Dependence of Edge Turbulence Dynamics and the LH Power Threshold on Toroidal Rotation

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THE UNIVERSITY of WISCONSIN MADISON

OVERVIEW

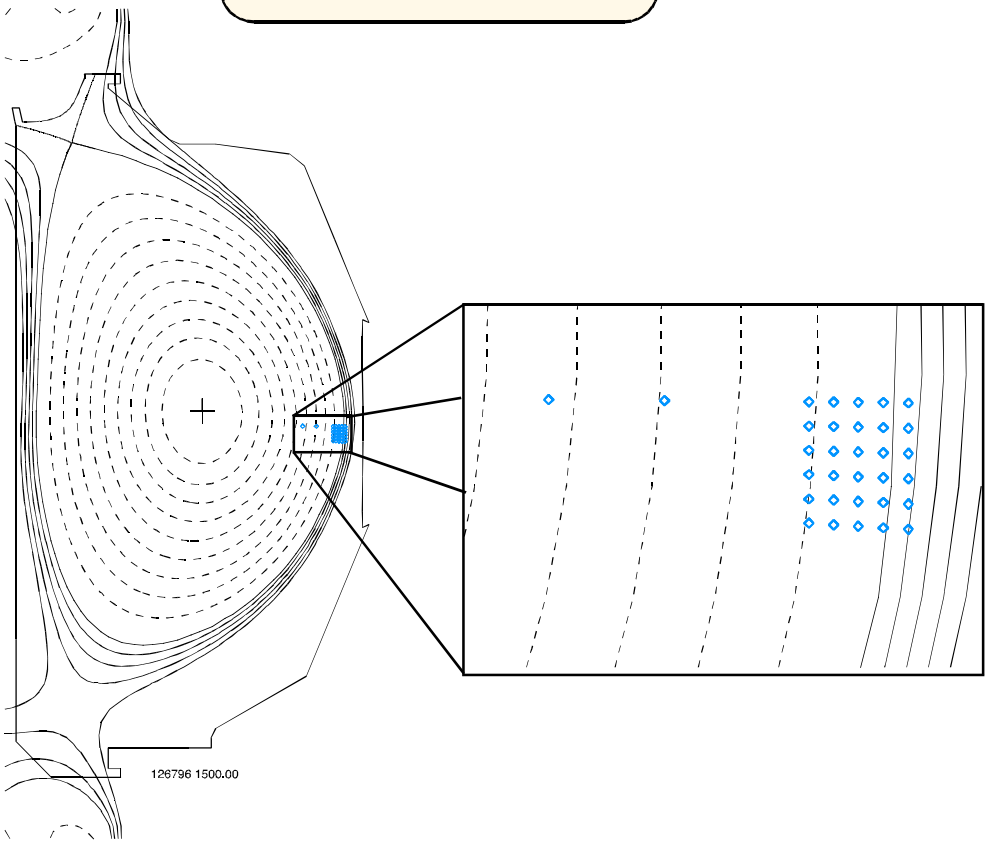
- **Power threshold for L-mode to H-mode transition depends strongly on injected neutral beam torque:**

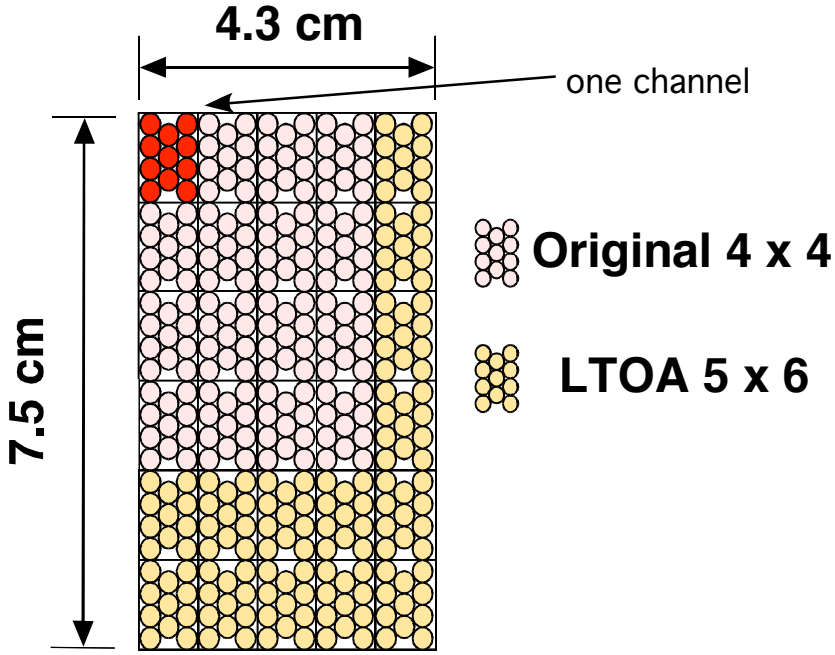
$$P_{THRESH,Co\text{-}injected} > P_{THRESH,Balanced\ injection}$$

- **2D edge turbulence and turbulence flows measured with BES**
- **Significant difference in edge turbulence behaviors:**
  - *Balanced-injection discharge exhibits two counter-propagating modes*
  - *May be a large "natural" shear near r/a~0.9-0.95*
- **Do turbulence changes relate to changing power threshold?**
- **Beneficial implications for ITER if P_{LH} lower than present extrapolations indicate**

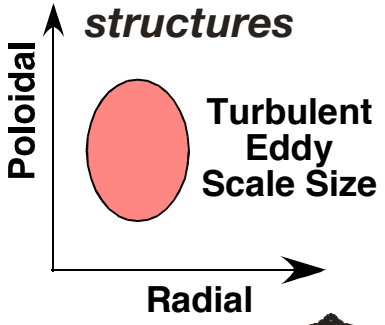
UPGRADED HIGH-SENSITIVITY BES DIAGNOSTIC MEASURES TURBULENCE AT THE L-H TRANSITION

Channel Layout



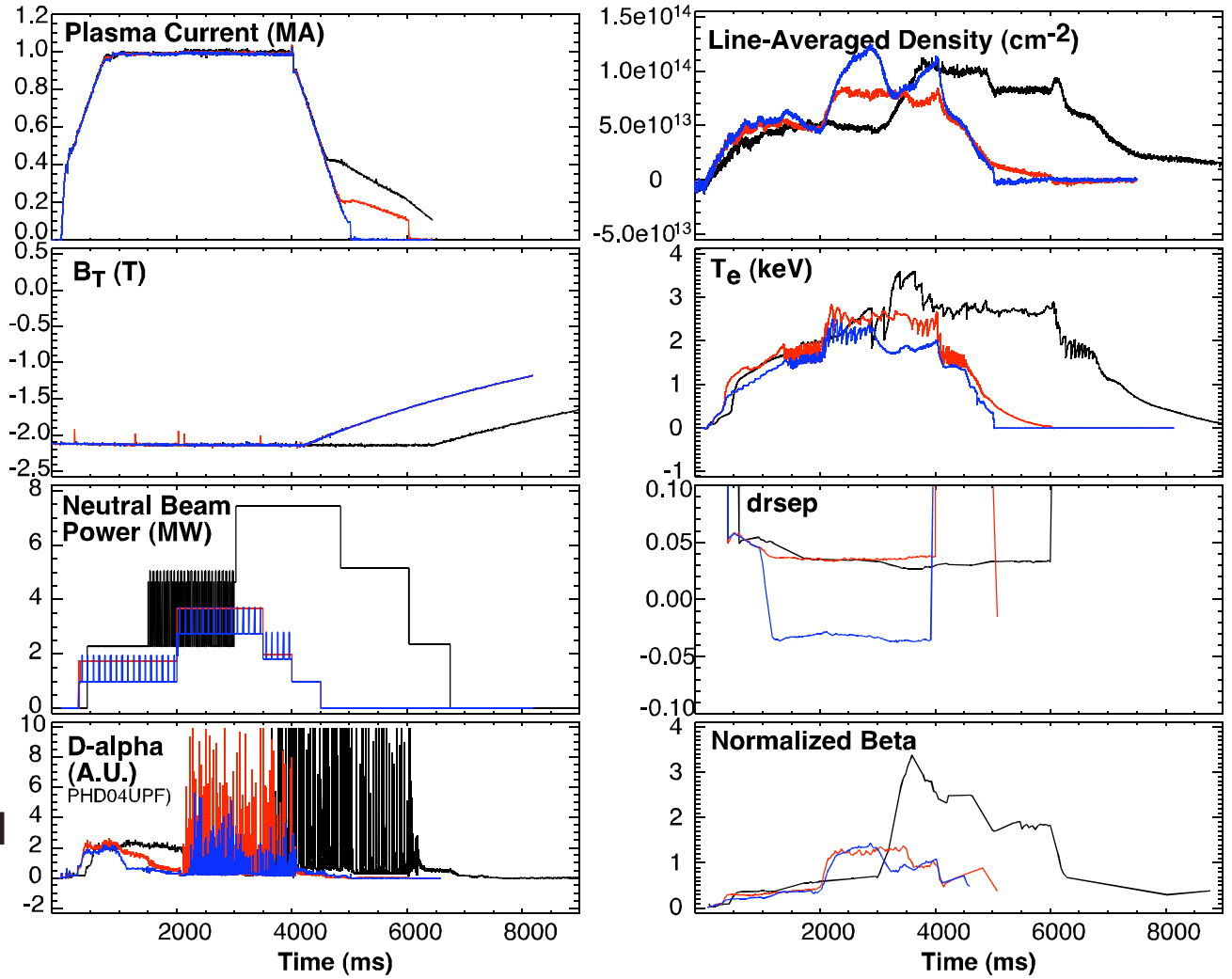


- **For this investigation, BES array located ~0.89 < r/a < ~1.01**
  - *Spans L-H "pedestal" region*
  - *2D array allows identification and visualization of eddy structures*



Turbulence Dynamics at L-H Transition Studied in Well-Characterized Plasma

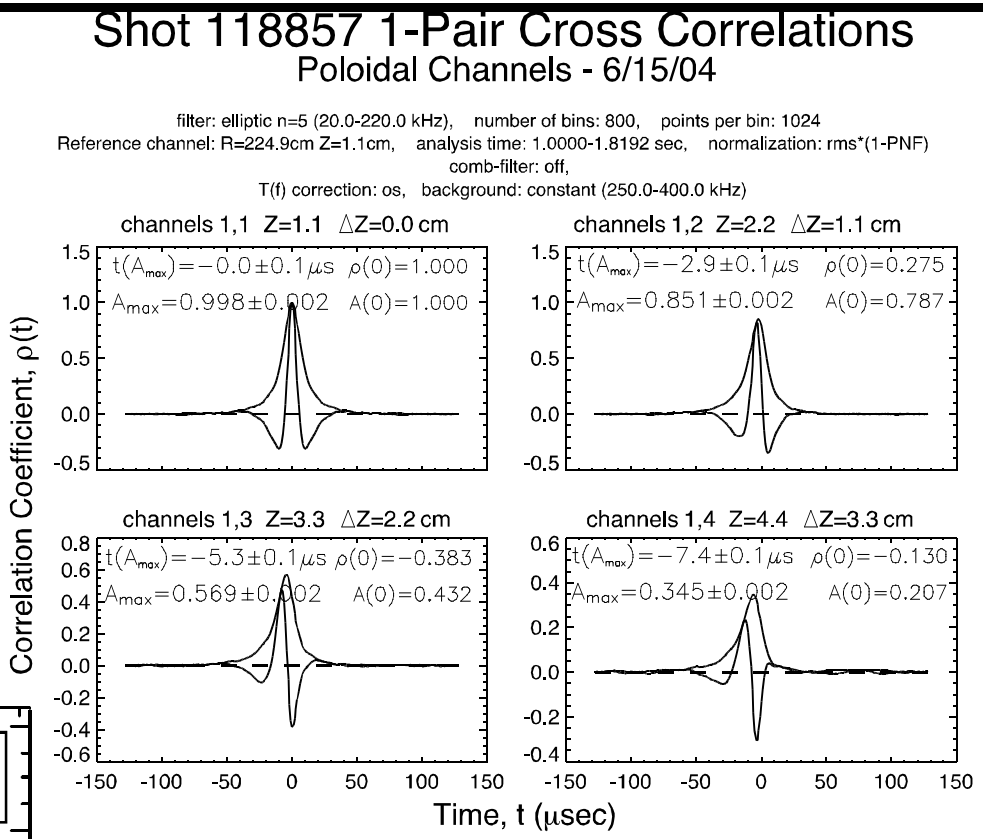
- ~1 MA plasma current
- ~2.1 T toroidal field
- Neutral beam power stepped within shot to induce transition
- Magnetic Geometry (DRSEP) held constant within shot; scanned between shots
- Plasma rotation varied using co-, counter-, and near-balanced neutral beam injection

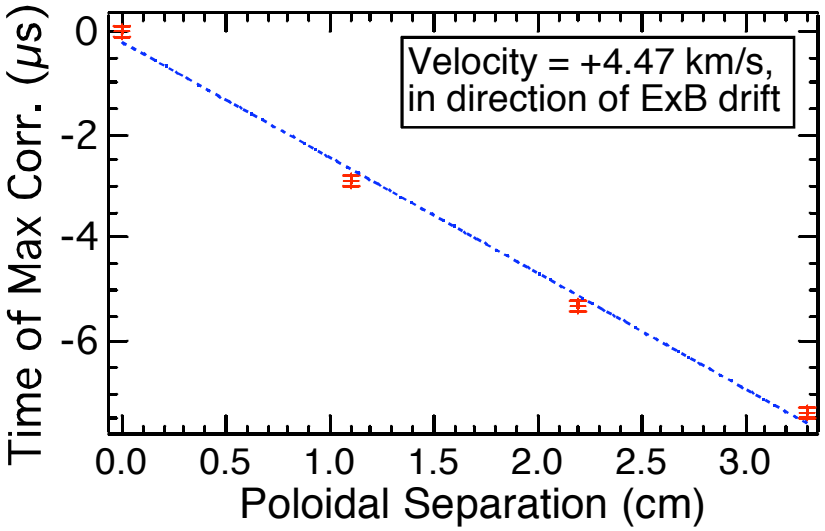


USN co-injection
USN balanced-injection
LSN counter-injection

Cross-Correlations Used to Estimate Velocity Between Two Coherent Signals

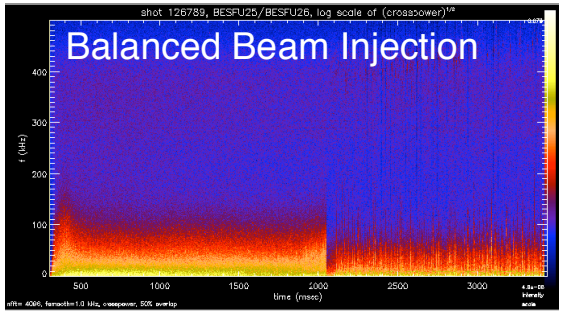
- **Find time of maximum value of envelope function, t(Amax), using cross-correlations**
- **Known spatial separation of channels**

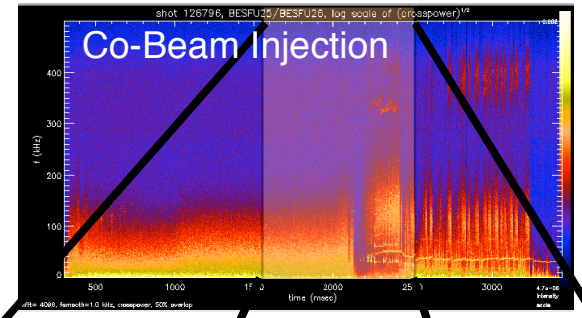


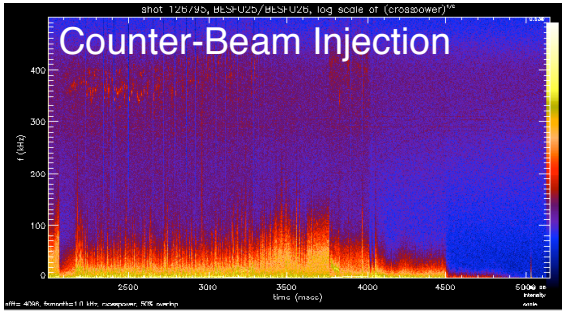


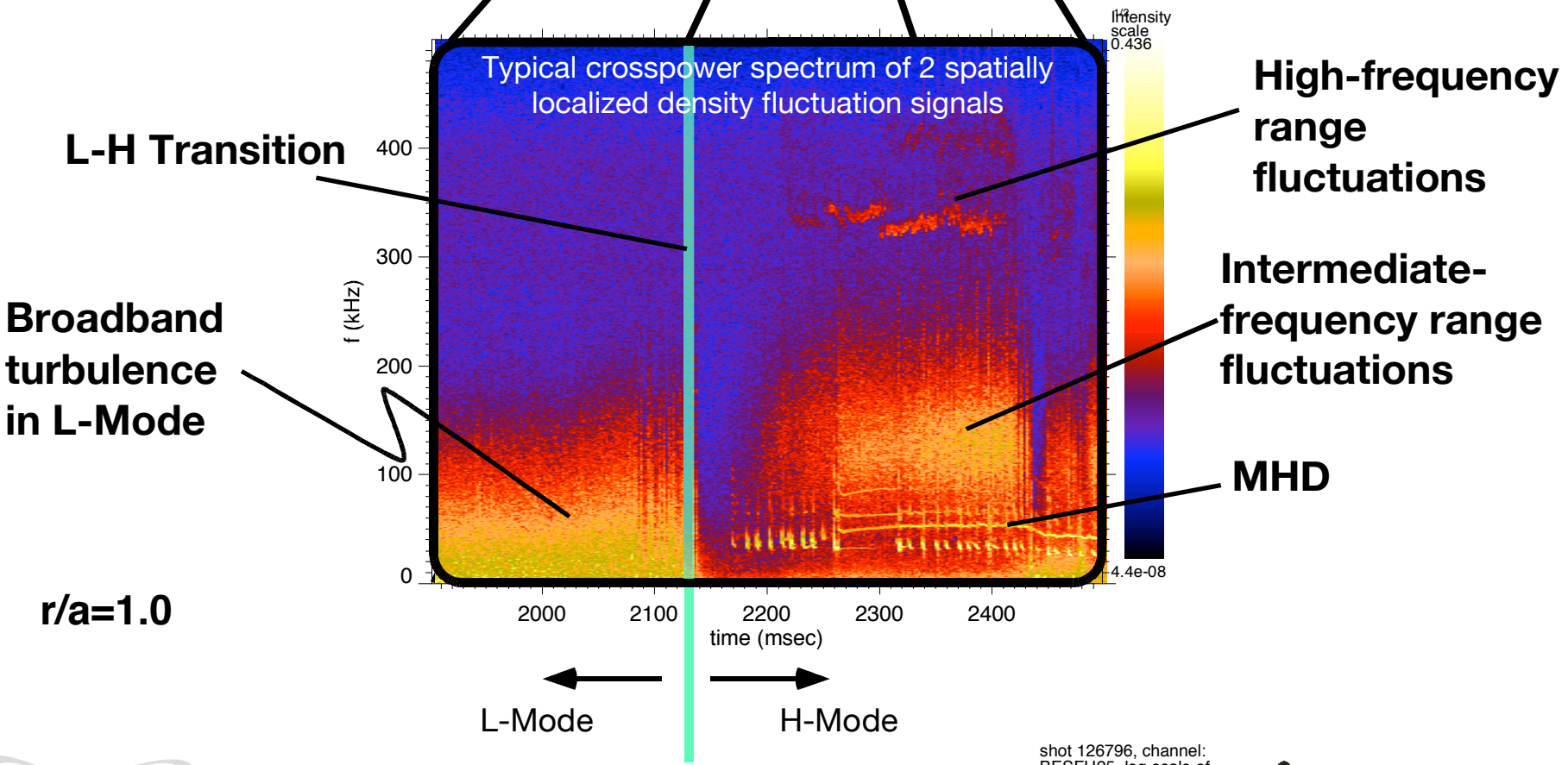
- **Linear fit to determine poloidal flow velocity**

L-H Transition Dynamics Investigated for Varying Plasma Rotation







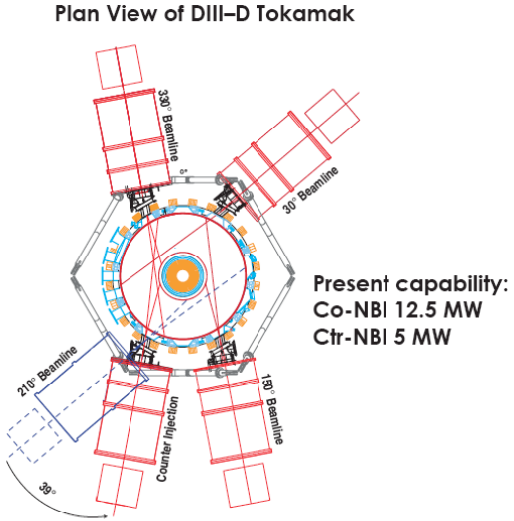


shot 126796, channel: BESFU25, log scale of (crosspower)

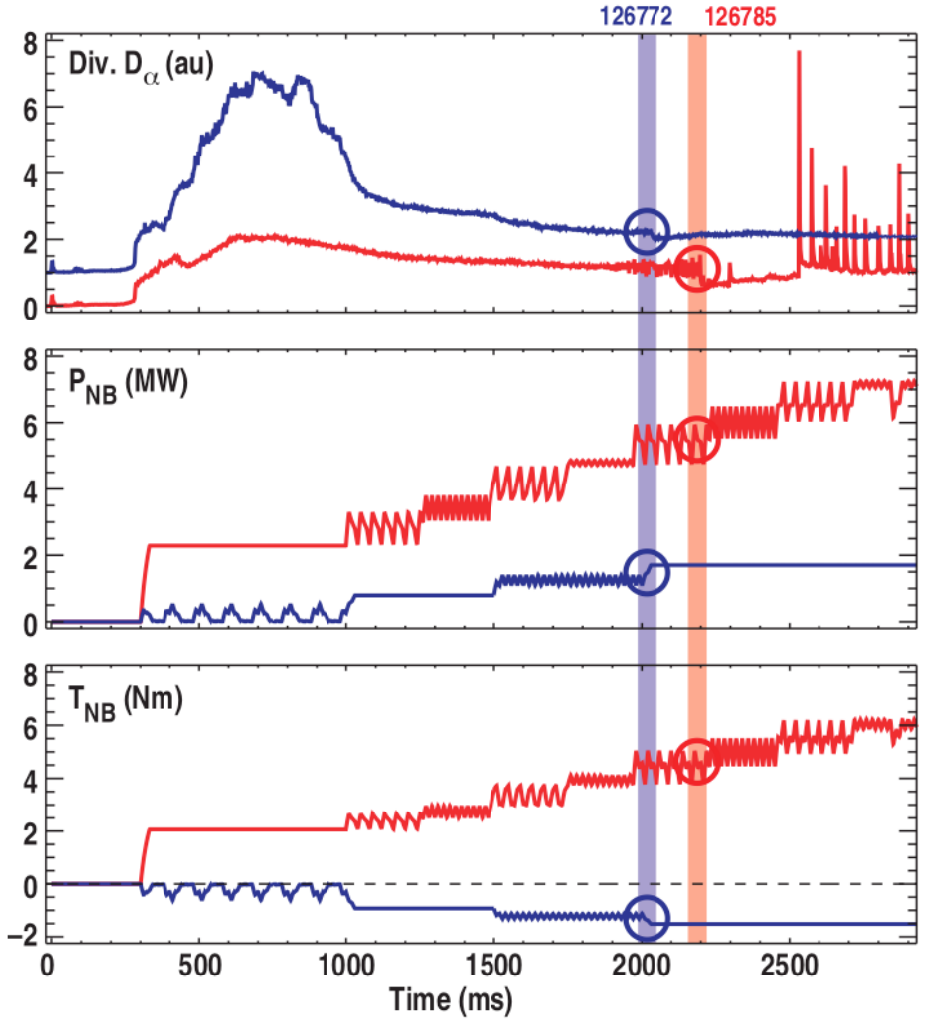
nfft= 4096, fsmooth= 1.00000 kHz, 50% overlap

L-H Power Threshold Higher with Co-Injection than Counter-Injection

- Newly upgraded counter beamline on DIII-D utilized

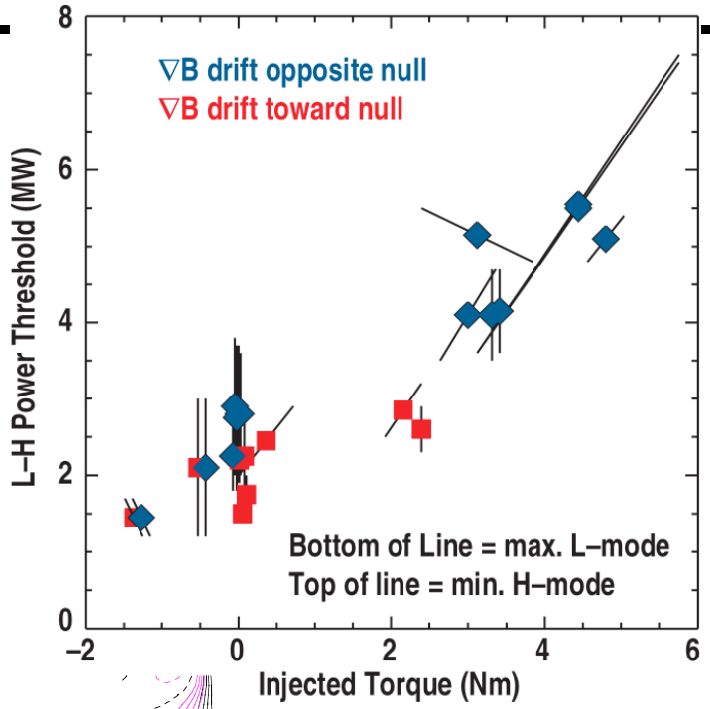


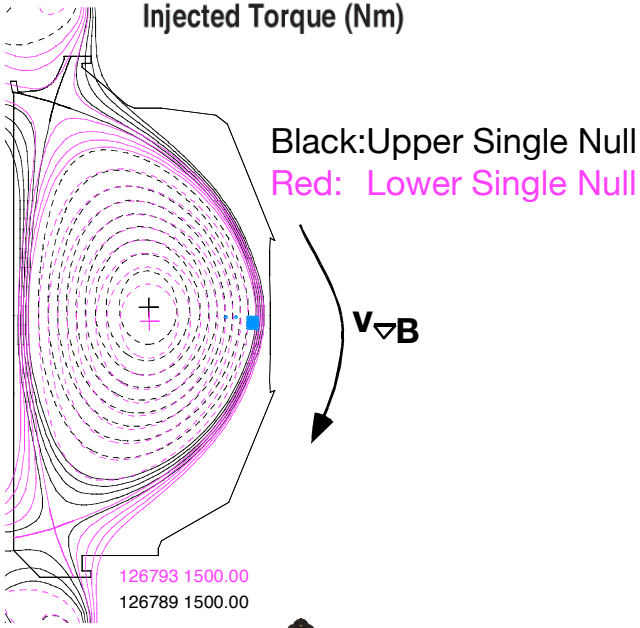
- Injected beam power increased within shot to identify P_{L-H}
- Mix of co-injection and counter-injection beams used to manipulate injected torque
- P_{L-H} in USN co-injection > 3x P_{L-H} in USN counter-injection plasmas



L-H Transition Power Threshold Increases with Injected Torque

- **Lowest threshold with counter-injection, increases for balanced- and co- cases**
- **For co-injection, plasmas with ion grad-B drift away from the x-point (USN) have higher L-H power threshold than with drift toward x-point (LSN)**
- **Difference in L-H power threshold between USN & LSN decreases in balanced injection, and disappears in counter-injection**
- **Range of shots taken from one day**
  - ***Injected torque varied via neutral beam injection***
  - ***L-H power threshold observed by stepping input power within a shot***
  - ***Magnetic geometry not used to induce L-H transition***

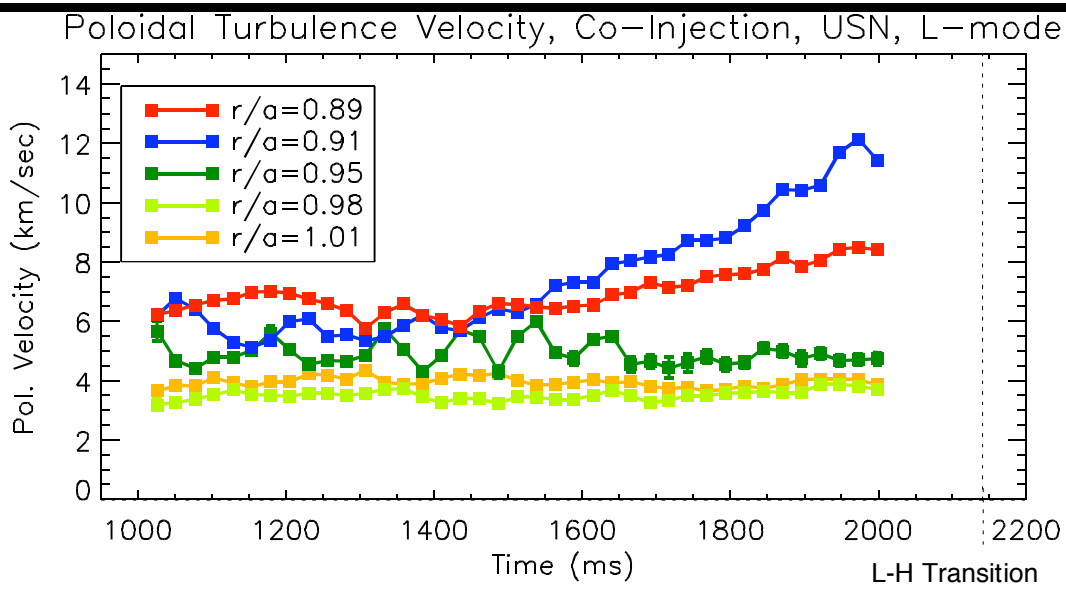


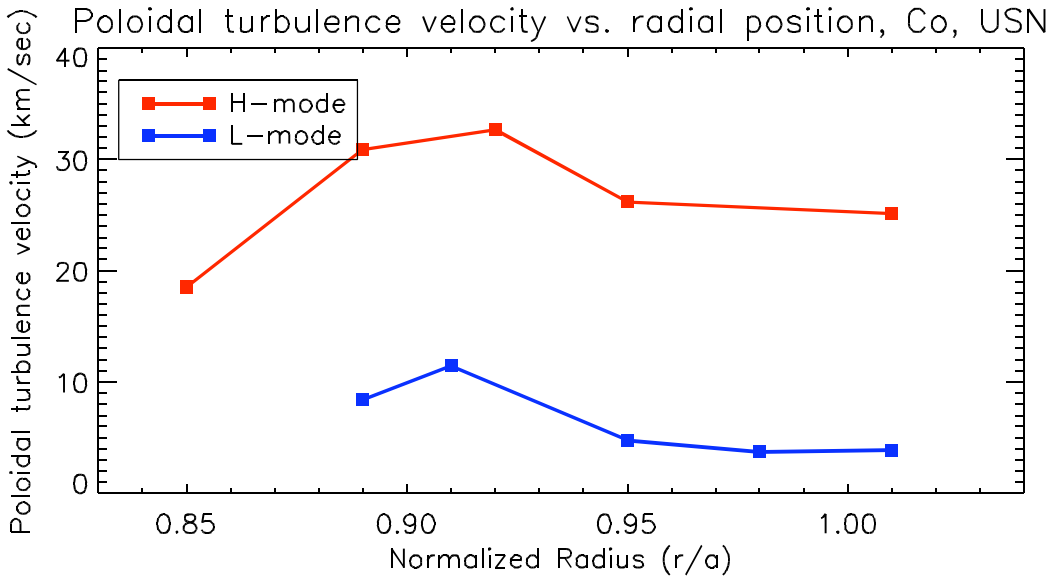


*Thanks to T.C. Luce for above figure

VELOCITY SHEAR INCREASES AS L-H TRANSITION APPROACHED IN CO-INJECTION, USN PLASMA

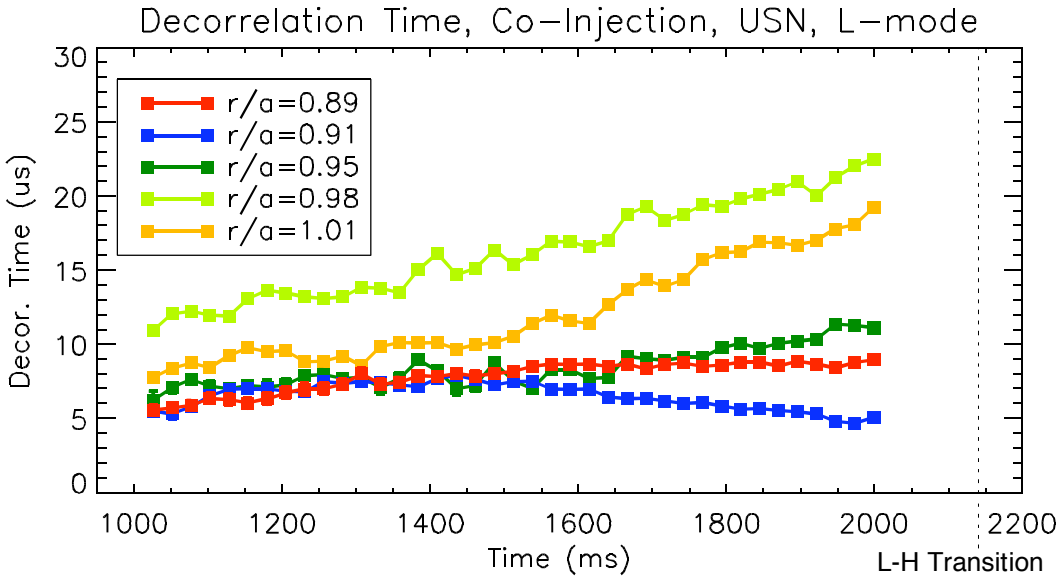
- L-H transition triggered by power injection (no drsep scan) at ~2140 ms
- Poloidal flow velocity of turbulence increases near L-H transition
  - *Flow shear increases from 0.89 < r/a < 0.95*
- In H-mode, $d\tilde{v}_\theta/dr$ roughly 5x larger than in L-mode near r/a = 0.9



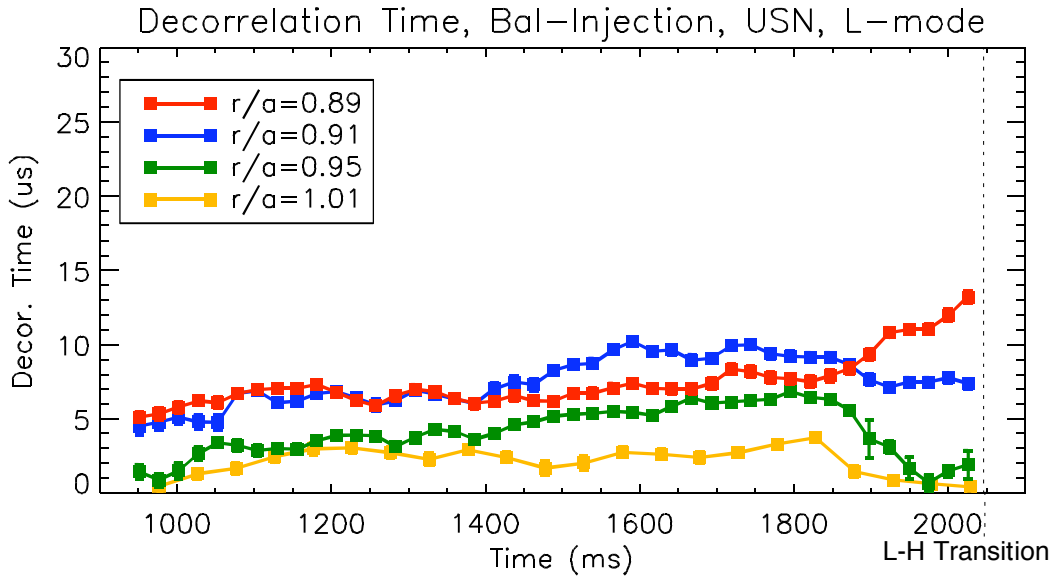


TURBULENCE DECORRELATION TIMES VARY WITH PLASMA ROTATION

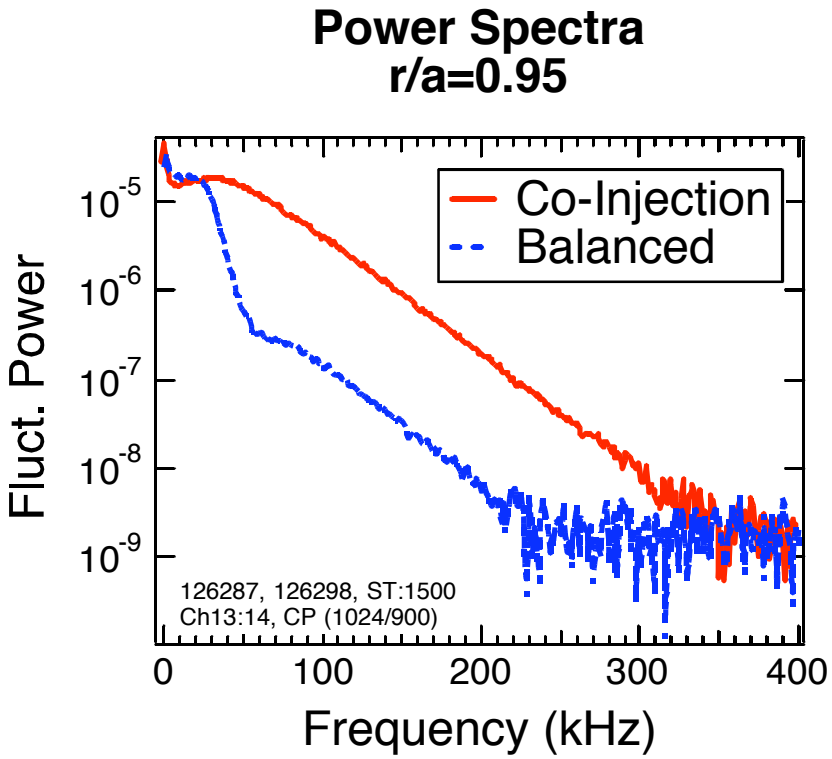
- **For USN co-injection:**
  - *Near separatrix, decorrelation time τ_c increases steadily throughout shot*
  - *Near r/a ~ 0.91, τ_c decreases as high shear develops*
  - *L-H transition at 2140 ms*

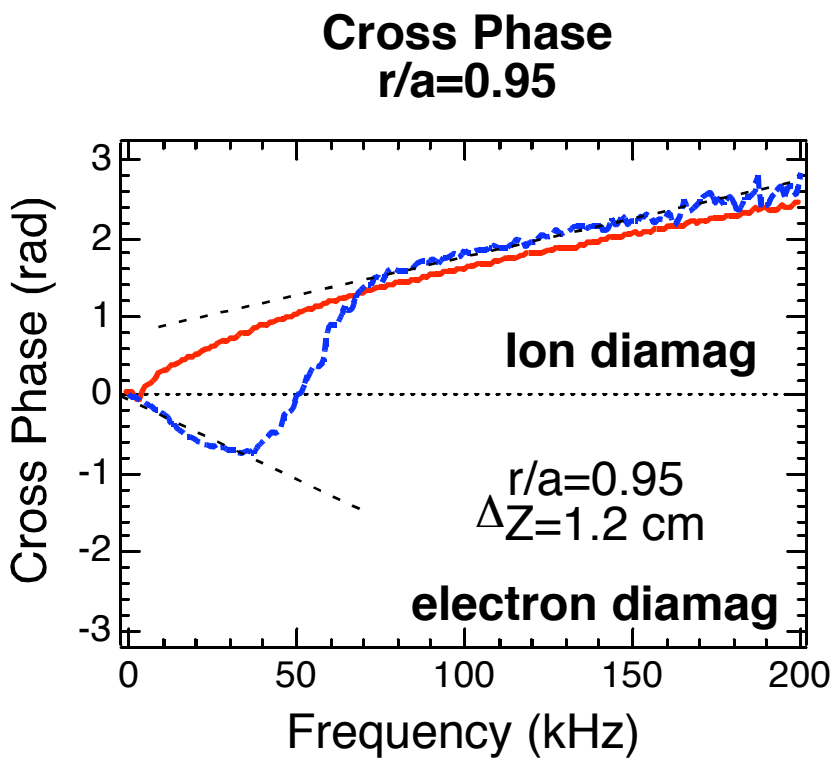


- **For USN near-balanced injection:**
  - *τ_c lower in balanced than co case*
  - *τ_c increases roughly uniformly in time and across plasma radius*
  - *L-H transition at 2045 ms*



Balanced-Injection Discharges Exhibit Significant Dispersion in Edge Fluctuations: Not observed in Co-Injection

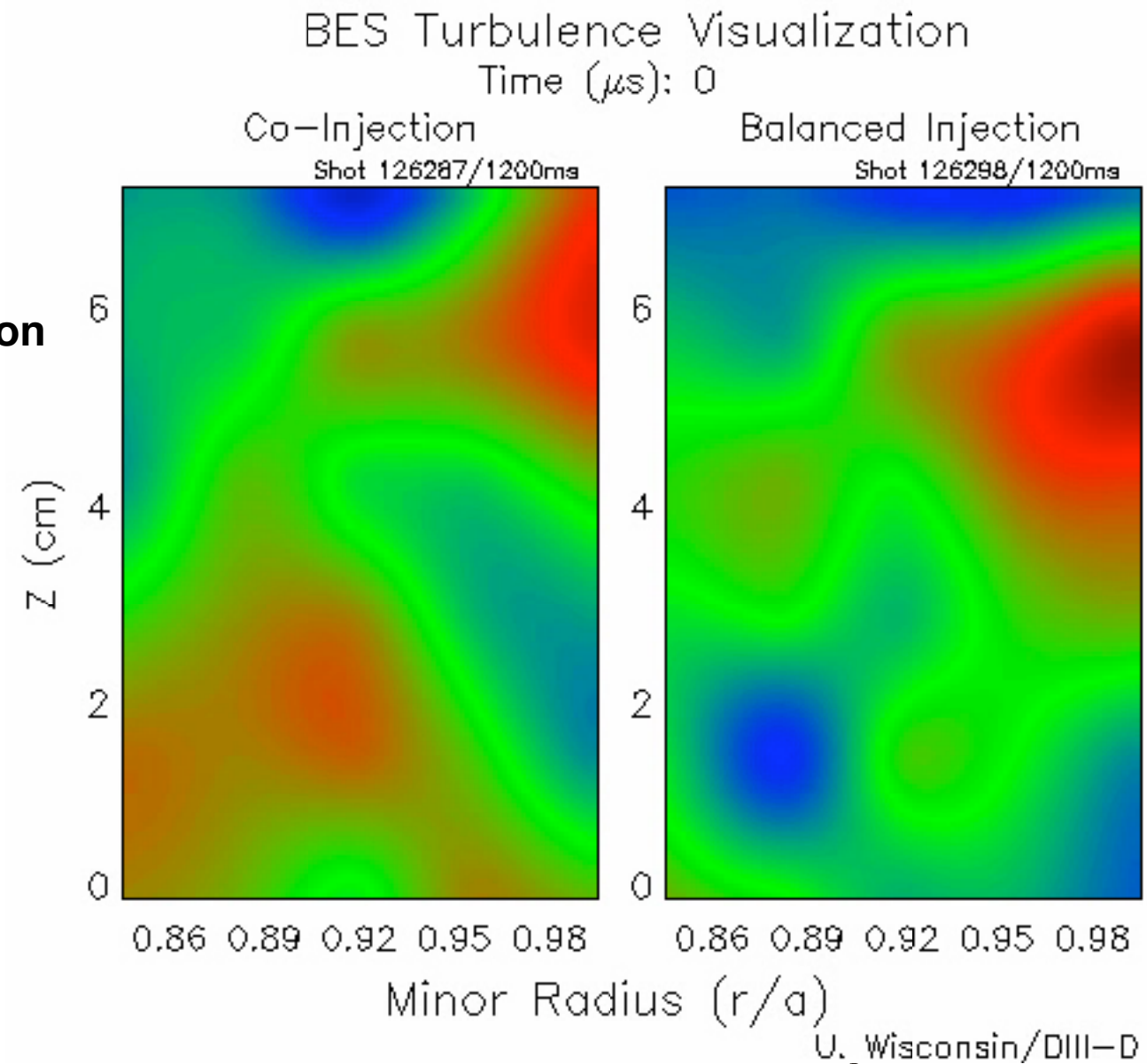




- **Dual-mode behavior in Balanced-injection discharge**
- **Counter-propagating low-frequency mode (electron diamagnetic direction)**

Turbulence Flows Near Edge Depend Strongly on Injected Momentum

- **Co-injected discharges exhibited uniform poloidal convection of turbulence in ion diamagnetic direction (ExB direction)**
- **Balanced-injected discharges have significantly different dynamics:**
  - no clear "flow" at edge



SUMMARY

- **Power threshold for L-mode to H-mode transition depends strongly on injected neutral beam torque:**

$$P_{THRESH,Co\text{-}injected} > P_{THRESH,Balanced\ injection}$$

- **2D edge turbulence and turbulence flows measured with BES**
- **Significant difference in edge turbulence behaviors:**
  - *Gradual evolution of poloidal turbulence flows leading up to LH*
  - *Balanced-injection discharge exhibits two counter-propagating modes*
  - *May be a large "natural" shear near r/a~0.9-0.95*
  - *Visualizations suggest time-varying flows*
- **Beneficial implications for ITER if P_{LH} lower than present extrapolations indicate**
- **Future work to include:**
  - ***Detailed analysis across the L-H transition, and in H-mode***
  - ***Comparison of counter-rotating plasmas with co- and near balanced***
  - ***Investigation of differences in turbulence dynamics between USN and LSN co-, balanced, and counter-rotating plasmas***
  - ***Application of 2D velocimetry techniques to infer V(r,z,t)***