Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: Comparison of Neutral-beam Heated H-mode Discharges with High Field Side and Low Field Side Gas Fueling

OP-XP-209	**Revision:**	Effective Date: 2/12/02 *(Ref. OP-AD-97)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Author: R. Maingi	Date 02/06/02
ATI - Task Force Leader: D. Gates	Date 2/12/02
RLM - Run Coordinator: R. Maingi	Date 2/12/02

Responsible Division: Experimental Research Operations

Chit Review Board (designated by Run Coordinator)

Kaye, Bell, Bush, Mueller, Sabbagh, Stutman

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

Comparison of Neutral-beam Heated H-mode Discharges with High Field Side and Low Field Side Gas Fueling

1. Overview of planned experiment

The physics goal of this experiment is to compare the characteristics of H-mode discharges fueled with gas puffing from the high field side injector and a low field side injector. We will compare the gas puff rates needed to maintain a constant line density with both injectors in ELMy H-mode discharges. If the discharges tends to be ELM-free or have significant dN/dt, we will compare the ratio of dN/dt and S_{gas} as a measure of fueling efficiency.

This XP also has the programmatic development goal of improving H-mode reproducibility and access. It is anticipated that the combination of the high field side fueling, error field reduction, and high temperature bake will widen the H-mode operating window. This is the first dedicated XP of the 2002 campaign to investigate the impact of these major machine changes on H-mode operation.

- Theoretical/ empirical justification

NSTX made several major facility upgrades during the fall 2001 opening, including installation of a high-field side gas injection system, shifting of the PF5 coil centroid to reduce intrinsic error fields, and implementation of a high temperature bake-out system.

The high-field side gas injection system was one of several operational upgrades which allowed the MAST device in Culham to routinely operate in H-mode in its most recent

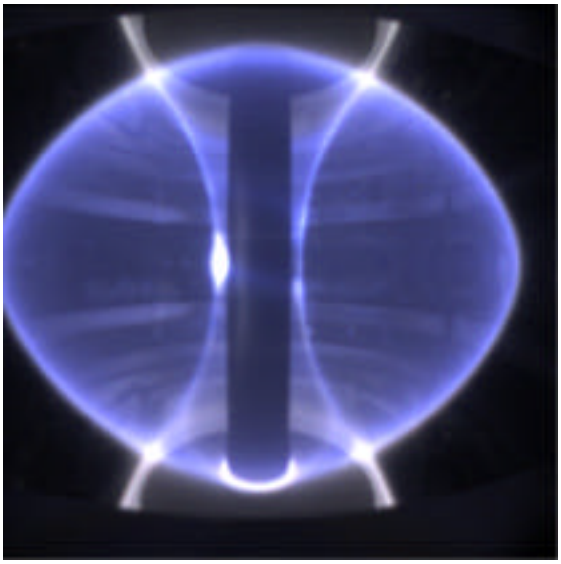

Fig. 1a – visible light picture of MAST discharge. The high-field side gas injector is visible on the center column. Courtesy R. Akers.

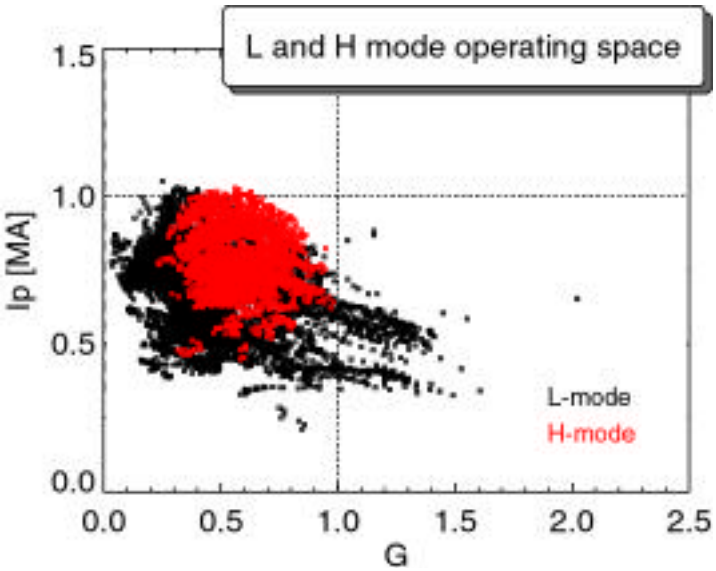

Fig. 1b – Survey of MAST operational space during summer 2001 campaign, with plasma current plotted against Greenwald number,G. Courtesy R. Akers.

campaign. Fig. 1a shows a visible camera picture of the MAST discharge, and the inner wall gas injection is visible as a bright spot on the center column. Fig. 1b shows that about 35% of the total MAST discharges during the recent campaign were operated in the H-mode. The use of the high field side fueling obviated the need for using high density, low-field side gas fueled discharges to optimize recycling for H-mode access. The ELMy H-modes on MAST are apparently limited only by pulse length duration after the advent of HFS fueling [1]. A HFS gas injection similar to MAST's has been implemented on NSTX.

The second NSTX major upgrade which could improve H-mode operation was the reduction in the edge error field by shifting of the PF5 coil centroid. Measurements indicated[2] that the edge error field was peaked just below the outer midplane and could reach up to 50 G at the plasma edge. In addition, a 10-20 G error field was predicted in the lower divertor region. It is believed that the high error field in the vicinity of the divertor may have contributed to the routine termination of lower-single null discharges by locked modes. For example, fig. 2 shows an ELMy H-mode which was terminated near t=0.24 sec. The locked mode onset near t=0.22s preceded the reconnection. This termination pattern was observed in nearly all ELMy H-modes, and also lower-single null discharges in general.

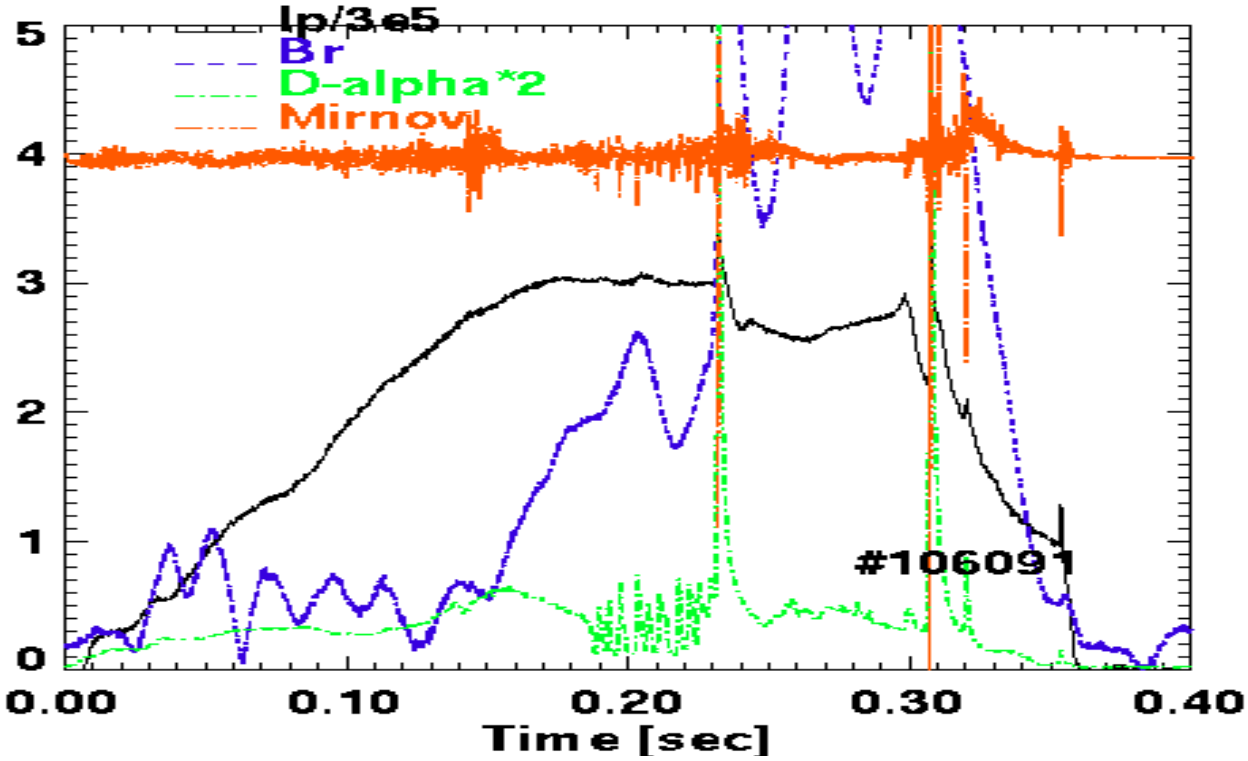

Fig. 2 – plasma current, n=1 Br component, Dα, and Mirnov trace plotted vs. time. The locked mode begins with the non-linear rise of the Br signal near t=0.22 sec.

It is anticipated that the high temp. bake will also help make H-mode operation more routine because of the reduction in impurities which has accompanied such bakes in other machines.

[1] R. Akers, APS 2001 Invited oral, private communication, 11/2001.
[2] J. Menard, Private communication, 8/2001.

3. Experimental run plan

We will develop ELMy H-modes with inboard gas puffing to compare with H-modes fueled by outboard gas puffing. If however, the H-modes are ELM-free, we will study these if we cannot get ELMy H-modes within a few shots. This experiment entails scans of several of the parameters thought to be important in a basic evaluation of H-mode access with high-field side fueling. In addition, we expect sawteeth at the lower TF and will evaluate their effect, if any.

1. Develop ELMy H-mode discharge with inboard puffing

   - Use 0.9-1.0 MA, B_t=0.45 T, src A, LSN shot like 106091 (*2-5 shots)*

   - Vary inner-wall gas puffing during ramp-up and flat-top: try 1000 torr, 1500 torr, and 500 torr fill pressures *(4 - 6 shots)*

2. Make comparison discharges (similar line density) with LFS fueling *(4 – 8 shots)*
3. Determine effect of B_t, inner-wall gap, and power level on H-mode performance
   - Compare HFS vs LFS at 2 other B_t levels; candidates: 0.3T, 0.35T *(8-12 shots)*
   - Scan inner gap up to 5 cm and down to 0-1 cm and compare HFS/LFS *(6-10 shots)*
   - Extend power level to 2 srcs. and then 3 and compare HFS and LFS fueling *(8-12 shots)*
4. Compare NBI src. dependence

   - Change to src. B and then src. C, switching between HFS and LFS fueling *(8-12 shots)*

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

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

5. Planned analysis

Confinement analysis requires EFIT and TRANSP. Estimates of fueling efficiency will be compared with comparable estimates from DIII-D. The global recycling will also be interpreted in the context of a 0-D model used previously for NSTX analysis.

6. Planned publication of results

The H-mode results will be presented at the IAEA conference and/or in APS talks. Results related to the fueling efficiency will be published in (refereed) PSI conference papers.

PHYSICS OPERATIONS REQUEST

Title: _Comparison of Neutral Beam Heated H-mode Discharges with High Field Sid and Low Field Side Gas Fueling **No.: _209_____**

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **24-52** Flattop start/stop (s): _____/_____

I_P (MA): **0.8-0.9** Flattop start/stop (s):**0.15/0.4(hopefully)**

Configuration: **Lower Single Null Diverted**

Outer gap (m): **__5-10cm_** Inner gap (m): **_~2-3cm__**

Elongation κ: **_1.8_** Triangularity δ: **__~0.3___**

Z position (m): **0.00**

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

NBI - Species: **D**, Sources: **A/B/C**, Voltage (kV): **80**, Duration (s):<**0.3s**

ICRF – Power (MW): **0**, Phasing: **N/A** Duration (s): _____

CHI: **Off**

Either: List previous shot numbers for setup: **106091**

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: Comparison of Neutral-beam Heated H-mode Discharges with High Field Side and Low Field Side Gas Fueling **No. 209**

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		✓	