Recent upgrades and results from the CMS experiment

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Abstract.

In 2016 the LHC restarted its operation with proton-proton collisions energies equal to \(\sqrt{s} = 13\) TeV. During 2016 the CMS detector collected an amount of data equal to \(~37 \text{ fb}^{-1}\), significantly surpassing any amount of data collected in previous LHC campaigns. At the end of 2016 the ‘Extended Year-End Technical Stop’ (EYETS) started, a period where specific upgrades were performed over the detector to improve its efficiency when the data taking process restarted in 2017. Most of the upgrades are part of preparation process towards the High Luminosity LHC (HL-LHC) when the LHC will deliver up to 7 times the LHC design luminosity to the experiments. These upgrades will have significant contributions during 2019-2020 (LS2) and 2024-2016 (LS3). In this document the main upgrades that took place during EYETS are shown, also the current and future status of the LHC and the CMS experiment are discussed. Main preliminary results obtained by analyzing Run 2 data (2015 and 2016) are also shown.

1. The Large Hadron Collider (LHC) and the CMS experiment

![Diagram showing the acceleration complex at CERN that provides proton or ion beams to the LHC. From [2].](image)

Figure 1. Diagram showing the acceleration complex at CERN that provides proton or ion beams to the LHC. From [2].

The successful operation of the LHC, and the Compact Muon Solenoid (CMS), experiment is the product of the hard work of thousands of people involved in their design, construction and careful
usage. The studies and results presented in this contribution could not have been possible without the support of this collaboration. The CERN laboratory directs the operation of the LHC which consists of $\sim$27 km circumference that extends to both sides of the border between France and Switzerland. This massive accelerator runs at unprecedented collisions energies, being able to operate at a design luminosity of $10^{34}$ cm$^{-2}$ s$^{-1}$ [1].

CMS along with ATLAS is one of the largest detectors located around the LHC ring ($\sim$28.7m long and diameter of 15m). These two experiments are ‘tagged’ as multipurpose detectors due to the huge variety of physics analyses that can be performed with them. Results corresponding to 2015 and 2016 data taking processes from proton-proton collisions at $\sqrt{s} = 13$ TeV are described in section 4. Proton bunches (made up of $\sim 10^{11}$ constituents) are produced, split and accelerated sequentially through different accelerators before injection to the LHC as it is illustrated in Figure 1. The acceleration process starts with the LINAC accelerator where protons are accelerated to 31% of the speed of light, the resulting beam is introduced to the Proton Synchrotron Booster (PSB), which increases the energy of the protons to 1.4 GeV and their speed to 91.6% of the speed of light. Protons are then accelerated by the Proton Synchrotron (PS) to 25 GeV and then injected to the Super Proton Synchrotron (SPS), where they are accelerated to 450 GeV. Finally the protons are injected to the LHC ring, being accelerated to an energy up to 7 TeV, reaching speed over 99.99999% of the speed of light, being able to produce proton-proton head-on collisions at up to $\sqrt{s} = 14$ TeV. At the end of this acceleration chain the proton bunches travel 25ns from each other [1]. The laboratory also hosts additional smaller experiments that are within the scope of interest of nuclear and particle physics such as NA61-SHINE, NA62, COMPASS, CNGS, incorporated to the SPS and TOTEM and LHCf incorporated to the LHC [1].

Rather than being a perfect circumference the LHC is made up of eight insertion straight sections of which four are dedicated to the experiments, one is used for radio frequency cavities, used to accelerate proton bunches, two for beam cleaning and one for beam dumping. The accelerator also comprises eight arcs (sectors) joining these straight insertions. A total of 154 dipole magnets are in each of the arcs and are independently connected in series in the same cryostat with its own power source [1].

![LHC / HL-LHC Plan](image)

**Figure 2.** Diagram showing the plan ahead considered for the LHC towards the HL-LHC. From [3] [4].

CERN has adopted the European Strategy for Particle Physics, which has as high priority the full exploitation of the LHC. This gave rise to the High Luminosity LHC (HL-LHC), project, which consists of a set of huge upgrades over the LHC machine and all its detectors. The current timeline towards the HL-LHC project is shown in Figure 2. The HL-LHC final installation is planned to start in $\sim$2024-2026, after the end of Run 3, where the LHC will be operating at its design head-on proton-proton collision energy of 14 TeV and will deliver a nominal luminosity about two times larger than
the LHC design luminosity. On the other hand, the HL-LHC when completed, is planned to operate (from ~2026) at 14 TeV as well but deliver between 5 to 7 times the design luminosity of the LHC, allowing the gathering of at least an order of magnitude more data than what will be achieved by joining together all the data collected during Run I, Run II and Run III (2011 to 2024) [3] [4].

The new upgrades and key innovative technologies that are planned for HL-LHC are for example the installation of 2 new 300-meters service tunnels and two accessing shafts at the ATLAS and CMS detectors sites. Also the installation of 12 powerful quadrupole magnets for the ATLAS and CMS detectors in order to increase the focusing of each of the beams before collision. A set of 4 pairs of bending magnets will be installed in the LHC tunnel, these ones are shorter and more powerful than the existing ones. This will free up some space for the installation of up to 20 new collimators and the replacement of at least 60, so the protection of the LHC machine is reinforced. Additionally, a set of 16 ultra-precise superconducting “crab” cavities for both ATLAS and CMS will be used to tilt the beams before collision, so the luminosity value increases substantially [3] [4].

![Figure 3. Illustration of the CMS detector and all its main systems. From [6].](image-url)

The CMS detector is located close to the French village of Cessy, between the Jura mountains and the Geneva Lake, it is designed to study the products from proton-proton, lead-lead and lead-proton collisions. The detector has a huge and powerful solenoid in its inner section (13m long and diameter of 6m) with a nominal high-magnetic-field of 3.9T that surrounds a tracking system composed by a Silicon Pixel and Silicon Strip Tracker in its inner sections and a calorimetry system composed by a Scintillating Crystal Electromagnetic Calorimeter and a Brass-Scintillator Hadronic Calorimeter [5]. It is the heaviest detector at CERN with ~14000 tonnes. An overview layout of the detector is shown in Figure 3, where all the detector main sub-systems are highlighted. The detector has specialized muon detectors in the region outside the solenoid with detection devices based in three main technologies, aluminium Drift Tubes (DT) in the barrel region, Cathode Strip Chambers (CSC) in the endcap region and Resistive Plate Chambers (RPC) in both barrel and endcap regions. The first two provide precise position measurement and trigger, whilst the third one offers precise timing information as well as a second an independent trigger. Forward sampling calorimeters extend the detection range to regions very close to the beam direction. CMS has highly efficient trigger and data acquisition systems to record interesting events. The collaboration uses highly distributed and efficient computing infrastructure, over which specialized software can execute numerous tasks such as reconstruction of
events, analysis of the collected data as well as the production of simulated data [5] [7].

2. EYETS: Extended Year-End Technical Stop

![Illustration of the new pixel system for the CMS detector.](image)

**Figure 4.** Illustration of the new pixel system for the CMS detector. It is located at closer distance than its previous counterpart with four layer in its forward and barrel sections. From [8].

After the successful data taking process during 2016 for proton-proton collisions and also proton-ion collisions, which are discussed in the following section, the LHC and all its detectors experienced a Technical Stop that lasted from December 2016 to May 2017. During this period the CMS detector suffered significant upgrades crucial for the coming increase in luminosity during the rest of Run 2, and also for Run 3 and HL-LHC phases.

The biggest upgrade for the CMS detector consisted in the replacement of its pixel detector. A diagram of this system is shown in Figure 4. This sub-detector is at closest distance from the beam line (∼ 29mm) than any other device, so a replacement was necessary due to radiation damage, and also due to the need of a more efficient tracking system, which determines the trajectories of charged particles. This new pixel system is designed to keep high tracking performance at luminosities up to 2 times the design luminosity of the LHC and in an environment where the number of primary collisions that are produced per proton bunch crossing (pileup) exceeds the value of 50. The new pixel detector has 4 barrel and forward layers instead of 3 that were present in the previous detector [8].

Another important upgrade was done over the Hadronic Endcap and Forward calorimeters. Over the first one a partial upgrade was performed, which will be continued during the long stop that will take place during 2019 and 2020 (LS2) as it is indicated in Figure 2. This upgrade consists in replacing a set of hybrid photodiodes for silicon photo-detectors which are expected to perform better in a higher luminosity environment [9]. For the case of the Hadronic Forward calorimeter, its photomultiplier boxes were split in to two different channels, to be able to discriminate more efficiently between signal and backgrounds, which is crucial in this forward region of the detector [10]. Also, during this EYETS period the installation of an additional set of muon detectors GE1/1 that use gas electron multipliers (GEM) technology in the first endcap muon station was started. This installation will continue also during LS2. This system, when successfully installed, is expected to improve substantially the forward muon triggering and reconstruction. Figure 5 shows with red color the location of this new system in the forward region where the background signals are higher [11].

As mentioned in the previous section, the CMS detector uses three main systems for muon detection in its muon spectrometer (muon chambers). For monitoring and for detector optimal performance pur-
poses, México collaborates strongly with RPCs system. The mexican team contributes with analysis of the RPC detectors currents dependence with the luminosity and the effect of installation of shielding layers in the muon detector barrel and endcap. Also studies are done to determine the optimal high voltage value used in these chambers for data collection [12]. Additionally, México has a leading role in this sub-system upgrade coordination, its central system, R&D activities and consolidation studies towards possible future upgrades. Finally, this team as well provides a crucial contribution in the development of the software that delivers the average chambers currents and integrated charge per data run. The total amount of charge (integrated charge) detected by these chambers has been analyzed as well by this team.

3. 2016 Data taking campaign

As it is indicated in Figure 2, Run 2 extends from 2015 to the end of 2018. Proton-proton head-on collisions have occurred so far at $\sqrt{s} = 13$ TeV during this phase. The integrated luminosity target over this period for both ATLAS and CMS detectors is $\sim 100\text{fb}^{-1}$; over three times more data than in Run 1, that extended from 2011 to 2015. CMS and the LHC have been upgraded so that the monitored peak instantaneous luminosity value has surpassed the LHC design (planned) luminosity during 2015 and 2016 data taking campaigns. This is the reason why the ongoing upgrade work is crucial (section 1, 2), as the LHC is producing a much higher luminosity environment than planned. This sets the need in all the experiments of highly as possible radiation-hard and efficient detectors. In terms of amount of collected data, both experiments ATLAS and CMS planned to record $\sim 25\text{fb}^{-1}$ of data during 2016. As indicated in Figure 6, both experiments surpassed this goal and ended up recording $\sim 37.8\text{fb}^{-1}$ (for proton-proton head on collisions). Figure 7 shows the amount of data delivered during
Figure 6. Cumulative proton-proton luminosity delivered by the LHC versus time for the different data-taking campaigns: 2011, 2012, 2015 and 2016. From [13].

Figure 7. Cumulative proton-proton luminosity delivered by the LHC versus time in 2016 compared with the data recorded by CMS. From [13].

Figure 8. Cumulative proton-ion luminosity delivered by the LHC versus time in 2016 at \( \sqrt{s} = 5.02 \) TeV, compared with the data recorded by CMS. From [13].

Figure 9. Cumulative proton-ion luminosity delivered by the LHC versus time in 2016 at \( \sqrt{s} = 8.16 \) TeV, compared with the data recorded by CMS. From [13].

2016 by the LHC with time compared with the amount of data recovered by CMS.

A proton-ion (lead nucleus) campaign took place at the LHC during November 2016. Two parallel data taking processes occurred, a short one at a centre-of-mass energy of \( \sqrt{s} = 5.02 \) TeV and another larger one at \( \sqrt{s} = 8.16 \) TeV as it is indicated in Figures 8 and 9. For the latter, the target was to record \( \sim 50 \text{nb}^{-1} \) and \( \sim 185.5 \text{nb}^{-1} \) were actually recorded, surpassing for more than 3 times the planned target for these collisions. These data will be used for forward physics and ultraperipheral collisions studies, where the production of \( J/\psi \), \( \Upsilon \) and \( \rho \) particles from photon-induced decays will be measured.
4. CMS Results from proton-proton collisions at $\sqrt{s} = 13$ TeV

The CMS experiment just started to operate with a proton-proton collision energy of 13 TeV in 2015 (section 1). It previously operated at 8 TeV during Run-I (2011 to 2015). So the analysis of these new type of data from higher energy became the center of interest at CERN due to the increased production rate for all processes under study. The experiment experienced a short data taking campaign at this upgraded energy during 2015 ($3.81fb^{-1}$ for proton-proton collisions), compared with the $37.8fb^{-1}$ recorded in 2016 (section 3). In this section some preliminary results corresponding to proton-proton collisions at $\sqrt{s} = 13$ TeV recorded during 2015 and 2016 are shown.

![Figure 10. Mass distribution for higgs candidates decaying to 4-leptons. The well modelled component in pink color corresponds to signal events. From [15].](image1)

![Figure 11. Mass distribution for higgs candidates decaying to two photons ($\gamma\gamma$). The pad below shows clearly the signal peak after subtracting the background component. From [15].](image2)

Measurements and observations performed during LHC Run 1 led a legacy. For example during this period a particle consistent with the Standard Model of particle physics (SM), higgs boson was observed using two independent channels ($H \rightarrow \gamma\gamma$ and $H \rightarrow ZZ \rightarrow 4\ell$) and two independent experiments (ATLAS and CMS). The final combination of the results considering these two channels and the two experiments gives a mass of $m_H = 125.09 \pm 0.21$ (stat.) $\pm 0.11$ (syst.) GeV, where the two uncertainties stand for statistical and systematic uncertainties respectively [14]. Also the observation and studies of this observed particle during Run 1 led to the conclusion that all its production and decay rates are consistent with the SM predictions. The top quark was as well studied during this period, precision measurements were performed over SM parameters, and also there was a continuous search of new physics, not finding in all these investigations any deviation from the SM. It is the main priority of all research teams to reproduce all these studies and searches at higher collision energy, from where much higher statistics and precision can be obtained easily. Some preliminary results towards this end are shown in what follows.

4.1. Observation of the Higgs boson at 13 TeV

Using the 2015 and 2016 proton-proton collisions datasets, the higgs-like particle was re-observed at $\sqrt{s} = 13$ TeV, but this time the signal can be extracted much easier. For example Figure 10 shows the mass distribution of Higgs candidates decaying to 4 leptons (known as the ‘golden channel’). These produced leptons can be any of the following combinations: $\mu\mu\mu\mu$, $\mu\mu\epsilon\epsilon$ and $\epsilon\epsilon\epsilon\epsilon$. Due to its relatively
large signal-to-background ratio, it is one of the most important channels for study of this particle properties. Here the component of the distribution with pink color with higher value at ≈125.0 GeV corresponds to signal decays, showing much higher significance than in Run 1 [14] [15]. Also a preliminary CMS-only measurement of the higgs mass using this distribution gives $m_H = 125.26 \pm 0.20{\text{(stat.)}} \pm 0.08{\text{(syst.)}}$ GeV, reaching already higher precision than the Run 1 combination [15]. The width of this particle has been measured as $\Gamma_H < 1.10$ GeV at 95% confidence level (C.L.) and its total production rate (relatively to the SM prediction) has been found to be $\mu_{\text{comb}} = 1.05^{+0.19}_{-0.17}$, not finding any deviation from the SM and reaching already higher precision from the Run 1 measurement. 7 channels for the production of this particle have been considered for the measurement of this production rate [15].

![Figure 12. Plot showing the SM prediction for production cross-section for different particle systems versus the corresponding measurements at $\sqrt{s} = 7, 8$ and 13 TeV. No deviation from the SM has been found so far. From [16].](image)

Additionally, the observation of this higgs-like particle has been reproduced in the $H\rightarrow \gamma\gamma$ channel as can been seen in Figure 11, here the background component is higher than with the $H\rightarrow 4\ell$ channel, but the resonance can be clearly seen at $\approx 125.0$ GeV in the pad below after substracting the background. A mass measurement using this channel and updated dataset is in progress [15]. Preliminary fiducial cross-section measurements were performed as well using these two channels, not finding any deviation from the SM predictions [15].

4.2. Standard Model cross-check
Production of system of particles involved with Standard Model processes has been measured as it is shown in Figure 12. In this plot are shown the predicted values from the SM of production cross sections for different products compared with has been measured experimentally at proton-proton collision energies of $\sqrt{s} = 7, 8, 13$ TeV, respectively. As the plot shows, no single deviation from the
Figure 13. Measured upper 95% C.L. values for the $g_{KK}$ cross-section $\sigma_{g_{KK}}$, the point where the experimental distribution intersects the theoretical curve and goes over, sets the exclusion limit. From [18].

Figure 14. Distribution for the reconstructed invariant mass of the $\gamma\gamma$ system. No resonance or excess out of the uncertainties is observed. From [19].

SM predictions has been found. For the case of the production of 4 top quarks (tttt), upper limits at 95% C.L. were set, which are over the prediction and then not in contradiction with the SM [16]. As can be seen in the figure, the production cross-sections for the different products increases with the center of mass energy of the collision.

4.3. Search of Beyond the Standard Model Physics

Unstable Beyond the SM standard model particles decaying to measurable products have been search extensively. For example there are Beyond the SM Models (BSM), that introduce massive particles that decay into a $t\bar{t}$ pair. For these studies the search has been focused over $Z'$ and a Kaluza-Klein (KK) excitations of gluons $g_{KK}$. The first one originated in a Sequential SM (SSM), theory, which is the SM + 1 additional massive boson with the same coupling constants [18]. On the other hand $g_{KK}$'s are originated by extending the Randall-Sundrum (RS) model [18]. $Z'$ particle has been searched considering masses up to $\sim 4$ TeV and relative width (to its mass) values $\Gamma_{Z'} = 1\%$, $10\%$ and $30\%$, while $g_{KK}$ has been searched with a relative decay width of $\sim 17\%$ [18]. Exclusion limits with this new dataset are improved for all models with respect previous results (at $\sqrt{s} = 8$ TeV). The $Z'$ particle with a relative width $\Gamma_{Z'} = 30\%$ is excluded up to a mass value of 4.0 TeV, while the exclusion limit is 3.9 TeV for a relative width of 10%, where the previous limit was 2.9 TeV. As it is shown in Figure 13, the upper exclusion limit for $g_{KK}$ is 3.3 TeV, the previous limit here was 2.8 TeV [18].

As indicated in Figure 14, a massive higgs resonance has been as well investigated. This extended search is based in the assumption that the production mechanism is completely due to gluon-gluon fusion (ggF). The decay channel used for this study is $H \rightarrow \gamma\gamma$. As the figure indicates, no resonance has been measured in this study. Similarly, no excess corresponding to an additional higgs particle has been seen when measuring the upper limit of the production cross-section (at 95% C.L) and scanning over masses between 0.5 and 4.5 TeV and widths relatively to the mass of $1.4 \times 10^{-4}$ and $5.6 \times 10^{-2}$. On the other hand, exclusion limits have been set for the mass of Randall-Sundrum gravitons that
may decay into two photons [19].

Figure 15. Measured upper 95% C.L. values for BSM particles cross-sections $\sigma$ decaying to a dijet pair. From [20].

Similar searches have been performed over massive particles decaying to a pair of jets (dijet) originated from gluons and/or quarks and also BSM particles decaying to a couple of leptons. Figure 15 shows experimental upper limits for cross-section at 95% C.L. where no sign of excess or signal from a BSM particle is seen. In this plot exclusion limits are set for 5 different models introducing massive particles decaying to a dijet system [20]. Similarly, Figure 16 shows that no excess has been observed for BSM particles decaying to a pair of leptons. Here a exclusion limit at 95% C.L. of 3.87 TeV has been set for a SSM $Z'$ particle and a limit of 2.82 TeV for $Z'_\phi$ from a ‘superstring model’ [21], where the previous limits were 2.90 and 2.57 TeV [21]. Additionally, limits were as well set for gravitons $G_{RS}$ decaying to a pair of leptons, and again, no sign of new physics is observed.

4.4. Supersymmetry search

Another search of BSM physics has been focused over Super-Symmetry (SUSY), theory, a strong candidate for dark matter making up $\sim$25% of the universe. In models based on SUSY, new particles are introduced such that all fermionic (bosonic) degrees of freedom in the SM are paired with corresponding bosonic (fermionic) degrees of freedom in an extended theory [23]. As it is displayed in Figure 17 exclusion limits have been set for particles predicted by SUSY, for example the gluino $\tilde{g}$ and the neutralino $\chi^0_1$. The plot in this figure shows a bidimensional region that excludes simultaneously low mass regions for these two particles. $m_3$ is excluded at up to $\sim$ 1.9 TeV. Similar search has been performed over charginos $\chi_0^\pm$ along with neutralinos as it is shown in Figure 18. So far, exclusion limits have been extended substantially with respect to what was achieved with the Run 1 dataset, and no deviation or signal BSM has been detected. Similar searches have been performed over stop quarks $\tilde{t}$, not finding any excess or BSM signal [23].

4.5. Top and B-physics

Properties of the top quark and composite states made up of a bottom b-quark have been measured. As shown in Figure 19 (in red color) a quite precise measurement of the top quark mass $m_t$ has been achieved by just using the 2015 dataset ($\sim 2.2 \text{ fb}^{-1}$). Still the final CMS combination from Run
Figure 17. Bidimensional distribution showing the exclusion limits at 95% C.L. for the gluino $\tilde{g}$ and neutralino $\tilde{\chi}_1^0$ supersymmetric particles. From [22].

Figure 18. Bidimensional distribution showing the exclusion limits at 95% C.L. for the chargino ($\tilde{\chi}_2^\pm$, $\tilde{\chi}_1^\pm$) and neutralino $\tilde{\chi}_1^0$ supersymmetric particles. From [23].

Figure 19. History of top mass measurements from CDF, D, ATLAS and CMS experiment. CMS Run 1 combination is more precise already than the current world combination. From [24].
Figure 20. History of inclusive $t\bar{t}$ cross section measurements. Most recent results correspond to the 5 analyses listed at the bottom of the legend, considering dilepton, semileptonic and all jets channels at $\sqrt{s} = 13$ TeV. From [16] [17].

1 dataset, is still more precise with a measured value of $m_t = 172.44^{+0.49}_{-0.49}$ GeV, this Run 1 result is even more precise than the current world combination, computed in 2014, as indicated in the plot [24].

Figure 21. $\mu^+\mu^-$ invariant mass distribution of the Run 1 CMS and LHCb combination analysis to measure the decays of $B^0_s$ and $B^0$ mesons to a pair of muons. From [25].

Figure 22. $J/\psi K^+$ candidates invariant mass distribution corresponding to $B^+$ decays in the Run 2. From [25].

Also the $t\bar{t}$ pair production cross section (corresponding to proton-proton collisions at $\sqrt{s} = 13$ TeV) has been measured. These measurements have been performed using the $t\bar{t}$ pair decay channels: dilep-
ton, semileptonic ($\ell + \text{jets}$) and all jets, not finding any deviation from the predicted values from the SM as shown in Figure 20. Still there are a lot measurements in progress as the measurement of $t\bar{t}$ spin correlation, W-boson polarisation, $t\bar{t}$ charge asymmetry, top-quark width between other important parameters measured during Run 1 [24].

An interesting parameter that could be sensitive to indentification of new physics is the measurement of the branching fraction of the rare decay $B^0 \rightarrow \mu^+\mu^-$. The most precise measurements over these parameters were obtained by combining the Run 1 proton-proton collisions datasets from the CMS and LHCb experiments (at $\sqrt{s} = 7$ and 8 TeV) [25]. This published analysis initiated a phase of precision in the measurement of these two rates. It has been estimated that the production of these decays during Run 2 will be doubled with respect to Run 1. So far the measurements are in agreement with the SM expectation, but the experimental precision reached during Run 1 was still not comparable with the theoretical uncertainty. This is the reason why this is one of the most interesting measurements to reproduce during Run 2 with proton-proton collisions at 13 TeV [26]. Figure 21 shows the invariant mass of the $\mu^+\mu^-$ system, here the resonances corresponding to the $B^0$ and $B^0$ mesons decays at $\sim 5.36$ and $\sim 5.27$ GeV can be clearly discriminated from each other [25]. Additionally, other analyses have been completed at 13 TeV, like the measurement of the total and differential inclusive $B^+$ hadron cross sections. The invariant mass of reconstructed $B^+$ candidates is shown in Figure 22. The results show a reasonable agreement with the theoretical calculations within the uncertainties [26]. In a similar way as with top physics, there are several ongoing measurements of the production and decays of $b$-mesons, production of bottomium and charmonium states, spectroscopy measurements and search of CP violation and exotic states like tetraquarks and pentaquarks (made up 4 and 5 valence quarks respectively) between others [27].

5. Conclusions

An intensive campaign of upgrade, data-taking, monitoring and analysis work is on-going within the CMS collaboration at CERN in the current Run 2 phase of the LHC. A crucial upgrade process (EYETS) took place at the CMS detector and the LHC from December 2016 to May 2017, being the most significant and important modification, the replacement of the CMS pixel detector in its innermost section $\sim 3\text{cm}$ away from the collision point. In terms of amount of recorded data from proton-proton head-on collisions at $\sqrt{s} = 13$ TeV, the initial target for 2016 was surpassed by a factor of $\sim \frac{3}{2}$, being as well the case for proton-ion collisions at $\sqrt{s} = 8.16$ TeV where the planned target was surpassed by a factor of $\sim 3.7$. CERN has decided to follow the European Strategy and its High Luminosity LHC plan, whose objective is the full exploitation of the LHC by performing a set of huge upgrades to the LHC itself and its detectors in order to increase the nominal luminosity by a factor of 5-7 times the LHC design luminosity. In terms of physics analysis using the recorded datasets with increased collision energies in 2015, 2016 and 2017, the CMS experiment has started to reproduce all the investigations and measurements that were performed during LHC Run 1. Preliminary results cross-checked the observation of the higgs-like particle discovered during Run 1, and discarded the existence of another higgs resonance $\sim 750$ GeV in the $H \rightarrow \gamma\gamma$ channel. There are good prospects to reproduce searches of new physics and precision measurements with this new dataset, as at the moment the amount of data recorded during Run 2 surpasses by more than a factor a 2 what was recorded during the full Run 1 campaign. This will deliver more precision in the measurements and hopefully some sign of new physics that clearly, as shown throughout this document, has not shown up.

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