Princeton Plasma Physics Laboratory
NSTX Experimental Proposal

Title: Halo Current Dependencies on I_P/q_{95}, Vertical Velocity, and Halo Resistance

OP-XP-833	Revision: **1**	Effective Date: Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Responsible Author: Stefan Gerhardt	Date
ATI – ET Group Leader: Steve Sabbagh	Date
RLM - Run Coordinator: Mike Bell	Date

Responsible Division: Experimental Research Operations

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

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DATE:

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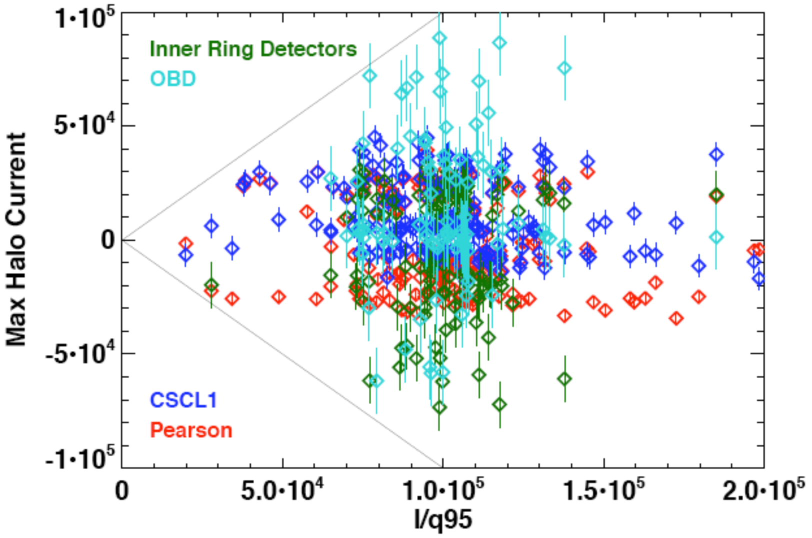
1. Overview of planned experiment

Halo currents are electrical currents which flow partially in the plasma, and partially in plasma facing components. They generally occur when control of the plasma vertical position is lost, either before or during a disruption (a scenario known as a vertical displacement event, or VDE). The goal of this experiment is the asses the scaling of Halo currents with certain important plasma parameters. Results from many tokamaks (Alcator C-mod, MAST, COMPASS-D, and JET) have seen an I_p/q_{95} scaling of the halo current magnitude, which this experiment will attempt to study with devoted scans for two very different halo current paths. In a separate scan, the dependence of the halo current magnitude on the VDE velocity will be studied. The next step will study if He and D_2 have different halo currents for otherwise similar conditions. Finally, the dependence of halo current magnitude on halo electrical resistance will be studied, by cooling the halo with Neon injection. Part of these experiments will be conducted in a special low-triangularity shape, developed to steer the Halo currents into a well-diagnosed path, linking the outboard divertor and the secondary passive plates.

2. Theoretical/ empirical justification

Halo current are known to provide a serious constraint on mechanical and electrical design of tokamak in-vessel components. For instance, they are thought to be the dominant source of electromagnetic loading during slow VDE current quenches in ITER. From the perspective of NSTX, an improved understanding of halo currents will provide important information for the mechanical design of the liquid lithium divertor (LLD), as well as future larger STs. New halo current detection hardware was installed in NSTX during the CY07 outage period, allowing improved measurement of these currents. For instance, the data in the adjacent figure provides information on the scaling of halo currents with the parameter I_p/q_{95}, for a large database of shots, and for four different halo current path measurements. One goal of the present experiment is to systematically vary this parameter for two different plasma shapes while generating large halo currents.



3. Experimental run plan

Step 1: Restore Target Shot: 127070, 600 kA He shot, B=0.45 Tesla. Reached flat-top at ~0.1 sec. Stored energy of 30kJ.
Take Shot Without Freeze: ______
Take Shot with Freeze @250msec, lasting 100msec, and downward bias on PF3 of 10 V and 5msec duration at the start of the freeze:______

All He shots run on a 10 minute shot cycle with no GDC between shots.

Step 2: Complete a scan of Halo Currents vs I_P/q_{95}, in the high triangularity reference shape.
The first 8 shots in this table to be completed as part of initial scan, the final 4 at the end of the day, time permitting.

Step #	Shot Number	I_P	B_T	I_p^2/B_T
2.1		500	.45	.55
2.2		600	.45	0.8
2.3		650	.45	0.94
2.4		700	.45	1.08
2.5		700	.4	1.225
2.6		700	.35	1.4
2.7		500	.55	0.45
2.8		500	.5	0.5
2.9		700	.35	1.4
2.10		500	.55	0.45
2.11		550	.45	.672
2.12		650	.45	0.94

Step 3: Develop Low Triangularity target:

Throughout this process, the timing and magnitude of the freeze and offset should be left alone, so that the halo currents can be studied as the triangularity is reduced. This allows a diagnosis of the halo current path during the VDE. The fully developed shot will have the halo current linking the secondary passive plates and outboard divertor.

	PF1A	PF2 (kA)	PF2 (kA/MA)	PF3 (kA)	PF3 (kA/MA)	PF5
Reference	7.38	4.2	7	-4.95	-8.25	
3.1	0	6.225	10.375	-4.95	-8.25	-6.06
3.2	0	8.225	13.7	-4.95	-8.25	-6.223
3.3	0	10.225	17.04	-4.95	-8.25	-6.554
3.4	0	12.225	20.83	-4.95	-8.25	-6.94
3.5	0	12.225	20.82	-3.95	-6.58	-7.45
3.6	0	12.225	20.83	-2.95	-4.92	-7.9

In order to bias down at any point in the scan: Add 600 A to PF3L (change of 1kA/MA)

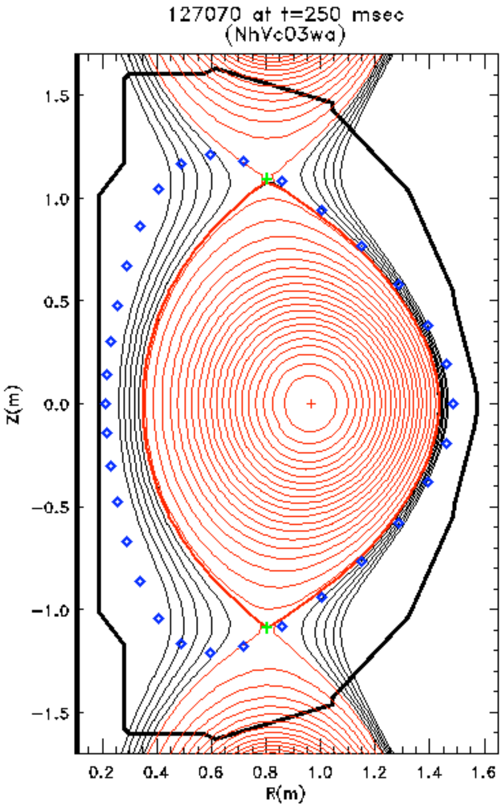


Figure 1: Approximate final target for low triangularity halo current measurement, after completion of step 3.6 above

Step 4: Complete a scan of Halo Currents vs I_P/q_{95} at low δ

As in step 2, *the first 8 shots are to be completed as part of the initial scan, and the last 4 later in the day, time permitting.*

Step #	Shot Number	I_P	B_T	I_p^2/B_T
4.1		500	.45	.55
4.2		600	.45	0.8
4.3		650	.45	0.94
4.4		700	.45	1.08
4.5		700	.4	1.225
4.6		700	.35	1.4
4.7		500	.55	0.45
4.8		500	.5	0.5
4.9		700	.35	1.4
4.10		500	.55	0.45
4.11		550	.45	.672
4.12		650	.45	0.94

Step 5: Complete a scan of the plasma vertical velocity.

Pick a shot from steps 2-4 that had reliably large and easily measurable halo currents, most likely the 700 kA case at either .35 or .4 Tesla. Also, note that there are two possible means to adjust the plasma vertical velocity: change the magnitude of the offset voltage, or the duration of the "kick". Fill in *either* of the following matrices, depending on which seems most plausible from the results of steps 2-4.

Step #	# of Shots	Shot Number(s)	I_P	B_T	Duration of Kick
5.1	1				5 msec
5.2	1				7 msec
5.3	1				9 msec
5.4	1				11 msec
5.5	1				13 msec

Step #	# of Shots	Shot Number(s)	I_P	B_T	Voltage Offset
5.6	1				10 V
5.7	1				20 V
5.8	1				30 V
5.9	1				40 V
5.10	1				50 V

Step 6: Comparison of Halo currents in D_2 and He.

Taking the reference shot from step 6, i.e. a shot with large halo currents, switch to D_2 operations. The switch should start with:

- 2 minutes D_2 glow
- 6.5 minutes He glow

A 10 minute shots cycle, with 5 minutes of He GDC between shots, should then begin. Fill in the following table in a scan over I_p/q_{95}.

Step #	# of Shots	Shot Number(s)	I_P	B_T	I_p^2/B_T
6.1	1		500	.45	.55
6.3	1		600	.45	0.8
6.5	1		700	.45	1.08
6.6	1		700	.4	1.225
6.7	1		700	.35	1.4
6.8	1		500	.55	0.45
6.9	1		500	.5	0.5

Step 7: Complete a scan of Neon Injection into the lower divertor during the VDE

Use the reference configuration developed in sections 2-4 and utilized in sections 5 & 6. Puff neon into the lower divertor, timed to enter just before the plasma begins its downward motion. Start with step 7.2, and then increase or decrease the Ne injection based upon result of scan.

Step #	# of Shots	Shot Number(s)	I_P	B_T	Torr-Liters
7.1	1				0.025
7.2	1				0.05
7.3	1				0.1
7.4	1				0.2
7.5	1				0.3
7.6	1				0.4

The successful implementation of this step will require that the Bay E lower piezo valve be calibrated for Neon gas flow. This exercise will be completed before the run day.

Note: Typical gas injection parameters for Neon seeding experiments are 1.5 TL/s for ~.006 sec., for a total injection of ~.01 TL.

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

It is anticipated that a 10 minute clock cycle will be used for the entire day, including the cases in D_2. It will not be necessary to "sync-up" with the neutral beam cycle.

The reference shot and shot development will be done using the pcc ("gap control") algorithm. Isoflux control will not be used, as that algorithm is not presently equipped with a voltage freeze command.

NBI, RF, and CHI are not required for the completion of this XP.

Between shot equilibrium reconstructions with 1msec time resolution are highly desirable.

A fast camera with ~1msec time resolution in fish-eye view is highly desirable

The injector 1 system should be configured for Neon injection into Bay E bottom.

Injector 3 should have Helium, and will additionally provide the glow-discharge gas during the D_2 shots.

Injector 2 should have D_2, for a prefill of about $1.6\text{x}10^{-5}$ T (this number take from 127070). This will also provide the gas for the D_2 glow to precede the switch to D_2 plasmas.

Extreme care must be take to not prefill or GDC in Neon

5. Planned analysis

These specialized scans will be used in conjunction with database analysis of the CY08 campaign results to determine the scaling of halo currents with various plasma parameters. High time-resolution equilibrium analysis with the EFIT (01) and LRDFIT (01) codes will be utilized.

6. Planned publication of results

It is expected that the Halo current data from this year, including the devoted scans in this XP, will be published in a Nuclear Fusion paper at the conclusion of the run campaign. The data will also be contributed to the ITPA disruption database activity.

PHYSICS OPERATIONS REQUEST

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Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **.3-.55 Tesla** Flattop start/stop (s): **0/0.5**

I_P (MA): **500-700 kA** Flattop start/stop (s): **.1/.4**

Configuration: **LSN**

Outer gap (m): **target 127070** Inner gap (m): **target 127070**

Elongation κ: **target 127070** Upper/lower triangularity δ: varied, see step 3.

Z position (m): **0, or slightly biased down**

Gas Species: **He, D_2, Ne** Injector(s): See section 4

NBI Species: **D** Sources: None Voltage (kV): Duration (s):

ICRF Power (MW): 0 Phasing: Duration (s):

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

LITER: Off

Either: List previous shot numbers for setup: **127070**

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

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Diagnostic	**Need**	**Want**	**Conditions**
Bolometer – tangential array		**X**	
Bolometer – divertor	**X**		
CHERS – toroidal			
CHERS – poloidal			
Divertor fast camera			
Dust detector			
EBW radiometers			
Edge deposition monitors			
Edge neutral density diag.			
Edge pressure gauges			
Edge rotation diagnostic			
Fast ion D_alpha - FIDA			
Fast lost ion probes - IFLIP			
Fast lost ion probes - SFLIP			
Filterscopes	**X**		
FIReTIP			
Gas puff imaging			
Hα camera - 1D			
High-k scattering			
Infrared cameras			
Interferometer - 1 mm			
Langmuir probes - divertor		**X**	
Langmuir probes – RF ant.			
Magnetics – Diamagnetism	**X**		
Magnetics - Flux loops	**X**		
Magnetics - Locked modes	**X**		
Magnetics - Pickup coils	**X**		
Magnetics - Rogowski coils	**X**		
Magnetics - RWM sensors	**X**		

Diagnostic	**Need**	**Want**	**Conditions**
Mirnov coils – high f.	**X**		
Mirnov coils – poloidal array	**X**		
Mirnov coils – toroidal array	**X**		
MSE			
NPA – ExB scanning			
NPA – solid state			
Neutron measurements			
Plasma TV	**X**		
Reciprocating probe			
Reflectometer – 65GHz			
Reflectometer – correlation			
Reflectometer – FM/CW			
Reflectometer – fixed f			
Reflectometer – SOL			
RF edge probes			
Spectrometer – SPRED			
Spectrometer – VIPS			
SWIFT – 2D flow			
Thomson scattering		**X**	
Ultrasoft X-ray arrays			
Ultrasoft X-rays – bicolor			
Ultrasoft X-rays – TG spectr.			
Visible bremsstrahlung det.			
X-ray crystal spectrom’r - H			
X-ray crystal spectrom’r - V			
X-ray fast pinhole camera			
X-ray spectrometer - XEUS			