H-mode Characterization and Edge Stability at Near-Unity Aspect Ratio in PEGASUS Discharges

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PEGASUS Toroidal Experiment

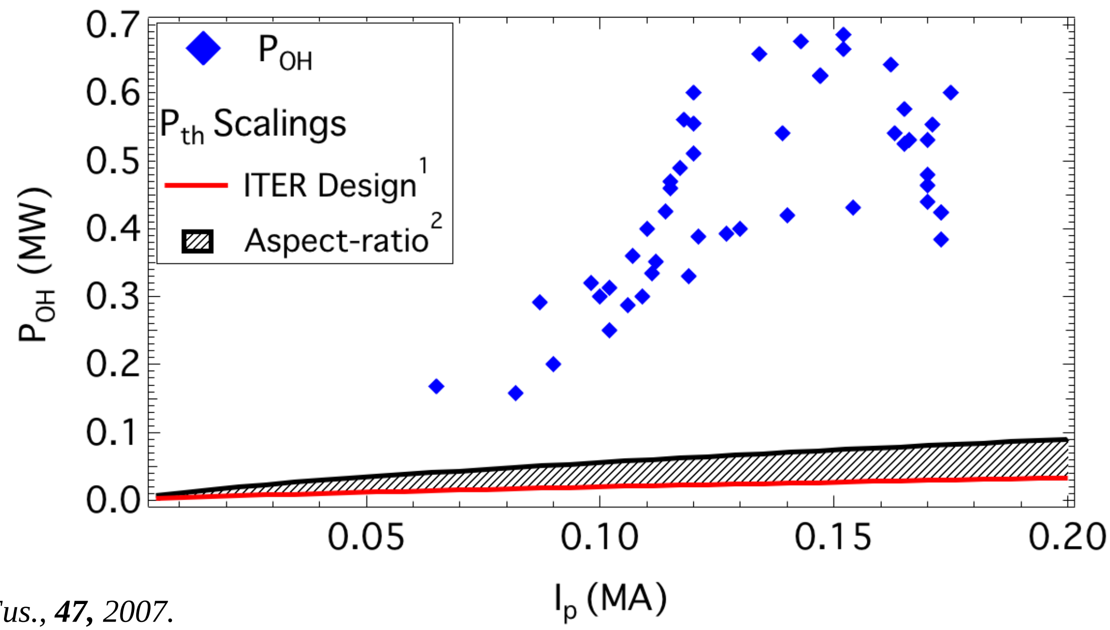
PEGASUS P_{OH} Exceeds P_{th} Predictions

- L-H power threshold scalings: $P_{th} \sim n_e^{0.7} B_T^{0.7} S$
  - At very low-A and hence low B_T, P_{th} is very low
  - Scalings[1,2] suggest PEGASUS $P_{th} < 0.1$ MW
  - P_{OH} = 0.2–0.7 MW

- Modest t_{shot} and $\langle T_e \rangle$ allow probes in pedestal

Experimental Parameters

Parameter	Achieved
B_T (T)	0.08–0.16
A	1.15–1.3
R (m)	0.2–0.45
I_p (MA)	$\leq$ 0.21
κ	1.4–3.7
t_{shot} (s)	$\leq$ 0.025
T_e (eV)	100–200



[1] *Accepted ITER design threshold P_{th}: K. Ikeda," Nucl. Fus., **47,** 2007.*

[2] *P_{th} with low-A data: I. H. mode Power Threshold, Plasma Phys. Control. Fus., **46**, 2004*

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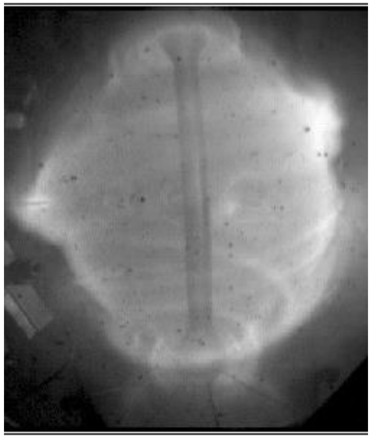
Fueling Location, Particularly in STs, is Critical for Achieving H-mode

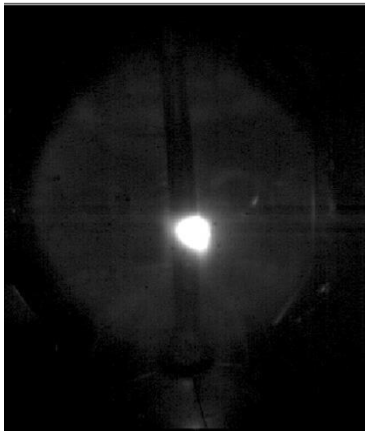
- LFS and HFS fueling
- H-mode achieved using HFS fueling
  - Similar to MAST and NSTX[1]
  - Both limited and diverted

<u>Limited</u>

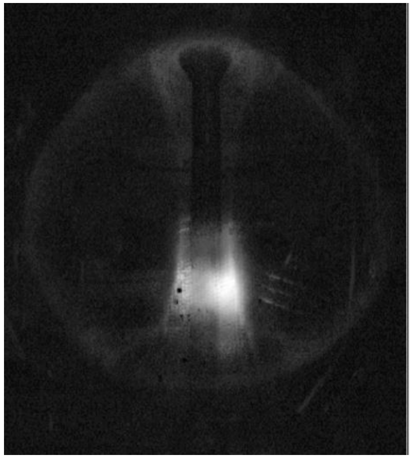
LFS Fueled (L)



HFS Fueled (H)



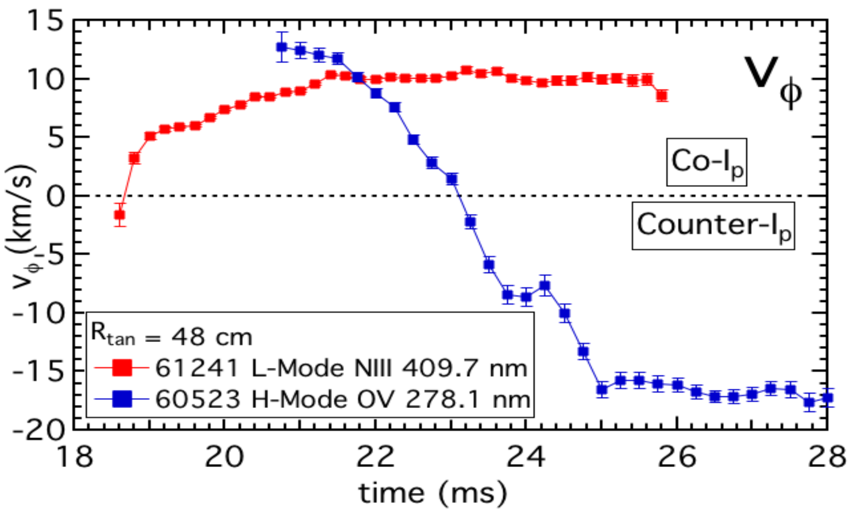
<u>Diverted (H)</u>

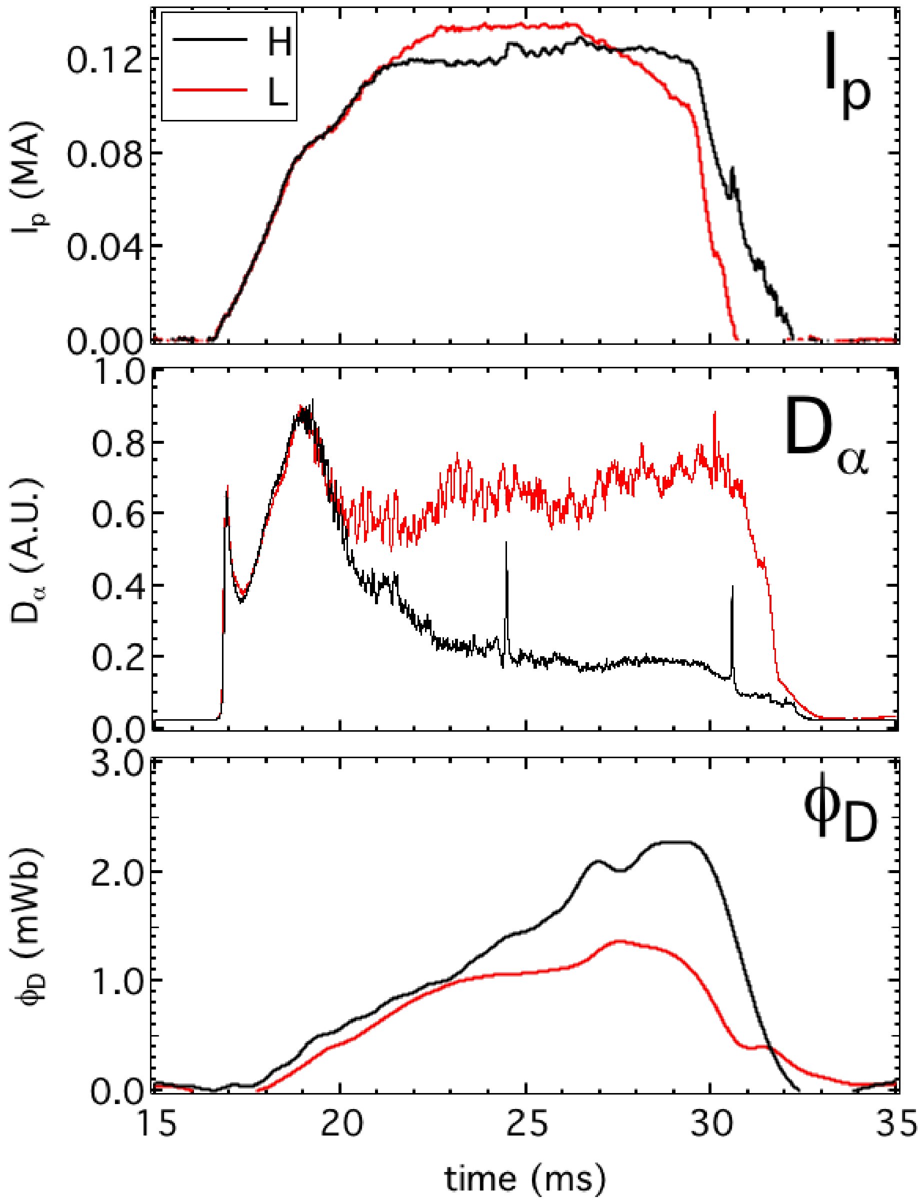


[1] *A. R. Field et al, Plasma Phys. Control. Fus.,* ***46****, 2004.*

Ohmic H-mode Plasmas have Standard Signatures

- H-mode signatures observed:
  - Quiescent edge
  - Increased core T_e, T_i inferred
  - Reduced D_α
  - Large and small ELMs suggested
  - Bifurcation in ϕ_D
  - Core v_ϕ reverses

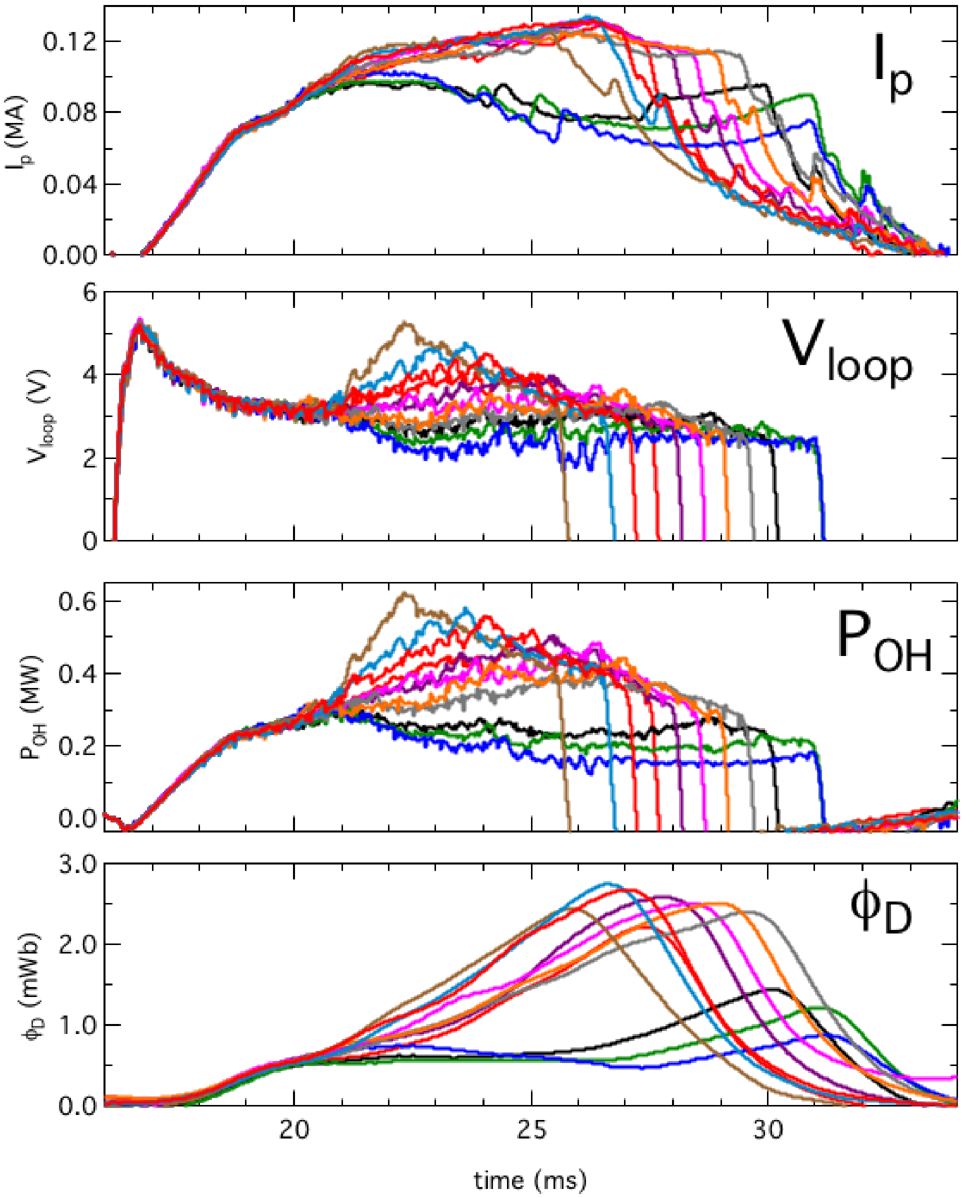




P_{th} Measured using V_{loop} Scans

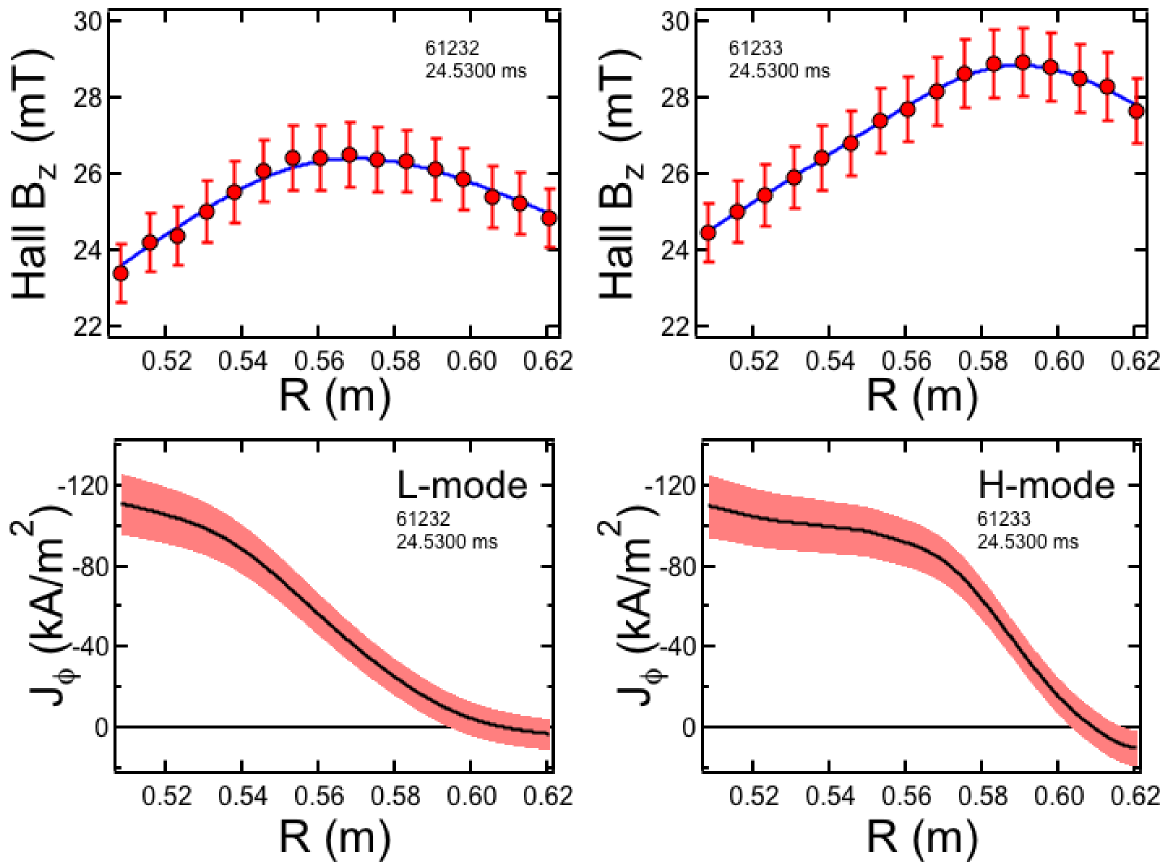
- Infer t_{LH} from bifurcation in ϕ_D
  - Vary $P_{OH} = I_p V_{loop}$
  - Constant I_{EF}, shape, fueling

- P_{th} ~ 0.25–0.30 MW
  - Scalings predict < 0.1 MW



Current Pedestal Measured using Hall Probe Array

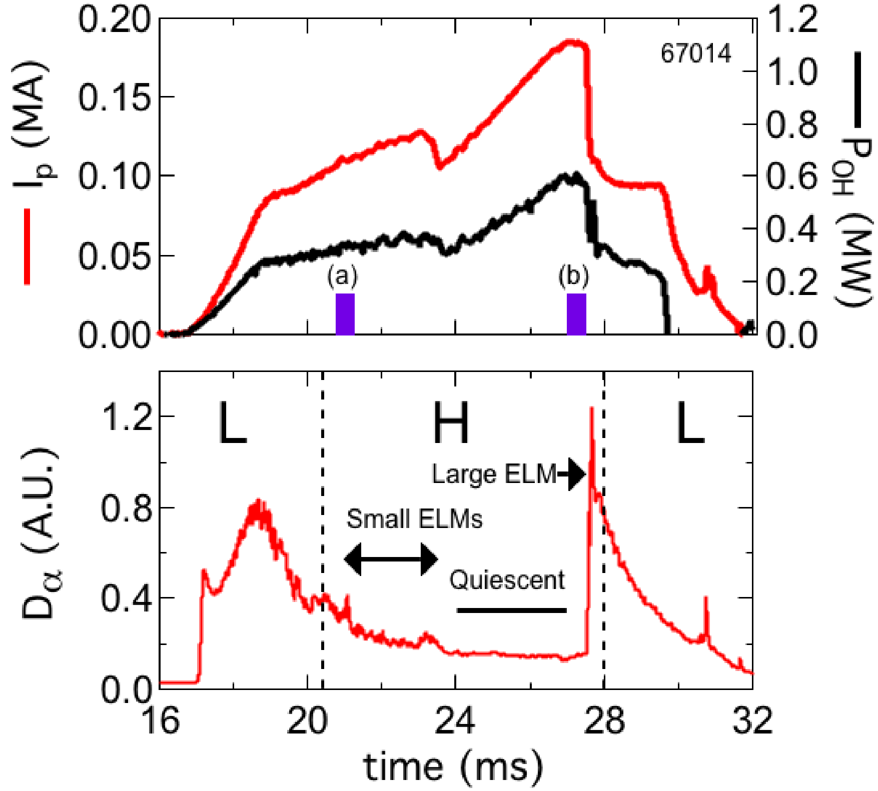
- Internal B_z measurements from Hall probe array yield local $J_\phi(R,t)$[1]
- Current gradient scale length significantly reduced in H-mode
  - L → H: 6 → 2 cm
  - $\rho_i \sim 1.8$ cm

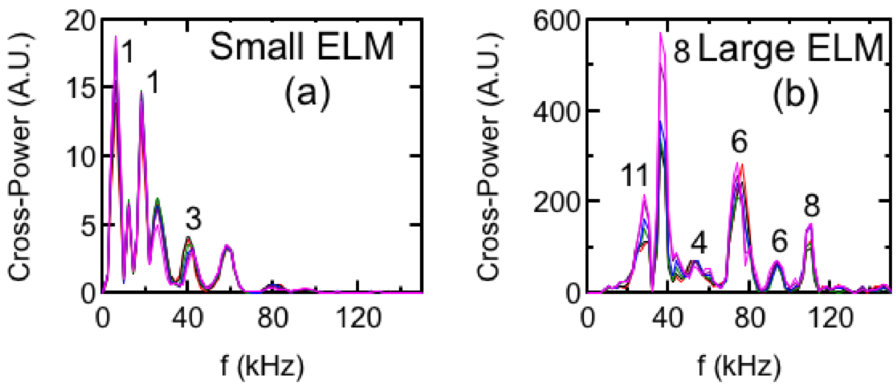


[1] *M. Bongard, Rev. Sci. Instrum.* ***81****, 10E105 (2010).*

Large and Small ELMs Suggestive of Type I and III ELMs are Seen

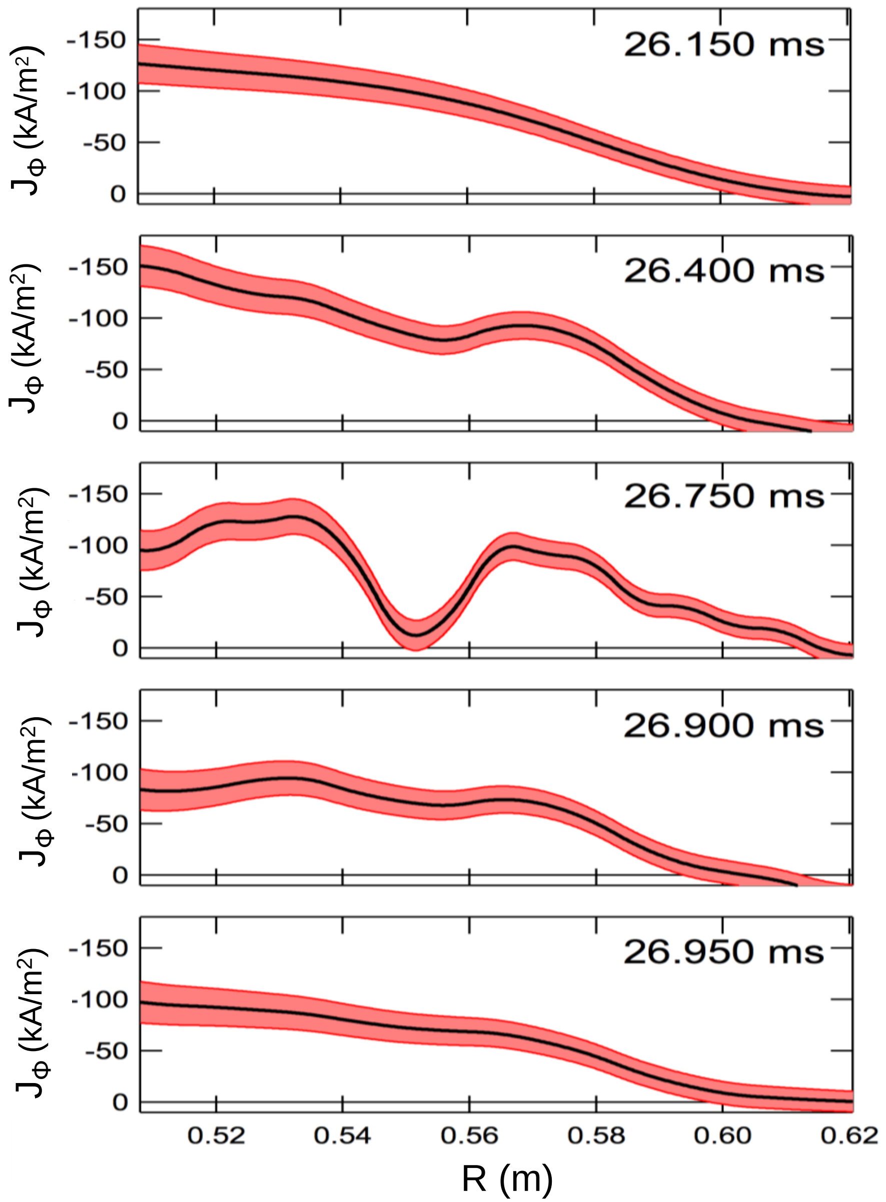
- Filament structures observed
  - Large ELMs infrequent and violent
    - Can cause H-L back-transition
    - Occur at high P_{OH}
  - Small ELMs more ubiquitous and less perturbing
    - Occur at lower P_{OH}
- n measured with close-fitting coil array through ELM crash
  - PEGASUS results similar to NSTX
    - Large ("Type I"): intermediate-n
    - Small ("Type III"): low-n
  - STs appear to have structure opposite that of ATs





Small ELM $J_{edge}(R,t)$ Dynamics Measured Throughout Single ELM Cycle

- Dynamic evolution measured at high time and spatial resolution
  - $n \leq 3$ precursor
  - Rapid collapse and recovery of H-mode pedestal
- Current-hole perturbation accompanies pedestal crash
  - Followed by current filament ejection and pedestal recovery
  - Dynamics are identical to those observed in earlier peeling mode studies on PEGASUS[1]

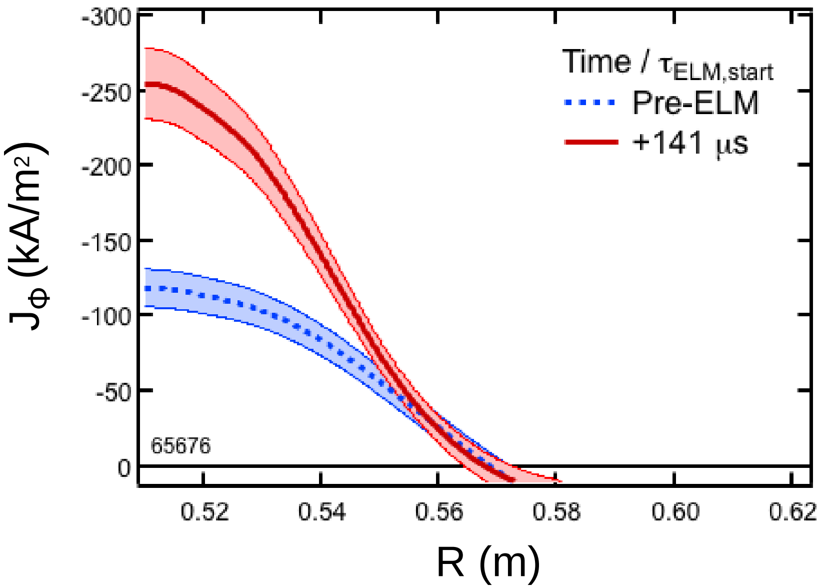


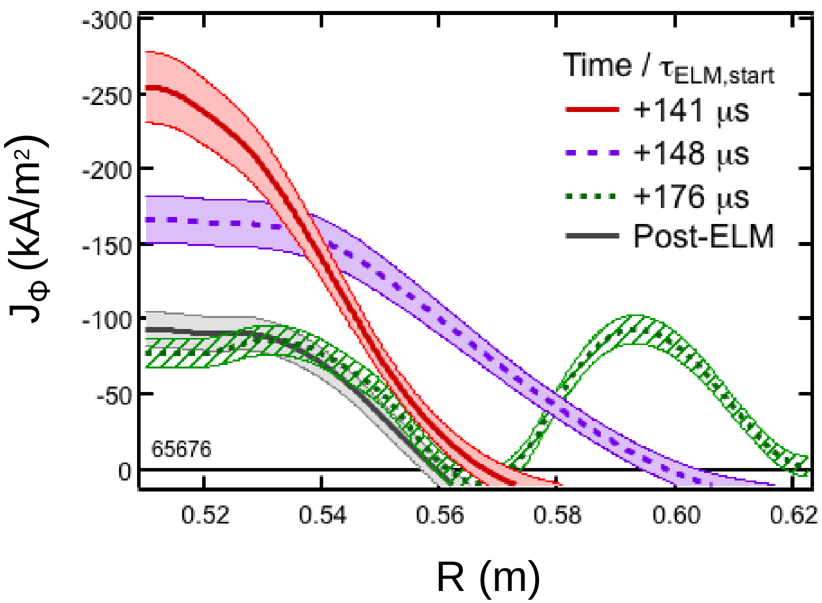
[1] *Bongard et al., Phys. Rev. Lett.* ***107****, 035003 (2011)*

Similar Sequence of Events Through Large ELM Crash

- $J_{edge}(R,t)$ profiles measured throughout single large ELM
  - No clear EM precursor but intermediate-n structure during ELM

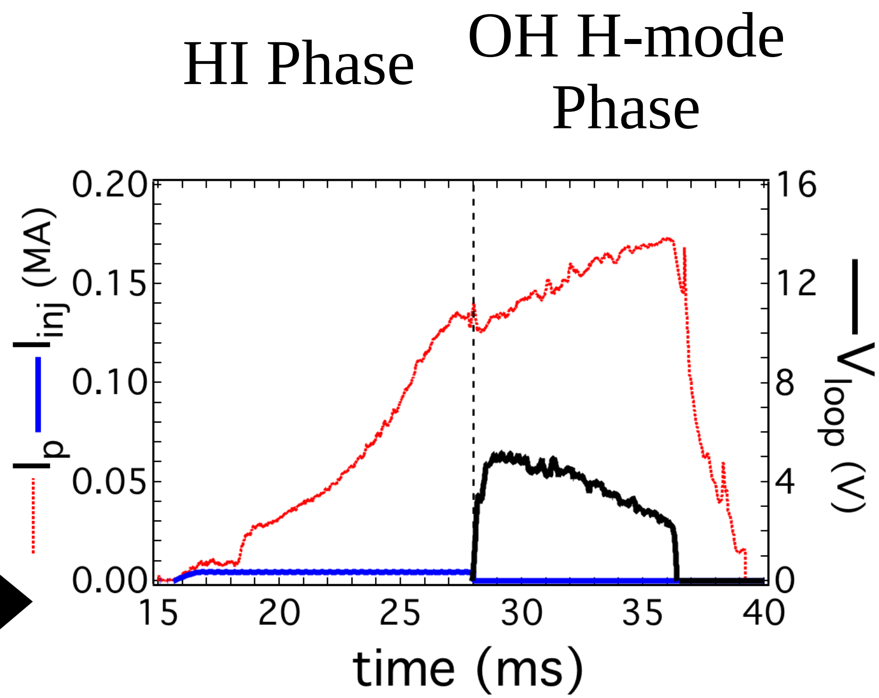
- Large ELM $J_{edge}(R,t)$ shows complex evolution
  1) **Modest but steep J_{edge} pedestal**
  2) **Rapid buildup of J_{edge} until crash**
  3) **Collapse with wider pedestal gradient (similar to L-mode)**
  4) **Current-hole filament ejection**
  5) **Recovery: slightly lower than pre-ELM pedestal**





Embarking on Studies of H-mode Access and ELM Characterization at Near-Unity A

- P_{th} characterization with I_p, shape, n_e, M, and fueling location
- Detailed ELM dynamics
  - Supported by edge diagnostic access
- Requires longer pulse and higher I_p: helicity injection (HI)
  - Provides additional Volt-seconds
  - HI startup to OH H-mode demonstrated
- H-mode may facilitate access to high β_t at A ~ 1



Conclusions: A ~ 1 Operation Enables Studies of H-mode Phenomena

- Low toroidal field at A ~ 1 facilitates access to H-mode
  - P_{th} ~ 5x greater than P_{th} scalings' predictions
  - Edge current pedestal observed
- Large, small ELMs observed and $J_{edge}(R,t)$ dynamics measured
  - Difference in toroidal mode numbers between large and small ELMs
  - Measured $J_{edge}(R, t)$ ELM dynamics show current-hole perturbation
- Extending studies to wider operational spaces to characterize H-mode access, ELM dynamics

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For more details, please see Thursday morning poster session:
TP8.00021: Access to and Characterization of Ohmic H-mode Plasmas at A ~ 1
TP8.00022: Initial Investigations of H-mode Edge Dynamics in PEGASUS