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XP943: Optimization of ELM Pace-making with 3D fields

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Princeton, NJ
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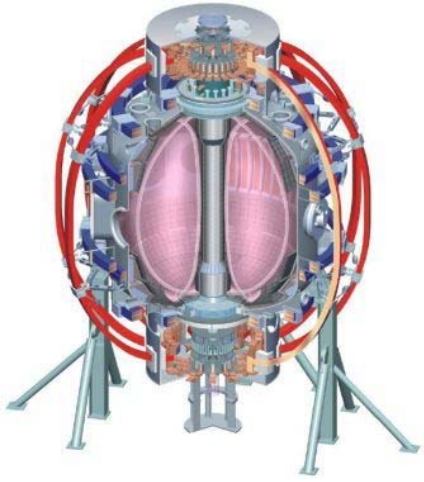
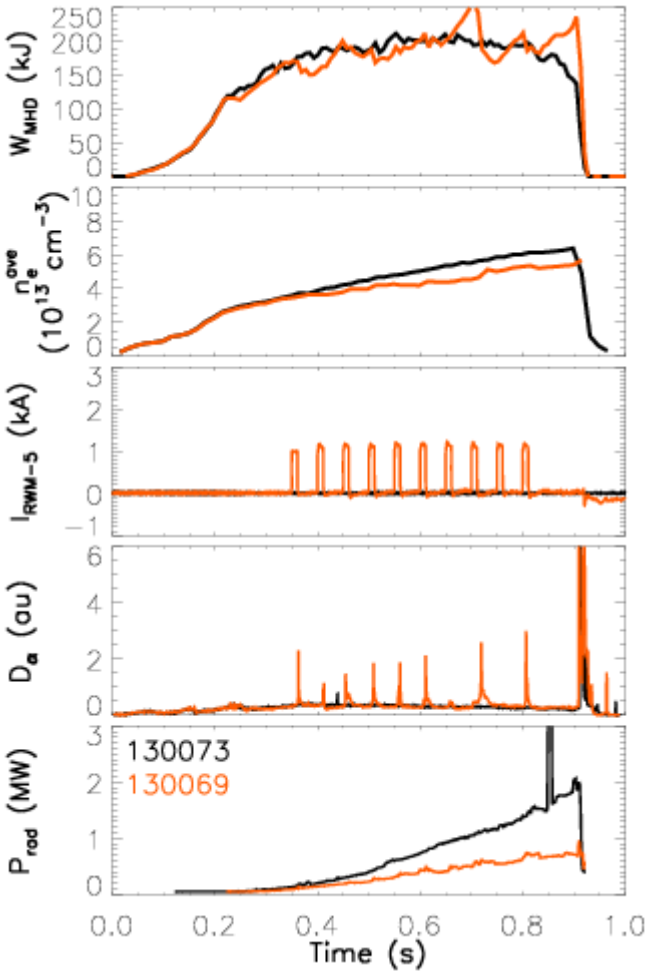


Magnetic ELM triggering has been applied to Lithium enhanced ELM-free H-modes

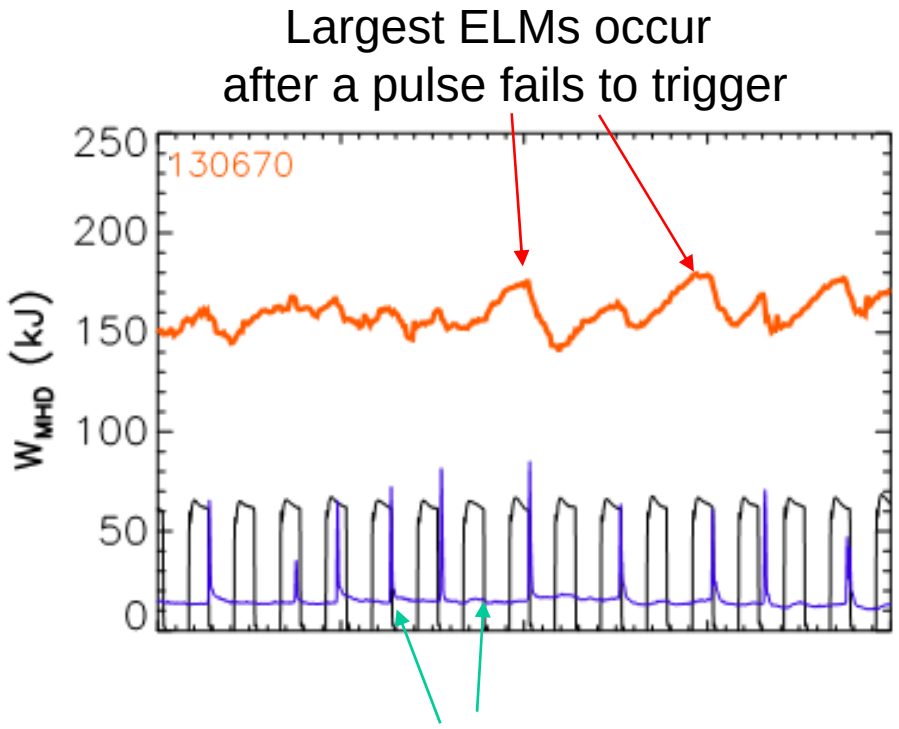
ELM-free H-mode shots have very large radiated power

ELM pacing able to reduce this problem

Need to develop scenario for long-pulse, steady-state

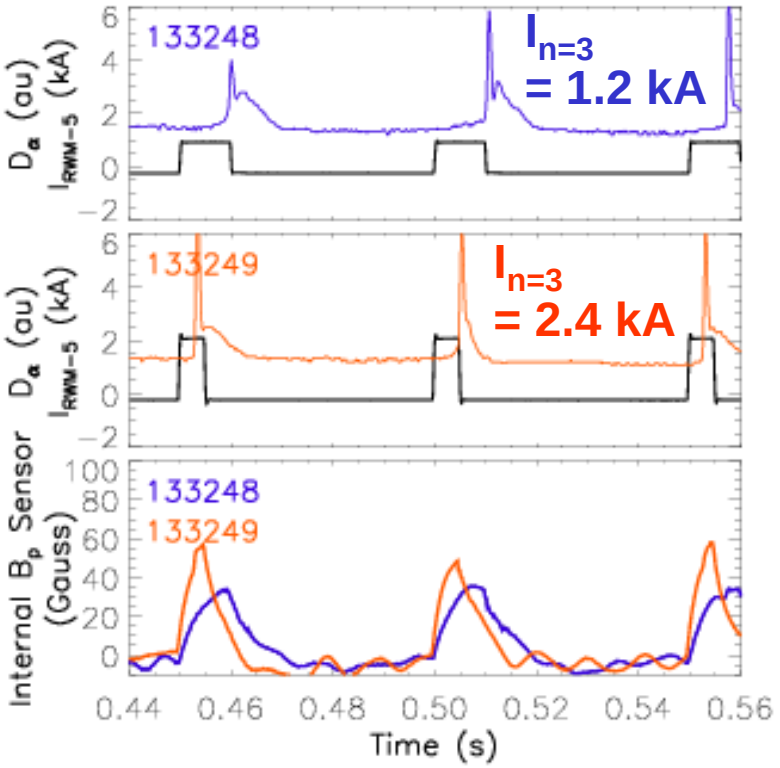


Triggered ELMs tend to be large



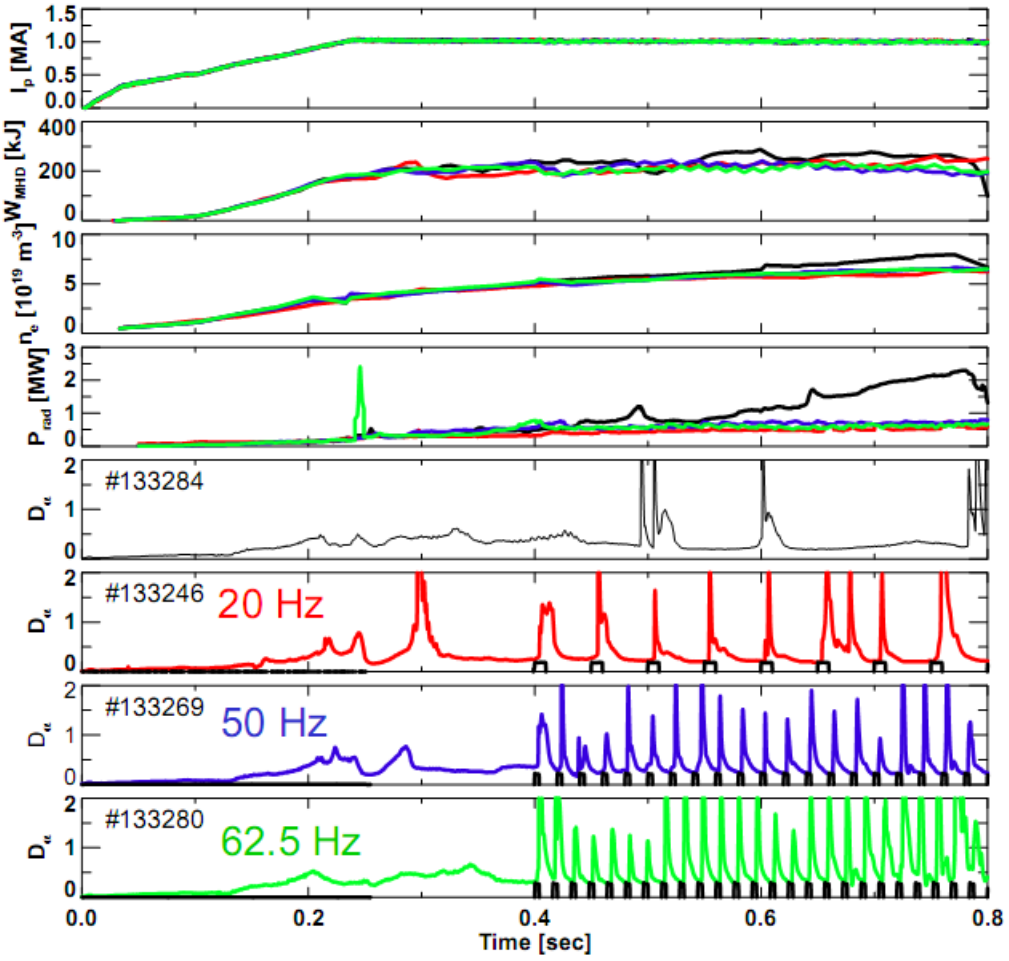
- Average triggered ELM size for a typical discharge is $<\Delta W/W_{tot}> = 10\%$
- Very large energy excursions occur on an ELM after the previous n=3 pulse fails to trigger
  - In these cases $<\Delta W_{tot}/W>$ can be 20% or more
  - Need to maintain high triggering reliability and frequency

XP943: Increasing the n=3 perturbation strength triggers ELMs faster



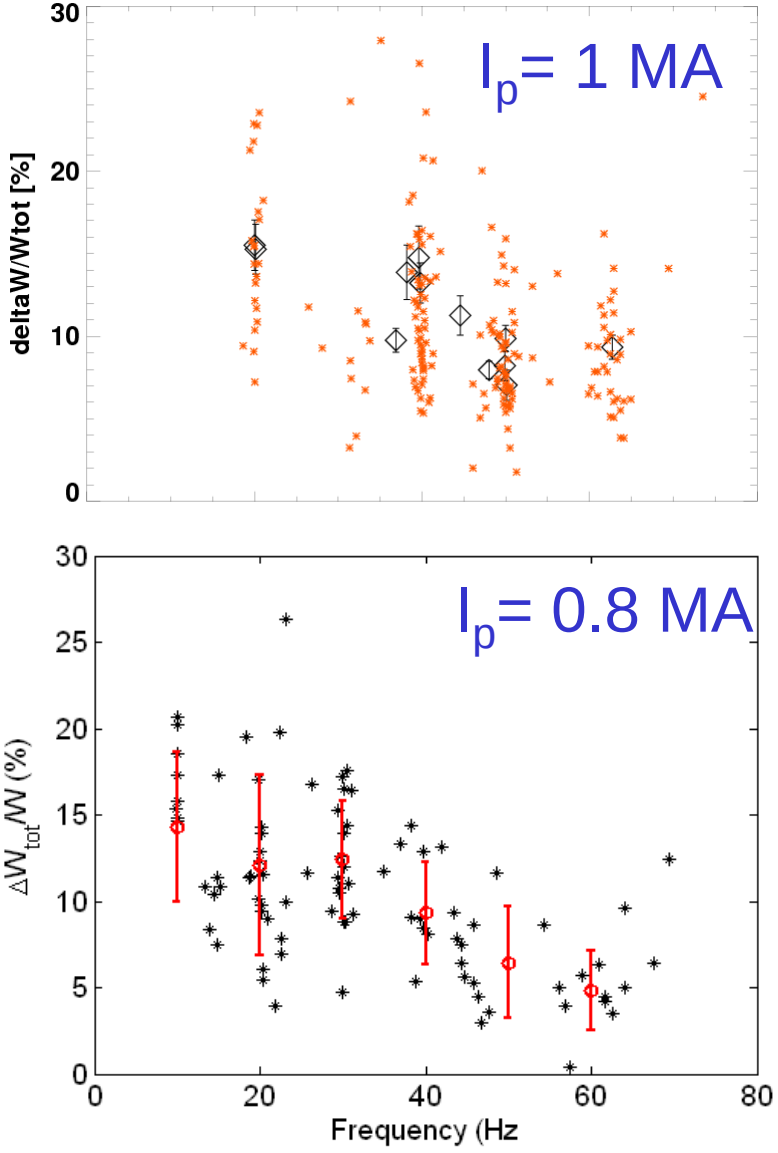
- With 1.2 kA pulses of in perturbation coils, ELMs are triggered in ~8 ms
- At 2.4 kA, ELM onset is reduced to ~3 ms
- Limited by field penetration time through vessel (estimated to be ~4 ms)
  - Internal coils may trigger much faster
- Provides a means for improving triggering efficiency for fixed pulse duration

Maximizing the n=3 pulse amplitude allows high frequency triggering with very high reliability



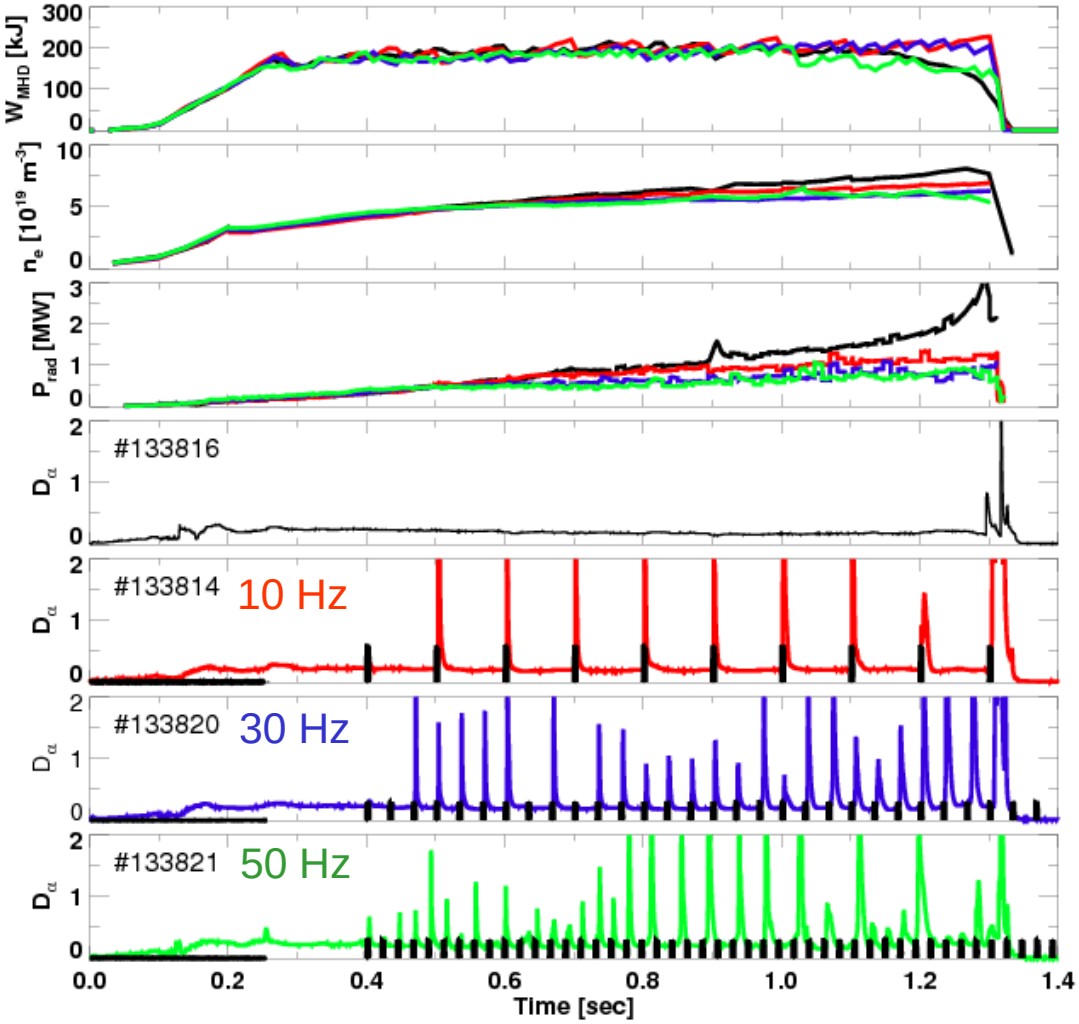
- ELM frequencies up to 62.5 Hz have been achieved while maintaining 100% triggering efficiency
  - Allows average ELM size to be reduced
  - Internal coils should allow faster triggering, higher frequency
- Time-average magnetic braking of rotation is strong at high frequencies
  - Can also be greatly improved with internal coils

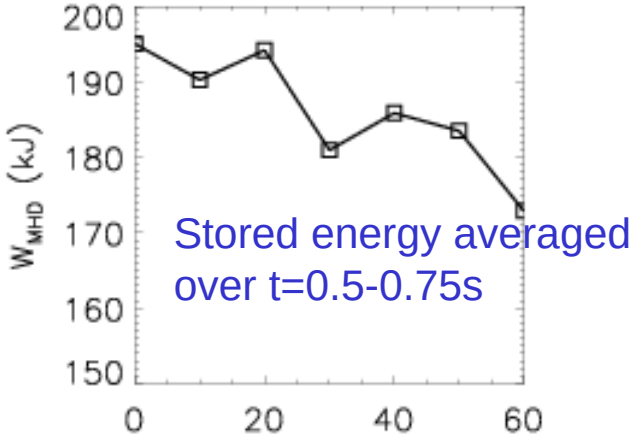
ELM size can be decreased by raising triggering frequency

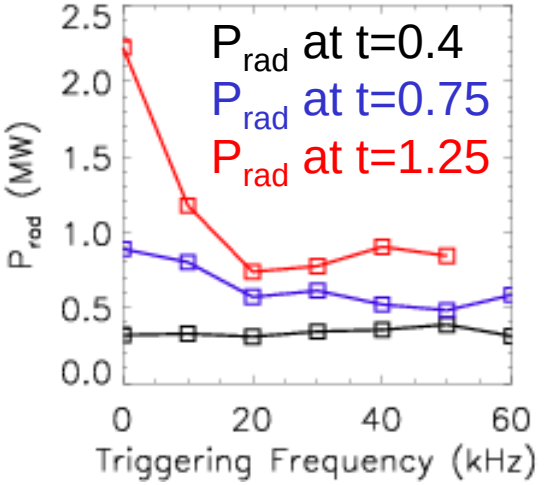


- ELMs are very large ($\Delta W/W_{tot}$ ~ 15%) when triggered at 10 Hz
- Average ELM size can be reduced to ~5% by increasing triggering frequency to 60 Hz
  - Some outliers remain
  - Triggering reliability drops at high frequency, might be improved with internal coils
- Some evidence that triggered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

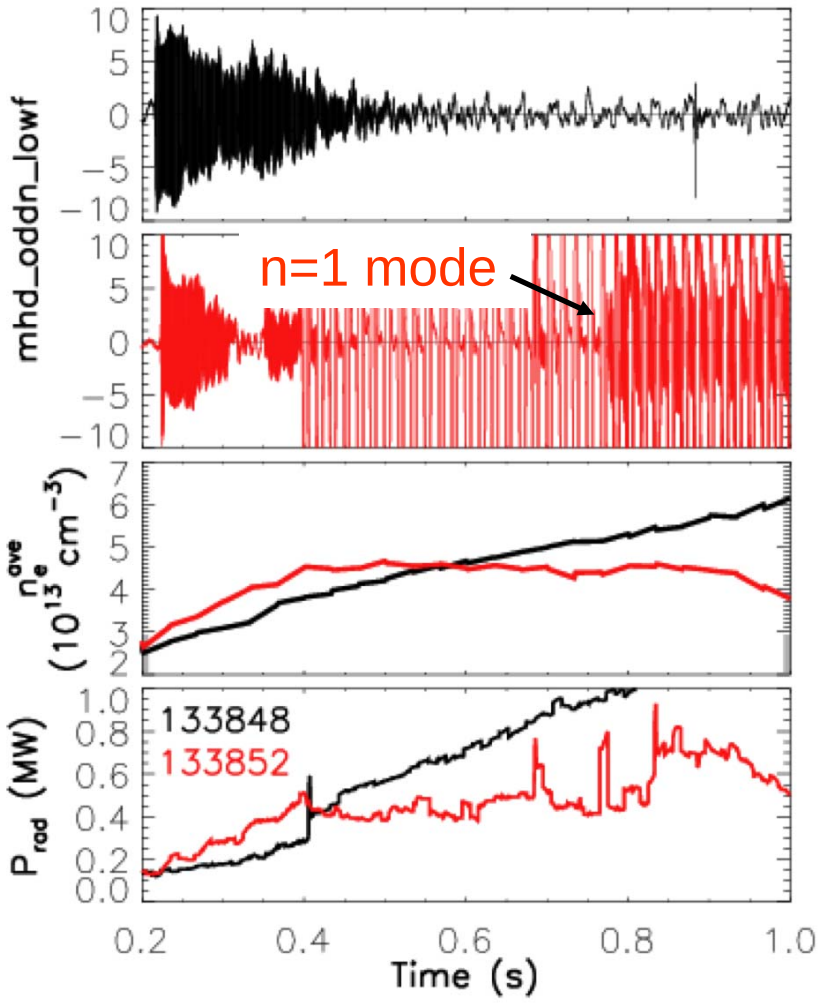
Lower triggering frequency may be optimal for impurity control without adversely affecting energy confinement





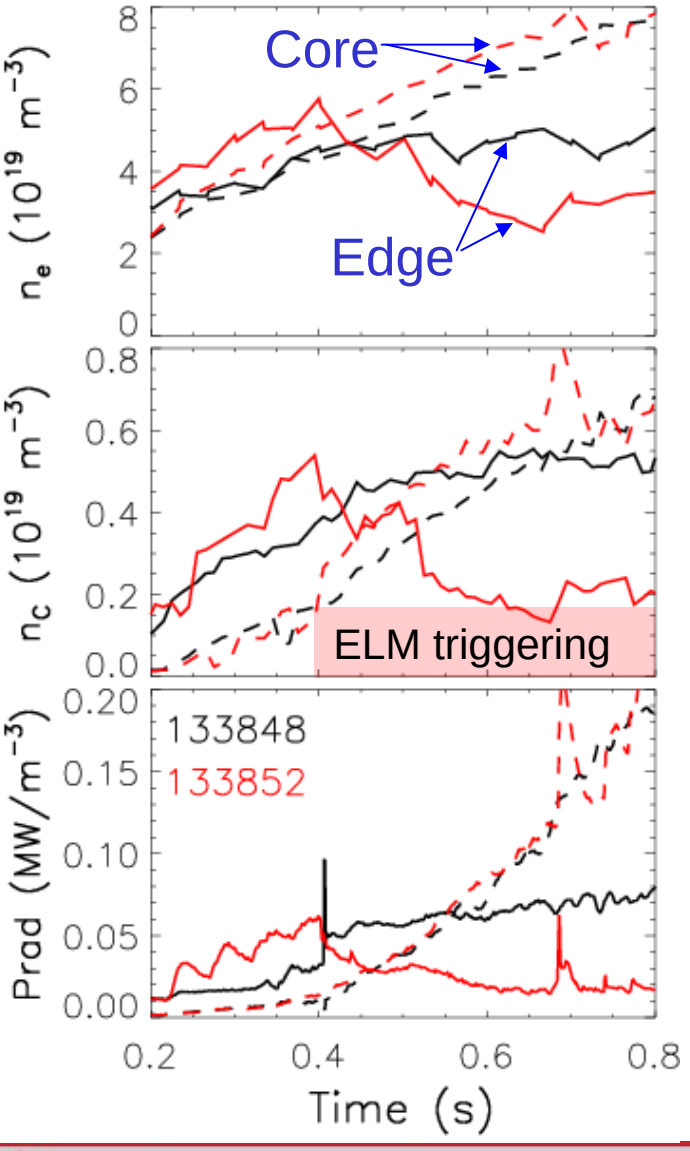


Combining ELM pacing with optimized fueling successful in producing quasi-stationary global parameters



- Fueling from center stack valve was reduced, replaced with SGI
- 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

...but profiles are still evolving



- Dashed lines: electron, carbon, and radiation densities at axis
  - Black: control shot, no ELMs
  - Red: ELM triggering begins at t=0.4s
- Solid lines: edge values (8cm inside separatrix at outer midplane)
- Trends of all are similar
  - Core values increase at a rate similar to control shot
  - Edge values decrease in time
- Implied pressure gradient increase may be driving n=1 activity