NSTX

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Advanced Scenarios and Control
NSTX 2010 Mid-Run Assessment

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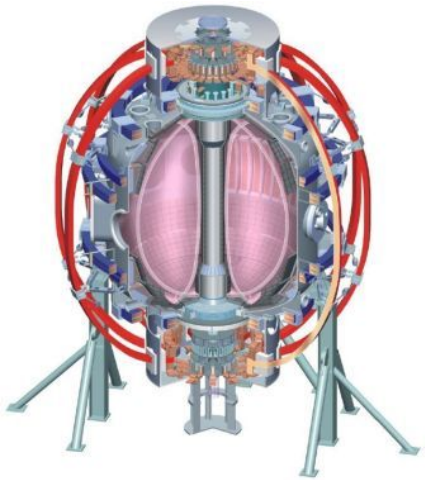
S.P. Gerhardt, M. G. Bell, E. Kolemen
ASC TSG Leaders

Mid-Run Assessment for 2010 Run Campaign
August 27th, 2010



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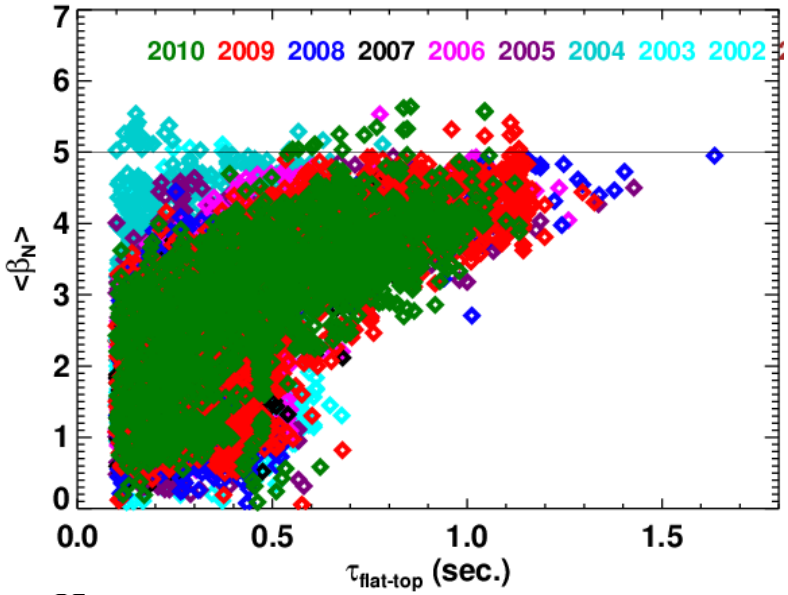
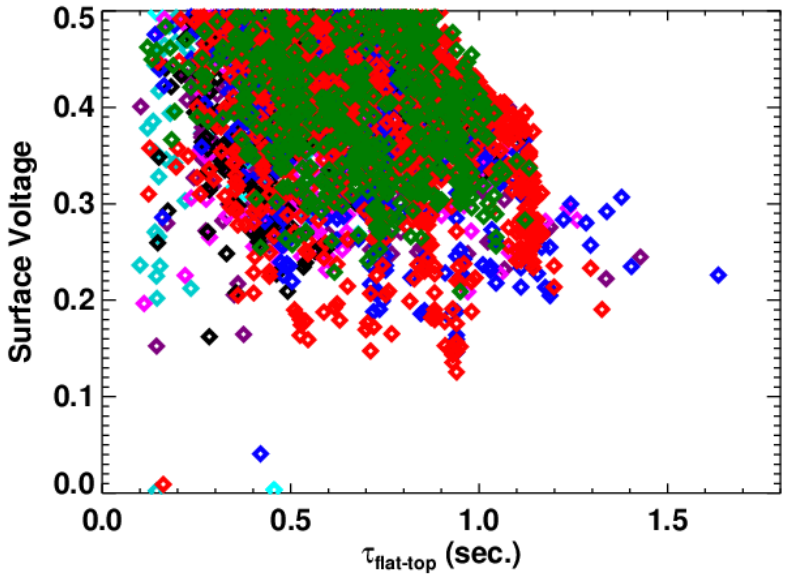
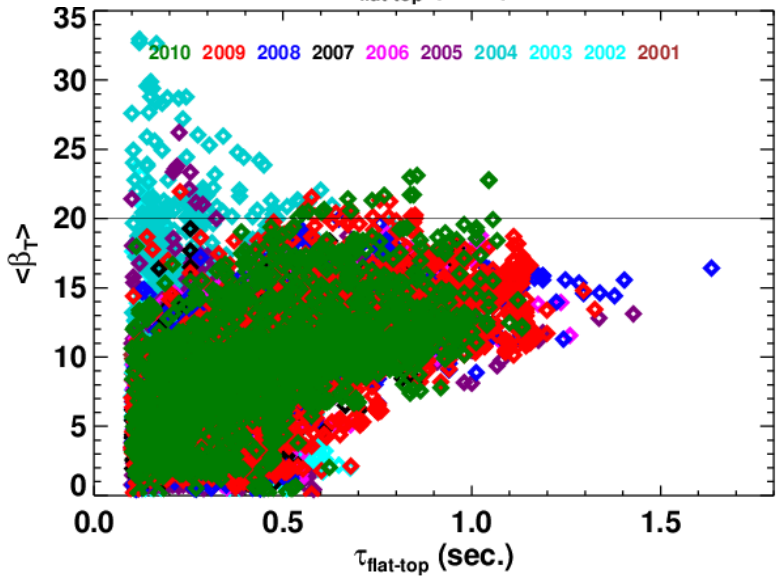
ASC Progress to this point in 2010

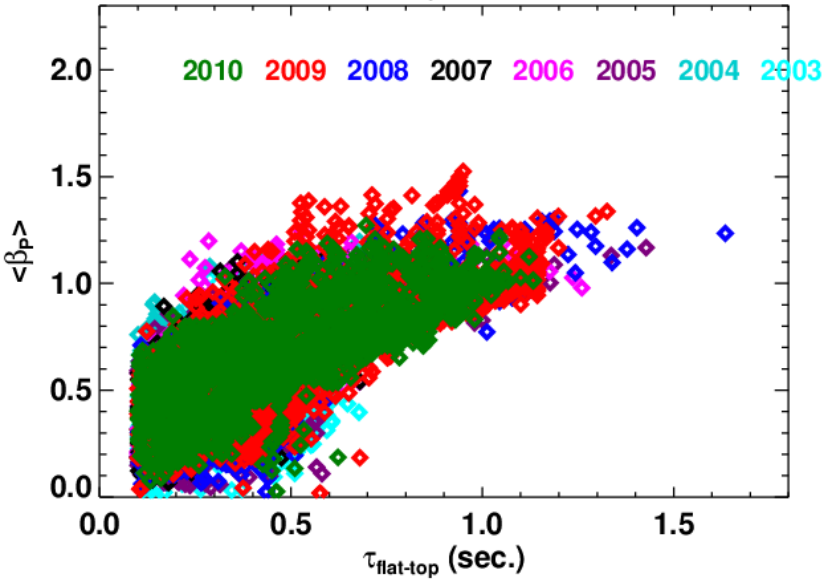
- Started 6 XPs.
  - XP-1003: X-point height and OSP control (Kolemen et al.)
  - XP-1027: Sub-threshold RMP for impurity reduction (Canik, et al.) [ITER Support]
  - XP-1064: Enhanced Pedestal H-modes (Canik, et al)
  - XP-1004: Early error field correction (Menard et al.)
  - XP-1058: Squareness optimization (Kolemen, et al.)
  - XP-1005: Modification of early discharge evolution for impurity reduction (Menard et al.)
- Developed the LLD target configuration
- May be difficult to run the ASC HHFW XPs (3 tier 1 & 2 XPs)
  - Highest priority among these is XP-1007: "HHFW Heating for Reduced Collisionality and Impurities" (Bell, Canik, et al.)
- 3 Proposed XPs Not Yet Started 2010
  - XP-1006: Development of high–f_{NI} discharges with reduced impurities. (Gerhardt et al.)
  - XP-948 High-β_T shot development (Gerhardt et al.)
  - XP-1025 Combined vertical jogs & RWM for ELM Pacing (Canik, Loarte,) [ITER Support]
- With respect to 2011 milestone…"advanced scenarios at reduced collisionality"
  - LLD pumping and HHFW-heating in H-mode were the assumed tools for reducing the collisionality.
  - May need to revisit the milestone verbiage at the end of the run.

NSTX Has Made Progress in 2010 On High β_T & β_N, But Not On high-β_P and low V_{loop}





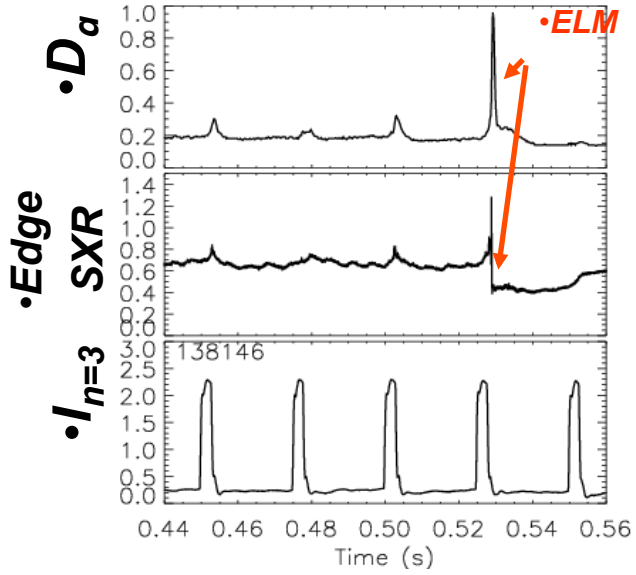


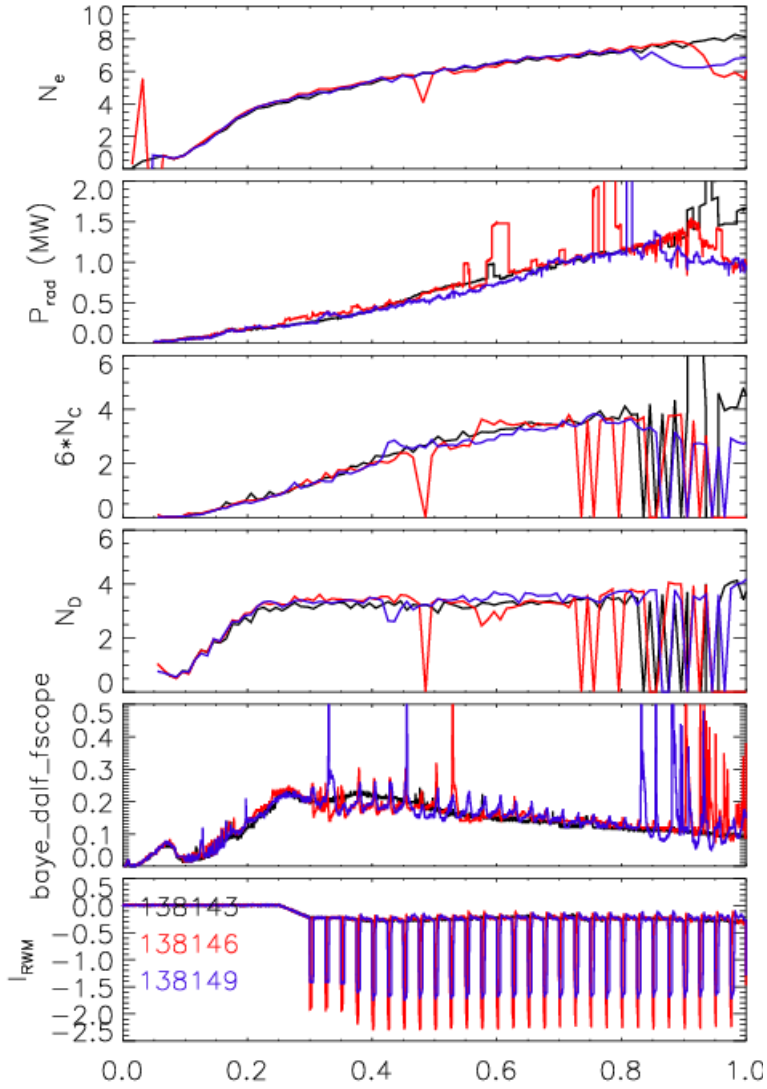


The XPs that are done!

XP-2027: 3D field pulses below threshold for ELM-triggering ineffective for impurity screening

- Response to n=3 field observed in divertor D_α even when pulse is too brief or low amplitude to trigger ELM
- 3D field optimized for sub-threshold pulses
  - Maximize n=3 amplitude, duration while avoiding large ELMs
- Without ELMs, particle expulsion insufficient for impurity control
  - No dramatic impact on P_{rad} or carbon inventory evolution



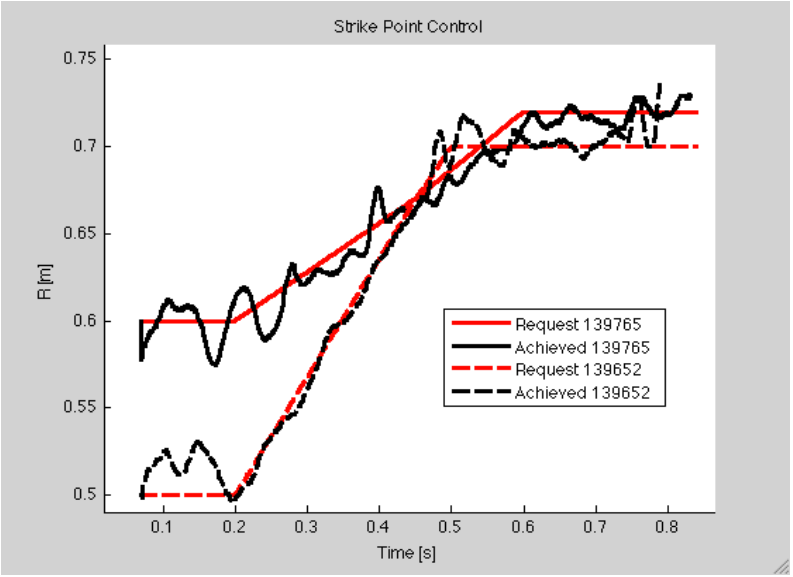


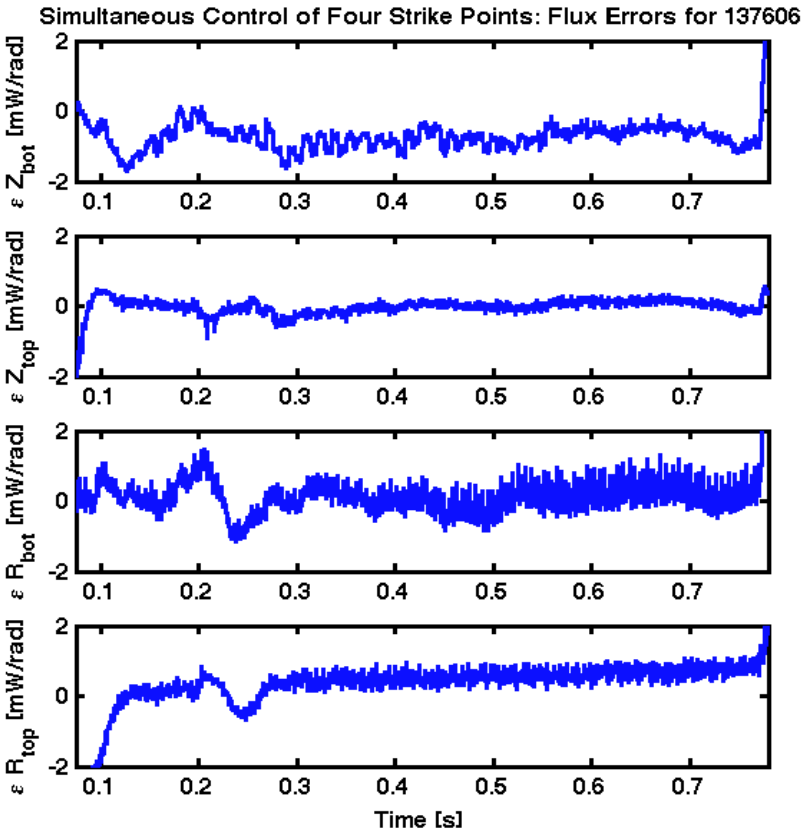
Canik, et al.

Direct ITER Support

XMP 66: Improvements for Shape Control

Control four strike points with PF1AU, PF1AL, PF2U, PF2L



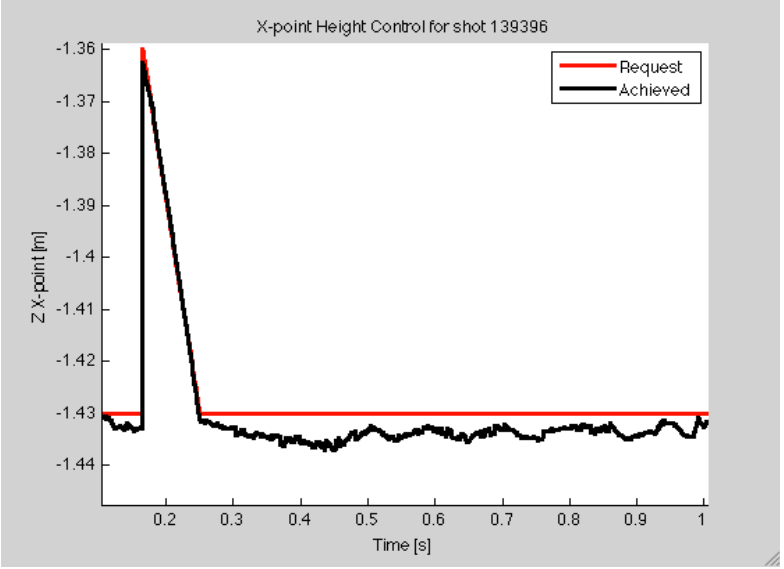


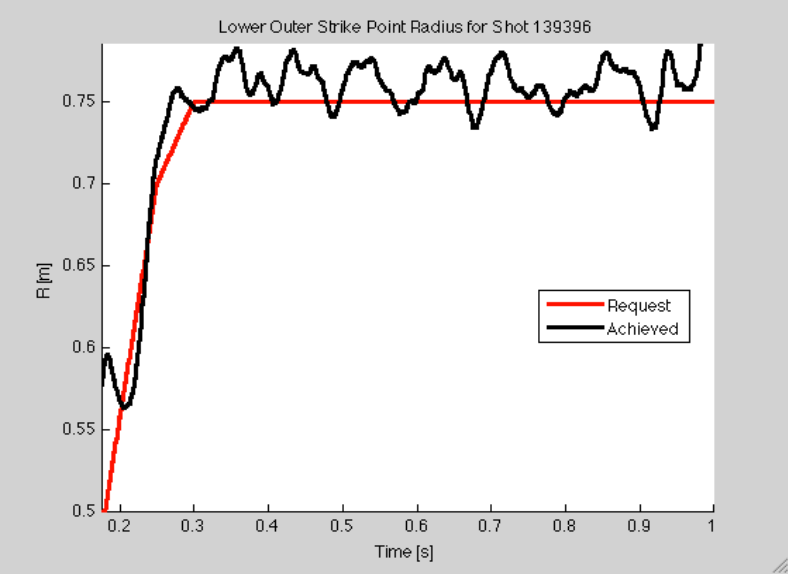
- *4 Div. Coils control 4 S.P.s*
- *Optimize/Tune PID gains.*
- *Added integral gain for PF3 coils.*
- *Scanned lower outer SP from 45 to 80 cm.*
- *Control hand-off (transition) was manually done.*
- *Smooth PF coil current evolution was achieved.*
- *The developed shot was used successfully in many experiments (>100 shots).*
  - *Includes the LLD reference shot*

Kolemen, Mueller, et al.

The XPs that are started, but could benefit from additional run time.

XP-1003: X-point Height / Strike Point Control

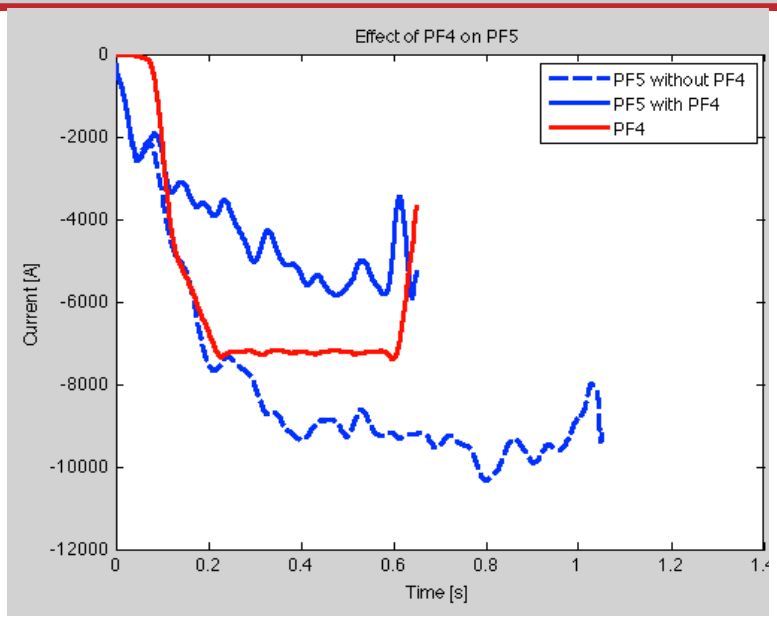


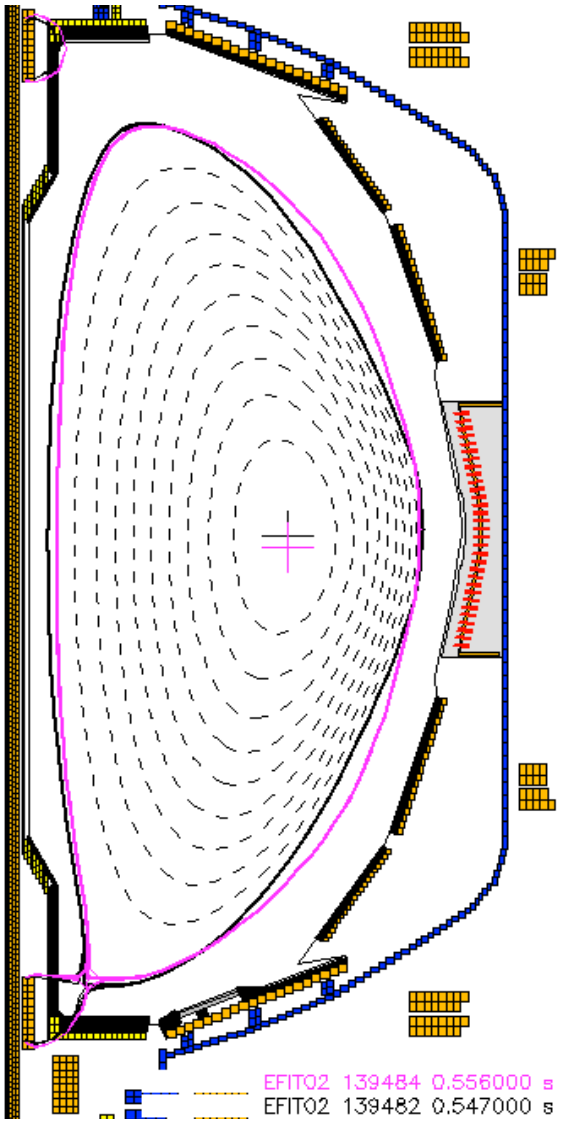


- *Developed combined X-point height strike point radius control*
- *Tuned by using Relay-Feedback*
  - *Advanced PID tuning algorithm…new PCS capability in 2010.*
- *Achieved <1 cm X-point height error and <2 cm strike point radius error.*
- *These shots were used in XP-1041a (LLD Auto-Activation).*
- *Could use:*
  - *More time to fix transient issues.*
  - *Test in high performance shots to see if better performance can be achieved.*

Kolemen, Mueller, et al.

XP-1058: Effect of Squareness/PF4 On High-Performance Plasmas



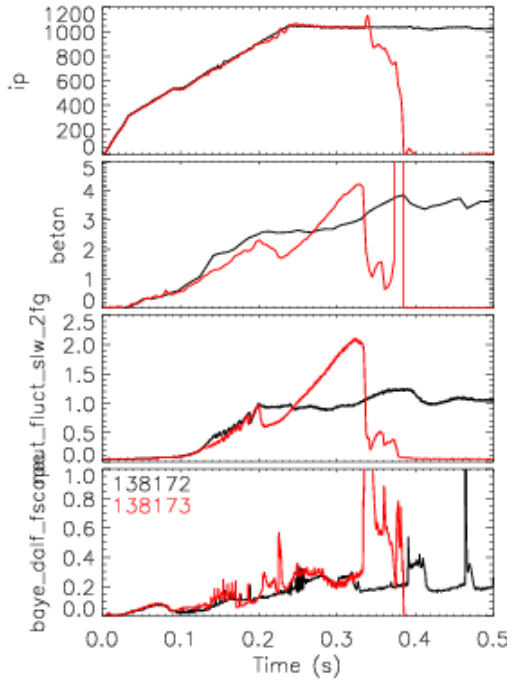


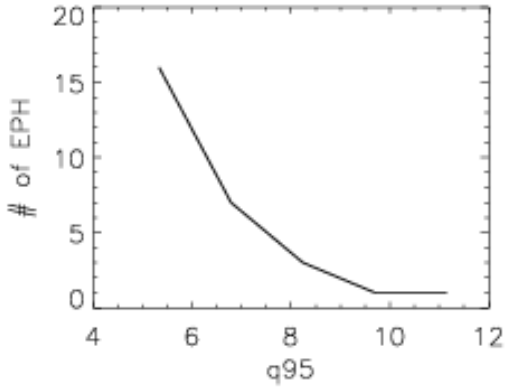
- Shown that PF4 can compensate for PF5.
  - PF4 and PF5 can work together.
- Used PF4 in
  - Preprogrammed mode
  - Feedback mode to control squareness.
- Need more time to see:
  - if combined PF4 and PF5 induces instabilities.
  - Dimple effect quantified.
  - ***More positive squareness.***

Kolemen, Mueller, et al.

XP-1064: Development of long-pulse enhanced pedestal H-mode

- Goals
  - Trigger EPH (with e.g. 3D fields, SGI)
  - Sustain using feedback (mainly beta, also RWM)
- Results
  - Able to produce EPH late in current ramp using SGI
    - Not successful in extending these into flat-top
  - Failed to get EPH in flat-top using 3D field pulses
    - But confinement improvement seen, especially at higher I_p
- Status
  - Database of observed EPH's this year suggests lower q95
  - Two scenarios where several EPH's seen:
    - Ip/Bt=1.2/.45 at high kappa, delta
    - Ip/Bt=0.9/.48 at intermediate kappa, delta
  - Possible new experiment: try low-q discharge
    - Begin with Ip/Bt=1.2/.45



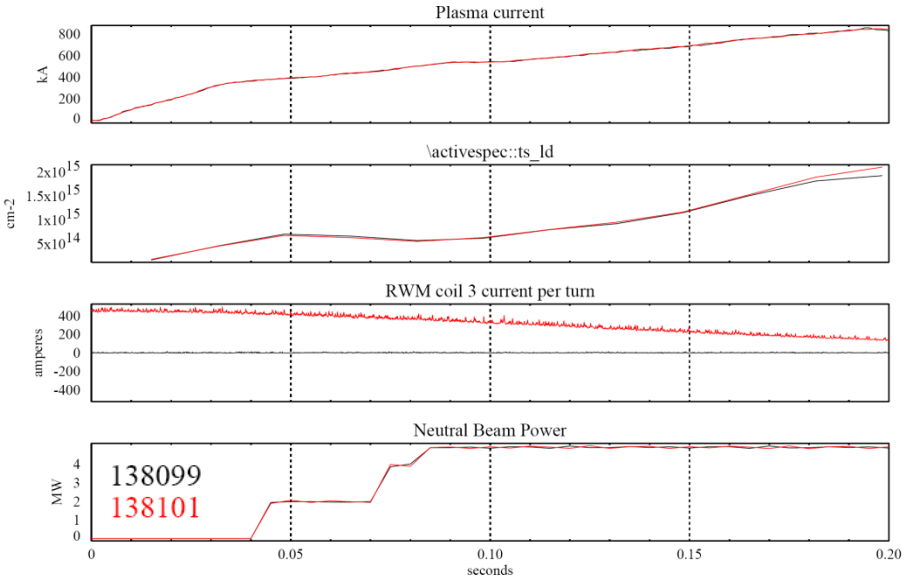


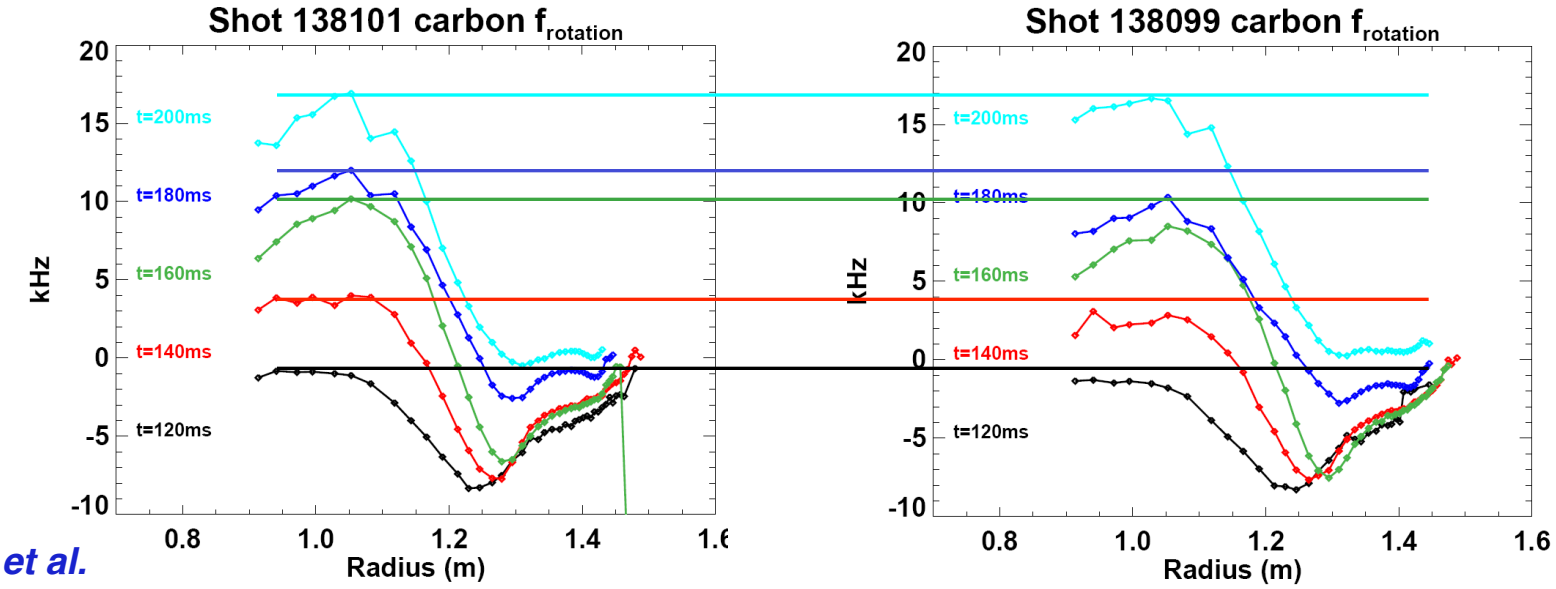
Canik, Maingi, Gerhardt, et al.

XP-1004: Low density plasmas with and without early EFC show early EFC increases rotation 10-20% for t=120-180ms

- Delay of early H-mode by reduced early fueling reduces density by 30-40% at t=0.2s (vs. reference)
  - Similar to what typically happens with increased LITER evaporation

- **Additional EFC <u>phase</u>, amplitude scans might be able to further increase rotation at reduced density**

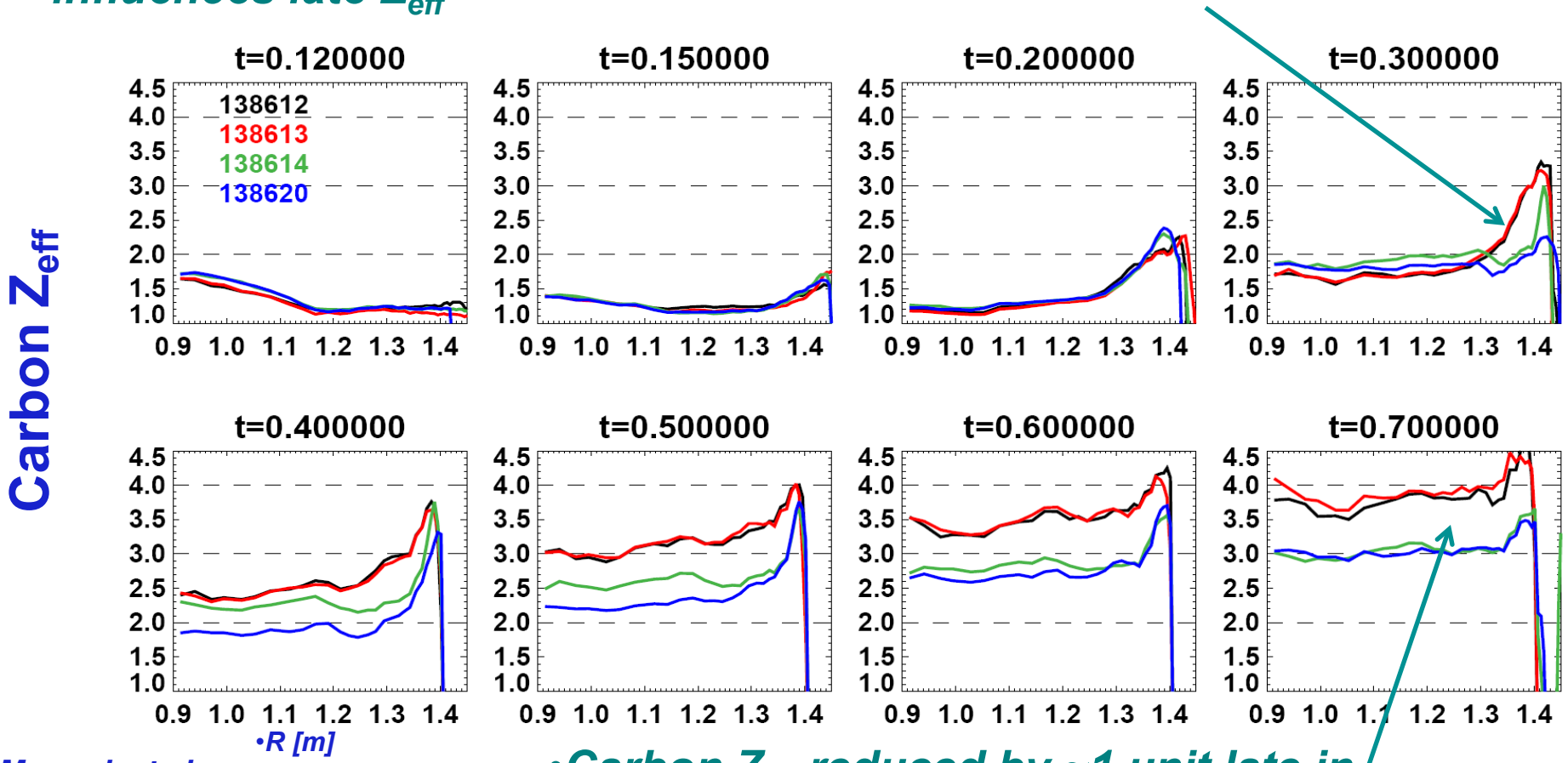




Menard, et al.

XP-1005: ΔR_{SEP} change from -7mm to 0 reduces impurity confinement and/or generation and reduces C Z_{eff} by ~1

- *Like 2009 result, size of H-mode C impurity "ear" near t=0.3s influences late Z_{eff}*



Menard, et al.

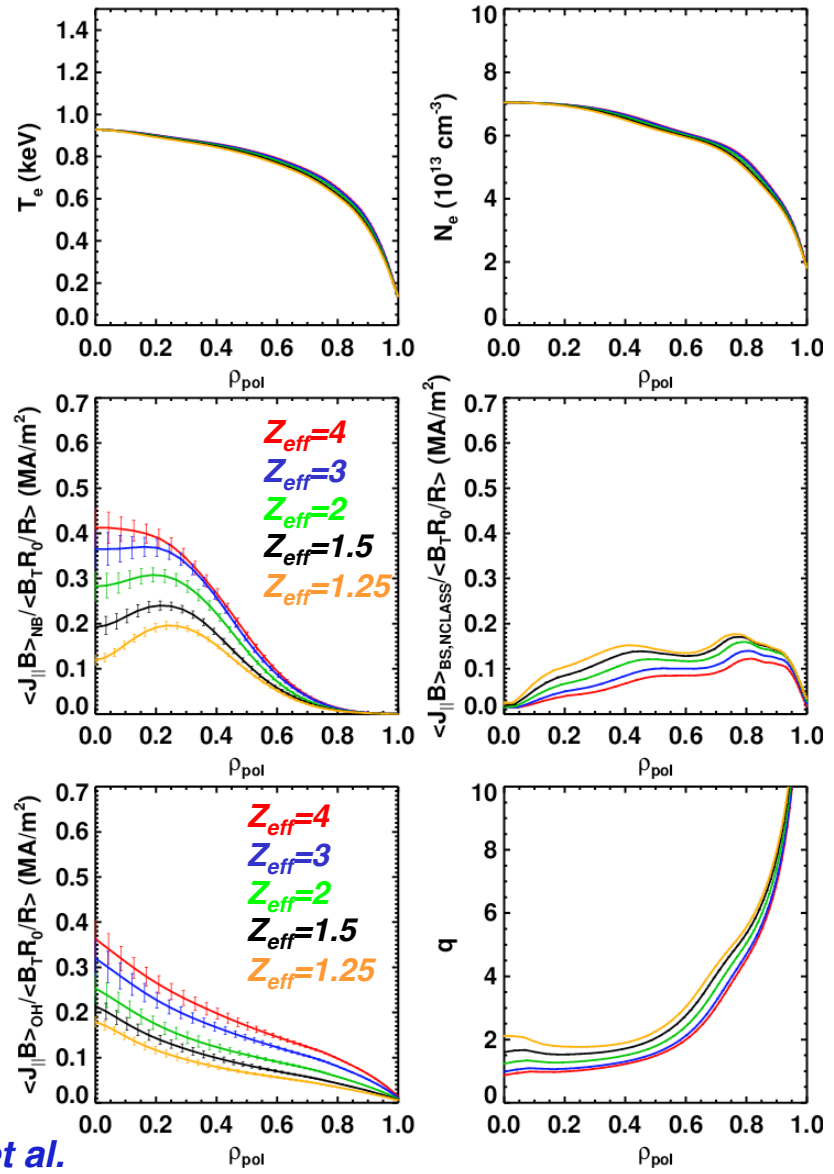
- *Carbon Z_{eff} reduced by ~1 unit late in*

Motivates testing combinations of this + divertor D puff + snowflake + …

XPs That Have Not Been Started

XP-1006 Would Test the Utility of Impurity Reduction Techniques to Increase Non-Inductive Fraction (Gerhardt, et al.)

- Target shot: 133964
  - Lowest $<V_{loop}>$ ever in NSTX
- ***Individual and combined impurity reduction methods***
  - ELM pacing w/ 3D Fields
  - Divertor gas puff
  - dr_{sep} optimization
- ***Reduced I_P to increase β_P.***
- Direct response to PAC request
- XP is finished with team review, pending chits.
- Provide data for IAEA talk by Canik, IAEA poster by Gerhardt, APS contributed talk by Scotti.
- Asking for a full day.



Gerhardt, Canik, Menard, Soukhanovskii, Gates, Kolemen, et al.

Revisiting XP-948 Would Provide Information on Plasmas With Simultaneously High κ & β_N, Very Low q_{95} (Gerhardt et al.)

- XP-948 was successful in developing a high-κ, low-l_i target
  - Primary configuration (135111) was κ=2.5, I_P=1100kA, B_T=0.45, q_{95}=7.8, β_T=25%
  - 1000 kA version was used for XP-1023 this year.

- Propose to continue the XP, looking for a more aggressive operation point… closer to an ST "Pilot Plant" target.
  - κ=2.6, q_{95}=6.0-6.5, I_P=1200-1300kA, B_T=0.4-0.45T

- Complements XP-1023, which looked at high β_N/l_i, but at lower β_T and higher q_{95}.
- Plan (simplistically)
  - Start with 139034 (6 MW, 1.2 MA, κ=2.3, β_T=22%, q_{95}= 6.5)
  - Increase the elongation, followed in subsequent shots by increase in I_P.
  - Drop the toroidal field in 250 kG increments.
  - Test stability limits, confinement…DCON, TRANSP,…

- Support IAEA presentations by Gerhardt, Menard, & Sabbagh, APS by Gerhardt and Sabbagh.
- Could make substantial progress with ½ day of good operations.

Gerhardt, et al.

XP-1025 Provides Direct ITER Support on Critical Question of ELM Pacing Techniques

- The ITER divertor cannot tolerate the expected type-I ELMs
  - One solution is to apply perturbations to trigger rapid ELMs.
- NSTX has demonstrated two ELM pacing techniques.
  - n=3 (N+R)MP pulses
    - Easy to trigger ELMs in lithiated plasmas, but significant magnetic braking.
  - Vertical jogs
    - Not so easy to trigger ELMs in lithiated plasmas, too large a jog kicked the plasma out of H-mode.
- XP aims to combine these in order to eliminate the deleterious effects of both techniques.
  - "Inspired" by some work at JET
  - Is the threshold jog size reduced when 3-D field are applied?
  - Is the 3D field required for triggering reduced by jogs?
  - What is the dependence of these triggering methods on pedestal parameters?
  - XP is group reviewed, awaits team review (next week).
- Asking for a full day.

Canik, Loarte, Gerhardt ***Direct ITER Support***

High-Power ASC HHFW XPs Will Be a Challenge

- Bell, Canik, et al, XP-1007, "HHFW heating in NB H-mode for higher f_{NI} and reduced impurities." (1st Tier)
  - ***Could make progress with reliable ~2-3 MW***
  - ***Highest priority***
- Yuh, et al, XP-939, "Reversed Shear H-mode Target Development" (2nd Tier)
  - ***Could make progress with reliable ~2-3 MW***
- Gerhardt, et al., XP-1008, "Early HHFW Heating For Current Profile Modifications" (2nd Tier)
  - Low Priority
- Menard, et al, "Tests of fast wave current drive for core q profile control" (3rd Tier)
  - Lower priority

Recommended Priority For ASC Tasks

-1: XP-1025: RMP +Jogs ELM Pacing

ITER Support, outside of the ASC prioritization.

1: XP-1006: High f_{NI} with reduced impurities.

Meets PAC recommendation

(may be wise to lead this with additional ½ day of XP-1002)

2.5: XP-1058: Squareness Optimization

Important for NSTX-U planning.

Would like to test "negative" squareness (PF-4 pulling)

2.5: Combine EPH (XP-1064) & High-β_T (XP-948) proposals for a single ½ day XP

Have similar targets…might not be able to avoid EPH.

If high-power (3-4 MW) HHFW were to become available, XP-1007: "HHFW Heating in H-mode For Reduced Collisionality and Impurities" (Bell, Canik, et al.) would jump to 2.

Contributes to both 2011 ASC and 2010 HHFW milestones.