1. Purpose of Experiments

The purpose of this experiment is to study the properties of the spontaneous internal transport barrier which forms following the H to L mode transition on Alcator C-Mod. This will start by establishing the experimental technique for forming it consistently particularly in conjunction with the diagnostic set needed to study it, then by using several possible rf injection scenarios to try and control it by prolonging its lifetime. The use of the rf injection for additional heating after formation should also be tested.

2. Background

The H to L transition on Alcator C-Mod is often followed by the formation of an apparent internal transport barrier in the core region of the plasma. This is manifested by a strong increase in the global neutron rate, up to a factor of 8. As the transition proceeds, the electron density collapses in the outer half of the plasma, causing the electron density to be strongly peaked in the center. Even though the density becomes peaked, the central value generally does not increase, which indicates that the rise in the neutron rate results from an increase in the central ion temperature. The steepening of the density profile results in a decrease of $\eta_e$ (at $r/a \approx 0.5$) to between 1 and 2 from a typical value of 4 to 6 during H mode. The electron temperature profile at this radius does not change significantly during these events, so that the entire change in $\eta_e$ results from the change in the electron density profile. These core barriers are observed following both ICRF and Ohmic H to L transitions. Several thousand have been recorded from the last two run campaigns. To date, this phenomenon is transitory, lasting only for two or three sawtooth cycles ($< 40$ ms). In a small number of cases (about 5) where the sawtooth has been nearly stabilized, the neutron rate remains high for a longer period of time. However, strong central MHD activity is then observed which acts to terminate the barrier. In one
case, when the sawtooth was completely stabilized during off-axis rf injection, the ITB apparently lasted up to 0.2 s (980206006).

The addition of several new diagnostic tools utilizing the Diagnostic Neutral Beam will enhance the study of this barrier formation. Spatially resolved measurement of the ion temperature and rotation from Charge Exchange Recombination, plus rotation and fluctuation measurements which could be available from BES diagnostics will also contribute to understanding this phenomenon.

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.

Formation of these barriers is predictable: dropping the rf power during an H-mode will trigger a transition to L-mode and the barrier will form. A two pronged approach is suggested, first to characterize the mode using the new diagnostic set available with the DNB and second to try and control the mode by using off axis rf injection.

First, set up a reliable H-mode plasma (the neutron peak is probably more pronounced following elm-free H-mode, but also appears following EDA H-modes) with 5.3 T, 1.5-2 MW rf. Time the rf to drop to half power part way through the DNB pulse to trigger a back-transition. The timing of the Hirex data collection window should be set to coordinate with the point that the rf power is cut, so that a pre and post transition ion temperature profile could be obtained from that as well.

Once the diagnostic performance and control technique are established, the effect of tailoring of the rf injection should be explored, as far as can be achieved within the 6T limit imposed on this run campaign. Three things should be examined: RF minority heating at the q=1 surface to stabilize sawteeth, which should preserve the transport barrier as long as possible; Off axis injection for D-H heating, (similar to 980206006, but with the heating on the high field side); Electron heating and/or electron current drive at 60 Mhz.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

**Toroidal Field:** nominal 5.3 T, 4.5 to 5.8 T as required

**Plasma Current:** 1 MA

**Working gas species:** D, H minority

**Density:** about $1 \times 10^{20} m^{-2}$ or as required by the constraints of the current drive experiments.

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

**Pulse length, typical current & density waveforms, etc.** Refer to database or sketch desired waveforms.
4.2 Auxiliary Systems

**RF Power, pulse length, phasing**: 1.5 to 2 MW, drop to 1 MW

**Pellet Injection (species)**: none

**Impurity blow-off injection**: none

**Special gas puffing**: none

**Other**:

4.3 Diagnostics

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

Hirex for Ti profiles

CHERS

Visible Bremsstrahlung array.

GPC 1 and 2

Neutron diagnostics

All standard core diagnostics

MSE

BES

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.)

less than $5 \times 10^{15}$

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.

These experiments should take at least 2 runs. The first for establishing technique and diagnostic efficacy and for exploring the 80 Mhz rf-off axis injection, both near q=1 and on the high field side. The second run would be after the J-port system is converted to 60 Mhz. This would look at both electron heating and electron current drive effects on the transport barrier.
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.

First run:

Part 1. (4 shots) Set up H-mode shots at 5.3 T with moderate ICRF power. Trigger a back transition during the DNB pulse by dropping the ICRF power. The DNB should be on in a single 100 ms pulse, so that the ion temperature profile can be obtained before, during, and after the ITB. A contingency plan would be to work with the HIREX data collection window to try and obtain ion temperature profiles before and during the ITB.

Part 2. (4 shots) Continue as in part 1, but bring the rf power up after 30 to 40 ms, which should be at the peak of ITB, to see if the neutron rate can be pushed up farther by this technique.

Part 3. (10 shots) Change the field to 5.8 T and continue as in part 2, trying to maintain the enhanced neutron rate as long as possible by stabilizing the sawteeth.

Part 4. (10 shots) Lower the field to 4.5 T and continue as in part 2, trying to reproduce the conditions which led to shot 980206006 with off axis heating on the high field side.

Second run: 60 Mhz DHe3, 80 Mhz DH

Part 1. (10-15 shots) Set up H-mode shots at 5.3 T with moderate ICRF power. Trigger a back transition during the DNB pulse by dropping the ICRF power. Inject power with the 60 Mhz J-port system to heat electrons off axis to see if the ITB can be maintained, either through sawtooth suppression or broadening of the temperature profile.

Part 2. (10-15 shots) Set up H-mode shots at 5.3 T with moderate ICRF power. Trigger a back transition during the DNB pulse by dropping the ICRF power. Inject power with the 60 Mhz J-port system with the phasing set to drive electron current off axis to see if the ITB can be maintained through sawtooth suppression.

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.

Learning to control the formation and lifetime of internal transport barriers could lead to a regime of vastly improved performance, resulting in higher fusion rates, better overall Q, and ultimately cheaper power. At minimum, publications leading to improved understanding of internal transport should result.

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