Abstract

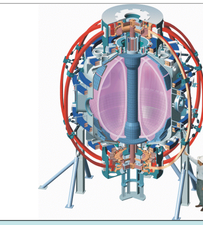
A new spectroscopic diagnostic on the National Spherical Torus Experiment (NSTX) measures the temperature and velocity of the plasma edge with both poloidal and toroidal views. The diagnostic is simultaneously sensitive to C III, C IV, and He II intrinsic emission light (between 4595 and 4705 Å) with 10 ms resolution, covering a radial region of 15 cm at the extreme edge of the outboard mid-plane. Combined with the local pressure gradient and EFIT reconstructed magnetic field profile, the edge flow gives a measure of the local radial electric field. Preliminary results include measurement of: 1) rotation, temperature and radial electric field changes during HHFW RF heating, and 2) indications of large Carbon influx when the RF antenna is powered, and 3) an anisotropic ion temperature during high power RF heating in conjunction with velocity changes.

This research is supported by the U.S. D.O.E. under contract: DE-AC02-76CH03073.

Edge Ion Velocity and Temperature Measurements in NSTX

T.M. Biewer, R.E. Bell, D. W. Johnson

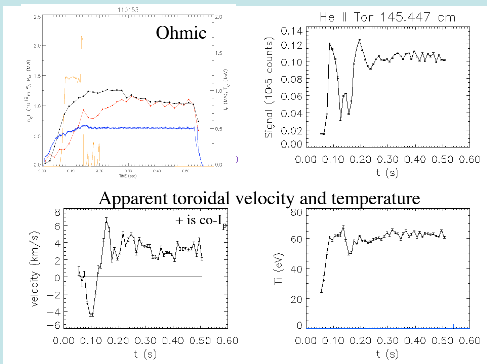
Princeton Plasma Physics Lab, Princeton, NJ 08543



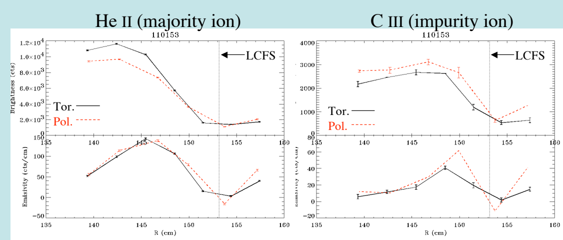
Observations in Ohmic and RF Heated Helium Discharges

New ERD Measures Brightness, Velocity, and Temperature

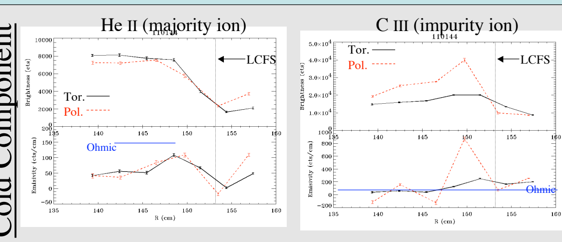
Ohmic



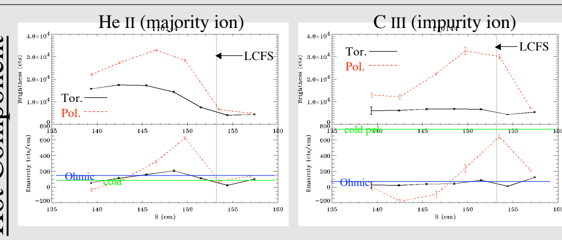
Modified Abel Inversion Yields Local Emissivity



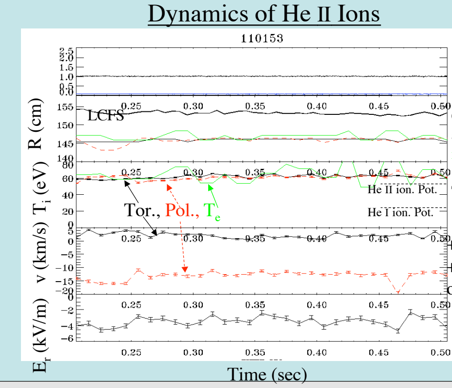
Cold Component



Hot Component



Dynamics of He II Ions



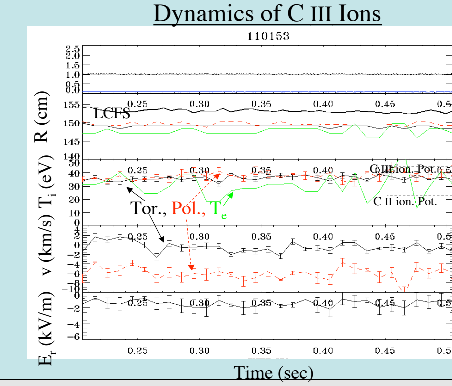
Good pol. & tor. agreement and w/ ionz. potential

T_i isotropic

+ tor. co-I_p
+ pol. down @ outboard mp.

E_r=vxB-∇p/Zn

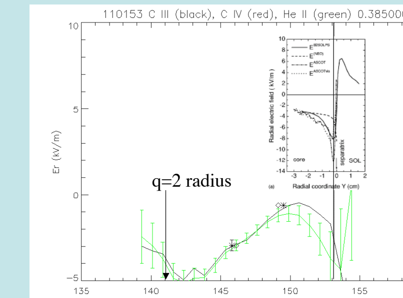
Dynamics of C III Ions



R_C>R_{He}~145 cm not surprising

T_C<T_{He}~60 eV not surprising

Radial Electric Field Profiles



E_r=vxB-∇p/Zn

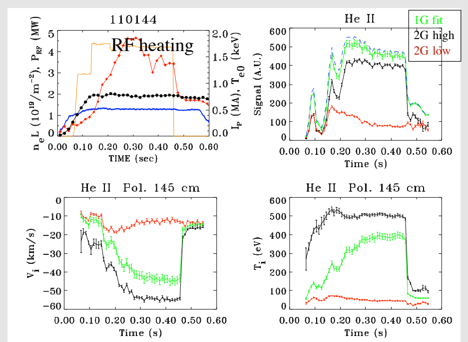
Good agreement between the E_r found from He II and that from C III

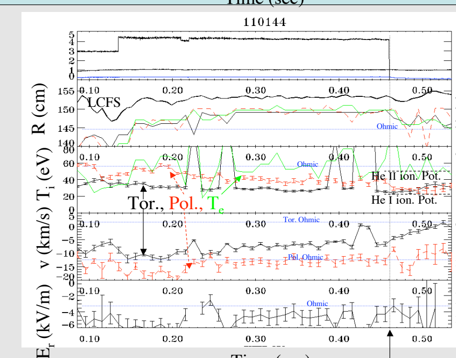
Shape around LCFS similar to simulations for ASDEX-U.

Kiviniemi *PoP* **10** 2604 (2003)

Other structure from TM islands?

RF Heated





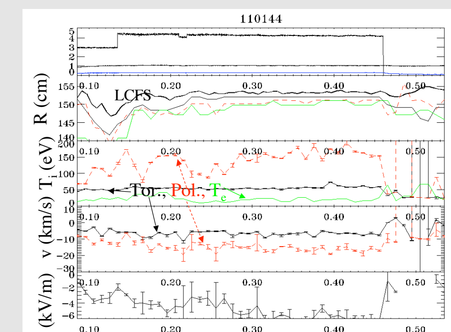
Rel. to Ohmic

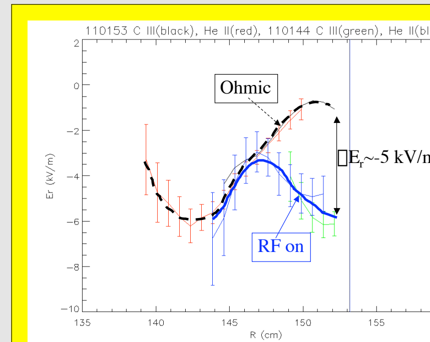
Peak emission has moved outward.

T_i lower (but n_e=2n_e), and is anisotropic (T_{pol}=1.5T_{tor})

Tor. velocity appears more negative (anti-I_p)

E_r slightly more negative





Ohmic v. RF heated

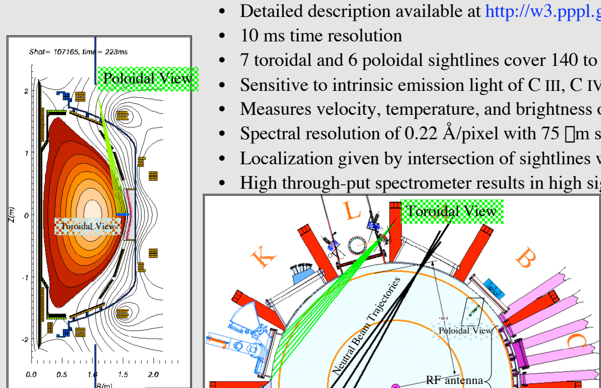
The E_r at the edge most region of the plasma (R>146 cm) is more negative during RF heated plasmas than during Ohmic.

For R<146 cm the E_r is similar (for the region measured)

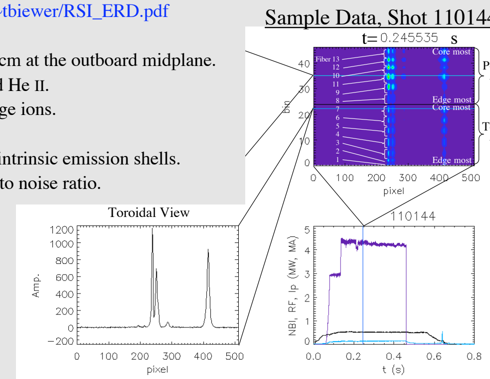
Implies that RF leads to ion loss at the edge of the plasma.

Overview of the Edge Rotation Diagnostic (ERD)

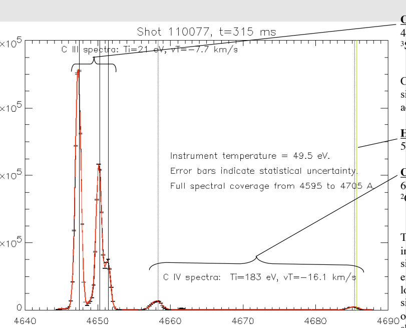
- Detailed description available at http://w3.pppl.gov/~tbiewer/RSI_ERD.pdf
- 10 ms time resolution
- 7 toroidal and 6 poloidal sightlines cover 140 to 158 cm at the outboard midplane.
- Sensitive to intrinsic emission light of C III, C IV, and He II.
- Measures velocity, temperature, and brightness of edge ions.
- Spectral resolution of 0.22 Å/pixel with 75 μm slits.
- Localization given by intersection of sightlines with intrinsic emission shells.
- High through-put spectrometer results in high signal to noise ratio.



Sample Data, Shot 110144



Ion dynamics from C III, C IV, and He II are studied.



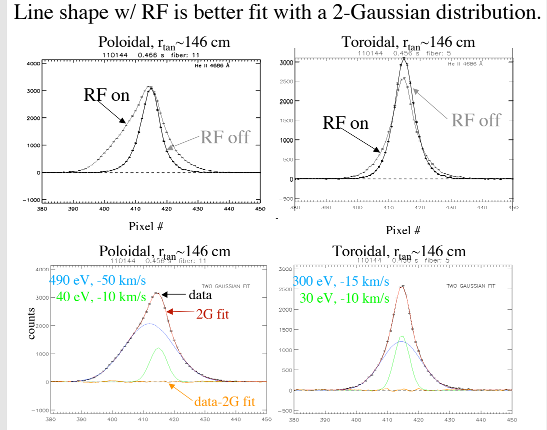
C III triplet
47.88 eV ionization
^3S to $^3P_0$ transition
relative amplitudes from theory
Can fit all 3 lines simultaneously to get very accurate v, T

He II
54.414 eV ionization

C IV doublet
64.489 eV ionization
^2G to $^2H_0$

The ERD relies on the intersection of the sightline with the intrinsic emission shell for localization. But each sightline measures aspects of different emission shells, which peak at different radii.

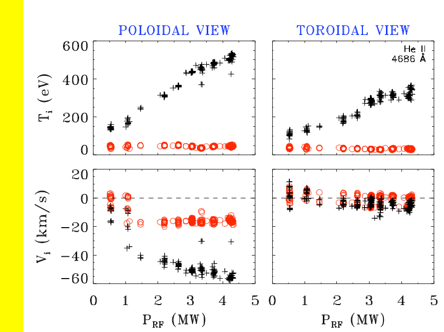
Line shape w/ RF is better fit with a 2-Gaussian distribution.



Charge Exchange in Helium Plasmas w/ Carbon Impurities

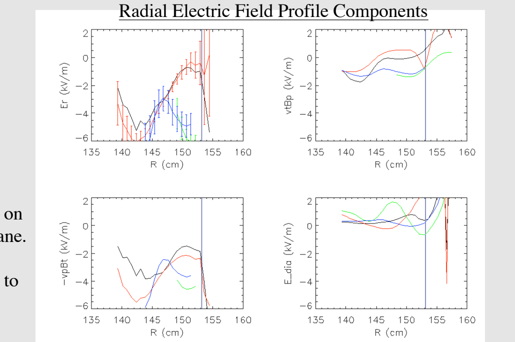
He II, C III, C VI (CHERS bkgnd)

		He II			C III			C VI	
		He^{+} ~54 eV	He^{2+} ~max T_i	C^{+} ~24 eV	C^{2+} ~48 eV	C^{3+} ~65 eV	C^{4+} ~392 eV	C^{5+} ~490 eV	C^{6+} ~max T_i
Single	C^{0} ~11 eV	He^{0} ~54 eV	He^{+} ~max T_i	C^{0} ~24 eV	C^{+} ~48 eV	C^{2+} ~65 eV	C^{3+} ~392 eV	C^{4+} ~490 eV	C^{5+} ~max T_i (CHERS signl)
		C^{+} ~11 eV	C^{+} ~11 eV	C^{+} ~11 eV	C^{+} ~11 eV	C^{+} ~11 eV	C^{+} ~11 eV	C^{+} ~11 eV	C^{+} ~11 eV
Double			He^{0} ~max T_i		C^{0} ~48 eV	C^{+} ~65 eV	C^{2+} ~392 eV	C^{3+} ~490 eV	C^{4+} ~max T_i
			C^{2+} ~11 eV		C^{2+} ~11 eV	C^{2+} ~11 eV	C^{2+} ~11 eV	C^{2+} ~11 eV	C^{2+} ~11 eV
Triple						C^{0} ~65 eV	C^{+} ~392 eV	C^{2+} ~490 eV	C^{3+} ~max T_i
						C^{3+} ~11 eV	C^{3+} ~11 eV	C^{3+} ~11 eV	C^{3+} ~11 eV



Negative poloidal velocity is upwards on the outboard midplane. Negative toroidal velocity is opposite to the direction of I_p.

Radial Electric Field Profile Components



Discussion

Observations in Ohmic, Helium plasmas with the new Edge Rotation Diagnostic (ERD) show very good agreement between calculations of the radial electric field, E_r, from both Helium (majority) and Carbon (impurity) measurements.

When High Harmonic Fast Waves (HHFW) are launched by the RF antenna into similar plasmas, a two-population distribution of ions is observed (in both He and C), which is interpreted as "cold" and "hot" populations. Calculations from the cold populations of He and C indicate that E_r decreases by 5kV/m in the edge of the plasma, while RF power is applied. This suggests that ion confinement is degraded in the edge during the time that the RF antenna is powered.

It is postulated that the edge ions loss rate is enhanced due to collisions with neutral Carbon (and possibly other atoms) which are injected (outgassed?) by the powered RF antenna. The Carbon emissivity in the edge of the plasma is observed to increase by a factor of ~10 near the antenna (poloidal view) and by a factor of ~3 away from the antenna (toroidal view, ~2 m). Additionally, the emissivity of hot Carbon and Helium near the antenna is observed to increase an order of magnitude.

The observation of the hot distribution of Carbon and Helium is attributed to charge exchange (or recombination) interactions between the fully stripped plasma ions and the neutral atoms injected by the powered antenna. In this way, the powered RF antenna has two effects: 1) it sources neutral Carbon, which leads to ion loss at the edge of the plasmas, and 2) it heats fully stripped plasma ions, which are made visible through charge exchange with the injected neutrals. The heating mechanism is discussed below, and in **Poster LP1.018 by Randy Wilson**.

Key to this interpretation of the observed bi-modal distribution is the heating mechanism of the RF power which creates the hot component of He and C ions. The HHFW launched by the NSTX antenna has a high phase velocity compared to the ion thermal velocity and is not expected to heat edge ions, but should damp on electrons in the core. Resonant heating at the ion cyclotron frequency (27th sub-harmonic for He, and 41st for C) is unlikely. One possibility for ion heating is parametric decay of the launched HHFW into a daughter ion Bernstein wave (IBW) and an ion quasi-mode at the fundamental ion cyclotron resonance. Ion heating could then occur either directly at the fundamental cyclotron frequency or by IBW heating. The observed anisotropic temperature is consistent with ions having a large perpendicular energy content, as expected from IBW heating.

Note: The emission time scale is ~1 ns, implying that light from both populations (hot and cold) would be readily observed. The time scale for thermalization between two populations of He ions is ~10 ms. However, the time scale for ionization is ~100 μs. Hence, thermalization between the hot and cold populations would not be observed before ionization occurs. Presumably, thermalization occurs among fully stripped He^{2+} ions, which do not emit.

Summary

- Non-invasive measurements of the radial electric field in the edge of NSTX have been made possible by the ERD.
- Applying power to the RF antenna coincides with large amounts of Carbon in NSTX
  - Antenna direct source? Probably.
    - Effect greater near antenna (poloidal view).
  - Surface waves scouring the walls?
- This Carbon is useful as a Charge Exchange Diagnostic
  - There are hot ions in the edge.
  - Parametric decay of HHFW on He^{2+} majority as heating mechanism.
    - Could also be responsible for heating edge Carbon.
- Will running the antenna clean itself up?
- Need experiments with CHERS and antenna camera.
- Need modeling of edge plasma (CRM, MIST, NCLAS).

Full-color reprints of this poster are available online:
http://w3.pppl.gov/~tbiewer/APS03poster.pdf
Or sign up below for an email copy:
