Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: Pulse-length limits of NBI-heated LSN H-mode plasmas

OP-XP-229	**Revision: 0**	Effective Date: 6/3/2002 *(Ref. OP-AD-97)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

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ATI - Task Force 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)

Pulse-length limits of NBI-heated LSN H-mode plasmas

1. Overview of planned experiment

The goal of this experiment is to extend NSTX pulse-lengths by improving the performance of LSN high β_P discharges similar to those studied in XPs 221, 222, and 226. The three dominant factors presently limiting pulse-length appear to be: 1) ELM-like MHD events which can cause minor or major disruptions depending on discharge conditions, 2) the amount of bootstrap and beam driven current which can be driven without violating global MHD limits, and 3) the significant amount of flux consumed to raise the current to 800kA and get into H-mode. To address the first element, the TF will be raised to 5-6kG to raise the global safety factor and hopefully reduce the impact of ELMs. In addition, Neon puffing will be employed in an attempt to cool the edge in a controlled way during the H-mode phase to suppress large MHD events during the I_P flat-top. To address the second element, assuming the flat-top MHD can be better controlled, more NBI heating power will be added to the optimized discharge resulting from the TF/Neon studies to assess if $V_{LOOP} \leq 0$ can be sustained for an appreciable duration, hopefully 100-200ms. To address the third element, the early I_P ramp-rate will be systematically increased to minimize early flux consumption while retaining good performance later in the discharge. Following that, early HHFW heating will be attempted again to determine if electron heating efficiency is improved by a more shallow or possibly reversed q profile. If strong early heating is successful, total flux consumption can in principle be reduced by 10-15%.

2. Theoretical/ empirical justification

Using LSN H-mode target discharges with optimized early and flat-top elongation and other shape modifications, plasmas with β_N = 6, β_P = 1.2, and low surface voltage of 0.1V (for 100ms) have been generated (ex: 108420). Nearly all such shots (including those at lower β_P) are eventually interrupted by either ELMs or a near-edge internal (r/a = 0.8 from MPTS) collapse which degrades confinement and the NI-CD fraction in the ELM-free phase. Prior to the collapse, there is a marked increase in β_P and drop in V_{LOOP} as additional NBI heating

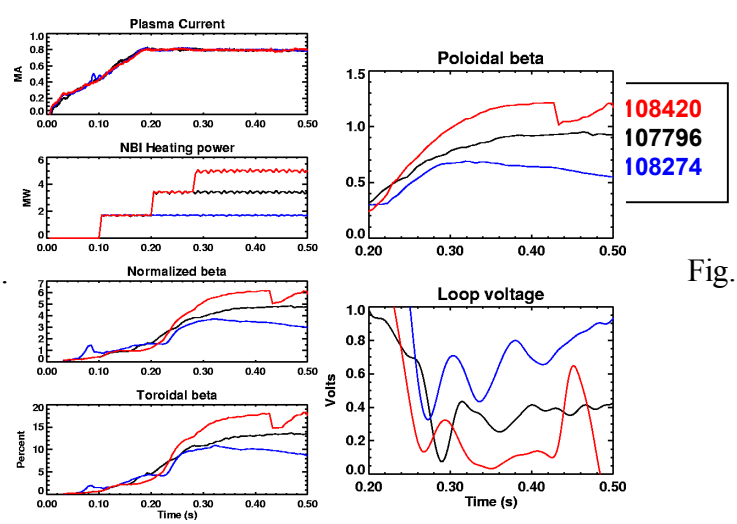

Fig. 1.

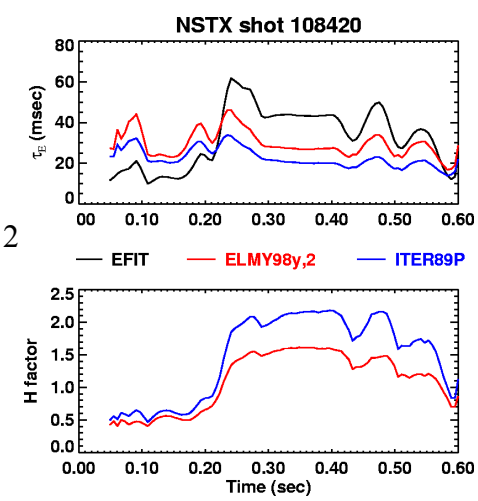

Fig. 2

power is added, as shown in Figure 1 above. If some control of ELM/MHD activity can be gained by either higher toroidal field and/or mild edge cooling from impurity injection, flat-tops extending to t=800ms or longer are in principle achievable with the available OH flux. Additional flux savings can be gained from faster I_P ramp-ups and early HHFW heating, provided the discharge stability and confinement remains good late in the discharge. Figure 2 illustrates that for the highest β_N=6 shot, the stored energy appears to saturate due to confinement since the H factor at full power is above 2 relative to ITER89P. This suggests that additional NBI power (3 sources at 90kV are desired) may be able to drive the surface voltage to 0 for extended intervals.

3. Experimental Run Plan (30 shots total)

A. Produce baseline discharge at 90kV NBI source voltage **(3 shots)**
   a. Injecting B at 100ms, A at 200ms, produce 4.2MW version of shot 108420
      i. Adjust HFS gas puff to match density evolution of 108420
      ii. If shot is disruptive due to too much power early, try source C at 100ms.
      iii. If power still too high, reduce source C power to 1.6MW (80kV).

B. TF scan **(6 shots)**
   a. Increase TF from 4.5kG to 6kG in 0.5kG increments
      i. Document:
         1. Onset time of first MHD event during flat-top and TM activity
         2. Loop voltage changes due to changes in Te and/or confinement
         3. Changes in q evolution, especially q(min)
      ii. Attempt TF ramp-down to 4.5kG if 6kG keeps minimum q(min) above 2.

C. Impurity puff scan **(8 shots)**
   a. Starting from longest discharge from 3.B., add Neon to attempt to modify edge J
      i. Start with non-perturbative puff from XP-223
         1. Inject at t=300ms, 5ms pulse width, 120 torr on Bay J, Injector 2
      ii. Increase puff width in 50ms increments so long as H-mode is retained
      iii. If longest puff doesn't induce L-mode, increase flow-rate in 100torrl/s steps
      iv. If MHD has improved, decrease start time of puff in 50ms decrements
   b. Monitor SXR for Neon penetration into core during edge MHD events

D. Attempt to reduce flat-top loop voltage to zero **(5 shots)**
   a. Add third source at 90kV at 250ms
   b. Change timing of 3rd source in 50ms steps to maximize length of low V_{LOOP} phase

E. Early J-evolution **(8 shots)**
   a. Increase I_P ramp-rate from 4MA/s **(4 shots)**
      i. Increment in 0.5MA/s steps – stop when late phase of shot is affected
      ii. Delay NBI injection time as needed to avoid hitting β limit at lower li
   b. With faster ramp-rate, inject HHFW early **(4 shots)**
      i. Start with 1MW from 50-200ms, try 1.5, 2MW
      ii. Adjust NBI source and timing to get through ramp-up and avoid β limit

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

A. TF commissioned to 6kG
B. Sources A, B, C conditioned to 90kV
C. Neon puff capability as in Transport ET XP-223
    a. Bottle of highest available purity Neon on Injector 2 at Bay J

This XP requires an operational NBI system and full HHFW capability, as well as the capability of generating lower-single null diverted discharges with the plasma control system. No CHI will be used during this experiment.

5. Planned analysis

Non-inductive current drive, confinement, and stability analysis will be performed utilizing EFIT and TRANSP output and ray-tracing analysis will be performed using HPRT.

6. Planned publication of results

The results will be presented at the EPS conference, IAEA conference and/or in APS talks and published in a suitable journal within 1 year.

PHYSICS OPERATIONS REQUEST

Title: Pulse-length limits of NBI-heated LSN H-mode plasmas **XP No. 229**

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **45-72** Flattop start/stop (s): **-0.05/0.9s**

I_P (MA): **0.8** Flattop start/stop (s): **0.15/0.8**

Configuration: **SND**

Outer gap (m): **2-10cm** Inner gap (m): **1-5 cm**

Elongation κ: **2.0** Triangularity δ: **0.5 lower, 0.35 upper**

Z position (m): **0.00**

Gas Species: **D_2, Ne** Injector: **Inner Wall and Outer Midplane**

NBI - Species: **D**, Sources: **A/B/C**, Voltage (kV): **90**, Duration (s): **< 1.0s**

ICRF – Power (MW): **0-6MW**, Phasing: **heating and/or CD** Duration (s): **< 1.0s**

CHI: **Off**

Either: List previous shot numbers for setup: **Shots from XP-221 based on 107796 and 108420**

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

Title: Pulse-length limits of NBI-heated LSN H-mode plasmas **No. 229**

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		✔	