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

1–2 and 8-9 March 2021 Remote Meeting

A. Andreazza* (Milano), P. Collins* (CERN), G. Corti (CERN),
M. Demarteau (ORNL), R. Forty (CERN), B. Gavela (Madrid),
G. Carlino* (Napoli), S. Gori (UCSC), W. Hulsbergen* (NIKHEF),
M. Ishino (Tokyo), V. Luth (SLAC), P. Mcbride* (FNAL)
P. Mato* (CERN), F. Meijers* (CERN), N. Neufeld (CERN),
K. Oide* (KEK), B. Ratcliff* (SLAC), A. Petrov* (Wayne State University),
M. Sullivan (SLAC), H. Tajima (Nagoya), M. Titov* (Saclay)
and chaired by T. Nakada (EPFL)

* Expert member.

3 April 2021

Short summary

Due to the COVID restriction, this year's annual review meeting of the B-factory Programme Advisory Committee (BPAC) took place remotely on the 1st, 2nd, 8th and 9th of March 2021. Since the meeting duration of the each day was limited owing to the time differences among the locations of the participants, slides and video recordings for the presentations were made available prior to the meeting so that the reviewers could pose their questions remotely in advance. The committee thanks the accelerator group and Belle II collaboration for their effort to provide slides in a timely way covering the status of the SuperKEKB machine and the Belle II experiment, as well as the physics analysis with the Belle data. This document provides the most important findings and recommendations of the committee and a full report will follow later.

The SuperKEKB machine has been operating at higher luminosities with lower beam currents than those of the KEKB machine and the committee appreciates the continuous effort and improvements by the machine group for stable running of the machine. It appears that there are persistent obstacles, such as the increase of emittance for the high energy beam in the injection line, which prevent the machine from increasing luminosities without raising the background above the acceptable level for the experiment. The machine group is invited to make a plan for analysing the issues currently limiting the machine to increase luminosities keeping the machine background under control and devising actions together with the resource requirement. Increased efforts in simulation would be a part of a such plan. In this context, the proposed "background fellow", who

will be financed by the Belle II common fund for maintenance and operation to work in the background study group, is an excellent idea. The committee fully supports this. For gaining more human resources in the simulation effort, collaboration with other accelerator laboratories worldwide should be strengthened. Interest in SuperKEKB operating with low emittance beams is increasing and there could be also accelerator experts elsewhere wishing to participate in the machine operation. The committee understands that the current COVID restriction makes such collaborative work difficult, but it should be explored with the long term gain in mind. Another important issue on a relatively short time scale is the consolidation of the ageing machine components, in particular for the injector linac. The committee urges the machine group and the KEK management to address deferred maintenance in a timely manner by making an inventory of critical spare parts and making a replacement plan.

For the longer term, the committee thinks that the characteristics of the machine must be fully understood and exploited first to increase luminosities, before attempting a major hardware upgrade such as the new superconducting focusing quadrupole magnets (QCS) in the interaction region. Understanding of the hardware limitation of the machine would allow a prioritised and optimal upgrade path to be made.

The committee is pleased to see that the analysis with Belle data is still very active and fruitful, resulting in many publications, and this effort should be supported till a comparable statistics will become available for the Belle II data. The analysis of Belle II data is advancing well. Although the priority of data taking till the long shutdown in 2022 (LS1) must be given to collecting high statistics $\Upsilon(4S)$ data, the committee supports a short run at higher energies since this will provide a physics opportunity unique to the Belle II experiment. Closer interaction between the Belle and the Belle II collaboration would be very beneficial. The experience in assessing systematic uncertainties gained by the Belle analysis will be very useful for the future Belle II analysis, although the detectors and beam conditions of the two experiments are different.

The committee did not find major concerns with the Belle II operation for data taking and processing. With continuous effort in improving the detector performance monitoring and automation of the operation, for both online and offline tasks, the efficiency for running the experiment during this difficult period with COVID has been impressive. The idea of opening "operation fellow" positions with financial support to Master and PhD students located at KEK for their shift work is very interesting and a good idea during the COVID epidemic when the number of people available at KEK is limited. The outcome of this programme must be carefully analysed before deciding whether it should be continued after the COVID restriction will be lifted.

The plan to operate the experiment with an increased beam background rate, i.e. up to 3 MHz per photo tube (PMT) of the barrel particle identification system (TOP), till the start of LS1 was presented. This would ease the machine operation at high luminosities for delivering ~ 0.7 ab^{-1} of data before LS1. There has been no indication of ageing in the PMT performance so far. Given projected PMT rates, such degradation is not expected to be observable in the data until about the summer of 2021. During LS1, all of the conventional PMTs, and eventually the normal ALD type PMTs if required, will be replaced with PMTs that have extended lifetime with ALD treatment. The

committee, therefore, thinks that running with this level of background to obtain high luminosities is, in principle, a sensible plan. In practice, the running condition should be continuously optimised to maximise the "useful" integrated luminosity by carefully monitoring the performance of the detector in particular the effect of ageing. The high level trigger (HLT) becomes important for running with increased background rates, in order to keep the collected data within the pledged computing capacity. There is some room for further improvement in the HLT performance. Work for the 2021 summer shutdown should be carefully planned for the repairs necessary to keep the detector operating at its best till the LS1.

Although the overall status of the Belle II experiment is good, the collaboration should further enhance efforts to understand and improve the detector performance in a systematic way. In particular, TOP needs increased efforts by detector and analysis experts working more closely together. Observed discrepancies between the data and simulation must be resolved for all sub-detectors. Further studies should be made to see if the detector performance can be boosted with improved use of the detector information, e.g. by studying the performance in full two dimension, momentum and polar angle, rather than in their projections separately, or analysing the impact of photons with long path lengths and/or steep polar angles in the quartz.

The committee noted the revised schedule for the LS1, which is now foreseen to start in July 2022 instead of January 2022 in the original plan. The duration of the shutdown is also extended to ten months. Those changes will give welcome margin for the experiment running under the COVID condition, including the preparation and installation of several detector components. Care should be taken so that the budget for the 2023 running would not be reduced. The committee is pleased with the general progress made for the LS1 preparation. Recently developed ideas to gain space needed for the cables from the vertex detector system, which includes modifying the front cap of the QCS, are very encouraging. Although further work is needed to examine their feasibility, the anticipated gain in space is such that the increased number of cables from the fully equipped pixel detector can be accommodated.

For the long-term future upgrade, the committee recommends that the collaboration make a more systematic approach to study how the overall performance of the Belle II detector can be improved for physics goals, rather than focusing too fast on some specific detector upgrades. The timeline for possible major upgrades appears to be more relaxed now. Those ideas should be separated from the consolidation effort for ensuring the running of the current Belle II detector, which should be planned carefully.

The resource request for the computing in 2022 was also presented and will be evaluated by the computing resource scrutiny group later. The committee learned that 2.5 PB more tape space has been used in 2020 compared to the pledge since more data were collected than anticipated. Since this shortage should not affect the 2021 data taking, it would be highly appreciated by the committee if the computing centres could provide the additional tape storage.

The committee is very pleased to learn that a total of seven months is granted for the running in the Japanese fiscal year 2021. It is important to collect as much data as possible before the LS1 and the committee is looking forward to following the progress.