1. Purpose of Experiments
   
   The purpose of these experiments is two-fold; one is to check whether the ELM-like bursts during high density (or $\beta$) plasmas are from high $\beta$ effects and the other is to see if the signal dips on GPC are also due to high $\beta$ effects, or something else, such as high density effects.

2. Background
   
   During high density (or $\beta$) plasmas of 1998 run campaign, ELM-like bursts were observed on top of EDA-like baselines, which are apparently different from those observed during normal (or low) $\beta$ plasmas. At the same time, there were short ECE signal dips on almost all of the GPC channels, like in the midst of density cutoffs. However, as the core densities were not high enough to cause density cutoffs for the core channels of the ECE diagnostics, those signal dips seemed to reflect either the edge characteristics of the ELM-like bursts or high $\beta$ effects.

   We do not know whether these kinds of high $\beta$ ELM-like bursts are entirely different from typical Type III ELMs or not. In particular, the signal dips on GPC are believed to be due to localized high edge density, rather than high $\beta$ effects because similar signal dips were observed during low $\beta$ plasmas. In a temporally well-resolved low $\beta$ plasma (971212032) with fast window, the signal dips lasted for $20 \sim 30$ $\mu$sec with $\sim 1$ kHz repetition frequency and their $T_e$ fractional changes were $10 \sim 50$ %. However, since most of the ELM-like bursts accompanied by the GPC signal dips occurred during high $\beta$ plasmas, we do not exclude a possibility of the high $\beta$ effects. The signal dips observed on GPC (i.e. 980217) appeared to have been underestimated during the high $\beta$ run because the GPC sampling frequency (20 kHz) was slower than the short dip durations ($20 \sim 30$ $\mu$sec). Moreover, the fundamental O-mode ECE radiometer was not available due to some
technical problems. Apart from some different features (spikes, rather than dips) observed on the ECE radiometer in other runs, ELM-like bursts were simultaneously observed on the two ECE diagnostics (GPC and Radiometer) that were capable of resolving such fast signals. Such ELM-like bursts were also observed on the divertor probes, whose spikes were almost the same as those of the ECE radiometer. This suggests that the edge conditions during the ELM-like bursts, as well as an Type III ELMs, change drastically.

In the upcoming campaign, as we have enhanced the capability of diagnosing various edge parameters (i.e. edge Thomson Scattering), we expect to obtain well-resolved edge parameters, in addition to the established diagnostic systems (GPC, GPC2, ECE fundamental O-mode radiometer, divertor probes, $D_\alpha$). Thus, this experiment is expected to provide a clear answer about whether high $\beta$ is a necessary condition for these ELM-like bursts, and whether it contributes to the GPC signal dips.

3. Approach

Describe the methodology to be employed; explain the rationale for the choice of parameters, etc. Describe the analysis techniques to be employed in interpreting the data, if applicable. If the approach is standard or otherwise self-evident, this section may be absorbed into the Experimental Plan.

Assuming that plasma current ($I_P$), magnetic field ($B_T$), and minor radius ($a$) are fixed, the key parameter to control $\beta$ (or $\beta_N$) will be power only. This will be controlled by the enhanced ICRF operability, while the plasma density will mostly be kept low in order to reduce high density effects. Using Greenwald’s scheduled EDA/ELM-free mapping experiments, the startup conditions for observing the ELM-like bursts are expected to be given (esp. $I_P$=0.8 MA, $B_T$= 5.3 T, $n_e$=1.6×10^{20} m^{-3}, where EDA will likely occur). Then, the power will be varied for $\beta$ control until the bursts are gone and/or the operation limits are met. Even if the ICRF power control is not enough to see any changes for the ELM-like bursts, changing the plasma density may be used as an additional knob for obtaining different plasma conditions. Nevertheless, if the density gets higher with high $\beta$, it is not easy to distinguish the high $\beta$ and density effects, which is one of the main themes involved in the GPC signal dips. Thus, another $\beta$ scan at different $n_e$ will enable us to separate the $\beta$ and density effects. If we want to simply answer the question associated with the GPC signal dips only, these experiments can piggyback on mapping experiments proposed by Greenwald. However, in terms of exploring a potentially new ELMy H-mode regime, these experiments are worthy of a dedicated run.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for :

**Toroidal Field:** 5.3 T

**Plasma Current:** 0.8 (1.0) MA

**Working gas species:** $D_2$
Density: See Sec. 5

Equilibrium configuration (if possible, refer to database equilibria):

Pulse length, typical current & density waveforms, etc. Refer to database or sketch desired waveforms: See Shot 980217013

4.2 Auxiliary Systems

RF Power, pulse length, phasing: $1 \sim 7$ (?) MW (at least 4 MW is required for upper limit)

Pellet Injection (species): none

Impurity blow-off injection: none

Special gas puffing: none

Other:

4.3 Diagnostics

List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.

All ECE diagnostics (GPC, GPC2, O-mode radiometer, X-mode radiometer), edge profile diagnostics (Reflectometer, PCI, Divertor probes, Edge Thomson), and magnetics should be operational.

All fast diagnostics should be available during H-mode.

4.4 Neutron Budget

Estimate the neutron dose rate at the site boundary. Give basis for estimate. (Once some experience has been gained a standard formula will be provided for estimating dose rates.)

nominal

5. Experimental Plan

5.1 Run sequence plan

Specify total number of runs required, and any special requirements, such as consecutive days, no Monday runs, extended run period (10 hours maximum), etc.

1 day run, requires well conditioned boronized machine

5.2 Shot sequence plan

For each run day, give detailed specification for proposed shot sequence: number of shots at each condition, specific parameters and auxiliary systems requirements, etc. Include contingency plans, if appropriate.

Preliminary Setup
1. Based on Greenwald’s mapping experiments, the startup conditions will be given (esp. $I_p=0.8 \text{ MA}$, $B_T=5.3 \text{ T}$, $\bar{n}_e=1.6 \times 10^{20} \text{ m}^{-3}$ (target density prior to RF heating), where EDA will likely occur).

2. If the ELM-like bursts do not appear at the 0.8 MA operation, go to 1.0 MA operation in reference to Shot 980217013, which showed typical ELM-like bursts.

   **Note:** Shot 980217013 ($I_p = 1.0 \text{ MA}$, $\bar{n}_e = 1.6 \times 10^{20} \text{ m}^{-3}$, $\delta_u=0.33$, $\delta_l=0.51$).

3. To suppress the high density effects, lower the target density to $1.2 \times 10^{20} \text{ m}^{-3}$ (or the lowest possible density). If the ELM-like bursts are gone, go back to the previous density, $1.6 \times 10^{20} \text{ m}^{-3}$. Otherwise, adopt the lowest possible density as a target density for observing the ELM-like bursts.

**Power (or $\beta$) scan**

As long as the ELM-like bursts are observed at any RF power, perform the power scan during ICRF application. If the ELM-like bursts, which should be discerned by edge diagnostics (i.e. $D_\alpha$ and divertor probes), are seen on top of enhanced $D_\alpha$ baseline without going to other regimes (say, Type I ELMs), keep increasing the RF power until the available power runs out or something else comes up.

There will be two types of power scans; coarse and fine, although both of them use similar step up and down schemes.

a) First, run coarse power scan to see where the lower and upper $\beta$ boundaries for observing the ELM-like bursts might be.

b) Then, run fine power scan near the lower and upper boundaries. The question about the existence of an upper boundary should be answered prior to the fine power scan for the upper boundary.

4. Regardless of the power scan types, each shot consists of 5 power steps. There will be two power step ups, followed by two step downs. The power step down is necessary to verify whether a certain power (or $\beta$) is a real key parameter for observing such bursts.

For example, the coarse power scan will be performed by 1, 2, 3, 2, and 1 MW. Next, 3, 4, 5, 4 and 3 MW scan is to be done and then 5, 6, 7, 6 and 5 MW scan might be necessary; 2 shots per each scan are necessary and the total will be less than 6 shots. The fine power scan with a smaller power step change will be similar to the coarse one. That is, if there is a big change near 3 MW based on the previous coarse power scan, the fine power scan will be composed of 2.75, 3.0, 3.25, 3.0, and 2.75 MW at first. Then, if the change is more sensitive to 3.25 MW, rather than 3.0 MW during the fine power scan, the next scan will be like 3.0, 3.25, 3.5, 3.25 and 3.0 MW. Prior to entering a sensitive boundary, it will be necessary to perform 2 or 3 fine power scans for picking up the right conditions. Then verify whether such conditions are reproducible. Thus, the total number of fine scans for each boundary investigation may be 5 shots. If necessary, a finer power scan (i.e. 200 kW RF step) will be performed.

**Note:** For fine (coarse) power scan, the RF power will be stepped up and down in 250 kW (1 MW) increments and decrements with approximately 120 msec between steps to
allow temperatures to stabilize. The input power should be kept greater than the H-mode threshold (say, 1.0 MW for 1.0 MA and 1.2 MW for 0.8 MA). Especially, since the EDA is a prerequisite for these experiments, take a note for a EDA power threshold if EDA follows ELM-free.

5. While the lower boundary is expected to be found without any doubt, there are three possible cases we may encounter during the upper boundary investigation.

a) During the whole RF power scan up to 7 MW, the ELM-like bursts persist.

b) At a certain high power, the ELM-like bursts are gone.

c) At a certain power higher than 3 MW, a totally new phenomenon, such as Type I ELMs, occurs.

In each case, we need to check whether the lower and upper boundaries are from $\beta$ changes only. Thus, we can try a different density, which will also be as low as possible in order to exclude any high density effects, while each $\beta$ should be kept constant in spite of the density change. Then, perform the power scan in the same way as the aforementioned. This time the number of shots can be reduced as follows: Coarse power scan - 2 shots for each boundary, Fine power scan - 3 shots for each boundary, Total - 10 (at most).

6. Comparing the results of the power scans at two different low densities, we may conclude as follows;

A. If there is no difference at the two different densities, the ELM-like bursts are definitely associated with $\beta$ (or $\beta_N$) values. For 5-a), we need to lower magnetic field ($B_T$) to increase $\beta_N$ ($\propto 1/B_T$), even if it will not be explored in these experiments in detail. Although the ECE diagnostics may not be accessible under the lower magnetic field, other diagnostics will be able to see if there is any change associated with a lot higher $\beta$. For 5-b), the ELM-like bursts are apparently determined not to be from high $\beta$ effects. Instead, there will be certain $\beta$ regime, where the edge conditions may change drastically. For 5-c), there must be a certain $\beta$ regime which is involved in such ELM-like bursts, after which something else can prevail. Hence, for 5-b) and 5-c), we need to find physical mechanisms for explaining the ELM-like bursts associated with $\beta$.

Note: Just in case we need to discriminate the effects of $\beta$ and $\beta_N$, we may try a different current because $\beta$ is proportional to $I_P$, whereas $\beta_N$ is not.

B. If there is difference, perform density scan with $\beta$ fixed as before. In this case, the density need not be so low as in the previous cases, as long as it is lower than the cutoff densities of GPC core channels. At most, 4 shots will do, including reproducing a critical density case, if it exists. In the end, additional density scans with power (or $\beta$) fixed will not only give us a clear answer about the question whether the ELM-like bursts during EDA H-modes are from density effects, but also enable us to find a critical edge density, if it exists, for observing the signal dips on GPC.

6. Anticipated Results
Discuss possible experimental outcomes and implications Indicate if the program may be expected to lead to publications, milestone completions, improved operating techniques, etc. Indicate if the experiments are intended to contribute to a joint research effort, or an external database.
Whether high $\beta$ plays a role in producing ELM-like bursts during EDA, and in causing the GPC signal dips or not is to be found. If the density effects are the only source for the cause of the GPC signal dips, the critical density is expected to be found.

7. References
Include references both to external and internal literature or communications which bear on this proposal. See Section 2.