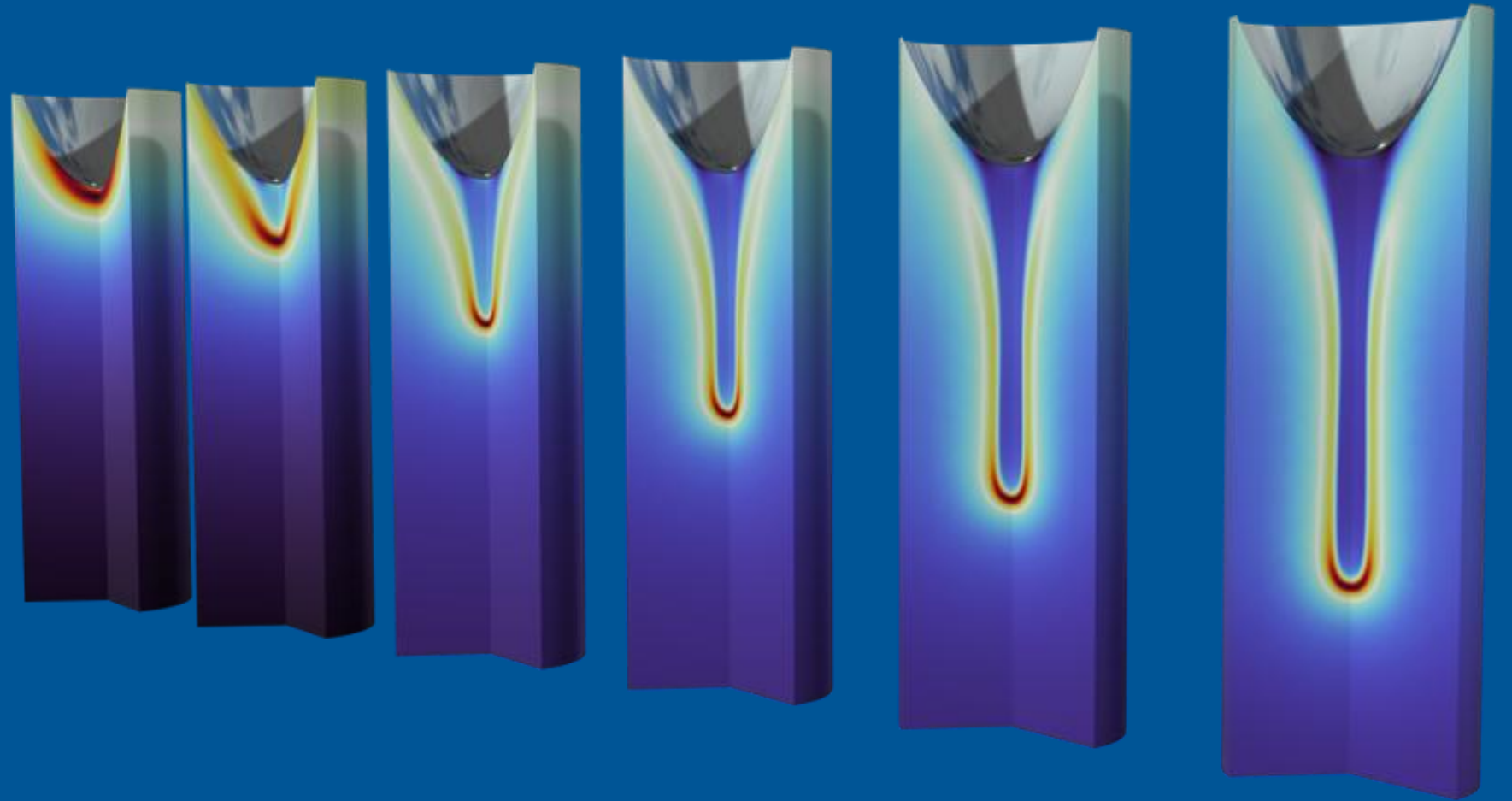


Electric Discharge Module: Printer Head Simulation



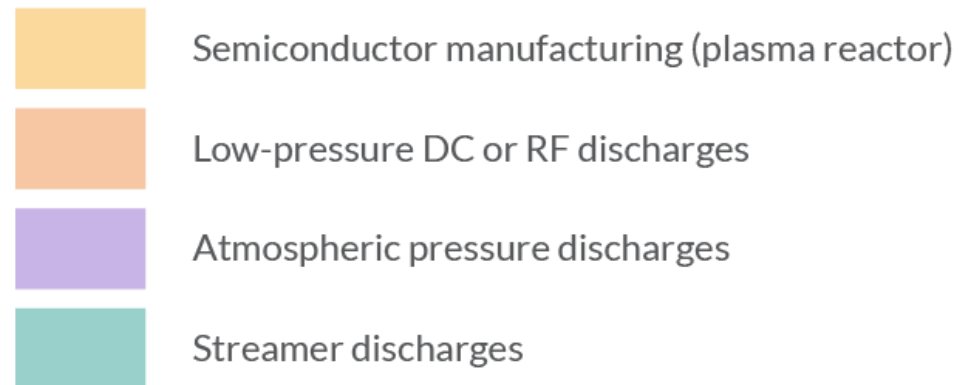
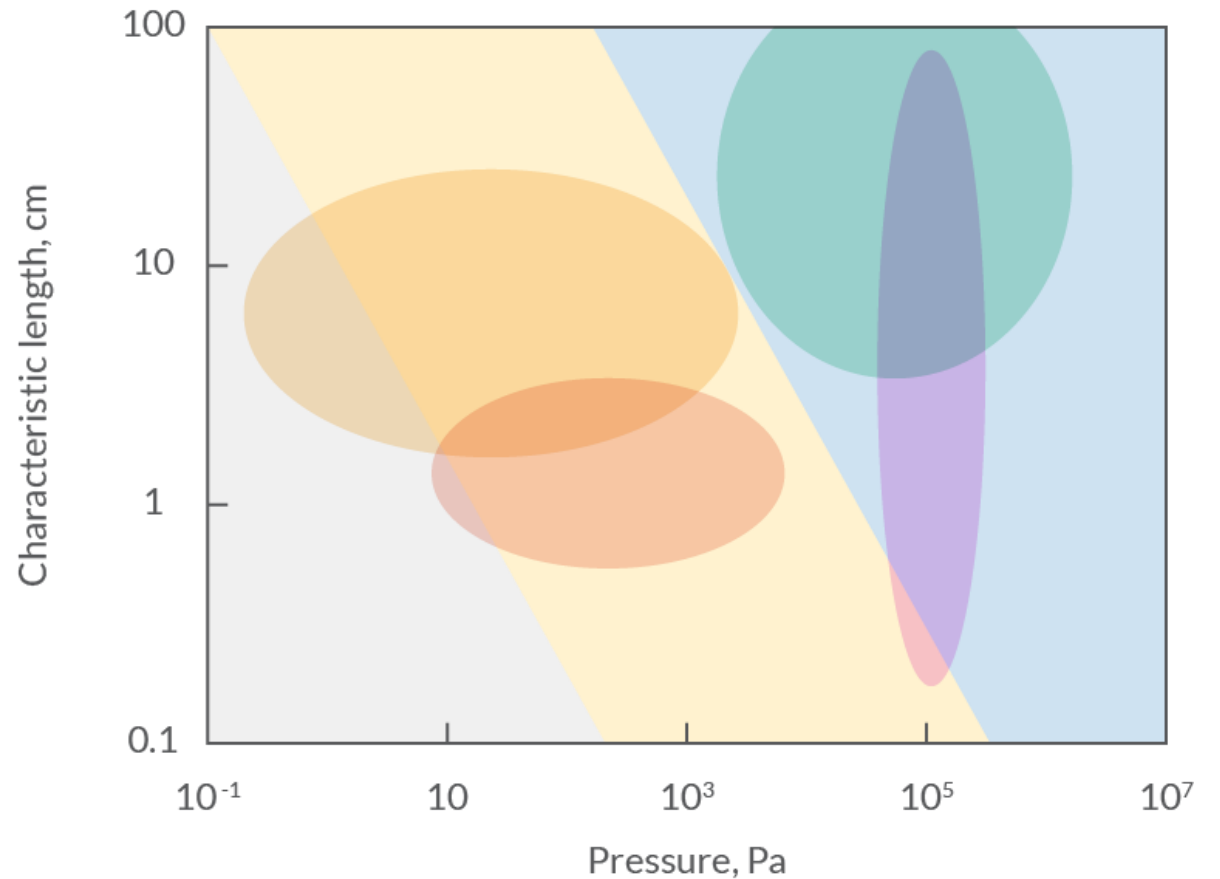
Matouš Lorenc
lorenc@humusoft.cz



Electric Discharge Module

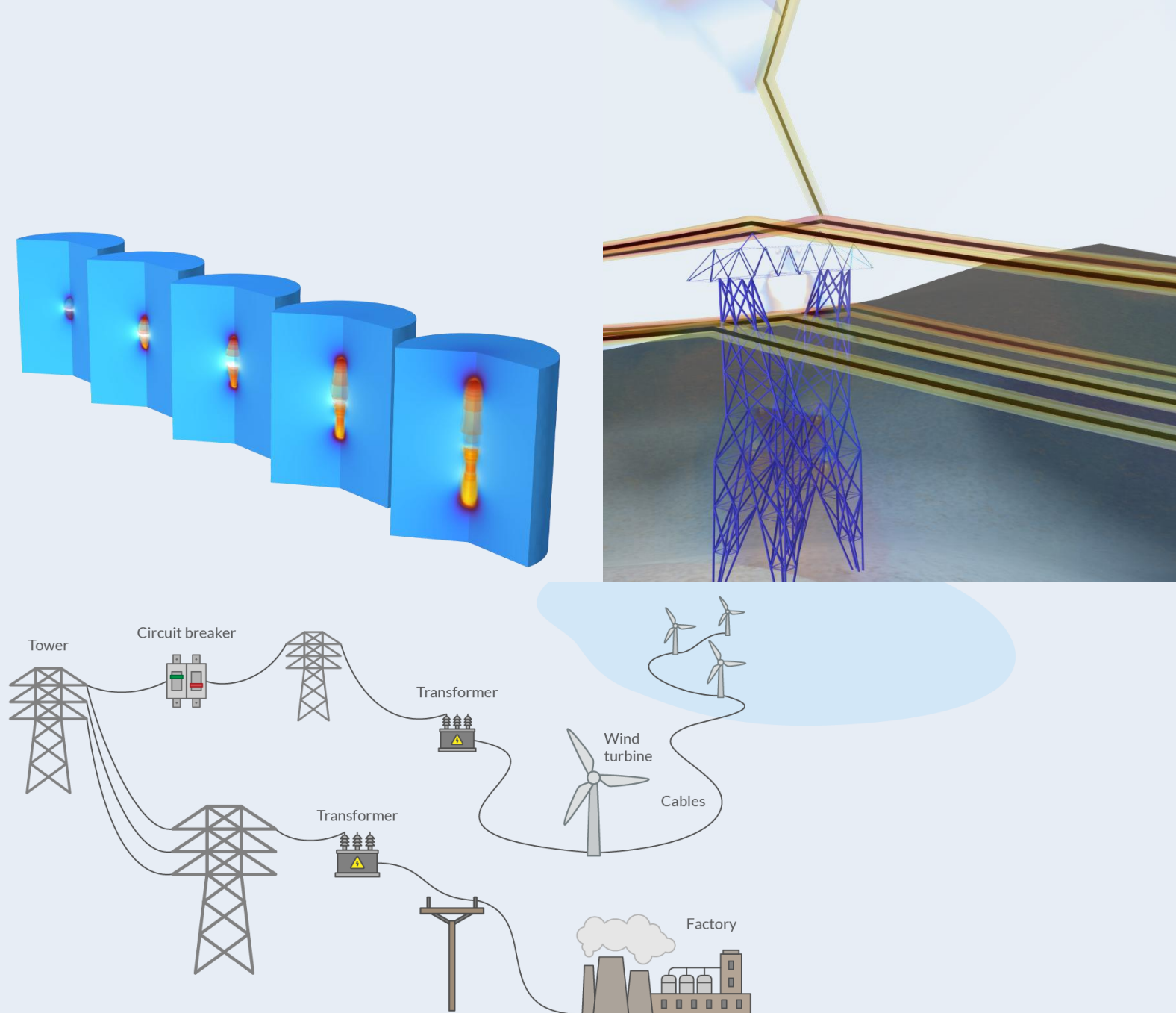
Electric Discharge Module or Plasma Module?

- The Electric Discharge Module is designed for atmospheric and high-pressure gas discharges, while the Plasma Module focuses on low-pressure gas discharges
- The Electric Discharge Module also enables simulations of discharge and charge transport in liquids and solids, unlike the Plasma Module, which is limited to plasma modeling in gases



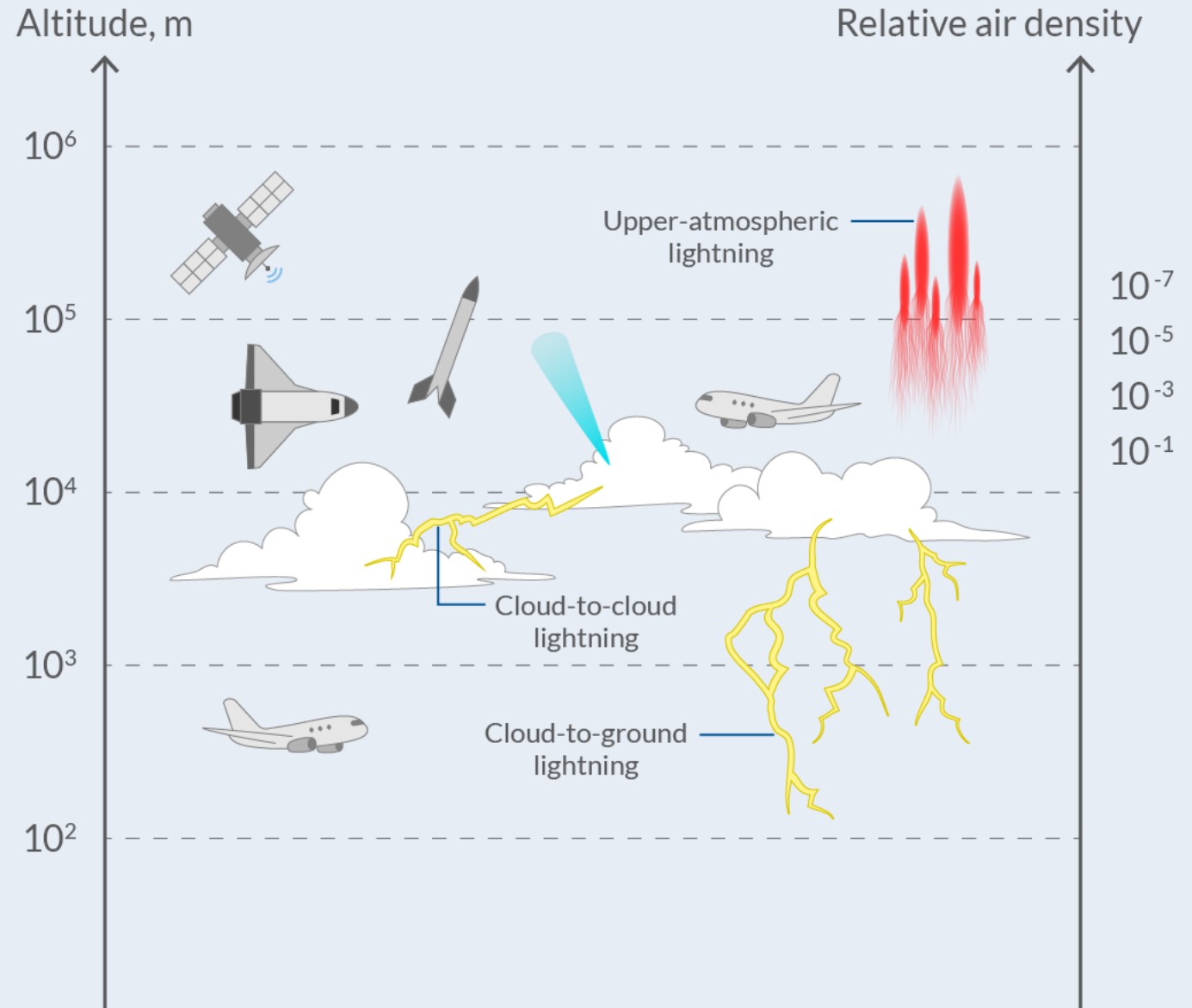
Electrical Insulation in Power Systems

- Internal insulation
 - Transformers
 - Circuit breakers
 - Cables
 - Gas-insulated switchgear (GIS)
- External Insulation
 - Insulators (overhead lines)
 - Bushings
 - Switching overvoltage
 - Lightning overvoltage



Electrical Insulation in Aerospace

- Aerospace vehicles are subject to a variety of electric discharges that can cause electrical insulation failure:
 - Internal discharge such as electric arcs
 - External discharge such as lightning
- The aerospace environment can be extreme, and the discharge is highly dependent on air pressure.
- Sustainable and clean energy drives greater use of composites, making electrical insulation more challenging.
- Simulation is an important tool for understanding and designing new insulation systems before experimentation.



Electric Discharge Processes

Charge

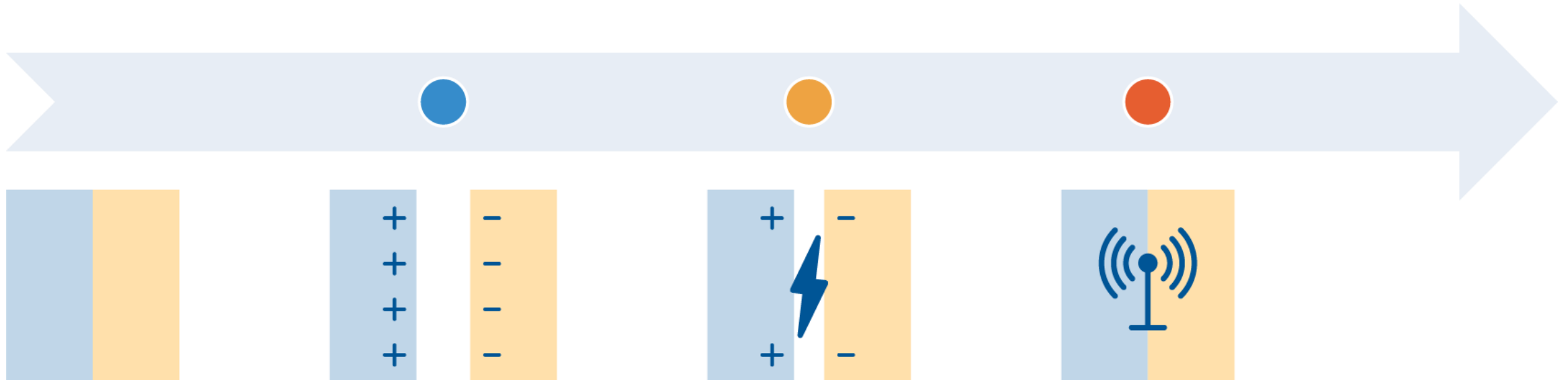
- Charge generation:
 - Charge separation
 - External charging
- Charge accumulation

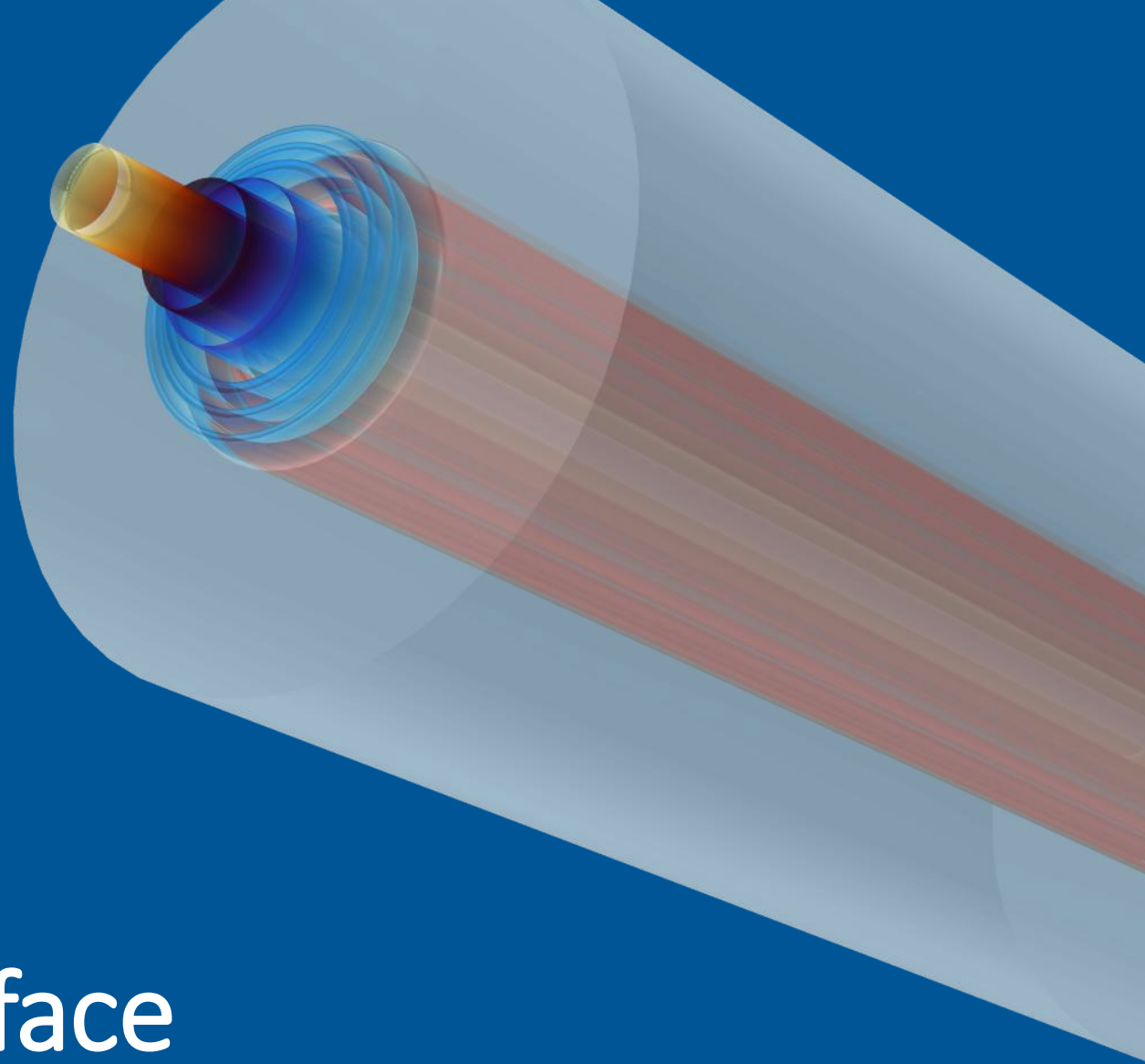
Discharge

- Charge relaxation
- Electric discharge:
 - Conductor–conductor
 - Insulator–conductor

After Discharge

- Direct effects
- Indirect effects:
 - Electric field coupling
 - Magnetic field coupling





Electric Discharge Interface

Gas/Liquid/Dielectric Discharges

- Define your medium:
 - Model atmospheric and high-pressure gas discharges using fluid and local field approximations
 - Model liquid dielectrics, such as transformer oil
 - Model solid dielectrics, such as a polyethylene layer
- Solve transport equations for electrons, positive ions, and negative ions
- Incorporate processes like impact ionization, attachment, and recombination

streamer_in_transformer_oil.mph - COMSOL Multiphysics

File Home Definitions Geometry Sketch Materials Physics Mesh Study Results Developer

Application Builder Model Manager Component 1 Add Component 1 Parameters Variables Functions Equation Contributions Build All Import LiveLink Add Material Electric Discharge Add Physics

Workspace Model Definitions Geometry Materials Physics

Model Builder

streamer_in_transformer_oil.mph

- Global Definitions
- Component 1
 - Definitions
 - Geometry 1
 - Materials
 - Electric Discharge
 - Liquid 1
 - Initial Values 1
 - Insulation 1
 - Electrode 1
 - Electrode 2
 - Axial Symmetry 1
 - Mesh 1
 - Study 1
 - Step 1: Time Dependent
 - Solver Configurations
 - Results
 - Datasets
 - Derived Values
 - Tables
 - Color Tables
 - 2D Plot Group 1
 - 1D Plot Group 2
 - 1D Plot Group 3
 - Export
 - Reports

Settings

Liquid

Constitutive Relation D-E

Dielectric model:

Relative permittivity: ϵ_r From material

Transport Properties

Transport mechanisms

- Electric field drift
- Magnetic field drift
- Convection
- Diffusion

Drift

Electron mobility: μ_e From material

Positive ion mobility: μ_p From material

Negative ion mobility: μ_n From material

Reactions

Field ionization

Number density of ionizable species: n_{ioni} From material

Molecular separation distance: a From material

Effective electron mass: m^* From material

Ionization potential: φ_{Δ} From material

Parameter: φ_{γ} From material

Attachment

Attachment time constant:

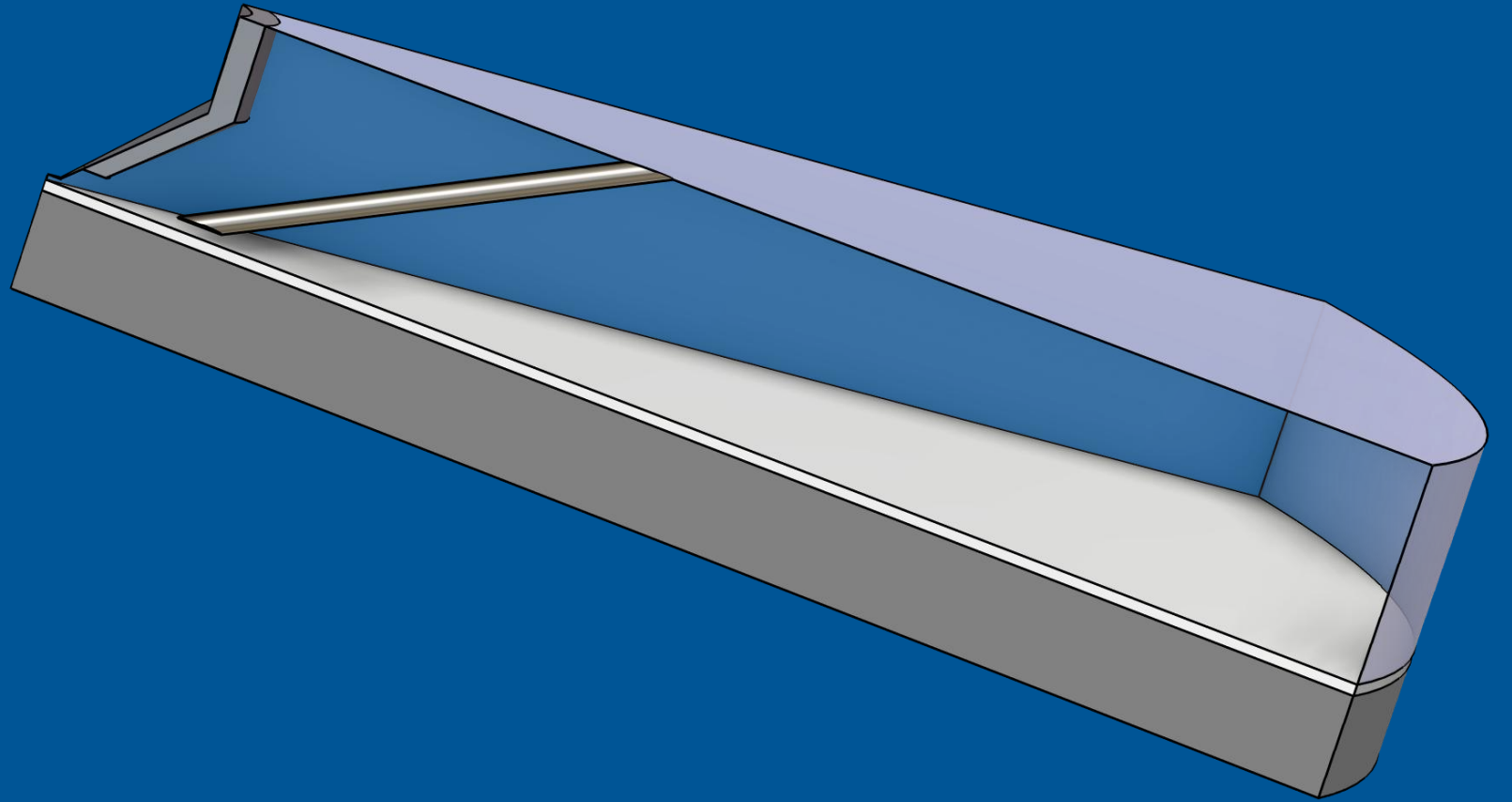
Graphics

Space Charge Density and Electric Field

Time=90 ns

Surface: Space charge density

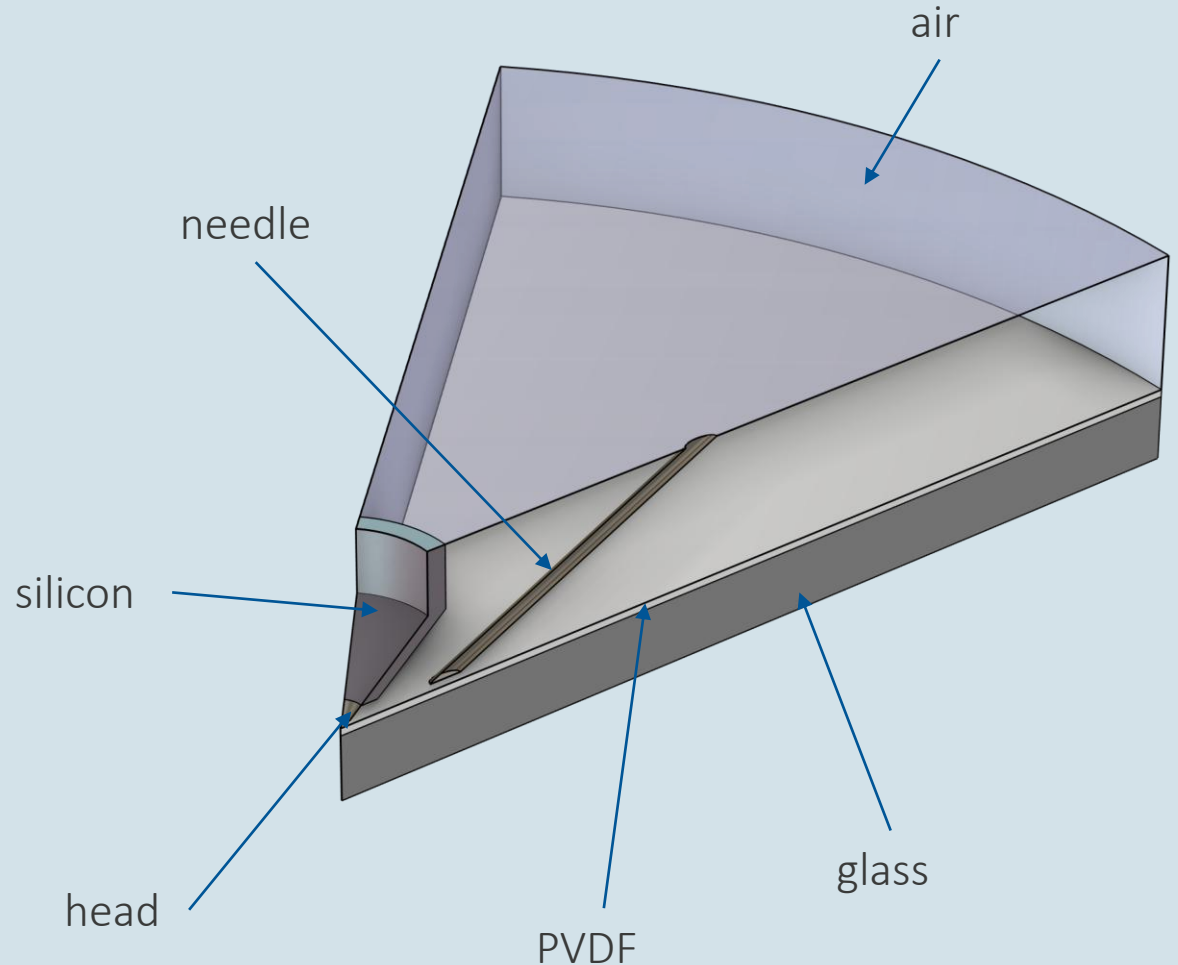
Messages Progress Log



Printer Head Simulation

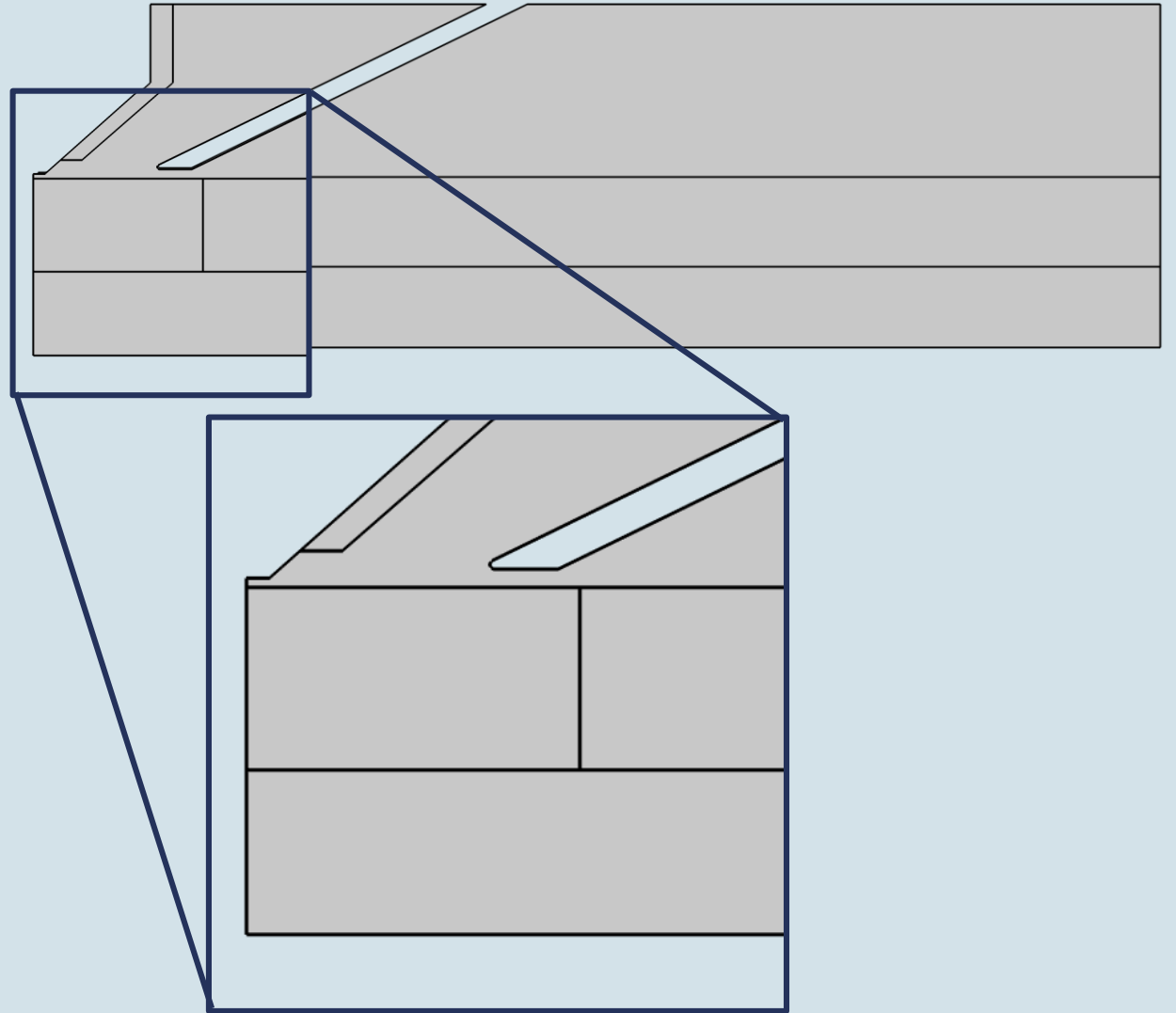
Adding The Space Charge Density

- Electrostatic base model substituted by Electric Discharge interface
 - Is there an influence of the space charge density?
- Challenges:
 - High mesh sensitivity
 - Finding the right initial potential value
- Setup tuning done in 2D

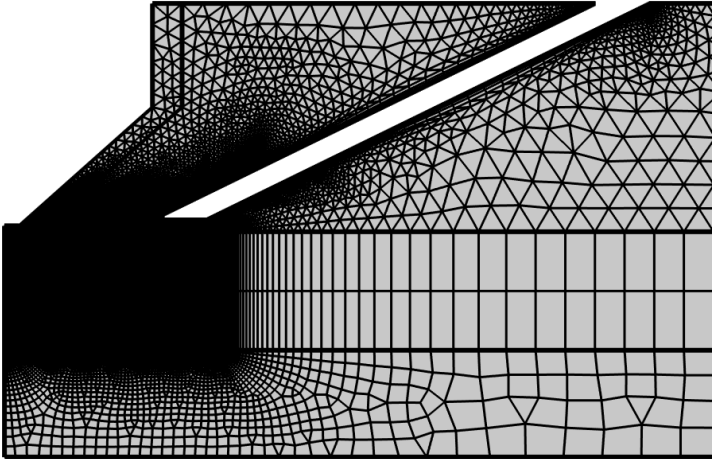


Model Adjustments

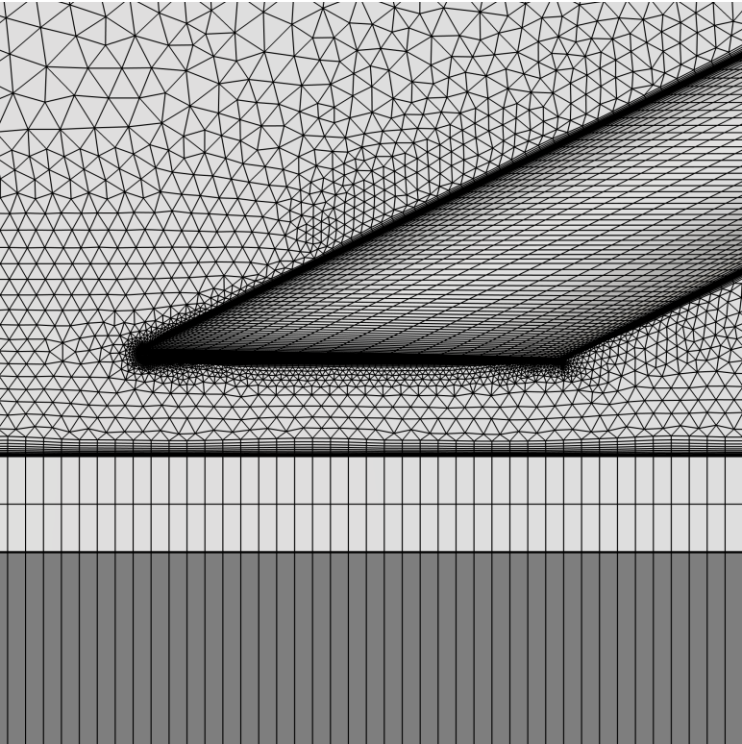
- Reducing the geometry radius
 - Verified geometry downsizing
 - Reduced computation time and increased stability
- Filleted needle tip
 - Removing the electric field singularity



Starting from 2D



2D: 134k DOF

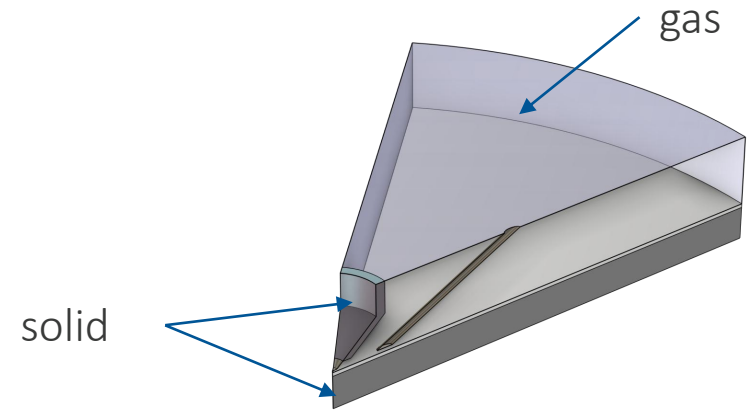


3D: 4000k DOF

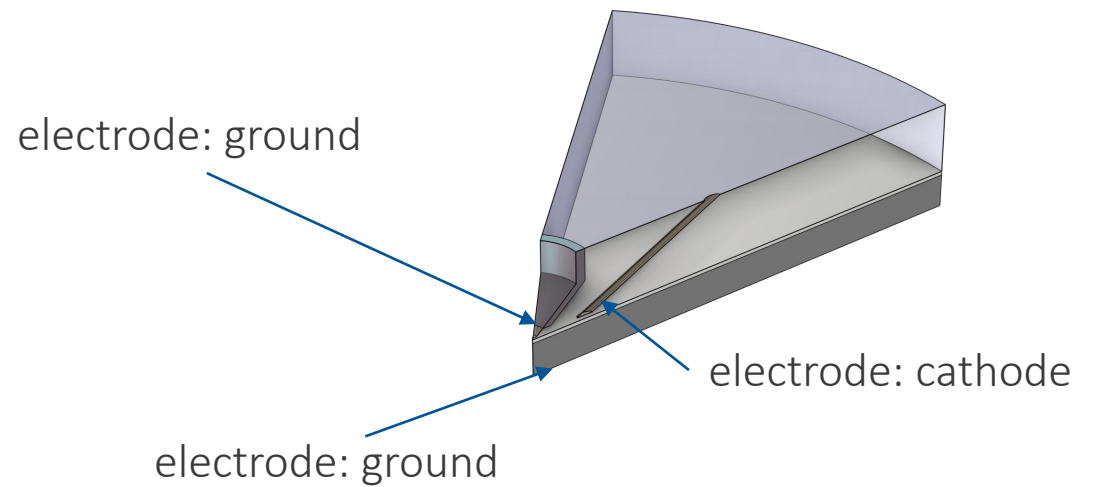
3D Model

- Solid medium doesn't allow charge transport and ionization
- Gas medium does: Air [Kang et al. 2003]
- Electrodes
 - Ground: head and glass base
 - Cathode: needle

Domain conditions

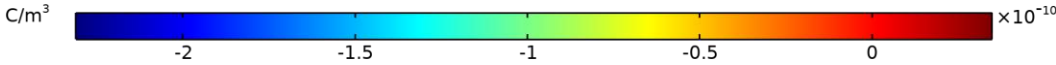
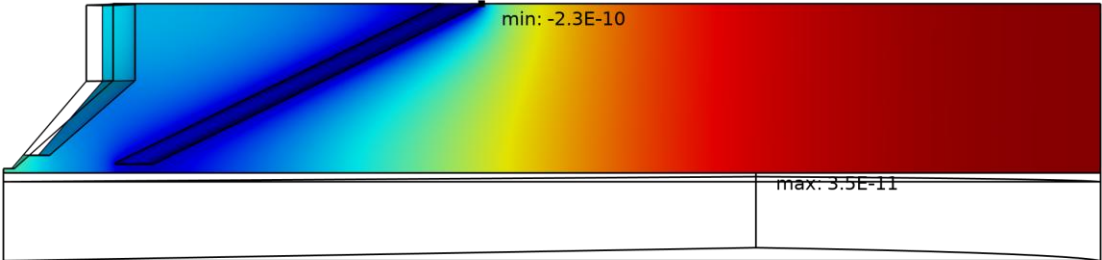


Boundary conditions

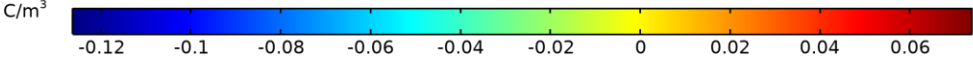


Space Charge Density Role

Initial step: 1E-3 V

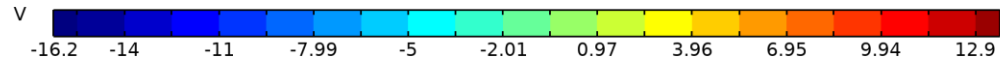
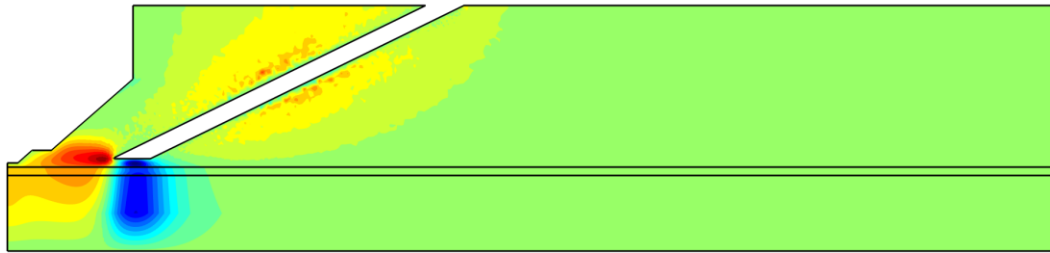


Final step: 1805 V



Electrostatics vs. Electric Discharge

Corona opening around: 1725 V



Final step: 1805 V

