B-factory Programme Advisory Committee
Summary Report

8th meeting, 9 – 11 February 2014 at KEK

G. Buchalla (München), D. Cassel (Cornell), P. Collins (CERN)*,
M. Demarteau (ANL), M. Kuze (Tokyo Inst. Tech.), H. Lacker (HU Berlin),
Z. Ligeti (Berkeley), P. Mato (CERN)*, N. Neufeld (CERN),
B. Ratcliff (SLAC)*, E. Sexton-Kennedy (FNAL)*, J. Schwiening (GSI)*,
T. Sugitate (Hiroshima)*, M. Sullivan (SLAC),
and chaired by T. Nakada (EPFL)
* Expert members

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1 Introduction and Short Summary

The 8th meeting of the KEK B-Factory Programme Committee took place from 9th to 11th February 2014 at KEK. The committee was pleased to hear that the Belle II Collaboration has increased to 95 institutes from 23 countries with a total of 599 members. Many of newcomers also join the Belle collaboration for physics analysis enabling the sustained effort to fully exploit the Belle data.

Construction of the SuperKEKB machine is progressing well and the first beam commissioning is scheduled for the beginning of 2015, which is still within in the Japanese Fiscal Year 2014. The committee hopes that the budget cut initially announced for the 2014 KEK operating budget can be avoided and that the SuperKEKB commissioning work will remain on schedule.

The installation schedule of the Belle II is now adjusted to the commissioning plan of the SuperKEKB. After the first commissioning run of the machine, rolling-in of the Belle II detector is scheduled for the middle of 2015 with no vertex detector and only partially installed barrel particle identification detectors. Together with the superconductive quadrupole magnets at the interaction region, this will allow the SuperKEKB to commission the beam collision. After this commissioning phase, the Belle II vertex detector will be installed during the 2016 summer shutdown, followed by the start of the first physics run. During the first and second machine commissioning period, specialised detectors (BEAST) will be installed to help the machine commissioning and to locate the sources of machine background. The thickness of the sputtered gold on the beam pipe, in order to reduce the synchrotron radiation background, is set at 10 micron. However, this may need modification following the first background measurements.

For completeness, a short summary report that has been submitted to the KEK and Belle II managements on 27th of February is presented here, followed by the full report.

Short Summary of the Review

During the 8th review meeting, the committee heard the status of the Belle physics analysis, physics programme of the Belle II experiment and the construction of the Belle II detector. This report is a short summary of the committee's findings and recommendations.

The committee is very pleased by the ongoing analysis work with the Belle data and strongly encourages the collaboration to exploit the Belle data for the coming years until the Belle II data become available. The Belle II collaboration has started to set-up a physics programme for the first period of physics data taking with a partial barrel particle identification system and limited amount of collected data. The committee thinks that this work is very important and should be continued.

For the construction of the Belle II detector, the committee heard presentations on Interaction Region, Pixel Detector (PXD), Silicon Strip Vertex Detector (SVD), Central Drift Chamber (CDC), Barrel Particle Identification system (TOP), End-cap Particle Identification system (ARICH), Electromagnetic Calorimeter (ECAL), K-Long Muon Detector (KLM), Trigger and Data Acquisition, Software, and Computing Resources.

Steady progress in understanding of the machine background at the interaction region has been made and it is found that the new beam pipe design further decreases the synchrotron background. The committee is very interested in learning the results of further studies on the synchrotron background due to misalignment and beam halo.

While the schedule remains tight, the current plan for the PXD and SVD is compatible with the overall schedule of the Belle II experiment. The committee congratulates the VXD group with their successful test beam run at DESY which provided very valuable running experience. Thermal management of the VXD is quite complex and the proposed program for a full thermal mockup of the VXD is strongly supported. The committee hopes to see the prompt start of the SVD ladder construction in the coming months.

The committee congratulates the Central Drift Chamber (CDC) group for the completion of the wire stringing. However, remeasurements show that the tension of many sense wires became lower and they need to be restrung. The wire tension must be continuously monitored for the coming month. Further irradiation tests of electronics are encouraged.

Recent progress achieved on the design of the TOP bar box is impressive, and the current design appears to address the essential requirements. However, further mechanical analyses and prototype mockups are needed to attain and confirm the final design. We believe that any necessary bar box design refinements could be accommodated with bars as presently specified, so that, given the long time needed to procure the quartz bars, the committee feels that the purchase of the quartz bars should proceed as soon as possible. For the ARICH, careful monitoring of the quality of the photon detectors being delivered must continue.

The committee noted, with pleasure, the success of the barrel KLM detector installation and progress being made for the commissioning. The delay in the production of the preamplifiers for the end-cap KLM is a concern, since this will have an effect on the ECAL electronics installation that follows the end-cap KLM installation. The committee recommends a swift action to mitigate this delay. The ECAL group is recommended to monitor carefully the progress on the KLM installation and to consider alternative installation plans if necessary.

The work on the Trigger and Data Acquisition is advancing well. The PXD group made good progress on the development of the slow control system, which could benefit other groups. The committee particularly acknowledges their work on the interlock system to protect the PXD detector and recommends a similar effort to be made for the whole Belle II detector. The committee supports the increased effort by the collaboration to better coordinate the software effort. Further understanding of the required computing resources is strongly encouraged.

Radiation hardness of the front-end electronics is a common problem for most of the subsystems. In addition to the work by the individual subsystem group, a common effort by all the subsystems concerned is encouraged.

2 Belle Physics Achievement

2.1 Overview

Belle data-taking ended in 2010 with $\sim 1\,\mathrm{ab}^{-1}$ of data recorded, constituting the world's largest data sample on the 1S, 2S, 4S, and 5S Υ resonances. Since the last BPAC meeting, new groups have joined the Belle collaboration, which now comprises 469 physicists from 80 institutions in 18 countries. This increase is significant. The intense analysis efforts using Belle data have continued. In 2013, 30 papers were published, slightly more than in 2012, and a similar rate of interesting results may be anticipated for the next few years. A comprehensive review paper (over 900 pages) on the physics of the B Factories prepared in collaboration with the BaBar experiment is nearing completion.

2.1.1 CP Violation and Hadronic B-Meson Decays

In addition to the publication of the important results on CP violation in $B \to \pi^+\pi^-$ discussed last year, the final analysis of $B \to \rho^0\rho^0$ gives the branching fraction of $\mathcal{B}(B \to \rho^0\rho^0) = (1.02 \pm 0.30 \pm 0.15) \times 10^{-6}$, with $3.4\,\sigma$ significance for observing a non zero value of the branching fraction. The longitudinal polarisation fraction $f_L = 0.21^{+0.18}_{-0.22} \pm 0.13$ is more than 2σ smaller than the BaBar measurement. These results make an update of the analyses of the other $\rho\rho$ modes particularly timely and important.

The investigation of CP violation has further been pursued in the $\eta' K^0$ and ωK_S modes. The new Belle measurement, $S_{\eta' K^0} = 0.68 \pm 0.07 \pm 0.03$, is the most precise to date, and is more consistent with the value of $\sin(2\phi_1)$ than earlier results. For the measurements of $A_{\omega K_S}$ and $S_{\omega K_S}$, $S_{\omega K_S} = 0.91 \pm 0.32 \pm 0.05$ constitutes the first evidence

(3.1σ) for CP violation in this mode. Many other important results have been obtained, such as the evidence for $B^0 \to K^+K^-\pi^0$ decays.

Concerning some noteworthy puzzles, the most recent angular analysis of $B^0 \to \phi K^{*0}$ shows that the longitudinal polarisation fraction remains below 0.5, whereas it was measured to be close to 1 in the ϕK_2^{*0} mode. With the most recent analysis of the $B \to hh$ branching fractions and CP asymmetries, the "$K\pi$ puzzle" is less severe than it used to be with either the former Belle results or the world average.

Analysis of the $120\,\mathrm{fb}^{-1}$ of $\Upsilon(5\mathrm{S})$ data sample, which is by far the largest in the world, has continued as well and a number of interesting opportunities remain.

2.1.2 Semileptonic and Leptonic B-Meson Decays

The improved hadronic tagging algorithm (NeuroBayes neural net) increases the effective statistics of data by a factor of two to three, and is particularly useful for the study of semileptonic, leptonic, and radiative B meson decays. It has already resulted in improved measurements of the leptonic $B \to \tau\overline{\nu}$ and semileptonic $B \to (\pi, \rho, \omega)\ell\overline{\nu}$ branching fractions. Belle presented interesting measurements on the baryonic semileptonic decay $B \to p\overline{p}\ell\overline{\nu}$, and B_s semileptonic decays.

Decays mediated by flavour changing neutral currents are sensitive probes of new physics. Belle presented a new measurement of the forward-backward asymmetry in $B \to X_s\ell^+\ell^-$, a channel which will be very important for Belle II. Theoretically even cleaner are the predictions for decays involving a $\nu\overline{\nu}$ pair, and new limits were obtained in searches for $B \to (K, K^*, \pi, \rho, \phi)\,\nu\overline{\nu}$, which are promising for the future. For the interpretation of inclusive radiative $B \to X_s\gamma$ decay measurements, it is important to demonstrate that all X_s states are included in the experimental analysis, and the new search for the $B \to p\overline{\Lambda}\pi\gamma$ baryonic decay is an important step for this purpose.

Many ongoing analyses are hoped to produce new results soon. These include the $B \to X_s\gamma$ branching fraction, A_{CP} in the fully inclusive $B \to X_{s,d}\,\gamma$ decay, and the time dependent CP asymmetry in $B \to K^0\eta\gamma$ decays. The final results for $B \to D^{(*)}\tau\nu$, as well as a planned measurement of $B \to X_c\tau\nu$ are of great interest.

2.1.3 Charm Hadrons and Charmonium

Recent hints of CP violation signals in charm decay have put both $D^0 - \overline{D}^0$ mixing and decay measurements in the spotlight. Using the full, nearly $1\,\mathrm{ab}^{-1}$ data set, Belle recently obtained the first 5σ evidence for $D^0 - \overline{D}^0$ mixing in a single e^+e^- collider measurement. A complementary analysis of $D \to K_S\pi^+\pi^-$ decay gives the most precise constraint at present on CP violation in $D^0 - \overline{D}^0$ mixing in a single measurement.

In the study of Λ_c, $\Lambda_c \to pK\pi$ is used as a reference channel for obtaining the branching fractions of other decay modes and the very large, 26%, uncertainty of the world average, $\mathcal{B}(\Lambda_c \to pK\pi)$, from old ARGUS and CLEO measurements has been a serious limitation. The recent Belle result $\mathcal{B}(\Lambda_c \to pK\pi) = (6.84 \pm 0.24^{+0.21}_{-0.27})\%$ improved this situation dramatically.

Understanding charm hadron spectroscopy poses many challenges both for experiment and theory. Recently, Belle observed the $Z(3895)^+$ state in $Y(4260) \to Z(3895)^\pm\pi^\mp$

decay, determined that the $Z(4430)^+$ likely has $J^P = 1^+$, and made studies of several Ξ_c states. Some of the theoretical ideas can be distinguished by searching for not yet seen particles predicted by theory. Belle has made searches for $\Xi_{cc}^{+(+)}$, $B^+ \to D^- D_{sJ}^{++}$, and $e^+e^- \to J/\psi\, X(1835)$ with negative results.

2.1.4 Tau and Two-photon Physics

The physics of τ leptons continues to be an active field. Recent highlights include a measurement of the τ lifetime, better than the previous world average, and big improvements in τ branching fractions involving K^0. The ongoing measurement of the Michel parameters promises to improve their accuracy by a factor of a few, and the CP and lepton flavour violation searches are also important.

In two photon physics, a new result on $\gamma\gamma \to K_S^0 K_S^0$ complements earlier $\gamma\gamma \to MM'$ measurements, and the ongoing $\gamma\gamma \to \pi^0\pi^0$ analysis.

2.1.5 $\Upsilon(5S,\, 2S,\, 1S)$ Decays

The Belle data provide a rich source of information for bottomonium physics, spanning a wide range of topics. There is an interesting program to understand the anomalously large rates for $\Upsilon(5S) \to \Upsilon(1S, 2S, 3S)\, \pi^+\pi^-$, the resolution of which may be connected to the $Z_b^{(\prime)}$ states, and their possible $B^*\overline{B}^{(*)}$ molecular nature. This is supported by recent measurements that favour $J^P = 1^+$ for the $Z_b^{(\prime)}$ states. Belle observed for the first time the neutral $Z_b^0(10610)$ state via its decay to $\Upsilon(3S)\pi^0\pi^0$. Mass measurement of $\Upsilon(1D)$ was also made. Many open questions remain, which are also relevant to Belle II data taking, such as whether $B^{((*)*)}\overline{B}^{**}$ resonances exist, and whether there are molecular states at baryon thresholds.

A new measurement of the R_b scan in the 10.75 – 11.05 GeV region was also reported with much improved accuracy.

2.2 Recommendation

We congratulate the Belle Collaboration on continuing their impressive analysis work and producing exciting physics results using the Belle data. We are pleased to see that new groups are joining the collaboration, and we strongly support their integration into the analysis efforts. The committee encourages the collaboration to continue exploiting this opportunity in order to make optimal use of the entire Belle data set, until it will be superseded by Belle II data.

3 The Belle II Physics Plan

3.1 Update of the Plan

Belle II will bring an improvement in statistics by almost two orders of magnitude in order to probe new physics at the shortest distance scales with precision measurements.

This will complement both the LHC searches for new heavy particles, as well as the flavour physics studies at LHCb and other facilities.

The current plan calls for Phase-1 (October 2016 – April 2017) collecting 200–300 fb^{-1} data, and after the completion of the detector, a higher luminosity Phase-2 (October 2017 – June 2018) collecting 3–4 ab^{-1}, followed by the design luminosity operation. The Belle II collaboration has started to develop a physics program for the first period of physics data taking (Phase-1), with a partial barrel particle identification system and limited amount of data.

The excellent opportunities for precision flavour physics at Belle II are well documented in the literature, and will not be repeated here in detail. Important examples have been identified as benchmark modes. These 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, studies of rare decays $B \to X_s \gamma$, $B \to X_s \ell^+ \ell^-$, and $B_s \to \gamma\gamma$, and decays with large missing energy such as $B \to \tau\nu$, $B \to \mu\nu$, $B \to K^{(*)} \nu\bar{\nu}$. The ability to study in detail semileptonic decays with high statistics 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.

The collaboration has increased its effort on the preparation for upcoming physics analyses, and an update of the physics projections is planned to appear in the near future. In addition, the Belle II physics working groups have been reorganised into: 1. Semileptonic and missing energy decay, 2. Electroweak penguin, 3. Time dependent CP violation, 4. Hadronic B decay, 5. $\Upsilon(nS)$, 6. Charm and charmonium, 7. τ and 2γ. Simultaneously, Theory-Experiment Interface working groups (golden modes, QCD, new physics) are about to be set up. The expectation is that these will lead to a "KEK yellow report" to be delivered by Summer 2016. It will foster collaboration between experimentalists and theorists, refine and develop the Belle II physics program, and test the analysis tools.

A number of technical developments are gaining momentum, which could have large impacts on Belle II physics analyses. Important examples include the ongoing development of B_s full reconstruction, as well as the tuning and refinement of EvtGen, which would have broad impacts, e.g., on full reconstruction analyses, background modelling in many modes, and semileptonic decay measurements.

3.2 Recommendation

The collaboration is strongly encouraged to optimise the Phase-1 physics output which will have limited event statistics and a partial particle identification system. The committee welcomes the development of establishing the Theory-Experiment Interface working groups. This may be useful to jump-start the collaboration to be ready for the large variety of interesting analyses to be carried out. The Belle II management should be vigilant to ensure even-handed theoretical inputs, and that the report should not subsequently limit experimentalists from exploring analyses and searches not covered by the report.

4 The Belle II IR, Beam-pipe and Machine Background

The 8th campaign studies of background at the interaction region were presented and the committee is very pleased to see that continuing efforts are being made for a better understanding of the detector background rates. Beam pipe designs and final focus magnet designs are very nearly complete now, making it difficult to make further changes in the mechanical design. Nevertheless, background calculations can now make use of these constraints and develop more precise background calculations based on the final (or near final) mechanical design. It was discovered that the background contribution from the radiative Bhabha scattering had been slightly overestimated because the finite size of the beam had not been properly taken into account. The predicted Synchrotron Radiation (SR) background rate for the Pixel Detector has been significantly reduced with some adjustments to the inner beam pipe surfaces and by applying the inner Au coating to the neighbouring Ti sections of the central chamber. The SR backgrounds are now reduced by a factor of 10 compared to the previous calculation and become eight times smaller than the two-photon rate. The initial runs with the commissioning detector, BEAST II, will be of critical importance in both characterising detector backgrounds and in checking out various background monitoring detectors. The detectors that work the best can then be used in the final design to monitor machine backgrounds.

4.1 Concern

The background level for the PXD is still very close to the limit allowed by the detector. This appears to be dominated by the two-photon background rate (mostly $e^+e^- \to e^+e^-e^+e^-$). The backgrounds from the radiative Bhabha process are also a major concern, primarily the neutron production rate resulting from off-energy beam particles striking the beam pipe inside the detector.

4.2 Recommendation

The committee would first like to commend the background team for the tremendous effort that has gone into understanding the present background levels.

- The committee welcomes continued studies of detector backgrounds and especially studies that include the BEAST II initial runs. This is especially true for the two-photon rate.
- Cross-section calculation for the two-photon process is even more complicated than that of the radiative Bhabha process and collaboration with the new Italian Belle II members who have also made background estimates for the two-photon process is beneficial. This would allow for important generator cross-checks.
- The backgrounds due to the radiative Bhabha process may very well be dominated by irreducible terms that are the result of the overall interaction region design. In this case, inserting shielding wherever possible may be the best solution. One possibility to reduce this background mentioned is to lower the detector magnetic

field. This may help to reduce the radiative Bhabha background but in exchange, lowering the solenoid field will make the two-photon background worse.

- The background team should keep in mind that both major sources of backgrounds (two-photon and radiative Bhabhas) are luminosity driven backgrounds and that these backgrounds will reach the predicted levels only when design luminosity is achieved. This means that there will be some time for better understanding of the backgrounds prior to reaching design luminosity. In addition, the team will have actual measured background rates and this data may help to find new ways to reduce these backgrounds.

5 The Belle II Vertex Detector

5.1 Pixel Detector: PXD

5.1.1 Status

The schedule is still dominated by the production of the PXD9 DEPFET sensors done in three steps: the Front Of Line (FOL) processing, the Back Of Line (BOL) processing and the Back End (BE) processing. The FOL is related to the implantation and poly-silicon deposition and patterning, while the BOL centres around the deposition and patterning of the two metal layers. The BE processing entails the thinning and passivation. The FOL processing of a first batch of 13 wafers has been successfully completed ahead of schedule. Wafers of the second batch were all lost due to a failed ion implantation. The third batch has also completed the FOL processing. A new batch of eight wafers, batch four, was started immediately after the second batch was lost and is expected to be complete in June 2014.

The BOL is a crucial step in the process since it involves the complex metal layers and their interconnections. This processing step is being validated using the Electrical Multi-Chip Modules (EMCM). Four batches of EMCM modules were processed. The problem of the aluminium hillock formation creating shorts between metal layers 1 and 2 was rectified in the third batch by applying an additional Al_2O_3 layer. A fourth batch has now been processed with a further optimisation of the parameters. These modules are currently being tested and show excellent performance. Tests of fully populated EMCMs show no major problems. Some minor issues have been observed with multi-chip operation and switcher communication. A last batch of EMCMs will be processed to confirm all the processing parameters. The BOL processing of the real sensors is on hold until this last batch has been thoroughly tested. The metal processing, which was originally scheduled to start in September 2013, will thus not start before May 2014. However, it is estimated that the BOL processing can be completed within 2-3 months compared with the original estimate of 6 months. The BOL and BE processing of the DEPFET sensors will be split into 4-5 smaller batches thus making more efficient use of personnel and machine capacity and avoiding bottle-necks in testing. The first final sensors should be available by October 2014, almost as originally scheduled. The team is to be commended to be so vigilant with regard to the process line and the schedule implications.

Prototypes of all auxiliary ASICs have been produced successfully. To address some observed performance issues of the Drain Current Digitiser (DCD) – higher noise at 320 MHz, position dependence of the channel noise, and limitation in the pedestal correction procedure – two new DCD chips were submitted: the DCDBv4 chip and the DCDBPipeline chip. The latter is the baseline choice and introduces pipeline ADCs and has common mode compensation. The DCDBPipeline has been tested and meets all requirements. Another version of the Data Handling Processor (DHP) chip is foreseen to address a minor issue to run the serialiser at full speed at nominal voltage. The SWITCHER chip needs only minor modifications. The issue with the bump bonding has been resolved by using IZM for industrial style wafer level bump bonding.

The PXD operation in the test beam was the first time that a large thinned multi-chip module has been operated, and in spite of the loss of one layer due to wrong bias voltage that destroyed switchers, the test beam proceeded very successfully with the second layer, and tracks were successfully reconstructed using the SVD and PXD Region of Interest extrapolation method.

The assembly steps for the PXD are clearly laid out and the sharing of the tasks has been fully defined. It has been decided that the mounting of the passive components on the DEPFET sensor module will be done at Valencia and the bonding of the ASICs at IZM, Berlin. Ladder construction and assembly of the PXD half-shells will take place at MPI in Munich. A full system test is foreseen at MPI including the CO_2 cooling. After this system test the half-shells will be sent to KEK for integration into the detector. Prototype kapton readout cables have been obtained from Taiyo in Japan and are undergoing extensive tests. The final production order is expected to be placed in the summer of 2014.

The PXD modules are screwed onto the Support and Cooling Block (SCB), which is mounted on the beam-pipe and provides the cooling. The SCBs are made using 3D printing and two out of the four prototypes passed the pressure test to 120 bar. A new design was required due to a change in mounting procedure of the modules. Also CO_2 and air channels were optimized and a grounding bus had to be provided. New blocks have been ordered and are expected soon to be used in internal cooling tests. A grounding concept for the PXD was presented, which ties analog and digital grounds together which are coupled to the cooling blocks and cooling pipes. The details of the grounding scheme are being developed.

5.1.2 Concerns

The schedule contingency for the PXD sensor production is becoming very tight. The team is very well aware of the pressures and have taken every precaution possible to mitigate adverse effects. The electrical tests of the EMCMs have revealed some issues that are not fully understood.

5.1.3 Recommendations

- The work on the EMCMs should receive a very high priority within the project to ensure there are no latent issues before the metallisation of the PXD sensors is started and the final version of the various ASICs is produced.
- The work on grounding of the VXD as a whole should receive higher priority and a baseline grounding scheme for the VXD should be developed and tested before the project is too far along to easily implement changes.

5.2 Strip Detector: SVD

5.2.1 Status

All large rectangular sensors, except 17, have been delivered by HPK and tested and exceed the performance criteria. The first trapezoidal sensors have been delivered by Micron. Micron was expected to do a complete electrical characterisation of the sensors, which delayed the production. Full strip scans are currently being performed at Vienna and Trieste. The manpower issues to carry out these tests have been resolved. The sensors are of good quality and the number of bad strips is well below the acceptable limit. For two batches, the measured bias resistance was too high and the production was put on hold. Investigation revealed that the contact holes on the p-side are resistive, though all design rules were being respected. Given that this has only marginal effect on the sensor performance, the collaboration decided not to change the production process. Full delivery of all sensors from Micron is expected in April 2014.

The ladder assembly procedure has evolved since the last review and many simplifications have been introduced while improving the overall design. The ladder ribs are now secured using a simple pin and fastened to the end mounts through a glue joint which prevents distortions of the assembly. This new procedure also provides more space for the pitch adapters between the ladders and hybrids. The ladders are attached in the forward region through a sliding mechanism to allow for thermal motion. Two versions of this connection are still being considered and a decision will be taken when the results from the thermal tests will be available.

Ladder production is shared by the collaborating institutes as follows: for the cylindrical part the first layer by Melbourne, the second layer by TIFR at the IPMU clean room, the third layer by HEPHY and the fourth layer by the team of IPMU, KEK, the university of Tokyo, KNU, SNU, Niigata university and Tohoku university. INFN Pisa will build the forward/backward modules used by the second to the fourth layers. The collaboration has addressed the required modifications for the assembly stage and the increased logistics complexity, in particular the shipping of modules to the assembly sites. A very clear assembly procedure has been established and exercised. All ladder assembly fixtures have been designed. All components for ladder production, including the delicate origami circuits, are either in hand or full delivery is expected soon.

Ten variants of pitch adapters are required. The original design called for a single layer with 40 μm pad width with 88 μm pitch. The first samples from the company

Tokai-Denshi had pads with width less than 30 μm and gave very poor wire-bonding results. The cause for the symptoms is the difficulty in controlling the etching process in the presence of large passive areas. Also the thickness of the Ni layer was reduced to 1 μm. In a second prototype the pad size was increased, the empty areas were filled in, and circuits with two different Ni-layer thicknesses were obtained. The test results are not conclusive and further tests are being carried out, but this should not affect the production schedule.

The committee was very pleased to see all production sites gearing up for ladder assembly and that all assembly fixtures are being finalised. The detailed manpower tables with the respective responsibilities of everyone involved demonstrated thorough review of required resources. The establishment of a quality control and quality assurance group to ensure uniformity in procedures and specifications across the different production sites and to provide the as-built documentation of the modules was an excellent step to make certain that the quality of the detector will meet the physics goals.

The full readout of the SVD with the associated firmware development has been exercised during the DESY test beam and has performed quite well. Still, numerous features were uncovered which will be addressed in the new version of the front-end boards. In particular, hardware changes will be implemented for the FADC, the FPGA daughter board will be outfitted with a more powerful pin-compatible FPGA, the junction card will be adapted for a new DC/DC conversion and capacitive grounding will be implemented. There is room in the schedule for yet another iteration if required. A test system for readout tests at the assembly sites is based on the APVDAQ system. Identical systems have been built and shipped to all assembly sites for stand-alone tests during ladder construction.

A proposal to replace the existing Kenwood power supplies with CAEN power supplies was presented. New CAEN power supplies would provide for a state of the art power supply system that would meet the requirements for the full BELLE-II data taking period. A technical review is planned for the summer 2014.

5.2.2 Concerns

The committee was very pleased to see that many remaining issues had been addressed. However, the list of remaining outstanding issues is still uncomfortably large. One of the main concerns is the current status of the pitch adapter, which now is on the critical path. Samples produced so far do not fulfil the requirement. The committee was also pleased to see a detailed work plan for ladder production had been developed with manpower assigned by name with clearly spelled out responsibilities. However, the ladder production schedule is very tight and the current problems with the pitch adapter do not help.

5.2.3 Recommendations

- It is recommended that the collaboration make the production of the pitch adapter the highest priority and establish very close communication with the current vendor as well as pursue different vendors in parallel.

- Although problems exist with the pitch adapters, the collaboration is urged to finalise the ladder assembly design as quickly as possible and complete a first working prototype ladder for every layer using the final design albeit with certain elements of poorer quality.
- Although the manpower for ladder production has been secured and was presented in detail, the committee recommends that the collaboration try to develop contingency plans to prepare for a scenario where, due to unfortunate circumstances such as delay in delivery of components, the project experiences significant time pressure.
- The committee suggests that quality assurance group be given large authority in interacting with the production sites in order to accomplish its demanding task of ensuring that the detector meets its specifications. It is also suggested that this group take a proactive role in ensuring that critical information will be available electronically and interface with the developers of the detector parameters database.
- Given the very tight schedule, the committee recommends that the collaboration keep a very narrow focus and prioritises the outstanding issues and address them in a coordinated, systematic way from major to minor importance.

5.3 Cooling

5.3.1 Status

The PXD and SVD detectors form one mechanical unit with a total of 4/8 CO_2 cooling circuits for the PXD/SVD systems. In addition N_2 or dry air will be provided to maintain the dry volume, which has a dew point of $\sim -30°C$, and provide additional cooling for the PXD switcher ASICs and DEPFET sensors. The cooled VXD is thermally isolated on either side against the CDC, which operates at room temperature, and the beam pipe at 15°C. The target temperature for the PXD sensors is $< 25°C$ and for the ASICs below 50°C. For SVD, the APV25 should operate with a surface temperature close to 0°C for optimum signal to noise. For both systems the cooling block should be maintained at below $-20°C$. The total power consumption is 700 W for the SVD and 360 W for the PXD, plus about 540 W of parasitic heat influx. When heat loss through the 15 m of transfer lines is added, a total cooling capacity of 2-3 kW is required for the cooling plant.

A prototype cooling system “MARCO” has been built in collaboration among MPI, CERN and NIKHEF and successfully operated at the PXD/SVD test beam. The system will be upgraded to “IBBelle”, rated at 3.3 kW, which is completely compatible with the ATLAS IBL cooling requirements and is being built in two identical copies. Specific items to be modified relate to the CO_2 distribution system from IBBelle to VXD, principally the junction box, manifold and transfer lines. The junction box is in the final stages of manufacture and test, and a prototype of the vacuum transfer lines has been successfully tested at CERN. The cooling plant will be controlled by a Schneider PLC containing all monitoring, hardware interfaces and control logic. A supervision layer will be added for which the preferred supervisory control and data acquisition (SCADA) choice is EPICS, for which there has been excellent VXD experience. The cooling system will be TÜV certified.

The individual cooling circuits within the VXD volume are roughly matched in terms of detector power consumption. The incoming CO_2 lines are super-insulated outside the VXD flange and custom made microconnectors are used to make the transition to the warm dry volume with the separated inlet and outlet pipes. In the case of the PXD the Support and Cooling Blocks (SCBs) at each end of the ladder then perform the bulk of the cooling, circulating within novel 3D printed non-magnetic INOX structures. The SCBs also house the inlets for the cooled N_2, and have differing designs for the FWD and BWD locations. The design is expected to be finalised by the end of February 2014, including the change of fixation screws and addition of grounding bus.

In the case of the SVD the heat on the origami ladders is removed by cooling pipes mounted with a reinsertable heat-conductive clamp system, and is removed from the PCB hybrids mounted on the end rings via the integrated cooling pipes. The ladders are secured with a glued joint on the backwards side and a sliding mechanism on the front side. The sliding mechanism, which must simultaneously provide thermal contact and allow linear motion has been redesigned with a simpler mechanism giving improved performance. The thermal contact will be tested soon.

Various aspects of the cooling are integrated into the grounding scheme (specifically mentioned where the SCBs and ceramic isolation on the cooling pipes). The common grounding policy will be finalised in the coming months, after which the cooling structure must be reviewed to ensure all parts are compliant.

5.3.2 Concerns

The VXD presents a complex cooling environment, and the work on the cooling system has advanced significantly. The committee also notes the significant effort which is being put into the development of a realistic VXD mock-up. However, many uncertainties still remain. The issues of safety with the potential high pressure development in the CO_2 system has not been addressed in a uniform way across all components, although various tests were made for individual components. The CO_2 distribution pipes have thin walls and navigate distances within the VXD where they may be subject to mechanical and thermal strain. The system has a large total temperature gradient between the cooling blocks and the expected sensor temperature on the PXD ladders. There is also a reasonable gradient between the cooling pipes and the APV operating temperatures. The role of the N_2 or dry air is critical for the continued safe operation of the detector, and also provides additional cooling. It is not apparent that a homogeneous air flow would be guaranteed within the detector volume, especially once a detailed understanding is built in on the other cables and piping filling the space.

5.3.3 Recommendations

- The pressure tests up to 300 bar as required by the KEK regulation must be applied to the completely constructed cooling paths including the final versions of all connectors, and a procedure must be developed to qualify the individual parts, welds, and connectors.
- The thermal behaviour of the VXD system should be confirmed with the thermal mock-up and FEA calculation to see how close the cooling performance is to expectations.
- The committee encourages an assessment of the performance of the N_2 or dry air cooling after analysis of thermal mock-up data with realistic gas flow conditions.
- The committee encourages a careful choice of technology for the SCB production.
- The group is encouraged to build up an inventory of the interlock and powering behaviour of the integrated system under a complete set of failure scenarios, detailing the possible risks, mitigating actions and consequences of leaks in different parts of the system. Sources of dry gas should have sufficient buffering to ensure that dry gas flow continues to keep the humidity above dew point until the temperature of critical elements become room temperature.

5.4 Integration and Installation

The software development for the VXD has been revisited and a more coherent approach has been adopted integrating the PXD and SVD. Many of the software related tasks, though, still need to be addressed such as full integration of the detector database, calibration data management, slow control and alignment parameters among others.

The complete assembly sequence of the VXD detector was presented. The VXD as a mechanical unit is dimensionally defined by the carbon fibre outer shell and the end flanges. Although one mechanical unit, the PXD and SVD have independent supports. The PXD is supported by the beam pipe and the SVD is supported by the CDC. All three elements are fabricated as half-shells. The SVD ladders are mounted on stainless steel end rings. The end rings are in their final design and prototypes will be used in the thermal mock-up. The design will be frozen, pending the outcome of the thermal tests. The order for the end rings is scheduled for June 2014. The carbon fibre end cones are currently being fabricated. Two assembly scenarios are still being considered for the SVD. The first method follows the assembly procedure used for the Belle-I detector, where the end flanges are connected through a steel connection bar and a cage fixture that sets the alignment. The same connection bar is used later for the module placement. Two separate cages will be prepared for each detector half. The alternate method uses a flat plate with precision holes on which the end rings are aligned. The plate sets the alignment and the carbon fibre cones are inserted and glued to the rings. Both assembly methods will be tested independently. Once the end rings have been placed, the ladders will be successively mounted on a ladder mount table that allows a survey of the ladder after placement to determine the initial alignment constants. Two ladder placement techniques are being considered. The first method places ladders horizontally; the other method places them vertically. Both methods will be evaluated over the next few months. Testing of ladder mounting is scheduled for November 2014, with final ladder placement to start in January 2015 for layer 3 and ending in March 2015 with the ladders for layer 6 for the first half-shell. The SVD is scheduled to be complete by June 2015 when system tests will start.

Two options for the VXD installation are still being considered. The baseline option calls for the VXD and QCS to be connected before installation. In this configuration the cables and pipes from the VXD are fixed to the QCS before installation. In the alternative installation option the VXD and QCS can be installed independently. This option requires a Remote Vacuum Connection (RVC) since the area between the VXD and the QCS in the forward region is inaccessible. A lot of progress has been made since the last review. The mechanical analysis for the baseline installation has been completed and has been tested with a mock-up. A comfortable clearance of 7 mm between the QCS and the CDC was measured. Only a cable stress evaluation on the VXD structure remains to be carried out. A mock-up for the alternative installation has been built at MPI and is in the process of being validated. The positioning of the VXD relative to the CDC has to be demonstrated, the cabling and piping procedure and the ability to extract the VXD in case of a failure of the RVC. An RVC system has been delivered to KEK and the reliability of the connection and the vacuum performance have been demonstrated. The KEK accelerator division seems close to approving the option of an RVC connection for the backward region.

5.4.1 Concerns

The collaboration is moving more and more towards viewing the detector as an integrated unit and the committee is very pleased to see the development of an integrated approach in the areas of slow controls, heat management, electrical systems, online data processing with region of interest builders, all the way to offline track reconstruction. However, there are still major open points. Options still exist in the assembly and installation procedures of the VXD are typical examples.

5.4.2 Recommendations

- The committee recommends revisiting the number of plies and layup orientation of the carbon fibre layers for the outer shield to ensure that the structure can withstand the expected loads with significant margin. Solutions for the stress relief of the anticipated 80 kg of cables must be prioritised, in case additional extension supports need to be added.
- As for the VXD assembly procedure, it is recommended to decide on a final assembly procedure as quick as possible.
- Concerning the VXD installation, the same recommendation made for the September 2013 review remains valid namely: A decision on whether to employ the remote

vacuum connection should be made quickly so that the project can focus on one unique installation scenario for the VXD system. The committee recommends to conduct a risk analysis of the remote vacuum connection system together with the machine group. Studies of possible failure modes may result in an improved design and establishing procedures to avoid dramatic consequences for the machine and detector in case of eventual problems. The result of risk analysis should be vied against the eased access to the VXD system for the final decision.

6 The Belle II Drift Chamber: CDC

6.1 Status

The drift chamber stringing went well and was finished on schedule. The small cell chamber was completed in June 2013 and the main chamber was completed in January 2014. The chamber has held voltage with acceptable leak currents and cosmic ray data have been taken with prototype readout electronics.

Remeasurement of the sense wire tensions identified 421 wires out of 10,752 with tensions less than 80% of the nominal value. From the distribution of the number of loose wires per layer, this problem appears to be due to a crimping tool defect that started at a definite time. The Belle drift chamber also had aluminium crimp pins holding tungsten sense wires and this problem did not occur there, supporting the hypothesis of a crimp tool defect. Uniform tension is important to avoid large variations in drift-time corrections due to sense wire sag within cells. The loose wires are being replaced and all other sense wires will be crimped again. Finally after recrimping is complete, tensions in all sense wires will be measured.

The prototype electronics performed well in bench tests and beam tests, and mass production will start soon and should be completed within about a year. Generally the electronics tolerated radiation well, but samples of the optical transceiver for the trigger have worse tolerance than others did previously, up to 300 Gy rather than 1000 Gy. This will be studied further and more spares will be ordered before production stops.

The radiation safety factors from the 8th Campaign of background simulation are quite reasonable for the CDC hit rate and total ionising dose, but the safety factor for the neutron flux is only about 1.2.

Extensive modelling of the drift length versus drift time relationship using Garfield is underway, along with other software development.

6.2 Concern

Losses of tension in the sense wires will remain a concern until the restringing and recrimping are finished and tests have demonstrated that the resulting tensions are stable. The radiation hardness of the electronics may be somewhat marginal.

6.3 Recommendation

The committee is pleased with the general status of the CDC construction and congratulate the completion of the wire stringing.

- Monitoring the sense wire tension should continue until stability has been established.
- Careful attention should be paid to radiation safety factors for CDC electronics components as understanding of backgrounds develops, and additional possibilities for reducing backgrounds and improving radiation hardness should be considered.
- The goals of CDC software development should include having fully-functioning tracking and reconstruction software available to make full use of the cosmic ray tests scheduled to start at the end of 2014.

7 Particle Identification

7.1 Barrel Particle Identification: TOP

7.1.1 Status

The TOP group has achieved much during the past year, and has made substantial progress towards a buildable design. Signature achievements include a large prototype run at LEPS in early summer 2013 with detailed analyses of data obtained using two different readout systems; first examples of the production optics delivered and examined in the Fall of 2013 and early 2014; construction of fabrication facilities and mock-ups at KEK, and a complete design for the bar box as presented in December 2013 with updates at this review.

The group has been proactive and effective in responding to comments and suggestions made by a number of review panels since the last BPAC in March 2013, including the Belle II Focused Review in September 2013, and a TOP mini-review in December 2013. Although significant progress continues to be made, a number of crucial issues identified earlier remain open and are not yet fully resolved.

The presentations at this review focused on the project schedule and leadership; the quartz pre-production; the electronics; and the TOP engineering design. The issues with the largest immediate impact are those that need to be addressed at the DOE CD2/3 review presently scheduled for March 19-20, 2014. This report addresses the most pressing issues, but as the present review was substantially less detailed for TOP than the two reviews in September and December 2013, these comments are incremental in nature and those earlier review reports should be consulted for further details.

The project schedule features several major milestones coming due in the very near future. An especially urgent one is the validation of quartz specifications and optics manufacturers, since that is needed by the CD2/3 review. Approval, if attained there, will need to be followed quite quickly with the release of production orders for the major optical components in order to meet the revised bar box fabrication schedule as presented. The completed design of the bar box with appropriate validation and testing using mock-ups and assemblies of preproduction prototypes is also an urgent need, as these elements are in the critical path to bar box completion even on the somewhat more forgiving schedule presented at this review. The electronics board final design and validation is also quite close to the critical path, as the final version of the ASIC chip (IRSX) must be validated in May 2014. A full-scale beam test of Module 1 in July and October 2014 is a crucial final step in validating the designs being fabricated and the performance attained with a complete system across the particle phase space.

The TOP optics preproduction procurements have made significant progress in the last few months and are typically meeting specs on delivered components. However, a number of the vendors seem to have difficulties in meeting their promised delivery dates. Zygo has produced and delivered a beautiful bar that is well-studied at KEK and meets or exceeds all important specs. They promise to deliver two more bars by the end of February and two more in early March. They have delivered four prisms to date that are good to excellent. Although Zygo appears to be doing well so far, a demonstration that they can meet schedule for the bars is still to be provided, hopefully by the time of the CD2/3 review. The Aperature/Okamoto bar production is less certain. Their first preproduction bar was inspected at Okamoto already in December, but had just been delivered to KEK during the week of this review.

The bar inspection and qualification system at KEK has been successfully exercised on the first Zygo bars and looks suitable to qualify the parts as they are received.

The bar box mechanical design remains a challenge. Since the mini-review in December 2013, a complete mechanical design has been developed and assembled in mock-up, showing that the device is indeed buildable, appears to be robust, and that an oiled silicon cookie attains good optical coupling with the photon detector. This design is a significant achievement which provides confidence that the quartz components with dimensions as specified will be usable in the bar boxes and can be purchased. However, the forces on the quartz, both in the button region and the wedge region, are uncomfortably large in the present design, and need to be better modelled and brought under control through future design improvements.

The Micro Channel Plate Photo Multiplier Tube (MCP-PMT) production and testing program are progressing at the scheduled rate. Detailed scans of the gain uniformity have been added to the quality assurance tests. While most of the MCP-PMTs performed well with only moderate gain variations of below a factor of 2, about 5% of the units show significantly larger variations. An exchange of units with a non-uniformity of worse than a factor of 2.5 is being discussed with Hamamatsu to ensure that the operation of the MCP-PMTs at the gain of 5×10^5 is possible without loss of performance.

At the time of the last BPAC in March 2013, a break-through was presented for the lifetime of the MCP-PMTs, which increased to more than 10 C/cm^2 due to Atomic Layer Deposition (ALD)-coating of the MCPs. However, at the focused review in December 2013 it became apparent that the lifetime of the recently produced MCP-PMTs is substantially lower, at or below 50% of values obtained for the initial ALD-coated samples. This observation has been confirmed by additional measurements but the reason for the degradation is not yet understood. Therefore, an extensive R&D program has been initiated at Hamamatsu to improve the MCP-PMT lifetime. It is now planned that all MCP-PMTs will be operated at the lower gain of 5×10^5. This will create a lifetime safety factor of 2 to 2.5 for the recent MCP-PMTs compared to the predicted total anode charge during 10 years of Belle II operation. It is expected that less than half of the MCP-PMTs will be of the older types without ALD coating, which will have to be replaced after a few years of operation at full luminosity, even with lower gain.

The TOP readout electronics design continues to progress. The time resolution during the test beam campaign at LEPS was just below 100 ps, and subsequent tests of the same boards using laser pulsers demonstrated a resolution of 60 ps. Four versions of the waveform-sampling ASIC chips will be produced by April in an engineering run, including the baseline IRSX chip and two versions of the IRS3 as back-up. A strategy was presented for obtaining good time resolution for MCP-PMTs with large gain variations. Amplification is set to match the smallest pulses and a time over threshold algorithm was shown to obtain 50 ps resolution even for pulses in saturation.

The analysis of the data from the beam test campaign in the LEPS beam at SPring-8 in June 2013 is becoming more advanced. Backgrounds taken from side bands in the data are used to tune the probability density functions in simulation. This leads to better agreement between data and simulation, including a better description of the photon yield. The performance obtained in the beam test is adequate to achieve a 1 to 2% measurement of $|V_{td}|/|V_{ts}|$. The cosmic ray telescope test stand is starting to produce data. The photon yield for steep tracks agrees with simulation, demonstrating that the setup is nearly ready to test the performance of completed bar boxes.

7.1.2 Concerns

The production rate (and perhaps the quality) of bars produced by Okomoto remains unclear, and it is not certain when these concerns will be resolved. If fabrication does not go well there, it may be shifted in part or in whole to Zygo. This would almost certainly result in very well-made bars, but would increase the overall cost and reduce the number of bars available for the 2015 installation. There have been some yield issues on fused silica blanks at both ITT and Zygo which need to be further assessed, as they may impact schedule. The non-Fresnel angular dependence of the PMT/cookie optical coupling needs to be understood, and also the long term performance of the oiled cookie interface. Radiation hardness of ALD-coated MCP-PMTs are not yet confirmed.

7.1.3 Recommendations

- Though we believe that the bar box design is sufficiently mature that the final bar dimensions can now be fixed, a more thorough understanding of the structure of the bar box, and especially the forces on the fused silica both in the radiator region and the wedge/PMT camera region, needs to be obtained (both by detailed FEA analyses and direct mock-up and preproduction tests) before a first bar production bar box can reasonably be fabricated.

- The further use of preproduction mock-ups must continue to validate designs and practice fabrication techniques. The committee encourages the use of direct reflectance tests with high sensitivity for all materials in the bar boxes that may out-gas and pollute the bar surfaces.

- The committee encourages the TOP group to pursue another beam test of a full prototype with the final optics and IRS ASIC readout electronics to demonstrate that the complete system is capable of achieving the design performance.

- We support the proposed study of the lifetime of ALD-coated MCP-PMTs with the hope that a significant number of units can still be produced from an optimised process to reduce the need for MCP-PMT replacement in situ.

7.2 Endcap Particle Identification: ARICH

7.2.1 Status

At this BPAC review meeting, a report was provided on the following topics: beam test results from May 2013; decision on the choice of the aerogel refractive index for mass production; status of the Hybrid Avalanche Photo-Diode (HAPD) production; readout electronics; software; installation procedure, and time schedule.

A focusing aerogel prototype was studied at the electron test beam facility at DESY in May 2013. The latest version of the electronics was used, including the front-end board with the SA02 and the SA03 ASIC chips.

Tests included measurements with irradiated HAPDs and irradiated aerogel tiles. In the study, one out of the six HAPDs was replaced by one of three irradiated HAPDs, which had been exposed to doses of up to 2.1×10^{12} neutrons/cm^2, and 1000 Gy γ radiation. By choosing a higher threshold to compensate for the doubling of the noise level, it was possible to detect the same number of photons per track as with the other five non-irradiated HAPDs. The irradiation doses were about a factor of 2 larger than those applied in former irradiation tests. The results provide a comfortable safety margin compared to the background expectation from the most recent (8th) background simulation campaign where additional shielding was implemented.

The production of aerogel tiles with the high refraction index of 1.065 involves the so-called pin-drying method. Test beam results have previously shown that the performance of such aerogel tiles is very good. However, it was reported that in a recent test production of large-size tiles, all produced tiles had cracks. The pin-drying production technique seems to work well for smaller tiles but has a low yield for the tile size required for the ARICH. For this reason, the ARICH group has decided to accept the fallback solution and produce aerogel tiles by the conventional method with refraction indices of 1.045 and 1.055.

The mass production of such aerogel tiles started in October 2013. In total, 448 tiles are to be produced; assuming a crack-free rate of 80% and fraction of good-quality tiles of 70% the production should also provide a large number of spares. 150 out of 448 tiles have been delivered so far. Currently, the production is on track and it is expected that all tiles will be delivered by May 2014, ahead of schedule. The quality of the first 100 tiles delivered in 2013 is very good. 92% of the tiles are crack-free and 80 out of 100 tiles tested were labeled to be good, that is without damage. The refraction indices of the tiles is within specification with some minor acceptable batch dependence and excellent transmission lengths.

HAPD mass production started in September 2013 and is scheduled to be completed by September 2014. A total of 140 HAPDs were delivered so far. However, a problem in the photocathode activation stage of the production process was discovered at the HPK in the time period December 2013 to January 2014, which would result in a delay of the production. HPK has added a fourth production line for the alkali activation to recover time once the problem is solved. It is expected that the HAPD production can be completed as scheduled.

Quality checks are done for all delivered HAPDs. Two samples showed high leakage current after delivery which was not observed during the test at HPK before delivery. After these units were sent back, HPK confirmed the high leakage current. These samples will be replaced by HPK. One sample was found to be broken after delivery, likely caused by a small object inside the tube. More than 10 samples showed a strange hit map distribution which was caused by noise after exposure to light and hence is not of concern. However, in some samples, $O(10\%)$, a low quantum efficiency in the diagonal line is observed. This is currently under investigation by HPK.

The mass production of the SA03 front-end ASICs started by the end of 2012 and was supposed to be finished by beginning of 2014. It was discovered that due to a mistake by the company the bare chips were produced with a larger size than foreseen. The problem will be solved by re-cutting the bare chips which will cause a 2-months delay with respect to the original schedule. The ASIC test system developed at TMU is mostly ready but needs more software automatisation which is underway.

A decision has been taken on the FPGA for the Front-End Board (FEB). Due to the delay in designing a new board with the Artix 7 FPGA, no radiation studies with a new board with Artix 7 could be performed. Therefore, the ARICH group decided in favour of the original choice, Spartan 6. A production of 10 boards with Spartan 6 is planned for March 2014 and mass production is scheduled to start in June 2014. Simulation studies have shown that the borated polyethylene shield inside the ARICH stops effectively thermal neutrons, which are the most dangerous source for Single Event Upsets (SEUs) in the FEB FPGA. The remaining fast neutrons are peaking just below 1 MeV and are, according to literature, less likely to produce SEU. Therefore, the plan is to fill the inner free space in ARICH with borated polyethylene. A test of such a borated polyethylene shield is scheduled for March-April 2014 in a reactor at Ljubljana.

After a problem with the optical link of the first prototype was discovered in late 2012, it was decided that the KEK group will strengthen the effort on the merger board design. A new prototype design was completed in June 2013. Two boards were delivered in August 2013. Combined tests with the FEB started in January 2014. A first version of the merger logic is ready and working but still needs to be adapted to Belle2Link. Basic functions have been tested with the FEB. More tests are envisaged (reading HAPD signals, using high rate, stability performance, establishing the connection to Belle2Link). The final design is foreseen for April 2014.

Progress has been made on the software side. Full GEANT4 based simulation is redone with the final (conventional) aerogel configuration and realistic quantum efficiency of the HAPDs. Studies with the full simulation have started, and simulation and analysis of the beam tests are ongoing.

A detailed plan for the installation and integration steps was presented including 12 milestones ending with the ARICH system ready to install in December 2014.

7.2.2 Concerns

The delay in the HAPD production due to problems with the photocathode activation at HPK is a concern. Another smaller concern is the issue with noise and lower QE for some of the HAPDs and the damage of some samples after delivery.

7.2.3 Recommendations

In general, the committee sees the ARICH project on a good track and congratulates the collaboration for their achievements. The committee is pleased to see that the background problem now looks less severe, according to the simulation studies with additional shielding and with the result of testing the HAPDs and the aerogel with higher irradiation doses. We support the continuous work on further mitigation and understanding of the background and its effects, for example, in SEU in the FEB FPGA.

- We recommend that the collaboration tightly monitors the HAPD production and delivery schedule.
- The committee recommends the continuation of the efforts that go into physics analysis studies using realistic simulations.
- We recommend that the work on more detailed planning of the various installation and integration steps proceeds, in order to make sure that interference between the steps is avoided and sufficient manpower and the test facilities are available for that period.

8 Electromagnetic Calorimeter: ECL

8.1 Status

The committee is pleased to hear about the progress on the readout electronics. For the barrel a total of 432 DSP shaper modules are needed, and for the end-cap, 144 of modified ones are required. A large fraction of them has been produced and tested and construction will be completed in 2014.

The development of the Collector module has converged. All functions including the Belle2-link performance up to 30 kHz trigger rate were tested in 2013. A total of 55 collector modules have been ordered and expected to be delivered in March 2014. In addition, the grounding scheme to minimise the noise has been elaborated and the noise dependence on the trigger rate has been studied.

The VME crate for the ECL has been designed and will be tested in February and March 2014.

The resistors for the PIN diodes for the backward end-cap were replaced in 2013 and this will be done will be done in Mar-Apr 2014 for the forward end-cap. This is to avoid a large voltage drop due to high dark currents.

Crate and electronics installation is scheduled for the period May through July 2014. In parallel it is foreseen to start testing the system with cosmic ray data.

There is steady progress in software and a development plan for the 2014 has been presented. A raw data packer/unpacker and database have to be developed in time for the cosmic ray runs in the autumn 2014.

Concerning the ECL trigger electronics, new FAM and TMM prototypes have been developed. A data link scheme for the trigger has been chosen. A tool for trigger simulation was developed, and optimal algorithms of trigger time reconstruction are being elaborated and tested.

The committee is pleased to see that new manpower from new Canadian and Italian collaborating institutes are reinforcing the Phase-2 upgrade effort, i.e., replacing the end-cap crystals with more radiation hard ones. The new institutes have applied for funding which would allow replacement of a part of them. Another 600 counters are needed to realise a complete replacement of all counters in the forward end-cap. The decision on which photosensor (photopentode (PP) or Avalanche Photo Diode) to use is still to be taken. A working group preparing a formal upgrade proposal to the collaboration has been formed targeting for June 2014.

8.2 Concern

A delay in the end-cap KLM installation might effect the following ECL electronics installation. Although, continuous efforts in simulation and shielding studies have resulted in significantly reduced background level, there are still areas (diode neutron flux, pile-up noise) where a larger safety margin would be welcome. A large amount of work is still required for the decision of the photon detector for the new crystals.

8.3 Recommendation

- The ECL group should monitor carefully the progress on the KLM installation and to consider alternative installation plans if necessary.

- The committee is pleased to see the progress in the background mitigation efforts which have substantially reduced the expected radiation level and neutron flux in the crystals and diodes. Studies of additional mitigation options should be continued.

- The committee supports the continued efforts in pure CsI development and is pleased to see the new manpower joining the project. The committee underlines the importance of the Phase-2 upgrade working group preparing a formal upgrade proposal to the collaboration.

9 K-Long Muon Detector: KLM

9.1 Endcap KLM

9.1.1 Status

The RPCs in all layers of the Endcap KLM (EKLM) are being replaced by scintillator strip detectors with Multi Pixel Photon Counters (MPPC) as photodetectors. Production of the scintillator strips at ITEP has gone well and the last batch should be delivered to KEK in mid-March. The average detected light yields from the near and far end of the detectors are about a factor of two larger than the TDR assumptions, providing an additional safety factor. Even with a rejection threshold a factor of 1.3 larger than assumed in the TDR, the rejection rate is only $\sim 1\%$.

Two modules were successfully installed in the Backward EKLM last year. Based on that experience, an installation rate of 4 modules/day is anticipated.

Module assembly at KEK had proceeded well at the rate of about 1 module/day. Of the total of 104 modules that are required (56 for the Forward KLM and 48 for the Backward EKLM), so far 13 are complete. Completion of the remaining EKLM modules is delayed due to a lack of preamps and carrier boards, which are being reworked, but have not been delivered.

Simple oscilloscope channel-by-channel tests are used to detect broken preamps and carrier boards. The rate of dead channels found is about 2% to 3%. These are being replaced.

Software progress varies: simulation of the detector response and signal digitisation is mostly done, event reconstruction and particle identification has started, and strip characteristics are stored in a temporary database that can be uploaded to the Belle II database when it becomes available. However, effort on calibration and slow control software has not yet started.

9.1.2 Concerns

Support for ITEP personnel at KEK is limited and the possibility of finishing the EKLM installation on schedule could be compromised due to the missing reworked preamps and carrier boards. A delay in the installation could also seriously impact the ECAL installation schedule and timely resolution of this reworking problem is critical.

9.1.3 Recommendations

- If timely completion of the preamps and carrier boards in accord with the current plans is not possible, alternatives, such as shipping the devices to KEK for reworking should be considered. The ECAL group should monitor EKLM installation progress and develop alternative plans, if necessary.

- As construction of the EKLM nears completion, turning more attention to completing the software for the device is essential.

9.2 Barrel KLM

9.2.1 Status

The RPCs in the first two layers of the Barrel KLM (BKLM) have been replaced with scintillator strips with MPPCs for photon detection. The remaining 13 BKLM layers will retain the original RPCs, with new front-end boards and readout electronics.

The BKLM scintillator strips were fabricated at Fermi National Accelerator Laboratory. The scintillator strips with MPPCs were completed and delivered to KEK in 2013. Bench tests of the detectors, their installation in Belle II, and post-installation quality tests have been performed. A few minor problems were found and fixed both before and after installation. The net result is that only 1 dead channel (out of about 3,000) remains after installation and repairs. In cosmic ray tests, at least 30 pixels fire. With a threshold set at 7.5, the efficiencies of the scintillator strips are above 99%. The BKLM scintillator strips are the first new Belle II detectors installed.

The MPPCs and readout electronics are identical for the BKLM and EKLM. Ribbon cables for MPPC power and signals terminate on RHIC boards connected to mother boards. A prototype of the RHIC board and mother board is available for testing. Mechanical design for the RHIC card support and cable relief is underway.

Tests with the prototypes of the full readout system and final design front-end boards are ongoing at the present time. Except for EKLM assembly and installation, completion of these prototype tests is the next major step toward completion of the KLM detectors. Work on the trigger system for the entire KLM system is underway.

Software development has started, but much remains to be done.

9.2.2 Concerns

Production of readout electronics awaits the results of the current test program. It is not clear whether there is a well-organised program that will lead to timely completion of the software.

9.2.3 Recommendation

- Belle II management should pay close attention to the ongoing tests of prototype readout electronics to ensure timely start and completion of production of these modules.

10 Data Handling

10.1 Data Acquisition: DAQ

10.1.1 Status

Smooth progress in the central data acquisition system has been reported. Production of custom modules is either finished or going as planned and no delays are expected.

Assuming funding continues as agreed, there should also be no problem for the timely acquisition and commissioning of commercial-off-the-shelf (COTS) equipment.

Two successful integration tests at SPring-8 and DESY give confidence for the start of the overall integration during spring 2014. The test-beams are also a validation of the Pocket-DAQ and prove its value.

The idea of a "Non-stop" DAQ is very attractive. The system was tested during the DESY test beam activities and a serious problem was found. When a run is stopped, some subsystems have already sent data and they stay in the input buffer of the event builder. Those data destroy the synchronisation in the event builder when a new run starts. The group is working hard to find a solution.

10.1.2 Concern

There are still many individual items to be checked and potentially fixed and/or improved. At this moment, none of them appears as a true "show-stopper" but a host of small problems can still hamper efficiency and make commissioning painful. A global inventory of all such issues, a problems-database seems to be missing.

10.1.3 Recommendation

- Despite some problems discovered with the "Non-stop" DAQ, the committee recommends continuing to invest resources. If it works, it should increase the overall efficiency and robustness of the system.
- The committee recommends creating a problems-database that could be easily implemented, for instance by a simple wiki or using one of the many tools made for this purpose.

10.2 Trigger

10.2.1 Status

The progress in the trigger is encouraging. The synchronisation of triggers via timestamps has been successfully validated in the CDC-test in SPring-8. Work is now ongoing on the simulation framework and on the implementation of the Global Decision Logic.

10.2.2 Concern

The optical transmitter modules (transceivers) for the trigger presumably are affected by radiation in the same way as other transceivers in the same location.

10.2.3 Recommendation

- The committee thinks that it is important to consider building up a pool of trigger and DAQ electronics spares, which have been identified by a common effort of all the subsystem groups.

- The group is encouraged to set up a "problems-database" to track open issues of firmware and simulation code as recommended for DAQ.

10.3 Experiment Control System

10.3.1 Status

The baseline run-control based on the Belle II baseline control framework (NSM2) was validated, in particular in the DESY test beam activities. A first version of a combined PXD/SVD slow-control system was also operated successfully in the DESY test beam. Many important aspects have been tested. A decision to use EPICS as the underlying SCADA system has been taken, augmented with custom-developed web-interfaces. The VXD group is planning to install various environmental sensors, including radiation monitor based on CVD diamond detectors.

10.3.2 Concern

Although the baseline framework (NSM2) exists, there seems to be no strong central effort to enforce the common framework for the control system, while some subsystems have started to develop their own control system. Despite the undeniable progress, there is a lot of work to do to have a fully working control-system. Not much work has started in most of the subsystems and they need to be fully integrated with the central Belle II run-control and the KEK-B control and stress-tested. It was not clear where the boundary between autonomous systems responsible for detector hardware protection and human operated SCADA system is.

10.3.3 Recommendation

- It is strongly encouraged to use the occasions such as the test beam activities and the full integration test to develop more centrally controlled activities and common solutions on the slow control system.
- The committee suggests holding a workshop on control system where all sub-detectors and the central controls team present status and their understanding of common interfaces and tools.
- A failure mode and effects analysis should be conducted during the development of the slow control framework. An evaluation should be made of services that need to be preserved under abnormal conditions, such as an electrical power outage, and how they will be preserved. That evaluation should consider which sub-systems should be on uninterruptable power, and the possible need for auxiliary power sources (emergency generators).
- The committee suggests to use the BEAST for testing a full control system including integration with all collaborative systems (EPICS and NSM2).

10.4 Software

10.4.1 Status

The software development process is now well established. The C++ and Python codes in a central repository are organised in packages with responsible librarians. Software quality shifts are put in place to give support to developers. The collaboration has established coding conventions, automatic style checker and continuous builds. Monthly integration builds are used by the developers to provide new functionality, which is then validated. A documentation generator, together with an issue tractor, completes the full suite of tools supporting the development process.

The committee took note of the progress made in the various software domains. The event generators with the decay packages and beam background models are in good shape, with their validation coordinated by the physics groups. The Geant4-based simulation is progressing well, with the geometry and detector response implemented by the detector groups. For the reconstruction, multiple pattern recognition strategies are being followed. Initial results were shown for the reconstruction of ECL, KLM and particle identification. Useful lessons have been learnt from the first alignment exercises with the VXD test beam data. Definition and better understanding of the event data model are progressing well together with the initial set of required analysis tools. The committee is very satisfied by the adaptation and integration of the Genfit tracking package into the Belle II framework.

10.4.2 Concerns

A reasonable set of milestones for the software development and a high level release plan have been defined. They match with the overall experiment's milestones, however they are in some cases quite aggressive. Completing the optimised and reliable event reconstruction software will require quite a lot of effort from the collaboration and the track reconstruction code is mission critical. Although code optimisation itself is not in general the first priority, the collaboration should be more critical and take adequate actions when performance diverges from expectation. For example, the background mixing algorithm doubles the CPU time needed for the particle transportation and the and the digitisation step takes as much CPU time as the full Geant4 simulation step.

10.4.3 Recommendations

- Software performance should be monitored regularly. It is recommended to run a selected set of benchmarks jobs as a part of the dally integration builds, such that any regression in CPU performance is detected as soon as possible and can be correlated.

- The committee noticed the presence of Monte Carlo truth information in the tracking software. It is highly recommended to develop reconstruction software that uses only the digitised data for both real and simulated events. The calculation of efficiencies using the Monte Carlo truth information should be factorised out from the reconstruction software.

- Support for calibration and other run-dependent data needs to be addressed. A model and the corresponding software that connect the conditions database, containing the calibration and alignment constants, to the reconstruction algorithms using them should be designed soon.

10.5 Belle II Computing Model

10.5.1 Status

The Belle II offline computing model consists of two large "raw" data centres at KEK and PNNL with tape capability and high network bandwidth, a small number regional data centres for mDST (the result of reconstruction) analysis, and possibly a fairly large number of sites for MC production implemented as Grid or Cloud resources or as local computer clusters. This is radical change with respect to the current Belle computing model, which has been based on a single centre, the KEK data centre, providing most of the resources for the collaboration. To schedule jobs and manage the workload they plan to use the DIRAC system, which has been developed originally for LHCb and is now used by several other experiments. This is a system that maps well on different type of resources and allows implementation of the proposed heterogeneous computing system by mixing Grid, Cloud and local resources.

The Computing Steering Group has been created by putting together the resource provider's representatives and the consumers represented by the Belle II management and relevant subsystem coordinators. This group is essential for agreeing on the necessary computing resources and their allocation.

10.5.2 Concern

The committee noticed that KEK data centre representative and the Belle II computing coordinator is the same person. This may pose some conflicts of interest.

10.5.3 Recommendation

- The proposed computing model with two large centres and a limited number of regional centres seems very reasonable. The committee recommends to avoid splitting the resources in a too large number of small data centres. For the event reconstruction, it is advised to concentrate resources in larger data centres by joining the contributions from the collaboration into larger infrastructures.

- The committee suggests identifying a KEK data centre representative who is different from the Belle II Computing Coordinator.