CMS

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1 Introduction

The Compact Muon Solenoid (CMS) experiment [1) 2)] in 2015 as started to explore the new energy regime of 13 TeV collisions to improve the precision on the Higgs boson [3)] parameters and to search for new physics beyond the standard model. The key element of the CMS detector is the highly performing and redundant muon system. Drift tubes and Resistive Plate Chambers (RPC) in the Barrel and Cathode Strip Chambers and RPCs in the endcap are used for both triggering and tracking of muon particles. In the Long Shutdown 2 (LS2) in 2018 CMS will install in the The activity of the CMS Frascati group is focused on various responsibilities in the construction, operations and monitoring of the RPC detector, as well as in the quality control of data and physical data analysis. In view of the high luminosity LHC upgrades of phaseII, the group is also highly involved in studies of longevity of the present system and in the development of GEM detectors, for the completion of the muon system at high η, that will be installed in 2019.

2 Activity of the CMS Frascati

The Frascati group is deeply involved in the muon project of the CMS experiment since 2005 and covers position of responsibility since many years. The group has been responsible of the construction and of the maintenance of the Gas Gain Monitor system and is heavily involved in all the activities both during the running periods and during the last years shutdown efforts. Several responsibilities have been covered by members of the group during these years: In 2010 and 2011 the RPC DPG (Detector Performance Group) coordinator was a Frascati charge.
In 2011 and 2012 the RPC Run coordination.
From 2013 the CMS GEM hardware coordination is covered by Frascati with the charge to coordinate the R&D and the construction of the CMS GEM detector.
For the period 2013-14 a member of the group was the RPC national responsible.

In 2015 the main efforts of the group were devoted to the support to the commissioning activities of CMS RPC and on studies and R&Ds for the future muon upgrades at high eta.

Since 2015 the Frascati group has the responsibility to coordinate the general CMS GEM production. A member of the group is the CMS GEM Resource Manager since 2015 while another

member has the charge of RPC Italian National responsible.

3 GGM maintenance and data analysis

The Gas Gain Monitoring (GGM) construction has been the first contribution of the Frascati group to the RPC collaboration. The system monitors the changes in working point due to gas variations, by means of monitoring of anodic charge in small RPC gaps in a cosmic ray telescope. During 2016 few hardware intervention have been necessary to fix a leaky chamber and some electronic channels.

4 GEM Resource Management

Both GE1/1 and the proposed Phase2 projects (GE2/1 and ME0) have required the setting up of Resource Management procedure and tools peculiar of new activities. The core funding of GE1/1 was structured by means of an Addendum to the CMS Construction Memorandum of Understanding. Such Addendum was drafted, proposed and is being approved by the 34 participating Institutes and 11-Countries funding agencies. Funding plan for 5-year periods was proposed and approved for Maintenance and Operation (type B) funds. A sharing algorithm based on the FTE participation of various Institutes was devised and implemented. New, integrated accounting procedures were adopted and implemented, in synergies with the three other Muon projects.

5 AIDA2020

The CMS Frascati group is responsible for WP 13.8 "Control of MPGD foils mechanical tensioning via optical methods". The goal is to apply FBG sensor to monitor the stretching of foils over time, and to use interferometric techniques during chamber construction. For the latter, it was proposed to use moiré techniques for the first time in HEP detectors. By using moiré interferometry a 30um precision on the transverse plane was reached on small field of view. The programme will be concluded in 2017 by realising the engineering prototype apt to large scale MPGD production, and to verify that the design resolution is reached on large field of views (approximately half a GE1/1 chamber).

6 New materials for HL-LHC gas detectors

The use of gas detectors for muon at HL-LHC poses challenges due to high-rate, and detector lifetime due to ageing caused to increase radiation levels. The search for new, eco-friendly gases is also dictated by the changing conditions of the market in terms of industry-produced fluorocarbons. Both conditions ask for detailed investigations on the interaction of materials used in gas detectors with the new gases, and the tolerance of materials to increase radiation levels.

The Frascati group was funded by INFN Phase2 R&D programme to carry on a set of investigations on both ecogases and materials. The material characterisation is carried on by means of the component of associates from Sapienza University of Rome, Materials Engineering.

Collaboration with associates of Turin Polytechnic allowed to address issues on polymer deposition and 3D-printing of coatings. The FBG programme is carried out with the CMS Frascati associates from ENEA.

During 2016, in order to perform material characterization of the GEM detector, mechanical tests were performed to examine the mechanical performance of Polyimide (Kapton) and GEM foil. Bearing in mind the mechanical stresses imposed during the assembly and subsequently during operation of the detector for many years in the harsh radiation and environmental conditions at the CMS, a series of the tensile tests were performed by using different samples which were prepared accordingly, i.e. a set of the samples was exposed to neutrons and another exposed to gamma radiation, and then these were made extra dry and wet to assess the effects of radiation and humidity on their tensile properties. Lastly, a set of the samples was thermally treated between 300^oC and 360^oC to check the temperature response of the foils in terms of surface morphology and tensile behaviour. It was found how the radiation and environment variation conditions the degradation of the GEM material is not so significant with respect to its toughness, but the Youngs modulus was effected. The heat treatment significantly affected the tensile properties of the material but no chemical and composition changes were detected.

CERN has recognised the importance of such studies and actively collaborates with the Sapienza associates of the Frascati group. A summer student fellowship was granted for the third year in a row (with a member of Frascati group as co-supervisor along with A.Sharma - GEM Project Manager), by the title "Analysis of Mechanical Properties for the GEM Foil". Tensile tests are performed both at CERN and at Sapienza, by using high resolution microscope and tensile test setup. The samples are cut in the transverse directions (no HV sector grooves) and were made dry and wet.

To study long-term stability of GEMs under constant stress, the creep tests were performed on the GE1/1 samples which were prepared in the transverse and longitudinal directions. Two creep tests were performed for 29 days and 40 days continuously respectively. The HV grooves effects are significant such as the elongation rate was faster for the grooves samples than the samples without grooves, in both cases it is seen that after 20-25 days the elongation was negligible small. New materials and coatings for Resistive Plate Chambers (RPCs) are being also investigated, by modifying the existing materials and by proposing new materials. Several coating techniques are tested, with equipments available both at Sapienza and Turin Polytechnic. Surface morphology and roughness are studied using Scanning Electron and Atomic Force Microscopes. For chemical structure of the surface the Fourier Transform - IR analysis was performed. In the second approach, we are trying to develop a new material for the RPCs electrodes. The work on the second approach is ongoing in close collaboration with the Synchrotron Radiation Lab in Frascati.

7 GEM chamber assembling at Frascati

The GE1/1 production will start after summer 2017. CMS Frascati play a central role having a member of the group in charge as general production supervisor, with responsibility to follow the

production in the other assembly sites, INFN Bari, Florida Institute of Technology and CERN.

Frascati is also a production site of GE1/1 chambers. In the Frascati CMS laboratory the chambers will be assembled and also tested in several Quality Controls requested to to accept a chamber for the final installation in the experiment. The assembly will take almost 10 months and will involve the whole Frascati group.

The Group has also the responsibility of the installation and operation of a network of FBG temperature sensors mounted in two chambers of eight of GE1/1 chambers installed in CMS for the so called slice test. The aim of the slice test is to test the GE1/1 integration and in the CMS experiment in terms of DAQ, Trigger and DCS. The FBG sensors will provide a detailed map of the temperature gradient in the GE1/1 region, allowing to understand possible effects of local high temperature spots on the chamber performances.

In the final installation a network of FBG will be mounted on the chambers and this activity will be under the Frascati responsibility.

8 GEM and RPC gas mixture R&D

During 2016 the Frascati group was continuing to develop an intensive R&D program to find an ecological replacement for the tetrafluorethane $C_2H_2F_4$ (commonly called r134a) used for the Resistive Plate Chambers. Two candidates have shown interesting properties: Tetrafluoropropane ($C_2H_2F_4$) and Trifluoroiodometano (CF_3I). Both of them are very electronegative and cannot be used alone to replace the r134a because the working voltage is moved at very high values. Several combinations of these components with CO_2, Argon, Helium have been tested.

For each gas mixture the efficiency, the induced charge and the time resolution have been measured.

Many results have been presented to the XIII workshop on Resistive Plate Chambers and related detectors showing interesting properties. More studies are needed to find the correct balance between different components in order to be used for the CMS experiment and to verify the aging properties of such gases in high background environments.

At the end of 2016 an important activity to produce the Technical Design Report for the CMS muon upgrade started. A big effort is ongoing to develop the RPC section of the TDR.

Studies are also ongoing about the possibility to develop a trigger strategy for the Heavy Stable Charged Particles search, based on the upgraded RPC system.

9 GEM Phase2 R&D

For the post LS2 phase, the High Luminosity LHC run, CMS is planning to instrument new areas of the experiment in order to maintain the excellent trigger efficiency with the new high luminosity foreseen. The CMS GEM community is proposing different options of detector to be installed in the so called GE2/1 region covering the pseudo-rapidity region $1.55¡|\eta|$. The CMS Frascati group is working on one of these new detector together with the LHCb Frascati group. The new detector under study is called Micro-Resistive WELL (μ-RWELL). It is a new Micro Pattern Gas Detector

(MPGD) which will extremely simplify the GEM technology, since it has a single GEM-like foil glued directly on the readout board with a resistive layer in between. This detector maintains an high detection efficiency even at reasonable high particle rate (some kHz/cm^2), as the GE2/1 region has, but it reduce dramatically the construction cost. CMS Frascati participated to the assembly of the first large size μ-RWELL prototype and to the beam test where the prototype demonstrated the expected performances requested. This detector actually has been installed in the Gamma Irradiation Facility (GIF++) at CERN for measuring the aging effect after 10 years of HL-LHC operation.

10 Physics analysis: high mass resonances

The Frascatis group is also involved in the physics analysis activity of Run2.

During the 2016 the analysis on we mainly spent our efforts has been the search for heavy resonances, like Z boson, decaying into a muon pair. This is one of the hot line legacy analysis for CMS, therefore after the end of data taking (Nov 2016), a lot of work has been done to get results with the full statics available so far, while recently, the combination of the results using the first 3 fb^{-1} of data at 13 TeV and the full 8 TeV data have been published [15)]

This search got some delay in order to address some issues related to the different behaviour of the dimuon mass in MC with respect to the data for values above 2 TeV. This is a crucial aspect in order to trust about the background expectation.

Another analysis which is in progress is the search for the MSSM Higgs decaying into 2 muons, which needs to be optimized for the 13 TeV data, and it is expected to give results by the end of the year.

11 Activity planned for 2017

Frascati group will support the data taking of the CMS RPC system and will continue to maintain and operate the Gas Gain Monitoring system during the whole 2017. Beside this the GEM installation foreseen in the second long shutdown (LS2) is approaching quickly and the GE1/1 chamber production will start in Autumn 2017.

Frascati is one of the GE1/1 production site and has also the responsibility to follow the production in the other four assembly sites, INFN Bari, Florida Institute of Technology and CERN.

Frascati group also started a new activity at the end of 2015 concerning the development of a new kind of Micro Pattern Gaseous Detector (MPGD) called μ-RWELL detector. This activity is in the framework of the Phase2 upgrade of CMS which goal is to install new detector in the endcap covering the pseudo-rapidity region 1.55¡$|\eta|$

Concerning the physics analysis, Frascati will continue to give efforts in the search for a high mass resonances decaying in two muons with the new 2016 data. The amount of data expected in the 2016/17 could be promising to see/exclude some of the theories extending beyond the Standard Model. Given the experience in the dimuon searches, frascati will be also involved in the searches for a BSM neutral higgs-like particles decaying in two muons.

12 Conference Talks by LNF Authors

For the complete listing of CMS papers in 2016 see /www.slac.stanford.edu/spires/

1. L. Benussi *et al.*, JINST **11**, no. 08, P08002 (2016). doi:10.1088/1748-0221/11/08/P08002
2. M. Abbrescia *et al.*, JINST **11**, no. 09, C09018 (2016) doi:10.1088/1748-0221/11/09/C09018 [arXiv:1605.08172 [physics.ins-det]].
3. M. Abbrescia *et al.*, JINST **11**, no. 08, P08019 (2016) doi:10.1088/1748-0221/11/08/P08019 [arXiv:1605.01691 [physics.ins-det]].
4. D. Abbaneo *et al.*, Nucl. Instrum. Meth. A **824**, 493 (2016) doi:10.1016/j.nima.2016.01.059 [arXiv:1512.08481 [physics.ins-det]].

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1. CMS Collaboration home page is /cms.cern.ch/.
2. R. Adolphi *et al.*, "The CMS experiment at the CERN LHC," JINST **3** (2008) S08004
3. S. Chatrchyan et al., "Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC", Phys. Lett. B 716 (2012) 30
4. M. Tytgat, *et al.*, "The Upgrade of the CMS RPC System during the First LHC Long Shutdown," PoS RPC **2012** (2012) 063 [JINST **8** (2013) T02002] [arXiv:1209.1979 [physics.ins-det]].
5. D. Abbaneo, *et al.*, "A GEM Detector System for an Upgrade of the High-eta Muon Endcap Stations GE1/1 + ME1/1 in CMS," arXiv:1211.1494
6. A. Colaleo, *et al.*, "CMS TECHNICAL DESIGN REPORT FOR THE MUON ENDCAP GEM UPGRADE," CERN-LHCC-2015-012 ; CMS-TDR-013. - 2015. (Technical Design Report CMS ; 13)
7. L. Benussi *et al.*, "Fiber Bragg Grating sensors for deformation monitoring of GEM foils in HEP detectors," arXiv:1512.08629 [physics.ins-det].
8. D. Abbaneo *et al.*, "A novel application of Fiber Bragg Grating (FBG) sensors in MPGD," arXiv:1512.08529 [physics.ins-det].
9. D. Abbaneo *et al.*, "Fiber Bragg Grating (FBG) sensors as flatness and mechanical stretching sensors," arXiv:1512.08481 [physics.ins-det].
10. L. Benussi *et al.*, "Fiber Bragg grating sensors for deformation monitoring of GEM foils in HEP detectors," doi:10.1109/IWASI.2015.7184954
11. L. Benussi *et al.*, "Characterization of the GEM foil materials," arXiv:1512.08621 [physics.ins-det].

12. L. Benussi *et al.*, "Candidate eco-friendly gas mixtures for MPGDs," arXiv:1512.08542 [physics.ins-det].

13. L. Benussi, S. Bianco, M. Ferrini, L. Passamonti, D. Pierluigi, D. Piccolo, A. Russo and G. Saviano, "A study of HFO-1234ze (1,3,3,3-Tetrafluoropropene) as an eco-friendly replacement in RPC detectors," arXiv:1505.01648 [physics.ins-det].

14. L. Benussi *et al.*, "Properties of potential eco-friendly gas replacements for particle detectors in high-energy physics," arXiv:1505.00701 [physics.ins-det].

15. V. Khachatryan *et al.* [CMS Collaboration], Phys. Lett. B **768** (2017) 57 doi:10.1016/j.physletb.2017.02.010 [arXiv:1609.05391 [hep-ex]].