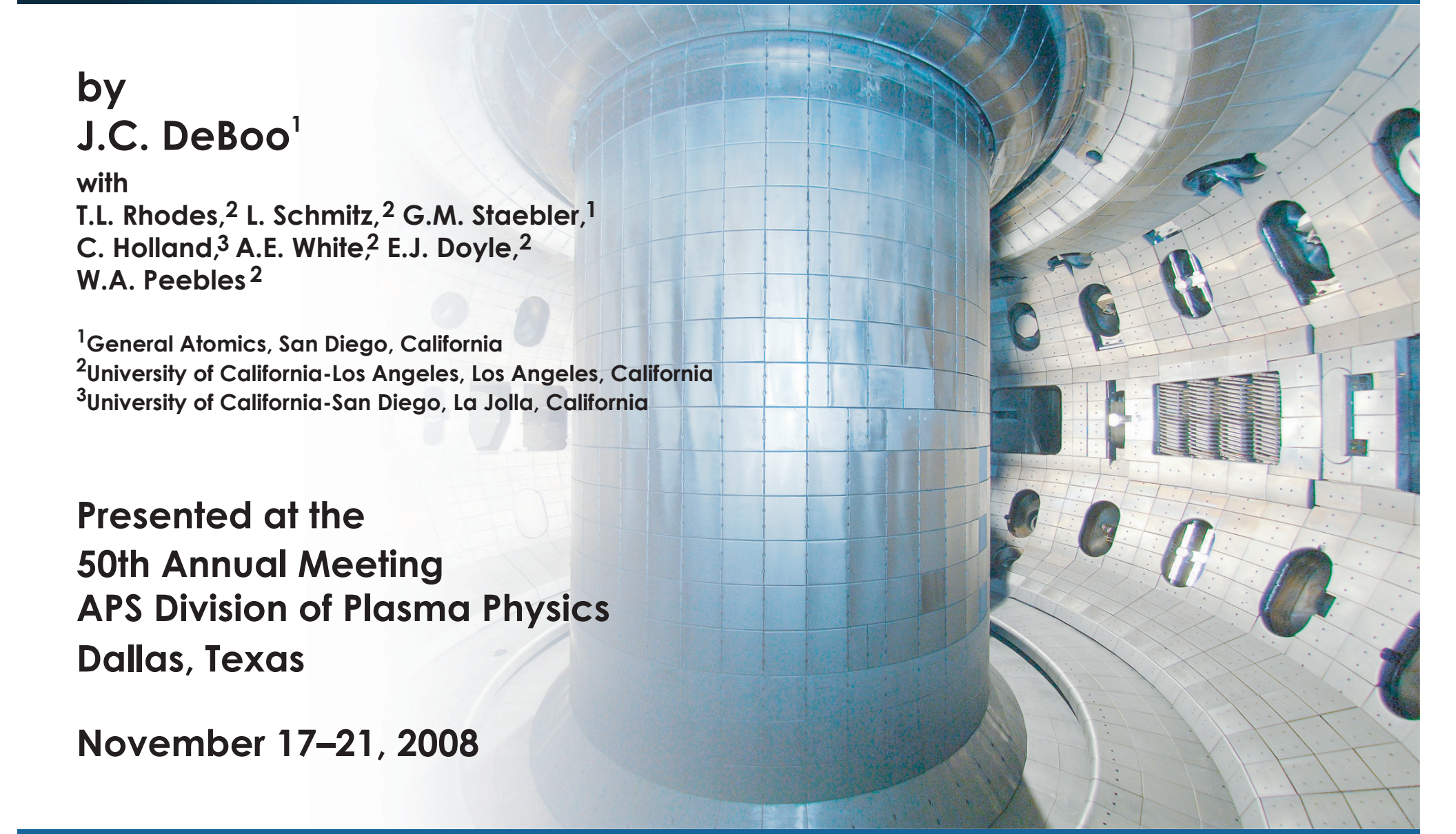
Modulation of TEM Turbulence in DIII-D L-mode Discharges



by
J.C. DeBoo[1]

with
T.L. Rhodes,[2] L. Schmitz,[2] G.M. Staebler,[1]
C. Holland,[3] A.E. White,[2] E.J. Doyle,[2]
W.A. Peebles[2]

[1]General Atomics, San Diego, California
[2]University of California-Los Angeles, Los Angeles, California
[3]University of California-San Diego, La Jolla, California

Presented at the
50th Annual Meeting
APS Division of Plasma Physics
Dallas, Texas

November 17–21, 2008

DIII-D NATIONAL FUSION FACILITY

GENERAL ATOMICS

APS08/jcd

Introduction

Goal

- Produce a set of detailed turbulence measurements that will allow a qualitative and quantitative comparison with driftwave stability code predictions

Method

- Choose a turbulence drive term to modulate and look for correlations in measured turbulence activity
- Focus on TEMs. Use ECH to modulate local value of ∇T_e and temperature gradient scale length a/L_{Te}

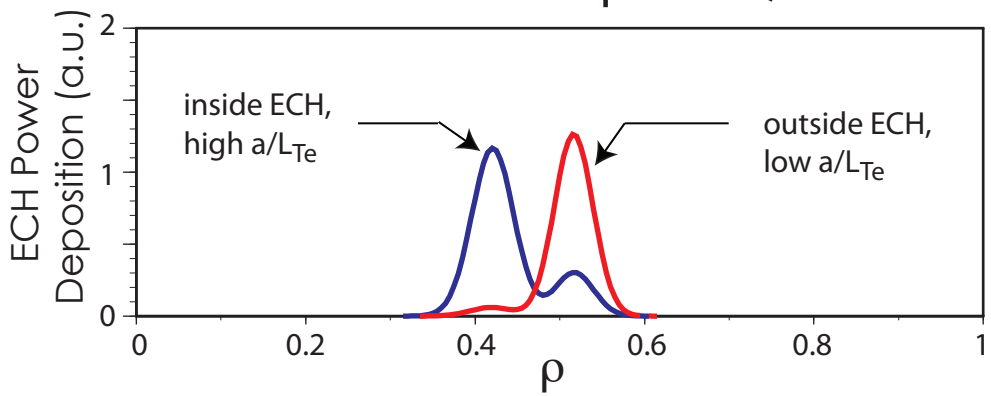
Results

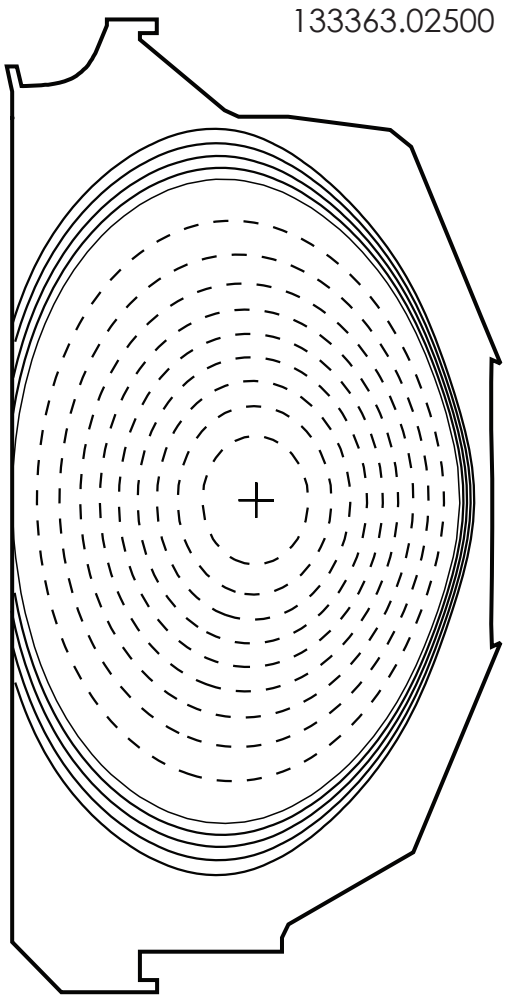
- Modulation of drive term resulted in modulation of measured turbulence amplitude and frequency. A good dataset obtained for code validation studies.

Target Discharge

- **L-mode discharge**
  I_p = 0.8 MA
  B_T = 1.96 T
  $n_e = 2 \times 10^{19}$ m^{-3}
  q_{lim} = 6.1
- **Fluctuation diagnostics optimized for viewing ρ ~ 0.5, good spatial resolution required**

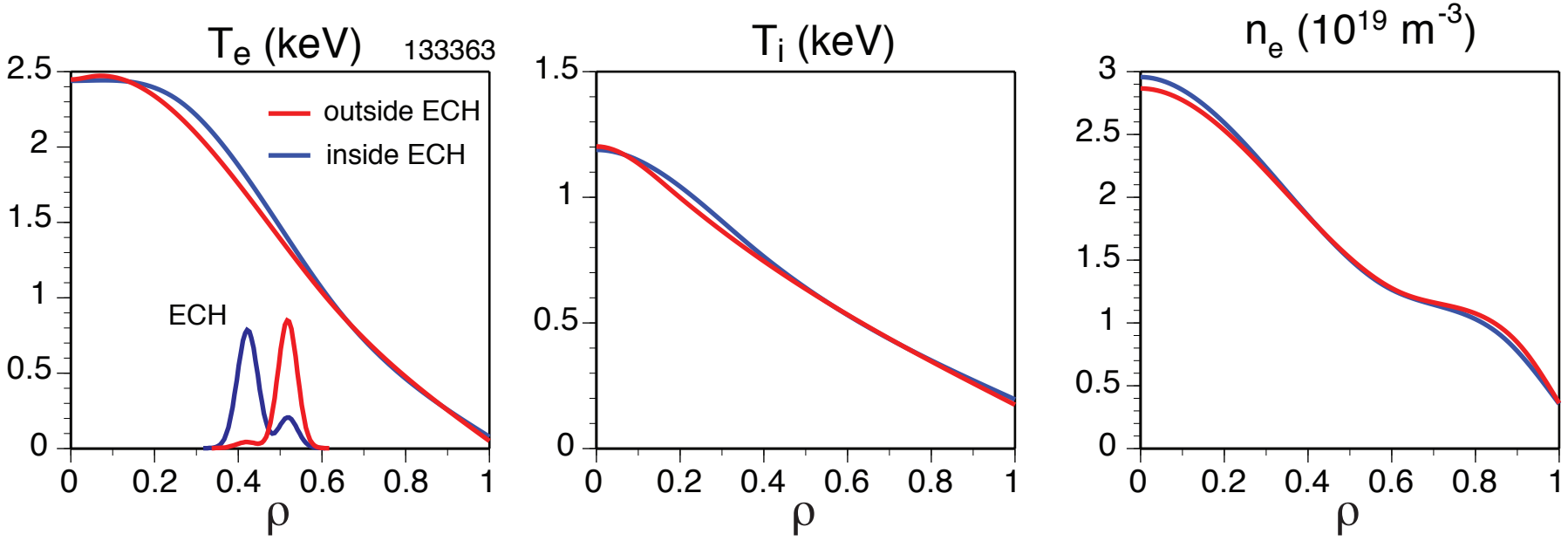
~1.2 MW ECH at ρ=0.42, 0.52





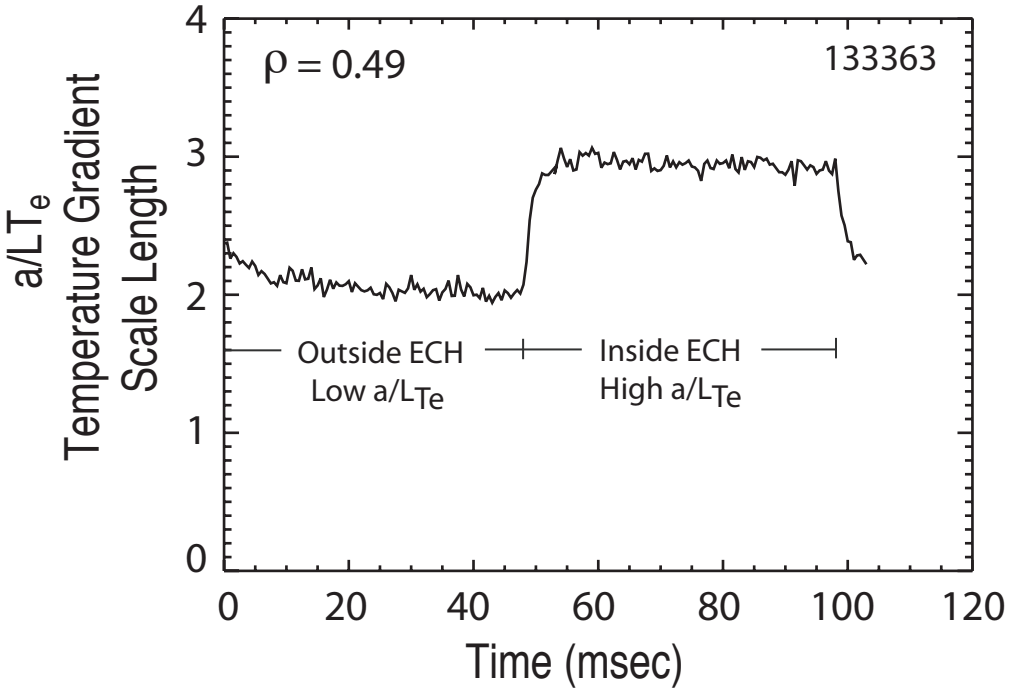
Very Little Change in Profiles with Inside and Outside ECH

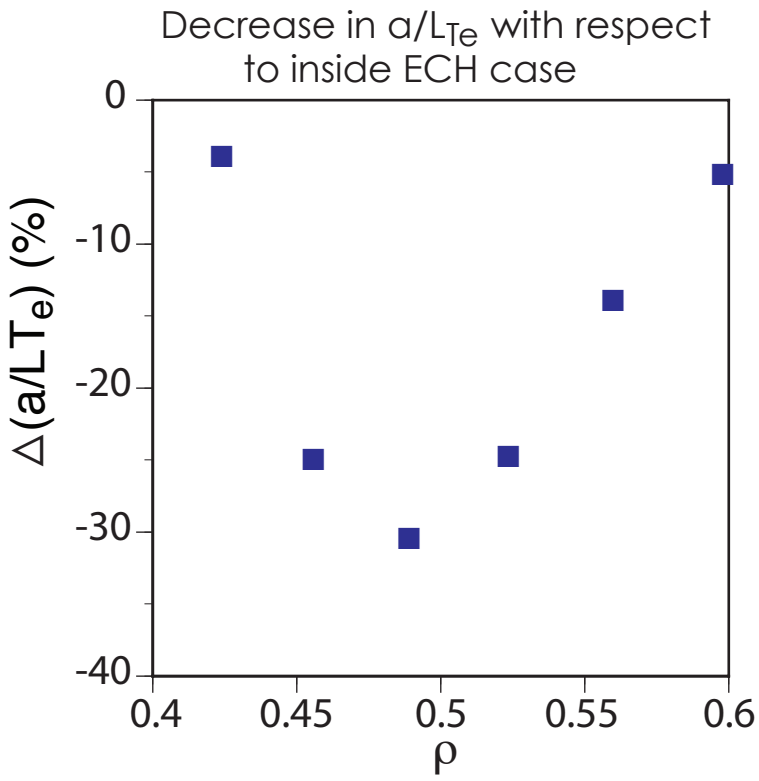
- T_e/T_i ~ 2 favoring electron mode turbulence



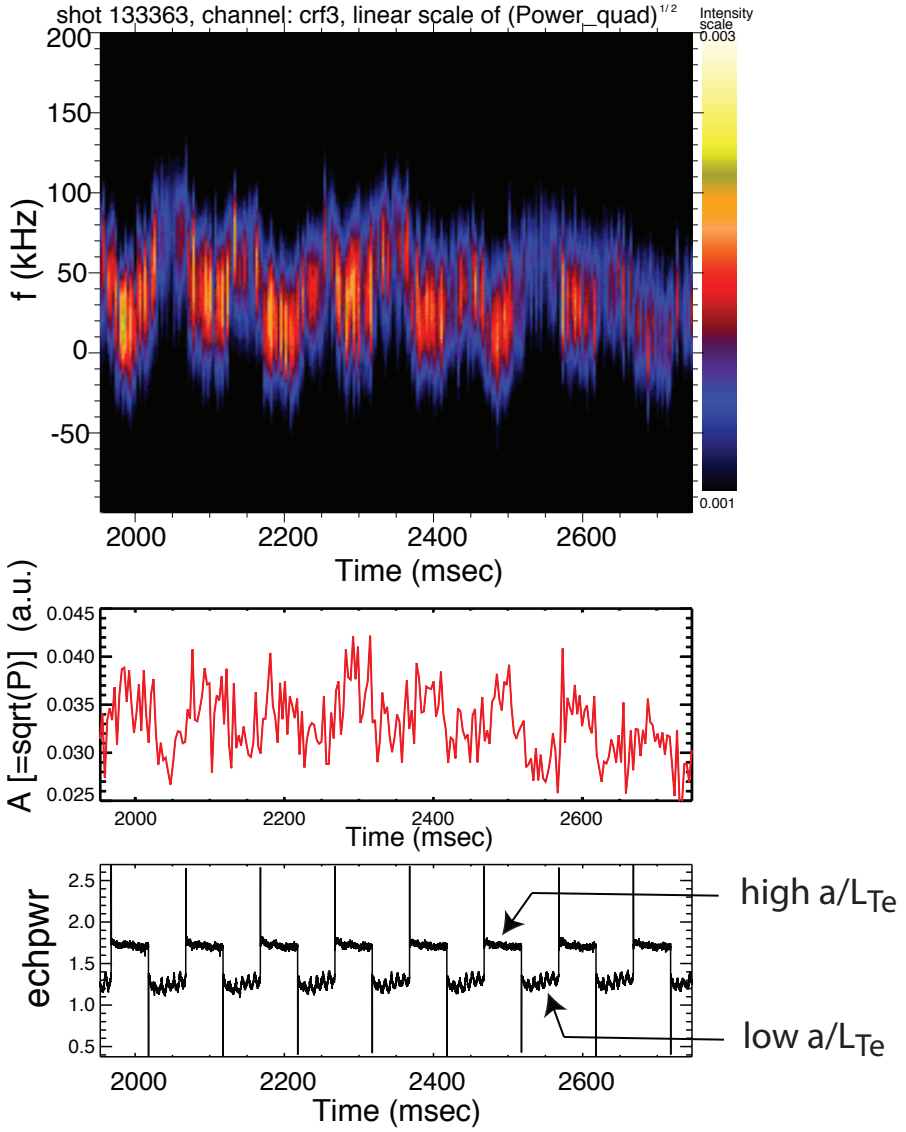
Temperature Gradient Scale Length Decreased Up To 31% With Outside ECH And Variation Is Spatially Localized

- Phase lock average ECE signals over 9 ECH periods, 2020 - 2920 ms
- ∇Te computed by differencing adjacent ECE channels



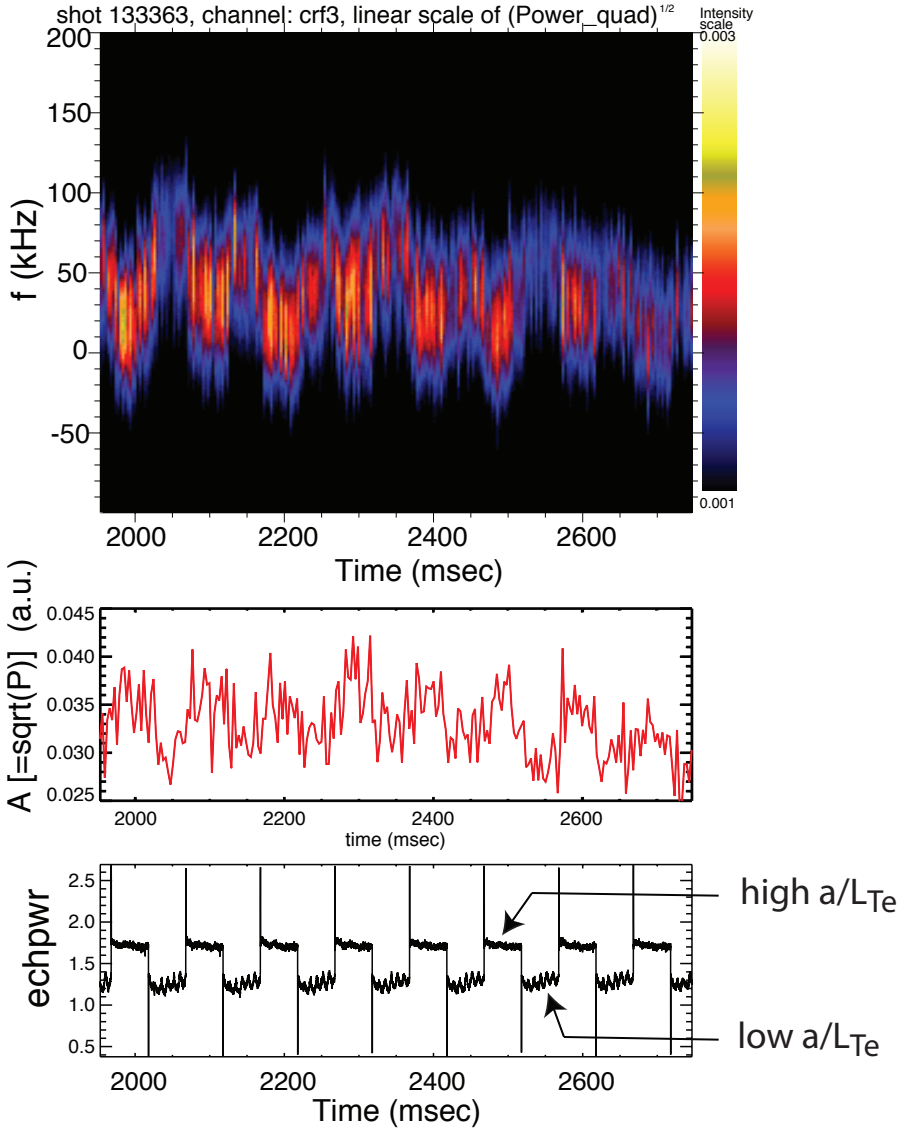


Amplitude and Frequency of Density Fluctuations Measured by Doppler Backscattering (DBS) Were Modulated



- DBS views poloidal density fluctuations at $k_\theta \sim 5$ - 6 cm^{-1} at r/a = 0.5 with good spatial resolution (~ 1 cm)
- Sign of the amplitude modulation is consistent with the variation in a/L_{Te}
- Modest modulation seen on FIR system viewing intermediate-k which spatially averages over ~half the plasma radius
- Little or no modulation of $\tilde{T}_e$ seen on CECE system at lower k_θ
  - possibly due to reduced sensitivity at r/a = 0.5

Amplitude and Frequency of Density Fluctuations Measured by Doppler Backscattering (DBS) Were Modulated

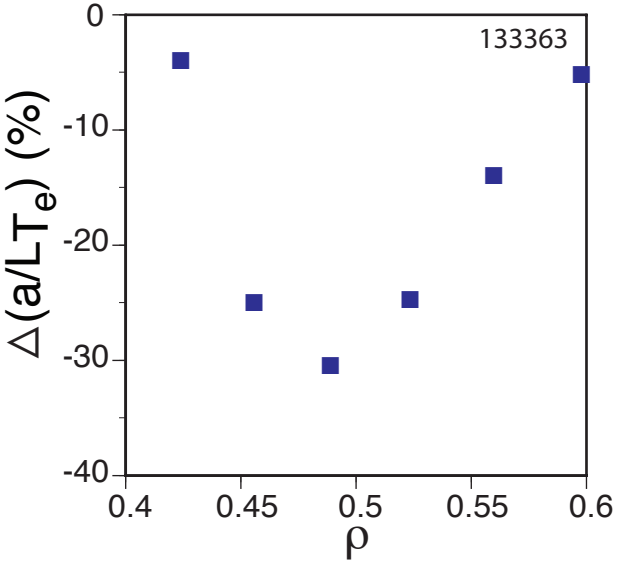


- DBS measures lab frame frequency
  $$\mathbf{V}_{DBS} = \mathbf{V}_{ExB} + \mathbf{V}_{ph}$$
- $\mathbf{V}_{ExB}$ is in the ion diamagnetic drift direction while $\mathbf{V}_{ph}$ is in the electron diamagnetic drift direction for an electron mode:
  $$f_{DBS} = f_{ExB} - f_{turb}$$
- Measured an increase in f_{DBS} when a/L_{Te} decreased
  - consistent with a decrease in f_{turb} or an increase in f_{ExB} or both
- Preliminary nonlinear analysis indicates only small changes in f_{turb} , making the likely cause of an increase in f_{DBS} an increase in f_{ExB}

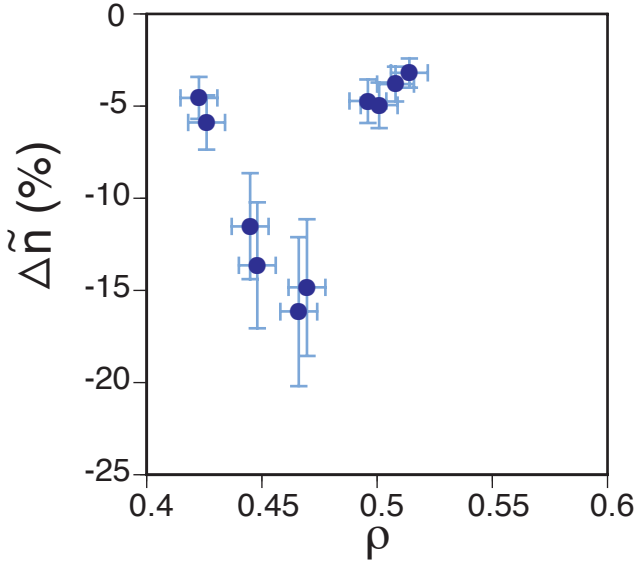
Intermediate-k (TEM scale) Density Fluctuations Measured By DBS Found To Be Positively Correlated With a/L_{T_e} Drive

- Performed small spatial scan with DBS to obtain spatial extent of turbulence modulation
- Turbulence response is spatially localized to region where drive term was modulated
- 15% decrease in density fluctuation level observed at $k_\theta = 5.7\ cm^{-1}$
- 20 kHz increase in lab frame frequency observed

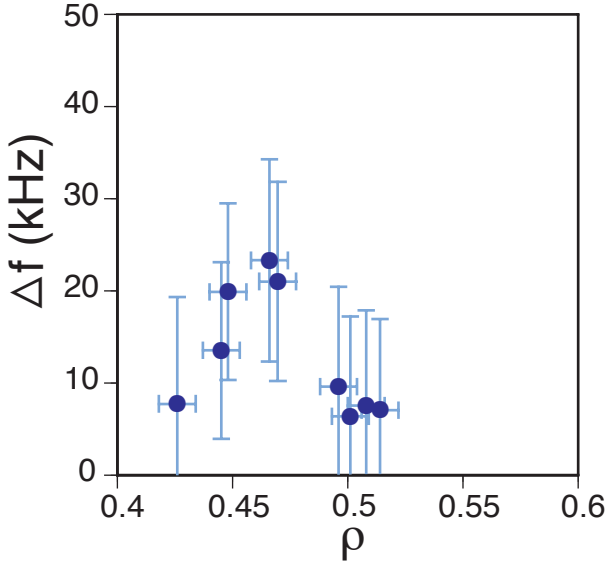
Decrease in drive term



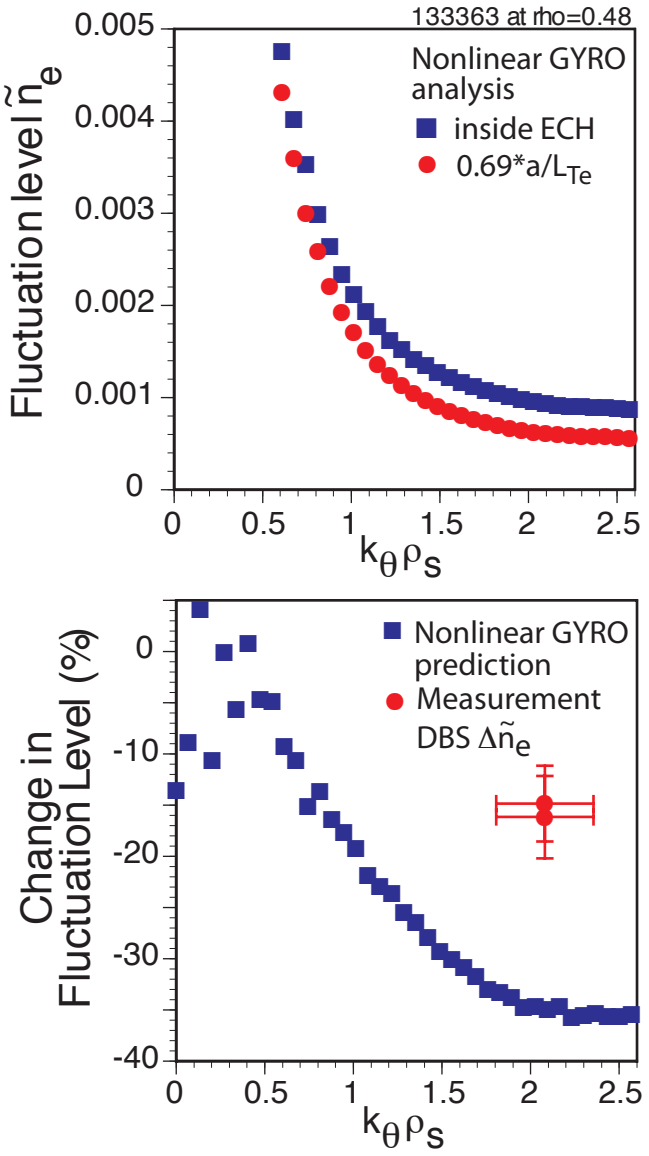
Decrease in turbulence level



Increase in lab frame frequency



Predicted Change In TEM-scale Turbulence Activity Is Factor 2 Larger Than Measured Change in Fluctuation Level



- Predictions performed with GYRO code
  - Nonlinear calculation of density turbulence for the high gradient case, then the gradient scale length is reduced by 31%, the measured value, to compute the growth rate in the low gradient case
- Direction of predicted change consistent with measurements
- Magnitude of predicted change about 2x larger than measured
- Caveats:
  - these preliminary results overpredict the experimental heat flux
  - synthetic module for DBS not yet implemented

Summary

- **Target L-mode EC heated discharges were produced where intermediate-k, TEM scale turbulence was calculated to dominate ITG turbulence**
- **ECH was alternately applied at two spatial locations to modulate the local value of the temperature gradient scale length, a/L_{Te}**
- **Changes in electron density turbulence measured at intermediate-k were well correlated with the repeated variation in a/L_{Te}**
- **Comparisons with GYRO predictions were performed and showed that the predictions were consistent with the direction of the changes in the measured turbulence level and about factor 2 larger in magnitude**
  - successful initial step toward detailed code validation studies