PLASMA DIAGNOSTICS ON AN ELECTRON CYCLOTRON RESONANCE THRUSTER

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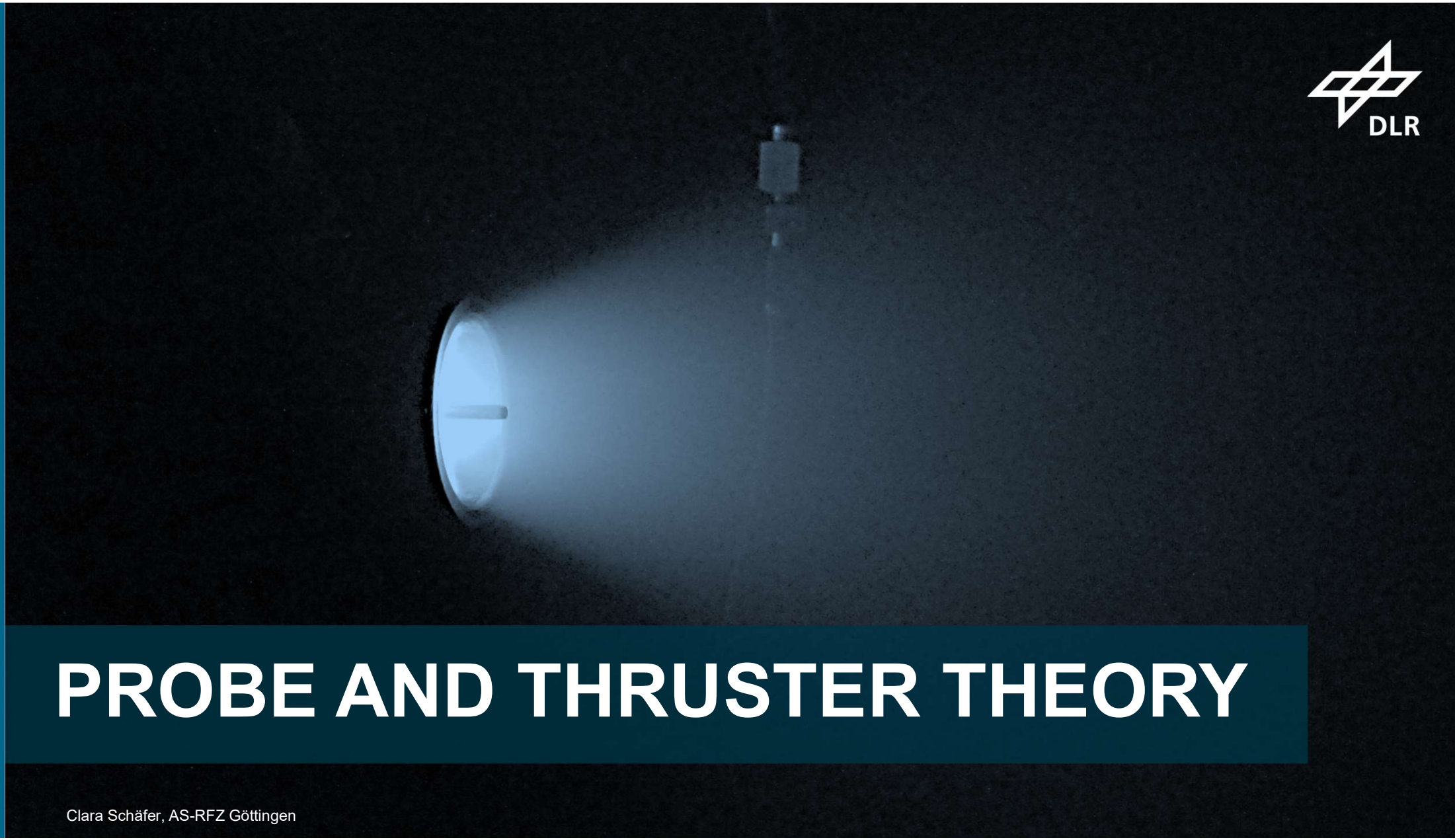


PROBE AND THRUSTER THEORY

Clara Schäfer, AS-RFZ Göttingen

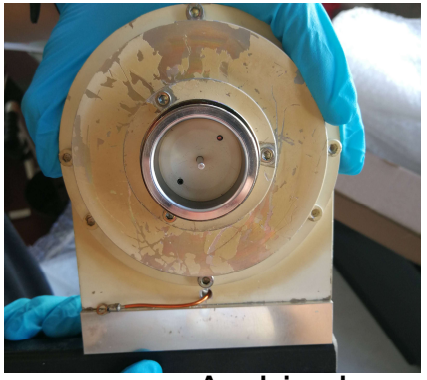
ECRT with magnetic nozzle

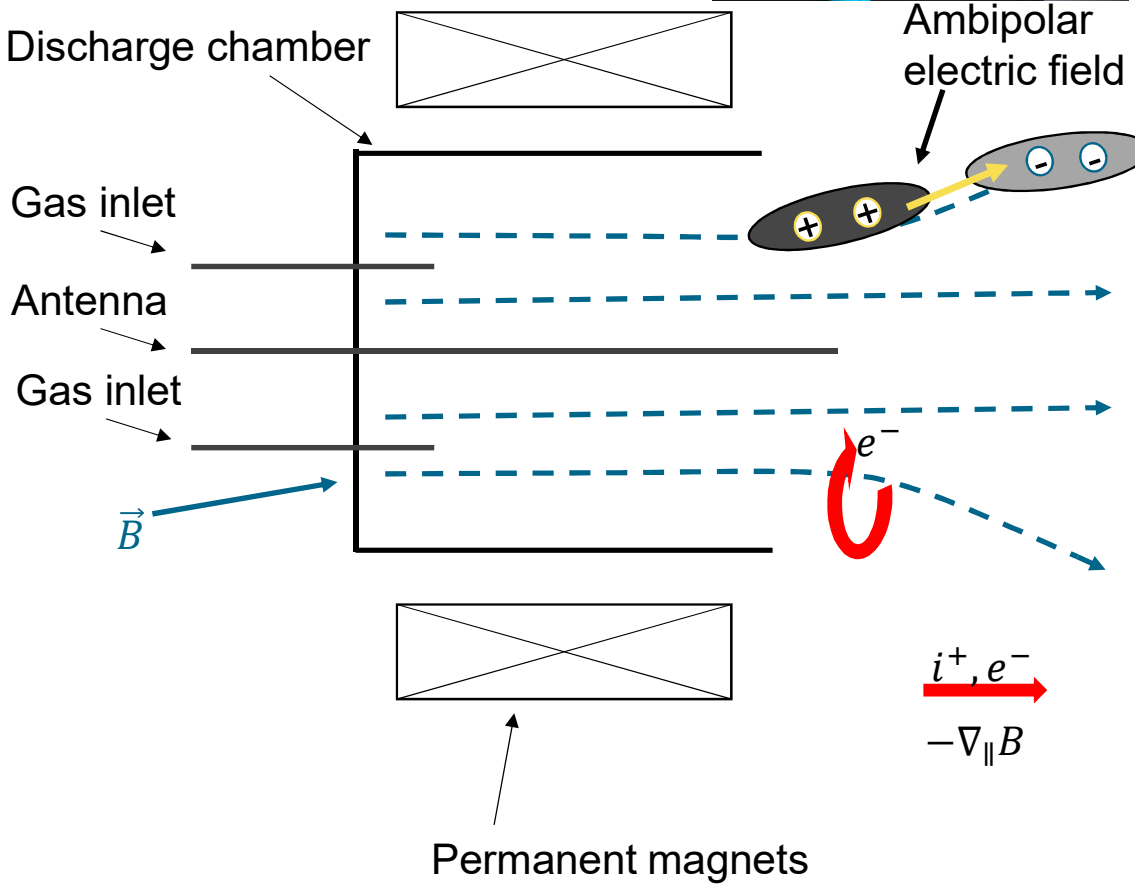
ECR

- Plasma ignition and sustainment by electron cyclotron resonance (ECR).
- Magnetic field: 875 Gauss
- Microwave: 2.45 GHz

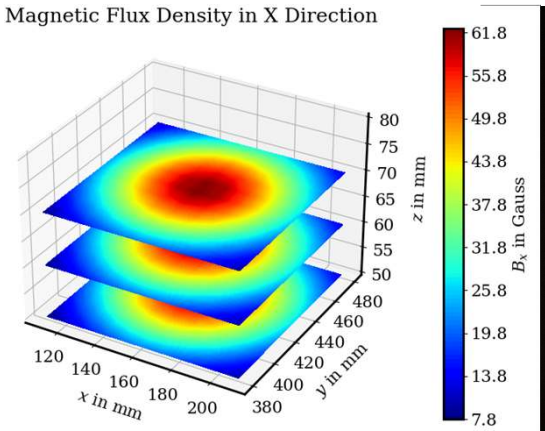
Magnetic nozzle

- Divergent magnetic field leads to acceleration of quasineutral plasma by ambipolar electric field.





Objective

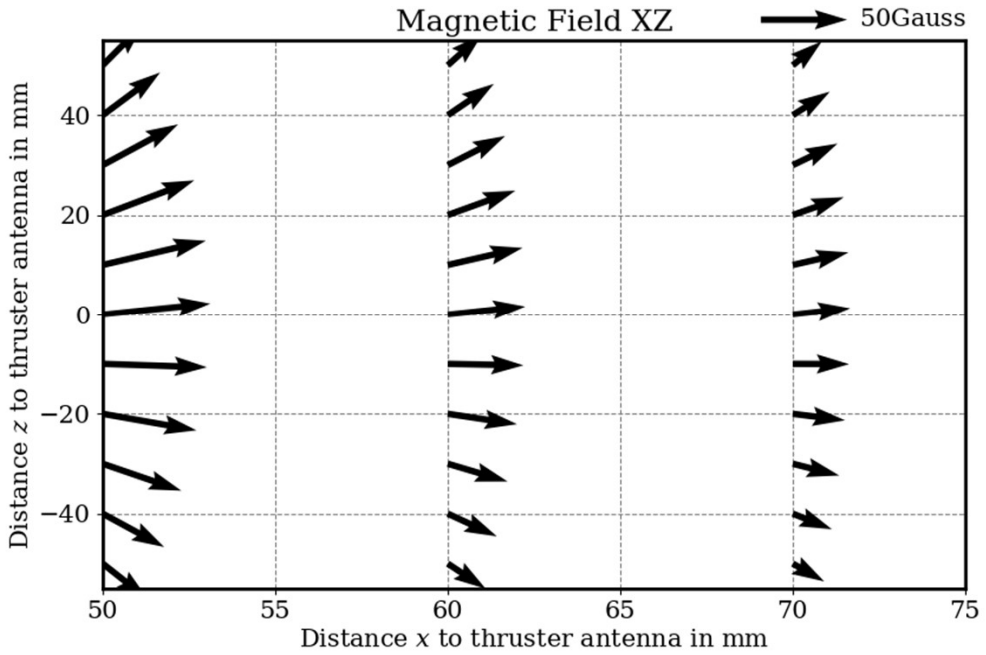


Ignition and performance

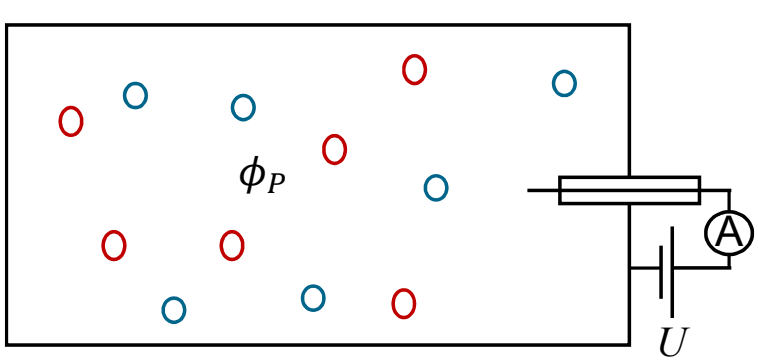
- Ignition possible and how (mass shock)?
- Stable running conditions (thruster potential stable?)
- Performance (forwarded power vs reflected?)

Plasma diagnostics on ECRT

- FC, RPA, magnetic field measurments
- Influences on Langmuir probe
  - In parallel and orthogonal orientation



Langmuir probe

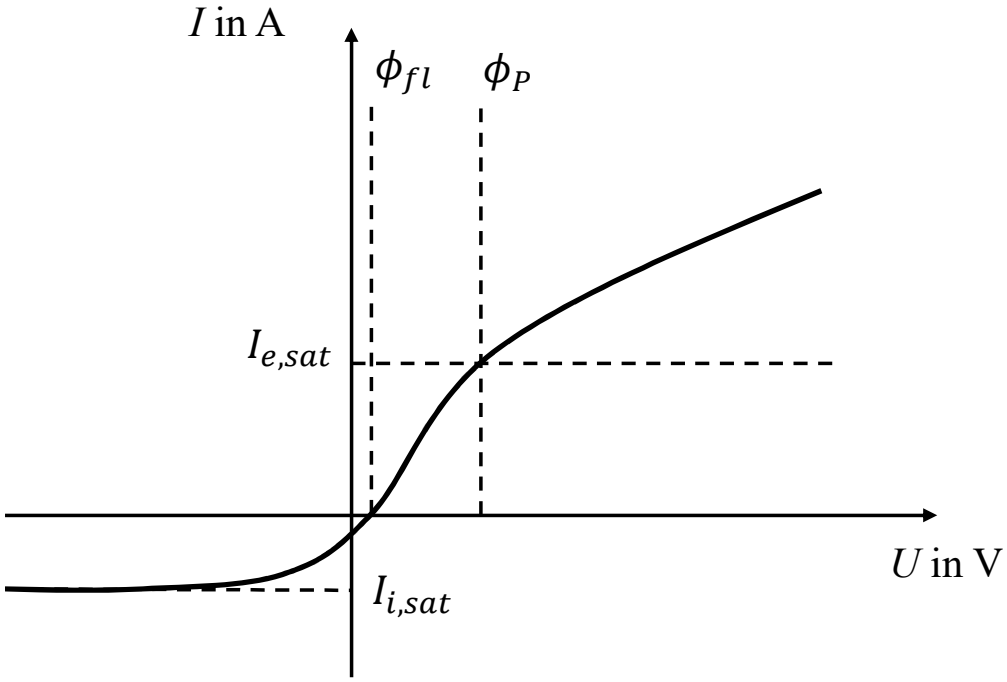


Working principle

- Particles hit surface in dependancy of difference in potential and energy distribution (respectively for ions and electrons).

Interpretation

- Measured current delivers plasma parameter: Floating & plasma potential, ion & electron saturation current, electron energy distribution function (EEDF).



Influences on Langmuir probe measurements by magnetic field

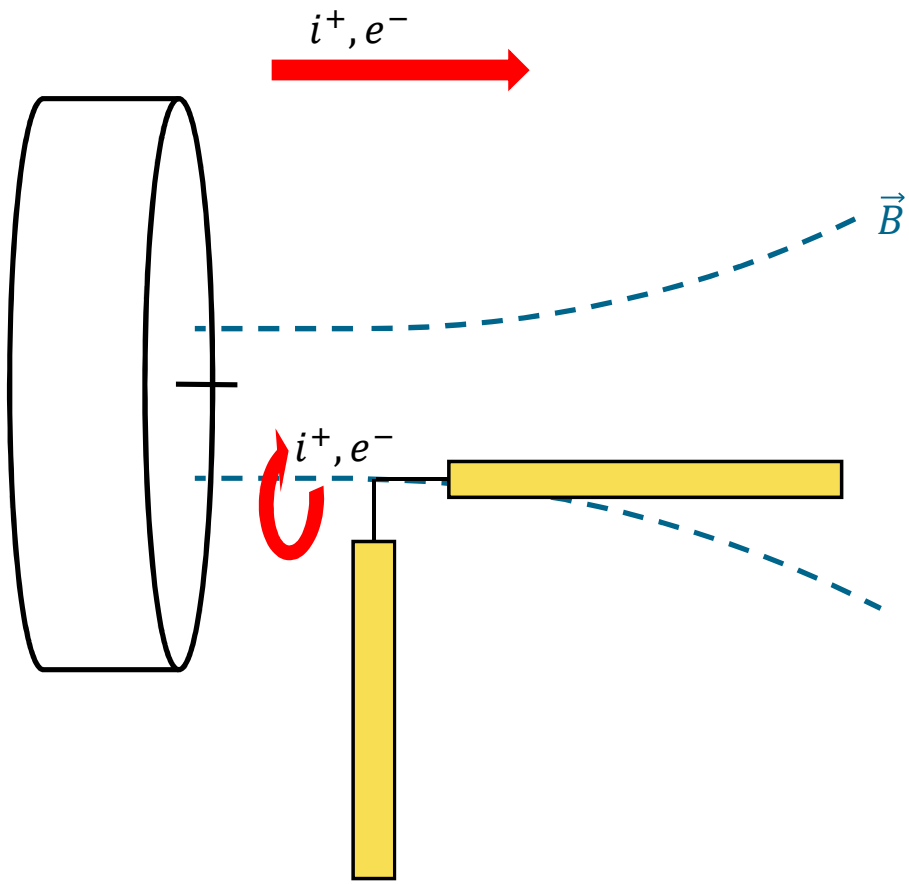
Dryvesteyn method

- Determination EEDF $f(E)$: use proportionality to second derivative of current-voltage-characteristic:

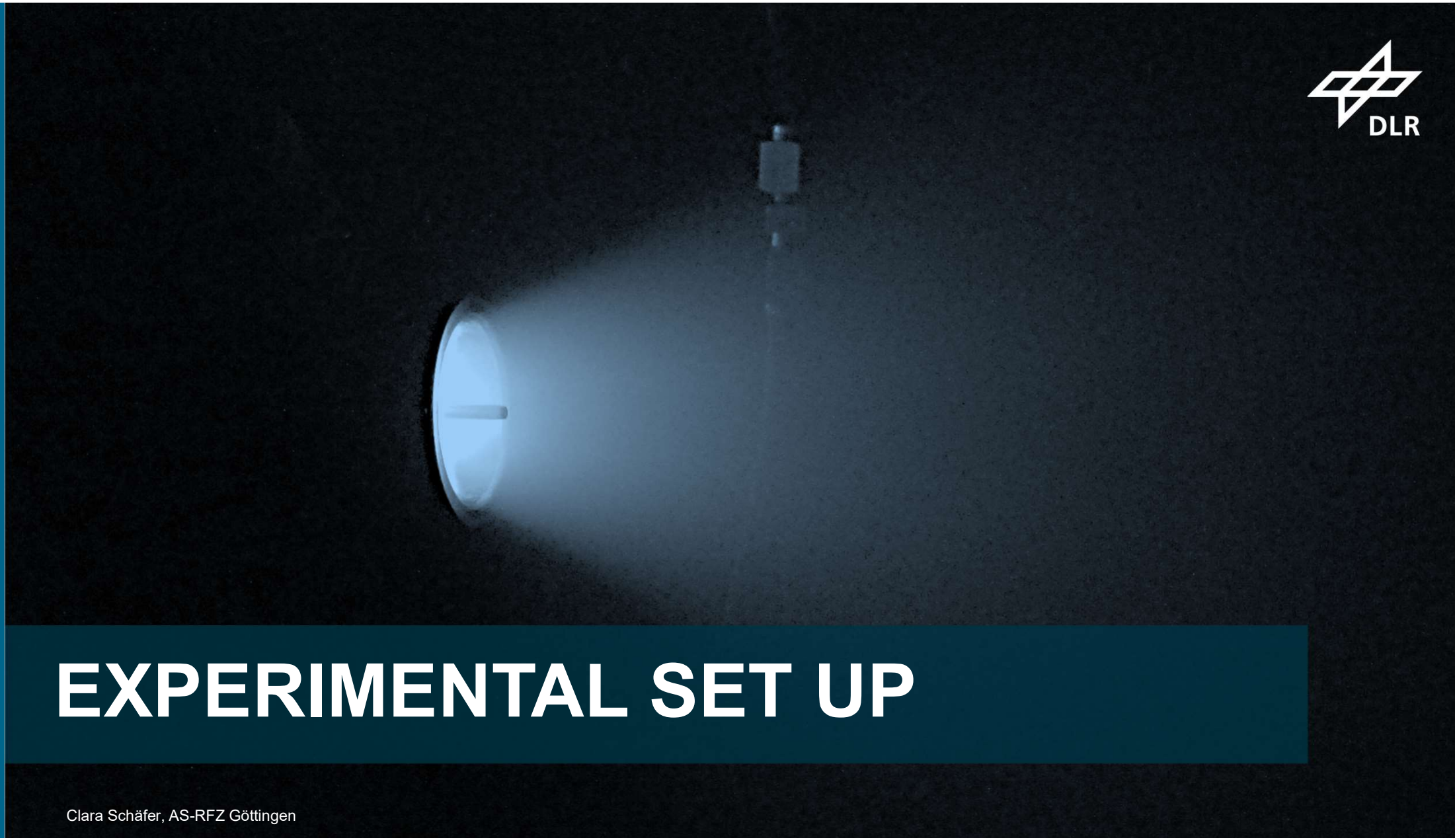
$$f(E) = \frac{2}{e^2 A_\mathrm{P}} \sqrt{(2 m_\mathrm{e} E)} \frac{\mathrm{d}^2 I_\mathrm{e}}{\mathrm{d}E^2}$$

Deposition of particles

- Lobbia et al. [1]:
  - Larmor radius of the particles is much bigger than radius of probe → magnetic field effects can be neglected. Otherwise orthogonal orientation recommended.
  - Anisotropic effects mitigated for probe orientation parallel to drift component.



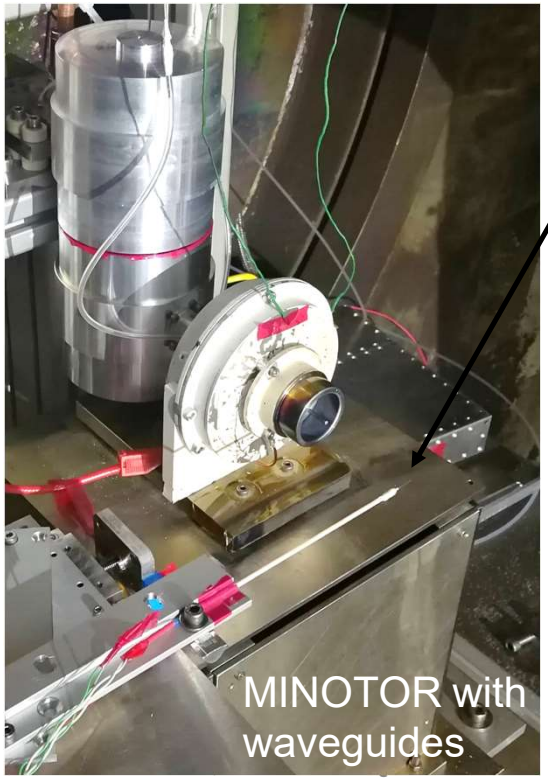
[1] Robert B Lobbia and Brian E Beal. „Recommended practice for use of Langmuir probes in electric propulsion testing“. In: *Journal of Propulsion and Power* 33.3 (2017), pp. 566-581.

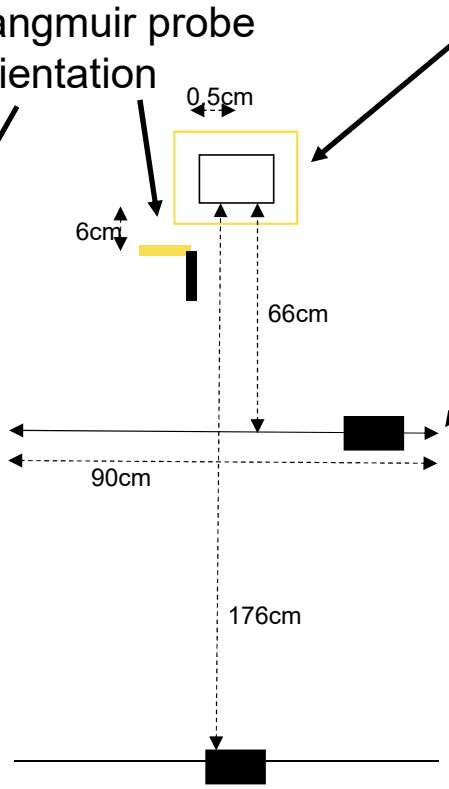


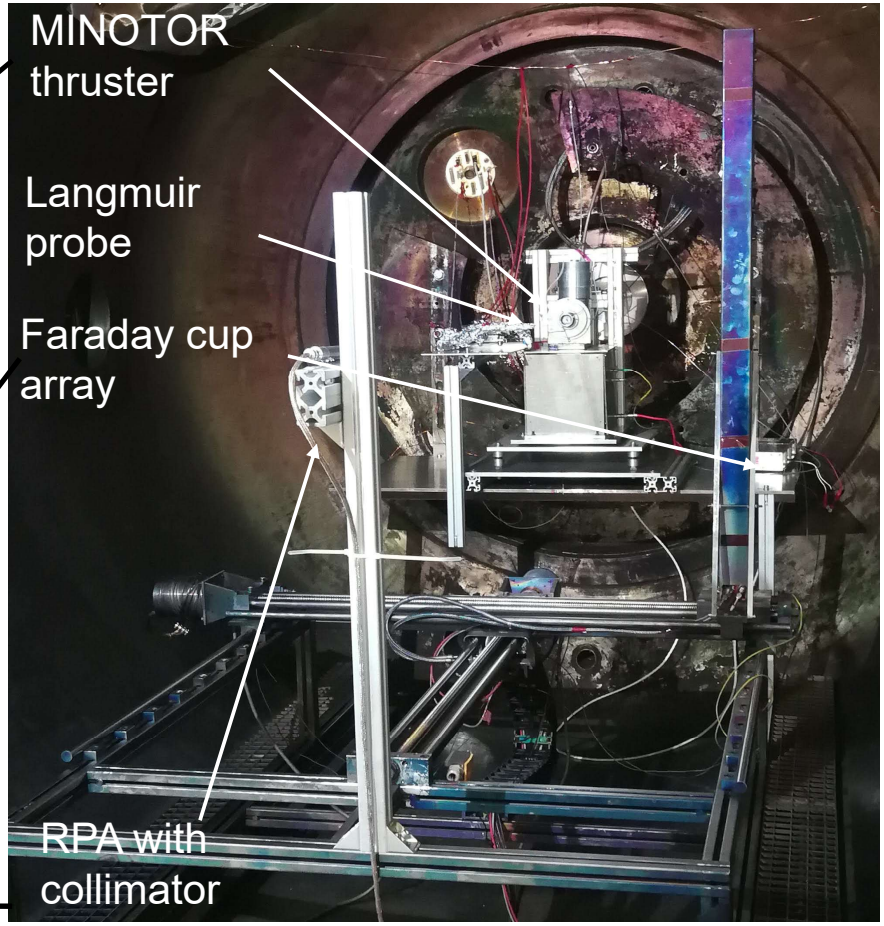
EXPERIMENTAL SET UP

Set up in ‚JUMBO‘- JLU Gießen

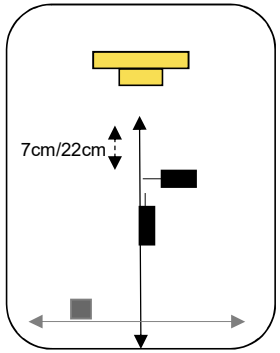
Performance, FC, RPA, magnetic field and Langmuir measurements.





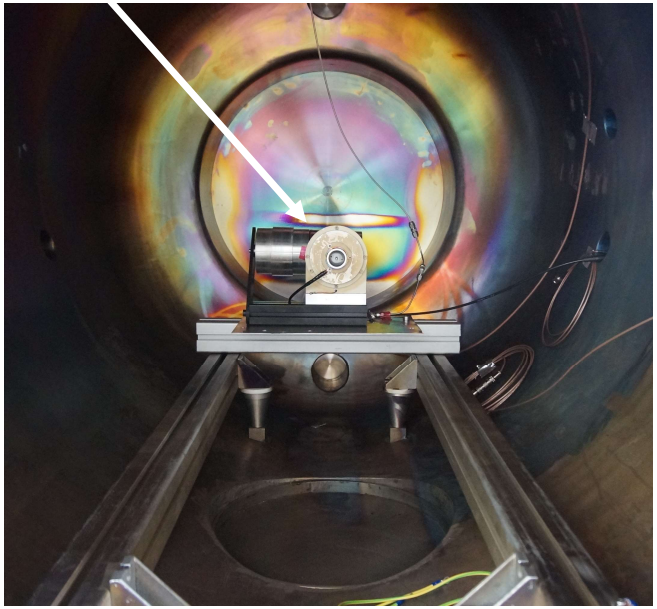


Set up in STG-MT – DLR Gö

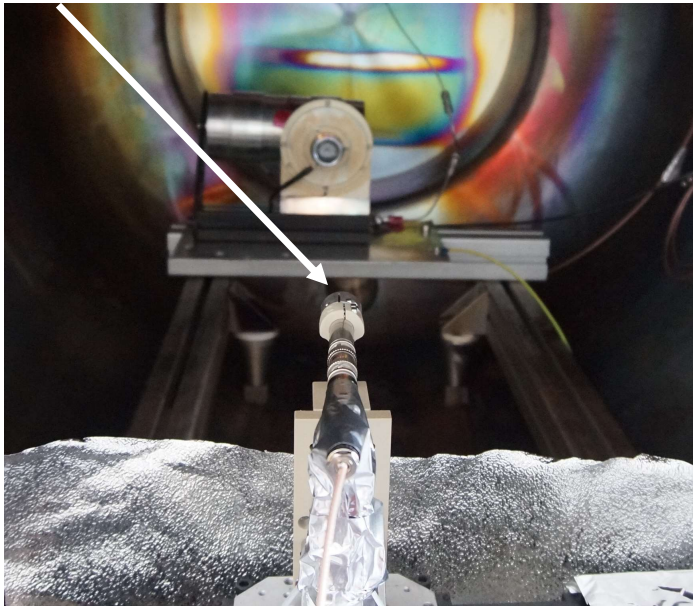


Performance, FC and Langmuir measurements.

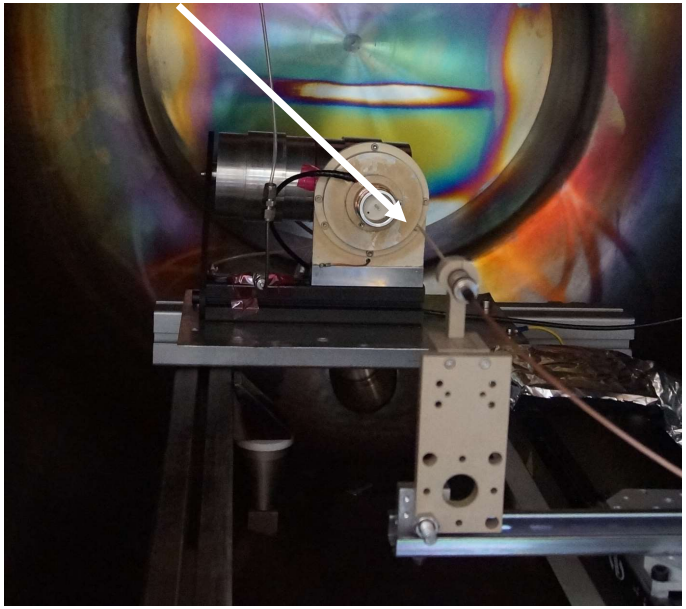
Minotor

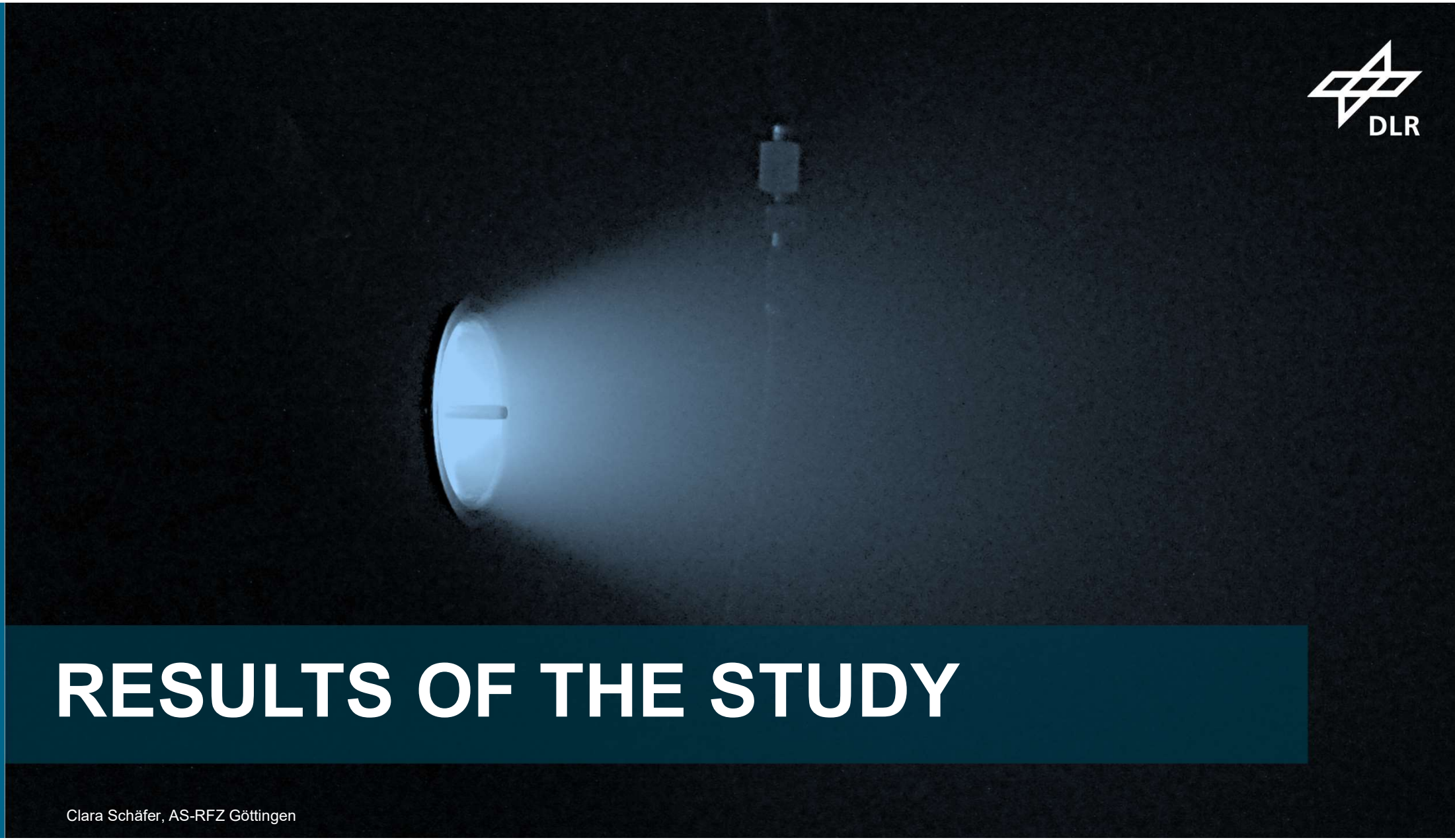


FC



Langmuir probe





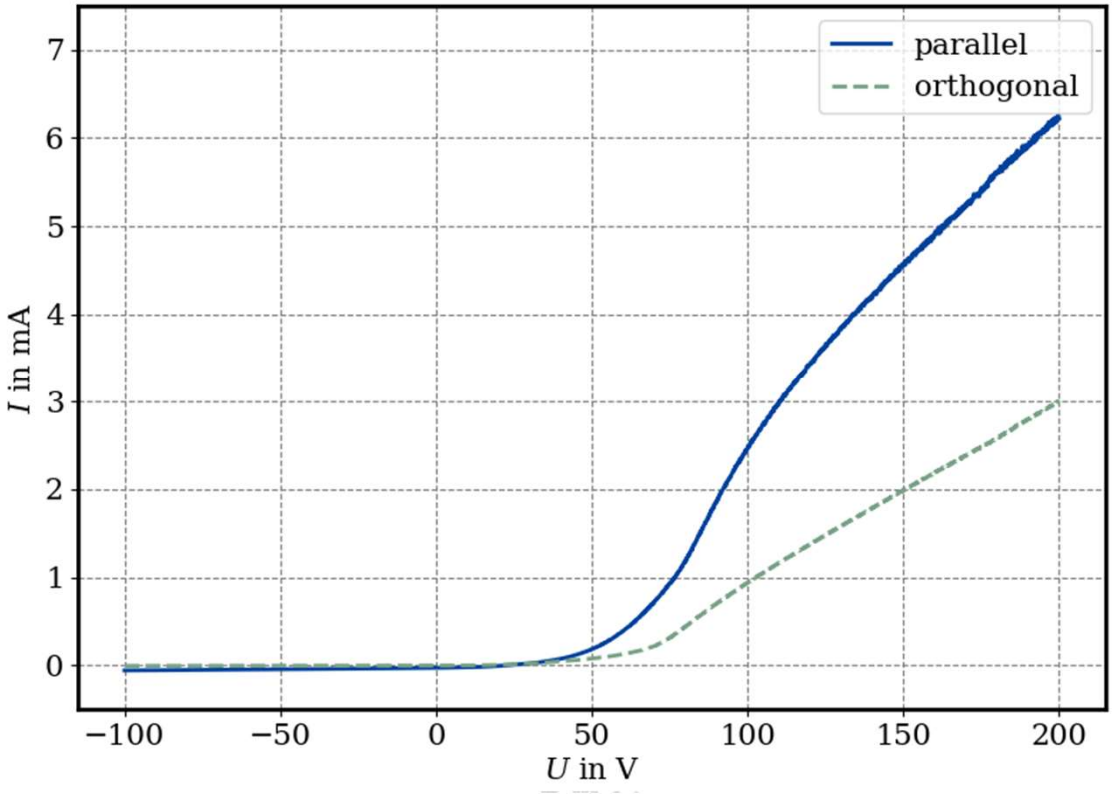
RESULTS OF THE STUDY

EEDF Langmuir Probe - JUMBO

Thruster settings:
1sccm Xenon, 22W microwave power,
background pressure $\sim 10^{-6}$ mbar

Raw data

- Shows significant difference at the same thruster condition and same position in dependency of orientation.



Observations EEDF

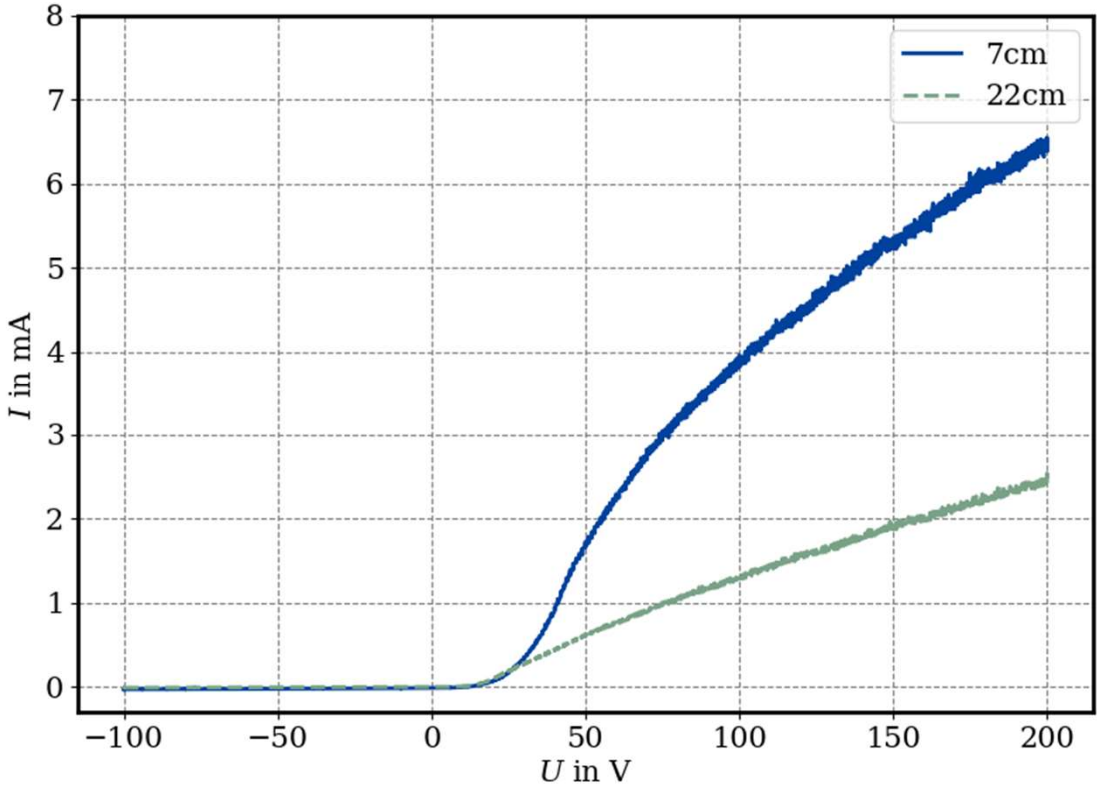
- EEDF shows minimum two energy species in parallel orientation.
- Orthogonal orientation is almost Maxwellian.

EEDF Langmuir Probe – STG-MT

Thruster settings:
1sccm Xenon, 25W microwave power,
background pressure $\sim 10^{-6}$ mbar

Role of distance: Raw data

- Parallel orientation: Shows significant difference at the same thruster condition in dependency of distance.



Role of distance: EEDF

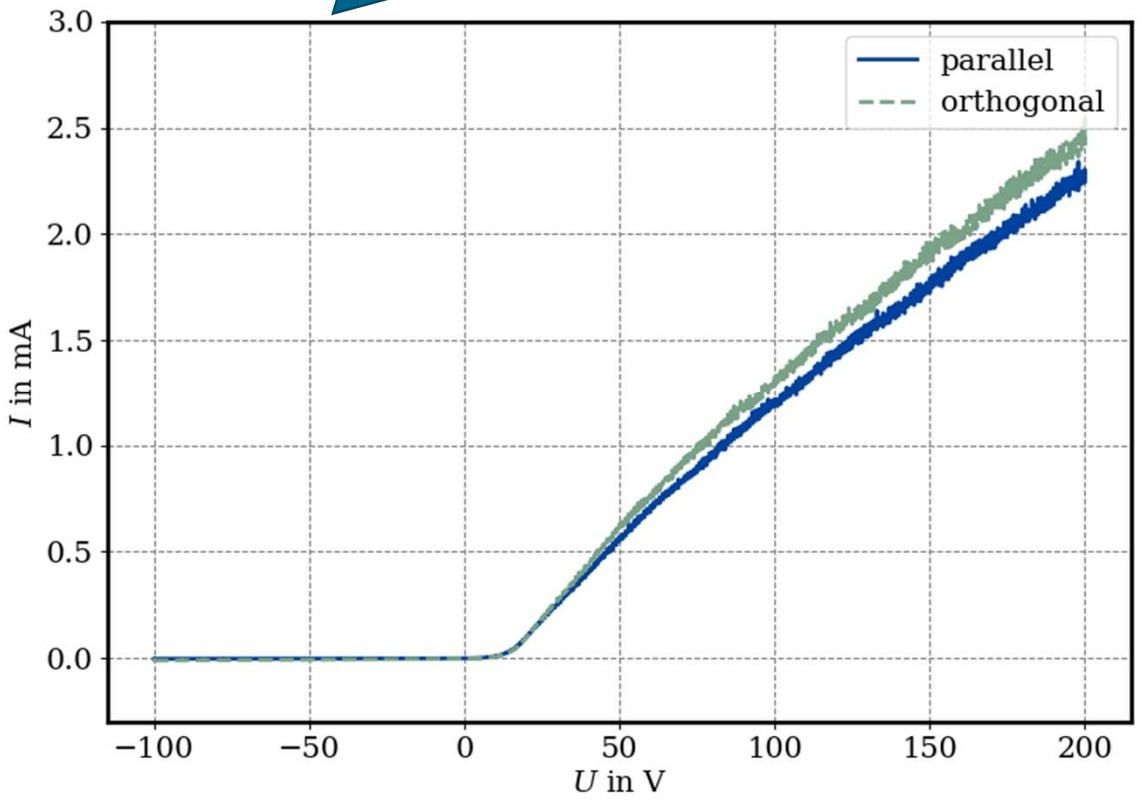
- EEDF shows minimum two energy species near the thruster.
- Further away the energy distribution seems Maxwellian.

EEDF Langmuir Probe – STG-MT

Thruster settings:
1sccm Xenon, 25W microwave power,
background pressure $\sim 10^{-6}$ mbar

Role of orientation: Raw data

- At distance of 22 cm: Shows no significant difference at the same thruster condition and same position in dependency of orientation.



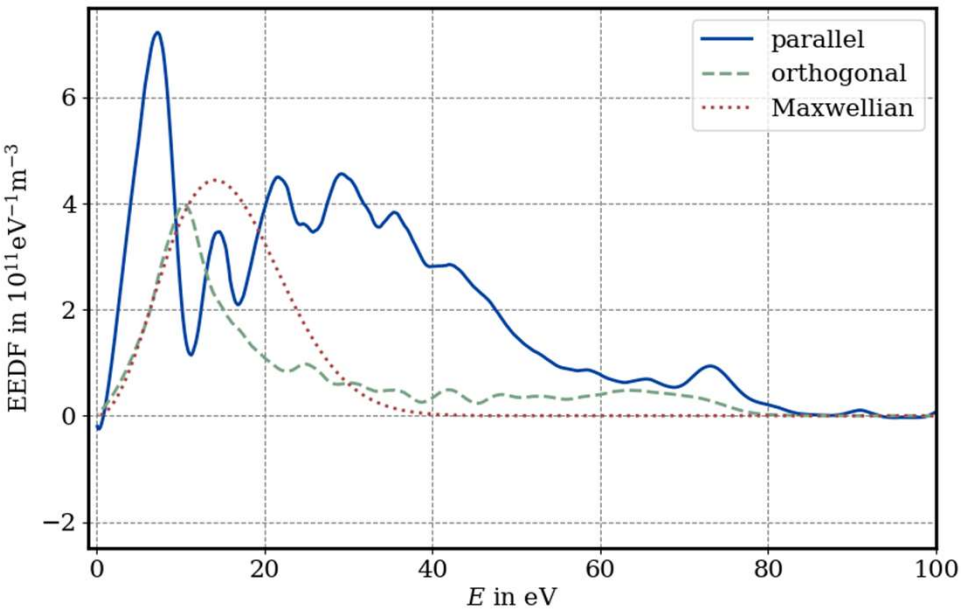
Role of orientation: EEDF

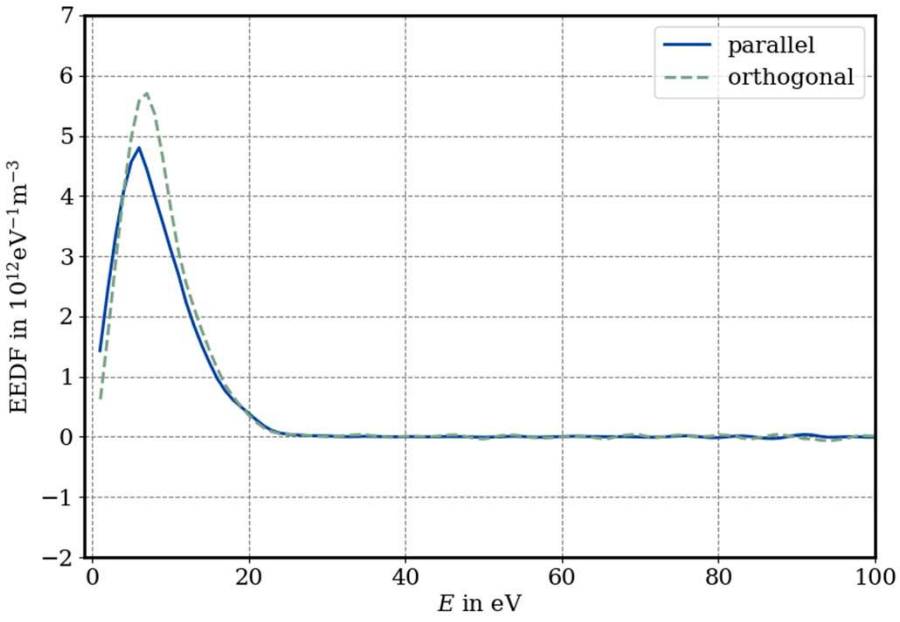
- EEDF is in both cases Maxwellian.
- Both orientations deliver similar plasma parameter.

Next steps

- More precise alignment procedures (3D probes, precise positioning systems).
- Statistical analysis of raw data → no smoothing necessary?!
- Inclusion of non-Maxwellian distribution in evaluation of double Langmuir probe measurements.
- Comparison with non-intrusive diagnostic tools (OES, LIF, …).
- Studies regarding influences due to microwaves.
- Further investigations regarding influences due to background pressure and chamber effects.

Findings

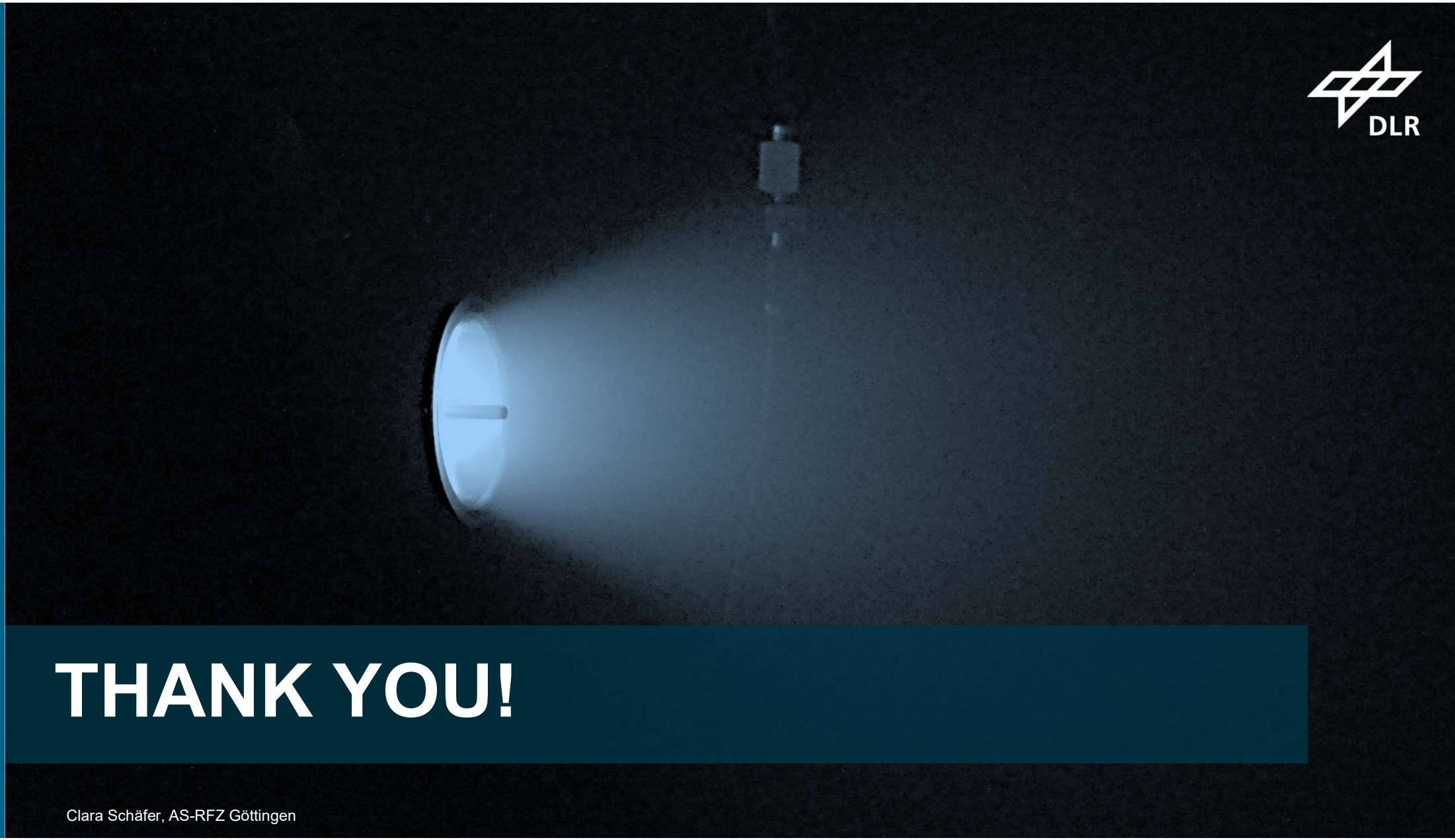




- Langmuir probe orientation with respect to magnetic field lines plays a role in vicinity of the thruster (even though Larmor radius 4×10^{-3}m vs a probe radius of 0.5×10^{-3} m)!
- The electrons have near the thruster a non-isotropic, non-maxwellian distribution.
- Decrease of the magnetic field cause of irrelevance of the probe orientation: In further distance the orientation of the probe plays a minor role with respect to the resulting energy distribution!

Acknowledgment

Warmest thanks to the ion thrusters group at JLU Giessen for their active support in carrying out the experiments!!



THANK YOU!

Bibliography

[1] Robert B Lobbia and Brian E Beal. „Recommended practice for use of Langmuir probes in electric propulsion testing“. In: *Journal of Propulsion and Power* 33.3 (2017), pp. 566-581.

[2] Sara Correyero et al. „Plasma beam characterization along the magnetic nozzle of an ECR thruster“. In: *Plasma Sources Science and Technology* 28.9 (2019), p. 095004.

[3] Walter R Hoegy and Larry H Brace. „Use of Langmuir probes in non-Maxwellian space plasmas“. In: *Review of scientific instruments* 70.7 (1999), pp. 3015-3024.

[4] Ulrich Stroth. *Plasmaphysik*. Springer, 2011. Chap. 2, 9.

Impressum

Thema: Plasma diagnostics on an ECRT:
Influences on Langmuir probe measurements by an ECRT with magnetic nozzle

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