Princeton Plasma Physics Laboratory
NSTX Experimental Proposal

Title: Dependence of momentum and particle pinch on collisionality		
OP-XP-908	Revision: **0**	Effective Date: **7/6/09** Expiration Date: **7/6/11** *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Responsible Author: Wayne Solomon	Date 4/8/09
ATI – ET Group Leader: K. Tritz	Date 7/6/09
RLM - Run Coordinator: R. Raman	Date 7/6/09
Responsible Division: Experimental Research Operations	

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

Neon puff: Prior to the day of experiment inform the gas systems operator to configure injector 3 for Neon. Use a plenum pressure of 200-400 Torr and a 5-10ms pulse width (at 1.5 Torr.L/sec) for Neon injection for diagnostics purpose.

If SGI is needed, then it should be configured for use with Injector 1 at a pressure of 5000 Torr (prior to the day of experiment inform gas systems operator).

If Li is used, a 10mg/min rate with a 12.5min clock cycle without HeGDC may provide stable wall conditions for reproducible discharges.

Inj. 4 will have deuterium and Inj. 2 could have He (if HeGDC is required). In this case for a previously run shot, the low field side gas injection should be changed from Inj. 2 to Inj. 1 at 1700-2000 Torr.

NSTX EXPERIMENTAL PROPOSAL

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AUTHORS: **W.M. Solomon, S.M. Kaye, L.F. Delgado-Aparicio, V. Soukhanovskii, …** — DATE: 4/8/09

1. Overview of planned experiment

The goal of the experiment is to look at the dependence of the momentum pinch velocity as a function of collisionality, and compare with analytic theory and/or gyrokinetic predictions. In addition, we will attempt to compare the momentum pinch velocity with the particle pinch velocity (which should be related), using separate density perturbation techniques.

2. Theoretical/ empirical justification

Measurements obtained from XP 723 demonstrated the applicability of the perturbation technique using n=3 non-resonant perturbations, and obtained first evidence of an inward momentum pinch on NSTX. Further studies in XP 813 showed good agreement between the experimentally determined momentum pinch velocity with theoretical predictions based on low-*k* turbulence [1, 2].

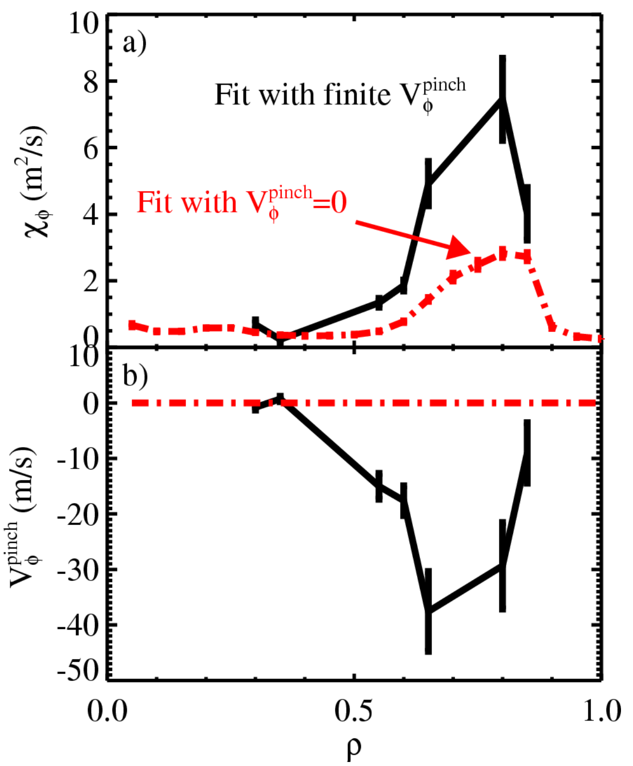

Figure 1 -a) Momentum diffusivity and (b) momentum pinch velocity inferred using n=3 non-resonant magnetic perturbations to the plasma. For comparison, the inferred diffusivity neglecting any momentum pinch is also shown (dashed).

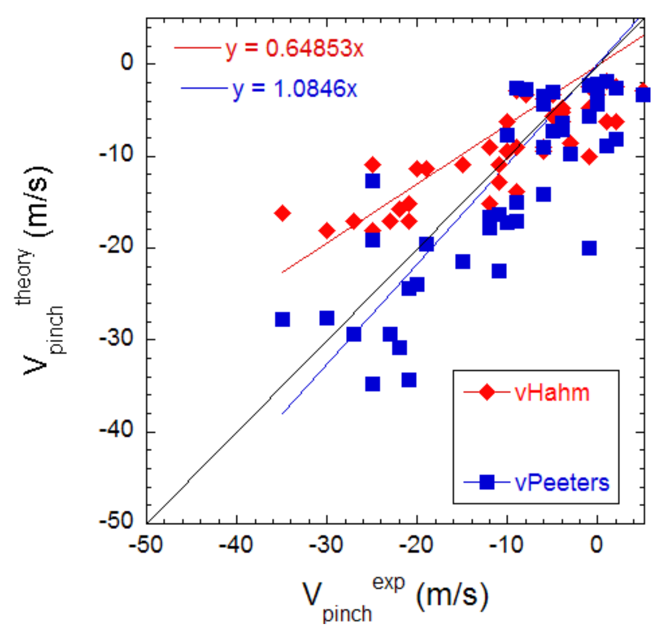

Figure 2 -Comparison of the theoretically predicted momentum pinch velocities from Hahm et al [1] vs Peeters et al [2] to the experimentally determined quantity.

The present experiment will attempt to further test theory by examining the role of collisionality on the momentum pinch, which is expected to be a sensitive parameter affecting the pinch.

3. Experimental run plan

The key requirement for success of this XP is to obtain reproducible long MHD quiescent phases of the discharge. We had reasonable success at achieving this in XP 813, using Li evaporation, coupled with optimal EF correction and n=1 mode control, whereas previous attempts were much more problematic. As such, this experiment requires Li evaporation and static and dynamic control. The baseline discharge will be comparable to #134119.

Once a suitable reference discharge is re-established in the absence of n=3 braking, we can proceed with the main part of the experiment. Since we wish to isolate the role of collisionality on the momentum pinch velocity, we obviously need to perform a collisionality scan. Results from Kaye et al IAEA 2006 showed that this can effectively be achieved on NSTX by varying Ip/Bt at fixed q, so this experiment will follow this technique.

A secondary goal of the experiment is to investigate the relationship between the momentum and particle pinch velocities. Therefore, in addition to the collisionality scan, we will use Ne puffing (and/or use the supersonic gas injectors) to perturb the edge density and watch the inflow of density up the density gradient to infer the core particle pinch. Use of the SGI will require close spacing of the MPTs lasers after the gas perturbation to assess the change in density profile and infer the particle diffusivity and pinch. If the discharge is sufficiently MHD quiescent, we may attempt to economize the number of shots by doing the Ne (or SGI) puffing as part of a second perturbation in the same discharge with n=3 braking. However, if we do this, we must be wary of the fact that the plasma conditions at the second pulse may have evolved.

If time permits, we will try repeating the measurements in L-mode (both to extend the collisionality variation, as well as changing the underlying low-*k* turbulence properties of the plasma). It may also be worth comparing discharges with and without Li evaporation as yet another way of changing the collisionality. Repeating the collisionality scan at a different q is another option to explore if things work well (q is the next most sensitive parameter affecting the momentum pinch). Performing this in L-mode will allow use of the UCLA reflectometer system to infer particle diffusivity and pinch.

1. Reproduce #134119 (no n=3 braking), Bt=0.55 T, Ip=1.1 MA — 1 shots
    a. Apply train of 50 ms n=3 braking pulses, at t=350, 450, 550, 650 ms with amplitudes (600, 800, 1000, 1200 A) to (re)establish suitable braking current amplitude — 1 shot
    b. Repeat with n=3 braking (two pulses of 50 ms duration @ t=400 ms and 700 ms, with ~800-1000 A (depending on results from step 1a) in the coils (beginning of collisionality scan, "Phase A") — 2 shots

 # shots: **4 + 4 contingency**

Decision: If unsuccessful at producing suitable MHD quiescent discharge, reevaluate and consider deferring. If plasma is very quiescent and second pulse is robustly usable, consider combining steps #2 and #3 together, with the density perturbations made during the second nRMP pulse.

2. Complete 3-point "collisionality" scan by varying Bt, Ip at fixed q (4+2 shots) ["Phase A"]
    a. (Bt, Ip) = (0.45, 0.9) — 2 shots
    b. (Bt, Ip) = (0.35, 0.7) — 2 shots

    # shots: 4 + 2 contingency

Decision: If lowest Bt produces MHD, try (0.4, 0.8), or skip. If we are not obtaining a good variation in collisionality (factor of 2), then consider adding a discharge at (Bt, Ip) = (0.55, 1.1) without Li evaporation.

3. Repeat 3-point collisionality scan, using edge density perturbations + NRMP
    a. (Bt, Ip) = (0.55, 1.1)
        i. SGI @ 440-450 ms, Ne @630-650 ms, MPTS "Phase B" — 2 shots
        ii. SGI @ 440-450 ms, MPTS "Phase C" — 2 shots
    b. (Bt, Ip) = (0.45, 0.9) — 4 shots
    c. (Bt, Ip) = (0.35, 0.7) — 4 shots

    # shots: 12 + 4 contingency

4. Compare particle transport without nRMP
    a. (Bt, Ip) = (0.45, 0.9)
        i. SGI @ 440-450 ms, Ne @630-650 ms, MPTS "Phase B" — 2 shots
        ii. SGI @ 440-450 ms, MPTS "Phase C" — 2 shots

    # shots: 4 + 1 contingency

5. Measure pinches in L-mode target (either reduce power in existing shots, or work with eg #132748, but modify to have outer gap at 10 cm, and constant beam power – 1 source)
    a. Establish target — 1 shot
    b. Use nRMP train to determine suitable braking amplitude — 1 shot
    c. (Bt, Ip) = (0.45, 0.9)
        i. nRMP only — 2 shots
        ii. SGI @ 440-450 ms, Ne @630-650 ms, MPTS "Phase B" — 2 shots
        iii. SGI @ 440-450 ms, MPTS "Phase C" — 2 shots

    # shots: 8 + 3 contingency

TOTAL: Approx 32 good shots

A q-scan, which is another sensitive parameter expected to affect the momentum pinch velocity, is another possibility if there is time or if one part is dropped for technical reasons…

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

Shot development may be needed to attain MHD quiescent H-mode depending on conditions (nominally want to repeat #134119) and L-mode conditions.

Use of SGI dependent on results of testing method for such in early Boundary Physics XP. Will require closely spaced MPTs laser pulses ($\Delta t\sim4$ ms, tweak as necessary) after SGI pulse. High time resolution profile reflectometry (1 ms) is also requested for particle pinch. Soft X-ray data for the particle pinch is also required with Ne puff.

5. Planned analysis

This data will be analyzed using EFIT/LRDFIT, with follow up analysis in TRANSP for computation of the torque sources and transport quantities. The TRANSP output will be processed using codes developed in XP 723/813 to extract perturbed diffusivity and pinch velocities. Similar analysis will be utilized for the particle pinch velocity, and/or following analysis of Delgado-Aparicio et al.

6. Planned publication of results

The data obtained from this XP will be required to write a more extensive paper (eg PoP) continuing from our PRL and IAEA/NF papers in 2008, and contribute to possible APS invited.

References

[1] T. S. Hahm, P. H. Diamond, O. D. Gurcan, and G. Rewoldt, Phys. Plasmas 14, 072302 (2007).

[2] A. G. Peeters, C. Angioni, and D. Strintzi, Phys. Rev. Lett. 98, 265003 (2007).

PHYSICS OPERATIONS REQUEST

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Describe briefly the most important plasma conditions required for the XP:

Discharge reproducibility, with significant periods of MHD quiescence (at least between times 300-600 ms)

List any pre-existing shots: #134119 (H-mode), #132748 (L-mode, but needs tweak to outer gap and beam program)

Equilibrium Control: Gap Control / rtEFIT(isoflux control): Outer gap control 10 cm.

Machine conditions *(specify ranges as appropriate, use more than one sheet if necessary)*

I_{TF} (kA): 41 – 64 (3.5 – 5.5 kG) Flattop start/stop (s):

I_P (MA): 0.7 – 1.1 Flattop start/stop (s):

Configuration: **LSN** *(strike out inapplicable cases)*

Outer gap (m): **0.1** Inner gap (m): Z position (m): **0**

Elongation κ: **2.3** Upper/lower triangularity δ: 0.8

Gas Species: **D, Ne** Injector(s): SGI + conventional

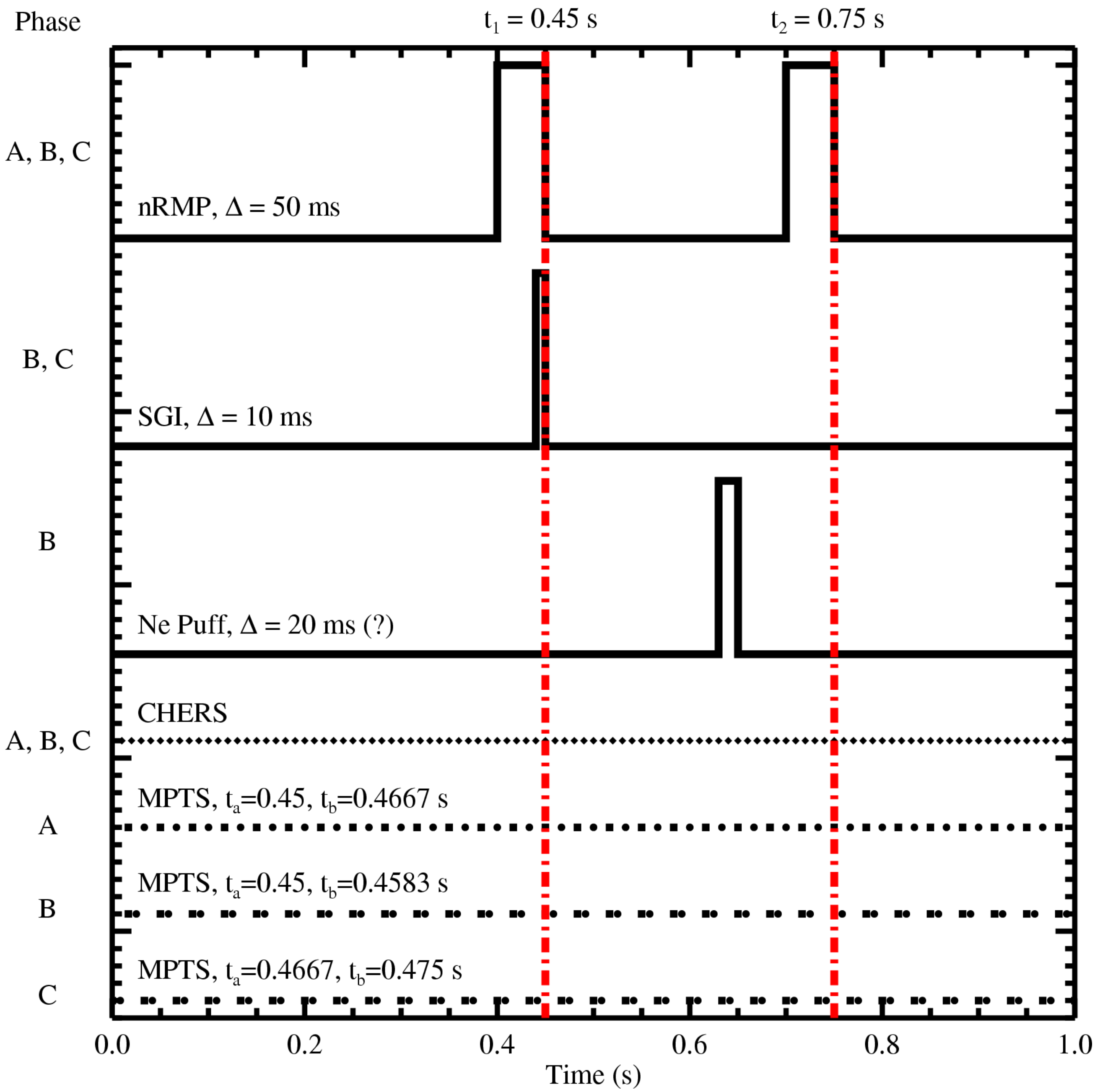
NBI Species: **D** Voltages (kV or off) **A: 90** **B: 80** **C:** 80 Duration (s): full shot

ICRF Power (MW): 0 Phasing: Duration (s):

CHI: **Off** Bank capacitance (mF):

LITERs: On Total deposition rate (mg/min): **15**

EFC coils: On Configuration: **Odd (n=1 correction with feedback)**


Phase
t1 = 0.45 s
t2 = 0.75 s
A, B, C
nRMP, Δ = 50 ms
B, C
SGI, Δ = 10 ms
B
Ne Puff, Δ = 20 ms (?)
CHERS
A, B, C
MPTS, ta=0.45, tb=0.4667 s
A
MPTS, ta=0.45, tb=0.4583 s
B
MPTS, ta=0.4667, tb=0.475 s
C
0.0
0.2
0.4
0.6
0.8
1.0
Time (s)

DIAGNOSTIC CHECKLIST

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Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
Bolometer – tangential array	√	
Bolometer – divertor		√
CHERS – toroidal	√	
CHERS – poloidal	√	
Divertor fast camera		
Dust detector		
EBW radiometers		
Edge deposition monitors		
Edge neutral density diag.		√
Edge pressure gauges		√
Edge rotation diagnostic	√	
Fast ion D_alpha - FIDA	√	
Fast lost ion probes - IFLIP		√
Fast lost ion probes - SFLIP		√
Filterscopes	√	
FIReTIP		√
Gas puff imaging		√
Hα camera - 1D		√
High-k scattering		√
Infrared cameras		
Interferometer - 1 mm		√
Langmuir probes – divertor		
Langmuir probes – BEaP		
Langmuir probes – RF ant.		
Magnetics – Diamagnetism	√	
Magnetics – Flux loops	√	
Magnetics – Locked modes	√	
Magnetics – Pickup coils	√	
Magnetics – Rogowski coils	√	
Magnetics – Halo currents	√	
Magnetics – RWM sensors	√	
Mirnov coils – high f.	√	
Mirnov coils – poloidal array	√	
Mirnov coils – toroidal array	√	
Mirnov coils – 3-axis proto.		

Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
MSE	√	
NPA – ExB scanning		
NPA – solid state		√
Neutron measurements	√	
Plasma TV		√
Reciprocating probe		
Reflectometer – 65GHz		√
Reflectometer – correlation		
Reflectometer – FM/CW	√	
Reflectometer – fixed f		√
Reflectometer – SOL		
RF edge probes		
Spectrometer – SPRED	√	
Spectrometer – VIPS	√	
SWIFT – 2D flow		
Thomson scattering	√	
Ultrasoft X-ray arrays	√	
Ultrasoft X-rays – bicolor	√	
Ultrasoft X-rays – TG spectr.		√
Visible bremsstrahlung det.		√
X-ray crystal spectrom. - H		√
X-ray crystal spectrom. - V		√
X-ray fast pinhole camera		
X-ray spectrometer - XEUS		√