Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: Study of the Aspect Ratio Dependence of Confinement via Comparisons between DIII-D and NSTX

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

PROPOSAL APPROVALS

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Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

OP-XP-???

1. Overview of planned experiment

This experiment is aimed at obtaining the comparisons of confinement between DIII-D and NSTX in co-injected neutral-beam-heated plasmas. It is intended to reveal differences in core transport and identifying the role of the very different aspect ratios of the two devices in governing these differences. The approach is one of matching select dimensionless parameters where possible and scanning others where such matches are not possible. Both global confinement times as well as the characteristics of the local fluxes will be compared. The starting point is NSTX plasma 109070. The first iteration was performed on DIII-D, as is described below. This experiment represents a second iteration on NSTX in light of what was learned in that effort and in light of diagnostic and control capabilities that have been improved since 109070 was run.

This experiment has value for NSTX alone as well. The NSTX diagnostic and control capability has improved considerably since plasmas like 109070 were generated at 5 kG. Also, the ρ^* scan on confinement has value on its own for projections of ST confinement to a CTF, which will have a smaller ρ^*.

2. Theoretical/ empirical justification

It is natural to think of varying the aspect ratio A between NSTX and DIII-D to develop an understanding of the role of A in governing all manner of plasma attributes, include confinement, MHD stability, edge characteristics, and the like. In this proposal, the second stage of a transport and confinement comparison between DIII-D and NSTX is outlined. The "zeroth" stage was carried out on NSTX - 109070, a LSN long pulse plasma that was quite well documented for its time. The first stage on DIII-D was carried out this spring, with dimensionless parameters matched as described below. This experiment is a needed iteration based on the results from that DIII-D run day.

In constructing the DIII-D run day, the following question naturally arose: what quantities can and should be matched between the two devices? The primary approach here is to match as many dimensionless parameters as possible, while trying to minimize the variations that are not associated with the one in question, i.e. the aspect ratio.

To design and interpret these experiments, it is assumed that the transport is driven by local quantities. Moreover, we make the simplifying assumption here that poloidal quantities predominantly drive the transport. As a consequence, beta poloidal is matched between DIII-D and NSTX. As it is impossible to simultaneously match aspect ratio, collisionality, and ρ^*, three quantities known or suspected to be of primary importance in governing transport, the approach here is to match what can be matched in poloidal quantities in any two discharges and to perform two-point dimensionless scans to assess the dependence on toroidal quantities, such as gyroradius with respect to toroidal field, that are unmatched.

The ε dependence is determined by comparison between NSTX and DIII-D. DIII-D has performed its own two-point scan of the collisionality and poloidal ion gyroradius. On NSTX, it is proposed here to perform a gyroradius scan at constant collisionality and q and β_p. Information on the collisionality dependence of the transport will be obtained from an experiment by Kaye.

As background, described here is the approach that was carried out on DIII-D, and the implications for this proposed experiment. On DIII-D, the poloidal normalized gyroradius and the poloidal beta β_p, the cylindrical safety factor $aB_T/(RB_p)$, as well as a simplified definition of the collisionality $(nqa)/T^2$ were matched between 109070 and the new DIII-D case as well as possible. This was aimed at reproducing the same density, temperature, and current as the NSTX case, but the B field was increased on DIII-D to match q95. However, when the NSTX and DIII-D densities and (volume-scaled) stored energy matched, the DIII-D temperatures were considerably higher (~40%) than 109070, consistent with the very low Z_{eff} on NSTX (1.5 on NSTX vs. 2 - 2.5 on DIII-D) and the high fast ion stored energy (25 - 30% on NSTX as compared to ~5% on DIII-D). Here, we do not propose to increase the NSTX Z_{eff} by extraordinary means such as CD_4 gas puffing, as this experiment will likely be run during the commissioning of high TF, when high priority, high performance experiments are likely going to be in the queue. However, effort will be made to reduce the fast ion stored energy through source number scans. A more detailed assessment of the DIII-D profiles reveals that there is advantage to be had in pursuing a somewhat lower electron density case on NSTX as well.

Implications for the NSTX run day - Variations of 109070 - We need to produce a variant of 109070 at 5 kG. Attention will be paid towards improved wall conditioning and/or edge fueling modifications to lower the density at a given stored energy by about 10 - 20%, as compared to 109070. To increase the thermal stored energy and reduce the fast ion component, the number of beam sources, including fractxional source numbers via modulation, will be used. At all times, 90 keV on source A for MSE will be maintained. Notches, blips, etc., - whatever is determined in the control room to increase the chances of good CHERS documentation - will be provided.

• ρ* scan - ρ* with respect to poloidal field was matched between NSTX and DIII-D, but not with respect to toroidal field. During the DIII-D run day, a two-point ρ* scan was performed in a first attempt to account for the effects of this variation. A ρ* scan will be performed here to see if the same ρ* dependence with respect to toroidal field is inferred from the NSTX data.

It is not possible to obtain a significant variation in ρ* on NSTX based on a 5 kG, 800 kA discharge, due to the requirement to keep q fixed across such a scan as B_T is varied. We can get around this constraint if it is assumed that the ρ* dependence of confinement will not be a strong function of q, and that this dependence can be determined from a separate ρ* scan at lower q. Taking a lower bound on the current for reasonable fast ion confinement to be 700 kA, we propose that the TF be lowered to about 3 kG for the large ρ* end of the scan, and that a higher current case at the maximum TF available (assumed to be 5.5 kG) be generated as well, with n_e and T_e scaled appropriately. If 3 kG operation is unacceptable from an MHD perspective, 3.5 kG will be used instead, with a plasma current of 820 kA. To keep the dimensionless parameters β, ν*, and q fixed while varying B_T, the engineering parameters need to be scaled as $n \propto B^{4/3}a^{-1/3}$, $T \propto B^{2/3}a^{1/3}$, and $I \propto Ba$ while keeping the magnetic geometry fixed (of course, the minor radius a is kept fixed here as well). Our knobs for controlling the density and temperature are (a) fueling with gas puffing and recyclingchanges via helium glow times between shots, (b) injected beam energy, and (c) injected power.

3. Experimental run plan

A. Build an ensemble of plasmas like 109070, with varying density and fast ion content. Optimize chances for good core documentation.

Overarching goals include:
• Create an ensemble of discharges that are 109070-like in many respects, but with the following characteristics
- If n_e is not slightly lower than the 109070 value naturally, generate lower n_e through source reduction and increase glow
- Aim for MHD quiescence through ramp modifications, error field correction, and source reduction
- A goal is reduction in the fast ion stored energy fraction, if possible. Primary means is through source number variation and varying the energy of the sources.

Condition	Beam energies	Comments	Number of shots
A.1 Starting point: 109070 configuration, with 3 source injection. 5 T, 800 kA	A @ 90 keV for MSE B, C @ 90 keV or best available without extraordinary effort. Emphasis is on reliability above 80 keV per source	• Beam timing the same as 109070, to be adjusted depending on MHD • D puffing adjusted as needed to minimize MHD • Usual glow interval. • EF modification to minimize MHD • Beam notches as needed to optimize chances for best CHERS measurements	5 shots, including 2 - 3 to reproduce 109070 shape and obtain reasonably long pulse without being plagued by MHD.
A.2 Same as A.1, with 2 sources	Source A for MSE, with source B. Possible source C blips for CHERS	• Intended to provide lower n_e, lower beam stored energy, possibly more MHD quiescent • Source C blips if needed for CHERS	2 shots
A.3 Same as A.2, 2.5 sources	Add source C at 50% duty cycle, 10 ms on, 10 ms off	Intermediate point between A.1 and A.2	1 shot
A.4 Identify best condition from A.1 - A.3 and redo following		• Increase glow/reduce puffing to yield lower n_e (10 - 20%) at a given stored energy compared to target. Beam notches as needed	2 shots

increased glow interval to reduce density.		to optimize chances for best CHERS measurements • MHD quiescence is an important figure of merit for determining "best"	
A.5 Drop source C. Also with increased glow		Same as above. Include beam notches, etc., to optimize CHERS measurements	1 - 2 shots
A.6 Add source C at 50% duty cycle (2.5 sources total). With increased glow, as above		Same as above. Include beam notches, etc., to optimize CHERS measurements	1 - 2 shots

B. ρ* scan

Parameter				
Toroidal Field	5.5 kG (priority 1)	4.5 kG (priority 3)	3.5 kG (priority 2)	3 kG (priority 4)
n_e	$7x10^{19}$ cm^{-3} best-guess	5.4 $x10^{19}$ cm^{-3} (or as appropriately scaled from 5.5 kG value)	$3.83x10^{19}$ cm^{-3} (or as appropriately scaled from 5.5 kG value)	$3.12x10^{19}$ cm^{-3} (or as appropriately scaled from 5.5 kG value)
T_e	1.2 keV best-guess	Scaled to 1.05 keV	Scaled to 0.9 keV	Scaled to .8 keV
I_p	1285 kA	1.05 MA	815 kA	700 kA
ρ*	1 (normalized)	1.14 (scales as $(1/B)^{2/}$ if T is matched)	1.35	1.40
Comments	• 3 sources, with long and short glow for density variation. • 4 shots total	• 3 kG will provide widest ρ* range when combined with 5.5 kG, but is lowest prioritiy because of anticipated challenges with MHD Fueling, number of sources to be varied (including modulation) to meet target profiles in n_e and temperature • 12 shots		

• 5.5 kG condition will likely use 3 sources with a power chosen to be consistent with MHD quiescence. Density should allow headroom for the scaled-down density of the low TF case.

• It is not essential that the precise shape be matched with the previous part of the XP, although that is preferred. Most important is robustness of ELM type across the scan, so as to keep pedestal characteristics matched.

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

MSE, CHERS, MPTS all required (see list).

For the first part of the experiment, 5 kG is required. All 3 NB sources. Match equilibrium of 109070.

For the second part (the ρ^* scan), highest available TF. 5 kG is acceptable, 5.5 is better, 6 kG is best.

5. Planned analysis

TRANSP analysis will be essential. EFIT, constrained with MSE and rotation, will be needed. There will be a set of analyses based on global scaling. The profile measurements will also enable a study of the local transport variations in the ion, electron, and momentum transport channels. Results will be compared to TRANSP analyses of DIII-D discharges.

6. Planned publication of results

Success in Part 1 will enable a refereed publication. Parts 1 and 2 make the publication even stronger. Target is a PRL An offshoot of Part 2 may well be NSTX plasmas with record or near-record stored energies.

PHYSICS OPERATIONS REQUEST

Error! Reference source not found. **OP-XP-???**

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): 34 - 64 kA Flattop start/stop (s): _-0.2_/_1-1.5 s_

I_P (MA): 0.70 - 1.4 MA Flattop start/stop (s): _0.15-0.3_/_0.6-1.2 s__

Configuration: **LSN**

Outer gap (m): 4 - 10 cm, Inner gap (m): 6 - 10 cm

Elongation κ: 2 - 2.3, Triangularity δ: 0.4 - 0.6

Z position (m): 0.00

Gas Species: **D**, Injector: **CS Midplane, outer midplane**

NBI - Species: **D**, Sources: **A/B/C**, Voltage (kV): **65 - 90**, Duration (s): **1 s**

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

CHI: **Off**

Either: List previous shot numbers for setup: **109070 is the goal. However, the shape of 117410 is very similar to 109070, and was achieved with the existing PF coil configuration. The rest will be iterations on this performed to reach the goals of a particular part of the XP.**

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

Error! Reference source not found. **OP-XP-???**

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		✓	**Only available by special request of T. Biewer @ MIT**
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 pinhole camera		✓	