B-factory Programme Advisory Committee Focused Review Meeting

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1 Phase 1 and Phase 2 background studies

1.1 Status

The Phase 1 background measurements were shown with an impressive amount of analysis on the data. This effort has been very helpful for commissioning the background studies and shaking down the BEAST I DAQ. With this experience, the Phase 2 run will have a solid starting point and the team should be able to more rapidly analyse the incoming background information coming from BEAST II detector. The Phase 1 data has no colliding beams information (this will only occur in the Phase 2 run) while the primary sources of background for Belle II will come from colliding beam background processes. Nevertheless, the background team was able to measure single beam backgrounds and compare the data to the predictions from the background MC. In general, there is reasonable agreement in spite of uncertainties in the actual state of the beam and of the vacuum in each ring. The committee notes that background estimations are more difficult when the calculation relies on accurately knowing the beam properties that may not be measured sufficiently well. There has also been considerable thought and simulation about how to use the BEAST II detectors in the Phase 2 run. The team recognises the importance for obtaining reasonable understanding of the backgrounds in Phase 2 as soon as they can. The final Vertex Detector system (VXD) consisting of Pixel Detector (PXD) and Silicon-strip Vertex Detector (SVD) will already be in the final assembly stage and any suggested modifications for background suppression in the central area near or around the beam pipe must be brought up as soon as possible.

1.2 Concerns

- The initial luminosity of the machine will most likely be low, and it would be difficult to identify backgrounds caused by beam collision since they will be masked by backgrounds coming from other sources that will tend to be high in this initial period. Backgrounds related to the colliding beams will ultimately dominate once the luminosities of the machine approaches the designed value and early identification of their sources would be important.
- The scattered photons from the tips located inside the incoming beam pipes has not been simulated and the background rate from this source is not known in the current Synchrotron Radiation (SR) background calculations.
- Some of the beam particles very far away from the nominal beam position in the QC1 magnet of the final focus will produce SR that can directly strike the central chamber. This rate is shown to be highest on the Ti section next to the central Be section. A part of these off beam particles will be removed by upstream collimators that will be positioned to reduce other beam backgrounds.

1.3 Recommendations

- The committee urges the background team to be very well prepared for Phase 2. The Phase 2 run with the BEAST II detectors will be more challenging than the Phase 1 run. There will be more detectors and the need for rapid analysis of the background signals will be more urgent. In addition, the accelerator team will be commissioning the final focus magnets with the detector solenoid.
- The committee suggests to Improve diagnostics for vacuum pressure around the ring for both beams, which would helpful in developing more precise models of the beam particle backgrounds (especially BGB and Coulomb scattering) for the detector.

2 Beam pipe and interlock

2.1 Status

The central beam pipe and the Remote Valve Closing mechanism (RVC) have undergone many tests and assembly trials. The RVC now has leak check piping and has been tested many times at DESY. The bellow sections are expected to arrive soon to complete the RVC assembly test. The beam pipe has been tested with the BEAST II PXD and SVD pieces. Some issues have been found with the routing of services and these are being addressed. The complete routing of services will not occur until the final PXD and SVD assemblies are complete for Phase 3. There has been a problem with the attempt to ion sputter a gold coating on the inside of the beam pipe over the Ti and Be central region.

2.2 Concerns

- Although the RVC assembly looks very good and has been well tested at DESY, there are still several final assembly tests to be done at KEK. The schedule still looks feasible but is starting to be tight.
- The trouble with the gold coating for the beam pipe has all but eliminated the contingency.

2.3 Recommendations

- Work carefully with the company that is doing the coating to ensure an adequate gold coating is achieved. Due to some uncertainty concerning the exact background rate from SR sources (i.e. not knowing what level the tip scattering might be) it is prudent to have the 10 micron of gold coating on at least the Be part of the chamber.
- If the Be section of the beam pipe remains bare on the outside, then it is suggested that a protective coating be applied to the metal in order to prevent oxidation of the Be from the air in the SVD especially if there is some small amount of water in the SVD atmosphere.
- The outside of the Ti part of the chamber can have an extra layer of high Z material (i.e. 25 μm Ta) wrapped around it since that part of the beam pipe is not in the detector acceptance. However, if the Ti part does not have some sort of high conductivity coating (i.e. Cu, Ag, or Au) on the inside then the Ti part of the pipe will absorb significant power from the image currents and may heat up.
- For the RVC, continue retesting the RVC as it arrives from DESY and also test with the bellow sections to insure there are no mechanical problems and that the mechanism seals properly.

3 Pixel detector

3.1 Status

The sensor production, consisting of five batches for a total of 29 wafers, has been completed with high overall yield. More than double the number of sensors than required are available for all four types. The final version of all ASICs are available and the probe station testing has been completed. The PXD modules in the BEAST for Phase 2 are outfitted with the final versions of the ASICs. The production of modules for Phase 2 has provided valuable information and has led the collaboration to the production of modules in small batches. The production of the kapton circuits has been problematic. The yield of the circuits, especially for the Layer 1 backward circuits, has been very low and may force the use of B-grade circuits for the production modules. Furthermore, the trace width of the lines on the circuits was about 10 μm less than specified, leading to a higher impedance which is, however, still acceptable. These various delays have caused a serious strain on the module testing, which will now be shared among four institutions. At the Max Planck Institute there are two test setups for module testing and one for ladder testing; Bonn and Göttingen have one test setup for each and a module testing setup exists at HLL.

The ladder assembly has experienced some significant setbacks. For the three ladders that were produced for Layer 1, all backward modules failed. The problem has been traced to an incomplete validation of the test setups and ladder production has resumed. As a consequence of the ladder production issues, the Phase 2 detector has only four PXD modules, instead of the two full ladders that were planned. At the time of the review, two Layer 1 ladders had been finished.

Modules and ladders are being tested at the four testing sites and the optimal running conditions are being determined. A database has been created to store the full test results, such as the scan settings and the results of the analysed data with plots. A grand summary is also provided that lists all modules and the status of the performed tests. Gated mode operation with the final ASICs is working well at the nominal frequency. The minimum interval between the two gates is defined by the pedestal oscillation after the gating. At the moment a dead time of 2 μs has been achieved, though further optimisation is still ongoing.

The work on the services for the PXD, such as power supplies, dock boxes, cables and patch panels is all on schedule. The ladder mounting procedure is still being developed. The mounting procedure has been successfully exercised for the installation of the Phase 2 modules. The final mounting procedure has been optimised in CAD software simulation. An interference between the kapton circuits has been identified during the installation of the second module of the inner layer. A support element connecting the wheels of the rotation stage needs to be implemented for the ladder mounting. The mounting of the half-shells is also being developed.

3.2 Concerns

- The committee is concerned that the failure of the modules for the first assembled ladders has not been fully understood and the root cause has not been fully pinpointed. The current understanding points to a non-optimal sensing of the critical V_{sub} voltage, which leads to a short.
- Although the uncertainty in the updated PXD production schedule is significantly reduced given the progress with the ladder assembly, the committee remains concerned about the overall schedule.

3.3 Recommendations

- The PXD group is strongly recommended to obtain solid confirmation that the root cause of the failure of the modules is indeed the sensing of critical voltages on the switcher chip.

- The Phase 3 schedule of the Belle-II detector remains very vulnerable to any further delay in the PXD schedule. The committee is pleased to see that the PXD group has identified key tasks that carry the priority in the areas of module and ladder production and testing. The collaboration is strongly urged to finalise the ladder mounting procedure as quickly as possible and produce the fixtures. A core group of people should be identified who will do the ladder installation and who will then practice the ladder and half-shell installation as often as possible.

4 Silicon strip vertex detector

4.1 Status

The committee is pleased to learn that the SVD group successfully completed the assembly of Layer-5 ladders including spares in September. The SVD group also successfully built two more Layer-4 ladders since June with four more ladders (33%) to be built, and built five Layer-6 ladders since June with seven ladders (35%) more to be built. Assembly of Layer-4 and Layer-6 ladders is expected to be complete by January and mid February 2018, respectively, which is on time for the ladder mounting of the second half. It is very encouraging that the production rate for the Layer-6 ladders has been steady for 8 months since February 2017.

There has been no further incident of the pitch adapter delamination from the forward (FW) sensors since the second reinforcement was introduced. The SVD group also performed a thermal cycle test of this reinforcement to make sure the reinforcement is stable and effective over the expected thermal excursion.

The SVD group also made the final review of the ladder mounting procedure in September. After the approval of the procedure, they started the ladder mounting for the first half. The schedule of the ladder mounting is slightly behind the original schedule due to the deformation of a layer-3 ladder. However, the amount of the deformation is within the tolerance.

4.2 Concerns

- The committee notes that the schedule for the Layer-4 ladder assembly is getting tight due to the limited availability of the expert personnel.

- The assembly of the Layer-6 ladder is still demanding due to the 7-day per week work schedule.

4.3 Recommendations

- The SVD group should pay close attention to the availability of the Layer-4 personnel and any evidence of fatigue for the Ladder-6 assembly personnel in order to avoid fatal errors.

5 DAQ, readout electronics and controls

5.1 Status

The SVD readout electronics team has demonstrated successful long-term operation with random triggers at a rate of 30 kHz, which is comfortably higher than what is required. The committee congratulates the SVD-team for this achievement. The FADC V4 has been received and first tests demonstrate significantly improved noise performance without showing any regression. The noise improvements are the result of careful grounding studies, for which the team is to be commended. The production schedule of the FADC is on time for the full SVD system test before the integration with the PXD.

A full chain test was performed for the PXD readout electronics. While all hardware is available and in its final form, the firmware is still being developed to overcome issues encountered during integration. The ONSEN system has passed a full system test successfully. In addition, its robustness has been improved in order to cope better with errors generated by the systems connected to it. The committee noted that the network problems (buffer overruns) when sending to the HLT have been taken seriously and that mitigation measures (flow-control) have been taken.

The slow- and run-control systems of the VXD are progressing. While they currently still require expert attention, more and more systems reach a state where they can be handed over to shifters. Advantage is being taken of synergies between SVD and PXD, for example in the server infrastructure for the slow-control.

Implementation work for environmental monitors and interlocks is advancing according to the schedule.

5.2 Concerns

- While all initial tests of the FADC V4 seem to indicate significant improvements, still there were many changes and a test of a large slice has not yet been done.
- The committee is concerned that the root cause of the APV ASIC damage is not completely understood.
- The SVD group has not verified all DAQ modes, for example, the 3-sample and 6-sample mixed modes.
- There is still a lot of work to be done to get the full readout chain for the PXD to run flawlessly. Many firmware and software items are still very actively being developed. Although it is not very likely, it cannot be excluded that the current state of firmware and software may hide small hardware issues which have not been identified.
- While significant progress has been made in the slow-control work, a lot remains still to be done.

5.3 Recommendations

- A multi-board test with as many FADC V4 as possible should be done as soon as possible
- The SVD group should check whether suspected cause for the APV ASICS damage can be reproduced (without connecting APV ASIC).
- The PXD team is encouraged to continue the integration tests of the readout-chains with utmost vigour. Stable versions of software and firmware should be established to make sure that long-term tests certify the reliability of the full system.
- The VXD management should make sure that enough effort and medium-term continuity is there for preparing and commissioning the slow-control systems. This includes documentation, in particular in view of the vital importance of the slow control for efficient long-term operation of the detectors.

6 Beam Test

6.1 Status

To examine the performance of the VXD together with its controls and readout systems, a test with a duration of approximately four weeks was conducted during February and March 2017 at the DESY test beam facility. The test was performed with a 4 GeV electron beam in a 1 Tesla magnetic field. Elements of all VXD layers were present in a “Phase 2 configuration”: one ladder for each PXD layer and one ladder for each SVD layer, all parallel to one another and at nominal radii and longitudinal positions. Three FANGS and two CLAWS completed the array of instrumentation in the test. The full data acquisition chain, the Belle II slow control system, and CO2 cooling were employed.

The test beam had led to the discovery of noise issues in FADC V2. Improvements in FADC V3 are attributed to larger capacitors and better grounding. Finally, it is hoped that FADC V4 will work even better as a result of numerous changes, including the elimination of parallel ground paths.

Final ONSEN hardware was used. Various issues were encountered in the end and start of run control. That led to changes in ONSEN firmware to protect it from three types of major external problems.

No problems in monitoring and interlocks were reported in the test beam presentation.

6.2 Concerns

- The test beam led to a flurry of activity to address hardware and software issues that were discovered. Before memories of those issues fade too far into the past, it would be good to document them and associated changes more completely.

6.3 Recommendations

- We recommend that a final test beam report be written which summarises what was learned and the changes that followed.

7 VXD installation and commissioning plan and schedule from end of Phase 2 to start of Phase 3

7.1 Status

The schedule for the transition from Phase 2 to Phase 3 is divided into two portions: one associated with the interaction region and a second associated with assembly and testing of the VXD. Opening of the Belle II detector and preparing the interaction region sets the date (early October 2018) on which VXD installation could begin. The VXD should be completed and commissioned at Tsukuba hall B4 floor in advance of that date. Providing a second set of outer cables would allow a portion of the interaction region cabling to be done in parallel with VXD commissioning at B4 floor.

Initial major operations during this period are the removal of shielding and the opening of end-yokes to allow BEAST II to be removed and VXD cabling to be added. In preparation for its installation and in parallel with those operations, VXD commissioning at B4 is to be completed. The VXD is expected to be ready to be installed at the beginning of October 2018. Installation is estimated to take 47 days. Re-closing and restoring the interaction region is to be finished early enough to allow the start of Phase 3 in January 2019.

The SVD is to be assembled at Tsukuba hall B1 floor. The first half shell is to be completed by the beginning of January 2018 and the second by the end of April 2018. FADC V4 is expected to be available in February 2018 and its functionality would be checked in the B4 clean room. Provided it performs as expected, it would be available for testing of both VXD half-shells. The VXD would be cooled with CO2 during the testing, which sets an operations schedule for the CO_2 system.

The PXD is expected to be at KEK by the end of May. Since approximately a month is needed to mount and align the Phase 3 beam pipe on a granite table, the beam pipe should be available by the end of April. Working backwards in time, this argues for the selection of which beam pipe will be used by the end of March 2018.

After the PXD is at KEK, ten weeks are planned for installation and testing of its half-shells on the beam pipe. Another two weeks are scheduled for mounting the SVD half-shells and closing the VXD volume. That would allow a four week cosmic ray run of the VXD in the clean room at B4 floor to be completed by the end of September and allow installation of the VXD to begin at the start of October.

A clear plan with the sequence of installation steps has been developed for installing the VXD into Belle II. The plan was tested with a VXD dummy in 2016 and during installation and extraction of the B-field mapping device in April and September 2017, respectively. Normal and emergency de-installations have been considered. Support points for the VXD during moves have been understood. In addition, equipment to support a person within the limited space available during cabling from the VXD to the dockboxes has been specified and demonstrated. While some tuning may still occur, it has been shown that plans and equipment to perform the required tasks exist and should work.

The readiness of the online and offline reconstruction and calibration software is a relevant component for the detector commissioning. The status of SVD and PXD specific software, and of the overall track reconstruction, has been presented. It shows significant progresses on every aspect, also driven by the experience from test beams.

SVD online software is mostly ready for Phase 2, with some work still ongoing in the environmental monitoring. A refactoring of the reconstruction algorithm has been implemented in order to allow for the implementation of alternative clusterisation algorithms (basic and neural network based), the addition of timing information, and different sampling option. PXD software has been stress tested in test beams and is ready for Phase 2 operation with some stricter error checking being implemented. For both the PXD and SVD detector there is ongoing activity on the databases for calibrations, conditions and configurations and on simulation improvements. In particular targets for the Phase 3 simulation are the pulse shape emulation in SVD and the gated mode to be still implemented in the PXD.

The implementation of the new version of the VXD Track Finder (VXDTF2) provides significant efficiency gains, delivering 5% more tracks, with large improvements at the edges of polar angle and momentum acceptance. Nevertheless the cellular automaton at the core of the new algorithm requires too much computing resources when background hits are also included. Mitigation strategies include a tighter time selection in SVD and an optimisation of the training samples.

7.2 Concerns

- Although various portions have been tested separately, proper operation of the full and final VXD, including its readout chain, remained to be demonstrated at the time of the review.

- The schedule which was presented does not explicitly include contingency. The time to complete some operations following installation of the VXD, for example, those associated with interaction region recovery, should be known well enough from past experience. However, there will always be uncertainties in the time it takes to address potential vacuum leaks, the time it takes to obtain sufficiently good vacuum for good accelerator/detector performance, and the time necessary for machine tuning.

- The overall software status is ready for the starting of Phase 2, but still some major developments are still needed for Phase 3, even if the initial low luminosity may allow to operate the same reconstruction algorithms also for the beginning of Phase 3. Full implementation of the interfaces between the calibration results, including dead channels maps, with the configuration database and reconstruction software are of special concern.

7.3 Recommendations

- The committee recommends that the detail shown in the schedule be increased as the time for the transition from Phase 2 to Phase 3 nears. Resources (people, skills, equipment, et cetera) for each schedule task and contingency should be shown explicitly.
- The committee encourages the introduction of redundancy to all critical installation tasks.
- The committee notes that surprises can sometimes be avoided by carefully coordinating routine site and building operations, such as the service and maintenance of HVAC, electrical, lighting, lifting equipment (cranes), et cetera. These should be scheduled so they will not interfere with installation and commissioning operations.
- The SVD and PXD software groups are strongly recommended to implement for the beginning of Phase 3 all the necessary calibration and configuration databases, together with interfaces to the reconstruction software.
- The VXDTF2 memory requirements should be brought down at a level compatible with the computing model. Alternative algorithms might be required as backup solutions.

8 Outer detector

8.1 Outer detector status

The committee is pleased with the collaboration's progress in completing the outer detector since the DAQ review in June. Assembly of the ARICH detector was completed and it was combined with the forward ECL and KLM in the forward endcap. Then the endcap was installed in the Belle II detector. In a concerted effort, the RPC readout electronics for all of the BKLM were successfully fabricated, installed, and commissioned.

Outer detector subsystems participated in a Global Cosmic Ray test (GCR), with events triggered by CDC and barrel ECL coincidences. Data from the CDC, TOP, barrel ECL, backward ECL, and BKLM were readout during the GCR. After some adjustments and workarounds, data taking was stable enough for runs lasting a few hours.

The GCR was the platform for significant progress in understanding the performance of individual subsystems and identifying issues that are now receiving attention. The rest of this section includes discussion of the status of individual subsystems, along with concerns and recommendations. Finally, some issues and plans looking into the future to the transition from short-term Phase 2 running to stable long-term Phase 3 running are discussed.

During forward endcap installation, a 2 mm (out of 22 mm) space conflict was encountered. Moving the endcap back by 2 mm was the only practical workaround. Options, including possible modification of some parts, for dealing with this conflict for Phase 3 are being studied.

8.2 CDC

Utilising the large data sample obtained in the GCR, the CDC group made significant progress in understanding momentum and dE/dx resolution. Transverse momentum resolution of about 0.4% at $p_t = 1$ GeV/c was achieved. Inclusion of the field mapping material in the Monte Carlo simulations of momentum resolution significantly improved the agreement between data and the Monte Carlo estimates.

dE/dx resolution was studied utilising carefully selected cosmic ray muons. After making gas gain and Bethe-Bloch corrections to the data, dE/dx resolution of about 6% was achieved. The CDC group expects to be able to achieve similar resolution to a much wider class of tracks, after studying and applying other corrections.

The event rates in the GCR ranged between about 8 Hz and 150 Hz, not enough to significantly stress the readout systems. Still, stable operation of the HLT, DAQ, and CDC tracking systems at those low rates was encouraging. Stable CDC operation was achieved with 100 kHz Poisson random triggers, albeit without the HLT and data storage.

8.3 TOP

During the GCR, signals were observed in TOP modules matching the tracks found in the ECL and CDC. The distribution in the number of hits in TOP modules peaks between 15 and 20, as expected. Initial results for the module efficiency are reasonably high; 12(7) modules have efficiencies greater than 90%(95%) for tracks that also have BKLM hits. Several issues remain to be studied carefully, including the stability of the number of hits, detailed comparisons between Monte Carlo simulations and data, and the time-calibrated Cherenkov ring image.

During the GCR run a problem with misaligned or missing waveforms was discovered. The problem was largely resolved with bug fixes and configuration updates and work on this issue is continuing.

The manpower for firmware development has been somewhat marginal, but now appears to be adequate. Currently there is intense effort in SCROD and Carrier firmware development and debugging. There is an organised plan to integrate them around the end of October in order to produce stable production software by the end of this calendar year.

A serious mechanical problem was reported at the June 2017 BPAC meeting: the delamination of the glue joints between the PEEK frames and the prisms in TOP modules. Possible causes and consequences were discussed in that BPAC meeting and a number of suggestions for studying the problem to understand the causes were included in the full BPAC report. Since then some evidence that thermal expansion may play a role has appeared, i.e. the visible delamination area appears to depend on whether or not the electronics are off or on. The TOP group is taking this concern very seriously and has initiated an urgent program to study the problem in accord with the suggestions in the BPAC report.

8.4 ECL

The barrel and backward ECLs were included in the GCR. The firmware was updated and a stable version was obtained. Time differences between crystals and energies deposited by 0, 1, 2, and 3 or more tracks were studied.

The forward ECL was connected to the DAQ, and some data were also taken with it and the barrel ECL. The forward ECL appears to be functioning well with all channels active.

Again event rates in the GCR were not high enough to stress the readout systems. Stable ECL operation was achieved with 30 kHz Poisson random triggers, albeit without the HLT and data storage.

8.5 KLM

As noted above, fabricating, installing, and commissioning the readout electronics for the RPCs in the BKLM was a major achievement since the June BPAC meeting. As a result, the BKLM could be included in the GCR. For various reasons, not all RPCs were functioning. Nevertheless, RPC efficiencies above 90% were achieved for tracks triggered by the CDC or self-triggered by the BKLM.

After installation of all readout electronics, problems with the available VME crates were discovered. There is a plan to purchase new crates for Phase 3 and there is a short-term workaround for Phase 2.

The situation with the scintillators in the BKLM and the EKLM is less optimistic. Due to a lack of personnel, firmware development for these detectors lags, resulting in low efficiencies. The collaboration is increasing the personnel working on this firmware, both by training postdocs, and attempting to engage the attention of a more experienced expert.

There had been a mechanical problem with some EKLM modules in April before the roll-in; two modules shifted downward, putting stress on preamplifier boards. These modules were replaced. It is possible that 9 modules installed in the backward EKLM might develop the same problem, but all EKLM channels now function. The behaviour of the suspected modules is being monitored.

There are not enough low voltage supplies for the 14 layers in the forward EKLM. Running only 13 layers is the current workaround.

8.6 ARICH

Assembly of cables and cooling pipes for the ARICH was completed and the ARICH was combined with the forward ECL and EKLM to complete the forward endcap. ARICH integration and testing was delayed by the availability of HV bias supplies and the cables between the electronics hut and the ARICH. Using a Pocket DAQ, the LED monitoring system was tested and found to be working. Currently the integration of the ARICH with the global DAQ is being tested. Due to these limitations, the ARICH did not participate in the GCR.

8.7 Preparation for Phase 2

8.7.1 Concerns

- The successes of the GCR suggest that most detectors will be ready to take useful data during Phase 2. However, there remains much to be done in a very limited time to raise the readiness and performance of each subsystem to the point of being able to produce high-quality data during that run.

8.7.2 Recommendations

- The committee urges members of the Belle II collaboration to continue their efforts to complete integration and commissioning of each subsystem in order to obtain high-quality data during Phase 2.

- The committee endorses the efforts of the collaboration management to identify and train personnel who can shore up efforts that are lagging.

8.8 Phase 2 to Phase 3 transition

Now that the Belle II collaboration has largely completed the transitions from R&D to construction and commissioning, the transition to Operation is the next big step. The collaboration is developing plans for this transition and stable operation of the detector in Phase 3. Some elements of the plan being considered include on-site coordinators for each detector subsystem, reinforcing the Run Coordinator with deputies, strengthening communication and coordination with the SuperKEKB control room, and organising shifts. The collaboration intends to have a version of this plan ready for BPAC review in February 2018.

8.8.1 Concerns

- As final issues in the completion and commissioning of subsystems are being addressed, a more general concern is becoming evident: ensuring that multiple members of the collaboration have the skills required to maintain and upgrade the readout, DAQ, and trigger systems for each sub detector. Elements for addressing this concern include training, documentation, and plans for succession of individuals.

8.8.2 Recommendations

- The committee endorses the efforts of collaboration management to ensure that a self-perpetuating group be developed for each major detector and software component and would like to see the implementation plan during the next review meeting in February 2018.