Status of CMS

Progress Summary Report for April 2012 RRB34

The CMS detector performed at remarkably high levels in the last data-taking period of 2011 despite increasing challenges such as pile-up reaching an average of more than 15 interactions per bunch crossing. A very successful heavy ion run in November accumulated data of very high quality. The LHC delivered more than twenty times the luminosity of 2010, in total $167\mu b^{-1}$ that was recorded with an efficiency close to 95%. The collaboration successfully met the challenge of completing a broad array of physics analyses for presentation at the winter conferences, most of them using the full 2011 dataset. In parallel CMS succeeded in improving the trigger, data reconstruction and analysis tools as required for the extremely high pile-up conditions expected in 2012. This report details the activities of the collaboration by coordination area and subprojects, including the new coordination area Physics Performance and Datasets (PPD) created in 2012.

Infrastructure and Magnet

Since the last status report, 2012 p-p and ion-ion operations were completed with magnet, common systems and infrastructure faults accounting for only about 1/5 of data-taking losses, most of this concentrated in the cooling incident of 2-3 August 2011 as described in the last status report.

The inadvertent turning off the CMS solenoid in October, due to a mix-up in an instruction intended for LHC power converters, highlighted some weaknesses in the protocols of the control system. Improving the cryogenic and electrical systems of the magnet to reduce accidental or obligatory on-off-on cycles and major down-time was an important objective of the year-end technical stop and remains a high priority in the consolidation and upgrade programme.

As beam currents increased during 2011, pressure spikes in the CMS beampipe at around -18.5m were increasingly observed. CMS Technical Coordination assigned highest priority to diagnosis and correction of this feature; observations elsewhere in LHC soon suggested that the cause might be distorted RF continuity fingers in the bellows at -18.5m and every effort was made to access and X-ray this region before CERN closed for the Christmas break. Indeed the X-rays showed an incorrect configuration of the fingers, probably caused by over-extension related to an unintentional displacement of the TAS in late 2007. As the bellows in question is not isolatable from the central beam-pipe, the repair relied on a novel method of neon protective flow developed by CERN TE-VSC and successfully applied several times to open the LHC vacuum system and exchange parts without poisoning the "NEG" getter coating on the inner surface of adjacent beamline elements (which, if it befell the CMS central beampipe, would require a full opening of CMS to correct). This repair was successfully carried out in January and normal vacuum conditions re-established.

Although the vacuum work prevented any opening of the yoke, work on the dismounted forward calorimeters continued in their garages; a highlight was the installation of new Beam-Halo Monitors for p-p operation. A demonstrator of the Pixel Luminosity Telescope (due for installation 2014) was installed within the forward shielding to gain experience during 2012 for operation of the final system. In further preparation for LS1, supports for the ME4/2 and RE4 chambers and one dummy RE4 module were mounted on the outside of both YE3 disks.

A "show and tell" engineering review demonstrated that re-installation of the CASTOR calorimeter (now removed) will be possible for 2012 heavy ion physics, without undue risks (beam pipe under vacuum). The procedure was later endorsed by the LHC Machine Committee. Similarly the Zero Degree Calorimeter was removed, with a reasonable hope of re-installing it for heavy ion physics.

Work on the fluorocarbon cooling distribution started in line with the major Long Shutdown 1 (LS1) objective of reducing the Tracker coolant temperature to -20 °C. Insulation in distribution cabinets reduced the dew point from around 0 °C to -20 °C, while extensive tests of the primary and secondary loops showed that the system needs substantial modifications in order to meet the required target.

The other critical path objectives of LS1 are the installation of a 4th endcap muon layer and its associated shielding wall (YE4) at each end of the experiment, the installation of a reduced diameter (45 mm outside diameter) central beampipe, compatible with the proposed pixel upgrade and the first stage of phototransducer replacement in the hadron calorimeter. The first YE4 recently passed its pre-assembly and magnetic load deflection test at Pakistan. The new beampipe, after passing the long process of design review by both CMS and the LHC is now being ordered. Technical Coordination is advancing steadily with developing a planning for LS1 consistent with the LHC planning announced after the February 2012 Chamonix meeting.

Run Coordination

The proton-proton run finished at the end of October 2011. During the last days of the run the LHC increased the bunch charges to 1.45 x 10^{11} protons per bunch, which gave the highest instantaneous luminosity of the year, 3.5x10^{33} cm^{-2}s^{-1}. The total luminosity delivered to CMS in 2011 was 6.1fb^{-1} and CMS recorded 5.5fb^{-1} for 91% efficiency. The data certified as good for the data analysis corresponds to 92% of the recorded luminosity.

The heavy ion run took place in November 2011 and was very successful also as noted above. In total 167μb^{-1} that was recorded with an efficiency close to 95%. The L1 trigger rate was close to 3kHz and the tracker and calorimeters were read out in non-zero suppressed mode. Zero-suppression was done at the HLT.

CMS held a Run Coordination workshop at CIEMAT 2-4 November 2011 to review operational experience and to prepare for 2012 data taking period. In the workshop we analyzed our experience with a high pile up fill that was provided by the LHC at the end of October 2011. The conclusion from the high pile up fill was that an increase of the HLT CPU by 50% was needed in order to deal with bunch luminosities close to 5x10^{30}cm^{-2}s^{-1}. It was also found that the tracking and reconstruction code needed improvements to optimize the memory usage and CPU consumption.

As the integrated luminosity increased, we observed an increase in the number of soft errors (a.k.a. Single Event Upsets, or SEU), as expected from the increase of radiation in the collision hall. The main systems that were affected were Pixel, ECAL, HCAL and CSC. A software mechanism to recover from soft errors was developed to complement the (already existing) hardware mechanism.

The option that has been chosen for running in 2012 is 50ns bunch spacing with bunch charge increased to 1.6x10^{11} protons, emittance of 2.5 μm and β*=0.6 m, as this configuration will give the highest integrated luminosity in 2012 at the cost of running with higher pile up. The expectation is that during this year the LHC could reach instantaneous

luminosities close to $7x10^{33}$ $cm^{-2}s^{-1}$ and an average pile up of ~35 events/crossing at start of fills. During the technical stop CMS has been preparing for these new conditions.

CMS restarted operation with Mid-Week Global runs on the 15 February 2012 to check that all systems were operational and running. We have also used cosmic data to check the relative timing between the different sub-detectors. About 500'000 cosmic tracks for tracker alignment with the magnet off were acquired. The machine will start the beam commissioning on the 13 March for three weeks. The first collisions with low number of bunches are expected early April.

Tracker

The pixels and silicon strips systems completed 2011 data-taking maintaining the previous high levels of performance and availability. Tracker services continue to run very well and did not cause any significant downtime: power supply failure rates remain low, cooling fluid leak rates remain low, dry gas supply ran without interruption, and the Tracker safety system is very reliable. The Tracker is again ready for Physics after the year-end technical stop and the working fraction of the detector remains steady at 98% for the strips and 97% for the pixels.

Radiation effects, both in terms of instantaneous single-event upsets (SEU) and accumulated fluence and dose effects, are being closely monitored. Accumulated radiation damage in the pixels has reached levels where the most irradiated sensors are going through type-inversion, whilst for the silicon strips the amount of effective doping change is still very small. In 2012, the pixel system was recalibrated to operate at 0°C, which reduces leakage currents by 50% relative to the previous 7 °C running condition.

A series of detailed tests on the Tracker cooling system was made during the year-end technical stop to determine the ultimate capacity of this system. After LS1, the Tracker must be able to run colder to mitigate the effect of increasing radiation damage. The tests showed that we are presently limited to supplying fluid at approximately -4 °C to the silicon strips and -14 °C to the pixels when running with maximum heat load, whilst the target temperature for the cooling fluid supplied to the Tracker is -20 °C. An extensive revision of the cooling system is therefore being planned in LS1.

Other activities related to the future cold-running of the Tracker are also being integrated into the LS1 planning. To avoid condensation work is underway to develop better solutions for sealing and flushing the service volumes inside YB0 as well as to better monitor these volumes.

Electromagnetic Calorimeter

The procedures to achieve channel response uniformity and time response stability within ECAL were steadily improved during 2011, with the development of a suite of tools to monitor the laser performance and the corrections. At the end of 2011, upon a thorough recalibration of the monitoring system, a set of optimized single channel calibrations and energy corrections was delivered, which provided excellent energy scale stability and resolution performance for the entire 2011 dataset. These corrections were used to improve the sensitivity of the $H\rightarrow\gamma\gamma$ search, and were incorporated into the CMS results submitted for publication. The resolution in the end-caps is noticeably worse than in the barrel due to several factors, which likely include an increased material budget in front of the calorimeter and less precise single channel calibrations. Work is ongoing to further improve the single channel calibrations, the corrections to the photon and elec-

tron energy, and the reliability of the monitoring system. In particular, a new laser that requires less maintenance and is more stable is being installed at P5 and will be available for the 2012 run.

During the year-end technical stop, many interventions have taken place. The ECAL zero-suppression settings applied online and the algorithm to reduce the rate of anomalous signals ("spikes") are being retuned to cope with the LHC running with high pile-up conditions. A procedure to mitigate the effect of crystal transparency loss in the ECAL end-caps at both Level-1 and HLT has been developed.

At the end of 2011, the percentage of working channels was at ~99% in the barrel and endcap, and ~95% in the preshower in front of the endcap crystals. The latter figure is expected to increase to above 97%, upon the installation of an upgraded high voltage distribution system, planned in 2010.

Hadron Calorimeter

During 2011 running period, all hadron calorimeters (HCAL) continued to operate reliably with unchanged number (> 99%) of good channels. However, towards the end of 2011, two problems have become evident.

The first problem is related to the drifts in response of HB/HE HPD pixels. Approximately 6% of the channels exhibit response drifts beyond 10% in the period October 2010 to December 2011. The HCAL Detector Performance Group (DPG) has launched a study to determine when the observed drifts in HPD pixels would start affecting HCAL performance. The answer to this question will determine which HPDs may have to be replaced during LS1.

The second problem is related to the loss of the gain in HF Photo Multiplier Tubes (PMTs). For 5 fb^{-1} of integrated luminosity in 2011, the level of degradation was 7% in the highest rapidity region, and approximately 5% in the middle rapidity region of HF.

During the Year-end Technical Stop we have replaced a HF readout box with 24 photo-multipliers (PMTs) on a 10 degree phi sector of HF Minus. The PMTs were replaced with new multi-anode PMTs. This readout box will allow us to verify that all PMTs, even at high eta region, can handle ~500 fb^{-1} based on the data collected up to Long Shutdown 1.

For 2012, the HCAL energy reconstruction window was reduced to better handle high pile-up conditions, with further optimization of noise filters. The 2012 start-up Look-Up Tables (LUTs) contain corrections for HF PMT dynode gain loss and HF energy scale adjustment. In HB/HE, corrections were applied for HPD response drifts. In 2012 HCAL LUTs will be periodically updated to account for changes in detector response.

Muon Detectors

Endcap Cathode Strip Chambers (CSC):
During the current Technical Stop many improvements have been made to the CSC system. The system is currently up and running well with cosmic rays.

During 2011 data taking after September 1st an apparent 4% efficiency loss for endcap muons was traced to a problem of lost data blocks when the front-end readout rate exceeds 70 kHz. The problem was easily reproduced with high rate, and firmware fixes have been identified and implemented in the CSC readout electronics.

Many changes have been made to online software. Our TTC machine has been upgraded to SLC5 / 64bit / new TTC software. New CSC online software and a big upgrade of the DCS system have been deployed and are being tested.

Meanwhile, a new and improved scheme for CSC data certification based on Run Registry 3 is being developed. Improvements to DQM itself have been made. Our data monitoring and calibration procedures were assessed during CMS-wide DQM and AlCaDb reviews in January, and no significant problems were uncovered.

A chamber factory at Prevessin B904 has been set up to build 72 new ME4/2 chambers. The very flat cathode panels, which are at the heart of the new ME4/2 chambers are in production and large numbers are now arriving at Fermilab for strip milling. Electronics and other parts are arriving in large quantities at B904. A new 1-crate chamber testing setup has been created in B904. Improved electronics for ME1/1 such as the new cathode readout (DCFEB) board are now in the pre-production phase.

Barrel Drift Tubes (DT):
The DT system is ready for 2012 data taking: the fraction of good channels is 99.1 %. The year 2012 will be the third year without access to the chambers and the Front-End electronics. The trigger timing has been cross checked during the first data taking with cosmic rays in 2012 and it is as accurate as in 2011.

During the 2011 data taking, the DT group had to intervene many times to deal with overheated LV connectors, whose failure can affect larger fractions of the detector. Such interventions were done in the shadow of an LHC access with no contribution to CMS downtime. During this Year-End Technical Stop, a major activity of the DT group was the reworking of LV modules. The solution involved removing ~150 CAEN modules from the detector, soldering of "pigtails", and thorough testing of all the modules in a local test stand installed in USC. The system is now back in good shape and ready for commissioning. In addition, HV USC racks have been equipped with water detection cables.

Other significant activities have taken place during this YETS, such as the installation of a new and faster board for the Minicrates secondary link and the migration to Scientific Linux 5, together with various software upgrades. Firmware upgrades have also been performed in order to tune small details seen during the year.

The upgrade activities planned for LS1 are evolving according to schedule, both for the Trigger Board replacement and for the Sector Collector relocation from UXC to USC.

The DT DPG has focused on preparation for 2012 data. The DQM plots have been improved in order to be able to spot changes in the running conditions quickly. This will allow the DT team to have a quicker reaction when the calibration constants change.

Resistive Plate Chambers (RB and RE):
The RPC system ran very smoothly in the 2011, showing an excellent stability and very high data tacking efficiency.

During 2011 the number of disconnected chambers increased from 6 to 8 corresponding to 0.8% of the full system while single gap mode chambers increased from 28 to 31. Most of the problematic chambers have bad high voltage connections and electronics failures that can only be solved during LS1. The percentage of operating channels is 98.4%.

Average detection efficiency in 2011 was about 95%. During the summer period we decided to introduce an automatic correction of the high voltage working point as a function of the atmospheric pressure in order to reduce efficiency oscillations. This correction reduced the oscillation envelope from 3.5% to 1.5%.

A new method to measure chamber efficiency using DT-CSC segments associated to a reconstructed muon track is under validation. Preliminary results are very encouraging.

A linear dependence of the background rate and of the detector current versus luminosity was observed in the 2011. Extrapolations of the rate and current to 10^{34} cm^{-2} s^{-1} has shown that all chambers are still far from the theoretical limit of 100 μA and 100 Hz/cm^2.

The main activities of the 2011-2012 winter shutdown were: gas leak survey, gap resistance measurement and high voltage scan. Preliminary results show a stable gap resistance and a very encouraging stability of the gas system (no new leaky chambers).

The upgrade project is on schedule. The Korean gap production site is ready and the first set of Bakelite sheets was delivered there at the end of 2011. Thirty gaps will be produced in April 2012 and sent to the three test sites (Ghent, Mumbai/Chandigarh and CERN).

The off-detector electronics project for the RE4 chambers is ongoing. Eight prototype boards were successfully tested at building 904 and then installed at P5 in order to test them during the CMS global run and give a final green light to the full production.

Muon Alignment:
A new track-based alignment for DT chambers was approved for use in 2012 data processing. It shows improvements in mass resolution for pairs of stand-alone muons, curvature resolution at high momentum, and DT segment extrapolation residuals.

The validation workflow for high-momentum muons has been extended to include energetic muons decaying from heavily boosted Z's: the di-muon invariant mass for global and stand-alone muons is reconstructed, and the invariant mass resolution is compared for different alignments.

From the hardware side, the number of MABs with readout problems has increased from 1 to 4. These MABs can't be recovered until LS1. Studies of the effect of the missing data on the overall alignment are ongoing. The preliminary conclusions are that these effects are relatively small (~0.5 mm) except in the vicinity of the missing MABs.

Trigger and Data Acquisition

L1 Trigger:
Various improvements to the L1 trigger algorithms for 2012 have been studied since late last year and are being deployed. These include new high P_T patterns for the RPC endcap, an improved CSC P_T assignment, a new P_T matching algorithm for the Global Muon Trigger, and new calibrations at L1 for the ECAL and HCAL trigger primitives and for the Regional and Global Calorimeter Triggers. All of this should improve the efficiency, rate, and stability of the L1 trigger. New L1 trigger menus have been developed for luminosities from $5x10^{33}$ Hz/cm^2 to $7x10^{33}$ Hz/cm^2. For the first time, the L1 menu includes cross-triggers with angular correlations between objects (e.g. electrons, muons and jets) to maintain acceptable rate and good efficiency.

In addition, the L1 group upgraded the data links between the Global Calorimeter Trigger and the Global Trigger to a more reliable optical system. These links are installed at Point 5, have been synchronized using ECAL signals, and are completing commissioning.

Trigger Coordination:
The Trigger Studies Group has been developing menus for the 2012 run with luminosities ranging from $5x10^{33}$ Hz/cm^2 to $7x10^{33}$ Hz/cm^2 and covering large pile-up exceeding 25 interactions per crossing. Additional "Trigger Reviews" were organized in February to develop the trigger strategy for 2012. Important HLT developments for the 2012 run included widespread use of Particle Flow, substantial improvements to muon HLT algorithms, use of pileup corrections for jets and isolation quantities for leptons, revised

ECAL and HCAL noise filters better suited for high pileup and improvements to tracking and primary vertex reconstruction.

The TSG continues to closely monitor the CPU performance of the HLT. There have been major gains in CPU performance of tracking and vertex finding.

The TSG is developing additional options in the menu to provide additional streams for data to be stored ("parked") before reconstruction. Data parking explores the additional bandwidth available at the HLT and DAQ, which is capable of writing up to ~1 kHz of data on tape. As the ability to reconstruct these data promptly is limited to ~300 Hz, we are now building the system that allows to "park" these extra data for processing either during the LHC downtimes or in 2013, when the LHC is going to be shut down for an energy upgrade. Possible physics cases for such parked data are new VBF triggers; B-physics triggers for studies of, e.g., Upsilon polarization; multijet triggers with low ME_T for searches for SUSY in regions of parameter space where there is a compressed mass spectrum; and large-statistics precision studies related to inclusive W samples.

DAQ:
The DAQ system reliably operated in 2011 for pp physics data taking and also during November for Heavy Ion (HI) PbPb physics. The system performed with high efficiency. Compared to 2010, the PbPb collision rate increased from ~250 Hz to ~4.5 kHz. The DAQ configuration for HI running was optimized to meet the requirements of a L1 rate of ~2 kHz and an event size of ~20 MBytes. After the event selection and tracker zero suppression by the HLT, ~150 Hz of events with a size of ~2 MB were written to disk.

It has been decided to extend the DAQ/HLT system for the 2012 pp run, in anticipation of a peak instantaneous luminosity of $7x10^{33}$ Hz/cm^2 at 50 ns bunch spacing. The expansion is aimed at increasing the total HLT capacity of about 100 ms/event at 100 kHz L1 rate to about 150 ms/event. Various candidate PC models were evaluated and PC nodes based on dual 8-core CPUs of the new 'Sandy-Bridge' architecture have been ordered. Deployment is foreseen for May before high intensity running.

The preparation for the 2012 physics run is ongoing. All online systems are migrating to SLC5/64 bits. New online software releases have been produced, including framework and services, run control and central DAQ applications. Various parts of the IT infrastructure have been upgraded during the end-of-year shutdown. The online database moved to a blade system and a NAS for storage as the old hardware become obsolete.

The CMS Electronics Integration Center, located in Building 904, allows sub-detector groups and the level-1 trigger to test and validate revised versions of the readout firmware and software. An IT infrastructure similar to the one at Point-5 has been installed and is operational.

Offline Software

The high pileup fills were extremely useful for Offline. We learned that the response predicted by high pile-up simulations did not match the technical performance of the reconstruction on high pileup data. In response, the pileup performance task-force (PPT) was formed with the goal to improve the CPU performance by a factor of 2 and decrease memory consumption to below the 2GByte threshold required of GRID applications.

The first step was to build and test a 5_1_X release including upgrades to ROOT, the GCC compiler and a new memory allocator, jemalloc. This combination improved the average memory consumption by 250Mbytes.

The next step was to try to improve the technical performance of the CMS code without changing the physics performance. Many valuable contributions, especially in the areas of tracking and electron reconstruction, were integrated into a later phase of the 5_2_X release cycle. The CMSSW_5_2_0 release, delivered on the 6 March 2012, reached all of the technical performance goals set for it. In a test with 100 events from the most challenging high pileup data the CPU time to reconstruct the events goes from 80s/event in CMSSW_4_4_X to 30/event in CMSSW_5_2_X. The peak memory use was reduced by 450Mbytes. Preliminary measurements show that it has similar or improved physics performance as the fall release. By all measures this effort has been a huge success.

Computing

Since the last RRB, the CMS Computing Project has handled the processing for the 2011 Heavy Ion run, reprocessed the proton-proton data and simulation, and started the early preparations for the 2012 run at 8TeV.

The Tier-0 completed the 2011 Heavy Ion run, which in many ways was easier to manage than the 2010 run. The input rate for the reconstruction farm was substantially reduced compared to the previous year even with a new, higher selection rate. The raw events were promptly reconstructed and replicated to archive in France and the US. The reconstructed events were shipped to a dedicated heavy ion processing center at the Vanderbilt Tier-2.

At the end of the heavy ion run the Tier-0 center was used for production of 8TeV simulation in preparation for 2012. The Tier-1 centers performed many reprocessing passes on sections of the data during the year with improved calibrations. These were mostly intended for the initial Higgs search results. The Tier-2 centers continue to serve as the primary analysis resource. CMS had about 60M grid jobs submitted in 2011. The Tier-2 pledged CPU resources are nearly 100% used every month.

An evaluation study of the computing implications of data parking was performed, showing that with a modest increment of resources in 2013 at Tier-1s (CPU 20%) and Tier-2s (CPU 15%, storage 10%) it is possible to acquire an additional event rate of 600 Hz (on top of the 300 Hz that's promptly reconstructed) to be processed and analyzed during LS1. This can significantly increase the CMS physics potential.

Physics Performance and Datasets

Activity has been focused on preparation for the 2012 data taking. This involved the validation of the new releases for physics performance, Monte Carlo (MC) production and data processing in 2012.

In preparation for the February 6-10 LHC Chamonix Workshop, the PPD group together with Physics groups, worked to understand the effects of the high PU scenario foreseen for 2012 on some of the flagship Higgs analysis. Preliminary results indicate that losses of performance could be largely compensated by the higher integrated luminosity.

In parallel, a task force was setup with the goal of optimizing the reconstruction algorithms to cope with the high event occupancy without impacting physics performance for analysis. Work mostly concentrated on improving tracking algorithms and resulted in a 2.5 times increase in reconstruction speed with a 1/3 reduction in RSS memory usage.

The PPD team is coordinating the release (52X) validation effort of the various DPGs and POGs as well as of the HLT group and is organizing a higher, analysis-level validation together with the Physics Analysis Groups (PAG) in order to guarantee a deep understanding of the potential of the new release for final physics.

Concerning the preparation for the analysis of the new data, a new MC production has been launched. The new samples, simulated at 8TeV, are already being produced and the digitization and reconstruction steps have also begun.

In parallel, the PPD group supported the analysis of 2011 data, releasing a new certification of the datasets reprocessed over the Christmas break with the 44X release. Two separate reviews of the DQM/Data Certification and Alignment/Calibration Database infrastructures have been held. These reviews assessed their readiness for data-taking with the new LHC running conditions.

Another important activity started in collaboration with Physics Coordination is the organization of a new team that will work at the consolidation of the algorithms for the Global Event Description for the benefit of all CMS analyses using these advanced reconstruction tools. Finally, in preparation for the new HLT menu, the PPD is also setting up a Dataset Definition Team (DDT), together with Physics and Trigger, to coordinate the work for dataset definition.

Physics

Recent months have been incredibly productive for the CMS Physics groups, which have over 50 approved new results since the last RRB meeting. The majority of these results are based on the full 2011 dataset of nearly 5 fb^{-1}. Many have been already submitted or published, led by nine Higgs publications submitted in February 2012.

A number of new Heavy-Ion (HI) analyses have been approved recently. They include a study of jet-quenching extending last year's published results to very high jet E_T with the significantly larger 2011 HI data-set, as well as measurement of elliptic flow with 2011 data. A number of publications are being finalized with the 2010 dataset as well, including detailed papers on elliptic flow and one on W production in HI collisions.

The B-physics group has completed a number of precision measurements, including the inclusive b-jet production cross section, and a comparison of various b-hadron production rates. The highlight of the group's work is the search for the rare $B_{s/d} \rightarrow \mu\mu$ decays with the full 2011 dataset. The new results set the following limits on these decay rates: $Br(B_s \rightarrow \mu\mu) < 7.7 \times 10^{-9}$ and $Br(B_s \rightarrow \mu\mu) < 1.8 \times 10^{-9}$ at 95% confidence level. These results were just superseded by a slightly more sensitive LHCb analysis.

In 2012 we have combined the small-x part of the QCD PAG and the Forward Physics PAG into a new Forward and Small-x QCD (FSQ) PAG. The new group has been very productive in the past few months and completed a number of important measurements, including the new determination of total inelastic pp cross section at 7 TeV.

In 2012, we also merged the high-p_T part of the QCD PAG with the EWK PAG to become a new Standard Model Physics (SMP) PAG. This PAG has been very active in continuing precision tests of QCD and EWK theory. The highlights of their work are the measurement of associated production of Z boson with one or two b-jets, as well as angular correlations between the B-hadrons produced in association with a Z boson, measurement of the W charge asymmetry in the $e\nu$ decay channel, W production cross section in the $\tau\nu$ decay mode and the DY cross section. The group also performed a study of dijets produced in association with a W boson where the CDF experiment saw a peak-like structure with a dijet mass ~150 GeV. CMS studies do not confirm the CDF result.

The TOP PAG has completed a number of precision measurements of the top production cross section and properties, including the most precise measurement of the top mass in the dilepton channel as well as a top-mass measurement in the lepton+jets channel (172.6 ± 0.4 ± 1.2 GeV) which is comparable to the current Tevatron average (173.2 ± 0.6 ± 0.8 GeV). The group also produced a precise measurement of the ratio of top quark decays

into Wb and Wq, consistent with unity, measurement of the top-quark charge, W polarization in top decays, and a first differential measurement of the top quark-antiquark forward-backward asymmetry at the LHC.

With the LHC having delivered nearly 5 fb^{-1} of data in 2011, a primary focus has been on the search for the Higgs boson, and significant strides have been made in limiting the allowed mass region for the minimal SM Higgs. Overall, with all channels combined, CMS should have been able to rule out the SM Higgs at the 95% CL in the entire mass range up to 600 GeV; however, due to an excess of events in data, mainly in diphoton and ZZ channels at low mass, we cannot rule out SM Higgs in the small mass window between 114 and 128 GeV. The largest excess seen in the CMS data is at a mass of ~125 GeV and corresponds to a local significance of 2.8 standard deviation, which is reduced to 2.1 (0.8) standard deviations, after look-elsewhere effect in the 110-140 (110-600) GeV range.

The SUSY searches in CMS are shifting their focus from light gluino pair production to more complicated SUSY scenarios. The new searches are focused on a light third-generation scenario, compressed mass spectrum scenarios, and chargino-neutralino production. The first result of this program of searches based on full 2011 statistics has been already presented at Moriond 2012 – the search for a b-squark in the same-sign dilepton channel with b-tagged jets. The SUSY group also produced a number of limits in the CMSSM plane in other channels with full 2011 statistics that rule out gluinos with mass less than ~1 TeV in this scenario. Searches for a very wide variety of new physics models have also been performed in the Exotica physics group. Most of these analyses are based on the full 2011 dataset. New searches for pair-produced dark matter (DM) particles were performed. These searches allowed CMS to set the most stringent limits on the production cross section of DM with spin-dependent couplings, some three order of magnitude tighter than the sensitivity of direct-detection experiments.

Heavy Ions

The LHC accelerator and the CMS experiment had another excellent PbPb run in November of 2011. Out of the total delivered luminosity of 167 μb^{-1} we recorded 157 μb^{-1} with 150 μb^{-1} available for physics analyses. The data was collected at $\sqrt{s_{NN}}$ = 2.76 TeV, increasing the overall usable data volume by about a factor of 20 compared to 2010.

To fully exploit the high instantaneous luminosity, in 2011 CMS was recording predominantly events with high p_T jets, photons and muons. Only a moderate fraction of minimum bias events was written in the data stream.

Since last RRB the HI group in CMS submitted 5 papers for publication, bringing the total number to 10 since the beginning of the HI program. Several more publications are in their final review stages and are expected to appear within the next 2-3 months.

Our results take advantage of the high energy of LHC and the large acceptance of CMS, allowing very detailed studies of hard processes. We made detailed measurements of dijet production, jet-hadron correlations, jet fragmentation and quarkonia production. The 2011 data already improved the accuracy of measurements of charged particle and jet production at the highest momenta. We're performing in depth studies of the large parton energy loss that was first observed in 2010. We plan to utilize new probes, e.g. photon-jet events for further detailed understanding of the energy loss mechanism.

The higher statistics will allow better understanding of the suppression of the excited states of the Υ and differential studies of J/ψ and Υ family production as a function of collision centrality and transverse momentum.

We plan to complete studies of electroweak boson production. The new results will include W and Z production, including Z to e^+e^-.

In 2012 we expect to collect data with pPb and pp collisions at matching center-of-mass energies. The pPb run provides an important physics reference for the interpretation of PbPb data as well as better insight into the parton structure of the nucleus.

Upgrades

An integrated plan and schedule is being developed for the consolidation and upgrade projects LS1, scheduled for 2013-2014. Production facilities at CERN, Ghent and Mumbai are being readied to start RPC chamber fabrication by summer. For the CSCs, two initial prototype chambers were fabricated, one of which has undergone long-term HV testing. Additional preproduction chambers will be fabricated this spring with the first batch of production panels. Over 50% of the Photomultipliers for the Forward Hadron Calorimeter, the HF, have been received from Hamamatsu and tested. The SiPMs (Silicon Photomultipliers) and the associated electronics cards for the Outer Hadron Calorimeter (HO) are being tested.

Three projects are planned for the period after LS1: the Pixel, HCAL and L1-Trigger upgrades. Simulation studies are underway for each of these projects, and R&D and design work is proceeding, with TDRs planned this year. Designs of the next Pixel readout chip and two other ASICs were submitted in January for production by IBM. The new design will allow operation at higher luminosity and event pileup. The mechanical design of the detector achieves a significant reduction in mass. The new pixel detector design is optimized with a smaller radius for the innermost layer.

The HCAL upgrade in which the present HPD photodetectors in HB and HE are replaced with SiPMs has demonstrated the SiPM front-end using the present QIE chip in test beam, and is building a prototype slice of the backend electronics. Further development with the SiPM manufacturers is still needed to optimize the SiPM parameters. A prototype design for the next generation readout chip, the QIE10, has been submitted. This is a common development effort for CMS and Atlas.

For the L1-Trigger upgrade, demonstration of capability in microTCA electronics is well along, and the overall trigger design is being developed. Performance of the present trigger algorithms is being studied in high pileup conditions. A plan is being developed to allow a new trigger to be developed in parallel to the present operating trigger by optically splitting input signals.

R&D and studies continue for the Phase 2 upgrade beyond 2020. The Forward Calorimetry Task Force is carrying out simulation studies of the performance degradation expected for the present detectors with radiation, and modeling new configurations for forward calorimetry. Work continues on the design of a new tracker for Phase II, with the capability of providing track information to the hardware trigger.

Publications

Since the start of LHC collisions, CMS has published physics results in a variety of forms, most notably papers in refereed journals and conference reports (CRs). The list and details of these publications are being updated regularly and are publicly available from the CERN Document Server (CDS) at http://cdsweb.cern.ch/collection/CMS?ln=en.

As of 17 March 2012, CMS has published 135 physics papers in PRL, PRC, PRD, EPJC, PLB and JHEP. The members of the CMS collaboration, who gave talks at international conferences worldwide, wrote their contributions to the conferences' proceedings; so far,

766 conference reports were published (since 1 January 2010). The corresponding increments in these categories since the last RRB are: Papers 28; CRs 172.

The five most cited CMS physics papers to-date, each with at least 100 citations are:

1. Search for Supersymmetry in pp Collisions at 7 TeV in Events with Jets and Missing Transverse Energy - Phys.Lett.B698:196-218, 2011; 155 citations.

2. Transverse momentum and pseudorapidity distributions of charged hadrons in pp collisions at $\sqrt(s)$ = 0.9 and 2.36 TeV - JHEP 1002:041, 2010; 131 citations.

3. Observation of Long-Range Near-Side Angular Correlations in Proton-Proton Collisions at the LHC - JHEP 1009:091, 2010; 115 citations.

4. Transverse-momentum and pseudorapidity distributions of charged hadrons in pp collisions at sqrt(s) = 7 TeV - Phys.Rev.Lett.105:022002, 2010; 113 citations.

5. Search for Supersymmetry at the LHC in Events with Jets and Missing Transverse Energy - Phys.Rev.Lett. 107 (2011) 221804; 111 citations.

Conclusion

The CMS detector performed extremely well in the pp and in the heavy ion run at the end of 2011, meeting every challenge it has faced. Data collected in 2011 have been extensively analyzed to obtain a very wide range of important physics results including very extensive results on the SM Higgs with wide ranges of masses excluded at 95% CL. Most of these results use the full 2011 dataset. The CMS collaboration made enormous progress on preparation for running in 2012, being now ready to profit from instantaneous peak luminosity up to $7.0 \times 10^{33} cm^{-2} s^{-1}$ corresponding to an average of 35 pile-up events. Good progress on the upgrades to be installed in LS1 is also observed. It is an extremely intense and exhilarating period in the LHC program with expectations for important results to appear in 2012.