EDGE TURBULENCE FLOW SHEAR AND DECORRELATION TIME DYNAMICS AT AN L to H MODE TRANSITION

George McKee[1]

C. Fenzi[1], R.J. Fonck[1], M. Jakubowski[1], B.P. Leslie[1], K. Burrell[2], T. Carlstrom[2]

[1] University of Wisconsin-Madison, Madison, WI, USA
[2] General Atomics, San Diego, CA, USA

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ABSTRACT

Two-dimensional observations of turbulent density fluctuations with the BES diagnostic system at the edge of DIII-D plasmas allow for direct measurement of the velocity flow field and the resulting flow shear of the fluctuations. These measurements also allow for determination of the radially-dependent turbulence decorrelation times as well as radial and poloidal correlation lengths. The dynamics of these quantities just prior to an LH transition are examined and compared with expectations from the ExB shear suppression model. Decorrelation rates ($1/\tau_c$) near 10^5 s^{-1} are typical, while flow shears, $\partial v_\theta/\partial r$, of this order of magnitude are observed in the edge.

MOTIVATION & OVERVIEW

- Low (L) confinement mode to High (H) confinement mode transition critical to tokamak operation and understanding of transition physics and transport improvement
- Turbulence dynamics, in turn, critical to LH transition physics
- Beam Emission Spectroscopy (BES) at DIII-D provides 2D density fluctuation measurement capability which has been applied to study edge turbulence dynamics during LH transition experiment. Measurements include:
  - Radial and poloidal correlation lengths at high spatial resolution
  - Decorrelation times (τ_c)
  - Poloidal flow velocity (v_θ) *and* velocity shear ($\partial v_\theta/\partial r$)
- This study provides preliminary examination of these fluctuation characteristics in the L-mode phase just prior to an LH transition
  - Velocity flow shear rate comparable to decorrelation rate
  - Dynamics indicate "slow" flow evolution until LH bifurcation

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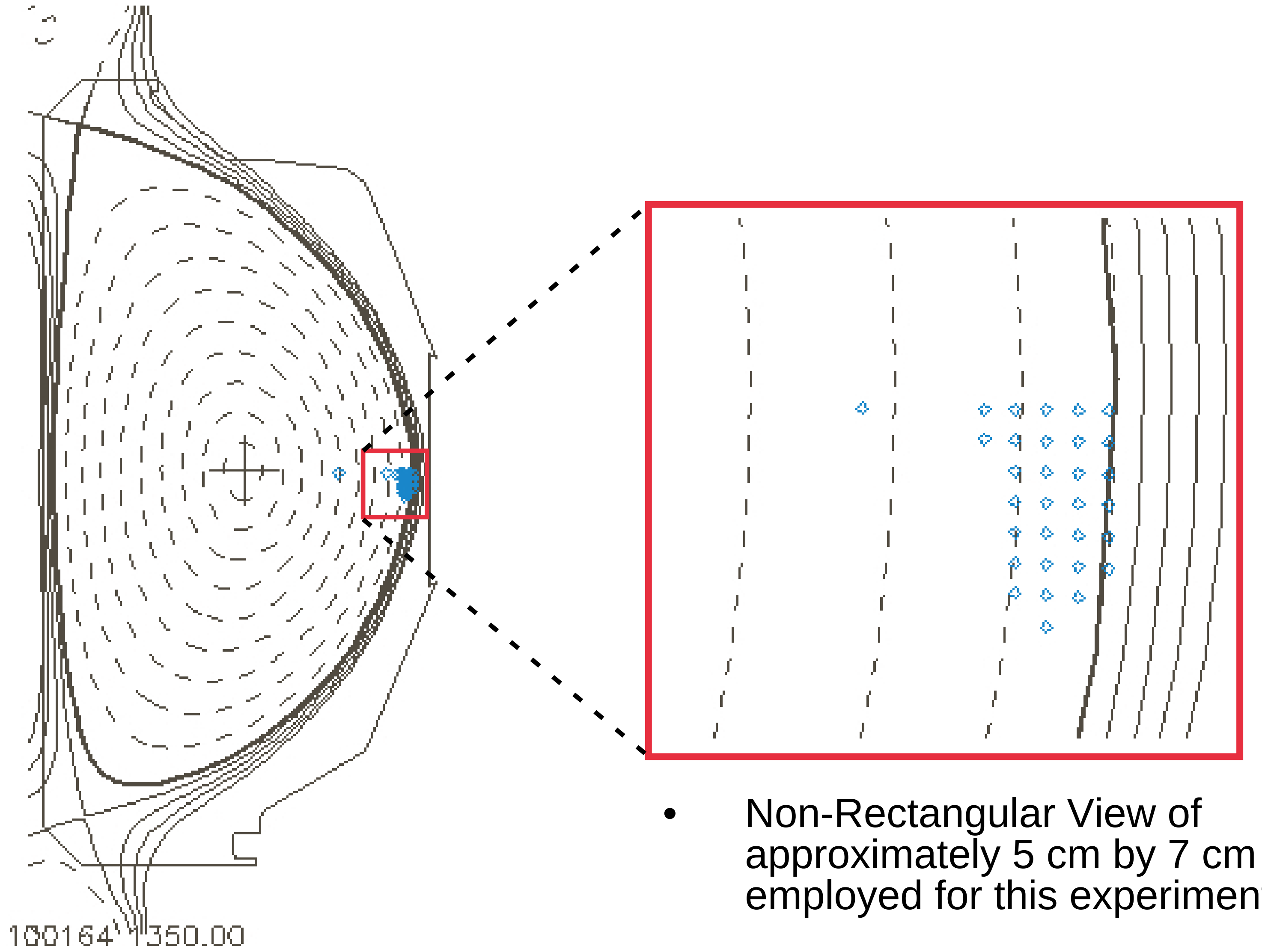
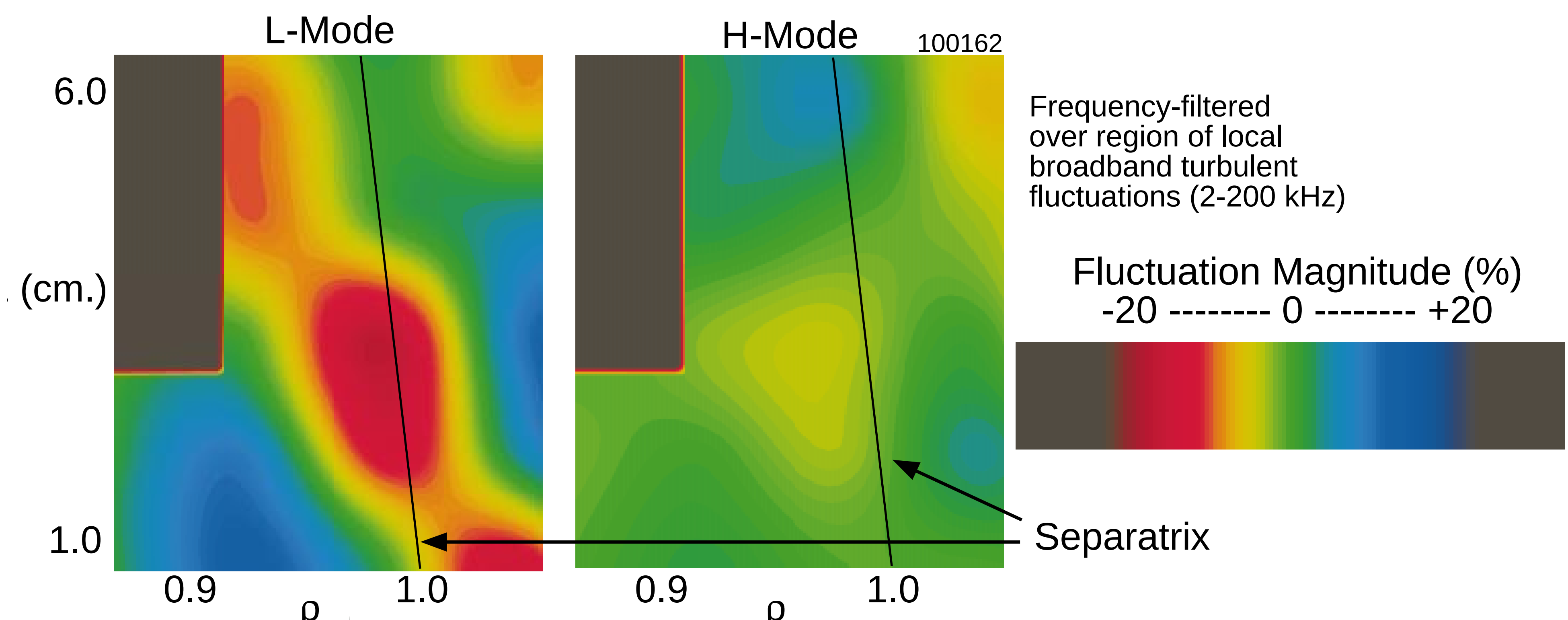
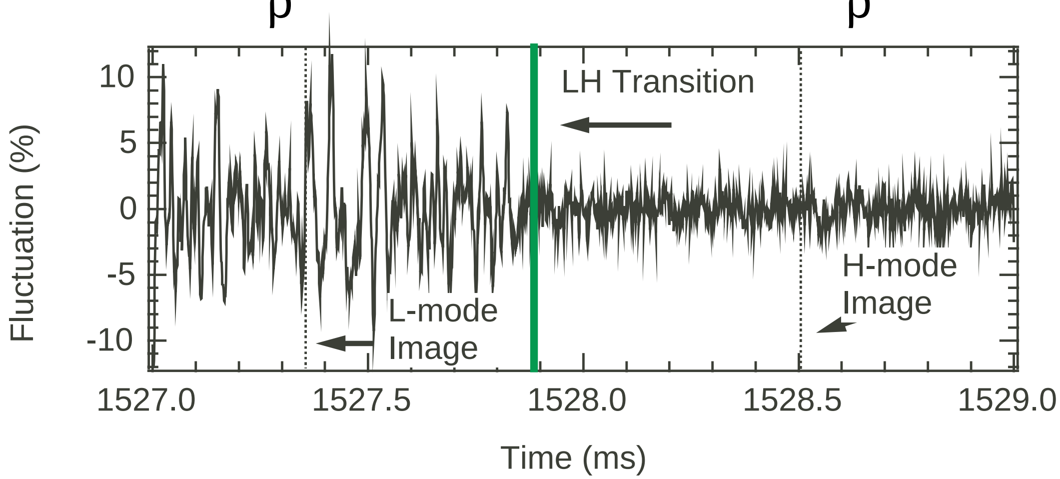
BES VIEWING GEOMETRY NEAR OUTER MIDPLANE



- Non-Rectangular View of approximately 5 cm by 7 cm employed for this experiment,
- Spatial resolution and separation ~ 1 cm. ($k_\perp \leq 2.5$ cm^{-1})

2-Dimensional Edge Turbulence Images Obtained with Beam Emission Spectroscopy at L-H Transition

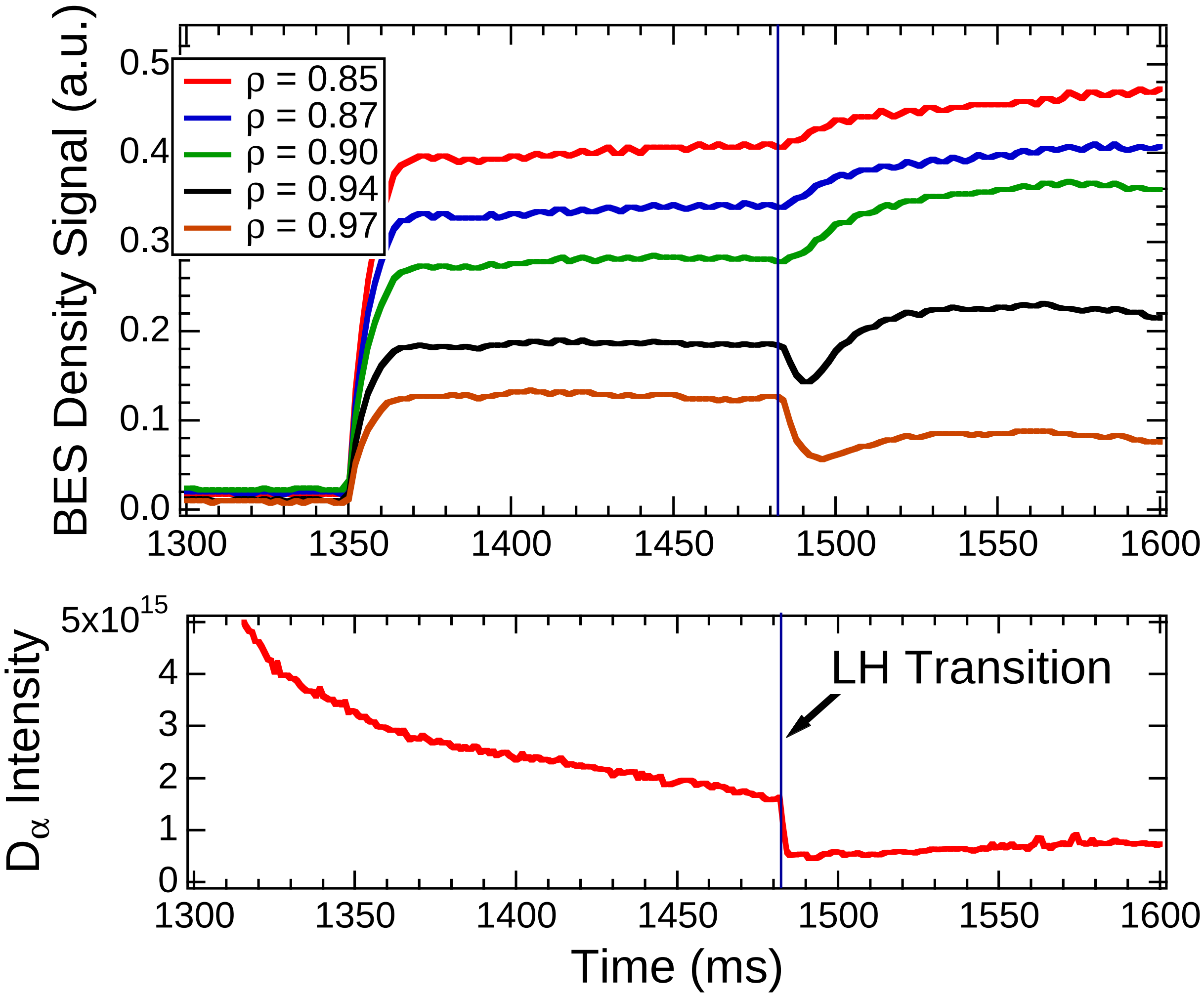




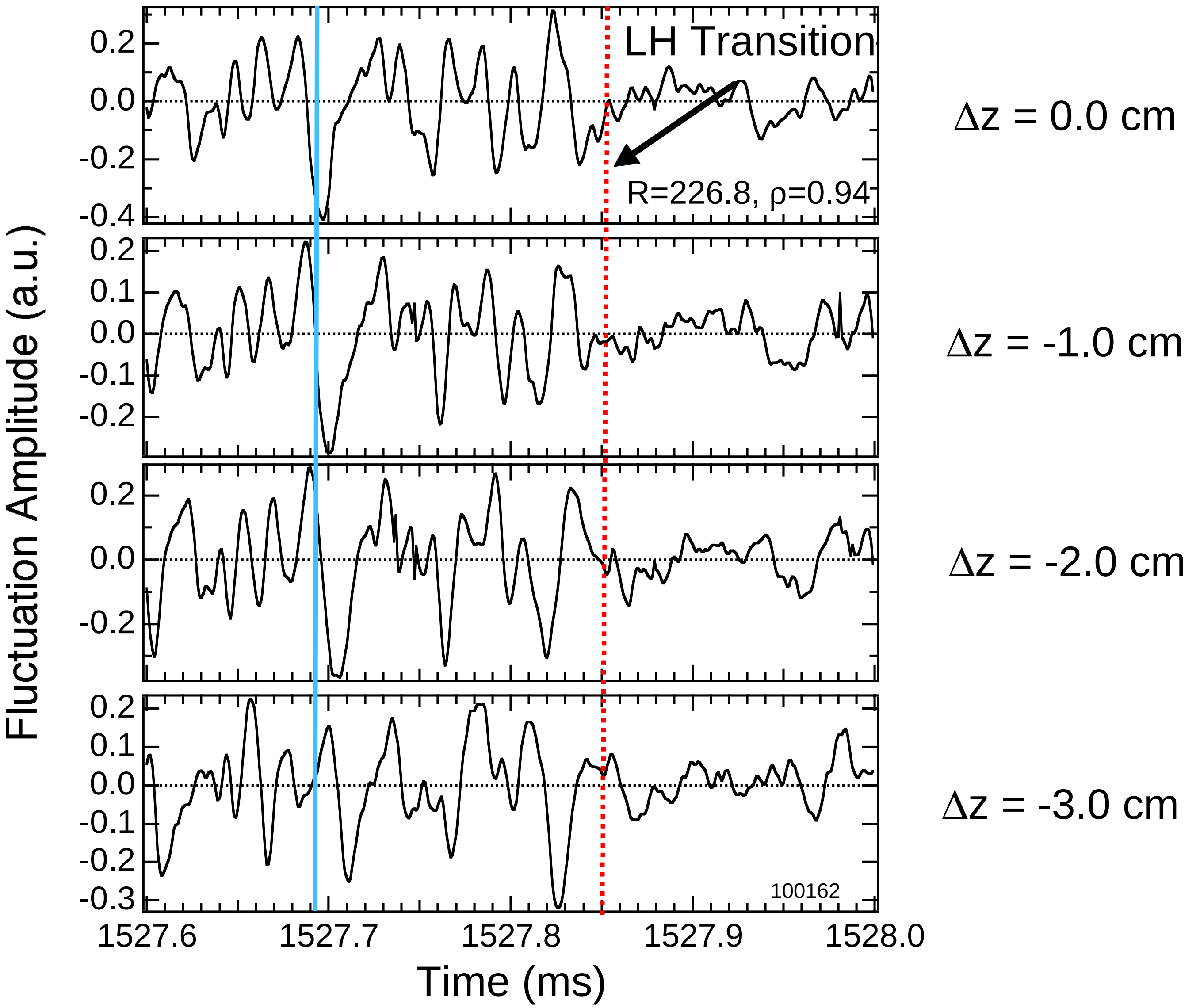
- Large, transient, coherent structures observed
- Dramatic suppression at LH Transition

BES 2D Array Stradles Pedestal Region at LH Transition

- Density signals at inner three arrays increase at LH transition: inside of symmetry point, while outer two arrays outside of symmetry point
- Shafranov shift after H-mode transition evolves to push fixed BES channels inward in plasma frame



Poloidally Adjacent Measurements Exhibit Propagation of Turbulent Structures



$v_{pol} \approx 5$ km/s

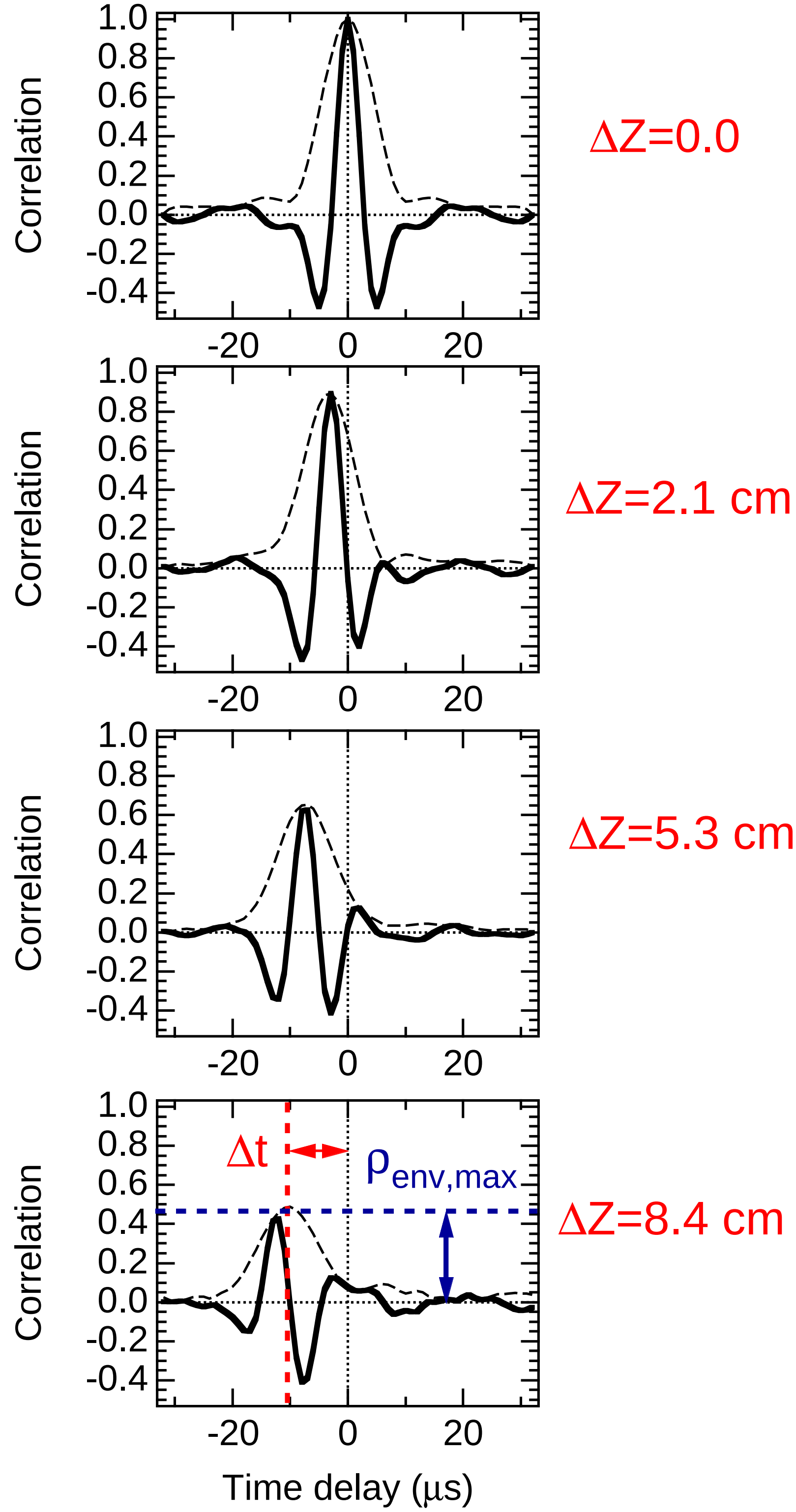
Decorrelation Time (τ_c) derived from Poloidal Correlation Functions

As with radial measurements, obtain two-point correlation functions between poloidally separated channels

Poloidal correlation functions exhibit spatially decaying and temporally shifting correlation functions:

1) Finite poloidal correlation length

2) Poloidal convection (near ExB velocity)

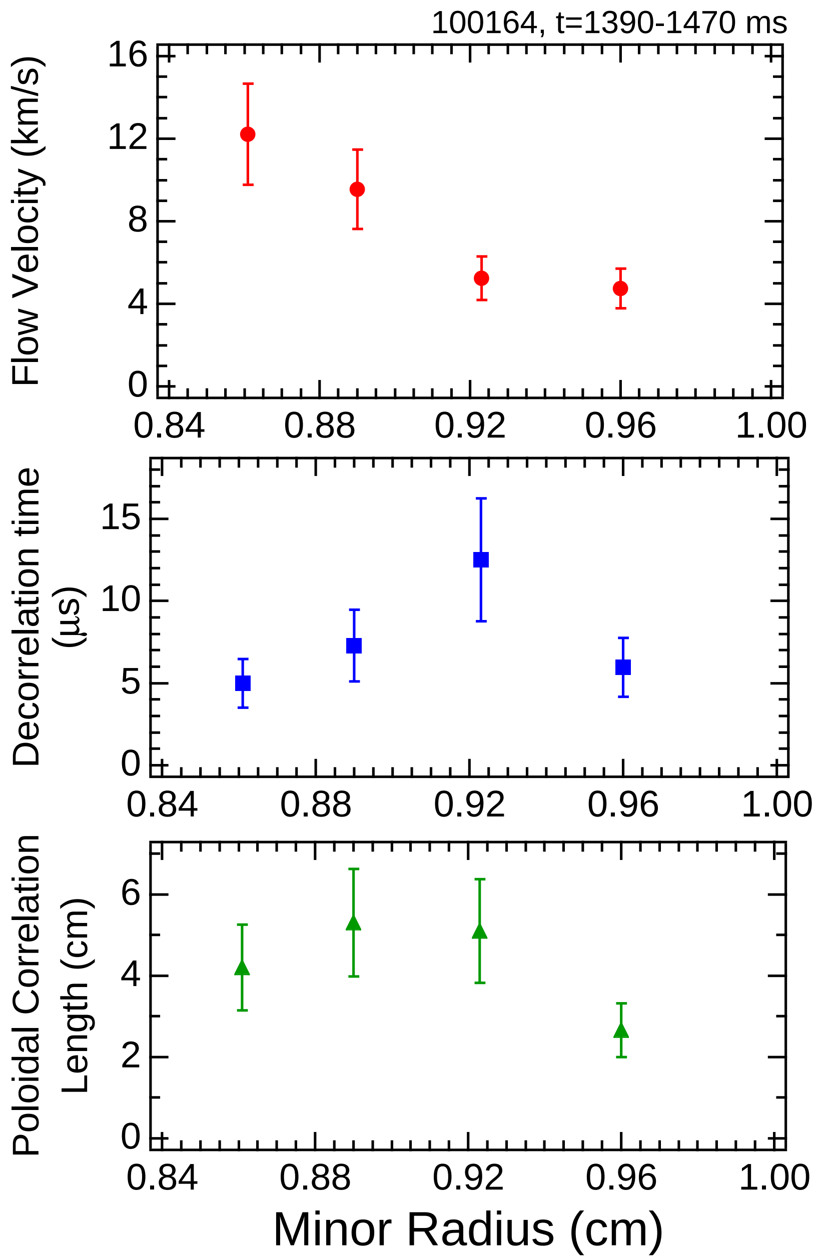


Turbulence Characterisitcs Prior to LH Transition

- Poloidal flow velocity *of the density fluctuations* exhibits strong shear near edge

- Decorrelation times of order the sound speed transit time (a/c_s), or inverse diamagnetic frequency

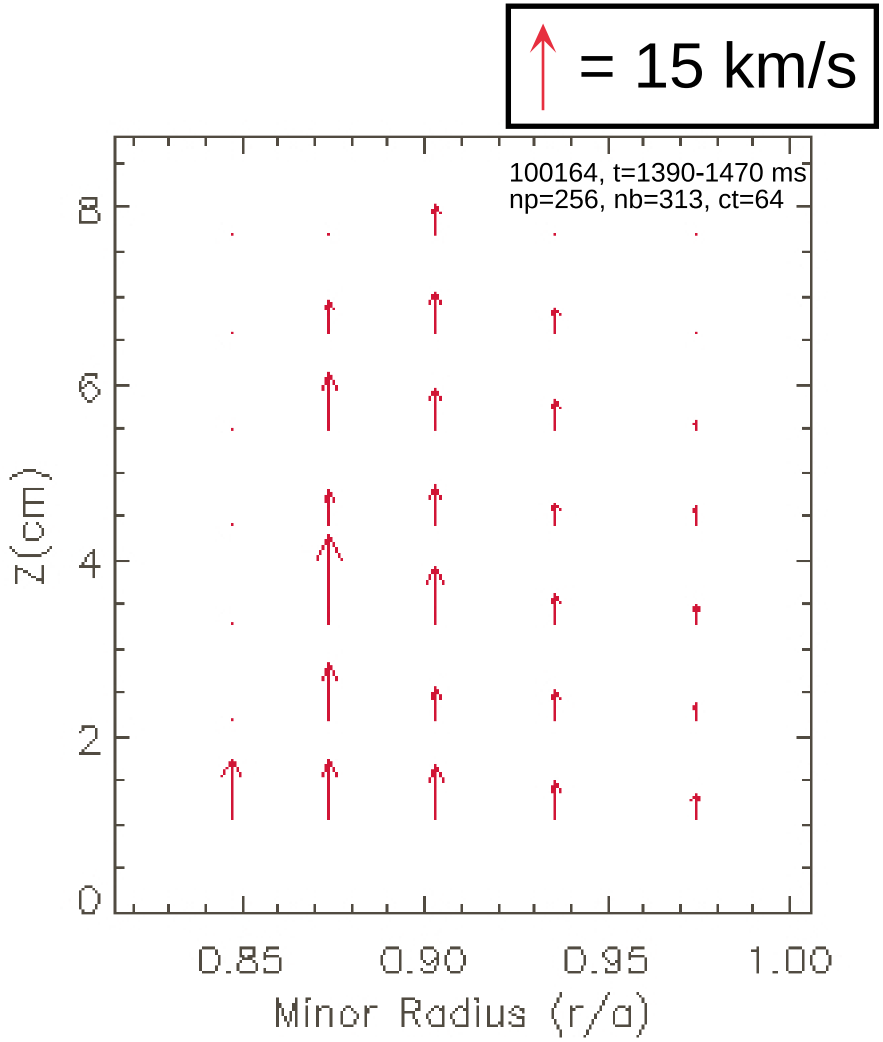
- Strong asymmetry in eddy structure: Poloidal correlation lengths 2-3 times longer than radial ($L_{c,r} \approx 2$ cm.)



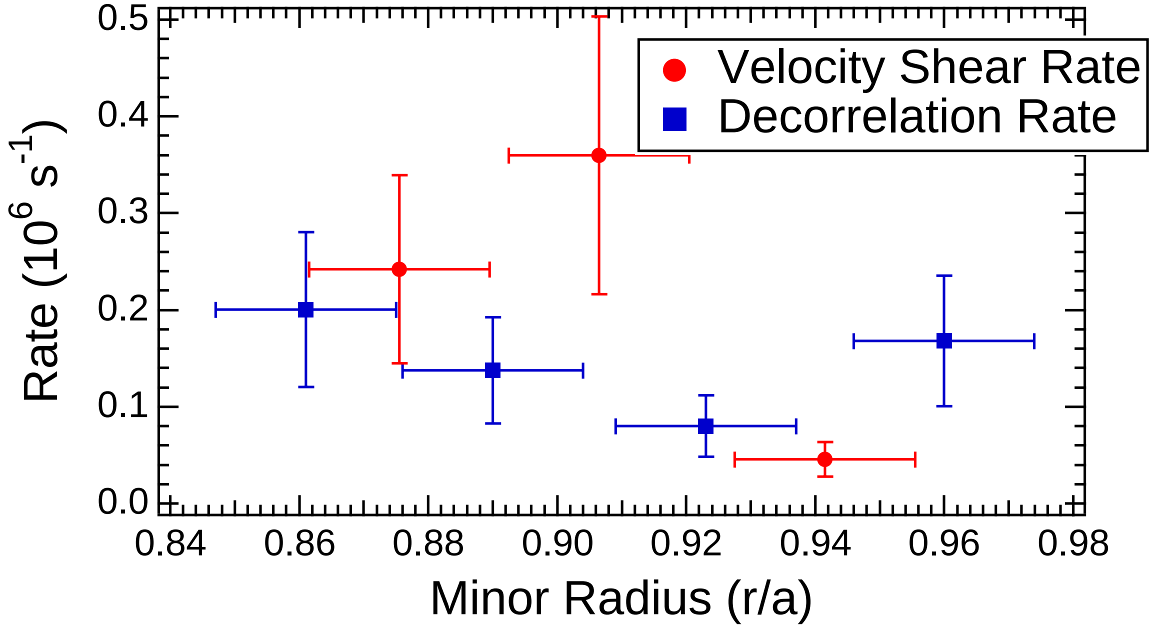
Density Fluctuation Poloidal Velocity Flow Field Exhibits Strong Spatial Variation

- Flow increases from edge into core, exhibits poloidal variation (not well understood)

- Evaluated from time-delay of peak correlation of two-point correlation functions



Velocity shear similar in magnitude to decorrelation rate prior to LH transition

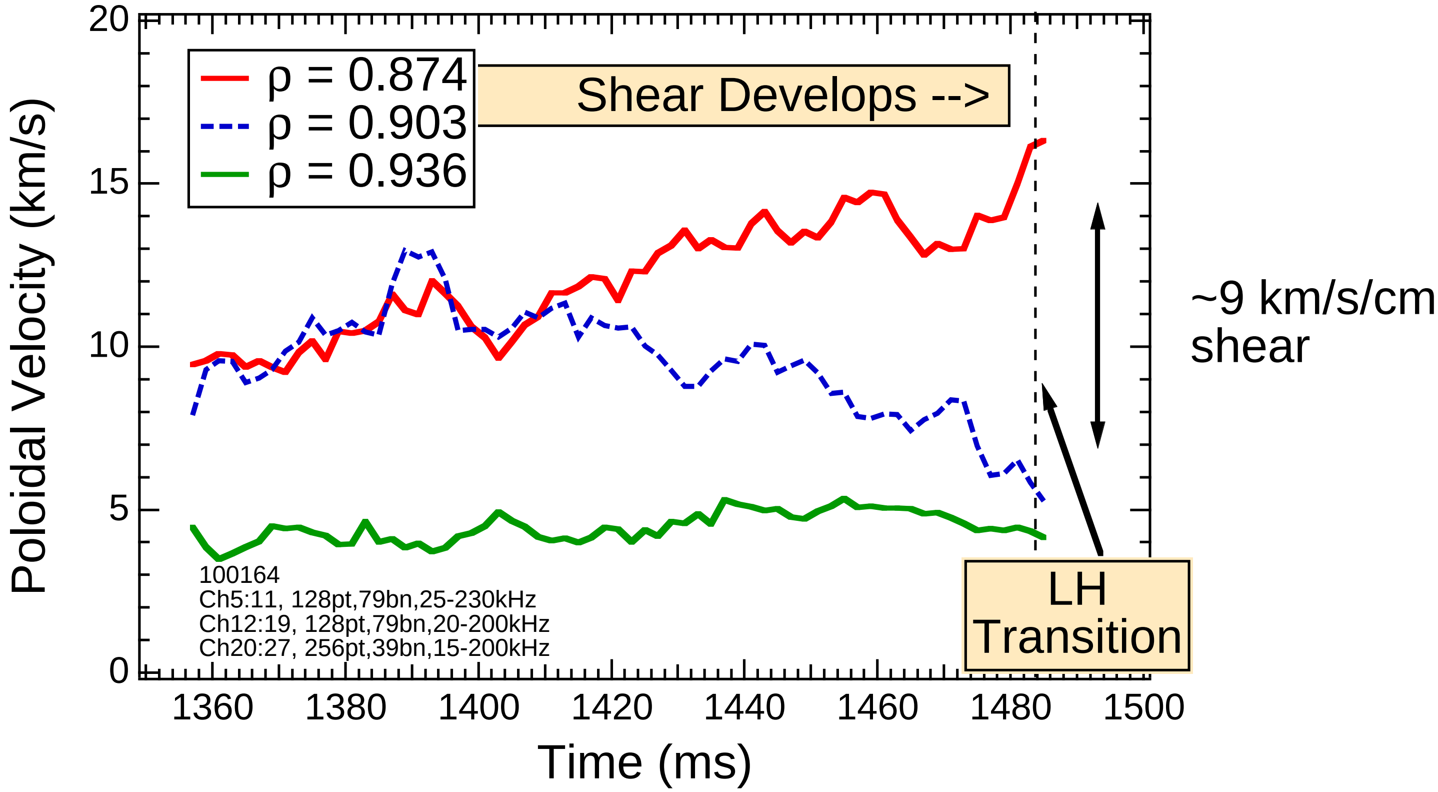


- Velocity shear measured as dv_θ /dr, with adjacent poloidal arrays in 2D data providing spatially-resolved flow measurements

- Decorrelation times obtained from two-point correlation functions

- ExB shear suppression model has been invoked to explain bifurcation at LH transition, would predict these quantities to be of similar magnitude for "eddy shearing" condition to be satisfied: $\omega_{ExB} \geq \gamma_{max}$; provide direct measurements of these quantities

Velocity shear develops near edge gradually prior to LH transition

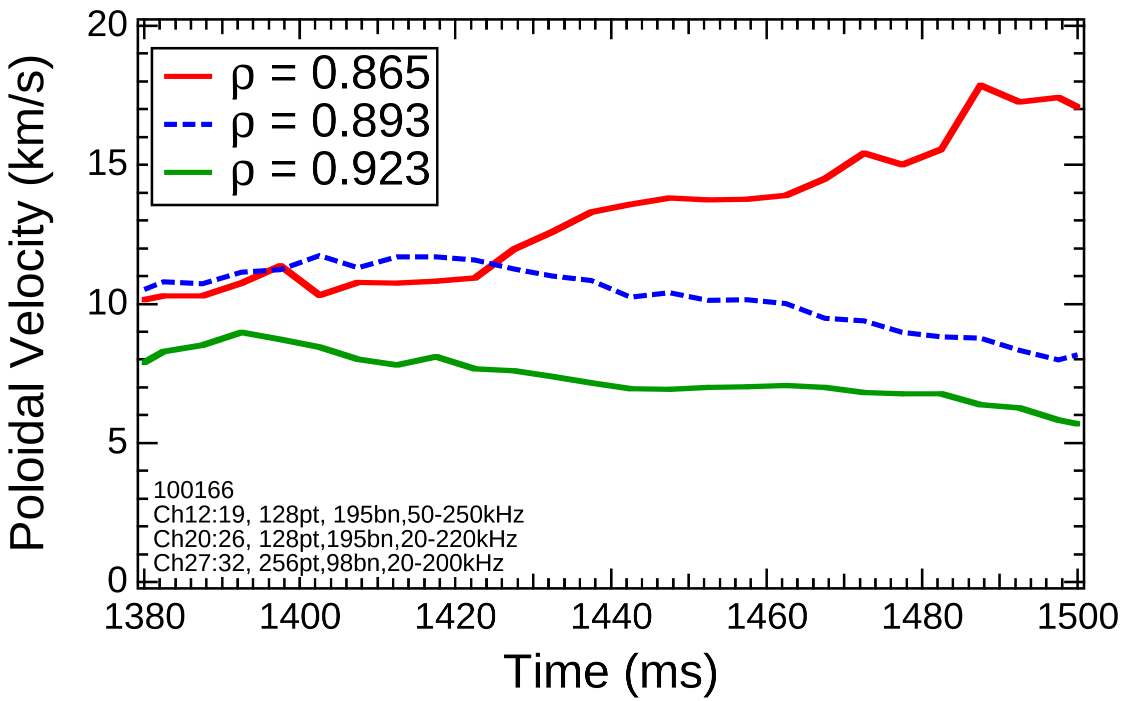


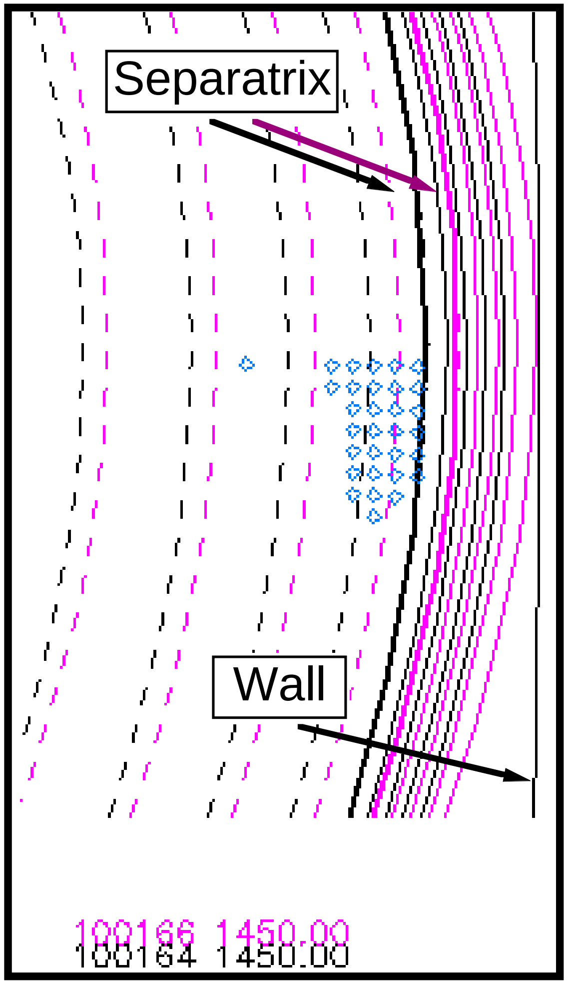
- Strong shear develops over 1 cm separation near ρ ≈ 0.9 during 100 ms leading up to an LH transition
- LH Transition occurs at 1483 ms.

Similar Shear Flow Develops: Different Discharge, Different Detectors, Same Phenomenon

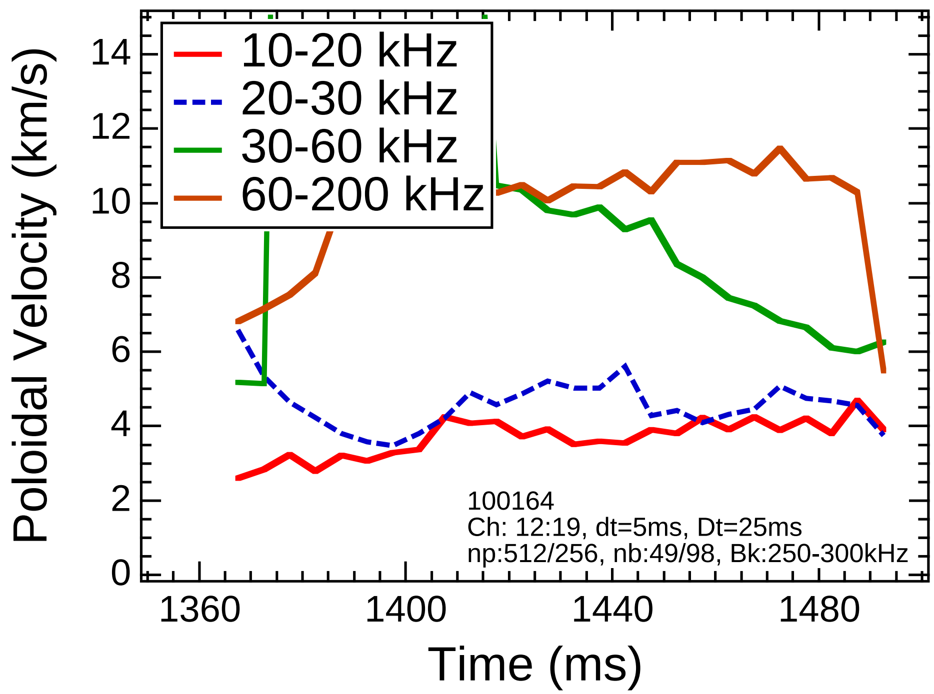
- 2D BES detector array fixed in physical space while GAPOUT (distance from wall to separatrix at outer midplane) scanned on different shots

- Here, detectors are moved about 1.5 cm in plasma frame via GAPOUT scan; Shear layer develops *at nearly the same normalized minor radius (ρ≈0.88)*





Strong Dispersion Observed: Higher Frequencies Propagate and Higher Poloidal Velocity



- Frequency-filtering time-delay correlation functions indicates that poloidal velocity varies significantly with frequency or wavenumber

- Dual-mode structure apparent, leads to "excursion" near 30-60 kHz (artifact of dual-mode nature, and break in frequency)

Conclusion & Future Directions

- 2D measurements of density fluctuations have allowed for detailed characterization of turbulence parameters, including velocity flow field and flow shear, decorrelation rates, radial and poloidal correlation lengths at high spatial resolution
- Turbulence characteristics compared with expectations from ExB shear suppression model of the bifurcation that leads to an LH transition
- Decorrelation rates of turbulence are comparable to poloidal flow shearing rate:

$$\frac{1}{\tau_c} \cdot \frac{dV_\theta}{dr}$$

- Flow evolution indicates clear bifurcation in flow, i.e., increasing flow shear, during 100 ms period leading up to an LH transition
- Qualitatively consistent with turbulence suppression via shear flow, invoked to explain transition

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FUTURE DIRECTIONS

- Larger field of view (fast CCD cameras w/on-chip storage)
- Higher sensitivity diagnostic system: Vacuum UltraViolet BES System to observe Lyman-alpha beam emission
- Wavenumber dependence in flow shear dynamics
- Bi-spectral analysis to examine wave-wave coupling

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