LARGE HADRON COLLIDER COMMITTEE
Minutes of the one-hundredth-and-twenty-fourth meeting held on
Wednesday and Thursday, 2-3 December 2015

OPEN SESSION – STATUS REPORTS
1. LHC Machine Status Report: Laurette Ponce
2. LHCb Status Report: Silvia Borghi
3. ALICE Status Report: Francesca Bellini
4. ATLAS Status Report: Alessandro Polini
5. CMS Status Report: Anne Dabrowski
6. TOTEM Status Report: Valentina Avati

CLOSED SESSION:

* part-time

Apologies: S. Bertolucci, B. Gorini, T. Kuhr, M. Lancaster, C. Sfienti

1. EXECUTIVE SUMMARY

Report from the Director for Research and Computing

On behalf of the Director for Research and Computing, the Chairman reported on issues related to the LHC. He reported on the very successful proton-proton run in 2015, with more than 4 fb\(^{-1}\) of data delivered to ATLAS and CMS at 13 TeV collision energy. In addition, 28 pb\(^{-1}\) of proton-proton reference data for the Pb-ion run was delivered at 5 TeV collision energy, and the Pb-Pb run is in progress. He reported on the deliberations at the Resources Review Boards (RRBs) of October 2015 regarding the ATLAS and CMS Scoping Documents for the Phase-2 upgrades. The RRBs consider the Step 1 of the approval process for the Phase-2 Upgrades for the ATLAS and CMS experiments successfully completed. A scale of funding between the full funding and the intermediate scenario seems to meet the performance requirements. The CERN Management, supported by the recommendations of the LHCC and the UCG, deems as realistic the availability of prospective funds contained in the preliminary “Money Matrices” submitted by the experiments. The experiments are therefore encouraged to proceed to the next step of the Phase-2 upgrades, as described in the document CERN-LHCC-2015-007. The LHCC and the UCG as well as the Management will regularly update the RRB on progress of the process.
Report from the LHC Programme Coordinators

The LHCC heard a report from the LHC Programme Co-ordinators on a summary of the 2015 proton run, the status of the heavy-ion run and a first look at the LHC run in 2016. They reported on a very successful proton-proton run in 2015, with more than 4 pb$^{-1}$ of data delivered to ATLAS and CMS at 13 TeV collision energy. In addition, 28 pb$^{-1}$ of proton-proton reference data for the Pb-ion run was delivered at 5 TeV collision energy. The Pb-Pb run is in progress. The injected charge for the Pb-Pb run is, however, 40% less than anticipated, resulting in a reduced luminosity. The Co-ordinators also reported on the successful $\beta^*=90$m run for elastic and diffractive physics studies. For 2016, about 160 days of proton-proton running are scheduled and will be followed by 30 days of proton-Pb running (including setting up). The precise beam parameters are to be confirmed. J. Boyd will be the LHC Programme Co-ordinator for 2016 with C. Schwick being the Deputy LHC Programme Co-ordinator.

Report and Discussion on LHC Experiment Upgrades

General

The LHCC, together with the UCG, will continue monitoring progress in the LHC experiment upgrade projects. In order to help in the review process, the experiments are requested to provide summaries of their Engineering Design Reviews (EDRs), the updated global schedule, a list of milestones that will allow effective monitoring of progress and information on resources. This information should be available on a central and easily-accessible repository.

ALICE

Good progress was reported on the ALPIDE read-out chip for the new Inner Tracking System (ITS), with the choice of architecture being made and the chip exceeding all specifications. Nearly all aspects of production have been addressed and technical solutions have been found and procedures established. The schedule is considered to be aggressive but feasible. For the upgrade of the readout chambers of the Time Projection Chamber (TPC), technical solutions matching the physics requirements have been developed. ALICE decided on a 4-GEM (Gas Electron Multiplier) stack. The design of the Read-out Chambers (ROC) is complete and a pre-production of the chambers has started in order to finalise the design for the Production Readiness Review in March 2016. The TPC upgrade passed successfully the Engineering Design Review (EDR). Issues of data errors with the RCU2 radiation-tolerant SmartFusion2 FPGA read-out chip for the TPC, supplied by Microsemi, have been mitigated by reducing the link speed to 3.125 Gb/s. This yields stable operation and a factor 1.9 gain in speed with respect to RCU1. The Online-Offline ($O^2$) discussions with CERN services have been concluded successfully and no unexpected costs were identified in the project. The SAMPA read-out chip for the TPC and Muon Chambers is fully funded by Brazil but its schedule is delayed by six months.

ATLAS

A status report was given on the Phase-1 upgrade projects. All projects are progressing, although delays have been incurred with the development of some components. The Phase-1 upgrade for the muon New Small Wheel (NSW) is advancing, but the Micromegas and small strip Thin Gap Chamber (STGC) production capability is not yet at the nominal rate and significant delays have been accumulated. The ATLAS Fast TracKer (FTK) upgrade is progressing much slower than planned, with the main issue being the demonstration of the functionality of the AM06 read-out chip still pending. The
Level-1 Calorimeter Trigger Upgrade is proceeding slower than planned, and the Level-1 Muon Trigger Upgrade is proceeding steadily. ATLAS is undertaking a re-write of the analysis software framework ATHENA. Good progress was reported on the Phase-2 upgrade projects for the Inner Tracker (ITK), LAr Calorimeter, Tile Calorimeter and Muon System.

CMS

The LHCC heard a report on the CMS Phase-1 upgrades yearly in-depth review. The upgrade of the HCAL electronics is advancing. The back-end electronics have been completed successfully, while the front-end electronics have been delayed by one year, translating into a corresponding delay of exploiting its benefits. The calorimeter trigger has been a complete success, and the muon trigger is approaching a successful completion also. Due to significant delays in the procurement and qualification of critical components, the production schedule for the Pixel Detector upgrade is extremely tight. The LHCC encourages the CMS management to closely monitor the progress and evaluate alternate options in case the foreseen schedule cannot be met. For the Phase-2 upgrades, CMS is concentrating on technical developments in all sub-systems and the respective Technical Design Reports are being prepared. Good progress was reported in qualifying a second vendor for the silicon sensors for the Tracker and High Granularity Forward Calorimeter (HGCAL). The Tracker Technical Design Report is expected in mid-2017.

LHCb

Excellent progress was reported on the LHCb upgrade projects for Long Shutdown 2 (LS2), including for the Upstream Tracker (UT), the Vertex Locator (VELO), the Ring Image Cherenkov (RICH), the Muon System, Calorimeter and the Scintillating Fibre (SciFi) tracker. All milestones are being met in the revised milestone schedule. The schedule for completion of construction of the SciFi is considered to be tight, with issues arising from the radiation hardness of the fibres and from the fibre bumps in the production. A revised design of the detector with less sensitivity to the fibre bumps is being investigated.

ALICE

Good progress was reported on the ALICE physics analysis, with six papers published, four papers accepted for publication and 11 papers submitted for publication since the LHCC meeting of September 2015. Among the new results are the measurement of direct photon $p_T$ spectrum and the detailed studies of energy loss in the quark-gluon plasma. ALICE had a successful proton-proton run at 13 TeV collision energy and an excellent proton-proton run at 5 TeV collision energy of reference data for the Pb-ion run. All new ALICE detectors were fully integrated in the experiment and are operating well. ALICE has had a good start to the Pb-Pb run at 5.02 TeV/nucleon energy, with the design luminosity of $10^{37}$ cm$^{-2}$ s$^{-1}$ reached and luminosity levelling activated. Some larger than expected space-charge induced distortions have been observed during the high rate data taking and are under investigation.

ATLAS

ATLAS physics analysis is progressing well. The Collaboration has submitted 488 scientific papers so far, including 17 since the previous LHCC session in September 2015. ATLAS has been taking data smoothly and with high efficiency. ATLAS has recorded about 4 fb$^{-1}$ of proton-proton collisions at 13 TeV collision energy and the heavy-ion run is progressing well with about 0.15 nb$^{-1}$ of Pb-Pb data collected. ATLAS
and CMS will be presenting at a CERN seminar their results on the complete 2015 proton-proton data, with many analyses to be reported. The LHCC took note of issues with a rise in current in the Inner B-Layer (IBL) read-out electronics, which is correlated with luminosity. The resulting temperature rise causes distortion of the detector geometry. ATLAS reacted promptly by creating a task force to understand the effect, which has been traced to a known effect in NMOS transistors. The issue does not affect the functionality of the IBL and the effect is expected to improve with higher radiation because of compensation. ATLAS will continue monitoring the effect and should develop a long-term plan to cope with the increased current. One new large Xenon leak was reported for the Transition Radiation Tracker (TRT) and is inaccessible for repair. The detector is currently running on Argon for the Pb-Pb collision period, and in 2016 a hybrid running configuration of Xenon / Argon (or with Krypton) will be implemented. The LHCC took note of the bellows distortion in the End-Cap Toroid (ECT) magnet, the origin of the distortion is now understood. A plan is in place for the Year End Technical Stop (YETS) to provide a temporary precautionary vacuum seal, to inspect the current leads and make any required repairs, and to encase the distorted bellows with permanent outer bellows to provide the necessary vacuum seal.

**CMS**

The CMS Collaboration has published or submitted for publication a total of 445 scientific papers. The CMS sub-systems, including detectors, trigger, online and offline reconstruction and analysis are performing well in Run II. Many improvements in the CMS experiment having been completed successfully during Long Shutdown 1 (LS1) and the experiment started data-taking in Run II well. The proton-proton run for 2015 at 13 TeV collision energy has been completed successfully with about 4 fb⁻¹ of data recorded by CMS and the heavy-ion data-taking is in progress. CMS and ATLAS will be presenting at a CERN seminar their results on the complete 2015 proton-proton data, with many analyses to be reported. The operation of the CMS solenoid magnet remains an issue. CMS, together with CERN, is preparing an extensive clean-up and replacement programme of the magnet cooling system cold box during the upcoming YETS. A long-term magnet operation risk analysis review will also be held on 7-8 December 2015.

**LHCb**

The LHCb physics analysis is progressing well. In 2015, 53 scientific papers have been published or have been submitted / accepted for publication and many new analyses are ongoing for the winter conferences. In total, LHCb has published 290 scientific papers. The Run II performance of the LHCb experiment is excellent, with about 320 pb⁻¹ of proton-proton data recorded at 13 TeV collision energy. Several SMOG runs have been taken, studying proton-Ne, proton-He and proton-Ar interactions. The SMOG runs have been used to determine a 1% uncertainty on the luminosity, allowing for the most precise W/Z measurements at the LHC. LHCb has also taken data for the first time in Pb-Pb running mode. LHCb has deployed successfully its new trigger scheme with the Level-0 triggers being written directly to disk. For all detector systems, alignment and calibration constants are automatically adjusted online.

**TOTEM**

The TOTEM Collaboration presented new and interesting results from recent studies of elastic cross-sections, both at low and at high four-momentum transfer squared |t|. Good progress according to the schedule was reported on the Vertical Roman Pot Timing Detectors. Collaboration with CMS is progressing on a beam pipe replacement aimed at guaranteeing a volume slot for the TOTEM T2 Telescope or possible upgrades. The
LHCC acknowledges the need to maintain detector coverage in the region occupied by the TOTEM T2 Telescope, and welcomes the efforts to adapt the design of the new CMS beam pipe to accomplish this goal. Good progress was also reported on the CMS-TOTEM Proton Precision Spectrometer (CT-PPS), with excellent results presented for the Roman Pot insertion tests, the tracking detectors and the DAQ hardware. The time resolution performance for the Quartic modules Timing Detectors is, however, below specification. The LHCC endorses the TOTEM plan to install the current detectors and prepare a replacement programme for the Quartic modules based on silicon (from RD50) or diamond (from the TOTEM Vertical Timing Detectors) sensors. For 2016, TOTEM should discuss with the LHC Machine Committee a proposal for running compatible with the achievable machine optics and running time.

LHCf

The LHCf Collaboration has completed successfully the calibration of new detectors for the experiment by using electron, proton and muon beams at the CERN SPS. The first physics results on the photon energy spectra analysis from the proton-proton run at 13 TeV collision energy were also presented. The joint analysis with ATLAS on diffractive physics is progressing well. LHCf intends to submit a Letter of Intent to the next session of the LHCC for data-taking in proton-Pb running mode of the LHC.

WLCG

The WLCG and the experiment computing have had an excellent start to Run II. Considerable optimisations have been made, yielding physics results in record times. Many new records have also been achieved in terms of data volume, speed and number of jobs. Improvements are being prepared based on new paradigms such as Clouds, streamlined data models and automated procedures. The available resources matched the needs for 2015 and extrapolations for 2016 and 2017 are being discussed. The computing requirements for Phase-1 and Phase-2 are also being considered. The LHCC will continue following ongoing activities. The requirements for HL-LHC will start to be discussed in the WLCG Technical Forum, targeting the LHCC session in February 2016 to produce the timeline for the HL-LHC computing activities and to define the process leading to the Technical Design Report.

Test Beams

The LHCC took note of the report from the PS and SPS Physics Co-ordinator on the LHC test beams. The proton and Pb-ion test beam runs for 2015 have been completed successfully. The Co-ordinator also showed the draft schedule for the East Area and North Area test beams for 2016. The possible extension of the NA61 Pb run by one to two weeks will have an impact on the LHC-related test beams and will also be discussed in the SPS Committee. The draft schedule will be finalised following discussions with the beam line physicists. He also reported that the experimental spectrometer magnets used in the EHN1 North Hall are ageing and need some dedicated efforts to keep these valuable assets available to the User community.

2. PROCEDURE

The minutes of the one-hundredth-and-twenty-third LHCC meeting (LHCC-2015-017 / LHCC-123) were approved. The dates for the second LHCC meeting in 2016 have been moved to 25-26 May due to a conflicting workshop concerning several referees.
3. REPORT FROM THE DIRECTOR FOR RESEARCH AND COMPUTING

On behalf of the Director for Research and Computing, the Chairman reported on issues related to the LHC. He reported on the very successful proton-proton run in 2015, with more than 4 fb\(^{-1}\) of data delivered to ATLAS and CMS at 13 TeV collision energy. In addition, 28 pb\(^{-1}\) of proton-proton reference data for the Pb-ion run was delivered at 5 TeV collision energy, and the Pb-Pb run is in progress. He reported on the deliberations at the Resources Review Boards (RRBs) of October 2015 regarding the ATLAS and CMS Scoping Documents for the Phase-2 upgrades. The RRBs consider the Step 1 of the approval process for the Phase-2 Upgrades for the ATLAS and CMS experiments successfully completed. A scale of funding between the full funding and the intermediate scenario seems to meet the performance requirements. The CERN Management, supported by the recommendations of the LHCC and the UCG, deems as realistic the availability of prospective funds contained in the preliminary “Money Matrices” submitted by the experiments. The experiments are therefore encouraged to proceed to the next step of the Phase-2 upgrades, as described in the document CERN-LHCCC-2015-007. The LHCC and the UCG as well as the Management will regularly update the RRB on progress of the process.

4. REPORT FROM THE LHC PROGRAMME COORDINATORS

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5. REPORT & DISCUSSION WITH LHC EXPERIMENT UPGRADE REFEREES

CMS

The LHCC carried out an in-depth review of the Phase-I upgrades of the CMS Hadron Calorimeter (HCAL, the Trigger and the Pixel detector.

*Hadron Calorimeter*

The upgrade of the electronics for Hadron Calorimeter (HCAL) consists of an upgrade of the front-end and of the back-end. The new back-end electronics replaces the VME-based system with a µTCA-based system and is the same for the different HCAL sub-detectors (Hadronic Forward (HF), Hadronic Barrel (HB), Hadronic End-cap (HE), and Hadronic Outer (HO)). It only differs in firmware implementation. This upgrade is going very well. The new electronics has been exercised with data for all four subsystems; for the HF, HB and HE it has already been implemented in the trigger for data taking, albeit at a lower readout speed. Plans for the HO are being developed, as are plans for the higher (4.8 Gb/s) readout speed.
The upgrade of the front-end is lagging. For the HF 144 QIE cards, holding the new QIE10 chips, and 470 Versatile Link Dual Transmitter (VTTx) cards are needed. The production and testing of the QIE cards is a major bottleneck and the throughput is limited by the VTTx availability; currently only 26 VTTx modules out of the 470 required are available. These issues limit the quadrant scale test and QIE card calibration. Furthermore, the required re-work of the PMT boxes does not fit in the 2015/16 YETS. Due to the hardware availability and firmware issues and the lack of time for the PMT rework, the Collaboration has decided to defer the HF front-end electronics installation effectively by one year to the Year-End Technical Stop (YETS) of 2016/2017.

The upgrade of the front-end for HB and HE consists of replacing the HPDs with SiPMs and the associated readout electronics. This gives better photon sensitivity and allows for better longitudinal segmentation. Most of the elements of the upgrade are on schedule, but the production and testing of the QIE (and VTTX) cards is on the critical path, as is the Clock Control Module; the SiPM Bias control is also near the critical path. The schedule for installing the HE upgrade during the YETS, in parallel with the HF upgrade, is tight and close monitoring is recommended. The HB upgrade is scheduled for installation in Long Shutdown 2 (LS2) and its schedule has significant float. The LHCC congratulates the experiment on the success of the back-end upgrade and takes note of the schedule constraints for the front-end upgrade. It regrets that the experiment will be unable to take advantage of the front-end upgrade earlier.

**Trigger**

The upgrade of the calorimeter and muon trigger is proceeding exceedingly well. The calorimeter upgrade, with the new optical serial link and receiver boards and new µTCA cards has been run in parallel with the legacy system. New trigger algorithms have been run and the results show near perfect agreement with the emulator results. All triggers have been commissioned for proton-proton as well as heavy ion running. There is marked improvement for electron, photon, tau and missing E_T triggers. The new trigger also enables a more powerful pile-up subtraction at Level-1. The global calorimeter trigger is undergoing tests and is expected to be ready by February 2016. More data will be collected with the calorimeter and global trigger to better understand the data and to ensure that the transition to the new system is flawless. The new trigger system is ready for data taking in 2016 and a final decision to transition to the new trigger system is expected soon.

The upgrade of the muon trigger aims at using the redundancy of the three muon detection systems earlier in the trigger chain to create a higher resolution and more robust muon trigger and provide calorimeter isolation. All hardware components for the upgrade – TwinMux, CPPF, MTF7 and MP7 – are in hand and have been tested. The Muon Track Finder (MTF) has been installed for all three regions: barrel, end-cap and overlap. Parts of the new system have been run in parallel with the legacy system and the performance has been as expected. The Collaboration anticipates an irreversible decision to disconnect the fibres from the drift tube system by January 2016. The emphasis is on commissioning the full muon trigger in parallel with the legacy trigger. Some extra manpower needs are being addressed. The LHCC congratulates the CMS Collaboration on a very successful trigger upgrade. The overhead on running two systems is large and the Collaboration has set well-defined validation goals to switch off legacy trigger. The LHCC looks forward to a smooth transition so that the Collaboration can start taking full advantage of the new triggers for the 2016 physics run.
**Pixel Detector**

The CMS Collaboration plans on replacing the current pixel detector in the YETS in 2016/2017 with a new pixel detectors, which has four layers in the barrel region and three disks each for the forward and backward regions.

**Barrel**

Including spares, 1300 modules need to be produced for layers 2 – 4 and 115 for layer 1. Five centres for module production have been certified. At the time of the LHCC meeting only three centres were in production; module assembly at INFN and PSI had been paused. Bare barrel module production, that is a sensor with the readout chips bump bonded, is 40% complete with a 90% yield. Full barrel module production, that is, modules with the HDI, token bit manager (TBM) and readout cable, is 20% complete with a 76% yield. Nominal output of about 30 modules per week has not yet been achieved, and is essentially limited by bump bonding. To meet the schedule, the current production rate needs to be approximately doubled.

The mechanical design for the barrel and the installation of the modules is well advanced. Designs are final for the support structures and all tooling. Assembly fixtures are being produced and all parts are on order or in production, including the cooling lines. Module mounting and testing procedures are in place and the schedule calls for the first modules to be mounted in April 2016. The supply tube, which provides a lot of the services, is in production. All parts, including those for the readout tests, are scheduled to be delivered and tested by the end of January 2016. The design of the barrel pixel detector foresees a dedicated readout chip (ROC) with a different readout architecture to cope with the expected data rate from the innermost layer with an acceptable readout inefficiency. Presently the readout chip (ROC) for Layer 1 presents a project risk. The first version of the Layer 1 ROC was submitted in October 2015. Prototype devices are expected in January. The ensuing tests to verify performance and radiation tolerance will take at least two months. The project has considered two outcomes of these tests. The first option is that only minor or low-risk changes are needed to the chip. The plan is then to implement these changes and proceed with the production run so that module assembly can start in the July 2016 timeframe. The other possibility is that more significant changes need to be made. In that case, a production run is deemed too risky and Layer 1 modules will be built with the Layer 2-4 version of the ROC. This would result in a first layer with limited performance until Long Shutdown 2 (LS2) when the modules with the final Layer 1 ROC can be, finally, installed. This back-up plan will affect the performance of the detector for nominal LHC machine performance, but these effects are mitigated if the machine does not yet reach its ultimate performance in the pre-LS2 running period. The barrel pixel schedule is very tight, especially given the fixed endpoint set by the start of the YETS.

**Disks**

The pixel disks consist of a set of six half disks with 672 pixel modules. To account for spares and yield, 1000 modules will be built. Nearly all sensors have been received with good yield (>95%). Module production will take place at two production sites that have been qualified. To date only 30 modules have been produced with unknown yield since the statistics is too small. Module assembly needs to proceed at a rate of 40 modules/week and may need to go higher to meet the schedule. At the time of the review the module production is on hold because the HDI production had significant issues: of the 871 HDIs delivered only 171 were accepted, due to solder-mask misalignments and too small wire bond pad spacing. Currently two other vendors are
being qualified. The testing of assembled modules uses many of the same procedures as the barrel detector and is in good shape. Four half-cylinder support tubes are required for the disk assemblies. Most of the parts are in hand and the assembly of the +z cylinders is progressing well with two half-disks already completed. The group is investigating if the material chosen for the cooling pipes and joints, stainless steel 316L, can potentially be affected by “hot cracking” induced by the laser welding. The investigation is ongoing in the shadow of the (delayed) module production. The procurement of the cables and readout components and their testing is on track. Module assembly procedures are in place and are being exercised.

**DAQ**

To accommodate the new pixel detector, which has more modules, more optical readout links and higher data rates, the pixel DAQ system needs to be upgraded. The two key areas of the upgrade are the Front-End Driver (FED) and the Front-End Controller (FEC), both based on the common CMS µTCA platform. A total of 56 FED modules (barrel/disk: 40/16) and 16 FEC modules (barrel/disk: 8+1/6+1) are needed. Two pre-production versions of the µTCA boards are being evaluated, as well as the FMC RX for the FEDs and the firmware is being developed. The cards are being thoroughly tested at multiple sites with production test stands and a dedicated soak-test stand for the µTCA boards is being setup at CERN. A FED crate test will be setup at Point 5 in the spring of 2016 with emulated data. Integration in the clean room at Point 5 is foreseen for the summer/autumn of 2016. It should be noted that the pilot blades, installed in CMS, will be read out with the same system. Overall the development of the DAQ system for the pixel upgrade appears to be advanced and on schedule and the LHCC commends the group for providing the detector builders the required testing infrastructure well in advance of module assembly.

**Integration**

When the Forward Pixel (FPiX) detector arrives at CERN it will be reassembled and tested at the Tracker Integration Facility (TIF), which is equipped with a CO₂ cooling plant. Testing of the barrel pixel detector is foreseen in the Point 5 clean room. Two identical CO₂ cooling plants are installed at P5, one for the BPIX and one for the FPiX, but both are capable of running both detectors simultaneously. All the needed power supplies are in hand and nine modified supplies have been used extensively for testing. A well-developed plan for testing of the cooling system exists. The current target for the total duration of the shutdown (from beam-to-beam) is 19 calendar weeks. A lots of work remains to be done to define all details and proper sequence for the work, but this is actively being worked on and the collaboration has ample time to fully define the assembly, testing and installation schedule. The LHCC wishes to congratulate the collaboration on their advance preparation of the infrastructure for the pixel integration.

The LHCC notes that an uncomfortable number of significant issues remains to be resolved in the overall pixel project that affect the overall schedule. The Committee strongly recommends that CMS management provide adequate oversight of the project to ensure that the very tight schedule is kept and performance of the detector is not compromised. When contingency can be bought, it is recommended to do so.
ALICE

The ALICE experiment gave an update on the status of the Inner Tracker System (ITS) and the Time Projection Chamber (TPC) upgrade. The ITS is a complete replacement of the current inner tracking detector with a seven-layer MAPS pixel detector of ~24,000 sensors with a total active area of 10.3 m², with 12.5 Giga-pixels. The detector has modest radiation dose requirements of 2.7 Mrad / 1.7 × 10¹³ 1 MeV neutron equivalent, which includes a safety factor of 10. The ALPIDE pixel chip architecture, with 28 × 28 µm² pixels, and a power density of 40 nW/pixel, has been chosen as the baseline architecture for all layers. The chips have in-pixel signal amplification, in-pixel discrimination, in-pixel hit buffer and in-matrix sparsification. Data is read out with a global shutter in triggered or continuous acquisition mode. Four variants of the pALPIDE-2 full-scale prototype chip have been tested on the bench and in beams, and all variants meet the specifications with wide margin. Of the pALPIDE-3 version, 25 chips are available and first results look very similar to the performance of the ALPIDE-2 chip. It is especially noteworthy that in the latest design a modest bias voltage can be applied to the substrate to increase the depletion zone around the n-well collection diode and provide for better signal to noise performance. The collaboration had a successful Engineering Design Review in October 2015. The project schedule calls for completion of the design of the ALPIDE chip in January 2016 and a prototype run in February 2016 with subsequent testing. A Production Readiness Review is planned for July 2016, after which the chip will be submitted for production. The LHCC recognizes that the schedule is aggressive but is impressed by the progress that has been made.

The upgrade of the TPC consists of the replacement of the present Multi-Wire Proportional Chamber (MWPC)-based readout chambers by a new design, consisting of quadruple Gas Electron Multiplier (GEM) planes allowing continuous operation without active ion gating, as well as new pipelined readout electronics. Prototypes of the new readout chambers were tested extensively during the past year and meet the experiment’s requirements for ion backflow blocking and energy resolution, although with only modest contingency. The TPC is crucial to the success of all ALICE upgrades. The Collaboration held an Engineering Design Review in November 2015 with positive feedback from the reviewers. Currently, the design of the Inner and Outer Readout Chambers (IROC/OROC) is complete and preproduction of two ROCs of each has started. The IROC is read out with a single pad plane, whereas the OROC, due to its size, is read out with three separate pad planes. Prototype pad planes for the IROC and IROC3 have been produced. GEM foil design and layout has been completed. A cascaded power supply chain has been adopted to power the chambers that provides good operating margin. A detailed assembly and QA protocol for the distributed chamber assembly is in place and the sites have been qualified and assembly procedures are being put in place. “High definition” scans of the GEM foils allow prediction of the gain, which could potentially allow for qualification of the gain uniformity without gain measurement. The Collaboration clearly benefits from the extensive experience and expertise from the construction of the present detector. The pre-production is used to fine-tune the design parameters and procedures. The Committee suggests that a beam test of the first pre-production ROCs might be very beneficial. A Production Readiness Review is scheduled for March 2016. The LHCC congratulates the Collaboration on the progress made and urges ALICE to remain singularly vigilant on the quality assurance of the full production chain of the chambers.
ATLAS

The ATLAS experiment reported on the status of the Fast Track Trigger (FTK) and the Phase-1 Trigger-DAQ upgrade. The FTK is a system of custom electronics that does global track reconstruction in the pixel and silicon strip detectors after every Level-1 trigger, that is, at 100 kHz. By adding the FTK to the current trigger architecture, the experiment is able to retain its physics capabilities within the 100 kHz Level-1 bandwidth. The rapid pattern recognition and track fitting allows global track reconstruction of all tracks with $p_T > 1$ GeV/c to be done in about 100 µs, thus providing the tracks at the beginning of Level-2 event processing. The pattern recognition uses content addressable memory (CAM) custom chips, which store the $10^9$ patterns. With this architecture all patterns see each hit almost simultaneously. The FTK architecture is based on massive data parallelism, with all silicon hits, from both the pixel and strip detector, transferred to the FTK at each bunch crossing. The readout chain consists of the following elements: the Input Mezzanine (IM), Data Formatter (DF), Auxiliary (AUX) card, Associated Memory Board (AMB), a Second Stage Board (SSB) and the Front-End – Level-2 Interface Card (FLIC). A key element is the AM06 chip in 65nm technology that holds 128k patterns. The chip was submitted for production in June but there were issues with the packaging, which has caused schedule delays. Test sites are up and running and are exercising the system with the AM05 chip. Production versions of all boards are expected for June 2016 and the barrel coverage should be installed by July 2016. The overall schedule of the FTK with respect to the schedule presented at the 2014 winter LHCC meeting is about 8 to 9 months late. The LHCC takes note of the delays and regrets that the ATLAS experiment is unable to take advantage of the FTK at the originally scheduled early date.

The ATLAS experiment also presented the status of the Trigger/DAQ (TDAQ) Phase-1 Upgrade. This upgrade is motivated by the requirement to maintain thresholds within the 100 kHz Level-1 bandwidth to improve the performance of the Level-1 single object triggers. For the calorimeter, this is achieved by the use of ‘Super-Cells’ and increase of the digitization precision. One $(\Delta \eta \times \Delta \phi) = (0.1 \times 0.1)$ trigger tower will map into 10 super cells, with readout for each of the four longitudinal layers and four azimuthal readout segments for layers 2 and 3 each. This will enable the implementation of very effective shower shape variables at the trigger level, which provides for a more effective identification of electrons, photons and leptons, sharpens the electromagnetic, jet, and $E_T$-miss efficiency turn-on curves and allows for an event-by-event pileup subtraction. Also the tau-identification would see considerable improvement. The trigger hardware consists of a Jet Feature Extractor (jFEX) module, an electromagnetic FEX (eFEX), and a global FEX (gFEX). Prototype test modules are available and are being tested. The layout for the jFEX modules is on-going and the boards will be manufactured in the first quarter of 2016. Production issues have hampered the production of eFEX modules, but new boards are expected in early 2016. The gFEX prototype modules will be submitted for production at the end of 2015. The speed of the LAr–L1Calo link is not yet defined. Tests are foreseen in the timeframe of January to March 2016 before a decision will be taken.

The muon trigger upgrade is progressing well. The first prototype of the trigger interface card is expected around March 2016. The interface with the new end-cap sector logic for the New Small Wheel (NSW) will have a production design review in December 2015 and the first prototypes are expected in the fall of 2016. The FELIX development is progressing well and a mini-FELIX will be integrated in detector test beds early 2016. A design review is scheduled for spring 2016. The LHCC regrets to hear about the
manufacturing problems with the calorimeter modules and encourages the Collaboration to monitor all steps of the upgrade closely.

The ATLAS experiment also reported on the activities for the software upgrade for Phase-1. For off-the-shelf electronics, the doubling of the transistor density does not double the computing throughput. Each die can have more and more cores, integrated network controllers and other features, but none of these features are trivial to take advantage of in the code. The ATLAS experiment realizes that the frameworks and algorithms were written for an earlier era of hardware that is hard to adapt to the next generation platforms. The requirements for a future framework have been articulated, with multi-threading a crucial element. The key concept changes have also been identified with, for example, enabling event views per region of interest and dynamic scheduling. Some new elements are already being tested. Also getting multiple GEANT-simulated events running on different threads is being tested on High Performance Computers. A timeline with well-defined deliverables has been proposed for both the framework as well as the algorithm development. The LHCC wishes to congratulate the experiment with the early preparations of the software for Run III and the substantial progress that has been made already in many areas. The Collaboration is encouraged to maintain its momentum in its preparations of the software for Run III and beyond.

LHCb
The LHCC deliberations on the LHCb Phase-1 upgrades are given in Section 9 below.

6. DISCUSSION WITH ATLAS

Physics
The Collaboration has submitted 488 scientific papers so far, including 17 since the previous LHCC session in September 2015. Analysis of the first Run II data is proceeding well, with preliminary results to be reported (along with those of CMS) at a special CERN seminar on 15 December 2015.

ATLAS Run II Operation
ATLAS has been taking data smoothly and with a high data-taking efficiency, of around 92%, and has recorded a total of about 4 fb\(^{-1}\) of proton-proton collisions at 13 TeV collision energy, with 3.3 fb\(^{-1}\) being utilised for analysis. The heavy-ion run is progressing well with about 0.15 nb\(^{-1}\) of Pb-Pb data collected so far. All of the sub-systems are operational with close to 100% channels live.

The Pixel Detector and Semiconductor Tracker (SCT) are working well. Minor SCT data ‘hiccups’, causing inefficiency and data corruption, were fixed via firmware modifications. A low level of increased noise has been seen in some end-cap modules but is not serious. The Pixel Layer-2 readout will be upgraded in the Year End Technical Stop (YETS).

One new large Xenon leak, which is inaccessible for repair, was reported in the Transition Radiation Tracker (TRT); the Xenon leak rate has increased accordingly to 150 l/day. The detector is currently running on Argon for the Pb-Pb collision period, and in 2016 a hybrid running configuration of Xenon / Argon (or with Krypton) will be implemented.

The dew point in the service region just outside the inner detector tracking systems has been worked on, and the worst measured dew point is now at -32 C, giving 12 C of headroom with respect to the inner detector operating temperature of -20 C. Side A will
not be opened in the YETS and the detector will probably be operated in this manner for 2016.

The LHCC took note of issues resulting from a rise in current in the Inner B-Layer (IBL) read-out electronics, which is correlated with luminosity. The resulting temperature rise causes distortion of the detector geometry. ATLAS reacted promptly by creating a task force to understand the effect, which has been traced to a known effect in NMOS transistors. The issue does not affect the functionality of the IBL and the effect is expected to improve with higher radiation dose because of compensation. ATLAS will continue monitoring the effect and should develop a long-term plan to cope with the increased current. The geometry distortions are being tracked by the alignment procedure on a stave-by-stave basis for batches of luminosity within each beam fill.

The LAr calorimeter system is working well; the long-observed low-noise bursts have been found to be correlated with the LAr purity monitor high-voltage system. Two Tile Calorimeter modules have had to be turned off, and one is at 50% high voltage. It is planned to repair two of these modules during the YETS. The Tile Calorimeter muon trigger is being commissioned ready for 2016 operations.

The muon systems are stable. The Cathode Strip Chamber (CSC) system has two planes (with broken wires) turned off—these are planned to be fixed in the YETS—and 8 planes which have been showing sparking have had the high voltage reduced. The Resistive Plate Chamber (RPC) system leak repairs will continue in the YETS and the new trigger towers will be commissioned. The Thin Gap Chamber (TGC) inner middle coincidence has been deployed, resulting in a 22% reduction in the respective muon trigger rate.

The LHCC took note of the bellows distortion in the End-Cap Toroid (ECT) magnet, which was first reported at the September 2015 LHCC meeting; the origin of the distortion is now understood. A plan is in place for the YETS to provide a temporary precautionary vacuum seal, to inspect the current leads and make any required repairs, and to encase the distorted bellows with permanent outer bellows to provide the necessary vacuum seal.

Eight photomultiplier tubes in the ATLAS luminosity monitor LUCID are to be replaced with bismuth-calibrated devices. The Zero Degree Calorimeter (ZDC) has been refurbished with new fibres and reinstalled. The ALFA (Absolute Luminosity for ATLAS) detector was fully installed for the special runs. The AFP (ATLAS Forward Proton) detector trigger cables and services for both arms will be installed in the YETS, and at least one station will be instrumented for 2016 operations.

The trigger/DAQ system is working well. The L1TOPO boards are being used to trigger ATLAS when there is energy in the region covered by the ‘LAr demonstrator’ test boards. Saturation effects were observed with the L1CALO trigger, resulting in ‘early triggers’ for a small number of events; this affects high-ET events and will need to be fixed for 2016 running. The trigger menus (containing 1500 items) are almost ready for 2016 operations and are suitable for luminosities of up to $2 \times 10^{34} \text{ cm}^{-2} \text{s}^{-1}$.

The YETS overview work plan and schedule were noted.

The offline systems are working well. The Tier-0 system is able to keep up with the data rate so far but an increase in capacity will be needed in 2016. Data are being turned around to users within roughly 6 days of being recorded. Reprocessing of the 2015 data sample with the IBL time-dependent alignment constants has started. Heavy-ion data processing is very demanding of the Tier-0 system and is expected to spill over into
Tier-1 systems. Implementation of Tier-2 peer-to-peer transfers has reduced local data storage needs.

Monte Carlo event production for the 2016 run is expected to start in February 2016. The new xAOD analysis model is working well and has resulted in a factor of three saving in analysis-format data storage. Computing needs for the LHC Phase-2 upgraded detectors are still being evaluated. Comments on the general shortage of software expertise were noted; this limitation is taken into account in setting goals for software upgrades and releases.

**ATLAS Phase-1 and Phase-2 Upgrades**

A status report was given on the Phase-1 upgrade projects. All projects are progressing, although delays have been incurred with the development of some components. The Phase-1 upgrade for the muon New Small Wheel (NSW) is advancing, but the Micromegas and small strip Thin Gap Chamber (STGC) production capability is not yet at the nominal rate and significant delays have been accumulated. The ATLAS Fast TracKer (FTK) upgrade is progressing much slower than planned, with the main issue being the demonstration of the functionality of the AM06 read-out chip still pending. The Level-1 Calorimeter Trigger Upgrade is proceeding slower than planned, and the Level-1 Muon Trigger Upgrade is proceeding steadily. ATLAS is undertaking a re-write of the ATHENA reconstruction framework in order to allow multi-threading.

These issues will be discussed and followed up at the detailed review of the Phase-1 upgrade projects, which has been scheduled for 29 February 2016.

Good progress was reported on the Phase-2 upgrade projects for the Inner Tracker (ITK), LAr Calorimeter, Tile Calorimeter and Muon System.

7. **DISCUSSION WITH CMS**

**Physics**

The total number of papers submitted by CMS since the beginning of the data taking is 445 with an additional 68 studies ready for the internal reviews. Among those ready for the internal reviews, ~30 analyses are based on the Run II data. There is one published analysis based on 13 TeV data and three submitted with six more public as preliminary results. Many more 13 TeV results are expected to be presented at the special LHC seminar on 15 December 2015 which is a clear indication of the success of CMS with data collection and analysis at the new energy frontier.

All Run II data will be re-processed by early 2016 with final calibration and alignment constants in time for the analysis to use re-processed data for the winter 2016 conferences, where a large number of new 13 TeV results are expected by CMS.

Highlights of the 13 TeV results include inclusive W and Z cross sections at the new centre-of-mass energy which are in a good agreement with NNLO predictions. Di-jet resonance searches have been performed and no resonance structures have been observed up to ~6 TeV excluding a wide range of predictions in this mass range. In-depth results on the underlying event studies have been obtained.

Total amount of “golden” data collected by CMS in Run II is 2.2 fb⁻¹, 2.7 fb⁻¹ for the analyses with muons, and 3.6 fb⁻¹ total to tapes. The total LHC luminosity delivered to CMS is 4.0 fb⁻¹. The relatively low “golden” luminosity is mainly due to the issues with the CMS solenoid magnet (see below).
CMS Run II Operation

Many improvements and upgrades have been successfully accomplished by CMS during the Long Shutdown 1 (LS1). As a result, CMS was “a new detector” at the beginning of Run II. The main elements of the LS1 improvements are:

- Data acquisition: new architecture, hardware, software.
- Trigger Control and Distribution System: new (uTCA).
- Level 1 trigger: new calorimeter trigger (uTCA)
- Silicon pixels: new modules.
- Silicon tracker: new lower operating temperature (–15 C).
- Electromagnetic calorimeter: new trigger optical links.
- Hadronic calorimeter: new SiPMs, front- and back-end (uTCA).
- Drift Tube chambers: new trigger electronics.
- Resistive Plate Chambers: new chambers.
- Cathode Strip Chambers: new chambers and electronics.

The commissioning of the CMS detector progressed smoothly and efficiently with the number of operating channels in all systems exceeding 97%. Since the first week of the data collection with 25 ns bunch spacing, the data taking efficiency was steady at ~90-92% level, which is similar to the steady data collection during operation in Run I.

Overall, the CMS detector performance was smooth with only a few issues, which have been quickly addressed. In the Tracker the higher luminosity resulted in less hits on the tracks and smaller cluster charge. This effect is under investigation while not affecting high level algorithms or tracking efficiency after the calibration has been performed. In the electromagnetic calorimeter, timing shifts of a few ns have been observed and addressed with more calibrations. The hadron calorimeter exhibited loss of synchronization in the forward calorimeter electronics for a small fraction of the data. Special Monte Carlo sets have been generated to take into account this effect when analyzing the affected data. Muon systems are working well with all parameters within specifications.

CMS is already benefiting from partial implementation of the Phase-1 trigger upgrade. The efficiency for the tau lepton triggers improved by almost a factor of two. Runs with ~25 kHz output rate from the high level trigger have been successfully collected.

During this LHCC meeting, CMS was smoothly collecting heavy-ion data and with proton calibration data at 5.02 TeV having already been completed. Preliminary object reconstruction results from the heavy-ion run are impressive, including Z boson mass peak reconstruction and di-jet events with quenching of one of the jets in the hot nuclear matter.

CMS Solenoidal Magnet

From February 2015 the CMS magnet operation is affected by a not-yet-understood contamination problem. The problem presents itself as an increase in the pressure drop and increase in the temperature difference over the cold box heat exchangers resulting in not enough liquid helium produced to keep the solenoid cold. Major efforts have been devoted by CERN and CMS to understand this issue and even more important to fix it. While some interventions first produced encouraging results (and provided an
opportunity to collect physics quality data) the issue has again reappeared. It is still affecting CMS as of the time of the December LHCC meeting.

Between June and August 2015 various attempts to fix the clogging issue were tried. None worked for more than a few days. The mode of operation of CMS was to deal with the contamination by regenerating the clogged filters, absorbers and heat exchangers (mostly requiring the magnet to be off, often also requiring partial warm up of the cold box). Or replacing filters, absorbers or turbines (some requiring opening the cold box) and repeating when progressive clogging compromised operation.

In the middle of August 2015 more filters were added, 200 K regeneration was repeated, and the system operated quite stably until late October 2015. On 25 October 2015 a very quick and un-expected instability developed. Recovery required exchanging turbine filters as well as several 200 K regenerations. Operation between end of October and early December was less stable but predictable. Clogging was controlled by planned 200 K regenerations (18 hours) on about a weekly basis. Some luminosity has been lost.

Major efforts are/were devoted by CERN and CMS to address this issue

- A special task force was formed.
- Industry and other laboratories became involved.
- Many technical solutions were tried.

While there is no clear understanding of the reason(s) for the issue, it is most probably related to the contamination of the cold box by the oil from the compressors. As such, the main efforts are concentrated on cleaning the system and adding filters.

The short-term plan is to proceed with collecting data, when the magnet is cold and regenerate heat exchangers when they are clogged and to finish the heavy-ion run in such mode. As soon as the 2015-2016 Year End Technical Stop (YETS) starts, major efforts will be devoted to replace as much of the potentially contaminated equipment as possible and clean, with special solvent, the remaining of the system. This plan has been developed jointly by CERN and CMS and has a good chance of success. Extra layers of protection are planned in the cooling system, like a water dryer, to be installed before the cold box. A detailed schedule of the magnet cooling system consolidation is in place to finish in time for the first colliding beams late March 2016.

CMS is calling for an in-depth review of the magnet and its cooling system to understand potential challenges in short, medium and long-term operation. The review by CERN and CMS experts and also external experts is planned for 7-8 December 2015.

**CMS Phase-1 and Phase-2 Upgrades**

The CMS Phase-1 upgrade was reviewed in-depth by the LHCC upgrade reviews team and is discussed in a separate summary in these LHCC meeting minutes (see Section 5).

During the October 2015 meetings of the Resources Review Boards (RRBs) the CMS Phase-2 upgrade scope and cost range have been approved. The CMS Phase-2 upgrade activities since the September 2015 LHCC meeting concentrated on

- Tracker design.
- Forward calorimeter design.
- Muon upgrade.
- Simulation developments.
With the scope of the upgrade defined, major efforts are now directed toward R&D with the goal to have Technical Design Reports (TDRs) for various sub-systems ready, starting with the TDRs for the Pixel Detector and Outer Tracker upgrades in early 2017. Both of these systems require a substantial design, construction and assembly time.

Full-size “long” sensors for the Outer Tracker upgrade are produced at INFINEON which was the first production of n-in-p sensors and the first production on 8” wafers with physical thinning to 200 µm. The first five such wafers are delivered to HEPHY Vienna with the rest of the batch expected at CERN in December 2015. Initial tests show very good quality while some small issues have been observed and are expected to be addressed in the next production cycle.

The high granularity forward calorimeter is among the most challenging of the Phase-2 CMS upgrades. During the Summer and Fall of 2016 test beams studies of Si-HGC electromagnetic and fine hadronic slices with SKIROC-CMS chips were progressing, which included detailed studies of the calorimetric response and performance of the baseline ASIC architecture. The plan is to perform timing studies of the electromagnetic and hadronic showers evolution with ~ 50 ps calorimeter cell timing resolution.

A detailed plan for the Phase-2 TDRs and reviews between early 2016 and the end of 2017 has been developed. During this time frame the tracker, muon and barrel calorimeter as well as end-cap calorimeter TDRs are expected to be submitted. The rest of the TDRs (trigger, Beam Radiation Instrumentation and Luminosity (BRIL) and DAQ) are planned to be submitted in 2020.

8. DISCUSSION WITH WLCG

General

The computing at the LHC continues to deliver adequate capacity for a rapid publication of the analyses based on recent data. Besides the physics results, mostly as preliminary notes but also a few papers, the solidity of the LHC computing is demonstrated by the increasing capacity to exploit the allocated resources and by the constant increase in the performance indicators. As examples one can cite the quantity of data treated in one day at the Tier-0 that reached 450 Tb, the data amount transferred by ATLAS and CMS that reached 20 PB in the last month, the 5 PB of raw data collected by ALICE, exceeding the Run I data sets, as well as the impressive installation of the express ("turbo") stream by LHCb, which made possible for the first time the production of a full online data analysis stream leading to a physics publication. This performance has been obtained as a thorough process of consolidating the resources and the infrastructure, adjusting the models and preparing the necessary development for the future needs and paradigms in computing.

The referees congratulate WLCG, the sites, and the experiments' computing teams for the successful operations, efficient resources usage and innovative approach towards the next computing challenges at LHC.

WLCG

The resources scrutiny reveals a good agreement with the overall picture explored within the global assumption of a flat budget. The adjustments are in general absorbed in a judicious resources re-distribution. The 2017 resources, for which the scrutiny just started, revealed a potential deficit in tape provisions that can be absorbed in a purchase rescheduling.
The long-term perspective is mentioned in a context that becomes more structured for all experiments and for WLCG. The intensive preparation work during the Long Shutdown 2 (LS2) demonstrated the capacity to evolve from adiabatic to more drastic changes, with a clear support from the User communities. The three pillars of the long-term action are: experiment core algorithms, software performance and infrastructure evolution. All experiments have started the upgrade task forces or working groups, either as a resources driven schedule (via Technical Design Reports) or by re-orienting the implicit internal resources. The common project and the method exchanges are now part of the common development culture. The HEP Software foundation, though evolving slower than expected, may provide the expected framework for further cooperation; the forum on tracking started recently may provide a first concrete action for LHC experiments and is to be followed attentively. The Cloud tender initiative has started to produce the first feedback, that is positive and promising, and the extension of that tender to significant and complex resources will soon give the necessary feedback concerning the exploration of this computing alternative for the future. The road towards the computing for the Phase-2 upgrades is expected to be clarified during the next year, including an overview of the necessary R&D and a first estimation of the schedule for Technical Design Reports. An initial discussion will take place in the next session of the LHCC.

**ALICE**

The data processing is stable and efficient. The number of tasks in the pipeline is manageable and all requests are fulfilled in due time. The infrastructure is growing according to the plan and is able to cope with the expected load for reconstruction, Monte Carlo production and analysis. Unexpectedly large distortions in the Time Projection Chamber (TPC) at high interaction rates required an extra calibration step and additional software development, which successfully reduced the memory per job to the normal range. The remaining items around the Online-Offline (O²) upgrade project were clarified, including an increase of the bandwidth from Point 2 to the Tier-0, the compatibility with the WLCG development and the projected resources evolutions at CERN.

**ATLAS**

The 2015 data have been processed, distributed and analysed without major issue. The monitoring of the network usage across sites reveals an increased activity with around 100 Gb/s bandwidth occupancy and 20 million files transferred per week. An evolution of Grid sites typology and topology within the WLCG framework is under study. Given the complexity and the need for detailed simulation, sizeable computing resources will have to be booked for the studies related to the future upgrade Technical Design Reports to be produced in the next years. The ATLAS software long term planning is well on track, with several prospective workshops planned and a document summarizing the upgrade computing is circulated within the Collaboration.

**CMS**

The data processing proceeds smoothly and reached about 150 kjobs in parallel, with an efficient usage of resources (up to 98% in Tier-1s). A global pool for resources managed through glideInWMS allows to centrally prioritize jobs and manage the opportunistic resources. The data sets are finalized and the Monte Carlo production for winter conferences is well underway. The analysis and production workflows see constant improvements. The User community around CRAB3 is constantly increasing. An improved allocation of priorities and sites improved the latency for digitization and
reconstruction jobs by a factor three. The High Level Trigger (HLT) continues to act as a flexible and significant computing resource, the inter-fill usage is at study. The future paradigms are explored in connection with CERN open lab. The workload extension to Amazon Web Services (AWS) Cloud computing will be tested towards a large-scale production.

**LHCb**

The Run II data processing is well underway and proceeds at the design level. Increasingly efficient usage of the resources has been observed. Opportunistic computing as well as the usage of the CERN-IT cloud are explored. The heavy-ion data (Pb and Ar) are in the first pass, while the re-stripping of proton-proton data has started. The Run II workflows have been successfully exercised (turbo stream, Tiers re-tuning etc.), as well as optimizations of the data flows through file merging. The mesh processing allows the Tier-2 sites to dynamically contribute to workflows and is proven to be a very flexible way of distributing work across sites. The simulation version Sim09 is being validated. The next major step in the simulation framework will be using new versions of the connected libraries (GEANT4, generators, Root 6 etc.), with foreseen support both Run I and Run II configurations. The brainstorming towards Run III has started, with a dedicated workshop and an internal organization towards the Technical Design Report expected next year.

9. **DISCUSSION WITH LHCb**

**Physics**

The scientific production of the LHCb Collaboration proceeds well. Since the last LHCC meeting, 14 papers were published and ten papers were submitted, yielding 53 papers for 2015 and 290 papers in total. This number is slightly lower than that in 2014. The reduction is mainly attributed to the activity focusing on the Run II start-up and, in particular, on the preparation of the new HLT and turbo stream data management. LHCb performed a search for the lepton-flavor-violating decay $D^0 \to e^+\mu^-$ setting a branching fraction upper limit of $1.3 \times 10^{-8}$ @ 90% confidence level, which 20 times lower than the Belle result. Via double parton scattering, they observe $Y$ production in association with open charm at $\sqrt{s} = 7$ TeV and $\sqrt{s} = 8$ TeV, evidence for the strangeness changing weak decay $\Xi^- \to \Lambda_b^0 \pi^-$, a measurement of forward $W$ and $Z$ production in proton-proton collisions at $\sqrt{s} = 8$ TeV and new studies of the angular analysis of $B^0 \to K^{*0} \mu^+\mu^-$. At center-of-mass energies of 7 TeV and 8 TeV, LHCb measure $W$ and $Z$ cross sections in the forward region $(2<\eta<4.5)$ of $\sigma(W^{+} \to \mu^{+}\nu) = (1093.6 \pm 2.1 \pm 7.2 \pm 10.9(E_{LHC} \pm 12.7(L))$ pb, $\sigma(W^{-} \to \mu^{-}\nu) = (818.4 \pm 1.9 \pm 5.0 \pm 7.0(E_{LHC} \pm 9.5(L))$ pb and $\sigma(Z \to \mu^+\mu^-) = (95.0 \pm 0.3 \pm 0.7 \pm 1.1(E_{LHC} \pm 1.1(L))$ pb. Using both the SMOG system and van-der-Meer scans, LHCb reduce the uncertainty from the luminosity measurement by over a factor of five with respect to that in ATLAS and CMS yielding the most precise vector boson cross section measurements at LHC. They also calculate double ratios of $W$-to-$Z$ cross sections for 8 TeV compared to those at 7 TeV, which deviate from several theory predictions by two standard deviations. For the $B^0 \to K^{*0} \mu^+\mu^-$ angular analysis, a method of moments in $q^2=1$ GeV$^2$ bins and a fit to decay amplitudes modeling the $q^2$ dependence for crossing points more precisely were performed in addition to the maximum likelihood fits. Due to larger errors in the moments method, the discrepancy in the $S_5$ variable is less significant. Using EOS software, the ML fit is extended to include a modified $C_9^{SM} + \Delta C_9$ Wilson coefficient in the fit yielding a new physics
contribution of $\Delta C_9 = -1.04 \pm 0.25$. Vincenzo Vagnoni is the new physics analysis coordinator for 2016 taking over from Patrick Koppenburg.

**LHCb Run II Operations**

The high-intensity 25 ns proton-proton running at 13 TeV was conducted successfully in October and November 2015. With trigger settings for core physics, LHCb recorded an integrated luminosity of 320 $\text{pb}^{-1}$, 88.4% of the luminosity delivered by the LHC. Since the detector and the DAQ performed extremely well, the largest inefficiency resulted from a 7.7% average dead time, which varied from 15% to 5% for fills with a small and large number of bunches, respectively. For the remainder of the year, LHCb participated for the first time in a three-week Pb-Pb run. In addition, several special runs were taken: van-der-Meer scans, proton-Ne, proton-He and proton-Ar SMOG (System for Measuring Overlap with Gas) runs at 6.5 TeV, a 5 TeV proton-proton reference run as well as proton-Ar and Pb-Ar runs at 2.51 TeV.

Conditions in Run II varied a lot since intensity increases occurred in small steps due to limitations in the LHC operation caused by various problems (e.g.: TDI vacuum, electron cloud and heat overload) that were partially solved. Under stable beam conditions, the average number of interactions per crossing was set to $\mu = 1.1$. It was leveled for each fill by moving the beams with respect to each other. The Level-0 trigger and High Level Trigger (HLT) were adapted constantly to maximize efficiency. The 40 MHz bunch crossing rate was reduced to 1 MHz by the Level-0 trigger that selects events based on multiplicity and calorimeter/\mu-detector information. The Level-0 operates at fixed latency of 4 ms and with higher thresholds than in Run I. The HLT farm has nearly doubled with respect to that in Run I using 50880 logical cores. It is split into two applications: HLT1 and HLT2. After HLT1, events are buffered on a 5 PB disk so they can be used to update alignment constants for direct application in HLT2 and in HLT1 in the next run. The HLT2 also outputs a turbo stream providing data than can be analyzed without any further offline processing. The HLT output rate is 12.5 kHz and event processing is 40% faster than that in Run I. The same online and offline reconstruction and Particle Identification require prompt calibrations and alignments: to align the Vertex Locator (VELO), the Trigger Tracker (TT), the Inner Tracker (IT) and the Outer Tracker (OT) once per fill; to calibrate the Ring Image Cherenkov (RICH) detector, OT and global time-zero once per run; to perform the CALO calibration occupancy method once every 50 pb$^{-1}$; to perform the muon alignment and RICH mirror alignments every few fills; and to perform the CALO calibration with $\pi^0$ once per month. The evaluation and update of calibration and alignment constants is fully automatic. Shift personnel regularly check reference plots.

For Pb-Pb running, the VELO and tracker alignments have been switched off temporarily and are monitored closely by experts. The real-time alignment and calibration of all sub-detectors work very well. The HLT2 online performance is the same as the offline performance in Run I. For $B^+ \rightarrow D^0 \pi^+$, the efficiency in Run II is $>90\%$ compared to $75\%$ in Run I. The interaction point resolution, track efficiency and kaon identification efficiency are the same as those in Run I. Due to the removal of the aerogel system, the pion misidentification at low momenta improved in Run II. For the Pb-Pb run, all subdetectors were switched on following pre-established procedures and were constantly monitored to look for aging effects by checking parameters such as occupancies and currents. Using the same settings as for the proton-proton running, the detector operation was very smooth despite a heavier load on trigger and reconstruction.
LHCb Phase-1 Upgrade

In September 2015, LHCb revised the milestone schedule for the Phase-1 upgrade. Since then all seven milestones (four on the Muon System, two on the VELO and one on the RICH) were met. The Upstream Tracker (UT) is progressing well. However, two issues on top biasing and the embedded pitch adapter have not been resolved. The test beam data analysis is still ongoing. A Progress Readiness Review is scheduled for the first quarter of 2016. The UT SALT8v2 ASIC was submitted. The first version of SALT128 is planned for spring 2016, an engineering run for the end of 2016 and production in the second quarter of 2017. The schedule is aggressive and critical; in particular the test infrastructure is crucial. New flex cables with reviewer remarks implemented are under test. The Production Readiness Review is scheduled for the third quarter of 2016. The VELO is progressing well. Two Engineering Design Reviews were conducted since September 2015 on microchannel cooling and on hybrid/electronics. Concerning the microchannel cooling of the 400 µm thick Si sensors with 200×120 µm² channels using CO₂ at a pressure of 20 bar, three issues remained on safety, connector design and mounting procedure. The tender will be launched in the first quarter of 2016. The VELO electronics, comprising the opto-power board, feed-through boards, the VELOPIX hybrid and the flex tapes for data and control, has no major issues but the high-speed data transmission is challenging. The VELO foil has no showstopper. The box has an impedance of 4.7 mΩ compared to the 90 mΩ of the full LHC and poses no problem. NIKHEF produced a 500 µm thick half-sized box from an aluminum block that is leak tight. NIKHEF is presently machining a 250 µm thick half-sized box. A full-size 500 (250) µm thick box is expected to be finished in the second (third) quarter of 2016.

The RICH upgrade programme is well advanced. Two prototype photon detector modules, each equipped with two ECs mounted on a cooling bar, CLARO8v2 ASIC and digital board prototypes, were studied in a test beam in the summer of 2015, in time to present results in the Production Readiness Review held in September 2015. The design for the photon detector assembly for RICH-2 is almost finalized. The RICH-1 mechanics is progressing and converging to its final design. The tender for the MaPMTs was finalized and the order was placed. The Production Readiness Review for the elementary cell at the boundary between small and large PMTs, the packaged CLARO8v2 ASICs and frontend boards plus backboards will be held in the first quarter of 2016. The Engineering Design Review for the RICH-1 and RICH-2 mechanics is planned for the first quarter of 2016 while the Engineering Design Review for the photon detector assembly will follow in the second quarter of 2016. In the test beam data, Cherenkov rings were recorded. The radius of the fitted ring was (60.6±0.6) mm, which is in good agreement with a radius of (59.9±0.76) mm reconstructed in simulations.

The ICECALv3 ASIC and the front-end boards for the calorimeter have been tested with the full calorimeter module in a test beam in September 2015. An Engineering Design Review for the readout electronics is planned for the third quarter of 2016. The new muon electronics has undergone a full review. The system uses new TDC chips (nSYNC), new data transmission boards (nODE boards) as well as new control and new
configuration boards (nPDM, nSB). The design of all four key elements is well advanced and there are no apparent technical showstoppers.

The Scintillating Fibre (SciFi) tracker is advancing rather well. The detector uses about 12000 km of 250 µm thick scintillating fibres with double cladding that are arranged in a six-layer mat at a pitch of 275 µm. The fibres have an attenuation length $\Lambda > 350 $ cm. A single fibre measured with a PMT yields six photoelectrons at the readout end corresponding to 16 photoelectrons at the mirror end when read out with SiPMs. The fibre bumps still pose a problem although the manufacturer reduced the number of bumps by a factor of two. While bumps with $\leq 300 $ µm thickness can be handled, thicker bumps have to be cut out. The production schedule, however, can tolerate at maximum eight thick bumps per eight kilometre fibre. A fall-back solution is to increase the pitch to 350 µm. To compensate for the larger gap size, eight-layer mats are needed increasing the number of fibres by 4%. The impacts of the new layout are under study. An eight-layer mat was tested already together with six-layer mats in a test beam in November 2015. The data analysis is still ongoing.

The maximum radiation dose for the fibres near the beam pipe is 35 kGy. Measurements show that the light output is reduced by 40%. Low-dose irradiation is under study. First results from the November 2015 beam test of a 2.5 m, six-layer fibre mat show excellent efficiency and position resolution measuring $\varepsilon = 99\% \ (99.6\%)$ and $\sigma = 79 \ \mu m \ (82 \ \mu m)$ after charge weighting for track angles of $0\degree (10\degree)$, respectively. The fibre mat production will start in January 2016. The fibre quality is first checked at CERN before shipping fibres to the four fibre mat production centres (Aachen, Dortmund, EPFL and Kurchatov). A winding machine will produce individual six-layer mats. Alignment pins on the mat produced through glue-filled holes on the wheel define the centre and fibre direction. The brittle fibre mats need further treatment. The baseline design consists of lamination with a 25 µm thick polyimide foil. After cutting the mats to the correct size and polishing the fibre ends, they are tested before shipping them to one of two module production centres (Heidelberg, NIKHEF). Every week, 16 fibre mats are produced, of which eight mats are needed to build a module. Thus, each module production centre produces one module per week. Tested modules are shipped to CERN.

Hamamatsu produced new SiPMs with improved trenches, which have an expected cross talk of 4%, an expected photon detection efficiency of 47% and a better-adapted geometry with smaller gaps. LHCb ordered 150 SiPMs for tests. Studies with KETEK SiPMs are continued though, but due to packaging problems new detectors are not expected before February 2016. Neutron irradiation studies were performed with fluences up to $12 \times 10^{11} \ \text{n/cm}^2$. Though the dark rate increases significantly, the dark count spectrum recorded with the PACIFIC chip shows individual photoelectron peaks. The noise cluster rate is expected at 3 MHz per 128 channels in accordance with the assumptions in the Technical Design Report. With the PACIFIC 3 chip, LHCb expects to measure the noise cluster rate, which will be lower for the new SiPMs due to reduced cross talk. Using the cold bar, the dark rate will be reduced and SiPMs can be positioned.

All elements of the readout electronics are in hand. The master board houses four small boards, each carrying four PACIFIC ASICs that digitize SiPM data. It holds four clusterization boards, each equipped with two clusterization FPGAs (Microsemi Flash FPGA IGLOO2) and eight GBTx chips serializing data in wide bus mode. Optical data transmission is done with four optical VTTx links. The PACIFICv3 readout chip ($4 \times 3.7 \ \text{mm}^2$) has 64 channels in 130 nm TSMC technology. It was received in September 2015 and tests of bias blocks, I2C slow control, DACs, input stage, anode
voltage control, internal charge injection and offset trimming were successfully performed. Further improvements are needed for the TSMC output buffers and clock tree. The integrator needs to be faster to allow for a larger signal variation of the signal time. A threshold scan with a SiPM clearly shows individual photoelectron peaks. Three master boards and ten clusterization boards were tested. Two setups were mounted on the cooling frame while one setup was used for temperature tests. Test of data processing and data transmission are ongoing.

For the SciFi, the milestones for 2016 include a Production Readiness Report for fibre mats in April, an Engineering Design Review for SiPM and the readout electronics in May, a Production Readiness Review for module construction in June and an Engineering Design Review for the cold box in July. The PACIFIC will have a Production Readiness Review in May 2017. The schedule is very tight leaving little margin for delays.

10. DISCUSSION WITH ALICE

Physics

Since the LHCC meeting of September 2015, six ALICE papers have been published and four have been accepted for publication by journals. A further 11 new papers have been submitted. This brings the total number of ALICE papers to 139.

The new papers cover a broad range of topics in all three collision systems, proton-proton, proton-Pb, and Pb-Pb, among them the first publication of pseudorapidity and transverse-momentum distributions of charged particles in proton-proton collisions at $\sqrt{s}=13$ TeV.

An important milestone is the publication of direct photon production in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. Deconfined quark-gluon matter, as well as hadronic matter created in the course of the collision, emit thermal direct photons, carrying information about the temperature, collective flow and space-time evolution of the medium. Different $p_T$ regions are dominated by photons radiated at different stages of the collision. The direct photon spectrum at low $p_T$ contains information on the initial temperature of the plasma created. ALICE observes an excess of direct photons in the region where thermal radiation is expected ($0.9 < p_T < 2.1$ GeV/c), while the larger $p_T$ part of the spectrum is in agreement with perturbative QCD calculations. The excess can be associated with an effective temperature of $T_{\text{eff}} = (304 \pm 11 \pm 40)$ MeV, 30% higher than that reached at RHIC energies.

The recent publications also reflect the increasing importance of jets in the study of the properties of the plasma, which is expected to modify the jet yield and fragmentation relative to proton-proton collisions. The measurement of such modifications gives insight into the mechanisms of energy loss of partons in the medium and ultimately into the properties of the medium itself.

One of the studies aims at exploring possible medium modifications to the substructure of inclusive charged jets in Pb-Pb relative to proton-proton collisions by measuring a set of jet shapes including the radial moment and the momentum dispersion. They provide complementary information on the fragmentation and can help to discriminate between two different scenarios: intra-jet broadening or collimation as a result of jet quenching. The observed jet shape modifications suggest that the in-medium fragmentation is harder and more collimated than vacuum fragmentation as obtained by a PYTHIA calculation validated with proton-proton data at 7 TeV.
The Quark Matter conference series is the major meeting in the field of heavy-ion physics. At the 2015 Quark Matter in Kobe Japan (Sep 27-Oct 3) ALICE was well represented with one plenary talk, 27 parallel talks, one flash talk, and 50 posters.

The LHCC congratulates ALICE on these accomplishments.

ALICE Run II Operations

ALICE has completed a successful 13 TeV proton-proton data taking period. Data taking rates up to 5 Hz/μb with rare triggers and minimum bias data taking at low pile-up have been achieved. A total of 600M events of minimum bias data were taken with 4.3 pb⁻¹ muon triggers and 1.8 pb⁻¹ high multiplicity triggers been recorded. ALICE reached or exceeded all data taking goals in this period. All new detectors (the Electromagnetic Calorimeter (ECAL) / Dijet Calorimeter (DCAL), the forward shower detectors ADA and ADD, and the Charged Particle Veto (CPV) detector) were included in the runs and all new triggers (Transition Radiation Detector (TRD) sub-Level-0, CALO Level-0 and Level-1g, jet) were running in production mode. The new electromagnetic DCAL is now fully calibrated and integrated in the trigger. All detectors were running stably and efficiently. With the new gas mixture, ArCO₂ (90:10), the Time Projection Chamber (TPC) showed a stable response to the high fluxes up to 800 KHz interaction rate (14 Hz/μb). The Muon Chambers were tested up to the equivalent Run III rates of 2.5 MHz (42 Hz/μb). The beam induced backgrounds were a factor 10 better than those in the 2012 run, allowing ALICE to take data right from the beginning of each fill.

In Week 47, the LHC collided protons at √s=5.02 TeV, the same centre-of-mass energy per nucleon pair as the Pb-Pb run at full energy. Data taken at this energy is an important reference for the heavy-ion experiments, allowing a more precise comparison of Pb-Pb with proton-proton collisions without the need of extrapolating proton-proton spectra to the relevant Pb-Pb energy. The run was a complex operation with short set-up times and little contingency. ALICE successfully recorded data for three days, accumulating 2.5 nb⁻¹ minimum bias and 112 nb⁻¹ muon triggers. One van der Meer scan was performed during the reference run.

During the start-up period of the heavy-ion run, ALICE ran without the TPC and Muon System due to unstable conditions, using this time to tune the Zero Degree Calorimeter (ZDC) and V0 trigger detector high voltage. Early in the run, the Pb-Pb luminosity suffered from problems in the injector chain (SOURCE - LINAC - LEIR - PS – SPS) providing only 1.1×10⁸ Pb⁸⁺ ions instead of the expected 1.6×10⁸ Pb⁸⁺ ions. Only in the last two days before the LHCC meeting did the situation improve with increased bunch charges close to 1.4×10⁸ Pb⁸⁺ ions. A modified filling scheme (100/150ns) might bring the intensity up by 20%. Since the beginning of the LHCC week, ALICE reached the desired top luminosity and started to level of 1×10²⁷ cm⁻² s⁻¹ for ~1.5h at the beginning of each fill. At rates of 1000 Hz/b, ALICE is reading out 16 GB/s, a rate that is reduced through the Higher-Level Trigger (HLT) compression to 6 GB/s before going to tape. Tests showed that 8 GB/s can be sustained.

Overall, ALICE is running stably and is collecting data with good efficiency at close to design luminosity (1000 Hz/b). Due to the higher multiplicity in √s_{NN}=5 TeV Pb-Pb collisions and the switch from NeCO₂ to ArCO₂ as TPC gas mixture, slightly increased distortions in the TPC were expected. However, ALICE reports unexpectedly large localized distortions that are currently not fully understood. Work on calibration and distortion corrections is in progress. Whether or not these distortions have any impact on the requirements for the Phase-1 upgrade of the TPC is unclear at this point.
Current Upgrades

As documented in the minutes of September 2015 LHCC meetings, there have been problems in the commissioning of the RCU2 upgraded readout cards for the TPC. The problems were related in particular to data errors in the SmartFusion FPGAs, when operating the full card with four readout branches per card at the design DDL2 speed of 4.25 Gigabits per second (Gb/s). Intense work has been carried out since the last LHCC meeting in collaboration with manufacturers MicroSemi. In the absence of a full solution to the problem and given the increasingly strong time pressures, a compromise solution has been found in which the data rate is reduced to 3.125 Gb/s. The boards have been stress-tested at this speed and perform without errors (7 boards tested over several days with a total throughput of 110 TBytes). The overall increased performance in readout rate compared with the original RCU cards is a factor of 1.9, which can be compared with the design improvement factor of 2.6 at 4.25 Gb/s.

Modification of all 240 boards to 3.125 Gb/s is now taking place, which requires replacement of one component per board. Each modified board is being tested with a 24-hour shift schedule. One sector is to be installed during the Year-End Technical Stop (YETS), with the remainder to follow in February 2016 if no further problems arise.

Phase-1 Upgrades

Online-Offline Computing System (O2)

The main goal of the ALICE O2 upgrade is a complete redesign of the online computing system to address the major challenge of sampling the full 50 kHz Pb-Pb interaction rate after Long Shutdown 2 (LS2). In the O2 Technical Design Report, ALICE presented a well-developed design for a drastic reduction of the data volume, from 1.1 TB/s to 90 GB/s. The project was approved by the LHCC in September 2015. The UCG report emphasized that in making this recommendation it was assumed that the O2 computing arrangements are acceptable to the WLCG. It was further commented that the implementation of O2 involves several CERN support groups, personnel, and infrastructure and requested a clear agreement on the division of these responsibilities between ALICE and CERN to be reached prior to the actual implementation of the project. The O2 Technical Design Report was approved by the Research Board, under condition that the issues listed in the UCG report are resolved.

The LHCC takes note of the positive results of the meeting held on 16 October 2015 between ALICE and representatives of the IT Department and WLCG, clarifying the compatibility of both, (i) the overall O2 architecture with the WLCG, and (ii) the GRID resource evolution with the assumptions presented in the Technical Design Report. The agreement on the precise amount of disk/tape storage available on the GRID in the years 2018-2020 will be discussed with the Computing Resource Scrutiny Group at a later stage of the project.

The O2 operation also implies the upgrade of the network bandwidth from the experiment site to the Tier-0, as well as from CERN to the Tier-1 sites. While requests for the latter will be discussed in the near future, the cost for the bandwidth increase to the Tier-0 is being established.

On 6 October 2015, the CERN Directorate convened a meeting with the four LHC experiments to examine the global requirements for the operation of online/offline computing after the LS2.
In a series of meetings between ALICE and CERN services, it has now been verified that the O² cost breakdown in the Technical Design Report is complete and the budget for services and infrastructure is adequate.

The costs of the fibre optic network from the new detectors (Inner Tracking System (ITS), Muon Forward Tracker (MFT) and TPC) to the computing farm, and the additional electrical power (2.5 MW) needed for the O² operation have been evaluated by the EL group of the CERN Engineering Department (EN-EL) and are covered with proper contingency by the O² budget as specified in the Technical Design Report. In particular, the electrical power increase can be obtained with the installation of two standard CERN transformers of 2 MVA, possibly during the YETS in 2016.

A new computer room (CR0) is needed to install part of the computer and storage system. The most convenient choice is the purchasing of a commercial Modular Data Center (MDC) that includes cooling, racks and power distribution and limits the requests to CERN services to the connection to the electrical and water distribution networks. ALICE plans to complete a first market survey and the purchasing of 20-30% of the total capacity in year 2016. The acquired lab could be moved to the experimental site (Point 2) in year 2018 when 10% of the computing system will be installed. Full deployment of the computing room and of the computer and storage facilities is scheduled for year 2020.

**SAMPA Chip**

The SAMPA ASIC is a vital component of the Phase-1 upgrades, allowing continuous readout of the TPC and muon chambers. Full funding for the production of all required chips has now been secured from Brazil. The lead engineer for the analogue part of the chip has moved to Colombia, where he will continue to work on the project, whilst Sao Paolo will hire a replacement as well as a further electronics engineer to work on the project.

There has been a delay of five months (from July 2015 to December 2015) in the MPW2 submission due to design changes in the front end as well as overall chip optimization. ALICE decided to proceed with a third iteration (MPW3) independently of the outcome of MPW2. Funding for MPW3 is in place and this is planned to go ahead with submission on a timescale of November 2016. An internal design review of the SAMPA chip is taking place imminently.

**Muon Forward Tracker (MFT)**

The Technical Design Report and the UCG addendum of the MFT were approved by the LHCC in September 2015. Funding for the project is almost exclusively through the French funding agencies, IN2P3 and CEA (IRFU at Saclay).

Since the previous LHCC meeting, CEA funding has been allocated and the IN2P3 included the MFT budget in their overall funding envelope for experiments at the LHC. The ALICE groups expect the Memorandum of Understanding with IN2P3 for the MFT project to be signed within the next few weeks.

The discussion with ALICE on the ITS and TPC upgrades is a part of the LHC Upgrade section (see Section 5).
11. DISCUSSION WITH TOTEM

The LHCC congratulates TOTEM on the interesting physics results from the most recent published analysis of elastic scattering data at 8 TeV over a very broad range of momentum transfer, \( t \). The results confirm the need to modify the traditional assumption of a constant phase and a purely exponential modulus of the hadronic amplitude. The first analysis of the 13 TeV elastic scattering data was also shown, showing a continuous behaviour, without secondary structures, from the diffraction dip up to the largest measured value of \(|t|\) of around 3.5 GeV\(^2\).

The LHCC heard a report on the CMS beam-pipe replacement during the upcoming Long Shutdown 2 (LS2). CMS and TOTEM are collaborating to develop a new set of possible designs, which do not conflict with the presence of the T2 telescope or possible upgrades of it. The LHCC recognizes the need to maintain detector coverage in the region occupied by T2, and welcomes the joint efforts by CMS and TOTEM to adapt the design of the new CMS beam pipe to accomplish this goal.

The work plan regarding the timing detectors for the vertical Roman Pots outlined during the previous LHCC has been accomplished. One complete 4-plane detector package was installed in a Roman Pot during the third Technical Stop in 2015. Tests in the presence of beam, with the Roman Pot in its garage position, were then performed in the last part of the run. The tests confirmed the expected behaviour of the detector, but pointed to the need for minor modifications to the high-voltage distribution system, due to the observation of discharges. This will be fixed during the Year-End-Technical Stop (YETS). The available detector components will be assembled during the YETS into four partially instrumented detector packages. Each detector will have three planes with four crystals each, compared to the four planes and eight crystals/plane of the final configuration. The detectors will then be installed in the roman pots.

**Progress of the CMS-TOTEM Precision Proton Spectrometer (CT-PPS) Project**

The Roman Pot insertion tests performed during the autumn 2015 have been very successful. The pots were kept in position at 20.7\( \sigma \) from the beam during stores with up to \( 4.8 \times 10^{33} \) cm\(^{-2} \) s\(^{-1} \), and for up to 20 hours, without any issue of beam instability, pressure, temperature or vacuum. The goal for 2016 is to continue tests and operate with luminosities up to \( 10^{34} \) cm\(^{-2} \) s\(^{-1} \), and possibly down to 15\( \sigma \).

Two quartic modules of the timing detectors have been built and put on the SPS test beam in the autumn. The time resolution performance was significantly worse than expected, and worse than earlier tests done at Fermilab in 2012 with a detector composed of just two adjacent bars. A large amount of signal sharing across the multiple bars of the 2015 module has been observed as a cause of the deterioration in time resolution, from the 30-35 ps of the 2012 test to the 75-125 ps measured in 2015. A crash programme has started, with the ultimate goal of replacing the quartic modules with silicon or diamond detectors (from the RD50 project and from the TOTEM vertical timing projects, respectively). At least one of the available quartic modules would be possibly installed in a Roman Pot during the YETS, to enable commissioning tests of the readout, DAQ and integration in CMS throughout 2016, while waiting for the availability of the improved detectors (possibly by the autumn 2016). The progress with the other elements of the project (e.g. the reference timing system, tracking detectors, DAQ hardware) is consistent with the goal of carrying out the above-mentioned commissioning tests during 2016.
12. DISCUSSION WITH LHCf

During Run II LHCf recorded 13 nb\(^{-1}\) of proton-proton collision data at 13 TeV in a dedicated (low-luminosity) run just before Technical Stop 1 (TS1), when the detectors were removed from the LHC tunnel.

Data analysis is currently focused on the measurement of the energy distribution of photons emitted in the very forward region. In particular, the ongoing LHCf physics analysis aims to improve the precision of the energy scale, the photon/hadron separation power and the rejection of multi-hit events. The LHCf goal is to publish the photon spectra in February 2016.

A successful test beam with protons, electrons and muons was carried out at the SPS in July-August 2015 to obtain the absolute scale of the calorimeter energy for both electromagnetic and hadronic showers. The measurements confirm the relative energy resolution of 4\% for electromagnetic showers, in agreement with the Monte Carlo predictions.

The production of Monte Carlo samples needed for the evaluation of the detector acceptance and the corrections relating with particle identification is in progress and will be completed in January 2016.

The first meeting after the 13 TeV run of the joint LHCf-ATLAS Collaborations was held on 27 October 2015 to plan the analysis of diffractive events exploiting the information on the charge multiplicity measured by ATLAS.

LHCf expressed interest to the LHCC for a proton-Pb run during Run II. A Letter of Intent is in preparation and will be presented at the LHCC meeting in March 2016. Simulations are being carried out to define the physics goal and to study the operation feasibility. The TAN absorber activation at the end of the high-luminosity proton-proton run is being evaluated in collaboration with the CERN radio-protection group.

13. TEST BEAMS

The LHCC took note of the report from the PS and SPS Physics Co-ordinator on the LHC test beams. The proton and Pb-ion test beam runs for 2015 have been completed successfully. The Co-ordinator also showed the draft schedule for the East Area and North Area test beams for 2016. The possible extension of the NA61 Pb run by one to two weeks will have an impact on the LHC-related test beams and will also be discussed in the SPS Committee. The draft schedule will be finalised following discussions with the beam line physicists. He also reported that the experimental spectrometer magnets used in the EHN1 North Hall are ageing and need some dedicated efforts to keep these valuable assets available to the User community.

14. CLOSE-OUT WITH THE DIRECTOR-GENERAL

The LHCC informed and discussed with the Director-General the status of the LHC experiments and their plans for future upgrades. The discussion focused on a status report concerning the LHC machine, experiment and computing from LHC Run II; the status of the physics analysis of all the LHC experiments; as well as the Phase-1 and Phase-2 experiment upgrades.
15. REFEREES

The LHCC referee teams for this session are as follows:

ALICE: C. Bloise, P. Newman, C. Sfienti, T. Ullrich (Co-ordinator)
ATLAS: P. Burrows (Co-ordinator), F. Kunne, M. Lancaster, B. Ratcliff
CMS: M. Demarteau, D. Denisov (Co-ordinator), H. Yamamoto
LHCb: C. Diaconu, G. Eigen, T. Kuhr, S. Miscetti (Co-ordinator)
LHCf, MoEDAL, TOTEM: M. Mangano (Co-ordinator), C. Bloise, P. Newman
LCG: C. Diaconu (Co-ordinator), T. Kuhr, M. Lancaster, H. Yamamoto

Experiment Upgrades:
  General: M. Demarteau (Co-ordinator)
  RD39: G. Eigen
  RD42: M. Demarteau
  RD50: G. Eigen
  RD51: D. Denisov
  RD52: P. Burrows
  RD53: M. Demarteau

16. The LHCC received the following documents:

- CERN-LHCC-2015-017 Minutes of the 123rd meeting held on 23-24 September 2015
- CERN-LHCC-2015-019/LHCC-G-165 CMS Phase II Upgrade Scope Document

DATES FOR LHCC MEETINGS

Dates for 2016
2 – 3 March
25 – 26 May (new)
21 – 22 September
30 November – 1 December

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