APrinceton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: Optimization of Neoclassical Bootstrap Current in NSTX

OP-XP-226	**Revision:**	Effective Date: 5/6/02 *(Ref. OP-AD-97)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Author: S. M. Kaye, J. Menard, D. Gates, F. Perkins	Date 5/6/02
ATI – ET Group Leader: D. Gates	Date
RLM - Run Coordinator: R. Maingi	Date

Responsible Division: Experimental Research Operations

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

Assessment of Neoclassical Bootstrap Current in NSTX **OP-XP-226**

1. Overview of planned experiment

In this experiment we will attempt to assess and optimize the neoclassical bootstrap current in NB heated discharges. We will do this by starting off with a high β_{pol} reference discharge, 107796, and lowering current and attempting to peak up the density profile to maximize the bootstrap current drive. Various H- and L-mode conditions will be documented to study the effect of these changes. A key element of the run plan will be to clamp the OH current (V_{loop}=0) at a time in discharges of different conditions where β_{pol}, and thus the bootstrap current, is sufficiently high to drive the bulk of the current non-inductively to document the level to which the current relaxes. Auxiliary heating will be maintained during the V_{loop}=0 phase; this will provide the means to maintain high β_{pol} as well as contribute non-inductive beam-driven currents.

This experiment addresses a key component of the NSTX mission, which is to develop and demonstrate non-inductive current drive schemes.

2. Theoretical/ empirical justification

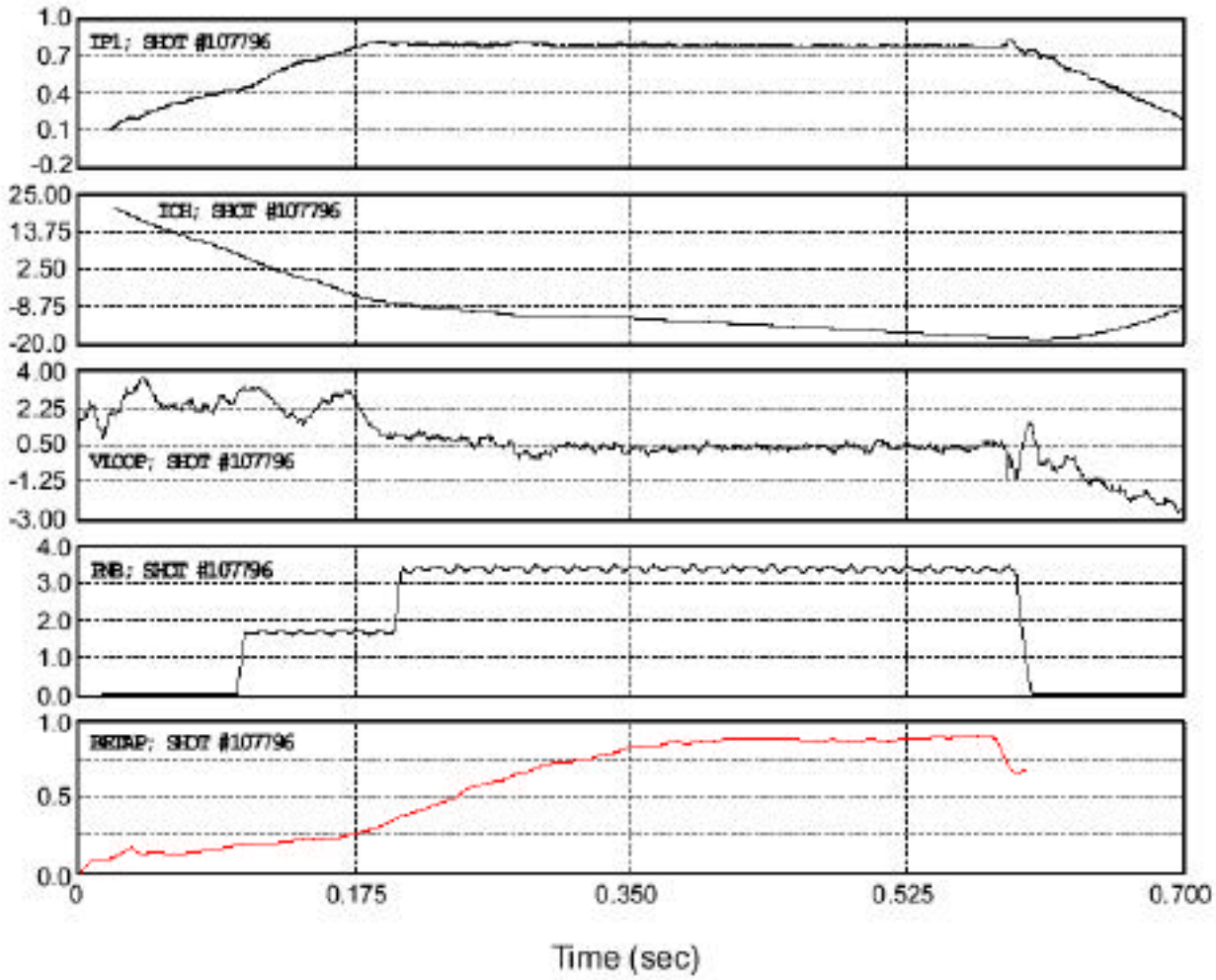
The neoclassical bootstrap current is a complicated function of density and temperature gradients in the plasma, but it can be expressed in global form as $I_{bs}/I_{tot} \sim C_p\ \varepsilon^{1/2}\ \beta_{pol}$, where C_p is a function of the plasma temperature, density, and current profiles. At fixed aspect ratio, higher β_{pol}, along with lower l_i, higher q_0, and more peaked density profiles lead to higher bootstrap current fractions. We will attempt to do all three in this XP.

To date, shot 107796 has shown a long period of constant β_{pol}=0.9 at I_{tot}=800 kA. During the steady-state portion of this discharge, approximately 25% of the total current was driven by bootstrap current, and 10 to 15% of the total current was driven by beam-driven current.

3. Experimental run plan

The XP will use shot 107796 as a reference discharge. Various waveforms for this shot are shown in the figure below. The shot will first be reproduced. Then, attempts to increase b_{pol} will be made by lowering the plasma current in steps of 50 kA to a level of 650 to 700 kA. Below this level will seriously compromise beam ion confinement (only 7% of the beam ions are lost through bad orbits in the discharge below). To compensate for additional beam ion loss (and to ensure an increase in β_{pol}) a third source will be added. In addition, if necessary, the outer gap will be increased from 8 cm to 13 cm to increase beam ion confinement. These tactics will be employed based on the change in β_{pol} as I_{tot} is decreased. The decrease in I_{tot} will serve not only to increase β_{pol}, but also to lower l_i and increase q_0, both of which will serve to enhance the bootstrap current. As a test of the effect on profiles, the inner gap will be reduced in order to have the discharge limited on the center stack and thus avoid the H-mode. The effect of peaking the density profile on bootstrap generation will thus be assessed. In addition, if approved by Engineering, several shots at 5 kG will be run in order to test the effect on raising T_e and increasing the bootstrap current further.

An important element of this XP will be to maintain density control in order to maintain as high T_e as possible at each condition. This will possibly involve developing either gas injection scenarios or scenarios that produce high frequency ELMs. A possible prescription is given in the Shot Sequence. If density control is not attained, a back-up reference shot, 107052, an ELMy H-mode, will be used, and current will be reduced in this shot in order to increase β_{pol} and the bootstrap current.



For each step, an important part of this XP will be to clamp the OH at the beginning of the steady-state portion of β_{pol}. This will be done in the various conditions after the discharge has been developed. This will allow the non-inductive current drive to dominate, and will give a more direct assessment of the level of this non-inductive drive.

The control system algorithm will have to be modified slightly to support clamping the OH. Testing of this will be done during this XP.

Shot Sequence:

1) Reproduce steady-state condition of H-mode shot 107796.
2) Reduce total current in increments of 50 kA to a level of 650-700 kA
    a. Maintain density in range of 4e19 m^{-2}
        i. Start injecting gas from HFS gas feed ~1 sec earlier
        ii. Produce ELMy H-mode
            1. low initial plenum pressure (500-750 Torr) in HFS injector
            2. small inner gap (1-2 cm)
            3. inner gap decreasing from 5-6 to 1-2 cm range
            4. if no success, move to shot 107502 as reference
    b. Add third source to compensate for additional beam ion loss (if β_{pol} decreases)
    c. Increase outer gap to 13 cm to reduce bad orbit loss of fast ions (if β_{pol} decreases)
    d. Document, and at each current level, clamp OH at beginning of steady-state portion of β_{pol}
3) Increase TF to 5 kG at lowest I_p. Redo OH clamp shot to test effect on bootstrap current generation.
4) Move plasma onto Inner Wall to avoid H-mode and document the effect of increase electron density profile peaking
    a. Document and clamp OH in this condition

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

Reference shot 107796 (107052 as backup). Control system algorithm must be changed and tested to support OH current clamp. The XP would benefit from results of the H-mode gas puff and ELM characterization XPs.

5. Planned analysis

Data will be analyzed using EFIT, TRANSP, TSC and a standalone code to determine bootstrap current fraction between shots.

6. Planned publication of results

If successful, results of this XP lend themselves to publication in PRL. Additionally, the results will be presented at various conferences such as IAEA, EPS, APS, etc.

PHYSICS OPERATIONS REQUEST

Assessment of Neoclassical Bootstrap Current in NSTX **OP-XP-226**

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **54 (60) kA** Flattop start/stop (s): =

I_P (MA): **<800 kA** Flattop start/stop (s):

Configuration: **see reference shot**

Outer gap (m): **8-13 cm**, Inner gap (m):

Elongation κ: , Triangularity δ:

Z position (m): **0.00**

Gas Species: **D**, Injector: **Inner Wall**

NBI - Species: **D**, Sources: **A/B/C**, Voltage (kV):**80 keV**, Duration (s): **≤1 sec**

ICRF – Power (MW): **0 MW** Phasing:, Duration (s):

CHI: **Off**

Either: List previous shot numbers for setup: **107796 (107502 backup reference)**

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

Assessment of Neoclassical Bootstrap Current in NSTX **OP-XP-226**

Diagnostic system	**Need**	**Desire**	**Requirements** (timing, view, etc.)
Magnetics	➽		
Fast visible camera	➽		
VIPS-1		➽	
VIPS-2		➽	
SPRED		➽	
GRITS		➽	
Visible filterscopes	➽		
VB detector	➽		
Midplane bolometer	➽		
Diamagnetic flux	➽		
Density interferometer (1mm)			
FIReTIP interf'r/polarimeter	➽		
Thomson scattering	➽		
CHERS	➽		
NPA		➽	
X-ray crystal spectrometer			
X-ray PHA			
EBW radiometer			
Mirnov arrays	➽		
Locked-mode detectors	➽		
USXR arrays	➽		
2-D x-ray detector (GEM)			
X-ray tangential camera			
Reflectometer (4 ch.)			
Neutron detectors	➽		
Neutron fluctuations			
Fast ion loss probe		➽	
Reciprocating edge probe			
Tile Langmuir probes			
Edge fluctuation imaging			
H-alpha cameras (1-D)			
Divertor camera (2-D)			
Divertor bolometer (4 ch.)		➽	
IR cameras (2)			
Tile thermocouples			
SOL reflectometer			