

H-mode Access and Characterization with NBI

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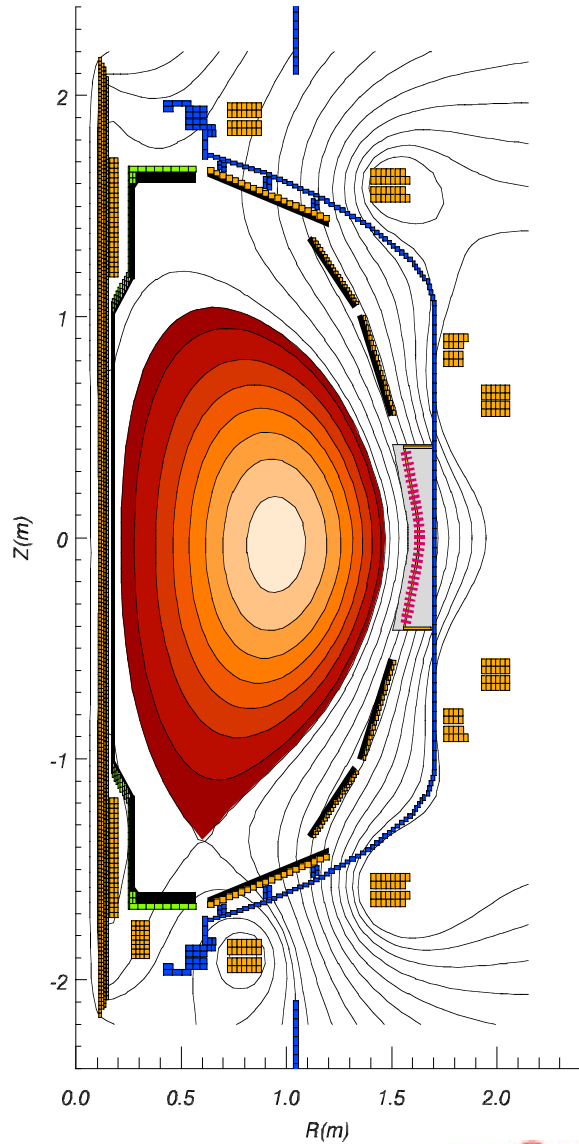
NSTX Results Review / Forum 2002
Princeton Plasma Physics Laboratory
Princeton, September 9 & 10, 2002

NSTX H-modes are being obtained in an increasingly wider operating window.

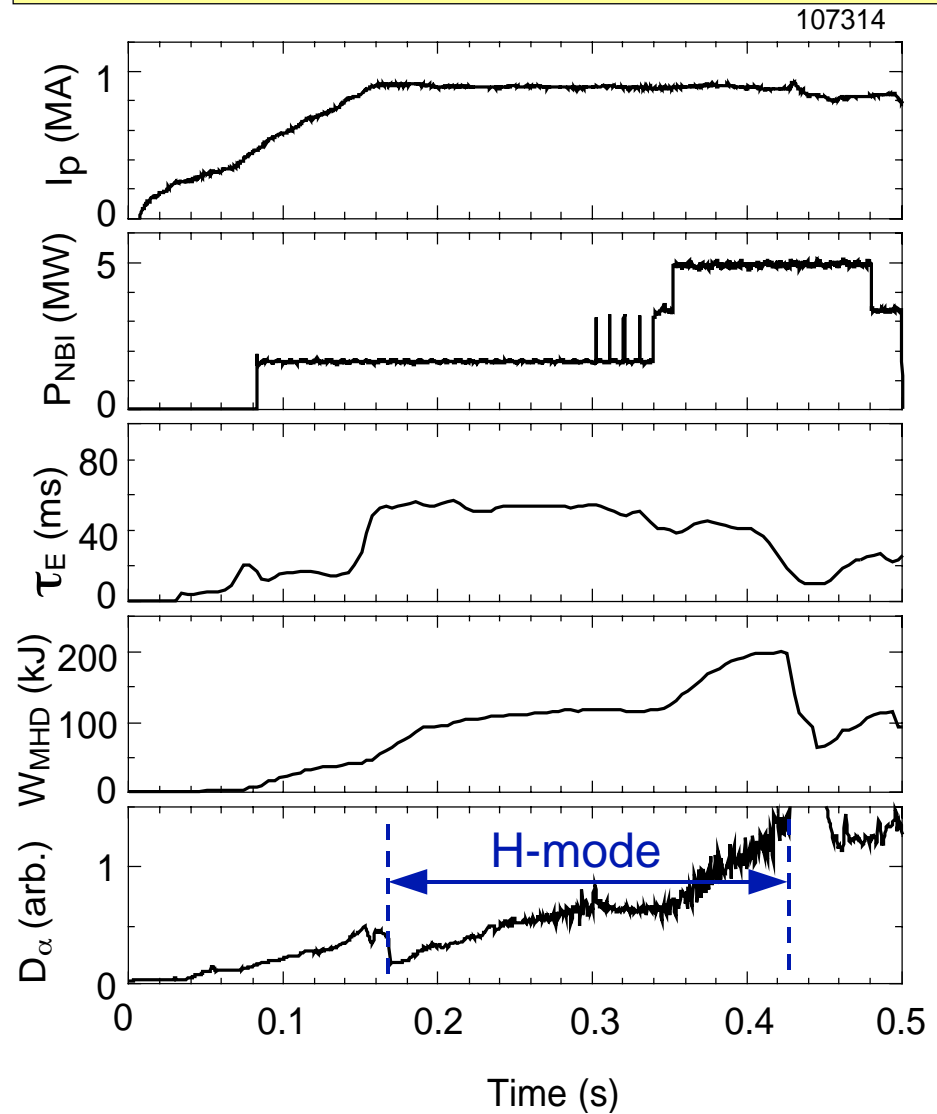
- Obtained in lower-single null (LSN) and in double null divertor (DND) Obtained with NBI or RF heating, or both.
- Wide range of NBI heating power: 0.32 - 7 MW
- Wide n_e range at transition: $1.5 - 4.8 \times 10^{19} \text{ m}^{-3}$
- Good I_p range: 0.7-1.3 MA (NBI)
- B_t range: 0.3 - 0.6 T
- The β range: $\beta_t = 32\%$, $\beta_p \leq 0.95$
- Duration $> 500\text{ms}$ (NBI)
- Power Threshold Studies underway - interesting results
- ELM characterization underway

NSTX H-modes in LSN and DN Divertor

Shot= 105587, time= 250ms

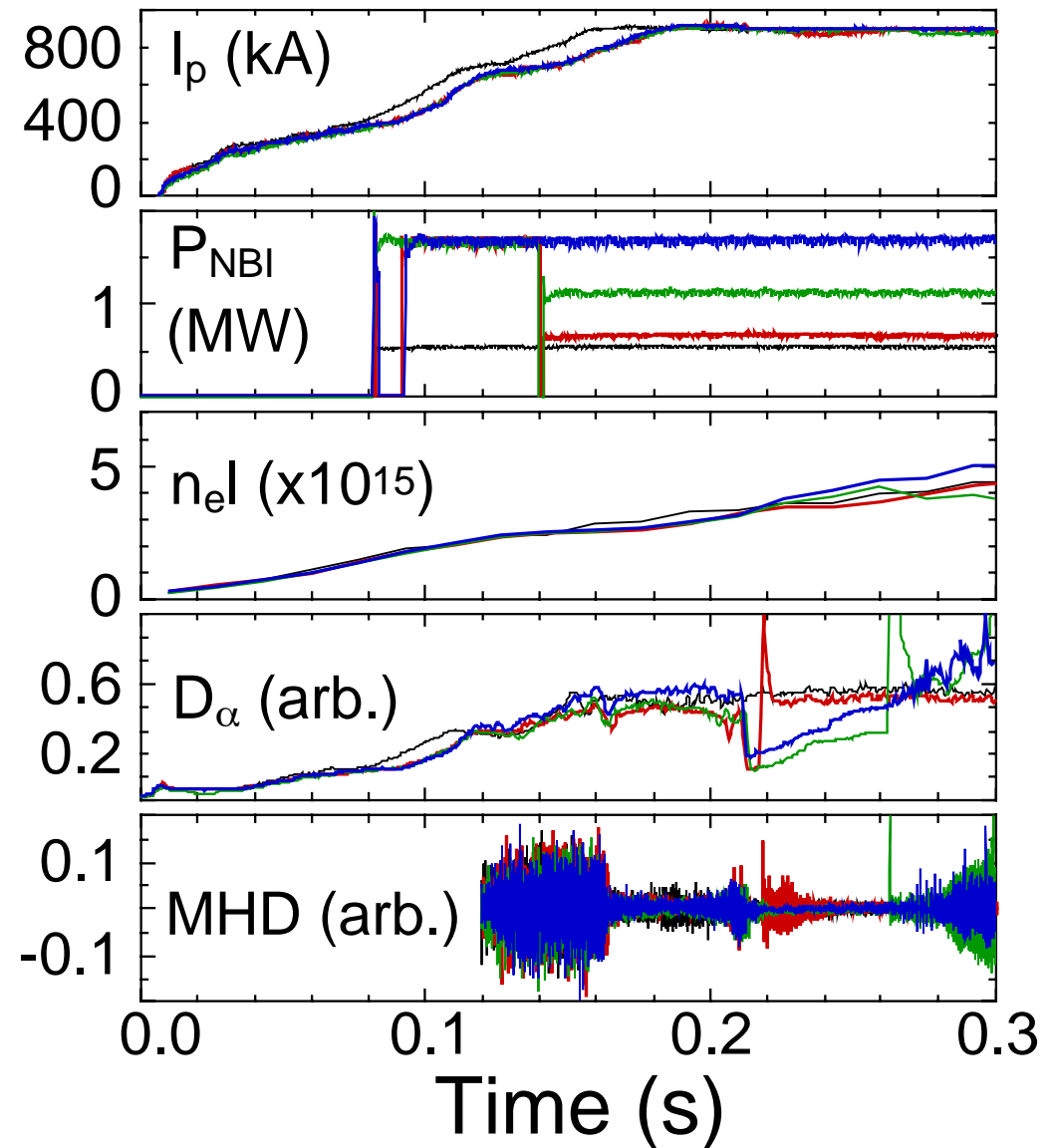


Now Get > 500 ms Long H-modes

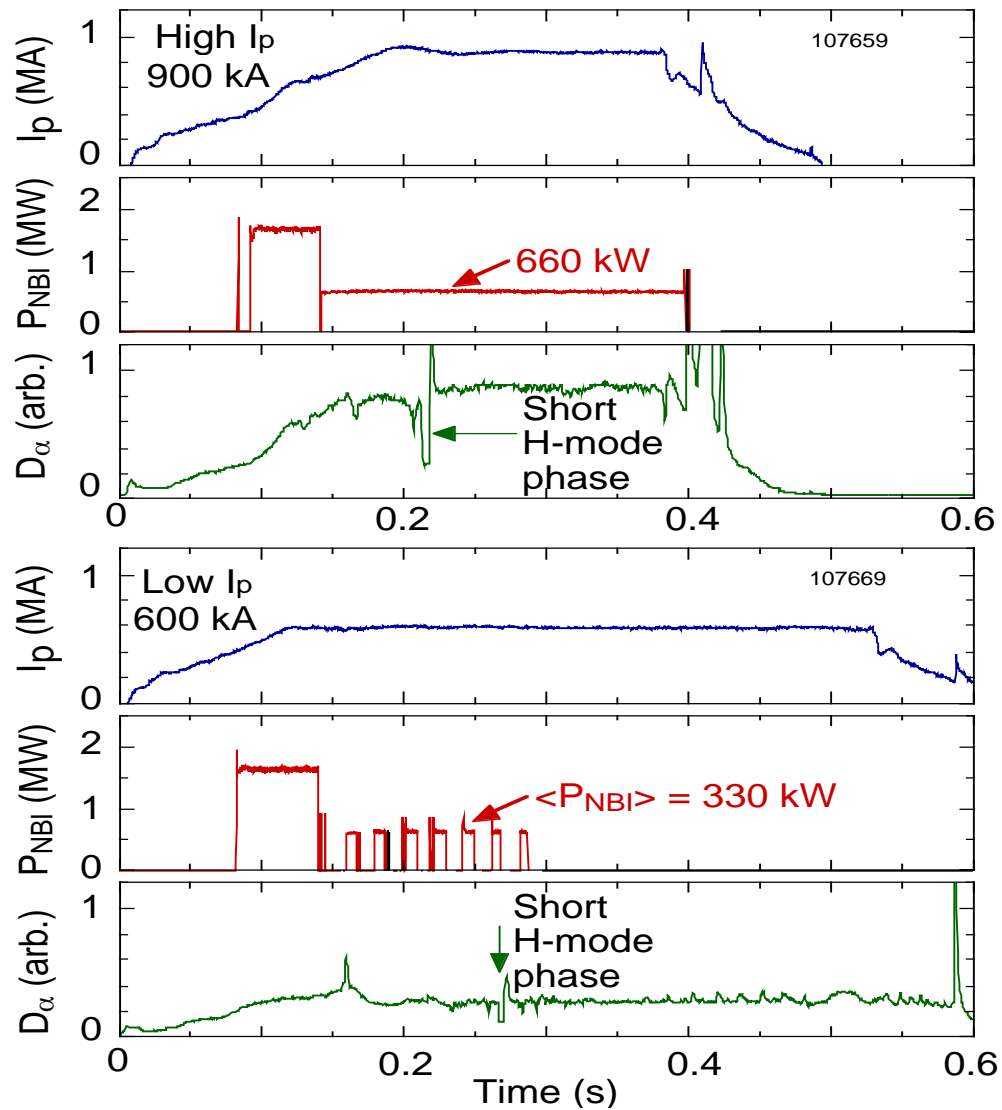


Threshold Powers (P_{th}) Obtained using Parameter and Configuration Scans

- H-mode studies with
 - Pb, I_p, B_t scans
 - Configuration scans
 - Inner Gap scans
- Here B_t = 45 kG, I_p = 900kA
 - P_b(@P_{th}) = 530 kW
 - Note: L-H transition at the same time for all P_b
- At B_t = 45 kG, I_p = 600 kA
 - P_b(@P_{th}) = 315 kW
 - ==> Lowest P_{th} to date

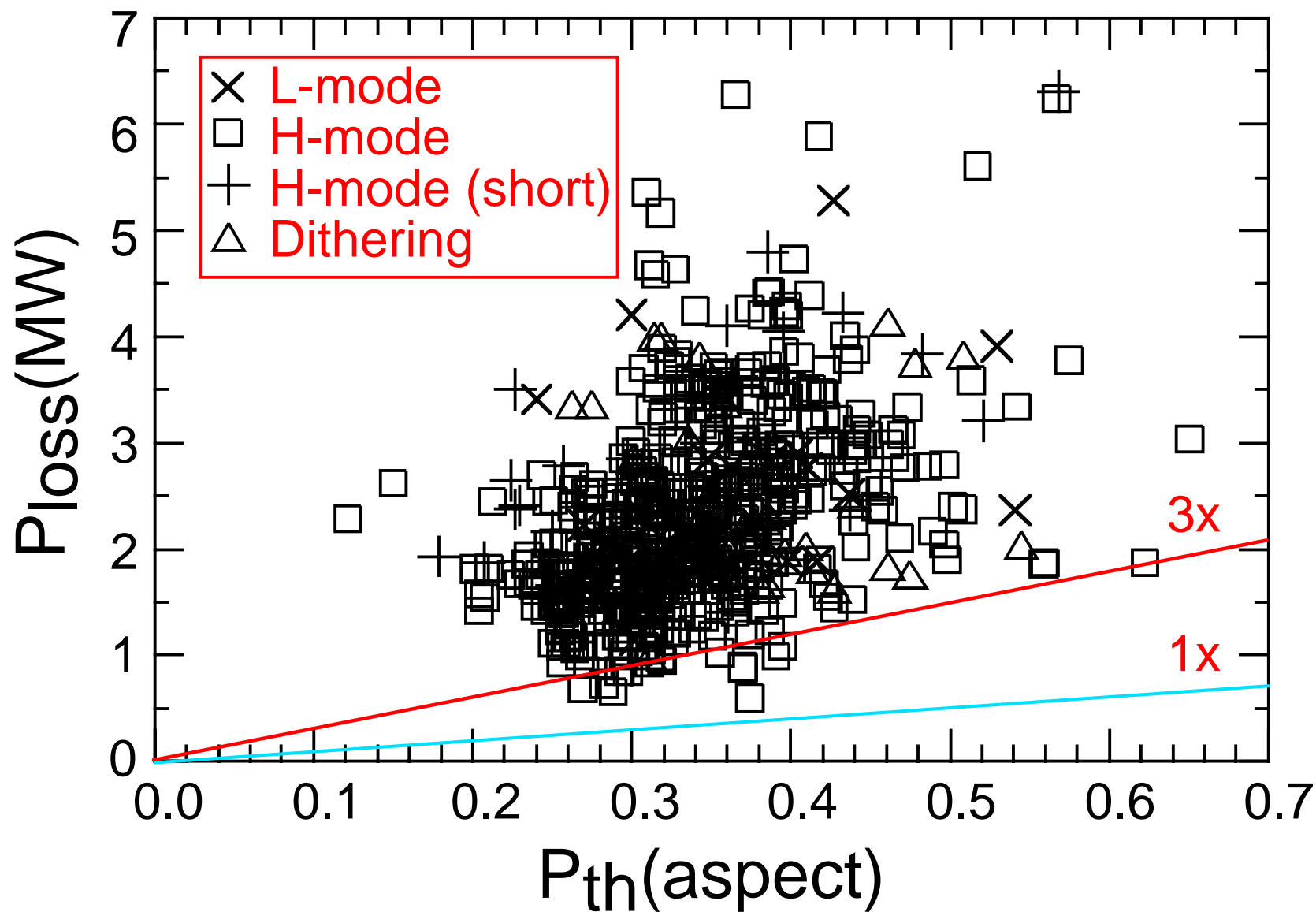


Power threshold presently at 2 times the aspect ratio scaling by Snipes based on ITER H-mode Database

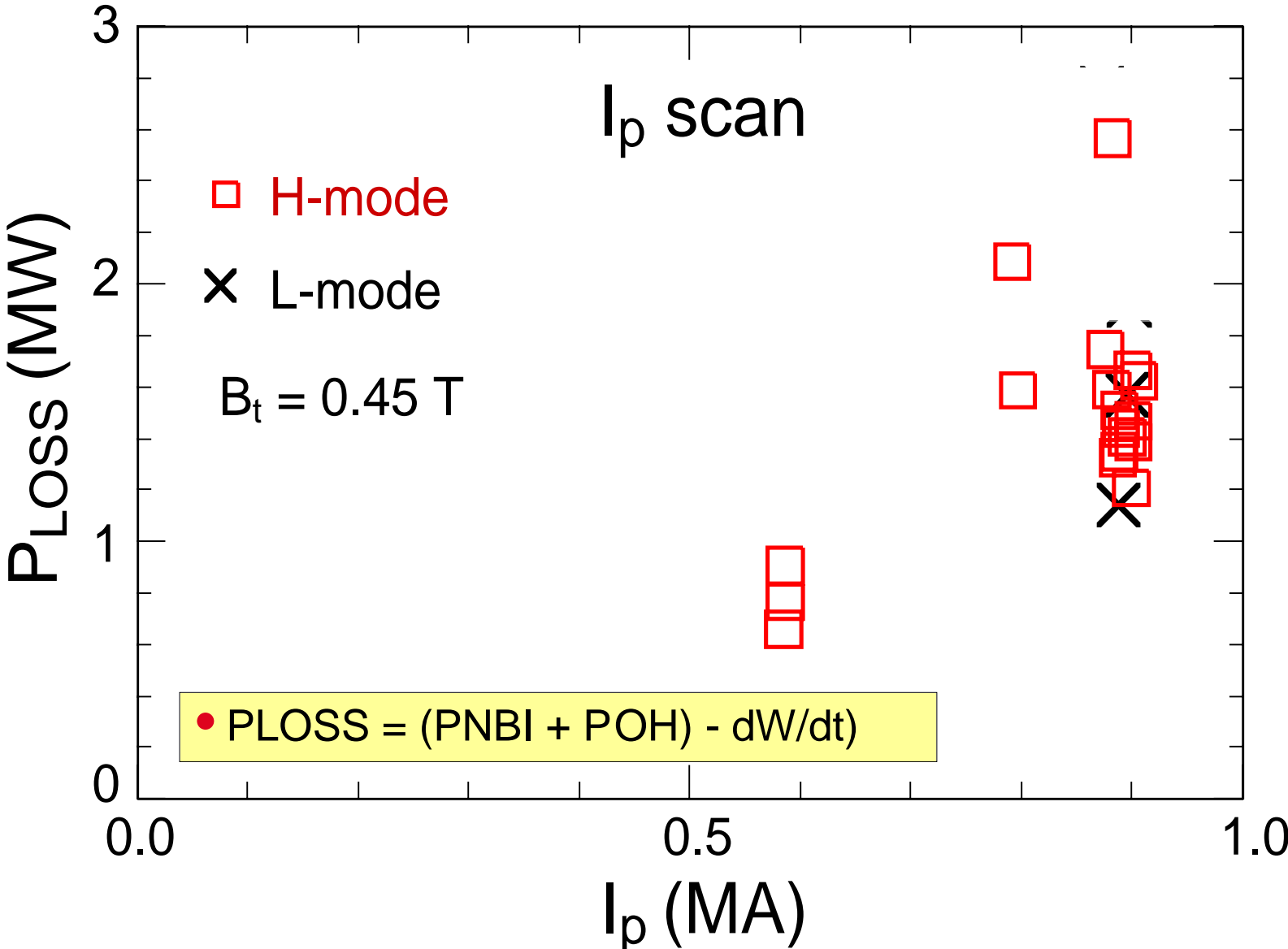


- Vary plasma current
- NBI power varied by voltage scan:
- $P_{loss} \sim 2 * P_{thaspect}$
- Dithers or short H-mode phase show up in D_α near threshold.

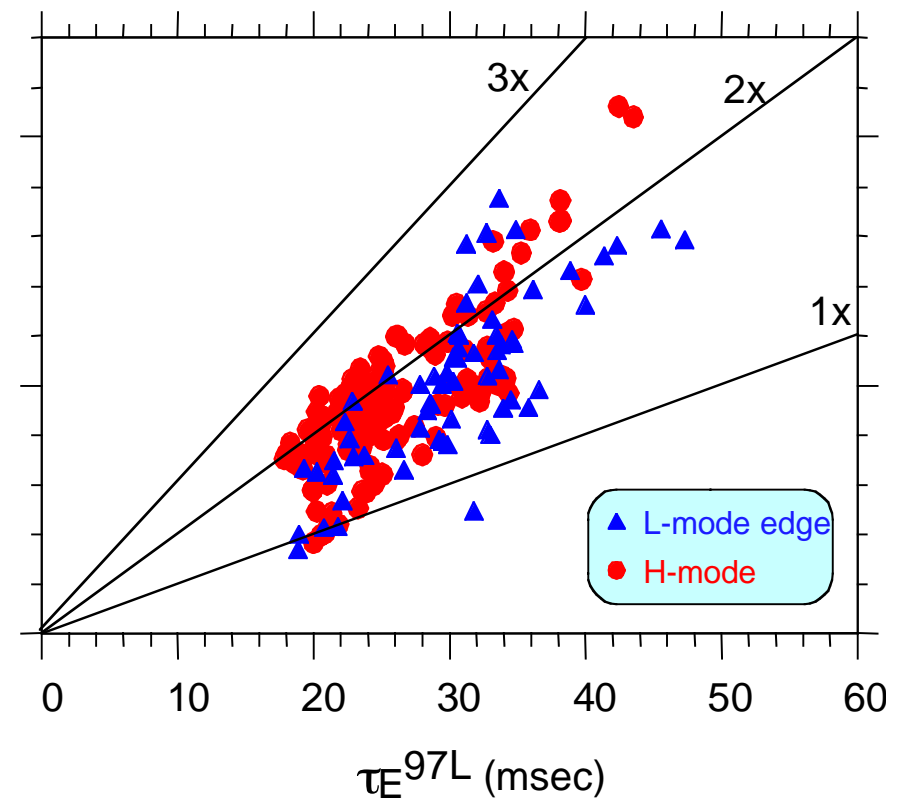
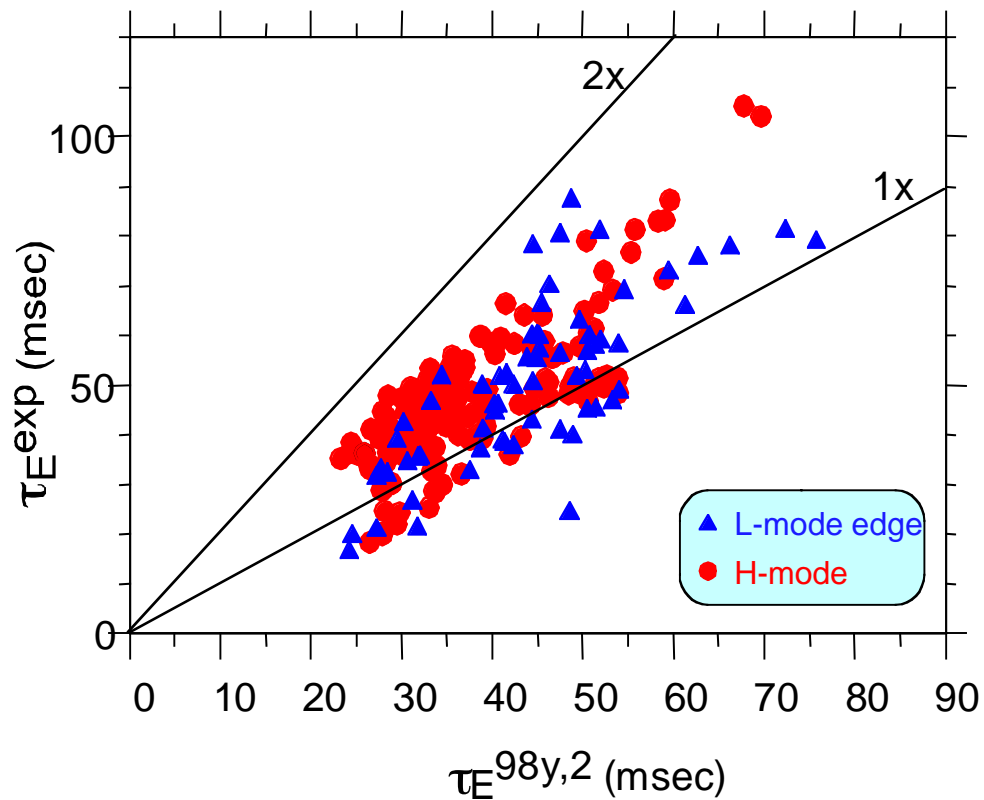
The NSTX H-mode Database Contains more than 500 shots following the "Good" bakeout



L-H Threshold Study Shows Possible I_p Dependence of P_{th}



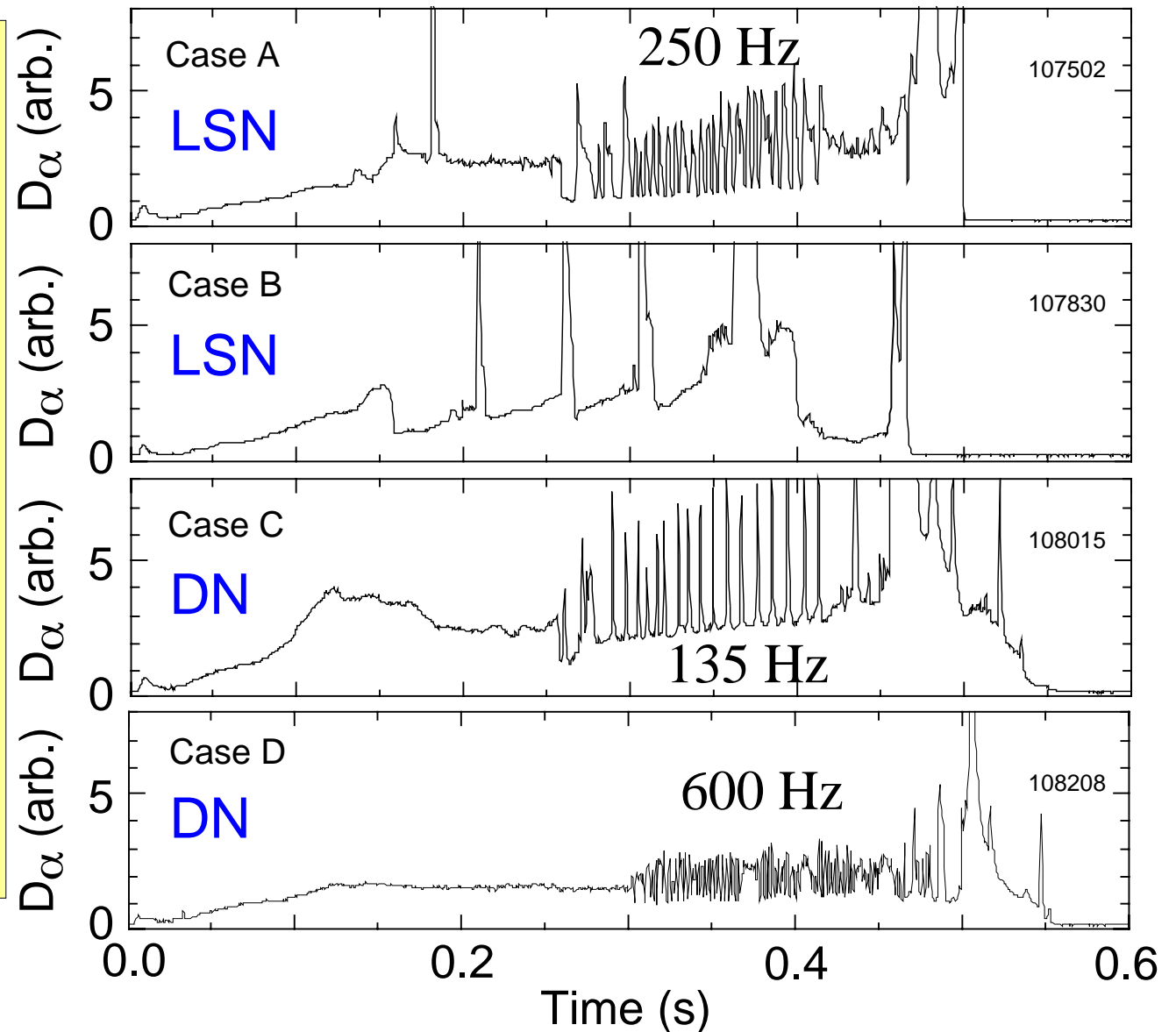
H-mode Global Confinement is Enhanced in NSTX over that for Conventional Aspect Ratio Tokamaks.



Wide Spectrum of ELM Characteristics Realized on NSTX

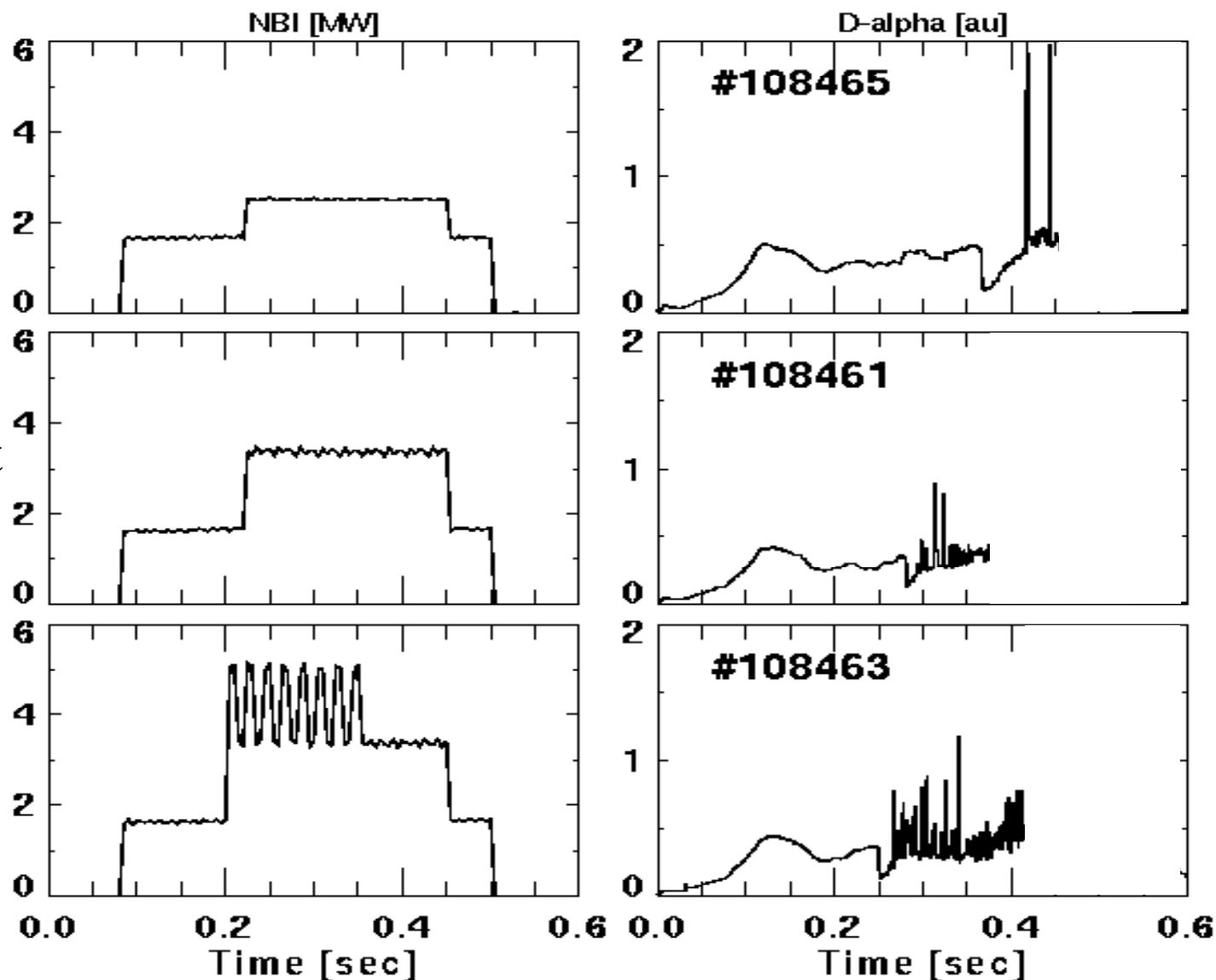
- Variety of ELM behavior observed in NSTX:

- From Grassy to Giant ELMs to ELM-Free
- Long Pulse ELM-free and ELMY (> 500 ms)
-- Steady-state ELMY possible
- ELMs w/DN and LSN
- ELMs w/NBI and RF
- Precursors? -Possibly seen by GPI
- Frequency: from < 135 Hz to > 600 Hz

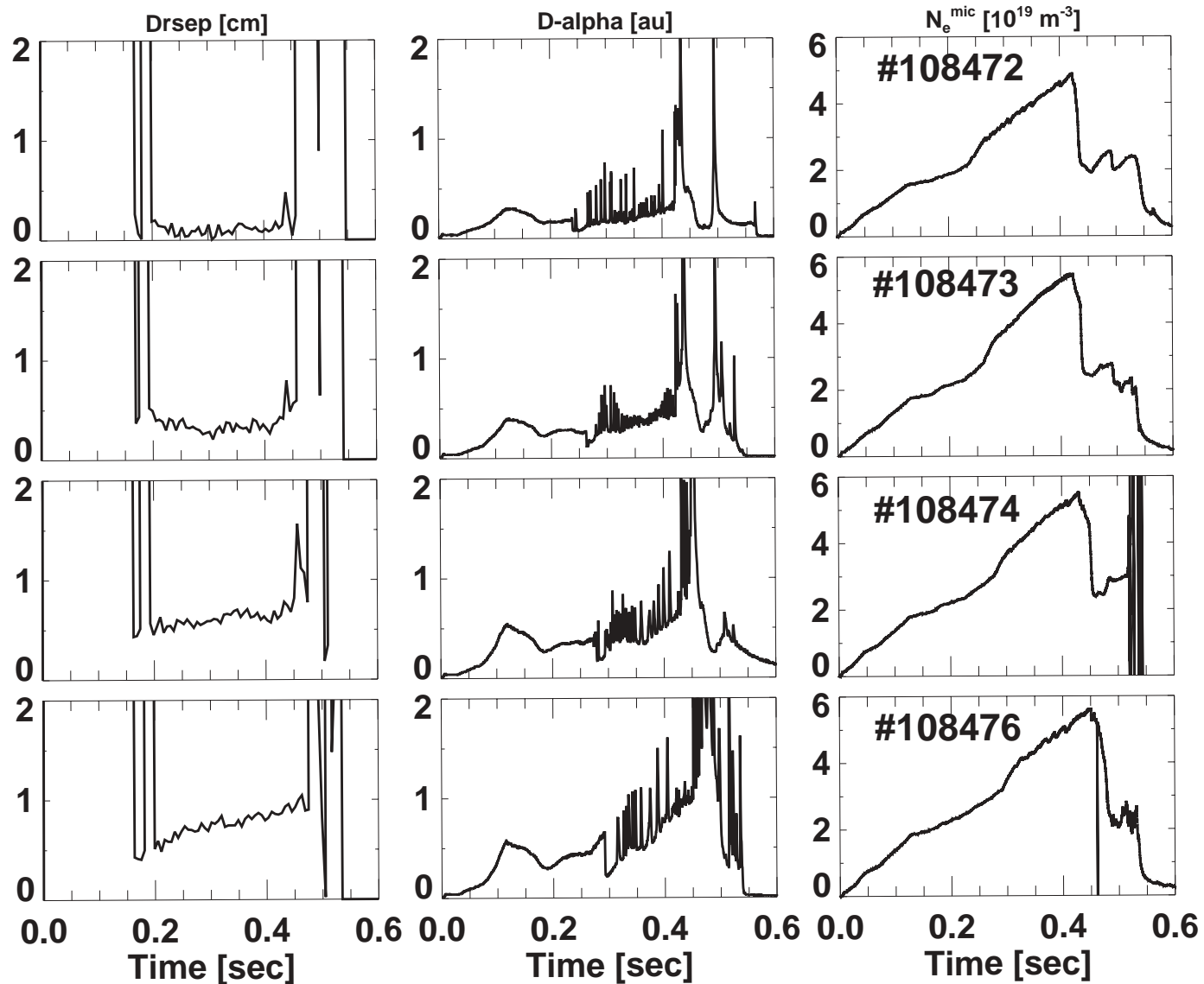


Edge Localized Modes Decrease(Increase) in Amplitude(Frequency) with Heating Power

* Similar to
type 1
ELMS in
low aspect
ratio
tokamaks

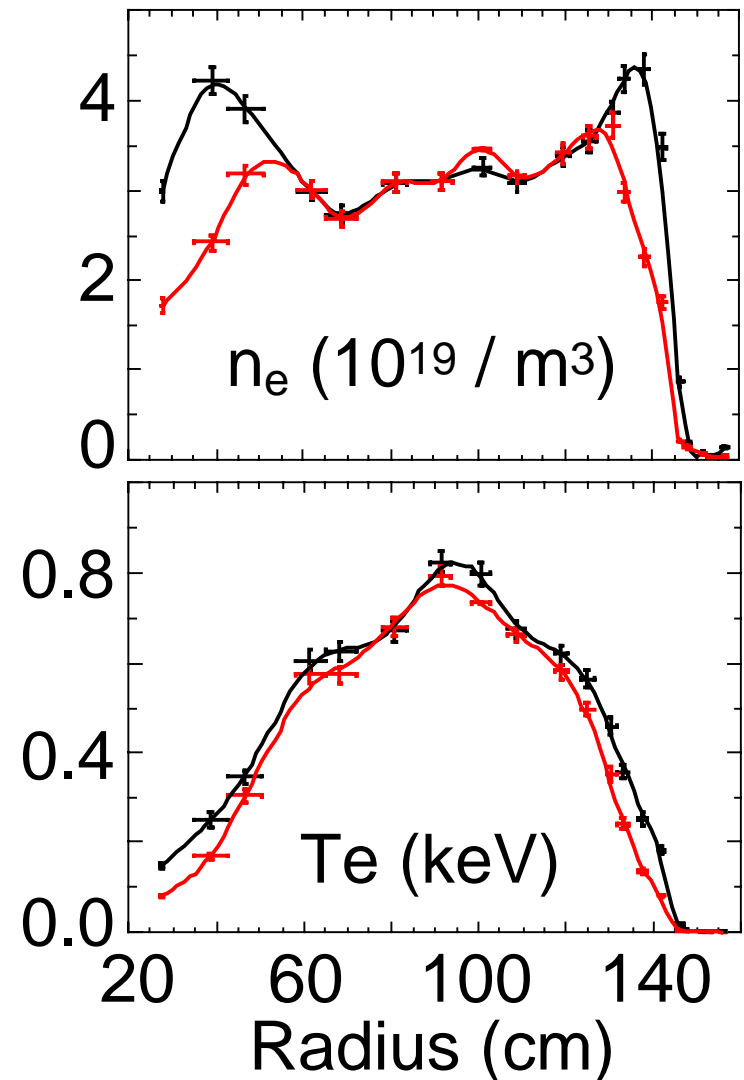
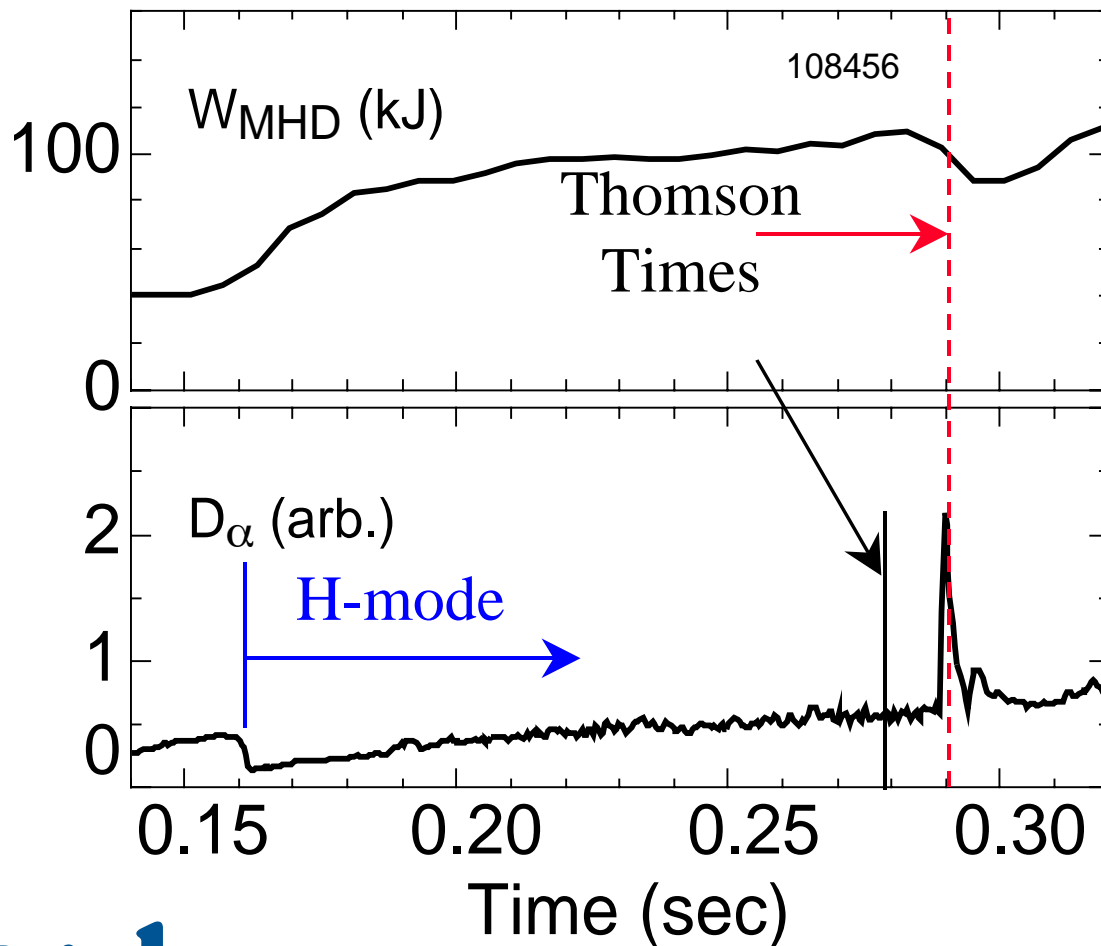


The Divertor Configuration Affects the Transition and the ELM Behavior in NSTX



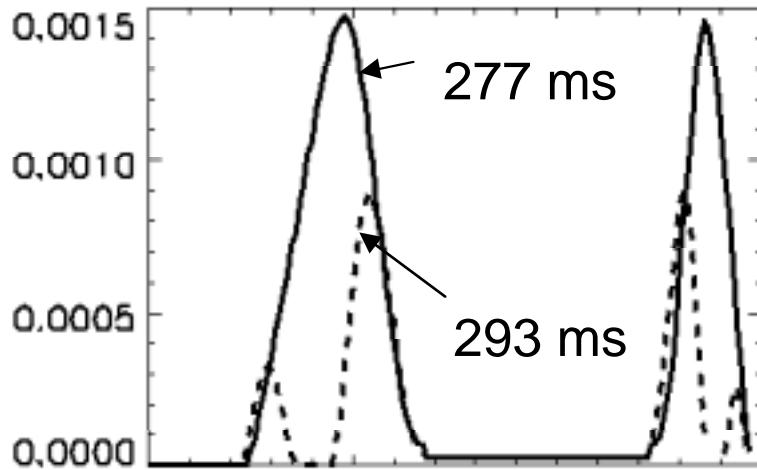
Large ELMs dump edge plasma and effect is radially deep into plasma

- Effect to $r/a \sim 0.4$, edge $\Delta n_e/n_e > 50\%$ observed. Can return to sustained L-mode.

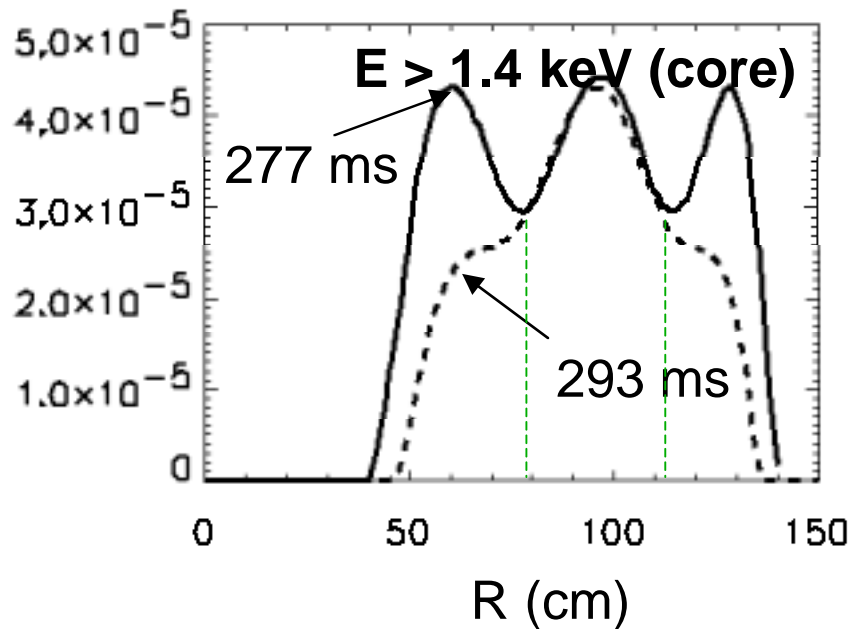
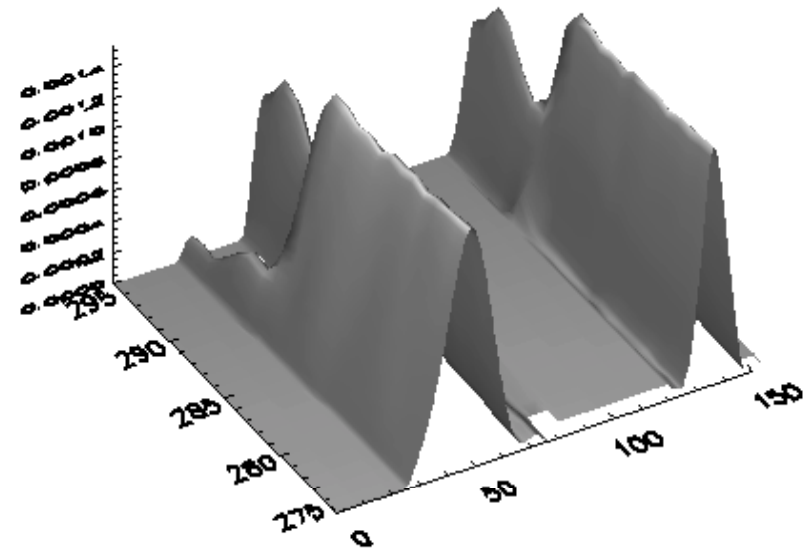


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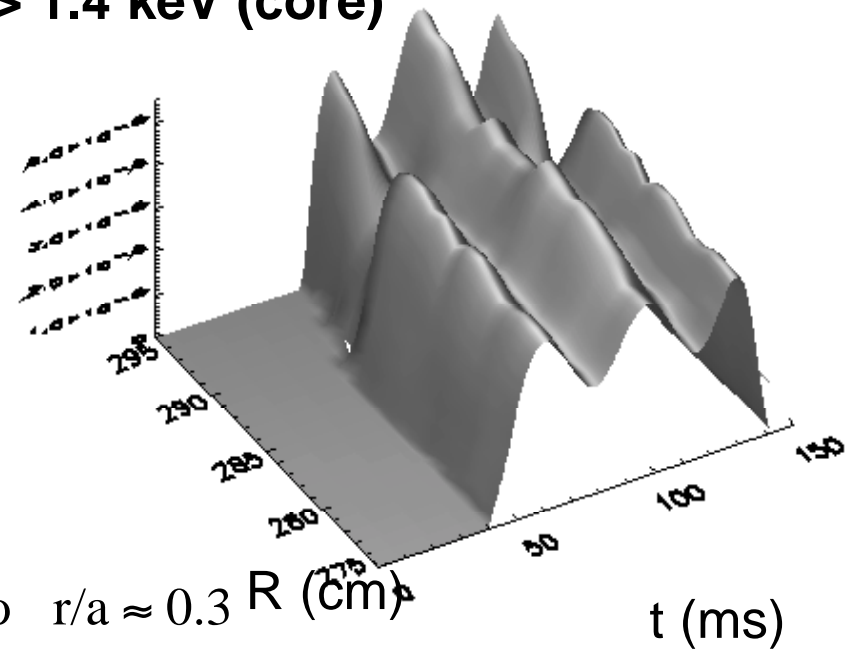
$E > 0.4$ keV (pedestal)



$E > 0.4$ keV (pedestal)



$E > 1.4$ keV (core)



- large crash in high energy emissivity (highly sensitive to temperature) extends to $r/a \approx 0.3 R$ (cm) t (ms)

What ELM Studies are Needed?

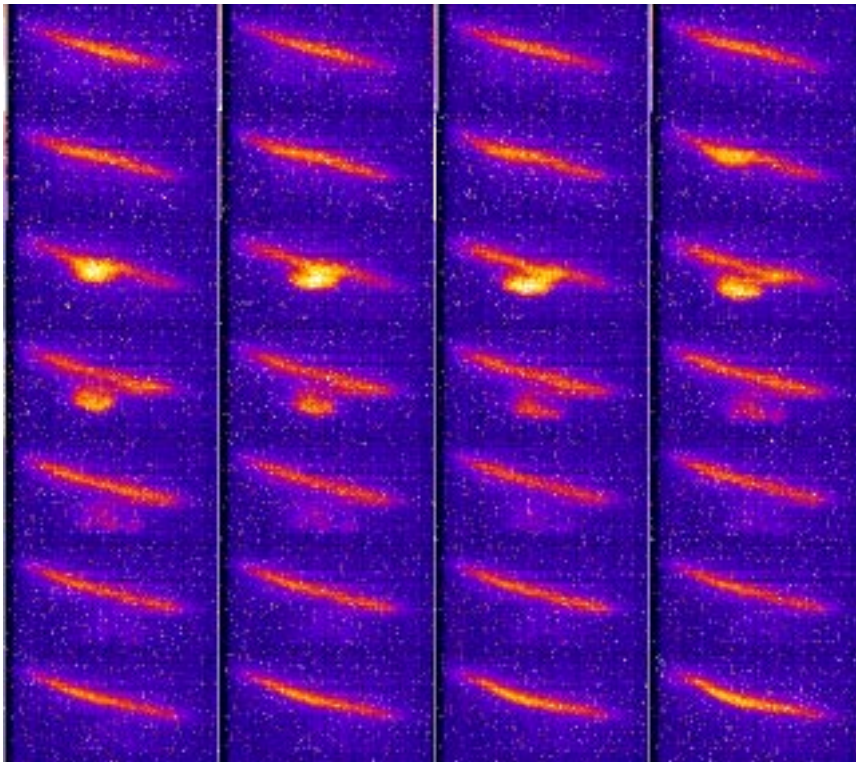
- **Studies for control:**
 - ELM studies have just begun on NSTX
 - Need control of ELM parameters, divertor loading, accumulation
 - Must scale ELM behavior to next generation ST - and ST reactor
 - Is ELM behavior the same for Tokamak and ST?
- **Studies needed:**
 - Stability - Determination of precursors - Mode numbers, n
 - Scaling of energy loss per ELM
 - Particle loss per ELM - n_e and impurity control
 - ELM control - Variation of ELM with ST scenario
- **Needs for APS:**

END

More examples of H-mode Images

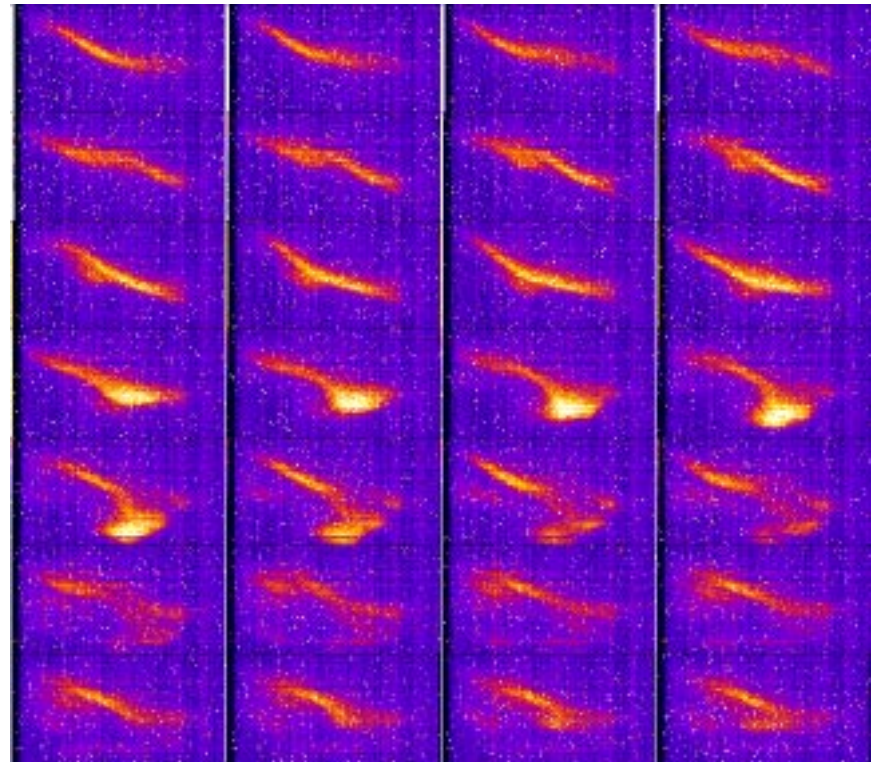
H-mode with blob

NSTX Shot # 108587, 100 kHz, 1000 kA, 4.5 kG, He



Wavy H-mode with blob

NSTX Shot # 108466, 100 kHz, 900 kA, 4.5 kG, He



- for more examples see <http://w3.pppl.gov/~szweben/psi/>