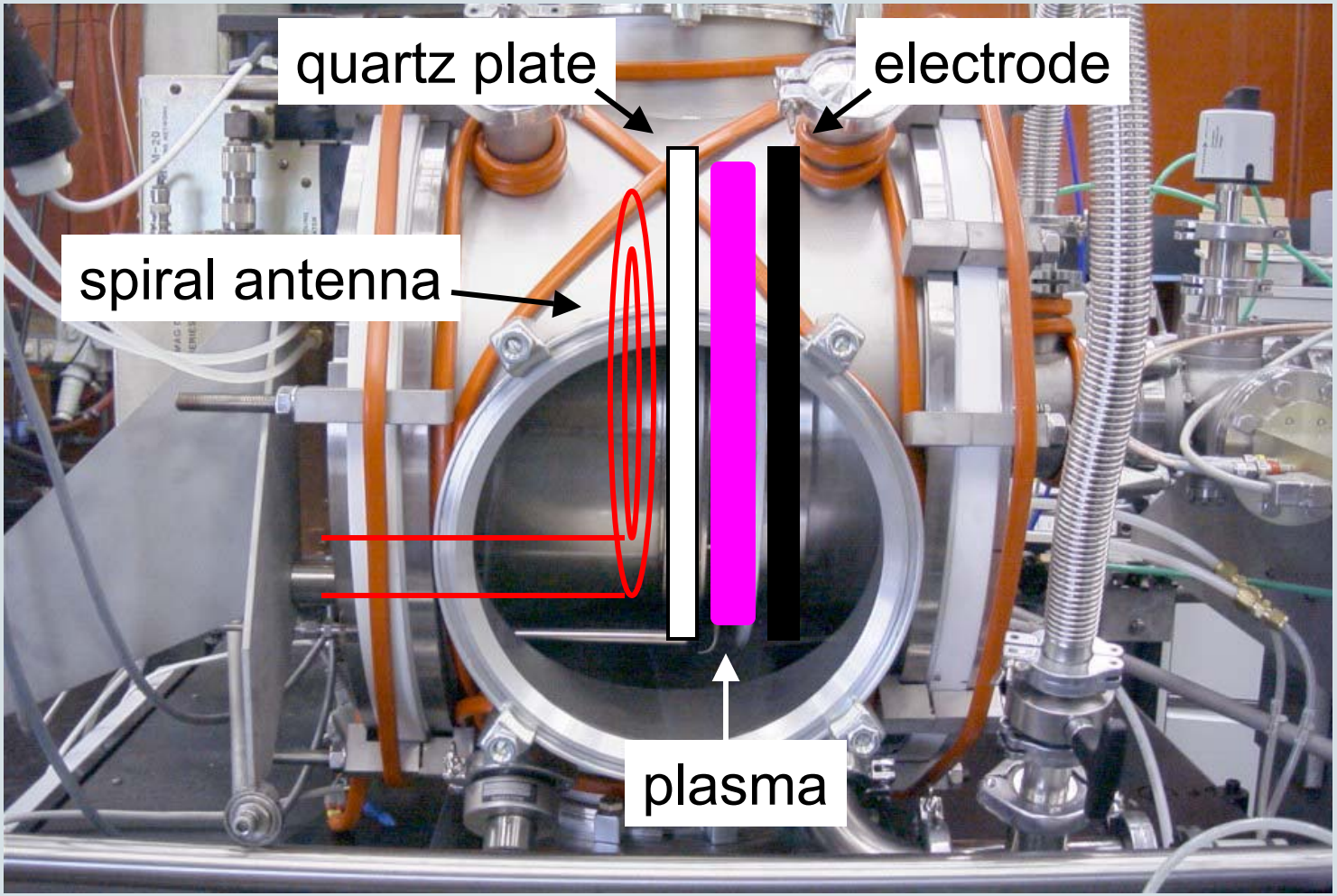
- In Capacitively Coupled Plasmas: distinctive regions
  - Glow: small E-field, ions nearly at rest
  - Pre-sheath: acceleration of ions to Bohm velocity
  - Sheath: space charge region, large E-field
- How about Inductively Coupled Plasmas?

REACTOR

- Pancake, spiral electrode
- 30 cm diameter
- 4 cm axial length
- 13.56 MHz



REACTOR

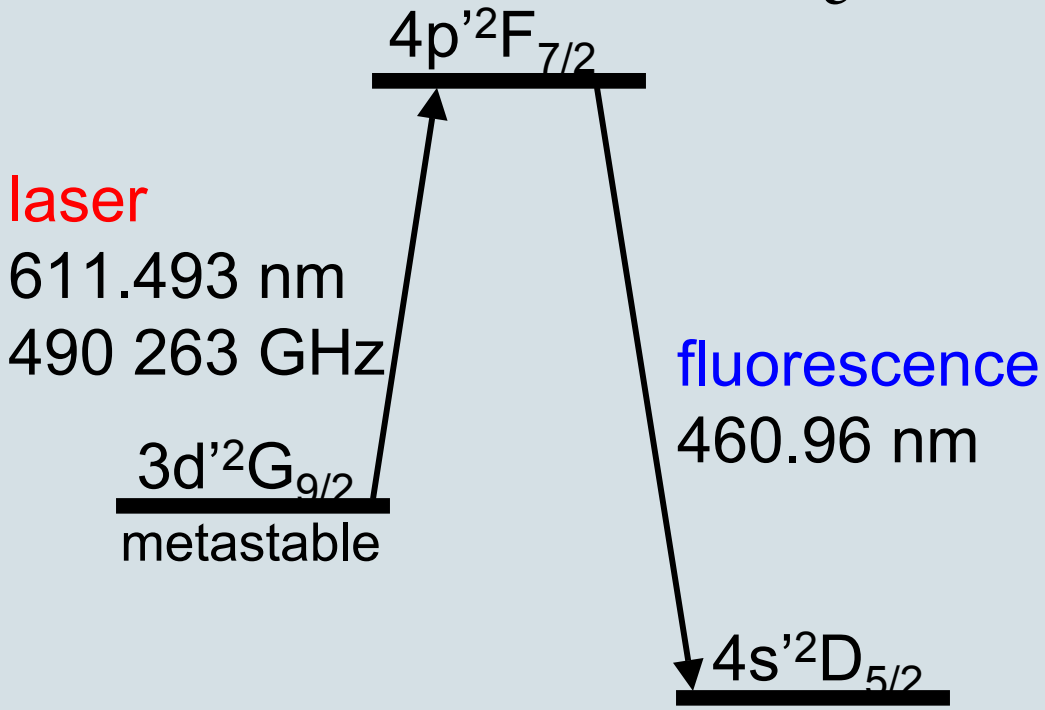


DIAGNOSTICS

- Doppler shifted LIF for ion velocity in the plasma volume
- Langmuir probe for plasma potential, ion density and electron density
- Energy resolved mass spectrometry for ion energy distribution at electrode

DOPPLER SHIFTED LIF

- Measure ion transport in plasma
- Argon LIF scheme
- Moving ion → Doppler shift $\Delta f_L = \frac{v_i}{c} \cdot f_{tr}$



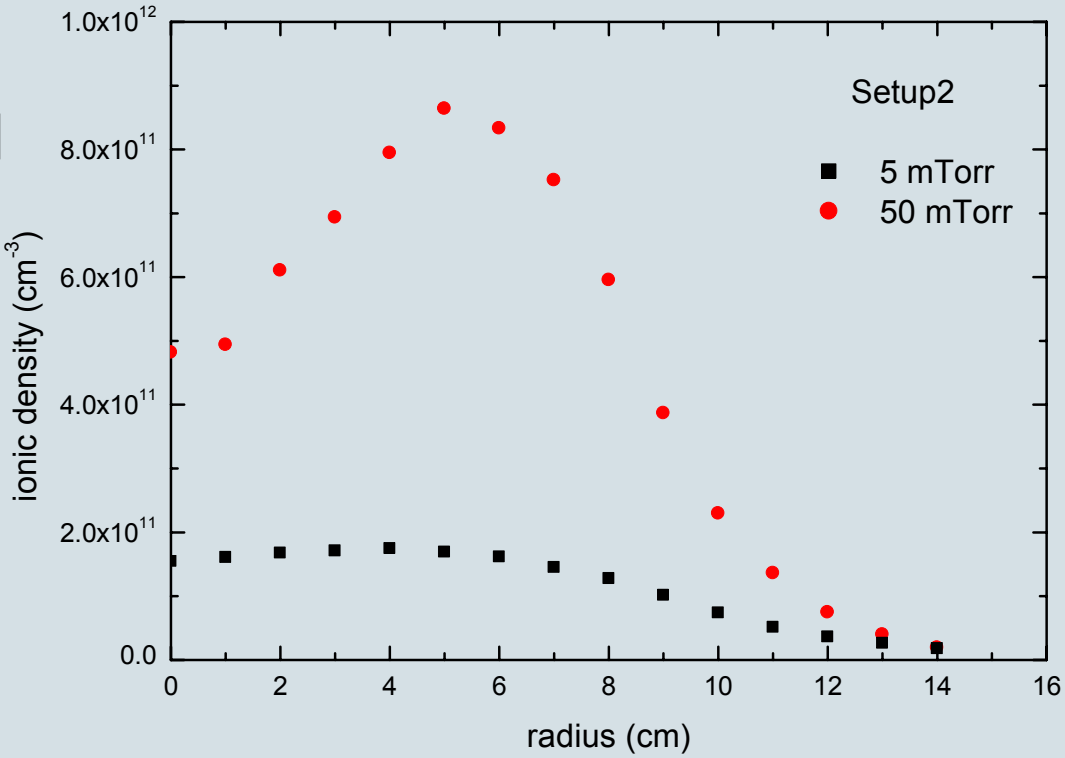
Model: Hybrid Plasma Equipment Model (HPEM)

- Monte Carlo Simulation for EEDs
- Kinetically derived current in Maxwell's Eq's.
- Ion & Neutral Continuity, Momentum, Energy
- Ion Monte Carlo Simulation to obtain velocity distributions; energy/angle distributions to substrate.

LANGMUIR PROBE ELECTRON DENSITY

- Electron density is mid 10^{11} cm^{-3}.
  Off axis maxima at higher pressures denotes transition to collisional plasma.

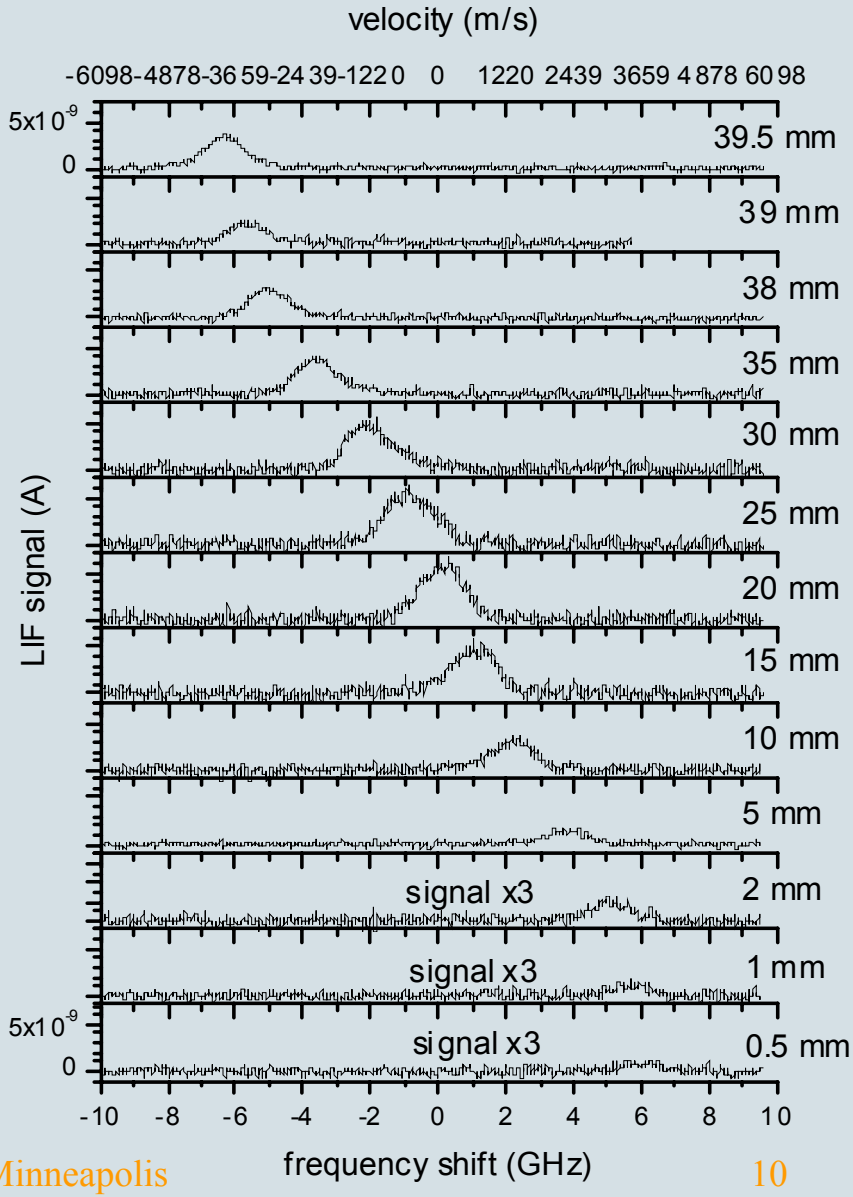
  400 W



DOPLLER SHIFTED LIF

- Ion velocity distribution is a drifting Maxwellian.

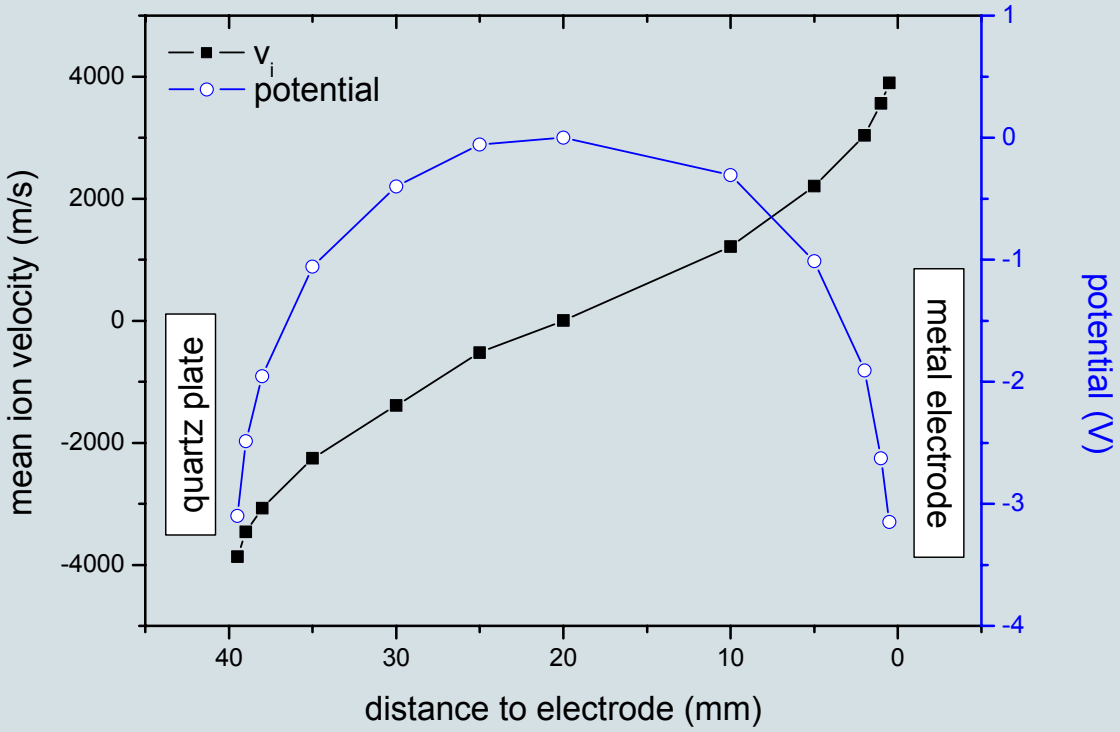
  5 mTorr, 400 W



AVERAGE ION VELOCITY AND PLASMA POTENTIAL

- No low E-field region Ions are in continuous acceleration from midplane to surfaces.

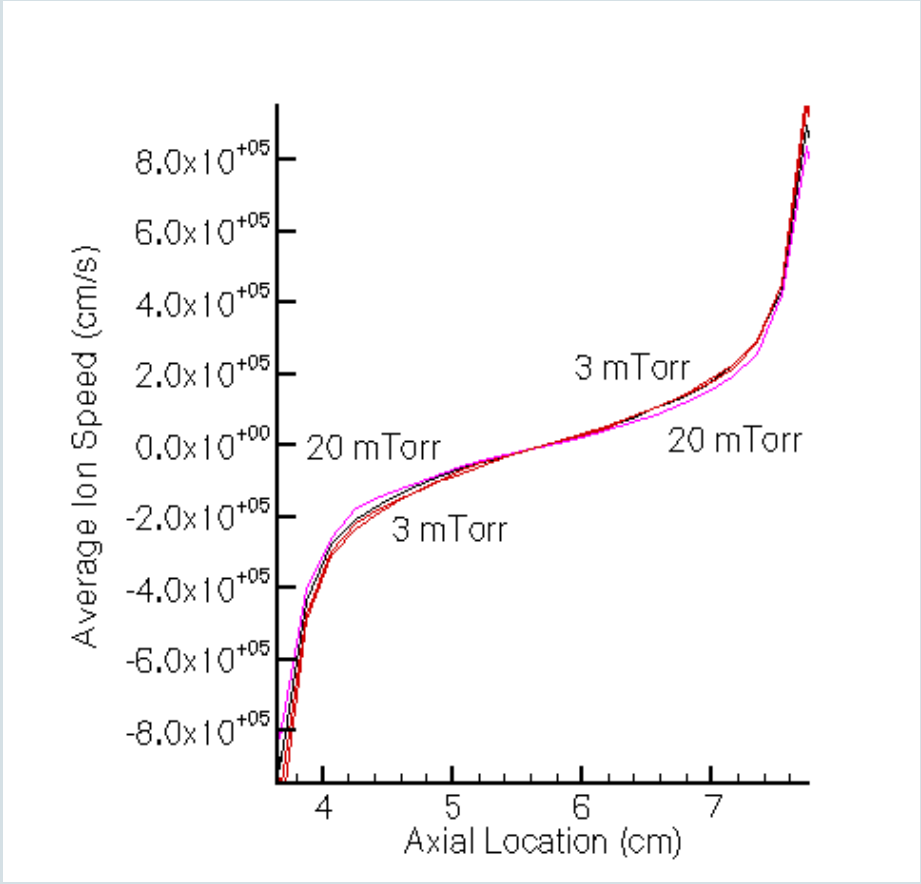
  5 mTorr, 400 W



AVERAGE ION VELOCITY (MODEL)

- Average ion velocity tracks the electric potential with nearly continuous acceleration from midplane.

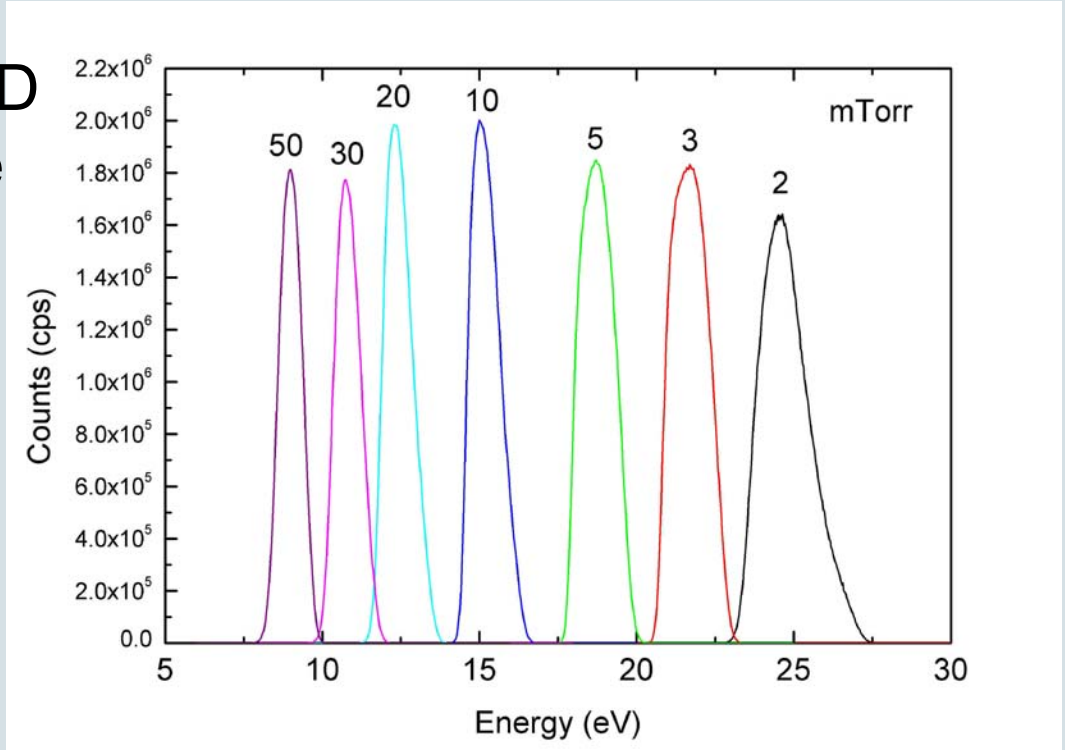
  400 W



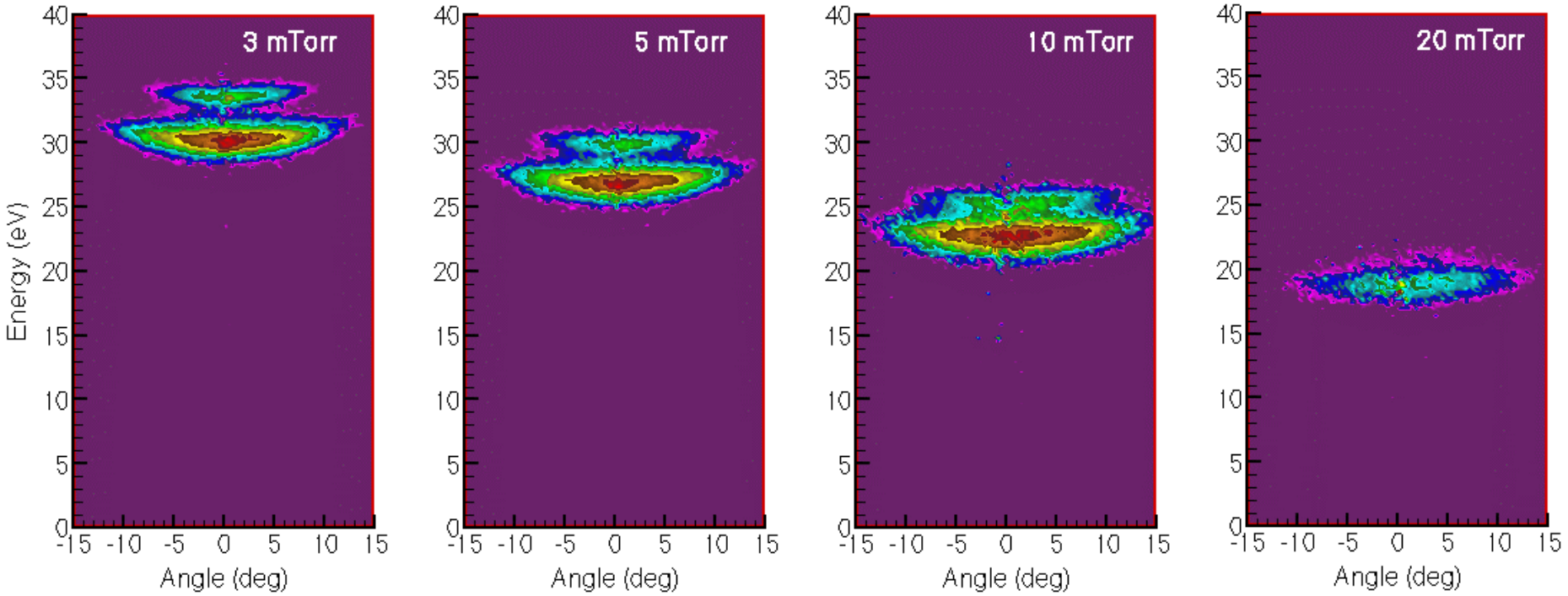
ION ENERGY DISTRIBUTIONS (r=0)

- Monotonic increase in IED with decreasing pressure reflects:
  - Increase in plasma potential
    Decrease in collisionality

400 W

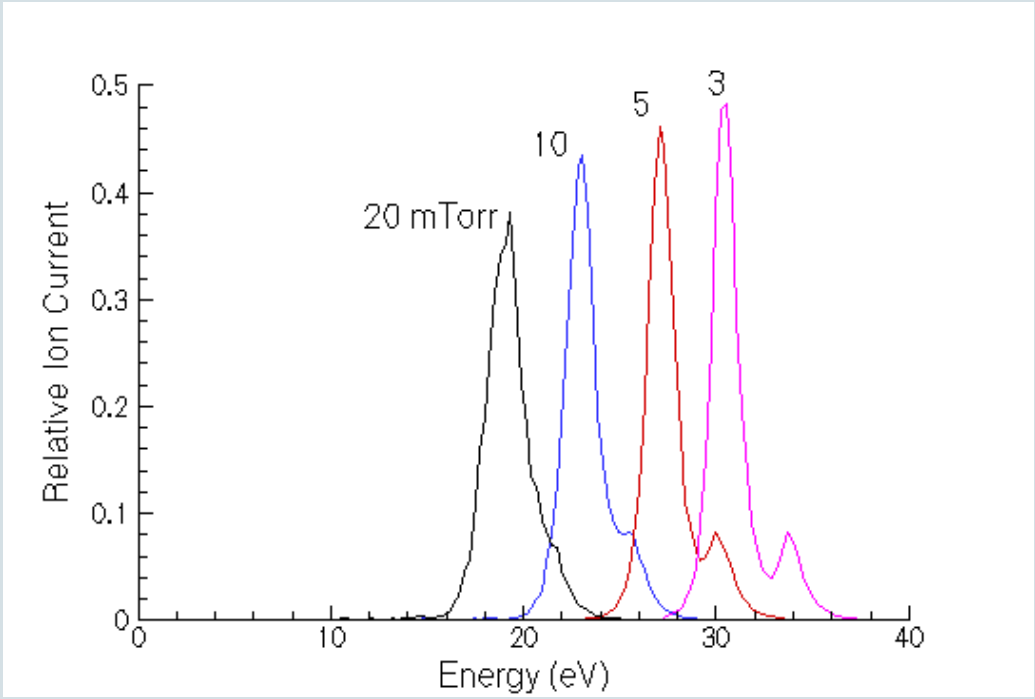


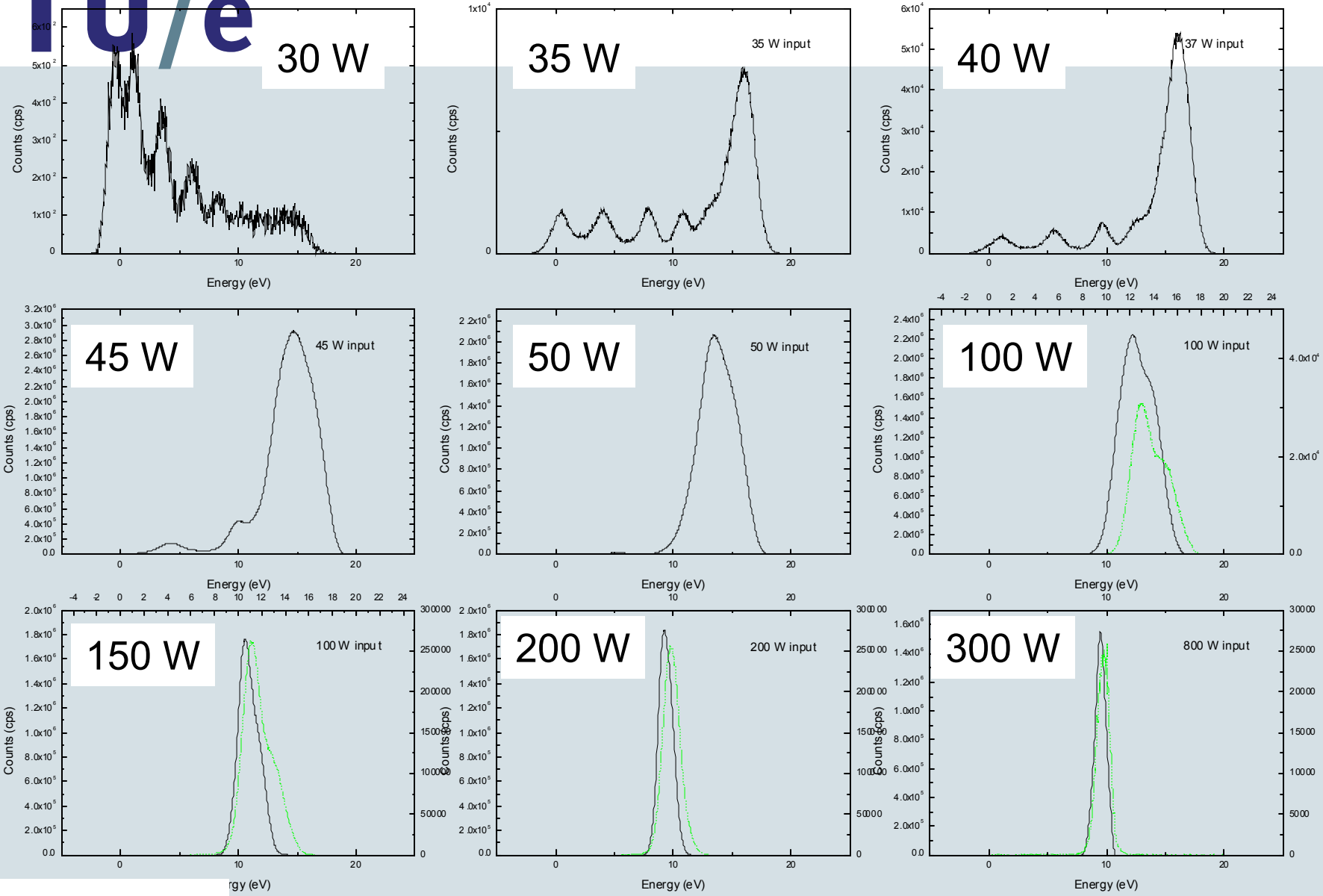
ION ENERGY DISTRIBUTIONS (r=0) (MODEL)



ION ENERGY DISTRIBUTIONS (r=0) (MODEL)

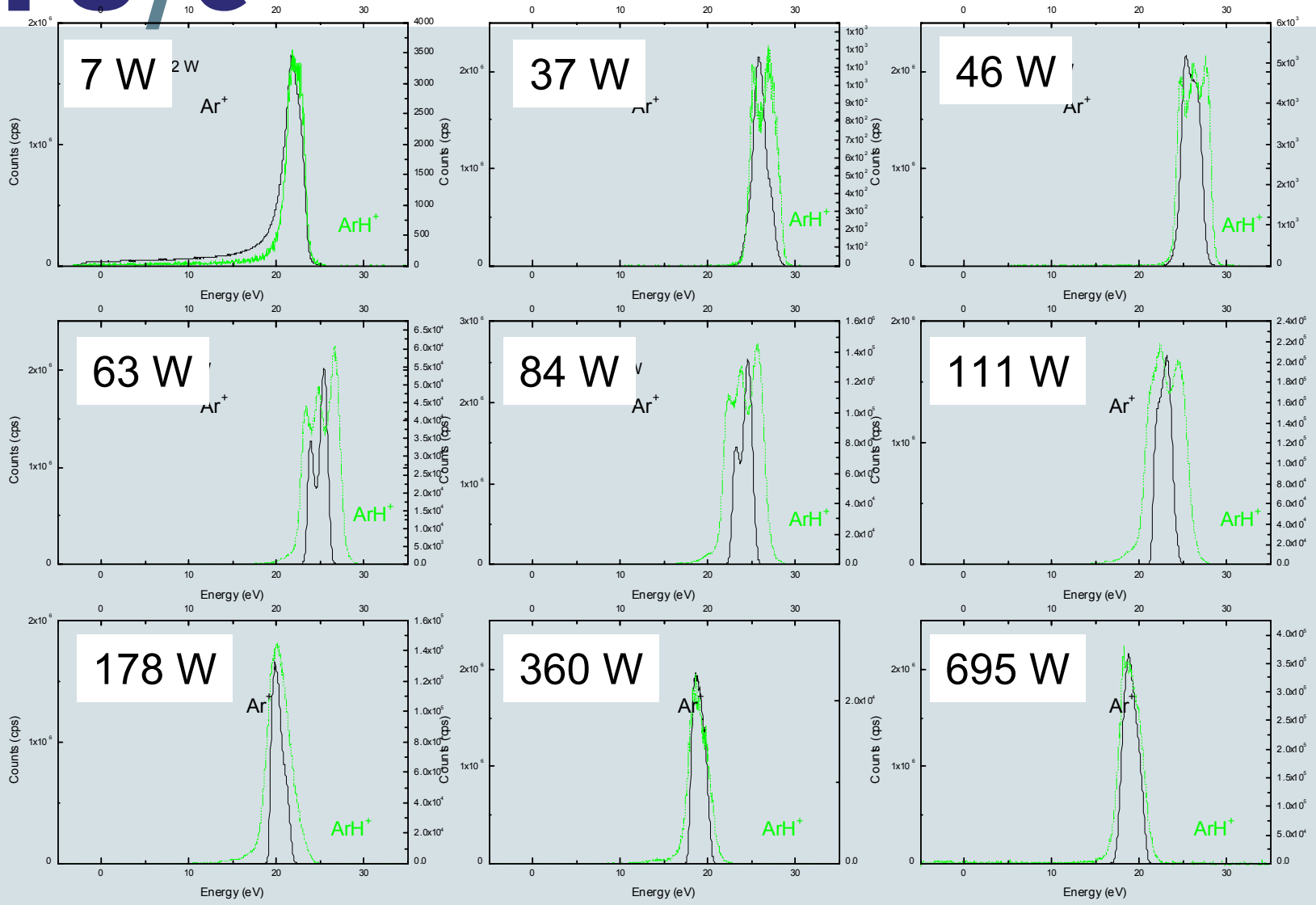
- Monotonic increase in IED with decreasing pressure is captured
  400 W





Black: Ar+
Green: ArH+

Argon, 50 mTorr, Power series, 0-25 eV



Black: Ar+
Green: ArH+

5 mTorr, argon plasma, power dependence

CONCLUSIONS

- Acceleration starts from center of plasma, in both (!) axial directions.
- Ions gradually accelerate to Bohm speed.
- There is no real glow, just one big, symmetric presheath.

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