

LARGE HADRON COLLIDER COMMITTEE

Draft Minutes of the one-hundredth-and-twenty-sixth meeting held on

Wednesday and Thursday, 25-26 May 2016

OPEN SESSION – STATUS REPORTS

1. LHC Machine Status Report: Enrico Bravin
2. LHCb Status Report: Manuel Schiller
3. ATLAS Status Report: Yu Nakahama Higuchi
4. TOTEM Status Report: Emilio Radicioni
5. RD50 Status Report: Michael Moll
6. RD53 Status Report: Jorgen Christiansen
7. RD42 Status Report: Harris Kagan
8. RD39 Status Report: Vladimir Eremin
9. RD51 Status Report: Leszek Ropelewski
10. RD52 Status Report: Silvia Franchino
11. ALICE Status Report: Friederike Bock
12. CMS Status Report: David Anthony Petyt

CLOSED SESSION:

Present: C. Bloise, J. Boyd, H. Burkhardt, P. Burrows, M. Demarteau, D. Denisov, C. Diaconu, G. Eigen, E. Elsen, F. Forti (Chairperson), P. Krizan*, T. Kuhr, F. Kunne, A. Kuzmin, M. Mangano*, P. Newman, B. Panzer-Steindel, B. Ratcliff, C. Schwick, T. Wengler (Scientific Secretary), T. Ullrich, H. Wilkens, H. Yamamoto

* part-time

Apologies: M. Lancaster, C. Sfienti

1. EXECUTIVE SUMMARY**General**

The LHC had a successful start-up in 2016, with several problems encountered that led to delays on the order of 1-2 weeks, such as power failure due to a small animal, a vacuum issue on a SPS internal beam dump, and a fault on a capacitor power bank switch. A delivered luminosity of 25 fb^{-1} is still a realistic goal, with the aim of providing 5 fb^{-1} in time for results for ICHEP. The experiments had a successful start-up as well. Notably the CMS magnet is now back to stable performance. The Phase-I upgrades are generally progressing well. During the recent RRB positive interactions on the Phase-II upgrades with the funding agencies took place; several reported that resources for Phase-II have already been allocated.



Report from the LHC Programme Co-ordinator

The LHC start-up progressed well, with first stable beam a few days ahead of schedule on April 23rd. A local orbit ‘bump’ was introduced in IP5 to increase the physics acceptance for the CT-PPS experiment. The number of bunches in the machine has been steadily increased in line with machine protection guidance to 1200 bunches to date.

The 2016 running periods are well defined, including the special running conditions ($\beta^*=2.5\text{km}$) and heavy ion running period.

After a dedicated meeting where the physics justifications for the experiment requests for the 2016 p-Pb period were presented, planning for this run has progressed with the foreseen programme including running at both $\sqrt{s_{NN}} = 5.02$ TeV and 8.16 TeV. The default schedule foresees reversing the direction of the beams during the high energy running if sufficient luminosity has been delivered by the halfway point. In addition one fill at $\sqrt{s_{NN}} = 8.16$ TeV will be dedicated to low luminosity data taking by the LHCf experiment.

- The **LHCC endorses** this proposal for the 2016 HI running period, recommending a flexible approach to cope with the actual running conditions.
- The **LHCC notes** the relevance of the physics program that can be achieved with non-standard running conditions and will convene a dedicated discussion during the December meeting on the long term prospects and detector preparedness for special runs.

Test Beams

The restart of the test-beam facilities proceeded with several problems this year: a broken extraction septum and a vacuum leak on an internal beam dump at the SPS, and two power supply failures at the PS. Despite the difficulties with the beam availability the irradiation facilities showed strong performance. A proposal for an important consolidation of the East Area is being prepared, and will be instrumental in keeping this unique facility operational over the next decades. There are 9 requests for beam tests parasitic to the NA61 Pb run. All request have been scheduled, with some periods shorter than requested.

ALICE

Scientific output and current activities:

- ALICE has made excellent progress on their physics analysis, with a total of 155 papers submitted to date.
- The detector systems have been re-commissioned and are ready for data taking, including the new RCU2 read-out control units.
- The large local distortions in the TPC in about 20% of the cross area of the TPC remain a concern, as the origin of these distortions is not understood.
 - The correction procedures are well established and sufficient for 2016 conditions, however rapid fluctuations of the distortions lead to additional uncertainties on the nominal cluster errors.
- The TPC distortions are a major issue that raises two classes of concerns:
 - Effects on the current TPC, especially if the current stable situation changes.
 - Impact on the TPC upgrade: local distortions and related short time fluctuations would be very difficult to counter.

Upgrades are progressing well with some non-critical delays.

- An in-depth review of the ALICE upgrade will be carried out during the September 2016 session of the LHCC.
- Regarding the TPC distortions, the **LHCC recommends** the formation of a task force of experts both from ALICE and external to analyse the existing data, try to understand the source of the problem, and identify the operational options. In addition the task force could propose a program to study the effect and the possible impact on the TPC upgrade.

ATLAS

Scientific output and current activities:

- The physics programme is progressing well, with 538 papers submitted to date. Plans to search for a 750 GeV resonance with 2016 data are well established.
- All detector systems are operational and ready for 2016 data taking, with close to 100% of the signal channels operational.
- The strategies on the running temperature of the IBL and the gas distribution of the TRT have been defined and implemented. Many gas leaks in the RPC muon chambers have been fixed. The newly installed first arm of AFP has been integrated into the ATLAS DAQ. The ALFA detector observes a large increase in radiation dose when AFP is in-beam. AFP will only be inserted for a few fills for commissioning in 2016.
- ATLAS experienced 3 slow dumps in the magnets, pointing, together with problems encountered in the past, to some loss of knowledge and experienced personnel over time.

Phase-I upgrades are progressing well, however with delays in several areas:

- NSW: There are concerns about delays on chamber production and readout chips. The schedule situation is difficult but well managed by the project leader. Additional support from CERN on logistics and procurement would be welcome.
- There has been much progress on FTK, although also some delays. The goal of full barrel coverage by October 2016 is still possible.
- LAr: There are delays for two readout chips. The ADC v15 has passed tests in March; the final review will take place in October 2016. The serialiser chip is going through a further iteration, however backup plans will be put into action now, with a final decision in early 2017, still compatible with the schedule.

Phase-II upgrades are progressing well, on track for first TDR submissions.

- A UCG progress review will be held during the September LHCC week.
- With respect to the possible 750 GeV resonance the **LHCC recommends** to maintain the very high standards for full scientific verification of the results before they are announced.
- The **LHCC encourages** ATLAS in its decision to pursue the backup plans for the serialiser chip for the LAr Phase-I upgrade.
- The **LHCC encourages** ATLAS to maintain the high level of activity and close management to keep the NSW on schedule for installation in LS2.
- The **LHCC recommends** that additional support be made available from CERN to help with logistics and procurement for NSW and other projects, as the Phase-I projects are going into full production.

CMS

Scientific output and current activities:

- CMS continues to produce a strong scientific output, with 489 physics papers submitted to date. Much attention is given to the preparation of the search for a 750 GeV resonance.
- The magnet issues have been fixed; the cryogenics system is operating stably. All detector systems are in good shape and ready for 2016 data taking.
- The integration of TOTEM and CT-PPS into the CMS readout has been completed in record time.

Phase-I upgrades:

- The trigger upgrade for 2016 run is now complete and used for data collection.
- HCAL upgrade: The HF front-end upgrade is on schedule for installation in the 2016/17 EYETS. The HE HPD replacement with SiPMs is on a tight schedule. The decision to go ahead or not for 2016/17 EYETS will be made in September 2016.
- Pixel detector upgrade: There is great progress and currently a good chance for installation during the coming EYETS, but the schedule is still very tight. The decision to proceed or not with the pixels installations this year will be made following an enhanced Engineering Design Review scheduled on June 16-17, 2016.

Phase-II upgrades:

- Concentrating on R&D in all areas, with substantial progress in all systems: tracker, calorimetry, muons, simulation. A detailed schedule for TDR submissions is now available.
- A UCG progress review will be held during the September LHCC week.
- With respect to the possible 750 GeV resonance the **LHCC recommends** to maintain the very high standards for full scientific verification of the results before they are announced.
- The **LHCC endorses** the plan regarding the decision on pixel installation and **recommends** that this time schedule be kept to ensure proper planning for the EYETS.
- The **LHCC notes** that it is important that the Phase-II TDR timing is well matched to the R&D and technical progress, to ensure well developed solutions are presented in the TDRs.

LHCb

Scientific output and current activities:

- LHCb continues to have a rich scientific output with a total of 314 papers submitted to date.
- The detector is in excellent shape for data taking in 2016. The alignments and calibrations of all subsystems are done automatically now; they were validated and perform well. The Turbo stream was extended from 2 to 6 working groups. Mass plots extracted from the Turbo stream in 2016 yield the same resolutions as those in 2015 offline reconstruction.
- First plots from heavy ion physics analyses look very promising, however, further work

is needed on the reconstruction for these events.

Upgrades:

- An in-depth review of the LHCb upgrades was carried out in this session of the LHCC.
- The upgrades are progressing very well and within the original budget.
- No critical delays have been accumulated, however close monitoring of especially Upstream Tracker (UT), Vertex Locator (VELO) and Scintillating Fibre Tracker is suggested.

- The **LHCC notes** that the experiment pushes the technical limitations in various areas, which is commendable, however the associated risks need to be closely monitored.

TOTEM

TOTEM and CMS have successfully deployed and commissioned the first phase of the CT-PPS tracking detectors, relying on TOTEM silicon sensors. Timing detectors, using TOTEM's diamond sensors, are being readied for installation during the first technical stop. A schedule for the transition to the final configuration has been produced, and all deadlines have been met so far. The combined operation and readout of the TOTEM systems with CMS has been demonstrated.

- The **LHCC notes** the impressive progress that has been made on this project in a short time period, also demonstrating excellent collaboration between TOTEM, CMS and the LHC.

WLCG

LCG computing is in excellent shape, with 2016 data processing now under way as well as reprocessing of previous data and MC production. Across the experiments several 100k jobs run concurrently, making efficient use of the resources.

Work is on-going on the long-term computing plans, with progress in all experiments. A HEP software foundation workshop was held in May with good participation across the HEP community. A community white paper on longer-term strategy for HEP software will be produced, with a kick-off meeting towards the end of 2016, and a delivery date of mid-2017. The white paper will be kept in line with the discussions on the HL-LHC computing TDR.

- The **LHCC takes note** of the progress on long-term computing models and **recommends** pursuing these plans, noting that some injection of person-power is required to carry out this essential activity.

R&D Projects

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

RD39: Cryogenic Tracking Detectors

- Development of cryogenic BLM and thick detector for Aegis. However progress is relatively slow and there is no real match to the LHC experiment needs.
- Given the small size of the group and limited available effort, as well as the large overlap

with RD50, the **LHCC recommends** that this effort becomes part of RD50.

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

- The value of diamond detectors for the community is well recognized and the LHCC congratulate the collaboration on the progress this year.
- Following the successful model of the other large RD collaborations, the **LHCC recommends** that RD42 create a slightly tighter collaboration to advance the overall scientific output.
- The **LHCC recommends** continuing the support for RD42 for one year.

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

- Very productive and diversified collaboration.
- The **LHCC recommends** continuing the support for RD50 for one year. The **LHCC further recommends** to focus on the advanced technologies required for HL-LHC.

RD51: Development of Micro-Pattern Gas Detectors Technologies

- Very active and vibrant community.
- The **LHCC recommends** continuing the support for RD51 for one year. The **LHCC supports** the request for extra lab and office space.
- The **LHCC recommends** to further develop industrialization of the technologies involved.

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

- Interesting and novel concept, but cannot be advanced any further unless a specific application is found.
- The **LHCC recommends** continuing the support for RD52 for a final year to complete and document the R&D. No further prolongation should be proposed unless there is a significant interest from an experiment.

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

- The LHCC congratulates the collaboration with the progress to date and the very well managed research program and gives its full support for the submission of the full-scale demonstrator RD53a chip by early 2017. It is a critical step in the development of pixel detectors for the HL-LHC for which the design work remains critical.
- The collaboration is under pressure to deliver a chip so the results can be incorporated in the TDRs of the ATLAS and CMS experiments. The **LHCC recognizes** the challenges RD53 faces and notes that the final chip design will depend on the outcome of the test results.
- The committee **encourages** the collaboration to perform all the necessary checks and simulations before submission to deliver a radiation hard chip that meets the

specifications and **realizes** that the final design will depend on the outcome of the test results.

- The **LHCC recommends** continuing the support for RD53 for one year.

2. Procedure

The Chairman welcomed the new member of the LHCC, P. Krizan. The minutes of the one-hundredth-and-twenty-fifth LHCC meeting (LHCC-2016-002 / LHCC-125) were approved provisionally, pending comments during the next few days.

3. REPORT FROM THE DIRECTOR FOR RESEARCH AND COMPUTING

The Director for Research and Computing reported on issues related to the LHC. Several problems on the LHC injector chain caused delays in the ramp up of collected luminosity this year, such as 60 kV power transformer problems and a vacuum leak at an internal beam dump of the SPS. However the overall impact on the LHC program is expected to be small, with the projection for 2016 still at 25 fb^{-1} . He reported that the issue with the CMS magnet has been successfully resolved, and that no other major problems are currently present in the LHC experiments. On the Phase-II upgrades the input of the LHCC to the RRB was much appreciated and inspired confidence in the procedure to arrive at the detector design that is most suited for the physics goals of the upgrade program within the financial constraints. He also reported that there have been encouraging messages from the Funding Agencies regarding the funding for the Phase-II upgrades. The development of the computing model of the future program is on-going, with emphasis on shared cloud resources.

4. REPORT FROM THE LHC PROGRAMME CO-ORDINATOR

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The 2016 running periods are well defined, including the special running conditions ($\beta^*=2.5\text{km}$) and heavy ion running period.

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5. TEST BEAMS

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Area is being prepared, and will be instrumental in keeping this unique facility operational over the next decades. There are 9 requests for beam tests parasitic to the NA61 Pb run. All request have been scheduled, with some periods shorter than requested.

6. DISCUSSION WITH ALICE

Scientific output

The ALICE collaboration continues to have a diverse and sound scientific output. Since the last LHCC meeting 6 papers were submitted, 9 accepted for publication, and 8 were published. The total number of paper submissions is 155 papers. Among the physics highlights is the measurement of D meson production over the whole kinematic range down to $p_T = 0$ GeV/c in p-p and p-Pb collisions, thus providing the to-date most precise determination of the total charm cross-section in these systems. In Pb-Pb collisions, ALICE conducted a novel study of fluctuations of anisotropic flow harmonics using multiparticle cumulants. Together with the existing measurements of individual flow harmonics these results provide further constraints on initial conditions and the transport properties of the quark-gluon plasma.

Current activities and short-term plans

After successful re-commissioning ALICE was able to fully exploit early and special runs and to record ~ 0.5 pb⁻¹ of p-p collisions at 13 TeV during the LHC luminosity ramp-up in May. A new LHC beam optics was adopted this year in IR2 increasing and switching the sign of the crossing angle from -120 μ rad to +200 μ rad at flat top. This allows ALICE to switch the polarity of their dipole without impacting machine operation. After ramp up ALICE plans to level at a luminosity of 5 Hz/ μ b (300 kHz), with a pile-up rate of 1% aiming at recording an integrated luminosity of 7.5 pb⁻¹ for analysis based on the central barrel and 12 pb⁻¹ for muon arm-based physics. The trigger mix includes the minimum bias trigger, muon trigger, a high multiplicity trigger, rare triggers (jet, photon, diffractive double gap), as well as cosmic 4-fold coincidence. The commissioning of the new TPC readout units (RCU2) requiring a firmware upgrade was performed in March with cosmics and with first stable beams in April. The readout of all channels was achieved at the required transfer rate of 3.125 Gb/s for large events while further work is ongoing to obtain the same performance on smaller block data transfer. As discussed in the dedicated session, ALICE requested for the 2016 heavy-ion run period p-Pb collisions at 5.02 TeV in order to collect 10⁹ minimum bias triggers. This would improve the p-Pb data sample taken in 2013 by a factor 10 allowing more in depth studies of collective effects in the heavy flavor sector. For p-Pb collisions at 8.16 TeV, ALICE plans to focus on the study of quarkonium production in hadronic and ultra-peripheral collisions with the muon spectrometer data for which they expect to integrate 16 nb⁻¹ in 10 days, levelling at a luminosity of 0.1 Hz/ μ b (200 kHz of interaction rate).

TPC Distortions

As previously reported, large localised distortions have been observed in the TPC cluster positions measured in the 2015 run, leading to TPC track losses and shortening, distorted kinematics, problems with ITS-TPC and TRD-TPC matching and with vertex DCA evaluation. The distortions are typically close to the edges of the IROC and approximately scale with the luminosity, though there are also short and long timescale variations. The gas was completely purged during the end of year shutdown, but this did not produce an improvement. Test data to further study the dependences have been taken and are under investigation. In the meantime,

the track reconstruction algorithm has been modified with relaxed TPC tolerances for the initial track-finding and correction maps for the distortions applied in a refitting step. The distortion maps are evaluated in 40-minute time slices. This deals effectively with long timescale changes, but fluctuations on short timescales typical of ion drift times (~ 200 ms) cannot be corrected and additional uncertainties are therefore added to the cluster positions.

Taking time to characterise the distortions and devise a modified reconstruction approach has caused a major delay in starting the reprocessing of data for analysis. The low rate 2015 data sample (<500 Hz) has now been processed and the QA procedure confirms an improvement. The processing of the high rate data (~ 5 kHz) has begun. The correction procedure used for 2015 data is expected to also be applicable in 2016. No changes in gas mixture from the current Ar-CO₂ mixture are currently planned for 2016, although the collaboration has enough neon in hand to switch, should it become necessary.

In addition to the effects on the current running, the unexpected TPC distortions raise concerns with regard to the TPC upgrade, where much higher rates and ion back-flow will be encountered, resulting in larger distortions and stronger short timescale fluctuations.

Phase-I Upgrades

The Engineering Design Review (EDR) for the ITS (inner tracker) HIC and Staves took place in May 2016, with a positive outcome. The committee concluded that the component designs, assembly set-ups and initial results on early HIC prototypes and staves look generally convincing, and that there are strong and experienced teams involved. It stated that there are no show-stoppers at this point.

In the CTP (central trigger) upgrade, a change of FPGA from Kintex-7 to Kintex-Ultrascale has been required, due to a frequency hole. The implication is a delay of 4 months to the LTUs, which is non-critical, with no significant change to the overall costs. The CTP EDR is scheduled for June 2016.

The remaining upgrades are progressing well with some small, non-critical delays. Successful PRRs and EDRs have recently taken place for the MID front-end and readout and the DRM2 prototypes for the ToF. Milestones have also been met for the software process and DDS release for O2. The SAMPA MPW2 prototype submission was submitted in February 2016. There are small (~ 1 month) changes to the planned schedule for MPW3. There are also small changes to the schedules of the CRU, FIT and TRD.

7. DISCUSSION WITH ATLAS

Scientific output

ATLAS has successfully started beam operations in 2016; to date 0.73fb^{-1} of p-p collision data have been recorded with a data-taking efficiency of about 93% and a recorded data quality efficiency of about 96%. The Collaboration has submitted 538 scientific papers so far, including 25 since the previous LHCC session in March 2016, 18 of which are on Run 2 data. An additional 20 papers on Run 2 data are in circulation. A paper on new-particle searches in the gamma-gamma decay channel is in final circulation and is expected to be finalised within about 2 weeks; this will be submitted for publication concurrently with a corresponding paper from CMS. New results on B meson decays to muon pairs, submitted for publication, were noted. The 2015 Pb-Pb collision data have been successfully reprocessed and analysis is in progress.

Current activities and short-term plans

The detector operational status is excellent, with close to 100% channel availability in all subsystems. Some points worthy of note include:

- The increase in current in the Inner B-Layer (IBL) read-out electronics has been studied further via laboratory irradiation tests. In order to minimise the current increase the IBL will be operated at +15C in the near term. The operating temperature will be reduced, to minimise long-term radiation-damage effects, as soon as feasible.
- A hybrid running configuration of Xenon/Argon in the TRT has been implemented so as to minimise Xe leaks with only a very minor impact on the electron-identification performance.
- A leak developed in the Liquid Argon Calorimeter front-end electronics cooling system; this was quickly diagnosed and repaired. A precautionary inspection of the complete system will be made during the next YETS.
- 3 slow dumps within a 4-day period took place in the magnet compressor system. The causes are technically uncorrelated, but this has reiterated the importance of continuity of expertise in the relevant maintenance teams.
- AFP has been integrated into the ATLAS DAQ system without latency penalty and diffractive proton data have been recorded. With AFP in-beam, ALFA has observed a significant increase in radiation dose to its electronics.

The trigger/DAQ and offline data processing systems are all working well. All of the 2015 data have been reprocessed with the latest reconstruction software release.

Phase-I / II Upgrades

The Phase-I upgrade projects status was reviewed. All projects are progressing. For the muon New Small Wheel (NSW) upgrade progress has been made in production of both the Micromegas and small strip Thin Gap Chamber (STGC) detectors, as well as in the readout electronics. The schedule remains extremely tight, and there is almost no remaining contingency if the NSW is to be installed in LS2. There remain concerns about progress with the LAr readout upgrade serialiser ASIC chip. The LHCC will continue to monitor closely the Phase-I upgrade projects, in particular the NSW.

Six TDRs are expected to be delivered for the Phase-II upgrade projects between December 2016 and December 2017. A meeting of the LHCC referees, the UCG and ATLAS will be held in September so as to review progress towards the Phase-II upgrades.

8. DISCUSSION WITH CMS

Scientific output

The total number of papers submitted by CMS is 505 with an additional 47 ready for internal review. Run 2 data provided 82 public results, including 21 papers. CMS demonstrated remarkably smooth transition from Run 1 to Run 2 analyses. A large number of new 13 TeV results are expected for ICHEP 2016 in August, including results based on 2016 data.

Highlights of the recent results include re-discovery of the Higgs boson at 13 TeV in four-lepton and di-photon modes. The “750 GeV excess” in the di-photon mass spectrum for CMS has a global significance of ~ 1.6 sigma after combining 8 TeV and 13 TeV data. No un-

expected structures in other channels that a X(750) resonance might be decaying to, like $Z\gamma$, are observed. With data to be available by ICHEP 2016 this excess will most probably be confirmed or disproved. CMS developed a strategy for analyzing new data in this study, with all main selection cuts to be frozen and cross-checked (by a second group). CMS is in a good position to discover and study this new object, if it exists.

CMS Collaboration

In the last 18 months 11 full and 2 associate members joined the CMS experiment. Five more institutes are in the approval pipeline. This is an indication of an exciting physics program ahead as well as attractiveness of the CMS experiment for new groups interested to join studies at the LHC.

Current activities and short-term plans

CMS reconstruction and data analysis infrastructure are ready for the new data analysis and calibration of various detectors and Monte Carlo simulation is progressing on schedule. 2016 YETS cleaning of the magnet cooling system and related consolidation activities were successful and the magnet is cold and operating at full field since the first physics collisions in late April. An active commissioning period with long cosmic data taking periods during February and March of 2016 helped CMS to commission all detectors, trigger and DAQ systems to be ready for physics data collection in April 2016. The number of operating channels in all systems is above 2015 levels and in the range between 97% and 100%.

The Level 1 trigger Phase-I upgrade has been fully completed and CMS is running with the upgraded trigger system collecting data. This major upgrade provides CMS with unique triggering capabilities including highly efficient triggering up to an instantaneous luminosity of $2 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$.

The CMS DAQ has gone through a major consolidation for the 2016 run including improved framework and monitoring, replacement of obsolete nodes and integration of TOTEM and CT-PPS into the CMS readout.

CMS started the 2016 run with a data taking efficiency of 92% and all detectors operating smoothly. By the time of the May LHCC meeting $\sim 0.7 \text{ fb}^{-1}$ of data had been recorded. Trigger tables for luminosities up to $1.4 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ have been developed as well as initial calibration and alignment of all detectors performed. Performance of all detectors is at the level or better than in 2015.

CMS released CMSSW 80X in March and this release version is ready for production as of April 1st. The plan is to use this version, with improved performance in comparison with 2015, for high level triggering, data processing and Monte Carlo generation for the duration of the 2016 run. A well-defined plan for Monte Carlo simulation of ICHEP samples and beyond as well as calibration and re-processing of early 2016 data has been developed to assure efficient use of available CPU resources.

Phase-I Upgrade

The upgrade of the Hadron Forward (HF) calorimeter is actively progressing. QIE cards re-work completion is expected by the end of August. All other elements of the HF upgrade are on schedule with installation expected during 2016-2017 EYETS.

The Hadron End (HE) calorimeter upgrade is in full swing. The plan is to start batched front end integration at CERN at the end of June. The front end manufacturing progress review is expected early July. Installation readiness reviews and "go-no-go" decision for installation

during 2016-2017 EYETS is expected in September. If "go", HE installation will progress in December 2016 to April 2017.

The CMS pixels Phase-I upgrade team demonstrated major progress since the March 2016 LHCC meeting. Serious technical issues (like cooling pipes welding) have been resolved and detailed production, assembly, testing and installation schedules have been developed. At this moment, based on the provided information, there is a good chance for CMS to succeed with readiness for the central and forward pixels installation during the coming EYETS. CMS will have an enhanced engineering design review on June 16-17 to decide to proceed or not with the pixels installation later this year. LHCC major concern is little time contingency: any delay or resources shortage could affect the plan.

Phase-II Upgrade

Substantial progress has been achieved in all areas of the upgrade, including tracker design, forward calorimeter, muon upgrade and developments of the simulation. A detailed schedule for the Phase-II upgrade, including review and delivery of the TDRs, is now available. This schedule is in line with the overall high luminosity LHC program. Main medium term goal is to finalize remaining technical choices in time for the TDRs, which are scheduled to be delivered to the LHCC in 2017.

9. DISCUSSION WITH LHCb

Scientific output

LHCb submitted 13 papers plus 4 conference reports since the last LHCC week, yielding 314 submitted papers in total; an additional nine papers are close to submission and 41 analyses are in the pipeline for ICHEP. The new, world's-best results include Z^0 boson production at 13 TeV, precision measurement of the Δm_d , precision measurement of γ in $B \rightarrow DK^+$ (K^{*0}), precision measurement of CP violation in B_s mixing and a tetraquark search yielding no confirmation of a D_0 observation. LHCb made significant progress in understanding the Pb-Pb data seeing clearly relevant reference signals (J/ψ , D^0 , Λ^0). Though further work is needed on the reconstruction code, LHCb will provide results in the forward production that are complementary to ALICE, ATLAS and CMS.

Current activities and short-term plans

LHCb performs automatic online alignments and calibrations of all subsystems achieving the best offline performance already online. Depending on the task, alignments and calibrations are done either each run, each fill or as necessary. The full RICH information is available at HLT2 level; the full online/offline chain was validated; the data acquisition system runs smoothly. The prompt DQ allows to check and flag the data immediately. The system works nicely but a few problems were spotted already. The Turbo stream with an additional stream for alignment and calibration allows to do physics analyses directly from the trigger output, saving CPU time and disk space. It was debugged and extensively tested with 2015 data. So LHCb has started already to do the commissioning of the upgrade. The extended Turbo++ stream is now used by six physics working groups, compared to the two who were customers in 2015. In particular, 80% of the charm lines are now Turbo++ based. It can save not only reconstructed objects for selected lines, but can create and save new variables. It processes about 50% of all events (6 kHz) corresponding to a data volume of 30% (250 MB/s). LHCb sees clear physics signals in the 2016 data despite small statistics using the Turbo stream. From

the physics point of view, the LHCb detector is working very well. LHCb requests p-Pb running at 8 TeV with a luminosity of 20 nb^{-1} split equally into p-Pb and Pb-p.

Phase-I Upgrades

The progress of Phase-I upgrade is discussed in the in-depth review. Beyond the current upgrade, LHCb started discussion about the further evolution of the LHCb detector. The LS3 shutdown provides an ideal opportunity for consolidation of existing improvements and further modest developments, which could significantly enhance the experiment's capabilities in specific areas. For example, to improve the acceptance for low-momentum tracks such as the slow pions from D^* decays, LHCb could insert side chambers in the magnet. To allow for operation at high luminosity, LHCb started to look into further upgrades for the LS4 shutdown, including the physics case and machine aspects. The LHCC acknowledges the thoughts about HL-LHC but remarks that this work should not impact the Phase-I upgrades.

In-depth review of the LHCb upgrade

The LHCC carried out an in-depth review of the upgrades of the LHCb experiment. The LHCC wishes to commend the collaboration for its progress with a well-managed upgrade and with its continued success in pushing technical barriers and creating new paradigms for particle physics detectors. The organizational structure has been adjusted with the addition of four new upgrade specific coordinators, which will serve the collaboration well. The next twelve months will be critical for the project and close monitoring of all activities, in particular the VELO, UT and Fiber Tracker is suggested.

The experiment will move towards an all software trigger, handling 40 Tbit/s of data, based on commercially available network and server technology. Good progress has been reported in all TDAQ areas. Given that LHCb will have the highest throughput data acquisition system ever built, an expedient incremental buildup of the readout chain and processing farm to a sizeable fraction of the final number of nodes, operating within 60-70% of the target bandwidth specifications, is highly encouraged. It is suggested that a decision with regard to a new Data Center be viewed in light of the long-term needs of the experiment and the host organization. The experiment has already implemented upgrade features in the current trigger, albeit at lower readout rate. Calibration and alignment of the detector are carried-out in real-time and a Turbo stream with reduced data format has been created. This has been a resounding success and provides a fruitful training ground for the new trigger paradigm. The software resources to develop the infrastructure for the upgrade, however, are short by at least a factor of two. The experiment should quickly focus on a limited number of options for the various architectures and actively recruit the required software expertise to address the framework, processing and simulation needs for Run 3.

The upgrade of the detectors overall is progressing well. The PRR for sensors for the VELO detector has been postponed to September 2016 to implement some minor modifications to improve their performance, which is well justified. The prototype sensors perform very well. The VELOPIX ASIC is behind schedule. The chip has been extensively simulated and the experiment hopes that a single submission will suffice. The risk and the implications of a second submission ought to be considered. As of yet, no vendor has been fully validated for the fabrication of the micro-channel cooling plates. Close monitoring and engagement with the vendor(s) for the micro-channel cooling plates is critically important. A $500 \mu\text{m}$ thick prototype RF foil was produced with some minor leaks which are under investigation. A foil with the

target thickness of 250 μm is imminent. A thorough mechanical design review of the important VELO detector will mitigate many risks and ought to be carried out with due diligence. It is recommended to carry out mock assembly, mounting and installation procedures to the greatest level of detail as early as possible to reveal any potential risks with the assembly, construction and installation of the detector. Most elements of the Upstream Tracker (UT) are progressing well. The 128-channel SALT ASIC, critical for the debugging of the full readout chain, is behind schedule and submission is planned for June 2016. The yield of the flex circuits is also low. The verification, submission and subsequent testing of the SALT ASIC and the full readout chain should have high priority. The scintillating fiber project has a very dedicated team that is making good progress in all areas. The extra fabrication run of SiPMs is well motivated and it is suggested to decide on one supplier of SiPMs as baseline. The “bumps” in the fibers have been resolved, allowing 6-layer mats as the baseline. The RICH, CALO and MUON systems are to be congratulated on their progress, excellent test beam and test bench results and on some tasks being ahead of schedule.

The effort of the collaboration in the area of software development is laudable. Furthermore, a lot of thought and effort has been put in developing a resource loaded schedule for the activities during LS2 which is, relatively speaking, not very long for the multitude of highly intricate tasks to be carried out in the hall and has already little contingency. The committee commends the LHCb collaboration on the excellent progress on the well-managed upgrade project.

10. DISCUSSION WITH TOTEM

CMS-TOTEM PPS

TOTEM and CMS have successfully deployed and commissioned the first phase of the Precision Proton Spectrometer (CT-PPS). Insertion tests for the Roman Pots were performed as planned, at the second fill of each step of the luminosity ramp, 2 hours after reaching stable beams. Insertions during fills with up to 1177 bunches ($L \leq 3.2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$) were successfully completed, reaching $15\sigma + 0.5 \text{ mm}$ from the beam. No problems were detected with the vacuum pressure during insertions and with the temperature evolution during the fills. Beam-loss levels were within tolerance, and have been tested to be insensitive to the presence of the extra 0.5mm margin ($\sim 3 \sigma$) up to $L \sim 1.6 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$. The orbit position was reproducible between fills to within $\sim 100\mu\text{m}$. In view of these positive tests, the Machine Protection Panel would consider the permanent removal of the 0.5 mm safety margin in mid-June. Under these conditions, and considering the recent work by the accelerator team on the optics to optimize the acceptance of CT-PPS, two out of three stations will now meet the target of having full acceptance for a 750 GeV resonance produced within 0.5 units of rapidity. The LHCC acknowledges the LHC team for having addressed and successfully solved the acceptance concern that was raised during the March LHCC.

The tracking detectors, relying on TOTEM silicon sensors, have been completed, installed, commissioned and fully integrated in the CMS data acquisition. The combined operation and readout of the TOTEM systems with CMS has been demonstrated. CT-PPS has therefore been able to collect 200 pb^{-1} of physics data during the last fills before the LHCC meeting. Timing detectors with tracking capability, using TOTEM’s diamond sensors, are being readied for installation during the first technical stop. An RF noise problem that appeared after the assembly of the 4 detector planes has been understood and is in the process of being solved. The geometry of the four planes has been reconfigured, to optimize the x-space resolution for the exclusive production of a resonance with mass in the 750-1000 GeV range. The timing detectors are therefore on track to contribute to this summer’s data taking.

Work towards the final configuration of the CT-PPS is also proceeding very well. A schedule has been produced, and all deadlines have been met so far. The second and final batch of 3-D pixel-tracking sensors has been delivered by CNM. Bump bonding has been performed on 10 single-ROC sensors, and tests were made, including on test beams at FNAL. A first set of final modules has been produced. The rest will be completed after tests on the first set have been performed. Work on the ultra-fast silicon sensors for the timing detectors is likewise progressing. A final design for CT-PPS was obtained, and delivery expected by June 2016. Electronics is to be delivered by this summer. 60 ps resolution were achieved with 75 μm sensors, and two 50 μm productions are expected this summer from CNM. The challenging goal is to be ready for installation during the 2016-17 YETS.

TOTEM

The vertical-timing upgrade is still moving on a fast track. Two detector packages are scheduled to be assembled in August, and be ready for installation during TS2 in September. The goal is to test their functionality during the $\beta^* = 2.5$ km run, and to have all four packages ready for a possible $\beta^* = 90$ m run in 2017.

Concerning the replacement of the CMS beam pipe during LS2 and its impact on the T2 telescope, TOTEM confirmed that it would not reinstall T2 after LS2, and that, while it is interested in a future upgrade for this forward region, it is not in a position today to work towards a TDR. TOTEM believes that the current CMS beam pipe design is an acceptable boundary condition for the design of a future forward telescope, and is open to a future collaborative effort with CMS, along the lines of CT-PPS.

11. REPORT ON R&D PROJECTS

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

RD39: Cryogenic Tracking Detectors

RD39 is a small collaboration that develops super-radiation-hard silicon sensors operated at cryogenic temperatures for use as beam loss monitor at the LHC. However, the interest in these detectors by the LHC machine is limited. A second activity consists of developing thick silicon detectors for the AEGIS experiment. In 2015, RD39 published results from 2012-2014 test beam studies in NIM. They performed new radiation hardness tests of 16 sensors of different thickness showing that 100 μm thick sensors perform well after high irradiation.

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

The LHCC heard a report from the RD42 collaboration on its ongoing program to develop intrinsically radiation-hard Chemical Vapor Deposition (CVD) diamond tracking detectors for experiments at high luminosity colliders. The collaboration has 127 participants from 31 institutions, broadly organized in five working groups. The two main technologies being pursued are poly-crystalline chemical vapor deposition (pCVD) and single-crystal CVD (scCVD) diamonds. Diamond detectors are currently being used as beam condition monitors in all four LHC experiments. Sensors with 300 μm charge collection distance (40% more than that used in the ATLAS DBM) have been obtained. Using diamond detectors, injection losses at the LHC have been studied. The nanosecond timing resolution allowed for the first time the

identification of the time structure of the losses and a local loss reduction of 35% was achieved. The collaboration has been heavily involved in the construction of the ATLAS Diamond Beam Monitor (DBM). An attempt to lower the signal threshold of the DBM sensors has so far not been successful and encouraging beam test studies have been carried out. Good progress has been made in the development of 3D pCVD diamond detectors. These sensors have, similar to the 3D silicon sensors, electrodes penetrating the diamond. This provides for higher electric fields at the same bias voltage and allows for higher segmentation with distance between the electrodes smaller than the charge collection distance. In 500 μm thick sensors twice the charge compared to planar strip detectors was measured and for the first time more than 85% of the charge in pCVD sensors was collected. In addition, sensors have been fabricated with more than 1000 cells, an order of magnitude larger than to date, with cell size down to 100 μm . The rate independence of signals in pCVD diamonds was confirmed up to 10 MHz/cm^2 ; no better understanding of the rate dependence in scCVD diamonds was gained.

The RD42 collaboration is to be commended for its publication record this year, with 11 publications and 11 conference submissions. The progress in the development of 3D diamond sensors looks promising. The prioritized goals for the coming year are to work with CMS to prove the diamond-based beam loss monitor concept and to continue the study if pCVD is an option for future luminosity telescopes. Scaling up a 3D detector by another factor of 10 and constructing a 3D-diamond based pixel module will be initiated. The study of rate effects will be continued.

The value of diamond detectors for the community is well recognized and we congratulate the collaboration on the progress this year. Following the successful model of the other large RD collaborations, it is suggested RD42 create a slightly tighter collaboration to advance the overall scientific output.

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

RD50 studies radiation-hard semiconductor devices for very high luminosity colliders. The collaboration consisting of 282 physicists from 50 institutes is organized into four subgroups. RD50's most recent work includes defect characterizations, TCAD simulations and the study of new structures. For example, in low-resistivity p-type silicon, B is removed after irradiation. Simulations start to model observations well. LGAD sensors have good timing properties, HVCMOS sensors work well at moderate fluence and 3D sensors, due to better hole quality, retain a high efficiency at 9×10^{15} n/cm^2 radiation levels. ATLAS and CMS have profited and will profit in the future from the work conducted by RD50. For example, the n-in-p is the preferred choice for the upgrade. RD50 continues to have a very active program for the next years.

RD51: Development of Micro-Pattern Gas Detectors Technologies

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 high-rate

environment while improving the space-point resolution and the radiation hardness of the detectors.

The Collaboration has ~500 members from 86 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 a 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 TPC upgrade. 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. The RD51 collaboration organized important academia-industry matching events over the last year, including on Photon Detection with MPGD. They also organized topical workshops at CERN, including a workshop on discharges in MPGDs. Maintenance and development of the CERN's MPGD laboratory by RD51 was critical for continuing MPGD R&D.

RD51's 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 about MPGD technology; and the organization of specialized workshops.

In summary, RD51 is a successful R&D Collaboration with well-defined and important future plans. RD51 collaboration is asking LHCC to recommend continuing limited support of the collaboration by CERN including access to RD51 test beam facility, access to the CERN Micro Patten Technology workshop (similar to present availability level), a small amount of extra office and laboratory space for students and users of RD51, and continuing access to the central computing resources for simulation.

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

RD52 is a small R&D effort (currently 15 collaborators working part-time) dedicated to a 'dual readout' approach aimed at improving the resolution of hadronic calorimeters for future collider detectors. Interesting results were shown from the most recent RD52 prototypes, which were exposed to a short test-beam run in November 2015, including energy resolution and longitudinal shower profiles. The LHCC noted that the group possesses very limited resources, but it is producing interesting results. The LHCC also noted that the RD52 approach has not been adopted by any current or planned experiment. The LHCC encourages the collaboration to complete their R&D tests in a timely manner - a further test-beam run is planned for October 2016 - and write up their results for publication.

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

The objective of the RD53 collaboration is to develop pixel readout integrated circuits for the extreme rate and radiation environments of the HL-LHC using the 65 nm CMOS technology as the baseline. The vertex detectors at the HL-LHC must be able to withstand radiation levels

up to 1 Grad and 10^{16} MeV neutron equivalent/cm², require small pixels ($\sim 50 \times 50 \mu\text{m}^2$), large size, and triggering capability up to 1 MHz, combined with the “standard” requirements of low power and low mass. The requirement on the hit rate has been increased to 3 GHz/cm², to enable data taking at a pile-up of 200. Creation of the RD53 collaboration was approved during the 114th LHCC meeting with the goal to have a full-scale demonstrator pixel chip within the three-year R&D program of RD53. The collaboration has made tremendous progress towards achieving this utmost important goal for the physics program for the HL-LHC.

With the focus being the submission of a full-scale demonstrator chip, dubbed RD53A, the collaboration, which was organized along six working groups, adopted a more formal project structure to bring all components together to make a working large-scale chip. The critical radiation working-group has been retained. The specifications for the demonstrator chip, which will be about $\frac{1}{2}$ the size of the full chip but designed for the full size, have been agreed upon with CMS and ATLAS. The size reduction allows engineering sharing with other projects and results in significant cost savings. A pixel sensor in both ATLAS and CMS, compatible with this chip, is being prepared. The schedule calls for submission readiness of a final version at the end of the calendar year, plus some months for extensive verifications.

To date several test chips have been submitted. The DRAD chip, intended to measure radiation effects of the digital electronics, has been submitted at the end of March and will be tested over the summer. The CHIPIX65 is scheduled for submission in June and will test analogue and digital aspects. The FE65-P2 chip has already been tested and performs very well up to a radiation dose of 350 Mrad. Bump bonding to pixel sensor is ongoing.

The various working groups have also made tremendous progress, in particular the radiation testing and simulation working groups. Radiation effects are better understood. With appropriate design changes, such as moving to larger transistors, a possible running scenario has been developed indicating radiation hardness up to 500Mrad. The radiation effects have all been incorporated into the simulations, which are extensively used for circuit simulation and optimization. The collaboration builds on an extensive set of different IP blocks and various FE designs that have been developed over the last two years.

The LHCC congratulates the collaboration with the progress to date and the very well managed research program and gives its full support for the submission of the full-scale demonstrator RD53a chip by early 2017. It is a critical step in the development of pixel detectors for the HL-LHC for which the design work remains critical. The collaboration is under pressure to deliver a chip so the results can be incorporated in the TDRs of the ATLAS and CMS experiments. The LHCC recognizes the challenges RD53 faces and notes that the final chip design will depend on the outcome of the test results. The committee fully supports the collaboration in its approach to perform all the necessary checks and simulations before submission.

12. CLOSEOUT WITH DIRECTOR GENERAL

The LHCC chairman summarised the meeting and informed and discussed with the Director General the status of the LHC experiments and their plans for future upgrades. With the Phase-I upgrades in full swing and the Phase-II upgrades coming up, increased support was requested by the experiment from CERN on procurement. The DG stated that discussions with the experiments’ resource coordinators have already started, and that strong support at CERN is indeed crucial and will be provided. The DG briefly mentioned that CERN’s share of the contributions to the experiments is secured in the medium term plan, and reported that the HL-LHC will be proposed for formal approval to the Council in June.

13. REFEREES

The LHCC referee teams for this session are as follows:

ALICE: C. Bloise, P. Newman, C. Sfienti, T. Ullrich (Co-ordinator)

ATLAS: P. Burrows (Co-ordinator), F. Kunne, M. Lancaster, B. Ratcliff

CMS: M. Demarteau, D. Denisov (Co-ordinator), A. Kuzmin, H. Yamamoto

LHCb: C. Diaconu, G. Eigen (Co-ordinator), P. Krizan, T. Kuhr

LHCf, MoEDAL, TOTEM: M. Mangano (Co-ordinator), C. Bloise, A. Kuzmin, 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

14. The LHCC received the following documents:

CERN-LHCC-2015-002

Minutes of the one hundred and twenty-fifth meeting of LHCC held on 2 and 3 March 2016

CERN-LHCC-2016-007

Agenda of the 126th meeting – Wednesday and Thursday 25-26 May 2016

DATES FOR LHCC MEETINGS

Dates for 2016

21 – 22 September

30 November – 1 December

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