

**Princeton Plasma Physics Laboratory  
NSTX Experimental Proposal**

**Title: Dependence of ELM size and Power Balance on drsep**

**OP-XP-609**

**Revision: 2**

Effective Date: 2/27/2008  
*(Ref. OP-AD-97)*

Expiration Date:  
*(2 yrs. unless otherwise stipulated)*

**PROPOSAL APPROVALS**

**Author: R. Maingi**

Date

**ATI – ET Group 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)

Original proposal has been updated with revised plan for scans, more recent reference shots and updated diagnostic list.

# NSTX EXPERIMENTAL PROPOSAL

TITLE: **Dependence of ELM size and Power Balance on drsep**  
 AUTHORS: **Rajesh Maingi**

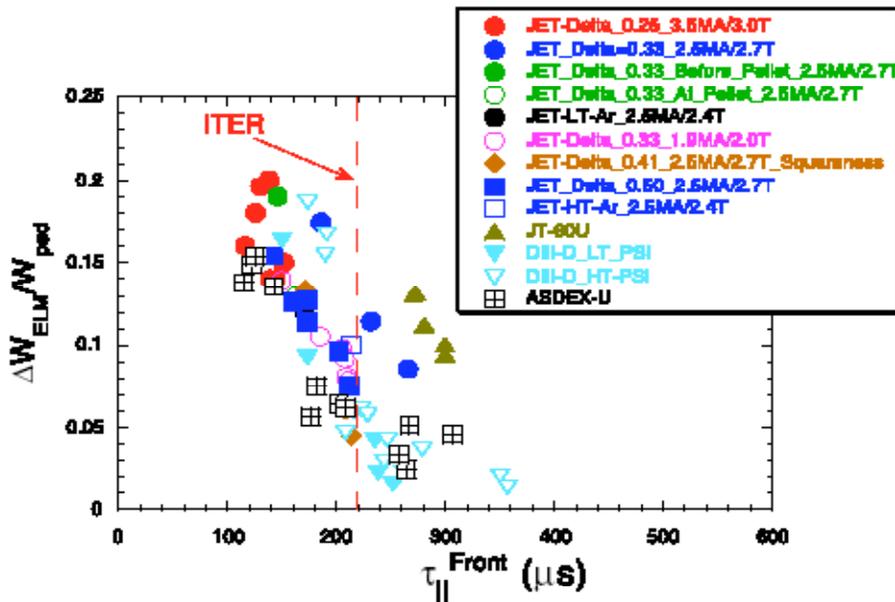
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## 1. Overview of planned experiment

The primary goal of this experiment is to measure the transition point(s) from small ELMs to large ELMs as a function of the magnetic balance as characterized by the EFIT  $\delta_r^{sep}$  parameter. The secondary goal is to measure the dependence of the up/down divertor power balance split on magnetic balance.

## 2. Theoretical/ empirical justification

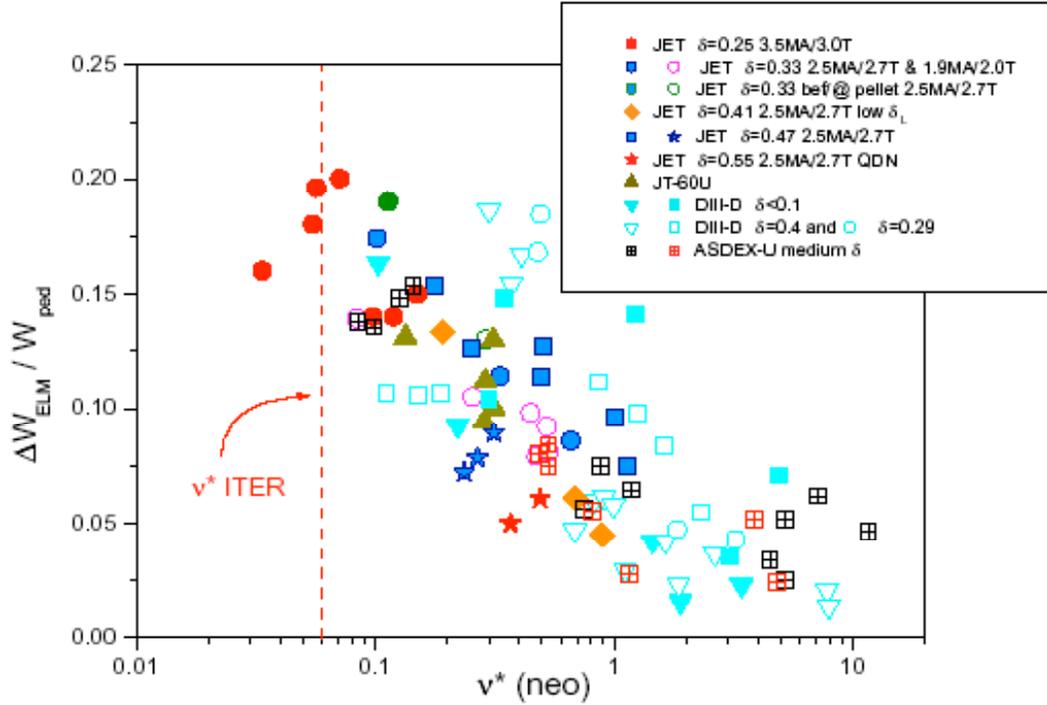
Projections<sup>1</sup> of the energy loss from Type I ELMs for the International Thermonuclear Experimental Reactor (ITER) have yielded a pedestal energy loss fraction between 5% and 20%, depending on the model used for extrapolation. Here the pedestal energy loss fraction is given by  $\Delta W/W_{ped}$ , where  $\Delta W$  is the stored energy change during the ELM and  $W_{ped}$  is the stored energy in the H-mode pedestal. Figure 1 shows the extrapolation for Type I ELMs assuming ELM power carried by ions flowing at the ion sound speed in the scrape-off layer, which yields a prediction of 4-12% for ITER. Figure 2 shows the dependence of ELM power loss on collisionality at the top of the pedestal  $\nu^*$ ; it is seen that  $\Delta W/W_{ped} \sim 20\%$  for the predicted ITER  $\nu^*$ . The power loading problem in ITER would be greatly simplified by the elimination of ELMs with resonant magnetic perturbations<sup>2</sup> or by access to small ELM regimes.



**Figure 19.** Normalized ELM energy loss ( $\Delta W_{ELM}/W_{ped}$ ) versus SOL ion flow parallel time calculated for the pedestal plasma parameters ( $\tau_{||}^{Front}$ ), for a large range of Type I ELMy H-mode plasmas in ASDEX Upgrade, DIII-D, JT-60U and JET including various plasma triangularities, ratios of  $P_{INPUT}$  to  $P_{L-H}$ , impurity seeding (Ar) and pellet triggered ELMs.

Fig. 1 from reference<sup>1</sup>, where extrapolation to ITER is done via a physics-based model assuming ELM power flow on the open field lines at the ion sound speed.

We have identified<sup>3</sup> a small ELM regime in NSTX, named Type V ELMs to distinguish them technically from Type II and grassy ELMs seen on other devices. These ELMs were observed in lower triangularity  $\delta \sim 0.4$  discharges, when the  $\delta_r^{\text{sep}} \leq -1\text{cm}$ . Note that the convention for  $\delta_r^{\text{sep}}$  is negative (positive) when the lower (upper) X-point is favored; a balanced double-null has  $\delta_r^{\text{sep}} \sim 0$ . When the discharge was changed to a balanced double-null, Type I and III ELMs were observed. In the LSN configuration, large Type I ELMs between the Type V ELMs were observed when  $\nu^* \leq 1$  which also corresponded to  $\beta_N \geq 5$ .



**Figure 11.** Normalized ELM energy loss ( $\Delta W_{\text{ELM}}/W_{\text{ped}}$ ) versus pedestal plasma collisionality for a large range of Type I ELMy H-mode plasmas in ASDEX Upgrade, DIII-D, JT-60U and JET including various plasma triangularities, ratios of  $P_{\text{INPUT}}/P_{\text{L-H}}$  and pellet triggered ELMs.

Fig. 2 from reference<sup>1</sup>, where ‘extrapolation’ to ITER is based solely on pedestal  $\nu^*$ .

In more recent high  $\delta \sim -0.75$  discharges, a small ELM regime was observed when  $\delta_r^{\text{sep}}$  was  $\sim -0.5\text{cm}$ , and large Type I ELMs were observed with  $\delta_r^{\text{sep}} \sim 0$ . These small ELMs appeared similar to Type V ELMs on several diagnostics, except perhaps with toroidal mode number  $n > 1$ . The observed pedestal temperature was higher in this shape, leading to a pedestal  $\nu^* \sim 0.3$ , and yet no Type I ELMs were observed. Thus, it is evident the plasma shape plays an important role in determining the boundaries between large and small ELMs.

To give confidence in edge stability predictions for ITER, the boundary between small ELMs and large ELMs should be measured experimentally and simulated. In particular, any dependencies which extend the operating range of small ELM regimes, e.g. high  $\delta$ , to more ITER-like parameters, e.g.  $\nu^*$ , should be studied. This is the focus of this experiment.

In addition, we will measure the power balance as a function of  $\delta_r^{\text{sep}}$  in piggyback mode, to complete our previous study<sup>4</sup>, in which we inferred an improved power accountability in DN discharges as compared with LSN discharges.

### 3. Experimental run plan (1 day, prioritized list below)

Perform  $\delta_r^{\text{sep}}$  scan in high  $\delta \sim 0.75$

- Reproduce rtEFIT long pulse #123876 with  $\delta_r^{\text{sep}} \sim -0.5$  cm, except drop  $I_p$  to 0.9 MA (2 shots)
- Do a  $\delta_r^{\text{sep}}$  ramp from 0 to -3 cm and back down to 0 (2)
- Increase  $\delta_r^{\text{sep}}$  in 0.2 cm steps from -0.5 cm until H-mode lost (5)
- Reproduce baseline #119085 (1)
- Decision point: Perform  $\delta_r^{\text{sep}}$  scan at -1.0 cm, -1.5 cm, -2 cm, -2.5 cm until H-mode lost and/or ELMs change substantially or do a binary search to find  $\delta_r^{\text{sep}}$  window for small ELMs (6)
- Time permitting, localize  $\delta_r^{\text{sep}}$  value if/when ELMs change or H-mode lost as  $\delta_r^{\text{sep}}$  decreases (4)

Perform  $\delta_r^{\text{sep}}$  scan for PF2L LSN with low  $\delta \sim 0.4$

- Reproduce rtEFIT #119840 with  $\delta_r^{\text{sep}} \sim -2$  cm, increase to the higher acceptable value of 0.9 or 0.8 MA (3)
- Do a  $\delta_r^{\text{sep}}$  ramp from -2 to 0 cm and back to -3 cm (2)
- Decision point: Perform  $\delta_r^{\text{sep}}$  scan at 0 cm, -0.5 cm, -1 cm, -1.5 cm or do a binary search to find  $\delta_r^{\text{sep}}$  window for small ELMs (4)
- Localize  $\delta_r^{\text{sep}}$  when ELMS change (4)

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

This XP requires an operational NBI system, as well as the capability of performing a detailed  $\delta_r^{\text{sep}}$  scan with rtEFIT. We desire HeGDC between shots of  $\sim 6.5$  minutes for a 12.5 minute repetition rate.

### 5. Planned analysis

Edge stability calculations will be done with a number of codes, including PEST, DCON, and ELITE, and possibly MARS. The power balance will be compared to calculations with simple 2-point and 1-D models.

### 6. Planned publication of results

Data and analysis will be presented at ITPA pedestal and SOL group meetings and published in Nucl. Fusion.

<sup>1</sup>A. Loarte, et. al., 2003 Plasma Physics Controlled Fusion 45 1549.

<sup>2</sup>T. E. Evans, et. al., 2004 Physical Review Letters 92 article #235003.

<sup>3</sup>R. Maingi, et. al., 2005 Nuclear Fusion 45 264.

<sup>4</sup>S. F. Paul, et. al., 2005 J. Nucl. Materials 337-339 251.

## PHYSICS OPERATIONS REQUEST

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Machine conditions (specify ranges as appropriate)

$I_{TF}$  (kA): **52**                      Flattop start/stop (s): \_\_\_\_\_/\_\_\_\_\_

$I_p$  (MA): **0.8-1.0**                      Flattop start/stop (s): **0.15/1.5 (max)**

Configuration: **Lower Single Null / Upper SN / Double Null**

Outer gap (m): **5-15cm**,                      Inner gap (m): **2-10cm**

Elongation  $\kappa$ : **1.8-2.3**,                      Triangularity  $\delta$ : **0.4-0.8**

Z position (m): **0.00**

Gas Species: **D**,                      Injector: **Inner wall Midplane**

NBI - Species: **D**, Sources: **A/B/C**, Voltage (kV): **90**,                      Duration (s): **<1.5 sec**

ICRF – Power (MW): \_\_\_\_\_, Phasing: \_\_\_\_\_,                      Duration (s): \_\_\_\_\_

CHI: **Off**

Previous shot numbers for setup: **119085 (DN), 119136 (LSN), 123876 (high  $\delta$ )**

## DIAGNOSTIC CHECKLIST

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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		✓
H $\alpha$ 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	✓	

Diagnostic	Need	Want
Magnetics - RWM sensors	✓	
Mirnov coils – high f.	✓	
Mirnov coils – poloidal array	✓	
Mirnov coils – toroidal array	✓	
Mirnov coils – 3-axis proto.		
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'r - H		
X-ray crystal spectrom'r - V		
X-ray fast pinhole camera		✓
X-ray spectrometer - XEUS		✓