NSTX

Supported by U.S. DEPARTMENT OF ENERGY Office of Science

Overview of Results from the NSTX FY09 Run

College W&M
Colorado Sch Mines
Columbia U
Comp-X
General Atomics
INL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
Old Dominion U
ORNL
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U Colorado
U Maryland
U Rochester
U Washington
U Wisconsin

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For the NSTX Research Team

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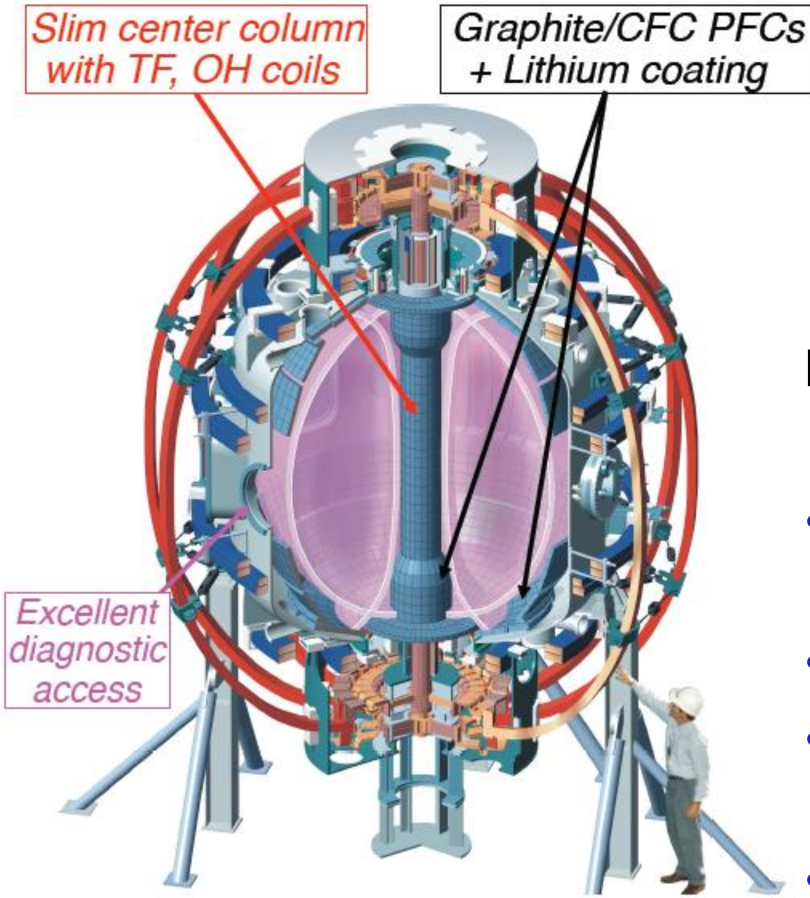
51st Annual Meeting of the Division of Plasma Physics
November 2-6, 2009
Atlanta, Georgia

Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
KBSI
KAIST
POSTECH
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

NSTX Studies High-Temperature Toroidal Plasmas at Low Aspect-Ratio

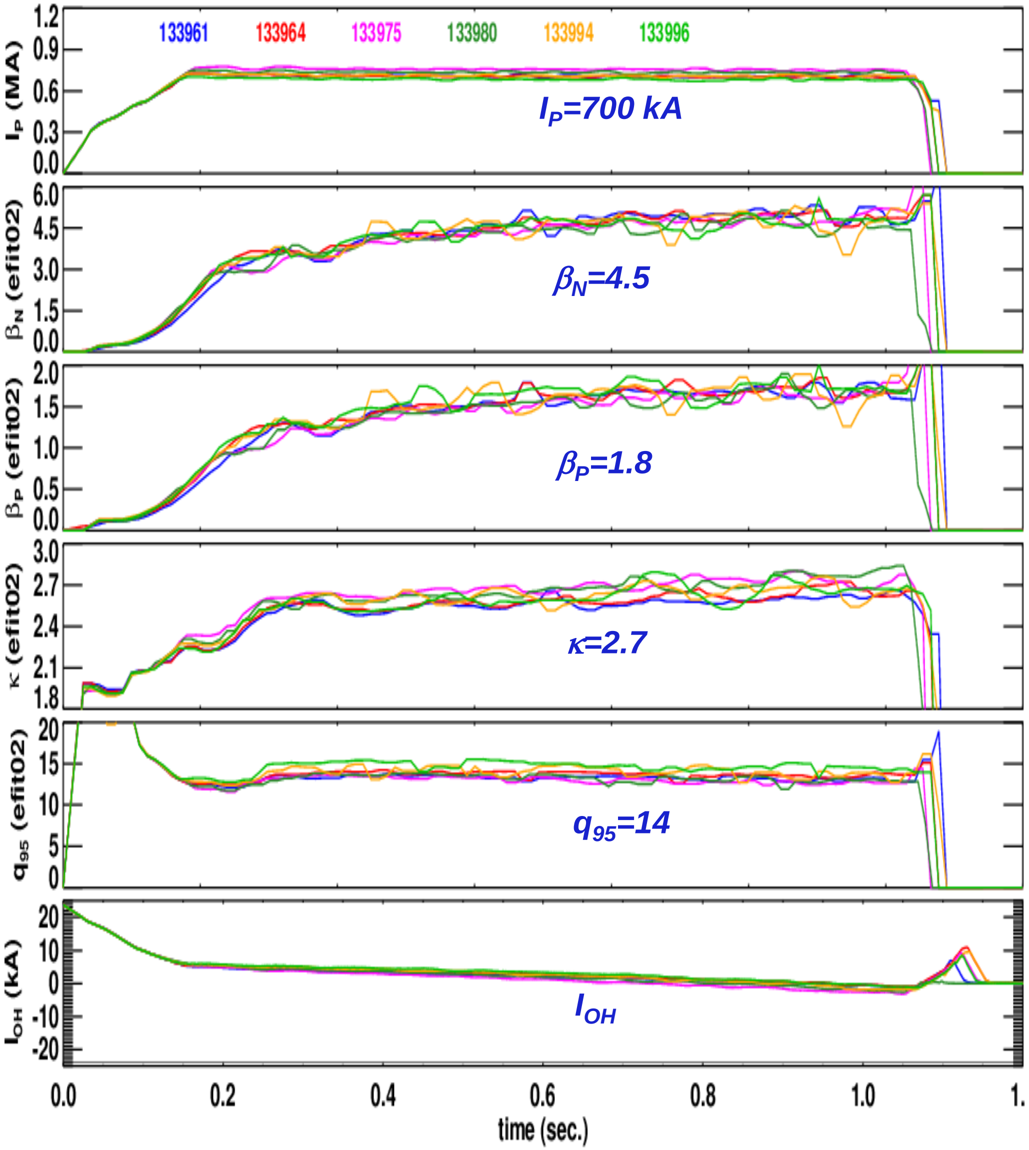


Aspect Ratio	1.27 – 1.6
Toroidal Field	0.3 – 0.55
Plasma Current	≤ 1.5 MA
Central Temperature	1 – 6 keV

New Capabilities for 2009:

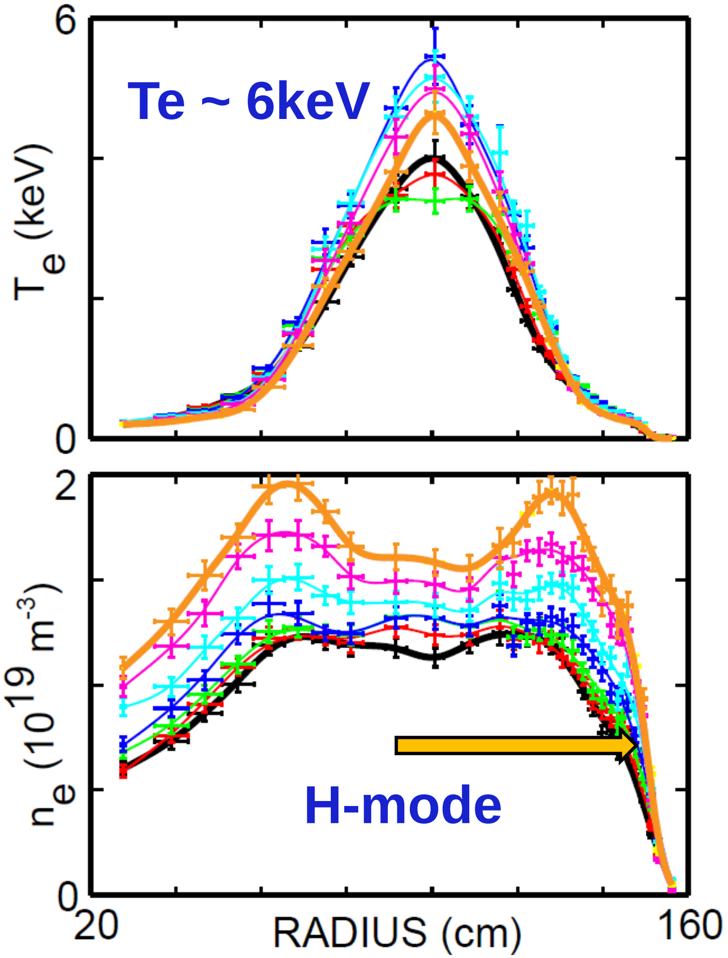
- Routine use of Li (80% of discharges)
  - New Li coating methods
- CHI Absorber PF coils
- HHFW antenna grounding modified & system commissioned
- Operation with Reversed TF

Achieved Highly Reliable Scenario with High-κ, High-β_N 60-65% Non-Inductive Fraction

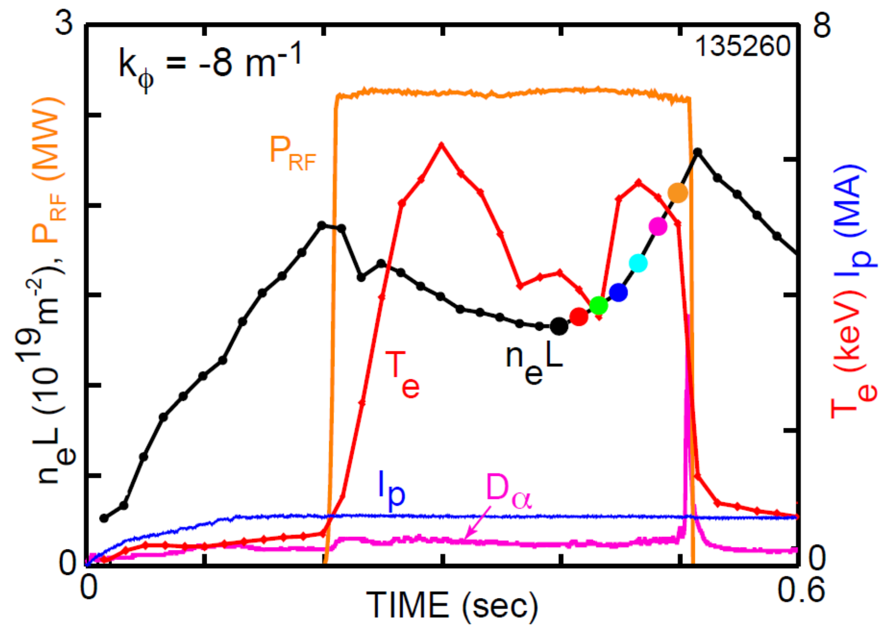


- Key features for this scenario
  - High elongation to increase bootstrap fraction: $f_{BS} \propto 1+\kappa^2$
  - High confinement provided by lithium conditioning and RWM feedback/DEFC
  - All cases limited by I^2t limits on the TF coil.
- Scenario then extended to higher normalized current $I_N = I_P/aB_T$
  - High elongation assists in avoiding edge-q limits for high normalized current
  - Long pulse obtained with $\langle\beta_T\rangle > 23$ %
    - sustained periods with β_T~30%
  - Provide a severe test of MHD control techniques at ST-CTF relevant parameters

HHFW: Moved Strap Ground From End to Center to Reduce Voltage by Factor Two for Same Strap Current

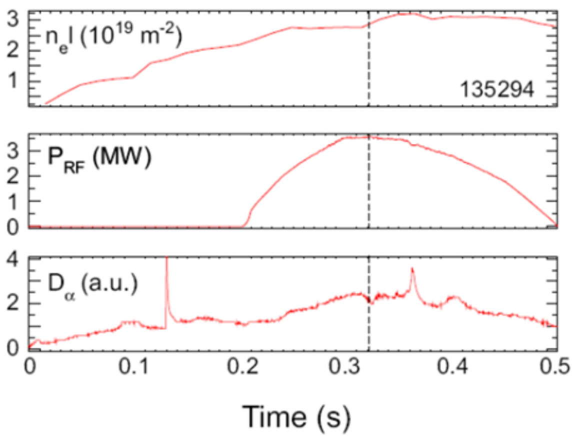


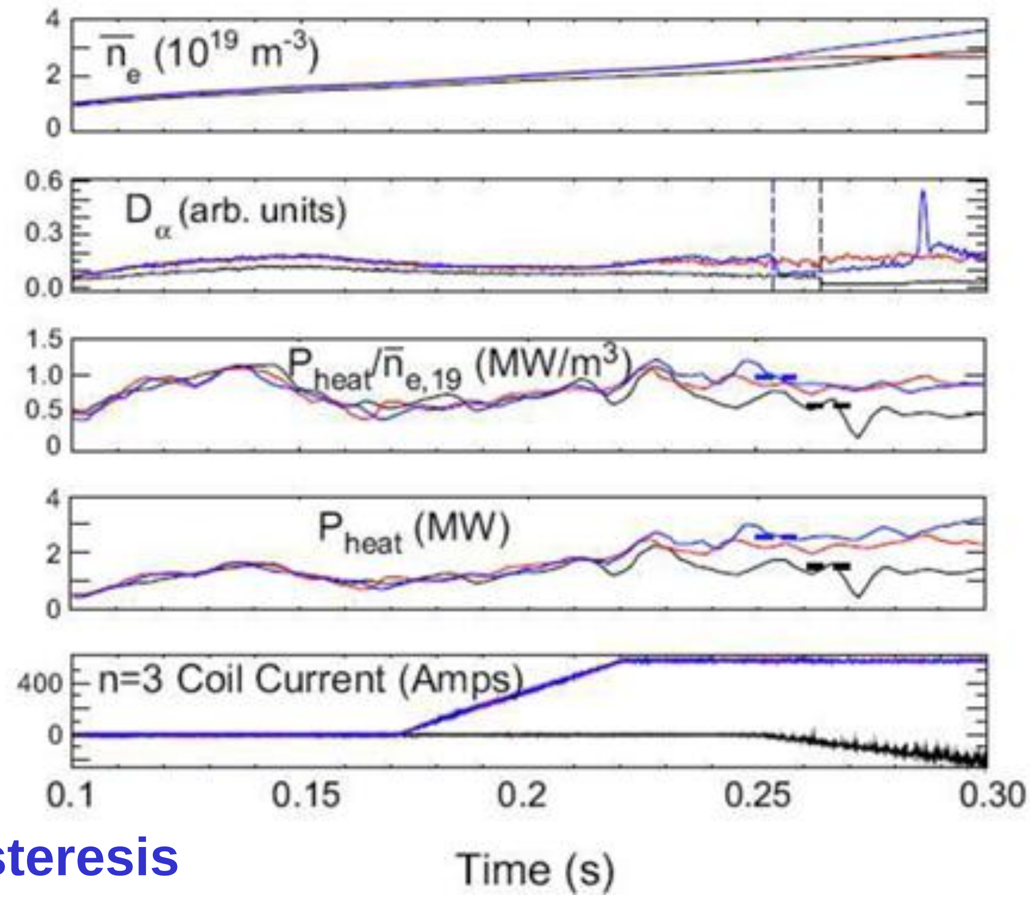
Maintained coupling through L-H transition in presence of ELMs



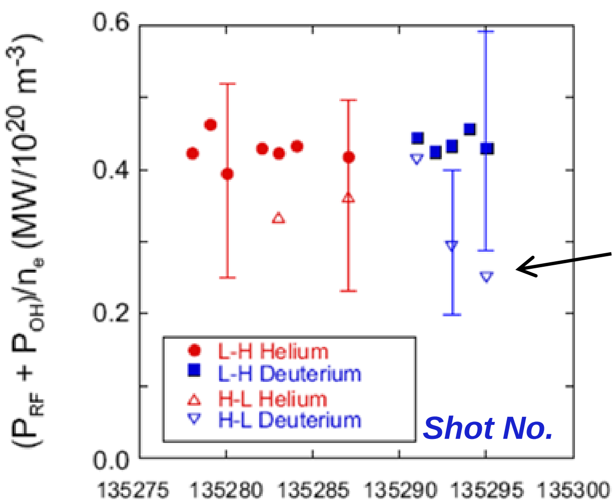
- System quickly commissioned to previous power levels (2-3 MW)
  - Additional conditioning, combined with improved ELM/arc discrimination should allow P_{RF} > 5MW

$P_{L\text{-}H}$ / n_e Same for He and D_2 with RF Heating
$P_{L\text{-}H}$ Increases With Higher n=3 Field Perturbation





Continuous ramp in P_{RF} allowed fine resolution



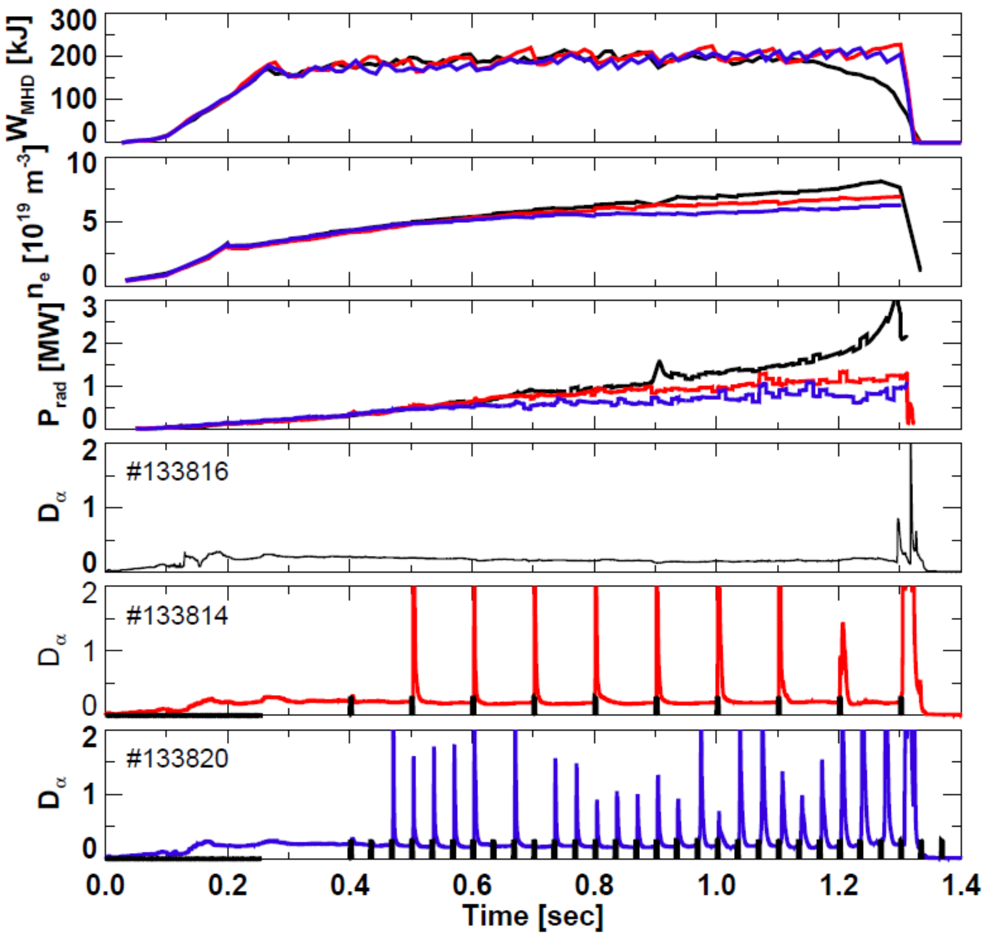
Hysteresis

P_{RF} is power to electrons

- **$P_{L\text{-}H}$ increased from ~1.4 to 2.6 MW at higher n=3 currents**
- **Rotation does not appear to be key**

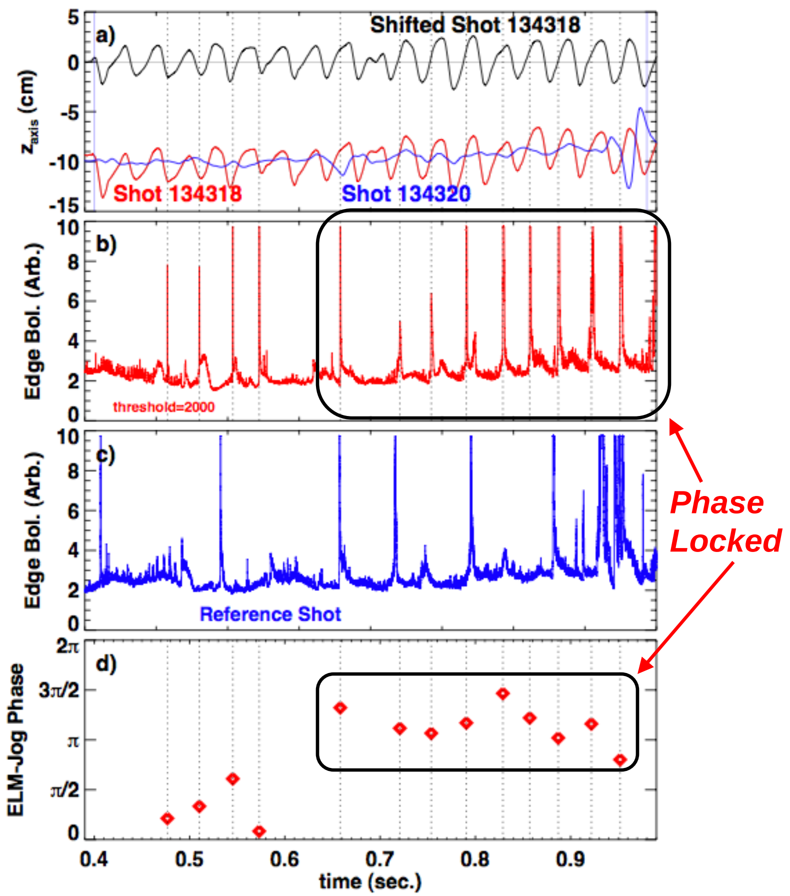
ELM Pacing Developed With Pulsed Non-Resonant Fields and Vertical Jogs

Rapid, Reliable Triggering with Pulsed 3-D Fields



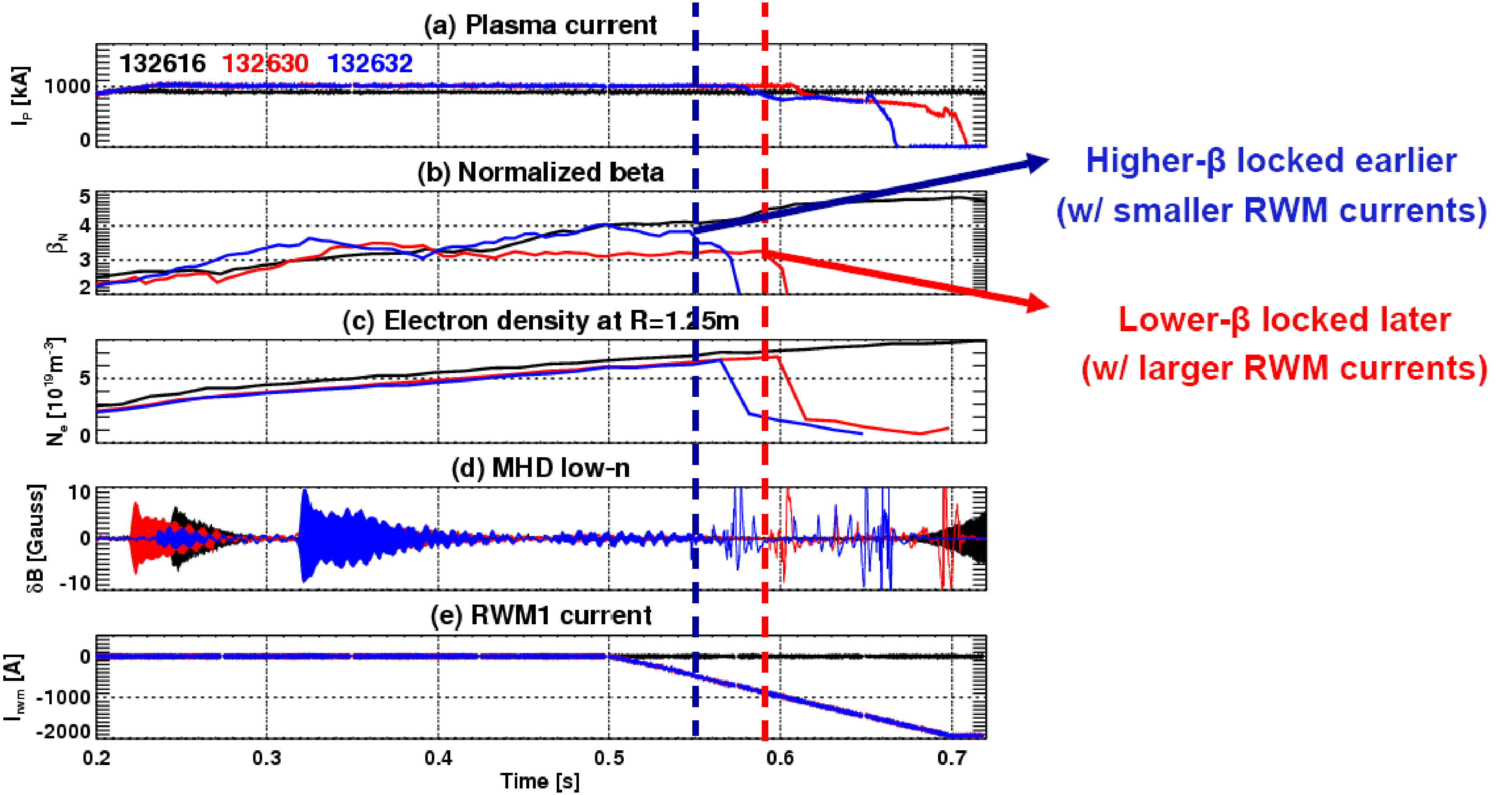
- Reduction in radiated power
- Rapid ELMs lead to smaller per-ELM energy loss

ELM Pacing Via Vertical Jogs



- Vertical jogging successful despite thick continuous vacuum vessel.
- ELMs become phase locked to upward motion

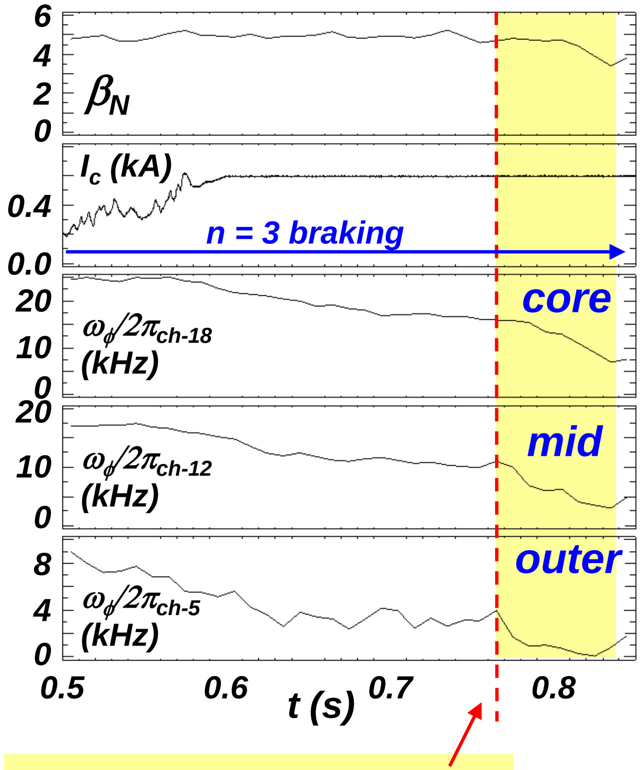
Locking Density Decreases as Beta Increases

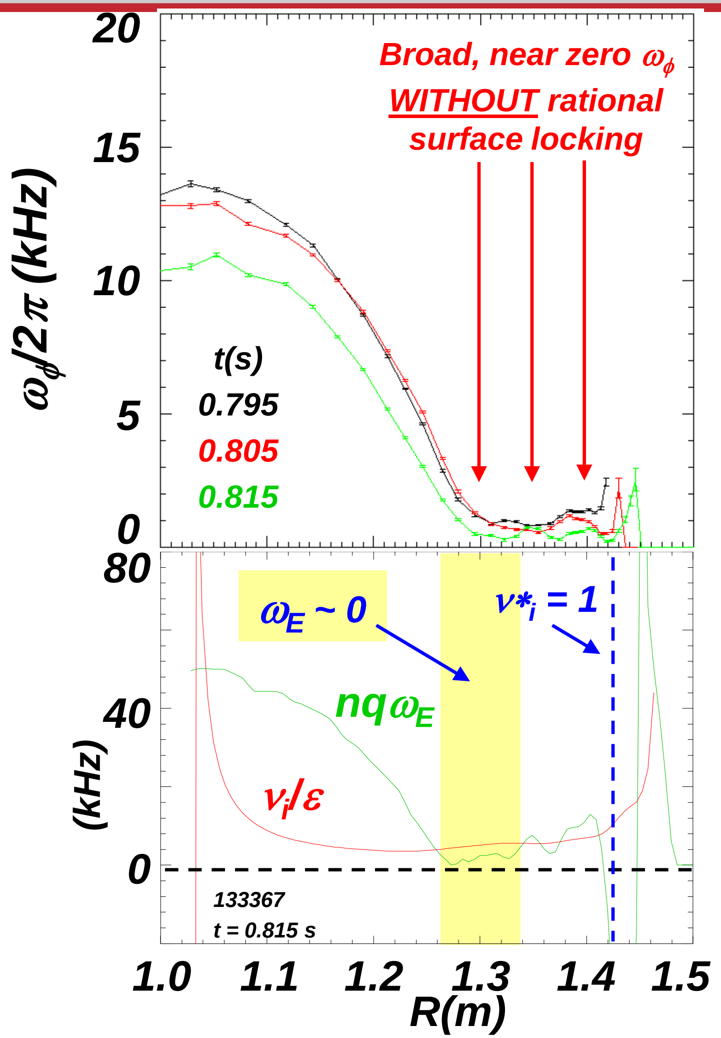


Previous work has focused on low beta plasmas

At high β, EF amplification due to plasma response leads to lower locking density

Stronger braking with constant n = 3 applied field as ω_E reduced – accessing superbanana plateau NTV regime

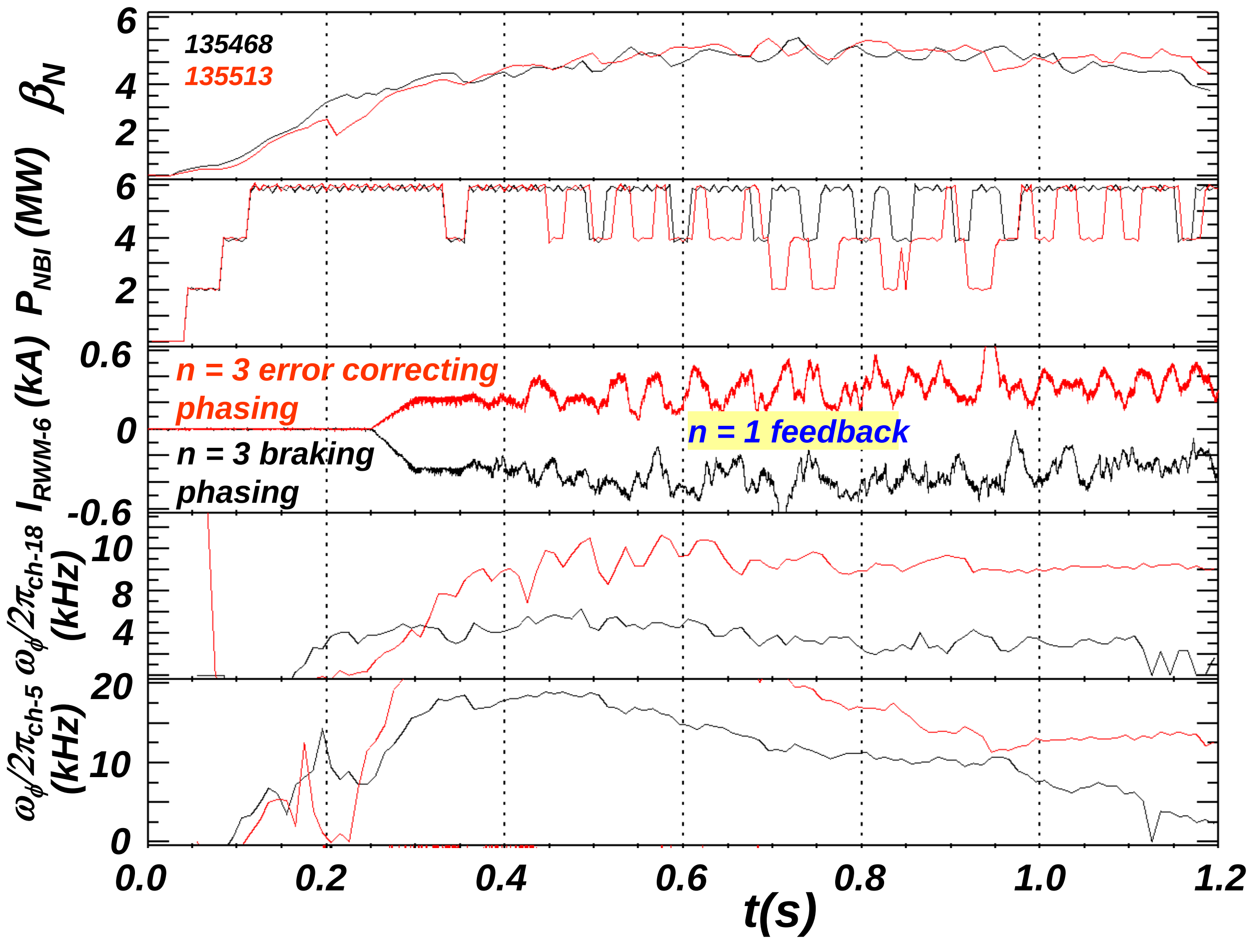




- ***Faster braking with***
  - ***Constant β_N, applied n = 3 field***
  - ***No mode activity***

- Torque not $\propto 1/\omega_\phi$ (non-resonant)
  - NTV in "1/ν regime" ($|nq\omega_E| < \nu_i/\varepsilon$ and $\nu^*_i < 1$)
  - Stronger braking expected when $\omega_E \sim 0$ (superbanana plateau)

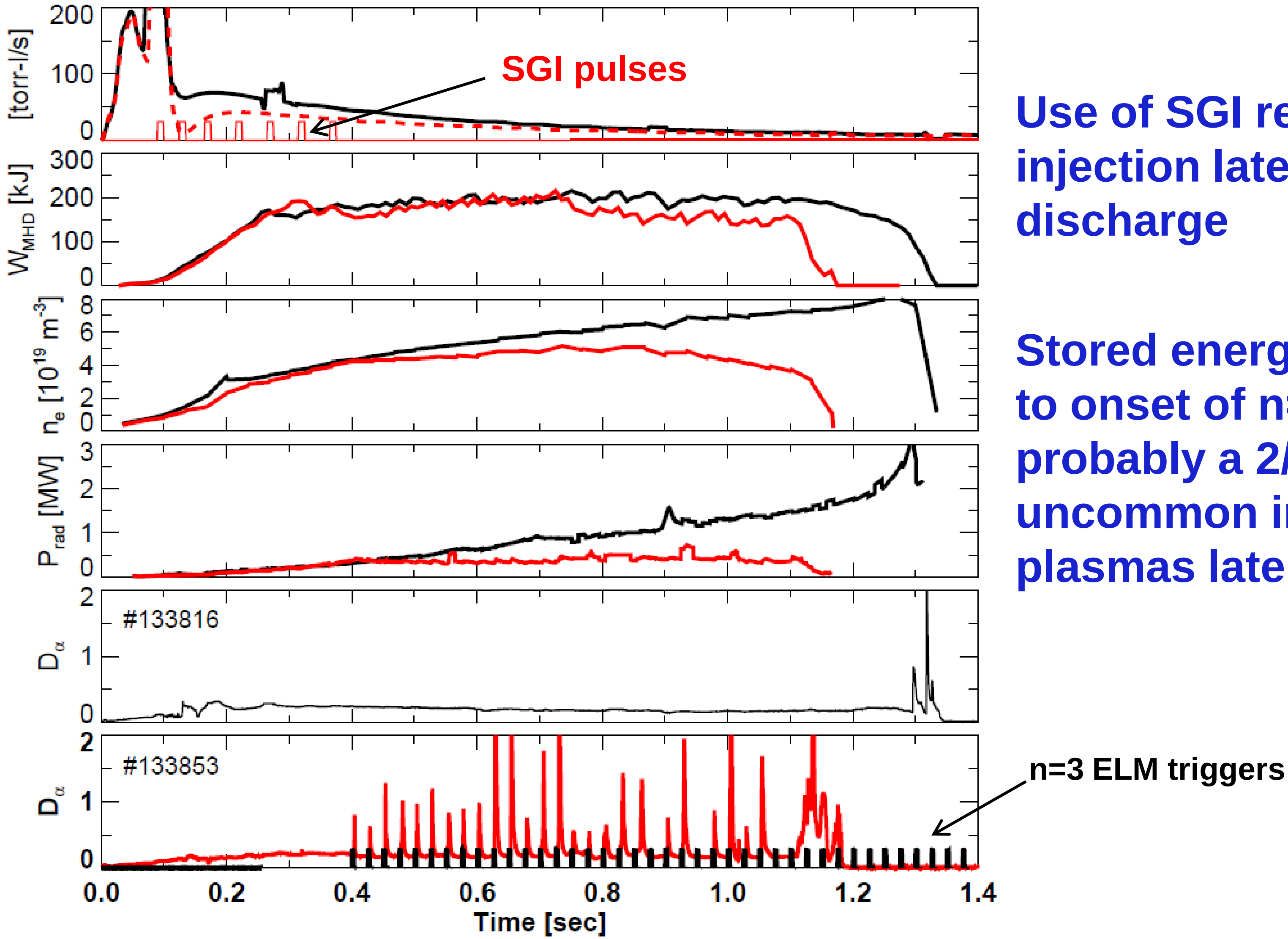
Successful β_N feedback at varied plasma rotation levels



- Prelude to ω_ϕ control
  - Reduced ω_ϕ by n = 3 braking does not defeat FB control
  - Increased P_{NBI} needed at lower ω_ϕ
- Steady β_N established over long pulse
  - independent of ω_ϕ over a large range

S.A. Sabbagh, S. Gerhardt, D. Mastrovito, D. Gates

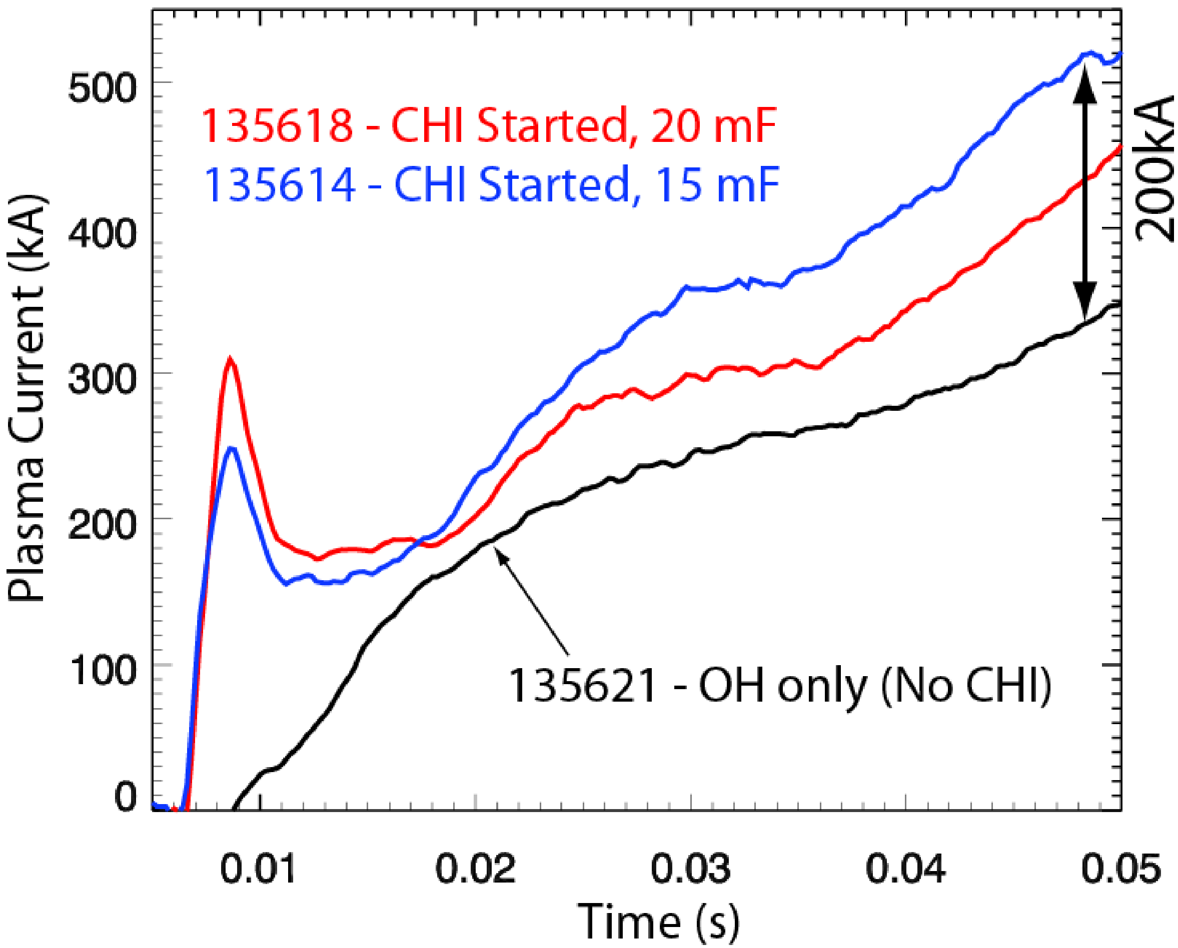
Controlled Triggering of ELMs in Combination with Super Sonic Gas Injection (SGI) Used to Control Density Rise



Use of SGI reduces gas injection late in the discharge

Stored energy drops due to onset of n=1 mode, probably a 2/1 NTM, not uncommon in NSTX plasmas late in time

Using Only 27kJ of Capacitor Bank Energy 300kA of CHI Started Discharge Generated and Coupled to Induction



Methods used to reduce Low-Z impurities:

Long-pulse (400ms) CHI conditioning

Deuterium GDC to reduce oxygen

Buffer field in Absorber to reduce oxygen

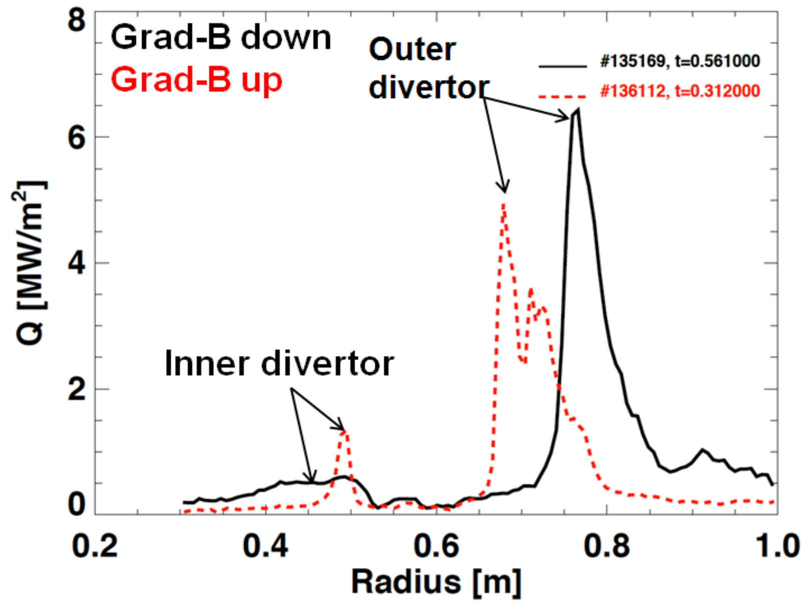
Lithium evaporation

- **Discharges with 3-capacitors (20kJ) reaches 525kA**
  - **200kA higher than induction-only discharge**
  - **Induction-only discharge reaches only 325kA**

Operated with reversed TF (B×∇B away from lower X-point) with I_p & NBI directions unchanged

- Easier to generate USN H-modes, even with unconditioned upper divertor plates, and Li deposited on lower divertor

- Divertor detachment
  - More structure in lower divertor heat and particle flux profiles w/Grad-B up
  - Inner divertor reattaches and heat flux profile has standard exponential character w/Grad-B up



- L-H Power Threshold
  - P_{LH} for USN similar to LSN with normal TF
  - Li has a strong effect, even in unfavorable ∇B direction
  - P_{LH} significantly reduced, even under normal B_T

P_{NBI} (D plasma)	USN	LSN
No Li	2.5 - 3.0 MW	2.9 - 3.2 MW
200mg Li/shot	0.4 - 0.6 MW	1.15 - 1.75 MW

Other Important Results From NSTX

- Surface dust detected remotely for first time *ITPA DSOL-21*
  - Skinner XP8.60, Friday, Ses. IX, 9:30AM Post-Deadline posters
- Lowest $P_{L\text{-}H}$ at largest X-point radius
  - R. Maingi
- Te profiles flatten with GAE activity *ITPA EP-2*
  - Tritz PP8.61, Wed. 2pm, NSTX session
- Fast particle population has stabilizing effect on RWMs *ITPA MDC-2*
  - Berkery GI3.5, Tues PM - invited poster session
- τ_E is weakly dependent on β_T *ITPA TC-1*
  - S.M. Kaye
- NTM onset delayed by Li, appears sooner with Ne *ITPA MDC-14*
  - Volpe PP8.52, Wed. 2pm, NSTX session