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Stability and Current Drive at High-I_N: Toward a High Neutron Flux ST-CTF Operating Point

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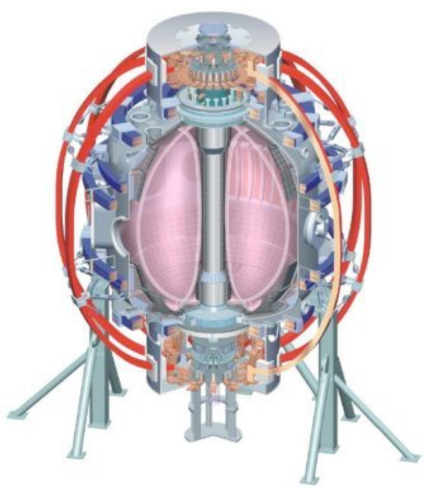
S. Gerhardt, M. Bell, E. Kolemen, R. Kaita, H. Kugel, R. Maingi, J. Menard, D. Mueller, S. A. Sabbagh, C. Skinner, V. Soukhanovskii

NSTX 2010 Research Forum
ASC TSG Breakout Session
Dec. 2nd, 2009



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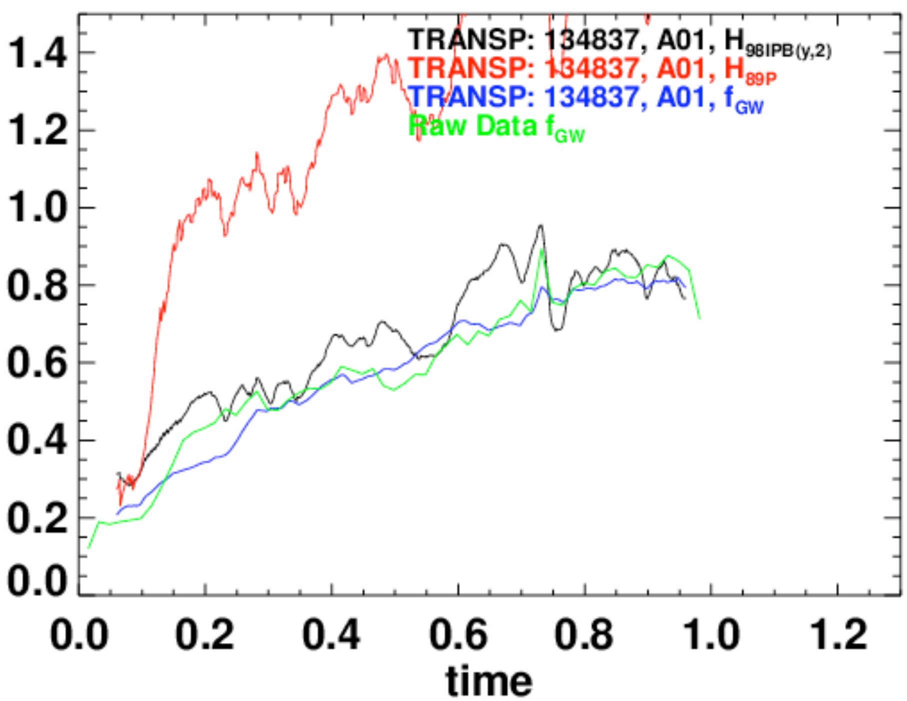
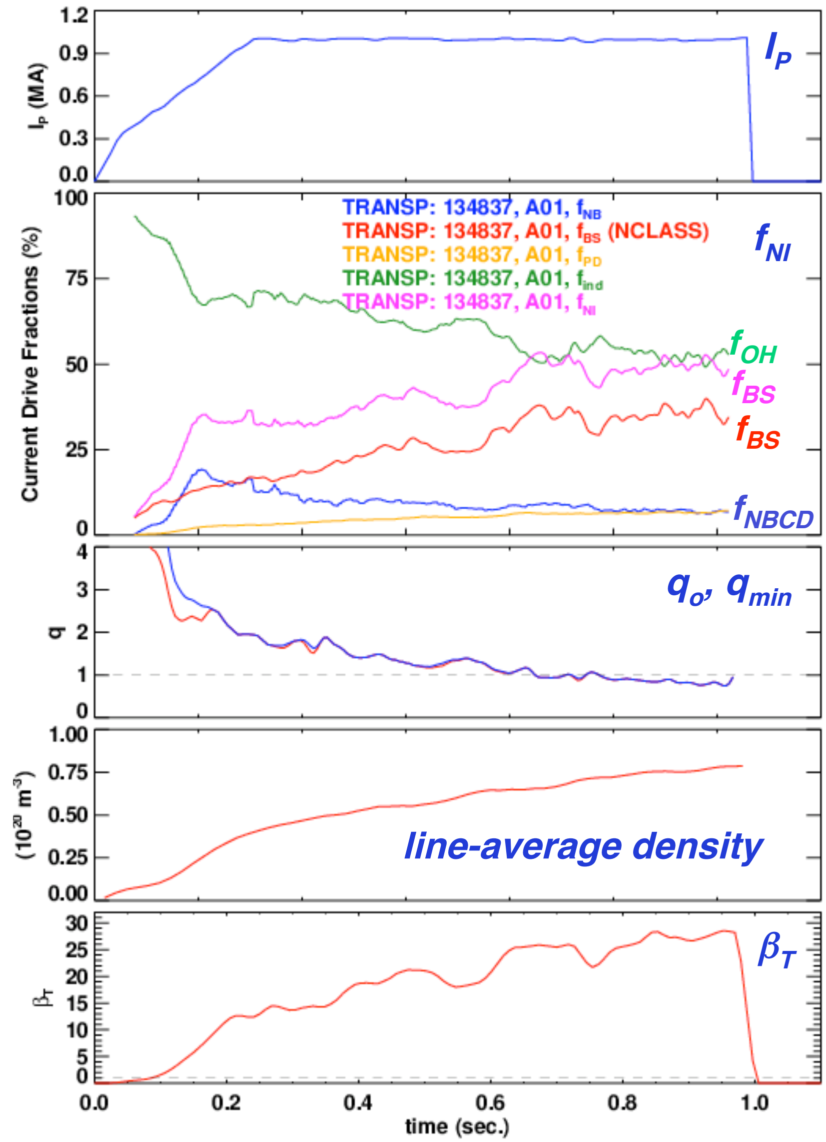
Overview

- Background:
  - High neutron flux ST-CTF designs generally stipulate high κ, I_N, & β_N, but lower f_{GW} in order to increase the NBCD.
  - Shots in XP-948 last year achieved (essentially) appropriate values of κ, & β_N, but too much density, too little NBCD, I_N too low.
- Goals:
  - Add improved control tools (β_N control, X-point height control, improved RWM control ?) to high κ, I_N, & β_N scenario with a cold LLD.
  - Rerun best cases with a warm LLD to examine operation at reduced density.
    - Assess changes in confinement, NI current components, stability.
    - Parallel proposal in the LiTSG for this step.
- Contributes to:
  - Long term ST programmatic goals.
  - Research Milestone R(11-2): Assess the dependence of integrated plasma performance on collisionality.
  - Research Milestone R(11-3): Assess the relationship between lithiated surface conditions and edge and core plasma conditions.

Results Last Year Showed Operation with β_T~25%, But Too Low NBCD

- XP-948
- Proposed to follow-up on this XP using improved tools.





New Tools This Year Offer Hope For Improved Performance

- Improved rtEFIT basis vectors
  - Implemented on 2nd to last day of run
  - Use the EFIT01 formulation
  - Appeared to reduce transients in gap-out, β_N.
- β_N-control via NB modulations
  - First implemented last year, showed considerable promise.
  - Proposal in MS-TSG to optimize gains, test performance
    - MS milestone on disruption avoidance
- RWM/RFA control development
- Liquid Lithium Divertor
  - Should provide significant pumping capability, leading to density reduction, increased T_e/n_e.
  - Key to increasing the NBCD efficiency.
- Upper/Lower X-point Height Control
  - Proposed in ASC-TSG by E. Kolemen
- Squareness control
  - Pending progress on PF-4/PF-5 mutual force interlock

Good Problem: More tools than we can hope to exercise in a single XP.

Proposed Run Plan: Very Tentative Pending LLD Experience

- Establish baseline scenario with improved control. (1 day)
  - Pick scenario from 2009 (134837, 135129 are good candidates)
  - This step with a cool LLD.
  - X-point height control critical for maintaining finite bottom gap at high-κ when I_{OH} is large.
  - Scan β_N request in order to achieve highest β_N consistent with ideal stability.
  - Modifications to squareness (I_P too large?), RWM control?
- Repeat with LLD (same day?, different day?) (1/2 day? LR TSG?)
  - Parallel proposal in LiTSG
  - Take best parameters from first day
  - Repeat with reduced density.
    - SGI? Would be nice to actually *scan* the density.
  - Divertor puff for reduced Carbon influx? Other impurity reduction techniques.
  - Implement early EFC as needed.
  - Need LLD operating experience to properly address this step.

Backup

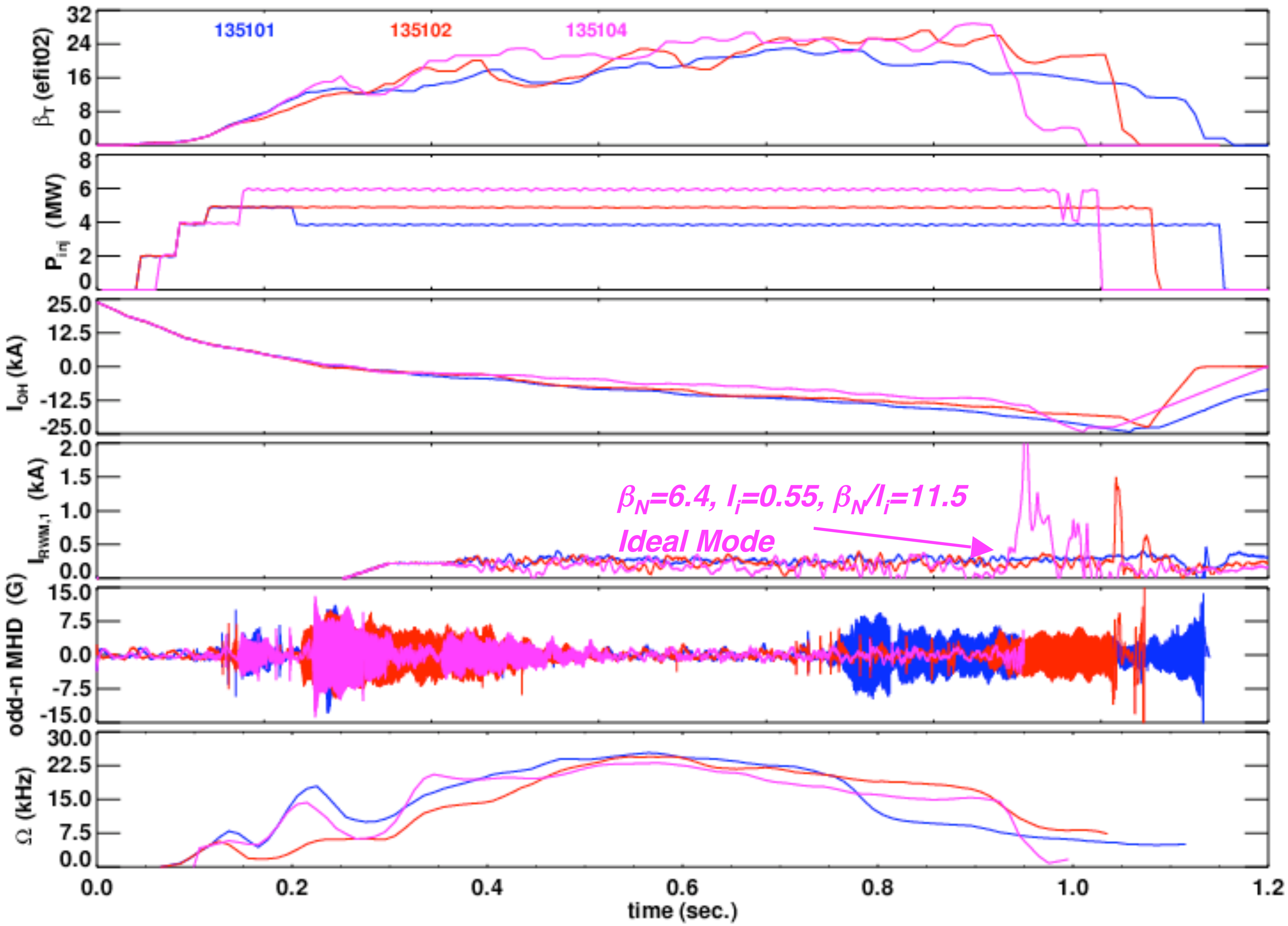
Too much power→Ideal MHD
Too little power→Rotating MHD.

135101: 4 MW Early Rotating Mode

135102: 5MW, Delayed Rotating mode

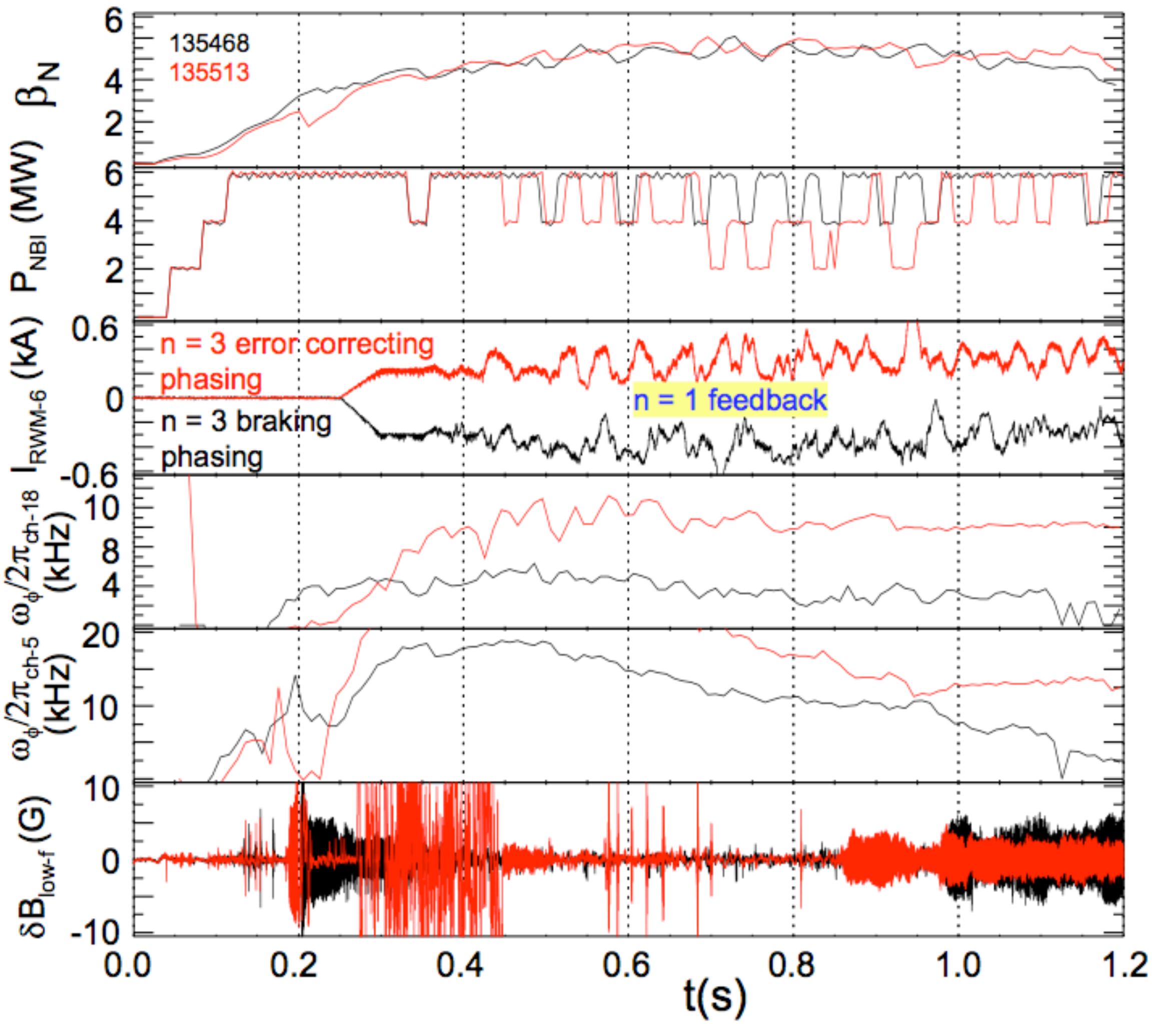
135104: 6 MW, Ideal Mode

All I_P=1MA, B_T=0.4 T



Need to operate at the highest beam powers consistent with stability -> β_N control

β_N Control Has Been Demonstrated in 2009



- ***β_N algorithm compensates for loss of confinement with n=3 braking.***
- ***Control works over a range of rotation levels***
- ***Proposal by SPG in MS-TSG to optimize the system.***

S.A. Sabbagh, 2009 NSTX Results Review

Modifications to the rtEFIT Basis Functions Resulted in Improved Real-time Reconstructions

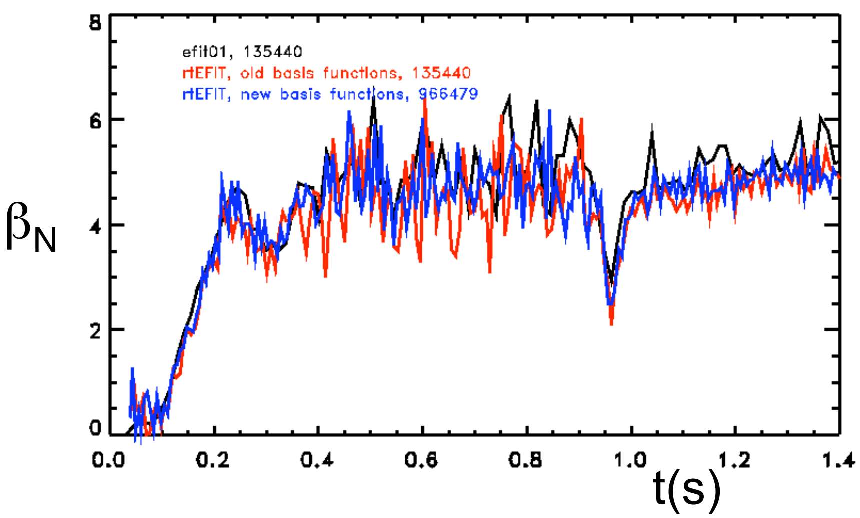
- Occasional poorly converged equilibria lead to incorrect outer gap, β_N
  - Kick off an deleterious transient in the vertical field coil current.
  - Edge current not allowed
- New basis function model based on those developed for off-line magnetics-only reconstruction (Columbia University)
  - Tested on literally > 2 million equilibria
  - Finite edge current through ff'(ψ_n)

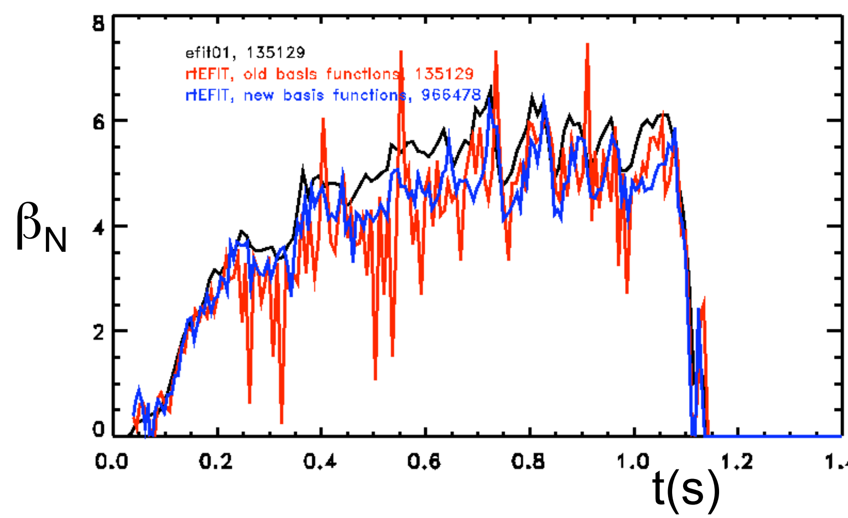
$$p'(\psi_n) = a_1\psi_n(1-\psi_n)$$

$$ff'(\psi_n) = b_0 + b_1\psi_n\left(1-\frac{1}{3}\psi_n^{\,2}\right) + b_2\psi_n^{\,2}\left(1-\frac{2}{3}\psi_n\right)$$

- Considerable real-time reconstruction improvement
  - Reduction in β_N "noise" indicative of improved reconstructions

rtEFIT, Old Basis Functions ***rtEFIT, New Basis Functions*** ***Offline Calculation***





Improvement made on 2nd to last day of run….we should take advantage of it.

NSTX is Beginning To Approach Interesting Regimes For an FNSF/ST-CTF

- ITER-era goal for ST: make a CTF, irradiate materials (would like $2MW/m^2$).
- Biggest gap between NSTX and ST-CTF may be current drive

	NSTX, 134837	Peng 2005[1], Phase 3	Wilson 2004[2]	Peng 2009[3]
Wall Loading (MW/m^2)	Ha!	2	1.5	
κ	2.7	3.1	2.5	
I_N	4	5.8	6.1	
f_{GW}	0.8			
β_N	6	5.9	3.5	
β_T	28	28	22	
f_{BS} (%)	35	0.5	0.38	
f_{NBCD} (%)	10			
H_{98}	0.8	1.5	1.3	

[1] Peng et al, PPCF 2005 [2] Wilson, et al., IAEA 2004 [3] Peng, et al., APS 2009