# Modeling Light Ion Helicon Plasma Sources

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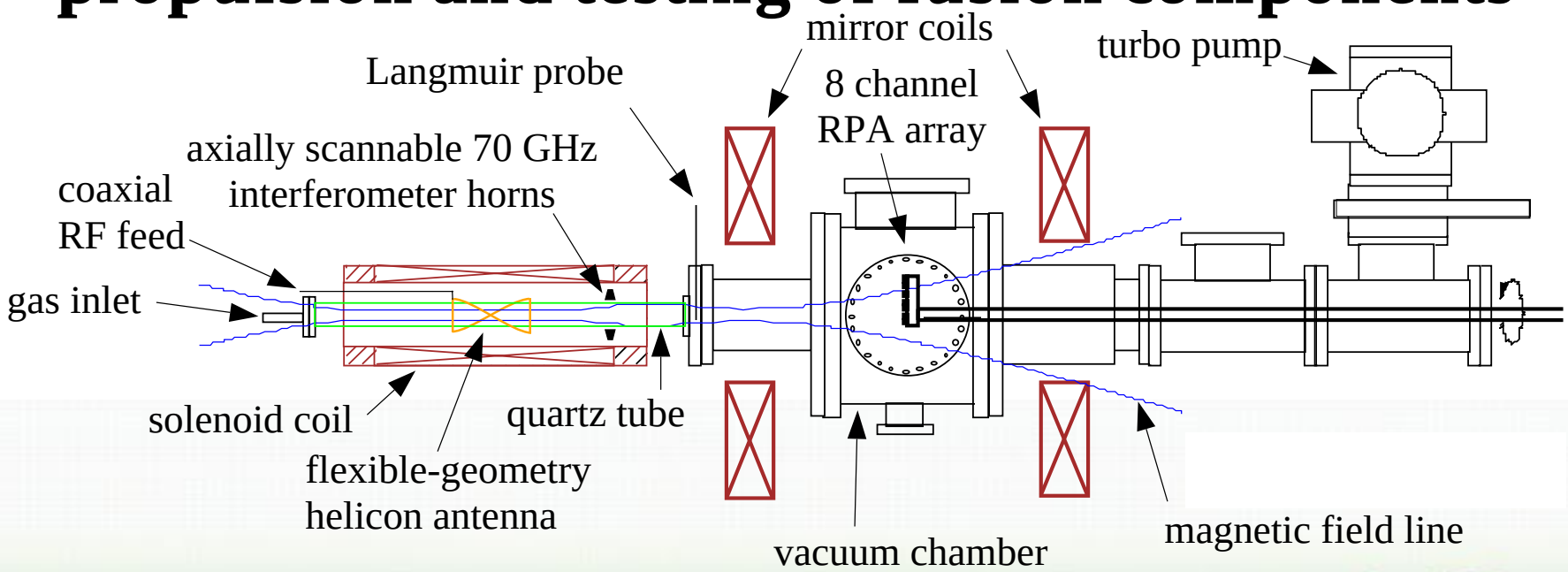
# Experiment and modeling comparison

- **Mini-RFTF**
  - Magnetic field scan results for "quadrupole" antenna at fixed mirror ration

- **Preliminary EMIR3 modeling**
  - Finite difference on staggered mesh in cyclindrical coordinates
  - Includes E parallel in cold plasma dielectric
  - Calculates magnetic fields based on filament models of experimental coils
  - Handles helical antenna shapes

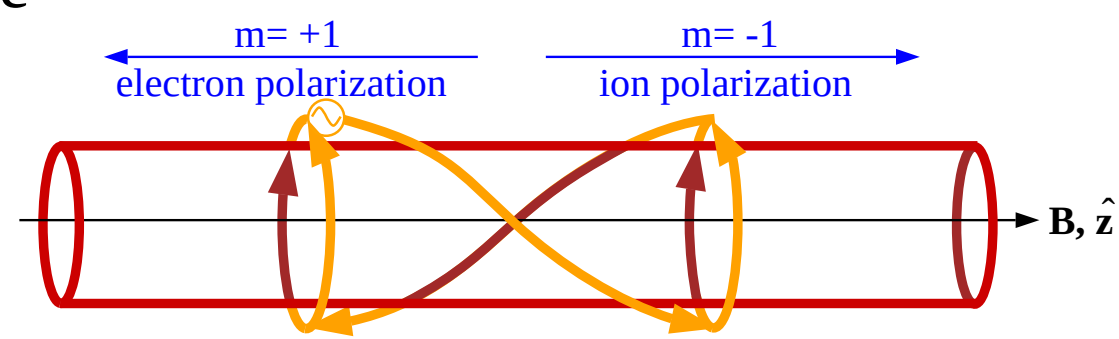
# The Mini-RFTF facility is a helicon with strong axial variations

- **Light ions are the primary topic for study**
- **Applications include plasma sources for space propulsion and testing of fusion components**



# Typical antennas try to match the fast helicon dispersion relation

- **| m | =1**
  - Two azimuthal modes are excited
  - The wave with the electron polarization will couple power near the axis
  - The wave with the ion polarization will be mostly reactive




- **m=0 antennas are also used**
  - Other field components can play a role

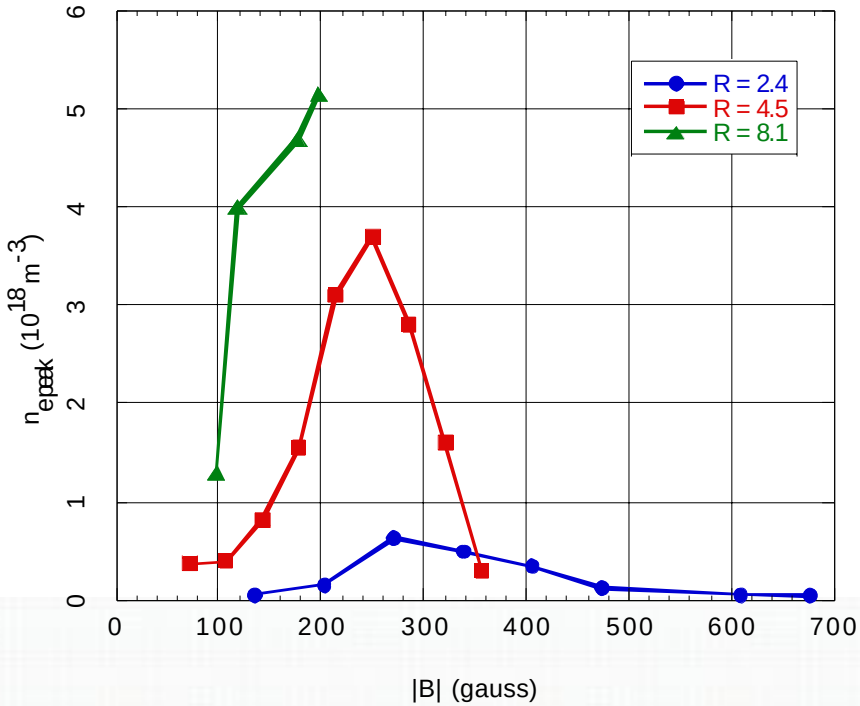
# Quad antenna for cases under study

- $\pi/2$ phasing on helical elements
- Isolate single m=1 downstream mode

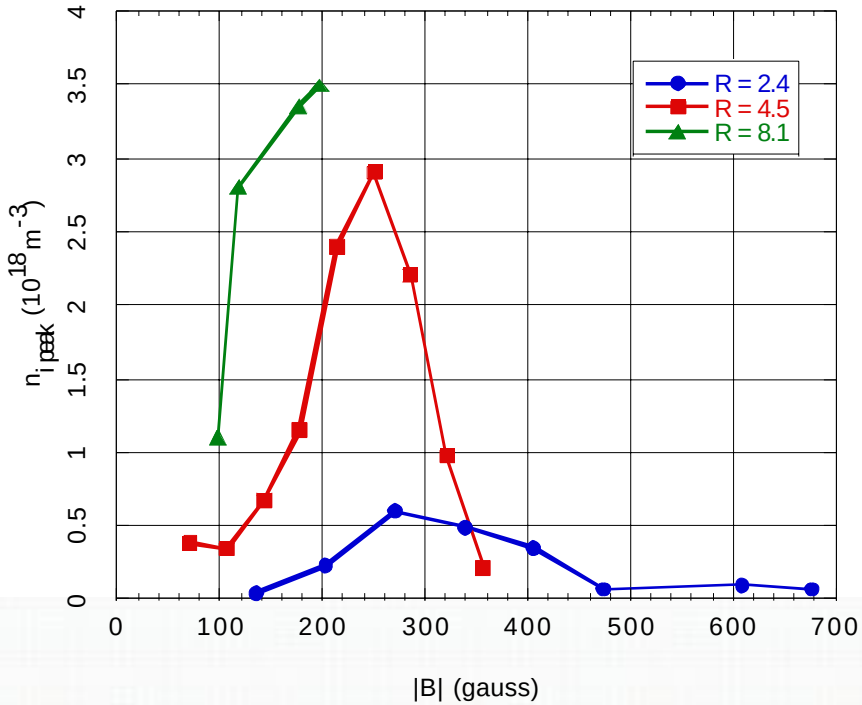
# Maximum achievable density depends on mirror ratio and field values in gas tube

- Hydrogen at 16 MHz, 2.5 kW, field scans with constant mirror ratios

Interferometer

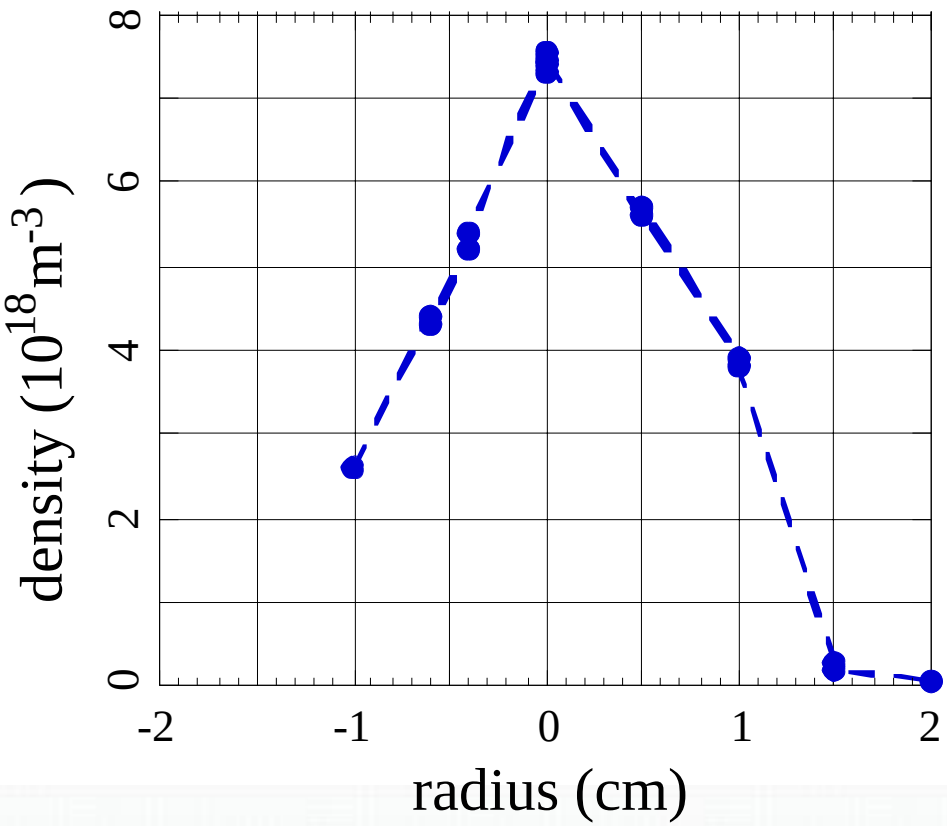



Langmuir probe



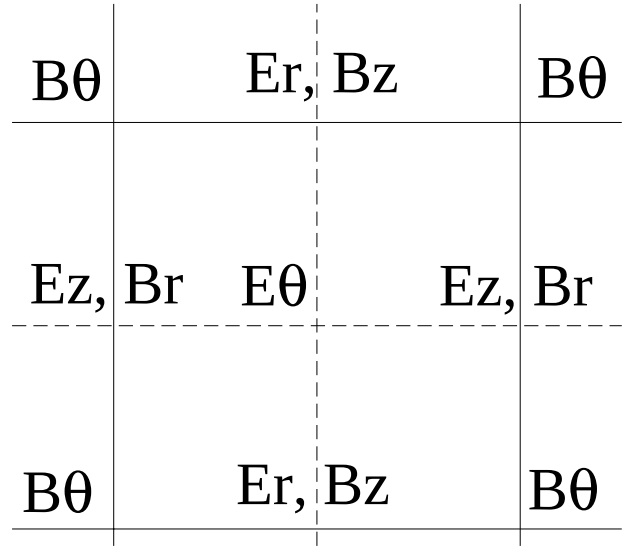
# Radial profiles tend to be highly peaked for high density modes

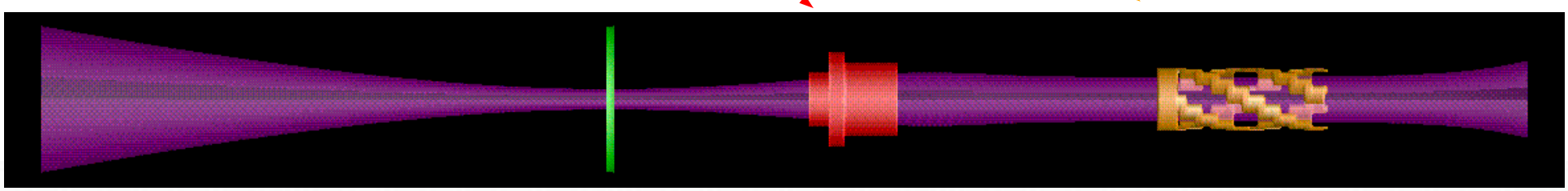
- Variations in profile for different fields not extensively measured
- Modeling assumes "tent" shape, some efforts beginning for self-consistent profiles



# EMIR3 electromagnetic model

- Maxwell's equations finite differenced on staggered mesh
- Cold plasma dielectric with parallel electric field
- Helical antenna geometries
- Internal perfectly conducting boundaries



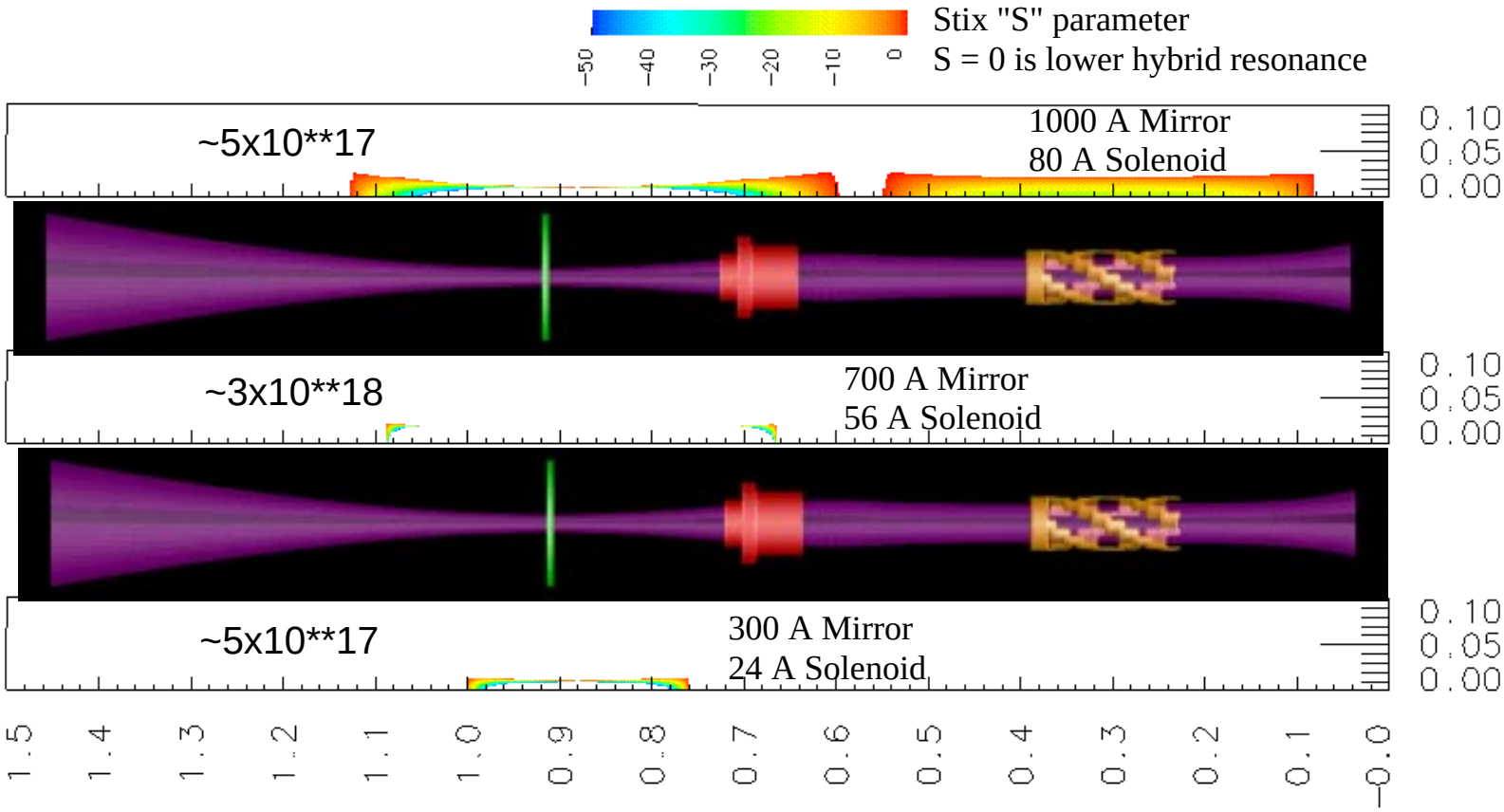



maximum |B|
(mirror coil)

solenoid section

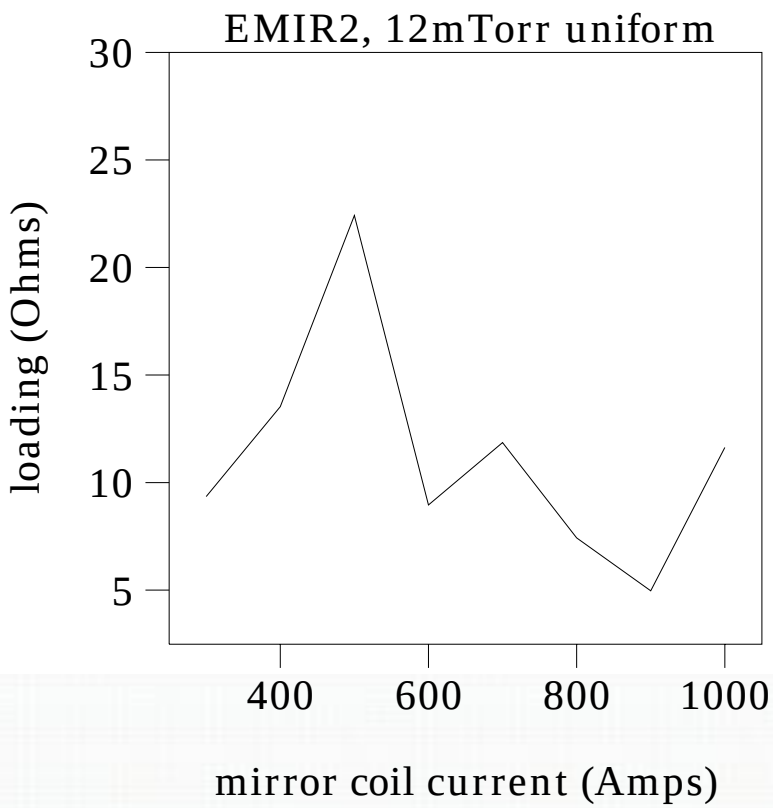
# Lower hybrid location using approximate experimental parameters

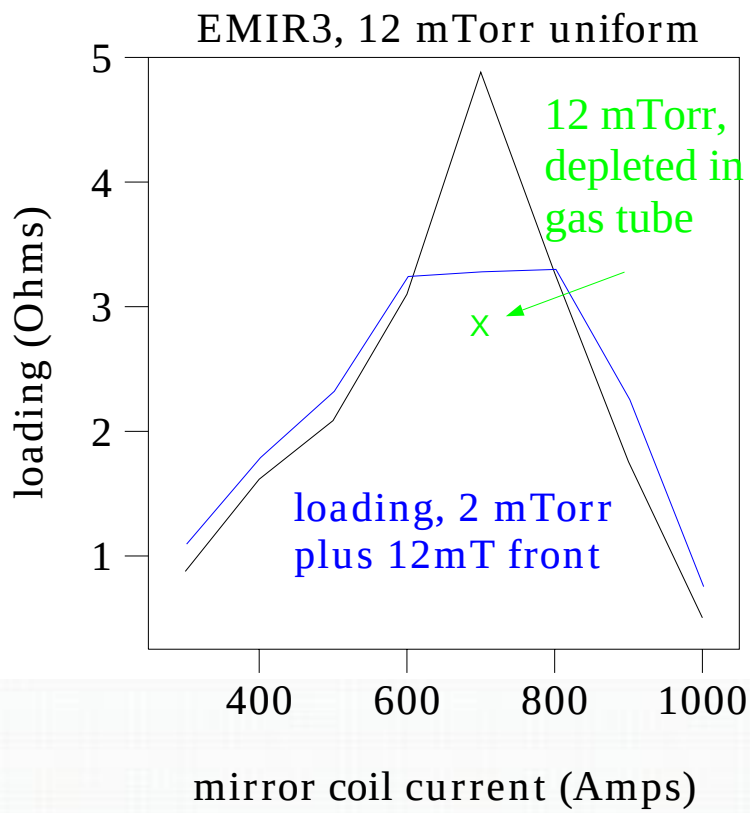
- High density operation associated with lower hybrid resonance in downstream "trap"?



# Loading comparisons for "tent" profiles, constant mirror ratio, different gas pressures

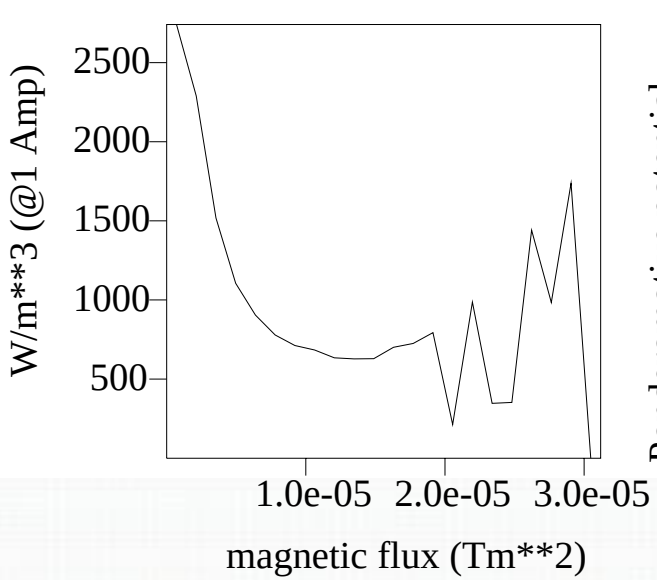
- EMIR2 has no parallel electric field
- EMIR3 has parallel electric field

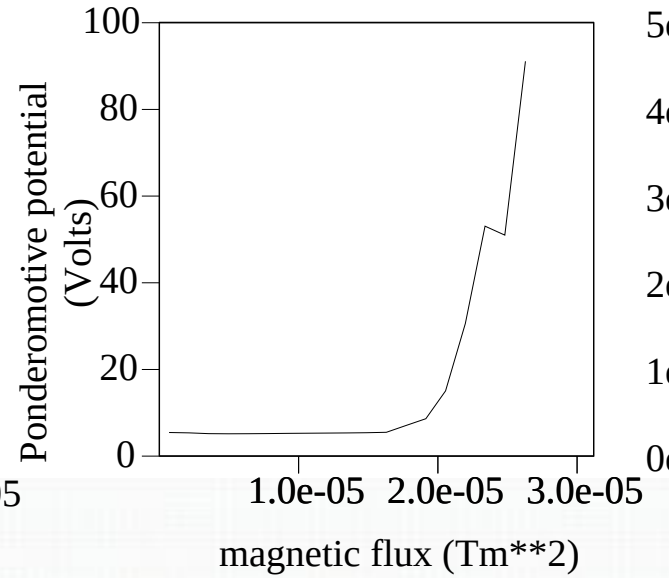


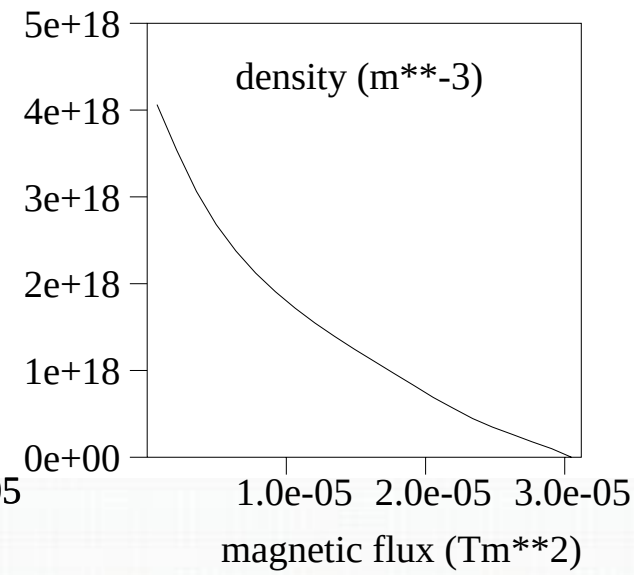



# Crude particle balance estimates

- Simple radial diffusion (0.1 Bohm) with ponderomotive expulsion (under construction)
  - 600 Amp case beginning to converge?
  - Power deposition from "tent" profile
  - 36eV per ion pair, Hydrogen, 1 kW to plasma



# Conclusions

- **High density discharges with Hydrogen are obtained in Mini-RFTF using standard and "quad" antennas**

- **Preliminary results from EMIR3 code are promising for resolving the power split between helicon waves and lower hybrid waves**
  - High density operation associated with lower hybrid resonance in downstream "trap"?
  - Downstream leakage observed for some discharges

- **Resolution of the lower hybrid is difficult,**
  - requires >200 to 300 radial, >1000 axial grid points

# Future plans

- Calculate loading vs mirror coil currents and compare with experiment
- Better use of measurement information to determine three-dimensional density profiles
- Self-consistent profiles
  - Radial diffusion and axial losses
  - Long and thin, Bohm diffusion could be larger than axial losses
- Check ponderomotive forces near edge
- Look for ways to separate breakdown from high density coupling