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

C-Mod is the only high field tokamak that can compare L-mode and H-mode regimes at high power density approaching burning plasma conditions. It is important for C-Mod to assess the physics of internal and external modes and particle and energy confinement under such conditions to better understand what is needed for next step burning plasma experiments. The goals of the experiment are to measure the impact of sawteeth and ELMs on neutron rate, profile peakedness, and fast particle content at as high a $\beta_p$ as feasible with $q_\psi \approx 3$. Some of the questions we hope to answer are: 1) Can $Z_{\text{eff}}$ can be maintained < 1.5 under these conditions? 2) Can a near steady-state such as EDA H-mode be maintained or is higher $q_{95}$ required? 3) Can peaked density profiles be maintained under such conditions to enhance reactivity?

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

Sawteeth, large Edge Localized Modes (ELMs), and other MHD instabilities could have a large impact on the fusion yield in future burning plasma experiments through their effects on particle and energy confinement. Sawteeth flatten the core temperature and density resulting in a reduction of the core fusion reaction rate. Since the sawtooth mixing radius increases with decreasing safety factor, the effects of sawteeth will be particularly apparent at low $q$. While the fast $\alpha$ particles may help to stabilize sawteeth for some period of time, the resulting final collapse could then dramatically reduce the reaction rate and quench the burn. Furthermore, impurity accumulation during such a long sawtooth could substantially dilute the DT fuel as well as radiate away much of the core energy. So, it is not clear whether or not small rapid sawteeth are preferable to large long period sawteeth.
In H-mode, ELMs have both positive and negative influences on the fusion yield. By reducing core impurities, they improve the reaction rate and can lead to steady-state high confinement conditions. However, particularly large ELMs remove fast particles from the plasma and strike the first wall and divertor with such tremendous heat loads that excessive erosion is predicted for next step devices like ITER and FIRE. At higher power densities and lower collisionalities, ELMs are expected to become more severe both in their effects on particle and energy confinement as well as on the first wall.

Given these concerns, it is important for C-Mod to attempt to approach, as far as possible, burning plasma conditions and look for the effects that these and other instabilities have on the fusion reaction rate, particle, and energy confinement.

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.

The approach is to start with an optimized current rise as obtained in MP247b at high current and 5.4 T with strong core ICRF heating to achieve as high a $\beta_p$ as feasible. Vary the density to determine the range of conditions over which high $\beta_p$ can be maintained and still have relatively low $Z_{\text{eff}}$. Vary $I_p$ to change $q_\psi$ in a few steps up to at least 3.5 to determine how $q_\psi$ affects these conditions. Then, inject pellets to peak up the density profile to see if such conditions can be maintained or improved with profile peaking. Linda Sugiyama will run BALDUR simulations to compare the measured confinement properties with the simulations and attempt to extrapolate them to next step devices.

4. Resources

4.1 Machine and Plasma Parameters
Give values or range for:

- Toroidal Field: 5.4 T
- Plasma Current: 1.0 - 1.4 MA
- Working Gas Species: D$_2$
- Density: 0.8 - 1.5 x $10^{20}$ m$^{-2}$
- Equilibrium configurations (if possible, refer to database equilibria): LSN and inner wall limited with $\kappa$=1.6

4.2 Auxiliary Systems

- RF Power, pulse length, phasing: > 4 MW, 0.5 s, 0 $\pi$ 0 $\pi$, H minority, 78 + 80 MHz
- Pellet Injection (species): Li though D would be preferable
- Impurity blow-off injection: N
- Diagnostic Neutral Beam: if available
- Special gas puffing: N
- Other: This run requires a very well conditioned machine to obtain good confinement.
4.3 Diagnostics
List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.

Core and edge Thomson scattering for density and temperature, H/(H+D), fast magnetic fluctuations, soft x ray diagnostics, HIREX rotation and Ti profile measurements, neutron Ti measurements, TCI, GPC and FRCECE, VB for $Z_{eff}$ measurements and density profile information, spectroscopy diagnostics for main impurity concentrations. All diagnostics should concentrate on the current rise from $t = 0$ to $0.5$ s.

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.

Two separate runs would be preferable for limited and diverted experiments, but if one run day is all we can get, then we’ll do what we can with that much time.

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.

Begin with the optimized current rise found in MP247b in limited plasmas. Choose the plasma current to give $q_{95}=3$. Start ICRF heating at $0.05$ sec increasing it rapidly to at least 4 MW and maintain high power throughout the current rise to at least $0.55$ sec. Optimize the ICRF heating in the core to obtain as high a $\beta_p$ as feasible with a starting density of $1 \times 10^{20}$ m$^{-2}$ (5 shots). Reduce the density to $0.9 \times 10^{20}$ m$^{-2}$ and see if $\beta_p$ continues to improve or gets worse (2 shots). Continue the density scan in small steps both up and down until the optimum density is found for obtaining high $\beta_p$ (6 shots) and keeping $Z_{eff} < 1.5$. Then, decrease the flattop current in a few steps up to at least $q_{95}=3.5$ to determine if changes in $q$ affect these conditions (4 shots). Finally, inject Li (or preferably D) pellets to see if these conditions can be maintained or improved with peaked density profiles (6 shots). If time permits, repeat the experiments with diverted plasmas, though another run day would invariably be required.

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.

The results from these experiments will be simulated using a predictive transport code (e.g., BALDUR) to help constrain possible ignition scenarios for a future high field compact ignition machine as well as determine limitations due to sawteeth, ELMs, and transport. The L-mode and H-mode current rise scenarios will be compared to determine their relative merits toward achieving ignition. These results should lead to journal publications and conference presentations.

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