

# Biased Electrodes for SOL Control in NSTX

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*Poster P3-O3 @ PSI Meeting May 2008*

## 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  $E_{\text{pol}} \times B$  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  $E_{pol} \times B$  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  $\parallel$  and  $\perp$  B ?

# Previous Experiments

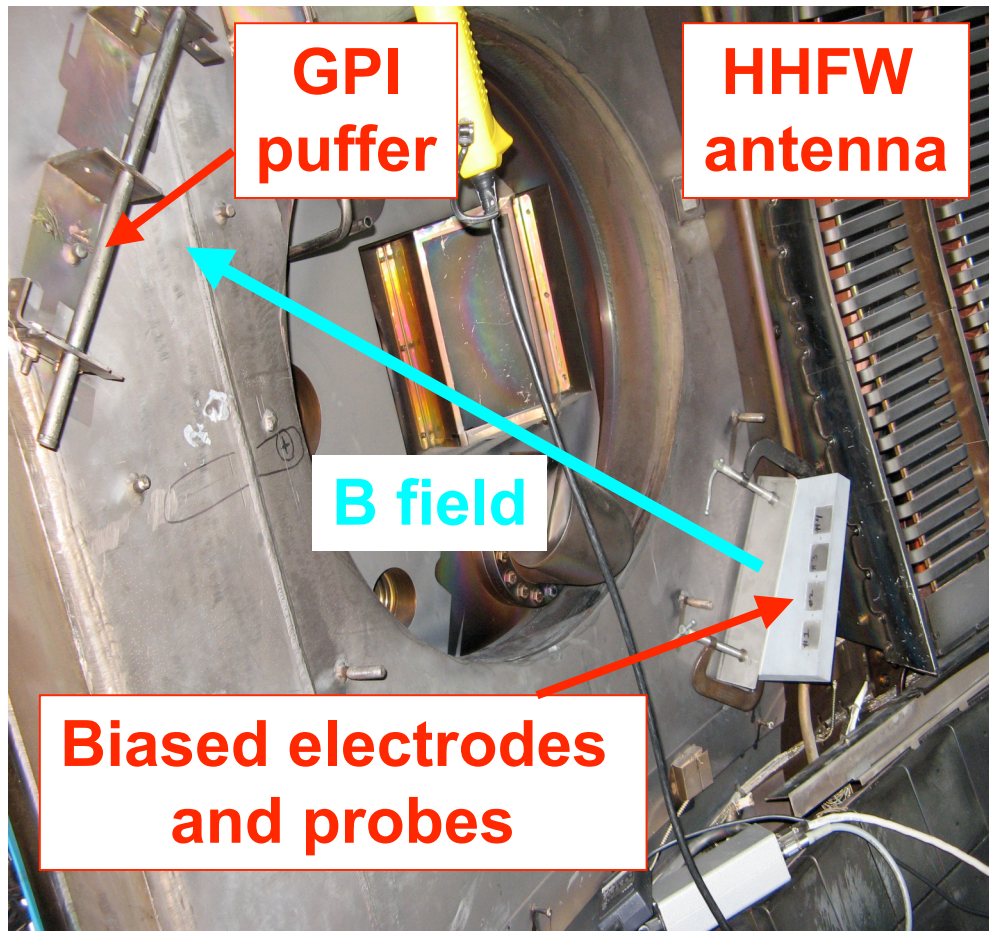
- Most tokamak biasing experiments aimed to create  $E_r$  and not  $E_{pol}$  [e.g. PBX-M, DIII-D, TdeV, TEXTOR...]
- Some experiments have shown creation of local  $E_{pol}$  in SOL
  - JFT-2M [Hara et al, J. Nucl. Mat. 241-243, 338 (1997)]
  - MAST [Counsell et al, J. Nucl. Mat. 313-316, 804 (2003)]
  - 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  $D_\alpha$  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)] 4

# 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  $D_\alpha \sim 1$  m along B
- => Applied  $E_{\text{pol}} \leq 200$  V/cm (vacuum) could create a  $E_{\text{pol}} \times B$  of  $V_r \leq 5 \times 10^6$  cm/sec,  $\sim 50$  times larger than the typical radial velocity in the SOL ( $\sim$  blob velocity)

***bias should have strong effect on local SOL (it did)***  
***bias should not affect global plasma (it did not)***

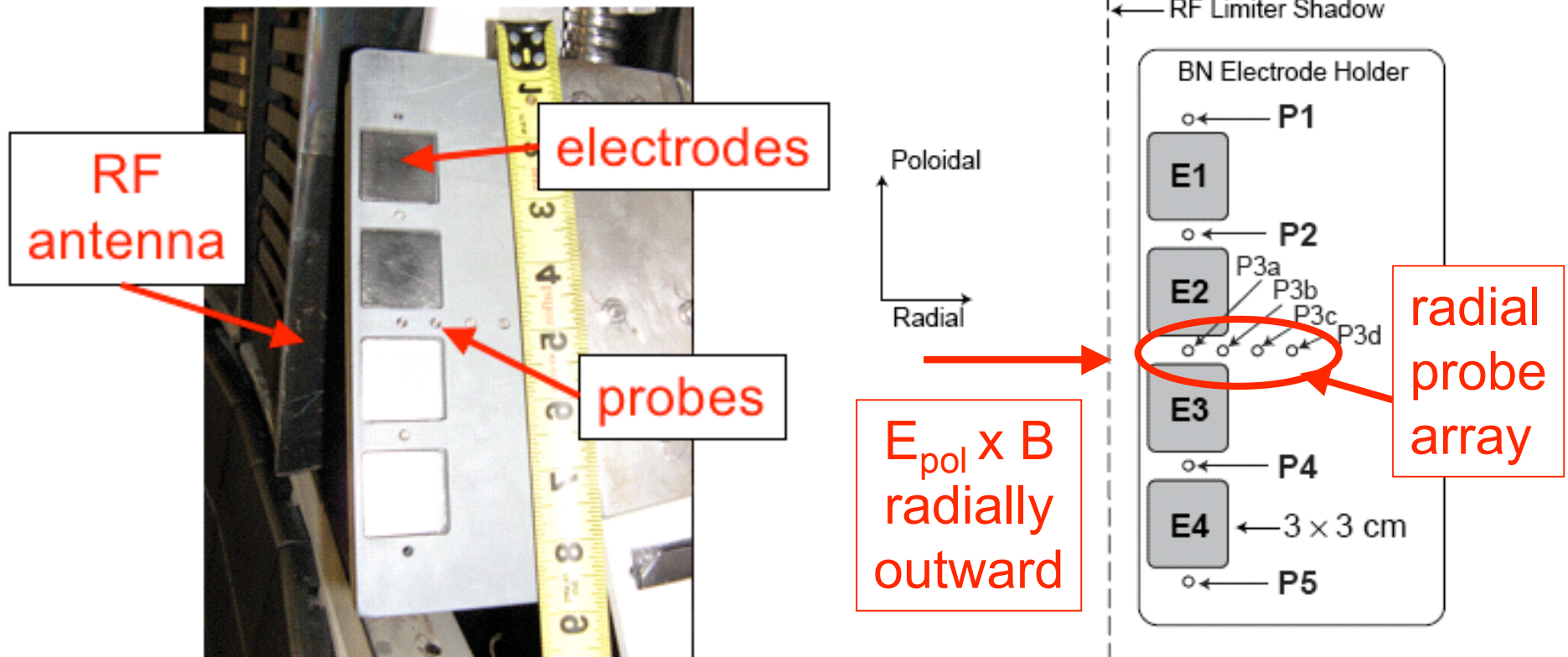
# Biased Electrodes and Probes in NSTX



- 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

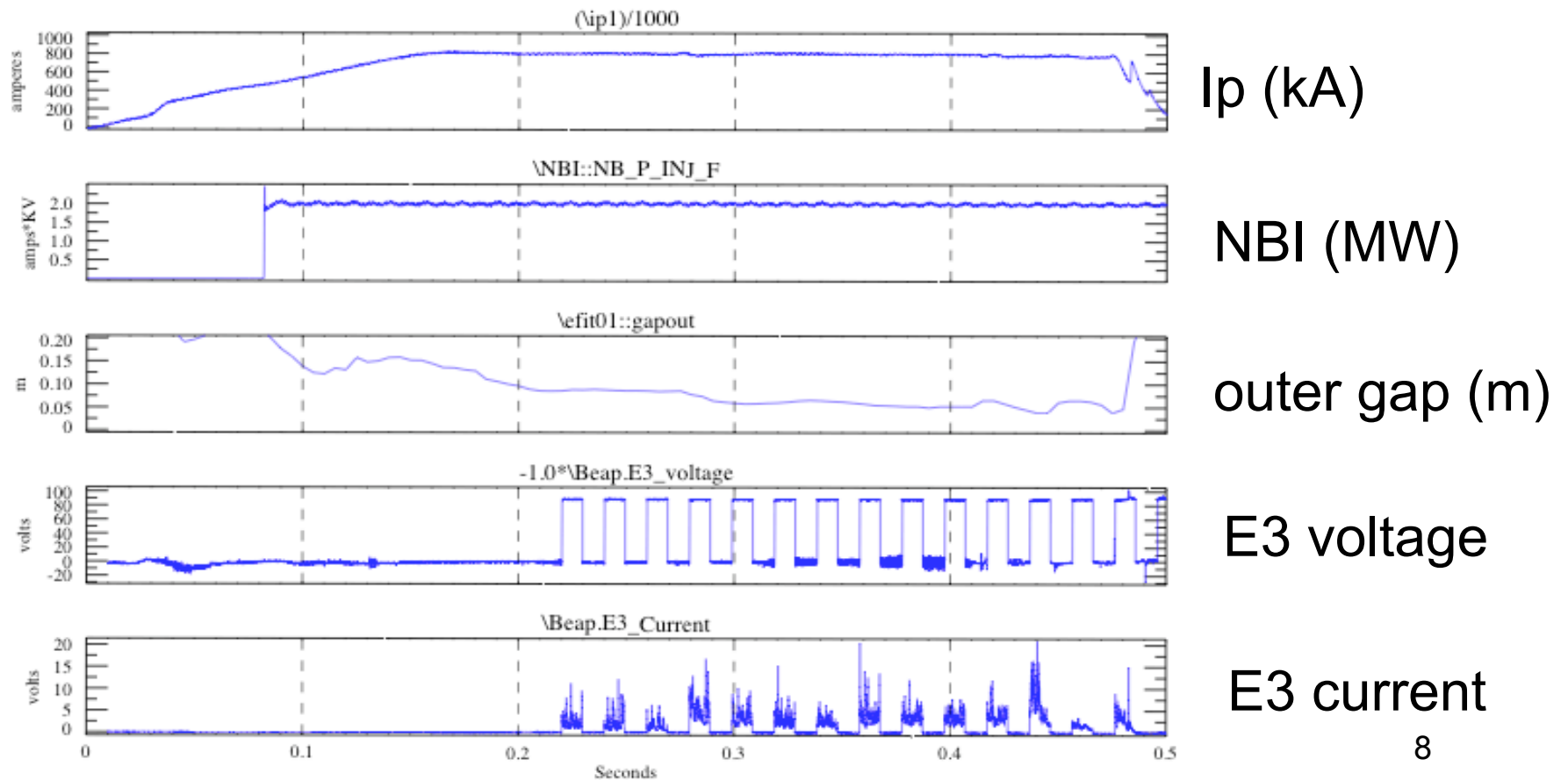
# Biased Electrodes and Probes

- Electrodes  $\leq 100$  V@30 A (or -100V@10 A), mod. @ 50 Hz
- Nearby Langmuir probes biased DC or swept  $\pm 50$  volts



# NSTX Discharge Conditions

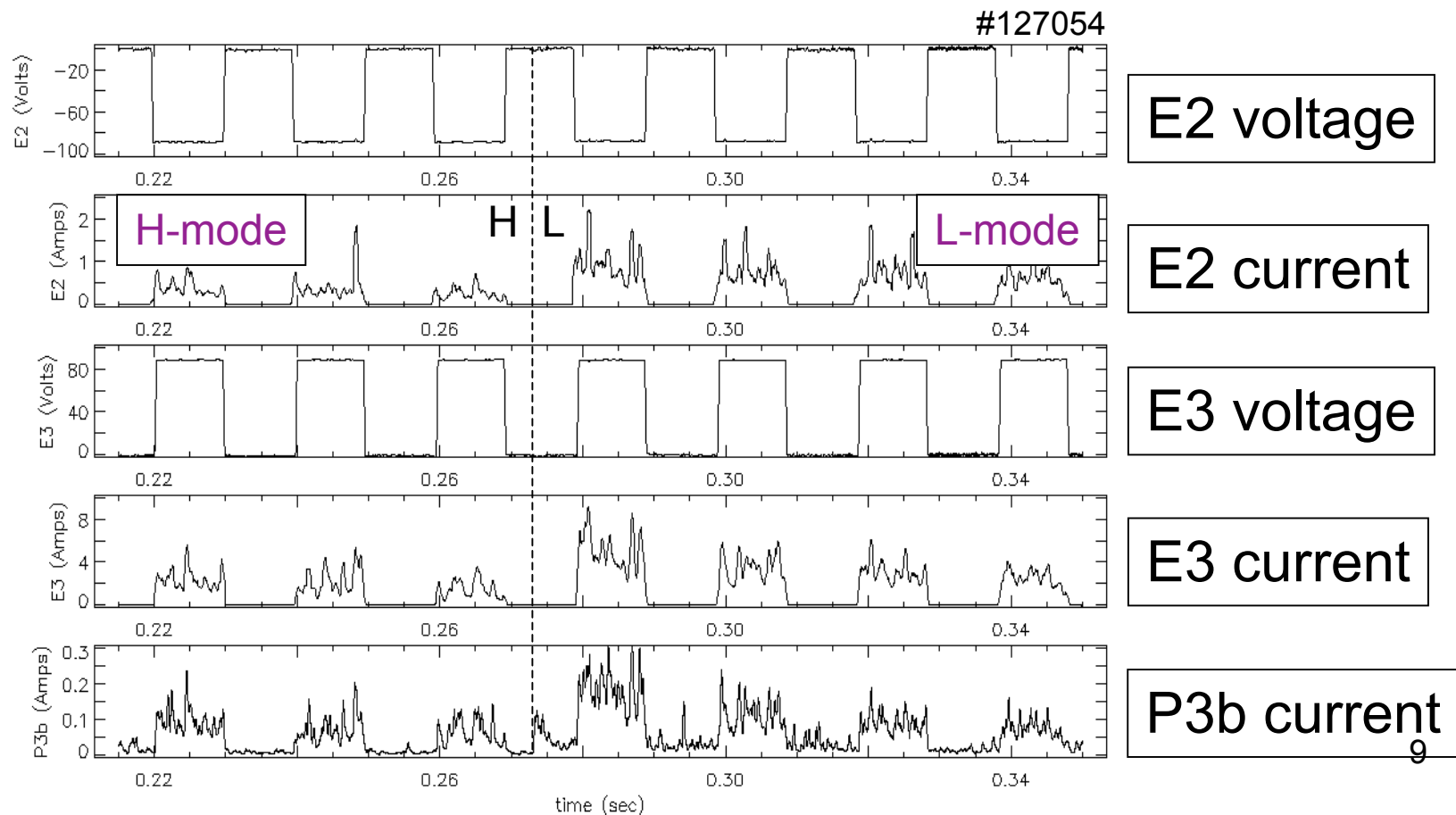
- Typically  $I=0.8$  MA,  $B=4.5$  kG,  $P_{\text{NBI}} = 2-4$  MW
- Edge density in SOL increases with smaller outer gap



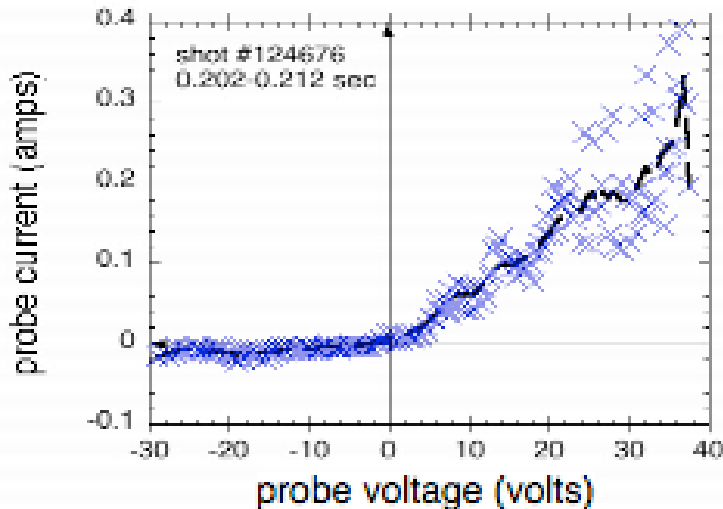
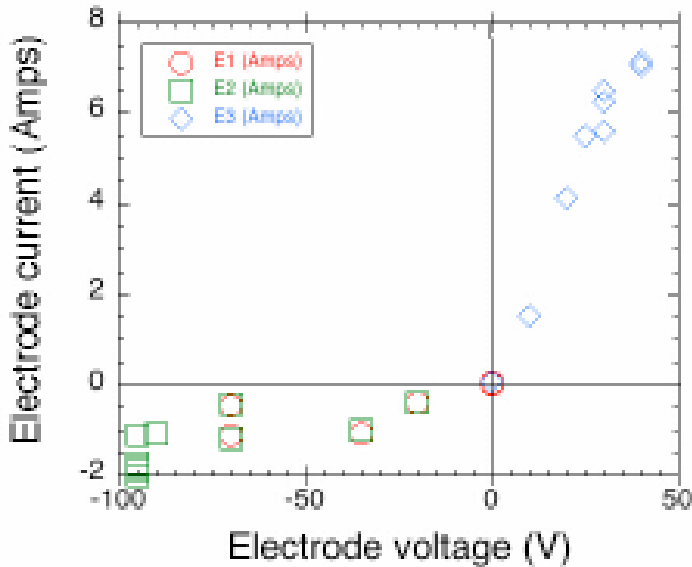


# Electrode and Probe Signals vs. Time

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

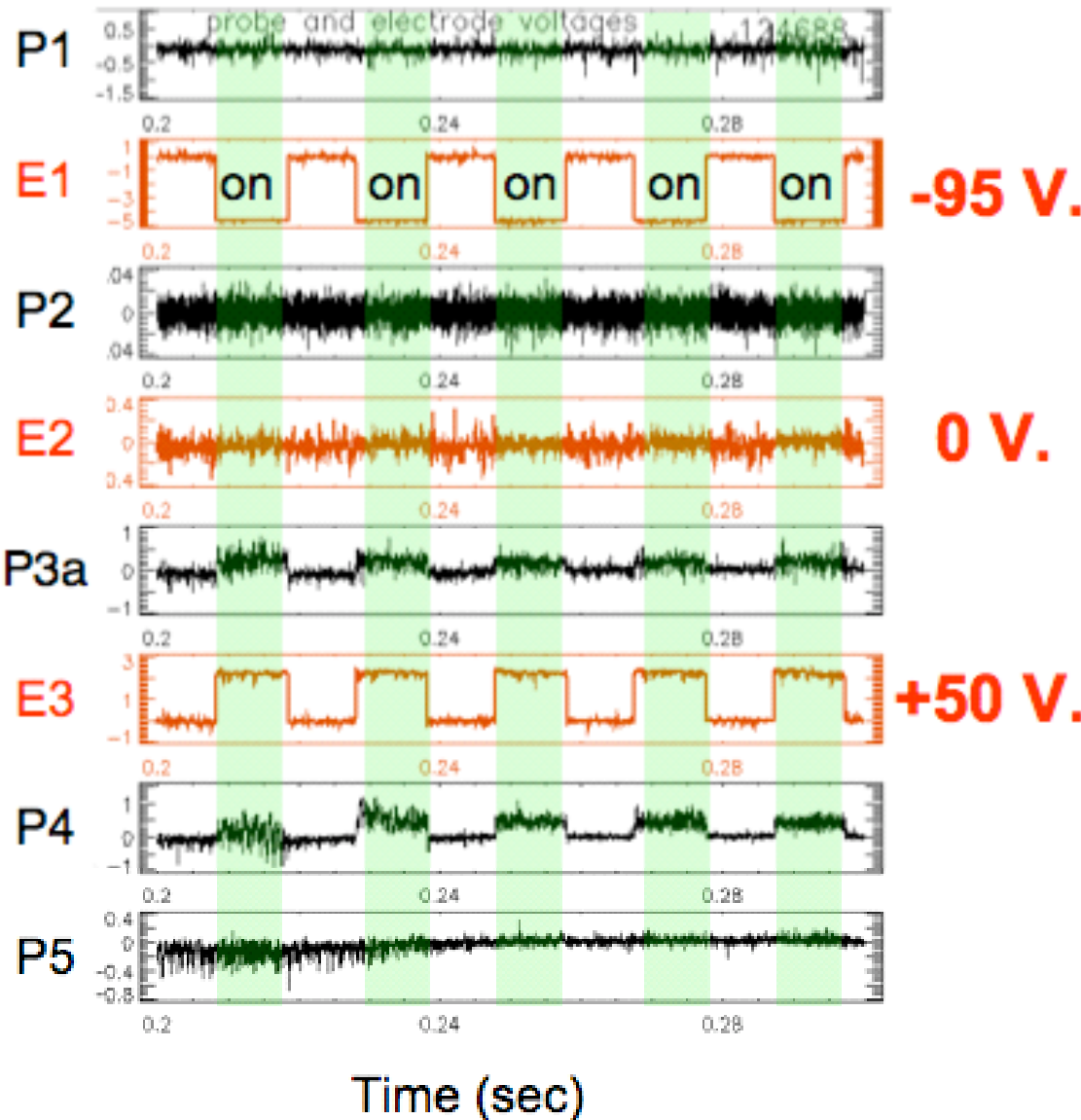


# Typical (I,V) Characteristics



- Electrode current  $I_e/I_i \sim 7$  at  $\pm 40$  V
- Probe current  $I_e/I_i \sim 24$  at  $\pm 40$  V  
 $n_e \sim \text{few} \times 10^{11} \text{ cm}^{-3}$   
 $T_e \sim 8 \pm 5 \text{ eV}$
- $I_i(\text{electrode}) / I_i(\text{probe}) \sim 100$ ,  
about area ratio (as expected)
- Electrode electron current more than 'double-probe' limit, but less than 'single-probe' limit

# Probe Floating Potential Response



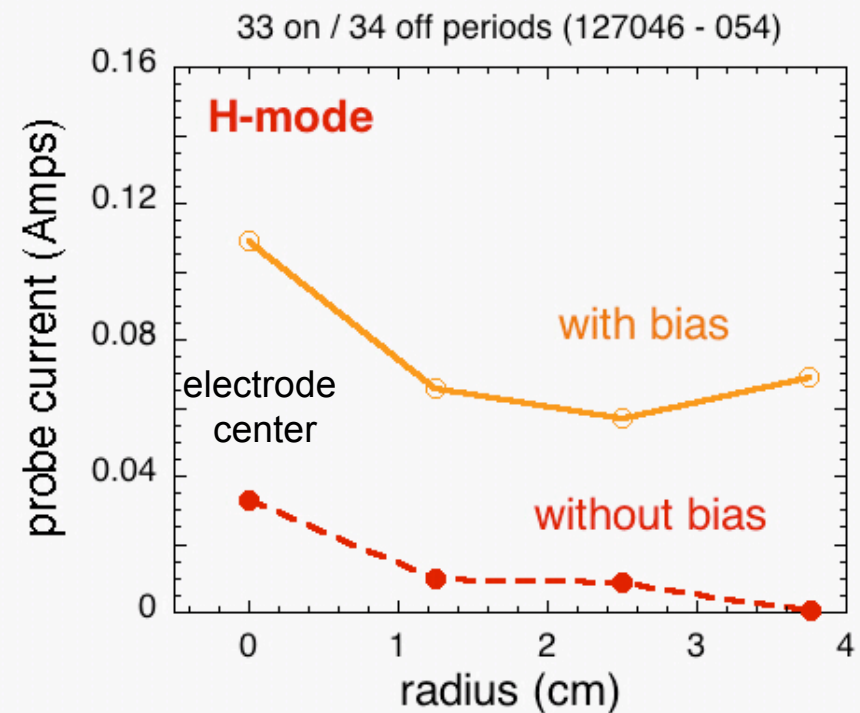
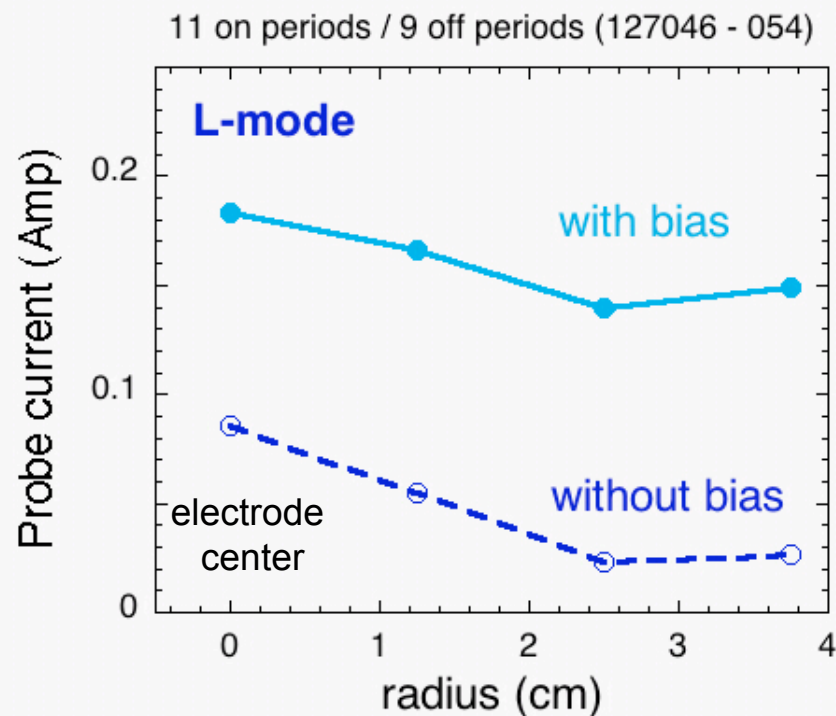
- floating potential of probes near - bias electrode doesn't change significantly
- floating potential of probes near + bias electrode go up ~20% of voltage on electrode

=> positive electrode affects local  $V_f$

negative electrode does not

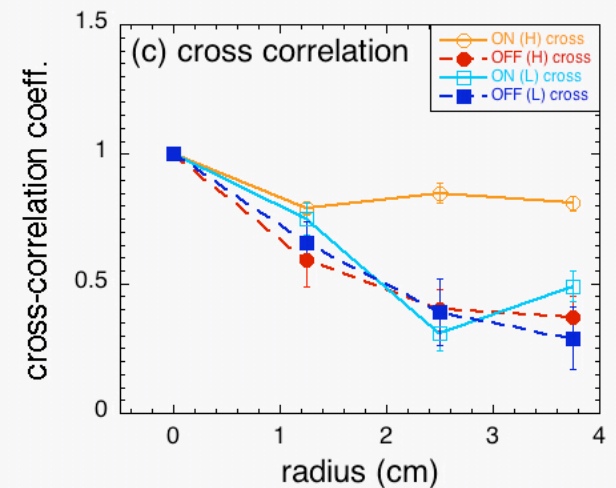
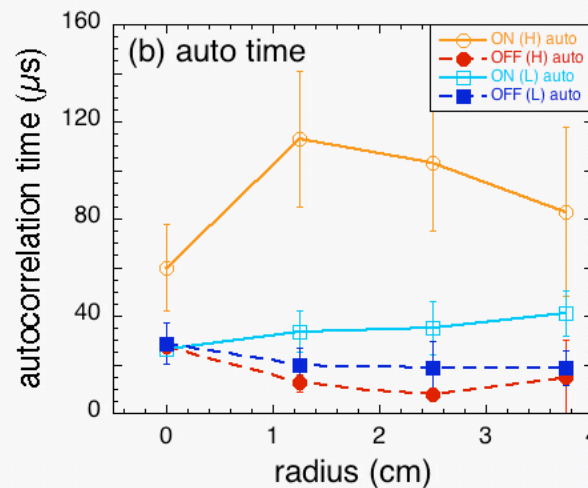
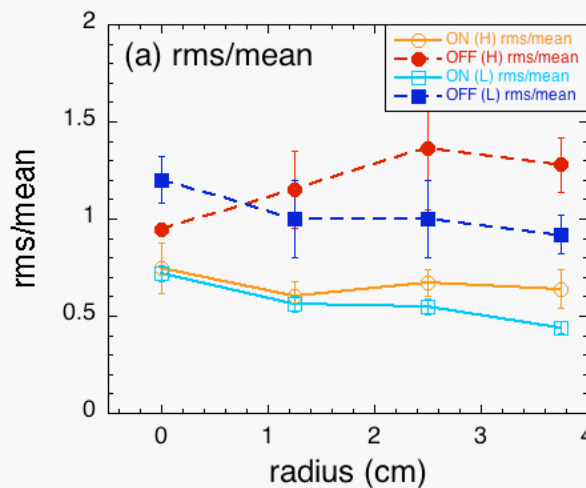
# Local SOL Density Profile Effects

- $E_{pol} \times B$  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  $\pm 90$  volts on E2-E3



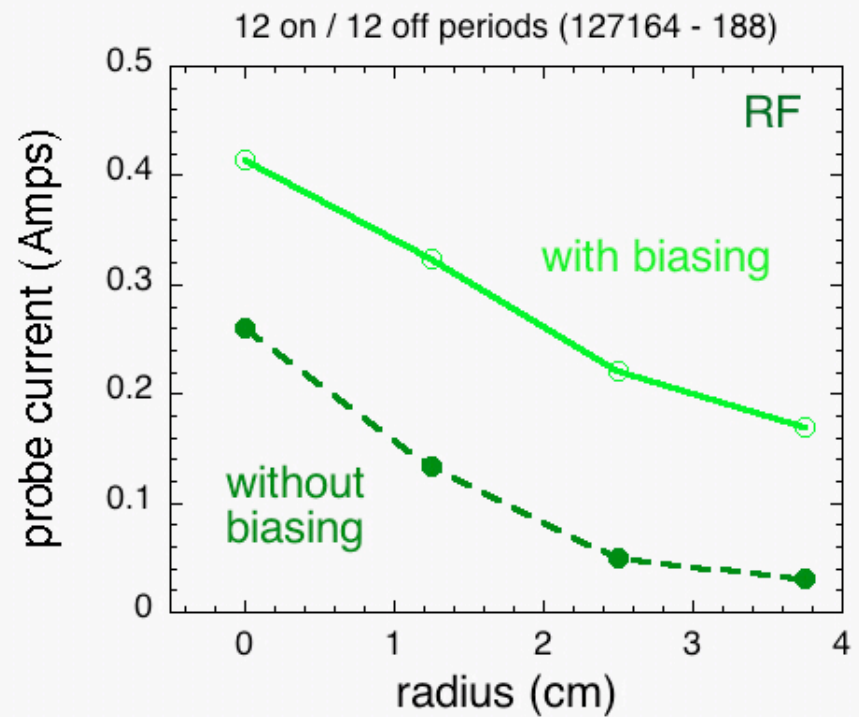
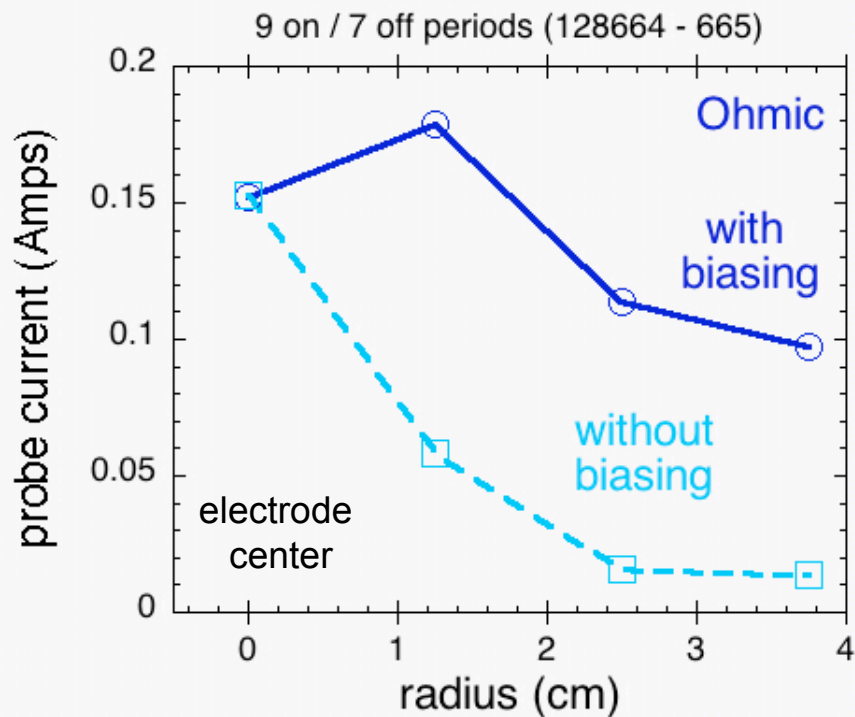
# Effects on Local Turbulence

- 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

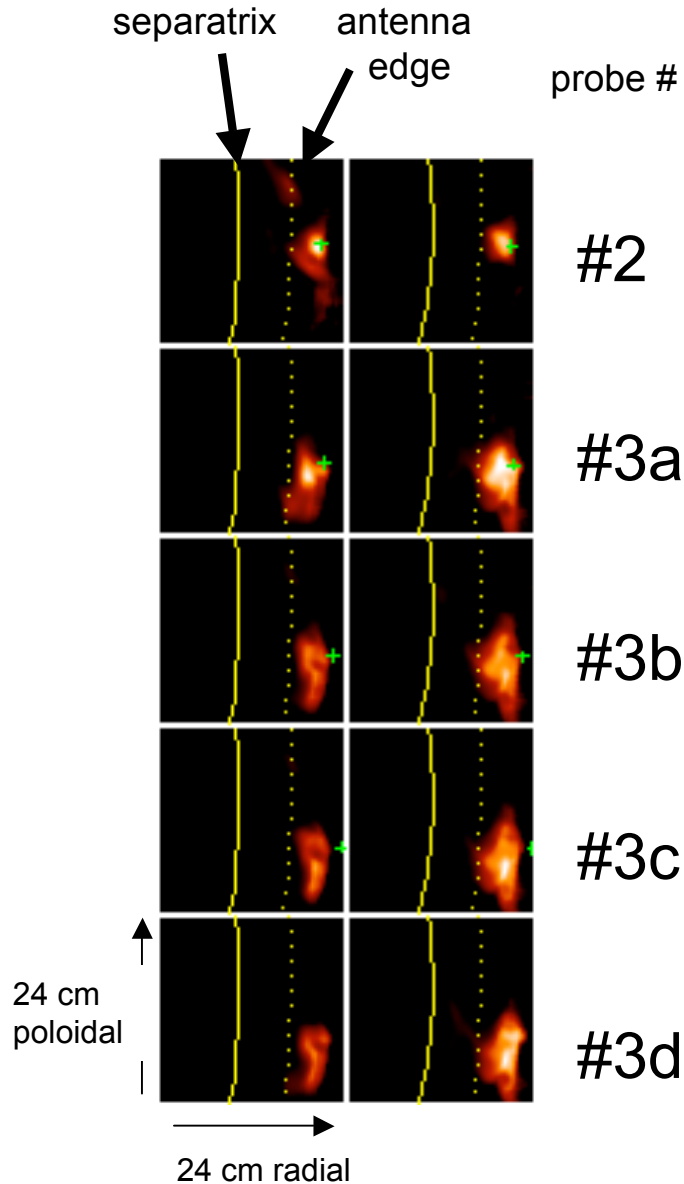


# Ohmic and RF Heated Cases

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



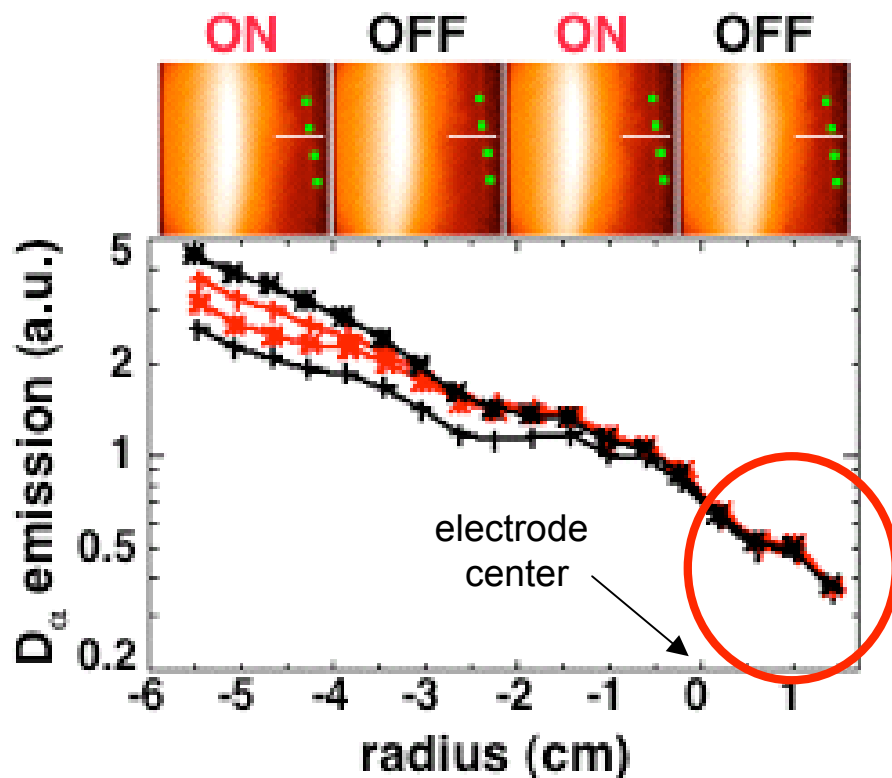
# Correlation of Probe & GPI



- GPI field of view showing regions of high correlation with fluctuations in each probe (white ~ 80% correl.)
  - Regions of high correlation are near to projection of probes along B field line (green dots)
  - Size of correlation region ~ 4 cm, about size of turbulence 'blob'
- => probes and GPI are seeing same turbulent 'filaments' or 'blobs'

# Radial Profile of $D_\alpha$ Emission

- $D_\alpha$  emission from a GPI gas puff measured  $\sim 1$  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  $D_\alpha$  profile and turbulence in the GPI diagnostic ~1 m away along B

# Tentative Theoretical Interpretations

- Outward  $E_{\text{pol}} \times B$  caused the increase in SOL density, but a quantitative comparison with theory can not be done without more information on penetration  $\parallel$  and  $\perp$  to  $B$
- Changes in local potential seen with (+) bias, and not (-) bias, is  $\sim$  consistent with sheath model of Ryutov et al
- Ratio of electron/ion current to electrodes  $I(+)$   $\sim 7 \times I(-)$  suggests a significant cross-field current, which may explain the absence of effect on  $D_{\alpha} \sim 1$  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