Material studies for gaseous muons detectors at HL-LHC

A.V. Franchi[1], G. Saviano[1], B. Teissandier[3], M. Taborelli[3], L. Benussi[2], S. Bianco[2], D. Piccolo[2], S. Muhammad[1,2,4], G. Raffone[2], L. Passamonti[2], D. Pierluigi[2], A. Russo[2]

1) University of Rome "La Sapienza" (IT) - Facoltà di Ingegneria, Ingegneria Chimica Materiali ed Ambiente, Italy
2) INFN-Laboratori Nazionali di Frascati Via E. Fermi 40, I-00044 Frascati, Italy
3) CERN- Vacuum, Surfaces and Coatings (VSC) TE Department, Switzerland
4) National Centre for Physics, QAU, Islamabad, Pakistan

Abstract

The systematic studies of the GEM foil material are made which may possibly proceed later to see the effects at the performance and behaviors of the detector, as a result of interaction with the fluid and of the radiations. These studies are focused on the foil contact with ambient air and moisture, therefore we want to determine the value of the diffusion coefficient of water in the detector polyimide. Because the presence of this compound inside the detector's foil can determine the changes in its mechanical and electrical properties. A model is developed with COMSOL Multhiphysics v. 4.3 [1], which described the adsorption on a sample. So the following poster will illuminate the model and its experimental verification results and diffusion within the entire sheet geometry of GEM, gaining concentration profiles and the time required to saturate the system.

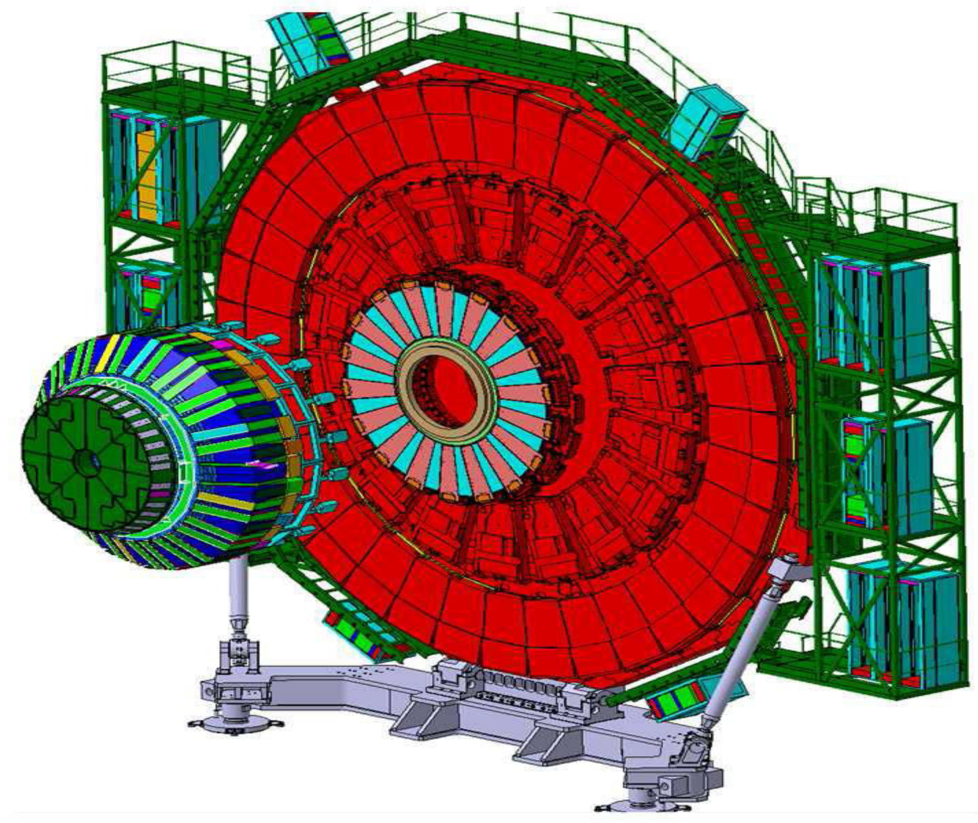
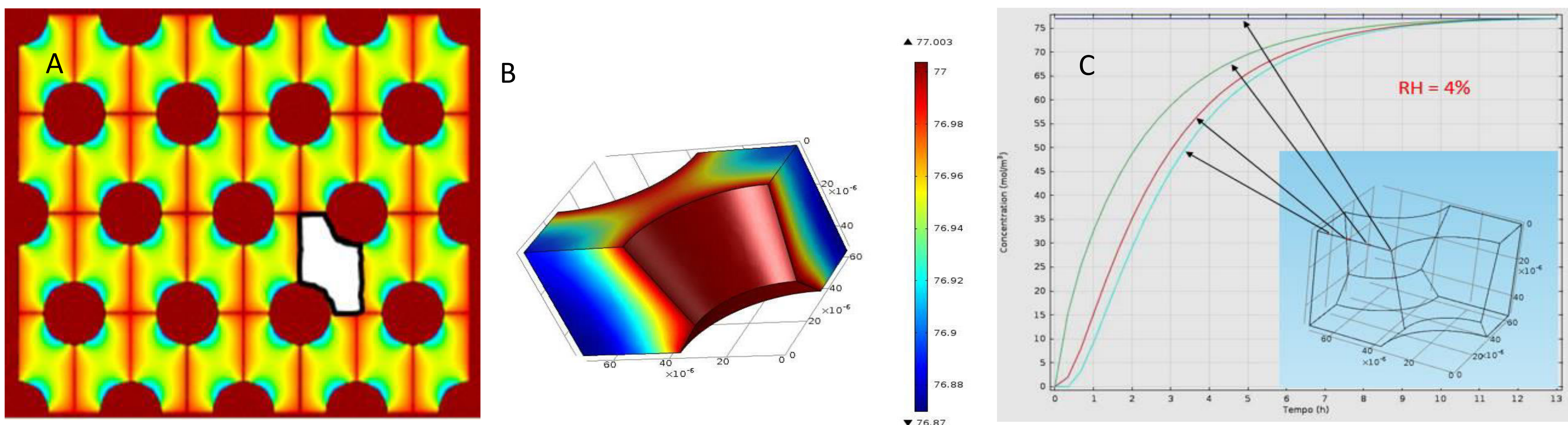


Figure 1:GE1/1 proposed installation position at CMS [2]

Introduction

For upgrade of the forward muon system of Compact Muons Solenoid (CMS) at Large Hadron Collider (LHC), the Gaseous Electron Multiplier (GEM) is being considered a most suitable detector, due to its good timing and position resolution, it can meet the particle detection requirements of the eta region 1.6 < |η| <2.2 where high particle flux 5kHz/cm² is expected [2]. GEM foil is a major part of the detector which is responsible for signal amplification, this phenomena is happened due to the especial shape of very dense micro holes with in a thickness of 60µm (50µm Kapton cladded with 5µm copper on each side).



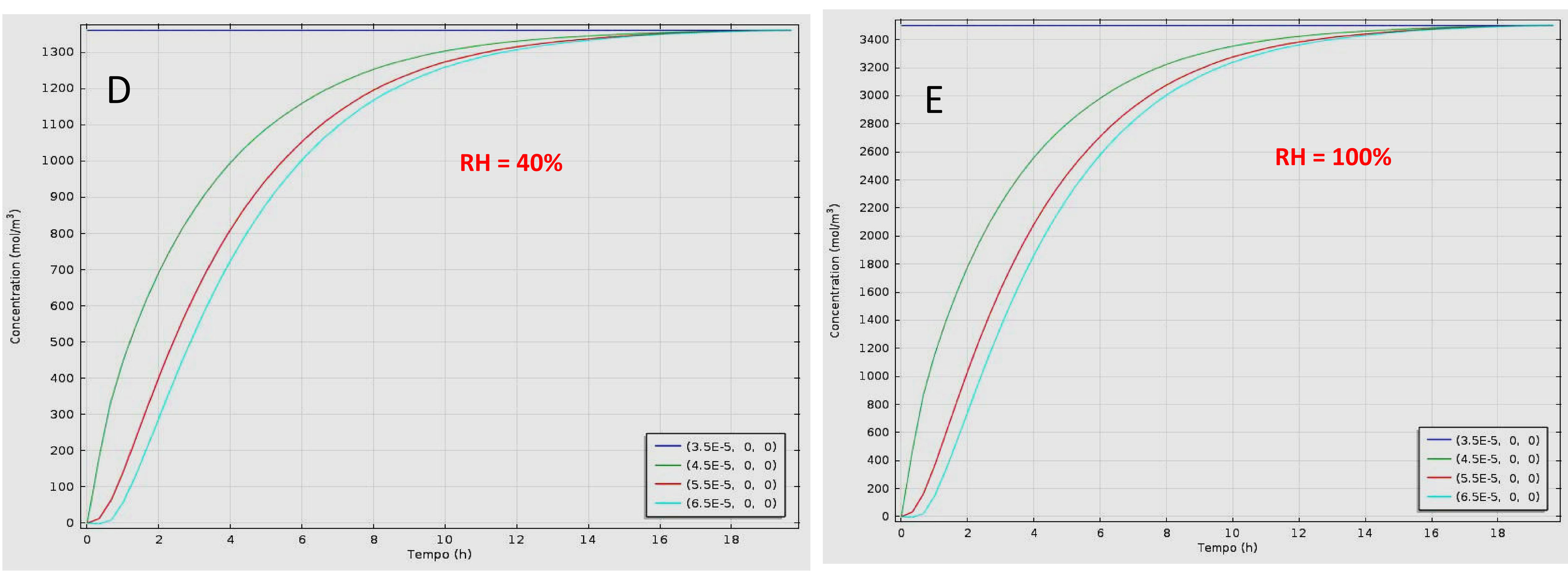


Figure 2. (A) Geometry of a GEM and detail analysis part is in black and white [4], (B) Concentration profile after 44400 s with RH = 4% (C) Time vs. concentration for different points of the geometry, with RH = 4% , (D) Time vs. concentration for different points of the geometry, with RH = 40% and (E) with RH =100%.

Development of a diffusion model using COMSOL Multiphysics

It is considered the diffusion of H_2O from only the hole surface, the water cannot penetrates inside the polymer from the copper which behaves as a waterproof barrier. It is also overlooked the presence of any stagnant film around the surface of the hole because the gas is continuously flushed inside the chamber, allowing to always have a constant and uniform concentration on the surface of the hole, this value represents the maximum concentration of water that can get inside the structure. In general the moister comes from the surrounding environment and spreads within the polymer, has condensation on the surface of solid and gas exchange (i.e. on the inner surface of the holes in the sheet). The relation, that allows to obtain the value of this concentration on the surface of a polyimide (Kapton) as a function of the external humidity, it is derived from the literature [3], $c_1 = 4.520 * 10^{-4} * RH - 8.319 * 10^{-4}$ (1), c_1 expressed in grams of water to grams of polymer. The formula used is empirical and it is compatible with the official data released by the manufacturer [5]

Experimental setup for verification of the diffusion model

An experiment is arranged at the lab of INFN (Laboratori Nazionali di Frascati dell'INFN). The experimental setup is shown in Figure 3, it consists of a weighing balance "Analytic balance Gibertini E42S", the measurements are recorded by using a camera in front of the analytical balance display and connected to a computer, which has a data acquisition program to obtain regular interval weight measurements. For the test, a sample of GEM foil is prepared with standard dimensions and production: its dimensions are 105 mm X 50 mm X (50 + 5 +5) µm and previously it is conditioned in an oven at (105 ± 5) ° C for 36 hours. A hook in the balance is used to hang the sample in this particular test, it is employed to a wire whose one end is connected to the sample, the other to the plate of weigh balance, using a slot at the bottom of the scale. During test small oscillations in the wire are noticed that are due to the low weight of the GEM sample which is attached. So it was not possible to obtain very precise measurements, at least in the range of the tenth of a milligram. Since this digit is the most significant for this type of measurement which we are doing. Therefore we placed a sample of known weight (a small bolt) at the plate in the balance, this helped to stop the oscillations of the wire.

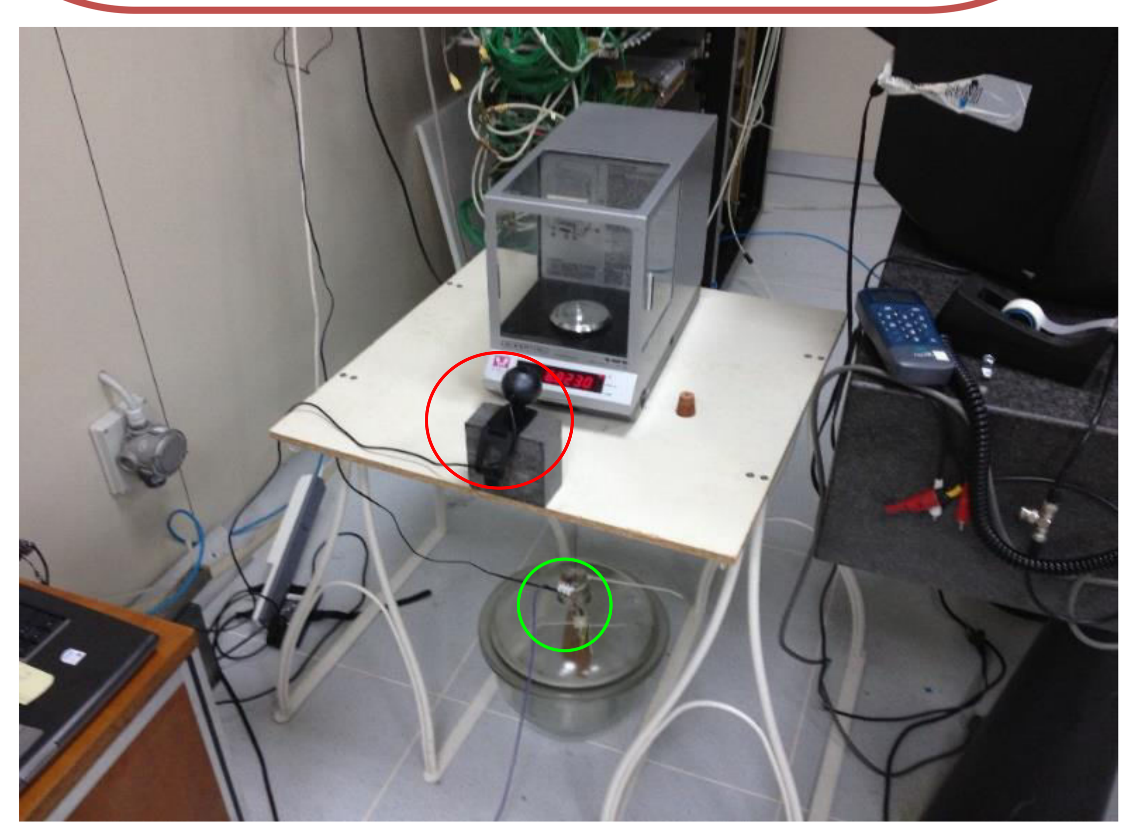


Figure 3. Data acquisition (in red) and instrumentation for monitoring environmental conditions parameters within the glass container (green)

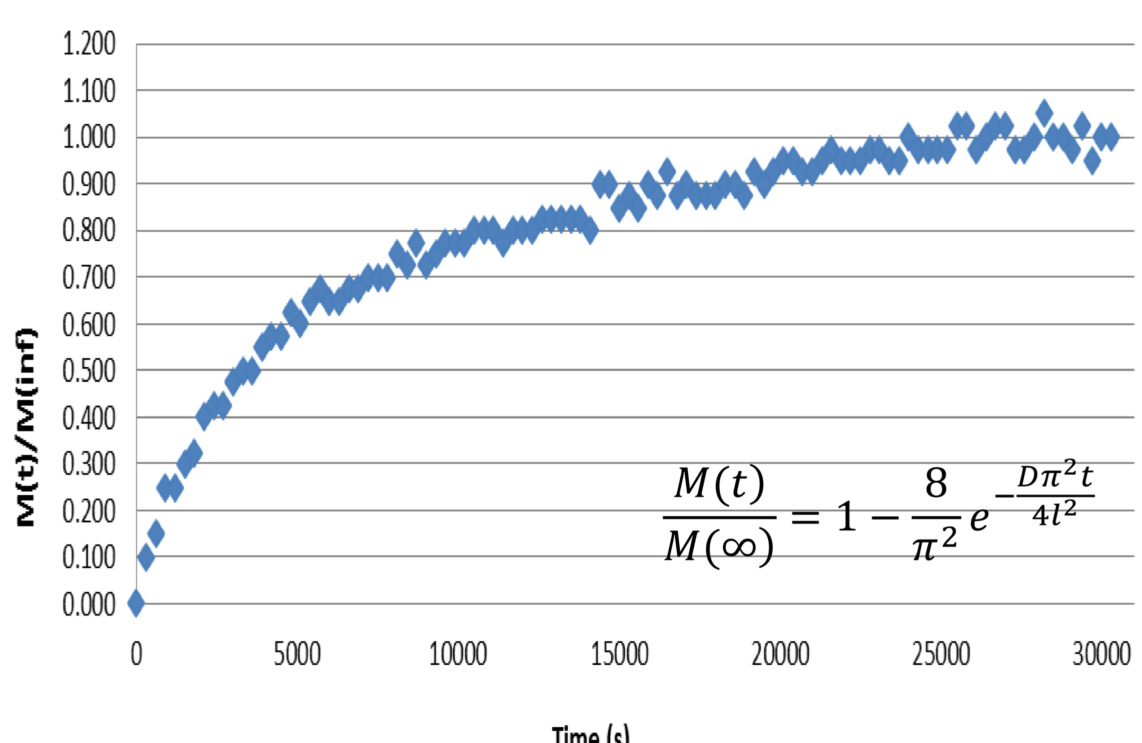


Figure 4. Saturation trend of the GEM foil

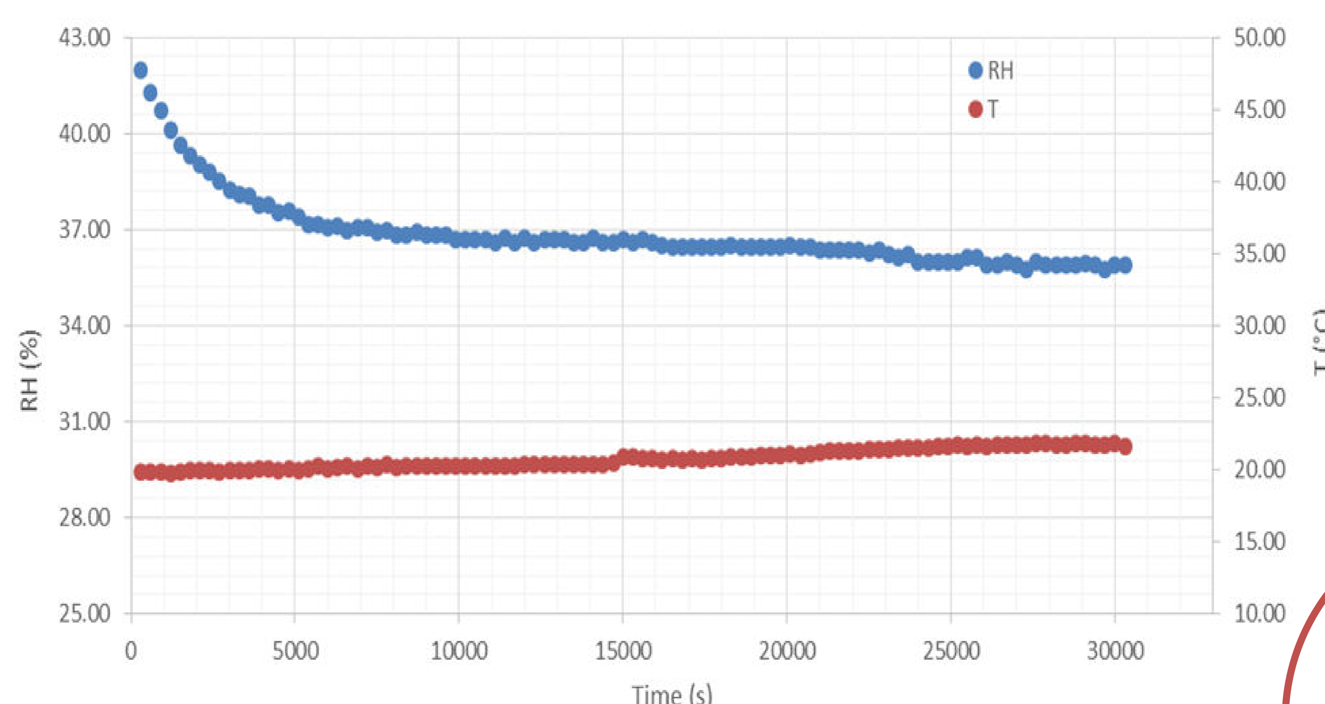


Figure 5: Temperature and relative humidity with respect to time within the glass container during the test

Results discussion

After the conditioning in oven, the sample is weighed and found a value of (0.6575 ± 0.0002) g, while the bolt placed on the scale plate had a weight of 5,725 mg. The Humidity and temperature range during this test is selected as RH = 37-38% and T = 19-20° C, the images are taken from every 5 minute interval. The trends of saturation along with temperature and humidity during test are shown in Figure.4 and Figure 5 respectively , in 8-9 hours it is possible to saturate completely the GEM foil. These results are exactly matching with the model as described above. Furthermore, the measurements showed the presence of 0.004 g water at saturation, perfectly comparable with what is obtained from the official datasheet by the manufacturer [5] or from the formula (1) for a value of RH = 37.5%. By using the experimental data calculated the diffusion coefficient of water in the foil which is $D_{GEM} = [3.3 \pm 0.1(stat)]10^{-10} cm^2/s$. [6]

Summary and Conclusion

A model for describing the diffusion phenomenon within GEM foil is developed. It is assumed that all the water, coming from the humidity, condenses on the surface of solid, gas exchange internal surface of the holes where the electronic avalanche will produce; this surface is the only available for the penetration of the water inside the sample, because the copper coating (on the top and bottom) behaves as a waterproof barrier. It is also assumed that near the surface of exchange there is not a stagnant film, hypothesis certainly validated by the presence of a gas flow in continuous circulation. To experimentally verify the model a test is performed at the GEM foil sample, doing some continuous measurements of the weight in a well-conditioned system, built for the occasion: using a mixture of potassium carbonate and saturated water to get a stable value of RH in the range of 37-38% inside the container, the sample is hung to a wire, connected to the analytic balance. After 9 hours the equilibrium is achieved and the amount of water absorbed is 4 mg, this value is perfectly comparable with the official datasheet released by DuPont and used the experimental data to calculate the diffusion coefficient of water in GEM foil.

References:

[1] COMSOL Multiphysics ®; Vers. 4.3, Copyright© 1998-2013 by COMSOL, Inc.
[2] CMS TECHNICAL DESIGN REPORT FOR THE MUON ENDCAP GEM UPGRADE, CERN-LHCC-2015-NNN CMS-TDR-15-001, ISBN 978-92-9083-396-3, Draft V06-00, 27 February 2015
[3] Sacher E., Susko; *"Water Permeation of Polymers Films. I. Polymide"*; Material and Engineering Analysis, IBM Corporation System Division Endicott, New York; 1978
[4] G.Raffone "*CMS Trapezoidal GEM Foils Structural Analysis*" preprint LNF-10/20(IR)
[5] Kapton® HN Technical Info; DuPont
[6] D Abbaneo *et al* **"**Study of film and foil materials for the GEM detector proposed for the CMS muon system upgrade" 2014 *JINST* **9** C04022 doi:10.1088/1748-0221/9/04/C04022

Contacts:
saleh.muhammad@cern.ch