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

31 October and 1 November 2022 Remote Meeting

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Short summary

This focused review meeting of the B-factory Programme Advisory Committee (BPAC) took place, as a remote meeting, with the following questions posed by the director of the Institute of Particle and Nuclear Studies:

- Long Shutdown 1 (LS1) schedule
  Is the proposed schedule for LS1 appropriate? Point out if there are any particular concerns in the preparation and execution of the detector replacement work.
- Yearly Plan
  Are the operation and study plans for machine and detector in the coming months reasonable to achieve maximal integrated luminosity?
- Selected items
  - Progress in understanding the Central Drift Chamber (CDC) and photon detectors (PMT) for the barrel particle identification system (TOP) lifetime.
  - Improvement plan of data production and processing.
  - Analysis strategy toward winter conferences.

The following report addresses these questions.

The LS1 work appears to be mostly progressing well. The production of the new beam pipe, which was reported to have met a serious setback during the last focused review in June, is now on track again with a few weeks of delay and is expected to be completed by the end of November 2022. One major concern now is the delivery of a new Pixel Detector (PXD2) with two complete layers. While the ladder construction and assembly of the half-shells of PXD2 had been successfully completed, mechanical damages occurred during the pre-commissioning of a half-shell at DESY, where two ladders of the first layer were bent. A dedicated BPAC review meeting of experts took place on October 19th. A detailed presentation on the accident was given by the PXD team, and a written report by the BPAC expert group was distributed to the full members before this meeting. The most likely cause of the mechanical damage of the ladders was identified to be a thermal expansion, when the sliding mechanism failed to act correctly. A plan to prevent this to happen again was presented, but further investigations are needed to be certain to assure the safe operation of PXD2. The PXD2 group has also started to make a plan for replacing the damaged ladders. Here too, further work is needed to establish a safe procedure, since some ladders from the second layer have to be temporarily removed. The number of spare ladders is limited and there is no room for mistakes in this repair work. The experts' report calls for a very careful approach, not pushed by the overall LS1 schedule. The original plan was to start the Japanese Fiscal Year (JFY) 2023 run in October. This has now been deferred to the beginning of 2024. Modification in the PXD2 design or an accident in the repair would further delay the start of the run. The JFY 2023 ends in March 2024. The committee takes note that the Belle II collaboration is now developing two installation scenarios. The original one is to replace the current interaction point setup by a new one with the new beam pipe, PXD2 and current micro-strip silicon detector (SVD), and the alternative scenario to continue using the current set-up without extracting it from the Belle II detector. The second option would allow the run to start in October 2023, and the PXD2 would be installed some years later, before serious radiation damage of the PXD, requiring a one-year shutdown. Although the second option would allow a reasonable amount of run time in JFY 2023, there is a clear risk that the performance of the current Vertex Detector (VXD) would not be adequate for the SuperKEKB future luminosities and beam backgrounds. It should be noted that the current PXD is equipped with only a few ladders in the second layer and has been irradiated for several years. A further concern is the availability of experts in the PXD group for such an extended period. The Belle II collaboration should prepare a detailed risk analysis by monitoring the progress of the PXD2 work as well as the realistic JFY 2023 run time based on the funding availability and the development of the electricity cost.

The committee was impressed by the progress being made by the SuperKEKB and injector machine group for overcoming the various problems to increase the luminosity. The group is now focusing on two major issues, i.e. instability of the beam injection and catastrophic beam losses in the rings. Although there are still several open questions, the LS1 work plan presented by the machine group looks promising. The committee highly appreciates the close collaborative effort among experts of the injection system, SuperKEKB, and the Belle II collaboration.

The slow but steady loss of gain of the CDC remains a major concern, and may be an indication of ageing of the detector. The committee encourages the CDC group to fully exploit the LS1 and to consider a wide range of interventions together with an appropriate risk analysis. The committee is pleased to see the progress being made to implement and operate a laboratory set-up to study the effect of ageing in a controlled environment. Stable operation of the CDC requires a team of experienced physicists. The Belle II collaboration is encouraged to build up such a team for the coming runs.

The committee acknowledges the work in progress to understand the behaviour of efficiency drops due to ageing for the TOP PMTs. Laboratory tests of unmounted PMTs from the Slot-16 will provide important information, and in-situ testing with cosmic rays will bring in further interesting comparisons. Between the two replacement strategies currently considered, the one which involves the rearrangements of all PMTs in view of overall optimisation is quite interesting. However, the time needed for such an operation has to be carefully assessed.

The committee observes continuous efforts to improve the efficiency of data production for the real and simulated events. While a further reduction in the time needed for (re-)calibration and validation is desirable and increased participation by detector and physics analysis groups is encouraged, the overall progress and plan for the future activities are good.

The committee is very impressed by the wealth of physics results published in journals or presented at various conferences. The one related to dark sector searches are unique. A number of ICHEP contributions with very interesting results are a great preparation for high precision journal papers. With a total sample of $428\,\mathrm{fb}^{-1}$ of data collected prior to the start of LS1, about half of the Belle data sample, the Belle II collaboration is preparing physics results of high precision on a very broad range of topics. The ambitious plan is to fully exploit the data for beauty and charm physics and to be ready for the new data taking after LS1 is convincing. The preparation of physics publications for the full data set is in the early state, but with the extended LS1 and the past preparations, we expect very significant publications. However the most recent data might be impacted by large beam injection backgrounds. The committee stresses again the importance of run dependent MC simulation becoming available as fast as possible.

In addition to the responses to the questions, some important observations by the committee are given here. The KLM (K-long muon detector) group has responded well to the problem of the efficiency loss in the RPC detectors. The cause of the problem is understood and the proposed improvements in software and hardware to monitor the detector operation should prevent similar incidents in the future. A dedicated RPC test-bench has been installed in Tsukuba Hall to reproduce and test efficiency recovery mitigation strategies.

After some experience in operating the detector and taking data, LS1 is a good moment to review and consolidate the detector control and monitoring, as well as the whole operational scheme during the data taking. The committee fully supports the new organisation, the Detector Control System (DCS) group, that has started to review and document the current control system. Case studies must be made to make sure that the control system guarantees the safety of the experiment in any incident during the

detector operation. It is recommended to extend these activities to cover also the data taking procedure. It is expected that the DAQ group will play a central role with strong participation of detector groups. The Belle II management needs to pay attention that adequate human resources are allocated to these activities.

Although there are some major concerns, such as the PXD2 installation and gain loss of the CDC, the overall picture of the Belle II detector and physics achievements has been good. The committee urges that adequate resources will continue to be provided for the Belle II experiment and machine operation.