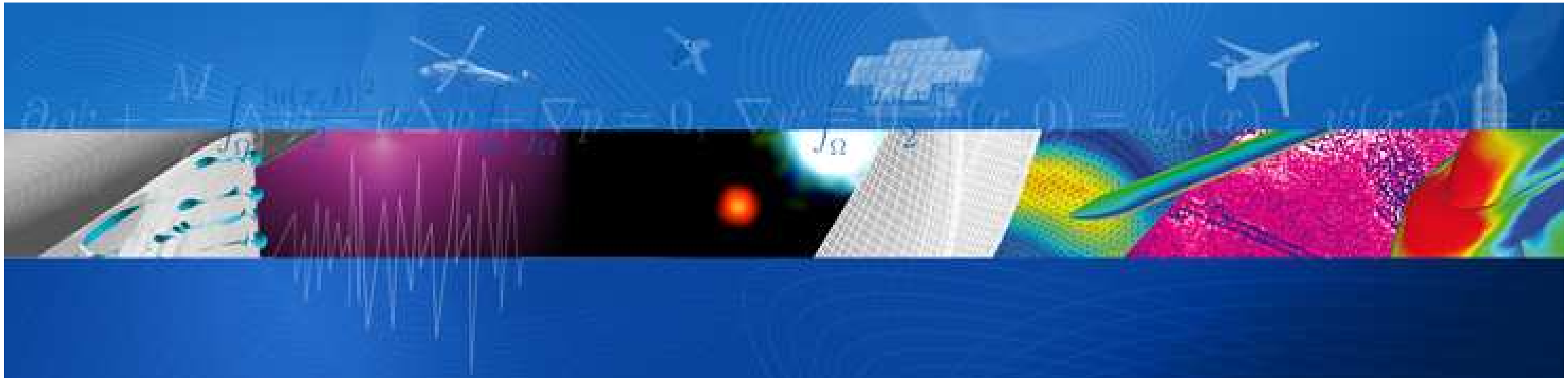

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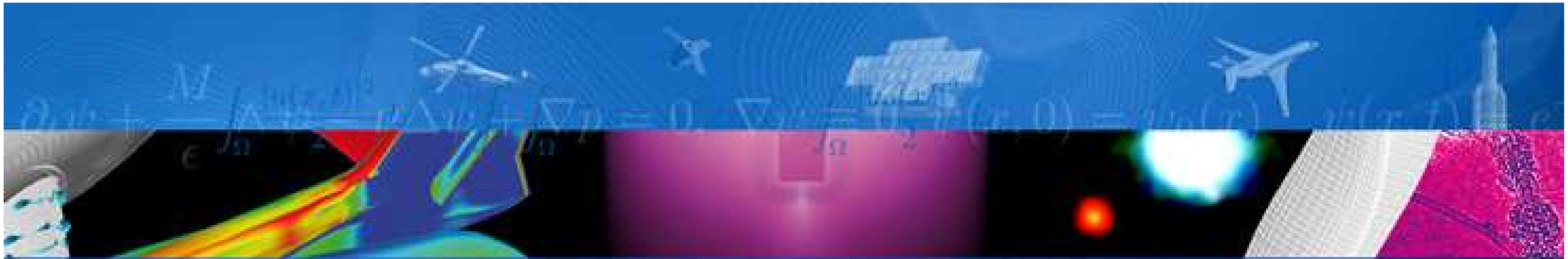

SPIS-Muscat comparison on LEO-like environment

SPIS workshop, SPINE meeting, September 28 2009

Jean-Charles Matéo-Vélez
Jean-François Roussel
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Introduction

- Complex interactions between spacecrafts and the environment can be simulated with dedicated numerical tools (SPIS, MUSCAT, NASCAP-2k,…)

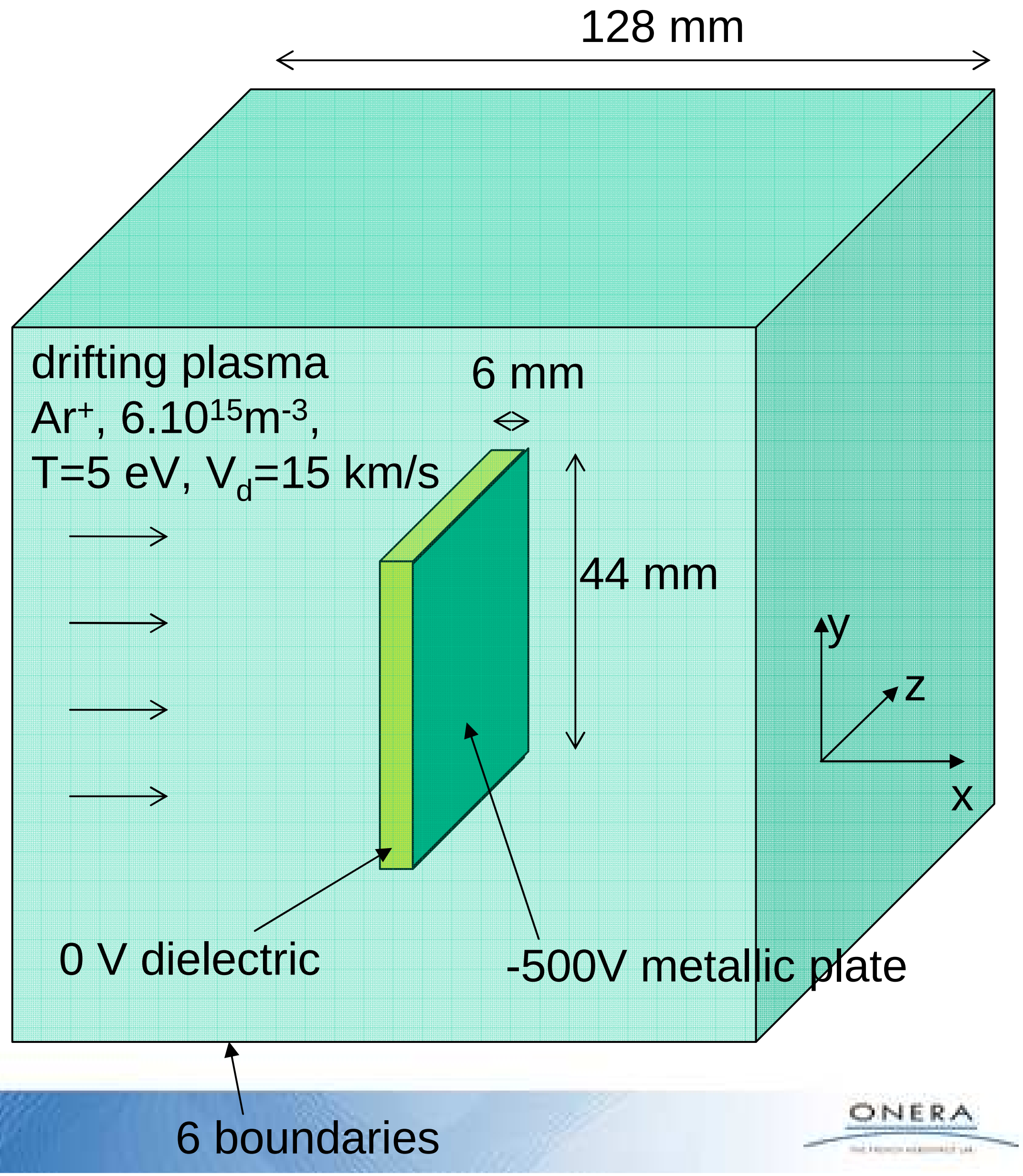
- Compare SPIS and MUSCAT
  - SPIS : open source code, development supported by ESA, with multiple improvements through CNES R&D funding
  - MUSCAT : Multi Utility Spacecraft Charging Analysis Tool (JAXA and KIT, Japon)

- CNES R&D funding (2008)

- Chosen configuration
  - Simulation of an experiment conducted in KIT
  - Reference : Hosoda et al., "Laboratory Experiments for Code Validation of Multi-Utility Spacecraft Charging Analysis Tool (MUSCAT)", IEEE Trans. Plasma Sci., Oct 2008.
  - Simple geometry : a plate
  - LEO plasma environment

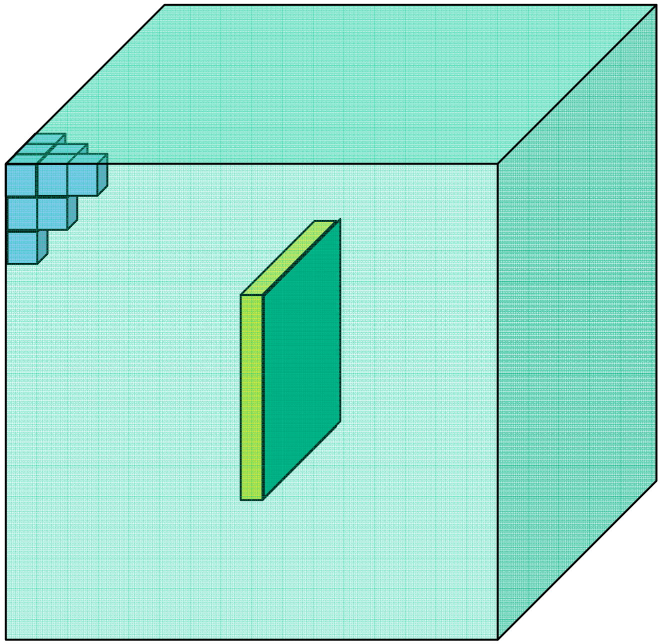
Description of the simulation

- Previous MUSCAT simulation
- Flat plate immersed in a LEO-like drifting plasma
- General model
  - Input data obtained from experiments
  - no change in the plate potential (0V on the dielectric ram face and -500V on the rear side)
  - no charge exchange reaction
- Physics to simulate
  - plasma dynamics
  - wake effect
  - plasma sheath
  - collection of ions on the -500V rear side



MUSCAT modelling

- Uniform mesh (MUSCAT limitation)
  $64 \times 64 \times 64$ = 260,000 cells of 2mm edge
- Electron and ion dynamics
  PIC
- Electric field
  Fast Fourier Transform
- Boundary conditions
  0V on plasma boundary
- Particle collection on the plate
  Forward tracking



SPINE meeting, SPIS Workshop, ONERA, Toulouse, 28-29 September, 2009

SPIS modelling

- <u>Tetrahedral unstructured mesh</u>

  155 000 tetra
- Ions dynamics

  PIC
- <u>Electron dynamics</u>

  Boltzmann distribution $N_e = N_0 \exp\left(\frac{e\phi}{k_B T_e}\right)$
- <u>Electric potential</u>

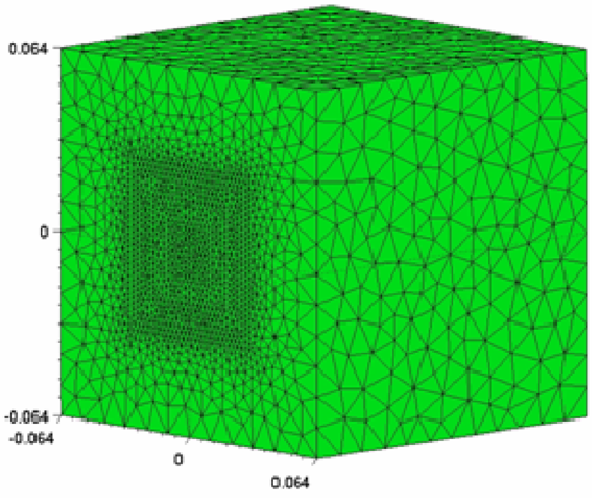
  Non-linear Poisson equation – implicit solving

$$-\Delta\phi = \frac{e}{\varepsilon_0}\left(N_i - N_0 \exp\left(\frac{e\phi}{k_B T_e}\right)\right)$$

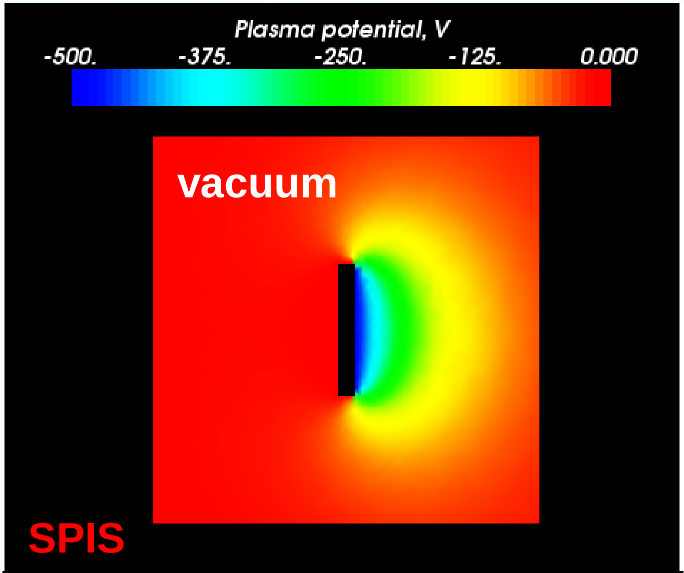
- <u>Boundary conditions</u>

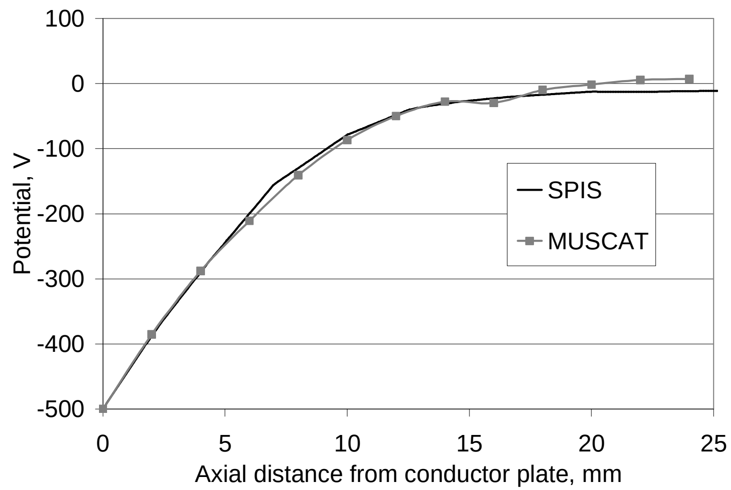
  $1/r^2$ potential decay (pre sheath condition)
- Ion collection

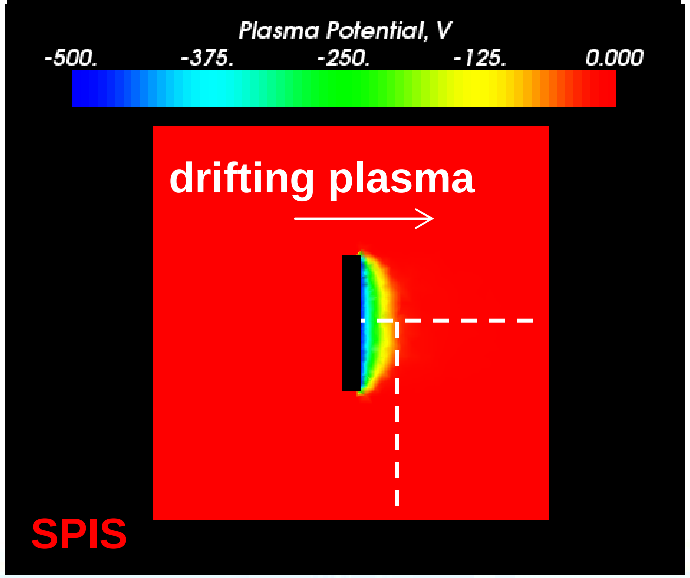
  Forward tracking

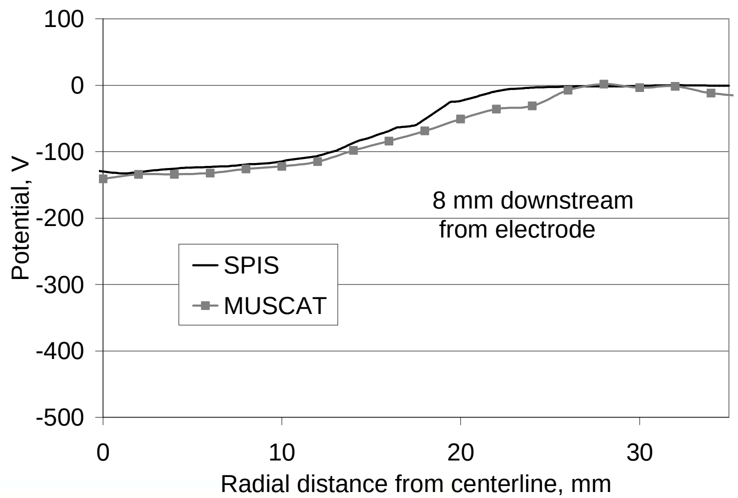


Results – Electrical Potential

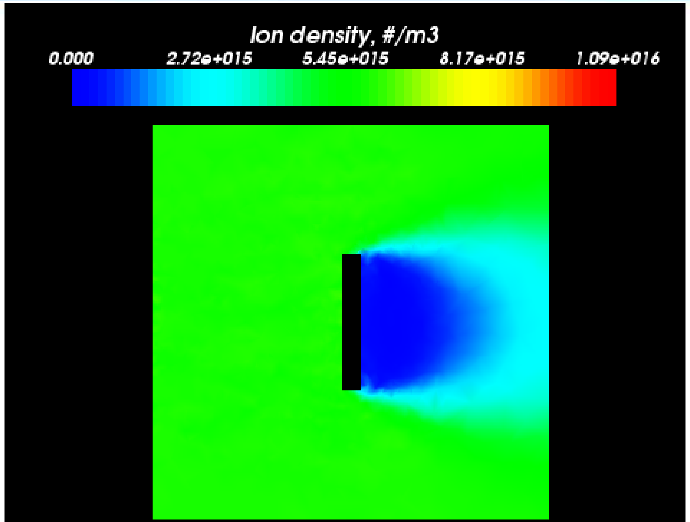




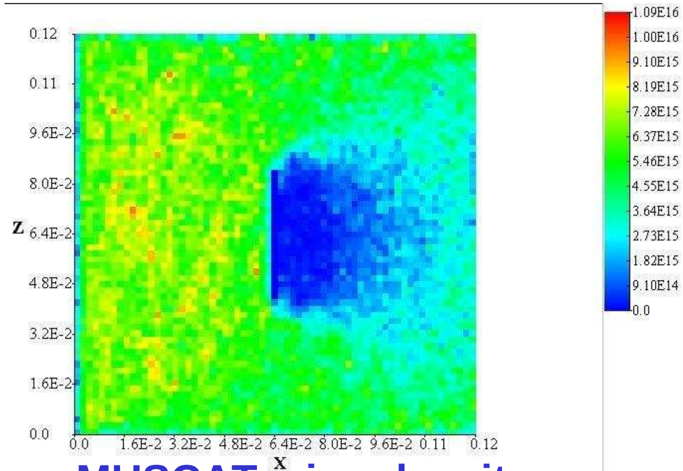




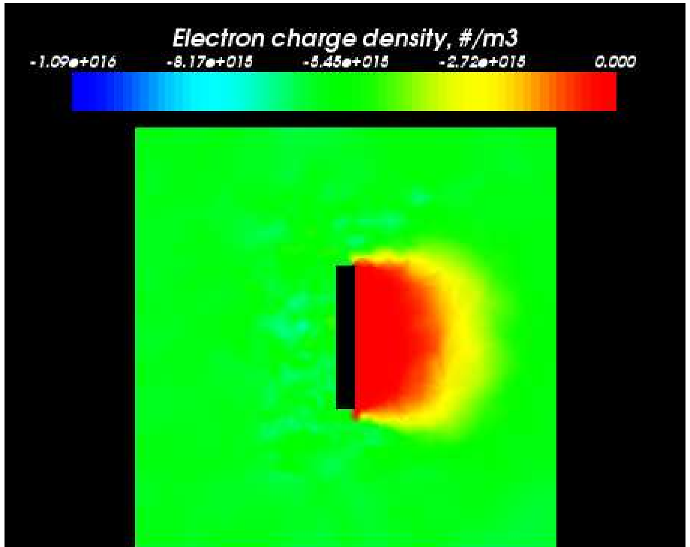
Results - Particles



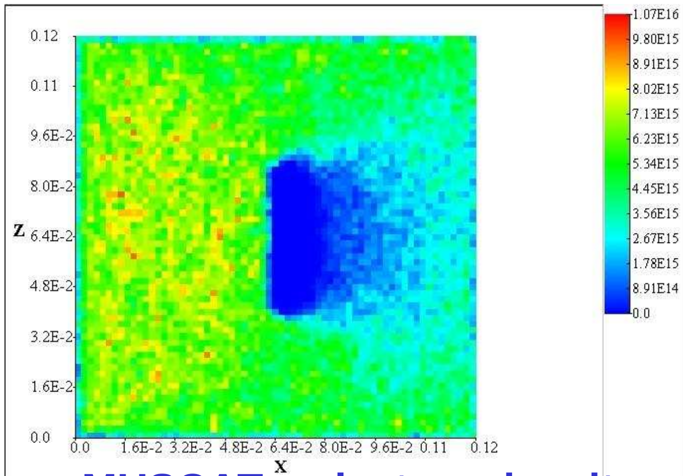
SPIS – ion density



MUSCAT – ion density

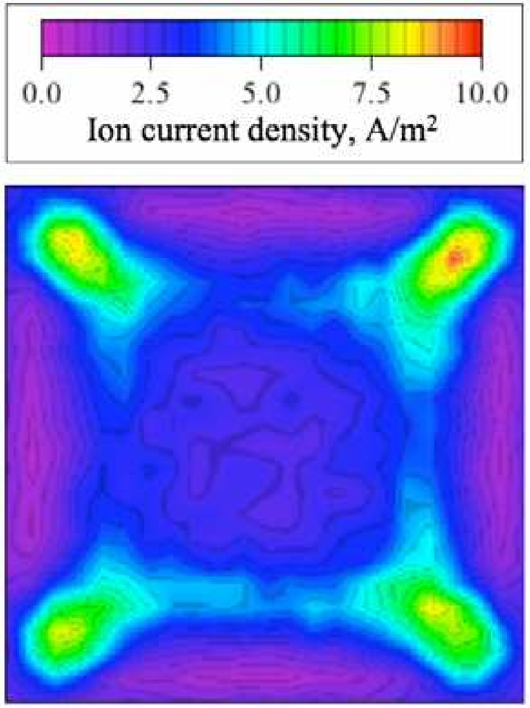


SPIS – electron charge density

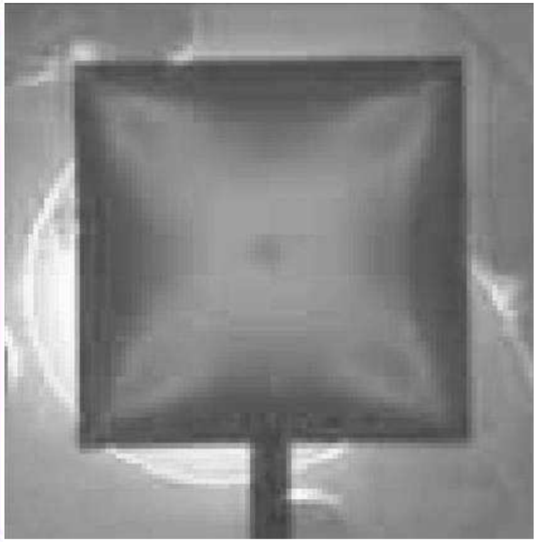


MUSCAT – electron density

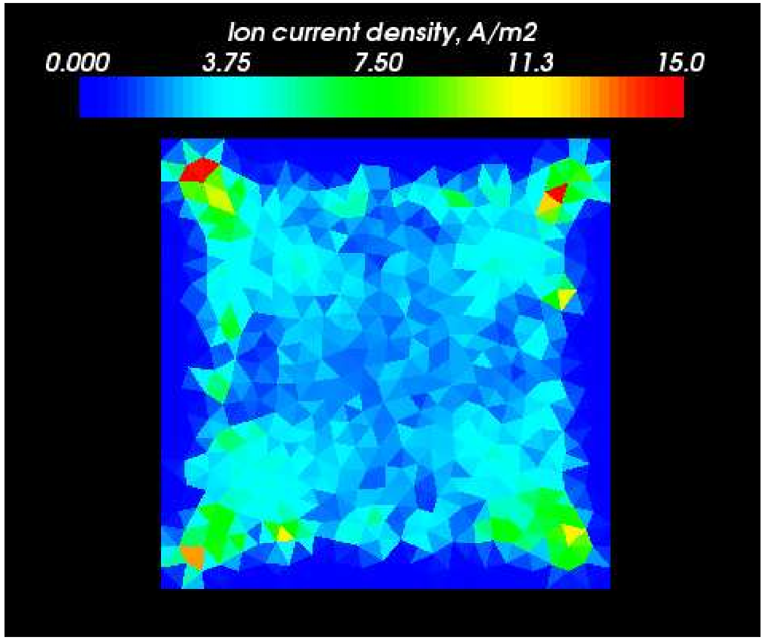
Results - Ion collection on the rear side



MUSCAT



KIT exp.



SPIS

Hosoda et al., "Laboratory Experiments for Code Validation of Multi-Utility Spacecraft Charging Analysis Tool (MUSCAT)", IEEE Trans. Plasma Sci., Oct 2008.

Conclusion

- Good comparison between SPIS and MUSCAT on
  - Plasma sheath
  - Particle dynamics
  - Forward tracking for ion collection on the plate
- Future comparison: GEO spacecraft satellite?
  - Spacecraft electrical circuit
  - Backtracking on sufficiently big domain to assess which trajectories are filled or not
  - Same boundary conditions