MAX-PLANCK-INSTITUT FÜR PLASMAPHYSIK

Turbulent Impurity Transport in the Edge and SOL

HEPP Introductory Talk

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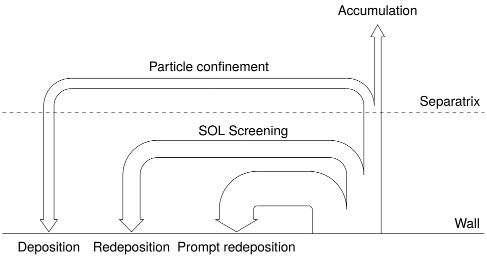
Where am I from?[1]

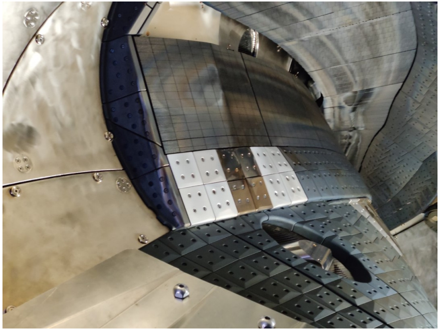
[1] Wikimedia Foundation. *Wikimedia Commons*. URL: https://commons.wikimedia.org.

Some fun facts[2]

[2] Wikimedia Foundation. *Wikimedia Commons*. URL: https://commons.wikimedia.org.

Master thesis: Modeling Tungsten Impurities Transport in W7-X





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Master thesis: Modeling Tungsten Impurities Transport in W7-X

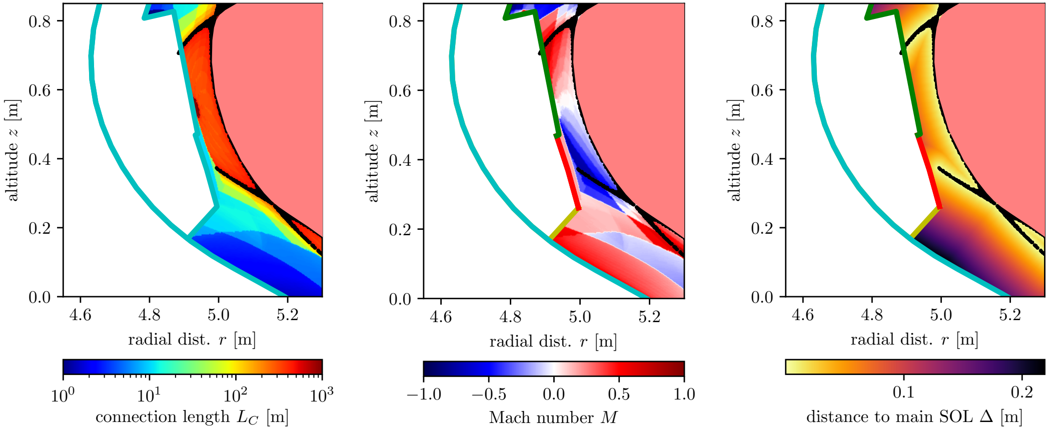

Figure: Background plasma defined by a simple model

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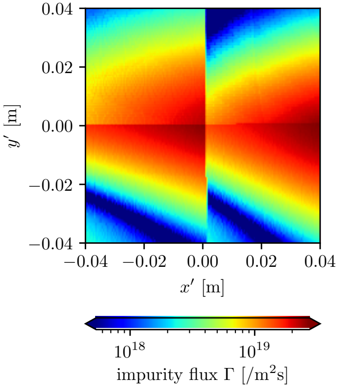

Figure: Front view of tungsten baffle tiles and the impurity flux

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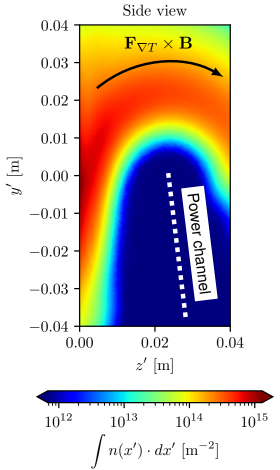
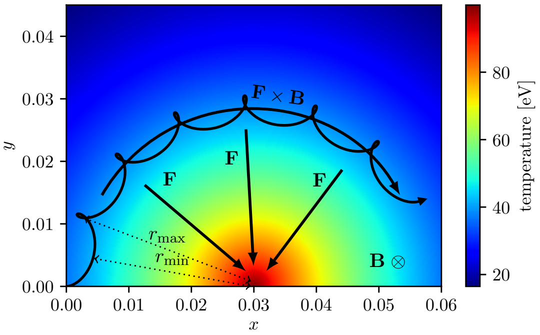
Transport of impurities are heavily influenced by thermal and friction forces





PhD topic: Turbulent Impurity Transport in the Edge and SOL

Aspects of impurity simulations:

- Highly collisional due to higher charge state and slow velocity
- Consisting of several different species and charge states
- Studying transport of impurities
- Studying impurity effects on turbulence

To-do list:

- Implement an accurate but fast collision operator
- Analyze neoclassical transport
- Develop multispecies batching model
- Code application
- Lots of reading

PhD topic: Turbulent Impurity Transport in the Edge and SOL

GENE-X is:[3]

- **Gyrokinetic:** suitable model to study microturbulence in strongly magnetized plasma
- **Global:** accounts for the entire system
- **Full-f:** solves the full distribution function, not only the fluctuations
- **Flux-coordinate-independent:** Suitable for edge region

[3] Dominik Michels et al. "GENE-X: A full-f gyrokinetic turbulence code based on the flux-coordinate independent approach". In: *Computer Physics Communications* 264 (2021), p. 107986

PhD topic: Turbulent Impurity Transport in the Edge and SOL

GENE-X Vlasov equation:

$$\frac{\partial f_\alpha}{\partial t} + \dot{\mathbf{R}} \cdot \frac{\partial f_\alpha}{\partial \mathbf{R}} + \dot{v}_\parallel \cdot \frac{\partial f_\alpha}{\partial v_\parallel} = \sum_\beta C_{\alpha\beta}(f_\alpha)$$

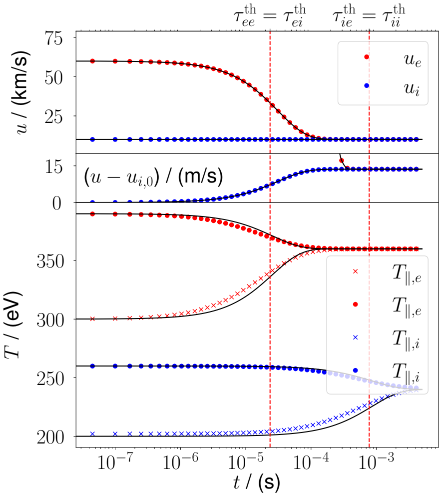
Previously implemented collision operators:

$$C_{\alpha\beta}^{\mathsf{BGK}}(f_\alpha) = \nu_{\alpha\beta}(f_\alpha - \mathcal{M}_\alpha)$$

$$C_{\alpha\beta}^{\mathsf{LBD}}(f_\alpha) = \nu_{\alpha\beta} \frac{\partial}{\partial \mathbf{v}} \cdot \left((\mathbf{v} - \mathbf{u}_{\alpha\beta}) f_\alpha + \frac{T_{\alpha\beta}}{m_\alpha} \frac{\partial f_\alpha}{\partial \mathbf{v}} \right)$$

$$C_{\alpha\beta}^{\mathsf{FPL}}(f_\alpha) = \frac{\partial}{\partial \mathbf{v}} \cdot \left(\frac{m_\alpha}{2} \Gamma_{\alpha\beta} \int \mathrm{d}^3\mathbf{v} \frac{u^2 \mathbb{1} - \mathbf{u}\mathbf{u}}{u^3} \cdot \left(\frac{f_\alpha}{m_\beta} \frac{\partial f_\beta}{\partial \mathbf{v}'} - \frac{f_\beta}{m_\alpha} \frac{\partial f_\alpha}{\partial \mathbf{v}} \right) \right)$$

First implementation: Lorentz collision operator



- Textbook collision operator
- Limit of $m_\beta \gg m_\alpha$

$$C_{\alpha\beta}(f_\alpha)$$

$$= \underbrace{\frac{\partial}{\partial \mathbf{v}} \cdot \left(\frac{\nu(v)}{2} (v^2 \mathbb{1} - \mathbf{v}\mathbf{v}) \cdot \frac{\partial f_\alpha}{\partial \mathbf{v}} \right)}_{\text{Pitch angle scattering}}$$

$$+ \quad \underbrace{2\nu_{\alpha\beta} \mathcal{M}_\alpha \frac{\mathbf{u}_{\alpha\beta} \cdot \mathbf{v}}{v_{\text{th},\alpha}^2}}_{\text{Momentum restoring term}}$$

Thank you for listening!