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.

   It is important for future tokamaks to be able to handle large power flows into the divertor. One method envisaged for handling this power is to use impurities to radiate the power away to the walls instead of allowing it to flow to the divertor surfaces. In this Mini-Proposal we will attempt to determine the scaling of the quantity of impurities required to obtain the detached divertor condition in discharges heated with a large amount of RF power (1 - 3.5MW). The understanding of the physics of detachment is of extreme importance for ITER in that they have based their divertor design on the physical principles underlying detachment; ion-neutral gas dynamics. It is also desirable to achieve an operating scenario that combines the detached divertor condition with the H-mode confinement regime. Gaining knowledge about the selection of impurity gas and whether or not it is possible to have a detached divertor with high RF power is a valuable part of this Proposal.

2. Background

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

   It had been previously observed (Mini-Proposal #073) that a detached divertor can reattach with the addition of RF input power. It is presumed that this RF power results in additional power flowing in the scrape-off layer (SOL) that heats the divertor to >5eV, thus removing a necessary condition for detachment. Also, Mini-Proposal #095 investigated the regime of high plasma density with RF heating and observed that even with NL04=1.8×10^{20}m^{-2} the divertor reattaches for RF power > 0.7MW. A goal of this Mini-Proposal is to determine the amount and type of puffed impurities in the divertor region required for divertor detachment at even higher RF power. It has been observed that the radiation
emissivity patterns for neon and methane in the divertor region are different. Also to be investigated is the role of radiation inside the last closed flux surface in divertor detachment.

A detached H-mode regime is also desirable. A second goal of this Mini-Proposal is to survey the conditions under which H-modes and divertor detachment exist to see if they can be made compatible. During the operation of Mini-Proposal #095, low divertor temperatures were observed during RF-heated H-mode plasmas. These plasmas appeared to be on the verge of detaching from the divertor. This suggests that some impurity injection may have pushed the divertor into the detached regime.

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 for these studies is to create a lower single null diverted plasma with fixed $\bar{n}_e$ and varying RF heating. At each of these power levels, neon and methane will be injected into the divertor region. The amount of each impurity necessary to obtain a detached divertor will be determined while also monitoring the effects on the core plasma.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

- Toroidal Field: 5.3 T
- Plasma Current: 0.8 MA
- Working gas species: $D_2$.
- Density: $\bar{n}_e = 2.5 \times 10^{20} m^{-3}$ ($NL04 = 1.5 \times 10^{20} m^{-2}$)
- Equilibrium configuration (if possible, refer to database equilibria): Lower SN diverted equilibria with acceptable gaps for both the RF and EDGE groups, e.g., shot 950329015
- Pulse length, typical current & density waveforms, etc. Refer to database or sketch desired waveforms: see shot 950329015

4.2 Auxiliary Systems

- RF Power, pulse length, phasing: varying power depending on the desired SOL power (up to maximum available)
- Pellet Injection (species): None
- Impurity blow-off injection: None
- Special gas puffing: Neon and methane puffing through the divertor gas puff system
- Other: None
4.3 Diagnostics
List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.

All core temperature and density diagnostics; Divertor probe array; Bolometer arrays; Fast scanning probe; Visible bremsstrahlung; OMA spectrometer viewing divertor, 20nm bandwidth, 0.1nm resolution, centred at 431 nm to detect O II and CII; Chromex; Molybdenum monitor; McPherson spectrometer looking at neon and/or carbon; All reticon arrays with \( H_\alpha \) filter; Ratiomatic pressure gages; Divertor pressure gages; C-top \( H_\alpha \) array.

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.)

minimal

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.

One run will be required. Given a value of the power flowing in the SOL, the amount of impurity gas puffed into the divertor region will be varied until the divertor detaches. The amount of power flowing in the SOL will be adjusted using RF power.

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) Obtain a plasma acceptable to both the EDGE and RF groups, starting from shot 950329015 (5 shots). This plasma should have gaps \( \approx 2 \text{cm} \) and SSEP > 1.6cm. FSP control is desired to give the probe a nice target at which to shoot. The amount of injected RF power should be \( \approx 1 \text{MW} \).

(2) Begin puffing neon through a capillary in the private flux region of the divertor. Determine the necessary amount of neon to detach the divertor (5 shots). Monitor the radiated power in the core plasma, the radiated power in the divertor, and the number of neon atoms in the core plasma.

(3) Try to inject \( \approx 2 \text{MW} \) of RF power (presumably raising the power in the SOL also) and repeat step 2 (5 shots).

(4) Try to inject \( \approx 3 \text{MW} \) of RF power (presumably raising the power in the SOL also) and repeat step 2 (5 shots).

(5) Repeat steps (1)-(4) with methane injection (15 shots), but monitor the amount of carbon in the core plasma.
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.

It is hoped that the results of this Mini-Proposal will determine the amount of injected impurities required for a given power flowing in the SOL in order to detach the divertor. Also, the amount of impurities (puffed in the divertor) which reaches the core plasma will be determined. Obviously, in an ITER scenario, there is a maximum allowable core impurity density. Furthermore, by comparing the results of neon and methane injection, the effect of the radial distribution of the core radiation on the conditions necessary for a detached divertor will be investigated. The operating conditions necessary for simultaneously achieving a detached divertor and H-mode may be determined.

7. References

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