Supported by

XP802: Active RWM stabilization system optimization and ITER support

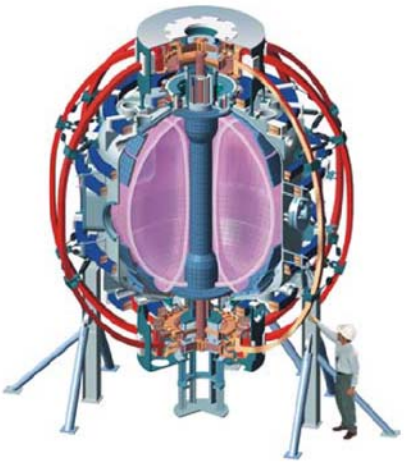
S.A. Sabbagh[1], R.E. Bell[2], S. Gerhardt[2], J.E. Menard[2], J.W. Berkery[1], J.M. Bialek[1], D.A. Gates[2], B. LeBlanc[2], F. Levinton[3], K. Tritz[4], H. Yu[3]

[1]Department of Applied Physics, Columbia University, New York, NY

[2]Plasma Physics Laboratory, Princeton University, Princeton, NJ, USA

[3]Nova Photonics, Inc., Princeton, NJ, USA

[4]Johns Hopkins University, Baltimore, MD, USA



NSTX Research Team Review

April 8th, 2008

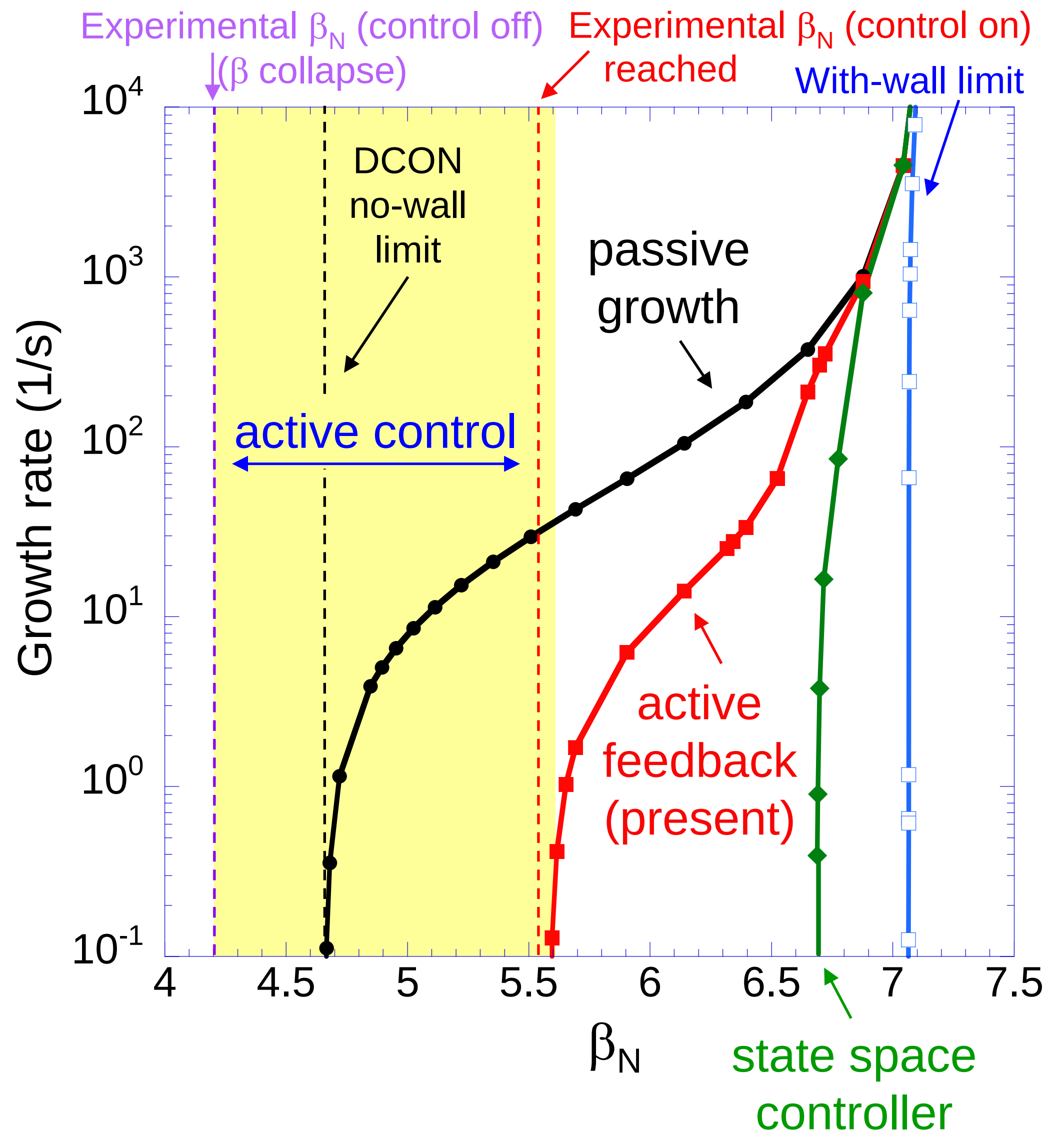
Princeton Plasma Physics Laboratory

XP802: Active RWM stabilization system optimization and ITER support

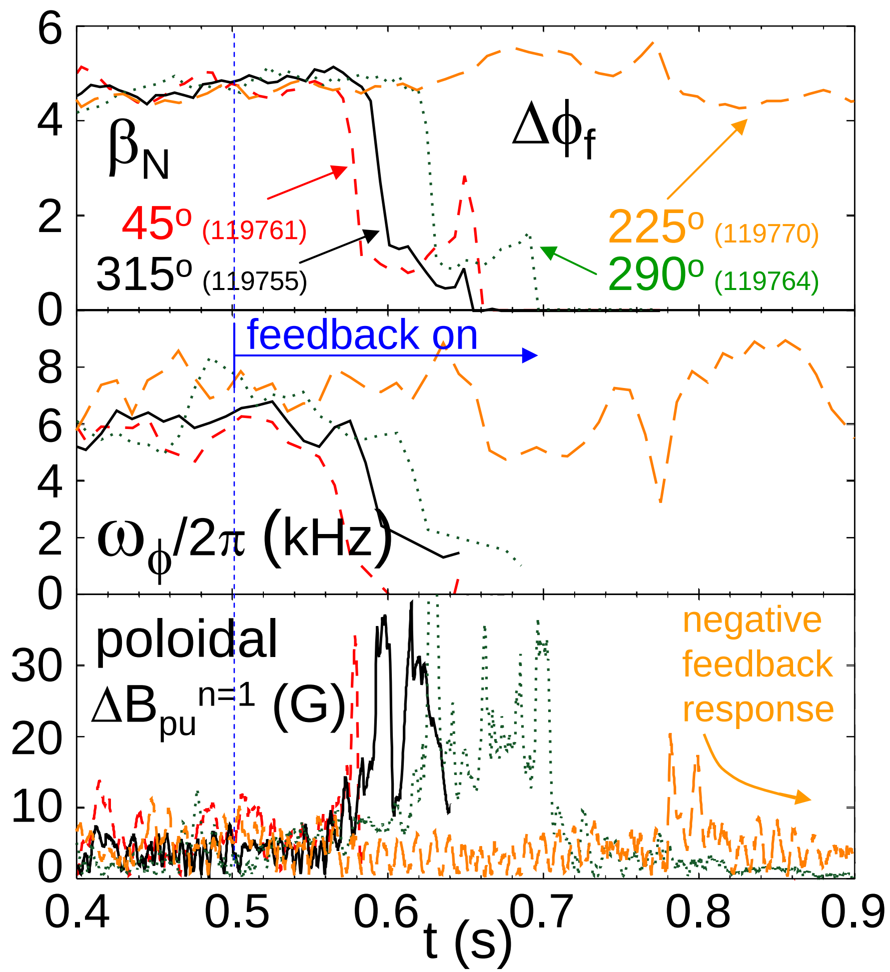
- Goals
  - Alter active control configuration to achieve reliable RWM stabilization at various plasma rotation, ω_ϕ
    - Upper/lower RWM B_r, B_p sensors, follow from best CY2007 feedback settings
    - B_r sensor feedback provides RFA correction, B_p provide RWM stabilization
    - Determine if stable, low $\omega_\phi < \omega_{*i}$ operation exists with feedback turned off
    - If achieved, control system open as a tool for all NSTX XPs as desired
  - Specific ITER support requests
    - Study effect of applied time delay on feedback (new control system capability)
    - Determine impact of a large toroidal gap on active RWM stabilization (take out one of six control coils)
- Addresses
  - Joule milestone, ITER Organization (IO) request, NSTX PAC request
  - ITPA experiment MDC-2, ITER issue card RWM-1

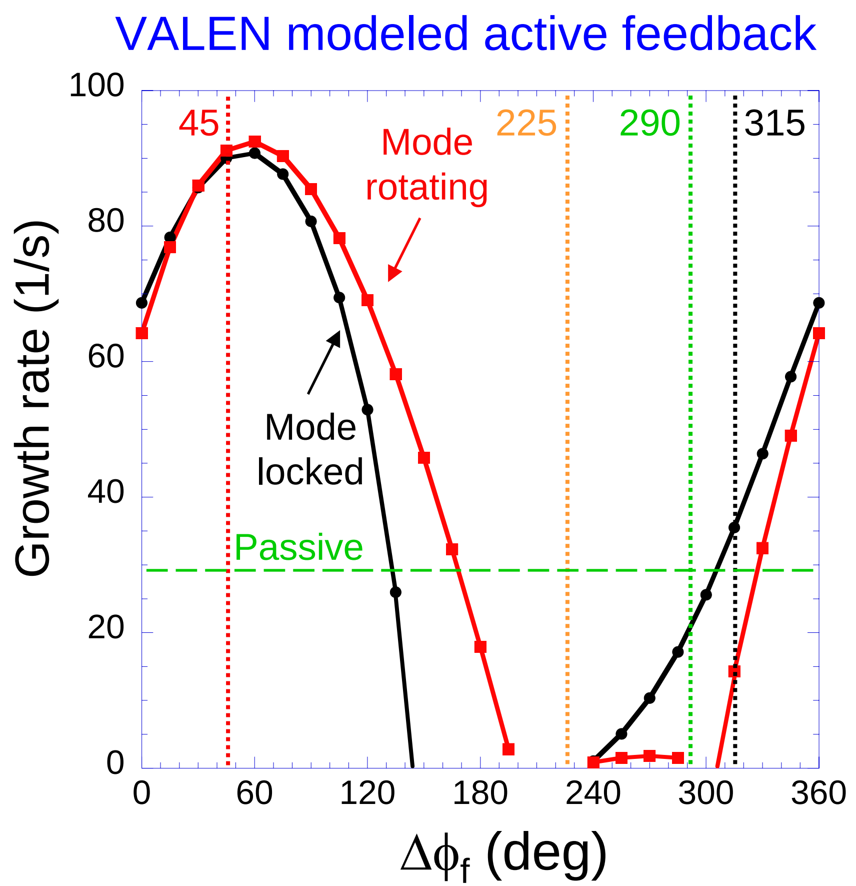
VALEN code reproduces B_{pu} sensor feedback performance

- New model simulates experiment
  - Upper B_p sensors located as on device
  - Compensation of control field from sensors
  - Experimental equilibrium reconstruction (including MSE data)
  - Proportional gain



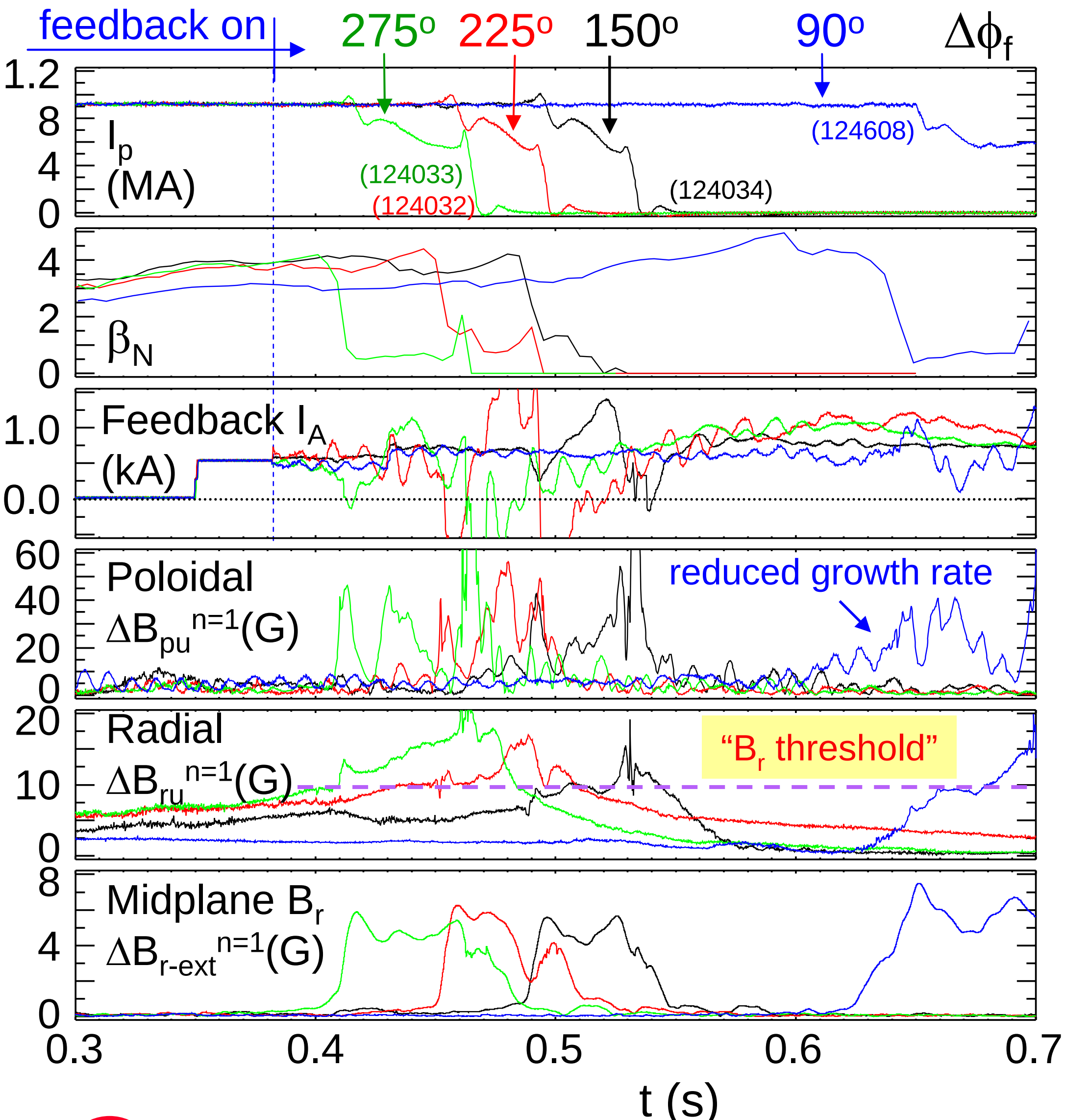
Varying relative phase shows positive/negative feedback





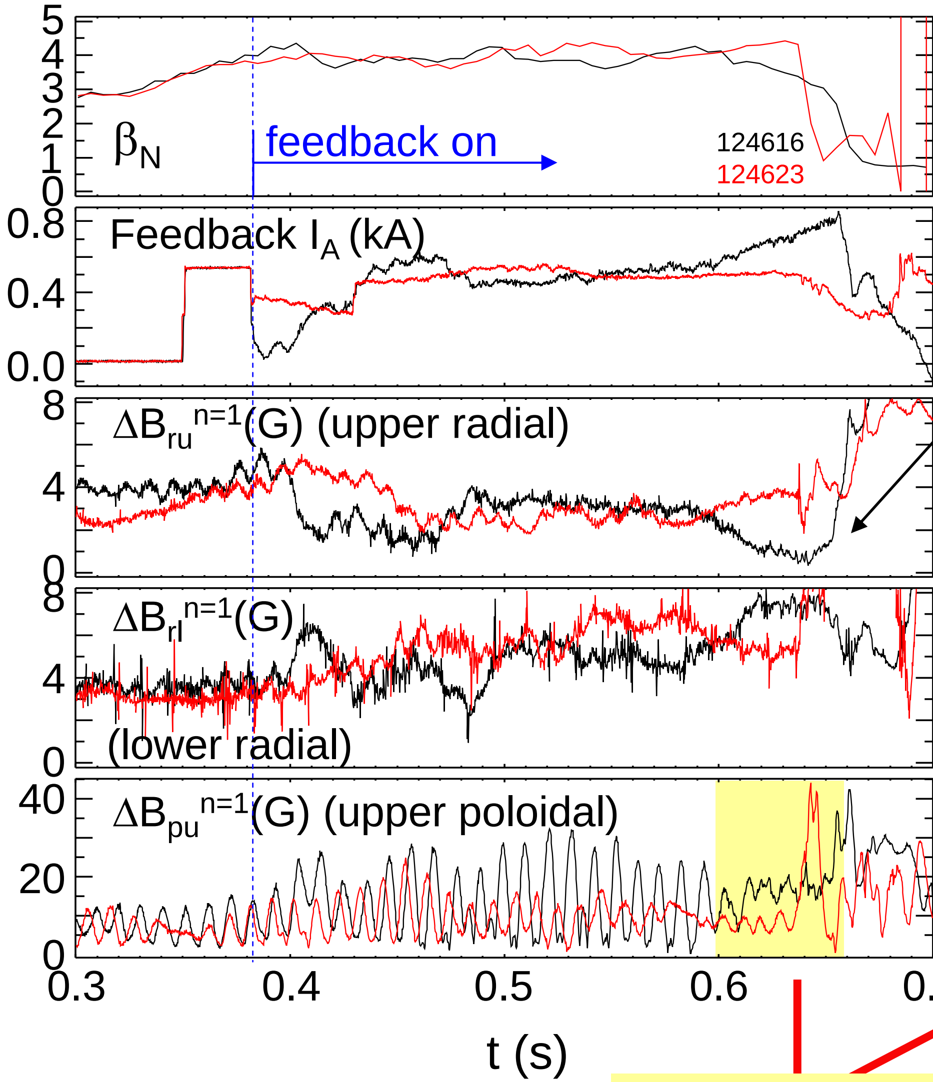
- Feedback control current has relative phase $\Delta\phi_f$ to measured ΔB_{pu}
  - Internal plasma mode seen at $\Delta\phi_f$ = 225°, damped feedback system response
- Phase scan shows superior settings for negative feedback
  - Agreement between theoretical and experimental feedback behavior

Combination of upper/lower B_p sensors used to improve control



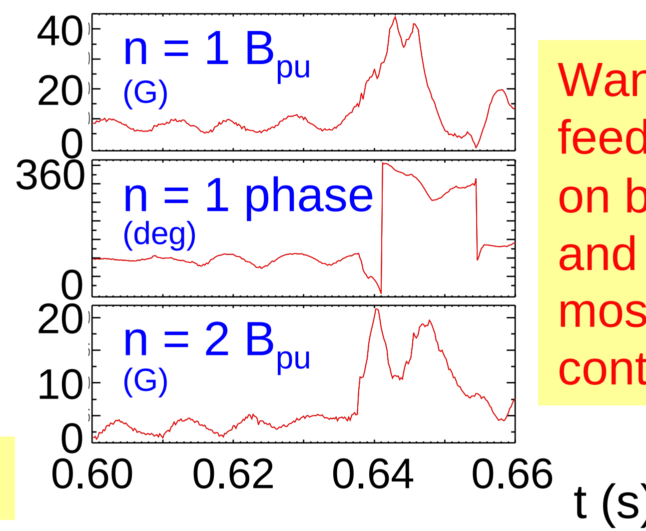
- Feedback phase scan using B_{pu} and B_{pl}
  - Best phase shown 90°, not optimal configuration
    - Reduction in $\Delta B_{pu}^{n=1}$ growth rate
  - Spatial phase offset between upper/lower B_p sensor flux can improve feedback further
- Control using B_{pu} and B_{pl} also reduces ΔB_r
  - Correlation of β_N collapse and $\Delta B_{ru}^{n=1}$ amplitude
  - Suggests that feedback on ΔB_r may allow mode control

Feedback on B_r sensors alone insufficient for control



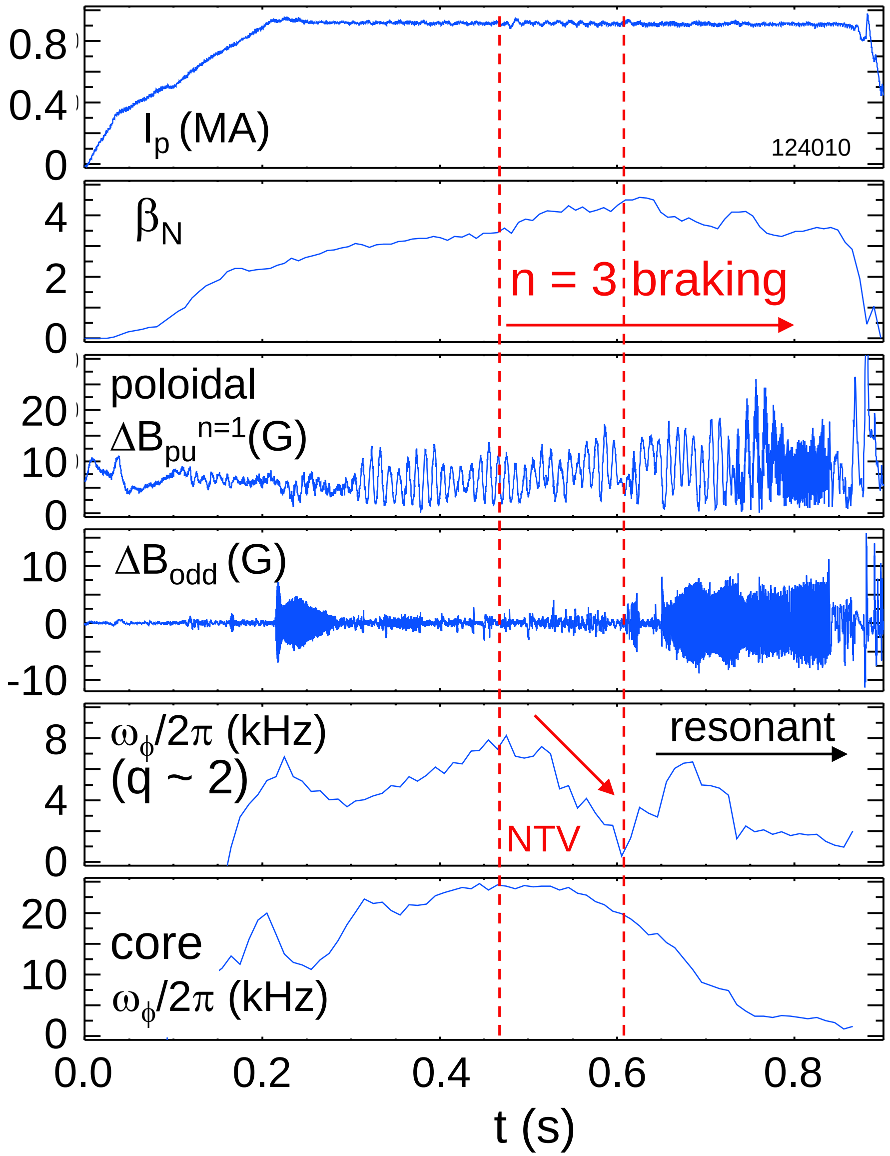
unstable RWM

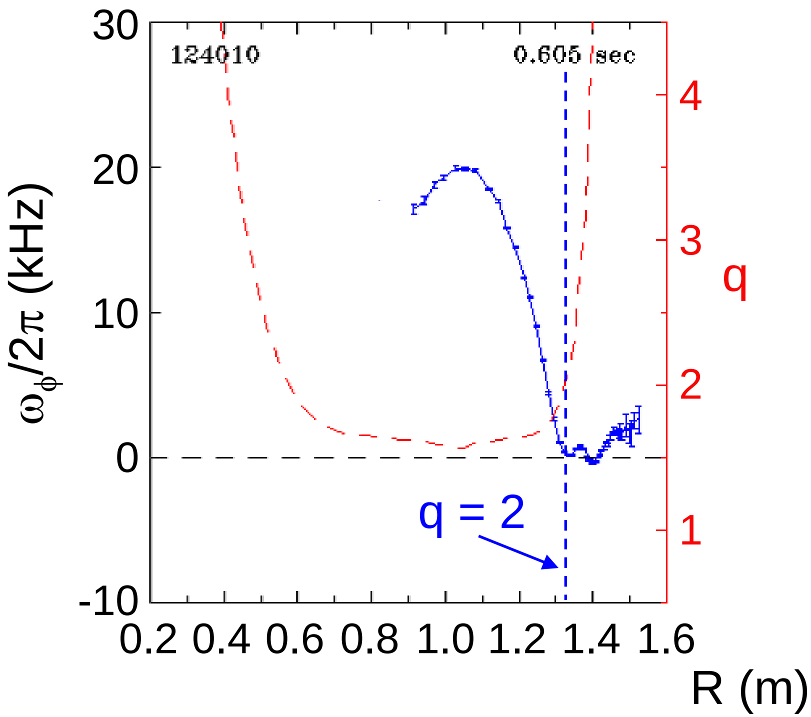
- Feedback on ΔB_{ru} alone
  - Clear initial drop in ΔB_{ru}
  - Continued drop in ΔB_r and *increase* in ΔB_{rl} (also ΔB_{pu})
  - leads to β_N collapse
- Feedback on ΔB_{ru} and ΔB_{rl}
  - Controlled, steady ΔB_{ru}, ΔB_{rl}
  - rapid RWM growth, rotation: β_N collapse



Want feedback on both ΔB_r and ΔB_p for most reliable control

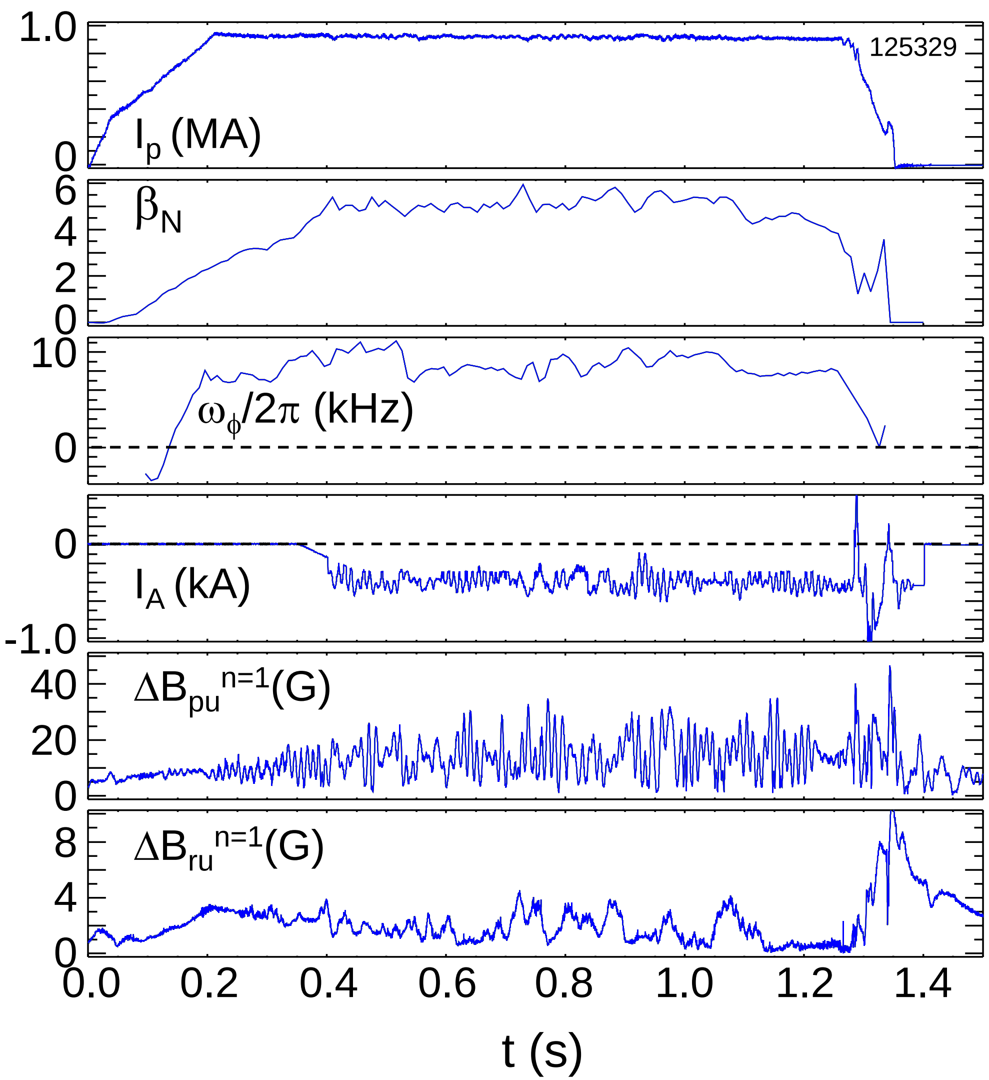
Rapid braking $\omega_\phi^{q=2}$ =0 leads to rotating mode, β reduction





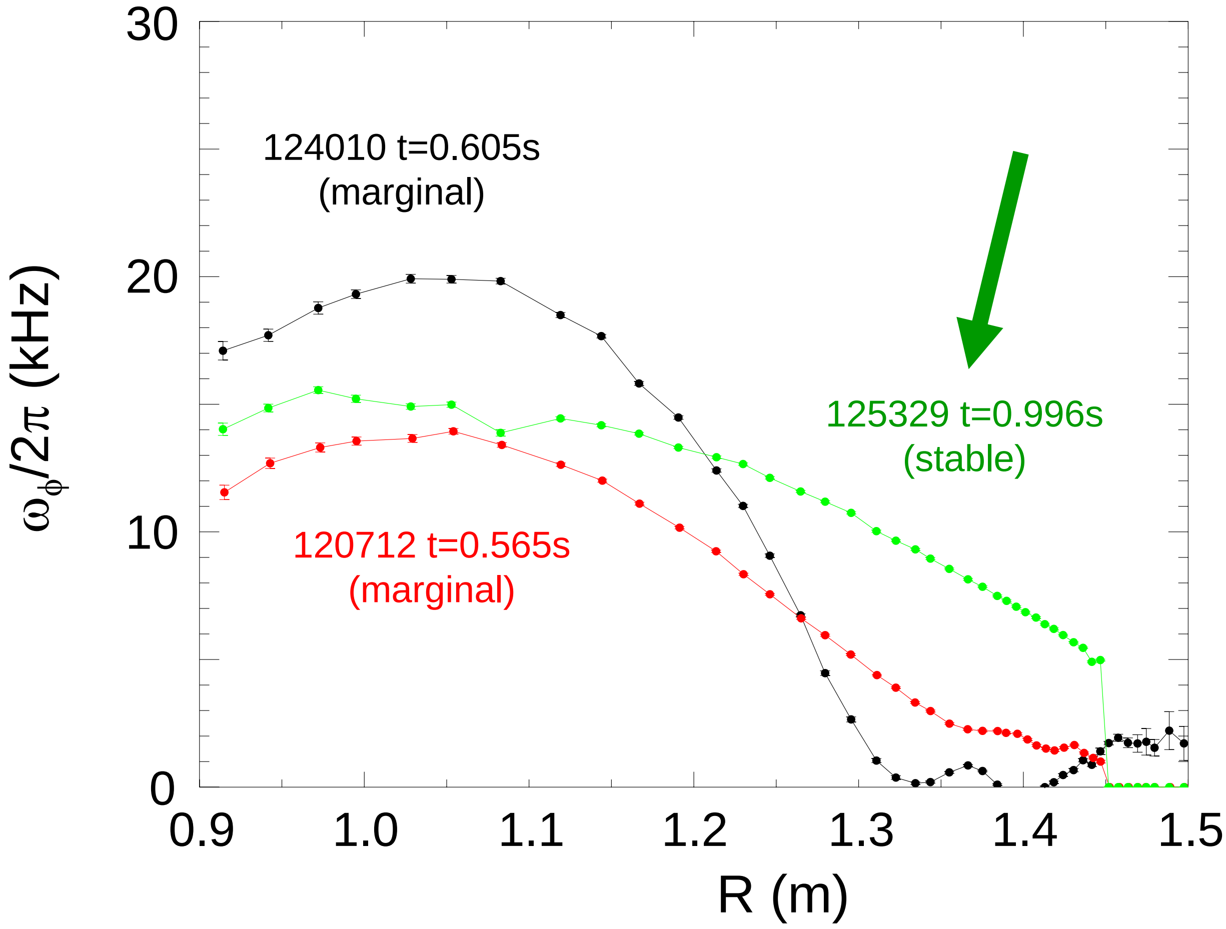
- Evolving braking physics
  - Non-resonant n = 3 (NTV), then additional braking seen at resonant surfaces
  - Peaked ω_ϕ profile leads to strong momentum diffusion (due to island growth?)
  - Minimize this with broad ω_ϕ

Reliable feedback stabilization, various plasma rotation



- Approach for optimization
  - Start from optimal feedback, using correcting n = 3 phase (medium $|\omega_\phi|$, unique, broad ω_ϕ profile)
  - Feedback using all B_r and B_p sensors – determine best feedback phase / gain
  - Slow reduction of ω_ϕ using n = 3 braking to vary ω_ϕ profile
  - Maintain high $\beta_N > \beta_N^{nowall}$

Goal: create lowest possible ω_ϕ for feedback stabilization



- Approach reduced rotation from broadest rotation profile possible
  - Use n = 3 in correcting phasing first, then change to braking phasing
  - Gate off n = 1 feedback once rotation is slower than typical marginal profiles

Several issues need to be addressed for RWM feedback optimization / ITER support

- Optimization
  - Feedback with B_r sensors to stay below $B_r^{n=1}$ threshold for RWM destabilization
  - Combined with RWM feedback with upper/lower B_p sensors
    - faster control computer for 2008 run
  - Create low ω_ϕ plasma from broader ω_ϕ, n = 3 corrected target
- ITER support
  - Demonstrate RWM feedback control with one coil removed to simulate ITER port plug RWM coil design
  - Initial shots with neon to support RWM SXR tomography (Tritz)

XP802: Active RWM Stabilization / ITER Support (I)

Task	Number of Shots
1) Create target plasma	
A) Run active feedback in piggyback mode in prior experiments to verify operation	-
B) 3 NBI, $\kappa > 2.2$, $\beta_N > \beta_N^{no\text{-}wall}$ (control shot) - 125329 as setup shot (n=3 correction)	2
C) moderate n = 3 braking once core ω_ϕ is reduced; generate RWM	3
2) Optimize n = 1 feedback sensors at intermediate ω_ϕ	
A) Upper/lower B_r sensor feedback (start with past "best" FB phase; vary phase)	4
B) Vary B_r gain	2
C) Add upper/lower B_p sensors to feedback circuit, vary FB and u/l spatial phase	6
D) Vary B_p gain	2
3) Active RWM stabilization at low ω_ϕ	
A) vary onset time, ramp rate, magnitude of n = 3 braking	4
B) gate off feedback at low ω_ϕ	2
4) Reliability testing	
A) Repeat best low rotation stabilized shot in repeated shots (feedback gated off - add neon for SXR tomography)	4

Total: 29

XP802: Active RWM Stabilization / ITER Support (II)

Task	Number of Shots
5) Examine feedback performance vs. feedback system latency	
A) Increase feedback system latency from optimized settings to find critical latency for mode stabilization	4
6) n = 1 RWM stabilization with one RWM coil omitted	
A) Create low rotation target plasma with “n = 3” braking; generate RWM	2
B) As (A), but with neon for SXR tomography	3
C) Upper/lower B_r sensor feedback; vary phase	4
D) Add upper/lower Bp sensor feedback ; vary phase	2
E) Vary feedback gain	3
	Total: 18

XP802: Active RWM stabilization - Diagnostics

- Required diagnostics / capabilities
  - Ability to operate RWM coils with one coil turned off (Part 6 of run)
  - Internal RWM sensors
  - CHERS toroidal rotation measurement
  - Thomson scattering
  - USXR
  - MSE
  - Toroidal Mirnov array / between-shots spectrogram with toroidal mode number analysis
  - Diamagnetic loop
- Desired diagnostics
  - FIReTip
  - Fast camera