OPEN SESSION – STATUS REPORTS

1. LHC Machine Status Report: Katy Foraz
2. ALICE Status Report: Raphaëlle Baillehache
3. ATLAS Status Report: Peter Onyisi
4. CMS Status Report: Louise Skinnari
5. LHCb Status Report: Blake Leverington
6. TOTEM Status report: Laurent Forthomme

CLOSED SESSION:

Excused: V. Beckmann, D. Glenzinski, T. Wengler, C. Hearty

1. Procedure

The chair welcomed the committee members. The schedule for the next LHCC meetings was presented and it was noted that the LHCC142 meeting has been shifted by one week to June 4-5, 2020 to avoid overlap with the LHCP conference. An Expression of Interest has been received for a new neutrino experiment at the LHC, XSEN. A Letter of Intent for XSEN is foreseen for the September LHCC followed by a Technical Proposal for the November LHCC if the LoI is accepted. The minutes of the previous session were already approved by email.

2. Report from the Director of Research and Computing

The Director of Research and Computing (DRC) reported on issues related to the LHC. The LS2 work is proceeding well and according to schedule with only minimal cost overruns. The many LS2 activities for i.e. LIU, HL-LHC and the overall consolidation require significant expenditures
which puts a strain on the immediate CERN budget. To stay within budget constraints, some activities are being delayed, in some cases to LS3, but at the same time an effort is being made to maintain a diversity of activities at CERN, for instance related to PBC and R&D projects. A meeting will be held on November 27th to review the overall status of the LS2 work in the accelerators and experiments and to assess the plans for Run 3 and the long-term schedule up to and including LS3. Currently no extension of LS2 is foreseen. The MoUs for the ATLAS and CMS Phase-II upgrades are being signed at the expected rate.

3. Report from the LHC Programme Co-ordinator

Preparations towards a baseline Run 3 beam configuration are proceeding. Based on the magnet training campaign at the end of Run 2, reaching 14 TeV collision energy will require more time to be devoted to magnet training. This could be done either at the end of LS2 or as part of the 2021/22 YETS as all experiments have requested to have a stable collision energy in 2022 and 2023. A decision will be taken on November 27th.

In the most optimistic scenario for Run 3 proton running, all experiments could be luminosity-levelled for the majority of each fill in the second half of Run 3. This could lead to significant luminous region size changes during a fill in ATLAS and CMS as well as to changes in the acceptance of their forward detectors. The impact of the former is still under study, while the latter is deemed manageable, provided the LHC stays with round beam optics. In case of flat optics, which might be needed to prolong the lifetime of the inner triplets, the acceptance of the Roman pot detectors is strongly degraded and is almost reduced to zero for the PPS diamond timing sensors in CMS. Both ATLAS and CMS therefore strongly prefer to stay with the round beam optics for 2022 and 2023. Based on studies of the 2018 run, it is expected that the bunch-to-bunch luminosity spread might grow during luminosity levelling which could impact trigger and physics performance. All experiments have therefore been encouraged to study the potential impact of this.

There is an interest from the heavy ion community to have LHC collisions with light ions, such as Oxygen, to for instance study the emergence of collective effects and possible parton energy loss. There is also a strong interest from the cosmic ray community in measurements of proton-Oxygen collisions at the LHC energy to improve the modelling of very high energy cosmic ray showers. A very preliminary study of injecting Oxygen into the LHC has been performed. No show-stopper was identified and the potential Oxygen bunch intensity appears sufficient to complete a basic physics programme with a few days of LHC beam time. It was emphasized that the preliminary studies done so far were oriented towards a rudimentary evaluation of the feasibility of an Oxygen run in the CERN accelerator complex. Even a short LHC run would come with a considerable overhead for the injector complex and the exact cost remains to be established.

- The LHCC fully supports the physics case for a short run with Oxygen-Oxygen and proton-Oxygen collisions in the LHC and encourages the CERN accelerator management to initiate a full study and cost evaluation of possibly injecting Oxygen into the LHC during Run 3.
4. Test Beams

The renovation of the PS East Area is progressing as planned. The civil engineering works on the walls is nearing completion and the roof works have started. Inside the hall and service building the beam lines and power converters have been removed and roof access to the primary areas is being prepared. In the North Area the GIF facility is operating for gamma irradiations and primarily used for mass production tests for the ATLAS NSW, ATLAS RPCs and ALICE TPC. These activities drive the schedule. The extension of the GIF bunker is planned for July, with 3 weeks needed to complete the work. CERN test-beam related publications are being catalogued by the CERN library team in CDS.

5. Discussion with ALICE

Scientific output and current activities:

- ALICE continues to deliver high quality physics results, with 14 papers submitted since the last session of the LHCC, bringing the total number of publications to 256. Recent results include femtoscopy measurements in small systems, anisotropy of charged particles and \( \Upsilon(1S) \) in heavy-ion collisions, and studies of ultra-peripheral and peripheral PbPb collisions with the first results from the 2018 PbPb data as well as jet measurements in pp collisions.

- The TPC was successfully extracted and brought to the SXL2 clean-room. Service installation activities are continuing at a steady pace to ensure completion of all activities within 2019 in order to begin with the re-installation sequence in February 2020.

Phase-I upgrades:

- The TPC field cage has been cleaned and irradiation tests have been performed. The adaptation for the new ROCs is ongoing. All ROCs have been produced, tested and are ready for installation. The FEC production is on track and preliminary sector tests have shown good noise performance.

- The commissioning of the ITS inner barrel has started, while the outer barrel HIC production has been completed and stave production is expected to be finished by August, one month ahead of schedule. Commissioning of the first outer half-barrel is ongoing as well. FEE production has been completed and tests will be performed until the end of July.

- There has been good progress on the Muon System upgrade. Two production time plans are of concern: the DualSampa board and the flex delivery. Negotiations with the production companies for an earlier delivery are on-going.

- The delivery of the CRUs from the European manufacturer is foreseen for September 2019, which includes the CRUs for all ALICE subsystems except the TPC. The purchase order of 266 CRUs for the TPC, to be produced in India, was rejected by the selected company and a re-tendering was necessary. The present plan foresees a conclusion of this tendering process by end of June, leading to a signed
purchase order by mid-July, which would in the best case result in a delivery of the TPC CRUs by April 2020, just in time for global ALICE commissioning.

Phase-II upgrades:

- An Expression of Interest for an upgrade of the inner three layers of the ITS to a fully cylindrical very low-mass tracker based on CMOS MAPS to be installed in LS3 was submitted to the LHCC. Significant R&D for such as a project is needed, but some funding is already available, pending LHCC recommendations.

- The LHCC congratulates ALICE on its continuing rich physics output, and on the progress made on its upgrade programme.

- The LHCC encourages ALICE to continue its effort to speed up the deliveries for the Muon System upgrade and requests definite schedules for the MCH upgrade by the next in-depth review in September.

- The LHCC urges ALICE to keep the QA of the TPC CRU pre-series and successive mass production in India in place as originally planned. In case the production order is not signed by mid-July at the latest, the LHCC urges ALICE to move the full CRU production to Europe in order to avoid a severe impact on the ALICE upgrade schedule.

- The LHCC requests ALICE to provide an updated EoI by July 22 with a break-down of the required R&D for ITS3 with clear targets and with an overview of the physics channels which are expected to profit from this upgrade.

6. Discussion with ATLAS

Scientific output and current activities:

- ATLAS continues to make excellent progress on its physics programme, with 849 papers submitted to date, including 22 since the last LHCC. Recent new results include more than a dozen searches using the full Run 2 pp sample, light-by-light scattering in ultra-peripheral heavy-ion collisions including PbPb data from 2018, and a new measurement of $\phi_s$ in $B_s \rightarrow J/\psi \phi$ decays.

- There has been good progress on the LS2 activities at Point 1, in readying the trigger for Run 3, in data preparation, and in addressing the transition to multi-threading in the offline software. New Software Development Grants provide an interesting opportunity to introduce more people into the software team at a time where they are very much needed.

- The two Roman pot detector groups, ALFA and AFP, were joined to form the ARP system by ATLAS management last year but remain badly understaffed. The AFP data recorded in 2018 was aligned to the wrong bunch crossing and is not usable. The under-staffing and lack of integration into the common data quality system is partially to blame for this.
Phase-I upgrades:

- The Phase I upgrades for LAr and TDAQ are making good progress. Delays accrued thus far do not appear to threaten the timely completion of these upgrades.

- There has been considerable progress made on the NSW since the last LHCC meeting. Many of the tasks have been completed, and many others are proceeding on schedule. However, a large number of tasks are running late, though recovery may still be possible. The number of outstanding tasks leaves the installation of NSW Side-A during LS2 uncertain and the planned go/no-go review in early November is crucial.

- The ATLAS internal review of FTK had recommended a set of requirements for continuing the effort. Management adopted a process for moving forward based on the recommendations. The FTK team was not able to fully identify the personnel required to make the success of the FTK effort in LS2 likely. Management set up guidelines for moving forward with a de-scoped effort. The FTK team has proposed such an effort. A decision on the viability of the project is expected soon.

Phase-II upgrades:

- The HGTD project has seen significant progress since the Technical Proposal, but a considerable amount of R&D still has to be done. The project strongly depends on design choices and the evolution of material estimates for the ITk detector. A recent increase of the expected level of radiation due to substantial increases in the material budget for ITk pixel services forced a reconsideration of the design to cope with the new conditions. The TDR submission has been delayed to April 2020 to allow a more mature detector design with input from a considerable set of tests to be performed. The R&D is expected to continue until early 2021.

- The first P2UG review took place May 7-8 with in-depth reviews of the ITk-Strip, Muon and LAr projects. A detailed review report will be provided to ATLAS and CERN management and to the LHCC shortly. A schedule re-baselining for all Phase-II projects was carried out before the review, but has not yet converged for the TDAQ, ITk-Pixel and ITk-Common projects. The projects have in general made substantial progress after the TDR approval and their new schedules look now much more solid and include realistic estimates of durations for both R&D and production phases.

- The LAr, Muons and Tile projects appear to be well on track. The ITk-Strip project is progressing well but has a tight schedule with its contingency likely to be reduced significantly once the contractual sensor delivery schedule from Hamamatsu is included.

- For the ITk-Pixel project, several open-ended issues remain and the process towards adoption of key decisions has accumulated delays of 6-8 months. No overall project schedule was presented to the P2UG. A possible solution for the data-transmission scheme has been identified by the project. This presents several critical aspects, in particular the addition of substantial material in the forward region with respect to the design presented in the TDR. This is expected to have a
negative impact on multiple detectors systems, including but not limited to the HGTD, that has not been evaluated yet.

- For TDAQ, the HTT is the most critical part for the schedule re-baselining, with the AM08 chip submission being delayed until October 2019. Alternatives to the associative memory implementation based on commodity solutions are under investigation.

- The LHCC congratulates ATLAS on the large amount of new physics results produced, as well as the good progress reported on the upgrades. The Committee commends the intention of the Collaboration to publish full data set results rapidly.

- The LHCC urges ATLAS management and the Forward systems Project Leader to ensure that there is adequate coverage of all tasks in the system. The forward detectors must be better integrated into ATLAS to form a functioning system and the quality of the data should be assessed as soon as possible after data acquisition. The team should review their operations to see if there are other unrecognised failure points.

- The LHCC endorses the decision of the Collaboration to postpone the HGTD TDR submission to April 2020 and supports the management’s plan for reaching a decision on the FTK project.

- The LHCC commends ATLAS for the progress in the schedule re-baselining of the Phase II Upgrades but is concerned about the lack of convergence in the ITk-Pixel and partly in the TDAQ project. The LHCC supports the P2UG plan of examining the re-baselined schedule and the status of the key open issues in detail during the P2UG video meeting in September, in advance of the in-depth review to be held in November.

- The LHCC requests that ATLAS assesses the global physics impact of the increase in ITk pixel material, including the HGTD track-matching performance degradation and the impact on downstream detector performance. The LHCC urges that solutions with a lower material budget continue to be explored.

7. Discussion with CMS

Scientific output and current activities:

- CMS continues to have a rich scientific output, with 882 collider-data papers submitted to date, including 26 since the last LHCC. The observation of the $B_c(2S)^*$ and $B_c^*(2S)^*$ states and the measurement of the $B_c(2S)^*$ mass is the first publication with the full Run 2 data. Recently over 50 new results, out of which 9 with full Run 2 data, were released including: $t\bar{t}H(\rightarrow bb)$, $t\bar{t}bb$ and 4-top production, SM $ZZ$ and $H \rightarrow ZZ$ measurements, as well as searches for new physics signals such as delayed jets, prompt and long-lived SUSY particles, and dark photons.

- Processing of the large parked dataset of unbiased B-decays and of the 2018 heavy-
ion datasets is on-going. An “ultra-legacy” reconstruction of the 2016-2018 dataset is in preparation to enable subsequent analyses with consistent and ultimate performance datasets (data and MC).

- The LS2 work is progressing well and remains on schedule for completion by March 1st, 2021. The work includes preparation for and in some cases also installations of HL-LHC systems.

- On May 25, a UPS battery bank located next to the CMS control room caught fire, rendering the control room unusable for now and limiting the use of the DAQ server room equipment. This has had a limited impact on the LS2 activities, and a full recovery is expected by July. The CMS Technical Incident Panel and CERN HSE team are conducting inquiries into the event and the response. This should result in recommendations for minimizing the risk of a re-occurrence of such incidents.

- Preparations of Run 3 are progressing well and are addressing multiple aspects: impact of machine operating conditions, improved and leaner operations, early deployment of future technologies and open discussions on the physics goals.

Phase-I upgrades / LS2 activities:

- The pixel refurbishment is proceeding well with all ASIC wafers available and under validation tests. A cooling loop broke during tightening, but a solution is expected by summer. A not understood small increase in the leakage current of the v2.1 and 2.2 of the FEAST ASIC (DCDC converter) has been observed; the designers do not expect this to be an issue.

- The HB FE electronics upgrade is on track after some assembly stage QC issues have been fixed.

- The Phase-II upgrade of the muon system is on the critical path for LS2 and will likely stay there until its completion in June 2020.

- A change in the radiation safety regulations is inducing an overhead of procedures that were not planned for and which might have a schedule and financial impact.

- CMS needs to build and prepare some Phase II infrastructure already during LS2. To avoid additional difficulties in the planning of these commonly executed tasks, a clarification of the LHC schedule and of the hostlab contributions to common costs would be very welcome.

Phase-II upgrades:

- The TDR for the MTD was submitted to the LHCC in April and underwent the LHCC scientific and technical review this session. The corresponding report from the review is included in the appendix of these minutes. The LHCC recommends proceeding to the UCG review. The UCG kick-off meeting took place this week, with no major problem apparent at this point.

- The first P2UG review took place May 20-21 with in-depth reviews of the HGCAL and Tracker and status reports of the Muon and Barrel Calorimeter projects. A detailed review report will be provided to CMS and CERN management and to the
LHCC shortly. The collaboration is very strong and highly motivated. All subsystems have undergone significant revisions since the submission of the TDRs, which have increased the reliability of the schedules. The designs have been advanced and the systems are much more mature and well-understood. The Muon System and the Barrel Calorimeter are generally in good shape. The largest risks reside in the Tracker and HGCAL projects where the schedules are success driven. The critical path in both projects is driven by the production of the sensors; other critical components, however, have little float with respect to the critical path. Overall the float in the schedule is already now only 6 to 9 months for the most critical systems.

- The LHCC congratulates CMS on its very productive physics programme as well as the substantial progress made on the upgrade projects.
- The LHCC recommends that for the next LHCC week, CMS tries to evaluate the time and financial impact of the additional procedures required by the new radiation safety regulations and the recommendations and/or requirements that will be produced by the CMS Technical Incident Panel and CERN internal inquiry following the UPS Fire.
- The LHCC recommends that at the next LHCC week, the work required to be done in LS2 for the muon system be presented and discussed at the CMS Referees Meeting separately from the general LS2 Progress talk, to allow the LHCC to better assess the management and progress of this rather complex (comprising several sub-systems) system.
- The LHCC recommends a provisional approval of the CMS MTD project conditional to the answering to the recommendations made and the requested update of the TDR document. The LHCC recommends its review by the UCG as the next step towards full approval.
- The LHCC commends CMS for focusing the efforts on the designs of the Phase II upgrades to bring them to much higher level of maturity and for developing and maintaining a sound risk registry for the HL-LHC upgrades. The LHCC expresses its concern that the probability for multiple high impact risks to be realized is uncomfortably high. A targeted effort to finish the remaining R&D is strongly encouraged, especially the full characterization of the silicon sensors under irradiation and concluding a full and complete understanding of the fluences with the most realistic geometries. Strong oversight of the ASIC development is advocated and, generally, a strong engagement of management at all levels is required to try to retire any high impact risk.

8. Discussion with LHCb

Scientific output and current activities:

- LHCb continues to make excellent progress on its physics programme, with a total of 482 publications to date, including 16 new papers since the last session of the
LHCC. New results include the first observation of CP violation in charm mesons using the full Run 1-2 dataset, new results on penta-quarks in $\Lambda_b$ decays, an updated result on lepton flavour universality using $R_K$ and a precision measurement of $\phi_s$.

- The dismantling of the existing detector has been completed in preparation of the installation of the Phase-I upgrades. Installation of the new detector services has started.

- The computing resources, including the existing HLT farm, are being fully utilized with more than 90% of the resources being used. A re-stripping campaign of the full data set is on-going and expected to be completed by the end of 2019.

Phase-I upgrades:

- Most upgrade projects are on schedule for installation and commissioning before the end of LS2.

- The UT project has faced considerable challenges, especially related to key electronics components, but is now in the production phase. The 8-chip hybrid is still missing, but assembly and commissioning plans have been reoptimized for the current production flow. The project remains on the critical path.

- The VELO project is still on track but is entering a critical phase and needs to demonstrate it can reach the target of two modules produced per week.

- Further improvements in the real time analysis have achieved the full 30 MHz processing rate for HLT1, but the full processing chain remains to be demonstrated at the design rate.

- A TDR on the SMOG2 project has been submitted as an addition to the VELO TDR. This addition of an unpolarized gas storage cell to the upgraded VELO system will enable significantly improved fixed-target measurements with order-of-magnitude increased luminosities and a wider range of possible targets. The physics opportunities have been presented to the PBC study, and the technical implications have been discussed in and approved by the relevant LHC panels. The project is fully approved and funded within LHCb, and ready for final production, with installation foreseen for mid-November 2019.

- The LHCC congratulates LHCb on its rich scientific output and commends the collaboration for the progress made on its upgrade programme.

- The LHCC recommends approving the SMOG2 project, which enables improved fixed-target measurements using an unpolarized gas target in the LHC.

- The LHCC is relieved to see decisive progress in the preparation of the Upstream Tracker. The LHCC supports the activities of the LHCb and UT managements in trying to optimise the construction plan for a complete UT installation in LS2.

- The LHCC notes that also the progress of other components (e.g., VELO) has to be monitored carefully.
• The LHCC is pleased to observe substantial progress in the implementation of the upgrade to an all-software trigger but recommends careful monitoring of the development of the project.

9. Discussion with WLCG

The LCG and the computing systems of the experiments are currently running smoothly. There are no anticipated resource limitations for the successful processing/reprocessing/analysis of the full Run 2 datasets. There has been significant progress in preparations for the Run 3 computing challenge (e.g., excellent progress in LHCb HLT1 throughput), though considerable effort is still required to meet all milestones. There has been significant progress in numerous aspects of software, for example a better understanding of the CPU performance of event generators. Work on hardware acceleration (GPU, FPGA) continues and holds the promise of a big leap in performance but will require further investment of effort. The 2021 machine performance envelope is needed for the upcoming computing resource requests and will be provided by the LPC to the experiments shortly.

• The LHCC congratulates the WLCG and the experiments on the successful and efficient use of the computing resources.

• The LHCC encourages the experiments to continue discussions with funding agencies regarding the provision of resources when future cost estimates are very uncertain. Furthermore, influence on future HPC specifications should be sought to improve their suitability for data-intensive applications.

• The LHCC urges the experiments to continue the work on hardware acceleration and to coordinate the efforts across experiments.

• The LHCC will establish an indicative timetable for the upcoming Phase-II computing model reviews before the next LHCC.

10. Discussion with TOTEM

The analysis of the data from the 2018 run at 900 GeV is well advanced, and the data quality confirms the sensitivity to a range of momentum transfer, t, broad enough to reach both in the deep Coulomb and in the purely hadronic regions. A joint analysis with the D0 Tevatron experiment, comparing the structure of the dip-region in pp and in ppbar collisions, is well underway.

TOTEM has completed and submitted to the LHCC the Technical Design Report for a new T2 telescope. A first review of the content of the TDR, based on the presentation made by TOTEM during the meeting with the referees, shows excellent progress in the project. In particular, the installation procedure has been endorsed by CMS technical coordination. The experiment appears ready to proceed to the construction phase. The complete review by the LHCC referees will take place before the next LHCC meeting, when the final decision on the TDR approval will be discussed.
• The LHCC congratulates TOTEM for the continued progress in understanding the structure of elastic and total pp cross sections.

• The LHCC welcomes the finalization of the TDR describing the T2 upgrade and is looking forward to a completion of its review and possible approval by the September session of the LHCC.

• The LHCC acknowledges the importance of delivering to TOTEM, as soon as possible, the approved documents defining the activities of relevance to the levelling of the PPS Roman Pot system.

11. Report on LHCf

Following the recommendations of the 137th LHCC meeting, the LHCf collaboration submitted their Technical Proposal (TP) for the detector upgrade and the extension of their data taking during Run 3. The main elements of this programme are: a few days of proton-proton collisions at \( \sqrt{s} = 13 \) or 14 TeV, with a luminosity ranging from \( 10^{29} \) to \( 10^{30} \, \text{cm}^{-2}\text{s}^{-1} \) and a few days during the proton-Oxygen or Oxygen-Oxygen runs, should these be approved. The key goal of the pp run is to increase the statistics collected so far by a factor of 10, enhancing the sensitivity to rare final states such as \( \eta \) and \( K^0 \). While data taking at 14 TeV is preferred, the run is worthwhile even if it were only possible while the LHC is still running at 13 TeV. A joint data taking with the ATLAS detectors would enable the separation between diffractive and non-diffractive events, further adding to the physics output. The proton-Oxygen or Oxygen-Oxygen runs would provide complementary inputs for the improvement of the MC generators used in the study of cosmic ray showers. The installation of ATLAS ZDC detector downstream of the Oxygen beam would force LHCf to operate only the detector arm on the proton side, but this would not compromise the physics measurements. In general, possible limitations to the proton-Oxygen or Oxygen-Oxygen would not compromise the value of the LHCf Run 3 physics programme, which is scientifically justified even by the sole proton-proton data taking. It was noted that the detector acceptance requires the crossing planes to be in the vertical direction, with beams pointing downward: these criteria are consistent with the plans for IP1, at least during the early phase of Run 3.

The LHCC referees reviewed the TP, and, following additional discussions with LHCf, concluded that:

• The physics goals are of great interest.

• The detector upgrade plan, focused on the upgrade of the electronics for Arm 2 to sustain a higher rate and operate up to luminosities of \( 10^{30} \, \text{cm}^{-2}\text{s}^{-1} \), is adequate and the funding has been secured.

• The collaboration has begun the proper procedures to review, in collaboration with the relevant CERN technical groups, the implications of the installation and operation of the detectors, in terms of access, radiation-protection, infrastructure, schedule, etc. No obstacle has been detected.

• The ATLAS collaboration is interested in continuing the cooperation with LHCf in
view of a joint data analyses.

- The LHCC recommends approval of the TP and endorses the running requests of LHCf for Run 3. The detailed implementation of these requests, with the scheduling and the duration of the dedicated runs, will nevertheless be left to the decisions of the LPC coordinators, in the context of the overall planning of Run 3.

12. Report on FASER

The LHCC received a note from the FASER collaboration, with an update on their progress towards construction. Several new institutions have joined the collaboration since the last LHCC meeting, and the available person-power is estimated to be sufficient to complete the project. CERN's management has accepted charge of the additional civil engineering costs that were identified prior to the last review, and the detector construction is estimated to be on budget. The calorimeter and tracking modules needed by FASER have been provided, as planned, by the LHCb and ATLAS experiments, respectively. They passed all quality assurance tests, and spares are available. The magnet design is finalized, and a market survey for the purchase of the magnet blocks is under way. Studies are ongoing on a possible programme of neutrino physics measurements, possibly using emulsion stacks to be added in front of the current FASER detector. A more thorough review of the construction status is scheduled for the next LHCC meeting. In the meantime, the LHCC requires a detailed plan and schedule, to facilitate the monitoring of the progress of the project.

13. General Comments

The following comments are applicable to more than one project.

- The Phase-II Upgrade Group (P2UG) review process for ATLAS and CMS Phase-II Upgrades is under way. The first meetings with the experiments took place during May. A consistent tracking of milestones is being implemented.

- There is a critical dependence on HPK as Silicon sensor vendor for both the ATLAS and CMS trackers and the CMS HGCAL. The sensor delivery schedule as originally foreseen by the experiments turned out to be too optimistic; the current production schedule is approximately ten months longer as foreseen, making the sensors the critical path for the affected upgrade projects.

- The design of ASICs, the ASICs under the purview of the experiments as well as the common ASICs, is a general concern in the Phase-II upgrade projects, with significant delays having occurred already.

- The overall schedule of the Phase-II upgrades is brittle. Credible mitigation strategies to absorb occurrence of problems have been established by both ATLAS and CMS, but the probability for realization of high-impact risks appears
uncomfortably high.

- There is an overall need for clarification on longer term LHC schedule and on the specification of the hostlab responsibilities during Run 3. While the civil engineering - in particular at the remote location for CMS - proceeds largely during LS2, the provision of common services e.g. CO2 cooling needs to be clarified. A discussion is planned between CERN and the experiments on Nov 27th to clarify the LHC schedule and hence allow better assessment of the required services and financial contributions.

14. REFEREES

The LHCC referee teams for this session are as follows:

ALICE: G. Casini, J. Dunlop, P. Salabura, C. Sfienti (Co-ordinator)
ATLAS: V. Beckmann, R. Calabrese, F. Di Lodovico, W. Wisniewski (Co-ordinator)
CMS: D. Glenzinzki, E. Kajfasz (Co-ordinator), A. Kuzmin, D. Waters
LHCb: C. Hearty, P. Krizan (Co-ordinator), K. Krüger, M. Kuze
LHCf, MoEDAL, TOTEM: A. Kuzmin, F. Di Lodovico, M. Mangano (Co-ordinator)
LCG: V. Beckmann (Co-ordinator), J. Dunlop, M. Kuze, D. Waters
FASER: M. Mangano (Co-ordinator), W. Wisniewski, K. Krüger

15. The LHCC received the following documents:

CERN-LHCC-2019-002 Minutes of the one hundred and thirty-seventh meeting of LHCC held on 27-28 February 2019
CERN-LHCC-2019-005 LHCb SMOG2 Upgrade TDR

DATES FOR LHCC MEETINGS

Dates for 2019
11-12 September
20-21 November

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APPENDIX

Report on the LHCC review of the CMS Phase-II MTD

Review Panel: Gianluigi Casse, Marcel Demarteau, Dmitri Denisov, Doug Glenzinski, Christian Joram, Eric Kajfasz (chair), Alex Kuzmin, Michel Raymond, Martin Van Beuzekom, Marcel Vos, David Waters

General assessment:

The TDR for the MIP Timing Detector (MTD) project for the CMS Phase-2 Upgrade has been submitted by CMS on Mar 29th, 2019. Over a period of two months, the CMS MTD Review Panel evaluated the scope of the project with respect to its scientific reach and to the technical choices used for the optimization of its design. Two Vidyo meetings with CMS took place mid-April and beginning of May to discuss the details of the project. In addition to the online questions during the Vidyo meetings, over one hundred written questions and comments were sent to CMS shortly after the meetings, which were answered by CMS expeditiously and satisfactorily. The culmination of the review was an extended half-day session on Jun 3rd, 2019, when the project and the remaining Review Panel questions were discussed.

The primary motivation of the MTD is to preserve and enhance the physics performance of the current Run 2 detector in an environment where much higher data rates, interactions per crossing, and radiation dose are expected. This device will bring to CMS the ability to measure precisely the production time of minimum ionizing particles (MIP) for use in disentangling the approximately 200 nearly-simultaneous pileup interactions that will occur in each bunch crossing of the LHC. It will also provide new TOF (time of flight) capabilities to search for long-lived particles and PID (particle identification) capabilities for p/K/π separation in the 1-5 GeV momentum range. The improvements expected to be provided by the MTD translate into a 25%-40% increase in effective luminosity, depending upon the physics analyses considered. The basic idea is to exploit the time spread of collision vertices (RMS ~180 ps) to provide extra separation power against pileup collisions. A time resolution of 30-50 ps is sufficient to provide extra separation power in the 4th (time) dimension. This resolution translates into design choices which are based on: cost-effective coverage of large areas; radiation hardness up to $2.5 \times 10^{14}$ n_{eq}/cm$^2$ in the barrel, and up to $2 \times 10^{15}$ n_{eq}/cm$^2$ in the endcaps (4000 fb$^{-1}$); mechanics, services and schedule compatible with existing upgrades; minimal impact on calorimeter and tracker performance. The resulting CMS MTD design consists of:

- A barrel timing layer (BTL: $|\eta| < 1.45$), based on matrices of LYSO crystal bars with double-ended SiPMs readout, with a surface of about 38 m$^2$ and 332k channels, to be installed within the tracker support tube in a 40 mm thick volume located between tracker and ECAL.

- Two endcap timing layers (ETL: 1.46 < $|\eta| < 3.0$), based on Silicon sensors with internal gain (LGAD), installed in an independent volume on the HGCAL nose and 45 mm thick, with a surface of about 12 m$^2$ and 8M channels.
The review panel has very much appreciated the very professional and responsive attitude of the project team; it found also very encouraging to see the dedication and motivation of the (younger) people involved in the project.

The review panel recognizes the huge work and substantial progress made in all areas by the project team since the Technical Proposal (TP) review a year ago; the project appears now well-motivated from a physics point of view and technologically sound.

**The main findings of the Review Panel are as follows:**

The project is by now well developed and progressing well on all fronts, with a well-defined organizational structure with most positions filled, and a team of excellent experts working closely together.

Substantial work has been done since the TP to optimize the detector design and technical choices; the majority of main design choices is completed; technical design and optimizations are in progress. The highly modular designs, with a minimum of variants, of both BTL and ETL should help keeping engineering time under control. However, the MTD cost increased since the TP stage by over 30%.

Given the large number of channels involved, the clock distribution and calibration are critical for the MTD to reach its required timing performance. Two options are being pursued for the clock distribution with possibly different options for the barrel and end-cap; however, the clock distribution description in the current TDR is still lacking detailed information.

The radiation simulations have undergone a significant revision, mainly due to a more accurate detector description, beam-pipe and other geometry updates. These changes result in an increase of the estimated fluence by 25% in certain areas of the detector, but nevertheless stays within the safety margin assumed.

For the BTL, the use of commercially available components (LYSO crystals, SiPMs) and relatively simple mechanics is a big advantage. The main challenges are the TOFHIR ASIC, which appears to be on the critical path, and the necessity to have sufficient safety margin for the radiation levels and corresponding degradation of the SiPMs in the BTL. The integration of the BTL system inside of the tracker support tube poses significant challenges in terms of project schedule, since key aspects of the tracker installation can only begin after the completion of the BTL installation. After this point, the BTL is not accessible anymore, also not in subsequent shutdowns, excluding the possibility for the replacement of ageing components and placing stringent requirements on longevity and safety margins.

The ETL is in the process of getting out of the R&D phase. Its main challenges are the sensor production and delivery time, and the ASIC development and production. In this context, the option of skipping one step in the ETROC ASIC development by making use of simulation tools seems attractive. This would allow going directly to full size of the chip and would also allow for testing in-chip clock distribution at an earlier stage on the full chip scale. Margins for operating ETL to reach the required timing resolution after substantial irradiation seem close to the edge, somewhat mitigated by the built-in possibility for sensor replacements in extended year-end technical stops and shutdowns.
The main recommendations of the review panels to CMS include requests to:

- Provide a thorough description of the clock distribution system in the TDR, together with a detailed schedule and a list of milestones. Both options for the implementation of the clock distribution should be pursued in parallel to avoid extra delays if the baseline option performance is eventually found not to be sufficient.

- Decide as soon as possible whether or not MTD will be used in the L1 Trigger, as this starts affecting progress in MTD development and testing.

- Converge rapidly on a HL-LHC radiation model with estimated systematic uncertainties in which the collaboration has confidence. This model should be used to inform the final MTD design (e.g. optimizing the neutron moderator thickness between the HGCAL and ETL), but also to reliably estimate the fluence effects on other systems in CMS. In this context, it should be estimated how MTD resolution degradation will affect pileup rejection, to provide a clear understanding of when the MTD performance is expected to become marginal. A full set of studies (time resolution, etc.) with devices (both bars and SiPMs) irradiated with maximum expected fluence should be performed and documented as an appendix to the TDR.

- Add to the TDR a discussion of a broader range of physics processes that profit from the MTD, including particle ID for the heavy ion program.

The committee provided a list of specific recommendations to CMS, in addition to those described above. These recommendations are expected to be addressed in the updated version of the TDR in the next stage of the review, or, for longer-term items, on the way towards the EDRs.

Conclusions of the LHCC:

The LHCC considers that there is a strong physics and technical case for the addition of the MTD detector to the CMS HL-LHC upgrade. The TDR describes all major elements of the upgrade at a level that was required for this review. There are still challenges, including performance at high irradiation, clock distribution and total project cost which have to be addressed within the next 6-12 months.

Concerning the 30% cost increase of the MTD project, solutions found to ensure availability of funding for the project should not compromise the HL-LHC core upgrades.

Some clarifications and additional information (including the ones specified in the written questions addressed to CMS by the Committee) need to be added to the current TDR document either directly in the main text or as annexes.

- The LHCC recommends a provisional approval of the CMS MTD project conditional to the answering to the recommendations made and the requested update of the TDR document; it also recommends its review by the UCG as the next step towards full approval.