Plasma Wall Interactions in Ignitor

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Characteristics of the SOL

Edge density $n_a = 2 - 3.5 \times 10^{20}$ m^{-3}
Edge temperature $T_a = 35 - 60$ eV

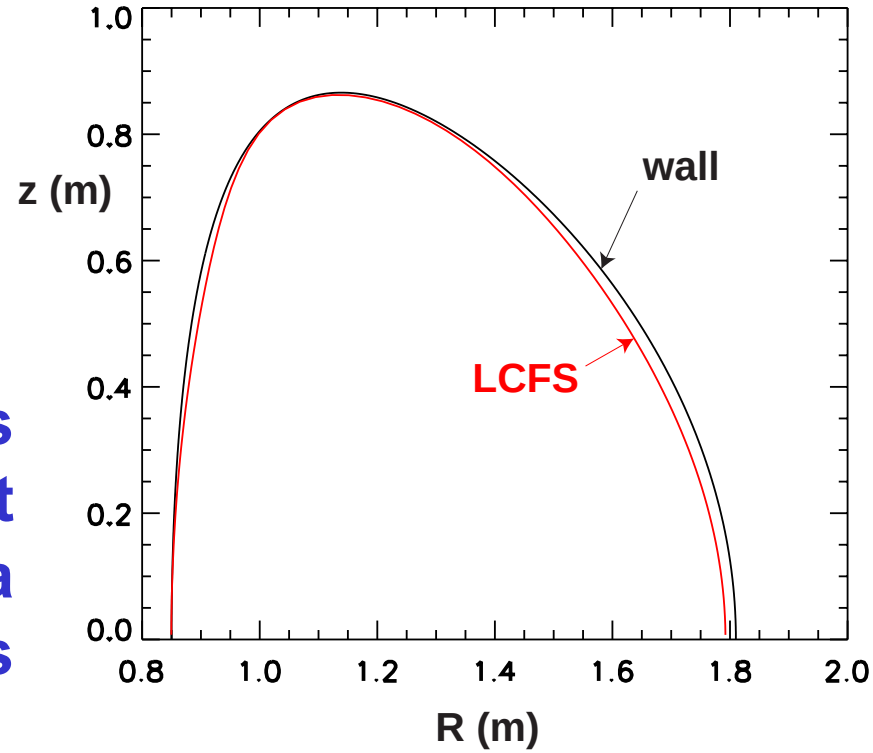
⇒"complex SOL regime": radiation, ionization and charge exchange are all important in reducing particle energy and spreading out the power transported across the LCFS by energetic particles

⇒ "High Recycling Regime" (ions)
⇒ "Edge Radiative Regime" (electrons)

The crucial parameter is the <u>edge density</u> (not its value relative to the density limit).

The “extended” limiter solution

First wall almost conformal: Field lines tangent or nearly tangent to the wall



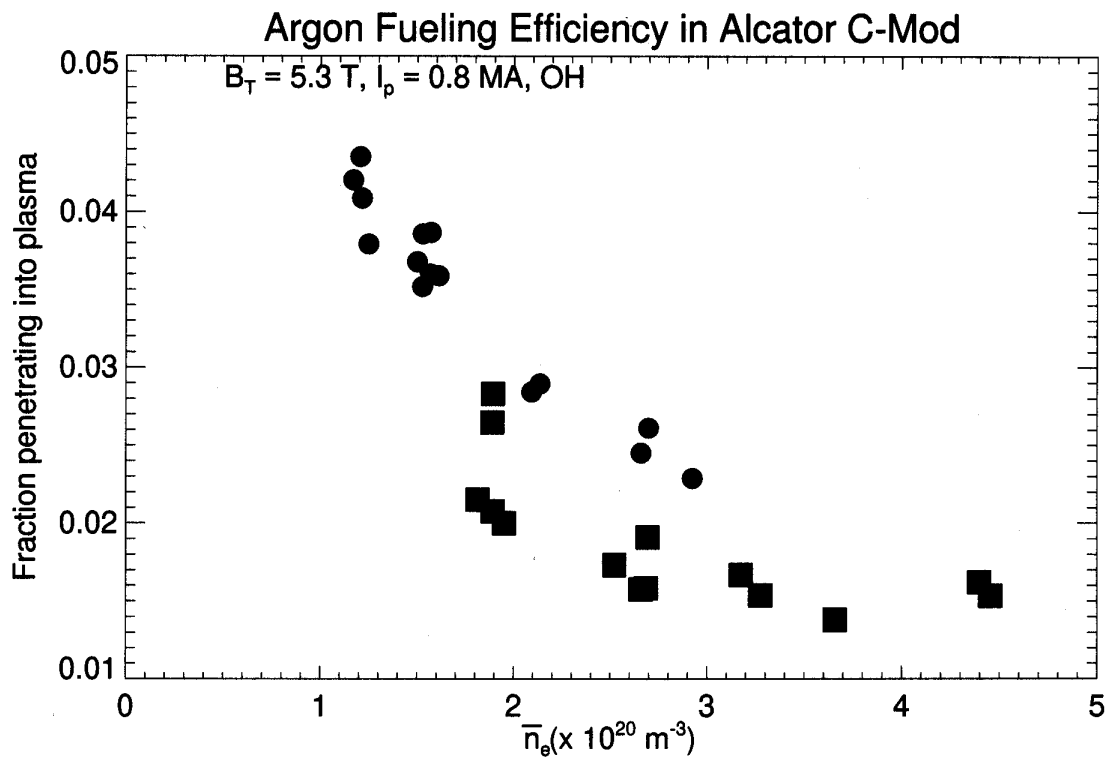
Most of the plasma energy is lost by impurity radiation at the edge of the plasma column by <u>intrinsic</u> impurities (impurity injection possible).

Approximately half of the power is radiated from the outer main plasma, the other half by the SOL

Impurity Screening

At high density, the low temperature reduces sputtering from the wall and (medium/high Z) impurities are effectively screened from the main plasma.

Density has less influence in reducing low Z impurities (C, O).



Thermal Wall Loading

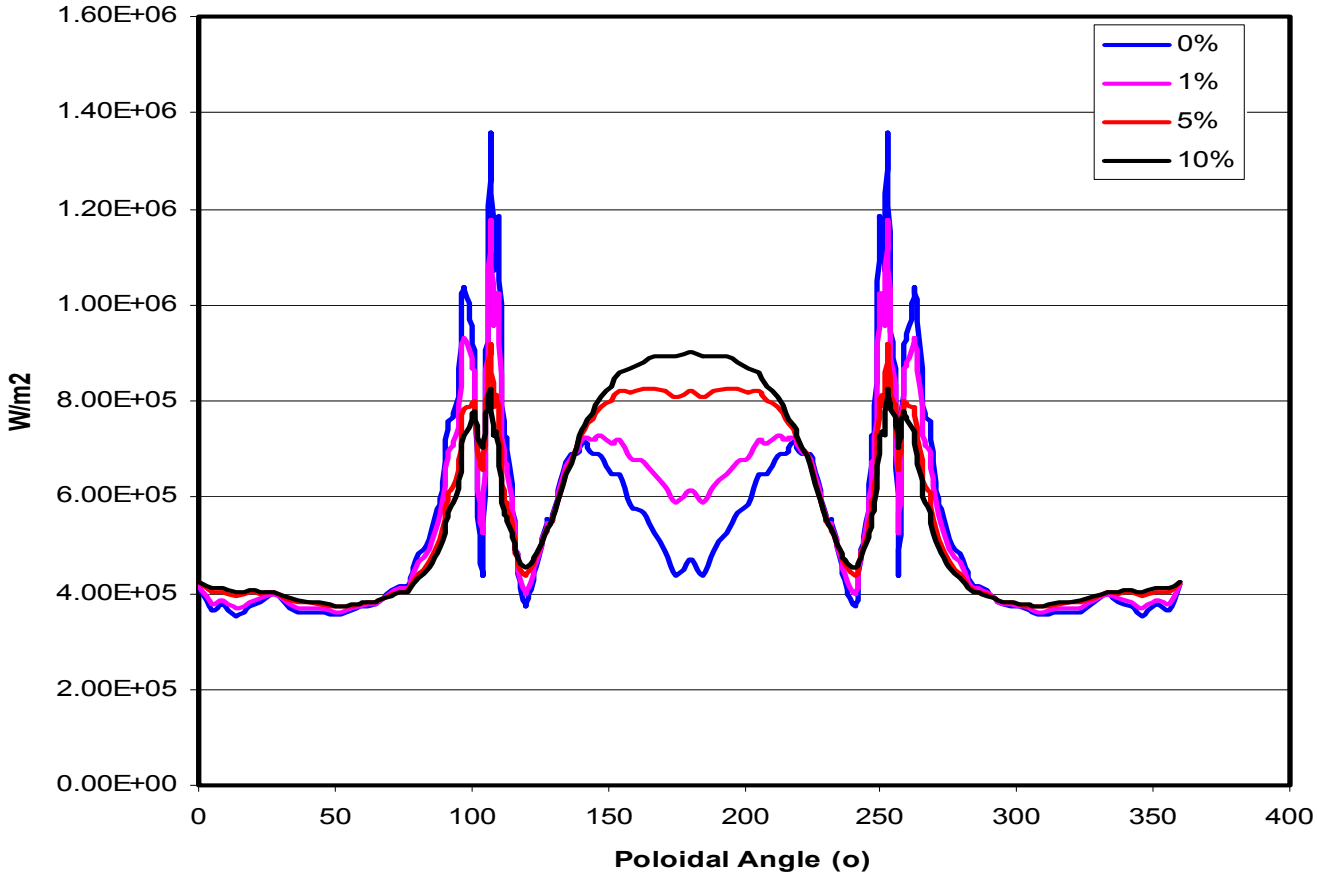
Three components:

1. Parallel convection $q_{//}(r)=q_0\exp(-r/\lambda_E)$
2. Cross-field diffusion $q_\perp = F\, q_{//}$
3. Radiation $q_{rad} = f\, P_{rad}/A_{pl}$, $\quad P_{rad} \propto Z^3 \langle n_e \rangle^2 \dfrac{Z_{eff}-1}{\langle Z \rangle (\langle Z \rangle - 1)}$

$$q_w = q_{\square} \sin(\alpha) + \left(q_\perp + q_{rad}\right)\cos(\alpha)$$

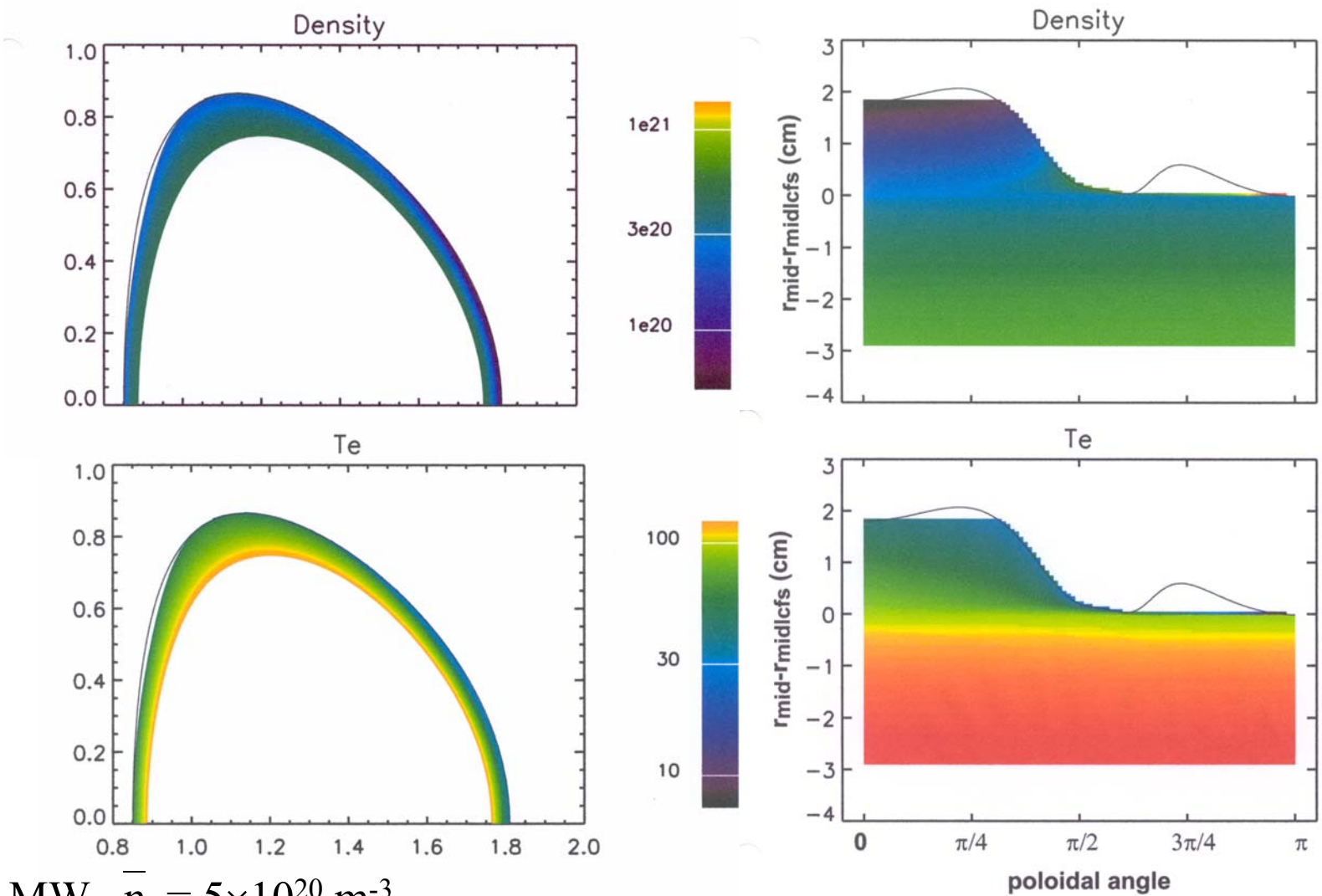
Thermal loads are calculated assuming only 70% of radiated power and a continuous first wall, but results are relatively insensitive to the assumptions.

Ignitor Heat Loads with Different Diffusive Particle Flux



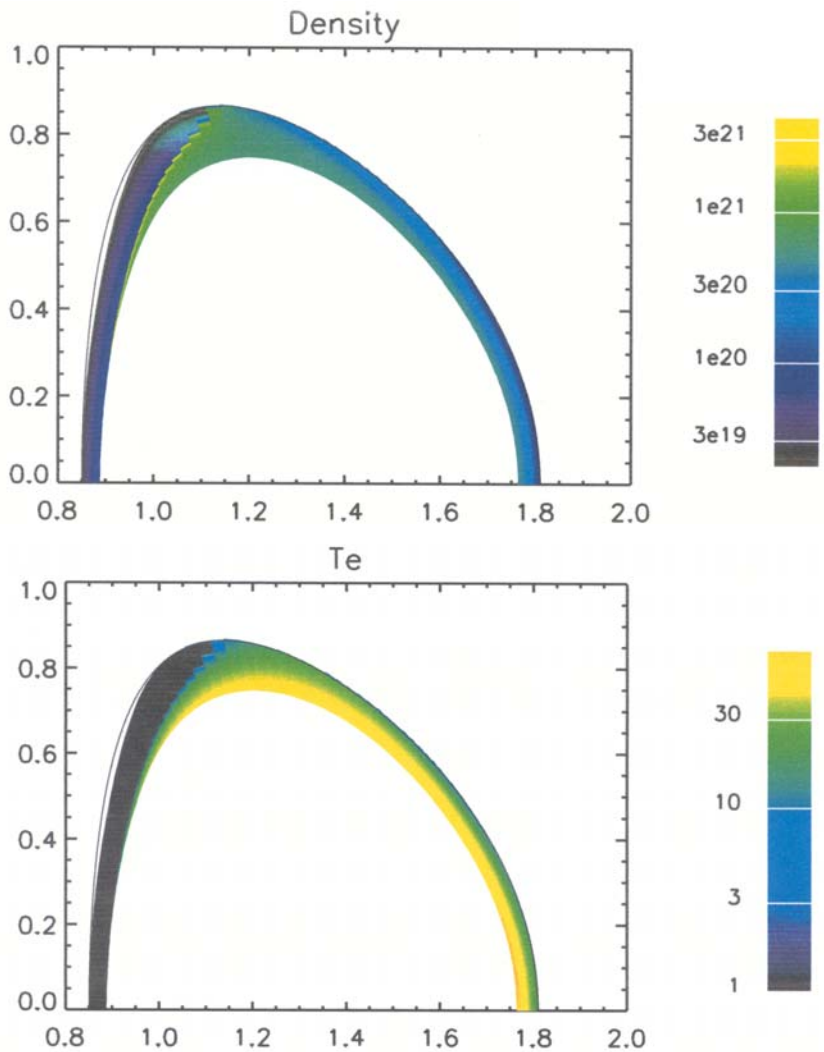
Edge Parameter Profiles

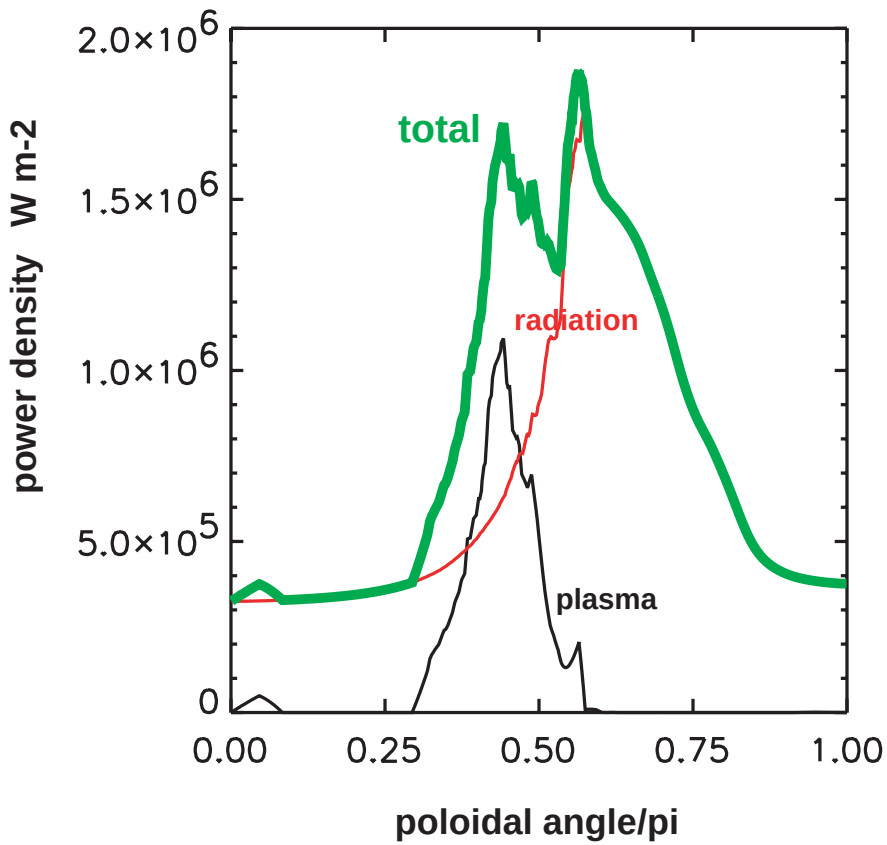
C.S.Pitcher, EDI code



30 MW, $\overline{n}_e = 5\times10^{20}\ m^{-3}$

Plasma Detachment (MARFE)





Tile Alignment

In a "Complex SOL", volumetric power losses reduce the risk of hot spots. Tile alignment is necessary, but less critical than in the " Simple SOL" case, where particles from the core impinge on the wall with their full energy.

Tile alignment is prescribed as follows:

±0.1 mm between adjacent tiles

±0.2 mm between tiles on adjacent carriers.

These values are technically achievable and represent about half the width of the "transition layer" (~ $\sqrt{6}\,\rho_i$, Chadura '86).

On TFTR C blooms were avoided by aligning the tiles to within 0.5 mm [1]. No hot spots observed on the FTU Mo toroidal limiter, which was installed entirely by RH (tolerances ≅0.5 mm)

[1] J. Strachan, et al., *J. of Nucl. Material* **196&198**, 28 (1992).

Summary

- **High density, low temperature at the edge ⇒**

  High level of ionization in SOL
  Radiative edge with intrinsic impurities
  Effective impurity screening

- **Magnetic field topology limits thermal loads in contact areas (e.g. inner wall).**
  Maximum peaks for plasma shifts of ± 1 cm:

  $$Q_{max} \leq 1.8\ MW/m^2$$

- **Prescribed tile alignment (± 0.2 mm) better than the one achieved on TFTR that avoided carbon blooms.**

Summary (2)

- The possible formation of a MARFE is not expected to produce higher loads on the wall