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November 2021

LARGE HADRON COLLIDER COMMITTEE

Minutes of the one-hundred-and-forty-eighths meeting held on

Wednesday and Thursday, 17-18 November 2021

OPEN SESSION – STATUS REPORTS

1. LHC Machine Status Report: Matteo Solfaroli
2. ALICE Status Report: Taku Gunji
3. ATLAS Status Report: Alexander Tuna
4. CMS Status Report: Freya Blekman
5. LHCb Status Report: Oscar Augusto de Aguiar Francisco
6. RD42 Status report: Harris Kagan

CLOSED SESSION:

Present: C. Biscarat, A. Boehnlein, D. Calvo, G. Casini, R. Calabrese, M. Demarteau, F. Di Lodovico, I. Efthymiopoulos, B. Gorini, C. Hearty, J.J. Hernández-Rey, T. Higuchi, E.B. Holzer, E. Kajfasz, M. Krammer, K. Krüger, M. Mangano, J. Mnich, F. Moortgat, J. Nagle, D. Newbold, S. Niccolai, P. Pakhlov, B. Panzer-Steindel, P. Salabura, F. Simon (Chairperson), S. Smith, B. Petersen, D. Waters, A. Weber, P. Wells, T. Wengler (Scientific Secretary), W. Wisniewski, E. Worcester

Due to the COVID-19 pandemic, all sessions were held via videoconference.

1. Procedure

The chairperson welcomed the committee members. The minutes of the previous session were already approved by email. The chair welcomed Juan José Hernández Rey (IFIC, Valencia) as a new member of the committee, who will join the ATLAS referee team. The chair also welcomed Benedetto Gorini (CERN) as the new scientific secretary from the beginning of next year and thanked the current scientific secretary for his contributions to the committee. Several committee members will come to the end of their term in the next months, suggestions for new members for all experiment referee teams are therefore highly welcome. After outlining the programme for the present meeting, the chair reported on the ongoing reviews of the LHCb Upgrade II Framework TDR, the Letter-of-Intent for ALICE-3 and the ATLAS Phase-II TDAQ Event Filter TDR Amendment, which are all scheduled to conclude by the March 2022 sessions of the LHCC and Research Board. The chair concluded with a look ahead at the programme of the March LHCC session, and planning for the remaining sessions of the committee for 2022.

2. Report from the Director of Research and Computing

The DRC reported on the general situation at CERN, which is presently in COVID-19 level Yellow. At this level working on site is the default, and visits are possible, as well as meetings in hybrid mode (in-person concurrently with remote participation) with 50% occupancy of the meeting rooms, all while following the safety measures put in place to avoid the spread of COVID-19 on site. There is very good progress on the LS2 activities, as reported by the LPC and experiments in this meeting, including the recent very successful pilot run. To have both the machine and the experiments in such good condition already at this point is a major achievement, in particular given the difficult circumstances created by the pandemic. Beyond LS2 the HL-LHC is ever more moving into the centre of attention. Significant delays have been accumulated for ATLAS and CMS, with a schedule review under way, that is expected to conclude by the March 2022 Council week.

3. Report from the LHC Programme Co-ordinator

The LHC had a successful pilot beam test in the last two weeks of October. The machine set up the initial beams at injection energy quickly and within days the optics was comparable to 2018. This enabled system commissioning to start, and all key instruments were confirmed to be working. Extensive measurements of both global and local apertures (primarily in the triplet regions) were performed and with one exception found to be consistent with apertures measured in 2018. In Sector 23, an obstruction was found at the bottom of the interconnect to cell 21L3. Subsequent x-ray and tomography measurements identified this as a bent RF finger. Thanks to the high availability of the machine, it was possible to go beyond the baseline programme and successfully test a ramp to 3.5 TeV with a pilot bunch as well as test the crystal collimation system for beam 2.

During the pilot beam test, about five shifts (40h) were dedicated to stable beam collisions for the experiments to use for early detector commissioning. Prior to the collisions, several "splash events" with a pilot bunch stopped by a collimator in front of each experiment were provided for initial detector timing.

All experiments successfully collected data with the available detector components during this period and have reported very good progress on their detector commissioning.

The readiness for Run 3 was discussed at the LS2 schedule meeting between CERN, LHC and experiment managements on November 1st. The experiments all expected to be able to close their caverns on 21 February 2022 at the latest. However, in the case of LHCb there was a significant risk that one or more of their three tracking systems would not be fully installed/commissioned by that date. Despite this risk, LHCb on balance did not wish to delay the start of Run 3. Instead, they plan to use (un)scheduled stops of the machine and requested that an extended Technical Stop (2 weeks) be considered for June as that should allow them to complete the installation. After the meeting, it was decided that Sector 23 would need to be warmed up to repair the buckled RF finger. This will delay the start of Run 3 by about 5.5 weeks to 31 March 2022 and will give the experiments more time to complete their LS2 installations and commissioning.

The LHC task force on the Run 3 beam energy has concluded. Training the dipole magnets to 7 TeV was estimated to require around 340 additional training quenches, which results in too high a risk that an additional warm-up would be needed. Therefore, it was decided that the maximum beam energy in Run 3 will be 6.8 TeV. Sector 78 has

finished its training to 6.8 TeV, while Sector 23 will still need to be trained following its repair.

The 2022 run schedule is being revised following the delay of the run start. The VdM scans and LHCf low pile-up run were expected to take place after the Technical Stop in June but might have to be delayed to after the Technical Stop in September if the LHC cannot provide enough colliding bunches after the June Technical Stop in a revised schedule. The schedule will still have about four weeks of heavy ion running at the end of 2022 dedicated mainly to PbPb collisions. The period will also include about one week of pp reference data taking at the equivalent per nucleon energy. The length of the pp reference run is driven by the request of ALICE for 3 pb^{-1} at their maximum recording rate.

4. Test Beams

The test beams stopped on Monday 15 November 2021 as scheduled. All beam lines of the new PS East Area were successfully commissioned, including fast and slow extraction of Pb ions to the IRRAD/CHARM radiation facilities. During the eight weeks of operation of IRRAD and CHARM, commissioning activities were interleaved with user experiments. The T9, T10 and T11 beam line users were progressing as scheduled with extensive parallel usage of the lines, except for LDMX, which was delayed by a problem with international transportation and CLOUD, which cancelled the beam time due to various delays.

The availability of the SPS improved from 73% during the first two thirds of the run to above 80% during the last third. While the experiments which accumulate statistics and CERF were badly impacted by the low availability, most of the test beam users could achieve their goals due to re-scheduling and extensive parallel activities in the beam lines. The slot freed by NP07 at the beginning of October was taken by SND HCAL and STI. GIF++ had a very successful run in the enlarged bunker, where now 14 setups operate in parallel.

The injector schedule for 2022 is currently being re-negotiated. It is due to be presented at the Research Board on 1 December 2021. The first draft of the user schedule is going to be presented at the SPSC in January 2022.

New Booster and PS cycle sharing target values were proposed. The aim is to keep all the target values for IRRAD/CHARM, ISOLDE and nTOF unchanged, while providing one extraction in twenty PS cycles each to the two new targets of the T9 and T10/T11 lines of the PS East Area.

In the framework of the North Area consolidation project 70km of cables are scheduled to be removed in EHN1. The resulting power cut and stop of the gas systems of more than a month are being coordinated with the user requirements and the test activities taking place during the YETS. During the YETS, GIF++ continues the radiation campaigns using the Cs source, CMS GEM tests will take place in the GOLIATH magnet, and MADMAX plans an equipment test in the MORPURGO magnet.

5. General Comments

The following comments are applicable to more than one project.

- ASICs are generally the most critical items in the Phase-II projects of ATLAS

and CMS. The **LHCC recommends** that ATLAS, CMS and CERN together work out a strategy to address these challenges, to arrive at an integrated solution providing robustness for all ongoing ASIC projects.

- The **LHCC notes** that RD53 is essential for the success of the inner tracker projects of both ATLAS and CMS. The **LHC reaffirms** its strong recommendation that the team needs to be kept at full strength until the complete delivery of both chips (ATLAS and CMS variants), also considering important follow-up contributions to testing and integration.
- Good progress has been reported for the lpGBT development. New chips are in hand, with very good results so far and radiation tests in progress. For now, 10k chips are in hand, with productions for 2022 secured, which would produce a total of 150k chips.
- The **LHCC acknowledges** the progress made on the implementation of the new Experiment Associate scheme (EXAS), which is similar to a Project Associate (PJAS) but allowing subsistence payments up to a duration of 8 years. CERN is encouraged to monitor situations (e.g., tax) that may arise related to personnel from the participating institutes and render advice as is reasonable.

6. Discussion with ALICE

Scientific output and current activities:

- ALICE continues to have a rich scientific output, with 10 papers submitted since the last session of the LHCC, bringing the total number of publications to 362. Recent results include a measurement of light (anti)nuclei production in pp collisions at $\sqrt{s}$ = 13 TeV, a measurement of inclusive charged-particle b-jet production in pp and pPb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV, and a measurement of prompt D^0, D^+, and D^{*+} production in PbPb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV.
- Excellent progress has been made in preparation for Run 3, with the detector now complete and in commissioning. The beam test was very successful, allowing to test detectors and online systems. A few remaining activities are now being carried out on cabling and last replacements of repaired VTRx modules. ALICE is well poised for physics data taking in early 2022.

Run-4 upgrades:

- Good progress has been reported on Run 4 upgrades. R&D on ITS3 is making rapid progress, with a successful verification of bent ALPIDE sensors in extensive beam tests investigating the tracking performance.
- Beam tests have also successfully been carried out for FOCAL at the SPS in September and October 2021, with beam tests of a full demonstrator tower planned for May/June 2022.

Future upgrade plans:

- The review of ALICE-3 is under way, with a kick-off meeting held and a first round of comments and questions recently provided to ALICE.
- Additional documentation on the competitiveness and complementarity of the ALICE-3 programme with respect to other experiments, and on cost and schedule are expected in the coming weeks. The next steps of the review are now being planned, noting that completing the review before the March 2022 LHCC will be challenging.

- The **LHCC congratulates** ALICE on its continuing rich physics output, and for its tangible progress in installing and subsequently commissioning of upgrades at P2, despite the COVID-19 challenges.
- The **LHCC commends** the ALICE collaboration for taking full advantage of the 900 GeV pp pilot beam data.
- The **LHCC notes** that the proposed ALICE-3 detector, with a first, still incomplete, draft of the LOI currently under review, will require advances in key detector technologies relevant for HEP as a whole and thus **supports** R&D in these areas.

7. Discussion with ATLAS

Scientific output and current activities:

- ATLAS continues to make excellent progress on its physics programme, with 1024 papers on collision data submitted to date, of which 118 use the full Run 2 data set. Since the last session of the LHCC 13 new papers have been submitted. Recent new results include a combination of HH non-resonant and resonant searches, a measurement of the $t\bar{t}$ cross-section in boosted all-hadronic final states and a search for heavy resonances in four-top-quark final states.
- The LS2 activities are progressing towards completion, and ATLAS is making good progress towards readiness for Run 3. Apart from finalising the Phase-I upgrades, remaining activities include the installation and commissioning of valves to increase the granularity of the Tile calorimeter front-end cooling loops, beam pipe bake-out and magnet tests, as well as the repair of RPC gas leaks, which increased significantly after the restart of the full gas system.
- ATLAS took full advantage of the pilot beam, with all splash events recorded and data taken in all the collision periods. The pilot beam period was very useful to iron out some operational procedures in combined systems running and to train new shifters.

Phase-I upgrades:

- All hardware installation for the LAr upgrade is finished, and commissioning is ongoing with the first level calorimeter trigger. For the TDAQ upgrades the production of eFEX boards is expected to be completed by the end of this year. Commissioning of the new systems is ongoing in the cavern.
- The NSW Side-A was already fully cabled in August, with commissioning in full swing until the start of the pilot beam period. The electronic noise levels were measured in the cavern for all sectors (MM and sTGC) and found in agreement with the measurements done during the surface commissioning. No new HV failures on sTGC chambers were observed. Large progress in DAQ and DCS allowed the participation of NSW-A in the pilot run. The NSW Side-C was successfully completed and installed in ATLAS.

Phase-II upgrades:

- A P2UG review of ATLAS took place on 8-12 November 2021, more details are given in the P2UG section below.

- The **LHCC congratulates** ATLAS on the wealth of very interesting new physics results produced, as well as the good progress reported on the upgrades and in preparing for Run 3.
- The **LHCC is aware** that the combination of final efforts leading to Run 3 operations and the efforts needed to plan the Phase-II upgrade installation schedule will put increased load on the Technical Coordination team; experiment management should remain prepared to render assistance to the TC team as needed.
- The **LHCC congratulates** ATLAS on the successful completion and installation of NSW Side-C, but **notes** that in the current schedule very little time is left for its commissioning. This effort should be given priority when allocating additional time made available due to the warm-up of LHC Sector 23.

8. P2UG report ATLAS

The ATLAS P2UG met with the upgrade project leadership from 8th-12th November 2021, following an intermediate update meeting on 2nd August 2021. An in-depth review of the TDAQ, ITk-Common, ITk-Pixels and Tile Calorimeter projects was held. For the other projects, more compact updates were provided. The only part of the project not reviewed was the Event Filter track-finder, as the new proposal for this system is currently under review by the LHCC and UCG. The P2UG is impressed by the progress shown across all projects, by the comprehensive and transparent presentations, and by the responsiveness of the whole ATLAS team.

With regards to the schedule, it is observed that the COVID-19 situation continues to affect the projects severely. The effects are not uniform across ATLAS. For some projects, good progress and even some recovery in the last quarter was seen; for some a further reduction in float, but at a controlled level; and for others, a further worsening not just of the overall schedule situation, but of the rate of slip has occurred. The worst-affected project appears to be the ITk-Strips, which continues to see a high slip rate owing to a combination of COVID-19 effects and re-appraisal of the longer-term schedule. The overall distance-to-critical-path based on the need-by dates for installation is around minus six months, as compared to an expectation of plus twelve months. No project currently has a twelve-month float for its tightest deliverables, though there are projects for which many subcomponents maintain an acceptable float.

The TDAQ project has made very important structural changes since last P2UG meeting in May 2020. A decision has been taken to terminate the Hardware Track Trigger (HTT) development and instead base the EF tracking on commodity technology. This carefully prepared step, which involved all relevant executive levels of the collaboration, has eliminated some major technological risks and simplified considerably the overall layout of the TDAQ system. As the tracking part of the EF is thus currently under major restructuring and subject to a TDR amendment currently in the LHCC/UCG review process, its internals have been excluded from this in-depth review. Nevertheless, it is very apparent in the other TDAQ areas that the overall complexity has been greatly reduced, which clearly benefits the successful execution of the project.

The ITk common items have reported good progress in all areas but, at present, the ITk readiness date is more than seven months late without any float. The integration and commissioning schedule depends most crucially on the availability of modules and sub-

assemblies, i.e., on sensors, ASICs, and hybrids, which are known to be problematic. Therefore, the credibility of this part of the schedule depends to a very large extent on confidence in the schedules for the major components.

The ITk pixel project has completed two FDRs and a PDR, sensor market surveys are complete and preproduction sensor delivery has commenced for the 3D sensors, and most importantly the production of the penultimate ASIC ItkPixV1.1 is complete, testing is progressing, and modules with this ASIC will be available soon. Overall, the prototyping effort is closing the remaining R&D questions as the pixels move into the pre-production era. In terms of schedule, additional delays stemming from the delays in producing RD53A modules have occurred. This is mitigated by active schedule management, particularly through the actions of the Schedule Task Force (TF), which has suggested changes from the original plan to recover the delays. The overall seven month delay has stayed essentially constant over the last year.

The ITk strips project has shown important advances, for example the completion of the sensor pre-production QC & QA tests, the submission of pre-production HCCStarV1 and AMACStar ASICs and the passing of the PRR of ABCStarV1. On the other hand, the site qualification process evolved more slowly than foreseen, and the ASIC developments continue to introduce significant delays in the schedule. The ITk strips schedule drives the critical path, and the project keeps losing significant float despite ongoing mitigation measures.

The TileCal project continues to make progress and there were no major worries. It has been particularly pleasing to see progress with outstanding radiation testing and integrated or Vertical Slice Tests.

The LAr project has progressed quite well despite delays related to COVID-19 (availability of irradiation facility) and foundry planning which have not been recovered. The schedule float is however still positive (~six months) and the distances to critical path have not increased.

The Muon project also continues to make good progress. A significant baseline change proposal to the RPC Chamber and Front-End Electronics has been implemented. Several internal reviews have been passed (3 PDRs, 2 FDRs, 1 SPR2/FDR1). With the exception of TGC trigger and readout electronics, the schedule has remained relatively stable.

The HGTD project is still in a relatively early stage. Beam test evaluations of LGAD sensors have been undertaken, with encouraging preliminary results. ALTIROC2 was delivered in September and preparations for testing are well underway, including sensor-ALTIROC assemblies.

The **LHCC congratulates** ATLAS on the progress made in all areas of the Phase-II upgrade projects despite the difficult circumstances. The **LHCC notes** that the current schedule is not realistic, with the ITk project driving the critical path. The **LHCC and P2UG note** that with an anticipated additional year for Run 3 and a three-year long LS3, the schedule remains tight. The **LHCC agrees** with the recommendations of the P2UG given in the Appendix, and **strongly encourages** ATLAS to follow these recommendations. In particular, the LHCC and P2UG recommend:

- ATLAS should prepare for an intense period of re-baselining of the project schedules in order to generate a detailed plan for an eighteen-month extension of the Phase II upgrade schedule and demonstrate that delivery of the full project

scope is possible under those conditions with reasonable certainty. The new schedule should be flexible enough and sufficiently well-provisioned with contingency to withstand additional delays in individual components, taking into account the supply-chain and COVID-19 related challenges expected over the next two years.

- ATLAS should not allow projects which do not dominate the critical path analysis (e.g., muons, calorimetry) to relax from their current rate of progress or lose further time; the early delivery of these projects will be a vital element in maintaining flexibility in both the construction and installation schedule.
- Any proposals to reduce or redefine QA/QC procedures should be the subject of a full documented risk analysis.

A full list of global and project-by-project P2UG recommendations is given in the Appendix.

9. Discussion with CMS

Scientific output and current activities:

- CMS continues to make excellent progress on its physics programme, with 1076 papers on collider data submitted to date, including 17 since the last LHCC. Recent results include the observation of triple J/ψ meson production, a measurement of the Drell-Yan forward-backward asymmetry at high dilepton masses, and a search for invisible decays of a Higgs boson produced via vector boson fusion in pp collisions $\sqrt{s}$ = 13 TeV.
- The endgame of LS2 is proceeding well with no substantial delays w.r.t. the original schedule, including the magnet cool down. The magnet commissioning and Free Wheel Thyristor test have been completed successfully. CMS was ready for the pilot beam with the magnet running at 3.8T.
- CMS had a very successful pilot beam run, including recording the beam splash events at the beginning. First calibrations and timing alignments were derived and the full data taking workflow exercised.
- Except for New Forward Shielding (NFS) and opening system, all LS2 projects are finished. The NFS is not mandatory for safe operation in 2022 and will be finished at the latest in YETS 2022/23. The installation of the demonstrators for GE2/1, RE3/1 and RE4/1 is ongoing.
- A water leak was discovered at the -z Endcap of CMS and traced to the connection of a purge valve. The failure was due to a mix of thread standards used in the connection; all purge valves have been modified.
- MilliQan, a detector for the search for millicharged particles, is being proposed, to be implemented as a subdetector of CMS with a specific MoU to define authorship and connection of MilliQan and the wider CMS collaboration. The detector is fully funded, and ready for installation for Run 3. The project has been reviewed by the LHCC.
- Zero-degree calorimeters for HL-LHC (HL-ZDC) are proposed, also as a small upgrade project. The design of the detectors themselves are common with ATLAS (already endorsed at the last LHCC), with CMS-specific electronics and installation infrastructure. Funding is provided via US DOE NP, with a common construction of all four detectors for ATLAS and CMS. The project has been

reviewed by the LHCC.

Phase-II upgrades:

- A P2UG review of CMS took place 20-25 October 2021, more details are given in the P2UG section below.
- A noise study by the HSE group of the Phase-II layout of P5 revealed noise levels in excess of the permitted levels at CMS next neighbours. Further studies are being carried out to address the situation and find a solution that should take into account the interests of all projects at P5.

- The **LHCC congratulates** CMS on its very productive physics programme as well as on keeping to the LS2 schedule, getting ready for Run 3, and progressing on HL-LHC upgrade preparations despite COVID-19 related restrictions.
- **The LHCC encourages** CMS and CERN to work together to find an operationally acceptable solution towards the reduction of the noise of the cooling towers.
- **The LHCC recommends** that the contributions from the Hostlab budget line be secured for the CMS buildings approved to be in the scope of the Hostlab Phase-II project.
- The **LHCC endorses** the execution of the MilliQan and the HL-ZDC projects as CMS sub-detectors.

10. P2UG report CMS

The P2UG virtual review of the CMS Phase-II upgrade took place October 20th – 22nd, 2021, with an in-depth review of the MIP Timing Detector (MTD), and an abbreviated in-depth review of the Barrel Calorimeter and the Muon System. The status of the HGCAL and Tracker was reviewed. The P2UG also heard introductory presentations on the Data Acquisition (DAQ) System and the High-Level Trigger (HLT) and on the Beam Radiation, Instrumentation and Luminosity (BRIL) project.

The P2UG is impressed by the steady progress that has been made in all areas, despite the difficult working environment. There were many noteworthy achievements over the course of the last six months, including the successful conclusion of the V1 sensor prototyping for the HGCAL, the delivery of the V2 prototype sensors for the HGCAL with excellent quality, the submission of ECON-T-P1 and many test beam campaigns.

The muons systems are showing good progress, with the first systems installed. Significant crosstalk was observed inside the PETIROC-2C chip. There is also a dispersion across the chip that is not yet understood. The GE2/1 project has reached the construction stage; solutions have been found for ME0 to handle the rate capability and to protect against discharges. Because of a 12-month delay in the FEB design and production the new RE3/1 and RE4/1 chambers are not on track to be installed during EYETS 23/24.

The bench tests of the TOFIR2X show good performance and a time resolution matching the TDR, when adequate light input is provided. The MTD-BTL has observed in test beam studies a ~30% lower light yield than expected. The timing resolution at end of life with 30% less light yield and SiPM gain loss could reach ~ 80 ps to be compared with TDR expectation of less than 60 ps. The design of the TOFIR2B chip, including a tuning

of the gain to match lower signals, is nearing completion. An MPW submission is planned for November 2021 with an 11-month delay with respect to the baseline date.

For the MTD-ETL, the single event burnout, which causes sensors at high voltages to permanently break down when exposed to highly energetic particle beams has been understood to be due to the average electric field in the device. The design parameters of the sensors have been narrowed and will be completed during the market survey tests. The sensors can be further optimized to meet the end-of-life timing requirements. The ETROC1 chip shows a 40 MHz noise, the source of which has been identified and has been addressed in the ETROC2 design. The submission of ETROC2, a full-size chip, is planned for March 2022.

Despite the good progress of the HGCAL project, it has realized an additional 6-months delay since the last review and now carries a negative float of about 5 months and **the current schedule is no longer viable**. The critical path is determined by the ECON chip. The ECON-T-P1 was submitted at the end of June 2021. Devices are imminent from TSMC. ECON-D design efforts have been intensified; chip submission is foreseen for April 2022. The HGCROC-v3 arrived in April 2021 and has been tested over the summer. The overall performance of the chip is good. A problem was found in the DRAM, with a fix being implemented. First module prototypes are available and silicon modules equipped with the HGCROC-v3 were tested in the test beam in October 2021. The V2 prototype sensors have been delivered with excellent quality. Cast and moulded scintillator tiles are available, but the moulded tiles have ~40% less light yield as observed in the test beam. A reassessment of the expected performance of the detector in the final experiment has been made and a relatively large region of the scintillator-based calorimeter has a S/N < 5.

The Barrel Calorimeter upgrade is making excellent progress. The CATIA v2 and LiTE-DTU v2 production drive the schedule.

The Outer Tracker is making good progress, but has only four month of schedule contingency left, with the hybrids and MaPSAs driving the schedule. Modules of both types have been built. The CBC ASIC, that is already in production, shows two issues which are being studied. It has been determined that 3D sensors are the only option for Layer 1 and Ring 1 for the full duration of run 4 and 5. Various layouts for pixel geometry and use of 3D sensors are still being studied. The CROCv1 ASIC (RD53B_CMS) is now available and testing is ongoing. The availability of the Proto-CROC is now the critical path.

The **LHCC congratulates** CMS on the progress made in all areas of the Phase II upgrade projects despite the difficult circumstances. The **LHCC notes** that the current schedule is broken. The key driver is the development of the ECON chip. This development needs to be closely monitored and the submission of the ECON-D is a critical milestone. The **LHCC and P2UG note** that with an anticipated additional year for Run 3 and a three-year long LS3, the schedule remains tight. The **LHCC agrees** with the recommendations of the P2UG given in the Appendix, and **strongly encourages** CMS to follow these recommendations. In particular, the LHCC and P2UG recommend:

- A deep-dive re-assessment of the schedule is recommended, and agile, pro-active risk management is strongly recommended moving forward. “What-if” scenarios should be run and a fully worked-out mitigation strategy developed in case the scenario is realized.
- The project should ensure that the technical specifications of all the systems are

met and that the physics performance is well understood if the performance is different from the TDR specifications.
- The development of the ECON ASICs and their testing should be very closely monitored.

A full list of project-by-project P2UG recommendations is given in the Appendix.

11. Discussion with LHCb

Scientific output and current activities:

- LHCb continues to deliver high quality physics results, with a total of 598 publications to date, including 17 new papers since the last session of the LHCC. New results include a simultaneous determination of CKM angle γ and charm mixing parameters, a study of B_c^+ decays into charmonia and three light hadrons, and tests of lepton universality using $B^0 \to K_s^0 l^+ l^-$ and $B^+ \to K^{*+} l^+ l^-$ decays.
- LHCb had a very successful beam test with all installed detectors, which were all time-aligned within a few days. HLT1 and HLT2 were integrated and running in pass-through mode, the data flow was validated using real detector data for the first time.

Phase-I upgrades:

- Good progress has been reported on the upgrades. MUON, CALO, and RICH2 are all completed. RICH1 is on track to be completed before the end of the year.
- For the SciFi the first two (of six) A-side c-frames have been installed, with the last two scheduled for February 15th (a 3 week slip since the last meeting). The installation will be done before cavern closure, even if the front-end boxes are still missing at that point.
- For the VELO enough modules have been produced; work continues on several more. The C-side assembly has been completed. System tests and metrology will be finalised prior to shipping on December 7th. The A-side assembly is awaiting vacuum feedthrough boards currently being reworked at CERN. The assembly will be faster than the C-side. There is still a contingency of about three weeks for a cavern closure date of February 21st.
- UT stave construction has been completed for the C-side with installation expected in mid-February. LHCb is requesting a two-week technical stop in June to install the A-side UT box. The installation may however require up to three weeks.
- HLT1 GPU procurement and installation are under way, with one NVIDIA A5000 GPU per server. Trigger and reconstruction studies are under way for partial UT / SciFi installation scenarios.
- A first round of questions and responses has been completed in the review of the Upgrade-II framework TDR.

- The **LHCC congratulates** LHCb on its rich scientific output and **commends** the collaboration for the progress made on the upgrade programme and for the successful participation in the pilot beam run.
- The **LHCC acknowledges** the request by LHCb for a technical stop in June 2022 to install UT side-A but **notes** that sufficient overall pp run time in 2022 must be

preserved.

- The **LHCC notes** that the UT project would profit from strengthened coordination and is expected to need increased support by LHCb management and more generally at CERN during installation. Nevertheless, the priority of the collaboration will have to remain on the projects that are driving the critical path for cavern closure.
- The **LHCC notes** that the proposed Upgrade-II, with the Framework TDR currently under review, will require advances in key detector technologies relevant for HEP as a whole and thus **supports** R&D in these areas.

12. Discussion on the Phase-II Upgrade Schedule of ATLAS and CMS

The Phase-II upgrade projects of both ATLAS and CMS are making progress in all areas. Nevertheless, significant delays continue to occur on most projects. The COVID-19 pandemic, with travel restrictions and laboratory closures around the globe, and increasingly also via global supply chain issues, is an important, but by no means the only reason for these delays. Both ATLAS and CMS re-affirm their analysis that a delay of the start of Run 4 by 18 months is needed to make the successful completion of the Phase-II upgrades feasible. This should be implemented as an extension of Run 3 by one year up to the end of 2025, and an extension of LS3 to a duration of 3 years. The main drivers for this are delays in critical upgrade projects, in particular ATLAS ITk and CMS HGCAL. Detailed analysis has shown that these projects cannot be staged due to their design, and further descoping beyond measures already taken would lead to significant loss of performance that would cripple the experiments throughout the HL-LHC phase. The **LHCC agrees** with this analysis, and **strongly supports** the request to delay the start of Run 4 by 18 months, noting that also with this additional time the successful completion remains a significant challenge. The **LHCC recommends** that the focus of schedule planning and optimisation should now be on increasing the robustness of the Phase-II schedule to ensure that no further shifts are required. This will require the injection of additional resources both from CERN and the collaborating institutes to strengthen projects in key areas. The **LHCC urges** the experiments to also prepare for staging and phasing of projects where this is possible, with the goal to have measures that would free up resources that can be diverted to the most critical projects ready to deploy when additional needs arise, or further delays occur. It is understood that such measures require increased flexibility of groups, institutes, and funding agencies up to a possible re-negotiation of deliverables already documented in MoUs and will require strong support from the experiment managements and from CERN. The LHCC notes that the success of HL-LHC as a whole is of the utmost importance, and can only be achieved by the accelerator, ATLAS and CMS together. Good communications of all parties are essential, and CERN management has a central role to play in this.

13. Discussion with WLCG

The WLCG infrastructure continues stable operations, with the CPU usage at WLCG sites exceeding pledges for all experiments. Network data challenges took place in preparation for Run 3 on 4-8 October 2021, testing the new data transfer protocol and the network infrastructure. The data challenge met its targets for both nominal and peak data transfer rates. A tape throughput challenge as recommended by the LHCC was carried out on 11-15 October 2021 to ensure the archive storage systems can fulfil the

experiment needs for Run 3. ATLAS and ALICE fully achieved their targets. CMS reached both read and write targets after tuning the interaction between FTS and RUCIO. LHCb focussed on tape writes (T0 →T1 export), where the average target rate was met after addressing some bottlenecks, however tape recall was not tested. Apart from achieving the respective targets, the challenges are an opportunity for further development of common tools and services particularly in the area of monitoring. This opportunity should be pursued further. On a longer timescale, the LHCC concurs with WLCG to see tape challenges as part of a process towards HL-LHC, similarly to network challenges. The experiments took the opportunity of the recent pilot beam test to test their offline chain and seek further improvements. The requests for computing resources for 2022 are generally matched by the sites, with some shortfalls for ALICE and LHCb CPU requests, and LHCb disk and tape requests. While opportunistic CPU resources may help with the former, there is little mitigation for the lack of tape. The Funding Agencies are encouraged to secure enough tape for the experiments to secure smooth operations at the beginning of Run 3.

Progress has also been reported on Common Software projects, such as MadGraph demonstrating excellent speed-up on GPU, a pilot workshop on running physics analysis at scale and many more.

- The **LHCC congratulates** the WLCG and the experiments on the successful and efficient use of the computing resources.
- The **LHCC congratulates** WLCG and the experiments for setting up the network data challenges. The **LHCC acknowledges** that running a data challenge in a production environment is a challenge in itself, however understanding the results is crucial. The **LHCC concours** with WLCG in having additional dedicated and limited in scope tests before the start of Run 3.
- The **LHCC congratulates** the WLCG for demonstrating the capability to transfer data for the start of Run 3 with the new http protocol at the needed rates.
- The **LHCC commends** the WLCG and the experiments for results achieved during the tape challenge. As for the data challenge, this is difficult to organise across the 4 experiments, however the **LHCC recommends** further testing to consolidate the results and ensure smooth operation in Run 3.
- The **LHCC commends** the Common Software bodies for their fundamental role in bringing together technical experts, from different experiments and backgrounds, to exchange on their experiences and foster new ideas and developments.
- The **LHCC is concerned** about the strength of the LHCb computing team, which compromises their ability to fully participate in the challenges in preparation for Run 3. It is noted that currently most of the person-power is provided by CERN. The **LHCC welcomes** the effort of the collaboration to increase the engagement of institutes via dedicated “online software and computing agreements”.

14. Report on the HL-LHC Computing Review

The review carried out in November 2021 focussed on common software activities. All activities and the experiments are showing excellent technical progress. The review committee was uniformly impressed by the quality of the documentation and the presentations, noting that the agreement on the machine parameters for the start of the

HL-LHC facilitated the work of the committee. ATLAS and CMS have an appropriate understanding of the R&D needed relative to the performance/budget for HL-LHC and have made much progress in using heterogeneous architectures. Further investments in R&D activities are however essential to achieve cost and sustainability goals. It should be noted that software and computing activities in the experiments often take place on a continuum between daily operations and R&D, which impacts timelines and effort profiles. A detailed report from the review is expected in January with observations and comments on all projects, and a small number of recommendations suggesting concrete action. The schedule and format of future reviews are expected to be adjusted to maintain alignment with the evolving overall Phase-II schedule and to ensure a process that achieves an appropriate balance between being light-weight and sufficiently complete and thorough. The main points highlighted by the review committee are:

- The success of the ATLAS developed data management framework RUCIO is impressive. The adoption of RUCIO as a common tool by CMS (and others) is a very positive step. Contributions from CMS and experiment independent effort would strengthen this project.
- The HEP Software Foundation discussion forums were particularly useful in fostering positive collaboration around the event generator community and the pythonic analysis community.
- The Geant4 project and the experiments have strong relationships that should continue. Increased coordination on fast simulation is encouraged.
- For the ROOT foundations, excellent progress has been made on RNTuple, with the RNTuple lite library a welcome development.
- The DOMA activity has played a key role ensuring the 10 Common Software Activities (6 storage, 2 data management, 1 IAM, 1 networking) make progress towards a common goal, by taking an agile approach of continuous interactions between the experiments and the activities coordinated by DOMA. Regular, realistic exercises of increasing ambition and complexity, involving the DOMA activities, the experiments and WLCG sites are of great importance and should be pursued.

15. Report on RD42

RD42 has shown new results on the understanding of radiation damage effects in diamond detectors. The collaboration has a good record of publications and presentations to international conferences; several PhD students are involved. Their work together with producers has been important to establish and maintain sources of such detectors that are also used by the machine, and other users world-wide. The design of the CALYPSO ASIC with diamond and silicon detectors has made progress, but issues have been observed with the data transmission foreseen in the ATLAS BCMs, and significant questions remain concerning the use with silicon detectors in CMS. RD42 appears to be putting a higher priority on a broad R&D programme rather than developments more focused towards the needs of HL-LHC experiments. While the collaboration is rather large and stable on paper, the number of people actually involved appears to be relatively small. CMS should consider assigning contact people, so that the CMS FBCM project can fully profit from RD42 activities via exchange of information on ASIC design and a possible use of the CALYPSO ASIC and of the RD42 test facility.

- The **LHCC congratulates** RD42 on the progress made on its research into very radiation resistant planar and 3D diamond detectors as well as for the progress

made on the Calypso readout chip.

- The **LHCC strongly urges** RD42 to improve the communications with CMS, and more generally to better align with the priorities of the HL-LHC experiments.
- The **LHCC recommends** an extension of RD42 (including access to CERN facilities, lab and office space, test beams) for two years rather than the originally requested three years, to align the end date of RD42, RD50 and RD51 in anticipation of the definition and concrete implementation of the European Detector R&D Roadmap coordinated by ECFA, as recommended by the 2020 Update of the European Strategy for Particle Physics.

16. Report on TOTEM

The LS2 activities have progressed and are on track. The Roman Pots movement system has been fully commissioned, including the CCC interface. Some remaining software instability issues have been identified, which are being debugged. The interlock tests were completed before the pilot beam test, which proceeded without issues, with the RPs in bypass mode. The RP strip detectors have been installed following the pilot beam test. The pixel detector movement system has been tested and validated in H8, and the detector packages are ready for installation in the tunnel soon.

The production tiles of the new T2 detector have been successfully tested in the second round of test beam operations, where efficiency scans verified their response uniformity. The production of scintillator tiles has thus restarted in Helsinki. The mechanics is ready for the final mounting. The full performance test, with all quarters and with the final readout chain, will be performed on the test beam next summer. A novel option, to use the T2 detector also during the heavy ion run, is under discussion with CMS, in view of its implications for the radiation exposure of the scintillator tiles.

A new paper, reporting the search with CMS of high-mass diphoton exclusive events, has been submitted to Physical Review D. A further analysis, on the dip/bump structure of the differential elastic scattering cross section at 8 TeV, was completed, and the paper is to be submitted to EPJC.

- The **LHCC congratulates** TOTEM for being on track with all activities needed to ensure readiness for data taking in 2022.
- The **LHCC welcomes** the completion and submission of the new physics analysis papers.

17. Report on FASER

The commissioning of the FASER detector achieved a further milestone with the successful operations during the pilot beam test. The detector collected multitrack signatures resulting from beam splash events in front of ATLAS and from beam halo interactions with the collimators between ATLAS and FASER, as well as single-track events during the beam collisions period. All detector and data acquisition systems performed as expected. The study of beam backgrounds revealed an important contribution from interactions of the beam halo with the LHC Q12 quadrupole, situated at the junction between the LHC tunnel and the TI12 gallery, arising from beam-1 (the incoming beam). While this would result in an acceptable additional trigger rate during high-luminosity running, estimated of the order of a few tens of Hz, the possibility is

under discussion to add some shielding to fully isolate the exposed downstream elements of the detector.

The interface tracker (IFT), to operate between FASER and the FASERν detector, collected on the order of 1M tracks during a recent test beam, in coincidence with a set of emulsions. The scanning and analysis of these data is in progress in Japan, following the development of the emulsions at CERN. The IFT is now ready for installation, which is expected to take place in the two weeks following the LHCC meeting. A further test of the installation of the FASERν box, fully loaded, is planned. The tungsten for the target is also now available at CERN.

The neutrino-candidate paper is to appear in PRD. The TDAQ paper has likewise been submitted, the tracker paper will be submitted in about two weeks, and the paper with the overall description of the detector is available as a first draft.

The delivery to the LHCC of the Technical Proposal for the pre-shower upgrade project has been postponed to late December, to allow for the update of the project schedule, following the 4-month delay in the delivery of the pre-production chip. The project remains on schedule for installation following the 2023 run.

The collaboration with SND@LHC and with CERN for the refurbishment of the emulsion facility has progressed, with delivery expected by April. A suitable location for the temporary storage of emulsions has been identified, in the AWAKE access tunnel, where access restrictions appear compatible with the experiments' needs.

- The **LHCC congratulates** FASER for the successful operations during the pilot beam test, and for the publication and submission of its first papers.
- The **LHCC congratulates** FASER for the persistent progress on all fronts of the project, from construction to commissioning, consistent with readiness of the full detector to take data at the start of Run 3.
- The **LHCC notes that CERN** has worked with FASERν, SND@LHC and other experiments, to realise the extension and refurbishment of the emulsion facility, and to identify a suitable underground location for the storage of emulsions. The **LHCC encourages** this close collaboration to continue.

18. Report on SND

The Scattering and Neutrino Detector (SND@LHC, hereafter simply "SND") experiment was reviewed in a Focus Session along with FASER. A joint presentation on common infrastructure needs was also included in the schedule for this meeting.

SND have made impressive progress since the last LHCC meeting. Test-beam and surface commissioning campaigns have been used to integrate the detector elements and provide calibration data; the additional test-beam days that were allocated proved to be critical. The detector installation underground started at the beginning of November, and currently comprises the target area support structure, the muon system absorber and the cooling plant.

The steps for exchanging the emulsion bricks have been tested on the surface (with full-weight bricks) and also underground (with empty bricks), giving significant confidence that the planned procedures will work well. Radio-protection assessments have given a preliminary indication that the brick replacement activity can take place within a few hours of machine cool-down, and no materials that need to be removed from TI18 will

be activated above the clearance limit. Therefore, no complications in access or handling of the emulsion bricks are expected.

All elements of the detector have been shown to be working well, with the exception of the muon PCB boards (for the SiPM readout of scintillator bars) which have been found to have manufacturing issues with component soldering and connector alignment. A new production run is being planned in order to ensure that the experiment can handle further failures and to have a sufficient stock of spares. A set of emulsions was found to have been exposed during cargo screening on the journey from Moscow to Geneva; this will be mitigated by drawing up scientific equipment transport protocols for future shipments. SND have also experienced some materials delays (notably for the neutron shielding cold box that surrounds the target area) but have adapted their integration plan to avoid any overall delays to the project. The experiment is confident that it will be ready for beam commissioning; the additional access weeks due to the Sector 23 work will be used by the experiment and will significantly mitigate any remaining schedule risk.

A discussion of common facilities with FASERν and SND covered the emulsion facility at CERN and underground storage for the emulsion bricks. Refurbishment of the emulsion facility is underway; the old chiller will still be used but with a backup plan by the Cooling & Ventilation group in case of failure. The new space will be ready for operations in mid-April, which means that SND will need to find another dark space for the assembly of the first (partial) set of emulsions; however, this should be relatively straightforward. The baseline plan for underground storage is the AWAKE access tunnel. Transport to/from this location has been considered and is feasible. Current indications are that FASERν and SND will be able to work around any access restrictions due to AWAKE operations. Both collaborations may still consider alternative locations on the CERN site, should they become available.

The collaboration reports no problems in terms of funding and manpower. The collaboration structure is being further populated, with the appointment of a Physics Coordinator and Editorial Board. MoU's for M&O are currently out for signature.

- The **LHCC congratulates SND** on making rapid progress in the preparation of the experiment since the last LHCC meeting. The **LHCC notes** the importance of the additional test-beam time, and that further test-beam time may be requested for detector R&D work in 2022.
- The **LHCC notes** the problems with the muon system PCBs and the accidental emulsion exposure, and **supports** the actions being taken by SND to resolve these issues.
- The **LHCC notes that CERN** have worked with FASERν, SND and other experiments to realise the extension and refurbishment of the emulsion facility, and to identify a suitable underground location for the storage of emulsions. The **LHCC encourages** this close collaboration to continue.

19. Report on MoEDAL

The first draft of the Technical Proposal for the new MAPP-mQP detector was received by the referees on October 26th. Its review was completed shortly after, and a set of questions was sent to the collaboration, to be discussed in meetings with the referees during the LHCC week, in view of a possible recommendation for approval. The key new element of the project is the complete assessment of the infrastructure and safety implications of installation and operations in the UA83 gallery. The Engineering Change

Request documenting the detector installation in UA83, and the Safety Derogation for the use of plastic scintillators, identified by the safety groups as the only non-conformity, have been approved by the relevant bodies at CERN. Among other advantages, the UA83 location decouples the access to the MAPP detector from the LHCb area. The physics studies have also been updated, to account for the new location, and confirm a projected sensitivity reach well beyond the current constraints on fractionally charged particles. The detector construction is in progress at the University of Alberta, on schedule for a prompt start of partial installation. The current installation plan foresees the mounting of the support structures and of up to 50% of the scintillators and readout electronics, to be completed by February in case of approval at this meeting, on time to take test data during the 2022 run. The detector would then be completed during the YETS 2022-23.

The main issues raised by the LHCC referees included:

- The availability and supervision of experiment personnel, to cover critical tasks during installation and operations, including the safety responsibilities and the monitoring of the detector and data taking
- The performance compatibility of the HZC and Hamamatsu PMTs, their pre-calibration strategy, and the evaluation of the overall PMT photon detection efficiency, in the regime of low photon multiplicity corresponding to the lower edge of the millicharged sensitivity, $Q \sim O(10^{-3})$ e.
- The robustness of the physics reach studies, in relation to the estimates of backgrounds, detector efficiencies, transport modelling from the interaction region, and production modelling in pp collisions.

All questions raised by the referees have been addressed satisfactorily.

The agreement with LHCb for the installation of the upgraded MoEDAL baseline detector is making further progress. The detector drawings are being translated into CERN's CATIA system, for the final review by LHCb's technical coordination. Meanwhile, installation of cable trays has been authorized, and power and internet connections have been installed. A new constraint has emerged, on access to a viewport in the vacuum vessel of the VELO detector. A proposal to address this is under review. LHCb requests the installation of the MoEDAL baseline detector to take place in February. This is compatible with the brief installation time needed.

- The **LHCC reiterates** the support for the physics case of the MAPP-mQP detector and acknowledges its potential to search for millicharged particles at the LHC.
- The **LHCC urges** the collaboration to confirm and secure the human resources needed for the effective and safe operation of the MAPP-mQP detector.
- The **LHCC considers** that the targets set for the MAPP-mQP detector are achievable and recognizes the value of a test data taking in 2022. The **LHCC recommends** the approval of MoEDAL MAPP-mQP.

20. REFEREES

The LHCC referee teams for this session are as follows:

ALICE: D. Calvo, G. Casini, J. Nagle (Co-ordinator), P. Salabura

ATLAS: C. Biscarat, R. Calabrese, F. Di Lodovico, J. Hernandez-Rey, W. Wisniewski (Co-ordinator)

CMS: E. Kajfasz (Co-ordinator), S. Niccolai, P. Pakhlov, D. Waters, A. Weber

LHCb: T. Higuchi, C. Hearty (Co-ordinator), K. Krüger, E. Worcester

LHCf, TOTEM: F. Di Lodovico, M. Mangano (Co-ordinator), P. Pakhlov

MoEDAL: F. Di Lodovico, M. Mangano (Co-ordinator), E. Worcester

WLCG: C. Biscarat (Co-ordinator), P. Salabura, D. Waters, A. Weber, E. Worcester

FASER: K. Krüger, M. Mangano (Co-ordinator), W. Wisniewski

SND: D. Waters (Co-ordinator), F. Di Lodovico, K. Krüger, M. Mangano

R&D projects:
RD42: E. Kajfasz

21. The LHCC received the following documents:

CERN-LHCC-2021-015	Minutes of the one hundred and forty seventh meeting of the LHCC held on 1-2 September 2021
CERN-LHCC-2021-020	Report and extension proposal of RD42
CERN-LHCC-2021-024	Technical Proposal of MoEDAL-MAPP

DATES FOR LHCC MEETINGS

Dates for 2022
9-10 March,
1-2 June,
14-15 September,
30 November-1 December

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Appendix A. **Recommendations from the CMS P2UG Review**
Appendix B**. Recommendations from the ATLAS P2UG Review**

A. Recommendations from the CMS P2UG Review

Review panel: Franco Bedeschi, Alessandro Cardini, Marcel Demarteau (chair), Alexander Kluge, Gregor Kramberger, Mario Martinez-Perez, Roman Pöschl, Petra Riedler, Chiara Roda, Marcel Stanitzki

The P2UG virtual review of the CMS Phase-II upgrade took place October 20th – 22nd, 2021. The P2UG is impressed by the steady progress that has been made in all areas. Despite its successes, however, the **current schedule no longer viable**. Here, the project-by-project recommendations are given, without including the comments and observations of the review.

Muons

- Carefully complete the longevity studies for all detectors.
- Continue attacking the greenhouse gas issues from many sides: new gases, gas recuperation, leak repairs.
- Continue to carefully monitor the iRPC FEBv3 board design, production, and validation under radiation.
- Pursue the root cause of the crosstalk in the PETIROC chip, validate the observations through simulations and address the threshold problems to ensure that the chip meets the design specifications.
- Start chamber production for GE2/1 without delays at all construction sites.
- Continuously monitor component quality for the GE2/1 production.

MTD-BTL

- Proceed with the MPW of TOFIR2B as planned; this ensures that devices will be available for testing since the MPW schedule is secure.
- Continue study of light output optimization.
- Steer the LYSO and SiPM purchases toward maximum light output.
- Evaluate the impact of reduced time resolution on physics in the 30 -100 ps range.
- Verify the TEC lifetime given by the producer carefully and evaluate the consequences of different failure modes on performance over the entire lifetime.

MTD-ETL

- Decide on the module design as soon as possible.
- Based on the sensor measurements, estimate the optimum performance of the system in terms of timing resolution over the course of the lifetime of the experiment, particularly if the construction will be done in stages.

Barrel Calorimeter

- None

HGCAL

- Follow a strict plan, as presented during the review, of testing completed modules and chains.
- Plan for another beam test that includes a substantial part of the modules expected to be produced by Q2 of 2022.
- Make a detailed analysis of the performance of the already produced Si Modules.
- Closely follow the development of the ECON ASICs and take appropriate action at the first signs of further delays.
- Initiate a detailed assessment on the reliability of the involved connectors.
- Plan to exercise the assembly steps in the different MACs with sufficient components. This applies in particular for the change from non-stepped hole to stepped-hole hexaboards and for handling of the bare sensors.
- Develop a strategy to pass on expertise to new team members.
- Provide an assessment of the impact of the region in the scintillator-based section of the HGCAL where the S/N is less than five on calibration and physics performance.
- Develop a schedule to decide on the final configuration of the scintillator based HGCAL and the use of cast versus moulded scintillator tiles.

Tracker

- Understand the potential impact of the CBC issues on the production and the schedule and evaluate the impact of the CBC issues on OT performance.
- Fully evaluate the yield for all hybrid types.
- Follow closely the testing of the MAPSAs now that testing will be done in house by US CMS institutes.
- Decide on the planar geometry as soon as possible and move towards tendering.
- Investigate the 3D sensor noise issue and the bump-bonding issues by the first quarter 2022.

DAQ/HLT/BRIL

- None

General

- A deep-dive re-assessment of the schedule is recommended, and agile, pro-active risk management is strongly recommended moving forward. “What-if” scenarios should be run and a fully worked-out mitigation strategy developed in case the scenario is realized.
- The project should ensure that the technical specifications of all the systems are met and that the physics performance is well understood if the performance is different from the TDR specifications.

B. Recommendations from the ATLAS P2UG Review

Review panel: Gary Barker, Jean-Louis Faure, Geoff Hall, Rainer Mankel, Michael Moll, Mauro Morandin, Steve Nahn, Dave Newbold (chair), Pierluigi Paolucci, Darien Wood, and contributions by Stew Smith

The ATLAS P2UG met with the upgrade project leadership from 8th-12th November 2021, following an intermediate update meeting on 2nd August 2021. The P2UG is impressed by the progress shown across all projects, by the comprehensive and transparent presentations, and by the responsiveness of the whole ATLAS team. Here, the overarching general and the project-by-project recommendations are given.

General

GE-6-1: ATLAS should prepare for an intense period of re-baselining of the project schedules in order to generate a detailed plan for an eighteen-month extension of the construction schedule and demonstrate that delivery of the full project scope is possible under those conditions with reasonable certainty. The recommendations of the ITk schedule task forces should be adopted where relevant as part of this process.

GE-6-2: ATLAS should build into that process the expectation that further significant supply-chain delays due to COVID-19 will be experienced over at least the next 24 months. The new schedule should be flexible enough and sufficiently well-provisioned with contingency to withstand the delay of any single component by up to twelve months. This may require an increase in the rate of deliverables that are in the hands of the collaboration, to offset delays in supplies.

GE-6-3: As part of the overall schedule replanning, a detailed update of the schedule for LS3 installation should be made, to understand the necessary contingency provision. The personnel need for the post-installation commissioning phase should also be examined, as should the overlap with the installation period, since these also affect the total cost of the project as seen by the funding agencies.

GE-6-4: ATLAS should begin discussions and negotiations with funding agencies and NCPs at technical level, to understand (a) how recovery from COVID and re-convergence to the necessary rate of progress can be best accomplished in each country, and (b) what flexibility exists on responsibilities, personnel, and funding profiles to allow optimisation of risk and schedule.

GE-6-5: ATLAS should not allow projects which do not dominate the critical path analysis (e.g., muons, calorimetry) to relax from their current rate of progress or lose further time; the early delivery of these projects will be a vital element in maintaining flexibility in both the construction and installation schedule.

GE-6-6: Any proposals to reduce or redefine QA/QC procedures should be the subject of a full documented risk analysis.

TDAQ

TD-6-1: The TDAQ project should keep a very close eye on the evolving procurement delays of electronic components. These might result in the need to place orders considerably further in advance, which should be proactively anticipated.

TD-6-2: Concerning the ATCA/PCIe choice in the Global Common Module, it might be advisable to clarify with Technical Coordination whether the issue could not be mitigated with exceptional arrangements in USA15, like wider spacing of ATCA modules, and preferably not keep this ambiguity of the architecture unresolved until the FDR.

ITk Common

IC-6-1: The collaboration is very attentive to issues of infrastructure (cables, power, cooling, DAQ) and should continue to be so. This includes the services needed for the surface integration activities, which are still being defined. The collaboration should continue implementing and deepening all three proposed schedule slip mitigation actions, while focusing on completing the pre-productions.

IC-6-2: Everything possible must be done to ensure the ASIC schedule is maintained and that preparations are well in hand for high throughput once deliveries start.

IC-6-3: The BCM is a small project on the scale of the overall upgrades, but it is quite an essential element for the functions it provides to ATLAS. The project will have to evolve soon from R&D to the final design of all components and interfaces and therefore a solid and viable team in charge of the activities is essential. We would like to see, at the next Review in May, an updated and consistent resource loaded schedule for the BCM system, with the time profile of the engineering/technical resources that are needed versus those available or pledged.

ITk Pixel

PI-6-1: The test beam and irradiation studies on full modules equipped with ItkPixV1.1 ASICs are ‘mission critical’. We would like to see even preliminary results in the May 2022 P2UG.

PI-6-2: Keep on working (even harder).

ITk Strips

IS-6-1: The collaboration should continue following the three major schedule mitigation actions (Pre-production A/B, Priming production, Accelerated Production) across the project (see P2UG May 2021).

IS-6-2: ITk strip is expected to give detailed feedback on the Schedule Optimization Task Force report and all its recommendations including a risk assessment that clarifies the adequate float for the project by the May 2022 P2UG.

IS-6-3: Continue to closely monitor the path of the HCCStar project towards PRR and production and deeply evaluate and mitigate risks of delays.

IS-6-4: Identify and realize opportunities to gain contingency, in particular in accelerating the module production rate. Carefully consider the pitfalls of reduced/relaxed QA and QC procedures.

IS-6-5: Assure that the tasks fully under project control, such as the site qualification process, do not introduce further delays.

TileCal

TI-6-1: Almost all subsystems are facing issues with supply chain delays and associated price increases from pre-COVID-19 levels. Sub-systems where this is a worry must ensure that a dedicated risk is assigned. The project must learn from experience of pre-production and moving towards production it is prudent to start looking to procure as much as possible e.g., the Main Board project found their production components took a full year from order date to be delivered.

TI-6-2: If a Cs-based calibration remains mandatory for TILE calorimeter performance monitoring during Run 4, it is clear that using the existing system is not a realistic solution. It is important to distinguish the two aspects of the Cs calibration system development. Separate milestones are needed for the water replacement investigation and the system segmentation study, so that the P2UG can track progress from this point on. The installation of the new system may not be easy and there could be consequences for the rest of the detector – hence collaboration with ATLAS Technical Coordination is going to be particularly important.

LAr

None

Muons

MU-6-1: Prepare a backup plan with schedule updates if original vendor is not able to deliver Bakelite of sufficient quality.

MU-6-2: For the next review, present more detail about how the RPC front end ASIC will be qualified on a readout board and tested with a chamber.

MU-6-3: Consider proactive actions to avoid delays due to component procurements such as those delaying the PS board preproduction.

MU-6-4: If a global change is made to the Run 3 + LS3 schedule: (a) resist any tendency to slow down except where it is justified by mitigating risk; (b) review in detail the muon installation plans for LS3 and their impact on the LS3 schedule.

HGTD

None