1. Purpose of Experiments

The low density regime in RF heated discharges which consists in large hydrogen ion tails, has not been well documented in Alcator C-Mod. Usually at these lower densities, RF coupling is not as high and H-modes are not obtained. This mini-proposal aims at studying the following:

- Quantifying and documenting hydrogen tail populations for various plasma conditions, mainly at low density.
- Attempt to quantify experimentally the stored energy found in tail population, verify result with global stored energy measurements. Study power balance with tail population after RF using sawteeth reheat.
- Examine fast ion confinement in Alcator C-Mod, and attempt to establish correlation (or lack of) with impurity influx.
- Search for potential causes for the low density threshold for H-mode transitions. Study possible effects of first-orbit loss mechanism.

2. Background

Lower density ICRF heated discharges are characterized by lower heating efficiency, propensity for higher impurity content and L-mode confinement. However, the exact role of high energy tail ions in this behavior is unclear and undocumented, at least for Alcator C-Mod. The code FPPRF is especially well suited to characterize tail (H or $^3$He) ion populations, both in a global way such as stored energy, losses, beta, etc., and in pitch angle and radial distributions of particles. It is also capable of predicting signal as would be seen with a neutral particle analyzer through the charge-exchange process.
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 most straightforward approach in this kind of study consists of a density scan, especially at lower density \( n_e = 0.4 - 0.8 \times 10^{20} \) at constant RF power, constant current and configuration. For example, shot 960116020 had a large tail population, no H mode, large CX signal and significant power deposition. In order to vary the amount of first orbit losses we then propose to increase the hydrogen concentration, at constant density. The concentration scan should be performed at the highest density where no H modes were observed. If first orbit losses are responsible for the failure to go into H mode (power unavailable at the edge), then a concentration scan should vary directly the losses. In appendix we tabulated power losses through first-orbit losses as a function of density and concentration as calculated by FPPRF for the given parameters. It is also interesting to look at the time dependence of the tail formation, predicted to be as long as 50-70 msec (appendix). If time allows we propose to do the scan at 2 different currents (and thus 2 different first-orbit confinement conditions). At optimum conditions, presumably at maximum tail energies and CX signal we propose to scan the PCX tangentially (and possibly a few points poloidally) in order to document pitch angle distributions in order to compare with FPPRF calculations and evaluating tail stored energy.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

- **Toroidal Field**: 5.3 T
- **Plasma Current**: 600 kA, 1 MA. (0.8 MA if only 1 current is possible)
- **Working gas species**: D, H
- **Density**: variable, up to \( 0.8 \times 10^{20} \text{ m}^{-3} \).
- **Equilibrium configuration**: a simple single-null
- **Pulse length, typical current & density waveforms, etc.** Refer to database or sketch desired waveforms: end of flattop at 1.1 sec

4.2 Auxiliary Systems

- **RF Power, pulse length, phasing**: 3 steps 100 msec long, 1.5MW reproducible power level
- **Pellet Injection (species)**: none
- **Impurity blow-off injection**: none
Special gas puffing: D/H

Other:

4.3 Diagnostics

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

All core diagnostics.

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.)

maybe 2 or 3

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.

A one-day run is requested and should be sufficient to carry the bulk of the proposal.

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 medium-low density shot, fiducial could be a good start. Then lower progressively density until H-mode is no more visible during RF period. Ultimately avoid Hard X-rays regime. Shot 960116020 is a good example of L mode conditions with large tail, significant CX signal level at high particle energy (above 50keV, in H).

At highest density L mode only conditions and with sufficient CX signal, start PCX tangential and poloidal scans for a few shots to document distributions.

Follow by a scan in hydrogen concentrations and look for H modes. Document tail distributions.

Standard diverted plasma, flattop from 0.5 to 1.0 sec, 3 steps of RF (100 msec long, 0.7-1.0sec at a reproducible level of about 1.5 MW (higher step).

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.

Largely unknown and undocumented, low density RF heated discharges may help in the understanding of H mode lower thresholds, confinement of fast ions, measurements of stored energies (tail) and impurity generation.

7. References

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