B-factory Programme Advisory Committee
Full Report for
Focused Review Meeting on LS1

13-14 November 2023

P. Collins* (CERN), G. Corti (CERN),
M. Demarteau (ORNL), R. Forty (CERN), B. Gavela (Madrid),
S. Gori (UCSC), M. Ishino (Tokyo), V. Luth (SLAC), P. Mato* (CERN),
F. Meijers* (CERN), N. Neufeld (CERN), B. Ratcliff* (SLAC),
A. Petrov* (Univ. South Carolina), M. Sullivan (SLAC),
H. Tajima (Nagoya), M. Titov* (Saclay)
and chaired by T. Nakada (EPFL)

* Expert member.

21 January 2024

1 Short summary

A focused review meeting of the B-factory Programme Advisory Committee (BPAC) took place on the 13th and 14th of November 2023, in remote mode, with the following charges:

- *Are all LS1 works properly completed?*
- *Are the preparations for Run 2 being addressed and planned appropriately?*
- *Are we ready to use run dependent MC for physics analyses targeting winter conferences?*

Here are the responses of the BPAC to those questions.

The LS1 work for the machine, i.e. the injector complex and SuperKEKB rings, has been successfully completed. Extensive consolidation and improvement work should lead to more stable machine operation with increased luminosity compared to that achieved during Run 1. The committee considers that a goal of achieving luminosities above $10^{35}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ is realistic. The committee appreciates that the major Belle II LS1 work, such as the installation of the new pixel detector (PXD2) and replacement work of photon detectors for the barrel particle identification system (TOP), has been successfully completed. Completion of replacing the old DAQ modules from the Belle era with

more performant modules is also well appreciated. Concerning the incident encountered during the insertion of the superconducting quadrupole focusing magnet (QCS) in the forward region, where the QCS hit the cable cage, it was fortunate that no serious damage occurred to the cables. This, nevertheless, delayed the start of Run 2 towards the end of January 2024. The committee thinks that the incident could have been avoided by paying more attention to the installation procedure and should be reflected in the future work. Although a little more work is left to complete the LS1 detector work, the BPAC is confident that it will be completed by the revised Run 2 starting date.

The committee considers that the commissioning plan for the machine has been well thought out and adequately developed. With many changes introduced in the machine, commissioning must proceed cautiously and the plan to start with β_y^* at 1 mm and gradually reducing to 0.8 mm is very much appreciated. The Belle II detector commissioning plan also appears to be in good shape. Monitoring, error detection and error handling must be reviewed and well tested before the start of Run 2. Onsite detector experts must be secured during the commissioning period.

The Belle II collaboration has reconfirmed their commitment to use run-dependent simulated data for the analyses to be presented in the winter conferences. The necessary computing environment and production tools are in place, though some issues related to data fragmentation and the corresponding need of many user jobs to access data still exist. The committee would like to see the actual production plan and progress during the next review in February 2024.

In conclusion, **the committee's responses are positive for the three questions of the charge**.

Here are some important additional reflections on the subjects presented during the review meeting. Much more detail can be found in the following sections.

Operation of the two PXD2 ladders, which exhibit limitations in the gliding mechanism, must be carefully planned. This is important not only for those ladders themselves but also for the whole PXD2. Tests with the mock-up detector would be very useful.

For the DAQ, outstanding installation of optical links is important and the work should be pursued.

Various trigger algorithms are now in place. The committee thinks that they are sufficient to cope with evolution of the running conditions resulting from the increasing luminosity.

While the ageing problem of the Central Drift Chamber appears to be under control, careful monitoring of the water content in the gas mixture should continue. The committee is looking forward to hearing the progress with work on the laboratory ageing test that is now ready to start.

The committee understands that the ammonia treatment for the damaged Resistive Plate Chambers of the K-long Muon detector system could be done in an isolated gas environment. However, even a very small amount of residual ammonia in those chambers could damage the other chambers, once those chambers are put back into the normal gas circuit. The collaboration must be absolutely sure that any intervention will not damage

the other chambers and a review that includes external experts should be conducted before making a decision.

For the calibration, the BPAC supports the policy to keep data processing at a single dedicated site rather than using distributed sites. Long-term maintenance of the workflow management tool based on Airflow is uncertain due to the departure of an expert. A solution should be developed by consolidating with other Belle II computing tasks that use different workflow management tools.

Continuous effort by the Belle II collaboration to gain further understanding and improvement of the detector performance is highly appreciated. The committee would like to hear in-depth presentations, in particular those on the responses of sub-detectors, during the next meeting in February 2024.

Physics analyses have been producing many very interesting results. The committee is looking forward to seeing further exploitation of the Run 1 data and combined analysis results with the Belle data.

An upgrade project to introduce longitudinal beam polarisation in the Belle II experiment is considered to be a very interesting option by the committee. However, this should be judged together with the other upgrade projects being considered by the collaboration, and weighed against potential disturbance of the approved programme. In order for the BPAC to provide its opinion, an overall comprehensive upgrade plan for the machine and the Belle II detector with well-defined physics objectives would be required. The committee is looking forward to receiving further information in future meetings.

2 Accelerator and machine detector interface

2.1 Status

With an impressive peak luminosity of $4.65\times10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$, SuperKEKB is now the highest luminosity collider. However, the accelerator is aiming for even higher luminosity goals well above 10^{35} and ultimately $(5-6)\times10^{35}$. The accelerator is now in ?new territory? and has found several issues impeding progress toward higher luminosity. During LS1, a great deal of work has been accomplished in addressing the various challenges going forward. The LINAC did not have a long shutdown and continued delivering beam to the Photon Factory. However, during the regular summer shutdown period, the LINAC has been improved with pulsed quadrupoles that will allow for pulse-to-pulse optics optimisation. This should improve reproducibility and reliability of injection. The injection point into the Main Ring for the HER has been enhanced with a larger aperture beam pipe and a new septum magnet with improved magnetic field. In addition, studies were conducted to test beam tuning by machine learning, which was proved to be effective. This may be effective to improve injection quality and to reduce injection-related backgrounds.

The accelerator and Machine Detector Interface (MDI) teams made a number of improvements for the IR and for both rings of SuperKEKB. The damaged collimator jaws have all been replaced and extra spares have also been made. The nonlinear collimator has been installed in the LER. Improved shielding has been successfully installed near the

front of the QCS magnets close to the IP. More beam-orbit-recorders have been placed around the rings. A new central beam pipe with the completed PXD detector has been installed and is expected to reduce the synchrotron radiation background for the PXD. Work is ongoing to further reduce the beam abort time. Acoustic monitors have been placed at various locations to look for sound waves in the vacuum chamber produced by a possible arc inside the vacuum chamber. The number of loss monitors has been doubled and now includes loss detection for the HER beam as well. The accelerator and MDI teams have formed a cohesive partnership that has proven to be beneficial to both the accelerator and to the detector. The committee recognises this important step and looks forward to further collaborative efforts leading to improvements in performance for both the accelerator and for the detector.

2.2 Concern

- Cause for the sudden beam loss events is still not understood. With increased beam currents, these events will most likely happen more frequently.
- There are still mysteries concerning beam emittance blowup in the beam-transport lines.

2.3 Recommendation

- Continue to improve recovery time from a sudden beam abort. If the sudden beam losses happen without damaging equipment, it is important to shorten the recovery time in order to maximise integrated luminosity.
- Continue to try understanding the emittance issues with the beam-transport lines.

3 Belle II detector

Major work on the Belle II detector has been successfully completed during LS1, including the installation of the new pixel detector (PXD2) and replacement work of photon detectors for the barrel particle identification system (TOP). Details were presented at this BPAC review for the VXD, CDC and KLM systems, which are discussed below along with a summary for the TOP.

3.1 Vertex detector (VXD)

3.1.1 Status

The VXD team is to be congratulated on the successful installation of the full detector during LS1. After extensive testing of the half-shells and the full detector in the clean room, including the SVD, the VXD was installed on 28 July, 2023. The detector was then cabled up and its performance was tested using cosmic rays. On October 4, the QSC was inserted and the remote vacuum coupling (RVC) was found not to lock. The investigation into the cause revealed that the PXD cables were slightly damaged and

the RVC had hit the cable cage due to a misalignment by a few mm. The RVC front wheel was modified to gain space and both QCS insertions were successfully completed on October 23 and 27, respectively.

All 40 sensors are working well and the noise performance, pixel charge and hit efficiency is as expected and similar to the pre-LS1 performance. The overall hit efficiency is greater than 98%. Also the environmental sensors, such as the radiation sensors, and fibres are working properly. Observed "features" in the sensor performance correspond to known issues. The team should be congratulated on having very successfully installed the full complement of PXD ladders and the VXD safely without loss of any sensors.

Although the detector has been installed successfully, there remain several concerns. Two ladders at positions L2.7 and L2.8, are bent with a sagitta of about 1 mm, which was already observed at DESY. This is attributed to a compromised sliding mechanism. In the worst case scenario, where one of the bent ladders is not powered and the adjacent bent ladder powered normally, they could touch at the glue joint. The running strategy to mitigate any issues with the bent ladders is still to be decided. Furthermore, a second short was found between the heavy metal shield and the beam pipe. The cause of the short is uncertain, but seems to be related to damaged isolation of a water cooling pipe. A short between the PXD and the beam pipe was already uncovered during the installation of the ladders. The grounding scheme has been revised and a solid ground connection to the machine ground is to be installed. No adverse effects are anticipated.

To mitigate the effect of the bowing of the two bent ladders, changing the operating temperature of the PXD2 is being considered. At the previous review an operating temperature of -25 °C was being considered. Now an operating temperature of -30 °C is being contemplated.

3.1.2 Concerns

- The bowing of ladders and the open issue of how to power the ladders remain a concern. At our last review it was suggested that a small working group of experts of the affected systems be appointed to evaluate the full impact of this change. At this brief review no update was provided.
- The grounding of the PXD2 to the beam pipe seems to have no adverse effect, but further studies seem warranted.
- Preservation of the knowledge, which lead to the successful installation of the detector needs to be guranteed.

3.1.3 Recommendations

- Continue to study the ladder bowing as best as possible, understand its behaviour and develop mitigation strategies.
- Decide, after careful study, a safe operating temperature of the detector.

- Document in full detail the as-built PXD2 detector (repeat of the July recommendation).

3.2 Central drift chamber (CDC)

3.2.1 Status

Several CDC upgrades have been successfully accomplished during LS1, such as resistor replacement in the HV dividers to decrease the voltage drop, a hardware repair to fix HV trips in a few sectors, and readout electronics software updates for the SEU controller of the FPGA and for error handling. Significant LS1 improvements have been made for the CDC gas system: e.g. implementation of gas condition monitoring and hardware changes for safety operation, increase in the number of outlet ports from four to eight to improve uniformity of gas distribution and replacement of the tube causing large pressure drop to allow for a higher flow rate. CDC DAQ has been also migrated to PCIe40 from the old COPPER system in LS1.

The gas condition and CDC performance is recovered and better understood after a large leak occurred in September 2022. Relative/absolute pressure and oxygen/water content measurements are now included into the monitoring system for control room shift personnel and detector experts. Additionally, a pressure sensor nearer the detector with a wider sensing range and a gas dryer system for long-term usage will be installed. Additional CDC performance monitoring, in particular, gas gain through ADC median and dE/dx and tracking efficiency is being implemented. The baseline amount of water content for physics running will be determined by considering the CDC performance and HV conditions. Analysis of cosmic-ray runs in 2023 shows that the intrinsic spatial resolution of the CDC in September-October 2023 is quite similar to the resolution in 2017. Note, the former was taken at $B = 0$.

The ageing test is almost ready to start. Some constraints exist from time-sharing with other groups and maintenance of the irradiation facility. The schedule is being optimised based on the availability of the ageing setup and human resources, which were reinforced thanks to participation of Kyoto University and RIKEN personnel. The first irradiation target is to achieve 0.1 C/cm with beta-ray source (^{90}Sr with $\sim$ 30 MBq), which is the approximate accumulated charge in the CDC innermost layers until run period 2022b. The final target is to irradiate the test chamber up to 1 C/cm, which will take between 3 and 10 months of irradiation, depending on the source intensity and operating conditions. Chamber current, as well as water and oxygen content, will have to be monitored during the entire campaign. Regular pulse-height measurements with a ^{55}Fe source, at irradiated and reference spots of the wire to compare gas gain, are envisaged.

3.2.2 Concerns

- The reason for the water content currently increases by 60-70 ppm/day without the gas dryer system is not understood. Water might be accumulated in some parts of the gas system, outside of the CDC.

- For the physics and cosmic-ray runs between 2017 and 2022 data, better understanding of the correlation between the water content and CDC gas gain needs to be developed.

3.2.3 Recommendations

- Define the target water content for Run 2 operations by considering HV conditions and CDC performance. It is recommended that the amount of water should not be less than 1300 ppm. Careful monitoring of any sporadic activity in the chamber, e.g. increased sparking rate or leakage current, needs to be implemented as the water content decreases.

- The optimal set of operating conditions during the test chamber irradiation have to be identified and finalised. Careful monitoring of parameters during the ageing test and regular ^{55}Fe pulse-height measurements at irradiated and reference wire spots have to be done.

3.3 Barrel particle identification system (TOP)

3.3.1 Status

In the period preceding the June meeting, the TOP group successfully performed the planned LS1 replacement program for the PMTs, and exchanged and repaired the front-end electronics, all within the scheduled time frame. This excellent work was discussed in the June report.

Additional projects for TOP operations are underway to improve the data taking efficiency in the coming run at higher luminosities. These includes TOP boardstack recovery while running, and bringing the TOP to a non-zero HV during standby so that the transition back to full HV is faster than during the Run 1 data taking.

The PMT quantum efficiency (QE) measurement program at Nagoya University was very active in characterising the PMTs taken out from the detector during the installation period. A clear correlation was observed between the bench measurements at the university and those measured by the detector monitoring. However, the slope in the ratios between the two measurements was different from unity, and neither this nor the effects of temperature on PMT efficiencies were understood by the June meeting. No update was provided at this meeting.

3.3.2 Concerns

- As further PMT production is needed. This already underway and it would be helpful to present the production and testing plan at a future BPAC meeting.

- Although not a focus of this meeting, the overall performance of TOP still seems to be not yet fully understood.

3.3.3 Recommendations

- The differences in QE measurements between the bench and the detector monitoring need to be understood.
- Efforts to better understand the loss of PMT QE, and especially to understand and mitigate the effects of temperature on the PMT efficiencies, should continue.
- Increased contributions from the TOP group to characterise the performance at the detector level would be very helpful.

3.4 K-long muon detector (KLM)

3.4.1 Status

Low efficiency of the RPC BB2 layers began in June 2021 when the gas circulation was interrupted. The continuous operation under water vapour contamination may have caused damage of the RPCs. It was confirmed that circulation of fresh gas with high rate during 2021-2022 did not cure the efficiency problem.

The degradation of the physics performance due to the low efficiency of RPCs was determined. The muon identification efficiency in this particular region, BB2 and BF2 corresponding to 1/8 of the barrel system, is lower by 10% for low-momentum muons below 1.0 GeV/c, while there is no visible impact on the K_{L} identification. The effect has been taken into account for the run-dependent simulation samples and when physics analyses are performed.

Preparation for recovering the efficiency by flushing the chambers with a gas mixture containing ammonia is progressing. The first step is to learn the recovery procedure using test RPCs and then, if the tests are successful, apply the method to the damaged RPC layers. In the last June 2023 BPAC meeting, it was reported that the efficiency drop was reproduced when the test RPCs were operated with water vapour contamination, and a recovery of efficiency from 10% to 70% and a modest recovery from 5% to 20% were reported on the two test chambers, respectively. Additional tests on three test chambers were performed and a modest recovery from 10% to 50% were obtained.

The KLM group is reinforcing slow control monitoring and data monitoring to find similar problems in real time in the future. The gas flow for each inlet and outlet line will be monitored for a total of 832 channels. All of the monitoring system is installed and the system commissioning is progressing. Integration to the alarm system should be completed.

3.4.2 Concern

- The benefit of the treatment with ammonia gas on the test RPCs is observed but the efficiency is not fully recovered in most of the cases.
- A small amount of residual ammonia after treatment could damage the other good chambers.

3.4.3 Recommendations

- Further comprehensive and systematic studies of all the test RPC chambers should be performed to draw a conclusion on whether the inefficient layers should be treated with ammonia gas.
- A review including external experts should be held before starting the ammonia gas treatment, to be sure any intervention will not result in damaging the other chambers with good performance.

4 Online and trigger

4.1 Data acquisition, detector control and operation

4.1.1 Status

The transition to the new PCIe40 based readout of the detector back-end systems has been done for the SVD, CDC, ECL and TRG systems during LS1 and is now complete. The old COPPER system is still available as backup in case of serious problems. The event building scheme has been changed from using FPGA on-chip memory in the PCIe40 cards to PC server memory giving a much larger buffer capacity. High throughput tests gave an event rate in excess of 30 kHz.

The HLT processing capacity has been increased during LS1 from 10 to 13 units. The HLT13 unit is successfully used as evaluation unit for development and testing for the time being. This brings the total to about 6200 CPU cores. After tuning the reconstruction software, the HLT processing power has been studied as a function of luminosity and estimated to be capable of handling about 20 kHz at a luminosity of about $9 \times 10^{34} \mathrm{cm}^{-2} \mathrm{s}^{-1}$, with some margin when enabling hyperthreading.

A new HLT software framework has been introduced. This framework has the capability to recover from processing faults without starting a new run. Furthermore, the event builder to HLT communication has been enhanced to allow a partial (SALS) restart, which reduces the restart time.

The revision of the online data recording and transfer to offline has been completed. The HLT records file in the ROOT format directly, rather than serialised ROOT (SROOT) avoiding a later conversion in offline. Furthermore, the protocol for the transfer between online and offline has been revised and the file handling process has been improved by merging small files already online.

All the above mentioned enhancements to increase performance, functionality and robustness have been commissioned and will be the baseline for Run 2. A large number of test involving the full chain from detectors to offline have been performed during LS1.

The committee took note of the continuation of the provision by collaboration M&O funds of three persons working on core DAQ. Two positions were refilled this year. This scheme appears to be effective.

4.1.2 Concern

No particular concern.

4.1.3 Recommendations

- The DAQ together with trigger and readout sub-detector groups have put a lot of effort in improving the system. This should be continued. For example, the TOP system is considering to migrate the processing from the front-end SoC (System on Chip) to the readout PC, to improve robustness against SEU.

- The reliability of the b2tt copper links used for synchronisation and trigger throttling has been a long-standing concern. The DAQ and Trigger have studied a replacement with optical connections between the FTSW and PCIe40 boards. A prototype using the Arria10 GPIO port is under test. These tests should be pursued. If successful, a full replacement could be envisaged during the 2024 summer stop.

4.2 Trigger

4.2.1 Status

Several developments have been done to enhance the trigger performance for low multiplicity physics channels. The primitives from the CDC subsystem trigger have been improved, as well as the 2D tracking. The firmware is ready for the start of Run 2. Furthermore, implementation of conventional and neural net 3D tracking has progressed and is expected to yield a 50% reduction of the beam back ground away from the IP. It needs testing and commissioning.

The Bhabba veto has been studied and optimised with better radiative Bhabba reduction with only a slightly reduced endcap acceptance.

A neural network based tau-tau selection has been implemented in the GRL (Global Trigger Logic) with about a factor two better rejection compared to the cut-based trigger condition.

A new development is the displaced vertex trigger based on the CDC. It has been studied by simulation. The implementation in firmware has started and is aiming for next summer.

The collaboration did a substantial effort evaluating trigger strategies for the coming run, in particular improving the sensitivity to low multiplicity channels. Starting with the trigger menu of 2022, the rate after LS1 has been estimated taking into account improvements in the trigger firmware and increased pre-scaling for calibration and control trigger conditions. A decrease of the trigger rate from about 12 kHz by a factor of about two is expected at the same beam conditions.

The injection veto has been studied with a special non-veto run taken in 2022. Using the hit occupancy of the ECL and CDC trigger sub-systems, a new veto has been developed that has the potential to reduce the dead time from 8% to 2–3%. The firmware and software is planned to be ready by the coming physics run.

4.2.2 Concern

- It is difficult to estimate at which luminosity the DAQ limit will be reached. Although the trigger rate has been studied with 2022ab data as a function of luminosity, it proved difficult to estimate the trigger rate for higher luminosity due to the dependence on the background situation and the extrapolation model.
- Progress has been made with the injection veto with the promise of a substantial dead time reduction. However, the effect on trigger rate, DAQ stability and detector data quality remains to be assessed while commissioning.
- Although some progress has been made with identifying long-term institutional commitments for the trigger sub-systems, the situation remains worrisome.

4.2.3 Recommendations

- It is encouraged to test and commission the new trigger enhancements as soon as possible taking advantage of the possibility to run those in parallel with the well established trigger conditions.
- Commission the new injection veto as soon as possible in the coming physics run.

5 Performance

5.1 Status

The detector performance has been studied in detail during LS1. The committee is impressed to learn that Belle II has measured the tau lepton mass with the world's best precision using only 190 fb^{-1} of data, thanks to better efficiency and mass resolution, and smaller systematic uncertainty associated with beam energy and momentum scale.

The committee is also pleased to learn that agreement between the data and simulation has been improved. The data-simulation ratio was improved from 63% to 80% in the FEI study (Full Event Interpretation).

On the other hand, a couple of bugs were found in the KLM and ECL reconstruction software. The effects of the KLM bug can be seen in the $J/\psi K_{\text{L}}$ efficiency loss of as much as 50% and the veto efficiency for $e^+e^- \to \gamma\gamma(\gamma)$ backgrounds in the dark photon search.

Another systematic issue was found in the electron ID efficiencies where the muon-electron ratio varies with the electron ID requirements, indicating the electron efficiencies were not properly understood. Improper treatment of the HTL prescales caused an ECL clustering bug which is seen in the high beam background environment. Revision of the entire Bhabha events analysis resolved the issue and the muon-electron ratio is stable against electron ID cuts.

5.2 Concern

- There was no report on the automation of the detector performance studies. Such an automated and systematic monitoring of the detector performance would have been useful to find the bugs reported in this review earlier.

5.3 Recommendations

- The committee strongly suggest to continue the efforts to monitor and improve the data-simulation agreements. The speaker pointed out that the data-simulation agreement is not critical for physics analysis since the physics performance is often derived from the data and the poor agreement is mostly due to inaccurate simulation. While the statement may be correct for most cases, there are still cases where the data-simulation agreement plays a critical role.

- The committee encourages the efforts to automate systematic monitoring of the detector performance to be continued, in particular the effect of the beam backgrounds.

6 Software and Data Processing

6.1 Status

The Belle II software is steadily evolving to support future data taking and Monte Carlo productions. A new *release-08-00* was deployed just before the time of the BPAC meeting. It will replace the last production *release-06-00* in the coming data taking and prompt calibration, in the full reprocessing of Run 1 data and production of the corresponding new run-dependent Monte Carlo. A full validation of the new release took place over summer. The validation process profited from the experience gained since mid-2022 with a series of *prerelease-07* candidates. Physics-based validation was streamlined by using the new *VIBE* validation framework, allowing the analysis of high-level physics variables in a number of representative modes. The analysis was performed on MC run independent samples produced at the end of July with a *prerelease-08* candidate. Some delay was experienced in the production of samples for overlay of beam background and in the submission of productions on grid sites. This was partly due to concurrent development being carried out by separate groups, and some miscommunication among them. Few operational issues related to memory consumption and rare crashes were also reported. Computing performance of the software is continuously monitored in the nightly system and is well within the limits for HLT requirements.

Major changes were introduced on both data processing and simulation software, as anticipated in the BPAC meeting in February. They range from more recent versions of HEP-wide libraries (ROOT 6.24/06, Geant4 11.1.p01, MadGraph 3.4.0) to new and improved algorithms. Updates in tracking, ECL clustering and particle ID software were reported, resulting in improved overall performance, e.g. higher tracking efficiency and lower fake rate as well as reduced charge asymmetry. Algorithmic optimisation of

tracking software has reduced execution time. Bugs identified in the software during the validation processes were addressed. In particular a bug in the analysis software causing the significant inefficiency in K_L^0 reported in June, was identified and the fix deployed for immediate use by analysts. Update of the EvtGen decay table resulted in improvement of data-MC agreement.

There was no dedicated report at this BPAC on production of run-dependent Monte Carlo. The *MC16-rd* production with the new software was expected to start soon after the BPAC. The available *MC15-rd* samples will be used for the analyses to be presented at the winter conferences.

An exhaustive report was given on calibration strategy, with prompt calibration performed immediately after data taking and re-calibration of all data collected up to a given year run sparsely when a new or an updated calibration becomes necessary. Prompt calibration is well established at BNL with an appropriate level of computing resource allocated. It will continue to be carried out there. Until this year, re-calibration was run on local resources at DESY/NAF, where it will no longer be possible to do so from next year onward. Two alternative solutions were considered. The first is to run at a single site, in practice transferring the workflow performed at DESY to this site, with KEKCC as candidate local site replacement. The second is to exploit multiple grid sites combined with a calibration server. Careful review of the needed computing resources was carried out to evaluate the two options. The computing requirements are in line with the simpler solution of a single site at KEKCC, where appropriate level of resources are already available. A dedicated AirFlow-based job scheduler is used to manage the calibration workflow. Development and maintenance relied on a single expert, as past attempts to increase workforce failed. There is no other expertise on AirFlow in the collaboration at this moment, as the tool used for analysis validation and data production quality control is performed with *b2luigi*. The expert recently left Belle II with an agreement to transfer necessary knowledge to the calibration managers. While this is deemed sufficient to ensure short-/mid-term maintenance of the tool, further development would require dedicated new effort.

6.2 Concerns

- The update of the EvtGen decay table based on latest PDG values is done by hand. This is a repetitive task that could benefit from a concerted effort with the EvtGen authors.

- Long-term maintenance of the workflow management tool based on Airflow is uncertain due to the departure of an expert.

6.3 Recommendations

- Submission of jobs for the production of validation samples should be streamlined based on the experience gained in the exercise carried out for *release-08*

- No report was given on data nor MC productions at this meeting. The Committee

would like to hear about the issues reported in February on data fragmentation and the corresponding impact on the production of MC signal samples, and the need of many user grid jobs to access data. A production plan should be prepared and progress monitored.

- The committee supports the choice to keep re-calibration at a single dedicated site rather than using distributed computing with several sites. The impact on other jobs, grid and local users analysis, needs to be carefully monitored to match the total KEKCC resources allocated to Belle II.

- A consolidation of the workflow management tools used in separate computing tasks should be pursued.

7 Physics

7.1 Status

The Belle II collaboration completed 11 new analyses for the summer conferences. Eight papers were published in international journals, and three were submitted. In 2023, the Belle II collaboration submitted 28 new analyses. This is a much larger number than in previous years. Twenty additional analyses are in the pipeline and are expected to be completed by the end of the year. This includes analyses from Belle that moved to Belle II after the merger of analysis procedure of the two experiments. In the long term, the goal will be to have 40-50 new publications per year.

The new analyses include new results for hadronic and semi-leptonic B-decays, electroweak and radiative penguins, time-dependent CP violation, spectroscopy, and dark sector searches. The Committee congratulates the Belle II Collaboration for its portfolio of new analyses. In particular, the search for $B \to K\nu\bar{\nu}$ showed the first evidence for this decay, with a mild excess above the Standard Model. This is the result of the combination of the inclusive and the hadronic analyses, where the inclusive analysis is the most sensitive one. The collaboration also finalised the analysis for $B \to X\tau\nu$ based on 189 fb^{-1} of data obtaining a similar sensitivity as previous B-factories.

The collaboration is planning to finalise the first result for the lepton universality test in $R(D)$ and $R(D^*)$. Additional tests for lepton flavor universality are also in the pipeline, as the analysis of the ratio of branching fractions between $\tau \to \mu\bar{\nu}_\mu\nu_\tau$ and $\tau \to e\bar{\nu}_e\nu_\tau$. The expected sensitivity is similar to the best measurement of the ratio of branching fractions by BaBar.

The analyses are getting more sophisticated. In particular, the Belle II collaboration has reconfirmed its commitment to using run-dependent simulated data for all the analyses starting next year.

Belle II is now a stable collaboration in terms of the number of members. Several conveners of working groups have changed since the last B2GM. Belle and Belle II analyses have formally merged. This will facilitate joint analyses based on Belle + Belle II data. In fact, more and more combined analyses have been finalised. Last October, the collaboration initiated a new platform for meeting with theorists. These

meetings aim to discuss special topics at the interface of theory and experiment that are priorities for the Belle II program and will be held annually. In addition, part of the meetings will be dedicated to pedagogical lectures on a broader set of topics. This year, the meeting was focused on the determination of $|V_{cb}|$. Next year, the focus will be on tau physics and searches for dark sectors. This new initiative has been successful so far, with the participation of more than 100 physicists in this year's meeting.

7.2 Concern

No particular concern.

7.3 Recommendations

- The Committee is happy to see the formal merging of the Belle and Belle II collaborations. Further publications based on the combination of Belle and Belle II data are encouraged, especially for those analyses that are statistically limited using only Belle data.
- The Committee congratulates the collaboration for the successful start of the new theory-experiment platform, and recommends the collaboration to continue in the coming years.
- The Committee would like to see the progress on using run-dependent simulated data for the analyses during the next BPAC review.
- The Committee suggests finalising the $R(s)$ measurements that are needed to resolve the discrepancy between the KLOE, BaBar, and CMD3 results that affects the data-driven determination of hadronic vacuum polarisation (HVP) contribution to the muon $(g-2)$. This is a very timely topic and it would be good to have results in a relatively short time scale.

8 Upgrade plan with beam polarisation

8.1 Status

With Run 2 about to start with an expected running period from 2024 to 2028, reaching a peak instantaneous luminosity of 2×10^{35} cm^{-2}s^{-1}, aiming for a total integrated luminosity up to 10 ab^{-1}, the collaboration is considering a major upgrade of the detector in parallel to the upgrade of the accelerator.

At this meeting, no update was provided on the upgrade of various detector components, but the implementation of longitudinal electron polarisation was discussed in more detail. Longitudinal polarisation of the electron beam, where the electron helicity can be flipped bunch-train by bunch-train, combined with the prospect of large integrated luminosity, opens up the possibility for an interesting and unique physics program. Precision electroweak studies via the measurement of $\sin^2\vartheta_{\mathrm{W}}$ with a precision similar to

that at the Z-pole but at a different centre-of-mass energy of 10 GeV would be possible. The measurement would be very competitive with, and complementary to, a similar measurement from the MØLLER experiment at JLab and measurements at the EIC. It also opens the possibility of measuring $g-2$ for the tau-lepton at the 10^{-5} level to be compared to the current level of precision of $\mathcal{O}(10^{-2})$. The physics program with polarisation requires high statistics, with integrated luminosities of 20?50 ab^{-1} assumed for the quoted goals. The proposal is to run with polarised beams while also accumulating high statistics for the approved Belle II program of flavor physics.

There are three key elements that are required for running with polarised beams: a low-emittance polarised electron source with about 80% polarisation, spin rotators in the High Energy Ring (HER) that do not reduce the luminosity, and a high precision Compton polarimeter that can measure the polarisation to better than 1% precision. When running with a polarised electron beam, transversely polarised electrons would be injected into the HER and rotated to longitudinal right before the interaction point (IP). Tau-decays would be used to get the absolute average polarisation at the IP.

Simulation studies of the proposed spin rotation setup show minimal impact on beam and polarisation lifetime, but these simulations do not take into account collisions. It will be important to cross-check the simulation results with data. To that end, a two-day experiment with a transverse polarised beam in SuperKEKB is proposed to validate the Touschek-polarisation lifetime on the timescale of the end of 2024. The studies will initially be performed without collisions, then the impact of collisions on the lifetimes will be measured. This would require the installation of a source of transversely polarised electrons and a suitably adjusted transfer line for the HER injection, and a polarimeter. A formal proposal is being prepared with a realistic schedule in consultation with KEK source experts and the LINAC team, to be submitted to the Belle II executive board. It was noted that the original machine configuration could be recovered with the spin rotator design that is being considered by turning off various beamline elements and retuning the machine.

8.2 Concerns

- The physics goals of running with polarised beams require high statistics, with integrated luminosities of 20?50 ab^{-1}. This implies that the upgrade would need to be made in a timely manner to profit from the accumulation of such a large dataset. It will be crucial to validate that the complication of adding polarisation does not perturb the achievement of high integrated luminosity, both during the testing and setting up of a polarisation upgrade as well as its final operation.

- Having data with polarised beams is expected to lead to more demands on resources, in particular for the physics analyses, simulation and reconstruction. It will also require a significant amount of effort from the accelerator team.

- The installing of another gun in the injection chain is not trivial and is expected to require significant resources.

- To be ready for the polarisation tests by the end of 2024 without limiting the approved programme of integrating luminosity looks overly optimistic.
- The idea of a polarisation upgrade will be documented in a forthcoming CDR. How this upgrade interfaces with other proposed upgrades to the Belle II detector and SuperKEKB machine upgrades are very important and were not discussed at this review. There is a serious concern that the forthcoming CDR (and possibly multiple CDRs) will not yet be a well thought-out overall package of upgrades, supported by the full collaboration, but rather a collection of possible options, and none of the other machine changes that are being considered will be included there.
- The full scope of the upgrade remains ill-defined. The timeline for LS2, planned for 2028, is very short. There is a serious concern that the timescale and resources required for realising the overall upgrade are underestimated and that the process is not as coordinated across the collaboration and the machine team as should be.

8.3 Recommendations

- Evaluate the feasibility of installation of another electron gun in the injection chain.
- Initiate a study on the overall resource needs for the polarisation upgrade and its downstream requirements on analysis, simulation and reconstruction.
- Develop a realistic schedule, including cost and resources, for the planned Touschek-polarisation lifetime test for 2024 as quickly as possible.
- Develop a coherent overall upgrade plan, coordinated with other Belle II detector and SuperKEKB machine upgrades being planned, with a well-defined scope as soon as possible.