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.

A thorough understanding of impurity transport during all types of operating conditions is necessary to develop a consistent picture of particle transport in Alcator C-Mod. There exists a number of unique operating scenarios in which a measurement of impurity transport characteristics would be useful. Transport information during detached plasmas, H-mode, and pellet fuelling is now of key interest to the overall programme, as is the development of general scaling relationships of impurity confinement times and penetration efficiencies over a range of standard operating conditions. This proposal will therefore undertake to inject trace impurities for the purpose of transport analysis into as many different discharges as possible. Any subsequent analyses which seek to use knowledge of impurity behaviour (i.e. concentrations, total radiated power, etc...) are dependent on the database supported by this mini-proposal.

2. Background

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

During the first run campaign we were able to demonstrate that trace amounts of non-recycling metallic impurities could be injected into discharges via the laser ablation injection system without causing disruptions. A database of particle confinement times was begun and presently contains about 40 shots representing a range of parameters (Ip from 0.4-1.0 MA, nl from 2e19-2e20 m^-2, background gas H2 and D2). Indications thus far are that the confinement time scales approximately linearly with current, and that an isotopic effect (proportional to the square root of the mass of the background gas) is also present. A dependence on electron density has not yet been established. Interesting extensions to this database include a range of q* achieved by changing Btor as well as Ip, and a range of $\kappa$.

Injections have also been made into detached divertor discharges. Strong differences in the effects of the injection on XUV emission in the divertor have been observed. It is
yet unclear whether this is solely due to the dramatically different edge conditions which are present during these detachments, or whether fundamental changes in SOL transport are responsible.

It has been observed (on Alcator C, among others) that deuterium pellet injection causes a peaking of impurity profiles and an enhancement of impurity confinement. This should be easily verifiable with a series of injections into pellet fuelled shots.

A direct measurement of particle confinement time during H-mode discharges, when it is known that transport characteristics have changed, can also readily be made. H-modes should be able to tolerate lower Z injections. If they do not, that too provides a useful piece of information regarding H-L transition mechanisms.

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 injection system is capable of introducing a number of different impurity species into the machine on a shot-to-shot basis. For this run period, the injector will be loaded with Si, Ti, Sc, V, Fe, Cr, and Mo. The species chosen for a given injection will be tailored to the goals of that injection. Baseline transport measurements are most easily made with injected scandium, due to the large number of diagnostics (HIREX, McPherson, X-ray arrays) capable of viewing line emission from various charge states (esp. H-, He-, and Li-like) of scandium. Other elements can be injected for more detailed information about relevant materials (say, titanium and molybdenum).

Observations of emission time histories and profiles will be compared with MIST code predictions and our in-house atomic physics model to determine impurity concentrations in the core plasma and total radiated power due to the injections. Confidence in the model established in this way will allow for reliable determination of profiles in the future.

4. Resources

4.1 Machine and Plasma Parameters
   Give values or range for:
   
   **Toroidal Field:** 5 T at first–then a range for q* scaling
   
   **Plasma Current:** variable, to 1.0 MA (or highest achievable)
   
   **Working gas species:** D, then H and maybe He
   
   **Density:** variable, to investigate screening; with and without detachment
   
   **Equilibrium configuration** (if possible, refer to database equilibria): single lower null
   
   **Pulse length, typical current & density waveforms, etc.** Refer to database or sketch desired waveform: as on 931019
4.2 Auxiliary Systems

**RF Power, pulse length, phasing:** none

**Pellet Injection (species):** as prescribed (piggy-back)

**Impurity blow-off injection:** as prescribed

**Special gas puffing:** possible fuelling in He after breakdown in D

**Other:** none

4.3 Diagnostics

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

McPherson, HIREX, U. Maryland OMA, Moly monitor, soft x-ray arrays, bolometers, visible arrays (with filters as appropriate), ECE, TCI, fast-scanning probe, etc...

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 dedicated run day is requested. A series of non-detached deuterium shots which scan current (from 0.4 - 1.0 MA) at constant density \((ne=1.0e20 \text{ m}^{-3})\), and then scan Btor (to achieve about a factor of 2 change in \(q^*\)) at constant density and current will be useful for filling in the impurity confinement database. Scandium would be the injected impurity of choice during this scan. (total: 15 shots)

A series of deuterium shots at constant current (say \(Ip=0.65 \text{ MA}\)) and variable density \((ne=8e19-2e20 \text{ m}^{-3})\) will provide a mechanism for obtaining detached divertor plasmas. Injections on successive shots before and after detachment will be useful for highlighting transport or penetration differences. (total: 15 shots)

In addition to the dedicated time requested above (which may be incorporated into any complementary mini-proposal with similar requirements – eg. Impurity Transport and Sputtering in the Divertor, G. McCracken), the ability to perform these injections into any other discharges of suitable interest is also requested.

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.

This proposal will enlarge the existing impurity transport database and extend it to unique operating scenarios of interest. A reliable database will then allow for measurements of radiated power by specific intrinsic impurities to be made on a regular basis.

This work also is integral to thesis work being undertaken by M. Graf and others (in the global context of impurity behaviour).