NSTX

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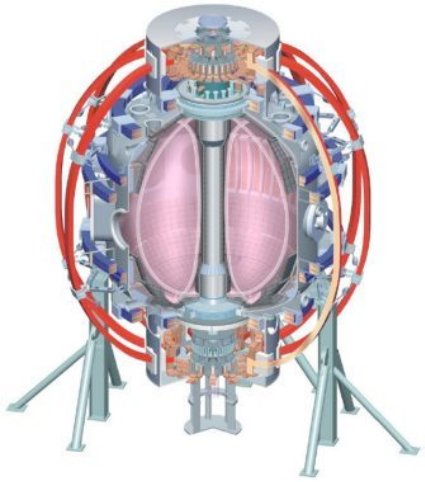
Mid-Run Assessment: MS TSG

Stefan Gerhardt, Steve Sabbagh, members of the MS TSG and larger NSTX team.

NSTX Mid-Run Assessment
Room, Location
Month Day, 2008



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INEL
Johns Hopkins U
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Nova Photonics
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IPP, Garching
ASCR, Czech Rep
U Quebec

Status as of the Research Forum (For Reference)

- XP Idea presentations (23 ideas)

Would Benefit From Counter-Injection

- Continued Search for the n=3 EF Source in NSTX (Gerhardt) 0.5 days
- Optimization of Squareness for Improved Stability & τ_E at High β_N (SPG) 1.0 days
- Error Field Threshold Study in High-Beta Plasmas (J.-K. Park) 0.5 days
- Influence of fast particles in Resistive Wall Mode Stabilization (Berkery) 1.0 days
- Effect of RWM Stabilization on Background Plasma (Delgado-Aparicio) 0.5 days
- NTV physics at varied $\nu_i^*/q\omega_E$ and search for offset rotation (Sabbagh) 1.0 days
- Error field influence on 2/1 NTM onset through rotation (Buttery) 0.75 days
  - NSTX/DIII-D Aspect Ratio Comparison of 2/1 NTM Physics (LaHaye) 0.75 days
  - Effects of Impurities and Wall Conditioning on NTM Stability (Volpe) 0.5 days

7.5 days

- Improving $<\beta_N>_{pulse}$ vs. rotation under RWM Feedback (Sabbagh) 1.0 days
- Global MHD and ELM stability at low, near-integer n*q (Sabbagh) 1.0 days

9 days

- Disruption Mitigation in NSTX using CHI (Raman) 0.5 days
- Formation and suppression of disruption runaways (Gerhardt) 1.0 days
- Effect of toroidally localized field perturbations: ITER support (Sabbagh) 1.0 days
- Physics of RWM Triggers During Active Feedback Control (Sabbagh) 1.0 days
  - Assessment of kinetic modeling on fishbone driven-RWM (Okabayashi)

ITER Support

- Achieving High I_p/I_{TF} by Wall and Rotational Stabilization (Jarboe) 1.0 days
- XP743: Island-induced Neoclassical Toroidal Viscosity (NTV) (Sabbagh) 1.0 days
- RWM Stabilization Physics Investigation in Counter-injection (Berkery) 1.0 days
- NSTX/DIII-D RWM joint XP - Verify Common Physics Basis (Berkery) 1.0 days
- Measurements of Transient Heat Fluxes During Global MHD (Gerhardt) 1.0 days
- Exploration of Different FB Timescales for Optimal Performance (SPG) 1.0 days
- Real-time Techniques for Disruption Soft-Landing (Gerhardt)

MS TSG Working Toward 2 Milestones

- FY-2009 Milestone on RWM Physics
  - **R(09-1): Understand the physics of RWM stabilization and control as a function of plasma rotation.**
  - **Near finished with this.**
- FY-2010 Milestone on Disruptivity
  - **R(10-X): Assess sustainable beta and disruptivity, as a function of proximity to the ideal n0-wall limit and control techniques.**
  - **Need to work toward this milestone.**
- Remaining high priority XPs focus on these milestones.

Macrostability TSG Has Had A Successful Campaign So Far…

- Started 10 experiments with 8 XP leaders, Completed 9 of them to date.
- Error Fields (done)
  - XP 902: Search For the n=3 Error Field Source in NSTX and Implementation of Improved n=3 EF Correction (Gerhardt,…)
  - XP 903: Error Field Threshold Study in High-beta Plasmas (Park,…)
- RWM/Ideal Stability Physics (2 of 3 are done).
  - XP-931: Effect of the active stabilization of RWMs on the background plasma (Delgado,...)
  - XP-932: Influence of Hot Ions on Resistive Wall Mode Stability (Berkery,..)
  - XP-935: Search for multiple RWM behavior at high β_N (Sabbagh,…)
- NTV (done)
  - XP-933: NTV physics at varied ν^*/qw and search for offset rotation in NSTX (Sabbagh)
- NTMs (done)
  - XP-914: NSTX and DIII-D Aspect Ratio Comparison of NTM Physics (LaHaye,…)
  - XP-915: Influence of rotation and error fields on tearing mode beta limits (Buttery,…)
  - XP-918: Effect of Impurities and Wall Conditioning on NTMs (Volpe,…)
- Disruptions (done)
  - XP-901: Exploration of Fast Discharge Shutdown Using Coaxial Helicity Injection (Gerhardt, Raman,…)
  - Collected lots of piggy-pack data with new halo current diagnostics.

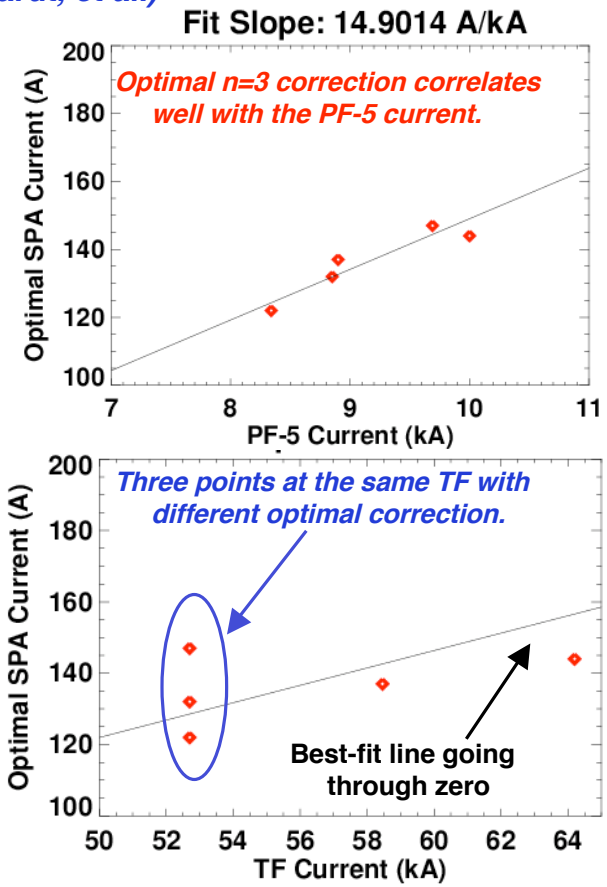
…But There are Still XPs to Run

- Have 2 high priority experiments to run, and one (potentially) to add to, which contribute to 2009 and 2010 milestones.
  - XP-930: Use of Resonant Field Amplification Measurements To Establish MHD Stability Boundaries
  - XP-934: Improving Pulse Average β_N via RWM feedback
  - Pending results from DIII-D experiments (next week?), additional time for XP-932
- Additional scientifically interesting experiments.
  - XP-743: Island Induced Neoclassical Toroidal Viscosity
  - Counter-B_T XPs
  - Global/ELM stability vs integer nq

Next, a very brief summary of results

Error Field Experiments Isolated the Source of n=3 EF, Studied n=1 Field Penetration at high-β

XP902: Find n=3 SPA current which maximizes angular momentum, then repeat for various [I_P, B_T] combinations. (Gerhardt, et al.)

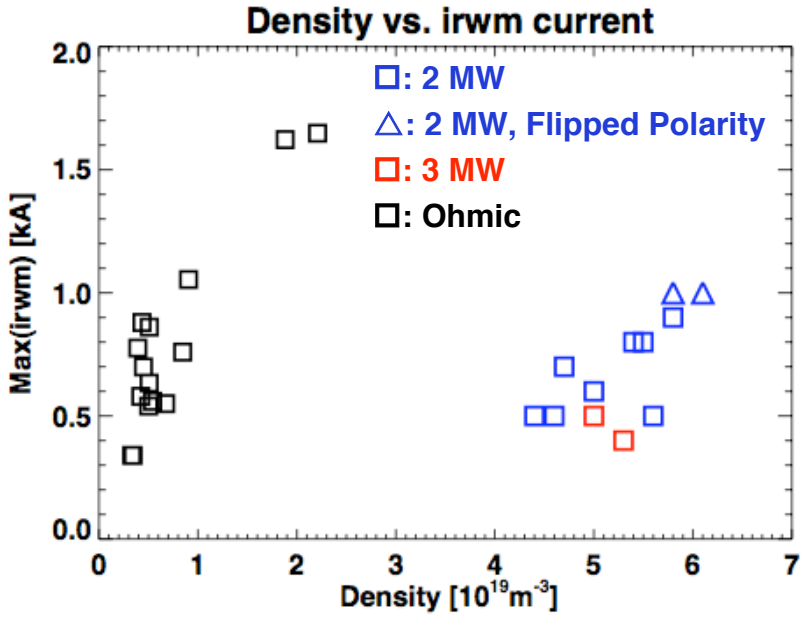


Observed optimal correction matches predicted n=3 correction, based on vacuum fields and PF-5 triangularity (18 A/kA, from J. Menard and J.-K. Park)

Analysis with IPEC in progress.

XP903: Apply n=1 error field ramps to NB heated plasmas with β_N below the no-wall limit. Examine n_e threshold of magnetic island opening. (Park, et al.)

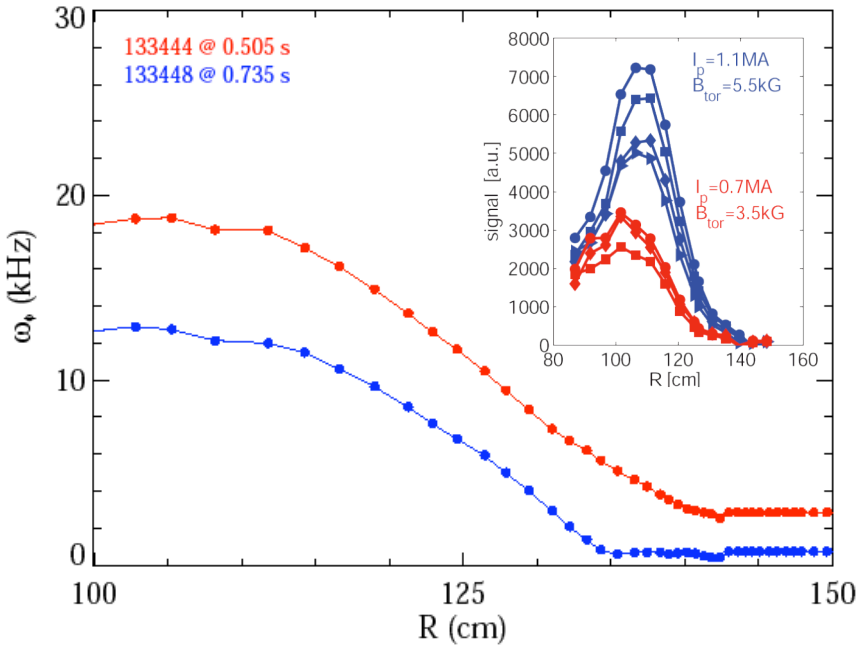
- *At low-β, locking density scales with applied field.*
- *For higher-β, this correlation fails, implying*



Analysis with IPEC starting, in order to determine the resonant 2/1 field including the plasma shielding/amplification.

RWM Physics Studied the Effect of Fast Ions on Stability, Used Kinetic Measurements to Study the Stable RWM

XP932: Vary the fast-ion population through changes in I_P, B_T, and source voltages. Study the onset conditions for the RWM in these cases, including critical rotation profile. (Berkery, et al.)

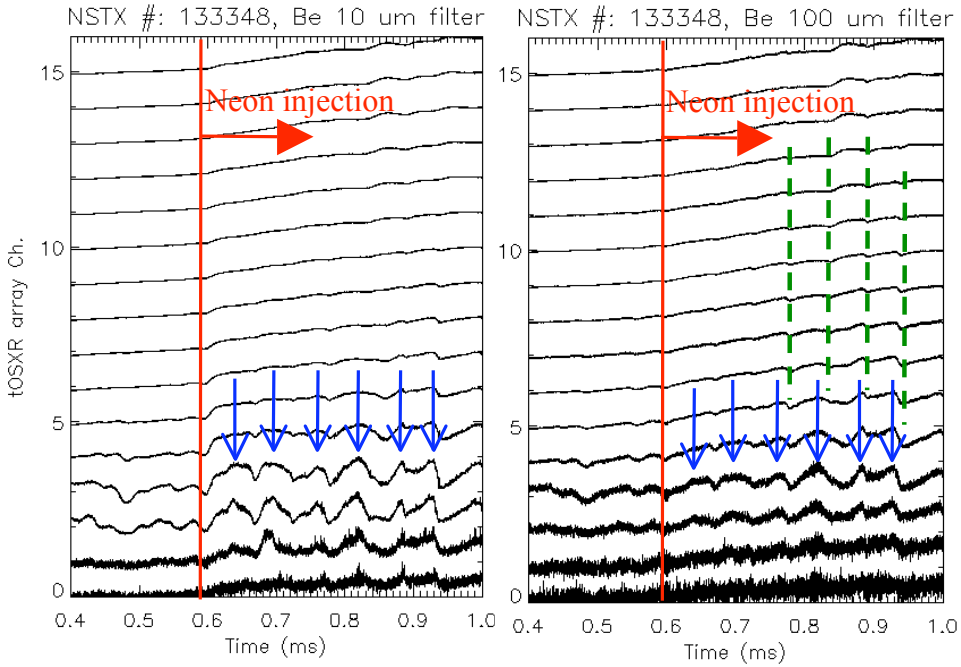


Use CHERS, FIDA, RWM Sensors

Lower energetic particle density means lower kinetic stabilization, requiring higher rotation for stability.

S. Sabbagh and J. Berkery at DIII-D right NOW for a companion experiment.

XP931: Effect of the active stabilization of RWMs on the background plasma. (Delgado-Aparicio, et al)



***Four* MHD XPs have used Neon-injection to enhanced the SXR SNR in order to follow the density and temperature effects of the actively stabilized RWMs or to increase collisionality/resistivity.**

RWM edge-n_e and core T_e fluctuations show the expected offset!

L. Delgado-Aparicio, K. Tritz, D. Stutman, S. Sabbagh S. Gerhardt and J. Berkery will work on the analysis.

XP935: "Multiple RWMs at high β_N" + XP933: "NTV Physics"

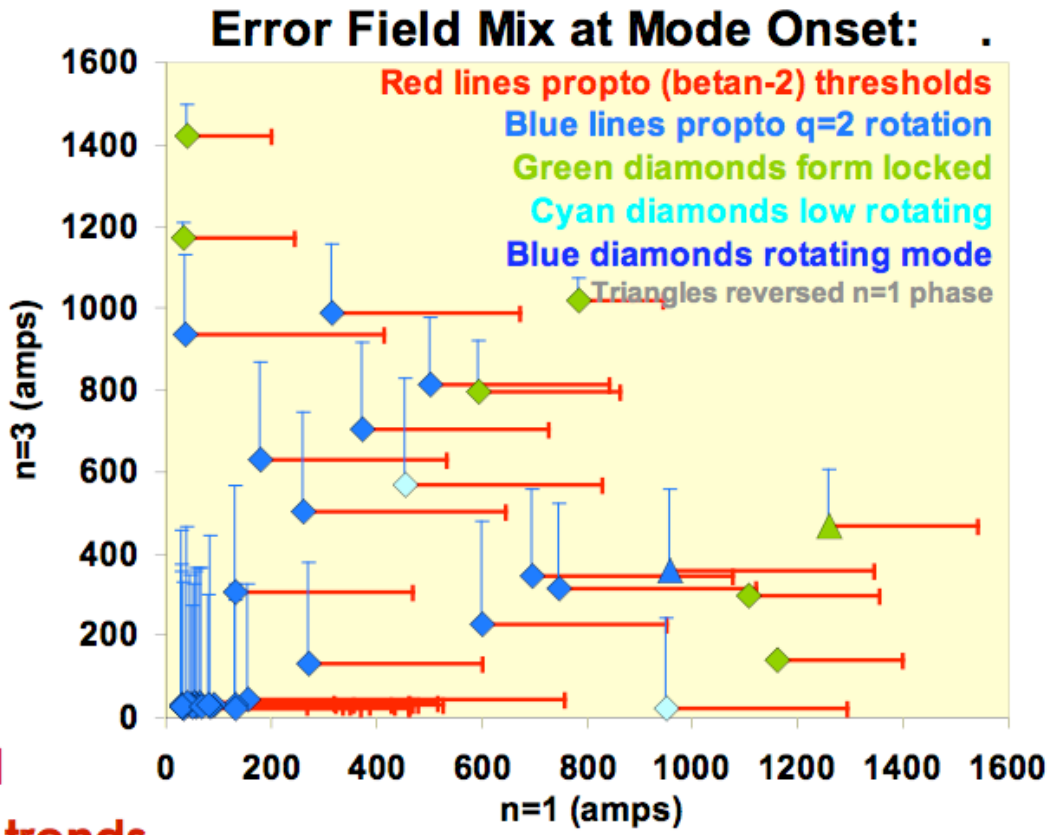
- XP935 Goals
  - Determine if unstable RWM is born from observed, stable RWM, or a 2nd mode. Determine β_N dependence, ω_ϕ , n = 1 active control on both modes near marginal stability
- Status
  - Scan in normalized beta completed, now with MSE data
    - Note: six shots with $\beta_N > 6$, reduce I_p = 0.52 MA reached β_N = 7.4
  - co-rotating 30Hz seed fields appear to be amplified more strongly than counter, consistent with RFA – several long-pulse (~ 1.3s) shots with RFA seed fields
  - ~ 30 Hz activity increases in radial extent as β_N increased
  - The observed growing RWM appears to be independent of the 20 - 30 Hz activity

- XP933 Goals
  - Examine expected variation of NTV with $\nu_i^*/q\omega_{E\times}(R)$; look for offset rotation; examine n = 1 control
- Status
  - NTV braking observed from all initial $\nu_i^*/q\omega_{E\times}(R)$ tested (n = 3 configuration)
    - Strong braking observed with lithium, saturation of braking not observed
    - With $\nu_i^*/q\omega_{E\times}(R) > 1$, should observe $T_i^{5/2}$ scaling
  - No clear NTV offset rotation
    - Further analysis needed. If $\omega_{\phi-offset}$ exists, it would appear to be small
    - Use of lithium, n = 1 control greatly reduced resonant surface locking
    - Strong desire for *counter-injection* data – MAST observes strong NTV with counter-inj, n = 2

First report XP915: Rotation and error field influence on tearing mode beta limits

New techniques (inc. l_i) led to broad and reliable scan:

- Wide data set scan with n=1 & n=3 braking
- Large new regime identified of rotating mode onset with decreased β_N onset when braking applied
- Great data to study rotation profile and error field roles



Next steps:

- Trend exploration in detail
- MSE FITS, local parameter trends

Great thanks to the NSTX team for their excellent, generous and expert support

NTM Experiments Collected Good Data Sets on Restabilization, Onset Dependence on Impurities and Li Conditioning

XP914 designed to study the marginal island width in NSTX and DIII-D. (La Haye. et al.)

Method: In both DIII-D and NSTX

- Strike a 2/1 mode in an NBI heated H-mode discharge.
- Ramp-down β_P by reducing the beam power
- Determine the marginal island width (island width at the value of β_P just sufficient to support an NTM).
- Marginal island width contains critical information about the small-island physics.

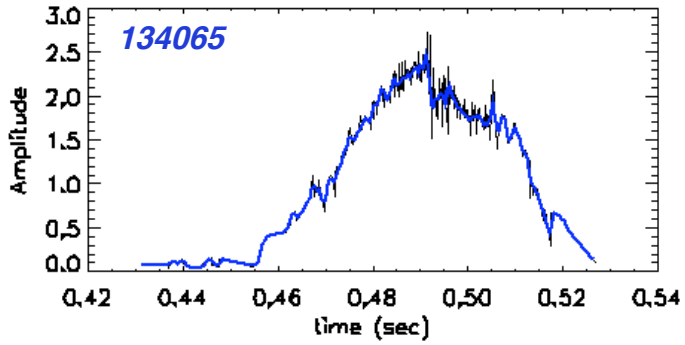
Result:

DIII-D:

- 5 good cases where the 2/1 mode restabilizes (data collected over the previous 2 years)

NSTX:

- Achieved a reproducible onset condition using 4 or 3MW, modest Li evaporation
- Up to 9 good cases, 8 collected this year.



XP-918 designed to examine impurity/Li effects on 2/1 mode onset. (Volpe, et al.)

- Mode onset delayed by Li (or by the consequent global accumulation of C)
- Onset anticipated by puffing Ne (more localized)
- n=3 EFC and n=1 f/back had little effect

- Ne visible in CHERS background view, SPRED and USXR.
- Ne penetrated to island location.
- Resolved in time penetration and permanence in plasma.

- Good reproducibility after Lithiumizations (modest cumulative effects?)
- Scanning Li low-to-high qualitatively similar to scanning high-to-low

- Analysis:
  - extract radial profiles of Ne emissivity
  - NIMRAD?
  - Further Modified Rutherford Equation

Continued Progress Made in the Area of Disruption Studies

- XP-901 designed to study fast-discharge shut-down using CHI. (Gerhardt, Raman, et al.)
  - Future tokamaks will need a means to rapidly terminate the discharge with minimal plasma motion, uniform radiation of plasma energy, no runaways…test possibility of CHI to do this in NSTX
  - Ran for ~4.5 hours on May 18.
  - CHI gas (He) could cause VDEs, but absorber arcs limited the utility of the applied voltage.
  - Come back to this next year, when PFAB coils have been tested and used.
- New halo current measurements are successful
  - Four tiles in lower outboard divertor instrumented with under-tile shunts, to measure local halo currents.
  - Ran 75 minutes of XP-827, generating 4 VDEs to test the tiles.
  - Work is underway for improved halo current measurements in 2010.
    - 12 tiles in the lower divertor
    - Rogowskis on the LLD trays
  - ITER TA submission for TSC modeling of halo currents, including benchmarking on NSTX.
- Possibly supporting an experiment by C. Skinner on dust migration during disruptions, to be discussed in a different presentation.

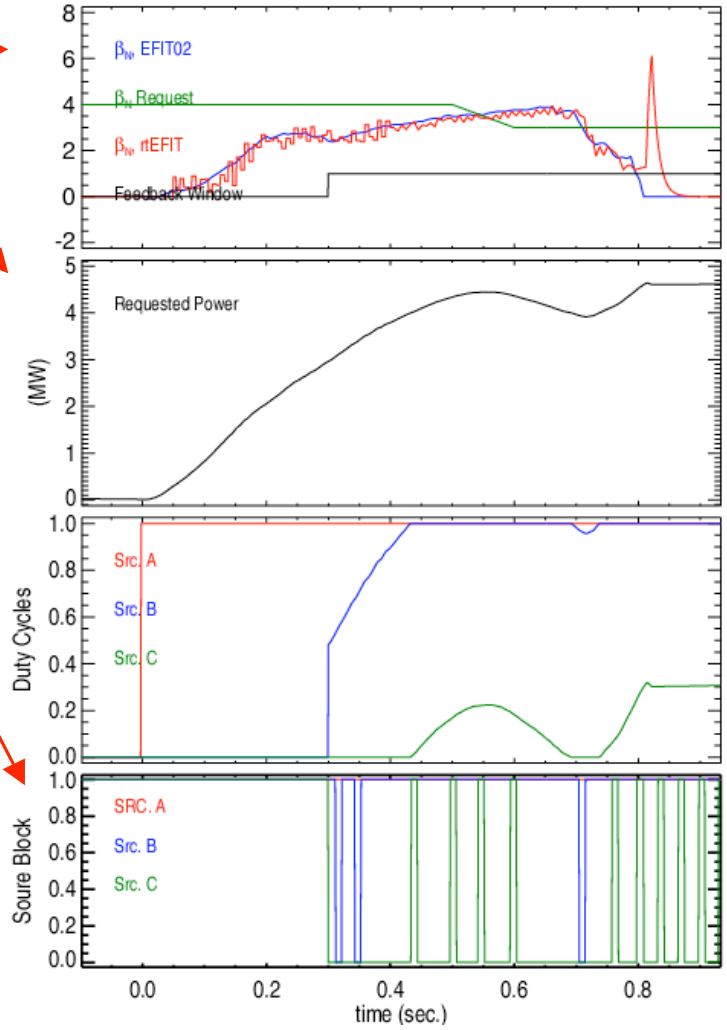
Remaining Experiments Emphasize Control Techniques, Contribute to FY09/FY10 Milestones

- XP-930: Use of RFA for Ideal Stability Limit Detection (Gerhardt, et al)
  - RFA is the high-β amplification of externally applied error fields.
    - Generally speaking, the amplification increases as the plasma approaches the no-wall β_N limit.
    - Comparatively benign way of measuring RFA is to apply an n=1 traveling wave, and look for the plasma response.
    - If in realtime, can be used as a means of detecting the proximity to stability limits ($\rightarrow$2010 Milestone on Disruptivity)
  - Goal is to assess RFA as a function of parameters that are thought to govern stability.
    - Triangularity, l_i, q*
    - Provides the experimental basis for realtime stability limit detection in 2010.
- XP-934: Improving $<\beta_N>_{pulse}$ vs. rotation under RWM Feedback (Sabbagh, et al)
  - "Standard" feedback +error correction uses B_P sensors only for mode-identification
  - XP goal is to add B_R sensors to feedback scheme, for improved control.
    - Operate at highest possible β_N, with varying rotation evolution.
    - Optimize gain, phase, and re-zeroing time for optimal control, building on 2008 experience.
    - Ultimately, demonstrate longest possible, highest β_N sustained state.
- Both can make use of the eminent β_N control.

Capability for β_N Control Is Ready To Test "Live", and Hopefully Use.

- Scheme: Use PCS & NBs to control β_N
  - Use rtEFIT to get β_N or β_T in realtime.
  - Compare to a requested $\beta_{N,T}$ evolution, adjust requested power.
  - Translate requested power to duty cycles for each source.
  - Modulate the sources to achieve the requested duty cycles.
- Code has been tested offline
  - Significant algorithm debugging on the 2nd realtime machine.
  - Compared archived realtime calculations to "identical" idl code.
- Few steps required to bring it online
  - Need to install the algorithm on the primary computer
  - Check that commands received at the 138' level match those sent from PCS.
  - Try it with plasma!
- Could be a very useful tool for the final two high-priority XPs, necessary for FY-10 milestone.

Calculations done on the backup realtime computer



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

MS Group Could Utilize ~1 day in Reversed B_T

- NTV Physics (0.5 days)
  - Term in NTV theory (related to super-banana orbits) which might be important.
  - Add an 1/2 day addendum to XP-933.
- Error Field Studies (0.5 days)
  - Flipping B_T leads to a change in the field line helicity, of importance to error field studies.
  - Add addendum to XP-902 studying the modification of the OH-TF error field with reversed TF.
  - Add addendum to XP-901 looking for a modification to the optimal n=3 EF correction.
- However, we would ***not*** choose to reduce the time available to 930, 934, 932 in order to complete these experiments.
- Many experiments would benefit from counter-I_p operation.
  - Should keep trying to find a way to try this.

Summary: MS TSG

- Devoted experiments completed in the areas of:
  - NTMs
  - NTV
  - Error Fields
  - Disruptions
- Priority of remaining experiments:
  - XP-930: Use of RFA for Ideal Stability Limit Detection
  - XP-934: Improving $<\beta_N>_{pulse}$ vs. rotation under RWM Feedback
  - Possible XP-932 Follow-up: Influence of Hot Ions on Resistive Wall Mode Stability
  - XP-743: Island Induced Neoclassical Viscosity
  - Counter-B_T XPs
  - Global/ELM stability vs integer nq
- FY2009 milestone data collection is close to finished, be good to execute XP-930, may need 932 follow-up.
- FY2010 milestone preparation needs both XP-930 and XP-932.
  - Demonstration of β control via NBI modulation would also go a long way toward preparing for the FY2010 milestone on disruptivity reduction.