1. Purpose of Experiments

Include immediate goal of the experiments, scientific importance and/or programmatic relevance. Refer to any relevant program milestones.

The goal of the experiment is to carefully characterize the time histories of profiles and fluctuations in the pedestal region between ELMs. The key question of this experiment is to determine the fluctuations responsible for transport during the evolution of the pedestal gradient in between ELMs. In fact, the leading model for predicting the pedestal height (EPED) shows that the maximum pedestal pressure gradient evolves as expected if kinetic ballooning modes (KBMs) limit the pressure gradient [1]. The hard onset of the KBM growth rate enables strong transport in all channels (electrons and ions), which clamps the pedestal pressure gradient while keeping the expansion of the pedestal width and height. The analogue to this in EDA H-mode is the quasi-coherent mode (QCM), which is likely a manifestation of a resistive ballooning mode [2]. By obtaining EDA and ELMy H-modes in a common equilibrium and with common diagnostics, this experiment could allow us to observe and understand the transition between these regimes.

2. Background

Discuss Physics Basis of the proposed research. Prior results at Alcator or elsewhere, and any related work being carried out separately.

Previous pedestal experiments on C-Mod [3], including experiments during the FY11 DOE Joint Research Target Milestone on pedestal physics experiments with NSTX and DIIIID, have helped advance the physics of the pedestal evolution between ELMs. On DIIIID [4] and NSTX [5], the pedestal pressure gradient after the ELM crash is found to evolve until saturation. This saturation is fast and occurs on transport time scales of a few milliseconds. On C-Mod, preliminary inter-ELM analysis of the pedestal parameters showed a linear dependence between the pedestal pressure width and height suggesting a fixed gradient throughout the ELM cycle. Furthermore, recent tests of the EPED model on C-Mod have shown good agreement of the pedestal width scaling with beta poloidal [3]. This scaling (based on the EPED model) suggests the existence of KBMs for limiting the pressure gradient. Note that KBM-like fluctuations have been observed on DIIIID using the BES diagnostics [6]. KBMs are known electromagnetic fluctuations with short perpendicular wavelengths propagating in the ion-diamagnetic direction. In addition, KBMs have
a hard-onset, which could be characterized experimentally by a large fluctuation increase occurring during the inter-ELM phase.

For higher values of collisionality, C-Mod H-modes operate in the EDA regime, in which the pedestal transport is largely regulated by the QCM. This mode reduces in strength as collisionality is reduced, and the EDA H-mode is replaced by either ELM-free or ELMy H-mode with a relatively quiescent edge dynamics. Documenting the gradual disappearance of the QCM and perhaps its replacement by something more KBM-like would be an interesting result of this experiment.

![Figure 1: Left: Dalha time trace showing the fast and slow ELMs. Right: Trends of the pedestal height and width during the various parts of the ELM cycle.](image)

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.

For this work, the aim is to carefully document the pedestal evolution and to observe the fluctuations turn on as the electrons pedestal gradient evolves and saturates. In addition to Thomson measurements, a suite of fluctuations measurements are required to quantitatively estimate relative changes of the fluctuation levels. Such suite of measurements should include the reflectometers (both SOL and pedestal), PCI and fast-TCI for density fluctuations, the GPI for estimate of the radial and poloidal wavenumbers, the magnetic probes. In order to maximize the chance of detecting KBMs, we will use the latest-generation magnetics probe head attached to the ASP, and scan into some modestly powered H-mode edges as far as possible.

In order to obtain clean, steady H-modes, an overnight boronization will be required before the run. Thus several shots of boronization recovery will be needed in the morning of the experiment, and the initial H-modes will have large amounts of wall fueling. We will take advantage of this to achieve high-collisionality EDA H-modes early in the run,
then transition to ELMy H-mode by gradually reducing the plasma density throughout the day. To obtain EDA and ELMy H-mode in a common shape will require operation with moderate elongation ($\kappa \leq 1.55$), a weakly shaped crown ($\delta_u \approx 0.2$) and an outer strike point either in the divertor slot or very low on the vertical plate ($\delta_l > 0.7$). This is the so-called “JFT-2M” shape. The reference shot is 1101214029.

EDA pedestals have high-frequency (~100kHz) oscillations from the QCM, and therefore profile data can be analyzed under steady-state assumptions. Profiles in ELMy H-mode must be analyzed according to their timing within the ELM cycle. The mechanism to do this exists for the Thomson data, via the python tools imported from GA by T. Osborne. The ELM-syncing of the edge CXRS data is being developed by C. Theiler. In order to facilitate ELM-synced analyses of the data, we will (a) attempt to slow down the ELM cycle as much as possible by optimizing power and density programming and (b) take a number of repeated shots in an optimized condition to improve statistics.

Successful completion of the experiment will result in accurate kinetic profiles as a function of (a) collisionality and (b) time relative to time-of-ELM event, as well as a complete set of fluctuation diagnostics which might be used to identify candidate modes for cross-field transport drive in the pedestal. Macroscopic discharge data will be collected for inputs to pedestal simulations, including M3D, BOUT++, GYRO, et al.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

- Toroidal Field: 5.4T
- Plasma Current: 0.9MA
- Working Gas Species: D2
- Density: 1—2 x $10^{20}$ m$^{-3}$
- Boronization Requested (if yes, specify whether overnight or between-shot, how recently needed, and any special conditions.): yes, overnight
- Equilibrium configuration (if possible, refer to database equilibria): $\kappa \leq 1.55$, $\delta_u \approx 0.2$, $\delta_l \approx 0.8$ (e.g. 1101214029)

4.2 Auxiliary Systems

- ICRF Power, pulse length, phasing: 2—4MW, D(H) heating
- LHCD Power, pulse length, phasing: none
- Pellet Injection (species): none
- Impurity blow-off injection: none
- Diagnostic Neutral Beam: yes, if available
- Special gas puffing: NINJA with D2 for CXRS, He for GPI fluctuations; Ar for Hirex Sr
- Cryopump: no
- Non-axisymmetric Coils (Connections, Current); standard locked-mode correction
- Other:
4.3 Diagnostics
List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.

Core/edge TS with both lasers. Edge CXRS. Hirex Sr. Bolometry. All available D-alpha, Ly-alpha diagnostics
X-mode reflectometer, O-mode reflectometer, PCI, fTCI, GPI, magnetics, shoelace antenna in receiving mode
ASP with magnetics probe head

5. Experimental Plan
Both sections must be filled in.

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 extended run is requested, following an overnight boronization. A 10 hour day will allow for shots lost to boronization recovery, and give sufficient time for the density to come down and yield ELMy H-modes.

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.

Initial shots will be used to recover ICRF operation following boronization. The first H-modes will be high-density EDA H-modes at moderate amounts of RF power. By systematically reducing density over the course of the day, ELMy H-modes will be obtained.

1. Load from 1101214029. Set target nl04 to 1.0x10^{20} m^{-2}. Apply ICRF power after 0.6s. Recover from boronization. (3—6 shots)

2. At same conditions as in 1, obtain EDA H-modes at modest input power (2—3MW ICRF) and begin optimizing: (a) passive diagnostic coverage (b) NINJA puffs (c) probe plunges (2—3 shots).

3. Begin reducing target nl04 in steps of 0.1 x10^{20} m^{-2} down to nl04 = 0.5 x10^{20} m^{-2}. For each condition verify collection of good set of profile and fluctuation data. (3 shots per condition = 15 shots)

4. Find a suitable ELMy H-mode from the density scan in 3 and repeat several times with constant ICRF power, density, in order to get best possible Thomson data. (10 shots)

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, an ITER request, or an external database.
The experiment will extend our knowledge of the dynamics of pedestal evolution in standard H-mode, a major goal of ongoing ITPA research, and an important follow-on to the FY11 JRT in pedestal physics. Including the reciprocating magnetics probe in the experiment gives us a reasonable chance of identifying short-wavelength electromagnetic modes which may be responsible for limiting the pedestal structure between ELMs. Such an identification would allow a validation of the physics model behind EPED, which is widely used to predict the pedestal in future fusion devices.

There is great potential for publications, including Hughes’s APS invited talk, and complementary papers from Diallo, Walk and Theiler. Walk’s PhD thesis would also be supported.

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