High-Frequency Edge Fluctuations During High-Pedestal-Pressure Quiescent H-mode Plasmas

by

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with

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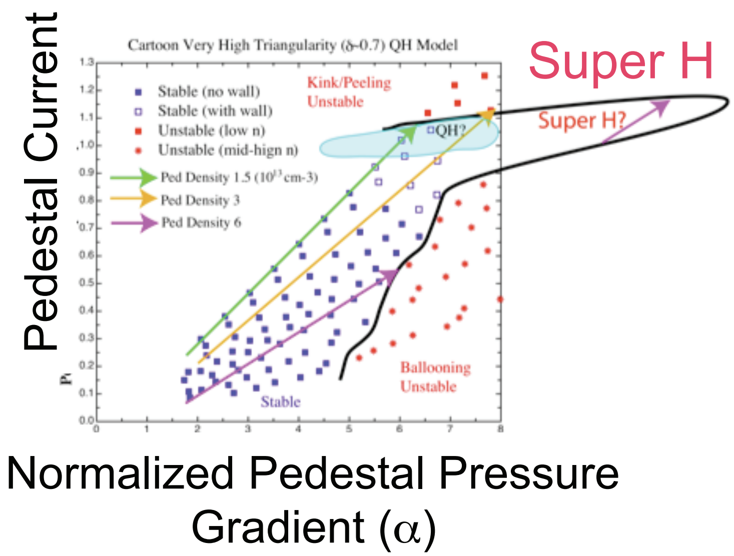
Overview

- **High frequency coherent (HFC) modes (100-220 KHz) are observed in QH mode discharges at high electron pedestal pressures**
  - Peak near 150 kHz; uniform frequency separation of ~8 kHz
  - Edge Harmonic Oscillation (EHO) disappears w/HFC mode onset
- **Localized to the pedestal, peaking just inside separatrix**
- **Modes have low poloidal mode number, k_θ~0.4 cm^{-1}, short correlation time, τ_c~a few μs, and de-correlation rate comparable to high ExB shearing rate**

  - similar features predicted for kinetic ballooning modes (KBM)
- **No magnetic component observed for these modes**
- **ELITE analysis shows pedestal not near ballooning mode stability boundary**
  - QH mode pedestal typically near kink peeling-ballooning limit: thought to drive EHO

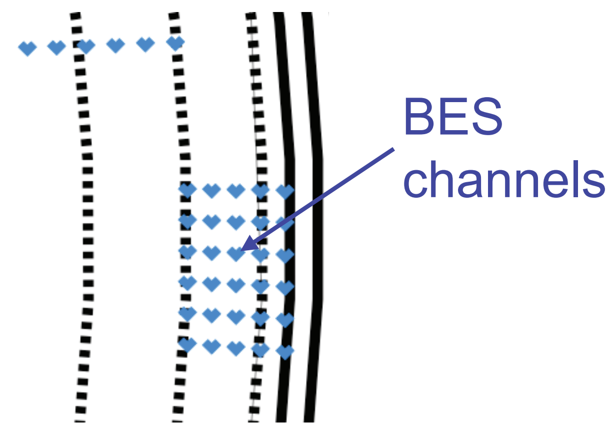
Experiment Goal: achieve high pedestal pressure

- **High pedestal pressure may yield high core plasma performance in QH mode plasmas**
  - ELM-free operation
  - Strongly shaped DND plasma
  - Density later increased to achieve high pressure
  - ‘Super H-mode’ regime proposed by Phil Snyder



- **Unusual high impurity radiation prevented optimal conditions**
  - good conditions to study physics of pedestal instabilities

- **5×6 array of high-sensitivity BES channels employed across pedestal to study edge/SOL fluctuation characteristics**



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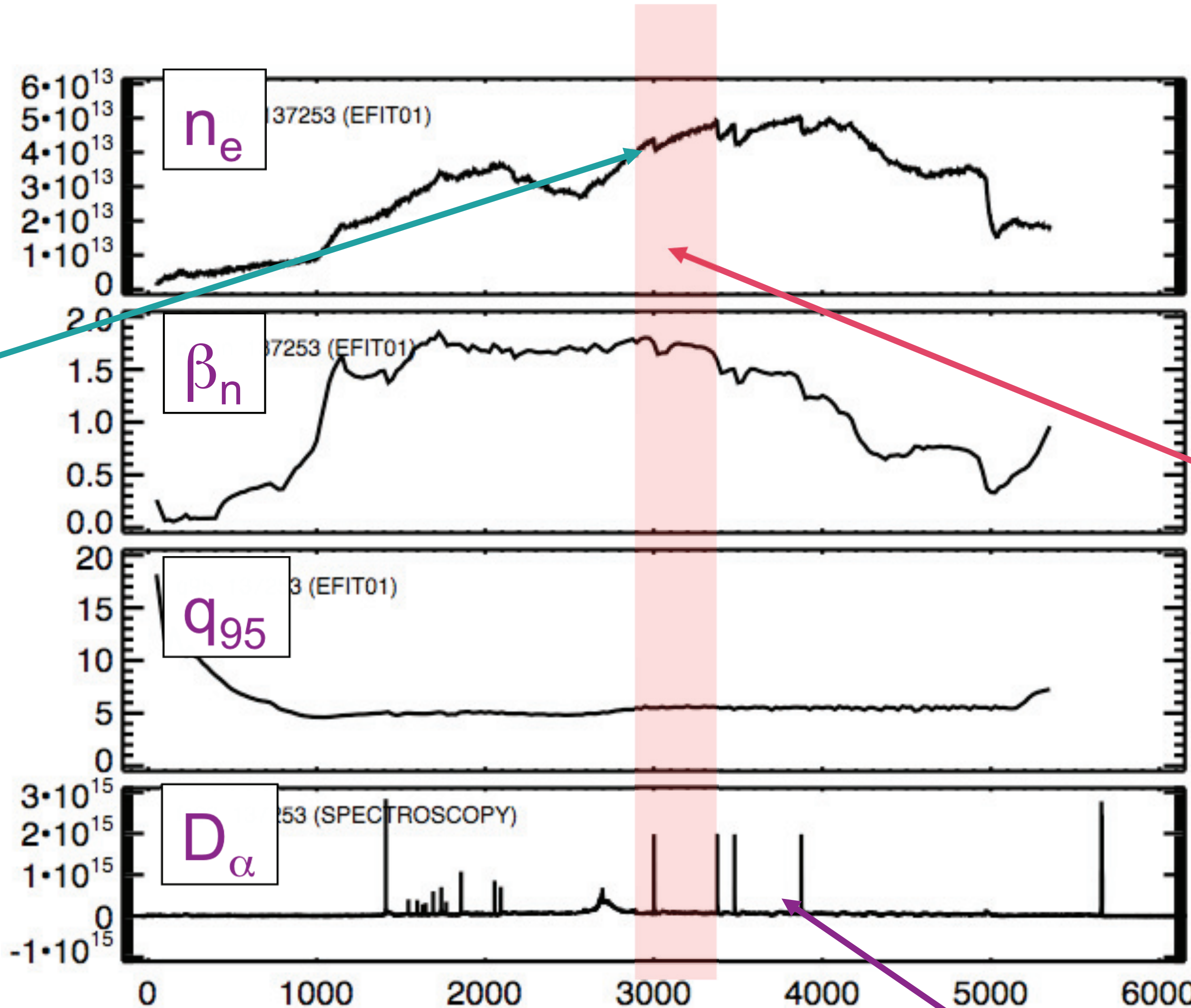
Density Increased to Raise Electron Pedestal Pressure

B_t=-2T
I_p=-1.2MA

X point geometry changes to increase density



Time of Interest

t (ms)

Long ELM free window

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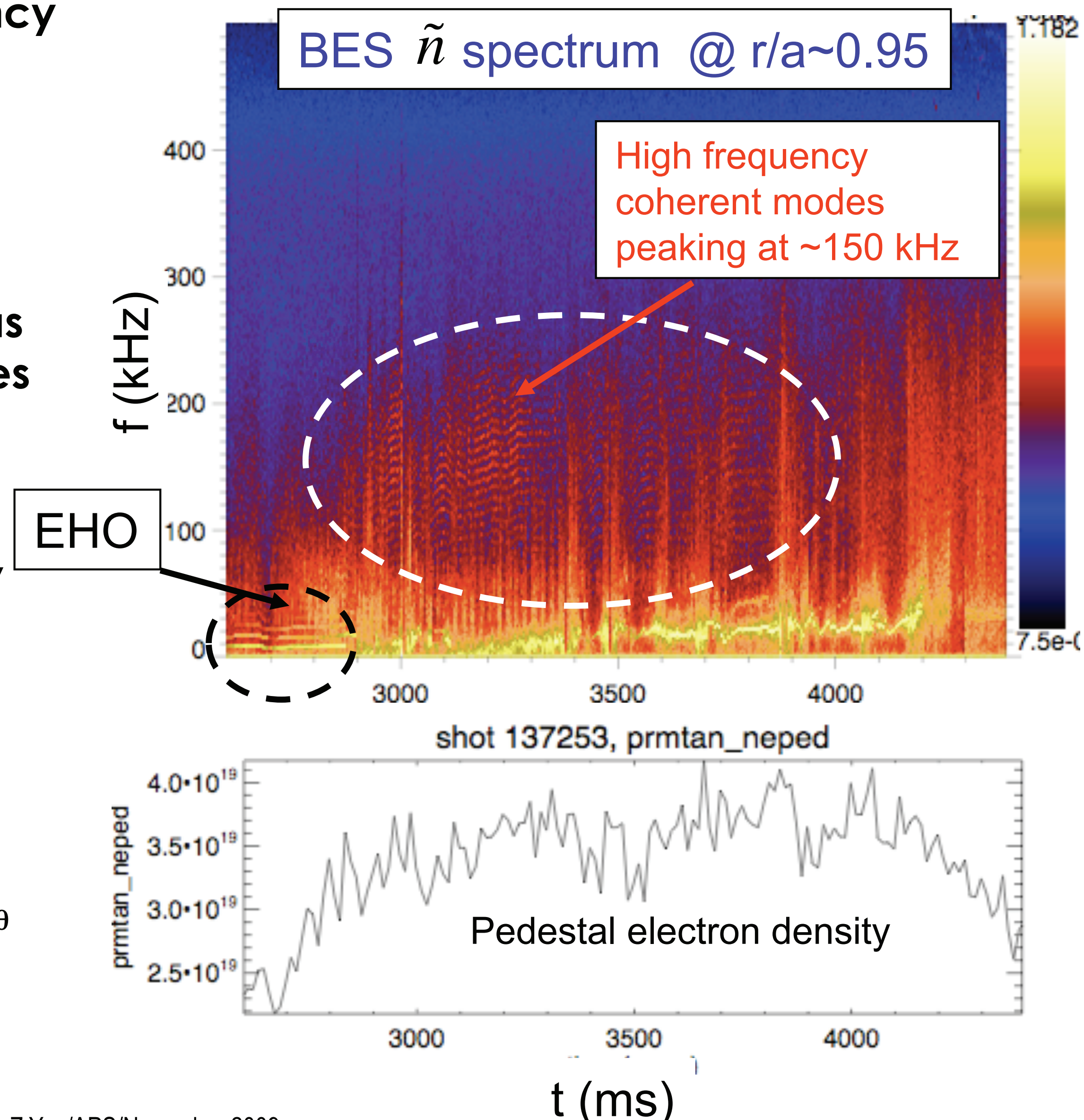
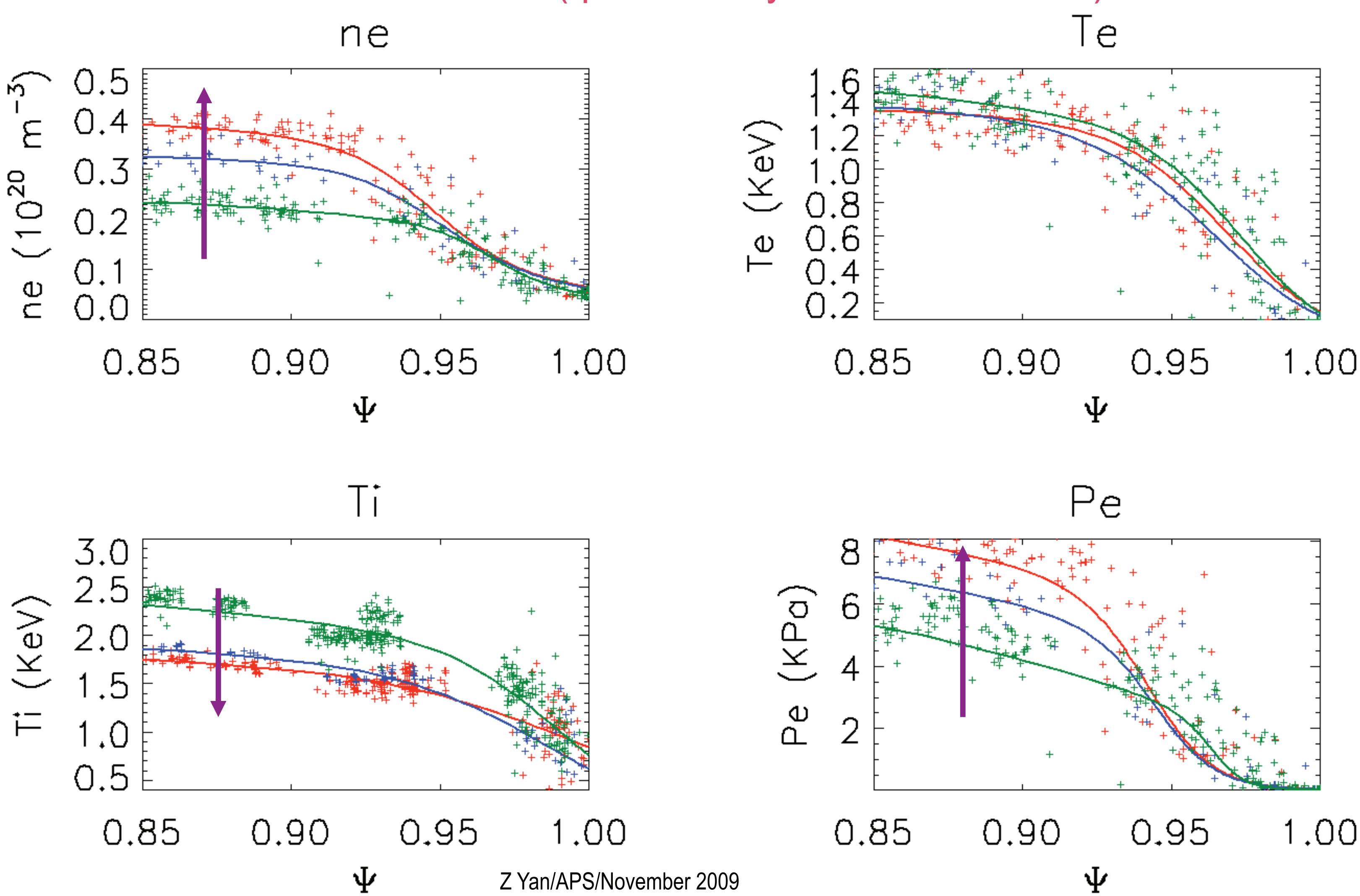
High Pedestal pressure QH mode Discharges Exhibit High Frequency Coherent Modes

- Some QH shots exhibit high frequency coherent (HFC) modes peaking ~150 kHz
- HFC modes appear when EHO disappears
- Transition from EHO to HFC occurs as electron pedestal pressure increases
- Pedestal pressure saturates when modes appear
- 4 discrete ELM events occur, widely separated in time. HFC modes disappear at ELMs and rapidly reappear after
- EHO: n~1-3 — magnetics
- HFC mode: n~20 — (inferred from k_θ measurements and ELITE mode structure comparisons)



Edge Electron Pedestal Pressure Rises with Density Increase

t = 2400 (standard QH edge pressure: EHO)
2800 (early high pressure)
3210 (quasi-steady state HFC modes)



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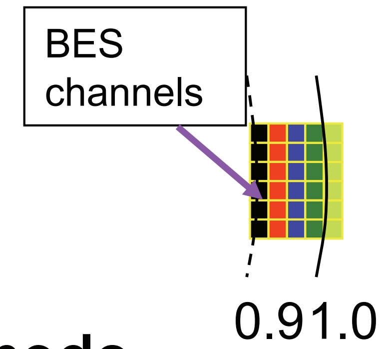
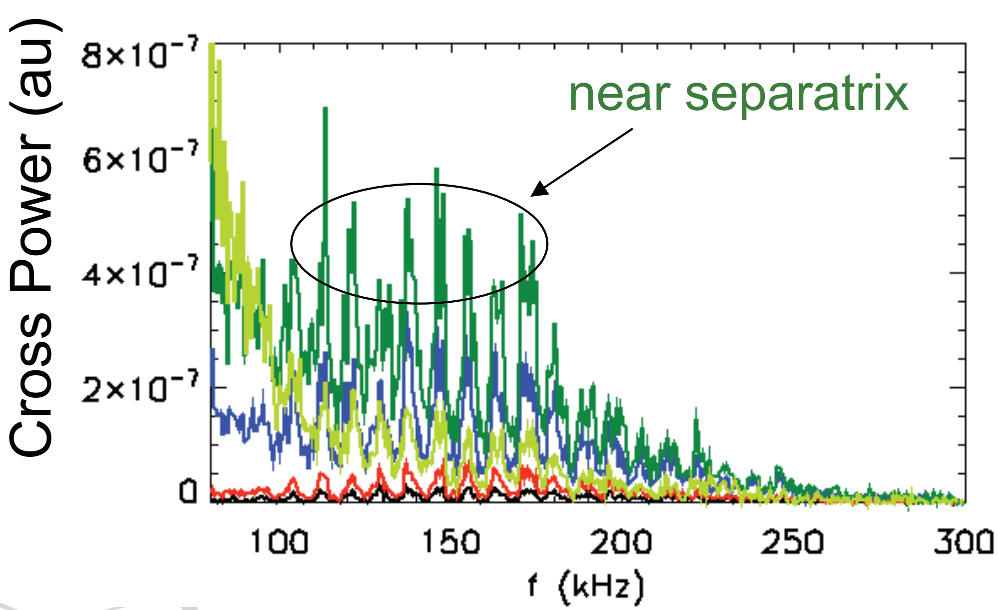
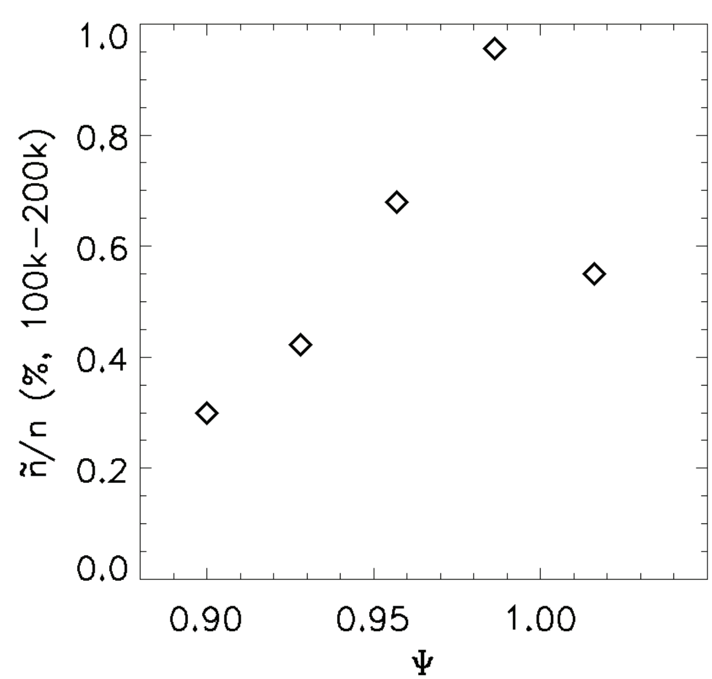
High Frequency Coherent Modes Localized in the Pedestal Region and Peak just inside Separatrix

- **Modes not observed deeper in plasma**
  - BES radial array extends from 0.3 < r/a < 0.9
- **Extend from 100-220 kHz, Δf~8 kHz**
- **No measurable phase coherence between individual mode**



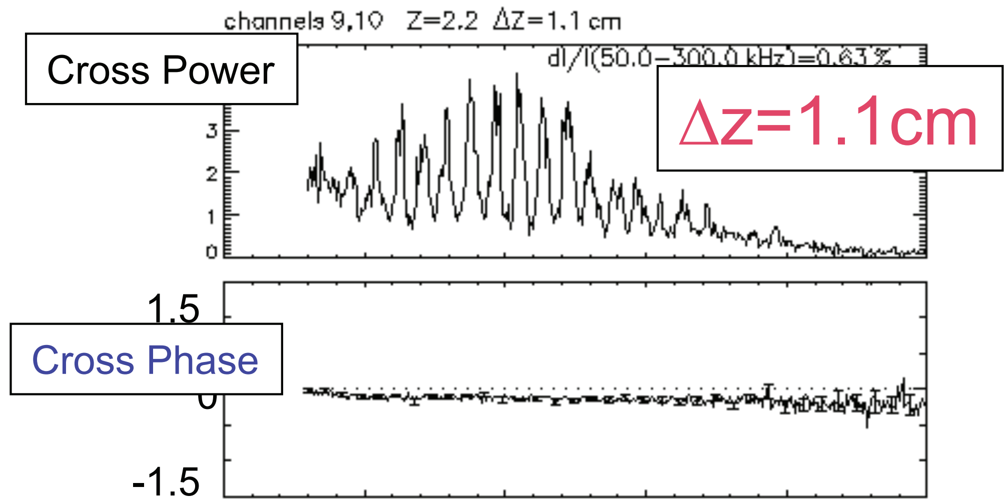


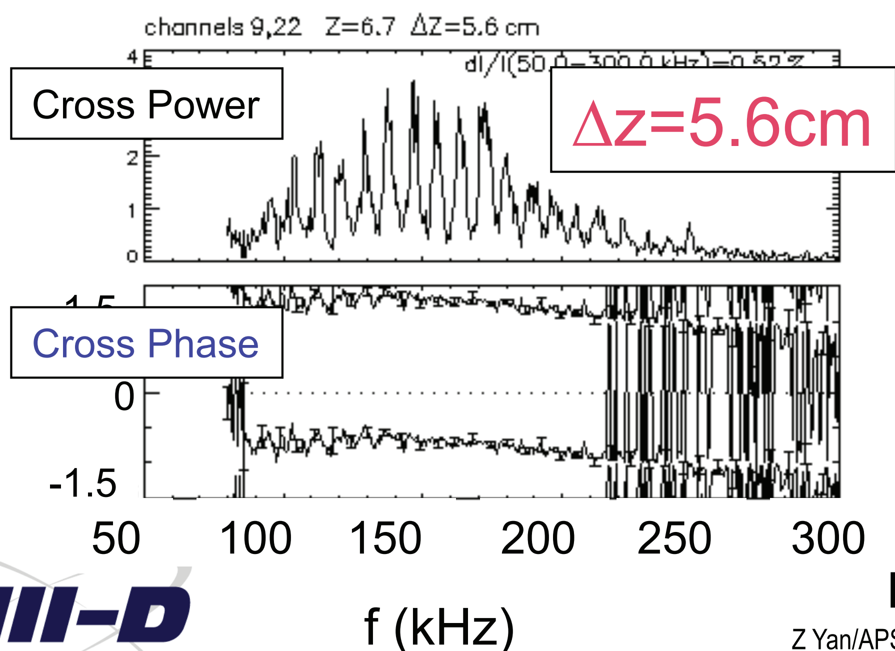
HFC amplitude profile

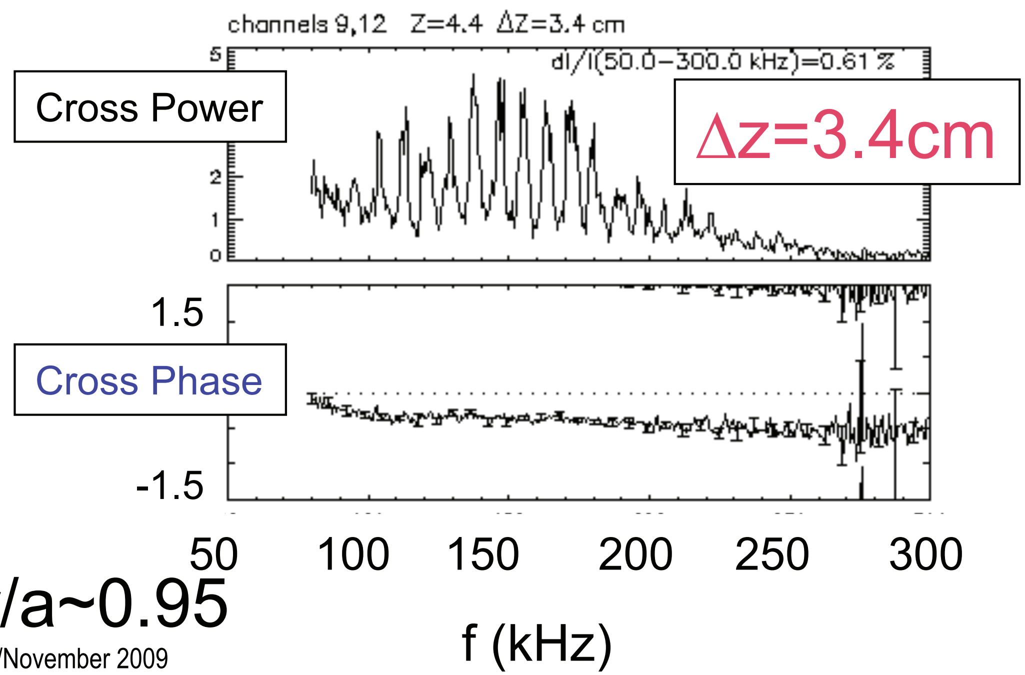


High Frequency Coherent Modes: k_θ~0.4 cm^{-1}

- k_θ~0.4 cm^{-1} , somewhat lower than ITG mode.
- Comparison with ELITE mode structure suggests n~20
- Modes propagate in electron diamagnetic direction





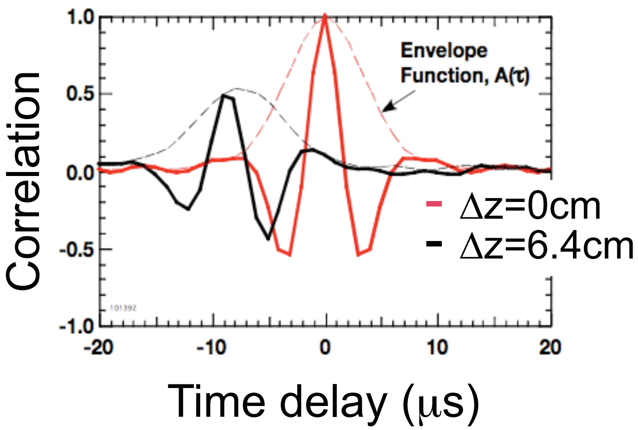


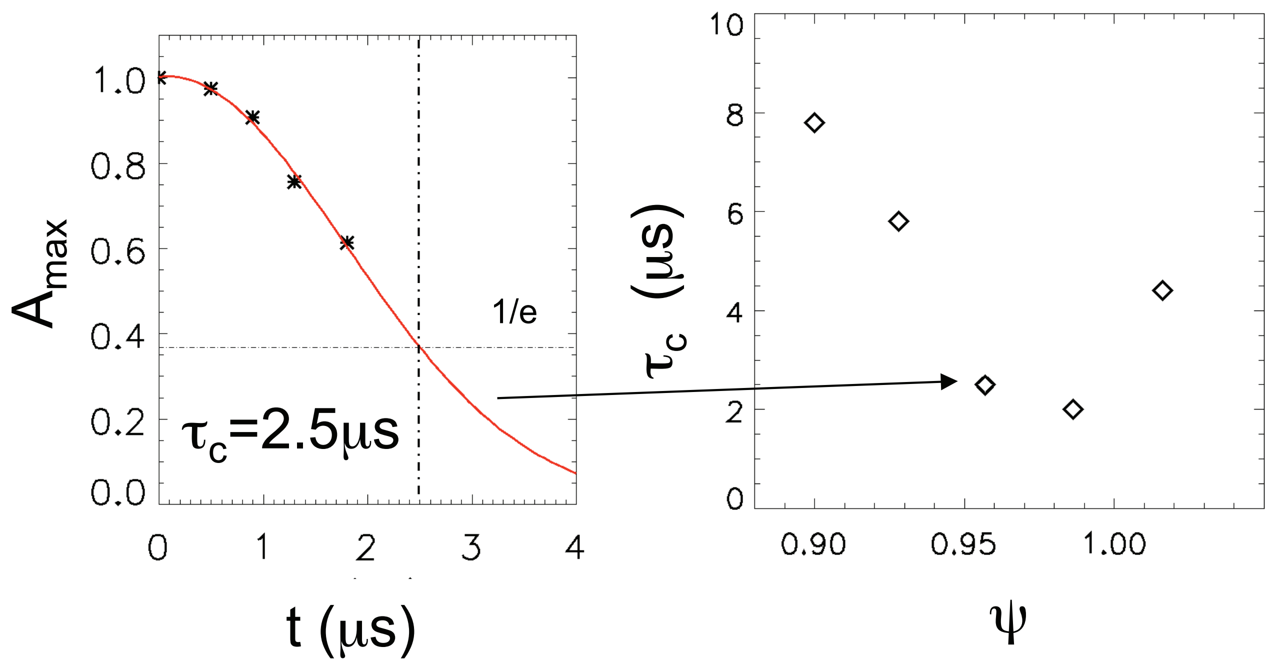
r/a~0.95

High Frequency Coherent Modes Exhibit Short Autocorrelation Time

- **Autocorrelation time decreases with radius**
  - Shorter than typical ITG autocorrelation time scale ~10 μs
- **Similar feature predicted for kinetic ballooning modes**

Poloidal Separated Cross-Correlation

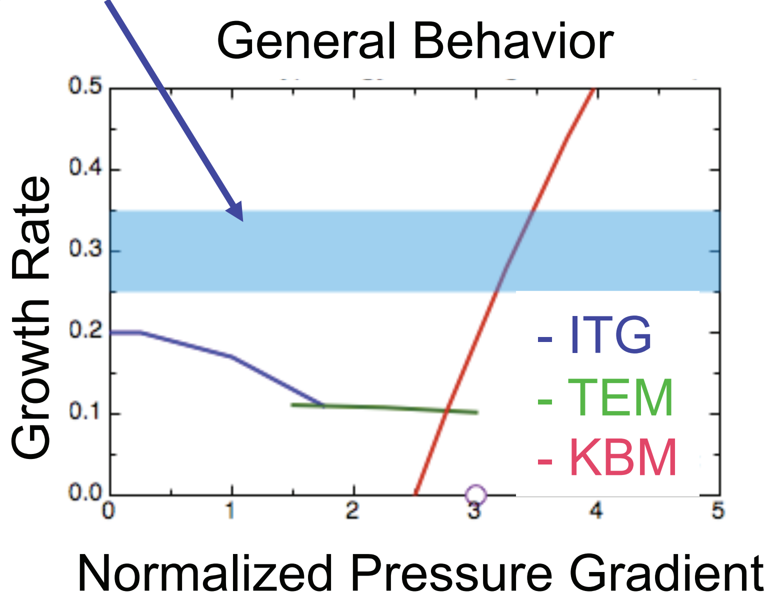


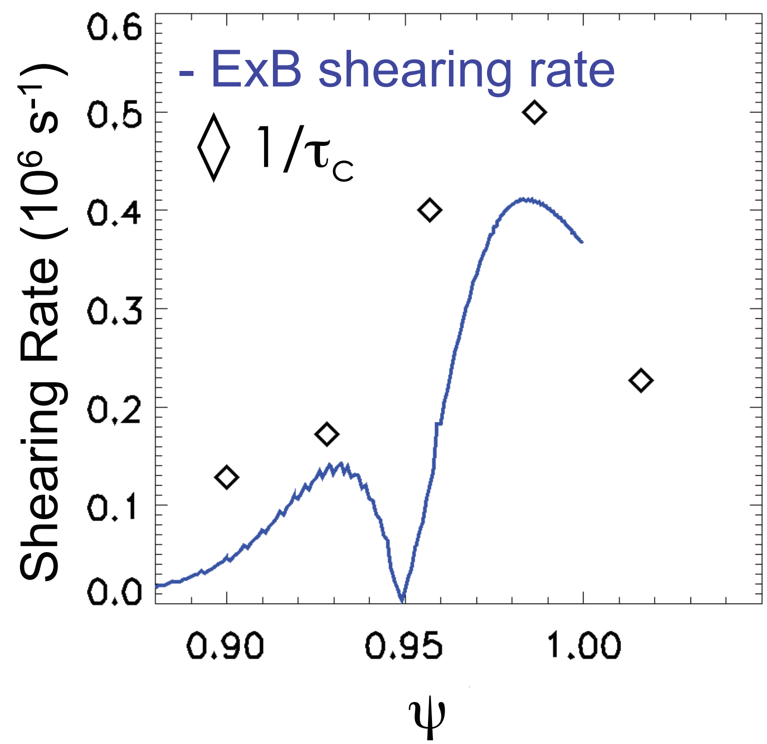


HFC Mode Decorrelation Rate ($1/\tau_c$) Comparable to ExB Shearing Rate in the Edge Barrier

- **High ExB shearing rate expected to quench ITG, TEM**
- **At high pedestal pressure gradient KBM expected to be driven unstable**
- **HFC $1/\tau_c$ comparable to ExB shearing rate at the edge barrier**
  - Similar regime as KBM that the high growth rates can exceed ExB shear and potentially saturate pressure gradients

Typical ExB shearing rate in edge barrier





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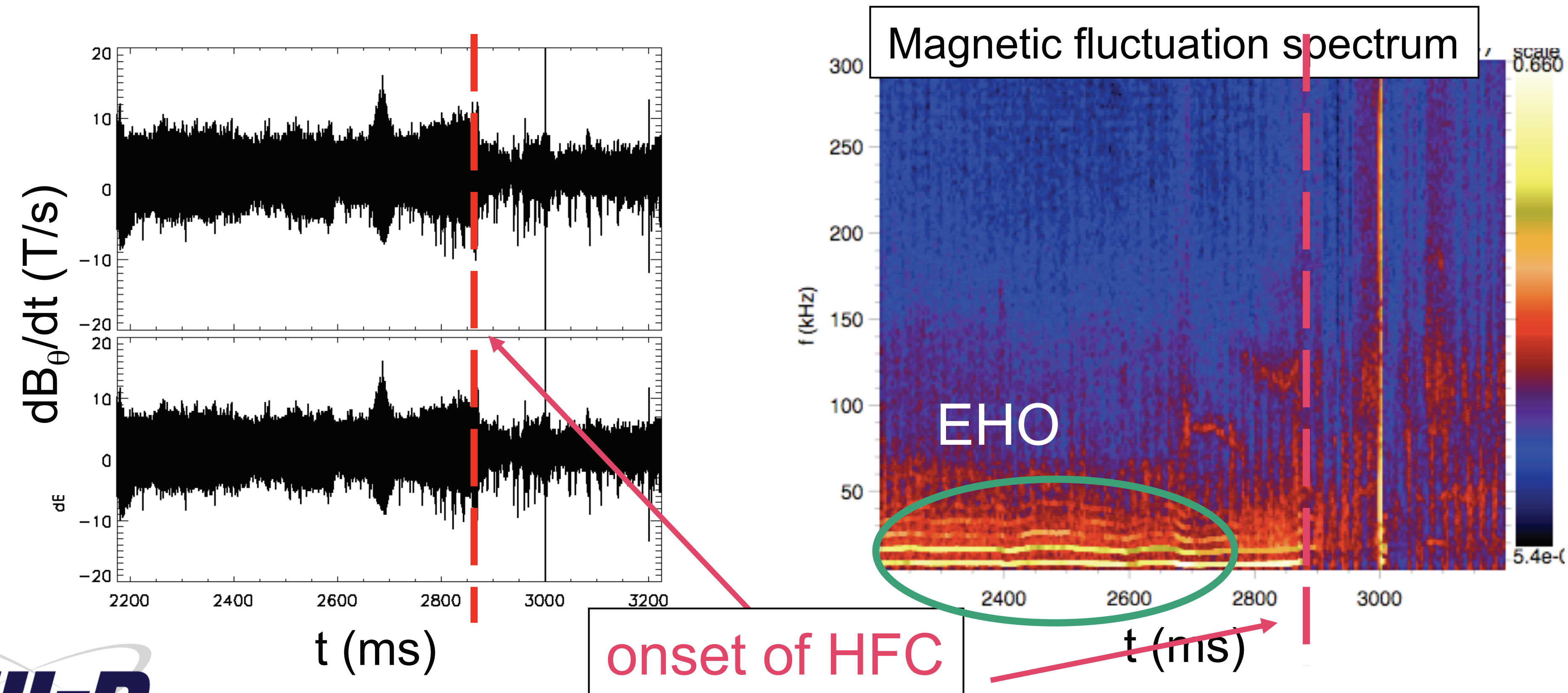
No Magnetic Signature Observed for These High Frequency Coherent Modes

- **Magnetic fluctuation amplitude decreases as HFC modes appear and EHO disappears**
- **Magnetic probe measurements clearly show low n EHO, but not high frequency coherent modes**
- **n/m may be too high to be detected**



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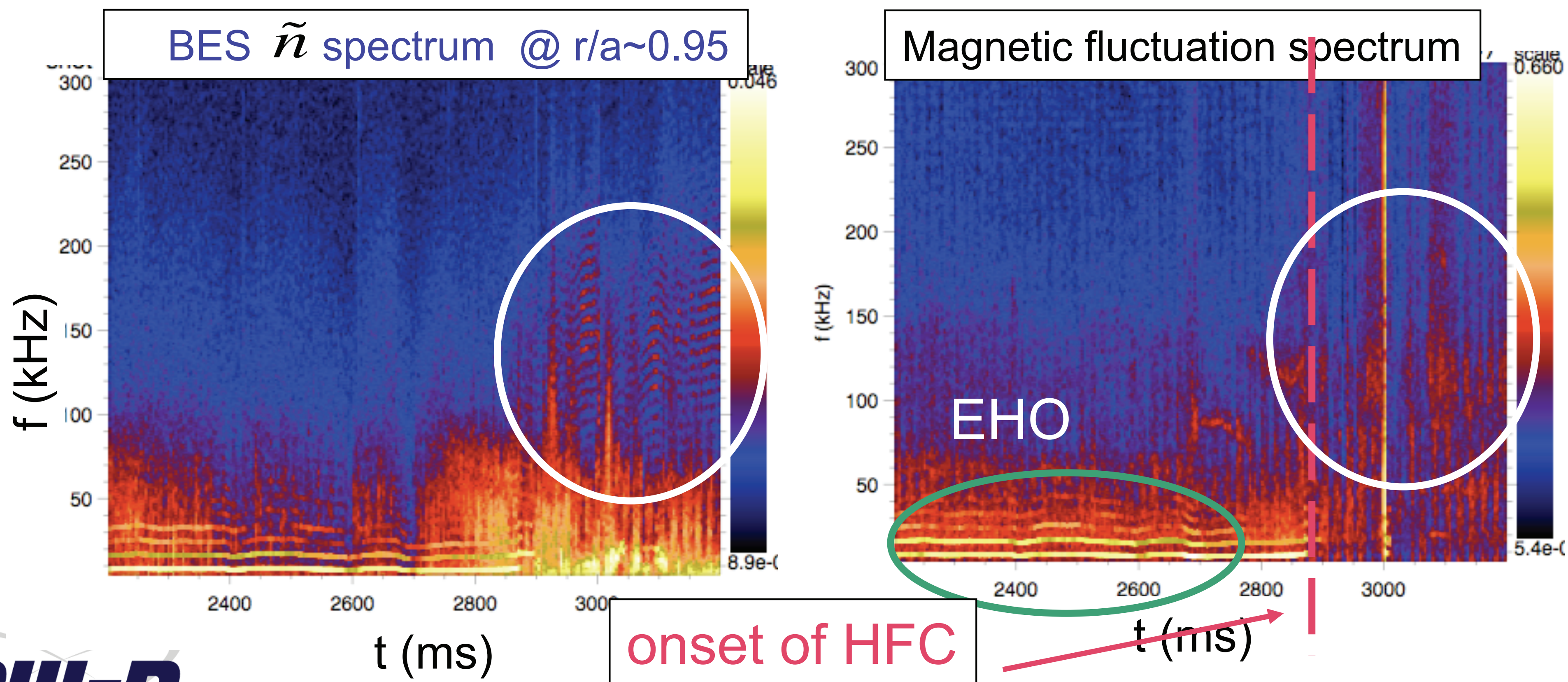

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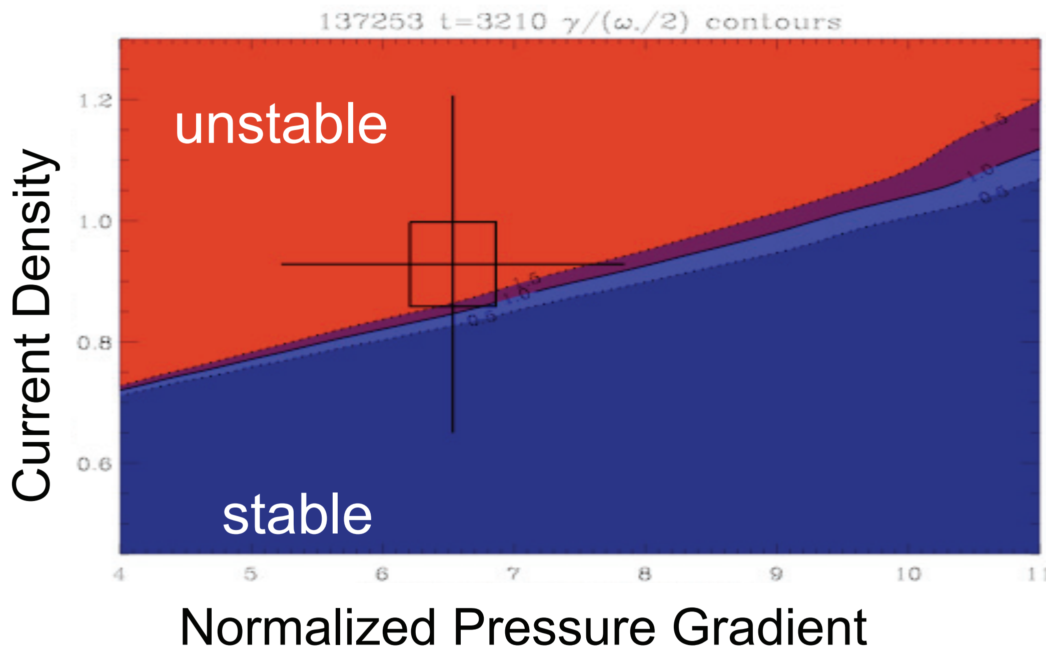
ELITE analysis indicates pedestal not near a ballooning mode limit

- **ELITE shows the pedestal at the peeling mode stability boundary**
  - Typical QH mode regime
  - Dominant unstable mode n~5
  - Thought to drive EHO
- **Strong shaping put the ideal ballooning mode very deeply in the 2nd stable regime**
- **HFC modes appear at higher density when the KBM predicted to become more unstable**
- **Requires nonlinear simulations to reveal nature of modes**



Summary

- **In high edge-electron-pressure QH mode discharges, high frequency coherent modes appear in 100-220 kHz range**
  - EHO disappears with onset of HFC modes
  - Peak ~150 kHz, Δf~8 kHz difference between different modes
  - Localized in the pedestal region, $0.9 < \psi \leq 1$
  - Appears to limit increase in pedestal pressure
- **Modes exhibit k_θ~0.4 cm^{-1}, n~20 (inferred), and short autocorrelation time τ_c ~ a few μs**
- **De-correlation rate of the modes is comparable to or exceeds the high ExB shearing rate**
- **ELITE analysis shows pedestal not near a global linear ballooning mode stability boundary limit**
- **HFC modes have several characteristics predicted for KBM**
  - Nonlinear simulations are required to assess nature and identification of modes