NSTX

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The NSTX BES System for Measuring Small-Scale Density Fluctuations

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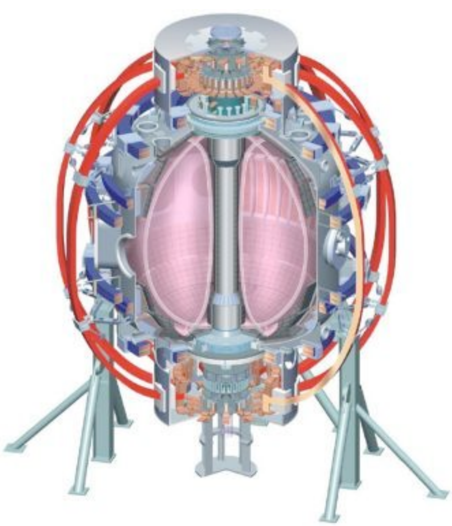

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Abstract

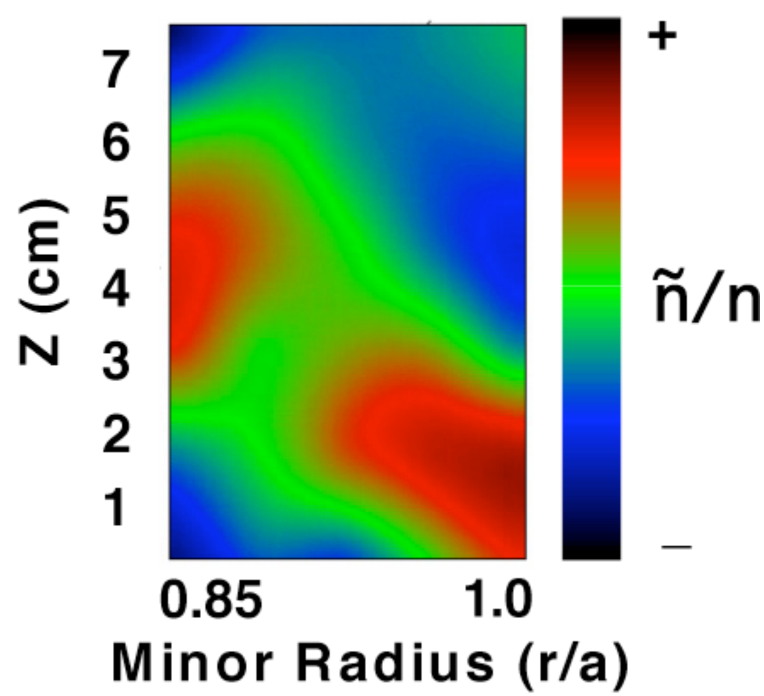
A new Beam Emission Spectroscopy (BES) diagnostic has been deployed at the NSTX. It exploits new detectors and optical systems adapted to the large pitch angles on the spherical torus. The detectors consist of surface-mount, wide-area photoconductive photodiodes and a new frequency-compensated broadband preamplifier to achieve photon-noise limited measurements. Advantages of the new system include an increased effective bandwidth of 1 MHz and elimination of the need for cryogenic cooling. First measurements have been obtained using 16 channels, with plans to expand to 32 in the near future. These measurements show coherent and broadband plasma turbulence in high gradient regions, and coherent modes that mainly correlate with Alfvén energetic particle modes. To support these BES experiments at NSTX and similar ones at DIII-D, Langmuir probe measurements in Pegasus ST plasmas are being evaluated for validation of velocimetry techniques using 2D BES ñ measurements.

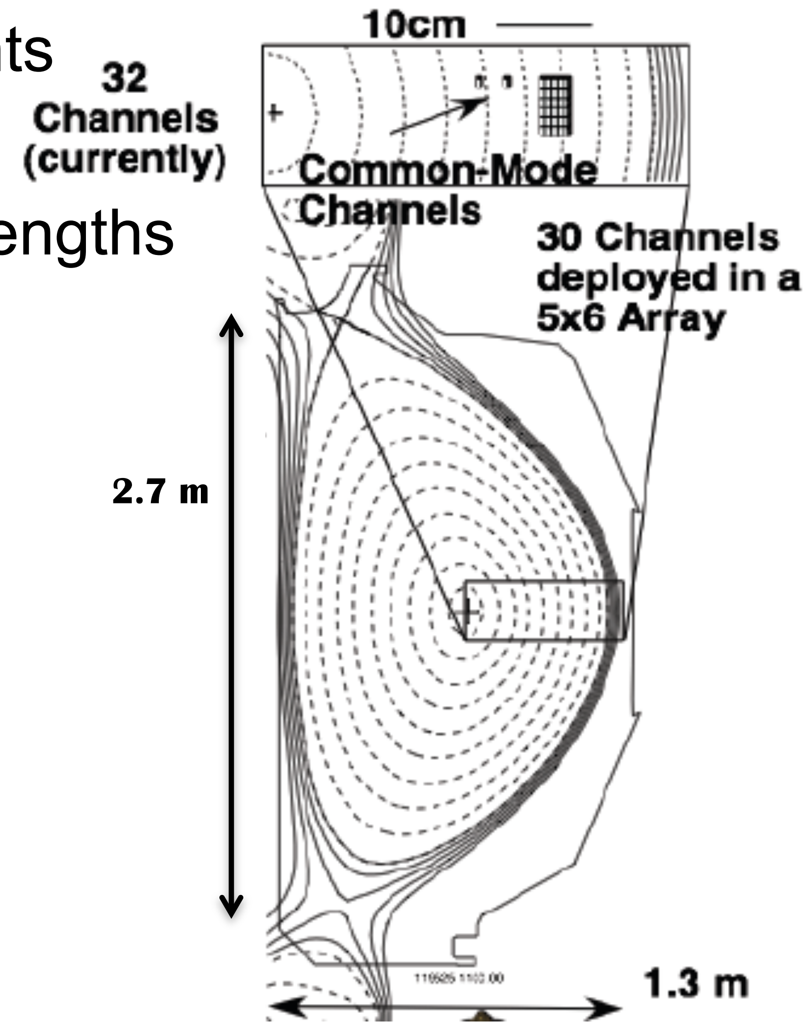
Outline

- BES motivation and background
- Newly deployed BES diagnostic at the NSTX
- NSTX BES preliminary results
- Supporting work on the Pegasus Tokamak
- Pegasus Langmuir probe experimental setup
- Pegasus turbulence measurements
- BES measurement summary and future work
- Acknowledgements

Fluctuation measurements via BES already established at DIII-D and TFTR

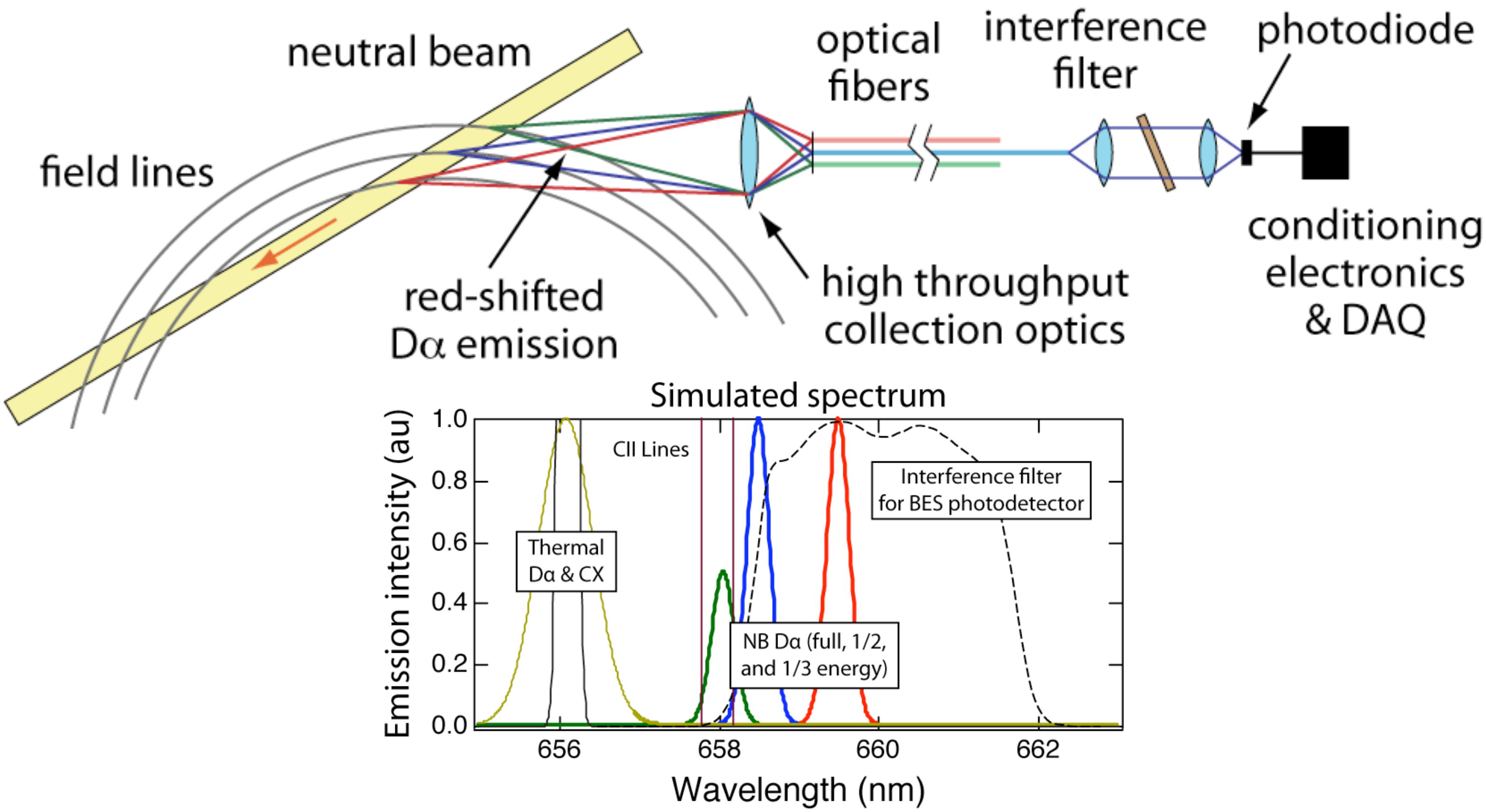
- Density fluctuation measurements
- Turbulence and transport
- Radial and poloidal correlation lengths
- 2D fluctuation imaging



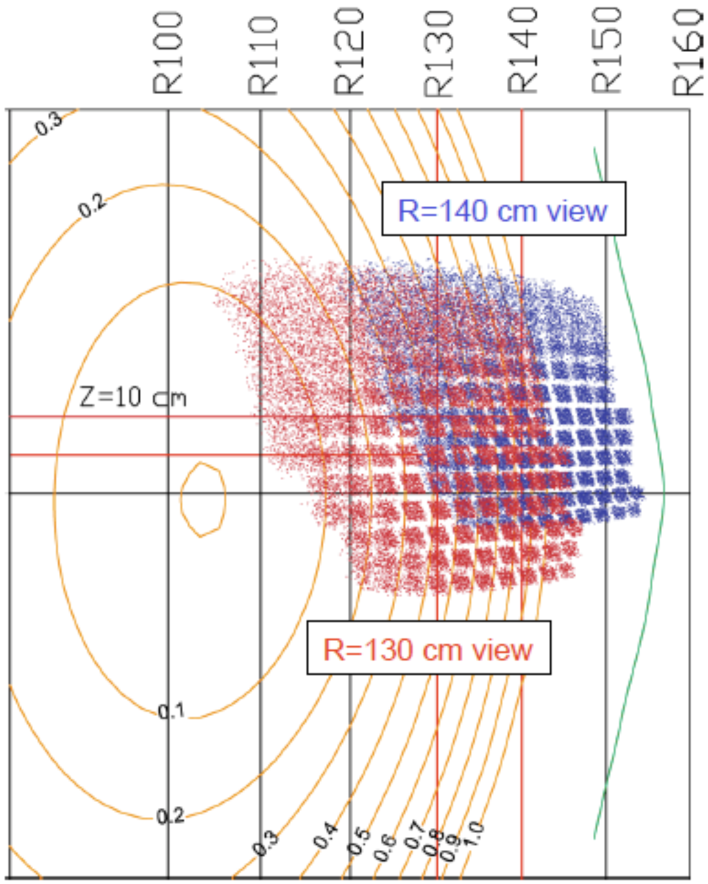


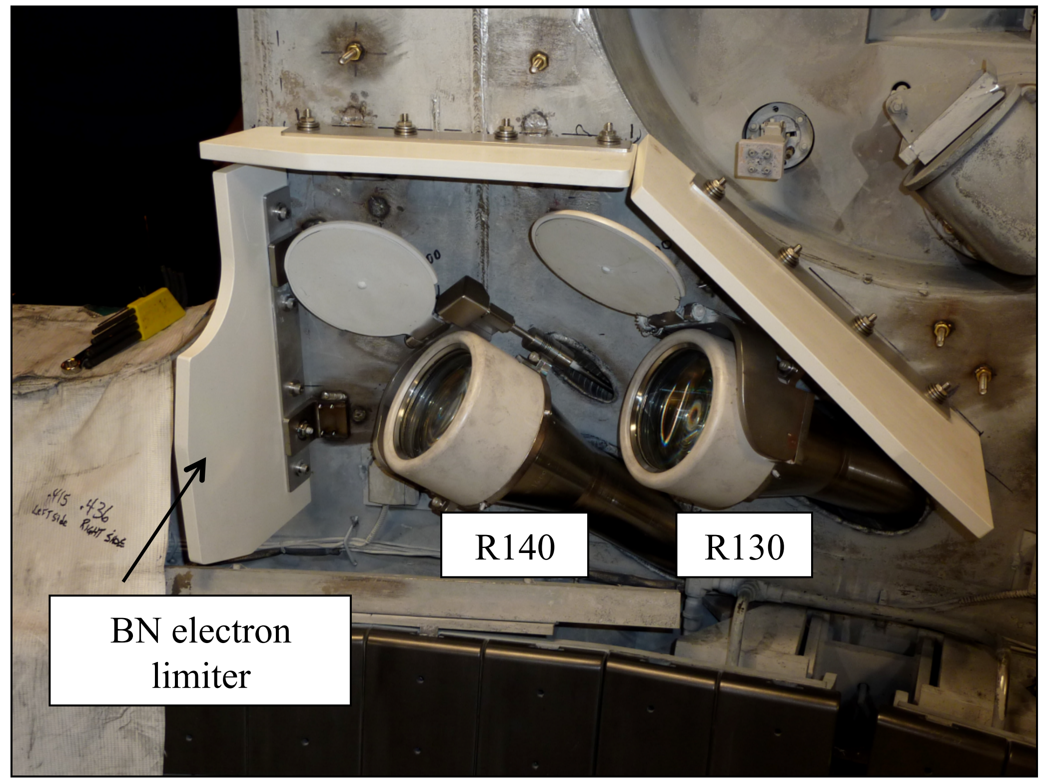
BES Measurement Technique at the NSTX

- Detects Doppler shift of D_α light
- NBI required to generate localized fluorescence
- Collection optics focus signal on preamplifier photodiodes



NSTX BES Plasma Imaging Optics Measure Fluctuations Across the Plasma Radius

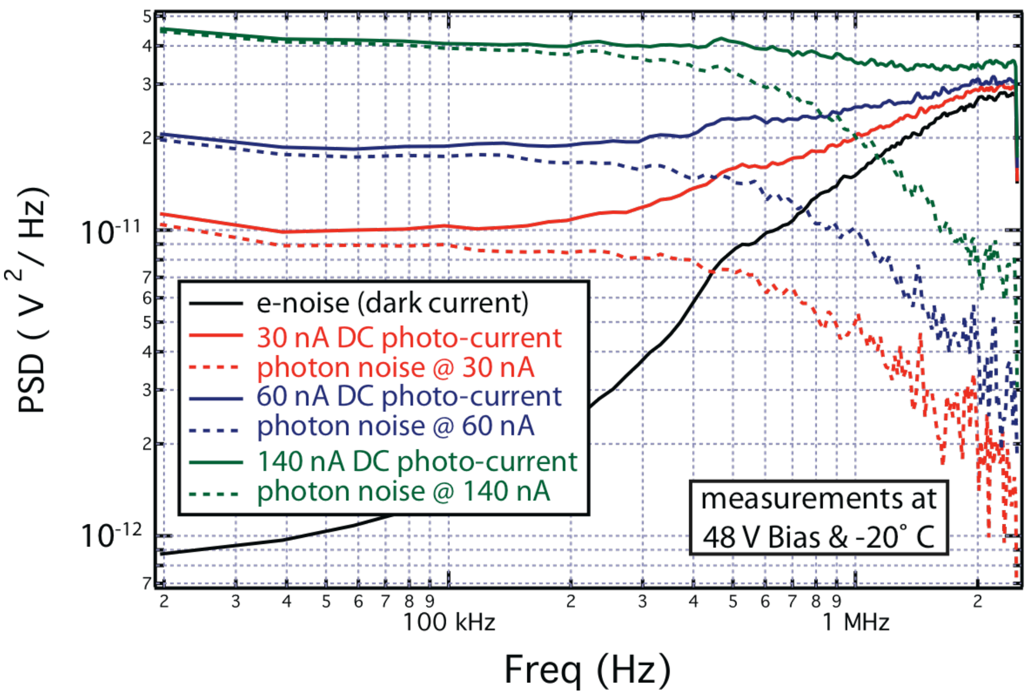




Each pixel represents a location that is imaged via a fiber optic cable. 24 detectors are currently available to read the signal from the cable (in 2011 this will be expanded to 32 detectors)

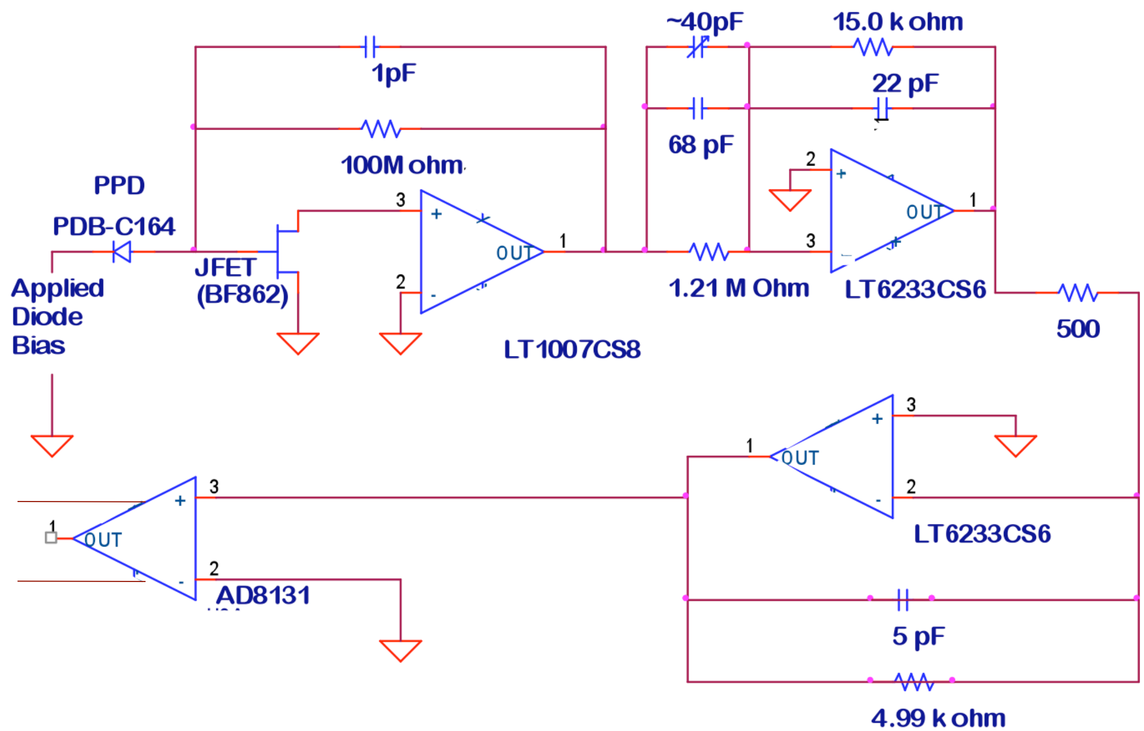
NSTX System Includes New Detectors with Increased Bandwidth

- New detectors exhibit reduced stray capacitance and overall improve signal to noise ratio.
- Detector boards are cooled to -20C to optimize FET performance, with photodiodes biased to -48V to further decrease noise.
- Photon noise dominates the spectrum at low frequencies, allowing measurements into the MHz range



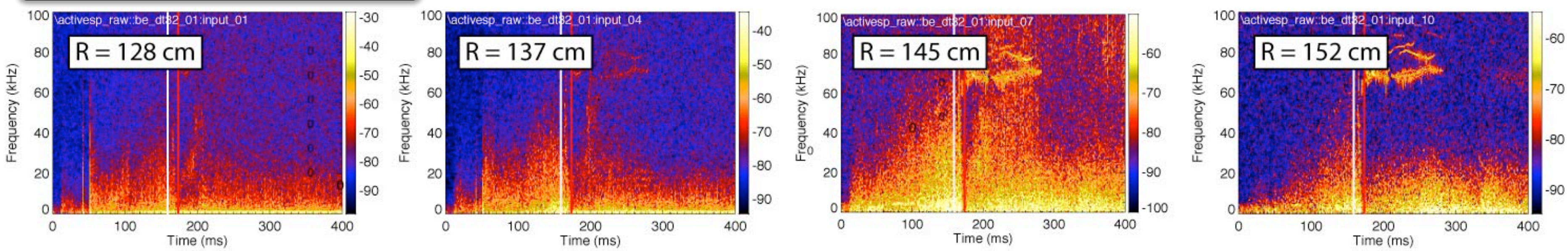
Detectors Designed with Low Capacitance FET and Frequency Compensation Stage

- New detectors operate at -20 C, eliminating the cryogenic cooling used on the previous generation system.
- Low-noise, low-capacitance surface-mount components
  - Photoconducting Photodiode
  - FET

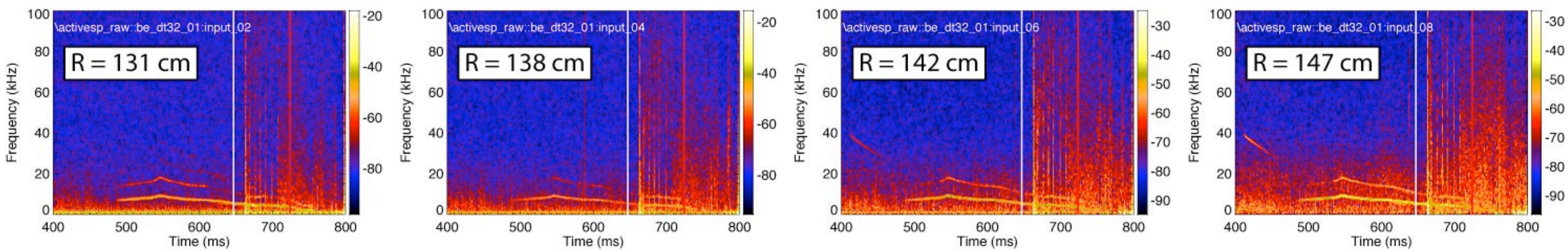


Fluctuation Amplitudes and Frequency Components Depend on Confinement Mode

•*At the L-H transition*



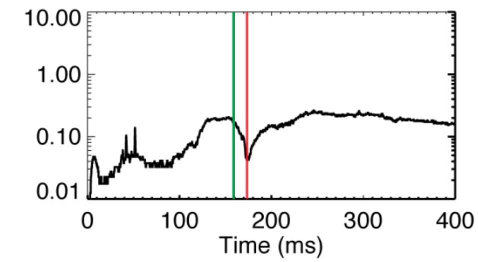
•*At the H-L transition*

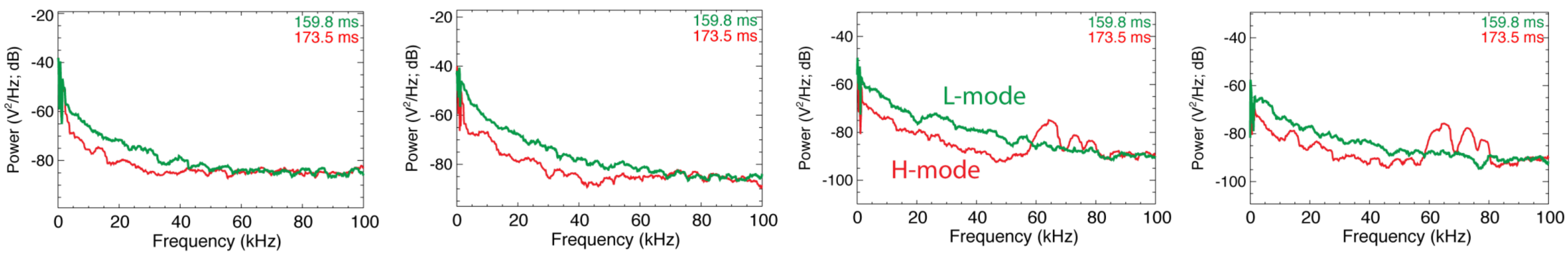


- Fluctuation amplitude decrease for the LH transition around 165 ms
- Following HL transitions, around 680 ms, more high frequency fluctuations appear and have higher signal power

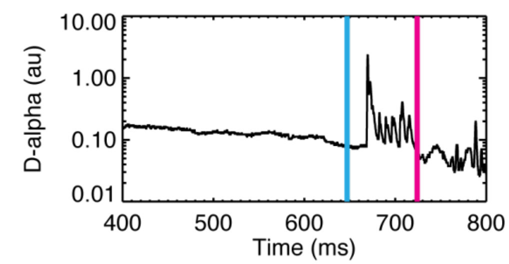
H-mode Confinement has Smaller Amplitude Fluctuations

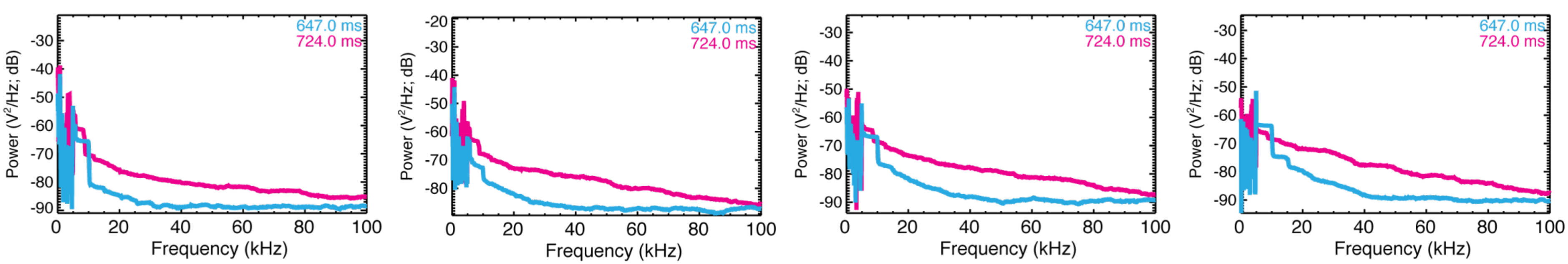
- LH transition reduces amplitude fluctuations:





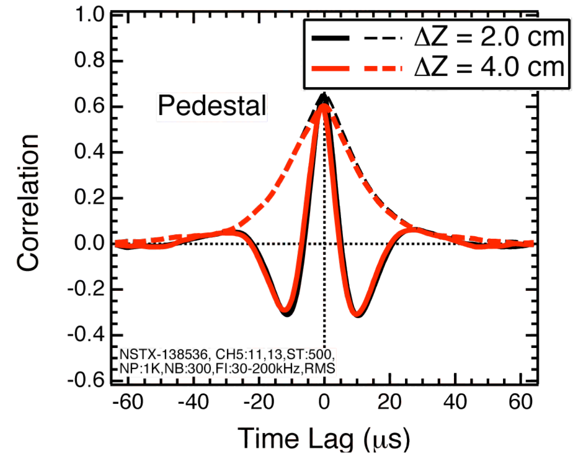
- HL back transitions increases amplitude fluctuations:

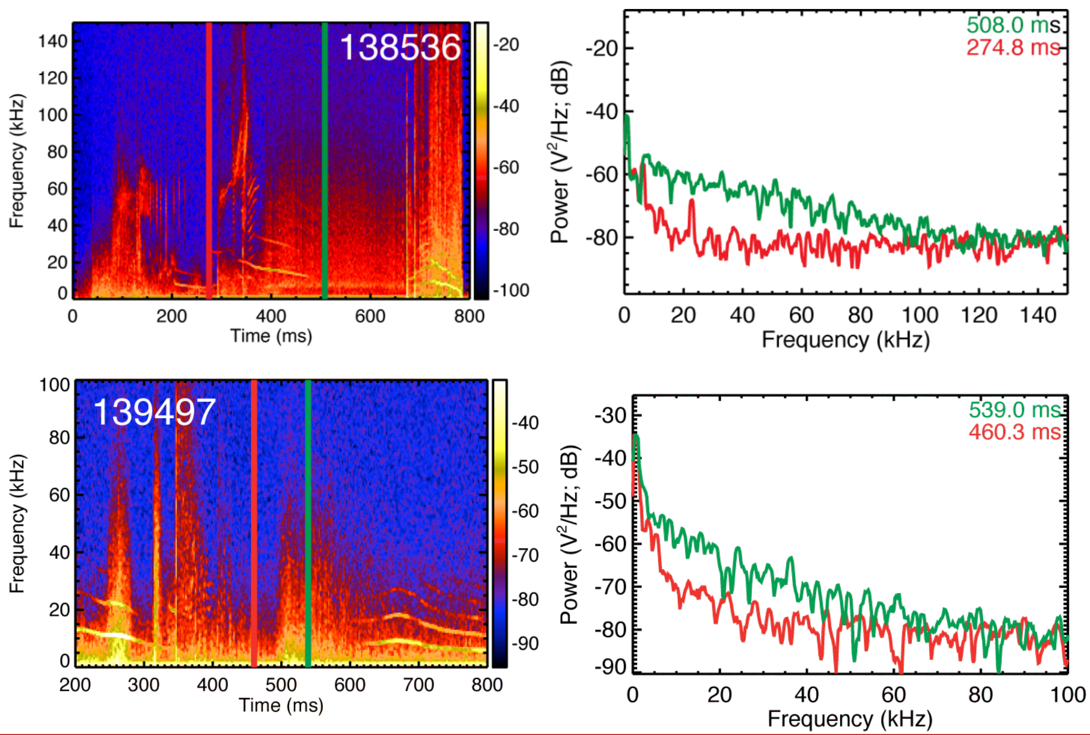


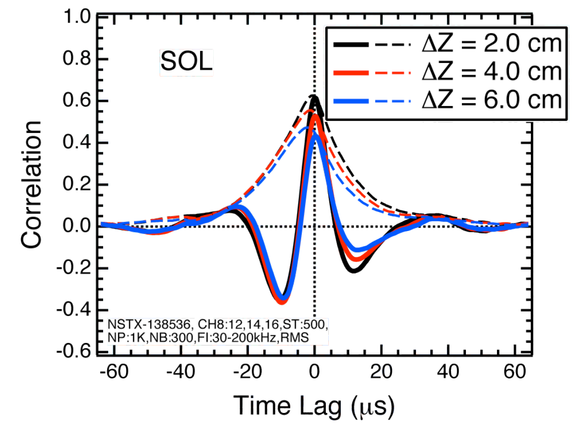


Broadband Fluctuations are Present in NSTX

- BES measurements on the NSTX show coherent and broadband plasma turbulence in high gradient regions
- These fluctuations will be examined for their role in anomalous transport

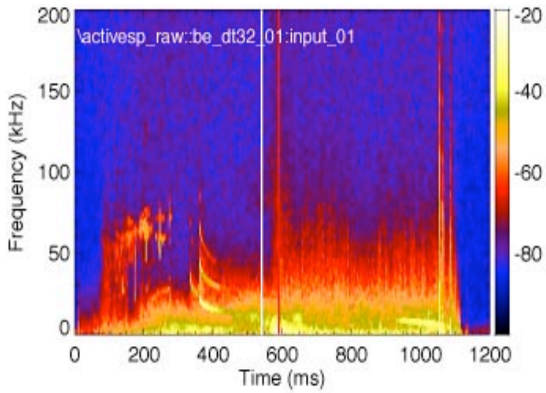


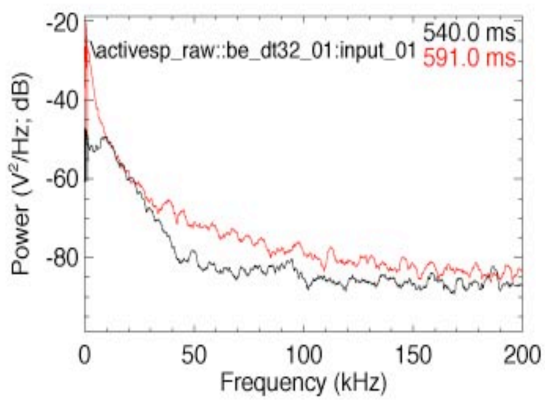




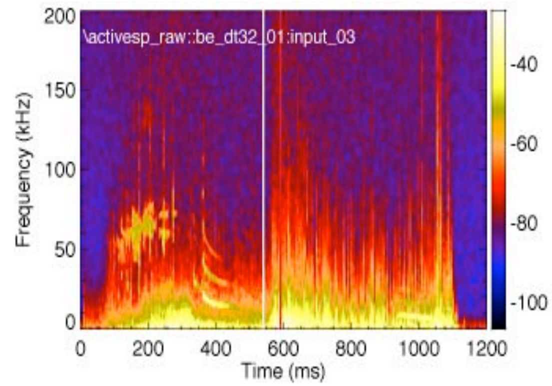
Fluctuation Amplitudes Increase when Rotation Slows

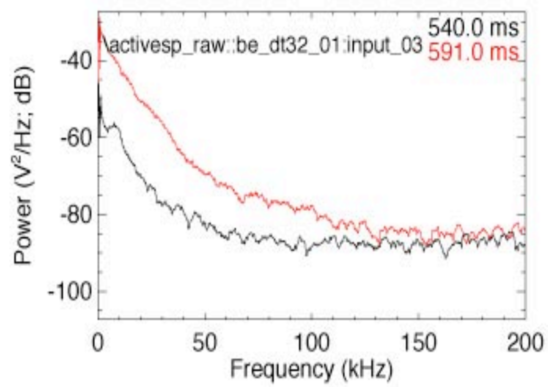
R = 128 cm

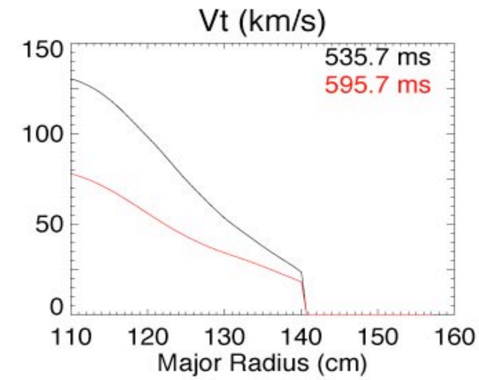


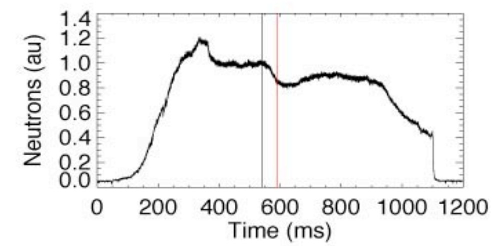


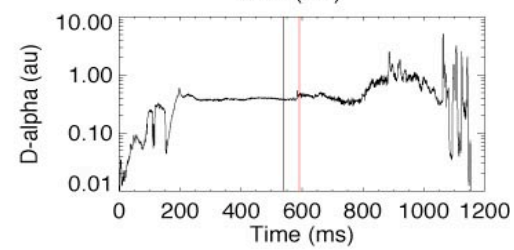
R = 134 cm



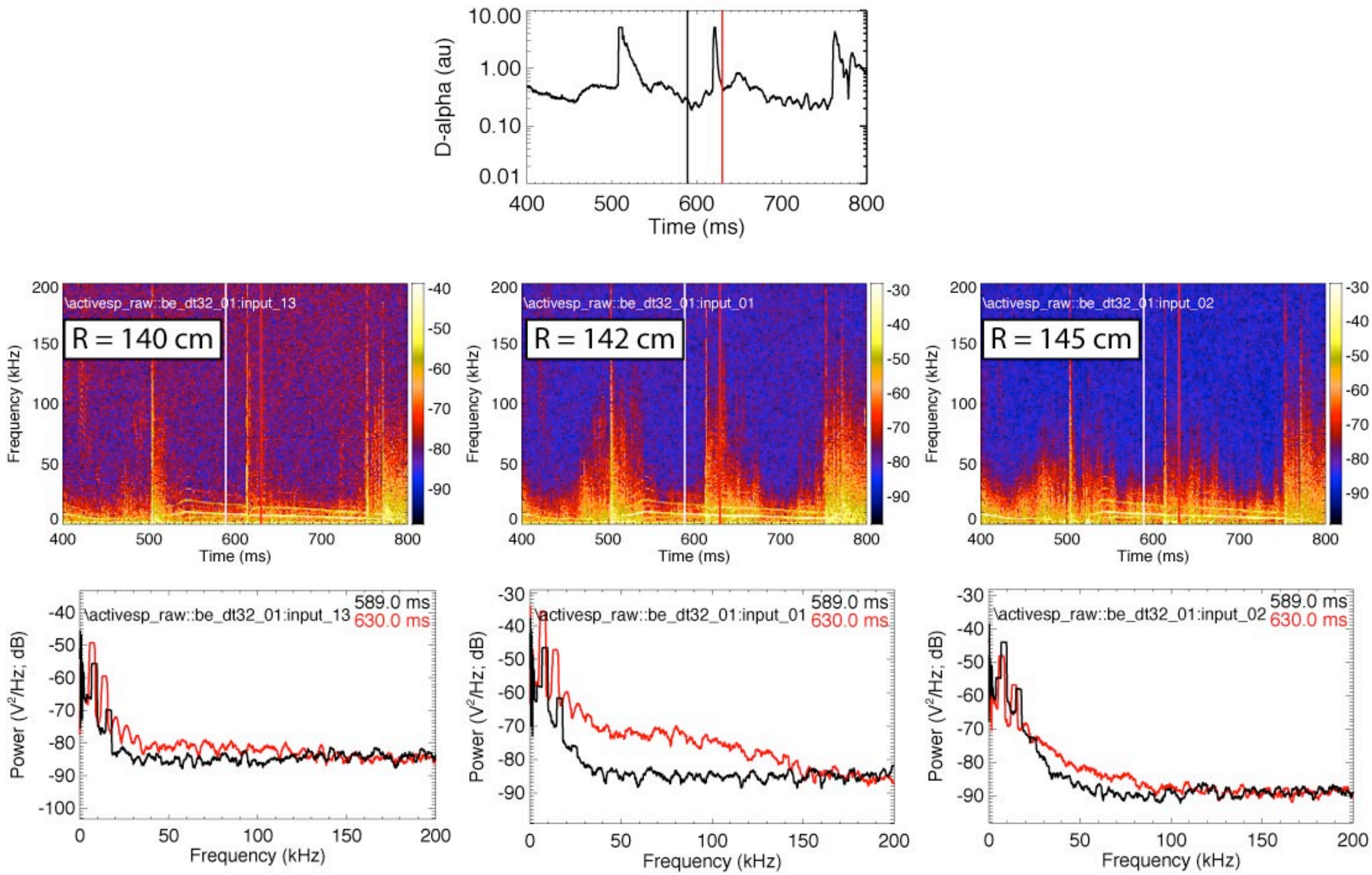




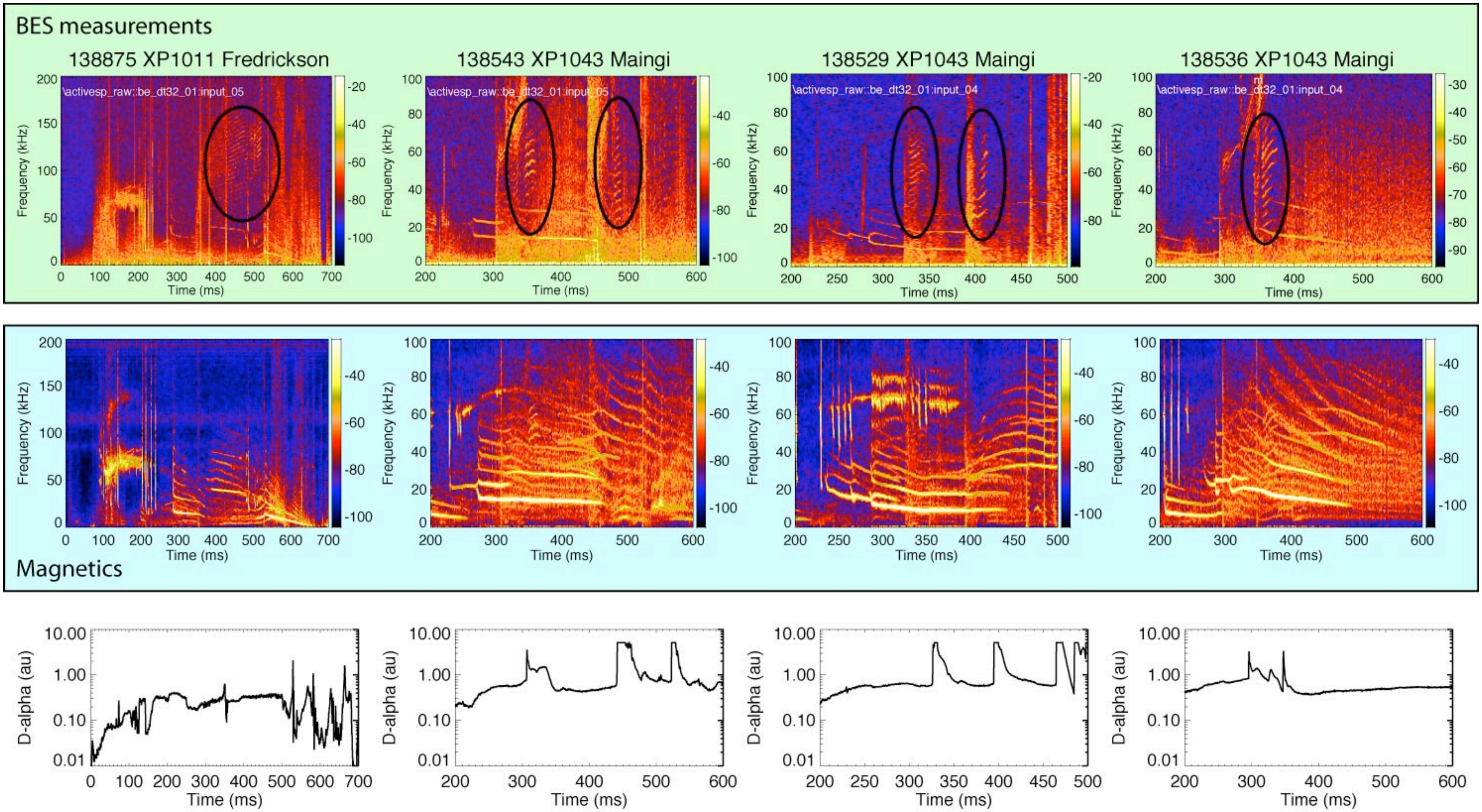




Fluctuations Increase Following ELMs

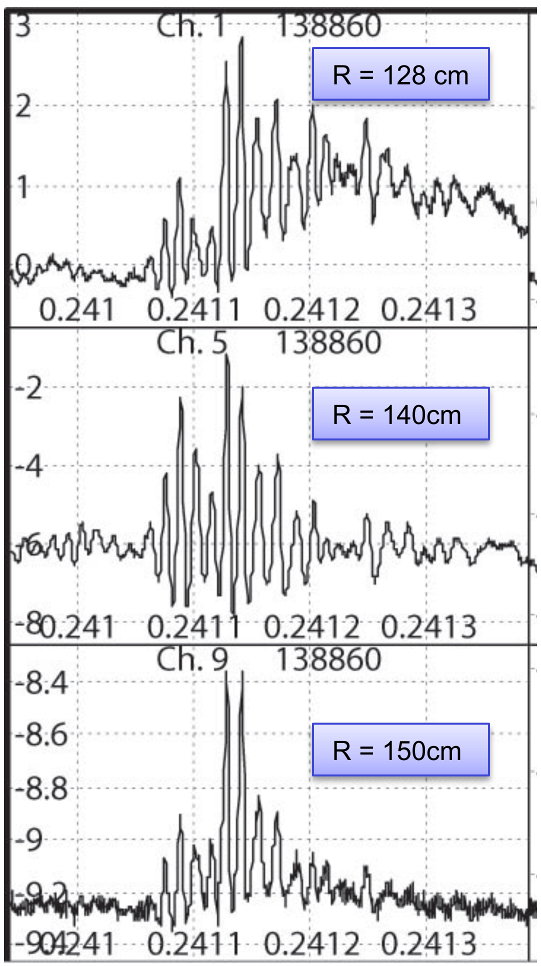


Harmonic Features up to 150 kHz after ELMs

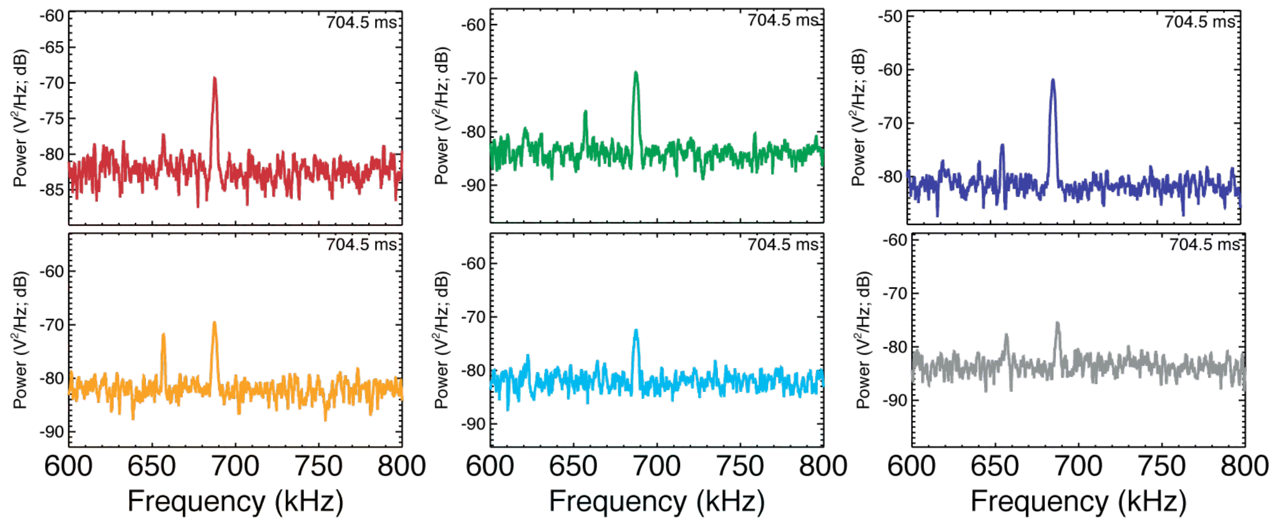


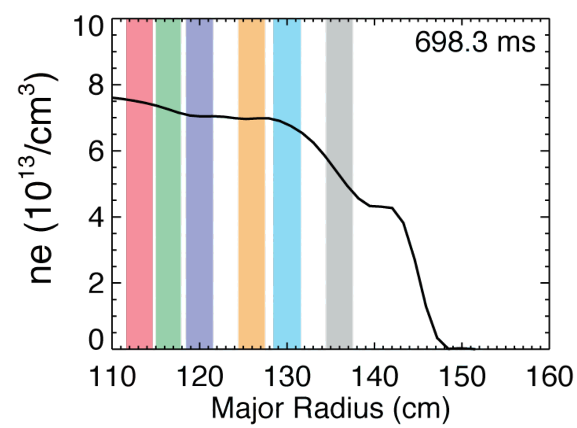
Toroidal and Global Alfvén Eigenmodes are Visible on NSTX BES Detector System

TAE bust



GAE bust



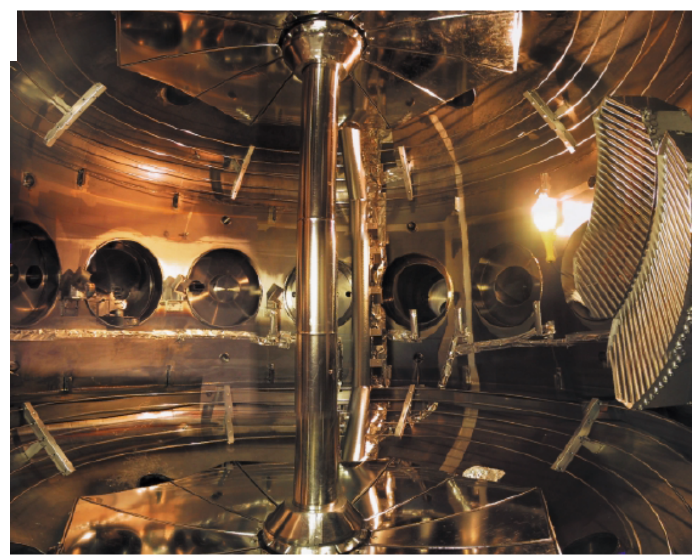


Supporting Work on the Pegasus Tokamak for Velocimetry Validation

- Evaluate and validate 2D velocimetry methods to extract the time-dependent turbulence flow field from measurements of the 2D ñ field.
  - Pegasus ST plasmas are a unique environment where it is possible to detect fluctuations in the plasma interior via electric probes : highly shaped tokamak plasmas ($I_p \sim 0.1 - 0.2$ MA) at reasonable collisionality, with a short pulse length (~20 msec) allowing measurements of the plasma parameters with Langmuir probes within the closed flux surface

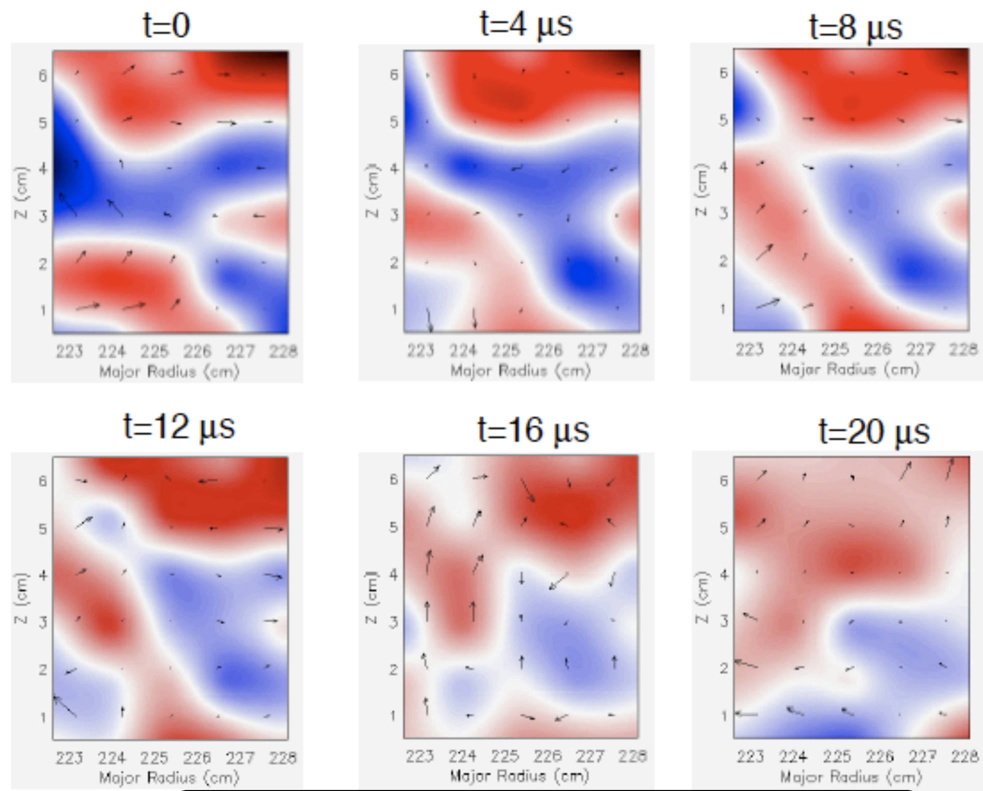
Experimental Parameters

Parameter	To Date
A	1.15 – 1.3
R(m)	0.2 – 0.45
I_p (MA)	$\leq$ .21
I_N (MA/m-T)	6 – 12
l_i	0.2 – 0.5
κ	1.4 – 3.7
τ_{shot} (s)	$\leq$ 0.025
β_t (%)	$\leq$ 25
P_{HHFW} (MW)	0.2



Velocimetry Concepts and Motivation

- Velocimetry techniques
  - Spatial cross-correlation
  - Energy and phased based analysis
  - Time–delay estimation
- The time-resolved images reveal key aspects of the turbulence dynamics
  - zonal flows
  - geodesic acoustic modes
  - radial and poloidal transport



•Arrows represent velocity flow fields at DIII-D
•G. R. McKee HTPD 2004

- Quantifying the turbulence flow field is crucial to more fully exploiting these data sets to challenge theoretical models of turbulence

Fluctuation Measurements on Pegasus using Langmuir probes within the LCFS

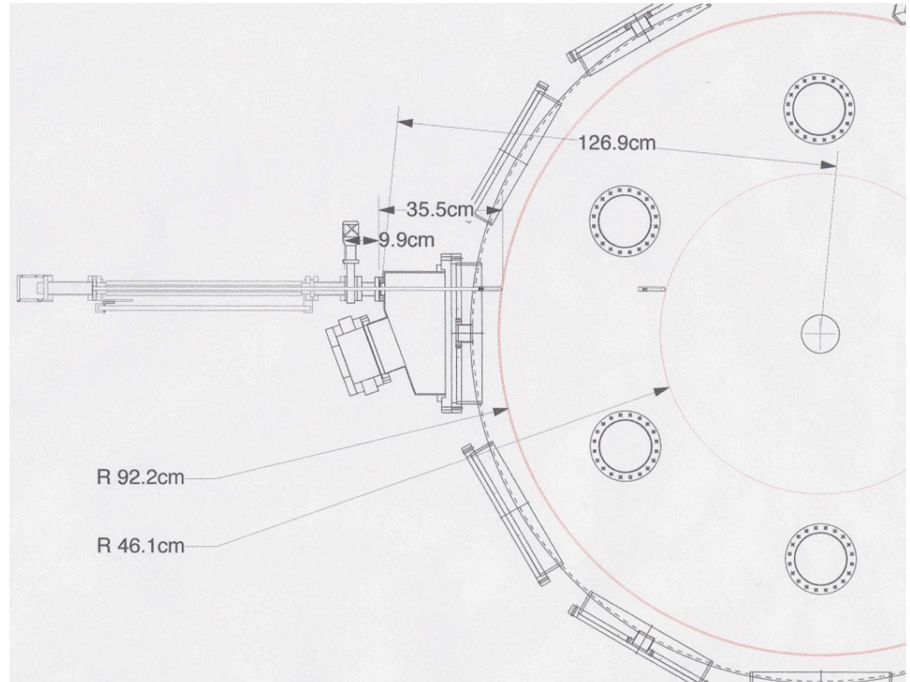
- Preliminary work on the Pegasus tokamak is to determine the feasibility of a 2-D array of probes in the outer plasma region, an initial determination of the properties of the density and potential fluctuation fields is performed using a pair of scanning probes to map out the 2-D correlation functions for the fields

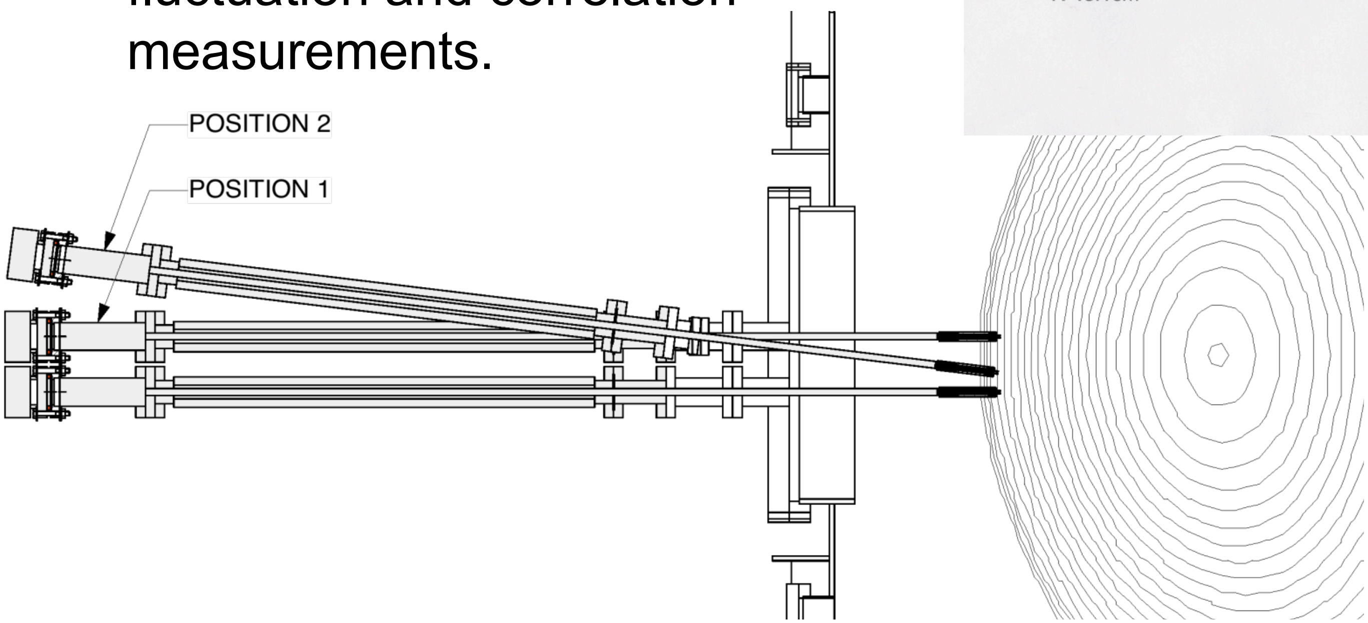
$$k_\perp \rho_i \sim 1$$

- Fluctuations to be examined are expected to have $L_{poloidal} \sim 2.5$ cm evaluating ρ_i at $T_e \sim 10$ eV
- Radial correlation lengths will also be examined
- Effects of Toroidal field, density and temperature on the fluctuation fields will be examined

Position Scanning Langmuir Probe for Close Proximity Measurements

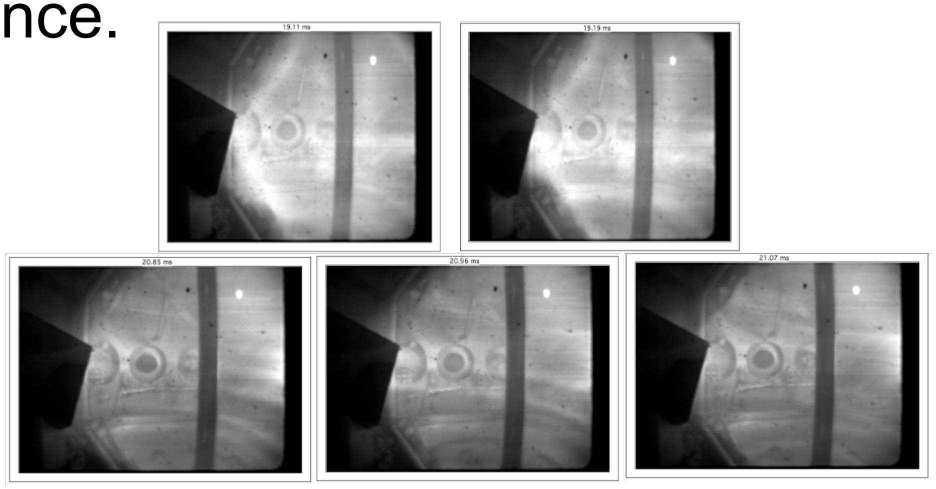
- Upper probe is mounted to allow 7° of motion in the vertical or horizontal plane.
- Horizontal probe positions are 1.0 and 7.5 cm above and below the mid-plane
- Probes separation is ≤ $L_{poloidal}$ for fluctuation and correlation measurements.

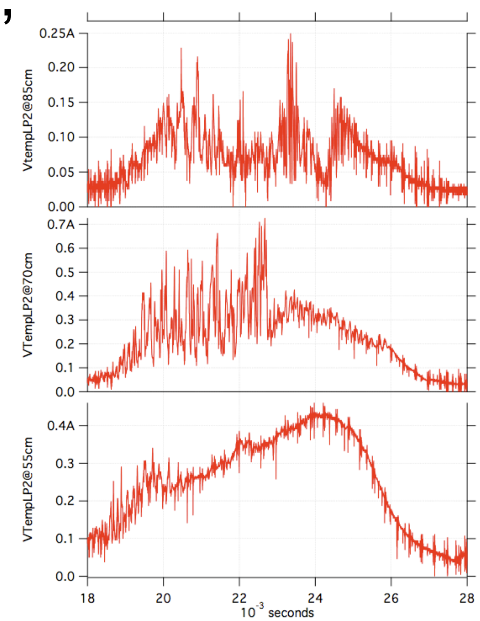




Detected Frequencies Depend on Probe Radial Location Relative to Plasma Edge

- Frequencies change when the plasma envelops the probe tips
  - With a repeated discharge, the time the probe enters the plasma depends on the radial position
  - Indicates behavior is different in the SOL compared to the LCFS, which is promising for development of a Langmuir probe for turbulence studies
  - The current probes are designed for edge and scrape-off measurements, the probe structure will need to be modified to prevent perturbing the plasma
- Large filaments are visible on imaging camera, suggesting that the probe should see turbulence.





A New BES Diagnostic is in place at NSTX and Successfully Measuring Turbulent Fluctuations

- The BES diagnostic is in place at the NSTX with 24 channels and plans to expand to 32 in the near future.
- Measurements across all radial channels show H-mode confinement has higher density and lower amplitude fluctuations the L-mode plasmas. This is especially prominent in the outer channels (R > 140 cm)
- Broadband fluctuations are present across all of the channels
- The present BES system also detects TAEs, GAEs, and harmonic features
- A BES related study is being done to validate velocimetry through the use of Langmuir probes to measure density and potential fluctuations

Acknowledgements

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