Variation of Turbulence and Transport with the T_e/T_i Ratio in H-Mode Plasmas

by

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with

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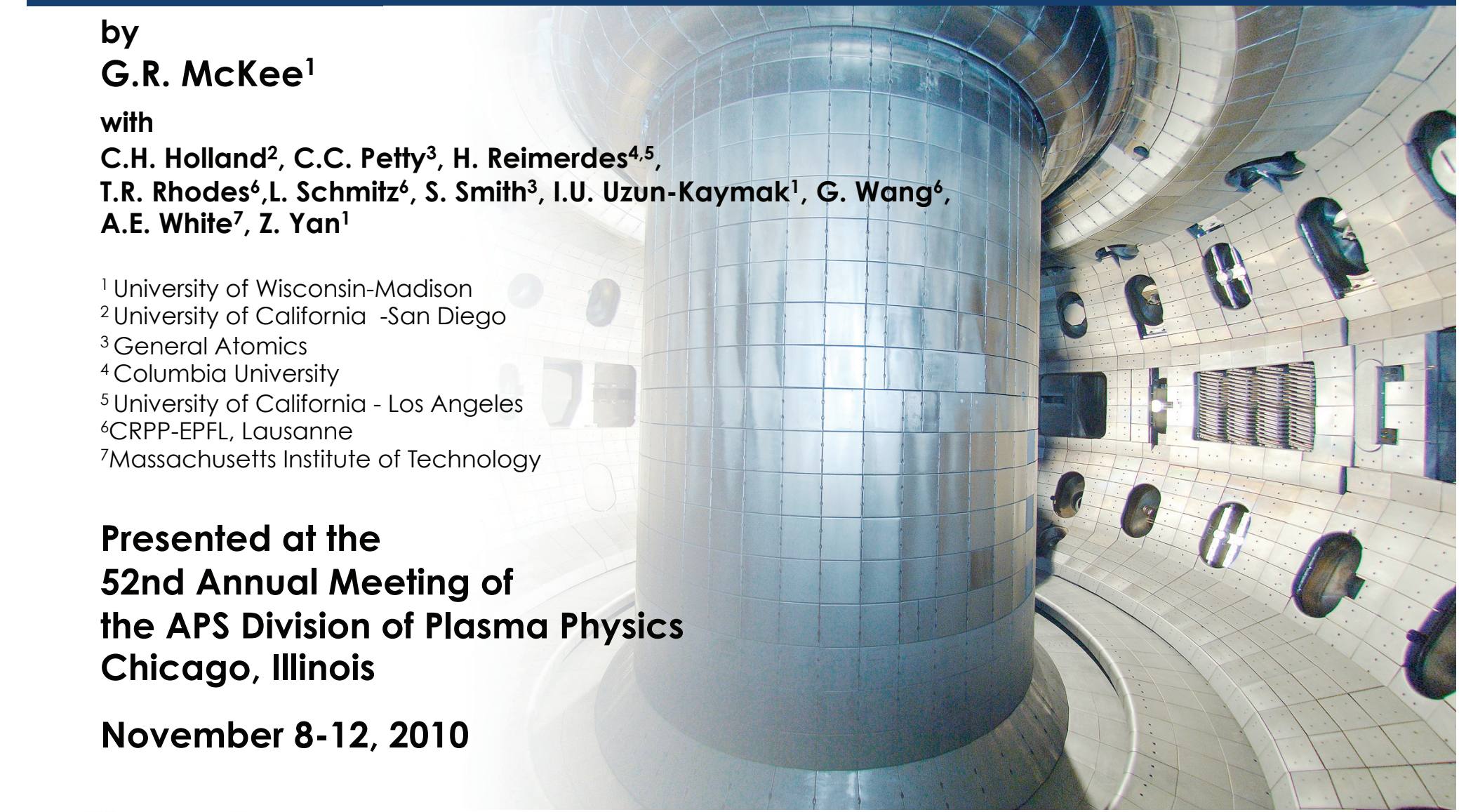

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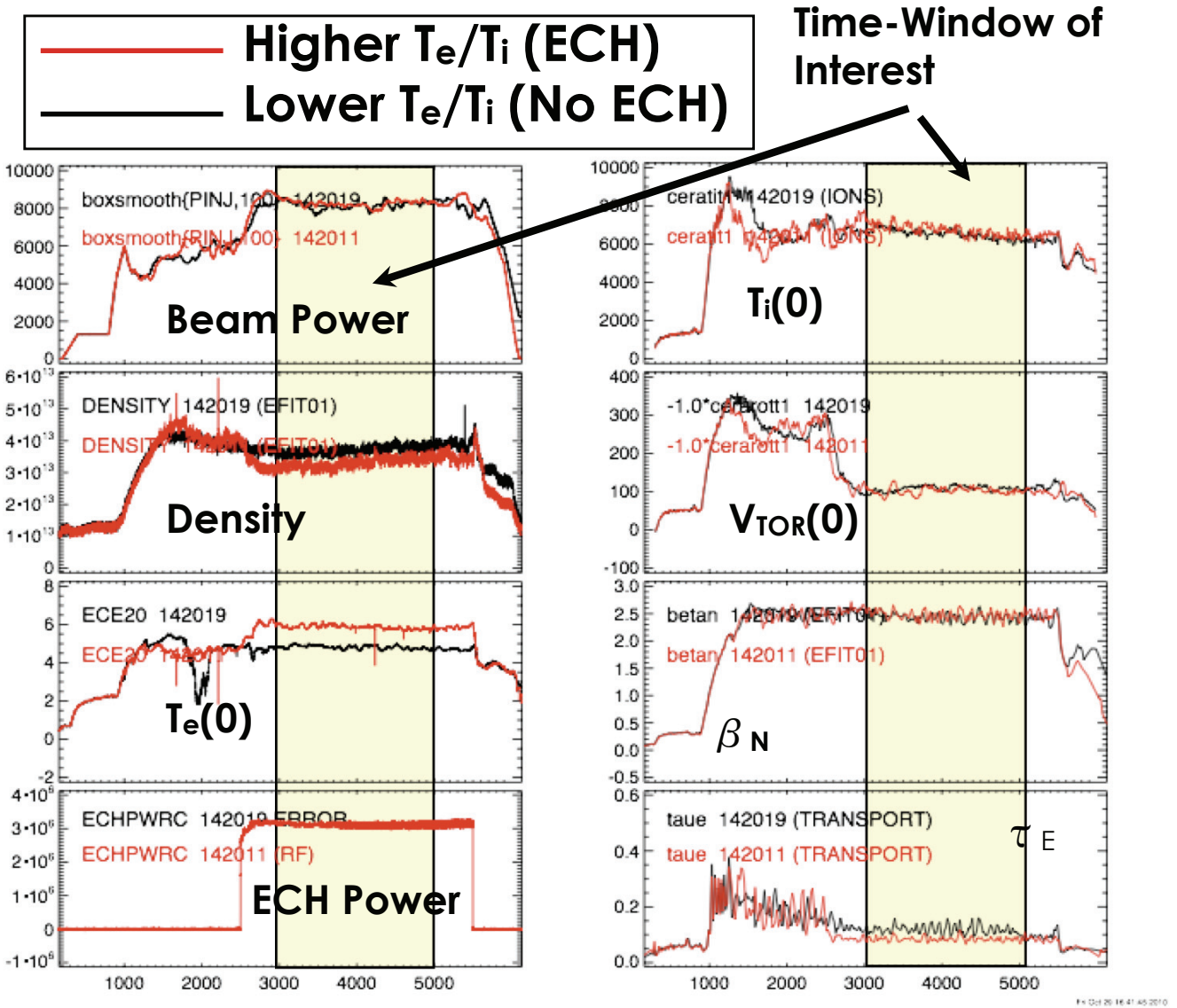
THE UNIVERSITY of WISCONSIN MADISON

Overview

- **Increasing T_e/T_i influences transport in L and H-mode plasmas**
  - Reduces density
  - Reduces rotation
  - Reduces τ_E
- **Current experiments typically operate with $T_i > T_e$**
  - Reactors/ITER will have $T_e \sim T_i$
- **Previous studies in related L-mode experiments find that**
  - Transport increases with T_e/T_i, but;
  - Long-wavelength density fluctuations relatively constant
  - T_e fluctuations increase (CECE, A. White, PoP 2009)
- **Turbulence increases significantly with T_e/T_I in H-mode plasmas**
  - Contrasts with behavior in L-mode discharges
- **These H-mode plasmas exhibit two core fluctuation modes**
- **Performed as part of the Transport Model Validation Task Force**
  - Future work will compare turbulence and transport with simulations

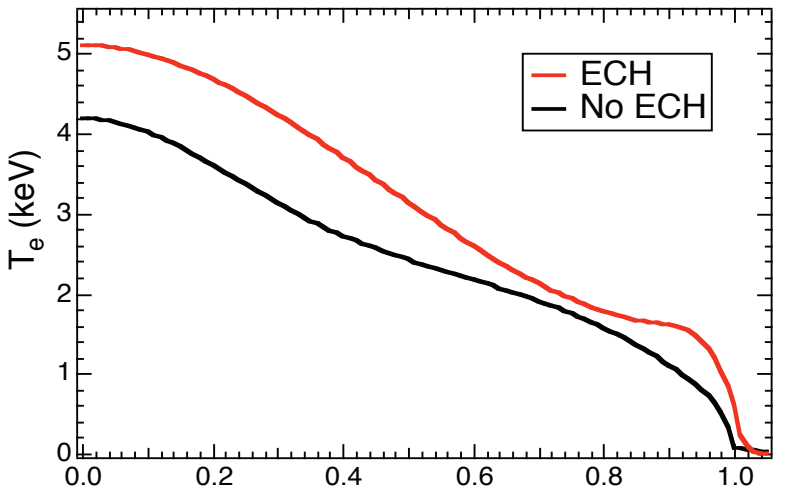
Turbulence and Transport Response to T_e/T_i Investigated in Hybrid H-mode Plasmas

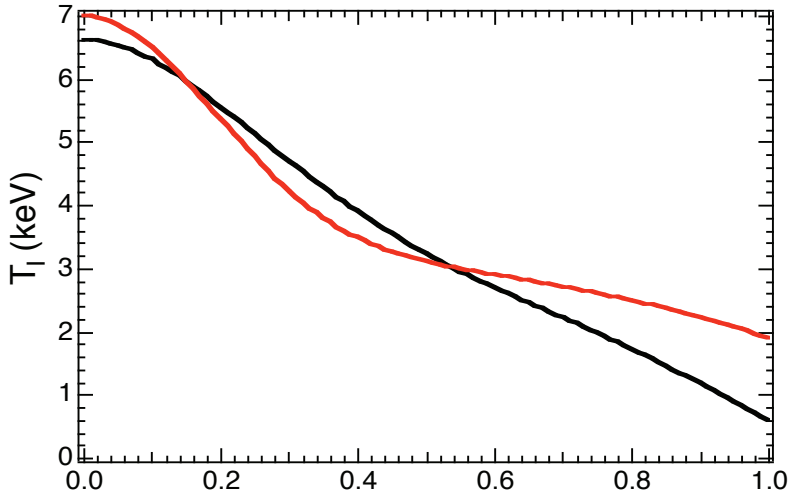
- **Hybrid H-mode Plasmas**
  - Long, quasi-steady (2.5 s)
  - Sawtooth-free
  - High-performance
- **Discharge Parameters**
  - I_p = 1.06 MA
  - B_T = 1.9 T
  - q_{95}=5.9
  - ITER Shape (ISS)
- **PCS Feedback control**
  - Density
  - T_I, Rotation (CER)
- **ECH/RF increases T_e/T_i**
  - 3.3 MW ECH/0.8 MW RF
  - 25% increase in T_e
  - 20% drop in τ_E

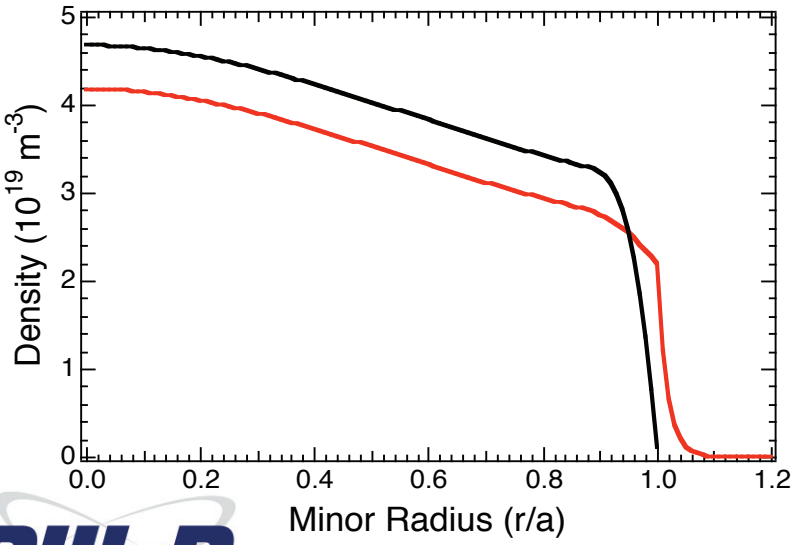


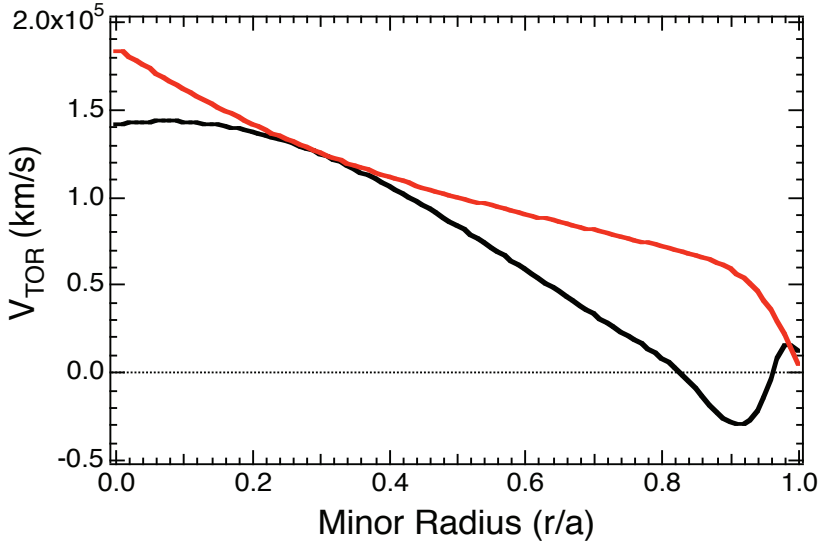
ECH Increases T_e: Impacts all Profiles

- **PCS feedback of density and beams employed to minimize variation**
- **~25% increase in T_e**









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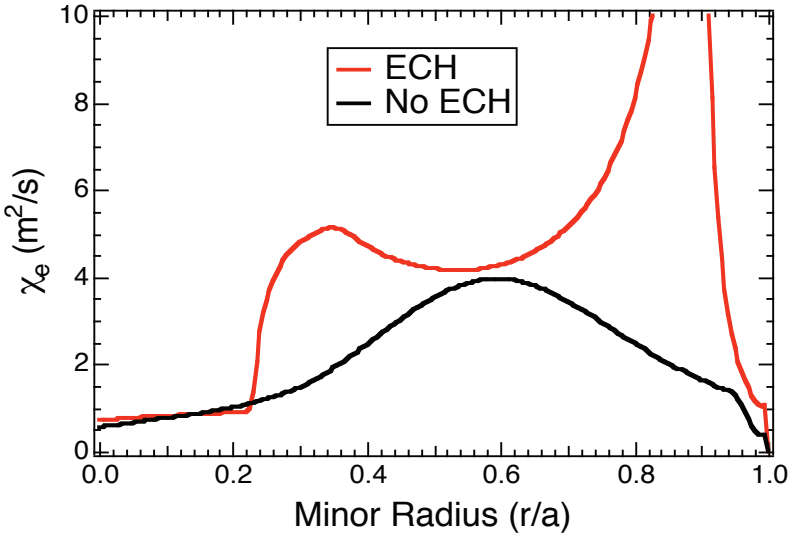
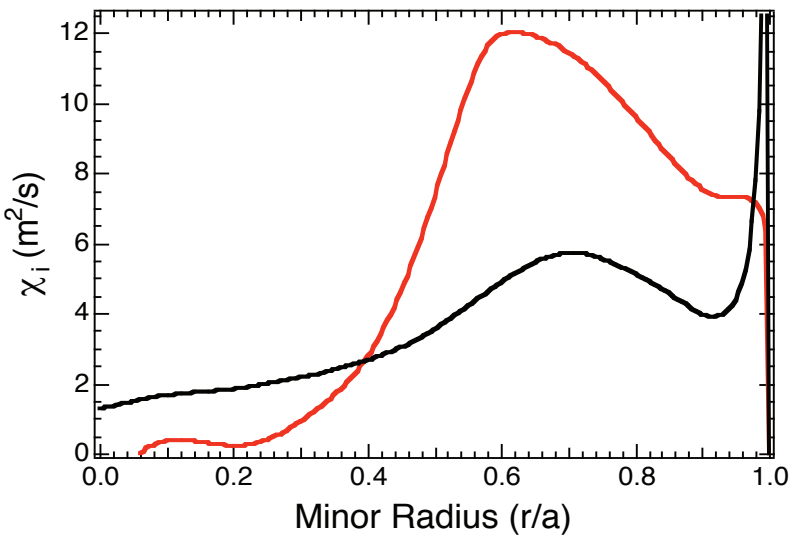
Thermal Transport Increases Significantly at Higher T_e/T_i

Thermal Diffusivity Profiles

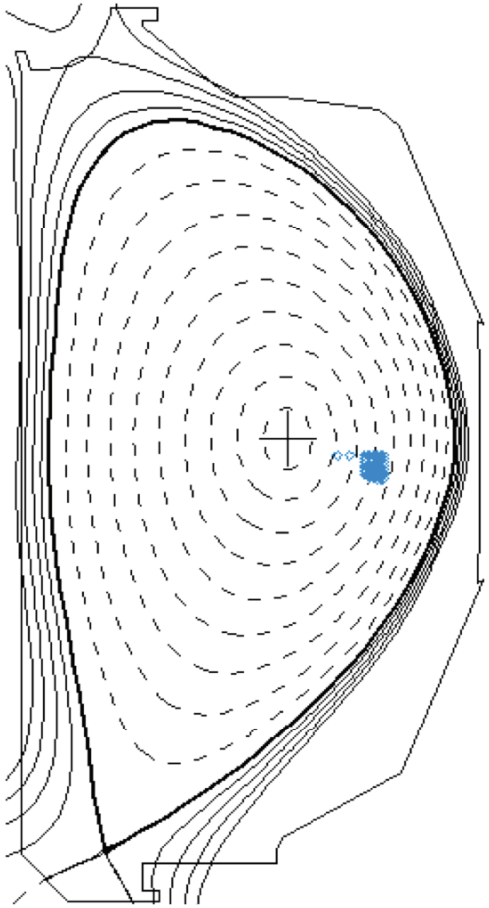




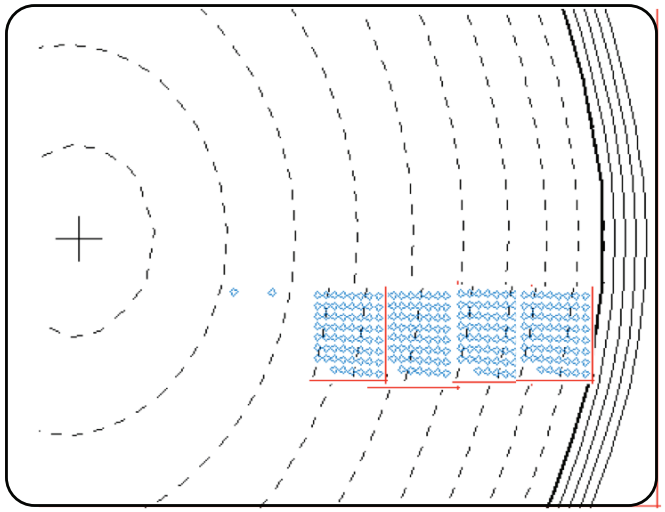
ONETWO Transport Analysis

Turbulence Measured with Beam Emission Spectroscopy

- Long-wavelength density fluctuation data acquired with high-sensitivity 8x8 BES 2D array
- Highly repeatable discharges allow for diagnostic scans (r, k)



$k_\perp \rho_i < 3\ cm^{-1}$



Long discharges (2.5 s steady phase) allow for ensemble averaging to discern low amplitudes ($\tilde{n}/n<0.5\%$) fluctuation characteristics

Fluctuation data also acquired with CECE, DBS-5, DBS-8

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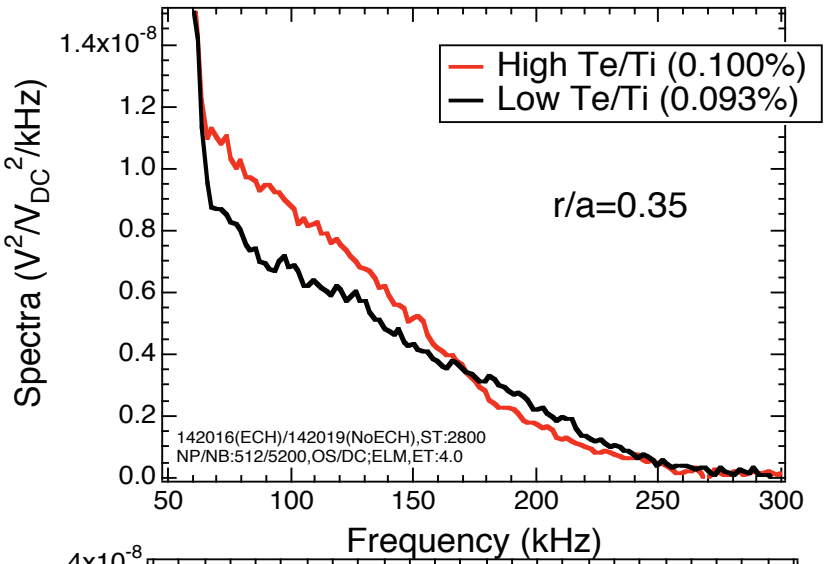
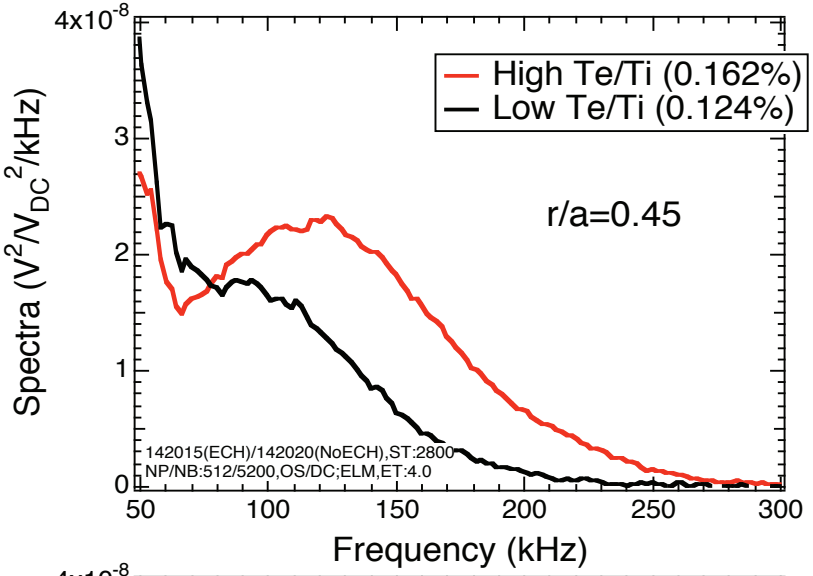
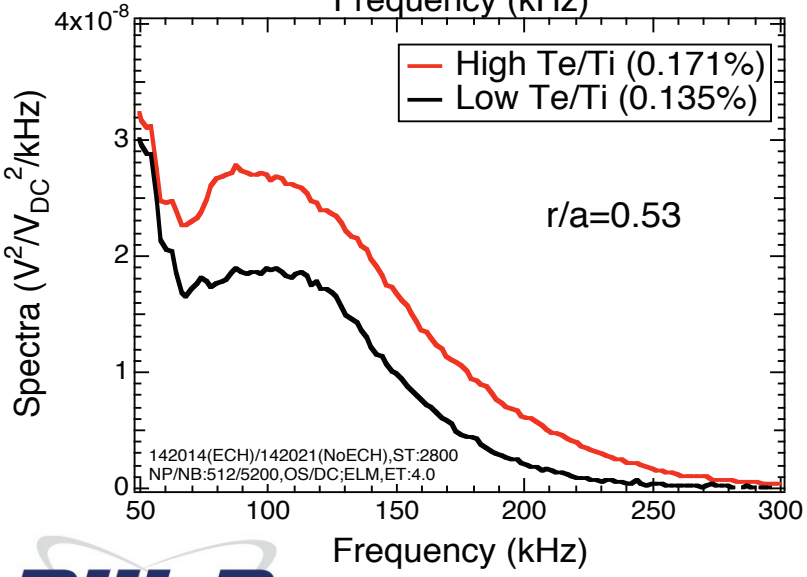
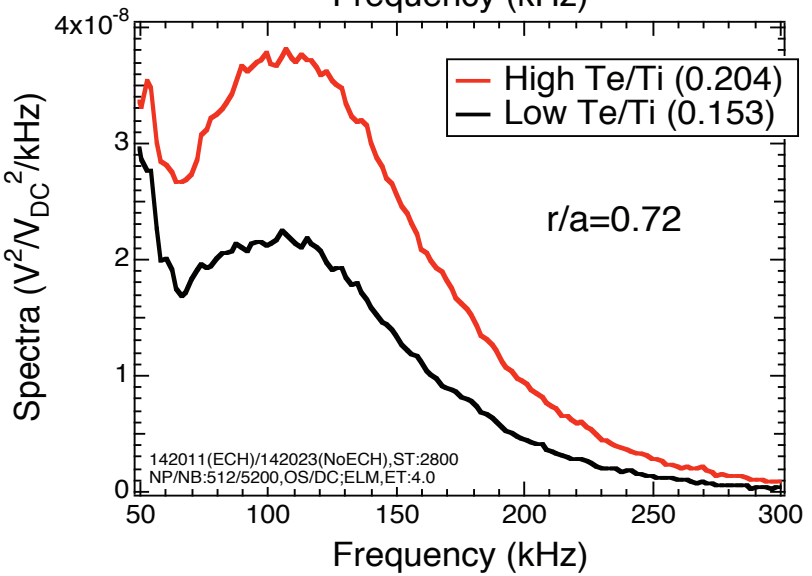
Long-Wavelength Density Turbulence Increases with T_e/T_i

- **Qualitatively similar behavior observed across radius**









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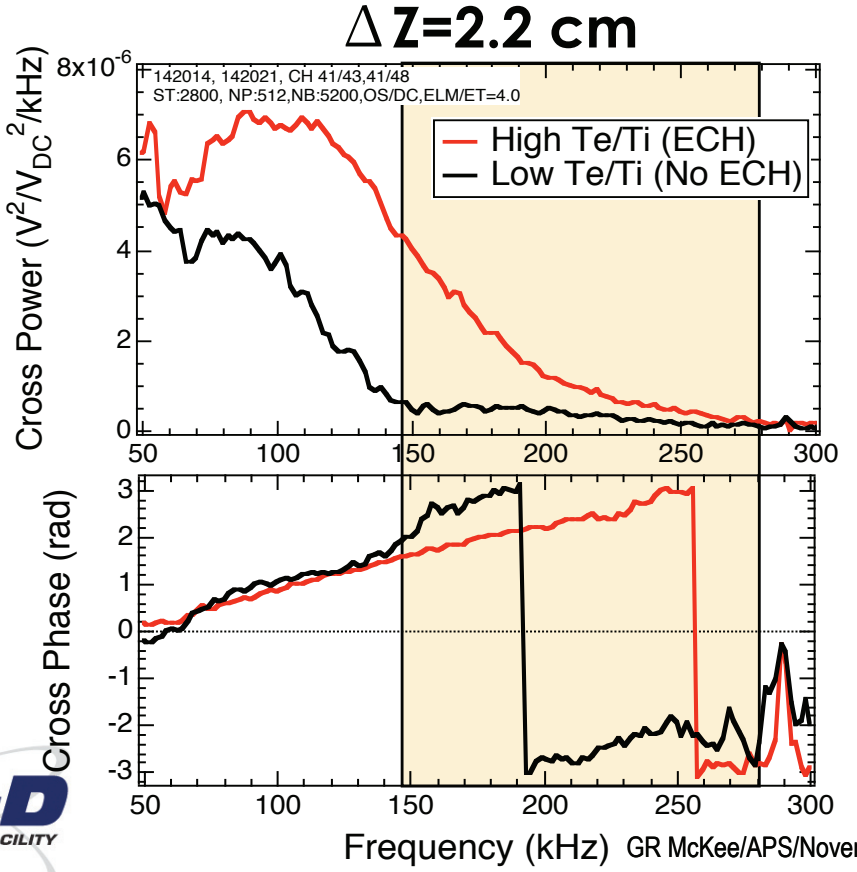
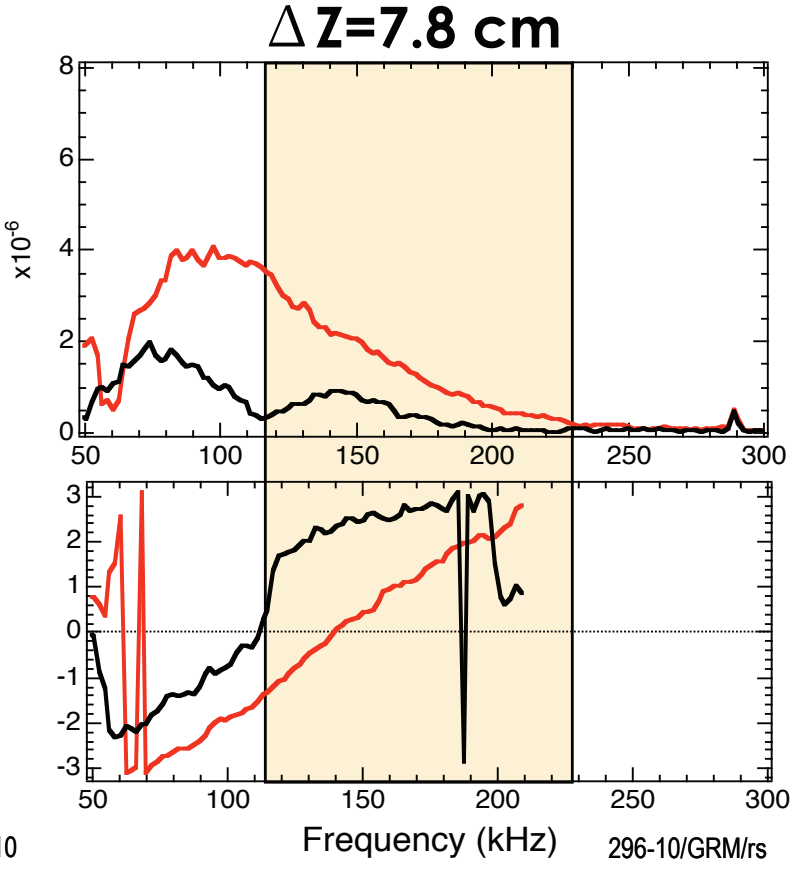
H-Mode Core Fluctuation Spectra Exhibit Two

- **Non-ECH heated discharge has 2 frequency regions with distinct spectral and phase shift (propagation velocity) characteristics**
  - Likely reflects two different modes/instabilities
  - ECH-heated discharge exhibits single mode
  - Poloidally-separated channels required to distinguish modes
  - Higher frequency mode has lower amplitude; longer correlation length





GR McKee/APS/November 2010

296-10/GRM/rs

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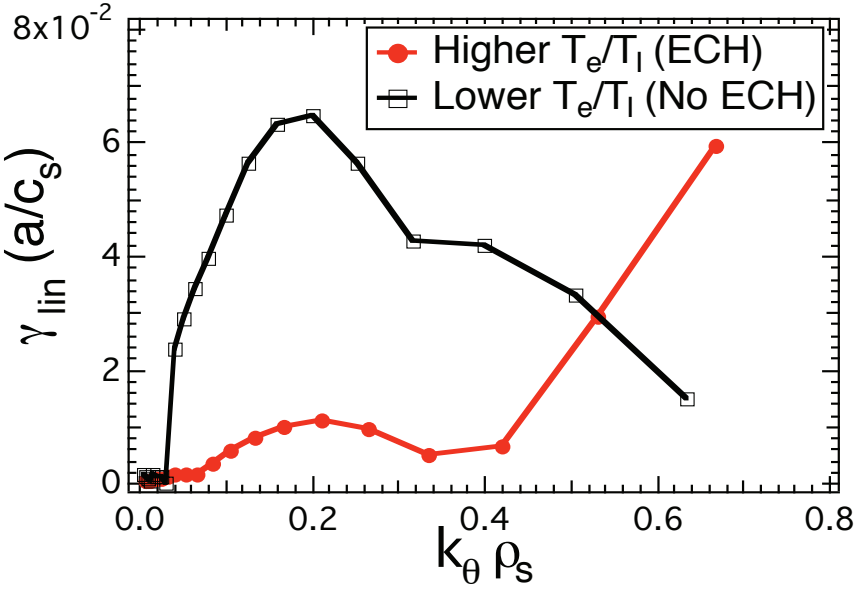
TGLF Calculations Show Lower Growth Rates at Higher T_e/T_I

- **TGLF analysis with measured n, T, rotation profiles**
- **Mixture of ion modes at lower-k, electron modes at higher-k**
  - Higher T_e/T_i discharges show significantly higher growth rates at higher k ($0.6 < k_\perp \rho_s < 10$)

ρ **=0.6**

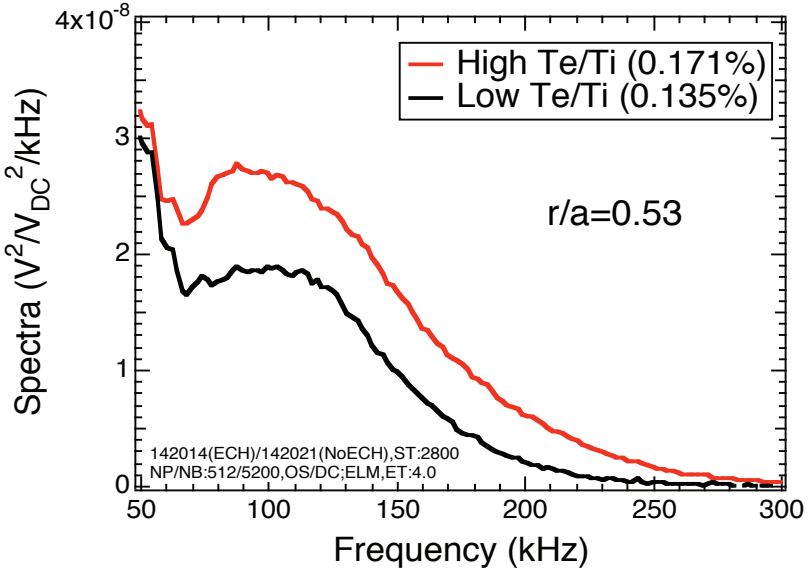


See C. Holland, NI2.005, Wed.

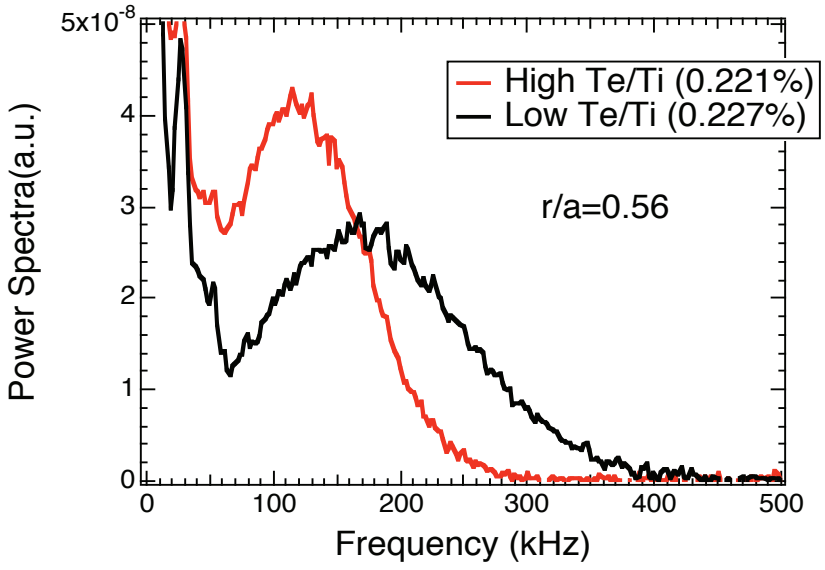
L-Mode and H-mode (Hybrid) Discharges Exhibit Different Turbulence Response to T_e/T_i Variation

- **L-mode: long-wavelength density fluctuations exhibit small change in magnitude with T_e/T_i**
  - Spectral shape change reflects local changes in ExB Doppler shift
  - T_e-fluctuations increase (CECE)
- **H-mode: long-wavelength density fluctuations increase measurably in magnitude with T_e/T_i**

H-mode (Hybrid)



L-mode



v_θ (low Te/Ti) = 8.0 km/s

v_θ (high Te/Ti) = 6.9 km/s

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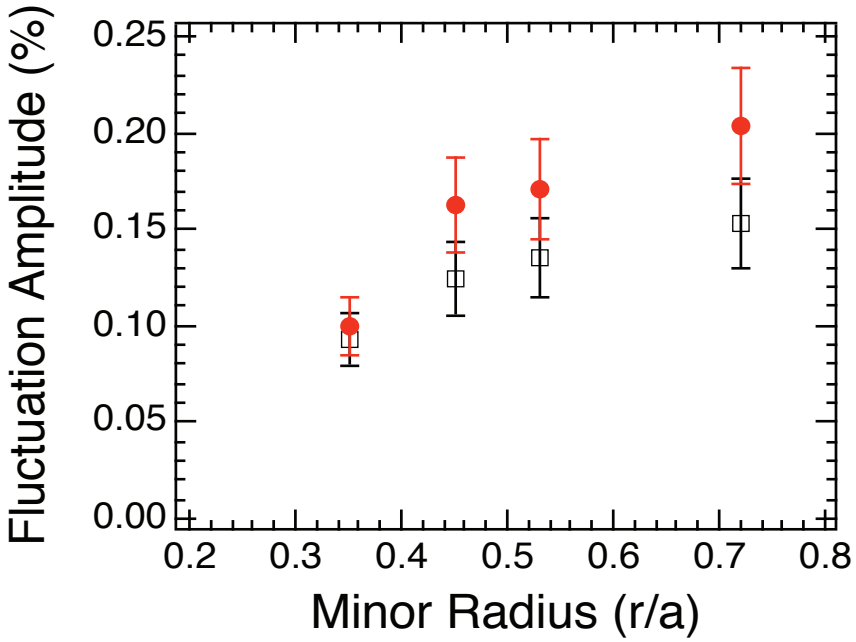
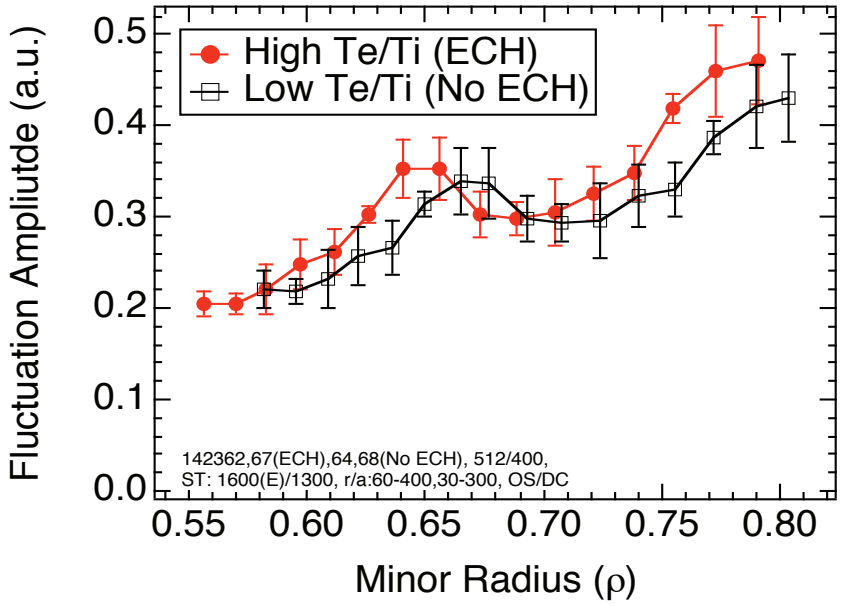
Fluctuation Variation with T_e/T_i Different for L-Mode & H-mode

- **Hybrid H-mode discharges exhibit a clear 30-40% increase in low-k density fluctuation amplitude with increasing T_e/T_i**
- **L-mode plasmas exhibit small, if any, increase with T_e/T_i**
  - Consistent with previous and recent experiments L-mode

H-Mode



L-Mode



T. Rhodes, IAEA-2010

Summary

- **Turbulence and transport response to variation in T_e/T_i examined in Hybrid H-mode plasmas**
  - $T_e/T_i < 1$, increased by 25% via 3.3 MW ECH + RF heating
  - 20% reduction in τ_E
- **Low-k density turbulence increases by 25-40% with T_e/T_i**
  - Related L-mode experiments show much small increase in $\tilde{n}/n$ with $T_e/\tilde{T}_i$, but T_e/T_e increases significantly
- **Core H-mode turbulence exhibits signature of two distinct turbulence bands at different (but overlapping) frequency/ wavenumber ranges**
  - Mode structure varies appreciably with T_e/T_i
- **Initial TGLF growth rate calculations do not appear consistent**
  - But: higher k growth rates increase significantly at higher T_e/T_I
- **Future analysis with nonlinear simulations (e.g., GYRO) for model validation studies**