B-factory Programme Advisory Committee
Full report for the 14th Focused Meeting
Review on Readiness toward Phase 3

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1 Short Summary

The Belle Programme Advisory Panel held its focused review meeting on the 21st and 22nd of October 2018. The committee listened to presentations on the status of the experiment and machine by the Belle II collaboration and the SuperKEKB machine team, respectively, who have been busy with the preparation for the Phase 3 run.

The committee congratulates the SuperKEKB team for achieving a peak luminosity as high as $\sim 5\times 10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ during the Phase 2 run. Machine parameter studies showed that a target luminosity of $10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ could have been achieved if the beam currents were increased, which will be possible for the Phase 3 run already before the summer shut down in 2019, with some hardware being installed during the shutdown. While a path to increase the luminosity is defined, the cause of the unexpectedly high machine background observed by the BEAST detector at the interaction region during the Phase 2 run has not yet been understood, introducing uncertainties about how the machine will continue to improve performance while keeping the background levels at tolerable levels for the experiment. With the Vertex Detector (VXD) installed, the background remediation and measurement must now be fully integrated into Belle II activities. Commissioning work for the machine and the Belle II detector must be done in close contact. The operation plan of the machine should be discussed together with the detector group so that the best condition for physics can be achieved efficiently. With increasing beam currents, utmost care must be taken for protecting the machine and detector from beam related accidents. The person who leads the Belle II commissioning should also be entrusted to coordinate with the machine group and follow closely the background studies.

In order to ensure high integrated luminosity, the machine must run with continuous injection and the Belle II detector must be ready to cope with this.

The BPAC is very pleased to hear that the Phase 3 VXD has been assembled and is being commissioned with cosmic rays and is ready for the installation. Although only one layer of pixel detectors is fully placed, rather than two as designed, the committee believes that it will be sufficient for the early stage of the Phase 3 run, since the machine will not reach the design luminosity then, and the pixels will play a vital role in the physics analysis. The committee notes that the gating mode of the pixel readout operation is a critical component for the continuous injection and still has to be shown to work reliably. Since the VXD cooling is a specialised system, all the spare parts must be made available at KEK so that repairs can be made swiftly if required.

The BPAC is very impressed by the Belle II analysis work with the Phase 2 data showing fully reconstructed B mesons. However, the committee also notices that there are several issues to be sorted out for the Phase 3 run to achieve the planned physics programme.

In order to understand the noise and cross talk observed in the Central Drift Chamber (CDC), the frontend electronics must be checked systematically. For keeping the CDC dark current under control, the chamber must be kept at high voltage with continuous gas flow and the current monitored. The gas system should be prepared so that H_2O or alcohol could be added later if the dark current persists. Chemical analysis of the exhaust gas would also be necessary in such a case.

The end-cap particle identification system (ARICH) was not fully operational during the Phase 2 run. During the shutdown, the ARICH had to be removed from the Belle II structure in order to install a cooling system for the frontend electronics and will be put back after the installation. This is an unforeseen major operation. The ARICH group needs to make a careful commissioning plan of the detector after the reinstallation. The barrel particle identification system (TOP) is generally in a good shape, but still requires effort by the engineers for debugging frontend electronics, in particular the FPGA firmware.

While the status of the Electromagnetic Calorimeter is satisfactory, the situation with the K-Long Muon (KLM) system, in particular for the barrel, is rather worrisome. For the barrel part, much effort is still ahead of the group in order to make the detector ready for physics data taking. The Belle II management should monitor progress carefully to ensure that enough resources are provided for timely completion of their work. Engineering effort for the readout electronics is also needed for the endcap KLM. Unifying the operation effort of the endcap and barrel KLM should be considered.

Data Acquisition (DAQ), Slow Control and Trigger are the areas where central teams need to work closely with the detector teams and must often support the detector groups. Lack of experts has been a long standing problem for the central teams. The committee is pleased to observe that some progress has been made to mitigate this problem for the central DAQ team. The effort should continue to increase the number of experts to that will be needed for Phase 3. This problem remains for Slow Control. Although some people became available for the operation of the system, the number of experts, who are still needed to make the system viable for physics data taking, is extremely limited. Recruiting young people and training them for the coming period is a good idea. The human resource situation for the Trigger is critical. Effort is needed for not only implementing hardware functionality but also monitoring carefully the performance, where physics groups can contribute. Stronger cooperation among the three central teams would also be very helpful and a Belle II collaboration wide effort should be made to bring in more human resources.

The committee does not find major problems with the progress in software and computing and expects them to be ready for Phase 3.

The committee recommends the collaboration to take a holistic view of the next six months identifying key vulnerabilities and areas of concern for the experiment. This should help in developing an overarching plan to ensure adequate resources for critical tasks and the proper organisational structure with well-defined responsibilities and authorities to be in place well before data taking starts. The BPAC is looking forward to seeing the progress made during the next BPAC meeting in February 2019, just before the start of Phase 3.

2 Machine Background and other machine related issues

2.1 Status

The SuperKEKB accelerator has made significant progress during the Phase 2 running time. They have successfully demonstrated the nano-beam scheme by observing an increase in the luminosity when the transverse spread, σ_y, of the beam drops below the longitudinal spread, σ_z. The specific luminosity is approaching the design value and the peak luminosity achieved is 5.5×10^{33} cm^{-2}s^{-1}. With the help of the background team for Beast II, they have found that the Touschek lifetime is shorter than anticipated and work is ongoing to further understand this.

A tremendous amount of background data has been collected by the BEAST II detectors as well as the other sub-detectors of Belle II. The background team has worked on analysing and comparing data to the simulations. They have analysed many different background channels and running conditions and in general the comparison with simulation has been reasonable. However, they have found some surprises in an overall higher background rate from the High Energy Ring (HER), in the Touschek lifetimes mentioned above and in higher than expected rates in the PXD, probably from the synchrotron radiation (SR).

2.2 Concerns

- Although many of the background signals collected during Phase 2 running agree reasonably with expectations, there are a few background signals that are unexpectedly high.

- Some of the high backgrounds, if sustained, may cause early degradation of some subsystems, e.g. the TOP PMTs. In particular, the HER background levels were

10 to 100 times higher than expected. There was also a high peak of background from SR at about 10 keV photon energy.

2.3 Recommendations

- The background team is encouraged to continue working on the background data as this will guide the team in planning further background studies during the initial Phase 3 running.
- The background team is recommended to look into possible higher beam-tail distributions as a way of getting a better agreement between the simulation and measurements. A new accelerator will generally produce more out-gassing during initial running but the condition of the vacuum will improve with time and beam running. Whatever the vacuum pressure is, the remaining gas in the vacuum system will generate a beam-tail distribution. Beam-tail distributions in which the integral of the tail distribution is up to 1-2% of the total beam bunch integral are possible and the background team could consider such high tail distributions in their ongoing effort to understand the backgrounds.

3 VXD

3.1 Overall status

The schedule calls for the VXD to be installed and fully tested by December 21, 2018 and the committee is looking forward to a successful installation and start of preparing the full detector for Phase 3 data taking. Additional monitors to track various parameters of the detector will be installed.

3.2 Concerns

No particular concerns were identified for the VXD work.

3.3 Recommendations

- The committee recommends verification of the spare part count at KEK to ensure that there are enough spare parts for all detector control and monitoring devices to ensure repairs can be completed promptly if needed.

3.4 VXD-PXD

3.4.1 Status

The operational experience of the Phase 2 configuration and the status of the preparations for Phase 3 were presented. Four B-grade modules were installed during Phase-2 running and were read out using the final readout configuration, with pedestals and local runs taken with the PXD-only data acquisition system. Many valuable operational improvements were implemented during this run and no significant hardware failures were observed. Several issues with the hardware and data acquisition system could be taken care of rather easily during the run. Firmware was developed in parallel with the data taking. The firmware development for the 30 kHz overlapping trigger operation could not be completed, however. The collaboration has exercised the slow controls system and has put an emphasis on preventing human error to cause any damage to the PXD detector. Although at the last meeting it was reported that the PXD had been smoothly integrated into the Belle II Phase 2 data taking with a level of automation that did not require a permanent presence of a PXD shifter, it was reported at this meeting that for run startup there was a severe limitation of availability of expert shifters.

The PXD group is making very detailed studies of the background. Various techniques are being used to evaluate the background dose and its origin. The total ionising dose, inferred from the measured threshold voltage shift of the installed Phase 2 modules, gives an estimate of a total received dose of around 2-5 kGy, which is a factor 50-100 larger than the dose estimated from the rates monitored in the diamond detectors. This could be due to the different positions of the detectors and the distinct angles of mounting. Other sources could be the possible large contribution from low energy photons, that have an unconfirmed source, or the ϕ-position of the PXD sensors. It is noted that the luminosity related dose in this running period is about two orders of magnitude less than expected for the final detector running. The PXD, however, is designed to withstand about 20 kGy per year based on simulations, with the dose completely dominated by 2-photon QED background not including any additional dose accumulated during injection. Although the effects of total ionising dose are visible in the threshold shifts of the DEPFET devices, they are not expected to be a concern for the longevity of the device.

The Gated Mode operation of the PXD could not be exercised during the Phase 2 run, though a continuous Gated Mode test was performed. An unexpected cross-talk between modules on the same side was observed. The effect on the pedestals is still being investigated. The readiness of the data acquisition system for Phase 3 running is relatively good, although smooth running at full trigger rate is still not in place and the overlapping trigger hardware still has to be completed. In particular, the DAQ system stopped frequently, triggered by events with huge occupancy in the PXD. Also the event filtering has not been tested yet on the HLT.

The committee would like to congratulate the PXD group and the collaboration with the completion of the PXD detector with a complete Layer 1 (8 ladders) and a partial Layer 2 (2 ladders out of 12). Its installation on the beam pipe and integration with the SVD is a major achievement, despite the fact that the PXD is only partially populated. At the time of the last review it was thought that damaged parylene coating on the support cooling block (SCB) caused a high Ohmic contact with the sensor, which resulted in performance degradation of the sensors. Additionally, a full short was discovered during the mounting of ladders on the second half shell, which was attributed to the same cause. It was proposed to add a 20 μm thin mylar foil between the sensor and cooling block. Because of the inherent risk in damaging ladders, it was decided not to implement this retroactively but only apply it to the ladders still to be assembled. So, the installed PXD has four Layer 1 ladders without the mylar foil added and the remaining four Layer 1 and two Layer 2 ladders with the foil added. It will be interesting to see if there is a difference in performance. Many issues during the assembly and the cabling were successfully addressed.

With the current PXD construction completed, with 20 out of 40 modules installed, the PXD group has shifted its attention to ensuring that a full PXD can be installed during the summer shutdown of 2020 (PXD2020). A post-mortem was held on the work for the Phase 3 detector and an inventory of available parts was completed. A total of 71 modules were built for the Phase 3 detector. Although some modules are still to be tested, to date four (five) Layer 1 (2) modules were lost in the production. Rework on 12 modules during the module production was successful in eight cases. A total of 17 ladders were built, 13 for Layer 1 and four for Layer 2. Three Layer 1 and two Layer 2 ladders were lost in the ladder assembly process for an overall ladder assembly yield of 77% and 50%, respectively. The failure causes are attributed to either operator mistake, damage during testing or particulate contamination. A modified assembly strategy has been proposed for the PXD2020 minimising the handling of the sensors and modules, improving the cleanliness of the facilities, adding manpower and improving the quality control. The committee appreciates that the collaboration has undertaken a critical review of the production and assembly process to ensure a full PXD will be available by 2020.

There are 15 (12) Layer 2 backward (forward) modules available, with six modules still to be tested. There are no A-grade sensors available anymore from the current production runs. Folding in the assembly yield, the number of Layer 2 modules to complete the detector is adequate, though marginal. However, there are not enough modules to build a full new Layer 1. The PXD group has decided to build a complete new PXD for installation in 2020 and two full production batches of sensors, staggered by five months, have been started with seven and twelve wafers, respectively. The anticipated completion date is summer and late autumn of 2019 for the first and second production batch, respectively. The availability of ASICs for the new PXD is not an issue. Use of a new version of the Switcher chip is proposed, which has a slightly lower power consumption. In January of 2019 the new production and assembly protocol will be exercised by building 14 Layer 2 ladders from existing modules. Construction of Layer 1 modules is scheduled to start as soon as the sensors from the first production batch are available, around August 2019. Layer 1 ladder assembly is expected to be completed by the end of 2019. A possible fall back option is to use the Layer 1 ladders from the current PXD.

Despite the setback with regard to a only partially populated PXD, the collaboration is to be congratulated on completing the installation of the PXD detector on the beam pipe and integrating the PXD with the SVD. The schedule calls for the VXD to be installed and fully tested by December 21, 2018 and the committee is looking forward to a successful installation.

3.4.2 Concerns

- At this stage of a new project it is not unexpected that the many sources of background are not yet fully understood. This lack of understanding, though not surprising, remains a concern.
- The 30 kHz gated mode could not be tested during Phase 2. In addition, errors due to large event size were observed. It is not clear how this will scale in a full-size system and is concerning.
- There was a lack of experts during the data taking period. Having enough scientists to adequately staff the shifts during Phase 3 is a concern. Given the overall difficulties of the experiment to have a smoothly running data acquisition system and the persistent demand on FPGA programmers, the fact that the full data acquisition system has not been fully exercised will have to be dealt with rather sooner than later.
- With the start of the Phase 3 run, expertise will be required to commission and operate the full PXD detector and analyse its data. The construction of a complete new PXD detector requires the continuous availability of additional resources for nearly another two years. To keep the expertise and enthusiasm of the current PXD crew will require good resource management. Furthermore, the modified assembly procedures will require the construction of new clean room infrastructure at HLL and additional technical resources have to be identified for the assembly.
- The current schedule is quite demanding on the PXD team in the first half of calendar year 2020 with the assembly of the modules and half shells.

3.4.3 Recommendations

- The committee reiterates its recommendation from the last review that adequate effort be directed towards understanding the various background sources to ensure that the detector can be protected for Phase 3 running.
- The background team has done a great job characterising the various backgrounds. Despite heroic efforts, understanding the various sources of background has had limited success. This is to be expected given the frontier aspects of the SuperKEKB collider and the early stages of running. It is suggested, though, to reevaluate the approach towards understanding the background for Phase 3, including the organisational aspects. Exploring the appointment of a dedicated liaison between the experiment and the accelerator is recommended.
- The committee supports the decision of the PXD group to attempt to build a complete new PXD detector to be installed during the summer shutdown of 2020 and urges the group to ensure the required level of resources is available to meet this challenge. It is suggested that formal commitments from collaborating institutions

are obtained to ensure that all required resources are available during at least the next 1.5 years.

- Development and testing of the firmware for 30 kHz operation before the start of Phase 3 is encouraged.
- It is in general recommended to exercise the full data acquisition system under realistic running conditions before the start of Phase 3 running.
- The collaboration has set a target integrated luminosity of 10 fb^{-1} by the summer of 2019 and 50 fb^{-1} by the end of 2019. This goal is ambitious but not unrealistic. Utmost caution is urged not to endanger the pixel detector during this critical startup phase. Understanding and controlling of the background is higher priority than integrated luminosity.
- An adequate pool of well-trained shifters should be available for the start of Phase 3 running. Training more staff to enlarge the pool of available experts is highly recommended.
- It is highly recommended that the Layer 2 ladder assembly be started as soon as possible to exercise the assembly procedures and the quality control process to ensure maximal yield and create schedule contingency.
- The committee encourages continued detailed simulation of the VXD with the latest beam pipe design, backgrounds at various levels and full performance evaluation of the VXD with zero, one and two layers.

3.5 VXD-SVD

The collaboration presented the operational experience with the Phase 2 slice and the status of preparation for the Phase 3 detector.

The Phase 2 SVD consisted of one ladder for each layer from 3 to 6, located along the horizontal axis on the external side of the SuperKEKB ring. The priority of Phase 2 running was the evaluation of the radiation and background, to assess safety of operation in Phase 3. Requirements for operation are a dose rate less than 1 Mrad/yr and an occupancy lower than 2-3%, but with a safer target of 100 krad/yr and 1% occupancy. The occupancy measurement as a function of the beam parameters allowed to disentangle beam gas and Touschek backgrounds. The rate is higher than expected from simulation, especially for the HER. Extrapolation to the beginning of Phase 3 provides an occupancy of 1.4–3.6%, therefore operation will be safe, but it will be too high for the nominal luminosity. It is expected that it can be pushed down to an acceptable level by SuperKEKB tuning and the installation of additional collimators. The total dose has been measured with radiochromic films. Comparison with simulation is not available yet, but no concern is expected. A linear correlation between the SVD silicon occupancy and the diamond beam monitor is observed, giving confidence that the radiation monitor will correctly protect the detector. The offline tracking performance of the detector shows good stability during the data taking period, with high signal-over-noise ratio and a time resolution of 3.5 ns, relative to the CDC. Overall tracking efficiency is at the 95% level. This low value is under investigation, but it may be due to the reduced acceptance and fake tracks. No single point resolution study was available at the review, but residuals are acceptable, with tails dependent on the momentum spectrum.

The SVD operational experience revealed two features not observed during the detector assembly and integration: crosstalk on the origami hybrid, related to the digital signals of the APV25 chips, and multiple failures of the dew point sensors. The former is being investigated, but no effect on performance has been seen yet. The latter is likely due to the very low dew point inside Belle II, out of the Vaisala transmitter specifications. Replacement of the humidity sensors with a model suitable for the actual operating condition is foreseen.

After the completion of building the half shells in July, the SVD has undergone commissioning in the VXD clean room at Tsukuba Hall. During July-September 30 million cosmic events have been collected and cluster size, noise and efficiency studied. For horizontal planes, where particle incident angles are similar to collision events, an efficiency well above 99% is achieved.

The SVD has afterwards been integrated with the PXD and joint commissioning and integration are proceeding in order to be ready for Phase 3. Integration requires to increase by 5 mm the gap between barrel and endcap, in order to route safely the SVD cables and services, even after removing the cable insulation to increase flexibility. A detailed plan to complete the detector installation and cabling, and to perform a dry volume test by the end of 2018 has been developed. The radiation monitoring and beam abort system will be completed by adding 12 sensors on the SVD rings in addition to the eight placed on the beam pipe. Besides the above mentioned repair of the humidity monitoring, an additional redundant system is under preparation.

Transition towards a sustainable operation mode is being prepared based on Phase 2 experience, with two Operation Coordinators, two shifters, one local and one remote, with clearly defined tasks, and a pool of experts. Plans are drafted for calibrations every two weeks, with more frequent pedestal and noise runs. The committee acknowledges the large amount of work and the impressive results by the SVD group.

3.5.1 Concerns

- The background rate is about one order of magnitude higher than expected. Given the early state of machine tuning and missing collimators, it is not a concern for the beginning of Phase 3, but it should be understood and monitored in close collaboration with the machine.

3.5.2 Recommendations

- There is no major recommendation, but to prepare for the background occupancy studies in Phase 3 and to follow the path for integration of the SVD with the PXD, the rest of the Belle II detector and SuperKEKB operation, especially for what concerns the radiation monitoring, beam dump and interlock systems.

4 CDC, TOP, ARICH, ECAL, KLM

4.1 CDC

4.1.1 Status

The excellent performance of the CDC in early Phase 2 data was already described in the June 2018 BPAC. By the time of this review an analysis of the full Phase 2 data set yielded a total of about 571 B mesons (389 $B^{\pm}$ and 182 B^0 or $\bar{B}^0$) fully reconstructed in a variety of hadronic modes involving charged and neutral mesons. Furthermore, a robust 1 versus 3 $\tau^+\tau^-$ signal has been observed, and there are hints of $B \to K^*\gamma$ radiative penguin signals.

Although some hardware problems occurred just before or during the Phase 2 run, CDC operation was generally stable. The origins of HV problems encountered in four regions were identified and solutions were found. FADC and DAC issues were traced to insufficient current supply capabilities of their respective DC power supplies. The FADC issue was addressed by replacing power supplies and the DAC issue was addressed by increasing one supply voltage. On the long run there is a plan to redesign the front end boards to reduce FPGA and FADC power consumptions.

Cross talk among wires has been seen in random trigger data for beam background studies. This issue has been studied in bench tests, which have not yielded conclusive results, so tests are ongoing. Intermittent common mode noise has appeared in some outer layers. There is inconclusive evidence that a SVD crate on the roof of the detector structure may be a source of this noise. Studies to identify the source (or sources) and mitigate the noise are ongoing.

The most serious problem encountered in CDC operation was intermittent persistent currents in some sectors of some (mostly outer) layers particularly those around layer 54 out of 56 layers. The general pattern was a sudden increase in current until the preset current limit was reached. The current persisted even if the HV or the beam current were decreased and stayed at the limit level until the HV was turned off. When the HV was turned on again, the currents were back to normal levels. After the Phase 2 run, the persistent currents also occurred in other layers nearer the centre.

There is not much experience with this sort of behaviour in central drift chambers at e^+e^- colliders. This problem did not occur in the Belle drift chamber, or in any of the three CLEO drift chambers. The CLEO drift chambers were operated with a dry gas from a gas recirculating system that removed oxygen, water, and long-chain hydrocarbon molecules. In the BaBar drift chamber, high currents leading to HV trips were encountered in early beam running. This was cured with the addition of a small amount of water vapour to the gas mixture. For the rest of the experiment, the BaBar drift chamber ran at 30 V below the original design voltage.

After the Phase 2 run, the CDC group did a number of experiments to try to isolate the cause or causes of the persistent currents. These results were inconclusive. Based on discussions during and after the BPAC meeting, the committee has a number of suggestions for experiments that may help to isolate the causes of this problem as described in subsection 4.1.4.

4.1.2 Concerns

- The observed cross talk and coherent noise are matters of some concern.
- The persistent current problem is the matter of most concern for efficient operation of the CDC in Phase 3.

4.1.3 Recommendations

- The CDC should continue studies aimed at mitigating the cross talk and noise.
- The committee recommends that a dedicated program of identifying the source(s) of and mitigating the persistent currents is embarked on. Reaching out to drift chamber experts from other experiments who may have insights into how to deal with the persistent current challenge is particularly important.

4.1.4 Special recommendations on the persistent current issue

Here are suggestions and questions for addressing the persistent currents

1. Try to disentangle "surface current" (current along the surfaces of the endplates, e.g. due to humidity on the outer chamber surfaces or other leaks from HV to ground wires) from current drawn in the chamber gas, which could be a pre-cursor of the Malter effect.

    - Fill the CDC with pure nitrogen and apply nominal HV in the range 2.2–2.4 kV, at which no gas amplification takes place in nitrogen. The absence of currents in outer layers (e.g. L54, L55) with nitrogen at this HV would indicate that CDC currents are due to onset of the processes in the normal CDC gas, appearing only with gas amplification ON.
    - Monitor currents on a regular basis (during the shutdown) until March 2019. Surface currents will tend to show irregular behaviour, while currents inside the chamber should systematically decrease, without irradiation. (Observation that the current increases after HV is turned ON and afterwards decreases within an hour is consistent with Malter effect, since current heats the wire and increases conductivity.)
    - Increase the amount of water in the CDC through a bubbler while keeping gas flow constant. In particular, monitor current behaviour on a regular basis in the most affected layers, L54 and L55.

2. Study the gas flow distribution inside the CDC. Could insufficient gas replacement in the CDC outer layers be the reason for earlier degradation, thus leading to larger currents?

    - Simulate the gas flow distribution inside the CDC to find the optimal gas flow, based on the gas inlet and outlet structure. (Is the gas flow pattern the same as it was in the Belle I drift chamber, which did not have persistent currents?)

- Increase the gas flow to the CDC, since the actual gas flow used during Phase 2 appears to be low (i.e. less than one chamber volume per day) and there is no forced gas flow through outer CDC layers. (Caveat: high-rate experiments usually keep gas flow rate at a level of one chamber volume per hour.)
- Simulate the possibility of operating the CDC with a hydrocarbon-free gas mixture (e.g. He/CO_2). Will this lead to significant performance degradation due to the lower and non-saturated drift velocity for a given electric field? (Drift velocity may not be an issue, since the electronics shaping time is comfortably large, 600–700 ns.)

3. Dark current could potentially be related to the insufficient "surface resistivity" of Al field wires, or can result from polymerisation deposits on Al field wires.

   - Ask the company producing Al-wire if they have specifications on wire "surface resistivity". Has the production process been identical to the earlier one, when Al wires were produced for the Belle I chamber?
   - Do SEM analysis of non-irradiated Al-wires (e.g. a blurred SEM image would indicate surface conductivity is not good). If there are irradiated Al wire samples extracted from the CDC do SEM analysis on them.
   - Build a test chamber, using exactly the same sense and field wires, endplate material, and glue. Irradiate this test chamber with heavily ionising particles, e.g. Am^{241} alphas. (Caveat: irradiation with Fe^{55} and Ru^{106} may be not sufficient to trigger dark current problems.) If the dark currents appear in the test chamber, one could use it to study the optimal quantity of water and/or alcohol to be added.

4. Study if dark currents can be due to CDC surface effects and/or leaks inside HV cables.

   - Increase dry air circulation to the surface of the endplates (there was an indication that some CDC surface effects were observed during chamber construction).
   - Make new HV connectors (from the side of HV distribution module) and/or reshuffle HV connectors between inner/outer layers on the CDC surface (if technically feasible).

5. Depending on the outcome of the studies, there are some possible or probable methods for remediation of the problem.

   - If water addition helps to suppress currents in L54 and L55.
     - Optimise the amount of water and/or alcohol to be added to the gas mixture (Caveat: larger amounts of water do not necessarily improve chamber resistance to the Malter effect).
     - Increase gas flow, based on simulation results, to make sure the gas mixture is exchanged sufficiently often in the outer CDC layers.

  - Precisely monitor the He/C_2H_6 gas composition, by studying the gas exiting the chamber. Use gas chromatography to search for silicon related contaminants and high molecular hydrocarbon-components. (This will be possible after beams are back in March 2019.)
  - Use a hydrocarbon-free gas mixture, as mentioned above.
- If dark currents are due to surface effects, define next steps depending on these findings. At this moment, there is no indication what could be the source.

4.2 TOP

4.2.1 Status

The TOP group made good progress in the development of the readout firmware and the evaluation of the TOP performance using the Phase 2 data.

The new readout firmware introduced in March 2018 has been relatively stable, although there are still remaining issues like the DAQ limit at around 10 kHz, truncated waveforms, loss of timing and abnormal pulse shape when the look-back time is long. Three issues identified for the TOP Level 1 trigger in the June BPAC have been resolved. Low efficiency for hadronic events was due to a tight cut on a timing parameter. The modified cut improved the efficiency from 18% to better than 90%. The basic functionality of the TOP slow control and monitoring is in place with several minor issues. Some improvements are required for stable and robust operation. The TOP group has formulated the operation plan for Phase 3, which requires more experts.

The performance of the TOP detector has been evaluated using the data taken in the Phase 2 run, which revealed that the particle identification efficiency is lower by 15–20 % at a certain fake rate. The tests with laser pulses indicate that the time resolution is $\sim$120 ps, which is worse than expected. Residual non-linearity of the sampling circuits can explain both effects. New calibration algorithms are being developed to correct the non-linearity. The numbers of TOP hits in di-muon events are compared between the data and the MC. While the conventional PMTs give a good agreement between the data and the MC, the ALD PMTs give higher numbers of TOP hits in the data than in the MC. The alignment between the TOP and the CDC has been performed, showing that the timing parameter between the TOP and the CDC is not stable for one slot.

The beam backgrounds were also a major concern in the June BPAC meeting. The result of scaling the current background level is about five times more than the tolerable level. It is not clear whether any progress was made in the understanding of the beam backgrounds from the perspective of the TOP lifetime.

The TOP group plans to replace 224 conventional PMTs with ALD PMTs in 2020. They have acquired 84 ALD PMTs so far, leaving 175 remaining including 35 spares. They have plans to order 126 ALD PMTs, but no plan for the remaining 49 PMTs yet. There might be a production yield issue since the recent production rate is about ten per month.

Monitoring of the PEEK delamination issue is on going. The TOP group started monitoring the dew point and gas flow rates for each module to detect possible breaks of the gas sealing. They also started measurement of quartz reflectance to monitor the optical oil contamination in the quartz region.

4.2.2 Concerns

- The TOP DAQ is not still ready for the full data taking with a DAQ rate limit of 10 kHz.
- There are still many issues to be resolved in the readout firmware, slow control and monitoring system.
- The TOP performance in Phase 2 is less than expected from the simulation. While the TOP group has an idea about the cause, it has to be verified and addressed.
- It is worrisome that the origin of the higher background for the TOP is not well understood yet, since the background rate is 5 time higher than the lifetime limit of the conventional PMTs.
- Production of the replacement PMTs with ALD might be completed by 2020.

4.2.3 Recommendations

- The TOP group should allocate sufficient resources to complete the DAQ firmware and software so that it can operate with full functionality in a stable manner in Phase 3.
- The TOP group should work together with the background task force to reduce the TOP background rate so that the conventional PMTs can survive until the shutdown in 2020.
- The lifetime of the recently produced ALD PMTs needs to be verified.
- The TOP group is recommended to examine carefully the production plan for the replacement PMTs.

4.3 ARICH

4.3.1 Status

The ARICH was not operated in the full configuration in the Phase 2 run due to insufficient cooling. Only three or four out of six sectors were operated most of the time.

During the Phase 2 data taking, ten out of 72 merger boards had some communication issues. Seven of them were traced to the issues with the cables or the connectors between the ARICH and the DAQ. One of them was due to a DAQ issue. Two of them were due to internal cables of the ARICH. The ARICH also had additional issues in 11 out of 420 HAPDs.

The calibration and alignment studies using Bhabha events in the Phase 2 data yield the average number of hits and the standard deviation of the Cherenkov angle that are about 10% worse than those expected by the simulation. The ARICH group estimates that this corresponds to $\sim 4.3\sigma$ K/π separation at 4 GeV, although it was not demonstrated by the data analysis. Better alignment should reduce the discrepancies between the data and the simulation.

During the shutdown, a new cooling system was installed in the first sector after successful mockup tests. The cooling test of the full sector at the flow rate of 1.2 ℓ/min shows that the temperatures of the merger boards and front-end boards are 12–13°C above the water temperature. No significant change in the noise is observed after the installation of the new cooling system. The installation of the rest of the cooling system is ongoing at the time of this BPAC meeting and was expected to finish by the end of October. The ARICH group intends to test the new cooling system and the DAQ in November.

4.3.2 Concerns

- Particle identification performance with the Phase 2 data has not been demonstrated yet.

4.3.3 Recommendations

- The ARICH group should continue efforts to demonstrate the particle identification performance using the Phase 2 data.
- Although the ARICH group documented the material introduced and removed in the new cooling system, it is still important to verify that the simulation programme properly reflects those modifications.

4.4 ECL

4.4.1 Status

The ECL group had a very successful Phase 2 run. Briefly: All counters functioned, the DAQ worked well, data quality monitoring histograms provided useful information, luminosity monitoring worked well and provided online luminosity measurements for SuperKEKB, environment monitors functioned and the software for sending data to the global Network Shared Memory is nearly ready, and the ECL shift operators were able to manage ECL operations with the slow control system. The most serious problems encountered were a high level of pileup from beam background and excess noise unrelated to beams in 30 endcap channels.

At the current level of understanding and calibration of the ECL, π^0s and ηs are reconstructed with masses close to the PDG averages. This was achieved with a 2.5% photon energy correction between cosmic ray data and Phase 2 data, that was chosen to match the π^0 mass. This capability of neutral meson reconstruction contributed significantly to the reconstruction of approximately 571 B mesons mentioned in the CDC section of this report.

The peak of the centre of mass energies of γs measured with $\gamma\gamma$ events is close to $M_\Upsilon/2$, although there remains a modest discrepancy between data and predictions of this energy distribution. Pulse shape discrimination firmware has been developed that provides excellent discrimination between γs and K_L s with $E_{\text{Lab}} > 0.5$ GeV and good discrimination below that energy.

Beyond photon detection, neutral meson reconstruction, and luminosity measurement, the ECL is also an essential trigger element, providing the triggers for Bhabha and $\gamma\gamma$ events, and contributing to triggers for hadronic events. The ECL furnishes energy, timing, cluster counts, and Bhabha information to the Global Reconstruction Logic and Global Decision Logic. During Phase 2, the ECL trigger was the most mature of the subsystem triggers. The efficiency of the ECL trigger in Phase 2 was already about 98%. The 3D Bhabha trigger works well, but with lower efficiency than expected. Efforts to resolve remaining relatively-minor concerns with the ECL trigger are ongoing.

Altogether, ECL performance in Phase 2 was excellent and augurs well for Phase 3 physics.

The excess noise in 30 endcap channels was traced to a grounding problem. A temporary ground wire in one sector substantially reduced the noise in that sector's noisy channels. New ground belts are being prepared and there are plans to study noise performance in February and adjust the grounding scheme while the endcap is open.

There is a plan for training more ECL shift operators in February. Resources available for this effort include manuals for troubleshooting, shift operations, and local run operations.

4.4.2 Concerns

- The unexpected amount of beam-related noise in the ECL is a serious concern.
- The current level of calibration and simulation of the ECL is a significant accomplishment, but more work will be necessary for the ECL to reach its ultimate potential.

4.4.3 Recommendations

- The ECL group should continue to work effectively with the beam-background and SuperKEKB groups to improve understanding of the beam-related noise and find ways to mitigate it.
- Efforts to understand the fine details of the calibration and simulation of the ECL should continue.

4.5 KLM

4.5.1 Status

A part of the KLM system was integrated in the Belle II data taking system during the Phase 2 run and debugging and commissioning of the system has been progressing. The KLM detector consists of the barrel (BKLM) and the end-cap part (EKLM). Scintillator strips with Multi Pixel Photon Counter (MPPC) readout are installed in the the first two layers of BKLM and all of the 14 (12) layers of Forward (Backward) EKLM. The remaining 13 layers of BKLM are covered by the Resistive-Plate Chambers (RPCs) from the Belle detector.

Concerning the BKLM, the data of a few sectors were not readout due to failures of the aged hardware, the power supplies of the VME crates and the Data Concentrator boards. For the EKLM, 30% of the whole system was not integrated in the Belle II DAQ during the Phase 2 run. The main problems have been identified as a wrong cable connection to the Frontend Timing Switch (FTSW) module and a power supply failure of the VME crates. The cable connection to the FTSW board was corrected after the Phase 2 run and the recovery of the data flow was confirmed in cosmic ray runs. A platform to solve the problems of access to the power supplies and to the readout electronics has been designed and ordered.

There are still many more tasks to be completed before the physics run starts. The firmware development of the readout board is one of the major deliverables. The scintillator readout of both KLM systems have been recording the timing information only instead of the waveform to cope with the trigger rate in the Phase 2 run. To achieve the design performance of the KLM, the firmware with full functionality should be prepared as early as possible and the detector commissioning, including the HV and the threshold tuning should continue.

4.5.2 Concerns

- The firmware of the readout board was not in final shape during the Phase 2 run and there are a large number of tasks to be completed before physics data taking.
- The infrastructure is aged in general and the strategy of the procurement does not appear to be entirely clear.

4.5.3 Recommendations

- A proper amount of manpower should be allocated to the firmware development and the complete firmware and software should be used in further commissioning as soon as possible. The accumulation of experience and various feedback to the developer may be the key for the stable operation during the physics run.
- Reinforcement of the aged infrastructure should be discussed with the Belle II management and a plan should be established quickly.

- Merging the organisation of the BKLM and EKLM should be seriously considered, including the merits of personnel reorganisation, uniform development of the detector operation, monitoring, etc.

5 Trigger, DAQ and Slow control

5.1 Trigger

5.1.1 Status

The trigger was operating stably during the Phase 2 run providing three main physics triggers as well as calibration and background triggers. Steady progress was made in fixing hardware problems and improving efficiency. The physics trigger rate was about 65 Hz, well below the design values of the trigger and DAQ systems. Physics triggers were based on 2D tracks from CDC and calorimeter energy and timing from ECL. Background rejection was found to be difficult without 3D-track reconstruction. Efficiency for hadronic events was acceptable.

The ECL trigger is the most advanced one among the sub-trigger systems. The CDC trigger still needs some hardware work to reduce noise and to implement 3D-track trigger and timing. The BKLM trigger worked stably, but the EKLM was not connected. The reason for the low efficiency of the TOP trigger has been understood. The TOP needs firmware work to operate at high background.

A strategy for the Phase 3 trigger was presented.

5.1.2 Concerns

- The efficiency is not optimal for low multiplicity events.
- The 3D-track trigger with the CDC is not yet implemented. As a result, background classification and rejection are difficult.
- The integration of the trigger in the run control was identified as a high priority task at the June review. This would give operational experience and potentially enable automatic recovery. Progress has been made but the work has not yet been completed for all sub-triggers, the overall trigger control and archiver.
- The monitoring, both event-by-event as well as statistical, is not well developed.
- Work is needed on the Global Decision Logic (GDL) to prepare for continuous injection in Phase 3. The timing system is supposed to distribute the "injection veto" signal to detector readout. This is essential for gated operation of the PXD in order to obtain acceptable dead time. Items to be addressed for the GDL are the ability of the veto logic to cope with the injection noise beyond 10 ms, addition of monitoring bits and the interface to DAQ. The overall mechanism still needs to be commissioned.

- The trigger consists of many sub-groups responsible for the sub-detector trigger primitives and the global trigger (GDL and Global Reconstruction Logic). Good communication and project priorities are paramount. The fully implemented Belle II trigger will be a system with high efficiency, redundancy and background rejection capabilities. It is not obvious what the project priorities are towards reliable deployment for physics operation of the various triggers.
- The manpower for the trigger operation during Phase 2 was subcritical. It is believed to be better for Phase 3, but still marginal. The human resource situation for hardware and firmware development remains critical.

5.1.3 Recommendations

- Remaining hardware issues with the fast timing distribution, noise, etc. should be followed up rapidly.
- At least one of the two 3D-track trigger systems should be brought online.
- The work to integrate all trigger subsystems in the slow control remains a priority.
- The committee urges that effort should be devoted to the implementation of trigger monitoring. This should cover both event-by-event monitoring by emulating the trigger chain in the C++ software, as well as done statistically by counters and histograms. Possibly, in this area physics groups could contribute manpower.

5.2 DAQ

5.2.1 Status

The data acquisition system performed satisfactorily during Phase 2 data taking, considering that it was still in an early phase of integration and commissioning. Causes for DAQ downtime have been analysed. Operation with a sub-set of detectors with cosmic triggers, as well as stress testing continues during the current shutdown period. A "full dress rehearsal" is foreseen to start in January 2019. Furthermore, a dedicated setup is being established for commissioning the readout of the full (one layer) PXD. Fixes, stability improvements and functional enhancements have been implemented progressively during Phase 2 and are continuing during the current shutdown period.

The long standing problem of a very small team of experts has been mitigated by forming an extended DAQ core group of a dozen persons who were able to do routine operation during Phase 2 and adding a number of new persons (students), who will contribute to the development. The new developers started initially working in the area of slow control.

The committee took note of the plan to replace the COPPER CPUs for the 2020 run and the process to reach a decision on the remaining options.

5.2.2 Concerns

- The state of development of the interface software between online and offline, including transfer of files and conditions database, was a concern at the last June review. Progress has been made with the design, but the implementation has not been completed.

- There are still many issues to address before the full dress rehearsal and data taking with high efficiency for Phase 3. These pertain to functionality and robustness of software and the interconnect between central system and the sub-detectors.

- The system worked globally satisfactorily in Phase 2. However, the rates were still much lower than what Belle II is aiming for. Progress has been made towards operating at 30 kHz and a 200 ns trigger back-off time. However, this goal has not been reached by all sub-systems yet. It would also be useful to understand how much headroom there is in terms of trigger rate and event sizes, in case backgrounds turn out to be considerably larger than expected.

- The system has still to scale out from the Phase 2 configuration, in particular the completion of one layer of PXD and associated increase in ONSEN and HLT/storage nodes, and commissioning of the full ROI mechanism.

- The core team is still small and the addition of new developers has just started. Further reenforcement is critical for slow control, but also in DAQ areas outside slow control.

5.2.3 Recommendations

- The training of the new developers must be followed up vigorously. Newcomers could be able to provide documentation and developments for extending functionality of existing components will be good sub-projects for them to learn further.

- For handling pathological events arising from unbiased silicon detectors, it is suggested to consider a mechanism used at other HEP experiments, where the payload is suppressed using the slow control voltage information.

- Monitoring and cataloguing of the limitations in the sub-detector DAQ systems done in Phase 2 must continue during the current shutdown period and forthcoming full dress rehearsal. Whenever possible, the root cause should be followed up to avoid that problems remain because of unclear responsibility between the central and sub-detector DAQ groups.

- Extensive stress testing is strongly encouraged during the full dress rehearsal. It should include high trigger rates and where possible with large and varying size events, as well as exercising corner cases, such as back-to-back triggers.

- Concerning future upgrade plans, the committee also suggests considering parts beyond the COPPER CPUs, taking advantage of improved technology since the original design, in order to simplify operation and maintenance in the long term.

- Consistent management of versions of code and conditions should be introduced to deploy and to track revisions used in online operation.

5.3 Slow control

5.3.1 Status

The slow control encompasses run control, HV control, monitoring applications, a GUI, communicating via a software backbone (nsm, EPICS). The slow control has made significant progress in functionality and robustness. A small shift crew was able to do the routine operation in Phase 2.

The committee was pleased to see that in the current shutdown a systematic approach was pursued to reproduce problems identified during Phase 2 and to address them. Action has been taken to install computing infrastructure with high-availability and redundancy.

New students already contributed to developments in the area of run control and HV control.

5.3.2 Concerns

- Despite of the increase in the number of members, the central DAQ and slow control teams is still uncomfortably small. For example, reenforcement is needed in the area of the GUI.

- The system was affected on several occasions by computer hardware or operating system issues, which had to be fixed by the central team. A substantial part of the EPICS archiver data has been lost. Action has been taken to install computing infrastructure with high-availability HA and redundancy. However, it is not clear if the chosen solution for mirroring and duplication is an automatic commercial (HA) system or if this is done by hand by the DAQ team. It appears that the cluster of about 100 PC nodes has a large diversity in hardware and system configurations and is managed by hand. It is not clear how long it would take to recover from a situation with a broken node.

- There was concern about the interlock system at the June review. It is unclear what the actual situation is, as no report was provided at the October review.

5.3.3 Recommendations

- The Belle II management is encouraged to continue finding human resources to help the slow control and DAQ team. In particular, dedicated system management technical support would not need to be knowledgable on DAQ and would free the small core team from these duties. Commercial HA solutions exist at reasonable price, which would reduce routine work.

- It is suggested to consider a configuration management system for the administration of the nodes of the online computing infrastructure.

6 Software and computing

The committee does not find major problems with the progress in software and computing and expects these functions to be essentially ready for Phase 3. Some issues have been identified in the preparation of data processing and computing operation that will need to be streamlined to cope with the evolution of the experiment from its commissioning in Phase 2 and the early stages of Phase 3 to its full physics exploitation of later Phase 3 running.

Software and computing developers are to be commended for the efforts they are putting in training new data "consumers" combining topics on software and grid analysis in the latest Starter Kit workshops. Feedback from the trainees has identified areas for improvements that are already being addressed.

Reprocessing of Phase 2 data has been performed a few times on the whole data set with significant improvements in physics performance in later processing. This, combined with the ongoing efforts in Monte Carlo (MC) production and skimming, has allowed gaining considerable experience and stress testing existing procedures. Key requirements to prepare effectively for Phase 3 i.e. good communication between calibration and processing and computing experts, fast software updates and efficient global database tags management, have been identified. Refinement and automation of the procedures for Phase 3 is planned and is critical in particular for prompt calibration and alignment.

6.1 Software

6.1.1 Status

Experience is being gained in the analysis of data for understanding of physics performance of the detector. Many improvements have been made in simulation, reconstruction and analysis tools. Tracking efficiencies are being studied with specific data sets and preliminary comparisons with MC agree at a level of a few percent. Similarly the ECL software is working reliably both on HLT and offline. Timing calibration work has started and more complex algorithms with neural networks to improve photon/hadron and muon/pion separation are under study. Charged Particle identification (PID) likelihoods and likelihood ratios show large discrepancies with MC expectations. However, the quality of those quantities depend on the related sub-detectors performance for which dedicated studies are still necessary.

The committee was pleased to note that the software group has started to address the concern raised in the June BPAC report regarding compatibilities between database global tags, software versions and data samples. Tools have been developed to ease the choice of global database tags to be used when processing a given dataset.

Fast releases to allow fast access to new analysis features have been put in place and recent improvement in analysis-level software are becoming mature and performing well, e.g. for vertex fitter.

Preparation for new software for Phase 3 data processing is in progress with the aim to have a validated release for DAQ use by early 2019. The release is expected to provide improvements as better logging for online processing, algorithmic enhancements for analysis, speed up of the calibration framework and code modernisation. Most calibrations have moved to the Calibration and Alignment Framework. Feedback obtained from the experience of Phase 2 users is also being addressed including improvements in the trigger information provided in the events. Development of the event display framework is on hold due to lack of personnel.

Migration to the latest released version of Geant4, 10.4, will take place immediately after the release for Phase 3 processing. Improvements in the physics modelling have been suggested by Geant4 authors and manpower is being sought for their implementation.

New software responsibilities have been identified to match the evolving needs for the experiment data and MC processing. The committee was pleased to learn that young researcher are volunteering for these tasks.

6.1.2 Concerns

- One of the core software developers is leaving at the end of the year and not all replacements for his responsibilities had been identified at the time of the review with the potential risk of being unable to maintain the know-how. Although software and computing are in good shape for the moment, there appear to be many single points of failure and continuity and knowledge transfer will be a concern, in particular if many people will shift their focus to data analysis when Phase 3 will be at full steam.
- Further effort is needed to obtain sufficient understanding of the sub-detector performances from the data, in order to achieve high quality physics analysis.

6.1.3 Recommendations

- The current level of quality of the software must be maintained and continuity in the group ensured. The committee encourages the software group to provide experts' documentation with the option of leveraging on the existing JIRA tasks followup to mitigate the risk of having to rebuild the know-how on software experts tasks due to personnel turnover.
- In order to gain confidence on the understanding of the physics performance, a concerted effort between sub-detector experts and analysts should be carried out. Dedicated data based sub-detectors studies should be complemented with Monte Carlo studies where the observed sub-detector performance can be inserted. Introducing further degradation in the behaviour of the sub-detectors would allow robustness studies enabling the evaluation of Belle II physics reach in extreme conditions.

- The committee encourages the analysis of HLT validation with trigger emulation studies on collected data. For this, it is essential to be able to access all quantities entering the trigger decision, in addition to trigger results on an event-by-event basis, in mDST files. It is suggested to provide the software emulating the trigger in a form that could also be run on MC samples.

- The committee supports the plan by the software group to provide tools to interface software and computing for processing configuration and book-keeping by producing files of metadata information while processing the data. This is also to be used for consistency checks of the output by the computing group. The schema will need to be agreed on between the software and computing groups. While the format should be kept as fixed as possible, a mechanism to allow for schema evolution for additional information that may become necessary should be considered.

6.2 Computing

6.2.1 Status

The primary activities of data productions until the start of Phase 3 physics run consist in producing large MC samples to be used for physics and detector performance studies as well as performing stress tests of different aspects of the central production system including the capability to transfer large amount of data between different sites.

Development of the system to distribute raw data by uploading them into the KEK Grid storage element and registering them into the file and metadata catalogs and to make a second copy on the Grid by using the Belle II Distributed Data Management (DDM) system used in production has continued. All ROOT RAW data files up to Phase 2 Exp3 are now registered and were being copied to BNL at the time of the review. The system now needs to be automated. Automatised procedures for online-offline raw data copy are still under development on the offline side and web-based monitoring tools are also being developed.

The DAQ replica server at KEK Computing Centre for offline use was being filled at a rate of 2 GB/day during Phase 2 and was almost filled in the three months operation. An upgrade to a bigger server to cope with the expected load of Phase 3 is planned. It should have sufficient capacity to provide some buffer for Phase 3 in case faster updates will occur.

The BelleDIRAC production system has switched from being a proto-production to a full system that has allowed a continuous and stable operation over the last several months for MC and Skim productions as well as user analysis. The release of a new gbasf2 version since the June review is making the system more robust and allows for multiple output files. Nevertheless several features and user documentation are missing due to lack of human resources. The computing group has an exhaustive list of developments planned for Phase 3. In terms of production management simplification of the production definition and improvements in the raw data processing are planned as well as an automatic consistency check of the output and setting of job priorities. Improvements in the production monitoring for raw data and an automatic detection of problems are planned. New collaborators from BNL have taken the responsibility for the current Belle II DDM where automatic data distribution and storage cleaning as well as data archive are the priority tasks for Phase 3. The computing group is justifiably concentrating in deploying a fully functional reliable system for Phase 3 and the evaluation of existing DDM solutions used by other experiments has not yet started. The computing group intends to start a complete evaluation of Rucio as potential future DDM in the near future.

While user jobs on the Grid still constitute a low fraction of the jobs running in the system, there are a big variety of them both in type and purpose. Training and user support is continuously provided.

Tests are ongoing to verify raw data processing with Grid tools. A well defined procedure and responsibilities for the latest Phase 2 reprocessing preparation and sequence has been put in place as well as mechanisms for followup via JIRA epics. Luminosity determination has been included in the reprocessing steps and added to the run information. Tools to extract the run information from the offline DB are in preparation. Calibration procedures are ready but the reprocessing was sometimes slowed down by the preparation of database global tags, hence effort has shifted into automating the prompt calibration tasks for Phase 3. The whole reprocessing procedure will also need to be automated.

Quality Assurance Monitoring has been run and has been working well for Phase 2. Improvements like the uploading of the resulting plots on a web server are planned for Phase 3.

In the ongoing MC production and skimming campaign, the importance of the skim validation has been highlighted. Solutions to the different operational problems encountered have been found and will be deployed in the a new Skim Data Challenge. Combined skims where a single job runs multiple skims and produced multiple uDST output have been deployed profiting from the new features of the production system. This has resulted in a decrease of the resources needed for skimming. The committee was pleased to notice that extensive testing and dress rehearsals to exercise the evolving offline processing scheme continue to be planned.

Precision analysis requires a good agreement between data and simulated samples. One issue is the modelling of beam backgrounds where the preferred solution is the overlay of background events collected during data taking into the Monte Carlo. While run-independent MC productions would use a complete background set, the run-dependent MC would use background samples collected during each run. Best practices for background files distributions are being discussed for an optimal use of the distributed computing resources due to the limitations in storage at smaller sites.

A Network Data challenge to check the network for future raw data activities is planned.

The computing CPU power available at the Grid sites available to Belle II has been almost constantly used in 2018 and has doubled since 2016 with peaks of up to 300kHS06 used in two months before the review. The available storage has also almost doubled in the last year with up to 8 PB available and used at a 75% level. A Memorandum of

Understanding (MoU) for Collaboration in the Deployment and Exploitation of the Belle II Computing Grid is being finalised, where 48.5% of the resources should be pledged by the biggest sites while negotiations are proceeding with other sites to cover another 27.2% of the resources. Although it is unclear whether other smaller sites will be able to sign the MoU for the remaining 24.5%, some have already provided computing resources to Belle II. The MoU will be signed either at national or site level.

6.2.2 Concerns

- The lack of automation for many of the data management operations was a concern in the June report. Automatised procedures for online-offline raw data copy are still under development on the offline side and while new developers have assumed the responsibility for DDM its automation is not yet in place. This could become an issue for Phase 3 when the number of files will increase with the increase in luminosity .
- A small group of five people are providing expert shifters for the production system. This could be critical for Phase 3 operation as the same people are also developers of the system.
- A concern in the June report was the fact that user analysis jobs on the Grid were not yet taking off. The situation is essentially unchanged despite improvements in the gbasf2 tools and the deployment of new ones for example to find samples of interest. The lack of automation in the data distribution exposes the users to site issues, and therefore it needs to be addressed. The number of user analysis jobs is expected to increase with the accumulation of data in Phase 3 and the higher number of users will expose more and rare issues in the system. Known problems should be tackled before hand and mechanisms to provide fast fixes and user support should be put in place.
- The computing sites are being used at high capacity both in term of CPU and storage. Background Monte Carlo needs for Phase 3 may be difficult to handle efficiently with the availability of samples at different sites. Careful planning on the use of the resources will have to be considered and optimal solutions for their use devised and proactively advertised, like it has been the case for combined skims.
- The evolution of the amount of CPU and storage necessary for the full exploitation of the physics program were not presented at the review but the forecast of their coverage by collaboration sites is currently at $\sim$75% level. While some contributions will likely be provided by sites unable to sign the MoU, the collaboration should make all efforts to cover the needs and consider how to cope with a potential shortage in resources. Particular attention should be paid to smaller sites with such low CPU and storage capacity to make them unusable versus the effort to include them in the production system.

6.2.3 Recommendations

- The committee recommends that the collaboration continues to streamline and automate data operations from the online system to the user analysis on the Grid. Experience gained with recent Phase 2 reprocessing and skim production should be used to address issues that will be more critical for Phase 3 due to the increase in amount of data. Ways to avoid exposing users to Grid site issues for data access and associated recovering mechanisms should be investigated.

- The committee recommends that shifters for the whole production system operation are recruited to complement expert shifters for ensuring a smooth Phase 3 operation. A fraction of normal shifters could be encouraged to shadow the experts and become themselves expert shifters as well as being potential candidates to joining the development team. At the same time developers should continue to provide experts shifts as this experience brings invaluable insight for setting priorities for development.