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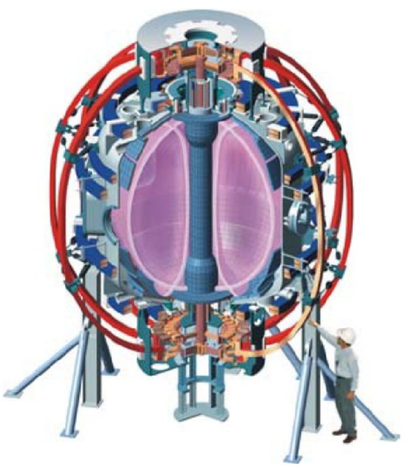
XP830: Resistive Wall Mode Stabilization Physics – Comparison to Theory

J.W. Berkery, S.A. Sabbagh, H. Reimerdes

Department of Applied Physics, Columbia University, New York, NY



NSTX Team Review Meeting

April 21, 2008

Princeton Plasma Physics Laboratory

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Lodestar
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XP830: Resistive Wall Mode Stabilization Physics

- Goals
  - Determine stabilization physics - compare between experiment and theory
    - Expand RWM critical rotation profile database – destabilize RWM with n=3 braking
    - Kinetic effects: using University of Rochester code, and possibly MARS-K
  - Investigate the effect of various rotation profiles on kinetic stabilization
    - Wide range of rotation profiles available, from very broad to peaked with no rotation at the q=2 surface.
  - Investigate stabilization over the widest possible range of ion collisionality
  - Make comparisons to DIIID
    - Aspect ratio and trapped ion fraction are expected to be important
- Addresses
  - Joule Milestone (2008) and FY2009 milestone (R09-1)
    - "Further understand the physics of RWM stabilization and control as a function of plasma rotation"
  - ITPA MDC-2: Joint experiments on RWM physics.

RWM Energy Principle – Kinetic Effects

$$\gamma \tau_w = -\frac{\delta W_{tot}^{\infty}}{\delta W_{tot}^{b}}$$

(Haney and Freidberg, PoF-B **1** (1989) 1637)

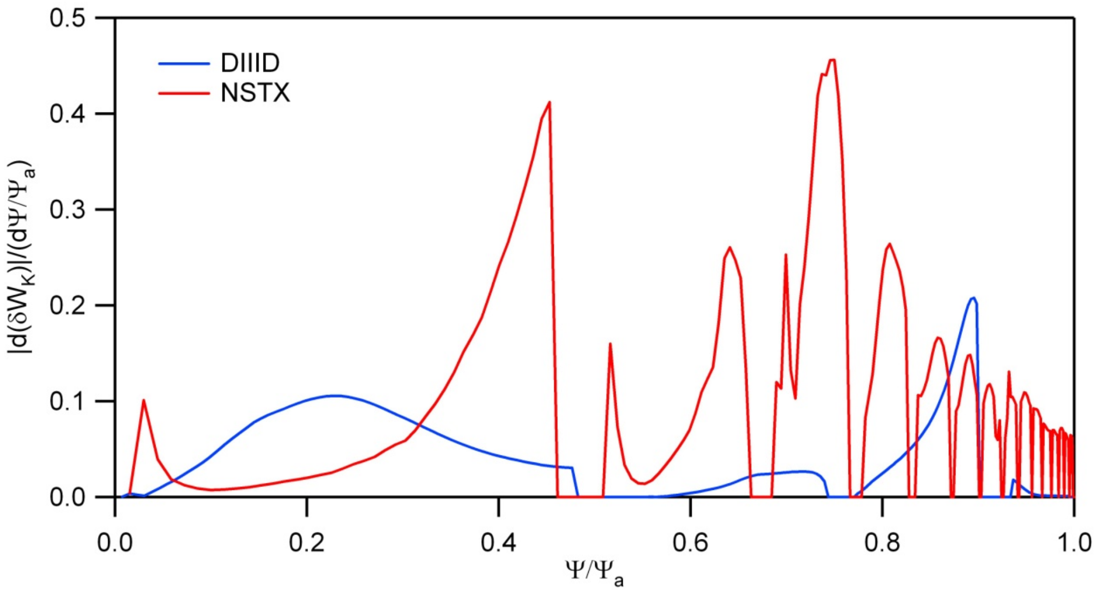
$$(\gamma \tau_w)_K = -\frac{\delta W_{tot}^{\infty} + \delta W_K}{\delta W_{tot}^{b} + \delta W_K}$$

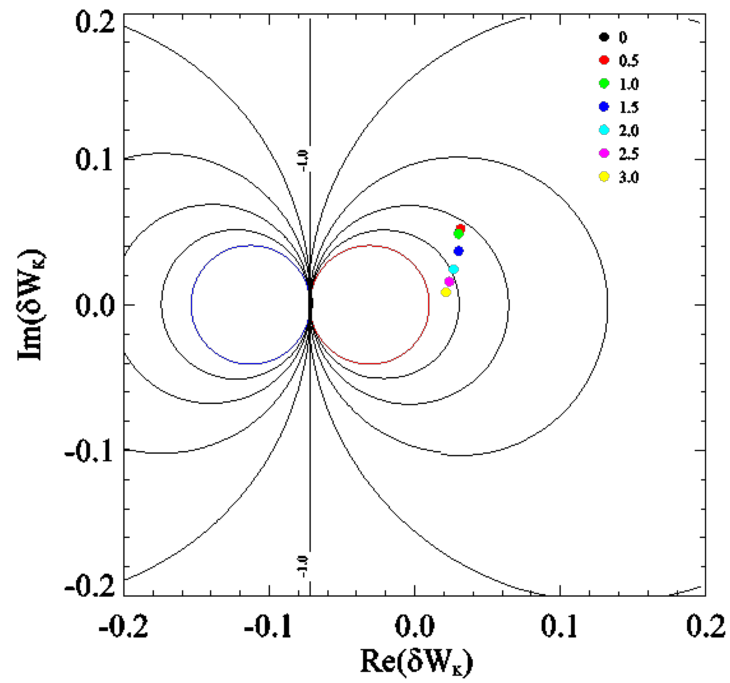
(Hu, Betti, and Manickam, PoP **12** (2005) 057301)

PEST → δW_{tot}^{b}

Hu/Betti/Manickam → δW_K

Preliminary NSTX Results from Hu/Betti Code

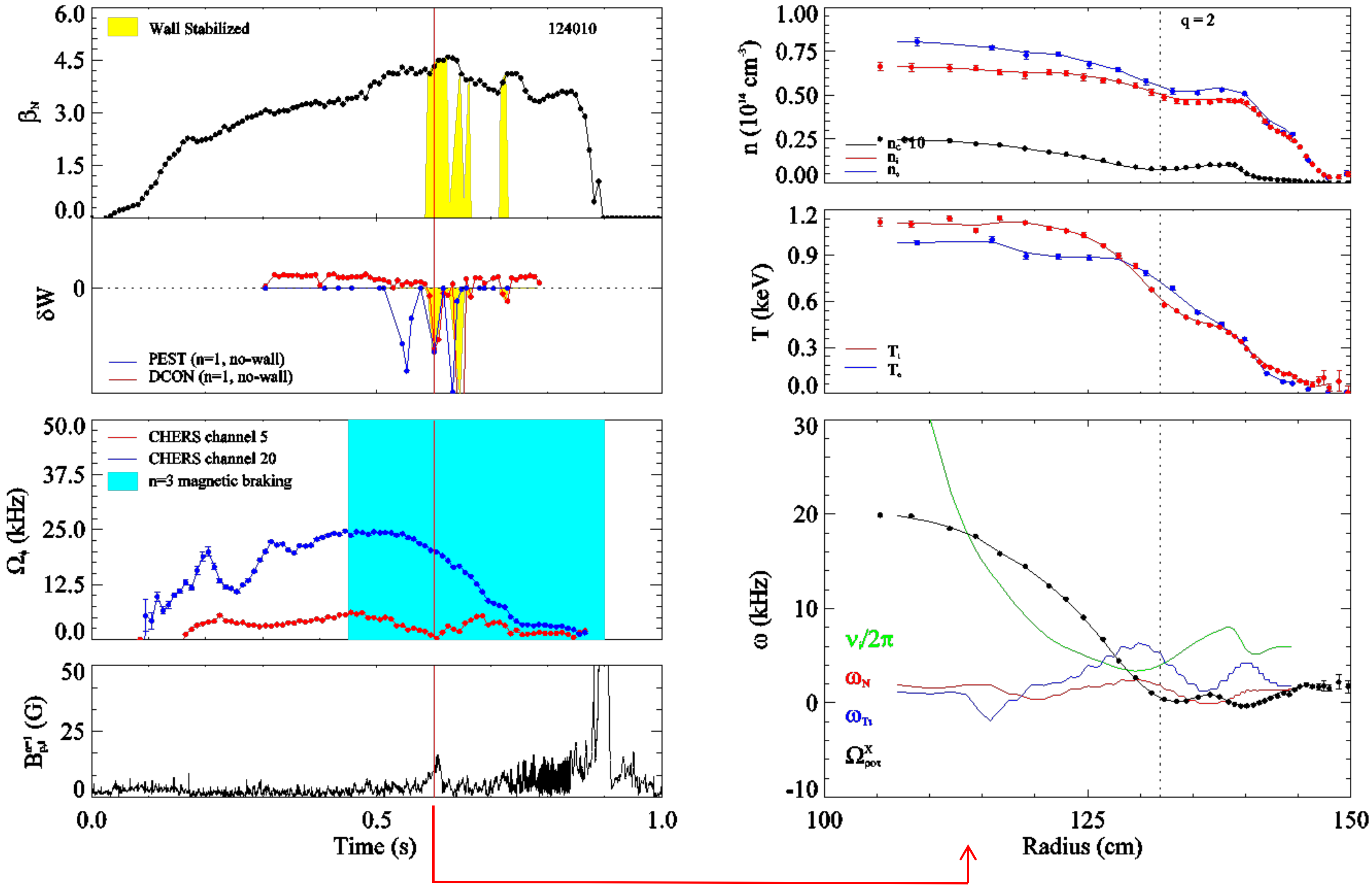




$$\delta W_K \propto \int_0^\infty \left[\frac{\omega_{*N} + \left(\hat{\varepsilon} - \frac{3}{2}\right)\omega_{*T} + \omega_E - \omega}{\langle \omega_D \rangle + l\omega_b - i\nu_{\text{eff}} + \omega_E - \omega} \right] \hat{\varepsilon}^{5/2} e^{-\hat{\varepsilon}} d\hat{\varepsilon}$$

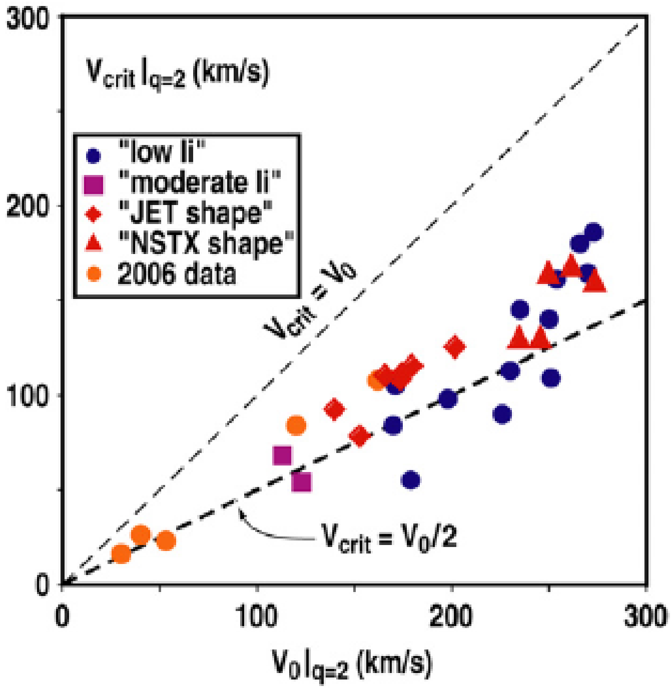
- Strongest kinetic effect: trapped ion precession drift frequency
  - Depends inversely on ion collision frequency
  - Depends on rotation frequency through ω_E.

Various Frequencies are Important

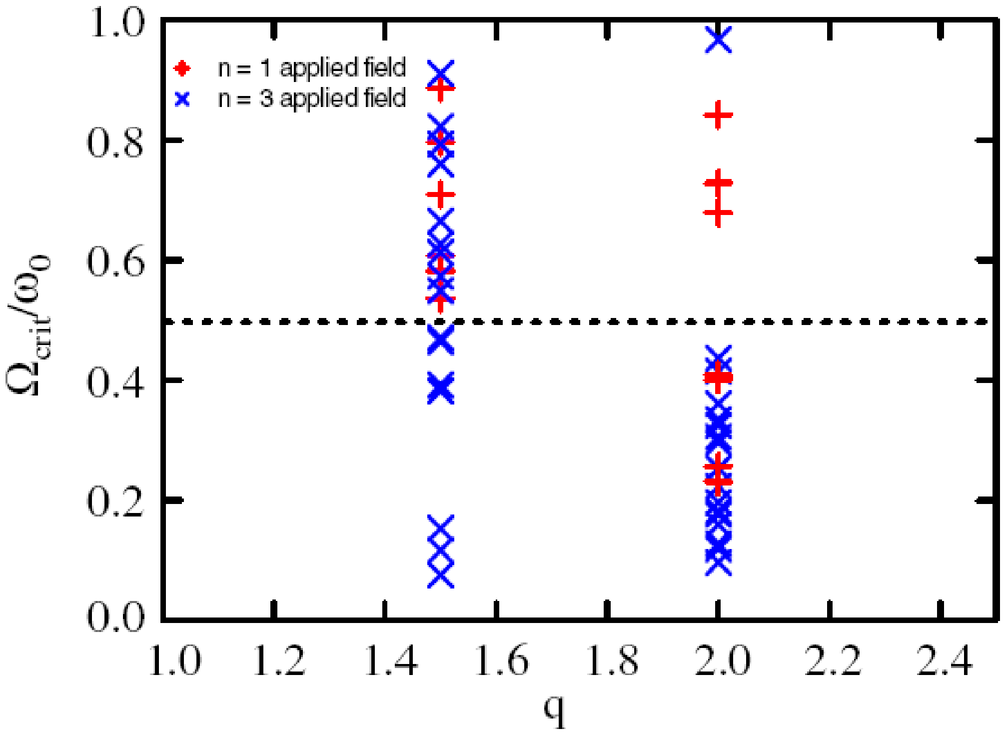


(profiles at t = 0.601s)

NSTX and DIII-D Rotation Thresholds not Consistent



(Garofalo, et al., NF **47** (2007) 1121)



(Sontag, et al., NF **47** (2007) 1005)

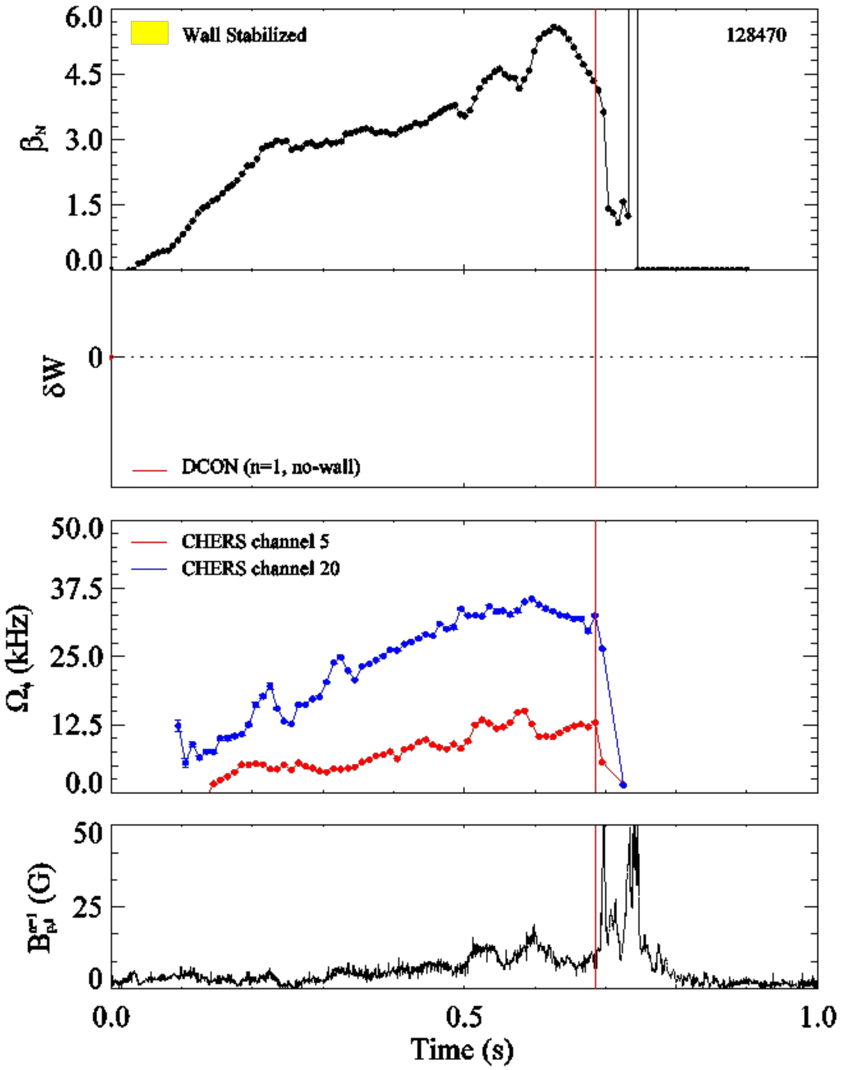
DIII-D

- Rotation threshold may be dominated by error field.

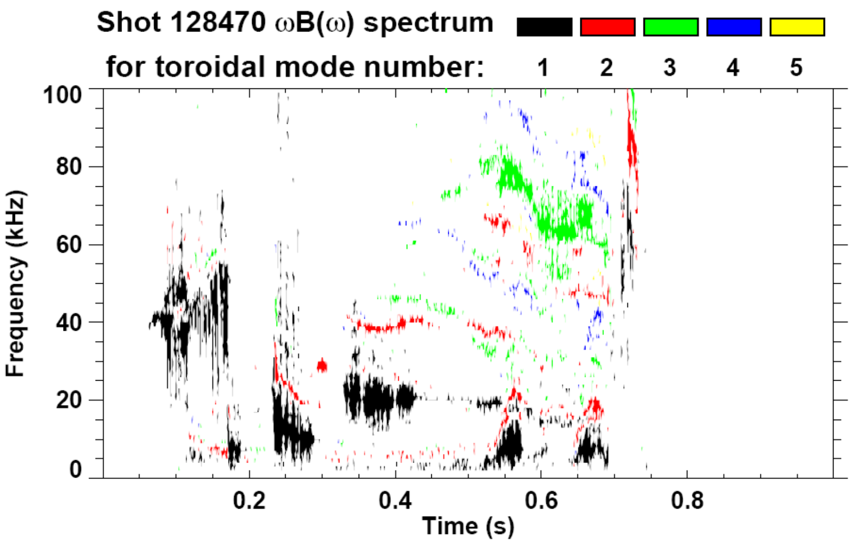
NSTX

- Not consistent with this model
- Possibly due to large trapped ion fraction, which may stabilize RWM through kinetic effects.

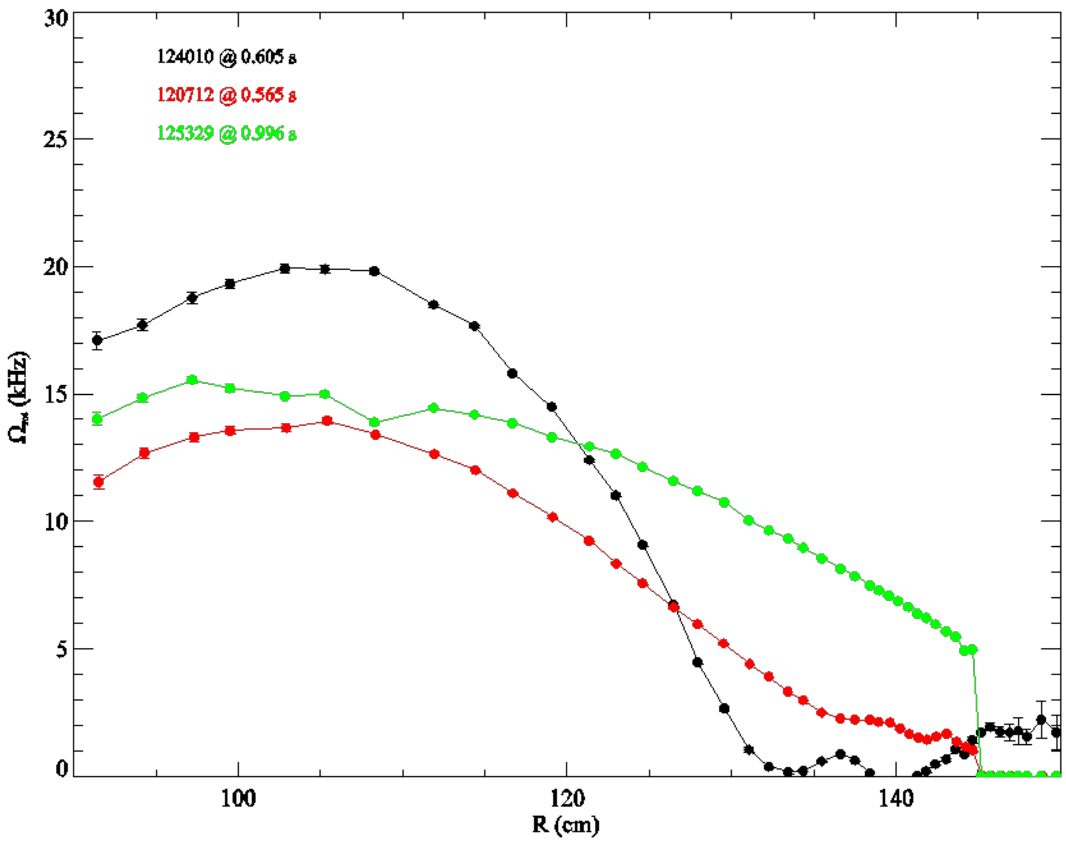
Setup Shot – Create a Long n=1 Mode Free Period



- 128470 from Sabbagh's XP 802, 4/11
  - Create a long window free of n=1 rotating modes
  - Ramp the n=3 braking field.

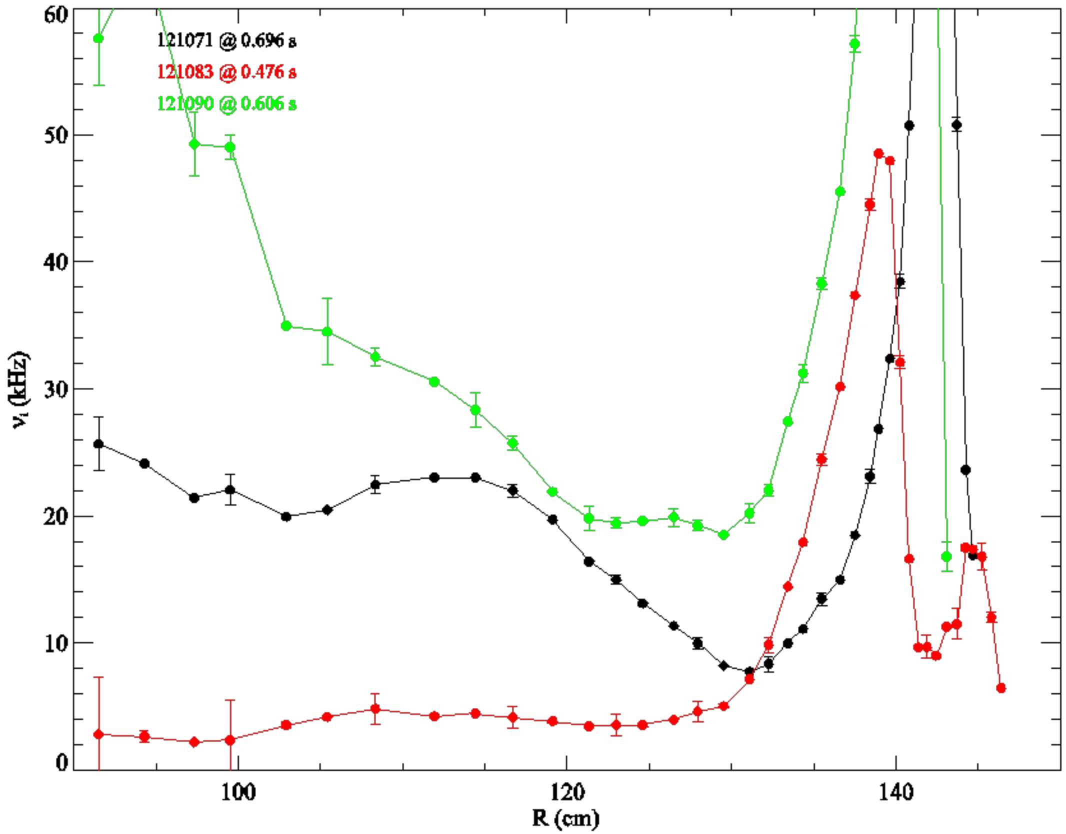


Rotation Profiles



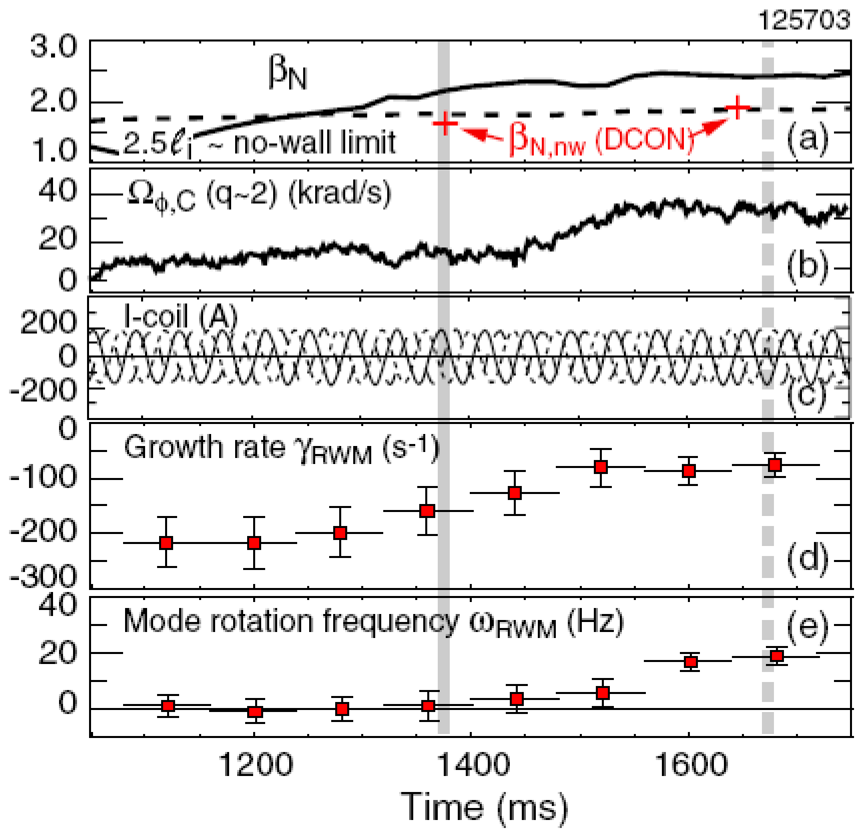
- Variety of rotation profiles
  - From very broad to peaked with zero rotation at q=2
  - Created by varying the timing and magnitude of the n=3 DC correction/braking field.

Collisionality



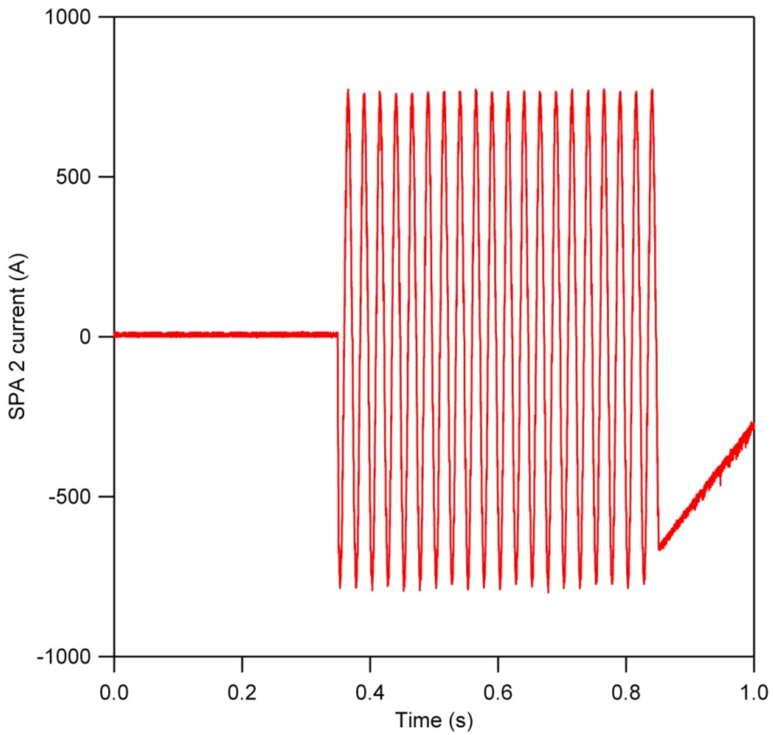
- Variation of collisionality
  - Demonstrated by XP619.
  - Accomplished by changing the density (changing B_t and I_p at fixed q).

Active MHD Spectroscopy



(Reimerdes, et al., PPFC **49** (2007) B349)

- Gives a measurement of the growth rate and rotation frequency of a weakly damped, stable RWM.



XP830: RWM Stabilization Physics - Run plan

Run plan:

Task	Number of Shots
1) Establish target	
A) Use 128470 as setup shot (relatively high elongation ~ 2.3 to avoid rotating modes). Increase I_p from 0.8 to 0.9 MA (B_t = -0.45T), start n=3 correcting field at 0.250 s, ramping to full amplitude at 0.300 s.	3
2) Add the AC active MHD spectroscopy field	
A) Vary the frequency and n=1 applied field amplitude (will provide full waveform details for PCS).	5

f (Hz)	Propagation	Peak to peak amplitude (kA)
50	counter	1.9
30	counter	1.55
40	co-	1.7
70	co-	2.0
100	co-	2.7

Task	Number of Shots
3) Vary the n=3 DC field timing and magnitude	
A) Correct n=1 error filed using feedback system, Bp sensor filter time = 50 ms.	3
B) During the period devoid of n=1 rotating mode activity, vary the DC field from correcting phase to braking phase, and vary the SPA current ramp rate.	6
C) Vary SPA current timing to further alter rotation by moving the n=3 correcting pulse later in time for a more peaked profile. Vary the braking time as needed.	4
4) Ion collisionality variation	
A) Vary ν_i by operating at Ip = 1.1 MA, B_t = -0.55T (constant q). Drop B_t if bN < 4. Change ramp rate on the braking field to get 3 different rotation profiles (based on step 3).	6
B) Vary ν_i by operating at Ip = 0.7 MA, B_t = -0.35T (constant q). Change ramp rate on the braking field to get 3 different rotation profiles (based on step 3).	6
5) Comparison to DIII-D	
A) With above steps completed, determine if closer matches to DIII-D can be made and alter plasma conditions and SPA currents to allow this.	6
Total:	39

XP830: RWM Stabilization Physics - Diagnostics

- Required diagnostics / capabilities
  - Ability to operate RWM coils in n = 3 configuration
  - 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