Simulation of plasma and neutral particles during H gas puffing in the divertor region of GAMMA 10/PDX using the fluid and kinetic neutral code

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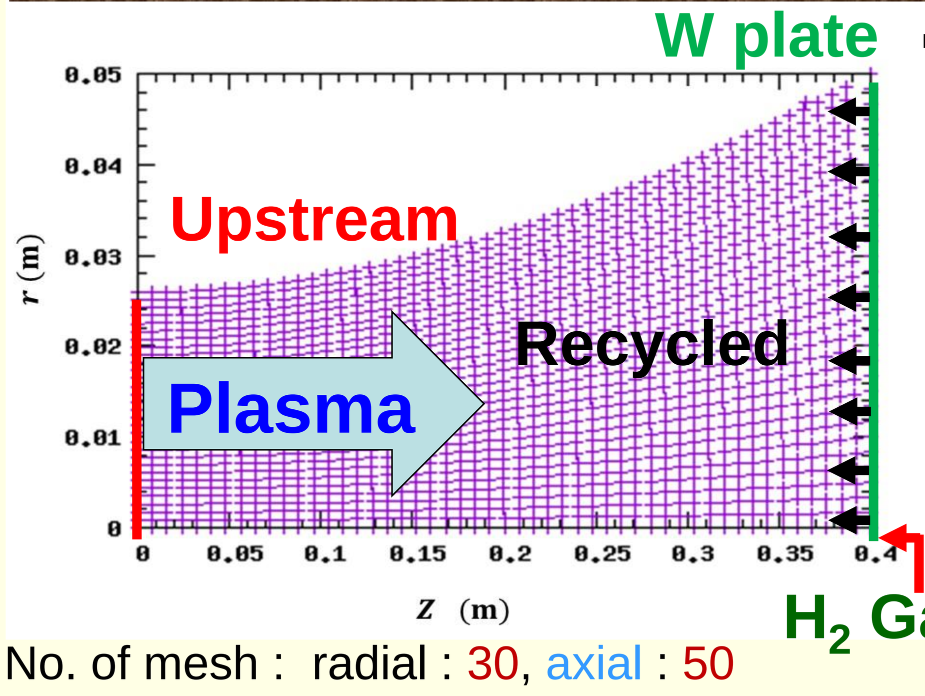
Overview

The divertor simulation research has been progressed in the west end-cell of GAMMA 10/PDX for understanding the physics of plasma detachment. This research numerically studies the plasma and neutral particles behaviour in the end-cell of linear fusion device GAMMA 10/PDX [1-3] by using the LINDA fluid code [4-8]. In this research, the **plasma transport is modelled by solving the fluid equations while the neutral profile is solved by the Monte-Carlo calculation in the self-consistence manner**. The neutral test particles (H_2) are launched into the H plasma to investigate the plasma-neutral interactions. The source of the neutral particles is assumed to be located on the target plate. The neutral particles are introduced in the bulk plasma with the cosine distribution. **The plasma parameters are updated according to the given source profile from the Monte-Carlo calculation**.

The aim of the study is to understand the impact of H neutral particles on the plasma parameters and energy loss processes. The outcomes are summarized as follows:

- **The neutral particles is concentrated near the target plate.**
- **The ion temperature is reduced near the target plate when gas puffing is performed.**
- **The ion density increases near the target plate due to the ionization of neutral particle.**
- **The electron temperature reduces slightly by gas puffing.**
- **The ion energy loss processes enhance remarkably near the target plate for gas puffing cases. In particular, the charge-exchange loss is greatly enhanced.**

Physical model



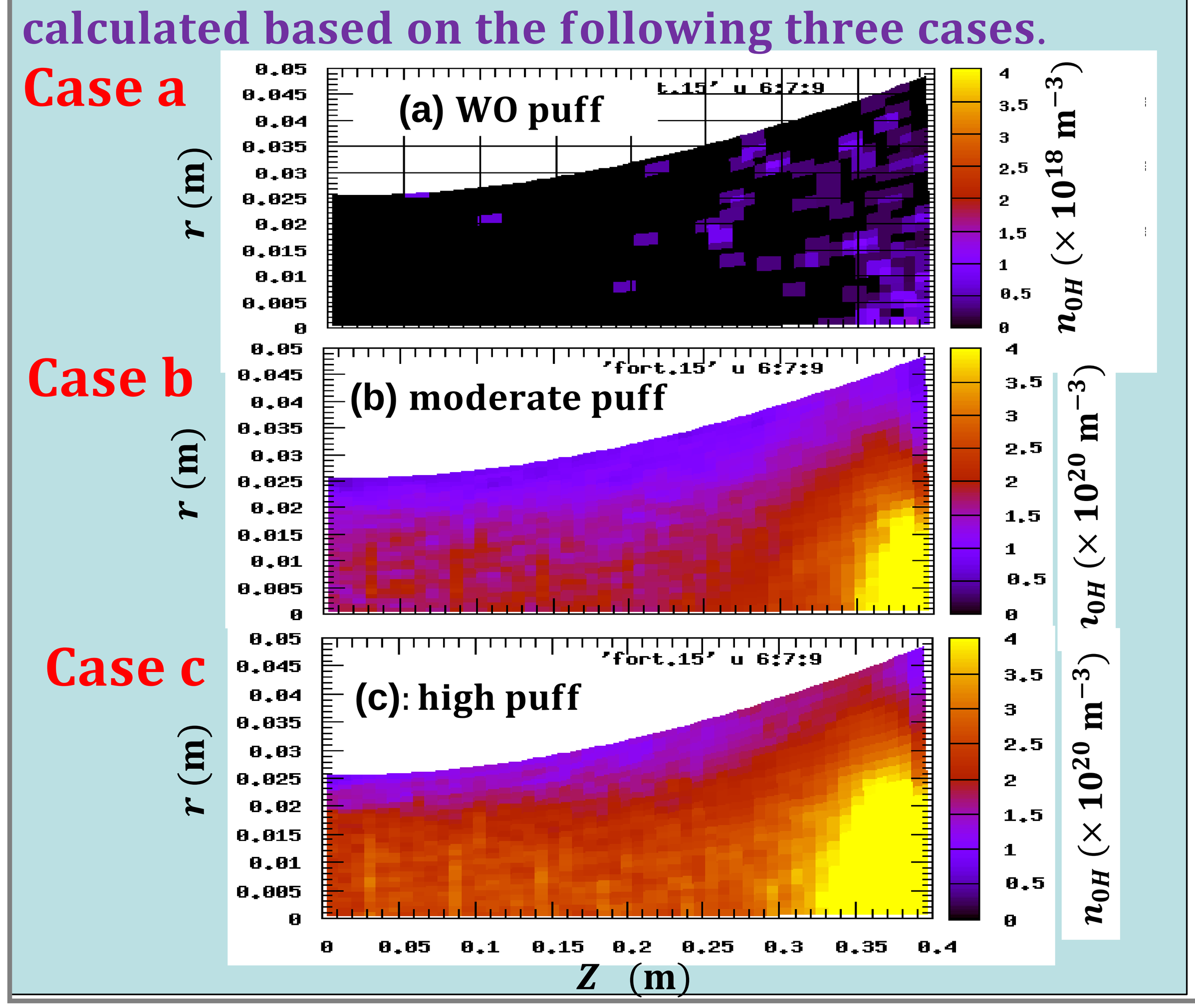
- The plasma and neutral particles are solved by using the same mesh.
  - Basic equations and numerical scheme are the same as the B2 code [9].
  - The convergence of the LINDA code has been validated by carefully checking the residual error.

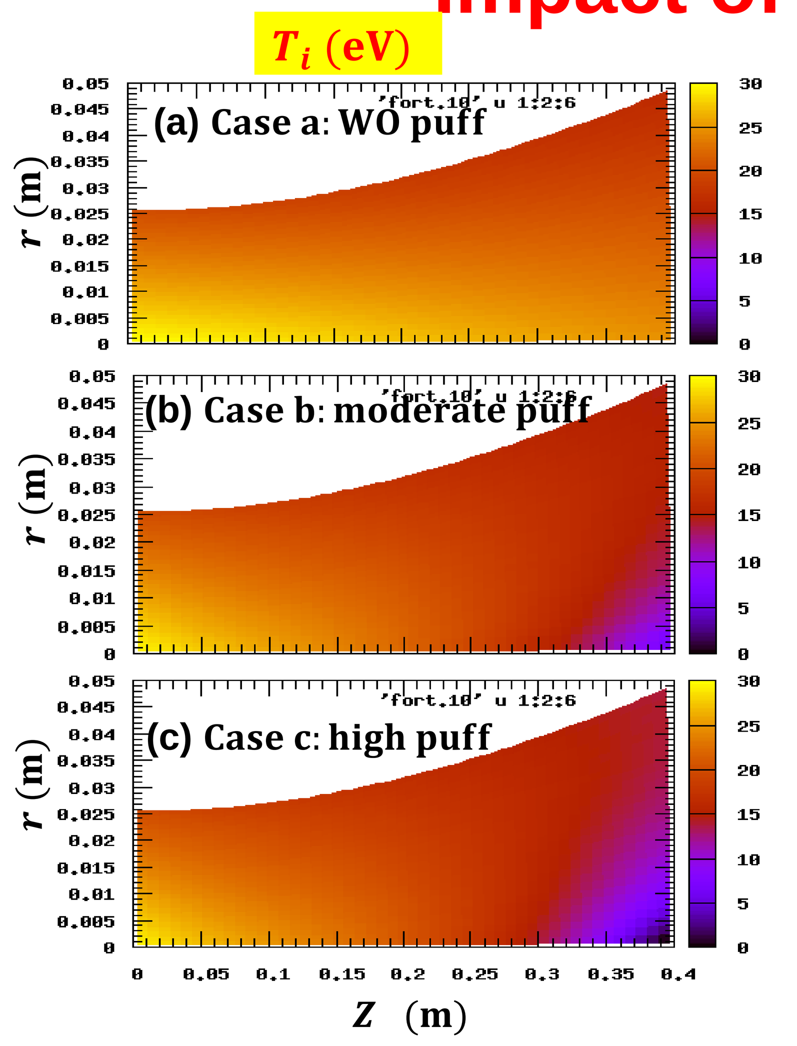
No. of mesh : radial : 30, axial : 50

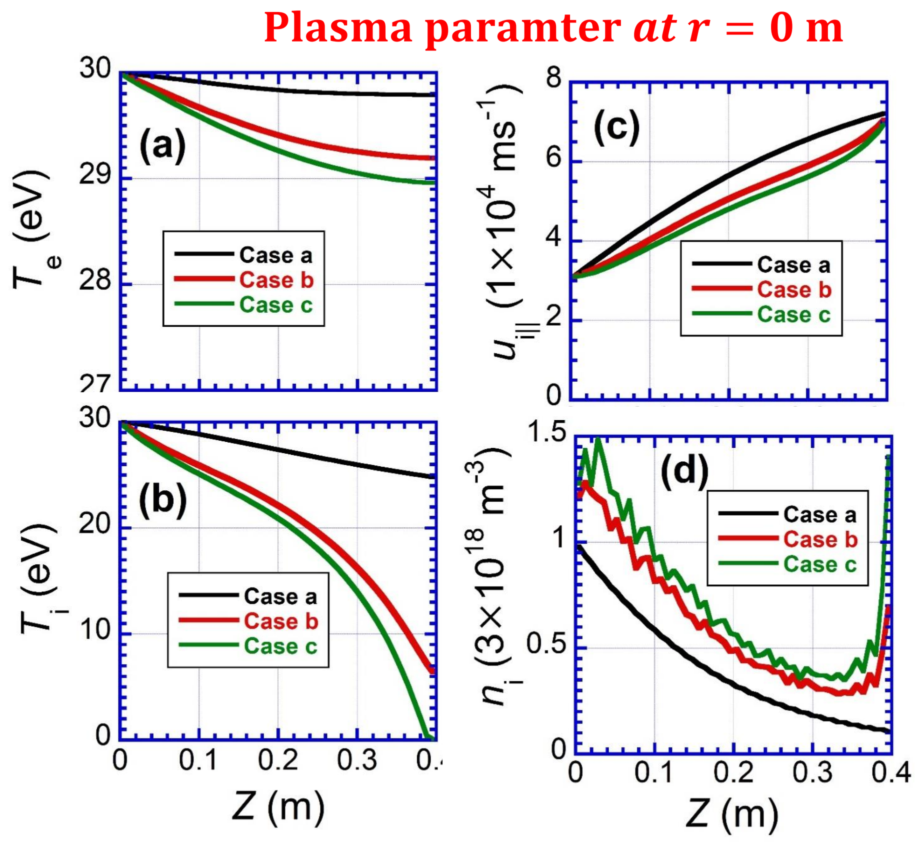
- The neutral test particles (H_2) are injected on the axis (r = 0 cm) at Z = 0.4 m with the cosine distribution.
- The H neutral particles are produced by the dissociation of H_2.
- The Boltzmann equation has been solved by applying the Monte-Carlo technique to model the neutral particles.
- As for the collision process, the null collision method is used [10].

Impact of gas puffing on plasma parameters

Simulation case: **H neutral density is calculated by the Kinetic neutral code. Plasma parameters are calculated based on the following three cases.**

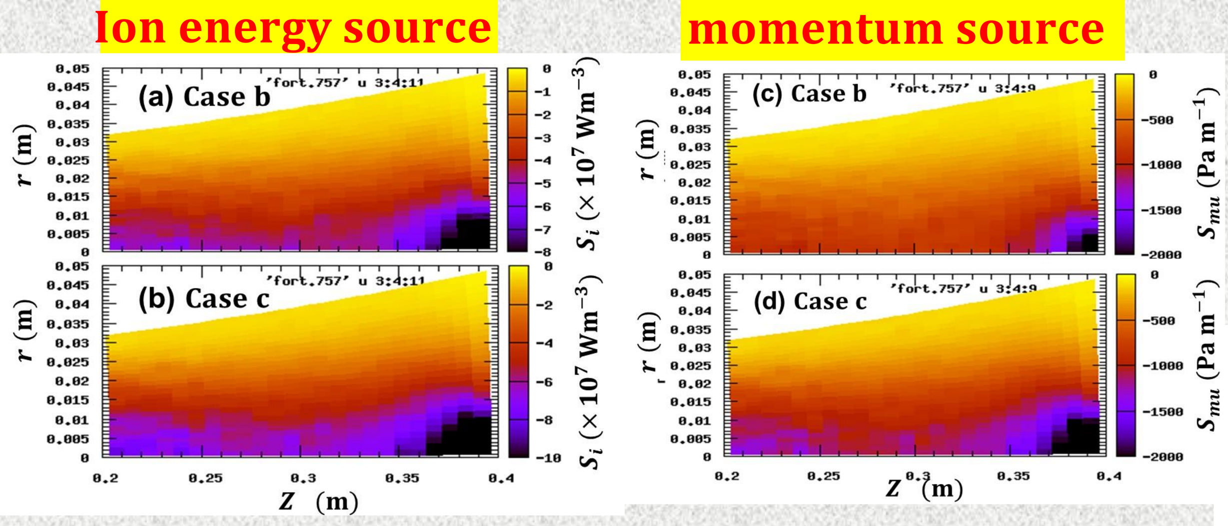


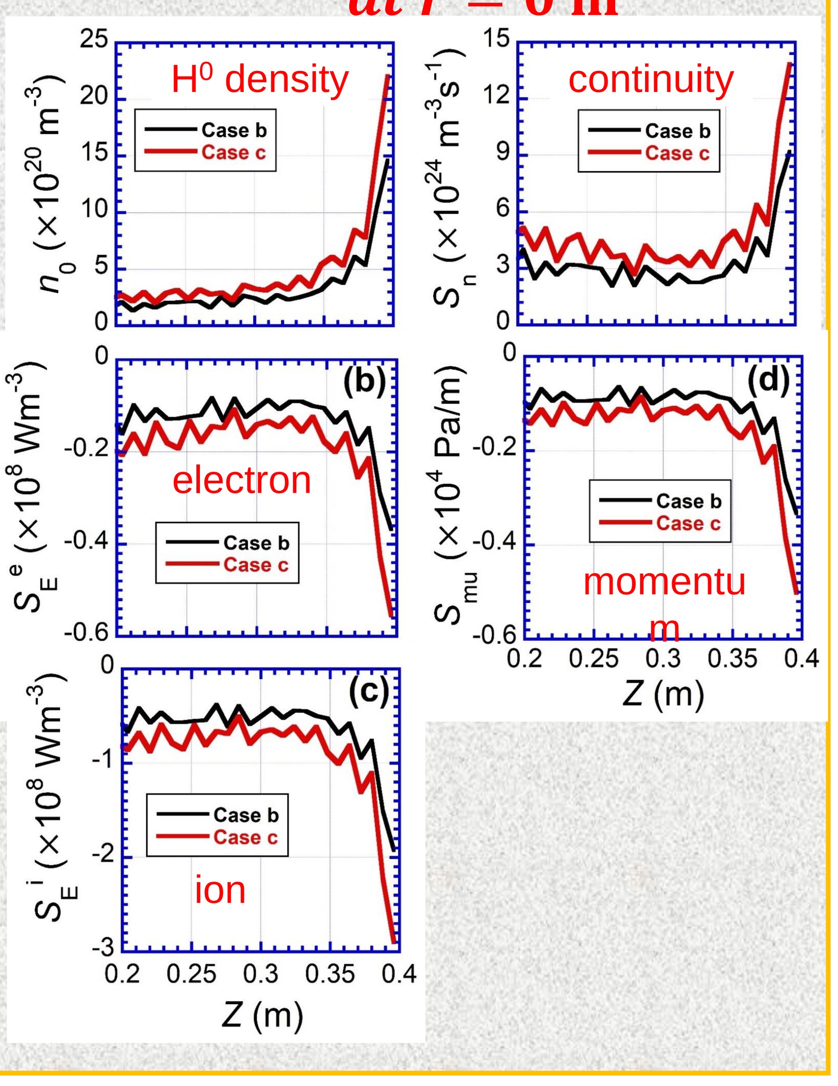




- T_e reduces slightly by gas puffing cases.
- T_i reduces significantly in the direction of target plate for gas puffing cases.
- For the higher gas puffing case (case c), T_i reduces less than 1 eV.
- plasma density increases near the target plate by ionization.
- The parallel velocity slightly reduces during gas puffing case.

Energy loss during plasma-neutral interactions: Source and sink terms of fluid equations



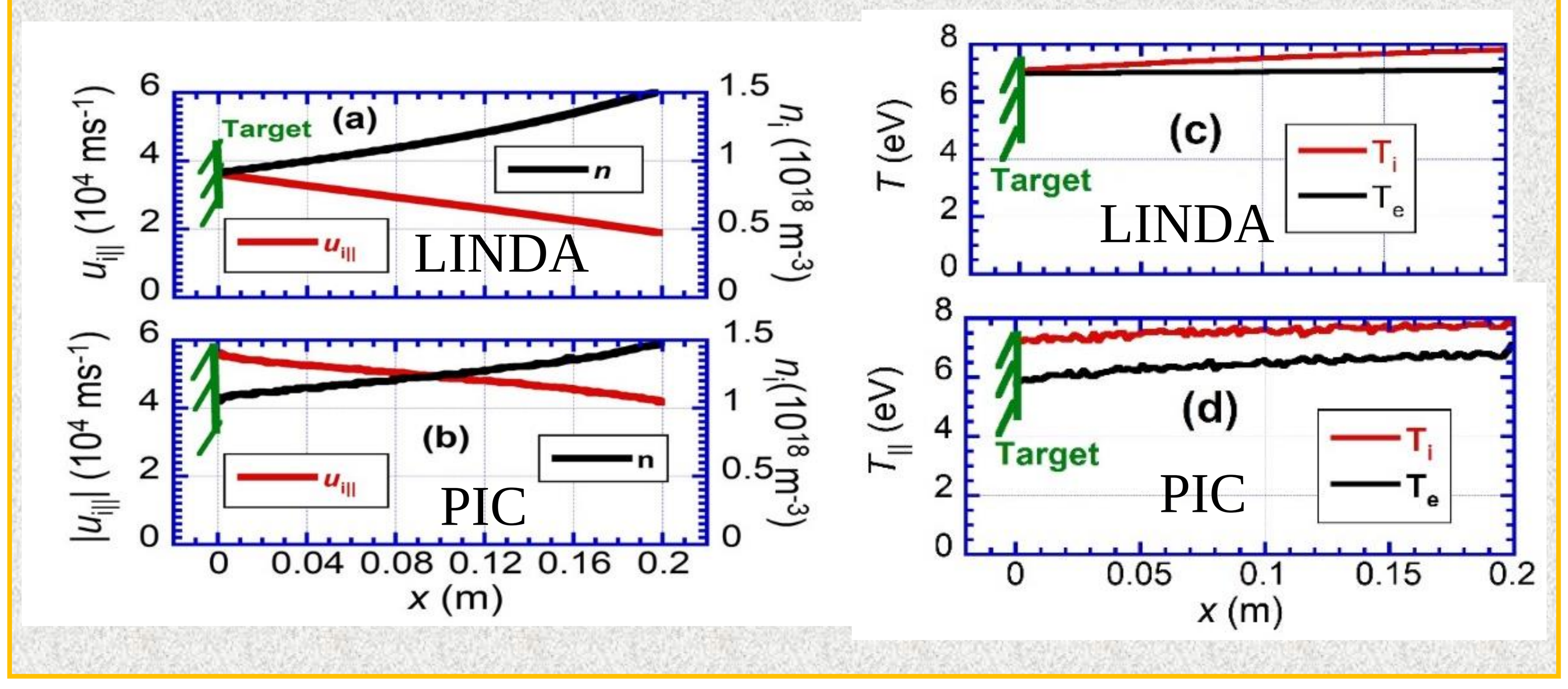


Near the target plate:

- ✓**Ion generation**: increased by ionization.
- ✓**Ion and electron energy loss**: increased by CX loss and ionization.
- ✓**Momentum loss**: increased by CX loss.
- ✓$S_E^i > S_E^e$: CX loss dominates the ionization loss.
- ✓E-I relaxation is small because of lower plasma density.

Comparison between the LINDA and the PIC code

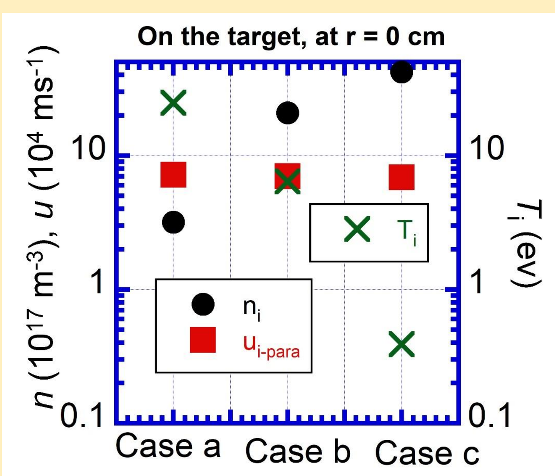
- The outcomes of the LINDA code are consistent with the outcomes of the PIC code [11-12].
- The following outcomes are shown for both the codes:
- The parallel velocity increases toward the target plate.
- The plasma density is decreased toward the target.
- The plasma temperatures are reduced toward the target.



Summary

The plasma and neutral particles are numerically investigated by solving the fluid and kinetic neutral code in the self-consistence manner to study the plasma and neutral particle behavior at the end-cell of GAMMA10/PDX.

- The simulation outcomes are summarized as follows:
- ✓ The neutral particles are concentrated close to the target plate.
- ✓ The plasma density is increased close to the target plate.
- ✓ The ion temperature is reduced remarkably by H gas puffing.
- ✓ Influence of H gas puffing on the electron energy is small.
- ✓ The source term of the momentum and ion energy loss terms are increased by CX loss.



- ❑ From the above discussion, it is found that H gas puffing is effective to reduce the ion energy. The H gas puffing can increase the momentum loss, which leads to a strong reduction on the ion energy.

Acknowledgment

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