1. Purpose of Experiments

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

The primary goal is to determine the effect of noble impurities of different atomic number on the growth/decay of relativistic runaway electrons (RE’s) during quiescent flattop conditions. The injection of impurity gases is one method being proposed for mitigation of RE’s on ITER.

2. Background

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

Considering collisional damping only, the theoretical growth rate of runaway electrons depends on $Z_{\text{eff}}$ (see eqs 61-64 in [1]). In addition, medium- and high-Z impurities can greatly increase the power radiated by relativistic electrons, thus enhancing the rate of RE energy loss. Therefore, the injection of modest amounts of impurities into the current quench phase of ITER disruptions may be a more plausible RE mitigation scenario when compared to rapid D$_2$ fueling to the critical density required by collisional damping only. Well-diagnosed documentation of this scheme is difficult during disruptions, but should be more feasible during the quiescent flattop portion of non-disrupting plasmas.

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 would be to duplicate one of the discharges from MP730 (2014/04/03) to obtain a reproducible plasma with relativistic runaways during the $I_p$ flattop. A small increase in electron density is then done by puffing $D_2$, as in shot 1140403025 (but probably smaller; $\Delta$nebar) $\approx 0.1 \times 10^{20}$ m$^{-3}$, so that the forward-peaked emission from the relativistic RE’s continues rising. This will serve as the baseline shot. Subsequent shots will use puffs of different impurity gases (He, Ne, Ar, and perhaps Kr) instead of $D_2$ to achieve the same $\Delta$(nebar). For each of these shots, measure the growth rates of the relativistic emission and the HXR signal.

While executing this run, we will have one optical fibre (inv_pltfrm_2) viewing opposite the relativistic emission, and one optical fibre (inv_pltfrm_1 or _3) viewing into the relativistic emission, with both fibres going to the Chromex spectrometer. The continuum of the view opposite the RE emission will provide a surrogate measure of $Z_{eff}$. A calibration shot can be done at the end of this run by ramping the density to a relatively high value ($\sim 1.5 \times 10^{20}$ m$^{-3}$).

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

Toroidal Field: 5.4 T
Plasma Current: 0.8 MA (either direction can be accommodated)
Working Gas Species: deuterium
Density: $n_{l_0} = 0.4 - 0.6 \times 10^{20}$ m$^{-2}$
Boronization Requested (if yes, specify whether overnight or between-shot, how recently needed, and any special conditions.): no
Equilibrium configuration (if possible, refer to database equilibria): LSN, 1140403025 for example

4.2 Auxiliary Systems

ICRF Power, pulse length, phasing: none
LHCD Power, pulse length, phasing: none
Pellet Injection (species): none
Impurity blow-off injection: none
Diagnostic Neutral Beam: yes, but only if $I_p$ is in clockwise direction
Special gas puffing: yes, He, Ne, Ar, and maybe Kr
Cryopump: no
Non-axisymmetric Coils (Connections, Current); standard m=2/n=1 feedback mode to prevent locked modes at the relatively low densities for this run.

Other:

4.3 Diagnostics

List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.
ECE for $T_e$, and for spectra below the 2$^{\text{nd}}$ harmonic.
Chromex with the lowest-resolution grating, with fibre hooked to inv_pltfrm_1, _2, _3.
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.

one-half run 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.

Fill B-side-lower with 0.1 bar of helium. Keep valve DISABLED for beginning of run.

4 shots: replicate 1140403025, except change $\Delta$(nebar) to $0.1 \times 10^{20}$ m$^{-3}$. Observe RE growth on HXR (SSD_X02), MSE polarized light, Z-meter brightness, and WIDE2 video. Look for line-free region in Chromex spectra (change wavelength range if necessary).

4 shots: Remove $D_2$ puff programming, and replace with puff of He from B-side-lower. Adjust timing and/or amplitude to obtain $\Delta$(nebar) to $0.1 \times 10^{20}$ m$^{-3}$. (Shorter puff is better, i.e. < 100 ms.) Observe RE signals.

Fill B-side-lower with 0.1 bar of neon.
3-4 shots: Puff Ne from B-side-lower. Adjust timing and/or amplitude to obtain $\Delta$(nebar) to $0.1 \times 10^{20}$ m$^{-3}$. Observe RE signals.

Fill B-side-lower with 0.1 bar of argon.
3-4 shots: Puff Ar from B-side-lower. Adjust timing and/or amplitude to obtain $\Delta$(nebar) to $0.1 \times 10^{20}$ m$^{-3}$. Observe RE signals.

If there is sufficient time:
Fill B-side-lower with 0.1 bar of krypton.
3-4 shots: Puff Kr from B-side-lower. Adjust timing and/or amplitude to obtain $\Delta$(nebar) to $0.1 \times 10^{20}$ m$^{-3}$. Observe RE signals.

1 shot: $Z_{\text{eff}}$ calibration: ramp nebar to $1.5 \times 10^{20}$ m$^{-3}$. with $D_2$ fueling (no impurity puffing). Obtain Chromex spectrum.
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, an ITER request, or an external database.

Obtain the RE growth rate vs $Z_{\text{eff}}$ at constant electron density.

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