B-Factory Programme Advisory Committee Full Report

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1 Introduction and Short Summary

During the 9th review meeting, the committee heard the schedule of the SuperKEKB, the status of the Belle physics analysis, the physics programme of the Belle II experiment and the progress in the construction of the Belle II detector.

There have been uncertainties in the start of SuperKEKB commissioning work during the last one year due to budgetary problems. A revised plan was shown in this meeting, where the start of physics data taking would be delayed by one year, compared to the original plan, to October 2018. This would allow the Belle II experiment to start physics with the complete detector, rather than with a partially installed barrel particle identification system as considered during the last committee meeting in February 2014. However, a further delay should be avoided.

Strong analysis effort with the Belle data continues to be carried out, with 21 papers published in peer reviewed journals in 2014. The committee strongly endorses the effort to enable the Belle data analysis in the Belle II software framework, which ensures exploitation of Belle data till the Belle II will start taking physics data. The collaboration must keep providing adequate computing resources for the coming years. Preparation work for the analysis with Belle II data is advancing well. The current idea for the initial Belle II physics programme may require a revision in view of the new machine-detector installation schedule where the physics data taking will start only in October 2018, e.g. a physics programme during the Phase II machine commissioning period. Close collaboration with theorists is encouraged for developing the physics programme.

Good progress has been presented for the work at the intersection region between the machine and experiment. It is particularly important to develop commissioning and operation plans for the SuperKEKB and Belle II in close collaboration. The committee suggests forming a machine-experiment working group for this purpose.

The current idea for the BEAST phase 2 detector for the Phase II machine commissioning period was presented. During this period, the Belle II detector will be at the intersection point and the BEAST phase 2 detector will be inserted instead of the Belle II vertex detector together with a temporary beam pipe in order to understand the machine related background. The committee urges the collaboration to develop a concrete project plan for the BEAST phase 2 detector with well justified goals and a priority list. It must take into account the required and available resources, and it should not affect the rest of the Belle II construction and commissioning effort.

The pixel detector project is on a good track. The team has successfully verified crucial steps in the production process, which gives strong confidence in the forthcoming detector production. However, the overall schedule is very tight. The committee thinks that the construction of a mockup for the cooling system must be completed according to plan so that crucial cooling tests of the components and the whole system can be started as soon as possible.

A recent change in the project structure, which established a project leader concentrating on the overall aspects of the silicon strip detector project, is highly appreciated. Good progress in the electronics development was reported. Production of pitch adapters remains on the critical path and its progress must be carefully monitored in a systematic manner along with other critical tasks. The committee appreciates the procedures put in place to qualify assembly sites and procedures to sign off components.

The first quartz bar box for the barrel particle identification system has been constructed and a production procedure established. However, various problems discovered during the construction demonstrate that the production process must be further improved and a very stringent Quality Control (QC) procedure must be in place. In parallel, an R&D study on the glueing procedure is encouraged to understand long term stability of the detector. The current plan is that the module acceptance test will be carried out at the Cosmic Ray Stand which is in operation now. A detailed programme must be urgently established for this test. An idea to perform a combined test with the central drift chamber with cosmic rays using a prototype of the Belle II data acquisition system has been presented. This idea must be developed as a proper project in order to judge the goal of the project and required time scale and resources. This effort should not affect adversely the overall schedule of the experiment. Good progress has been reported for the electronics development, but completion of the firmware and production of the final electronics remain on the critical path.

Construction of the end-cap particle identification system is generally making good progress. The project team still needs to gather operational experience for the Hybrid Avalanche Photo Diode to ensure longterm stability of the detector.

There is no major concern for the central drift chamber, neither for the electromagnetic calorimeter nor K_{Long}-muon detector. While a cosmic ray test is being prepared for the central drift chamber, no clear commissioning plan has been presented for the two other detectors.

A coherent software development plan is now in place and performance optimisation work has started. Developments in data acquisition and detector monitoring and control system are advancing well. Recent evolution in the Belle II computing model shows the increased importance of the US and European computing centres and institutes. The committee thinks that it is important to adapt the model and infrastructure requirement to the real needs of the experiment, while avoiding unnecessary complexity. The committee also notes that human resources in the computing related issues are rather limited.

2 Belle I Physics Achievement

2.1 Overview

Many interesting analyses continue to be carried out using Belle data, after the end of data taking in 2010 and the reprocessing with better tracking software in 2011. Numerous measurements are expected to yield large improvements in precision, reducing uncertainties by a factor of two or more. Publications continue to appear at a substantial rate with a total of 21 in 2014. The joint Belle and BaBar publication, "The Physics of the B Factories", a 928-page review, was completed and appeared in EPJC. The Belle collaboration now comprises 473 members from 81 institutions in 18 countries.

The committee was pleased to see the first joint Belle–BaBar physics analysis. In this effort, an identification of studies in which a combined analysis may bring more improvement than just combining the results of two independent analysis, is needed. For example, a combined analysis for the $B \to \mu\overline{\nu}$ decay might be able to reach a level of significance above the threshold to be interesting, which would be impossible for either Belle or BaBar alone.

2.1.1 CP Violation and Hadronic B Decays

The new results obtained in this area include measurements of $B^+ \to K^{*+}K^{*0}$, $B^0 \to \eta' K^*$, $\eta\pi^0$, $\pi^0\pi^0$, $D_s K_S \pi^+$ and $B^+ \to D_s K^+ K^-$, time-dependent CP violation in $B^0 \to \eta' K^0$ and $\eta K_S \gamma$, as well as the determination of CKM angle ϕ_3 from $B \to DK$ using the GLW, ADS and GGSZ methods.

The study of $B^+ \to K^{*+}K^{*0}$ resulted in a measurement of the branching fraction $(0.77^{+0.35}_{-0.30} \pm 0.14) \times 10^{-6}$ and the longitudinal polarisation fraction $f_L = 1.06 \pm 0.30 \pm 0.14$. Preliminary first evidence (3σ) was reported for $B \to \eta\pi^0$. A new analysis, with a better understanding of background, yielded a branching fraction for the $B \to \pi^0\pi^0$ decays to be $(0.90 \pm 0.12 \pm 0.10) \times 10^{-6}$, a central value roughly a factor of two smaller than that of the previous measurements. This result is more in line with theoretical expectations, but it shows a tension with the BaBar result.

The analysis of $B^0 \to \eta K_S \gamma$ shows no significant CP violation. At the moment, the measurement is consistent with standard model expectation but is of great interest in view of the anticipated order of magnitude improvement in sensitivity at Belle II.

The new determination of $\phi_3 = (73^{+13}_{-15})^\circ$ represents the almost final result from Belle on this parameter.

2.1.2 Semileptonic, Leptonic, Electroweak B Decays

The Belle Collaboration continued to utilise the improved hadronic tagging algorithm developed a few years ago, which resulted in 2–3 times larger statistics for the tagged sample bringing significant improvement in the analysis of semileptonic, leptonic, and radiative B decays. It has been used for a new analysis of the exclusive $B \to D\ell\overline{\nu}$ rate and a measurement of $|V_{cb}|$. Improved bounds on the leptonic decays $B^+ \to e^+\nu$ and $B^+ \to \mu^+\nu$ have also been obtained; the sensitivity in the latter mode is approaching the standard model expectation.

A new measurement of $\mathcal{B}(B^+ \to \tau^+\nu) = (1.25 \pm 0.28 \pm 0.27) \times 10^{-4}$ used semileptonic tags, and had comparable statistical, but larger systematic uncertainty than the earlier Belle measurement using hadronic tags.

For electroweak penguin decays, new results for the forward-backward asymmetry, $A_{\mathrm{FB}}(B \to X_s \ell^+ \ell^-)$, have been obtained, using a sum over exclusive modes up to 5-body final states. No significant tension from the SM is seen (1.8σ in 1 out of 4 bins). A similar new measurement of $\mathcal{B}(B \to X_s \gamma) = (3.51 \pm 0.17 \pm 0.33) \times 10^{-4}$ sums over final states with 1 or 3 kaons and up to 4 pions, which is estimated to be about 70% of all final states. The strongest bounds on direct CP violation, $A_{CP}(B \to X_{s,d}\,\gamma)$, was obtained using inclusive gammas with lepton tags on the other Bs.

Many ongoing analyses are hoped to produce new results soon. These include a new measurement of $B \to \ell\overline{\nu}\gamma$, the final results for the $B \to D^{(*)}\tau\nu$ rates, and measurements of $B \to X_c \tau\nu$ and $B \to \pi\tau\nu$, all of which are of great interest.

2.1.3 Charm Physics and Exotic Hadrons

The search for CP violation in charm hadron decays and in $D^0 - \overline{D}^0$ mixing, as well as better measurements of the mixing parameters remain very important. New results for the direct CP violating parameter A_{CP} in $D^0 \to \pi^0\pi^0$ and $D^0 \to K^0_S \pi^0$ have been obtained. A search for CP violation in $D^0 - \overline{D}^0$ mixing in the $D \to K^0_S \pi^+\pi^-$ mode with high sensitivities has been published.

The Belle Collaboration has also continued to obtain interesting new results on the spectroscopy and decays of the "$X, Y,$ and Z" charm- and charmonia-like states. Search for possible new states and better measurements of the quantum numbers and branching ratios of the existing ones are needed to understand the dynamics of strong interactions in each of these systems, and to distinguish between competing theoretical descriptions (such as tetraquark, molecule, hybrid, etc.).

In addition to these new results, several important ones discussed in the last BPAC report, such as the precise measurement of $\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)$, were published in 2014.

2.1.4 Tau and Two-photon Physics

By exploiting the copious production of τ leptons at a B factory, a large array of exciting precision measurements can be performed. Belle has collected the world's largest sample of τ leptons. This led in particular to a determination of the τ lifetime as $(290.17 \pm 0.53 \pm 0.33)$ fs, about a factor of two more precise than the previous world average, and to the first upper limit on the ratio of the lifetime difference between τ^+ and τ^- over the average lifetime of 7.0×10^{-3}.

In the study of hadronic τ decays with K_S, branching fractions have been measured for six exclusive and one inclusive mode. A preliminary result was obtained for the $\tau^- \to \pi^-\pi^-\pi^+\pi^0\nu_\tau$ branching fraction, where the 4π mass spectrum is being analysed. Work on determining the Michel parameters in leptonic τ decays with improved systematic uncertainties is ongoing.

An improved sensitivity of about 3×10^{-18} e cm could be achieved in searching for an electric dipole moment of the τ lepton.

In two-photon physics, measurements of $e^+e^- \to e^+e^- K^0_S K^0_S$ have been made. The study of $e^+e^- \to e^+e^-\pi^0\pi^0$ is ongoing. It is relevant for the determination of the hadronic light-by-light contribution to the muon anomalous magnetic moment.

2.1.5 $\Upsilon(1S$, $2S$, and $5S)$, Dark Sector

A rich phenomenology is available through the $\Upsilon(1S$, $2S$, and $5S)$ samples, which continue to be studied by the Belle Collaboration.

The $\Upsilon(5S)$ data sample of $121\,\mathrm{fb}^{-1}$ allowed the measurement of $\mathcal{B}(B_s \to \phi\gamma) = (3.6 \pm 0.5 \pm 0.3 \pm 0.6) \times 10^{-5}$ and establishing an interesting upper limit, $\mathcal{B}(B_s \to \gamma\gamma) < 3.1 \times 10^{-6}$, which reaches the upper range of standard model predictions.

Belle has also searched for dark Higgs h' and dark photons A' in channels of the type $e^+e^- \to A'h'$, $h' \to A'A'$, $A' \to e^+e^-$, $\mu^+\mu^-$, $\pi^+\pi^-$, or missing energy.

2.2 Recommendation

The committee congratulates the Belle Collaboration on continuing their impressive analysis work and producing exciting physics results. The necessary resources should be made available to enable the full exploitation of the Belle data.

3 Belle II Physics Plan

Belle II will increase by almost two orders of magnitude the existing e^+e^- B-factory data sets, to improve the sensitivity to new physics at the shortest distance scales. The measurements will complement both the LHC searches for new heavy particles, as well as the flavour physics studies at LHCb and other facilities.

The excellent opportunities for precision flavour physics at Belle II are well documented in the literature. Many important measurements have been identified as benchmark modes, some strongly favouring the e^+e^- environment, e.g., inclusive decays, decays with large missing energy and decays with neutral final states. The benchmark modes include time-dependent CP asymmetries in $B \to \phi K_S$ and $B \to K_S \pi^0 \gamma$ decays and other related modes, precise determinations of ϕ_3 from tree-level B decays, the rare decays $B \to X_s\gamma$, $B \to X_s \ell^+\ell^-$, and $B_s \to \gamma\gamma$, and decays such as $B \to \tau\nu$, $B \to \mu\nu$, $B \to K^{(*)}\nu\bar{\nu}$. The ability to precisely measure semileptonic decays and determine $|V_{ub}|$ and $|V_{cb}|$ is unique to the e^+e^- environment. There are many important charm and tau physics measurements which could discover new phenomena, and a rich program of quarkonium physics is also of great interest.

Compared to the well established long-term goals of the Belle II physics program, the latest accelerator commissioning schedule with one year delay poses some challenges for the initial physics programme. While the highest priority during the initial running period should be to achieve the designed luminosity and a stable running condition of the machine as fast as possible, developing some unique physics programme for that period is also important and a necessary step toward the ultimate physics goals of the experiment. Interesting analysis topics must be identified, including some for the Phase-2 machine commissioning period with the BEAST phase 2 detector. The Belle II Collaboration needs to work in close collaboration with the machine team to develop an optimal detector and machine commissioning plan, which facilitates an interesting physics program at each stage.

The Belle II Collaboration has initiated the "Belle II Theory Interface Platform" (B2TIP), a series of joint theory-experiment workshops, to study the impacts of the Belle II program and the complementarity with LHCb, and to be ready for the large variety of interesting analyses. The workshop is charged to deliver a KEK report by the end of 2016, describing benchmark measurements and performance predictions in three scenarios: 1 ab^{-1}, 5 to 10 ab^{-1}, and $50\,\mathrm{ab}^{-1}$. The collaboration could also consult the B2TIP workshops for input and new ideas on early physics analysis topics (including Phase 2, mentioned above). The working groups have been set up to parallel the Belle II physics working groups, which is ideal to foster collaboration between experimentalists and theorists for developing and refining the Belle II physics program, and to test the analysis tools. The committee welcomes this effort and encourages the collaboration to continue developing the necessary tools for reliable performance estimates in the B2TIP report.

Preparation for the analysis of Belle II data is advancing well. The committee strongly endorses the effort to enable analysis of Belle data in the Belle II software framework, which which aids the development of Belle II software and ensures exploitation of Belle data until larger Belle II physics data sets become available. Continuing work to improve simulation tools is important, e.g., learning the impact of beam backgrounds in the performance for studies of decay modes with missing energy and for measurements using a fully tagged B sample. The committee was pleased to learn that the flavour tagging efficiency at Belle II is now estimated to be around 32%, about 1.1 times what it was in Belle. The planned development of a single photon trigger for dark sector type searches is encouraged. Many of these needs from physics in the experiment will naturally come up during B2TIP. Thus, the Belle II management should make the necessary resources available for the studies required for the B2TIP report.

3.1 Concerns

The recently announced delays in the start-up of the machine may affect the competitiveness of the Belle II experiment with the LHCb experiment in the area which can be addressed by both. The committee hopes that further delays can be avoided.

4 IR & Beam-pipe Designs and Machine Related Issues

4.1 Status

Background remediation has been ongoing and efforts are continuing to minimise detector backgrounds. In general, background estimates look good with the notable exception for the TOP PMTs, where the background rate is a factor two to three too high over a large range of azimuthal angle. The BEASTs (phase 1 and 2) hardware has been described and plans have been presented as to what each BEAST layout will be. The interaction region of the machine is nearly complete and the remaining accelerator components will soon be installed. BEAST I can then be installed and the IR will be ready for first beam presently planned for Jan. 2016. Work is ongoing and mockups have been made to carefully plan and develop procedures for assembly of the inner components around the beam pipe. This effort is quite impressive and crucial to the success of the inner detectors. Service and signal cable integration and their installation are also being carefully planned.

4.2 Concern

BEAST detectors will be very crucial for the machine commissioning. Although hardware preparation is well advanced, a significant effort is still needed to understand and evaluate the full potential of the detectors for the commissioning.

4.3 Recommendation

- There have been good examples of collaboration between sub-detector simulations and engineering efforts of the beam line design. This type of interaction is strongly encouraged for the machine commissioning period.

- It is recommended to make a plan for how to monitor the machine conditions during the Phase I and Phase II with BEAST detectors.
- BEAST phase 1 running will be primarily vacuum scrubbing while the beam currents are slowly raised. This will in a sense limit background estimates since the rates will be high due to the beam pipe scrubbing. Synchrotron radiation measurements should be useful in spite of this, as these backgrounds are independent of vacuum issues to a large extent. Beam-gas and Coulomb backgrounds as well as other issues related to beam size and stability will be difficult to estimate during this time. The committee recommends that the Belle II collaboration and the machine group develop a series of background dedicated running times with known beam conditions. These dedicated runs do not have to be long (hours perhaps). A couple of examples might be:

  1. Running with lower beam currents than used for the beam pipe scrubbing. This would restore the ring vacuum to a more nominal level and make it easier to measure the IP backgrounds due to beam related particle losses.
  2. Run with one beam at a time. The committee assumes that the scrubbing will in general be with both beams.
  3. Run with design bunch currents but with fewer bunches to see if there are any unexpected sources of background.

  There should not be too many runs as significant effort will be required to fully analyse the data. But some runs may want to be repeated as the vacuum improves and as the beam currents rise.

- With BEAST phase 2 running, it will be important to get good estimates of expected background rates in order to confirm background levels for the PXD and SVD prior to installation. In light of this, the committee recommends that criteria be set for the background levels expected during Phase II commissioning. The minimum would be to confirm calculated background levels with measured background levels. This validates the background calculations which allows for a decision as to when to install the inner detectors. Some suggested tests are:

  1. Background measurements with colliding and non-colliding beams.
  2. Single beam steering tests at lower beam currents to validate masking designs and collimator designs and find under what conditions a mis-steered orbit can cause trouble for the inner detectors.
  3. Injection produced backgrounds. Look for backgrounds with injection on and off.
  4. Different β^* machine configurations. This will be useful to judge how sensitive backgrounds are when β^* values are decreased down to the design values (and even to smaller than design values).

  The inner detector groups will have to agree that conditions are acceptable for installation. One must always keep in mind that machine related backgrounds except for luminosity produced backgrounds should in general decrease as machine performance improves and the luminosity increases.

- Currently, nine detectors are proposed to be part of BEAST phase 2, each of which will require resources. It is recommended to balance the value added of each detector to the understanding of running the experiment compared to the resources that will be required for inclusion in the BEAST phase 2 run.

5 Vertex Detector

The committee was presented with a detailed overview of the assembly procedures of the Vertex Detector (VXD) and a tour of the assembly facilities. A complete mock-up of all elements is in place and all assembly steps have been exercised. The committee was unanimously impressed by the huge amount of work done by the groups and the level of detail implemented. The QCS magnets were mimicked with less detail and detailed routing of cooling lines also remained to be implemented. The committee is very appreciative of the dedication of the Pixel Detector (PXD) and Silicon Strip Vertex Detector (SVD) teams and the progress made to date.

It is noted that in November 2014 there was a focused review of the SVD. Concerns and recommendations presented in the report of that review, pertaining not only to the mechanical assembly but also the electrical performance and thermal management, which have not been addressed yet during this meeting, are still valid and will not be repeated. The current set of recommendations as they pertain to the SVD should be considered an incremental update to the November report.

5.1 Pixel Detector (PXD)

5.1.1 Status

The PXD project uses three key ASICs for the readout: the data handling processor, the drain current digitiser and the switcher chip. All ASICs have been characterised in detail and no major issues have been uncovered to date. However, rigorous characterisation and simulation before and after final submission should be continued. The latest DHP-chip prototype has been implemented in the TSMC 65 nm CMOS process and has been tested stand-alone and on EMCM module. Irradiation tests with neutrons and x-rays are planned. Only a few minor issues are remaining with the DHP chip: delay lines cause problems in the data clocking, the output buffers are a bit too slow and there are errors in the serialiser output. All issues are understood and will be fixed in the next submission.

The drain current digitiser (DCD) chip receives and digitises the DEPFET signals. Each chip has 256 channels with a current receiver and an 8-bit ADC. Together with a 2-bit offset correction DAC it has 10-bit resolution with a dynamic range up to 90 μA. A distribution layer, under bump metallisation and solder bumps are added at another company, after chip fabrication at UMC. The DCD chip was extensively tested in three different configurations: with a probe station; mounted on PCBs or mounted on an EMCM. The tests revealed that some ADC channels did not perform properly, resulting in an increased noise, which was caused by a transistor mismatch. This can be solved easily by changing the layout of the transistors. Simulation studies are also ongoing. The final chip submission is foreseen for May 2015.

The switcher chip generates the fast high-voltage pulses (up to 20 V) to activate the gate rows and to clear the internal DEPFET gates. It is a 32-channel chip in the AMS 180 nm HV technology. Very few minor modifications need to be made and the final version will be submitted in May 2015.

The pixel group has reacted to the new Belle II schedule by nearly fully absorbing the one year schedule shift into the pixel detector schedule. Originally the PXD was scheduled to be installed in Belle II in August 2016. The new schedule calls for the PXD to be delivered to KEK in March 2017. The extra time will be used to introduce a pilot run for module production. A few wafers will be processed for pre-qualification and will allow for a check of the correctness of the latest layout changes and will permit testing ASICs with real detectors. The PXD project has started this pilot run already with the final PXD9 sensors. These are the first DEPFET modules with thin gate oxides and the first results are as expected from the simulations. Two months have been allocated to test the pilot modules and the processing of the final sensor wafers will wait for results from this pilot run. Additionally, during the pilot run a few test modules can be produced for beam tests and for BEAST phase 2. With the final ASIC submission to occur in May 2015, this would allow module assembly to start in February 2016.

Preparations are being made to start assembly of the modules. The flip-chip bonding of the ASICs has been extensively tested at IZM and is ready to go into pilot production in the summer of 2015. The placement of the surface mount devices (SMD) has been moved to IFIC/NTC in Valencia, because of issues with the vendor in Berlin. There are, however, still balling yield problems at NTC that are being addressed. The attachment of the kapton flex cable is not expected to give any problems. The ladder assembly concept has been defined and the construction of assembly fixtures has started. Samples are available of thinned modules and will be used to practice module and ladder assembly.

The committee learned that the production of sensors will be continued after completion of current production and funding for electronics has been requested to support the construction of a second PXD. This is seen as a potentially very beneficial initiative.

5.1.2 Concerns

- Although the introduction of a pilot run for production is a good tactical move and maximises confidence in proper operation of the detector, sensor production remains a critical step in the overall process.
- Balancing the availability of resources and ensuring that high priority issues discussed below get adequate, timely attention is a concern to the committee.

5.1.3 Recommendations

- The joint test beam with the SVD remains a very important system test and the committee strongly encourages the collaboration to give it the priority.
- The thermal mockup of the VXD is critically important. There have been several schedule delays. The committee urges that the thermal mockup test commence as soon as possible.
- The detailed mock-up of the assembly of the two sub-detectors and their integration with the beam line elements is highly commendable. The committee recommends that the attention to detail be kept up and even increased, especially with regard to the cooling requirements.
- Grounding concepts for the global vertex system were presented but are still at the conceptual design level. It is recommended that the grounding scheme be regarded

as an integral part of the project and the various grounding options be developed and tested before the project is too far along in building modules.

5.2 Strip Detector (SVD)

5.2.1 Status

The SVD was the subject of a focused review 9-10 November 2014, which provided a comprehensive status of the project. The collaboration has already implemented some of the recommendations of the review report and in the current meeting illustrated the progress in the project organisation and schedule, the construction plans, the electronics status, and the development of the detector online and offline software.

The SVD group has been reorganised with a project leader and six sub-group leaders with defined tasks and interfaces to SuperKEKB and the other Belle II groups. A revised schedule with respect to the November review has been provided, accommodating also the delay in the SuperKEKB commissioning schedule. Production sites will complete qualification by the end of May 2015. After that ladder production will start with all ladders completed by September 2016. Ladder mounting will last from April 2016 to February 2017, when the SVD will be available for integration at KEK. VXD integration will start one month later when the PXD will be available. A 3-month VXD commissioning period is scheduled to start at the end of June 2017.

The ladder assembly requires multiple pitch adapters (PAs) for connection of the strips to the APV25 chips at the edge of the ladder (FlexPA) or the one dedicated to read the n-side of the origami modules (PA0). The fabrication of the PAs has been a major problem during the last year. A dedicated task force is now following the PA production. The FlexPA production was affected by wire bonding issues due to bond pads being too small. This was solved by rearranging the pads into multiple rows, but the initial pre-production had shorts, due to a lack of specifications given to the manufacturer. A new production run is expected to deliver a first lot in March, followed by full production in May. The PA0 showed cracks on the trace neck near the bonding pad. A solution was found using thicker necks, keeping the necks under the cover layer and using laser cutting to reduce the stress on the substrate. A pre-production batch will be available in May, but a detailed schedule has not yet been developed with Taiyo. Based on the experience of setbacks during the flex production the Quality Control Group has implemented a sign-off procedure for all specifications and a change-control protocol for modifications to either the specifications or construction procedures.

The ladder production is distributed over several sites. The qualification for production requires a review for partial qualification after building a class-C (mechanical, not electrically working components) ladder and full qualification with class-B (fully functional components, but of reduced quality) or class-A ladders. The Pisa, TIFR (at IPMU), HEPHY and IPMU assembly sites passed partial qualification according to the schedule presented in November. In general mechanical jigs are ready, wire bonding capabilities established, the electrical test equipment and database usage standardised among sites. Except for some site specific issues regarding alignment tolerances and gluing, which are currently being addressed, assembly precision is better than 100 μm. No explicit requirements, however, have been specified. The Melbourne site aims for full qualification in April, while for the other sites no date has been set.

To provide as quickly as possible electrically-functional ladders for system tests, some ladders using repaired PA0-cracked-origamis will be assembled, as part of the site qualification procedure. The group is also planning to perform mechanical stress tests, in particular covering shock and vibrational stress during transport, ladder mount and connection of the cooling pipes. Thermal tests and thermal cycling with class-C ladders are also foreseen.

An inventory of available components has been performed to evaluate the availability of parts for building ladders with the requirement of at least 20% spares and the required class-B modules. There is a lack of components for L3 and marginal availability of DSSD modules for the other layers. A quotation for an additional purchase has been requested to HPK.

5.2.2 Concerns

- Prototypes of the PA final design are not available and unforeseen issues could show up in the future.
- Neither clear testing procedure nor specification for ladder acceptance has been presented. Also specifications for site qualification have not been clarified.

5.2.3 Recommendations

Concerns and recommendations presented in the November focused review report that have not been addressed at this meeting are still valid and will not be repeated here; the current set of recommendations should be considered an incremental update to the November report:

- The current schedule foresees a large gap between VXD integration and commissioning and VXD installation. The collaboration should carefully consider balancing the contingency in ladder production, integration and commissioning in favour of a brief delay in ladder production to allow feedback from system tests into the detector design.
- Clear specifications should be given about the tolerances in ladder production and in the electrical quality assurance procedure.
- The committee encourages the early production of class-C and class-B modules to be devoted to extensive mechanical, thermal and, for class B ladders, electrical tests.
- The attempt to purchase additional DSSD sensors and obtain the component availability required to reach the target of at least 20% spares should be pursued.

5.3 Cooling

5.3.1 Status

The SVD cooling system is complex and brings together a variety of cooling path designs. Vacuum isolated concentric lines bring the CO_2 into the cold dry volume where the dew point must be kept below -30 °C. The PXD is cooled by four Support and Cooling Blocks (SBCs), which act as heat sinks and integrate the cooling lines in a 3D-printed structure. The principal role of the SCBs is to drain the ∼360 W generated by the PXD readout chips. A coolant target temperature of -20 °C is estimated to achieve the goal of a sensor operational temperature of less than 25 °C and ASIC temperatures below 50 °C. The heat contribution of the sensors is removed with dry nitrogen flow. The SVD contributes an additional ~ 700 W to the thermal load, which is removed by circuits in the four end-rings, and additional "Origami" cooling pipes, which are required to drain heat from the electronics mounted directly on the sensors via a keratherm interface. The goal here is to keep the APV25 surface temperature close to 0 °C, leading to the same requirement for the coolant temperature as the PXD. Globally, the cooling must respect a constant temperature of ~ 23 °C at the inner surface of the CDC. This requires an insulated thermal enclosure, must account for parasitic heat loads on the detector and cooling supply lines, and avoid condensation in the dry volume.

The goal of the thermal mockup has evolved considerably, now targeting a system using as many final components as possible in order to properly model heat transport through the entire structure, while at the same time adding complexity due to the number of sensors installed for monitoring. It is hoped that in addition to the core goal of understanding the cooling design, the mockup will also provide information on mounting procedures, failure modes and interlock logic, and may prove useful for debugging eventual problems in the real system. The mockup will provide invaluable information on the simultaneous and continuous operation of different types of cooling circuits under varying conditions in addition to studying the interplay between the CO_2 and N_2 cooling, enabling a prototyping of the distribution systems, and testing the integration of the environmental monitors.

For the PXD thermal mockup dummy sensors are produced at MPI and the SCBs have been integrated with silver coated carbon tubes and are being tested at MPI, with pressure tests to come. On the SVD side, the L3 dummy ladders are prepared and the assembly of the L4-L6 ladders will start once all end mounts are at DESY. The SVD end ring connections represent an intricate assembly with many narrow bends in the cooling pipes. The brazing procedures are being optimised. In the meantime an interim test with "flat" SVD L6 ladders has gone ahead, providing invaluable experience for the bending and installation of the long origami cooling pipes as well as first thermal measurements. It is still the goal to assemble the complete VXD mockup by August 2015.

The CO_2 plant itself, "IBBelle", is an exact copy of the recently installed system for the ATLAS IBL. The VXD will profit not only from the design but also from the commissioning experience. ATLAS has two copies of the cooling system operating for redundancy and additional power during the bake-out of the beam pipe. The IBBelle concept was originally based on a double cooling unit to be installed outside Tsukuba hall, however this turns out to be impractical and the new baseline concept is to install a single unit version inside Tsukuba hall, easing the transport and space requirements. The location within the hall is being finalised and the decision has been taken to route foam insulated pipes from IBBelle to the manifold rather than commercial vacuum isolated lines. During the tour the committee was pleased to see the work already put in place to study the cooling pipe routing within the experiment. The system will be controlled with an EPICs supervisory interface and there is a clear division of responsibility between the KEK team providing routing servicing of the plant, and the VXD team which will intervene in case of major failure.

5.3.2 Concerns

- Delay in the construction of a thermal mockup is a concern given the commissioning experience of the ATLAS IBL.
- There is not yet an inventory of all failure scenarios and procedures for interven-

tions, which is essential for a complex system.

5.3.3 Recommendations

- Given that the MARCO system does not have the cooling capacity appropriate for thermal mockup tests, it is recommended that in addition to the plan to replace the MARCO pumps, it be considered to build the "second" single IBBelle plant, not for installation in the experiment but for use with the thermal mockup.
- The intensive testing of the SCBs is just starting. It is recommended to evaluate the performance very carefully, by probing the full range of temperatures and pressures, and subjecting the parylene coated assemblies to the same kinds of violent thermal shocks that can be expected in normal operation of a CO_2 system to check for eventual delaminations. The performance of the SCBs in particular with respect to the roughness, cleanliness and quality of thermal contact of the integrated cooling tubes must be evaluated.
- The thermal mockup will hopefully provide valuable input on the location of the boiling onset of the coolant. In case this is not according to expectation, the causes should be carefully studied, as the design must ensure that the onset of evaporation does not occur too soon (or too late) and that the vapour quality is maintained in a regime well away from potential dry-out.
- The quality control procedure should be put in place for all components of the system which could be subject to leaking, may undergo multiple insertion-connection cycles during production and installation and may need servicing. The recent changes to the system, in particular the additional clip on the slanted modules and the sliding lock mechanism must be carefully validated for a range of temperatures and thermal cycles.
- It is recommended to make sure that the controlled tests of the thermal mockup be correctly modelled by Finite Element Analysis simulations. For those areas where the thermal mockup is only an approximation of the real detector, this will provide the basis for reliable extrapolation.

5.4 Electronics, Slow Control and Software

5.4.1 Status

The Electronics and Grounding status was presented to the committee in the context of the new management structure. There are 6 work packages with identified leadership. The status of the individual electronics boards are mostly finalised, with a series production planned for the second half of 2015. A dedicated daughter board test system is under development.

The grounding scheme is being developed for the whole VXD in consultation with the Belle-II grounding group. The SVD front-end is operated with floating positive and negative bias potentials. Wires connect the HV return to the BW end flange, which functions as the SVD ground point, connected to the Belle II ground, and, for example to the ground of the FADC readout boards. The cooling pipes are electrically isolated to the outside and are connected to the end flange and end rings, and the outer shell connects the BW and FW end flanges. Mechanically the grounding is a challenge, with a range of shapes and materials to be interconnected. Different options are being considered for the end flange connection, including conductive glue, or a mechanical connection. The power supplies are floating and referenced to ground at the front end.

During the January 2014 joint SVD+PXD test with beam, excessive noise was measured in the L3 n-side. In the November beam tests and in lab tests this was not reproduced. A full scale measurement campaign was launched, revealing that the noise pattern could be generated at a frequency of ~ 1.5 MHz in the APV25, and that the effect of environmental noise sources close to the cables could be mitigated by connecting the front-end ground of PXD and SVD. This solution was implemented and it was clearly demonstrated in the lab that the noise issue could be reproduced, and then suppressed. Further GND/EMC test plans are in place for 2015, at ITA (Zaragoza) and in CERN and DESY beam tests.

The slow control and detector control has been developed in EPICS for both SVD and PXD and interfaced with the Belle II slow control NSM2. The development has shown good progress and is expected to be completed by spring 2015. Work has progressed on the alignment software, with the goal being to align the whole detector with Millepede II and provide standalone sub-detector alignments for cross-checks. Work has started on implementing monitoring plots and incorporating calibration data. The SpacePoint Creator has been developed for use by the track finding and work is ongoing to improve the use of SVD information, exploiting timing and charge correlation data and using dE/dx for detector calibration checks. In parallel the simulation is being developed and new mechanisms are being incorporated to digitise the data format, incorporate shifts from nominal alignment and add beam background overlay. Overall the goal is to have production ready simulation and reconstruction software by the beginning of 2016.

5.4.2 Concerns

- A study of electric noise is progressing, but further effort is needed including the PXD-SVD combined beam test.
- Various decisions are being taken which are not backwards compatible, e.g. freezing the number of parameters allowed for the alignment description or merging the SVDDigits to contain all the APV25 waveform samples. At the same time the tracking efficiency so far presented is now below nominal.

5.4.3 Recommendations

- The committee learned that a separation voltage for pinhole mitigation is incorporated for the p-side and is being explored for the n-side. In view of the complexity of the system the evaluation of n-side implementation is encouraged and should be done if possible.
- It is recommended that, when the new Belle II software framework becomes available in April, the VXD software must be reviewed again, to ensure that the algorithms are sufficiently efficient and fast. In addition a detailed set of diagnostic histograms should be developed, so that software performance, data quality, and alignment effects can be easily monitored.

6 Central Drift Chamber (CDC)

6.1 Status

The committee is pleased by the steady progress in the construction work of the Central Drift chamber (CDC) in the past year. The wires with out-of-tolerance tension were replaced, the device was rotated to the horizontal position, the small cell chamber was installed, the assembly was moved to Tsukuba Hall and ground and HV wiring was installed on the forward end. After all of these operations, a HV test revealed only 1 broken wire.

The results of chamber surveys agreed reasonably well with prior calculations and the discrepancies were within tolerances. The measured leak rate after installation of the gas seal was acceptable. Currently wire tension is being remeasured and installation of the front end boards in the backward side has started.

All front end boards from the production run were received and tested. A total of 330 were received and 312 passed all tests, where 300 are required.

After remeasuring wire tension, replacing out-of-tolerance wires, and installing the FE boards, a Cosmic Ray Test (CRT) is the next major step. Since the CDC is not in its final location, special cables are required for this test, limiting the test to about 50 FE boards at a time. Also, a special trigger and DAQ will be required. Currently there is some interest in including a few barrel particle identification (TOP) modules in this CRT, so that tracks measured by the CDC can be used to study performance of the TOP modules.

6.2 Concerns

- There are only 12 spare front end boards for the CDC. This may be somewhat marginal since this represents only 4% of the 300 boards required.
- Including TOP modules in the CDC CRT test could impact the CDC test schedule substantially.

6.3 Recommendations

- Since the committee considers that 12 spare front end boards may be marginal, efforts to repair the remaining 18 should be continued.
- Acquiring the cables, trigger, and DAQ for the CDC CRT test should have high priority.
- A decision to include TOP modules in the CDC CRT test should be based on the potential benefits to the TOP, impact on the CDC CRT test, and the availability of the required technical and human resources. If such a test were done, a clear objective and prioritised study plan would be required.

7 Particle Identification

7.1 Barrel Particle Identification (TOP)

7.1.1 Status

The TOP group is to be congratulated for the substantial progress they have made in the year since the last BPAC review, and indeed in the short time period since the focused review of November 2014. They have complete designs for all elements of the bar boxes and electronics, and have fabricated and assembled these elements into a first bar box (module 01) together with electronics. At the time of this review, the fabrication of the last major element of Module01 (with its full electronics stack) was being optimised and tested. Although camera space is tight, progress to date suggests that a satisfactory outcome which integrates the full electronics package is likely, and that the electronic heat loads can be handled. Unfortunately, following the November 2014 optical and mechanical fabrication, there was a failure in a small portion of the window-to-wedge glue joint, and a number of other issues have arisen, such as small pits or bubbles, and glue "striae". If the joint is truly stable, it seems unlikely that these would degrade performance excessively as they are relatively small features. However, these issues and their impacts remain to be investigated and understood. A glue-joint R&D program is underway to understand the nature and impact of these problems.

Much of this review was incremental to the focused review of November 2014, as is reflected in this writeup. The committee commends the TOP group for their hard work in finalising numerous crucial design details and fabricating the first module. There have been significant schedule delays in fabrication of major TOP components since the schedule was presented at BPAC in 2014 and at the CD2/3 review in March 2014, and this slippage continues into module assembly. The final completion of the first bar box, including camera elements, scheduled in November 2014 for December 2014, was just approaching completion at the time of this review in February 2015. At the same time, the schedule slippage in the overall SuperKEKB project has, somewhat paradoxically, added pressure to the production schedule for completing and installing the TOP already for the first physics run. This change in overall schedule promises substantial benefits to the total project - leading to a complete Belle-II detector when physics starts - but constrains development, production, and testing time for TOP, and thus, increases technical risk. The assembly and installation of completed bar box modules is on the detector installation critical path. All elements of the production and the schedule will require very close attention if timely success is to be attained.

The committee thanks the TOP management and group for their interesting and helpful tours of the fabrication facilities, and their open and forthright responses to concerns and recommendations made by earlier reviews, including those of the previous BPAC review in February 2014, and the recent focused review of November 2014. Many of these concerns and recommendations, especially from the November review, cannot be fully addressed until fabrication details and tests have been finalised, and more parts have been fabricated and thoroughly tested. Not all of these previous recommendations have been addressed nor will they be repeated here, but it is hoped that these will be kept in mind. The US project underwent a satisfactory DOE CD2/3 progress review in December 2014, including the optical components and electronics provided by the US, the cost and schedule, and the US project management.

7.1.2 Top Module Production Status

The specifications of the optical components are well understood and the orders for their fabrication have been completed. Components being produced are of high quality. Costs have increased with the shift to sole sources, but adequate financial resources appear to be available within contingency. Quality Assurance (QA) procedures are formalised and seem sound. The delivery schedules for mirrors and prisms look to be off the critical path. The bar delivery schedule from Zygo, while reasonable, remains on the critical path, and needs to be monitored carefully.

The clean rooms and other facilities for making the bar boxes are built and available at KEK, and have been utilised to provide a crucial demonstration of the group's ability to fabricate optical joints and a high quality bar box enclosure. Based on the first bar box assembly, it is plausible that the production time for bar box fabrication can be reduced to the required three weeks per box, although this remains to be demonstrated. Cleaning, testing, and fabrication procedures seem acceptable and continue to be improved. Production staffing is complicated and challenging, but appears plausible. Some PEEK parts need to be modified, and the design and fabrication procedures improved. Significant leaks were seen after Module01 was first sealed, with smaller leaks remaining after the initial repairs, and since fixing leaks is time consuming, this may be an important time factor in completing a module. Thus, the box sealing procedures (and testing) need to be better understood and improved. Full optical imaging of all joints for fabrication QA, and future reference, is recommended. The present QA for module acceptance includes a two month's long Cosmic Ray Test (CRT). The committee believes this may need to be rethought, both because of limited efficacy of the test and its practicability, given the tight time scale. In any case, a full CRT test of each module will require an expansion of the CRT test system's capability.

As discussed above, though the basic gluing procedures seem to be well developed, the defects and failures in a portion of the glue joints are major concerns and have prompted a detailed re-examination of gluing. In the meantime, module production has been halted until March. The schedule for the remaining 16+1 bar boxes is very ambitious (approx. 3.5 weeks/bar box), and bar box fabrication and testing are very much on critical path.

7.1.3 Electronics and Readout

The Committee commends the significant progress in the readout system reported by the TOP group at this review. This progress included the major technical choice of adopting the IRSX ASIC in July 2014. However, the circuit board redesign required by this choice continued into November, and resulted in at least 3 months delay in production, and the electronics was seen to be well onto the critical path at the November 2014 review. Other elements required to operate the electronics, such as firmware/software, were late, and the integration of the package into Module01, with its cabling, thermal integration, and calibration system was a major challenge which is just now approaching resolution. An enormous effort has been made by the electronics team in the last 3 months to complete all of the design issues, and to understand remaining production issues, including radiation and magnetic fields sensitivities, thermal design, mechanical fit, cabling, and overall integration. These issues must be addressed in the context of Module01 integration, which serves as a crucial test bed for addressing many of these concerns, but can serve as a complete testing vehicle only when all hardware and software elements are available.

To summarise, the pilot production for Module01 is many months behind schedule, but was nearly complete at time of this review. Testing experience to date is encouraging, and it seems plausible that a good thermal solution has been (or will be) found. The firmware work remains on the critical path. Full tests of this module are expected in the cosmic ray test stand very soon.

The group continues to work very hard to catch up with delays in mass production and testing of all electronic components. The fabrication/testing organisation is complex and is spread across a number of institutions. It requires that one TOP module's worth of electronics be produced per week. It will be a challenge to keep on schedule, and will require constant oversight. Laser test stands at Hawaii and KEK remain to be fully commissioned by late March. Even with this schedule, the electronics production remains behind the module production until about June, but if the production pipeline stays filled, it is plausible that electronics could be completed by Mid-August. This would be a great success.

Production HV boards are available and are being tested, and there is no indication that HV boards will be on the critical path for TOP electronics.

7.1.4 MCP-PMTs

The production and testing of the 515 MCP-PMTs produced in the first phase was discussed. Nearly all tubes have now been inspected, with a small number of failures to date. The MCP-PMTs will be monitored repeatedly until they are installed. As has been noted in previous reviews, the uncoated 285 conventional MCP-PMTs appear to be unable to survive to the integrated luminosity of 50 ab^{-1} while the ALD coated PMTs seem to have sufficient margin. Careful thought is being given to tube installation strategies that could slightly mitigate the loss of tubes early, but it would seem that the conventional tubes will eventually require replacement. An extended lifetime R&D program is underway using 42 tubes in order to understand and optimise lifetimes versus tube production process. This will hopefully lead to tubes with even longer lifetimes than the ALD tubes now in hand. A total of 35 tubes made with this optimised process should be ready for installation by Jan 2016, with up to 19 more later.

The performance of readout electronics for channels with low gain remains to be studied (averaging over MCP-PMTs set to 5×10^5, there is a factor 2 gain variation across MCP-PMT).

7.1.5 TOP Module Testing Plan

The time frame available for tests has been substantially reduced due to production delays. Cosmic Ray Tests (CRTs) without tracking at Fuji Hall are proposed as part of the primary QA test of each module, but this is still an extensive and challenging program; requires expanded capacity to be able to test every module; and the performance of the test may be inadequate to fully qualify modules. The suite of acceptance tests done for each module needs a careful grounds up review (as discussed in the concerns and recommendations sections), taking schedule and resource concerns into account, and further integrated tests, which perhaps include high quality tracking, may need to be postponed given the time left.

The proposal to defer a beam test in 2015 in favour of CRT tests without tracking (and, as proposed, with CDC tracking) seems inevitable given the schedule, production concerns, and lack of manpower. The committee agrees that the ultimate decision can be deferred until after installation, and may be superseded by tests with CDC tracks, if these become available. The new plan to take cosmic data with the CDC sounds promising and could be very useful in obtaining data that allows check/improvement of analytical understanding of the analysis method, but a concrete added value to understanding of the TOP performance was not demonstrated neither were the required resources identified.

7.1.6 Software

The Committee is pleased to see further progress in the area of software, calibration and alignment. The first versions of the raw data formats have been defined, and the raw data packer and unpacker modules are ready. The software TOPCAF has been migrated into the Belle II software framework with the ability to use the new conditions database interface (see below) and is already in use for the CRT data analysis for commissioning. The CRT simulation code is complete and being used to study different triggers. The TOP has been selected as the first use-case sub-detector to test the conditions database for which a first condition database design has been developed in close collaboration with the TOP group. The first database prototype is running at KEK and PNNL.

7.2 Concerns

- The production schedule for the remaining 16+1 bar boxes is very ambitious (approx. 3.5 weeks/bar box). Routine production needs to start as soon as feasible, and, even under optimal circumstances, will remain on the critical path until completed.
- The Committee is concerned that the presented set of QA/QC tests for completed modules is not well documented and will not always provide timely go-no-go decisions, and, at the same time, may require too many resources to perform. Systematic optical QA of assembled bars should be carefully considered. These procedures are likely to be helpful in the long term and relatively quick to qualify the optical assembly, but a formal procedure must be in place (specifying photos to be taken, laser reflection criteria, etc.).
- Backgrounds remain a concern, even at lower gain, exceeding limits for conventional MCP-PMTs. Simulation should be further improved, and the localised shielding for radiative Bhabha background should be explored further.
- The proposed combined cosmic ray test with the CDC is very intriguing, but, given the very tight schedule and manpower constraints for TOP module production, it is not obvious whether benefits can justify the extra effort required also from the groups outside of the TOP project.
- The committee commends the recent progress towards producing final electronics, but many aspects of production and testing remain on the critical path.
- Manpower remains critical. Bar production methodology and techniques seem to be spread over several people and are reasonably well documented. However, potential single point failures remain, especially in electronics.

7.3 Recommendations

- It is urgent that the first production box be thoroughly tested as soon as possible in the Cosmic Ray test stand. A program for this test should be specified.

- The present round of gluing fabrication tests must be completed as soon as possible. Bar box assembly should be resumed as soon as these glue tests are completed-no later than mid-March in order to avoid significant schedule delays. It may be necessary to accept some technical risk at this point in order to avoid future schedule risk. Further tests of the glue joints should continue in parallel even after the start of Module02 construction.
- A clear and well considered plan including all criteria for TOP module QA and acceptance; how this incorporates CRT testing; and the need and timing of a possible test with beam or CDC tracking that fully accounts for the available resources needs to be developed urgently. No manpower can be taken from the module fabrication and electronics and firmware teams, which must have the highest priority.

7.4 Endcap Particle Identification (ARICH)

7.4.1 Status

The committee heard presentations on the general status of the ARICH system as well as a detailed talk on the readout electronics and commends the ARICH group for the steady progress made since the last BPAC review.

The mass production of the aerogel tiles was completed successfully. The yield of good quality tiles for both types of aerogel meets or exceeds the requirement. The transmission length and refractive index for each tile have been measured and stored in a database. The mechanical support structure for the tiles is scheduled for delivery by early March and a plan for holding the tiles in the structure, using thin strings, was presented.

The production of the Hybrid Avalanche Photo Diode (HAPD) sensors is progressing well and is expected to be completed in September 2015, depending on the availability of funding. Shortly after the last BPAC, the system used for the HAPD evaluation broke, leading to a significant delay in the HAPD quality assurance. After the system was repaired the measurements resumed and have now almost caught up to the planned schedule.

The measurements demonstrate that the quantum efficiency is significantly higher than expected, especially for the more recent batches. Image distortions, observed in scans of the HAPD uniformity across the anode pads, are not present when the HAPD is measured inside the 1.5 T magnetic field. The measurements identified a number of HAPDs with unacceptably large leakage currents, including a few units which had passed QA a few months earlier. Studies by the manufacturer, Hamamatsu Photonics, show that the large leakage currents are associated with small cracks in the APD, requiring the HAPDs to be replaced. The leakage current of all HAPDs will be remeasured before installation.

Plans were presented for the calibration system and a database for the measured ARICH component properties as well as calibration and configuration. The software development is making good progress and the code for the packing and unpacking of raw data has been completed. No significant changes to the expected ARICH radiation dose were observed from the latest beam background simulation campaign. Background expectations are still below the critical level.

The ASICs for the FEE and merger boards have been produced and tested. The yield of accepted ASICs is more than adequate to provide a sufficient number for production of the boards and spares.

The new front-end boards were tested and performed as expected until occasional damage to the ASICs due to very large pulses was observed during the HAPD tests. Preliminary results indicate that the ASIC damage issue may be solved by adding electrostatic discharge (ESD) protection. Providing that the modified board design is successfully tested, mass production of the FEE and merger boards will start within the next 3 months. Meanwhile a study of the source of the large pulses continues.

The updated ARICH project plan, adjusted to the new overall Belle II schedule, was shown with a target date for the completion of ARICH production in December of 2015, leaving sufficient time for system tests before installation in the summer of 2016.

7.4.2 Concerns

- The large leakage currents in some HAPDs, and in particular the observed significant increase of the leakage current for HAPDs that had previously passed the QA tests and now fail QA, is a concern. The ARICH group is working with Hamamatsu Photonics to identify the cause of the problem and plans to remeasure all HAPDs.
- The ASIC damage from large pulses are also a cause for concern although the ESD protection approach looks promising.

7.4.3 Recommendations

The committee congratulates the ARICH group for their good progress since the last BPAC, which puts them on track to a completion date with sufficient time for full system tests prior to installation.

- The committee encourages the ARICH team to monitor the long-term stability of the HAPDs closely to gain more operational experience with the HAPDs and to continue the detailed studies of the source of the HAPD cracks with Hamamatsu Photonics.
- The committee supports the plans to continue the investigation of the discharge-like phenomena causing ASIC damage even if the electrostatic discharge protection appears to prevent serious damage.

8 Electromagnetic Calorimeter (ECL) and K-Long Muon Detector (KLM)

8.1 Status

8.1.1 Electromagnetic Calorimeter (ECL)

Stability of the Belle II mechanical structure including ECL, TOP, CDC and VXD has been analysed using finite element methods. Both ends of the barrel ECL are assumed to be tightly connected to the solenoid structure and in addition to the gravitational force, a static force corresponding to 0.3 g is applied vertically or axially to account for possible effects of an earthquake. A maximum deformation of 0.11 mm is obtained at the forward end of the TOP structure and at the backward end plate of the CDC, which is sufficiently small. Maximum stress of 30 MPa is found at the backward CDC support structure that is attached to the ECL. This stress is approximately 1/3 of the maximum stress allowed for the aluminium alloy used for the structure and bolts.

The ECL data acquisition system is now fully equipped, being tested end-to-end and debugged.

8.1.2 Barrel KLM (BKLM)

The installation of scintillation detectors for the two inner most layers was completed in November 2013 and the Resistive Plate Chambers (RPCs) used in Belle I remain in the other 13 layers. All the HV cables for RPCs have been reconnected and are ready for the new HV power supplies. For detector testing, HV and gas are supplied to half of a sector and dark currents are monitored. So far, the levels of dark currents measured are consistent with those in Belle I. The test continues until May 2015. At this moment, availability of readout electronics is limited to only one RPC sector due to budget constraints. Concerning the service of the scintillation detectors, HV is supplied to the MPPC photo sensors in both scintillator layers of one sector.

The KLM DAQ system is being integrated into the Belle II DAQ framework. Signals from two scintillation detectors and 13 RPCs in one octant are readout by the front-end boards and then sent to the backend readout boards. The full path of the data flow up to the COPPER board has been demonstrated, although there are some problems on event building and data transfer. Since the firmware for the trigger board, UT3, is still under development, a standard cosmic ray trigger was not generated and an ad-hoc solution to use the OR signal of the MPPC was utilised as a cosmic ray trigger.

8.1.3 Endcap KLM (EKLM)

The installation of scintillation counters in all the 14 layers in the forward side and 12 layers in the backward side was successfully completed in July 2014. The neutron shields made of polyethylene will be inserted to the outermost two layers in the backward side by June 2015.

8.2 Concerns

- (ECL) Details of modelling for bolted joints are not known at the review. Since maximum stress appears at bolted joints for most cases, it is not clear whether a factor of three is a sufficient margin.
- (BKLM) Funding for the upgrade of the RPC electronics has not been secured yet. The shortage may impact the speed of commissioning of the detector system.
- (BKLM) Readout and trigger electronics are not fully developed.

8.3 Recommendations

- (ECL) The committee recommends that modelling of bolted joints should be evaluated whether they have adequate strength.
- (KLM) Further efforts to bring the electronics to final shape in a short time scale is strongly encouraged.
- (KLM) The committee recommends that a clear plan of the system commissioning using cosmic rays be developed. A detailed timeline to extend the commissioning

test from one sector to the full system is necessary and a check list for each test item should be developed.

9 Detector Control, Trigger, Data Acquisition and Electric Signals

9.1 Status

Clear goals and requirements for the slow control system were presented. The system should provide a smooth and safe operation of the detector for both the expert and the shifter in a friendly manner. The collaboration has decided to build the run control and slow control using two communication backbones: EPICS and NSM2. The consequences of having two systems are well understood and the collaboration is acting accordingly. All the functional elements they need have been identified. These elements consist of the gateways and the common Control System Studio (CSS) to develop graphical displays for both systems providing the unification at the supervisory level. The overall design of the slow control system is well advanced. The finite state machines for the different components have been specified as well as the naming conventions and common look-and-feel. Many of the systems are already controlled via NSM2 or EPICS. Some components were in operation in the 2014 for the DESY beam test and for the ECL cosmic ray test, making the operation much easier for the shifters. The conversion to EPICS of sub-detector controls is processing rapidly, for example the SVD slow control plans to be completed before the next test beam. The next major step is the design of the global user interface.

The committee noted the progress achieved with the integration of the ECL and KLM DAQ. The integrated system was tested with dummy data produced by the CPU in the COPPER boards (without front-end electronics no trigger and distribution system), showing stable operation over one or two days. They also exercised the DAQ for the ECL cosmic ray test (CRT).

The procurement of DAQ hardware and preparation work for the installation are proceeding well and mostly on schedule. All required hardware components will be ready for the ECL, KLM, CDC cosmic ray test, and for the tests of other outer detectors (TOP, ARICH). Assembly work for the COPPER board will restart in April and May after reception of 230 High Speed Link boards at KEK in JFY 2014.

The collaboration plans to run multiple cosmic ray tests independently and this should be ready before this summer. The team is addressing a number of remaining DAQ issues, such as the calibration scheme, the handling the multi-stream DAQ until the start of physics run, the non-stop DAQ, and the finalisation of the PXD integration.

9.2 Concerns

- The partitioning of the slow control is mostly based on functions such as low-voltage, high-voltage, etc., and not on sub-detectors The partition per sub-detectors will be necessary during the commissioning and cosmic runs to operate the different sub-detectors or combinations of them concurrently.

- There are still a number of open questions concerning the actual implementation of the Event Builder 2, such as the protocol to use for data transfer, the need for intermediate buffering, etc.

- Multiple DAQ streams must run concurrently during the cosmic ray tests and commissioning period. This has implications in the design of many hardware and software components of the DAQ system. In some cases, the only solution could be to re-cable parts of the trigger when changing the contents of the partition, which is defined by the sub-detectors participating to the test or commissioning run.
- The DAQ system during ECL CRT showed a number of operational issues. For some of the problems, still no DAQ expert has been able to diagnose them. This may show a resource problem or that the team of DAQ experts is very thin.
- The "event mismatch" problem observed on the PXD beam test at DESY in January 2014 has not been solved yet. This is now being investigated using mini ONSEN (pocket ONSEN) connected to KEK test bench.

9.3 Recommendations

- The committee recommends a careful study on how to implement partitioning involving all the sub-systems such as slow control, DAQ and trigger that will be needed for the multiple concurrent DAQ systems required during the cosmic ray tests and commissioning.
- The stability of the DAQ system is very important. This can only be achieved by ironing out all problems that may desynchronise and eventually stop the system. This requires a systematic recording of all incidents and devote sufficient effort in understanding and diagnosing each one of them.

10 Software and Computing

10.1 Software

10.1.1 Status

The committee was presented with an update of the organisation of the software project. New roles in the organisation have been identified to cover areas such as generators and background. The software development process and all the services to support it are now well established, which makes it easier for people in the collaboration contributing to software. Automated builds, tests, and validation together with the monthly integration builds provides a solid base for developing new functionality. Resource (CPU and memory) usage monitoring has been included in the integration builds allowing the development team to keep software performance under control. Large performance improvements have been noted for some of the components such as the background mixing in the simulation, and TOP reconstruction. Feature driven and validated software releases are made available to users on a regular basis.

The framework BASF2 has been validated for event-by-event parallel execution with its reduced memory consumption. The complete palette of MC generators are now made available, and the EvtGen package is being validated with the PDG tables. For the simulation, the nominal geometry of all detectors is implemented as well as the digitisation, but still there are questions on how to treat the signal overlay of beam backgrounds. The validation of the physics list is already planned. The alignment strategy is getting clearer. The definition of the vocabulary and the selection and integration of the tools such as Millipede II goes in the right direction but a lot of work is still needed, similarly for the calibration strategy.

Effort was put in enabling the Belle data analysis within the Belle II software framework. This will extend the lifetime of Belle data analysis with limited maintenance effort and gives an opportunity to test the Belle II software framework with real data. Although there has been quite a lot of progress the collaboration requires more volunteers for software quality shifts and to cover many holes in the more than 200 software tasks identified in the overall software plan produced following the DOE review recommendation.

10.1.2 Concerns

- The software project has made a lot of progress but the number of tasks is still very large, as it is shown in the recent work breakdown. The effort involved in evolving software from an ideal detector to a more realistic one with calibration, alignments should not be underestimated.
- The tracking software team has made good progress in understanding and improving the software. However there are important areas that require further investigations such as the low track efficiency obtained when 100% is expected, and some uncovered activities that are important such as the design of the reconstruction data model.
- Solid progress has been made in the design of the distributed database system. The committee appreciates the effort the collaboration is putting in there and the approach taken by learning from the experience of the LHC collaborations. However, the design and implementation of the interface for accessing conditions data from the reconstruction and analysis software are somewhat behind. The longer it takes the more ad-hoc solutions will be developed that will be needed to change later.

10.1.3 Recommendations

- The committee recommends starting integration of the conditions database, which supports the interval of validity, in the reconstruction and analysis software.
- For the validation of the EvtGen package, a collaboration with LHCb who is currently maintaining the version of the software used by the LHC community is recommended, if it is not the case already.

10.2 Computing

10.2.1 Status

The Belle II computing model is based on a hierarchical structure composed of four layers of data centres with different functionalities: the *Raw Data Centres* with tape capabilities and high network bandwidth where raw data are stored and processed, the *Regional Data Centres* where copies of the reconstructed data (mDST) are stored and Monte Carlo production is performed, the *MC Production Sites* dedicated to the Monte Carlo production and physics analysis and the *local sites* where the last step of the user analysis is performed. In the first three years of data taking, Raw Data will be stored only in the two major Raw Data centres of KEK and PNNL, one full copy each. In the following years KEK will store the first copy and the second one will be shared among the centres in America, Europe and Asia with different shares.

Many sites are joining the Belle II computing effort, in particular the increased importance of the US and European centres, with a great variety of distributed resources: grid, cloud and local clusters. The DIRAC framework, originally developed by the LHCb experiment and now used by many HEP experiments, is the workload management system for the job distribution and management, providing access in a transparent way to all of them.

A large computing activity has been performed by the Belle II experiment in 2014. Two Monte Carlo production campaigns have produced about 17 billions events, corresponding to the amount of data expected in the second year of data taking. Quite a lot of progress has been achieved in the development of the computing infrastructures. The distributed computing environment has been improved with a new user interface gbasf2 allowing use of the analysis framework over the GRID, and a basic production system has been put in place for the MC campaigns. Many improvements have been also achieved on the network infrastructure, which plays a fundamental role on a distributed computing model. The Belle II collaboration has joined the LHCONE organisation, a dedicated network for the LHC sites, and all the milestones set for KEK-PNNL and Trans-Atlantic data transfers have been satisfied.

In order to achieve a fully functional Belle II computing infrastructure, many services still need to be improved or developed. For this, the collaboration has provided a list of near and long term work items, some of them quite critical; for example the Data Management System and a full Production System.

The collaboration has presented the new computing management organisation, which has been defined in order to cope with the challenges in incorporating fast developing computing technologies in the coming years and with the required coordination between the computing resource needs and allocations. All the subsystems are represented in the new organisation.

10.2.2 Concerns

- AMGA is the File Metadata Catalogue used by the Belle II in the Monte Carlo campaigns. The performance of the service has been improved significantly in the last MC4 campaign and further optimisations are planned by the development team. However, AMGA is used by many scientific projects but Belle II is the only HEP use-case and the scalability of the service and its maintenance might be a concern.

- It is well known from the LHC experience that an easy interaction of the physicists with the GRID is necessary in order to obtain good physics results. No particular awareness on the user-friendliness in the development of the user interface for GRID running was noted.

10.2.3 Recommendations

- The committee notes that the human resources dedicated to the development of the central services are rather limited and therefore recommends that the collaboration evaluates carefully the required manpower and makes its best effort in order to involve people from all the institutes that have joined the computing infrastructure.

- The committee finds that the list of items to be developed in the near and long term is rather long and a prioritisation of these tasks is necessary in order to adapt the computing model to the real needs of the experiment and to the available manpower. The usage of common tools developed by other experiments (as it is already the case of DIRAC and CVMFS for example) is very much encouraged. Exploiting existing features of these selected tools rather than to develop Belle II specific ones is recommended. For example, if the monitoring functionality of DIRAC is not sufficient for Belle II, perhaps it would be better to convince the DIRAC development team to add the missing feature or to collaborate with them to develop the missing functionality, than developing a complete and independent monitoring system.