Biased Electrodes for SOL Control in NSTX

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Abstract

Small electrodes were installed near the outer midplane of NSTX to control the width of the scrape-off layer (SOL) by creating a strong local poloidal electric field.

Clear increases were seen in the plasma density and potential in between these biased electrodes when the applied E_{pol} x B drift was directed radially outward.

However, little or no change was seen in the D_a emission profile ~1 meter downstream from the electrodes along the magnetic field, implying that the poloidal electric field did not propagate this far along B.

Theory of SOL Control by E_{pol}

- Create localized E_{pol} in SOL near divertor plate to cause radial E_{pol}xB flows to move SOL strike point or induce turbulent broadening of SOL

  R.H. Cohen et al, NF 37, 621 (1997)
  D.D. Ryutov et al, PPCF 43, 1399 (2001)
  R.H. Cohen et al, PPCF 49, 1 (2007)]

- Main questions:
  - do these perturbations affect the local SOL ?
  - do these perturbations locally induce turbulence ?
  - how far do perturbations extend II and $\perp$ B ?

Previous Experiments

- Most tokamak biasing experiments aimed to create E_r and not E_{pol} [e.g. PBX-M, DIII-D, TdeV, TEXTOR…]

- Some experiments have shown creation of local E_{pol} in SOL

  JFT-2M [Hara et al, J. Nucl. Mat. 241-243, 338 (1997)]
  MAST [Counsell et al, J. Nucl. Mat. 313-316, 804 (2003)]
  CASTOR [Stockel et al, PPCF 47, 635 (2005)]

- MAST experiment was done to test idea of Cohen/Ryutov, resulting in partial confirmation of theory, e.g. movement of D_α strike point at biased divertor “ribs”

- Other experiments have seen potential propagate along B

  DITE [Pitts and Stangeby, Plasma Phys. Cont. Fusion 32, 1237 (1990)]
  TEXT [Winslow et al, Phys. Plasmas 5, 752 (1998)]
  W7-AS [Thomsen et al, Plasma Phys. Cont. Fusion 47, 1401 (2005)]

NSTX Electrode Biasing Experiment

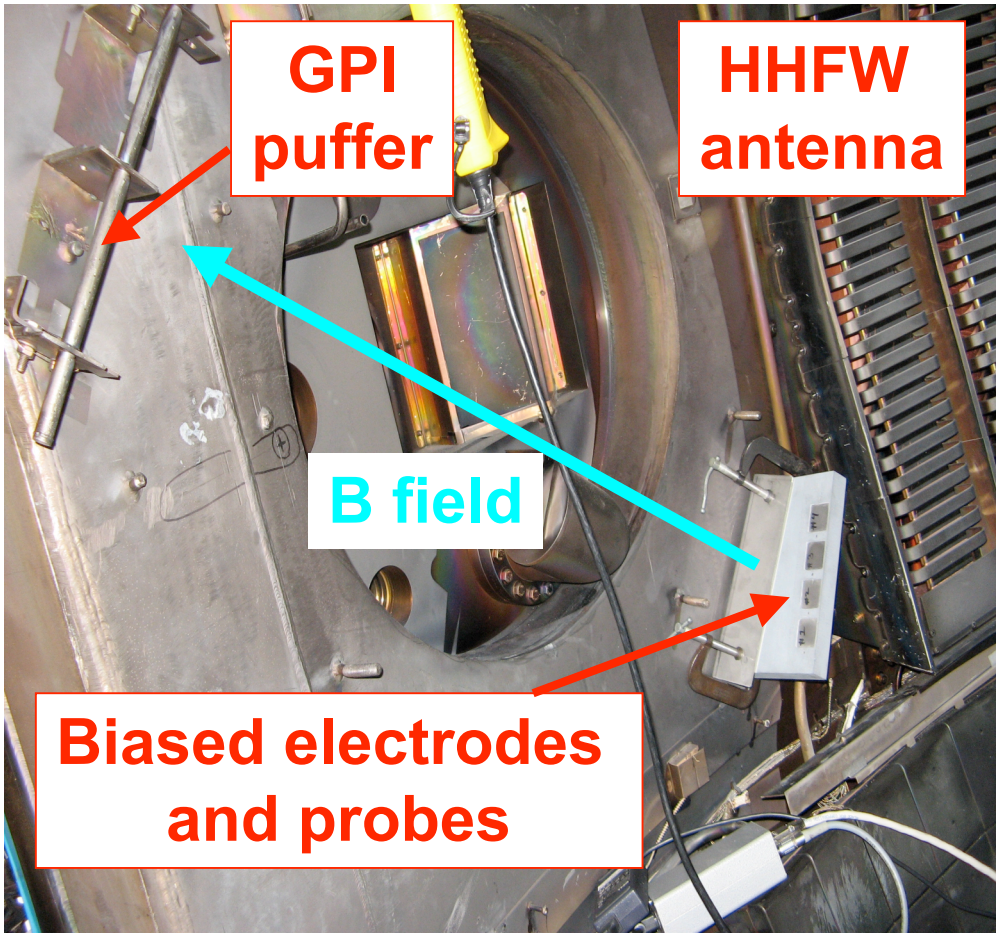
- Uses electrodes near outer midplane in far-SOL
- Uses probes to measure local potential, n_e and T_e
- Uses GPI to see effects on D_α ~ 1 m along B

=> Applied $E_{pol} \leq 200$ V/cm (vacuum) could create a E_{pol}xB of $V_r \leq 5 \times 10^6$ cm/sec, ~50 times larger than the typical radial velocity in the SOL (~ blob velocity)

bias <u>should</u> have strong effect on local SOL (it did)

bias <u>should not</u> affect global plasma (it did not)

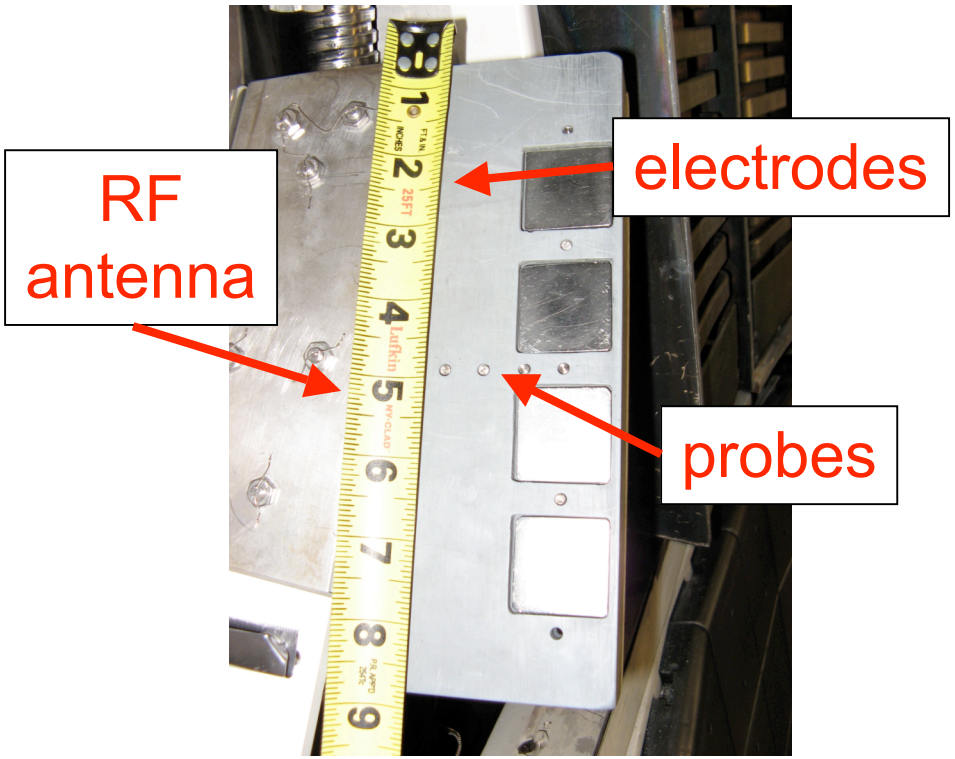
Biased Electrodes and Probes in NSTX

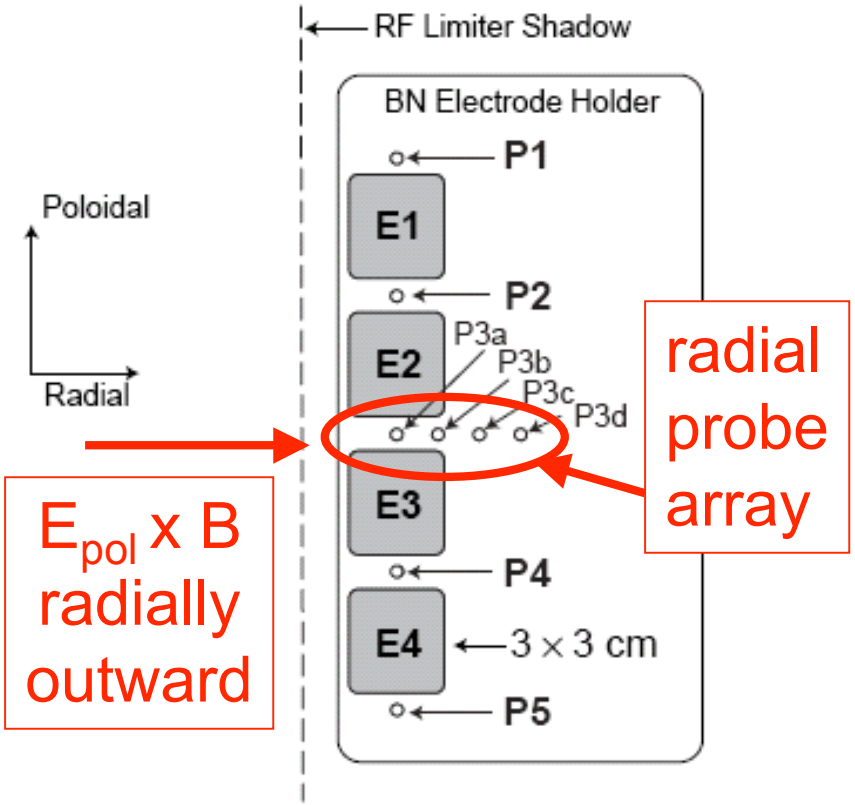


- 4 electrodes of size 3 cm x 3 cm
- 8 Langmuir probes next to electrodes
- leading edge ~ 1 cm behind RF antenna
- biased field lines seen by GPI diagnostic

Biased Electrodes and Probes

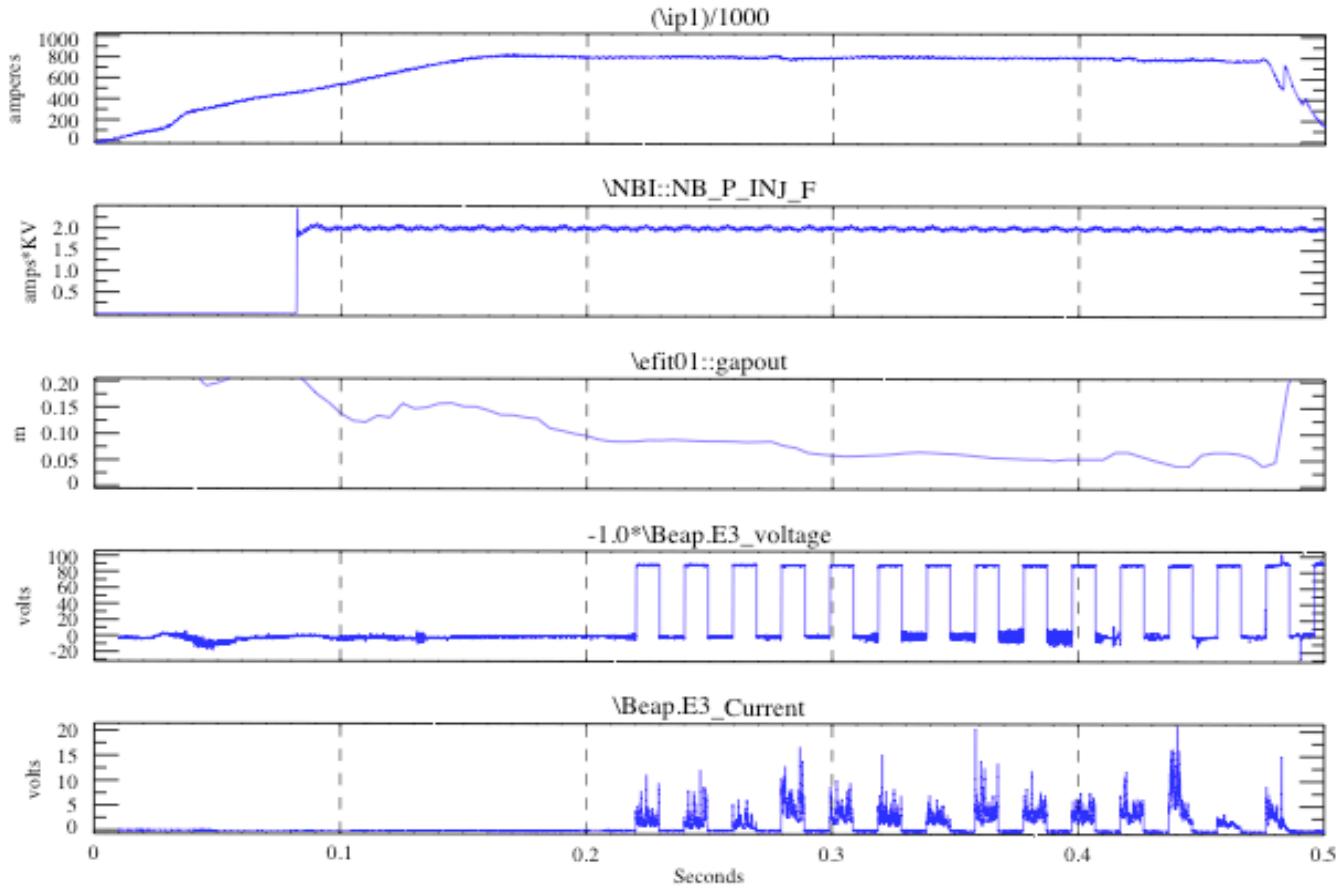
- Electrodes ≤100 V@30 A (or -100V@10 A), mod. @ 50 Hz
- Nearby Langmuir probes biased DC or swept ± 50 volts





NSTX Discharge Conditions

- Typically I=0.8 MA, B=4.5 kG, P_{NBI} = 2-4 MW
- Edge density in SOL increases with smaller outer gap



Ip (kA)

NBI (MW)

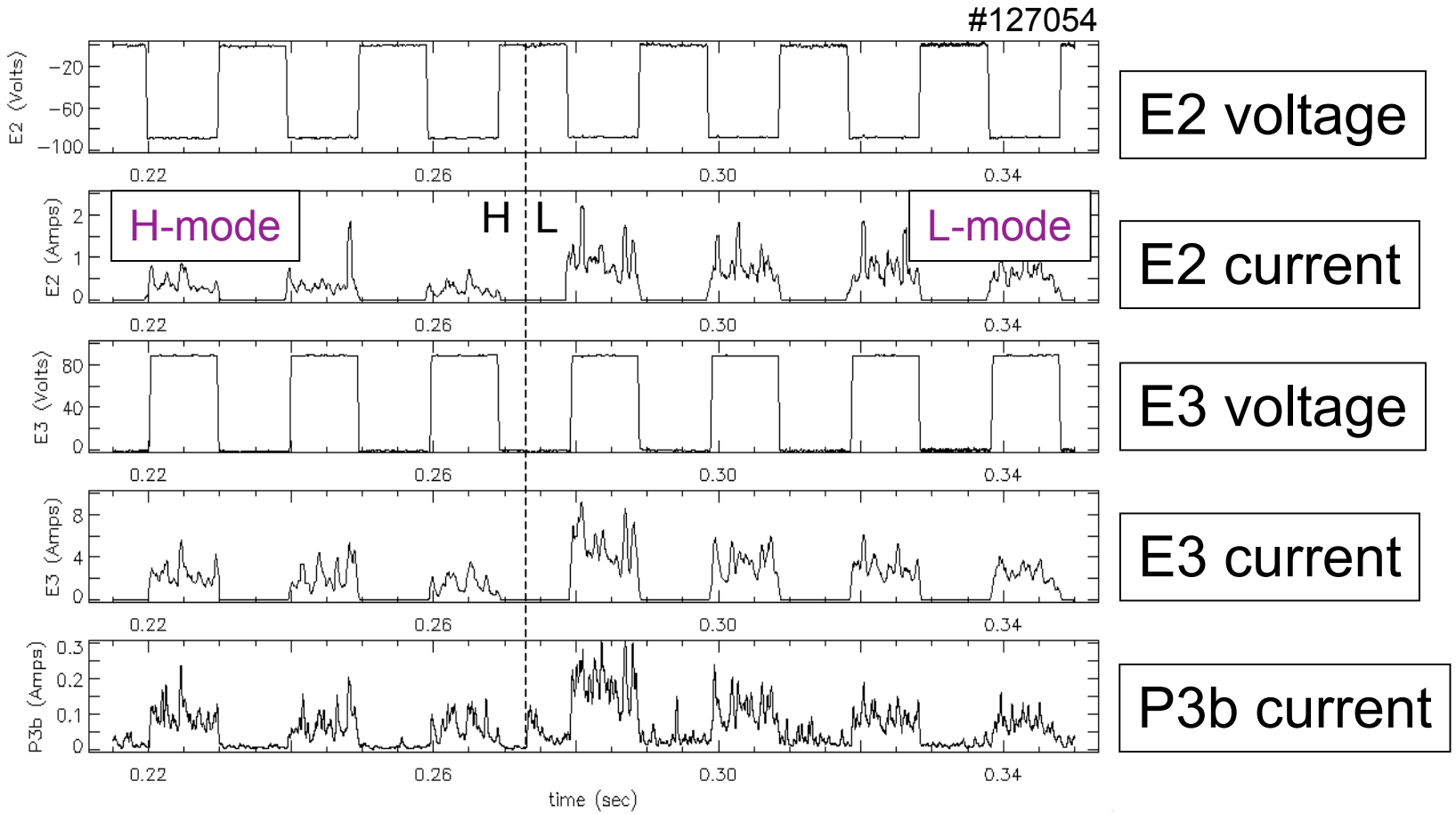
outer gap (m)

E3 voltage

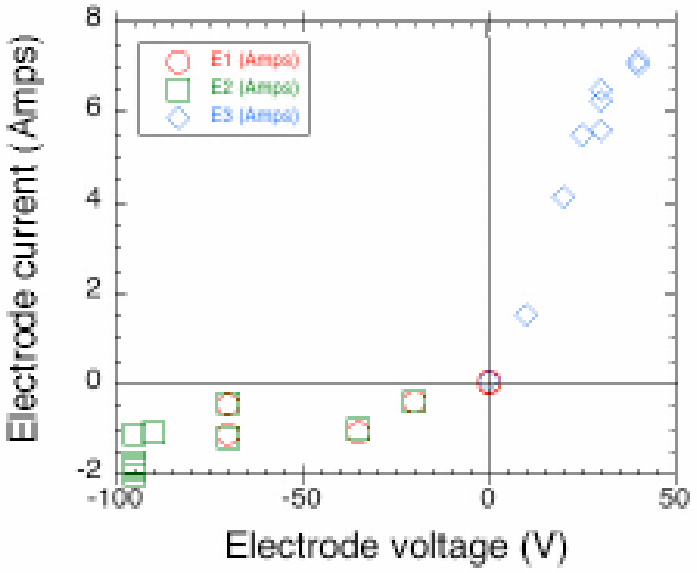
E3 current

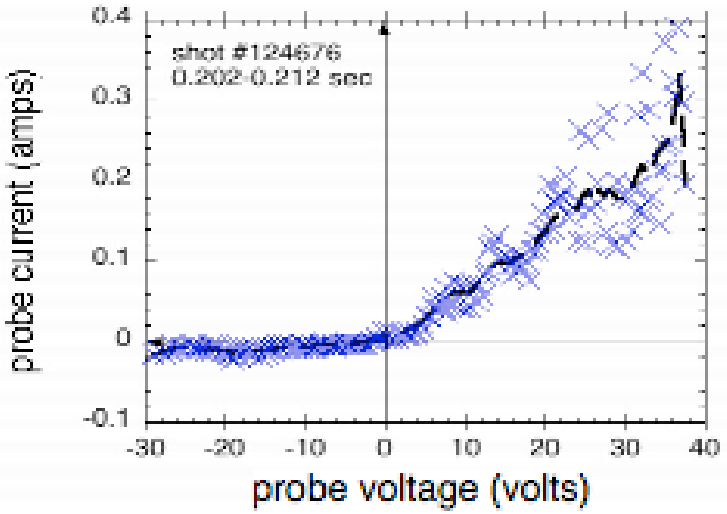
Electrode and Probe Signals vs. Time

- Here E2 @ - 90 volts, E3 at + 90 volts, P3b @ +45 volts
- See clear increase in probe current with each biasing



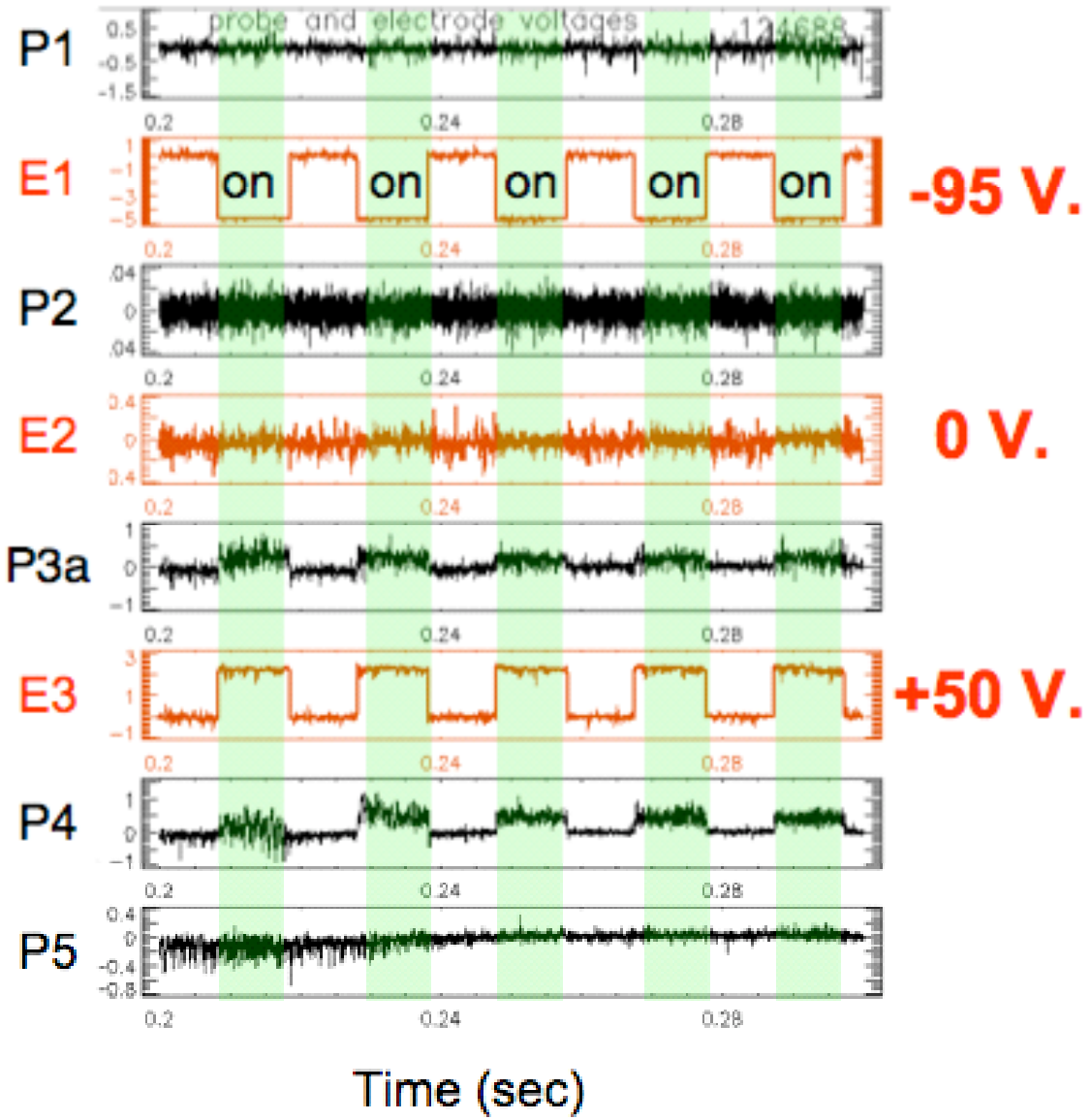
Typical (I,V) Characteristics





- Electrode current I_e/I_i ~ 7 at ±40 V
- Probe current I_e/I_i ~ 24 at ±40 V
  n_e ~ few x10^{11} cm^{-3}
  T_e ~ 6±3 eV
- I_i(electrode) / I_i(probe) ~ 100, about area ratio (as expected)
- Electrode electron current more than ‘double-probe’ limit, but less than ‘single-probe’ limit

Probe Floating Potential Response



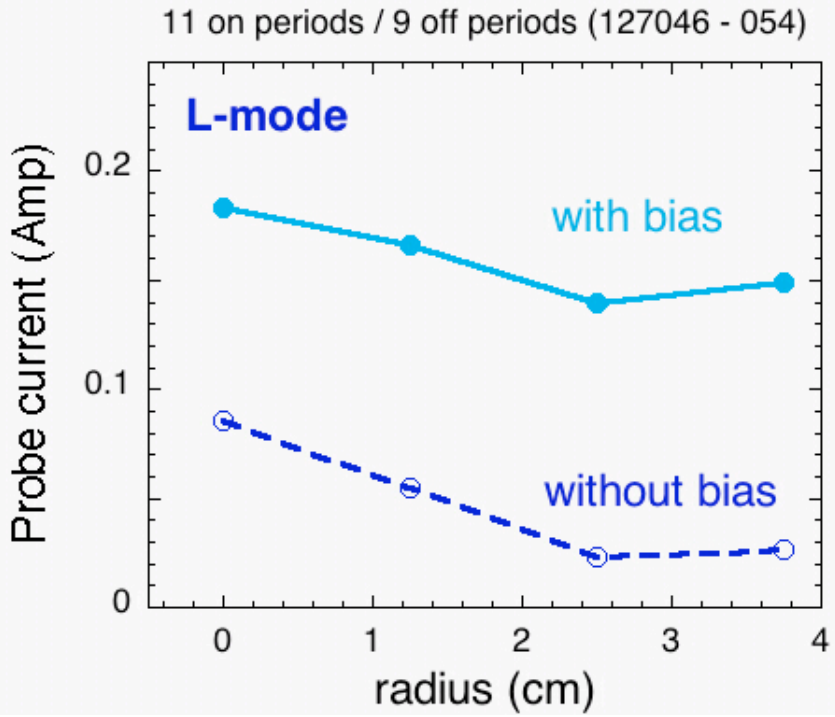
- floating potential of probes near - bias electrode doesn't change significantly
- floating potential of probes near + bias electrode go up ~20% of voltage on electrode

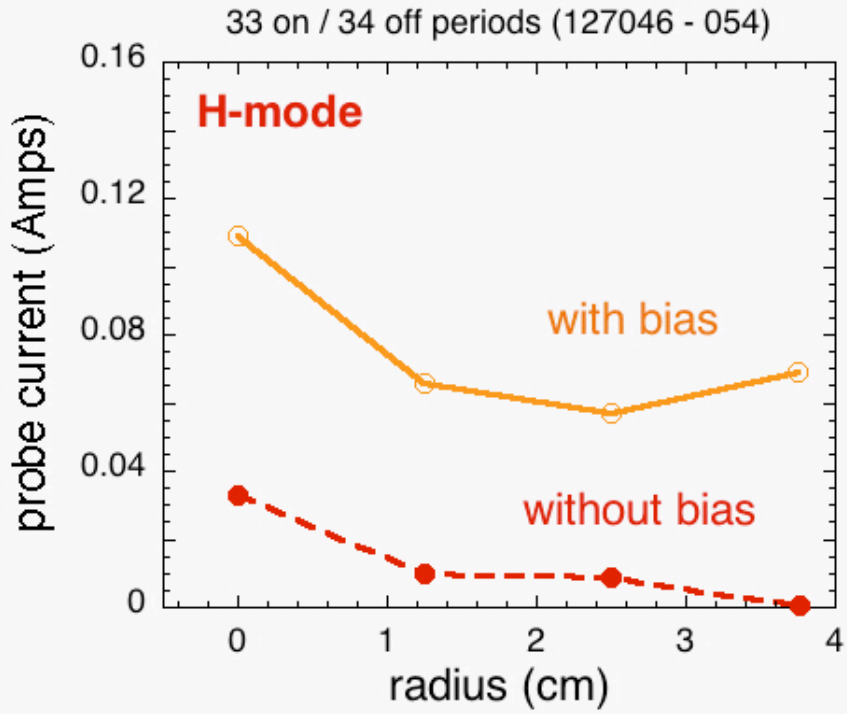
=> positive electrode affects local V_f

negative electrode does not

Local SOL Density Profile Effects

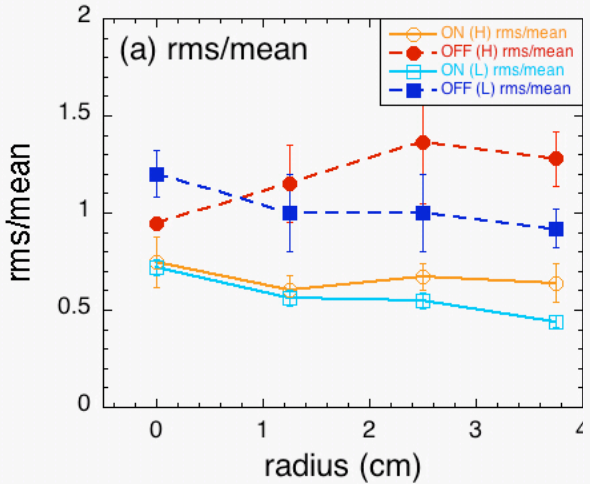
- E_{pol} x B directed outward between electrodes E2 and E3
- Radial profiles of I_e ($\propto n_e$) measured with probes P3a-P3d
- Local density increases x3 to x10 with ±90 volts on E2-E3

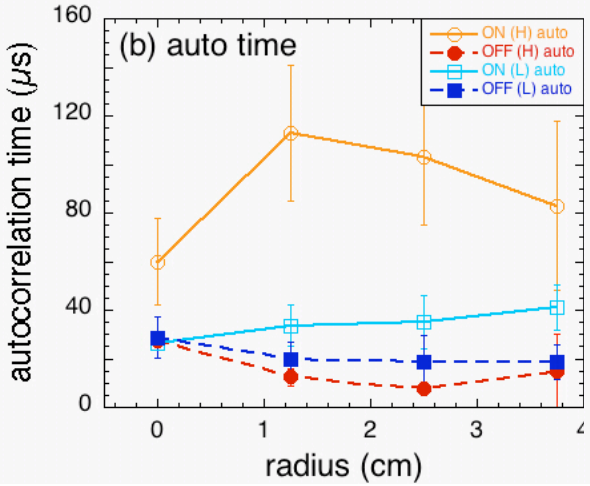


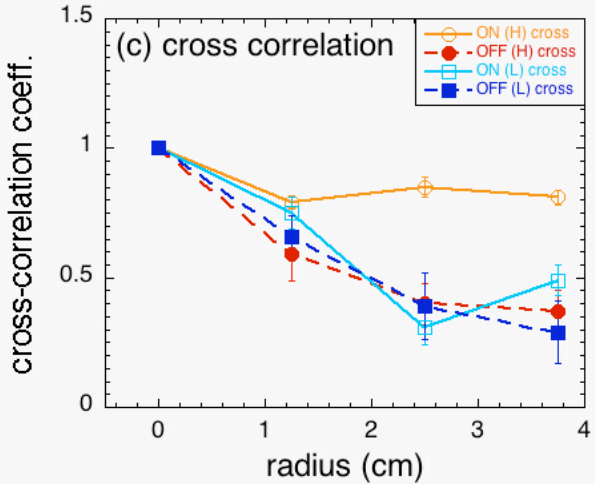


Effects on Local Turbulence

- Relative density fluctuations decrease x2 with biasing (floating potential fluctuations increase with biasing)
- Autocorrelation times and radial correlation lengths in L-mode are ~ unchanged by biasing
- During H-mode biasing, small ELMs are seen at probes, which increases correlation times and lengths

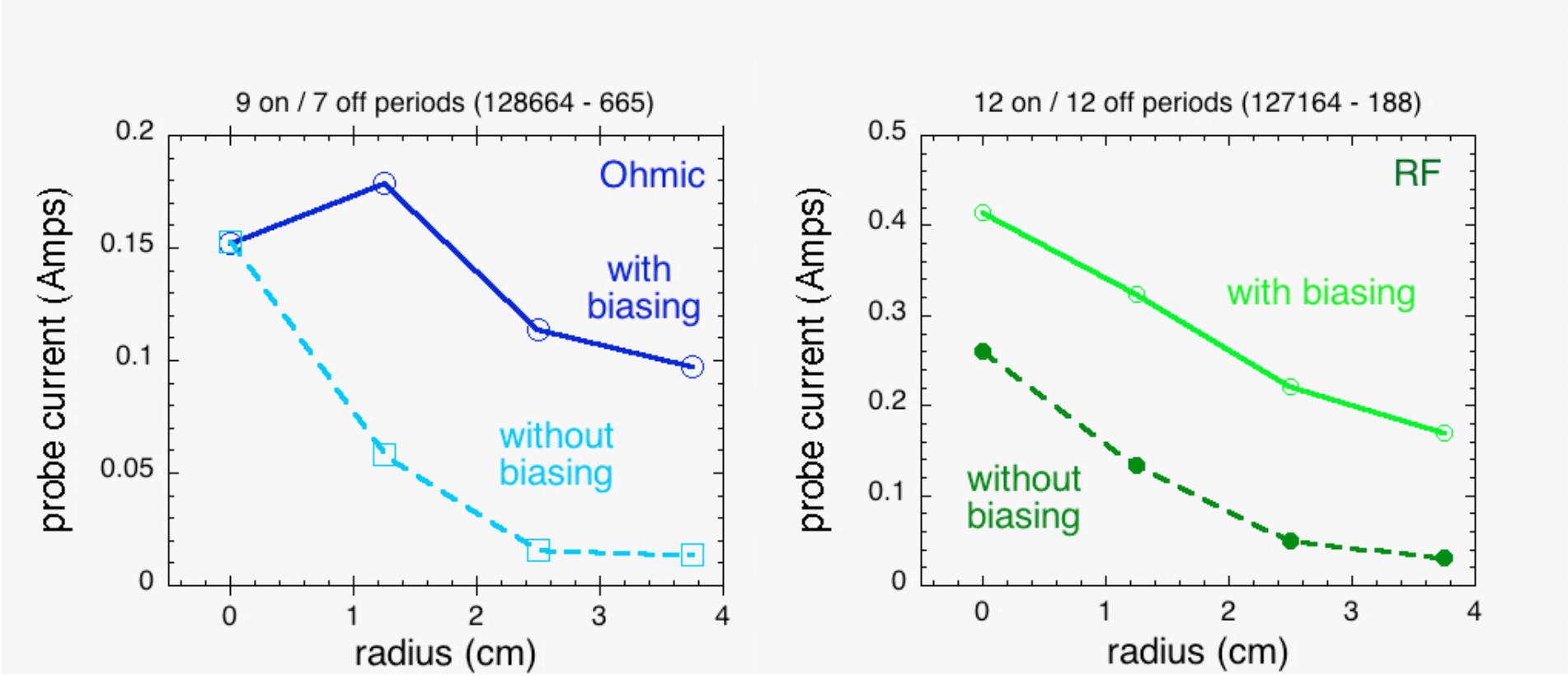






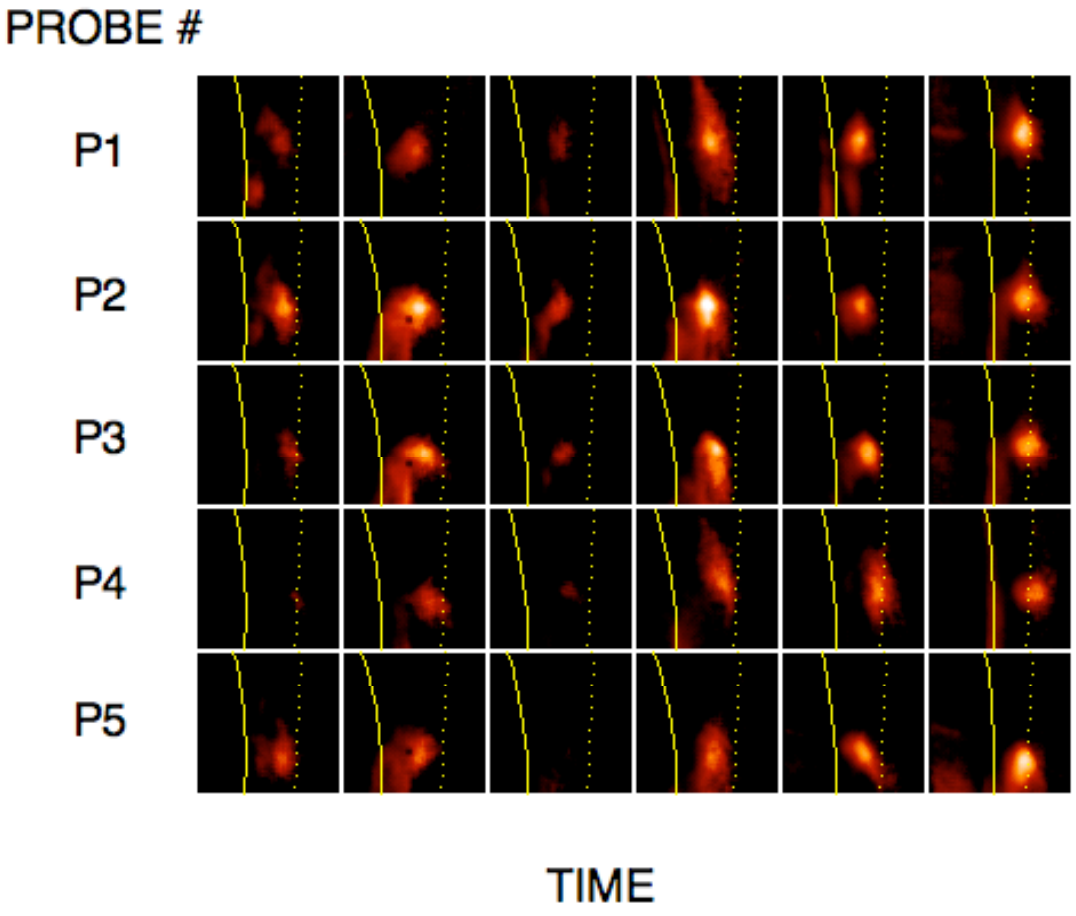
Ohmic and RF Heated Cases

- Similar density profile changes were seen in Ohmic plasmas (±90 volts) and RF heated plasmas (± 50 volts), with biasing between E2 and E3



Correlation of Probe & GPI Fluctuations

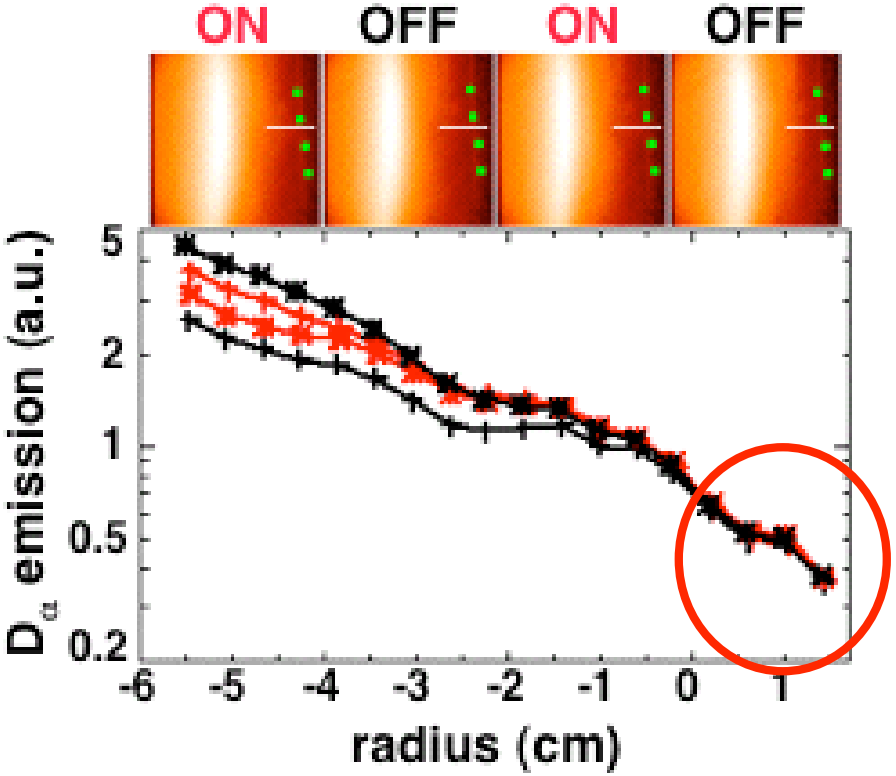
GPI imaging region overlayed with probe correlation strength (red)



- Good correlation of fluctuations along ~ 1 m along B field (C ~ 50-80%)
- Mapping of probes to GPI agrees with EFIT02 field lines
- Size of correlation volume ~ 4 cm, as expected (~ blob)

Radial Profile of D_α Emission

- D_α emission from a GPI gas puff measured ~ 1 m along B
- No significant change seen with biasing



- radial profile as measured between E2 and E3, using alignment from correlations

green dots = electrode centers

white line = range of this plot

red circle = overlap with probes

Summary of Experimental Results

- Poloidal electric field had a significant effect on the SOL profiles as measured the local Langmuir probe array:

  SOL density increased by ~ factor of x3-10 over ~ 4 cm

- Poloidal electric field did not have a significant effect on the local turbulence (except during small ELMs)

- Positive bias had a small effect on the local floating potential, but negative bias did not have any effect

- No significant change was seen in the D_α profile and turbulence in the GPI diagnostic ~1 m away along B

Tentative Theoretical Interpretations

- Outward E_{pol} x B caused the increase in SOL density, but a quantitative comparison with theory can not be done without more information on penetration II and $\perp$ to B
- Changes in local potential seen with (+) bias, and not (-) bias, is ~ consistent with sheath model of Ryutov et al
- Ratio of electron/ion current to electrodes I(+) ~ 7 x I(-) suggests a significant cross-field current, which may explaining the absence of effect on D_α ~ 1 m along B
- No clear evidence of increased turbulence due to biasing, as might be driven by local K-H instabilities

Sorry I could not come to this meeting

If you have questions or comments, please ask Ricky Maqueda at Poster P3-23, or email me at:

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Stewart