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XP728: RWM active stabilization and optimization – ITER scenario

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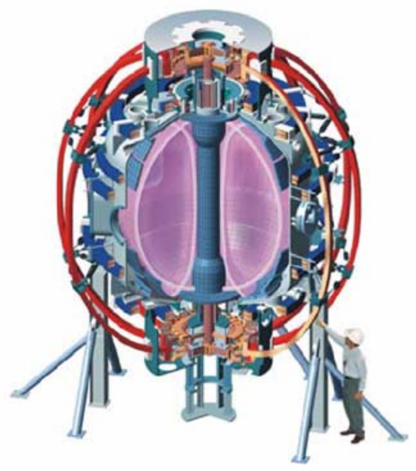

NSTX Team XP Review Meeting

May 8th, 2007

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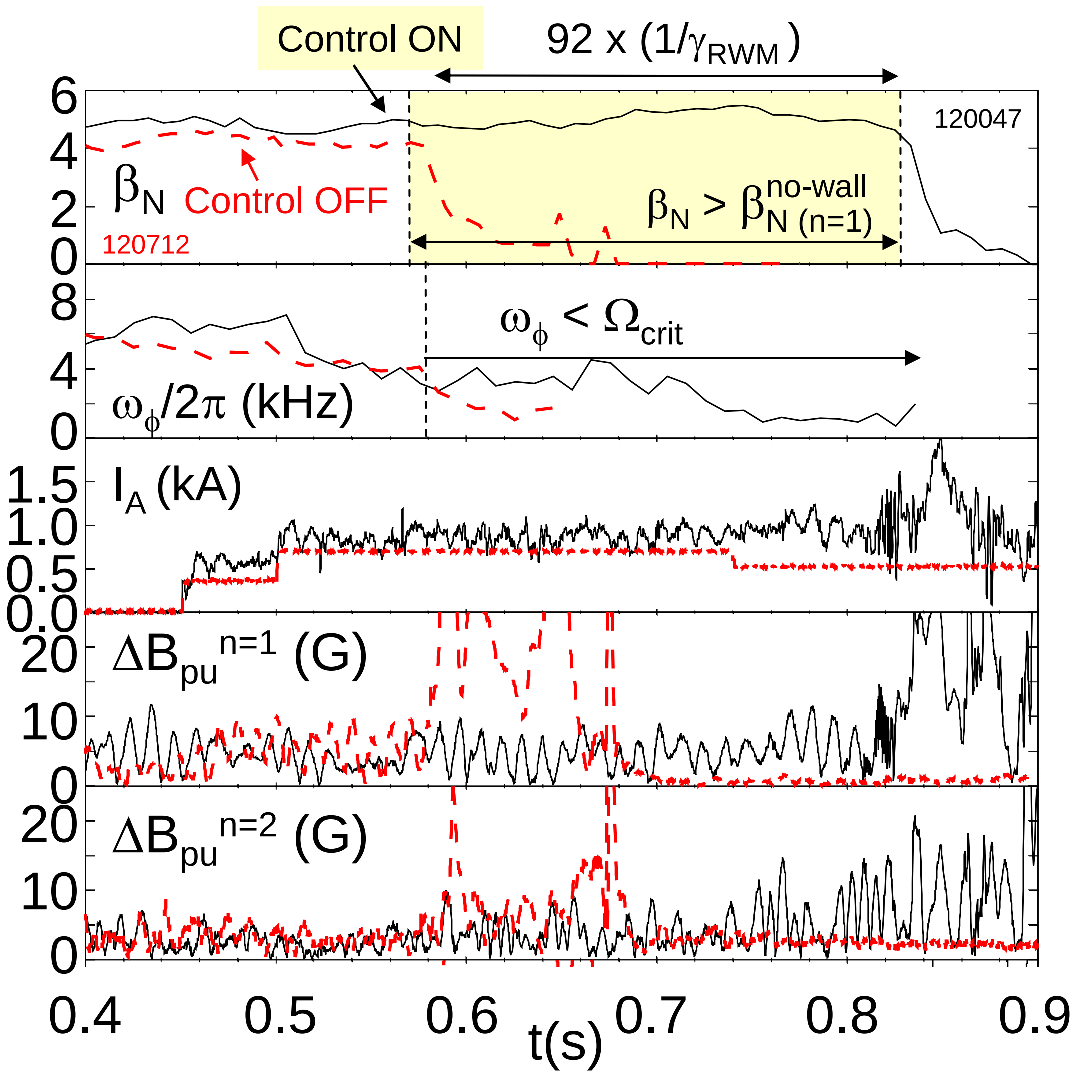
XP728: RWM active stabilization and optimization

- Goals
  - Investigate variations of control sensor combinations to optimize RWM stabilization at low plasma rotation, ω_ϕ (more robust, reach higher β_N)
    - Use upper/lower RWM B_r, B_p sensors for feedback (ran out of time in 2006)
    - Examine possible poloidal deformation of RWM during feedback
  - Investigate active stabilization of recent plasmas that exhibit unstable RWM activity leading to discharge termination at *high* ω_ϕ.
  - Explore possible stable region at $\omega_\phi < \omega_{*i}$ with feedback is turned off
  - Investigate RWM active stabilization of low ω_ϕ plasma with superposed time-averaged n = 1 error field correction + n = 3 magnetic braking
    - (Fredrickson, Garofalo suggestion from 2006, but no run time)
  - Measure n =2-3 RFA, attempt to destabilize n = 2 RWM with n = 1 stable
  - Introduce and study effect of applied time delay on feedback (ITER support)
    - Depends on control system time delay capability in 2007
- Addresses
  - **NSTX milestone R(07-2),** NSTX PAC request
  - ITPA experiment MDC-2, ITER issue card RWM-1, USBPO MHD task

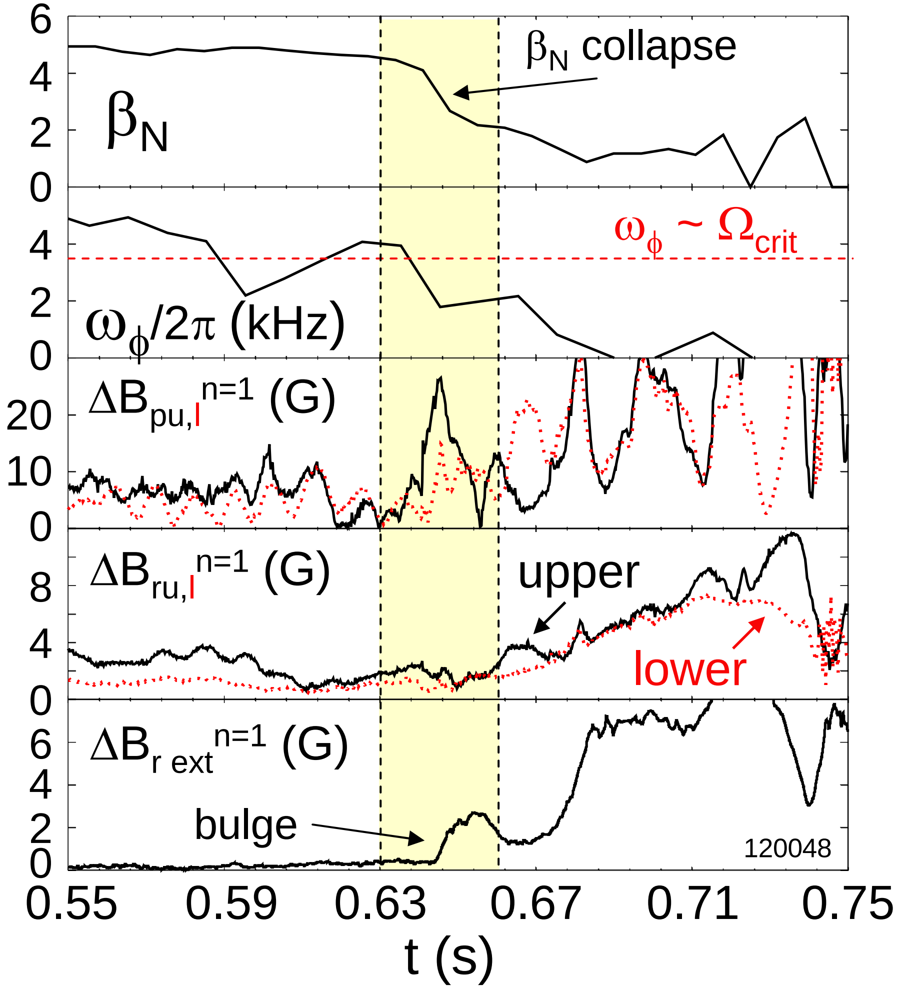
RWM actively stabilized at low, ITER-relevant rotation



(Sabbagh, et al., PRL **97** (2006) 045004.)

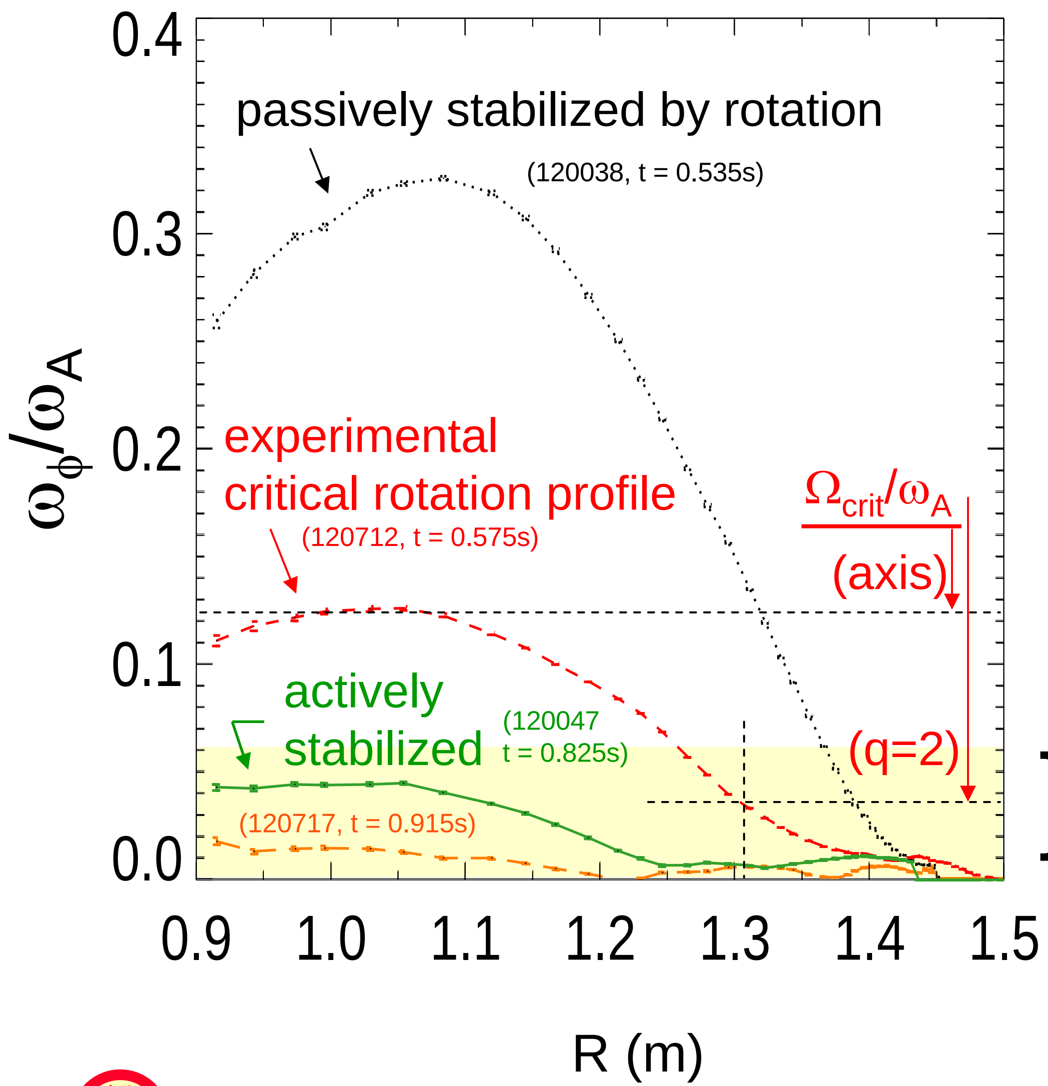
- Logical next-step of XP615 addresses several key issues
  - Optimal RWM sensor configuration
  - Dependence of active stabilization on ω_ϕ
  - Possible stable region at sufficiently low ω_ϕ without active stabilization
  - If stable region with low ω_ϕ is found, scan magnitude to determine range of stable ω_ϕ.
- Approach
  - Follow established Xp615 procedure to generate RWM stabilized, low rotation target
  - Make control system parameters scans, rotation scans to fulfill stated goals

Test improved control with addition of new sensors



- Poloidal deformation of RWM sometimes observed
  - Poloidal n = 1 RWM field decreases to near zero; radial field increasing
- Subsequent growth of poloidal RWM field
  - *Asymmetric* above/below midplane
- Radial sensors show RWM bulging at midplane
  - midplane signal increases, upper/lower signals decrease
  - Theory: may be due to other stable ideal n = 1 modes becoming less stable
- Approach
  - Include full set of RWM sensors (upper and lower, B_p and B_r) in feedback circuit – new PCS capability (tested piggyback 2006)

Does stable high β_N, low ω_ϕ region exist *without* feedback in NSTX?

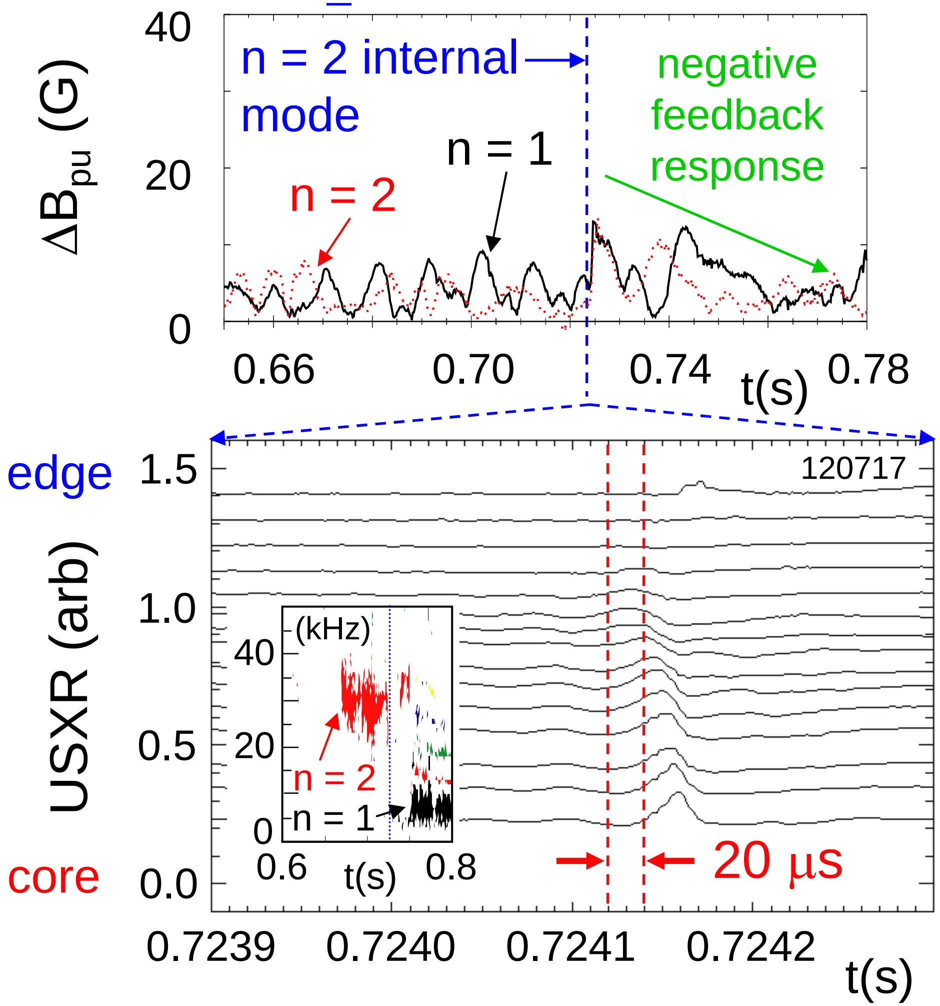


- Non-resonant n = 3 magnetic braking used to slow profile
  - The $\omega_\phi/\omega_A < 0.01|_{q = 2}$
  - The $\omega_\phi/\Omega_{crit} = 0.2|_{q = 2}$
  - The $\omega_\phi/\Omega_{crit} = 0.3|_{axis}$
  - Less than ½ of ITER Advanced Scenario 4 $\omega_\phi/\Omega_{crit}$ (Liu, et al., NF **45** (2005) 1131.)
- Possible energy dissipation at low rotation speeds
  - trapped particle precession drift stabilization at $\omega_\phi < \omega_{*i}$ (Betti and Hu, PRL 93 (2004) 105002.)
- Approach
  - Generate $\beta_N > \beta_N^{\text{no-wall (n = 1)}}$ actively stabilized plasma at low ω_ϕ magnitude
  - Gate feedback off/on to probe low rotation stable operating regime (seen in DIII-D – Reimerdes, et al. PRL **98** (2007) 055001.)

n = 2 RWM does not become unstable during n = 1 stabilization

Control ON

(fast β_N drop, plasma recovers)



- Internal mode ~ 25 kHz (n=2)

- …but, can the n = 2 RWM be driven unstable at higher β_N?
  - Unstable n = 1 – 3 RWMs already observed in NSTX (Sabbagh, et al., NF **46** (2006) 635.)
  - Generate controlled, measured n = 2 RFA during n = 1 stabilization, and drive unstable

- Approach
  - RFA measurements for n = 2 and 3 can be made for most conditions
  - To destabilize n = 2 RWM, use "optimized" control system configuration and plasma configuration to maximize β_N

XP728: Active RWM Stabilization - Run plan (Part 1)

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 - 123529 as setup shot)	1
C) Drop I_p to 0.9 MA from 1.0 MA	1
2) Reproduce active RWM stabilization at low plasma rotation	
A) n = 3 braking, n = 1 feedback w/B_{pu} sensors, adjust n = 3 braking if $\omega_\phi > 0.5\ \Omega_{crit}$	2
B) Reproduce (2A) with n = 1 feedback off - demonstrate unstable RWM at low ω_ϕ	2
3) Optimize n = 1 feedback sensors at low ω_ϕ	
A) Adjust relative phase between sensors / RWM coil current if (2A) <> shot 120717	3
B) Add B_{pl} sensors to feedback circuit	1
C) Use B_{pu} + B_{pl} average (150 degree spatial offset)	1
F) Vary relative phase between sensors / RWM coil	4
D) Add upper/lower B_r sensors to feedback circuit	1
E) Add B_{ru} + B_{rl} average (260 degree spatial offset)	2
G) Vary relative phase / feedback parameters to further optimize performance	6
	Total: 24

XP728: Active RWM Stabilization - Run plan (Part 2)

Task	Number of Shots
4) n = 1 RWM stabilization with various rotation profiles < Ω_{crit}	
(best feedback settings from step (3))	
A) Vary n = 3 braking current to create scan of profiles 0 < ω_ϕ << Ω_{crit} Gate off active feedback for many wall times (100 ms) to determine which, if any profiles are stable at low rotation without n = 1 feedback	8
B) If any ω_ϕ profiles are stable without n = 1 feedback in (5A), re-run shot with feedback turned off	2
5) Check pre-programmed average of n = 1 feedback current for stabilization	
A) Attempt stabilization using avg. n = 1 feedback current for best case of (3) above	2
B) If successful, vary plasma parameter(s) (e.g. κ) to test robustness of stabilization	2
6) Measure n > 1 RFA at maximum β_N; attempt n = 2 RWM destabilization with n = 1 stable	
A) Take highest β_N stabilized plasma at low and run at maximum $\beta_N/\beta_N^{no-wall}$ (options: increase NBI power, optimize DRSEP, use lithium, drop I_p by 100A)	2
7) Examine feedback performance vs. feedback system latency	
A) Increase feedback system latency from optimized settings to find critical latency for mode stabilization	6

Total: **16** w/o latency scan; 22 with latency scan

XP728: Active RWM stabilization - Diagnostics

- Required diagnostics
  - Internal RWM sensors
  - CHERS toroidal rotation measurement
  - Thomson scattering (30 point)
  - USXR
  - MSE
  - Toroidal Mirnov array / between-shots spectrogram with toroidal mode number analysis
  - Diamagnetic loop
- Desired diagnostics
  - FIReTip
  - Fast camera