Pedestal Height Scalings and Initial Turbulence Analysis in NSTX

A. Diallo

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and the NSTX Research Team

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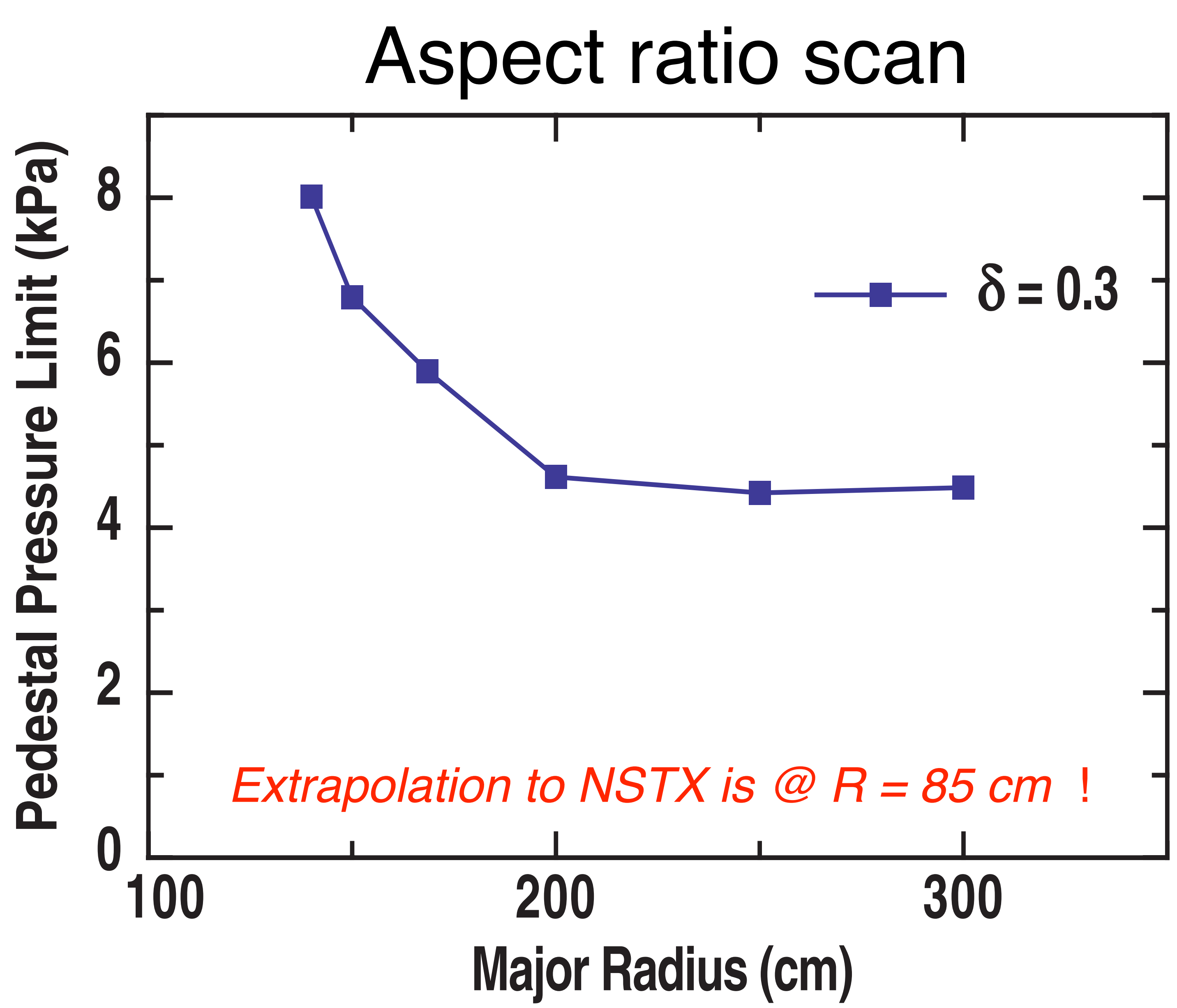
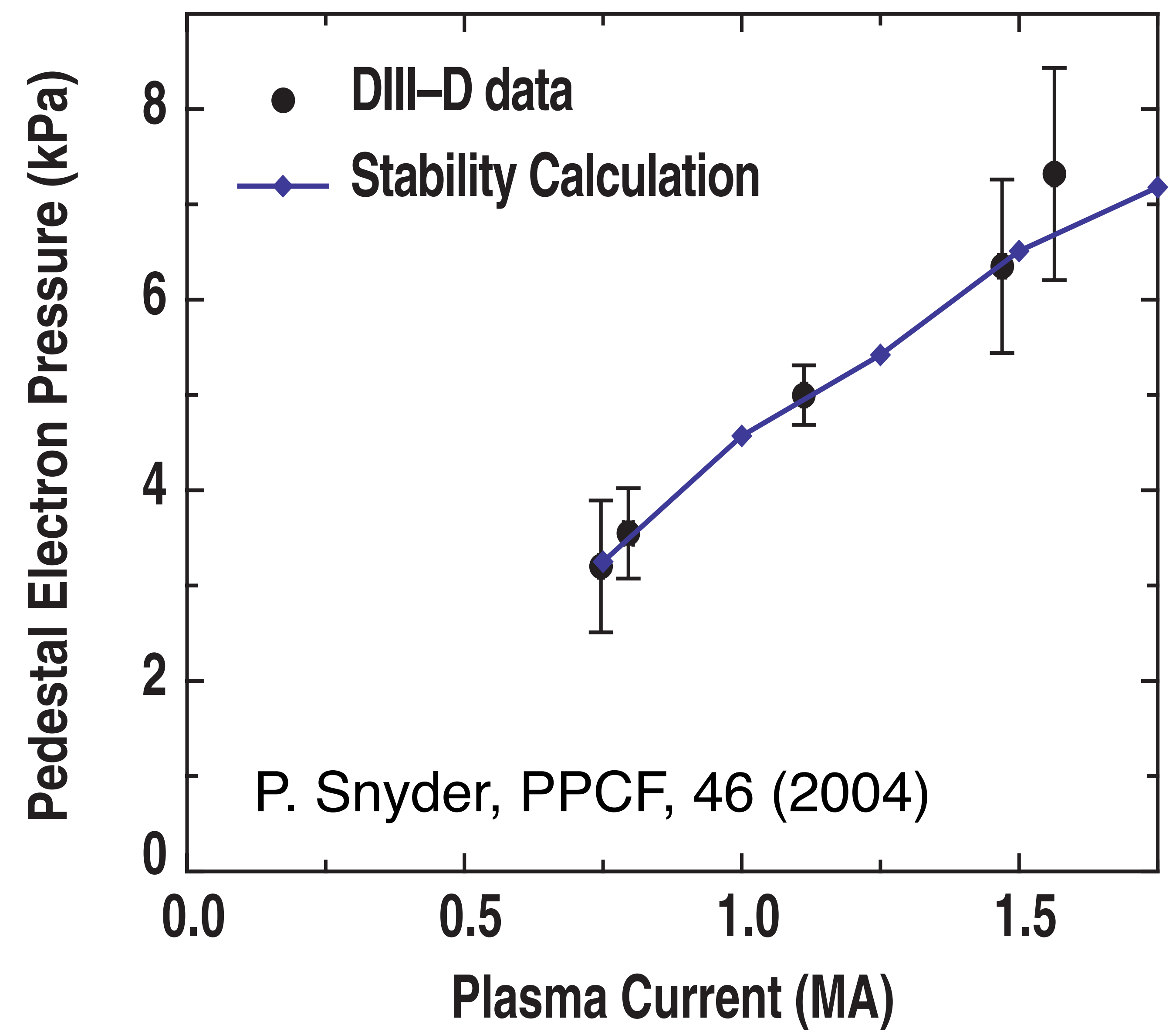
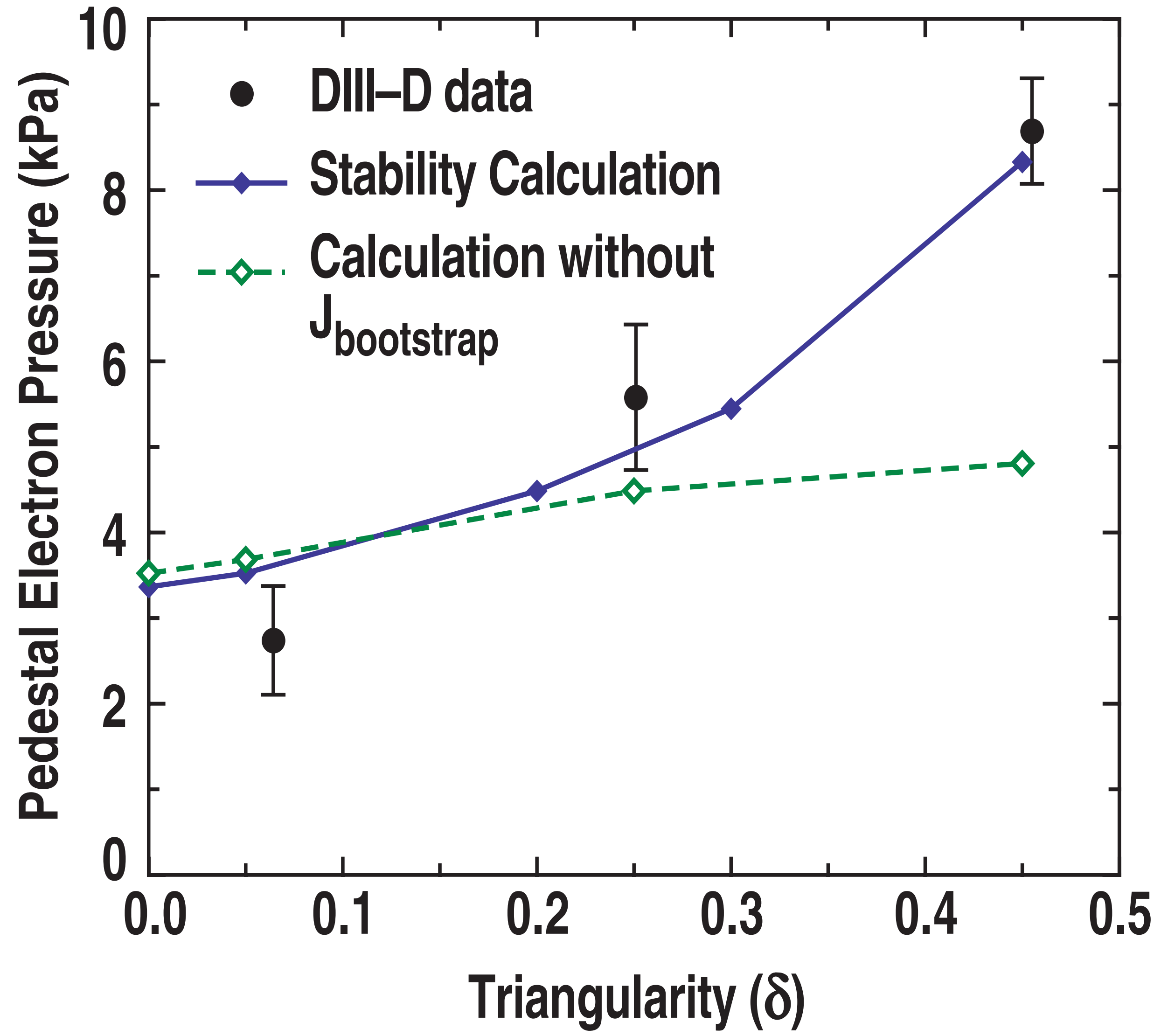
Original Motivation





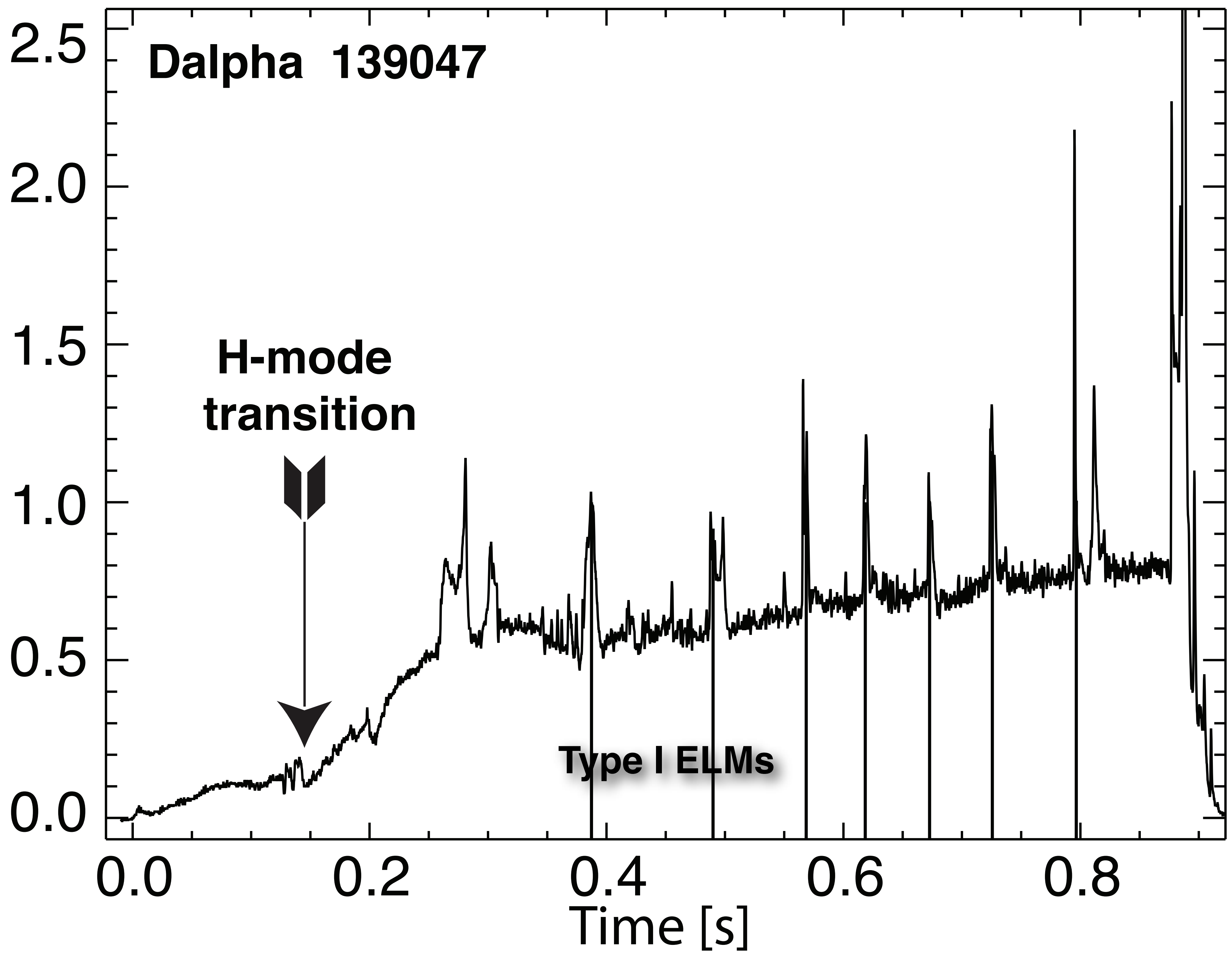


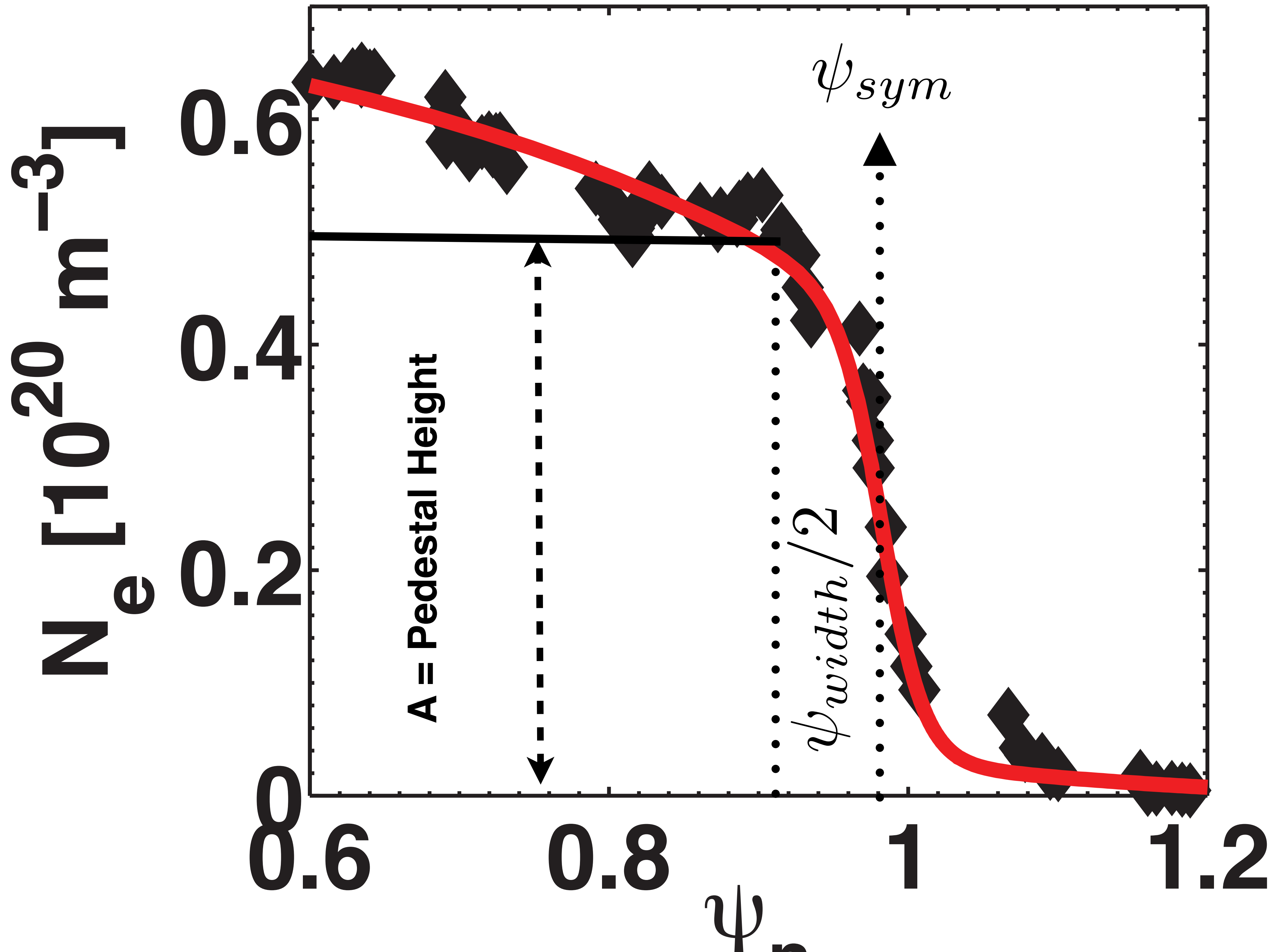
- ELITE predicts enhanced edge stability at low R/a
  - ELMy discharges in NSTX at the kink/peeling boundary from ELITE R. Maingi, PRL, 103 (2009)
- Higher R/a tokamaks have shown the pedestal height increases with triangularity and plasma current (I_p)
  - Consistent with ELITE modeling

Understand the pedestal structure prior to the onset of ELMs as a function of key plasma parameters

- Investigation of the plasma current and triangularity scalings
  - Pedestal pressure ~ I_p^2 as at higher R/a
  - Pedestal pressure increases with triangularity
- Assess the edge fluctuations during the multiple stages on an ELM cycle.
  - Continuous increase of the density fluctuations at the top of the pedestal and “cascade” to lower frequency before the ELM crash.
  - Mod k fluctuations and consequently the flow shear decays before the ELM in order to increase after the ELM crash.

Composite radial profiles of density, temperature and pressure synced to Type I ELM cycle





$$N(\psi) = A \tanh\left(\frac{\psi_{sym} - \psi}{\psi_{width}}\right) + offset$$

R. Groebner and T. Osborne PoP **5** 1800 (1998)

- N_e and T_e profiles fitted using modified tanh function
  - Ion profiles fitted with splines (no clear pedestal)
- Fits done in discrete windows throughout ELM cycle.

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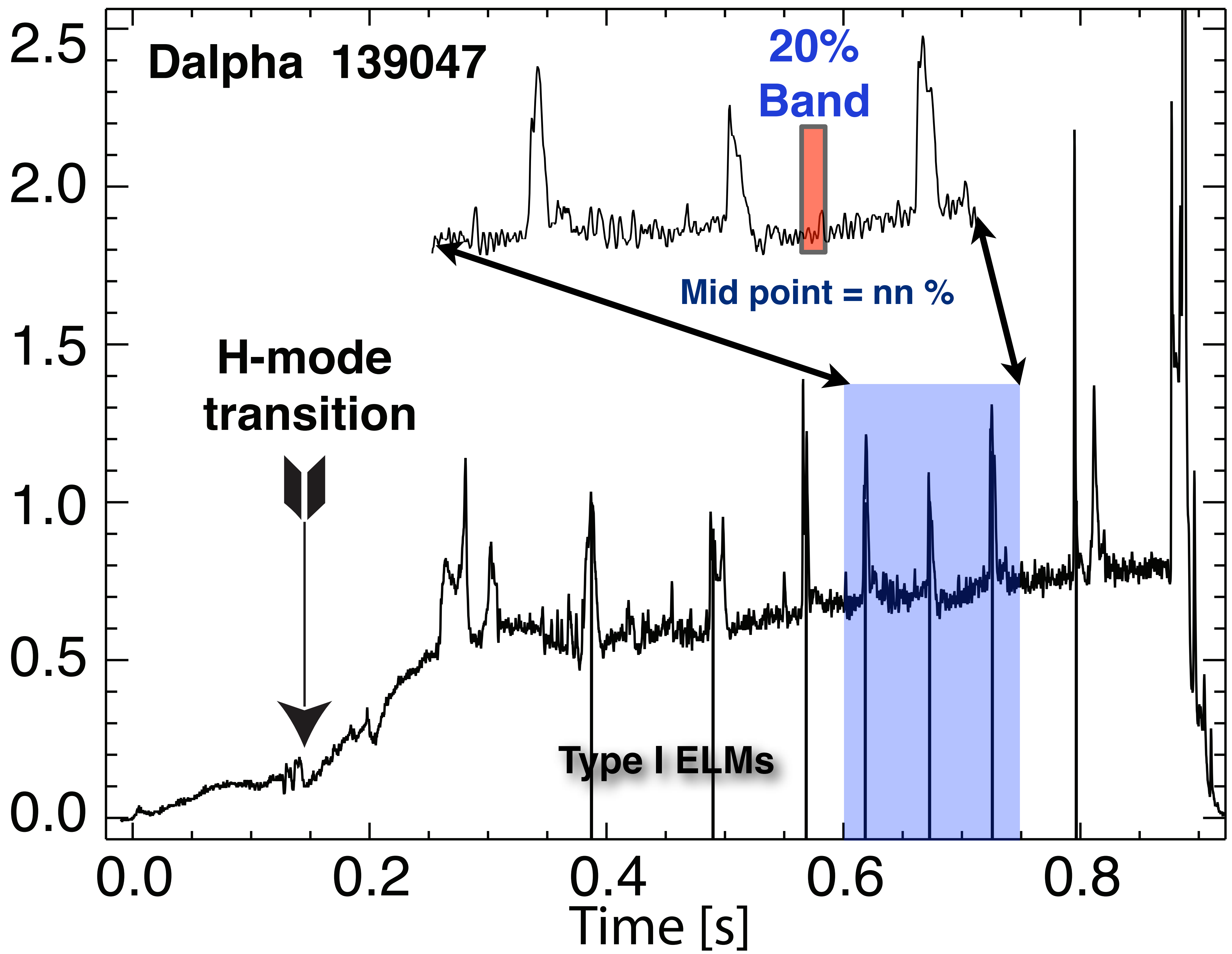

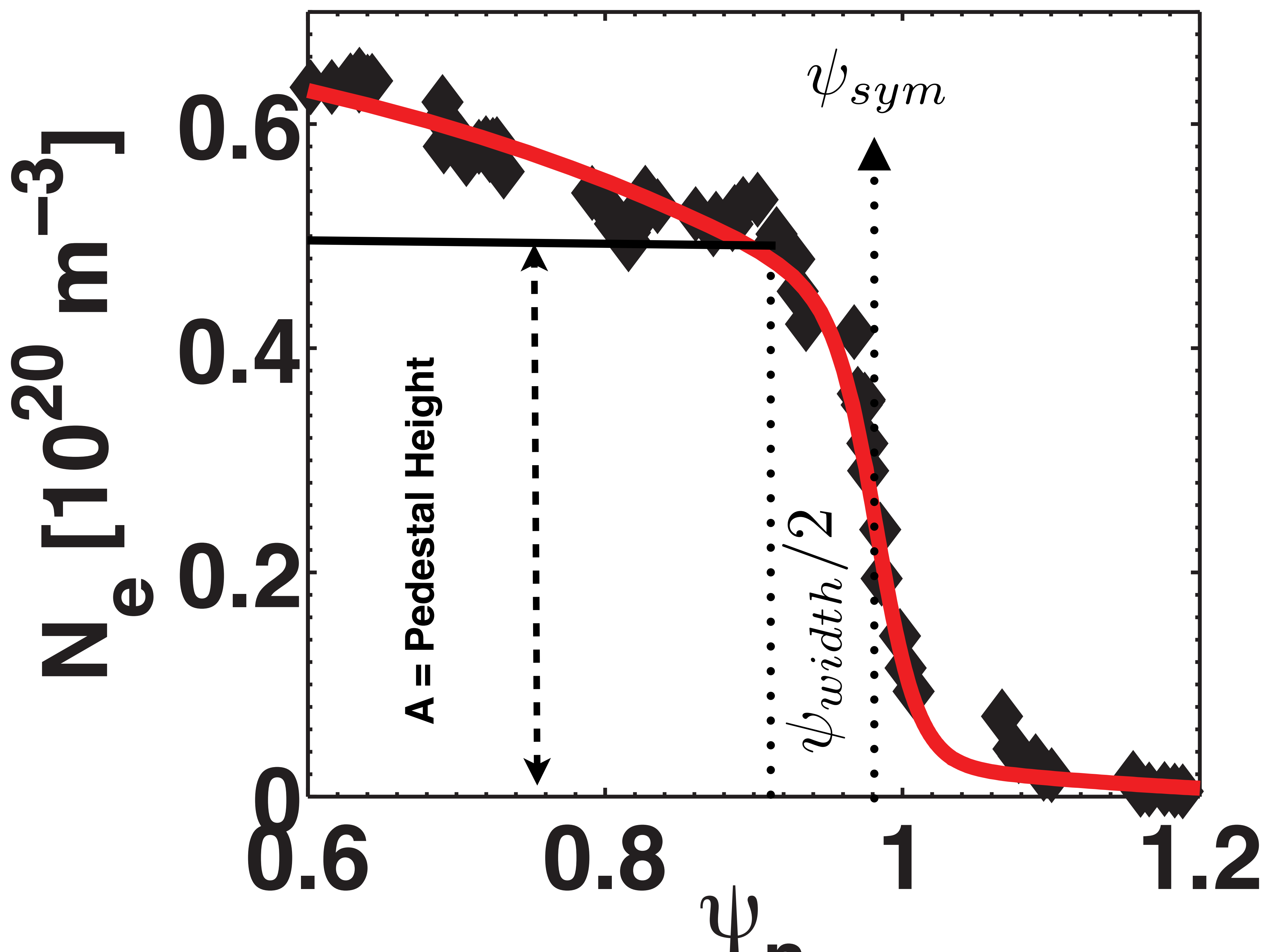

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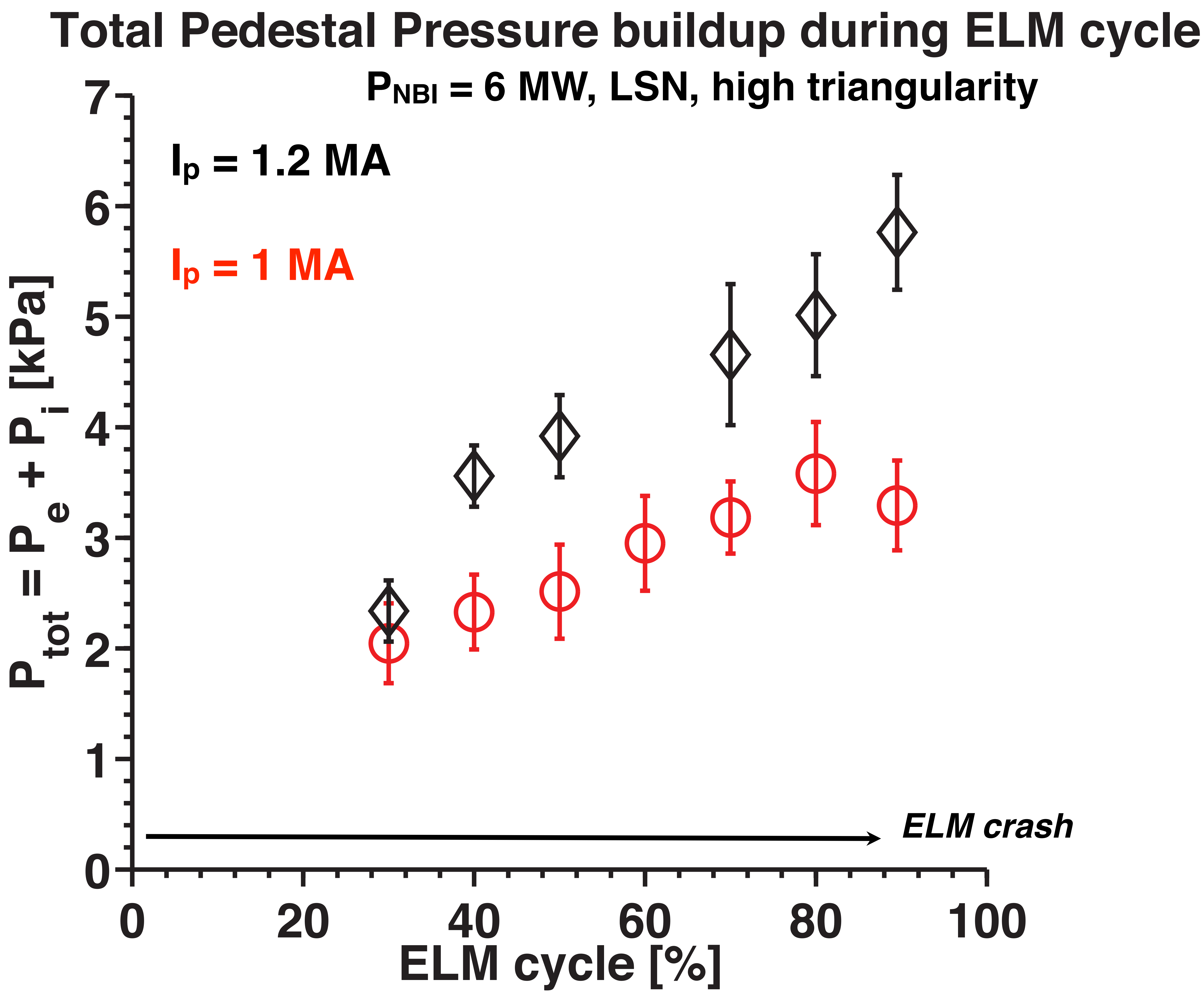
Pedestal height builds up during an ELM cycle

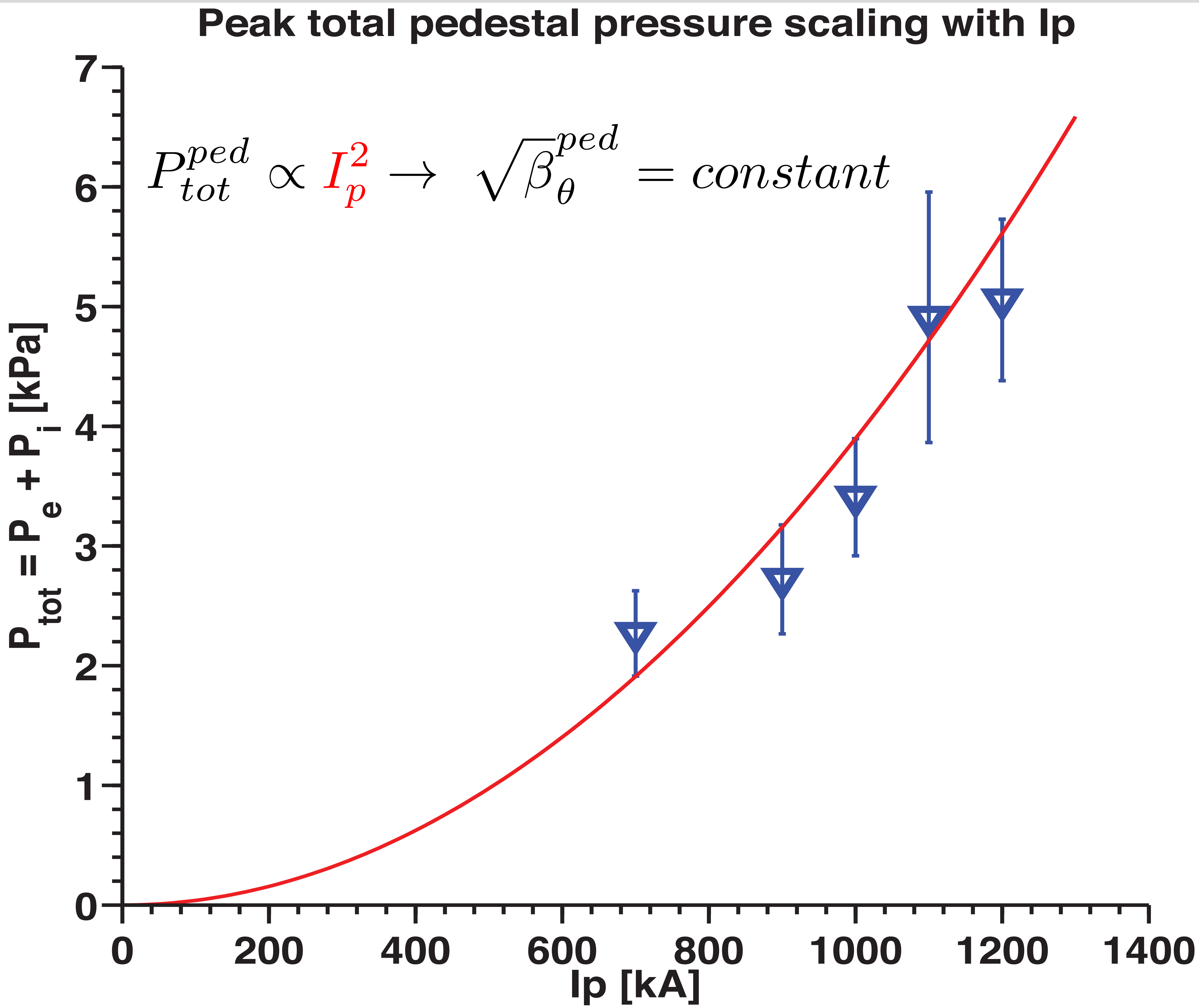


- Pedestal pressure increases with I_p
- Pedestal pressure increases by a factor ~ 3 before the ELM crash
  - No clear saturation at high I_p
  - Saturation late in cycle at lower I_p
  - In contrast to rapid saturation within first 20-50% of ELM cycle observed in AUG and DIIID

[Maggi, Nucl. Fusion (2010)]

[Zohm, PPCF (2010)].

P_{tot}^{ped} increases quadratically with Ip, but at constant β_θ^{ped}



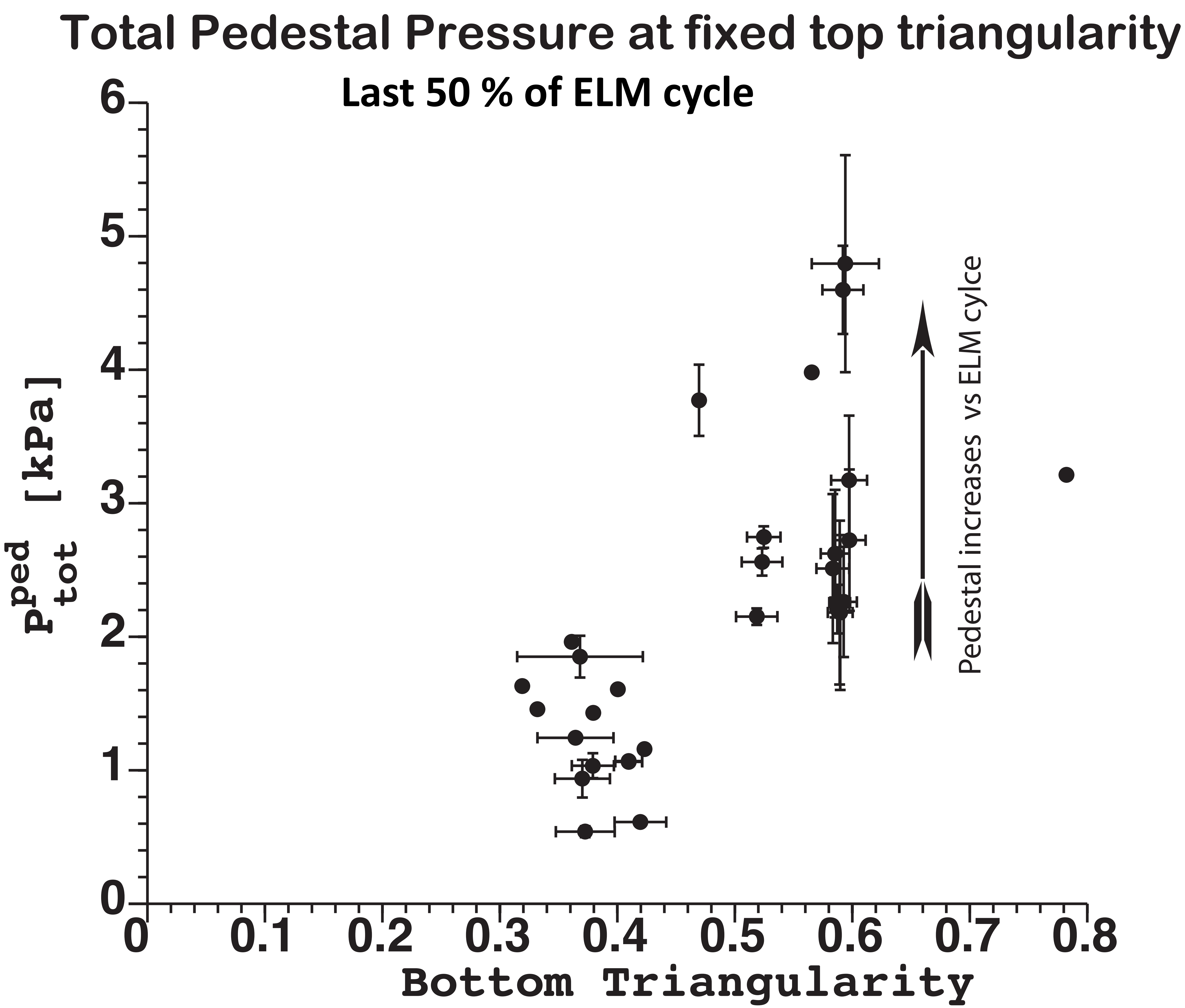
Consistent with higher R/a, e.g. DIIID, C-MOD,and AUG

Hughes, PoP, 13 (2006)

Suttrop,PPCF, 42 (2000)

Osborne,PPCF, 4 (2000)

Pedestal pressure height increases with triangularity



- I_p=0.8 MA, P_{NBI}=4 MW, B_t=0.45 T, LSN(drsep ~ - 0.5 cm)
- Density and temperature pedestals both increase
- Similar to DIII-D [Osborne,PPCF 42 2000]

Understand the pedestal structure prior to the onset of ELMs as a function of key plasma parameters

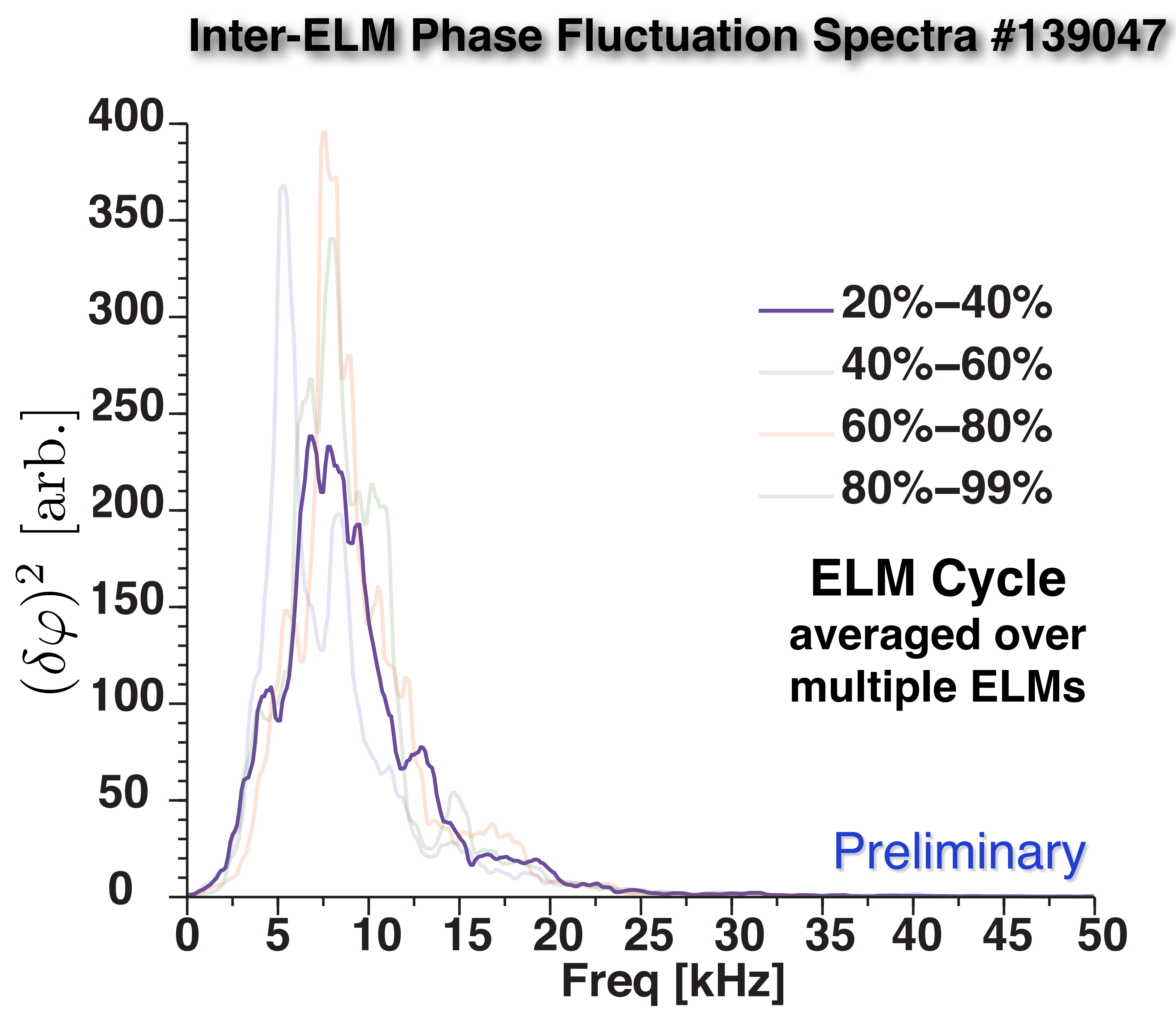
- Assess the edge fluctuations during the multiple stages on an ELM cycle.

  .....Density fluctuations through reflectometry

  .....Mod |K| fluctuations through GPI

Phase fluctuations at the top of the pedestal increase continuously during ELM cycle and "cascade" to lower frequency just before ELM crash

- Phase fluctuations from reflectometry localized at the top of the pedestal
  - Phase and density fluctuations are correlated. Nazikian, PoP 8 (2001)
- Increase of initial mode amplitude
  - e.g., at 7.5 kHz
- Mode activity late in ELM cycle
  - e.g., 5 kHz
- No evidence in Mirnov signals, modes appear to be electrostatic.



Mode remains to be identified ?

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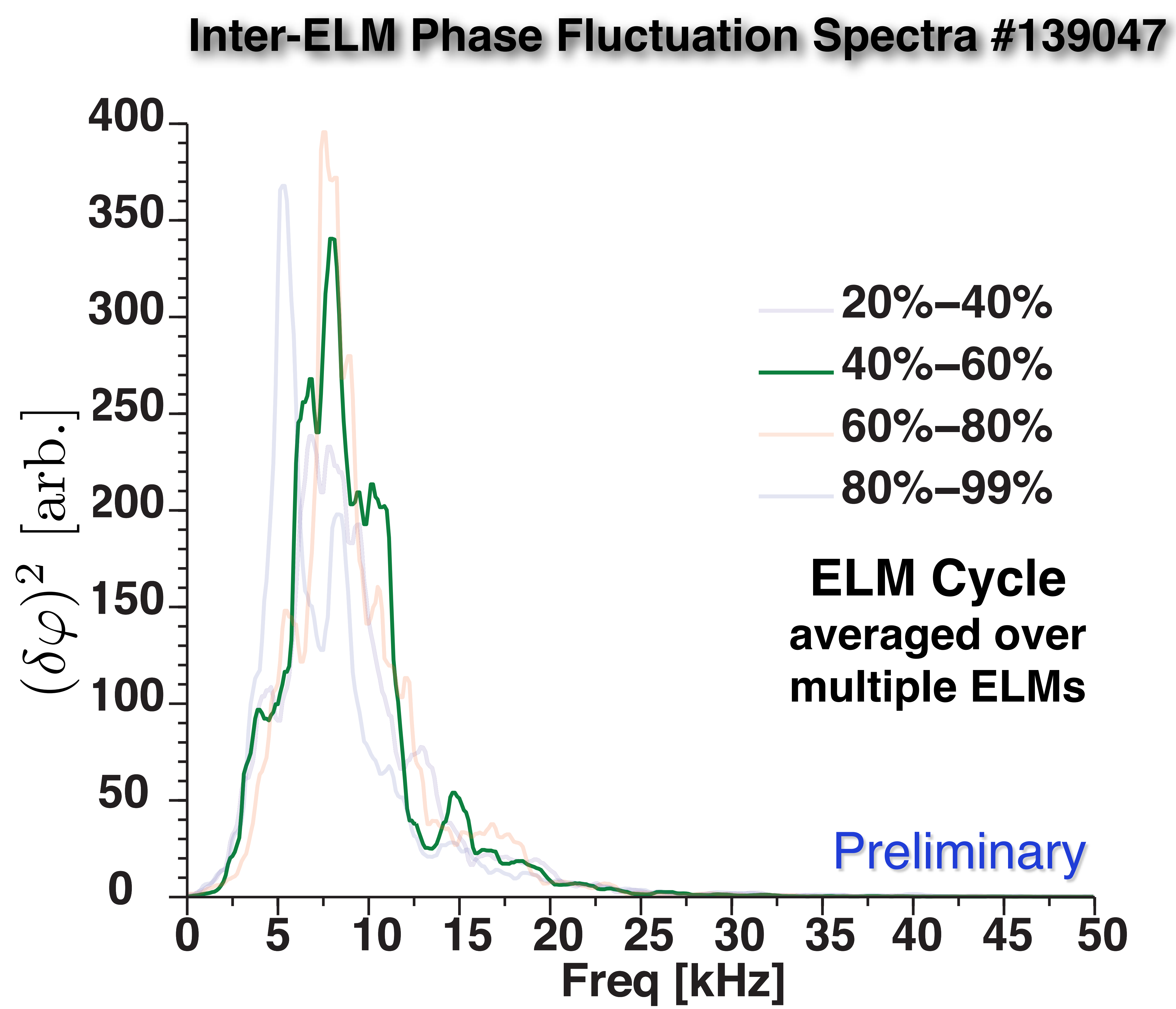

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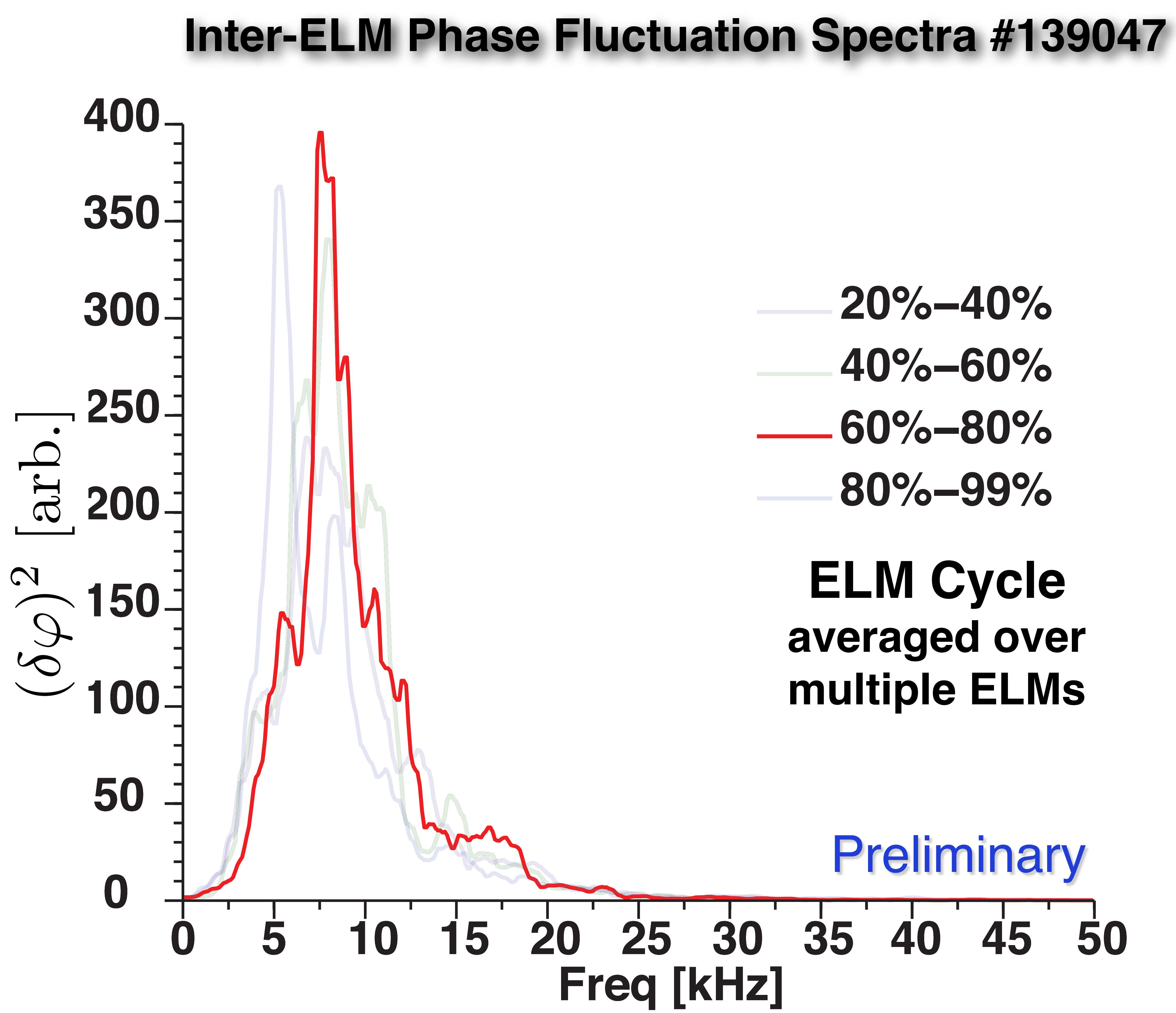

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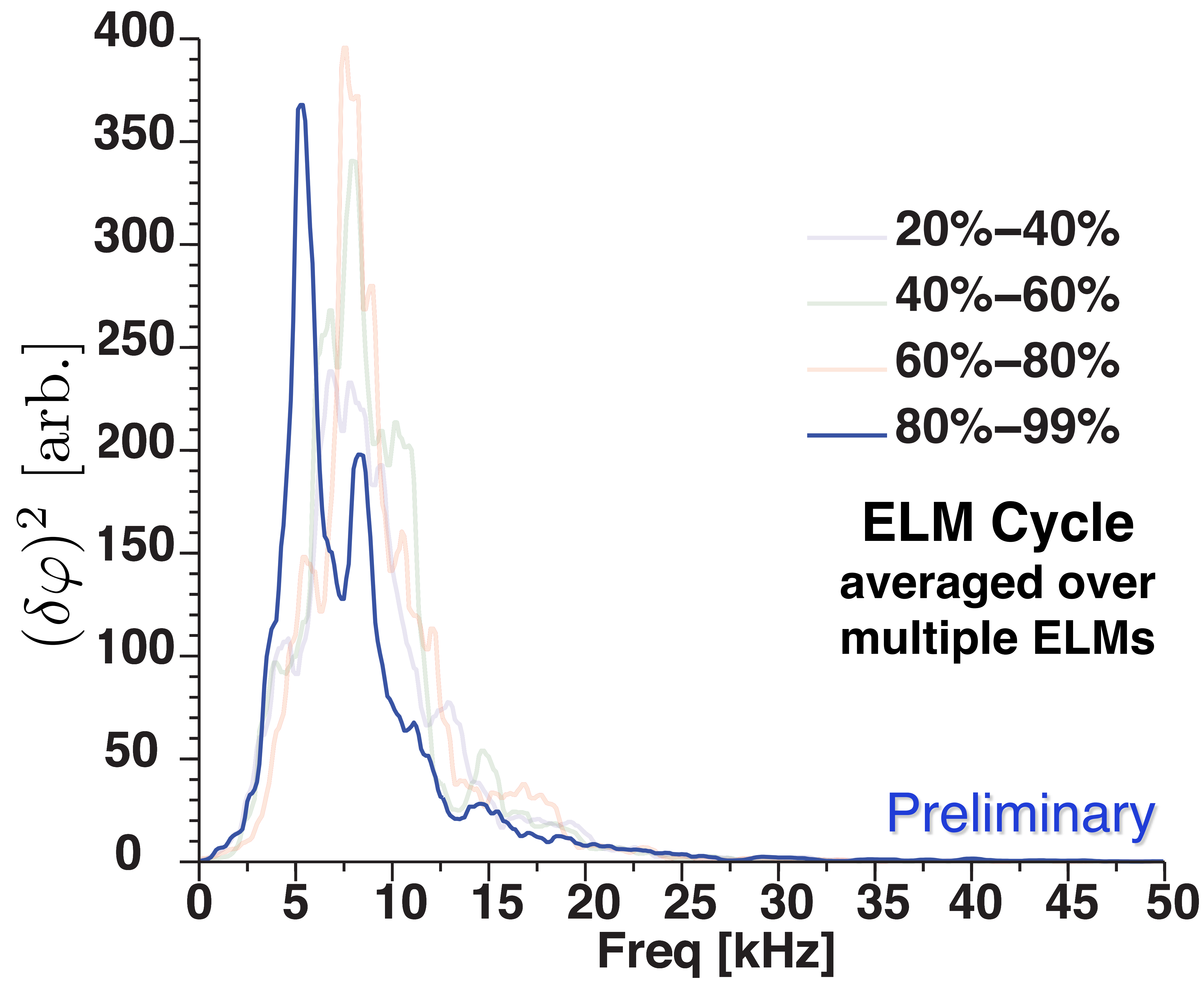
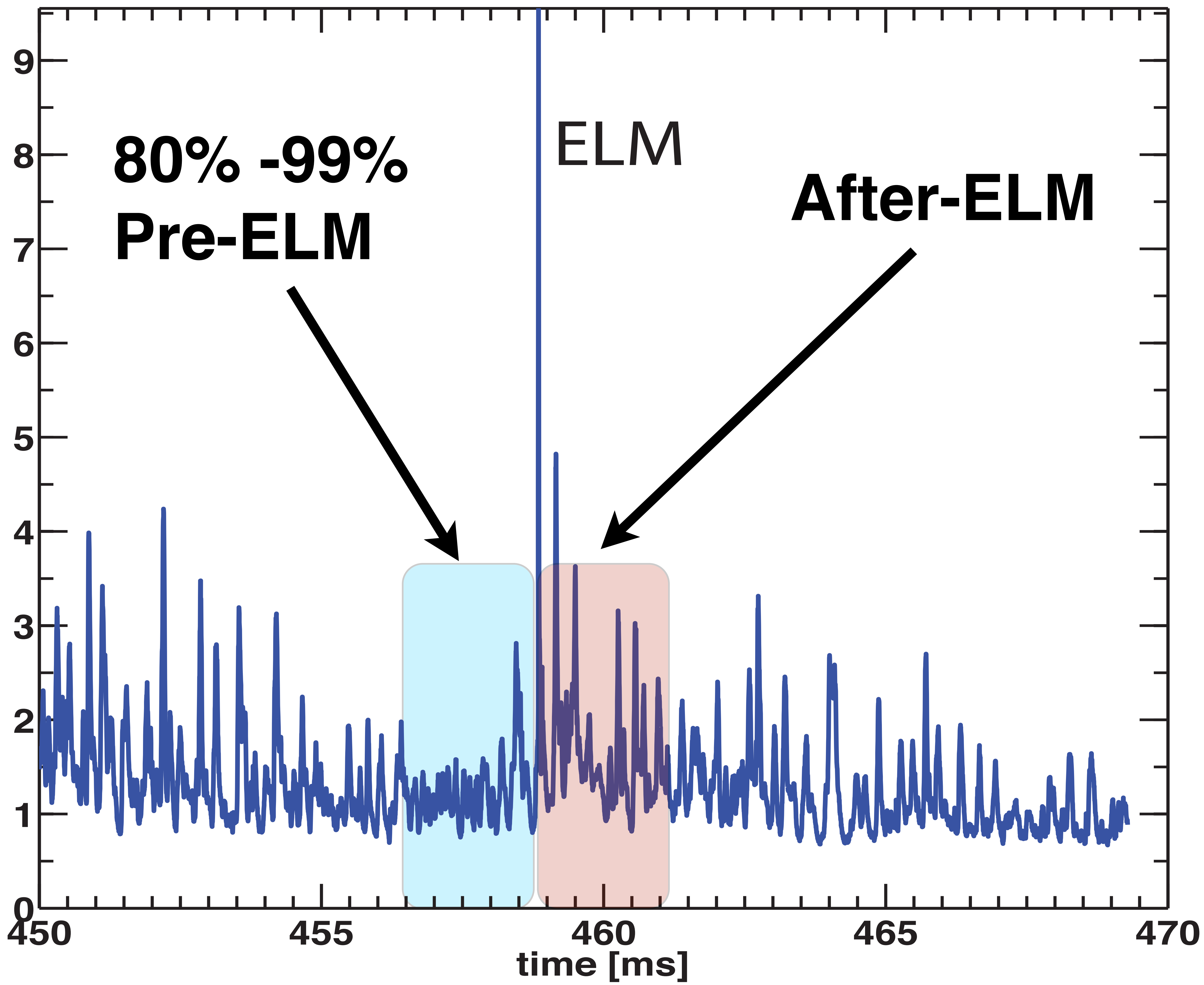
Inter-ELM Phase Fluctuation Spectra #139047



Mode remains to be identified ?

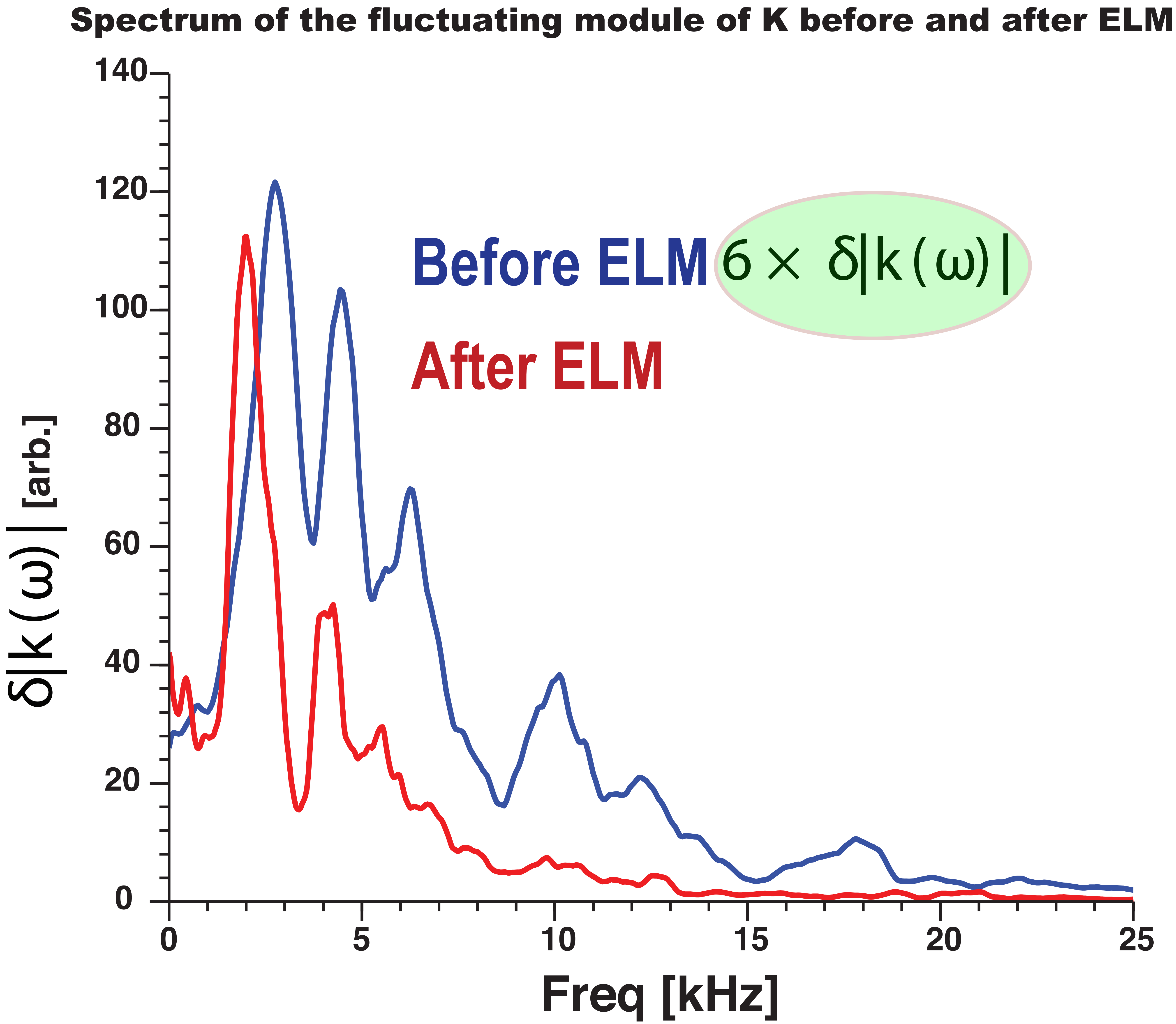
Using the gas puff imaging, the wavenumber module fluctuations peak after ELM and decay between ELMs

$$\delta|k|(\tau) = \Sigma|k|\delta I(k_r, k_\theta, \tau)$$



- Extract the fluctuating brightness from the GPI and project it to the wavenumber space.
- The edge flow shear is encoded in the fluctuations of |**K**|.

RMS fluctuations in the norm of K is higher after ELM than just before ELM



- Observation of coherent fluctuations.
  - same frequency range as in reflectometry.
- RMS fluctuation increases after the ELM crash.
  - consistent with previous observations in NSTX

    [Maqueda,JNM 390, (2009)]
- Using the advection-diffusion equation, the rms of mod |k| can be linked to the flow shear.

Summary and future directions

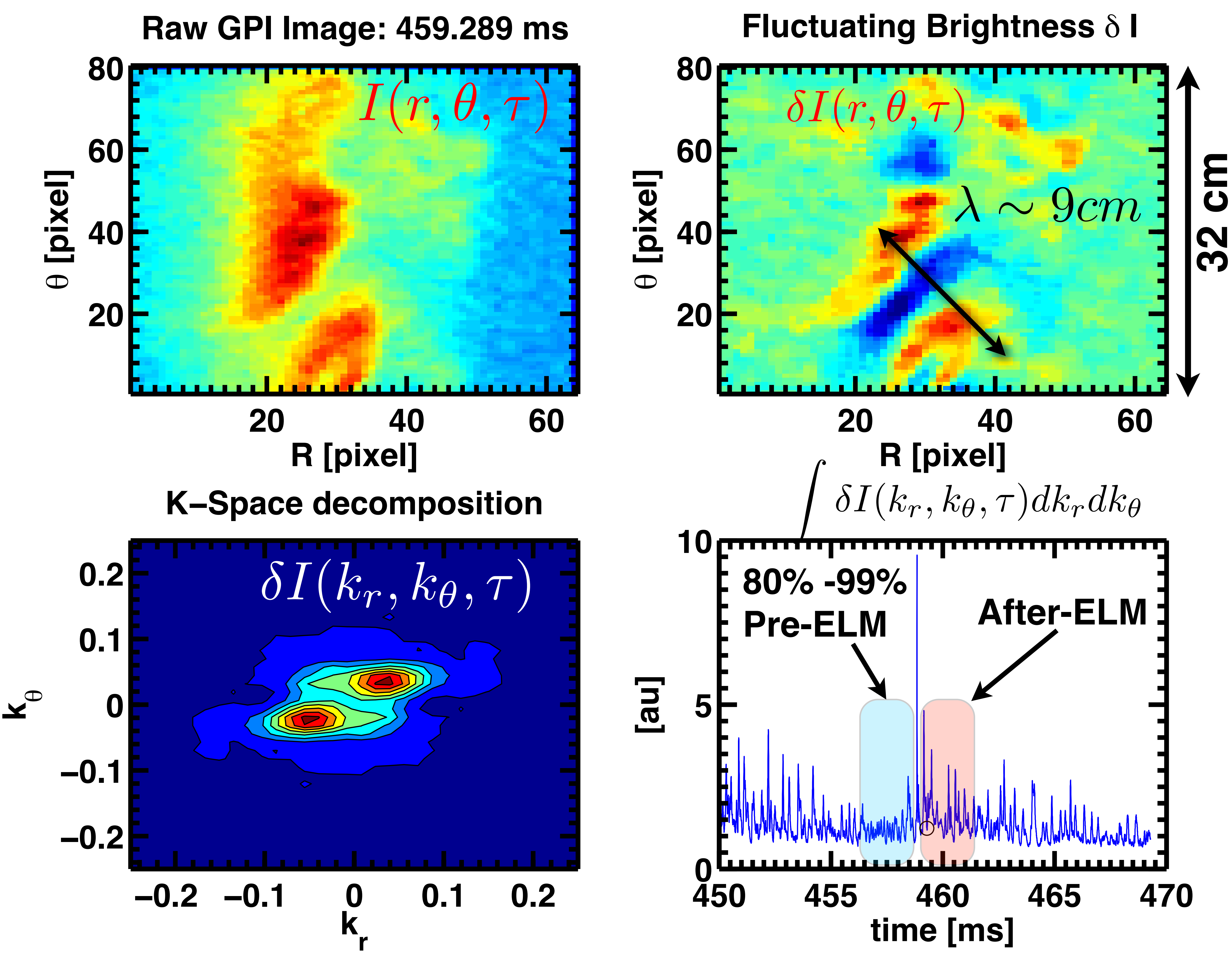
- We observe $P_{tot}^{ped} \propto I_p^2$,which is consistent with higher aspect ratio tokamaks
- We observe P_{tot}^{ped} increases with triangularity: similar to DIII-D
- We show that the pedestal pressure builds up continuously during an ELM cycle, with saturation observed at lower plasma currents near the end of the cycle
  - appears to be in contrast with AUG and DIII-D

- Pedestal top density fluctuations increase during ELM cycle, with a frequency "cascade" to lower frequency just before the ELM crash
- Mod |k| fluctuations and consequently the flow shear peak just after ELM crash, and die away slowly in the inter-ELM cycle: same frequency range as density fluctuations.

✦ FY11: extra 7-8 edge Thomson channels are currently being implemented
  - for a finer resolution of the edge during the ELM cycle.

Backup Slides

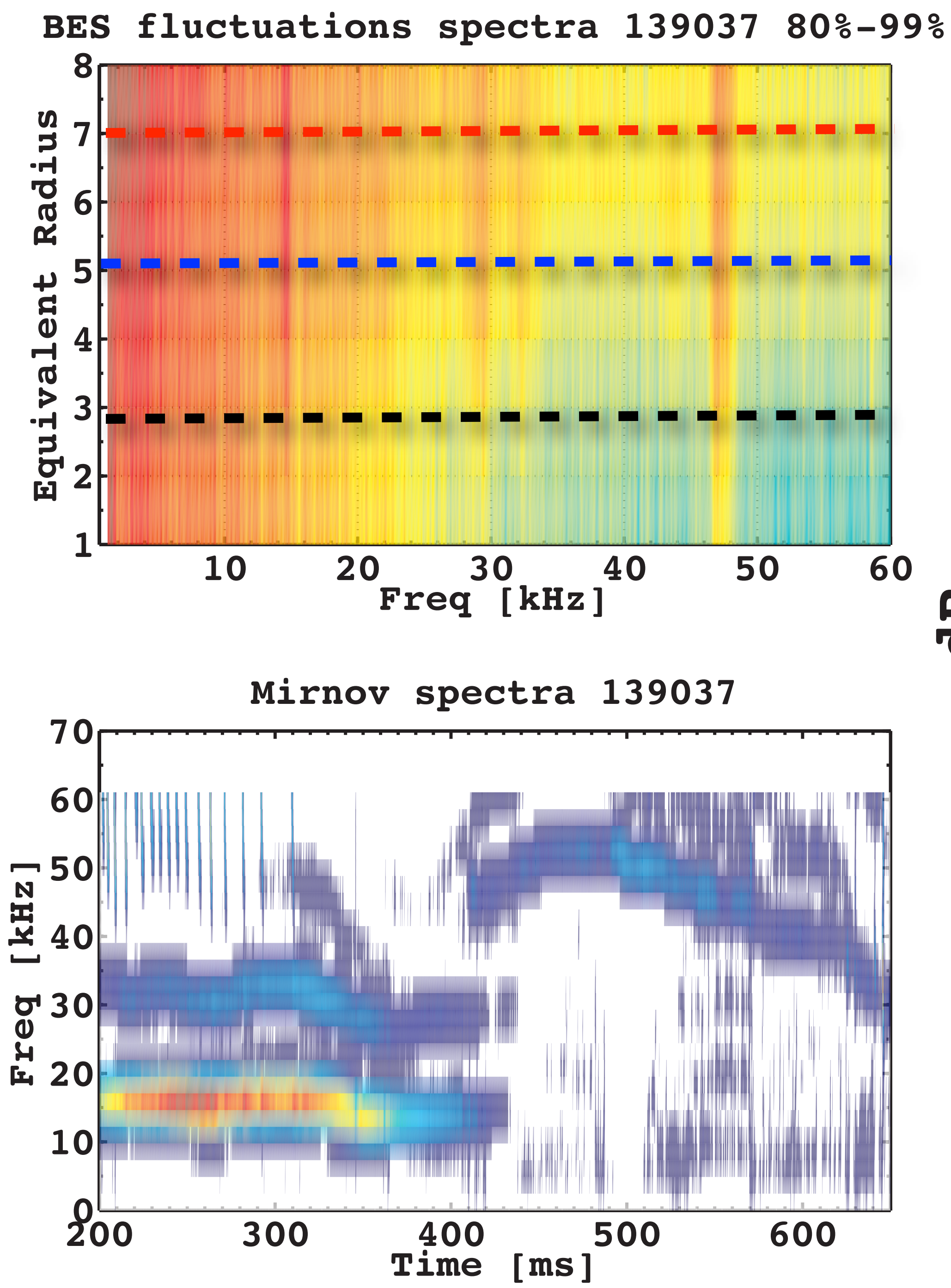
Using GPI, the fluctuations of the norm of K in the region of steep gradient can be determined

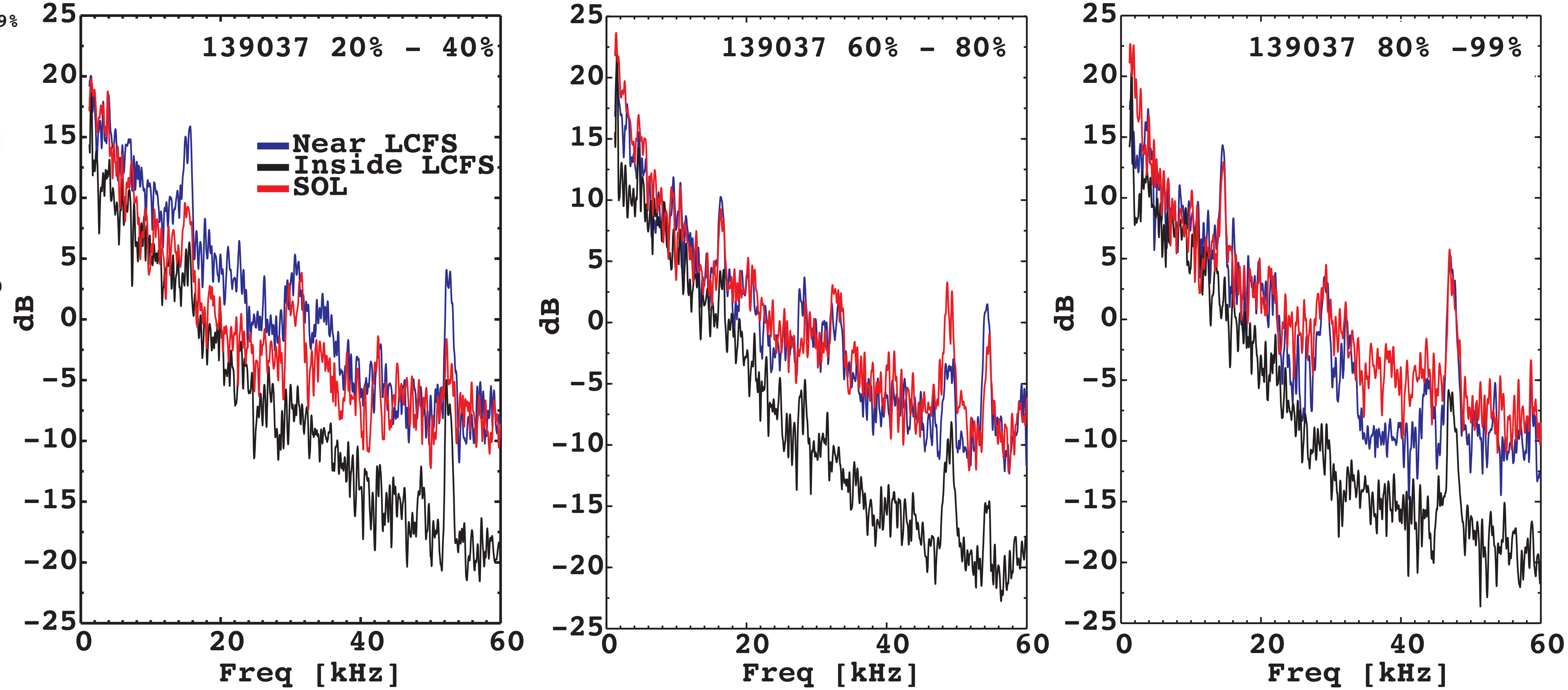


- Step 1: subtract *spatial* DC component
- Step 2: GPI brightness fluctuations are projected into K-space.
  - Discriminates large events and select spatial structure.
- Step 3: Evaluate |**K**| in the camera frame of reference
  - equivalent to the module in the advected frame of reference
- The edge flow shear is encoded in the fluctuations of |**K**|.

Y. B. Zel'dovich Sov. Phys. Dokl ,27 (1982)

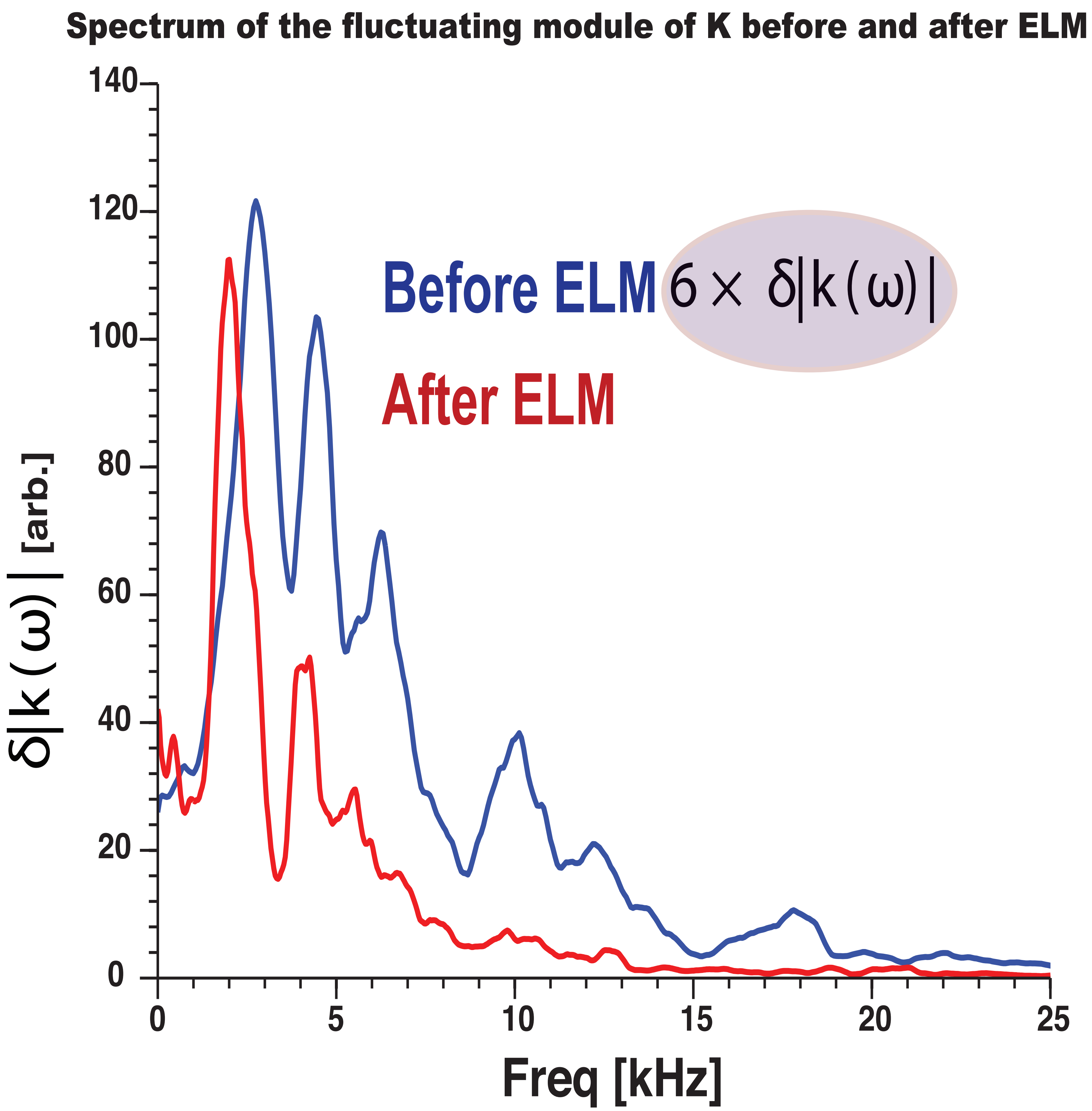
Inter-ELM fluctuations from BES indicate generic changes in fluctuations spectra during the ELM cycle with no signature of modes correlated with the pedestal buildup





Inter-ELM density fluctuation through BES enables the localization of fluctuation peaks detected on Mirnov coils but no clear signature of modes correlated with the pedestal structure.

The flow shear is encoded in mod |k| fluctuations



Advected-diffusion equation in k-space:

$$\frac{d\widehat{I}_{\mathbf{k}}}{d\tau} = \mu \underbrace{\left[(k_\xi \pm \frac{\partial V_0}{\partial r}k_\eta)^2 + k_\eta^2\right]}_{\mathbf{k}^2} \widehat{I}_{\mathbf{k}}$$

Let $\frac{\partial V_0}{\partial r} r cos(\omega\tau)$

$$\mathbf{k}^2 = (k_\xi \pm \frac{\partial V_0}{\partial r}k_\eta \tau \sin(\omega\tau)/(\omega\tau))^2 + k_\eta^2$$

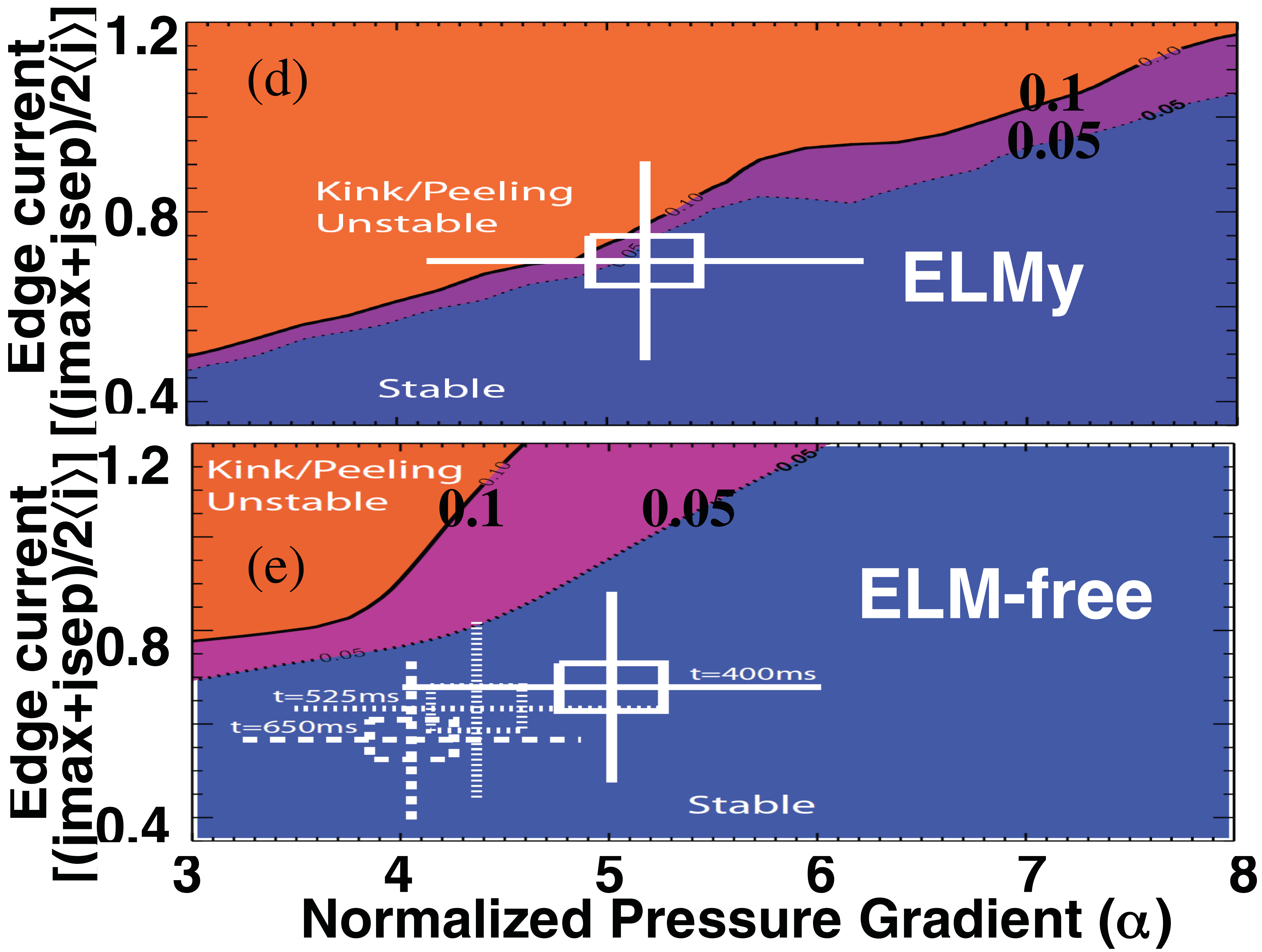
$$\mathbf{k}^2 = k_{eff}^2 + \underbrace{2\frac{k_\xi k_\eta}{\omega}\frac{\partial V_0}{\partial r}\sin(\omega\tau) + (k_\eta/\omega\frac{\partial V_0}{\partial r}\sin(\omega\tau))^2}_{\delta k^2}$$

The limit $\omega \to 0$, one has the linear drift in k. Diallo. PRL, 101 2008

In harmonic fluctuations at constant k_η/k_ξ; from δk^2, we extract $\frac{\partial V_0}{\partial r}$.

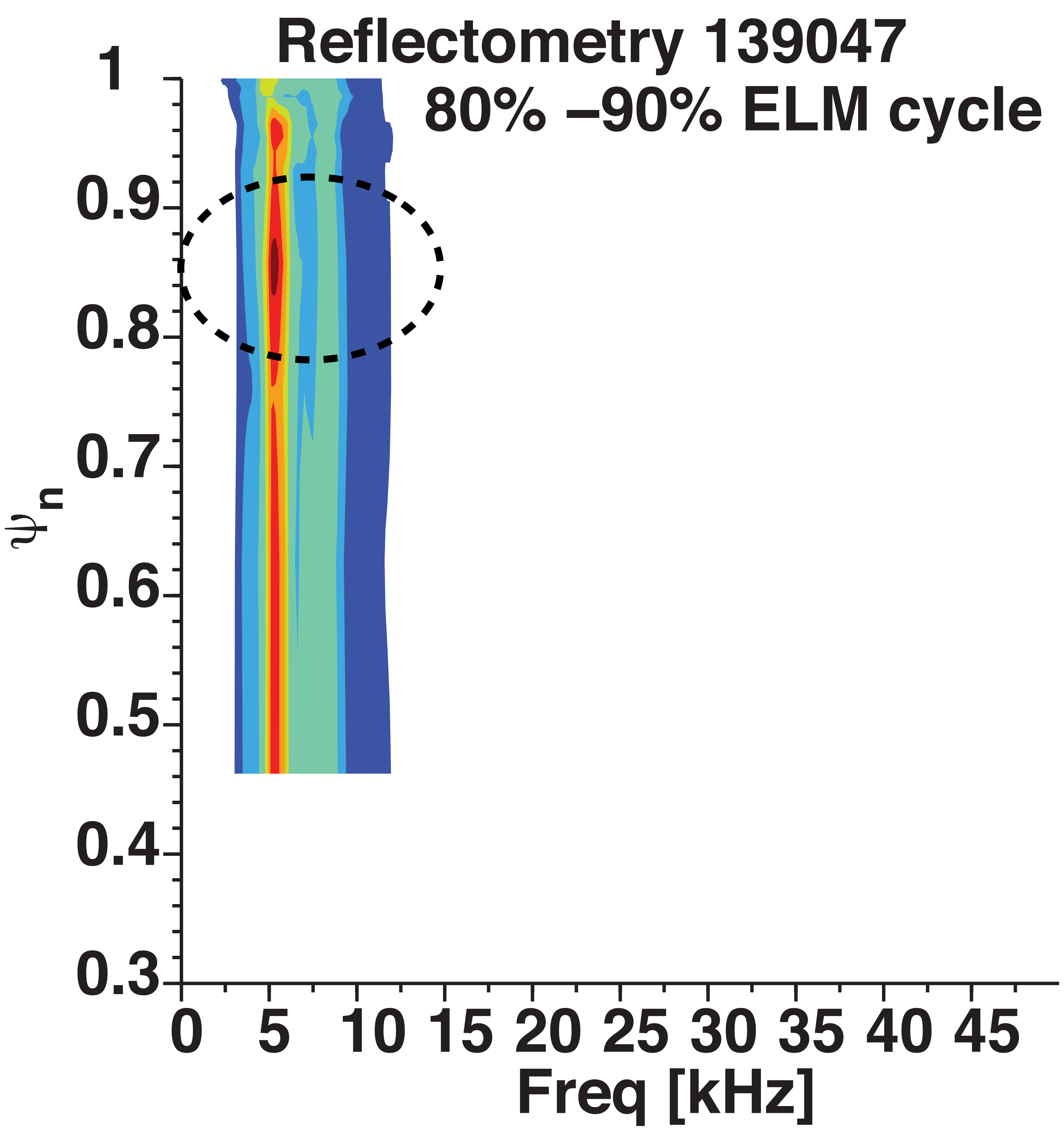
Essentially, we obtain the change of flow shear before and after the ELM

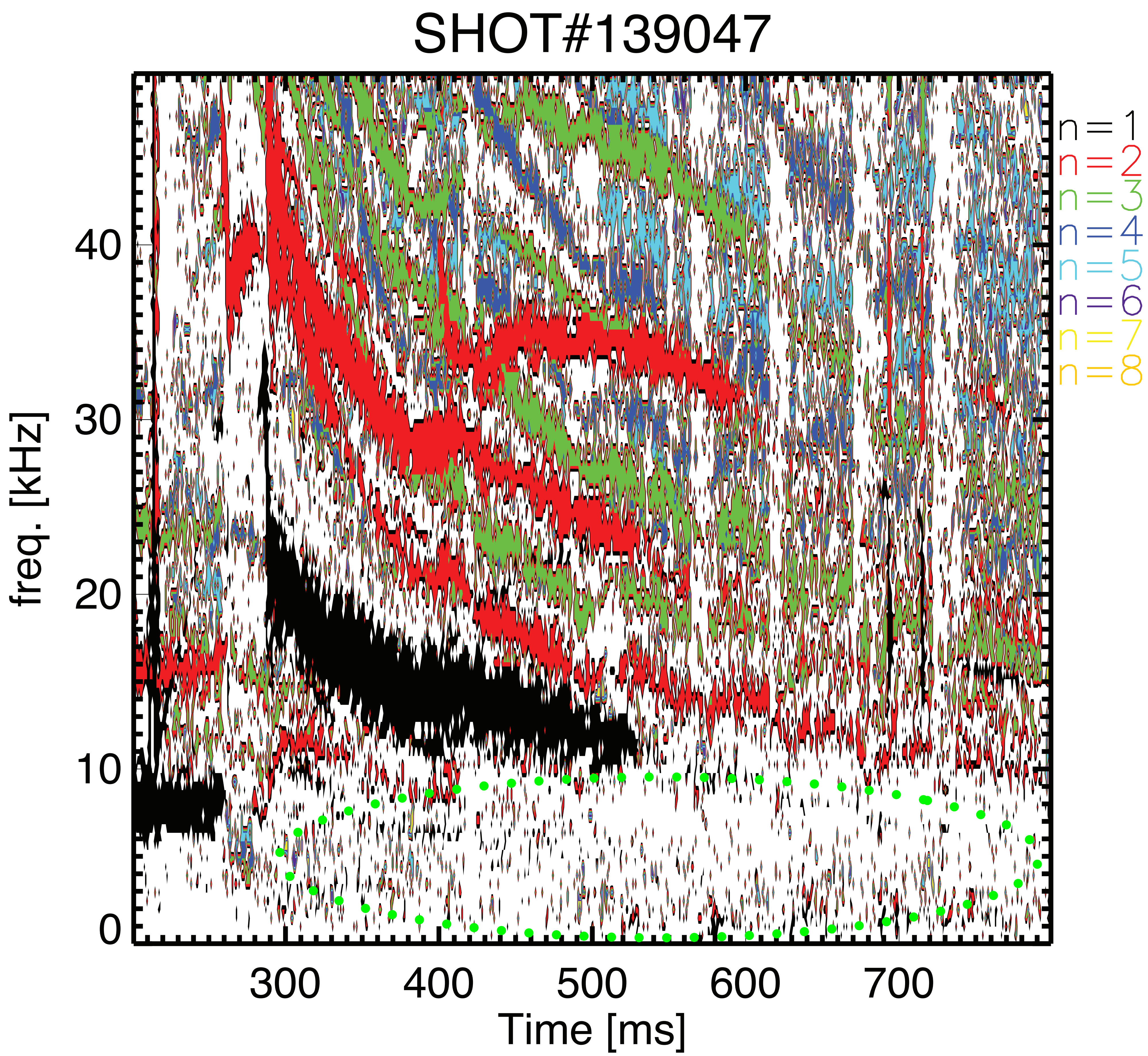
ELMy discharges in NSTX at the kink/peeling boundary from ELITE



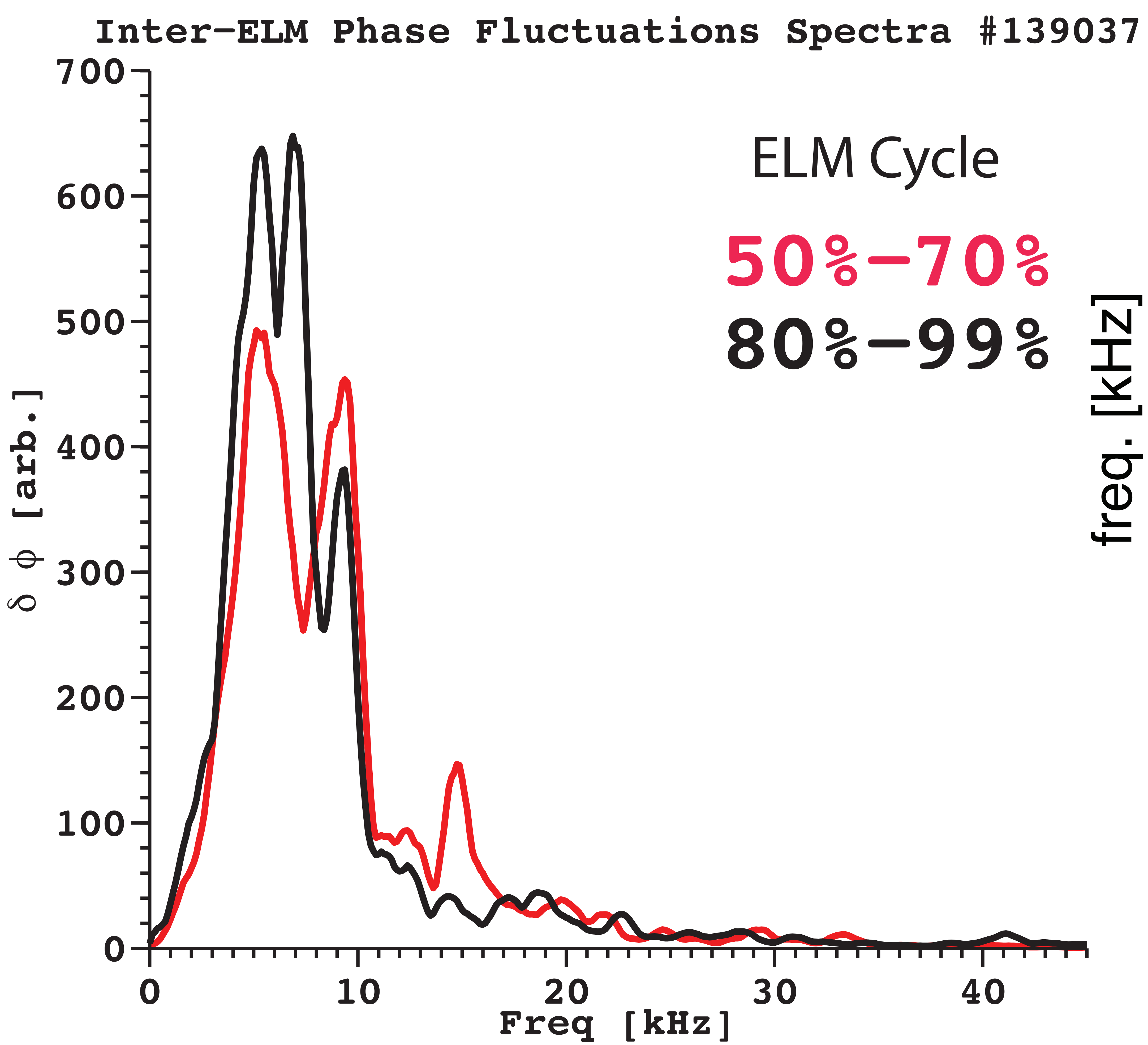
R. Maingi, PRL, 103 (2009)

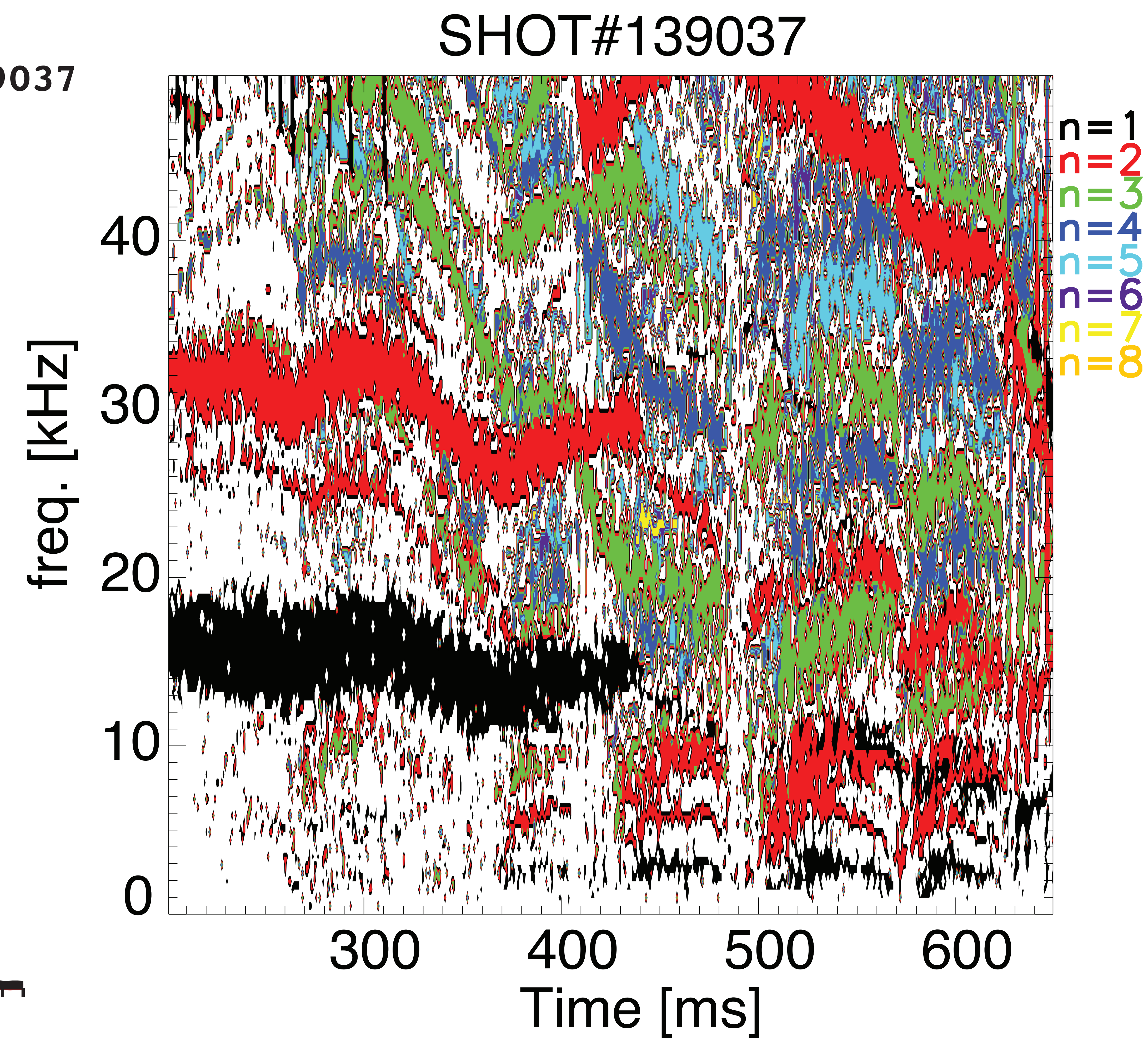
Mapping the reflectometer signals to normalized flux coordinates allow for better targeting of density fluctuation at the pedestal top



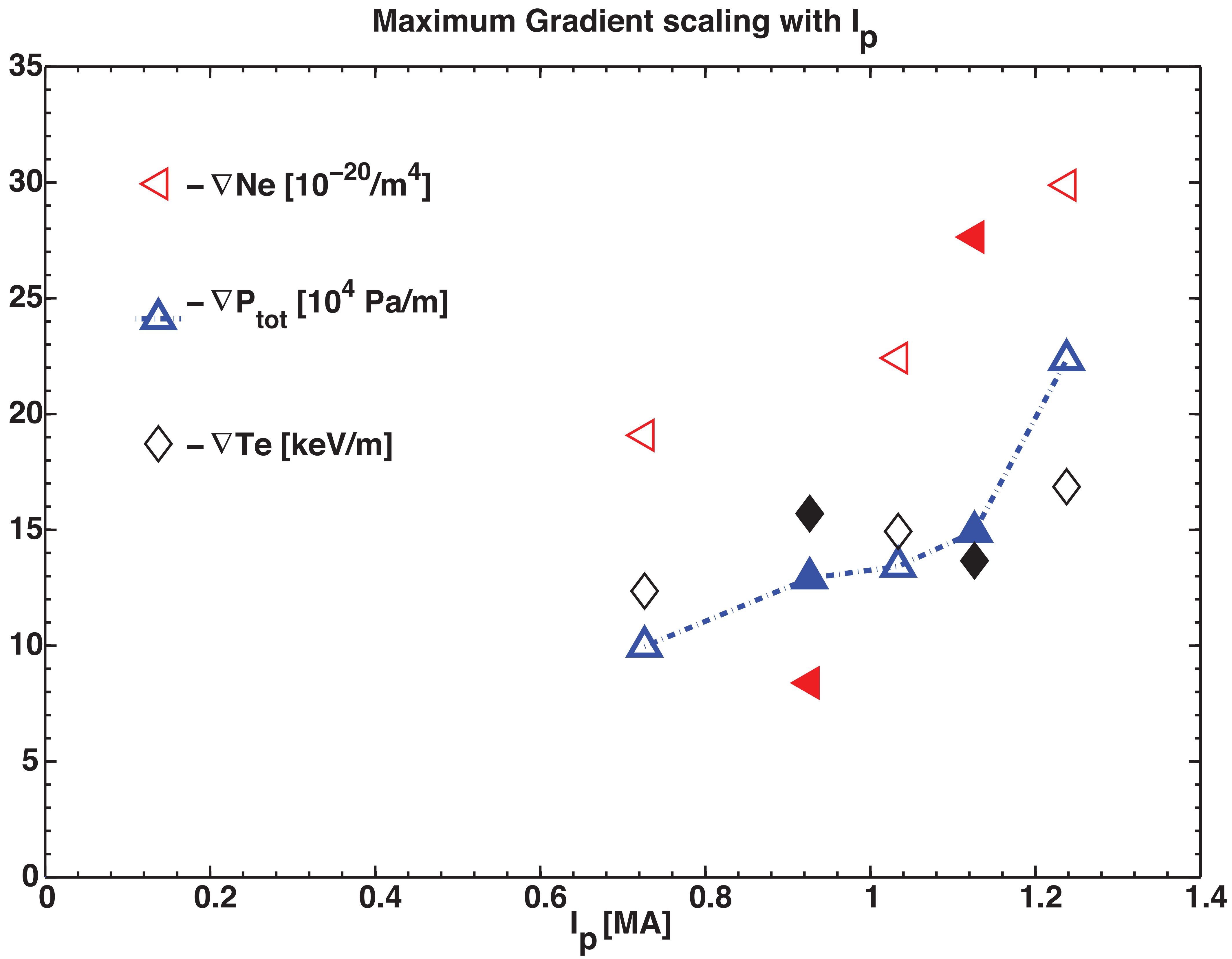


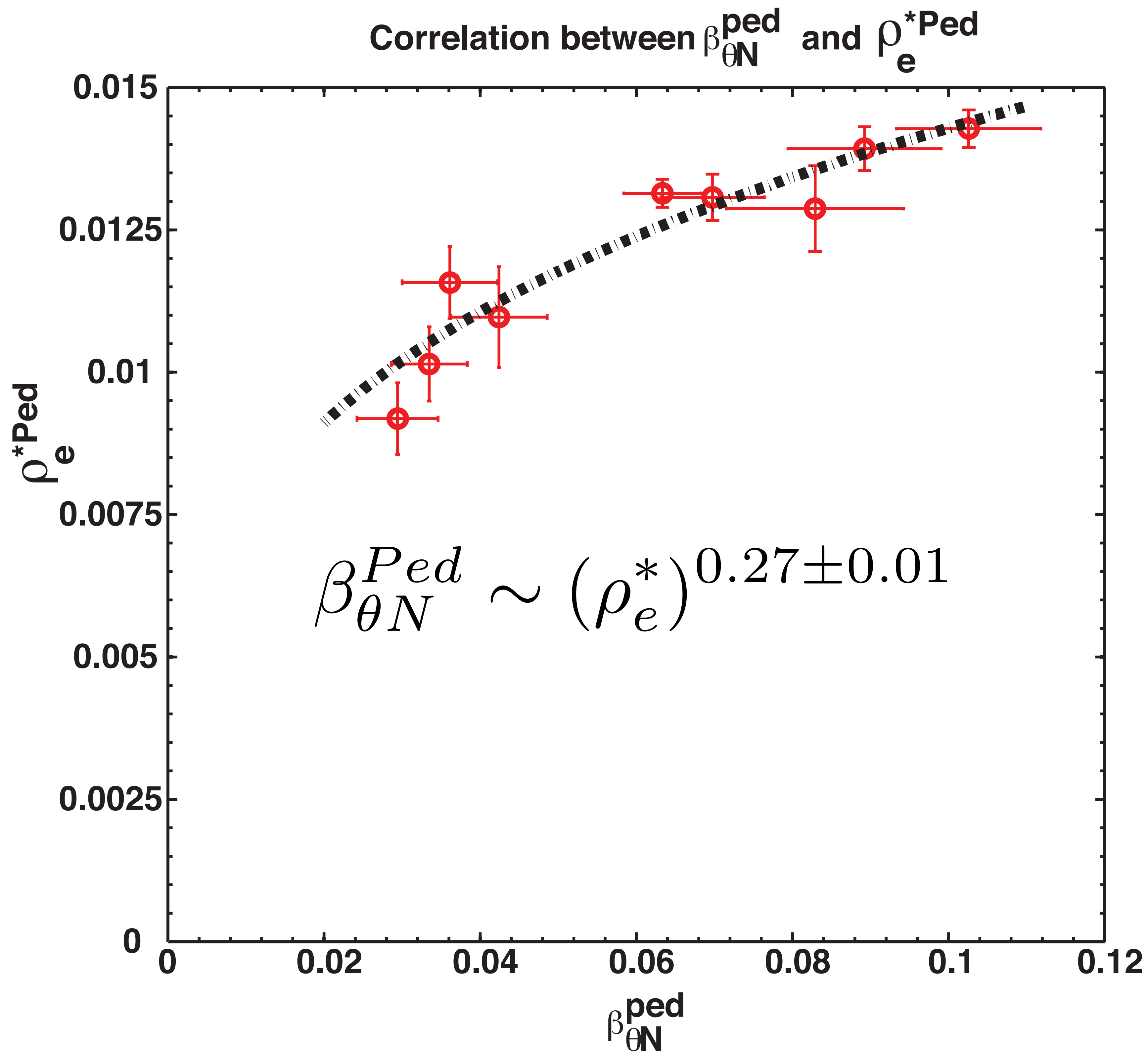
Wave activities before ELM crash, difficult to discern as intrinsic MHD activity already present





Dominant contribution of the density gradient in the critical pressure gradient and weak correlation of the ρ_e^* with normalized beta poloidal





The pressure gradient scales with Ip at constant toroidal field and the density gradient increases much faster than temperature gradient.

Correlation between the normalized poloidal beta with ρ_e^* evaluated at electron pedestal temperature is weaker than similar scaling in MAST.