

LARGE HADRON COLLIDER COMMITTEE

Minutes of the one-hundredth-and-thirty-ninth meeting held on
Wednesday and Thursday, 11-12 September 2019

OPEN SESSION – STATUS REPORTS

1. LHC Machine Status Report: Katy Foraz
2. ALICE Status Report: Mohamad Tarhini
3. ATLAS Status Report: Bogdan Malaescu
4. CMS Status Report: Gaelle Boudoul
5. LHCb Status Report: Mark Tobin
6. RD42 Status Report: Harris Kagan
7. RD50 Status Report: Michael Moll
8. RD51 Status Report: Silvia Dalla Torre
9. RD53 Status Report: Maurice Garcia-Sciveres

CLOSED SESSION:

Present: H. Burkhardt, V. Beckmann, R. Calabrese, G. Casini, F. Di Lodovico, J. Dunlop, E. Elsen, E. Kajfasz, M. Krammer, P. Krizan, K. Krüger, M. Kuze, A. Kuzmin, M. Mangano, F. Moortgat, M. Morandin, P. Salabura, C. Sfienti (by video), F. Simon (Chairperson), S. Smith, B. Panzer-Steindel, B. Petersen, D. Waters, T. Wengler (Scientific Secretary), H. Wilkens, W. Wisniewski

Excused: D. Glenzinksi

1. Procedure

The chairperson welcomed the committee members. The minutes of the previous session were already approved by email. The chair then introduced a more standardised labelling of the different types of meetings throughout an LHCC week and clarified the expected attendance. Looking ahead to the next session of the LHCC, the open session will be somewhat extended, with presentations from FASER and XSEN in addition to the usual reports. The CMS in-depth review will take place on the Monday of the next LHCC week, with Focus session still being planned for the Tuesday.

2. Report from the Director of Research and Computing

The Director of Research and Computing (DRC) reported on issues related to the European Strategy process, the LHC and CERN in general. The briefing book reporting on the recent strategy meetings and discussions will be shown to CERN Council in about



two weeks and then become public. The DRC stressed the importance to stay in close contact with the funding agencies in following up on the strategy discussions and in defining the priorities going forward. LS2 is progressing well, however CERN resources, financial and personnel, are largely committed and priorities will be defined to ensure support for projects that must not be delayed. Hostlab responsibilities are currently defined until the end of next year. The priorities for 2021 and beyond will be discussed next year as part of the next Medium-Term Plan (MTP). The computing area has seen very nice developments on making the software more efficient in recent times. GPUs look promising as a cost-effective way to complement traditional CPUs to supply the computing needed for HL-LHC, however a software environment that can serve both architectures needs to be found to avoid double developments.

3. Report from the LHC Programme Co-ordinator

The baseline Run 3 beam configuration remains unchanged since the last LHCC and all experiments could be luminosity-levelled for the majority of each fill in the second half of Run 3. For luminosity levelling in ATLAS and CMS the plan is to use β^* levelling, which implies a change in the luminous region size by almost a factor of two during each fill. No significant impact of this has been found in studies by the experiments, although the studies are still on-going in ATLAS. CMS sees a small tracking efficiency loss in the forward region when the length of the luminous region exceeds 50 mm.

Further studies on the growing bunch-to-bunch luminosity spread during fills observed in 2018 have improved the understanding of the effect. It appears likely the effect could be partly mitigated during luminosity levelling and studies by CMS and LHCb show that only a small impact on trigger performance is expected. This has reduced the concern about this effect for Run 3, although the experiments still need to be prepared to handle large bunch-to-bunch luminosity variations.

If Run 3 is extended beyond 3 years, it will likely be necessary to switch to flat optics to reduce the integrated radiation dose for the inner triplets. This affects the acceptance of the ATLAS and CMS roman pots, in particular the acceptance is reduced to almost zero for the PPS diamond timing sensors in CMS. CMS therefore requests that round optics are used for as long as possible.

The possibility of injecting Oxygen into the LHC during Run 3 was discussed in the July LMC. No showstopper has been identified but work on infrastructure and additional effort would be needed in the injector chain. A formal working group to study Oxygen injections will therefore be set up by the IEF. Any run with Oxygen would likely happen in 2023, but it might be possible to advance this to 2022 if the slip-stacking commissioning in the SPS is successful in 2021. ALICE, ATLAS, CMS, LHCb and LHCf have all reiterated their interest in a short Oxygen-Oxygen and/or proton-Oxygen period through documents submitted to the LHCC. The luminosity needed for both an Oxygen-Oxygen and proton-Oxygen run is $O(1/nb)$ in both cases. This would be possible with less than one day of physics data taking for each type with the exception that LHCf has requested very low pile-up proton-Oxygen collisions which would require up to 40 hours of data-taking. Optimisations of the LHCf data taking request will be studied. The collision energy for Oxygen-Oxygen collisions is still under discussion, as it would be advantageous to run at the same per-nucleon energy as in PbPb, but this would require some additional setup time.

There is no agreement between the experiments on how the associated beam time (up to one week including setup time) should be assigned, with ATLAS preferring to take the time out of PbPb running, while ALICE and CMS prefer for any Oxygen run not to affect the baseline PbPb/pPb programme. The LPC would not like to reduce the time allocated for PbPb/pPb as this would reduce the delivered heavy-ion luminosity significantly and would consider an Oxygen run as one of the yearly special runs.

- The **LHCC acknowledges** the interest expressed by the experiments in Oxygen running **and expresses support** for such a run to take place during Run 3. The **LHCC follows** the LPC assessment to consider this a special run, and not part of the time allocated for the baseline PbPb/pPb programme. The **LHCC suggests** anticipating this run to 2022 if possible, to reduce the impact on the pp data set, assuming pp data taking efficiency will rise towards the end of Run 3.

4. Test Beams

In the East area the roof has been completed. The primary area has by now been fully dismantled, slightly ahead of schedule. The dismantling of building 251 is progressing well and should be completed by early September. Cooling/Ventilation and false floor installation will follow. In the North Area the GIF extension was completed in July on schedule. The new experimental area in H4 is being prepared, with currently the installation of gas lines for the NA64 experiment under way. ATLAS is removing the LAr cryostats from the H6 beam line, which will free an additional experimental area for H6 users. A follow-up proposal to the AIDA-2020 project is being prepared for submission to the EU in 2020. Fourteen EOIs have been submitted for the consolidation of the testbeam infrastructure, covering the maintenance and operation of the existing telescopes and associated software, and development of the next generation of telescopes with enhanced timing capabilities. Twelve more EOIs support the existing irradiation facilities, their instrumentation and common tools. In total 162 EOI have been submitted, covering a wide range of detector R&D and infrastructure topics, the selection has started by the proposal preparation team.

5. Discussion with ALICE

Scientific output and current activities:

- ALICE continues to deliver high quality physics results, with 8 papers submitted since the last session of the LHCC, bringing the total number of publications to 264. Recent results include a measurement of the global polarisation of Λ and $\bar{\Lambda}$ hyperons in PbPb collisions, a measurement of the $Y(1S)$ elliptic flow at forward rapidity in PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV and a measurement of the multiplicity dependence of light (anti-)nuclei production in pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV.
- The LS2 activities are progressing well and are on schedule.

Phase-I upgrades:

- An in-depth review of the ALICE Phase-I upgrades took place during the present session of the LHCC.
- The ITS project is on track. Assembly of the outer barrel is almost complete (75%)

done) and since May 2019 a 24/7 commissioning of the whole system is under way.

- Steady progress has been reported on the TPC upgrade. All MWPCs have been uninstalled, the A-side GEM installation has been completed and the C-side installation is ongoing. A TPC Sector test with final readout electronics and HV system is currently set up at P2. The committee is looking forward to first results from the TPC commissioning on the surface.
 - Good progress has been reported in all areas of the electronics upgrade. The tendering process for the production of CRUs in India was not successful, and the production of the corresponding cards needs to move to the European vendor.
 - The Muon System upgrade is progressing well, although there are still shifts in the schedule leading to a reduction of the contingency.
 - Good progress has been reported on the MFT upgrade: 70% of the ladders have been already produced and are undergoing qualification tests. Mechanics and services are well on track.
 - The FIT upgrade is also proceeding well: FT0C is now fully assembled, tested, and ready for integration. Delivery and tests of MCP-PMTs are almost completed. Assembly and commissioning of the whole detector is foreseen for the end of 2019. The FV0 are also almost complete and will be assembled at CERN for the end of 2019 as well.
 - A new Forward Diffractive Detector (FDD) will also be installed as part of the FIT upgrade, consisting of two layers of four modules each of plastic detector readout via WLS and PMT. A preliminary schedule has been presented. An updated and a final time plan will be presented at the next LHCC.
 - Good progress has been reported in all three sub-projects of the O2 framework. The First Level Processor (FLP) procurement is underway with the first batch expected for acceptance tests in September 2019. Physics and Data Processing (PDP) is managed under a new structure, coupled more strongly to analysis. The vertical slice test has been delayed due to procurement delays. A separate system for continual benchmarking of code changes has been set up. Prototype options for the Event Processing Nodes (EPN) are under test.
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- The **LHCC congratulates** ALICE on its continuing rich physics output, and in particular on the progress made on its upgrade programme, with all projects progressing well and on schedule, and in preparing for Run 3.
 - The **LHCC is impressed** by the new concept for the ITS3 with significantly reduced material budget, recognises the physics case presented in the LoI and in the dedicated ITS3 session and appreciates the on-going simulations on various physics channels to further demonstrate the expected gain from better resolution and efficiency at low transverse momentum. The **LHCC endorses** the plan of ALICE to carry out the necessary R&D studies to demonstrate the technical feasibility of this upgrade project. A TDR to be submitted on a timescale compatible with installation in LS3 will have to include in addition a comprehensive study of its physics gains with respect to the ITS2 detector.
 - The **LHCC recognizes** the good progress made in the muon upgrade but remains concerned about continuing shifts in the schedule and reduction of contingency.
 - The **LHCC expects** at the next session a set of benchmarks of the final algorithms, including clusterisation performance, on the final hardware options in preparation for the December EPN PRR.

- The **LHCC is extremely concerned** about the schedule for finalising the production of the CRUs. Additional delays will jeopardise the ALICE upgrade thus it is crucial that no further delays are accumulated. With the necessary move to the European vendor for the second production batch the **LHCC deems it essential** that the resources pledged for this production are being transferred immediately, to ensure all CRUs can be produced, tested and installed within LS2.

6. Discussion with ATLAS

Scientific output and current activities:

- ATLAS continues to make excellent progress on its physics programme, with 880 papers submitted to date, including 31 since the last LHCC. Recent new results include new measurements of the $H \rightarrow \gamma\gamma$ and $H \rightarrow 4l$ decays with the full Run 2 data set, the observation of Vector Boson Scattering in $ZZjj$ events, and the observation of a non-zero charge asymmetry at 4σ in $t\bar{t}$ events.
- Work on refurbishment of detectors (cooling loops, electronics, gas leaks) is progressing well on Liquid Argon, Tile Calorimeter and Muon system (RPC). Good progress has also been reported on readying the trigger for Run 3, in data preparation and in the transition of the software to multi-threading. The ATLAS software development grants have been rolled out successfully.

Phase-I upgrades:

- The Phase-I upgrades for LAr and TDAQ are making good progress. Delays accrued thus far do not appear to threaten the timely completion of these upgrades.
- There has been considerable progress made on the NSW since the last LHCC meeting. Many of the tasks of this project have been completed, with many others proceeding on schedule. Schedule extrapolations have become more reliable. There are no apparent showstoppers, however a larger number of items are still late, making the installation of NSW-A in LS2 as scheduled uncertain. Adding two months to the duration of LS2 would provide a significant buffer against the risk of failure, however this will still not guarantee that the installation of NSW-A will be possible in LS2.
- FTK has demonstrated the principle of track finding using pattern matching in associative memory banks at the LHC using a detector slice during Run 2. However unresolved hardware and firmware issues have prevented a fully running system so far. FTK currently aims to commission a down-scoped version with a processing rate of 35kHz in time for the Run 3 production years 2022/23. FTK is not part of the Run 4 detector. However, given that the running conditions in Run 3 are expected to be very similar to those in Run 2, and the increased performance of the HLT farm and algorithms, the physics case for FTK is diminished today with respect to the approval of the project in 2012. FTK is hence not the highest priority for ATLAS at this point. The resources needed for the high priority NSW and Phase-II projects have made it difficult to identify sufficient resources to bring the full system online at the beginning of Run 3. A set of key milestones has been defined by the ATLAS TDAQ Project Leadership, that will lead to the project being stopped if not fulfilled. A further necessary condition is to identify sufficient resources without impacting the high priority projects.

Phase-II upgrades:

- Five of the six MoUs have been finalized and sent out for signature to the funding agencies. The pixel MoU is in draft and is expected to be finalized by the October RRB.
- Submission of the TDR for HGTD is planned for April 2020; substantial R&D progress has been made.
- ATLAS is in the midst of evaluating the effects of the material due to the ITk pixel post-TDR lay-out. In order for this process to be thorough, it was not possible to complete it in time for the current meeting of the LHCC. A brief summary of the recent evolution of the ITk pixel baseline and material budget was presented, including the impact on event reconstruction performance and physics drivers. The most important results are expected to be available by the next meeting of the LHCC.
- The **LHCC congratulates** ATLAS on the large amount of new physics results produced, as well as the good progress reported on the upgrades and in preparing for Run 3.
- The **LHCC endorses** the plan of the ATLAS management decision to make a go/no-go decision for the installation of the NSW-A in LS2 after the review in November.
- The plan developed by ATLAS Management to deal with the problems posed by slow progress in FTK due to shortage of appropriate manpower is well thought out and represents a reasonable approach. The **LHCC endorses** the plan presented by the ATLAS Management.
- The plan proposed by ATLAS for moving ahead on determining the impact of pixel materials on forward detectors appears to be sound. The **LHCC looks forward** to the presentation of key results of the study at the next LHCC meeting.

7. Discussion with CMS

Scientific output and current activities:

- CMS continues to make excellent progress on its physics programme, with 910 papers submitted to date, including 28 since the last LHCC. Recent results include the first CMS results on $H \rightarrow cc$ in the VH channel, new measurements of the properties of $B_s^0 \rightarrow \mu^+ \mu^-$ and $B^0 \rightarrow \mu^+ \mu^-$ decays, and the first observation of $\Lambda_b \rightarrow J/\psi \Lambda \phi$.
- The LS2 activities are making good progress. The installation of the GE1 GEM chambers is on track. An extensive leak reparation campaign is under way on the accessible parts of the RPC system. So far 40% of the leaky chambers have been fixed, aiming for 50% by the end of LS2. The pixel refurbishment is making good progress. Good progress has also been reported on the P5 surface infrastructure project.

Phase-I upgrades:

- The only remaining Phase-I upgrade for CMS (in addition the pixel detector refurbishments) concerns the front-end electronics and photosensors of the hadron barrel calorimeter, which will follow closely the already complete upgrade of the

endcap calorimeter. All new readout and control modules have been installed. One half of the detector has been commissioning and is ready for ^{60}Co calibration. The commissioning on the other half is expected to finish before the end of September.

Phase-II upgrades:

- Most projects are entering the engineering design review phase, with the exception of the PPS, where the LoI is currently being written, and some projects with different TDR timescales (Level-1 Q1 2020, BRIL Q4 2020, DAQ/HLT Q2 2021). For the HLT part of the DAQ/HLT TDR, the collaboration requested and has received input from the committee on the level of concrete implementations needed for the TDR of new architectures and algorithms.
- The final UCG review of the MIP Timing Detector (MTD) TDR took place this week. The CMS collaboration should be commended for the very impressive and extensive work they accomplished to comply with the recommendations of the panels. The LHCC and the UCG review panels recommend the approval of the CMS MTD TDR.
- The **LHCC congratulates** CMS on its very productive physics programme as well as the substantial progress made on the upgrade projects and in preparing for Run 3.
- The **LHCC recommends** that CMS clearly defines a long-term strategy to deal with the occurrence and implications of leaks in some of the muon-system RPC chambers.
- Following the review by the LHCC and the UCG, the **LHCC recommends** the approval of the CMS MIP Timing detector TDR.
- The **LHCC is pleased** to see that the work on the radiation model for HL-LHC, that was started in the context of the MTD review, is becoming a longer-term effort going beyond MTD, involving all systems.

8. Discussion with LHCb

Scientific output and current activities:

- LHCb continues to have a rich scientific output, with a total of 490 publications to date, including 8 new papers since the last session of the LHCC. New results include a search for $K_S^0 \rightarrow \mu^+ \mu^-$, the observation of $\Lambda_b^0 \rightarrow \chi_{c1}(3872) p K^-$, and the observation of new resonances in the $\Lambda_b^0 \pi^+ \pi^-$ system.
- The LS2 activities are progressing well. The detector dismantling is completed, and all obsolete equipment has been removed. The installation of the upgraded detector has started. Good progress has already been achieved installing the detector services. The online farm is used for MC production.

Phase-I upgrades:

- Good progress has been reported on the Phase-I upgrades. The RICH, SCIFI, CALO, MUON and online computing projects are progressing well, with no significant problems reported.
- The schedule for the VELO is tight, but still feasible, if a production rate of 2 modules per week and site is reached.
- On the UT, version 3.5 of the SALT chip has been produced and tested with a

good yield of about 82%, resulting in enough chips to equip all 4-ASIC hybrids, covering more than 80% of the detector. ASICs on 8-ASIC hybrids need different power routing, addressed in version 3.8 of the SALT chip. The first wafer of these chips is just being tested. The correct functioning of the 8-ASIC hybrids still needs to be demonstrated. The installation schedule is critical.

Upgrade-II:

- The framework TDR for the proposed upgrade in LS4 is expected for the middle of 2021. This document will demonstrate that technologically feasible options for both detector and computing are available for the envisaged physics case, including costing options, schedule, and national interests. Individual sub-detector TDRs will then follow.
- The **LHCC congratulates** LHCb on its rich scientific output and commends the collaboration for the progress made on its Phase-I upgrade programme and in preparing for running during Run 3 and beyond LS4.
- The **LHCC commends** the collaboration on reaching a major milestone with the operation of the Real Time Analysis at the required HLT1 rate.
- The **LHCC is concerned** about the delays in the UT upgrade project and **supports** the LHCb and UT managements in considering alternative solutions, should problems appear with SALT version 3.8 for the 8-ASIC hybrids.
- The **LHCC encourages** LHCb to proceed with the preparation of a framework TDR for Upgrade-II to be submitted in 2021.

9. Discussion with TOTEM

The LHCC completed its review of TOTEM's Technical Design Report for a new T2 telescope. This detector, replacing the old T2, will contribute to the acceptance for inelastic events, whose rate is one of the ingredients of the luminosity-independent measurement of the total cross section using the optical theorem. The referees requested only minor clarifications, which have been satisfactorily addressed and documented in the final TDR. No relevant issues are left. The total cost amounts to approximately 90KCHF, of which 7.5KCHF will come from CERN, and the rest to be carried by Helsinki and INFN Pisa. The needed 6.5 FTE are already identified and active. The project does not present critical technical issues, it is well under control, and the schedule has ample margin for completion by Spring 2021, to allow for installation tests in situ before Run 3 starts.

A serious issue, first raised during the 138th LHCC meeting and still unresolved, concerns the input needed to finalize the positioning of the TOTEM/PPS roman pot detectors, following the realignment of LHC components around IP5. TOTEM/PPS renews the request of a document (equivalent to the ECR in terms of tracking and approval) relevant for the levelling of the PPS Roman Pot (RP) system during LS2. The RP system is an integral element of the LHC beam line and as such a misalignment would have implications on the relative position of the RP system to the other machine elements. To assure that the information is shared among relevant groups responsible for LHC optics and operation we propose that this document is forwarded to the LMC for approval.

- The **LHCC congratulates** TOTEM on the progress made on physics analysis and in preparing the TDR for the T2 detector.
- The **LHCC recommends** the approval of the T2 TDR.
- The **LHCC notes** that the pending issue of the positioning of TOTEM and PPS Roman Pot units has become of critical urgency, and a formal response and documentation must be provided as soon as possible.

10. Discussion with WLCG

WLCG and the experiment computing systems are working well. Due to the ongoing shutdown the operations have been calm in recent months, however the resources are being used fully for reprocessing, simulation and analysis. Reasonable estimates are available for the Run 3 resource needs, which need to be further consolidated, potentially making greater use of High-Performance Computing. Work is on-going on software R&D and on Data Organisation, Management and Access (DOMA) for HL-LHC, which needs to converge in preparation for the upcoming review of the HL-LHC computing strategy in spring 2020. Progress has been made towards the definition of this review, with Amber Boehnlein (JLAB) identified as panel chair by the LHCC chair and the DRC. Concrete planning of the review will now begin. The next WLCG/HSF workshop will take place in May 2020 and a special workshop on open data resources is foreseen before the end of 2019.

- The **LHCC congratulates** the WLCG and the experiments on the successful and efficient use of the computing resources.
- The **LHCC encourages** the experiments to stay in close contact with the funding agencies in discussing what can be purchased under a flat budget requirement in which country.
- The **LHCC strongly encourages** the experiments to maintain and even increase their efforts on software and computing model development as the most promising method of reducing the resource needs in the future. In particular the experiments should search for solutions across all experiments whenever possible to further optimise the use of resources and effort.

11. Report on XSEN LoI

An LoI was submitted by the XSEN (X Section of Energetic Neutrinos) collaboration, that aims to measure high energy neutrinos coming from W and b, c decays. XSEN proposed an experiment to be placed in the TI18 tunnel, covering a pseudorapidity range with high sensitivity to charm decays. The experiment is performed in two stages. An initial Pilot Run in 2021 with a smaller detector and limited pseudorapidity that will collect about one hundred high energetic neutrinos. A second stage is expected to start in 2022, depending on the outcome of the Pilot Run, which can collect up to two thousand interactions of high energy neutrinos and up to a hundred tau neutrino events. The Pilot Run will allow to measure the background in situ, how long the emulsions can be exposed, the handling of the emulsions from preparation to development, logistical details such as the installation, laboratories for preparation and scanning of the emulsions and finally analysis (e.g. analysis sequence and reconstruction).

It was noted that at the present LHCC meeting there is also a proposal from FASERv with a complementary pseudorapidity range.

The committee observes that XSEN is a small project with an interesting and well-motivated physics case, with minimal impact on the machine and good staging scenario, from pilot run with B2 only, to full XSEN system with B1 and B2, with further possibilities for extensions to broaden the physics reach. The resource requests from CERN are minor. Detector construction, operation and analysis will mainly rely on resources available in the SHiP collaboration.

The next step should be the preparation of a Technical Proposal (TP) for the Pilot Run, which should clarify the collaboration membership and the organisational structure, the agreement on the usage of resources and which ones would be available for the Pilot Run, as well the responsibilities of the participating institutes and personnel. In addition, the TP should include a further development of the physics case. This refers in particular to the knowledge of the beam flux, the information from the Pilot Run and how it will be used for the physics case, the expected physics outcome for the Pilot Run and the possible physics reach of the experiment beyond the Pilot Run.

- The **LHCC recommends** for XSEN to submit a Technical Proposal on the pilot run with only the B2 detector for the November LHCC meeting.
- The **LHCC recommends** investigating a possible collaboration with FASERv on topics of common relevance, e.g. the simulation of the transport through the machine elements and rock, and their impact on backgrounds and neutrino flux.

12. Report on FASER

The LHCC received a comprehensive update on the status of the collaboration and of the construction work. The update was accompanied by a detailed breakdown of the schedule and of the evolution of the costs. Over 50% of the construction budget has been spent, and the costs remain within 10% of the technical proposal estimates. New institutions and collaborators have joined, giving confidence that the collaboration has reached the critical mass required to carry out the project. Few items pose now some concern: the limited time contingency for the magnet production, and the timely readiness of the full tracking system to allow for a system test before final installation. However, the project is not on a critical path. The LHCC congratulates FASER for the great progress on all fronts.

As anticipated in the previous LHCC meeting, FASER is considering the addition of a detector element, to enable the measurement of neutrino cross sections. A document was presented detailing the FASERv project: a stack of emulsions and tungsten slabs, with a total mass of 1.2 t, located in front of the FASER detectors. The civil engineering work required to accommodate this detector has already been included in the FASER plan and will be carried out as part of the trench excavation expected to take place in early 2020. During Run 3, over 1000 ν_e , 20000 ν_μ and 20 ν_τ interactions are expected. The energy spectrum of these events, in the TeV region, allows in principle the measurements of the neutrino cross sections in an energy range complementary to all existing data. A pilot run, carried out with a 30kg detector installed in the TI18 location during the 2018 run, provided valuable information on the expected backgrounds and hit-density rates expected in the emulsions. Candidate neutrino interactions have been observed, and further analysis is expected to lead to a first observation of neutrinos from the LHC collisions. The LHCC finds the scientific case for these measurements to be compelling

and encourages the FASER collaboration to prepare a technical proposal, to be reviewed at the next LHCC meeting. The TP must address, in particular, the following aspects:

- The definition of installation and removal/replacement procedures, including radio-protection implications.
 - The impact on the FASER collaboration of the extra load of work, during planning, construction, installation, data analysis, maintenance, etc: the approved FASER programme must not be penalized.
 - Significant new financial resources are needed for this project. One-off grants available for the construction must be complemented by institutional commitments to carry out the full scientific programme. There must be a robust financial plan going beyond the construction phase, and including the running costs, maintenance and operations, processing of emulsions, data analysis and storage, etc.
 - The neutrino flux normalization is a key element of the cross-section measurement. This calls for more in-depth studies of the current projected systematics, as well as of possible means to reduce the systematics using FASERv data themselves (e.g. the muon flux), or other data (LHCf, LHCb, ...)
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- The **LHCC congratulates** FASER for the great progress in all areas of the project.
 - The **LHCC encourages** FASER to submit a Technical Proposal on FASERv for the November LHCC meeting.
 - The **LHCC encourages** FASER to cooperate with XSEN on issues of common interest, e.g. the simulation of the transport through the machine elements and rock, and their impact on backgrounds and neutrino flux.

13. Report on R&D Projects

The currently active RD Collaborations have presented their longer-term plans and extension requests at the LHCC meetings in May 2018 (RD42, RD50, RD51) and September 2018 (RD53), and have been granted 3 year (RD42, RD53) and 5 year (RD50, RD51) extensions in the subsequent Research Board meetings as requested. The LHCC heard status reports from the R&D projects:

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

- The RD42 collaboration is commended for its excellent progress in design, fabrication, testing and performance of pCVD diamond detectors, both in planar and 3D technologies. Recent results include the demonstration of the rate independence of pCVD material for fluences of up to $8 \times 10^{15} \text{n/cm}^2$.
 - The LHCC notes the progress in the ongoing collaboration with ATLAS on beam condition monitors and welcomes the emerging new collaboration with CMS.
 - Among the goals of the extension period are 3D diamond sensor fabrication and characterisation, proof-of-principle for diamond-based HL-LHC beam monitoring devices, further development of pCVD material and the development of 3D diamond pixel module prototypes.
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- The **LHCC recommends** continuing the RD42 collaboration, including CERN

support at the level currently provided (access to CERN facilities, lab and office space, test beams when available).

- The **LHCC is pleased** to see that, as requested last year, the information and results on the collaboration web site have been fully updated.
- The **LHCC encourages** RD42 to keep sustaining close links and commonalities with the LHC and future collider infrastructures and experiments. The **LHCC encourages** RD42 to take the opportunity of their new collaboration with CMS to gain access to FNAL test beams (“high” energy protons), in particular while the CERN test beams are in shutdown.

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

- RD50 is a diverse but well-structured collaboration, with four separate activity areas on defect and material characterisation, detector characterisation, new detector structures, and the construction of full detector systems. RD50 has strong ties to the LHC experiments, which have already benefitted significantly from RD50 developments, in particular for the HL-LHC silicon detector upgrades. The collaboration is commended for its excellent progress over the last year.
 - Recent highlights include the proof of concept of a table-top TPA-TCT system, which allows for scanning of silicon sensors with excellent 3D spatial resolution, studies of the time resolution of LGAD sensors as foreseen for the timing layers in ATLAS and CMS and a workshop on radiation effects in LHC experiments.
 - The milestones of the programme underway have been largely achieved, with some well-motivated changes and delays. The RD50 model of collaboration between institutes and industry works remarkably well even with minimal funding (2kCHF/year per institute). The relation of the collaboration to the R&D initiative of the CERN EP-Department has been clarified and the access to the solid state detector lab secured.
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- The **LHCC recommends** continuing the RD50 collaboration, including CERN support at the level currently provided. Progress will be reviewed every year by the LHCC. The **LHCC considers** the structure of RD50, with a small but focussed core team and corresponding infrastructure at CERN, and many expert collaborators from around the world, to be an excellent setup. The **LHCC notes** that the CERN contribution to RD50 (access to facilities, person power) is crucial, and **strongly encourages** CERN to maintain its support of RD50.

RD51: Development of Micro-Pattern Gas Detectors Technologies

- RD51 is an established collaboration with the aim to develop Micro-Pattern Gas Detector (MPGD) technologies, to support experiments using this technology, and to disseminate the technology within particle physics and in other fields. The collaboration is well organised into seven working groups covering activities from new detector structures and electronics, to modelling, test facility management and industrialisation.
- Recent activities include the development of detectors with picosecond timing resolution, fast optical readout for GEM detectors and μ R-Well structures with

gain and rate capabilities sufficient for HL-LHC applications. The committee congratulates the collaboration for its progress since the last review session.

- The **LHCC recommends** continuing the RD51 collaboration, including CERN support at the level currently provided. The **LHCC considers** the working mode of RD51, with a small but focussed core team and corresponding infrastructure at CERN, attracting contributions and bright ideas to be explored from collaborators around the world, to be an excellent setup. The **LHCC notes** that the CERN contribution to RD51 is crucial for the collaboration, and **strongly encourages** CERN to maintain its support of RD51.

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

- The RD53 collaboration, after achieving the RD53A demonstrator chip at the end of 2017, has continued to make very good progress towards providing ATLAS and CMS with fully functional readout chips.
- Contrary to expectations last year (a common design for ATLAS and CMS with only different pixel matrix sizes) there will be two different analog front-ends, which will require more testing than expected but should not be problematic.
- RD53 will continue to work as a whole collaboration: CMS groups will be involved in testing and verification of the ATLAS chip to be submitted this month, and ATLAS groups are also fully committed to finalising the CMS chip. Regional readout, which is being considered as an option in ATLAS, has been left for a possible second version of the chip, to not delay the submission of the first version.
- The **LHCC recommends** continuing the RD53 collaboration, including CERN support at the level currently provided, which is crucial. The **LHCC strongly supports** that the current operation of RD53 as a single design team be continued and reinforced. Institutions involved are urged to keep the current (number of) experienced people fully committed until the end of the project, i.e. until fully functional production chips are available for both ATLAS and CMS.

14. General Comments

The following comments are applicable to more than one project.

- The **LHCC is pleased** that on August 23rd, 2019 the frame contract was signed between CERN and Hamamatsu for the production of the silicon sensors for the CMS and ATLAS trackers and the CMS HGCAL.
- The **LHCC encourages** CERN to keep strengthening its effort and support to the community in microelectronics. Special care should be taken that common projects like the lpGBT do not cause schedule delays.
- The **LHCC notes** that the CERN contribution to common costs and the Hostlab budget demands and constraints should be clarified for the coming years as soon as possible between CERN and the experiments, with clear priorities defined. A particularly critical area is infrastructure work related to services for the HL-LHC detectors already under way in LS2, such as the surface buildings at P5.

15. REFEREES

The LHCC referee teams for this session are as follows:

ALICE: G. Casini, J. Dunlop, P. Salabura, C. Sfienti (Co-ordinator)

ATLAS: V. Beckmann, R. Calabrese, F. Di Lodovico, W. Wisniewski (Co-ordinator)

CMS: D. Glenzinzi, E. Kajfasz (Co-ordinator), A. Kuzmin, D. Waters

LHCb: C. Hearty, P. Krizan (Co-ordinator), K. Krüger, M. Kuze

LHCf, MoEDAL, TOTEM: A. Kuzmin, F. Di Lodovico, M. Mangano (Co-ordinator)

LCG: V. Beckmann (Co-ordinator), J. Dunlop, M. Kuze, D. Waters

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

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

R&D projects:

RD42: E. Kajfasz

RD50: K. Krüger

RD51: C. Hearty

RD53: R. Calabrese, E. Kajfasz

16. The LHCC received the following documents:

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| CERN-LHCC-2019-006 | Minutes of the one hundred and thirty-eighth meeting of LHCC held on 5-6 June 2019 |
| CERN-LHCC-2019-007 | Upgrade of the TOTEM T2 Telescope, Technical Design Report |
| CERN-LHCC-2019-003 | A MIP Timing Detector for the CMS Phase-2 Upgrade |
| CERN-LHCC-2019-011 | Letter of intent: XSEN |
| CERN-LHCC-2019-012 | Letter of intent: FASER ν |

DATES FOR LHCC MEETINGS

Dates for 2019

27-28 Feb

5-6 June

11-12 September

20-21 Nov

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