Technical University of Denmark

The Influence of Blobs on Neutrals in the Scrape-Off Layer

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Why Study Dynamical Neutral Interactions with Plasma?

Neutrals in magnetically confined plasmas can originate from plasma-wall interactions or be puffed into the chamber for fueling or imaging purposes. Neutrals from gas-puffing are at room temperature and their mean-free path for ionization is short compared to the width of the Scrape-Off Layer (SOL), but similar to the perpendicular length scale of blobs.

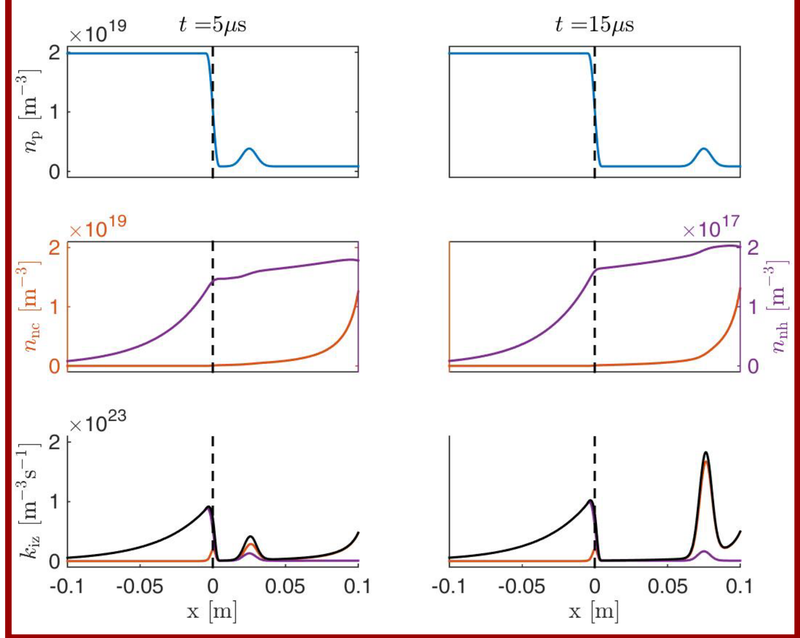
A coupled neutral-plasma model would allow for understanding the influence of SOL plasma filaments on the neutral particles, but also for obtaining realistic plasma density source profiles. The latter can also be used to assess plasma fueling efficiencies for various configurations.

The results presented here are to be published in [1].

1D Simulations

The plasma is simulated as a static profile with an outwards propagating perturbation to density and temperature. This allows for dynamically obtaining the neutral responses to plasma fluctuations.

It is observed that cold neutrals are ionized in the SOL, whereas warm and hot neutrals are mostly ionized in edge. Also, blobs induce a short interval of increased fueling, followed by a period of decreased fueling as steady state rebuilds.

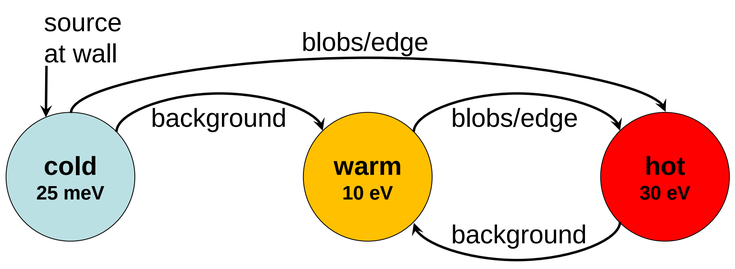


Cold, Warm and Hot Neutrals

The neutrals are described by a 3-species fluid model which includes cold neutrals ($T_{\text{cold}} \approx 25\,\text{meV}$), warm neutrals ($T_{\text{warm}} \approx 10\,\text{eV}$) and hot neutrals ($T_{\text{hot}} \approx 30\,\text{eV}$). All neutral densities evolve according to diffusion

$$\partial_t n_\sigma - \partial_x(D_\sigma \partial_x n_\sigma) = S_\sigma\,, \qquad D_\sigma = \frac{T_\sigma}{k_{\text{eff}} m_\sigma n}\,.$$

The neutral sinks in S_σ are due to ionization, whereas charge exchange collisions introduce both source and sink terms



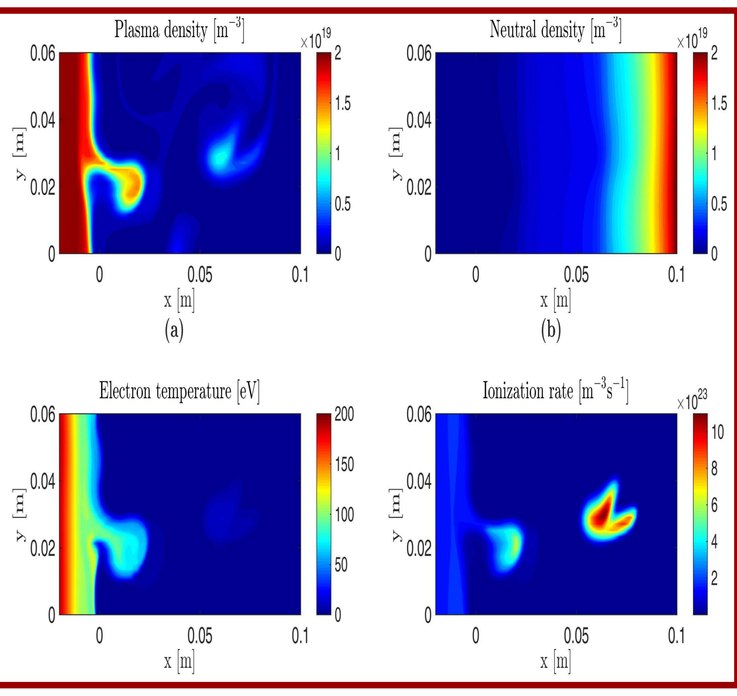
The mean-free paths for cold neutral atoms for ionization and charge exchange is much smaller than those for warm and hot neutrals. This suggests that the density flux of warm and hot neutrals across the LCFS exceeds that of cold neutrals.

2D Simulations

The 1D neutral model is extended to 2D, and reacts to both 2D fixed plasma profiles with Gaussian perturbations and plasma profiles obtained by the HESEL code.

The poloidally averaged results are similar to those of the 1D simulations, but the perturbations to the neutral density flux across LCFS are weaker.

This coupling of the neutral diffusion model to the HESEL code is an initial result of work in progress. As a next step we intend to also include the ionization term in the plasma density source to obtain a realistic source profile.

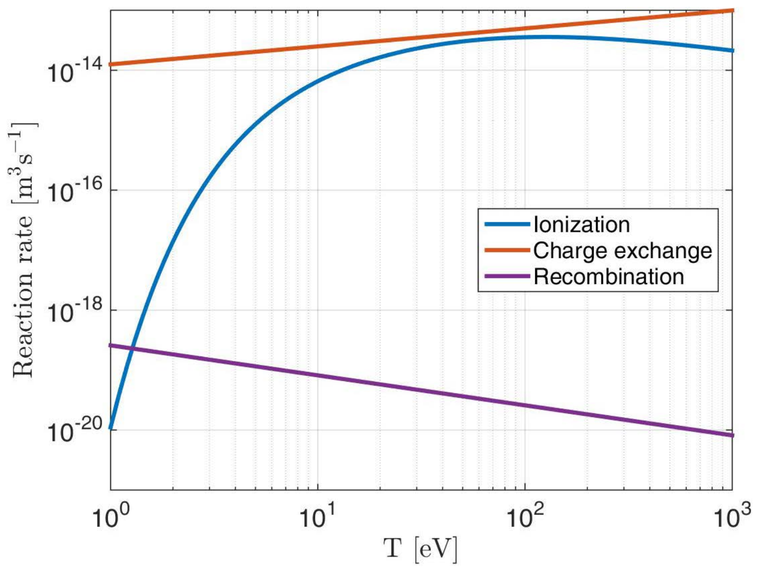


Interactions Between Neutral Hydrogen Atoms and plasma

For given collision reaction R between two species the reaction rate is given by

$$\nu_R = n_1 n_2 \langle \sigma_R v_r \rangle\,.$$

The most dominating rate coefficients for the interactions between neutral hydrogen atoms and plasma are ionization and charge exchange. In a charge exchange collision a hot ion and cold neutral atom exchanges an electron and result in a cold ion and a hot neutral atom. This generates a species of hotter neutrals.



Conclusions

- The neutral inward flux at LCFS from warm and hot neutrals is dominating over that of cold neutrals. I.e. the results suggest that gas puff fueling in tokamaks relies on the charge exchanged hot neutrals.
- Results of the 1D model were compared to those of both a similar simplified 2D model and those obtained from HESEL simulations. We observe that results from 1D simulations are reflected in 2D simulations.
- Improved coupling between a neutral diffusion model and the HESEL code is the basis of our current work.

References

[1] Thrysøe, et al., *The Influence of Blobs on Neutral Particles in the Scrape-Off Layer*, submitted to PPCF, special issue on "Edge Plasmas in Magnetic Fusion devices"

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