Princeton Plasma Physics Laboratory **NSTX Experimental Proposal**		
Title: **Study of the correlation between GAE activity and electron transport**		
OP-XP-840	Revision:	Effective Date: *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS	
Responsible Author: D. Stutman	Date 06/18/08
ATI – ET Group Leader: Stan Kaye	Date
RLM - Run Coordinator: Michael Bell	Date
Responsible Division: Experimental Research Operations	

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

TITLE: **Study of the correlation between GAE activity and electron transport** No. **OP-XP-840**

AUTHORS: **D. Stutman, L. Delgado-Aparicio, K. Tritz, M. Finkenthal (*JHU*), N. Gorelenkov, E. Fredrickson, S. Kaye, E. Mazzucato *(PPPL)***

DATE: **06/18/2008**

1. Overview of planned experiment

A large increase in central electron transport with beam heating power was observed in NSTX H-modes, by changing the beam power at fixed q-profile (XP 612). This increase appears to be correlated with a quantitative and qualitative change in the Global Alfven Eingemode (GAE) activity. To strengthen and document this very important observation we propose to run an experiment in which we compare electron transport in plasmas with and without GAEs. We will use several different scenarios to make this comparison:

(i) Create discharges heated by equal beam power, P_b but at different beam voltage, V_p

(ii) Add to a baseline discharge with low GAE activity additional beam power at increasing V_b

(iii) Evaluate effect of B_t change at fixed-q on the GAE/electron transport connection

(iv) Evaluate how RF heats the plasmas with most/least GAE activity, obtained in (i) and (ii) above

These scenarios will be run in H-mode, the main NSTX operating regime.

In addition, in a first part we will attempt to measure the GAE density fluctuation amplitude using the high-scattering in interferometric mode. In a second part, we will change the system in scattering mode to evaluate also the level of high-k fluctuations in the central plasma, both at low and at high field. In this configuration the GAE amplitude will be estimated using the cross-calibrated Mirnov signals.

The estimated run time is one long day.

2. Theoretical/empirical justification

Electron transport is the dominant loss channel in beam heated NSTX plasmas. An unusual effect is that the T_e profile flattens and the central χ_e strongly increases with increasing beam power in NSTX H-modes (Fig. 1a). The TRANSP sensitivity analysis, a host of perturbative electron transport experiments, as well as the recent FIDA data, indicate that the flattening is a genuine electron transport effect and not the result of a broadening of the heating (i.e., beam ion density) profile by MHD activity. Furthermore, the large central χ_e at high P_b in Fig.1a, together with a number of other observations, suggest that we are dealing with electron transport along stochastic magnetic field lines.

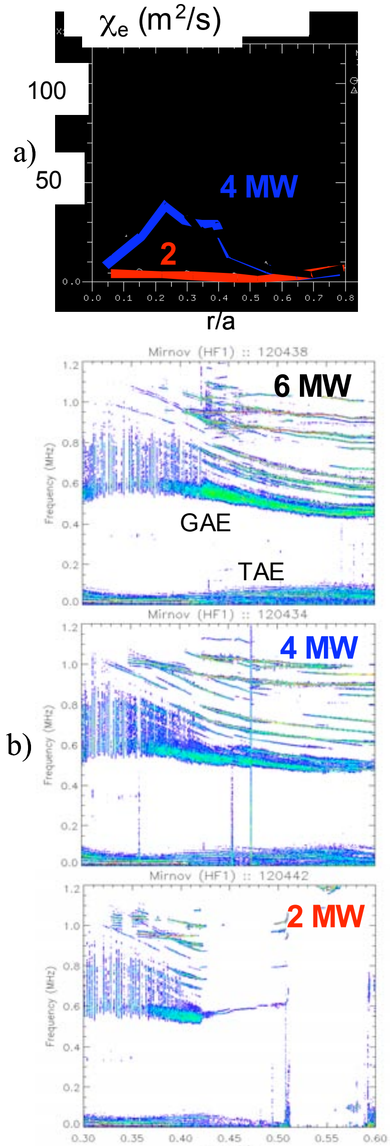

Fig. 1 χ_e behavior (a) and GAE behavior (b) as a function of beam heating power and at fixed -q. The power is stepped at 0.42s, from a steady 4 MW, to the level indicated.

The main puzzle is thus what is causing fast electron transport in the central NSTX plasma in the absence of a significant T_e gradient (or for that matter of any other significant thermal gradient). A logical (if unexpected) answer may be that the free-energy needed to drive this transport comes from the gradient of *non-thermal* particles. Indeed, the TRANSP analysis indicates that the fast ion density has by far the strongest gradient in the region $r/a \leq 0.4$-0.5.

Furthermore, a good 'mediating agent' between the fast ion gradient and the electron transport may be expected to be the persistent Alfven Eigenmode MHD activity driven by the fast ions in NSTX. In particular, shear Alfven Eigenmodes (*AEs) have been early on predicted to be able to induce electron transport through μ-tearing of the flux surfaces (see e.g., Lee, Okuda and Chance PRL 1981).

We therefore searched for a correlation between changes in central ce and changes in AE activity. A quite compelling correlation was found with the GAE (Global Alfven Eigenmode) activity. As recently shown at NSTX, these are high-n modes localized in the central plasma and have a substantial shear component [see e.g., N. Gorelenkov et al., E. Fredrickson et al.]. The correlation is illustrated in Fig. 1b, which shows that plasmas having high central χ_e have also intense, broadband GAE activity, while plasma with lowest transport is essentially GAEs free. Furthermore, the large χ_e increase for P_b>2 MW (Fig. 1a) suggests a threshold in the transition to stochastic electron transport, possibly correlated with a threshold in the GAE mode superposition, or 'coalescence', as seen in Fig. 1b also at P_b>2 MW.

Last but not least, the initial theoretical assessment of a possible GAE/electron transport connection is encouraging, in that multiple GAE modes seem to be able to induce stochastic transport of trapped electrons [N. Gorelenkov, preliminary]. If confirmed, this phenomenon could have deep implications for any burning plasma heated by a large population of fast beam ions and/or alphas.

3. Experimental run plan

Baseline shot: 129902 (4 MW, 0.9 MA, 4.5 kG, DN H-mode)

Initial high-k setup: interferometric mode, viewing at R≈115 cm

LITER OFF; error field correction coils OFF; beam pulse length 1 s

Part I: P_b step at increasing V_b and at two fields

No. of shots	Src. A	Src. B	Src. C	Neon (t=400ms)
B_t/I_p=4.5 kG/0.9 MA				
2	90 kV/40 ms	–	65 kV/80 ms	–
2	90 kV/40 ms	90 kV/450 ms	65 kV/80 ms	–
1	90 kV/40 ms	90 kV/450 ms	65 kV/80 ms	Y
2	90 kV/40 ms	77 kV/450 ms	65 kV/80 ms	–
2	90 kV/40 ms	65 kV/450 ms	65 kV/80 ms	–
1	90 kV/40 ms	65 kV/450 ms	65 kV/80 ms	Y
Increase B_t/I_p=5.5 kG/1.1 MA				
2	90 kV/40 ms	–	65 kV/80 ms	–
2	90 kV/40 ms	65 kV/450 ms	65 kV/80 ms	–
2	90 kV/40 ms	90 kV/450 ms	65 kV/80 ms	–
16 shots				
Time permitting				
1	90 kV/40 ms	90 kV/450 ms	65 kV/80 ms	Y
1	90 kV/40 ms	65 kV/450 ms	65 kV/80 ms	Y

Change overnight high-k to scattering mode (same R≈115 cm)

Condition in the morning before the run Source B to 95 kV

Part II: Compare plasmas with same P_b but different V_b

No. of shots	Src. A	Src. B	Src. C	I_p ramp	Neon (t=400ms)
B_t/I_p=4.5 kG/0.9 MA					
2	90 kV/40 ms	95 kV/80 ms	–	baseline	–
1	90 kV/40 ms	95 kV/80 ms	–	baseline	Y
2	90 kV/40 ms	65 kV/80 ms	65 kV/80 ms	baseline	–
2	90 kV/40 ms	65 kV/80 ms	65 kV/80 ms	baseline+50 ms	–
2	90 kV/40 ms	65 kV/80 ms	65 kV/80 ms	baseline+100 ms	–
1	90 kV/40 ms	65 kV/80 ms	65 kV/80 ms	best q match	Y
10 shots					

Part III: Compare RF heating in NB deuterium plasma with/w.o. GAEs

- **Apply 2 MW RF to plasmas having largest difference in GAE content**
- **Baseline RF setup as in shot 129389, B_t=5.5 kG (4 shots)**

Time permitting

Compare plasmas with same P_b but different V_b at increased field

No. of shots	Src. A	Src. B	Src. C	I_p ramp
Increase B_t/I_p=5.5 kG/1.1 MA				
2	90 kV/40 ms	65 kV/80 ms	65 kV/80 ms	best q match
2	90 kV/40 ms	95 kV/80 ms	–	baseline

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

(1) All neutral beams operational between 65 and 95 kV; **required**

(2) RF with phasing as in shot 129389, P ≤2 MW; **required**

(3) High-frequency and low frequency Mirnov coils; **required**

(4) MPTS at 16 ms spacing, with timing synchronized for a measurement at 450 ms; **required**

(5) CHERS synchronized for frame starting at 450 ms; **required**

(6) MSE synchronized for measurement starting at 450 ms; **required**

(7) High-k scattering at R≈115 cm in interferometric mode, to be changed later/overnight in scattering mode; **required**

(8) Neon injection with 1 atm line pre-fill, using Bay J midplane puffer; piezo valve PZV3 set for Neon flow rate of 1.5 Torr Liter/s, with one "Gaussian"-window between 400-406 ms; **required**

(9) Reflectometer 44.5 GHz frequency (3 10^{13} cm-3 cutoff) ; **desired**

(10) Three-color tangential optical SXR array; **required**

(11) USXR arrays in two-color configuration: Hor. Up – Be10, Hor. Down - Be100; **required**

(12) FIDA; **desired**

5. Planned analysis

TRANSP, multi-color SXR, impurity transport, ORBIT, GS2.

6. Planned publication of results

Contributions to international conferences and in refereed journals.

PHYSICS OPERATIONS REQUEST

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Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **53 – 65** Flattop start/stop (s): **-0.02/1.0 s**
I_P (MA): **0.9-1.1** Flattop start/stop (s): **0.12-0.3/0.8 s**

Configuration: **DN**

Outer gap (m): **0.05-0.10** Inner gap (m): **0.01-0.06**

Elongation κ: **2.25** Upper/lower triangularity δ: **0.6/0.6**

Z position (m):

Gas Species: **D, Ne** Injector(s): **Bay J midplane for Neon**

NBI Species: **D** Sources: Voltage (kV): **60-95** Duration (s): **1**

ICRF Power (MW): **2** Phasing: **TBD** Duration (s): **0.3**

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

LITER: **Off**

Shots for setup: **129902 (with TF waveform corrected for true flattop)**

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		