Broadband Magnetic and Density Fluctuation Evolution Prior to First ELM in DIII-D Edge Pedestal

Presented by
G. Wang [a],
In collaboration with

W.A. Peebles [a], P.B. Snyder [b], T.L. Rhodes [a], E.J. Doyle [a], T.H. Osborne [b], G.J. Kramer [c], R. Nazikian [c], M.A. Van Zeeland [b], L. Zeng [a], X. Nguyen [a], K.H. Burrell [b], R.J. Groebner [b], A.W. Leonard [b], E.J. Strait [b], M.E. Fenstermacher [d]

[a] *University of California, Los Angeles, CA*
[b] *General Atomics, San Diego, CA*
[c] *Princeton Plasma Physics Laboratory, Princeton, NJ*
[d] *Lawrence Livermore National Laboratory, Livermore, CA*

Presented at the
48th Annual Meeting of the Division of Plasma Physics
American Physical Society

Philadelphia, Pennsylvania

October 30-November 3, 2006

DIII-D
NATIONAL FUSION FACILITY
SAN DIEGO

UCLA

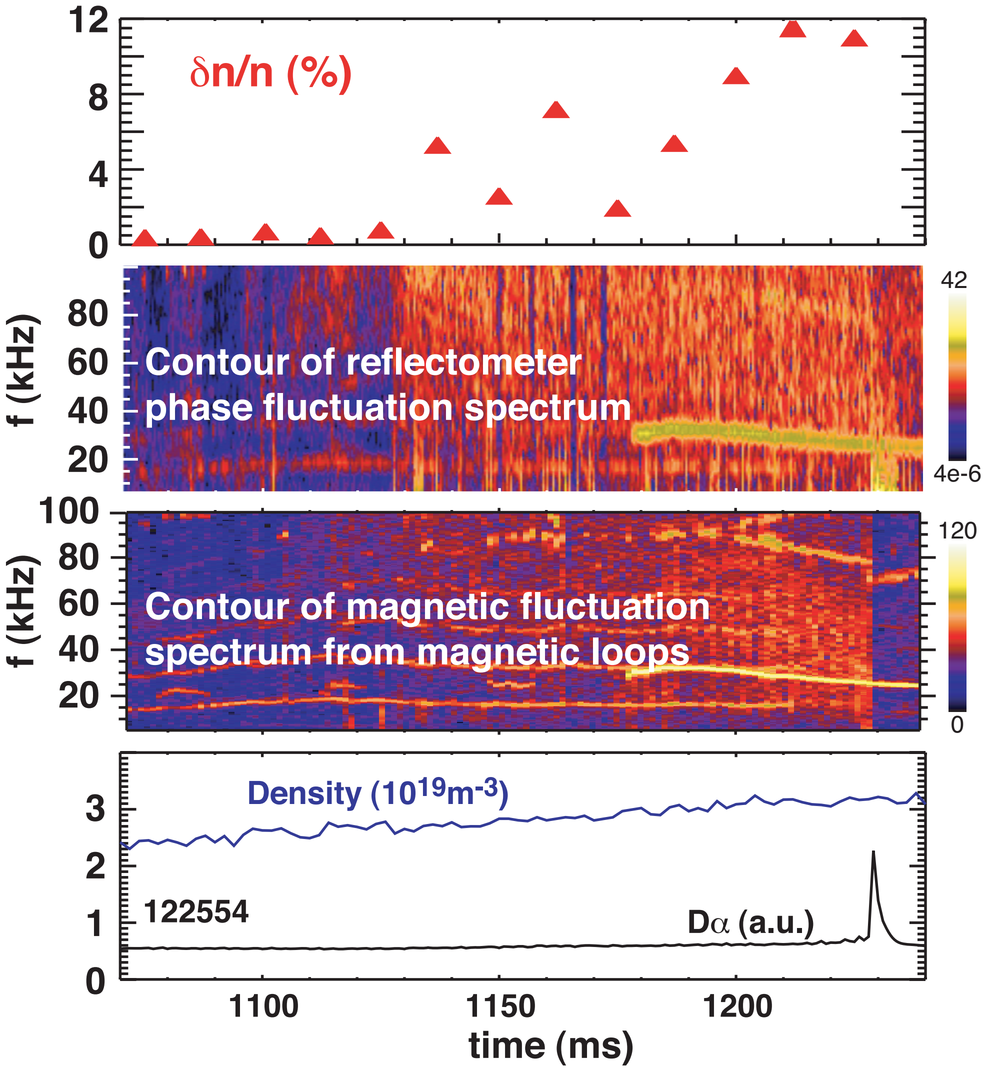
Motivation

- **Understanding H-mode edge pedestal is a key fusion plasma issue**
  - Pedestal height strongly impacts core confinement and consequently overall fusion performance
  - High priority for ITER
- **Recent progress shows that Peeling-Ballooning model can explain ELM onset and provide constraints on pedestal** [*P.B. Snyder, H.R. Wilson, et al., Phys. Plasmas* ***9*** *(2002) 2037 & Nucl. Fusion* ***44*** *(2004) 320.*]
- **However, pedestal transport and therefore its evolution is not understood**
  - Experimental turbulence measurements needed for pedestal and SOL transport models

Summary of results

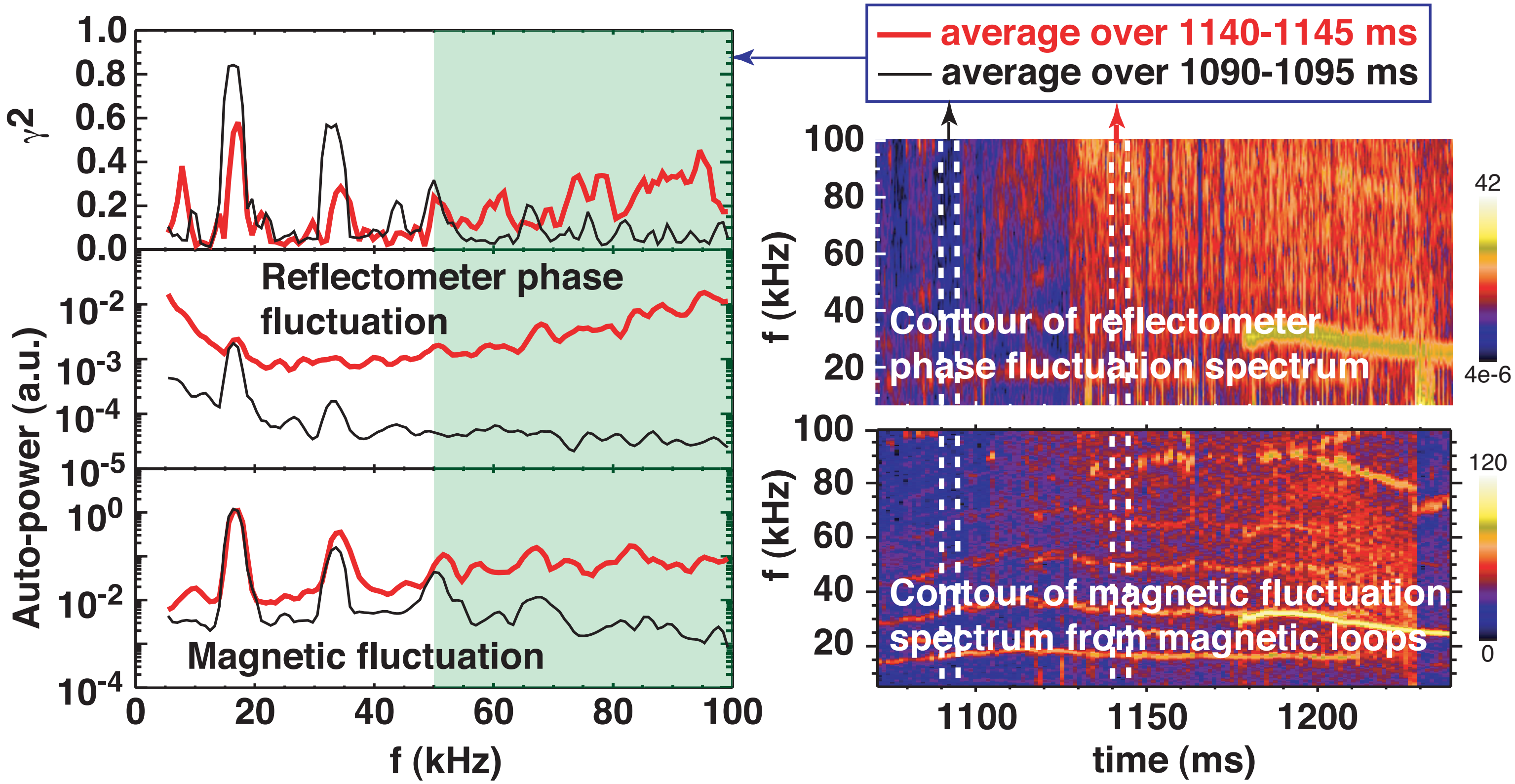
- Broadband density fluctuations localized to the edge pedestal have been observed to increase significantly prior to first ELM
- This broadband density fluctuation increase shows signature of correlation with observed increase in magnetic fluctuations measured by magnetic loops
- Increased density and magnetic fluctuations both exhibit a ballooning character
- Increase in pedestal density fluctuations correlated with increased total pressure gradient and reduced dP_e/dt of electron pedestal pressure P_e
- ELITE MHD stability code analysis indicates edge pressure gradient exceeds nominal ideal MHD ballooning stability limit at same time as observed magnetic turbulence increase

Broadband localized density fluctuations in pedestal and magnetic fluctuations increase significantly prior to first ELM



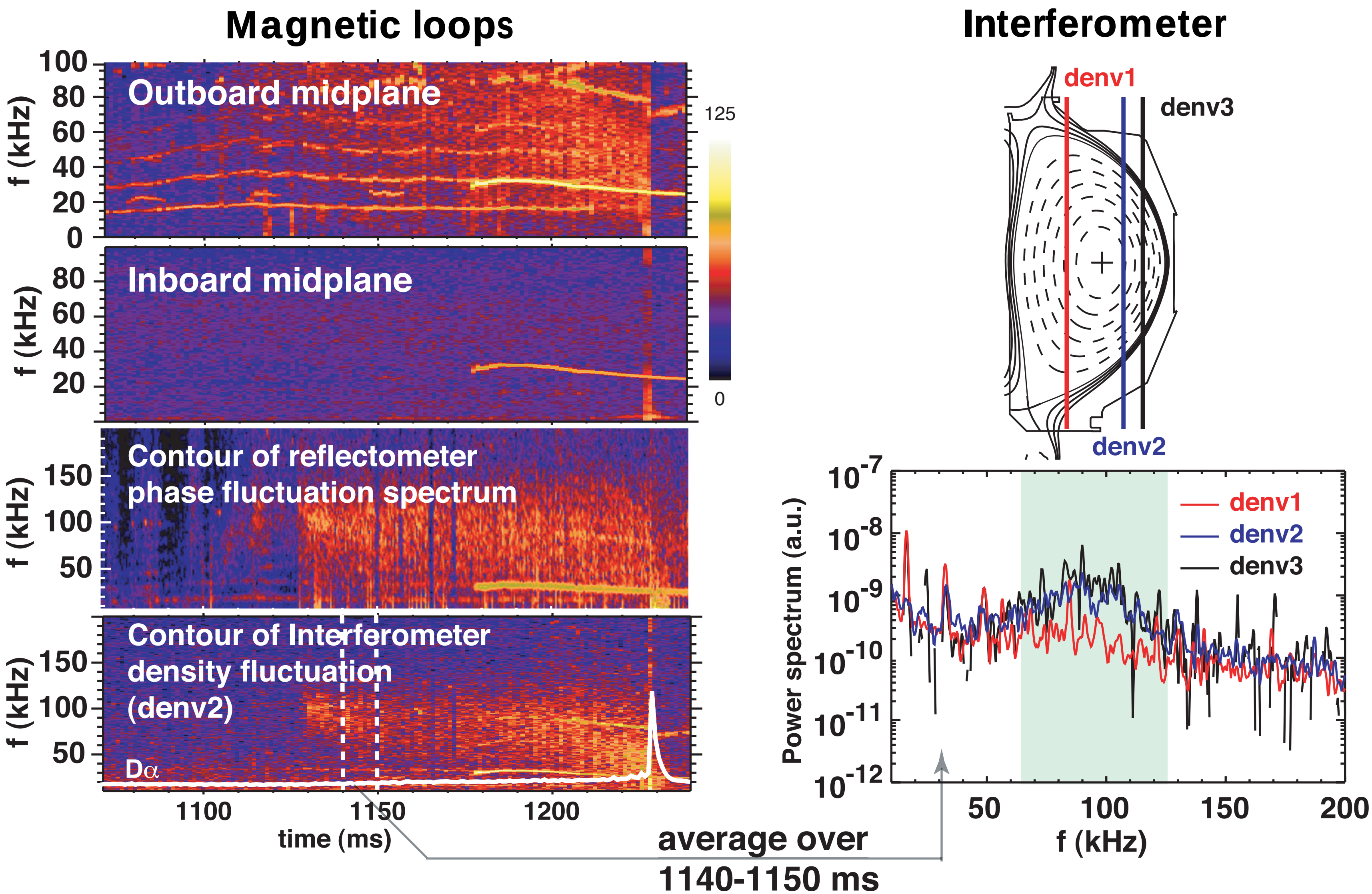
- **Reflectometer detection location at outboard midplane, in the steep ∇P_e region**
  - Reflection located ~ 1cm inside the separatrix, ±0.25 cm
  - Measured phase fluctuations from reflectometer in conjunction with PPPL 2-D reflectometer code provide quantitative value of $\delta n/n$
- **Magnetic fluctuation is from outboard midplane magnetic loops**

Increased broadband density fluctuation in pedestal shows signature of correlation with magnetic fluctuations

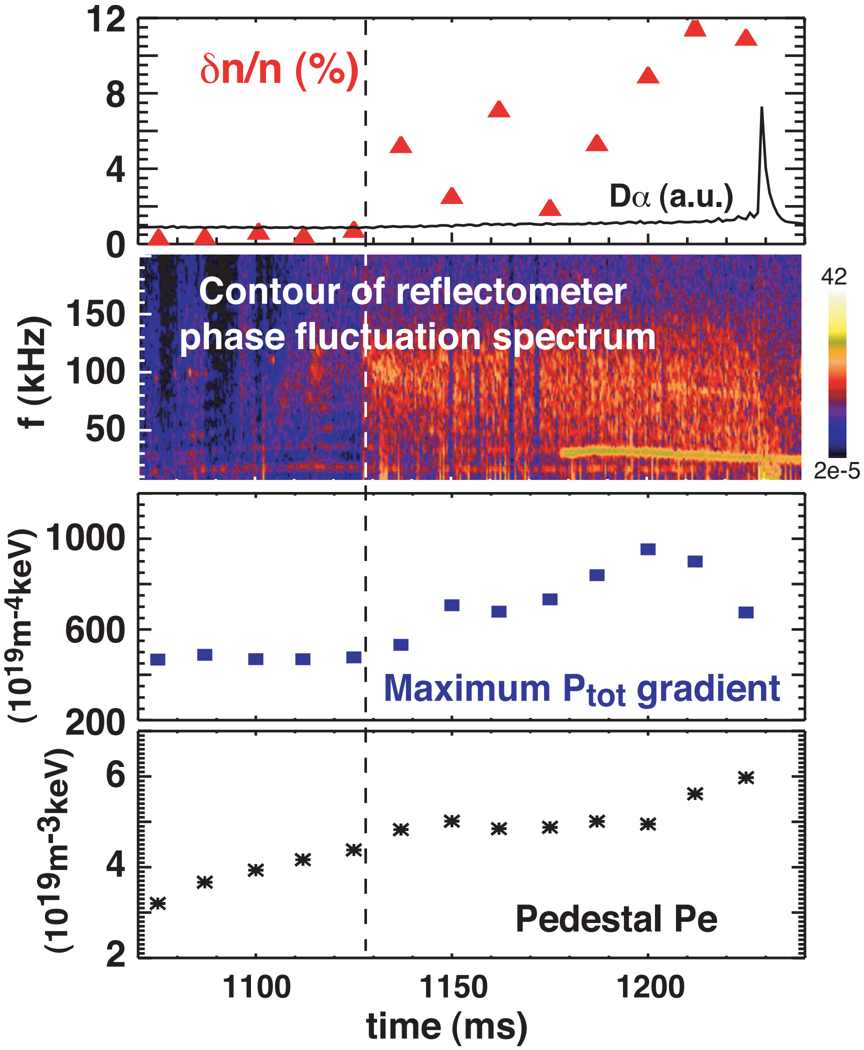


- **Coherence (γ^2): frequency resolved linear correlation between two signals. E.g., γ^2 =1: perfectly correlated, γ^2 =0: no correlation**
- **Coherence of phase fluctuation and magnetic fluctuation increased in the frequency range where enhanced fluctuations are observed**
  - Phase fluctuation down-sampled to 200 kHz sampling rate of magnetic signal

Increased density and magnetic fluctuations both exhibit a ballooning character

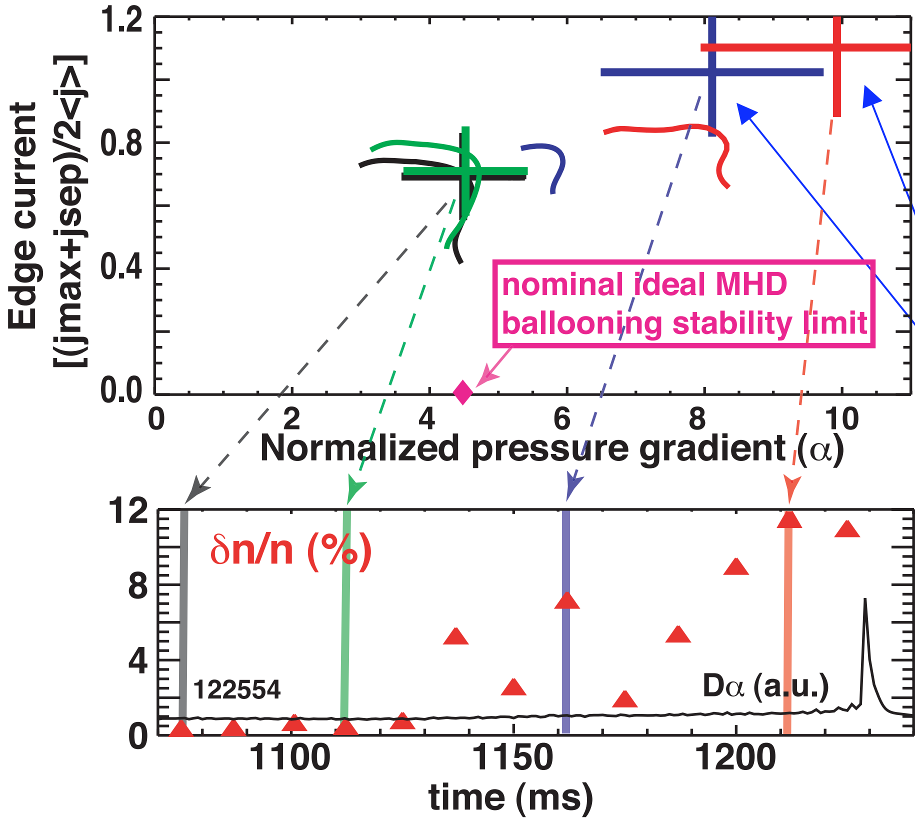


Increase in pedestal density fluctuations correlated with increased total pressure gradient and reduced dP_e/dt of electron pedestal pressure P_e



- **Pedestal pressure determined by averaging over 3 adjacent Thomson and/or CER data points in time**
- **∇P_{tot} shows an increase nearly coincident with change in pedestal turbulence**
  - consistent with ∇P_{tot} drive of ballooning type modes
- **Reduced dP_e/dt of pedestal P_e also coincident with change in pedestal turbulence**
  - consistent with increased electron transport from increased turbulence

Edge pressure gradient exceeds nominal ideal MHD ballooning stability limit at same time as observed magnetic turbulence increase



— Stability boundary
+ Operating point

Edge pressure gradient exceeds nominal ideal MHD ballooning stability limit

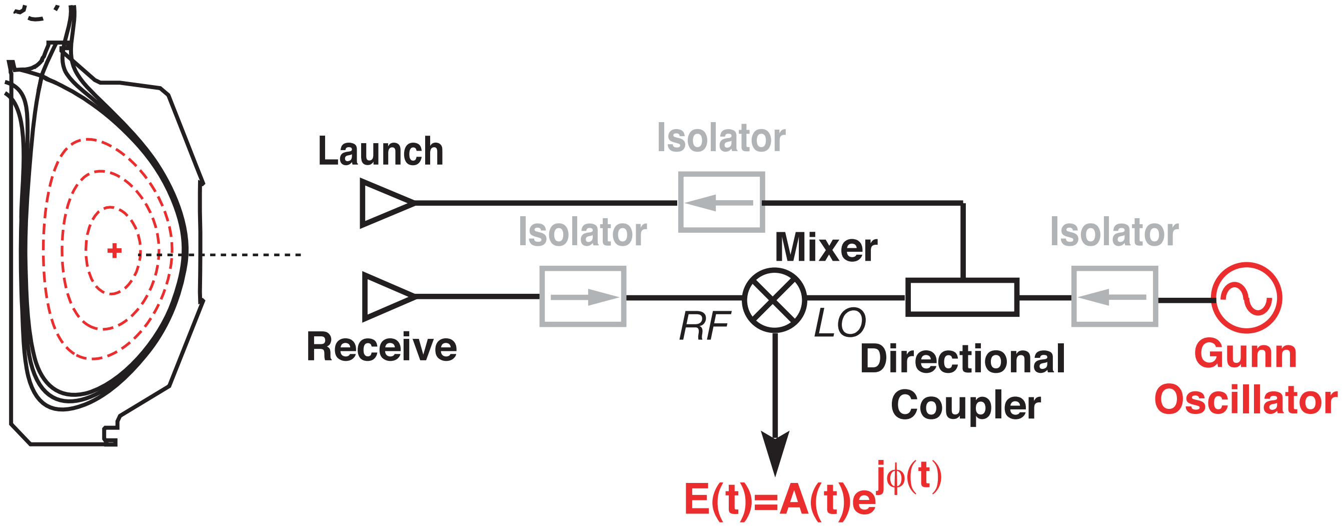
- ELITE code used to evaluate Peeling-Ballooning stability
- Suggest that as edge pressure gradient exceeds nominal ideal MHD ballooning stability limit, turbulence modes with magnetic fluctuation components, e.g. maybe kinetic/resistive ballooning modes, are driven unstable

Summary

- Broadband density fluctuations localized to the edge pedestal have been observed to increase significantly prior to first ELM
- This broadband density fluctuation increase shows signature of correlation with observed increase in magnetic fluctuations measured by magnetic loops
- Increased density and magnetic fluctuations both exhibit a ballooning character
- Increase in pedestal density fluctuations correlated with increased total pressure gradient and reduced dP_e/dt of electron pedestal pressure P_e
- ELITE MHD stability code analysis indicates edge pressure gradient exceeds nominal ideal MHD ballooning stability limit at same time as observed magnetic turbulence increase

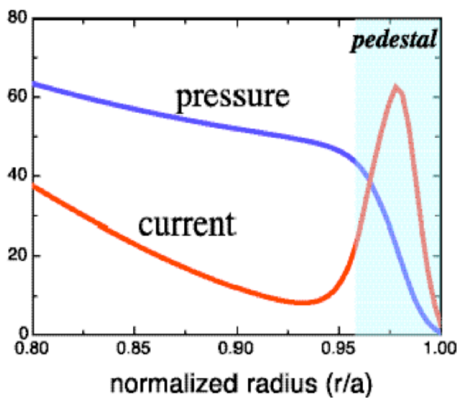
Backup VGs

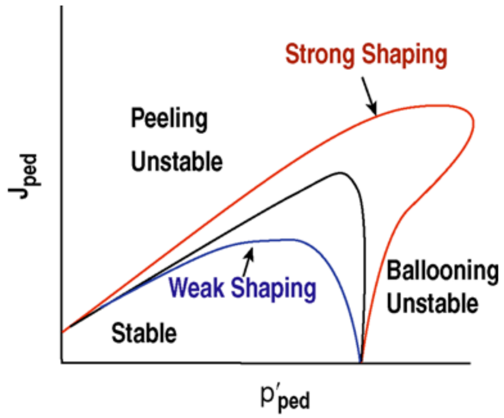
Quantitative, edge pedestal density fluctuation measurements from fluctuation reflectometer system

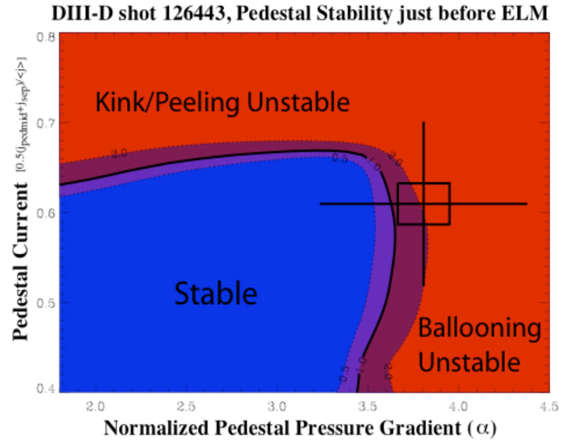


- **DIII-D reflectometer system: high time (<100μs) and spatial resolution (sub-cm),high sensitivity, non-perturbative, $k_\perp < 6\ cm^{-1}$, launch and receive antennas at outboard midplane**
  - Phase fluctuations of received microwave electric field provide qualitative indicator of evolution of localized density fluctuations
  - PPPL 2-D reflectometer code utilized to obtain quantitative value of $\delta n/n$ from measured microwave electric field

The Peeling-Ballooning Model and ELITE







Peeling-Ballooning model for ELM onset and constraints on pedestal

- **ELMs caused by intermediate wavelength (n~3-30) MHD instabilities**
  - Both current and pressure gradient driven, non-local
  - Complex dependencies on ν_*, shape etc.
- **ELITE code developed to efficiently evaluate P-B stability**
  - Extensively benchmarked against other MHD codes, includes rotation
- **Though stability is non-local, can roughly characterize it with local p'-j diagrams**
- **Extensive validation against experiment (>100 discharges)**
  - Discharge generally stable well before ELM, crosses P-B bound before ELM occurs

*[P.B. Snyder, H.R. Wilson, et al., Phys. Plasmas **9** (2002) 2037 & Nucl. Fusion **44** (2004) 320.]*