Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: Study of Transport with Reversed Shear in NSTX		
OP-XP-522	**Revision: 1**	Effective Date: *(Ref. OP-AD-97)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS	
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Responsible Division: Experimental Research Operations	

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

1. Overview of planned experiment

The plan of this experiment is to develop a robust reversed shear q-profile and study the thermal and particle transport properties of the ions and electrons. We will have available the MSE diagnostic and EFIT for between shot analysis. This will provide the needed guidance to develop the appropriate q-profile. When the reversed shear scenario was developed on TFTR the guidance from MSE was essential. The presence of MHD of various forms was the major impediment to achieving a high q(0) and strongly reversed shear q-profile. It was by systematically eliminating the deleterious MHD modes that a high q(0) was achieved. To obtain a reversed shear q-profile the plan proposed for NSTX, similar to TFTR, is to start with a large fully grown plasma as early as possible in the discharge with a high Te and then ramp up the plasma current. The large, hot plasma, before the current has ramped up will maximize the current penetration time leading to a hollow current profile and reversed shear. The main elements in the plan for reversed shear development will be;

2. <u>Document q-profile evolution in low density L-mode shots from XP-411:</u>

   Varying ramp rate and beam timing in L-mode discharges created in XP-411 documented changes in the Te and Ti profiles and thermal transport. We propose documenting three conditions with the MSE diagnostic, reproducing the conditions from that XP. The indication from the USXR diagnostic and TRANSP modeling is that the barrier is associated with a region of negative magnetic shear.

2. <u>Develop reversed shear with low density L-mode edge:</u>

   Vary ramp rate and NBI timing, avoiding MHD with pauses in ramp when necessary. Utilize helium conditioning and perhaps lithium pellets and/or RWM coils depending on results from XP's 501(RWM) and 515(lithium pellet injection). If HHFW is successfully coupled into the startup phase of a discharge to increase the plasma temperature, then this technique could be incorporated into the plan. This will depend on the results of XMP – 030 and XP-510. This section will more aggressively grow a larger plasma to increase the current penetration time scale.

3. <u>Develop reversed shear with H-mode:</u>

   As above but vary the inner gap to induce an H-mode transition.

2. Theoretical/ empirical justification

Many theoretical based models for stability and transport depend on the q-profile and in particular on the magnetic shear. Experimental observations of the effect of magnetic shear on transport and stability have been documented in several tokamaks, such as TFTR and DIII-

D. In this XP we propose to explore the stability and transport effects in the ST with reversed shear.

3. Experimental run plan

The conditions for this XP should be run at 4.5 kG with source A and B at 90 kV. If possible some conditions at higher magnetic field would be repeated. In order to slow the current penetration to the plasma core we want to elevate the electron temperature as much as possible and produce as large a plasma as possible.

1. <u>Document q-profile evolution in low density L-mode shots from XP-411:</u>

   We plan on documenting three conditions from XP411 with the MSE diagnostic. Shots 112996, 112988, 112989 have different ramp rates and very different electron temperature profiles. The discharge with the fastest current ramp and earlier neutral beam start time has the broader electron temperature profile. The original XP had source B injecting early. We will substitute source A in order to get MSE data. If higher field than 4.5 kG is possible we would like to try increasing the magnetic field for conditions 112996 and 112989. We would maintain the plasma current at 1.0 MA, but increase the beam power. Good machine condition was essential for XP411. Helium discharge conditioning was not used in XP411, and may have compromised the performance during the second half of the day when XP411 was run. We plan on trying to maintain good machine conditions during the course of the day. About 6 shots to achieve each condition for a total of 18 shots.

2. <u>Develop reversed shear with L-mode:</u>

   We propose using a fast current ramp, similar to 112989, but grow the plasma more rapidly to full size with high kappa and DND, keeping the discharge limited on the CS. Avoid MHD using the following techniques;

   (a) Vary current ramp rate (6 MA/s, 5MA/s, 4MA/s).

   (b) Start NB-A at 40 ms.

   (c) Pauses in the current ramp to allow some current penetration. This reduces the edge current density if external MHD modes are the problem.

   (d) Run at highest possible delta.

   The planned shots are;

   a. Keeping plasma on center stack, decrease outer gap to 6-8 cm by 0.1 seconds to produce a full bore plasma. (4 shots)

   b. Increase kappa to 2 by decreasing PF3--about 10% per shot. (4 shots)

   c. Minimize MHD as described above. (7 shots)

   d. Add NB-B at 100 ms and if beta limit has not been reached then also add NB-C at current flattop time.

Utilize helium conditioning and perhaps lithium pellets and/or RWM coils depending on results from XP's 501(RWM) and 515(lithium pellet injection). If HHFW is successfully coupled into the startup phase of a discharge to increase the plasma temperature, then this technique could be used here. This will depend on the results of XMP –030 and XP-510.

This scenario development will take about 15 shots.

3. Develop reversed shear with H-mode edge:

In contrast to L-mode plasmas, higher density H-mode offers a regime with a different collisionality and high pressure gradient at the edge. This will change the NBCD and bootstrap current profile. The approach for development would be similar to section #2 above, but with the aim of controlling the start of the H-mode. This could be done by pulling the plasma off the center stack at different times to scan H-mode time.

a. H-mode scan: Vary inner gap in small increments between 5 and 10 cm to obtain H-mode. Use CS gas injector to induce H-mode if necessary.
b. Vary timing (0.1 –0.2 seconds) of inner gap movement.
c. Add NB-B at 100 ms. If beta limit has not been reached then add NB-C at current flattop time.

This section will take about 15 shots.

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

Well conditioned operation at 1.0 MA and 4.5 kG. Source A at 90 kV, and source B and C available. For parts 2 and 3 of this XP it would be best to have done XP-501 and –515, as well as XMP-30/XP-510 for RF development.

5. Planned analysis

LRDFIT and EFIT for equilibrium reconstruction. Transp for transport analysis. Possible analysis of microstability with GS2 or other codes.

6. Planned publication of results

APS meeting and refereed journals.

PHYSICS OPERATIONS REQUEST

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **53** Flattop start/stop (s): _____/_____

I_P (MA): **1.0** Flattop start/stop (s): **.14-.33/ > .5**

Configuration: **Inner Wall / Lower Single Null / Upper SN / Double Null**

Outer gap (m): _____, Inner gap (m): _____

Elongation κ: _____, Triangularity δ: _____

Z position (m): **0.00**

Gas Species: **D** Injector: **Midplane / Inner wall / Lower Dome**

NBI - Species: **D**, Sources: **A/B/C**, Voltage (kV): **90**, Duration (s): **.7**

ICRF – Power (MW): ____, Phasing: **Heating / CD**, Duration (s): _____

CHI: **Off**

Either: List previous shot numbers for setup: **112996, 112988, 112989**

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