CMS

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1 Introduction

The Compact Muon Solenoid (CMS) experiment [1) 2)] in 2015 as starterd 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. 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 group in 2015

The Frascati group is involved in the muon project of the CMS experiment since 2005. The group has been responsible of the construction and of the maintenance of the Gas Gain Monitor system and is well integrated 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.
Since 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 (Stefano Bianco) is 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.

During the first Long Shutdown period (LS1) the completion of the muon system has been completed [4)] and a new station of RPC detectors has been installed in the outermost endcap regions to improve the muon trigger performances. The Frascati group maintained the Gas Gain Monitoring (GGM) system of the CMS RPC gas system and followed the commissioning of the upgraded GGM control software.

In view of the Phase II of LHC an extension of the muon system has been scheduled and GEM detector technology has been chosen in order to cope with the high background and hostile environment expected in the next years of LHC operations [5]. The Frascati CMS group had a major role in the editing of the CMS GEM project (GE11) Technical Design Report, which has been published in fall 2015 [6].

2.1 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 2015 few hardware intervention have been necessary to fix a leaky chamber and some electronic channels. The GGM has demonstrated, during the first CMS data taking period, to be extremely efficient to spot out quickly problems in the CMS RPC gas mixture. During LS1 it has been completely re-commissioned and maintained and now is monitoring the goodness of the RPC gas mixture for the new data taking period.

2.2 GEM chamber assembling at Frascati

CMS is planning an upgrade of the muon system with the installation of GEM detectors in the high eta region (GE1/1 chambers). These chambers will improve the muon trigger performance allowing to maintain low pt thresholds at Level 1 trigger level. Frascati will be one of the GEM assembling sites in view of the full production. The dimensions of these chambers will be of the order of 80 x 120 cm^2 a size very big with respect to previews experiences. During 2015 several activities have been completed and now the the laboratory is ready to assemble these large size GEM chambers for the final production which will start in the second half of 2016.

2.2.1 GEM foil tensioning R&D

The goal is to develop a simple, cost-effective, mass production tools to assess both planarity and parallelism of GEM foils within 100 μm over the 1 mm gap. This task addressed a specific question raised by the Apollinari review committee set-up by CMS in March 2013. Solution proposed is based on optical tools based on Moiré interferometry. Preliminary results show clear fringes with patterns sensible to 100 μm deviations from planarity. A factor of 5 improvement using phase-shift techniques is expected. The second goal is to discover if an *in situ* monitoring of stretching and planarity is possible. The solution being studied is based on the use of optical sensors installed on GEM films/frames. For both items the studies carried on by the Frascati group demonstrated the reliability for the new technology adopted by the CMS-GEM collaboration for the GE1/1 chamber. The results obtained demonstrated that the three foils are correctly stretched up the the final planar position with respect to the drift board. Those results have been successfully reported to the Apollinari review committee and published on the GE1/1 TDR.

Studies on the GEM foils planarity have been carried out also by using Fibre Bragg Grating (FBG) sensors. This simple devices are basically high sensitivity strain-gauges which allowed us to measure very precisely the mechanical tension applied to the GEM foils while stretched and also permitted to confirm the reliability of the technology used to assembly the CMS GEM chambers. The results of such studies have been presented in different international conferences [7], [8], [9], [10].

2.3 GEM materials ageing R&D

In view of the upgrade of CMS with GEM detectors, the Frascati group started an R&D program in order to study few critic issues important for the CMS GEM program: The R&D items, aimed to both the phase 2 Technical Proposal and the GE1/1 TDR and funded by INFN comprise studies on GEM gas mixtures studies, GEM materials analysis and stretching of the GEM foils.

In order to guarantee safe operation of a GEM detector made of composite materials over 20 years, in harsh high-radiation environment, a detailed programme aimed to the full characterisation of materials pre- and post-irradiation was funded and started (kapton, glue, gas, etc). Initial studies on the deployment of eco-friendly gases to replace R134a and CF_4 were also initiated. Results on first measurement of H_2O absorption in kapton and GEM films, and on measurement of tensile properties of dry/humid kapton/GEM films were presented at the internationl conference MPGD2105 [11].

2.4 GEM and RPC gas mixture R&D

The choice of the gas mixture is fundamental to keep an high detection efficiency in parallel to a time resolution of the order of ns. At moment the CMS GEM prototypes have been operated with a mixture of $Ar/CO_2/C_4$ in the ratios 45/15/40. With this gas mixture a time resolution of about 4-5 ns is reached, enough to maintain high efficiency detection inside the LHC time window of 25 ns. Nevertheless the European Community has prohibited the production and use of gas mixtures with Global Warming Power (GWF) above 150. Gas mixtures used by GEMs (and RPCs as well) contains CF_4 (and $C_2H_2F_4$ for RPCs) with GWF=5800 and 1430 respectively so an R&D to find new eco-friendly gas mixtures with same performance as the previews one is necessary.

The operations of Resistive Plate Chambers in LHC experiments require F-based gases for optimal performance. Recent regulations demand the use of environmentally unfriendly F-based gases to be limited or banned. In view of the CMS experiment upgrade several tests are ongoing to measure the performance of the detector in terms of efficiency, streamer probability, induced charge and time resolution. Prototype chambers with readout pads and with the standard cms electronic setup are under test. Several studies have been done on performance of RPCs operated with a potential eco-friendly gas candidate 1,3,3,3-Tetrafluoropropene, commercially known as HFO-1234ze and with CO2 based gas mixtures for the possible application in the CMS experiment.

Results of such studies have been presented in the international conference RPC 2016 and in other international conferences [12], [13], [14].

2.5 CMS RPC materials studies

New eco-friendly gas mixtures are being searched for use in RPC detectors. The search must be complemented by detailed studies of the interactions of candidate eco-gases with materials used in RPC detectors. The strategy followed is two-fold, namely a static and a dynamic search. The static search is performed by comparing materials properties (by means of SEM-EDS, XPS, XRD, FTIR analyses) before and after exposure to candidate eco-gases in standard operating conditions.The dynamic search consists of sampling and analysis (mass spectrography, F- and Cl- sensors) of candidate eco-gases as exhausted by detectors after operation in electric fields and irradiation conditions.

2.6 RPC longevity analysis

Studies of the present RPC system longevity in view of High Luminosity LHC (HL-LHC) operations have started in 2013 and are coordinated by Frascati member. The goal is to analyse the performance of the system from different point of view (detection efficiency, dark current, intrinsic noise) to correlate the results and to spot possible ageing effects, background dependent, or weak points that could generate failures on the long term. Up to now no visible signs of ageing have been identified but smaller effects are under study. In parallel the background rate on the RPCs have been systematically studied and clear extrapolations for the HL-LHC scenarios have been extracted . The conclusions of such studies will drive R&D programs to be carried out in the near future in local laboratories and at GIF++ at CERN.

2.7 Physics analysis: high mass resonances

The frascati in 2015 started to be involved in the search for a high mass resonances decaying in two leptons, focusing on the dimuon channel. New neutral gauge bosons, like Z, appear in various theories extending beyond the Standard Model. The CMS detector is optimised for searches using high-pT muons, therefore this could be one of the most promising channels for a new discovery at the LHC. Indeed with the luminosity collected during the 2015 we could have been sensitive enough to discover something if it was. The result of 2015 data at 13 TeV extends the exclusion limit on the dilepton mass. The expectation for the next data taking in 2016 is to go beyond this result.

3 Activity planned for 2016

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 2016. Beside this the GEM installation foreseen in the second long shutdown (LS2) is approaching quickly and the GE1/1 chamber production will start in Fall 2016.

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 experence in the dimuon searches, frascati will be also involved in the searches for a BSM neutral higgs-like particles decaying in two muons.

4 Conference Talks by LNF Authors

For the complete listing of CMS papers in 2015 see /www.slac.stanford.edu/spires/

1. L. Benussi *et al.*, "Fiber Bragg Grating sensors for deformation monitoring of GEM foils in HEP detectors," arXiv:1512.08629 [physics.ins-det]

2. L. Benussi *et al.*, "Characterization of the GEM foil materials," arXiv:1512.08621 [physics.ins-det]

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

4. D. Abbaneo *et al.*, "A novel application of Fiber Bragg Grating (FBG) sensors in MPGD," arXiv:1512.08529 [physics.ins-det]

5. D. Abbaneo *et al.*, "Fiber Bragg Grating (FBG) sensors as flatness and mechanical stretching sensors," arXiv:1512.08481 [physics.ins-det]

6. L. Benussi *et al.*, "Fiber Bragg grating sensors for deformation monitoring of GEM foils in HEP detectors," doi:10.1109/IWASI.2015.7184954

7. 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]

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

9. L. Benussi *et al.* [CMS Collaboration], "Performance of the gas gain monitoring system of the CMS RPC muon detector," JINST **10**, no. 01, C01003 (2015) doi:10.1088/1748-0221/10/11/C11003, 10.1088/1748-0221/10/01/C01003 [arXiv:1412.8039 [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].