Particle-in-cell modelling in SPICE2 and SPICE3 for TSVV7

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THERMIONIC EMISSION

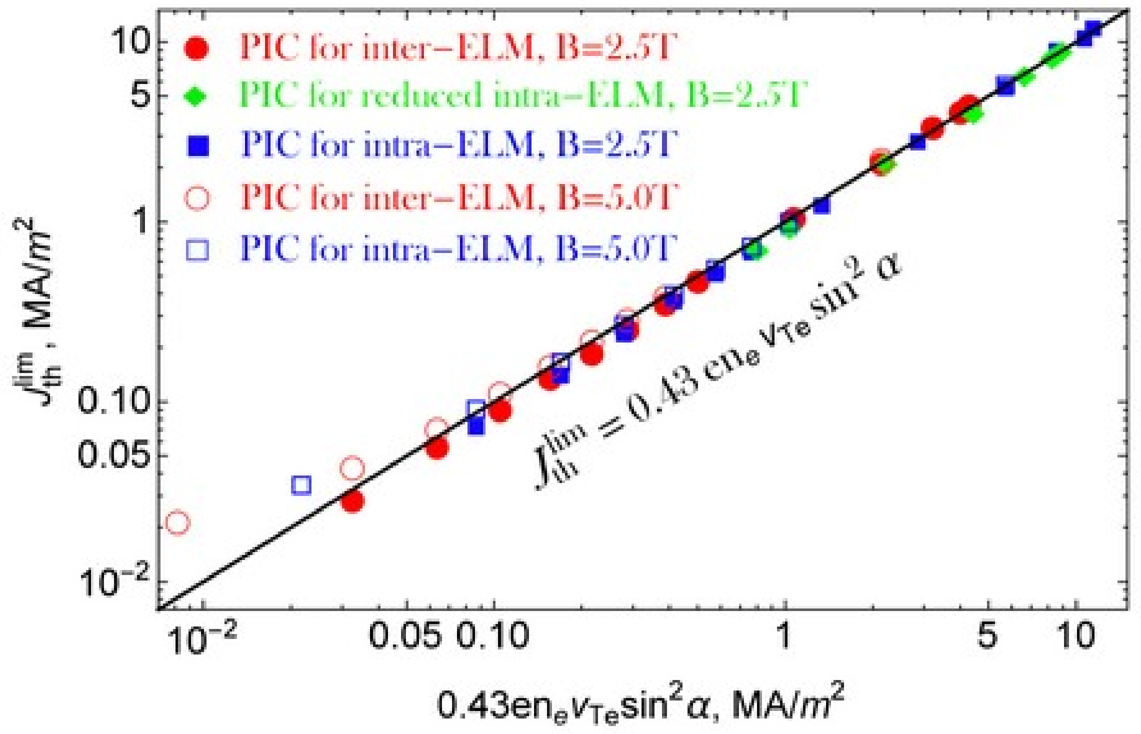
1. Simulations of thermionic emission at hot tungsten surfaces

SPICE2 has been extensively used to model escaping thermionic current in conditions relevant to AUG and JET melting experiments

We managed to derived an “extended Takamura formula”, which includes the effect of inclined magnetic field. This effect reduces the escaping current as $\sin^2\alpha$

This formula is valid for both inter- and intra-ELM plasma conditions provided that Te < 100 eV

[Komm PPCF 2017]
[Komm Phys. Scr. 2017]
[Komm NF Let. 2020]

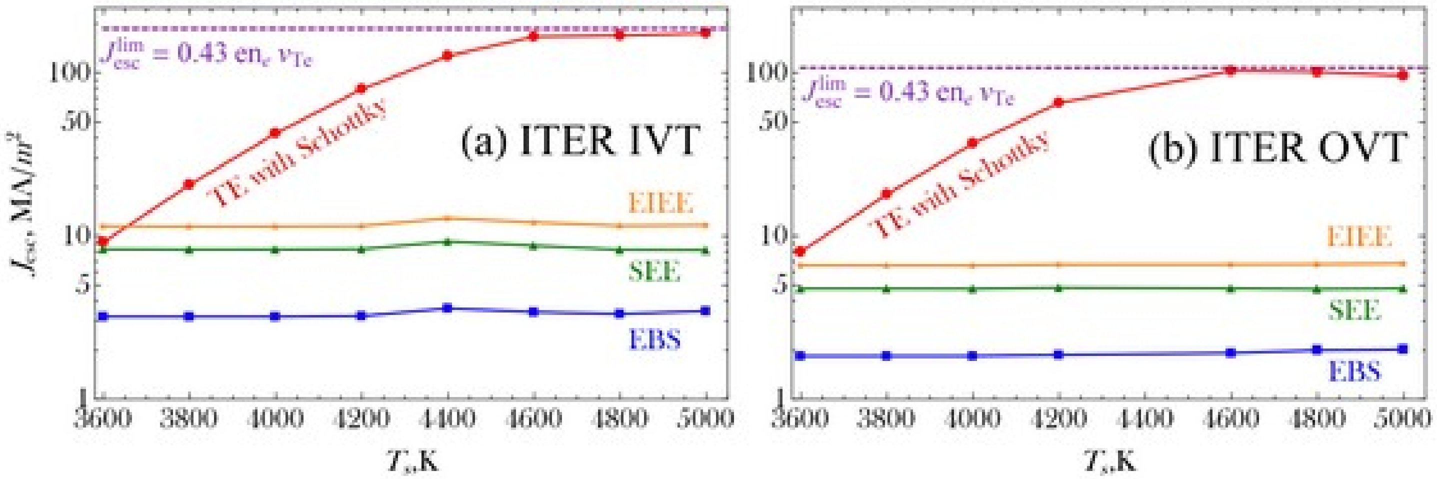


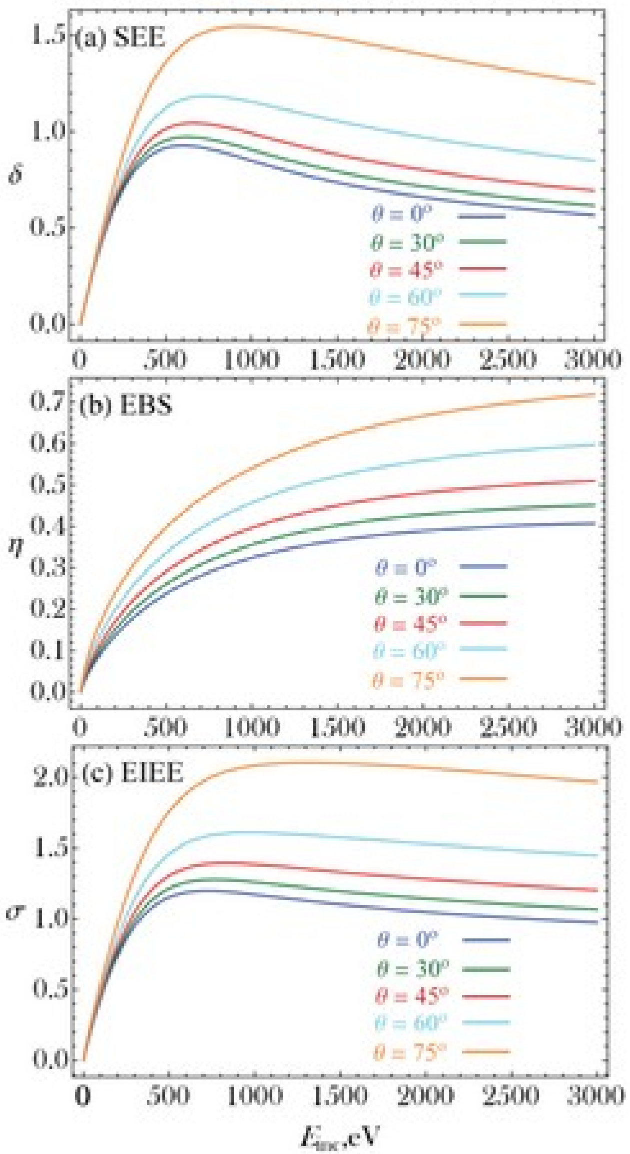
ELECTRON EMISSION IN ITER

The Te during ELMs in ITER is quite unknown but probably > 100 eV

At these temperatures, **secondary electron emission** and **electron back-scattering** can become important. Also the TE should be corrected for Schottky effect (which changes the work function of the material).

Detailed models of SEE and EBS have been implemented in SPICE2 [Tolias NME 2020] and first simulations for **ITER intra-ELM plasmas** were performed for **normal incidence of B field**





PLANS FOR 2021

Within TSVV7 we plan to address the following topics:

1. Simulations of ITER intra-ELM plasmas with inclined magnetic field – grazing angle of incidence (5^o nebo 2.5^o) including SEE and EBS

2. Influence of Ti on the escaping current – we go back to AUG-like conditions

The objective is to determine whether the escaping current scales with electron thermal velocity (which depends only on Te) or on ion sound speed (which includes influence of Ti)

This task is already underway. AUG intra-ELM condition suggest very small difference between case with Ti/Te = 1.0 and Ti/Te=5.0. Inter-ELM conditions should be achieved soon.

Implementation of non-uniform particle injection

Motivation – small λ_q for DEMO relevant conditions (~ 1 mm by Eich scaling [Eich NF 2013]) – in the scale of small surface elements (gaps etc.).

Implications

- **Physical**: any PFC at strike line is subjected to plasma w/spatially non-uniform parameters.
- **In simulations**: plasma injection should be also non-uniform.

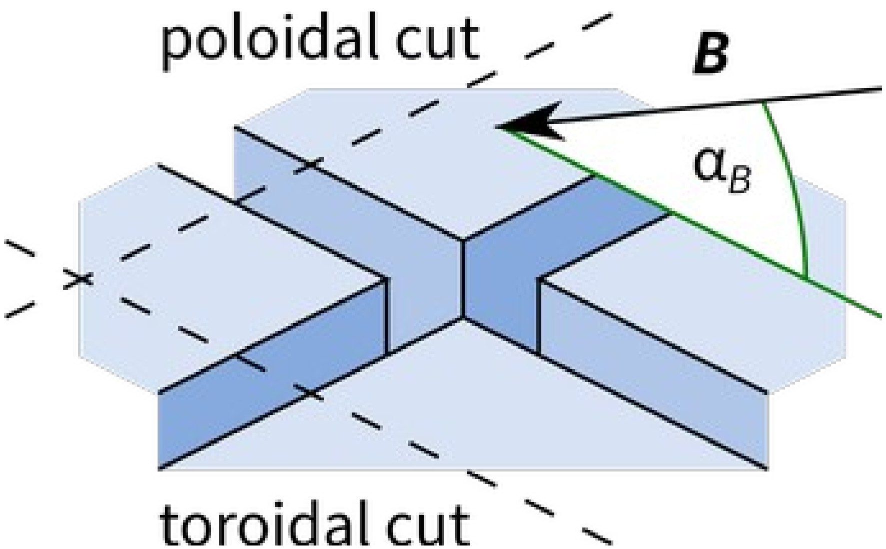


Illustration of the simulation

Gap crossing problem – extensive studies in the past [Komm PPCF 2011, 2013].

How does the particle/heat flux change when the strike line crosses the gap?

- Poloidal gap crossing
- Toroidal gap alignment

PLANS FOR FUTURE

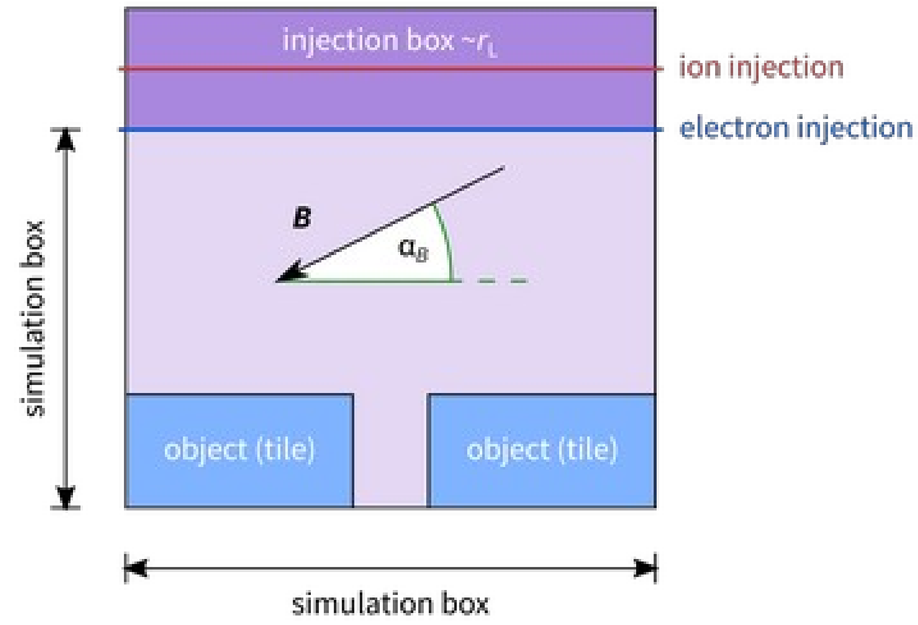
Status of injection in SPICE2/3

RHS figure – injection schema in the current code version of SPICE2.

- Simulation box – any number of conductive elements.
- Injection box for ions "bulk plasma" – no ***E*** force calculation in the box.
  - One injection plane for electrons
  - One injection plane for ions
- Periodic boundary conditions on sides, sink at the bottom.

SPICE3 shares the model philosophy, the implementation is similar.

Multiple ion species possible – simple non-uniform step-wise injection for initial simulations.



Typical gap simulation

Two neighboring tiles separated by a small gap, fixed plasma parameters

Arbitrary direction of ***B*** field (in 3D).

Common in 2D: ***B*** field either in-plane or perpendicular

PLANS FOR FUTURE

Development od proper non-uniform injection schema

Initial – update of current capabilities for step-wise injection.

Follow-up – continuous non-uniform injection schema

Result: Updated version of SPICE2 with proper non-uniform injection capabilities

Massive parallelization of SPICE2

Currently, scaling available up to 64 cores, further HLST support needed.

Simulations using the upgraded code

2D – toroidal and poloidal gap with strike-line

3D – full gap problem simulations

Results:

- Heat and particle flux profiles inside the gaps, comparison with previously obtained modelling results