1. Purpose of Experiments

Include immediate goal of the experiments, scientific importance and/or programatic relevance. Refer to any relevant program milestones or ITER R&D commitments.

Maintaining peaked density profiles in H-mode would greatly enhance fusion performance, particularly if they can be heated with ICRF to produce simultaneously peaked temperature profiles. In addition, the changes in transport responsible for the spontaneous peaking of the density profiles in Ohmic H-mode that has been observed (e.g., 990831015) is not understood. Through impurity injection into peaked density profiles in H-mode, we will attempt to determine the differences in particle transport under these conditions. With charge exchange recombination spectroscopy and the DNB we can also measure the ion temperature profile to look for internal transport barriers and calculate the ion transport coefficients. Small to medium sized pellet injection may also be used to attempt to further peak up the density profile if time permits.

2. Background

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

Spontaneous peaking of the density profile was observed in Ohmic H-mode runs on 990521 and particularly on 990831. The peaking was measured with the Thomson scattering diagnostic and was found to begin shortly after the start of the H-mode in an ELM-free phase. The peaking persisted for up to 0.7 sec throughout the H-mode in both Ohmic EDA H-mode and when the plasma returned to ELM-free H-mode as the toroidal field ramped back up before the end of the plasma current flattop.

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.
Start with shot 990831015 and attempt to reproduce the peaked density profiles in Ohmic H-mode. Then, vary the ramp rate and magnitude of the toroidal field to determine the optimum field waveform to peak up the density profile. Then, ramp the plasma current up during the field ramp to determine if the peaking of the density can be further improved. Having found the optimum current and toroidal field waveforms for peaking the density profile, then turn on the ICRF after the density profile is peaked up during the H-mode and attempt to heat the peaked density profile with central resonance ICRF as the toroidal field ramps back up to 5.2 T. Vary the timing of the start and ramp rate of the RF pulse to attempt to optimize heating of the peaked density profiles. With charge exchange recombination spectroscopy, look for peaking of the ion temperature profile as evidence of internal transport barrier formation. Then, optimize the ion temperature profile peaking and the neutron rate. In both the Ohmic peaked density H-modes and the later ICRF heated peaked density H-modes, inject trace impurities with laser blowoff to measure the particle confinement and look for an inward particle pinch. Use MIST modeling to calculate the transport coefficients. To attempt to further peak up the density profile, small to medium sized deuterium pellets may be injected during the peaked Ohmic H-mode phase for at most a few shots if time permits to see if the H-mode can be maintained with pellet injection and if the density profile can be peaked up further. To test the idea that the peaking may be related to the toroidal field ramp, a control shot or two should be taken without ramping the field back up similar to 990831012, which has a slightly lower neutron rate than shot 990831015, where the field was ramped back up.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

- **Toroidal Field:** 3 - 5.4 T
- **Plasma Current:** .75 - 1.3 MA
- **Working gas species:** D₂
- **Density:** \(1.5 \times 10^{20} \text{ m}^{-3}\)
- **Equilibrium configuration** (if possible, refer to database equilibria): e.g., 990831015

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

e.g., 990831015

4.2 Auxiliary Systems

- **RF Power, pulse length, phasing:** \(\geq 2 \text{ MW, 0.5 s, dipole 80 MHz}\)
- **Pellet Injection (species):** small - medium D₂
- **Impurity blow-off injection:** Sc or other trace impurities
Special gas puffing:

Other:

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

Core and Divertor Thomson Scattering
Fast magnetic pick-up coils (1 - 2 MHz sampling)
Edge reflectometer (1 MHz sampling)
DNB with Charge exchange recombination spectroscopy for Ti profiles
HIREX
McPherson VUV spectrometer
CHROMEX spectrometer
Fast Scanning Probes on A-side and F bottom
Divertor Langmuir probes
Fast Dα array (C-Top)
Interferometer
ECE polychromators and Michelson
Edge soft x ray arrays

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.)

10^{15}/day

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.

Two full run days may be required to investigate all of the possible scenarios for improving density profile peakedness in H-mode. They need not be consecutive runs. The first day will be more exploratory seeking the optimum ramping waveforms for BT and Ip to peak up the profiles. The second day will then sit at the optimum condition and concentrate on determining the transport coefficients with reproducible similar Ohmic and ICRF discharges. Pellets may be injected on both days if time permits. ICRF may only be needed for the second 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 990831015 and attempt to reproduce the density profile peaking in Ohmic H-mode (3 shots). Then, move the ramp back up to 5.2 T earlier to 1.1 sec and then to 1.0 sec and look for the effect on the density and temperature profile peaking and the neutron rate (2 shots). If the peaking improves, move the ramp in TF back to 0.9 sec (1 shot). Choose the optimum TF timing of these and then begin an upward ramp in the plasma current from 0.8 s to reach 1.0 MA by 1.3 sec then held constant until 1.5 sec (2 shots). If the profile peaking improves, then increase the ramp rate up to 1.1 MA for the same timing (1 shot). If it continues to improve, increase the ramp rate to 1.2 MA but maintaining the timing on the TF ramp so that \( q_{95} \) does not go below about 2.5 (1 shot). If the profile peaking improves, increase the ramp rate up to 1.3 MA (1 shot). If the profile peaking worsens with increasing current, then return to the optimum current (1 shot). Repeat optimum conditions as needed for obtaining reproducible data from the various diagnostics for initial transport measurements.

On the second day, return to the optimum condition found on Day 1 (2 shots). Inject Scandium or other trace foreign impurities to measure the particle confinement in the peaked density Ohmic H-mode (5 shots). Also use the DNB with charge exchange recombination spectroscopy to measure the ion temperature profile and look for peaking as evidence of internal transport barrier formation. The fast scanning probes may also be injected into these discharges to look for changes in the edge parameters. Turn on ICRF heating toward the end of the peaked Ohmic H-mode as the TF returns to 5 T and attempt to heat the peaked density profiles. Vary the ramp rate and timing of the RF pulse to attempt to improve the heating of the peaked density profiles (5 shots). If time permits, attempts will also be made to peak up the density profile more by injecting small to medium sized deuterium pellets late in the H-mode on both days. Although pellet penetration may be an issue with ICRF heating, if there is an inward particle pinch, the density may peak up even with relatively shallow penetration.

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.

If successful, the peaked Ohmic H-mode scenario with ICRF heating late in the H-mode may improve fusion performance on C-Mod. Even if fusion performance is not greatly improved, it is important to attempt to understand the peaking of the density profile under these conditions to determine if a spontaneous internal transport barrier is responsible or if there is an inward particle pinch. The transport and/or fusion performance results will be presented at conferences and written up for publications.

7. References

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