Status of CMS

Progress Summary Report for October 2011 RRB33

Since the last progress report in April 2011, the LHC has delivered roughly 4 fb^{-1} of data of which CMS has recorded over 90% with ~90% of these data meeting our most stringent requirements for performance of all subsystems. The CMS detector continues to perform at remarkably high levels despite increasing challenges such as pile-up reaching more than 15 interactions per bunch crossing. The collaboration has also continued to meet the challenge of this intense period with a broad array of physics analyses completed for the summer conferences that include major new revelations about where the SM Higgs is or is not likely to be located. This report details all of the activities of the collaboration by coordination area and subprojects. Many challenges have been confronted and overcome with more challenges ahead.

Infrastructure and Magnet

The magnet has operated smoothly and the backup features in the cryogenic and electrical systems have proven robust against the many power cuts experienced during the summer of 2011, mostly resulting from electrical storms. It seems likely that the magnet system will achieve the target of restricting the number of on-off magnetic field cycles to 6 during 2011. Remaining identified vulnerabilities, due to the lack of redundancy and spares for the surface compressor station and the link between the magnet bus bar cooling and that for the endcaps and yoke, are high on the list of consolidation priorities included in the upgrade project.

Our first major loss of data due to an infrastructure problem occurred in early August when a cascade of latent weaknesses in the primary cooling plant was initiated by a very minor error in following up an auto-recovered fault in underground air conditioning. A transitory cut provoked a dew point alarm, which shut down the rack cooling circuit. Restart of this circuit caused a safety valve in the primary mixed water re-fill line to jam open. Subsequent minor oscillations in mixed water demand were intermittently misinterpreted as serious, due to a control software bug, causing apparently random shutdown of the mixed water chillers, resulting in the CMS rack and detector cooling being cut. Diagnosis was complex, relying on excellent cooperation between the responsible experts in the Engineering department and the detector cooling specialists in CMS. A joint Technical Incident Panel was subsequently set up. CMS Technical Coordination agreed to several corrective actions, which were already implemented in the September technical stop. Much was also learned about CMS procedures for reaction to, and recovery from, major incidents such as this. In particular, the control system has been made more robust against accidental user actions and options to speed the recovery of ECAL cooling regulation from large anomalies in primary coolant temperature are under study.

The infrastructure needed for maintenance and upgrades is progressing well. In building 904, the extended electronics integration facilities are ready and the CSC production line is being commissioned with prototypes. The RPC assembly and test laboratory area will be completed by the end of October. Transfer of the ECAL workshop and laboratories to Building 892 is complete and work on the cold room and radioactive protection laboratory for the Point 5 Operational Support Centre, though somewhat delayed, will be complete in time for LHC Long Shutdown 1 (LS1). Meanwhile, the design of the complex radioprotection shielding, which will protect personnel from activated areas of the experiment during maintenance and upgrade activities is progressing very well. Manufacture needs to be launched very soon in order to have the shielding systems relay to test (and in some cases already deploy) in the available logistic window at the beginning of LS1.

Key common project activities for upgrade are progressing as dictated by the schedule for LS1. The first sector of the 24 needed for the YE4 disks was recently completed in Pakistan, with preassembly and load test of the first disk planned for February. Transport of the disks to CERN is foreseen in late spring and early autumn 2012 and EDR authorization for filling the sectors and assembly underground has just been completed. The LHC machine committee approved the reduced central diameter beampipe design needed for the pixel tracker upgrade for integration into LHC. This means that vacuum impedance, electrical impedance, higher order heating modes and particularly aperture, are judged to be acceptable. Tendering is imminent, with the EDR (including pixel integration) coming up in November and orders to be placed in early 2012. This is a critical path item that must be ready for installation by December 2013. Substantial consolidation of the electrical, cooling and humidity-control systems is also foreseen before the end of LS1, the latter being essential for the lower temperature operation which is vital for the future of the pixel and strip trackers. Concerning beam radiation monitoring, the beam-dump system (leakage current diamond sensors) has been made more robust, much progress has been made in exploiting the fast diamond monitors (BCM1F), which can now reliably detect beam-gas background, a workshop has been held to study replacement of the beam scintillation counters (now rate saturated) and the pixel luminosity telescope (single crystal diamond tracking telescopes with pixel readout) is undergoing beam-tests with a view to installing a prototype section in the forward region of CMS during the year end stop 2011-2012.

Preparations are well underway for the 2011-2012 year-end technical stop. Prioritizing of tasks is being done, taking into account risks and benefits both to 2012 operation objectives and to the program up to the end of LS1. The main issue will be whether to open the CMS magnet yoke and, if so, what minimum shutdown length is required to complete all the essential tasks.

Commissioning

Since the last RRB report, the LHC has made major progress in increasing instantaneous and delivered luminosity. In a first phase, the number of bunches stored per beam was increased to 1380. This was accomplished before the machine development and technical stop at the end of June. With $\beta^*=1.5$ m, bunch charges around $1.2\text{x } 10^{11}$ protons, and emittance of about 2.8 μm this gave a luminosity of around $1.4\text{x}10^{33}$ $\text{cm}^{-2}\text{s}^{-1}$. During July and August the goals of the machine were to reduce the emittance and increase the bunch charges. The limitations from the injectors were expected to be about $1.55 \text{ x } 10^{11}$ protons per bunch and an emittance of 2.0 μm. However, due to vacuum issues and other challenges the goal to increase the bunch charge was not met before the machine development period at the end of August. Bunch charges of about $1.3 \text{ x } 10^{11}$ protons were reached. It was decided to reduce β^* to 1 m before operations started again in September. The start after the technical stop in September was very efficient. Within four fills the LHC had ramped up to 1380 bunches and produced record luminosities. The highest instantaneous luminosity measured by CMS as of this writing is $3.29 \text{ x } 10^{33}$ $\text{cm}^{-2}\text{s}^{-1}$.

As of October 3, 2011, the LHC has delivered 4.33 fb^{-1} and CMS has recorded 3.91 fb^{-1} for an efficiency of 90%. For most of 2011 CMS has recorded data with an efficiency of around 94%. However, a significant incident with loss of cooling (described in the preceding section) led to large data losses. In addition, after the last technical stop we have had several equipment failures that have led to lower data taking efficiency. Nevertheless, data recorded is of outstanding quality. Most detector subsystems are more than

98% active. At the start of the fills with the highest luminosities there are of order 16 interactions per crossing. This has lead to challenges in the trigger, particularly with CPU usage of the HLT. Mitigating actions have been taken and we are now positioned to handle the expected further increases in luminosity this year.

During the last technical stop tests were done to prepare the DAQ for heavy ion operation. Tests were done to verify the throughput of the DAQ with non-Zero-Suppressed data from the strip tracker. It was demonstrated that the DAQ could run with 3.4 kHz L1 trigger rate with Zero Suppression performed at the HLT farm and an output rate of 300 Hz.

A run coordination workshop is planned for November 2-4, 2011, at CIEMAT in Madrid. Operational experience in 2011 will be reviewed and plans for the 2012 run will be discussed.

Tracker

The pixels and silicon strips systems operate stably and reliably with excellent (99%) availability. The working fraction of the detector remains 98% for the strips and 97% for the pixels. The performance remains excellent in terms of resolution and hit efficiency. The alignment is now described in greater detail, including sensor bow, small kinks in two-sensor modules, and accurate tracking of small movements of the barrel pixels. The pixels and strips DAQ systems continue to work well despite the increasing pile-up; headroom remains up to the nominal 100 kHz L1 trigger rate at 10^{34} Hz/cm^2 luminosity and 25 ns bunch spacing. Infrastructure continues to perform very well. Since the completion of work on the cooling plants and closure of leaky circuits in the last extended technical stop, the system has been operated at lower pressure and leak rates have remained stable and low.

Radiation damage is an emerging issue. Sensor leakage currents are increasing in proportion to received doses and the depletion voltage is changing in the pixel sensors. Periodic scans have been started to track these effects. The damage to date is broadly consistent with expectations and does not affect operations or performance for the time being. A detailed model of the radiation damage and annealing is being developed, aiming to account for the observed effects and to predict the future evolution of the radiation damage for any given set of operating conditions. Preparations are being made to lower the running temperature of the pixel detector in order to gain at least a factor of two reduction of the leakage current and damage in 2012. A series of interventions is also being prepared in anticipation of the next opening of CMS, aimed at reducing the present humidity levels inside the pixel detector, bulkhead region and neighboring service channels. These improvements will allow us to lower the temperature even further at the pixels and strips sensors and to suppress radiation damage more effectively.

Electromagnetic Calorimeter

The 2011 restart of ECAL systems went very smoothly. Since March the percentage of working channels in the barrel and endcap (EB, EE) was at ~99% (and actually increased by a small amount in this period). A low voltage connector problem in the endcap preshower (ES) led to a decrease in working channels by 1% to just over 95%.

The front-end information from EB used in the L1 trigger has been enhanced with a “strip fine grain veto bit” (SFGVB) that helps distinguish between real electromagnetic energy deposits (spread over many crystals) and deposits in single crystals that could be due to direct ionization in the Avalanche PhotoDiode (APD) (“spikes”). The performance of this “spike killer” is excellent, rejecting >95% of spikes while maintaining ~99% efficiency on electrons. As the luminosity has increased substantially this year, the spike killer has maintained its performance and the L1 e/γ rates are as expected. The SFGVB has 2 configuration parameters that will allow its efficient use up to the highest LHC luminosities.

With the increased luminosity seen in 2011, changes in the crystal transparency have been observed at the expected level. A blue laser is used to monitor these transparency changes *in-situ* and has been used to generate "corrections" to recalibrate the response of the crystals. The software framework for implementing these corrections, included in the prompt reconstruction step, has been developed, as well as a suite of tools to monitor the laser performance and the corrections. Residual instabilities of the monitoring system impact the constant term in the ECAL energy resolution, which is still not at the desired level. Work is ongoing to improve the correction methods and the laser system itself.

Hadron Calorimeter

All HCAL subsystems continue to operate with high efficiency and >99% of good channels. However, two operational problems have developed. The first, which was described in the last RRB report, is the occasional loss of data from a single RBX. Studies have shown that this is due to a beam-induced signal in the opto-isolation for the RBX reset. The operational solution for 2011 is to reconfigure only those RBX that are affected. This has been implemented as an automatic response when data-loss is detected. The longer-term solution will be to reconfigure a jumper in each RBX to bypass this reset signal (which is not actually used in normal operation). This will be done in LS1. The second issue is a loss of phase-lock in 2 specific locations; a 10-degree slice in HB+ and another in HE-. The total area affected is 2/144 of the entire HB and HE coverage. The pulse timing for these channels is essentially random in a 25ns range, resulting some of the time in a fraction of the energy being reported in BX-1 (where BX is the correct 25 ns beam-crossing). This is corrected in the reconstruction by including the energy from BX-1, for the affected channels. While this correction is included in the HLT, there is no correction for the L1 trigger where the energy in BX-1 is simply missing. CMS must be open to allow replacement of the failed modules. This is under consideration for the 2011-12 Extended Technical Stop.

The HCAL noise filters have been optimized for 50ns operation, and are included in the standard CMS software (CMSSW) release for general use. The filters are very effective at removing noise hits without loss of physics. A loose version of the filters is deployed in HLT to reduce the effect of noise on trigger rates.

Preparations for replacing the HO HPD photo-detectors with silicon photomultipliers (SiPMs) in LS1 are progressing well. All the SiPMs have been delivered and are being characterized. An initial batch of electronics boards is under test before release of full production. The HF PMT replacement is also scheduled for LS1 and PMT delivery and characterization are progressing well, with about 1/3 of the 1800 PMTs delivered to date. A full system slice test is planned for test beam in October.

R&D for the upgrade of HB/HE is also progressing well. A prototype for the front-end electronics with SiPM photodetectors performed well in test beam and will provide a baseline for the design. A test crate of the μTCA back-end electronics will be installed at P5 at yearend and will operate with real calorimeter data using optical splitters.

Muon Detectors

Endcap Cathode Strip Chambers (CSC): Between April and September 2011, the CSC muon detector ran smoothly and yielded muon triggers and data of excellent quality. The detector performance is essentially unchanged up to 3.3x10^{33} Hz/cm^2 luminosity and pile-up of 16 per crossing. During this period, the CSC readout electronics firmware was improved to avoid a problem where resynchronization commands would cause event number mismatches. Previously the readout buffers were not being cleanly drained upon resynchronization. High voltage trips are now being dealt with automatically: among the 9000 channels in the CSC HV system, approximately 5 trips per day occur during LHC collisions, depending on beam conditions. The full procedure as recommended by chamber experts is followed by the expert software, including the lowering of the HV setting if several resets in succession happen to fail. Two independent studies of neutron-induced late hits have shown that the rate of these hits is similar to the rate predicted by simulations; initial estimates indicated they could have been different by up to a factor of three.

The configuration of the muon trigger has become more restrictive with increasing luminosity. For single muon triggers, isolation is now required for luminosity above 3.0x10^{33} Hz/cm^2 in the range 24-40 GeV, and for luminosity above 4.0x10^{33} Hz/cm^2 the single muon trigger will be turned off in the far forward rapidity range 2.1-2.4.

For the CSC upgrade, a chamber assembly factory has been built in B904 at CERN to build ME4/2 chambers, and all procedures for production are operational (gluing of spacer bars, wire winding and tension checking, automatic soldering of wires, and HV testing). Production parts procurement is well underway, including electronics and cabling. A delay has been encountered in the procurement of panels: the contract with the original vendor has been cancelled and a new vendor is being sought. The panel procurement will need to be expedited and the chamber factory production rate may need to be increased above the originally planned rate of 4 per month.

Meanwhile, development of new electronics for ME1/1 chambers is proceeding well. The new cathode front-end DCFEB card has been successfully tested on the bench and with a CSC chamber, and the performance is good, with lower electronic noise than the existing electronics. Regulators and other components have been radiation tested. A chamber mockup has been built, mechanical specifications have been defined, and a prototype low voltage distribution board fabricated. The new optical communications interfaces and a new optical/FPGA card for the trigger motherboard have been proto-typed.

Barrel Drift Tubes (DT): During the 2011 data taking, the DT system has operated successfully: the fraction of good channels is >99 % and the downtime caused to CMS is negligible. This excellent performance does not come for free: the DT group requested 31 short UXC accesses in the seven months from March to September 2011. Dominant causes for these interventions are HV related problems, which typically affect a small fraction of a chamber, and interventions for dealing with overheated LV Anderson connectors, whose failure can affect larger fractions of the detector (a whole chamber, half a wheel of the CMS barrel). With respect to the CMS downtime, a successful effort in common with colleagues from the DT Track Finder (DTTF) of the Level-1 trigger system allowed us to overcome a relatively significant source of downtime from DTTF FED Out-Of-Synch errors, which would appear randomly during data taking.

A major milestone was reached on May 12 when the final synchronization was uploaded to the DT front-end electronics. Although already a very small correction affecting a few chambers, it marks the end of a long iterative effort that's worth celebrating. With the Phi view of the DT Local Trigger under control, the focus has moved to the Eta view, where recent understanding allows us to expect a significant improvement in the resolution of the eta seed provided by the L1 to the HLT for DTTF triggered muons.

The system of six VDC chambers that were installed for monitoring the DT exhaust gas has operated successfully. 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 variations, since they can induce a wrong measurement of positions and momenta in the DT system, are monitored by the VDC system: if large excursions should occur, they would trigger immediate follow-up actions on the DT gas system.

As the instantaneous luminosity rises in 2011, so do the beam backgrounds that appear on the DT chambers. The DT Performance and Operations groups have invested time and effort to analyze and monitor the relatively complex pattern of backgrounds: randomly distributed neutron hits, punch-through and pileup (fill scheme dependent). Rates as a function of the LHC luminosity appear to be consistent with expectations from the simulations performed back in 1997 when writing the Technical Design Report (TDR) of the Muon Project: the detector and its electronics are designed for standing that level of background. Those measurements also provide a solid basis for discussions on CMS improvements for future LHC higher luminosity running.

Offline, the ever-increasing 2011 data sample allows for detailed performance studies. The local trigger efficiency was evaluated using J/psi, W and Z decays, and was found to be ~1% better than TDR expectations. The “local” track reconstruction efficiency (within a chamber) was measured with a Tag & Probe method and found to be typically ~95% or higher. Resolutions range between 200-350 μm 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: 0.1 Hz/cm^2 for inner chambers and 0.3 Hz/cm^2 for outer chambers on average.

Resistive Plate Chambers (RB and RE): Thanks to the high LHC luminosity and to the corresponding high number of muons produced and recorded in the first part of 2011, the RPC community was able to do a high voltage scan and calibrate all 2172 detectors for the first time. Roughly 99% of the detectors have a perfect plateau curve. Efficiency, cluster size and noise were measured for each RPC at different voltages and fitted with various functions. All of the parameters were taken into account to determine the “best” working point of each detector. The latter is typically a compromise balance of high detection efficiency while remaining in a stable region of the plateau (pressure variations over the course of a year can generate shifts of the working point up to 200 volts) and also keeping the cluster size low (to simplify the trigger pattern) while working at a not too high voltage that would stress the detector and increase the number of streamers.

Average efficiency since February 2011 is monitored run by run and is stable at 95% ± 1.0% (RMS = 5%). The RMS of the high voltage value at 50% efficiency is about 70 Volts giving a clear demonstration of the high uniformity of the RPC detectors 8 years after they were constructed. The average cluster size is about 1.6 strips and the percentage of disconnected strips (due to 7 disconnected chambers, some broken front-end chips and noisy strips) is less than 1.5%.

An increase of the background rate as a function of luminosity and beam intensity is clearly visible in the RPC system since 2010. In the latest 2011 runs we have measured an average background rate of 1 - 1.4 Hz/cm^2/gap to be compared with the 0.4 - 0.6

Hz/cm^2/gap in 2010. At the same time we have observed, for the first time, a clear correlation between RPC currents and beam intensity. Note however that the average current per roll is still less than 2 μA even at the beginning of the fill.

An online, automatic pressure correction of the high voltage working point has been developed, tested and implemented this past summer with the help of the central CMS DCS group, in order to reduce and stabilize the cluster sizes obtained from each chamber.

Two major updates have been carried out for the RPC PAC trigger. A barrel muon candidate is now generated if at least 3 of 6 layers have fired as compared with 4 of 6 layers in 2010. This modification increased the RPC PAC trigger efficiency in the barrel by a few percent. The goal of the second modification of the algorithm (applied at the end of May) is to allow triggering on "slow" particles (e.g. Heavy Stable Charged Particles), which reach the muon system in BX+1.

Muon Alignment: A new set of alignment constants was provided, validated and approved at the end of August. The DT alignment, based on the hardware alignment system, is essentially identical to the previous alignment, showing good detector stability. Systematic differences between the hardware and track-based DT alignment have been proven to be a strong external constraint on a tracker alignment "twist" weak mode, and discussions are ongoing to include this information in the tracker alignment procedure. In the endcaps, pp collision tracks are now used instead of beam halo, and the new CSC alignment benefits from a factor ~40 increase in statistics, resulting in better precision and producing a good alignment of the ±ME13 rings for the first time.

Trigger and Data Acquisition

L1 Trigger: In 2011 the L1 Trigger menu was adapted to the increasing LHC luminosity in several steps. Presently the L1 trigger is tuned for 3x10^{33} Hz/cm^2 and can sustain up to 5x10^{33} Hz/cm^2 by prescaling some of the lower threshold triggers. A new menu optimized for the highest luminosity foreseeable in 2011 (5x10^{33}Hz/cm^2) is in preparation. In general the increased pile-up of collisions per bunch crossing only mildly affected the L1 trigger rates. However, multijet triggers and energy sum triggers saw a significant rate increase. Trigger thresholds were increased as necessary to keep the total L1 rate below 100 kHz, the maximum design rate. Multi-object triggers (e.g. dielectron and dimuon triggers) have now increased importance for the CMS physics program since the high single trigger thresholds have low efficiency for a number of important physics channels.

The L1 trigger systems have been operating reliably in 2011. No major failures were observed and the recovery time when problems do occur is normally short. L1 trigger shifts are provided by a large number of collaborators after receiving appropriate training. Expert on-call support has been provided by central manpower supported by the Trigger M&O-B budget and by subsystem's manpower. The institutes that built the subsystems are providing the maintenance of the hardware. Development of additional monitoring and trigger certification tools has been carried out, profiting from the contribution of technical and summer students.

Trigger Coordination: In 2011, the Trigger Studies Group (TSG) developed, integrated, validated and deployed 8 new versions of the trigger menu for each major step in the instantaneous luminosity delivered by the LHC from 5x10^{32} Hz/cm^2 to an anticipated 5x10^{33} Hz/cm^2. In order to fully capture the physics samples, over 400 Higher Level Trigger (HLT) paths are now provided which compose the 300 – 400 Hz output rate into about 20 primary datasets. In addition, dedicated trigger menus adapted to heavy ion (HI) collisions are being prepared. Triggers are being modified at each step to provide good performance in the presence of event pile-up rising from 3 events per crossing to 16 and above. Pile-up effects are being controlled through use of special jet energy subtractions and tighter cuts on track matching. CPU usage was kept under control with careful evaluation of resource-consuming paths, prescales and algorithm optimization. Important improvements were made with deployment of particle flow and iterative tracking techniques. More selective triggers involving combinations of objects provided effective rate control. Standardized weekly reports that include cross section trend plots and efficiency measurements have enhanced the thoroughness of HLT Data Quality Management (DQM). Improvements have been made to both offline and online HLT DQM.

DAQ: For the 2011 run, the HLT farm has been extended with additional PCs comprising 288 system boards with two 6-core CPUs each. This brought the total HLT capacity from 5760 cores to 9216 cores and 10 TByte of memory. It provides a capacity for HLT of about 90 ms/event (on a 2.7 GHz processor) at 100 kHz L1 rate in pp collisions. All central DAQ nodes have been migrated to SLC5/64bit kernel and 64bit applications. This resulted in ~20% performance improvement for HLT.

The DAQ system has, so far, been deployed for pp physics data taking in 2011 and performed with high efficiency (downtime is order of 1%). The DAQ was operating with a L1 trigger rate up to ~100 kHz and, typically, a raw event size of ~500 kByte, and ~400 Hz recording of stream-A (which includes all physics triggers) with a size of ~250 kByte after compression. The event size increases linearly with the pile-up, as expected. The CPU load on the HLT reached close to 100%, depending on L1 and HLT menus. By changing the L1 and HLT pre-scales throughout the fill, the system can be operated close to the operating limit of the DAQ/HLT – typically in steps of ~10%.

The DAQ system can be easily configured for high L1 trigger rates in proton physics or large events at moderate trigger rates during HI periods. The DAQ configuration for HI running has been optimized to meet the HI requirements for the 2011 run, with an L1 rate of ~3 kHz and an event size of ~20 MByte. After the event selection and tracker Zero Suppression by the HLT, ~300 Hz events with a size of ~1.5 MB can be written to disk.

The online cluster, the production online Oracle database, and the central Detector Control System (DCS) have been operational 24/7. Tools have been improved to support the DAQ and DCS shifter and training and supervision has been provided. On-call support for DAQ, DCS, and system administration has been provided.

There are options to further extend DAQ/HLT system for the 2012 run, should the evaluation of the CPU needs for the HLT deem this necessary. This will be determined based on the experience with the current pp run and LHC expectations for 2012.

Offline Software

The challenges for 2011 data taking are mostly due to the very successful LHC luminosity ramp: in this period, the luminosity ramped up from $2x10^{32}$ Hz/cm^2 to the current record of over $3x10^{33}$ Hz/cm^2. In these conditions, pile-up has increased from a negligible level to more than 15 interactions in the collisions recorded after the August Technical Stop. From the computational point of view, the reconstruction (and the simulation) of these recent events requires more CPU time and memory, generating problems that were foreseen by the CMS Offline group well in advance. Solutions that we have put in place enable efficient running even in the harshest LHC conditions.

The 2011 Run started with the CMSSW_4_1_X release at the Tier0. This release cycle, prepared with huge effort starting in the end of 2010, already contained all the technical changes we wanted to deploy in 2011: transitions to the newest ROOT, to the newest Geant4, and to a fully 64-bit enabled production environment. On the other hand, from a physics point of view, it was identical to the last release of the 3_11 cycle. The next cycle, CMSSW_4_2_X, free from technical transitions, was instead devoted to physics-related changes and already contained some adjustments for a high pile up environment. Among the various improvements for physics, there was the deployment of the first twist-free tracker alignment, improved particle-flow integration in all subsystems, and smaller RECO and AOD data tiers. Regarding the AOD data format we note that it had been decided for a long time that 2011 analyses would have to rely on AOD only, since a distribution of RECO to Tier2s would not be sustainable. The CMSSW_4_2_X AOD was verified to meet the needs of most people's needs (target was more than 90% of users) with the revised content, though it had been reduced in size by 20%. The revision was very successful. AOD usage has skyrocketed with respect to 2010. CMSSW_4_2_X was deployed at the Tier0 at the start of May.

As agreed with Physics Coordination, the change to CMSSW_4_2_X at the Tier0 was partnered with the reprocessing of the full 2010 data and the early 2011 data. The same was true of Monte Carlo: "Spring11" production, with 4_1_X, was processed with 4_2_X to allow comparison with the first low (but not negligible) pileup data. It contained in-time pileup up to 5 interactions per crossing, but no out-of-time pileup (since the effect of 75 ns bunch spacing collisions was negligible). In the spring, the LHC switched to 50 ns bunch spacing. The effect for CMS is small but non-negligible. "Summer11" Monte Carlo production was used to simulate higher pileup conditions (the actual distribution is complicated but can statistically cope with ~15 secondary collisions), and including out of time pileup at +50 ns and -50 ns collisions. The production has been used for many Summer Conference analyses, and involves nearly 3 billion events.

This summer it was clear that an additional factor 2 in luminosity (and thus in pileup) was not easily sustainable using the CMSSW_4_2_X cycle. It was decided to start a development only cycle, CMSSW_4_3_X, followed by CMSSW_4_4_X aiming to allow for operations beyond $3\text{x}10^{33}$ Hz/cm^2. Since studies pointed to the tracking code as the major CPU and memory user, a tracking task force was created at the end of July and delivered revised tracking code in early September. The tracking now available in 4_4_X is equivalent from the physics point of view to that in 4_2_X (same p_T thresholds, track yield etc.), but when used on $3\text{x}10^{33}$ Hz/cm^2 data it is much more economical. The full reconstruction chain on data events with 16 pileup collisions has improved by a factor 2.5, and uses 1 GB less RAM. With these specifications, the Tier0 could comfortably process 300 Hz (or more) without falling behind the data taking. The CMSSW_4_4_X release is ready to be deployed if the need arises. In any case, the "Summer11" Monte Carlo will be reprocessed with CMSSW_4_4_X using higher pileup conditions. The aim is to provide analysts consistent data and simulation samples, to be used for the Winter 2012 conferences.

CMSSW_4_4_X will also be used for the 2011 HI run. New code is needed with respect to standard proton-proton code and even with respect to 2010 HI run, since this year CMS will operate Tracker Zero Suppression during HLT and not offline, with a net reduction of RAW data size on tape. Also, with 2011 luminosities a much more selective HLT is needed. Initial versions of all changes have already been provided and the release to be used now needs a lot of testing ahead of the run.

In the meantime, the CMSSW_5_0_X release cycle has started its development. Many technical changes are expected, like new ROOT, new Geant4, a new compiler and many external changes. The CMSSW cycle 5 will be used for the 2012 LHC Run.

While just one release transition happened up to now (from 4_1 to 4_2), a number of incomplete and exceptional data reprocessings happened during the year. Most of these were performed to squeeze the best performance out of the CMS detector, specifically for the $H \rightarrow \gamma\gamma$ analysis.

The validation of the releases before their deployment at the Tier-0, validation of MC datasets before massive production, and coordination of the data quality certification and of the data reprocessing are managed by the Physics Validation Team (PVT). Regular weekly plenary meetings of the PVT ensure good communication about releases and validation across all of the relevant coordination areas: Offline, Computing, HLT, Detector Performance Groups, Physics Object Groups and Physics Analysis Groups to guarantee fast feedback for all these operations as well as timely delivery of calibrated datasets (data and MC) for analyses targeting conferences and publications.

In the period since March, the CMS Offline Group has organized an Offline & Computing Week at CERN, in April 2011, and two management "face to face" meetings, in July at CERN and in September in Brussels. Another Offline & Computing Week will be organized in October at CERN.

Computing

From the computing perspective 2011 has been the first nominal year for the LHC. The number of seconds in collision delivered by the machine has matched the planning estimates for this year, the performance of the trigger has been close to the expected value, and the event size, reconstruction time and resources usage have roughly matched expectations. The Tier-0, Tier-1, Tier-2, and increasingly Tier-3 centers have performed their expected responsibilities.

The Tier-0 has been able to keep up with the incoming data until the 40% rise in the number of interactions per crossing after the September technical stop for which the reconstruction time per event doubled. A new version of the reconstruction code, CMSSW_4_4 described in more detail above, is being validated and the Tier-0 will be ready to migrate to it if it becomes absolutely necessary though the goal is to stick with the 4_2 version throughout pp running.

The Tier-1 centers have been effectively used as the primary location of simulated event production and nearly 3 billion simulated events have been reconstructed in 2011. The Tier-1s have also performed the reprocessing of data. The frequency of event reprocessing matches the planning in the CMS computing model reasonably well and is a significant decrease from the number of reprocessing passes performed in 2010.

The Tier-2 centers continue to serve as the primary analysis resource in CMS and have seen a continuous slow increase in the number of analysis users submitting to the grid and the number of grid jobs per day. Currently CMS sees about 1.5M grid analysis jobs per week on the Tier-2s. The Tier-2 pledged CPU resources are nearly 100% used every month.

The closing months of 2011 will contain a large scale reprocessing of all the data collected this year and a large simulated event reprocessing. Computing preparations are also in process for the HI run in November.

Physics

The Physics groups have been active analyzing the first 1 - 1.5 fb^{-1} of the 2011 dataset to produce preliminary results for the summer conferences and to conclude the analyses of the 2010 data. A total of 30 analyses on the 2010 dataset and 52 on the 2011 dataset were approved since the last RRB meeting.

In May 2011 we held a series of topology-oriented workshops on dileptons, diphotons, inclusive W, and all-hadronic final states. The goal of these workshops was to reach a common understanding for the set of objects (ID, cleaning filters etc.), the handling of pile-up, calibration, efficiency and purity determination, as well as to revisit critical common issues such as the trigger for the analyses of the 2011 dataset.

For the HLT, we successfully deployed iterative tracking that allows CMS to use Particle Flow for tau reconstruction and for some jet triggers to achieve sharper turn-on curves. All physics groups have worked closely with the Trigger group to develop the menus this year that can satisfy luminosities up to $5\text{x}10^{33}$ Hz/cm^2. We have deployed more than 200 multi-object triggers (of ~400 total triggers) to cover our physics program efficiently.

The Jet-MET physics object group has submitted two technical articles to JINST on the performance of the missing transverse energy reconstruction and on the jet transverse energy calibration and resolution using 2010 data. As part of the first article, a missing-transverse-energy significance variable was developed and studied. For all jet types, the total energy scale uncertainty is smaller than 3% for $p_T > 50$ GeV. The b-tagging object group similarly has been carefully studying the performance of our b-jet identification algorithms, including the efficiency and fake rates, using the 2011 dataset and a variety of approaches.

Eight new HI analyses were approved before the QM2011 conference in May. They included a measurement of quarkonium production, indicating that the ratio of the yields (Y2S+Y3S)/Y1S is smaller in lead-lead collisions than in pp collisions, a measurement of the hard component of the jet fragmentation functions, various measurements of the energy flow and a measurement of the isolated photon production. These analyses, in addition to the results published on fast track just after the data taking, were among the highlights of the conference.

In the realm of quarkonium production CMS measured on 2010 pp collision data, in the $\mu^+\mu^-$ decay channel, the psi(2S) over J/psi cross section ratio vs. p_T and also the production cross section ratio of X(3872) and psi(2S) in the decays to J/psi $\pi+\pi-$. Measurements of beauty quark production are also an important part of the group's physics program and here we measured the cross section for correlated $b\bar{b}$ production using dimuons. The highlight of the group was the publication of the search for the rare decay $B_s \rightarrow \mu\mu$ on 2011 data that provided a very competitive limit of $1.9\text{x}10^{-8}$ on the branching fraction. This result was combined with the LHCb limit ($1.5\text{x}10^{-8}$) just before the EPS conference providing a limit of $1.1\text{x}10^{-8}$. These results have been possible due to the excellent performance of our dimuon triggers, despite the fact that less than 10% of the overall trigger bandwidth is devoted to heavy flavor physics.

The QCD and Forward physics groups concentrated mostly on the continued analysis of the 2010 dataset that is less affected by pile-up. In the high-p_T sector, CMS completed two analyses with photons in the final state: the measurements of the cross sections for differential isolated prompt photon and for isolated di-photon productions. These measurements have systematic errors of about 10% and show fair agreement with the NLO predictions of pQCD. CMS completed also three analyses involving forward jets. In the low p_T -QCD sector we measured the inelastic cross section, the underlying event activity in the Drell-Yan process, the exclusive production of muon pairs produced by di-photon collisions, inclusive forward energy flow and forward energy flow and central track multiplicities in W and Z boson events.

Precise and novel measurements were made in the electroweak sector using the 2011 data. A simultaneous fit of rapidity, dilepton invariant mass, and decay angle distributions of the opposite sign dimuon pairs has allowed the measurement of the effective weak mixing angle with a remarkable precision of $\sin^2\theta_W=0.2287\pm0.0020\pm0.0025$ limited by PDF uncertainties and the modeling of the process. Based on the 2010 dataset, publications on the differential Drell-Yan cross section, the Z0 rapidity and p_T dependence and the study of associated charm production in W final states have been submitted or are under review.

In the top sector, the most precise cross section measurement by CMS to-date has been made in the lepton + jets channels with a b-tag requirement: 164 ±3 (stat) ±12 (syst) ±7 (lumi) pb. The method makes continued use of our simultaneous fit to the distributions of the number of jets, number of b-tags, and secondary vertex mass distribution. The cross section also has been re-measured on 2011 data in the dilepton channel, including also the $\mu\tau$ channel. A measurement in the challenging all-hadronic decay mode channel has also been made. Additionally, a measurement of the top charge asymmetry vs. η has been made, which is interesting because the Tevatron experiments find an anomalously large value. The asymmetry is expected to be much smaller in pp collisions and we do not measure a larger than expected value. Also, the most precise measurement of the mass difference between top and anti-top has been made (1.3 GeV precision).

With the LHC having delivered more than 1 fb^{-1} of data by the time of the summer conferences, 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. CMS has conducted searches in many decay channels, including WW, ZZ, gamma-gamma, tau-tau, and also the very challenging bb. For the latter bb decay channel, we search for the Higgs in association with a W or Z in a highly boosted topology. A sensitivity between 8-20 times the SM cross section was achieved. The WW channel by itself reached below Standard Model sensitivity in the mass range 147-194 GeV. The ZZ to 4 leptons golden decay channel has just reached the SM sensitivity from about 180 to 300 GeV. Overall, with all channels combined, the CMS data disfavor at 95% CL the minimal SM Higgs in the mass regions: 145-216, 226-288, 310-400 GeV. The expected mass range was 130-440 GeV. The largest statistical deviation has a p-value corresponding to ~2 sigma, but with the look-elsewhere trials factor applied the global p-value is 0.4.

In searches for SUSY in the all-hadronic decay channel, CMS extended its pioneering approach using the "α_T" variable to 1.1 fb^{-1}, although no evidence for new physics has yet been found. A new approach using the "MT2" variable has also been completed, as has a search in the traditional multi-jet plus MET topology. A variety of searches using single leptons, same-sign leptons, opposite-sign leptons (on and off Z), and multi-leptons have also been performed, unfortunately all in good agreement with data-driven background estimates. In the mSUGRA m_0-$m_{1/2}$ plane the reach has been extended far beyond the 2010 limits to squark and gluino masses near 1 TeV. To remove the assumptions of CMSSM, limits have also been derived in several Simplified Models, where squark and gluino masses have been excluded to masses above 0.5 - 1 TeV depending on the neutralino mass assumption. Searches for general gauge mediated SUSY in single and diphton final states have also been performed.

Searches for a very wide variety of new physics models have also been performed in the Exotica physics group. Using 1.1 fb^{-1} of data, narrow dilepton resonances have been excluded to nearly 2 TeV depending on the coupling assumptions. A W' with SM couplings has also been excluded below 2.3 TeV. In searches for dijet resonances, excited quarks have been excluded below 2.5 TeV and string resonances below 4 TeV. A search for possible Z' decays to top anti-top pairs in a highly boosted topology using two "fat jet" algorithms has been performed as well. But this is only a small fraction of the ongoing searches for new physics, which include also 4th generation searches, extra dimensions, black holes, heave stable charged particles, and so on.

Heavy Ions

As reported previously, the LHC accelerator and the CMS experiment performed very well during the PbPb run period last November 2010. The total collected data set of about 9 $\mu\mathrm{b}^{-1}$ at $\sqrt{s_{NN}} = 2.76$ TeV allowed CMS to perform and publish multiple measurements. In early 2011 we also collected about 220 nb^{-1} pp collisions at the same average energy per nucleon. We were able to characterize soft particle production in detail by measuring the charged particle multiplicity, transverse energy flow, azimuthal asymmetry and dihadron correlations. A very detailed picture of collision dynamics emerged from higher order Fourier analysis of the azimuthal distributions. The data has relatively modest changes compared to RHIC indicating that the general properties of matter produced at LHC, as measured by soft particles, are consistent with the strongly interacting Quark Gluon Plasma.

The high energy of LHC and the large acceptance of CMS, allowed much more detailed studies of hard processes. We made detailed measurements of dijet production, jet-hadron correlations and jet fragmentation. The data indicate very large parton quenching where the energy lost by the partons is transferred to very soft hadrons scattered relatively far away in rapidity from the jet axis. The measurement of the jet fragmentation function shows that the jet structure is very similar to the structure of jets in pp events at the lowered energies resulting from parton energy loss. This indicates that the final fragmentation of the parton into a jet occurs outside of the strongly interacting medium. Parton energy loss was also studied by comparing momentum spectra of charged hadrons and isolated photons with their equivalents in pp collisions. Charged hadrons are strongly suppressed, even at high p_T, whereas photons and Z's appear unaffected.

Measurements of muons using the CMS muon system provided several exciting results. Probably the most remarkable was the indication of suppression of excited states of the Υ. The detailed comparison of Υ production in PbPb and pp collisions at the same average nucleon energy showed that there are about 3 times fewer Υ' and Υ'' states produced in PbPb as compared to pp collisions. Such a phenomenon was anticipated as a result of effective Debye screening of the bound states in the hot plasma. We are looking forward to increased statistics in 2011 to confirm and quantify the effect. The measurement was made possible due to the excellent dimuon mass resolution of CMS.

We also observed suppression of J/ψ production using the dimuon decay channel. The excellent position and vertex resolution of CMS pixel detectors allowed separation of direct J/ψ production from J/ψ's produced in the decays of B hadrons. This in turn allowed measurement of quenching of b-quarks for the first time in heavy ion collisions.

CMS results were presented at the most important conference of the heavy ion field, Quark Matter 2011 in Annecy. The group presented an unprecedented number of results, summarized in 20 talks, 6 of them plenary. So far 5 papers were published or accepted for publication, the group has also produced about 13 public Physics Analysis Summaries.

The heavy ion group is now preparing the last publications based on 2010 data and configuring the detector for the 2011 run. The heavy ion run 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. We expect to further reduce the output data size by turning on the Zero Suppression of ECAL and HCAL.

Upgrades

With the completion of the Upgrade Technical Proposal, attention has turned to implementing the parts of the proposal that will be installed in the first long shutdown, now scheduled for 2013-2014. Factories were set up to produce the fourth layer of RPCs and the fourth layer of CSCs. Parts procurement is underway. First items are being manufactured for both types of chambers. For the endcap CSCs, a successful prototype of the DCFEB (Digital Cathode Front End Board) was constructed and tested. Photomultipliers for the Forward Hadron Calorimeter, the HF, were received from Hamamatsu and tested. Deliveries are slower than expected as a result of supply problems due to the earthquake and tsunami in Japan. The SiPMs (Silicon Photomultipliers) and the associated electronics cards for the Outer Hadron Calorimeter (HO) are being prepared.

R&D and final design are being carried out for the subsystems that will be installed in the second long shutdown. The redesign of the pixel readout chip to enable it to handle higher luminosity without data loss is moving forward. There has been significant progress in the mechanical design of both the Barrel and Pixel mechanics to reduce their mass, and also in the design of a new carbon dioxide cooling system. A new approach to the use of large area SiPMs for the upgrade of the photosensors for the barrel and endcap HCAL has been demonstrated in test beams. Work on SiPMs continues with multiple vendors. Work on the back end electronics and calorimeter triggers is also underway. The replacement of the trigger infrastructure, which is currently based on VME, with a more modern, flexible, and easier to maintain system based on the microTCA platform is also proceeding.

CMS has proposed a smaller diameter beampipe so that the pixel detector can be moved closer to the interaction region. It is proposed that this beam pipe should be ready by December of 2013 for installation in LS1. Once the beam pipe is installed, the upgraded pixel detector can be installed in the first available Technical Stop after it is completed. R&D continues at a low level for the Phase 2 upgrade that will be needed after 2020. However, this work must be accelerated if the project is to be successful and ready on time.

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 September 22, 2011, CMS has published 107 physics papers 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, 630 conference reports were published. The corresponding increments in these categories since the last RRB in early April 2011 are: Papers – 44; CRs – 115.

The five most cited CMS physics papers to-date, each with at least 50 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; 122 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; 95 citations.

3. Observation of Long-Range Near-Side Angular Correlations in Proton-Proton Collisions at the LHC - JHEP 1009:091, 2010; 78 citations.

4. Transverse-momentum and pseudorapidity distributions of charged hadrons in pp collisions at sqrt(s) = 7 TeV - Phys.Rev.Lett.105:022002, 2010; 70 citations.

5. Search for Dijet Resonances in 7 TeV pp Collisions at CMS - Phys.Rev.Lett.105:211801, 2010; 54 citations.

Conclusion

The CMS detector has continued to perform extremely well in 2011 pp running, meeting every challenge it has received to date. Data collected in the first half of 2011 have been extensively analyzed to improve detector and software performance in more difficult high pile-up conditions and 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. The CMS collaboration is also making progress on preparation for running in 2012 and on the upgrades to be installed in LS1. It is an extremely intense and exhilarating period in the LHC program with expectations for important results to appear very soon.

CMS Financial Information

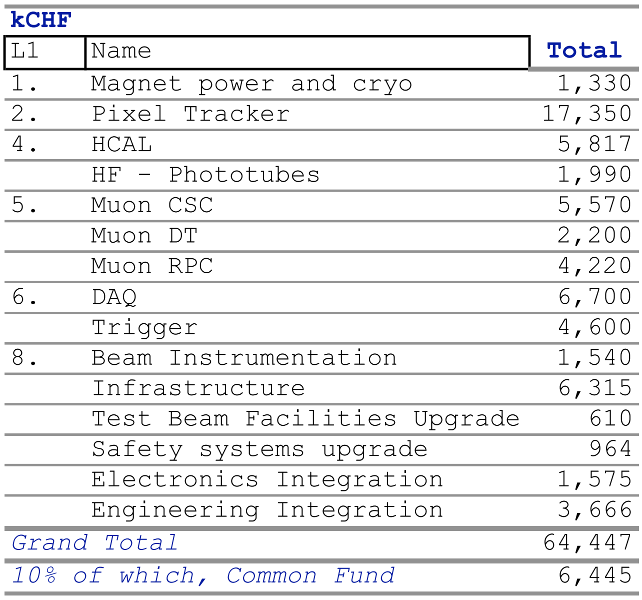
The RRB is reminded that the currently running CMS detector is what was originally called the “low luminosity detector” and, to cope with nominal LHC luminosity, additional investments will be needed.

In the last RRB meeting of April 2011 CMS described the content of the Technical Proposal for the Upgrades, covering all projects considered necessary to maintain and increase, the physics potential of the experiment for operation at 1-2x10^{34}cm^{-2}s^{-1} (Phase I of the Upgrades.

Phase II of the Upgrades will cover all projects needed for CMS be able to cope with the high luminosity running of LHC, (luminosity leveling at 4-5x10^{34}cm^{-2}s^{-1}). The high luminosity running of LHC is expected to happen in the years around 2020. 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 I.

Table 1 below summarizes our current understanding of the costs of the first phase of the upgrade. Details of the project and of the estimated costs for Phase I can be found in the document Technical Proposal for the Upgrade of the CMS detector through 2020 (CERN-LHCC-2011-006) submitted to the LHCC.

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 previous RRB meetings, 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 Phase I Upgrade.

We are continuing discussions with the Funding Agencies to prepare a global cost-sharing matrix for the Upgrade Phase I. 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 I is expected to cover the period 2011-2017.

At this October 2011 RRB meeting we present a very preliminary cost-sharing matrix for the Upgrade Phase I (Table 2).

All costs are in the usual CERN metric that includes material costs and contracted labor without contingency and are in Swiss Francs. CMS understands that each Funding Agency has its own process and timetable for reaching a final decision on the upgrade, therefore the actual numbers vary from firm commitments, based on approved funding, through proposals incorporated into national plans but not yet funded, to expectations for funding that are still at an early stage of discussion.

We expect to have a complete picture and receive firm commitments by most if not all Funding Agencies before the end of 2012.

We deeply thank the Funding Agencies for their interest towards the projects proposed in the Technical Proposal for the Upgrades of CMS and for their continuing support.

Table 2: Upgrade Phase I Preliminary Cost Sharing Money Matrix

12.10.2011			Subdetector-specific Upgrades						Detector-wide items											
									Beam/DAQ/Trigger			Common Fund (CF) Items								
Institute FA	**PhD #**	**PhD %**	**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**	**Total expected (projects)**	**Common Fund (CF)**	**Total Upgrade Due (incl. CF)**
			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**			
Common Fund												592,797	2,814,673	271,885	429,667	701,997	1,633,981		**6,445,000**	
Austria	22	1.6%	68,846								1,200,000							1,268,846	102,154	1,021,494
Belgium-FNRS	16	1.2%						236,000										236,000	74,294	742,905
Belgium-FWO	16	1.2%						270,000										270,000	74,294	742,905
Brazil	17	1.2%																0	78,937	789,336
Bulgaria	8	0.6%																0	37,147	371,452
CERN	80	5.8%	3,000,000					500,000	500,000	3,500,000			1,500,000		500,000		1,000,000	10,500,000	371,470	3,714,524
China	10	0.7%				200,000		500,000										700,000	46,434	464,316
Colombia	3	0.2%						10,000										10,000	13,930	139,295
Croatia	7	0.5%								200,000								200,000	32,504	325,021
Cyprus	5	0.4%																0	23,217	232,158
Egypt	3	0.2%						150,000										150,000	13,930	139,295
Estonia	4	0.3%					167,153											167,153	18,573	185,726
Finland	14	1.0%	420,000					130,000						35,000				585,000	65,007	650,042
France-CEA	15	1.1%																0	69,651	696,473
France-IN2P3	53	3.8%	100,000							350,000	600,000			100,000		600,000		1,750,000	246,099	2,460,872
Germany-BMBF	62	4.5%	1,600,000				612,000											2,212,000	287,889	2,878,756
Germany-DESY	39	2.8%	1,200,000	XXXXXXX														1,200,000	181,091	1,810,831
Greece	15	1.1%								XXXXXX	XXXXXXX							0	69,651	696,473
Hungary	10	0.7%		XXXXXXX			XXXXXX											0	46,434	464,316
India	29	2.1%		495,000				720,000										1,215,000	134,658	1,346,515
Iran	6	0.4%																0	27,860	278,589
Ireland		0.0%									XXXXXXX							0	0	0
Italy	173	12.5%	1,400,000				1,000,000	350,000										2,750,000	803,303	8,032,659
Korea	21	1.5%						400,000										400,000	97,511	975,063
Mexico	11	0.8%																0	51,077	510,747
New Zealand	2	0.1%																0	9,287	92,863
Pakistan	2	0.1%						345,000					800,000					1,145,000	9,287	92,863
Poland	15	1.1%																0	69,651	696,473
Portugal	7	0.5%									500,000							500,000	32,504	325,021
RDMS - DMS	21	1.5%		400,000		500,000												900,000	97,511	975,063
RDMS - Russia	61	4.4%		1,400,000		1,300,000												2,700,000	283,246	2,832,325
Serbia	3	0.2%																0	13,930	139,295
Spain	49	3.5%					264,000											264,000	227,525	2,275,146
Switzerland (ETHZ,PSI,UNIV)*	38	2.7%	3,800,000															3,800,000	176,448	1,764,398
Taipei	15	1.1%	1,000,000															1,000,000	69,651	696,473
Turkey	18	1.3%		XXXXXXX	100,000													100,000	83,581	835,768
United Kingdom	56	4.0%	500,000							250,000	1,500,000		126,000			126,000		2,502,000	260,029	2,600,167
USA (DOE-HEP, NSF)	440	31.7%	4,500,000	5,817,000	2,000,000	5,570,000				700,000	3,000,000							21,587,000	2,046,032	20,459,365
USA (DOE-NP)	22	1.6%																0	102,302	1,022,968
Grand Total	**1388**	**100.0%**	**17,588,846**	**8,112,000**	**2,100,000**	**7,570,000**	**2,043,153**	**3,611,000**	**500,000**	**5,000,000**	**6,800,000**	**592,797**	**5,240,673**	**406,885**	**929,667**	**1,427,997**	**2,633,981**	**58,111,999**	**6,445,000**	**64,447,000**