The investigation of dynamic properties of dust particles in RF plasma discharge

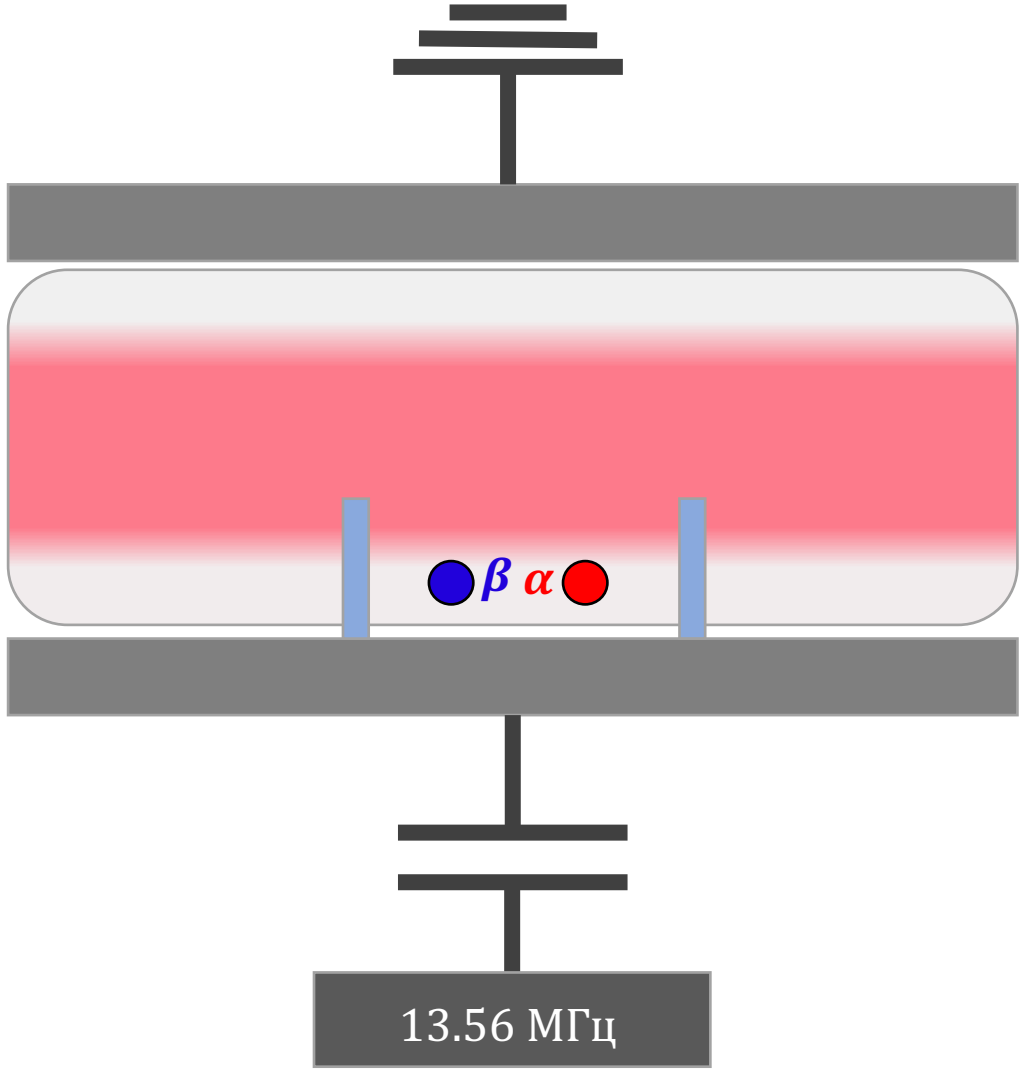
Scientific-Coordination Workshop on

Non-Ideal Plasma Physics

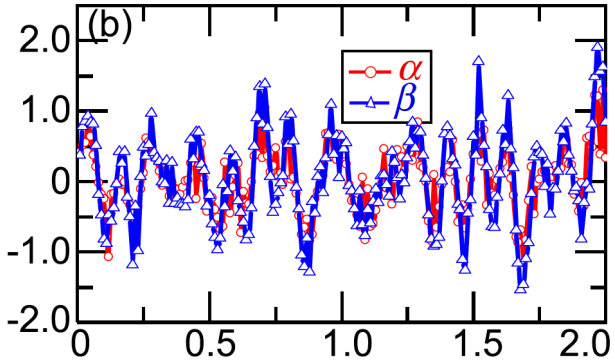
December 16-17, 2020, Moscow, Russia

Daniil Kolotinskii

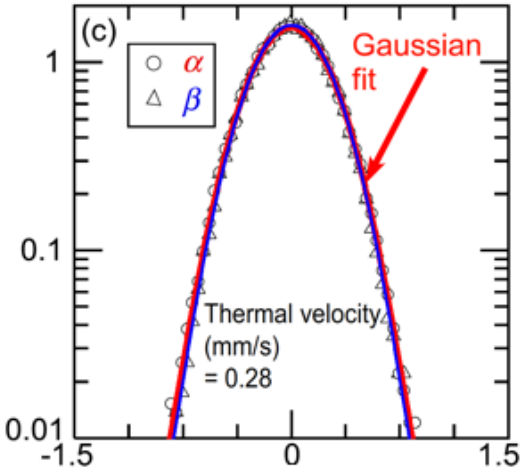
Reference experiment: parallel alignment of dust particles



Velocity of dust particles VS time



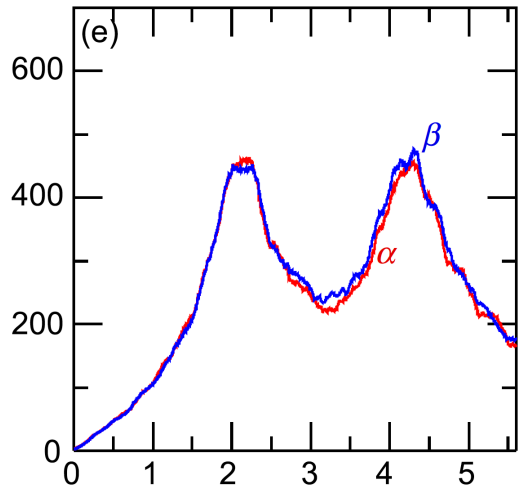
Dust particles velocity distribution



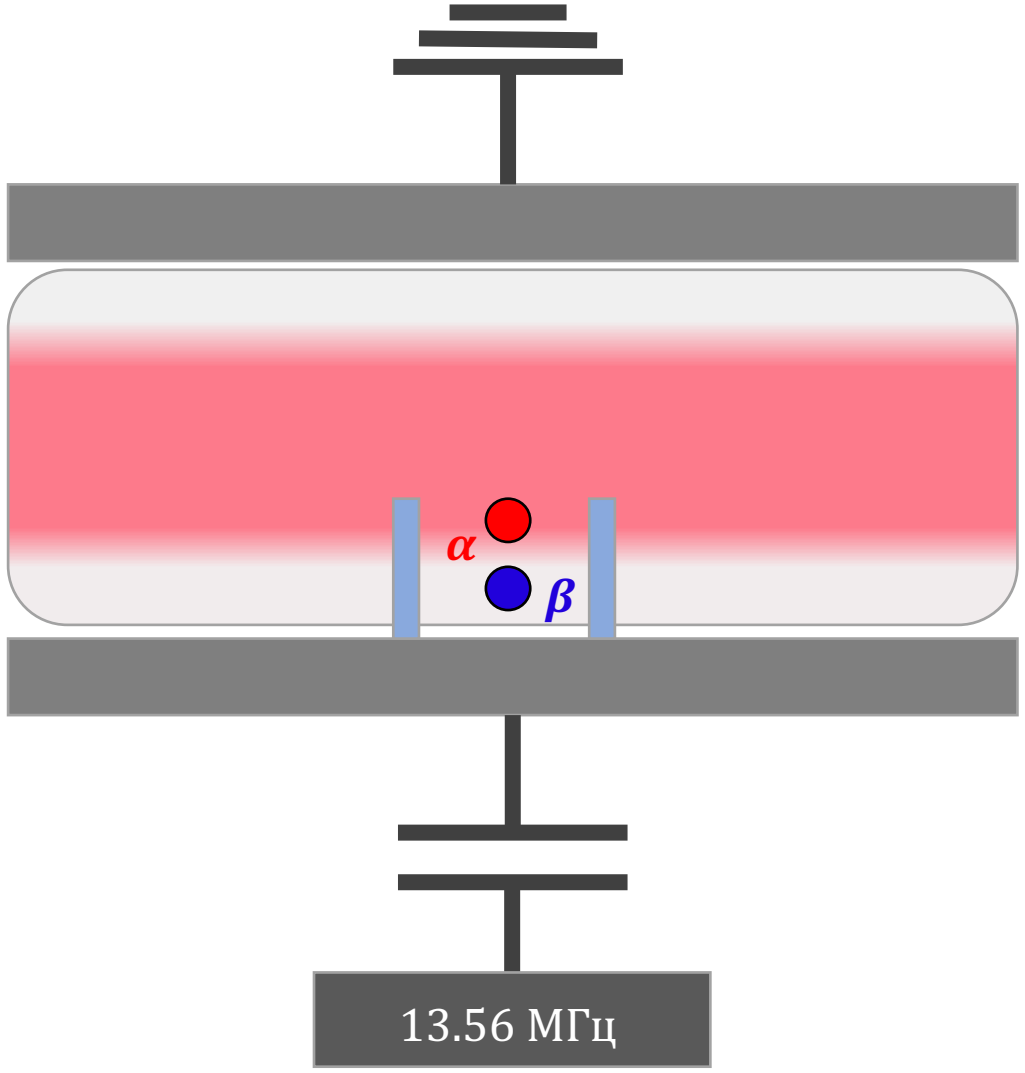
Experiment link

Mukhopadhyay A. K., Goree J. Experimental measurement of velocity correlations for two microparticles in a plasma with ion flow //Physical Review E. – 2014. – Т. 90. – №. 1. – С. 013102.

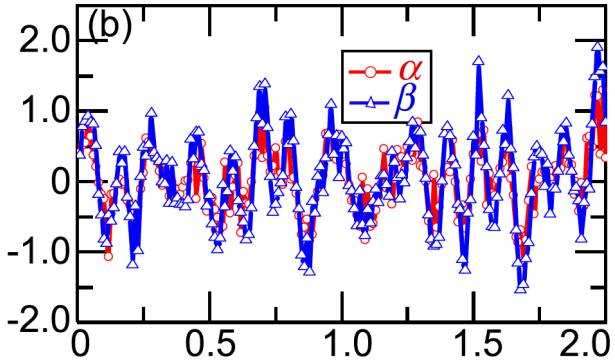
Spectral density of motion



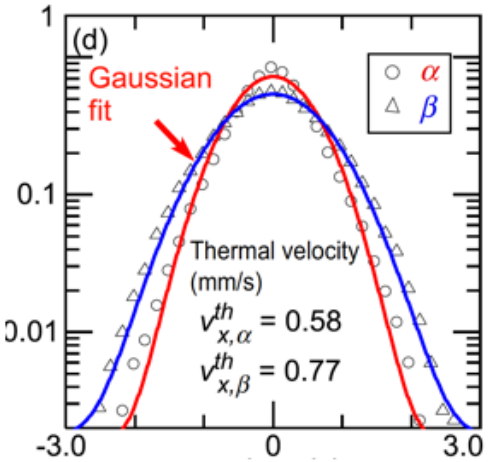
Reference experiment: vertical alignment of dust particles



Velocity of dust particles VS time



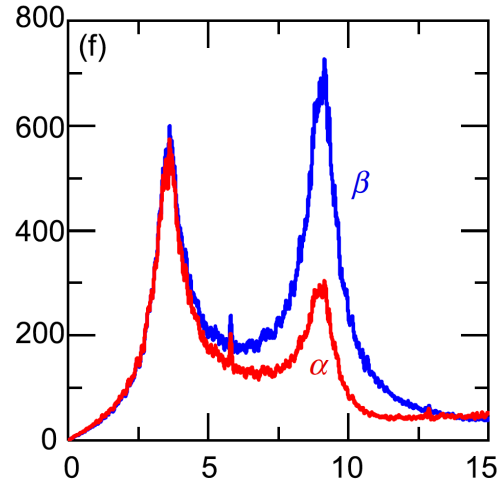
Dust particles velocity distribution



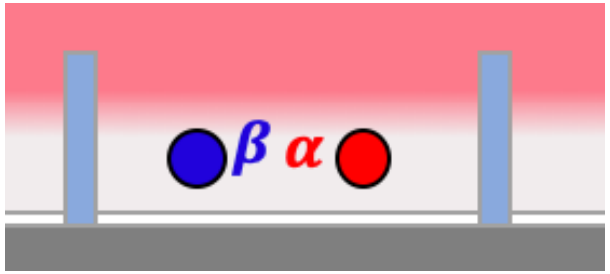
Experiment link

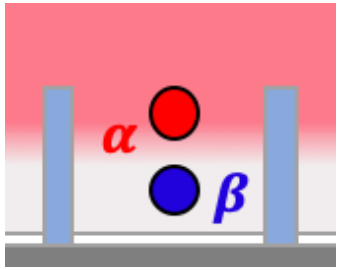
Mukhopadhyay A. K., Goree J. Experimental measurement of velocity correlations for two microparticles in a plasma with ion flow //Physical Review E. – 2014. – Т. 90. – №. 1. – С. 013102.

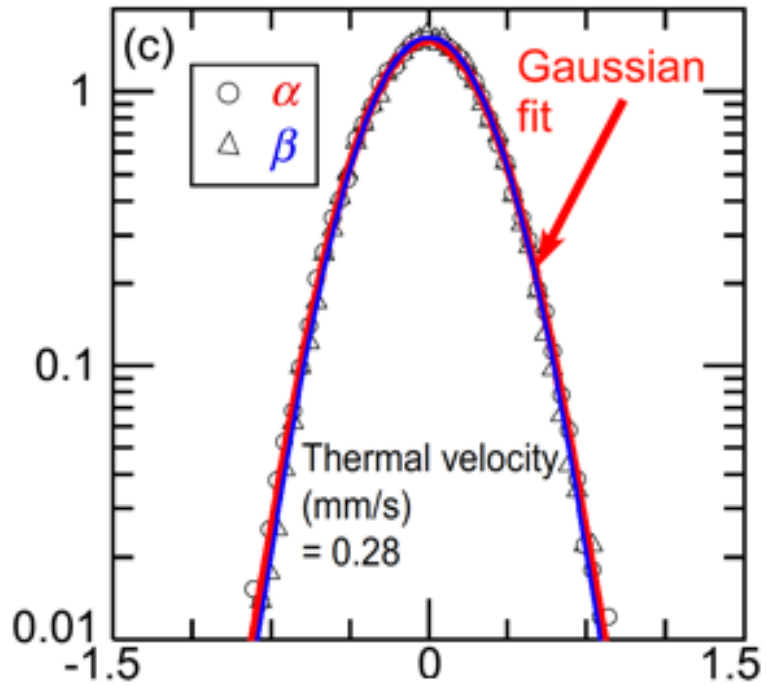
Spectral density of motion

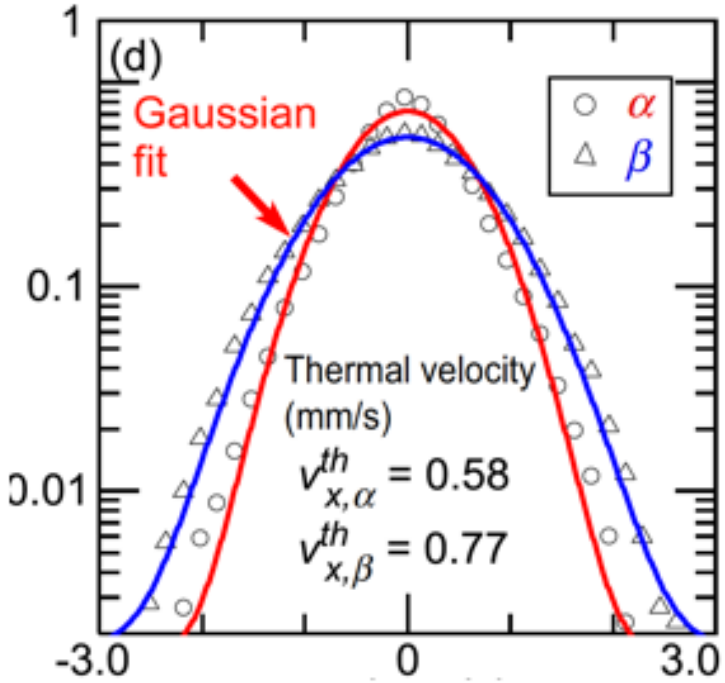


Difference in dynamics properties

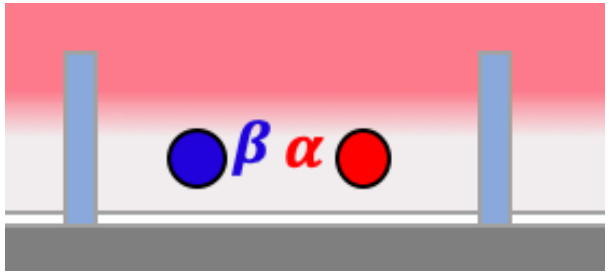


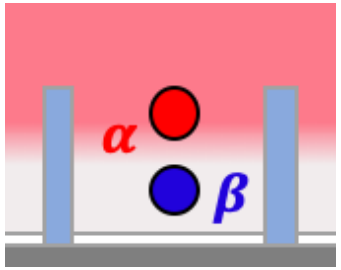


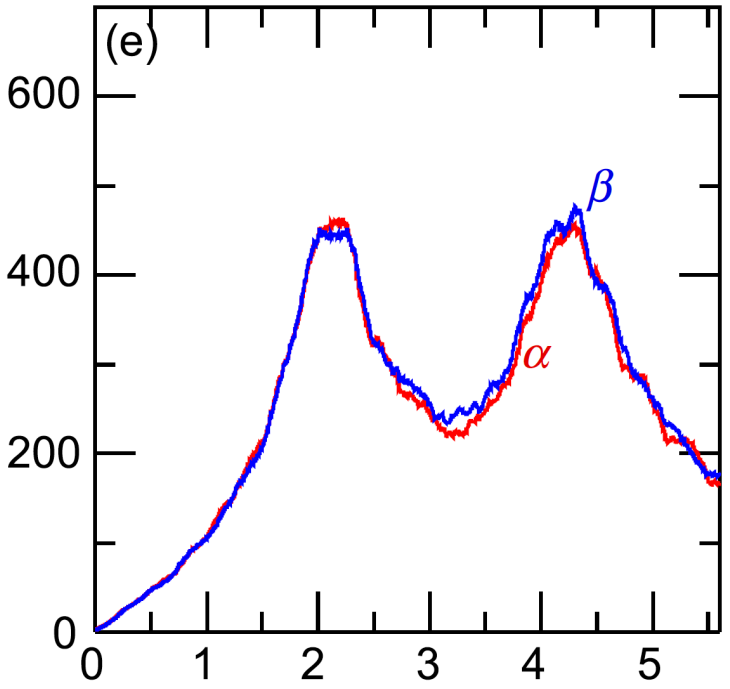


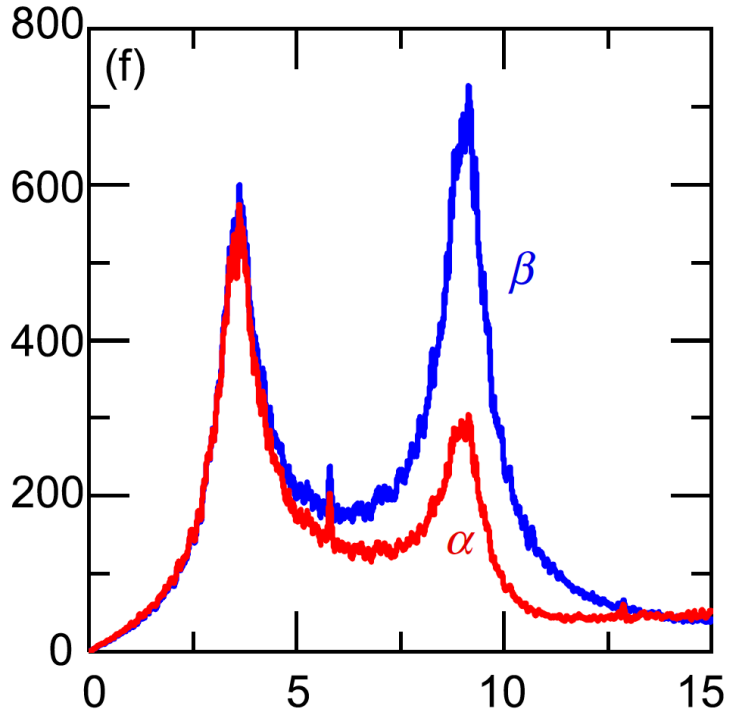


Difference in dynamics properties









Mathematical formulation of the problem

Particle-In-Cell ionwake potential calculation

Poisson-Boltzmann equation

$$\Delta\varphi = -4\pi|e|\left[n_i - n_e \exp\left(-\frac{\varphi|e|}{k_B T_e}\right)\right] - 4\pi Q\delta(\bar{r})$$

Ions kinetic equation

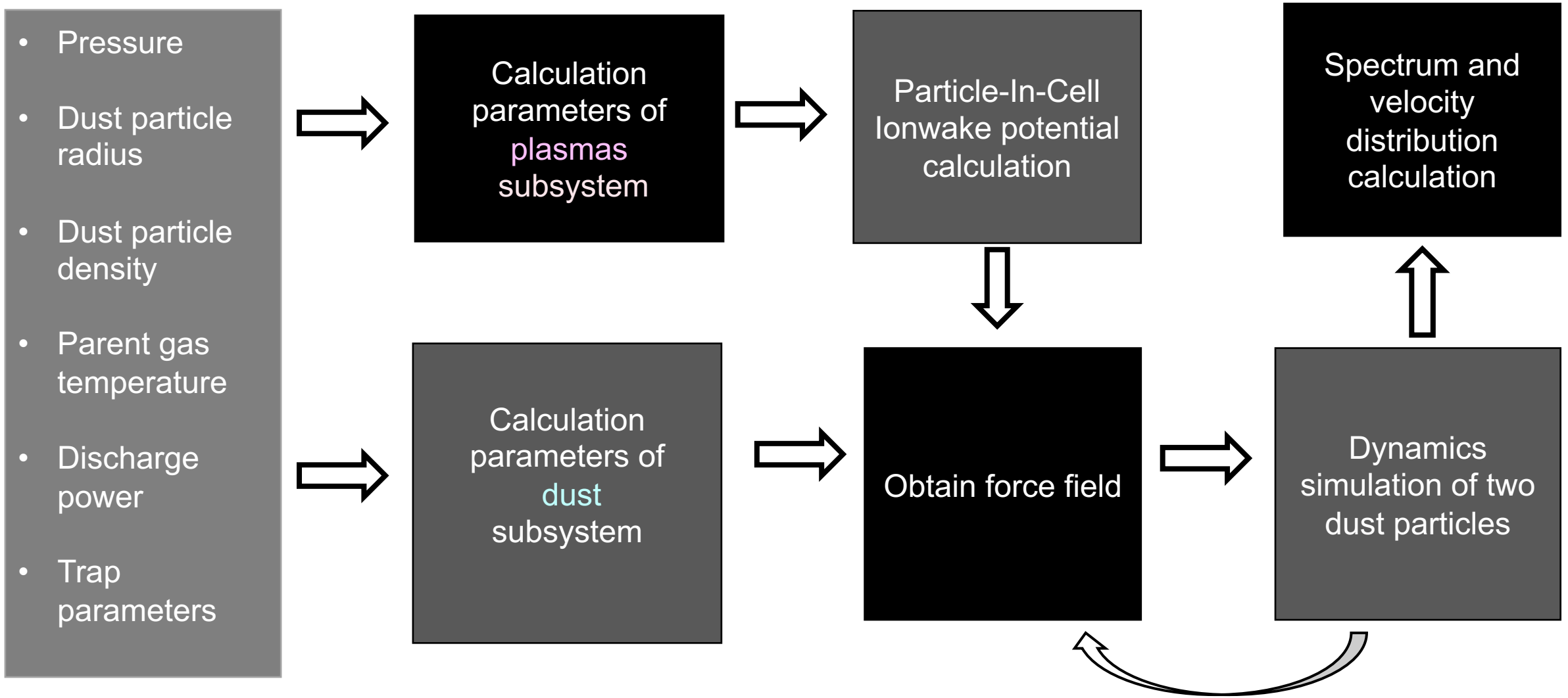
$$\frac{\partial f}{\partial t} + \bar{v}\cdot\nabla f + \frac{e}{m_i}\cdot(\bar{E}_0 - \nabla\varphi)\cdot\frac{\partial f}{\partial \bar{v}} = \vartheta_{in}\left(\Phi_M(v)n_i - f(v)\right)$$

Dust particle dynamics calculation

Newton's equation

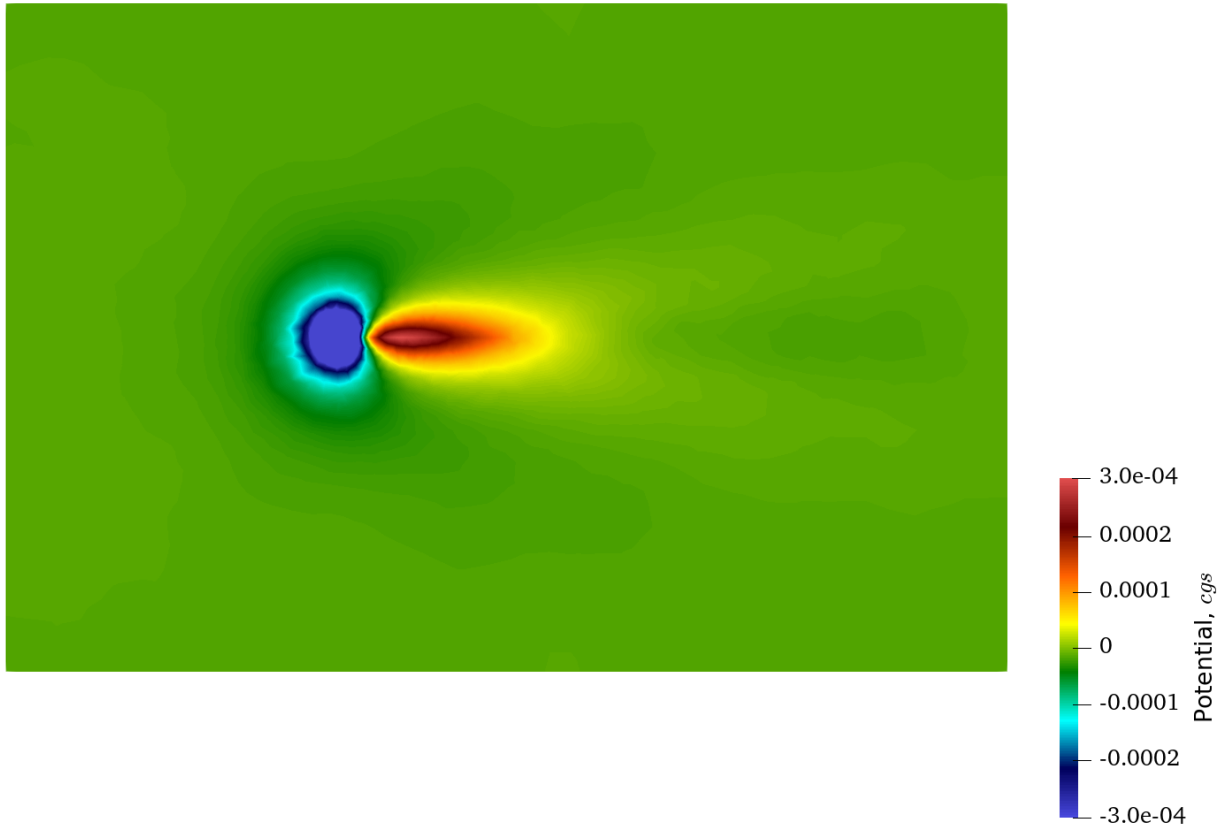
$$m_i\frac{dv}{dt} = -Q_i\nabla\varphi + \mathrm{F}_{\text{термостат}} + \mathrm{F}_{\text{ловушка}}$$

Computational scheme

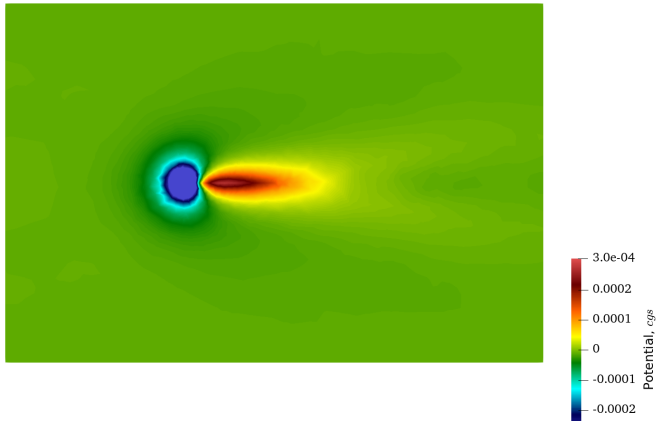


Ionwake potential for different gas pressure

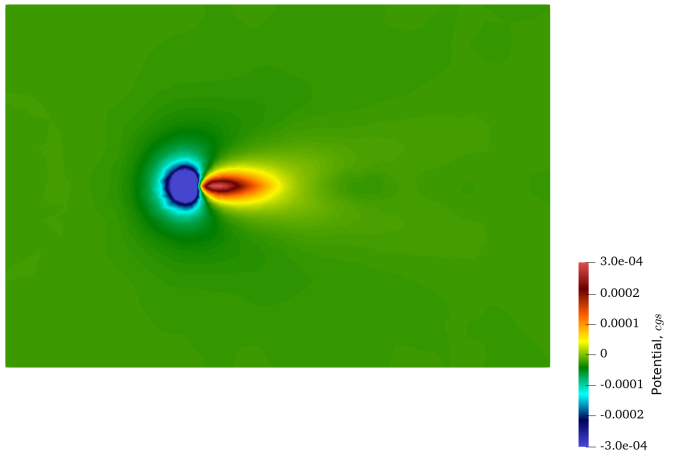
$P = 45\ mTorr$



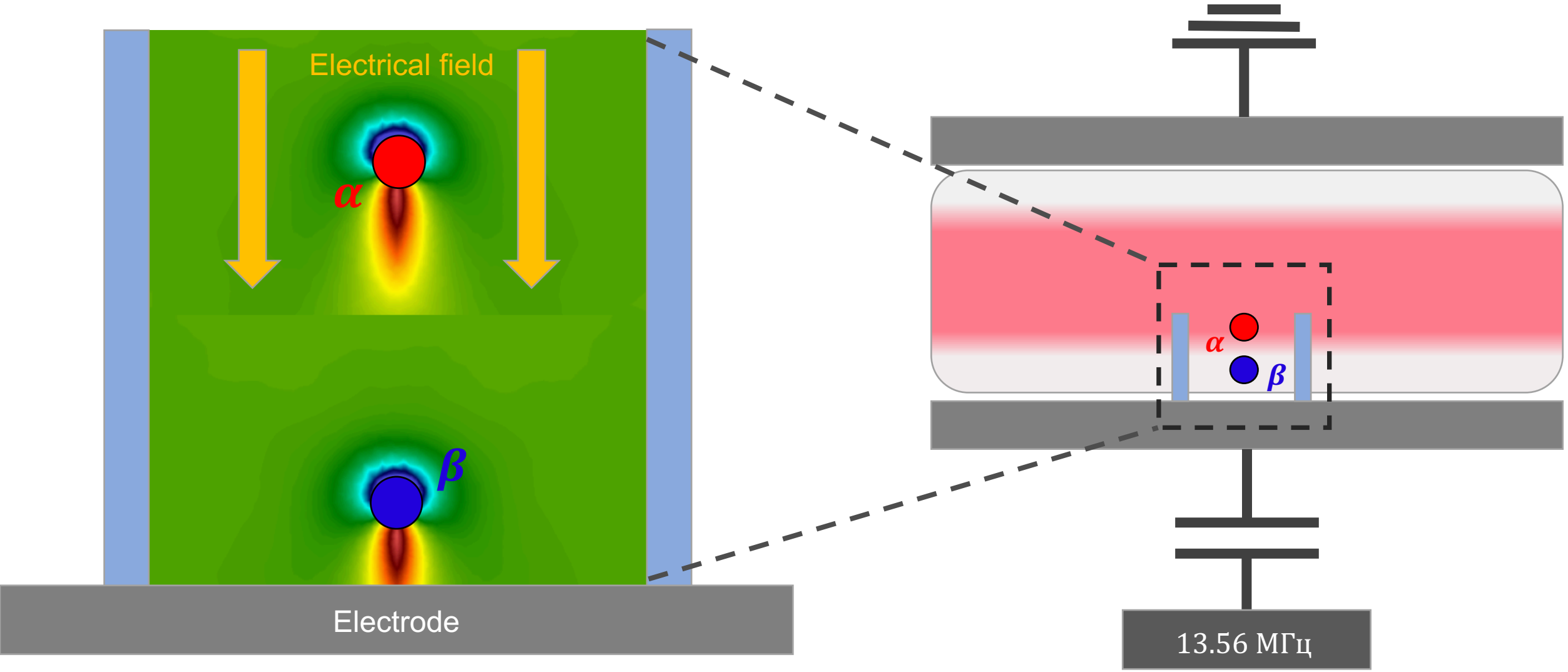
$P = 30\ mTorr$



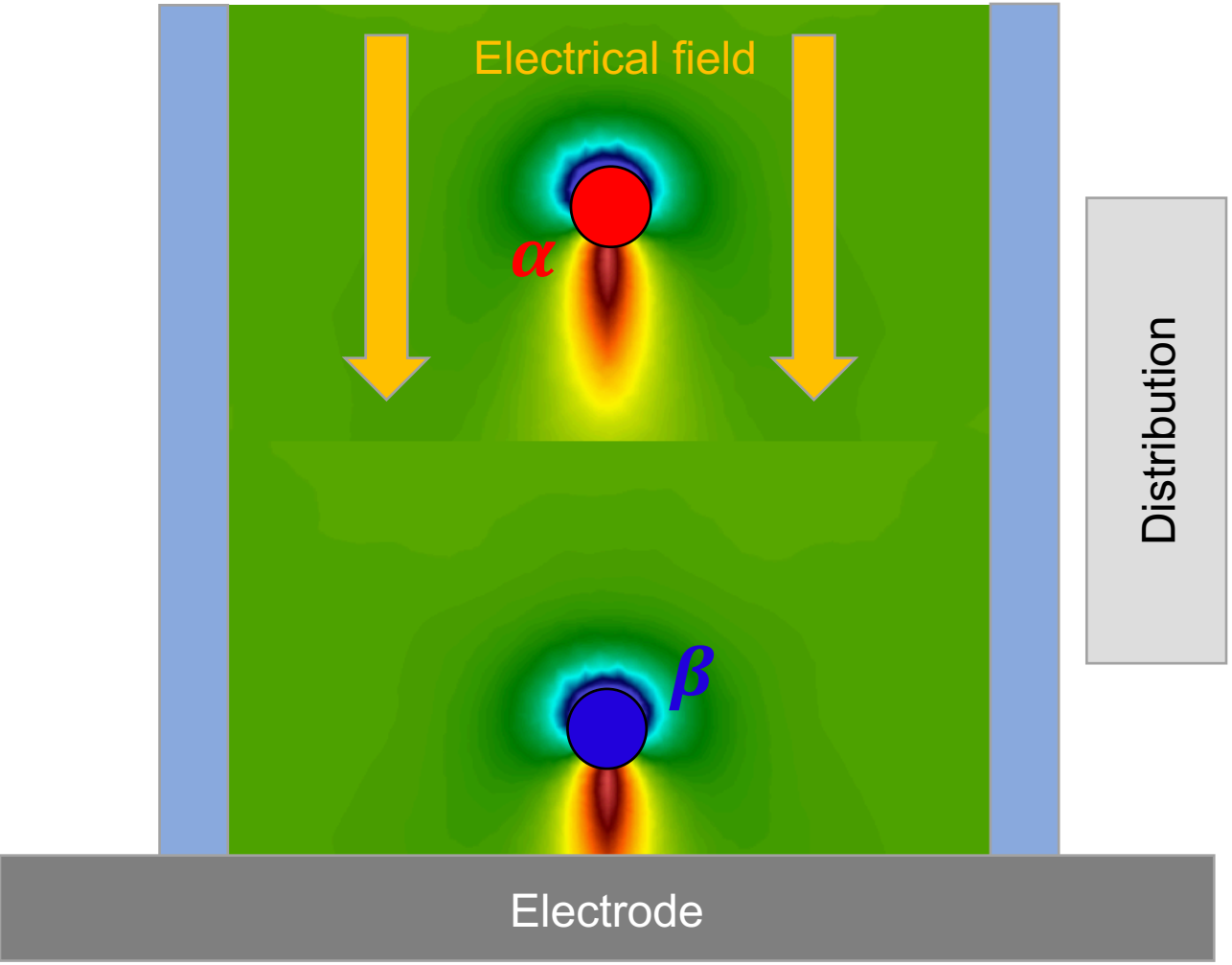
$P = 70\ mTorr$

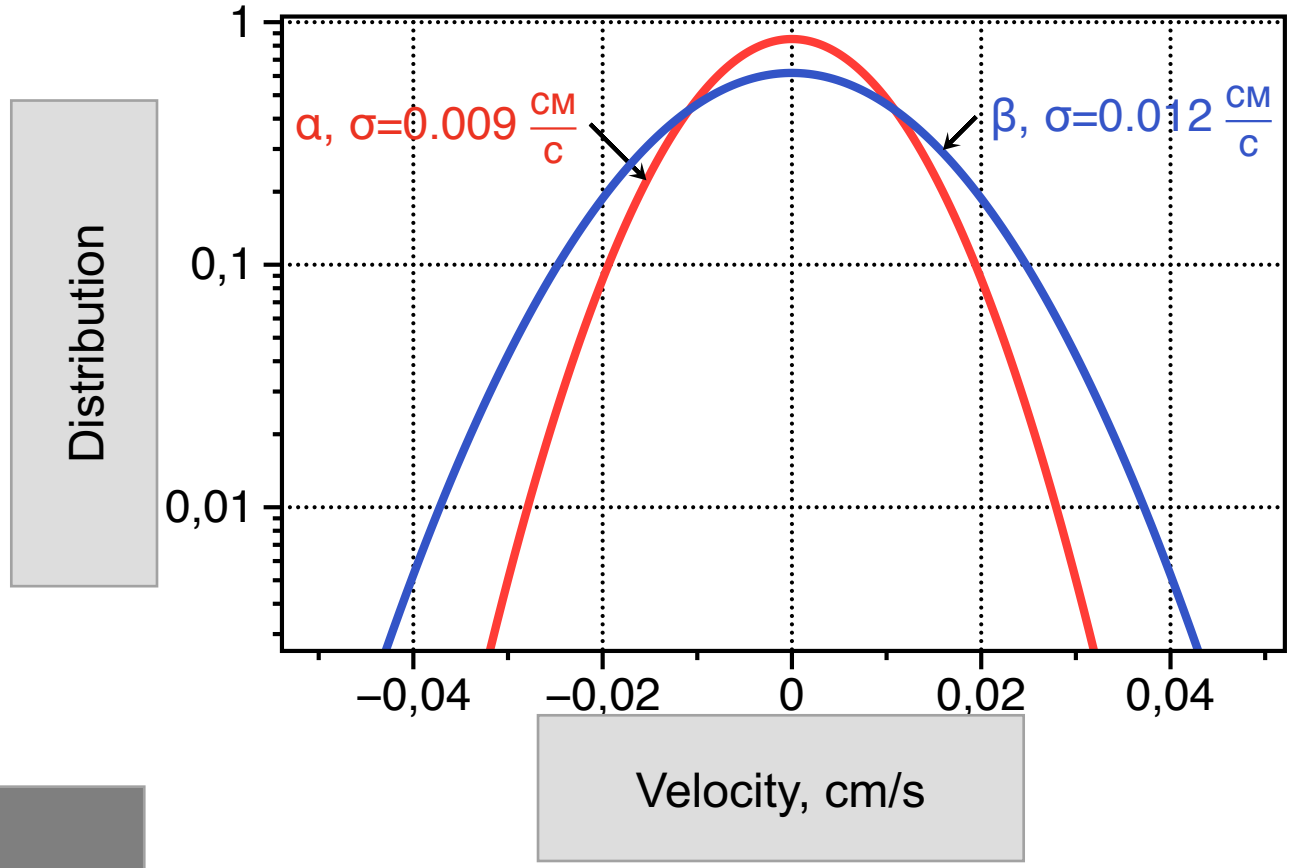


Dust particles interaction at discharge

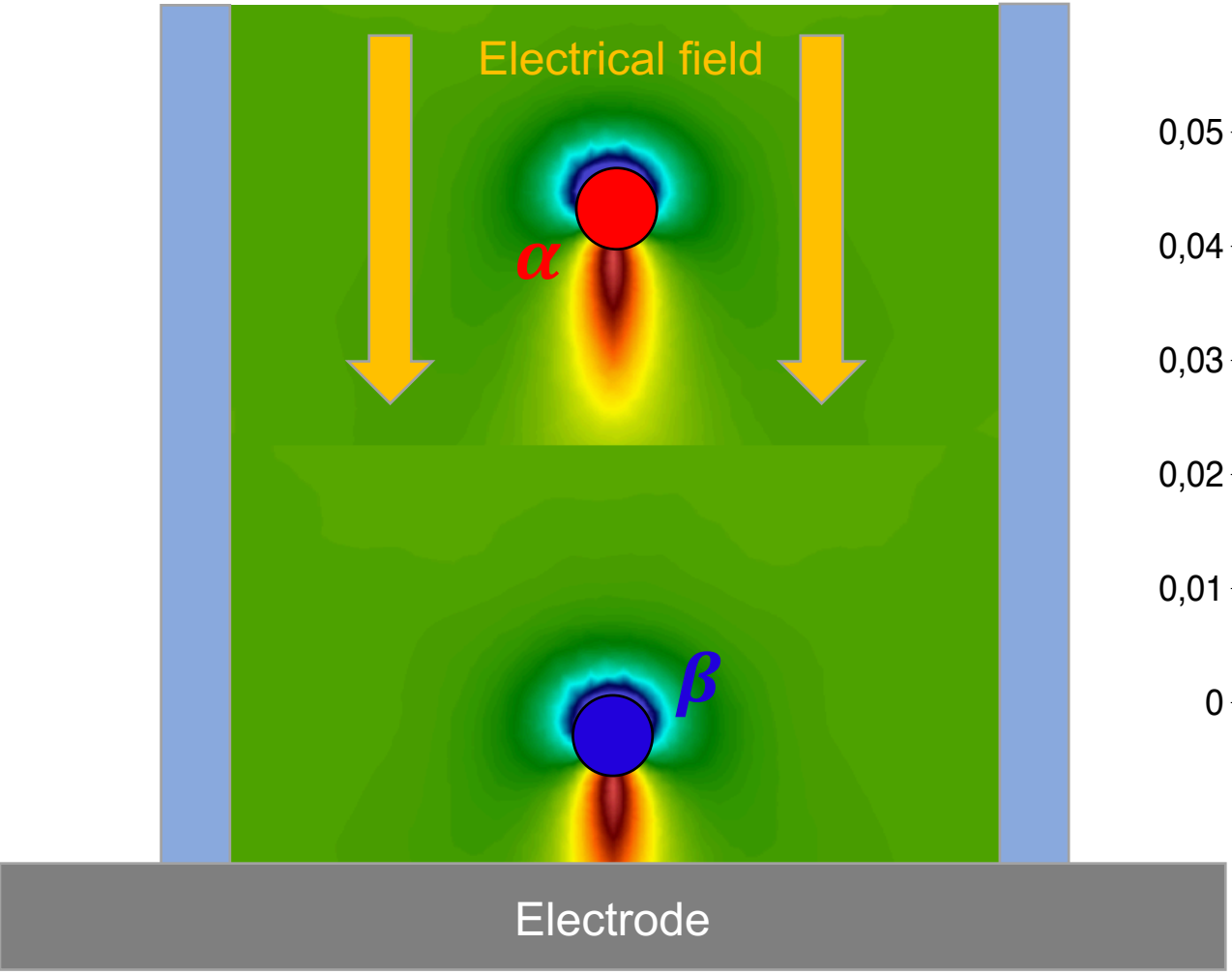


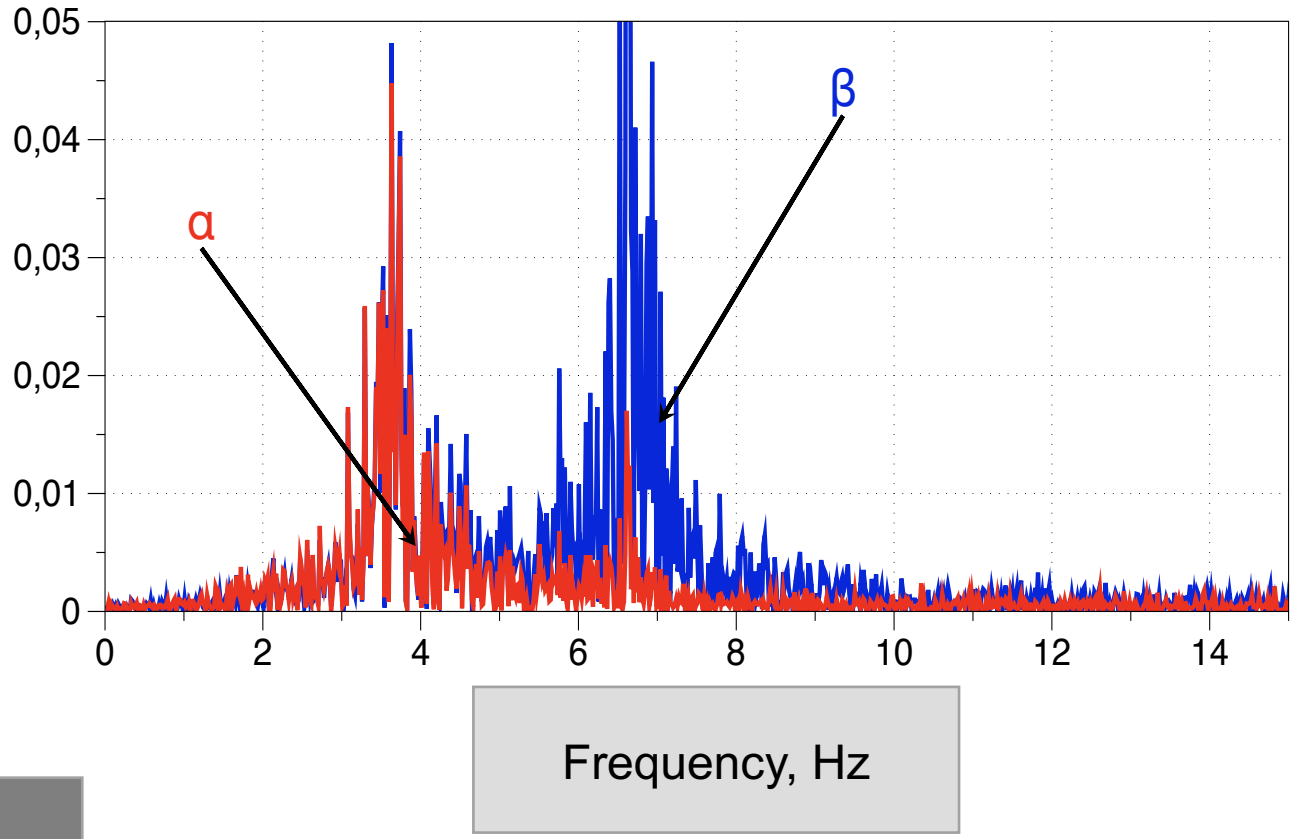
Simulated dynamics properties: dust particle velocity distribution



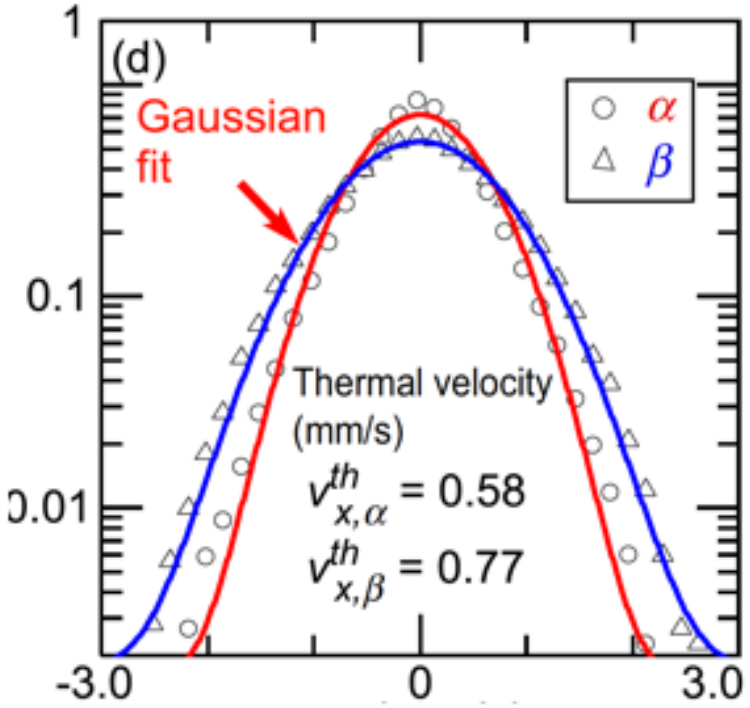


Simulated dynamics properties: dust particle spectral density



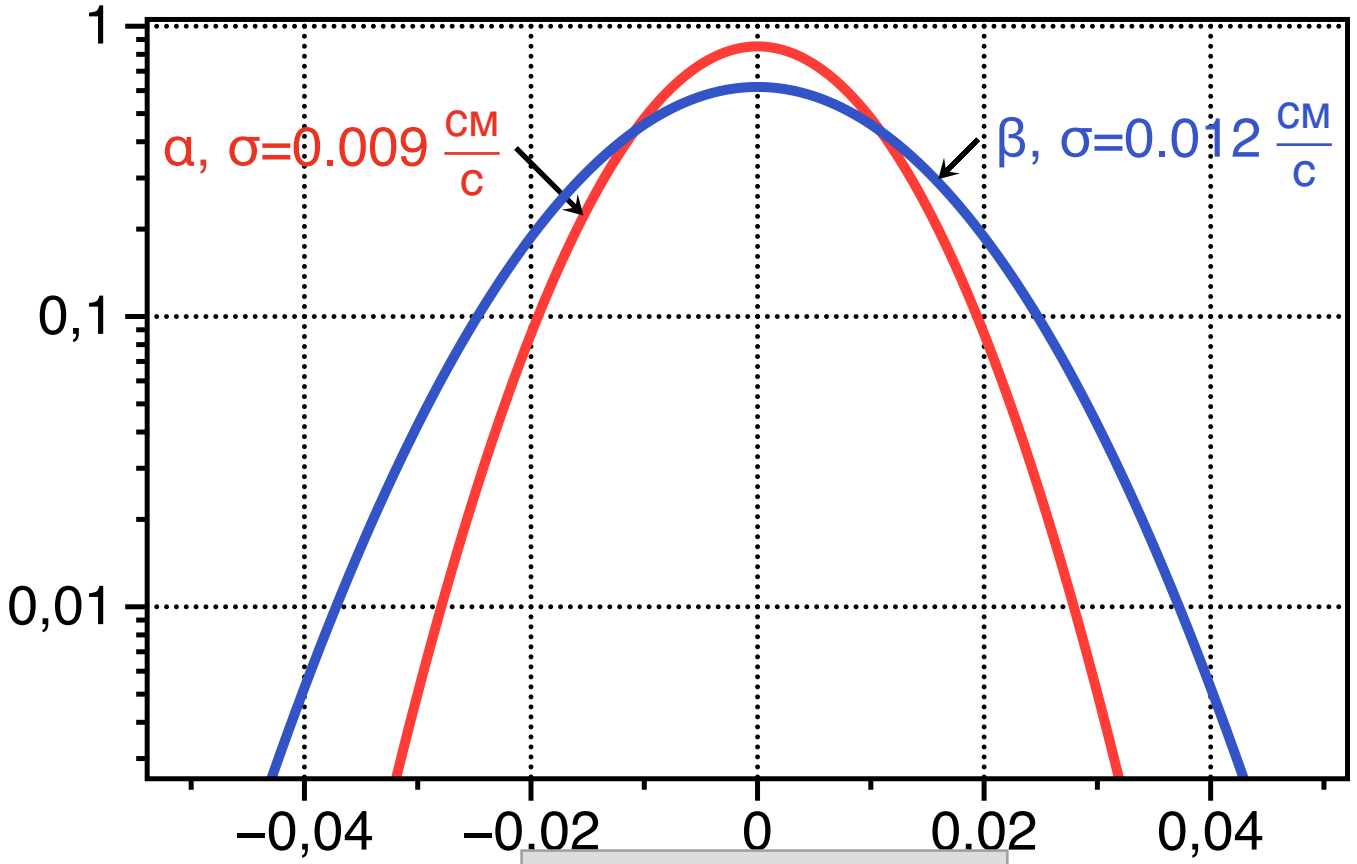


Comparison with the experiment ("Heating")



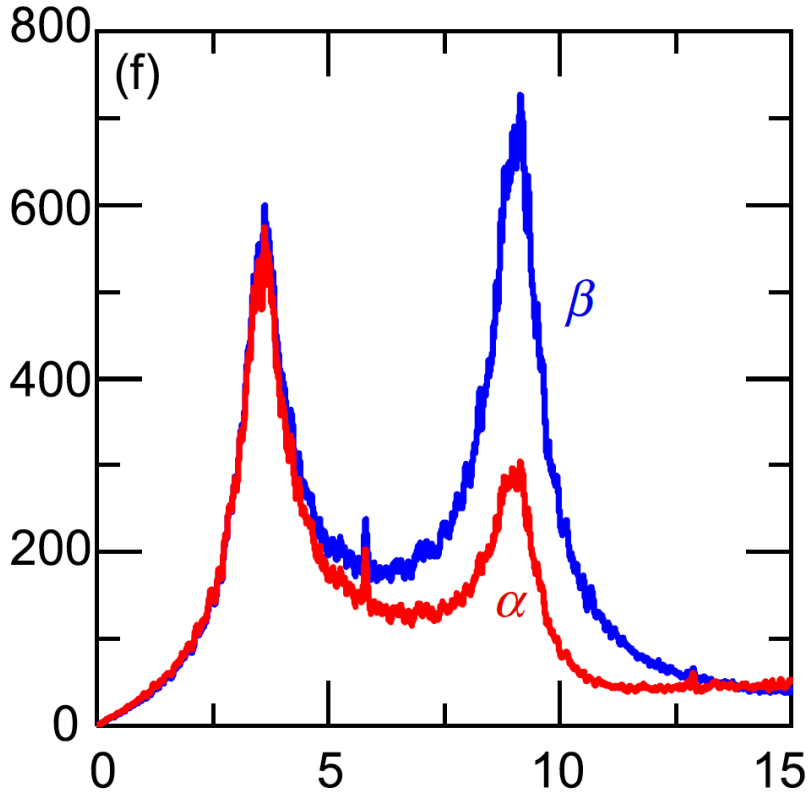
Distribution

Velocity, cm/s

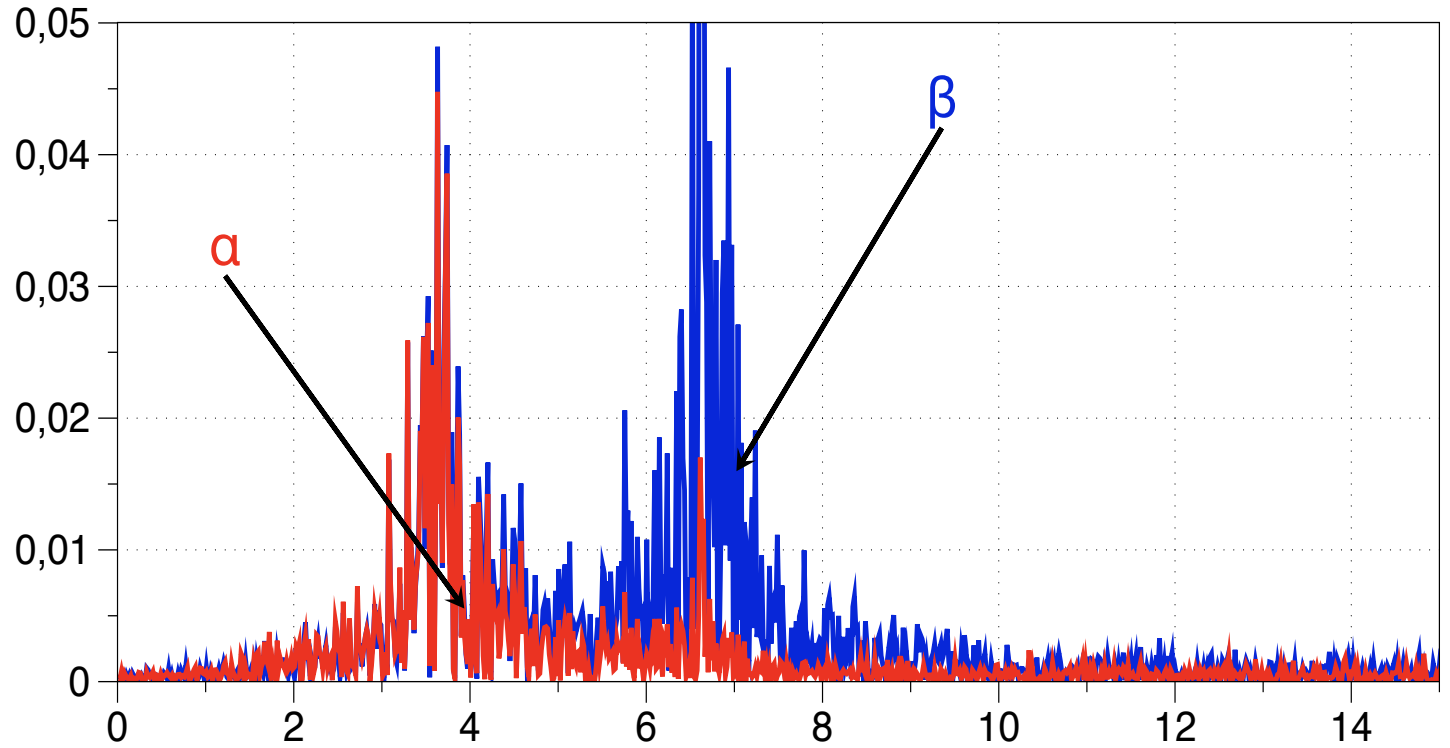


Velocity, cm/s

Comparison with the experiment (Spectral density)



Frequency, Hz



Frequency, Hz

Results

- A scheme for multiscale simulation of the dynamics of charged dust particles in plasma has been developed and implemented: PIC calculation of the interaction potential taking into account the plasma environment and MD simulation of dynamics
- The explanation of the experiment using Ionwake was confirmed by the proposed multiscale modeling