CERN/LHCC-2024-015
LHCC-159
September 2024

LARGE HADRON COLLIDER COMMITTEE

Minutes of the one-hundred-and-fifty-ninth meeting held on

Wednesday and Thursday, 11-12 September 2024

OPEN SESSION – STATUS REPORTS

1. Status of the Accelerator: Michi Hostettler
2. ALICE Status Report: Chiara Pinto
3. ATLAS Status Report: Antonio De Maria
4. CMS Status Report: Deborah Pinna
5. LHCb Status report: Irene Bachiller

CLOSED SESSION

Present: F. Alessio, M. Battaglieri, D. Calvo, M. Diefenthaler, I. Efthymiopoulos, T. Ferber, T. Galatyu, I. Gil-Botella, J.J. Hernández-Rey, T. Higuchi, A. Ianni, M. Kirby*, R. Leitner, M. Mangano*, G. Merino, J. Mnich, L. Moneta (Scientific Secretary), S. Niccolai*, B. Panzer-Steindel*, G. Signorelli, F. Simon (Chairperson), H. Tanaka, P. Wells, C. Young.

All sessions were held at CERN with some participants (*) connected remotely via Zoom.

1. Procedure

The chairperson welcomed the committee members. The minutes of the previous session were already approved by email.

The committee continued the discussion of a proposal from the chairperson to improve the layout of the LHCC weeks by moving the Open Session to Monday afternoon starting at 15:00, also allowing a seamless integration with the LHCC poster session happening once per year on Monday evening. This change will likely be tested for the next LHCC week in November 2024.

The chairperson reported on new proposals that may become relevant for the committee in the future and on a discussion with PBC leadership in this context. These proposals include SHIFT, a possible addition to the CMS experiment where a gas injection target is installed upstream of CMS in the LHC tunnel, and the installation of an atom interferometer as a gravitational wave detector in the PX46 vertical shaft. The latter would not make use of the LHC beam but would use LHC infrastructure. A key modification that would be required is a change in shielding and radioprotection configurations to enable access to the shaft during beam operations.

2. **Report from the LHC Programme Co-ordinator**

All the LHC experiments profited from a stable and steady proton physics production over the summer months. ATLAS and CMS have currently reached ~100 fb^{-1}, LHCb ~8.5 fb^{-1} and ALICE ~50 pb^{-1}. All experiments are on track to reach and exceed the required target for 2024. This is thanks to the excellent machine performance, operating with more than 70% availability and with more than 50% time spent in Stable Beams throughout the entire production year 2024. This is also due to the excellent injector complex performance, as well as the efficient data taking performance of all experiments. At the time of the LHCC meeting, there are roughly 4 full weeks of proton production left in 2024, in addition to two Machine Development blocks and one Technical Stop of 3 days. This is followed by the proton reference run and the ion run, amounting to a total of another roughly 4 weeks.

The running parameters of the LHC were defined in the first half of the year and they were maintained throughout the summer. However, since the last LHCC, all target parameters for 2024 have been finally achieved: the beta* levelling is now routinely down to 30 cm, owing to the resolution of the collimation hierarchy breakage; the number of protons per bunch is consistently at 1.6 x 10^{11} ppb at start of Stable Beams; the beam emittance is at 1.5-2 μm in both beams and both planes; the cryogenics is sustaining the beam-induced heat load and seeing even a slight conditioning. The remarkable stability of such parameters allows for a very stable and efficient luminosity production: the turnaround time is at the level of a few hours, very close to the ideal value of 2 hours, and the levelling time in ATLAS/CMS is around 7-8 hours which is also very close to its ideal and desired value for efficient production. These parameters and running conditions will be maintained unchanged until the end of the proton run.

During the summer, SND replaced 4 emulsion boxes in parasitic and unplanned accesses. It is to be noted that the replacement process has improved dramatically, now with a duration of just 3.5 hours and with higher flexibility on when the replacement happens such that it can be parasitic with other accesses.

Without affecting luminosity production and by profiting from the Machine Development slots, studies regarding low-tail beams and increased background at FASER/SND/AFP were performed. Low-tail (BCMS) beams, heavily scraped in the SPS, aim at providing more Gaussian beams, which would result in fewer losses at ramp and when going into collisions. Studies and machine tests have shown little difference in the LHC with respect to the standard BCMS beams, nevertheless, more studies are ongoing. Such scraping process is, however, very promising for Van der Meer scans, allowing to reduce the statistical impact on luminosity calibration due to non-factorized beams. Concerning the increased background at FASER/SND/AFP, significant simulation efforts have been made, improving the framework reliability and supported by additional tests of different configurations in the machine (one critical test is still missing but is planned). Unfortunately, no suitable settings that mitigate the background have been found so far, given the current optics around IP1. Discussions regarding the possible configurations for 2025 have started and will also consider the outcome of these analyses, among other limiting factors concerning the triplet and machine components irradiation.

Lastly, preparations for the pp reference and lead ion run have started, and details are being ironed out. The parameters for the pp reference run have been clarified: the integrated luminosity reach for ATLAS/CMS/LHCb is considered to be attainable, while the target for ALICE is challenging and hinges on good machine availability and the ability to keep fills for a very long time (~48 hours). Lead ion run settings and background studies are also imminent and will be the basis for the ion production period. The overall strategy for the lead ion run is to regain the performance reach of the ion run as expected but not reached in 2023, including the ion per bunch population from the injectors and the levelling at 6.4 x 10^{27} $cm^{-2}s^{-1}$. A recent discussion among experiment and management on the filling scheme resulted in a change of the baseline filling scheme for the lead ion run: the new filling scheme will provide LHCb with 557 colliding bunches with respect to 1032 colliding bunches in ATLAS/CMS/ALICE. This results in a +40% gain for LHCb with respect to the 2023 baseline filling scheme, at the cost of -5% of the other experiments. Finally, an effort to gain more scheduled days in the ion production period is ongoing, anticipating the proton reference setup before the Technical Stop 2. It will provide the LHC experts with enough time to analyse and study the outcome and effectively implement changes before the proton reference run itself. It is foreseen that such optimisation can add one or two more days to the overall schedule of the lead ion production period, depending on the schedule limitations around TS2.

- The **LHCC congratulates** the accelerator teams for the outstanding performance of the machine in 2024, achieving high availability and spending over 50% of the time in Stable Beam conditions.
- The **LHCC again takes note** of the challenges that the increased backgrounds due to the current triplet configuration impose on FASER, SND and ATLAS AFP. The **LHCC asks** the experiments to prepare for a discussion of the preferred 2025 machine configurations at the November 2024 LHCC.

3. Report from the Director of Research and Computing

The Director of Research and Computing (DRC) reported on issues related to the LHC and CERN. The LHC is running exceptionally well, and hopefully, it will keep these high performances for the remaining time this year. The important news to report is the ATLAS and CMS's request to delay the start of Run 4 by one year. They have produced, on his request, a document with the risks they will encounter in completing their upgrades. It is essential to know if one additional year is sufficient for them and that no further delays will be needed. The DRC stressed that it has not yet been decided to delay the start of the Run 4. There is an ongoing cost and schedule review of the HighLumi LHC project during the LHCC week, where the experiments will present their LS3 activities and timelines. The reviewed schedule will then be presented to the Council, and then a decision will be made by the CERN management. The High-Lumi project will also need an extension of 4 months for LS3 to accommodate some civil engineering work that will take longer than expected. CMS is also asking for a prolonged LS3. One of the options discussed is to run in 2026 until early Autumn since it will not be convenient for the machine to run in 2026 for a shorter time. The DRC stresses the importance of having LHC operating in 2026 since, in addition to producing valuable data, it will not be good for the reputation of CERN having a 5-year-long shutdown. The one-year shift in the starting time of Run 4 will imply an equivalent shift of the LS4, giving additional time for the ALICE and LHCb upgrades. However, to maintain the end date of LHC and have

adequate running time, it is proposed to suppress the one-year-long LS5. This will need to be discussed with the experiments and the machine to ensure they can sustain six years of running in Run 5 until 2041. Furthermore, a revised plan for the operations of the injectors is needed at the same time as the new LHC schedule. The final decision on the new schedule will probably be made at the beginning of October after presenting to the Council at the end of September.

The DRC also reported on the Phase IIb Upgrades for ALICE and LHCb. He is pleased to see that the scoping documents are now available. During their review, it is essential to consider the unique physics cases that can be covered by the detector upgrades, as the SPC has pointed out. The DRC will also start discussing with the funding agencies to understand the level of funding that will be available to decide on which level the detectors can be upgraded. Another important aspect to consider is that LS4 will last only for two years, and the experiments need to make sure they will be able to install the new detectors in such a limited time. The experience gained with the Phase II upgrade will certainly be valuable.

The DRC concluded by reminding that CERN is celebrating its 70th anniversary, with a party planned next week on the site and a big event on October 1st, with ministers and VIPs invited.

4. **Test Beams**

The most recent Injector Schedule version 2.1, dated July 9th 2024, was presented together with the release version 3.3.0 of the User Schedule. The number of change requests from the user groups is even higher than in previous years. Fifteen User Schedule versions have been produced since the last LHCC in May, 32 in total during 2024. 29 beam slots, comprising 33 weeks of beam time, have been cancelled by the users. This number does not take into account the beam slots which had been immediately re-scheduled. Despite some cancellations coming on very short notice, almost all the slots had been taken over by other users. Several new beam requests could be accommodated as well. Due to the extension of the proton run, all users, even the non-revied ones, could be scheduled if they were sufficiently flexible with the dates. Too many proton beam requests at the very end of the year require some not-reviewed activities to be postponed to 2025.

The high number of parallel beam users per beamline and the frequent change requests due to delays and cancellations were made possible by enlarging the team in charge of PS and SPS Physics Coordination to include a Deputy Physics Coordinator, as well as Administrative and IT Support, and by a custom made software tool. The team of experts for the PS East Area and SPS North Area secondary beam lines had already been enlarged in previous years to cope with the significant increase in workload due to parallel data taking in the lines.

- The **LHCC appreciates** that the team for physics coordination of test beams was enlarged, which has enabled smooth scheduling and execution of the program despite frequent changes in user requests. The **LHCC encourages** CERN to maintain the strength of the team also in the future.

5. **General Comments**

The following comments are applicable to more than one project.

Run 3, LS3 and long-term LHC Schedule

Following up on the recommendations of the previous LHCC meeting with regards to the Phase II upgrade schedule the LHCC held a dedicated session on this topic.

With respect to a cavern closure at the end of April 2029, the CMS HGCAL and the ATLAS ITk both have negative schedule contingency. At the same time, risks still remain in the Phase II upgrade projects, which will likely result in further schedule loss. The schedule and remaining risks have also been discussed in a dedicated meeting of the DRC, the experiment management, the LHCC and P2UG chairs in mid-August 2024. Based on the currently available information, a 12 months delay of the start of Run 4 is seen as necessary. CMS reported the need for an additional two months in the shutdown to fit all required work, and a total of 8 weeks in YETS prior to LS3, or partially in LS3, for the completion of the CO2 infrastructure.

ALICE and LHCb prefer LS3 to be as short as possible, and thus request significant running in 2026 in scenarios where the start of Run 4 is delayed. No significant issues are expected from detector ageing and performance perspective for an extended Run 3. Additional data taking in Run 3 is also welcome by ATLAS and CMS, although conflicts in priority between operations and upgrade work could arise.

All four experiments agree that a one-year LS5 will not be required towards the end of the HL-LHC, and could be replaced by an EYETS. This would retain the total running time of HL-LHC despite a delay of the start of Run 4. While CMS can perform a required replacement of the pixel detector in an EYETS, ATLAS requires at least a one-year shutdown for such an operation. In view of the significant Phase IIb upgrades planned by ALICE and LHCb, both stressed the importance of a sufficiently long LS4, and significant running time after LS4.

- The **LHCC concludes** that, given the present schedule situation of the most critical Phase II projects and the remaining risks, a delay of the start of Run 4 by approximately 12 months is required to limit the risk of failure of the Phase II upgrades.
- The **LHCC strongly supports** the efforts of ATLAS and CMS management to further increase the priority given to the upgrade project by collaborating institutes. The **LHCC stresses** that the Phase II projects have to be the highest priority of ATLAS and CMS until successful completion. The **LHCC notes** that this implies that reduced priority is given to operations in 2026, Run 2 and Run 3 data analysis efforts, and any possible new experiment and upgrade ideas being developed.
- The **LHCC notes** that additional Run 3 data taking in 2026 in case of a shift of the start of Run 4 is of particular importance for ALICE and LHCb to exploit their recently upgraded detectors and to have a significant data set to analyse up to the start of Run 4.
- The **LHCC recommends** that a holistic plan for the full HL-LHC phase is developed in response to the need for a shift of the start of Run 4 by one year, and is decided in a timely manner. The **LHCC notes** that a scenario where Run 3 is extended until early Autumn 2026, the start of Run 4 is delayed by one year to mid-2030, LS4 is shifted by one year maintaining the currently planned length of Run 4, and LS5 is replaced by an EYETS, is compatible with the needs and preferences of the four large experiments.

Potential Issues with lpGBT

Recently, issues have been observed with the lpGBT. The full extent of this issue, and its impact is not yet known, investigations are ongoing. The lpGBT is used extensively throughout all Phase II upgrade projects, and is also of central importance for the other experiments.

- The **LHCC is concerned** by the recently observed issues with the lpGBT, and **encourages** CERN-ESE and the experiments to work closely together to understand the extent of the problem and to develop mitigating measures and long-term solutions as needed.

Phase IIb Scoping Documents

Both ALICE and LHCb have submitted complete preliminary versions of their Phase II upgrade scoping documents. These documents present several different detector options with different cost and performance capabilities, and discuss the impact of these scoping scenarios of the physics program. The LHCC will set up a review process for these documents, which is expected to conclude by the March 2025 LHCC meeting. Key aspects to be covered during the review are the uniqueness of the physics delivered by the upgrade in view of the different scoping options, the trade-off of detector scope and physics performance in key channels, and a high-level analysis of risk vs scope. The latter includes schedule risks in development, construction and installation phases, cost risk, and personnel and resource availability. Mitigation possibilities, such as staging or descoping also late in the project, and their consequences on performance are also part of the review.

- The **LHCC congratulates** ALICE and LHCb for the completion of the Phase IIb scoping documents.

6. Discussion with ALICE

Scientific output and current activities:

- ALICE continues to make excellent progress on its physics program, with 12 new papers submitted since the last session of the LHCC, bringing the total number of publications to 496. The latest results include the measurement of the production yield of nuclei in Xe-Xe collisions, which provides a test of the coalescence and statistical models, the measurement of the charm non-prompt production in p-Pb collisions and the measurement of the isolated photon production in pp collisions. The Run 3 data analysis is in full swing, delivering the first physics results, such as complete reconstruction of B mesons for the first time in ALICE, thanks to new analysis level trigger selections in Run3.
- ALICE is having excellent performance in the Run 3 2024 data taking with synchronous data reduction and processing, reaching an overall efficiency of 95% (90% when including the period where the solenoid was down) and collecting more than 40 pb^{-1} of pp collisions at $\sqrt{s}$ = 13.6 TeV. The major problem encountered was a water leak in the solenoid cooling circuit, causing the loss of

almost a full day of stable beams. A quick repair was done, but a full investigation will be performed during the next YETS. Preparation of the PbPb run and the pp reference one is ongoing and well on track.

- The TPC-ITS alignment was improved, giving better tracking resolution and efficiency and an improved mass resolution. Ongoing studies to understand and correct high occupancy effects are of paramount importance. Significant progress has already been made in this area, and further progress is expected in the next few months.

ALICE upgrades:

- The two upgrades of ITS3 and FoCal for Run 4 showed some difficulties in keeping the scheduled timeline. For ITS3, the reduced contingency, from 7 to 4 months, although not yet critical, requires a check of timelines at the next meeting. For FoCal, difficulties in funding, which also resulted in a change of project leadership, have occurred. The current funding coverage shows a shortfall of 30%, calling for a revised budget, and a study of the physics impact of the decreased acceptance due to a reduced scope of the upgrade.
- The LHCC received the draft of the ALICE 3 scoping document, which presents an updated baseline scenario as well as options of scope reductions along three lines. These are the suppression of the electromagnetic calorimeter, a reduction of the main solenoid magnetic field, and a reduced forward acceptance. The impact on the ALICE3 physics reach has been discussed. The cost ranges from 180.2 MCHF for the updated baseline to 123 MCHF for the most reduced option, all including the cost for common items such as the beam pipe. For the magnet, the option of keeping the presently used L3 magnet is also analysed. The review will be carried out as presented in Section 5.

- The **LHCC congratulates** the ALICE collaboration on its continued physics output with results of high impact demonstrating a very broad physics program.
- The **LHCC congratulates** ALICE on the excellent performance during the 2024 data taking and **commends** the collaboration on the progress in calibrations, alignment, and data reconstruction.
- The **LHCC is concerned** by the funding and schedule difficulties in the FoCal project, and by the delays encountered by ITS3, and **asks** for the presentation of comprehensive updates on both upgrade projects at the next LHCC meeting in November.

7. Discussion with ATLAS

Scientific output and current activities:

- ATLAS continues to make excellent progress on its physics programme, with 37 new papers since the last LHCC, for a total of 1324 papers on collision data submitted to date, of which 374 use the full Run 2 data set and 12 use Run 3 data. Recent results include new Higgs measurement of the $H\rightarrow\tau\tau$ cross-section, improved measurement of the ttH, with $H\rightarrow bb$ and VH, with $H\rightarrow bb/cc$, thanks to new deep learning techniques used in heavy flavour tagging. New search results for magnetic monopoles using the Run 3 data and a supersymmetry search for long-lived particles using the combined Run 2 and Run 3 data sets have also been produced.

- ATLAS recorded over 90 fb^{-1} of data, bringing the total luminosity collected during Run 3 to approximately 157 fb^{-1}, which exceeds the 147 fb^{-1} recorded in Run 2. All Phase-I FEXes are running reliably and providing primary triggers for data taking. The Legacy Trigger items have now all been dropped from the physics menu. The Phase I systems, which are critical, are in general, performing well.
- Shift coverage has significantly improved, and a reduction of the shift crew from 7 to 5 (plus SLIMOS) is planned for next year. The operation team is highly motivated and efficient. Despite the lack of expert personnel in some systems, the collaboration is adapting well to the departure of the Russian and Belarus scientists and engineers, although some systems still need to identify substitutes.
- There has been a series of system incidents, with those related to the magnet system being of particular concern. All incidents have been promptly addressed, with some still under further study. Most of these issues were unforeseeable; however, the clogging occurrences of the shield and main refrigerator systems were not unprecedented.
- The AFP is suffering higher radiation damage and increased dose for interventions due to new optics in 2024 with partially reversed inner triplet polarity. Mitigation measures applied so far have not provided significant improvements. Further tests planned to address the backgrounds in FASER and SND may have a positive impact on AFP as well.
- An accelerated rate of high voltage failures in the NSW sTGCs has been observed. The reason is not understood at this point, there are indications that a reduction of the voltage and an increase of gas flow reduces this problem. The issue is under intense follow-up.
- The computing and software are making excellent progress. There has been a major MC campaign for 2022, 2023, and 2024 data, with the digitisation and reconstruction now underway for 2024 data. The grid sites provide efficient and beyond-pledge CPUs with opportunistic resources contributing significantly. ARM processors peaking up to ~20k cores (20% gain in CPU yield per watt). In early July 2024, the amount of managed data exceeded 1 Exabyte, an impressive milestone. On July 1, 25% of Run 2 data was released as open data for research purposes.

Phase-II upgrades:

- ATLAS Upgrade projects have steadily progressed, entered, or advanced towards production and many technical challenges have been addressed. The interposer solution proposed to address one of the most pressing issues, the cracking of the ITk strip sensors, appears to effectively prevent the problem; the first half-stave has been cooled down to approximately −70°C without observing any cracks. Overall, the progress on the upgrades has been remarkable. In view of the negative schedule contingency, ATLAS expressed the need for a delay of the start of Run 4 by 12 months. No extension of the duration of LS3 beyond 3.5 years is required.

- The **LHCC congratulates** the ATLAS collaboration on the wealth of very interesting new physics results produced and on the quality and quantity of ATLAS scientific output.
- The **LHCC commends** ATLAS for its successful running this year and **is impressed** by the excellent recording efficiency of 94%, the sustained target

pileup at levelling at <μ>=64, the completion of the Phase I L1 Calo trigger commissioning and the good performance in general of the Phase I systems.

- The **LHCC is pleased to see** that the issues in shift coverage could be successfully addressed, and **fully supports** the proposed reduction of the on-site shift crew.
- The **LHCC acknowledges** the prompt response to the incidents that have appeared during this year's running and **fully agrees** that it is highly recommended to regenerate the Main and Shield Refrigerator cold boxes during each maintenance period.
- The **LHCC is pleased** to see that 65 TB of data, corresponding to two years of Run 2, have been released as open data. They are now available, together with the needed analysis tools, as research-level open data.
- The **LHCC is impressed** with the progress made by ATLAS in the Phase II upgrade and **recognizes** the significant effort invested in solving the remaining technical challenges. The **LHCC stresses** that the schedule situation will remain challenging also with a delay of the start of Run 4, and **strongly urges** all members of the collaboration to further increase the priority given to the Phase II upgrade relative to other activities. The **LHCC emphasises** that sufficient funding and adequate human resource allocation are of critical importance for the progress of the Upgrade.

8. Discussion with CMS

Scientific output and current activities:

- CMS continues to make excellent progress on its physics programme, with 1316 papers on collider data submitted to date, including 26 since the last LHCC. The new results include the measurement of the fiducial differential Higgs production cross section combining various final states (WW, ZZ, $\gamma\gamma$, $\tau\tau$), the first statistical combination of CMS SUSY searches with the full Run 2 data and the search for high mass scalar particle up to few TeV. The new W mass measurement is completed, and it will be presented for the first time at a CERN seminar next week.
- CMS successfully collected 90 fb^{-1} of data in 2024 of the 95 delivered by LHC. Above 94% of the collected data are suitable for physics. The detector is operating well with a pile-up of around 62 to minimise the dead time. The high rates are challenging for ECAL, but mitigations are being explored. For 2025, a task force will study the possible approaches to sustain an additional 100 fb^{-1} of integrated luminosity. CMS also exploits complementary trigger approaches based on regular triggers, scouting, and parking to optimise the physics reach with the available resources.
- The ZDC forward calorimeter, required for PbPb collisions, has been repaired after the bake-out incident reported at the last LHCC. It will be ready to be installed for the heavy ion run.
- CMS reported on the progress made in reducing emissions of gases with high GWP. The CF4 recuperation system for the CSC is running with 70% efficiency, and the R134a recuperation for RPC is at 80% efficiency. This will further reduce the CO_2 equivalent consumption. The R&D on alternative gas mixtures is progressing well, but much work is still needed to validate their long-term sustainability.

Phase-II upgrades:

- The Phase II upgrade projects are progressing well, but the overall schedule is not tenable and CMS requires a 12-month shift for the start of Run 4. CMS's preferred solution is a 6-month shift for the start of LS3 and a 6-month extension of LS3; however, the scenario with an extension of Run 3 until September 2026 and a corresponding 2-month extension of LS3 can also be implemented. The most critical project remains the HGCAL, followed by the Outer Tracker. The Outer Tracker is now in full production, for the HGCAL many elements are in production, with final design work in the area of electronics and for some mechanical items ongoing.
- To secure adequate person power for the upgrade projects, upgrade coordination together with project managers and institutional boards are actively monitoring resources. Whenever needed, the evolution of the current operation-focused credit system to an upgrade-focused system is considered.
- The CO_2 Main Transfer Lines will have to be installed prior to LS3 to avoid interference with LS3 work. This activity was planned during the two last YETS before LS3, but can profit from a shift in the overall schedule.

- The **LHCC congratulates** the CMS collaboration on the wealth of very interesting new physics results produced with both Run 2 and Run 3 data. The **LHCC welcomes** the upcoming release of the W mass measurement and **looks forward** to seeing the much-awaited results.
- The **LHCC commends** CMS's Technical Coordination and the ZDC team for successfully repairing the ZDC following the bakeout accident.
- The **LHCC would like to review** the Collaboration's plan for dealing with the additional running in 2026 at the next meeting. The **LHCC encourages** CMS to evaluate the impact of two more years of running on the ECAL's performances.
- The **LHCC commends** CMS for the continued recuperation of CF4 and R134a and **reiterates** the encouragement to adopt the 5% CF4 mixture, following the positive results of the GIF++ tests presented at the previous LHCC meeting.
- The **LHCC would like to see** a summary of the time-for-publication task force report at the next meeting. The **LHCC appreciates** the CMS's responses to the concerns about the Collaboration's engagement in service and **recommends** implementing the proposed mitigation strategies. The **LHCC notes** that person power remains a crucial issue for the success of the CMS upgrade project.
- The **LHCC remains concerned** by the continuing problems with the engineering building and other new infrastructure at P5, and **acknowledges** the collaboration's efforts to mitigate them.
- The **LHCC is impressed** with the progress made by CMS in the Phase II upgrade and **recognizes** the significant effort invested in solving the remaining technical challenges. The **LHCC stresses** that the schedule situation will remain challenging also with a delay of the start of Run 4, and **strongly urges** all members of the collaboration to further increase the priority given to the Phase II upgrade relative to other activities. In this context, the **LHCC welcomes** the considered evolution from an operations-focused to an upgrade-focused credit system to improve the engagement in the upgrade projects. The **LHCC emphasises** that additional resources, both financial and human, are of critical importance for the progress of the upgrade.

9. Discussion with LHCb

Scientific output and current activities:

- LHCb continues to deliver high-quality physics results, with a total of 750 publications to date, including 17 new papers since the last session of the LHCC. New results include a new measurement of the CKM γ parameter using for the first time doubly Cabibbo suppressed decays, a measurement of the weak mixing angle from the forward-backwards asymmetry of di-muons events, and the first observation of $\chi_b \to \Upsilon(1S)\mu^+\mu^-$ decays.
- The 2024 data collection is progressing extremely well, with more than 7 fb^{-1} of data collected and on the way to achieving the goal of collecting 9 fb^{-1} this year. The UT has been successfully included in the HLT1 and HLT2 systems.
- Small issues that appeared during data taking, such as magnet trips, problems with the VELO belt, and DAQ synchronisation issues, were successfully mitigated without any serious consequences.
- LHCb is preparing for the Heavy Ion run. The PbPb luminosity will be increased by applying a magnet polarity inversion and by augmenting the number of colliding bunches.
- The LHCb performed an initial feasibility analysis for the Run3 prolongation and concluded that there are no obvious showstoppers.

LHCb upgrades:

- The LHCC received the final version of TDR for LHCb DAQ Enhancement during LS3. This upgrade covers two areas: An upgrade of the online DAQ system with a new generation of boards, the PCIe400, and an FPGA-based acceleration of the HLT for the downstream tracker (DWT). The new PCIe400 will enable to efficiently use the increased bandwidth provided by new generations of link technologies implemented in the PID enhancement. The HLT acceleration will improve HLT reconstruction performance via an early low-level reconstruction at the readout level, saving bandwidth and computing resources in higher-level tasks. Both elements of the proposed enhancement are important steps towards the Phase IIb detector upgrades currently being developed. The total cost of the upgrade is 2447 kCHF, with 600 kCHF contributed by the PCIe400, and 1847 kCHF by the DWT. Following a thorough review involving also an external expert the TDR is being recommended for approval. A report on the review is available in Appendix A of these minutes.
- The LHCC received the Phase IIb upgrade Scoping Document. Three scenarios have been studied in detail, which differ in peak luminosity and detector performance. The cost ranges from 182 MCHF for the baseline detector, 156 MCHF for a "middle scenario", to 125 MCHF for the most reduced option. The review will be carried out as presented in Section 5.

- The **LHCC congratulates** the LHCb collaboration on the excellent physics output with top-quality physics results and for producing prompt performance tests using 2024 data.
- The **LHCC congratulates** LHCb for the good performance in 2024 and for reaching the integrated luminosity goal, and is **very pleased to see** the full Upgrade I detector in operation.

- The **LHCC welcomes** the appropriate configuration in HLT1 and the use of additional GPUs to achieve the nominal instantaneous luminosity by the end of the 2024 run.
- The **LHCC congratulates** LHCb on the timely preparation of the DAQ enhancement TDR which provides a well-described, technically and scientifically justified case for an upgrade of the experiment. The **LHCC notes** that it also represents an important and effective step towards the future Phase IIb upgrade. The **LHCC recommends** approval to allow resources to become available and MoUs to be signed.

10. Discussion with WLCG

The WLCG infrastructure continues to perform extremely well, and the data collection in 2024 is progressing as planned. The WLCG data transfer infrastructure sustains average rates of 60 GB/s (over 150PB/month) of data transfer. Overall, WLCG sites provide a capacity of 45% larger than the pledged one. JINR continues to be a WLCG T1 site for CMS although no RAW data is being stored, and IHEP has been validated as T1 for LHCb. The WLCG strategy for 2024-2027 was endorsed by the OB in June, with seven major objectives identified and based on two main pillars: innovation and collaboration.
Concerning the LS3 schedule decision, WLCG decided to plan two scenarios for 2026, no data taking in 2026 or a full run with the same conditions as in 2025. ALICE reported steady progress in their computing operations with 36 pb^{-1} of data collected. The pp data are continuously skimmed to reduce the volume, which puts pressure on T0. There are sufficient resources for storing the anticipated data in 2024 and 2025.

ATLAS also has smooth data taking in 2024, with adequate computing resources to sustain the high data rate. The collaboration reported that fast simulation is used at 40% and is aiming to reach 65-90% for Phase 2. Due to power system upgrades, the ATLAS HLT farm will be unavailable when the LS3 starts. They will try to relocate it to continue using the farm computing capabilities.

CMS is taking data with high efficiency. The resources in tape and disk are sufficient for the longer data taking in 2024. In the case of an entire run in 2026, an increase in tape and disk requests is expected. Concerning the simulation, CMS is conducting extensive R&D studies on improving the fast simulation using Machine Learning techniques and is investigating a very fast end-to-end simulation (flash-sim).

LHCb has already recorded more data in 2024 than the full Run 2 and 6.5 fb-1 have been processed online. More resources than expected are needed in 2024 due to the extended run and also a higher expected luminosity in the HI run. In the data taking scenario in 2026 a large increase in storage (+40% in disk and tapes) and CPU (+60%) resources is needed.

Answering a request from the previous LHCC, the CERN EP-SFT group provided a presentation on how it is collaborating with the HEP software community to achieve the success of common and community software. A proposal for improving software project reporting by focusing on different key areas in a given LHCC session was made.

The HSF highlighted the success of its initiatives within the software community, including the PyHEP workshops for users and developers, efforts to explore Julia's role in HEP, and its training programs.

As a follow-up for the Analysis facilities, the LHCC will formulate a charge for experiments using the list of questions presented last meeting as input and share it with them before the end of October. Feedback on the charge from the experiments is expected by the next LHCC meeting in November. Answers to the questions are proposed for the following LHCC meeting in February.

The LHCC plans to organise a focus session in the November meeting to review the evolution and the physics motivation of the experiment-specific parameters such as trigger rates, including prompt and delayed streams, MC simulation statistics or RAW data size.

- The **LHCC congratulates** WLCG and the experiments on the successful and efficient software and computing operations, ensuring smooth data taking in 2024. The **LHCC commends** ALICE, ATLAS, CMS and LHCb for their multiple R&D efforts towards accelerating the simulation.
- The **LHCC welcomes** the new WLCG Strategy for 2024-2027, focusing on innovation and collaboration. The **LHCC commends** the reorganisation efforts to establish a Technical Coordination Board (TCB) to outline a technical roadmap and ensure its implementation through an Open Technical Forum. The **LHCC congratulates** WLCG on making the Open Forum a key component for overseeing the evolution and innovation of services and **encourages** them to utilise this opportunity fully.
- The **LHCC thanks** the CERN EP-SFT group for addressing the comment from the last LHCC meeting and **welcomes** the proposal for improving software project reporting. Starting from the next meeting, when preparing the agenda, focus topics for discussion with the stakeholders will be identified.
- The **LHCC commends** the HSF for its evolution and ongoing reorganisation efforts and **congratulates** the HSF on its software stewardship role within the community. Additionally, the **LHCC acknowledges** the potential stewardship that HSF-affiliated projects and software could provide to the wider scientific community.

11. Report on FASER

Two papers on the measurement and the predictions of neutrino production with FASERν have recently been published on PRL and PRD. Two more papers on neutrinos and ALPs, are in preparation. A further update of the emulsion measurements, with up to 7 times the statistics of the first cross section paper, is expected for the Winter 2025 conferences.

Operations during the 2024 run have been very smooth, with 95 fb^{-1} delivered to IP1 and over 97% recording efficiency. The calorimeter readout upgrade is working well. The development of the first emulsion module has confirmed the factor of 2 increase in track density per fb^{-1} of exposure, due to the higher muon background caused by the 2024 beam optics. Only a second set of emulsions has therefore been exposed so far and is currently under development. Since its removal in early July, the FASERν box has been equipped with spare calorimeter modules (CaloNu), aimed at reconstructing ν_e charged current interactions. CaloNu could provide guidance for the design of a possible alternative non-emulsion neutrino detector for Run 4, and its physics potential is under investigation with a dedicated simulation. The third emulsion module for the FASERν box is being prepared and will replace CaloNu on October 1.

Large simulation efforts with BDSIM and FLUKA have reproduced the muon background problem, but failed so far in proposing mitigation measures, short of returning to the 2023 optics. A further possibility, relying on orbit bumps to sweep away background muons, will be tested soon during an LHC MD run.

The yield of acceptable ASICs for the pre-shower upgrade is lower than anticipated. The new baseline is to equip only 4 planes out of 6, for installation during the YETS. Previous simulation studies show that reasonable performance can be achieved with 4 planes, but a re-optimisation of the layout would further reduce the impact on the performance. Furthermore, initially lower-graded ASICs could pass the quality test of a second planned testing campaign. Excellent progress has been made in the other aspects of the project, as evidenced in the successful recent test beam using many production hardware and software components.

FASER supports the extension of Run 3 to 2026. The ability to continue effective operations of FASERν relies however on the evolution of the background issue, and on the availability of resources to secure the emulsions needed for 2026.

- The **LHCC congratulates** FASER(ν) for continuing to successfully deliver the promised physics programme, and for the smooth data taking in 2024
- The **LHCC commends** FASERν for coping as best as possible with the background issue, including the novel idea of the CaloNu detector

Comments applicable to both SND and FASER:

- The **LHCC acknowledges** the efforts made by FASER, SND@LHC and the LHC team to identify mitigation scenarios for the background problems. The **LHCC supports** continued efforts, in particular MD tests of new options.
- The **LHCC takes note** of the request by the two experiments to return to the 2023 optics, should all other background mitigation strategies fail

12. Report on MoEDAL

The MoEDAL detector has been running smoothly during 2024; a new set of NTDs will replace the current one during TS2, for exposure during the latter part of the run. The focus of MoEDAL's activities is now on the completion of the MAPP detector, and the preparation for a possible installation of its outriggers, subject to review and approval. The difficulties with the completion of the MAPP electronics have been overcome. The DAQ components required to fully equip 200 (out of 400) of the scintillator units should be available by TS2, and personnel is available to carry out the installation during TS2. Commissioning of this 50% of MAPP, with scintillator units at the core of each of the four scintillator modules, is expected to start after TS2. The full completion of the detector is planned to take place during the November-December part of the YETS.

Preparation of the detector elements for the outriggers is likewise proceeding, with the group of University of Alabama having secured the required scintillator material and having completed 60 out of 80 of the detectors. Scintillator for the remaining 20 has been shipped to University of Alberta. The detector electronics, whose design is mostly inherited from that of the MAPP detector, is under way. Construction completion, and delivery to CERN, are on schedule for a possible start of installation during the Winter 2025 segment of the YETS.

- The **LHCC congratulates** MoEDAL for the progress towards completion of the MAPP detector.
- The **LHCC reiterates** that completion and proven operation with collider data of 200 detector elements, after TS2, is a required condition for the review and possible recommendation of the outriggers extension. A report on the advancements of both MAPP operations and the outriggers construction is expected following TS2, but in advance of the November LHCC, to allow the committee to review the latest version of the outriggers TP and decide on its recommendation, on time for a possible approval enabling installation during the 24/25 YETS.

13. Report on SND

The SND detector has been collecting data in 2024 with a much larger than expected muon background. This gives an upper limit of $12fb^{-1}$ of integrated luminosity recorded by one emulsion batch. Given the limited number of emulsions available, SND has used one full target and 7 half ones, with a total of $86.5fb^{-1}$ luminosity collected with emulsions. An additional half target is expected to be installed for the remaining running time. The emulsion replacement has been performed very smoothly, requiring only 4 hours of access and on a very short time notice, with a minimum of 8 hours.

For running in 2025 and 2026, 5 full emulsion targets will be ready. The reconstruction of the emulsion events with the previous collected data is in progress. An improved background estimate has been done in view of the search for ν-NC and νe-CC events with 2022-2023 electronic detectors data and a publication of the results is in preparation, first preliminary results were shown at Moriond. The veto efficiency improved by an order of magnitude and now at the level of 3×10^{-8}.

SND presented a revised version of the upgrade detector for Run 4, AdvSND, minimising the civil engineering work, as requested by the LHCC in its last session. The revised proposal maintains the unique physics case of running SND in Run 4, providing 100 more neutrino interactions compared to Run 3, and studying neutrino interactions in the 0.1-1 TeV range, probing energy much higher than other experiments such as SHiP.

- The **LHCC commends** SND for effectively managing the year's operations by accommodating the increased muon background rate due to the new optics and demonstrating flexibility in exchanging the emulsions whenever LHC time permits. The **LHCC looks forward to** the first analysis of the emulsion sample data.
- The **LHCC acknowledges** the unique high-energy neutrino physics potential of AdvSND and **welcomes** the improved detector design which minimises the need for civil engineering while maintaining the physics capabilities. The **LHCC recommends** postponing further steps towards realisation until the LS3 schedule is clarified, and recalls that the feasibility of the civil engineering work still needs to be established both from a technical and a scheduling perspective.

14. ALADDIN LOI

The LHCC has received the LOI for a new proposed experiment, ALADDIN (An LHC Apparatus for Direct Dipole moment INvestigation), which aims at directly measuring the magnetic and electric dipole moments of positively charged charmed baryons (Λ_c^+ and Ξ_c^+) with bent crystals. The dipole moments are sensitive to new physics beyond the standard model and have never been measured for heavy quarks. The experimental technique is based on a bent crystal to induce spin precession before the charm baryons decay. The protons will be extracted using a first bent crystal from the LHC beam halo colliding with a tungsten target paired to a second large bent crystal. The location of the experiment will be in the IR3; no civil engineering work is needed, and it is planned to be installed during LS3. The detector is designed to reconstruct high-momentum charm baryon decaying to charged particles. It will consist of a spectrometer for measuring charged particle momentum and a RICH detector for the PID up to 1 TeV energy. The spectrometer will be made of two silicon pixel tracking stations positioned upstream of an existing dipole magnet and two tracking stations positioned downstream. A proof-of-principle test, TWOCRYST, is scheduled at IR3 during Run 3 and is expected to take data in 2025 to prove the feasibility of the proposed ALADDIN experiment. The outcome of TWOCRYST is expected at the end of 2025, matching the timeline for a possible Technical Proposal for ALADDIN.

- The **LHCC acknowledges** the submission of the ALADDIN LOI, which targets unique physics opportunities such as the measurement of magnetic and electric dipole moments of charmed baryons at the LHC and **expects** to conclude its review by the committee's November 2024 session.

REFEREES

The LHCC referee teams for this session are as follows:
ALICE: M. Battaglieri (Co-ordinator), D. Calvo, M. Diefenthaler, T. Galatyuk
ATLAS: J.J. Hernandez-Rey (Co-ordinator), M. Kirby, G. Signorelli, H. Tanaka
CMS: A Ianni, I. Gil-Botella, S. Niccolai (Co-ordinator), A. Weber
LHCb: B. Golob (Co-ordinator), T. Higuchi, R. Leitner
LHCf: M. Mangano (Co-ordinator)
MoEDAL: T. Ferber, M. Mangano (Co-ordinator)
WLCG: M. Diefenthaler, M. Kirby, G. Merino (Co-ordinator), A. Weber
FASER: T. Ferber, M. Mangano (Co-ordinator)
SND: T. Ferber (Co-ordinator), M. Mangano

The LHCC received the following documents:

CERN/LHCC-2024-009	Minutes of the one-hundred-and-fifty-eighth meeting held on Wednesday and Thursday, 29-30 May, 2024
CERN/LHCC-2024-011	ALADDIN: An Lhc Apparatus for Direct Dipole moments INvestigation, Letter of Intent
CERN/LHCC-2024-014	Addendum to the AdvancedSND LoI

DATES FOR LHCC MEETINGS

Dates for 2024
20-21 November

Dates for 2025 (Preliminary)
5-6 March
4-5 June
3-4 September
19-20 November

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Appendix A: Report of the LHCb Data Acquisition Enhancement TDR review

A. Review report of the LHCb TDR 25, "LHCb Data Acquisition Enhancement"

Review Panel: Bostjan Golob, Takeo Higuchi, Rupert Leitner, David Cussans (external expert)

The panel thanks and commends members of the LHCb Collaboration involved in preparation and finalisation of the TDR on Data Acquisition for their great work, for the high-quality document that they produced, for the promptness and thoroughness of their replies and for their efforts to address the issues raised by the panel.

Overview

Timeline of the review (~5 months):

- Feb 23rd: First draft of TDR (~60 pages) received
- Feb 27th: First presentation at the LHCb – referees meeting during LHCC 157
- May 22nd: Online discussion among LHCb, referees and external reviewer
- May 27th: Focus session on TDR during LHCC 158
- June, July: Further offline submission of comments & answers
- August 11th: Referees sign off on the comments
- August 26th: Final version of the TDR received, decision to be taken during LHCC 158

The TDR describes in a concise manner plans for the upgrade of the online electronics and Real-Time Analysis (RTA) Downstream Tracker.

Considering more stringent requirements on DAQ after the LS3 due to foreseen upgrades of the PID (RICH detectors and ECAL), namely on timing distribution and input bandwidth, it is necessary to prepare for the Run 4 architecture of the event-building, which will be similar to that of Run 3, but adding more nodes to handle new front-end channels. It will also rely on a new readout board, PCIe400, to deal with the latest standard protocols used in data centres and accurate clock distribution.

Moreover, in LHCb Upgrade II, complex detector data will need to be reconstructed, in real-time, at a luminosity an order of magnitude higher than in Run 3. In these conditions, it is anticipated to be advantageous to perform early low-level reconstruction at the readout level, using custom processors to produce intermediate, more compact data structures ("primitives"). Therefore, a specially developed firmware system, running on an array of interconnected FPGA boards, to reconstruct tracking primitives transparently during the readout of LHCb T-stations is proposed (DownstreamTracker).

The Online upgrade part of the TDR is divided into 3 sections: description of the generic readout board PCIe400, evolution of the event-builder for Run 4, and project organisation.

The DowstreamTracker (DWT) part of the TDR comprises 8 chapters, including the principles of operation, the technical design of the DWT custom processor, and project organisation.

Main observations, comments and concerns

GENERAL

During the review and in exchange of comments, questions and answers between the referees and the LHCb team, no substantial changes to the project were proposed. There were several modifications / explanations in the description of the TDR suggested and implemented. In the following we only list a few examples of those.

ONLINE

A question on the obsolescence of PCIe40 components (being upgraded by PCIe400) was provided, explaining that the end of life for the optical transceivers, minipod from Broadcom, was in September 2021, but this issue has been anticipated by buying a sufficient amount of spare parts, to be able to maintain the card for 10 years.

Several comments were related to the timeline for the design and production of PCIe400 boards. They were all adequately addressed, and appropriate points in the risk mitigation scheme were pointed out.

DWT

A question has been raised about how the Retina architecture used in the DWT represents an enhancement of the Hough Transform, which has been used for triggering in several experiments for many years. A detailed mathematical answer has been offered, and the appropriate explanation has been added to the TDR.

A discussion developed on whether Retina architecture can also be applied to RICH detectors. While no simulation regarding this exists yet, it's been concluded that, at least in principle, there is no difference in the application of either circular (RICH) or linear (tracking) patterns of measuring points.

Comments were also oriented towards a (very welcome) demonstrator of DWT, built with 8 commercially available PCIe FPGA boards and installed and tested at the LHCb coprocessor test-bed facility. After a discussion of slight discrepancies between Demonstrator results and simulation, the reasons for the discrepancies were identified.

Main recommendations and conclusions

Findings of the refereeing team have been discussed during the 158th session of LHCC. Based on this, adoption of the following executive summary was proposed to the LHCC:

LHCC congratulates LHCb on the timely preparation of the DAQ enhancement TDR which provides a well-described, technically and scientifically justified case for an upgrade of the experiment;

LHCC notes that it also represents an important and effective step towards the future Phase IIb upgrade, and is synchronised with the planned upgrades during LS4.

The LHCC recommends approval to allow resources to become available and MoUs to be signed.