Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: **Test of β_N-Control for Disruptivity Reduction**		
OP-XP-1019	Revision: **0**	Effective Date: *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

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Responsible Division: Experimental Research Operations

RESTRICTIONS or MINOR MODIFICATIONS

(Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

TITLE: **β-Control for Disruptivity Reduction** No. **OP-XP-1019**
AUTHORS: **Gerhardt, et al.** DATE:

1. Overview of planned experiment

The purpose of this experiment is to test the efficacy of the β_N-control system for 1) reducing disruptivity and 2) minimizing stored energy transients, both across confinement transitions and during otherwise steady-state conditions. Discharges that are unstable without β_N control will be run with β_N control on, to determine the ability of the control system to interdict ideal instabilities. The required time response of the β_N control system will be tested by scanning the time-constant of the causal low-pass filter on the rtEFIT β_N value.

2. Theoretical/ empirical justification

It is desirable to run an ST with the highest β_N, in order to maximize the non-inductive current fraction (for constant q); there is typically an upper bound on the achievable β_N due to instabilities such as the RWM. NSTX has historically run with feed-forward control of the injected power. This has been successful in achieving high-noninductive fractions and reliable scenarios. However, it has often been necessary to reduce the injected power, in order to ensure that confinement transients do not push β_N above stability limits. This problem can be especially pernicious if those confinement transients are sustained as improved confinement regimes. It is hoped that feedback control of the injected power, in order to achieve a pre-programmed value of the requested $\beta_{N,}$, will allow more reliability operation near β_N limits and reduced disruptivity across confinement transients.

3. Experimental run plan

3.1 Development of target.

3.1.1 Target is high-κ, high-δ shape used in the 2009 fiducial discharge. Likely use I_P=800 kA and B_T=0.42 T, P_{inj}=6MW. These parameters are historically prone to disruption. (2 shots)

Shot Numbers ______ ______ ______ ______

3.1.2 Reduce power to 4 MW. Add square n=3 pulses at t=0.4, 3 kA amplitude, 3 msec long. If the pulse does not trigger a transition to Enhanced Pedestal H-mode (EP H-mode), then i) move pulse to t=0.5 seconds or ii) increase current to 900 kA. If improved confinement regime occurs, plasma will likely disrupt. If no transition occurs, then discharge should be stable. (2 shots)

Shot Numbers ______ ______ ______ ______

Decision Point #1: If step 3.1.2 generated a transition to an enhanced confinement regime, the go on the "EPH Path" steps below using the shot with the transition as a reference. Otherwise use these as 4MW and 6 MW pre-programmed power references cases for the "HM Path".

3.2 EPH Path: Scan of β_N.

IC 3.2.1: Turn on β_N control, with a requested value equal to the value of β_N before the IC transition. Test that the beam power is indeed reduced after the transition. (2 shots)

Shot Numbers ______ ______ ______ ______

IC 3.2.2: Because gains scale like $(1/\text{confinement})^2$ for a similar response of the β_N control system, reduce proportional and integral gains during period after transition if necessary. (0-2 shots)

Shot Numbers ______ ______ ______ ______

IC 3.2.3: Increase the requested β_N in units of 0.5 during the IC phase until disruption occurs. Bracket the stability limit. (5 shots)

In all cases, leave the early part of the shot alone in order to ensure the regime transition is repeatable.

Shot #	$\beta_{N,req}$	Comment

3.2 HM (=H-Mode) Path: Scan of β_N.

HM 3.2.1: Note the β_N level of the disruptive case at 6 MW ($\beta_{N,6MW}$) and the β_N level of the non-disruptive case at 4MW ($\beta_{N,4MW}$). Turn on β_N control with a request of $\beta_{N,req}=(\beta_{N,6MW}+\beta_{N,4MW})/2$. (2 shots)

Shot Numbers ______ ______ ______ ______

HM 3.2.2: Use a bisection like approach to determine the β_N request that the plasma can tolerate. (5 shots)

Shot #	Average Power	$\beta_{N,req}$	typical β_N	Disruption
	6 MW	NA		
	4MW	NA		

3.3 Scan of filter time constant.

3.3.1 Take a typical stable case from 3.2 and repeat it. Then repeat with a low-pass filter time constant on the β_N request of 50 msec. Increase or decrease this value to find the stable limit. (5 shots)

Shot	τ_{LPF} (msec)	$\beta_{N,req}$	Comment

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

XMP-65 should have been completed before this XP is run.

All profile diagnostics are required: MSE, CHERS, MPTS, Bolometry.

6 MW injection must be available, but RF & CHI are not required.

5. Planned analysis

Equilibrium reconstruction with EFIT and LRDFIT. Likely TRANSP runs for interesting cases. Ideal stability calculations for low-n global MHD may also be useful. Devoted pedestal analysis my also be run if the "EPH Path" is followed, as these shots would be interesting beyond simply global-MHD.

6. Planned publication of results

Successful results (i.e. β_N control leading to improved performance) would make a nice Nuclear Fusion paper. Would get shown by multiple people at IAEA and APS. Also contributes strongly to the FY-10 MHD milestone on disruptivity reduction.

PHYSICS OPERATIONS REQUEST

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Brief description of the most important operational plasma conditions required:

1: The beta-control algorithm must have been successfully tested, as demonstrated by successful completion of XMP-65.

2: 6 MW of NBI power must be available.

3: Profile diagnostics and RWM control must all be available.

Previous shot(s) which can be repeated: This XP will likely use the 2009 high-kappa fiducial shape, though with different vales of I_P and (maybe) B_T.

Machine conditions *(specify ranges as appropriate, strike out inapplicable cases)*

I_{TF} (kA): **0.4-0.45 T** Flattop start/stop (s): **To the I^2t limit of the coil.**

I_P (MA): **700-800 kA** Flattop start/stop (s): **Longest consistent with getting f_{dia}**

Configuration: **DN (maybe slightly biased down)**

Equilibrium Control: **Isoflux** (rtEFIT)

Outer gap (m): **10-15 cm** Inner gap (m): Z position (m):

Elongation: Triangularity (U/L): OSP radius (m):

Gas Species: Injector(s):

NBI Species: **D** Voltage (kV) **A: 90** **B: 90** **C:** 90 Duration (s): **~1.3**

ICRF Power (MW): **0** Phase between straps (°): **N. A.** Duration (s): **0**

CHI: **Off** Bank capacitance (mF):

LITERs: On Total deposition rate (mg/min): **TBD, likely 200 mg/shot**

LLD: Probably no. Temperature (°C):

EFC coils: On Configuration: **Odd**

DIAGNOSTIC CHECKLIST

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Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
Beam Emission Spectroscopy		
Bolometer – divertor		
Bolometer – midplane array		
CHERS – poloidal		
CHERS – toroidal		
Dust detector		
Edge deposition monitors		
Edge neutral density diag.		
Edge pressure gauges		
Edge rotation diagnostic		
Fast cameras – divertor/LLD		
Fast ion D_alpha - FIDA		
Fast lost ion probes - IFLIP		
Fast lost ion probes - SFLIP		
Filterscopes		
FIReTIP		
Gas puff imaging – divertor		
Gas puff imaging – midplane		
Hα camera - 1D		
High-k scattering		
Infrared cameras		
Interferometer - 1 mm		
Langmuir probes – divertor		
Langmuir probes – LLD		
Langmuir probes – bias tile		
Langmuir probes – RF ant.		
Magnetics – B coils	√	
Magnetics – Diamagnetism		
Magnetics – Flux loops	√	
Magnetics – Locked modes		
Magnetics – Rogowski coils	√	
Magnetics – Halo currents		
Magnetics – RWM sensors		
Mirnov coils – high f.		
Mirnov coils – poloidal array		
Mirnov coils – toroidal array		
Mirnov coils – 3-axis proto.		

Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
MSE		
NPA – E||B scanning		
NPA – solid state		
Neutron detectors		
Plasma TV		
Reflectometer – 65GHz		
Reflectometer – correlation		
Reflectometer – FM/CW		
Reflectometer – fixed f		
Reflectometer – SOL		
RF edge probes		
Spectrometer – divertor		
Spectrometer – SPRED		
Spectrometer – VIPS		
Spectrometer – LOWEUS		
Spectrometer – XEUS		
SWIFT – 2D flow		
Thomson scattering		
Ultrasoft X-ray – pol. arrays		
Ultrasoft X-rays – bicolor		
Ultrasoft X-rays – TG spectr.		
Visible bremsstrahlung det.		
X-ray crystal spectrom. - H		
X-ray crystal spectrom. - V		
X-ray tang. pinhole camera		