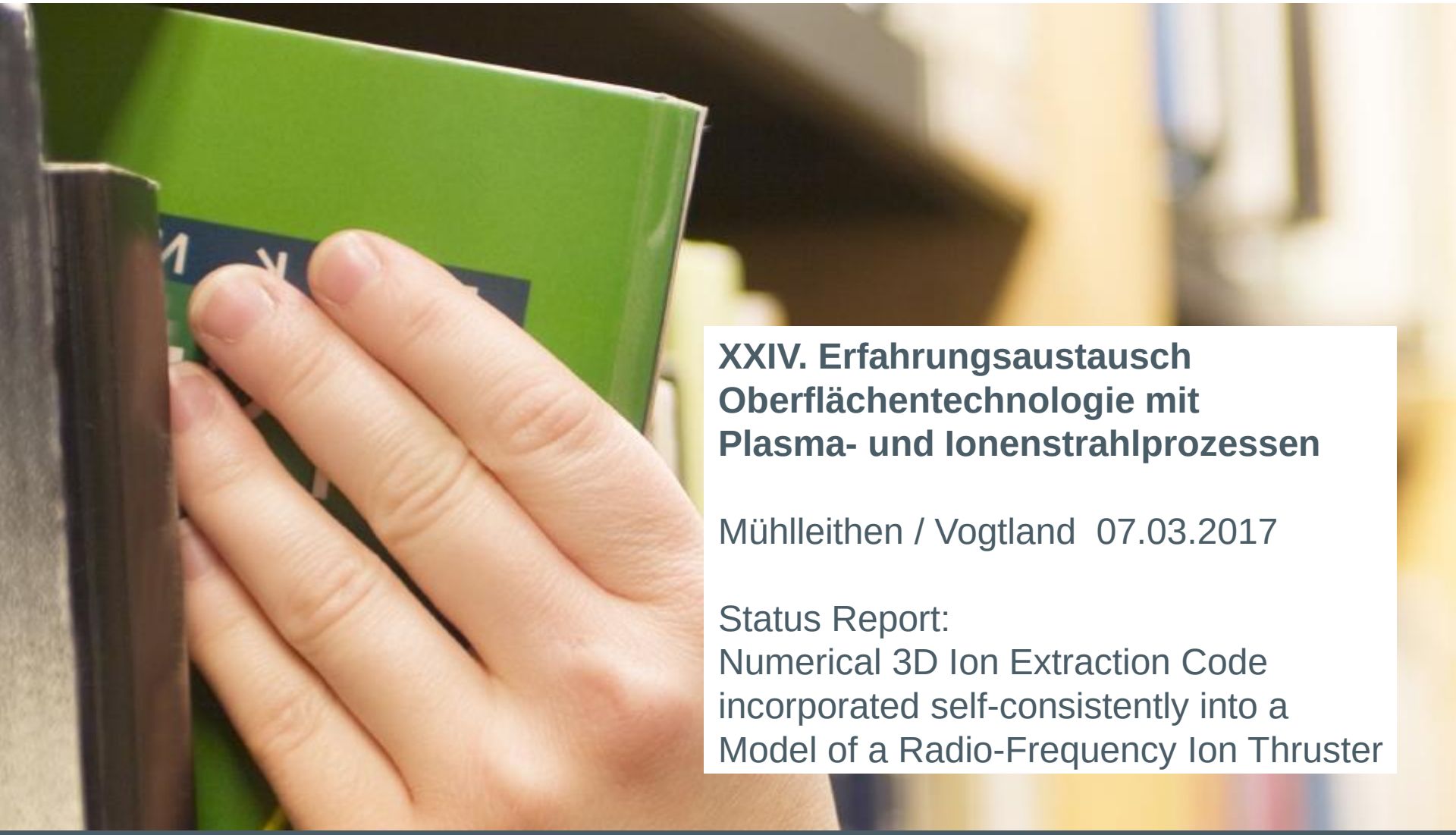

XXIV. Erfahrungsaustausch Oberflächentechnologie mit Plasma- und Ionenstrahlprozessen

Mühlleithen / Vogtland 07.03.2017

Status Report:
Numerical 3D Ion Extraction Code incorporated self-consistently into a Model of a Radio-Frequency Ion Thruster

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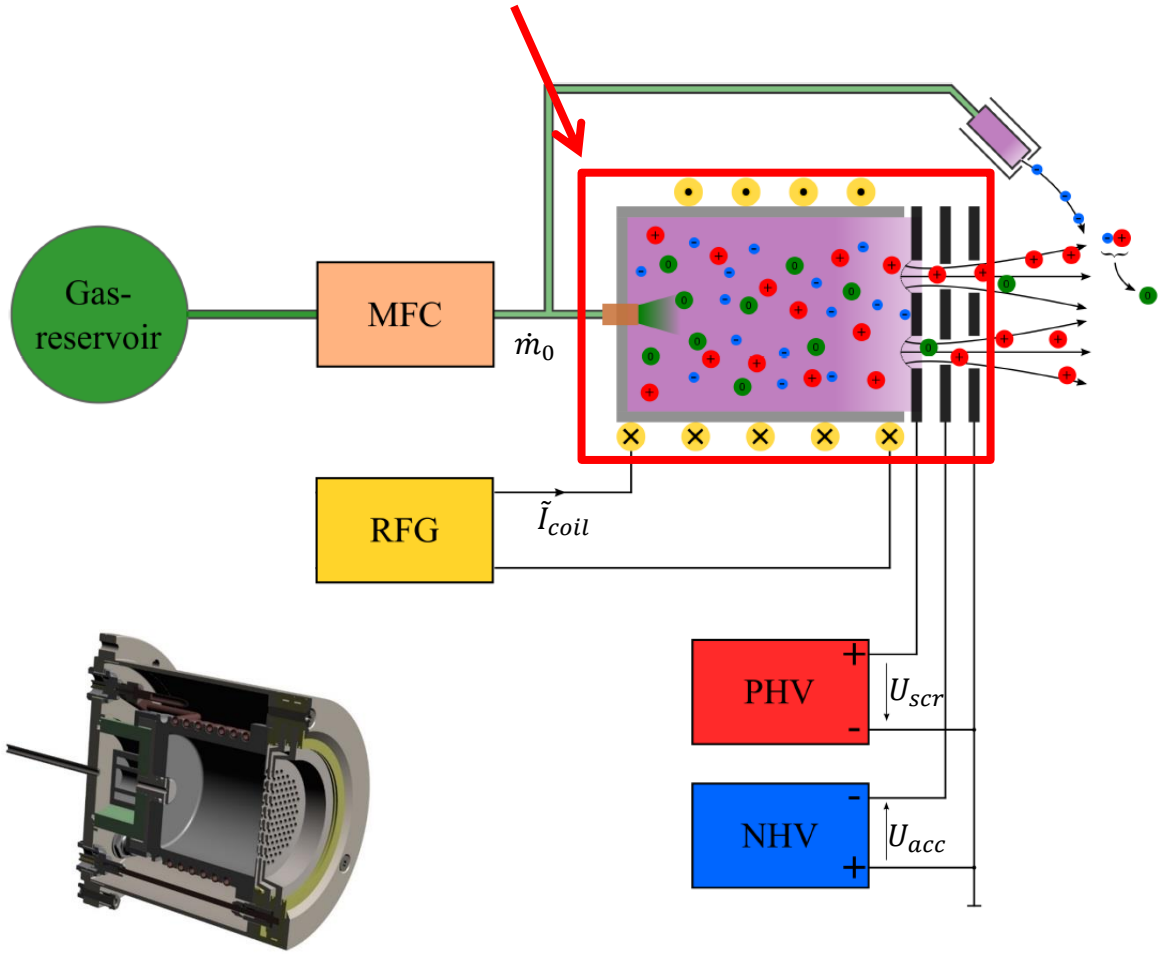
Self-consistent RF ion thruster model

System and boundary definition



Output

Coil System:

- $\tilde{U}_{coil}$
- $\tilde{S}_{coil}$, $\tilde{P}_{coil}$, $\tilde{Q}_{coil}$

Extraction System:

- $\dot{m}_i$, $\dot{m}_n$
- I_{beam}, P_{beam}
- v_i, v_n, F

Efficiency:

- μ_e, μ_m

Self-consistent RF ion thruster model

Core modules

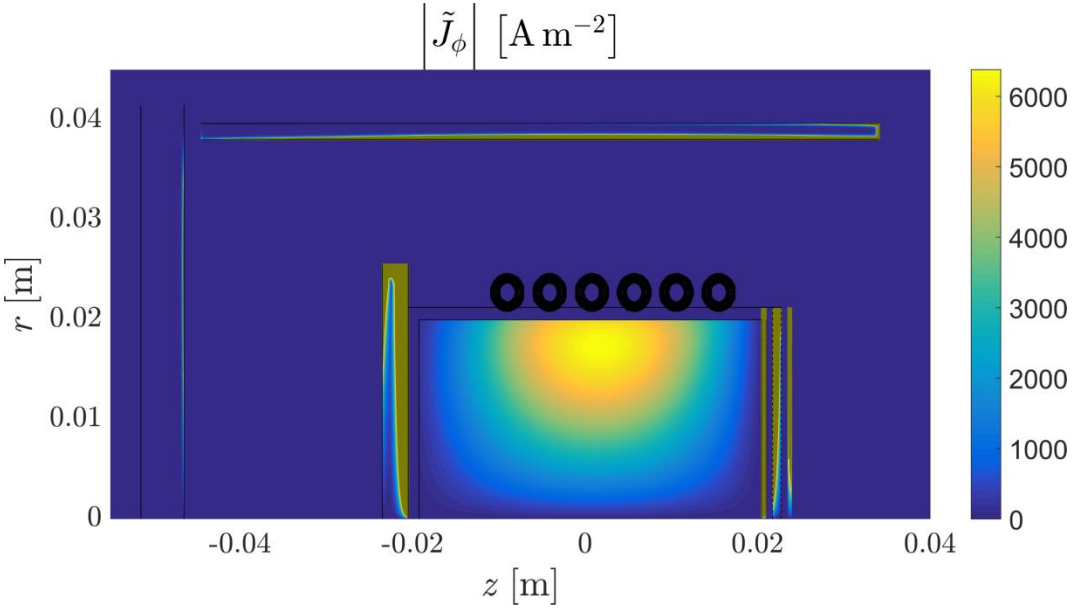
- Charge conservation model → Electron temperatur
- Energy conservation model → Ionisation degree
- Mass conservation model → Pressure

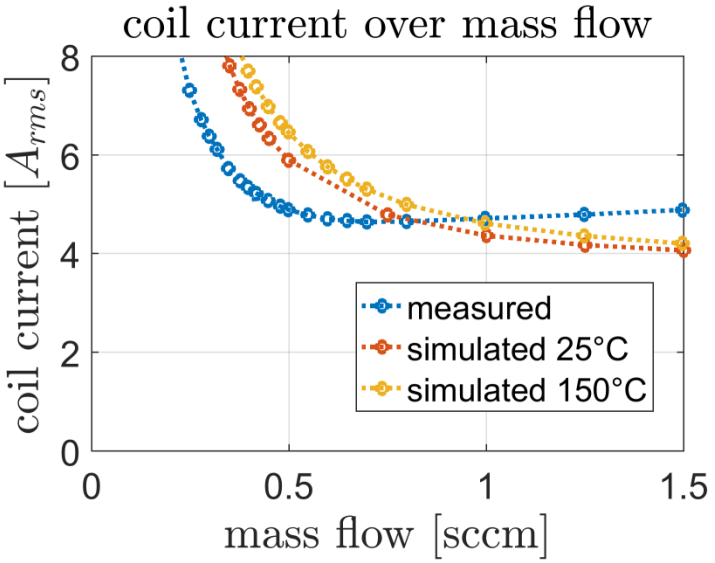
Self consistency:

The output of each model affect the remaining models

Self-consistent RF ion thruster model

Results





RIM4, 2D-Modell, heuristic density profile,
temperature: 150°C, extraction current: 10mA,
propellant: xenon, mass flow: 1 sscm,
frequency: 2 MHz

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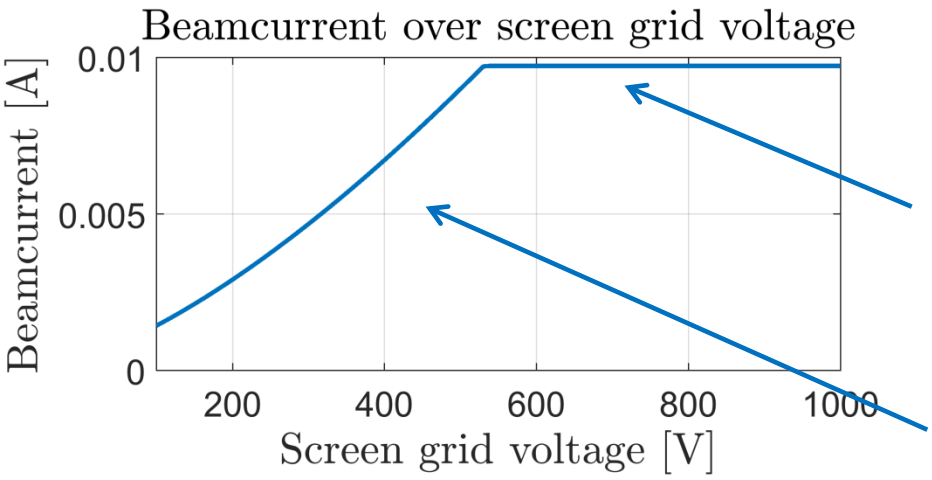
Planned expansion

Currently: Analytical plasma extraction model



- **Plasma limitation**

$I_{extraction} = v_b \cdot n_{i_s} \cdot A \cdot T$

v_b: *Bohm velocity*

n_{i_s}: Ion density at the sheath

T: Grid transparency

A: extraction surface

- **Modified Child-Langmuir Law**

New: Numerical plasma extraction model

- **Transparency** (plasma meniscus)
- **Thrust** (consideration of divergence)
- **Grid currents** (overcrossing and direct impingement)

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Chosen approach

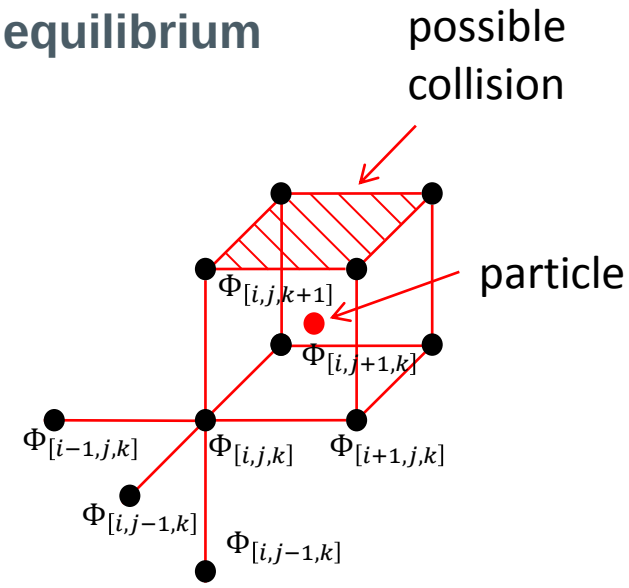
Collisionless electrostatic particle-in-cell (PIC)

- **3D** — **Simulation of non symmetrical grid structures**
- **In time domain** — **Simulation of DC and AC-grid-voltages**

- **Ions:** — **Considered as particles**
- **Elektrons:** — **Assumed to be in thermal equilibrium**

$$\Delta\varphi_{(\vec{r})} = -\frac{\rho_i+\rho_e}{\varepsilon_0}; \rho_e = en_{e_o} exp\left(\frac{e}{k_B T_e}\left[\varphi_{(\vec{r})} - \varphi_0\right]\right)$$

- **Finite-difference methods (FDM)**
- **Voxel for geometric modelling**



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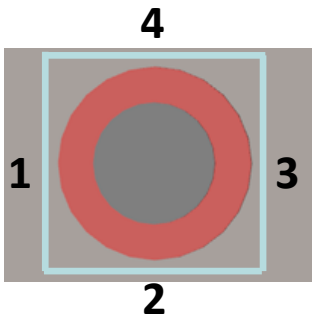
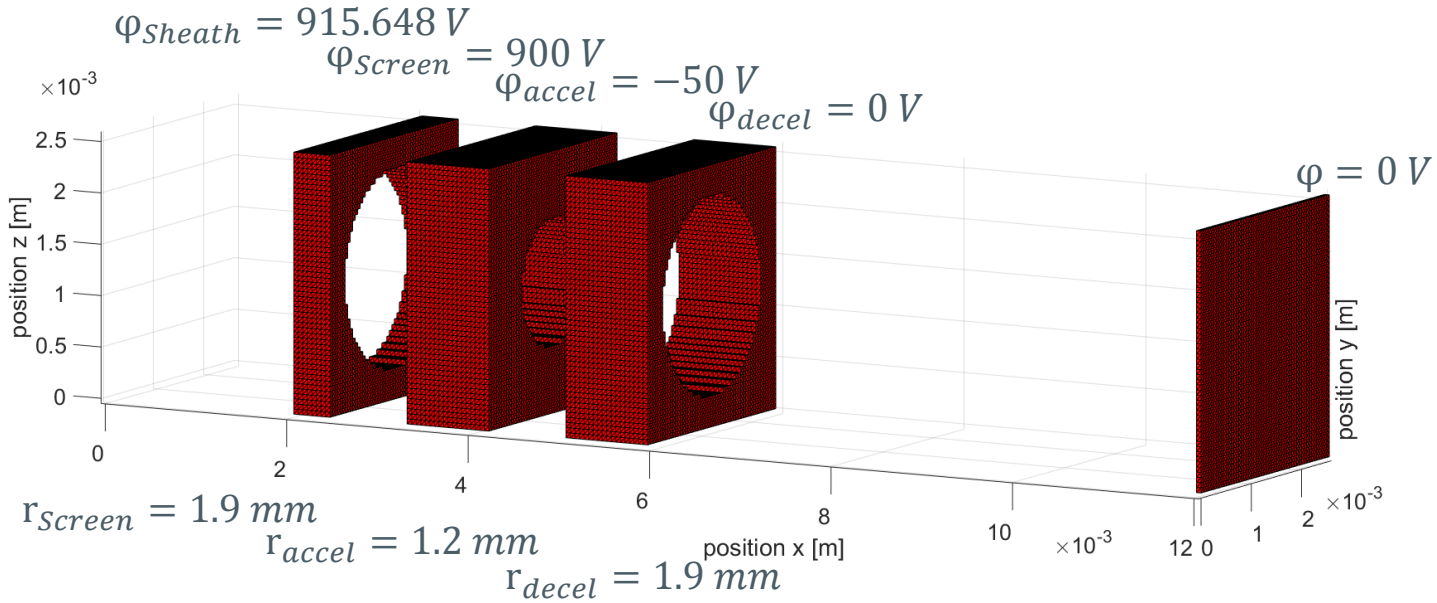
First results

System and boundary definition





Symmetrical boundarys

- Reflection of particles
- $E_t = 0$

Discretization

$h = \Delta x = \Delta y = \Delta z = 0.05\ mm$

$N = 241 \cdot 52 \cdot 52 = 651,664\ Points$

$\Delta T = 1\ ns$

Plasma boundary

$n_{e(x=0)} = 2.913E+16\ \#/m^3$

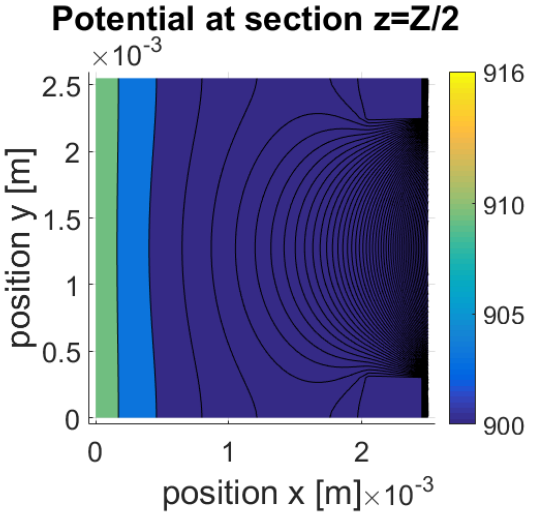
$T_e = 2.97\ eV$

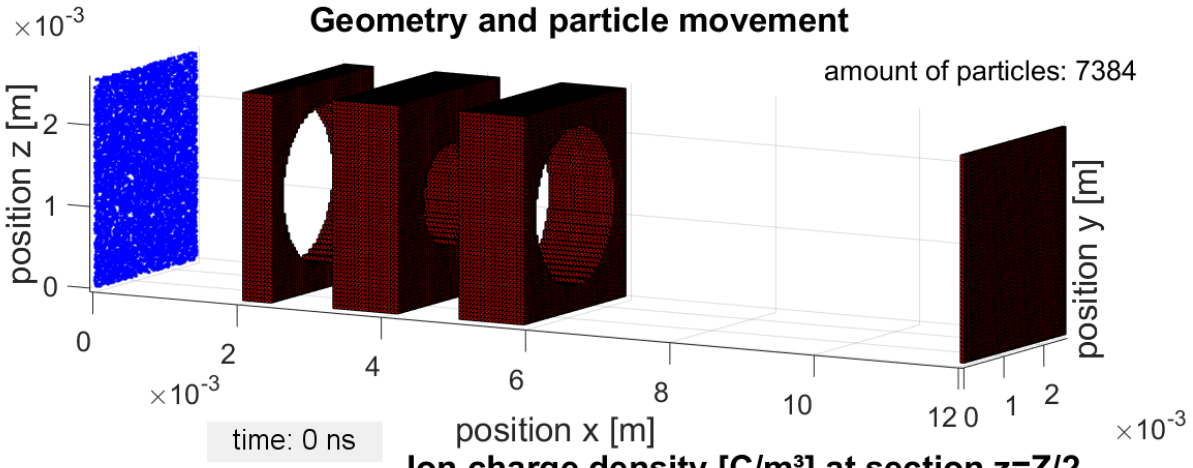
$n_{i_{(x=0)}} = n_{e_{(x=0)}}$

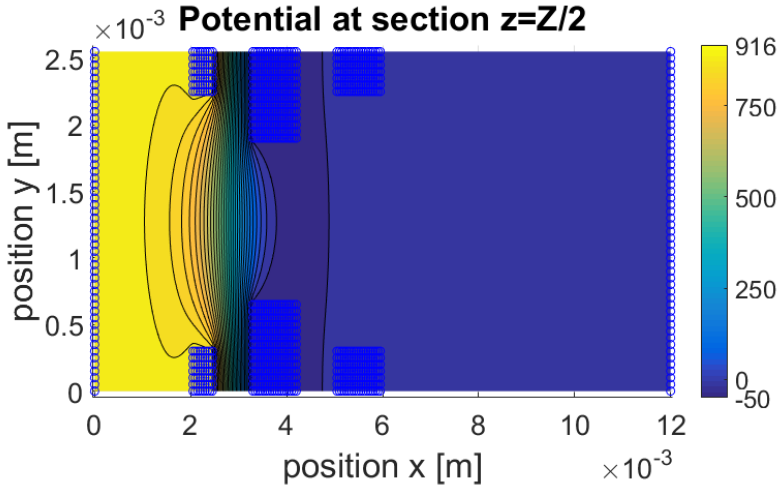
$v_b = 1{,}476\ m/s$

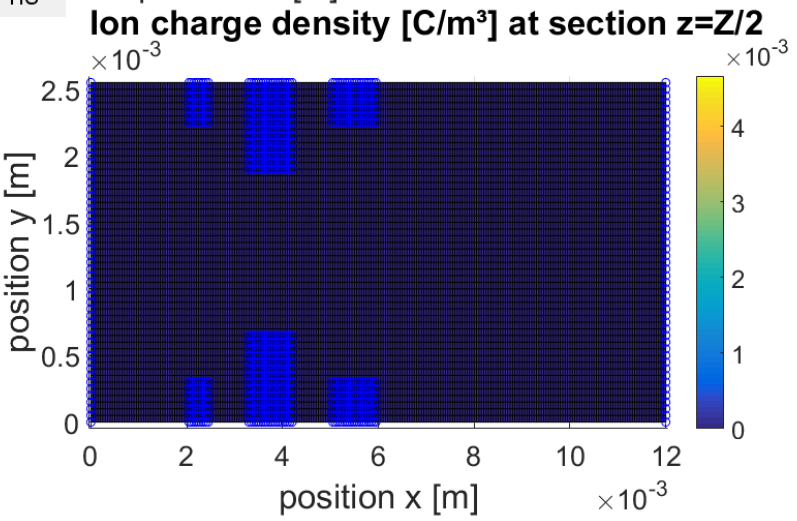
First results

Comment from 15.03.2017:
In the original presentation a video was shown









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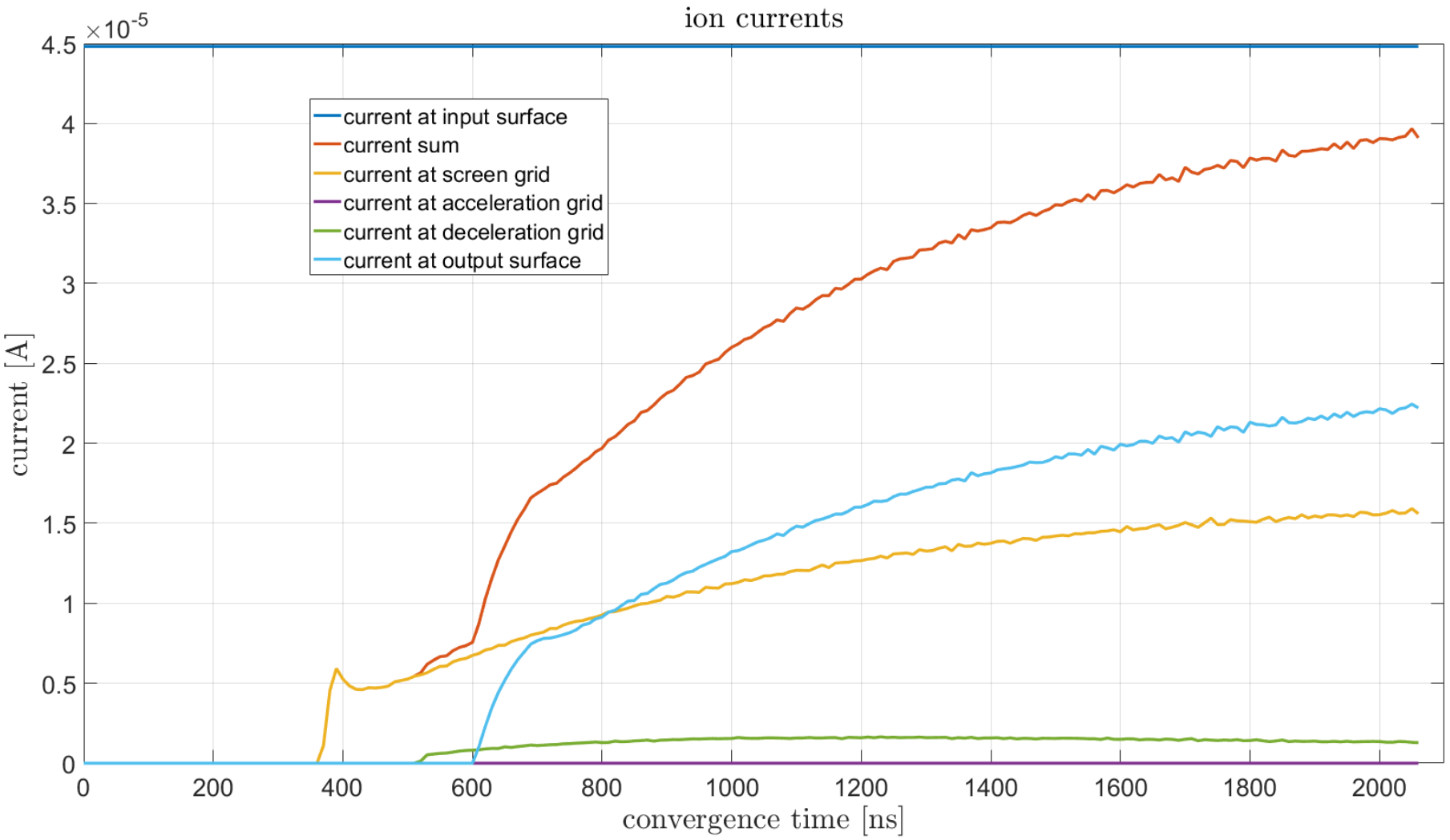

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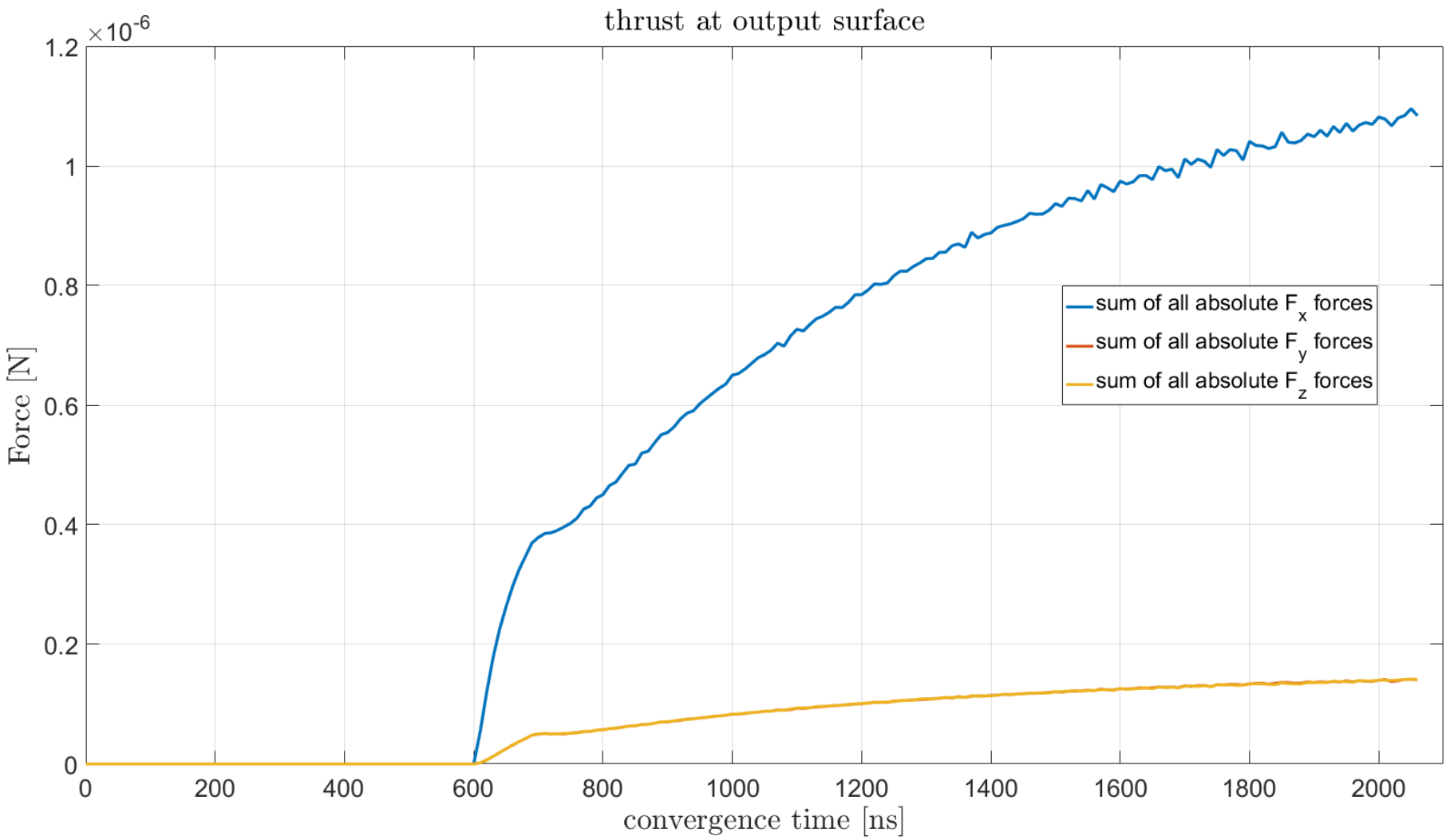

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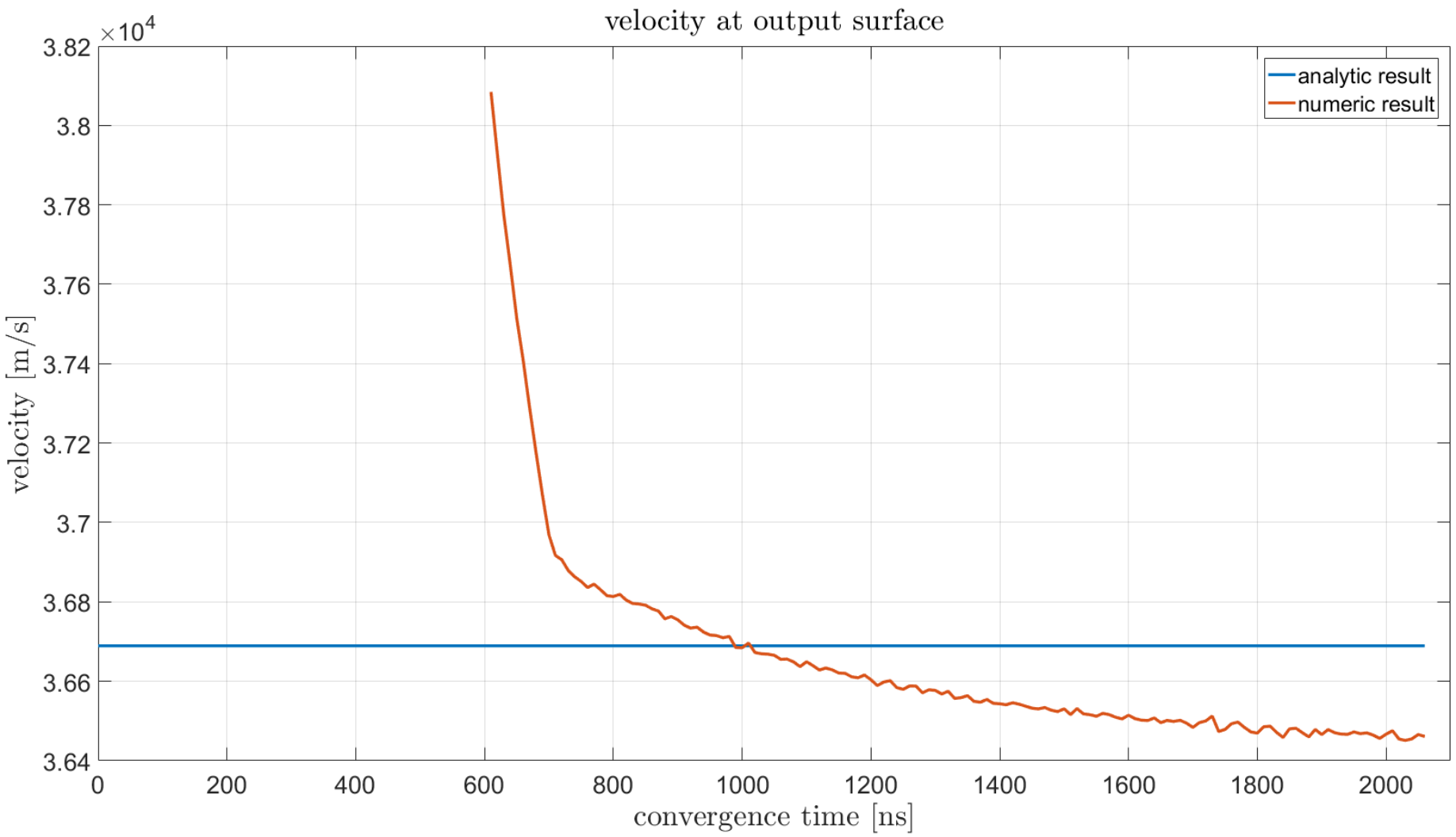

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Outlook:

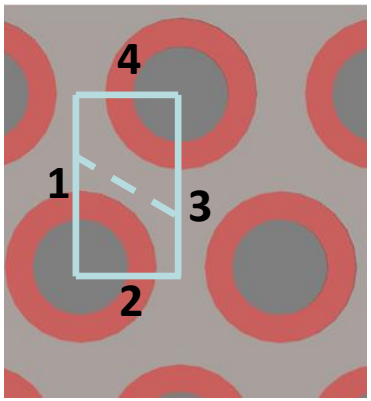
- Validation
- Numerical Efficiency
  - Multidimensional Newton's method
  - Multigrid or Preconditioned biconjugate gradient stabilized method
  - Optimised Multicore Performance
- Incorporation in RF Ion Thruster Model

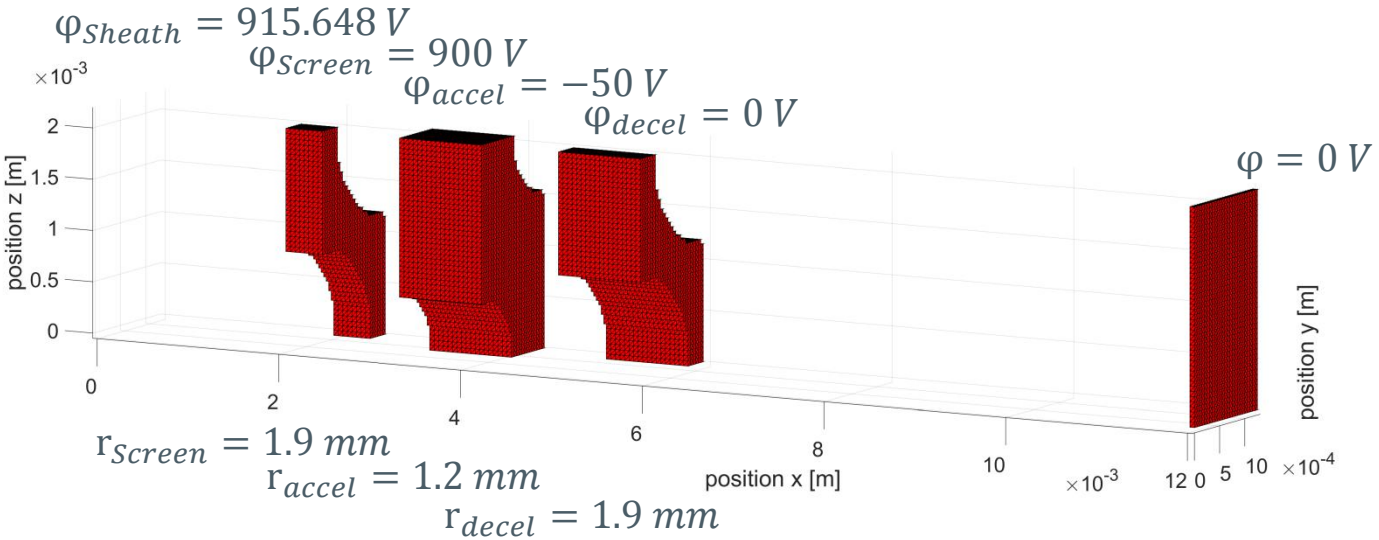
THANK YOUR
FOR
YOUR ATTENTION

ANY QUESTIONS?

First results

System and boundary definition





Symmetrical boundarys

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$n_{i(x=0)} = n_{e(x=0)}$

$v_b = 1{,}476\,m/s$