Princeton Plasma Physics Laboratory **NSTX Experimental Proposal**		
Title: Non-solenoidal Ip Rampup		
XP-627	**Revision:**	Effective Date: 4/18/06 *(Ref. OP-AD-97)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS	
Author: C. E. Kessel, O. Mitarai, D. Mueller, J. Hosea, P. Ryan, R. Wilson	Date 04/05/06
ATI – ET Group Leader: S. Kaye and D. Gates	Date
RLM - Run Coordinator: R. Raman	Date
Responsible Division: Experimental Research Operations	

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

Non-solenoidal Ip Rampup **XP627**

1. Overview of planned experiment

Part A – HHFW: Use the solenoid to ramp up the plasma current to various values, then either flattop Ip or clamp the OH current, and inject HHFW power to observe the heating/CD effectiveness in sustaining the plasma current. Starting with 250 kA at $t_{flattop}$ = 40 ms. A $k_{||}$ = 14 m^{-1} heating phasing will be used first, and then $k_{||}$ = 10 m^{-1} co-CD, heating, and cntr-CD. Advantage will be taken of the RF voltage-power control to reduce the injected power as the voltage on the antenna increases to avoid trips. If time permits, the plasma current values will be progressively reduced below 250 kA, and we will revisit $k_{||}$ = 7 m^{-1} co-CD, heating, and cntr-CD. **Part B – NBI:** Use the solenoid to ramp up the plasma current to various values, then flattop Ip, and inject NB power to observe the heating/CD effectiveness in sustaining the plasma current. Starting from 600 kA, using a standard 1.0 MA rampup at 210 ms, the plasma current values will be progressively reduced. NB sources A and B will be injected in various combinations and at 70 keV to develop a data base for understanding the capability of NBI to provide non-solenoidal plasma current rampup either with HHFW, following HHFW, or following CHI. If time permits examine HHFW and NBI combined at low plasma current.

2. Theoretical/ empirical justification

The goal of non-solenoidal current startup and rampup can be broken into 3 phases; the breakdown and early startup, the RF plasma current rampup, and the RF+NBI plasma current rampup. These can be separated and developed independently.

At low plasma currents which we expect CHI or PF coil startup to provide, say 50-200 kA the NBI confinement is poor, and an RF method for heating and driving current is preferable. The HHFW system is suited to this purpose, and efforts to develop this capability should be pursued. In the 2005 run campaign, experiments at Ip ranging from 400 kA down to 250 kA were done in deuterium plasmas. Both flattoped Ip and clamped OH current experiments were done to examine whether the HHFW heating/CD was replacing inductive current. The best examples were with flattoped Ip, with 14 m^{-1} heating phasing which produced robust H-modes, and transiently drove the loop voltage to 0 and the $d(I_{OH})/dt$ to 0. However, the HHFW system was tripping causing the power to shutoff and then turn on multiple times in a discharge, creating the transient. Experiments also showed that the 7 m^{-1} heating, co-CD, and cntr-CD were less effective than the 14 m^{-1} in producing H-modes and replacing inductive current, although this phasing did not experience the tripping that 14 m^{-1} did. The isoflux/rtEFIT control was shown to be effective in maintaining desired plasma-antenna gaps, and the OH current clamp algorithm was effective. Three new aspects will be tried this run period, 1) RF trip avoidance software, 2) lower plasma currents, and 3) intermediate phasing at 10 m^{-1} between 7 and 14 m^{-1} to look for synergy effects where 14 m^{-1} may make 7 m^{-1} more effective in order to get some CD.

Although it is known that the confinement of the NB fast ions worsens as the plasma current is lowered, the actual capability to heat and drive non-inductive current at plasma current below 600 kA is largely unknown. In the 2005 run campaign, experiments at Ip = 500 kA were done in deuterium plasmas, injecting source A at 90 keV, and source B at 70 keV. Although there were very few discharges, source A raised the plasma stored energy to 40 kJ by itself, while source B appeared to have only a weak influence on the discharge at all. It did not appear that the plasma entered the H-mode in these discharges, and the li showed a progressive increase throughout the discharge indicating the inductive current was still substantial and diffusing to the plasma core. Mapping of this regime will enable the determination of how to use the NBI in non-solenoidal current rampup discharges that will ultimately combine the CHI, HHFW, and NBI+HHFW phases.

3. Experimental run plan

Part A - HHFW Plan

Reproduce 117605 (Ip = 250 kA, B_T = 0.45 T, $k_{||} = 14\ m^{-1}$, P_{HHFW} = 2.7 MW) **(5 shots)**

$k_{||} = 14\ m^{-1}$ heating

Run Ip flattoped discharges, examine RF trip avoidance effects on reproduced 117605 at Ip = 250 kA

$k_{||} = 10\ m^{-1}$ co-CD, cntr-CD, heating

Run Ip flattoped discharges with RF trip avoidance at Ip = 250 kA

Using best phasing do OH clamp to examine Ip sustainment

For additional HHFW run time (with RF trip avoidance)

$k_{||} = 14\ m^{-1}$ heating

Run flattoped Ip = 200 kA

Run flattoped Ip = 150 kA

OH clamp on lowest Ip case

$k_{||} = 10\ m^{-1}$ co-CD, cntr-CD, heating

Run flattoped Ip = 200 kA

Run flattoped Ip = 150 kA

OH clamp on lowest Ip case

Higher elongation request with isoflux control

Part B – NBI Run Plan

Use settings from 119031 (Ip = 1.0 MA, B_T = 0.45 T, clamp Ip from this rampup trajectory, all other settings from this shot)

Ip = 600 kA

Run ohmic ref. shot

Inject source A @ 70 keV

Inject source B @ 70 keV

Inject source A and B @ 70 keV

Ip = 500 kA

Repeat above

Ip = 400 kA

Repeat above

Ip = 300 kA

Repeat above

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

Part A – HHFW

Should follow J. Hosea B_T scan XP to allow more high power HHFW conditioning

HHFW system, P_{HHFW} > 3 MW, 14 m^{-1}, heating phasing, and 7 m^{-1} and 10 m^{-1} heating, co-CD and cntr-CD phasing

CHERS NBI blips of source A 90 keV, 10 ms duration, separated by 50 ms

B_T = 0.45 T

I_P ramp, HHFW with rtEFIT/isoflux control, 14 m^{-1} reference is 117605 (250 kA), t_{ramp} = 40-80 ms, $t_{isoflux}$ = 100 ms, t_{HHFW} = 150 ms

rtEFIT/isoflux controller

NBI 1 sources, A at 90 keV

Gas should be same as reference shot 117605 for all cases

Requesting D. Mueller as operator to help with low Ip operation

Part B – NBI

CHERS for ion temperature and rotation

B_T = 0.45 T

rtEFIT/isoflux controller

Gas should be same as reference shot 119031 for all cases

Requesting D. Mueller as operator to help with low Ip operation

5. Planned analysis

EFIT

CURRAY

TRANSP

TSC

6. Planned publication of results

Results would be presented at the APS meeting and subsequently submitted to Nuc. Fusion or Phys. of Plasmas

PHYSICS OPERATIONS REQUEST

Non-solenoidal Ip Rampup **XP627**

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **54 (4.5kG)** Flattop start/stop (s): **0/1.5**

I_P (MA): **0.15-0.25, 0.3-0.6** Flattop start/stop (s): **0.04/0.8**

Configuration: **Double Null, diverted**

Outer gap (m): **<0.04**, Inner gap (m):

Elongation κ: **≈2.0**, Triangularity δ: **0.5**

Z position (m): **0.0**

Gas Species: **D**, Injector: **same as 117605 or 119031**

NBI - Species:**D**, Sources: **A**, B Voltage (kV):70-**90**, Duration (s): **0.8**

ICRF – Power (MW): >**3.0**, Phasing: **Heating/CD**, Duration (s): **0.8**

CHI: **OFF**

Either: List previous shot numbers for setup: **117605, 119031**

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

Non-solenoidal Ip Rampup **XP627**

Diagnostic	Need	Desire	Instructions
Bolometer - tangential array	X		
Bolometer array - divertor			
CHERS	X		
Divertor fast camera			
Dust detector			
EBW radiometers			
Edge deposition monitor			
Edge pressure gauges			
Edge rotation spectroscopy		X	
Fast lost ion probes – IFLIP	X		
Fast lost ion probes – SFLIP	X		
Filtered 1D cameras			
Filterscopes	X		
FIReTIP	X		
Gas puff imaging			
High-k scattering			
Infrared cameras			
Interferometer – 1 mm			
Langmuir probes - PFC tiles			
Langmuir probes - RF antenna			
Magnetics – Diamagnetism	X		
Magnetics – Flux loops	✓		
Magnetics – Locked modes	X		
Magnetics – Pickup coils	✓		
Magnetics - Rogowski coils	✓		
Magnetics - RWM sensors	X		
Mirnov coils – high frequency	X		
Mirnov coils – poloidal array	X		
Mirnov coils – toroidal array	X		
MSE	X		
Neutral particle analyzer	X		
Neutron Rate (2 fission, 4 scint)			
Neutron collimator			
Plasma TV		X	
Reciprocating probe			
Reflectometer - FM/CW			
Reflectometer - fixed frequency homodyne			
Reflectometer - homodyne correlation			
Reflectometer - HHFW/SOL	X		
RF antenna camera	X		
RF antenna probe	X		
Solid State NPA			
SPRED			
Thomson scattering - 20 channel	✓		
Thomson scattering - 30 channel		X	
Ultrasoft X-ray arrays	X		
Ultrasoft X-ray arrays - 2 color			
Visible bremsstrahlung det.	X		
Visible spectrometers (VIPS)	X		
X-ray crystal spectrometer - H			
X-ray crystal spectrometer - V			
X-ray PIXCS (GEM) camera			
X-ray pinhole camera			
X-ray TG spectrometer			