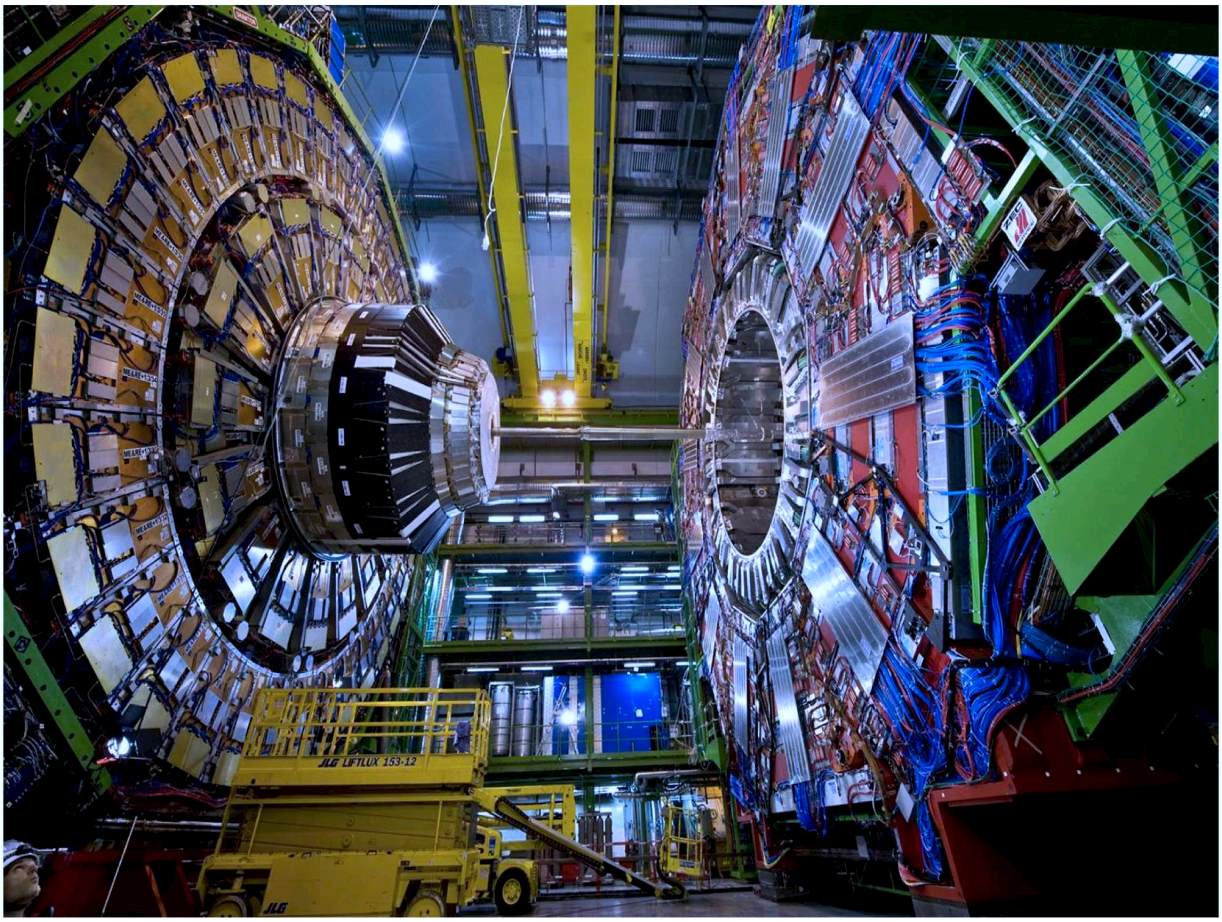
CMS

L. Benussi, S. Bianco (Resp.), M.A. Caponero (Ass.)
S. Colafranceschi (Dott.), F.L. Fabbri (Ass.), M. Ferrini (Ass.)
M. Parvis (Ass.), L. Passamonti (Tecn.), D. Piccolo
D. Pierluigi (Tecn.), G. Raffone, A. Russo (Tecn.), G. Saviano (Ass.), C. Vendittozzi (Dott.)

In collaboration with:
B.Dulach (SPECAS), D.Orecchini (SPECAS),



The Compact Muon Solenoid (CMS) experiment [1] will search for the missing block of Nature - the Higgs boson - and for new exotic elementary particles that are predicted by theory and by cosmological observations. A key element of the CMS detector is a highly performing and redundant muon system. Drift tubes and Resistive Plate Chambers (RPC) in the Barrel and Cathod Strip Chambers and RPCs in the endcap are used for both triggering and tracking of muon particles. The activity of the CMS Frascati groups is centered 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.

1 Status of the CMS experiment

The year 2012 has been historic for CMS [2)] Physics. The pinnacle of our physics programme was an observation of a new particle [3)], a strong candidate for a Higgs boson, which has captured worldwide interest and made a profound impact on the field of particle physics. At the time of the discovery announcement on 4 July, 2012, prominent signals were observed in the high-resolution H $\rightarrow \gamma\gamma$ and H$\rightarrow$ ZZ $\rightarrow$ (4l) modes. Corroborating excess was observed in the H$\rightarrow$ W^+W^- mode as well. The fermionic channel analyses (H$\rightarrow$ bb, H$\rightarrow$ $\tau\tau$), however, yielded less than the Standard Model (SM) expectation. Collectively, the five channels established the signal with a significance of five standard deviations. With the exception of the diphoton channel, these analyses have all been updated in the last months and several new channels have been added. With improved analyses and more than twice the integrated luminosity at 8 TeV, the fermionic channels are now more consistent with the SM expectation as can be seen in the figure 1. The larger dataset has also allowed for more precise studies of the properties of the new boson. The mass has been measured to be 125.8 $\pm$ 0.5 GeV and the data are now in favour of the 0 pseudo-scalar hypothesis, with a CLs value of 2.4%.

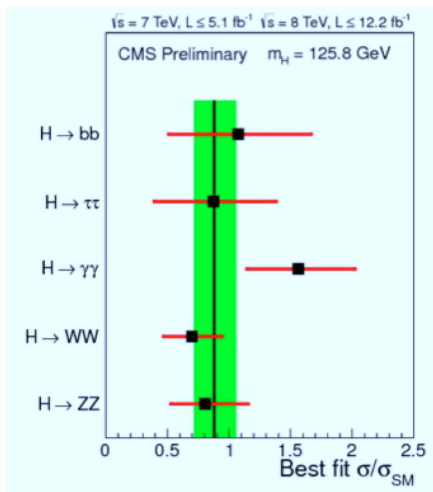


Figure 1: All five channels are consistent with the Standard Model expectation.

With the discovery of a strong candidate for a fundamental scalar, the question of what is stabilising its mass at 125 GeV has become a principle goal of our field. Though constrained by previous null results from the LHC, Supersymmetry remains a strong possibility for such a natural solution to this problem. Third-generation squarks play a special role in natural SUSY, so searches for stops and sbottoms have received increased attention in the SUSY Analysis. For stops/sbottoms produced via gluino cascades, searches have excluded gluino masses of 1.1 TeV for almost any stop/sbottom mass. For direct production of stops/sbottoms, 95% confidence level (CL) limits reach 600 GeV. Several new analysis studying the EW production of chargino/neutralinos have now excluded masses up to 650 GeV . With these increasingly stringent limits on R-parity-conserving SUSY models, R-parity-violating (RPV) scenarios must also be considered. At HCP conference, CMS presented 95% CL limits on the mass of RPV stops of 850 1000 GeV.

Meanwhile CMS continues its broad search programme for physics beyond the Standard Model.

In addition to these searches, CMS has performed a number of important SM analyses. The TOP physics has entered a new phase of precision measurements wherein it has been measured the top-pair and single-top (t-channel) production cross-sections at both 7 and 8 TeV, and the top-quark mass has been measured with 1 GeV precision to be 173.4 $\pm$ 0.4 $\pm$ 0.9 GeV, reaching the highest precision ever achieved by a single experiment. Other studies cover the physics programme of testing perturbative QCD and precision tests of electroweak interactions. In the B Physics field it has been demonstrated that CMS is competitive with dedicated experiments in the study of B-physics and quarkonia. In heavy-ion physics, CMS made a splash at the QM2012 conference where eight new analyses on 2.76-TeV PbPb collision data were presented. More recently, an observation of a ridge in proton-lead collisions based on a single pilot pPb run earlier this year (published in October) has captured the attention of the heavy-ion community.

There has also been a lot recent activity on the future physics of CMS. Physics studies have been carried out in the Higgs and Susy field to support the upgraded CMS detector of the pixel and Hadronic Calorimeter system. Similar performance studies have also been carried on to study the impact of the upgrade of the Level 1 trigger and of the Muon system. To conclude, the CMS Physics output has never been as rich as in the past six months. Nearly 85 new analyses on 7/8-TeV pp collision data, were presented at the ICHEP 2012 conference in July. In december 2012, CMS presented 25 new results on 8-TeV data at the HCP symposium in Kyoto. These preliminary results are being finalised for publication or have already been published, including the paper documenting the new boson discovery. CMS has also attained the milestone of 200 papers published with collision data from the LHC.

2 Status of the RPC Muon system

The RPC system operated in 2012 very smoothely, with an average chamber efficiency of about 95% and an average cluster size around 1.8. The average number of active channels is 97.7%. Eight chambers are disconnected and forty are working in single-gap mode due to high-voltage problems. The total luminosity lost due to RPCs in 2012 is only 88.46 pb^{-1} most of it due to dedicate calibration Runs required by the RPC system. One of the main goals of 2012 was to improve the stability of the endcap trigger that is strongly correlated to the performances of the detector, due to the 3-out-3 trigger logic. At beginning of 2011 the instability of the detector efficiency was about 10%. Detailed studies found that this was mainly due to the strong correlation between the performance of the detector and the atmospheric pressure (P). Figure 2 (red points) shows the linear correlation between the average cluster size of the endcap chamber versus P. This effect is expected for gaseous detectors and can be reduced by correcting the applied high-voltage working point (HVapp) according to the following equation: HVapp = HVeff (1 - α + α*P/P_0), where α is a parameter to estimate from the data ($\alpha \leq 1.0$) and HVeff is the effective HV working point (WP). By convention P_0 is chosen to 965 mbar.

Many improvements have been introduced since 2011 to stabilise the detector performance and they are: a slow (once per fill) WP automatic correction, with $\alpha = 1$, (July 2011); a fast WP automatic correction (anytime it changes of 3 V) (July 2012); and a detailed analysis to quote the correct value of α estimated equal to 0.8 with the first data of the 2012. Thanks to the first two steps the chamber efficiency instability went down from 10% to 4÷5% and, finally, with α equal to 0.8, the amplitude of the oscillations due to atmospheric pressure variations has been reduced by a factor of 10 for the cluster size and by a factor of 4 for the efficiency (1÷2%). Still in figure 2 (blue points) the clear imprvement in the stability is visible.

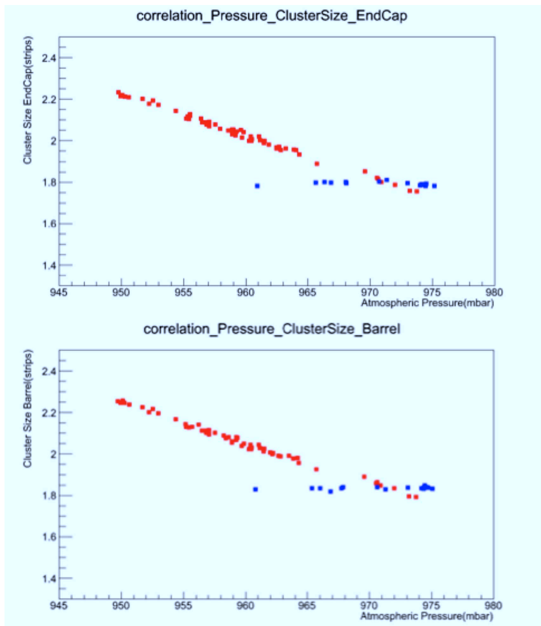


Figure 2: RPC Cluster size vs atmospheric pressure, before (red points) and after (blue points) authomatic HV correction.

A detailed study has also shown that the contribution of RPC hits to the standard Muon Reco is in a range of 1% to 7% [4]. The contribution reaches a value of 5÷7 % in some specific η regions: overlap between wheel 0 and 1 and overlap barrel-endcap. A new muon object, based on the matching between a Tracker track and RPC hits, has been released in the official code of CMS

One of the important activities started in 2012 has been the production of the first new RPC chambers that will be used to cover the outermost station of the endcap during the Long Shutdown of 2013-14. RPC gaps produced in Korea arrived at CERN for quality control, tests and assembling in the final chambers. Few imperfections on the graphite surface of the gaps have been detected and some improvements in the gap production have been already introduced. A first chamber has been produced at the laboratory of CERN and has been tested with cosmic rays in December. The RPC activities during 2012 were a big success thanks to a good organization of the Run Coordination and to the expert and enthusiastic work of the pool of people covering the main tasks in the operation, maintenance and analysis of detector performance. Starting from 2013 a new regime of operations will be entered to meet the new requirements of the shutdown activities.

3 Activity of the CMS Frascati group in 2012

The Frascati group has joined CMS in the RPC muon detectors at the end of year 2005 and it is now very well inserted in the main activities. During the last years many important responsabilities were covered by members of the Frascati group. In 2010 and 2011 the RPC DPG (Detector Performance Group) coordinator was a Frascati charge. In 2011 and 2012 the RPC Run coordination was covered by Frascati. And at the end of 2012 a member of the group was elected as Italian National responsible for RPCs. The success of the RPC activities during 2012 was so also due to the important role covered by Frascati group in the CMS RPC collaboration. Also, during 2012, many of the activities of the group were devoted to the maintanance of the GGM (Gas Gain Monitor) system in charge to monitor the quality of the gas in the closed loop of the RPC system with a system of RPCs in the gas house. This system was projected and build by the group. In February 2012 the important International conference "XI Workshop on Resistive Plate Chambers and Related Detectors" has been held in Frascati, organized by our group together with other people. Many of the talks given in the conference were done by RPC CMS collabroation people and the conference was a great success.

The Frascati group was also involved in 2012 in the analysis of the single top production with specific studies of trigger and selection for the s-channel cross section.

Finally the 2012 was an important year to plan the future upgrades in view of the improved LHC luminosity during the shutdowns of 2018 and 2022. A Muon Strategy Group was formed with people from the different muon subdetectors and with the charge to analyze the performance detector perspective toward 2020 versus the foreseen trigger scheme and the background conditions.Frascati was representing the RPC community in this group.

3.1 Physics analysis: single top production

In LHC the top quark can be produced both in pairs or as a single top via Electroweak mechanism. The single top production is possible through three different diagrams: t-channel, tW channel and s-channel, each of them sensible to different possible effects of new physics. The precise measurement of the cross section of the single top production is so an important standard model check and a window for new physics. The Frascati group joined in 2012 the group of Analysis of the single top and was involved in two main activities: study of the hadronic cross-trigger efficiency and study of selection for the s-channel cross section measurement. While for the t-channel [5] and tW channel CMS has produced papers with measurement, still no official measurement of the s-channel cross section is available. The signal coming from the s-channel single top production is very difficult to discriminate against background events (mainly single top t-channel and $t\bar{t}$). An apporoach based on multi-variate analysis is necessary and is under study to identify the signal events.

3.2 Gas Gain Monitoring System

The Gas Gain Monitoring (GGM) system of RPC detectors in CMS 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. The system is composed of three subsystem of RPC single gaps, readout by 45cm x 45cm pads in a cosmic ray telescope located in the SGX5 gas building. Each subsystem is flushed with a different gas. The Reference subsystem is flushed with fresh open loop gas mixture. The MonitorOut subsystem is flushed with Closed Loop gas downstream of CMS RPCs. The MonitorIn subsystem is flushed with Closed Loop gas upstream of CMS RPCs. Each subsystem is composed of three gaps, whose high voltage is set to the standard working point voltage at the efficiency knee, and to 200 V above and below the knee respectively. Each cosmic ray track therefore provides completely correlated pulses in the three subsystems, allowing one to study the differential response of gaps and by disentangling any effect due to changes in the gas mixture. In case a working point change is detected, an alarm condition is released and the gas quality monitoring system will verify what the change of work point is due to.

4 Muon Strategy Group

The Frascati group was involved in the Muon Strategy Group with the goal to identify possible weak points in the present RPC system in view of the increased LHC luminosity. Data collected during 2011 and 2012 have been analyzed in order to quantify the correlation between background rate and LHC luminosity. The background affecting RPC response is mainly due to photons and neutrons and this rate has been shown to be with good approximation linear as a function of Luminosity (figure 3). The expected performance of the RPC system up to the higher LHC Luminosity expected above 2020 seems to be under control in all the system with some concerns in the region at very high η where the rate (and by conseuqence the integrated charge) will reach values close to the limit for a correct RPC operation. Future data will be useful to give more clear results. One important point covered by the Muon Strategy group has been the High η coverage of the muon system. At moment the Muon system is covered by three independent detectors giving high redundancy to the system (Drift tube and RPC in the barrel, and Cathode Strip Chambers and RPC in the endcap up to $\eta = 1.6$). In the region $1.6 \leq \eta \leq 2.4$ no RPC (with present technology) can work and only the Cathode Strip Chambers are present. This is the region with higher background and an additional detector has been shown to be able to improve the performance of the muon system in view of the higher background expected. The Gas Electron Multiplier (GEM) detector has been identified as a possible solution to cover this region in the next long shutdown (2018-19) and is at moment under review from the CMS management.

5 Activity planned for 2012

The 2012 is the first of two years of long shutdown of LHC in which the group will be involved in the installation and commissioning of the outermost RPC layer in the endcap system [6]. During this period 144 new RPC chambers will be installed on the detector with services, readout electronics and gas system. The Frascati group will be involved in the commissioning and installation of the Link Board system responsible for the readout and zero suppression of the RPC signals to be sent to the CMS trigger and DAQ system. This period will also be used to reparation of the present system and Frascati will give his contribution on the HV system and on the fix of gas leaks found in some region of the detector. Main reparation and maintainance of the GGM system will also be part of the Frascati activities.

At the same time a GEM collaboration has been setup in CMS in order to propose and realize a system based on GEM detectors for the coverge of the high η region of the CMS muon system [7].

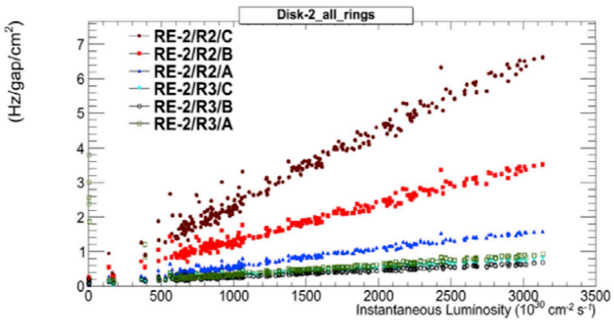


Figure 3: RPC background vs LHC luminosity for different regions of the endcap RPC system.

An approval of CMS is expected during the first half of 2012 and tdr should be prepared by the end of the year. Frascati is involved in this effort with a plan of R&D activities to be carried on in Frascati and with contributions to analysis of simulation data for the best layout definition. From the R&D point of view the Frascati group will study the tensioning of the GEM foils inside the CMS chambers. New techniques for the stretcing have been developed and used by the LHCb GEM collaboration but should be verified on the larger CMS chambers (120 cm x 60 cm). The quality control of this stretching in view of a massive chamber production and the long term monitoring are part of our R&D program. A crucial parameter for successfully operations of GEM at CMS is the time resolution that should be of the order of 4-5 ns in order to identify efficiently the LHC bunch crossing and to have a good discrimination power against photons and neutron backgrounds. These requirements will drive the Frascati group R&D that will be devoted to the studies of gas mixture and GEM geometry to improve the time resolution.

The Analysis of single top s-channel will be enforced during 2012. The Frascati group is well integrated and works in sinergy with the Napoli INFN group with the plan to finalize a paper with the measurement of the single top s-channel cross section by the end of the year. Also the studies of the hadronic cross trigger that will be important for the analysis of the single top will be finalized in the first half of 2012.

6 Conference Talks by LNF Authors

1. C. Vendittozzi et Al., "A model for the chemistery of defects in bakelite plates exposed to high-radiation environment" poster at RPC2102 conference, Frascati, Italy, February 2012.

2. S. Colafranceschi et Al., "Operational experience of the GGM at the CMS Experiment" poster at RPC2102 conference, Frascati, Italy, February 2012.

7 Papers

1. For the listing of CMS papers in 2012 see /www.slac.stanford.edu/spires/

2. L. Benussi, S. Bianco, S. Colafranceschi, L. Passamonti, D. Piccolo, D. Pierluigi, A. Russo and G. Saviano *et al.*, "Study of gas mixtures and high voltage in a single gap RPC monitoring system," PoS RPC **2012** (2012) 057.

3. S. Grassini, M. Ishtaiwi, M. Parvis, L. Benussi, S. Bianco, S. Colafranceschi and D. Piccolo, "SiOx coated plastic fiber optic sensor for gas monitoring in RPC," PoS RPC **2012** (2012) 072.

4. M. A. Caponero, A. Polimadei, L. Benussi, S. Bianco, S. Colafranceschi, L. Passamonti, D. Piccolo and D. Pierluigi *et al.*, "Use of fiber optic technology for relative humidity monitoring in RPC detectors," PoS RPC **2012** (2012) 073.

5. D. Abbaneo, M. Abbrescia, C. Armagnaud, P. Aspell, Y. Assran, Y. Ban, S. Bally and L. Benussi *et al.*, "Beam Test Results for New Full-scale GEM Prototypes for a Future Upgrade of the CMS High-eta Muon System," arXiv:1211.3939 [physics.ins-det].

6. D. Abbaneo, M. Abbrescia, P. Aspell, S. Bianco, K. Hoepfner, M. Hohlmann, M. Maggi and G. De Lentdecker *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 [physics.ins-det].

7. S. Bianco [CMS and ATLAS Collaborations], "Searches for supersymmetry and beyond the standard model physics in ATLAS and CMS," Frascati Phys. Ser. **54** (2012) 240.

8. S. Colafranceschi, R. Aurilio, L. Benussi, S. Bianco, L. Passamonti, D. Piccolo, D. Pierluigi and A. Russo *et al.*, "A study of gas contaminants and interaction with materials in RPC closed loop systems," PoS RPC **2012** (2012) 056 [arXiv:1210.1819 [physics.ins-det]].

9. S. Colafranceschi, L. Benussi, S. Bianco, L. Passamonti, D. Piccolo, D. Pierluigi, A. Russo and G. Saviano *et al.*, "Performance of the Gas Gain Monitoring system of the CMS RPC muon detector and effective working point fine tuning," JINST **7** (2012) P12004 [PoS RPC **2012** (2012) 046] [arXiv:1209.3893 [hep-ex]].

10. M. S. Kim, H. Seo, J. Goh, Y. Choi, K. Beernaert, A. Cimmino, S. Costantini and G. Garcia *et al.*, "CMS reconstruction improvement for the muon tracking by the RPC chambers," PoS RPC **2012** (2012) 045 [arXiv:1209.2646 [physics.ins-det]].

11. S. Costantini, K. Beernaert, A. Cimmino, G. Garcia, J. Lellouch, A. Marinov, A. Ocampo and N. Strobbe *et al.*, " Uniformity and Stability of the CMS RPC Detector at the LHC," PoS RPC **2012** (2012) 005 [arXiv:1209.1989 [physics.ins-det]].

12. M. Tytgat, A. Marinov, P. Verwilligen, N. Zaganidis, A. Aleksandrov, V. Genchev, P. Iaydjiev and M. Rodozov *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]].

13. P. Paolucci, R. Hadjiiska, L. Litov, B. Pavlov, P. Petkov, A. Dimitrov, K. Beernaert and A. Cimmino *et al.*, "CMS Resistive Plate Chamber overview, from the present system to the upgrade phase I," PoS RPC **2012** (2012) 004 [arXiv:1209.1941 [physics.ins-det]].

14. D. Abbaneo, M. Abbrescia, M. Alfonsi, C. Armaingaud, P. Aspell, M. G. Bagliesi, Y. Ban and S. Bally *et al.*, "An overview of the design, construction and performance of large area triple-GEM prototypes for future upgrades of the CMS forward muon system," JINST **7** (2012) C05008.

15. L. Benussi, S. Bianco, S. Colafranceschi, F. L. Fabbri, M. Giardoni, L. Passamonti, D. Piccolo and D. Pierluigi *et al.*, "A New approach in modeling the response of RPC detectors," Nucl. Instrum. Meth. A **661** (2012) S182 [arXiv:1012.5508 [physics.ins-det]].

16. Benussi:2010yx L. Benussi, S. Bianco, S. Colafranceschi, F. L. Fabbri, F. Felli, M. Ferrini, M. Giardoni and T. Greci *et al.*, "Study of gas purifiers for the CMS RPC detector," Nucl. Instrum. Meth. A **661** (2012) S241 [arXiv:1012.5511 [physics.ins-det]].

8 Volumes

L. Benussi, S. Bianco, D. Piccolo et Al. (Eds.), "XI Workshop on Resistive Plate Chambers and Related Detectors International Conference, RPC12 2012, Frascati, Italy, February 5-10, 2012" *PoS RPC2012 (2012) nonconsec. pag.*

References

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. S. Kim, *et al.*, "CMS reconstruction improvement for the muon tracking by the RPC chambers," PoS RPC **2012** (2012) 045 [arXiv:1209.2646 [physics.ins-det]].

5. S. Chatrchyan et al., "Measurement of the single-top-quark t-channel cross section in pp collisions at $sqrts = 7$ TeV " Phys. Lett. B 716 (2012) 30

6. 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]].

7. 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