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Combining n=3 ELM triggering with RF for edge and core impurity control

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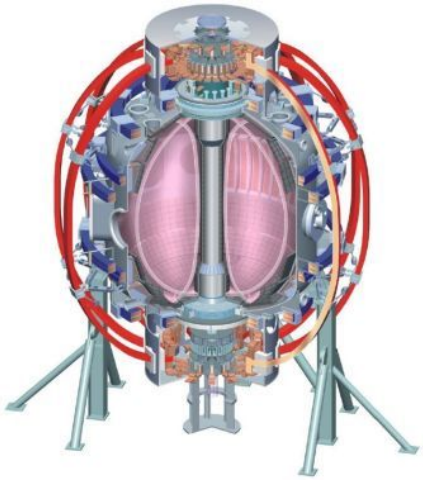
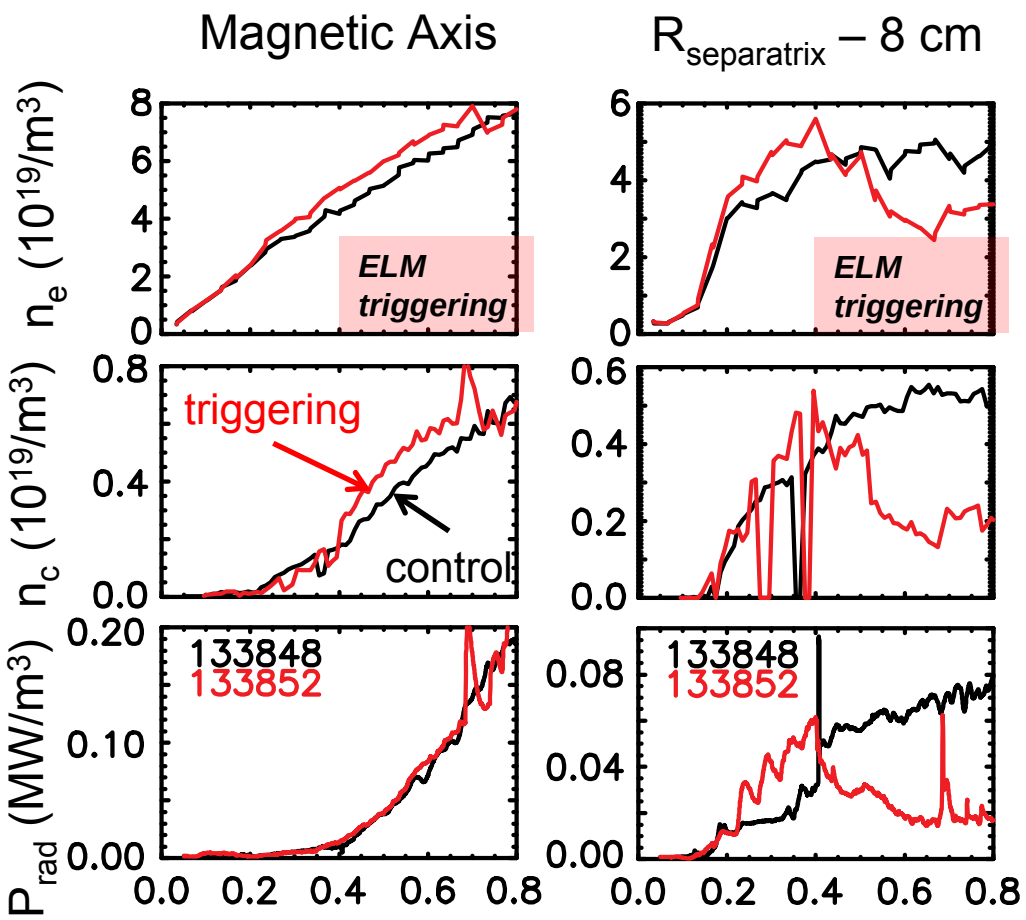


ELM pacing with 3D fields has been used to control impurity/denisty rise in Li ELM-free H-modes



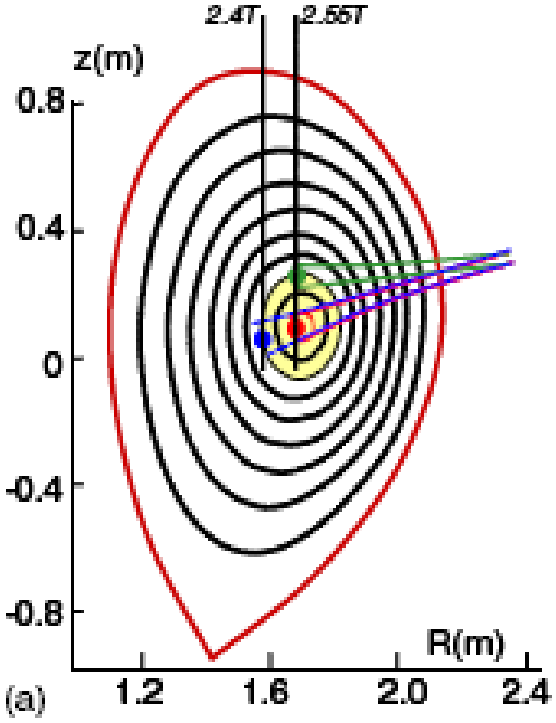
- 3D fields used to restore ELMs to high τ_E lithiated discharges for particle expulsion
- Combined with partial SGI fuelling to improve particle control
- Successful in fully arresting line-averaged density and total radiated power
- But plasma is not stationary, profiles evolving
  - Edge electron/impurity density decreases in time
  - Core accumulation remains strong

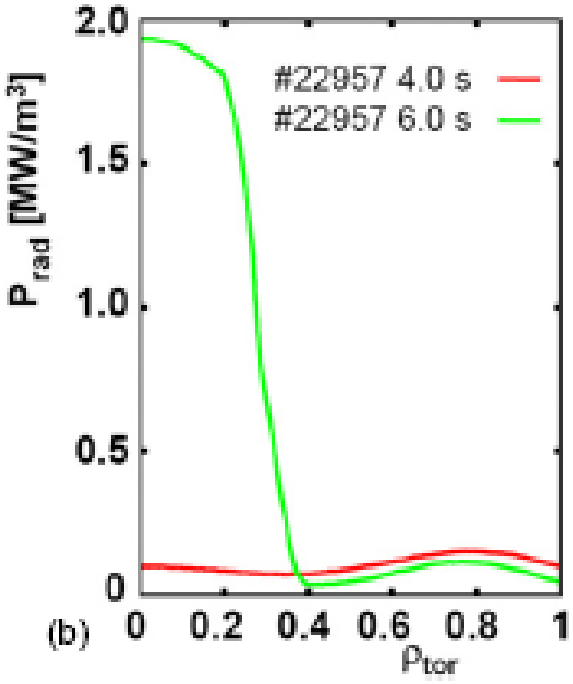
Central ECRH mitigates core tungsten accumulation in AUG

- Attributed to enhanced outward turbulent convection of impurities*
  - Modes only unstable if $R/L_{Te} >> R/L_{Ti}$
- Requires very central deposition (ρ<0.2)**

* Angioni, PPCF **49** (2007) 2027

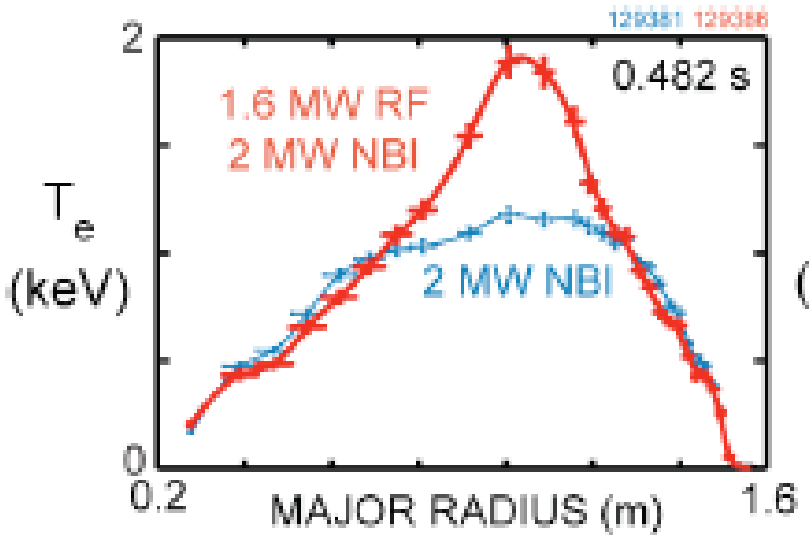
** Gruber, NF **49** (2009) 115014

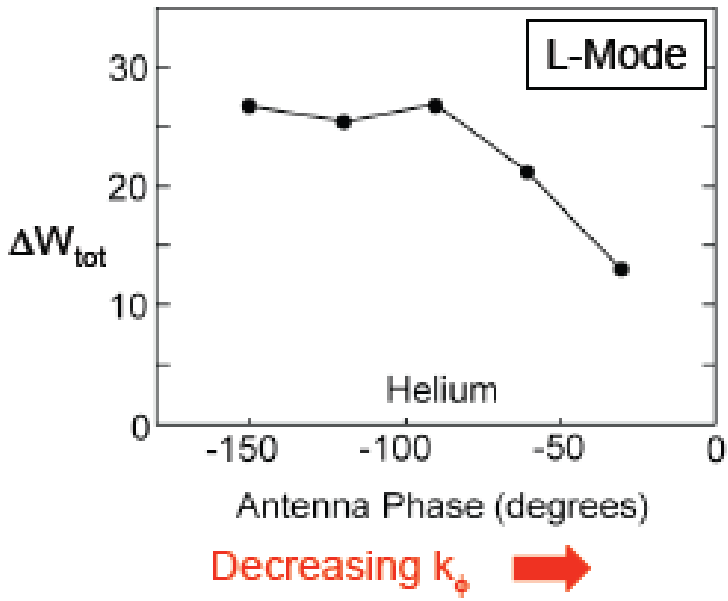




Run plan: use HHFW in increase Te(0) for central impurity control during paced discharge

- Rely on development of H-mode heating done elsewhere
  - Initially plan to use 180° phasing, since this has worked previously
  - Should have initial measurements of whether central impurity control is feasible
- Optimization of trade-off between conflicting needs
  - Outer gap for HHFW vs outer gap to minimize impurity sources
  - Trade NBI for RF power
- May need to notch RF power to avoid ELMs
  - Opportunity to test RF ELM triggering





Elm pacing shot list

- Assume that HHFW has been made to work (raise Te) earlier in the overall shot list, or else concurrently (but separately)
  - Maybe do the ELM pacing during the last part of each discharge?
  - Assuming day has been reasonably successful, move to earlier triggering for the last few shots of the day to try for full-shot control
- Try to take it as easy as possible on the RWM coils
  - Low frequency, low amplitude pulses
- Start at 10 or 20 Hz, using 1.5 kA, 10 ms pulses (compare to >60 Hz, 3kA, 4 ms pulses)
  - If not enough to ensure triggering, widen pulses or raise amplitude
  - Low frequency should avoid terrible things happening to plasma, so for now not planning on negative-going spikes

Elm pacing shot list

- Increase triggering frequency in increments of 10 Hz
  - 2-3 shots at each to readjust triggering (via pulse amplitude/duration)
  - Raise frequency until either density is arrested or engineers say stop
- Control shots mixed in, but important near end of day with "best" HHFW and ELM recipe
  - HHFW off, ELMs on
    - How much has HHFW affected core accumulation?
  - HHFW off ELMs off
    - What's the net win in particle/impurity control?
  - HHFW on ELMs off
    - Probably have a lot of these already, check for synergy between HHFW and ELMs, separate the two

Lower frequency ELMs combined with HHFW may be enough for density control

- Last year we achieved periods of ~300 ms with flat $\int n_e dl$ with pulse frequency > 60 Hz
  - But this was do to edge ne ↓, core ne ↑ in time
- Freq scan shown to right
  - Control, 20, 40, 60 Hz
- Edge density starts decreasing in time fairly quickly in frequency scan
  - If HHFW does increase core particle transport, low frequency triggering should be enough for density profile control