Summary XP1044 & XP1074
1. Pedestal Structure Scaling Studies
2. Initial Inter-ELM Turbulence Analysis

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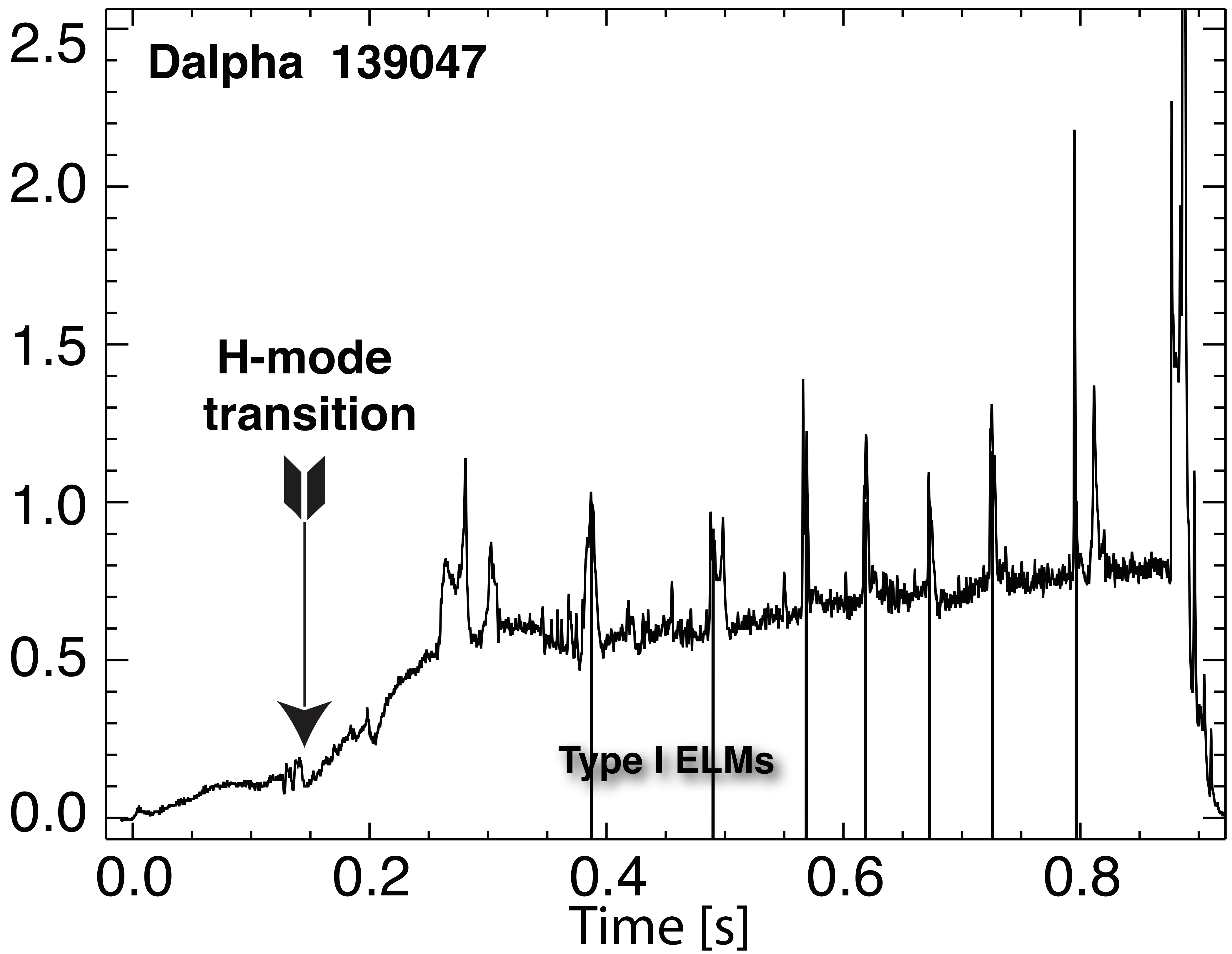
and the NSTX Research Team

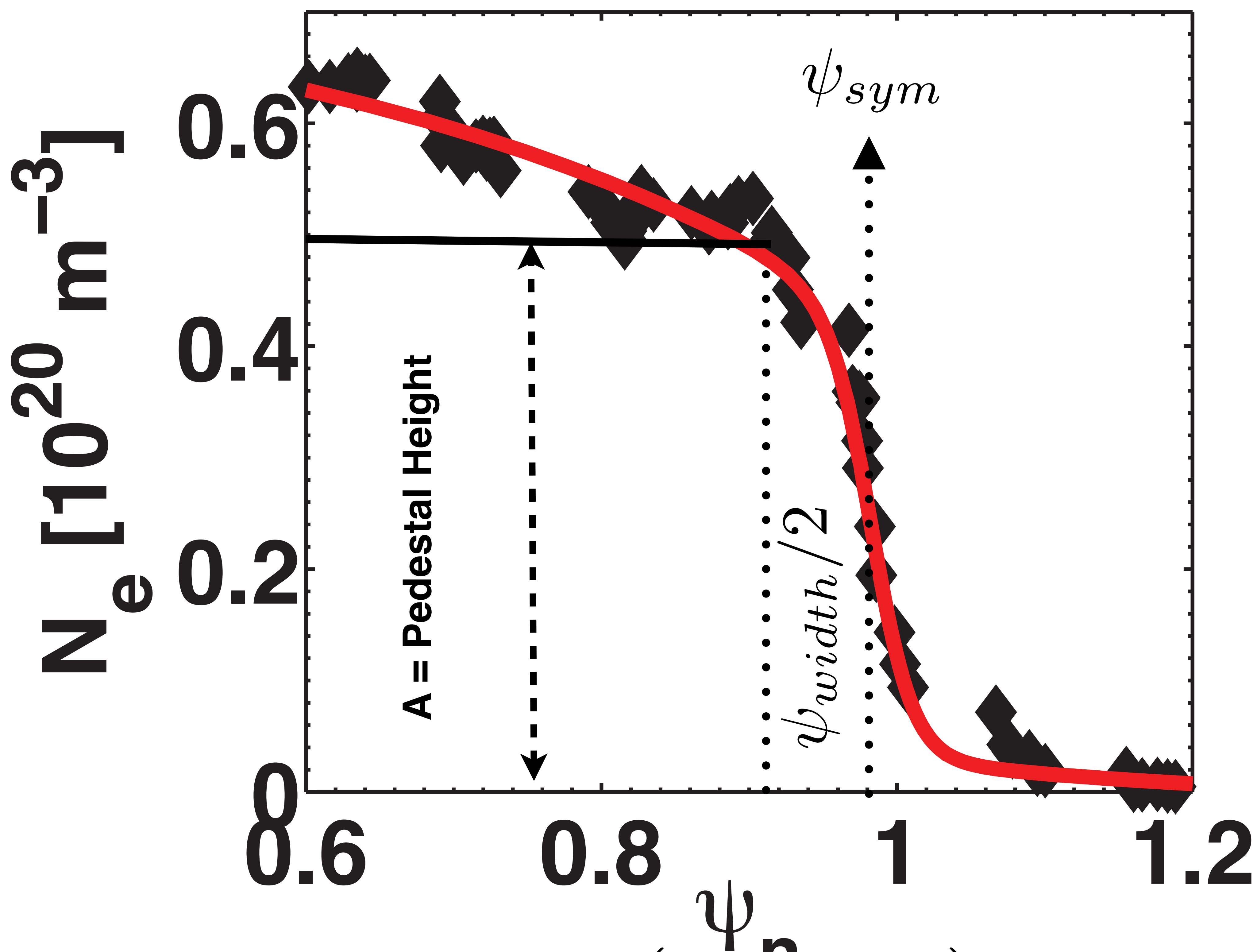
NSTX Results Review 01-Dec. 2010

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.
  - Pedestal width & height increase during an ELM cycle.
- Assess the edge fluctuations during the multiple stages on an ELM cycle.
  - Increase of the density fluctuations at the top of the pedestal. and "cascade" to lower frequency before the ELM crash.
  - Exploit GPI to determine the flow shear during an ELM cycle.

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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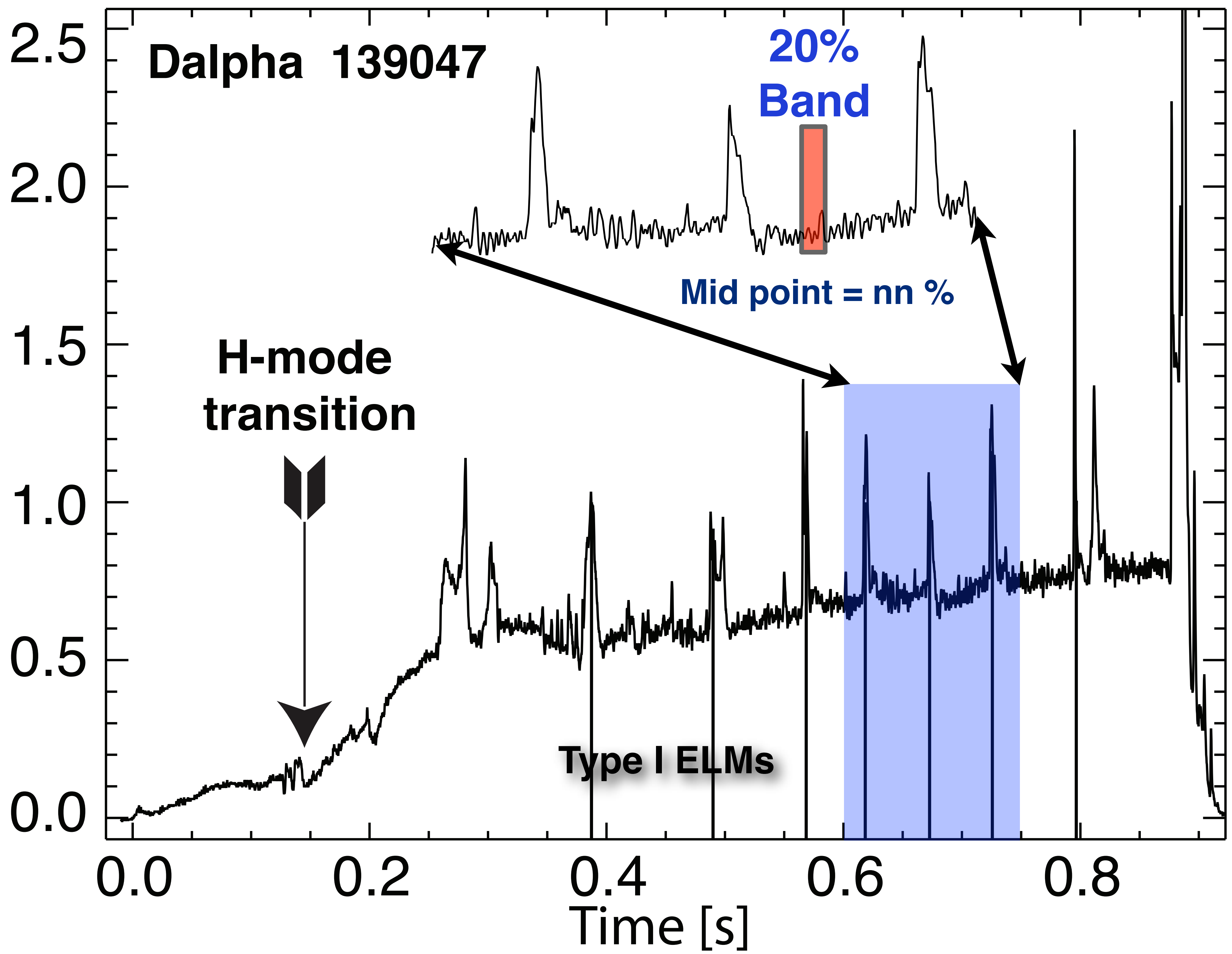

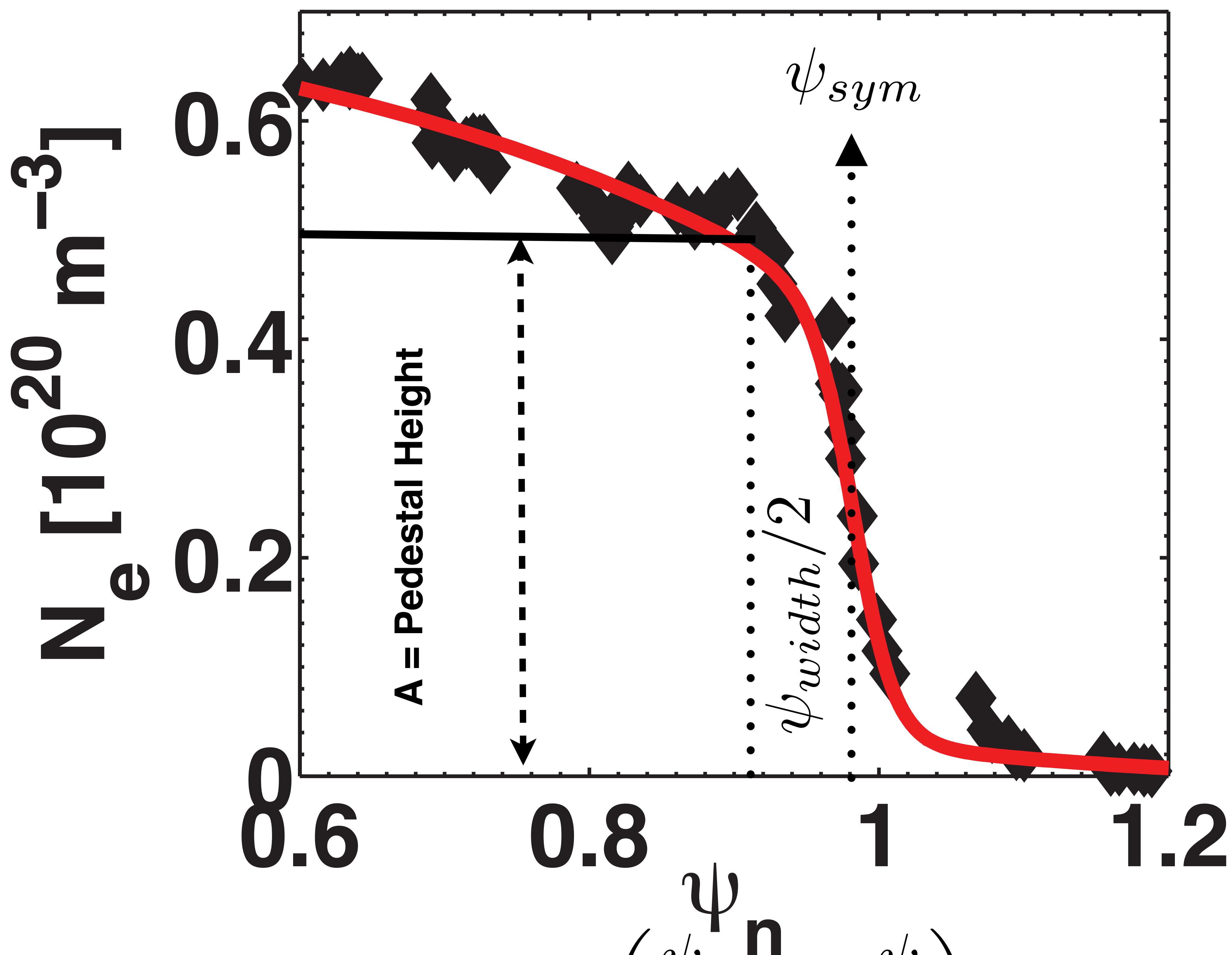

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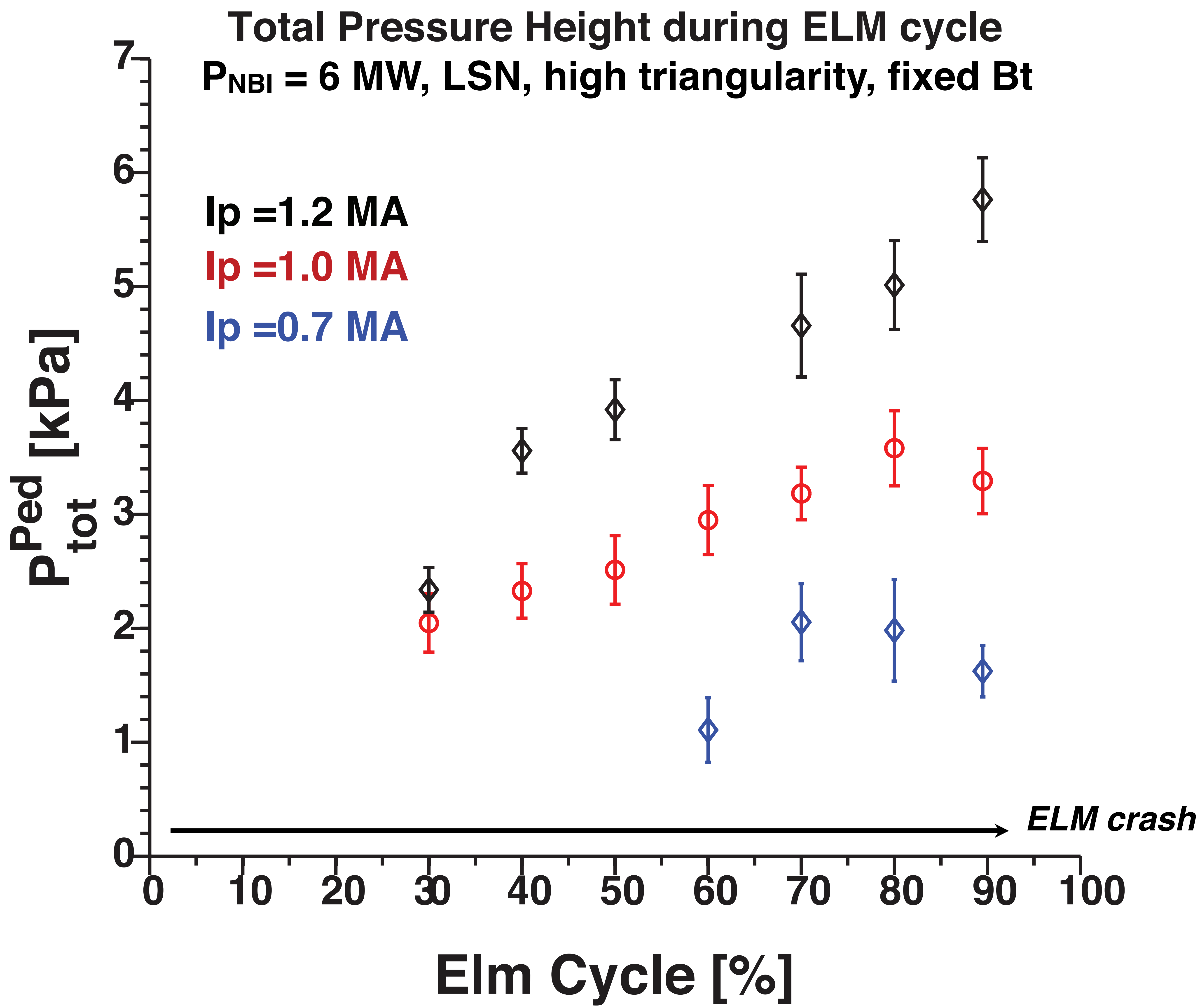
Pedestal height builds up during an ELM cycle

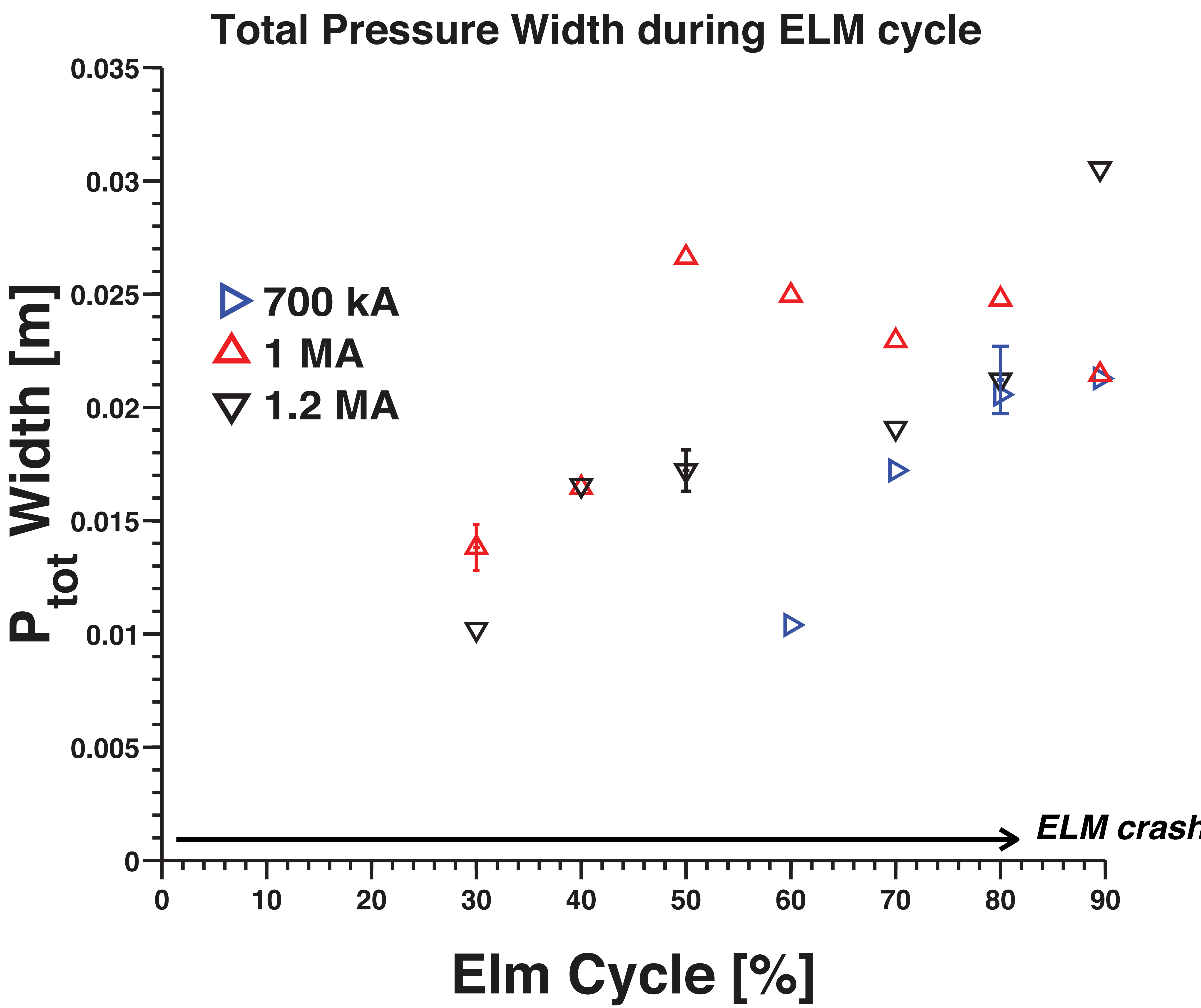


- Pedestal pressure increases with I_p
- Pedestal pressure increases by a factor ~ 3 before the ELM crash
  - No clear saturation at high I_p
  - Saturation late in cycle at lower I_p
  - In contrast to rapid saturation within first 20%-50% of an ELM cycle observed in AUG and DIIID

[Maggi, Nucl. Fusion (2010)]

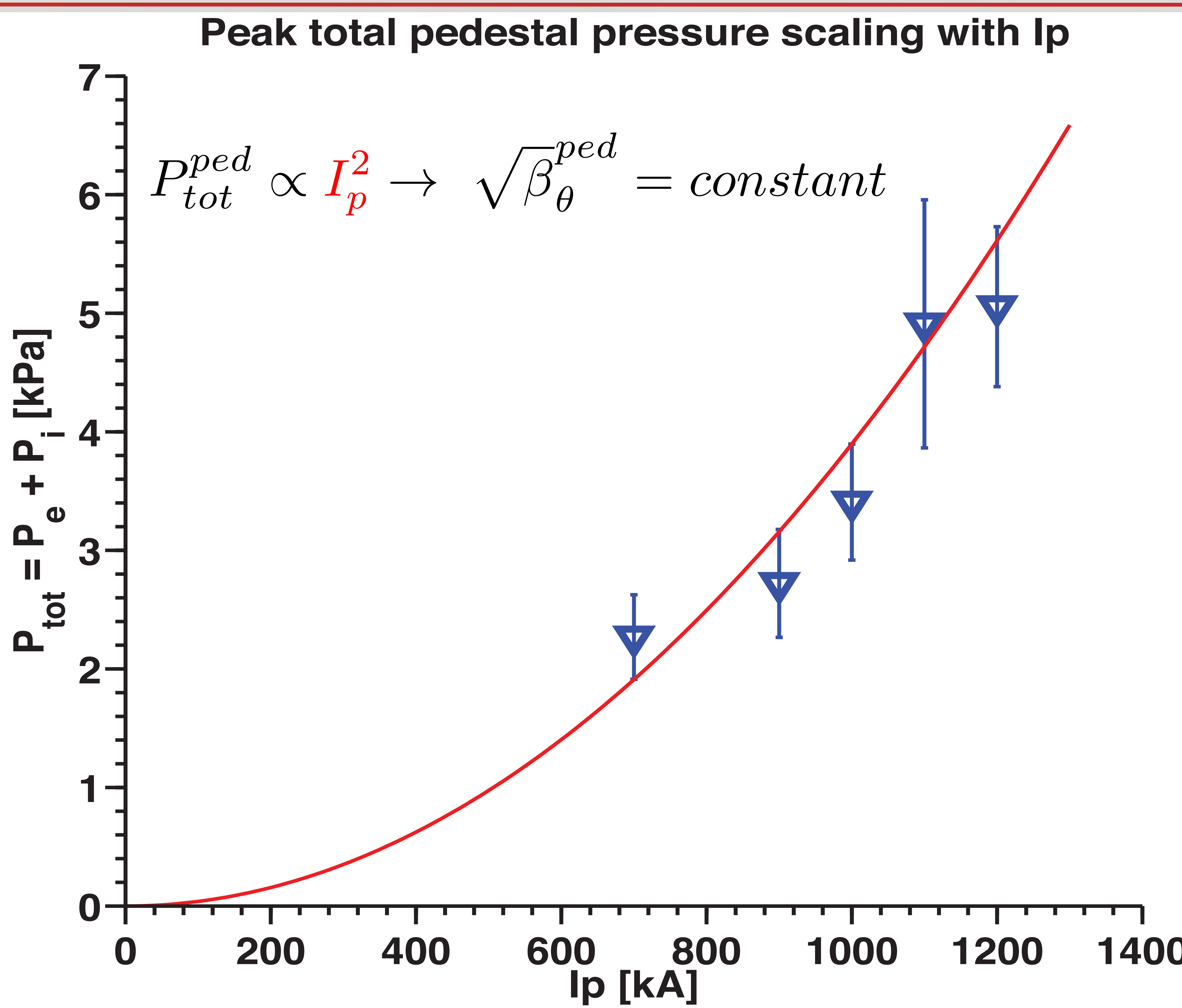
[Zohm, PPCF (2010)].

Pedestal width increases during an ELM cycle



- Pedestal width saturates at low I_p.
- Pedestal widens during an ELM cycle.
- Ongoing stability Analysis (PEST, ELITE)

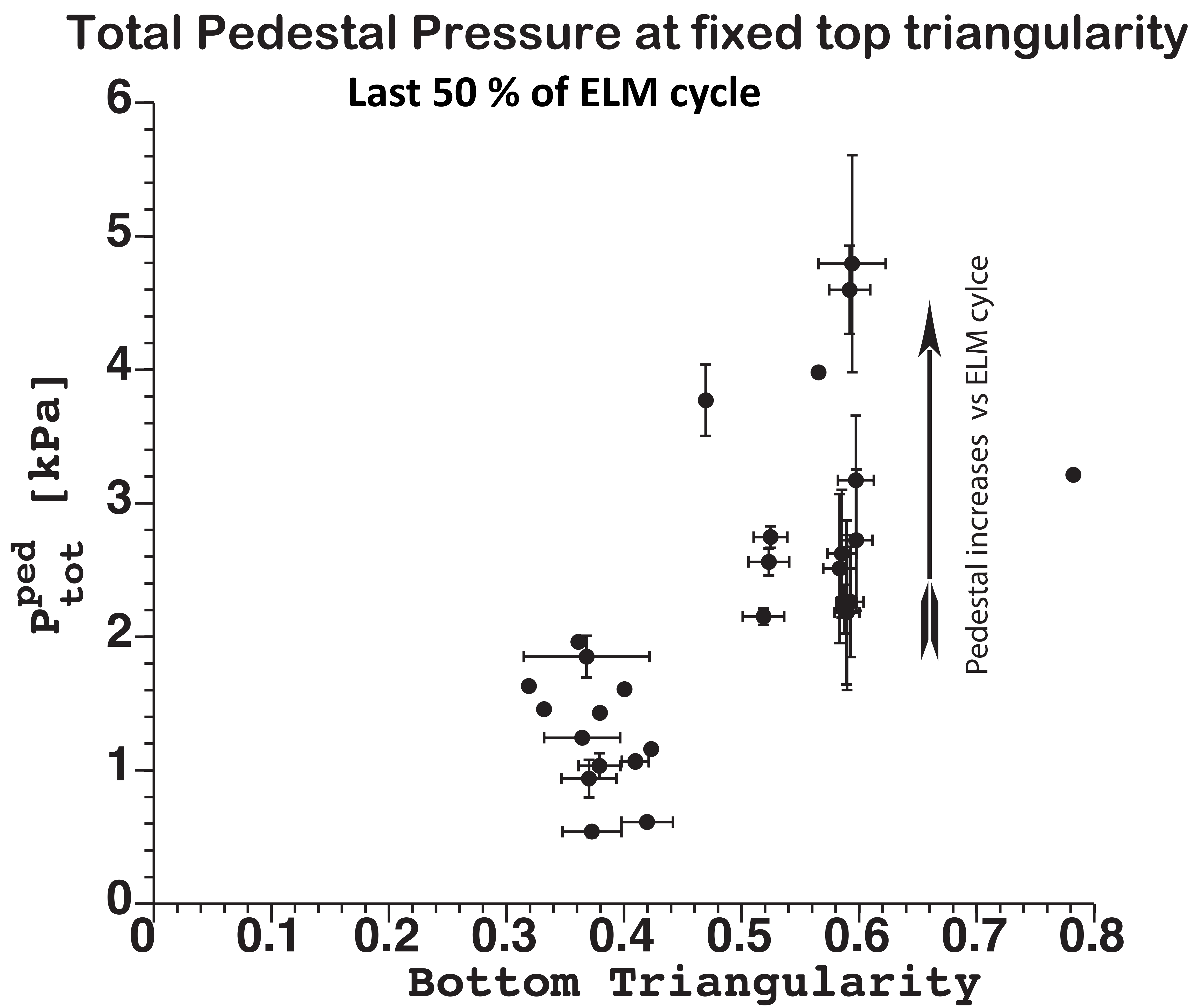
P_{tot}^{ped} increases quadratically with Ip, but at constant β_θ^{ped}



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 (XP1074)



- 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]

Ongoing analysis

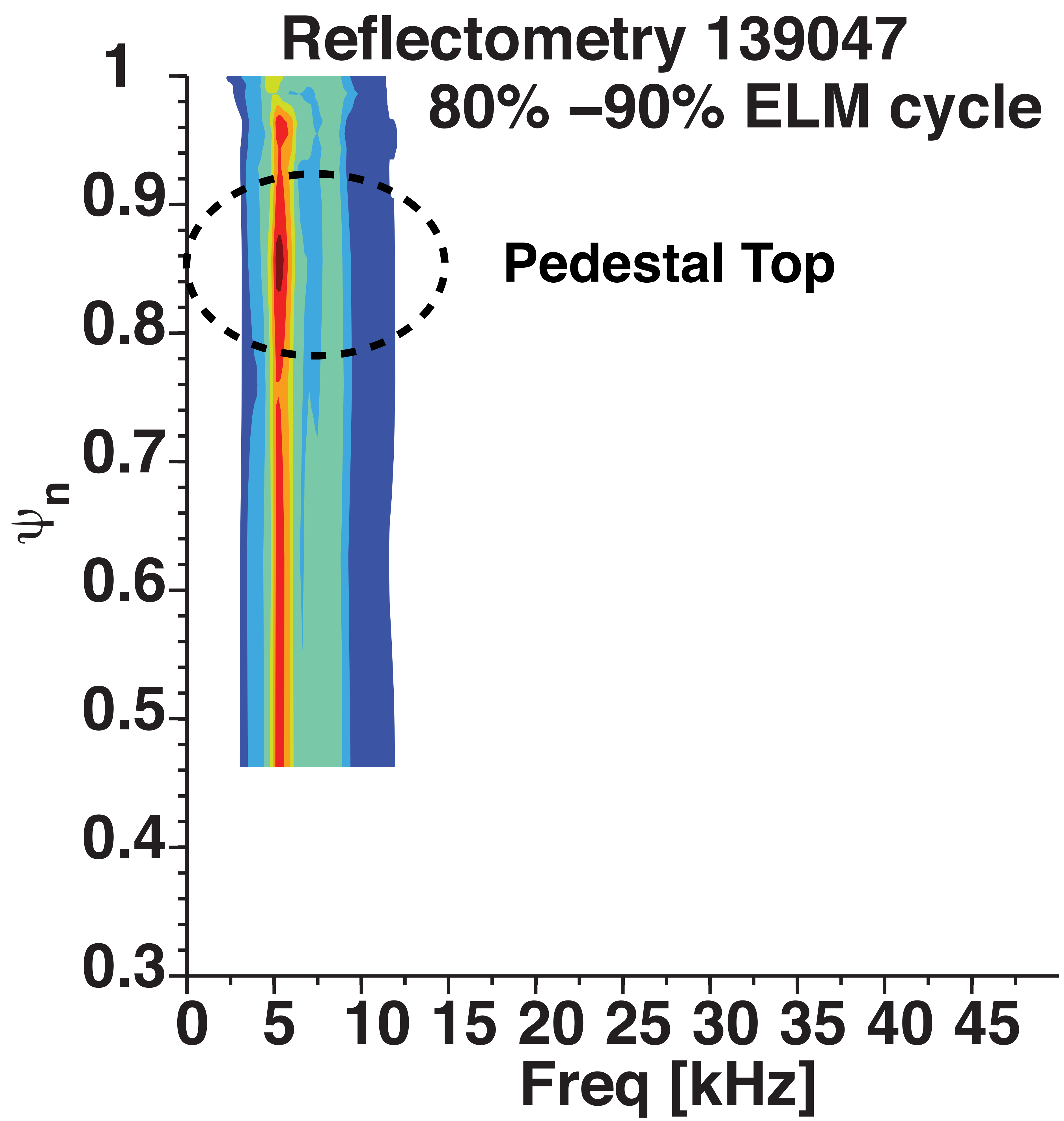
Initial fluctuations analysis during an ELM cycle

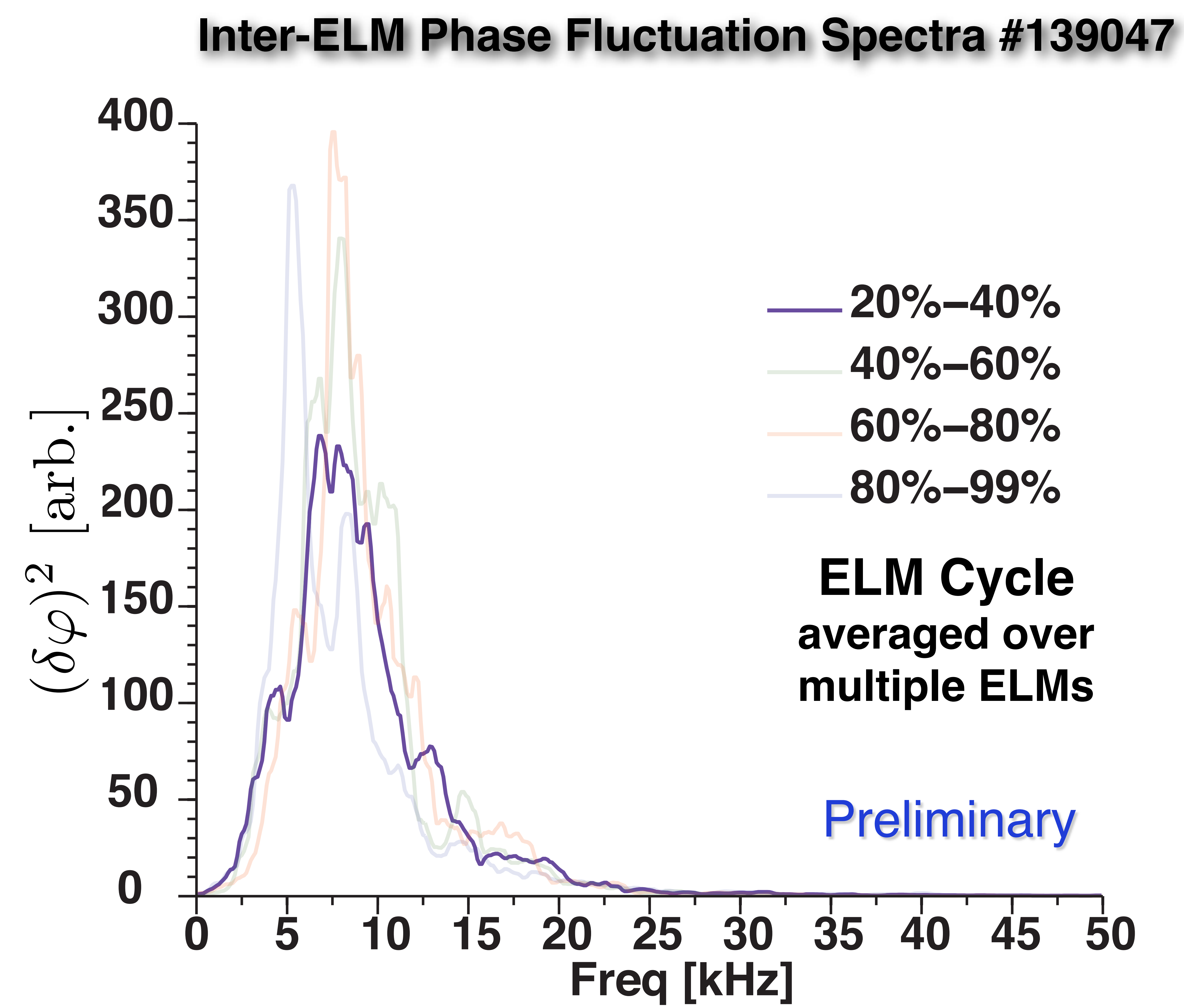
- Assess the edge fluctuations during the multiple stages on an ELM cycle.

  What are the fluctuations characteristics at the top of the pedestal during the ELM cycle?

  Determination of the flow shear using GPI

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





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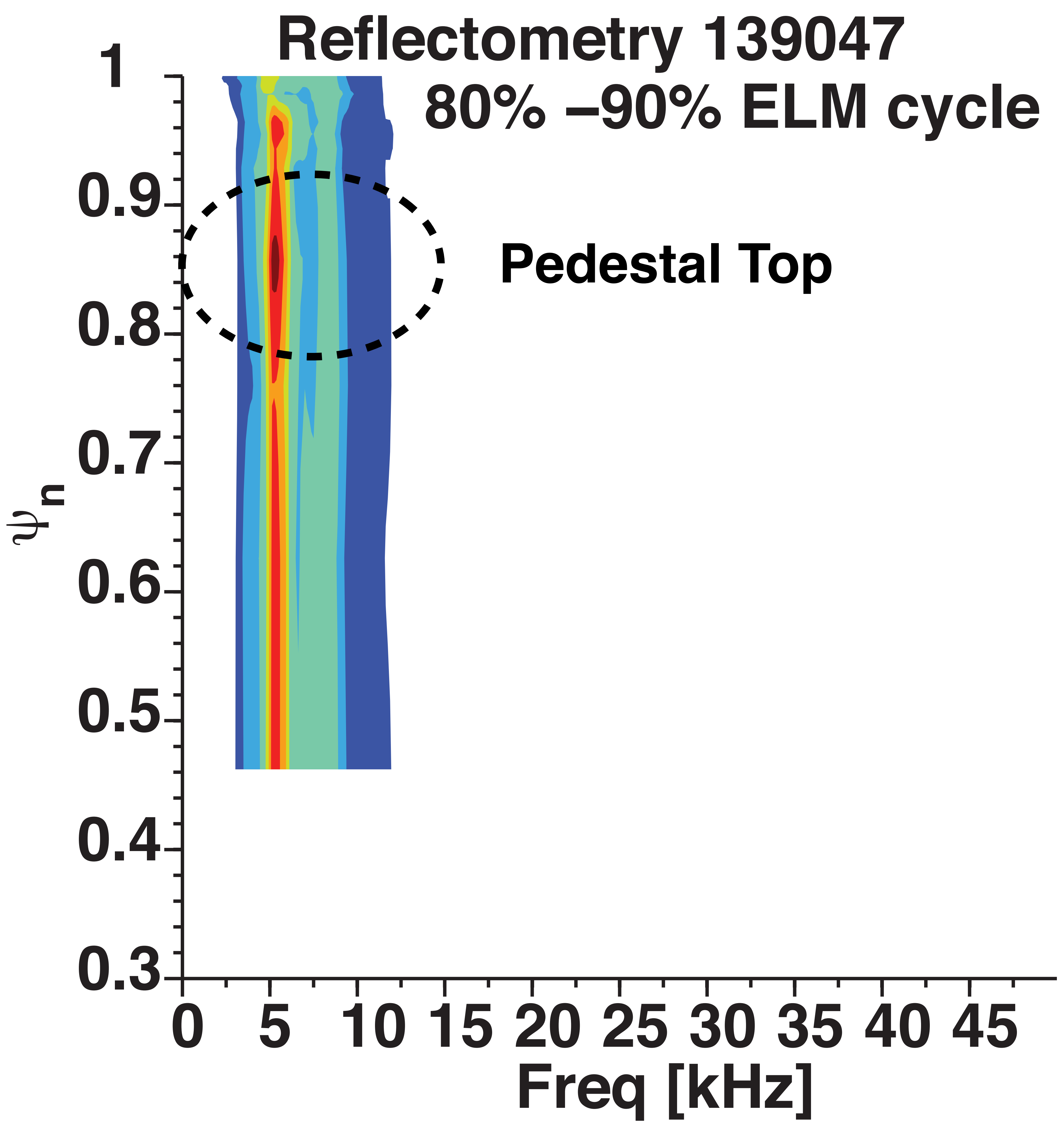

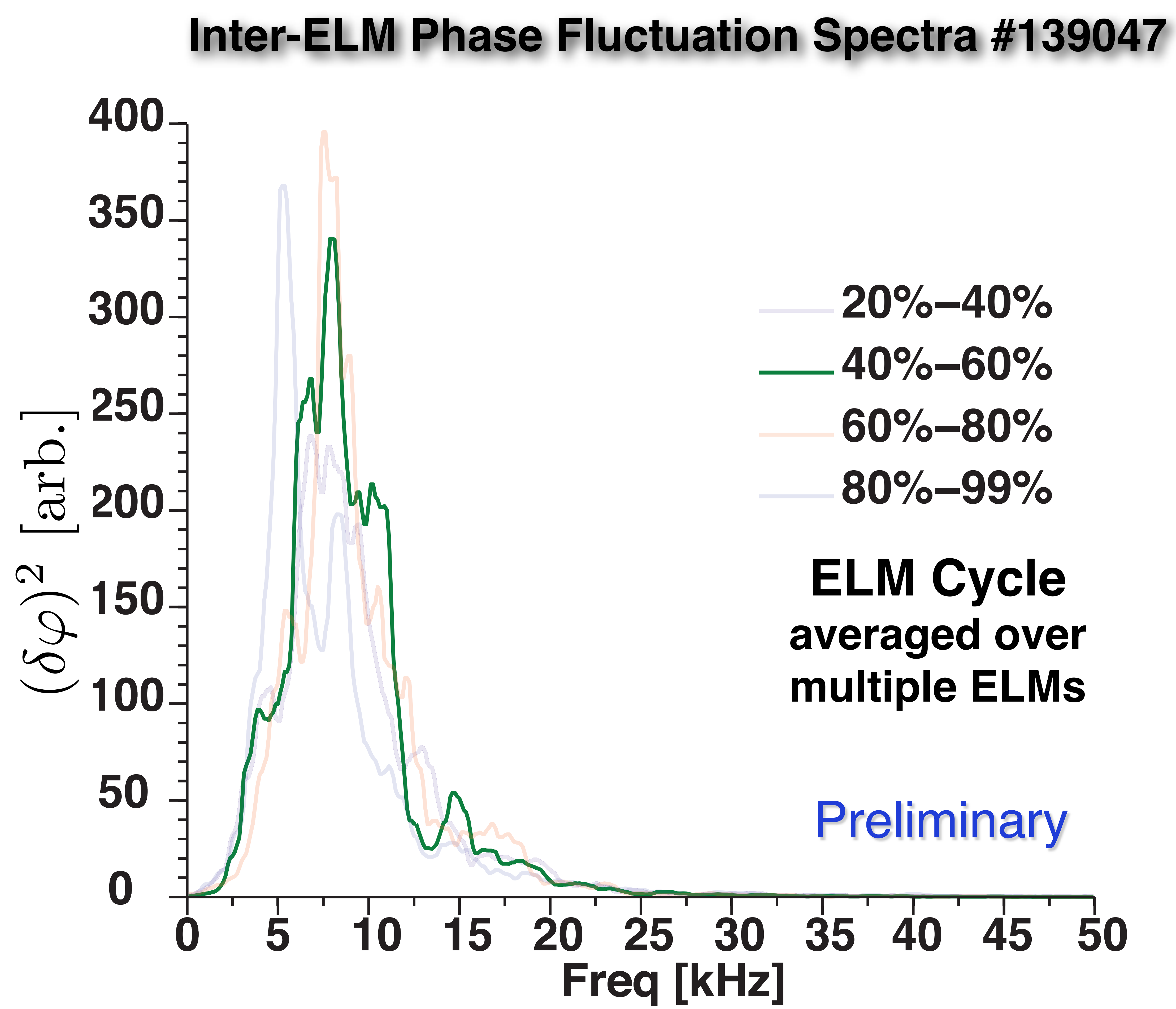

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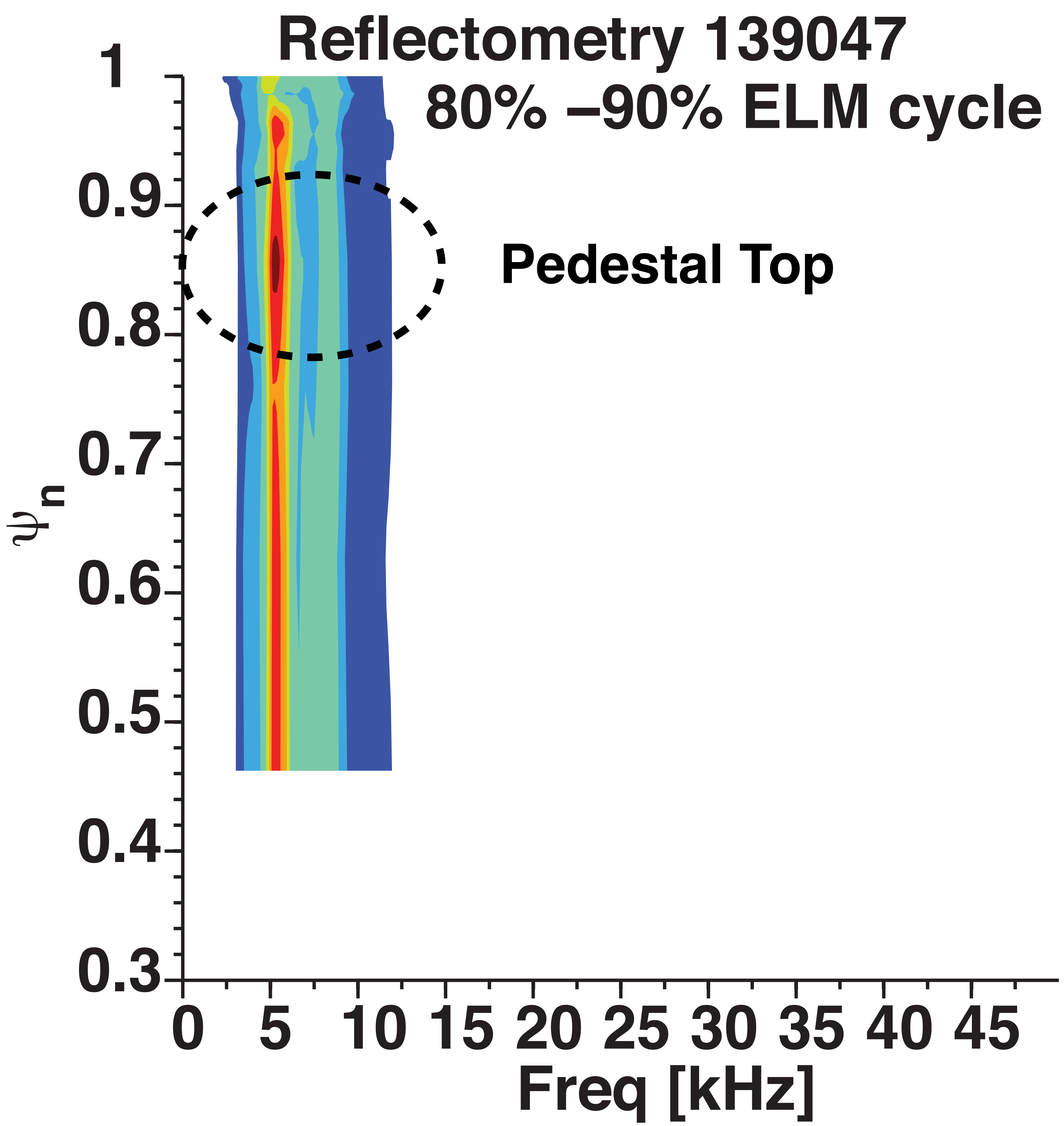

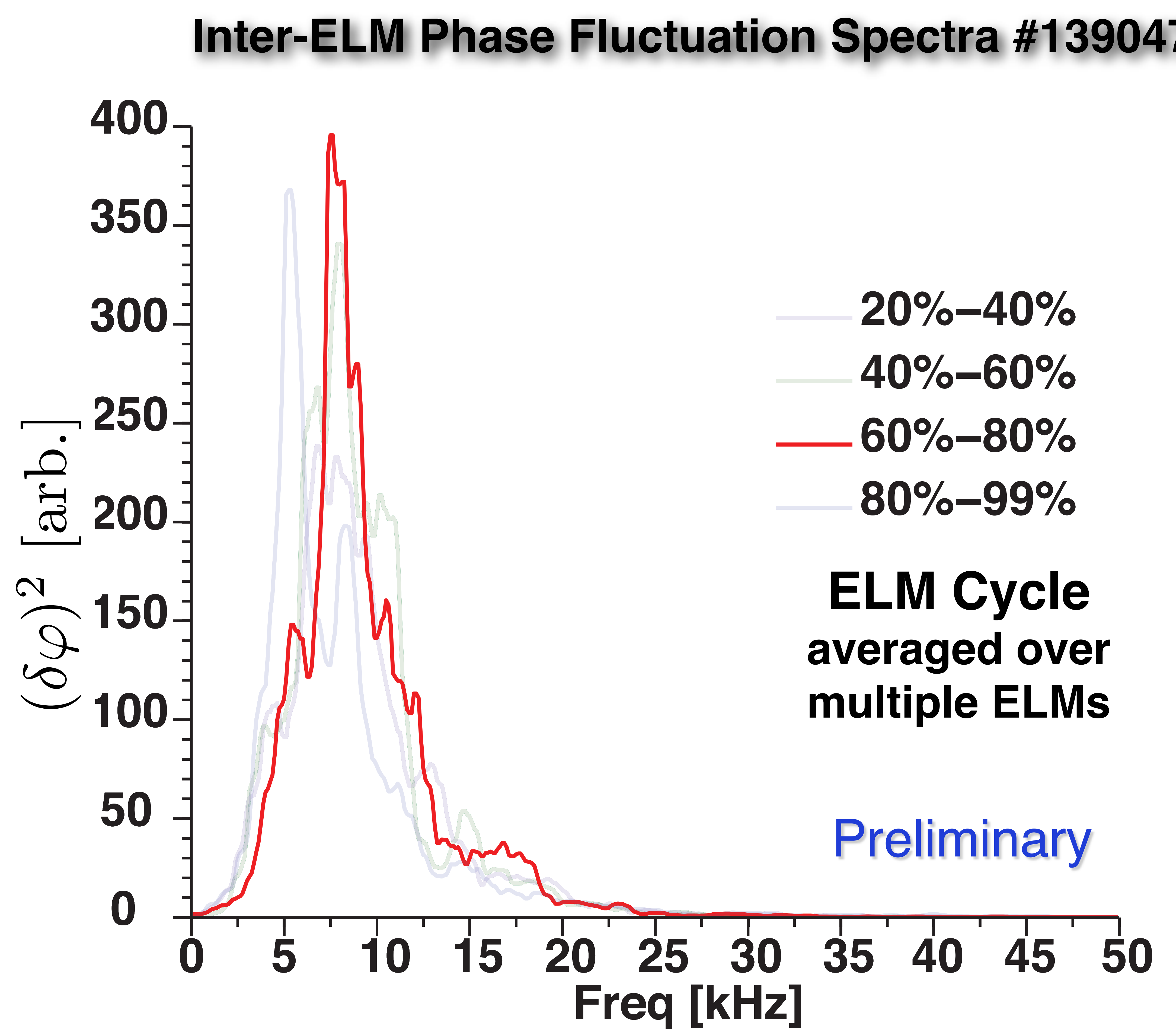

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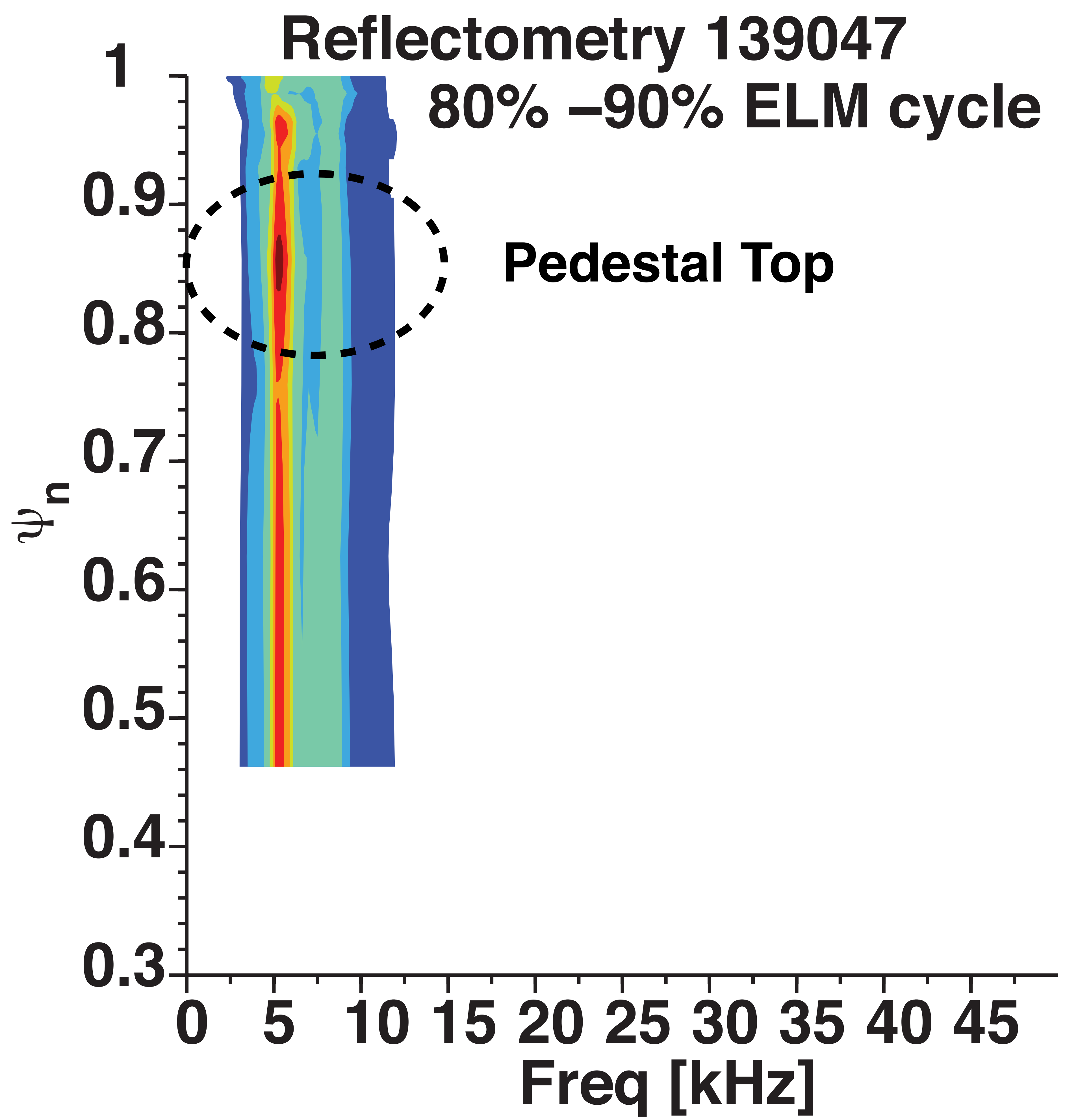

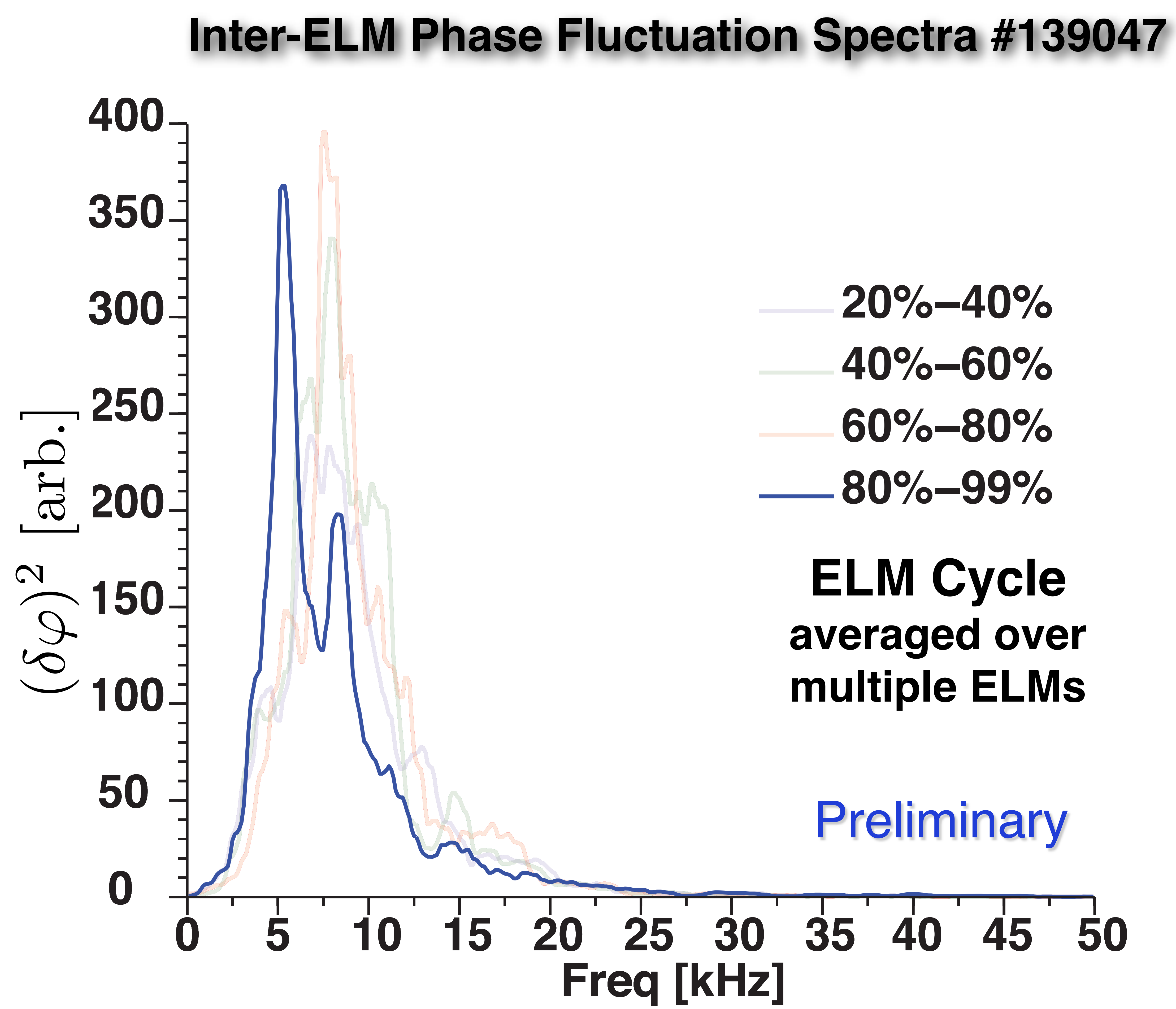

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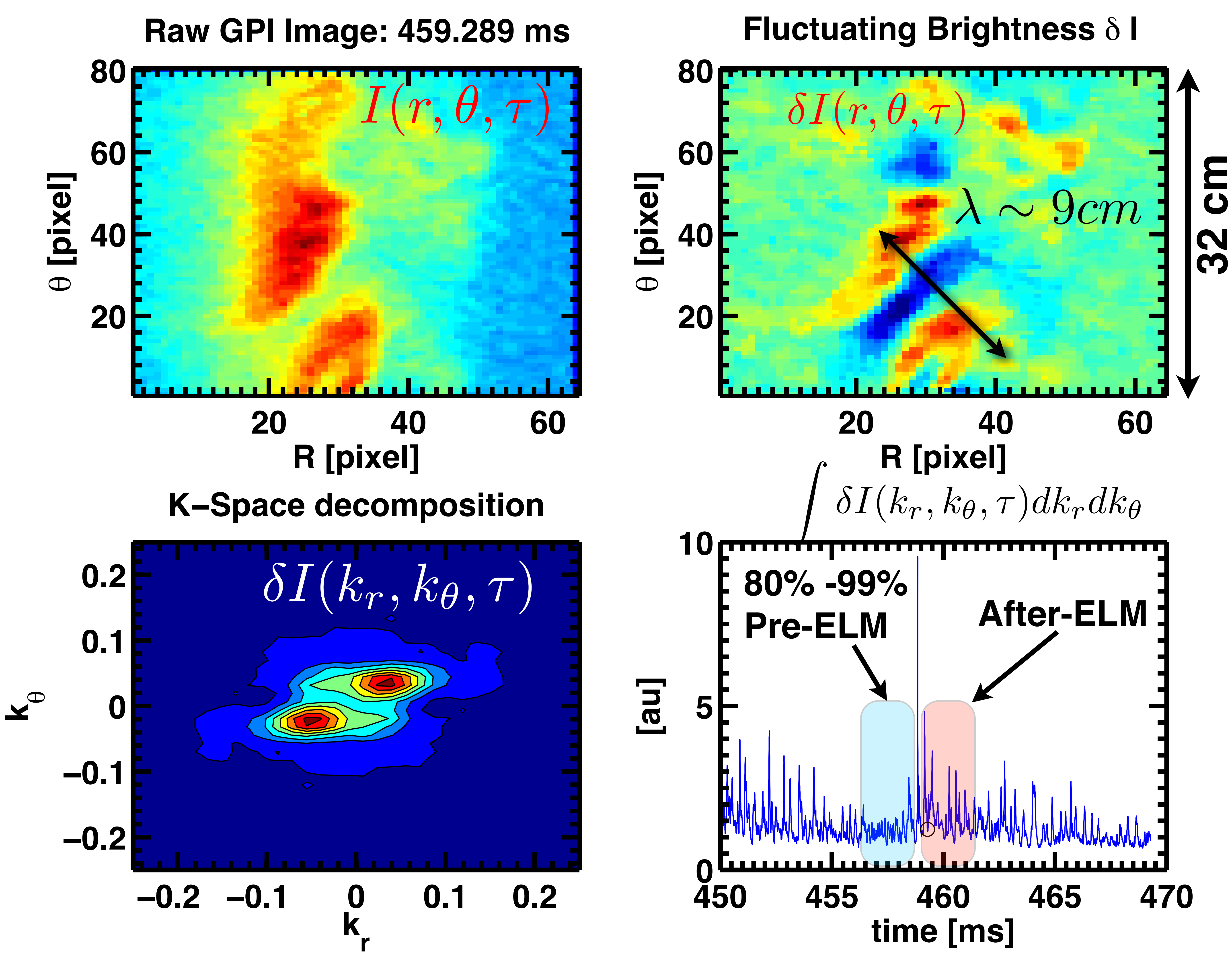
Using GPI, the fluctuations of the norm of K in the region of steep gradient can be determined



- 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)

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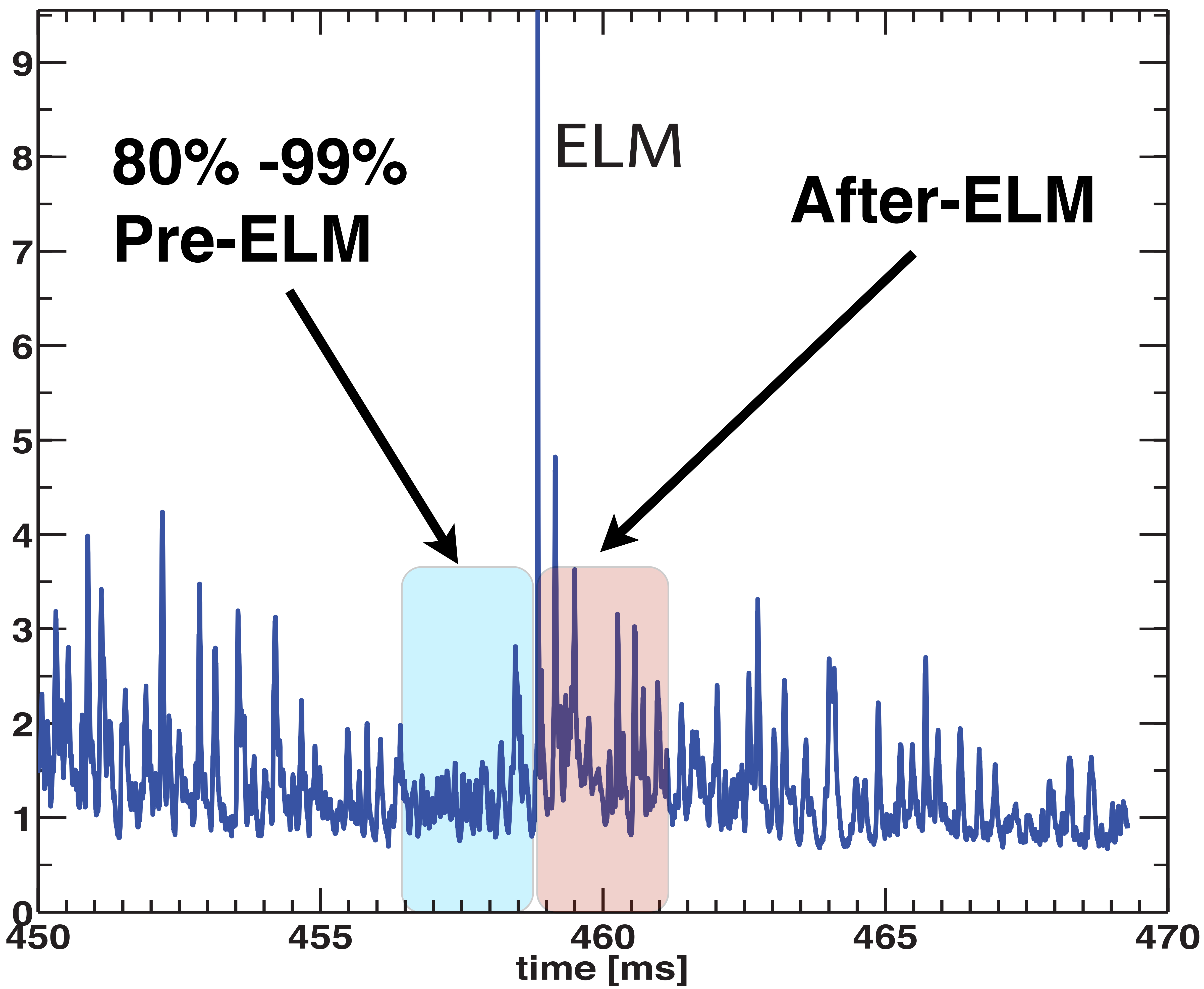
$$\delta|k|(\tau) = \Sigma|k|\delta I(k_r, k_\theta, \tau)$$



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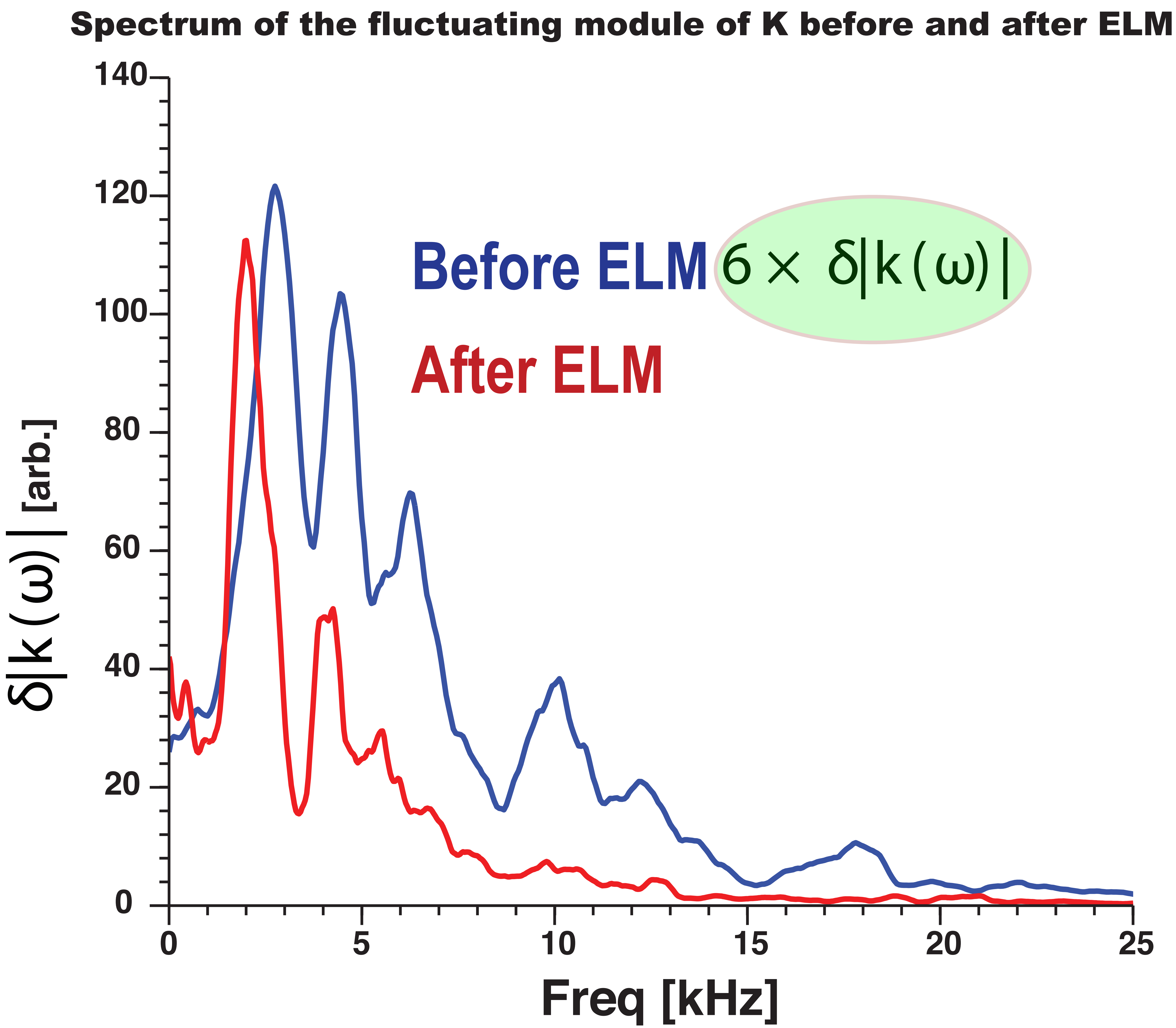
RMS fluctuations in the norm of K is higher after ELM than just before ELM

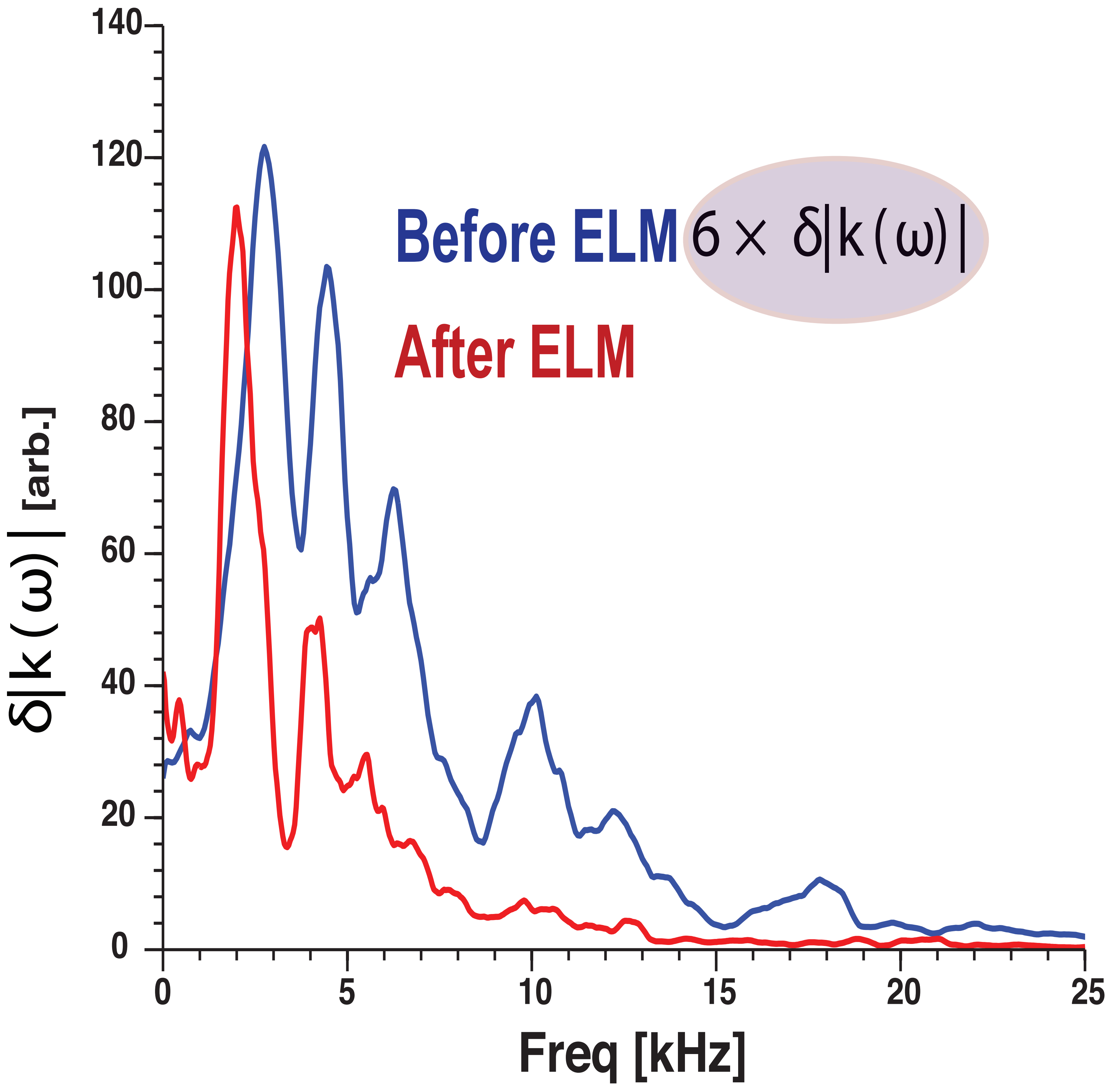


- Observation of coherent fluctuations.
  - same frequency range as in reflectometry.
- RMS fluctuation increases after the ELM crash.
  - consistent with previous observations in NSTX

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

The flow shear is encoded in mod |k| fluctuations

Spectrum of the fluctuating module of K before and after ELM



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

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

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

The limit $\omega \rightarrow 0$, 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

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

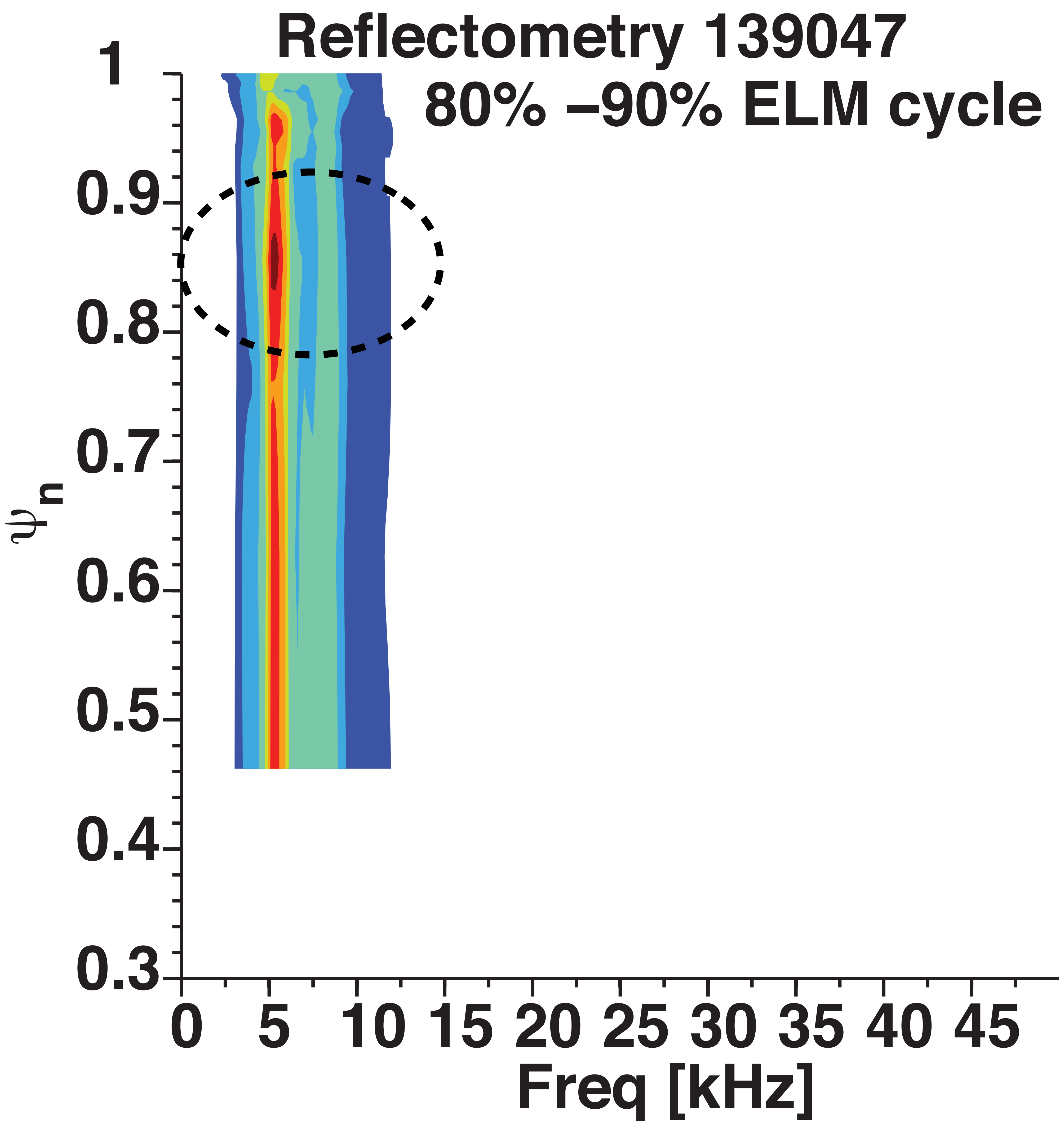
- No obvious change of the pedestal height with magnetic field *(not shown here)*
- Pedestal top density fluctuations increase during ELM cycle, with a frequency "cascade" to lower frequency just before the ELM crash.
- The oscillatory flow intensifies just after ELM crash, and dies away slowly in the inter-ELM cycle: same frequency range as density fluctuations.

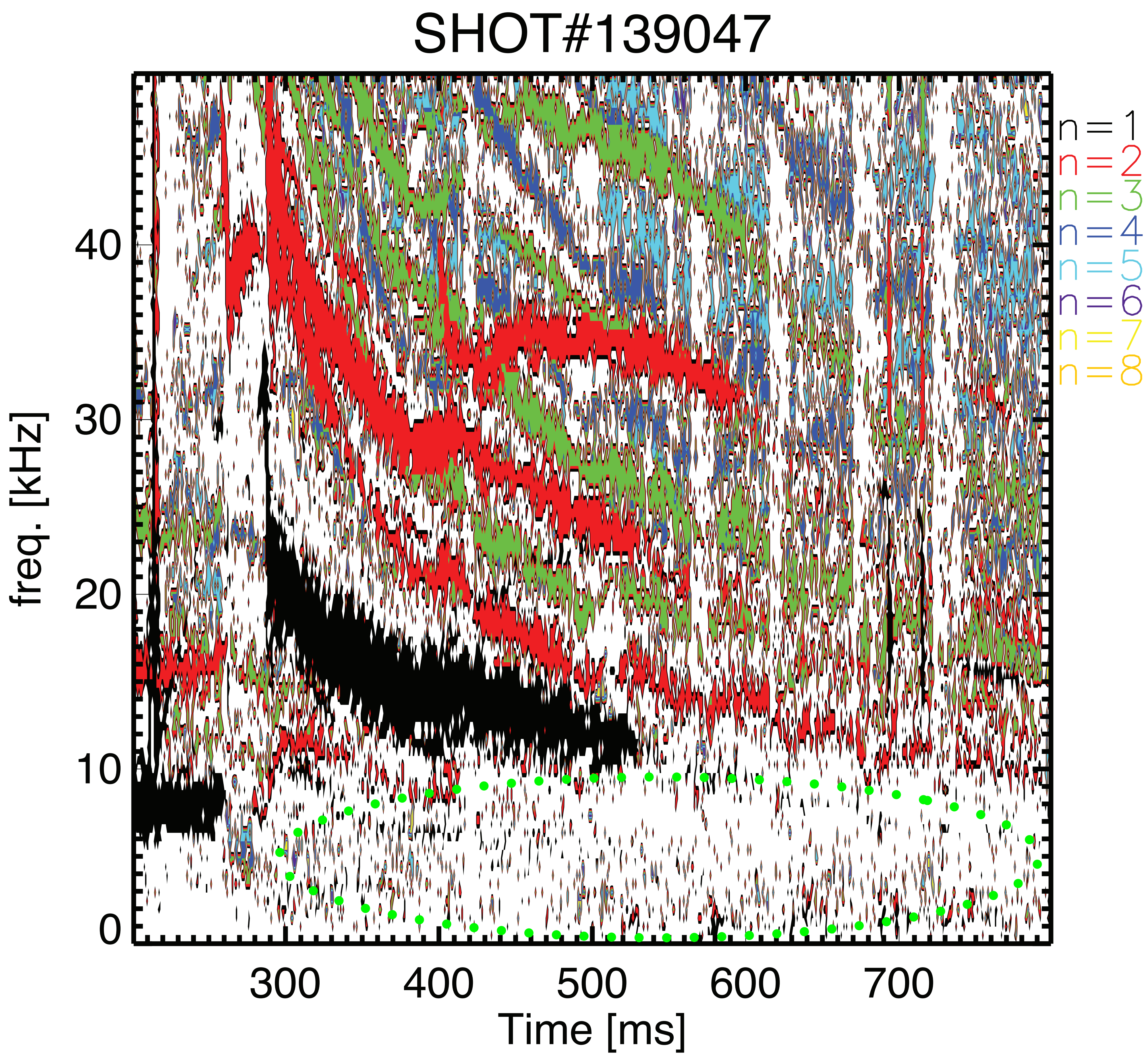
✦ Ongoing stability analysis with PEST and ELITE.

✦ Link fluctuations with pedestal transport & pressure build up

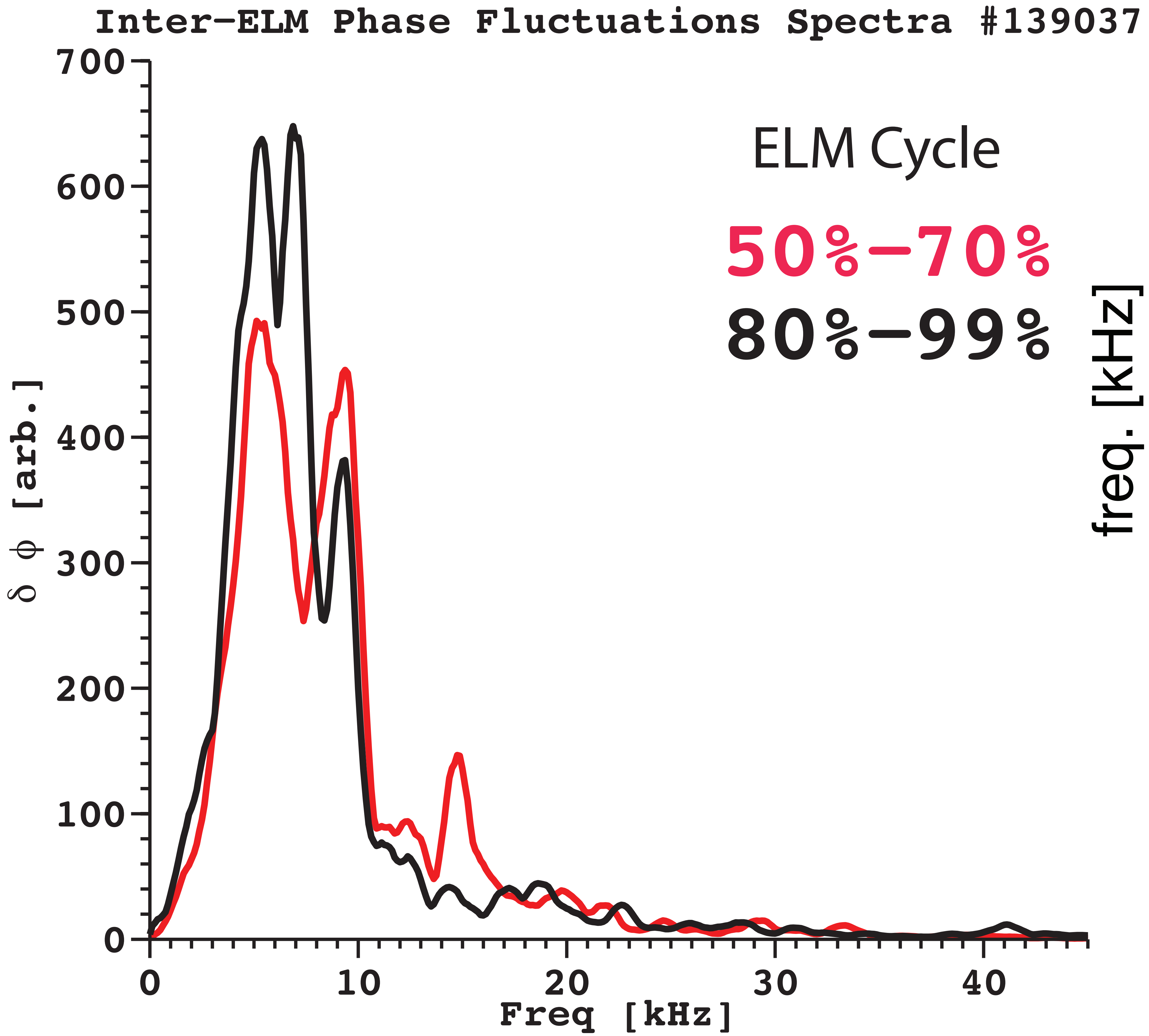
Backup Slides

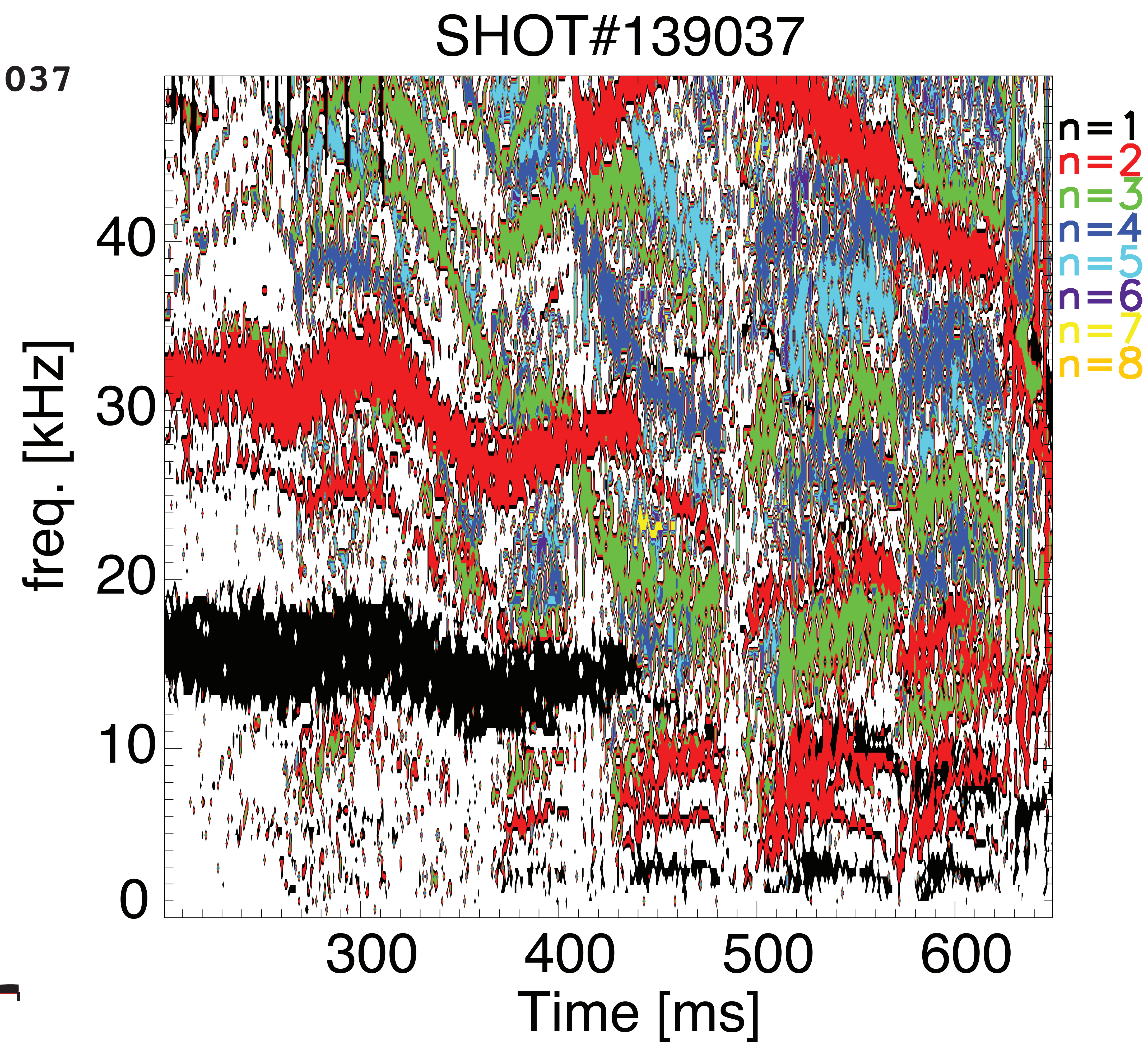
Mapping the reflectometer signals to normalized flux coordinates allow for better targeting of density fluctuation at the pedestal top



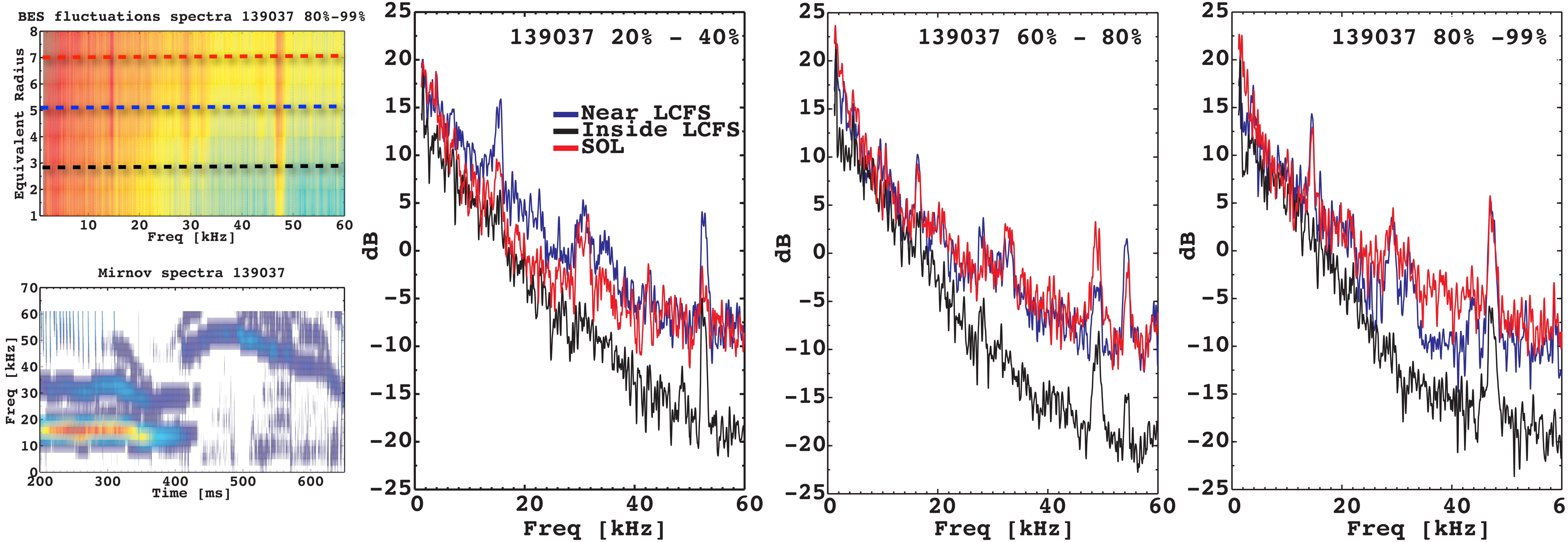


Wave activities before ELM crash, difficult to discern as intrinsic MHD activity already present





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.