

# Alcator C-Mod Mini-Proposal

MP No. 492

**Subject:** Lower Ip Long Pulse L-mode and H-mode Advanced Scenarios

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**Group:** Integrated Scenarios, Advanced Tokamak

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**Approved by:**

**Date Approved:**

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## 1. Purpose of Experiments

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

Examine Lower Ip discharges (600 and 450 kA) to obtain higher bootstrap and non-inductive current fractions. Establish the energy confinement in the lower Ip plasmas. Utilize longer Ip rampup times (established in pre-physics phase) to control the q profile and non-inductive current fraction, with ICRF heating and LH heating/CD, both separately and together. Produce discharges both in L-mode and H-mode to determine advantages of confinement regimes.

## 2. Background

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

As part of the effort to develop advanced tokamak discharges on Alcator C-Mod a combination of lower plasma current, slower Ip ramps, early ICRF and LH heating/CD, and L/H-mode are being used to achieve high non-inductive current fraction with higher q plasmas, and ultimately higher betaN plasmas. In order to reach this a database of discharges utilizing these features is being developed to better understand the plasma response to these features, and provide information for optimization. Systematic scans like these are not only useful for future discharge development, they provide a much needed basis for simulations to project to new discharges. Up to now simulations have relied on an H-mode target plasma from 2003 (1030612013) due to its desirable H-mode parameters, however it was generated in the standard H-mode discharge approach in C-Mod with fast Ip ramp (150 ms) and late ICRF heating (1000 ms).

## 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.

This experiment proposes to systematically study the plasma response to ICRF and LH heating/CD in discharges with slower  $I_p$  ramps, to establish techniques for producing advanced tokamak discharges with  $q$  profile control and high non-inductive current fraction. A systematic scan is proposed that injects ICRF only during and after the  $I_p$  ramp, injects LH only during and after the  $I_p$  ramp, and finally both ICRF and LH during the  $I_p$  ramp. A low power and a higher power are injected to produce (roughly speaking) an L-mode and an H-mode, although this is not strictly required should H-modes result at low powers. The plasma current is fixed at 600 kA, sufficiently low to provide reasonable non-inductive current fractions, and to allow an extensive power and source scan.

We will examine, in response to the heating level and timing, the  $l_i$  and surface voltage evolutions, sawtooth onset, kinetic evolutions of  $T_e$  and  $n$ , and  $q$  profile information if available.

## 4. Resources

### 4.1 Machine and Plasma Parameters

Give values or range for:

Toroidal Field: 5.4 T for ICRF

Plasma Current: 0.60 MA

Working Gas Species: D, H-minority.

Density: Target  $6-9 \times 10^{19} \text{ m}^{-3}$  (cryopump not precluded).

Equilibrium configuration (if possible, refer to database equilibria): *slow  $I_p$  ramp discharges 1070412 at  $I_p = 600 \text{ kA}$  listed below*

### 4.2 Auxiliary Systems

ICRF Power, pulse length, phasing: J-port essential, 1.0-2.0 MW. D and/or E desirable, 1 MW.

LHCD Power, pulse length, phasing: 0.5-1.0 MW, variable phase (probably 90 deg), longest pulse available.

Pellet Injection (species): no

Impurity blow-off injection: no

Diagnostic Neutral Beam: Highly desirable

Special gas puffing: NINJA (with D2) should be available.

Non-axisymmetric Coils (Connections, Current); Yes; optimized to reduce locked modes.

Other:

### 4.3 Diagnostics

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

Essential: Thomson, Magnetics, Hard x-rays, ECE, TCI, probes in LH grill.

Desirable: MSE, CXRS, SOL probes.

## 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.

The run plan is for 1 run day targeting  $I_p = 600$  kA only. Other  $I_p$  (450 kA) values will need to be done in a separate run day.

### 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.

Start with established discharges with slower  $I_p$  ramps: 1070412015 for 500 ms rampup, and 1070412022 for 1000 ms rampup, both  $I_p = 600$  kA.

- 1) tune plasma position for ICRF coupling if necessary (2 shots)
- 2) 500 ms rampup to 600 kA (4 shots)
  - a. ICRF only, 1.0 MW at 500 ms
  - b. ICRF only, 1.0 MW at 200 ms
  - c. ICRF only, 2.0 MW at 500 ms
  - d. ICRF only, 2.0 MW at 200 ms
- 3) 1000 ms rampup to 600 kA (4 shots)
  - a. same as above but with 1000 and 300 ms on times for ICRF
- 4) 500 ms rampup to 600 kA (2 shots)
  - a. LH only, (maximum available) 0.5 MW at 500 ms
  - b. LH only, (maximum available) 0.5 MW at 200 ms
- 5) 1000 ms rampup to 600 kA (2 shots)
  - a. same as above but with 1000 and 300 ms on times for LH
- 6) 500 ms rampup to 600 kA (2 shots)
  - a. ICRF 1.0-2.0 MW at 200 ms, LH 0.5-1.0 MW at 400 ms
  - b. ICRF 1.0-2.0 MW at 400 ms, LH 0.5-1.0 MW at 600 ms
- 7) 1000 ms rampup to 600 kA (2 shots)
  - a. ICRF 1.0-2.0 MW at 300 ms, LH 0.5-1.0 MW at 500 ms
  - b. ICRF 1.0-2.0 MW at 500 ms, LH 0.5-1.0 MW at 700 ms

## 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.

These systematic experiments will establish the plasma response to early heating and current drive with slower  $I_p$  ramps, which is the basis for advanced tokamak discharges where the  $q$  profile is modified and the non-inductive current fraction is maximized. Results can be reported at APS, and provide information for publications as well as simulations and the 5 year plan.

## **7. References**

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