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

The gas puff imaging diagnostic (GPI) [1-2] gives detailed measurements of edge and SOL turbulence, while gas puff charge exchange recombination spectroscopy (GP-CXRS) [3] provides radial profiles of impurity temperature, flows, and the radial electric field, $E_r$ [4-5]. Unfortunately, despite careful in-vessel calibrations, there is currently no reliable radial alignment of GPI and GP-CXRS measurements. This MP proposes experiments to resolve this issue and at the same time collect data to address important edge physics questions such as where the WCM is located inside the I-mode $E_r$ well, what its plasma frame phase velocity is, and what the role of the ExB shear is in the I-mode transport barrier. Similar measurements in EDA H-mode will allow benchmarking our results with recent measurements from the Mirror Langmuir Probe [6] and possibly generalize these finding to higher power discharges.

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

It is believed that edge instabilities play an important role in regulating particle and impurity transport [7,8] and/or in determining the structure of the pedestal [9,10]. For a better understanding of the drive and nature of these instabilities and comparisons with results from edge turbulence modeling [11] and ExB shear decorrelation theories of turbulence [12], it is necessary to have detailed measurements of time-averaged and fluctuating quantities. It is therefore highly desirable to develop ways to more reliably combine measurements from the extensive set of edge and SOL diagnostics on Alcator C-Mod.
The physics goal of this MP is complementary to current plans of the C-Mod team to develop low power discharges (e.g. ohmic I-modes) where extensive edge measurements can be obtained with probes, which are not subject to alignment issues.

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.

Both GPI and GP-CXRS collect light through optical chords, but at two toroidally separated locations (we only consider the LFS systems here). The GPI system features a 2D array of toroidal optical chords. The GP-CXRS system collects light through one row of toroidal views and two rows of poloidal views.

For these experiments, we will connect one row of poloidal views and the toroidal views of the CXRS system to the GPI detectors, as highlighted by the different colors in Fig. 1. Collecting data during He-puffs should then allow us to properly align measurements from the toroidal CXRS views with those from the standard GPI views. As the poloidal wavelength of e.g. the WCM or the QCM is not much smaller than the width of the gas puff (both $\approx$3-4cm), we also expect to detect the mode on the poloidal view. We can then compare this to the result of the toroidal view and already localize the mode with respect to the $T_z$ profile measured simultaneously with CXRS on the other set of poloidal views.

Once data is collected successfully in this setup, we will need a short cell access to switch back to the standard setup and rerun the discharge. This time, we will puff D2 for CXRS, while still puffing He for GPI. This should give us the full GPI and CXRS measurements under conditions where the relative alignment is well known.

To find out if the alignment between GPI and CXRS systems is discharge dependent, the above alignment procedure will be repeated in different discharges. The easiest way to align turbulence measurements from different locations is probably to align the mode locations. Since the QCM can be much better identified in the spectra than the WCM, experiments will first be performed in EDA H-mode (USN, Rev. B). There are no special requirements on this EDA H-mode, except that the QCM be well in the measurement range of GPI. An R-Gap of 10mm should be appropriate (QCM between R=88.5 and 89 cm).

After this, we will do some attempts for ohmic EDA H-modes, which could allow for a comparison with the Mirror Langmuir probe.

If there is time, we will do another high power EDA H-mode at a different current. Otherwise, we will directly go to I-mode (LSN, Rev. B). If the WCM is too weak to be visible in the GPI spectra, we will change the I-mode parameters (possibilities include varying Ip or nl04, depends on what the I-modes and WCMs are like during this campaign).

Due to the finite spatial resolution of the optical chords in the radial direction, gap scans of $\approx$ 7mm over a time of 100ms will be performed during all shots.
Figure 1: Experimental setup to radially align the toroidally separated imaging systems of GPI and GP-CXRS. The idea is to connect part of the CXRS views to the GPI detectors, such that GPI data obtained at both locations can be compared and properly aligned.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

- Toroidal Field: 5-6 T
- Plasma Current: 0.8-1.3 MA
- Working Gas Species: D2
- Density: $0.6-2 \times 10^{20} \text{ m}^{-3}$
- Boronization Requested (if yes, specify whether overnight or between-shot, how recently needed, and any special conditions.): Yes, overnight
- Equilibrium configuration (if possible, refer to database equilibria): EDA H-mode (Rev. B, USN): 1070718016 (or use 1140226018 as starting point and tweak it); I-mode (Rev. B, LSN): 1120921014;

4.2 Auxiliary Systems

ICRF Power, pulse length, phasing: at least 3MW for ~1s, heating phasing
LHCD Power, pulse length, phasing: no
Pellet Injection (species): no
Impurity blow-off injection: no
Diagnostic Neutral Beam: not required
Special gas puffing: Ninja for GPI (10 PSI He in C-port plenum) and CXRS (F-port plenum, several switches between 10PSI He and 10PSI D2, start with 10PSI He)
Cryopump: Desirable
Non-axisymmetric Coils (Connections, Current); standard error field correction setup
4.3 Diagnostics
List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.

Essential: ECE, Edge TS, magnetics (EFIT reconstruction), GPI, GP-CXRS, Reflectometer
Highly Desirable: Mirror Langmuir Probe (MLP), PCI, core TS

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.
1 full run day will probably be required in total. However, only ½ days have been allocated for it, and this is probably a good starting point. Especially the I-mode part can likely be done in piggy-back during a day where an I-mode with a clear WCM has been established. All that is needed then is a short cell access and a repetition of the same discharge.

It is important for this MP that there has been at least one prior H- or I-mode run where the edge CXRS system can be tested (check proper light levels, Tor-Pol periscope alignment,…)

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.

Part 1: Boronization recovery and ICRF-heated EDA H-mode (Rev. B, USN) (∼5 shots)

Establish a steady and reproducible EDA H-mode (Ip=900kA, target nl04 = 9x10^{19} \text{m}^{-3}, 2MW ICRF). Then do:
Simultaneous ninja puffs for GPI and GP-CXRS, followed by a 7mm gap scan over 100ms. Once successful, need cell access to change fiber connections. Also change gas in F-port plenum (He -> D2). Then, repeat the shot.
Before going to part 2, fill F-port plenum again with 10PSI He.

Part 2: Ohmic EDA H-mode (2 or ∼5 shots)

Try for 2 shots to establish an ohmic EDA H-mode (keep some flexibility here depending on machine conditions). If successful, repeat measurements in Part 1, including measurements with the Mirror Langmuir Probe.

Part 3: EDA H-mode at a different current (0 or 3 shots)
If Part 2 stopped after 2 shots, repeat measurements in Part 1 for a different ICRF heated EDA H-mode (Ip=600kA, target nl04 = 7x10^{19} m^{-3}, 2MW ICRF). Otherwise, skip Part 3.

Part 4: I-mode (Rev. B, LSN) (≈5 shots)

Attempt same procedure as in Part 1 for I-mode (Ip=1.2MA, target nl04 = 9x10^{19} m^{-3}, 4MW ICRF if possible, otherwise drop Ip and nl04). Change parameters if necessary to get a clearer WCM.

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.

These experiments are expected to provide a reliable radial alignment between measurements from GPI and GP-CXRS, at least for the discharges of this MP. This should allow gaining important insights on edge fluctuations such as their plasma frame phase velocity, their location in the pedestal, and possibly the role of the ExB shear. If the radial alignment is found to be shot-independent, this would be extremely valuable for both past and future experiments.

These results are expected to form an important part on a publication on the role of the Er well in the I-mode transport barrier and comparisons to L-, and H-mode, which would allow reaching the goals of the second part of C. Theiler’s fellowship. These experiments are also expected to be very beneficial for a lot of future work relying on CXRS and GPI measurements, e.g. for modeling efforts of EDA H-modes. The results may encourage the writing of a follow-up MP, or inform the inclusion of the developed technique into other MPs currently being drafted.

7. **References**

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