

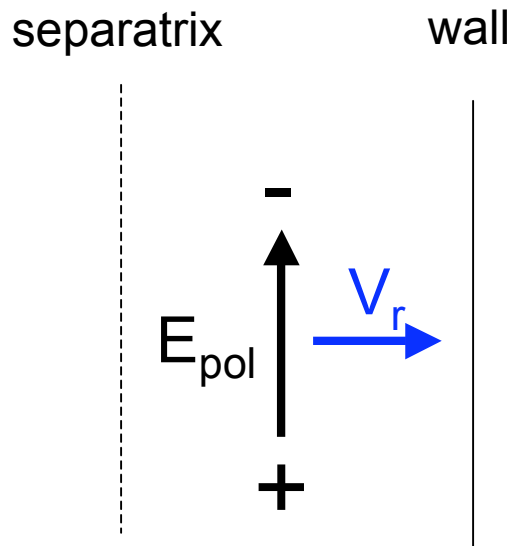
Edge Electrode Biasing Experiments on NSTX

S. Zweben, C. Bush, R. Maqueda, L. Roquemore, R. Marasla
M. Bell, J. Boedo, R. Kaita, Y. Ratises, B. Stratton
R. Cohen, D. Ryutov, M. Umansky (LLNL)
NSTX Meeting 5/21/07

- Basic idea for SOL control
- Theory and previous experiments
- Biased Electrodes and Probes (BEaP) in NSTX
- Initial results from checkout of hardware (XMP-051)
- Additional tests which can be done in this run

SOL Control by Edge Biasing

- Create localized poloidal electric fields in SOL to make local radial $V_r = E_{pol} \times B$ drift to drive plasma outward
- If V_r is larger than the outward turbulent transport speed, local SOL width will be increased (particles and heat)



- $V_r(\text{cm/sec}) = 10^8 E_{pol}(\text{V/cm})/B(\text{G})$
 - turbulent 'blob' speed $\leq 1 \text{ km/sec}$
- \Rightarrow need only $V_r \sim 5 \text{ V/cm}$ to broaden SOL in NSTX (because of low B)

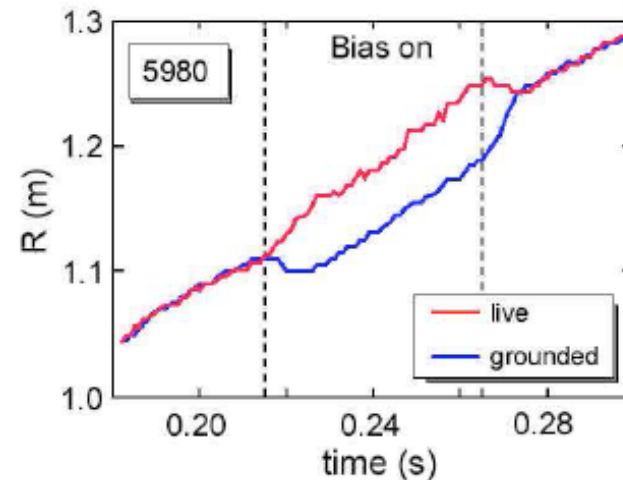
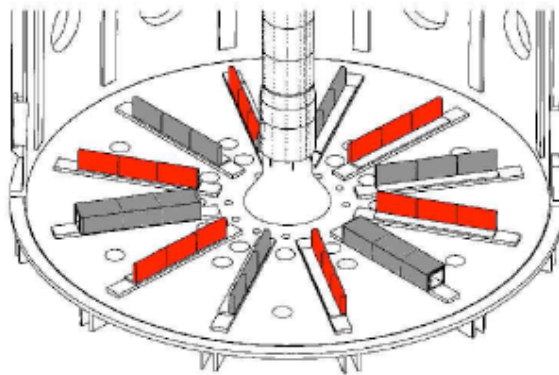
Theory of Active SOL Broadening

- Apply toroidally asymmetric perturbations in SOL near divertor plate to create ExB flows to induce turbulent broadening [R.H. Cohen et al, Nucl. Fusion (1997); D.D. Ryutov et al, PPCF (2001), R.H. Cohen et al, PPCF (2007)]
 - perturbations can be biasing, 'wavy' plates, gas puffing
 - effects confined to divertor region by X-point shear
 - potential distribution along B-field line was calculated
- Open questions:
 - how far do perturbations extend along and across B ?
 - do these perturbations locally induce turbulence ?
 - can the effects be simulated with BOUT (or XGC) ?

Previous Experiments

- Most tokamak biasing experiments aimed to modify E_r and poloidal flow [e.g. PBX-M, DIII-D, TdeV, TEXTOR...]
- MAST experiment done to test idea of Cohen and Ryutov, resulting in partial confirmation of theory

biased (and grounded) “ribs” in divertor (~ 80 V, 3 kA total)



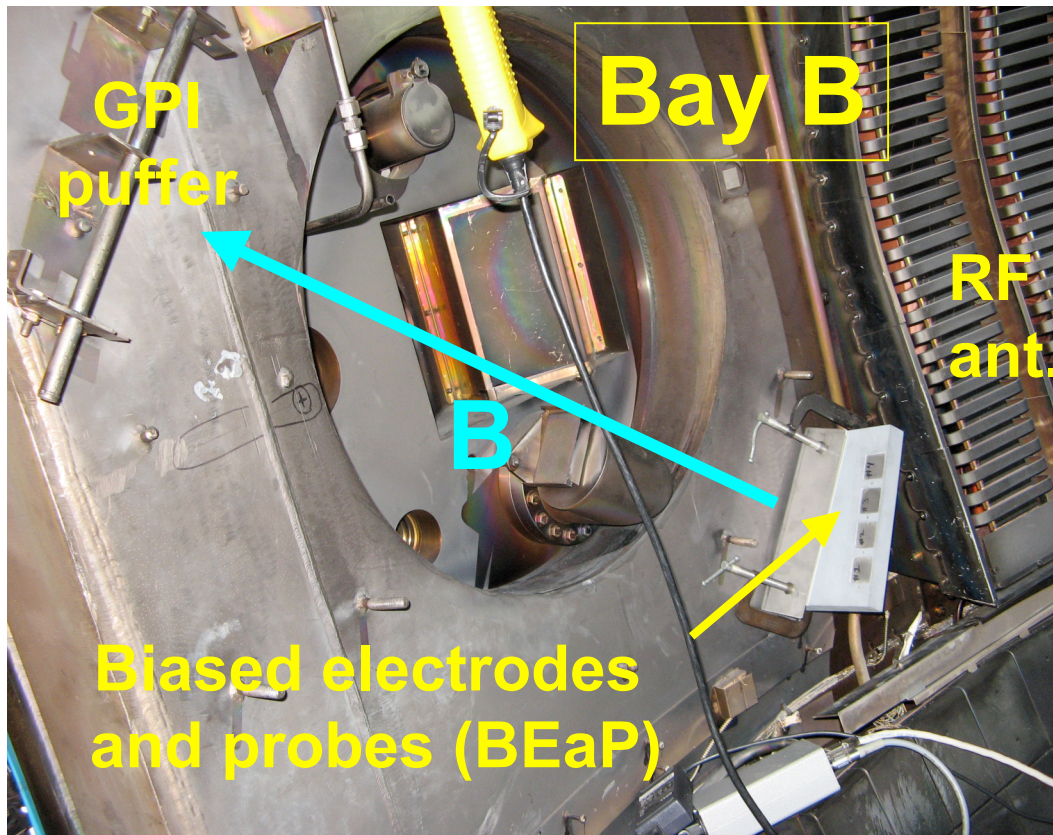
G.F. Counsell, EPS Conference (2003)

NSTX Electrode Biasing Experiment

- Locate electrodes on B field line of GPI to see effect of bias on local turbulence and D_α profile (e.g. see 'blobs' move faster outward, or inward)
- Include Langmuir probes between the electrodes to measure potential, n_e and T_e , and turbulence
- Correlate fluctuations in probe and GPI to determine location of electrodes in GPI field of view

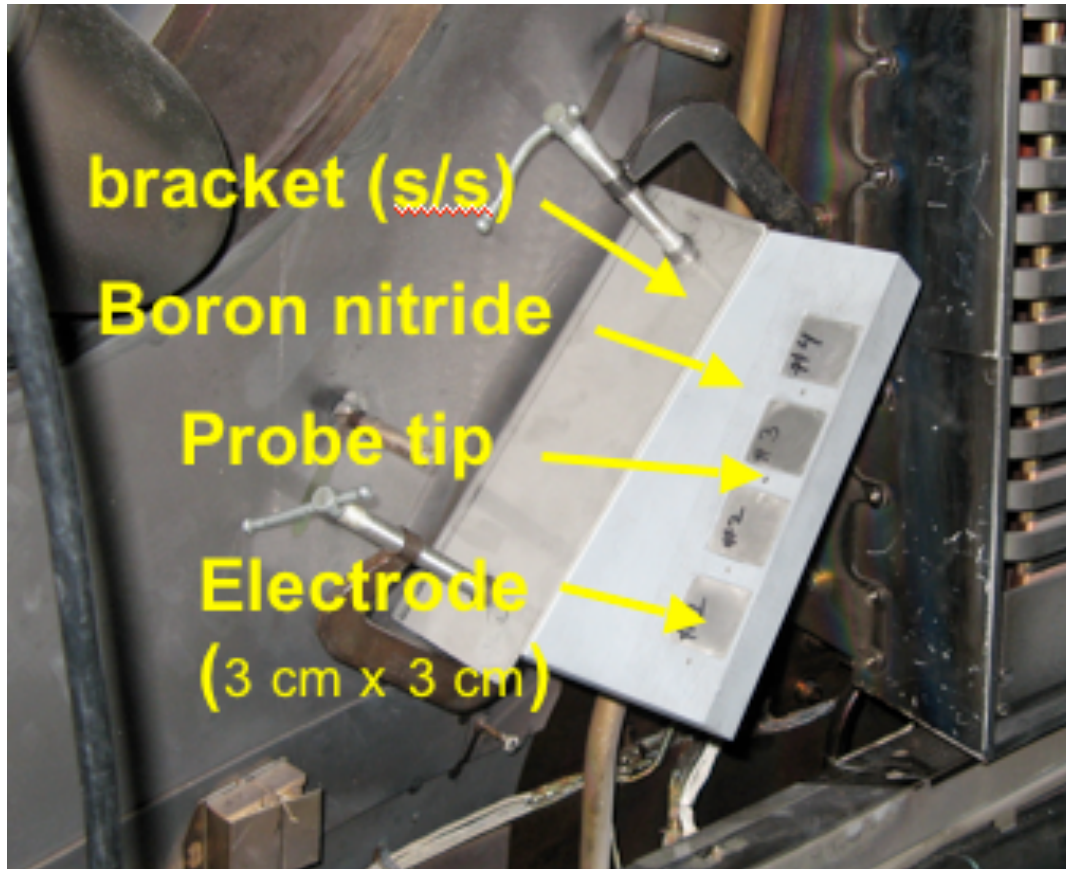
Did not expect to make “global” modification of SOL or plasma with this initial set-up !

Biased Electrodes and Probes in NSTX



- installed ~ Dec. '06
- leading edge ~ 1 cm behind RF limiter
- 4 electrodes and 5 Langmuir probes
- look for effect of bias in GPI and probes

Closer View of BEaP



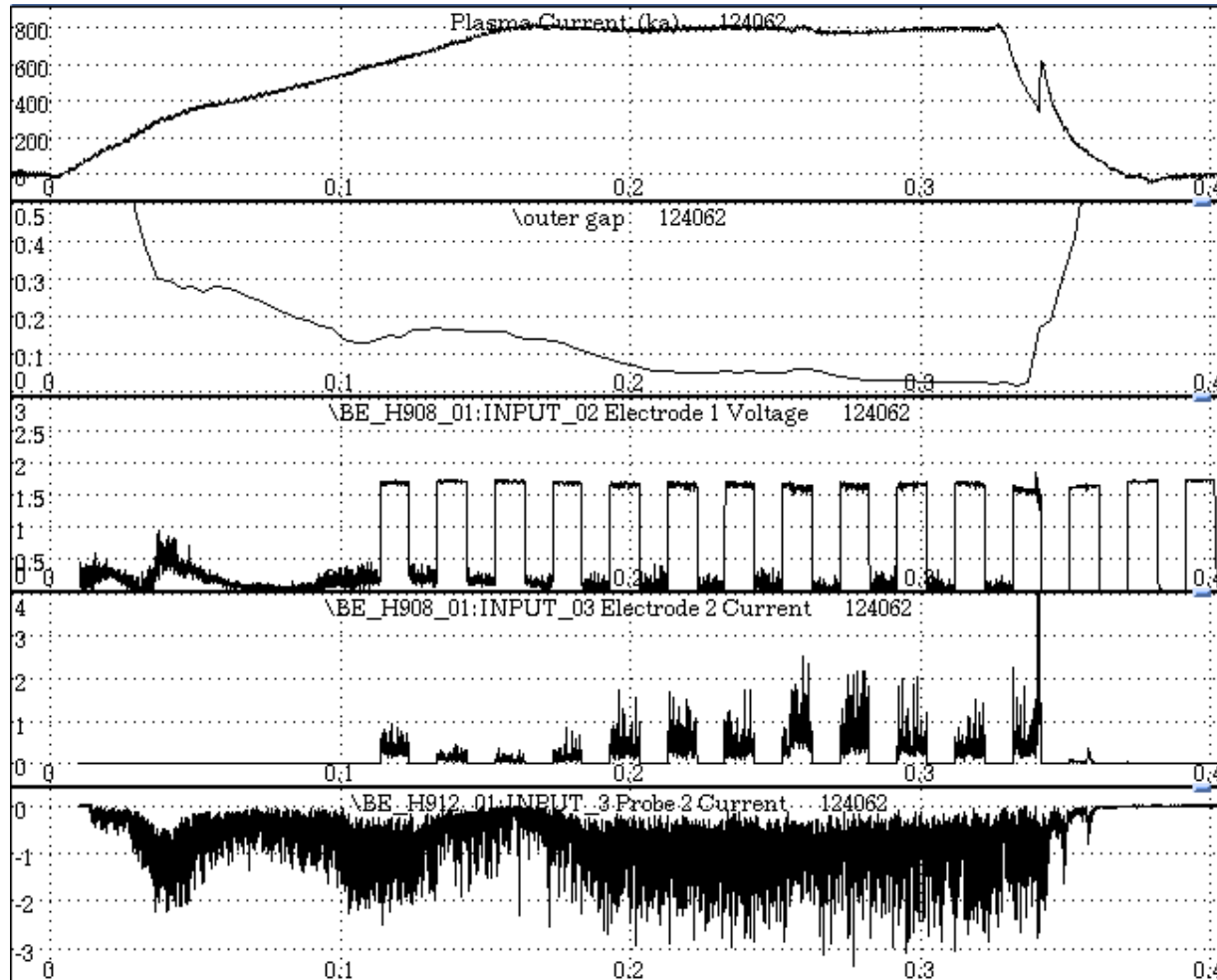
Present capabilities:

- ± 100 V, 10 A on any two electrodes
- 5 swept probes
- change outer gap to control density at electrodes

Initial Results (from 3 shots)

- Electrode and probe currents and voltages
- Effect of biasing on probe signals
- Mapping of fluctuations from probes to GPI
- Effect of biasing on GPI signals

Currents and Voltages vs. Time



$I=0.8$ MA
 $B=4.5$ kG

outer gap
15 cm \Rightarrow 1 cm

electrode V
-70 V @ 50Hz

electrode $I_{sat,i}$
 ≤ 2 amps ave.

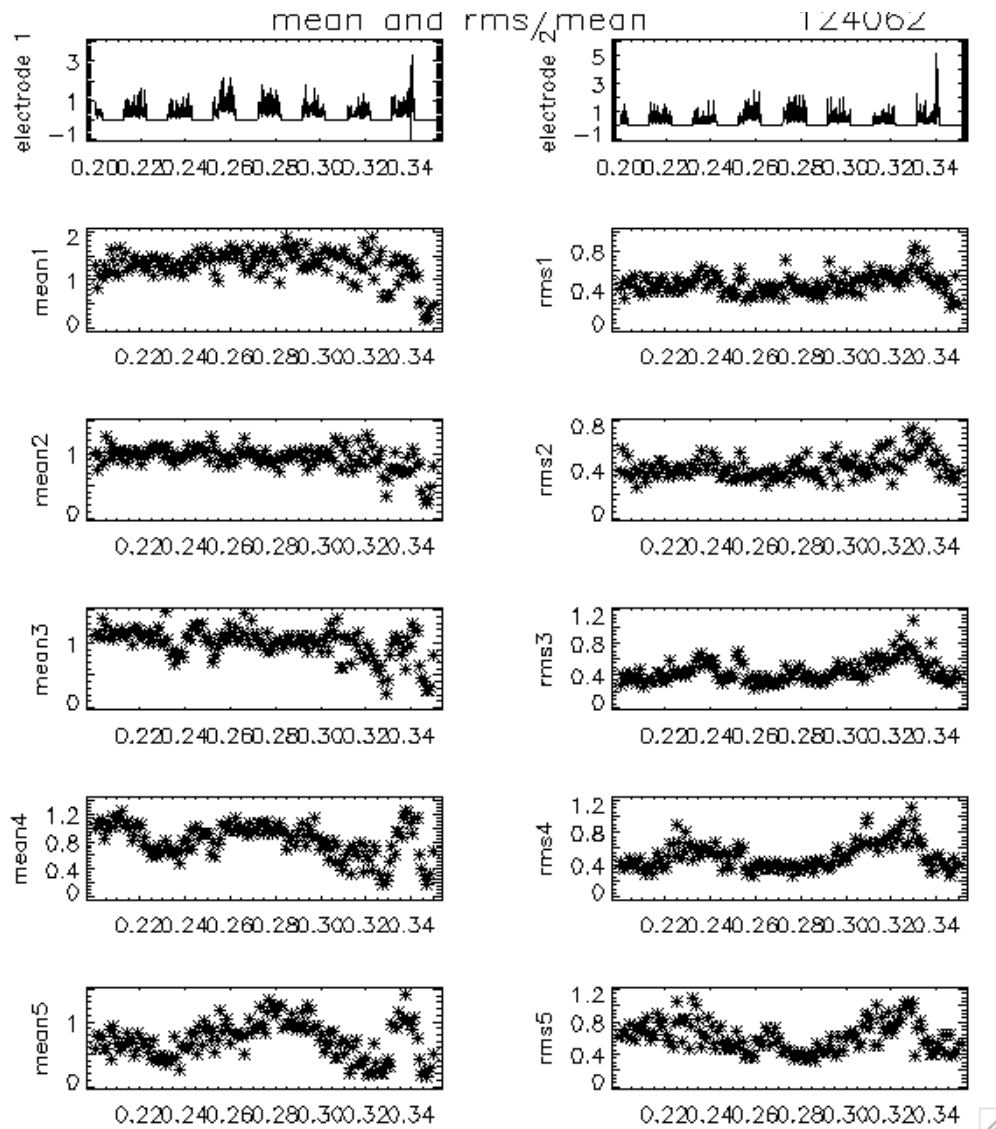
probe $I_{sat,e}$
 ≤ 0.3 amps ave.

Electrode Configurations Tried

Electrode #1	Electrode #2	Electrodes #3,4
-70 Volts	-70 Volts	grounded
-70 Volts	-35 volts	grounded
-35 Volts	-70 Volts	grounded

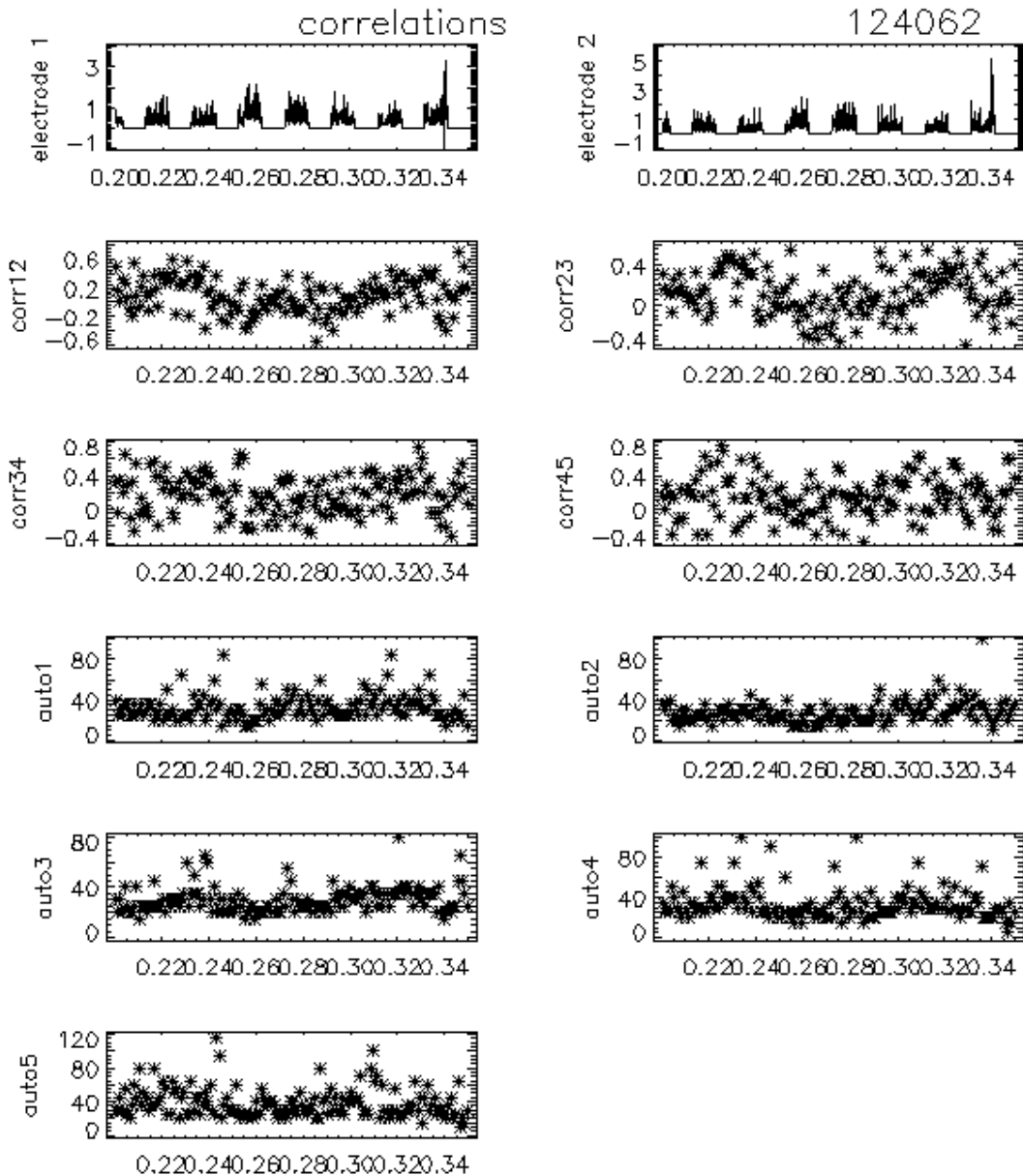
- Should have made $E_{pol} \sim \pm 35 \text{ Volts}/4 \text{ cm} \sim \pm 10 \text{ V/cm}$ between Electrodes #1 and #2
- Should have made $E_{pol} \sim 70 \text{ Volts}/4 \text{ cm} \sim 20 \text{ Volts}$ between Electrodes #2 and #3

Effect of Biasing on Probe Currents



- *No visible effect* of biasing on mean or rms/mean of any probes signals
- Might have expected density to change if large V_r were made
- Would have expected rms/mean to change if turbulence was affected by V_r

Effect of Bias on Probe Correlations



- No visible effect of biasing on probe cross-correlation or autocorrelation time
- Might have expected these to change if large V_r was created



Mapping from Probes to GPI

probe

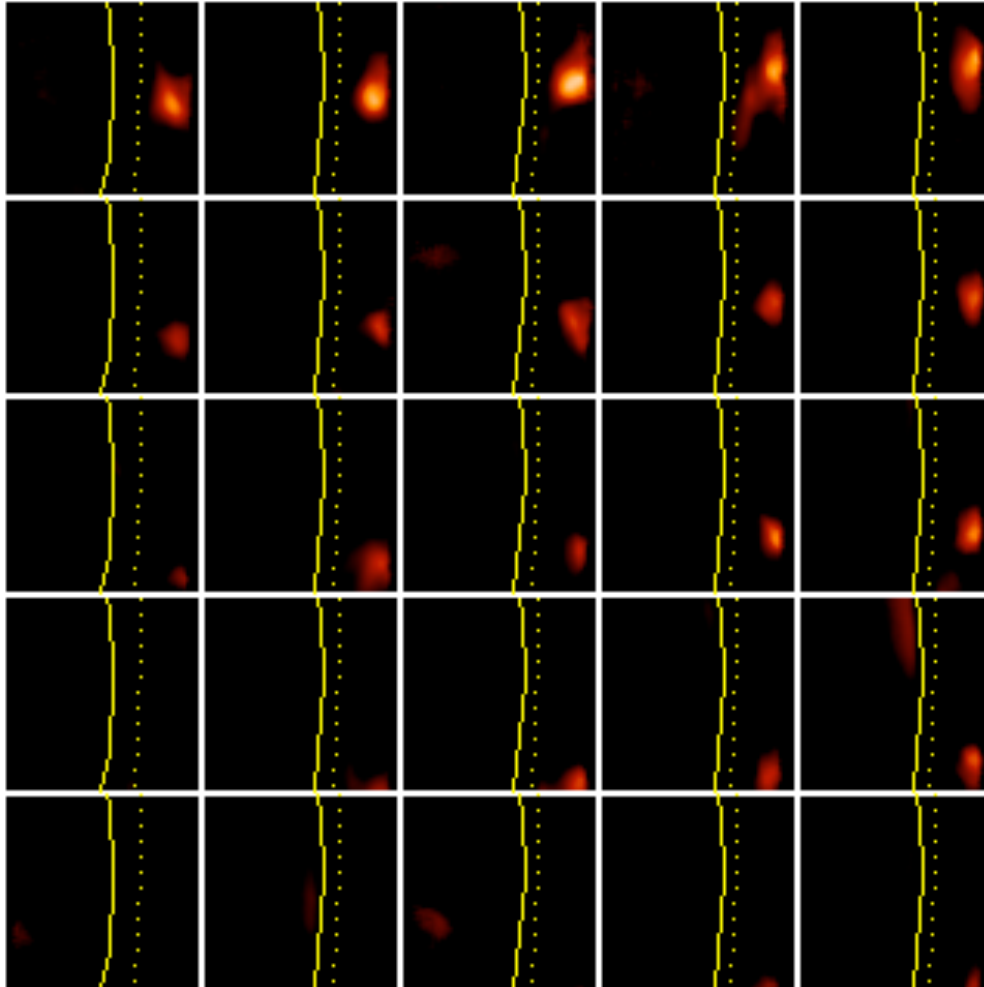
#1

#2

#3

#4

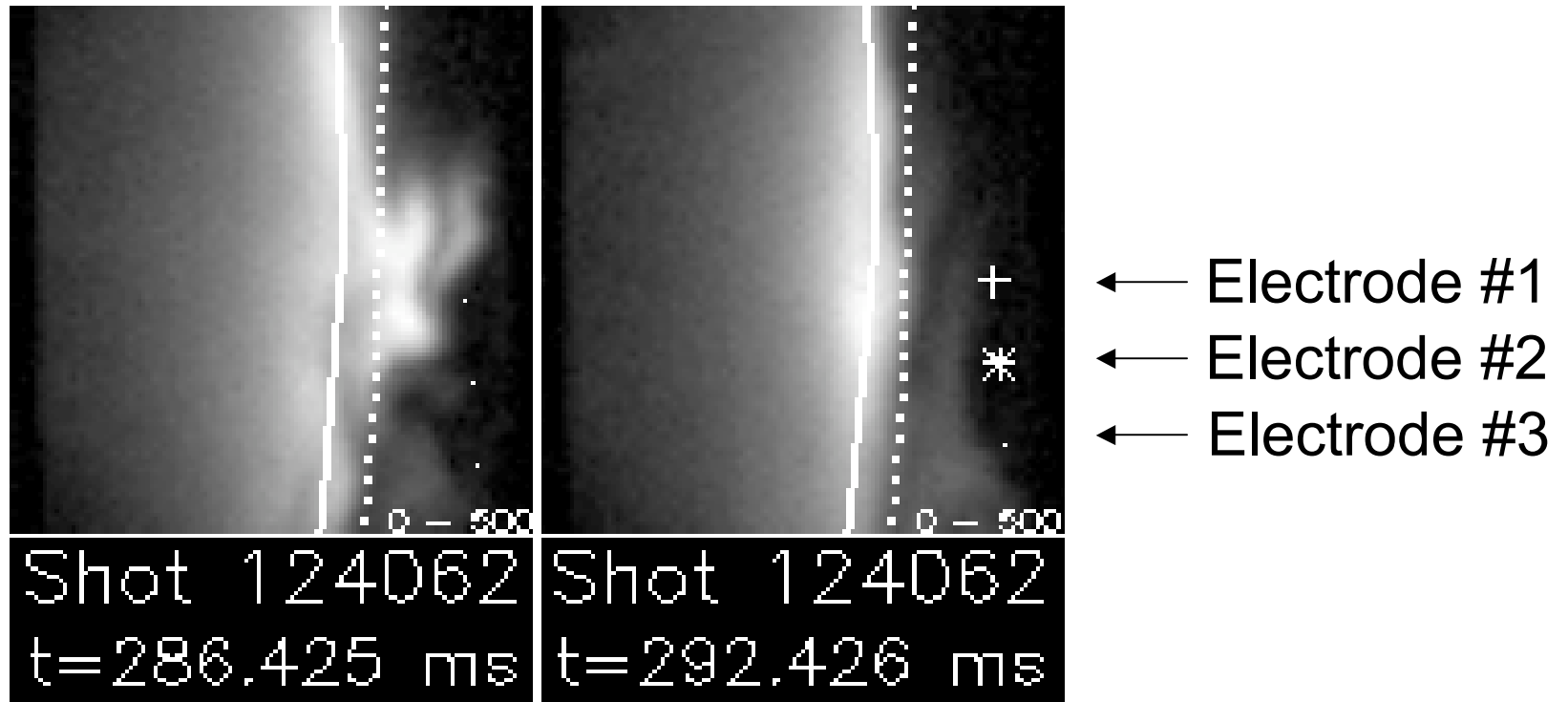
#5



Time ->

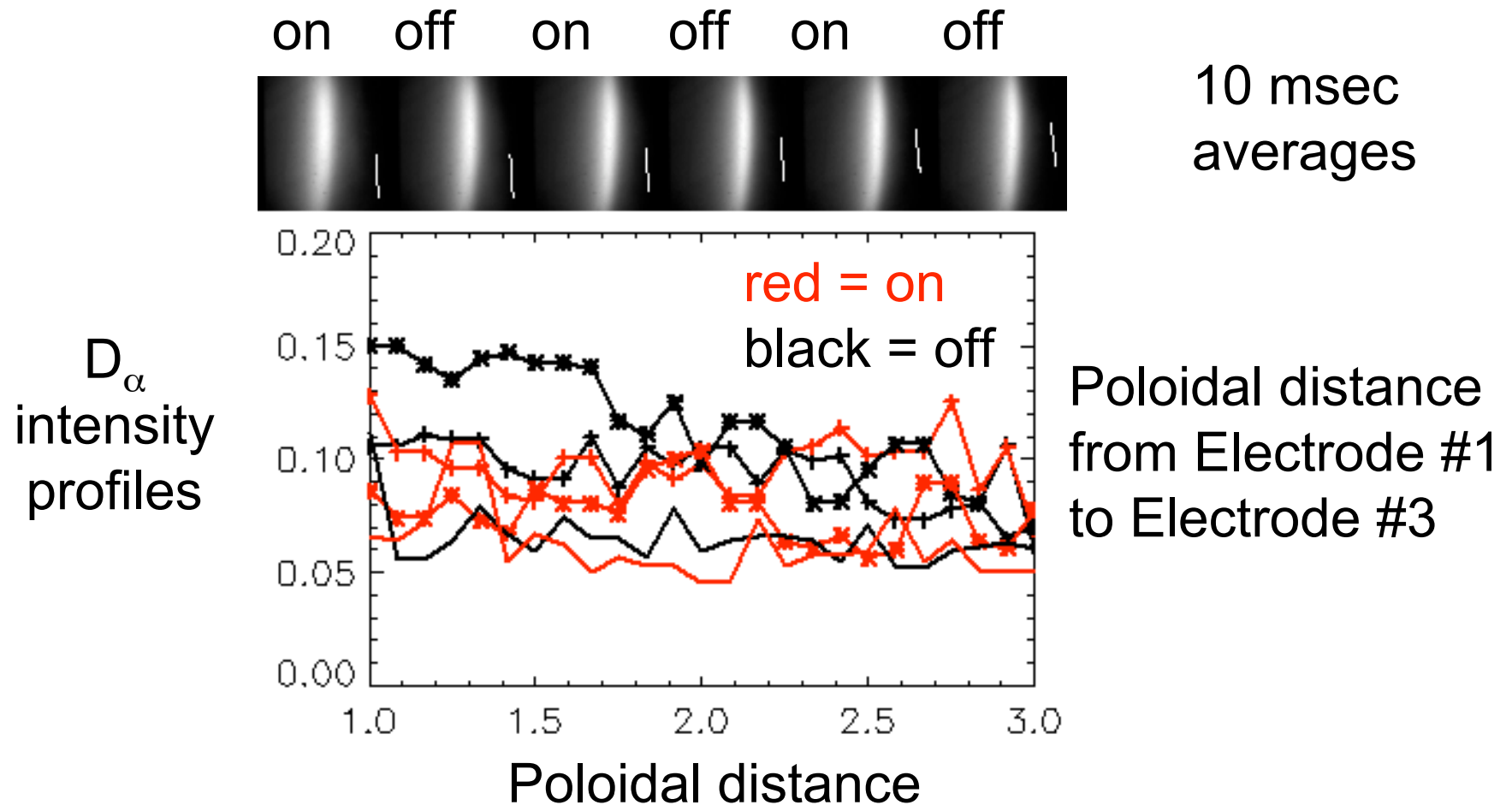
- Good correlation of fluctuations across ~ 1 m along B field ($C_{12} \sim 50-80\%$)
- Agrees well with EFIT02 field lines
- Size of correlation volume \sim blob size as expected

Effect of Bias on GPI Turbulence



- No visible effect on turbulent structures or motion

Effect of Bias on Local D_α Profiles



- No visible effect of bias on local D_α profiles

Summary and Plans

- So far, no visible effect of electrode biasing on local edge plasma (still can do more data analysis)
- Would like to try ~ 6-8 more test shots:
 - increase electrode voltage from -70 to -100 Volts
 - increase electrode current from ~ 2 to ~ 10 amps
 - decrease B field from 4.5 to 3 kG to increase V_r
- Collaborate with LLNL and CPES to understand results
- Possibly upgrade hardware for next run (divertor bias ?)