1. Purpose of Experiments

H-modes on Alcator C-Mod are easier to achieve at lower toroidal field. Other machines (ASDEX, DIII-D, JET, TCV, etc.) indicate that the H-mode power threshold is higher when the ion grad B drift direction is away from the dominant X point. Since the required input power to achieve H-mode is lower at lower toroidal field, our chances of achieving H-mode with the ion grad B drift away from the dominant X point are improved by running at low toroidal field. If the threshold power is not more than about a factor of two higher than the threshold with the ion grad B drift toward the dominant X point, we should be able to at least achieve ELMy ohmic H-modes running at $B_T = 3.5$ T. This is an important test of the H-mode threshold that may impact ITER.

2. Background

The early work on low q ohmic H-modes was done on the 931022 run where the TF was ramped down to about 3 T when ELM-free ohmic H-modes occurred and subsequently on the 950214 run at constant toroidal field of 3.5 T. Since the empirical H-mode threshold increases with toroidal field [1-3], it is expected that at lower toroidal field, the required ohmic power should be lower to get into H-mode and since other devices also show higher power thresholds with the ion grad B drift direction away from the dominant X point, we may need this extra power margin to achieve even ELMy H-modes in such a configuration.

3. Approach

The experiment will start with shot 950214014, which had $I_p = 0.7$ MA, $B_T = 3.5$ T, and $n_{el} = 6 \times 10^{19}$ m$^{-2}$, but will run with the toroidal field and plasma current directions
reversed. This discharge had $q(95) = 3$ to avoid possible disruptions crossing through $q=3$. A scan will be made in density down to about $3-4 \times 10^{19} \text{ m}^{-2}$ in search of H-modes. If H-modes are not observed, lithium pellets will be injected into the discharge to attempt to improve wall conditions, since there are indications from previous runs that Li pellets may reduce the H-mode power threshold. If H-modes are still not observed, the current will be raised gradually late in the discharge up to 0.85 MA to increase the input power. If H-modes are still not observed, we may try injecting Li pellets also into the higher current discharges, though there is a danger of disruptions associated with the pellets as found in previous runs, so care will have to be taken when injecting into low q discharges.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

- **Toroidal Field**: 3.5 T (reversed direction)
- **Plasma Current**: 0.7 MA - 0.85 MA (reversed direction)
- **Working gas species**: D$_2$
- **Density**: $3.0-7.0 \times 10^{19} \text{ m}^{-2}$
- **Equilibrium configuration** (if possible, refer to database equilibria): Lower single null diverted, e.g., 950214014
- **Pulse length, typical current & density waveforms, etc.** Refer to database or sketch desired waveforms: Pulse length $\geq 1$ s, constant current and density.

4.2 Auxiliary Systems

- **RF Power, pulse length, phasing**: none
- **Pellet Injection (species)**: Li pellets
- **Impurity blow-off injection**: none
- **Special gas puffing**: standard A and B valves
- **Other**: This run requires a very clean machine that is running well.

4.3 Diagnostics

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

- Lithium pellet injector
- Lithium spectroscopy diagnostics, e.g, MacPherson
- Full H$_\alpha$ coverage
Fast H$_\alpha$ for ELMs
Fast magnetic pick-up coils for ELMs up to 500 kHz sampling
Scanning probe
Langmuir probes
Fast I$_{sat}$ for ELMs up to 500 kHz sampling rate
Ratiomatic pressure guages
Charge exchange diagnostics
Plasma TV with H$_\alpha$ filter if not overexposed
Interferometer
ECE Michelson
ECE polychromator with grating set to look at edge profiles at 3.5 T
Thomson Scattering
Bolometers
Visible bremsstrahlung

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.)

Negligible

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.

If the reversed field and current do not change the breakdown parameters greatly, copying programming from the 950214 run should be sufficient to obtain decent plasmas at $B_T = 3.5$ T. From our previous experience in determining H-mode power thresholds, we know exactly what parameter ranges to expect H-mode, so a scan of those ranges should not take more than one run. At least two hours of ECDC in helium should be performed prior to the run to desorb deuterium from the walls.

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.

The run will begin with flattop current at 0.7 MA and a density ramp starting at a line average of $7 \times 10^{19}$ m$^{-2}$ and ramping down to $5 \times 10^{19}$ m$^{-2}$ by the end of the
flattop of the current. If the machine is well conditioned, H-modes should occur during the density ramp down. If H-modes are achieved, the density will be reduced to determine the low density H-mode threshold. Then, the plasma current will be ramped up gradually to perhaps 0.85 MA to increase the ohmic input power. If there are no H-modes, lithium pellets will be injected to attempt to improve the wall conditions [4]. In this case, care must be taken with the density feedback to avoid large gas puffs after the decay of the density from the pellet perhaps by stepping down the programmed density after the pellet or by switching off the density feedback for some period of time. If the run goes well and the H-modes are reproducible, pellets may also be injected into the H-mode to compare the lithium transport in L and H modes.

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 H-mode threshold scaling with density with reversed toroidal field at low $q_{95}$ should be determined by this experiment. The results will provide useful data for ITER and will be added to the ITER H-mode database. Conference publications and or refereed publications should come out of these results.

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