Ratio of Electron Temperature and Density Fluctuation Amplitudes During ECH in DIII-D Ohmic and L-mode Discharges

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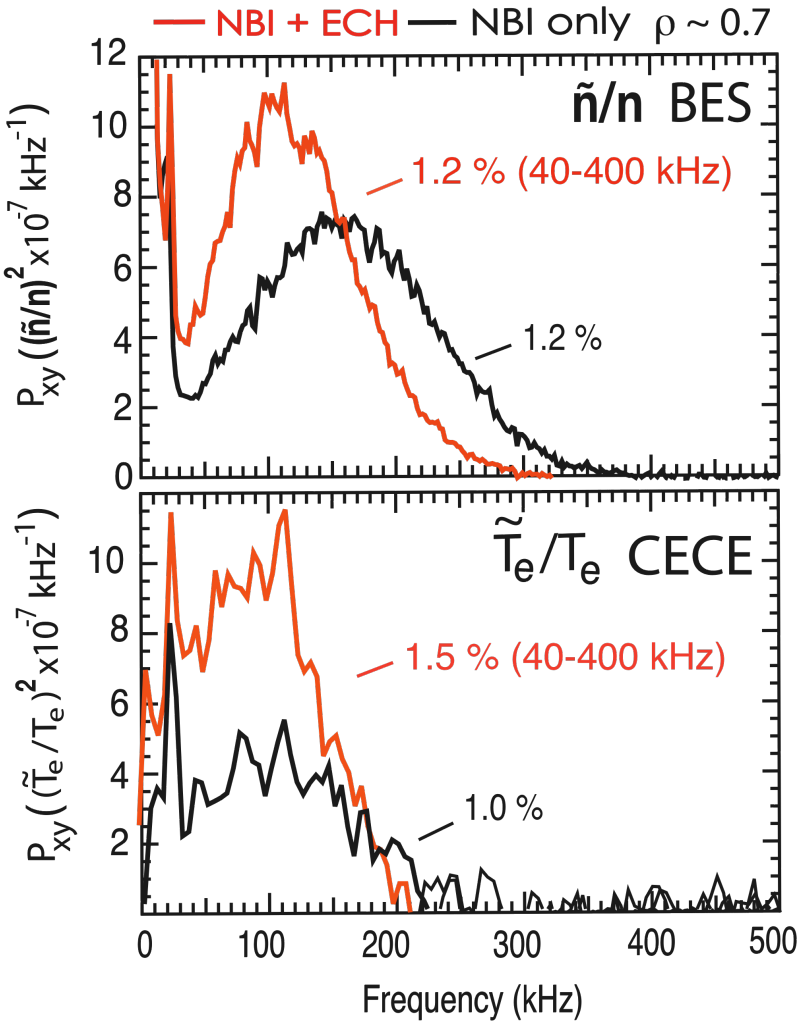

The ratio of two-field fluctuation amplitudes may be useful to test models of core turbulence and transport

Electron Cyclotron Heating (ECH) is used to modify profiles in L-mode and Ohmic plasmas, changing drives for turbulence and for Ion Temperature Gradient (ITG) and Trapped Electron Mode (TEM) instabilities

- Long wavelength ***electron temperature fluctuations*** and ***density fluctuations*** are ***measured simultaneously***
  - Correlation Electron Cyclotron Emission (CECE) ($\tilde{T}_e/T_e$: $k_\theta \rho_s < 0.3$)
  - Beam Emission Spectroscopy (BES) ($\tilde{n}/n$: $k_\theta \rho_s < 0.5$)
  - Tunable Multi-channel Reflectometer ($\tilde{n}/n$: $k_\theta \rho_s < 0.5$)
- **Experimental results:**
  - **The ratio of fluctuation levels ($\tilde{T}_e/T_e$)/($\tilde{n}/n$) increases during ECH in beam heated L-mode and Ohmic plasmas**
- **Linear Gyrokinetic Theory: Trapped Gyro-Landau Fluid (TGLF) Code**
  - The ratio of relative fluctuation levels, ($\tilde{T}_e/T_e$)/($\tilde{n}/n$), is expected to increase with increases in $\gamma_{TEM}/\gamma_{ITG}$ caused by profile changes during ECH

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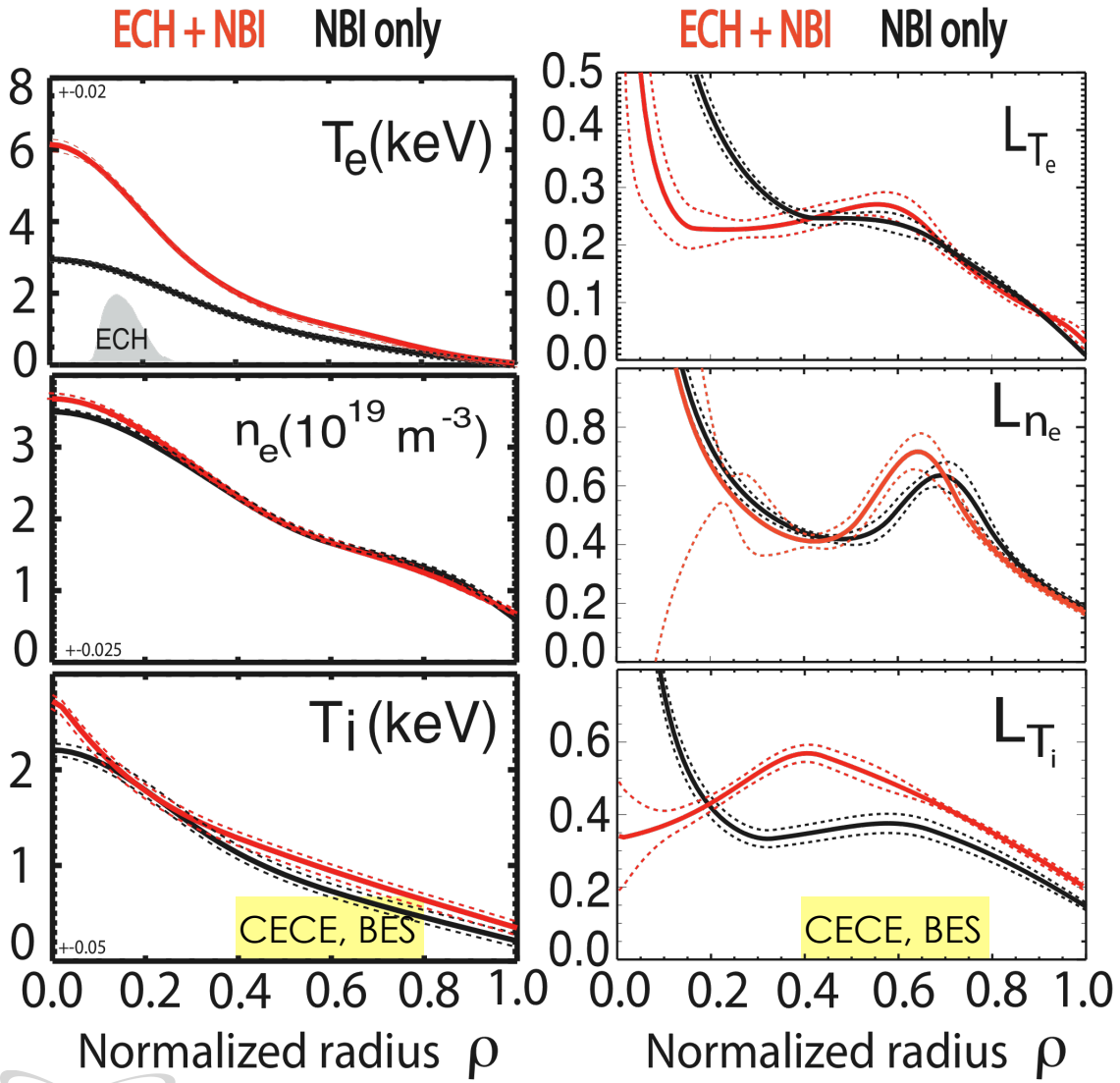
L-mode plasmas (~2.6 MW NB power): Dominant change is in T_e with ~2.5 MW ECH deposited at $\rho \sim 0.17$



- *Sawtooth-free L-mode*
  Inner wall limited

- B_T = *2.0* T, I_p = *1* MA
- 110 GHz ECH ($\rho \sim 0.17$)

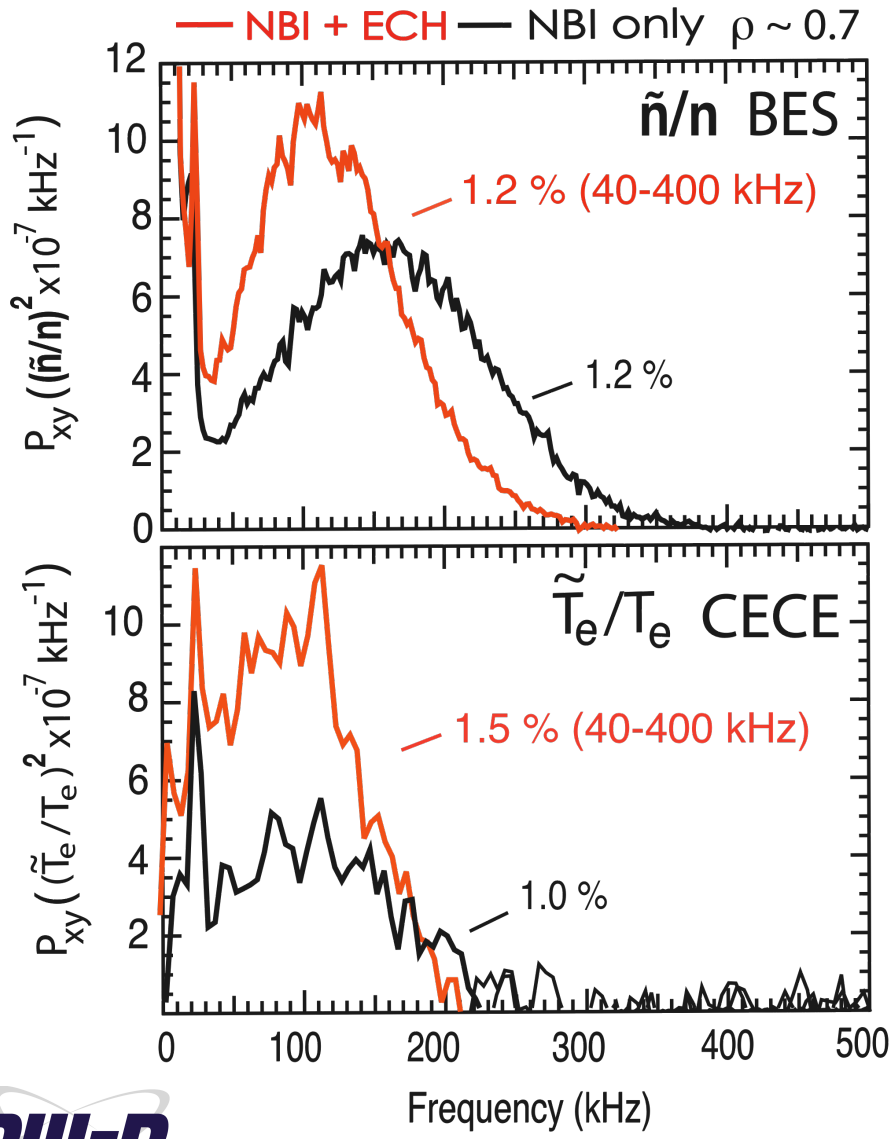
- Small changes in density

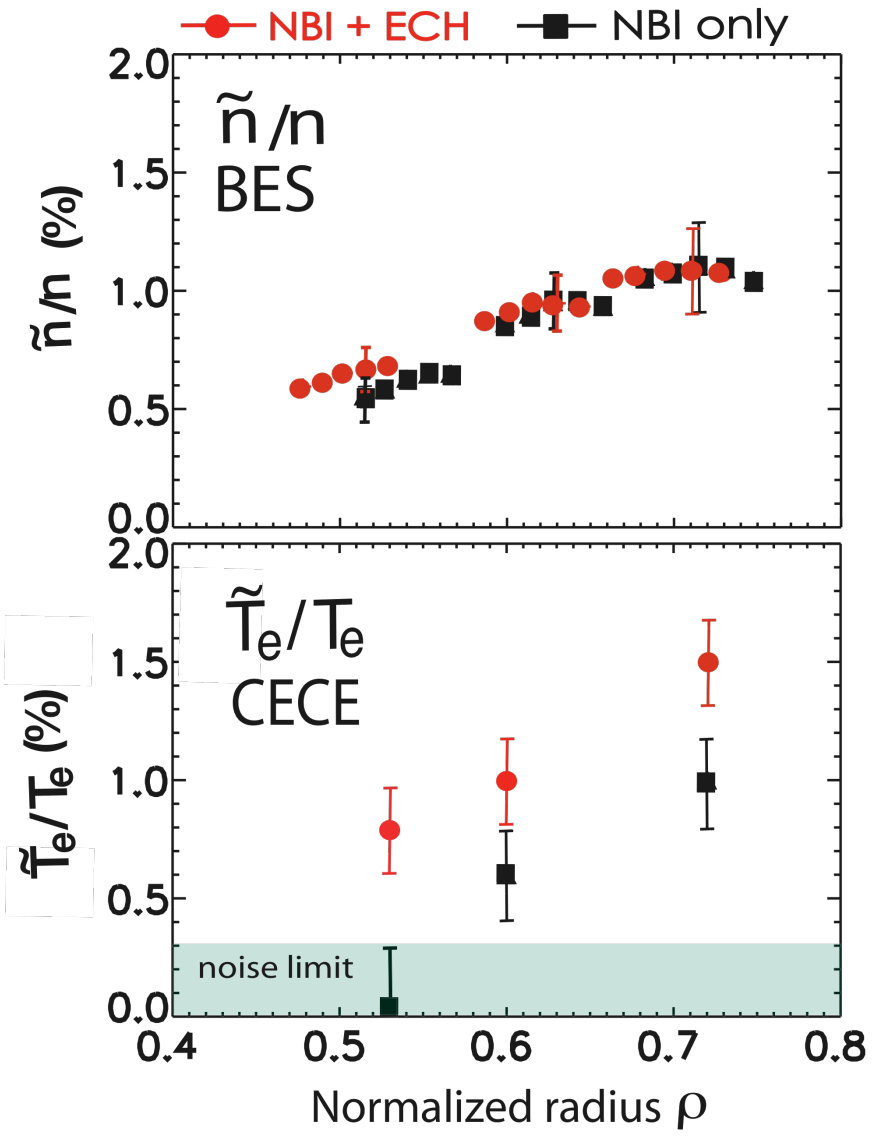
- Changes in scale lengths,
  $L_{Te} = T_e/(dT_e/d\rho)$, L_n are small

- Largest changes overall:
  - Increase in T_e (x1.5-2)
  - Decrease in collisionality

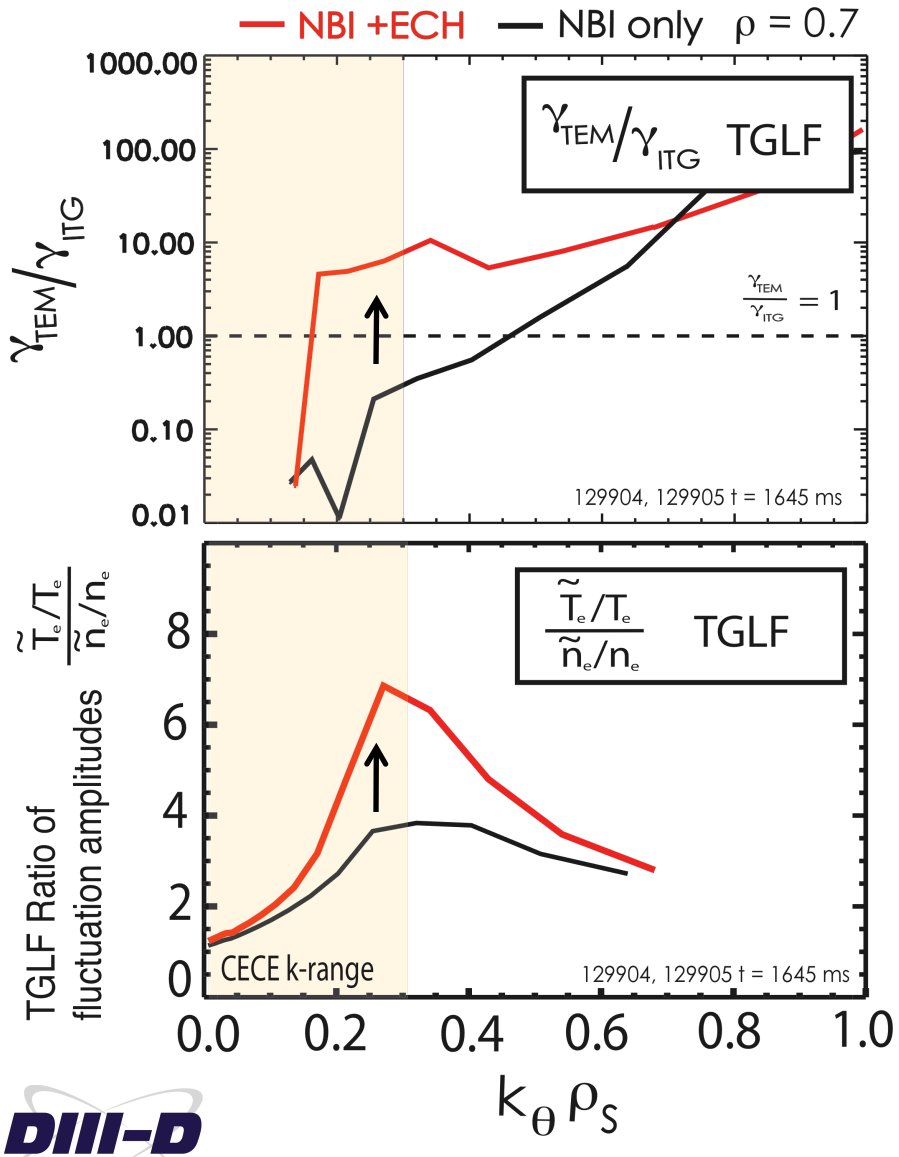
- BES and CECE measure simultaneously in range $0.4 < \rho < 0.8$

In beam heated L-mode plasmas, fluctuation levels ratio $(\tilde{T}_e/T_e)/(\tilde{n}/n)$ increases with ECH





Different responses of electron temperature and density fluctuations reflect different sensitivities to TEM/ITG drives

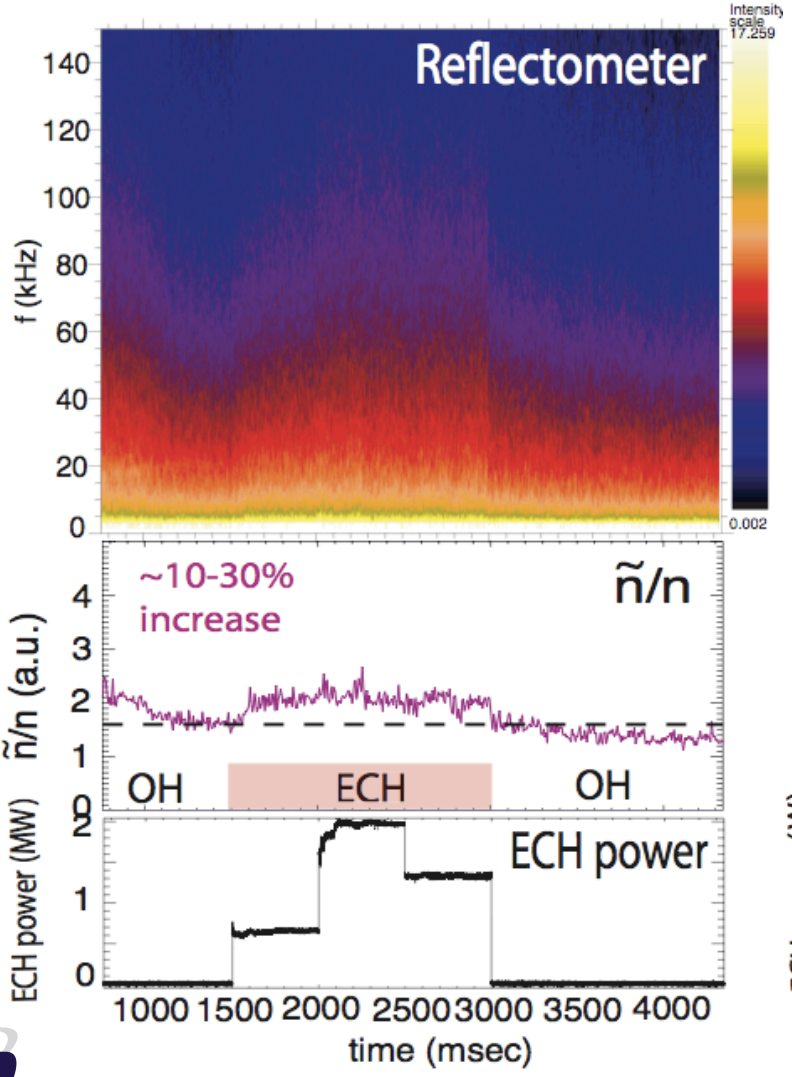


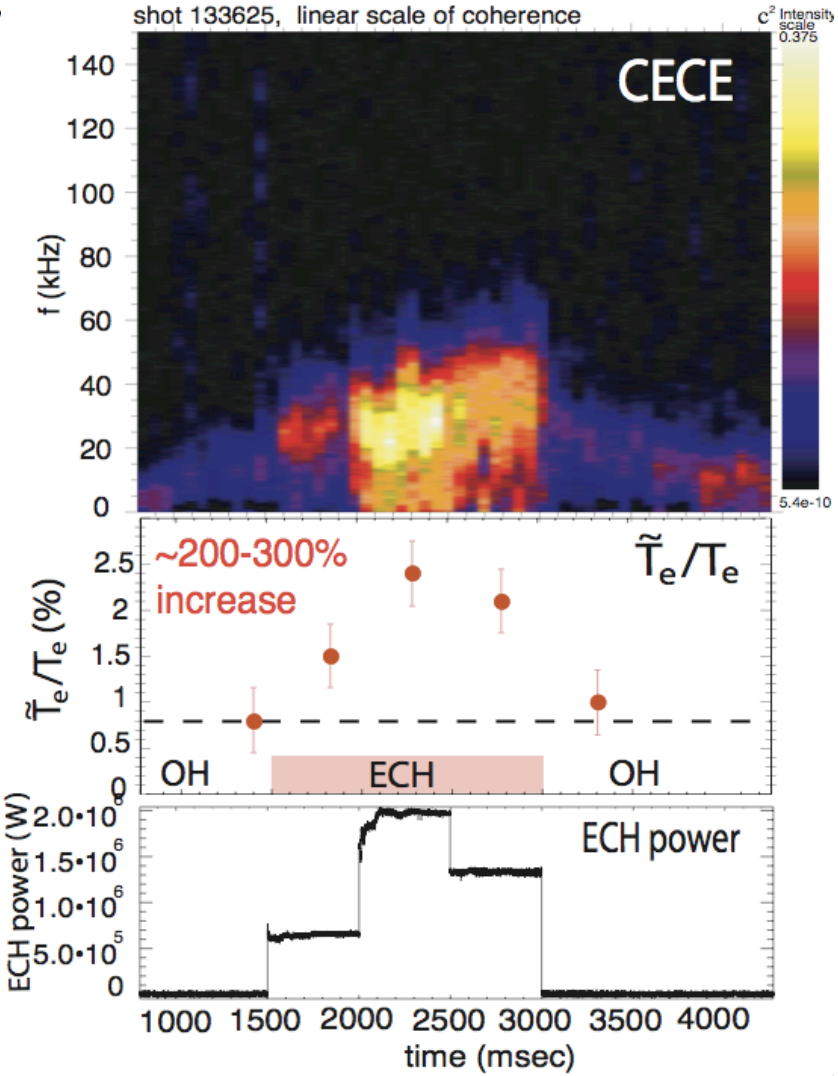
- **Electron temperature fluctuations arise from non-Boltzmann, trapped electrons**
  [Dannert POP 2005, White POP 2008]
- **$\tilde{T}_e/T_e$ sensitive to changes in TEM drive**
- **Fluctuation levels ratio scales with growth rates ratio, $\gamma_{TEM}/\gamma_{ITG}$**
  [Evensen Nucl. Fusion 1998]
- **TGLF outputs fluctuation levels calculated for each wavenumber from the nonlinear intensity of the turbulence and the moment equations**
  [Staebler POP 2007, Kinsey POP 2008]

- TGLF predicted trend is consistent with experimental observations in L-mode plasmas with ECH

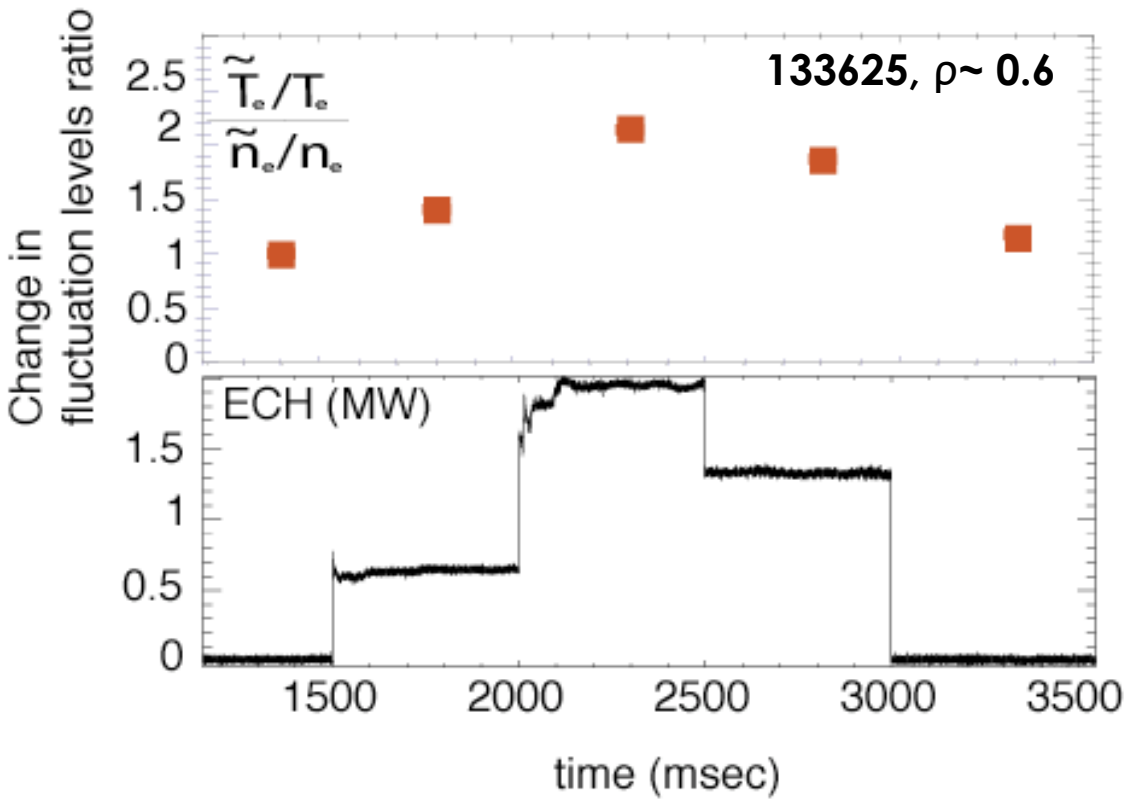
Ohmic plasmas: Dominant change is in T_e with $0.5 < P_{ECH} < 2.0$ MW ECH deposited at $\rho \sim 0.4$

- Ohmic plasma, Lower single null, $B_T = 1.9$ T, $I_p = 0.8$ MA,





In Ohmic plasmas $(\tilde{T}_e/T_e)/(\tilde{n}/n)$ increases during ECH



- Temperature fluctuations increase factors of 2-3
- Reflectometer and BES data indicate small increases in density fluctuations < 30%
- Ratio increases at least a factor of 2 from Ohmic to ECH phase in 133625
- Profile analysis and TGLF analysis are in progress

Summary and conclusions

- Scaling of fluctuation levels ratio with the growth rates ratio expected from theory
- $(\tilde{T}_e/T_e)/(\tilde{n}/n)$ ***increases*** during ECH in L-mode and Ohmic plasmas
- TGLF shows an increase in $\gamma_{TEM}/\gamma_{ITG}$ and an increase in $(\tilde{T}_e/T_e)/(\tilde{n}_e/n_e)$ in beam-heated L-mode plasmas

- Future work to test connection between growth rates ratio and fluctuation levels ratio:
  - TGLF sensitivity scans for L-mode plasmas (L_n, L_{Te}, T_e/T_i, etc.)
  - TGLF analysis for Ohmic experiments
  - Nonlinear gyrokinetic turbulence simulations

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