Comparison of High-Field Side and Low-Field Side Fueled H-modes

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Summary of XP209:
Comparison of H-modes Fueled with HFS and LFS gas puffing

Goals (Development and Physics):

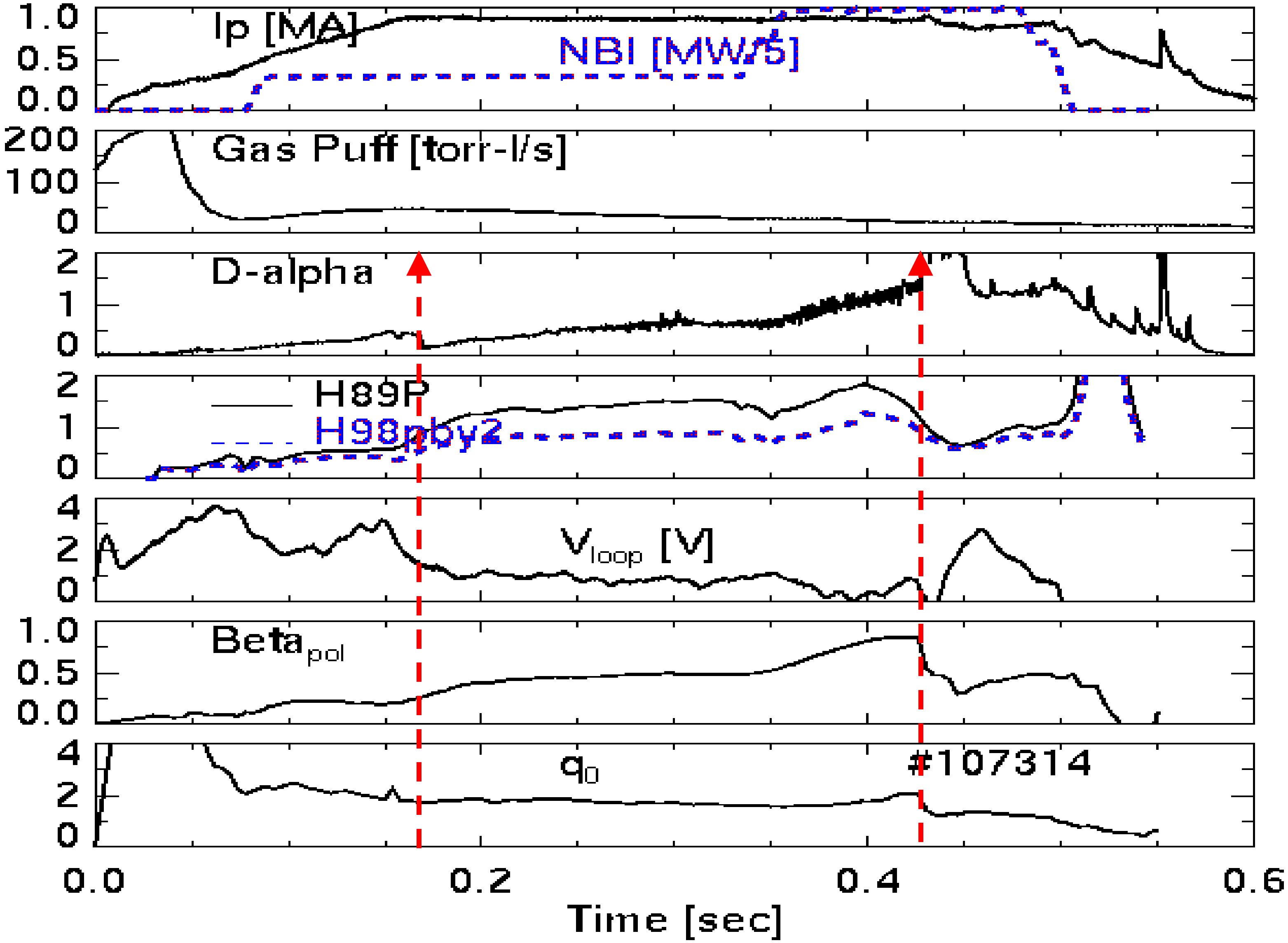
1. Develop long pulse H-modes scenarios
   - Done with HFS injection, and few cases of wall pre-loading
   - Wall pre-loading produced less reproducible discharges
2. Determine operational window of HFS H-modes (B_t, gas rate)
   - Can get H-modes with $B_t \geq 0.3$ T
   - There is an access window of fueling rates: 500 – 1300 Torr fill pressure, 12-50 Torr-l/s average fuel rate
3. Compare low-field side (LFS) fueled H-modes with HFS
   - LFS H-modes are shorter;tend to have delayed L-H transitions
   - As HFS rate reduced, discharge look more similar

Show movies

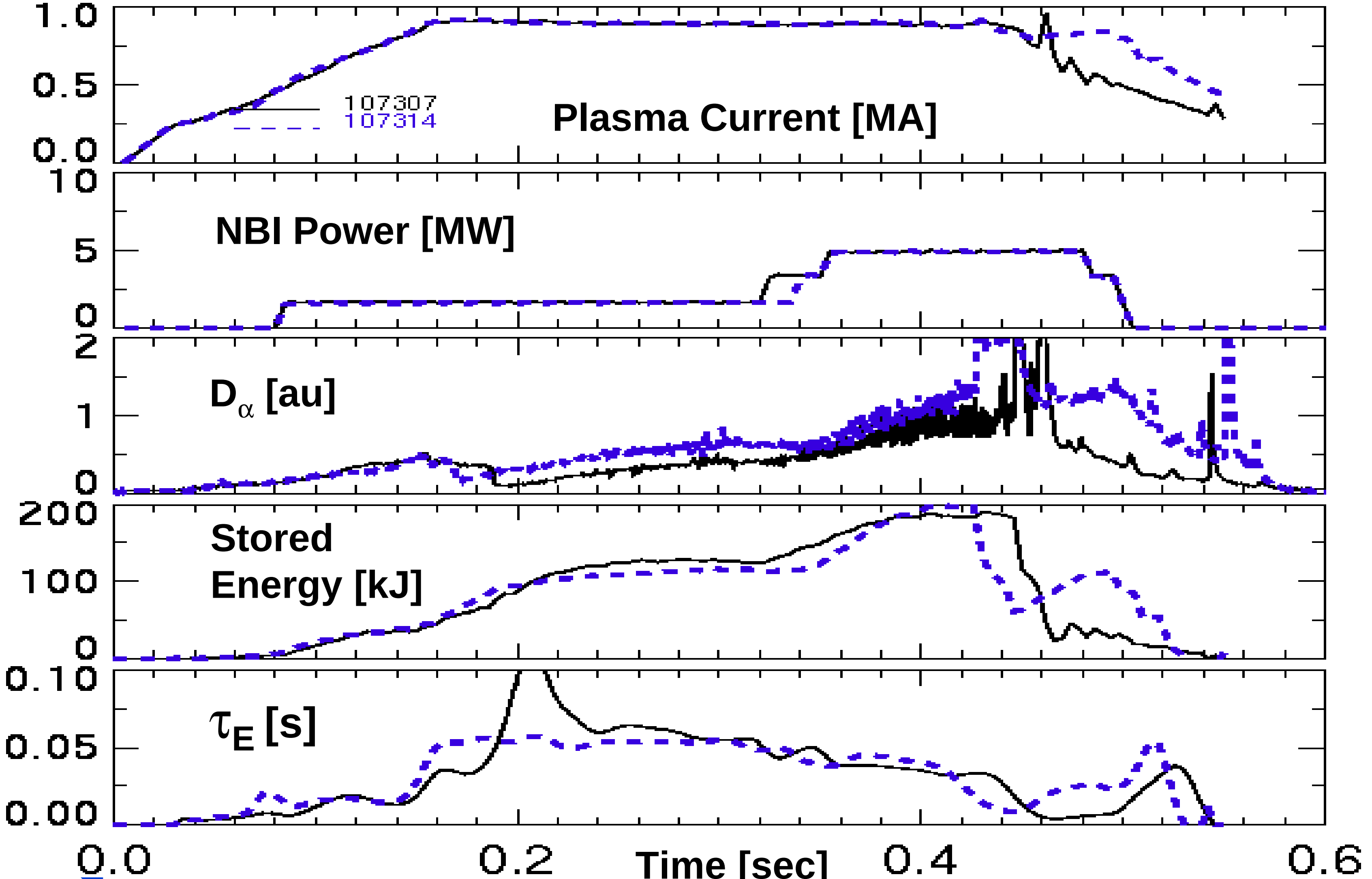
Summary of XP 209
Optimizations Performed

1. Calibrated HFS gas injector (after expt.)
   Plenum pressure varied from 125-1500 torr, and average/instant flow rates computed from Raman's micro-ion gauge
2. Varied plenum pressure of HFS gas puff (500 torr-1500 torr)
3. Varied amount of HFS and LFS gas puff
   LFS: 25-120 torr-l/s of differing durations, tried several combinations to minimize dN/dt
4. Made variations at I_p=900 kA, and B_t between 3.0 and 4.5 kG (mostly 4.5 kG). No H-mode transitions at 1.1 MA, but obtained H-mode at all Bt; also did a small fueling optimization at 3.5 kG

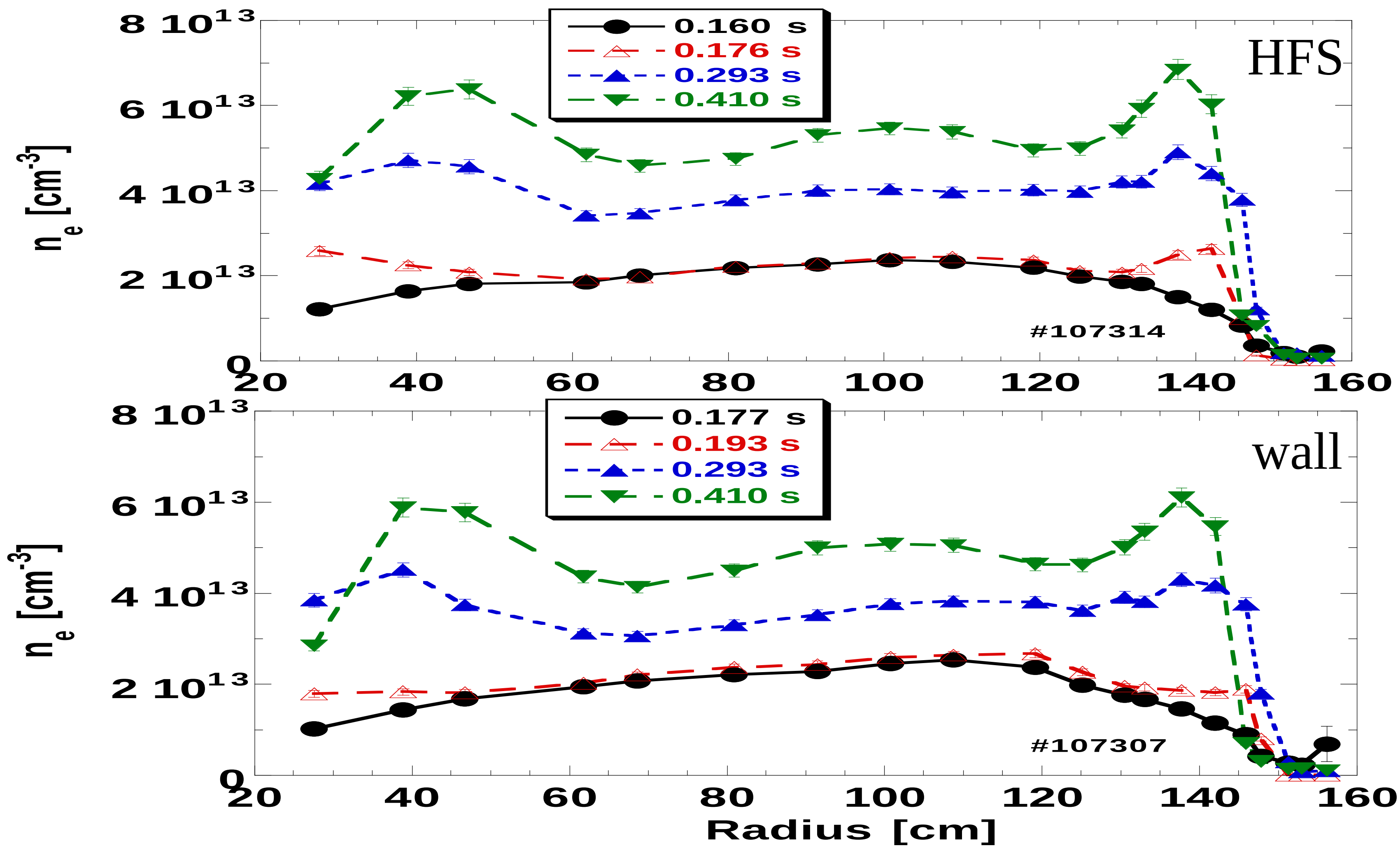
Long ELM-free H-mode with high β_p, rising q_0, obtained with high-field side fueling



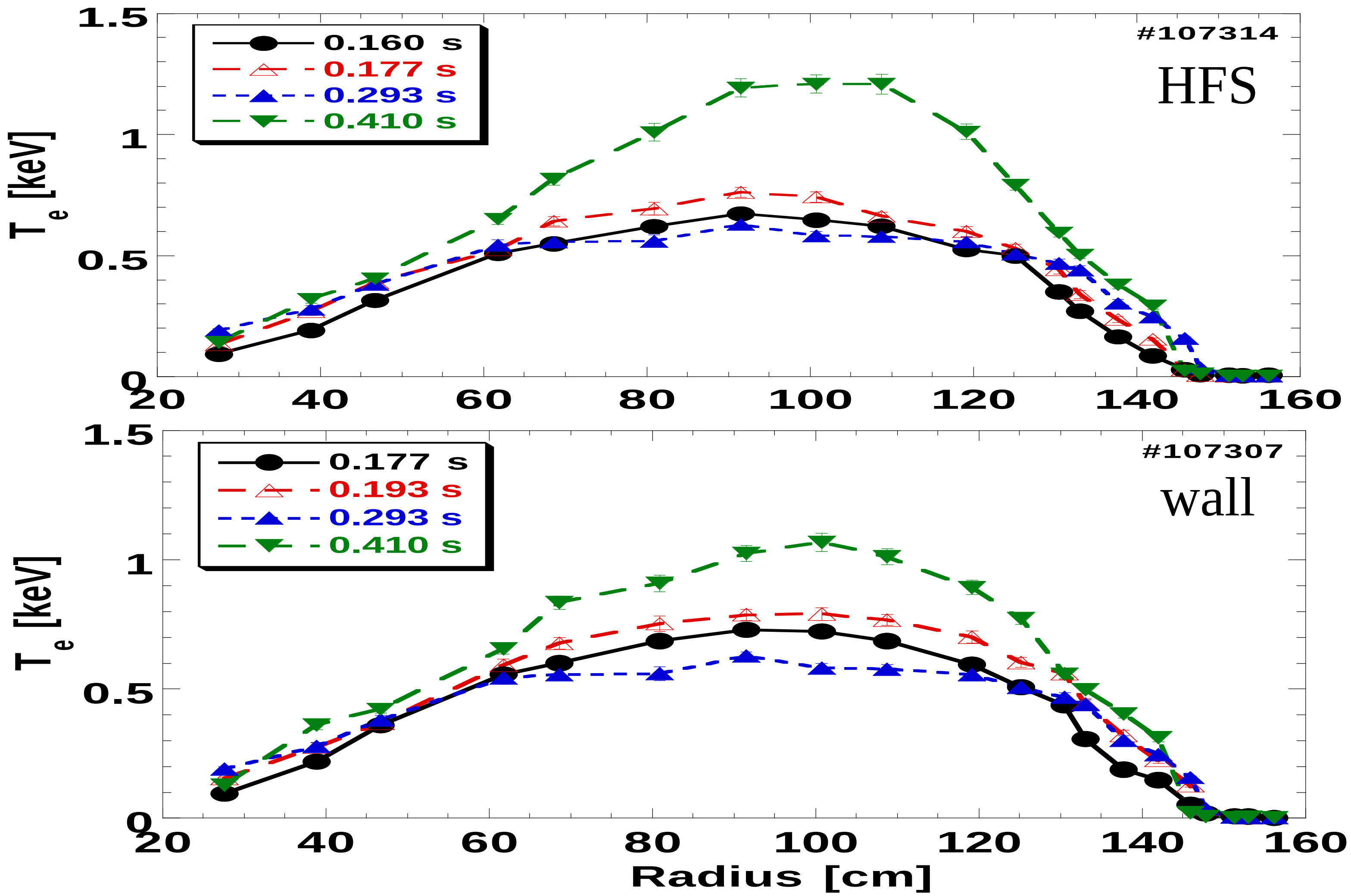
Comparable performance and improved reproducibility w/high-field side fueled H-mode over wall fueled



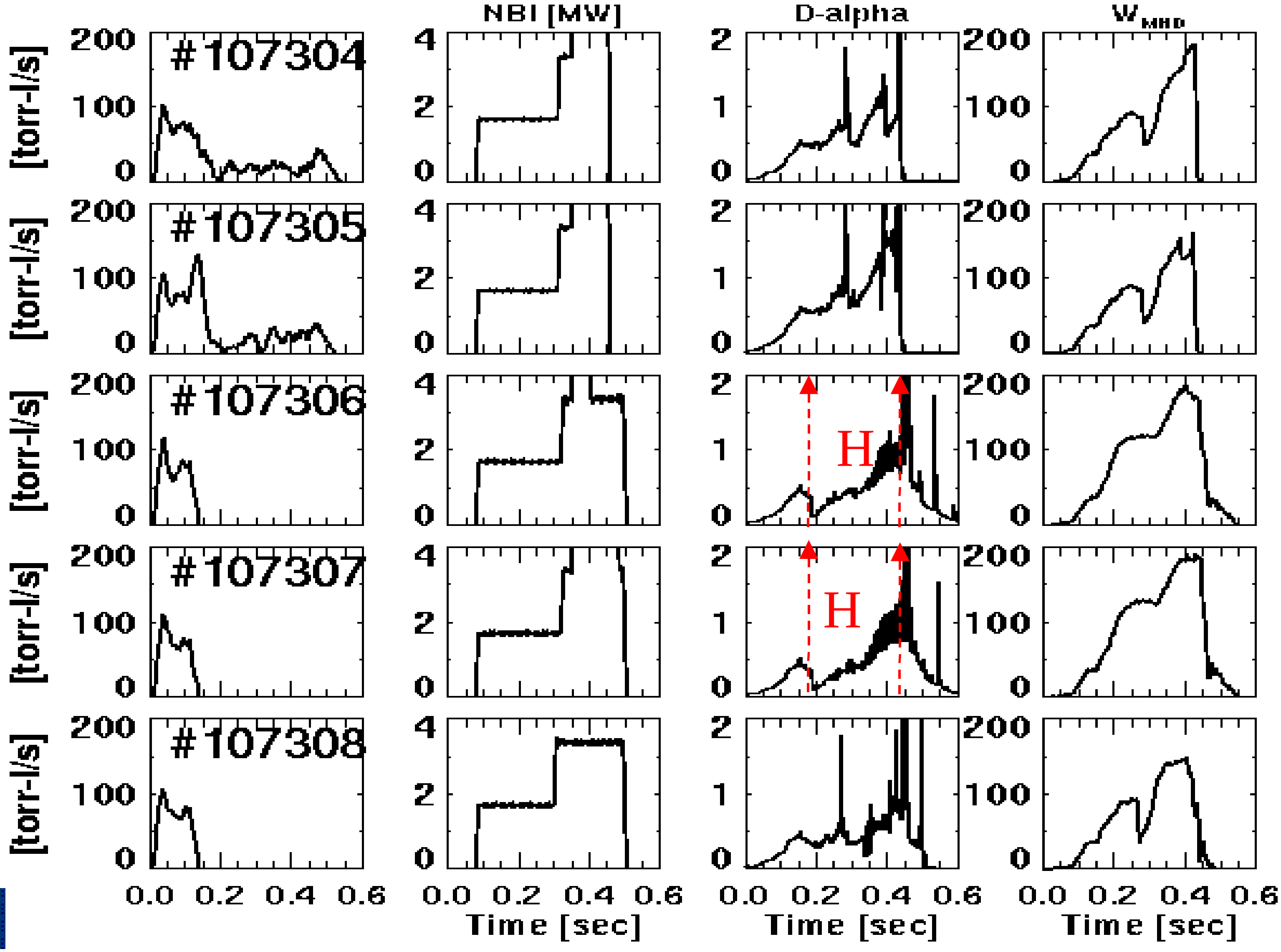
Both edge and core electron density rise continuously during long H-mode phase (HFS or wall fueling)



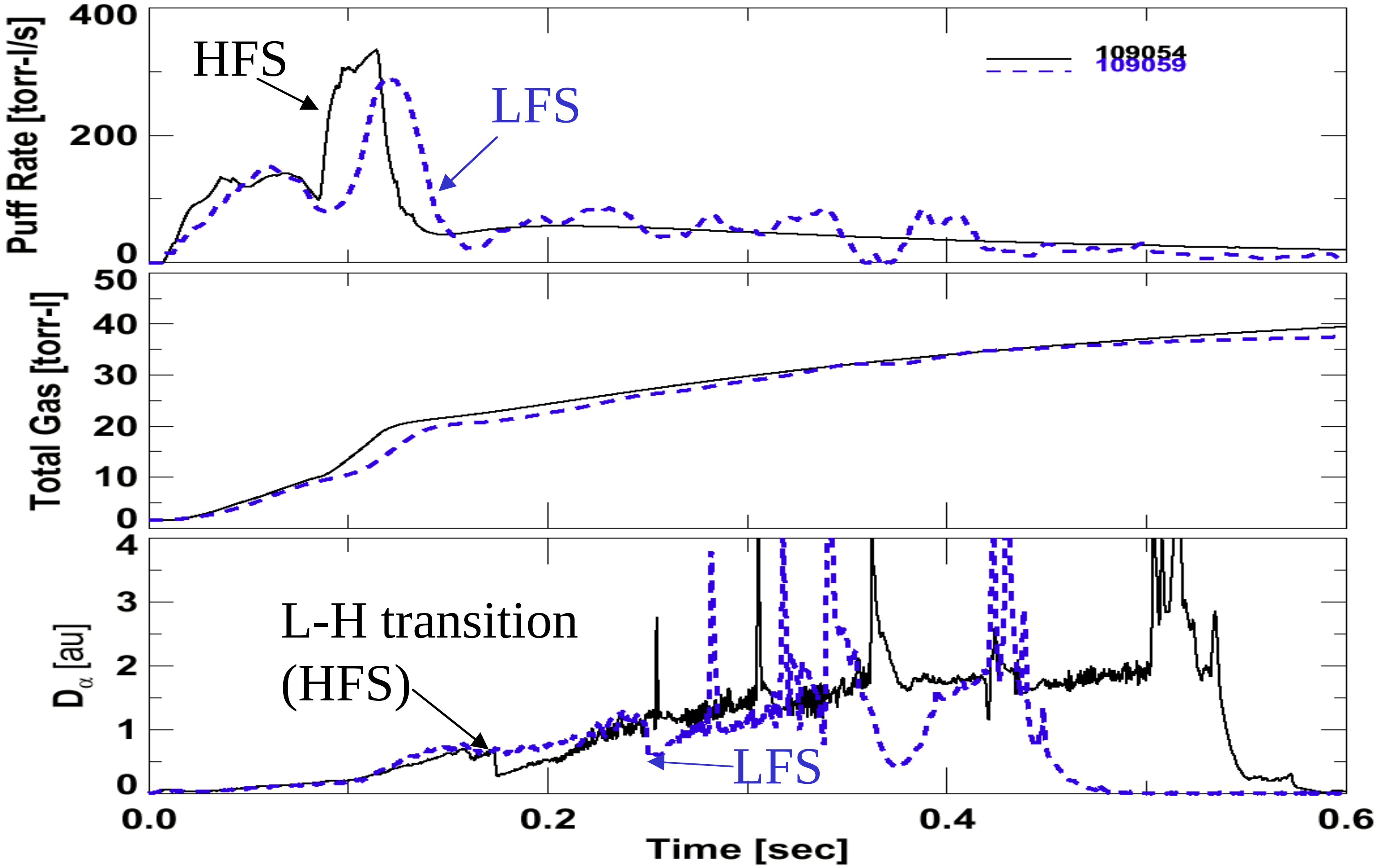
Core and Edge T_e rise after L-H transition, but core T_e falls as n_e increases with time (until more NBI power added)



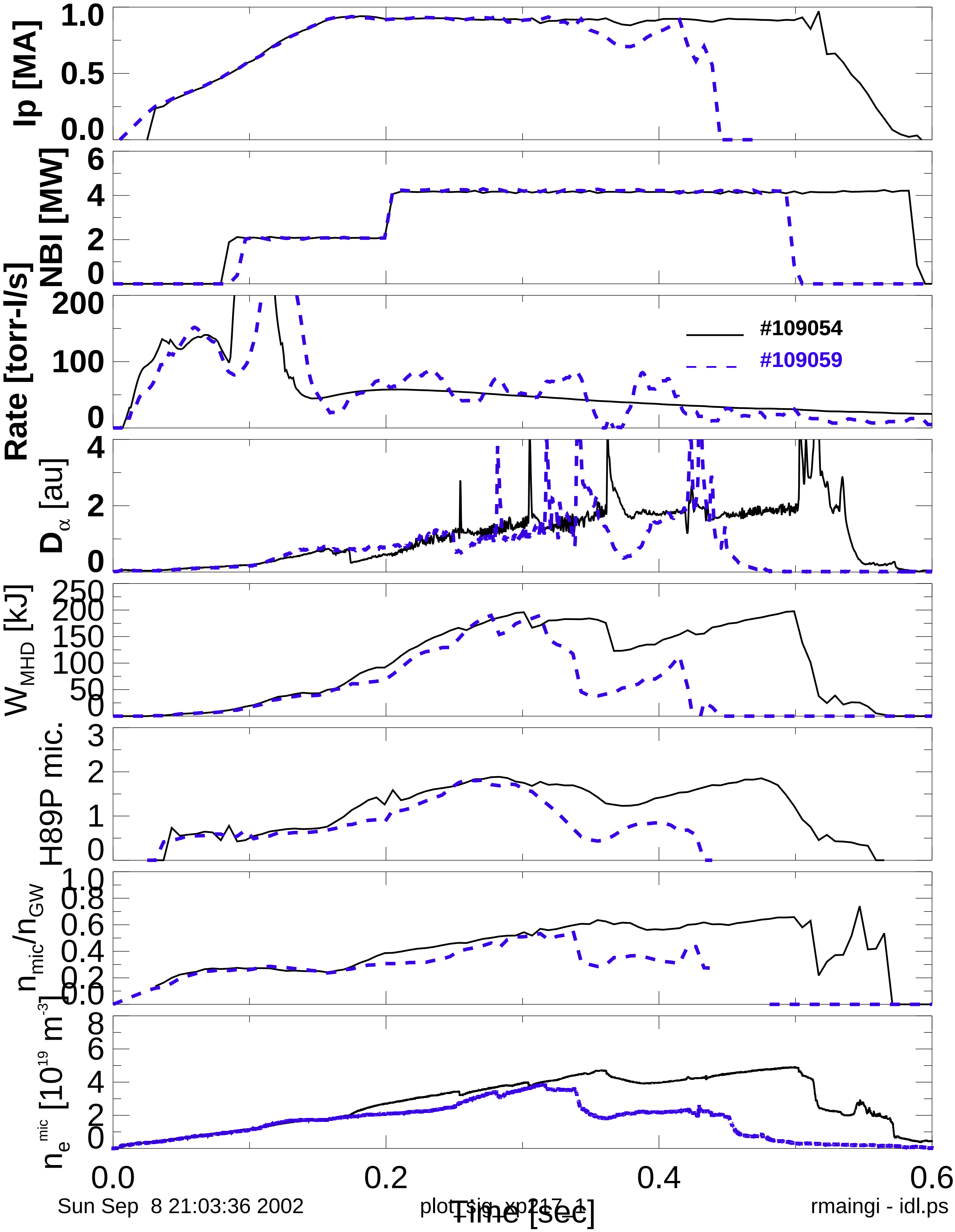
Long (Irreproducible) H-modes Observed After Discharges with Heavy Gas Puffing from Low Field Side



Low-field Side Fueling Delayed H-mode Transition at Comparable Fueling Rates to HFS Fueling



Low-field Side Gas Puffing(dashed) Delays L-H Transition



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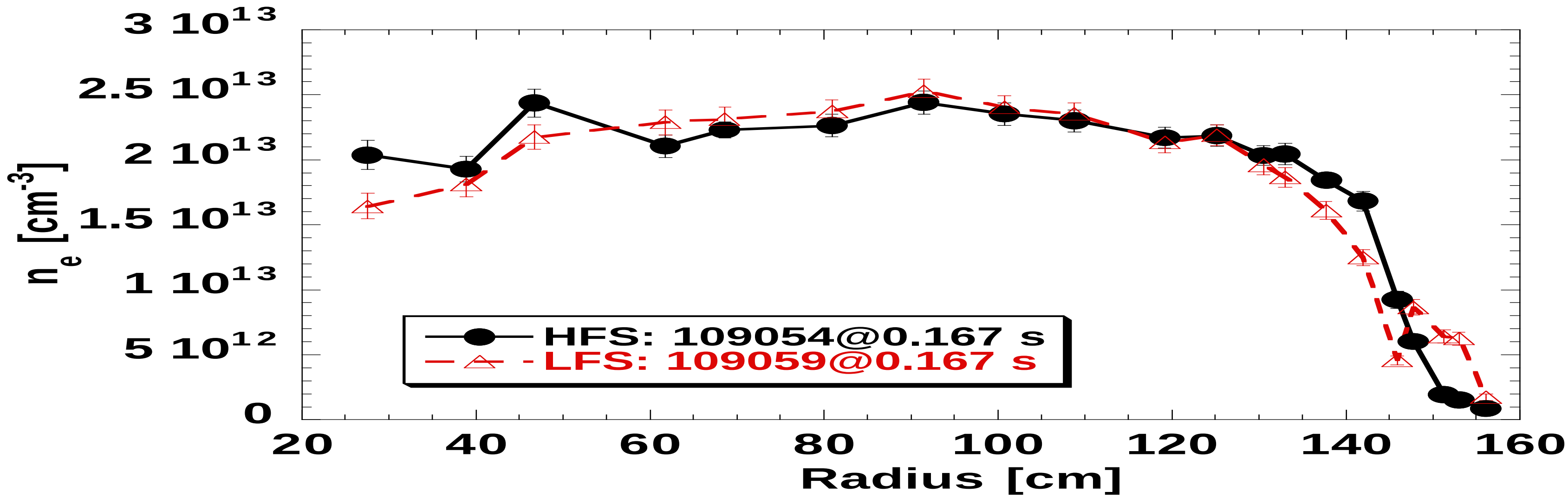
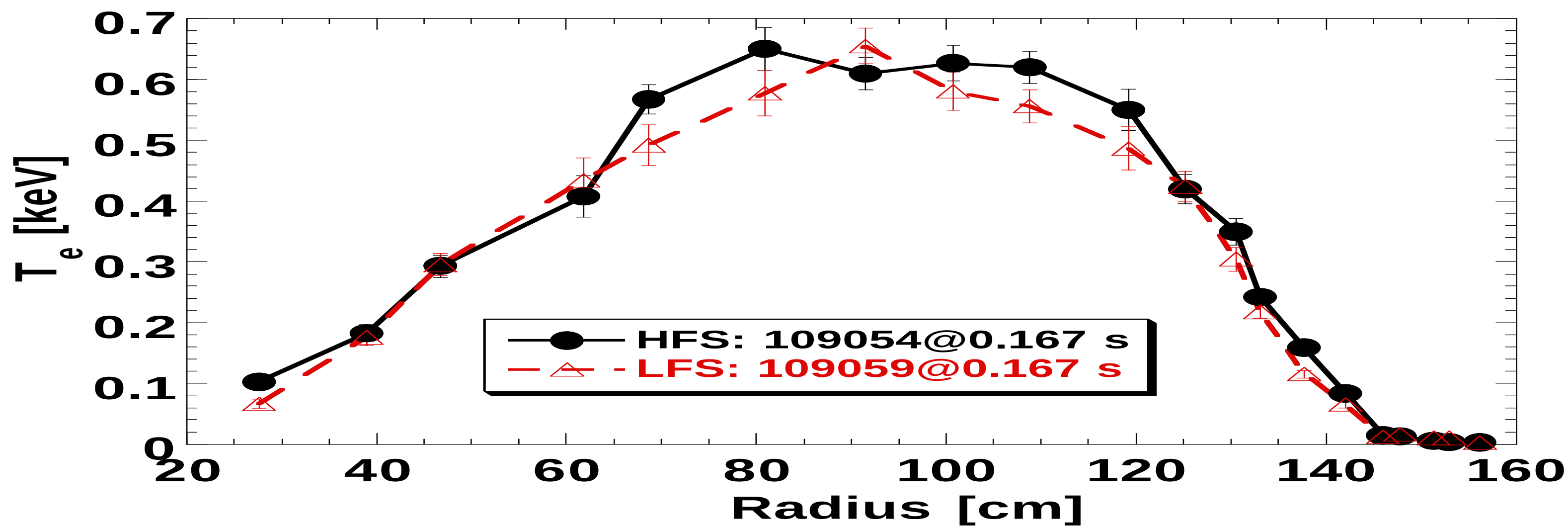
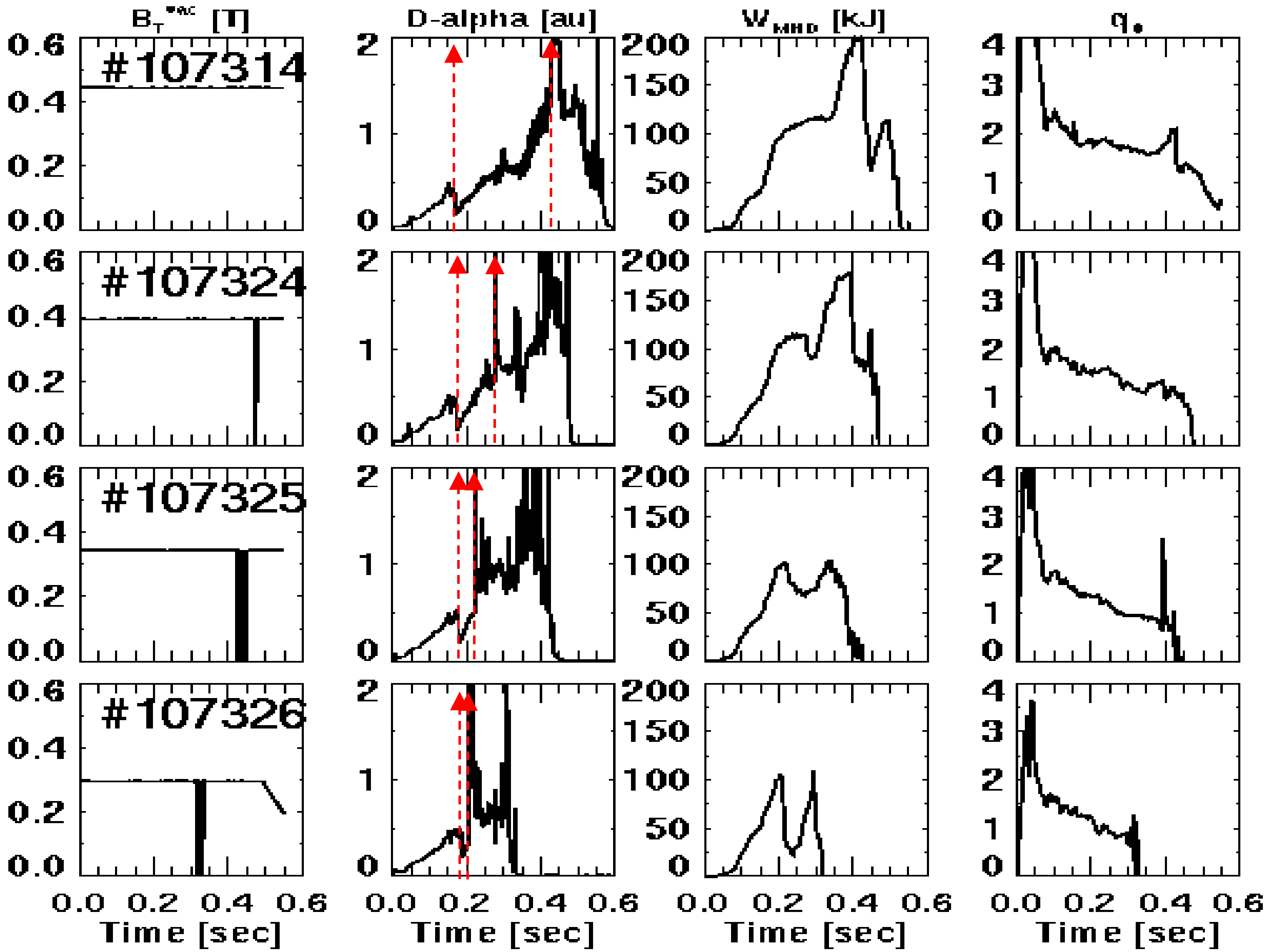
LFS puffing has higher outboard edge density and lower temperature in L-mode phase before transition

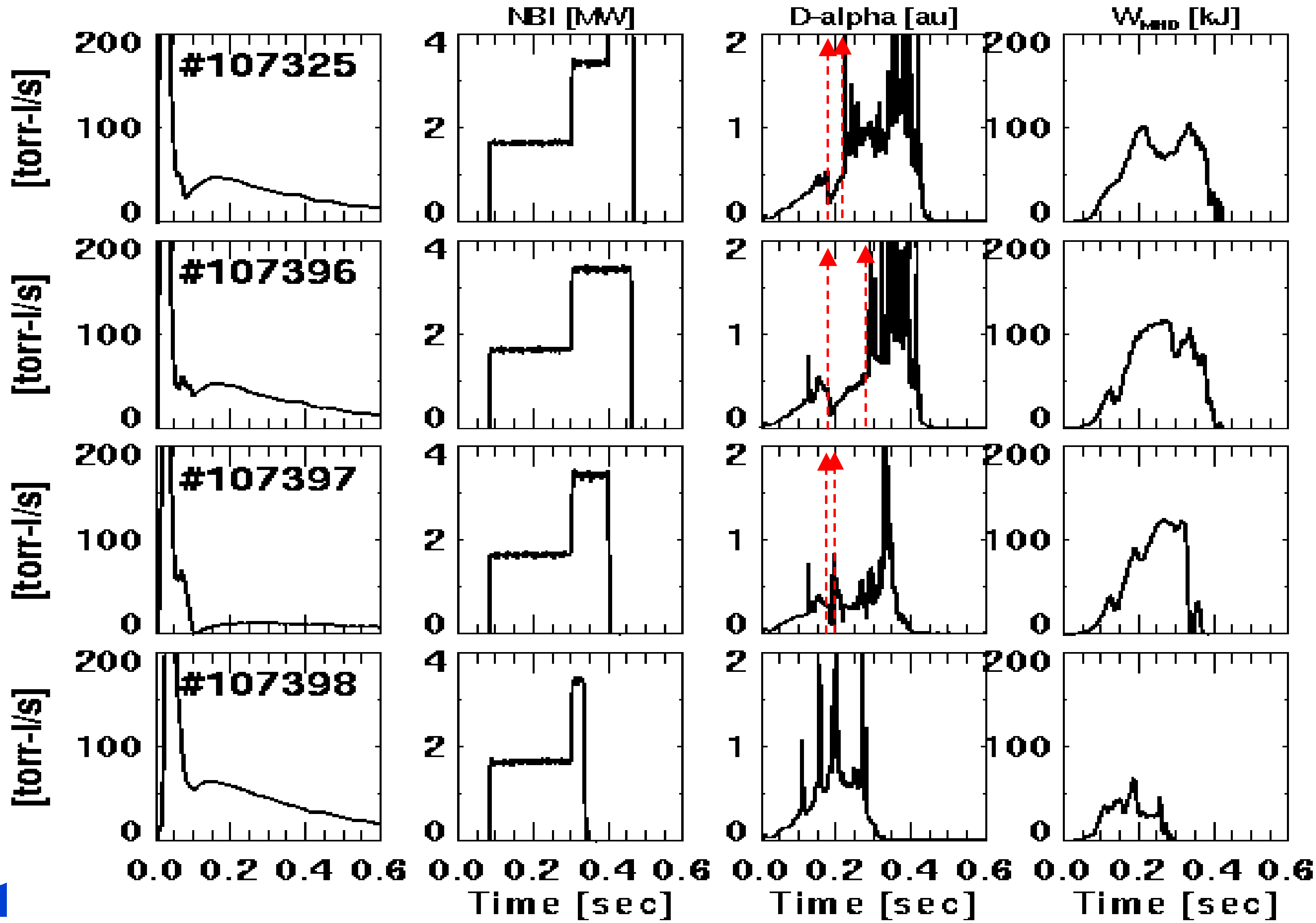




H-modes obtained at TF between 0.3-0.45 T, and duration (between red arrows) increased with TF



Best gas puff combination to use for B_t=3.5 kG was HFS fill pressure=1000 torr and LFS:70 torr-l/s from20-80ms



Summary of XP209: Results

1. Got long ~ 270ms ELM-free and shorter ELMy H-modes w/HFS fueling, with H98y(2)~1.4 and H89P~2.2, β_p =0.85, low loop voltage and rising q(0); terminated by event (difficult to identify) between 350 and 500ms
2. Also got 2 long ELM-free H-modes with LFS fueling following 2 high gas rate injection shots (MAST technique); 3rd shot did not achieve H-mode
3. Ideal HFS rate *was* HFS=1000 and LFS=50 torr-l/s from 20-60ms for long H-mode with decent performance
4. HFS plenum pressure below 1000 torr also led to H-modes but H-modes phases were often short and irreproducible, but did have somewhat lower dN/dt
5. H-modes obtained at all B_t levels, longer duration at higher B_t

Analysis Goals of XP209

1. Test Helander's theory that HFS puffing leads to larger rotation and easier H-mode access
2. Compare transport (w/TRANSP) in HFS vs LFS H-modes
3. Determine termination events (common with XP 229 – long pulse H-mode XP)
4. Determine why gas puffing required for H-mode access -> low density threshold?
5. Determine if delay in H-mode access in LFS fueled cases occurs due to timing mismatch in fueling rate
   -> better comparison shots needed?