COMSOL CONFERENCE
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Multiphysics Analysis of a Thermo Acoustic MHD Inductive Generator

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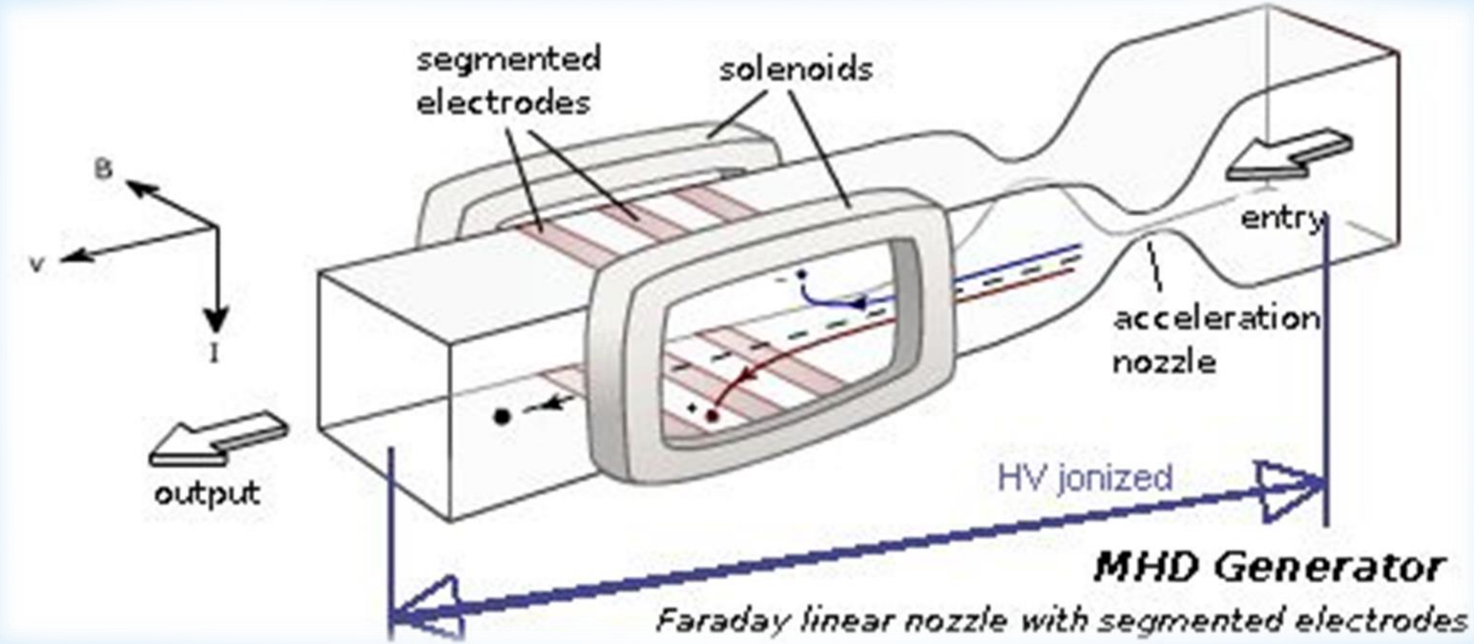
Outline

- Introduction
  - Main problems of known MHD generators
  - Main features of the proposed device
  - Principle of functioning
- FEM analysis
- Numerical Results
- Conclusions & Future work

Introduction



WIKIPEDIA
https://en.wikipedia.org/wiki/Magnetohydrodynamic_generator#/media/File:MHD_generator_(En).png

Schematic view of the MHD conversion principle

- **Drawbacks of classical MHD generators:**

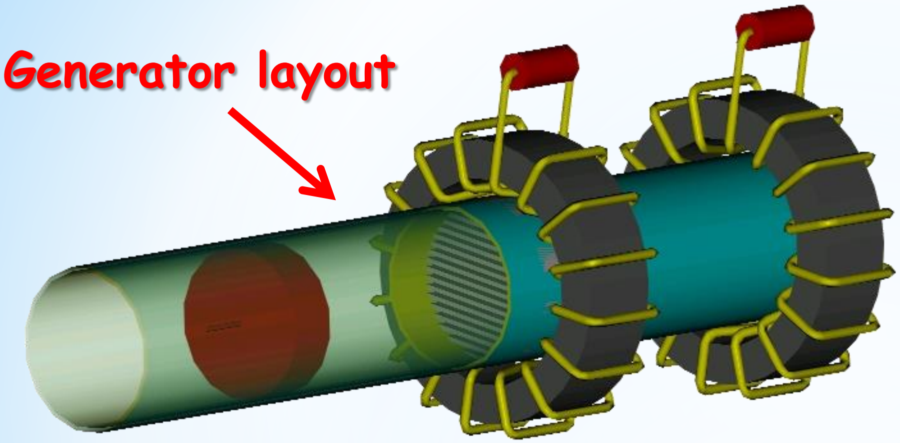
  - Need of very high external Magnetic Field
  - High temperatures are needed to ionize fluid
  - Seeding Recovery
  - Deterioration of electrodes
  - Need for flowing working fluid

- **Advantages of the proposed device**

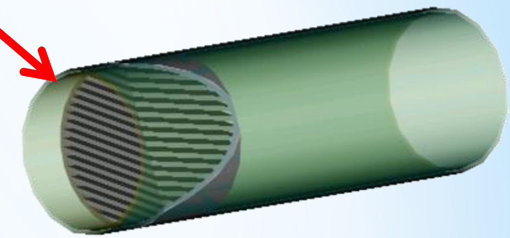
  - No external Magnetic Field
  - No Superconducting Coils
  - High Performance at Low Temperatures
  - No seeding
  - Quasi - Static working fluid

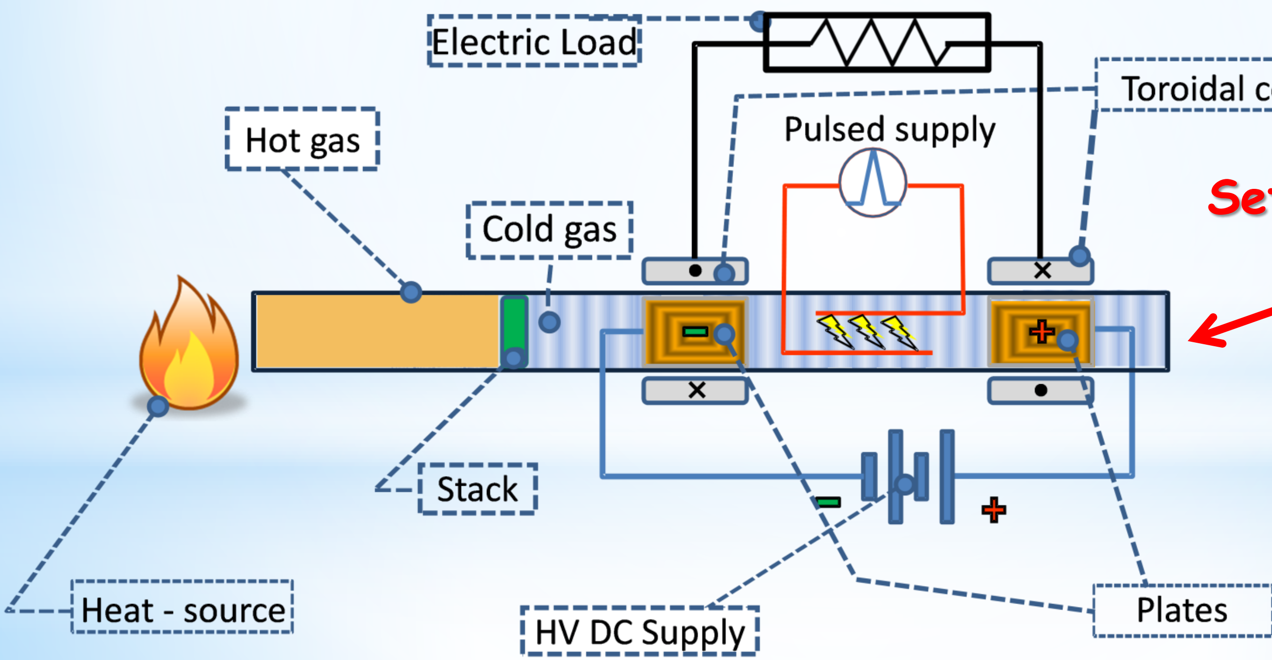
Principle of functioning

Generator layout



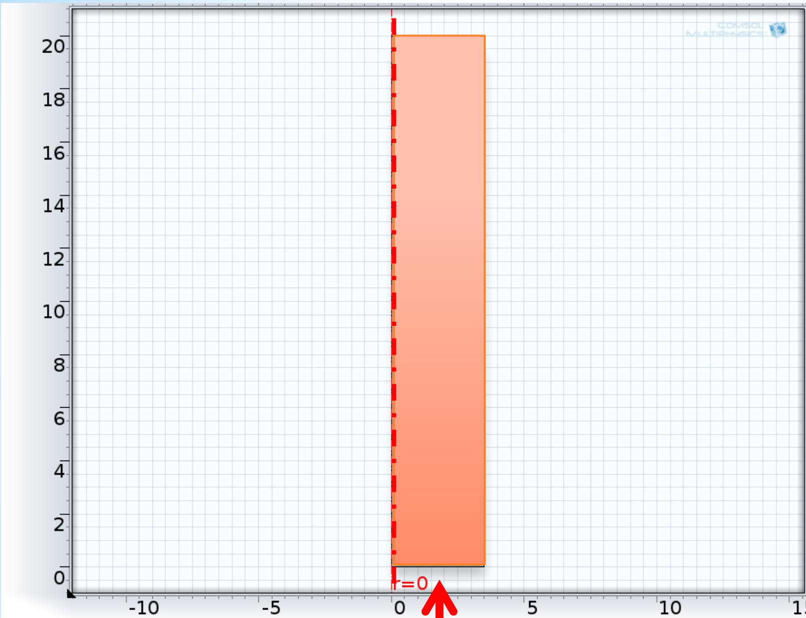
Stack – Capacitor detail





Setup functional scheme

FEM Thermo – acoustic analysis



Inlet Pressure

$$\delta_v = \sqrt{\frac{\mu}{\pi \cdot f \cdot \rho_0}}$$

Viscous layer

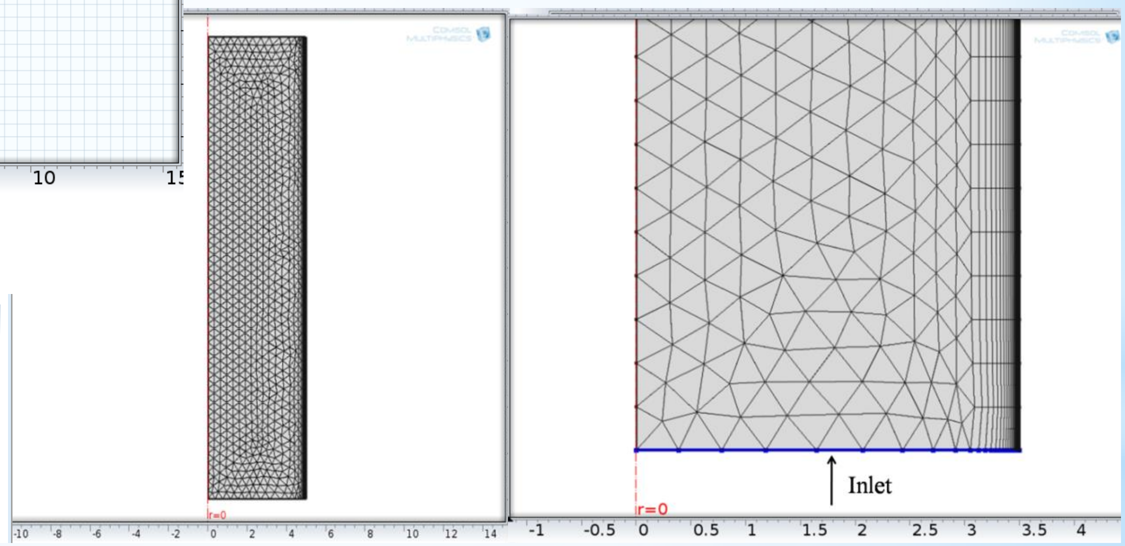
Boundary Layer Properties

Number of boundary layers: 64

Boundary layer stretching factor: 1.2

Thickness of first layer: Manual

Thickness: 0.8*sqrt(mu_He/(pi*f0*rho_atm)) cm



Meshed model with boundary layer detail

Governing equations

Variables

- Acoustic pressure (p)
- Particle velocity ($\mathbf{u}$)
- Temperature (T)
- Density (ρ)

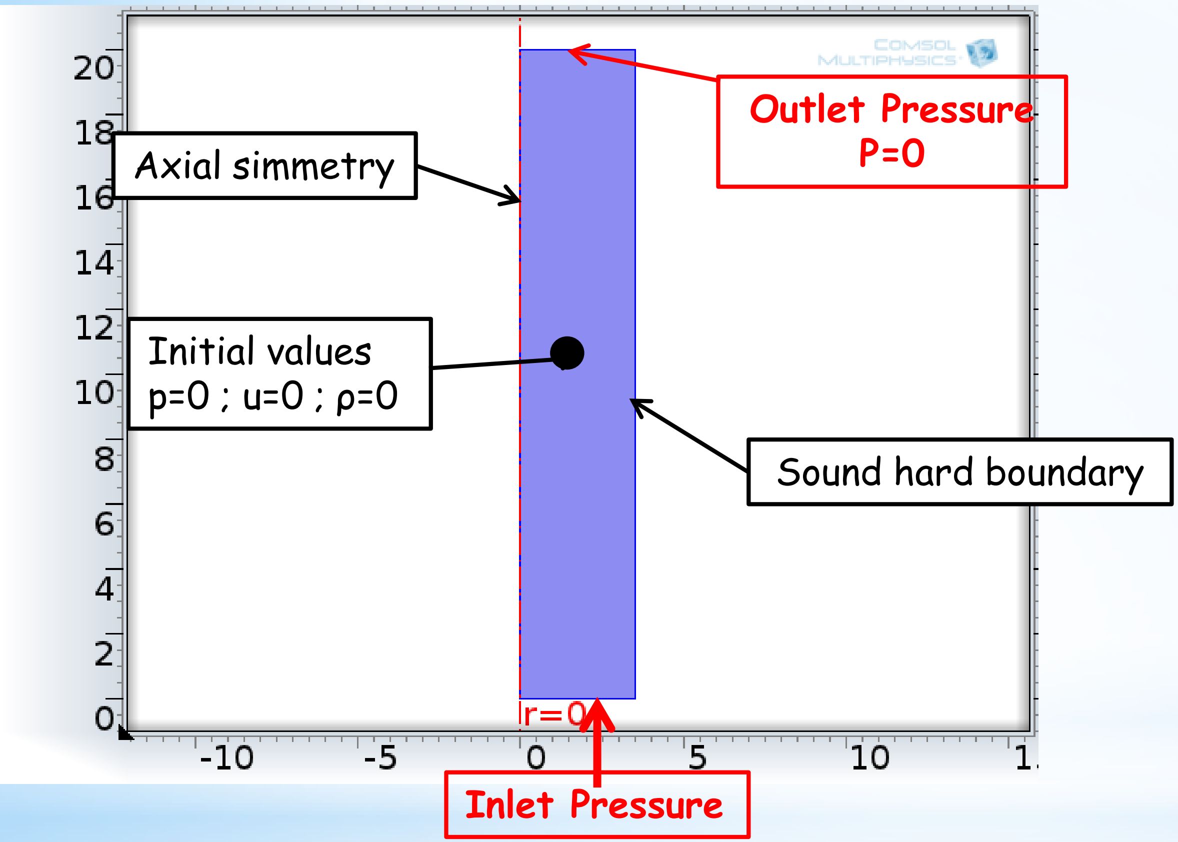
$$i\omega\rho_0\mathbf{u} = \nabla\cdot\left(-p\mathbf{I}+\mu(\nabla\mathbf{u}+(\nabla\mathbf{u})^{\mathrm{T}})-\left(\frac{2\mu}{3}-\mu_{\mathrm{B}}\right)(\nabla\cdot\mathbf{u})\mathbf{I}\right)$$

$$i\omega\rho+\rho_0(\nabla\cdot\mathbf{u}) = 0$$

$$i\omega\rho_0 C_{\mathrm{p}}T = -\nabla\cdot(-\mathrm{k}\nabla T)+i\omega p T_0\alpha_0+Q$$

$$\rho = \rho_0(\beta_{\mathrm{T}}p-\alpha_0 T)$$

Boundary conditions & Study



Variables

- Acoustic pressure (p)
- Particle velocity (u)
- Temperature (T)
- Density (ρ)

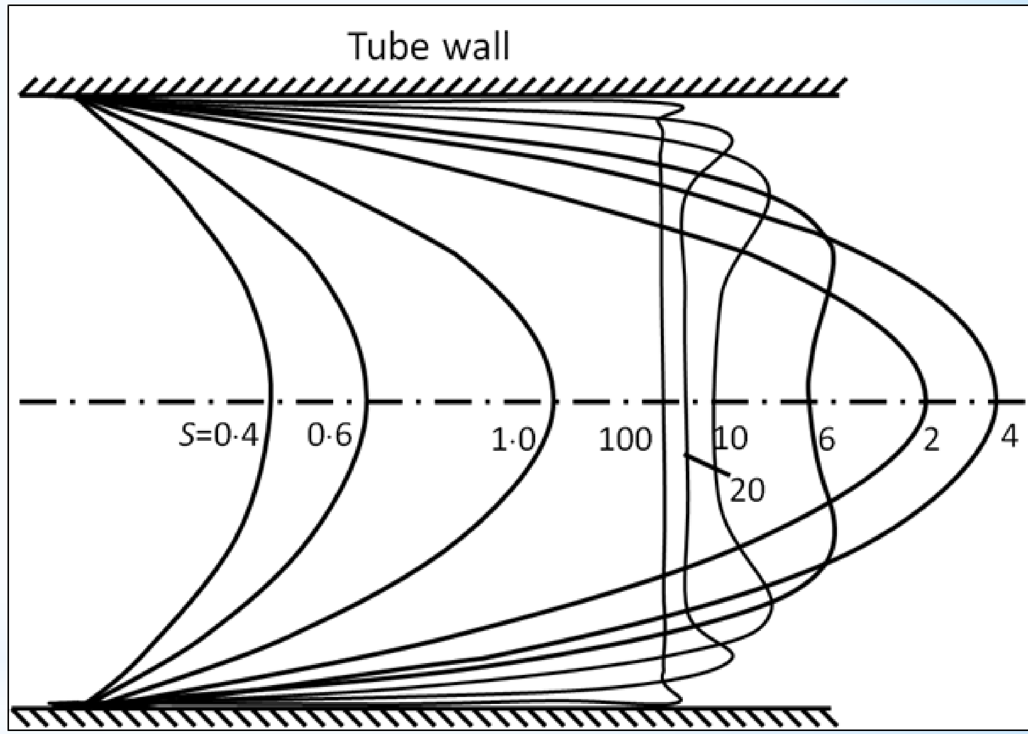
FEM Thermo – acoustic analysis

Meaningful parameters for a given gas

- Frequency
- Radius of the duct
- Pressure

$$s = R\sqrt{\frac{\rho \cdot \omega}{\mu}}$$

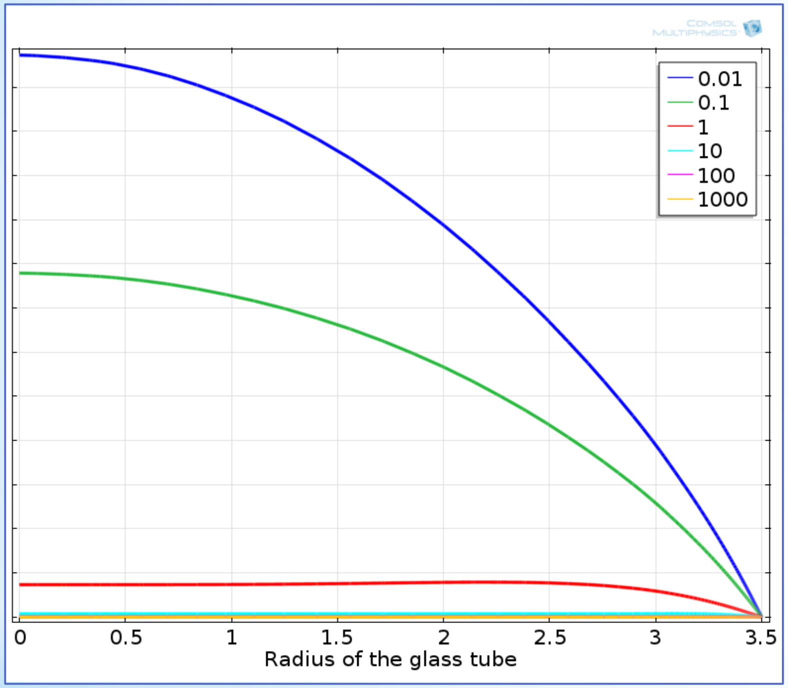
Shear wave number

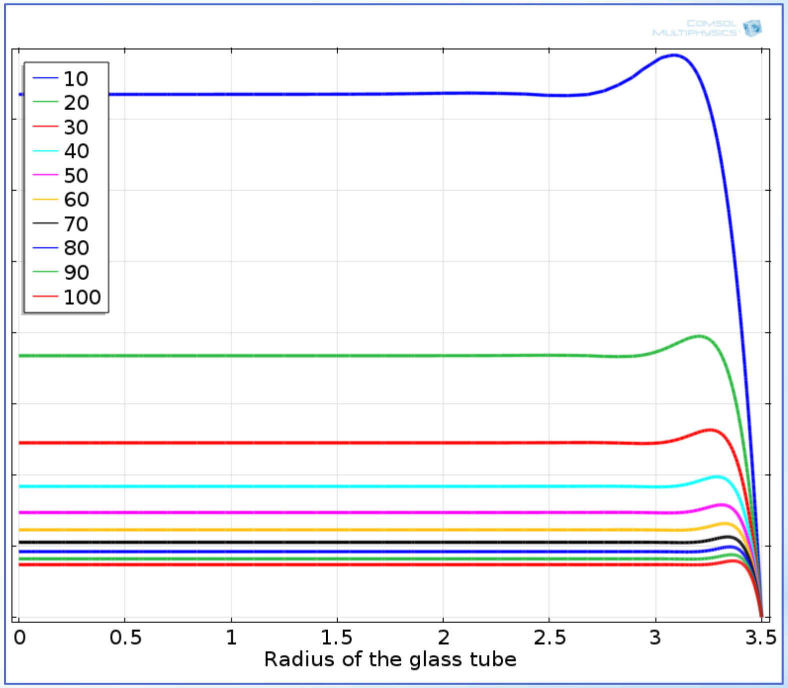


Velocity profiles from literature

H. Tijdeman. On the propagation of sound waves in cylindrical tubes. Journal of Sound and Vibration, Vol. 39 (1975), pp. 1-33.

FEM Thermo – acoustic analysis

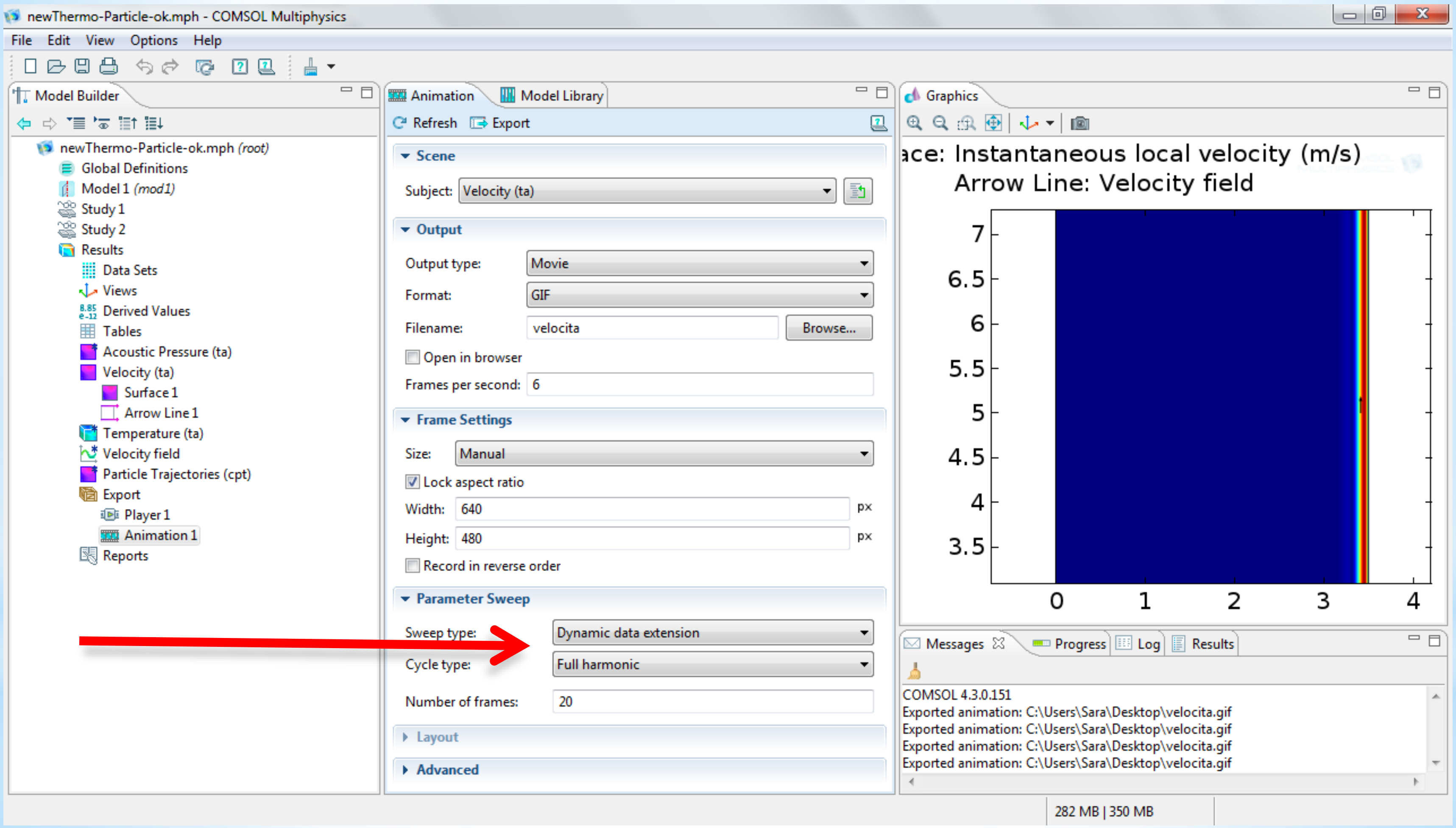




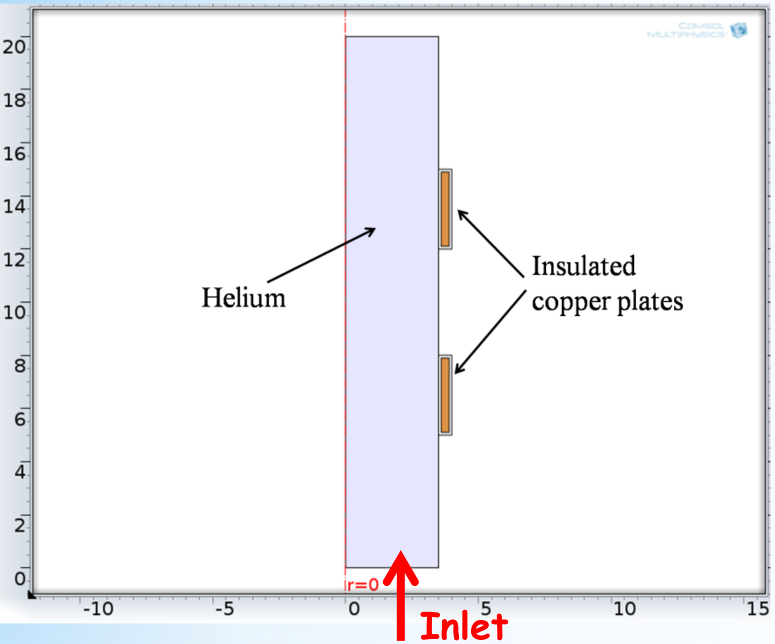
Velocity distribution (Rd=3.5cm; f=0.01 - 1000 Hz)

FEM Thermo – acoustic analysis

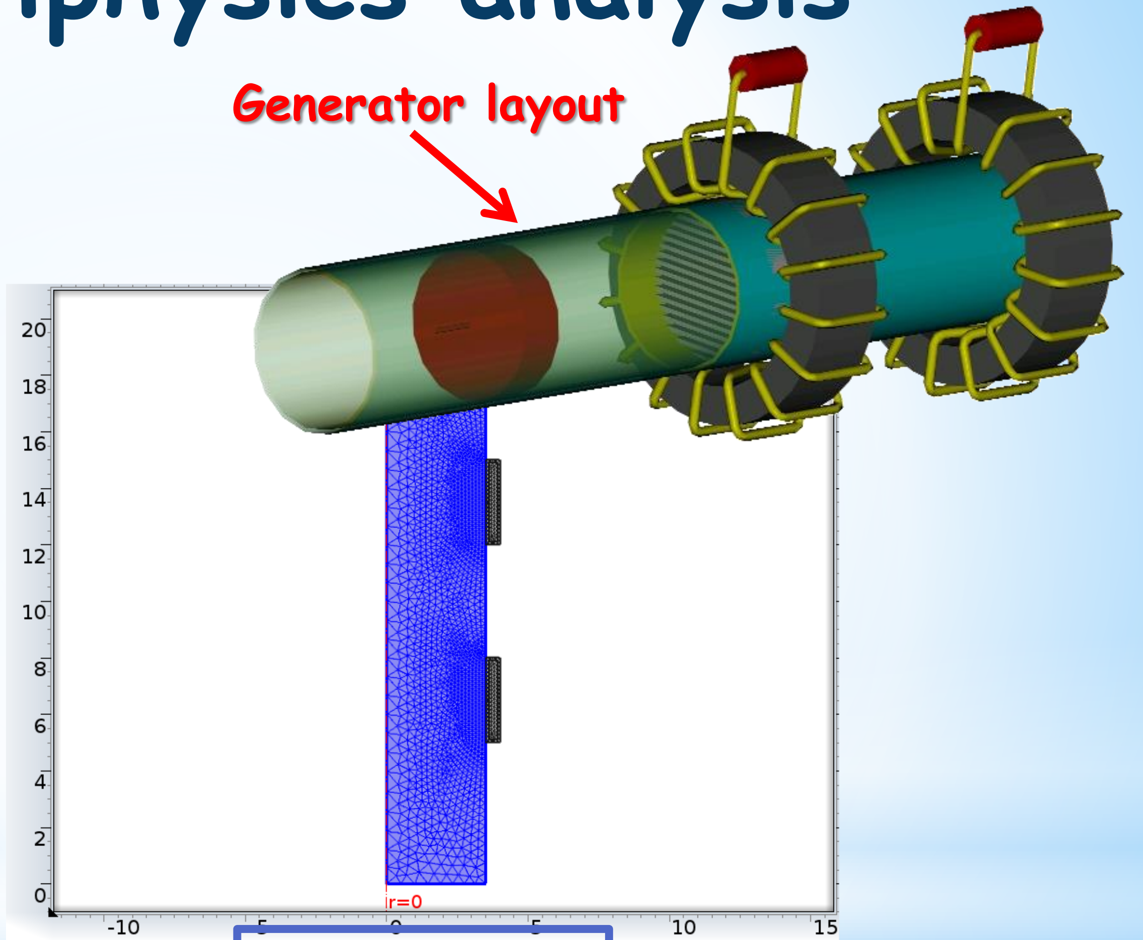
Post-processing



FEM Multiphysics analysis



Geometry and materials used



Meshed Model

Physic-controlled mesh
Extra fine (2091 elements)

Governing equations

Variables

- Acoustic pressure (p)
- Particle velocity (u)
- Temperature (T)
- Density (ρ)

$$i\omega\rho_0\mathbf{u} = \nabla\cdot\left(-p\mathbf{I} + \mu(\nabla\mathbf{u} + (\nabla\mathbf{u})^{\mathrm{T}}) - \left(\frac{2\mu}{3} - \mu_{\mathrm{B}}\right)(\nabla\cdot\mathbf{u})\mathbf{I}\right)$$

$$i\omega\rho + \rho_0(\nabla\cdot\mathbf{u}) = 0$$

$$i\omega\rho_0 C_{\mathrm{p}} T = -\nabla\cdot(-\mathrm{k}\nabla T) + i\omega p T_0\alpha_0 + Q$$

$$\rho = \rho_0(\beta_{\mathrm{T}} p - \alpha_0 T)$$

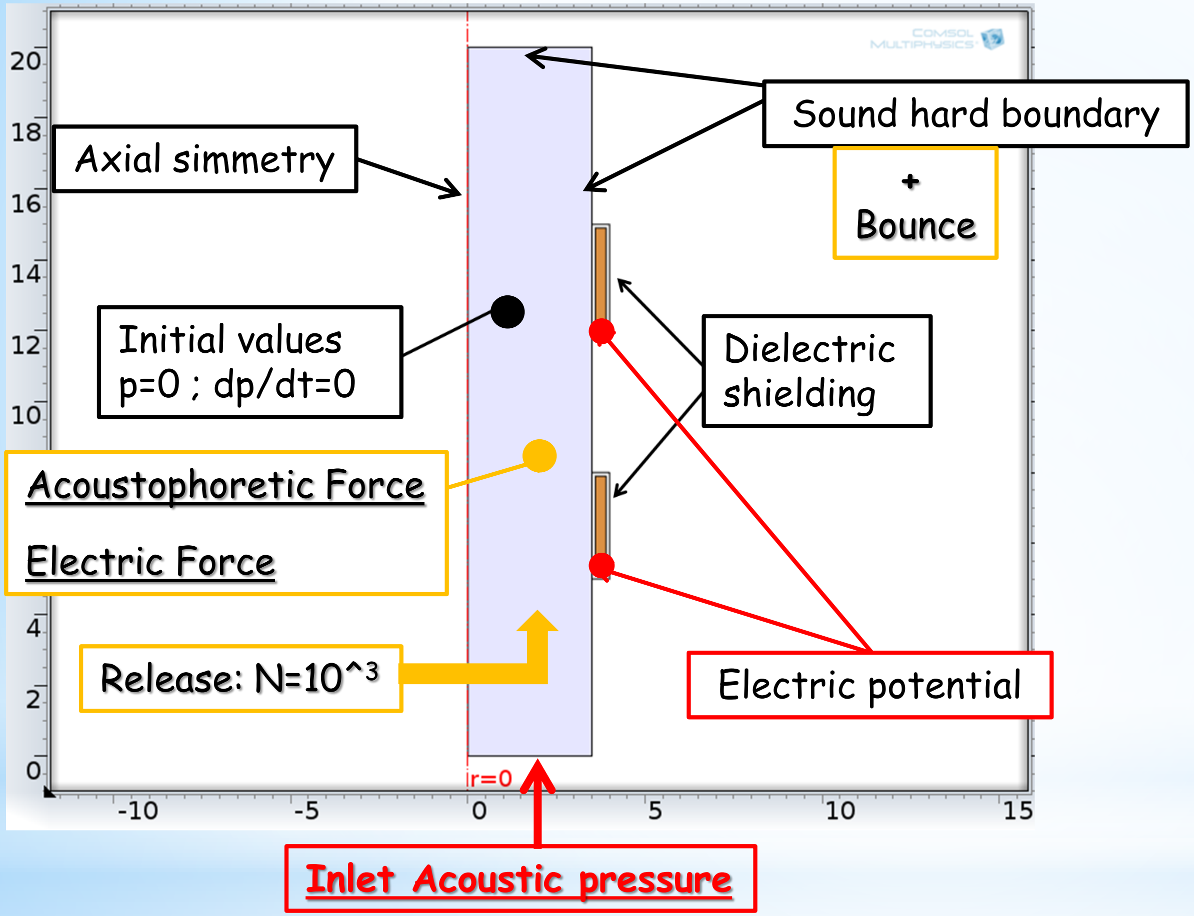
- Electric potential (V)

$$-\nabla\cdot(\varepsilon_0\nabla V - \mathbf{P}) = \rho$$

- Particles position

$$\frac{d}{dt}(m_p\mathbf{v}) = \mathbf{F}_D + \mathbf{F}_g + \mathbf{F}_{\mathrm{ext}}$$

Boundary conditions & Study



Variables

- Acoustic pressure (p)
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- Density (ρ)
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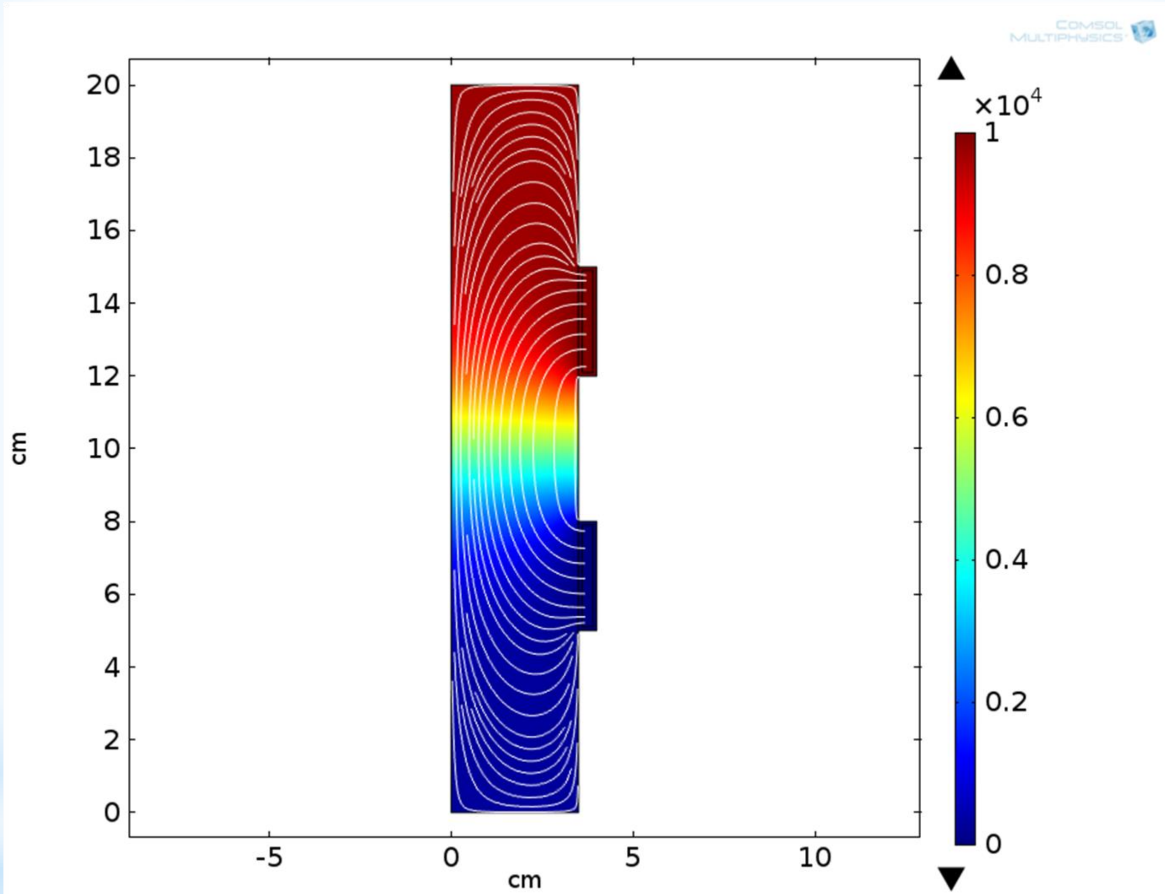
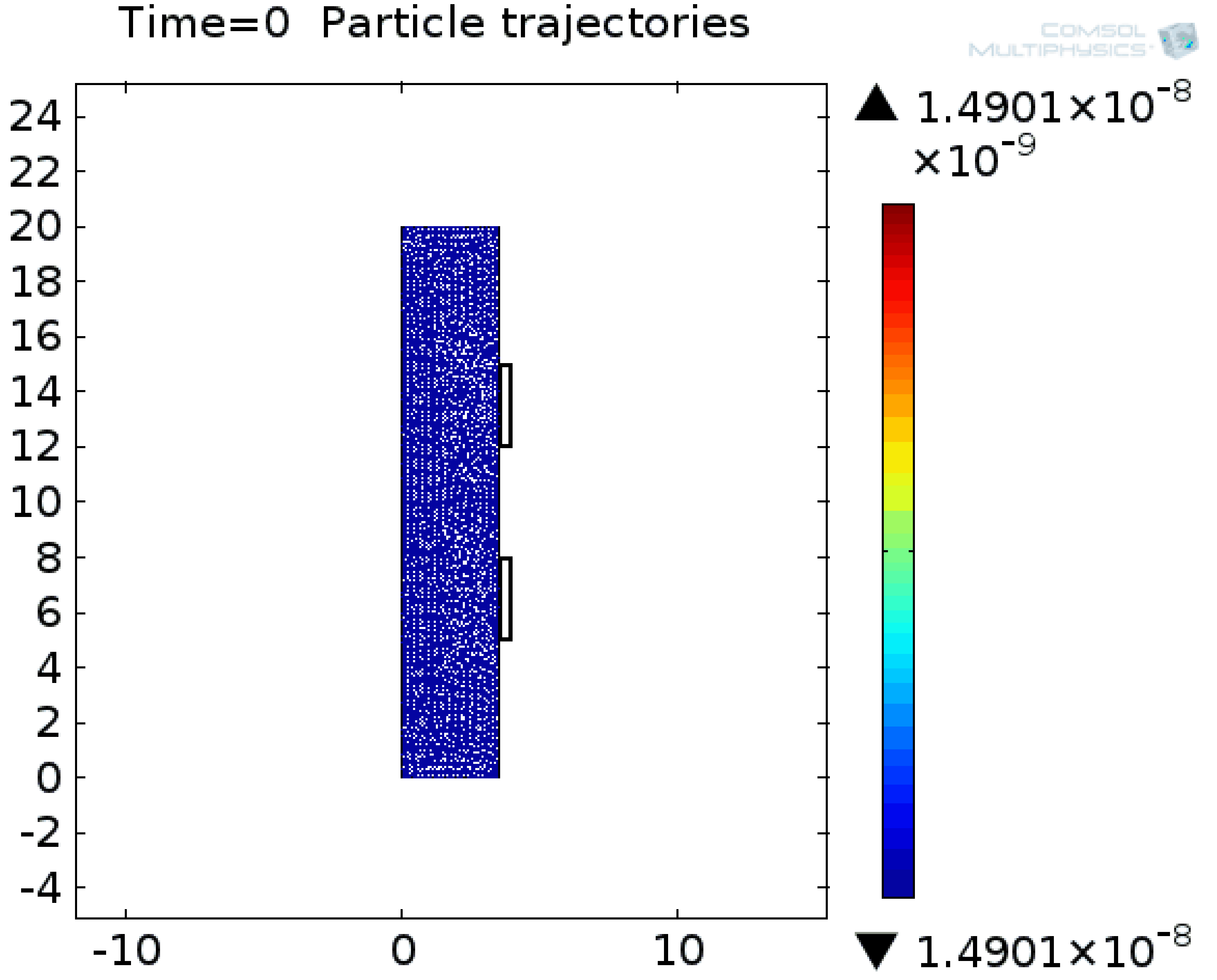
- Particles position

FEM Multiphysics analysis



Electric potential (Color Map) & Electric field lines



Time=0 Particle trajectories
COMSOL MULTIPHYSICS
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-10
0
10
▲ 1.4901×10^-8
×10^-9
▼ 1.4901×10^-8

CONCLUSIONS

- Simplified study about the device
- FEM analysis of 2 distinct problems
- Best velocity profile (acting on frequency or radius)
- Equilibrium condition for charge distribuition
- Encouraging preliminary results

FUTURE WORKS

- Reduce simplificative hypothesis
- FEM analysis of the complete system
- Develop a prototype

THANK YOU