Neoclassical impurity transport coefficients in HSX

S. T. A. Kumar, J. F. Castillo, J. N. Talmadge and D. T. Anderson

HSX Plasma Laboratory, University of Wisconsin-Madison, USA

Summary

- Neoclassical impurity transport coefficients are calculated for the standard quasi-helically-symmetric (QHS) configuration and a symmetry degraded ('Mirror') configuration of HSX using the PENTA[a] code.
- Contrary to conventional wisdom in stellarators, outward impurity convection due to temperature screening is observed for both configurations for a wide range of collisionality.
- Transport in QHS and Mirror configurations is similar, except at low collisionality.
- Experimental diffusion coefficient and convection velocity obtained from Laser Blow-off technique are much higher than the neoclassical values.

Introduction

- Unlike in tokamaks, neoclassical radial transport in stellarators is affected by the radial electric field (E_r):
  - Reactor relevant ion-root scenario (negative E_r) may lead to impurity accumulation.
  - In electron-root scenario (positive E_r), impurities may be pumped out.
- A recent study[b] found that in a mixed collisionality regime, E_r effect gets weaker and temperature screening can occur in stellarators .
- This work examines impurity (C^{+6}&Al^{+13}) transport in QHS and a more conventional like stellarators for various collisionality regimes.

The PENTA code is used to calculate transport coefficients

Radial flux of impurities can be written as,

$$\Gamma_z = -D\nabla n_z + v n_z \qquad (1)$$

Where D is the impurity diffusion coefficient and v is the convection velocity and n_z is the impurity density.

Neoclassical convection velocity is largely determined by the radial electric field, main ion density (n_i) and temperature (T_i) profiles.

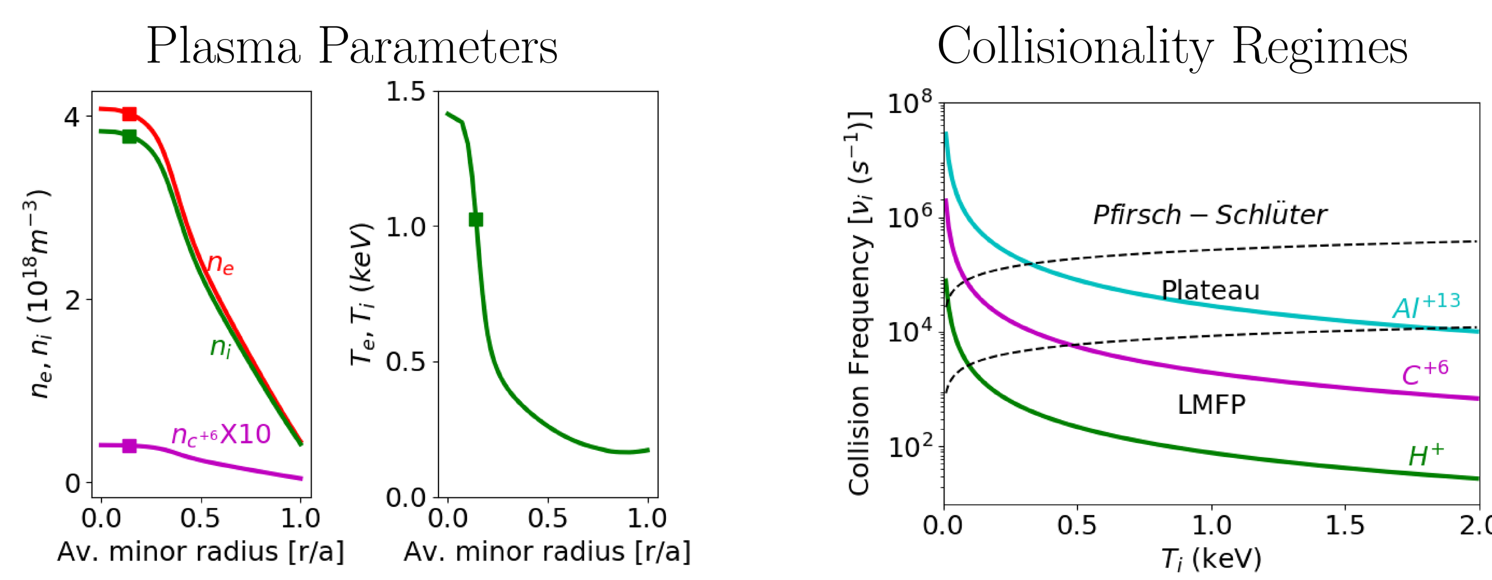
$$v n_z = [C_1 \nabla n_i + C_2 \nabla T_i]_{E_r} \qquad (2)$$

Individual components of the transport coefficients (D, v, C_1&C_2) are calculated using the PENTA code for various impurity collisionality regimes and radial electric field values.

a. J. Lore *et al.*, Phys. Plasmas (2010), D. A. Spong, Phys. Plasmas (2005)

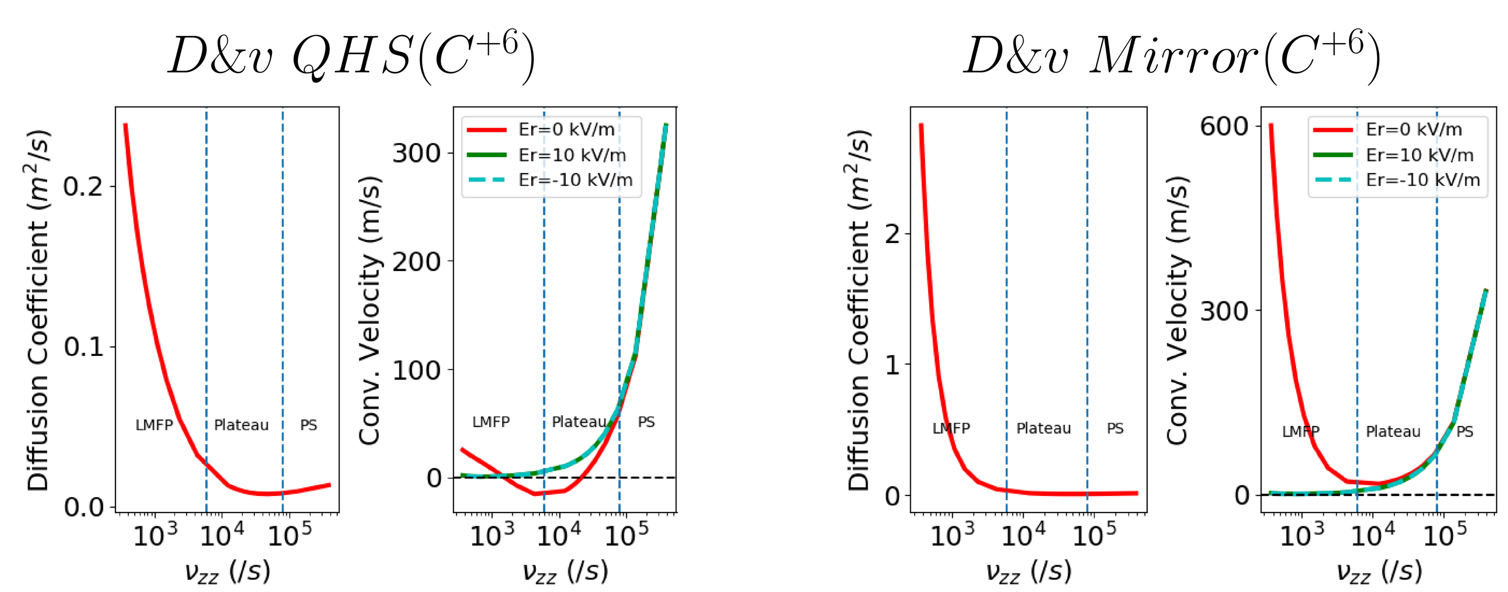
b. Helander *et al.*, Phys. Rev. Lett. (2017)

Calculations are done at r/a∼ 0.14 for a range of impurity collisionality

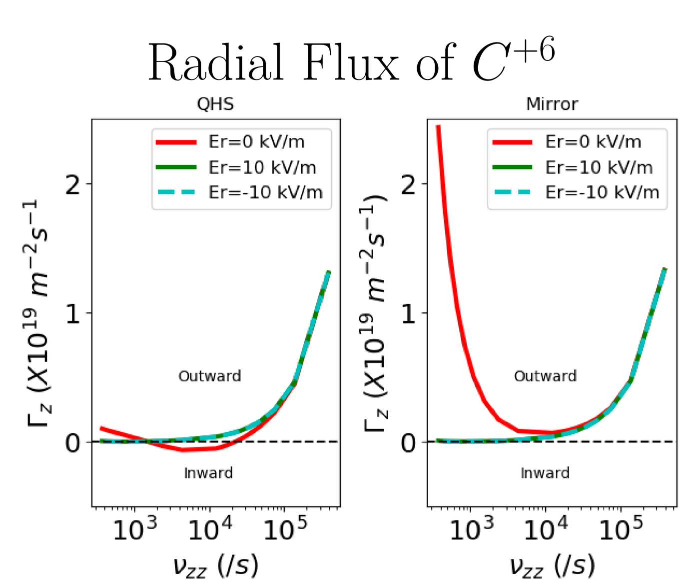


- Experimental values n_e & T_e are used, $T_i = T_z = T_e$ is assumed, impurity density = 1% of n_e is used.
- T_i is varied to scan the collisionality regimes, keeping all other parameters the same in the calculation.

Except for low collisionality, D & v are similar for QHS and Mirror configurations

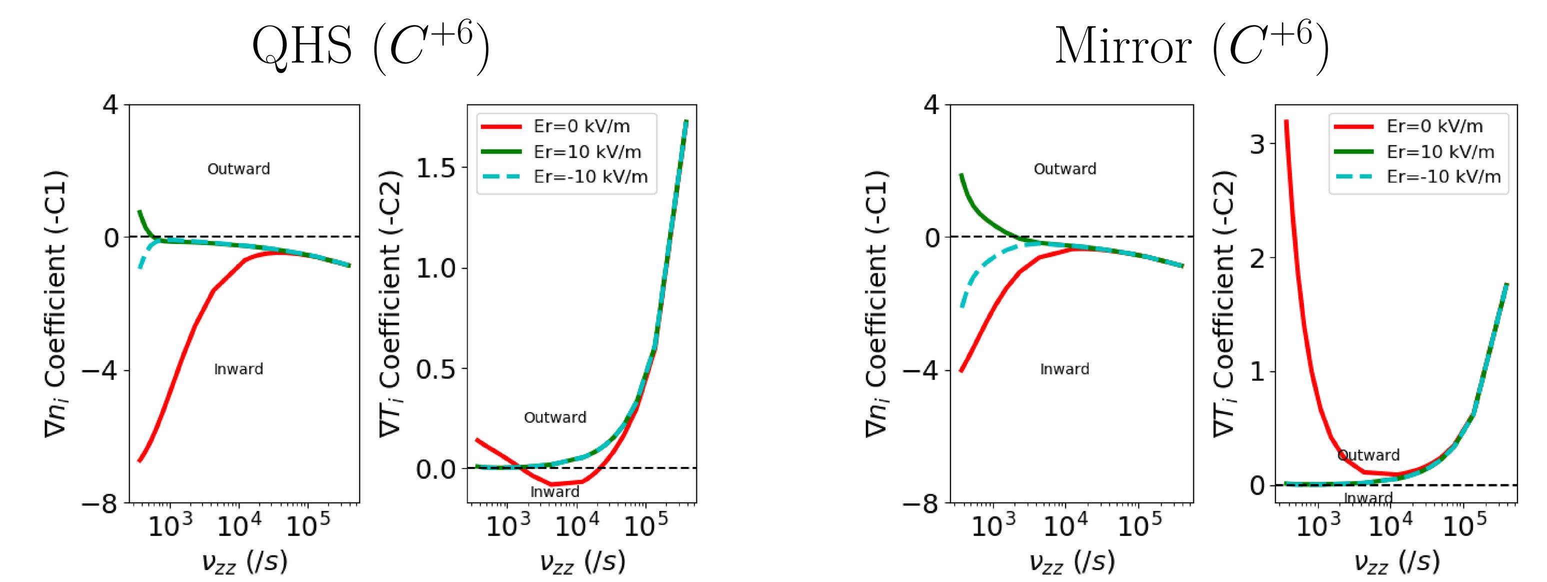


Outward impurity flux is calculated for both configurations

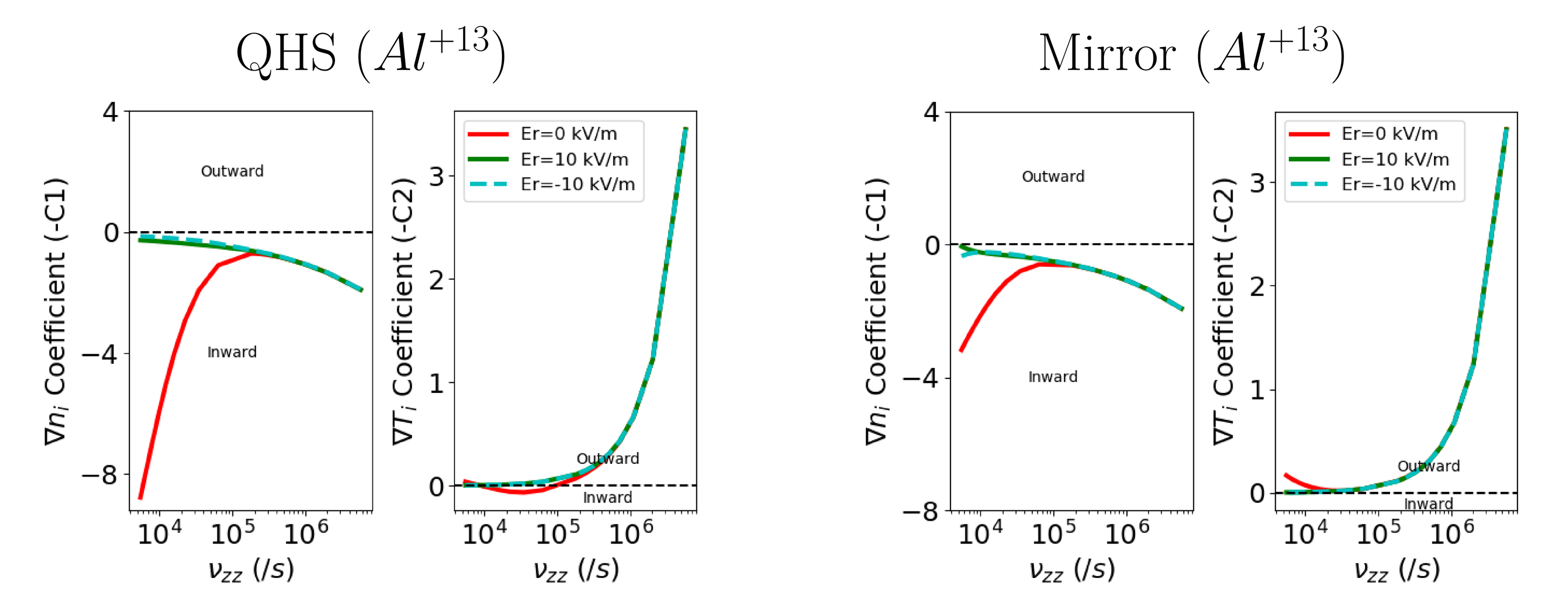


- Impurity expulsion, except for a narrow range of collisionality when E_r=0 in QHS.
- Transport is dominated by convection for the profiles used.

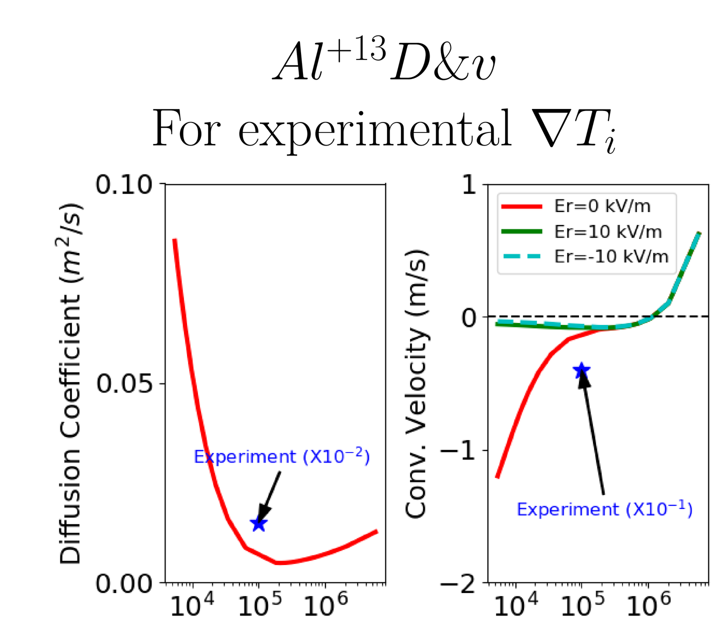
Outward directed convection velocity is due to temperature screening (∇T_i effect)



Higher Z impurities also exhibit temperature screening



Experimental aluminum D & v are much higher than neoclassical values



- Experimentally relevant ∇T_i [$T_i(0) \sim 60$ eV] is used for this calculation.
- Experimental D&v are obtained using Aluminum laser blow-off/ STRAHL code.
- See poster [J. F. Castillo *et al.*BP11.00027] for details.

Acknowledgments

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