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

   This experiment is intended to accurately diagnose the neutral density profile in the H-mode edge of C-Mod, in both EDA and ELM-free operational regimes. This is most effectively done using edge measurements of $D_e$ emissivity, in concert with electron density and temperature ($n_e, T_e$) data from edge Thomson scattering (TS). In performing this diagnosis, we will document the radial variation of the neutral density and ionization source, and examine how their characteristics change as the edge transport barrier changes. Accurate ionization profiles will allow calculation of particle transport coefficients, and subsequently can be used to evaluate the relative importance of plasma transport and neutral penetration in determining the plasma density pedestal.

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

   Interactions between plasma and neutral atomic species at the tokamak plasma edge are potentially important factors in determining the particle, energy and momentum transport in the vicinity of the H-mode transport barrier. In addition, edge neutral fueling may influence the profiles in the edge pedestal region, in particular the plasma density profile. Because edge pedestal quantities directly affect core plasma confinement, it is important to evaluate neutral-plasma interactions and to assess their influence on the pedestal. In particular, we desire to understand the relative strength of plasma transport and neutral ionizations in determining the shape of the $n_e$ pedestal.

   Simple transport modeling that predicts an $n_e$ pedestal width ($\Delta_n$) scaling with the neutral mean free path at the plasma edge, or roughly as the inverse of edge $n_e$. [1] Though the characteristic neutral penetration length in the C-Mod H-mode pedestal is of the same order as $\Delta_n$, dedicated experiments [2] have not revealed an inverse trend with...
suggesting that the plasma physics of the transport barrier is the dominant factor in setting pedestal width. However, a thorough understanding of the neutral density and ionization profiles is needed to clarify this picture. Previous work has relied largely on modeling and calculations from a kinetic neutral code, KN1D. [3] An experimental survey of neutral penetration has the potential to reduce uncertainties in the analysis and allow an accurate transport analysis to take place. The capability now exists to image Dα emission near the edge with high spatial resolution and to determine an emissivity profile. From this, together with \( n_e, T_e \) measurements, a high resolution profile of neutral density and ionization rate can be derived.

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 basic approach is to generate H-modes in standard lower single null geometry upon application of ICRF heating, then vary shot to shot both plasma current and L-mode target density such that the value of the \( n_e \) pedestal is altered. This technique will consequently vary the ionization and scattering frequencies for the neutrals at the plasma edge, resulting in varying neutral penetration length. Also, edge \( q \) and collisionality will change, resulting in EDA H-modes with varying degrees of particle transport (due to changing amplitude of the quasi-coherent mode), as well as ELM-free H-modes.

A dedicated run is preferred for this experiment, but much of it can likely be accomplished piggybacked on another experiment with similar parameter variation (in particular, J. Terry’s “Further Studies of the QC mode”). Even if begun in piggyback mode, the experiment would perhaps require subsequent dedicated shots to fill in points in operational space.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

- **Toroidal Field:** 5.4 T
- **Plasma Current:** 0.6–1.2 MA
- **Working gas species:** D₂
- **Density:** target \( n_e L \) varied from \( 6 \times 10^{19} \) to \( 1.2 \times 10^{20} \) m\(^{-2}\)

**Equilibrium configuration** (if possible, refer to database equilibria): Lower single null. (e.g. 1030630005) Shape should vary as little as possible between discharges.

**Pulse length, typical current & density waveforms, etc.** Refer to database or sketch desired waveforms: Standard pulse length, flat density, current and field program.
4.2 Auxiliary Systems

**RF Power, pulse length, phasing:** Sufficient power for H-mode: 1-3 MW, flat for 1s

**Pellet Injection (species):** none

**Impurity blow-off injection:** none

**Diagnostic Neutral Beam:** not required

**Special gas puffing:** none

**Other:**

4.3 Diagnostics

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

Edge TS and the midplane D\(\alpha\) camera are critical for this experiment. All standard diagnostics such as TCI, ECE and visible continuum are desired. The scanning Langmuir probes should be inserted into the near scrape-off layer as well, and edge Ly\(\alpha\) measurements should be available. PCI should be operating, in order that the amplitude of the QC fluctuation can be measured.

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.

At least 1/2 run, with a sample shot sequence outlined below.

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.

Reload equilibrium from 1030630005, or another suitable lower single null discharge. Achieve RF-induced H-modes in the following discharge conditions, with all relevant diagnostics available:

A. 3 shots at \(I_P=0.6\text{MA}\): Target \(n_eL = 6 \times 10^{19}, 9 \times 10^{19}\), and \(1.2 \times 10^{20} \text{ m}^{-2}\)

B. 3 shots at \(I_P=0.8\text{MA}\): Target \(n_eL = 6 \times 10^{19}, 9 \times 10^{19}\), and \(1.2 \times 10^{20} \text{ m}^{-2}\)

C. 3 shots at \(I_P=1.0\text{MA}\): Target \(n_eL = 6 \times 10^{19}, 9 \times 10^{19}\), and \(1.2 \times 10^{20} \text{ m}^{-2}\)

D. 3 shots at \(I_P=1.2\text{MA}\): Target \(n_eL = 6 \times 10^{19}, 9 \times 10^{19}\), and \(1.2 \times 10^{20} \text{ m}^{-2}\)

Total number of successful shots required: 12

If run in the background of another experiment or experiments, a similar array of current and density points is required, at fixed magnetic geometry and toroidal field.
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 empirical determination of neutral penetration and the analysis of neutral-plasma interactions should improve our understanding of edge particle transport in the H-mode edge barrier. As the fusion community attempts to understand the physical processes determining pedestal structure, and to extrapolate to future devices, C-Mod has the potential to contribute substantially. The edge neutrals analysis will be integral to this research, which is supporting Hughes’s Ph.D. thesis and should lead to a significant journal article.

7. References

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

