Princeton Plasma Physics Laboratory **NSTX Experimental Proposal**			
Title: **n = 3 magnetic braking with optimal n = 1 error field correction**			
OP-XP-729	Revision:	Effective Date: Expiration Date: *(2 yrs. unless otherwise stipulated)*	
PROPOSAL APPROVALS			
Responsible Author: A.M. Garofalo			Date
ATI – ET Group Leader: S.A. Sabbagh			Date
RLM - Run Coordinator: D. Gates			Date
Responsible Division: Experimental Research Operations			
Chit Review Board (designated by Run Coordinator)			
MINOR MODIFICATIONS (Approved by Experimental Research Operations)			

NSTX EXPERIMENTAL PROPOSAL

n = 3 magnetic braking with optimal n = 1 error field correction   OP-XP-729

AUTHOR: **A.M. Garofalo, J. Menard, S.A. Sabbagh**   DATE:

---

1. Overview of planned experiment

We propose to investigate the effects of n=3 magnetic braking of the toroidal rotation in a plasma with beta above the n=1 no-wall stability limit, where the n=1 error field correction (EFC) has been optimized. In particular, we plan to study the dependence of the RWM rotation threshold on the magnitude of uncorrected n=1 error field, and the dependence of the n=3 braking effect on the plasma rotation.

2. Theoretical/ empirical justification

Menard's 2005-06 NSTX experiments on error field identification and control have shown that Dynamic Error Field Correction (i.e. using RWM feedback) increases the toroidal rotation and optimizes performance of plasmas with beta above the no-wall limit, as shown in Fig. 1. This result implies that previous n=3 experiments on NSTX, conducted without dynamic error field correction, had residual, uncorrected n=1 error fields.

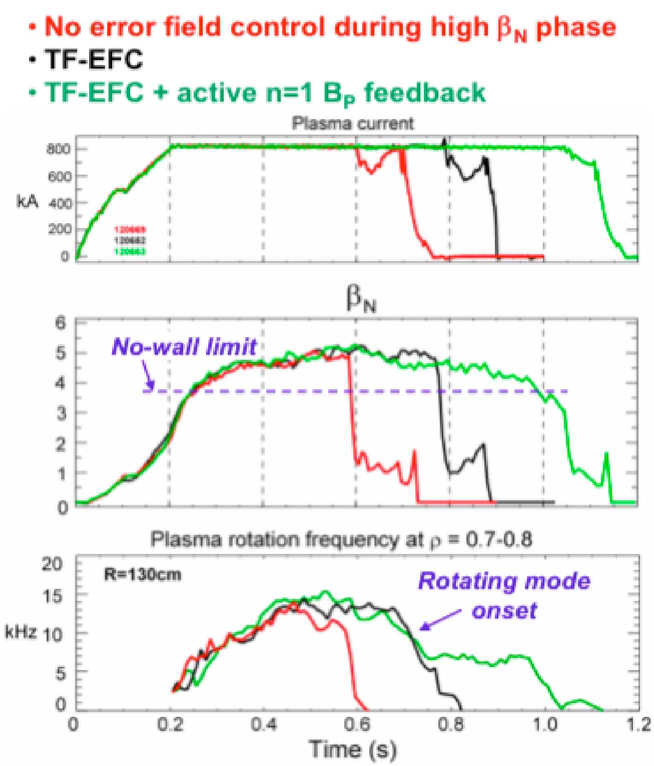

Fig. 1. Improvement of plasma performance using dynamic error field correction [J.E. Menard, et al., APS-DPP Meeting, Philadelphia, 2006].

On DIII-D, n=3 braking has been shown to destabilize the RWM at high plasma toroidal rotation, if the n=1 error correction is non-optimal. However, it was found that the resonant braking from an n=1 error field leads to an effective RWM threshold much higher than the true linear-stability threshold [A.M. Garofalo, et al., Proc. 21st Int. Conf. Chengdu, 2006 (Vienna: IAEA)]. With optimal n=1 error field correction, non-resonant n=3 braking in DIII-D does not produce an RWM onset. Furthermore, the non-resonant braking effect is observed to decrease with lower toroidal rotation. The braking becomes ~zero at an "offset" rotation which is above the rotation threshold for RWM stabilization [S. Driskill, et al., Bull. Am. Phys. Soc. 50(8), 152 (2005)]. This behavior of the braking effect vs. plasma rotation is consistent with theoretical predictions from a neoclassical toroidal viscosity (NTV) model of momentum dissipation [K.C. Shaing, et al., Phys. Fluids 29, 521 (1986)].

This experiment plans to investigate whether applying n=3 magnetic braking with or without an n=1 error field yields a different rotation threshold for RWM stabilization in NSTX.

3. Experimental run plan

We propose to carry out n=3 braking in discharges with beta above the n=1 no-wall stability limit for which the n=1 error field correction (EFC) has been optimized with respect to the plasma rotation using dynamic EFC with the RWM feedback system.

1. Operating above n=1 no-wall limit, determine the optimal n=1 EFC. *(5 shots)*
    a. Use as starting point discharge 124634. Keep max injected power below 5.5 MW.
    b. Add OHxTF compensation
    c. Pre-program the OHxTF compensation currents and add MODEID feedback using BPU (gain=0.6)
    d. Update shot-to-shot the pre-programmed currents, based on the request from the MODEID feedback. May need to iterate a few times with RWM feedback on, until the feedback currents do not deviate from the preprogrammed currents.
2. 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. (*4 shots*)
    a. Use steps of 0.5 kA, 1 kA, 2 kA of n=3 current
    b. Look for saturation of the braking effect with increasing n=3 amplitude

3. If n=3 braking alone <u>IS NOT</u> sufficient to destabilize an RWM:
    a. Vary q95, look for change on braking effect. *(3 shots)*
        1. Increase Ip and decrease Bt: go from (4.5 T, 900 kA) to (4.4 T, 1 MA), to (4.3 T, 1.1 MA), to (4.2 T, 1.2 MA)
    b. Reduce the n=1 correction currents until the RWM onset is observed. *(3 shots)*
        1. Reduce correction currents by factor of 1/3, 2/3, 3/3.

4. If n=3 braking IS sufficient to destabilize an RWM:
    a. Scan NBI energy, look for changes in rotation threshold. *(6 shots)*
        1. Try to keep constant the injected power, as the voltages for two of the NBI sources are varied.
        2. Start with 70 kV and max duty cycle; increase voltages to 75, 80, 85, 90 kV, stepping down the duty cycle to keep approximately the same injected power.

4. Required machine, NBI, RF, CHI and diagnostic capabilities

This experiment requires the completion, or near-completion, of experiments XP702 and XP728.

As usual, standard magnetic diagnostics are essential. Diamagnetic loop and Thomson scattering are required since partial kinetic EFIT reconstructions will be essential for this experiment. CHERS is required for toroidal rotation and ion temperature profile evolution. MSE coverag is highly desirable.

5. Planned analysis

EFIT/LRDFIT will be performed.

6. Planned publication of results

This XP will provide important results for the 2008 IAEA Fusion Energy Conference. The data would be shown in the conference paper, presentation, and associated Nuclear Fusion paper.

PHYSICS OPERATIONS REQUEST

Title **OP-XP-729**

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): 4.5 kG field Flattop start/stop (s):

I_P (MA): 0.7 – 1.1 MA Flattop start/stop (s):

Configuration: **see setup shot ######**

Outer gap (m): Inner gap (m):

Elongation κ: Triangularity δ:

Z position (m):

Gas Species: **D** Injector(s):

NBI - Species: **D** Sources:A,B,C Voltage (kV): 90 (MSE) Duration (s):

ICRF – Power (MW): Phasing: Duration (s):

CHI:

Either: List previous shot numbers for setup: use setup shot #####, 124437 for n = 3 waveform

Or: Sketch the desired time profiles, including inner and outer gaps, κ, δ, heating, fuelling, etc. as appropriate. Accurately label the sketch with times and values.

DIAGNOSTIC CHECKLIST

Title **OP-XP-729**

Diagnostic	Need	Desire	Instructions
Bolometer – tangential array		X	
Bolometer – divertor		X	
CHERS – toroidal	X		
CHERS – poloidal		X	
Divertor fast camera		X	
Dust detector		X	
EBW radiometers		X	
Edge deposition monitors		X	
Edge pressure gauges		X	
Edge rotation diagnostic		X	
Fast ion D_alpha - FIDA		X	
Fast lost ion probes - IFLIP		X	
Fast lost ion probes - SFLIP		X	
Filterscopes		X	
FIReTIP		X	
Gas puff imaging		X	
Hα camera - 1D		X	
High-k scattering		X	
Infrared cameras		X	
Interferometer - 1 mm		X	
Langmuir probes - divertor		X	
Langmuir probes – RF antenna		X	
Magnetics – Diamagnetism	X		
Magnetics - Flux loops	X		
Magnetics - Locked modes	X		
Magnetics - Pickup coils	X		
Magnetics - Rogowski coils	X		
Magnetics - RWM sensors	X		
Mirnov coils – high frequency	X		
Mirnov coils – poloidal array	X		
Mirnov coils – toroidal array	X		
MSE	X		
NPA – ExB scanning		X	
NPA – solid state		X	
Neutron measurements	X		
Plasma TV		X	
Reciprocating probe			
Reflectometer – 65GHz		X	
Reflectometer – correlation		X	
Reflectometer – FM/CW		X	
Reflectometer – fixed f		X	
Reflectometer – SOL		X	
RF edge probes		X	
Spectrometer – SPRED		X	
Spectrometer – VIPS		X	
SWIFT – 2D flow		X	
Thomson scattering	X		
Ultrasoft X-ray arrays	X		
Ultrasoft X-ray arrays – bicolor		X	
Ultrasoft X-rays – TG spectr.		X	
Visible bremsstrahlung det.		X	
X-ray crystal spectrometer - H		X	
X-ray crystal spectrometer - V		X	
X-ray fast pinhole camera		X	