Discharge Evolution Control via 3D Field ELM Pacing in NSTX

NSTX

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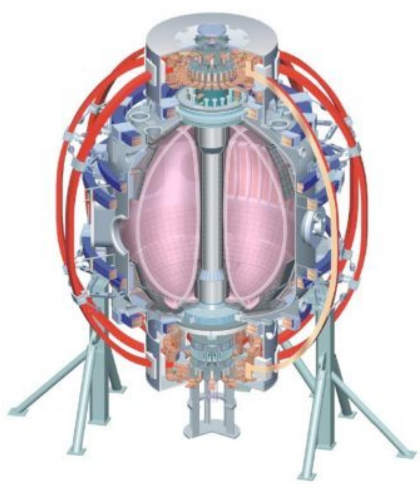
J.M. Canik (ORNL), R. Maingi (ORNL), D.A. Gates(PPPL), S.P. Gerhardt (PPPL), V.A. Soukhanovskii (LANL), and the NSTX Research Team

51st Annual Meeting of the APS - DPP
Atlanta, GA
Nov 3, 2009



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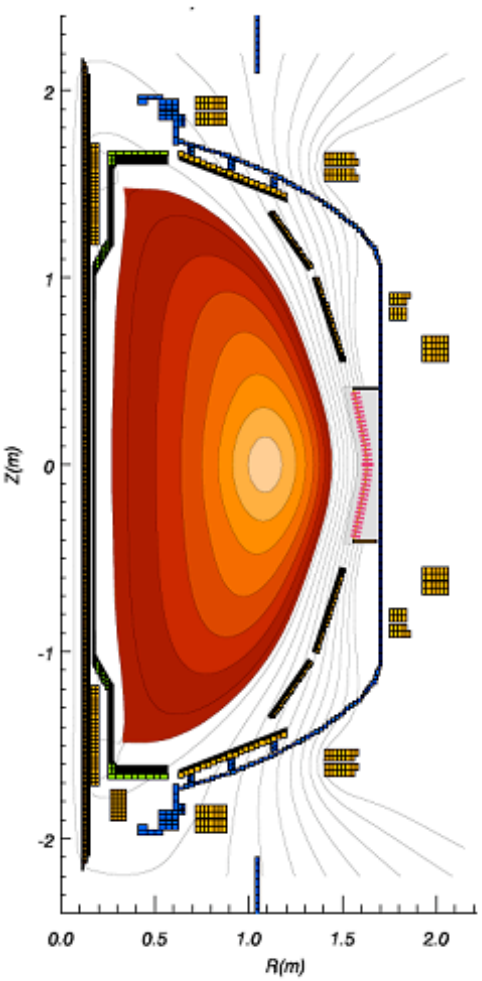
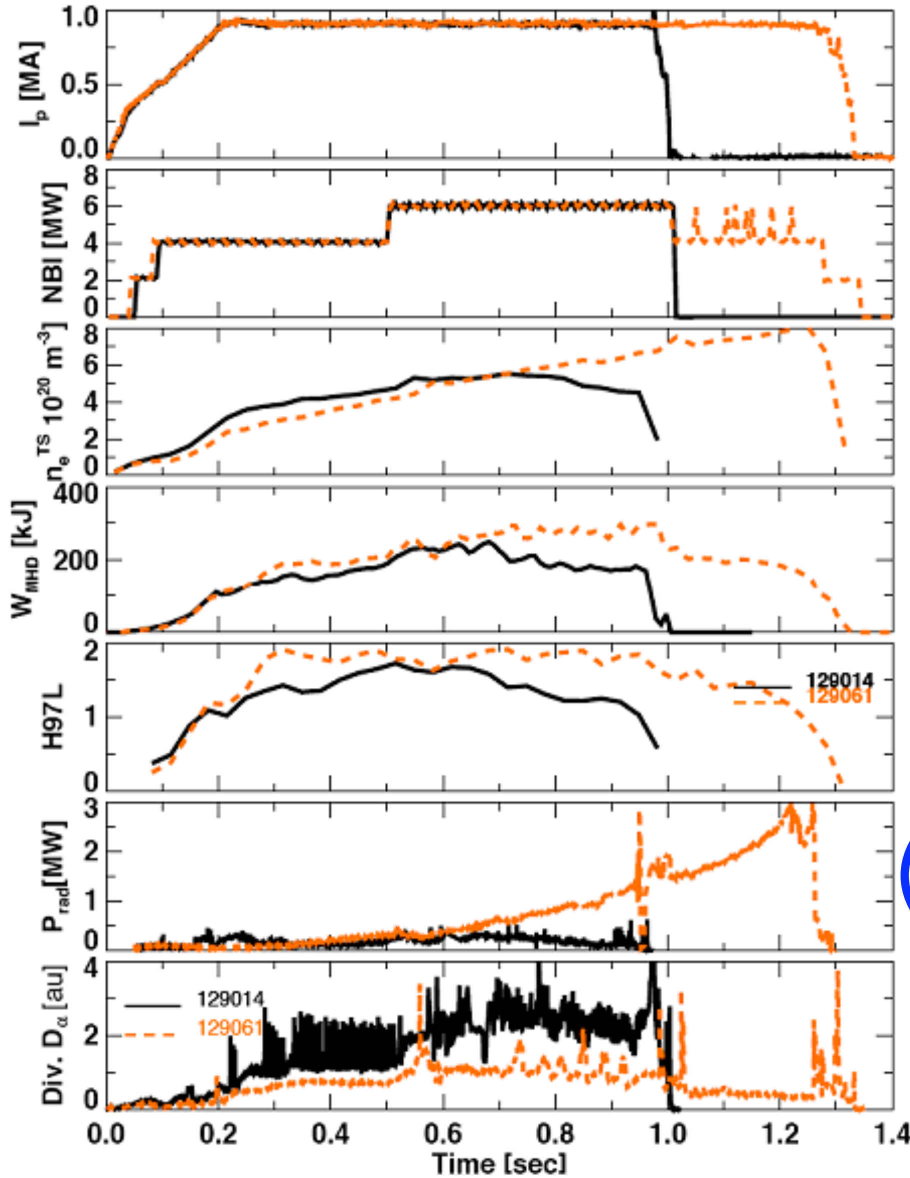
Li Wall Conditioning Allows ELM-free Operation, but Leads to Impurity Accumulation

Standard high
κ~2.3, δ~0.8 shape



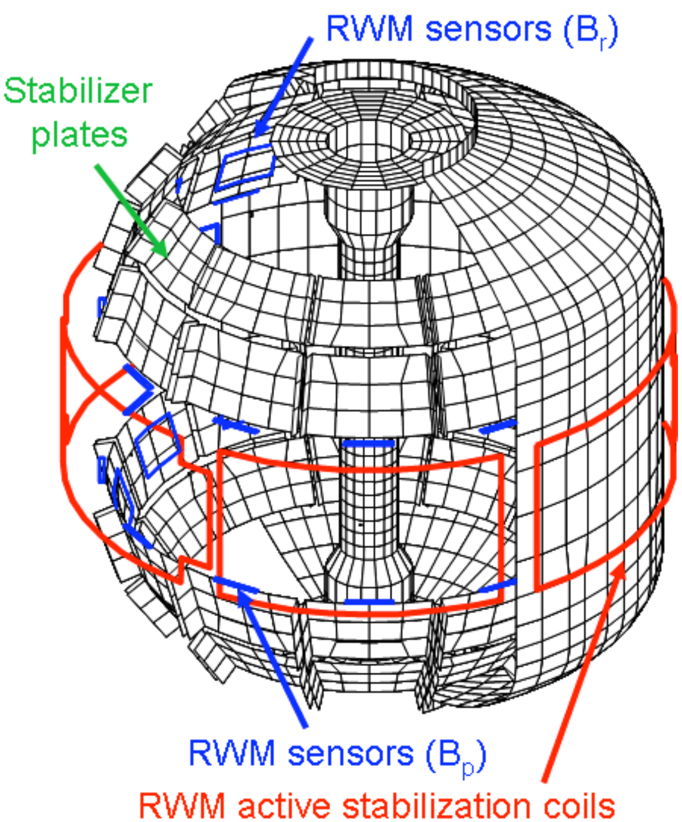


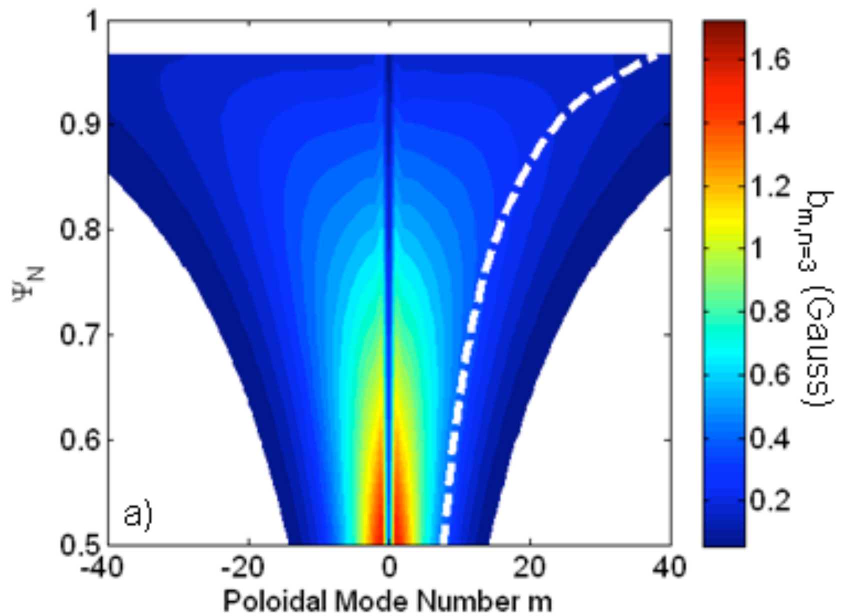
- Pre-Li, Post-Li
- Longer pulse
- Lower n_e early, higher late
- Higher stored energy
- Higher H-factor
- Higher radiated power from core
- ELM-free, lower recycling

Kugel PSI08

External midplane coils provide tool to perturb plasma edge

- Coils configured to apply n = 3 perturbations
  - minimize rotation braking
- Perturbations have both resonant and non-resonant components
  - resonant with q_{95} ~ 10

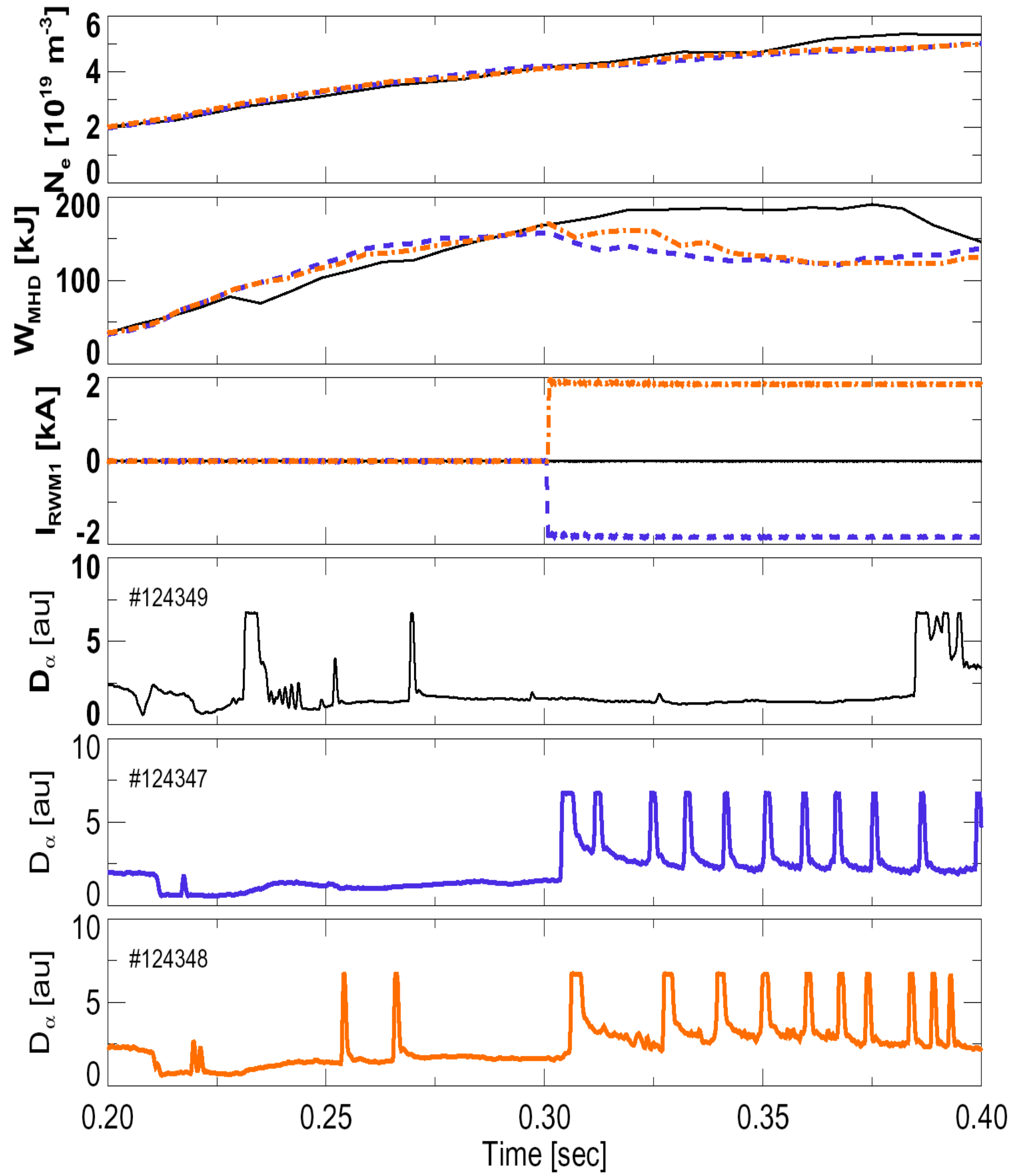




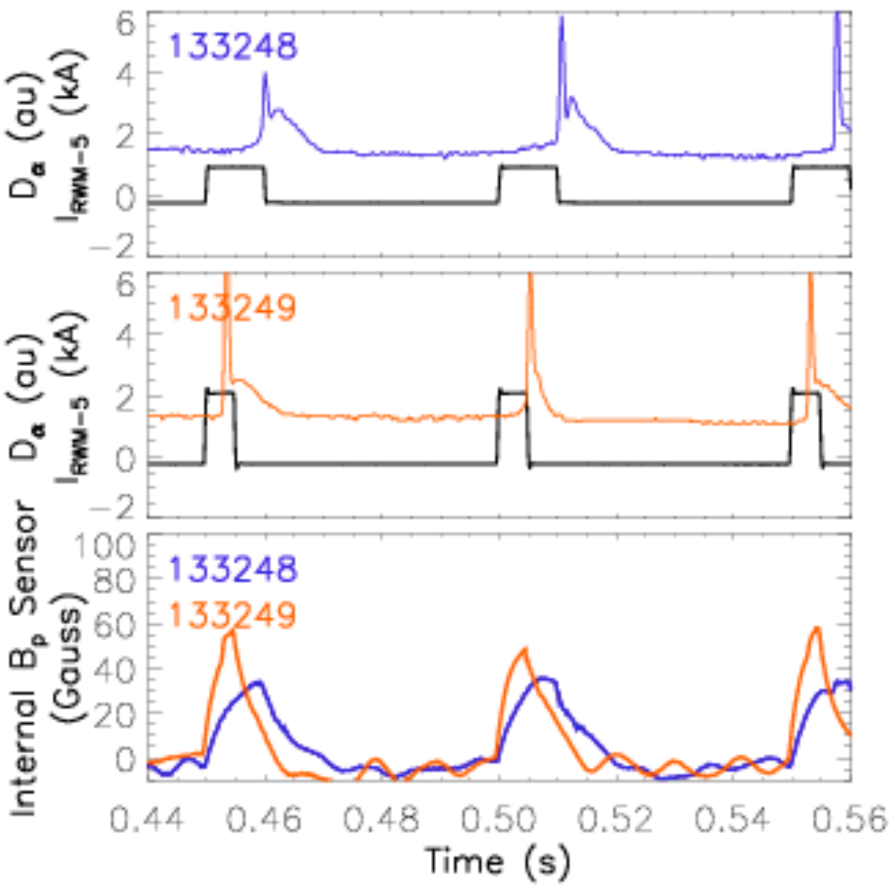
Application of 3D field can destabilize ELMs in NSTX

- ELMs triggered using applied n=3 fields
  - continuous triggering for DC pulse
  - toroidal phasing varied
  - triggering threshold at $\Delta B/B \sim 6 \times 10^{-3}$

- Triggered ELM sizes range from $<\Delta W/W_{tot}>$ ~5-15%
  - higher following failed trigger pulse



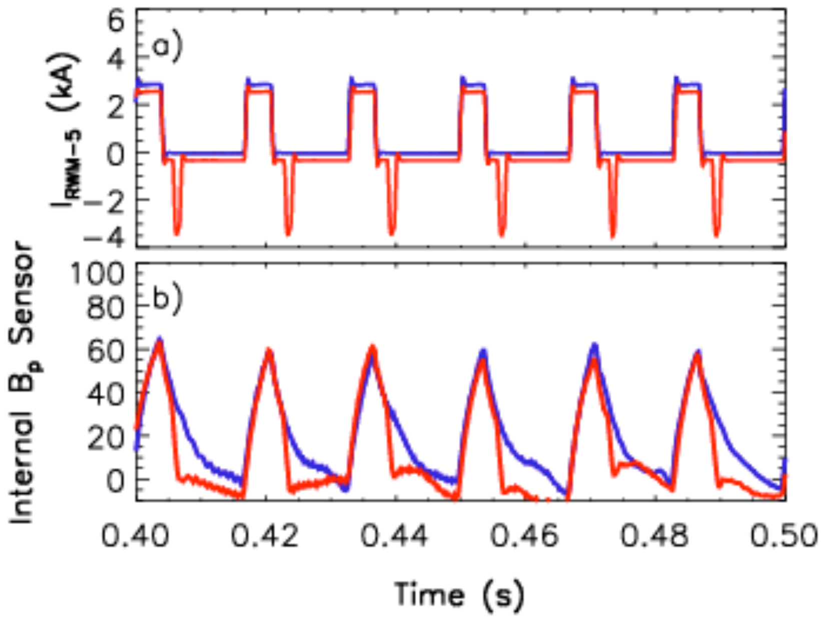
Square wave n=3 pulses give control of triggered ELM timing

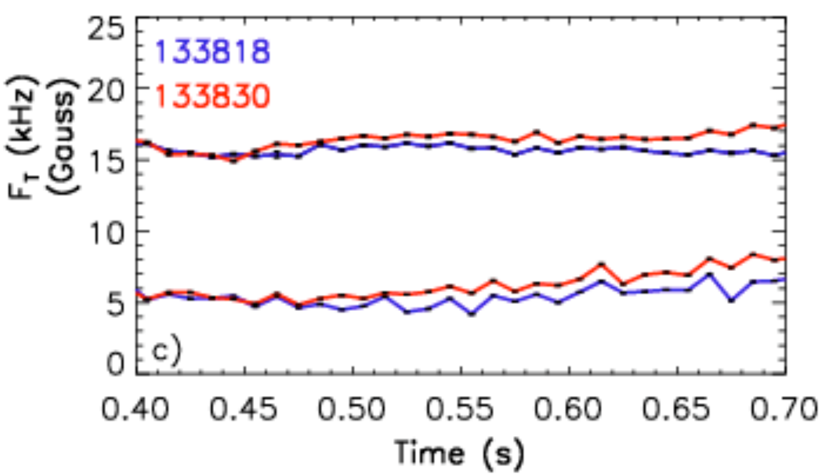


- Trigger time delay is amplitude dependent
  - ~8 ms with 1.2 kA
  - ~3 ms at 2.4 kA
- Minimum delay limited by field penetration time
  - estimated to be ~4 ms
- Improved triggering efficiency also observed at higher amplitude
  - up to 62.5 Hz with 100% efficiency achieved
  - increased rotation braking observed at higher frequencies

Fast negative-going pulses can reduce the time-averaged magnetic field

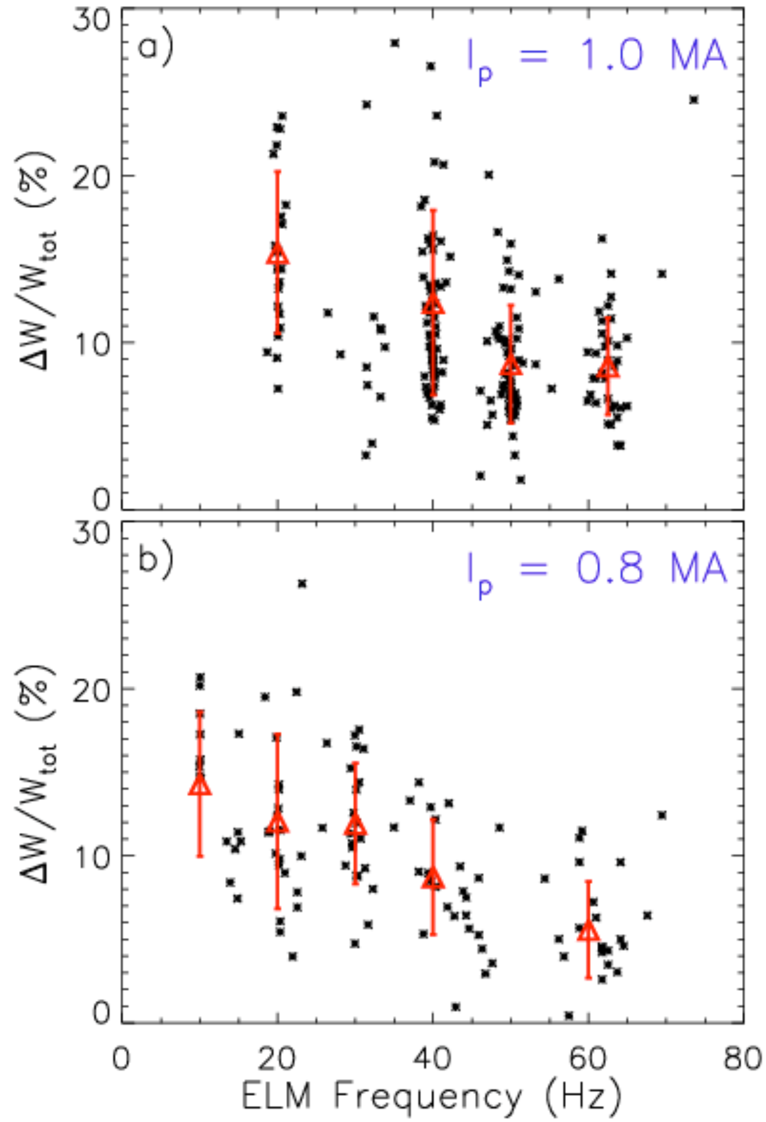
- Each trigger pulse followed by short pulse of opposite sign
  - cancels eddy currents
  - optimize to rapidly return internal field to ~ zero
- Results in reduced time-averaged perturbation
  - less magnetic braking



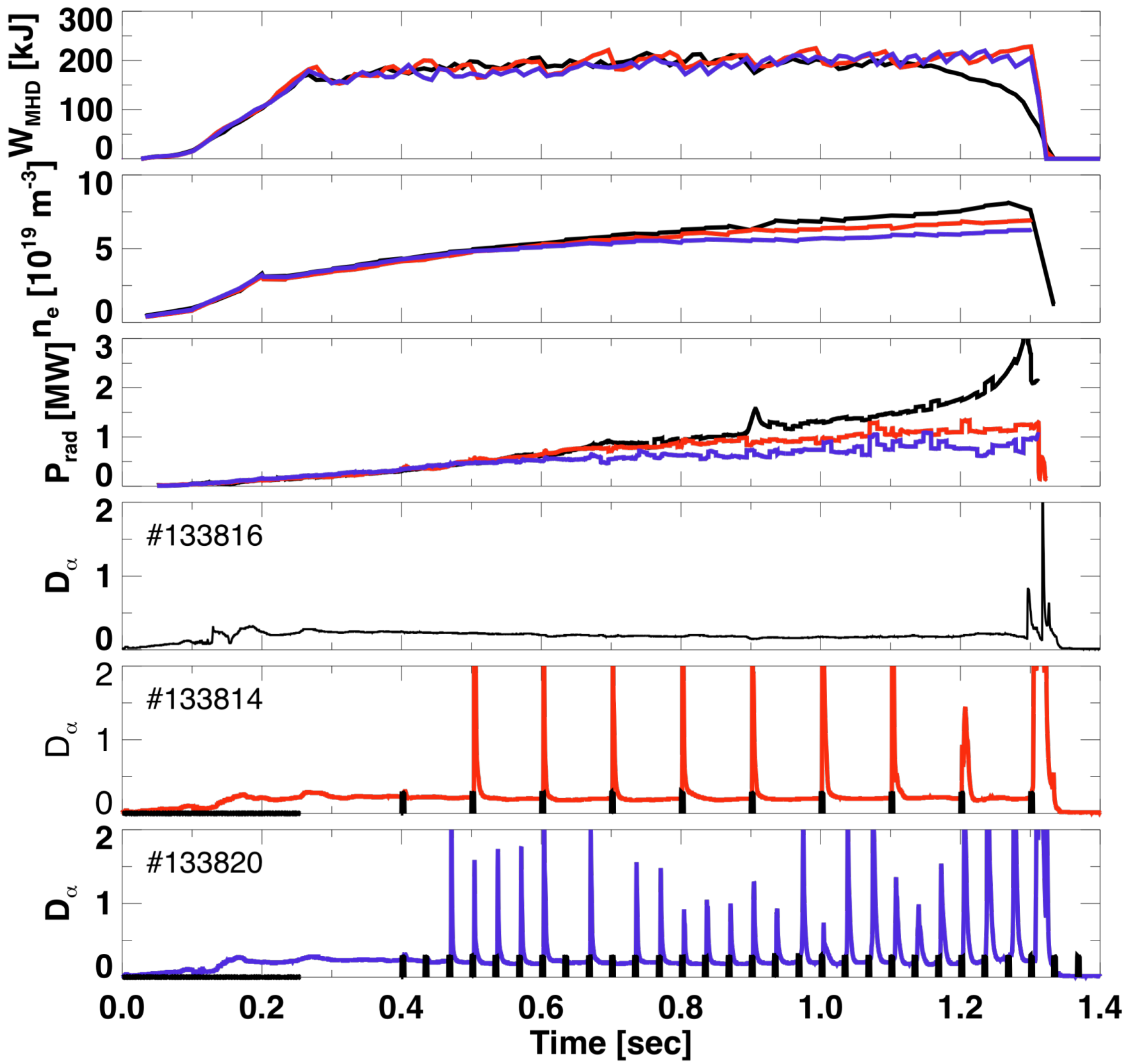


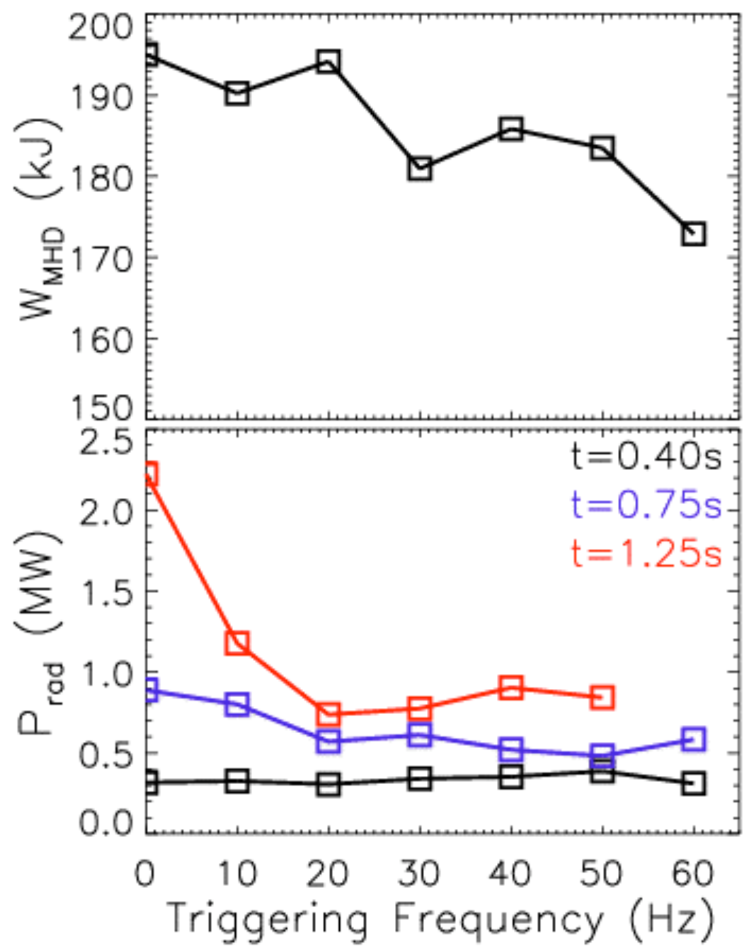
ELM size can be decreased by raising triggering frequency

- ELMs are very large ($\Delta W/W_{tot}$ ~ 15%) when triggered at 10 Hz
- Average ELM size can be reduced to ~5% by increasing triggering frequency to 60 Hz
  - Some outliers remain
  - Triggering reliability drops at high frequency
- Some evidence that triggered ELMs are smaller at reduced plasma current
  - Evident at highest frequencies

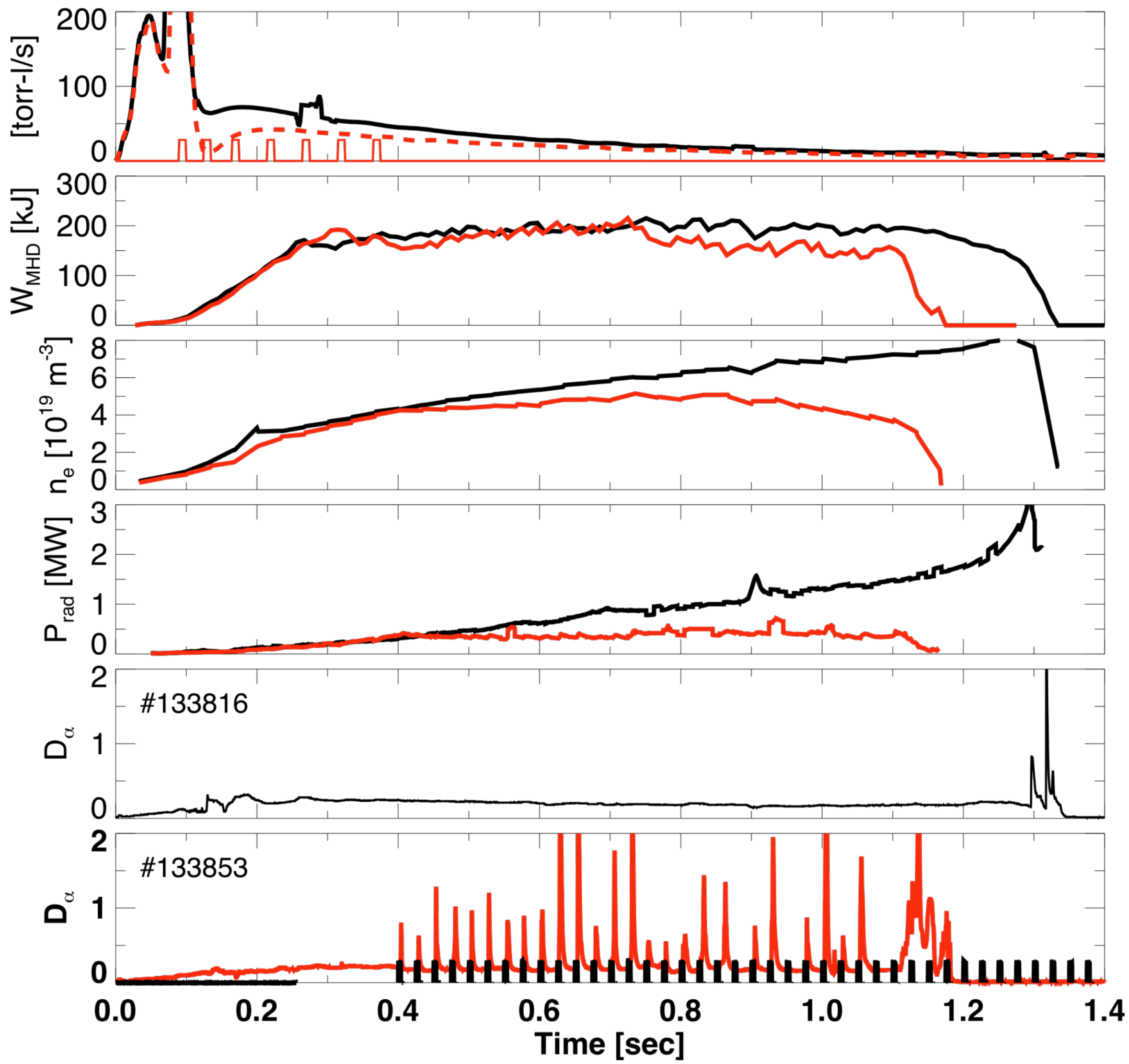


Lower triggering frequency gives impurity control with little impact on energy confinement



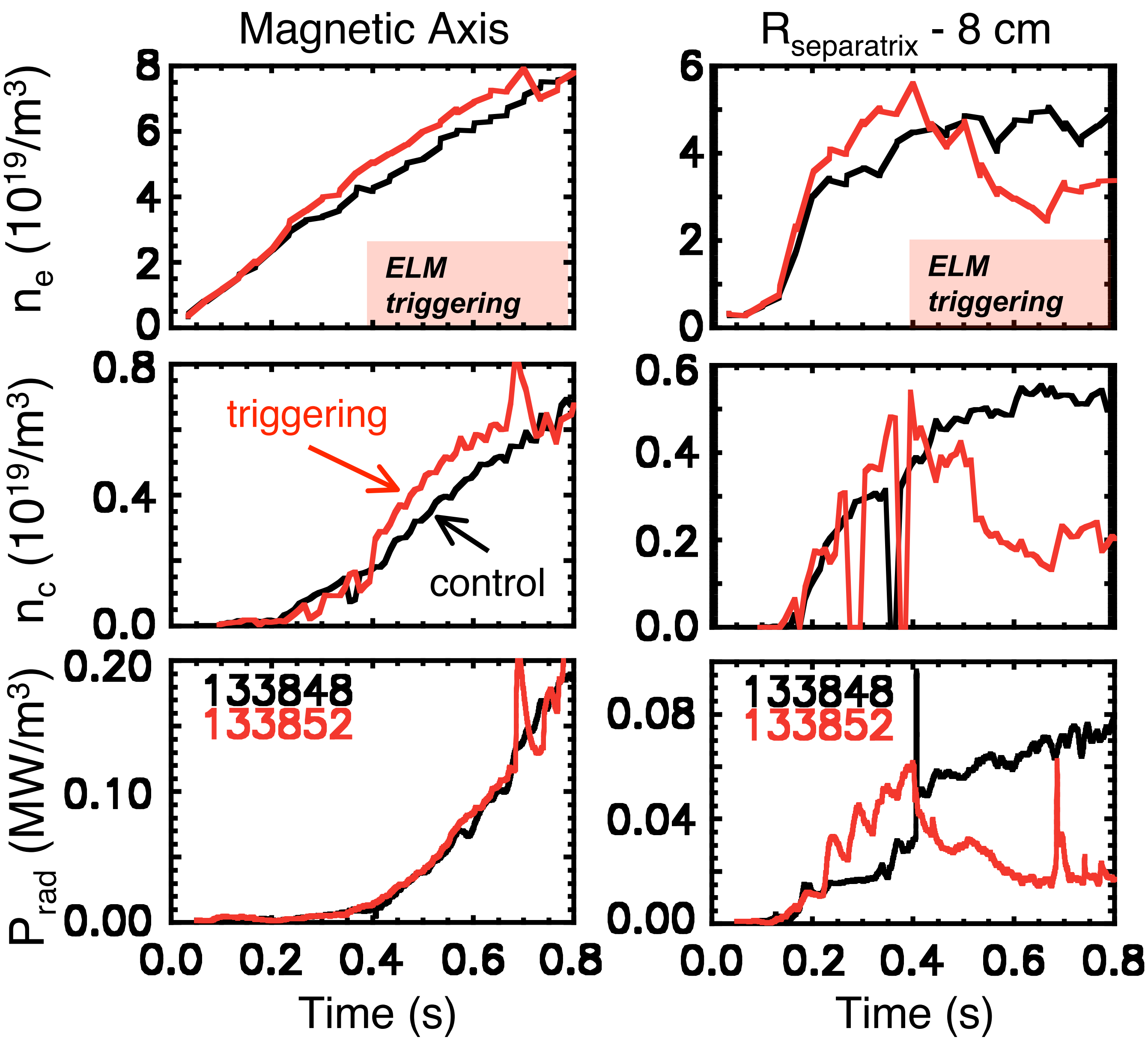


ELM pacing + optimized fueling allows quasi-stationary global parameters



- Slow center stack fueling reduced, replaced with SGI on LFS
  - Allows fuelling to be turned off quickly following startup
- Applying n=3 pulses arrested the line-averaged density and total radiated power for 0.3 s
- Discharge performance was limited by n=1 rotating MHD

Profiles still evolving while global parameters ~ constant



- Core densities increasing with and without ELMs
- All edge values decrease with triggering
- Core P_{rad} always increases
  - feature of Li discharges?

Application of 3D fields provides ELM pace-making technique

- Li coatings suppress ELMs & enhance τ_E but suffer from impurity accumulation
  - uncontrolled rise in n_e and core P_{rad}
- n = 3 perturbations successfully used to trigger ELMs and arrest rise in P_{rad} and n_e
  - little effect on plasma stored energy
- Triggering faster, more reliable at higher n = 3 amplitude
  - field penetration of vessel limits triggering time
  - 100% efficiency achieved up to 62.5 Hz
- ELM size reduced at higher frequency
  - P_{rad} effect saturates at 20 Hz
  - rotation braking increased
- Quasi-stationary P_{rad}, n_e achieved
  - core density increases as edge drops
  - n = 1 rotating mode limits discharge