B-factory Programme Advisory Committee
Full report for
Focused Review Meeting

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1 Short summary

A remote review meeting of the B-factory Programme Advisory Committee (BPAC) took place over two half days on 27th and 28th of June 2022. The meeting was focused on the current performance of SuperKEKB and Belle II, as well as the Long Shutdown (LS1) activities.

The BPAC members were informed that Run 2022c was terminated roughly one week earlier than planned and LS1 has already started. This was caused by a rapid increase of the electricity cost by $\sim 50\%$, that has followed from the war in Ukraine amongst other factors. The electricity cost will remain high and may increase even further in the coming years. Although it was explained that the budget request for the Japanese Fiscal Year (JFY) 2023 is based on a higher electricity cost, it will remain a concern for the future data taking of the Belle II experiment.

Since the start of data taking in 2019, the Belle II experiment collected close to $0.5\ \text{ab}^{-1}$ of data before the start of LS1, by steadily increasing the peak luminosity reaching $\sim 5 \times 10^{34}\ \text{cm}^{-2}\text{s}^{-1}$, twice the record luminosity achieved by KEKB. The committee congratulates the SuperKEKB team and the Belle II collaboration on these achievements. SuperKEKB pushes the boundaries of accelerator operation and enters domains that have not been explored to date. Reaching the final goal of collecting $50\ \text{ab}^{-1}$ of data is still a challenge where all components in the long chain from producing electron and positrons to collecting data on tape must work very efficiently. In particular, it will require:

1. an increase of the peak luminosity to a level of 5×10^{35} cm^{-2}s^{-1}, which needs to be maintained during data taking by continuous injections,

2. the machine and detector operating at high efficiencies,

3. sufficient running time.

Further boosts of the SuperKEKB luminosity will require an increase of the bunch current without higher injection background and with much fewer catastrophic beam losses, which could lead to damages of the superconducting final focusing magnets and Belle II detector components. The committee strongly supports the current effort to understand the emittance blow-up in the beam transport and origin of the catastrophic beam losses, as well as further efforts to improve the beam monitoring system and shorter beam abort times. Since the injector chain will be available during LS1, systematic studies of the beam transfer should be continued. The SuperKEKB is a unique accelerator system operating with very small emittance beams, which is a new feature. The BPAC appreciates the broad systematic approach by the accelerator group, including beam simulations, to identify sources of the beam instabilities leading to the beam losses. This should continue in parallel with further analyses of the data from the various beam monitors during catastrophic beam losses. After LS1 all those efforts should lead to an increase of the bunch currents beyond the current empirical limit of 0.7 mA. Installation of further beam monitors during LS1 is highly recommended. The committee notes that some of the ageing components in the injector chain will be replaced during LS1. Once COVID restrictions have been relaxed, more intense and in-person involvement of the worldwide accelerator experts of the international task force can be expected. However, the committee expresses its concern on the lack of human resources given the number of accelerator issues to be addressed, and repeats its recommendation to attract Belle II collaborators for accelerator related work. It might be useful to point out that worldwide demand for accelerator physicists is high.

The Belle II collaboration has been successfully improving the data taking efficiency. The committee notes that the vetoes, designed to suppress backgrounds during the beam injection, have become a significant fraction of the remaining inefficiency. While efforts are made to reduce the injection background by the machine team, the Belle II collaboration should optimise the veto scheme to minimise this inefficiency.

Rapidly increasing electricity costs resulting from the current unstable state of international affairs may persist for quite some time. It might not be easy to fully cover the rising electricity costs with a corresponding increase of the KEK budget. A KEK-wide strategy needs to be further developed for a sustainable operation of the laboratory. Maintaining annual accelerator operation periods of six months or so would be important. Periodic shutdowns of the accelerator, currently in winter and in summer, will be necessary but should be optimised to maintain efficient data taking.

It is unfortunate that a part of the gold coating for the inner surface of the replacement beam pipe peeled off. This will result in an extension of the LS1 schedule by one and a half to three months, unless the existing vertex detector (VXD) is taken out together with the beam pipe before the new VXD is confirmed to work at KEK. Currently three approaches are being considered: either to repair the peeled gold coating by adding a copper coating, or applying copper coating for the inner surface and gold coating for the outer surface to the remaining spare beam pipe, or reusing the currently installed beam pipe. The committee strongly encourages the development of a work-plan with well-defined criteria, agreed upon by the machine experts for acceptance in the machine, and evaluate the physics impact of the different options. The recent progress in the replacement pixel detector, PXD2, is very encouraging. It should be ready for transportation to KEK in October, as currently planned. The actual timing for the transport should be decided in view of the overall plan for the detector installation. The committee thinks that it is important to secure more spare ladders by reusing parts from the unqualified ladders, although this may require fabrication of new switcher chips. Concerning the issue of the photon detectors (PMTs) for the barrel particle identification system, the committee concurs with the decision by the Belle II collaboration to decide in January 2023 which PMTs should be replaced during LS1. However, more quantitative criteria than those currently presented should be developed for selecting the PMTs to be replaced. If it is proposed to delay replacement of the majority of the conventional PMTs until after LS1, the risks related to performing that intervention during a subsequent summer shutdown should be evaluated. The committee is very concerned to learn that the loss of efficiencies in some part of the KLM (K-long muon) detector, due to interruption of the gas circulation, was not discovered until recently. A plan to strengthen the real-time monitoring of the system during LS1 will help to detect similar problems early on[1]. In particular, more rigorous monitoring of the gas flow at both inlet and outlet is strongly recommended. Hardware interventions must be decided very carefully. The effect of using a gas mixture with ammonium to recover the damaged chambers must be first studied in a laboratory test. People experienced in operating gas detectors could reinforce the KLM group.

Data processing for the 2022 runs appears to proceed smoothly and the current effort should continue to ensure that the whole data set will be available for physics analysis by the autumn 2022. The committee notes that further effort to move toward using more run-dependent rather than run-independent simulations for the analysis is needed. In conclusion, the committee applauds the overall progress made by the SuperKEKB team and Belle II collaboration. The human resource issues need to be carefully monitored in order to maintain the progress. The future running time remains as one of the largest concerns of the committee.

[1] The committee would like to hear a presentation on the real-time monitoring for the whole Belle II experiment during the next review meeting.

2 Accelerators

2.1 SuperKEKB

2.1.1 Status

The SuperKEKB accelerator has continued to achieve new records in peak luminosity while raising the total beam currents of the Low Energy Ring (LER) and the High Energy Ring (HER). The luminosity peaks of 4.65×10^{34} cm^{-1}s^{-1} (with the detector on) and 4.71×10^{34} cm^{-1}s^{-1} (with the detector HV off) are now well above all other collider luminosity records. The previous B-factory record luminosities were achieved with higher beam currents than those presently used by SuperKEKB. The SuperKEKB accelerator is clearly moving into new collider territory. The nano-beam scheme is working as evidenced by the increase in specific luminosity when the β_y^* value is reduced from 1 mm to 0.8 mm. The scrubbing of the beam pipes continues and the scrubbing rate will increase as the beam currents increase, leading to further improvement in the dynamic gas pressure. Both storage rings now operate with the design number of bunches and with beam currents of well over 1A. This frontier accelerator is encountering some difficulties and we list some of them in the next section.

It is encouraging that newly installed fast loss monitors started to reveal where the LER beam loss is initiated and the committee is looking forward to learning about the progress at the next meeting.

2.1.2 Concerns

- It has been discovered that increasing the bunch current above 0.7 mA leads to a very fast and total beam loss. This is just under half of the design bunch current value. The cause of this empirical limit is not understood and studies are ongoing.

- It was discovered that the orbit of the beam becomes degraded at higher beam currents due to what looks like beam pipe motion.

2.1.3 Recommendations

- The committee encourages all efforts to further understand the empirical limit of the bunch current. This may take several dedicated days of machine studies while various approaches are tried to get more insight into this limit. At the same time, the machine should be made more robust against the fast beam aborts. This should include possible further improvements by speeding up the abort timing as well as adding more diagnostics around the storage rings. The current efforts to install newer collimators may also help in this direction if they can survive these fast aborts. The committee would like to encourage additional support from the detector group and Machine Detector Interface (MDI) group.

- Discovering that the beam orbit information from the beam-position monitors (BPMs) is changing as the beam currents increase is a major find. The committee encourages further studies of this effect and ways of correcting the errors to the orbit. This will no doubt become more important as the beam currents are further increased.

- As mentioned in the presentation, the introduction of non-linear collimators may improve the present beam instabilities. In addition, the committee encourages working with the detector group and the MDI group to investigate ways of relaxing the collimator settings. As the scrubbing continues and as the dynamic gas pressure goes down, it might become possible to open the collimator jaws a bit without a significant increase in detector background.

2.2 Injection

2.2.1 Status

The accelerator team has made significant strides toward the design performance for the injector. The Linac has been successfully filling four facilities under stable operating conditions. The positron yield is now approaching the design value of 4 nanocoulombs (nC). There are still difficulties in getting clean injection into the SuperKEKB rings. As was mentioned in the presentation, achieving design level injection efficiency with low background in the detector is important as only then can the injector maintain the design high beam currents. Efficient injection is also important because lowering the β_y^* further shortens the beam lifetime and the load on the injector increases. Injection aborts have been an issue to improve the operation efficiency. The CLAWS veto seems to work well to suppress injection aborts.

2.2.2 Concerns

- The injection kicker system for the LER is not completely tuned up as there is a residual stored orbit oscillation left after a pulse is injected into the ring.
- There is emittance growth in the HER beam transport (BT) line.
- Two bunch injection is still not routine yet.

2.2.3 Recommendations

- The committee encourages further injection kicker improvement to reduce or eliminate the stored orbit kick presently seen.
- The committee also encourages all efforts to understand and reduce the emittance growth seen in the HER BT line.
- The committee recognises the very good collaboration between the detector group and the linac team in helping to understand and improve injection backgrounds and urges to further strengthen it. As a side remark, the PEP-II B-factory got enormous help from the Babar detector team in tracking down and understanding

bad injection pulses. With their assistance, particular injection pulses were identified as bad that would have been very difficult to track down without the help of the detector team.

- Solving the two bunch injection issues may benefit from collaboration with the MDI detector team. Perhaps some dedicated time should be allocated for this study. It is an important part of the injector system and will help to keep up with the higher currents of the SuperKEKB.

3 Belle II detector

3.1 Operation

3.1.1 Status

The Belle II detector recorded an integrated luminosity of 160 fb^{-1} in runs 2022ab, resulting in a total integrated luminosity of 427 fb^{-1} (366 fb^{-1} at the $\Upsilon(4S)$ resonance). A major achievement was the increase in the peak luminosity by 23%. During the four-months run period, 29% of the time was reserved to address accelerator problems and optimisation. The average Belle II data taking efficiency was 87.1%, decreasing with increasing background. The detector operation was improved by means of automation and simplification. During beam injection, vetoes designed to suppress background occurred frequently and have caused a significant fraction of the dead-time. Studies are underway to reduce the high injection background which has led to degradation of the detector response, which in particular impacts the CDC performance.

The migration of the readout from the COPPER boards to the PCIe40 has progressed and resulted in stable data acquisition for TOP and ARICH, and also KLM. However, the new firmware for the KLM scintillator read-out has resulted in a lower trigger rate. Comparisons of the TRG rate with the trigger simulation are planned. Comparisons of the K_L^0 detection efficiency for data and simulation indicate some discrepancies. The side-bands in the RPC timing distributions have been traced to specific sectors and layers. They depend on event triggers and are different for colliding beams and single beams. The origins of these features are not understood.

Newly implemented muon efficiency plots have indicated a problem primarily in the KLM barrel backward sector BB2, Layer 5, but also in isolated layers elsewhere. Records indicated that the negative HV for one of the two Layer 5 RPCs was turned off in June 2021 because of multiple HV trips, resulting in an efficiency decrease. More recently, it was discovered that the power cable for the pressure regulator of the exhaust tank had been unplugged. After the power was restored, the BB2 efficiency temporarily recovered partially, but it dropped again within a day. It was recognised that the input gas tubes for BB2 are not made of copper as for other sections of the KLM, but of polyethylene and thus can be contaminated by atmospheric water vapour or condensation along the exterior. The efficiency drop tends to be correlated with polyethylene tube length. This effect was enhanced whenever the pressure regulator was not operating. Although the gas flow to the inner/outer RPC was doubled in May 2022 to dry the detector, the water-vapour contamination seemed to be on the high side. In addition, only five BB2 layers with highest efficiency were kept under HV operation close to the end of the Belle II run, in order to avoid permanent damage to the RPCs. It is planned to measure BB2 efficiencies and hit rates of the affected layers with cosmic rays to find ways of improvement over time and signal stability of the affected layers.

3.1.2 Concerns

- Higher luminosity will require higher beam currents which will result in higher backgrounds. In the past, sizeable beam losses have caused damages of collimators and QCS quenches, and have also caused radiation damage to some detector components. Single-event-upsets have resulted in lower data-taking efficiency. The DAQ dead-time was dominated by injection vetoes during the last data taking periods with higher backgrounds.

- A clear correlation between the degradation (mean, resolution) of the CDC dE/dx measurements and the beam background conditions, varying with time after the LER injection, has been observed. This could affect the CDC performance in data collected after April 2022.

- A variety of KLM performance issues, such as efficiency drop, higher single hit rates and HV leakage currents behaviour, have been observed. While gas problems and water vapour contamination are strongly suspected, the true cause is not fully understood.

- The fact that a major hardware malfunction, such as operation of RPCs without a continuous gas flow in several layers, went unnoticed for at least a year is extremely worrying. It raises the question of how many other operational problems might have been overlooked.

3.1.3 Recommendations

- While efforts to reduce the beam injection background are underway, the Belle II experts should collaborate with the machine group to try and find solutions that balance the machine operation and the risk of large backgrounds and radiation damage. Studies of background patterns may lead to a more effective selection of vetoes and thereby a reduction of dead time.

- Results of dedicated studies should be considered to develop mitigation strategies to make sure that the CDC tracking, dE/dx and triggering will not be compromised by background related performance degradation.

- Given the variety of KLM RPC performance issues in efficiency, single hit rates and leakage currents, high priority should be given to systematic studies of the recorded data to reveal the origin of these diverse problems and to develop measures to reduce their potential impact on data analyses. The RPC efficiencies and hit rates in affected layers measured with cosmic rays after the Belle II Run and their comparisons with data from the run period could give useful information to address these issues.

- Control and monitoring of all the subsystems should be revisited. The committee would like to have presentations for the detector-wide controls and monitoring, and also alarm handling, at the next BPAC meeting.

3.2 Long Shutdown 1 activities

3.2.1 Status

The Long Shutdown (LS1) has already begun, earlier than planned due to the increase in electricity cost. Presentations were made to the committee on the preparations made by the collaboration for the activities that need to be achieved during the shutdown, concerning the beam pipe replacement, PXD2 completion and installation, VXD de- and re-installation, and the replacement of TOP PMTs. An additional issue that has arisen concerns the repair of efficiency loss seen in the KLM, described in the previous section. These items are discussed in turn below. One issue that was not discussed in detail at the meeting is the vacuum leak in the final-focusing magnet (QCS) that remains to be repaired. Access to the location of the leak should be possible in a few weeks' time, at which point the scale of the repair should be better understood—at worst it might require to move from the experimental hall, resulting in a significant delay to the LS1 schedule, but it is currently anticipated that this will not be the case.

Beam pipe

To mitigate the effects of synchrotron radiation on the PXD, the decision was taken to produce a new beam pipe for the PXD2. Unfortunately, the first attempt to produce a new pipe showed delamination of the gold plating that cannot be repaired. The cause has been understood to be the presence of an unwanted titanium oxide layer on the solid titanium surface, as discussed at the last BPAC review. A new inner section beam pipe has been procured as a replacement and, as a precaution, the gold plating was extensively tested on mock titanium pipes. The gold-plating of the new beam pipe, however, showed an unexpected bulge on the backward titanium joint; the forward area is in good condition. The delaminated gold film in the bulged area was removed using scotch tape, but the cause of the problem is not understood. The removed gold will be inspected by the plating company, as will be the inner surface of the pipe. The vacuum group has expressed concerns about using this beam pipe given the delamination. No agreement has been reached on what would constitute an acceptable repair of the beam pipe, between the vacuum group and the experiment. As the committee understands it, the collaboration is now faced with five possible options:

1. replate the delaminated area with 10 μm of gold;

2. replate the delaminated area with 3 μm of copper;

3. on the spare beam pipe, apply 3 μm of copper on the inside and 10 μm of gold on the outside of the pipe;
4. on the spare beam pipe, apply 3 μm of gold on the inside and 7 μm of gold on the outside of the pipe;
5. reuse the current beam pipe; as this would not provide the additional synchrotron protection for the PXD2 it is considered only as a last resort.

It should be noted that for options 1 and 2, replating exactly the area that has suffered delamination will be difficult, so it is expected that the full inner surface would be replated. It has been verified that with 3 μm of copper the impedance will be low enough not to cause any beam pipe heating issues. Option 4 has been proposed to mitigate the impact on the material budget and to increase the effectiveness of the absorption of synchrotron radiation relative to option 3. For internal replating with gold a new gold electrode would need to be procured, which would add an additional six weeks' delay to the new schedule, which is already delayed by three months compared to the March 2022 schedule. The earliest the beam pipe will now be available is October 2022. In addition, the risk of a repeat of the delamination incident is considered to be significant, if internal replating with gold is attempted, so these two options (1 and 4) are currently disfavoured and were not included in the summary earlier. Sputtering of copper instead of gold, using chromium as a base material, has been tested and is not expected to present significant difficulties.

PXD2

Populating the first half-shell of the PXD2 has been completed and quality checks are being carried out comparing the performance at MPI and DESY. No major differences have been seen in performance and the overall quality of the modules looks good. For the second half-shell four Layer 1 (L1) and six Layer 2 (L2) ladders are needed. Four L1 ladders have already been mounted on the second half-shell; there are two spare L1 ladders available. The glue-gap of one repaired L1 ladder unfortunately opened recently and is no longer available. Three spare L2 ladders are available and these ladders are all A grade. For the system tests of the VXD, more than forty power supply units (PSUs) are needed, with 33 units available. An additional 31 units have been ordered in July 2021. Due to supply chain issues the delivery time of the final components is expected in mid-August 2022. A new calibration system for the PSUs is being set up at KEK. The new units have several improvements over the old units, such as the safe and fast shutdown of Switcher chip voltages. Also five new fibre-optical sensors for temperature measurements have been produced. The decision when and where they will be installed is still pending. The current schedule calls for the PXD2 to be completed by October 2022, well in advance of the required date, which is currently driven by the availability of the new beam pipe. The PXD2 team is to be congratulated by ensuring the availability of two key PXD experts for the installation of the detector and for organizing an on-site, in-person installation review at KEK at the end of this year with the possibility for remote participation.

VXD

The planning of the various VXD tasks in preparation for the installation of the PXD2 is well advanced. The current baseline is to use the new beam pipe. Installing the PXD2 on the old beam pipe would require an additional two months in the VXD reinstallation schedule. Given the three month delay in the availability of the new beam pipe, the schedule shows the reinstallation of the VXD to be complete in October 2023. This can be accelerated if disassembling the old VXD is done in parallel with the preparation of the PXD2. The design of the heavy metal shields around the bellows is complete and has been verified with 3D-printed parts. The production of the heavy metal shield has started with an expected installation date of May 2023. A study of the effect of earthquakes on the clearance between the heavy metal shield and the bellows and remote vacuum connection has been carried out. Gap sensors and accelerometers have been installed in the relevant areas and are constantly being read out to provide accurate information. Currently, the study indicates that the heavy metal shield, that is tied to the Belle detector, may move by more than the clearance, which is 3 mm. This study will be refined using the data being collected with the newly installed gap sensors. If this result is confirmed, the end-parts of the shields will have to be removed to avoid any interference. This decision is expected to be taken in September.

TOP PMTs

Following further monitoring of the behaviour of the TOP PMTs during recent running, the present understanding of the dependence of their quantum efficiency (QE) with output charge remains incomplete. Further bench tests during LS1 may improve the understanding but it is hard to be confident at this point. The shape of the deterioration as measured in situ also seems to be different than earlier measurements and may even indicate recent flattening-off of the degradation. It might be that the relative QE as measured has a substantial systematic error, at the level of a few percent, which is significant compared to the scale of the degradation measured to date. Projections of QE degradation for the longer term are dependent on rather poorly understood modelling. At this point, the life of the conventional tubes' QEs are about 10% used up, nominally, although this is poorly known. The lifetime-extended ALD tubes that would replace them are expected to have a lifetime that is about 12 times longer. The lifetime remaining on the 224 conventional tubes now in the detector is equivalent to about $224 \times 0.9/12 \approx 17$ new lifetime-extended ALD tubes. An early exchange during LS1 would sacrifice that remaining lifetime and the associated cost, but has to be weighed against the disturbance to future running if the replacement is deferred. There may be a minor gain in the TOP physics performance with the ALD-coated rather than conventional tubes because of the difference in operating gain. Continuing to run with the present tubes after LS1 would allow further understanding of the QE deterioration as the observed effects should become large and well outside the systematic uncertainties. The projection model predicts that the QE is likely to drop below 80% for the conventional tubes during the next run period. However, this model may be overly pessimistic given the expected extensive machine runs expected during the period. The loss of physics performance due to this QE loss is also not very well understood. There is some poorly quantified risk associated with another partial opening in 2024; it will surely take additional effort and may impinge on the run starting later that year. The TOP group seems motivated to delay the exchange of the bulk of the conventional PMTs, and limit the exchange to those tubes currently showing poor performance, with a final decision to be taken in January 2023.

KLM

To address the loss of efficiency observed in the Barrel Backward Sector 2 (BB2) of the KLM RPCs, it is proposed to measure the water vapour and oxygen density just after the detector, check the inlet tubes visually for any trace of liquid, and continue to measure BB2 efficiencies and hit rates with cosmic rays for signs of improvement over time. In addition, it is proposed to explore the possibility of flushing the detector with NH_3 to recover the efficiency. The flushing process for the ten problematic BB2 RPCs would each take about two weeks; at first it is proposed to do the recovery process on a dedicated test bench with full-size and small-size RPCs that is being established in Tsukuba Hall, and if a positive effect is confirmed there, then proceed to the BB2 layers. In parallel, the KLM RPC monitoring will be upgraded during LS1, reincarnating a bubbler optical monitoring system that was previously implemented in the Belle era to monitor the gas flow.

3.2.2 Concerns

- Given the importance of the beam pipe, it is disconcerting that the plans for its repair do not seem well defined. It is worrisome that there are no agreed upon criteria for what constitutes an acceptable repair of the beam pipe to the machine group.
- Copper will absorb most of the incident synchrotron radiation photons and subsequently will emit K-shell photons at 8.9 keV isotropically. Those should be mostly absorbed by the 10 μm of gold on the Be pipe, so this may not be a serious concern, but the impact of any changes on the protection of the PXD2 from synchrotron radiation should be quantified.
- The delamination of the gold at the titanium junction is unfortunate. As the cause of the delamination is unknown, repeating the process for the affected area by re-sputtering 3 μm of gold may not be successful.
- The number of spare ladders for the PXD2 is relatively small. New issues have often appeared in the past and the risk to fall short of the required complement of ladders remains uncomfortably high. It is understood that the availability of Switcher chips remains a bottleneck to producing more ladders.
- The loss of expertise for the pixel detector remains a key concern. Further delays in the LS1 schedule should be avoided to the extent possible and early assembly

of the PXD2 on the beam pipe should be targeted.

- The shortening of the heavy metal shields of the VXD to avoid interference in case of earthquake may increase the background in the detector.

- The long-term evolution of the TOP PMT performance with integrated luminosity remains unclear, as does the shorter-term evolution during the upcoming run. If the conventional PMTs are not replaced during LS1, there is a risk that they will suffer significantly degraded performance during the following run, and their eventual replacement will require a further intervention.

- The real reason for the KLM efficiency loss is not yet clear, as well as whether the damage in efficiency is permanent or can still be, at least partially, recovered. The currently planned intervention for the KLM appears to be insufficient: the gas flow would be monitored only at the bubblers and no check on the gas mixture performed. The committee considers that introducing ammonium in the gas mixture to recover the damaged chambers appears to be a highly risky operation, which should be first studied in the laboratory with an RPC test chamber made of similar materials as the KLM one, and copper gas lines.

3.2.3 Recommendations

- Urgently agree with the machine group what will constitute an acceptable beam pipe, for example, the tests against possible delamination of coatings that would be accepted.

- Develop a plan to repair the new beam pipe with high priority. It should be confirmed that sputtering copper has a higher probability of success than re-sputtering gold, and that the impact on synchrotron shielding is acceptable. If that is confirmed, it is recommended to plate the affected area on the new beam pipe only with copper.

- Pursue, in parallel, the option that has been agreed upon by the machine group for the spare beam pipe, such as plating its inner part with 3 μm of copper and the outer part with 10 μm of gold. This would maximise the probability of having a performant beam pipe available for the PXD2 in case repairing the new beam pipe is unsuccessful.

- Investigate the possibility to obtain more Switcher chips for the PXD2, and consider producing more modules and ladders to increase the spare count.

- Study the effect on the backgrounds due to the potential shortening of the heavy metal shields of the VXD. If the impact is small, and the potential for accidental damage during an earthquake is confirmed, then it appears prudent to proceed with the shortening.

- A more thorough assessment of issues associated with an installation of TOP PMTs during the summer 2024 shutdown would be welcome at the next BPAC review in November, along with an assessment of the impact of the various replacement strategies on the performance of the detector and its overall lifetime. It would be useful to include an assessment of the issues associated with the QE projection modelling, and the relationship of QE loss to physics performance.

- The gas flow for the KLM should be monitored at both the inlets and outlets. It is recommended that an optimised set of mass flow meters and mass flow controllers is installed at the inlet and outlet of the RPC chambers to accomplish this task. Any modification to the gas mixture, e.g. for recovery purposes, should be carefully tested first with a laboratory setup, under conditions as similar as possible to the KLM system. In case the cosmic ray tests indicate recovery of efficiency in the affected BB2 layers, one might consider to continue flushing the RPC chambers with a (very high) flux of nitrogen for the duration of a few months.

3.3 Data processing and software

3.3.1 Status

Data processing is proceeding smoothly towards the goal of processing the full data set by end of September 2022, to be ready for the winter conferences. Data up to 2021 (213 fb^{-1}) have been re-calibrated and reprocessed with the latest software release (rel-06), newer data (192 fb^{-1}) are promptly calibrated and reconstructed with the same software version. A detailed and realistic schedule was presented for both prompt and re-processing to achieve the mentioned goal.

A number of difficulties in the re-calibration have been encountered: complexity in calibrating old data, manual actions by experts and sign off at each step, job failures, etc. The data production group reached the conclusion that a “dry-run” for calibration would have been very useful to iron-out most of these difficulties and make the overall process smoother. Prompt processing is easier compared to calibration. The main problem reported is long tails in the processing due to limited space for absorbing any backlog, which is typically produced by job failures and heavy load in the production system because of concurrent Monte Carlo (MC) productions. Features freeze of the next software release (rel-07), that was under discussion at the February BPAC, has been fixed for July with its validation to be completed before the winter.

Serious effort has been put in the validation of MC productions. A number of quantitative analyses of high-level variables has been identified in a number of representative modes. Automation is certainly possible, combined with tools such as Mirabelle to show the results, and therefore could facilitate the validation by experts and non-experts. A “validation manager” role has been specified and a new person has been appointed. The committee finds this very encouraging.

A comprehensive validation of the latest run-dependent MC, MC14rd, is in progress with many studies presented at different venues in the last two months, including dedicated workshops and general meetings. This validation is a prerequisite before launching new productions and is essential for encouraging physics groups to make the transition to run dependent MC for analysis to be presented at fall/winter conferences. So far, the outcome of the validation has been very positive, with many examples indicating that MC14rd is closer to real data, or at least at the same level of the MC14ri run-independent simulation.

The committee is pleased to see that sharing of the workload between managers with long-term commitment and short-term service people (i.e. data production shifts) is being implemented. New managers have been hired and new people participate in the data-production services.

3.3.2 Concerns

- The data processing team claims that it is not easy to predict the time needed for reprocessing. The estimate of nine months to re-process 213 fb^{-1} is long and could be a real problem when the yearly integrated luminosity will grow substantially. Fortunately, the processing time does not scale linearly with luminosity due to several factors, because the calibrations should be based more and more on previous calibrations.

3.3.3 Recommendations

- To avoid surprises, the collaboration should continue to monitor the evolution of the time needed for reprocessing and prompt-processing and use any opportunity to streamline the full process to avoid scalability problems when Belle II will reach substantially larger luminosity.
- The committee strongly encourages to systematically perform a "dry-run" calibration to iron-out problems before launching the full production.
- The committee continues to encourage the ongoing Monte Carlo validation effort, in particular in view of the use of run dependent Monte Carlo simulations as the baseline for physics analysis.