Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: Implications of an external toroidal field on flux closure of CHI produced discharges

OP-XP- XP006b	**Revision:**	Effective Date: April, 2,2002 *(Ref. OP-AD-97)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

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RLM - Run Coordinator: M. Maingi	Date
Responsible Division: Experimental Research Operations	

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

Implications of an external toroidal field on flux closure of CHI produced discharges

1. Overview of planned experiment

- Starting from a 0.29T high current discharge, impose a toroidal field ramp-up to increase the toroidal field up to 0.6T.

- Starting from a 0.29T high current discharge, impose a toroidal field ramp-down to decrease the toroidal field to about 0.15T.

- Establish a 50 to 100ms current flattop at the end of the toroidal field ramp.

- Characterize the high current flattop portion of the discharge using EFIT, ESC, TSC codes and experimental measurements including: Thomson electron density and temperature profiles, soft x-ray, ion temperature, Mirnov coils and fast camera.

- The current flattop portion may serve as a plasma target for future characterization with auxiliary heating. The parallel feedback control XMP/XP will be used to improve these targets for future characterization with auxiliary heating. HHFW may be injected into some plasmas from this XP.

2. Theoretical / empirical justification

Applying voltage to poloidal flux that connects the lower divertor plates in the presence of ionized plasma and toroidal flux produces a CHI discharge. Experiments on SPHEX and HIST indicates that flux closure (as indicated by EFIT or equivalent reconstructions) and the associated external n=1 mode activity increases as the magnitude of the toroidal field is decreased. At the highest toroidal fields in these experiments (0.15T), the n=1 mode activity diminishes to a very small value or entirely disappears. On HIT, and HIT-II that have the highest toroidal field capability of experiments in this

class, very good n=1 is observed even at 0.5T. In addition, HIT-II is the only machine (other than NSTX) that has operated in a configuration that uses PF coils for equilibrium control. The plans here on NSTX are to operate at 0.15T and at 0.45T to 0.6T to understand the flux closure issue and its relationship to the externally imposed toroidal field, as this is where CHI discharges used on STs differ from that in a Spheromak.

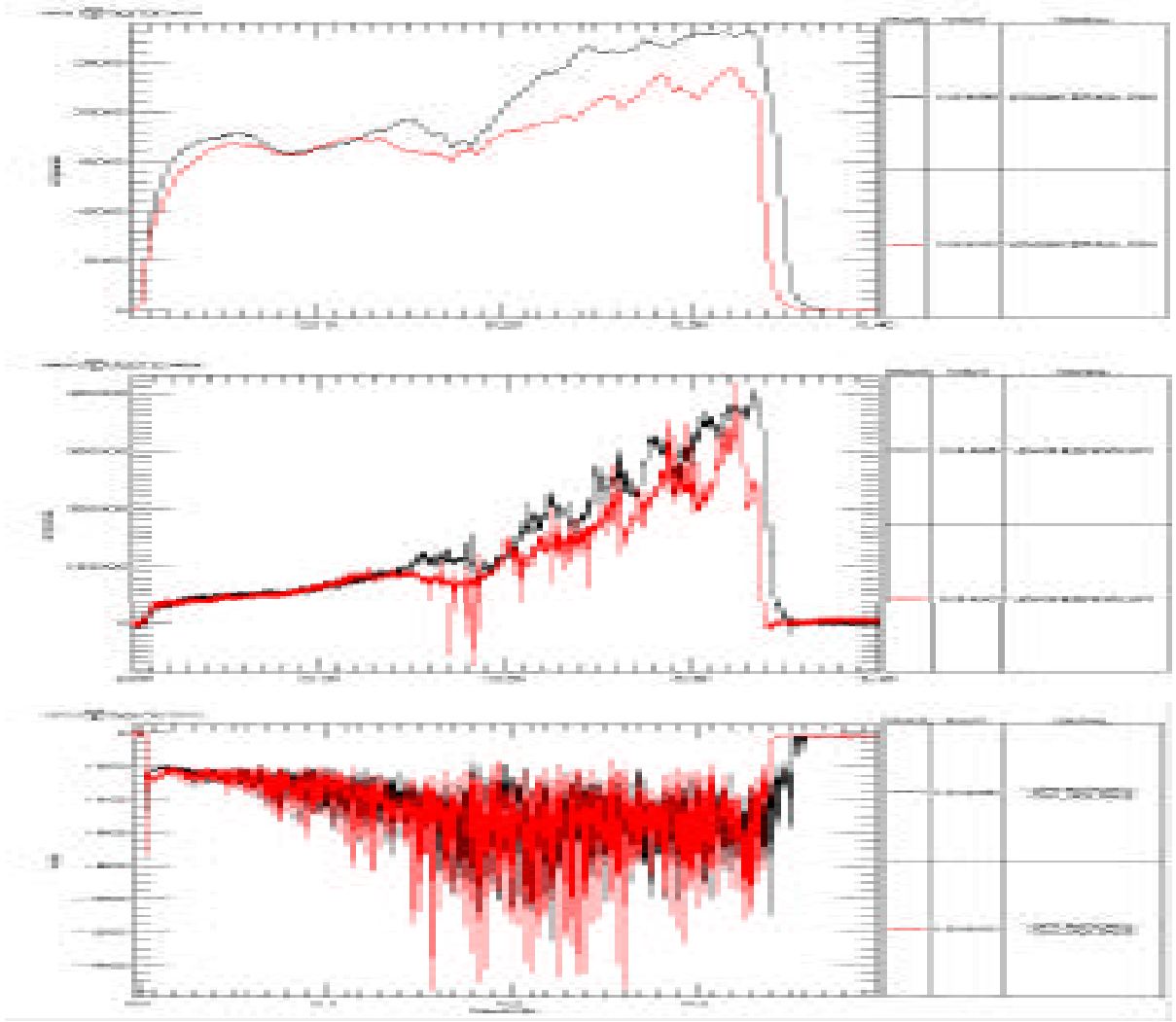
Flux closure may increase with increasing toroidal currents and at very high current multiplication factors because of the tendency for closely spaced parallel current rings to coalesce. These closed flux tubes with large aspect ratio could then merge with a 'larger' closed flux plasma in the interior and sustain it. Flux closure may also increase at lower values of the toroidal field because of an increased tendency for the flux footprints in the lower divertor region to reconnect. Some of these possibilities can be simulated using the TSC code; work is in progress to use TSC as a tool for understanding CHI discharge evolution. High current discharges produced at low and high toroidal fields will be studied as described in section1 to understand the effect of an externally applied toroidal field on flux closure.

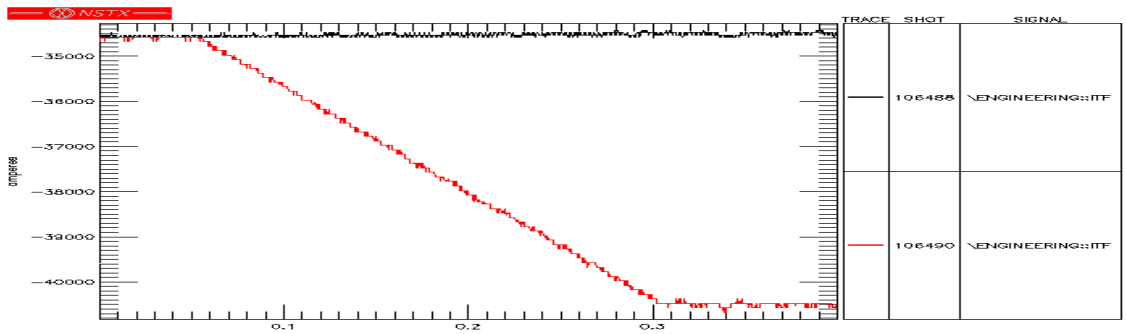
3. Experimental run plan

DAY-1

Obtain a high current flattop discharge for a toroidal field ramp from 0.3 to 0.45T.

On NSTX, as the toroidal field is increased, the injector impedance appears to increase proportionally. There is only one good data point at this time, under high toroidal current differing toroidal field conditions. This is the data from shot 106490 in which a toroidal field ramp was imposed to increase the toroidal field from 0.29 to 0.34T. The data from shot 106488 at 0.29T and from shot 106490 in which a TF ramp up to 0.34 T was imposed are shown below. For the same applied voltage, the injector current drops approximately in proportion to the toroidal field increase. This indicates that the injector impedance scales as the toroidal flux. The actual scaling should go as the ratio: (toroidal flux / injector flux), as this is a measure of the number of times a field line goes around the torus and therefore related to the length of the current path. In these discharge the injector flux time history was the same for both cases. In order to maintain the same injector current (at higher toroidal field) the applied voltage should be increased. Because of the occurrence of absorber arcs, the injector voltage cannot be arbitrarily increased (at least in this present NSTX absorber





configuration). The procedure will be to first repeat shot 106490, with the change that the toroidal field will be increased to 0.375T (instead of the 0.34T used in 106490). Then voltage ramps will be introduced in small steps to increase the injector current to the 30kA level.

Procedure: [Use 12-15 min HeGDC before shots. Use a Lower Dome fill pressure of 1330 Torr]

1. Restore 106490 and change maximum toroidal field to 0.375T from the original 0.34T.
2. Increase the applied voltage ramp by 50% of that needed to maintain the same injector current as in shot 106488.
3. Adjust the voltage ramp as necessary to obtain 30kA of injector current.
4. Adjust LDGIS pressure if necessary.
5. Repeat the above steps for a TF ramp of up to 0.45T
6. Repeat at two other plenum fill pressures (1000 and 1150 Torr)
7. Establish a 50 to 100ms current flattop (probably after the new absorber is installed).

DAY-2

Obtain a high current flattop discharge for a toroidal field ramp from 0.3 to 0.15 T (to be conducted after the new absorber is installed).

Procedure: [Use 12-15 min HeGDC before shots. Use a Lower Dome fill pressure of 1330 Torr]

1. Restore 106490 and ramp the toroidal filed down to 0.15T.
2. Reduce the Injector voltage to 40% of that used in 106490, as the injector impedance will be lower.
3. Obtain a stable discharge.
4. Adjust the voltage ramp as necessary to increase the injector current to 30kA.
5. Repeat at two other plenum fill pressures (1000 and 1150 Torr)
6. Establish a 50 to 100ms current flattop.

DAY-3

Obtain a high current flattop discharge for a toroidal field ramp from 0.3 to 0.6 T. (to be conducted after the new absorber is installed).

Procedure: [Use 12-15 min HeGDC before shots. Use a Lower Dome fill pressure of 1330 Torr]

1. Restore 106490 (or a more recent shot obtained from steps 1 and 2) and change maximum toroidal field to 0.6T from the original 0.34T.
2. Increase the applied voltage ramp by 50% of that needed to maintain the same injector current as in shot 106488 or for the new shot that is restored.
3. Increase the voltage ramp to that needed to obtain 30kA of injector current.
4. Repeat at two other plenum fill pressures (1000 and 1150 Torr)
5. Establish a 50 to 100ms current flattop.

DAY-4

Characterization with Thomson scattering. Other diagnostics listed in the diagnostics list will also be used, but the primary emphasis will be pressure profile characterization using the best shots for the differing toroidal field conditions.

1. Restore and repeat the best shot from case 1 (0.45T case)
2. After reproducible discharges are obtained, open the Thomson shutter and collect Thomson data for three high current discharges.

3. Restore and repeat the best shot from case 0 (0.3T case)
4. After reproducible discharges are obtained, open the Thomson shutter and collect Thomson data for three high current discharges.

5. Restore and repeat the best shot from case 2 (0.15T case)
6. After reproducible discharges are obtained, open the Thomson shutter and collect Thomson data for three high current discharges.

7. Restore and repeat the best shot from case 1 (0.6T case)
8. After reproducible discharges are obtained, open the Thomson shutter and collect Thomson data for three high current discharges.

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

Essential:

- LLNL fast camera showing entire machine view.
- Fast neutral pressure gauge(s).
- Spectroscopy for C and O and for C-III, IV and V line ratios.
- Mirnov coil array
- Magnetics for M-fit, EFIT, TSC.
- Ultra-soft x-ray system sensitized for 50 eV plasmas.
- Between shots HeGDC.

Desired:

- Core interferometer for density.
- Single-point Thomson for core temperature (on some shots)

5. Planned Analysis

Injector Impedance: Maximum injector currents that can be driven will be studied for the four different cases of toroidal field that have been used. Results are applicable to the NSST design work.

Flux closure: Thomson scattering will provide pressure profiles for the high current discharges produced at the four different toroidal flux conditions. TSC, EFIT and ESC codes will be used to simulate and reconstruct these plasmas to understand the role of an externally imposed toroidal field on flux closure.

6. Planned publication of results

- Results will be published in suitable journals and or presented at the 2002 IAEA, 2002 EPS and 2002 APS conferences.

PHYSICS OPERATIONS REQUEST

Title: Generation of a CHI produced plasma in NSTX
XP No.: OP-XP-006b

Machine conditions (indicate range where appropriate):

1. Ensure PF1B, PF2L and PF2U are configured to drive currents in the anti-clockwise direction as viewed from above the machine.
2. Ensure that the TF interlock is set at 10 kA.
3. Ensure CHI electrical bus work is configured for CHI operation and that the CHI power supply is configured for 12 pulse capability.
4. Ensure that the CHI power supply software 'branch over current' trip is set to 40 kA.
5. Ensure that LDGIS has been switched from "CS gas injection" to "Lower dome gas injection".
6. Ensure that the He regulator pressure (for the fast valve triggers) is set to 100 Psig.
7. Ensure that the LDGIS pressure interlocks (PE107, PE104) are functional and the gas pressure in the LDGIS plenum is set to 1750 Torr Deuterium.
8. Ensure that the LDGIS system has been tested in the "Puff" mode the day before the experiment.
9. Ensure that the LDGIS system interlocks are in the "green" state prior to conducting the CHI related "hi-pot" tests.
10. Increase the gain setting on the Mirnov coils by swapping the appropriate cables.
11. Ensure EC-Pi is working (look for light on fast camera image).

TF: Flattop (kA) 0.15 to 0.6T Flattop start/stop (s) -50 ms to 500 ms

I_p:Flattop (kA) NA Flattop start/stop (s) NA

Position: R (m) NA Z (m) NA

Inner wall / Single null / Double null - NA

Gas: Pre-fill 1E-4 Torr Upper dome EC Pre-fill

Puff from CHI-lower dome

NBI: Power (0-MW) Start / stop (s) NA Voltage (kV) NA

RF:Power (MW) EC 18-20 kW Start / stop (s) -10 ms to 50ms. Frequency (MHz) NA, 18 GHz for PI

CHI: Off / Start-up / Ramp-up / Sustainment - see XP text (-100 to 60 ms)

If this is a continuation of a previous run or if shots from a previous run are similar to those needed, provide shot numbers for setup.

Reload shot numbers:

106488: 390 kA case at 0.3 T, LDGIS press = 1330 Torr, gas trigger time = -15 ms

106490: 360 kA case with the TF ramped from 0.3 to 0.4 T, LDGIS press = 1330 Torr, gas trigger time = -15 ms.

If shots are new and unique, sketch desired time profiles and shapes. Accurately label the sketch so there is no confusion about times or values. Attach additional sheets as required.

DIAGNOSTIC CHECKLIST

Title: **XP No.:**

		Need	Desire	Special requirements
Magnetics	Flux loops, B-coils	y		
	Passive plate diag.	y		
n_e and T_e	Interferometer	y		
	Thomson Scattering		y	
T_i	CHERS		y	
	NPA		y	
Spectroscopy	H_a	y		
	SPRED (UV)	y		
	VIPS (H/D ratio	y		
	X-ray PHA		y	
	Visible Bremsstrahlung	y		
Particles	NPA		y	
Fluctuations	Mirnov Coils	y		Increase sensitivity by a factor of 10
	X-ray Array	y		
	Reflectometer		y	
Edge	Bolometer	y		
	Plasma TV	y		Configure for fisheye view using old camera.
	IRTV		y	

PPPL EXPERIMENTAL PROPOSAL REVIEW CHIT Chit No. _____

XP TITLE: _____ XP No. _____

PROPOSER: _____ DATE OF REVIEW: _____

COMMENT / CONCERN / RECOMMENDATION

Name _____

REVIEW BOARD COMMENT / RECOMMENDATION

q REQUIRES ACTION / q NO ACTION REQUIRED / q OTHER _____

Run Coordinator _____ Date _____

PROPOSER'S RESPONSE

Proposer _____ Date _____

RUN COORDINATOR REVIEW OF RESPONSE

q APPROVE / q DISAPPROVE RESPONSE

Run Coordinator _____ Date _____