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The L-H Transition and Turbulence Behavior in Ohmic H-modes on NSTX

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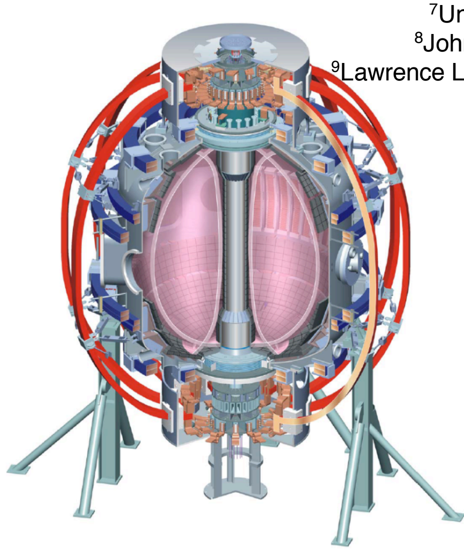

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Abstract

•Ohmic H-modes were only recently obtained on NSTX, several years after obtaining the first NBI heated H-modes. Ohmic H-modes are obtained without the added input and complication of fast particles and momentum that accompany NBI. This may allow a better chance of understanding the fundamental physics of the L-H transition and H-mode dynamics as well as turbulence simultaneously measured in the core and edge. On NSTX, two types of Ohmic H-modes have been observed, ELM free during lower single null (LSN) and ELMy, during double null (DN) divertor configurations. It was necessary for the plasma to be diverted for the L-H transition to occur. In several discharges, the edge electric field started to become more negative up to 20 ms before the plasma became diverted, when the L-H transition occurred. Bursts of fluctuations in edge electron density (ne) 10's of ms before the transition have also been observed. NBI heated H-modes are dominated by rapid peaking of the edge "ears" on the ne profile, which makes reflectometry of the core impossible. In contrast, for ELM free ohmic H-modes, the ne profile is initially peaked in the core. This allows access over tens of milliseconds for correlation relflectometry measurements in the core, which shows a decrease of more than two times in the correlation length across the L-H transition. At the same time, gas puff imaging (GPI) shows significant edge turbulence before the L-H transition as indicated by the "blob" activity, while after the transition the edge becomes very quiescent, similar to what is found in NBI heated H-modes.

Outline

- **Ohmic H-mode plasma characteristics**
  - Plasma must be diverted to obtain L-H transition
  - ELM-free in lower single null (LSN) divertor
- **Core turbulence characteristics**
  - Core correlation length decrease > 2x thru L-H transition
- **Edge turbulence characteristics**
- **Summary**

Introduction

Motivation

- **Study H-mode Physics without Complications of External Momentum and Hot Fueling**

- **Study Core and Edge Turbulence Simultaneously**
  - **Peaked n_e profiles allow reflectometry across whole profile.**

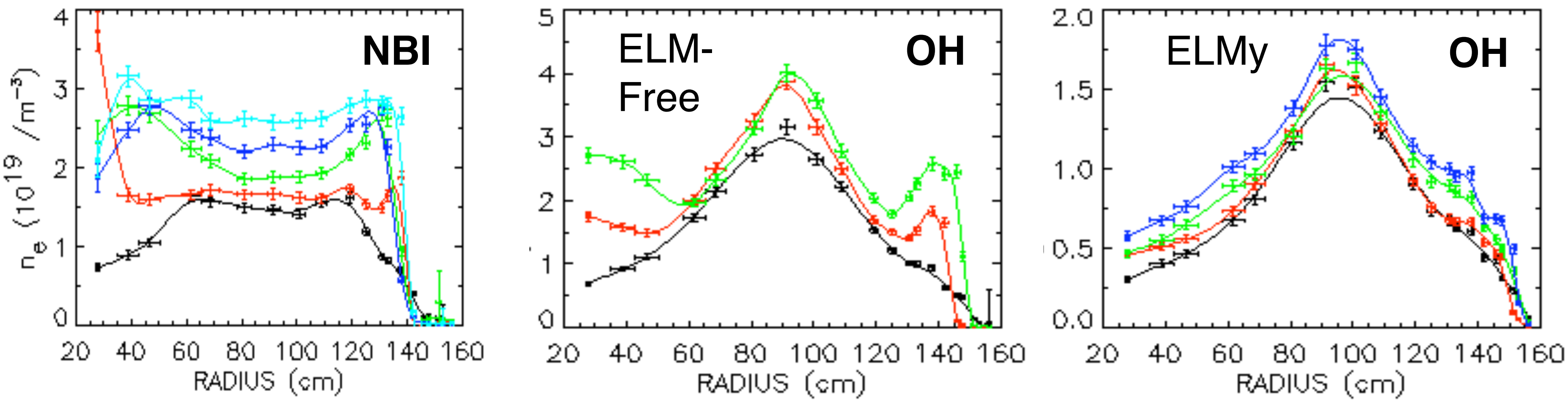
Also see Posters:

R. Maqueda - RP1.014 - Edge GPI

S. Kubota - RP1.029 - Core Reflectometry

Comparison of Density Profiles of NBI and OH H-modes

- Ohmic H-modes have low centrally peaked densities
  - Explore edge and core turbulence simultaneously
  - Target plasma for early NBI and combined ITB and ETB

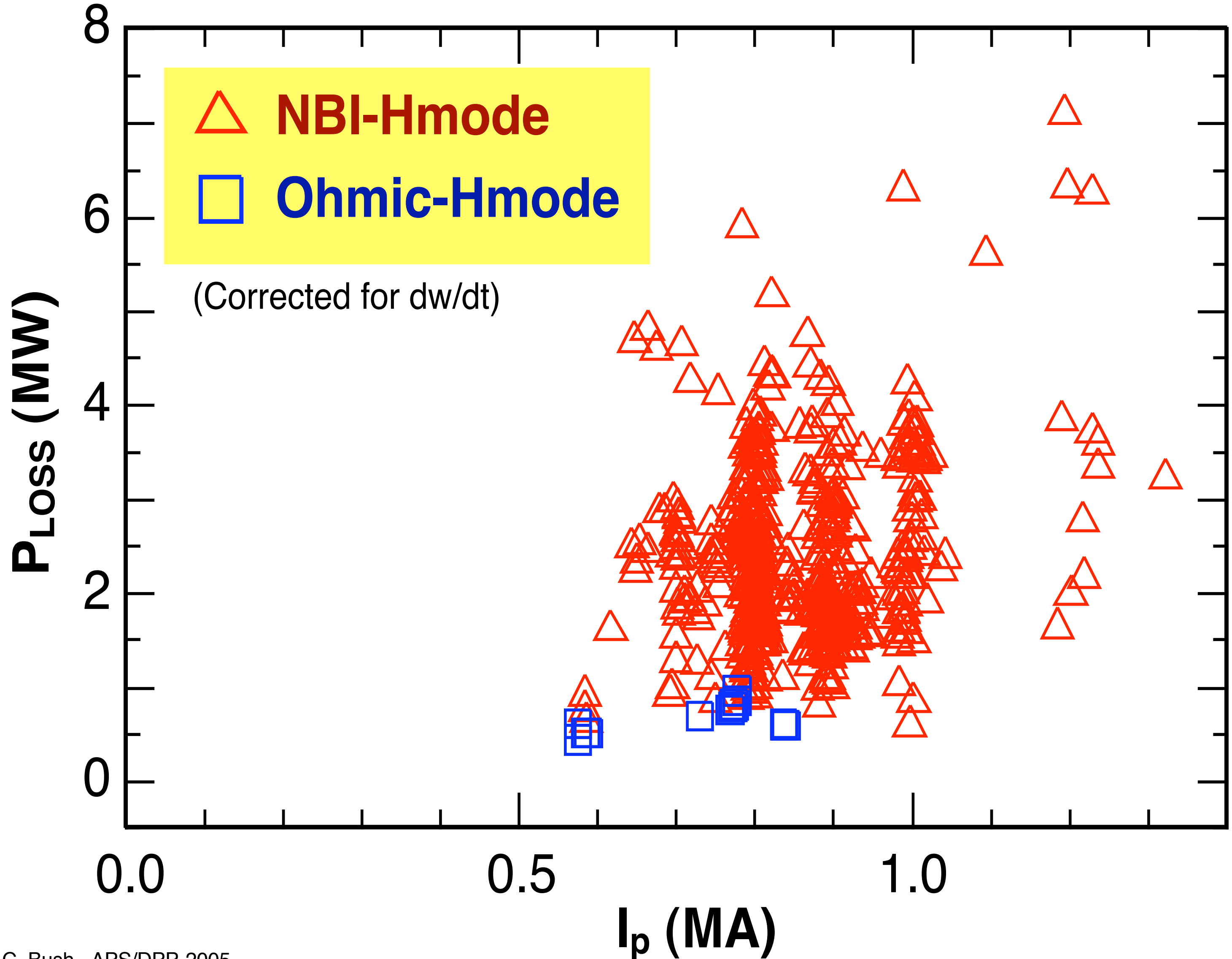


B. LeBlanc

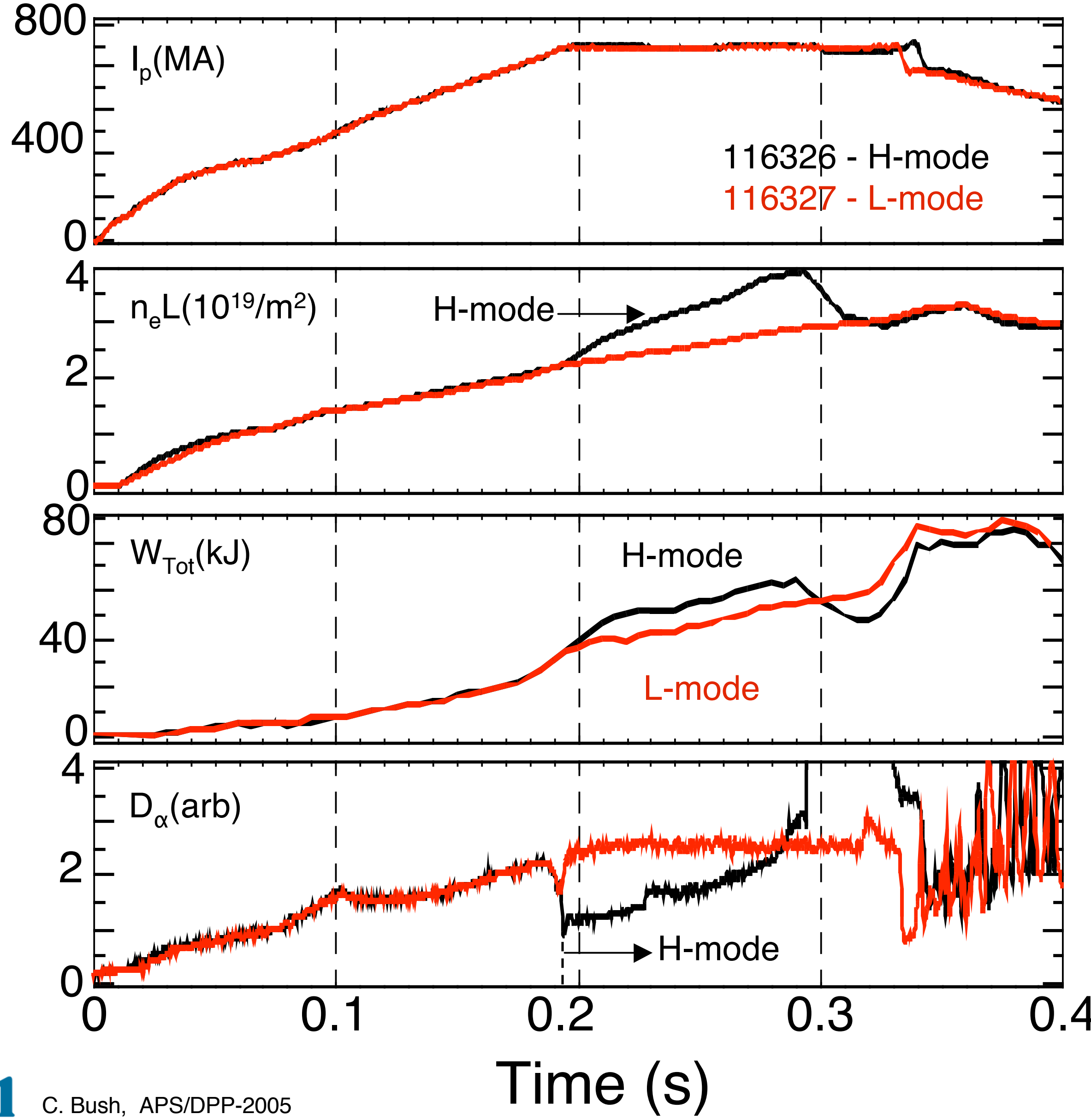
Characteristics of Ohmic H-modes

Lowest P_{th} Required for OH Hmodes

NSTX

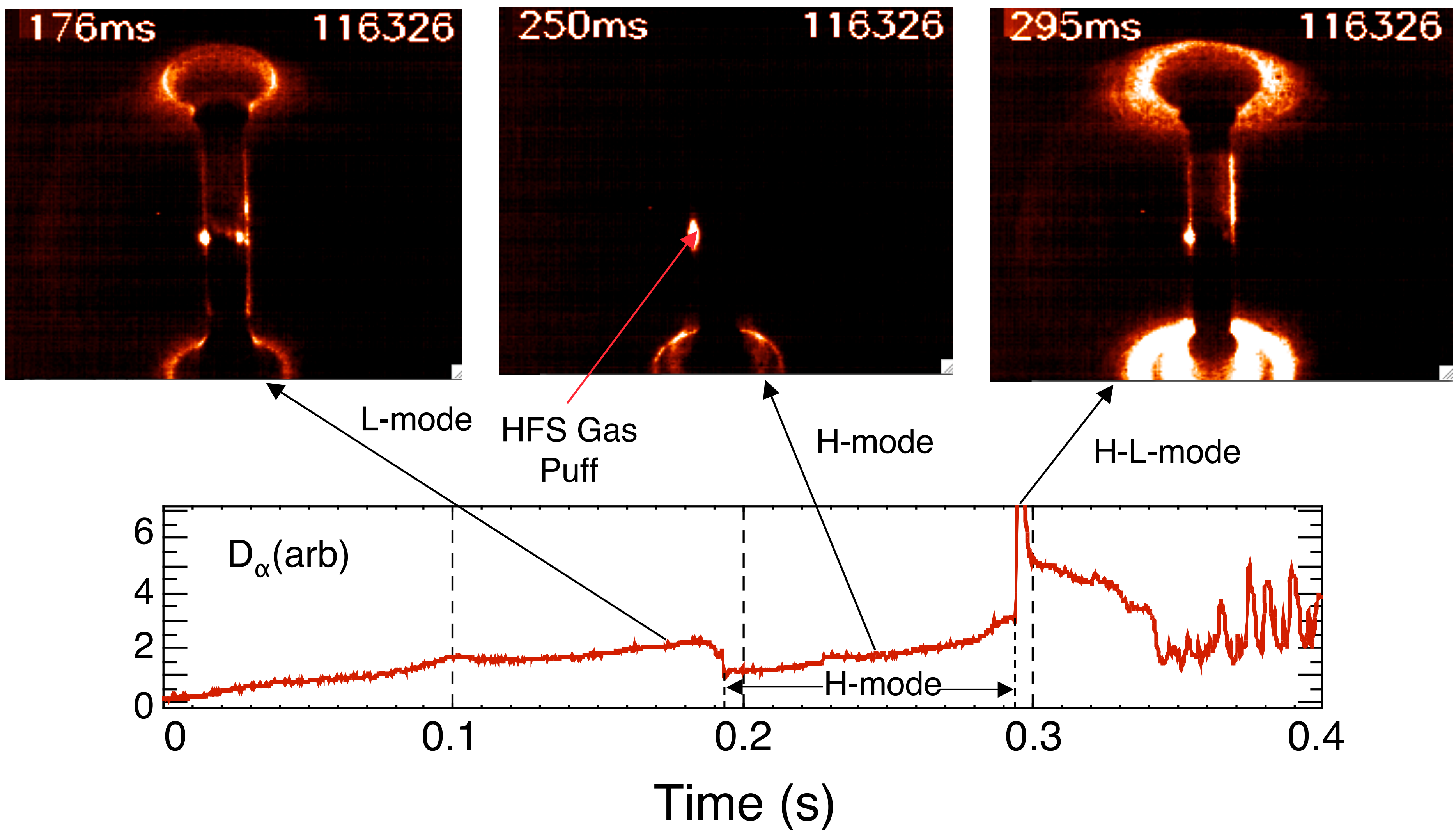


Plasma ne, W_{TOT} and Other Parameters Increase at the OHmic L-H-mode Transition

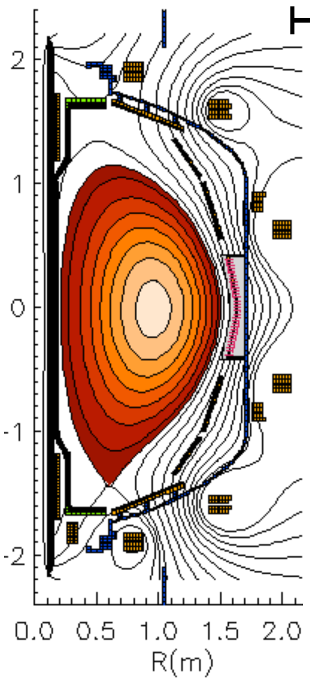


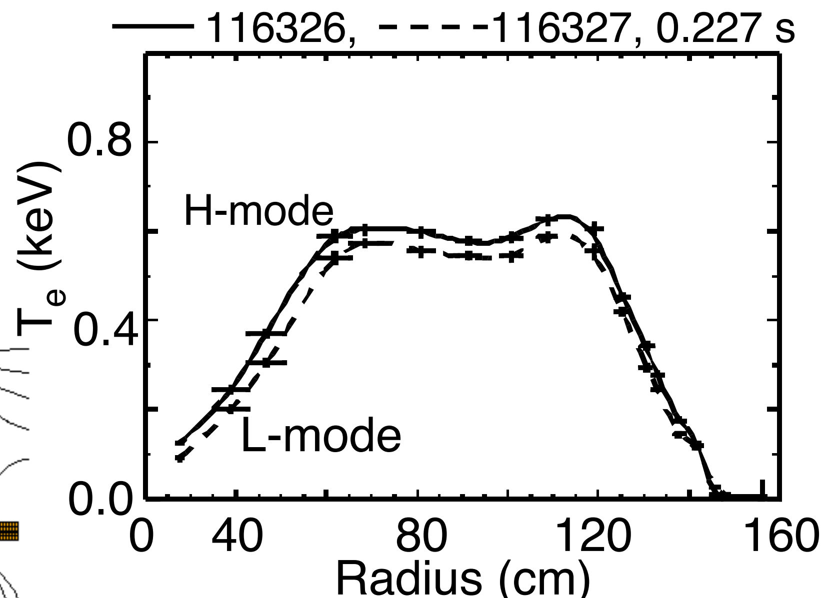
The Stored energy change Due to transition to H-mode is maintained through the H-phase

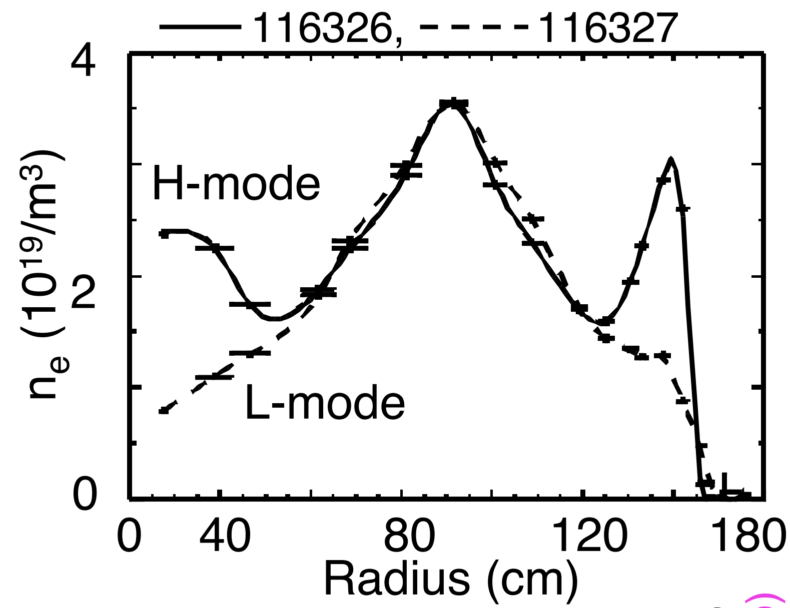
No Interaction with Centerstack when LSN Ohmic H-mode

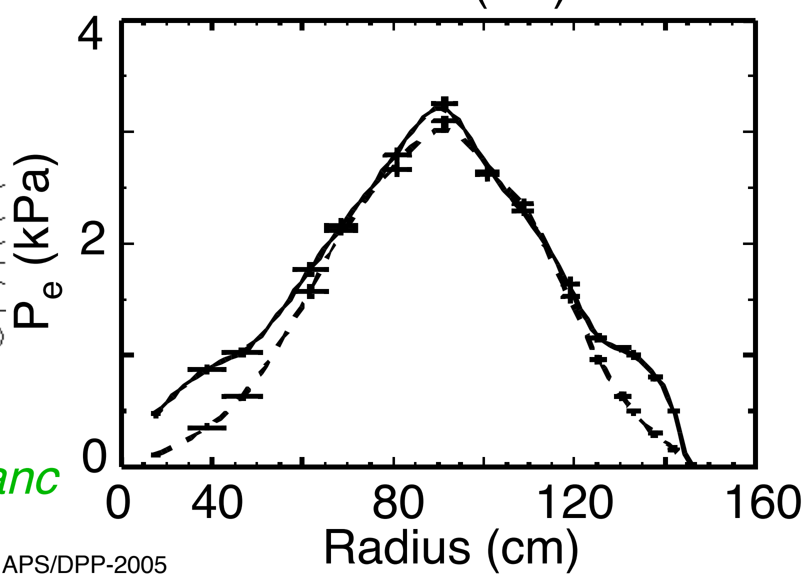


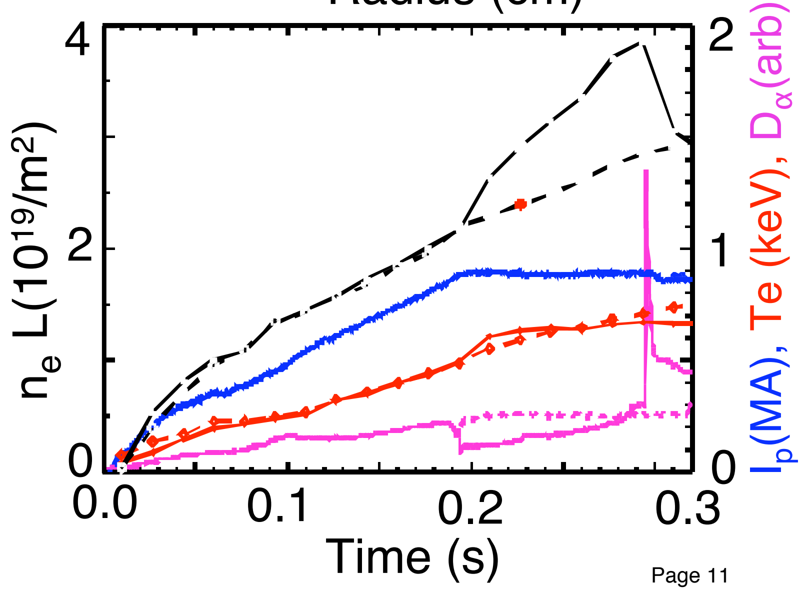
ELM-Free OHH-mode Obtained with LSN











B. LeBlanc

Model for the L-H Transition

Model: E x B Flow Shear Breaks Turbulent Eddies to Transition to a Quiescent State

NSTX

- Sheared ExB flow is expected to suppress turbulence leading to enhanced core confinement
- The ExB flow is determined from the zeroth order force balance equation for any species i:

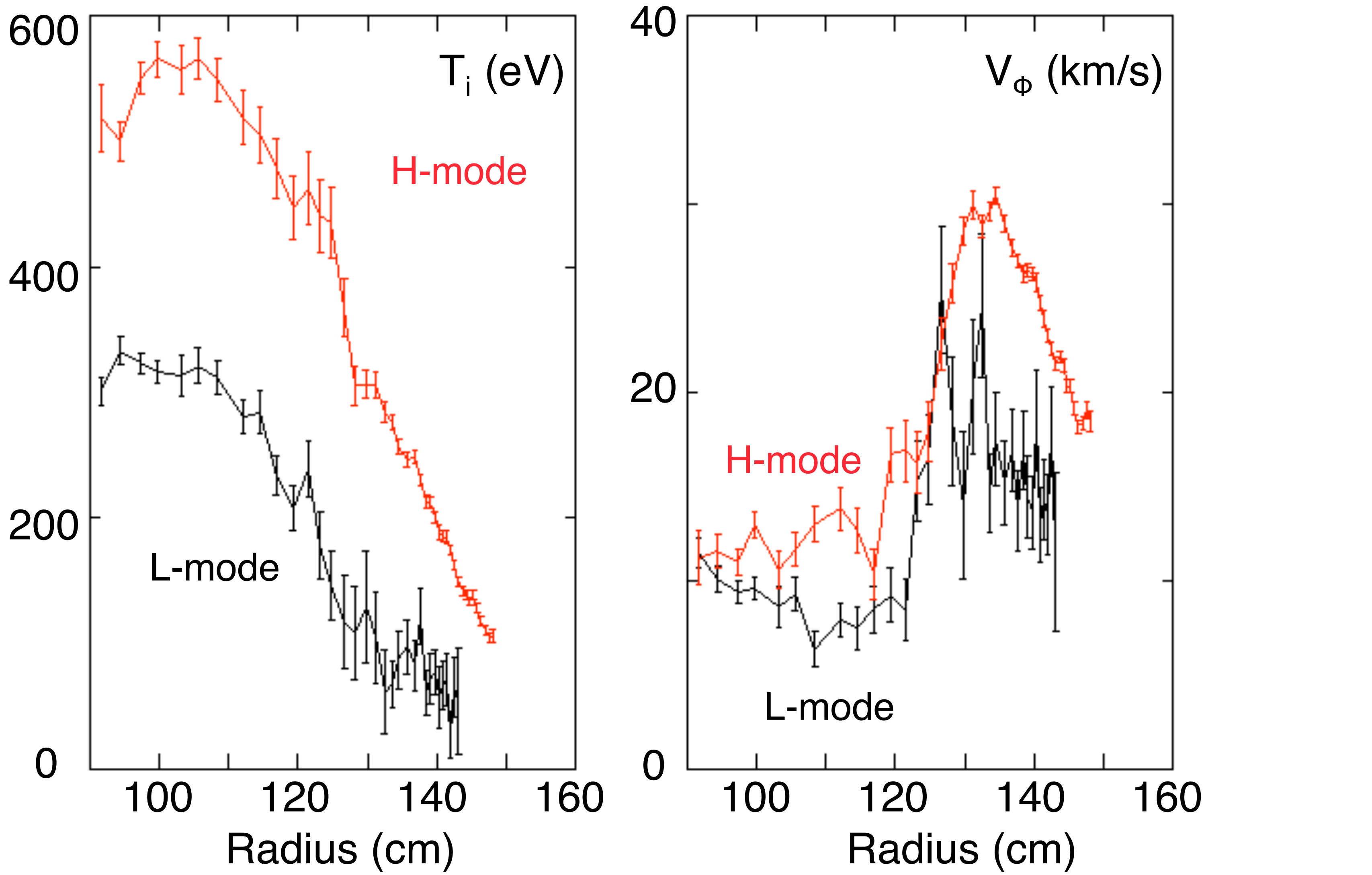
$$E_r = \frac{1}{Z_i e}\left[\frac{T_i}{n_i}\frac{dn_i}{dr} + \frac{dT_i}{dr}\right] - V_\theta B_\phi + V_\phi B_\theta$$

- E_r can be solved for by using measured profiles of:

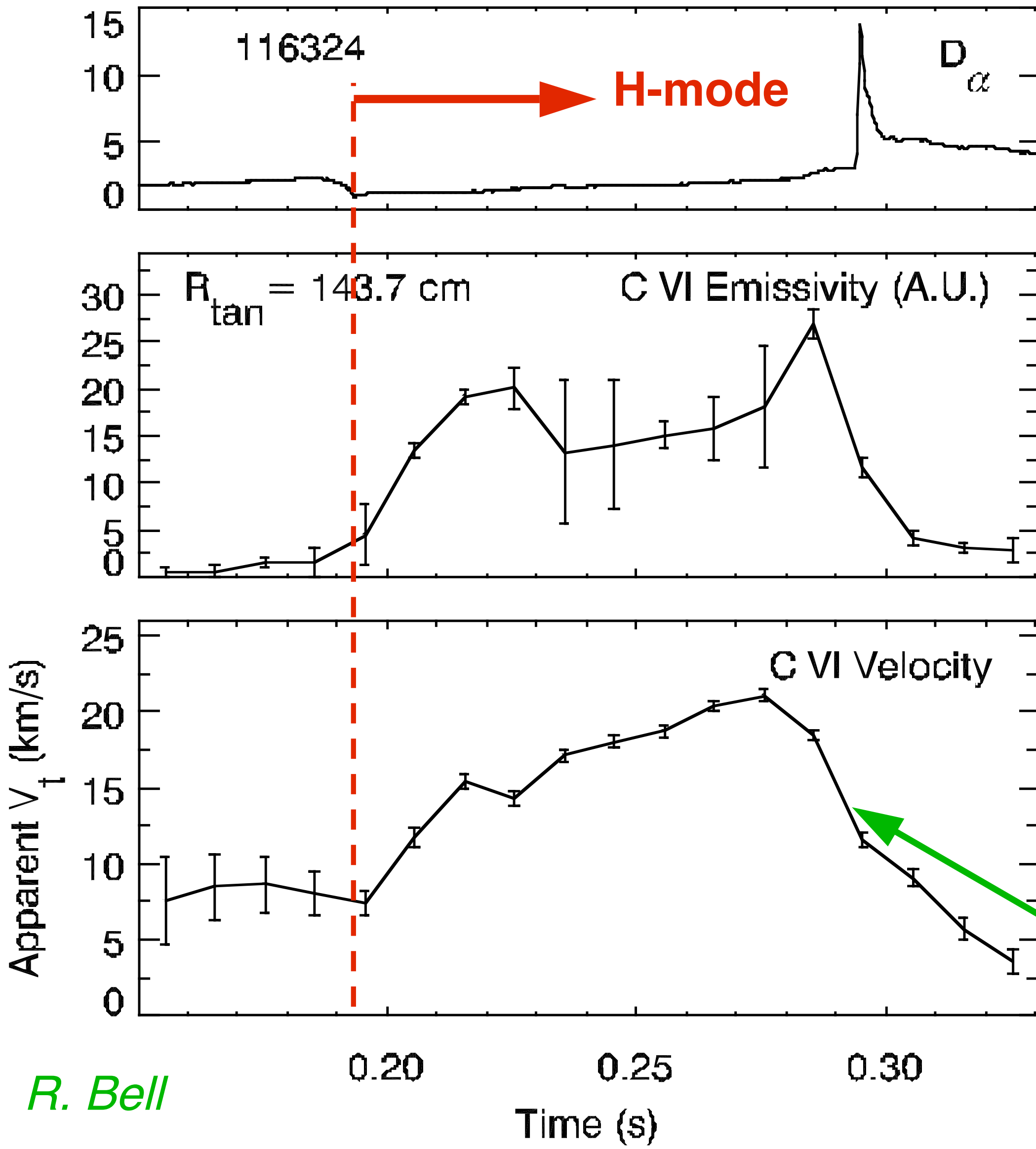
n_i, T_i, V_Φ: using charge exchange recombination spectroscopy (CHERS)

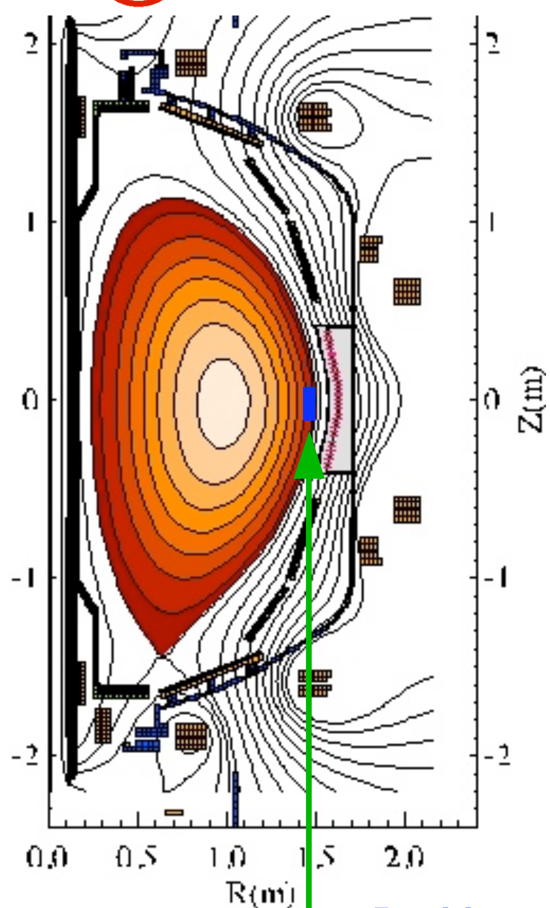
B_θ from MSE, combined with TRANSP simulations

Ion Temp. (T_i) and Toroidal Velocity (V_t) Increase during OHH-mode



C VI Emissivity and Toroidal Velocity Increase in Plasma Edge during Ohmic H-mode on NSTX





Position of measurement

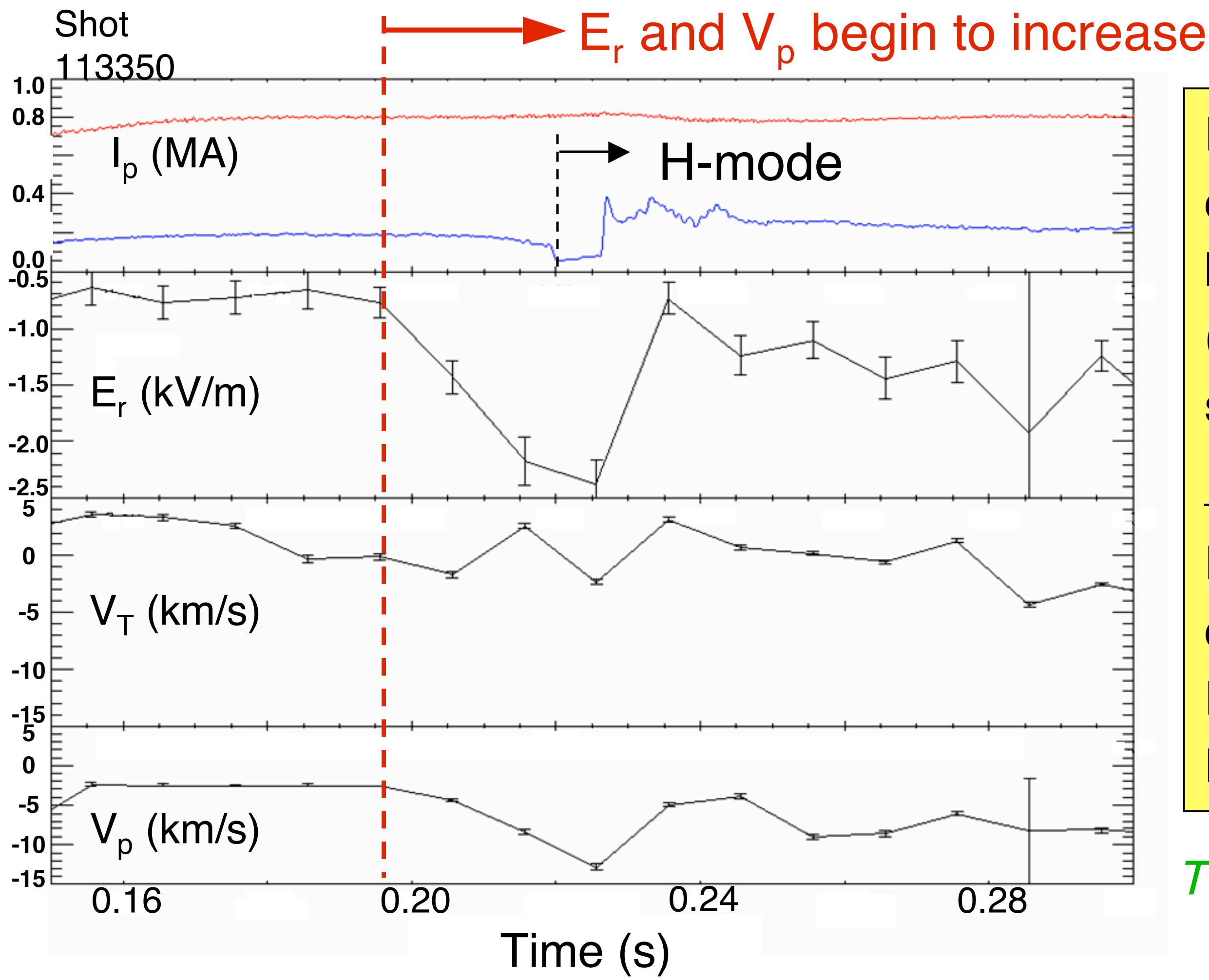
R. Bell

C VI Edge Toroidal Velocity, V_t, Increases During H-mode

Ohmic H-modes sometimes show E_r and V_p change ~ 20 ms prior to L-H transition

NSTX

- These changes are not seen on all shots so they are not *causal*



E_r and V_p begin to change 10 to 20 ms before L-H transition (here at t ~ 0.220 sec).

E_r and V_p are obtained from the Edge Rotation Diagnostic (ERD).

T. Biewer

Core Turbulence Studies

The Correlation Length in the Core Decreases by a Factor > 2 Across the L-H Transition

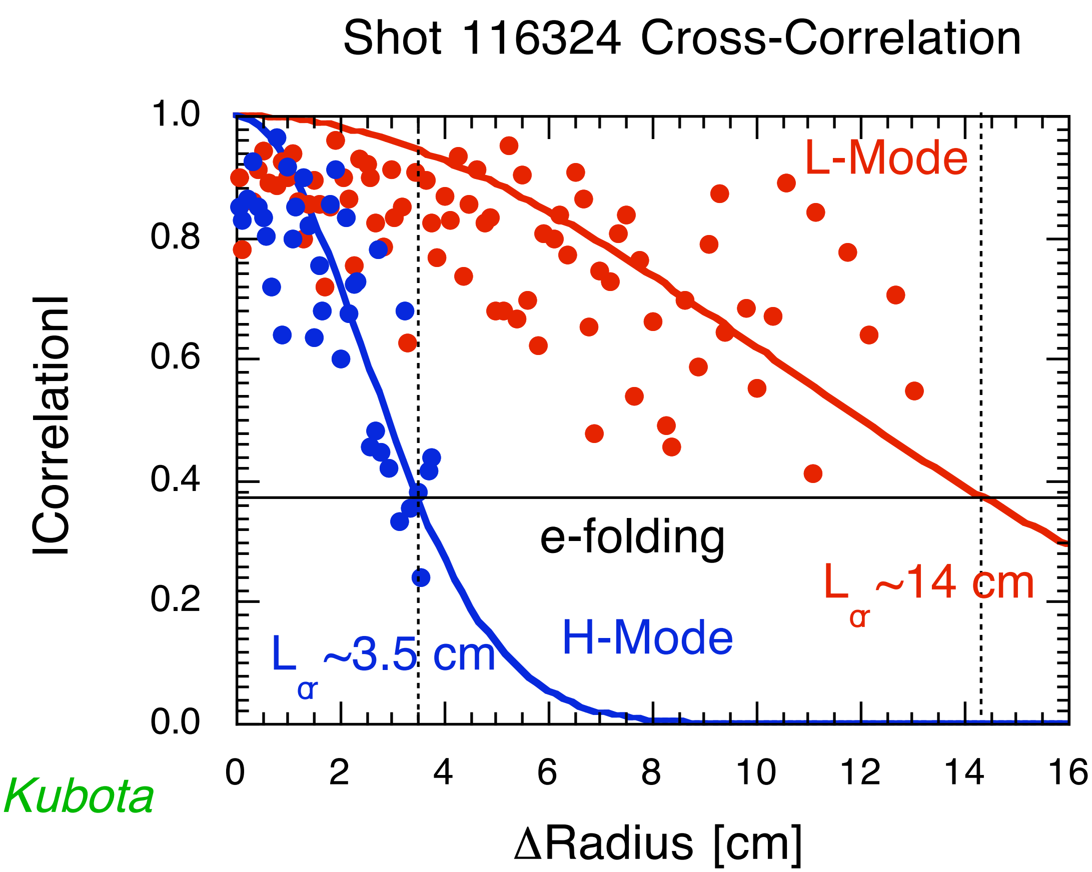
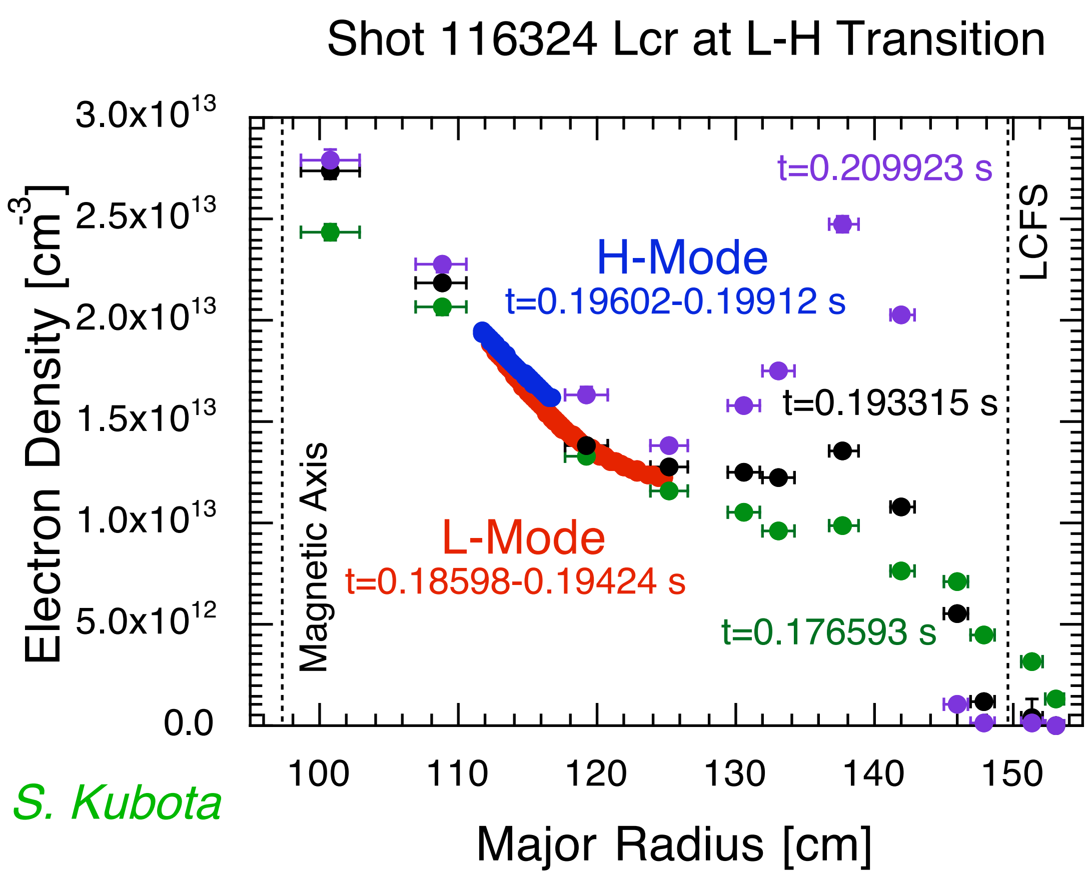


Figure: Shows the core correlation length drops by a factor > 2 across the L-H transition.

S. Kubota

The Density Change in the Core is Small Across the L-H Transition

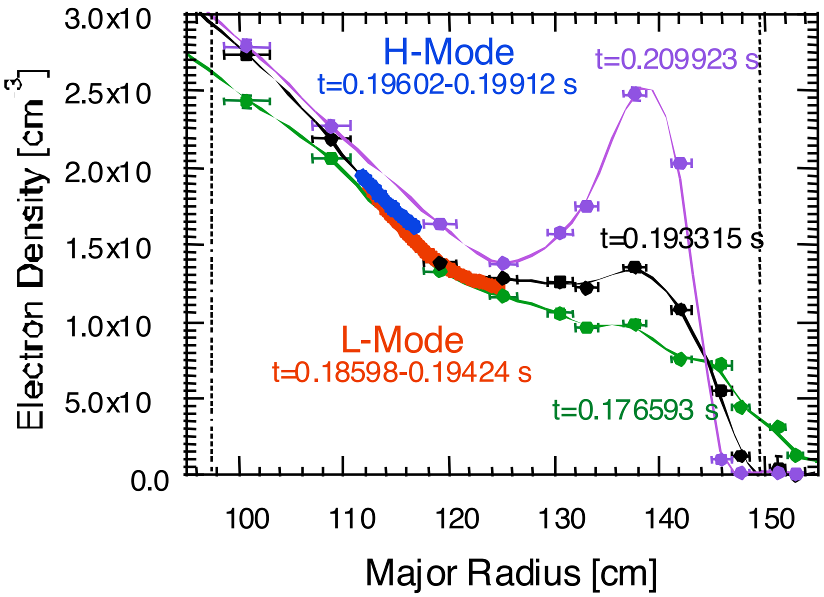
NSTX



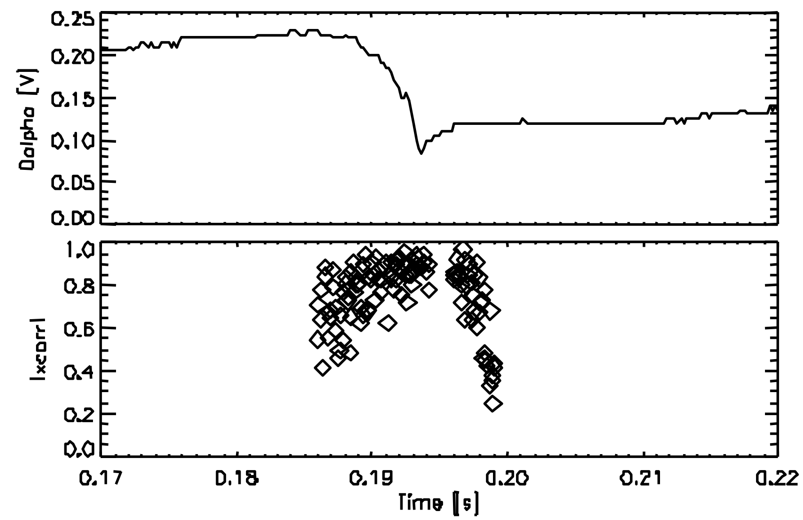
S. Kubota

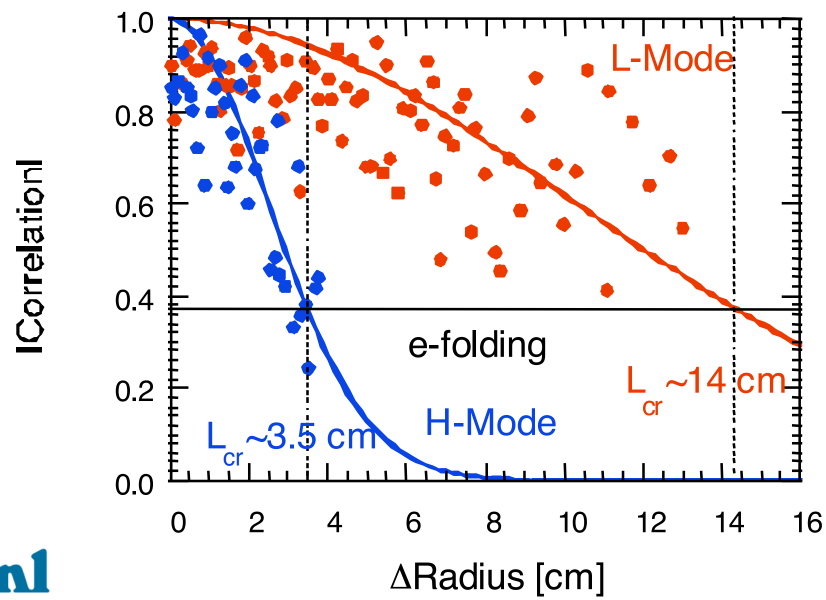
Figure: Shows density change at the edge is not large enough to account for the change in L_{cr} across L-H.

Correlation Length Decreases with L-H Transition



Time series of cross-correlation values near L-H transition.



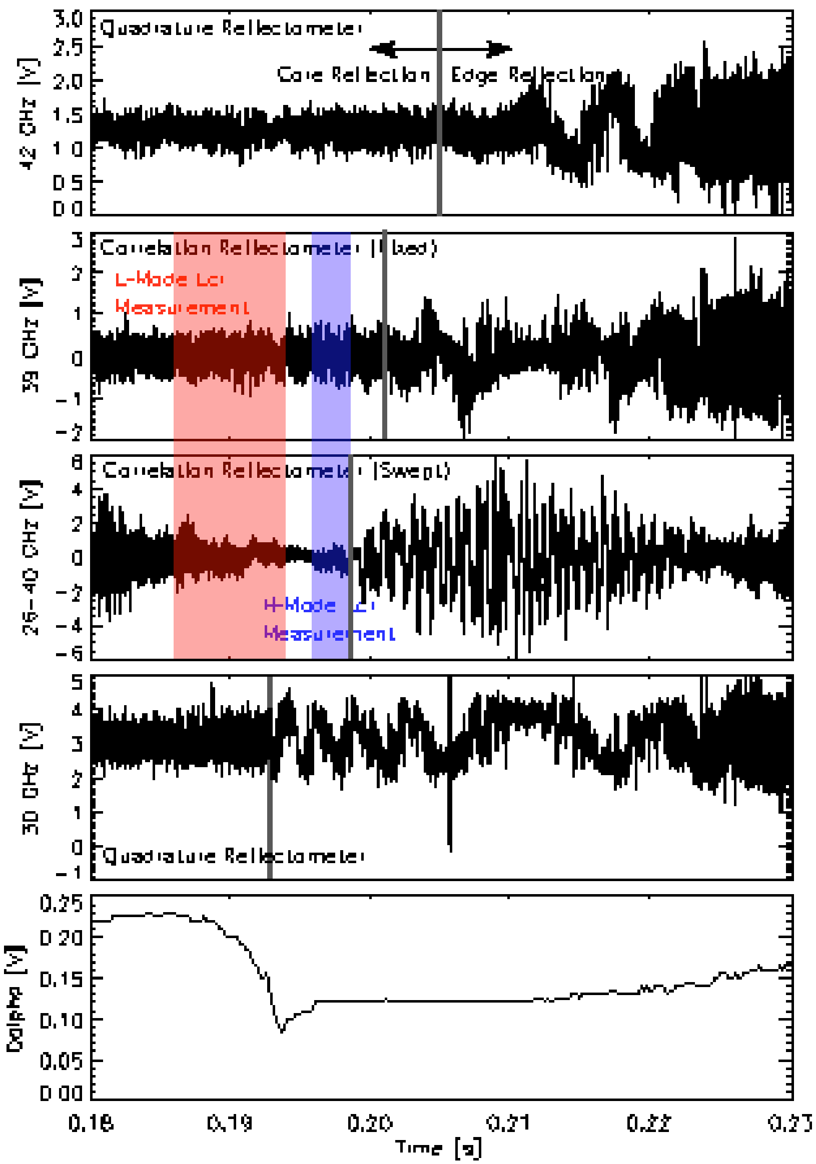


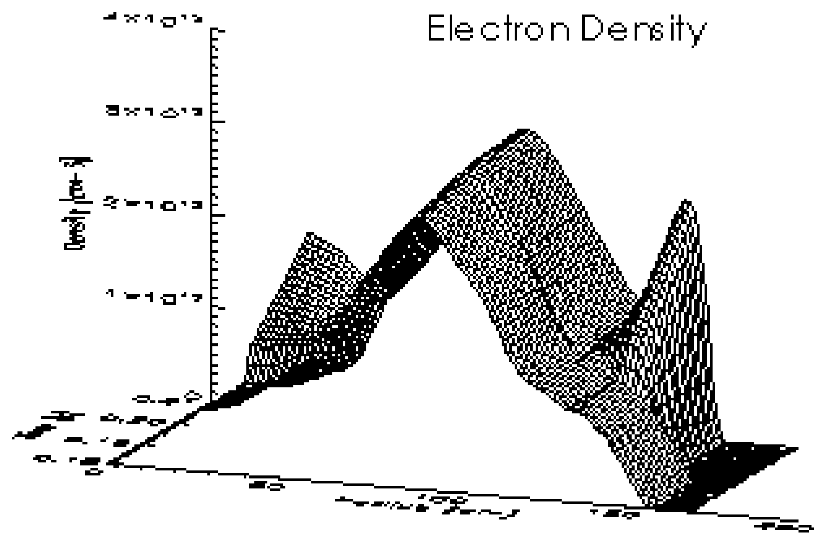
- Typical L_{cr} drops from ~10-20 cm to ~4-8 cm at L-H transition.
- Eventual rise in edge density cuts off reflectometer signal.
- For core 42 GHz channel, statistical properties of signal (amplitude histogram, complex spectrum) remain constant across transition -> turbulence properties closer to axis changing little.

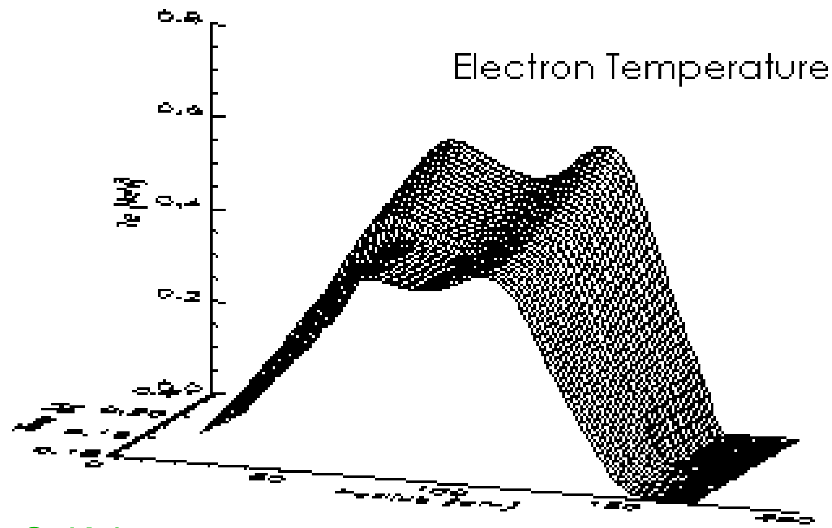
S. Kubota

Profile Evolution During Ohmic H-mode

Reflectometer Raw Signals and Dalpha





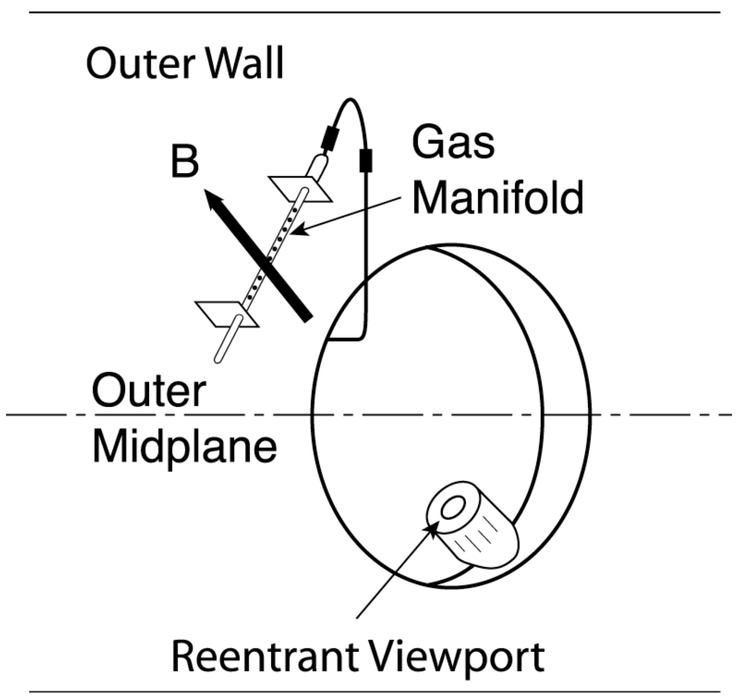


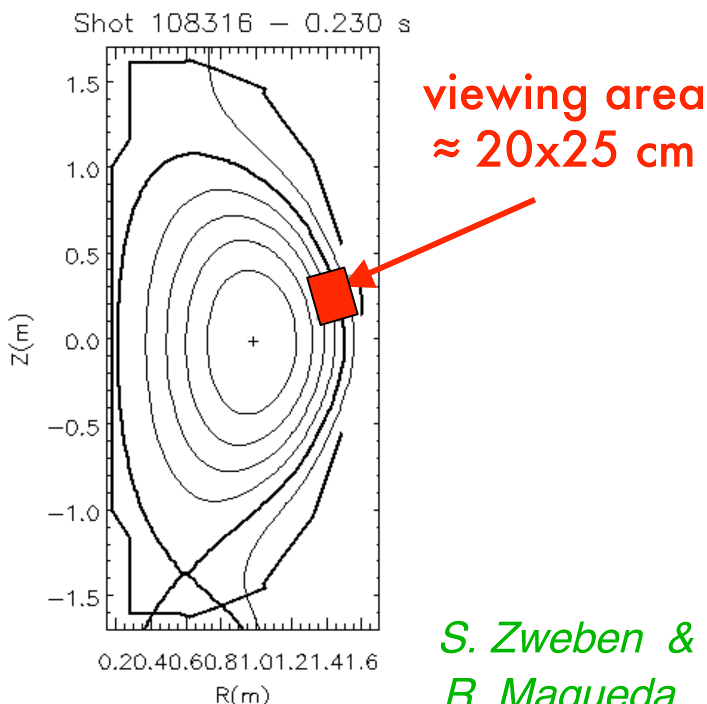
S. Kubota

Edge Turbulence Studies

GPI Hardware and Orientation

- Looks at D_α light from gas puff $I \propto n_o n_e f(n_e, T_e)$
- View ≈ along B field line to see 2-D structure ⊥ B
- Image coupled to camera with 800 x 1000 fiber bundle



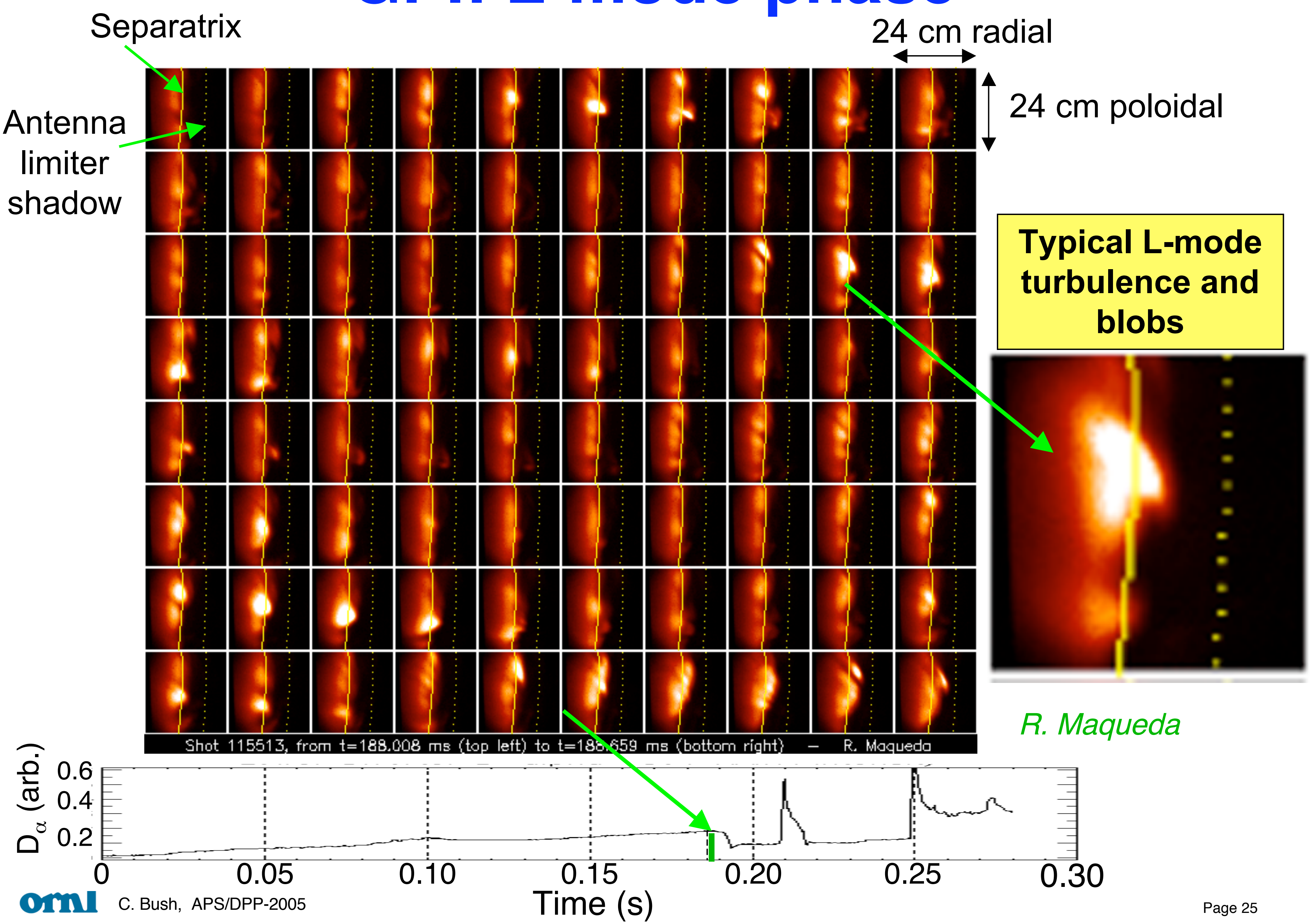


S. Zweben & R. Maqueda

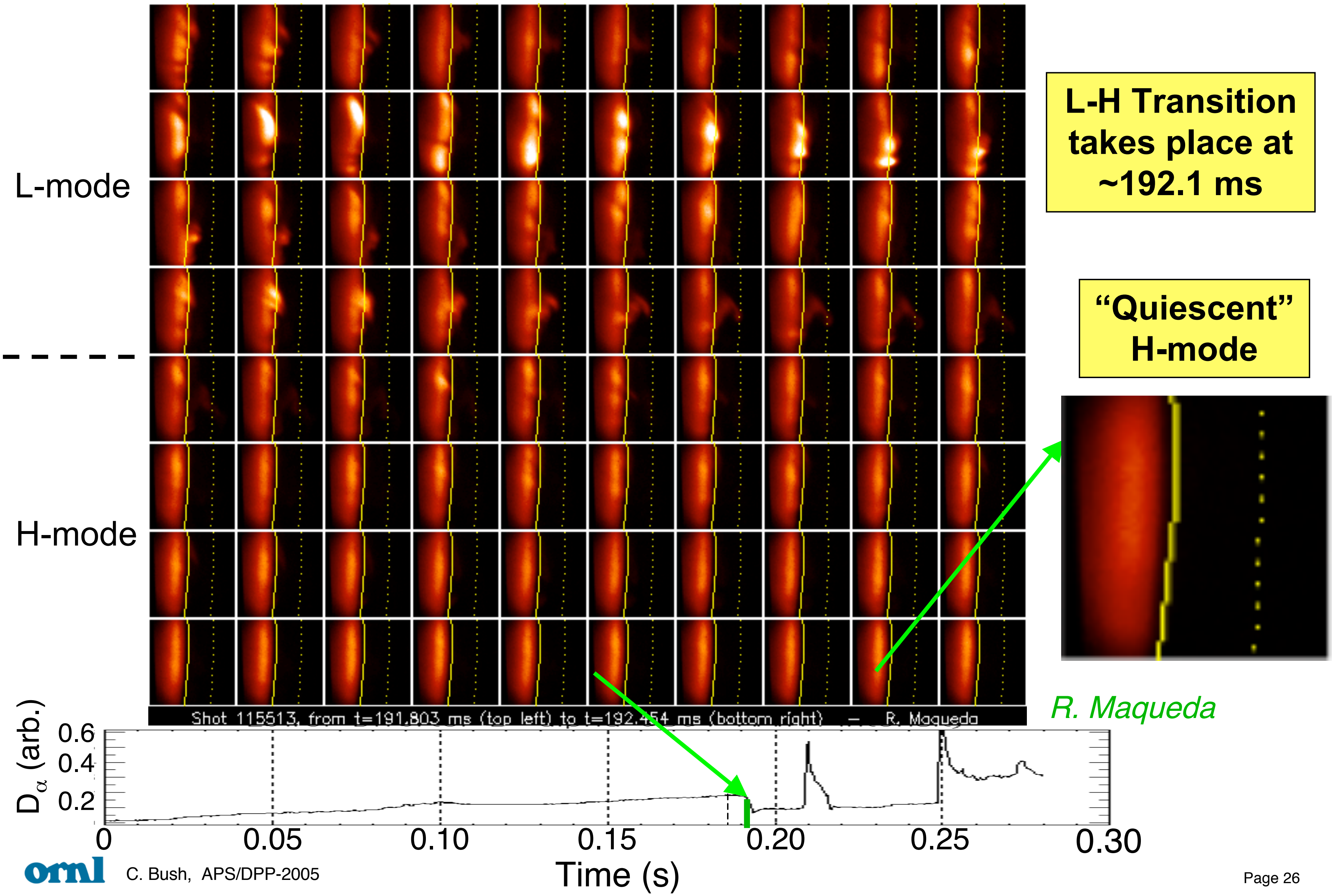
Summary of GPI Results

- Edge turbulence observed during Ohmic H-modes in NSTX is **similar** to that measured in neutral beam heated H-modes.
- **Quiescent** H-mode edge is present with the turbulence much reduced with respect to the preceding L-mode phase.
- **Only small amplitude poloidal modulations** of the emission has been observed during H-modes.
- The **fluctuation level decreases** from a typical 10%-40% RMS level in L-mode to an also typical 5% RMS level in a quiescent H-mode.
- The **poloidal autocorrelation lengths** appear to be somewhat <u>smaller</u> than those previously reported in H-modes.

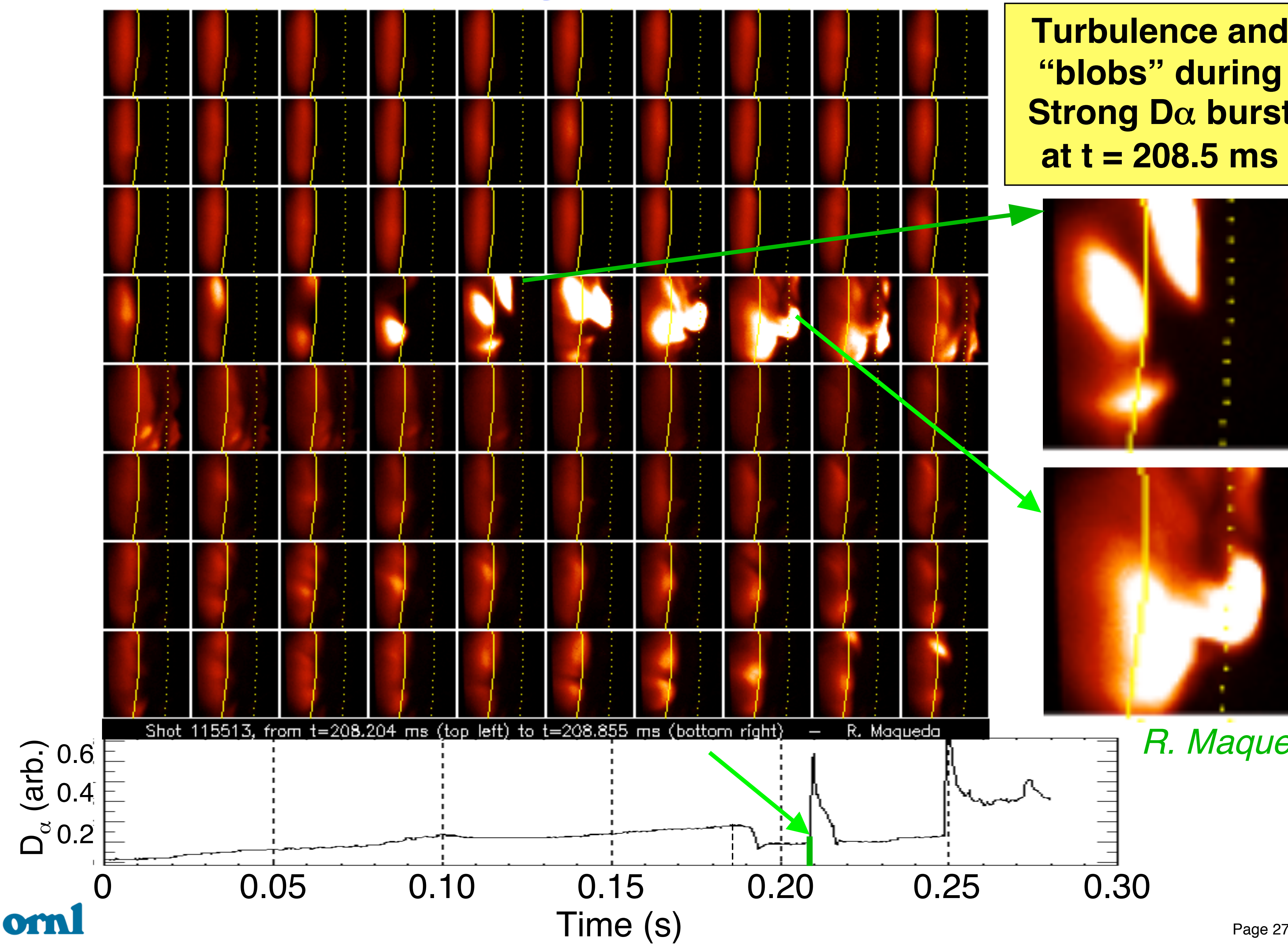
GPI: L-mode phase



GPI: L-H transition



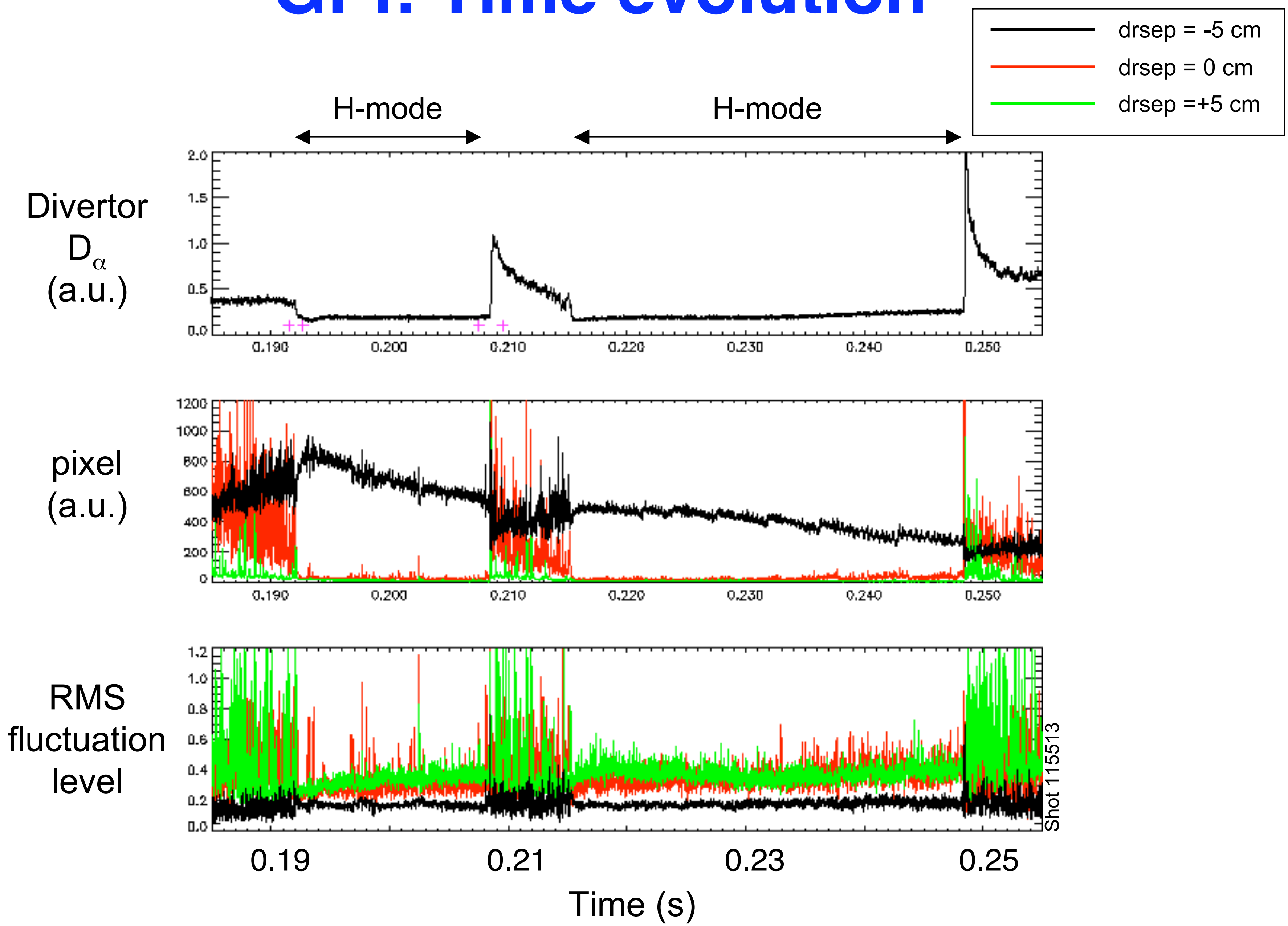
Turbulence & bright blobs, at ELM Burst?



Turbulence and "blobs" during Strong Dα burst at t = 208.5 ms

R. Maqueda

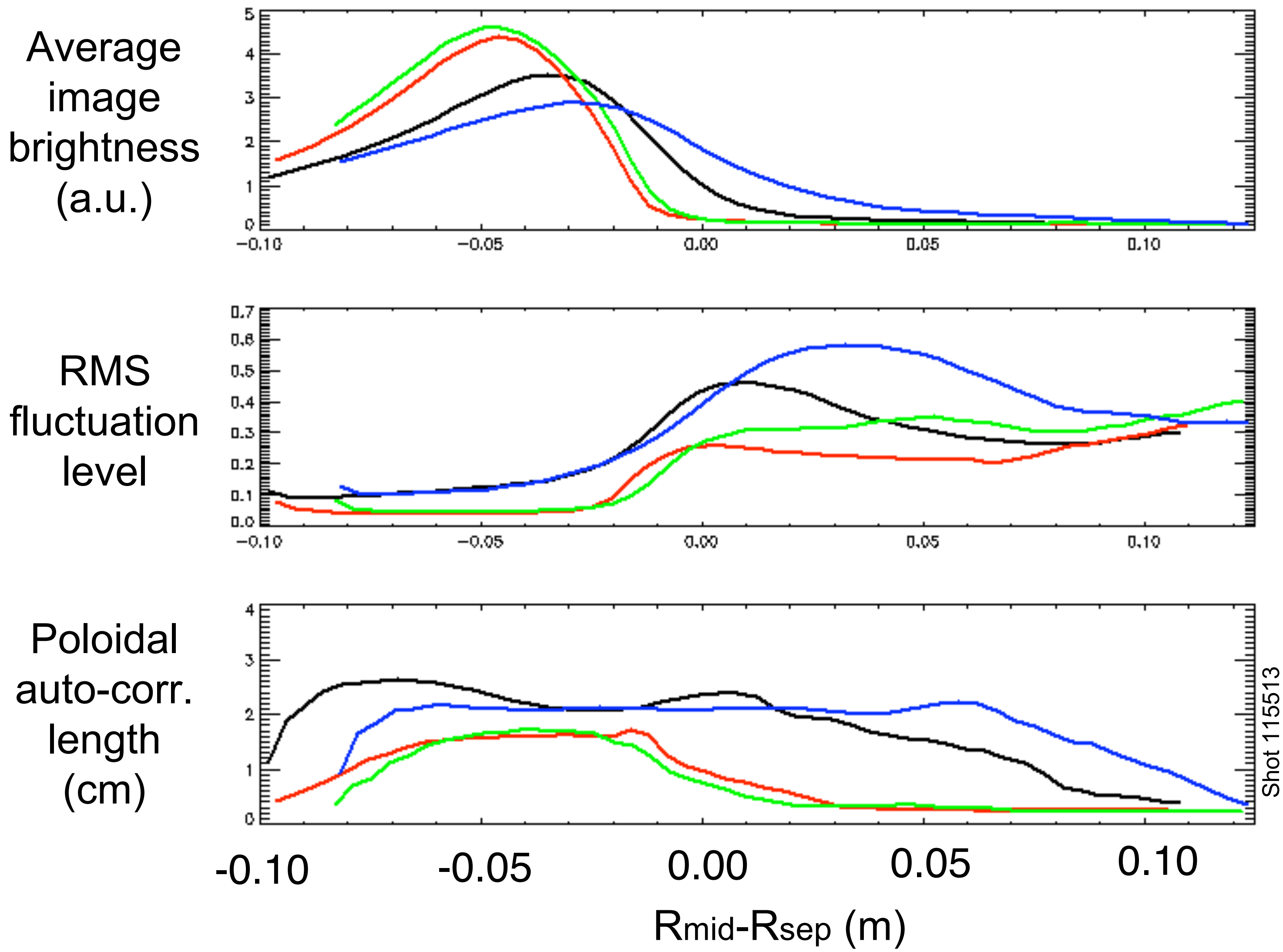
GPI: Time evolution



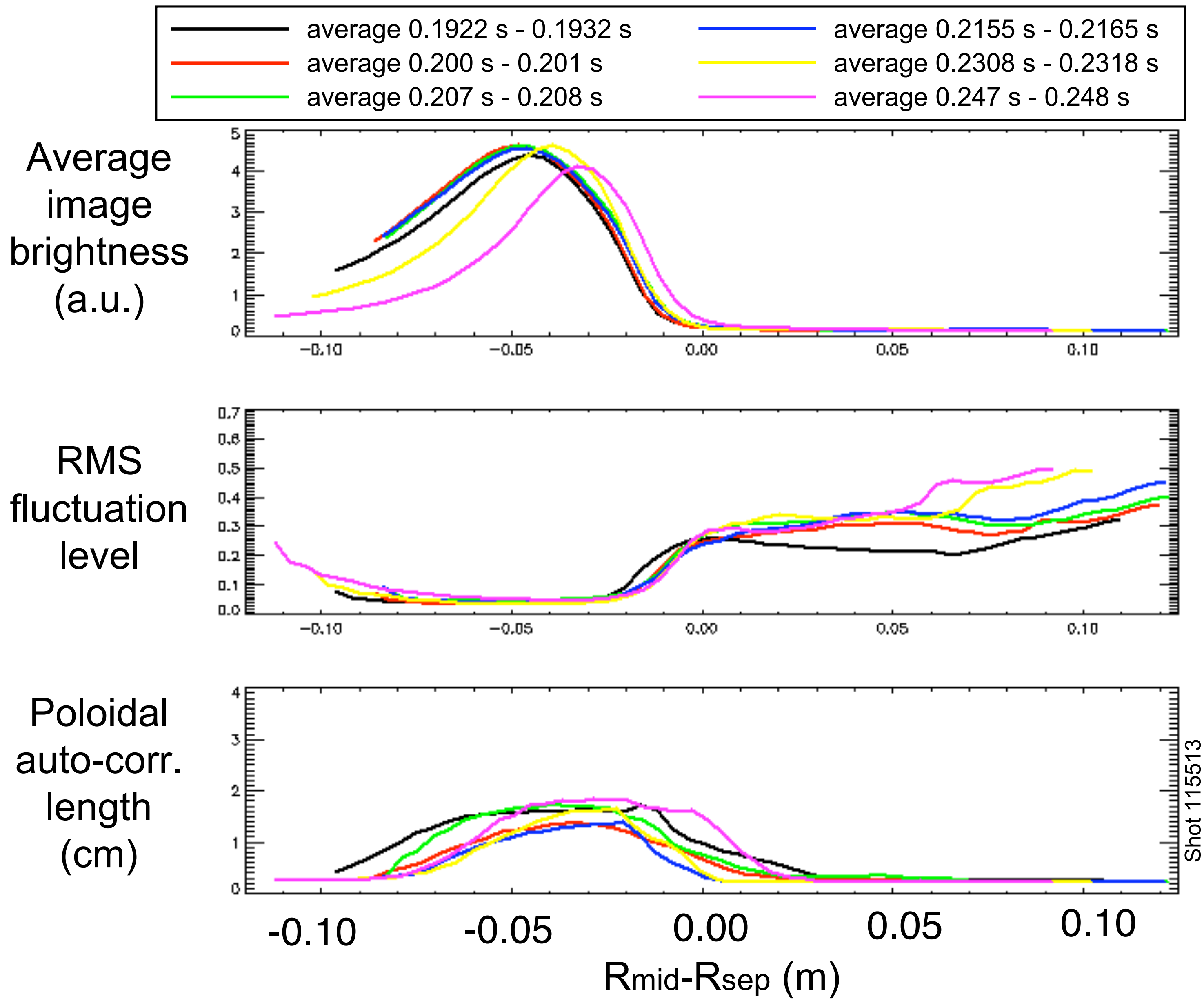
GPI: Radial Profiles

- average 0.191 s - 0.192 s (L-mode)
- average 0.1922 s - 0.1932 s (H-mode)
- average 0.207 s - 0.208 s (H-mode)
- average 0.209 s - 0.210 s (L-mode)

- Lower RMS Level and Poloidal Correlation Length in H-mode

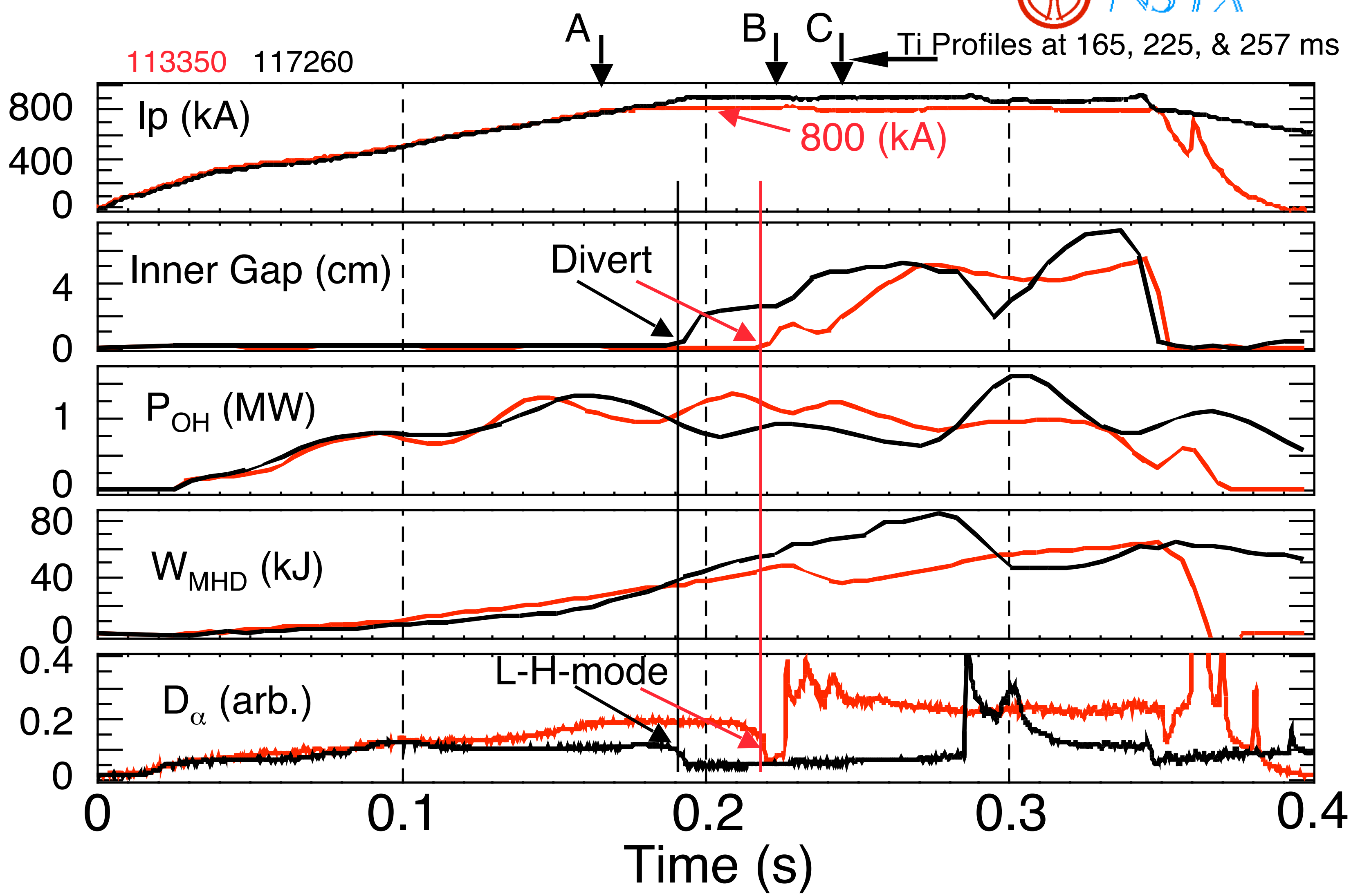


GPI: Radial Profile Evolution Shows Little Change During H-mode



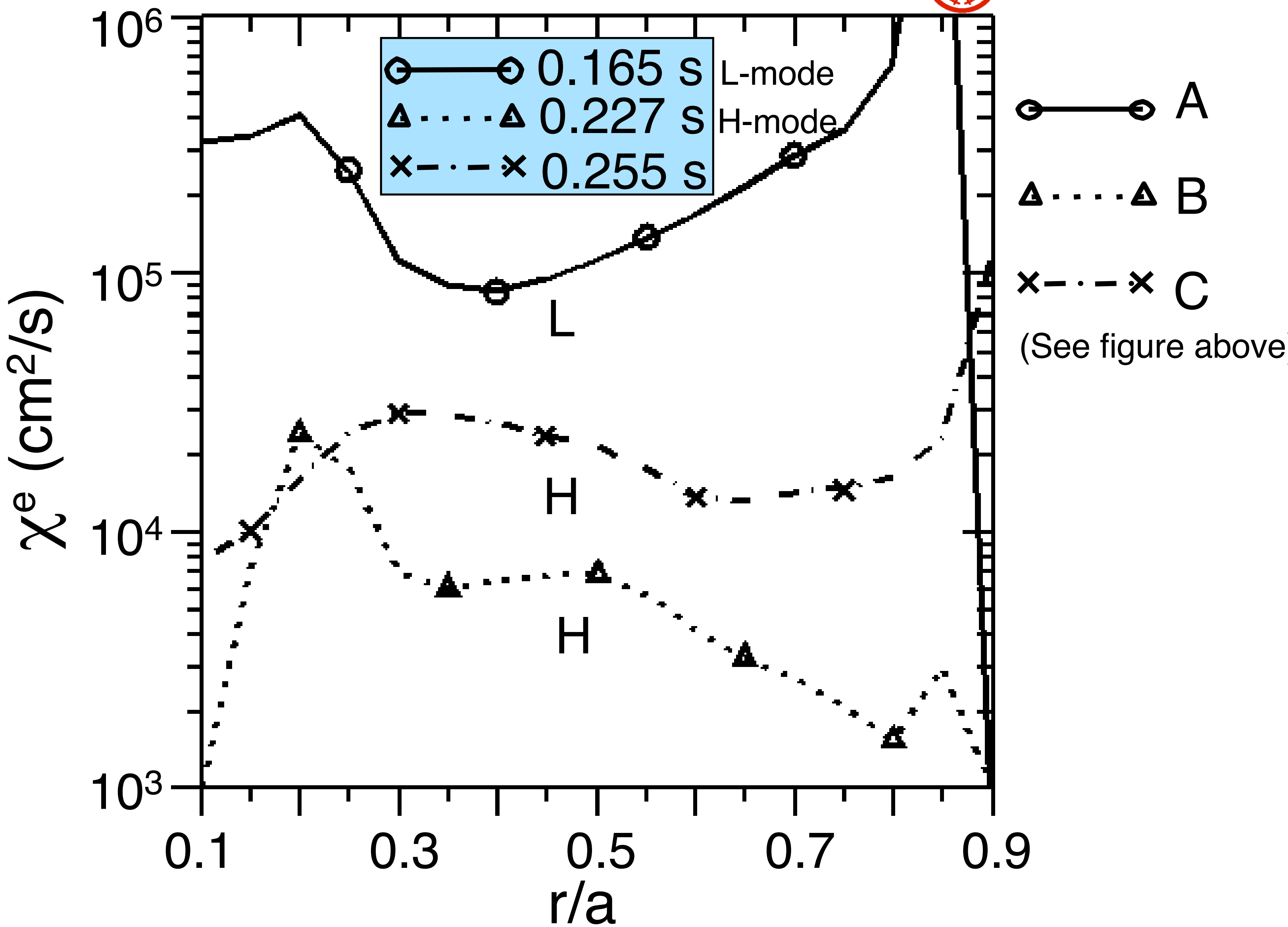
Transport Simulations

The NSTX Plasma must be Diverted for the OHmic L-H-mode Transition to Occur

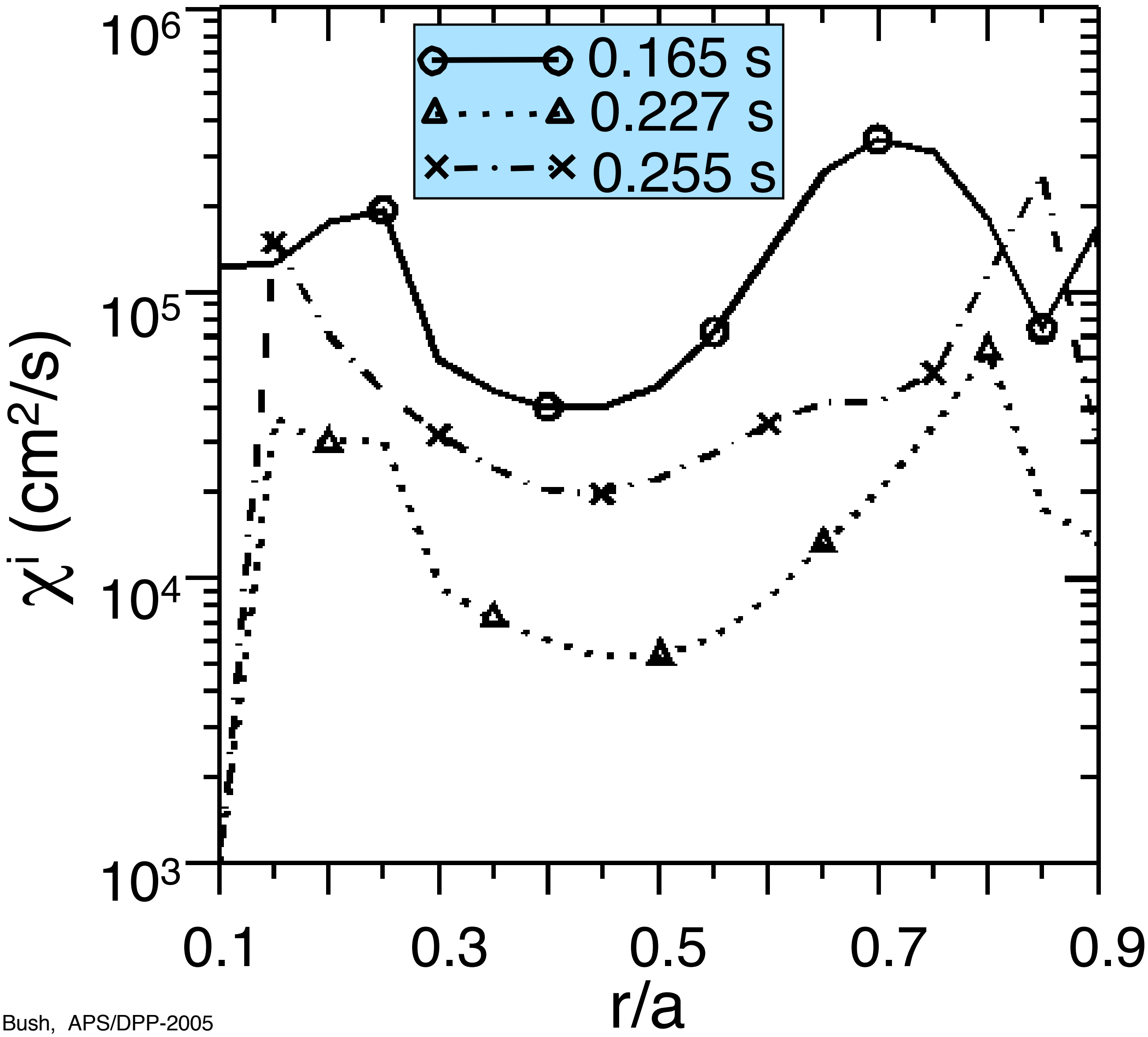


Electron Heat Diffusivity, χ^e Lower during OHH-mode

NSTX

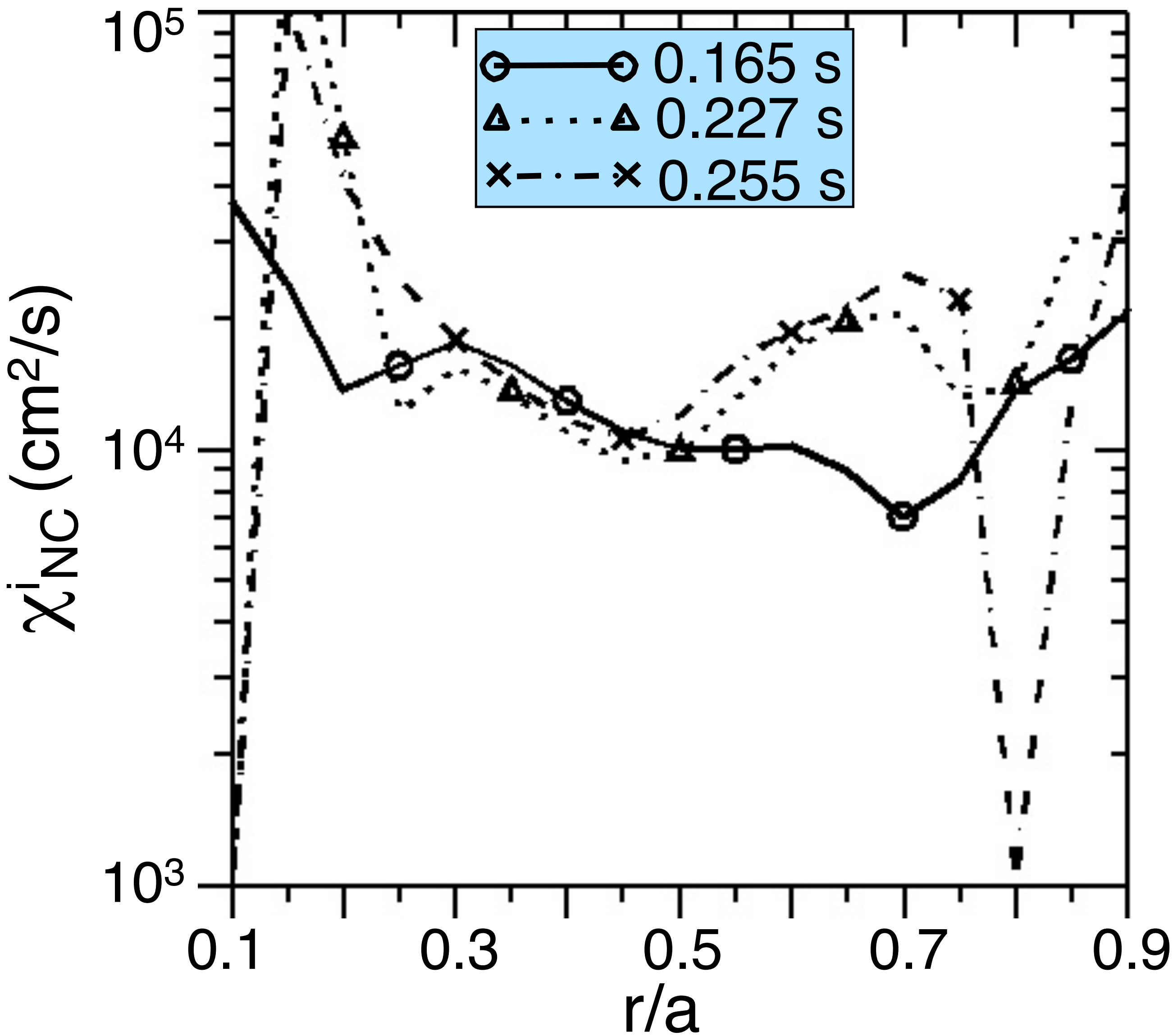


Profiles of Ion Heat Diffusivity, χ^i



Profiles of Ion Neoclassical Heat Conductivity, χ^i_{NC}

NSTX



Summary

- OHH-modes have centrally peaked density profiles.
  - Allows core turbulence studies during early H-phase
- OHH-mode $\chi i \sim \chi i_{NC}$
  - Short H-mode at I_p = 600 kA, B_t = 3 kG
- Core turbulence correlation lengths decrease in OHH-mode by > 2x.
  - Perhaps due to the centrally peaked density profiles
- Edge turbulence is very quiescent during OHH-mode.
  - Occasional bursts (ELMs ?)

END