Electron thermal fluctuation and transport in the ITB and L-mode plasmas without the large scale MHD instabilities

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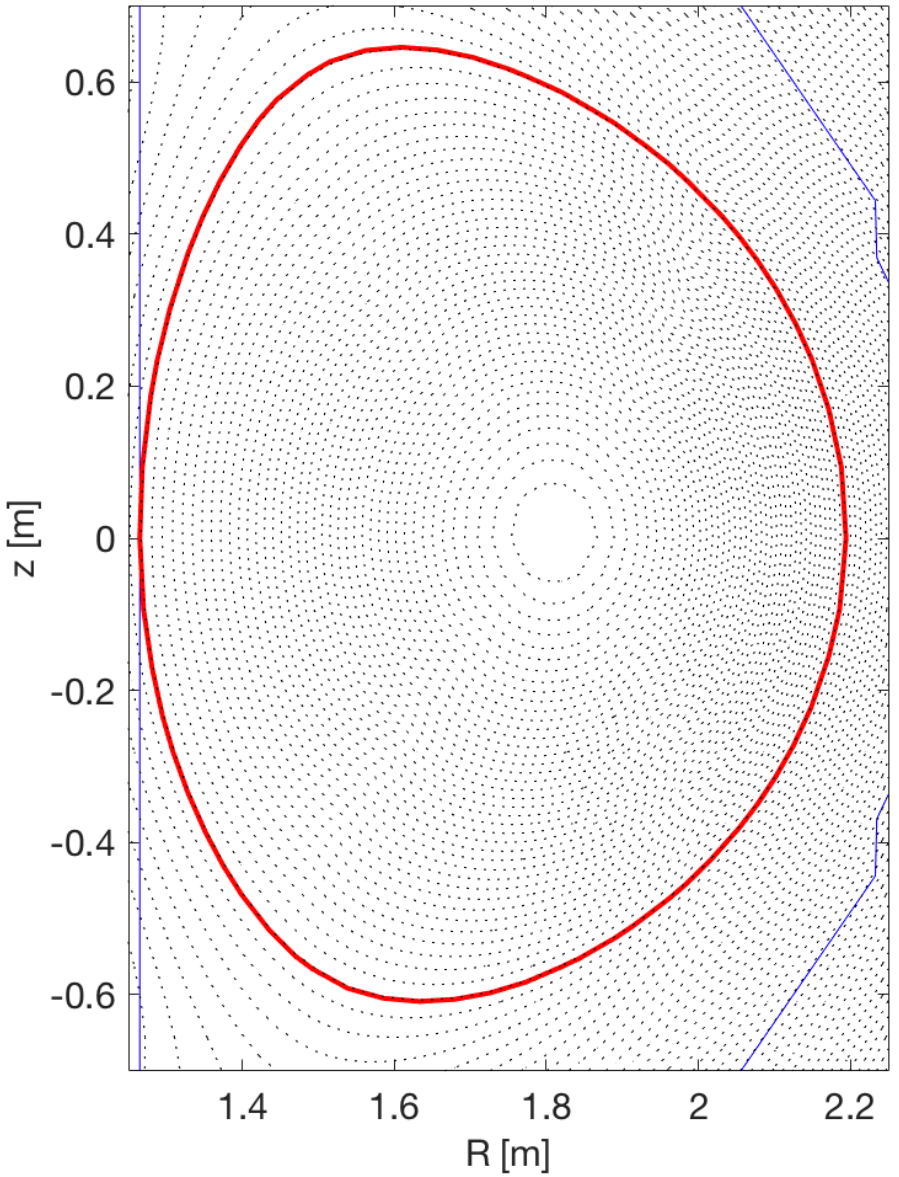
Introduction

- Different confinement states are observed with the similar heating power but different q profile
  - Flat (or reversed) q profile : internal transport barrier plasma (ITB)
  - Flat q profile : L-mode
    - Tearing mode (TM) unstable
  - Peaked q profile : L-mode
    - Sawtooth unstable
- How close is it to ITB if TM is suppressed in flat q L-mode?
- In this talk, I prepare two discharges with similar NBI power. One is in L-mode and auxiliary ECH is applied to suppress TM. The other is the ITB plasma without ECH. I will compare the electron thermal fluctuation and transport characteristics in these two plasmas

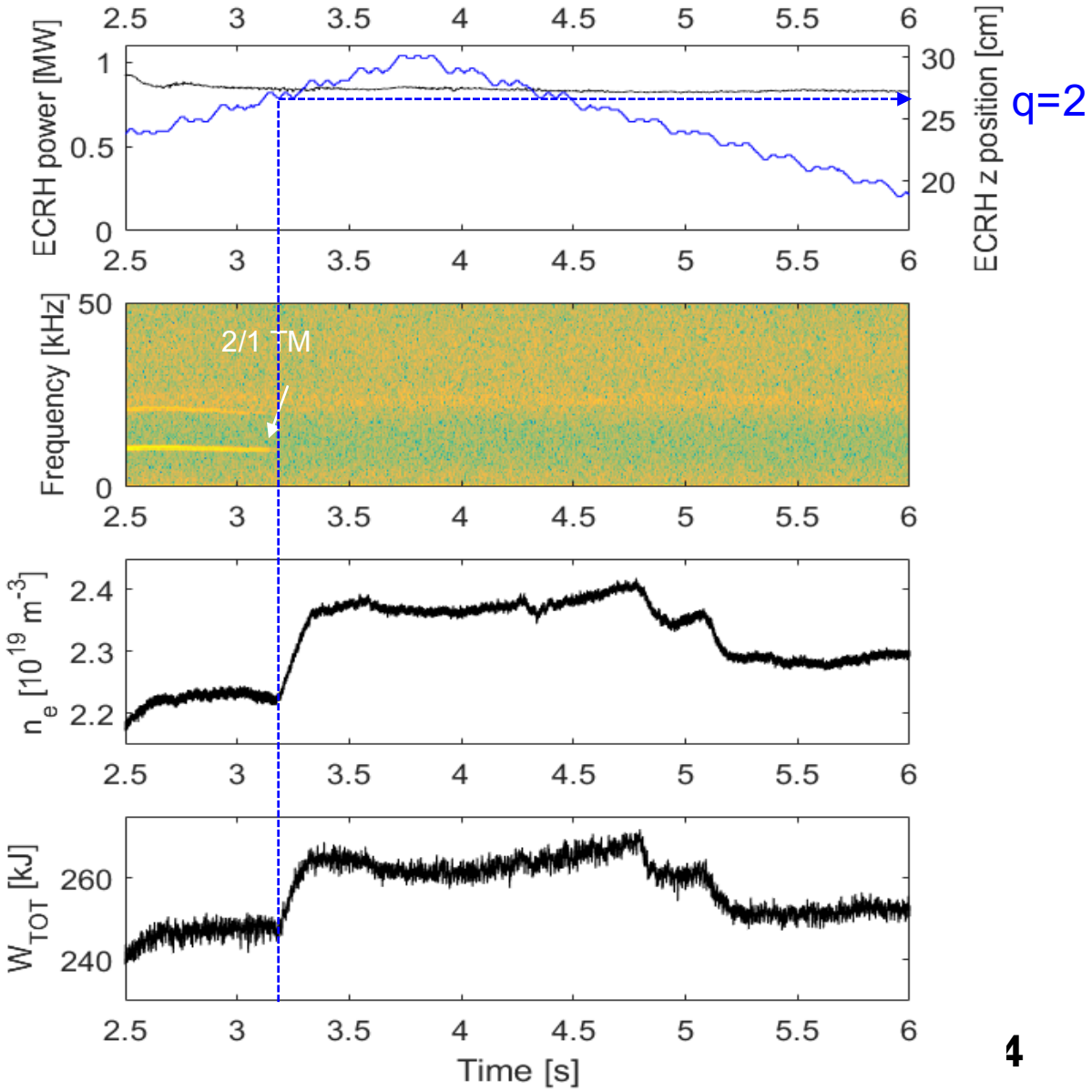
The KSTAR L-mode plasma #13728

- Plasma overall parameters
  - $B_T = 3.0$ T, $I_p = 500$ kA, limiter plasma
  - 4 MW from three NBI systems (turned on 0.5, 0.7, and 1.1 s respectively)
  - $q_0 > 1.0$ (no sawtooth), $R_{q2} = 155$ cm, $q_{95} \sim 6.6$
  - m/n=2/1 tearing mode unstable due to flat q profile
  - 0.8 MW from ECH for 2/1 TM suppression



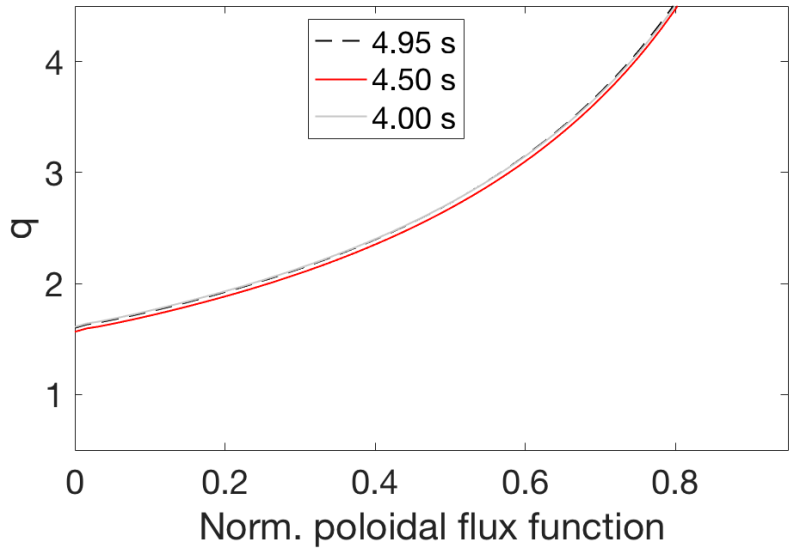
The KSTAR L-mode plasma #13728

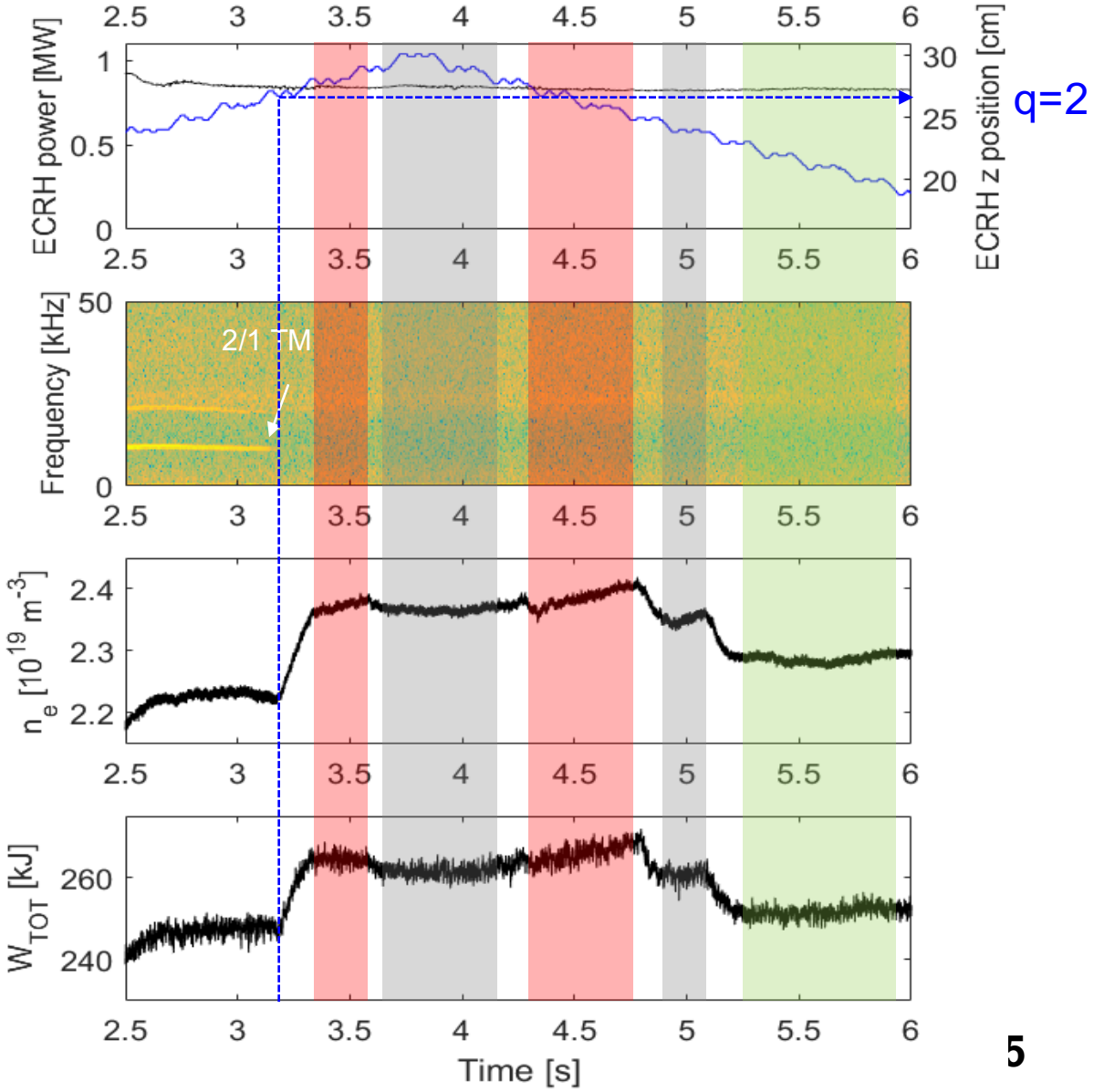
- m/n=2/1 tearing mode is suppressed when $z_{ECRH} \approx 26.5$ cm
  - Plasma confinement is improved significantly, stored energy > 260 kJ. But, not as much as ITB discharge (stored energy ~ 400 kJ) even we consider a little shape or volume difference



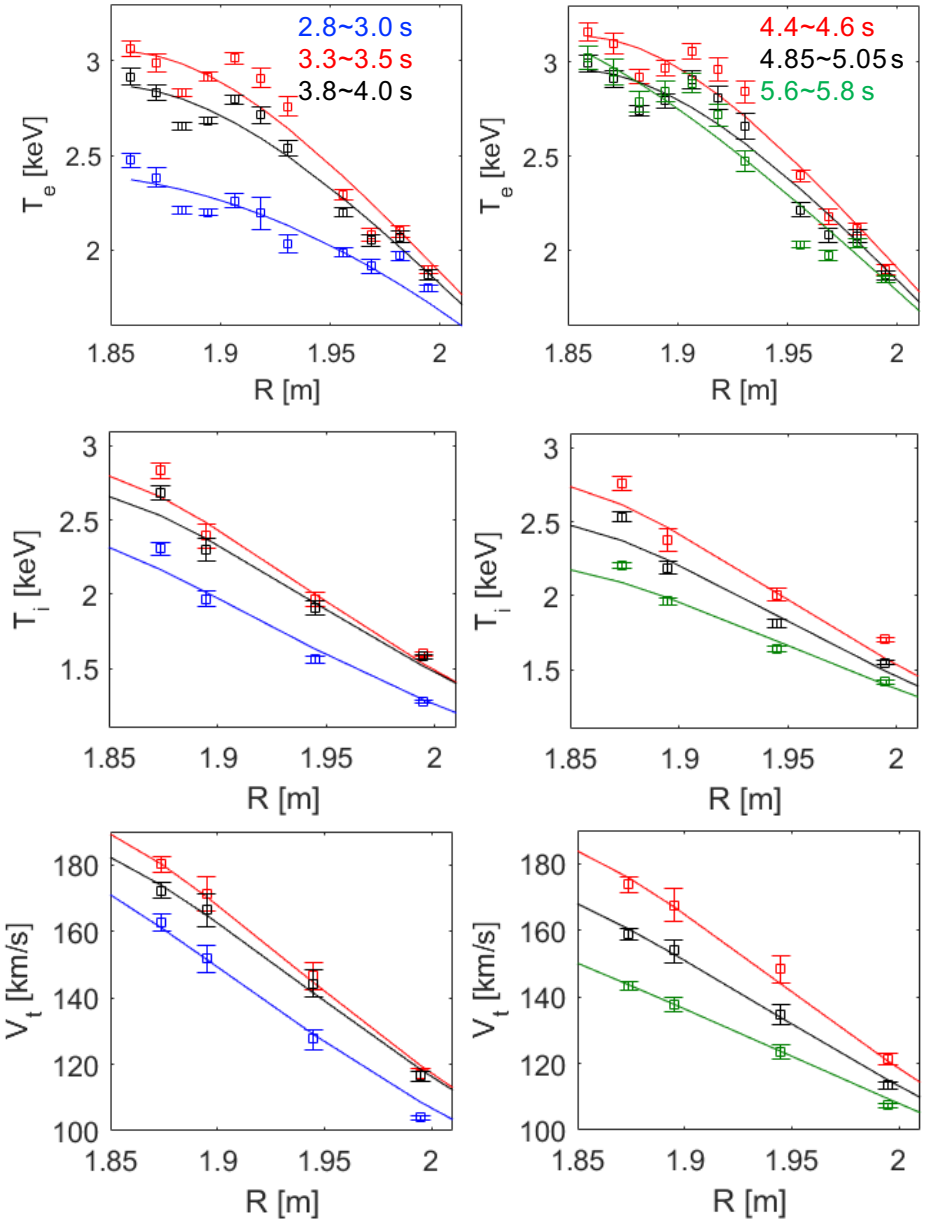
The KSTAR L-mode plasma #13728

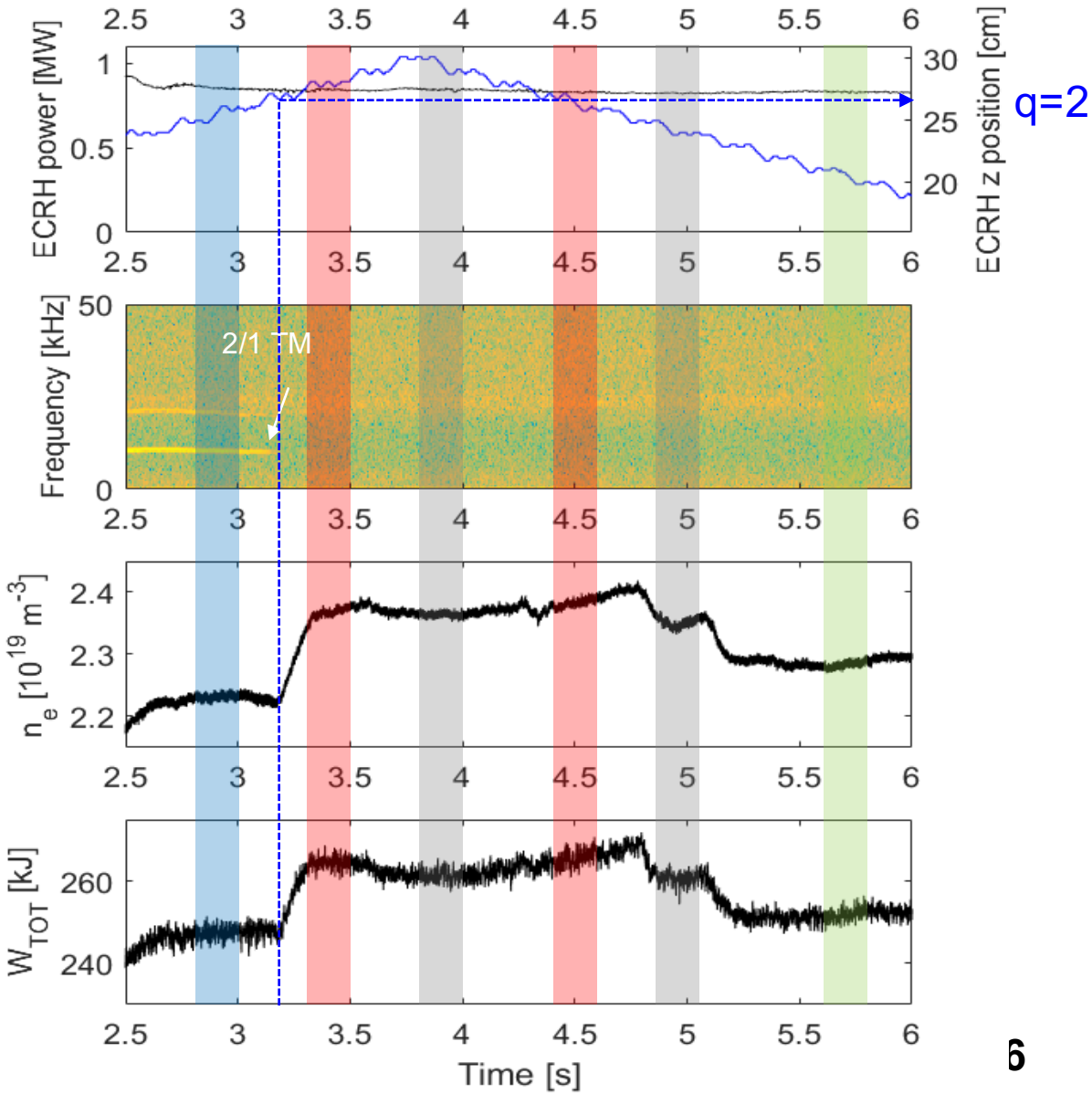
- Different z_{ECRH} (or different q profile)
  - z_{ECRH} close to q=2 (most broad?)
    - large stored energy > 260 kJ
  - z_{ECRH} away from q=2
    - 250 kJ < int stored energy < 260 kJ
  - z_{ECRH} far from q=2
    - small stored energy < 250 kJ





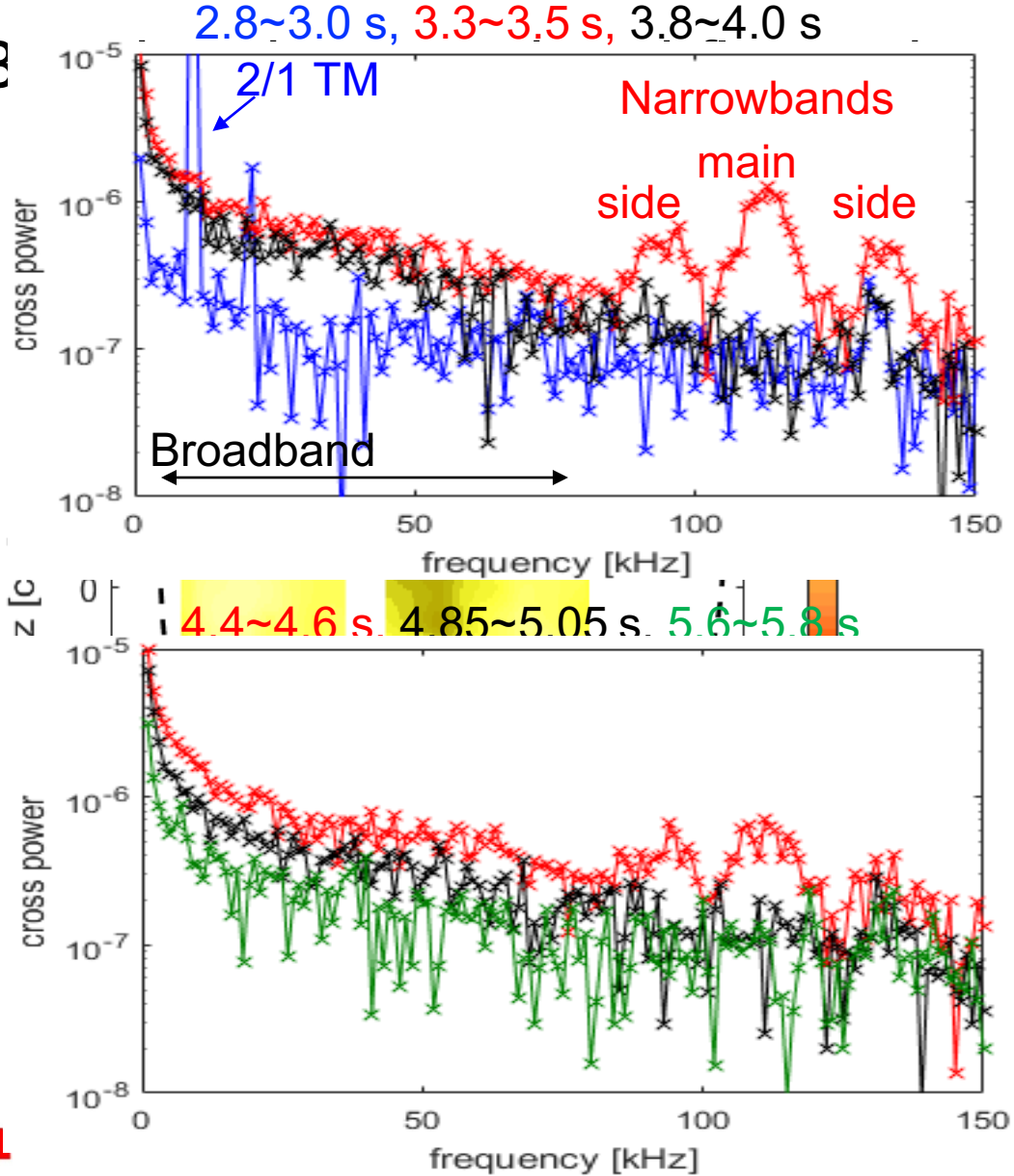
The KSTAR L-mode plasma #13728

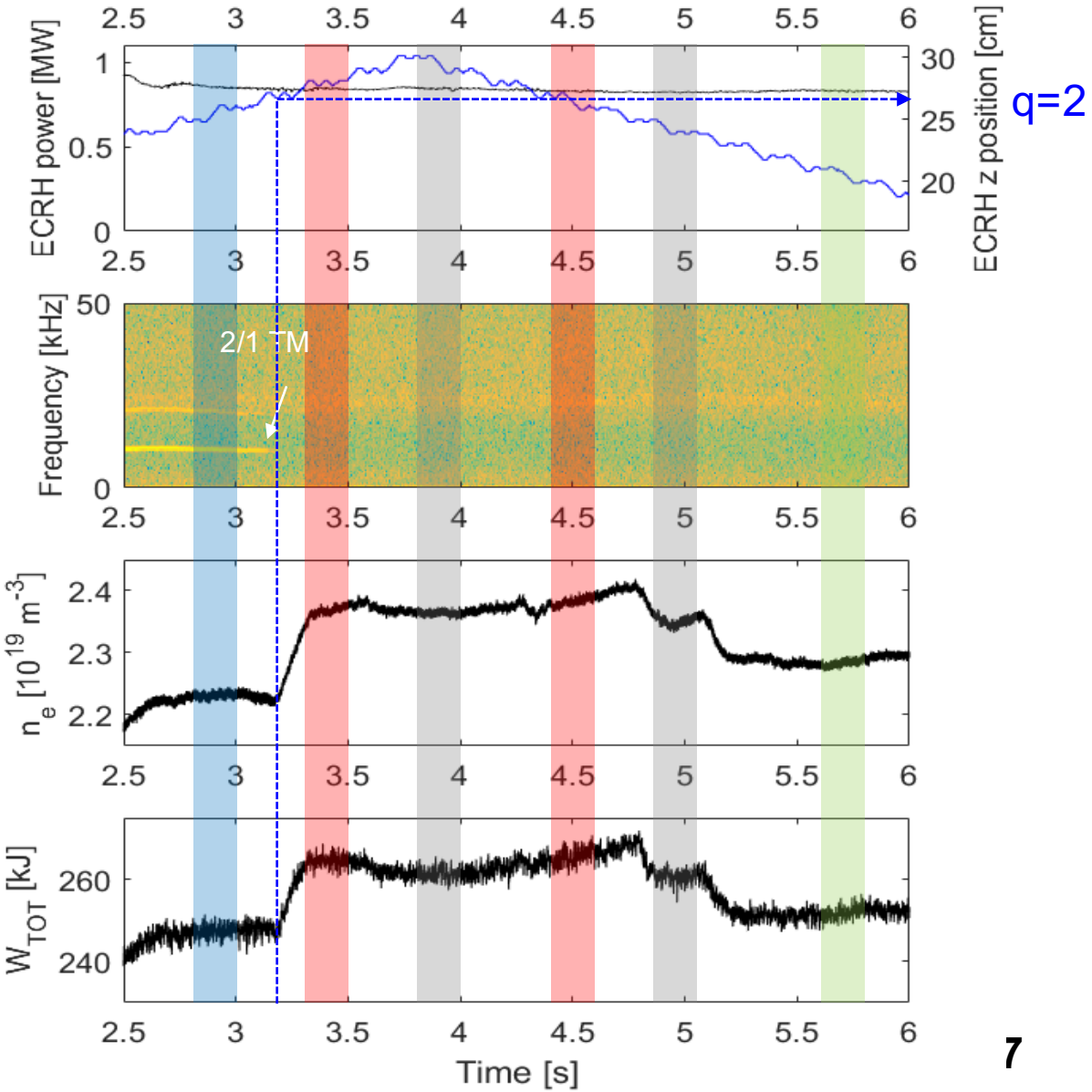




The KSTAR L-mode plasma #13728

- B

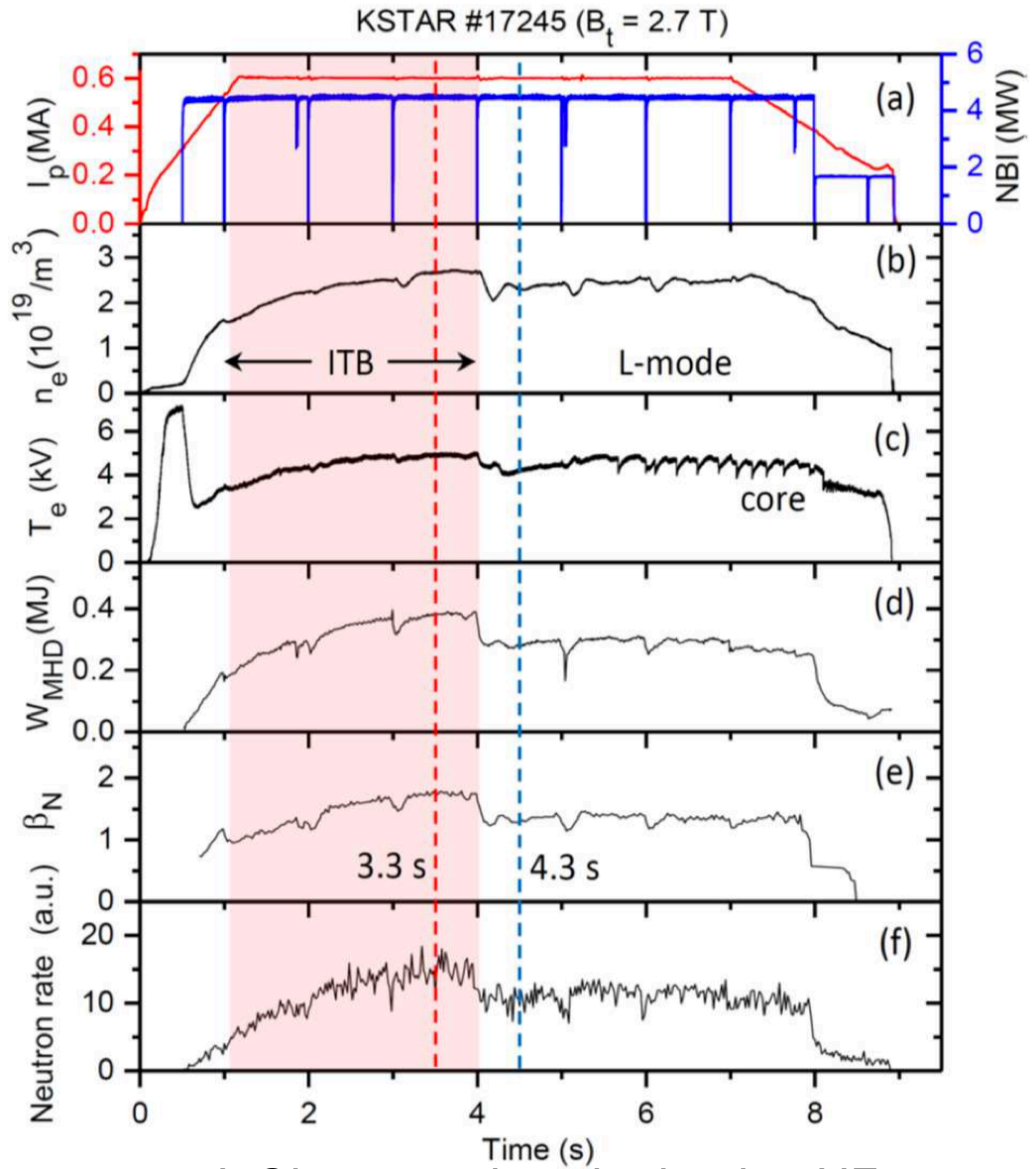




The KSTAR ITB plasma #17245

- Plasma overall parameters
  - $B_T = 2.7$ T, $I_p = 500$ kA, limiter plasma
  - 4 MW from three NBI systems (turned on 0.5 s simultaneously)
  - $q_0 > 1.0$ (no sawtooth), $R_{q2} = 152$ cm, $q_{95} \sim 6.5$
  - No tearing mode. No ECH

- Very large stored energy > 350 kJ during ITB (~ H-mode)



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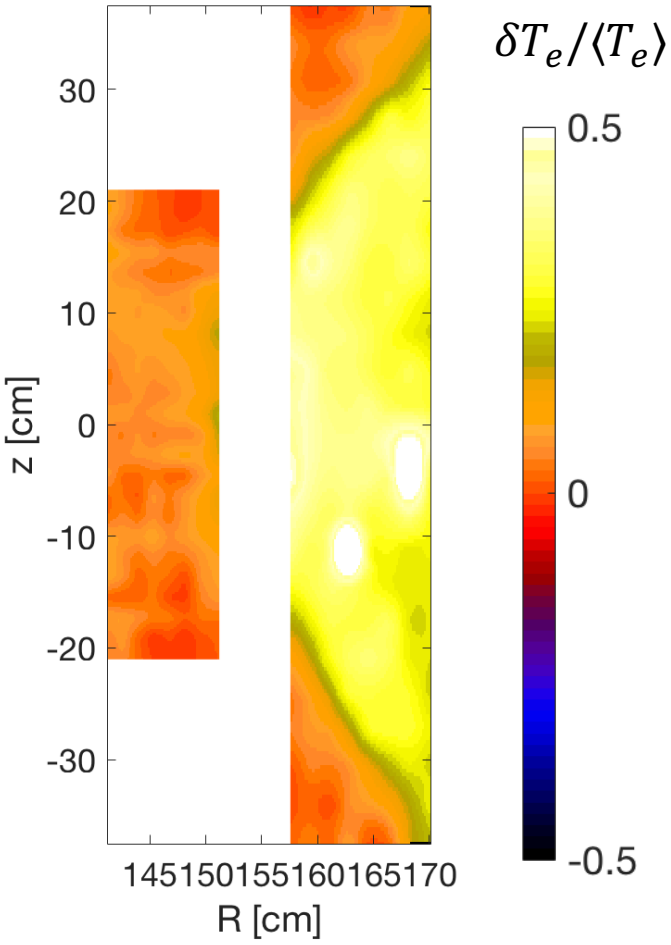
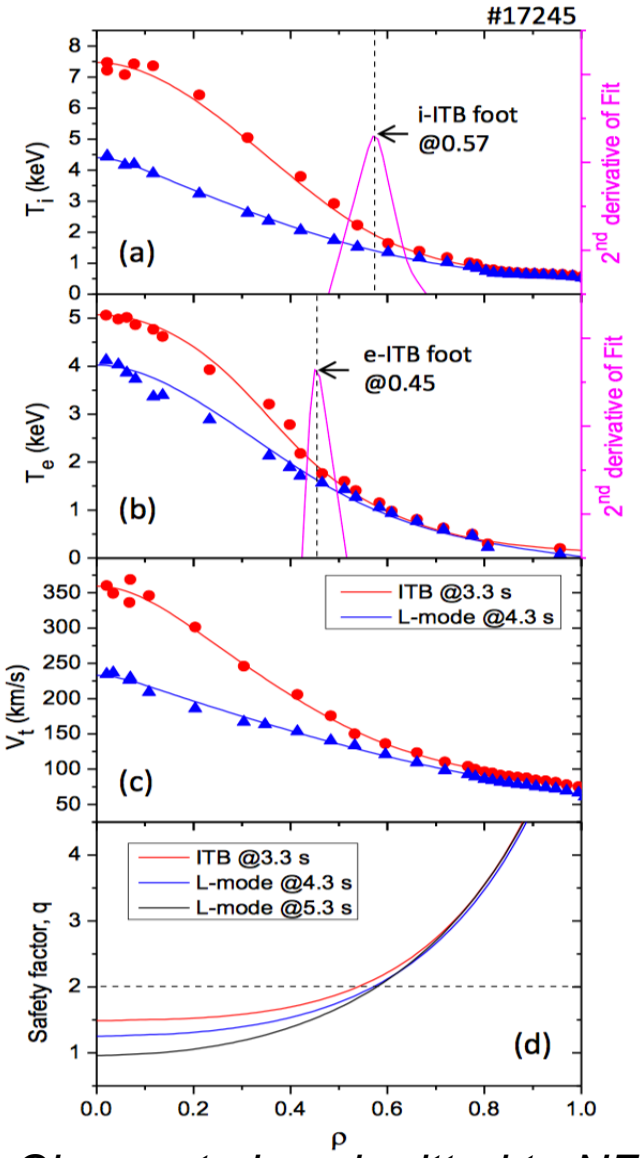
The KSTAR ITB plasma #17245

- T_e, T_i, V_t profiles are more peaked
- In particular, the T_e in 2-D shows increase clearly
  - Note that L-mode without TM in #17245 is transient
- But, no clear fluctuations
  - More careful investigation

Relative T_e change in ITB against L-mode w/o TM





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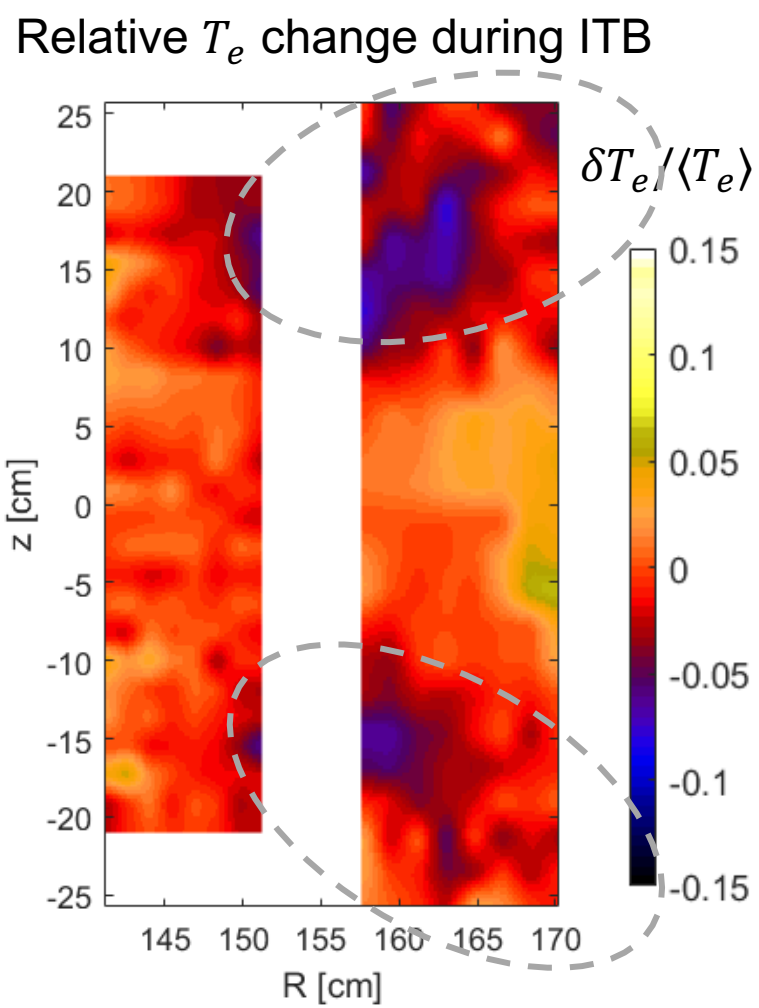
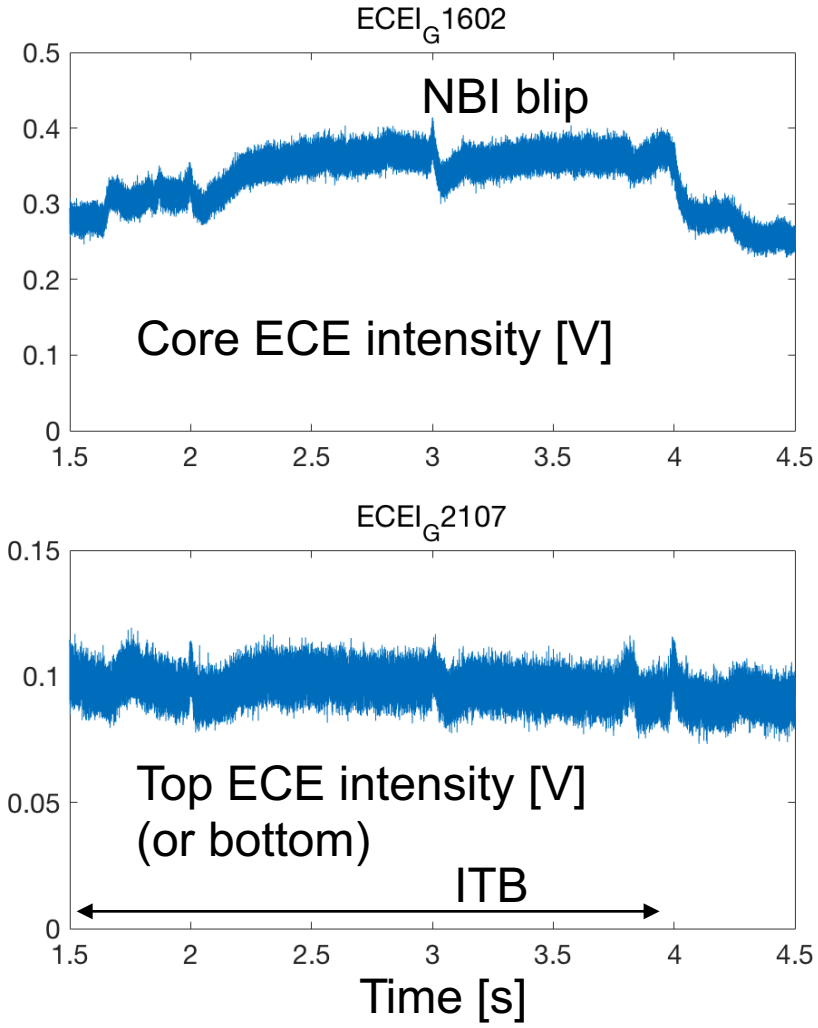
The KSTAR ITB plasma #17245

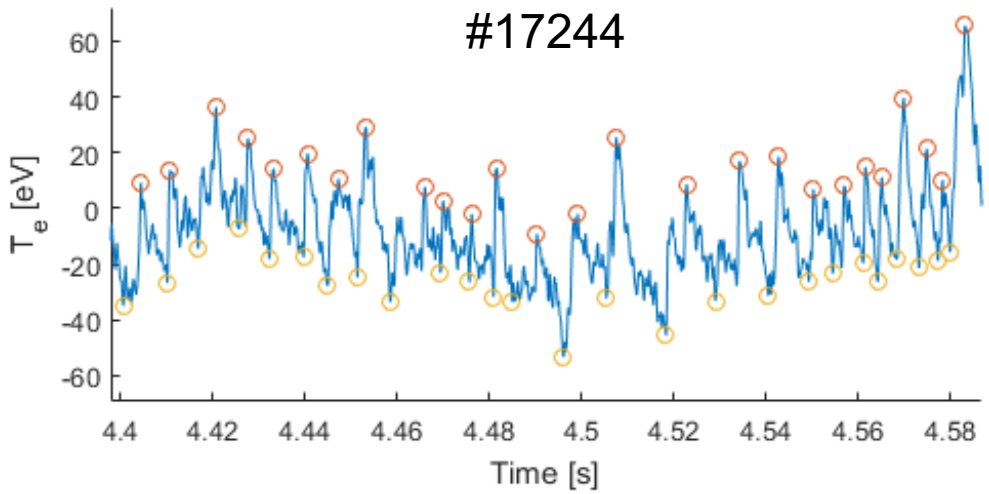
- Electron temperature evolution during ITB



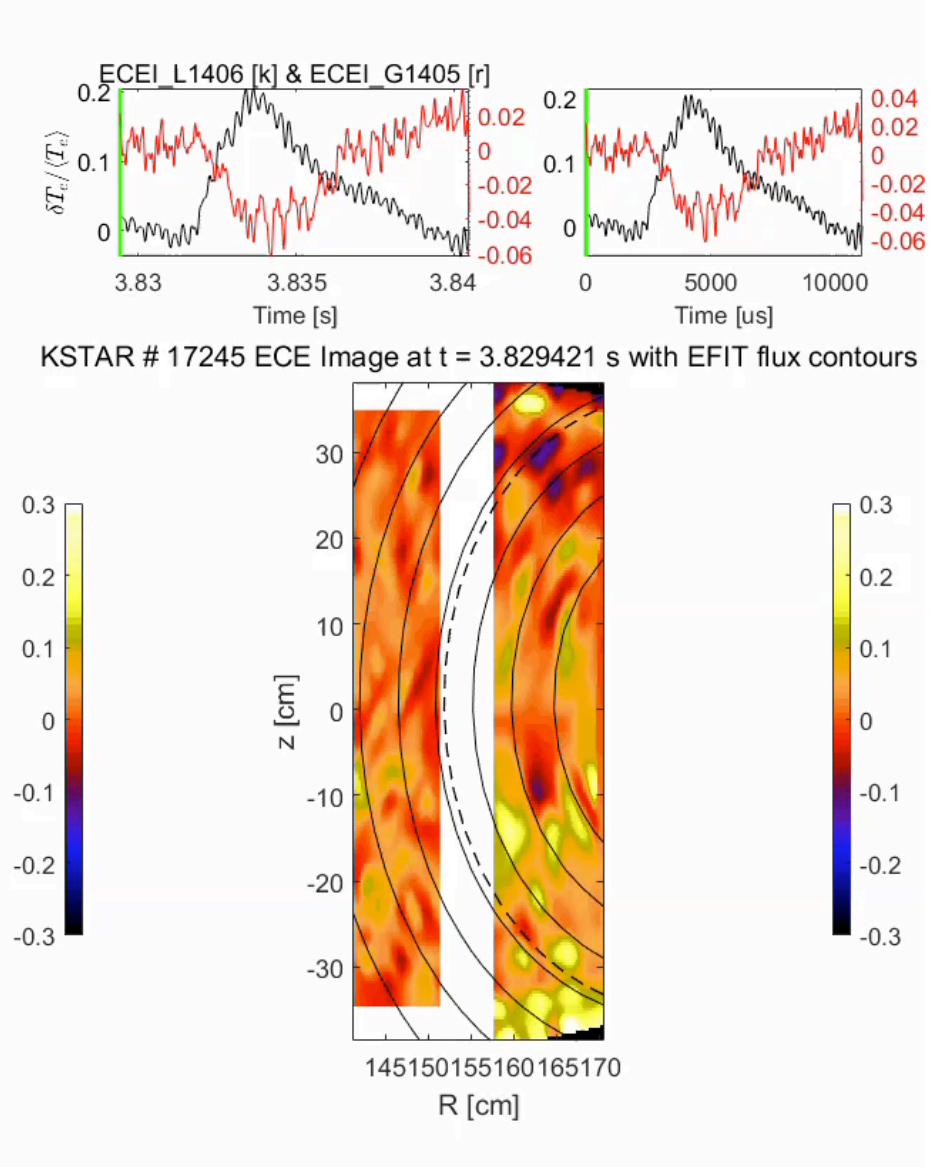


The KSTAR ITB plasma #17245

- Intermittent bursts for all ITB phase

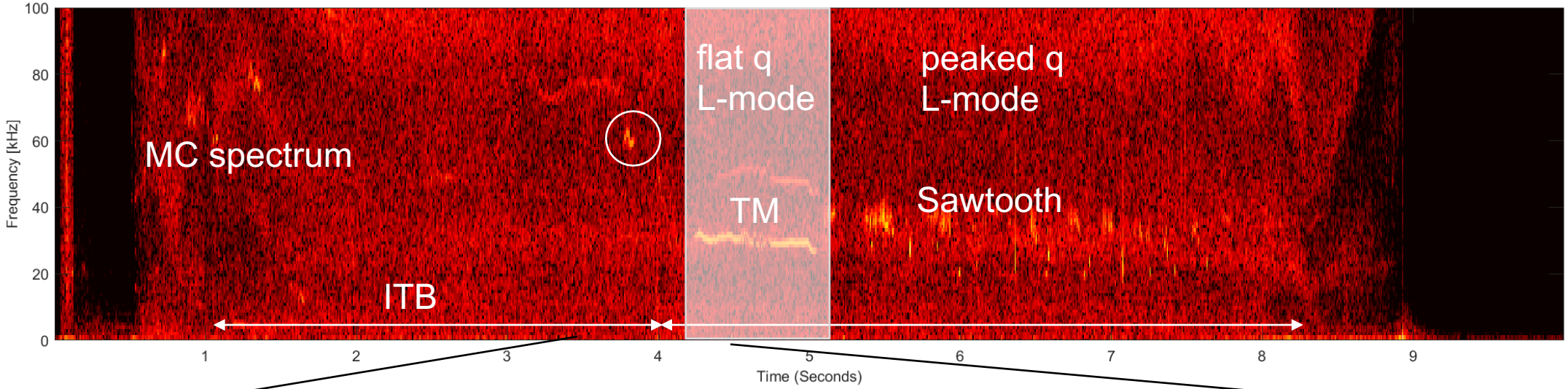


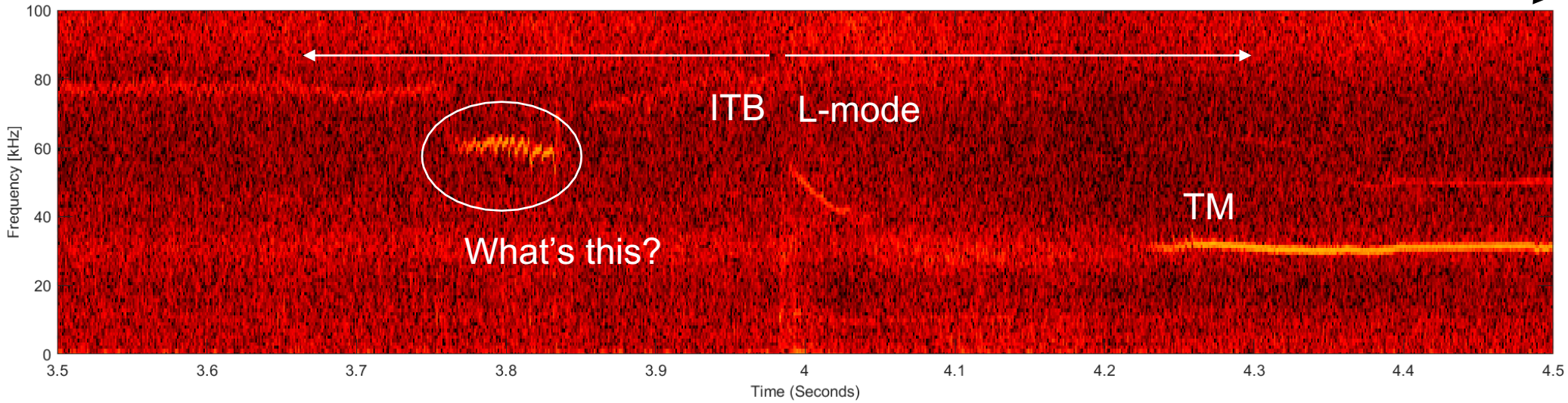
  - PDF analysis of heat flux or waiting time statistics is on going



The KSTAR ITB plasma #17245

- 60 kHz fluctuation before ITB disrupts

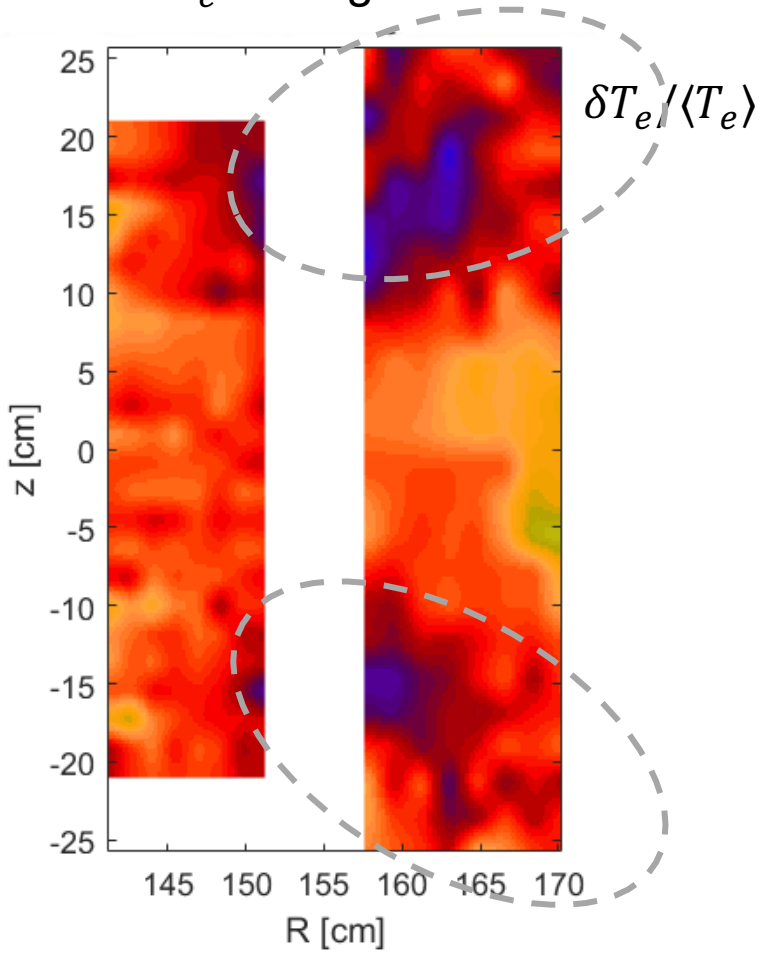


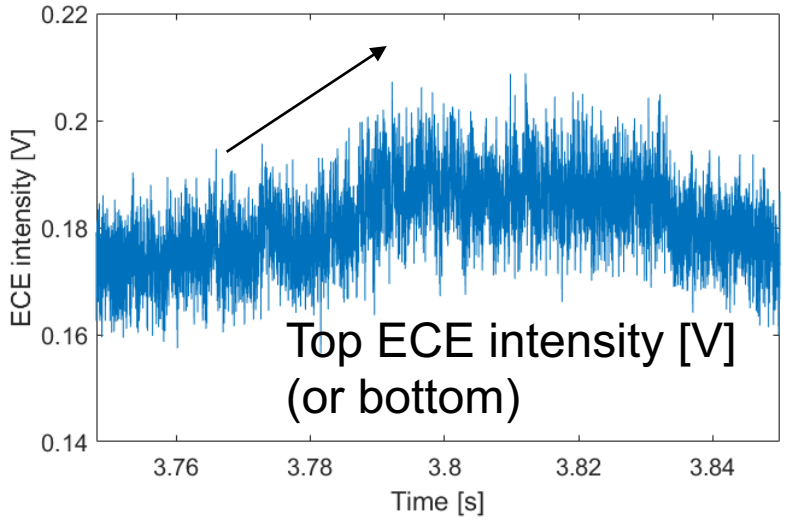


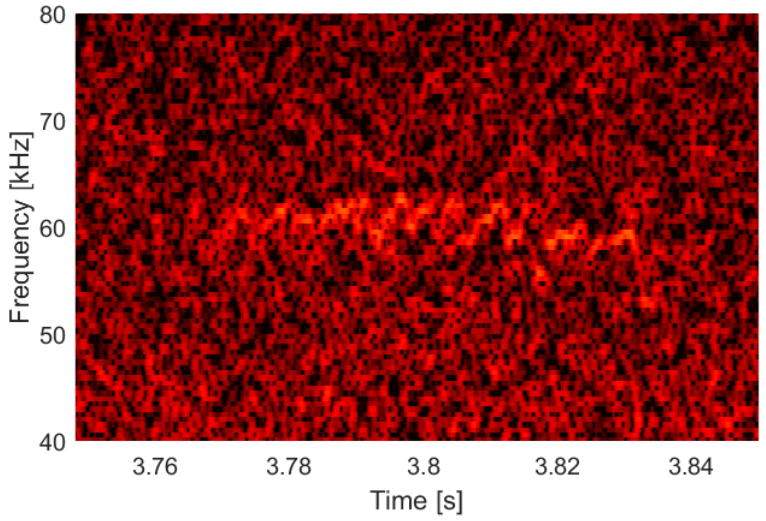
The KSTAR ITB plasma #17245

- 60 kHz fluctuation is also measured in T_e. Top and bottom T_e increase

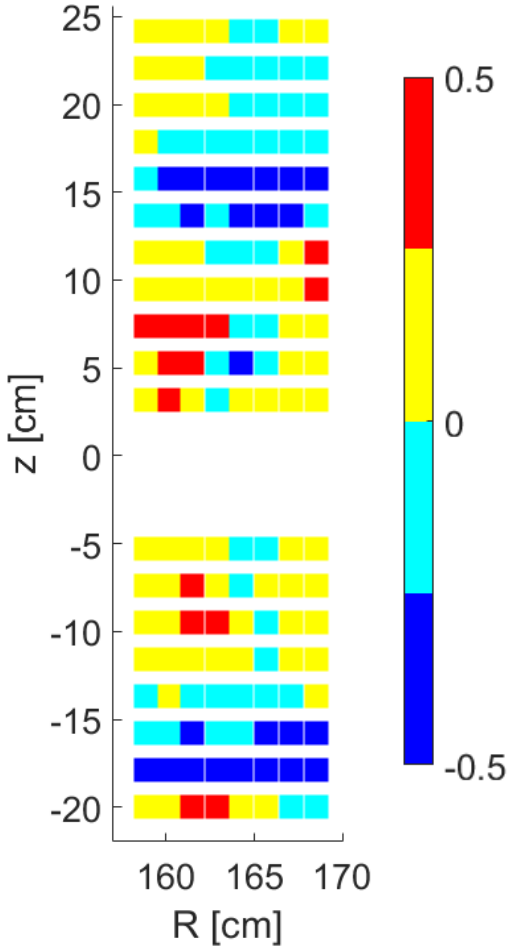
Relative δT_e in long time scale





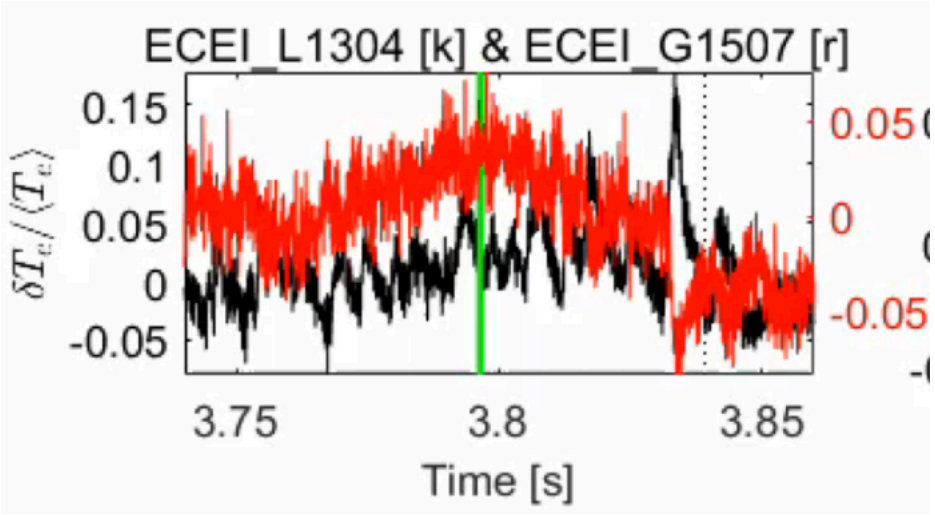


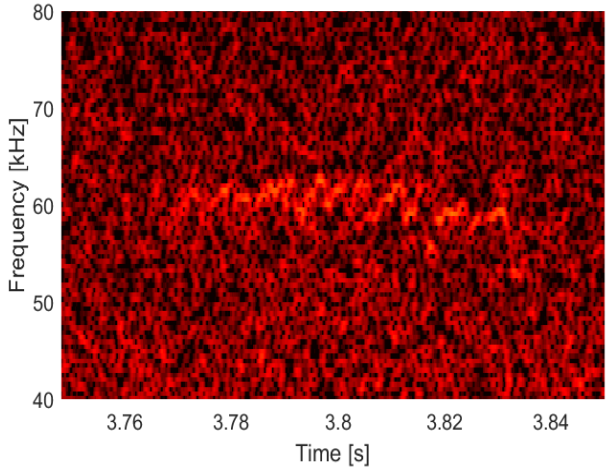
Zero time lag cross correlation coefficient

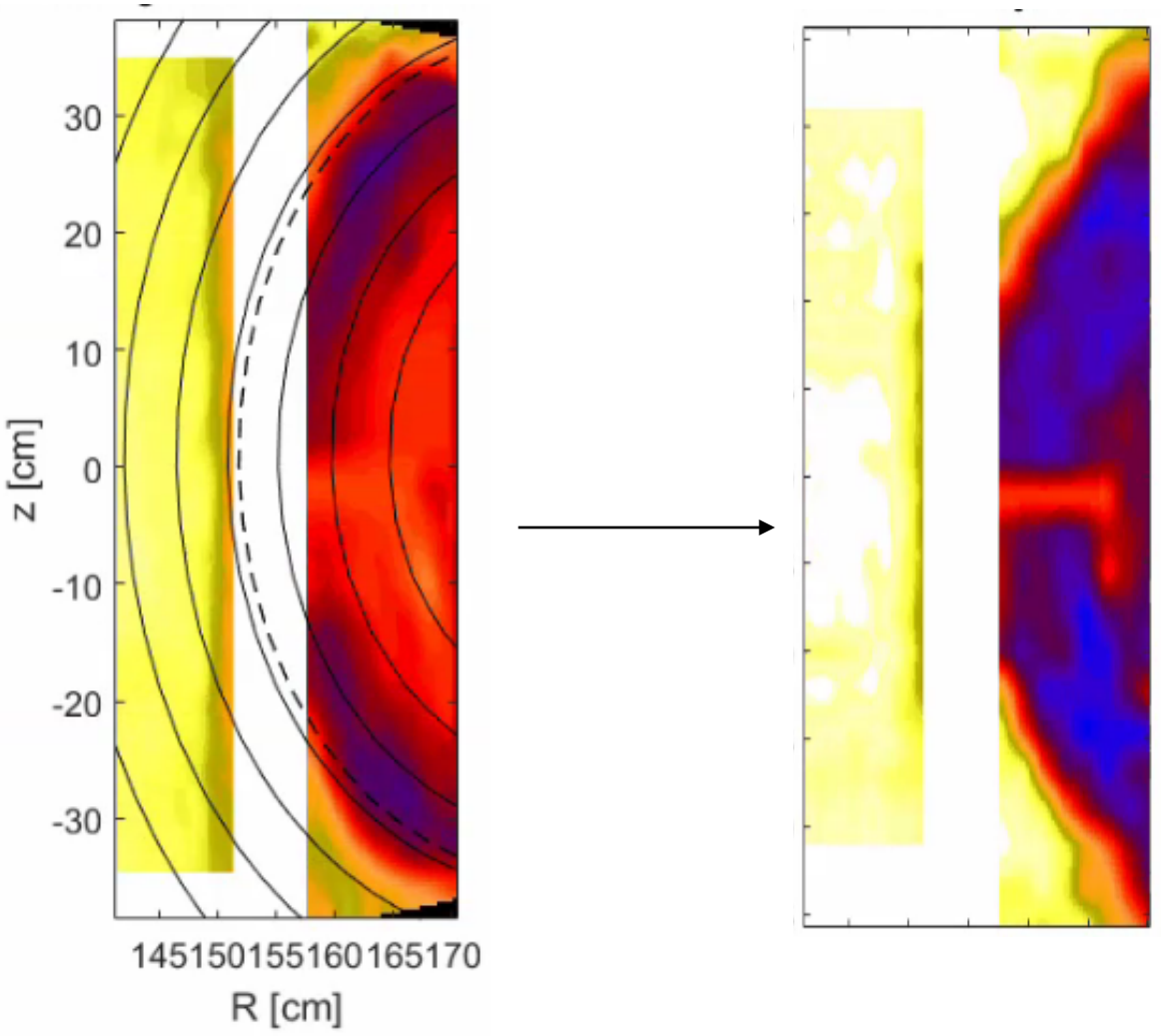


The KSTAR ITB plasma #17245

- Intermittent burst size (void size) increases with 60 kHz fluctuation

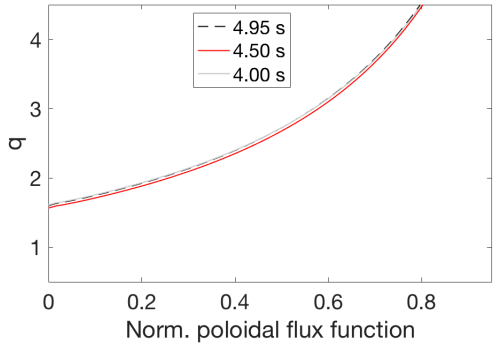


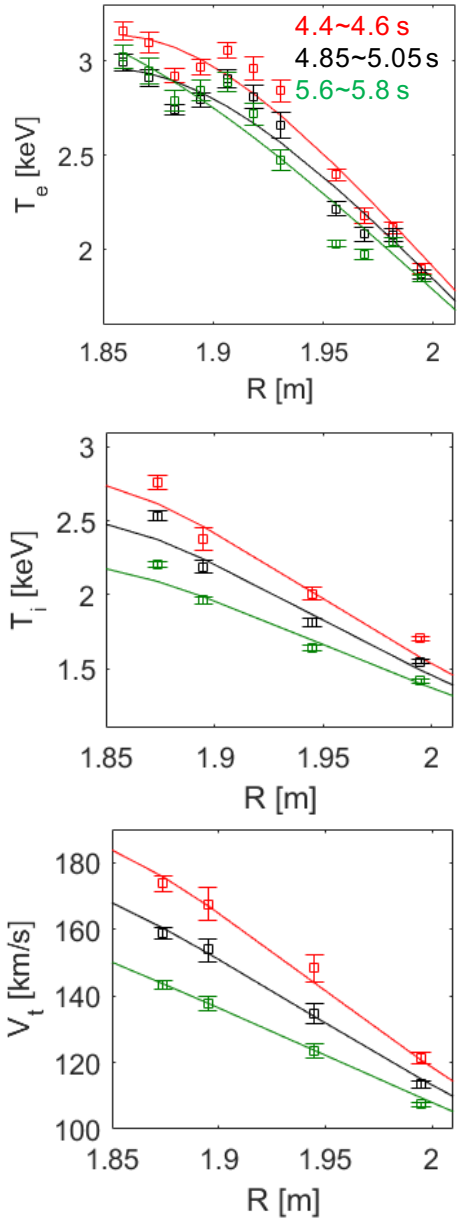


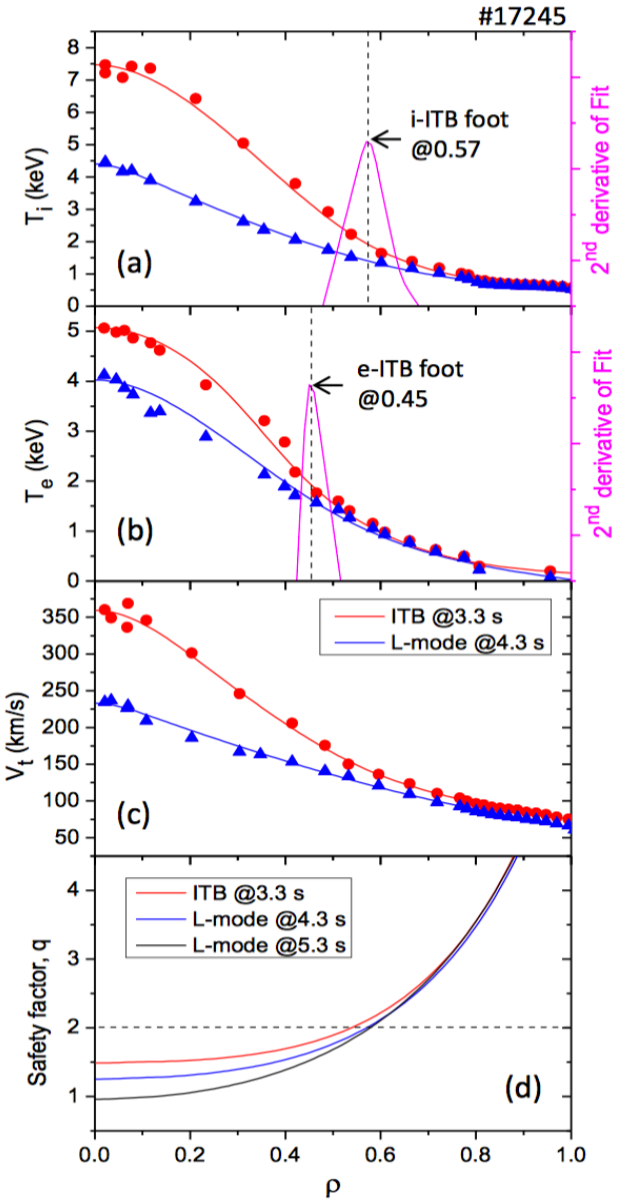


Summary : Differences between L-mode w/o TM and ITB

- Machine parameter
  - B_T and ECH
- Profiles
  - ITB T_e, T_i, V_t profiles are more peaked
  - Note that averaged density is similar
  - q profile can be a little different
    - L-mode : $q_0 > 1.0$, $R_{q2} = 155$ cm, $q_{95} \sim 6.6$
    - ITB : $q_0 > 1.0$, $R_{q2} = 152$ cm, $q_{95} \sim 6.5$







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Summary : Differences between L-mode w/o TM and ITB

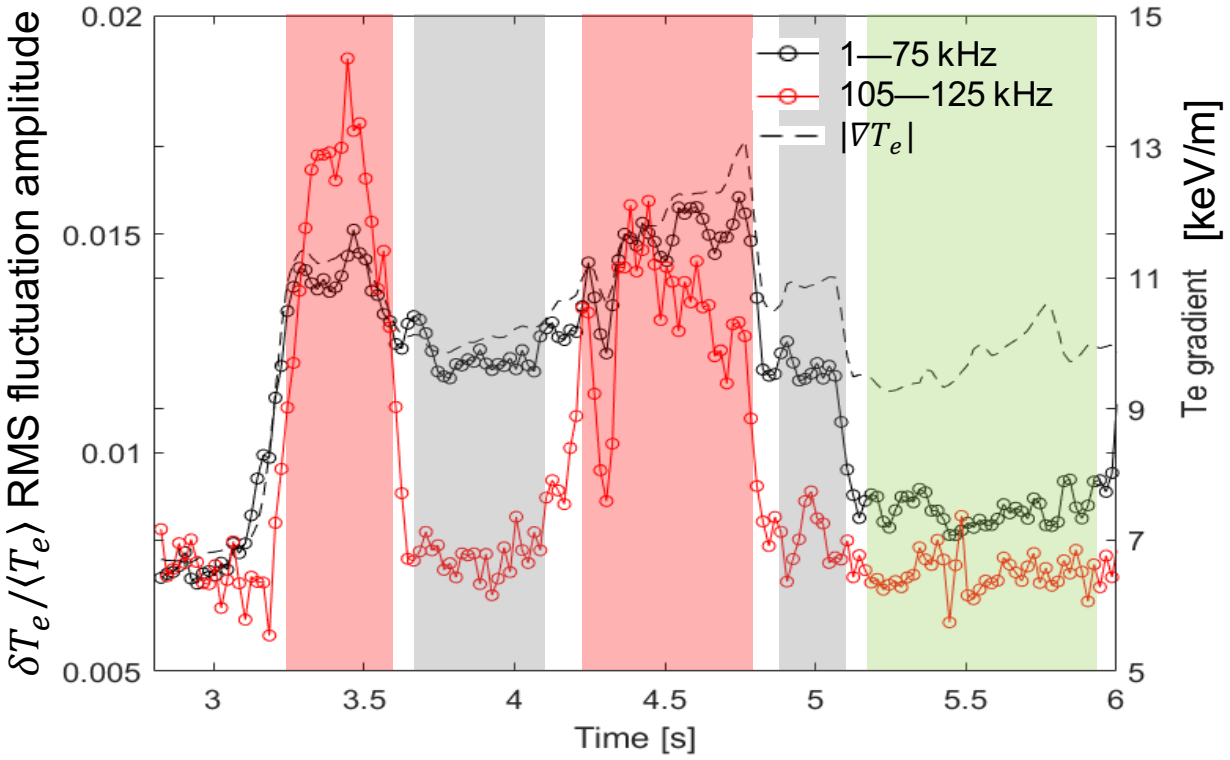
- Fluctuation and transport characteristics
  - The broad and narrow fluctuations are only observed in L-mode
  - Intermittent burst is observed for all ITB phase
  - 60 kHz Mirnov and T_e fluctuation appear in ITB and it is possibly related to ITB disruption with increase of the burst size

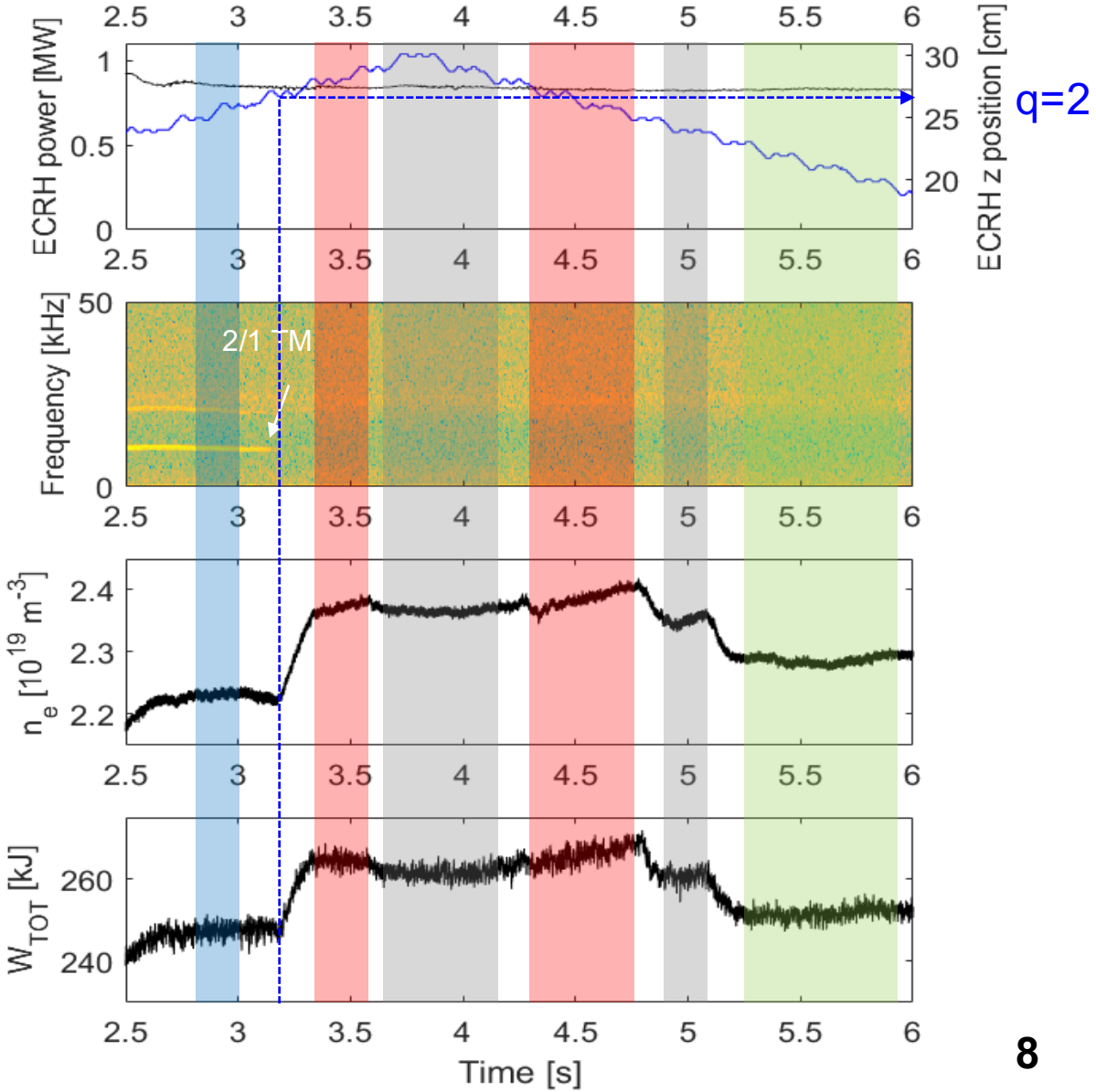
Summary : Questions

- What makes a huge difference between L-mode and ITB? ECH?
- What are the broad and narrow T_e fluctuations? Is ECH critical?
  - Linear gyrokinetic simulation (by Dr. SH Ko) provides some hint. TEM is most unstable. Note that their amplitudes are closely related to local T_e gradient at q=2.
- Do they make the significant turbulent electron thermal transport? Do they hinder the plasma from going to ITB?
- Is the narrow fluctuation driven by the broad one?
  - Nonlinear spectral energy transfer analysis is on going
- Is the intermittent burst the dominant electron thermal transport mechanism in ITB?
- Does the (avalanche-like) burst mean that the scale invariant transport in ITB?
  - More higher order statistics analysis is on going
- Why can't we see the broad T_e fluctuation in the ITB plasma? What is killing it?
  - Er field estimation is on going (by Dr. C Bae)
- What is the 60 kHz fluctuation? How are the 60 kHz fluctuation, the T_e profile, and the burst related?
- Can we go to ITB from flat q L-mode w/o TM if we turn-off ECH?

Back up : The KSTAR L-mode plasma #13728

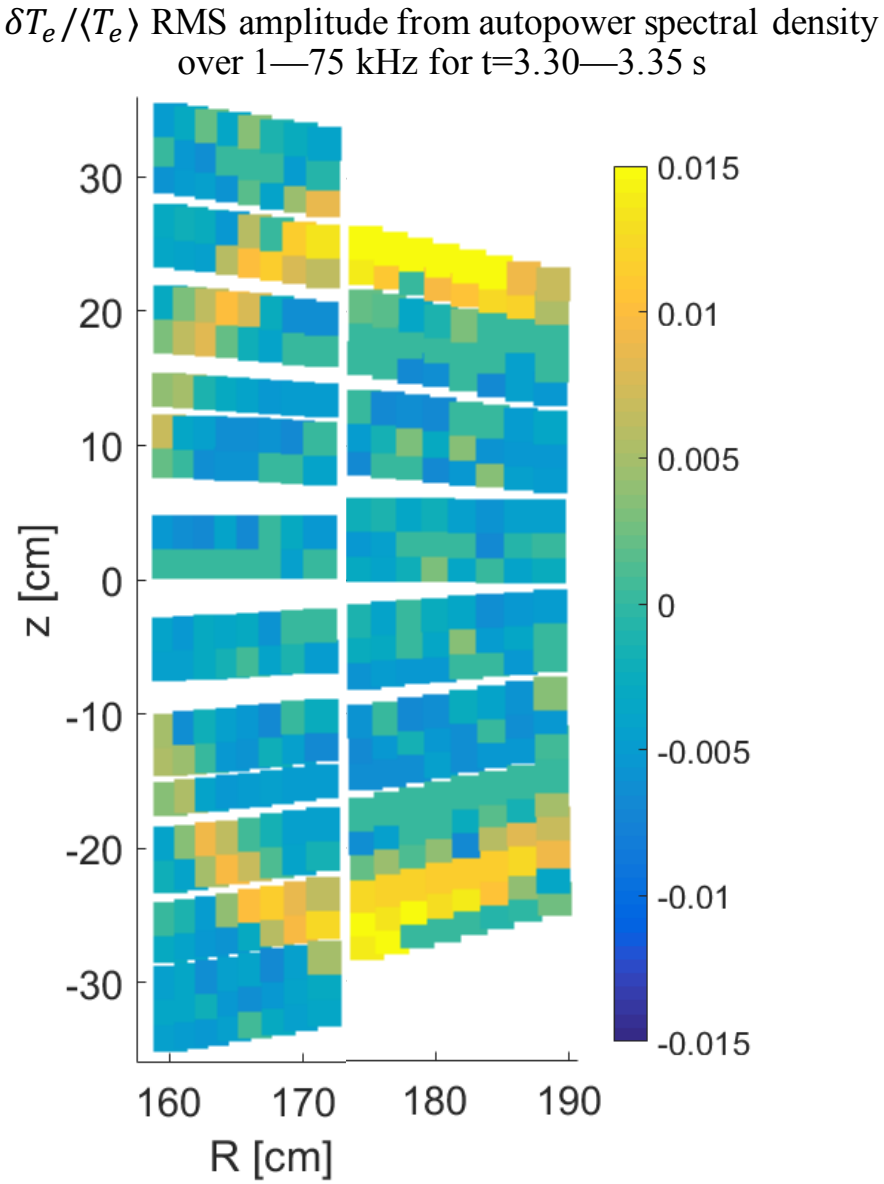
- Fluctuation amplitude evolution





Back up : The KSTAR L-mode plasma #13728

- Broadband fluctuation amplitude distribution
  - Localized near q=2 surface
  - Strong a top and bottom
    - Top > bottom
    - Weak near the midplane

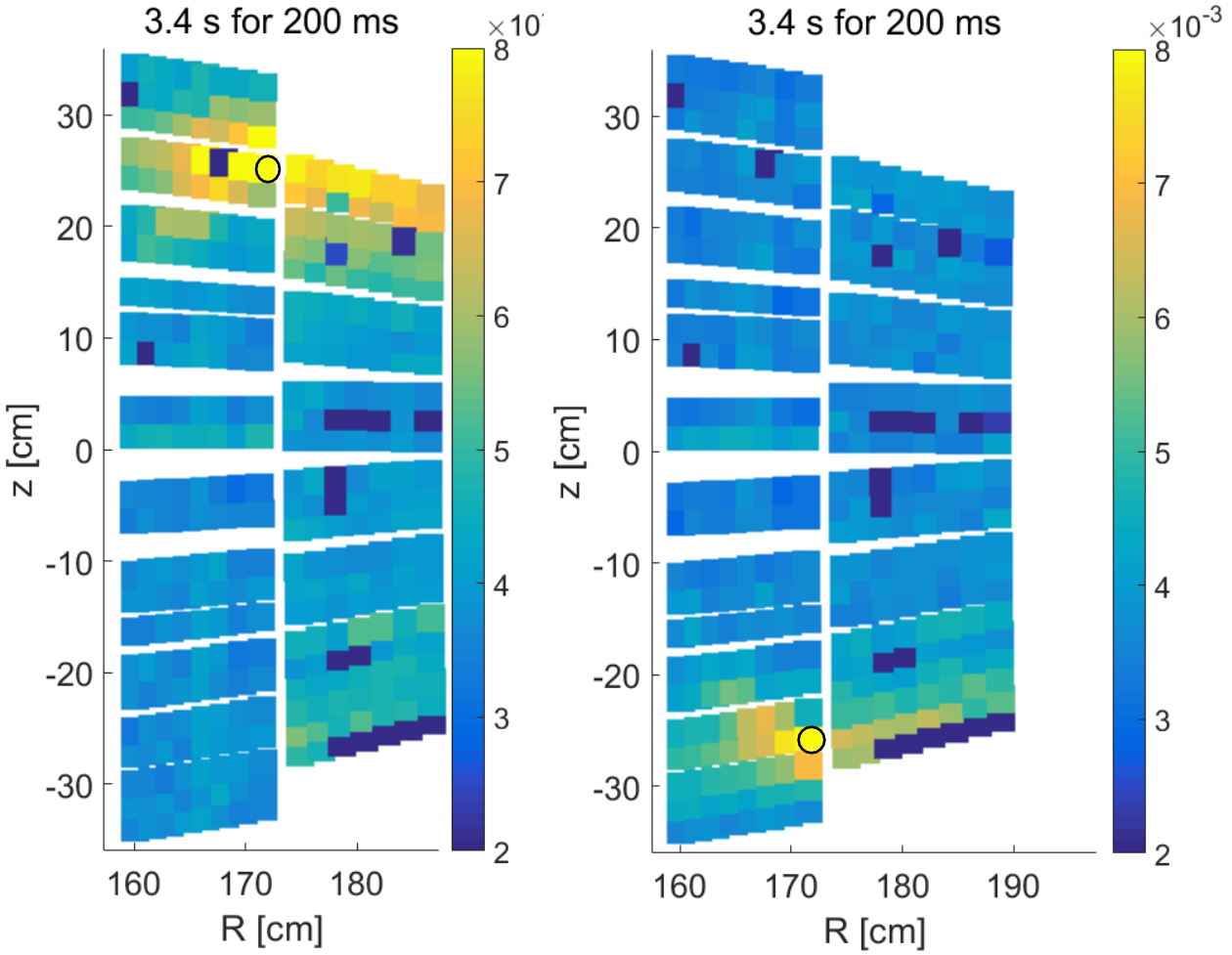


Back up : The KSTAR L-mode plasma #13728

- Broadband fluctuation amplitude distribution
  - Localized near q=2 surface
  - Strong a top and bottom
    - Top > bottom
    - Weak near the midplane

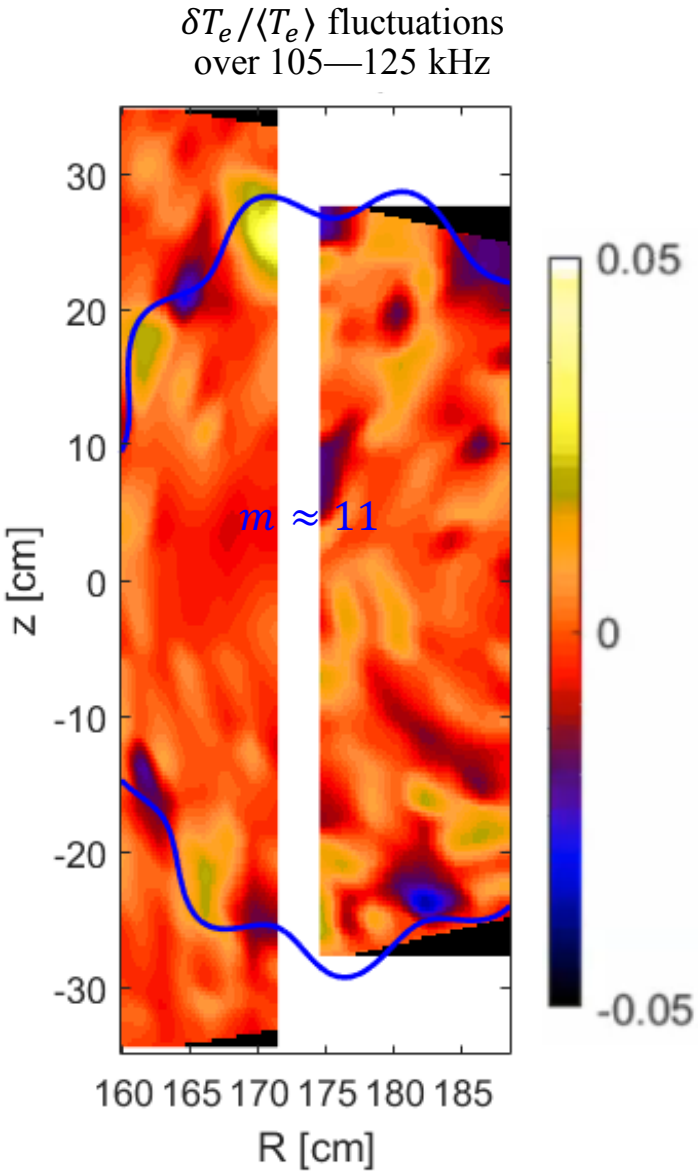
- Top and bottom broadband fluctuations seem to be decoupled

$\delta T_e / \langle T_e \rangle$ RMS amplitude from crosspower spectral density over 30—75 kHz for t=3.30—3.35 s



Back up : The KSTAR L-mode plasma #13728

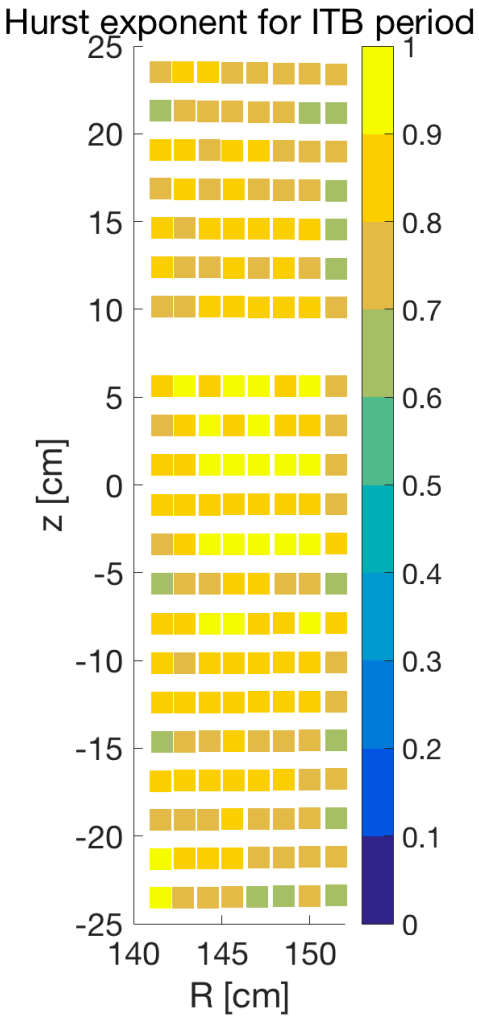
- Narrowband fluctuation mode
  - Localized near q=2 surface
  - Poloidal mode number ~ 11



Back up : Hurst exponent image

- Hurst exponent image

ITB (#17245)



L-mode flat q profile w/o TM (#13728)