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

This proposal aims to document the differences in L-H threshold conditions in the four available magnetic configurations, i.e. lower single null (LSN), upper single null (USN), double null (DN) and inner wall limited (IWL), with the usual field direction. In addition to measuring the power threshold, it aims to measure several of the physical terms which might be responsible for differences in the threshold, specifically edge n, T profiles, SOL flows and core rotation.

By doing this, the experiments aim to satisfy the threshold part of the C-Mod Level I milestone SC6-1b for FY04, “Compare energy confinement, H-mode thresholds, and divertor particle dynamics in single-null, double-null, and inner-wall-limited discharges in Alcator C-Mod, …”. The plasma physics goal is to understand the conundrum of the role of magnetic configuration in the L-H transition, which would be a breakthrough.

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

This proposal is a combination of Ideas Forum proposals by Hubbard, Rice and LaBombard, which were rated high priority by the Transport group and supported by the edge/divertor group.

There has been considerable prior work on measuring L-H thresholds on Alcator C-Mod, most of it in the ‘standard’ configuration with lower single null and favourable ion grad-
B drift direction\(^1\). In this configuration there is found to be an edge \(T_e\) threshold which varies only weakly with density. Fair agreement with predicted thresholds by Rogers and Drake, and more recently by Guzdar, has been found\(^2\). The power threshold with unfavourable drift direction (i.e. upper null, or reversed field) has been consistently found (since 1996) to be significantly higher. The edge \(T_e\) is also higher, though we do not yet have detailed ETS measurements in this configuration. No convincing H-mode has been achieved on C-Mod with plasmas limited on the inner wall; previous studies by Pitcher set a lower bound for the threshold of \(\sim 3\text{MW RF}\)\(^3\). This is an important issue for limiter operation of Ignitor, and we have an opportunity to clarify the threshold with higher available power. Some H-modes were achieved in rampup with the plasma apparently touching the inner nose.

In other studies, the SOL flows have been recently found to be substantially different depending on the null location and field direction. In single-null plasmas, a strong flow parallel to field lines (Mach \(\sim 0.5\)) is detected on the inner-wall scanning probe which is always directed from the low-field SOL to the high-field SOL\(^4\). This flow is consistent with the observation of large poloidal pressure asymmetries in double-null plasmas; the flow appears to re-symmetrize pressure imbalances when the high- and low-field parts of the SOL are connected along field lines. An implication is that volume-averaged SOL flows impose a toroidal-flow boundary condition at the separatrix with magnitude that depends on the null location. For discharges with normal field direction, the SOL flows result in a stronger (weaker) co-current rotation for LSN (USN, DN) plasmas with corresponding strong (weaker) radial electric fields in the SOL near the separatrix\(^5\). Thus, there may be a connection between magnetic topology, field direction, SOL flows, and ExB shear strength near the separatrix. By invoking an ExB velocity-shear turbulence-suppression paradigm, one can further speculate that these effects lead to the observed differences in the L-H power threshold. Along these same lines, a comparison of edge plasma beta-gradients and normalized collisionalities in forward and reversed-field LSN discharges point to significant differences (lower beta-gradient for reversed field)\(^6\), which may be related to a tendency for reduced velocity shear near the separatrix seen in these discharges. There also appear to be differences in edge \(n_e\) profiles (longer \(L_n\)) which would be qualitatively consistent with the Guzdar predictions.

Recently, it has been observed that the core rotation measured by HIREX is substantially different depending on the active null; stronger counter-rotation is seen in ohmic L-mode with USN; this becomes weakly co-rotating with sufficient RF power\(^7\). In the limiter configuration, strong counter-rotation is also seen. These observations appear to tie in with the SOL flows. However, no systematic study of these trends, or of rotation behaviour in H-mode, has yet been undertaken. We do not yet know even the power threshold in DN plasmas on C-Mod, which is of importance for FIRE.

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 taken is to utilize a fairly standard discharge condition, with density in the mid-range away from high or low density limits for H-mode, and to vary the discharge magnetic configuration. At each configuration (LSN, USN, DN, IWL) at least three power levels will be needed:

a) At power needed for L-H threshold in LSN (presumably the lowest of the configurations.)
b) At (higher) power needed for L-H threshold in new configuration.
c) At power well into the H-mode.

It will be important in each condition to obtain good data on edge profiles, rotation and SOL flows. This will mean keeping conditions constant for ~ 100 ms, and likely repeating some discharges, e.g. for probes.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

- Toroidal Field: 5.4-6.1 T
- Plasma Current: 800 kA
- Working Gas Species: D, ~5% H
- Density: ne~0.8 -1.3 x 10^{20} m^{-2}

Equilibrium configuration (if possible, refer to database equilibria):

4 equilibria,
- USN (shape selected to optimize ETS)
- DN (ditto)
- LSN, k, δ same as for USN
- Inner wall limited, similar, k, δ to above.

4.2 Auxiliary Systems

- RF Power, pulse length, phasing: RF up to 5 MW, 78-80 MHz.
  Ramped or stepped waveforms. May vary J-port phasing to reduce sawtooth size.
- Pellet Injection (species): No
- Impurity blow-off injection: No
- Diagnostic Neutral Beam: Desirable for CXRS
- Special gas puffing: Argon
- Other:

4.3 Diagnostics

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

Essential: HIREX, Edge TS, GPC, Langmuir probes (ASP, FSP, and ISP operated in a Mach-flow mode), TCI,
Desirable: CXRS, FRCECE, Bremsstrahlung, Chromex spectrometer looking a He+1 doppler flow through toroidal fiber views of inner and outer SOL
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.

1-2 run days. Requires well conditioned, boronized, upper divertor surfaces. Should run in conjunction with Meade/Marmar DN experiment for maximum conditioning benefit.

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.

1) Early in the day or, ideally, on a prior run such as the ohmic edge flows MP (scheduled for 11/14), establish the optimum shape for USN plasmas which gives the best pedestal region coverage and signal/noise on edge TS. Start from shots on 1031106. This will determine kappa and delta for the other configurations. 4 shots.

2) Switch to LSN. 800 kA, ~ 5.4 T. 3-4 shots.
   a) Power ramp up to ~ 3 MW, to determine L-H threshold.
   b) Discharge with fixed power just below threshold, for 100-200 ms, followed by high power phase (4-5 MW). Repeat as needed for probe, HIREX.

3) Switch to DN. 5-6 discharges.
   a) 2 Discharges at power which gave L-H threshold in LSN (eg. 1 MW). Document ETS profiles, flows, rotation.
   b) Power ramp to maximum available (5 MW>) to determine the new L-H threshold.
   c) As above, make discharges with power just below L-H transition for ~ 200 ms, followed by higher power to get H-mode phase.

4) Switch to USN. 5-6 discharges
   a) 2 Discharges at power which gave L-H threshold in LSN (eg. 1 MW). Document ETS profiles, flows, rotation.
   b) Power ramp to maximum available (5 MW>) to determine the new L-H threshold. (from prior experience, expect ~ 3.5 MW)
   c) As above, make discharges with power just below L-H transition for ~ 200 ms, followed by higher power to get H-mode phase (eg. 3.5, 5 MW).

5) Switch to Inner wall limited. Repeat sequence. 5-6 discharges.
   a) 2 Discharges at power which gave L-H threshold in LSN (eg. 1 MW). Document ETS profiles, flows, rotation.
   b) Power ramp to maximum available (5 MW>) to determine whether an H-mode is achievable. From prior experiments, expect to need at least 4 MW. If yes, document profiles at L-H threshold, as above, and in H-mode. If no, document at highest available RF power to set lower bound on edge T_e, rotation etc.
**Total:** 26 good discharges.

Given that this involves significant configuration changes, it is possible, perhaps probable, that some time on a second, preferably consecutive, run day will be required to complete the experiment. This will document thresholds at only one plasma condition. It would be highly desirable to repeat at least some of the configurations (eg. DN) at 1 or 2 higher densities to see how the thresholds trend. This is only worth doing for configurations for which the L-H threshold proves low enough to have some ‘headroom’ given the available RF power. It would also be valuable to repeat a few USN or DN discharges with off-axis heating (6.1 T) to reduce sawtooth heat pulses for more accurate evaluation of edge $T_e$ at the L-H threshold. We envisage a follow-up MP to complete such scans, and/or to study LSN discharges with Reversed $B_T$ (which gives the cleanest comparison of edge measurements).

There is some commonality with other DN proposals; eg. LaBombard et al, edge flows, and Meade et al, DN H-modes. If one or more of these is run first, we may save several discharges in the sequence.

### 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.

Obtain data to complete in a timely manner Level I milestone SC6-1b for FY04, “Compare energy confinement, H-mode thresholds, and divertor particle dynamics in single-null, double-null, and inner-wall-limited discharges in Alcator C-Mod, …”.

By systematically coordinating the measurements of all potentially relevant and measurable differences in L-H threshold conditions between various configurations (profiles, flows, rotation) and analyzing them together, we anticipate interesting results for spring meetings (TTF, PSI), for comparison with theories, and for publications and/or invited talks at fall meetings.

### 7. References

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

5. B. LaBombard, paper in progress.