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 this mini-proposal is to investigate the ability of MCCD to modify the sawtooth period of large sawteeth associated with high performance H-mode discharges in the presence of energetic ions.

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

Sawtooth pacing where the sawtooth period is regularized to relatively short periods has been considered for NTM prevention through reduction of seed islands and is likely necessary for high performance H-mode discharges where the first crash tends to terminate the discharge, see Figure 1. There is an ITPA experimental task, namely MDC-5 that calls for a comparison of different sawtooth stabilization techniques and this mini-proposal is part of this activity.

Previously, we have demonstrated sawtooth control in the absence of long sawteeth and energetic ions.[1] We intend to investigate discharges where the...
sawtooth period is long and energetic ions are likely resulting from high power H minority heating near axis in H-mode discharges. Such H-mode discharges with 3 MW of minority heating and long sawteeth (1070510011) have recently been obtained and are likely suitable targets. There are also a few near DN discharges with monster sawteeth (sawtooth period > 0.05 sec, 1031124020, 1031125021, 1031211017, 1031217012, and 1031217027) which could also be utilized. In a number of these discharges, modes in the 200-400 kHz range have been observed. These modes appear to scale with ICRF power and the mode frequency may be related to the ion tail energy. These modes also may regulate the sawtooth period.

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.

In order to maximize the ion energy and probability of long sawtooth periods, the target plasmas with high temperature and relatively low density need to be prepared. H-mode discharges from 1070510 are good targets and we are likely to require between shot boronization to maintain the hot plasmas. Furthermore, a number of discharges near double null have large sawteeth and are also good candidate discharges utilizing 4.5 MW of ICRF. To achieve a reasonable current drive efficiency, the discharges will likely utilize 0.8-0.9 MA plasma currents. This will keep the q=1 surface closer to the plasma axis where the MC current drive efficiency is highest and matches the available RF frequencies best. With 25% $^3$He and fields ~5.1-5.3 T, the MCCD (50 MHz) can access the q=1 surface on the high field side of the magnetic axis and have near central power deposition for the minority heating (80 MHz). Once we establish discharges with long sawtooth periods, we will scan the mode conversion deposition location around the q=1 surface at different power levels concentrating on the power required to stabilize sawteeth when their period is already long. We will scan the antenna phase and MCCD power to identify the minimum current required to pace the sawtooth period. We will likely have a small $B_T$ scan to move the MCCD through the q=1 surface within a discharge and depending on success we will try some static B discharges for comparison. The experiment has some risk in that the central temperature and likely the sawtooth period will vary a bit with the RF deposition moving the B field scan and thus would like to minimize the scan. This is also why we include heating phase as well. With time permitting, a similar set of discharges can be obtained if we decrease the $^3$He concentration to 15% and raise the $B_T$ to 5.6 T to investigate sawtooth pacing on the low field side of the magnetic axis. We will run a standard gas puff throughout the day and will use a couple of discharges to get power deposition profiles. If necessary, we will scan the $^3$He gas puff to calibrate the $^3$He monitor via comparison of measured power deposition profiles and comparison with TORIC.

4. Resources

4.1 Machine and Plasma Parameters
Give values or range for:
Toroidal Field: 5.1-5.6 T
Plasma Current: 0.8-0.9 MA
Working Gas Species: D
Density: n\text{04} \sim 0.8 \times 10^{20} \text{ m}^{-2}
Equilibrium configuration (if possible, refer to database equilibria): 1070510011
   near DN single null discharge like 107xxxxx

4.2 Auxiliary Systems

RF Power, pulse length, phasing: J-port: full power at 50 MHz, co-, ctr- and heating phasing for 0.75 sec.
   D and E-port: 2.5 MW to full power for 1 sec.

Pellet Injection (species): none
Impurity blow-off injection: none
Diagnostic Neutral Beam: desirable
Special gas puffing: $^3\text{He}$ (B-side upper at 15 psi) and similar waveform to 1050802010

Other:

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

Standard set with impurity monitoring, FRECE, GPC, $^3\text{He}$ monitor, and H monitor required. The PCI and CNPA if operational would be beneficial but not critical. Central MSE would also be useful but the plasma parameters will likely make this near impossible.

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.

One run.

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.

Establish a discharge using 1070510011 as a basis with 2.5 MW from D+E antennas and 2 MW from J in heating phase with the modulated power to determine the location of the deposition profile and to calibrate the $^3\text{He}$ monitor. (4 shots)

Scan the J antenna phase in discharges with 2.5 MW from D+E, 2.5 MW from J antenna, and B$_r$\sim-5.3\rightarrow 5.0. Phases to be used are \{0, π, π,0\} (heating phase), \{0, π /2, π,3/2 π\}, and \{0, −π /2, −π,−3/2 π\}. (3 shots)

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Scan the J antenna phase in discharges with 2.5 MW from D+E, 1.5 MW from J antenna, and \(B_T \sim 5.3 \rightarrow 5.0\). Phases to be used are \([0, \pi, \pi, 0]\) (heating phase), \([0, \pi/2, \pi/2, \pi]\), and \([0, -\pi/2, -\pi/2, -\pi/2]\). (3 shots)

Scan the J antenna phase in discharges with 2.5 MW from D+E, 0.75 MW from J antenna, and \(B_T \sim 5.3 \rightarrow 5.0\). Phases to be used are \([0, \pi, \pi, 0]\) (heating phase), \([0, \pi/2, \pi, 3/2 \pi]\), and \([0, -\pi/2, -\pi/2, -3/2 \pi]\). (3 shots)

If successful, attempt a few static B field scenarios:
Scan the J antenna phase in discharges with 2.5 MW from D+E, 2.5 MW from J antenna, and \(B_T \sim 5.3 \rightarrow 5.0\). Phases to be used are \([0, \pi, \pi, 0]\) (heating phase), \([0, \pi/2, \pi/2, \pi]\), and \([0, -\pi/2, -\pi/2, -3/2 \pi]\). (3 shots)

Time permitting move to the low field side experiments

Establish discharge using 1070510011 as a basis with 2.5 MW from D+E antennas and 2 MW from J in heating phase with the modulated power to determine location of the deposition profile. (3 shots)

Scan the J antenna phase in discharges with 2.5 MW from D+E, 2.5 MW from J antenna, and \(B_T \sim 5.3 \rightarrow 5.6\). Phases to be used are \([0, \pi, \pi, 0]\) (heating phase), \([0, \pi/2, \pi, 3/2 \pi]\), and \([0, -\pi/2, -\pi/2, -3/2 \pi]\). (3 shots)

Scan the J antenna phase in discharges with 2.5 MW from D+E, 1.5 MW from J antenna, and \(B_T \sim 5.3 \rightarrow 5.6\). Phases to be used are \([0, \pi, \pi, 0]\) (heating phase), \([0, \pi/2, \pi, 3/2 \pi]\), and \([0, -\pi/2, -\pi/2, -3/2 \pi]\). (3 shots)

Scan the J antenna phase in discharges with 2.5 MW from D+E, 0.75 MW from J antenna, and \(B_T \sim 5.3 \rightarrow 5.6\). Phases to be used are \([0, \pi, \pi, 0]\) (heating phase), \([0, \pi/2, \pi/2, \pi]\), and \([0, -\pi/2, -\pi/2, -3/2 \pi]\). (3 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, or an external database.

Establish a recipe for controlling the sawtooth period using MCCD particularly in high performance H-modes (where it will be necessary) in C-Mod.

Provide data for ITPA MDC-5 which is to compare sawtooth control techniques from various machines.

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