Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: Effect of Triangularity and Divertor Configuration on H-mode Access Conditions and Performance

OP-XP-220	**Revision: 0**	Effective Date: 4/20/02 *(Ref. OP-AD-97)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Author: R. Maingi, D. Gates	Date
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)

Kaye, Bell, Mueller, Sabbagh, Synakowski

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

Effect of Triangularity and Divertor Configuration on H-mode Access Conditions and Performance

1. Overview of planned experiment

One physics goal of this experiment is to quantity the effect of triangularity and number of divertor nulls on H-mode access requirements and performance. This will be accomplished by obtaining H-modes in high triangularity double-nulls and lower-single nulls for comparison with the standard triangularity lower-single null H-modes.

In addition this experiment will investigate the effect of broad pressure profiles on MHD stability. In particular it has been shown experimentally that the achievable beta depends inversely on the pressure peaking factor, Fp. Since H-mode plasmas have attained the lowest values of Fp to date on NSTX, it is anticipate that the beta limit will be increased during H-mode plasmas.

This XP also has the programmatic development goal of maximizing machine performance in several parameters: $\beta\tau$ product for long pulses, β_t^{max}, and maximum stored energy, W^{max}. It is anticipated that triggering of H-mode phases in L-mode high performance discharges will further improve machine performance.

2. 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 combination of these changes allowed NSTX to achieve quasi-steady H-mode discharges of > 300ms duration, with $\beta_p \sim 1$ and H98y2 > 1.5. The record β_t^{max} ~31.5% and W^{max} ~ 280 kJ occurred before the 'successful' high temperature bake, in high triangularity discharges. We propose to trigger H-modes in those high performance discharges to further improve performance.

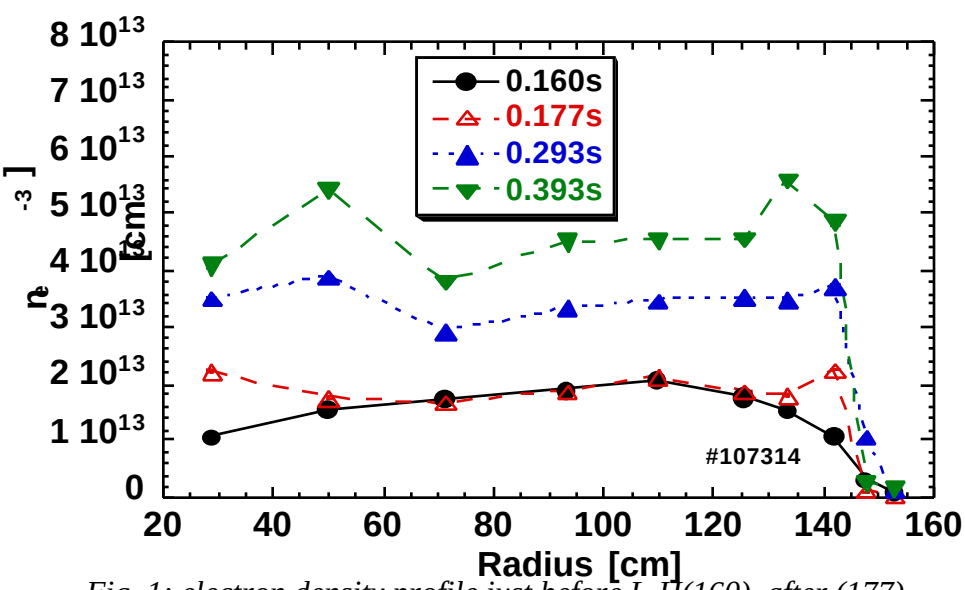

Fig. 1: electron density profile just before L-H(160), after (177), and during the ELMY phase.

There is some empirical evidence that the timing of the H-mode

transition affects performance. In long duration H-mode discharges, the dW/dt is larger after the L-H transition than in comparable L-mode discharges. However the dW/dt seems to flatten out more quickly than in comparable L-mode dicharges, so that by the end of the shot stored energy and confinement are nearly equal. We speculate that the reduction in dW/dt in the H-modes is caused partly by the NBI penetration becoming poor as the edge density rises uncontrollably (see fig. 1).

In several discharges which had an H-mode transition during the high performance L-mode phase, performance was further improved. These discharges usually had short H-mode phases after the I_p achieved flat-top and stayed in H-mode typically ~ 150ms after the I_p flat-top start. One example is shown in fig. 2, which achieved a 200 kJ stored energy with only 2 NBI srcs.

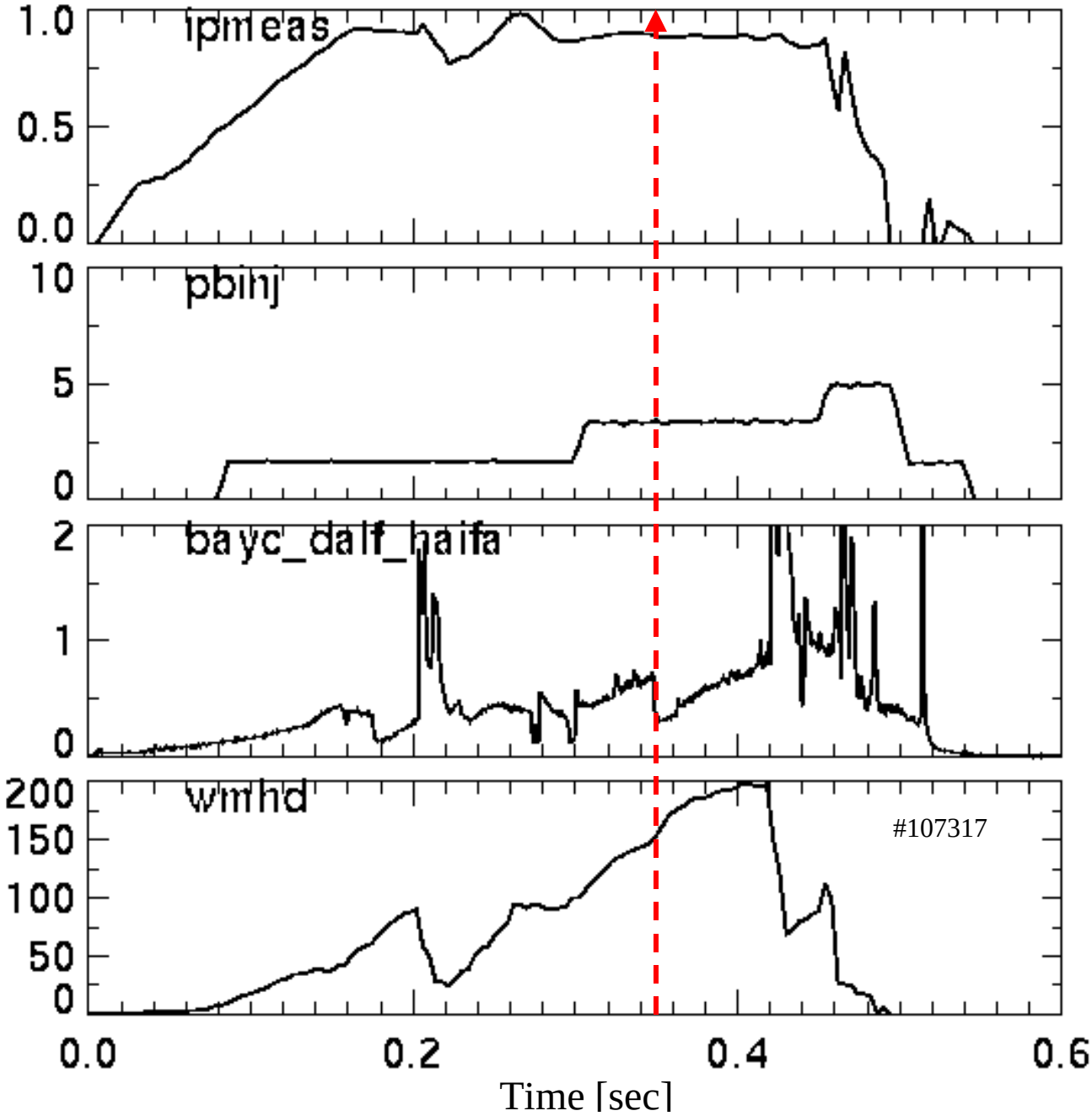

Fig. 2 - time evolution of discharge with late H-mode transition

In addition, the highest toroidal beta achieved to date on NSTX was in a plasma with high triangularity ~ 0.8. This result is predicted by ideal MHD stability theory, since high triangularity plasmas have a higher average toroidal field for the same minor radius. In addition to having a higher beta limit, high delta plasmas have the advantage of having a higher edge q for the same plasma current and applied toroidal field, helping to avoid low order rational surfaces near the plasma boundary (or conversely allowing operation at higher plasma current for the same value of q).

Given the above stated MHD and transport advantages for the high delta combined with H-mode, this experiment represents an obvious combination for improving performance of NSTX plasmas.

3. Experimental run plan (2 run days)

There are 3 separate performance goals: maximizing $\beta\tau$ product for long pulses, maximizing β_t, and maximizing stored energy, W. The first goal encompasses a day, and the other 2 goal encompass the second day.

Day 1: maximize $\beta\tau$ product, goal β_t ~ 20%, τ_E between 100-150ms. Desire I_p/B_t ~ 3.5-4.

1. Reproduce 107228 as well as possible (4 shots)
2. Drop I_p to 1 MA, and TF to 4.0kGauss, with 1 beam src (4 shots)
3. Trigger H-mode by moving slightly further off center stack, with 1 or 2 srcs, and adjust HFS/LFS fueling mix to avoid locked modes (4 shots)
4. Trigger H-mode by increasing weighting to lower divertor, increasing drsep from 0 – 3 cm (10 shots). Tweak I_p between 1.0 and 1.2 MA for max. confinement. (4 shots)
5. Adjust timing of H-mode transition by adjusting time when lower divertor is favored. Start with 200ms, 250ms, and 300ms (8 shots)
6. Vary TF between 4.0 and 3.5kGauss to maximize $\beta\tau$ product for 1-2τ. (4 shots)

Day 2: maximize β_t and stored energy by use of H-mode phases. Desire I_p/B_t ~ 2.5-3

1. reproduce 107227 as well as possible, δ~0.75, κ ~ 1.8, (4 shots)
2. Trigger H-mode by moving off center stack and/or favoring lower divertor, and also adjusting HFS/LFS fueling rates. Start with 1000 torr CS fill and drop to 750 if dn/dt too large (10 shots).
3. reproduce 107228 (1.5 MA, 0.45 T, 3 NBI srcs at 90kV) as well as possible (4 shots)
4. if higher B_t available, increase B_t to max. value (desire 0.6 T) (6 shots)
5. Trigger H-mode by moving off center stack and/or favoring lower divertor, and also adjusting HFS/LFS fueling rates (8 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 and double-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. Stability analysis will also be performed.

6. Planned publication of results

The results will be presented at the EPS conference, IAEA conference and/or in APS talks.

PHYSICS OPERATIONS REQUEST

Title: Effect of Triangularity and Divertor Configuration on H-mode Access Condition and Performance **XP No. 220**

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**

Configuration: **Double Null Diverted**

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

Elongation κ: **1.8-1.9** Triangularity δ: **0.7-0.8**

Z position (m): **0.00**

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

NBI - Species: **D**, Sources: **A/B/C**, Voltage (kV): **80-90**, Duration (s):<**0.5s**

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

CHI: **Off**

Either: List previous shot numbers for setup: **107227, 107228**

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: Effect of Triangularity and Divertor Configuration on H-mode Access Conditions and Performance **No. 220**

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		✓	