Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: Alfven Mode Similarity Experiment (with DIII-D)

OP-XP-	**Revision: 1.0**	Effective Date: 12/14/01 *(Ref. OP-AD-97)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Author: W. Heidbrink, S. Bernabei, D. Darrow, E. Fredrickson, G.Y. Fu, N. Gorelenkov, and E. Synakowski	Date 9/10//01
ATI - Task Force Leader:	Date
RLM - Run Coordinator:	Date

Responsible Division: Experimental Research Operations

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

Alfven Mode Similarity Experiment (with DIII-D)

W. Heidbrink (UC Irvine), S. Bernabei, D. Darrow, E. Fredrickson, G.Y. Fu, N. Gorelenkov, and E. Synakowski

1. Overview of planned experiment:

The major radius dependence of Alfven stability is studied by creating a plasma with a shape, field, density, and fast-ion population that matches DIII-D plasmas. The power threshold and toroidal mode number of beam-driven Alfven modes are measured.

2. Justification:

Potentially, the loss of alpha particles caused by Alfven modes could prevent ignition or damage the walls in either a conventional tokamak (CT) or a ST reactor. By improving our understanding of the physics of these dangerous modes, a similarity comparison between NSTX and DIII-D will improve projections of the performance of burning plasmas in a CT and will test the reactor potential of the ST concept.

In the MHD model of Alfven eigenmodes, gaps appear in the continuum of ideal MHD because of deviations from cylindrical symmetry. The TAE is caused by toroidicity, the EAE by ellipticity, the NAE by triangularity, and the BAE by beta and compressibility. In a ST, all of these gaps are quite large. Within the framework of ideal MHD, it seems likely that ST stability will be poorer than CT stability.

Kinetic effects are important too, however. When the pressure of fast ions is comparable to the background plasma pressure, the MHD eigenmode is modified, producing the RTAE (also called EPM) branch. The appearance of the EPM takes place more readily at higher beta, as the TAE frequency drops into the MHD continuum. Because of the larger gaps in the ST, it is possible that the transition from the TAE to the EPM will occur at higher beta in NSTX than in DIII-D.

Another important issue is the eigenfunction of the most unstable mode. The fast-ion drive for the TAE is largest when the mode width is comparable to the banana width of the fast ions. Different theoretical estimates yield different scaling predictions. Berk *et al.* [Phys. Lett. A 162 (1992) 475] predict $n \propto r^2/(q^2 s \rho R)$ for passing particles, where r, q, and s are the minor radius, safety factor, and magnetic shear at the location of the instability, ρ is the fast-ion gyroradius, and R is the major radius. Gorelenkov predicts a different dependence on aspect ratio, $n \propto r/(q^2 \rho)$. In projections to a CT reactor with large values of RB, it is expected that the most unstable toroidal mode number will shift to large values ($n \square 15-20$) and a "sea" of unstable TAEs will appear. It is thought that the appearance of this sea will alter the nonlinear saturation of the TAE from that observed in smaller devices. In the comparison between NSTX and DIII-D we will hold ρ and r approximately fixed, and see how the n of the most unstable mode scales with R.

A final motivation is to observe beam-ion loss. Theoretically, losses are enhanced strongly when $\gamma/\omega > 1/4N$, where N is the number of modes. The experiment may approach conditions where this criterion is marginally satisfied.

In addition, measurements of the spatial structure of the Alfven modes and of CAE activity are both highly desirable.

A companion experiment plans to compare the major radius dependence of thermal confinement. A valid comparison will require avoidance of Alfven modes, but the proposed experiment operates in a regime where the TAE is easily destabilized on DIII-D. Some initial information about the thermal confinement as well as guidance as to the best way to conduct a confinement experiment should be obtained in this stability experiment.

A comparison with all relevant parameters except the major radius matched is feasible. The early investigations of TAE physics on DIII-D included a toroidal field scan down to 0.6 T. Both the TAE (at lower power) and the BAE (at higher power) were unstable in these discharges. The plasma conditions were an inner wall limiter plasma with modest elongation (κ=1.6) and a plasma current of 0.6 MA. The low value of q and very large fishbone/sawtooth activity did cause some difficulties. In the comparison, a larger value of κ is desirable to facilitate low-field operation in DIII-D and to match the standard NSTX shape. It is also desirable to match the fast-ion populations. Both neutral beams operate at 80 keV, so it is straightforward to match the beam speed. We intend to match magnetic field |B| and density so, at least in an average sense, the Alfven speeds will be matched. It is also desirable to match the trapped/passing fraction of the beam populations. Use of the Right beams on DIII-D and the A and B sources on NSTX will nearly match the distribution functions.

A runday for this experiment is allocated on each of the devices during the 2002 campaign. The DIII-D experiment will be conducted first, using a standard NSTX shape to facilitate subsequent matching of the experimental conditions. The DIII-D experiment will attempt 0.60 T plasmas first, then vary the field in increments of 0.05 T if time permits. Because of the strong paramagnetic effects, 0.50 T NSTX operation will produce a field |B| similar to 0.60 T operation on DIII-D.

It is possible that sawteeth will have a strong impact on the beam-ion population in the DIII-D plasmas. Ideally, we will minimize these effects in the DIII-D experiment through early injection. If this fails, we may need to induce sawteeth in the NSTX experiment.

3. **Plan:**

The target shape for the DIII-D experiment is an inner-wall limiter configuration with κ=1.85 and δ=0.40. The actual shape will be a match to the EFIT from the prior DIII-D experiment.
Once a condition is obtained, a beam power scan is performed to find the threshold for Alfven instability (also to see if a transition from TAE to "BAE" activity occurs at higher beta.) Modulation of the beam sources is employed for better resolution of the threshold. Documentation of a condition requires plasma profile measurements for a TRANSP run.

For a given condition, we first match |B|, then attempt to match the density. Next, since it is not possible to match the poloidal gyroradius of the beam ions and the plasma q simultaneously, we

acquire data at two values of plasma current. The final step is to explore the sensitivity of the results to the beam distribution function by separately changing the angle of injection and the beam voltage.

1. Establish the baseline condition. Inner wall limiter, 0.50 T, 0.6 MA, κ=1.85, δ=0.40, with stairstep beam injection of source A and B.
2. Same as baseline but double null divertor with GAPIN ~ 3 cm.
3. Variations in gas puffing to match the DIII-D density.
4. Raise current to 1.0 MA (to match DIII-D q).
5. Substitute source C for source A in the baseline condition.
6. Reduce beam voltage to 70 kV then 60 kV.

If time permits, repeat sequence at a different value of toroidal field.

4. Required machine, beam, ICRF and diagnostic capabilities:

Machine: 4.5 kG, possibly 6 kG.

Beams: 60-80 keV deuterium, all three sources, with modulation to vary duty cycle.

No ICRF.

Diagnostics: For the fast ions, the neutrons are essential and the other fast-ion diagnostics are highly desirable. For instability analysis, toroidal array measurements to 250 kHz are essential; any possible radial eigenfunction measurements are highly desirable. For calculations of expected thresholds, full kinetic profiles of electrons, ions, and impurities are essential.

5. Planned analysis:

Basic experimental analysis (EFIT, magnetic spectrographs, toroidal mode number, expected versus measured neutrons) will be performed for all NSTX and DIII-D discharges to find the best "matches" between devices. Theoretical analysis with NOVA-K and HINST will then be performed.

6. Planned publication of results:

A major article on the results is anticipated within one year of completion of both experiments.

PHYSICS OPERATIONS REQUEST

Title: **Alfven Mode Similarity Experiment (with DIII-D)** **XP No.:**

Machine conditions (indicate range where appropriate):

TF: 0.45-0.55 T Flattop not essential

I_p: 0.5-1.1 MA (flattop not essential)

Position: R (m) ? Z (m) 0 Outer gap to match DIII-D shape
Inner wall: zero gap and matching DIII-D shape

Gas: Prefill D Puff D

NBI:Power (MW) all sources (modulation) duration (s) 0.4 Voltage (kV) 60-80

RF: Power (MW) 0 Start / stop (s) _____ Frequency (MHz) _____

CHI: Off

If this is a continuation of a previous run or if shots from a previous run are similar to those needed, provide shot numbers for setup

---

If shots are new and unique, sketch desired time profiles and shapes. Accurately label the sketch so there is no confusion about times or values. Attach additional sheets as required.

DIAGNOSTIC CHECKLIST

Title: Alfven Mode Similarity Experiment (with DIII-D) XP No.:

		Need	Desire	Special requirements
Magnetics	Flux loops, B-coils	x		
	Passive plate diag.			
n_e and T_e	Interferometer	x		
	Thomson Scattering	x		
T_i	CHERS	x		
	NPA		x	
Spectroscopy	H_α		x	
	SPRED (UV)		x	
	VIPS (H/D ratio			
	X-ray PHA		x	
	Visible Bremsstrahlung		x	
Particles	NPA		x	
	Neutron counters	x		
	Neutron fluctuations	x		
Fluctuations	Mirnov Coils	x		
	X-ray Array		x	
	Reflectometer		x	
Edge	Bolometer		x	
	Plasma TV		x	
	IRTV	x		Beam-ion losses?