THE UNIVERSALITY OF INTER-ELM PEDESTAL FLUCTUATIONS IN AUG AND DIII-D

DIII-D NATIONAL FUSION FACILITY — ASDEX Upgrade — PRINCETON UNIVERSITY — PPPL

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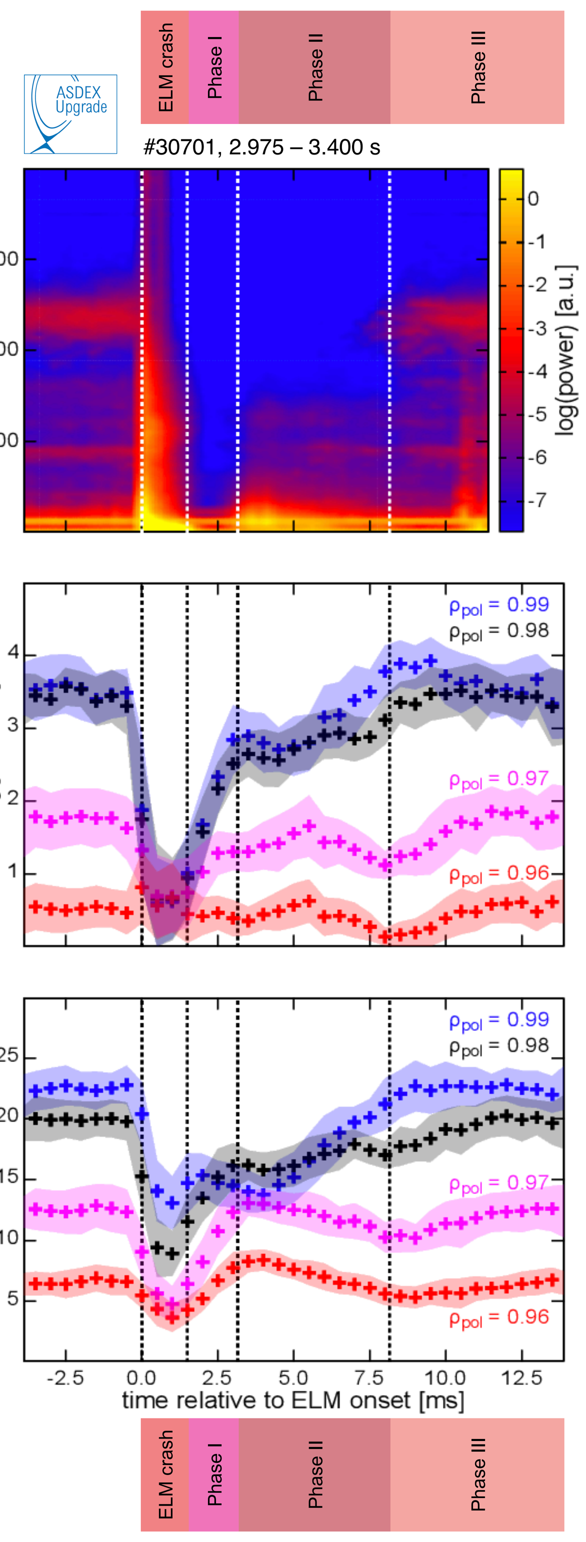
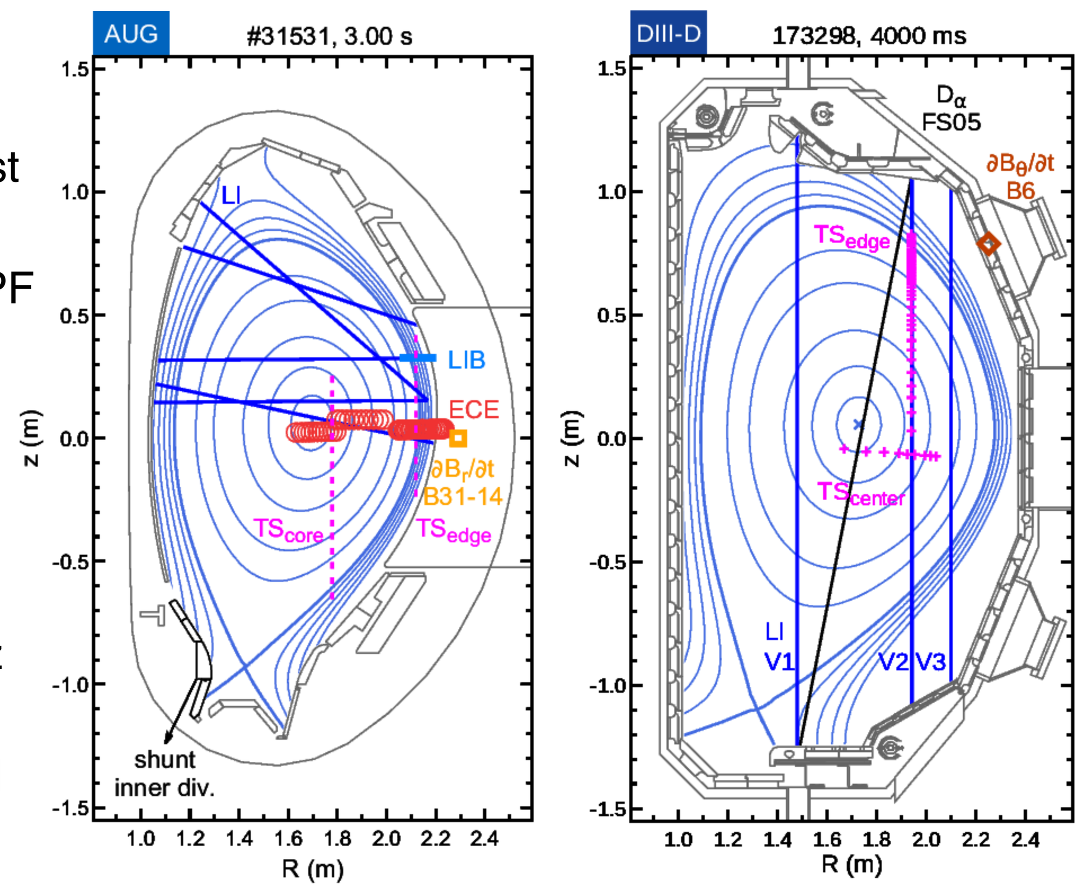
1. Introduction and Motivation

- High confinement mode (H-mode) enables high fusion performance
  - Comes with steep pressure gradients at the edge, the pedestal
  - Pedestal stability is limited by edge localized modes (ELMs)
  - ELMs expel large particle and heat fluxes towards the divertor and wall
    - → Potential risk for ITER or a fusion power plant
- Fundamental knowledge on underlying mechanisms leading to stability limit is required
  - Study of pedestal dynamics in between ELMs
- Distinct pedestal recovery phases observed:
  - Phase I: Electron density (n_e) gradient [1] and ion Temperature (T_i) gradient [2]
  - Phase II: Electron temperature (T_e) gradient
  - Phase III: gradient saturation
  - → Different recovery timescales
- Pedestal localized magnetic fluctuations observed in several tokamaks
  - In AUG, C-Mod and DIII-D their onsets are linked to the profile evolution [3,4,5]
- Why are observations similar across experiments?
  - Detailed experimental characterization provides guidance for pedestal modeling



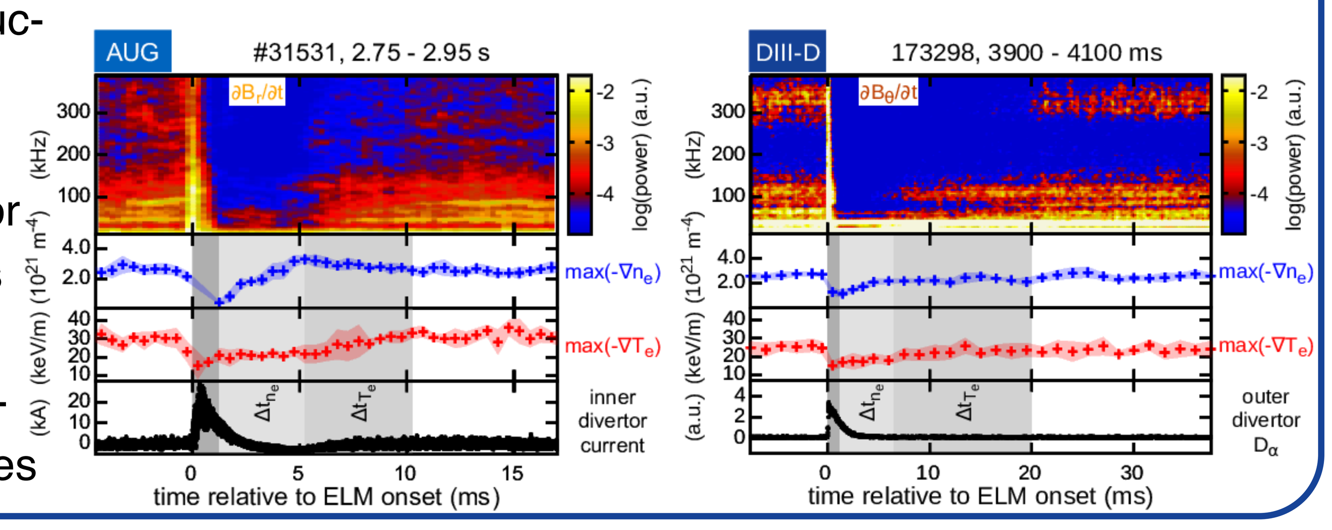
2. Comparison: AUG and DIII-D tokamak

- Medium sized tokamaks
  - AUG has metal wall and its divertor is optimized for exhaust
  - DIII-D has a carbon wall, a larger plasma volume and 18 PF coils for flexible shaping
- Compared plasmas are LSN with $\nabla B \times B$ drift to lower divertor
  - Variations in I_p, B_t, heating scheme and shape
  - ELMy H-modes with f_{ELM} 40 Hz at AUG and 15 Hz at DIII-D
    - → Allows for ELM synchronized profile analysis



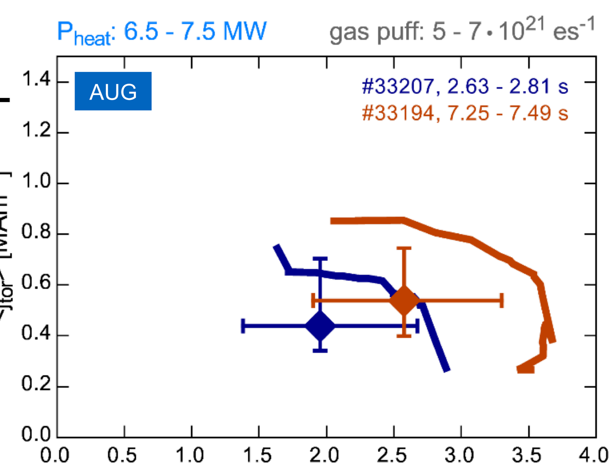
3. Same pedestal recovery phases

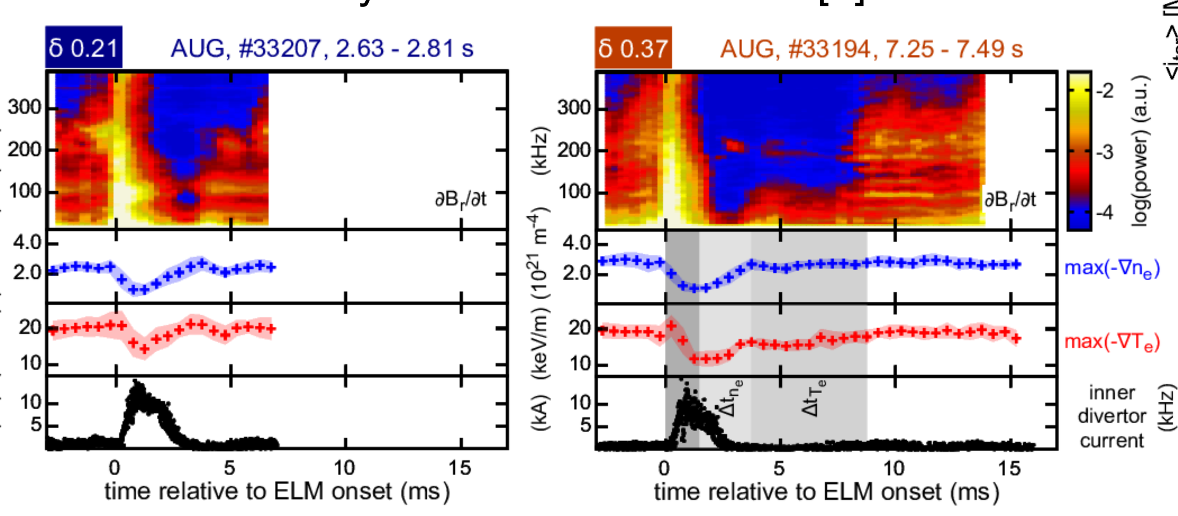
- Maximum n_e gradient builds up before max. T_e gradient and phase with clamped gradients
  - Similar magnetic fluctuations observed
    - → Same pedestal recovery behavior in both tokamaks
    - → Indicates similar underlying mechanisms/instabilities



4. δ variation: Fluctuations remain unchanged

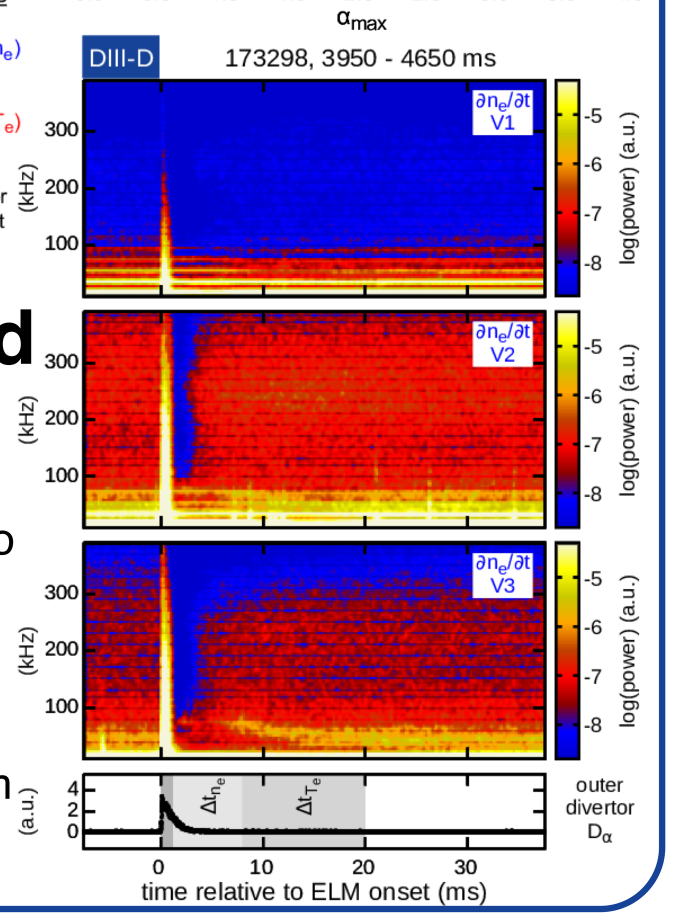
- Peeling-Ballooning modes (linear MHD) have a strong dependence on the plasma shape
  - Shape variation could suppress certain types of instabilities
- Upper triangularity (δ) varied in AUG [6] → PB stability and pedestal modified
  - But recovery sequence not affected
    - → Presence of fluctuations in both cases indicates independency of plasma shaping
    - → Non-linearly saturated instabilities [7]





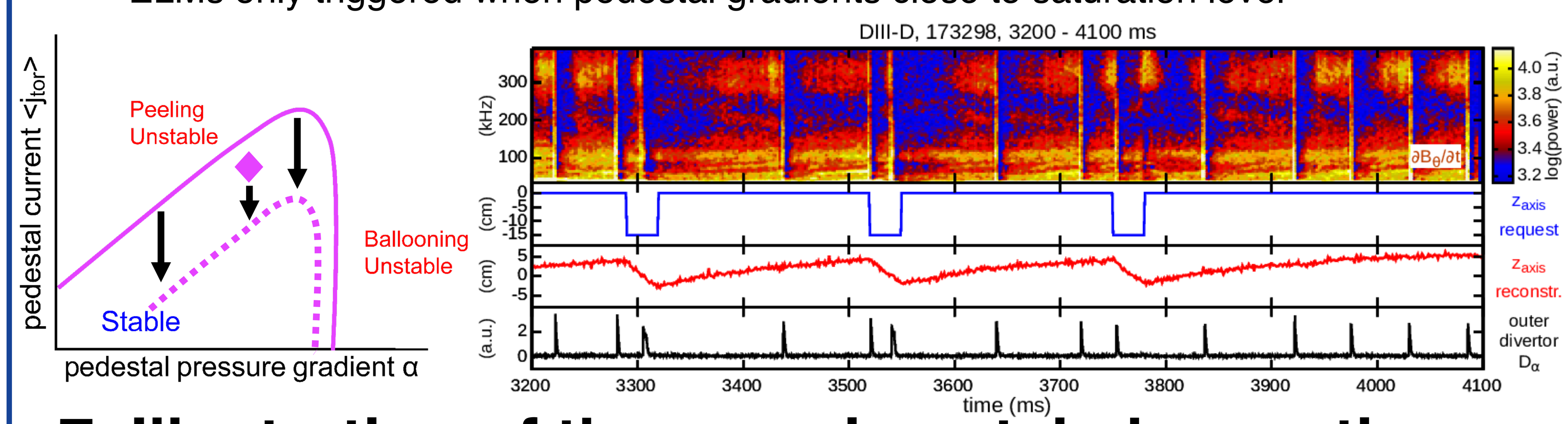
5. Core n_e fluctuations impacted

- Laser interferometer chords (from core V1 to edge V3) see reduced fluctuation level in the core after ELM crash
  - Likely the drive for central instabilities vanishes due to the loss of energy
  - On chord V3 (nearest to pedestal) a fluctuation band in the medium to low frequency range chirps down
    - → Onset is connected to the recovery of the maximum n_e gradient



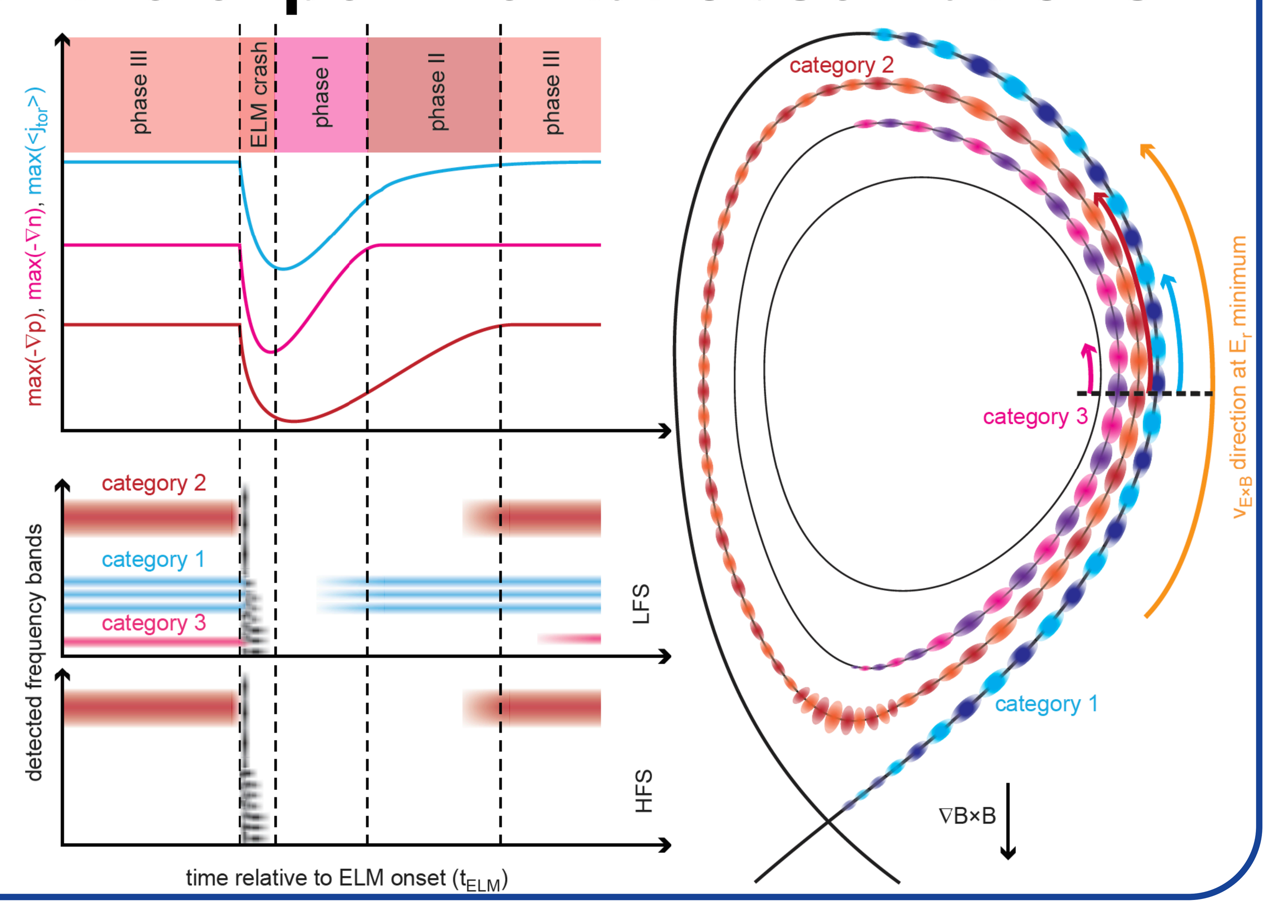
6. Vertical oscillations to probe the pedestal

- Oscillations introduce a perturbation to the edge current → used for ELM pacing [8,9,10]
  - ELMs only triggered when pedestal gradients close to saturation level



7. Illustration of the experimental observations

- Categories of instabilities:
  - Category 1: separatrix
    - → Ballooned structure, after phase I [11]
  - Category 2: E_r min.
    - → HFS response, after phase II [12]
  - Category 3: Ped. top
    - → Onset during phase III [13,14]
- Non-linear, global models required to reproduce experimental observations



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8. Summary

- Pedestal fluctuations with similar behavior identified and characterized in AUG and DIII-D
  - Experimental observations are independent over achievable range of parameters
    - → Points to a robust underlying mechanism in both machines
- Distinct frequency bands correspond to radially separated, pedestal localized modes
  - Onsets throughout the ELM cycle correlated to clamping of individual profile gradients
  - Three categories localized: (1) close to the separatrix, (2) E_r min and (3) pedestal top
    - → Relation of fluctuations and pedestal transport will be studied in further detail

9. Conclusions

- Modeling challenged by detailed experimental characterization
  - Pedestal localized instabilities behave similarly across wide parameter ranges
    - → Non-linear, global simulations might be necessary
- Future machines might exhibit similar inter-ELM dynamics

web version

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