Results of data-constrained B2.5/DEGAS modeling of Li/DiMES exposure discharge 105508 @ 3900 ms

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Discharge parameters @ 3900 ms:

Lower single null, L-mode, ion grad-B drift toward X-point

Average electron density $<n_e> = 2.5 \times 10^{19}$ m^{-3}

Plasma volume = 16.23 m^3

R (X-point) = 1.353 m, X-point height = 0.297 m

R (Outer Strike Point) = 1.476 m (on DIMES sample)

R (Inner Strike Point) = 1.016 m (on inner wall)

Total input power = 1.1 MW (1/2 NBI, 1/2 ohmic)

Stored energy = 0.12 MJ

Total (core) radiated power = 0.52 MW (0.16 MW)

Power across separatrix = 0.8 MW

Energy confinement time = 0.12/0.8 = 0.15 s

Experimental data:

Upstream n_e and T_e from core/SOL Thomson scattering

Upstream T_i from charge-exchange recombination spectroscopy (CER)

n_e and T_e from divertor Thomson scattering (DTS) - chord at OSP

n_e, T_e and ion flux from divertor Langmuir probes

D_α emissivity from lower divertor filterscope array

Core and total radiation from bolometry array

Analysis procedure:

Experimental data are analyzed with the B2.5 plasma transport code. Parameters that are adjusted to fit the data include primarily the particle and energy diffusivities, convective velocity, and recycling coefficients. Impurity radiation is simulated with hydrogenic radiation multipliers. The plasma solution is input to the DEGAS Monte Carlo neutrals transport code in order to check the core plasma particle balance (core fueling = core efflux + dN/dt), to generate the lower divertor D_α profile for comparison with filterscope data, and to generate neutral particle distributions in the plasma and on the plasma facing components.

Analysis results:

Total radiated power = 0.52 MW

Power crossing separatrix = 0.8 MW

Core particle efflux = 630 amps (B2.5)

Core fueling rate = 628 amps (DEGAS)

NBI fueling rate = 9 amps (dN/dt = 2-3 amps from $\langle n_e \rangle$ trace)

Average core particle confinement time = 0.10 s

Integrated core plasma charge-exchange rate = 5.8 x 10^{21} s^{-1}

Total core plasma charge-exchange power loss = 0.21 MW (DEGAS)

Integrated particle flux	inner divertor	outer divertor
	2589 amps	2778 amps

Required radiation multiplier = 2.1

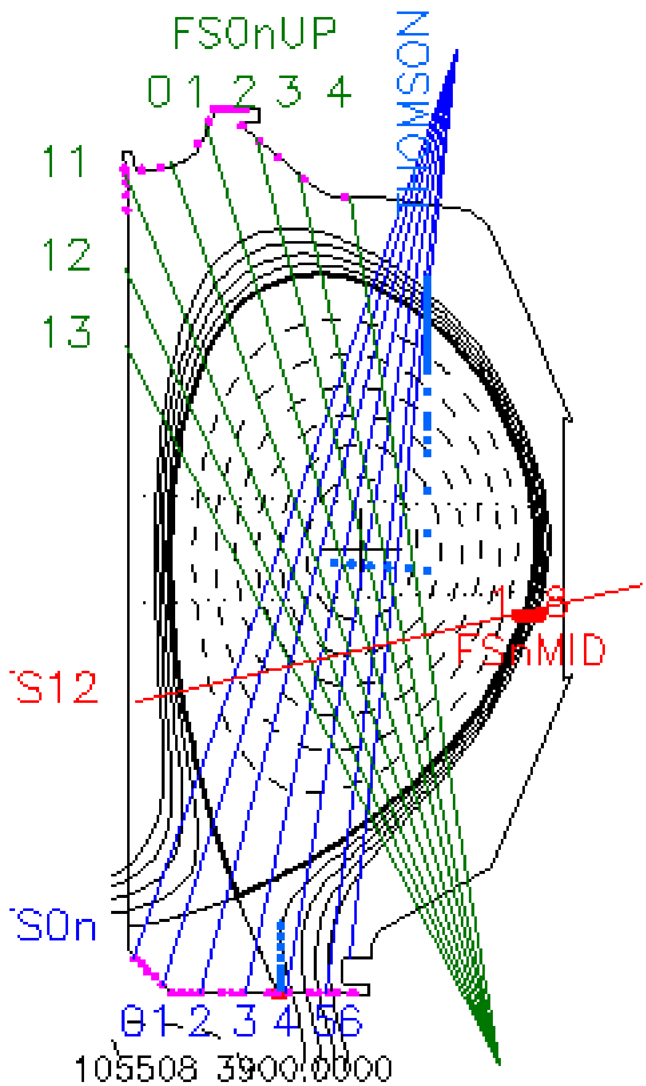


Fig. 1. The EFIT magnetic equilibrium at 3900 ms is shown with the locations of many of the diagnostics used in the plasma reconstruction. The outer strike point (OSP) is on the DiMES sample and the inner strike point (ISP) is on the inner wall at 3900 ms. Note that the divertor Thomson scattering chord, the filterscope chord FS04, and several divertor Langmuir probes are at or very near the radial location of the DiMES sample. Hence, the plasma near the sample is very well diagnosed.

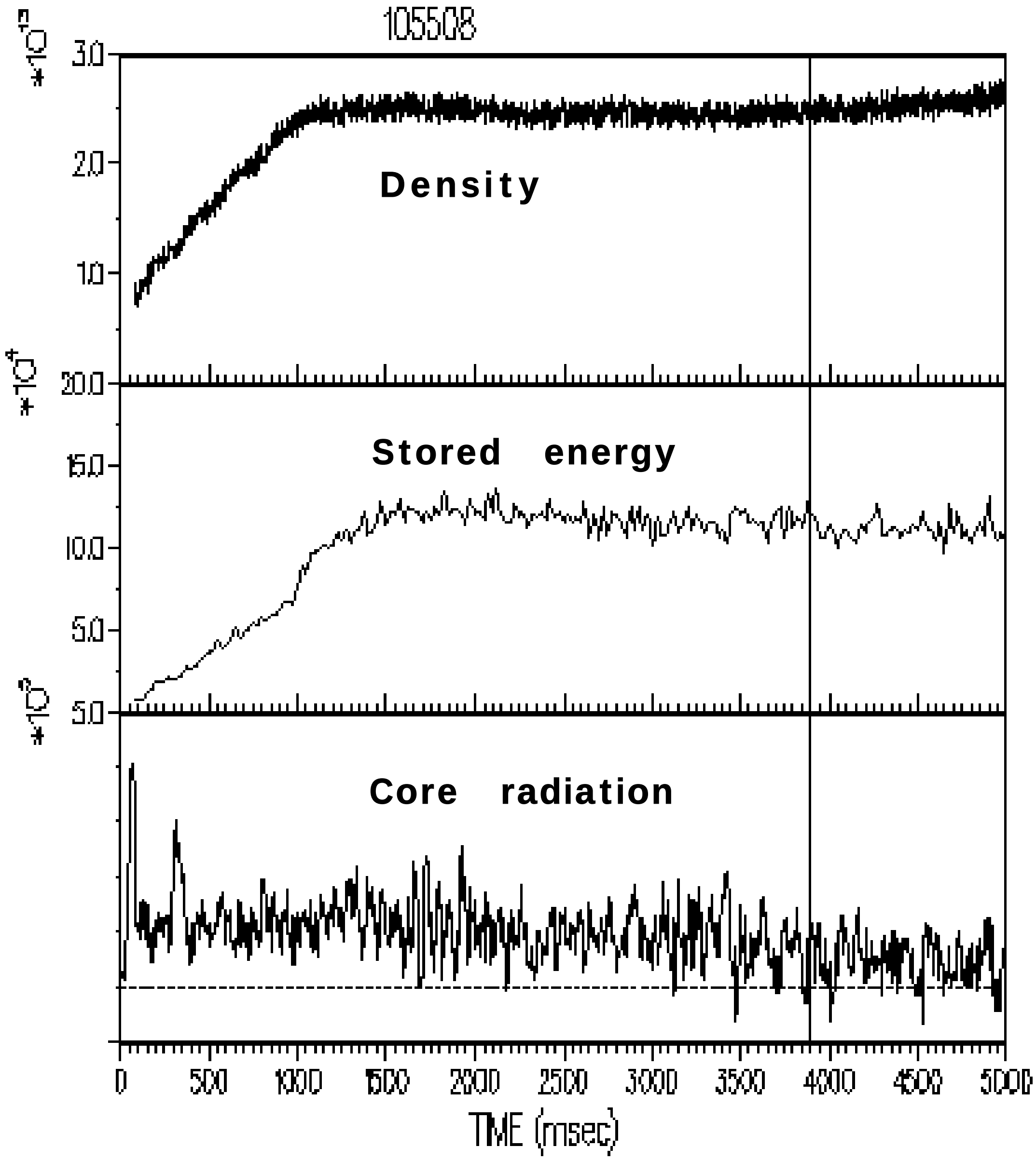


Fig. 2. Electron density, plasma stored energy, and core radiation traces are shown for 105508, with the analysis time denoted by the vertical line.

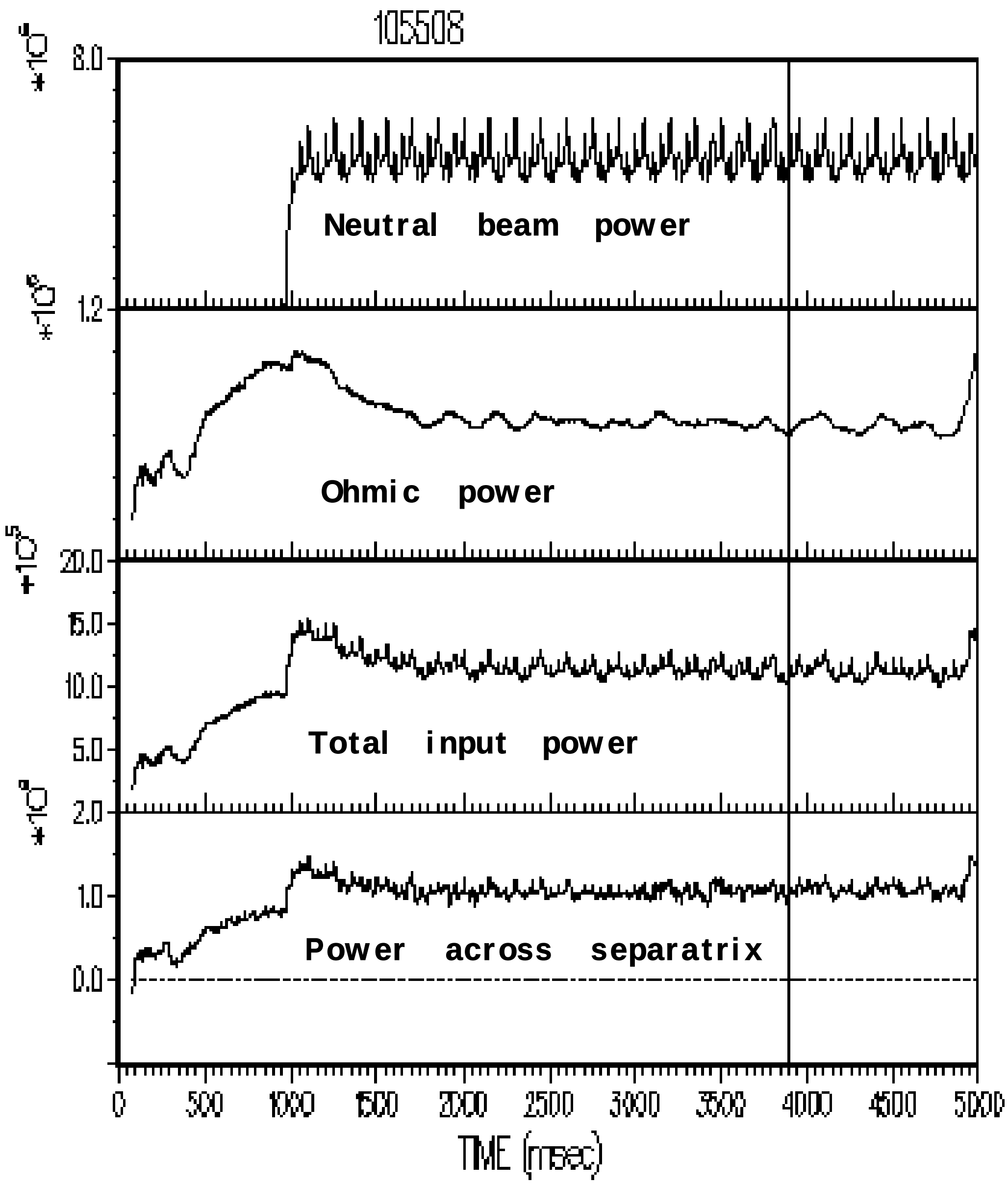


Fig. 3. Power traces for 105508 show that the ohmic and neutral beam input power fractions are roughly equal at 3900 ms. The power crossing the separatrix is computed as the total input power - dW/dt - core radiation. Core charge-exchange power loss, calculated with DEGAS to be about 200 kW, is not included here. These traces are back-averaged over 40 ms.

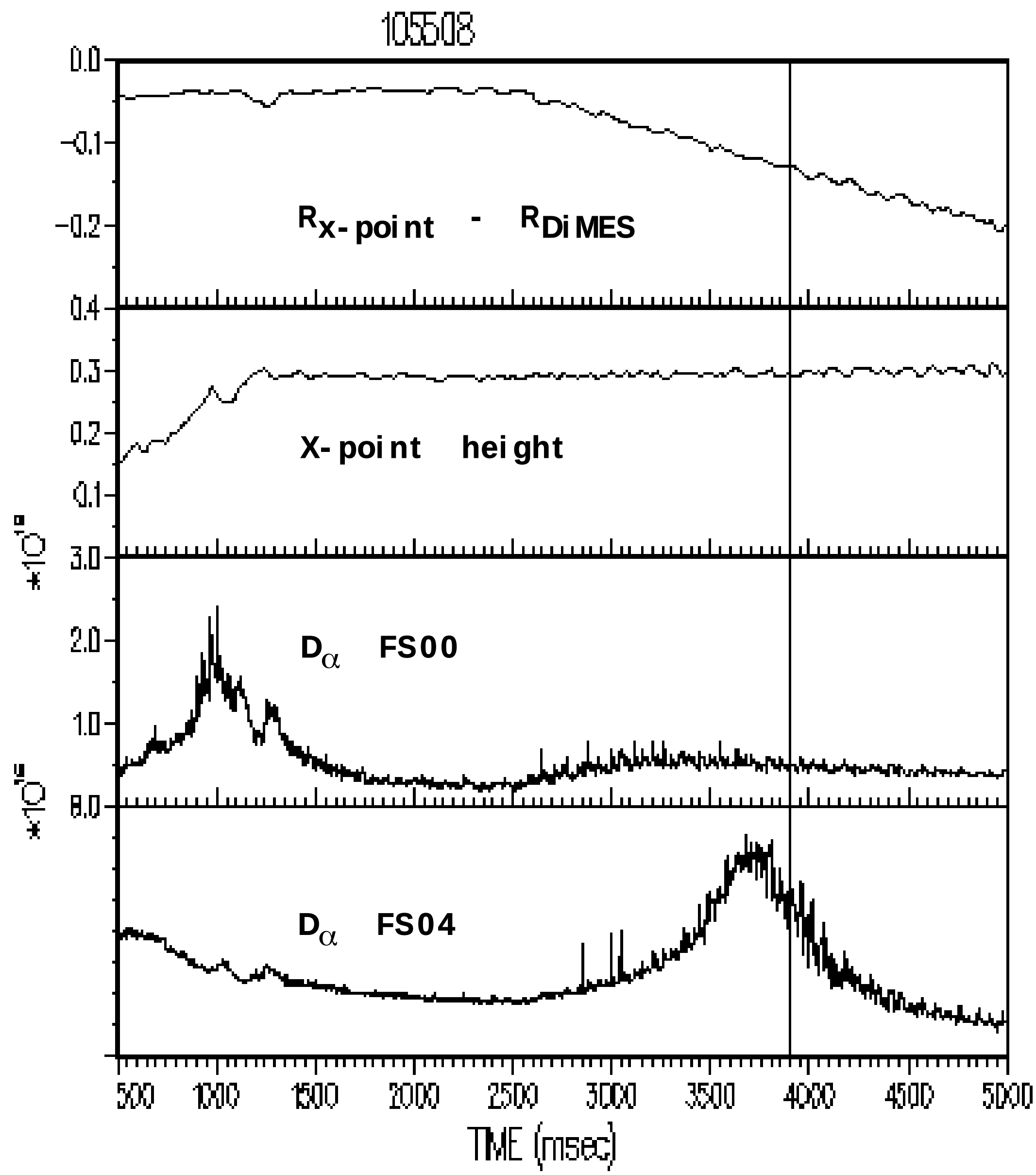


Fig. 4. The major radius of the X-point relative to that of the DiMES sample shows the inward sweep that begins at 2500 ms. The X-point height above the divertor floor remains constant at about 0.3 m during the sweep. The FS00 D_α data near 3900 ms is the primary constraint on the model description of the inner divertor leg. The FS04 D_α chord is closest to the sample at the analysis time.

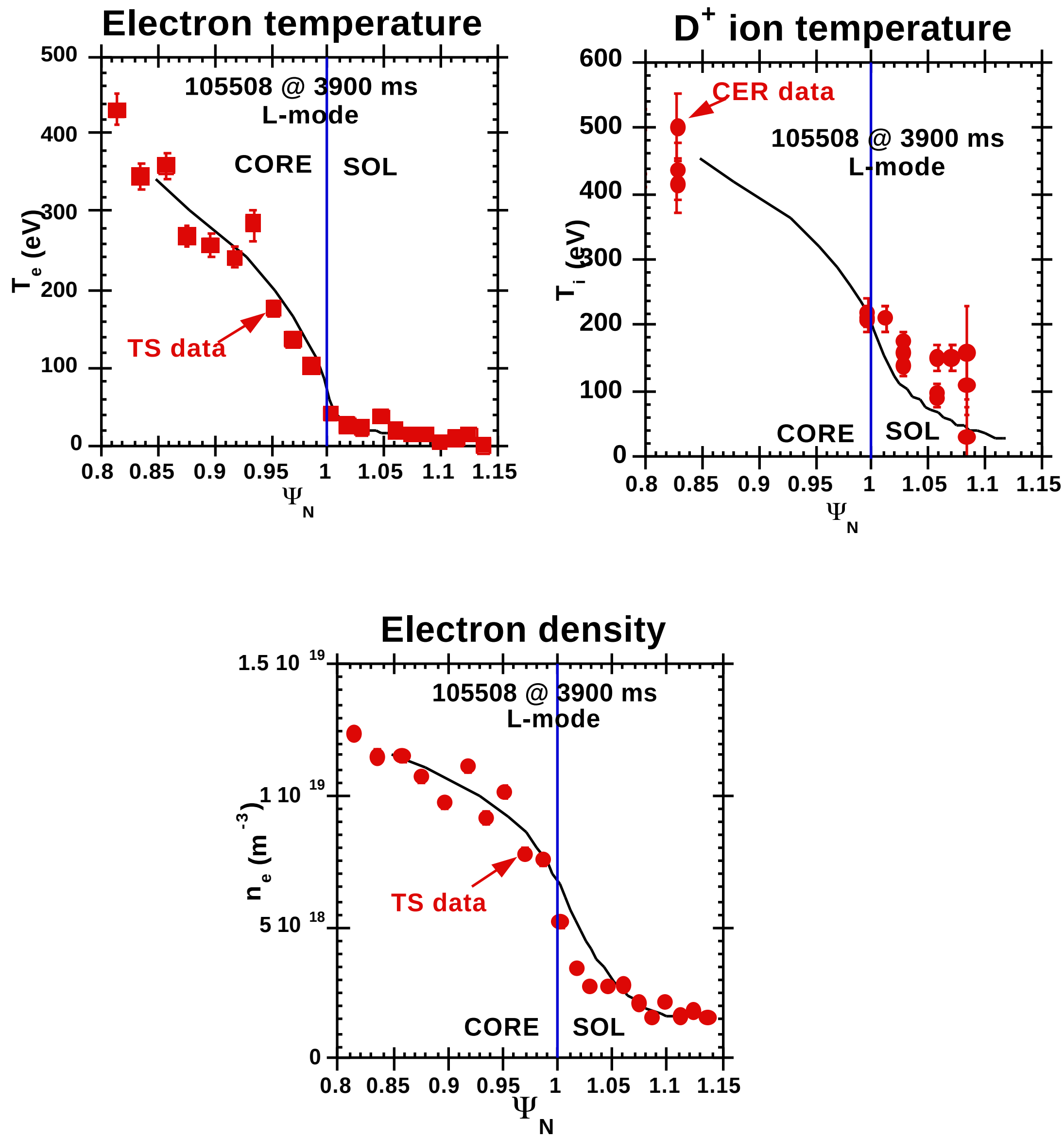
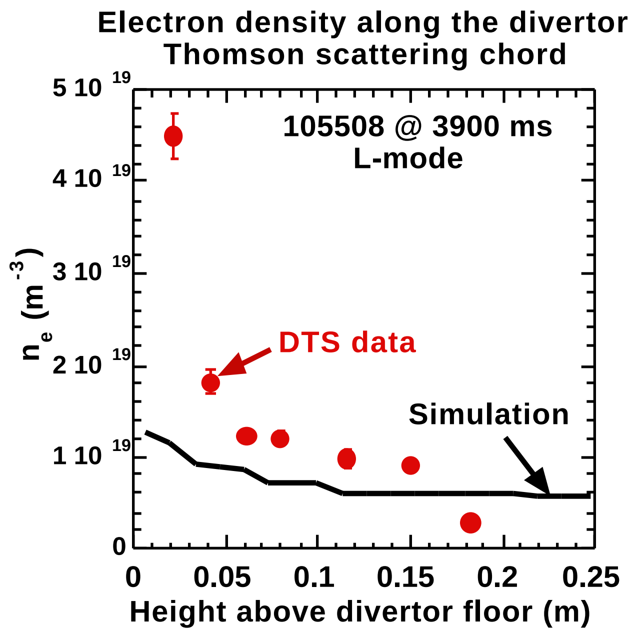


Fig. 5. Upstream radial profiles of electron density and temperature from the Thomson scattering system and ion temperature from the CER diagnostic are displayed as functions of normalized poloidal flux. These data are important for determination of the particle and heat diffusivities and the plasma convective velocity.



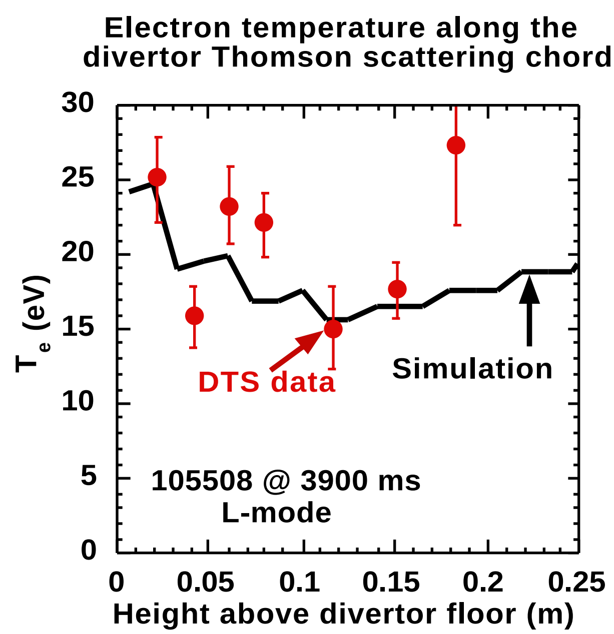


Fig. 6. The radial location of the divertor Thomson scattering chord is very near that of DiMES (see Fig. 1.). The measured and calculated electron density and temperature distributions along the chord are shown as functions of height above the divertor floor. There is some disagreement between the near-floor density distribution from DTS and the divertor Langmuir probes (Fig. 7). Our results agree with the probe data.

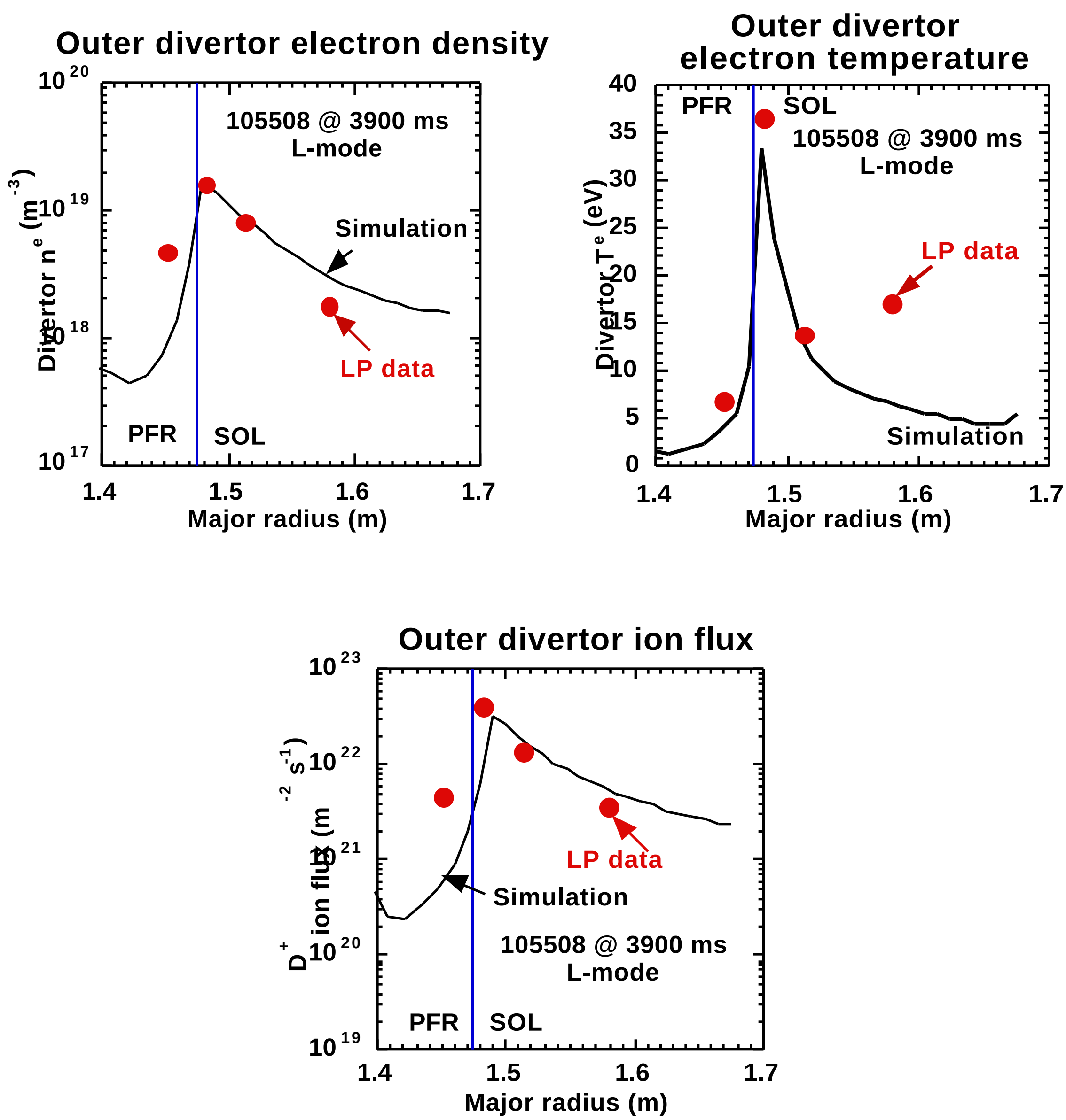


Fig. 7. Radial profiles of outer divertor electron density and temperature and of D^+ ion flux measured with Langmuir probes are well reproduced by B2.5 simulation results. (Langmuir probe data in the private flux region are seldom fit as well as those in the SOL by fluid model calculations.)

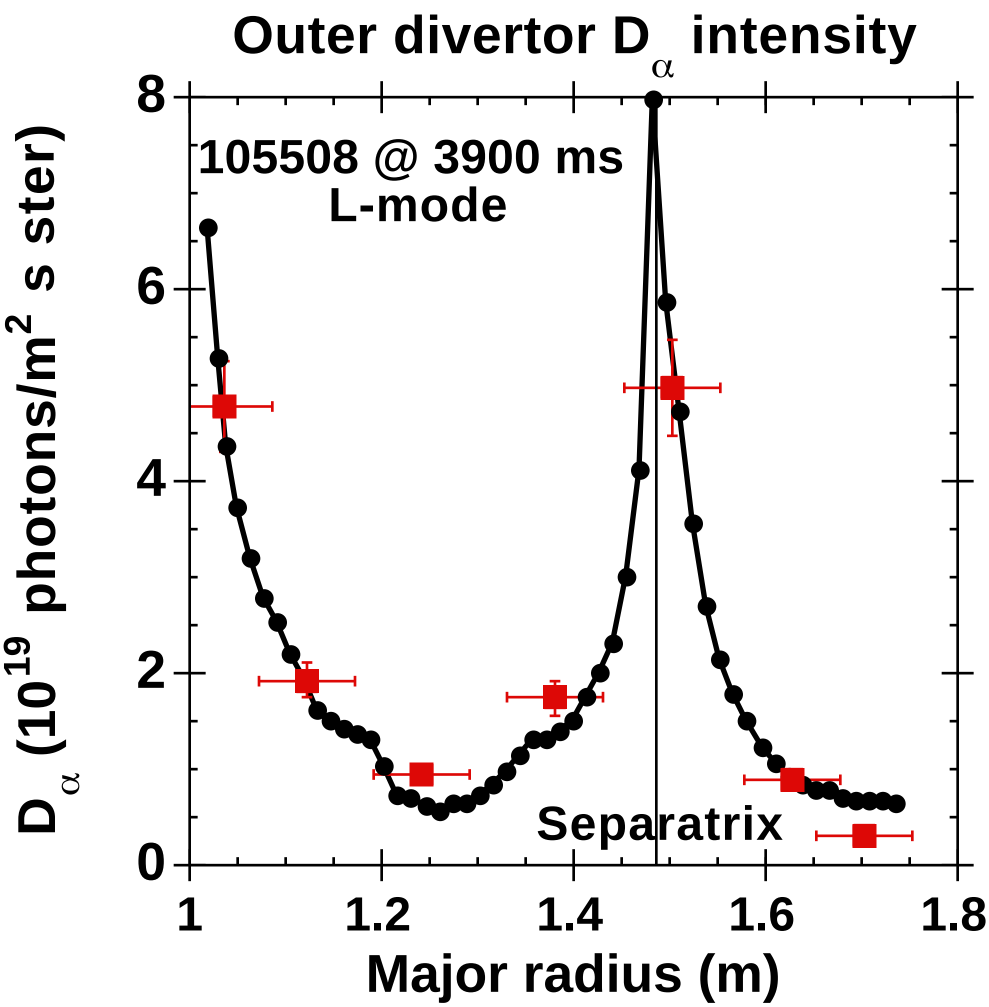


Fig. 8. The lower-viewing filterscope array spans the outer divertor and most of the private flux region for 105508 @ 3900 ms (see Fig.1). The good agreement of the calculated and measured D_α intensity, coupled with the Langmuir probe results shown in Fig.7, suggest that the reconstructed plasma in the region of the sample faithfully reproduces that obtained in the experiment.

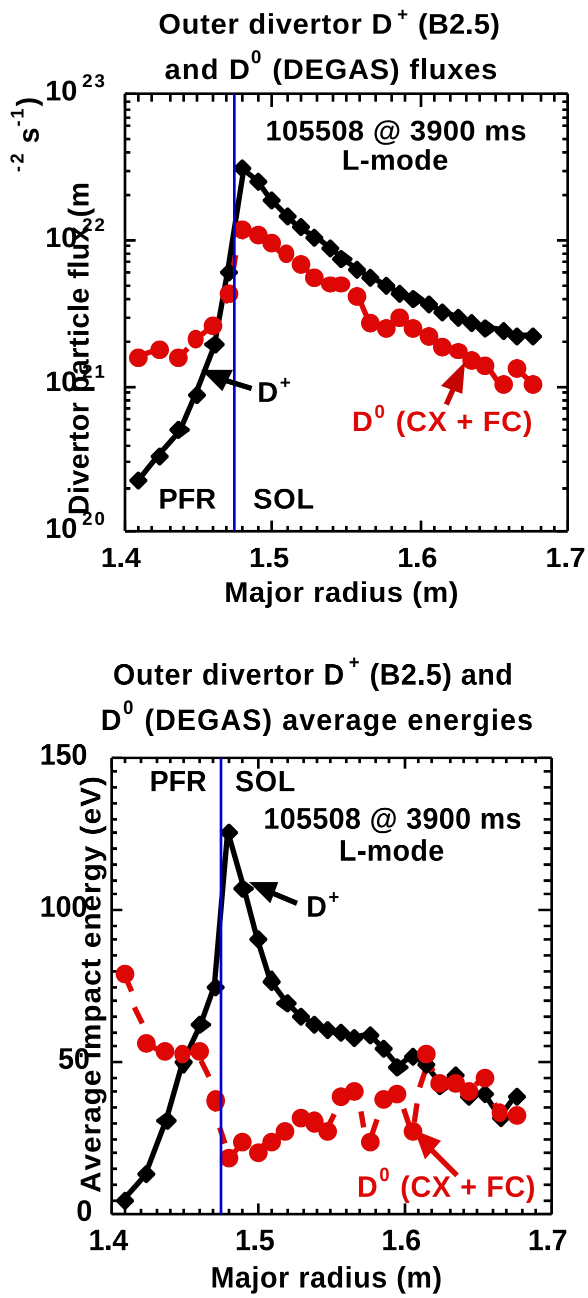


Fig. 9. The calculated outer divertor D^+ ion flux and average ion impact energy are compared with the corresponding D^0 neutrals distributions from DEGAS, obtained by recycling the ions at the plate. Here we have assumed a $3T_e$ sheath. The neutrals profiles contain both the Franck-Condon and the energetic charge-exchange components.

Regarding the following two figures - Figs.10 and 11.

The inner divertor leg is on the inner wall and therefore not well diagnosed. The FS00 D_α chord and the "0-1" divertor Langmuir probe are the diagnostics that are closest to the inner strile point at 3900 ms. They are located near the vertex of the inner wall and the 45° tile (see Fig.1). The inner divertor plasma parameters in the simulation are adjusted to obtain a good fit to the FS00 D_α chord measurements. Even though the footprint of this chord is in the PFR, it crosses the separatrix near the inner wall. Examination of the "0-1" lower divertor LP data as the inner strike point is swept over the probe shows a peak density of 3.7 x 10^{19} m^{-3} (at 2575 ms), at which point the electron temperature is 17 eV. This density (temperature) is about a factor of two smaller (larger) than that in the B2.5 simulation (Fig. 11). Even though the peak inner divertor ion flux measured by the "0-1" LP at 2575 ms in a factor of three larger than the peak outer divertor ion flux at 3900 ms, the corresponding inner and outer peak D_α values are roughly the same (see Fig. 4). The peak inner divertor ion flux (D_α intensity) is also roughly a factor of two larger (smaller) that the B2.5 simulation values at 3900 ms (Figs. 8 and 10). Since the inner strike point at 3900 ms is on the inner wall, quite far from the radial location of the DiMES sample holder, and since diagnostic data is available in the PFR at 3900 ms, an exhaustive effort to fit SOL profiles and peak values suggested by the earlier strike point data is not felt to be warranted.

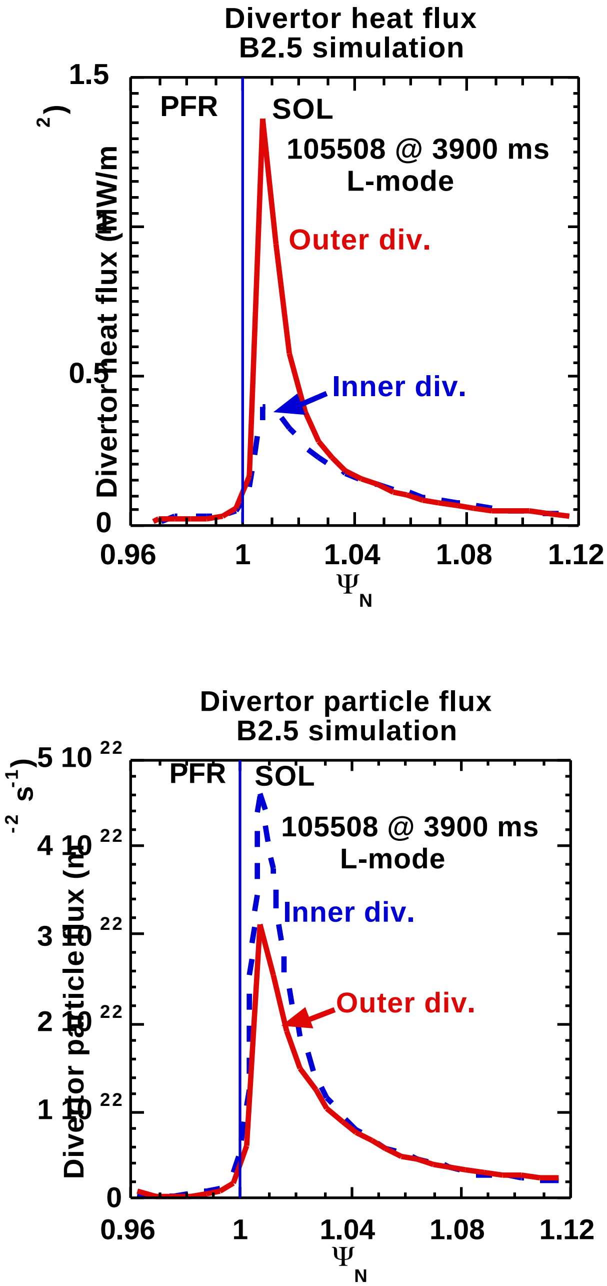


Fig. 10. The inner and outer divertor D^+ ion and heat fluxes computed with B2.5 are compared as functions of normalized Ψ.

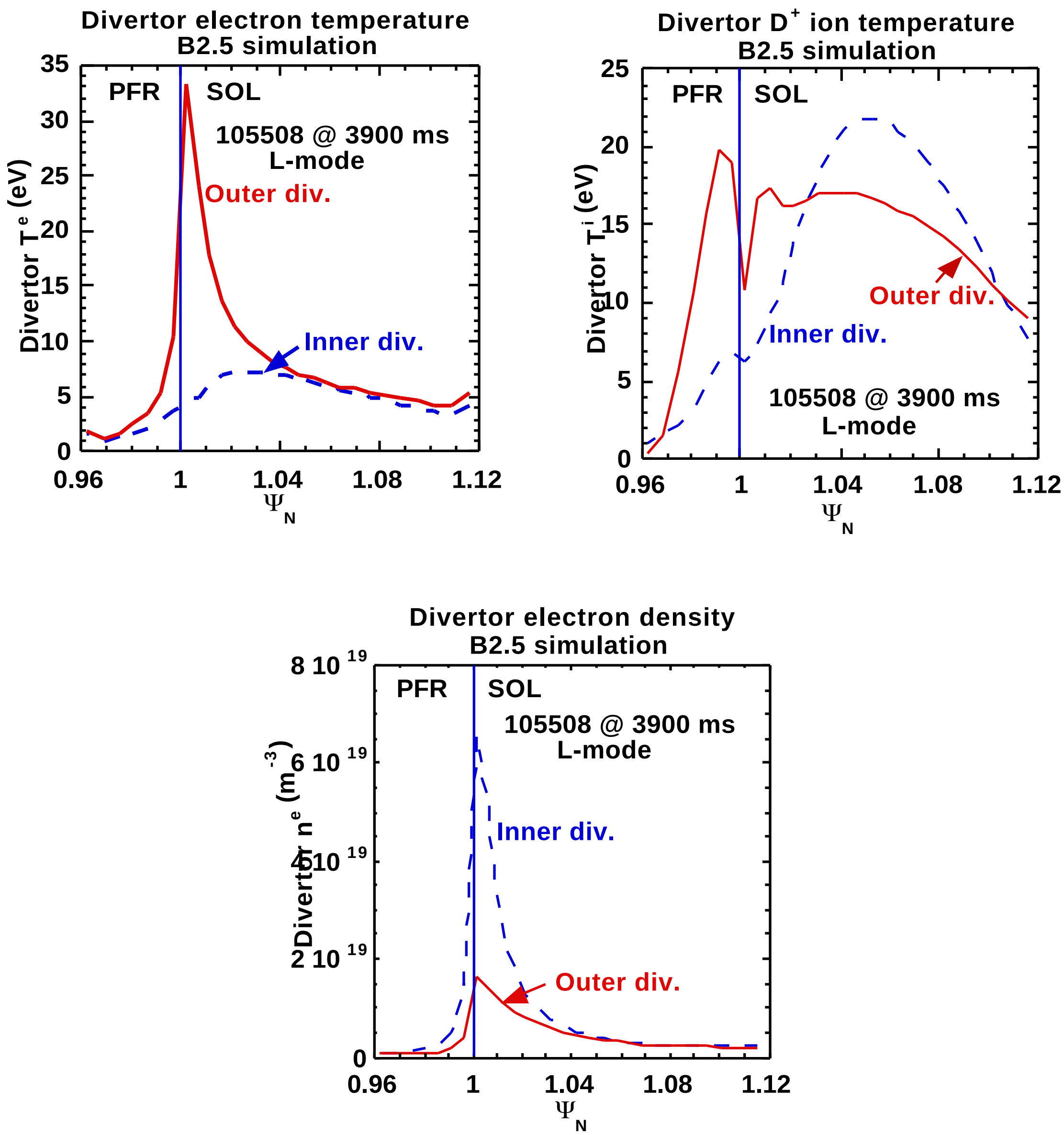


Fig. 11. The inner and outer divertor electron density and the electron and ion temperatures from B2.5 simulations are compared as functions of normalized Ψ.

Fig. 12 (ATTACHED AS A SEPARATE FILE DUE TO LENGTH) is the nonorthogonal grid used for the B2.5 simulations. The DEGAS grid is formed by extending the radial grid lines to the vacuum vessel walls. The plasma parameters in the "halo" grid cells are assumed to be the same as or a prescribed fraction of those in the radially adjacent outermost B2.5 cells. Here the core boundary is at Ψ_N = 0.85 (deep grid) and the outermost SOL flux surface is at Ψ_N = 1.12.

Summary and conclusions:

This report describes the procedure used in and results of an analysis of the lithium exposure discharge 105508. During the shot the plasma is swept over the DiMES sample holder but the Li sample is not exposed to an extended period of high heat flux. The data-constrained plasma reconstruction is performed with the B2.5 fluid model transport code at the midpoint of the time interval during which the outer strike point is on DiMES (3900 ms). Effects of impurity radiation are included with hydrogenic radiation enhancement factors. The B2.5 internal neutrals model is used in fitting the diagnostic data and consistency of core particle balance results is checked with neutral transport simulations using the DEGAS Monte Carlo code. The procedure is iterated as necessary to produce this consistency. The fit to the D_α intensity shown in Fig. 8, the core fueling rate, the core charge-exchange power loss, and the neutral particle flux and average energy profiles at the divertor plate were computed with DEGAS. Fits to the plasma data, divertor heat flux profiles, core plasma efflux, etc. are computed with the B2.5.

All of the available outer divertor diagnostic data, the measured upstream density and temperature profiles, and core particle and energy balances are satisfied by the analysis results.

This indicates that the 2-D model plasma is quite adequate as the background plasma for MCI transport and redeposition simulations.