Biased Electrodes for SOL Control in NSTX

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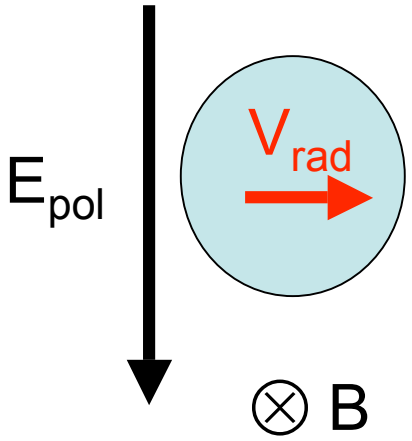
Idea

- Increase SOL width using localized poloidal electric fields from biasing (based on ideas of Cohen, Ryutov, et al)
- Understand physics of electric field penetration in plasma (surprisingly little is known from measurements)
- Develop physics basis for a SOL control technique for ITER (perhaps using RF as suggested by Myra, D'Ippolito)

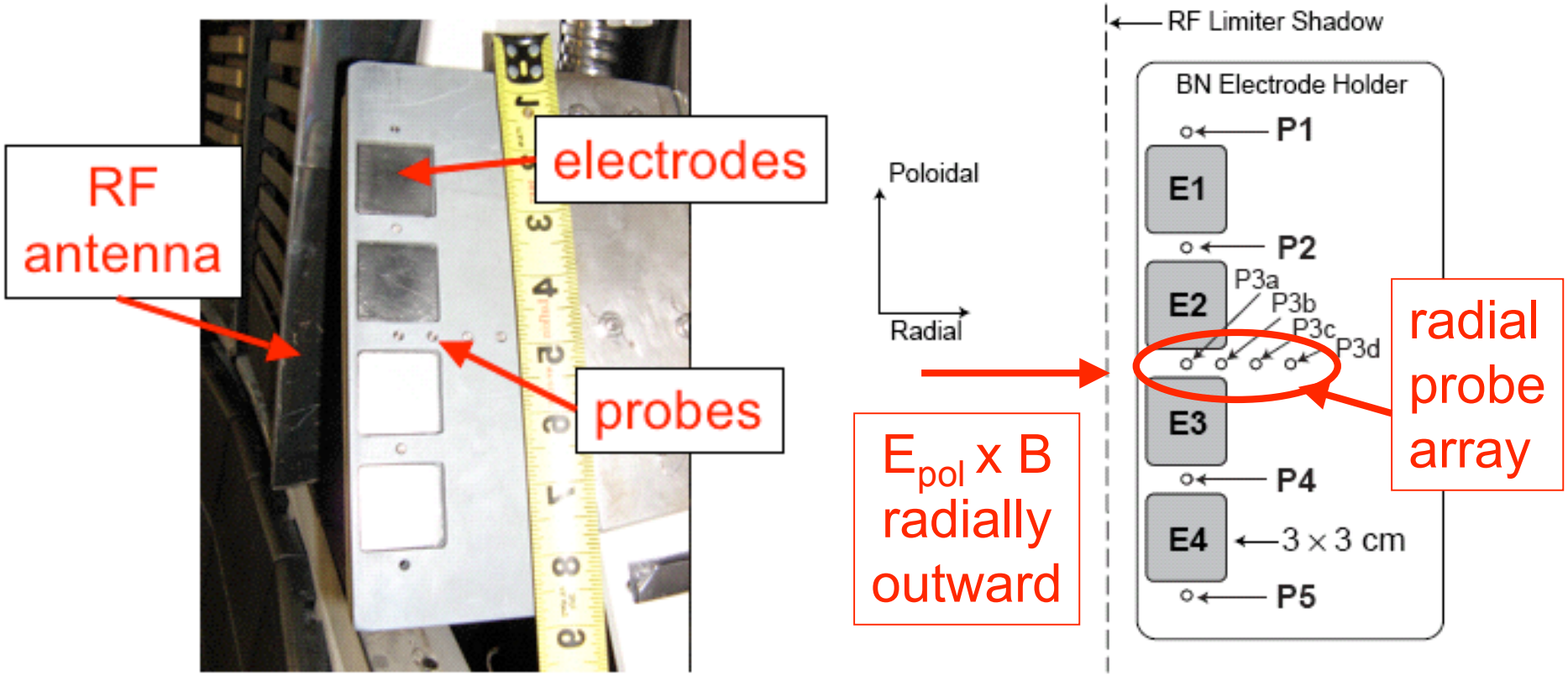


NSTX: $V_r(ExB)/V_r(blob) \sim 1$ @ 3 V/cm

C-Mod: $V_r(ExB)/V_r(blob) \sim 1$ @ 50 V/cm

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



Previous Experiments

- C-Mod has seen biased divertor probes change local plasma potential Winslow and LaBombard, JNM '99, CPP '01

- A few experiments have created a 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)]

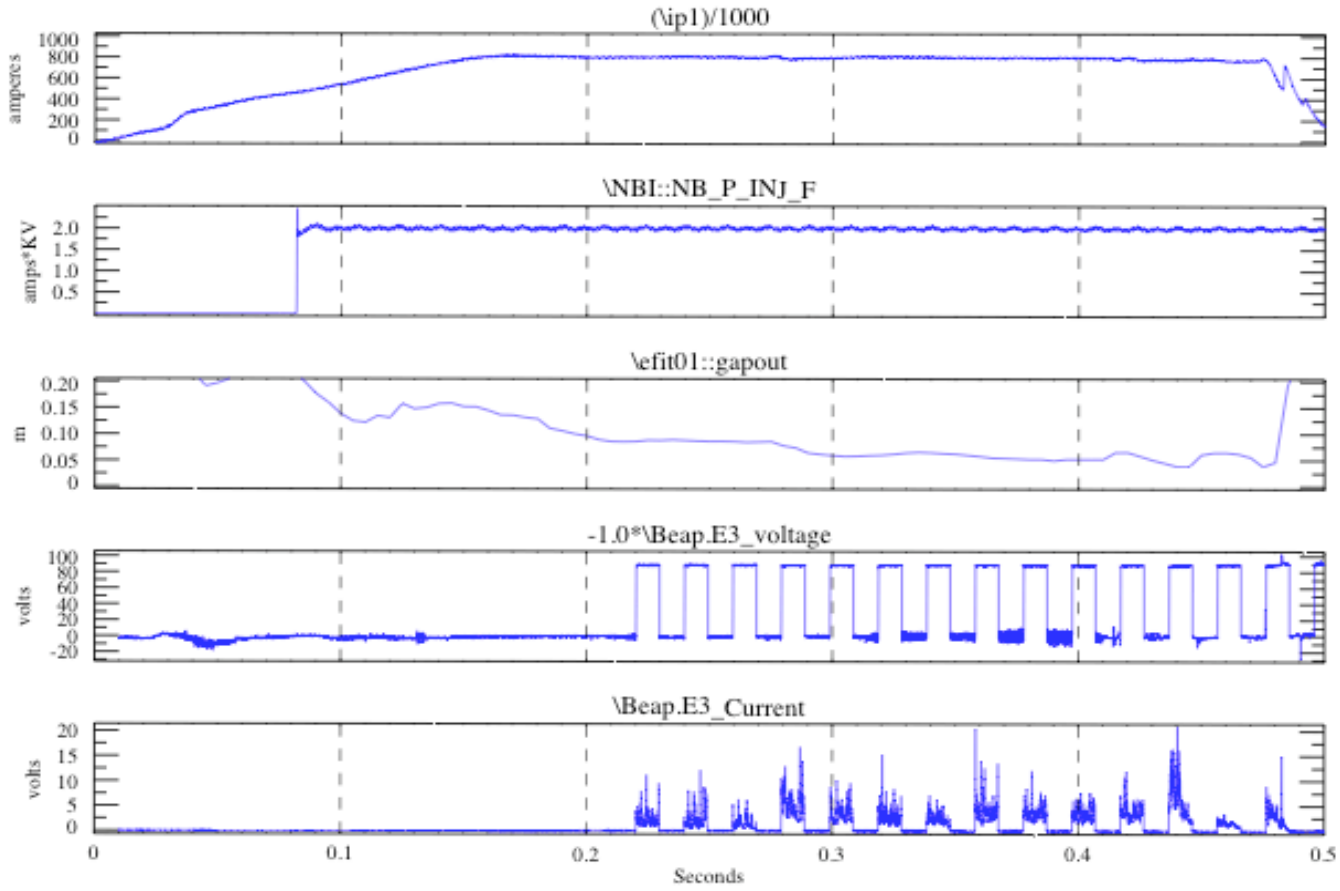
- MAST experiment was done to test idea of Cohen/Ryutov, resulting in partial confirmation of theory, e.g. movement of D_α strike point at biased divertor "ribs"

- 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 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)

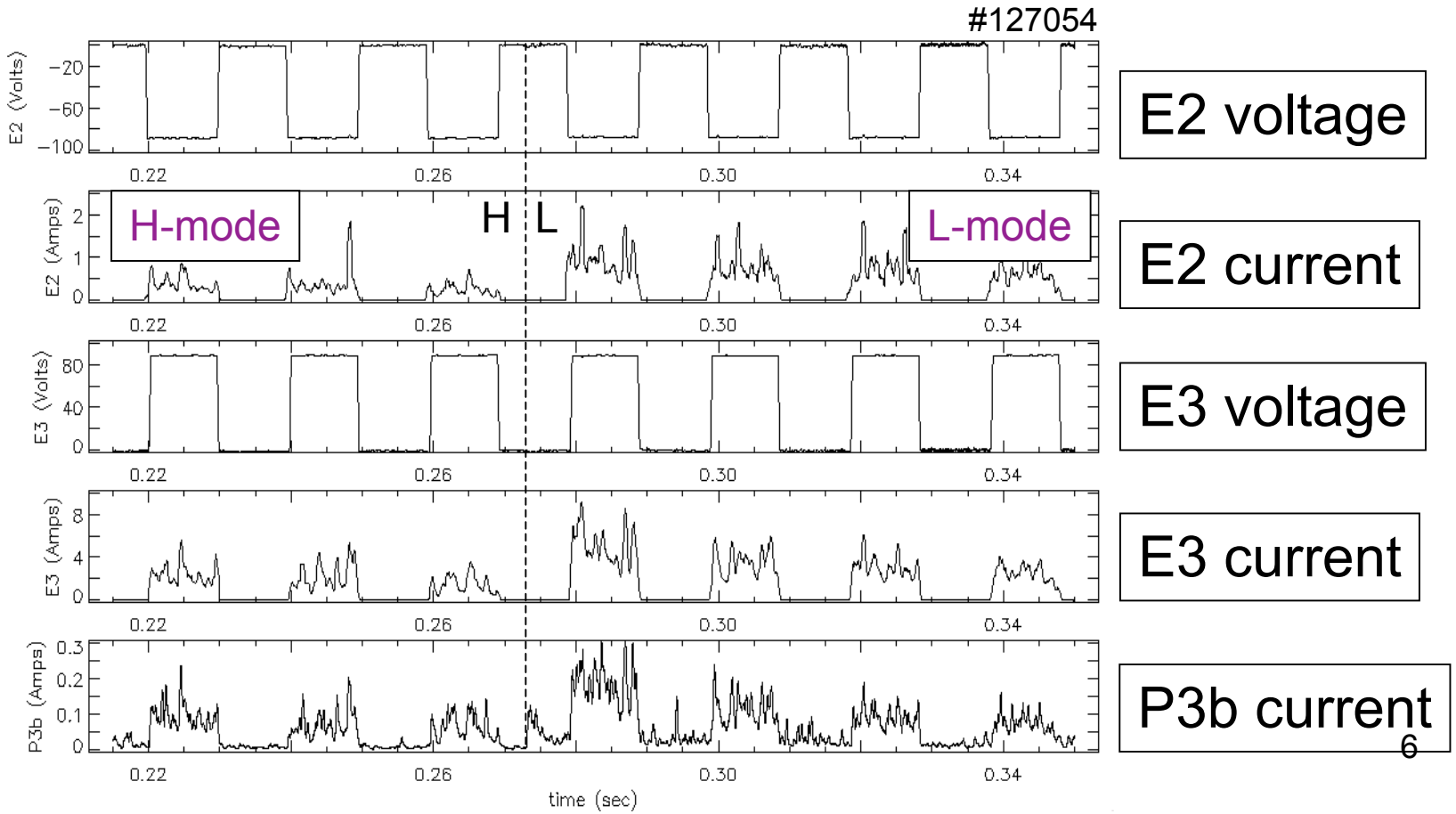
outer gap (m)

E3 voltage

E3 current

Electrode and Probe Signals vs. Time

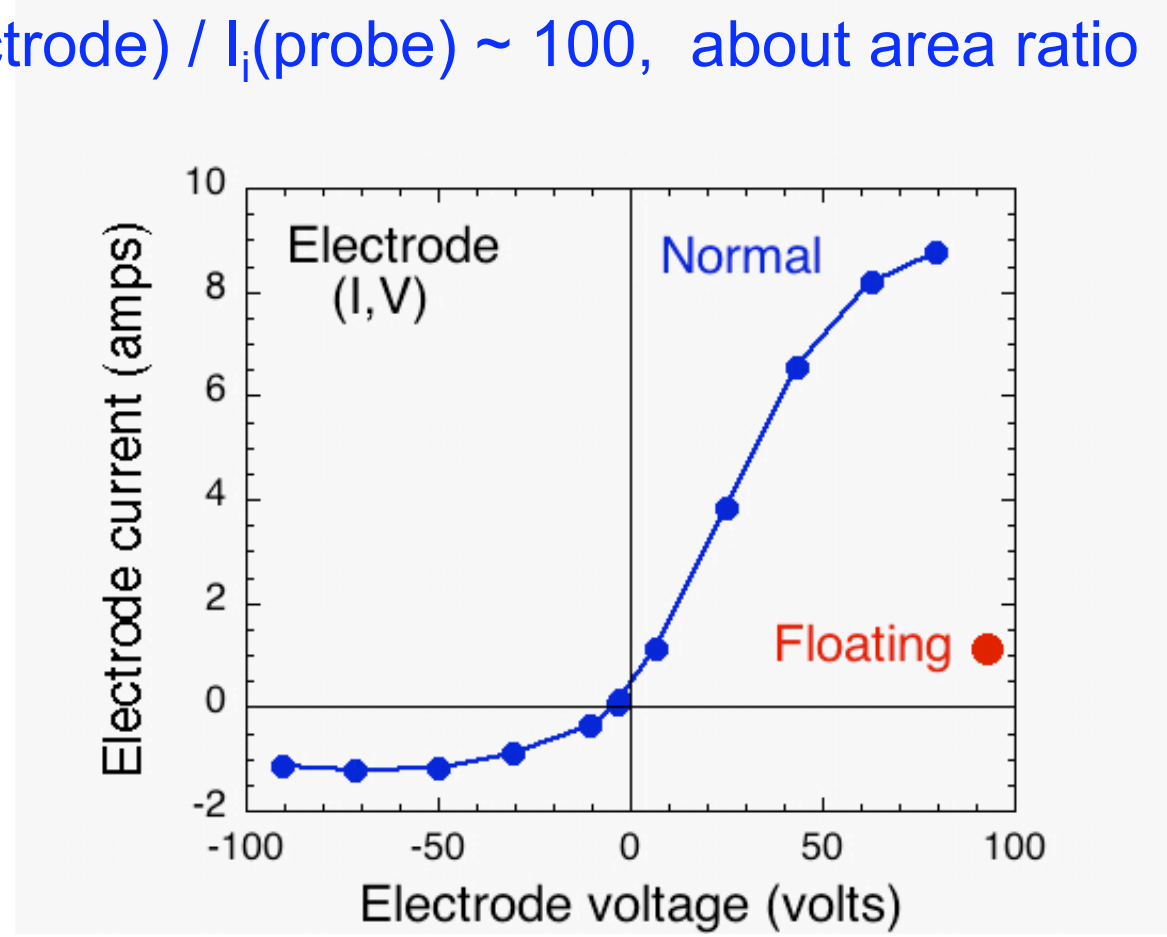
- Here E2 @ - 90 volts, E3 at + 90 volts, P3b @ +45 volts
- See clear increase in probe current with each biasing



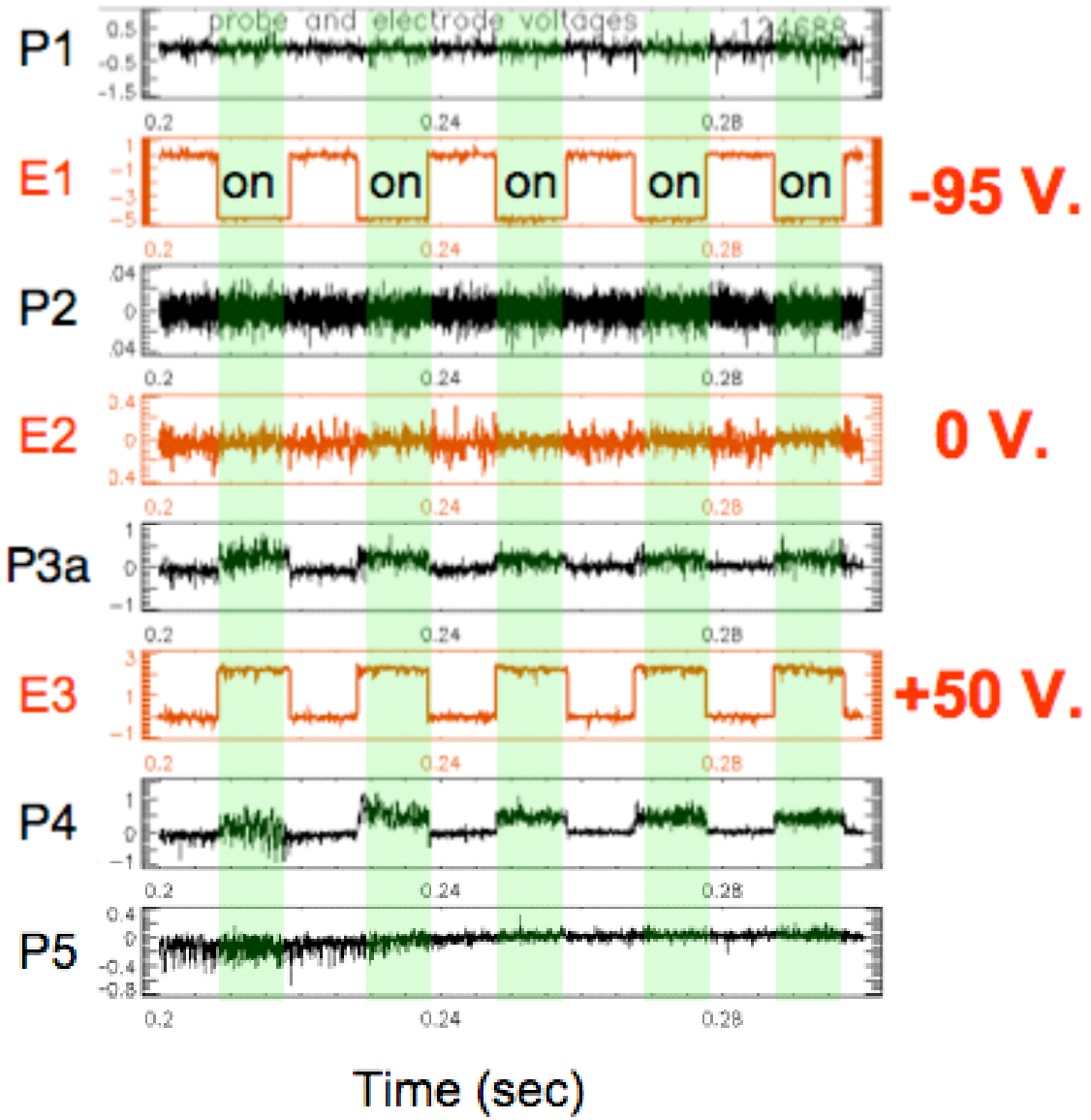
Electrode (I,V) Characteristic

- Electrode electron current more than ‘double-probe’ limit, but less than ‘single-probe’ limit

- I_i(electrode) / I_i(probe) ~ 100, about area ratio



Probe Floating Potential Response



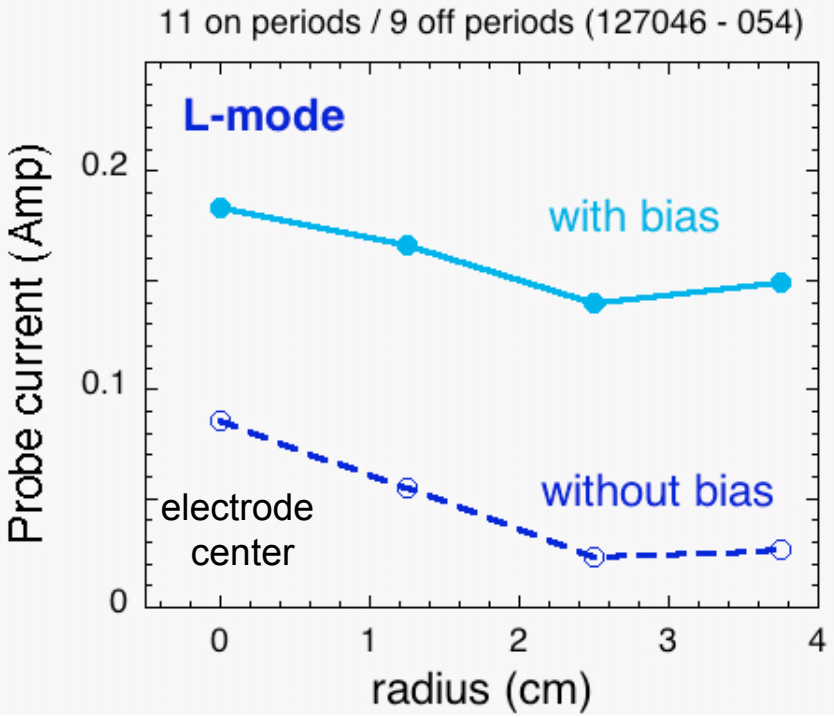
- floating potential of probes near - bias electrode doesn't change significantly
- floating potential of probes near + bias electrode go up ~20% of voltage on electrode

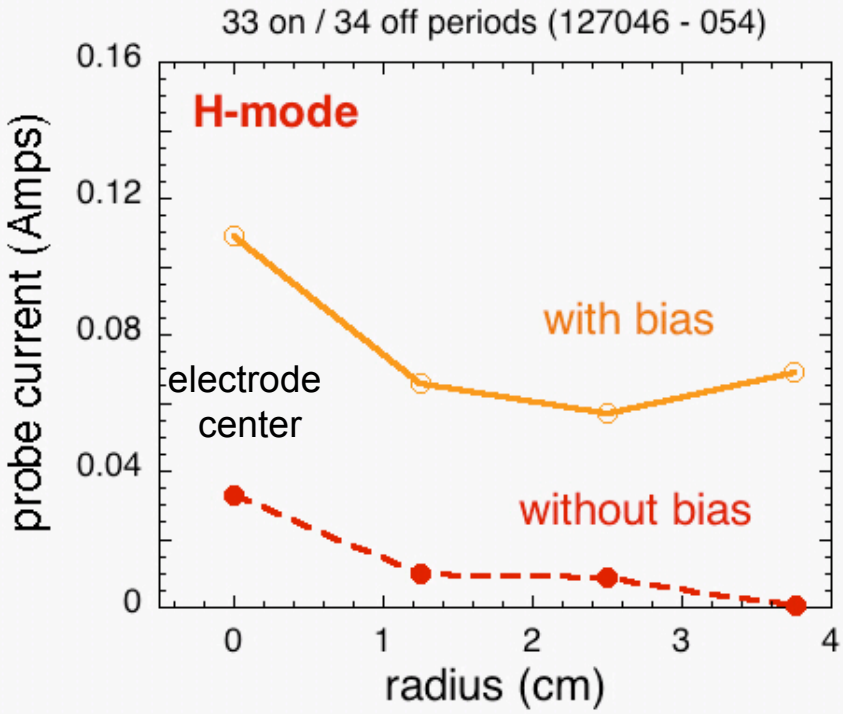
=> positive electrode affects local V_f

negative electrode does not

Local SOL Density Profile Effects

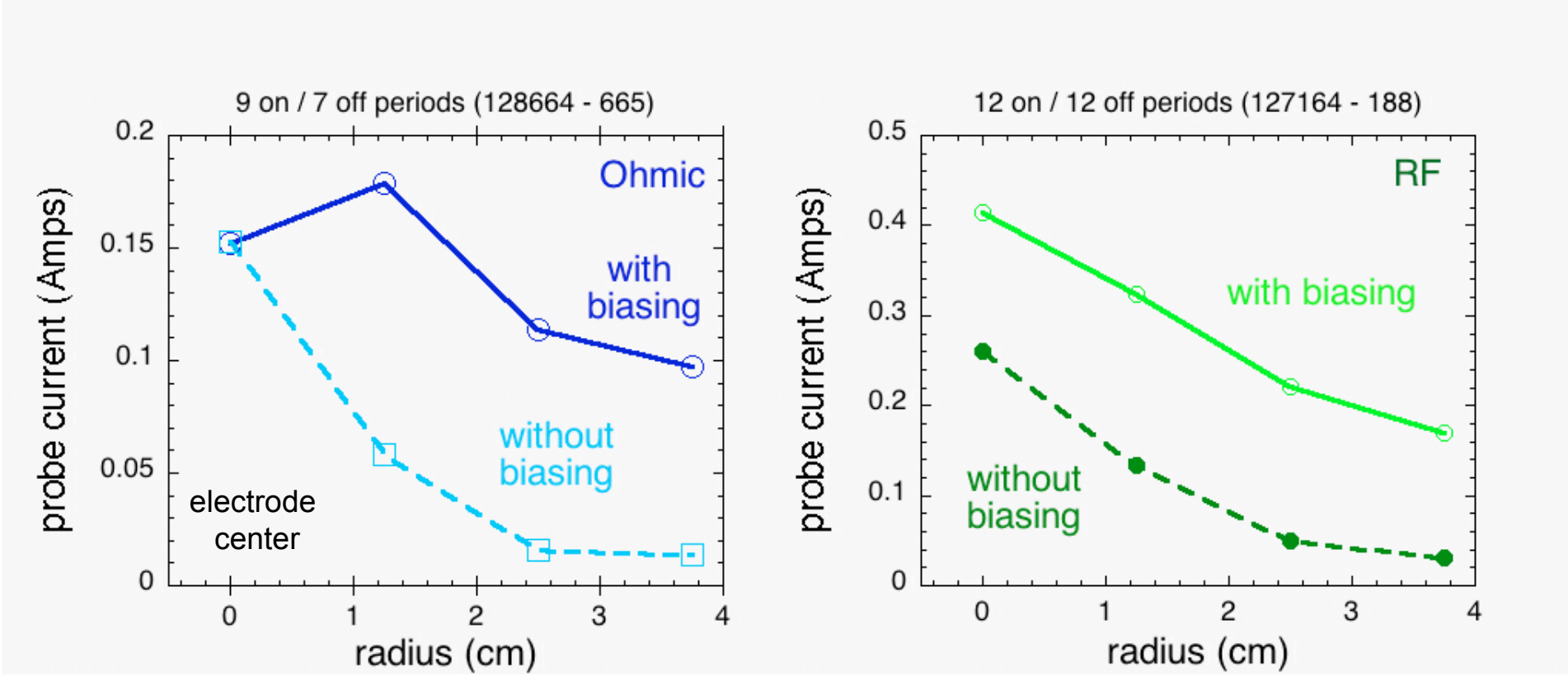
- E_{pol} x B directed outward between electrodes E2 and E3
- Radial profiles of I_e ($\propto n_e$) measured with probes P3a-P3d
- Local density increases x3 to x10 with ±90 volts on E2-E3





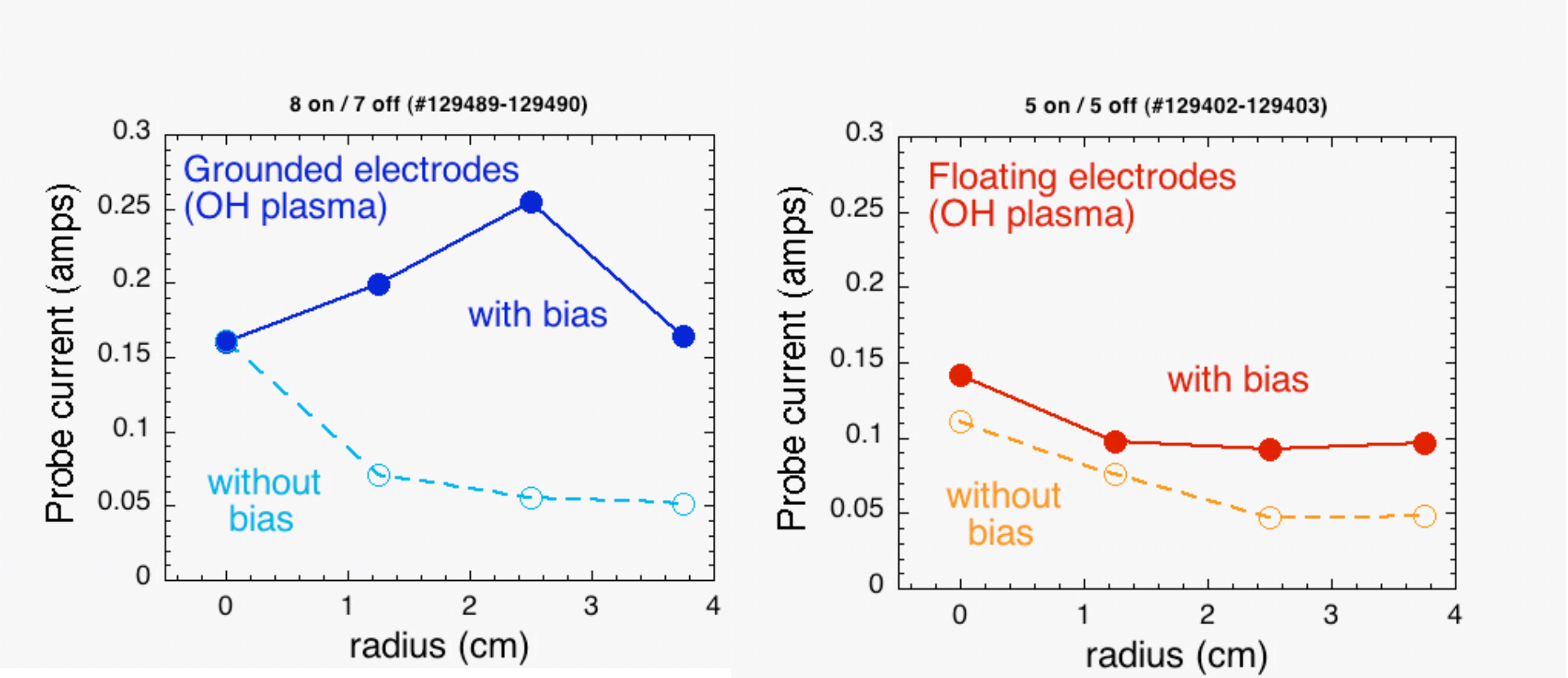
Ohmic and RF Heated Cases

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



Floating vs. Normal Electrodes

- Normal case density increases up to x5 @ ± 90 volts
- Floating case density increases up to x2 @ ± 45 volts

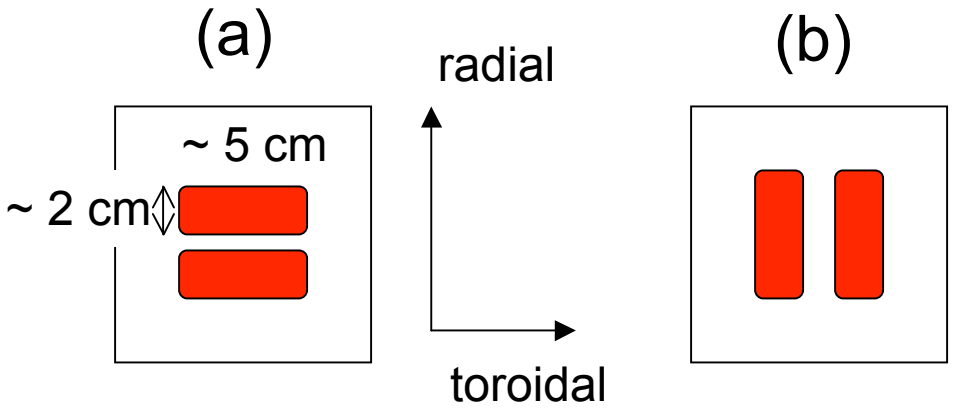


Tentative Theoretical Interpretations

- 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

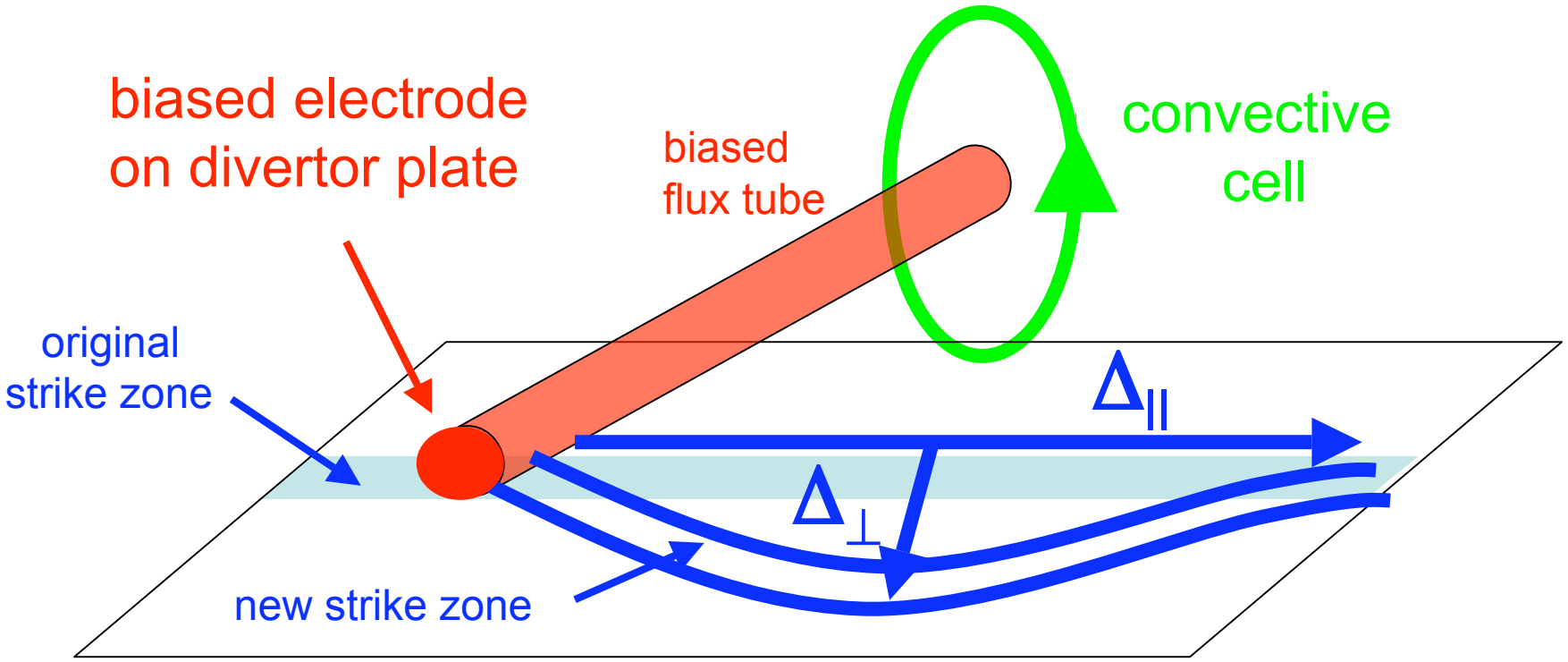
Divertor Plate Bias in NSTX

- Planned for new tiles between lithium divertor segments
- Effects to be measured with camera and local probes



- should have radial width ≥ SOL width
- should have poloidal height ~ 2-3 ρ_i

Expected Effect



- Displacements of strike zone depend on electric field penetration along and across B

Possible C-Mod Experiment ?

in collaboration with Jim, Brian, et al

- Bias tile(s) on upper divertor plate near outer strike point
- Modulate at 60 Hz with simple transformer supply
- Install nearby Langmuir probes to measure effect
- View from below using fiber bundle + camera
- Include local capillary nearby to do GPI also