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Density fluctuation measurements from the NSTX Beam Emission Spectroscopy (BES) diagnostic system

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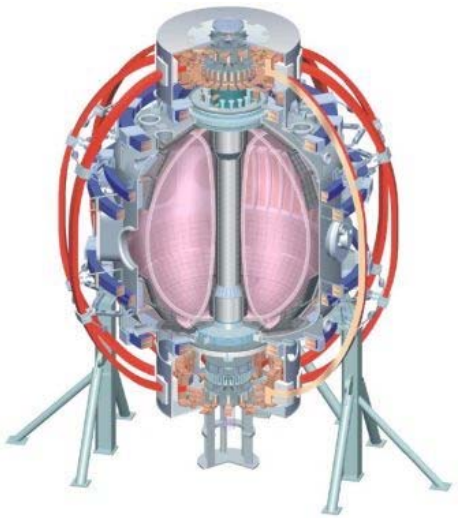
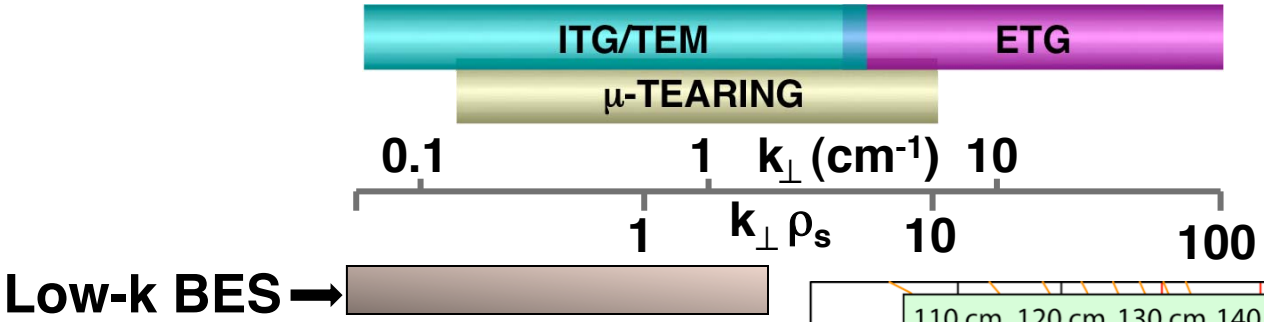
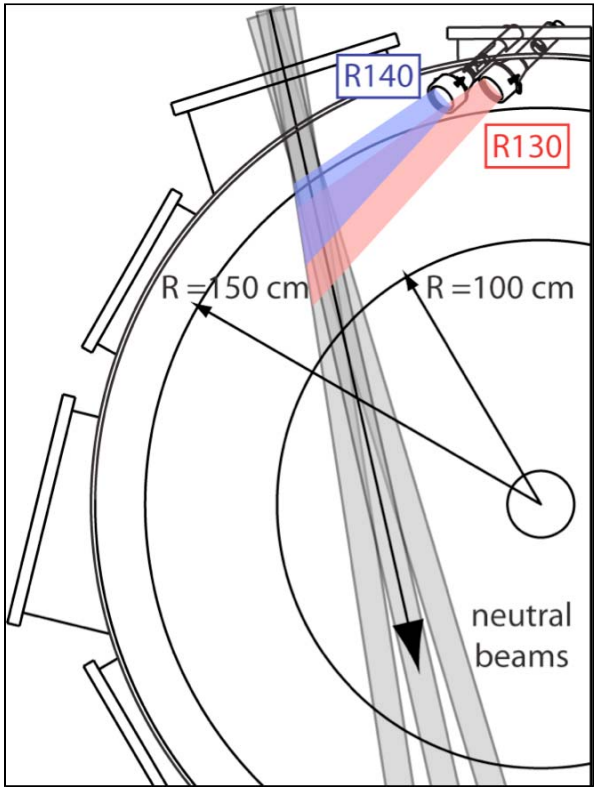
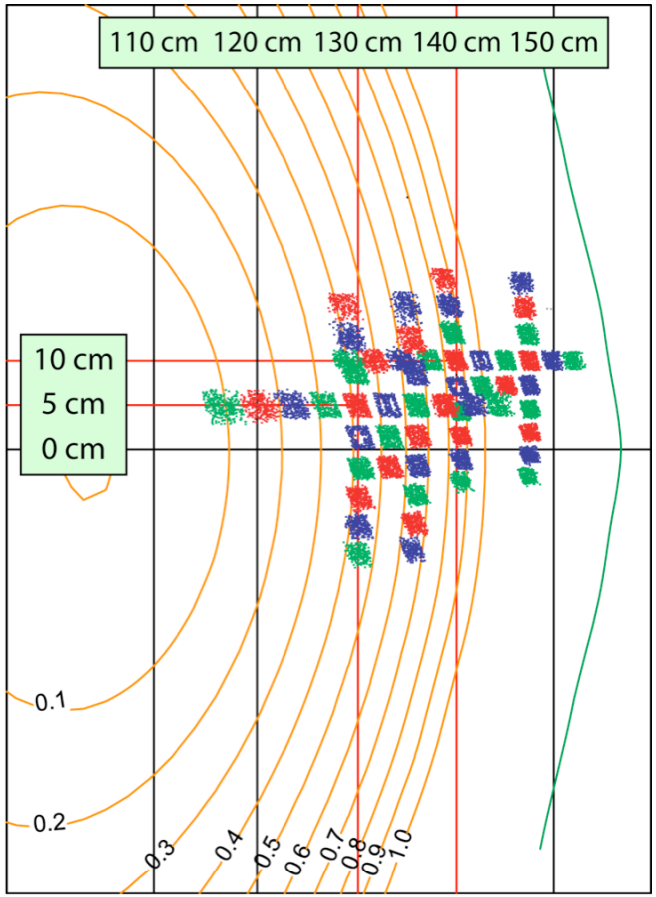
San Diego, CA
April 6-9, 2011



Beam emission spectroscopy (BES) provides low-k fluctuation measurements for studying plasma turbulence in NSTX







Outline

- BES diagnostic overview
  - Optical system
  - Detection system
  - Measurement capabilities
- Initial results
  - Fluctuations decrease at LH transition (increase at HL back-transition)
  - In pedestal, eddy poloidal motion reverses after LH transition
  - Poloidal correlation length dependence on |B| and Ip
  - Post-ELM harmonic features (~50-150 kHz) localized at top of pedestal
  - GAE and TAE mode structure
- Summary and plans

Beam emission spectroscopy provides localized, long-wavelength fluctuation measurements with $k_\perp \rho_i \lesssim 1$

- BES measurements contribute to several NSTX research areas
  - Turbulence and transport
    - ITG/TEM turbulence
    - ZFs and GAMs
    - Flow fluctuations
  - Boundary physics
    - LH transition
    - Edge & SOL fluctuations
    - ELMs and EHOs
  - Waves-particle interactions
    - TAE/EP/GAE mode structure

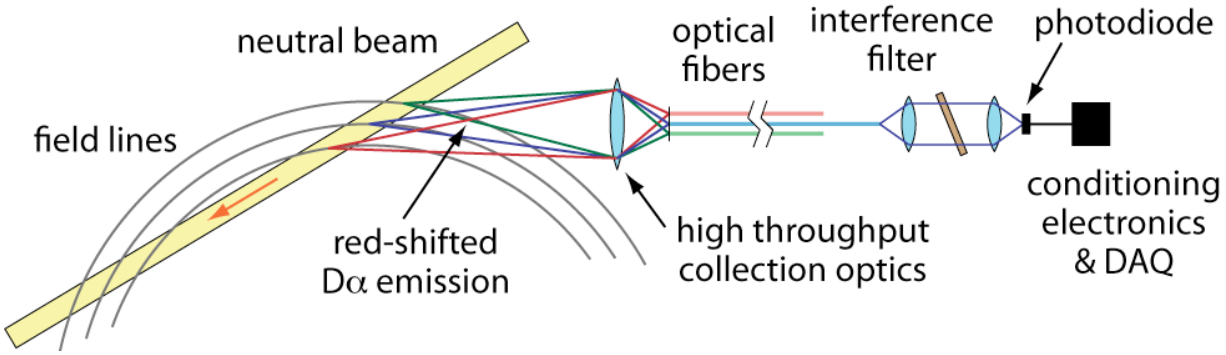
$$\frac{\delta I_{D\alpha}}{I_{D\alpha}} = \frac{\delta n_i}{n_i} \times C\left(E_{NB}, n_e, T_e, T_i, Z_{eff}\right)$$

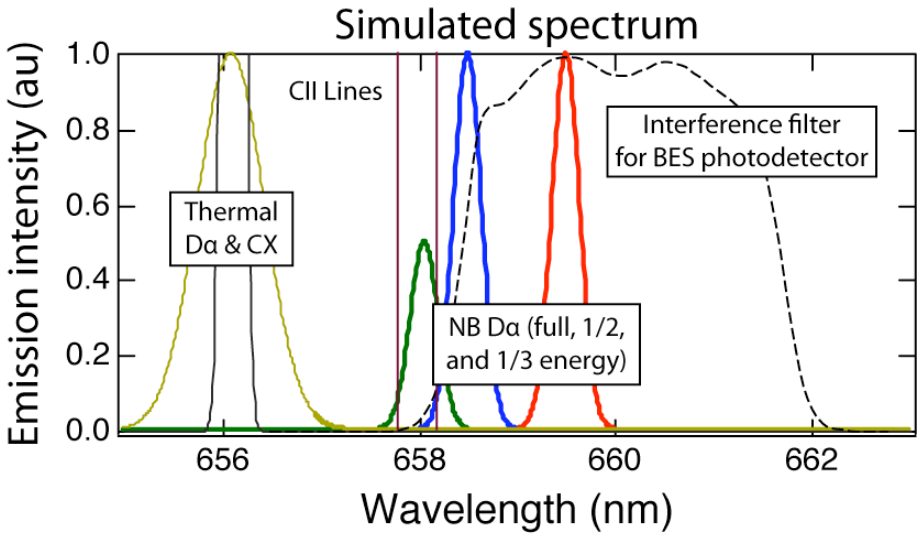
neutral beam D_α emission

ion density fluctuation

$C \approx 1/2$

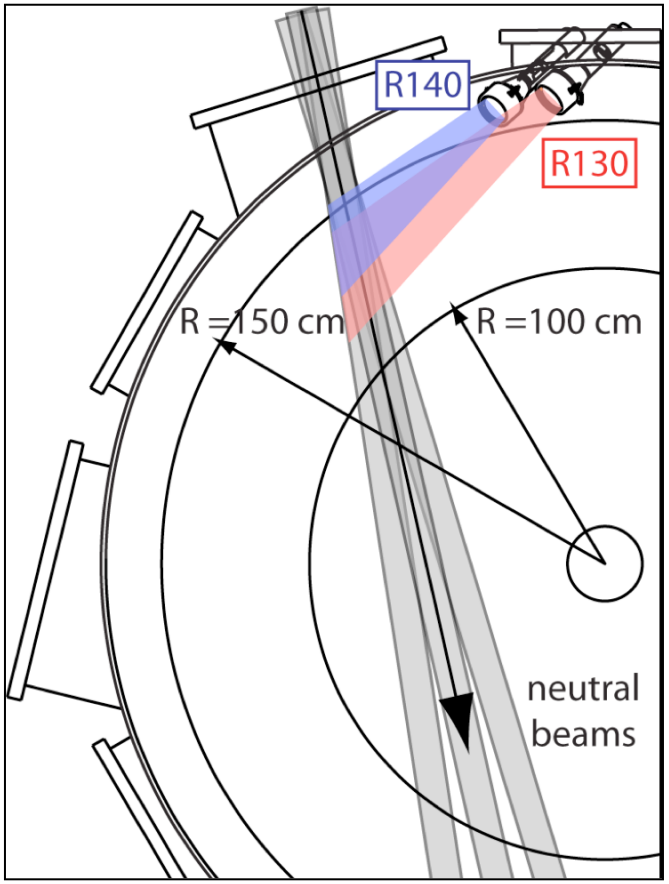
- Doppler shift and optical filter isolate NB D_α emission from thermal D_α





The NSTX BES system was commissioned in 2010

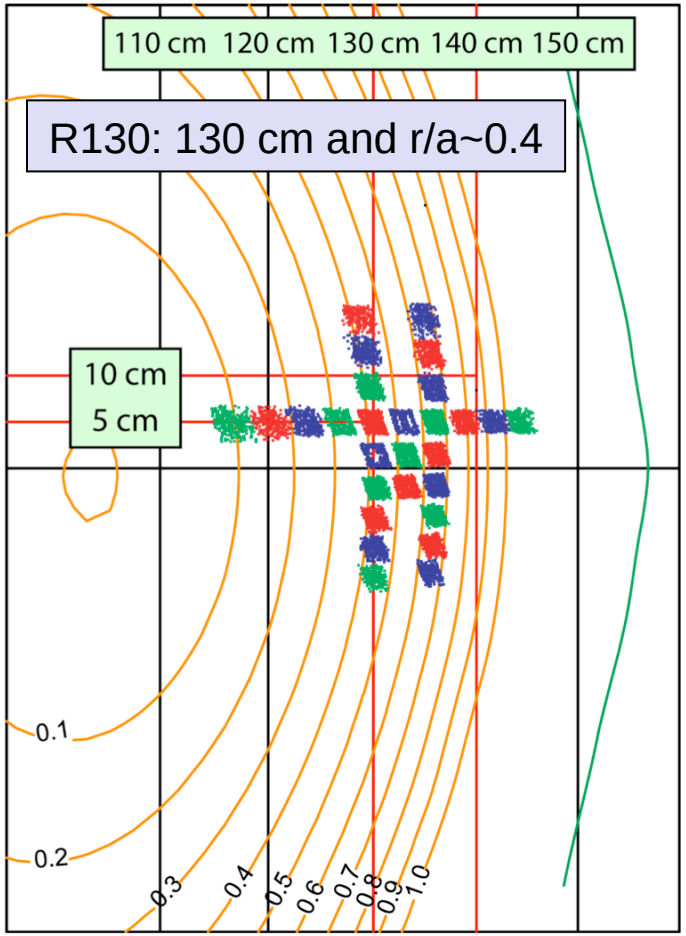
- Doppler shift and optical filter isolate NB D_α emission from thermal D_α
- Two optical views are aligned to steep pitch angles in NSTX plasmas

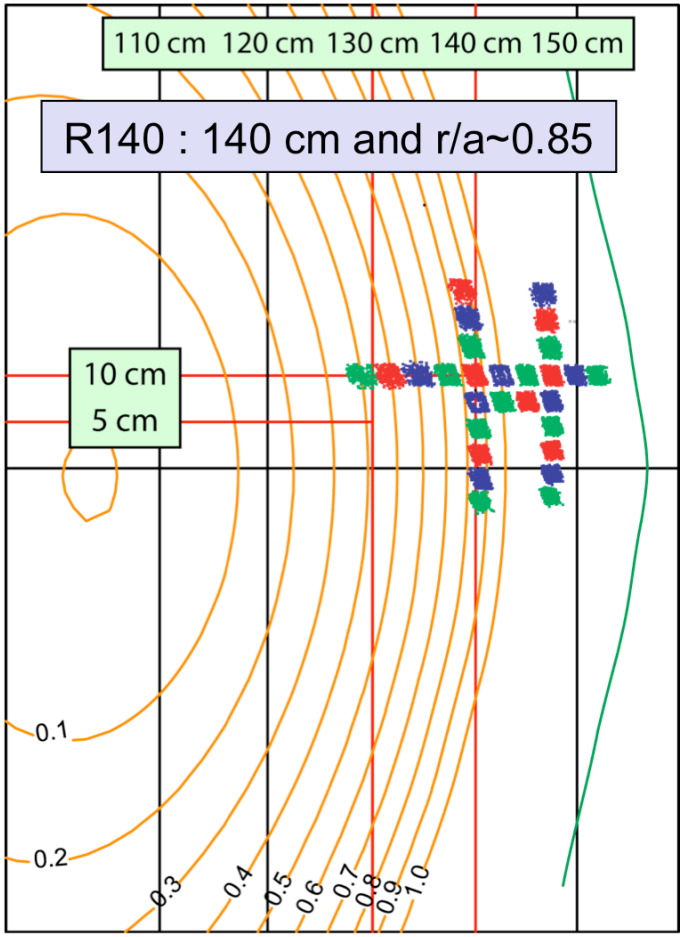


D. R. Smith et al, **RSI** 81, 10D717 (2010)
N. Schoenbeck et al, **RSI** 81, 10D718 (2010)

Two optical views with 56 fiber bundles provide radial coverage from r/a ≈ 0.1 to SOL with 2-3 cm spot sizes

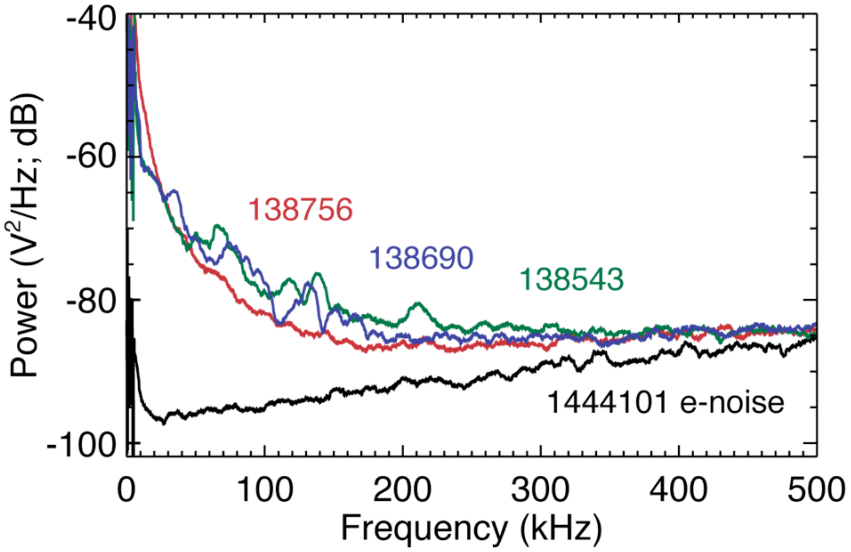
Image patterns provide radial and poloidal correlation lengths, k-spectra, and flow fluctuations

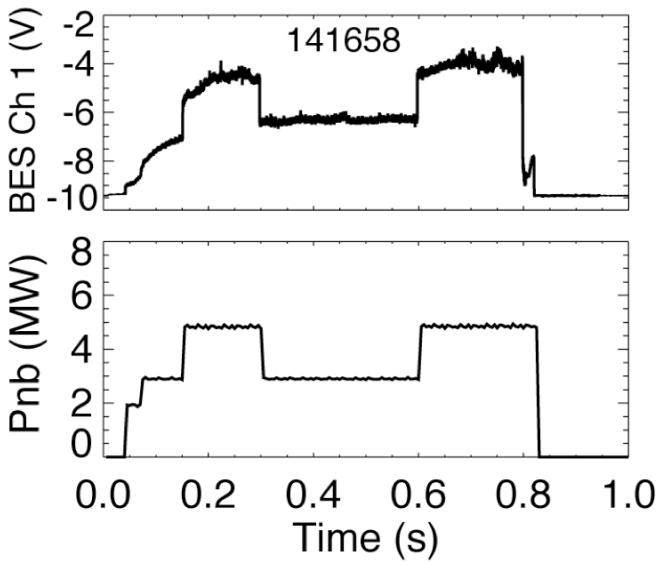




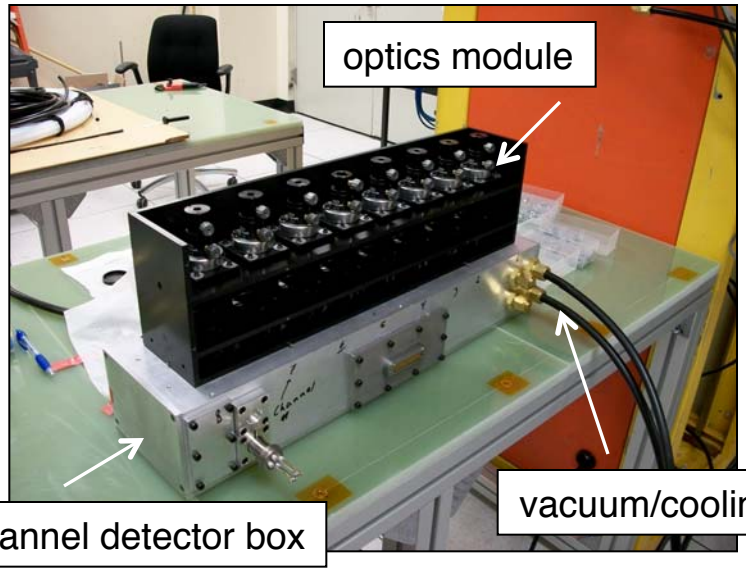
Measured signals exceed e-noise and respond to NB power

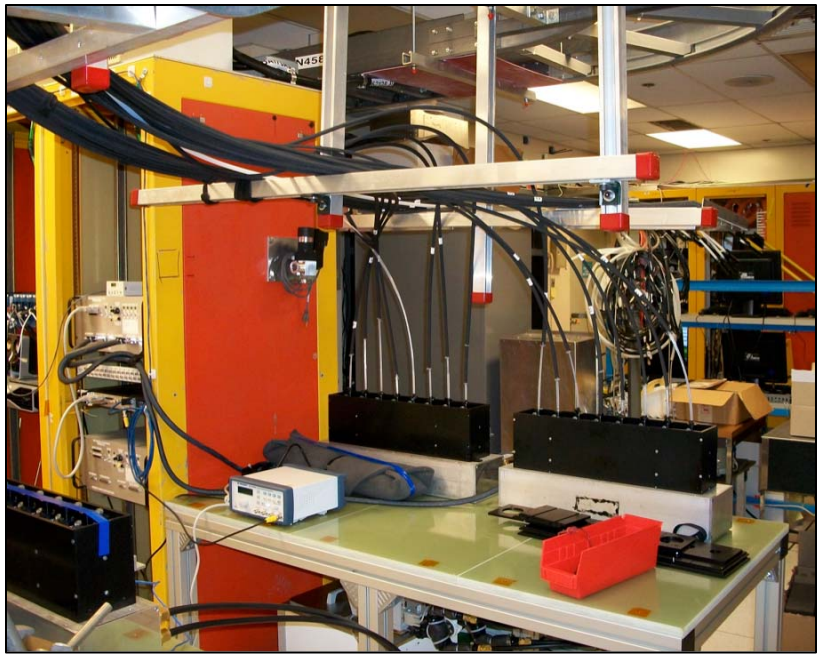
- Optical design
  - Red shift view
  - 2.3 mm^2-ster entendue
  - 4 nm optical filter at 661 nm
- Photodetector
  - Low-capacitance PIN PD and JFET
  - 4.5 mV/nW response
  - Refrigerant cooling at -20° C
  - Evacuated enclosure
- Digitizer
  - 32 MHz input sampling
  - Onboard FPGA provides 950 kHz low-pass FIR filter
  - 2 MHz output sampling
  - 16 bit resolution

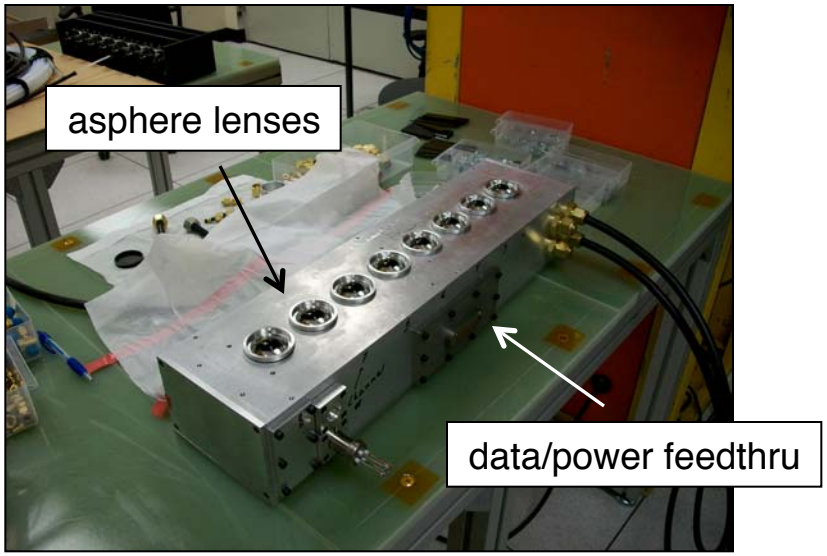


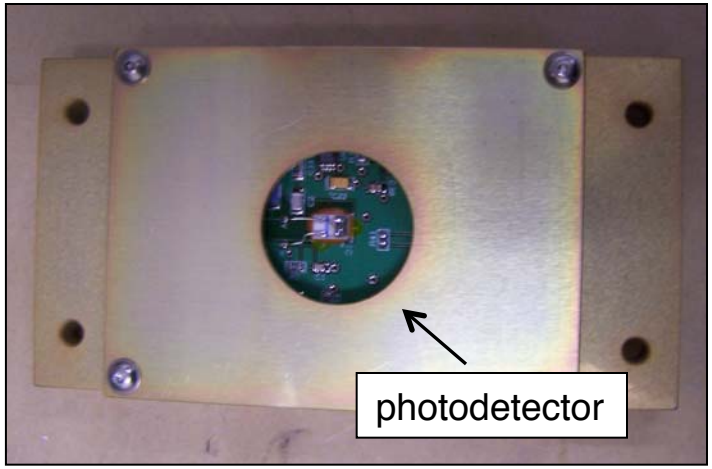


Photodetectors, detector box, and optics module

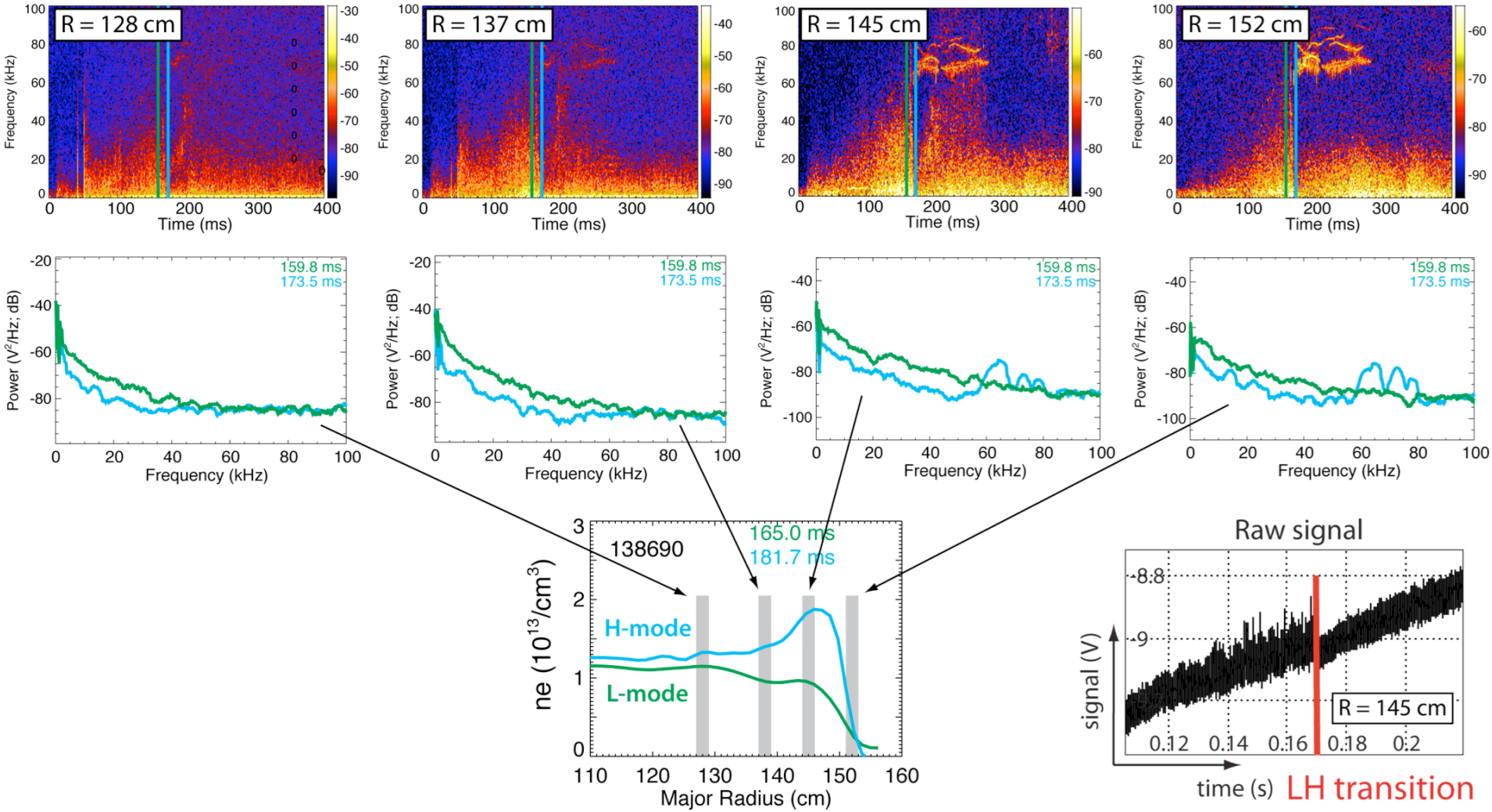








Decrease in fluctuations at LH transition observed from edge to core in some discharges



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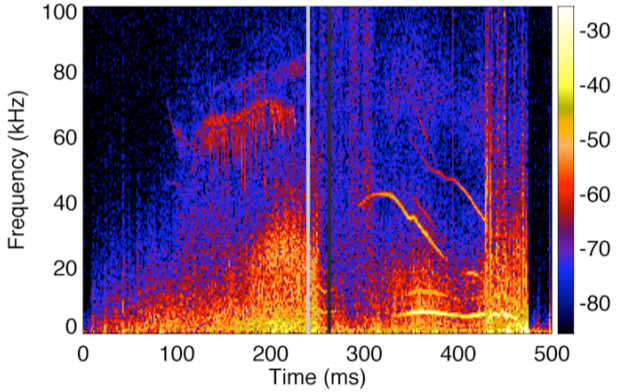
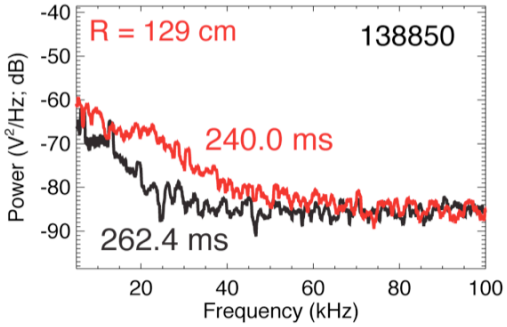
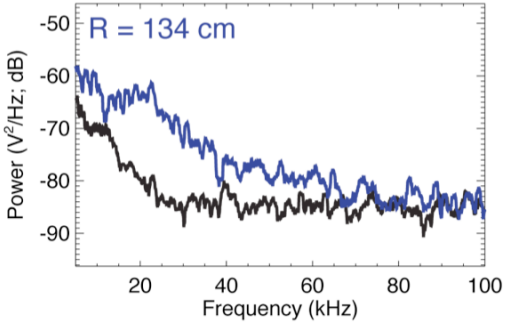
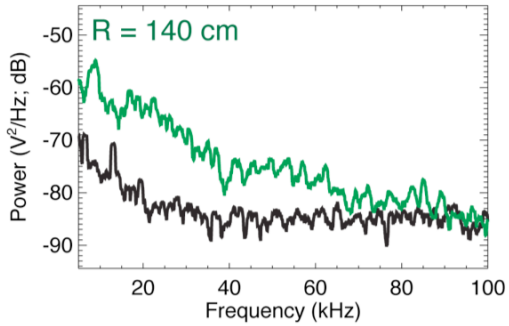
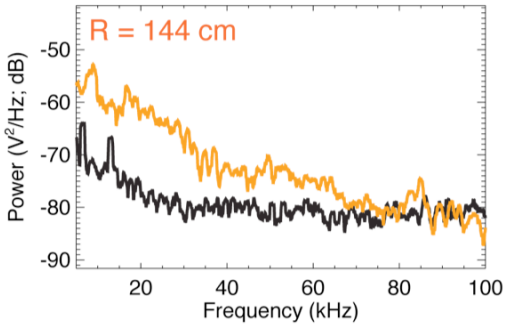
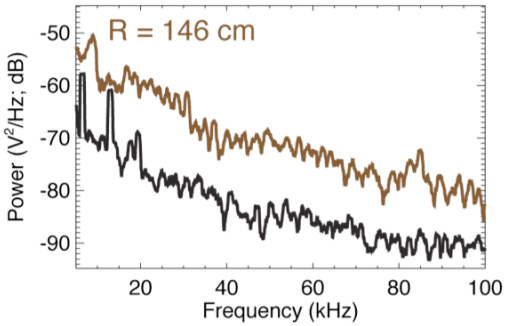


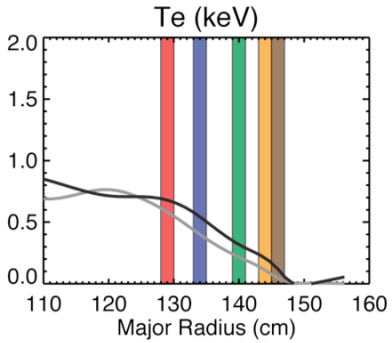


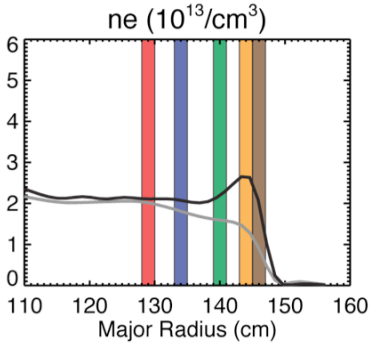


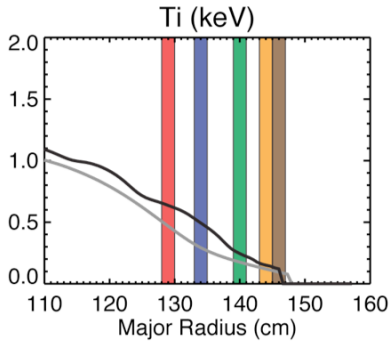


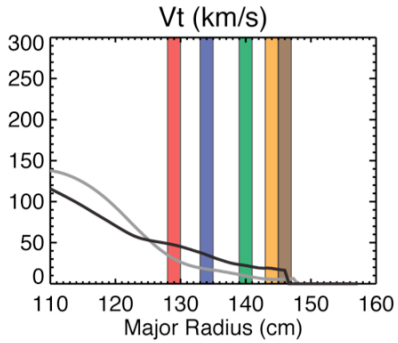








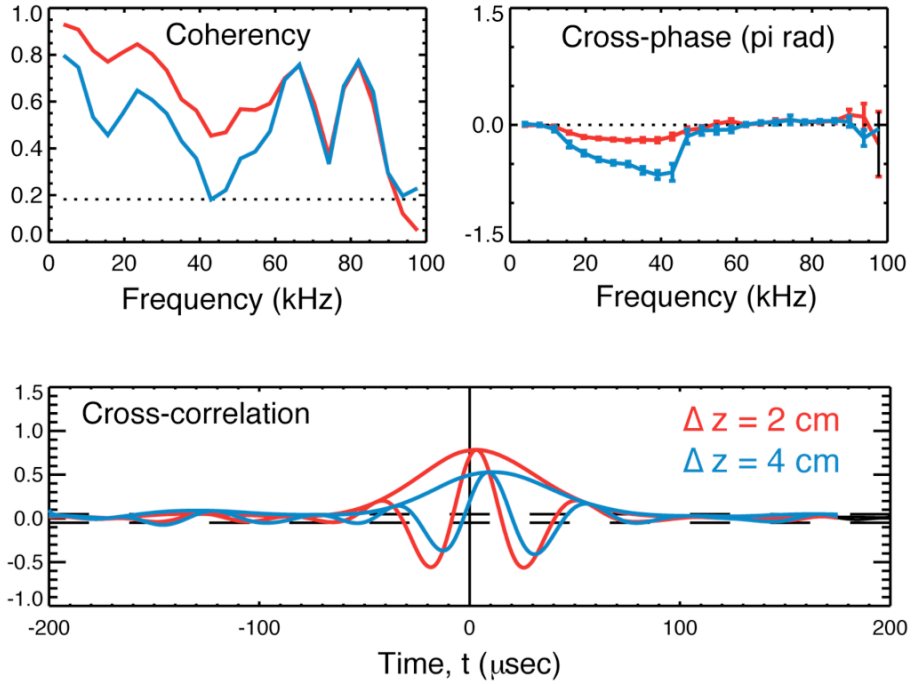




Correlation analysis indicates the apparent motion of eddies changes from up to down at the LH transition

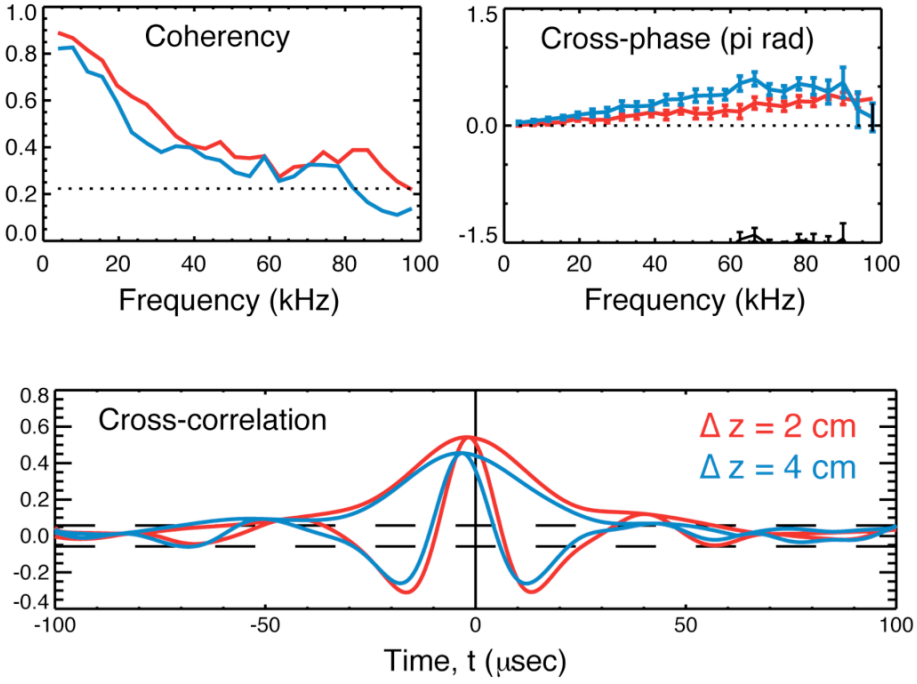
Poloidal coherency/correlation in 138850 at R = 140 cm

L-mode phase: 219-249 ms



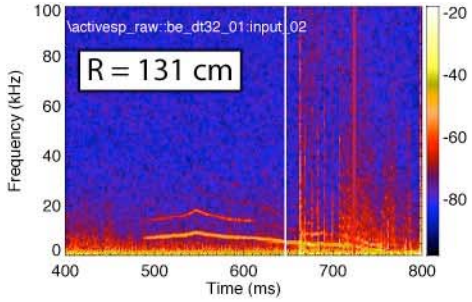
Time lag indicates upward motion
(electron drift direction)

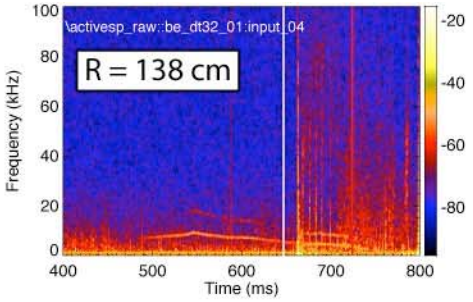
H-mode phase: 266-287 ms

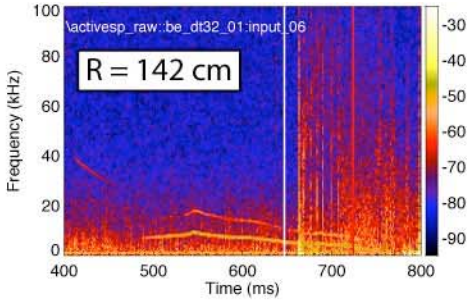


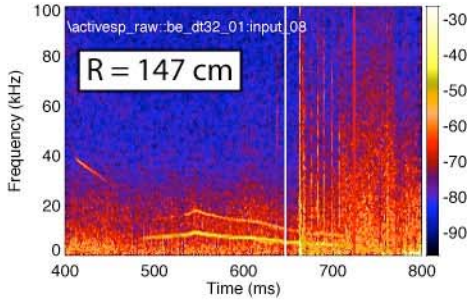
Time lag indicates downward motion
(ion drift direction)
Er increases at LH, so greater ExB
in ion drift direction

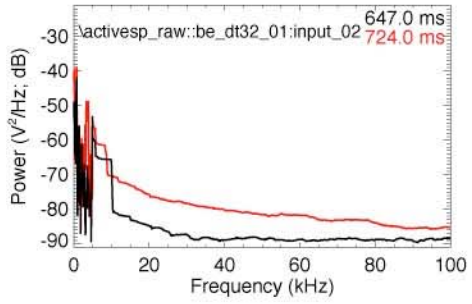
Fluctuations increase following HL back-transition

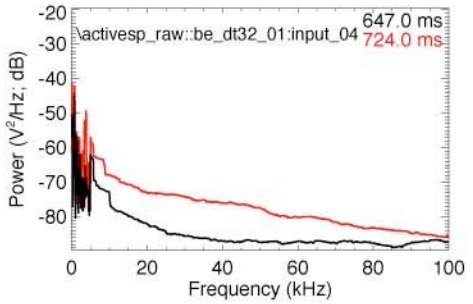


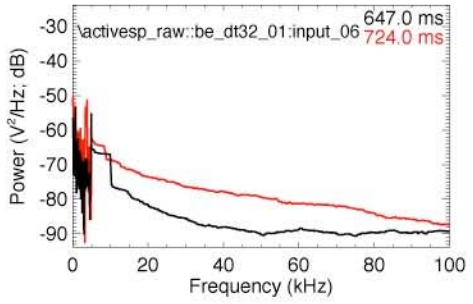


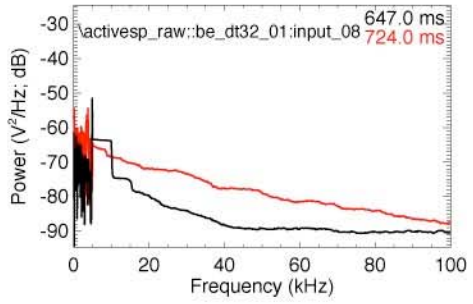


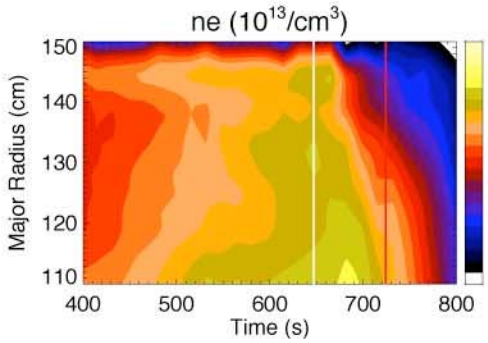


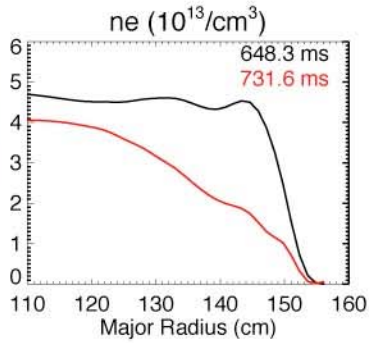


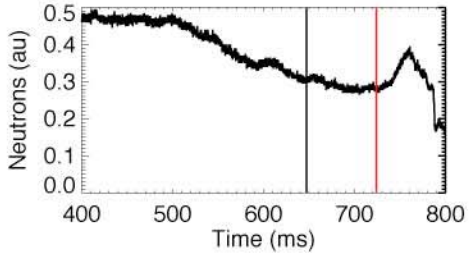


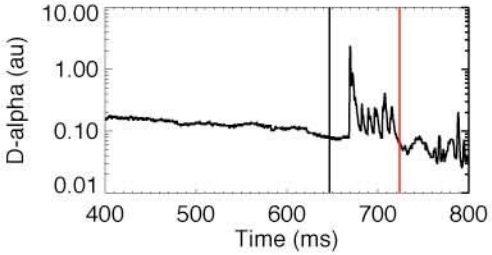








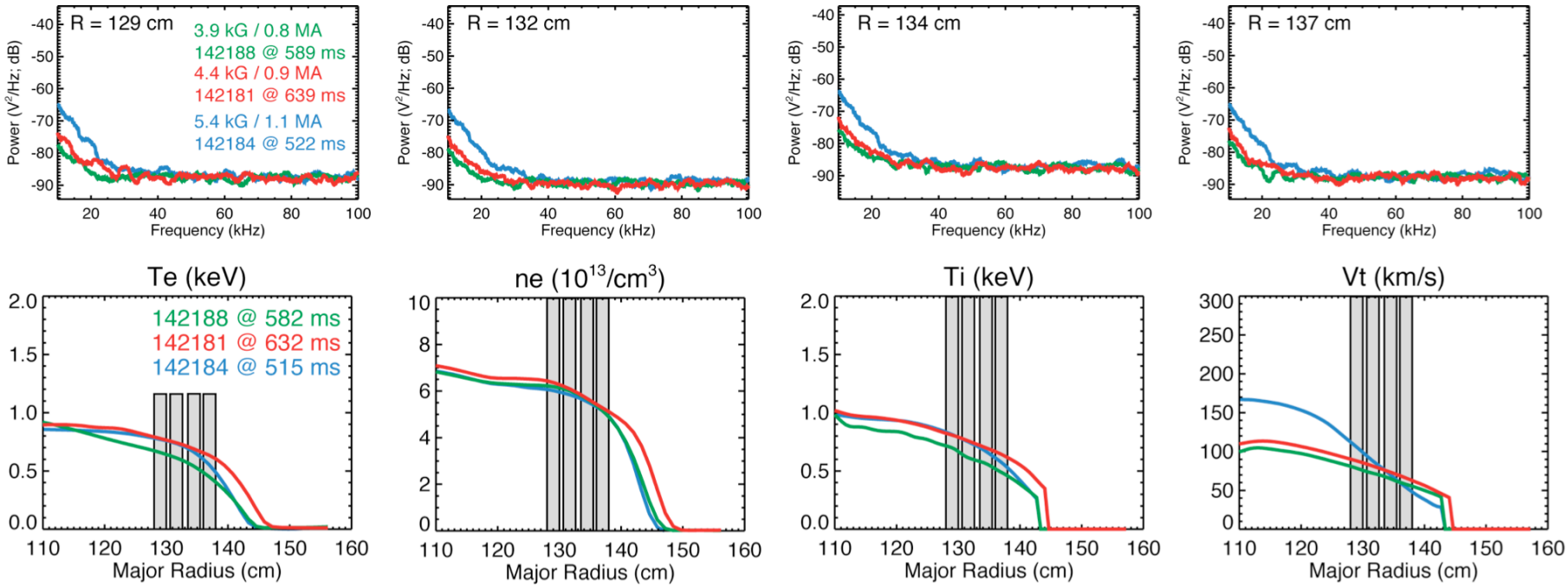




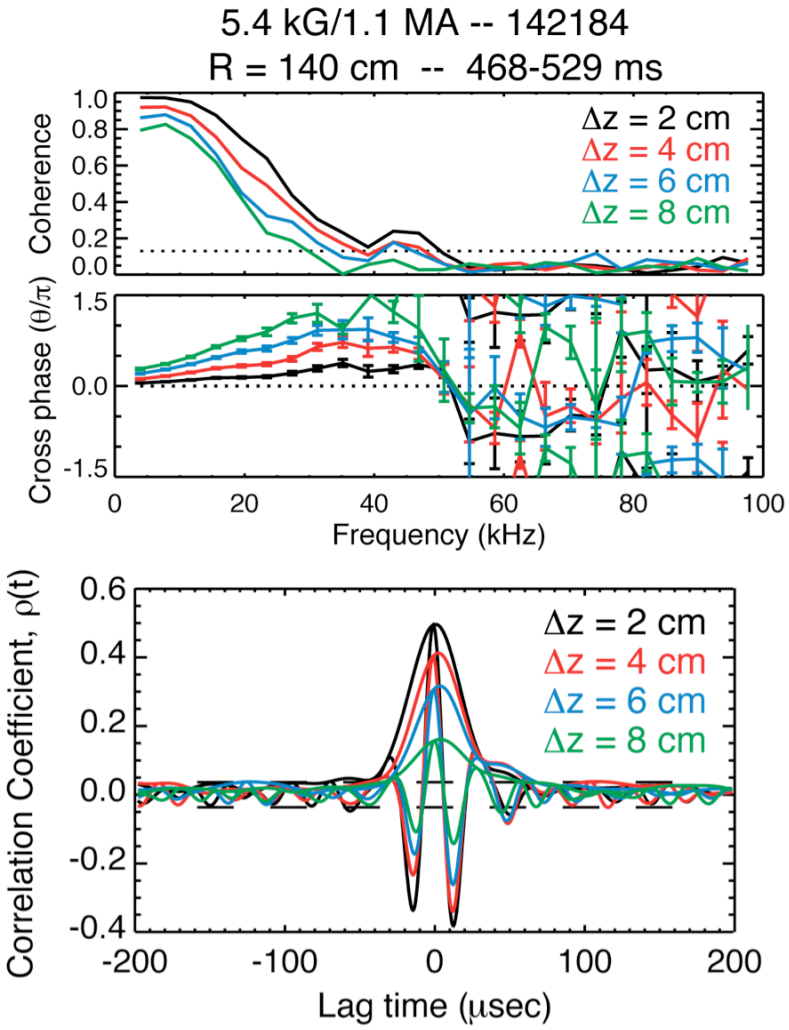
138690 XMP70 Smith

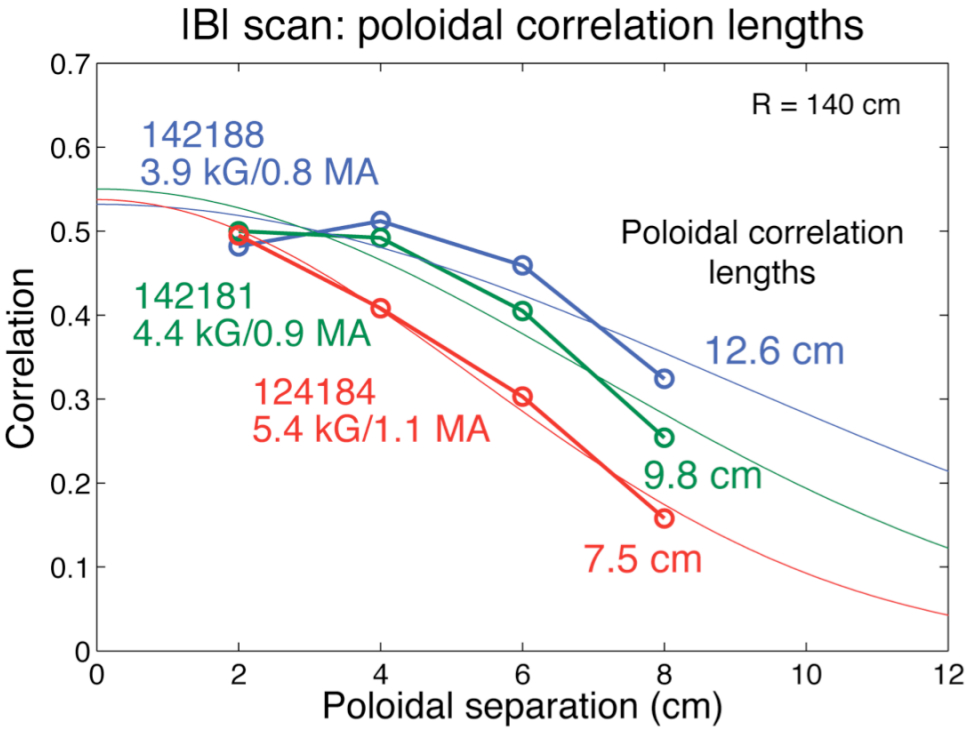
|B| scan: BES auto-power spectra do not show a clear trend

NSTX confinement scaling (Kaye et al, NF (2007)): $\tau_e \sim B_T \sqrt{I_P}$



|B| scan: Cross-correlation analysis indicates poloidal correlation lengths decrease at higher |B|

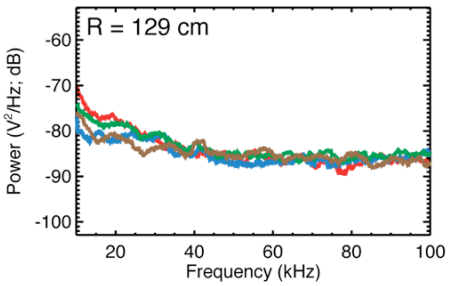


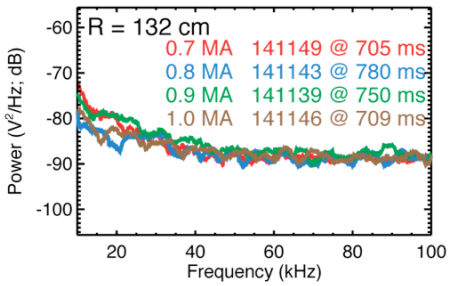


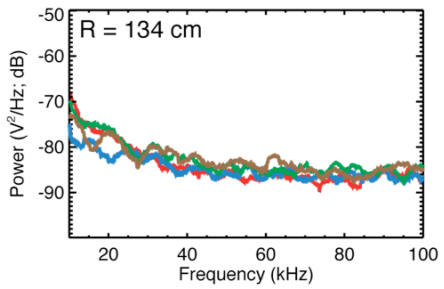
Intuitively consistent with NSTX scaling:

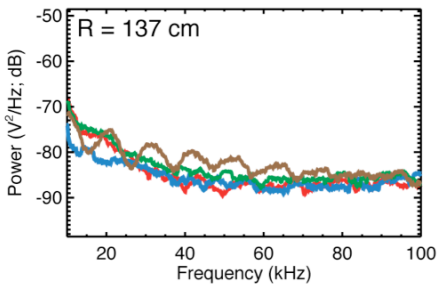
$$\tau_e \sim B_T \sqrt{I_P}$$

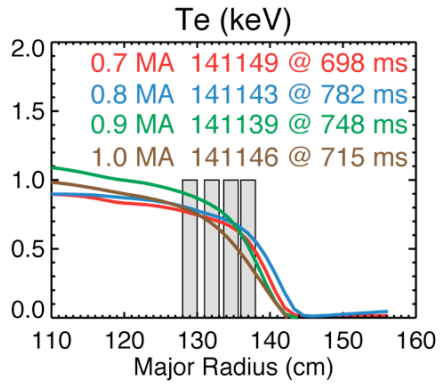
Ip scan: Auto-power spectra do not show a clear trend

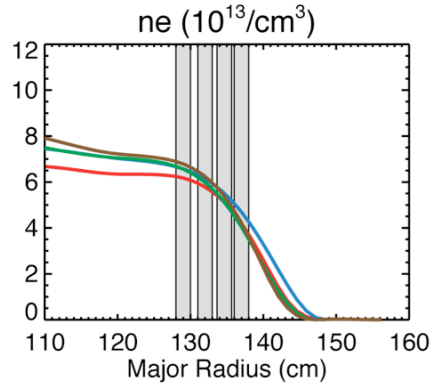


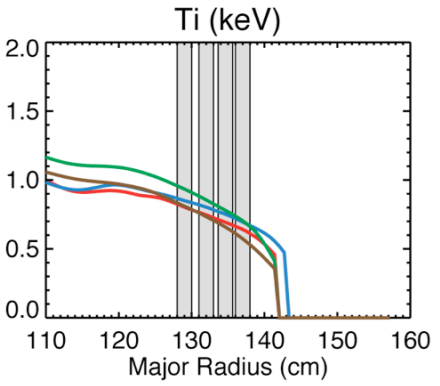


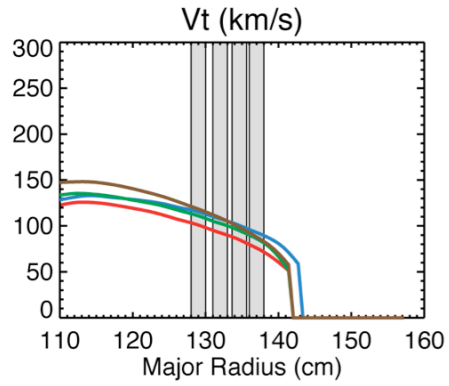




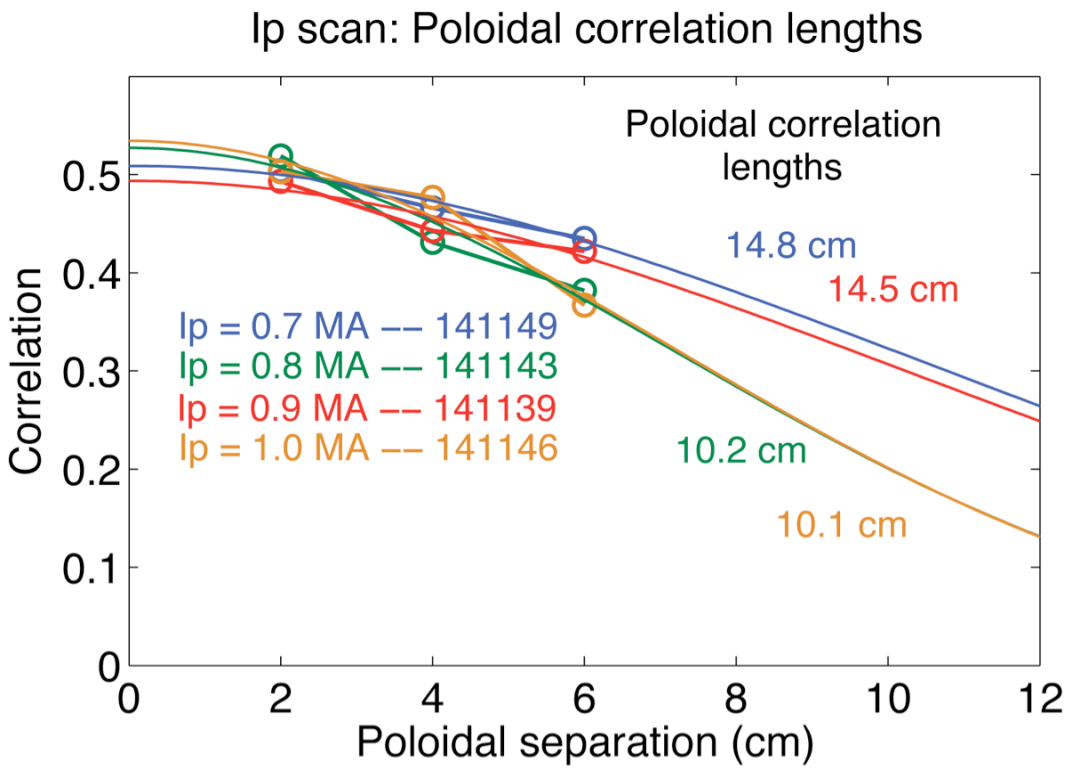




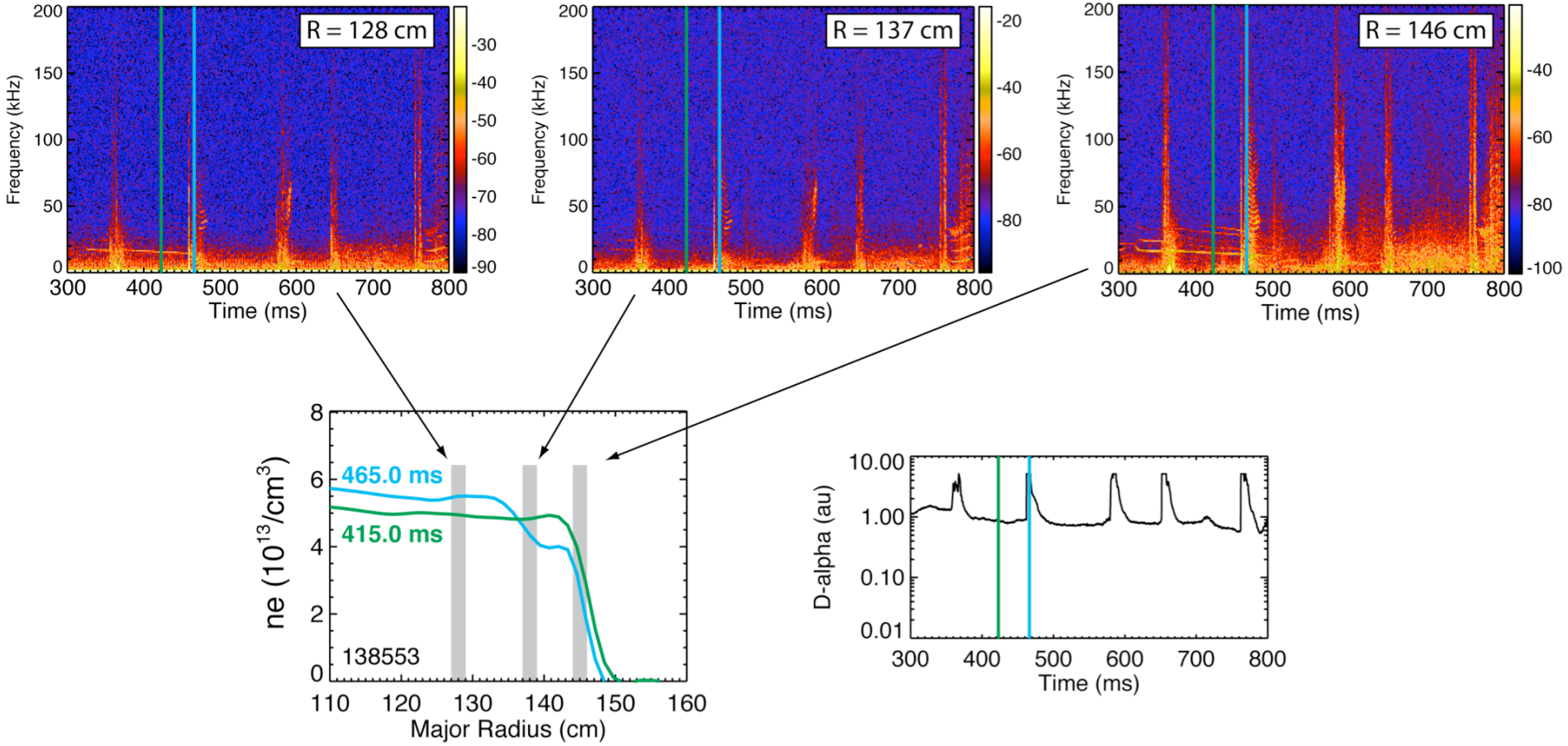




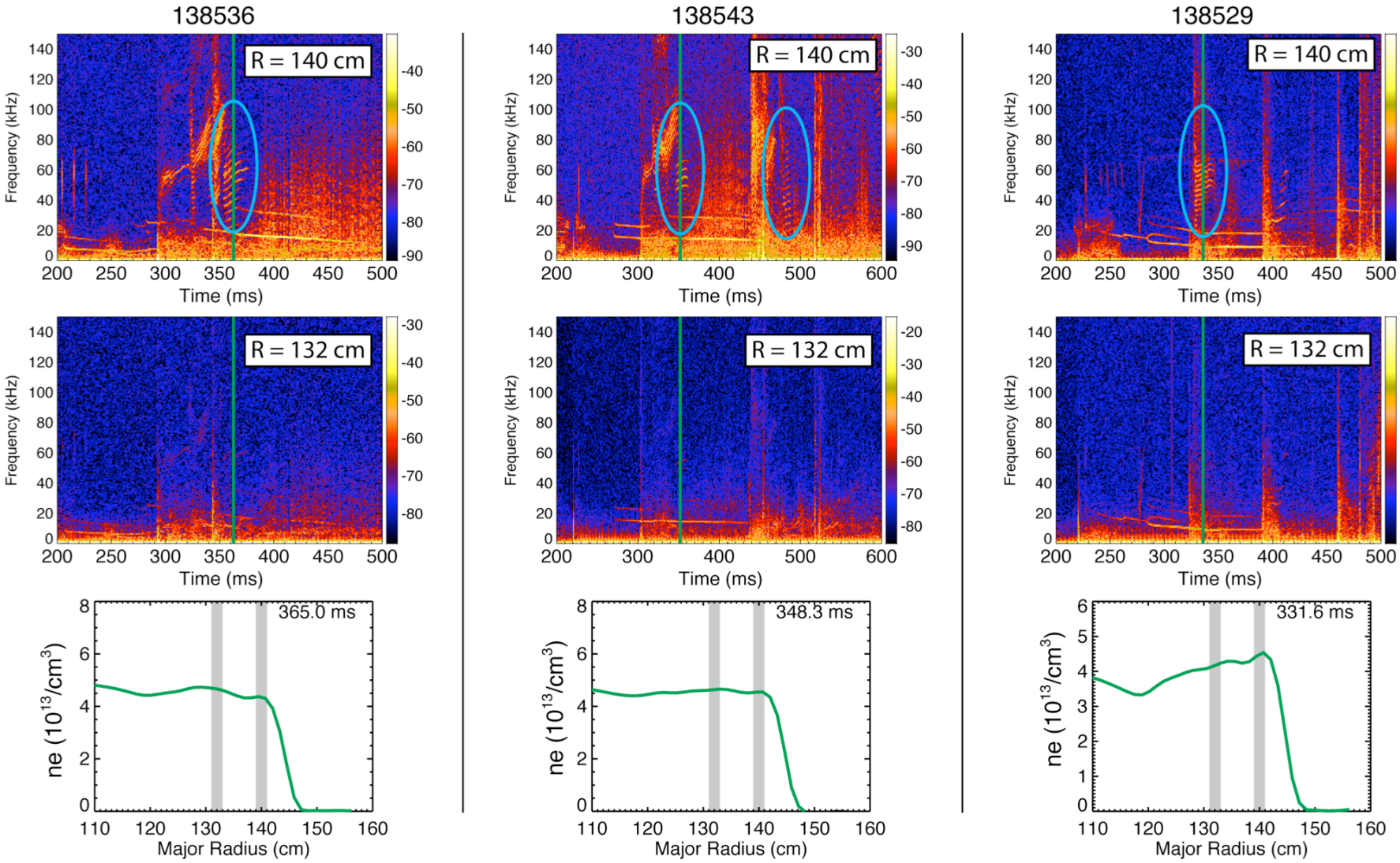
Ip scan: Poloidal correlation lengths do not show a clear trend



Fluctuations increase during large ELM events



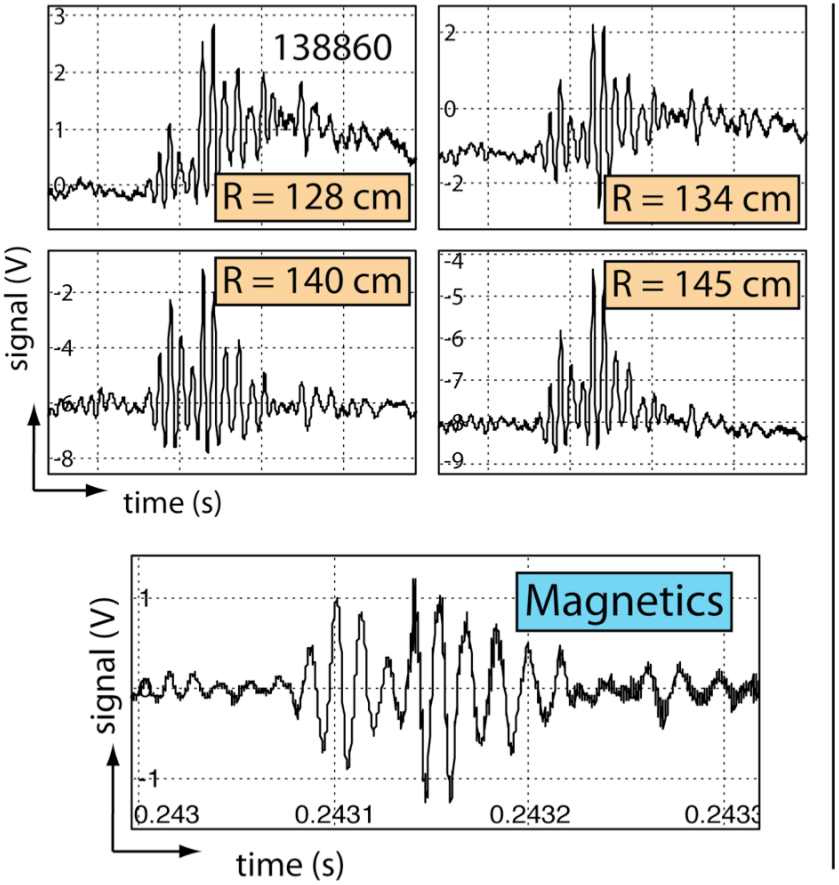
Post-ELM harmonic features at 50-100 kHz are localized at the top of the pedestal



Harmonic features are either absent from or weakly present in magnetic spectra

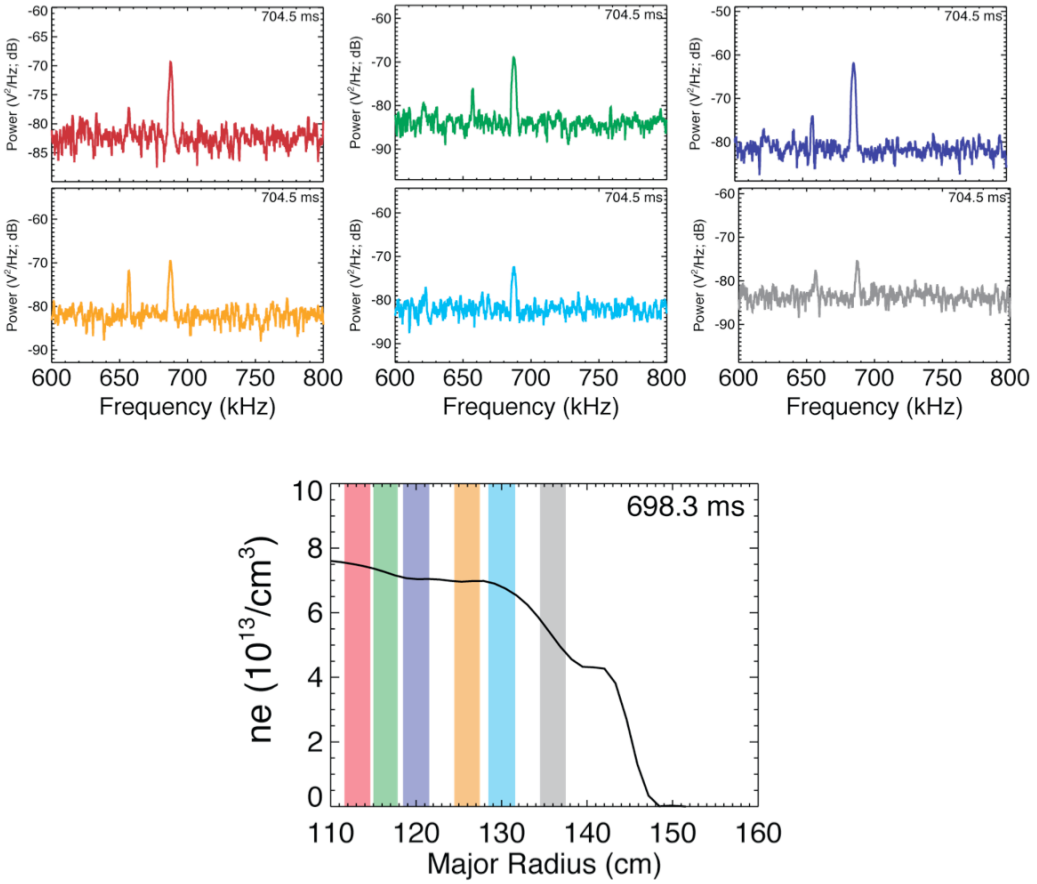
TAEs and GAEs have been observed in extended radial regions

TAE burst



Heidbrink, CO4

GAE mode



Tritz, PI2

Summary