Research Interns @ Strathclyde (RI@S) 2019/2020 Scheme

Electrostatic Precipitation Efficiency for a Multi-needle Plane Electrode Topology under DC Excitation

T. Wong*, I Timoshkin, M Given, M Wilson and S MacGregor
Department of Electronic and Electrical Engineering, University of Strathclyde
*E-mail: timothy.wong.2015@uni.strath.ac.uk

UNIVERSITY of STRATHCLYDE TECHNOLOGY & INNOVATION CENTRE

University of Strathclyde Glasgow

Objectives

- Demonstrate the Integration of a **Particle Charging Model** along with existing **FEA Analysis to Simulate Particle Dynamics** under **divergent Electric Field** conditions.

- Simulate and Predict **Electrostatic Precipitation (ESP) Efficiency** of a **novel 4-needle-plane electrode test cell.**

- **Compare** simulated trend to practical testing through the use of **Laser Aerosol Spectrometry** in laboratory air under dry and wet conditions.

Electrode & Test-Cell Configuration

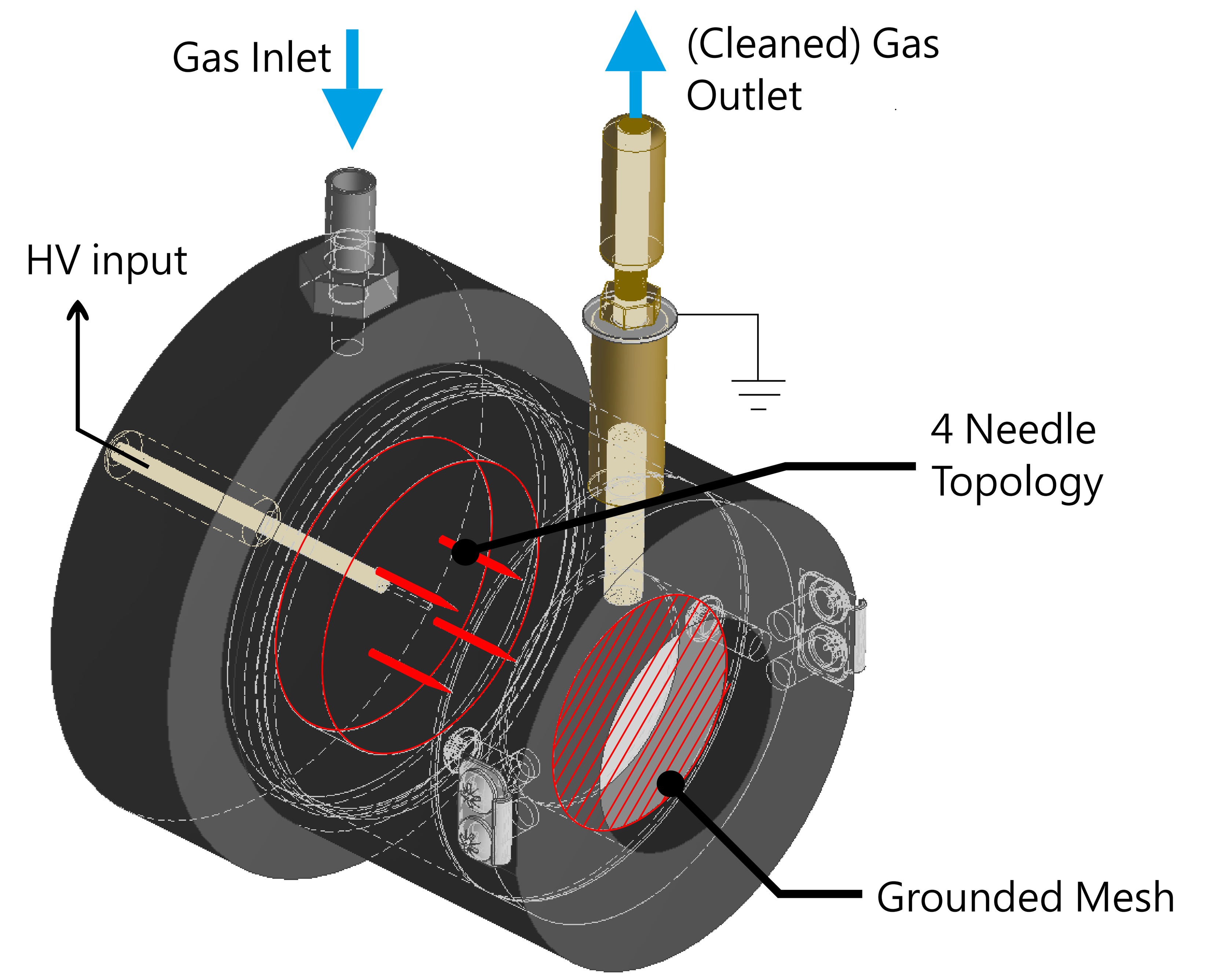


Figure 1: CAD Model of test-cell, with electrodes highlighted

Particle Dynamics Solver

Electric Field Topology solved using **QuickField FEA solver**

Custom **MATLAB variable-step** solver written to take Field solution output and solve for **Particle Dynamics and Trajectory** using above Charging Model.

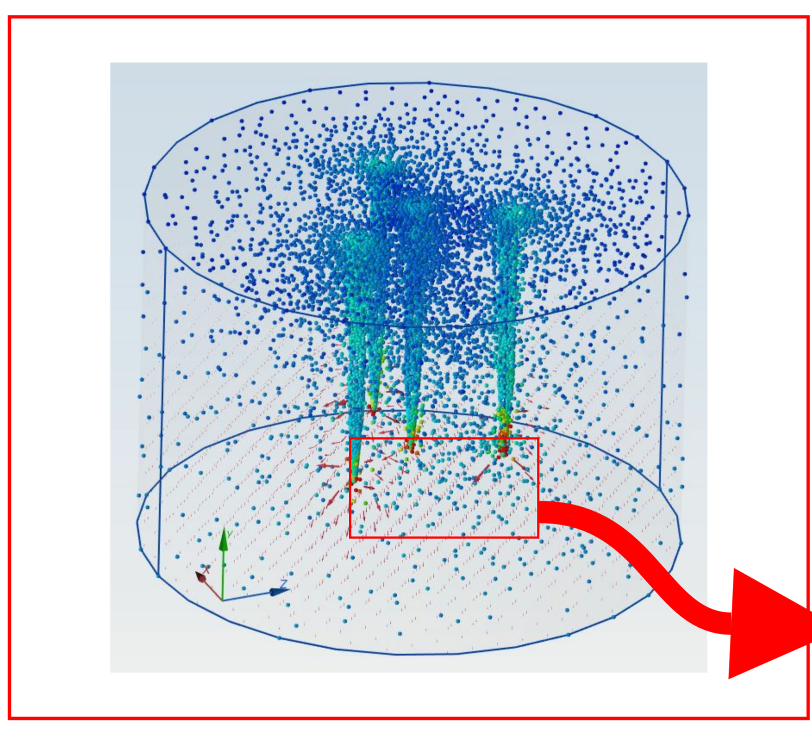


Figure 2: QuickField FEA Solution Visualisation

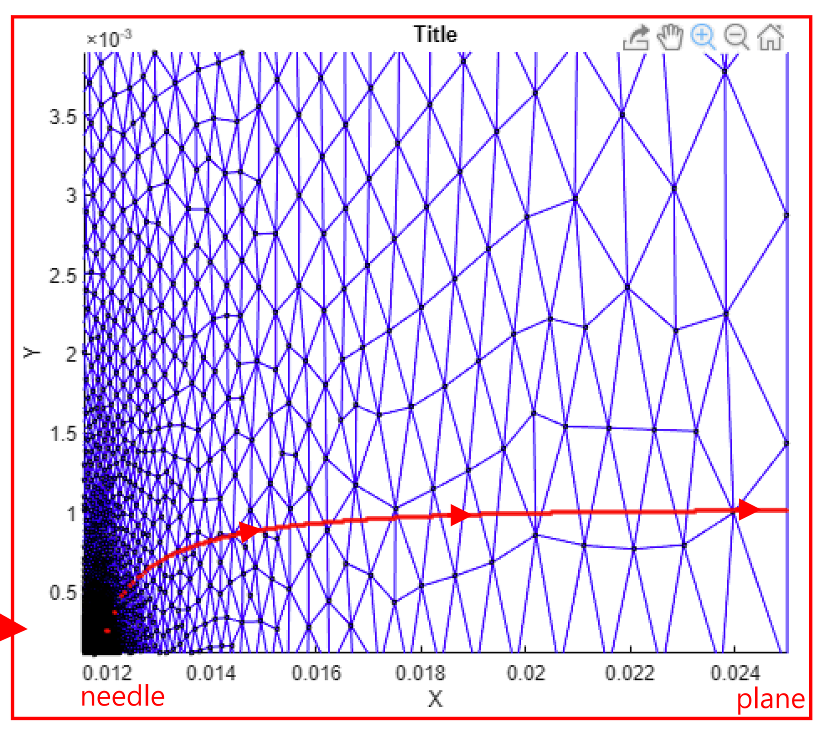


Figure 3: MATLAB Solver Particle Trajectory (Water)

Used to predict **Electrostatic Precipitation Efficiency**

Charging Model

Governing Differential Equation [1]:

$$m\frac{\mathrm{d}^2\mathrm{x}}{\mathrm{d}t^2} = mg + E(x)\left[q_c(t) + q_p(t) + q_d(t)\right] - \frac{F_d}{C_0}$$

Conduction Charge: $q_c(t) = 6\pi R_p^2 E(x)\ \epsilon_0 \frac{\epsilon_m\sigma_p - \sigma_m\epsilon_p}{2\sigma_m + \epsilon_p}\left(1 - e^{\frac{-t}{\tau_{mw}}}\right)$

Polarisation Charge: $q_p(t) = 6\pi R_p^2 E(x)\ \epsilon_0\epsilon_p\left(1 - \frac{\epsilon_p + \epsilon_m}{2\sigma_m + \sigma_p} e^{\frac{-t}{\tau_{mw}}}\right)$

Diffusion Charge: $q_d(t) = \frac{2\pi\epsilon_0 kTd}{e}\ln\left(1 + \frac{e^2 Ntd}{2\epsilon_0\sqrt{2\pi mkT}}\right)$

Viscous Drag Force: $F_d = 6\pi\eta R_p \frac{\mathrm{dx}}{\mathrm{dt}}$

Considers spherical particles **Diameter**, **Conductivity**, **Permittivity** and **surrounding medium** in any field **E(x)**

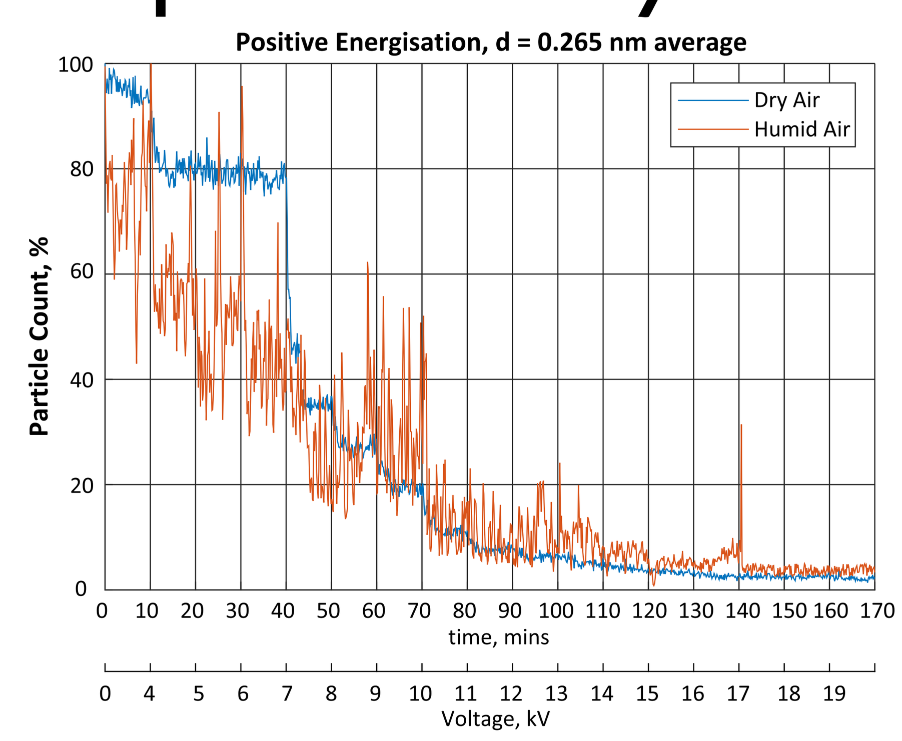
[1] I. Timoshkin et al. "Analysis of Particle Charging Mechanism for Optimisation of Precipitation Efficiency"

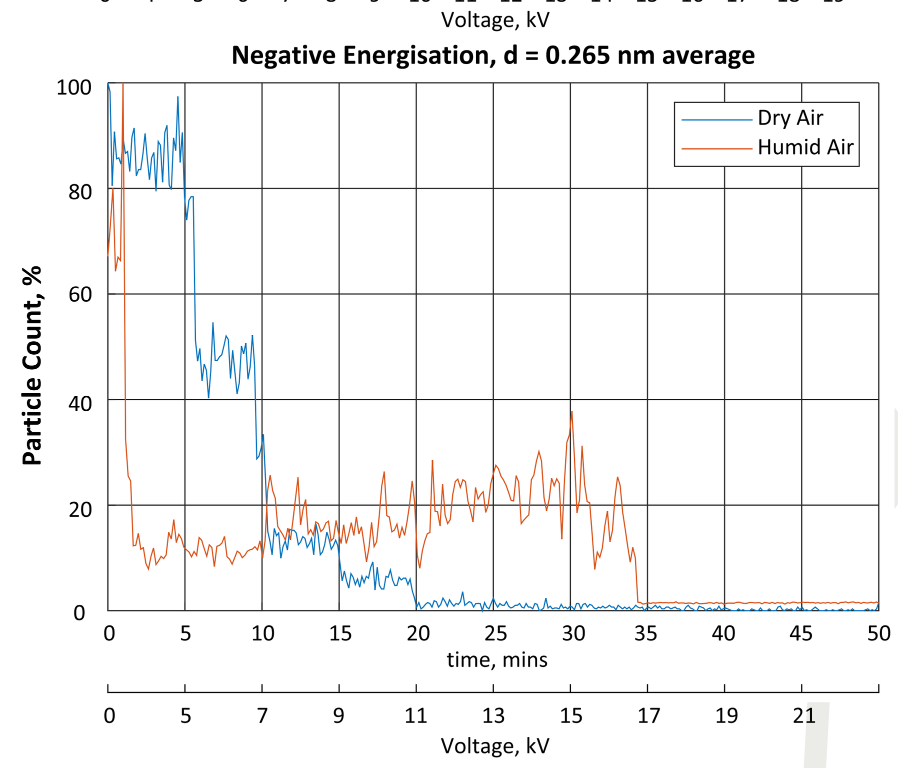
Laser Aerosol Spectrometry

Using the **GRIMM Laser Aerosol Spectrometer**

Concentrations of **PM 0.265 nm** and above in laboratory air were measured for a **DC voltage range of 0 to 21 kV**, for both **dry** and **humid air.** Both **positive** and **negative** energisation was tested.

All tests ultimately achieved **over 95% Precipitation Efficiency**, with dry air exhibiting **higher stability** in recorded PM count. **Negative energisation sees better precipitation performance overall.**





Discussion and Further Work

- Measured relationship between **precipitation efficiency** and **voltage** was found to **closely match predicted behaviour** from numerical solvers.

- Future line of investigation to **repeat study under pulsed regime** to **compare performance** to single point-plane topology.

- Potential interest with regards to the **precipitation of contaminants** on **HVDC power lines** under various atmospheric conditions.