"Multi-physics" studies for the Micromegas detector

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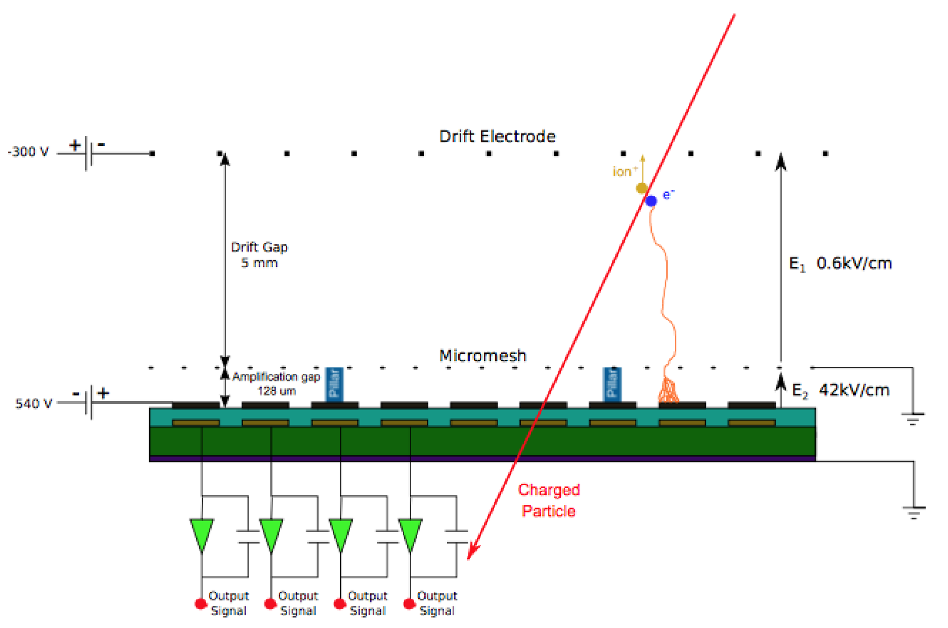
Introduction 1

The "Micromegas" (Micro-MEsh Gaseous Structure, MM) detector is a gaseous particle detector mainly used in experimental physics for the detection of ionising particles. Owing to its unique characteristics the MM has been selected for the New Small Wheel upgrade project of the ATLAS experiment at CERN LHC. Here we present studies of the electric field configuration in the detector's area and its importance. Furthermore, analysis of the gas propagation inside the chamber has been done. All the various studies which have been crosschecked with the COMSOL Multiphysics are in good agreement with the predicted theoretical results.

The MM Detector 2

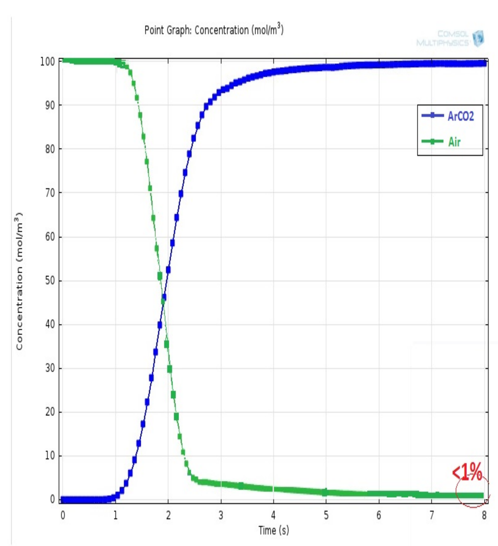
Micromegas consists of two parallel plate regions, the conversion (CR) of 5 mm and the amplification (AR) of the order of 128 μm. A charged particle passing through the chamber's volume ionizes the gas (CR) consequently creating an avalanche (AR) of charged particles (ion-electron pairs). As a result, the energy that deposited on the strips is determined from the two main operational parameters, the electric field and the gas gain which play an important role on the detector's efficiency. The figure below depicts the MM's operation principle.



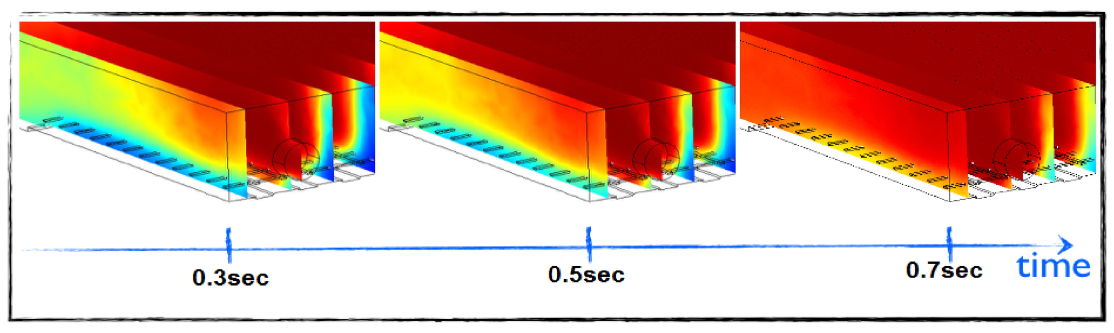
MM Mesh Flow Studies 6

This study includes the propagation of the gas mixture through the micromesh structure. The aim is to have a uniform distribution to avoid "inefficient" areas into the chamber's volume which would worsen its performance.

The diagram shows the concentration of gases in the chamber versus time. The gas mixture used for these studies is $Ar + 7\%CO_2$.

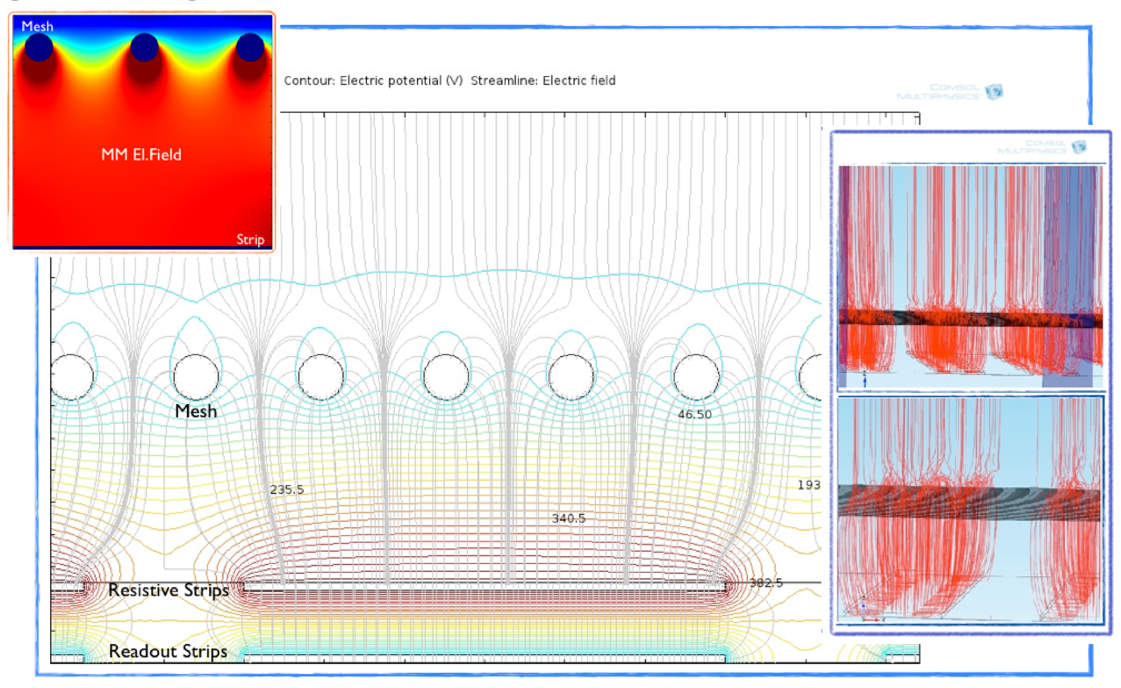


The following instances show the propagation of the gas through the micromesh.



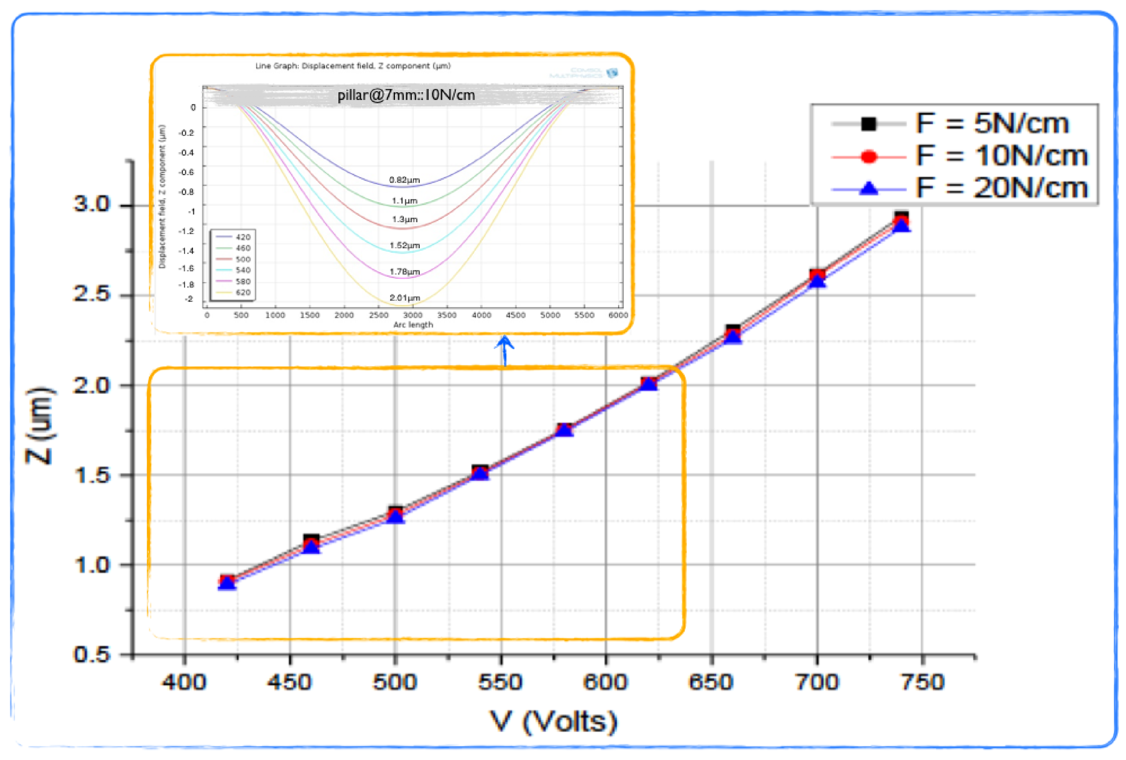
MM Electrostatic Study 3

A homogeneous electric field is produced in both regions via the micromesh. Its shape is of vital importance, because it directs the electrons to the strips and evacuates the ions from the AR using the "funnel effect", which is directly proportional to the ratio of the electric fields between the two regions. The electric field (grey) and the equipotential lines (coloured) are shown in the figure (2D&3D), accompanied by the electric field intensity in the AR. All the plots have been done via COMSOL Multiphysics and they are in good agreement with the theoretical results.



MM Mesh Sagitta Studies 4

MM as a "capacitor" formed detector strongly depends on the size of the AR, which could fluctuates locally (there are pillars which support the mesh at pitch=8mm), due to the strong attraction of the electric field. The main goal is to measure this deformation of the mesh due to the electrostatic force, in different mechanical tension values that have been applied during the mesh placement in MM. The diagram shows the sagitta[μm] versus the high voltage[V] in different tension values[N/cm], calculated by COMSOL Multiphysics.

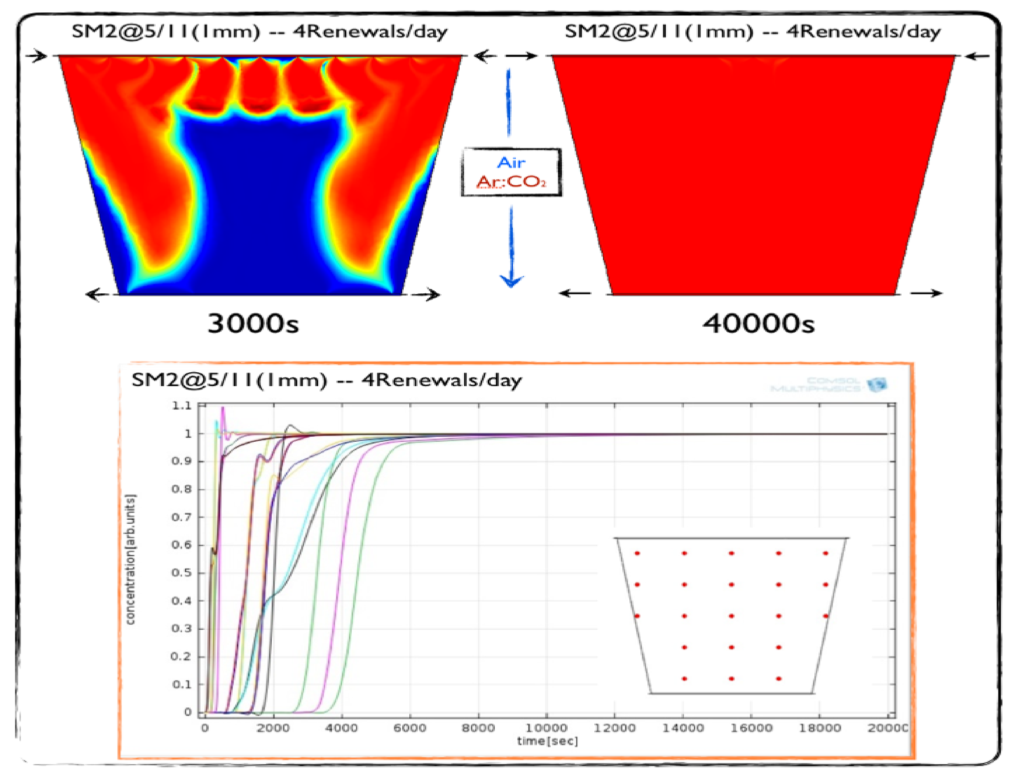


MM gas distribution 5

MM uses the technique for the gas distribution, called buffer zones (BZ). These areas provide the correct conditions for laminar flow. This configuration will ensure the avoidance of "inefficient areas", which will cause a decrease in the detection efficiency.

In order to preserve an optimal operation of the MM, this study is based on some restriction parameters. Namely: a) nominal flow rate at 5NL/h on each BZ inlet, b) hole number must be optimized and c) empirical ratio between the buffer's zone size and the hole diameter ($d_{bz}/d_{hole} \sim 10$).

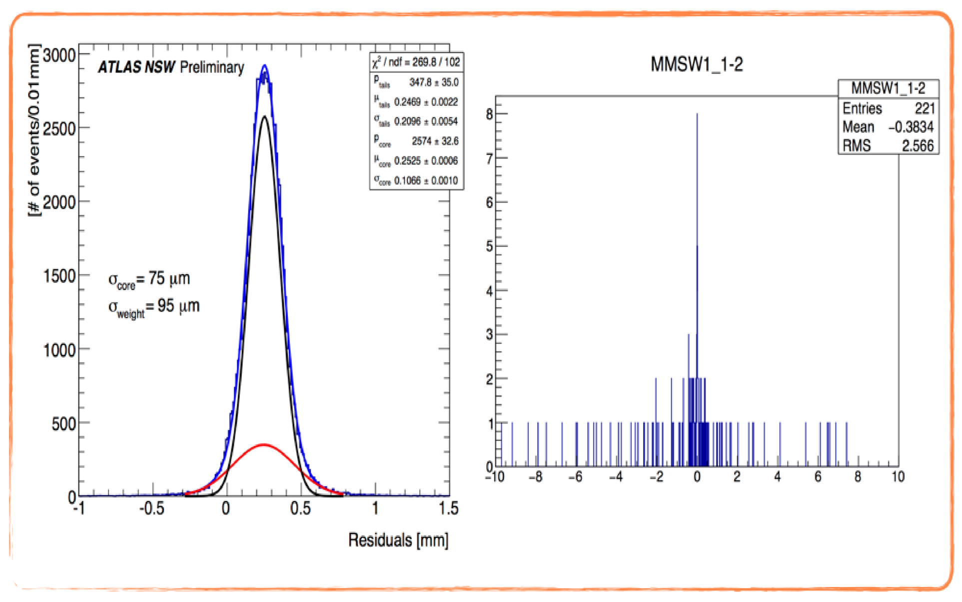
The plot on the top shows the movement of the gas inside the detector's volume. Red color refers to $Ar + 7\%CO_2$ (close to atmospheric pressure) and blue to air (initial condition).



The lower plot shows the normalized concentration of the gas mixture in various points inside the chamber versus time.

MM Spatial Resolution 7

Spatial resolution is one of the most merit parameters of the detector. It illustrates the uncertainty with which the detector can reconstruct an impact point of a passing charged particle. The spatial resolution is directly connected with the absolute gain. Here we validated the importance of the two main operational parameters (electric field & gas gain) on the detector's resolution. The plots on the right depicts the comparison between the resolutions of an inefficient detector (right histogram) and an optimal one (left histogram).



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