NSTX

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XP1027: RMPs below the ELM triggering threshold for impurity screening

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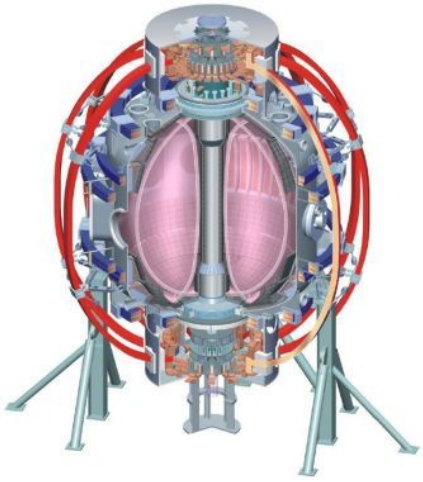
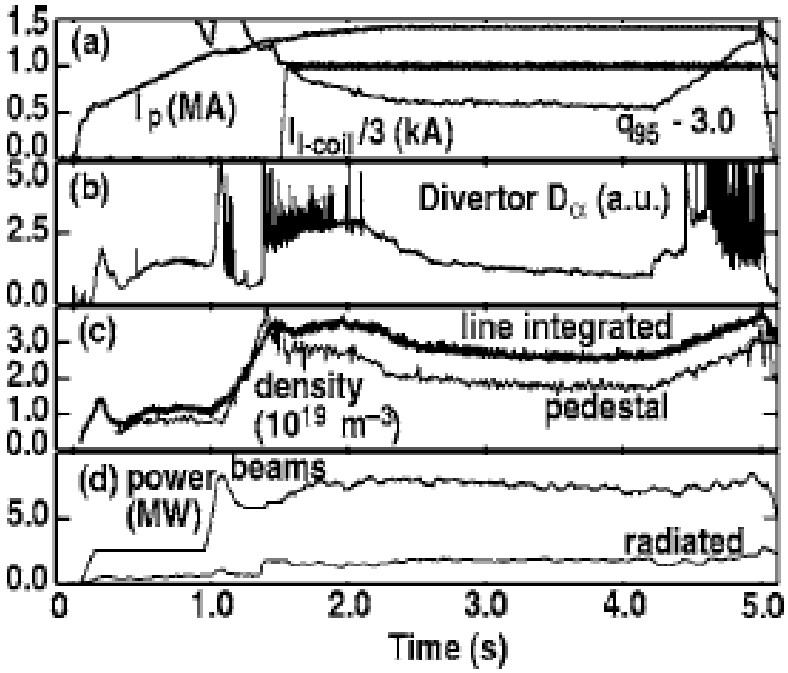
ASC Group Review
March 2, 2010



Impurity screening is often observed when 3D perturbations are applied

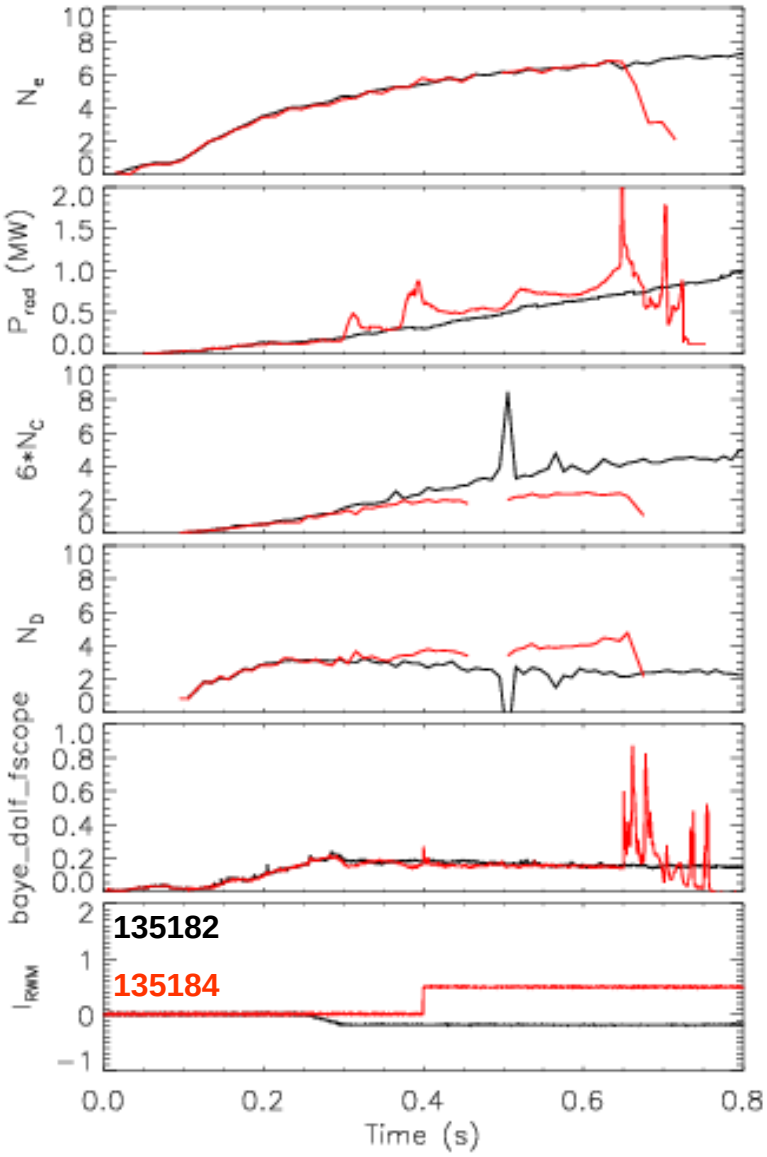
- Increased particle transport during RMP ELM-suppression keeps radiated power down
- Impurity screening also seen on limiter tokamak ergodic divertor experiments (Tore Supra, TEXTOR)
- Also seen on stellarators (LHD, W7-AS)
  - Attributed to large friction drag on impurities towards divertors
  - Happens at high density



*Evans, PoP **13** (2006) 056121

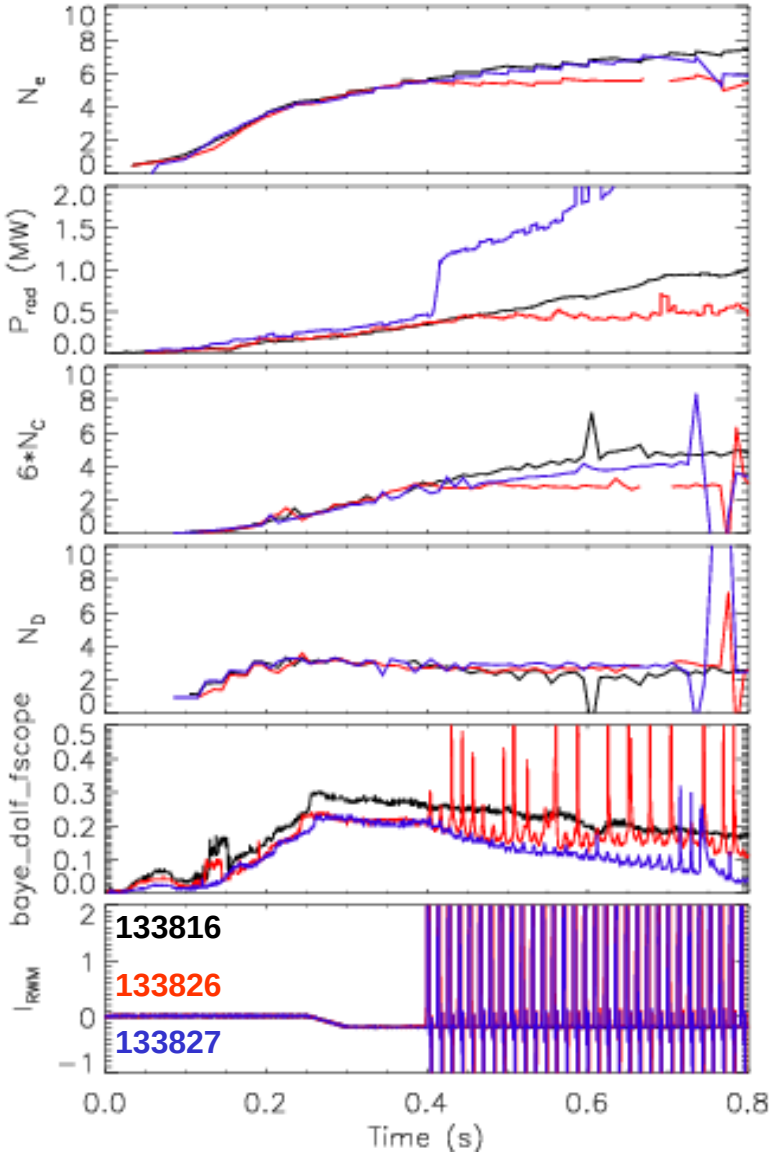
Some evidence exists for impurity reduction with 3D fields (but without ELMs) in NSTX

- From XP 926, SPA current scan to find threshold for ELM destabilization
  - Heavy lithium usage->ELM-free with significant impurity accumulation (black)
  - SPAs at 500 A, not enough to trigger ELMs (red)
- Electron inventory unaffected by 3D field, and radiated power has blurbs before SPAs that make behavior hard to interpret
- Carbon inventory is significantly (~30%) less in shot with 3D field



Sub-threshold triggering pulses show hints of increased particle transport without ELMs

- 3 kA SPA pulse train applied, each 4ms in duration: ELMs triggered
- Pulse duration reduced to 3ms: too short to trigger ELMs
- D_α shows small increase during non-triggering pulses, implying increased particle transport
- Even without ELMs, carbon inventory is reduced from control
- Radiated power is extremely high due to some terrible event at ~.4s



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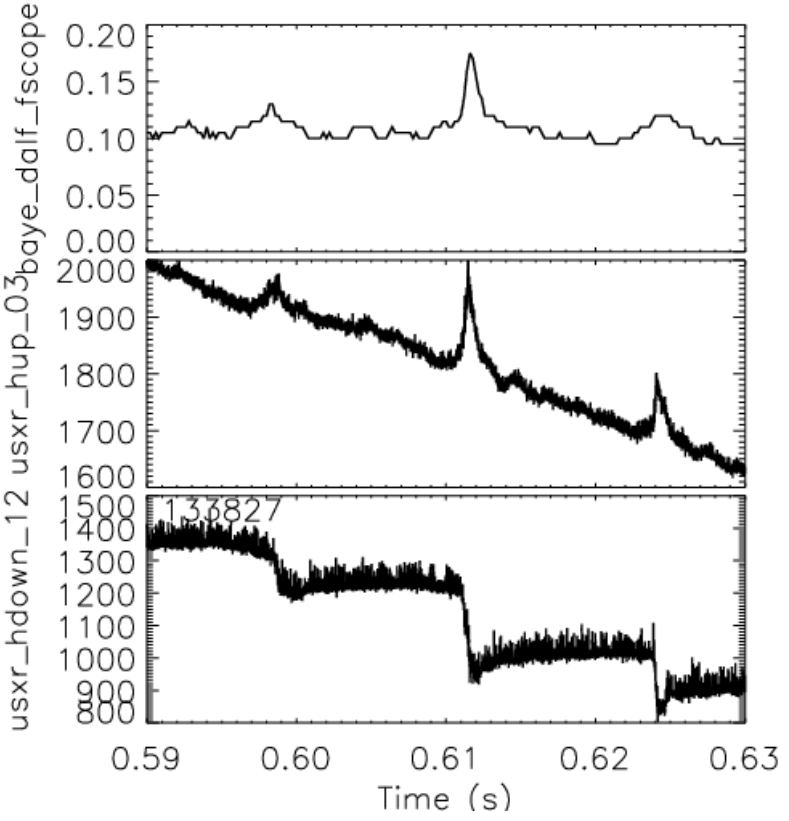
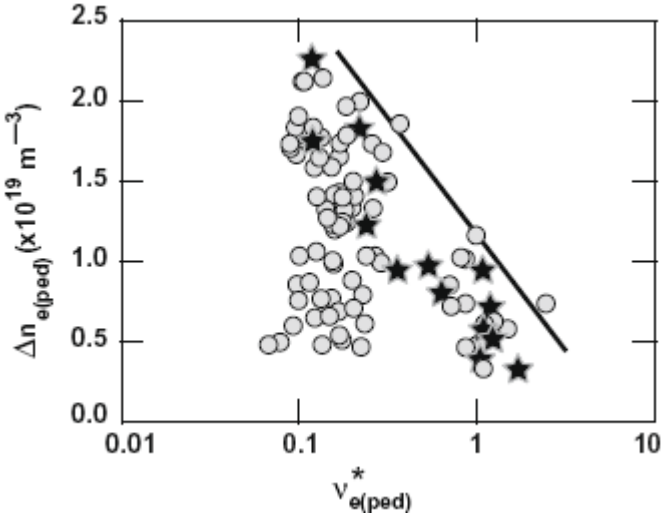


Effect of 3D fields may be stronger at low collisionality

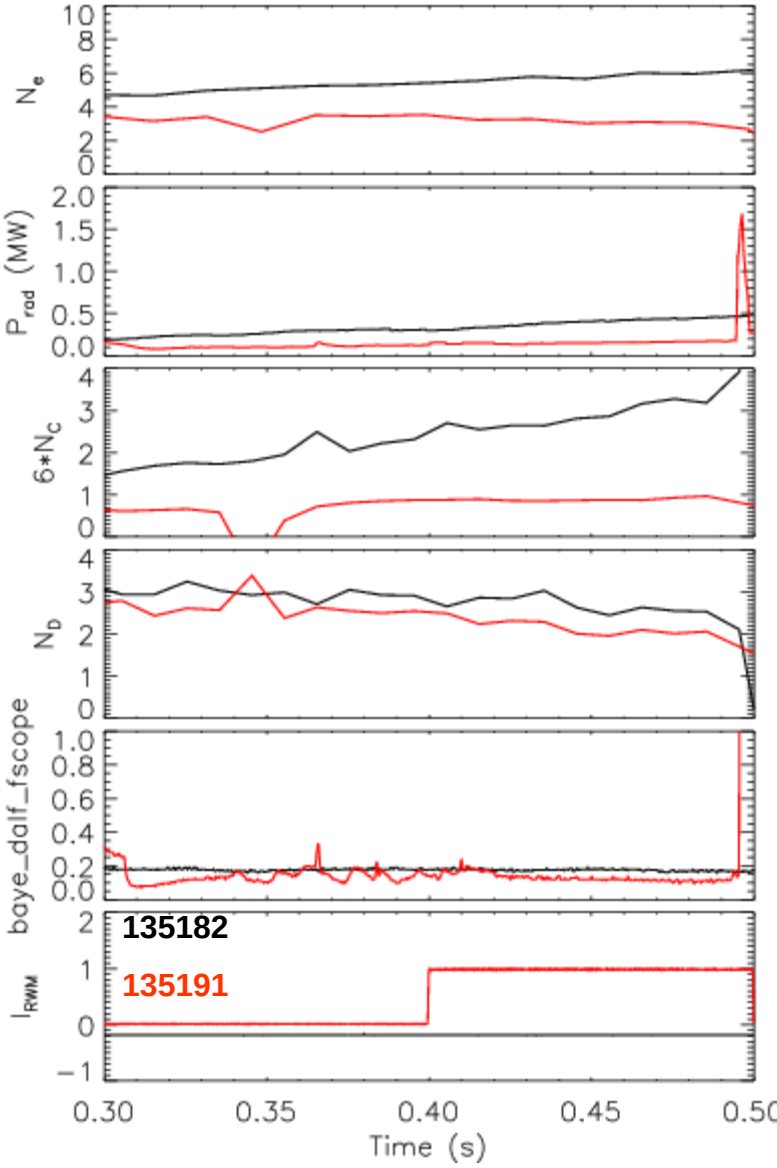
- DIII-D sees maximum pumpout at low collisionality



DIII-D density pumpout during RMP ELM suppression:

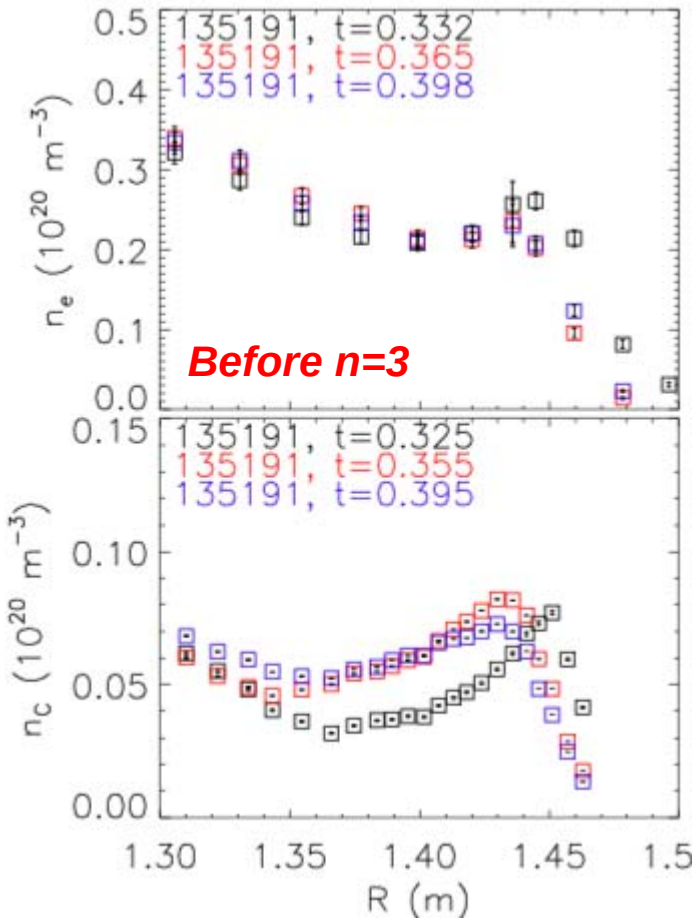
Unterberg, JNM ***390-391*** *(2009) 486*

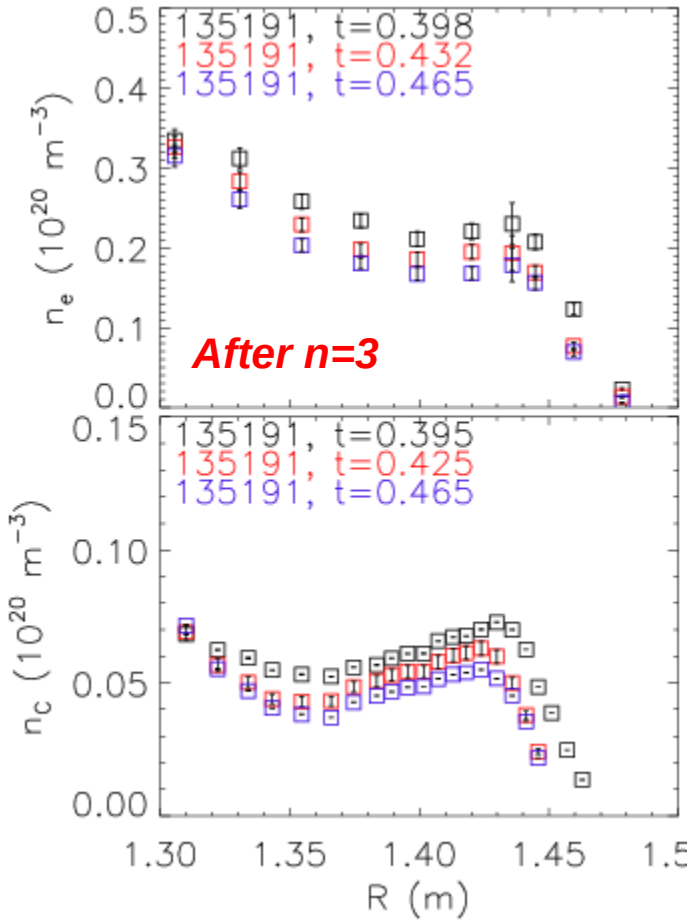
- One example from NSTX: shot after an aborted one (i.e., double lithium) ran through at low density
- 3D field turned on at 0.4s
  - No ELMs triggered
  - Electron inventory starts decreasing
  - Carbon inventory constant



Effect of 3D fields may be stronger at low collisionality

- Before n=3 field is applied, edge electron and carbon densities are reasonably constant or increasing in time
- After n=3 field is turned on, both start decreasing



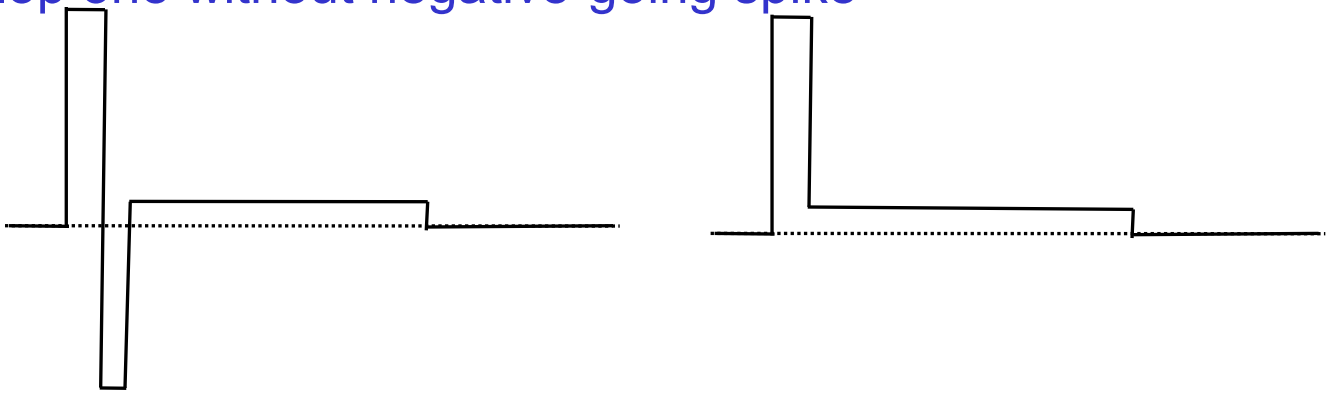


Run plan: use n=3 fields strong enough to affect particle transport, not strong enough to make ELMs

- Create reference shot (2 shots)
  - Reload of 135182: 800 kA, 0.45T, κ~2.4 δ~0.7, P=4MW
    - If possible, replace with lower-density shot (LLD)
  - Adjust lithium as necessary to be ELM-free (~250 mg/shot for 135182)
- Square wave n=3 fields (12 shots)
  - Start with 1 kA, 50 ms, pulses at 10 Hz (from XP926, triggering takes ~20-100 ms), adjust duration to avoid ELM triggering (3)
  - Change SPA pulses to 2 kA, 10 ms, 10 Hz, adjust to avoid ELMs (3)
  - Increase (double) pulse frequency (2)
  - Change SPA pulses based on Prad, NC, Zeff behavior so far: (4)
    - If higher ampiltude/frequency is more promising for impurity control, increase SPA current to 3 kA and shorten pulses
    - Else reduce SPAs to 500 A, increase duration

Run plan: use n=3 fields strong enough to affect particle transport, not strong enough to make ELMs

- Backup waveform to test if square waves don't affect impurities
  - Short, non-triggering pulses make blurps on D_α
  - If this really is due a stochasitization of the edge, can expect a hysteresis with perturbation strength (island opening at threshold field, don't close until field is reduced to << threshold)
  - New waveform: use strong initial 3D field to initiate stochastic response, then drop the field to low level to maintain it
  - Might be hard on RWM coils: previous observation of D_α blurps involved 3kA pulses followed by negative going spikes
  - Either use previous waveform to initiate stochastic response, or redevelop one without negative-going spike



Operational requirements

- Required/desired machine capabilities
  - This XP would benefit if LLD can be used to reduce density
  - Otherwise, LITER is needed, with high enough evaporation rate to fully suppress ELMs
  - RWM coil set and SPAs, configured as n=3 (and guidance on allowed amplitude and frequency of pulses)

- Diagnostics
  - Profile diagnostics: MPTS, CHERS
  - Impurities: boloms, VB needed, X-ray spec would be nice
  - Edge diagnostics: ERD, reflectometers, IR cams, D_α cam, etc.