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Combined methods for impurity control

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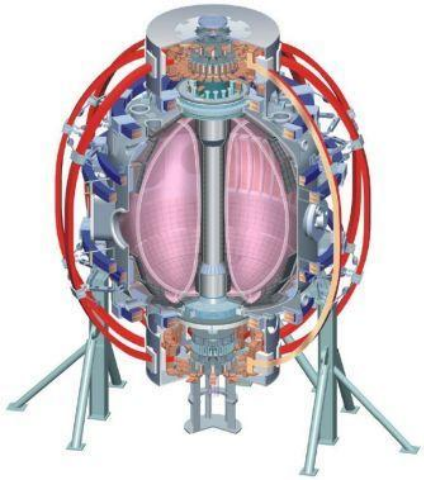
NSTX FY11-12 Research Forum
Princeton, NJ
Mar 17, 2011



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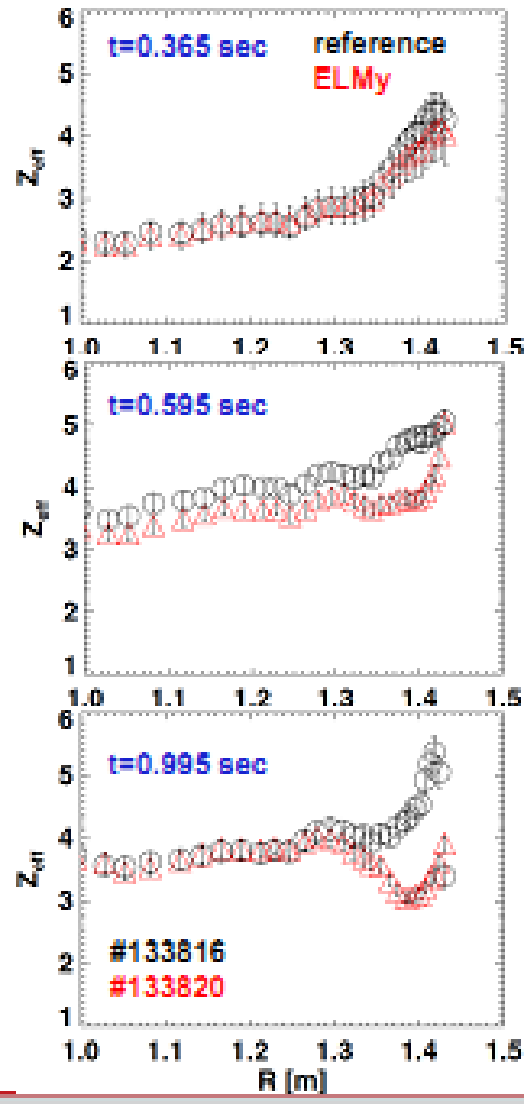
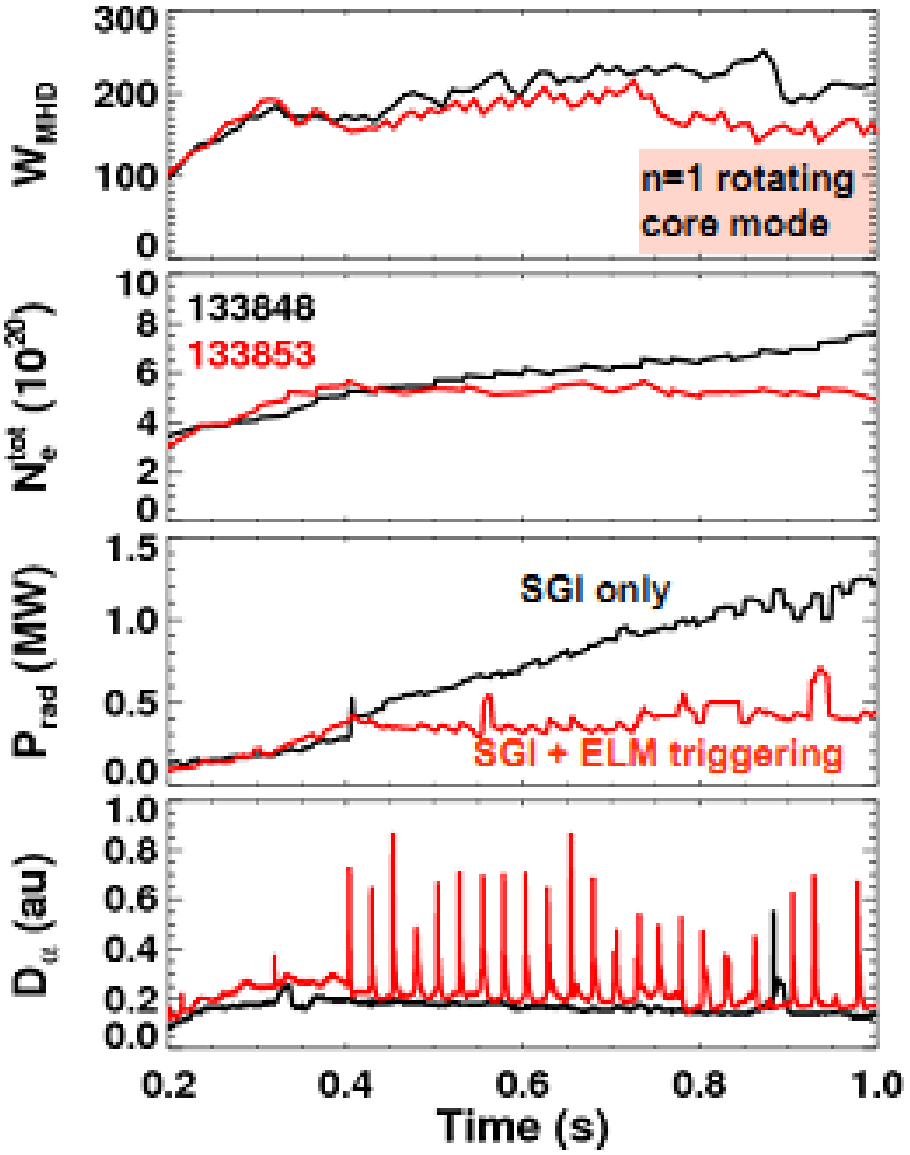
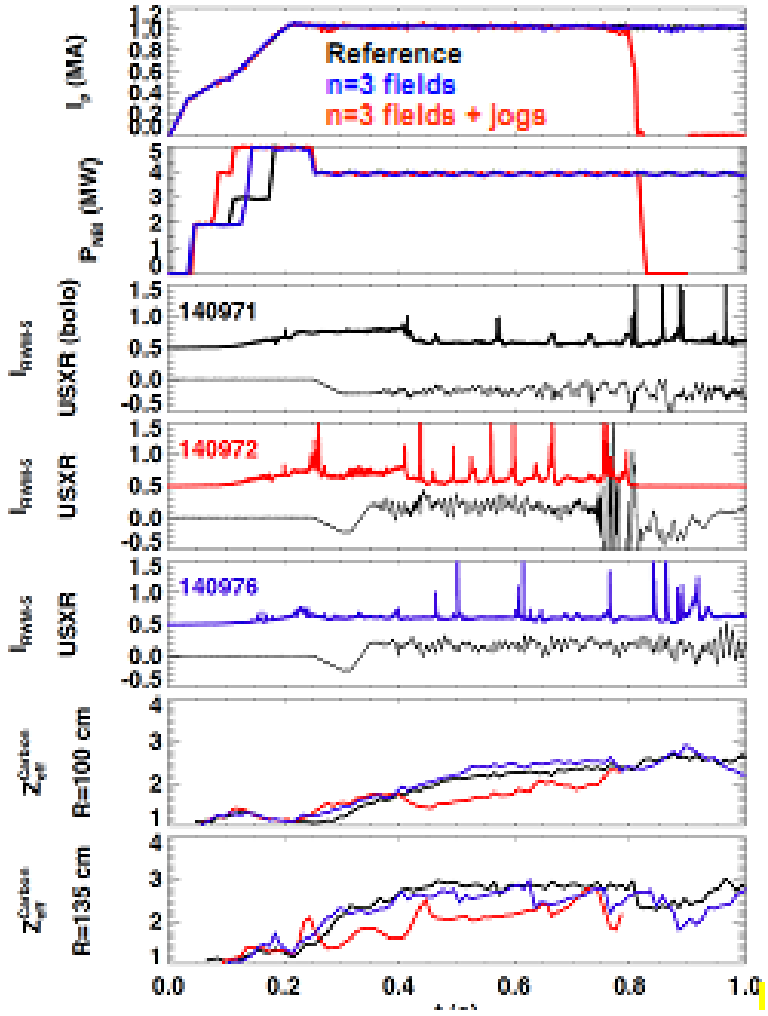
ELM pacing with n=3 fields can provide global particle control, at a price



- n=3 pulses trigger individual ELMs
- Ramp of n_e and P_{rad} can be stopped
- But at frequencies necessary confinement is degraded, core tearing modes triggered
- Central impurity accumulation is still strong



Combined with n=3 fields, vertical jogs may be a better pacing technique



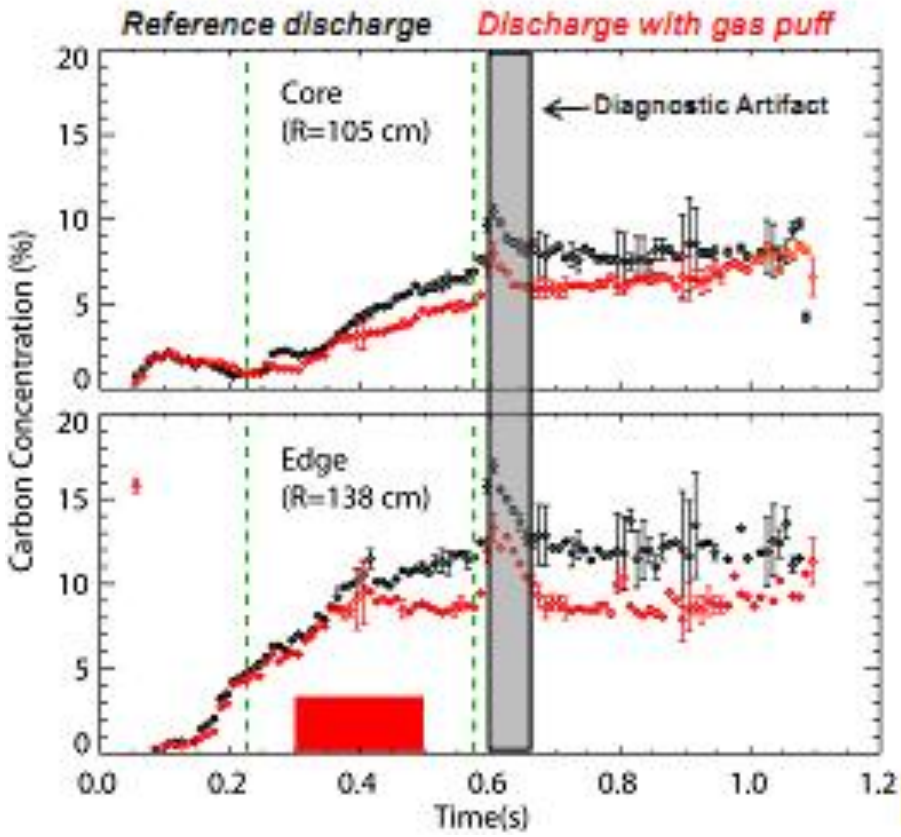
- Vertical jogging alone has been successful in ELM pacing [Gerhardt, NF 10]
  - Relatively benign to core plasma
  - Failed to trigger ELMs during lithium ELM-free discharges
- Initial experiments to combine the two techniques in FY10 were promising
  - Experiments done in ELMy plasmas
  - Evidence seen of a synergy between the two effects, as at JET (less n=3/jog amplitude to trigger ELMs)
  - Reduction in impurities also seen

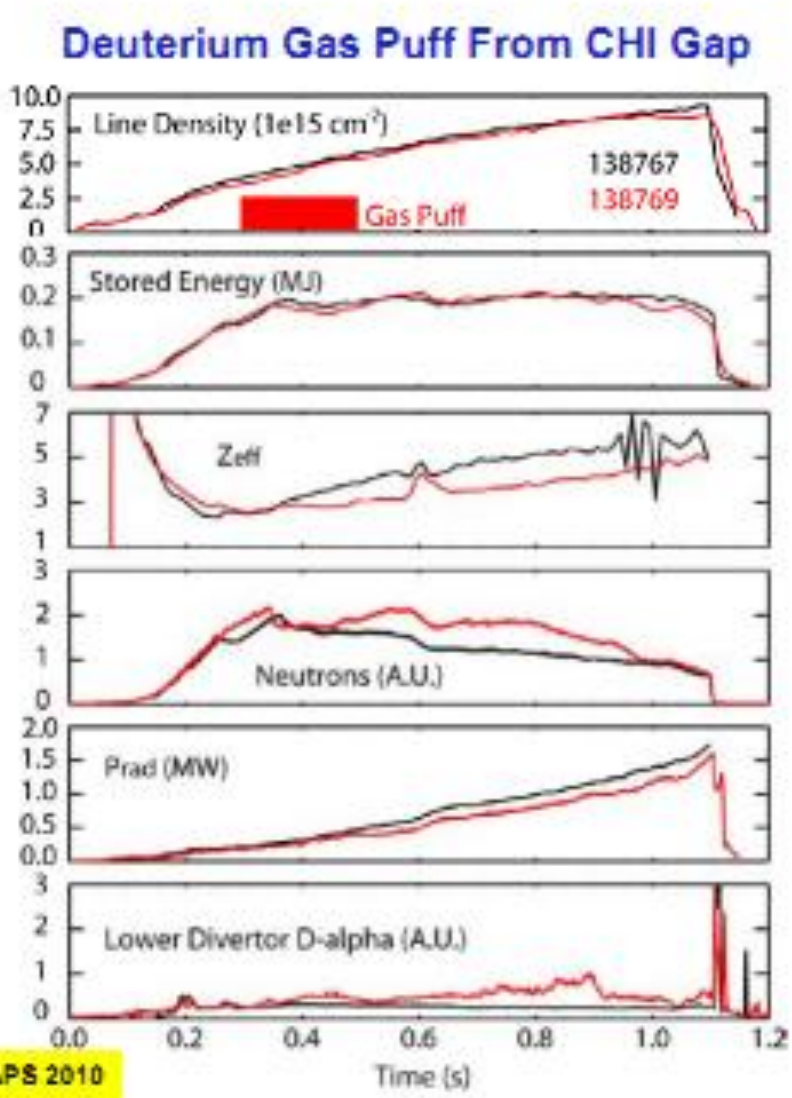
Run plans: augment vertical jogging with 3D fields to extend pacing to lithium ELM-free plasmas

- Hope is that this will result in pacing that is more friendly to core plasma performance
  - Partially motivated by vertical jogging in ELMy plasmas
  - Will reduce n=3 fields levels used during lithium pacing
  - Also contributes to ITPA PEP-29: vertical jogging
- Rough run plan, 1 day
  - Reload 133816 (lots of lithium, strong impurity accumulation)
  - Add drsep pulse requests to vertically jog plasma
    - Increase magnitude of jogs as much as possible
  - Apply DC n=3 fields
    - If VJ has produced ELMs, back off VJ to below threshold
    - Else keep VJ at highest level plasma will tolerate
  - If pacing is seen withVJ+3D, scan n=3/jog amplitudes a bit
  - Attempt to replace DC n=3 fields with pulses synchronized around jogs

Divertor D_2 puffing reduced core carbon density and ramp rate

- Drop attributed to reduced sputtering
- Central f_C and Z_{eff} still rising
  - *Need to develop ways to reduce central impurities*





Scotti, APS 2010

Add divertor gas puff to ELM pacing to reduce demand on ELMs

- Goal is to reduce impurity source rate, so that reduced ELM frequency can be applied to get same net effect
  - May be able to halt density/Prad/Zeff ramp without triggering core modes

- Rough run plan (1/2 day)
  - Reload previous shot used for pacing (133816)
  - If VJ+3D has been developed use this, otherwise stay with n=3 only
  - Do coarse pacing frequency scan, establish baseline impurity flushing vs. core degradation
  - Add divertor gas puff from previous case where impurities were reduced (138769-similar shot to pacing target)
  - Adjust puff parameters to maximize impurity reduction
  - Scan pacing frequency, test if ramp is halted at lower frequency

Central RF mitigates core tungsten accumulation in other tokamaks

- ECRH used in AUG to avoid central metal accumulation with tungsten walls
  - Attributed to enhanced outward turbulent convection of impurities*
    - Modes only unstable if $R/L_{Te} >> R/L_{Ti}$
  - Requires very central deposition ($\rho<0.2$)**

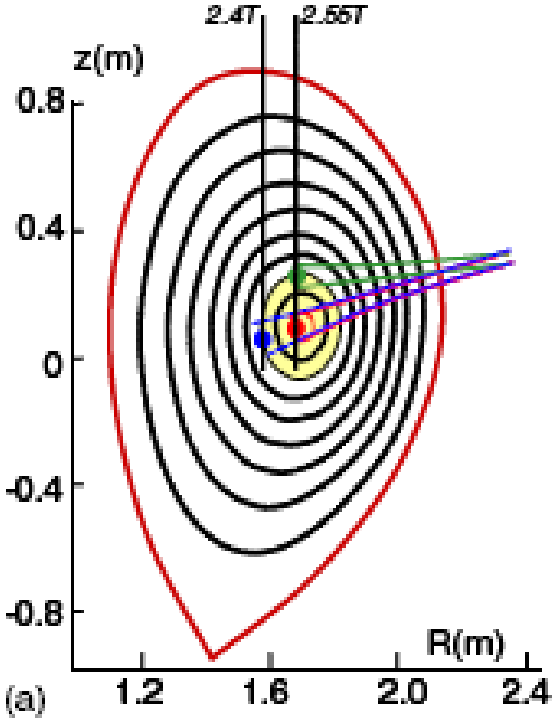
* Angioni, PPCF **49** (2007) 2027

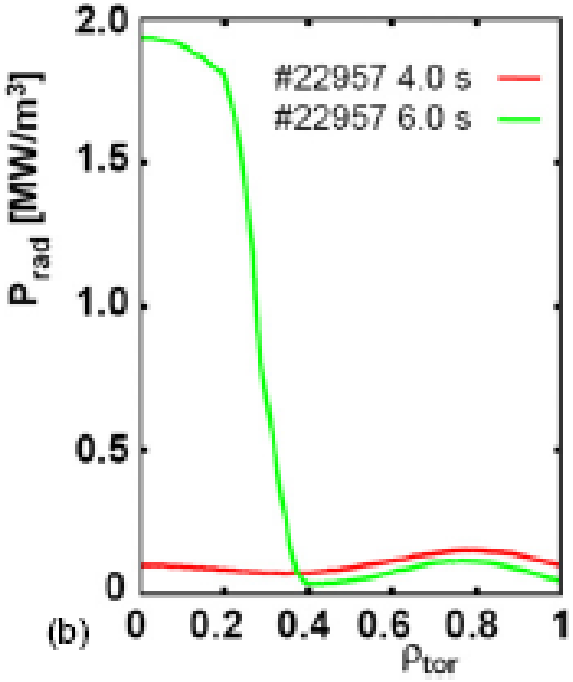
** Gruber, NF **49** (2009) 115014

- JET sees pumpout of metals with ICRH
  - Not understood in this case: not predicted by gyrokinetics, too large for neoclassical

*Valisa, NF **51** (2011) 033002

- NSTX HHFW heating of NBI H-mode showed small core carbon (129386)





Add RF for core impurity reduction

- If previous RF experiments have developed target with promising core heating (impurity reduction?), reload and try to add pacing
- Otherwise, start with previous pacing shots and add RF
  - Reload 133816, reduce outer gap to 8 cm
    - Need strongly accumulating reference->high LiTER
  - If VJ+3D developed consider this for pacing, otherwise use n=3 pulses (watch out for compatibility with antenna loading)
  - Start at low RF power (1 MW, -150/-90 degree phasing), optimize outer gap, lithium conditioning, antenna phasing to maximize coupling and heating
  - Increase RF power until core impurities are affecteds (reduce P_{NBI}?)
  - Scan ELM pacing frequency (10/30/50 Hz)
    - May need to preprogram notches in RF power to avoid ELMs