# Edge Turbulence Imaging on NSTX and Alcator C-Mod

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## Goal

Understand edge turbulence by measuring its
2-D structure vs. time and comparing with theory

# **Outline**

- Gas Puff Imaging (GPI) diagnostic

- Summary of C-Mod GPI results

    Comparison of k-spectrum with DBM and BOUT

- Summary of NSTX GPI results

    Radial profile during H-L mode transition

- DEGAS 2 Simulation of GPI signals

- Tentative Conclusions and Plans for 2002 run

# Gas Puff Imaging Diagnostic

- Gas puff imaging (GPI) telescope views neutral line emission from He or $D_2$ gas puff $\approx$ along B field at the plasma edge (like BES but uses neutral gas instead of NBI)

  $S(\text{photons/cm}^3) = n_o\, f(n_e, T_e)\, A$

  where the radiative decay rate is $A \gg 10^7 \text{ sec}^{-1}$ for these lines.



Gas puff nozzle

GPI telescope

B

Diode telescope

- Space and time variation of neutral light emission is measured with fast-fast gated cameras and PMs or PDs on discrete chords to determine edge turbulence structure (assumes $k_{\parallel} \ll k_{\perp}$)

- Gas puff changes plasma density by $\approx 1\%$ in C-Mod and $\leq 10\%$ in NSTX, but this does probably not to perturb the edge turbulence significantly
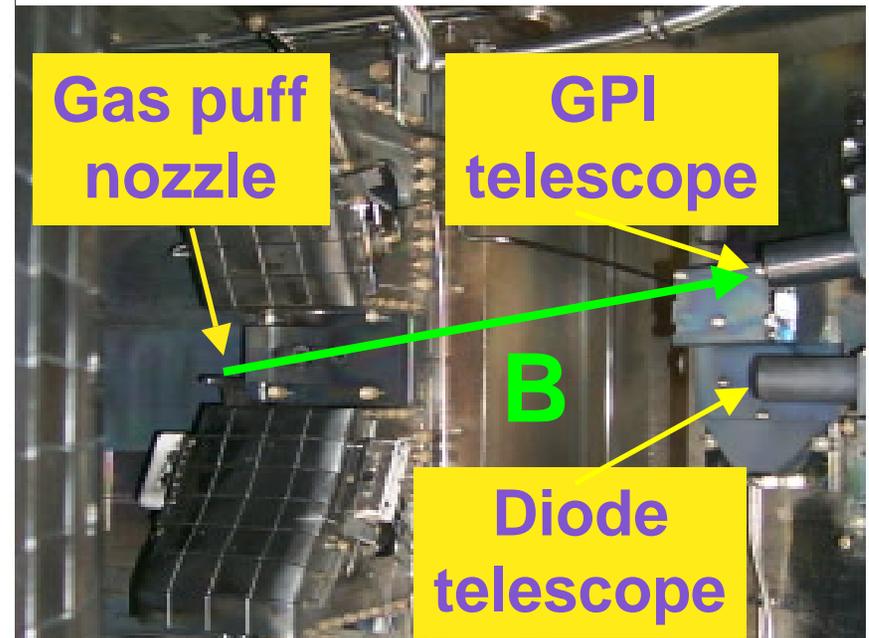
# Summary of C-Mod GPI Results

- Edge turbulence imaged over ≈ 6 cm poloidally x 3 cm radially at outer midplane

- Frequency spectra and fluctuation levels agree well with Langmuir probes

- Poloidal k-spectra from GPI compared with DBM code and BOUT for one case
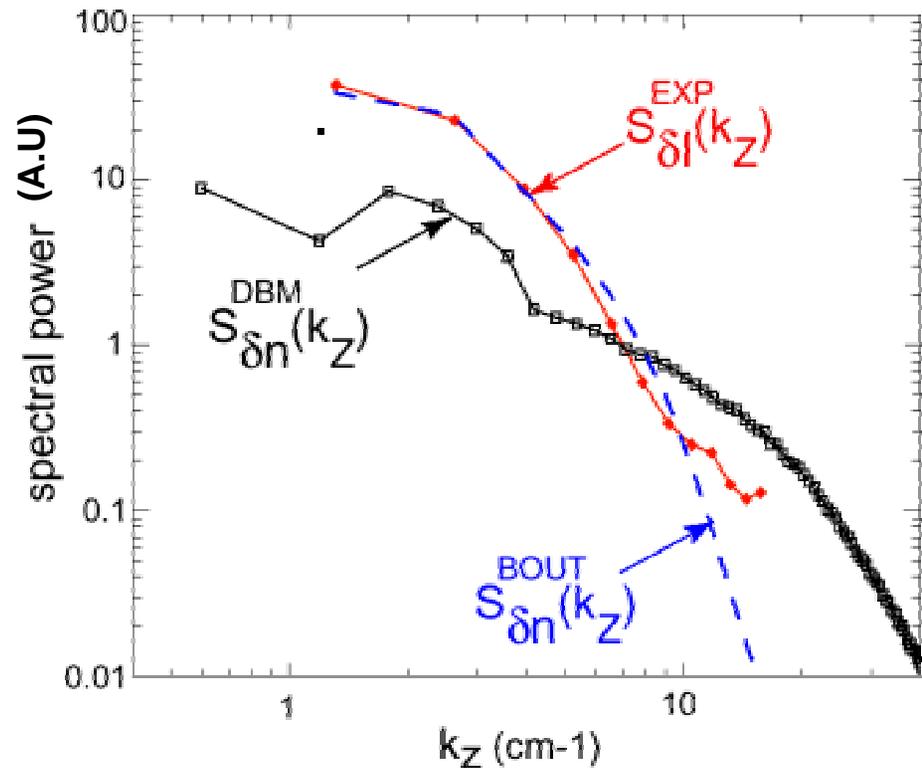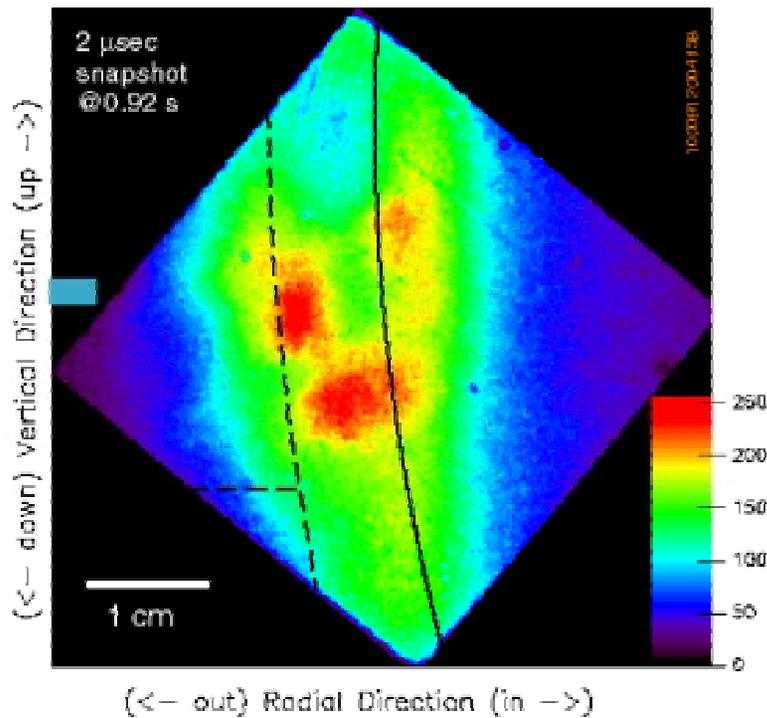
# Videos of Edge Turbulence in C-Mod

- Taken at 2 µsec/frame at 250,000 frames/sec with the 64 x 64 pixel camera made by Princeton Scientific Instruments (Model PSI-3)

- Usually appears to be "blobs" (local maxima) moving radially and poloidally through the edge and SOL

(C-mod MPEGS here)

# GPI Diagnostic Set-up in NSTX

- Similar to C-Mod system but using re-entrant port instead of coherent fiberbundle and elongated gas manifold instead of single-point gas nozzle

- Generally have used He puffs in NSTX and Deuterium puffs in C-Mod (although results from both are similar in each machine)
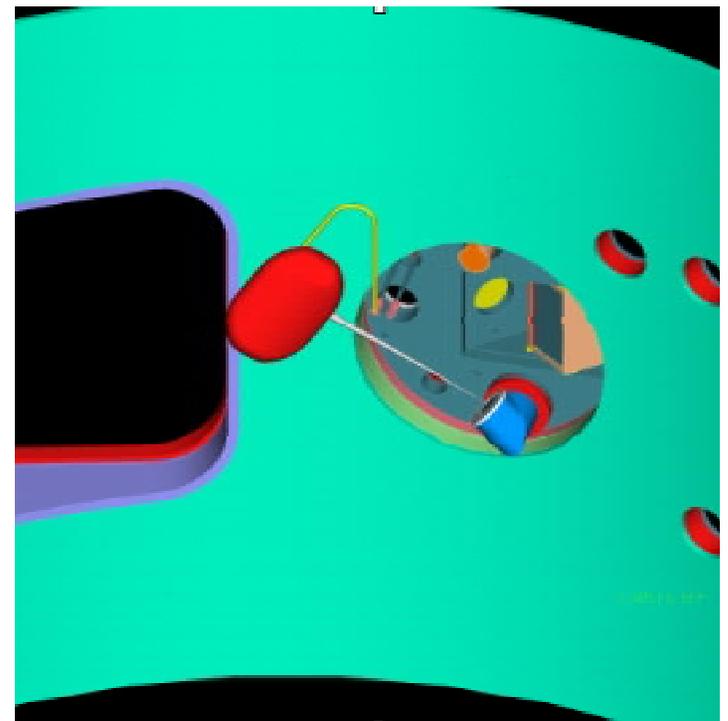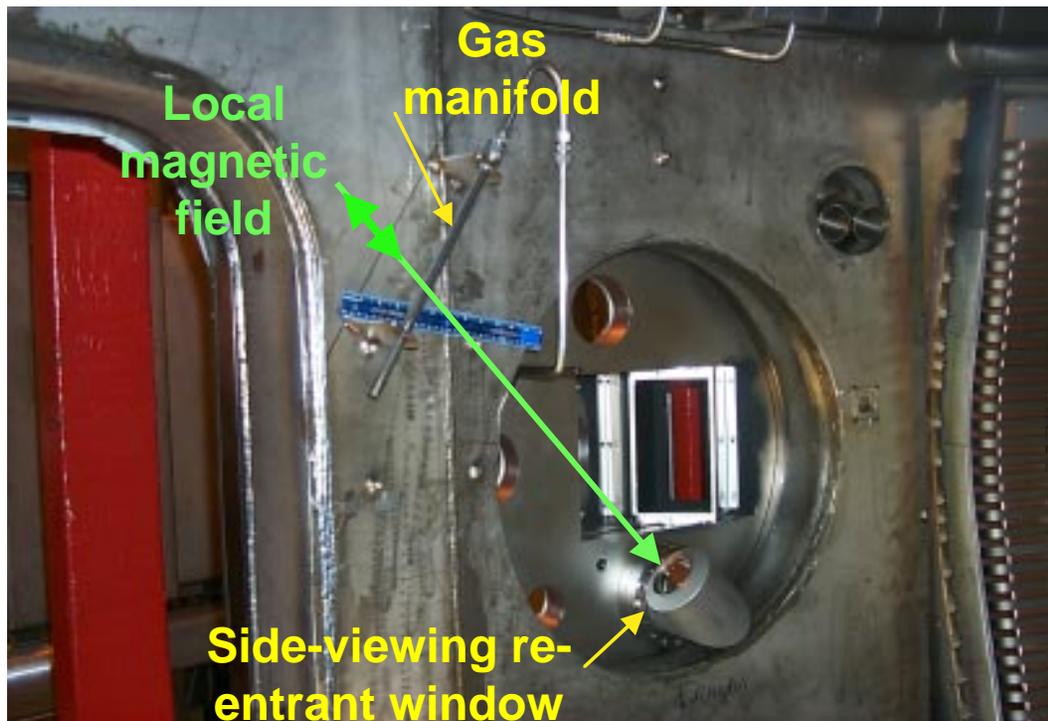
# Location of GPI View (2001 Run)

- LANL Kodak camera views ≈ 30 cm x 30 cm area just above outer midplane

- Fast chords view 2 cm diameter "spots" in 7 channel radial array with PM tubes
  (bandwidth ≈ 100 kHz, digitized at 500 kHz)
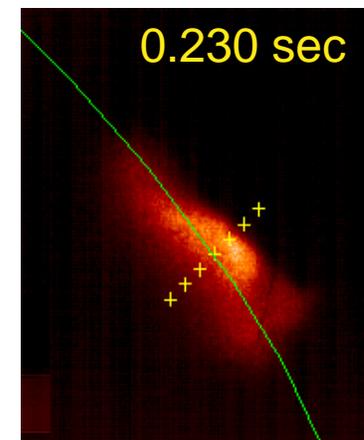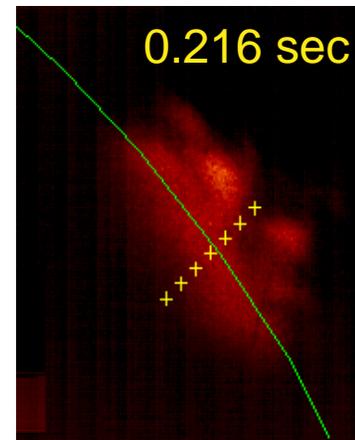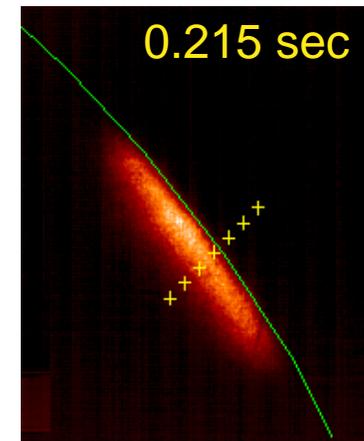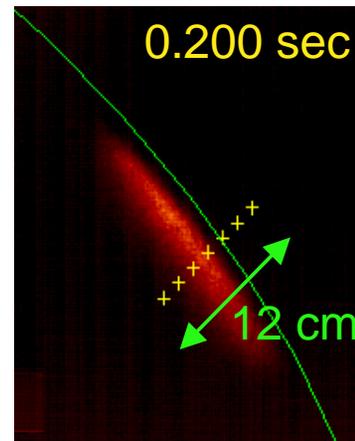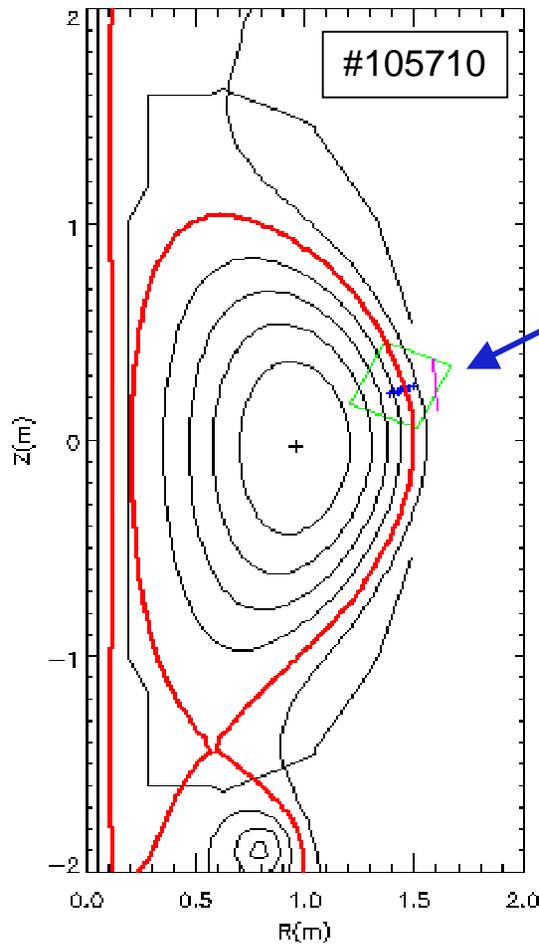
# Typical GPI Videos for NSTX

- Made using LANL Kodak camera at 10 µsec/frame and 1000 frames/sec

- Grossly undersamples turbulence of autocorrelation time ≈ 10-100 µsec

NOTE:  IMAGE ROTATED ≈ 90⁰ IN THESE MPEGS

| #105627 | #105710 | #105711 |
|---|---|---|
| (0.7 MA, 3 kG) | (0.7 MA, 4.5 kG) | (0.7 MA, 4.5 kG) |
| density scan | H-L transition | no-H mode |

# Typical Signals from Fast GPI Chords

- Signals from 7 radial chords digitized for 0.128 msec @ 500 kHz
- Near outer wall see "intermittant" fluctuations with ~ 100% modulation
- Nearer center, see "Gaussian" fluctuations with ≈ 20% modulation
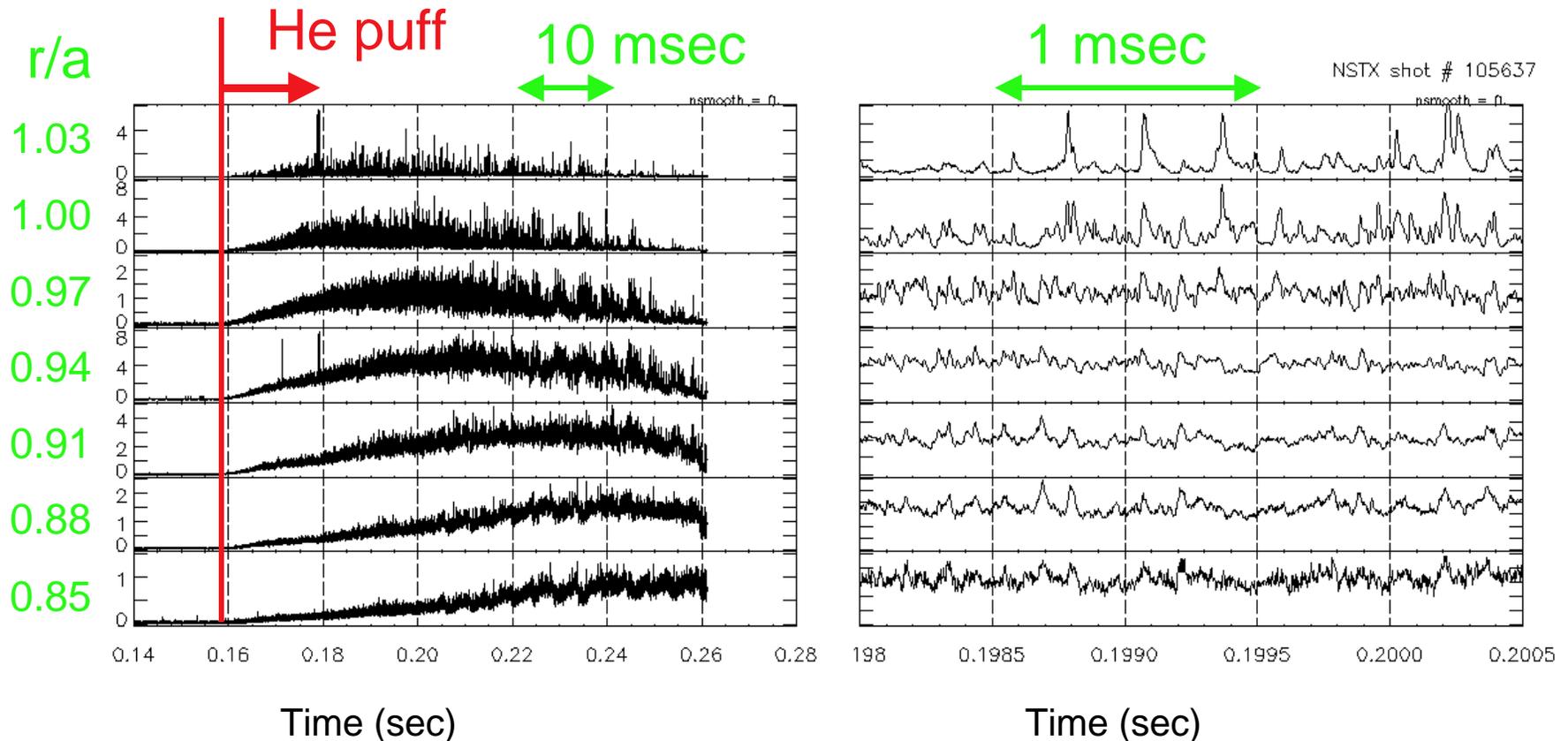
# Edge Turbulence Signals at L-H Transition

- L-H transition occurs within ≈ 1 msec on most channels

- Perhaps preceeded by large "bursts" in outermost channels
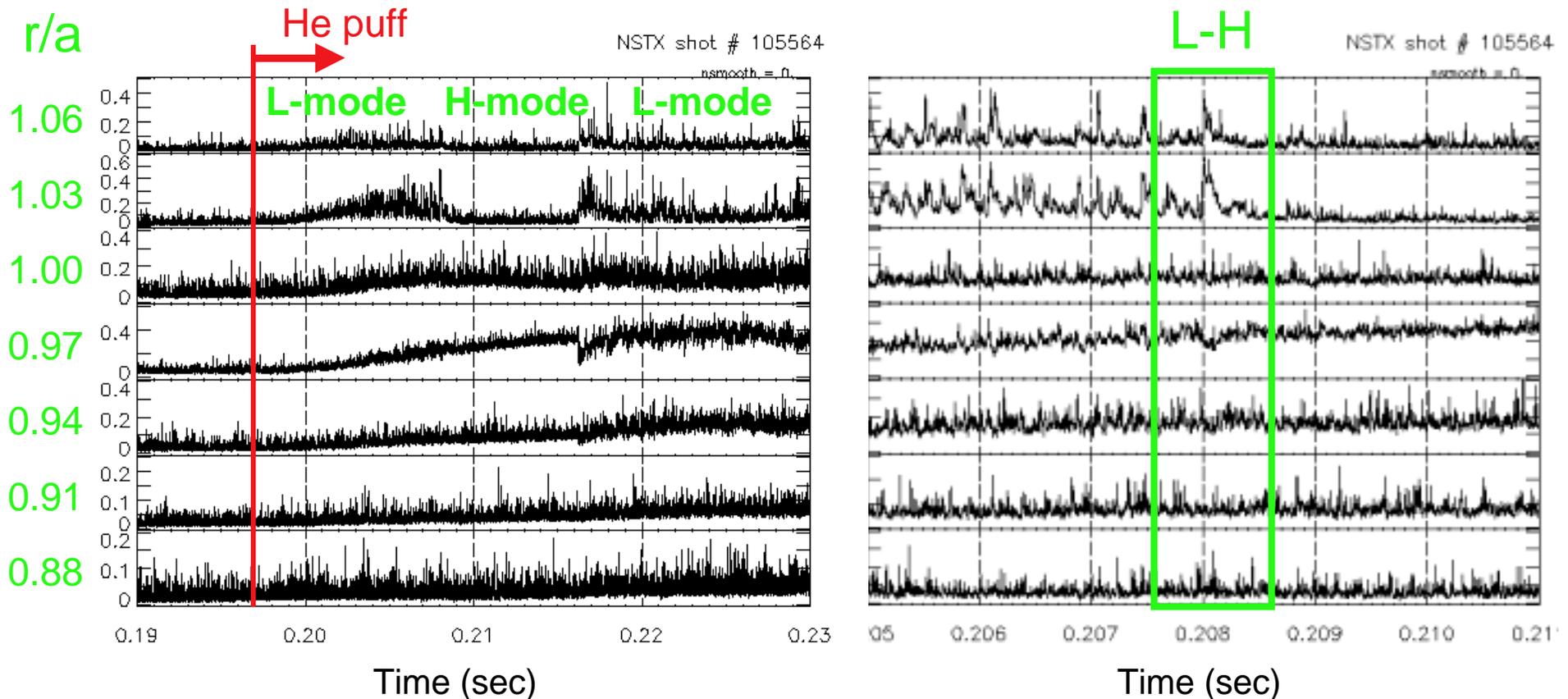
# Edge Turbulence Signals at H-L Transition

- H-L transitions occurs within ≈20 µsec in most channels

- Transition seems to propagate outward at ≈$10^6$ cm/sec

- Transition seems to start with coherent mode (ELM ?)
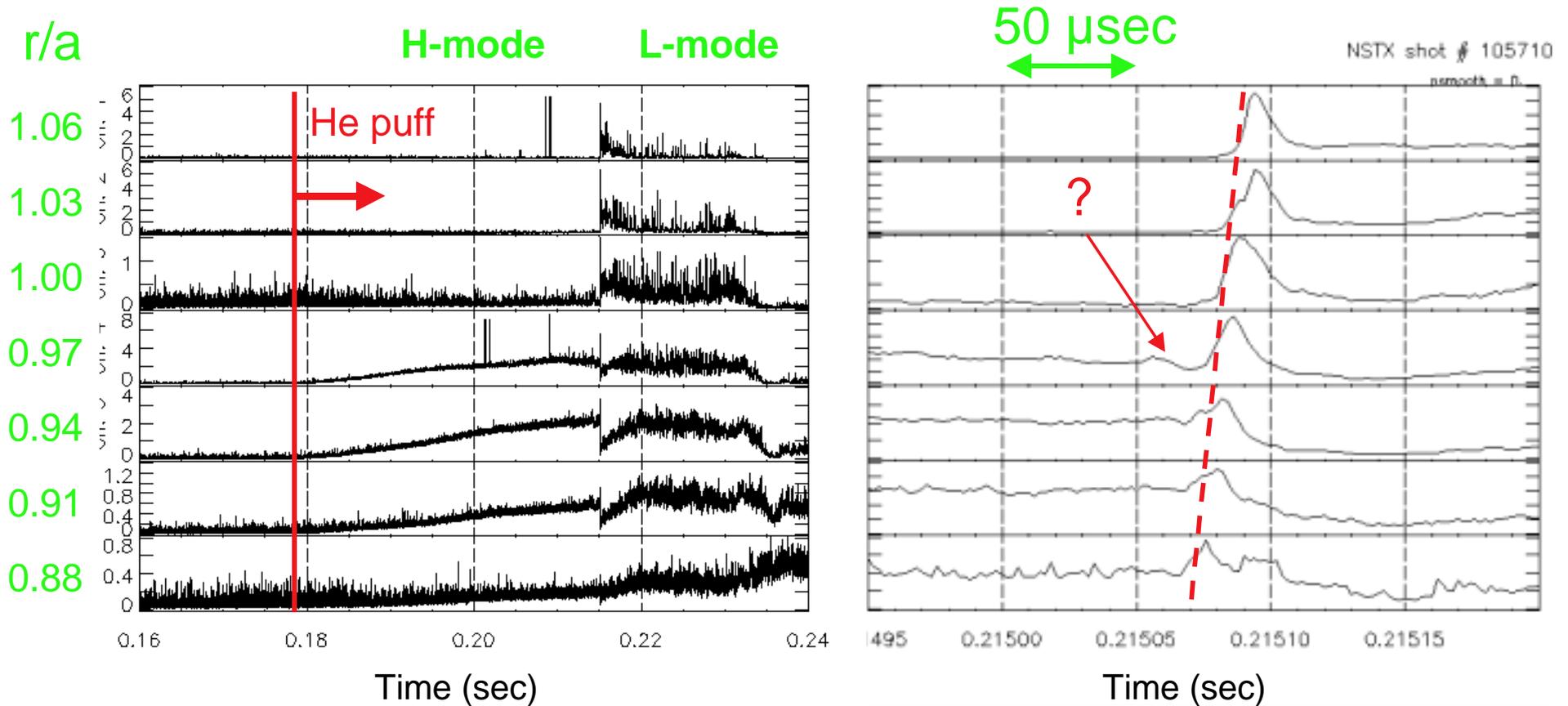
# Fluctuation Profiles in H-mode vs. L-mode

- Fluctuation level seems to be lower in H-mode (but non-zero) in #105710 etc, as expected from appearance of "brain-dead" H-mode emission in images

- Only one Thomson Scattering point within range of GPI data from '01
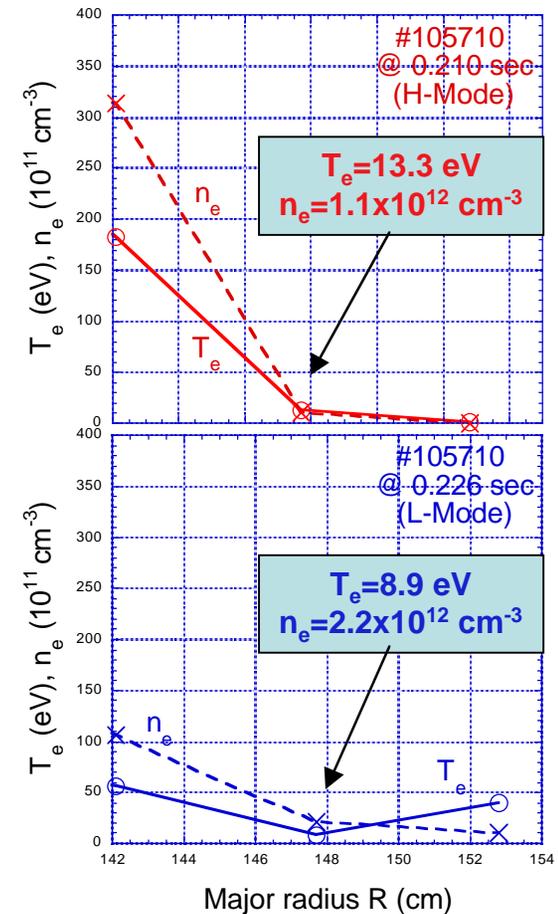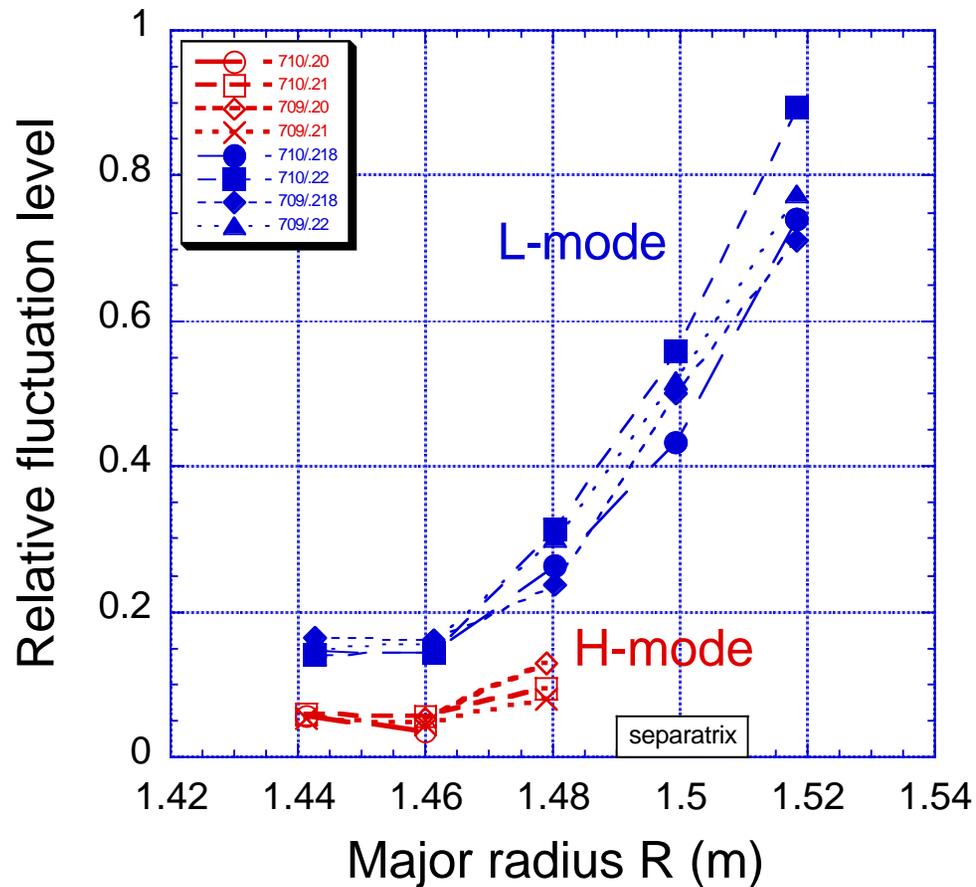
# Correlations in H-mode vs. L-mode

- Correlation lengths and autocorrelation times in "late-H" (0.21 sec) similar to "L", with cross-correlations of ≈0.4 implying fluctuation level is non-zero

- But correlation lengths and autocorrelation times in "early-H" (0.20 sec) lower !
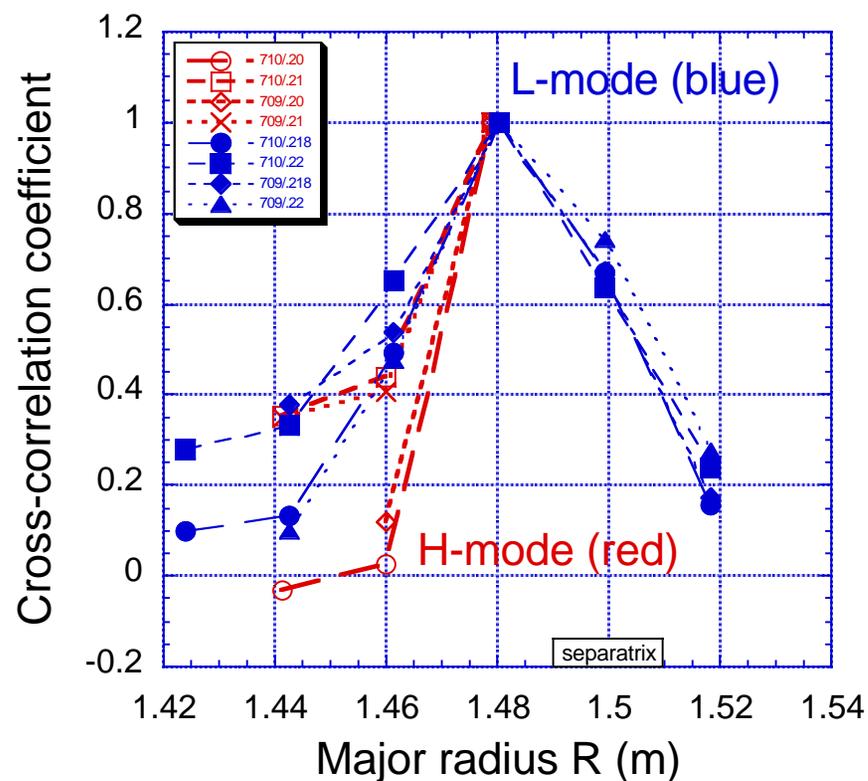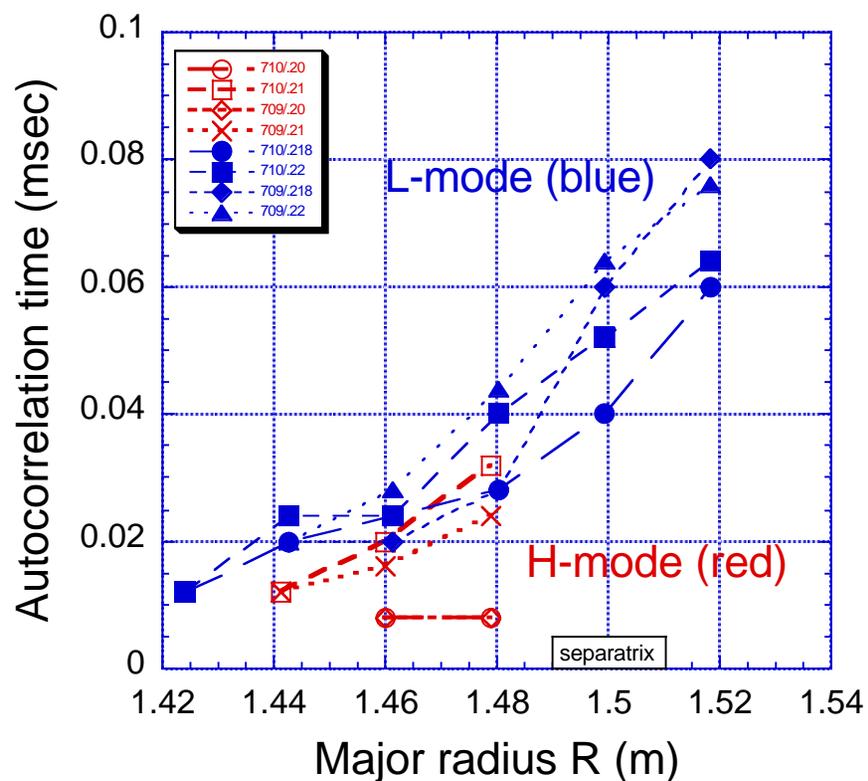
# DEGAS 2 Simulation of GPI

- Average $D_\alpha$ or He (587.6 nm) emission cloud simulated given edge profiles

- Near center of GPI cloud, $S \propto n_e^{0.5} T_e^{0.5}$ for C-Mod and $S \propto n_e^{0.7} T_e^{0.5}$ for NSTX

- H-mode emission profile is narrower simply due to narrower edge profiles



H-mode: Shot 105710 @ 208 ms     L-mode: Shot 105710 @ 226 ms

C-MOD- ave

C-MOD -fluct

NSTX H-mode

NSTX L-mode

Z (mm)

Distance from separatrix (mm)

Distance from separatrix (m

gas manifold

R (m)

R (m)

D. Stotler
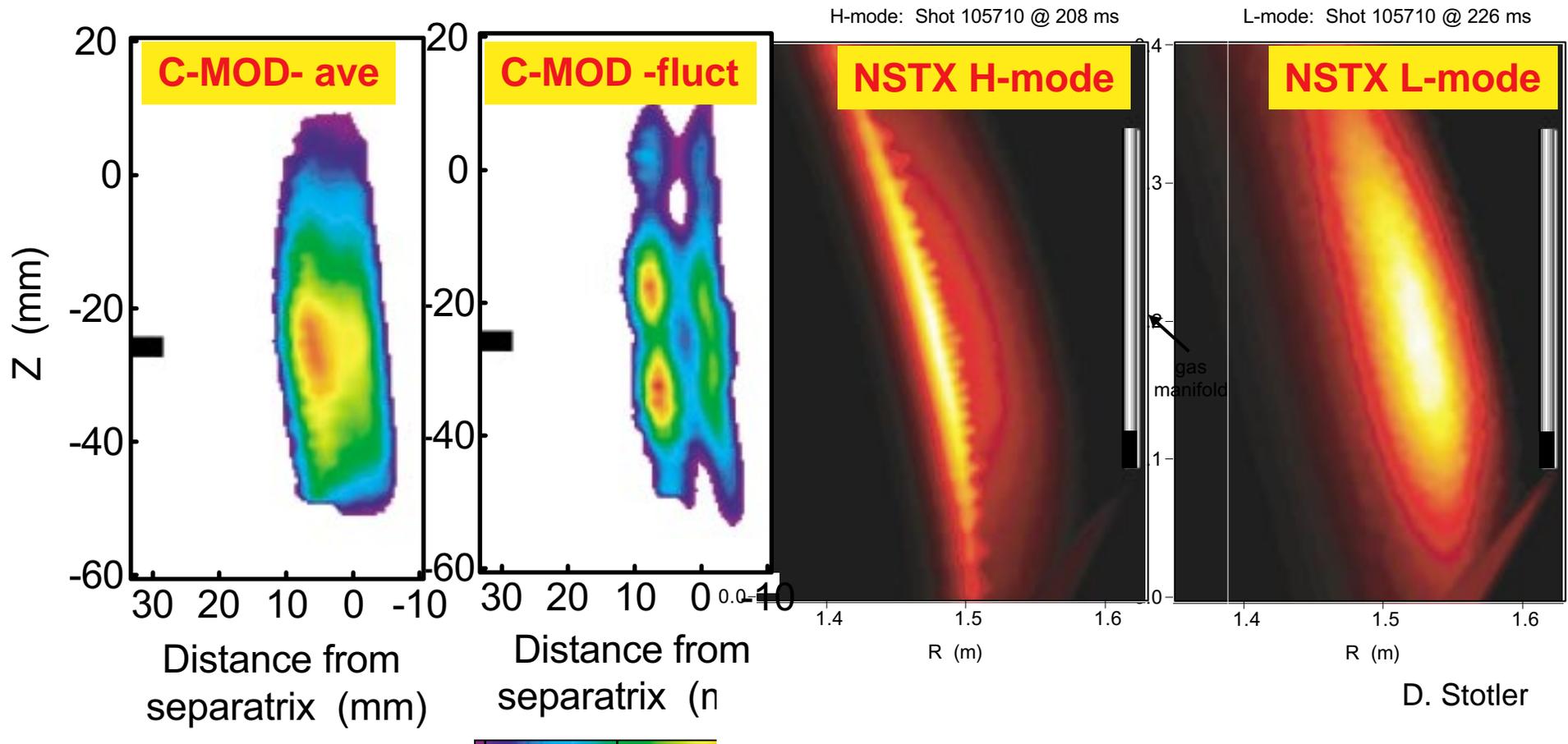
# Tentative Conclusions and Plans for 2002

- Edge turbulence in GPI looks similar to that seen elsewhere

- Initial comparisons with simulation / theory are encouraging

- Interesting radial profile changes during H-L transition in NSTX

- 2-color GPI imaging in Alcator C-Mod using two Xybions

- Make more ultra-fast videos using 28 frame PSI-4 camera

- Ask theorists to run simulations for more cases

- Feed simulation into DEGAS 2 and compare with GPI data