# Helicon Plasma Source as a Linear Divertor Plasma Simulator

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## National Institute of Fusion Science, Toki, GIFU, JAPAN

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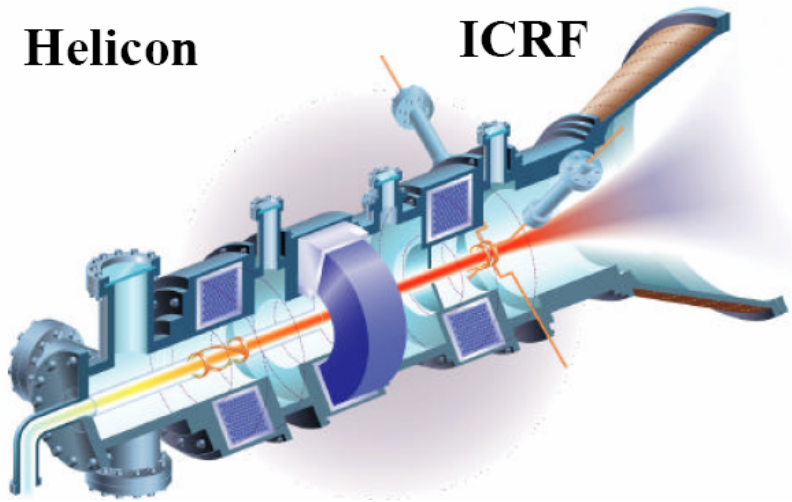
# Introduction

- **Helicon Plasma Research**

- **Space Propulsion**




**VASIMR Concept**

- **Current Free Double Layer/Wave Dynamics**

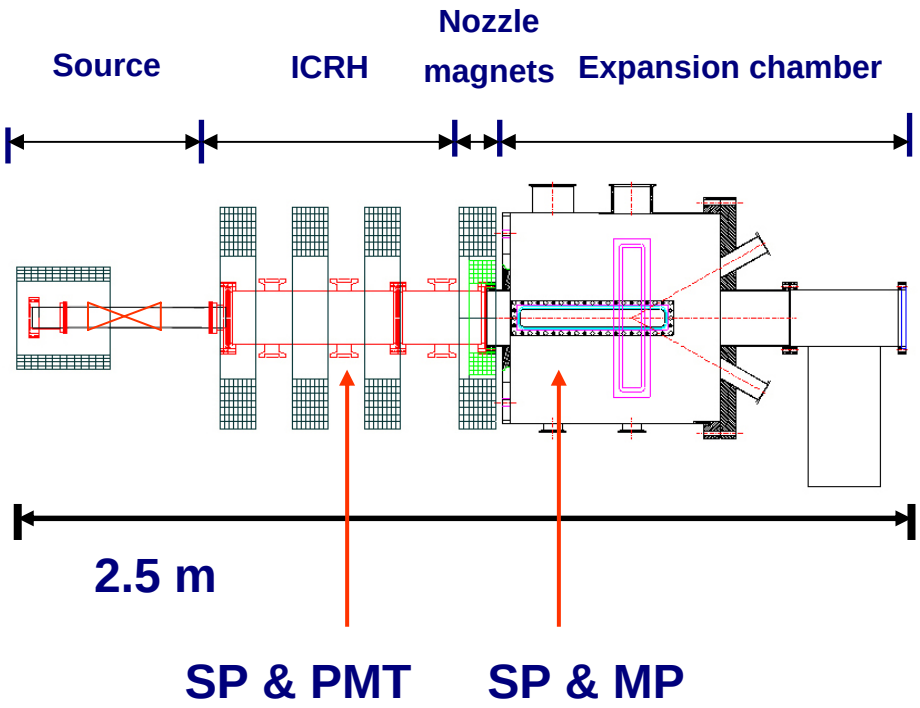
  - **Current Free Double Layer : Boswell Group (ANU, Australia)**

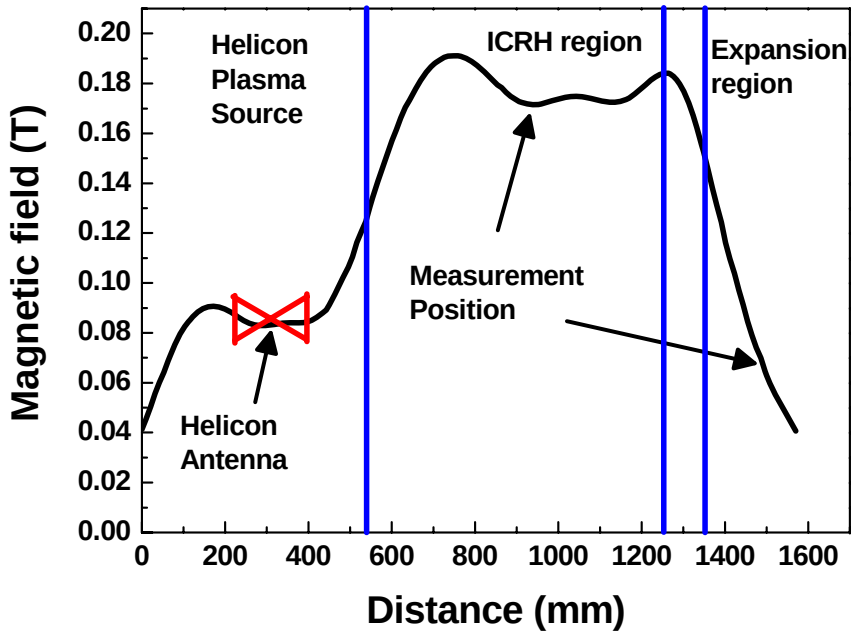
    **HELIX and LIEA (WVU, USA)**

  - **Wave Dynamics : VINETA (Ernst-Moritz-Arndt University, Greifswald, Germany)**

# K2H Helicon Plasma (1)

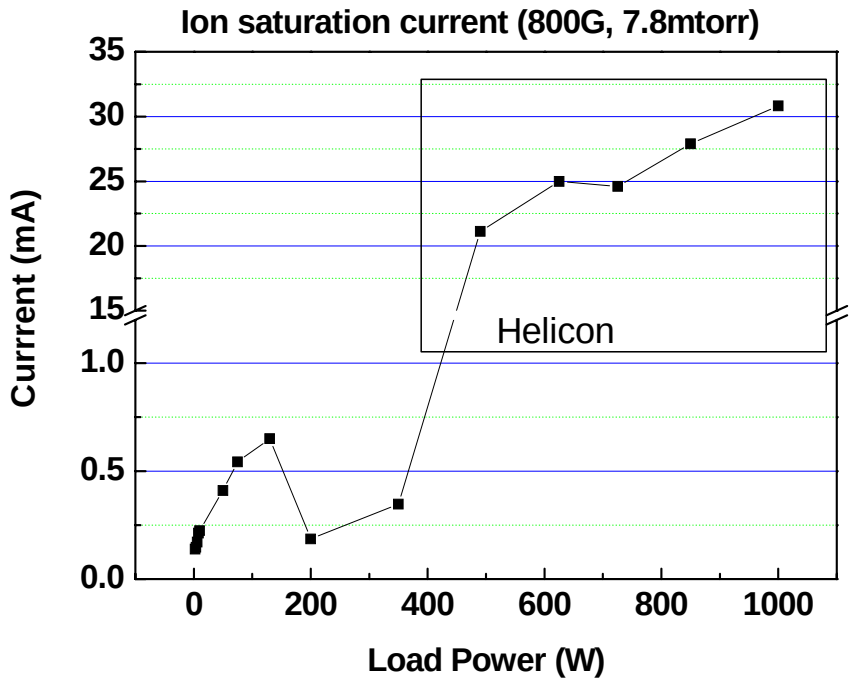
- **Schematic Diagram and Magnetic Profile**

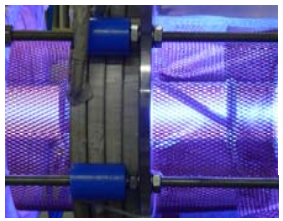


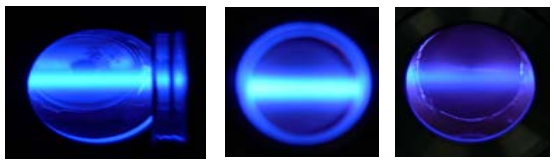



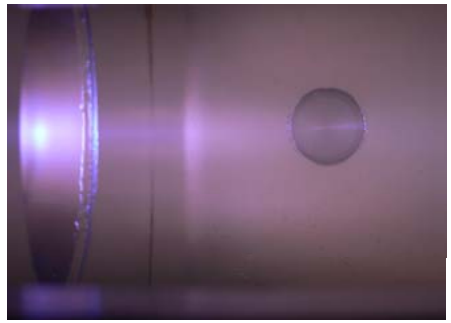
# K2H Helicon Plasma (2)

- **Photo and Mode Transition**



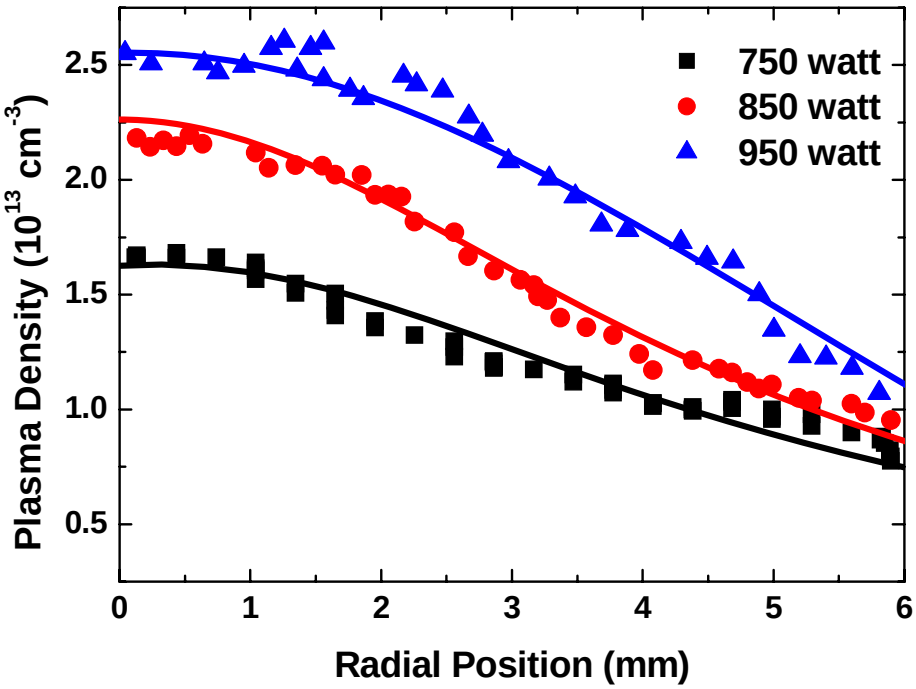



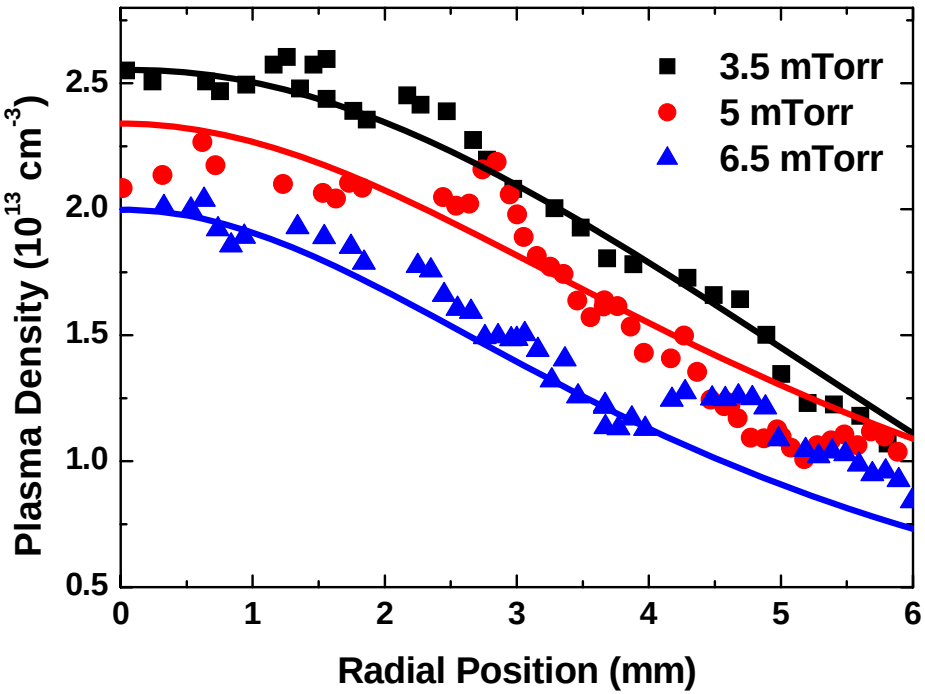




# K2H Helicon Plasma (3)

- **Plasma Density Measurement**

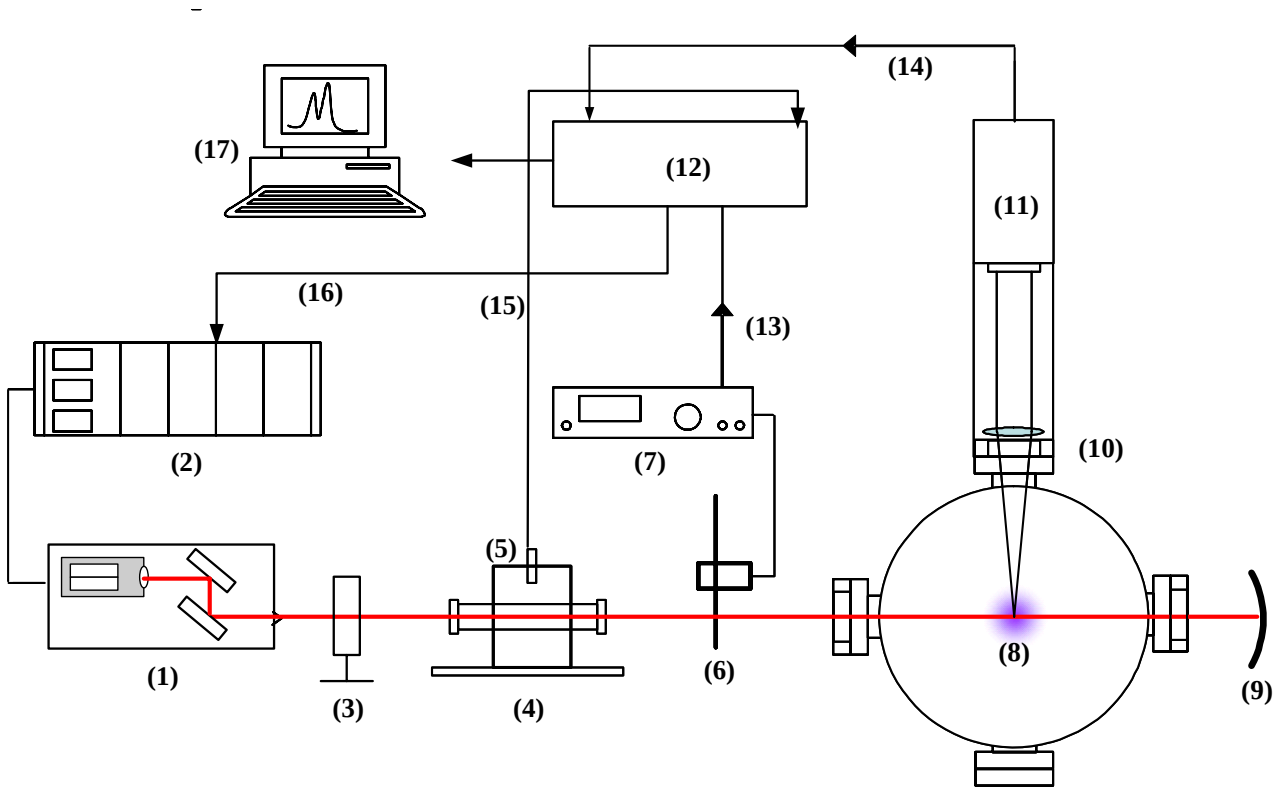



**electron temperature remains by 7 eV ± 2 eV with almost flat profile**

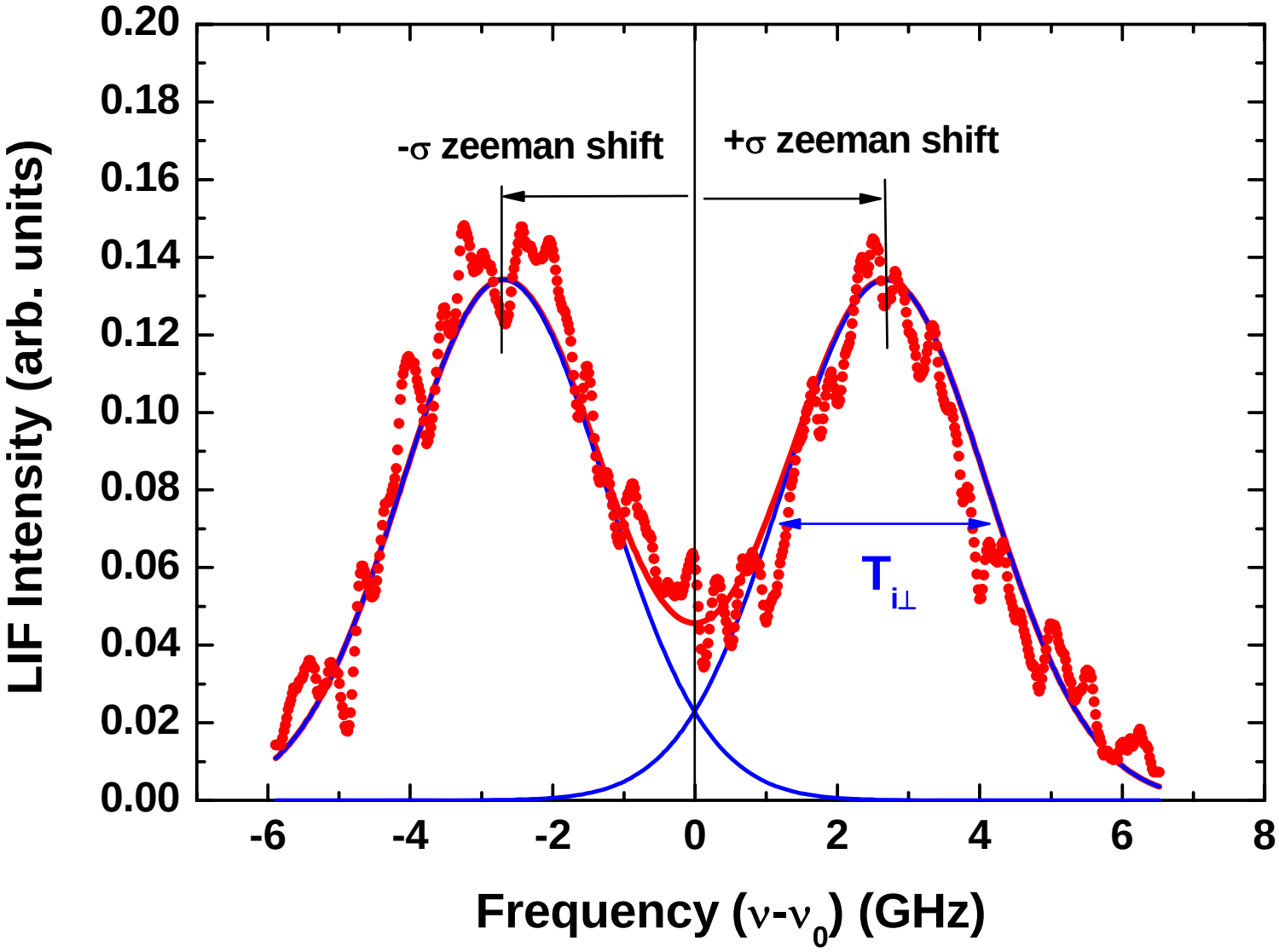
# K2H Helicon Plasma (4)

- **Diode Laser without Master Oscillator Power Amplifier**




(1) Littrow external cavity diode laser, (2) laser controller, (3) Iris, (4) Iodine cell, (5) Photodiode, (6) chopper, (7) chopper controller, (8) plasma, (9) beam dump, (10) imaging lens, (11) PMT tube, (12) lock-in amplifier, (13) reference signal input, (14) fluorescence signal input, (15) iodine cell signal input, (16) voltage ramp, (17) PC

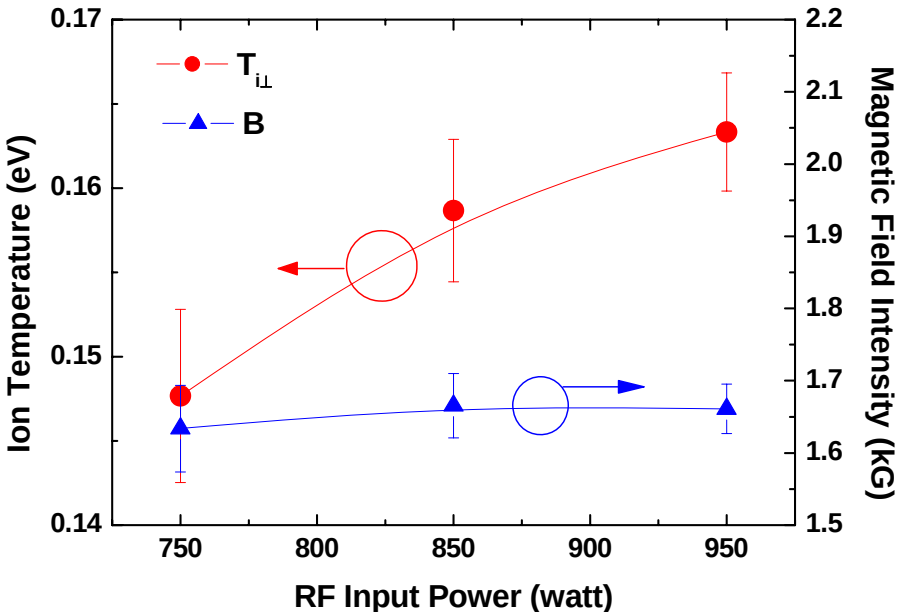
# K2H Helicon Plasma (5)



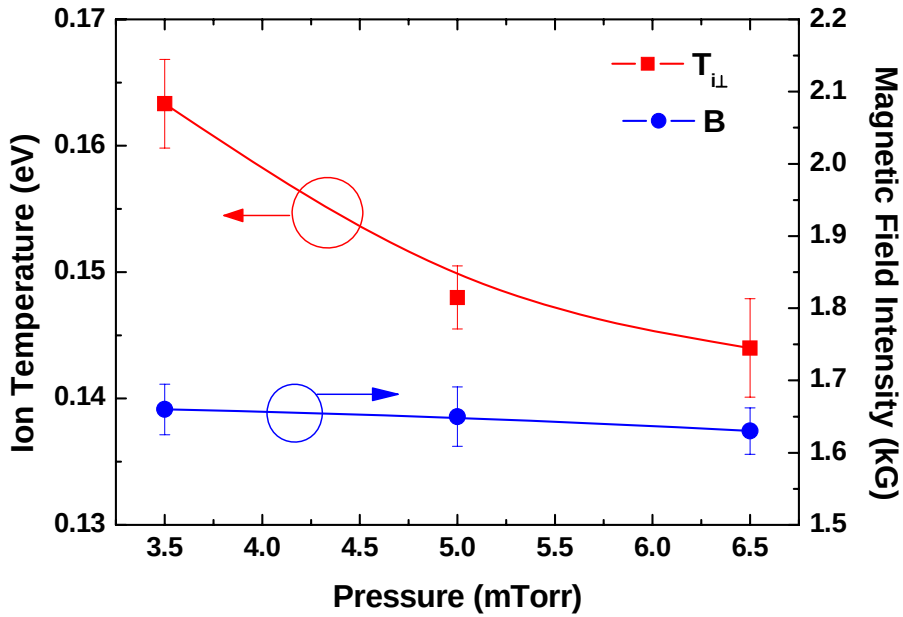
# K2H Helicon Plasma (6)

- **Perpendicular Ion Temperature & Magnetic Field Intensity**

## RF Power Variation

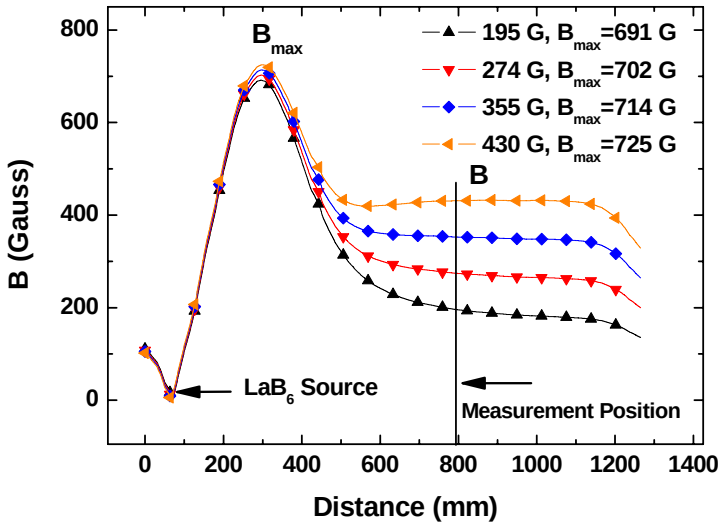


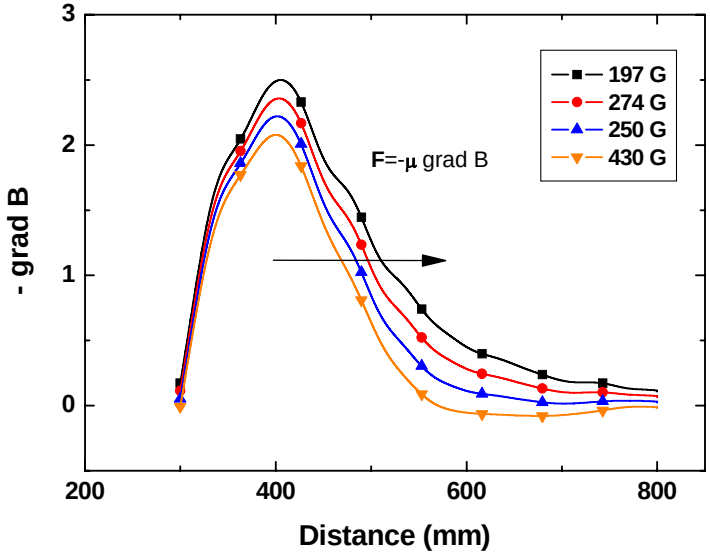

## Neutral Pressure Variation

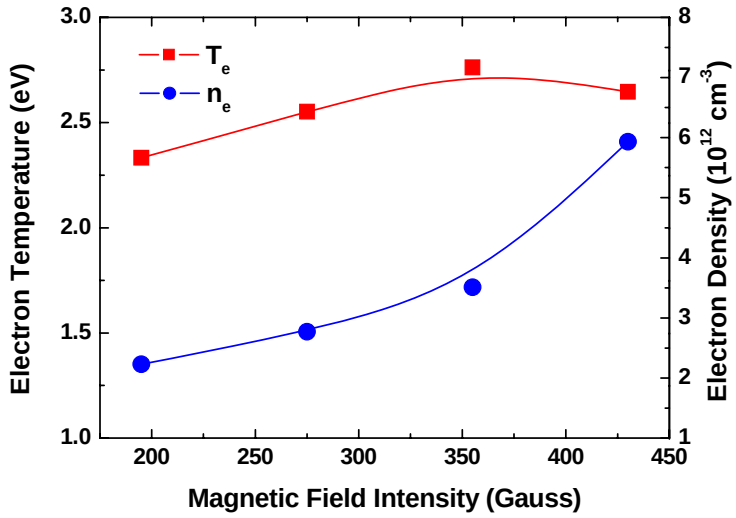


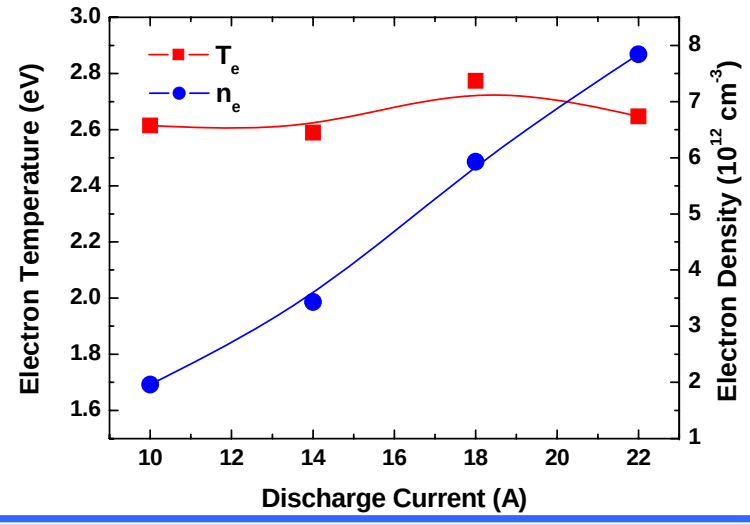
# K2H Helicon Plasma (7)

- **K2H LIF Back-up: LaB6 (DiPS) Experiment (1)**



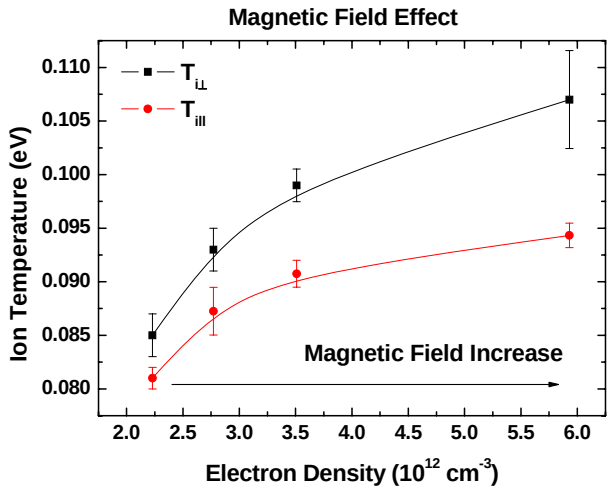



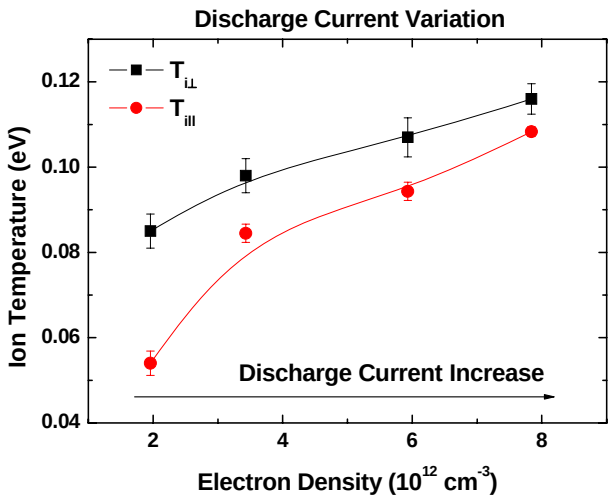



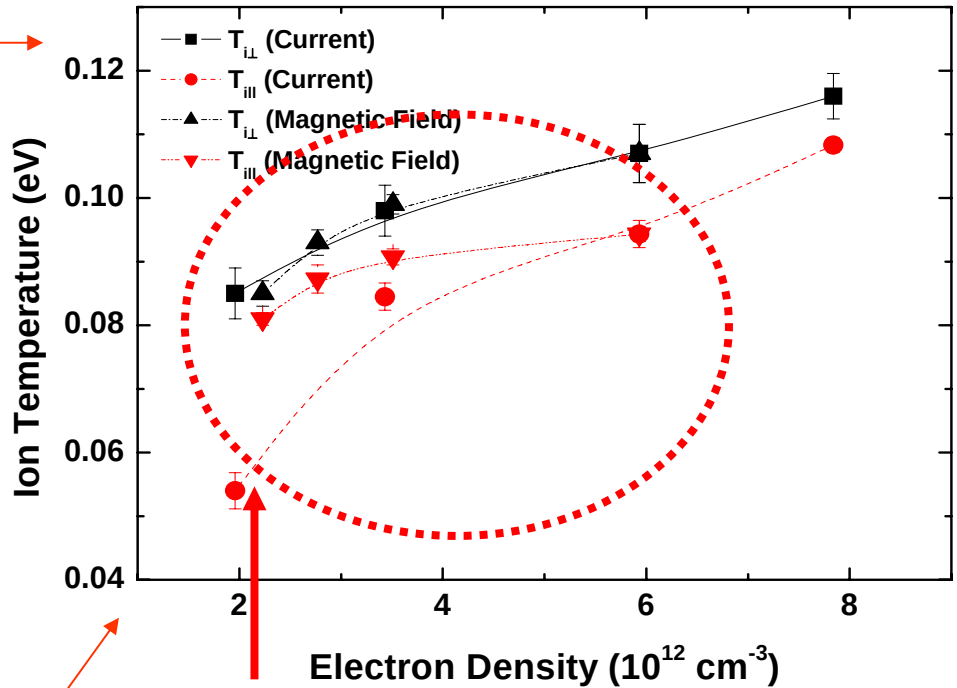



# K2H Helicon Plasma (8)

## K2H LIF Back-up:LaB6 (DiPS) Experiment (2)



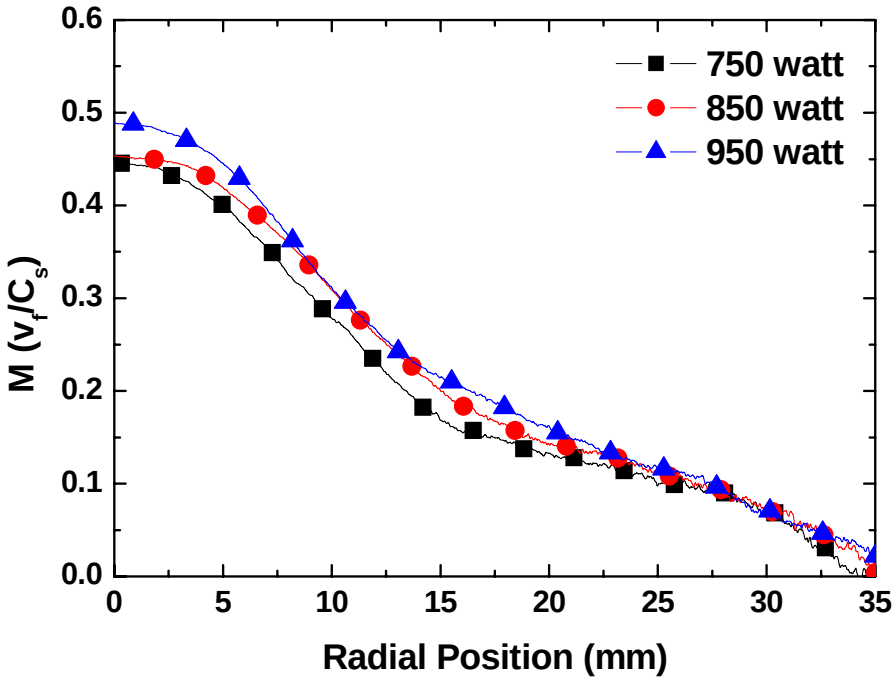



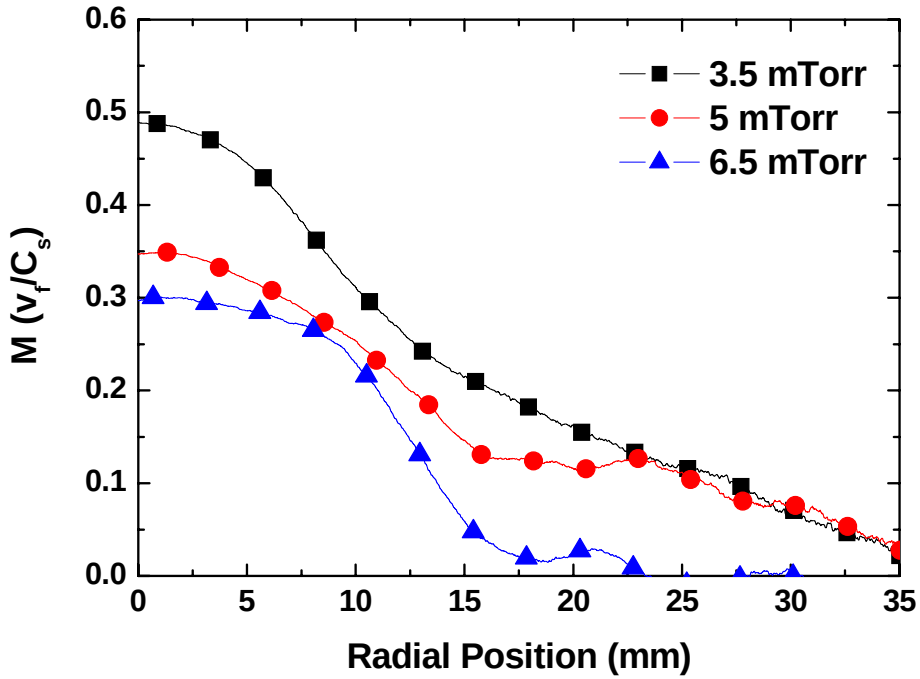

- **Change of ion temperature can not be explained by the 1st adiabatic invariant.**

- **$T_{i\perp}/T_{ill}$ could be explained by ion temperature anisotropy with β, (the ratio of thermal energy to magnetic energy).**

# K2H Helicon Plasma (9)

- **Plasma Flow Velocity after Nozzle Magnets**



# SPEX in DiPS (1)

- **SPEX (Space Propulsion EXperiment) Design Concepts**

1) Based upon the VASIMR concept.

2) Diagnostics – focused on Probe & LIF.

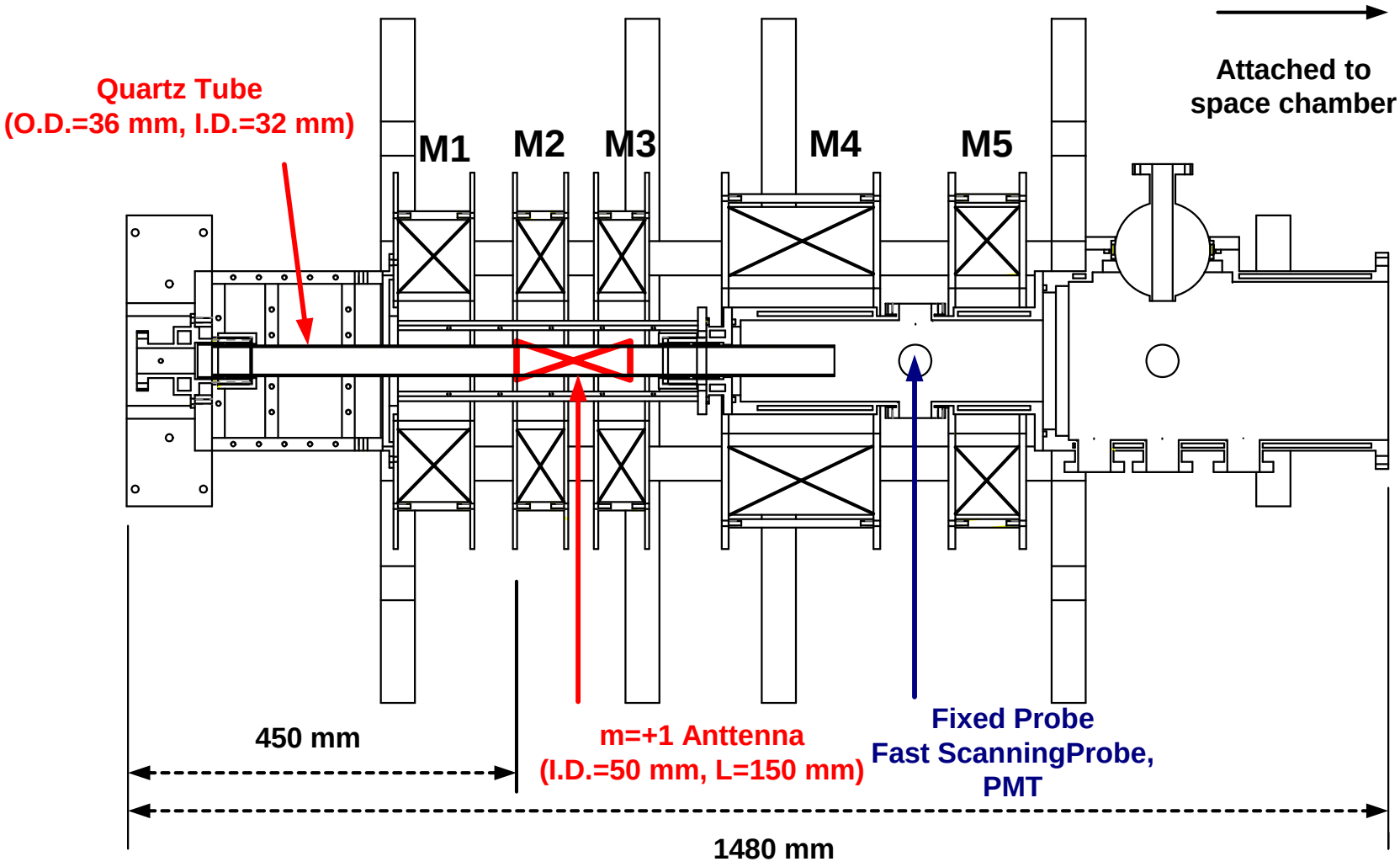
3) Diverging magnetic field for current-free double layer formation.

4) Spherical port for Z-scan (LIF)  along diverging magnetic field.

5) 3- Axial ports for plasma detachment with magnetic field line.

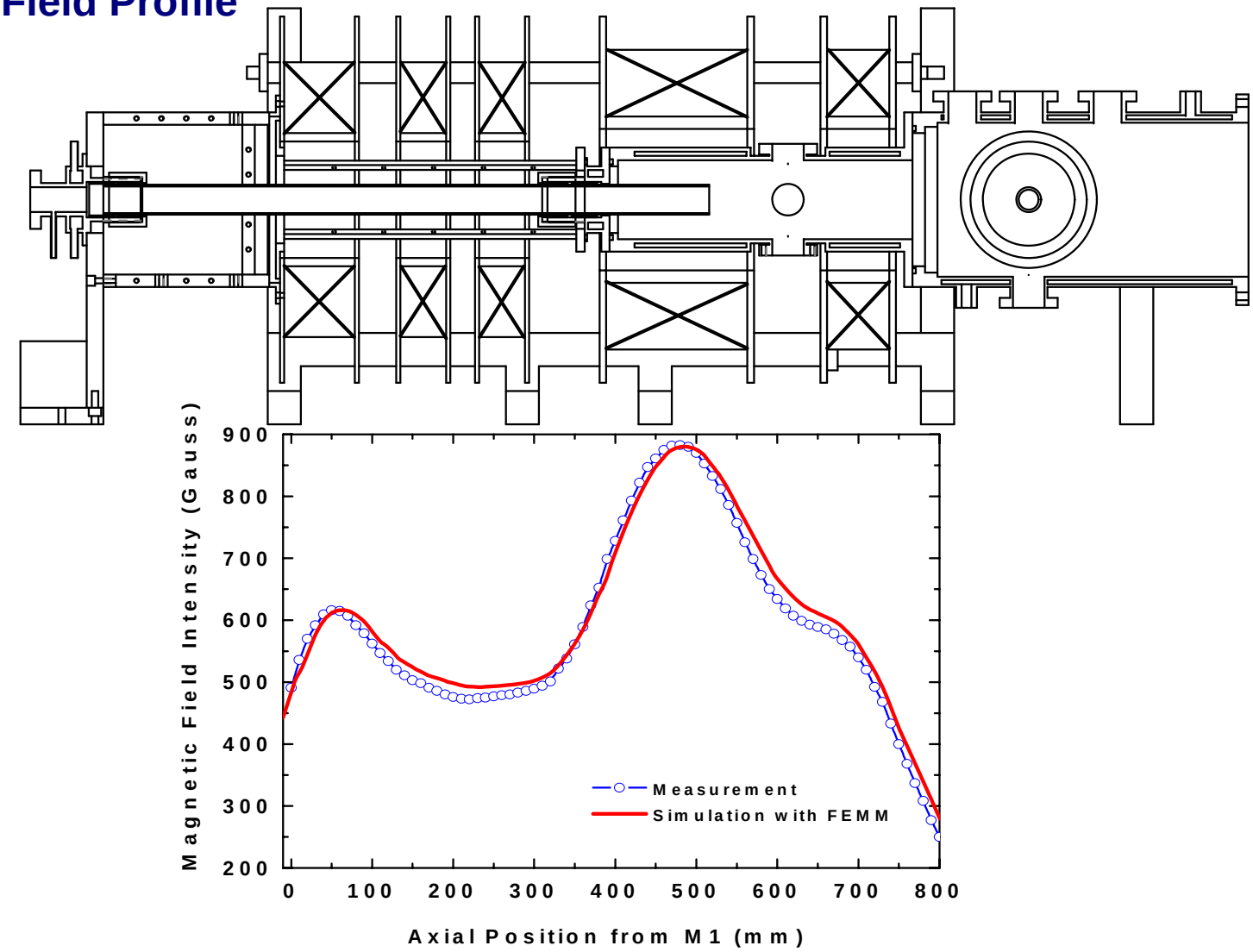
# SPEX in DiPS (2)

- **Schematic Diagram**



# SPEX in DiPS (3)

- **Magnetic Field Profile**



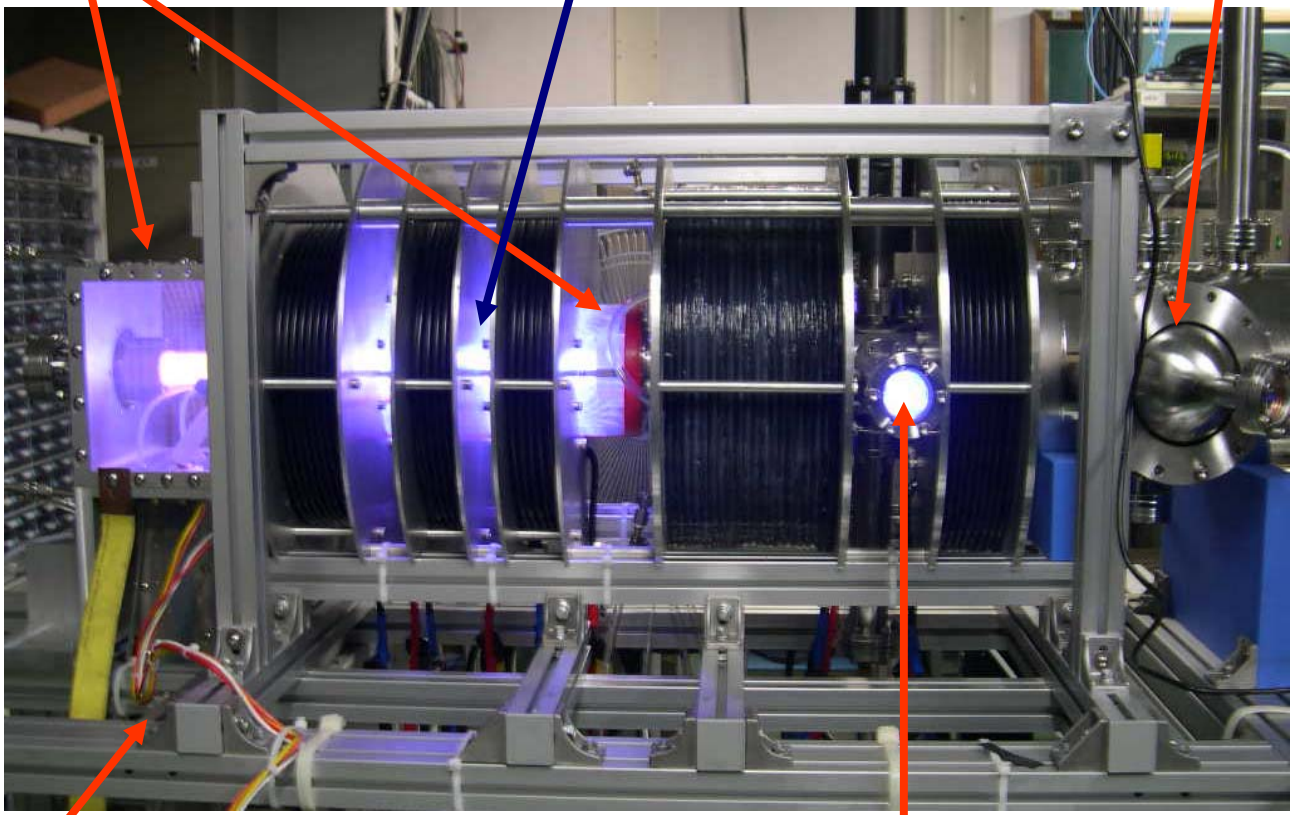
# SPEX in DiPS (4)

- Photograph

RF shielding structure

m=+1 Antenna

Spherical Port



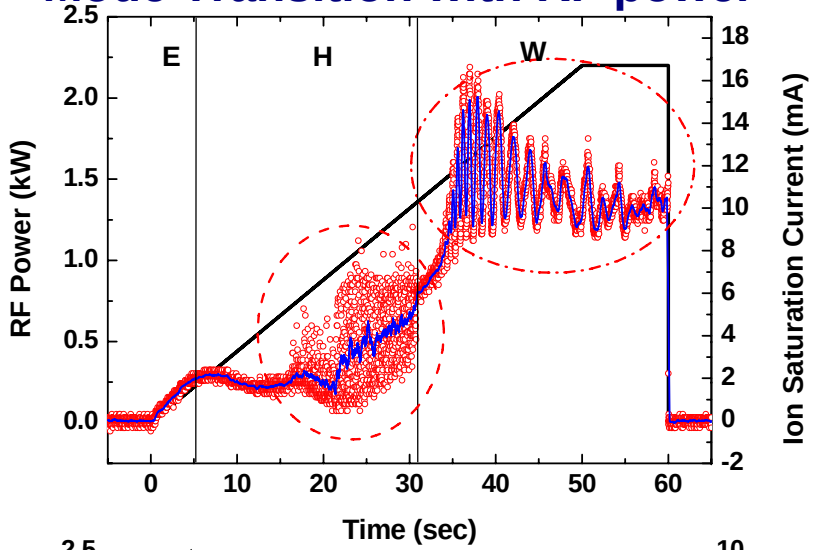
1.5 kW, 8 mTorr
Ar Plasma

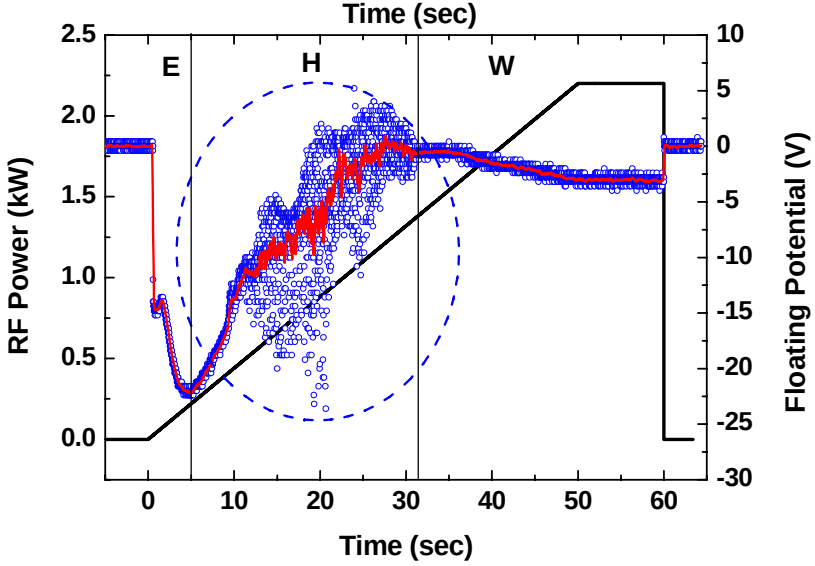
RF Matching Network

Fixed Probe, Fast Scanning Probe, and PMT

# SPEX in DiPS (5)

- **Mode Transition with RF power**



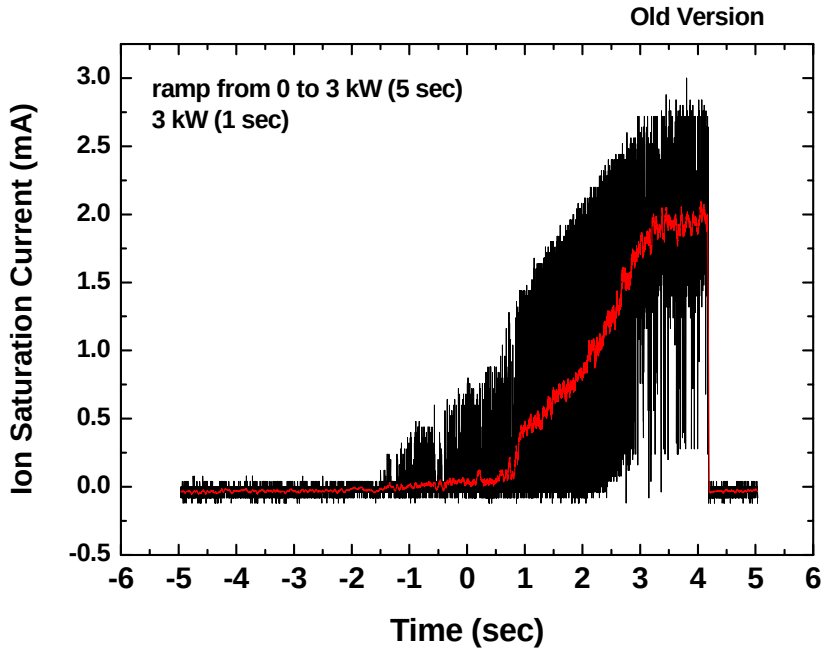




← • Raw Data ($V_b$=-180 V)

: Power ramp up to 2.2 kW,

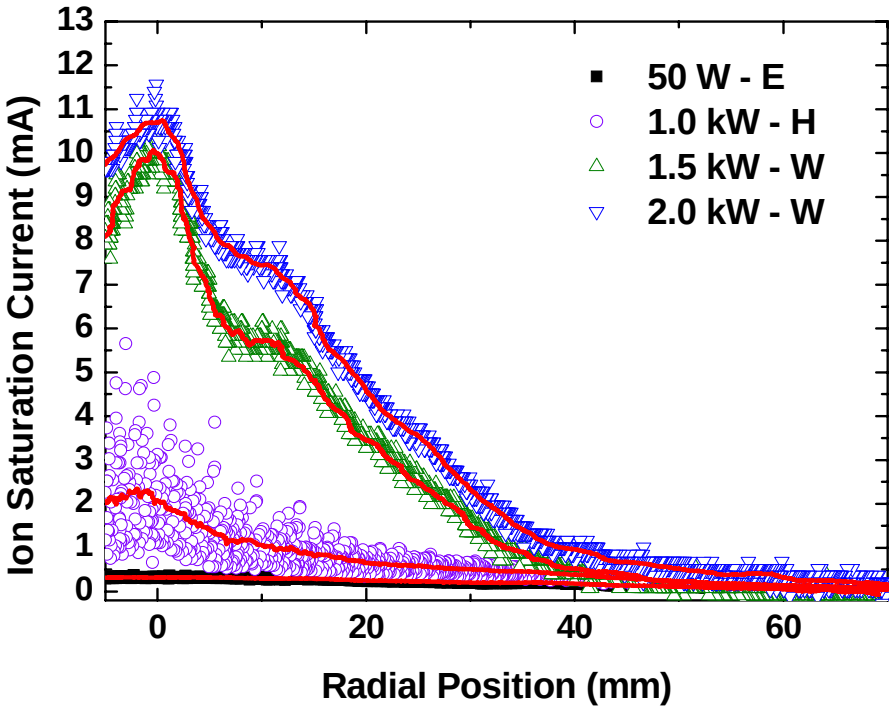
8 mTorr

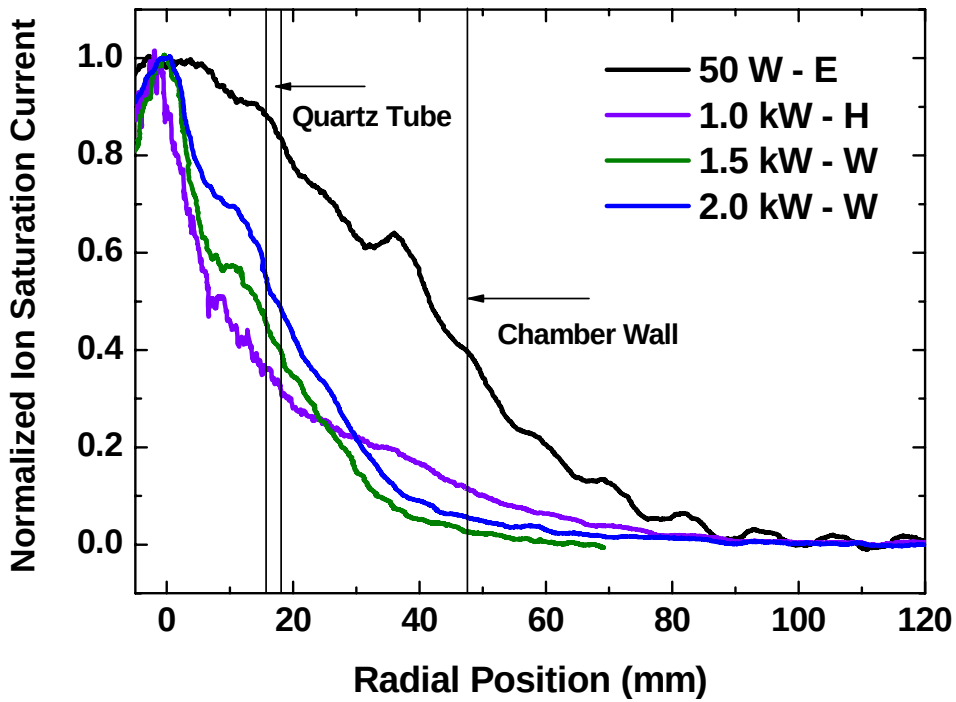
• Old Helicon source



# SPEX in DiPS (6)

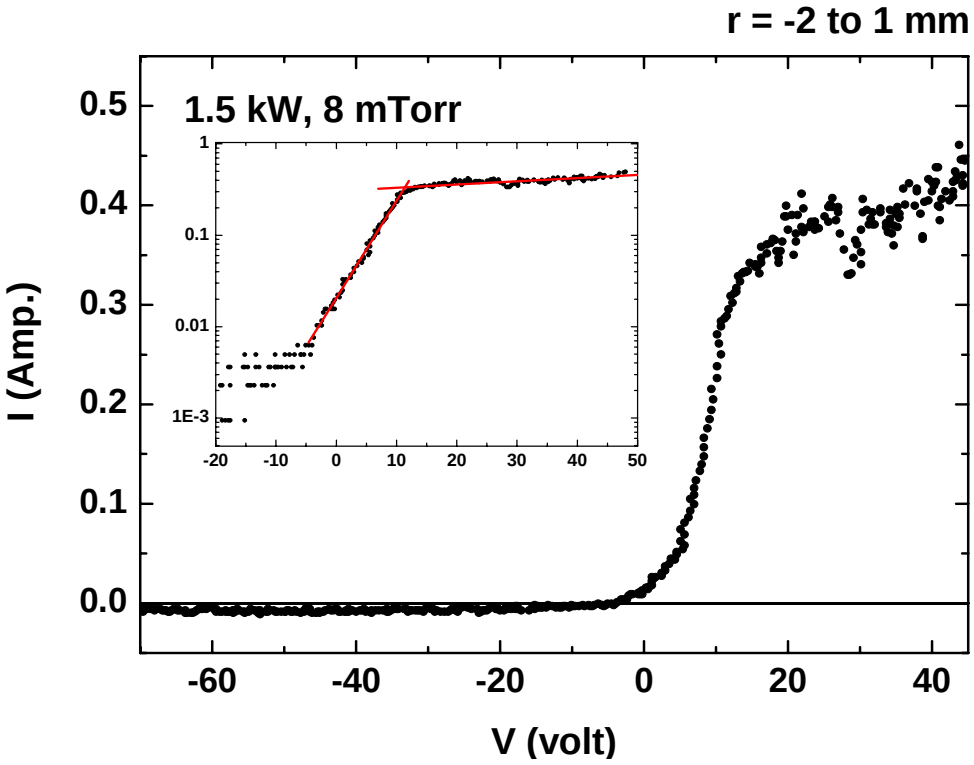
- **Radial Profiles of Ion Saturation Current with 3 different modes**



# SPEX in DiPS (7)

- I-V characteristics near plasma centre

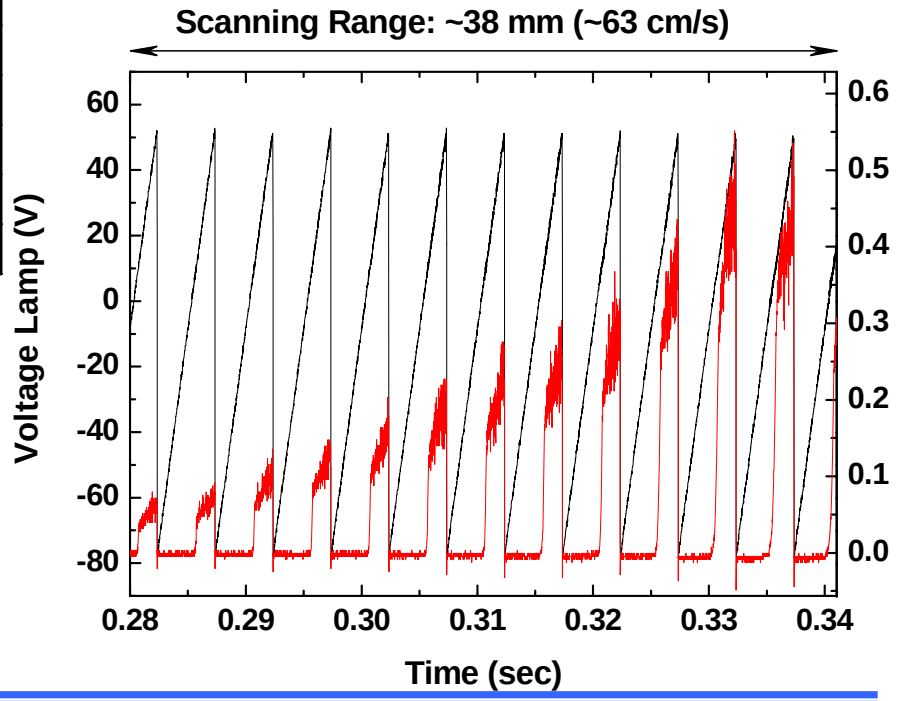



←

- Raw Data

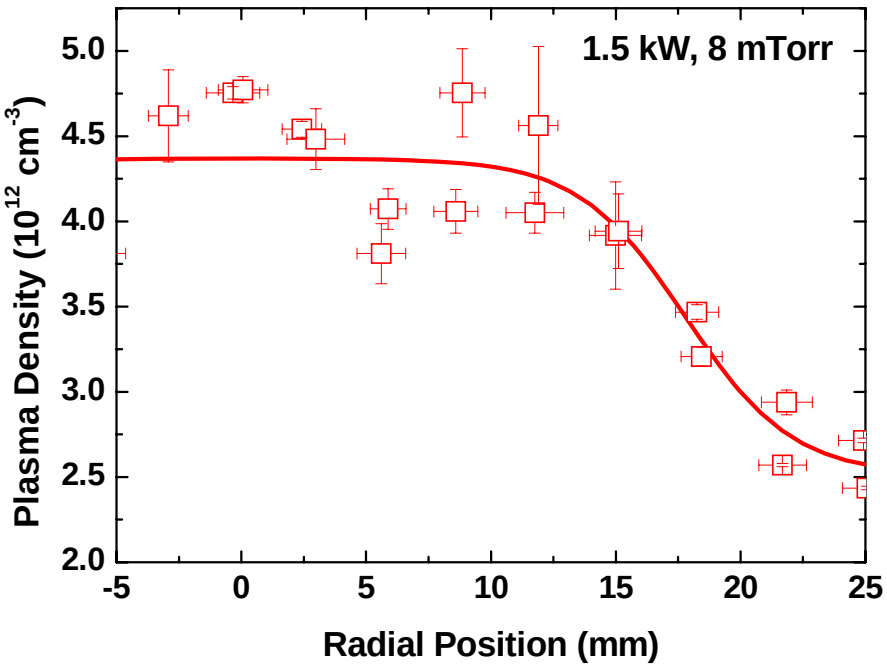
: 1.5 kW, 8 mTorr

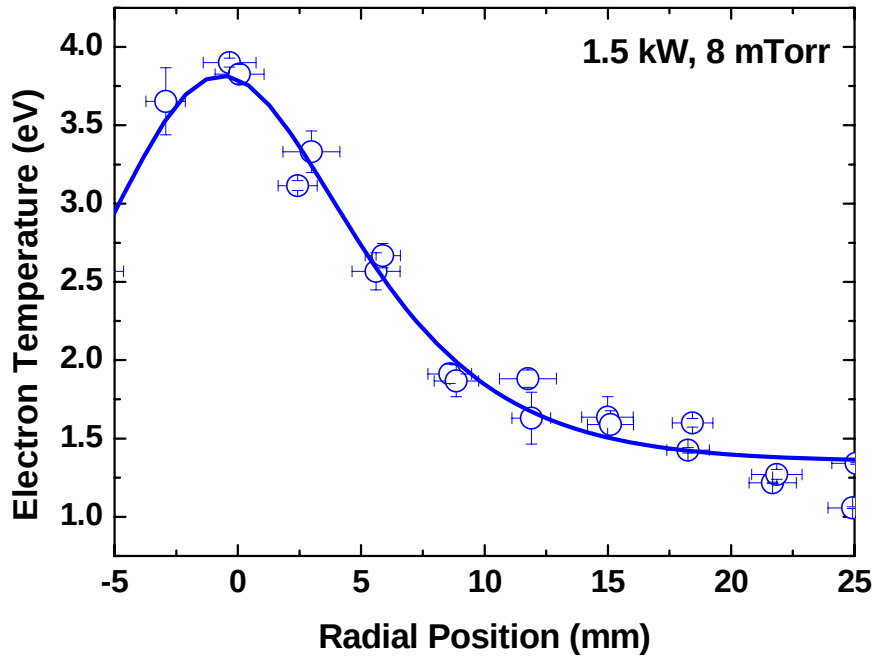
: Radial Position – btw -2 & 1 mm



# SPEX in DiPS (8)

- **Plasma Density & Electron Temperature**



# Helicon Source as a Divertor Simulator

- **Advantages or New Aspects of Helicon Source as a Divertor Plasma Simulator**

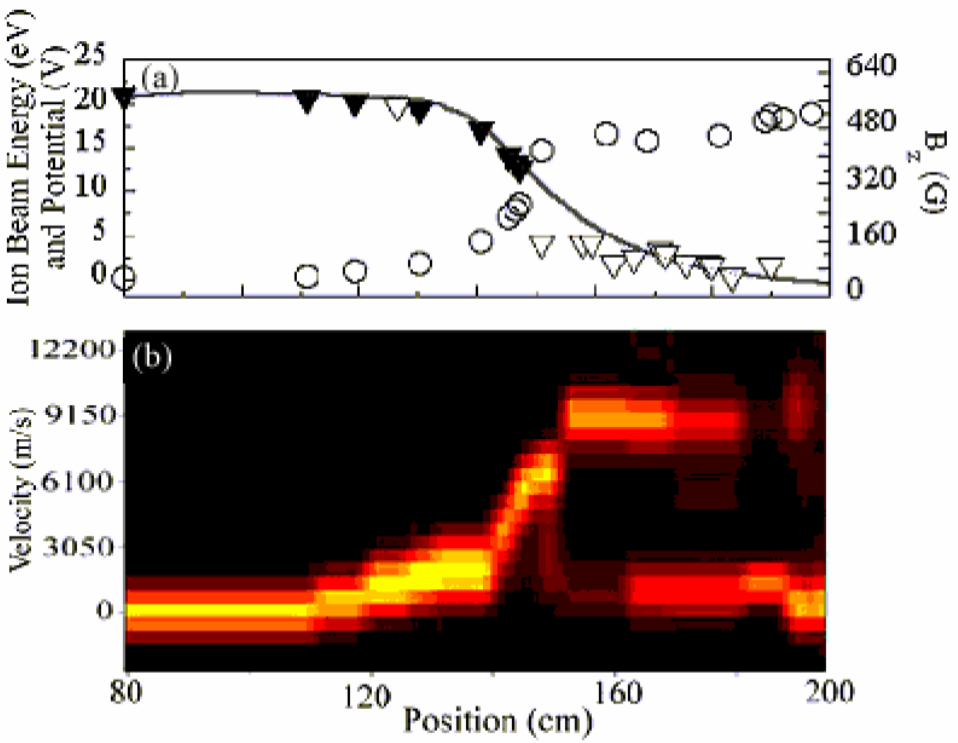
**1) Needs Low Power for High Density Plasma Production**
**(< 3 kW for $10^{13}$ $cm^{-3}$)**

**2) Stable Vacuum Condition : no out-gassing**

**3) Effect of Supersonic Ion Flow from Current Free Double Layer Formation**

# Helicon Source as a Divertor Simulator

## Current Free Double Layer Formation and Ion Acceleration in Helicon Plasma




- Solid line: magnetic Field
  Solid triangle: plasma potential measured by probe
  Open triangle: predicted plasma potential from LIF measurement
  Open circle: Ion Parallel flow velocity

HELIX and LEIA, West Virginia University

X. Sun, Phys. Rev. Lett. 95, 025004 (2005)

# SUMMARY

- The SPEX is upgrade for the space propulsion and PSI experiments.
- The initial plasma parameters are measured with electric probes and LIF.
- The initial plasma parameters in two helicon devices are different, especially, the SPEX has unique features of plasma parameters.
- The helicon plasma source has a possibility as a divertor plasma simulator related issues of supersonic ion flow and plasma-material interaction.