Status of CMS

Progress Summary Report for April 2011 RRB32

Since the last progress report in October 2010, the CMS detector reached a total accumulated data sample of ~43 pb^{-1} of pp collisions at 7.0 TeV in 2010 and gone on to efficiently accumulate another ~23 pb^{-1} in 2011. In late 2010 CMS also participated in a very successful Heavy Ion (PbPb) run. The 2010 data have led to a magnificent harvest of physics results that have exceeded all of our expectations in terms of their quantity and quality. A wide array of measurements has provided a very good first picture of the Standard Model at a new energy scale. The search for new physics has been extended into new realms. In PbPb collisions, dramatic evidence of jet quenching and observation of Z production has been reported. The LHC and the CMS experiment have demonstrated outstanding performance and 2011 has started off magnificently.

Technical Coordination

During the period since the last RRB report, the infrastructure, magnet and common systems of CMS operated well and remain generally in very good condition. In an important test just before the end of beam operations, the magnet cold box filters were regenerated at full operating field, implying that the magnet power cycling applied during several earlier 2010 regenerations will in future no longer be needed. This is a major step to assuring the long-term robustness of the magnet. During the extended year-end technical stop, from early December to mid-February, some major tasks were performed. The most significant of these was the installation of TOTEM T1 telescopes at both ends of CMS, in parallel with replacement of the reflective sleeves on the light-guides of the HF phototubes (described later) and a correction to the alignment system inside one endcap. The cooling for the HLT farm also underwent an upgrade to allow more processors to be installed, so as to preserve trigger bandwidth in view of increasing LHC performance. This required some significant construction work that had to be carefully planned along with many routine maintenance tasks that needed to be done during this period. The cooling of the farm has now 1MW capacity and was running again by the second week of January. Important improvements were also made to the electrical system, surface to underground communication and the fire protection compartment structure. The conclusion of the review of CASTOR-related radiation and background issues was that CASTOR can stay installed throughout 2011. A large number of other maintenance activities and improvements that have taken place during the winter extended technical stop are described below in the corresponding coordination and detector sub-system sections of this report. The experiment was closed on schedule and ready for beam in mid-February as foreseen. All systems are fully functional, including HF, CASTOR, and TOTEM T1.

Run Coordination

After commissioning of bunch trains at the beginning of September 2010 the LHC continued to achieve exponentially increasing instantaneous luminosities until the end of pp running in November. The peak luminosity in 2010 was 2.05×10^{32} $cm^{-2}s^{-1}$. The LHC delivered 47.03pb^{-1} during the 2010 pp run of which CMS recorded 43.17pb^{-1}. Towards the end of the intensity ramp-up, the LHC experienced electron-cloud effects that significantly increased backgrounds that prevented them from going beyond 368 bunches. The overall performance of CMS has been exceptional with 98% or more of fully functional channels in all subsystems. As the luminosity increased, adjustments were made to the trigger to keep the L1 rate at 50-70 kHz and the data logging rate at ~300-500 Hz until the end of the run where we were close to saturating the HLT bandwidth. Substantial effort went into optimizing the trigger for high luminosities.

The transition to PbPb running went very smoothly for both LHC and CMS. CMS operated in a mode without zero-suppression in the strip tracker and calorimeters. The LHC delivered 9.56 μb^{-1} and CMS recorded 8.7 μb^{-1}. A run coordination workshop was held in early November to review the pp running experience in 2010. For 2011 we have instituted a relatively large minimum shift quota per person for central shifts, thereby limiting the number of people involved so that they integrate more experience to become more proficient. Most central shifts have been subscribed for 2011.

After the extended winter technical stop we started central operation with global runs on February 2 and 3 followed by cosmics February 10-20. Many changes and upgrades were performed during the winter technical stop. Among them was the transition of the central DAQ to 64 bit applications.

The LHC started beam commissioning on February 20 and declared stable beams for the first time on March 13. The initial collisions involved only two pairs of colliding bunches in CMS, but with higher pileup than was seen in 2010 due to the LHC now using optics with β^*=1.5 m. The pileup in the initial fills has been around 5 to 6 interactions per crossing. CMS has used these first few fills to validate the timing and performing other commissioning tests such as HV scans on some set of RPC chambers. The LHC increased the number of bunches stored to 32, 63, 136, and 200 with about 20 hours of stable beams and three fills for each step. The LHC delivered about 25pb^{-1} and CMS recorded 23pb^{-1}. A new record instantaneous luminosity was achieved at 2.5x10^{32} $cm^{-2}s^{-1}$.

Tracker

Operations of the pixels and silicon strips remained very stable through to the end of 2010 running, with excellent performance, during both the pp and PbPb collisions. The working fraction of the detector since October is 98% for strips and 97% for pixels. The infrastructure continues to run well with full tracker availability during physics runs.

The long-term reliability of the Tracker cooling is being investigated following recent failures of pumps and increases in the coolant leak rate, particularly in circuits associated with the SS2 silicon strip cooling plant. Five cooling circuits out of 180 are switched off to reduce the leak rate. Data-taking and detector performance remain unaffected because most of the modules affected by leaks can be operated without direct cooling in the absence of significant radiation damage. In response to these concerns, some important improvements are being made to the silicon strip cooling plant hardware and operating procedures. The aim is primarily to smooth out the operation of the plants, particularly reducing pressure transients at start/stop transitions and the overall working pressure in the cooling plants. These modifications were largely completed during the extended technical stop. Radiation damage projections indicate that the present running conditions of the silicon strips, with coolant at 4ºC, will not result in significant impact on the strip Tracker before the first long shutdown, whilst for the pixel system it is desirable to lower the operating temperature to reduce the effect of leakage currents on detector performance. Preparations have started. The pixel detector has been operated for lengthy periods at -10 °C and calibration at this temperature is partially complete.

Following the successful experience of 2010 and the activities of the extended technical stop, the Tracker is again up and running, and smoothly taking data in 2011.

Electromagnetic Calorimeter

All components of the CMS Electromagnetic Calorimeter (ECAL) - barrel, endcaps and preshower - operated well throughout 2010 with few problems, and negligible changes of dead channels. About 2% of the preshower silicon sensors were unplugged in the second part of the year due to unacceptable increases in leakage currents attributed to surface radiation damage. With the increase of luminosity, transparency changes in the crystals have been observed and are consistent with expectations from radiation damage. The laser and LED monitoring systems follow this evolution excellently and a fast feedback from these systems will be incorporated into the single channel response calibration.

Data taken with a special HLT π^0 trigger stream were used to calculate inter-calibration constants, monitor the response stability and crosscheck transparency corrections. These data have allowed us to bring the inter-calibration of the barrel crystals close to the design target and to improve substantially those of the endcap crystals with respect to startup conditions.

The crucial ECAL trigger system has evolved substantially. Masking of individual problematic crystals, rather than whole trigger towers, improves efficiency and flexibility. The partial redundancy offered by the readout of energy through the trigger system (in addition to the normal data links) has been exploited to minimize the number of truly dead regions and, in early 2011, the dynamic range of the trigger information has doubled, providing improved performance.

In order to mitigate the impact of Anomalous Calorimeter Signals (ACS) at L1-trigger due to highly ionizing particles in the Avalanche Photo-Diodes (APDs), the trigger front-end readout was modified to tag energy deposits with ACS-like topologies at L1 and tested in late 2010. This is being further optimized with first 2011 collision data, before being incorporated in the standard running.

The stability of the complete system allowed ECAL shifts to become obsolete, with central shifters providing the necessary day-to-day monitoring, supported by a team of ECAL experts on call. This will be the modus operandi in 2011. Prompt feedback from early 2011 collisions has confirmed ECAL health and performance.

Hadron Calorimeter

Since the last RRB report, HCAL detectors have continued to participate in physics running with 99% of channels operational. The full 2010 dataset was used to derive calibration constants that have been applied in recent re-reconstruction passes and in the current prompt reconstruction. After the recent extended technical stop, the detectors have returned smoothly to global operations. The HO Ring 1 voltage was increased from 6.5 kV to 7.5 kV to improve performance for the 2011 physics run, and careful monitoring of the HPD discharge rate indicates that this is a safe operational voltage.

During the first period of operation, a form of anomalous noise in the HF was identified as being caused by scintillation when charged particles pass through a portion of the air light-guide sleeve. This portion was constructed from a non-conductive mirror-like material. During the recent extended technical stop all sleeves in the detector were replaced with new ones made of Tyvek. The detector has been fully recommissioned with all channels fully operational.

Preparations continue for the replacement of the HO photodetectors with silicon photomultipliers (SiPMs) and for the replacement of the HF PMTs. The first batch of SiPMs for HO was delivered and the full set of electronics boards has been fabricated. The Quality Assurance program has begun, as well as the planning for the installation during the next extended shutdown. For the HF PMT replacement, the order for the tubes has been placed and engineering work is underway on the cable plant and readout box changes that are required to support multianode PMTs. One box of eight phototubes was already installed in the detector, with one channel configured with split-anode readout for evaluation purposes. The results of these in-situ tests will help refine the final design for the multianode modification of HF.

Muon Detectors

Endcap Cathode Strip Chambers (CSC): During the 2010 LHC run, the CSC muon detector ran smoothly for the most part and yielded muon triggers and data of excellent quality. Moreover, no major operational problems were found that needed to be fixed during the Extended Technical Stop. Early collision data in 2011 already show that the CSC detector performance is very similar that seen in 2010, and the Level 1 trigger configuration and algorithm have been tuned to perform better at higher luminosity. The detector is now operating with only one on-call expert and one remote data quality monitoring shift per day. Provision is being made for automatic recovery from chamber high voltage trips. A few chambers (6 out of 473) have lost low voltage power and the problem is being investigated. As part of the latest CMSSW 4.2.0 software release, improved CSC track-based alignment using the 'untwisted' Tracker alignment removes the previous +/-1 mrad relative twist between the two CSC endcaps and the barrel muon detector (which was aligned using hardware sensors). Prototypes of the new ME1/1 cathode electronics are being assembled, and the Prevessin factory for 71 new ME4/2 chambers is being prepared using chamber-building machines shipped from Fermilab. The plans and status of this upgrade were presented at the ATLAS-CMS Common Electronics Workshop for the LHC Upgrades (ACES2011) at CERN on March 1st.

Barrel Drift Tubes (DT): The DT system has behaved very satisfactorily through all the LHC 2010 data taking period, with more than 99% of the system operational and very low downtime periods. This includes operation with PbPb collisions in which the rate of muons was low and no impact on buffer occupancies was observed. As a curiosity, an unexpected high out-of-time occupancy was observed in the outermost chambers (MB4) and its origin is under investigation.

During the winter technical stop many interventions took place with the main goal of optimizing the system. One of the main changes is the reduction from 10 to the originally planned 5 FEDs thanks to the good agreement of the event size with our expectations during LHC operation, thus increasing accordingly the spares count. Firmware upgrades have happened throughout the system. It is worth highlighting those for the Barrel and Wedge Sorter modules that will improve “ghost busting” mechanisms both with the cancellation of double tracks in the wheels and sectors crossings and with a ghost cancelation scheme based on timing that will reduce DT prefiring below the present 1%.

The complete system of six VDC chambers including HV, electronics, trigger and DAQ was successfully installed. These replace the single prototype VDC that monitored the DT exhaust gas for the past two years. The VDCs are small drift chambers the size of a shoebox that measure the drift velocity every 10 minutes with a small statistical uncertainty of 0.1%. A possible deviation from the nominal value could be caused by a contamination of the gas mixture or changes in pressure or temperature. These would be signaled by the VDC system since they would imply a wrong measurement of positions and momenta in the DT system.

Off-line, performance was studied in detail using the complete 2010 data sample. The local trigger efficiency was evaluated using minimum bias events and decays from W and Z bosons, and was found to be ~1% better than TDR expectations. The “local” reconstruction efficiency (track reconstruction within a chamber) is typically ~90% or higher.

Resolutions range between 200-350 microns in the ϕ view and between 250-450 μm in the θ view. The MC is well tuned to reproduce these resolution values. The overall resolution in the local arrival time measurement was evaluated to be about 2.4 ns. Systematic biases in the different chambers and ϕ regions are within 0.2 ns. Electronics noise during p-p collisions was measured from the rate of out-of-time background, i.e. by counting the number of hits in a time window where no signal from particles originating in the p-p collisions is expected. It was found to be low: 0.004 Hz/layer/cm^2 for inner chambers and 0.005 Hz/layer/cm^2 for outer chambers.

Resistive Plate Chambers (RB and RE): About 60 million muon events in a dedicated RPC monitoring stream have been analyzed by the RPC group to study the performance of the detector in detail. Data analysis is now finished and a large set of results and plots have been approved for public presentation.

In the 2010, the system was working properly with an average efficiency of 95.4% at 9.35 kV in the Barrel and 94.9% at 9.55 kV in the Endcap. Average cluster size ranges from 1.6 to 2.2 showing a clear and well-known correlation with the strip pitch. Average noise in the Barrel is less than 0.4 Hz/cm^2 and about 98% of the system has shown an average noise less then 1 Hz/cm^2. A linear dependence of the noise versus the luminosity has been observed and is now under study. Detailed chamber efficiency maps have shown a few percent of chambers with a non-uniform efficiency distribution. This could be a clear sign of chambers that are not working in a plateau region. A special calibration run was planned for the first day of 2011 data taking to perform an efficiency scan as a function of the high voltage in order to precisely determine the optimal working points of all of the chambers.

During the 2010-2011 shutdown many problems have been fixed and in particular the power system has been completely recovered and re-calibrated (more than 1000 channels). A few cable swaps, found with the detailed 2010 data analysis, have also been corrected. About 98.5% of electronic channels are now working properly. The present status of problematic chambers is: 6 chambers out of 912 are "disconnected" and 28 are working in "single gap mode". Most of the problems are due to broken high voltage connectors or electronic failures that can't be solved until the long shutdown foreseen for 2013-2014.

Muon Alignment: Alignment efforts in the first few months of 2011 have shifted away from providing alignment constants (now a well established procedure) toward a few remaining critical issues. The single most important remaining task was understanding the systematic differences observed between the track-based and hardware-based barrel alignments. A systematic difference in r-φ and in z, which grew as a function of z, and which amounted to ~4-5 mm differences going from one end of the barrel to the other, were observed. This difference is understood to be due to the tracker alignment. The systematic differences disappear when the track-based barrel alignment is performed using the new "twist-free" tracker alignment. This removes the largest remaining source of systematic uncertainty. Since the barrel alignment is based on hardware, it does not suffer from the tracker twist. However, untwisting the tracker causes the endcap disks (which are aligned using tracker tracks) to rotate around the beam line by about 1 mrad in opposite directions, resulting in a poor relative alignment between barrel and endcap. A new endcap alignment has been produced which makes CSCs consistent with the new tracker alignment and improves the relative barrel-endcap alignment.

Trigger and Data Acquisition

L1 Trigger: In 2010 the L1 trigger showed very good efficiency in physics data taking. All L1 triggers were enabled in the collision runs. The synchronization of the L1 trigger is such that the fraction of out-of-time triggers is less than a few per mil. The trigger efficiency of the calorimeter triggers (e/γ, jets, etc.) is very high (>99%) and the threshold turn-on-curves match simulation. The efficiency of the muon triggers (RPC, DT, CSC) for $p_T > 7$ GeV is about 95%, in agreement with expectations. Periodic adjustments of the L1 and HLT trigger prescales were used to keep up with the steep LHC luminosity time profile. The Trigger and DAQ were also operated for data taking with Heavy-Ion collisions without front-end zero-suppression. For the 2011 data taking new L1 trigger menus for luminosities from 5×10^{32} cm^{-2} s^{-1} to 5×10^{33} cm^{-2} s^{-1} were prepared. Using 2010 data a new configuration of the e/γ trigger was studied which rejects anomalous energy deposits in the ECAL APDs. Shower shape and isolation criteria were also introduced in the e/γ trigger to reduce the trigger rate. Several improvements were introduced in the muon triggers to improve the efficiency and to reject fake muon tracks.

Trigger Coordination: For 2010, the Trigger Studies Group (TSG) developed, integrated, validated and deployed new versions of the trigger menu for each major step in the instantaneous luminosity delivered by the LHC for pp collisions, which increased from 2×10^{29} cm^{-2} s^{-1} to 2×10^{32} cm^{-2} s^{-1}. For all final states, the online selection was gradually tightened such that reasonably low energy thresholds could be maintained. This led, for example, to refined J/psi and "Onia" triggers, and to the introduction of many "cross-triggers" needed in particular for searches for supersymmetric or exotic events. In addition, dedicated trigger menus adapted to heavy ion (HI) collisions were deployed. The TSG worked closely with the HI experts to react quickly to the rapid increase in luminosity, which went from a few 10^{23} to about 3×10^{25} cm^{-2} s^{-1}. The HLT recorded all collisions, at a rate of ~ 200 Hz. In preparation for the 2011 run, a new series of "Trigger Reviews" was held to converge on candidate trigger menus for a few benchmark scenarios, ranging from 5×10^{32} cm^{-2} s^{-1} to 5×10^{33} cm^{-2} s^{-1} in luminosity and covering several pile-up configurations. The initial set of trigger menus for the 2011 run have been determined and are ready for data-taking.

DAQ: In 2010, the DAQ system performed with high efficiency. The combined data taking efficiency of global DAQ and sub-detector DAQ exceeded 95%. The DAQ system has been deployed for pp and HI physics data taking. It can be easily configured for high level-1 trigger rates in proton physics or large events at moderate trigger rates during heavy-ion periods. The LHC operated at the end of the proton physics with ~350 colliding bunches and reached peak luminosities of ~2×10^{32} cm^{-2} s^{-1}. The DAQ was typically operating in those conditions with a ~80 kHz level-1 trigger rate, a raw event size of ~400 kByte, and a ~200 Hz recording of stream-A with a size of ~200 kByte. The CPU load on the HLT was typically ~60%, but occasionally reached close to 100%, depending on the level-1 and HLT menu. For PbPb physics, the LHC was operating with 120 colliding bunches and reached a peak luminosity of about 3×10^{25} cm^{-2} s^{-1}. The silicon-strip tracker was read out without zero suppression which led to an event size of ~20 MByte. The DAQ was operating typically with a level-1 trigger rate of 300 Hz and ~100 Hz recording of stream-A (with a compressed event size of ~11MByte).

The online cluster, the production online Oracle database, and the central Detector Control System (DCS) have been operational 24/7. During the end of year technical stop, the cooling of the on-line data center has been upgraded from 600 kW to 1 MW in order to enable the extension of the DAQ-HLT. All central DAQ nodes have been migrated to SLC5/64bit kernel and 64bit applications. The migration of the HLT, Storage Manager and online DQM has been done at the same time as offline. There is a ~20% performance improvement for HLT gained from the move from 32 to 64 bits.

To cope with the challenges of 2011 heavy ion running, the HLT farm has been extended with additional PCs comprising 288 system boards with two 6-core CPUs each. This brings the total HLT capacity from 5760 cores to 9216 cores. This will provide a capacity for HLT processing in 2011 of about 90 ms/event (on a 2.7 GHz processor) at 100 kHz L1 rate in pp collisions.

Offline Software

Since the last RRB report the CMS Collaboration has successfully achieved many milestones and the Offline Group has played a central role in the fulfillment of all of them. In particular, CMS took advantage of the exceptional performance of the LHC, in delivering higher than expected luminosity, by recording and processing collision data promptly and with very high efficiency. This was true in both pp and heavy ion running periods.

Following ICHEP, a new version of the CMS offline software was deployed (CMSSW_3_8) in preparation for on-going offline operations at the Tier0 and in support of physics analyses. Moreover, all data taken before the switch to the new version was reprocessed within one week, together with selected Monte Carlo simulations and with completely new Monte Carlo workflows. The release became operational at the start of September and contained many improvements; these included changes to the Input/Output (I/O) components, a beam spot determination per luminosity section, various algorithms for 'cleaning' detector data, a new definition of reduced datasets used in analysis (AOD), new tunings of the event generators, and other new features such as ECAL APD simulation and updated geometry descriptions. In addition this was the first release that could be used to commission the prompt calibration loop in the Tier0, which subsequently became fully operational later in the year.

At the same time CMSSW_3_8 was deployed, new developments continued in a new development cycle (CMSSW_3_9). The main goals were firstly to integrate all changes needed to optimize the reconstruction, simulation and calibration workflows for the Heavy Ion (HI) data, as well as to make a full re-reconstruction of the 2010 pp samples for both real and Monte Carlo data. This release was deployed in production during the week of the transition between protons and Heavy Ions, and allowed the first LHC HI run to complete with success all the reconstruction, calibration and data quality management tasks. It was gratifying to obtain displays of beautiful events a few seconds after the first collisions. All the efforts that had been made to optimize the performance of the visualization for extremely crowded events later enabled one to observe 'elliptic flow' and hints of 'jet quenching' in the online displays. The CMSSW_3_9 release cycle was also used to launch the full re-reconstruction of 2010 proton and HI data before Christmas to exploit improved detector calibrations obtained using the full 2010 data sample. As soon as CMSSW_3_9 went into production, the next development cycle started (CMSSW_3_10) with somewhat limited goals since it was to be used to start MC events at $\sqrt{s}$ = 8 TeV. The new Geant4 toolkit (version 9.4) was used to take advantage of the most recent improvements, and a huge production of simulated events was launched during the Christmas break.

The Offline Project had two major goals to accomplish before the re-start of data taking in 2011. In order to improve CPU performance, a switch to 64-bit compilation was requested to help DAQ/trigger. In addition, the version of ROOT we was updated to benefit from improvements in IO performance and new features in managing schema changes in data formats. These tasks required intense activity up until the beginning of March. The transition to 64 bit compilation was realized and validated in the 3_11 cycle by the middle of February and deployed at Tier0 before the start of the 2011 Cosmic Run. Performance gains varied with use cases. Reconstruction improvement was measured to be ~20%. The new version of ROOT required more time since we wanted to be sure the old custodial raw data was readable without problems. The Offline Project moved to the 4_1 release (ROOT, 64 bit) the 1st week of March. The online version was deployed the next week.

Following the decision to run the LHC at 3.5 TeV per beam in 2011, the √s = 8 TeV MC production was abandoned and restarted at √s = 7TeV. This new production used updated parameters for the Beam Spot as well as the number and structure of Pile Up events. The production started in March along with a re-reconstruction of 2010 MC with 2011 Pile Up parameters. Both are currently still in progress.

The current development cycle is CMSSW_4_2, and is not planned for deployment at Tier0 before the end of April. It contains many changes in event reconstruction, and additional improvements like the twist-free alignment of the CMS Tracker. In view of the 2011 LHC Run, all certification activities have restarted and the Physics Validation team is gearing up to provide validated data within one week of the data being taken.

The Offline and Computing groups organize joint Offline & Computing Weeks at CERN and an Offline Workshop held early February focused on the 2011 run. Efforts will be made to automate as much as possible all the validation, certification and calibration workflows, freeing manpower to address important development issues.

Two additional events targeting specific issues took place since the last RRB report:

- In November a Monitoring Review with an internal and an external reviewer looked at the monitoring of components such as MC Production, data operations, site certification etc. A more coherent approach within CMS and more collaboration with CERN IT were recommended. A task force was launched to consolidate the infrastructure this year.
- A workshop held in Bari in January addressed "Storage and Data Access Evolution" for 2012 and beyond. CMS, like other LHC experiments, is evaluating the consequences of new access patterns to data. Five working groups were formed and will report to Offline and Computing Projects.

Computing

The CMS distributed computing system handled the intense load of the heavy ion run in December well. Winter activities also included simulation, data reprocessing, and analysis of pp data in preparation for the 2011 winter conferences. All the computing center tiers performed their expected functions. The Tier-0 infrastructure was able to repack and promptly reconstruct heavy ion collision data. It was decided to not zero-suppress tracker data, leading to raw events in excess of 10MB. During repacking, where nearly equal sized events are read and written, and in reconstruction, where large raw events are read to produce smaller reconstructed events, the IO load on Castor was large. CMS routinely read at a rate of 5GB/s wrote at 1GB/s including writing to tape. CMS was able to promptly reconstruct all heavy ion datasets.

The performance of the accelerator during the first heavy ion run was an interesting indication of the pp running scenarios we will see in 2011. The machine was able to setup and collide within a few hours of dumping the previous beam. The reconstruction stretched into the inter-fill periods and good resource utilization was achieved.

The Tier-1s generally functioned well throughout the winter, performing two complete processing passes of the 2010 data. The first was generated just days after the end of the pp run for new calibrations and alignments. The second was performed over the Christmas holiday. Tier-1 reliability was good and the processing went well. The Tier-1s also efficiently served data to Tier-2s for analysis. The data rate from Tier-1s is much higher than the rate into Tier-1s. The analysis operations team subscribed more than 2PB of analysis data centrally, and the physics groups are actively managing group space. The Tier-2 centers were well utilized for analysis and simulation during the winter. Currently around 380 individuals submit analysis jobs to the Tier-2 centers during a given week with a significant dip only seen in the week between Christmas and New Year.

Physics

Physics groups have been busy studying the ~36 pb^{-1} 2010 dataset to produce preliminary results for the winter conferences. A total of 90 analyses were approved in a broad array of topics including precision QCD, top, and electroweak measurements, observation of single top, limits on Higgs production including the $\tau^+\tau^-$ final state, and searches for new physics in a wide range of topologies. Most analyses used the full 2010 data sample and most profited from the enhanced performance of particle-flow reconstruction. The integration of particle-flow reconstruction and derived physics objects within the physics object groups is underway with the goal of having the best physics objects for physics analyses together with a fully consistent event description for 2011 data reconstruction.

Other highlights in physics object reconstruction include jet substructure algorithms that tag jets from boosted heavy objects like top and W, jet energy corrections that take pile-up into account, and measurements of b-tagging efficiency and fake rates using dijet and tt events for counting tracks with significant impact parameters, secondary vertex finding, and jet probability algorithms. Tau identification and reconstruction algorithms were also commissioned with 50% reconstruction efficiency for 1% fake-rate from jets to perform in Higgs and SUSY analyses that already compete with Tevatron studies.

In the realm of beauty quark production, CMS performed inclusive cross-section measurements based on the identification of semi-leptonic b decays into muons and b-jet tagging with secondary vertices. Differential production cross-sections for several B mesons (B^+, B^0 and B_s) were also measured in exclusive decay channels. The dynamics of B hadron production was further investigated by measuring BB angular correlations with novel techniques based on secondary vertex identification that access the region of collinear B-hadron emission. Measurements of quarkonium production are also an important part of the group physics program. Differential cross-sections of Υ(1S, 2S, 3S) mesons have been released, while the measurement of J/ψ spin alignment is expected soon. Searches for rare decays and exotic states have been initiated, leading to the observation of the exotic meson X(3872) in the decay to $J/\psi\pi^+\pi^-$.

A large number of QCD results have been produced. In the low p_T sector, the charged particle transverse momentum spectra were measured for pp collisions at $\sqrt{s}$ = 0.9 and 7 TeV, and a measurement of the underlying activity in scattering processes was performed at $\sqrt{s}$ = 7 TeV. The production of charged particles with pseudorapidity $|\eta| < 2$ and $p_T > 0.5$ GeV/c is studied in the azimuthal region transverse to that of the leading set of charged particles forming a track-jet. In the high-p_T jet sector, a measurement of the inclusive jet cross-section was performed using the full 2010 dataset and found to be in agreement with perturbative QCD predictions at NLO. Additionally, jets in the region at large rapidities ($3<|\eta|<5$) have been measured, probing parton densities at small momentum fractions. A measurement of the dijet cross-section as a function of the dijet invariant mass also has been made. The experimental systematic uncertainties on these cross-section measurements are roughly comparable to the theoretical uncertainties, and a future reduction of the jet energy scale uncertainty will constrain PDF models. Finally, a measurement of the ratio of the inclusive 3-jet to 2-jet cross-sections as a function of the scalar sum of jet transverse momentum (H_T) for 0.2 TeV < H_T < 2.5 TeV was performed.

The top quark analyses based on 2010 data cover measurements of the $t\bar{t}$ production cross-section utilizing both the dilepton and the lepton plus jets decay channels – with and without b-tagging – as well as a determination of the top mass. Different approaches and cross checks on the cross-section measurements were made, including one approach that simultaneously fits many backgrounds and systematics across jet and b tag multiplicities. Single top electroweak production was confirmed by CMS with the 2010 data with the measurement of the single top production cross-section.

Many precise and novel measurements were made in the electroweak sector. Notable is a measurement of the spin polarization of the W boson, where the production of W bosons of both charges recoiling against hard jets have been measured to be predominantly left-handed, as expected from the dominant gluon-quark to W-plus-jet production process at the LHC. Precision cross-section measurements benefit from the reduced uncertainty on the integrated luminosity, which is now estimated to be ± 4%. The cross-section measurements of the inclusive production of W and Z bosons have systematic uncertainties at the level of 1%. This is much smaller than the theoretical uncertainties. The ratio of W to Z production cross-sections, for which the luminosity uncertainty cancels, constitutes a stringent test of the theory prediction with the most recent parton densities. Inclusive production of W and Z bosons in the tau-lepton channels were also obtained. Other electroweak measurements include W^+/W^- charge asymmetry, differential production cross-sections of the Z boson as a function of boson rapidity and transverse momentum, associated production of W and Z bosons with up to four inclusive jets, and the di-boson signals including WW as well as Wγ and Zγ.

A comprehensive strategy for SUSY searches has been exercised on the 2010 dataset. For searches in the all-hadronic final state, three complementary techniques using kinematics and detailed detector and background understanding have been pursued. This includes the "α_T" variable approach, recently extended to include b-tagging, a new approach using the dimensionless razor (R) variable, and a more traditional jets and missing H_T (MHT) approach. The reach from these searches goes far beyond the Tevatron. In addition to exclusions in the mSUGRA, limits are expressed in terms of model-independednt simplified models to help model builders use the results. The leptonic searches for SUSY include topologies with one lepton, same-sign dileptons, opposite-sign dileptons, and multileptons. Hadronically decaying tau leptons are also included in many channels. SUSY searches with photons include diphotons and photon + lepton searches have sensitivity surpassing previous experiments.

Searches for other exotic phenomena have extensively mined the 2010 data for a variety of new physics models, delivering about 20 analyses on the complete 2010 dataset. Of these, the searches for stopped gluinos and for first and second generation leptoquarks in the leptons+jet final state have been published, while the searches for W′, Z′, b′ and microscopic black holes have been submitted for publication. Additionally, preliminary search results have been derived for first and second generation leptoquarks in the lepton+MET+jets final state, excited leptons, Randall-Sundrum gravitons, large extra dimensions in diphotons, dimuons, and monojets, low mass ttbar resonances, boosted Z bosons in a search for excited quarks, lepton-jets in a search for low-mass dark matter, and an R-parity violation search in multi-jet resonances.

The CMS search for the Higgs was launched in earnest already with the 2010 data, with the completion of 4 analyses. These include the Higgs search in the WW decay channel. The search for MSSM Higgs to ττ exploits the excellent tau identification capability of CMS, significantly extending the reach beyond that of the Tevatron. The searches for doubly charged Higgs and singly charged Higgs in top decays have already achieved sensitivity similar to previous measurements performed at the Tevatron. Preparations are now underway to conduct an exhaustive search across many Higgs decay channels using the multiple fb^{-1} of delivered luminosity expected in the 2011-12.

Interest and excitement in heavy ion physics began even before the first LHC lead-ion run with the observation of a striking "ridge" in the two-particle correlation plot for high multiplicity pp events. This correlation persists to large eta differences between pairs of tracks that are at nearly the same azimuth, and is not modeled by existing Monte Carlo generators and tunes.

Heavy Ions

The LHC performed extremely well with heavy ion beams. CMS recorded about 8.7 μb^{-1} of PbPb collisions at $\sqrt{s_{NN}}$=2.76 TeV which was at the upper end of our expectations. At a collision energy 14 times higher than that of RHIC, it was immediately possible the first observation of Z boson production and direct observation of jet quenching as measured in the imbalance of dijet transverse energy.

The physics analysis of the first data is in full swing. We have published detailed studies of dijet properties in heavy-ion collisions, showing a very strong medium effect, and of Z^0 production that is in line with expectations based on a binary scaling of pp collisions. Analyses of charged hadron multiplicities and two-particle correlations were approved. Further analyses are underway in preparation of the 2011 Quark Matter conference.

CMS was configured to make sure that the collected data are of the highest quality. In particular, the data were collected in non-zero-suppressed (NZS) mode of the Si Strip tracker, ECAL and HCAL. In addition CMS used specially prepared trigger configure to collect all jets, muons and photons and a large fraction of minimum bias events. DAQ, DQM and computing resources were modified and optimized for heavy ion run conditions. During stable beams, the data were collected at a rate of about 2GB/s. This resulted in ~900 TB of NZS RAW data written to Tier-0. The data was reconstructed in real time and the resultant RECO files were available for analysis. After the run, the NZS RAW dataset was compressed to about 190 TB and re-reconstructed again with up-to-date calibration constants. The zero-suppression algorithm used during the compression was developed after looking at first data. The RAW and RECO data are being transferred to FNAL and Vanderbilt University for storage and further processing. A new Tier-2 at Vanderbilt is dedicated to the analysis of HI data and is now operational.

For the 2011 heavy ion run the luminosity is expected to increase by a factor of 5-10 compared to 2010. This necessitates further optimization of trigger and DAQ. In particular, CMS added cpu cores to the HLT system to allow zero suppression in real time and careful triggering in the heavy ion environment.

Upgrades

The Upgrade Technical Proposal was presented to the LHCC in November and March. The committee provided a number of useful comments as feedback and requested that some additional MC studies be conducted to understand object performance (such as b tagging) at very high pile-up levels (50-100 interactions per crossing). They also requested that the impact of the upgrades on specific benchmark physics channels be studied. The schedule was also reviewed and some adaptations were requested. A substantial effort in the period up to the March LHCC meeting produced many, but not all, of the requested information. The LHCC acknowledged the progress that had been made in their draft report that included the following comment:

"The CMS Draft Upgrade Technical Proposal, while needing some modifications and schedule adaptations, does provide a road-map for CMS that is sufficiently well documented to enable CMS to pursue avenues of funding in parallel to the development of detailed Technical Design Reports. The case for additional forward muon stations to complete the high luminosity Muon Detector is well established with a planned installation in 2013 and 2014."

It is worth noting that the work to add forward muon stations to complete the high luminosity detector as well as the replacement of the Outer Hadron Calorimeter Photo-sensors and the Forward Hadron Calorimeter photomultipliers is already underway as mentioned in the muon and HCAL sections above.

Publications

Since the start of LHC collisions, CMS has published its physics results in variety of forms, most notably papers in refereed journals, conference reports (CRs), and Ph.D. theses. 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 April 6, 2011, CMS has 41 papers from collisions data on arXiv of which 31 have been published in PRL, PRC, PRD, EPJC, PLB, and JHEP. Members of the CMS collaboration, who gave talks at international conferences worldwide, wrote their contributions to the conferences' proceedings; so far, 317 conference reports were published. During this period 33 graduate students obtained their Ph.D. degree based on analysis of CMS data. Corresponding increments in these categories since the last RRB in October 2010 are: Papers – 34, CRs – 174, and Theses – 11.

The five most cited CMS physics publications to-date are:

1. Transverse momentum and pseudorapidity distributions of charged hadrons in pp collisions at $\sqrt(s)$ = 0.9 and 2.36 TeV - JHEP 1002:041,2010 (Feb. 2010); 68 citations.

2. Transverse-momentum and pseudorapidity distributions of charged hadrons in pp collisions at sqrt(s) = 7 TeV - Phys.Rev.Lett.105:022002,2010 (May 2010); 44 citations.

3. Search for Supersymmetry in pp Collisions at 7 TeV in Events with Jets and Missing Transverse Energy - Phys.Lett.B698:196-218,2011 (Sept. 2011); 41 citations.

4. Observation of Long-Range Near-Side Angular Correlations in Proton-Proton Collisions at the LHC - JHEP 1009:091,2010 (Sep. 2010); 35 citations.

5. Search for Dijet Resonances in 7 TeV pp Collisions at CMS - Published in Phys.Rev.Lett.105:211801,2010 - 24 citations.

Conclusion

The CMS detector is now a veteran of 7 TeV pp and PbPb collisions. The 2010 run was very challenging due to the rapid increases in instantaneous luminosity that required nearly continuous changes to trigger menus and other adaptations in our operations. Nevertheless, CMS performed extremely well, collecting extremely high quality data with very high efficiency in all systems. CMS also produced its first major wave of physics results at a new energy scale for pp collisions. The Standard Model was "rediscovered" all the up to the observation of top quark pair and single top production and we have made completed a wide range of searches for new physics. The first Heavy Ion run was a big success with direct observation of jet quenching, production of Z's and many other new results submitted or in preparation for publication.

CMS Financial Information

The RRB is reminded that the currently running CMS detector is what was originally called the “low luminosity detector” and, to cope with nominal LHC luminosity, additional investments will be needed.

In the last RRB meeting of October 2010 it was anticipated that CMS would have included, in a Technical Proposal for the Upgrades, all projects considered necessary to maintain and increase, the physics potential of the experiment for operation at 1-2x$10^{34}cm^{-2}s^{-1}$ (Phase 1 of the Upgrades).

Phase 2 of the Upgrades will cover all projects needed for CMS be able to cope with the high luminosity running of LHC, (luminosity leveling at 4-5x$10^{34}cm^{-2}s^{-1}$) expected to be achieved not earlier than the year 2021. The preparations for the second phase of the upgrades, will require R&D, which has to be conducted in parallel with data-taking and with the construction and installation work necessary for Phase 1.

Table 1 below summarizes our current understanding of the costs of the first phase of the upgrade.

Table 1: Upgrade Phase I Costs (kCHF)

kCHF		
L1	Name	Total
1.	Magnet power and cryo	1,330
2.	Pixel Tracker	17,350
4.	HCAL	5,817
	HF - Phototubes	1,990
5.	Muon CSC	5,570
	Muon DT	2,200
	Muon RPC	4,220
6.	DAQ	6,700
	Trigger	4,600
8.	Beam Instrumentation	1,540
	Infrastructure	6,315
	Test Beam Facilities Upgrade	610
	Safety systems upgrade	964
	Electronics Integration	1,575
	Engineering Integration	3,666
Grand Total		64,447
10% of which, Common Fund		6,445

A small fraction of the upgrade cost (some 10%) would be required to be paid in cash into an Upgrade Common Fund.

As anticipated already in the October 2010 RRB meeting, the Step 3 upscope plan is a subset of the upgrade plan above. The funds already paid or pledged by the Funding Agencies towards Step 3 will be considered as paid towards the CMS first phase upgrade.

We have started discussions with the Funding Agencies to prepare a preliminary global cost-sharing matrix for the Upgrade Phase 1. The target would be to obtain commitments from each country equal or higher with respect to their fraction of PhDs in CMS. The construction budget for the Upgrade Phase 1 is expected to cover the period 2011-2017.

By the October 2011 RRB meeting we expect to have a preliminary cost-sharing money matrix for the Upgrade Phase 1 as well as a spending profile up to the year 2017.

Table 2 below summarizes the expressions of interest, notified so far, from several Funding Agencies towards the projects proposed in the Technical Proposal for the Upgrades.

We thank the Funding Agencies for their support. In particular we would like to thank those Funding Agencies that have participated in the Step 3 effort.

Table 2: Upgrade Phase I Expression of Interest

		Subdetector-specific Upgrades						Detector-wide items									
								Beam/DAQ/Trigger			Common Fund Items						
Institute FA	Step 3 already pledged or paid	Pixel Tracker	HCAL	HF - Phototubes	Muon CSC	Muon DT	Muon RPC	Beam Instrumentation	DAQ	Trigger	Magnet power and cryo	Infrastructure	Test Beam Facilities Upgrade	Safety systems upgrade	Electronics Integration	Engineering Integration	Common Fund
		17,350,000	5,817,000	1,990,000	5,570,000	2,200,000	4,220,000	1,540,000	6,700,000	4,600,000	1,330,000	6,315,000	610,000	964,000	1,575,000	3,666,000	
											592,797	2,814,673	271,885	429,667	701,997	1,633,981	**6,445,000**
Austria	171,000	XXXXXX								XXXXXX							102,154
Belgium-FNRS	311,000						XXXXXX										74,294
Belgium-FWO	109,000						XXXXXX										74,294
Brazil	0																78,937
Bulgaria	0																37,147
CERN	1,120,000	XXXXXX					XXXXXX	XXXXXX	XXXXXX			XXXXXX		XXXXXX		XXXXXX	371,470
China	500,000						XXXXXX										46,434
Colombia	0																13,930
Croatia	109,000																32,504
Cyprus	47,000																23,217
Egypt	0						XXXXXX										13,930
Estonia	31,000																18,573
Finland	0																65,007
France-CEA	218,000																69,651
France-IN2P3	0																246,099
Germany-BMBF	637,000	XXXXXX				XXXXXX											287,889
Germany-DESY	0	XXXXXX															181,091
Greece	0																69,651
Hungary	0																46,434
India	800,000						XXXXXX										134,658
Iran	0																27,860
Ireland	16,000																0
Italy	0	XXXXXX				XXXXXX	XXXXXX										803,303
Korea	405,000						XXXXXX										97,511
Mexico	0																51,077
New Zealand	0																9,287
Pakistan	1,146,000						XXXXXX					XXXXXX					9,287
Poland	0																69,651
Portugal	0																32,504
RDMS-DMS	0																97,511
RDMS-Russia	0		XXXXXX		XXXXXX												283,246
Serbia	0																13,930
Spain	0					XXXXXX											227,525
Switzerland-ETHZ	466,000	XXXXXX															88,224
Switzerland-PSI	0	XXXXXX															46,434
Switzerland-UNIV	0	XXXXXX															41,790
Taipei	171,000	XXXXXX															69,651
Turkey	280,000																83,581
United Kingdom	762,000	XXXXXX								XXXXXX							260,029
USA-DOE	0	XXXXXX	XXXXXX	XXXXXX	XXXXXX				XXXXXX	XXXXXX					XXXXXX		1,648,397
USA-DOE-NP	0																102,154
USA-NSF	0	XXXXXX	XXXXXX	XXXXXX	XXXXXX				XXXXXX	XXXXXX					XXXXXX		385,400
USA-NSF-NP	0																9,287
Grand Total	7,299,000	XXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX		XXXXXX		XXXXXX	XXXXXX	XXXXXX	6,445,000