CERN/LHCC-2024-005
LHCC-157
February 2024

LARGE HADRON COLLIDER COMMITTEE

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

Wednesday and Thursday, 28-29 February 2024

OPEN SESSION – STATUS REPORTS

1. Status of the Accelerator: Georges Trad
2. ALICE Status Report: Valentina Mantovani Sarti
3. ATLAS Status Report: Stefan Guindon
4. CMS Status Report: Matthew Nguyen
5. LHCb Status report: Valeriia Zhovkovska

CLOSED SESSION

Present: F. Alessio, M. Battaglieri, D. Calvo, I. Efthymiopoulos, X. Espinal, T. Ferber, T. Galatyuk, I. Gil-Botella, B. Golob, J.J. Hernández-Rey, T. Higuchi*, E.B. Holzer, A. Ianni, M. Krammer, R. Leitner, M. Mangano, G. Merino, J. Mnich, L. Moneta (Scientific Secretary), J. Nagle*, S. Niccolai*, B. Panzer-Steindel*, G. Signorelli, F. Simon (Chairperson), H. Tanaka, A. Weber, 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 chairperson reported on a first preliminary discussion with the main proponents for a new experiment at the LHC, which aims at directly measuring the dipole moments of charged baryons. This experiment will exploit particle channelling and spin precession in bent crystals. In addition to two crystals, one to direct particles from the beam halo onto a target, and one for the spin precession after the target, a magnetic spectrometer consisting of reusing LHCb VELO pixel layers, an existing 1T magnet and RICH for particle identification is proposed. The tracking detectors and the magnet would be located in Roman Pots. IR3 is foreseen as the location for the experiment, with IP8 and the LHCb detector being possible alternative. A cost estimate is not yet available. The submission of an LOI, possible time scales and next steps will be discussed in the near future.

The committee discussed a possible change of the meeting layout with the goal to improve the integration of the Open Session into the overall review process within the LHCC week and to add more room for further discussions in the referee teams prior to

the reports in the Closed Session. This would be achieved by moving the Open Session to Monday afternoon (14:00 - 17:00 / 17:30), and keeping the Wednesday morning for internal discussions and reduced-attendance Focus Sessions as required. The practicality of this change will be explored with all stakeholders in the near future.

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

The 2024 and 2025 LHC schedules were finalised. The remaining ion days were split in ~2.5 weeks at the end of both 2024 and 2025 and the Oxygen run is scheduled for 2025. Both ion runs are preceded by a proton reference run at the same energy as the ion run, with 6 days allocated to it in 2024 and 2 days in 2025. Each proton reference run is preceded by 2 days of setup and the Pb ions physics production period is also preceded by 4 days of setup. Experiments were requested to evaluate the impact of removing the proton reference run in 2025 to gain 3 days of Pb ions physics due to saving on setup time. ATLAS/ALICE/LHCb agreed to the proposal, CMS requested a proton reference run in 2025 as well.

The 2024 LHC re-commissioning period will last ~4 weeks, longer than initially planned by 5 days due to the need to commission new optics following the polarity reversal at the inner triplet around IR1. The optics are available and allow reducing the radiation levels at the D1 magnet by 30%, leaving enough safety margin in terms of integrated dose at the IT. The LHC re-commissioning will start with the Machine Checkout period on Wednesday 6 March with first beams injected and circulated a few days later. The detailed plan is being defined by the LHC OP teams.

The LHC experts reviewed the 2023 performance and set out plans for 2024 at the Joint Accelerator Performance Workshop and Chamonix Workshop. In terms of LHC availability, the fraction of short faults is steady at an average of 16% throughout Run2 and Run3. The majority of the downtime was due to long faults: 50 days due to a Helium leak, 4 days lost following RF fingers damage and the end of the high-intensity proton production as a consequence of a bellow leak in the TDIS8 imposing a limit on the possible injected intensity. The premature end of the high-intensity proton production meant that ATLAS/CMS were delivered only 32 fb^{-1} of data (out of an initial target of 75 fb^{-1}) and no proton reference run could be delivered in 2023. These long faults are the result of latent weaknesses, and some of these long faults may occur again in 2024 as definitive fixes can only be available from 2025 (TDIS and RF fingers) or after LS3 (bellows in Inner Triplets). Limitations to the LHC performance in 2024 are imposed by degradation of the RF fingers, which limit the bunch intensity to 1.6×10^{11} ppb, by the heat load as a consequence of e-cloud which limits the train lengths and possible filling schemes and by the cryogenic margins, which limit the maximum instantaneous luminosity up to 2.2×10^{34} cm^{-2} s^{-1} at ATLAS/CMS. These limits define the boundary conditions for the operational baseline scenarios, being fine-tuned for the year 2024.

The Pb ions beam performance was also reviewed at the workshops highlighting how the machine excelled in commissioning many new concepts, while suffering from degraded performance that resulted in achieving only 66% of the initial integrated luminosity targets, delivering 2 nb^{-1}. An exhaustive roadmap towards improving the ion run performance has been defined, notably addressing the ALICE background degradation, where simulation efforts have been increased to find its source. The ion run in 2024 aims

at proving the expected performance, balancing the risks of introducing new concepts with the needs of increased availability. Possible performance improvements are then foreseen for the ion run in 2025.

Experiments have expressed their wishes and plans in view of the proton run in 2024. ATLAS and CMS will commission their detectors and trigger systems to a maximum pileup of 65, while the actual value at which data will be collected will depend on the filling scheme and cryo margins. Both experiments wish to collect close to 190 fb^{-1} between 2024 and 2025. LHCb plans to reach its nominal instantaneous luminosity to $2x10^{33}$ cm^{-2} s^{-1} early in the year, after a pileup ramp-up plan to be achieved in parallel to the LHC intensity ramp-up. The LHCb VELO detector is fully repaired and ready for re-commissioning with beams. LHCb targets to collect ~7 fb^{-1} / year in 2024 and 2025. ALICE also plans to collect a sizable amount of data with proton collisions, at an average rate of 8.7 Hz/μb targeting to collect ~100 pb^{-1} in the full Run3 (~30 pb^{-1} / year). FASER and SND continue to collect data in 2024, with emulsion films to be replaced regularly: the limits for replacement are set to 30 fb^{-1} for FASER and 20 fb^{-1} for SND. An effort to strive for flexibility in the emulsion exchanges is being made, extending the available readiness period for exchanges to 2 weeks to profit from opportunistic stops at the LHC and not provoke extra stops.

Wishes were also expressed for the ion run in 2024. Experiments expect to reach the targets of 5.4 nb^{-1} at ATLAS/ALICE/CMS for the full Run3, while LHCb has put in a request for a factor 2 target increase for Run 3, up to 2 nb^{-1} delivered. A desired target of 350 pb^{-1} was put forward by ATLAS and CMS for the pp reference run, 100 pb^{-1} by LHCb and 4.5 pb^{-1} by ALICE.

While the proton physics production goals seem at reach, provided good machine availability and careful machine configurations, the ion production goals are challenging, and it heavily hinges on the ability to improve the availability and performance of the LHC in the ion periods.

Lastly, an extension of the 2024 LHC data-taking period by 5 weeks (6 weeks in the injectors) while reducing the 2025 period by the same amount was proposed by the LHC LS3 coordination. While precise dates are yet to be decided, the proposal implies shifting the end date of the 2024 physics run from 28 October to 2 December. The main reasons are driven by an optimisation of the YETS in the injectors to 15 weeks, resulting in a net gain of 4 weeks of physics operations at the injectors as well as the possibility of having more time for preparation for the 1st core drilling for the HL-LHC to validate this method. In terms of integrated luminosity, this can result in an increase of ~30% of the integrated luminosity for 2024, to a possible total delivered numbers of 125 fb^{-1} in ATLAS/CMS and 13 fb^{-1} in LHCb. Early feedback from the experiments was collected and no major showstoppers were identified. The main concerns regard the operational costs and organization in 2024, loss of physics for FASER and SND as they cannot produce extra emulsion films in time and the decommissioning of the ALICE PHOton Spectrometer (PHOS) that needs to be done before the end of the collaboration with the Russian institutes on the 30th of November. The experiments highly desire an early decision on the plan, latest by April.

- The **LHCC recognizes** the operational benefits of the shift of the starting date of the YETS 2024/25 and the corresponding extension of the 2024 pp running. The **LHCC notes** that this change can be accommodated by the experiments, and would have significant benefits for test beams due to the longer availability of the

injectors in 2024, but would have negative impacts on SND and in particular on FASER. The **LHCC supports** the request of the experiments for a timely decision.

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. He reminded that the Council decision to terminate the Collaboration Agreements with Russia will be effective from the 30th of November 2024. The procedures needed to implement this decision are currently being worked out. This involves the issue of authorship by Russian collaborators and access to the data, with a special emphasis on PhD students. A proposal for handling authorship and the data access in the period after expiration of the ICA will be submitted to the council in March.

Afterwards, the DRC reminded that the experiments are ready for the 2024 running, and major planned repairs, such as the LHCb VELO, have been completed successfully.

There are also no new negative surprises from the Phase II upgrade activities for ATLAS and CMS and he was pleased to see the benefits of the Fraunhofer workshops organised last year. Concerning the Phase IIb upgrades of ALICE and LHCb, the DRC reported that these upgrades were discussed at the last December SPC meeting. The SPC would like to better understand the uniqueness of physics reach provided by the upgrades and what elements of the detector are essential to achieve these goals. For ALICE, a scenario without a new magnet should be studied. It is then crucial to produce detailed scoping documents soon to have concrete discussions with the funding agencies.

4. Test Beams

The 2024 injector schedule v1.0 as approved by the Research Board in December 2023 has been presented. It comprises about 30.5 weeks of physics beam time for the PS East Area; 24 weeks of proton physics for the SPS North Area; 4 weeks of Pb ion physics for the SPS North Area and 2 weeks of Pb ions in the T8 beam line of the PS East Area for CHIMERA/HEARTS at the end of the proton run. The option to extend the 2024 proton run in the injectors by six weeks was discussed. It would entail a reduction of proton beam time by two weeks in 2025 and result in four additional weeks for proton physics in the period 2024 and 2025.

The requests for proton beam time as main user are 132% of the available beam time for the PS EA T9 and T10 lines; 138% for the SPS NA H2 and H4 beam lines and 173% for the SPS NA H6 an H8 beam line. While the overall beam time requested for LHC test beams is similar to previous years, the projected readiness of the user groups leads to a clustering of the requests in September and October. Consequently, a significant number of the requests for the end of the proton run cannot be scheduled.

The preliminary version of the user schedule was discussed. In the PS EA multi-user beam lines T9 and T10 a prolongation of the 2024 proton run by 6 weeks would allow to schedule the LHC test beams, which cannot start earlier than September: ALICE RICH, TIMING and MUON ID as well as LHCb RICH and MUONS. In the SPS H2 and H4 beam lines, extending the proton run would allow to schedule CMS HF, additional beam time for FASER pre-shower and to separate the beam times of SND and FASERν, which are currently scheduled in parallel in the H8 beam line. DRDC reviewed activities would profit as well. In the SPS H6 beam line, the limiting factor for parallel operation of the

high priority LHC test beams requested during the last two weeks is the availability of infrastructure, beam telescopes and cold boxes. In the H8 beam line the test beam requests from LHCb RICH and ATLAS Tilecal for the last two weeks of proton beam are mutually exclusive. Extending the beam time would accommodate both requests.

5. General Comments

The following comments are applicable to more than one project.

The different limits for the collected integrated luminosity per emulsion installation of FASER and SND make the synchronisation of exchanges, and the alignment of exchanges with planned accelerator downtimes challenging.

- The **LHCC notes** that the collection of the largest possible data set during pp running is the highest priority for the 2024 run. The **LHCC expects** that SND and FASER plan for maximal flexibility of emulsion exchanges during 2024 to avoid any interference with LHC operations, making use of planned stops and opportunistically arising downtimes of sufficient duration. The **LHCC encourages** SND and FASER to explore means to further increase flexibility, like the alternative storage solution at HL-LHC P1.

In 2023 four fast dumps of experiment magnets occurred, two each on ATLAS and CMS. These events represent a significant risk for these irreplaceable items. A thorough investigation has been carried out by TE-CRG and the experiments, with detailed findings and recommended measures presented and discussed in a dedicated Focus Session of the LHCC. Different causes have led to these events, including design issues of the systems and operator error in attempts to prevent Helium losses during an ongoing slow dump. Modifications in the systems and changes in operational procedures are being implemented in response to the investigation.

- The **LHCC is impressed by** the thorough investigation of the fast dumps of experiment magnets that occurred in 2023 and **notes** the excellent collaboration of the central cryo teams (TE-CRG) and the technical coordination of the experiments. The **LHCC fully supports** the measures implemented to improve the robustness of the systems and to reduce the risks in the operational procedures going forward.

The Phase II upgrade projects of ATLAS and CMS continue to make good progress, with projects transitioning to production and the first items being delivered to CERN. Technical problems and supply chain issues have, however, resulted in additional delays. For both experiments the schedule is very tight and consistent with zero schedule float for the most critical projects. The interactions with the Fraunhofer Institute for Manufacturing Engineering and Automation (IPA) have proven beneficial for the projects, have resulted in improvements in schedule robustness and contingency, and have triggered similar exercises on another project in CMS.

- The **LHCC takes note** of the success of the interactions with the Fraunhofer IPA and **encourages** the experiments to perform similar exercises for other projects with critical schedule situations.

- The **LHCC remains concerned** about the critical schedule situation and **notes** that several upgrade projects require additional personnel and resources to proceed on schedule and **urges** the collaborating institutes and funding agencies to respond to this need.
- The **LHCC notes** that the person-power of the technical support groups at CERN is limited. Given the significant needs in LS3 the **LHCC recommends** that CERN technical support groups carefully plan their work schedule and assess their person-power in order to be compatible with the experiment installation plans.

6. Discussion with ALICE

Scientific output and current activities:

- ALICE continues to make excellent progress on its physics program, with 3 new papers submitted since the last session of the LHCC, bringing the total number of publications to 476. The new results include the investigation of the nature of the $K_0^*(700)$ state with $\pi^{\pm}K_s^0$ correlations, a study on the interaction between charm and light flavour mesons and a measurement in pp collisions of the b-quark fragmentation to B_s mesons via non-prompt D mesons.
- A planned maintenance of the detector and infrastructure has been performed during the YETS. Significant progress has been achieved in understanding the observed space-charge distortions in the TPC, and new corrections have been developed and applied in data reconstruction. An additional distortion plaguing the whole data set was detected and corrected. The cause of this distortion has been identified as a leak in the cooling water circuit of one of the voltage dividers of the field cage and has been fixed now during the YETS.
- The data processing plan for 2024 has been defined. Given the short time for skimming the pp data before the Heavy Ion run, the nominal size of the online disk pool of 90 PB leaves no operational margin. An additional lease of 30 PB of disk from IT was requested to increase the operational margin.
- Since the PHOS is operated entirely by Russian teams its decommissioning is foreseen before to the termination of the ICAs at the end of November 2024. Extending the running in 2024 by 5 weeks will likely require the decommissioning to take place before the heavy ion run.

ALICE upgrades:

- The TDR for the ITS3 and the FoCAL upgrades for Run 4 were reviewed by the LHCC and the UCG (in the case of the FoCAL). Both were recommended for approval. The detailed outcome of the reviews is given in the appendix of these minutes.
- ALICE reported on the progress of the Run 5 upgrade studies. The baseline design has been optimised to provide more flexibility in the installation sequence in LS4 and the cost estimation has been updated to 20% higher than the costs presented in the LOI. The cost increase has been driven by more detailed estimates, inclusion of spare components and of technical personnel for general design and installation. The scoping studies for a layout without ECAL and with a reduced

magnetic field of 1 Tesla, instead of the nominal 2T, have also been presented. Furthermore, the impact of using the current L3 solenoid has been studied. The gain in operation costs in Run 5 and 6 by using a new superconducting solenoid compared to using the L3 solenoid is estimated to be around 10 MCHF, one-third of the cost of the new magnet.

- The **LHCC commends** ALICE on its steady rich physics output with high-impact results, demonstrating an extensive physics program.
- The **LHCC congratulates** the ALICE collaboration on the successful 2023 Pb-Pb data taking with the fully operational upgrade, showing enhanced statistics compared to Run 2.
- The **LHCC recognizes** the progress in calibrations, alignment, reconstruction and simulation. Given the plan for Pb-Pb data taking in both 2024 and 2025, the **LHCC notes** that a robust and reliable apparatus is required to fully exploit this opportunity and a maximum commitment by the collaboration is needed. The **LHCC commends** the clear road map for the 2024 run preparation and **supports** the request for additional disk space of 30 PB to gain operational margin.
- The **LHCC encourages** the ALICE collaboration to complete the ALICE 3 scoping document for April 2024, define the optimal magnetic field strength and bore radius, and finalise the decision about the inclusion of the calorimeter in the baseline. The **LHCC recommends** clearly documenting the impact of using the existing L3 magnet instead of a new higher-field solenoid on key physics channels in the scoping document.

7. Discussion with ATLAS

Scientific output and current activities:

- ATLAS continues to make excellent progress on its physics programme, with 1251 papers on collision data submitted to date, of which 313 use the full Run 2 data set and 6 Run 3 data. Since the last session of the LHCC, 34 new papers have been submitted. Recent new results include the measurement of the energy dependence of WZ polarization fractions, detailed measurement of the same-sign W boson pair production in association with two jets and the evidence of the associated Higgs production with a W or Z boson in the $H \to \tau\tau$ decay channel, a rare process which accounts for only 0.02% of all produced Higgs bosons. New Machine Learning tools, such as Graph Neural networks for flavour tagging, tau reconstruction and pion energy calibration, offer great potential for future analysis improvements.
- Significant maintenance and consolidation work has been accomplished during the EYETS. Several problems, including the clogging of cryogenic refrigerators, have been addressed and solved or mitigated. A sizeable quantity of Phase II-related work has been anticipated during the YETS, which will lighten the LS3 schedule. A detailed analysis of the incidents with fast dumps of the magnets was conducted, resulting in a consolidation of the control procedures and settings to improve operational robustness. The ATLAS detector is now in a good state to restart data taking.
- Well-attended shifter trainings have been carried out. Nevertheless, coverage for central shifts is a challenge, with unsatisfactory coverage already early in the 2024

running period.

- The committee thanked the ATLAS Technical Coordinator, Ludovico Pontecorvo, for the open and cooperative approach to the work and duties of the LHCC ATLAS Referee Team and welcomed Martin Aleksa as the new ATLAS Technical Coordinator.
- The preparation of the triggers for 2024 has been carried out, and the commissioning of Phase I upgrade triggers has continued. Phase-I L1 Calo will be the default trigger for physics in 2024, and the legacy triggers will only operate at the start of the run for validation and comparisons. The HLT farm has been tested after the change to Alma 9, and a major database consolidation work is in its final phases.
- The preparation for the ending of the ICAs with Russia and Belarus is proceeding smoothly. The ATLAS Collaboration highly appreciates the proactive help of their Russian colleagues in transferring knowledge and tasks, which will minimise the detrimental effects of this transition. The conditions for the transition are being discussed with CERN and the Russian colleagues.

Phase-II upgrades:

- The Phase II upgrade has made enormous progress. There have been significant achievements in several areas, and various technical issues have been sorted out. ATLAS identifies and acts swiftly when new problems appear and takes measures to correct delays. However, it is still a challenge to meet the schedule for the ITk, the float is being burnt at a high rate, and several issues, such as hybridisation and module cracking, remain matters of concern.

- The **LHCC congratulates** ATLAS on the wealth of very interesting new physics results produced with both Run 2 and Run 3 data. The **LHCC praises** the ambitious goal of releasing more physics analyses including Run 3 data.
- The **LHCC congratulates** the ATLAS Collaboration for the impressive work done during the EYETS including anticipated Phase II activities and **notes with satisfaction** that no major incident has occurred.
- The **LHCC notes** that the coverage of central shifts is more challenging than expected and **stresses** the importance of broad participation of the collaboration in this essential aspect of operations.
- The **LHCC commends** ATLAS for the preparation of the triggers for the start of the run and the understanding of the cause for lower efficiencies in the 2023 PbPb run and **looks forward to seeing** all the Phase-I triggers fully operational during this year. The **LHCC is pleased** to see that the areas of computing and software are making steady progress, and the Computing and Software TDR is on schedule for 2025.
- The **LHCC notes** the progress of the Phase II upgrades. The **LHCC is impressed** by the amount of work done and **welcomes** the schedule improvements already implemented and expected to still be realised following the discussions with Fraunhofer IPA. The **LHCC remains concerned** about the critical schedule situation and the continued loss of schedule float on some projects.

8. Discussion with CMS

Scientific output and current activities:

- CMS continues to make excellent progress on its physics programme, with 1258 papers on collider data submitted to date, including 28 since the last LHCC. The new results include the search for new resonances decaying to pairs of highly merged photons, the search for Baryon Number Violation in top production and decay and the observation of double J/ψ production in pPb collisions. Many new results will be presented at the coming winter conferences.
- A task force to speed up the time to publication has been established, and it will report its first findings to the CMS Management Board in March.
- The YETS work is almost completed, and the detector is now closed. The work was performed only on one side (-z end) due to the programmed maintenance of the crane on the other side, which also suffered a failure during recommissioning. Some repair work on the hadron calorimeter and RPC gas leaks was performed. Two GE2/1 and RE3/1 upgrade detectors were installed and the New Forward Shielding was installed in the -z side. An issue with the gas supply of one DT chamber remains. There is the possibility of switching on RPCs around to recover the trigger capability, although one of these RPCs has a gas leak. The new control room has been brought into operation.
- A thorough analysis of the fast dumps of the solenoid that occurred in 2023 has been carried out by the CERN cryogenics team (TE-CRG) together with CMS, and measures to avoid such incidents in the future have been identified and are being implemented.
- In September 2023 and February 2024, major thefts of material occurred in PT5. After discussions with the CERN security team, possible measures to increase security have been identified.
- CMS presented a detailed report on greenhouse gas emissions, showing a reduction in 2023 compared to 2022. This reduction is due both to reduced running time and significant efforts in that area, such as increased recuperation and reduced use of CF4, improved R134 recuperation and reduced usage of SF6 outside of beam operations. The efforts are ongoing and the decommissioning of some of the present cooling systems are expected to result in a reduction of emissions from 80 ktCO_2e in 2012 to 15 ktCO_2e for Run 4, corresponding to a 80% reduction. This translates into 180 ktCO_2e total emissions for the HL-LHC phase.
- The committee thanked the CMS Technical Coordinator, Wolfram Zeuner for his thorough presentations, always followed by open and frank discussions, and welcomed Paola Tropea as the new CMS Technical Coordinator.

Phase-II upgrades:

- The Phase II upgrade projects are progressing well, with transition to production after most of the engineering has been completed. One technical issue was encountered in the latest version of HGROC, the front-end ASIC for HGCAL. The HGCAL clean room construction is progressing, and the current delays have not affected the HGCAL schedule.
- A “Fraunhofer-like” workshop has been performed for the Tracker, organised with CMS-internal experts from other projects. Positive effects on the tracker schedule are expected as a result.

- The **LHCC congratulates** CMS on the wealth of very interesting new physics results produced with both Run 2 and Run 3 data and for the thorough and timely preparation for the upcoming run.
- The **LHCC congratulates** CMS for the successful YETS operations, during which all planned work was carried out. The **LHCC commends** CMS and the responsible support team for the crafty solution implemented to repair the broken crane.
- The **LHCC looks forward** to the findings of the Task Force on "Time to Publication" and **appreciates** the reported progress on the W mass analysis.
- The **LHCC recommends** that CERN works with CMS to establish security measures in response to the recent thefts of material at point 5.
- The **LHCC appreciates** the thorough presentation on greenhouse gases, the efforts on recuperation of R134a, and the progress towards recuperation of SF6. The **LHCC still encourages** the collaboration to pursue strategies to further reduce R134a leaks from the RPC barrel and to increase the effort on the ageing tests using alternative mixtures/gases.
- The **LHCC notes** the significant progress on the Phase II upgrades, **welcomes** the initiative to carry out a "Fraunhofer-like" review for the tracker, and looks forward to the positive impact on the tracker schedule. The **LHCC remains concerned** about the continued schedule slippage and reduced distance to critical path for several key items. The **LHCC shares** the concern of CMS management on the need for resources towards timely completion of the upgrade plan.

9. Discussion with LHCb

Scientific output and current activities:

- LHCb continues to deliver high-quality physics results, with a total of 714 publications to date, including 14 new papers since the last session of the LHCC. New results include a new measurement of the branching fraction $B^0 \rightarrow J/\psi\pi^0$ and the observation of the $B_c^+ \rightarrow J/\psi\pi^+\pi^0$ decay.
- The VELO has been successfully installed and its commissioning is in progress. A wide range of activities have been carried out successfully during the YETS, including maintenance and further consolidation of upgraded detectors. The detector is in good shape for taking data in 2024. The remaining commissioning work for UT is expected to be completed during early data taking, with the UT fully operational for the second half of the 2024 pp running.

LHCb upgrades:

- The TDR for LHCb PID Enhancement was reviewed by the LHCC and is recommended for approval. The detailed outcome of the review is given in the appendix of these minutes.
- A new TDR on the DAQ enhancement of LHCb for Run4 has been submitted to the LHCC. It includes two independent areas: an upgrade of the online DAQ system with new PCIe400 boards and an HLT acceleration of the downstream tracker using FPGA. The cost is estimated to be 600kCHF for the PCIe400 developments, which also benefit the enhancement of the RICH detectors, and 1.8 MCHF for the HLT acceleration.

- Activities on preparing the Phase IIb upgrade Scoping Document are progressing, with scoping scenarios studied at 85% and 70% of the baseline cost. The main dimensions studied are a reduced peak luminosity and correspondingly reduced detector requirements, reductions in acceptance and reduced sub-detector performance. The preliminary studies indicate a significant loss of physics performance for the lowest-cost scenario.

- The **LHCC congratulates** LHCb on the excellent physics output with top-quality flavour physics results with precision unattainable by other experiments. The **LHCC encourages** the efforts to include the 2023 data in the physics analyses.
- The **LHCC commends** LHCb for outstanding work during the YETS and **recognizes** the significant progress in preparing the detector for 2024 data taking. The LHCC **is pleased to see** the successful re-installation of the VELO and the achieved progress in data-taking stability of UT. The **LHCC encourages** LHCb to continue the commissioning of the UT and to prepare the detector for global DAQ as soon as possible in the 2024 data-taking period.
- The **LHCC welcomes** the LHCb's efforts in offering important high-quality data to the public and supports the continuation of such efforts.
- The **LHCC notes** the progress in the scoping studies for Upgrade II and **encourages** LHCb to make preliminary results available by April 2024.

10. Discussion with WLCG

The WLCG infrastructure continues to perform extremely well. The experiments are actively working and making progress on an impressive number of fronts to prepare for the upcoming data-taking period and beyond.

A new WLCG T1 site from Poland has been validated, and sites from China and Serbia are progressing towards becoming official T1 sites. The Russian sites, excluding JINR, will not be part of WLCG after November 2024, following the CERN Council decision of last year. There has been a notable increase in the usage of opportunistic resources by some of the experiments. To provide a coherent view, WLCG is working on consolidating the accounting of these resources. This will allow for a better understanding of the evolution of non-pledged resource usage, including HPC.

A data challenge occurred in February 2024, and its results will be presented at the next LHCC. As part of a joint computing initiative between ECFA, APPEC and NuPECC communities (JENA), 5 working groups were created and their outcome is expected by the end of the year. This will be relevant for the HL-LHC preparation, and it is an important step for the next European strategy for particle physics.

As a follow-up of the Analysis Facility focus session held in the June 2023 LHCC meeting, the committee has prepared a document defining the review process for the Analysis Facilities. This document has been handed over to the WLCG management and it is being discussed with the experiments. The stakeholders will agree on a list of questions that will be used to define the experiment requirements for the Analysis Facilities. The collected requirements will be presented by the experiments to the LHCC in November.

Here are a few highlights of the experiment computing activities. The pledged resources for ALICE without the Russia/JINR contributions in 2024 are sufficient for processing the 2023 data and for collecting the foreseen 2024 data. The adoption of a lossless compression strategy will generate an increase need of tape resources. LHCb computing requests for 2025 are 50-60% higher than in 2024, and the opportunistic CPU resources are only at 2%, with limited contributions from HPC. LHCb published its full Run 1 open data release just before Christmas and it is working on tools aimed to support larger volume future releases. ATLAS has been using CPU resources smoothly at the level of 800.000 CPU cores with a significant contribution from opportunistic resources. The preparation for Run4 is proceeding well and ATLAS is on track to complete the Software and Computing TDR for HL-LHC in early 2025. ATLAS had its first public release of Open Data upcoming. CMS reported on using opportunistic CPU at 90% of the pledged. CMS is writing a Conceptual Design Report for Phase-2 Software and Computing, which is expected to be finalised in the third quarter of 2024.

The work on the large-scale RNTuple testing started with teams from EP-SFT and IT and a production version of RNTuple is expected to be released by the end of the year.

A focus session on MC generators was held during the LHCC week. Significant performance improvements (factors 10-100) have been achieved by optimising the generators code and through parallelization (GPU or CPU vectorized). Various options have been developed in the Madgraph and SHERPA generators to address the challenging issue of negative weights. The generator software developers, who are professionals in the intersection of theory, experiment and software, need support for their career path.

- The **LHCC commends** the WLCG and the experiments on the successful and efficient use of the computing resources. The **LHCC encourages** WLCG and the experiments to continue working together to have a coherent view of resources accounting, and in particular of the HPC usage. The **LHCC welcomes** the activity from several experiments to validate their software for the power-efficient ARM architecture.
- The **LHCC is pleased** to note the progress in the Open Data program and **is interested** in following the outcome of the JENA computing activities.
- The **LHCC encourages** the HSF community to write a conclusion document outlining clear outcomes from the PyHEP developer workshops, that help defining a roadmap and priorities for the upcoming years.
- The **LHCC recommends** that ALICE closely follows the compression strategy of the data and its impact on future storage needs.
- The **LHCC encourages** the experiments to test, validate and integrate the new generator software optimizations into production workflows, and to work together with CERN-SFT to deploy a platform for automated test and validation of event generators to reduce the time to adoption by experiments.
- The **LHCC recommends** the generator developers and the experiments to exploit existing direct contact communication channels to get focused input on the actual use of the different packages and prioritize future development. The **LHCC encourages** the stakeholders to use the new LPCC MC WG forum to coordinate common efforts, such as the deployment of a dedicated HPC development environment or the maintenance of critical infrastructure tools such as MCPlots, Rivet or HepMC.
- The **LHCC is pleased** to see that the MCNet collaboration continued to be a

useful forum to educate the next generation and pursue common developments even in the period when it was not funded.

- The **LHCC notes** the importance of supporting MC generators as a key element of the long-term success of the LHC experiments. These include the development and support of the appropriate tools and the career paths for those working in these areas.

11. Report on FASER

FASER successfully completed the YETS activities. The calorimeter readout upgrade was completed, tested on the surface with cosmic rays and, following the installation, in situ with a led system. The tests confirmed the constant relative response of the high-energy and low-energy PMT channels, across the overlap energy range of 3 – 100 GeV, although with a spread slightly larger than expected. Measurements with collider data will allow monitoring and optimising the overall performance. A water leak detection system was installed and tested. The FORMOSA detector demonstrator, with associated infrastructure, was likewise installed, and the safety check was passed, opening the way for its data-taking in 2024.

The production of ASICs for the pre-shower upgraded detector is due for completion during the week of the meeting, leaving the project safely on track for deployment during the YETS 24-25. A commissioning area in EHN1 is being prepared and will be ready in April-May. Two weeks of test beam, in the H4 and H6 areas are requested for late August – early September. This test beam is critical to prepare the detector for data-taking in 2025.

Physics studies are continuing, with three targets for public release at the Winter conferences: a higher-statistics update of the preliminary electron-neutrino measurement; an improved analysis of the electronic measurement of neutrino rates, with full 2022-23 statistics; a first search for ALPs decays to two photons. An up-to-date estimate of neutrino fluxes expected for the rest of the run and for run 4, with a detailed assessment of the production modeling theoretical systematics, was also recently published. A new global alignment of the tracking system, still excluding the IFT, was completed and implemented in the reprocessing of all 2022-23 data.

The triplets' polarity shift for 2024 can potentially expose the detector to higher backgrounds, with a negative impact especially for the FASERν emulsions, which would sustain only smaller integrated luminosity. Previous studies suggest a correlation between background levels and the placement of the TCL6 collimators. If this correlation is confirmed with the new RP optics, the TCL6 collimators should be optimally positioned to minimise as much as possible the background to the detector, while still respecting other constraints in the machine and the overall optimisation, towards maximising the integrated luminosity for pp collisions. FASER will also be affected by the choice of crossing plane in 2024, which will reduce from 80% to 60% of its acceptance for dark photon signatures.

FASERν is on track to produce the emulsions required for three sets of exposures. The desirable integrated luminosity for each set is between 25fb^{-1} and 30 fb^{-1}, maximum, allowing the collection in 2024 of at most 90 fb^{-1}. Three installations are planned: one at the end of beam commissioning, one during TS1, and one at around the machine development time. If necessary, an opportunistic access before the end of the run would allow the extraction of the third set of emulsions (without replacement).

The extension of the 2024 run by 5 weeks, under discussion, would penalize FASER(ν) on all fronts: the extra luminosity cannot be collected by FASERν, and it would be collected by FASER in 2024, with respect to 2025, with reduced acceptance, and reduced sensitivity due to the absence of the pre-shower upgrade.

- The **LHCC congratulates** FASER(ν) for the successful completion of the YETS tasks, the continued progress in physics studies and performance and the readiness to operate in 2024.
- The **LHCC welcomes** the progress with the pre-shower detector construction. The requested two weeks of test beam will be critical to prepare the successful operation of the detector in 2025.
- The **LHCC recognizes** that the plan to extend the 2024 run would significantly penalise FASER's statistics and performance.

12. Report on MoEDAL

The MoEDAL detectors were successfully reinstalled, after being removed to allow LHCb maintenance YETS operations. It is now ready for data-taking in 2024. The work to complete the MAPP detector with its front-end electronics, planned for the YETS, was put on hold, pending the completion of the relevant boards. The completion was stalled following serious health issues of the electronics engineer responsible for the project. Given the circumstances, it is difficult to assess whether the readout system can be installed on time, or during the technical stop, for the 2024 run.

Following an iteration of comments with the referees, a new version of the Technical Proposal for the MAPP Outrigger detector was submitted on February 25. In view of the MAPP situation, the review of the document is postponed.

- The **LHCC commends** the experiment for the successful installation of the MoEDAL detectors.
- The **LHCC requests** an update about the MAPP electronics boards as soon as new information becomes available. In absence of concrete progress, the **LHCC requests** by its next meeting a clear and concrete roadmap to address the issue and complete the MAPP detector on time for the 2025 run.

13. Report on SND

SND progressed well in the physics studies with a new published measurement of the muon flux. Two physics results using the electronic detectors on ν_μ selection and ν_e and neutral current identification are expected to be presented at the coming winter conferences.

The YETS activities have been completed. The VETO has been upgraded with an third plane and their position has been lowered, to increase their coverage. A sRPC telescope has also been installed to measure the muon flux in a different angular region in order to constraint simulations. Additional shielding has been also installed to fill existing gaps with the wall.

SND is ready for the 2024 running with 5 emulsions, which can stand overall an integrated luminosity of 100 fb^{-1}, with a maximum of 20fb^{-1}/emulsion. This implies 4

exchanges during run, which cannot be always synchronised with FASER. No additional emulsions can be produced for 2024, therefore an extension of the pp run in 2024 would penalize SND if integrated luminosity larger than 100 fb^{-1} will be collected.

The emulsion scanning is progressing with 30% of the 2022 films scanned. One additional scanning station in Santiago will be operational in March. By using new scanning software, it is expected that the scanning speed will double to 2 films/day. However, there are some issues, which are under investigation, preventing the installation of the new software in all laboratories.

SND also presented their upgrade plans for Run 4 and Run 5. For Run 4 an upgraded far detector in TI18 is foreseen, with a magnetic spectrometer being able to separate neutrinos from anti-neutrinos. A near detector in UJ57/UJ56 (near to P5) is proposed for Run 5 with the capability to measure the nu cross-section and reduce the systematic uncertainties of the far detector. The far detector will require significant civil engineering work to enlarge the TI18 tunnel to make space for the magnet and to lower it in order to align the detector with the line of sight. A letter of intent will be soon submitted to the LHCC.

- The **LHCC congratulates** SND for the successful installation of the third veto layer and **is looking forward to** the new neutrino results that will be presented at the winter conferences.
- The **LHCC is looking forward to** receiving a letter of intent from SND for the run 4 upgrade plans and **strongly suggests** to also include two upgrade options with reduced scope, one which does not involve any civil engineering, and one with significantly reduced civil engineering requirements that do not imply a lateral enlargement of the TI18 tunnel.

REFEREES

The LHCC referee teams for this session are as follows:
ALICE: M. Battaglieri, D. Calvo (Co-ordinator), T. Galatyuk, J. Nagle
ATLAS: J.J. Hernandez-Rey (Co-ordinator), 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: F. Di Lodovico, M. Mangano (Co-ordinator)
MoEDAL: T. Ferber, M. Mangano (Co-ordinator)
WLCG: 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-2023-010	Minutes of the one-hundred-and-fifty-sixth meeting held on Wednesday and Thursday, 29-30 November 2023
CERN/LHCC-2024-001	LHCb Data Acquisition Enhancement TDR
CERN/LHCC-2024-003	Technical Design report for the ALICE Inner Tracking System 3 (ITS3)
CERN/LHCC-2024-004	Technical Design Report of the ALICE Forward Calorimeter (FoCal)
CERN/LHCC-2024-006/UCG-038	Report on the UCG review of the ALICE Forward Calorimeter (FoCal)

DATES FOR LHCC MEETINGS

Dates for 2024

29-30 May
11-12 September
20-21 November

Lorenzo Moneta
E–mail: Lorenzo.Moneta@cern.ch
Tel. 74886

LHCC Secretariat: csc.secretariat@cern.ch

Appendix A: **Report of the ALICE ITS3 TDR review**

Appendix B: **Report of the ALICE FOCAL TDR review**

Appendix C: **Report of the LHCb Particle Identification Enhancement TDR review**

A. Report of the ALICE ITS3 TDR review

Review Panel*:* Marco Battaglieri, Daniela Calvo, Tetyana Galatyuk, James Nagle (LHCC ALICE Lead Referee, panel chair), Frank Simon (LHCC chair), Stew Smith (UCG-lite chair), Flemming Videbaek

The panel thanks and commends the ALICE ITS3 (Inner Tracking System 3) team for their impressive work, for the high-quality document that they produced, for the promptness and thoroughness of their replies to comments and questions, and for working with the review panel to complete the review in a timely manner.

Timeline of the review, carried out primarily remotely (email and Zoom):

- September 11, 2023: LHCC Focus Session Introduction to ITS3 at LOI level
- December 13, 2023: ITS3 TDR draft V2.0 sent to review panel
- January 10, 2024: panel comments sent to ALICE ITS3 team
- January 30, 2024: new ITS3 TDR V3.0 and replies to comments sent to panel
- February 16, 2024: final review panel meeting with ALICE ITS3 team
- February 28, 2024: close-out meeting during LHCC week

The final version of the TDR, which incorporates changes made in reaction to comments and questions during the review process, will be delivered in time for the March 2024 Research Board meeting.

Given the core cost estimate of 3.6 MCHF (as detailed in Chapter 8 of the TDR and excluding the 2.5 MCHF research and development costs), no separate UCG review was performed. Stew Smith (UCG chair) and the panel carried out a "light-touch" UCG review and found the cost estimates to be well-motivated and of appropriate quality, a good understanding of the project schedule with adequate contingency and a reasonable analysis of the main project risks. Adequate funding and resources appear to be in place, the project schedule is well understood with adequate contingency, as are the main project risks. The single largest cost item is the CMOS sensor ASIC, where the team has extensive experience from the research and development phase of the project. No major concerns have been raised.

In the following, observations, comments, and recommendations from the LHCC scientific and technical review are summarised.

The ITS3 is an upgrade to the ALICE experiment to be installed during Long-Shutdown 3 for data taking starting in 2029. The ultra-thin bent wafer-scale monolithic pixel detector will replace the three inner-most vertexing layers of the current ALICE ITS2 making them closer to the interaction point. The ITS3 will thereby improve the impact parameter resolution by a factor of two resulting in improved precision in measurements in the heavy-flavour sector, particularly at low transverse momentum. The ITS3 also enables the precise subtraction of electrons/positrons from heavy-flavour decays from the electron-positron pair distribution, allowing access to measurements of thermal radiation from the quark-gluon plasma produced in PbPb collisions.

The TDR details an extensive, world-leading, multi-year R&D program that has demonstrated all key aspects of the detector design and performance. This ambitious project faced a number of key questions. Is 65 nm technology performance appropriate? Can sensors be thinned and bent without breaking and while maintaining full functionality? Can the full detector be assembled without stiff support structures? Is air cooling sufficient for the power dissipation? Can stitched wafer scale sensors be built

with reasonable yield and to specifications? These questions have all been answered positively as thoroughly documented in the TDR. The R&D phase of the project has reached all is goals and is ready to move into the ER2 and ER3 production phase.

The panel finds the team uniquely capable of carrying out this breakthrough detector construction, testing, and delivering the physics. It is notable that the team is very strong and has also drawn significant interest from outside the ALICE Collaboration.

The panel has no official recommendations regarding the above items.

Executive summary

The panel commends the ALICE ITS3 team for the excellent work in preparing the TDR and handling the review. The physics motivations for the various items of the project are sound, and have been well received in previous, separate science reviews. Extensive R&D and testing put the project on a positive trajectory towards finalizing the design, construction, and then data-taking.

We recommend approval to allow resources to become available and MOUs to be signed.

B. Report of the ALICE FoCAL TDR review

Review Panel: Marco Battaglieri, Daniela Calvo, Tetyana Galatyuk, Katja Kruger, James Nagle (LHCC ALICE Lead Referee, panel chair), Edward O'Brien, Frank Simon (LHCC chair), Stew Smith (UCG chair), Flemming Videbaek

The panel thanks and commends the ALICE FoCal (Forward Calorimeter) team for their great work, for the high-quality document that they produced, for the promptness and thoroughness of their replies to comments and questions, and for working with the review panel to complete the review in a timely manner.

Timeline of the review, carried out primarily remotely (email and Zoom):

- September 11, 2023: LHCC Focus Session Introduction to FoCal TDR
- October 13, 2023: FoCal TDR draft v0.3 sent to review panel
- November 20, 2023: panel comments sent to ALICE FoCal team
- January 22, 2024: new FoCal TDR v0.4 and replies to comments sent to panel
- February 01, 2024: panel comments on v0.4 and replies send to ALICE FoCal team
- February 06, 2024: final review panel meeting with ALICE FoCal team
- February 28, 2024: close-out meeting during LHCC week

The final version of the TDR, which incorporates changes made in reaction to comments and questions during the review process, will be delivered in time for the March 2024 Research Board meeting.

Given the core cost estimate of 8.0 MCHF (as detailed in Chapter 9 of the TDR), a separate UCG review was carried out and chaired by Stew Smith. Details and recommendations from that UCG review are included in a separate document, and thus we do not comment on the cost and schedule, and related risks, here. In the following, observations, comments, and recommendations from the LHCC scientific and technical review are summarized.

The FoCal is an upgrade to the ALICE experiment to be installed during Long-Shutdown 3 for data taking in the period 2029-2032, with the critical measurements in pPb collisions and pp collisions at the same center-of-mass energy per nucleon pair, often termed the "pp reference running." The FoCal consists of a high granularity Si+W electromagnetic calorimeter combined with a Cu-scintillating-fiber hadronic calorimeter, both covering pseudo-rapidity $3.2 < \eta < 5.8$. The hallmark and unique physics measurement is of very forward rapidity direct photons to probe the gluon distribution in nuclei and protons at small momentum fraction, down to $x \sim 10^{-6}$. Additional measurements of neutral mesons, jets, and photon-jet correlations will be necessary to fully interpret the results and that performance should not be compromised.

The TDR details an extensive R&D program with multiple test beam campaigns to validate the design and that the physics-driven performance specifications are met. At this time, effectively all performance specifications are demonstrated, and often exceeded, with test beam measurements (also submitted for publication). The electromagnetic calorimeter design is very advanced, while additional checks on construction techniques for the hadronic calorimeter are needed, for example in exploring the concept of building "raft" layers of Cu tubes instead of cubes. The panel encourages exploring collaborative efforts on the hadronic calorimeter where such techniques have been used.

The risk assessment and discussion of mitigation strategies are rather complete, and comments directly related to cost and schedule are included in the UCG report. One area of concern is the high radiation doses that will be received by the detector at this far-forward rapidity. There are concerns regarding the SiPMs and fibres for the hadronic calorimeter.

There are also planned further radiations tests at the PS in 2024 for the ALPIDE chips, that would qualify them at 10x the expected radiation load. The panel encourages pursuing these additional tests and fully exploring the proposed mitigation strategies. Prioritising data-taking quality in pPb and the associated pp reference running has impacts on the proposal to move the FoCal further out for other data taking, e.g., higher energy pp running and potentially PbPb running. The condition of the detector irradiation also depends on the exact timing of the pPb running. Another area worthy of some additional studies and simulations relates to potential beam backgrounds and ensuring the safe operation of the detector.

There are also two particularly notable areas where CERN plans are important to the project. The special Be beampipe is important for the FoCal in terms of reducing photon conversions and the current CERN plan for building a facility for such machining is thus important given the lack of other company options. Also, a final test beam calibration of the full, final detector at the SPS in 2028 would be very useful. Thus, we encourage CERN's continued support of the SPS team beam program.

The panel has no official recommendations regarding the above items, as opposed to just reinforcing risk items and mitigations already identified in the TDR.

Executive summary

The panel commends the ALICE FoCal team for their excellent work in preparing the TDR and handling the review. The physics motivations for the various items of the project are sound, and have been well received in previous, separate science reviews. Extensive R&D and test beam campaigns put the project on a positive trajectory towards finalising the design, construction, and then data-taking.

We recommend approval to allow resources to become available and MOUs to be signed.

C. Review report of the LHCb TDR 24, "Enhancement of LHCb Particle Identification"

Review Panel: Bostjan Golob, Takeo Higuchi, Rupert Leitner, Carsten Niebuhr, Frank Simon (LHCC chair), Stew Smith (UCG chair), Elisabeth Worcester

The panel thanks and commends members of the LHCb Collaboration involved in preparation and finalization of the TDR on Particle Identification (involving RICH detectors and Electromagnetic calorimeter) 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):

- the TDR (85 pages) was submitted to the panel before the LHCC week 155, Sep 11th – Sep 14th 2023;
- during the LHCC week 155 a Focus session on the TDR was held;
- comments and questions raised by the panel were submitted to LHCb by Nov 12th 2023;
- answers and explanations from LHCb were received on Nov 22nd 2023;
- during LHCC week 156, Nov 27th – Nov 30th 2023 another discussion between the LHCb and panel members was organized, as well as the meeting on the costs of the planned upgrade with UCG;
- a list of pertaining questions with proposed actions was sent to LHCb on Jan 21st 2024;
- an online meeting was held on Feb 13th 2024, with finalization of remaining open issues;
- the final version of the TDR resolving all raised questions by the panel was submitted on Feb 23rd 2024;
- a final report with recommendations from the panel on the TDR was presented at the LHCC week 157, Feb 26th – Feb 29th 2024.

The TDR describes in a concise, yet detailed enough manner plans for the upgrade of the RICH detectors (RICH) and Electromagnetic Calorimeter (ECAL) of LHCb, with installation activities in the period of Long Shutdown 3 (LS3; 2026-2028), but other activities (design, commissioning, etc.) of course taking place before and after the end of LS3 (activities started in 2022 and are planned beyond 2028).

For the ECAL, a replacement of the innermost modules, which will be affected by radiation damage incurred by the end of Run 3, is proposed, using a new design based on SpaCal technology; in the outer regions, the existing Shashlik modules will be rearranged to better match the occupancy map.

The ECAL upgrade part of the TDR is divided into 7 sections, including performance requirements in view of expected higher occupancy and dosage at Run 4 of LHC, physics performance with simulation studies of benchmark processes, technical design and project organization.

For the RICH system, a replacement of the front-end electronics is proposed, implementing a new ASIC with timing capabilities; this will allow the Cherenkov

photons to be time stamped with a resolution of ~ 150 ps, matching the response of the MaPMT photon sensors.

The RICH part of the TDR comprises 13 chapters, including the physics performance with the timing information, integration of new electronics, calibration, monitoring and alignment, infrastructure and services and project organization.

The total costs are planned at 5.5 MCHF (ECAL) + 2.6 MCHF (RICH).

Main observations and comments

ECAL

The energy resolution of the current LCHb ECAL is measured to be $\sigma(E)/E = 10\%/\sqrt{E} \oplus 1\%$. In Run 3 and Run 4 the most severe anticipated degradation of the calorimeter performance is due to very high radiation doses. For illustration, the constant term in the energy resolution expression above for modules closest to the beam pipe would increase above 6% after 4 years of Run 4, and as such would be unusable for physics output. In order to maintain the above resolution, 176 new "SpaCal" modules will be installed (144 with Pb and 32 with W absorber). In addition, the existing modules will be rearranged in rhombic areas for modules of the same cell size.

The panel raised a request for a more illustrative presentation of the radiation damage in individual modules of the ECAL. New results and plots of expected light output degradation for existing and upgraded modules were prepared, exposing in a clear manner the need for the proposed upgrade in view of maintaining the performance of the ECAL.

Several comments were directed towards the compatibility of the planned LS3 enhancement with the Upgrade II, to be prepared and realized in the Long shutdown 4. After discussion it has been clarified (and the TDR correspondingly edited) that the proposed changes to the ECAL are fully compatible with the Upgrade II.

Upon the request by the panel a list of studies to be performed regarding the service for the ECAL using a mockup column was prepared and included into the TDR.

A separate section in the TDR is devoted to the ongoing developments in view of the future Upgrade II, notably, studies of improved performance using front-end electronics with timing possibilities (determination of the electrons and photons arrival time to the ECAL surface). While such an upgrade is foreseen for Run 5, simulation studies of benchmark modes have been performed and proves significantly improved performances.

In the area of risks particular emphasis was placed on the mitigation of the impact of a decreased Russian participation by shifting the production of SpaCal-Pb modules to another company. This is also related to an originally unplanned greater CERN financial involvement in the project. In discussion the need for careful monitoring of progress, despite the currently encouraging progress, was emphasized.

RICH

After LS4, at the higher luminosity foreseen for LHCb Upgrade II, to keep similarly good performance the RICH system will require substantial improvement in both the precision of the emission angle measurements and the capability to reject background. The latter can be obtained by accurate measurement of the Time-of-Arrival (ToA) of the detected

photons. A RICH enhancement proposed for LS3 consists from new front-end ASIC, and the interface to the optical links and ancillary systems. As the upgraded detectors will occupy the same space as currently, the LS3 provides a good opportunity to realize the proposed upgrade, and ensures an improved performance already in Run 4.

New electronics enables time-stamping of photons time-of-arrival with high precision, much better than the time resolution of the current photon detectors (limited to around 150 ps). The pion misidentification rate at a kaon identification efficiency of 95% would drop by a factor around 0.7 with the new electronics.

In the course of review, the panel has raised questions about results of measuring the time resolution of MAPMTs of various dimensions. They have been clarified to yield result slightly below 150 ps.

There has been a discussion on the actual expected irradiation dosage expected at the end or Run 3 and during the Run 4. It became clear that the operational environment requires an upgrade solution using ASICs.

We clarified some properties of the Rayleigh Scattered Laser Beam used for calibration of the opto-electronic chain. It has been explained that the purity of the N2 used in the system does not influence the calibration and that the time resolution of the system is around 100 ps, satisfying also requirements for Upgrade II.

Special attention was given to descoping scenarios in case the ASIC development and production takes longer time than planned. In this case only a single of the two RICH detectors would be upgraded. For this, LHCb committed itself to perform further simulation studies. In any case the LHCb detector would have both RICH detectors ready for data taking in Run 4.

Main recommendations and conclusions

The panel congratulates LHCb on a timely preparation of the TDR which provides a well described, technically and scientifically justified case for a necessary upgrade in order for the experiment's performance to remain at least at the same level as in Run 3 also for Run 4.

In addition, the proposed upgrade represents effective and important initial steps towards Upgrade II, well aligned with the latter.

The panel has no official recommendations regarding the items detailed above, but notes the very tight schedule with limited contingency, which however appears sufficiently realistic at this point, and has built-in descoping scenarios in case of delays.

We recommend approval to allow resources to become available and MOUs to be signed.