n=3 Braking with Optimal n=1 Error Field Correction

Presented by:
Andrea M. Garofalo, *Columbia University*

Review of XP 729

June 5, 2007
Princeton Plasma Physics Laboratory

Columbia University

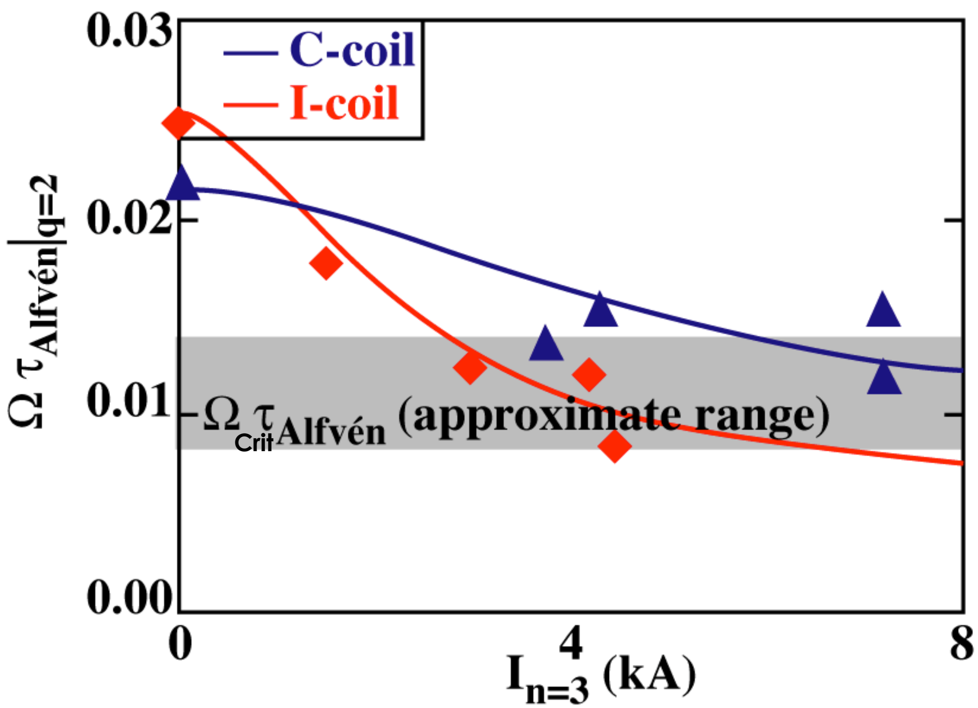
Background and Motivation

- **Magnetic braking of the toroidal plasma rotation using non-resonant, n>1 magnetic fields has been carried out in both NSTX and DIII-D in the past few years**
  - On NSTX, this technique has led to the destabilization of the n=1 RWM.
  - On DIII-D, the non-resonant braking effect was observed to decrease with lower rotation. The braking becomes ~zero at an "offset" rotation which is above the rotation threshold for RWM stabilization. This behavior of the braking effect vs. plasma rotation is consistent with theoretical predictions from the theory of Neoclassical Toroidal Viscosity by Kerchung Shaing.
- **Why is this behavior of the non-resonant braking effect not observed in NSTX?**
  - because the "offset" rotation is below the threshold rotation for stabilization of the RWM
  - or because residual, uncorrected n=1 error fields give origin to resonant braking effects (“induction motor model”, Fitzpatrick, Phys. Plasmas 1998) that lead to rotation bifurcation before either the "offset" rotation or the RWM rotation threshold is reached
  - or because …?

Columbia University

Non-Resonant n=3 Braking in DIII-D Does Not Lead to RWM Onset

- **n=3 magnetic braking can create large drag torque**
- **RWM remains stable when correction of n=1 error field is optimal (DEFC)**



$$dL/dt = T_{NB} - L/\tau_M - k(\Omega - \Omega_D)\, I_{n=3}^2$$

- **Braking effect saturates as braking field is increased**
- **Saturated rotation agrees with neoclassical toroidal viscosity model**

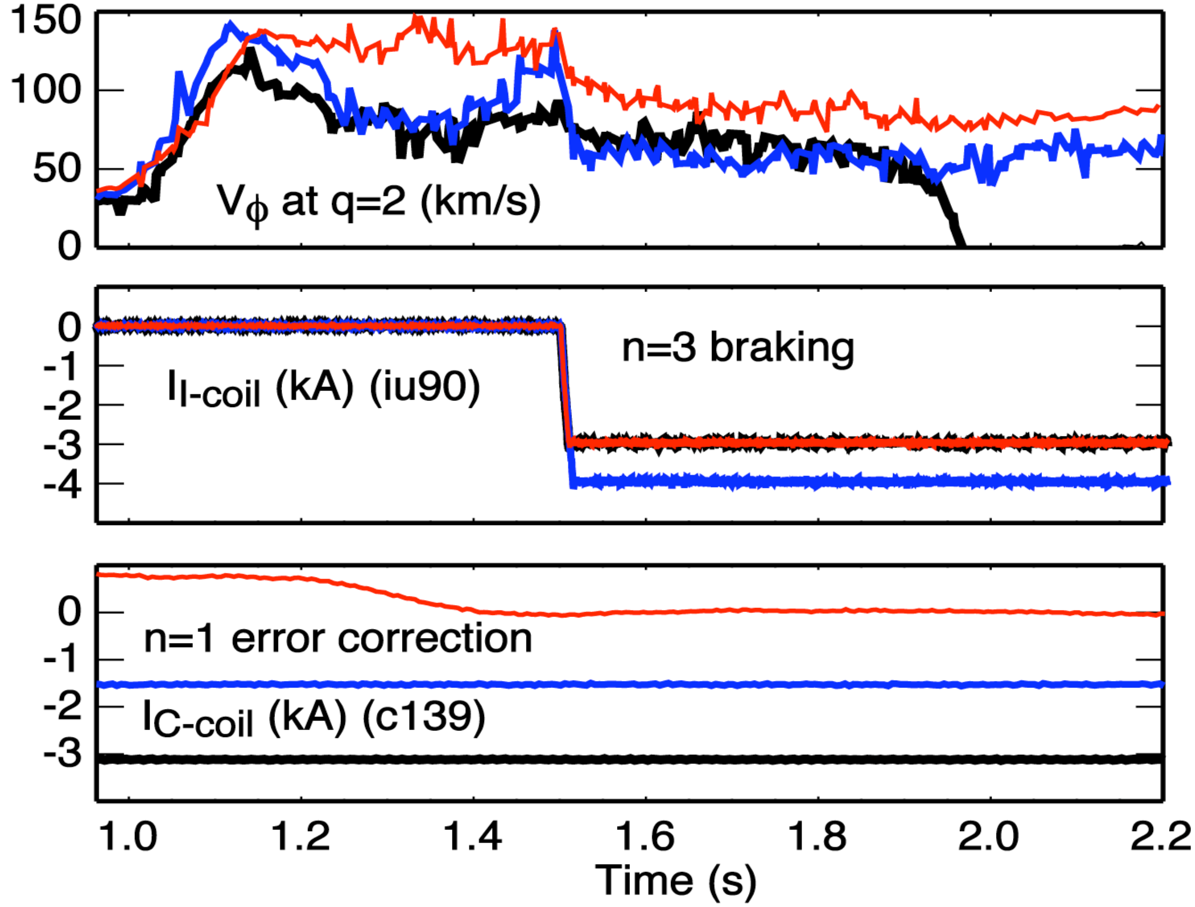
$$\Omega_D \sim 2/3 \nabla T_i /(Z_i e B_\theta R)$$

  - K.C. Shaing, S.P. Hirshman and J.D. Callen, Phys. Fluids **29**, 521 (1986)

DIII-D
NATIONAL FUSION FACILITY

Non-Resonant n=3 Braking Can Lead to Unstable RWM, If n=1 Error Correction Is Non-optimal

- C-coil used for n=1 error field correction (red=optimal)
- I-coil used for n=3 magnetic braking



- Small n=1 error field introduced accidentally (one C-coil pair)
- RWM onset observed for sufficiently large n=3 and n=1 error field

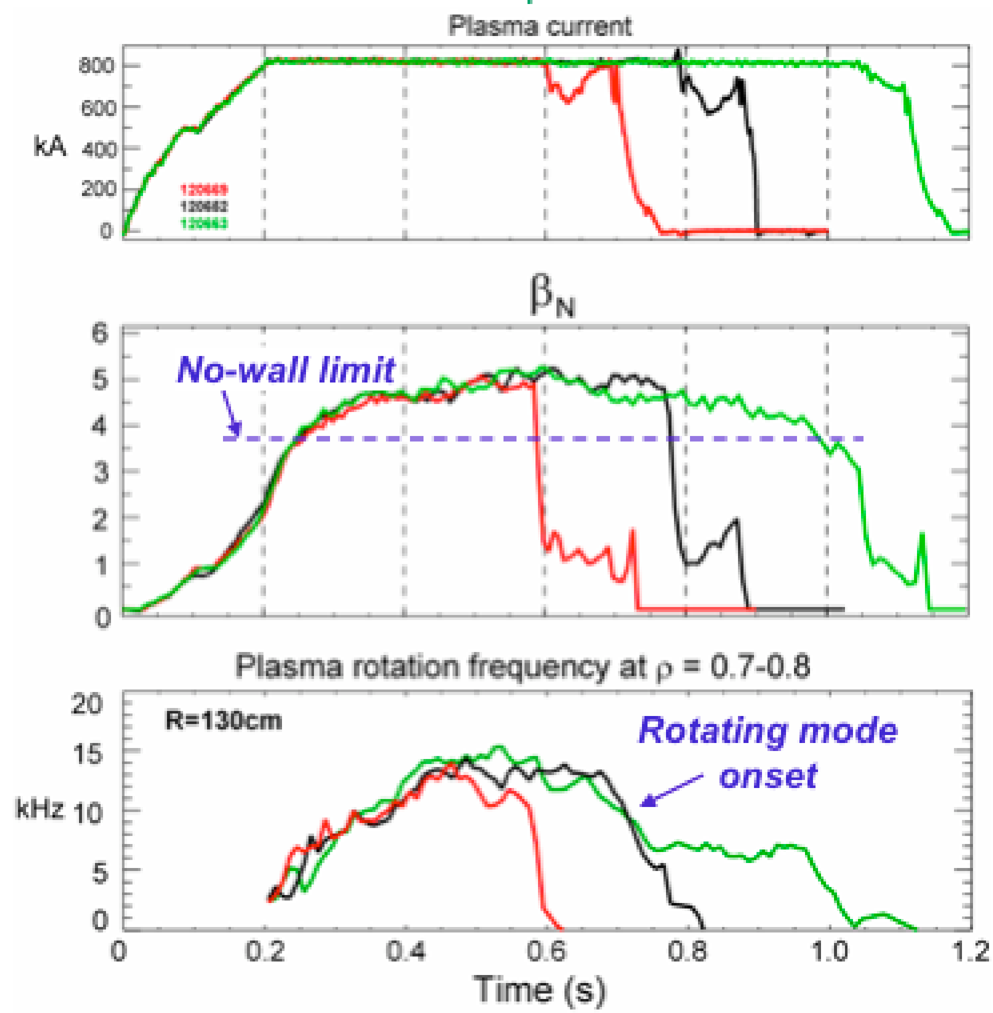
DIII-D NATIONAL FUSION FACILITY

Previous n=3 Braking Experiments in NSTX Have Been Performed Without Error Field Control

- **Menard's 2005-06 NSTX experiments on error field identification and control have shown that Dynamic Error Field Correction (i.e. using RWM feedback) optimizes plasma performance**
  - Suggests previous n=3 experiments had residual, uncorrected n=1 error fields

J.E. Menard, APS-DPP Meeting, Philadelphia, 2006 →

- No error field control during high β_N phase
- TF-EFC
- TF-EFC + active n=1 B_P feedback



Experimental Approach

- **We propose to carry out n=3 braking in discharges for which the n=1 error field correction (EFC) has been optimized by using dynamic EFC by the RWM feedback system.**
  - **Operating above n=1 NW limit, determine the optimal n=1 EFC using n=1 RWM feedback. Could use reference discharge from previous dynamic error field correction experiments by Menard, or use Menard's procedure on a new target.** ***(4 shots)***
    - May need to pre-program the feedback-driven currents and iterate a few times with RWM feedback on, until the feedback currents do not deviate from the preprogrammed currents.

Columbia University

Experimental Approach (cont.)

- Turn RWM feedback off and add n=3 braking currents (square-step waveform) on top of the currents for optimal correction of the n=1 error field. Vary the n=3 amplitude and sign. (*5 shots*)
  - Look for saturation of the braking effect with increasing n=3 amplitude

- If n=3 braking alone is NOT sufficient to destabilize an RWM:
  - Vary q95, look for change on braking effect. *(3 shots)*
  - Reduce the n=1 correction currents until the RWM onset is observed. *(3 shots)*

- If n=3 braking is sufficient to destabilize an RWM:
  - Reduce NBI energy, look for change in rotation threshold. *(6 shots)*

  or
  - Scale down Bt and Ip, look for change in rotation threshold. *(6 shots)*

  or
  - Using n=3 amplitude below max allowable:
    - Vary q95, look for change on braking effect. *(3 shots)*
    - Vary density, look for change on braking effect. *(3 shots)*

Columbia University