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Effect of Gas Injection Location on H-mode Access and Characteristics in NSTX

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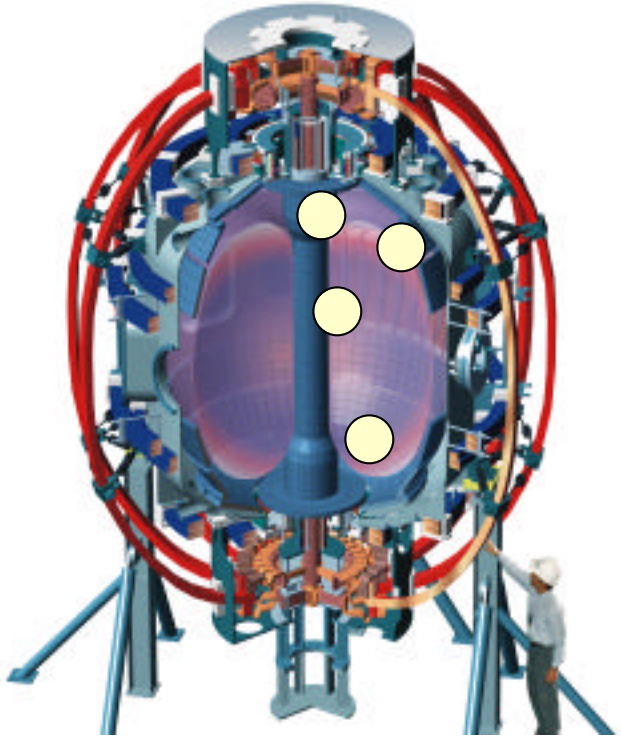
H-modes Obtained Routinely in NSTX

- Why is NSTX interested in H-modes?
  - * High stability limit due to low pressure peaking
  - * Long pulse due to low loop voltage
- Comparison of H-mode access and toroidal rotation w/fueling from gas injectors at 4 poloidal locations
  - * Center stack midplane
  - * Center stack top
  - * Outer midplane/top
  - * Lower X-point (dome) region



HIGH-FIELD SIDE (HFS) GAS FUELING PROVIDES REPRODUCIBLE H-MODE ACCESS IN STs

- Center stack midplane fueling during NBI enabled reproducible H-mode access in MAST
- NSTX installed center stack midplane gas injector in FY'02 - also better H-mode access
- Theoretical calculation shows poloidal gas source location affects electric field magnitude, more at small R/a

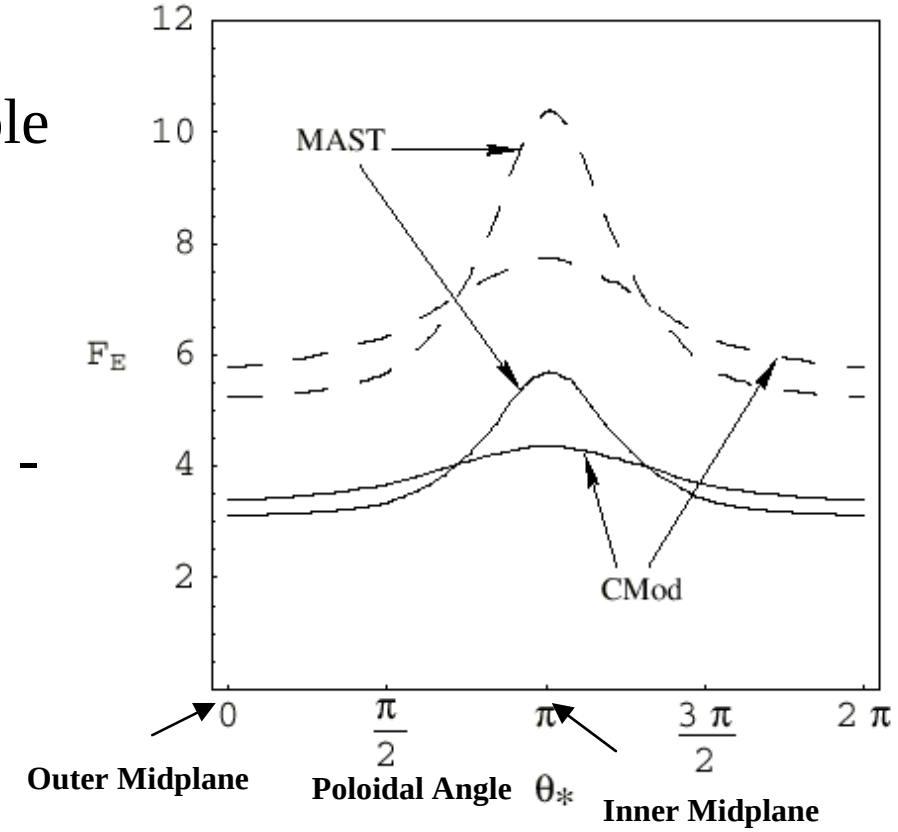


FIG. 2. Radial electric field at the outer midplane of MAST and Alcator C-Mod as a function of the gas puff location. The solid and dashed lines represent the short mean-free path limit for $\eta_i = 1$ and $\eta_i = 2$, respectively.

Fulop, Helander, Catto, PRL #225003-2; 25-Nov-2002

COMPARISON OF CENTER STACK MIDPLANE AND LFS FUELING OBSERVATIONS

- H-mode access most reproducible with high-field side (HFS) gas fueling from center stack midplane during NBI
- H-mode transition inhibited for high Γ_{puff}, with LFS fueling
- H-mode transition delayed for medium Γ_{puff} with LFS, compared w/HFS midplane
- H-mode transition similar at low Γ_{puff} for LFS and HFS mid
- Edge toroidal rotation (C-III) higher (co-) with HFS and becomes negative after L-H

SUMMARY OF CENTER STACK TOP AND LOWER DOME OBSERVATIONS

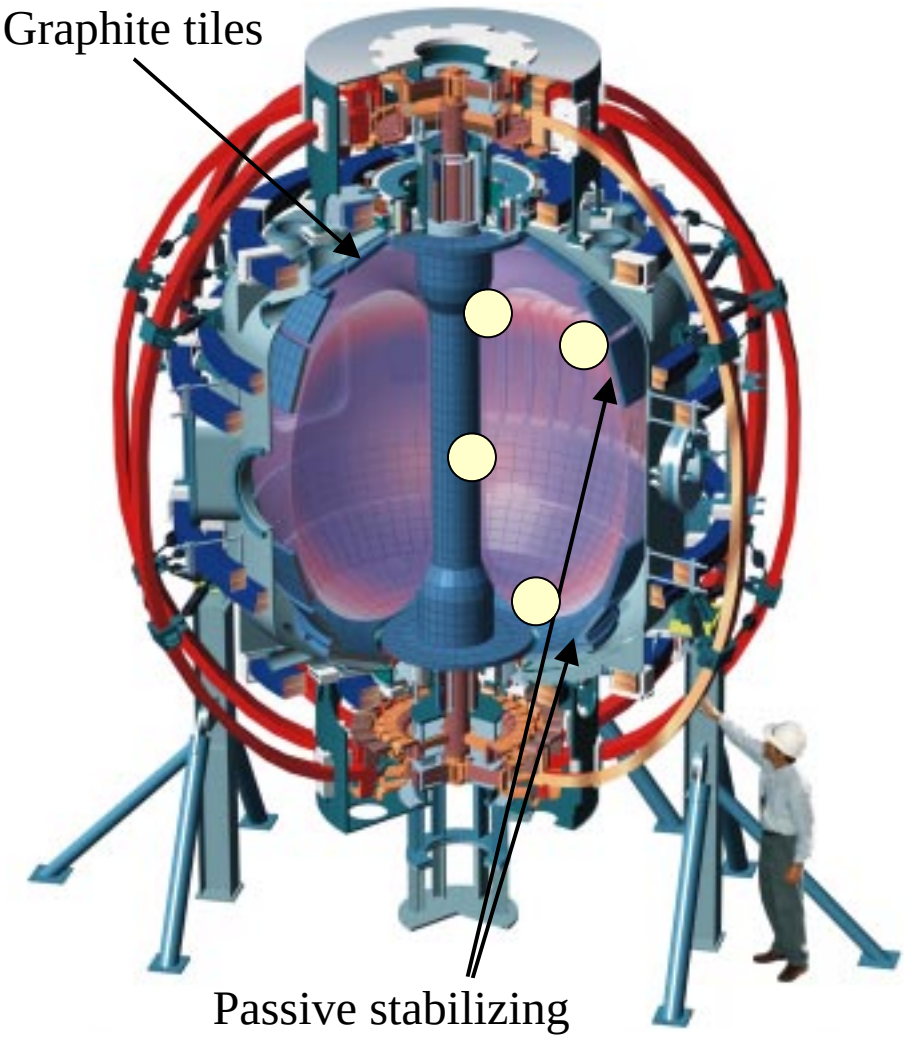
- Center stack injector has a smaller initial dump and shorter e-folding decay time of flow rate

- Center stack top injector enabled H-mode access in double-null but not lower single-null (gas trapped in DN?)

- Lower dome dumps gas in very quickly

- Lower dome did not enable H-mode access, but prevented locked/tearing mode reconnection in L-mode discharge when timing was ‘optimized’ (lucky)

NSTX Explores Low Aspect Ratio (A=R/a) physics regime



Parameters	Design	Achieved
Major Radius	0.85m	} ⇒A ≥ 1.27
Minor Radius	0.67m	
Plasma Current	1MA	1.5MA
Toroidal Field	0.6T	0.6T
Heating and Current Drive		
NBI (100keV)	5MW	7 MW
RF (30MHz)	6MW	6 MW

Wall Conditioning:

350 deg. bakeout of graphite tiles

Regular boronization (~3 weeks)

Helium Glow between discharges

Center stack gas injection

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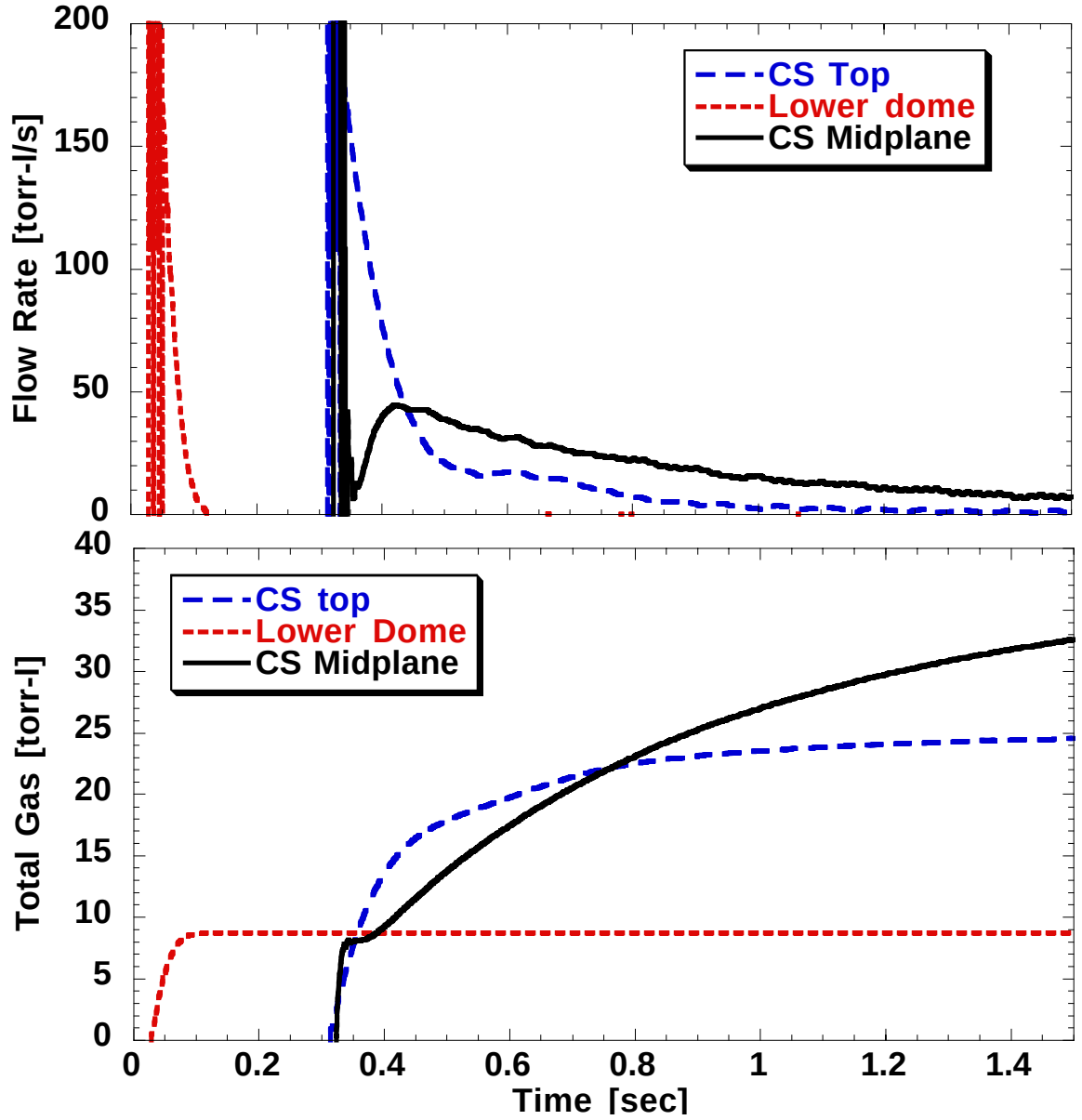
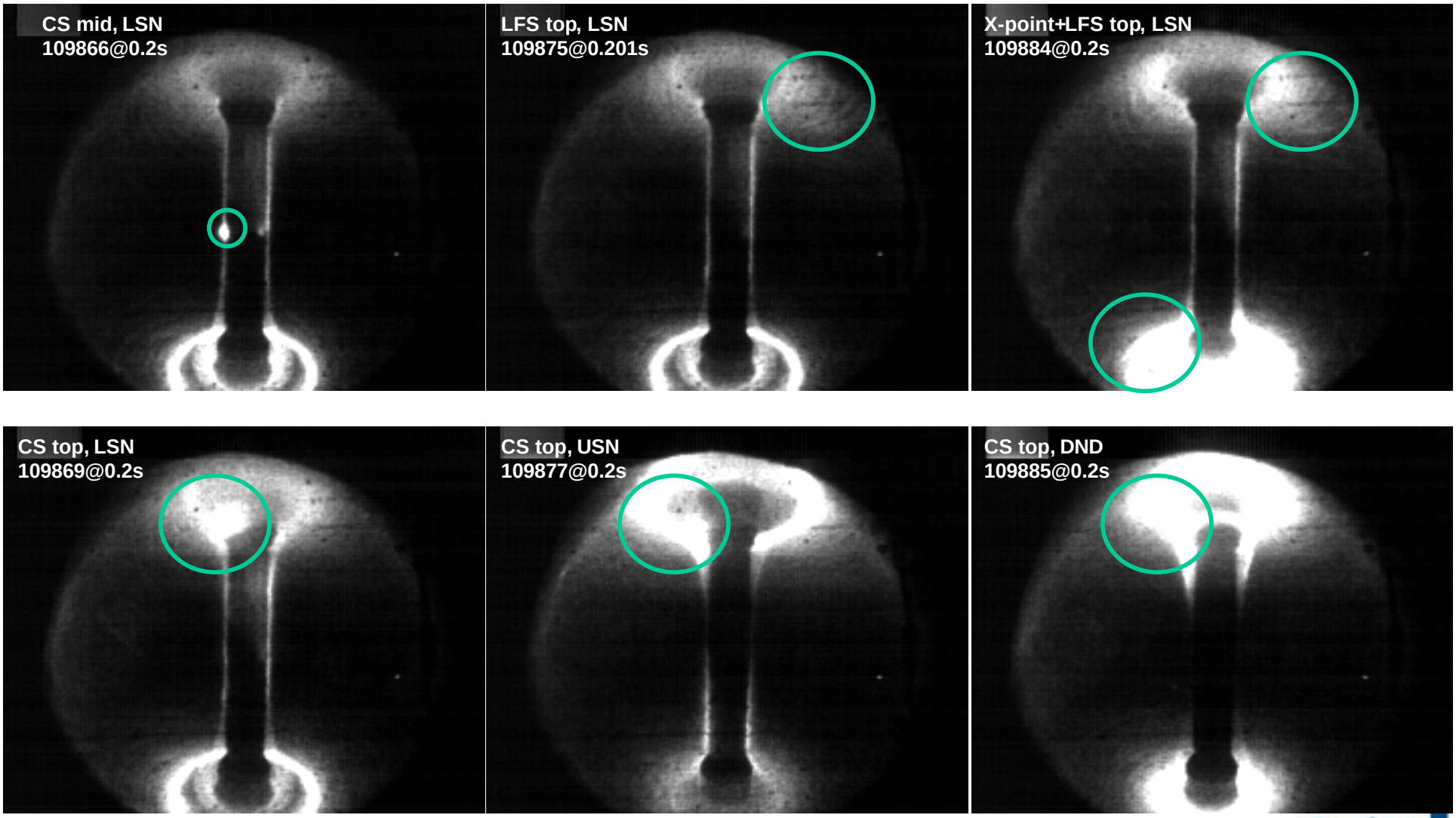
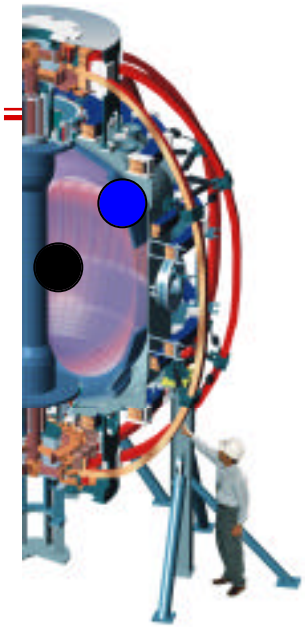
Load-and-Dump Gas Injectors Have Different Flow Characteristics and Delay Time

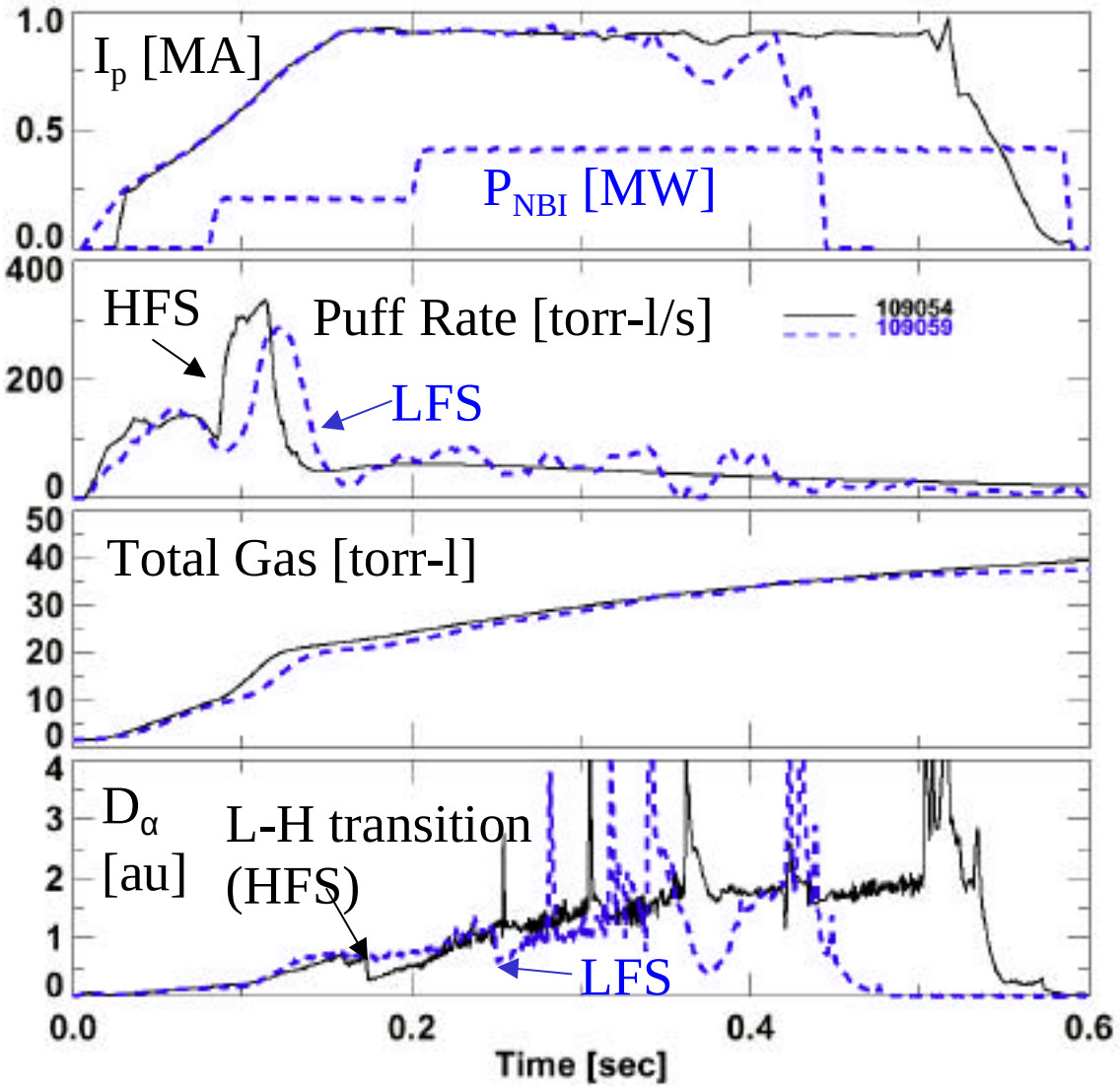


Different Gas Puffers Light up Different Plasma Regions (unfiltered)



Center-stack MP Gas Injector Fueling Allows Early L-H Transition and Longer H-mode Duration





- Experiment run when L-H power threshold was < 1NBI src (*end of run 2002*)
- Note LFS shot only had L-H with 2 NBI -> higher P_{L-H}

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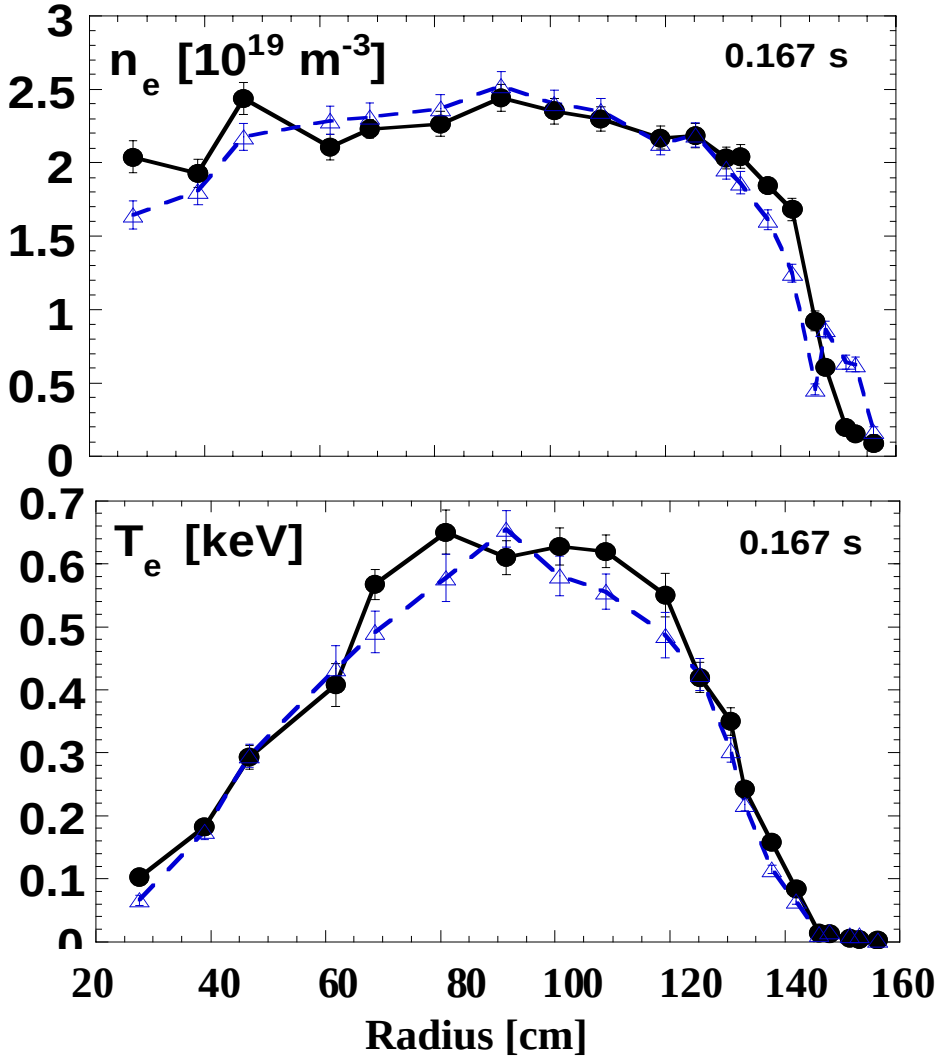
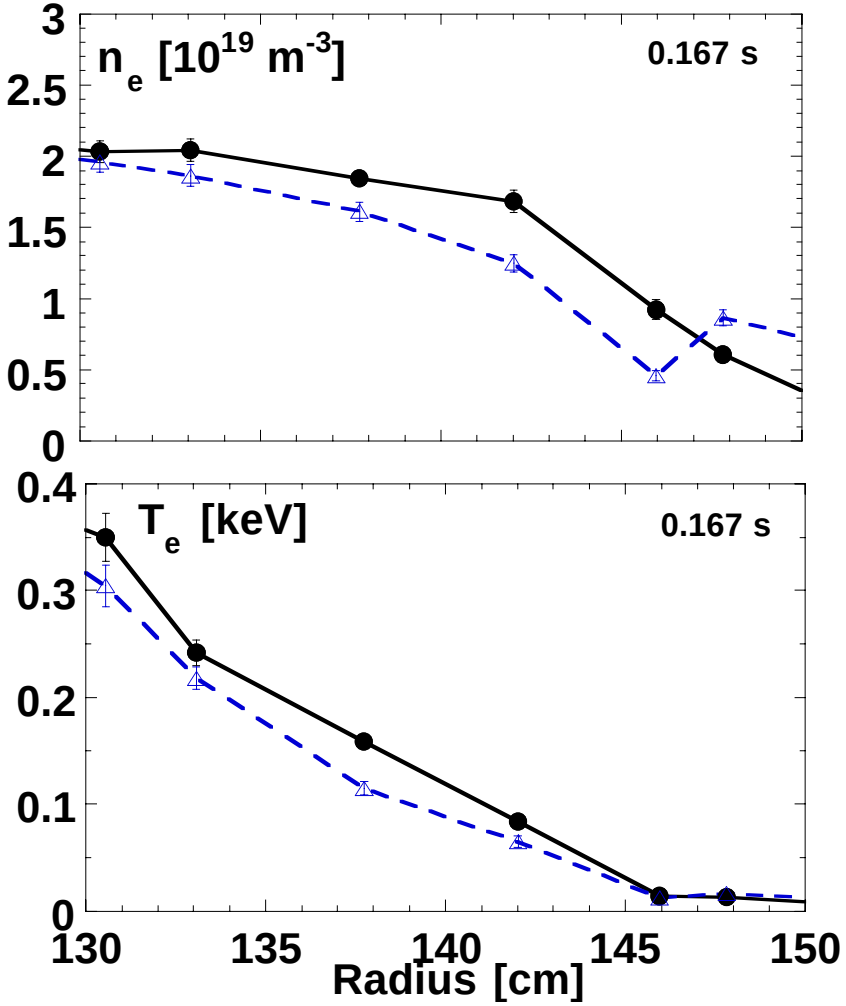
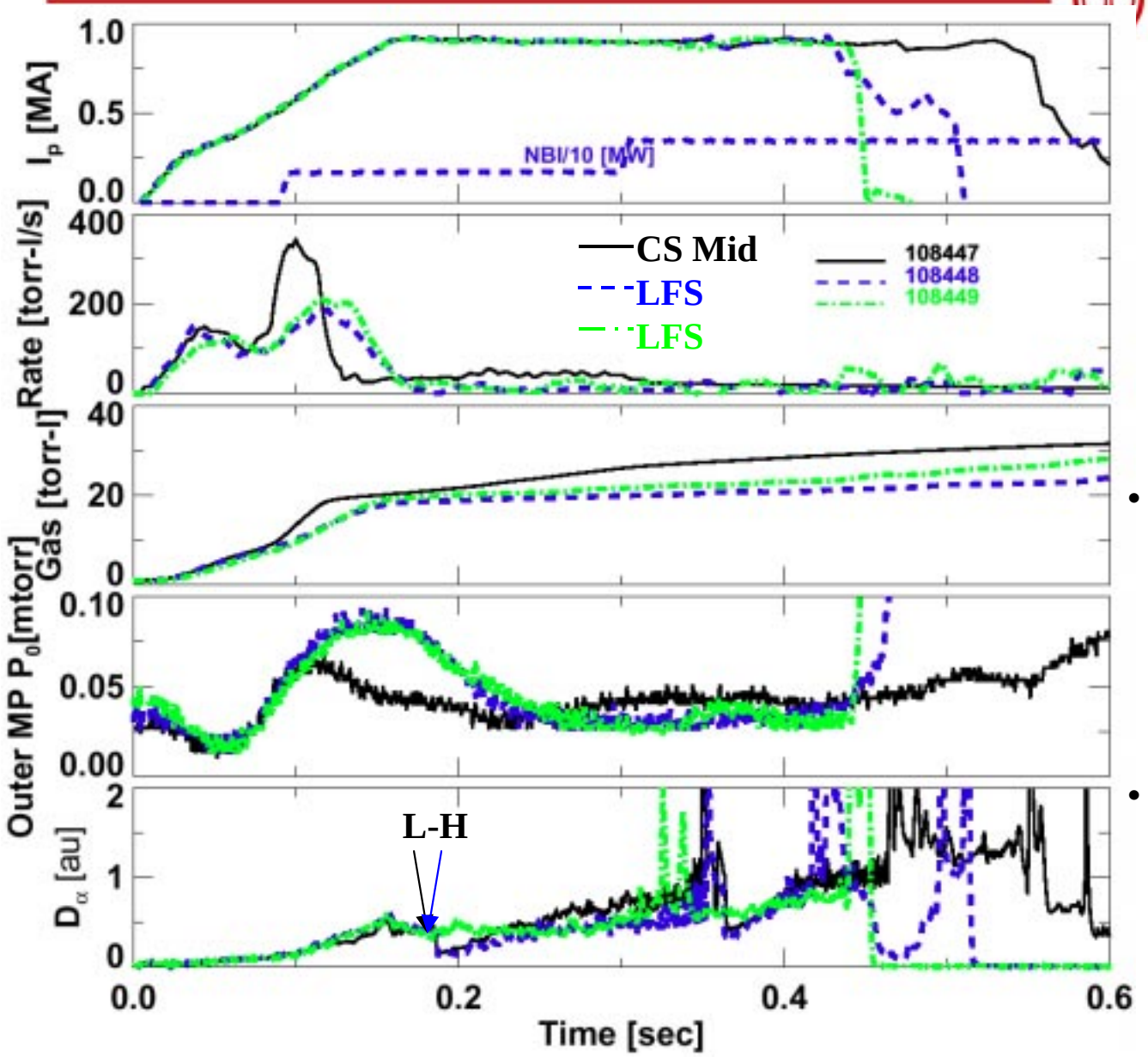
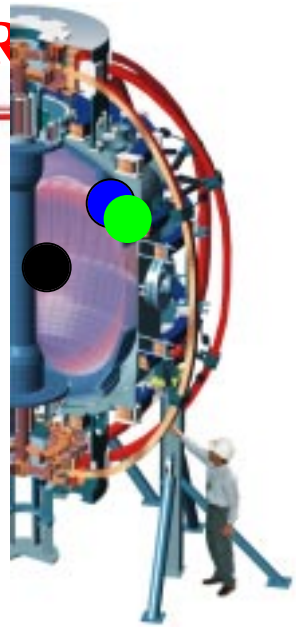
Center-stack MP Gas Injector Fueling Allows Higher Edge n_e and T_e Even Before L-H Transition





Center-stack MP Gas Injector Fueling Has More Reproducible H-mode Access, Even at Lower Puff R





- Experiment run when L-H power threshold was < 1 NBI src (*end of run 2003*)
- Note CS Mid and LFS shot had same t_{L-H}, but repeat LFS had no L-H -> higher P_{L-H} with L FS

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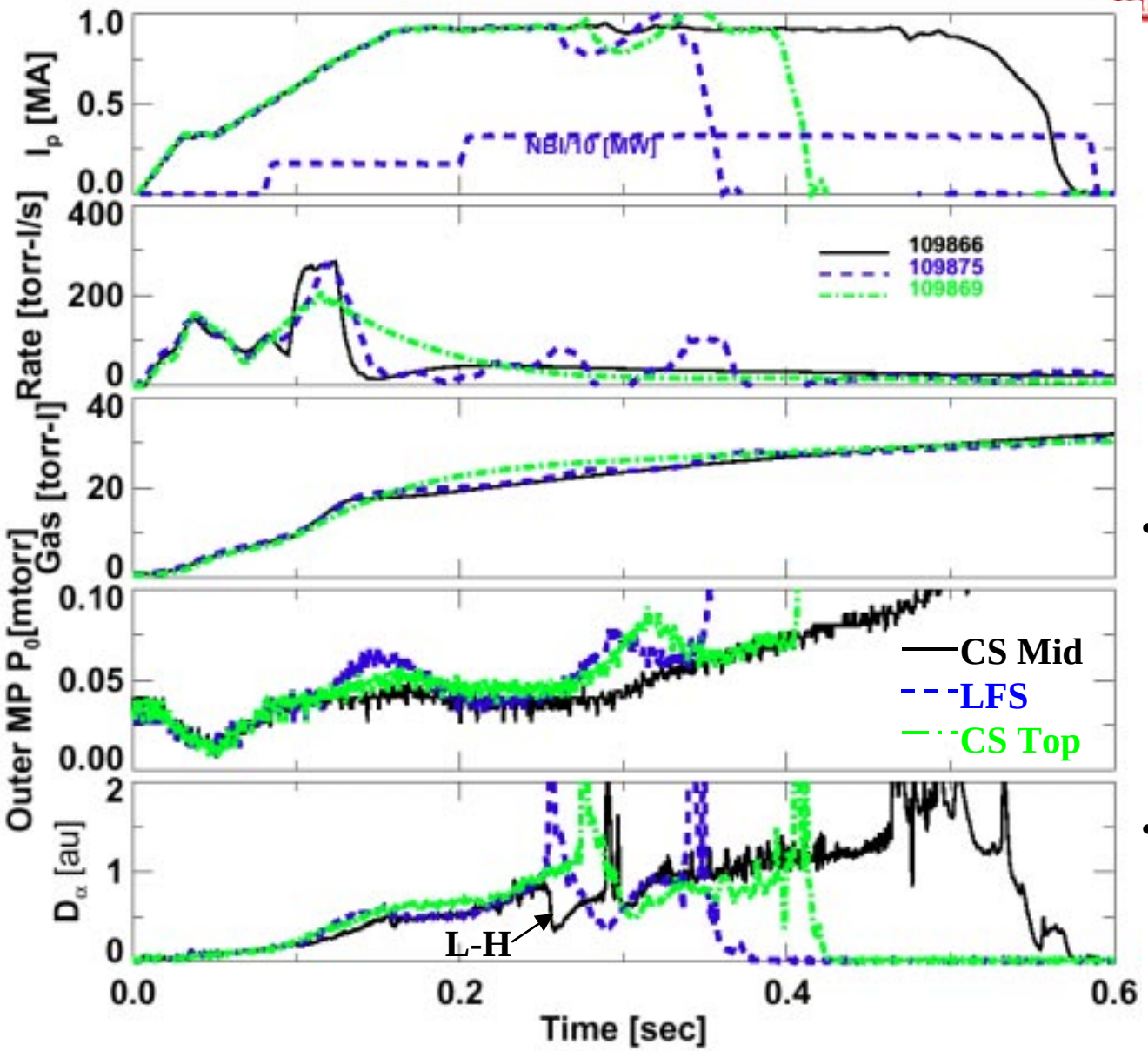
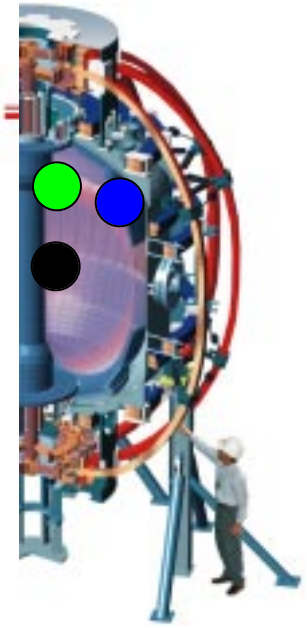
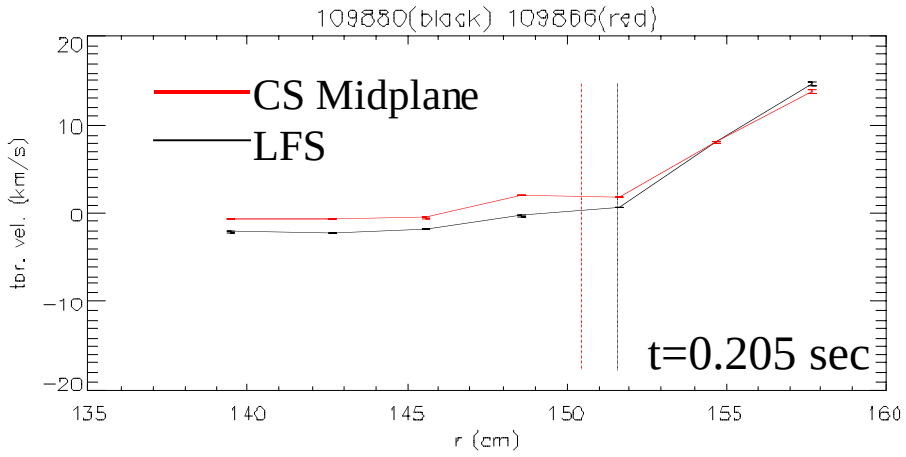
Center-stack Midplane Gas Injector Fueling Has Lower P_{L-H} Than LFS and CS Top

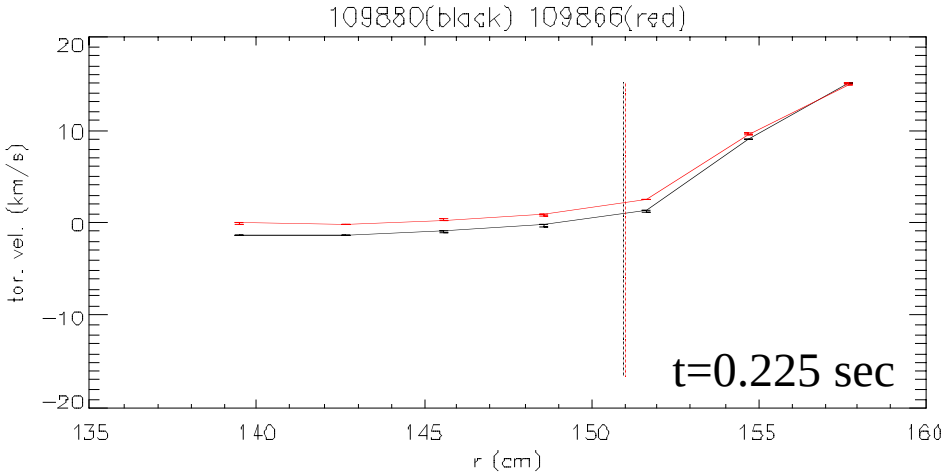




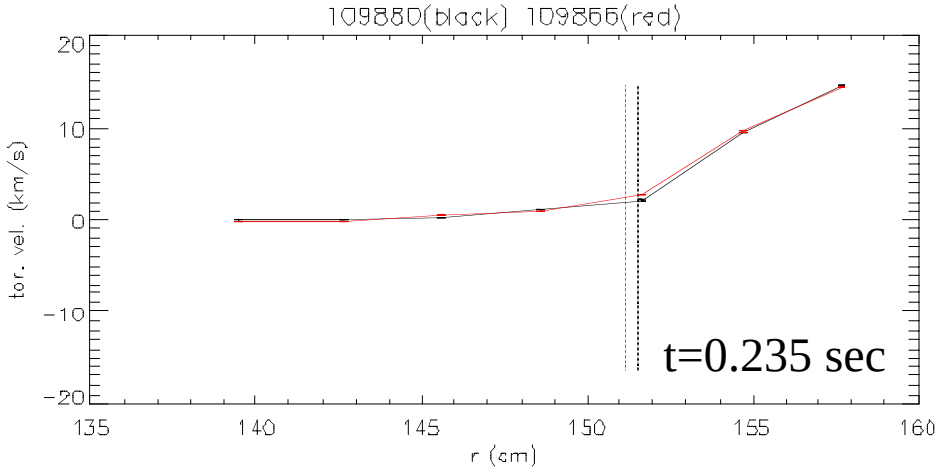
- Experiment run when L-H power threshold was ~ 1-2 NBI src (*start of run 2003*)
- Note LFS shot and CS top had no L-H -> higher P_{L-H}

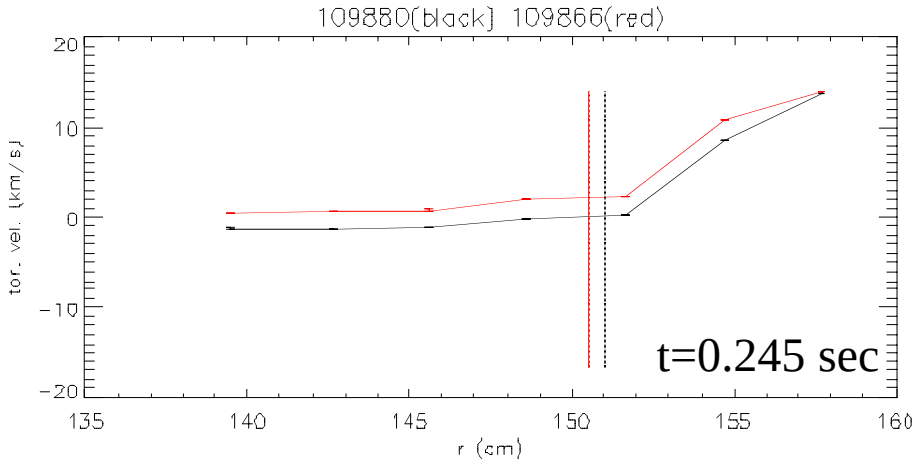
Toroidal Rotation Generally Higher (more co-I_p) for CS Mid. case (red) before LH transition at t=0.254 sec



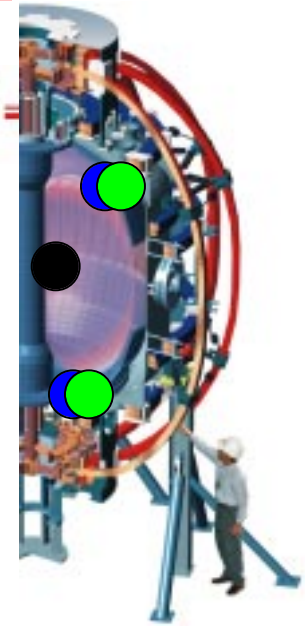


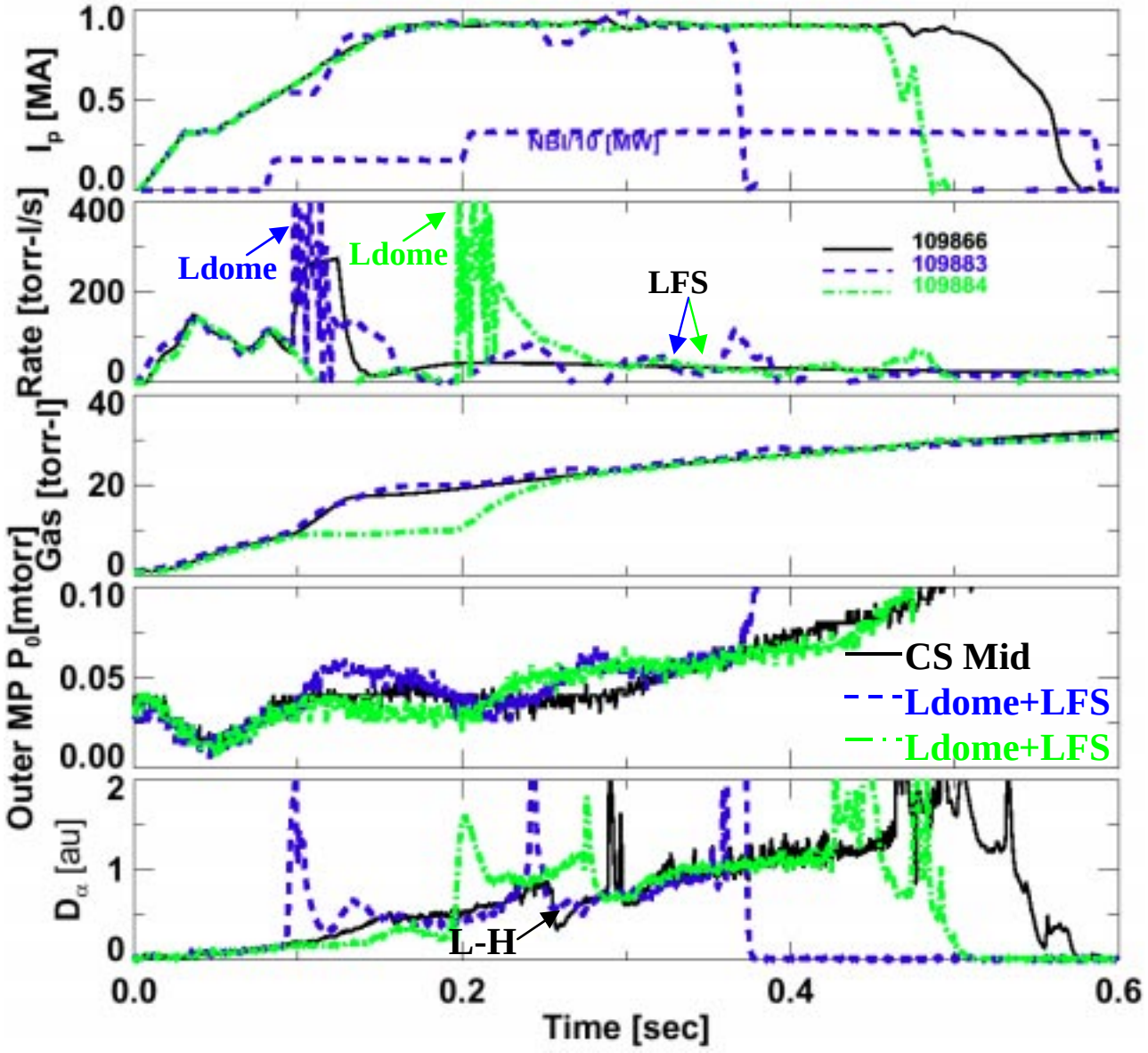
Preliminary





Lower dome + LFS Gas Injectors Can Match CS Midplane Flow Rate But Do Not Allow H-mode Access

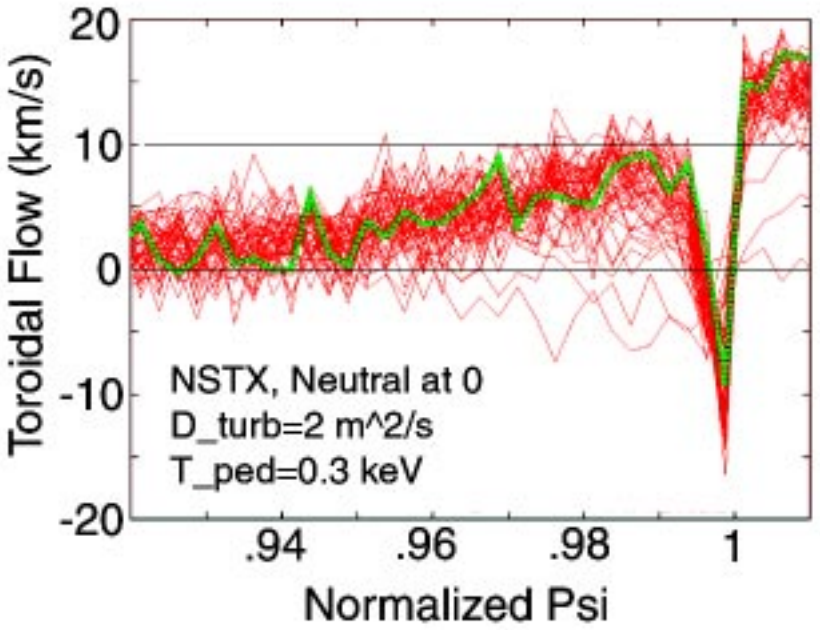




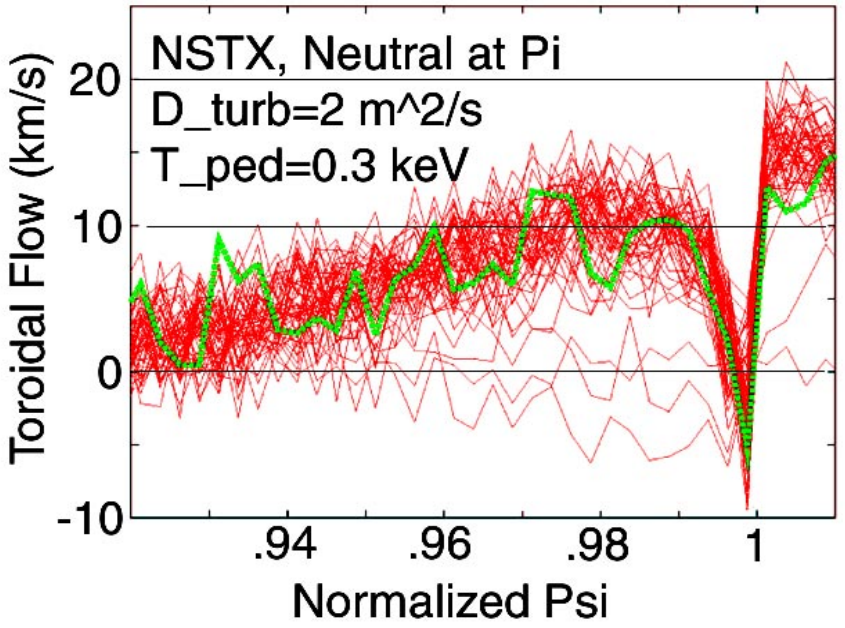
- Experiment run when L-H power threshold was ~ 1-2 NBI src (*start of run 2003*)

Higher Toroidal Rotation Predicted for Center Stack Midplane Fueling

Outside Midplane



Center Stack Midplane



- **50 x N_o is assumed around the fueling location.**
- **Simulated w/XGC code (guiding center, Monte Carlo)**

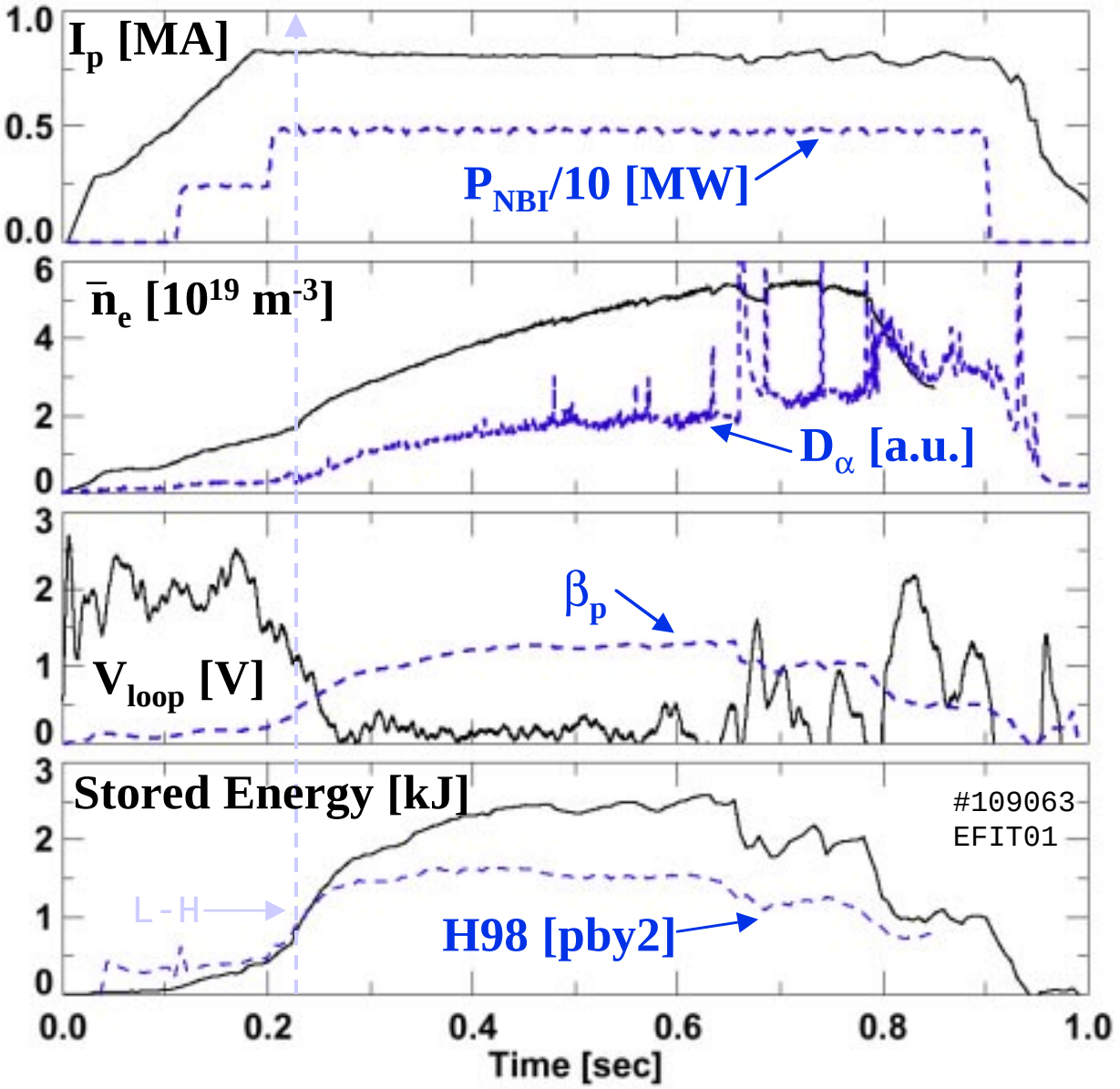
C.S. Chang, 3/2003

SUMMARY AND CONCLUSIONS

- High-field side (HFS) gas fueling from midplane during NBI enabled best reproducibility for H-mode access
- HFS fueling from top allows H-mode access in DND, but not yet in LSN
- LFS injection allow H-mode access, but with higher power threshold at high fueling rates
- Toroidal rotation predicted and measured to be higher with center stack midplane fueling than outer midplane fueling

Backup: H-mode slides

H-mode Plasmas Achieved Long Pulse, Owing to Low Volt-Second Consumption Rate



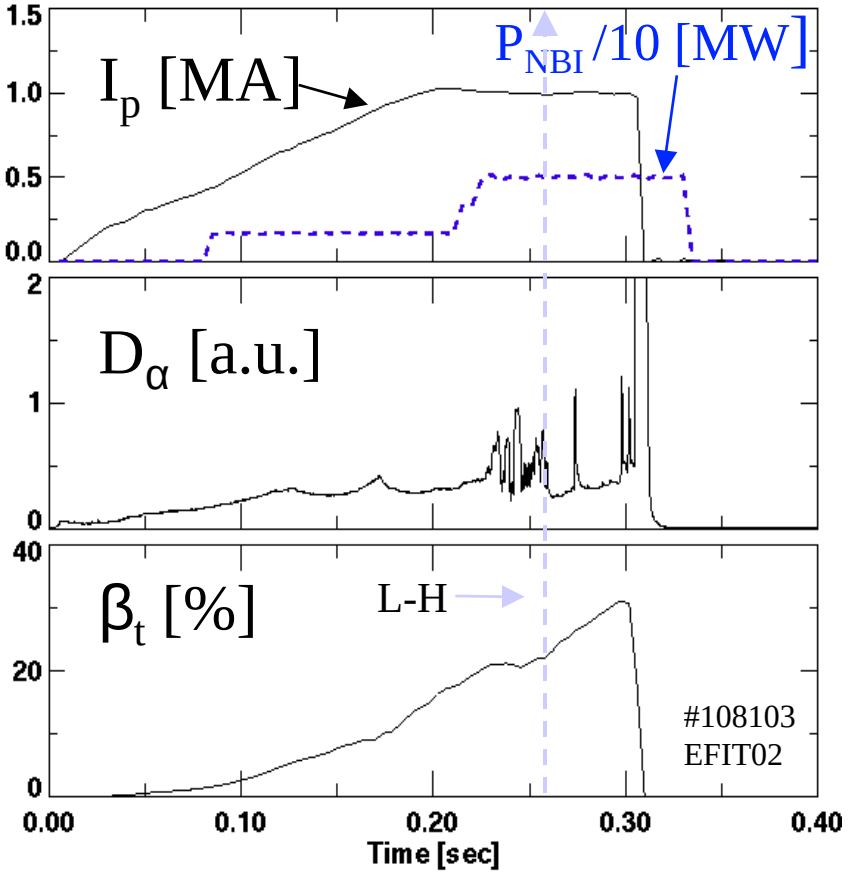
H-mode Plasmas Achieved High β_t, Owing to Reduced Pressure Peaking Factor

NSTX

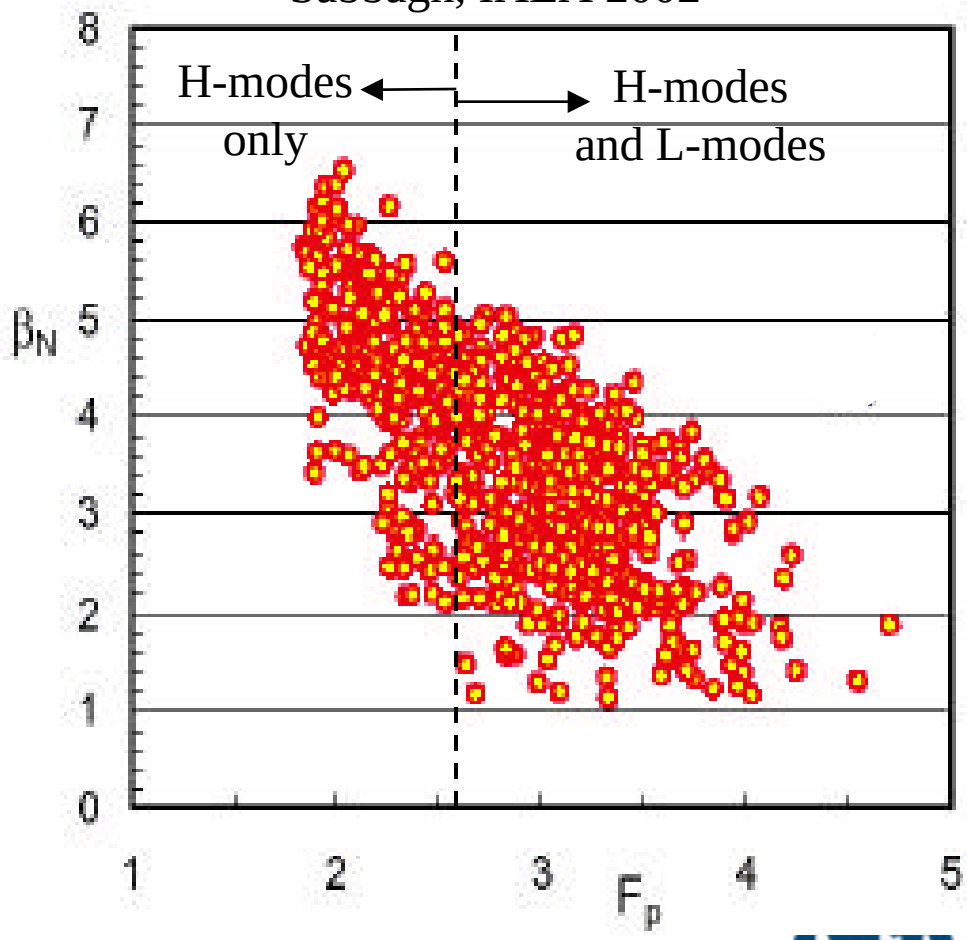
Max β_T = 31.5%
β_N^{max} ~ 6.2

Min f_p(H) ~ 1.9, Min f_p(L) ~ 2.6
$f_p \equiv p_e/\langle p_e \rangle$

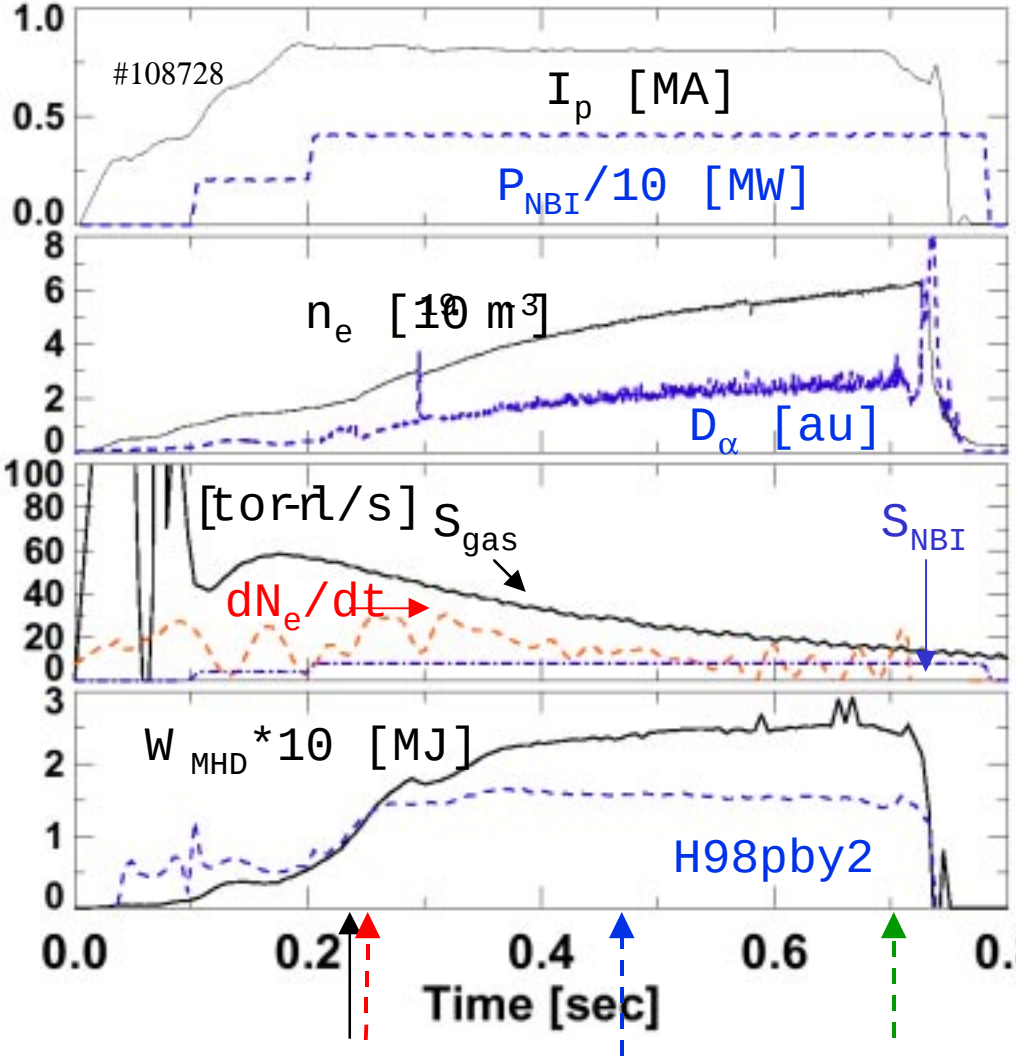
$\beta_T = 2\mu_o\langle p\rangle/B_0^2$



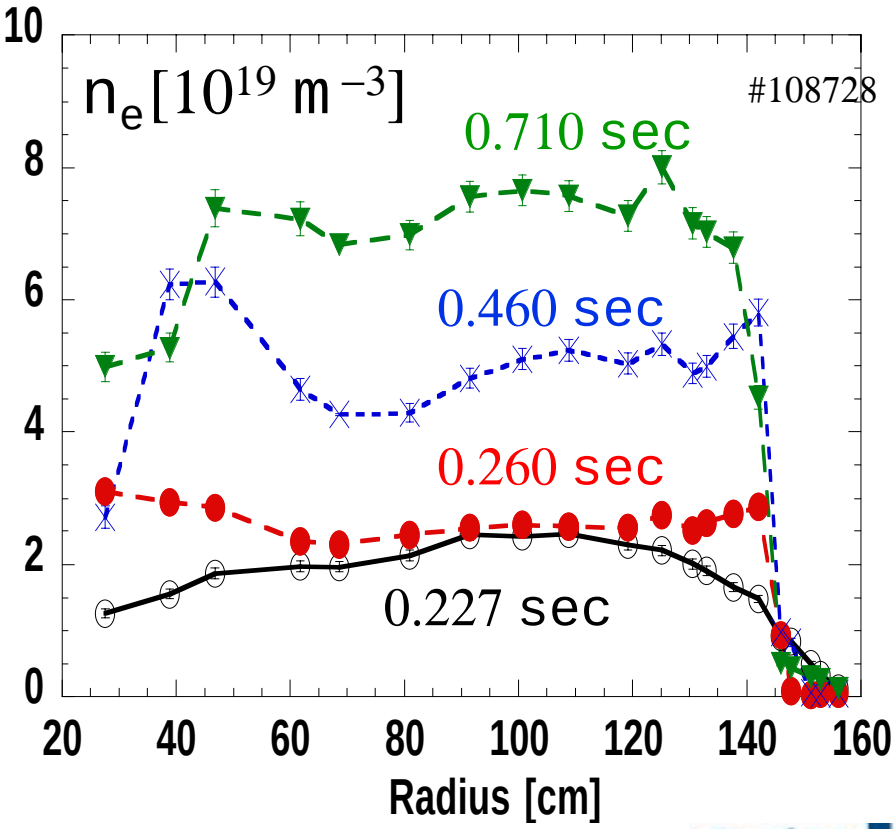
Sabbagh, IAEA 2002



Uncontrolled (non-disruptive) density rise in long pulse H-modes



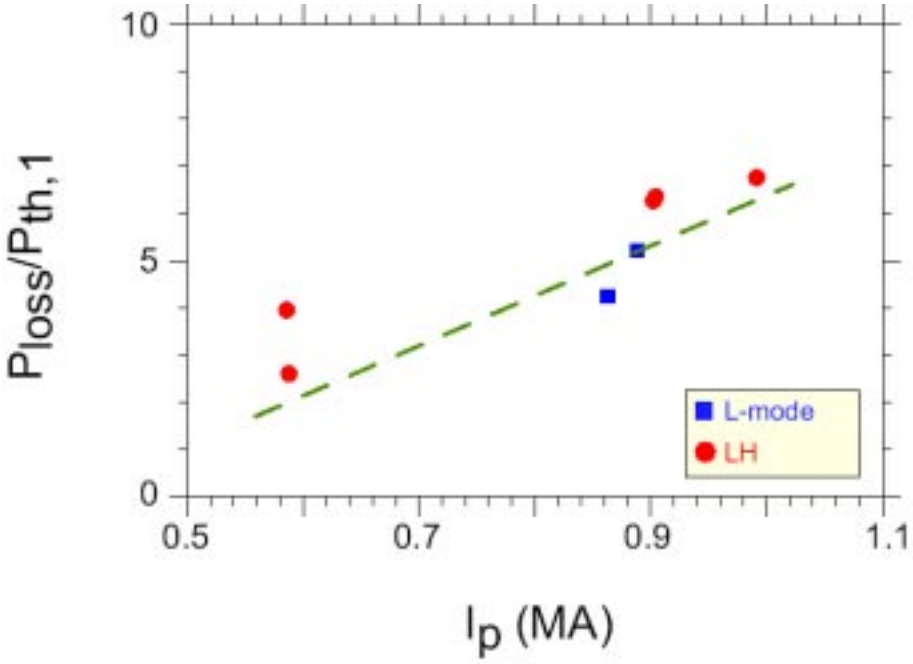
- Density control needed for improved current drive efficiency, transport studies, and power and particle handling research

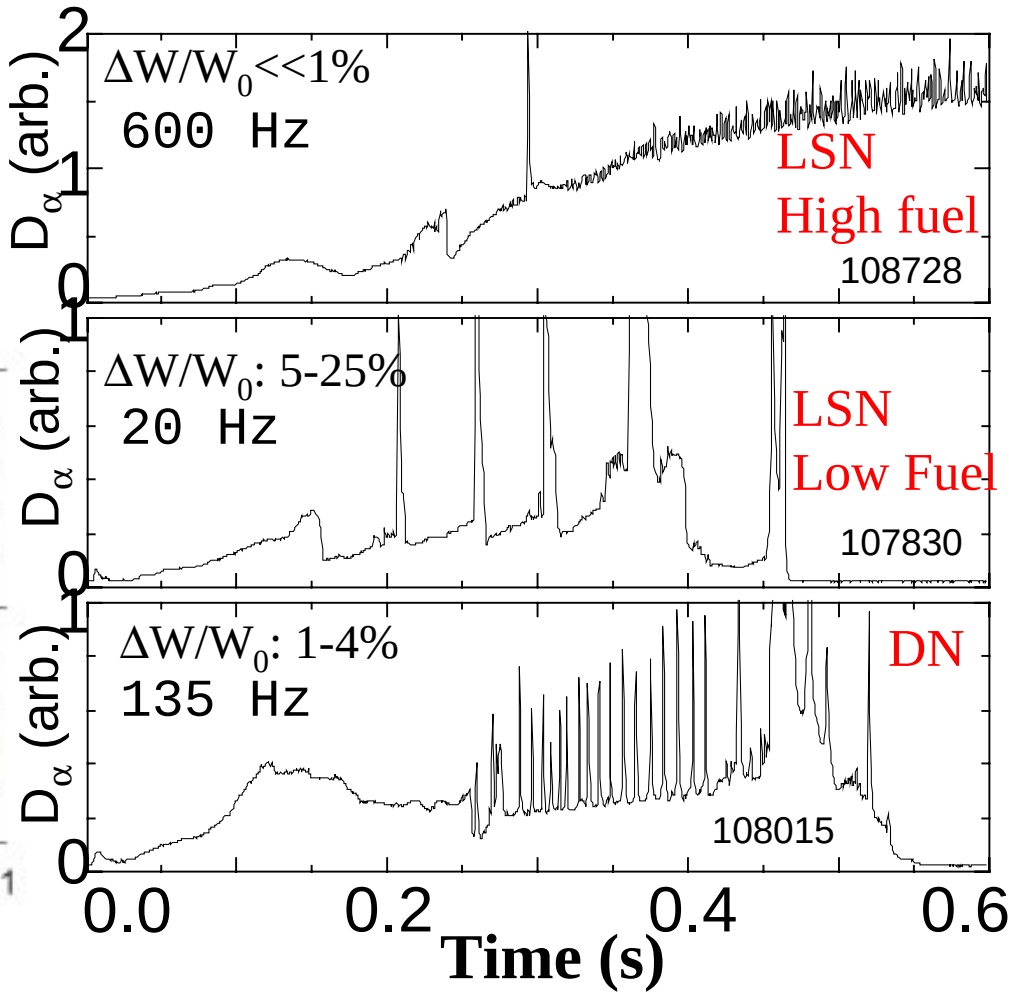


L-H power threshold and ELM studies reveal differences with conventional aspect ratio tokamaks

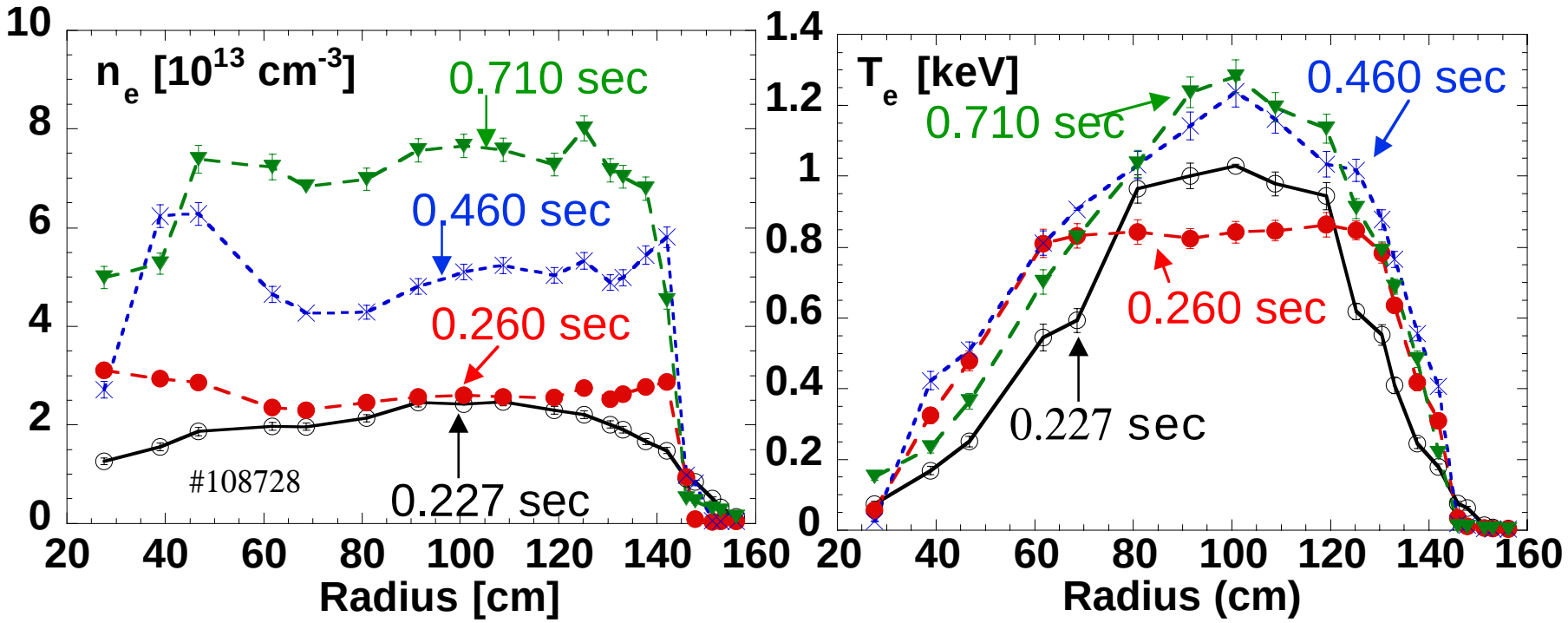
- L-H transition: $P_{L-H}^{NSTX} > P_{th,1}$
- I_p dependence
  - related to E_r through fast ion loss?

$$P_{th,1} \sim n_e^{0.61} B_T^{0.78} a^{0.89} R^{0.94}$$





High n_e and relatively low T_e pedestal observed



- n_e profile hollow after transition and fills in 300-500 ms
- Moderate in/out n_e asymmetry usually observed
- T_e profile flattens initially and peaks later in time