

LARGE HADRON COLLIDER COMMITTEE

Minutes of the one-hundredth-and-twenty-second meeting held on
Wednesday and Thursday, 3-4 June 2015

OPEN SESSION – STATUS REPORTS

1. LHCb Status Report: Andrea Contu
2. Physics Prospects for the LHC Run II: Michelangelo Mangano
3. ATLAS Status Report: Till Eifert
4. CMS Status Report: Michail Bachtis
5. LHC Machine Status Report: Mike Lamont (on behalf of F. Bordry)
6. ALICE Status Report: Marie Germain
7. TOTEM Status Report: Nicola Minafra
8. MoEDAL Status Report: James Pinfold
9. RD42 Status Report: William Trischuk
10. RD39 Status Report: Jasu Haerkoenen
11. RD51 Status Report: Eraldo Oliveri
12. RD50 Status Report: Michael Moll
13. RD52 Status Report: Silvia Franchino
14. RD53 Status Report: Jorgen Christiansen

CLOSED SESSION:

Present: S. Bertolucci*, C. Bloise, H. Burkhardt, P. Burrows, M. Demarteau, D. Denisov, C. Diaconu, G. Eigen, F. Forti (Chairperson), G. Giudice, B. Gorini, T. Kuhr, F. Kunne, M. Mangano, L. Mapelli, E. Meschi, P. Newman, B. Panzer-Steindel, B. Ratcliff, C. Sfienti*, S. Smith, E. Tsesmelis (Scientific Secretary), T. Ullrich, H. Yamamoto, H. Wilkens

* part-time

Apologies: R.-D. Heuer, M. Lancaster, S. Miscetti, C. Touramanis

1. EXECUTIVE SUMMARY**General**

LHC operation at 13TeV started on the morning of 3 June 2015, with Stable Beams being declared at 10:40am.

The LHCC examined the plans for the 2015 running period, including the special runs.



The Committee endorsed the proposal for one week of special runs in autumn 2015 to accommodate running with $\beta^*=90\text{m}$ and the van der Meer scans. The Committee also endorsed the proposal of differential levelling of the experiment luminosity during the heavy-ion run in order to optimize the luminosity for all experiments. The LHCC will re-examine in September 2015 the overall optimization of the proton-proton and Pb-ion running periods.

LHC Experiment Upgrades

A document describing the overall review and approval process for the Phase-2 upgrades of the experiments is in preparation. It foresees the submission of Scoping Documents for ATLAS and CMS covering three funding scenarios and including the corresponding physics performance and reach. The draft of the documents will be submitted in July 2015 and the final versions will be submitted to the LHCC by 1 September 2015. Deliberation at the Research Board is scheduled for its meeting prior to the October 2015 sessions of the Resources Review Boards (RRBs).

ALICE

ALICE has published many new and interesting results, including the measurement of the inclusive J/ψ production at mid-rapidity and the D-meson yield in proton-proton collisions.

The ALICE experiment is ready for Run II. The ALICE detector recorded first collisions at 13TeV proton-proton centre-of-mass energy. The production of the new RCU2 read-out electronics for the Time Projection Chamber (TPC) has been completed. The boards have been installed in one TPC sector, with the rest of them to be installed during Technical Stop 1 (TS1). The TPC has been commissioned and is ready for Run II data taking.

The LHCC carried out an in-depth review of the ALICE upgrade projects. Good progress was reported on the Inner Tracking System (ITS). The upgrade of the Trigger and Read-out system is also progressing well. Following the endorsement of the Upgrade Cost Group (UCG), the LHCC **recommended for approval** the ALICE Time Projection Chamber Technical Design Report. The UCG identified some remaining issues that will need close monitoring. Construction, assembly and testing of the TPC will require a substantial amount of expertise and proficient project management. Critical items are the timely delivery of the common front-end read-out chip for the TPC and Muon Chamber (MCH) upgrades and the development and testing of multi-channel cascaded high-voltage power supplies for the Gas Electron Multiplier (GEM) stacks. Moreover, the funding profile has a large peak in 2018, exposing the project to schedule risk if the Front End Cards (FECs) are delayed.

The Committee received the ALICE Online-Offline Computing System (O²) Technical Design Report and is currently reviewing the document. The LHCC also received the ALICE Muon Forward Tracker (MFT) Technical Design Report. A scientific and cost review has been carried out, showing that the detector is scientifically and technically sound, but with the organizational structure and financial plan requiring further discussion between the LHCC and the ALICE Collaboration.

ATLAS

ATLAS is ready for 13TeV proton-proton collision data-taking and first physics collision data have been recorded. All of the sub-systems are operational and close to all channels are live. The full event reconstruction chain has been exercised. Monte Carlo event

generation for the 2015 Run II data is progressing well.

The LHCC took note of progress in the Phase-1 upgrade projects. Significant progress was reported on the Associative Memory (AM) chip of the Fast Track Trigger (FTK), but there is still about 6 months of delay. ATLAS plans to have the complete barrel FTK detector operating by summer 2016. Good progress was also reported regarding all other Phase-1 upgrade projects – the LAr Calorimeter read-out, the New Small Wheels (NSW) of the Muon System and the Trigger / DAQ.

The LHCC **recommended for approval** the ATLAS Forward Proton (AFP) Detector Technical Design Report, subject to its approval at the next ATLAS Collaboration Board and by the LHC Machine Committee (LMC).

Good progress was also reported for the Phase-2 upgrades. The Technical Design Reports for the Phase-2 upgrades of the Trigger / DAQ, LAr Calorimeter, Tile Calorimeter and Muon System will be submitted in 2017 following ATLAS Internal Design Reviews (IDRs) in 2016, assuming the current LHC schedule. An interim Technical Design Report preparation review for the Inner Tracker (ITk) upgrade will take place within ATLAS in November 2015 and the corresponding two Technical Design Reports will follow – for the strip detector in 2016 and for the pixel detector in 2017, also assuming the current schedule. The draft Scoping Document will be submitted to the LHCC in July 2015 and the final version by 1 September 2015.

CMS

The Run I data analysis is converging with many papers submitted recently.

CMS completed successfully all planned activities during Long Shutdown 1 (LS1). The Phase-1 upgrade to the Level-1 Trigger System has been installed partially during LS1. It will run in parallel with the legacy Level-1 trigger for verification and will be brought gradually into operation.

All CMS sub-systems, except the solenoid magnet, are ready for Run II. The CMS detector recorded first collisions at 13TeV proton-proton centre-of-mass energy. Traces of non-volatile pollutant (Breox oil) from the compressor were found in the magnet system. All efforts are being made to prevent damage to the magnet while allowing a timely start-up of the detector operation at full field. The LHCC endorses the priorities presented by the CMS Collaboration. Should CMS not be able to proceed soon to effective data taking, the LHCC recommends CERN's Management to set up the proper framework to review possible options to optimize the overall scientific output of the 2015 LHC run.

The Phase-1 upgrade programme is progressing as planned. An in-depth review of the Phase-1 upgrades will be carried-out by the LHCC in December 2015.

The Phase-2 Technical Proposal has been submitted to the LHCC and the Committee will review the document over the summer months. The draft Scoping Document will be submitted to the LHCC in July 2015 and the final version by 1 September 2015. The LHCC **recommended for approval** the Muon End-cap Gas Electron Multiplier (GEM) Technical Design Report for muon tracker upgrade and the detector is expected to be installed already during Long Shutdown 2 (LS2).

LHCb

LHCb has presented several new and interesting results in published papers and at winter/spring conferences, including the combination with CMS of the $B_s \rightarrow \mu\mu$ channel.

Many further analyses are underway.

The LHCb experiment is ready for Run II. The online calibration and the split Higher Level Trigger (HLT), as well as a 'turbo stream' that performs online processing and provides ready-to-analyze data, are both in operation. The LHCb detector recorded first collisions at 13TeV proton-proton centre-of-mass energy.

Phase-1 upgrades of the individual detector systems – Silicon Upstream Tracker (UT), Vertex Locator (VELO), Scintillating Fibre Tracker (SciFi), the Ring Image Cherenkov (RICH) detector and Muon Systems - are progressing well. The revision of milestones is not expected to cause any implications on the overall upgrade schedule and will be presented to the LHCC in September 2015.

The LHCC took note of the discussions within the LHCb Collaboration to add heavy-ion running to the experiment's physics programme. The development of the gas injection technique via the SMOG (System for Measuring Overlap with Gas) provides unique opportunities for performing measurements of proton or Pb scattering on Ne or Ar ions. The LHCC encourages the LHCb Collaboration to develop a full heavy-ion physics programme, taking into account issues of detector safety and beam stability.

TOTEM

The LHCC took note of the readiness of the TOTEM experiment for Run II with all systems commissioned successfully.

Good progress was reported on the development of the vertical timing Roman Pots. Although ambitious, an opportunity for installing the first set of timing detectors in the LHC tunnel would be during the second Technical Stop of Run II.

Good progress was also reported on the CMS-TOTEM Precision Proton Spectrometer (CT-PPS).

MoEDAL

The LHCC took note of the good progress the MoEDAL experiment is making. The Committee encourages the MoEDAL Collaboration to complete the analysis of the plastic Nuclear Track Detectors from the LHCb experimental area as soon as possible.

Worldwide LHC Computing Grid (WLCG)

The LHCC took note of the successful preparations for computing for Run II. The WLCG and experiment computing are ready for Run II and computing resources are adequate for 2015 and 2016.

The LHCC took note of the general concern on the continued availability of qualified personnel over the long term.

The WLCG project is preparing for the future LHC computing needs. The exploration of Science Cloud options should be pursued in this respect.

The Committee urges the LHC experiments to start considering updates for their computing models for Run III, which would serve as a basis for preparations for the subsequent Phase-2 experiment upgrades.

R&D Projects

The LHCC heard status reports from the R&D projects:

RD39: Cryogenic Tracking Detectors

RD42: Development of Diamond Tracking Detectors for High Luminosity Experiments at the LHC

RD50: Development of Radiation Hard Semiconductor Devices for Very High Luminosity Colliders

RD51: Development of Micro-Pattern Gas Detectors Technologies

RD52: Dual-Readout Calorimetry for High-Quality Energy Measurements

RD53: Development of Pixel Read-out Integrated Circuits for Extreme Rate and Radiation

Much progress has been achieved since the previous status reports in June 2014. The LHCC **recommended** that the R&D projects be continued for one year. The Committee also encourages the R&D project groups to implement stronger co-ordination amongst themselves and to publish their results quicker, which represents an important added value to the community.

2. PROCEDURE

The Chairman welcomed the new members of the LHCC: F. Kunne and C. Sfienti.

The minutes of the one-hundredth-and-twenty-first LHCC meeting (LHCC-2015-005 / LHCC-121) were approved.

3. REPORT FROM DIRECTOR OF RESEARCH AND COMPUTING

The Director for Research and Computing reported on issues related to the LHC. He reported on the successful resumption of the LHC following Long Shutdown 1 (LS1). LHC operation at 13TeV centre-of-mass energy started on 3 June 2015. He also reported on programme of CMS following the contamination of the cryogenic circuit of the detector's solenoid magnet (see Section 10 below for further details). Discussions with the Funding Agencies regarding the process for the approval of the Phase-2 LHC experiment upgrades continue in view of deliberations at the next sessions of the Resource Review Boards (RRBs) in October 2015. He also reported that CERN's Medium Term Plan 2016-2020 that will be presented to the June 2015 session of Council includes re-scheduling of the LHC running and long shutdown periods to meet Council's directives for CERN's cumulative budget deficit. Specifically, Run II will be extended to the end of 2018 and will be followed by Long Shutdown 2 (LS2) until the end of 2020. Run III will thus commence in early 2021.

4. REPORT AND DISCUSSION WITH LHC EXPERIMENT UPGRADE REFEREES

General

A discussion was held addressing the planning of the Phase-2 upgrade approval process. It has been agreed to present a recommendation to the October 2015 Resources Review Boards (RRBs) with regard to the scope of the Phase-2 upgrade programme. The key elements of this process are the ATLAS Letter of Intent (LoI), the CMS Technical Proposal (TP) and the Scoping Documents from each experiment that will examine the trade-off between physics reach and detector scope. A preliminary money matrix is also required. The Committee is looking forward to working with the experiments to prepare for the next LHCC and RRB meeting.

The topic of special runs was also discussed. All experiments agreed on the set of special runs to be taken during the coming year and their respective priorities. These are the runs for LHCf and the luminosity calibration for ATLAS and CMS with van der Meer scans.

TOTEM and ALFA will try to run parasitically during these runs. The run for LHCf must be taken early, otherwise the experiment will suffer from radiation damage even if kept in the garage position. The removal of LHCf is thus mandatory during Technical Stop 1 (TS1). A second seven-day run is scheduled for later in the year, the exact date to be determined. This run will include a $\beta^*=90$ m run for TOTEM and ALFA, with two days of set-up, one day at low luminosity and one day at high luminosity for diffractive physics. The run is completed by two days for van der Meer scans with one day of contingency. Roman Pot insertions will be exercised a few hours at the end of elected fills and should have no impact on normal operation.

CMS

Shortly before this session of the LHCC, the Committee received the CMS Phase-2 Technical Proposal, a summary of which was given during the upgrade meeting. The CMS Phase-2 Upgrade Technical Proposal targets operation at 200 events pile-up (PU) with Phase-1 detector performance at 140 PU and with a radiation tolerance exceeding 3000 fb^{-1} . This will, among others, enable the study of Higgs couplings to 2-10%, and provide evidence of di-Higgs production. There is an enhanced role of the forward region after the upgrade to study Vector Boson Fusion / Vector Boson Scattering processes. Aging studies show that both the tracker and end-cap calorimeters need replacement. In addition, upgrades to the barrel Electromagnetic Calorimeter, the Muon System and the High Level Trigger (HLT) are foreseen.

The replacement of the current inner tracker is a dominant part of the upgrade. A total of 6/5 barrel/endcap layers/disks of strip detectors are planned with increased granularity. The sensor modules in all layers participate in the formation of a first level track trigger. The outer tracker system is complemented by 4/10 pixel layers/disks. The material budget of the proposed outer tracker is significantly reduced compared to the current tracker. Heat removal is through CO_2 cooling. The implementation of a track trigger is critical to control all-inclusive trigger rates at the first 40 MHz stage. Three methods are being pursued for a Level-1 (L1) track trigger, based on stubs as trigger primitive. They include Associative Memories and track fitting; a time-multiplexed architecture with Hough transform and track fitting; and a tracklet-seeded road search.

The second main element of the upgrade is the proposed high-grained end-cap silicon-tungsten calorimeter (HGCAL) followed by a backing hadron calorimeter (HE). The proposed HGCAL has 28 longitudinal Si/W segments, forming the electromagnetic section, followed by 12 depth segments of a silicon-brass front hadron calorimeter. It is completed by a 12 segment scintillator/brass backing hadron calorimeter. The active silicon, with 600 m^2 area, has pad readout with $0.5 \times 0.5 \text{ cm}^2$ and $1 \times 1 \text{ cm}^2$ pads, for a total of 6.1 million readout channels. With the added granularity, many more shower parameters can be defined, both online and offline, for enhanced electron, photon and jet identification in high pile-up environments.

The upgrade to the Muon System consists of upgrades to the readout electronics for full coverage, redundancy and high rate capability and new Resistive Plate Chamber (RPC) and Gas Electron Multiplier (GEM) chambers in the forward region. Most analyses benefit from the better performance of the detector compared to the Phase-1 performance. Also, the Beam Radiation Instrumentation and Luminosity (BRIL) systems will be upgraded. Active protection and background monitoring will be implemented, TIMEPIX-based radiation monitoring and bunch-by-bunch luminosity measurement will

also be implemented. The total core cost of the CMS Phase-2 upgrade is estimated to be 265 MCHF.

ATLAS

The ATLAS experiment also presented a comprehensive overview of the plans for the Phase-2 upgrade. The ATLAS experiment has submitted five Technical Design Reports (TDRs) for the Phase-1 upgrade that set the path for the Phase-2 upgrades. The LoI for the Phase-2 upgrade described its major components: the full replacement of the inner tracker, major upgrades to the Trigger/DAQ (TDAQ), upgrades of the LAr calorimeter electronics based on streaming of all data off-detector with 40/80 MHz digitization rate and upgrades to the Tile Calorimeter and muon electronics. An extensive programme of optimization has been carried out post-LoI, based on the Phase-1 TDRs. The current “reference design” for ATLAS is, as for CMS, optimized for ultimate luminosity conditions including running at PU=200. The proposed TDAQ architecture is based on a split Level-0/Level-1 trigger architecture. A Level-0 latency of 6 μs is foreseen and a Level-1 latency of 30 μs . This will allow the introduction of Level-1 Track Associated Memory (AM)-based track finding driven by Level-0 Regions of Interest (ROIs). It also enables a highly-performant Level-1 Calorimeter trigger based on Level-0 ROIs and the availability of full calorimeter data. The Fast Tracker (FTK) will be strengthened, enabling 100 kHz reconstruction of all tracks with $p_T > 1$ GeV. The HLT processing farm is specified for a maximum output rate of 10 kHz. Prototype trigger menus have been run and seem to be able to meet the physics goals.

A substantial amount of work has been directed towards the layout of the Inner Tracker (ITK). Extending the tracking to $\eta=4$ is especially challenging given the “short” solenoid. Tracking at $\eta=4$ is very different from the tracking at ATLAS today at $\eta<2.5$. Great progress is also being made in the prototyping of pixel and strip modules. The experiment has a vigorous R&D programme in HV/HR-CMOS detectors, which could potentially offer a cost-effective solution with embedded front-end electronics. Although the Collaboration admits that there is little time left for further development for the strips, this option would be an ideal candidate for the pixel layers at larger radius. A clear plan for upgrading the LAr calorimeter front-end and back-end electronics is being developed, which allows moving to a digital 40/80 MHz streaming output which also provides ROI-based finely segmented data to the Level-1 Calorimeter trigger.

The present Forward Calorimeter (FCAL) detector consists of four LAr modules: an electromagnetic section, two hadronic sections and a plug calorimeter. They share the cryostat with the Electromagnetic End-cap (EMEC) and Hadronic End-cap (HEC) calorimeters, an area that will be intensely activated. With the high particle fluxes during Phase-2, this calorimeter will experience ion build-up, possible HV droops and insufficient LAr cooling. Two approaches are being considered. The first option is to replace the FCAL with an improved detector (sFCAL) using smaller gaps and new summing boards, to avoid the HV drop, and additional cooling loops. This option requires opening of the cryostat. The second option is to install a small calorimeter in front of the current FCAL to mitigate the particle flux. This option would not require opening of the cold volume of the cryostat. Replacement of sFCAL is a very complex process and a decision is expected around mid-2016. The experiment is also exploring a 4D segmented timing detector in the far forward region. This region suffers from very high pile-up and is the only region where timing information could be used to associate energy depositions with vertex positions. A thin region in front of the End Cap Calorimeter, which has been occupied by a thin layer of scintillators, would permit installation of a “thin” ($O(5$ cm))

layer in the region $2.4 < \eta < 4.0$ to provide additional position and timing information in this complex region. W/Si or Cu/Si technologies are being considered.

The upgrade of the Tile Calorimeter involves the replacement of the current front-end electronics with new signal conditioning and digitization capable of continuous operation at 40 MHz to provide low-latency inputs to the Level-1 Calorimeter trigger and DAQ system. Presently, three different approaches to the front-end implementation are being prototyped and assessed in detail. A decision is being expected by the time of the TDR in 2017. Also, two approaches to the HV distribution being evaluated, one with internal regulation as in the current system, and one with remote regulation.

The upgrade envisioned of the Muon System has four components: the upgrade of the readout electronics for the Monitored Drift Tubes (MDTs), Thin Gap Chambers (TCGs) and Resistive Plate Chambers (RPCs) and implementation of the MDT information in the Level-0 Muon trigger. These upgrades are aimed at minimizing data loss in the trigger, and improving efficiencies, both online and offline. The Committee has been impressed by the development of the Phase-2 upgrade planning and is looking forward to the Scoping Document.

ALICE

An in-depth review of the ALICE upgrade was held during this meeting, the report for which is given in the ALICE section of these minutes (See Section 8).

5. REPORT FROM THE UPGRADE COST GROUP (UCG)

The LHCC heard a report from the UCG, concentrating on the ALICE Phase-1 upgrades of the Time Projection Chamber (TPC) and Online-Offline (O²). The UCG finds that the cost and manpower estimates for the TPC are reasonable and **recommends** approval to the LHCC. Given the vital importance of the TPC for the whole ALICE upgrade programme, the UCG urges the ALICE Collaboration to establish a rigorous quality assurance and testing programme to ensure that the chambers meet the technical requirements. The UCG presented a number of findings and recommendations to the ALICE Collaboration regarding the O² upgrade project: reconcile in detail the level of existing expertise with future needs; clarify the project working plan and schedule; revise the organization structure towards a clearer chain of command; update the cost estimates to avoid double counting. In addition, the ALICE Management should provide as soon as possible a Maintenance & Operation costs and budget; detailed cost estimates for the computing room(s); cost estimates for offline (analysis) computing needs and a list of costs needed for ALICE running beyond Long Shutdown 3 (LS3).

Moreover, the UCG reported that the ATLAS and CMS Scoping Documents for the Phase-2 upgrades are being evaluated in time for the Resources Review Boards in October 2015. The preliminary Scoping Documents for three funding scenarios will be available in July 2015, with the final versions due by the end of August 2015. Much interaction between the UCG and the ATLAS and CMS experiments are scheduled over the summer.

6. REPORT FROM THE LHC PROGRAMME CO-ORDINATORS

The LHCC heard a report from the LHC Programme Co-ordinators, concentrating on the status and plans for LHC Run II operation. LHC operation at 13TeV started on the morning of 3 June 2015, with Stable Beams being declared at 10:40am. The Co-ordinators presented detailed plans for the 2015 running period, including the special runs. The LHCC endorsed the proposal for one week of special runs in autumn 2015 to

accommodate running with $\beta^*=90\text{m}$ and the van der Meer scans. The Committee also endorsed the proposal of differential levelling of the experiment luminosity during the heavy-ion run in order to optimize the luminosity for all experiments. The LHCC will re-examine in September 2015 the overall optimization of the proton-proton and Pb-ion running periods.

7. TEST BEAMS

The PS and SPS Physics Co-ordinator reported on the LHC test beams. He presented the latest version of the test beam schedule in the PS East Area and in the SPS North Area, stating that only small modifications were made relative to the schedule shown at the previous meeting of the LHCC. Two weeks of test beams with Pb beams are scheduled for the end of November 2015. He also reported that the integrated intensity on the targets show that the PS and SPS are running smoothly. The new CERN Gamma Irradiation Facility (GIF++) in the SPS EHN1 experimental hall is operational since April 2015. Beam time and irradiation times are already fully booked for 2015, primarily for tests of the LHC experiment muon systems. The AIDA 2020 kick-off meeting was scheduled to take place during this week. AIDA 2020 is a trans-national access programme to support test beam and irradiation projects.

8. DISCUSSION WITH ALICE

Physics

Since the previous LHCC meeting in March 2015, ALICE has published four papers and 10 have been submitted, of which seven have been already accepted. This brings the total number of ALICE papers to 115. The recent publications cover a wide range of topics in proton-proton, proton-Pb, and Pb-Pb collisions. New, interesting results emphasize the importance of the low- p_T reach and the strong Particle Identification (PID) capabilities of ALICE. The comparison of inclusive low- p_T J/ψ production at mid-rapidity in Pb-Pb relative to that in proton-proton collision shows less suppression at LHC than observed at RHIC. This provides further evidence that at LHC energies, coalescence plays an important part in the production mechanism of charmonium at low- p_T while the data are consistent with colour-screening models at high- p_T . Most interesting is the observation of an unexpected steep dependence of charm production (D^0 , D^+ , D^* , and J/ψ) on the charged multiplicity in proton-proton collision with little dependence on p_T . The data are qualitatively consistent with a substantial role of multi-parton interactions. Among the recently submitted papers is a comprehensive and systematic study of K , π , p production in the p_T range of 0.2 to 6 GeV/c in proton-proton collisions that reveals large discrepancies with model predictions. None of the available event generators are able to simultaneously describe the observed yields. These results will provide crucial input in tuning Monte Carlo generators at the LHC. The LHCC congratulates ALICE on these accomplishments.

Commissioning

All new and upgraded detectors have been installed during Long Shutdown 1 (LS1). This includes the completion of the Transition Radiation Detector (TRD), the installation of the Dijet Calorimeter (DCAL) modules and the electronics upgrade and re-installation of four Photon Spectrometer (PHOS) modules. PHOS and DCAL rest on a new common support structure. The new ALICE Diffractive (AD) detectors were installed covering $4.8 < \eta < 6.3$ and $-7 < \eta < -4.9$ to enhance the experiment's capabilities for studying

diffractive processes. One module of the Charge-Particle Veto detector (CPV) for one of the PHOS modules is in place.

All subsystems are now integrated into the global DAQ, which, together with the High Level Trigger (HLT) clusters, was fully upgraded in terms of CPU, networking, and FPGA processing. The Central Trigger Processor (CTP) capacity was doubled and new wake-up logic plus relocation of electronics allows the CTP to issue fast Level-0 triggers (LM) to the TRD. The calorimeter readout is now being optimized and the trigger firmware is being finalized. The integration of the HLT is underway.

The switch over from Ne+CO₂ to Ar+CO₂ as the Time Projection Chamber (TPC) gas is completed. Argon is less prone to discharges and provides overall higher detector stability, at the expense of slightly longer dead times (350 μ s \rightarrow 500 μ s), which is only relevant for proton-proton minimum-bias running.

The new readout control unit (RCU2), which will enable doubling of the TPC readout rate, remains an issue. The second prototype (v1.2) is available since December 2014 and is shown to be free of the latch-ups that affected the earlier version. At the beginning of 2015, one TPC sector was equipped with the new RCU2s (6 boards) for further validation. By now the mass production of all RCU2 boards and backplanes is finished. Although tests showed stable operation and full functionality of the RCU2, after this LHCC meeting the Committee was informed by ALICE on a key issue with the firmware of the new FPGA, specifically the software provided by MICROSEMI. ALICE, therefore, decided to postpone the RCU2 installation to Technical Stop 2 (TS2), instead of Technical Stop 1 (TS1) as originally planned, in order to make sure that the RCU2 firmware and RCU2 readout is fully debugged and commissioned before installation. Installation during TS2 will still hit the target of high rate TPC operation for the heavy-ion run according to the current schedule.

ALICE is conducting technical runs with all detectors included. Since January 2015 more than 500 h of cosmic-ray runs with various field settings (B=0, +0.5T and -0.5T) were accumulated with the Silicon Pixel Detector (SPD), Silicon Drift Detector (SDD), Silicon Strip Detector (SSD), TPC, Time-of-Flight (TOF), and Transition Radiation Detector (TRD) included in the runs. New detector and DAQ capabilities, such as in-run recovery and fast end-of-run/start-of-run procedures are being commissioned.

LHC injection tests in March 2015 were successfully used by ALICE to check basic functionalities. The so-called splash events, generated by low intensity beams dumped into thick tungsten-alloy collimators at LHC Point 3 and the LHC Beam-2 dump in LHC Point 6, were used for calibration of the ALICE beam condition monitors (BCM, BLS, RADMOB, and BLM) and initial muon arm alignment.

ALICE successfully recorded proton-proton events at $\sqrt{s} = 0.9$ TeV with the SPD and SSD detectors as well as the muon system (MCH, MTR). In the first 13 TeV run, ALICE took data for several hours with 14 sub-detector systems included in the run. To reduce the risk of running with non-fully stable beams, the gaseous trackers and PID detectors (TPC, TOF, High-Multiplicity PID (HMPID), and CPV) were left out. All detectors participated in the first run with stable beams on 3 June 2015.

For the 25 ns proton-proton operation starting in August 2015. ALICE intends to run with luminosity leveling at $L=5 \times 10^{30}$ cm⁻² s⁻¹ requiring a separation of the two beams of about 4-5 σ . For the 2015 heavy-ion running, luminosity leveling at $L=1 \times 10^{27}$ cm⁻² s⁻¹ is foreseen. In terms of optimizing the luminosity for all LHC experiments, ALICE

supports the scenario where all interaction points are leveled differentially with an average fill duration of 5 h. In this mode ALICE can integrate up to 0.56 nb^{-1} per fill.

In-depth Reviews

The LHCC carried out an in-depth review of two ongoing ALICE upgrade projects.

Inner Tracking System (ITS)

For the Inner Tracking System (ITS), the ALPIDE pixel chip architecture has been chosen as the baseline for all detector modules, while the development of the alternative MISTRAL-O, and in particular the outer barrel data management unit, is continued as a potential backup solution for the outer layers. After the successful test of p-ALPIDE-1, a second full-scale prototype (p-ALPIDE-2) was delivered in April 2015 to be used for full integration in the inner and outer modules. The p-ALPIDE-3 is intended to be the last prototype before pre-series production and will contain all final elements, including the 1.2 Gb/s high-speed output link. It is expected to be delivered in August 2015, on time for the Engineering Design Review in October 2015.

The design of the Flexible Printed Circuit (FPC) and the assembly tooling for the Inner/Outer Barrel are being finalized. The contract for six Module Assembly Machines has been awarded to IBS (NL). Installation procedures including integration of FPC, power cables and cooling pipes are being studied on a 3D mock up. A first prototype Readout Unit will be ready in September 2015 for the production readiness review.

The LHCC recognizes the progress made on the ITS and congratulates the team for their competence and for the good management of the project.

ALICE Read-out & Trigger System

The ALICE Readout and Trigger system was reviewed in depth at this LHCC session. The architecture has been streamlined, with all upgraded detectors using now the Common Readout Unit (CRU) and having continuous readout capability. The CRU specification is driven by the TPC, with a common PC140 FPGA-based solution being developed together with LHCb. A design review has taken place and prototype development is underway. The SAMPA MPW1 ASIC for continuous readout has been produced and tested. The prototype chip containing the analog part (charge sensitive amplifier and shaper) showed substantial ringing on the shape of large pulses. This defect can now also be reproduced in simulations and the analog part of the layout is being revised for the next prototype cycle. The MPW2 (with all channels) is being prepared for submission in July 2015. The Fast Interaction Trigger has undergone successful prototyping tests. Three different solutions are under study to facilitate continuous readout at 200 kHz. Other aspects of the system are proceeding on schedule. The LHCC congratulates the collaboration on the recent progress.

Upgrades

Muon Forward Tracker (MFT)

On 22 May 2015 the LHCC received an Addendum to the ALICE Muon Forward Tracker (MFT) Technical Design Report for the Upgrade Cost Group (UCG), describing the organization of the project, the budget estimation, the schedule, and the manpower available in the project. Given the moderate cost of the MFT of 3.05 M€ the project will

not be reviewed by the UCG. Instead the LHCC ALICE referees conducted a small-scale cost and manpower review.

The LHCC is mostly satisfied with the document but has slight concerns regarding the organizational structure and the list of milestones requiring further discussion between the LHCC and ALICE.

The project benefits from a large technical overlap with the planned upgrade of the ITS and the synergy is being effectively leveraged. The additional risks different from the ITS ones are connected with funding and installation plans.

The overall cost estimate and the spending profile is sound. The responsibility for detector construction and funding is shared between four French institutes contributing to 72% of global, and to 87% of material costs. In particular, the rest of material costs are 70% of the Indian contribution. Such an asymmetric subdivision of funding and duties contains implicit risks that should be mitigated by developing a contingency plan against potential problems with fund securing.

The milestones provided are limited to Engineering Design (EDR) and Production Readiness (PRR) Reviews. A better defined set of milestones between the PRR and commissioning is needed. This will be particularly helpful in reviewing the man-power profile. In several cases participating institutions made no man-power commitment beyond 2017 and thus several numbers have only been estimated. The associated risk needs to be evaluated.

As an outcome of this in-depth review the referees will formulate a set of questions for the ALICE Collaboration for a second iteration of the document.

Time Projection Chamber (TPC)

The upgrade of the Time Projection Chamber (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 read-out 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 original TDR (CERN-LHCC-2013-020, 3 March, 2014) has been updated with an Addendum (CERN-LHCC-2015-002, 2 February, 2015). Based on the review of the Addendum for the TPC upgrade and following the endorsement of the UCG, the LHCC **recommended for approval** the ALICE Time Projection Chamber Technical Design Report. The UCG identified some remaining issues that will need close monitoring. Construction, assembly and testing of the TPC will require a substantial amount of expertise and proficient project management. Critical items are the timely delivery of the common front-end read-out chip, SAMPAs, for the TPC and Muon Chamber (MCH) upgrades and the development and testing of multi-channel cascaded high-voltage power supplies for the GEM stacks. The funding profile has a large peak in 2018, exposing the project to schedule risk, should the Front End Cards (FECs) be delayed.

Online-Offline Computing System (O²)

On 20 April 2015 the LHCC received the ALICE Online-Offline Computing System (O²) Technical Design Report and is now in the process of reviewing the document. ALICE plans to completely redesign the online computing system to address the major

challenge of sampling the full 50 kHz Pb-Pb interaction rate after LS2. This upgrade will also include the continuous trigger-less read-out of several detectors, most prominently TPC, ITS, and TOF among others. The total data throughput amounts to 1.1 TB/s of which 1 TB/s originates from the TPC alone. ALICE plans to reduce this unprecedented data rate by adopting an entirely new strategy where calibration and reconstruction are performed online, and only the post-reconstruction results are stored while the raw data are discarded. This implies a much tighter coupling between online and offline computing systems. In a first step the raw data flux is reduced to 500 GB/s by processing of sub-detector specific data (e.g. TPC cluster finding), in ~250 FPGA-based First Level Processors (FLPs). Around 1500 Event Processing Nodes with around 100k CPU cores augmented by 5000 GPUs will perform global processing such as track finding and first calibration. In synchronous data processing mode during LHC runs, the Compressed Time-Frames (CTF) constitute a data rate of 90 GB/s that is locally stored. In asynchronous mode, these data are further refined with improved calibration (“physics grade”), primary vertex finding, track-to-vertex association, and event extraction. This asynchronous data processing is not limited to the O² facility but can also be undertaken at the Tier-0 and Tier-1 Grid facilities. Only the CTF and Analysis Object Data (AOD) are written to permanent storage. Tests presented in the Technical Design Report show that an overall data compression factor of 14 is feasible (20 for TPC). While various technology options for input-output, data processing, disk storage (60 PB), and fast networking have already been evaluated and found adequate, ALICE is looking carefully at future technology with the clear strategy for late procurements to maximize performance and lower the costs.

The O² facility will be located at LHC Point 2 and will require two counting rooms of which one is currently available. One additional computing room will be needed on the surface. The facility will need a total power of 2.5 MW requiring major upgrades to the LHC Point 2 infrastructure. The same is true for the required cooling capacity of 2.4 MW. ALICE estimated that four professional FTEs need to be added to the existing workforce for facility maintenance.

9. DISCUSSION WITH ATLAS

Introduction

ATLAS is ready for 13 TeV proton-proton data-taking and first physics collision data have been recorded. All of the ATLAS sub-systems are operational with close to 100% channels live. The full event reconstruction chain has been exercised. Monte Carlo event generation for the 2015 Run II data is progressing well. The LHCC recommended approval of the ATLAS Forward Physics (AFP) Technical Design Report (TDR), subject to its approval at the ATLAS Collaboration Board and by the LHC Machine Committee (LMC).

Physics

The total number of physics publications has reached 425, an additional 31 since the previous LHCC meeting. The Run I analyses of Higgs physics, SUSY searches, exotics, and detector performance are being completed, and numerous papers are still in the pipeline.

Several interesting new measurements were featured. The joint ATLAS/CMS Higgs boson mass paper has been published. Work is ongoing on measurements of the various Higgs production and decay channels; the suite of preliminary results is consistent with

Standard Model expectations. A limit was reported on the invisible Higgs decay branching ratio of $<29\%$ at 95% C.L.

The final top-mass measurement using the full 7 TeV data sample was reported, with an error of $+0.91$ GeV. Work is ongoing with CMS and the Tevatron experiments to produce a combined top-mass result.

A search for new resonances decaying to pairs of vector bosons was reported. A feature is observed in W-Z invariant-mass bins around 2 TeV, with a local significance in excess of 3 standard deviations. This will be investigated further with Run II data.

Long Shutdown 1 (LS1)

All detector sub-systems have been consolidated and are operational with close to 100% channels live.

Task forces have been working on the Insertable B-layer (IBL) issue reported at the previous LHCC meeting whereby bowing of staves is observed under temperature changes. The effect seems to be elastic, reproducible, and of magnitude $10 \mu\text{m}/\text{degree}$. Given that temperature changes during beam fills are substantially smaller than 1°C , the bowing is not expected to have any significant impact on physics performance. A rise in the dew point in the service region just outside the inner detector tracking systems has been observed, apparently correlated with the switch from dry air to CO_2 flushing. The tracker systems are being maintained at a temperature of -10°C , giving about 15°C margin with respect to the dew point. Nevertheless, there is the possibility that some frosting of IBL service pipes has occurred. This will be investigated during the next Technical Stop, and, if necessary, remedial action will be taken.

The Transition Radiation Tracker (TRT) Xe leak-rate is stable, and the most affected chambers, in the inner barrel and two endcap wheels, have been switched to use Ar instead, with negligible impact on the electron identification performance. Fixes to HV power supplies that demonstrated overshoot upon beam dump are satisfactory. A number of readout drivers have been refurbished and there are now 12 spares. It is planned to switch over, during a convenient Technical Stop, the cooling to the muon-system cooling plant which is easier to access and maintain.

No anomalous noise has been observed in the LAr system with cosmic-ray and beam data. The muon systems are stable. The Resistive Plate Chamber (RPC) leak-rate has been halved, and flow-meters have been installed throughout to provide early-warning and location of possible future leaks.

The Level-1 (L1) Central Trigger Processor (CTP) is working well. The L1 trigger is running at 100 kHz with 2-3% dead-time, close to the nominal specification of 1%. (The dead-time is 5% at 100 kHz when running including ALFA). The Phase-1 upgrade L1CALO and L1TOPO trigger boards are working well. The Higher Level Trigger (HLT) menus are finalized and are expected to be good for luminosities up to $2 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$.

Beam-related data have been recorded as beam conditions permitted. 2 M minimum-bias events were recorded with 900 GeV collisions on 5 May 2015. Test collisions at 13 TeV centre-of-mass energy were established on 20 May 2015 and 20 M events were recorded with all detector systems with 'quiet beams' on 21 May 2015. Full event reconstruction was performed, and determination of the detector alignment has been exercised with the collision data. Shift-staffing lists have been established for the rest of 2015; extensive shift training is being provided for new and/or inexperienced shifters.

First 13 TeV physics data were recorded on 3 June 2015 with ATLAS fully operational. The ATLAS Collaboration was congratulated on this tremendous achievement. ATLAS expressed concern that schedule delays have effectively reduced the projected 2015 proton-proton 13 TeV running time by a significant factor. It was agreed that the 2015 run plan be discussed, noting the original aim of integrating approximately 10 fb^{-1} luminosity in 13 TeV proton-proton mode.

The new data production, management, quality-control, calibration and alignment systems are working well. Having collected the data, the time it takes to calibrate the data, process and distribute them and provide final user formats (derived *xAODs*) is up to six days. Work is ongoing to reduce this to about four days. The Monte Carlo generation production run is going well: 500 M events (50 ns bunch spacing) have been generated, and production of 1 B events (25 ns bunch spacing) has started.

The Computing Resources Scrutiny Group endorsed ATLAS's proposed increased use of tape storage, which is being implemented. The 'dataset lifetime' policy is being implemented; 11 PB of storage has been recovered both at CERN and at the Tier-1 sites. Recent Grid usage has averaged about 150 k jobs, with peaks up to 200 k jobs. ATLAS expressed concern about the difficulty of finding the expertise required to implement future upgrades and improvements to the 'core' software infrastructure.

ATLAS submitted the final draft version of the Technical Design Report for the Forward Physics (AFP) project; an almost-complete draft was considered at the March 2015 LHCC meeting. The project calls for installation of a single arm in the 2015 winter shutdown, which appears very ambitious. In practice both arms could be installed together during the 2016 winter shutdown. The LHCC **recommended for approval** this Technical Design Report, subject to its approval at the ATLAS Collaboration Board (expected within 2 weeks). As the AFP interferes potentially with the LHC Machine operation, approval is also required from the LHC Machine Committee (LMC) with documentation and approval via Engineering Change Requests (ECRs) for any beamline changes.

A brief status report was received on the Phase-1 upgrade projects. All are progressing, although minor delays have been incurred with development of some components. The FTK AM06 production chip is ~ 6 months delayed; it is hoped to have devices for the whole barrel by summer 2016. The LAr readout is on schedule. The TDAQ feature extractor boards are progressing. For the muon new small wheels, there are 3-4 month delays in producing 'module-0's for the sTGC and MICROMEAS systems. The production of on-detector ASICs is delayed, but the current front-end chip can be made adequate for chamber testing.

There was a discussion of the Phase-2 Scoping Document. No obvious omissions were identified in the draft outline that had been received. ATLAS was encouraged to provide as much cost/effort detail in the final document as is feasible at this stage. It was acknowledged that contingency is difficult to estimate, but it was agreed that a risk-register would be valuable, and an example was discussed. ATLAS agreed to provide a complete draft version by the end of July 2015, and the final version by the beginning of September 2015, with a 'resource matrix' due in mid-September prior to UCG scrutiny. It was agreed that currency exchange rates used in the cost estimation be specified. It was also agreed that, wherever possible, it would be desirable to agree with CMS on common costs for 'commodity' items (*e.g.* silicon, tungsten, etc.).

The LHCC referees welcomed the ATLAS invitation to participate, as appropriate, in some of the ATLAS internal reviews of the Phase-2 upgrade projects in the process of preparing the respective TDRs. The Inner Tracker (ITK) will have an interim TDR preparation review in November 2015; the TDR is expected in 2016. The other upgrade projects expect to undergo internal design reviews in 2016 and to produce TDRs in 2017.

10. DISCUSSION WITH CMS

Physics

The CMS Collaboration is progressing well with finishing the analysis of Run I 7 TeV and 8 TeV data. In total 394 papers have been submitted by the time of the LHCC June meeting. The largest number of published papers is on "Exotic Searches" as is natural for the main area of the studies at the energy frontier collider. Among the remaining to be completed Run I analyses, 29 are ready for collaboration review, 18 papers exist in draft form, and 57 are in the physics group's review. The total number of Run I publications is expected to be ~500. Among the remaining Run I analyses the largest fraction (~73%) are the high-precision Standard Model measurements, which usually require more time to converge. No interference between Run I analyses and the start of the Run II analyses is expected.

Preparations for LHC Run II

CMS was ready for the first physics 13 TeV LHC collisions provided on 3 June 2015, except for the solenoidal magnet. The CMS solenoid magnet ran smoothly during cosmic-ray tests from 20 March 2015 to 1 April 2015, while signs of pollution in the cryogenic box started to appear. The issue identified itself as a pressure drop across an input filter to the first expansion turbine over several cycles of regeneration with warm gas. Two campaigns of filter cleaning and then filter change proceeded from 1 April to 10 April and then from 30 April to 16 May. Both were unsuccessful with rapid clogging of the heat exchangers and filters preventing sustained operation. In late May, together with the CERN Director of Accelerators and the Head of the Technology Department, an urgent programme of advanced diagnostics and changes of components has been developed. This programme was almost completed by the time of the LHCC meeting and included replacement of the charcoal filter as well as replacement of a large number of the filters and turbines in the cold box. Visual and chemical analysis of all removed components is consistent with anomalously large Breox oil (used in the compressor plant) contamination of the cold box. The most probable cause of the incident is a poorly functioning oil separator, which started in November of 2014 and was corrected in February of 2015. At the time of this LHCC meeting experts were assessing effects of the recent invasive cleaning. Assuming the issue is resolved the CMS magnet is expected to be back running later in June 2015. CMS presented a list of priorities in addressing the issue with the magnet, which sets as the highest priority the goal to prevent the magnet itself from the contamination to assure its many years of operation with short-term readiness for the data taking being of lower priority. The LHCC supports the priorities proposed by CMS and recommends CERN Management to work closely with all LHC experiments to minimize the effect of the incident on the LHC physics programme.

During preparations for Run II CMS recorded ~400 hours of cosmic-ray data with no central magnetic field and ~200 h with 3.8 T solenoidal field, which provided enough data for the initial tracker alignment. These data also proved useful for initial synchronization of various detectors to each other. First "splash events" from the LHC

commissioning with beam have been used to “time in” the forward detectors of CMS. Tests collisions at 900 GeV and 13 TeV were used to commission various CMS systems: confirm detectors timing, begin fine timing scans, and to commission new beam monitoring BRIL detectors. These data were also used to read new Phase-1 upgrade calorimeter triggers and the results are in good agreement with legacy (Run I) trigger decisions. The CMS central tracker is fully ready for the data collection with all Long Shutdown 1 (LS1) goals met. Initial tracker commissioning with beam will include timing scans, bias voltages scans, and refinement of the alignment. The CMS electromagnetic calorimeter is ready for beam with ~99% of channels operating. The calorimeter is already timed in with better than 1 ns accuracy, and using test collisions at 13 TeV the π^0 invariant mass peak has been observed and used for the calibration. The CMS hadron calorimeter is also ready for data taking. Test collisions at 13 TeV provided data to exercise timing scans and determine optimal timing with ~1 ns accuracy. All elements of the CMS muon system are ready for the physics data collection. Muon drift tubes have their timing and stand-alone reconstruction verified. The Resistive Plate Chamber (RPC) system has ~98% of channels operating and tested with the first 13 TeV collisions. The Cathode Strip Chambers (CSCs) are running well and adjustments to high voltages to reduce gas gain variations are in progress.

The DAQ system of the CMS detector is ready for data taking with all planned tasks accomplished during LS1. Obsolete hardware has been replaced, a new operating system commissioned, as well as a new trigger control and distribution system. The CMS detector control system is integrated with new equipment installed during LS1. An entirely new DAQ system has been installed and commissioned (DAQ2). The High Level Trigger (HLT) farm is substantially extended to cope with higher event rate expected during Run II.

The Level-1 (L1) trigger system underwent substantial upgrades during LS1. During 2015 LHC operation L1 legacy trigger will be operational and will be used for data collection with 50 ns timing. The Phase-1 upgrade calorimeter trigger will be used starting from 25 ns data taking and will provide substantial improvements in the calorimeter triggering (including better pileup rejection). Starting in 2016 CMS will use the fully-upgraded trigger system as described in the Phase-1 Technical Design Report. This will be done after in-depth verification during parallel running of the legacy and Phase-1 triggers during 2015. CMS developed trigger menus for different running scenarios corresponding to LHC running periods. There are significant improvements in the trigger algorithms to handle the expected increases in rates as well as upgraded trigger hardware and software. The trigger menu for 50 ns is designed for the peak luminosity of $5 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ and pile-up up to 30 events. It uses the legacy L1 trigger and startup conditions for the alignment and calibration. There are two trigger menus developed for 25 ns operation. One is for the peak luminosity of $7 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ and pile-up of 20 events and another for the peak luminosity up to $1.4 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ and pileup up to 40 events. Both menus use the Phase-1 upgrade calorimeter trigger. A trigger menu is being developed for the end-of-year heavy ion run.

CMS computing is ready for the Run II challenges and the software release plan is driven by the LHC schedule. The release 7_4_0 (March 2015) will be used for the prompt reconstruction during LHC startup, release 7_5_0 (June 2015) will be used for 25 ns reconstruction using alignment/calibration constants obtained during initial phase of the Run II, and release 7_6_0 (September 2015) is planned for the year end re-reconstruction of the 13 TeV data using fully optimized calibration and alignment data.

The physics analysis strategy for Run II is under active development. Physics groups are working to produce a summary list with specific timelines with the goal toward “first plots” to be shown at European Physical Society (EPS) conference to be held late July 2015. The Exotic Searches group is developing “what if” scenarios in the case of unexpected physics events in 13 TeV data. CMS presented a first physics “very preliminary” physics (even without magnetic field!) 13 TeV results: charged particle multiplicity vs pseudorapidity. The observations are in agreement with theoretical predictions in the pseudorapidity region between -2.5 and 2.5.

CMS Phase-1 Upgrade

The CMS Phase-1 upgrade project is progressing on schedule with excellent progress in all areas. Some elements of the project, like the calorimeter and muon trigger upgrades, are already in the final stages of construction and in many cases installation, commissioning and even operation. LHCC plans for an in-depth review of the Phase-1 upgrade project during its December 2015 meeting.

CMS Phase-2 Upgrade

The LHCC received the Technical Proposal for the CMS Phase-2 upgrade on 1 June 2015. For the forward calorimetry, the high-density silicon/tungsten option was selected by CMS. CMS, in consultation with LHC experts and ATLAS, added an “ultimate HL-LHC” luminosity option with 200 pile-up event, which corresponds to $\sim 7 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ leveled luminosity. No Phase-2 scoping scenarios were discussed at the meeting. The Scoping Document is expected to be delivered to the LHCC later this summer and meetings between the LHCC, UCG and CMS are planned to review the scoping proposal.

The Phase-2 CMS upgrade main elements include a new tracker, new end-cap calorimeter, new trigger and DAQ systems as well as substantial upgrades to the front-end electronics, the barrel calorimeters and the muon system.

During in-depth presentations of the Technical Proposal to the LHCC referees, CMS demonstrated preservation and in some cases improvements of the upgraded detector for various objects: tracks, jets, b-tagging, electrons/photons, muons and missing energy. Without Phase-2 upgrades CMS will suffer in physics performance, while upgrades are preserving and in some cases improving the performance.

The Phase-2 trigger upgrade plans for the total Level 1 (L1) trigger rate of 750 kHz and a draft version of the trigger menu exists. Such a L1 trigger menu has a total trigger rate of 400 kHz at 140 events pile-up and 750 kHz at 200 events pile-up. Both rate numbers include a safety margin of 1.5.

Multiple examples of the physics performance of the upgraded detector were presented to the LHCC. For example, substantial improvement in the track momentum resolution is expected with the full replacement of the central tracker. This improvement will enhance detection of such process as Higgs decay to a pair of muons as well as studies of the B_s and B_d mesons decays to muons.

The total base cost of the proposed Phase-2 upgrade is 265 MCHF. The cost is driven by three major elements of the upgrade: a new tracker, new forward calorimeter, and new electronics. Phase-2 upgrades are on track to become active projects in the next few years. CMS plans to develop Technical Design Reports (TDRs) for the tracker by early 2017 and for the electromagnetic barrel and endcap calorimeters and the muon system by late 2017. The TDR for the trigger system is expected by early 2020 and the TDR for the BRIL is expected by middle of 2020. Last in a series of the planned TDRs is the DAQ

system upgrade, which is planned for late 2020. On the planned submission of TDRs, LHCC comments that the relatively late arrival of the Trigger and DAQ TDRs might not be optimal as the design of other systems depends upon the DAQ and trigger systems architecture.

During the March 2015 LHCC meeting, CMS presented the first of the Phase-2 TDRs for the very forward muon system based on Gas Electron Multiplier (GEM) chambers. This Phase-2 upgrade is critical for the muon detection, even earlier than HL-LHC, as CMS has a limited number of muon detectors planes in the forward region. Installation of this upgrade is planned during Long Shutdown 2 (LS2) and the total cost is 3.7 MCHF. After an in-depth TDR review and all referees' questions answered well, the LHCC **recommended approval** of the CMS Muon Forward Tracker Technical Design Report. CMS can proceed with the final agreements on the project funding and to start the construction.

11. CMS-TOTEM PRECISION PROTON SPECTROMETER (CT-PPS)

Fully-instrumented prototypes of the timing detectors are expected to take test beam data at FNAL in June 2015. They should then be shipped to CERN for integration work and further tests by August 2015. The first delivery of new 3D silicon sensors from CNM is expected in October 2015. The delivery should be complete before the end of 2015, on time for detector readiness by winter 2016. In the meantime, a few similar sensors, from the ATLAS Insertable B-Layer (IBL) production, will be shipped to FNAL from Turin for the test beam in mid-June 2015. Front-end cards are at PSI for tests, and will be available soon. The first of the four detector package modules will be completed in July 2015. The other three should be ready by end of September 2015, following the validation of the first one. The DAQ hardware is on a critical path for readiness by winter 2016: the boards must be ready by October 2015 to enable necessary tests. The components are under development at CERN as part of the CMS pixel upgrade. This is scheduled for the year-end-technical stop (YETS) 2016-1017, but it is expected that boards suitable for use in the CMS-TOTEM Precision Proton Spectrometer (CT-PPS) should be available soon. A possible positive answer is expected by the end of June 2015. If installation cannot be carried out before the start of the 2016 run, it can nevertheless take place during a technical stop during the 2016 run. All required resources for the project are now pledged.

12. DISCUSSION WITH TOTEM

The TOTEM detector is ready for data taking. All remaining installation and commissioning steps since the March 2015 LHCC meeting have been accomplished, without major issues. All detector systems (Roman Pots, T1 and T2 telescopes), as well as the trigger/DAQ systems (including the bi-directional trigger with CMS) have been commissioned with the early data, and are taking data at the time of this LHCC meeting (with the Roman Pots in the garage position). The Roman Pot movement and interlock systems have been tested and approved by the LHC Machine Protection Group. An instability in the software controlling the low-level movement system, causing occasional crashes, requires manual intervention by an expert to reboot the system. This is not a concern from the machine-protection perspective, but could induce spurious beam dumps. It should be fixed, removing the cause of the crashes and setting up an automatic reboot system, during the Technical Stop 1 (TS1).

The short-term plans include the Roman Pot alignment, to enable data taking during the LHCf and Van der Meer scan runs. The procedure to carry out end-of-fill insertions at low- β^* has been set up with the LHC Programme Coordination committee (LPC), the

LHC Machine Committee (LMC) and the LHC Machine Protection Panel (MPP). The insertions must take place during the second fill of each intensity step, after at least two hours since declaration of STABLE_BEAMS. If the insertion causes a beam dump, its origin must be understood before further insertions.

The work towards the construction of the timing detectors for the vertical Roman Pots is proceeding well. Further test beams have been carried out at DESY in March 2015, using the largest-size diamond sensors, and testing new metallization procedures. The results are consistent with the target of 100 ps resolution per detector. The first hybrid prototype detector is under construction in Pilsen (CZ), and is scheduled for delivery at CERN towards the end of June 2015 for mounting on the new detector sensors. Diamond sensors were delivered to CERN, and their quality will be certified after metallization, following test beams throughout the summer. The readout board should be available by the end of July 2015, and will be tested on the test beam before installation. While not foreseen and not required for the success of the physics run in October 2015 with $\beta^*=90\text{m}$, the fast pace of progress has opened an ambitious window of opportunity for installation of the detectors during the Technical Stop 2 (TS2).

13. DISCUSSION WITH LHCb

Physics

The scientific production of the LHCb Collaboration proceeds well. Since the previous LHCC meeting, 31 new papers were submitted or published. The publication rate in 2015 so far looks lower than that in 2014. However, since many analyses are in the pipeline, the LHCb Collaboration expects to reach the same publication level as that in 2014. Thus, the LHCC is not concerned about the publication productivity of LHCb. Many very interesting physics results shown at the spring conferences were presented during this LHCC meeting. Among the highlights is the measurement of the ratio of branching fractions of $B \rightarrow D^* \tau \nu / B \rightarrow D^* \mu \nu$, which agrees with the BABAR result and is consistent with the Standard Model (SM) at the 2.1σ level. It was not expected that the LHCb experiment would be able to do this analysis. Other highlights include the $|V_{ub}|$ measurement in $\Lambda \rightarrow p \mu \nu$ decays, a study of the decay $B \rightarrow \phi \mu^+ \mu^-$ and an update of the angular analysis in $B \rightarrow K^* \mu^+ \mu^-$ with 3fb^{-1} , which shows a deviation from the SM at the 3.7σ level in two q^2 bins below the J/ψ . With three times the data, the discrepancy remained at the same level. The combined LHCb and CMS analysis of $B_{s,d} \rightarrow \mu^+ \mu^-$ has been published in *Nature*.

Preparations for LHC Run II

The Run II preparations were successful. During the LHC Sector Test in March 2015, LHCb took three runs of four hours each (so-called “TED” shots). Except for the Ring Image Cherenkov (RICH) and Outer Tracker (OT), all other detectors including the new HERSCHEL detectors were turned on. The Vertex Locator (VELO) was operated in the closed position. Events with high multiplicity were used to test (i) the Level-0 (L0) hardware trigger, (ii) the time alignment of several detectors, (iii) the spatial alignment of the VELO and (iv) the new event display. In early May 2015, LHC delivered collisions at 450 GeV beam energy where LHCb took a six-hour run with one bunch per ring. All detectors were switched on and the VELO was operated in an open position. The data were used to determine the phase between LHC and the LHCb clock and all detectors were time aligned. In this run, rings in the RICH were recorded and π^0 s were reconstructed in the CALO calorimeter. In addition, two novelties were first tested: the split High Level Trigger (HLT) and the online calibration. For running at 25 ns bunch

spacing, the bunch-crossing rate will be 40 MHz. The L0 trigger selects high E_T/p_T events at a rate of 1 MHz (450 kHz of h^\pm , 400 kHz of $\mu/\mu\mu$, 150 kHz of e/γ). These events are partially reconstructed (identify displaced tracks, vertices and di-muons) by the HLT-1 algorithm that reduces the output to 250 kHz. For the HLT-2 processing, 50000 local CPU cores are used and the buffer space has a capacity of 5 PB. The events are stored in a buffer on disk in the HLT farm in the pit. Selected events are used to perform the online calibration and alignment constants. These constants, which can be determined run-by-run or fill-by-fill, are used by the HLT-2 algorithm and by the offline reconstruction of the full data stream. After completing the online calibration, the HLT-2 algorithm is run with a final output of 12.5 kHz: one fifth (called ‘turbo stream’) is produced in a way that data can be used for analysis without any further processing. The remaining data (10 kHz) are stored on disk, 50 % are processed offline and 50% are parked for later reconstruction.

First tests of the online calibration were performed on the CALO. Furthermore, the 450 GeV run was used to monitor the occupancy in the CALO and to adjust the PMT gains automatically to maintain constant occupancy. The SMOG (System of Measuring Overlap with Gas) system was also tested, whereby neon gas is inserted into the VELO. The proton-Ne collisions provide an independent luminosity measurement, which is typically achieved with van-der-Meer scans. Since several modifications of the hardware and software were performed during Long Shutdown 1 (LS1), the upgraded system was commissioned during this run. The VELO, which measures vertices, clearly separates Beam1-gas collisions from Beam2-gas and material interactions. During this test, LHCb also tested the trigger configuration that is necessary for operating the new split HLT scheme. In the last week of May 2015, test collisions were taken in a three-hour run at 6.5 TeV beam energy. The data were used to time align the CALO, RICH and HERSCHEL detectors. Stable beam operation was expected to resume during this LHCC meeting. LHCb resumed normal shift operations with two shifters (24/7) and one piquet per subsystem. Using one week in which the intensity is ramped up in three steps, the plan consists of performing initial calibrations of all detectors, commissioning the data flow for physics data-taking and then performing the initial alignment. The time alignments are achieved with the magnet turned off and global spatial alignments are performed using $D^0 \rightarrow K^- \pi^+$ and $J/\psi \rightarrow \mu^+ \mu^-$ decays. After the initial calibration, precise and continuous calibrations and alignments will be performed online. The last part of the calibration runs will be used to commission the new particle flow. The turbo stream will be added to the data written to micro DSTs that are directly usable for analysis without further offline processing. The luminosity calibration is done both with van-der-Meer scans and beam gas imaging using the SMOG system. The goal consists of reaching an initial precision of 5% that will be improved to 1-2% with van-der-Meer scans after the summer. Runs with special LHC optics are planned in the beginning of Run II using a betatron amplitude at the interaction point of $\beta^*=24$ m and a crossing angle of 930 μ rad. These runs should have good resolution and low parasitic encounter rates. For the early measurements during the ramp at 50 ns bunch spacing, the intensity will be gradually increased to 1400 bunches. The luminosity is leveled at the same value that will be used for the remainder of 2015 corresponding to 4×10^{32} cm⁻²s⁻¹ for running at 25 ns bunch spacing. The pile-up rate is kept constant at $\mu=1.1$ while the number of bunches is increased. The trigger is set for a loose muon p_T threshold and for minimum bias events. Nominal running will start at 50 ns bunch spacing that will be reduced to 25 ns bunch spacing later.

Upgrades

The achieved milestones for the LHCb upgrade have been slipping slightly behind the original schedule. Thus, LHCb started to put a revision into place that will be presented in the September LHCC meeting. The revision is based on new aspects: (i) focus on the preparation of the production phase and (ii) the monitoring of the component production and detector construction. The revision will not affect the overall schedule. Due to an extension of Run II by six months and an extension of Long Shutdown 2 (LS2) by six months, the constraints on the overall schedule are less stringent. For June 2015, five milestones will be achieved for the silicon Upstream Tracker (UT) consisting of the sensor Engineering Design Review (EDR), the stave EDR, the SALT silicon strip detector readout chip EDR, the flex cable EDR and the PEPI/LV EDR. By middle of July 2015, the fiber matts/module joint EDR milestone will be achieved for the Scintillating Fibre (SciFi) detector.

Progress on the UT is proceeding well. In an important workshop held in May 2015 (i) tests of the newly presented SALT-8 prototype were organized, (ii) results on the flex cable tests were presented, (iii) a new flex cable design was discussed in depth and was submitted for production, (iv) many details of the whole system were discussed in view of the June 2015 EDRs and (v) the remarks from the LHCC in March 2015 were considered seriously, starting with the preparation of a plan towards production in which the detailed dependences will be worked out. The LHCC acknowledges the recent developments in the UT.

Progress on the Vertex Locator (VELO) is also proceeding very well. A study on the longitudinal impedance of the VELO RF foil was performed yielding $Im(Z_{long})=3-5$ m Ω while the impedance for LHC is $Im(Z_{long})=90$ m Ω . The LHCb VELO group has good cooperation and mutual understanding with LHC impedance and vacuum experts. LHC experts continue with simulation studies with support of LHCb to minimize the longitudinal impedance since it is correlated with the path length of the image currents. The sensor EDR took place 1-2 June 2015. The VELO group had performed an intense test beam activity in the last weeks producing many positive results. They tested 11 different sensors from two manufacturers before irradiation and after irradiation with proton and neutron beams. The analysis is ongoing and results on efficiency and charge collection were shown at the EDR. The module design was chosen, selecting the single-point support with features of the carbon-fibre support design.

The SciFi tracker is also progressing very well. The first mat winding machine was delivered to Aachen 1 April 2015. The machine was commissioned and first mats were wound with new fibres from Kuraray having an attenuation length of about four meters. However, the new fibres still have the bump problem. A test beam is under way for the EDR in July 2015. The activity has been intense in the past two weeks. Tracking is performed with the TIMEPIX3 and AMS telescopes plus four old SciFi modules. The device-under-test is a 2.5 m six-layer fibre mat with 2015 fibres, cast and mounted between panels. For readout, the newest Silicon Photomultipliers (SiPMs) are used coupled to a SPIROC chip. The PACIFIC chip will be used in the next test beam. The data analysis is still ongoing.

The RICH and Muon System upgrades are progressing also very well. For the RICH, a two-day workshop was held on the Multi-anode PMT (MaPMT) Q&A, detailed workflow, schedule and test setups. The EC design for large-pixel PMTs is progressing well. The mechanical design is ongoing at full steam. The CLARO8v2 chip was

submitted in April 2015 and is expected to be available in August 2015. The signal shape improved considerably having a larger pulse height, shorter decay time and less noise. For the Muon System, the first spare Multi-wire Proportional Chamber (MWPC) was completed. Furthermore, detailed performance studies were accomplished under upgrade conditions. A new Boosted Decision Tree (BDT)-based muon identification algorithm was studied on present data and its performance was extrapolated to high luminosity via the number of primary vertices (nPV). Using an improved algorithm, that includes crossed pads, reduces the misidentification rate considerably. However, the new BDT algorithm provides further significant improvement.

Significant progress was made also on the CALO. The front-end chip EDR was held 24 April 2015 in which a thorough and detailed review of the chip design was performed. It was decided to perform several improvements in the next version of the chip. Additional improvements are expected from a test beam with the ICECALv3 chip at the end of June 2015. A new ICECAL chip version will be submitted in August 2015. Furthermore, LHCb defined the production plan including Q&A, schedule and manpower. The design of the frontend (FE) board is well advanced and components were already ordered.

The EDMS documents with common component definition and quantities are in preparation. Some have been released already. The first version of the infrastructure documents and a plan for discussion of individual service items are expected to be finished after the summer 2015. A plan for a second infrastructure workshop is foreseen for early next year. The LHCC commends the LHCb Collaboration for the progress on the upgrade status of the individual detectors. The LHCC has no concern with respect to the revision of milestones.

A dedicated presentation was given on the status of the readout boards. These are located in the event builder PCs interfacing the FE electronics with the event builder CPUs. The FPGA has up to 48 optical inputs and 48 optical outputs processing serial signals with a speed of up to 10 Gb/s. There are bidirectional serial links for the Timing and Fast Control (TFC). The readout board, TELL40, is connected to the FE electronics via 24 optical links running the GigaBit Transceiver (GBT) protocol with a speed of 100 Gb/s. The PCB has 14 layers of low-loss material. The chip operates with ten different voltages. The sequence to power on/off the FPGA is complicated. High currents (50A, 0.9V) are transported on a few traces to the FPGA core. The power dissipation is up to 160 W. 114 high-speed signals can be sent with a rate of 10 Gb/s. The board uses a BGA with a large number of pins (1932). The latest version of the FPGA is expected to go into production in September 2015. The present PCB prototypes use the engineering FPGAs ES1 and ES2. The firmware is prepared with a preliminary version of Quartus. The housing of the PC server has no well-controlled power supplies and cooling.

The first PCIe prototype board arrived in Marseille end of April 2015 and is equipped with the FPGA Arria10 ES1 running at 50 GB/s. Tests are ongoing. All basic functions work and several PCIe bus properties were tested successfully. The remaining work consists of testing the download of the FPGA firmware from the CPU. The manufacturing of the second board has been launched which uses the FPGA Arria10 ES2 that runs at 100 Gb/s. The high-speed optical links have been tested successfully. They ran on the previous version of the readout board, AMC40, in which receivers are connected to Stratix V FPGA. Since serializers and deserializers embedded in the FPGA evolve into the Arria 10 version, LHCb experts need to learn how to use the more sophisticated logic. Furthermore, tests of the PC enclosure were performed. The PC enclosure from the ASUS company shows excellent thermal stability.

The LHCb Collaboration considers an extension of the physics programme to include heavy-ion physics. Though the hot topic is the study of the quark-gluon plasma, other physics topics involve soft QCD and electroweak processes, which can be studied well in LHCb. Heavy-ion running at LHCb is unique since it provides a complementary physics programme to that of ALICE, ATLAS and CMS. LHCb can use the complete detector in the forward region with excellent mass resolution. LHCb is well suited to study open charm decays. Furthermore, to test charmonium suppression in another system, χ^0_c states can be studied down to low p_T . Since the LHCb detector is designed to reconstruct secondary vertices, LHCb can separate prompt decays from those involving b quarks and c quarks. In view of the ALICE results obtained in central exclusive production, interest recently focused also on ultra-peripheral collisions to which only LHCb has high sensitivity. Using the SMOG system, LHCb can study proton-Ne (Ar) and Pb-Ne (Ar) collisions in addition to proton-proton and Pb-Pb collisions. A test run from 27 min Pb-Ne interactions looks rather promising. Various particles, including Λ_s , J/ψ and K^0_S were reconstructed. Several groups in LHCb (LAL, Heidelberg, CERN, Beijing, Zürich and Budapest) have indicated interest in carrying out this physics. One group received a European Research Council grant to work on heavy-ion physics analysis. New groups are interested in joining this effort. The LHCb Collaboration is discussing this request. Computing resources are sufficient and the only remaining issue was an evaluation of detector safety. LHCC supports this new effort that will broaden the physics output of LHCb.

14. DISCUSSION WITH MoEDAL

The MoEDAL physics case is based primarily on magnetic monopole searches, and also includes highly-ionizing particle signatures for SUSY, extra dimensions and other models for new physics, as has been explored in recent publications by the Collaboration. The MoEDAL detector was successfully installed around the LHCb interaction point in the latter half of 2014 and is ready for the 2015 LHC physics run. The LHCC **congratulates** the Collaboration on reaching this important milestone. A detailed plan for the renewal and analysis of the passive detectors is in place. The rate at which the data can be analyzed is limited by the availability of high-rate optical scanners for the ‘Nuclear Track Detector’ plastic arrays, for which funding has yet to be secured.

15. DISCUSSION WITH LHCf

A physics paper on the joint ATLAS and LHCf analysis of proton-Pb collisions at 5.02 TeV centre-of-mass energy is in preparation. LHCf data taking is scheduled in the week before Technical Stop 1 (TS1), with a dedicated run of three good fills and a contingency of two days. The LHCf detectors will be removed from the LHC tunnel during TS1. Post-calibration of the calorimeter at the SPS is planned from 29 July to 12 August 2015. The upgrade of the trigger system for joint data-taking with ATLAS has been installed and a successful test run was performed on 6 May 2015. The result was full (100%) event matching using the event identification and cross-checking of both the bunch crossing identification and the time-stamp. The plan for common data-taking with ATLAS during the LHCf dedicated runs is to acquire 44 (+10) M events with tracker (full) information from ATLAS, corresponding to an integrated luminosity of about 15 nb⁻¹. The LHCf detector is ready and first 13 TeV centre-of-mass energy collisions were recorded.

16. DISCUSSION WITH THE WLCG

General

The consolidation and update programmes pursued by the computing teams of the LHC experiments in coordination with WLCG collaboration during the first long shutdown LS1 converged to very much improved data processing and analysis frameworks. Most of the solutions were adopted at early stages building upon the experience with Run I. The last three months have seen the confirmation of the computing systems readiness for Run II data taking. Indeed, massive Monte Carlo simulation campaigns are ongoing as a first challenge towards and as a preparation of the Run II data analysis. The first collision data at the energy-upgraded LHC were collected and processed successfully within the new frameworks. The next months will see an increase of the data amount and will certainly test the expectations in terms of performance and resources consumption, which is bound to fit within a flat multi-annual budget. The rapidly-evolving technology landscape is closely monitored and the trends are captured in interesting initiatives at the level of each experiment but also in a context of an increasing multi-experiment cooperation. The HEP Software Foundation raises hopes for an increase in the generic methods and frameworks relevant also for the LHC experiments. Efforts to use cloud computing are being developed in a multi-disciplinary environment, a configuration which is likely to become more cost effective than using in-house computing in the future. The Phase-1 perspectives are addressed in all experiments at various levels, either as Technical Design Reports for new systems (under scrutiny for ALICE and planned for LHCb) or as an adiabatic evolution closely followed within the experiments (ATLAS and CMS). The computing for Phase-2 is expected to be defined in parallel with the development of the detector upgrades, such that a discussion on computing for Phase-2 can take place within the LHCC by the end of the Run II data-taking period.

WLCG

WLCG sites are prepared for Run II and have been able indeed to promptly process large amounts of simulation and the first data samples. Some delays in deploying new resources were observed, but no major issues were reported at the Tier-1s. The Tier-0 delivery was delayed due to firmware issue on a large batch of hardware. All experiments now have 90% of the pledges, the rest is expected to be online soon. This major procurement exercise has essentially doubled the existing installations. Requests are viewed as reasonable, only minor adjustments – a moderate increase in tape capacity was granted. A pre-commercial procurement proposal was submitted to the Horizon 2020 ICT 8a call in April 2015 for innovative cloud services and is currently under evaluation by the European Commission. This initiative will help understanding the long-term sustainability of WLCG services and infrastructures.

ALICE

The experiment has observed a very productive period during the last three months with over 80000 concurrent jobs (a new record) mostly devoted to the simulation activity. The re-processing of Run I data with new software will complete by the end of June 2015. ALICE is ready for the start of Run II data taking. Resources request 2015-2017 endorsed by Computing Resources Scrutiny Group (CRSG) are adequate to cover the ALICE needs. The High Level Trigger (HLT) farm is using cloud technologies (OpenStack + HTCondor) and the first commissioning tests started (Virtual Machines deploying, job filling etc.). A new project for a Virtual Analysis Farm based on OpenStack is being prepared in order to replace the present proof-based farm. ALICE released the Technical Design Report for the Online-Offline (O²) computing system for the Phase-1 upgrade.

The plans include a new configuration for the high-end computing based on a dedicated analysis farm.

ATLAS

The renovated computing system is now successfully used to analyze the first data of the Run II. The MC15 digitization and reconstruction launched end of April 2015, which now includes three steps in each multi-core job; with up to 50 M events/day, 800 M events were reconstructed so far. The new derivation framework is operational and 90% of the planned derived samples (*DxAOD*) were produced. The usage of CPU resources continues to remain above the pledges and the origin of these extra resources is now investigated. Massive simulations and first data processing validate the Long Shutdown 1 (LS1) programme. The improvements for Long Shutdown 2 (LS2) start to be discussed, as well as the planning for the longer term.

CMS

The CMS Collaboration has also invested significant efforts during LS1 to improve the performance: the striking examples are the factor two gain in simulation due to a new sampling algorithm to reduce the time spent in tracking the low-energy particles in Geant4, as well as large gains in reconstruction. The release for multi-threaded reconstruction and digitization has been made available in March 2015. During the latest months the usage of the CPU resources was 100% for Tier-1 and 96% for Tier-2, reaching up to 100k jobs and dominated by large-scale simulation samples productions. While the first collisions were successfully treated, the planning for software updates includes an important release devoted to reprocessing of the end of the year.

LHCb

The High Level Trigger (HLT) is used in a shared mode (“split”) to allow a coherent calibration and reconstruction chain in online and offline, such that no reprocessing is needed. Identical online-offline tracking and particle identification has been achieved within the HLT time budget. The automatic calibration procedure is in place and has been tested during first collisions running. A special data flow, the ‘turbo stream’, takes advantage on the online reconstruction quality and implements analysis selections at the online level. The data flow is economically designed to use the micro-DST format, though in a first validation period the RAW data will also be recorded, in order to cross check and possibly reprocess. The stream has been tested with the first SMOG (System of Measuring Overlap with Gas) run and will be used for the first data in Run II. The data replication policy, in course of implementation, is expected to optimize the disk and tape space usage through less replication and prompt space recovery

17. REPORT ON RD39

The RD39 Collaboration is a small group consisting of 18 physicists from five institutes working on the development of very radiation-hard Si sensors that are operated at cryogenic temperatures to monitor beam losses at the LHC. So far, several different silicon and diamond detectors irradiated with protons with fluences between 10^{15} p/cm² and 10^{16} p/cm² were tested at 1.9K. The results from the 2012 test beam measurements were published in *Nuclear Instruments and Methods (NIM)* in February 2015. The RD39 Collaboration conducted another ten-day irradiation test in the PS at CERN in December 2014. Four new sensors were tested: a 100 µm thick Si pad, a 300 µm thick Si pad, a 3D Si detector and a 3D diamond detector. One member of the RD39 Collaboration has started a programme to study thick silicon (2 mm) sensors for a Time Project Chamber

(TPC) for the AEGIS experiment at the CERN Antiproton Decelerator. The LHCC **recommended** that RD39 be continued for one year.

18. REPORT ON RD42

The LHCC heard a report from the RD42 Collaboration on its ongoing programme to develop intrinsically radiation-hard Chemical Vapor Deposition (CVD) diamond tracking detectors for experiments at high luminosity colliders. The Collaboration has grown to 131 participants from 33 institutes. The two main technologies being pursued are poly-crystalline chemical vapor deposition (pCVD) and single-crystal CVD (scCVD) diamonds. Recently the RD42 Collaboration has developed two additional suppliers of high-grade material: II-VI in the US for poly-crystalline material and IIA in Singapore for single crystal material. II-VI has supplied sensors with 300 μm charge collection distance (40% more than that used in the ATLAS Diamond Beam Monitor DBM) and IIA has delivered about 10 scCVD devices. These devices show good charge-collection distance, and no signal loss at high rate has been observed. The behavior of the detectors as function of flux rate has been accepted by the *Journal of Instrumentation (JINST)* for publication. Particularly puzzling is the fact that irradiated scCVD diamond shows a rate dependence, whereas irradiated pCVD diamond does not show any rate dependence. This result was reported already last year and this behavior is still being studied. Since scCVD diamond shows the rate effect and pCVD does not, this indicates the effect probably has to do with the growth, since different processes grow the two materials.

A silicon pixel telescope, using CMS silicon pixel sensors, has been built and deployed at PSI. It allows for the detailed study of the spatial uniformity of devices.

The RD42 Collaboration has been heavily involved in the construction of the ATLAS DBM. The DBM consists of four 3-plane pixelated pCVD diamond stations on each side of the ATLAS experiment and has successfully exploited the synergy with the Insertable B-Layer (IBL) project. It is currently being commissioned with 13 TeV data. The Collaboration is also investigating 3D diamond detectors. These sensors have, similar to the 3D silicon sensors, electrodes penetrating the diamond. This provides for higher electric fields for the same bias voltage and allows for higher segmentation with distance between the electrodes smaller than the charge collection distance. Very good agreement in charge collection between planar and 3D devices has been observed, with a bias voltage of only 25V for the 3D devices, whereas 500V was applied for the planar device. These results have been published in *Nuclear Instruments and Methods A (NIM-A)*.

The RD42 Collaboration has developed pixelated diamond sensors for the community. Its benefit to the community is derived from developing the technology for the experiments and publishing in peer-reviewed journals. The publication record over the last two years, as presented during the meeting, seems relatively small for a collaboration this size. In order to continue their research programme, the RD42 Collaboration requests that the CERN RD42 group be maintained at the current level. The proposed research programme for next year is a continuation of the research programme of the last years with shifted milestones. The LHCC suggests that, since it is unlikely that diamond detectors will become a dominant technology for the HL-LHC and since there are clear synergies with other RD groups in terms of materials research, it would be beneficial for the group to re-evaluate its approach to boost the overall scientific output. The LHCC **recommended** that RD42 be continued for one year.

19. REPORT ON RD50

The RD50 Collaboration conducts R&D on radiation-hard semiconductor devices for very-high-luminosity colliders. The Collaboration consists of 275 physicists from 49 institutes and is structured into four subgroups that work on defect/material characterization, detector characterization, new structures and full detector systems. Many new results were obtained since the previous LHCC review in June 2014, including:

- The understanding of microscopic defects.
- Good progress on TCAD simulations.
- Systematic analyses of the charge multiplication mechanism.
- Consolidation of data obtained on p-type silicon and thin, segmented sensors.
- Characterization and radiation damage of high-voltage CMOS devices.
- Study of the two-photon absorption technique.

The LHCC congratulates RD50 for their achievements and acknowledges that RD50 followed the recommendation to start work on CMOS devices. Both ATLAS and CMS have profited from this work and will use n-in-p sensors for the upgrade. For next year, the RD50 Collaboration has announced a very rich programme of work. The LHCC fully supports the work of RD50 and commends them to continue with this pace. The LHCC **recommended** that RD50 be continued for one year.

20. REPORT ON RD51

The LHCC heard a report from the RD51 Collaboration on its progress and plans to develop advanced gas-avalanche Micro-Pattern Gas Detector (MPGD) technologies. The RD51 Collaboration aims to facilitate and advance the technological development of MPGDs and associated electronic read-out systems for applications in basic and applied research. The group serves as an access point to the MPGD technology for the worldwide community and its research focus has been on the development of techniques for the detectors in a high-rate environment while improving the space-point resolution and the radiation hardness of the detectors.

The Collaboration has ~400 members from 80 institutes organized around seven working groups. The main technologies being pursued are Micro-Mesh Gas Detectors (MICROMEGAS), thin and thick Gas Electron Multiplier (GEM) devices, and micro-pixel chambers. The deployment of the MPGD technology in running and planned experiments has increased substantially and RD51 now serves a broad user community.

The LHCC took note of the numerous RD51 achievements. Recent support for LHC-related activities includes development of MICROMEGAS for the ATLAS muon system upgrade, GEMs for the CMS forward muon system upgrade as well as GEMs for the ALICE Time Projection Chamber (TPC) upgrade. Contributions of the RD51 Collaboration to address challenges facing the ALICE upgrade work are invaluable. The RD51 activities have been shown to have direct relevance to the LHC experiments as the RD51 MPGD technology, electronics developments (SRS), and MPGD physics simulations are being demanded for the LHC experiments upgrades. RD51 organized important academia-industry matching events over the last year, including forums on neutron and photon detection with MPGDs. They also participated in the organization of the Danube School on Instrumentation in Elementary Particle and Nuclear Physics late in 2014. Maintenance and development of CERN's MPGD laboratory led by RD51 is critical for continuing MPGD R&D.

The LHCC referee also reported on RD51's plans for beyond 2015. The plans include continuation of R&D support for the LHC experiments and their upgrades; generic R&D; development and maintenance of software and simulation tools; development and maintenance of software of SRS electronics; industrialization of the MPGD technology; maintenance and improvements of the RD51 laboratory and test beam infrastructure at CERN; continued efforts in education and training for MPGDs; and the organization of specialized workshops.

In summary, RD51 is a successful R&D Collaboration with well-defined and important future plans. The RD51 Collaboration is asking the LHCC to recommend continuing limited support of the collaboration by CERN including access to RD51 test beam facility, access to CERN Micro Pattern Technology workshop (similar to present availability level), provision of limited extra office and laboratory space for students and users of RD51, and continuing access to the central computing resources for simulation. In view of the successes listed above and given the modest request for the resources for further work, the referees **recommended** that the RD51 R&D project be continued for one year and for CERN to continue to provide the requested support to the Collaboration.

21. REPORT ON RD52

RD52 is a small R&D effort (currently 12 institutes, 17 people) dedicated to a 'dual readout' approach aimed at improving the resolution of hadronic calorimeters for future collider detectors. Interesting initial results were shown from the most recent RD52 prototypes, which were exposed to a short test-beam run in December 2014, including energy resolution and longitudinal shower profiles. The LHCC noted that the group is small and possesses limited resources, but it is producing unique and interesting results on calorimeter R&D. The LHCC also noted that the RD52 approach has not been adopted for the upgrade of any current experiment, nor is it being planned currently for any explicit future experiment. The LHCC continues to encourage the Collaboration in having their technology adopted by a suitable experiment, and it looks forward to a report on the progress being made on this and the R&D programme in the next RD52 presentation. The LHCC **recommended** that RD52 be continued for one year.

22. REPORT ON RD53

This was the second status report to the LHCC of the RD53 Collaboration. The objective of this RD group is to develop pixel readout integrated circuits for extreme rate and radiation environments using the 65 nm CMOS technology as the baseline. There are unprecedented challenges for the vertex detectors at the HL-LHC. They must be able to withstand radiation levels up to 1 Grad and 10^{16} 1 MeV neutron equivalent/cm², require small pixels ($\sim 50 \times 50 \mu\text{m}^2$), large reticle size, and triggering capability up to 1MHz, combined with the "standard" requirements of low power and low mass. The requirement on the hit rate has been increased by about 50%, to 2-3 GHz/cm², to enable data taking at a pile-up of 200. The goal is to have a full-scale demonstrator pixel chip within the three-year R&D programme of RD53. The Collaboration is on track to achieve this goal.

The Collaboration currently consists of 20 institutes with 140 collaborators, about half of which are ASIC designers, with an equivalent FTE count of about 23. There are six working groups with well-defined goals and leadership with good progress reported by all groups. The radiation working group has carried out an extensive test programme of different test devices. Significant radiation damage has been observed above ~ 100 Mrad with strong temperature dependence and the results do not allow final conclusions. It

seems realistic to reach a radiation hardness of 0.5 GRad with a conservative design approach, which is a factor of two below the goal and would require the innermost pixel layers to be replaced every five years. An extensive array of further tests is foreseen and the results will be implemented in the simulations. The analogue working group has evaluated various designs of alternative front-end (FE) architectures. A second iteration of FE prototypes, extensive characterization and definition of the interface between FE and digital back end is foreseen.

A large number of building blocks are required to construct a full pixel chip and first prototypes have been characterized. Second generation of the building blocks is planned with integration in a global pixel design. The simulation models will be refined and updated. The control interface has been defined, simulated and verified and the readout protocol is being established for a rate of up to 4 Gbits/s and will be implemented in the pixel test systems. The floor plan for a full pixel chip has been laid out and refinements are foreseen for the integration with the full pixel chip demonstrator.

The RD53 Collaboration is on track for submission of a full-scale demonstrator chip by mid-2016. The goal is to demonstrate (nearly) all requirements for HL-LHC operation and the submission will also be used for the pixel sensor R&D programme. The LHCC congratulates the Collaboration on the progress to date and on the well-managed research programme and gives its full support for the submission of the full demonstrator chip in 2016. It is a critical step in the development of pixel detectors for the HL-LHC. Sustained effort should be given to expedite access to the design kits. Furthermore, continued research into radiation hardness to achieve the goal to sustain a dose of 1 GRad seems well justified given the recent change in the HL-LHC schedule. The LHCC **recommended** that RD53 be continued for one year.

23. CLOSE-OUT WITH DIRECTOR FOR RESEARCH AND COMPUTING

The LHCC informed and discussed with the Director of Research and Computing the status of the LHC experiments and their plans for future upgrades. The discussion focused on preparations of the LHC machine, experiment and computing for 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.

24. REREREES

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

25. The LHCC received the following documents:

- CERN-LHCC-2015-005 Minutes of the 121st meeting of the LHCC
- CERN-LHCC-2015-006 Technical Design Report for the Upgrade of the ALICE Online-Offline Computing System
- CERN-LHCC-2015-009 Technical Design Report for the ATLAS Forward Proton Detector
- CERN-LHCC-2015-010 Technical Proposal for the Phase-II Upgrade of the CMS Detector
- CERN-LHCC-2015-012 CMS Technical Design Report for the Muon End-cap GEM Upgrade
- CERN-LHCC-2015-013 UCG Report on the LHCb Trigger and Online Upgrade Technical Design Report (CERN-LHCC-2014-015)
- CERN-LHCC-2015-014 UCG Report on the ALICE Readout and Trigger System Upgrade Technical Design Report (CERN-LHCC-2013-019)
- CERN-LHCC-2015-015 UCG Report on the ALICE Time Projection Chamber Technical Design Report (CERN-LHCC-2013-020 and Addendum LHCC-2015-006)

DATES FOR LHCC MEETINGS

Dates for **2015**

23 – 24 September

2 – 3 December

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