COMPARISON BETWEEN GYROKINETIC SIMULATIONS AND EXPERIMENTS IN THE LITHIUM TOKAMAK EXPERIMENT-ß (LTX-ß)

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The Lithium Tokamak eXperiment-ß (LTX-ß) [1] is a small aspect-ratio tokamak (R_0=0.4 m, a=0.2 m) with nearly complete lithium (Li) coating of the plasma-facing components (PFCs). Lithium is deposited onto walls by two outboard midplane Li evaporators located at opposed toroidal locations and activated prior to a set of shots. Li is attractive for its ability to capture incoming hydrogen (i.e. result in low recycling of hydrogenic ions), which removes the source of neutrals and thus cold ions that would otherwise be present with other PFC materials. The ability to capture incoming hydrogen is measured by the recycling coefficient R, which is ratio of the flux of neutrals released by the wall to the flux of ions impinging on the wall. In the absence of such cold neutrals the edge temperature is much higher. Two benefits of this scenario are the flattening of temperature profiles [2], which helps reduce temperature gradient-driven turbulent transport and improve confinement, and another is the increase of the region where the plasma triple product is high (density being equal). Simultaneously, many new questions arise in the scrape-off layer (SOL) which now has very low collisionality, and decades' worth of fluid-based (theoretical, numerical and experimental) SOL knowledge needs revision. Adding to such questions, LTX-ß has a scant diagnostic of the SOL, limiting our characterization of this region.

Leveraging developments in gyrokinetic modeling of the tokamak edge, we carried out axisymmetric gyrokinetic simulations of LTX-ß plasmas with the Gkeyll code [3]. Such simulations encompass both freshly evaporated and passivated Li shots (the latter means after weeks of operation since the last Li evaporation, when Li is either absent or oxidized). Our objective is trifold: 1) to further diagnose the properties of the LTX-ß edge as they undergo changes induced by Li coated walls, 2) to obtain more accurate estimates of the ion fluxes to the PFCs and combine them with DEGAS2 and Lyman-α diagnostics to compute estimates of the recycling coefficient R [4], 3) to provide a validation of the Gkeyll axisymmetric gyrokinetic solver comparing synthetic and experimental diagnostics. Axisymmetric gyrokinetic simulations evolve the phase-space distribution functions of each species (f_s) to steady state, but do not directly evolve the turbulent transport and instead employ a diffusive transport model consisting of a simple diffusion operator on f_s with coefficient D. LTX-ß produces inner-wall-limited plasmas, modelled here using an infinitesimally thin limiter on the high-field side (see figure 1 left).

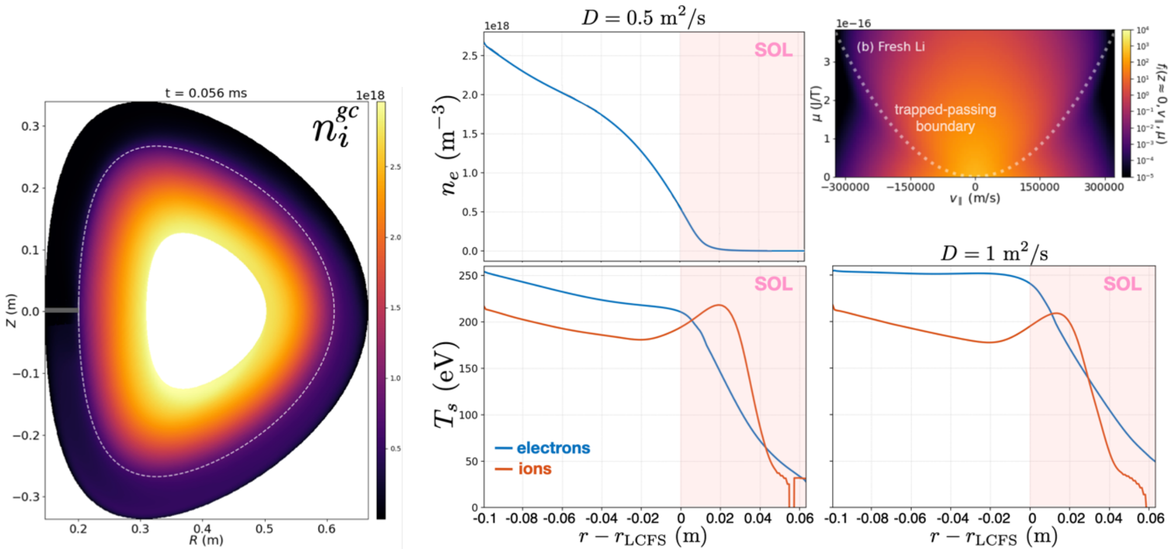

Figure 1. Left: ion guiding center density in a Gkeyll axisymmetric gyrokinetic LTX-ß simulation. Right: density and temperature profiles for fresh Li simulations with different diffusion coefficients, and a sample SOL ion distribution showing it is composed of thermal/Maxwellian and trapped contributions (upper right).

Axisymmetric gyrokinetic simulations contain sources of particles and energy in the core, such that drifts and anomalous diffusion carry the particles and energy outwards and along the field line in the SOL. The simulation evolves the plasma to steady state like axisymmetric fluid codes do [5] but using the 2D gyrokinetic model, at which point we can examine plasma profiles and use them for subsequent analysis. At first we do not directly evolve neutrals nor self-consistently model recycling, and instead simply evolve the charged species under fresh Li conditions (e.g. high edge electron temperature). An example of the density and temperature profiles produced by a Gkeyll axisymmetric calculation of a fresh Li LTX-ß discharge is given in figure 1 right. One can see that the electron temperature profile is relatively weak in the core, and as expected the T_e profile is flatter as the diffusive transport is increased. Also shown in figure 1 (upper right) is a snapshot of the ion distribution function in the SOL for this fresh Li scenario, showing that the distribution is not solely Maxwellian, it contains a trapped (e.g. mirror-like) component. As the collisionality decreases (~ 0.4) in the SOL this trapped contribution becomes more dominant (the trapped fraction reaches $\sim 85\%$), thus improving confinement in the SOL.

This work will present additional simulations (including passivated Li discharges) their comparison to experimental diagnostics (i.e. Langmuir probes, Thompson scattering, Lyman-α). We will also show a comparison of computing recycling coefficients R using the simple estimate $\Gamma_i = n_i c_s$ that was used in previous work [4] and a similar computation employing the ion flux Γ_i provided by the axisymmetric gyrokinetic calculations. The found profiles in the SOL will also be compared to commonly used two-point models, given their ubiquitous use in control systems and theory, showing the strengths and limitations for simple fluid models in these novel regimes. Lastly, preliminary 3D, turbulent simulations of LTX-ß will be exhibited, which produce turbulent densities that can be compared to reflectometry measurements of the density fluctuations in the experiment.

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