Design of an Experiment to Discriminate Between ITG and TEM Turbulence

by

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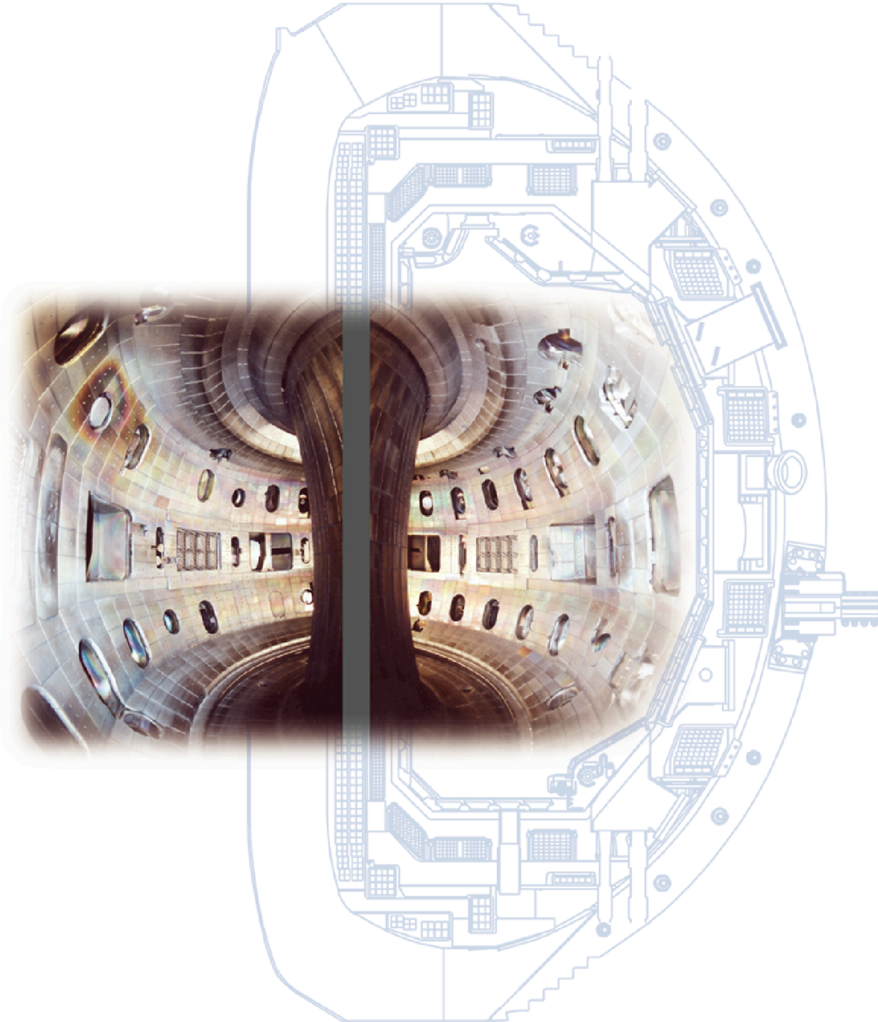

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Introduction

- **Motivation: Use turbulence code predictions to help determine best parameter regimes of interest for comparison with experimental turbulence measurements.**

- **Simplify initial comparisons by creating discharges where**
  - either ITG or TEM dominates the turbulence spectra or
  - line splitting allows identification of both modes simultaneously, where line splitting is positive or negative shifts of ITG or TEM frequencies about the Doppler shift frequency due to a radial electric field

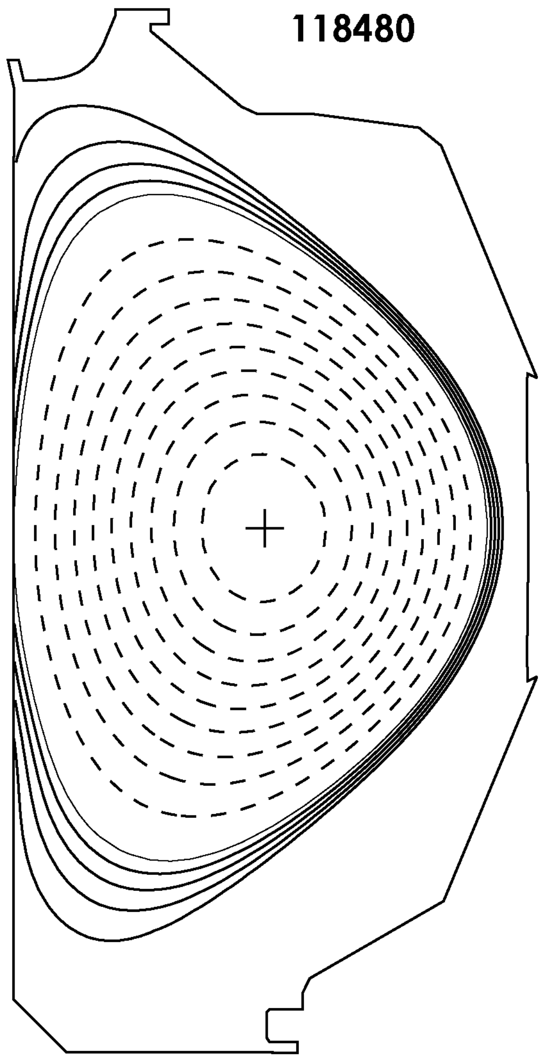
- **Two experimental approaches identified**
  - create a discharge where TEM dominates using ECH. By replacing ECH power with NBI power, ITG modes are expected to dominate.
  - attempt to turn the TEM mode on and off by driving the normalized local gradient scale length a/L_{T_e} above and below the threshold value, using the ECH swing technique where ECH is deposited at two closely spaced radial locations with power applied alternately at each spacial location.

Discharge Characteristics Favoring TEM Dominance

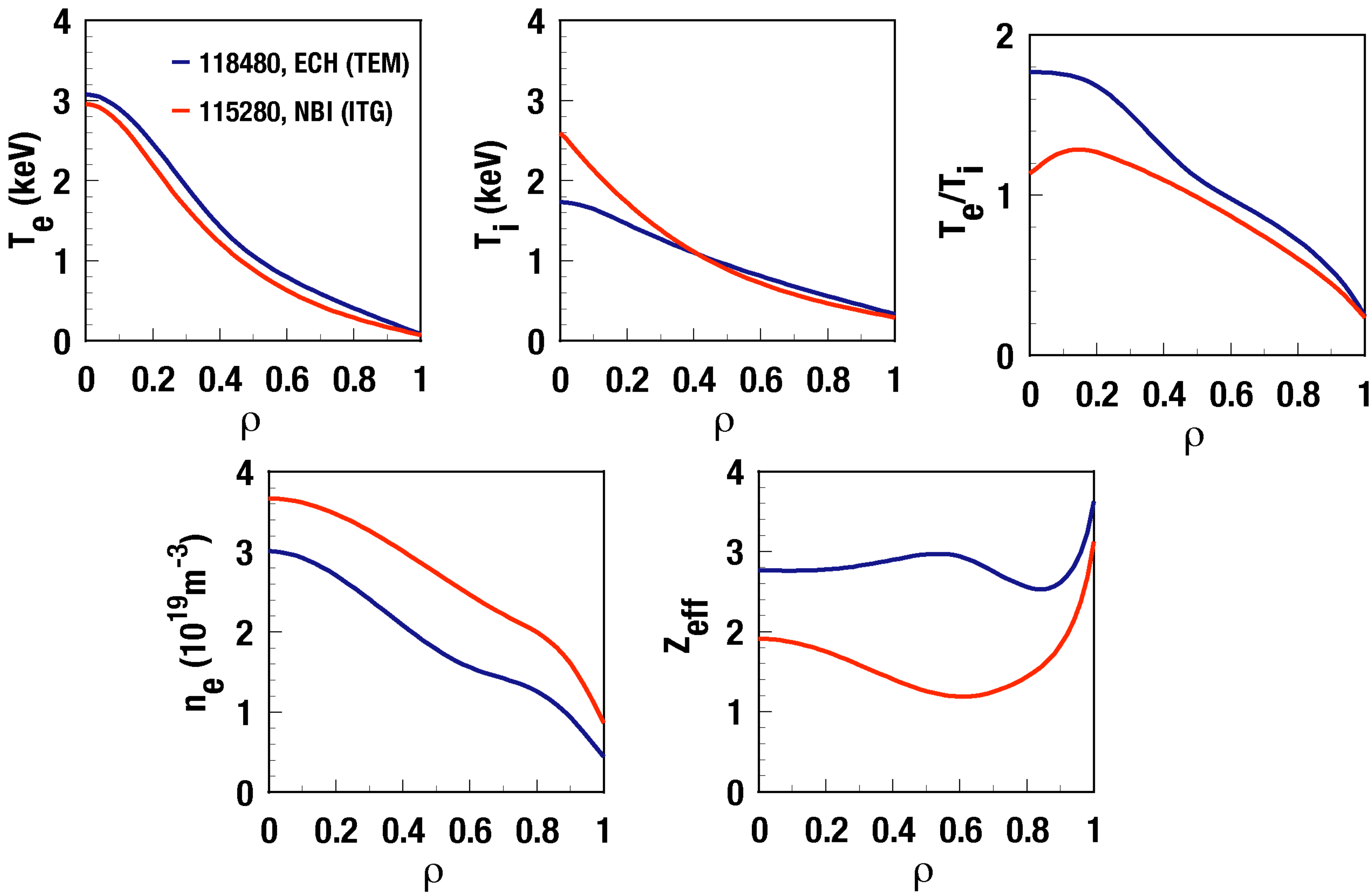
- **Low collisionality $\Rightarrow$ low density**
- **$T_e > T_i$ $\Rightarrow$ ECH auxillary power**
- **Low threshold for TEM activity**
  – large values of a/L_{T_e} $\Rightarrow$ peaked temperature profile
- **Replacing ECH power with NBI power will favor ITG dominance by**
  – increasing T_i/T_e
  – increasing a/L_{T_i}

L-mode Target Discharge Identified With TEM Dominant

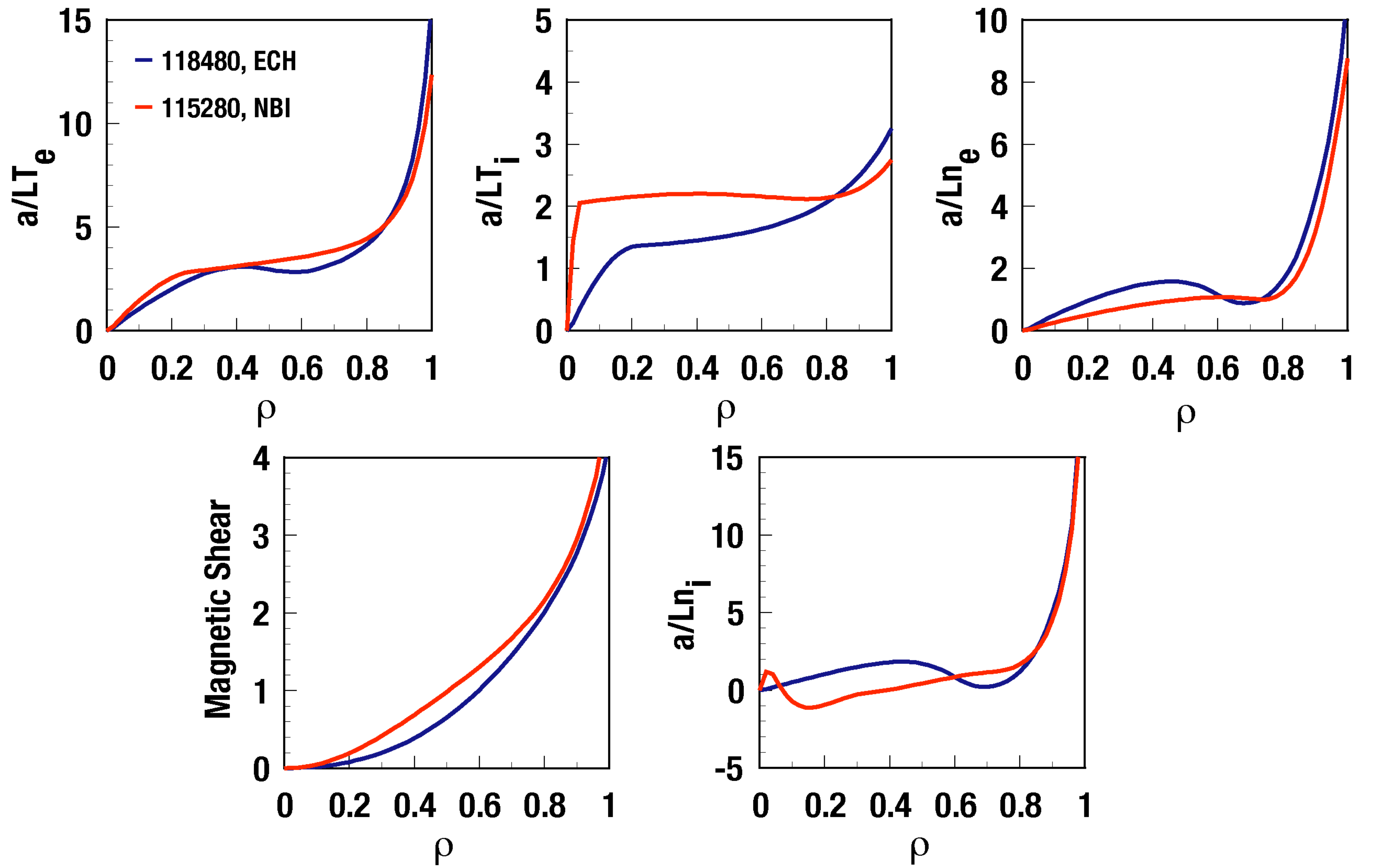
- Limited on inside wall to avoid H-mode transition
- I_p = 0.8 MA, B_T = 2.0 T, n_e = 1.7 x 10^{19} m^{-3}, q_a = 7
- Early NBI to delay onset of sawteeth, then NBI off and ~2 MW ECH power
- Similar discharge with 4 MW NBI (115280) has dominant ITG modes



Profiles for TEM Dominant and ITG Dominant Discharges



Normalized Gradient Scale Lengths



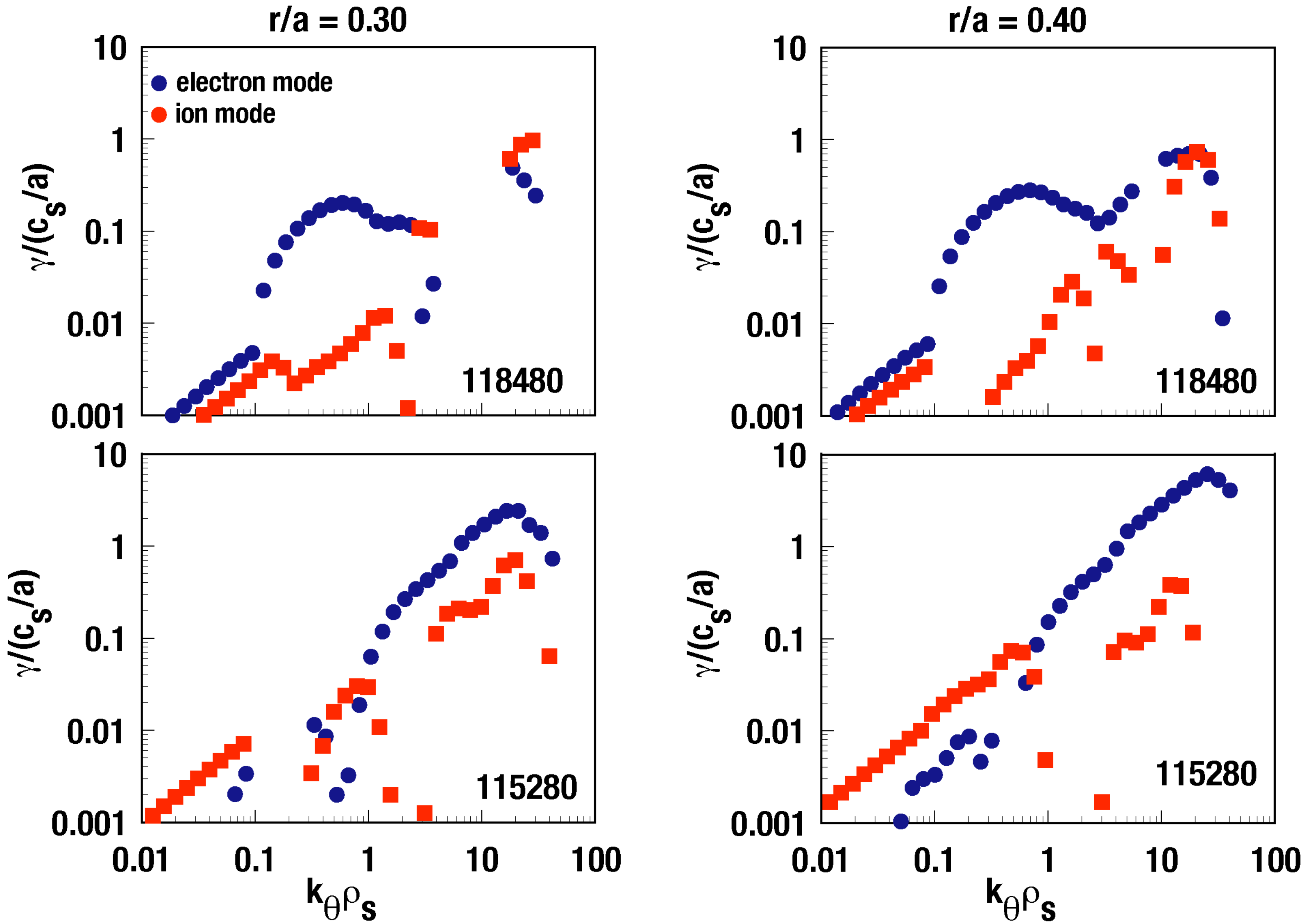
TGLF Model Used To Compute Drift Wave Turbulence

- **Trapped Gyro-Landau Fluid model (TGLF) is a significant improvement over the GLF23 model used worldwide**
  - provides better fit to non-linear gyrokinetic turbulence simulations
  - particularly improved the treatment of trapped particles
  - speed is 100x faster for linear stability analysis of experimental discharges
  - output includes growth rates for the dominant electron and ion modes

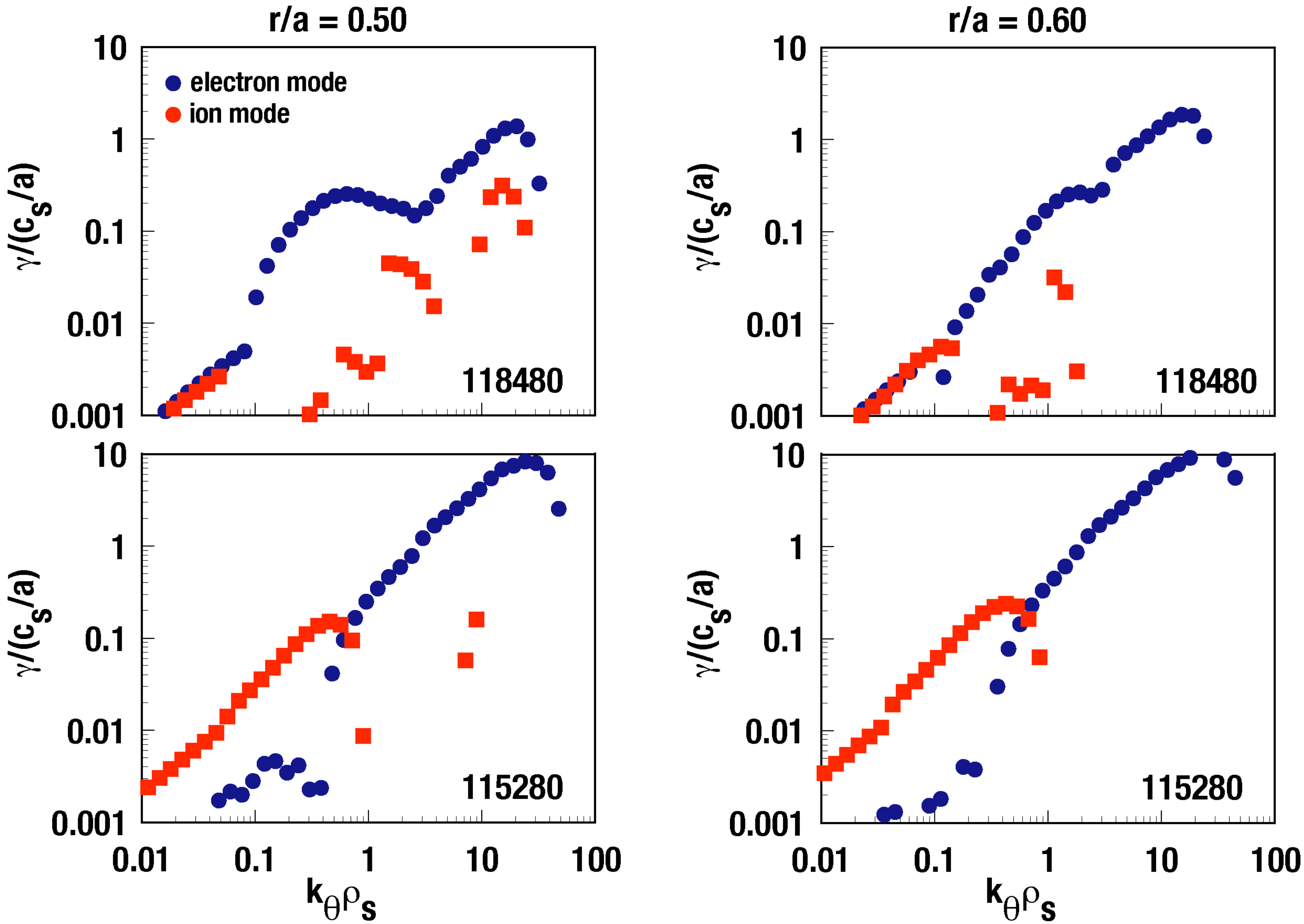
- **Contains comprehensive physics including**
  - TIM, ITG, TEM, ETG modes computed from a single set of equations
  - shaped magnetic geometry
  - electron-ion collisions
  - fully electromagnetic
  - dynamic electrons, ions and impurity ions considered

- **See IAEA07 paper TH/1-2 by G.M. Staebler for detailed comparison of TGLF and GLF23 models (also to appear in Phys. Plasmas May issue).**

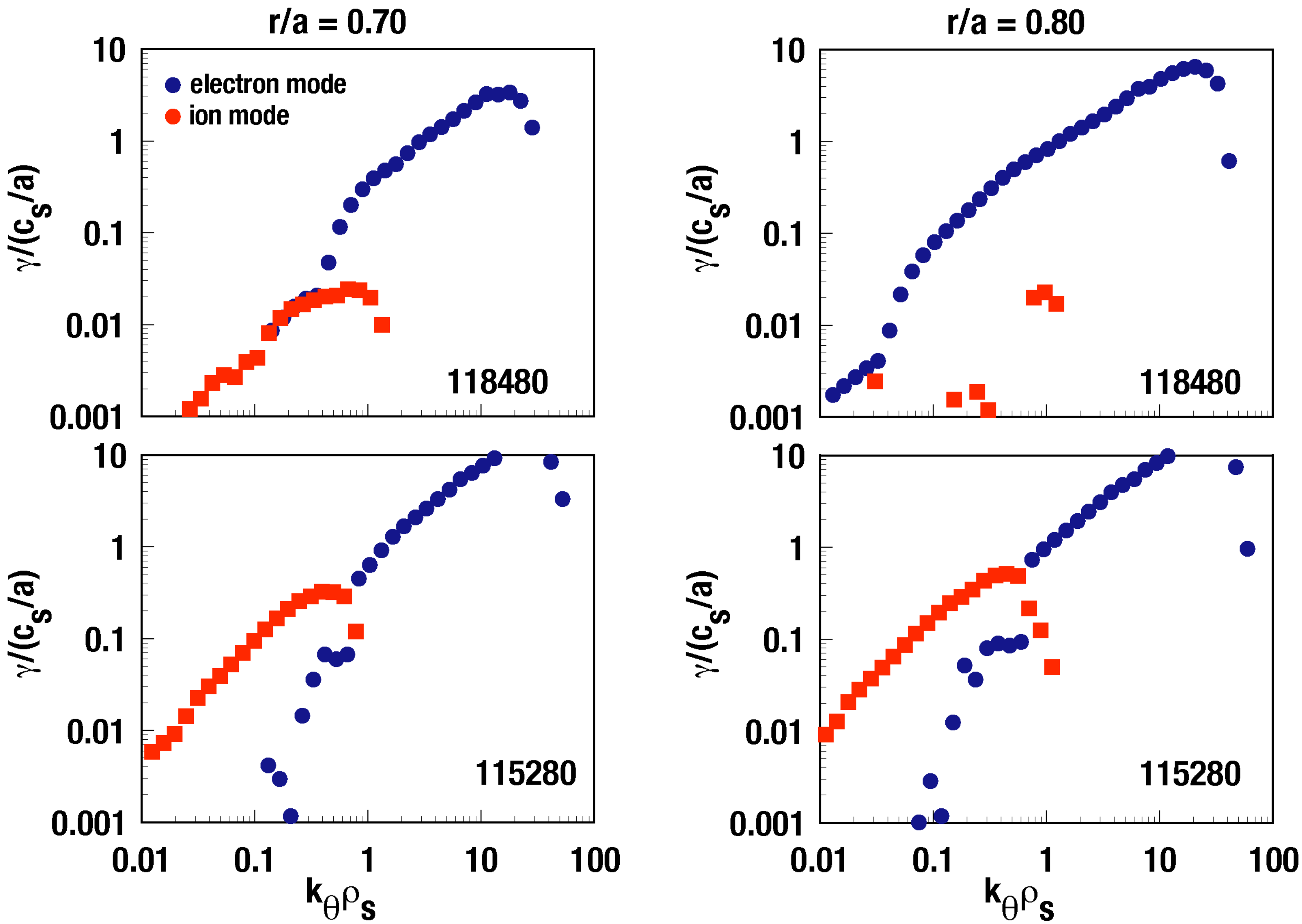
Growth Rate Spectra Dominated By TEM For 118480 In Spectral Range $k_\theta\rho_s \sim 0.1 - 1$ Or $k_\theta \sim 0.5 - 5\ cm^{-1}$



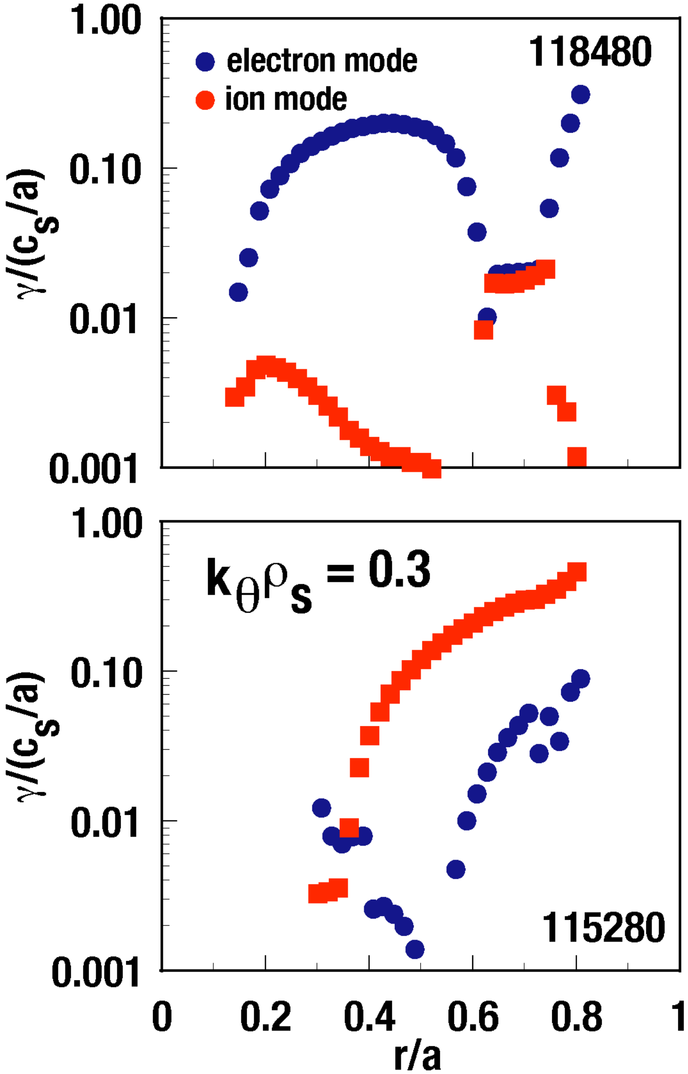
Growth Rate Spectra Dominated By ITG For 115280 In Spectral Range $k_\theta \rho_s \leq 0.4$ Or $k_\theta \leq 3\ cm^{-1}$



Growth Rate Spectra (continued)

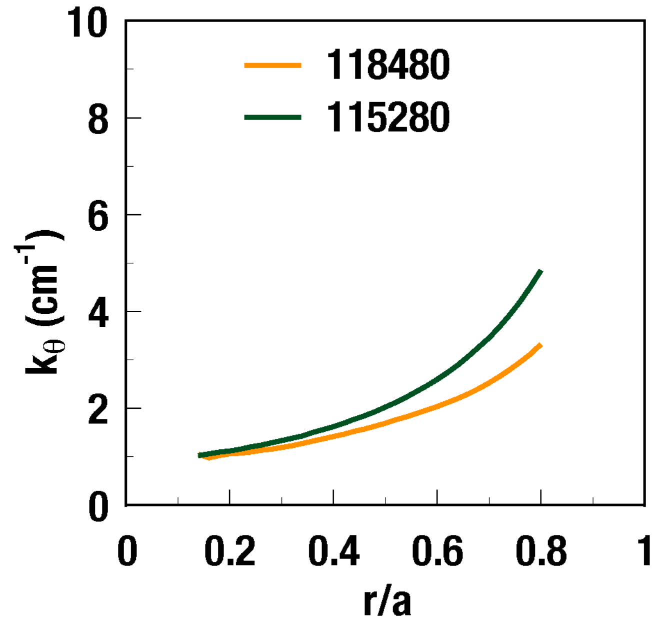


The Best Region To Look In The Plasma For Maximum Difference In Growth Rates Is r/a = 0.4 - 0.5



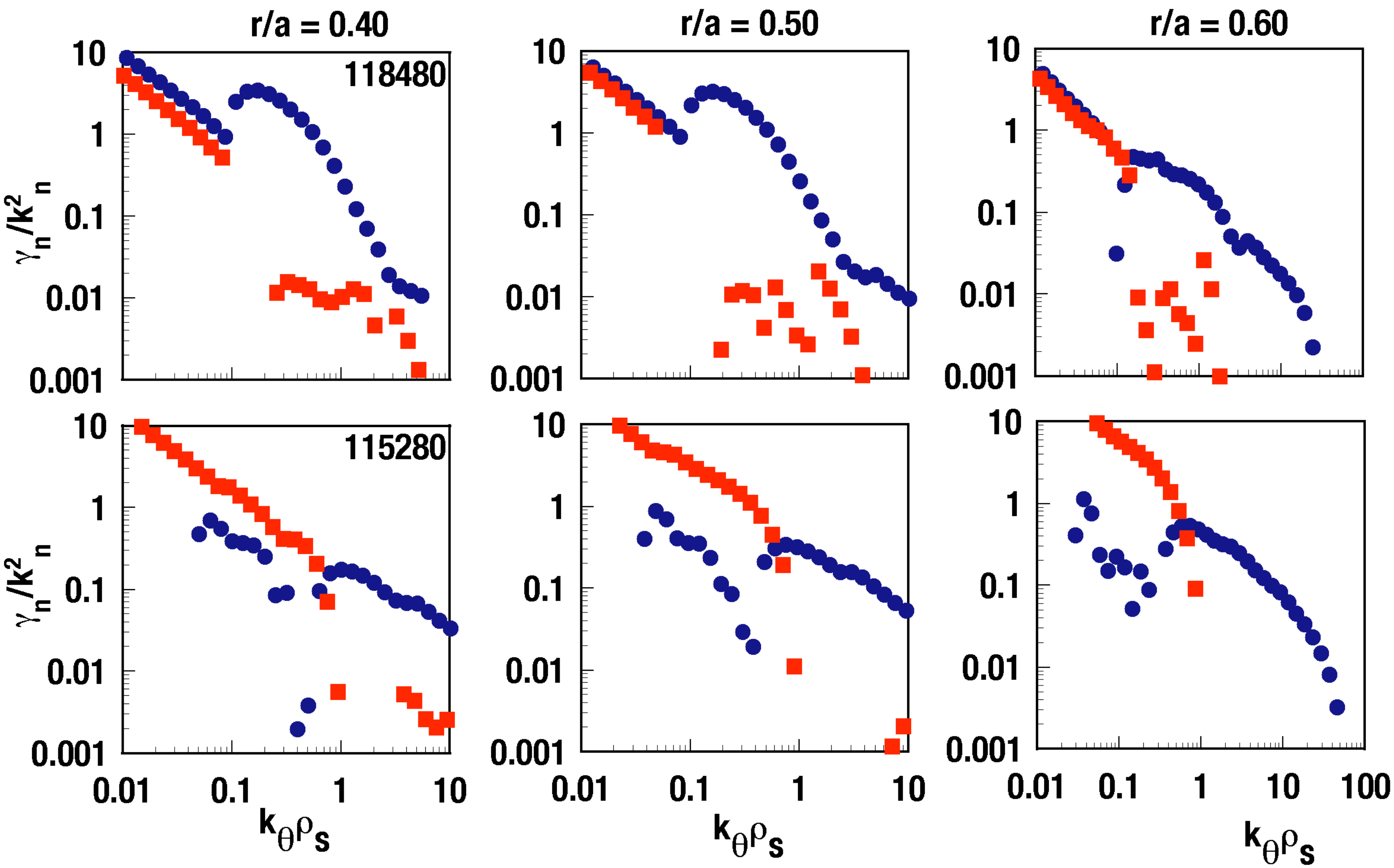
- Growth rate profile at $k_\theta \rho_s = 0.3$
- For r/a = 0.4 - 0.5 at $k_\theta \rho_s = 0.3$

  $k_\theta = 1.4 - 2.0 \text{ cm}^{-1}$

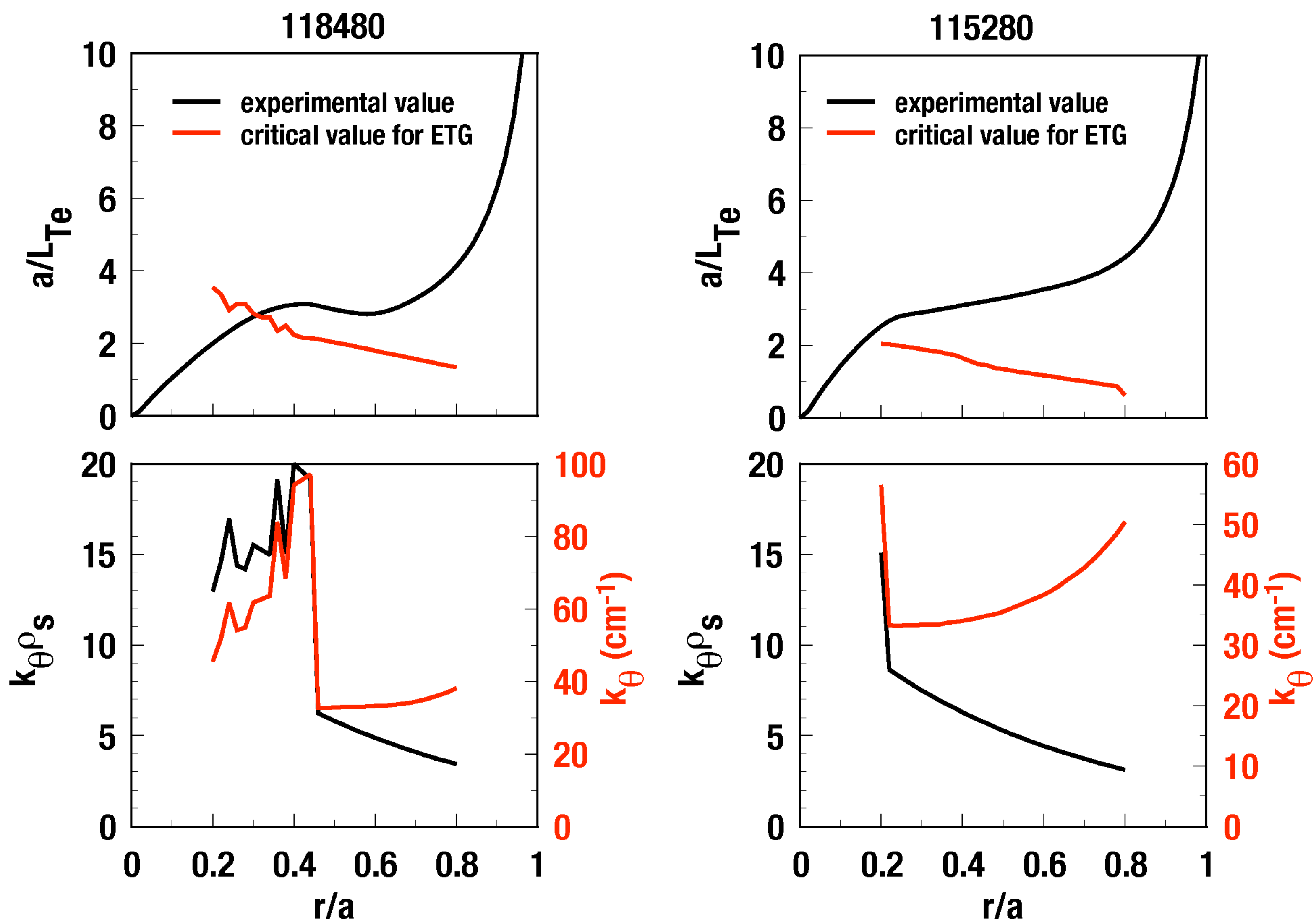


The Best Region To Look In The Plasma For Maximum Difference In Turbulence Levels Is r/a ~ 0.5

$$\frac{\tilde{n}_e}{n_e} \sim \gamma_n/k_n^2 = \frac{\gamma/(c_s/a)}{(k_\theta \rho_s)^2}$$

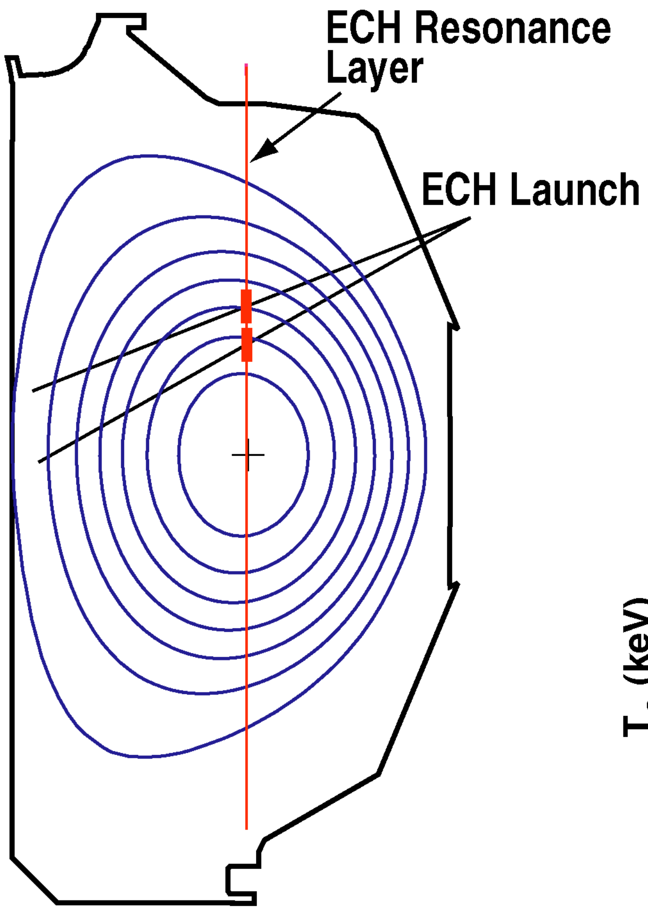


ETG Modes Are Calculated To Be Unstable Over Most Of The Plasma But With $k_\theta \geq 30\ cm^{-1}$

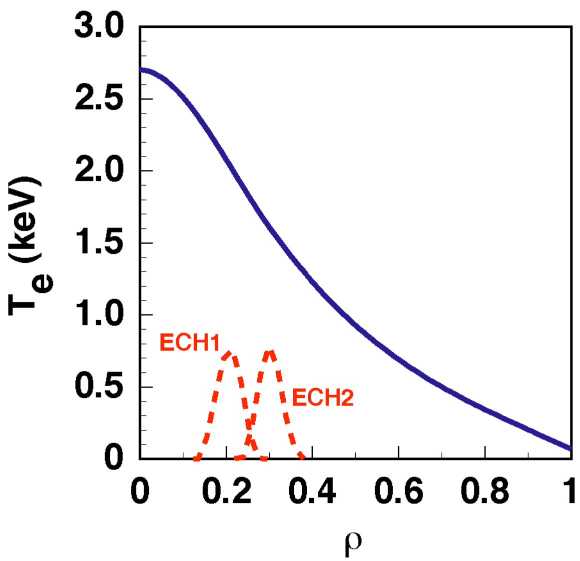


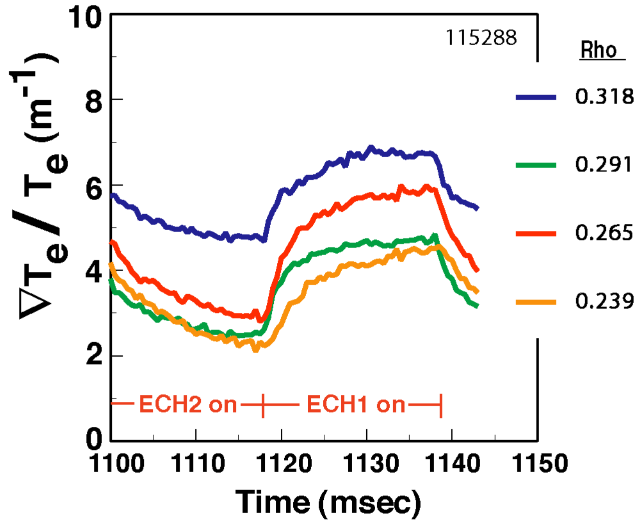
DIII-D NATIONAL FUSION FACILITY

ECH Swing Technique Can Be Used To Make Large Variations In ∇T_e and a/L_{T_e} At Constant T_e

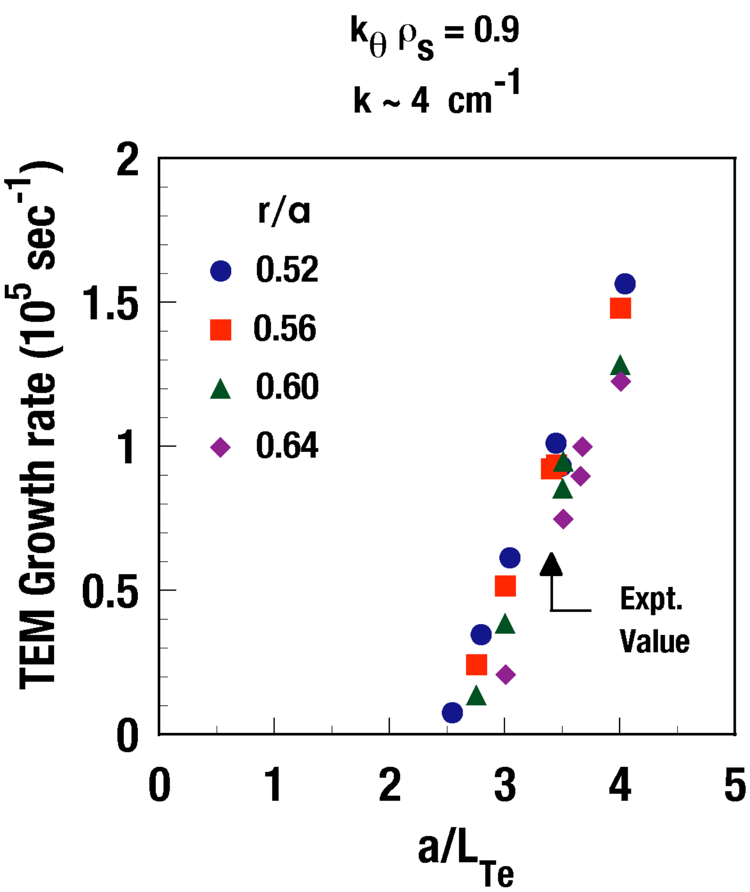


- Alternately apply ECH power at two closely spaced locations in the plasma
- The local value of ∇T_e can be significantly varied while keeping T_e roughly constant



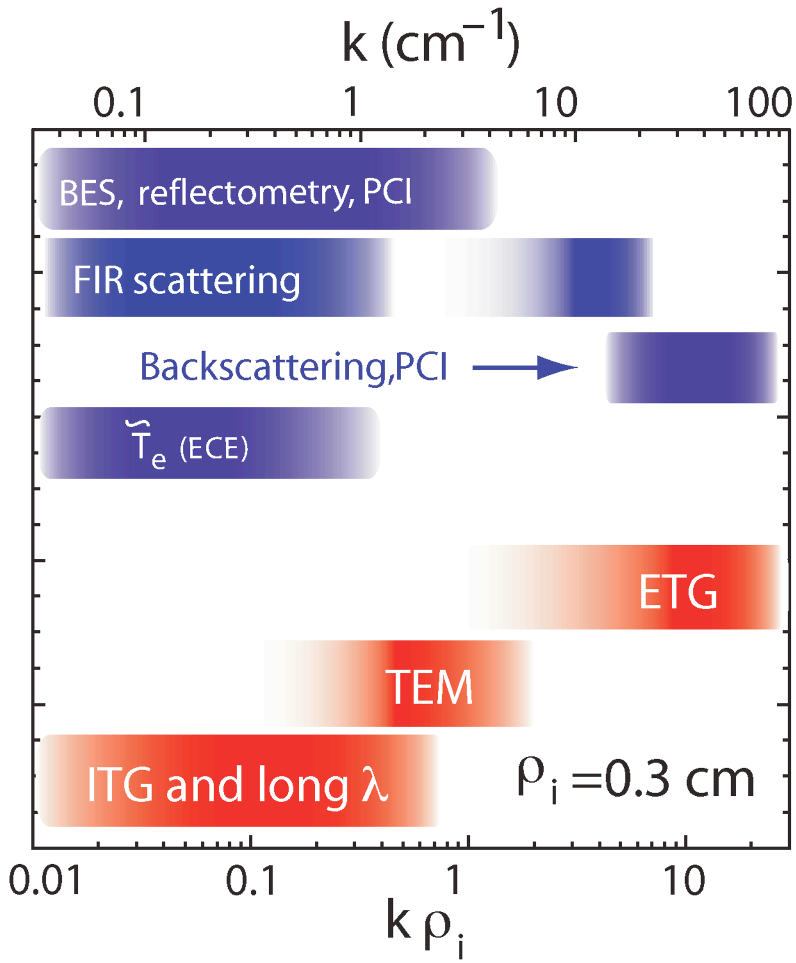


GKS Calculations Indicate Reducing a/L_{Te} By ~ 25% Can Stabilize TEMs



- Stability calculations with GKS done for fixed value of $k_\theta\rho_s = 0.9$ ($k_\theta \sim 3.9 - 4.7\ cm^{-1}$) and at several radii, r/a = 0.52 - 0.64
- a/L_{Te} varied to find the stability threshold
- Reducing a/L_{Te} by about 25% is enough to stabilize the mode

Turbulence Measurement Diagnostics on DIII-D Cover A Large Range in k-Space



- **Wavenumber region potentially occupied by ITG, TEM, and ETG instabilities**
- **Large k-space probed by fluctuation diagnostics on DIII–D**
  - U. Wisc. beam emission spectroscopy (BES), upgraded for improved sensitivity, probes 0–3.5 cm^{-1}
  - UCLA FIR scattering system upgraded to probe low (0–2 cm^{-1}) and intermediate wavenumbers (8–15 cm^{-1})
  - High-k backscattering systems (~40 cm^{-1}) (UCLA)
  - MIT phase contrast imaging (PCI) upgraded to probe core plasma, 0–30 cm^{-1}
  - $\tilde{T}_e$ measurement using ECE (0–1 cm^{-1}) (UCLA)
  - Fluctuation, Doppler and correlation reflectometry probe 0-5 cm^{-1} (UCLA)

Conclusions

- The TGLF model has been employed to aid in the design of an experiment to discriminate between ITG and TEM turbulence.
- By creating target L-mode discharges with low density and collisionality and peaked T_e profiles with ECH, the TEM mode is expected to clearly dominate the turbulence near the plasma mid radius.
- Replacing the EC heating power with NBI is expected to switch the dominant turbulent mode from TEM to ITG. Reducing a/L_{T_e} by about 25% should also allow ITG to dominate by stabilizing TEMs.
- The interesting region in k-space is $k_\theta \rho_s \sim 0.1 - 1$ ($0.5 - 5$ cm^{-1}) at $r/a \sim 0.5$.
- Turbulence diagnostics are deployed on DIII-D that are capable of observing this change in turbulence modes.