1. Purpose of Experiments

The purpose of these experiments is to explore the dependence of SOL fluctuation characteristics and attendant cross-field particle transport on the collisionality of the SOL.

2. Background

A number of preliminary experiments performed during the last run campaign suggest that a parameter like density or collisionality (defined here as parallel connection length divided by electron mean-free path) can be used to distinguish between fluctuation and transport behavior in the SOL: (a) Carreras and Lynch [1] analyzed divertor probe fluctuation spectra taken during an ohmic density scan. They found a marked change in the fluctuation spectrum and degree of long-time correlation events for core densities above a critical value. (b) Effective particle diffusion coefficients, $D_{\text{eff}}$, (inferred from the tangential Lyman-alpha diode array and analysis of main-chamber recycling fluxes) have also been studied during an ohmic density scan [2]. These data appear to show a strong dependence of $D_{\text{eff}}$ on local collisionality. It has been speculated that such a strong scaling of $D_{\text{eff}}$ with collisionality may naturally lead to a plasma density limit set by the condition when the heat convection dominates the cross-field power balance. Moreover, the ever-present ‘main-chamber recycling’ behavior in C-Mod appears to be a consequence of large $D_{\text{eff}}$ in the far SOL. (c) Winslow [3] compared adjacent divertor probe fluctuations and found them to change character with density. In some regimes, fluctuations on one divertor probe depend on the bias on an adjacent probe.
Cross-field particle fluxes arise from the details of the plasma fluctuations both in the SOL and divertor. Therefore, it makes sense to combine measurements of cross-field flux from particle balance, measurements of cross-field flux from electrostatic fluctuations, and characterizations of fluctuation properties in the SOL and divertor into an organized experimental plan.

As a point of focus, this miniproposal identifies collisionality as a key parameter. Our approach is to simultaneously and systematically explore the dependence of cross-field fluxes and fluctuations on SOL collisionality. Collisionality can be increased by increasing the density at fixed Ip and Bt or by increasing the parallel connection length (increasing Bt/Ip) at fixed density (assuming edge Te is not strongly affected). Thus in order to do even a very basic parameter scan requires two run days: 1-day for a fine density scan and 1-day for a series of coarse density scans at different fields and currents.

Another variable which is of interest is the divertor bypass condition. Carreras [1] has speculated that flows into the divertor may be responsible in part for the transition between the fluctuation behaviors. In order to investigate this, the flapper will be opened for a couple of otherwise identical shots.

At this time we do not want the complications associated with an H-mode confinement barrier. Here we focus on ohmic L-modes. H-modes, including ohmic H-modes will be studied in separate experiments.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

**Toroidal Field:** 6, 5.3, 4 tesla

**Plasma Current:** 0.5, 0.8, 1.1 MA

**Working gas species:** D_2

**Density:** NL04 = 0.6 - 1.4x10^{20} m^{-2}

**Equilibrium configuration** (if possible, refer to database equilibria): standard lower divertor with strikepoints on the vertical sections of the divertor plates. We may want to tweak the x-point programming to adjust the ever-present slow-sweep of the strike point across divertor probes so that it remains more or less the same for each discharge condition.

**Pulse length, typical current & density waveforms, etc.** Refer to database or sketch desired waveforms: current flat-top lasting to 1.1 seconds

4.2 Auxiliary Systems

**RF Power, pulse length, phasing:** none
Pellet Injection (species): none

Impurity blow-off injection: none

Special gas puffing: perhaps a couple of C$_2$D$_4$ puffs from the F-port scanning probe

Other:

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

The key diagnostics which must be operational for this study are: (a) A-port and F-port scanning probes operated in a fluctuation mode (The A-port probe will be used in both a spatially scanning and a fixed position mode.), (b) divertor probes operated in a fluctuation mode, (c) fast visible diodes viewing helium puffed from the A/B limiter capillary, (d) tangential Ly-alpha diode array, (e) limiter particle flux probes, and (f) edge thomson scattering.

If the Texas turbulence probe is ready, then these plasmas would be a great opportunity to collect some fluctuation data in the far SOL. In addition, if the new plume-imaging system is ready, then it makes sense to record dispersal patterns of C$^+$ and C$^{+2}$ near and far from the separatrix in a couple of discharges. However, until we verify that the plume does not affect the fluctuations recorded by the F-port probe, extensive ‘pluming’ should be avoided.

In preparation for this run, operation of the A-port and F-port scanning probes in a ‘swept triple probe’ mode will have to be tried and tested. (The technique may allow Te fluctuations to be recorded.) If this technique does not prove advantageous, then the scanning probes will be operated in the ‘standard’ mode where two probes are swept-single probes and two probes are floating. When the A-port probe is at a fixed location in the SOL, it will be operated with two probes in Isat and two probes in floating mode.

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.)

Less than $10^{14}$ per shot

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.

Two run days are required to complete a basic parameter scan.
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.

Day 1: Fine density scan at fixed plasma current (0.8 MA) and toroidal field (5.3 tesla).

Shot #1-3

\[ \text{NL04} = 1.0 \times 10^{20} m^{-2} \]

Setup equilibrium and FSP/ASP target.

Begin density scan with two shots at each density. Alternate between A-port probe in scanning- and fixed-location modes.

Shot #4,5 - NL04 = 1.0

6,7 - NL04 = 1.0, flapper open
8,9 - NL04 = 0.9
10,11 - NL04 = 0.8
12,13 - NL04 = 0.8, flapper open
14,15 - NL04 = 0.7
16,17 - NL04 = 0.6
18,19,20 - NL04 = 1.1
21,22 - NL04 = 1.2
23,24 - NL04 = 1.3
25,26 - NL04 = 1.4

Day 2: Coarse density scans at different plasma currents and toroidal fields.

Shot #1-3

\[ \text{NL04} = 0.6 \times 10^{20} m^{-2}, \text{Ip} = 0.53 \text{ MA}, \text{Bt} = 5.3 \text{ tesla} \]

Setup equilibrium and FSP/ASP target.

Take two shots at each condition to optimize scanning probe insertion depths.

Shot #4,5 - NL04 = 0.6, Ip = 0.53, Bt = 5.3

6,7 - NL04 = 0.8, Ip = 0.53, Bt = 5.3
8,9 - NL04 = 1.0, Ip = 0.53, Bt = 5.3
10,11 - NL04 = 1.1, Ip = 1.06, Bt = 5.3
12,13 - NL04 = 1.4, Ip = 1.06, Bt = 5.3
14,15 - NL04 = 0.8, Ip = 1.06, Bt = 5.3
16,17 - NL04 = 0.7, Ip = 0.8, Bt = 4
18,19 - NL04 = 1.0, Ip = 0.8, Bt = 4
20,21 - NL04 = 1.3, Ip = 0.8, Bt = 4
22,23 - NL04 = 1.3, Ip = 0.8, Bt = 6
24,25 - NL04 = 1.0, Ip = 0.8, Bt = 6
26,27 - NL04 = 0.7, Ip = 0.8, Bt = 6

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.

From these data we should be able to assemble relationships between cross-field particle transport, SOL and divertor fluctuation behavior and collisionality (or other) parameters. Through the use of limiter particle flux probes, Lyman-alpha emissivity, and Mach probe measurements, we will also directly investigate the dependence of the main-chamber versus divertor recycling level on the SOL collisionality.

Although the connection, if it exists, between the intrinsic scaling of $D_{eff}$ with collisionality (or density...) and the plasma density limit will not be studied directly in these experiments, the trends seen in previous experiments will be explored in much more detail. A more focussed investigation of SOL particle transport near density limit in ohmic discharges will be the subject of another miniproposal.

7. References

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