NSTX

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Source and effects of turbulence and intermittent events in the scrape-off layer of NSTX

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and the NSTX Research Team

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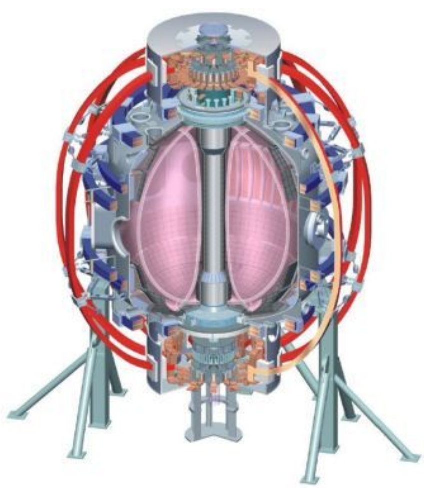

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ABSTRACT

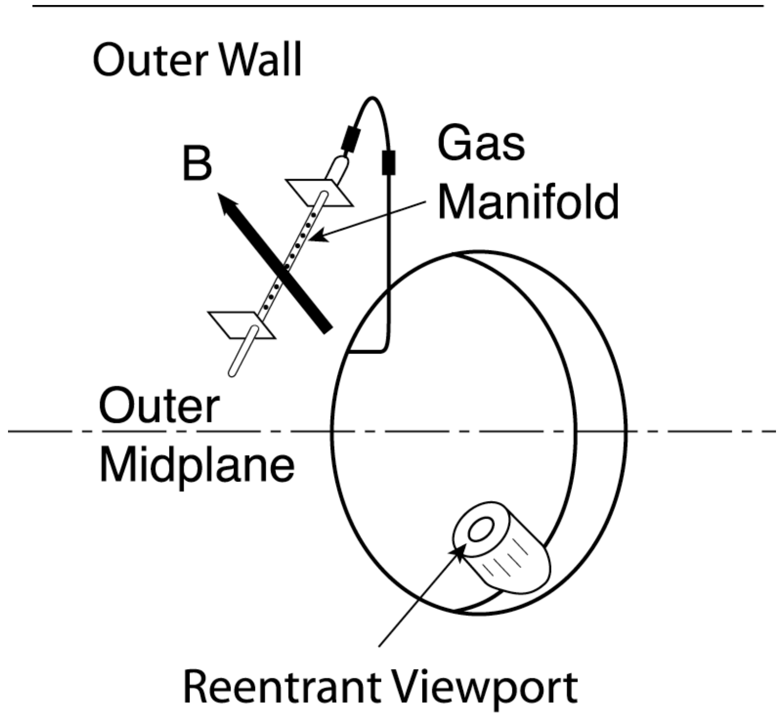
The gas puff imaging (GPI) diagnostic in NSTX is used to study the edge turbulence and intermittency present in the edge and scrape-off layer during H-mode discharges. Low power (and Ohmic) H-modes have quiescent edges with a low level of turbulence and intermittent blobs, while H-modes with strong auxiliary heating power exhibit intense edge activity. The turbulence and blob generation are studied in terms of global discharge parameters, edge profiles, and MHD activity. The possible contribution of enhanced cross-field transport due to the edge turbulence to the thermal scrape-off layer width is evaluated by comparing the outboard midplane GPI measurements with the heat deposition profiles on the divertor target plates measured by an IR imaging system. These results are also compared to ongoing modeling using the 2-D scrape-off layer turbulence code SOLT (Lodestar).

Introduction

- The Gas Puff Imaging diagnostic (GPI) is used to study the edge/scrape-off layer (SOL) turbulence and intermittency in NSTX.
- This turbulence (and blob generation) are greatly reduced in H-modes compared to L-modes. **See invited talk by S. J. Zweben (JI2), Tuesday PM.**
- **This work studies the edge characteristics during H-mode**, where the edge activity varies from quiescent (low power and Ohmic discharges) to highly active (high power discharges).
- Work is part of ongoing experimental/modeling study, with the participation of Lodestar Res. Corp.

GPI diagnostic

- Camera used to view visible **D_α emission** from 24 x 24 cm box of the edge plasma just above low field side (outer) midplane. Camera captures images at up to ~400000 frames/s.



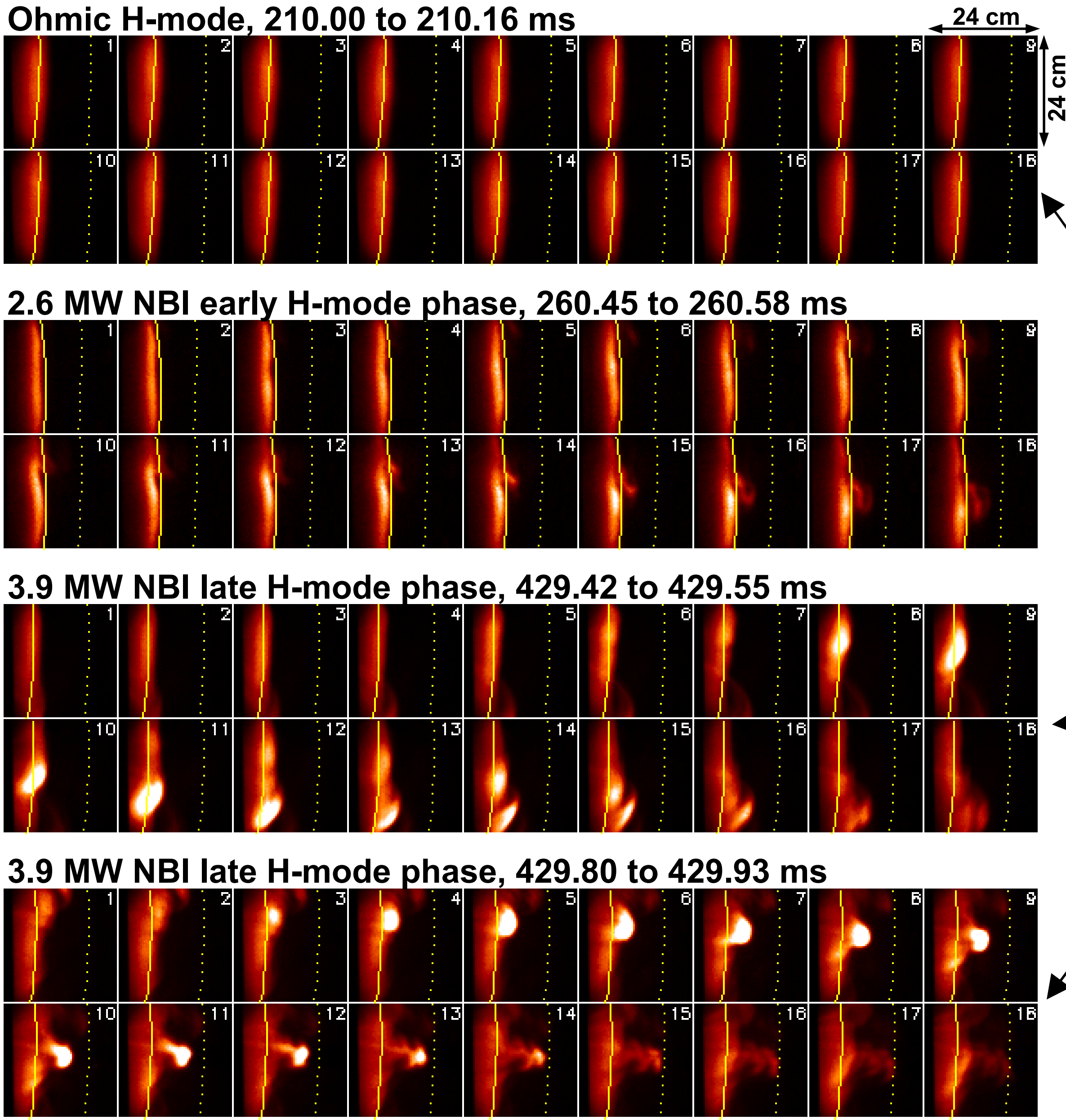
- Deuterium gas puff is injected to increase image contrast and brightness. Gas puff <u>does not perturb</u> local (nor global) plasma.
- View aligned along B field line to see 2-D structure ⊥ B. Typical edge phenomena has a long parallel wavelength, filament structure.
- The D_α image intensity (I_α) is given by:

$$I_\alpha = n_o A L^* F(n_e,T_e)$$

where n_o is the neutral deuterium density
A is the radiative decay rate
L^* is the line of sight integration length (and calibration factor)
$F(n_e,T_e)$ is the population ratio for the emitting energy levels, obtained from Degas2 modeling (D. Stotler)

- For more details: R.J. Maqueda *et al.*, Rev. Sci. Instrum. 74(3), p. 2020, 2003.

Midplane turbulence and blobs in H-mode

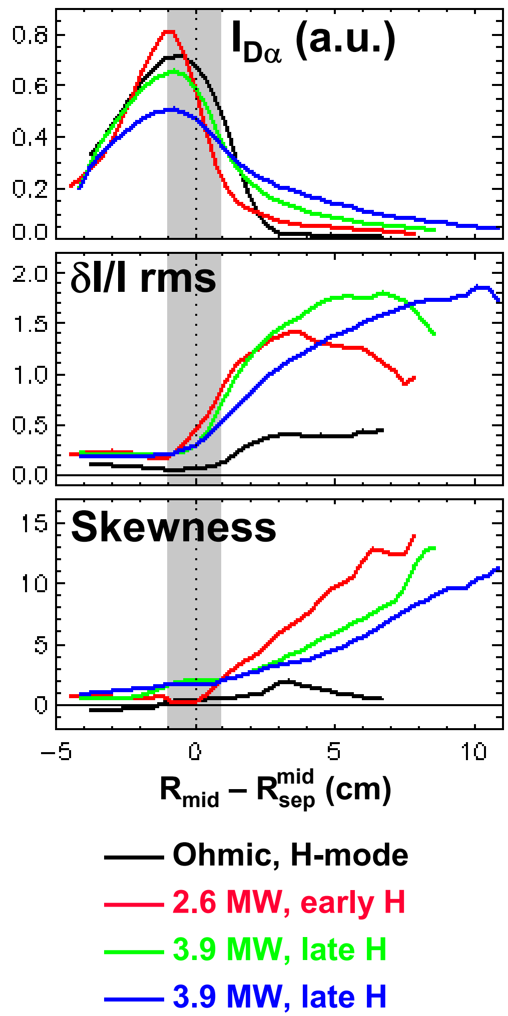


Quiet

to

Active

Turbulence/blob activity: Quiet to Active



20 ms long averages

- Low power (Ohmic) H-modes show no turbulence or blob activity.
- As power is increased, early H-mode phase shows a quiet edge (~R_{sep}) and an increasing level of activity in the SOL. Mean SOL D_α emission remains low.
- Late in the H-mode phase (high P_{nbi}) the SOL average D_α emission is broad with large contribution from intermittent (large skewness) fluctuations. Intermittency is also seen on the edge.

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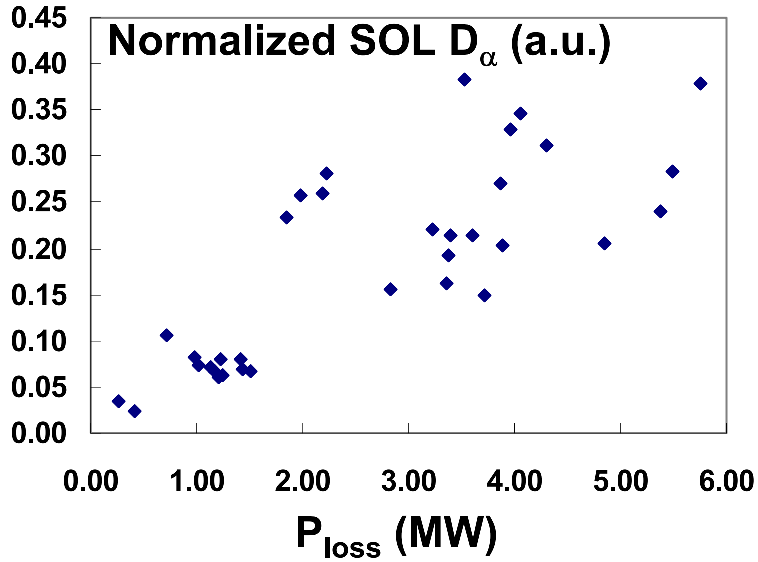
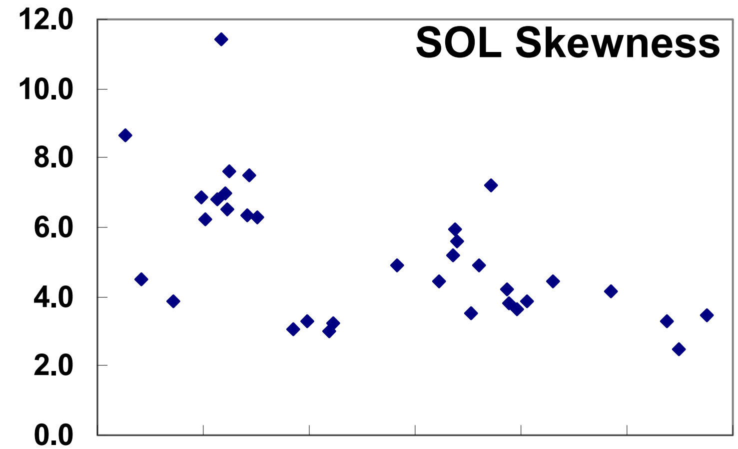
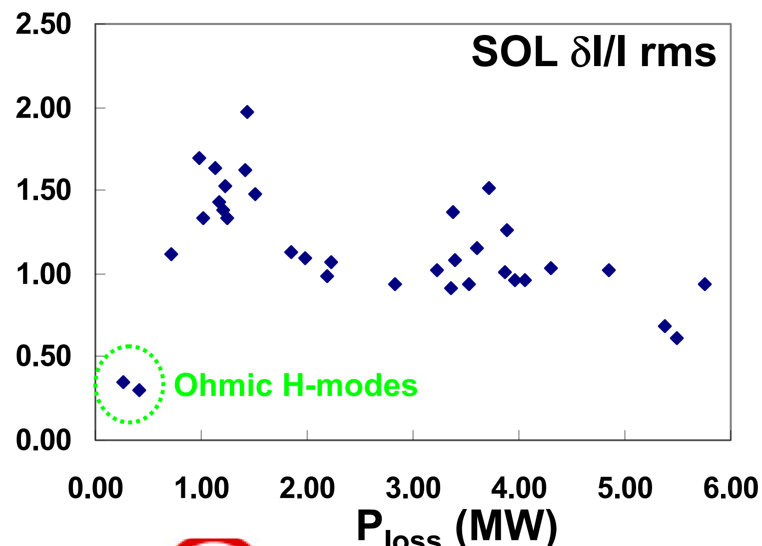
Midplane SOL "D_α width" increases with loss power







- RMS fluctuation level and skewness high in all conditions.
- D_α profile broadens with P_{loss}

$$P_{loss} = P_\Omega + P_{NBI} - P_{rad} - dW/dt$$

- Measurements 5 cm outside emission peak -> 3-5 cm outside separatrix.

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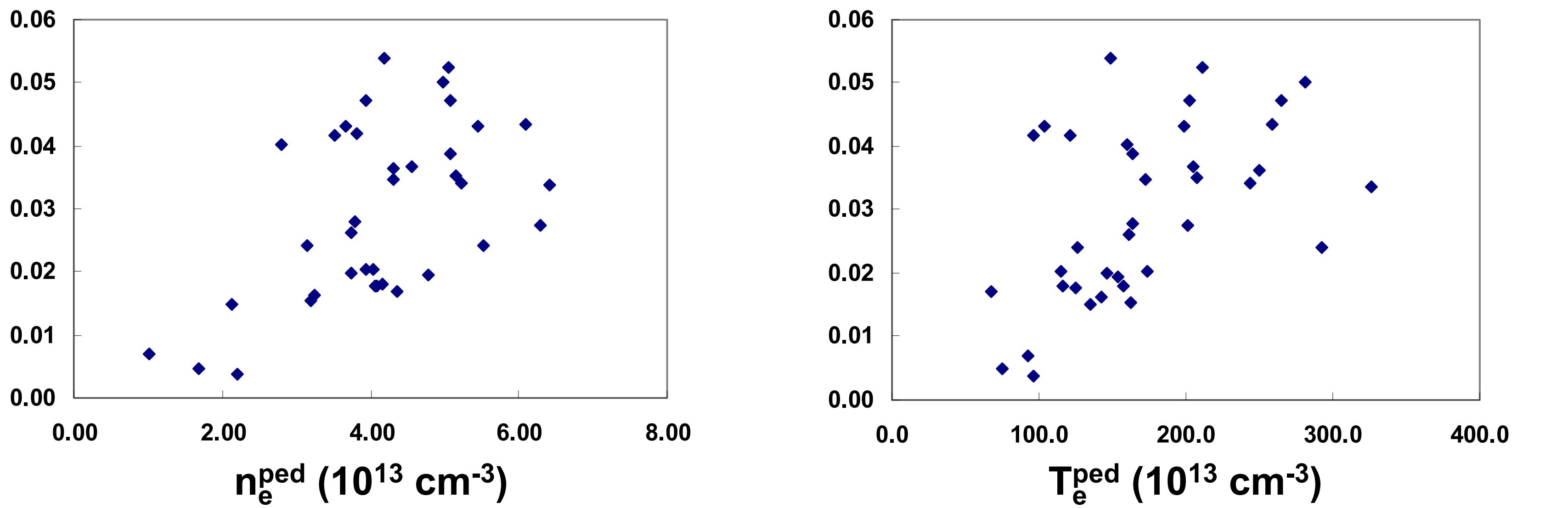
Midplane SOL “D_α width” scales also with pedestal height

Normalized SOL D_α (a.u.)



Thomson scattering data by B. LeBlanc and A. Diallo

- Measurements 5 cm outside emission peak -> 3-5 cm outside separatrix.

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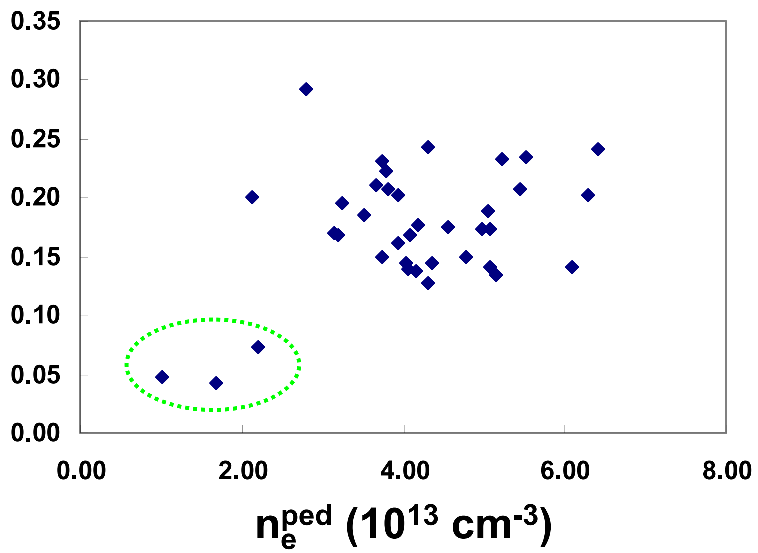
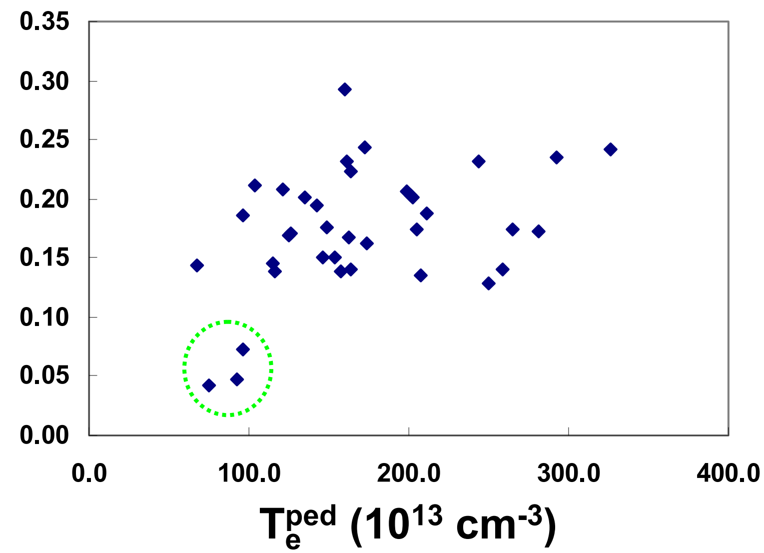
Edge fluctuations (may) scale also with pedestal height

Edge $\delta I/I$ rms @ D_α peak





Substantial difference observed during Ohmic H-modes!

Thomson scattering data by B. LeBlanc and A. Diallo

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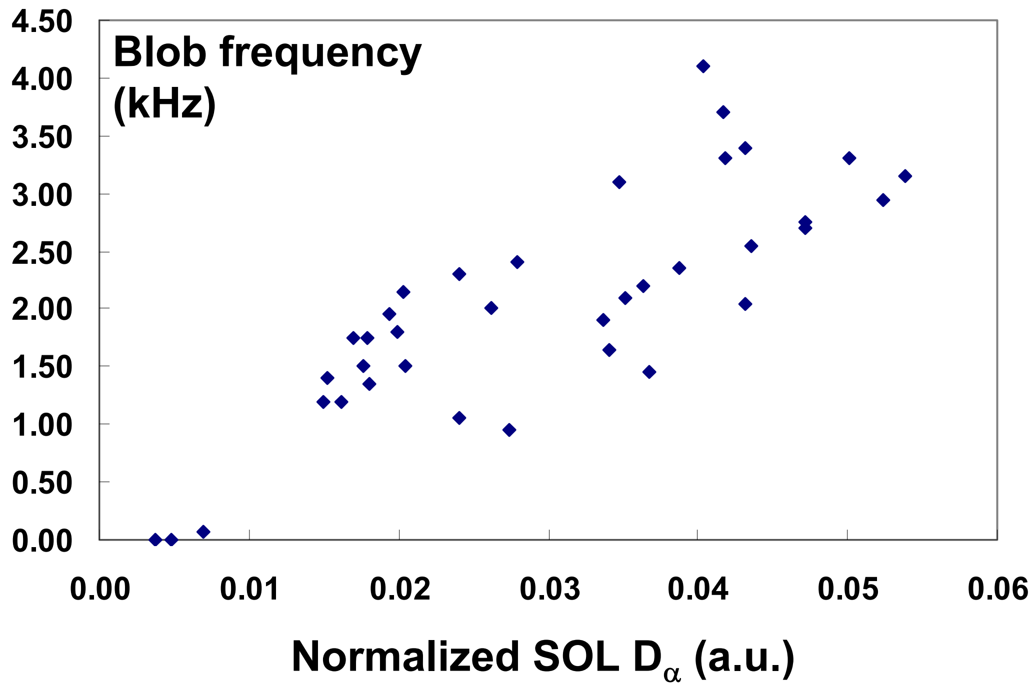
Intermittent blobs are more frequent as the midplane SOL "D_α width" increases



- Blobs detected at a fixed position in the scrape-off layer (5 cm outside emission peak -> 3-5 cm outside separatrix).

The SOLT code: physics model

D. A. Russell, *et al.*, Phys. Plasmas 16(12), 122304, 2009.

Scrape-Off-Layer Turbulence (SOLT) code

- 2D fluid turbulence code: model SOL in outer midplane
  - classical parallel + turbulent cross-field transport
- evolves n_e, T_e, Φ with parallel closure relations
  - sheath connected, with flux limits, collisional
- strongly nonlinear: $\delta n/n \sim 1 \Rightarrow$ blobs
- model supports drift waves, curvature-driven interchange modes, sheath instabilities
- flexible sources for n_e, T_e, v_y

Velocity shear layers and their relation to blob formation are studied here:

- blobs are entrained by a strong velocity shear layer
- reduced V-shear and increased drive (gradients) can trigger blob release

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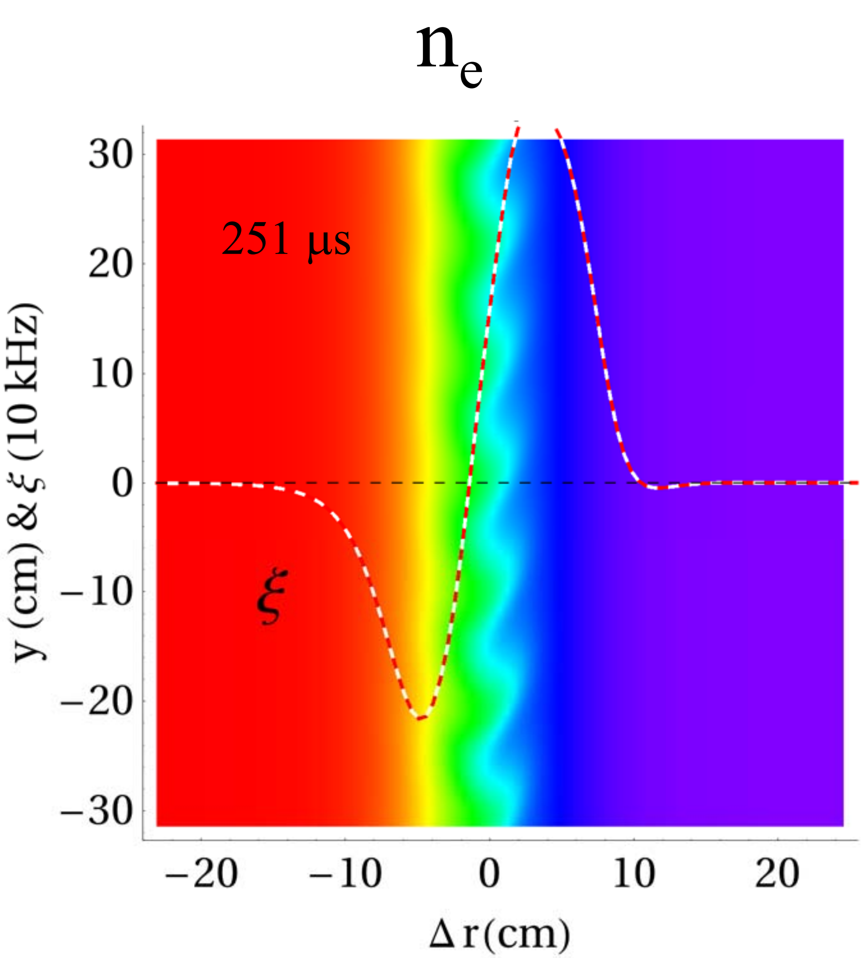
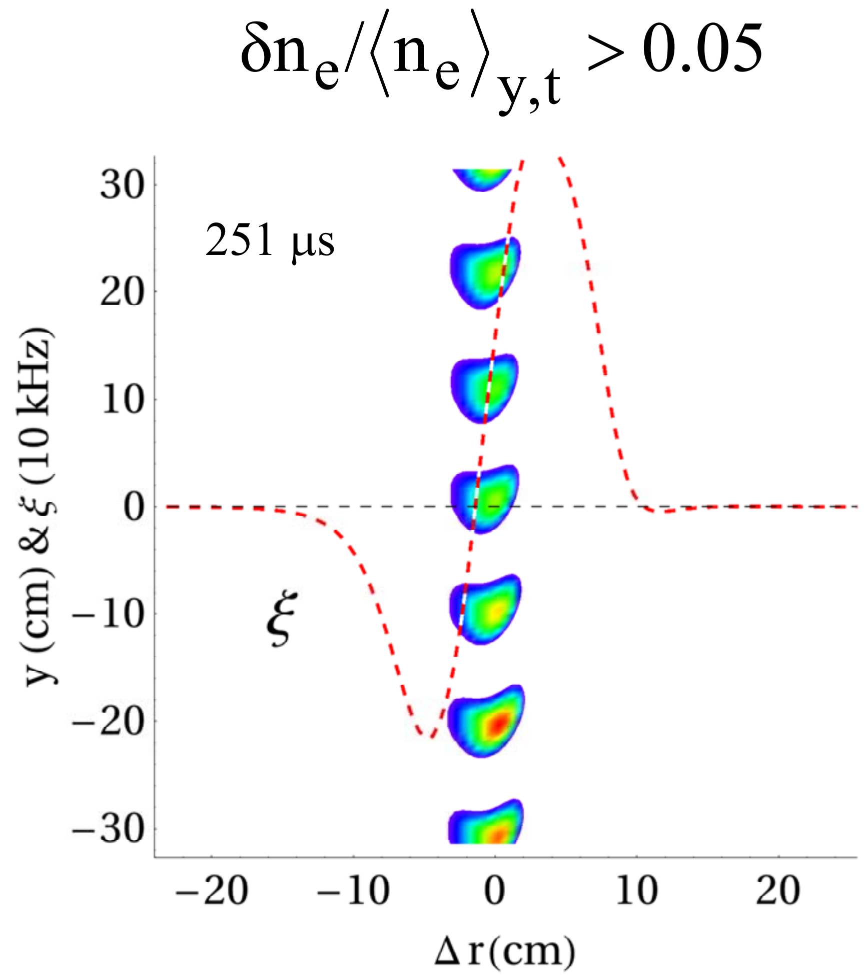
Blobs entrained near a local amplitude minimum of flow shear $\xi = \partial_x \langle v_y \rangle_{y,t}$

SOLT results

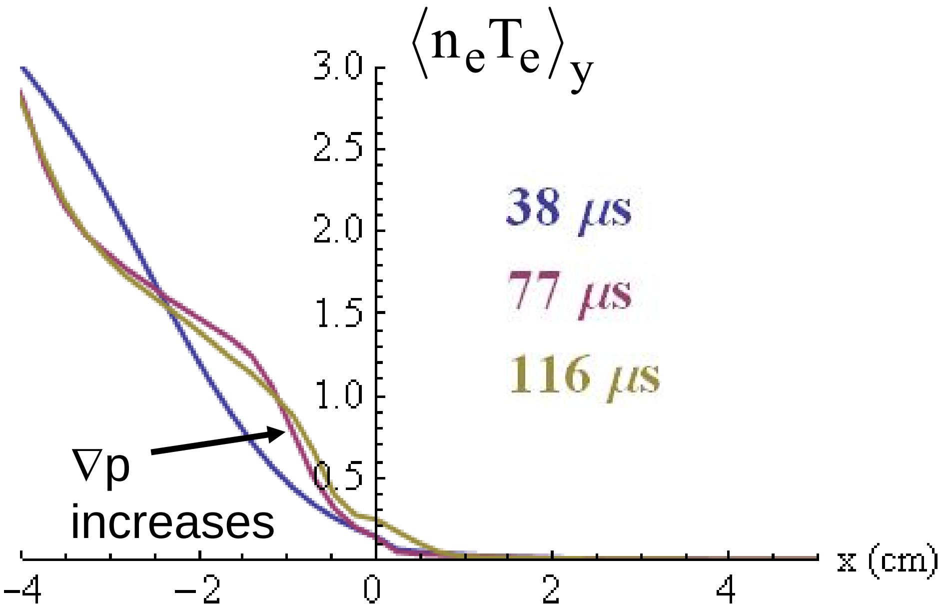


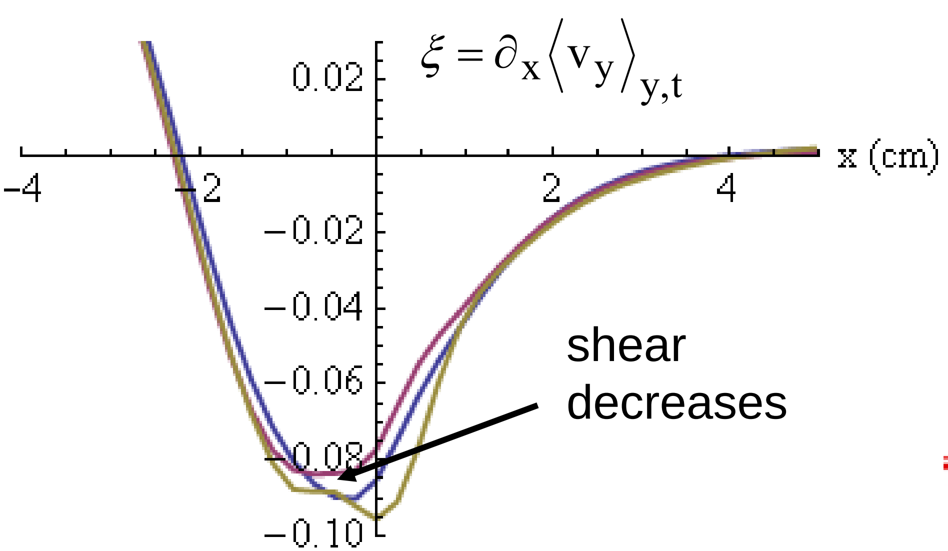


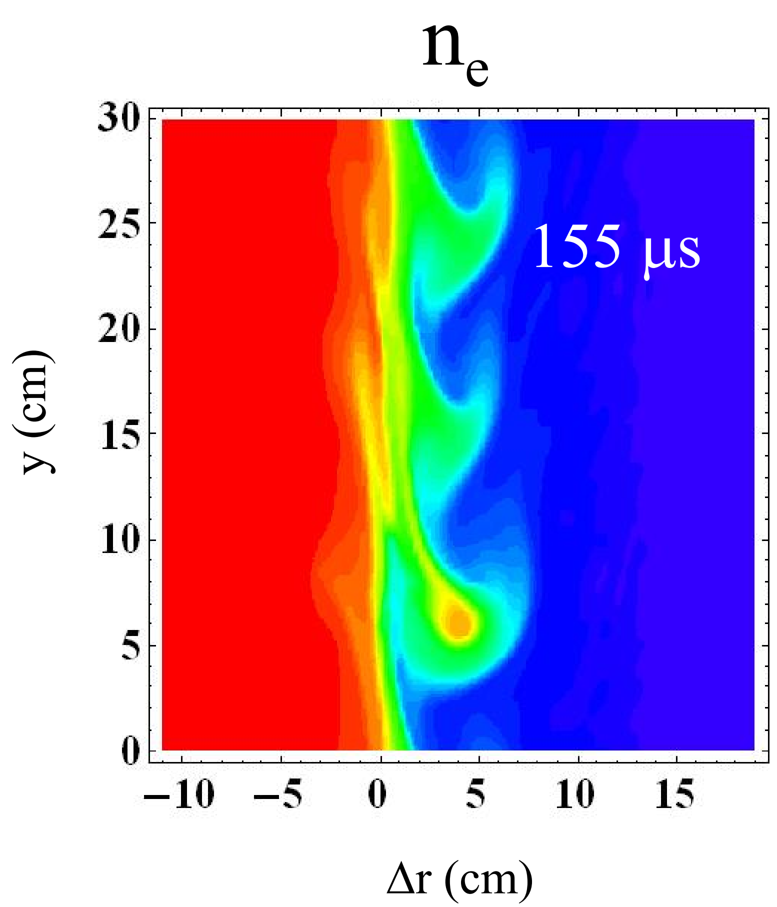
Russell, Myra, D'Ippolito
(Lodestar Res. Corp.)

Blob release triggered by reduced velocity shear and increased ∇p

SOLT results







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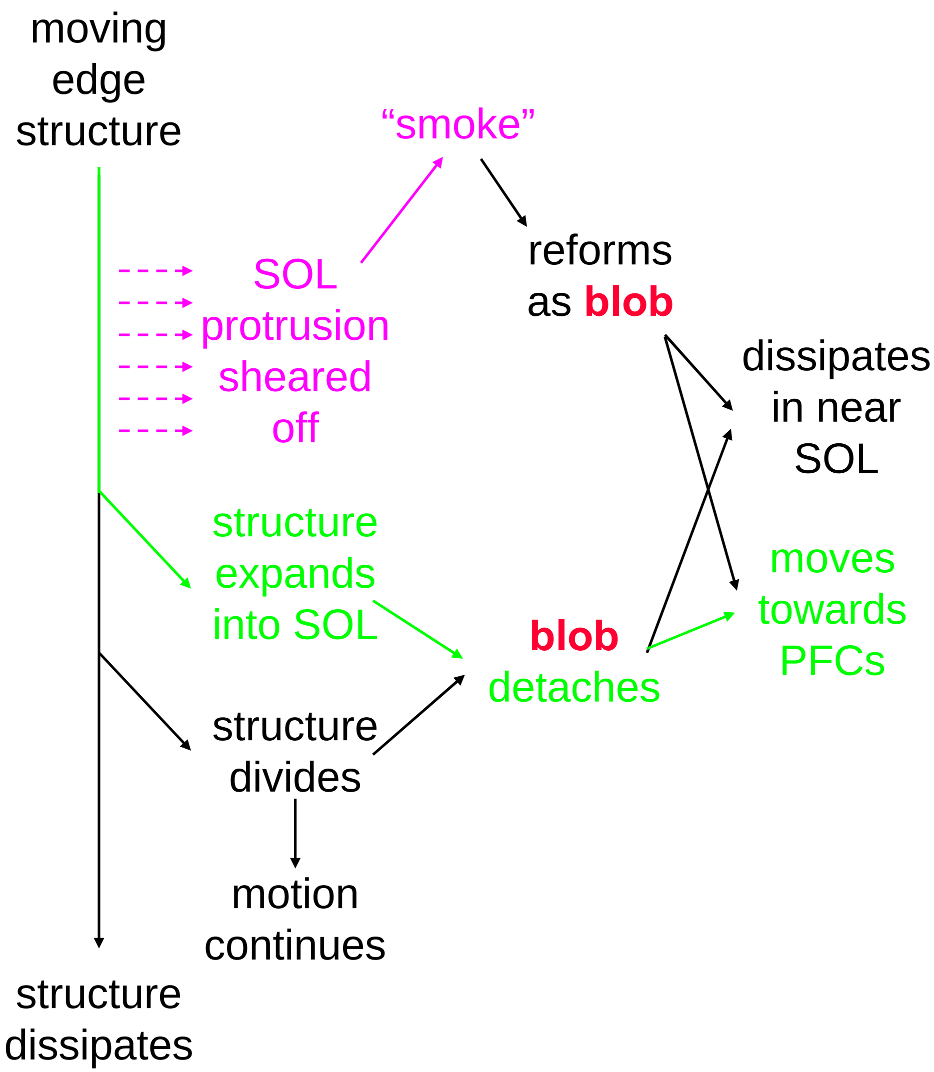
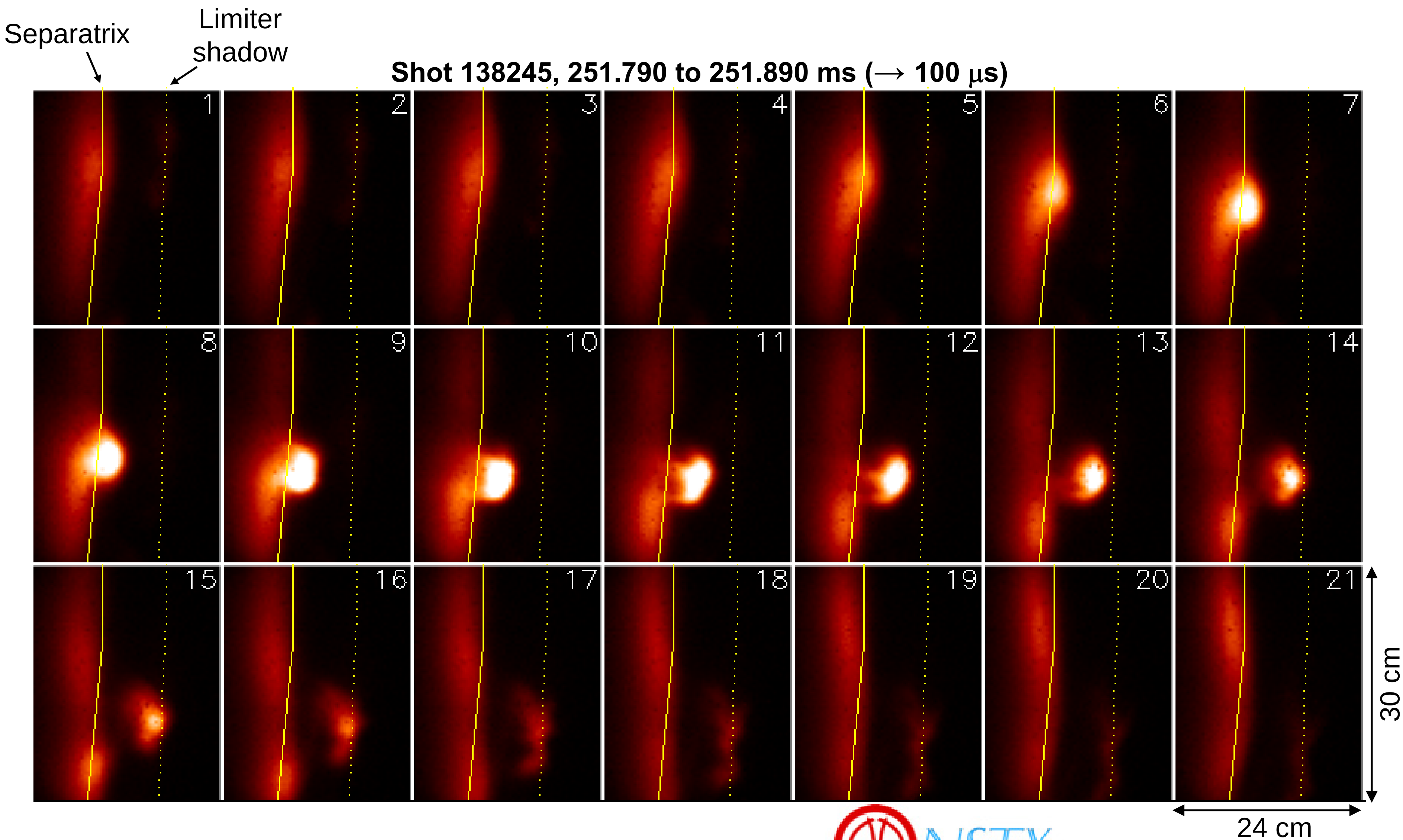
Blob formation in experiment (H-mode)



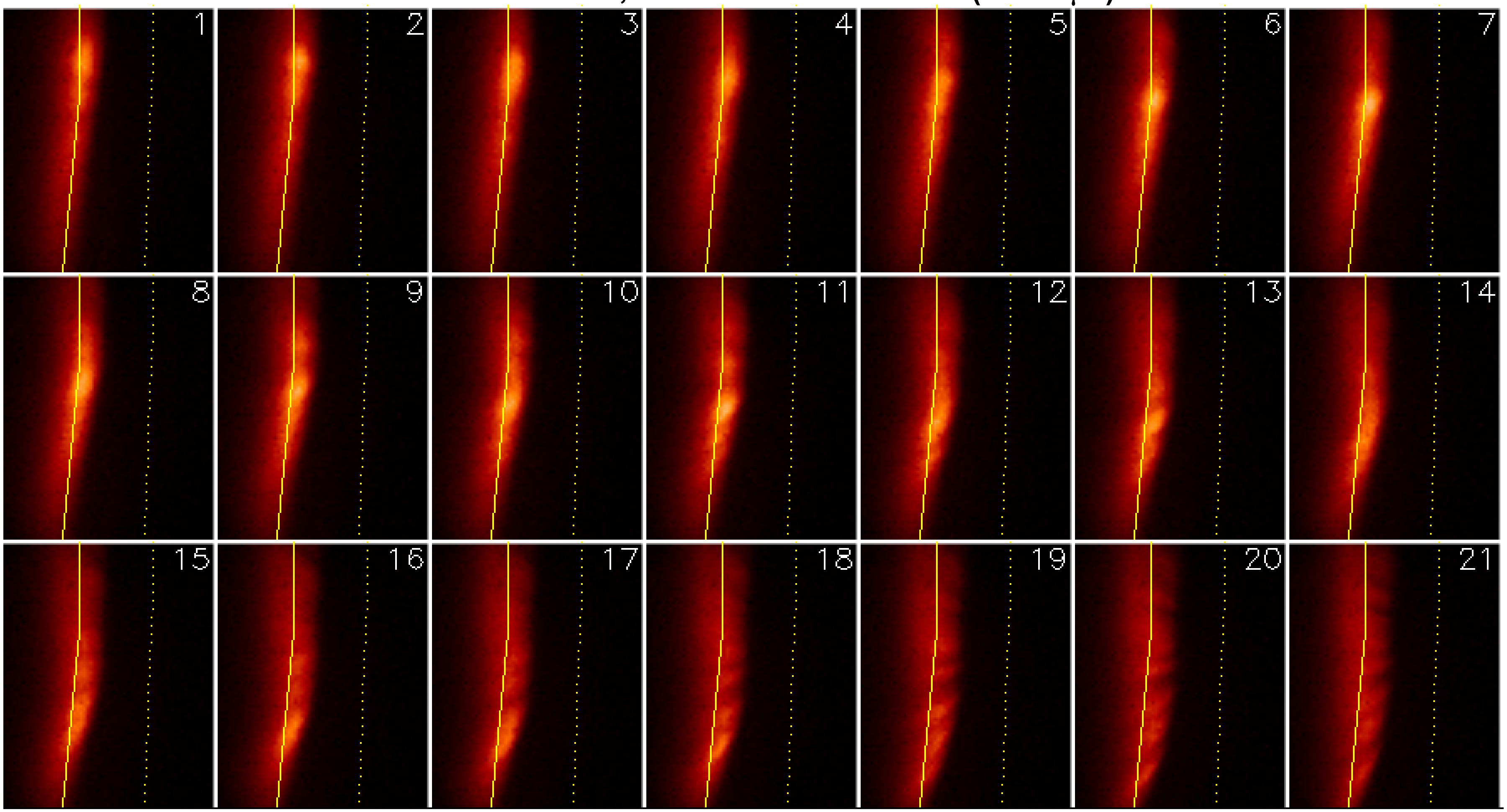
- Different sequence of events can lead (or not) to blob formation.
- Sheared flows in the SOL are seen in some cases during this sequence.
- Once formed, blob either dissipates in near SOL or travels radially towards the plasma facing components.

Blob detaches from moving structure



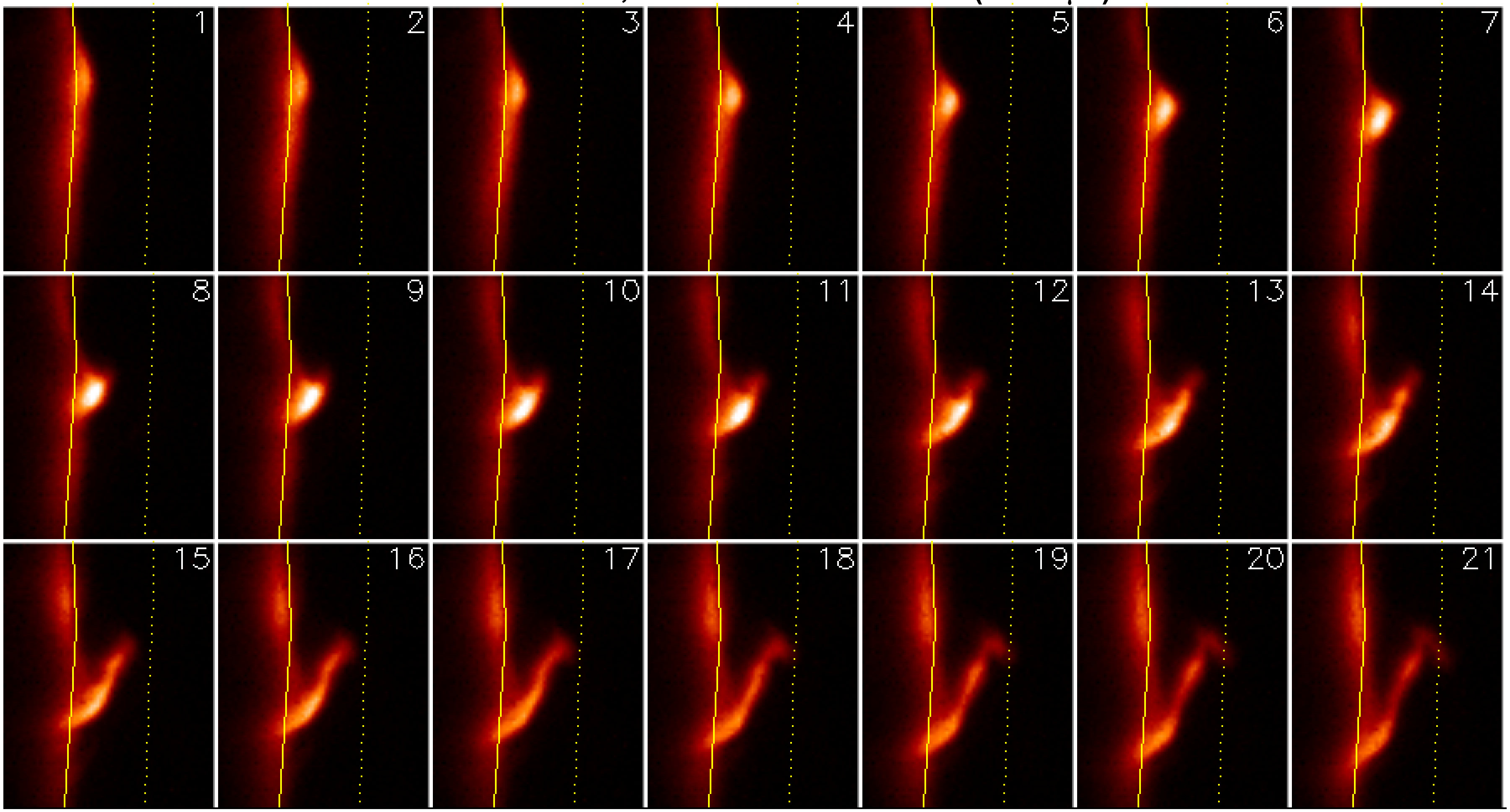
Moving structure sheared off: “smoke”

Shot 139045, 414.211 to 414.261 ms (→ 50 μs)

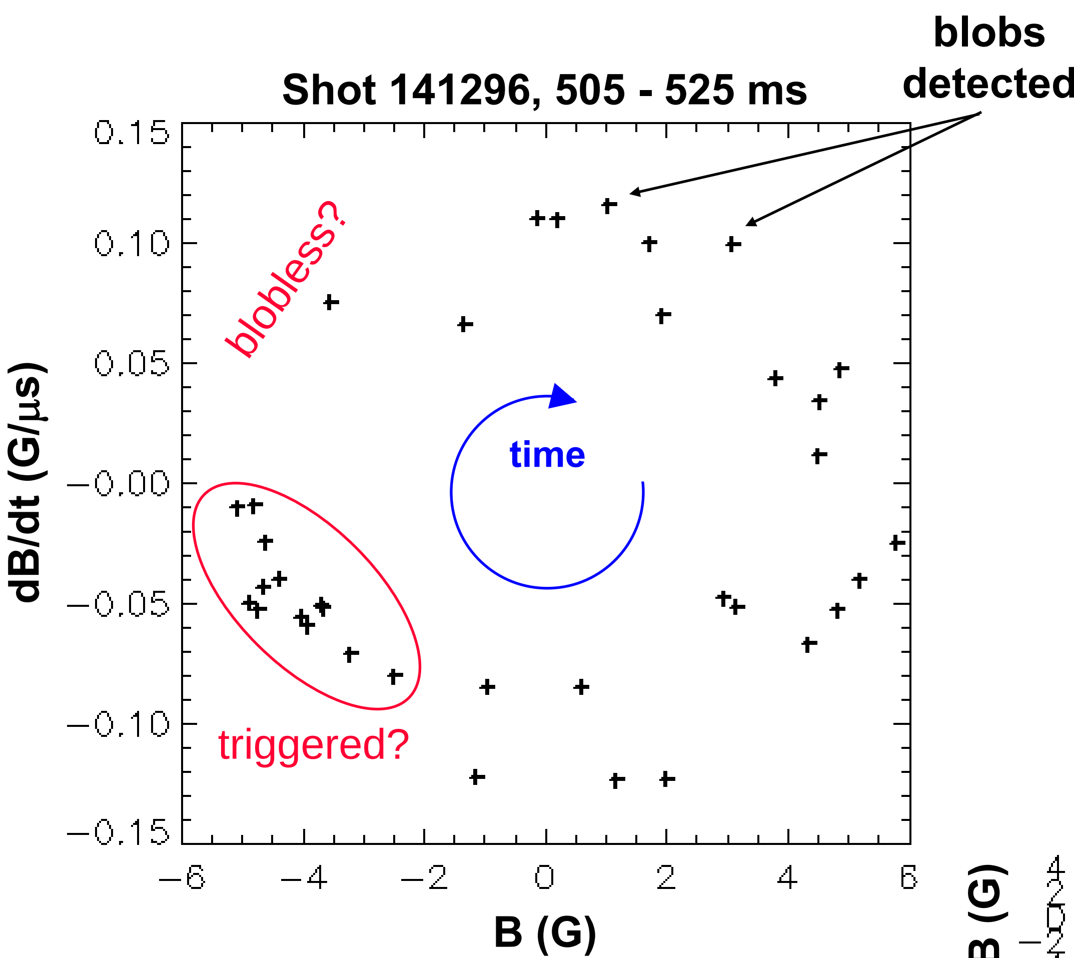


Sheared plasma carried by SOL flows

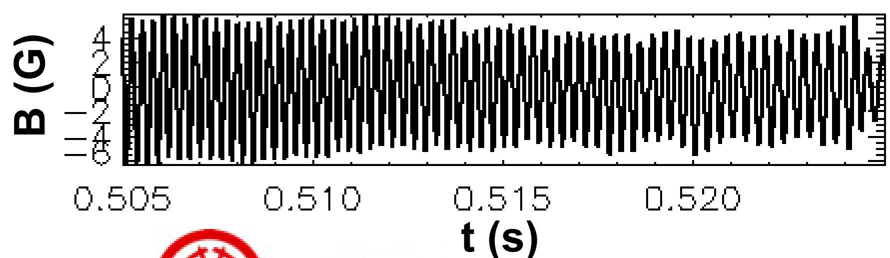
Shot 141296, 507.662 to 507.712 ms (→ 50 μs)



Can MHD trigger blobs? …may be, but rare



- Blobs can generally occur at any phase of MHD cycle.
- Higher concentration of blob events in bottom-left quadrant.
- Lower concentration of blob events in top-left quadrant.
- Cases like this example are rare.
- n = 1 tearing mode at 3.5 kHz.



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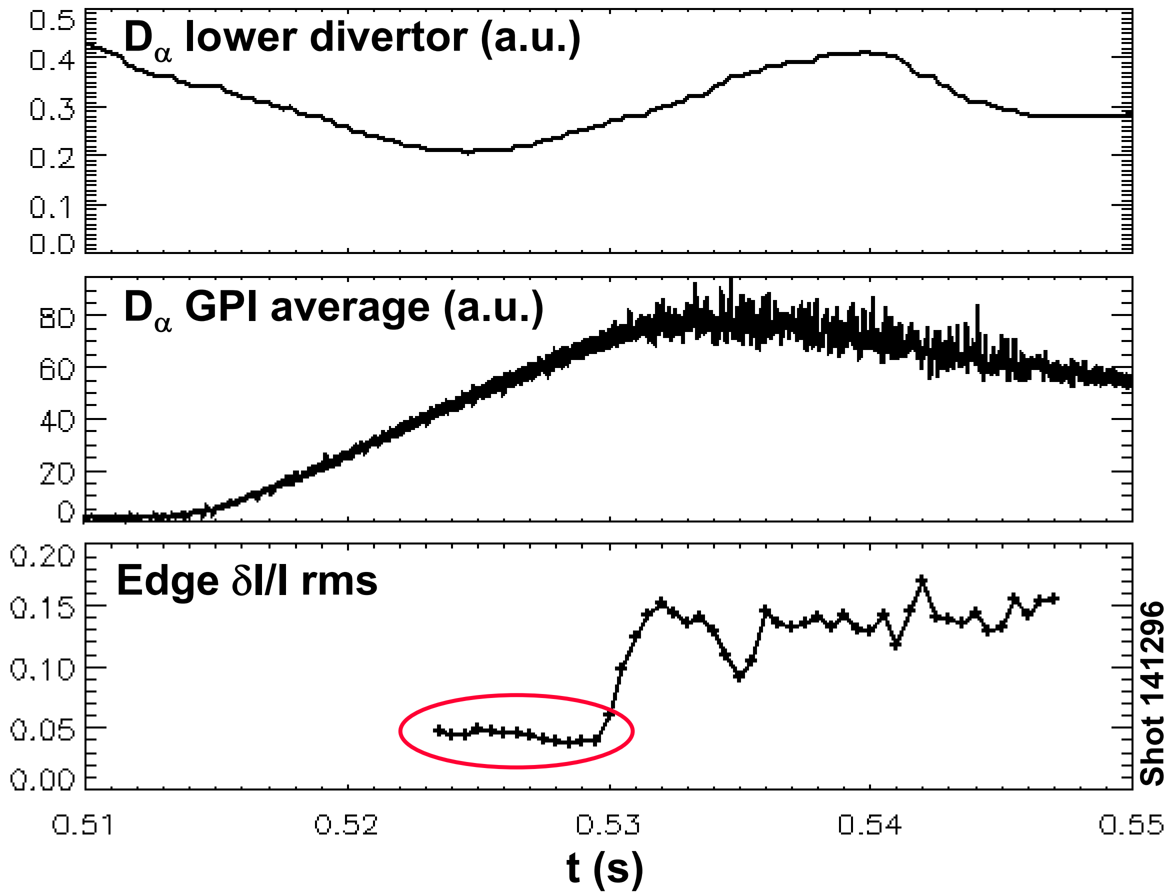
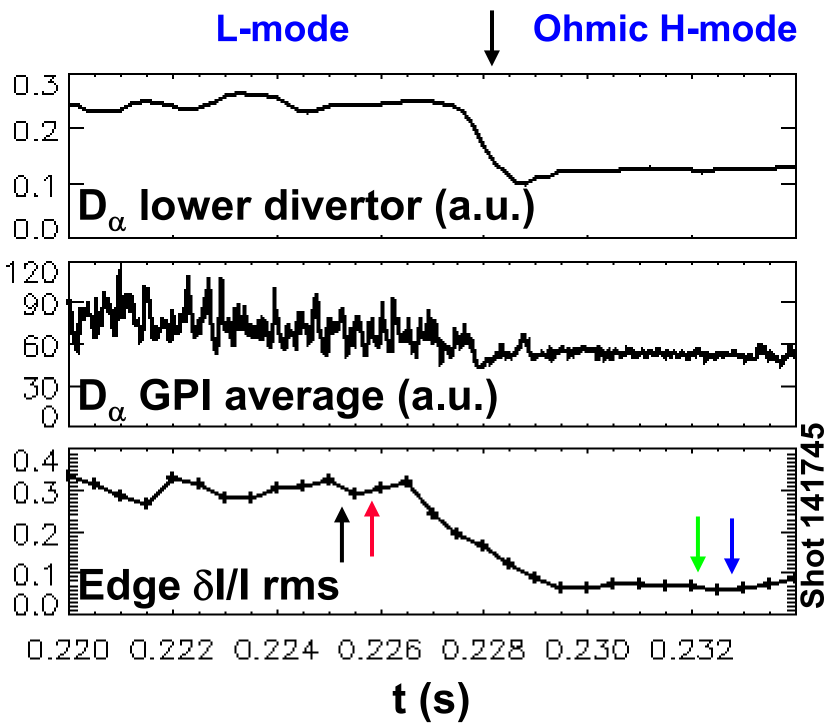
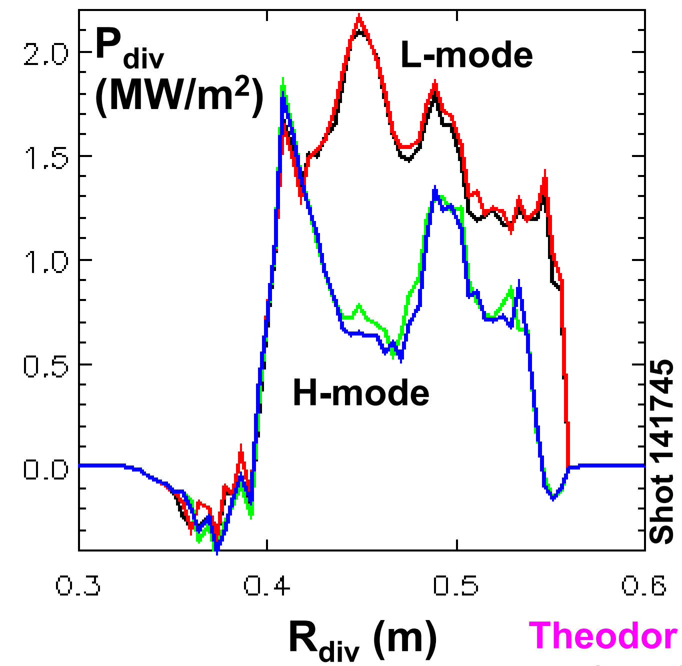
Extreme low fluctuation levels observed



- **H-mode, 3 MW NBI auxiliary heating.**
- **~5% RMS** fluctuation levels on edge comparable to Ohmic H-mode.
- Blobless.
- Change at ~0.53 ms to more typical **~15% RMS** fluctuations.
- Does this change in fluctuations affect transport and divertor heat deposition profile?

Quiet H-modes result in change in divertor heat profiles





- Is this change due to reduction in the near SOL/edge fluctuation level?
- Can a similar change be observed due to fluctuation reductions during H-mode?

Summary and conclusions

- Edge activity during H-mode ranges from quiescent in low power and Ohmic discharges to highly active in high power discharges.
- Midplane SOL width, as measured by average D_{α} light, increases with separatrix loss power.
- SOL fluctuations and skewness maintained at high levels as loss power increases, positive scaling with pedestal height also observed.
- Blobs are more frequent as the SOL width increases.

Summary and conclusions (cont.)

- Modeling of blob formation (SOLT by Lodestar) show "entrained" and "detaching" blobs.
- In experiments, "smoking", non-detaching blobs are also observed.
- Blob "smoke" carried by SOL flows ("wind").
- In rare occasions, MHD activity may be seen to trigger blob formation.
- Even within a given H-mode shot, different levels of fluctuations (and blob activity) can be seen... Does this indicate an important overall role for edge turbulence? (transport and divertor heat profiles)