The Seventeenth KEKB Accelerator Review Committee Report

March 7, 2012

Introduction

The Seventeenth KEKB Accelerator Review Committee meeting was held on February 20-22, 2012. The following members of the Committee were unable to attend: John Fox (who was able to connect via EVO), Stuart Henderson, Dave Rice and John Seeman. Appendix A shows the present membership of the Committee. The meeting followed the standard format, with two days of oral presentations by the KEKB staff members, followed by discussion between the Committee members. The Agenda for the meeting is shown in Appendix B.

The Committee was impressed by the high standard of the presentations, which dealt with the earthquake recovery as well as the design of SuperKEKB. It was particularly pleasing to have several presentations given by recently hired junior staff members. The Committee evaluated the present status of the project and prepared recommendations, which were presented to the KEKB staff members before the close of the meeting. The Committee wrote a draft report during the meeting that was then improved and finalized by e-mail among the Committee members. The report is available at **http://www-acc.kek.jp/kekb/**.

Contents

A) Executive Summary

The SuperKEKB Project has made considerable progress since last year despite the massive earthquake that did considerable damage to buildings and equipment. However, the effort applied to a rapid recovery of the linac and Photon Factory was not available to make progress on the project, so all the schedule float has already been used up. There has been rapid progress in some areas, for example the vacuum system, with large quantities of components being delivered; this has overloaded the staff assigned to inspection and quality assurance. In other areas, notably the Interaction Region components, the very specialized components are still being designed, and should be prototyped before going out for final order. The schedule is extremely tight to complete everything in the time available. The progress in the linac area is impressive; the earthquake caused considerable damage to the linac, but the linac group managed to resume beam operations within two months. In addition, the new linac is designed and components are on order. Magnet refurbishment is proceeding; the wiggler magnets survived being banged together in the storage area, but it is feared that the LER Magnets did not fare as well. Progress in the design and beam dynamics of the rings has been steady, but this is an extremely difficult machine and there are still unanswered questions.

Overall, the Committee considers the cost risk for the entire Project to be low; and the technical and schedule risks are considered low for the Injector chain, facilities and the ring components, but the committee considers the technical and schedule risk high for the Interaction Region. The committee therefore believes that a mitigation strategy should be developed, modifying the commissioning plan to enable the project to reach T=0 on time and to advance the start of physics operation as much as possible.

B) Recommendations: The Committee has made recommendations throughout the different sections below. Highlights of these recommendations are summarized here.

1) Develop a back-up plan to commission the collider rings without the Interaction Region components to establish the required beam current, to carry out low emittance tuning and to approach the required vacuum by beam scrubbing of the ring. This plan would be activated in case of delays in delivery of the interaction region components to minimize the impact to the start of the physics program.

2) KEK management should continue to do everything possible to ensure that the staffing needed for SuperKEKB is made available as soon as possible. Some progress has been made by short-term and some permanent hiring, and through collaborations with universities and other institutes, but shortage of qualified staff continues to be a major risk to successful completion of the project, the commissioning and operations.

3) Develop a clear set of milestones for the production of the IR SC magnets and cryostats so that progress can be carefully tracked and the high schedule risk, which concerns the committee, can be mitigated.

4) Re-examine the IR Vacuum design to ensure that the vacuum required for the experiment can be obtained in a reliable way. It is also necessary to find sufficient space and accessibility for vital machine elements.

5) Develop, with benchmarking, the necessary simulation tools to study the various critical-path beam dynamics effects impacting SuperKEKB performance. These simulations should include at least the 3D IR modeling, the error effects, dynamic aperture, beam-

beam interaction, intrabeam scattering, and the outcome figures of merit including the achieved luminosity, detector background, and Touschek lifetime.

6) Continue to aggressively pursue the timely completion of the components of the injector chain while maintaining the ability to simultaneously inject into the PF and AR. Complete hardware demonstrations of key components and simulations with the goal of a self-consistent end-to-end description of the injection system that meets all of the requirements.

C) Findings and Comments

1) KEK Roadmap

The KEKB management will be renewed at the end of March, with Prof. Katsunobu Oide retaining his position as Head of Accelerator and Prof. Nobukazu Toge, well known to the committee for his work on ILC, will be a KEK Trustee. In addition, several of the other appointees have been strong supporters of the B Factory program at KEK, for example, Prof. Masanori Yamauchi, Head of the Institute of Nuclear Science.

The existing Roadmap was presented and it is clear that the direction of the laboratory has been following the program that was set out. The Roadmap will be renewed in 2013, and this will establish the direction of the laboratory for the following five years. This will cover the start of the SuperKEKB physics program, but will also be the time that ILC could become an option for Japan.

2) Recovery of Linac after the Earthquake

An earthquake if magnitude 9.0 on the Richter scale struck the northeastern coast of Japan on March 11, 2011. The buildings and accelerators of KEK experienced an acceleration of 0.34g, which lasted for more than 3 minutes in the Tsukuba area. Even though the strength of the earthquake was not extreme, the long duration caused serious damage in KEK.

The 600 m linac tunnel was severely damaged, and the maximum movement of some supporting girders reached 10 cm longitudinally and 6 cm transversely. A section of a focusing triplet fell on the ground, and bellows and BPMs were deformed and seriously damaged. The Linac system was vented to air, and cooling water flooded the tunnel. There are 60 klystron-and-modulator units in the klystron gallery, and several units experienced vacuum leakage, ceramic window leakage, broken hybrids and waveguide leakage.

Excellent decisions were taken to reduce further damage to the Linac system, especially back-filling dry nitrogen into the vacuum system during the power outage period. The excellent decision-making and teamwork recovered 3/8 of Linac within two months. After the repair work, the Linac system was conditioned and reached a trip rate comparable to the operation records before the earthquake. 3 GeV electrons were injected into the Photon Factory on May 16, and injection into PF-AR on June 1. The remaining 5/8 of the Linac vacuum was recovered by the end of October, and high-power tests were done with no major problem in December. The upstream Linac section will continue to be upgraded as part of the SuperKEKB project.

Structural analysis of the Linac supporting structure showed a resonance frequency of 3.5 Hz after the shock. Reinforcement of the girder and insertion stopping-block to limit the oscillation amplitude was implemented to increase the stiffness of the girder system. This would be very useful in any future earthquake. This experience should be applied to SuperKEKB magnet support girders.

A great portion of manpower and resource was devoted to the recovery after earthquake last fiscal year. The committee would like to give high marks to the injector linac group for their great efforts on quick recovery. The committee is glad to hear that "The major goals and timeline to the SuperKEKB Injector Upgrade are not changed" in the conclusion.

Recommendation:

Earthquake is a natural disaster, a *Force Majeure*. In view of the manpower shortage in the Linac and Storage Ring groups, the committee suggests that the management team look into timeline, milestones and resources, and revise the schedule accordingly.

3) Overview of the Design Issues

The design effort of SuperKEKB continued last year. Most of the effort concentrated on the IR issues, including optics, magnets, vacuum chamber, background collimation, and collision feedback system. These efforts have yielded a much-improved IR overall design compared to last year. The Committee commends this effort and appreciates the good results obtained so far. We would like to reiterate however that the IR remains the critical path item of the SuperKEKB and, as such, still requires continued or even enhanced efforts along similar lines in the coming year. It was stated that the lattice design of IR would be finalized by the end of March this year.

Among the changes made, the committee notes the following:

- A modest adjustment was made to the HER emittance at T=0 to relax the x-y decoupling requirement. The HER horizontal emittance was reduced from 5.3 to 4.6 nm by installing 60% of the existing KEKB LER wigglers. The other key parameters, including the design luminosity, are unchanged. The remaining 40% wigglers are to be installed if the initial complement proves useful.
- Iron yokes were added to 3 of the IR magnets to reduce the effect of leakage fields on beams in the other ring.
- The vertical vacuum aperture in the QC1P magnet was increased from 10 mm to 13.5 mm to reduce the beam background.
- Iron shields were added in the detector magnet to substantially reduce the solenoidal field at the beam lines.
- The transverse solenoidal fields were also much reduced with the iron shielding. A welcomed outcome of this is that the solenoid-induced vertical emittance growth was significantly reduced.
- Synchrotron injection is now being considered for the HER to replace betatron injection because of the limited dynamic aperture.

The committee considers these good improvements on overall SuperKEKB parameters. Specific discussions are included in later sections of this report.

For the studies up to now, simulation studies have been used to optimize the Touschek lifetime, aiming to reach a level of 600 seconds (when other known effects are also included, the overall lifetime reduces to 360 seconds). The dynamic aperture limits the Touschek lifetime, and optimizing the strengths of 52 sextupole families maximizes the momentum aperture and the associated Touschek lifetime. The committee concurs that using the Touschek lifetime as the figure of merit at the present stage is reasonable. However, as the design evolves and the Touschek lifetime goal is more firmly established, it will be necessary to add other figures of merit to the optimization. Effects of beam-beam interaction on luminosity with and without error effects, for example, could be another figure of merit. In such an effort, the committee wishes to stress that attention must be paid to the additional loss of luminosity due to the interplay of multiple beam dynamics effects as observed at KEKB.

Realistic and 3D modeling of the IR optics is one key issue addressed in the past year. The simulation tool is implemented in 3D without paraxial approximation and takes into account the relative tilts between the solenoid axis and the beam directions. This is good progress. The 3D solenoid field distribution with magnets and iron shielding included is in preparation, and will soon be ready as part of the modeling effort.

The beam-beam interaction also has an effect on the injection background through vertical beam blow-up. This background has not been simulated yet. It is suggested that octupoles be used to shape the phase space profile to control this effect. How and whether this can be achieved remains to be seen.

The solenoid field of the detector is well compensated except for the space between QC2RP and QC2RE, where an additional long weak solenoid was inserted to improve the compensation. Unfortunately, the addition of iron shielding was not possible because the iron could not be sufficiently constrained against the force of the solenoidal field. It was noted that after compensation, this optics complication did not affect the dynamic aperture appreciably.

The solenoid orientation has been set to bisect the angle between the two beam lines, and is considered frozen because the magnet designs have already been launched. Following a study in 2010, an equal split of the crossing angle is expected to be very close to the optimum. More significantly, however, is the fact that after adding shielding to the solenoidal field, the expected increases of vertical emittances due to the solenoidal field have reduced from 4 pm to 1 pm. The choice of solenoid axis angle is no longer as critical an issue as in 2010.

Much effort was also devoted to the estimation of error tolerance and the development of optics correction systems. The error tolerances of IR magnets tend to be very stringent. The correction systems presently envisioned include skew quadrupole windings on each of the sextupoles, which replace the orbit bumps at the sextupoles as used at KEKB. Chromaticity compensation knobs include skew sextupole windings or rotating sextupoles. Designs of these systems and their parameters are progressing. The committee looks forward to hearing an update on this very important topic.

An impedance budget has been developed but not presented to the committee. It is suggested that a constantly updated impedance budget be maintained for SuperKEKB with inputs from the beam dynamics and the vacuum groups. In addition, a "policing function" should be implemented to enforce the limitations imposed by the impedance budget.

A detuned lattice was presented to the committee as an example lattice for T=0 operation. In this example, the beta functions at the IP were raised, so the natural chromaticities are about equal to the KEKB values. It was found that injection into the LER could be achieved without the damping ring as the dynamic aperture is quite large, and the Touschek lifetime is about an hour. However, it is assumed in this example that the IR is already installed as designed and is available at T=0. If this is not the case, the committee recommends considering another T=0 backup which utilizes temporary magnets or magnets at zero strength across the IR.

> Recommendation:
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> Maintain an updated overall impedance budget and consider appointing a responsible person or team ("impedance police") to evaluate and approve impedance-wise all items to be installed in the machine

4) Overview of Construction Status

The KEKB group continues on an aggressive and determined development and construction project for the SuperKEKB. This began with the announcement of ¥10 billion by the Ministry of Education, Culture, Sports, Science & Technology Japan (MEXT) over three years starting in the Japanese fiscal year 2010 (JFY2010) towards the upgrade of KEKB. The total construction budget is set at ¥31.4 billion with an operations budget beginning in JFY2014 once the construction is completed before the end of JFY2014, referred to as the T=0 milestone.

Like all aspects of KEK, the major earthquake that struck on 3 March 2011 had major impacts on the construction of SuperKEKB. Nevertheless, the SuperKEKB team believes that the T=0 milestone (defined as the completion of construction and commencement of operations) can still occur before the end of JPY2014. The damage from the earthquake was significant, but not catastrophic. Representative damage presented to the review committee included damage to the D5 Power Supply Building, the LLRF area also in D5 and damage associated with the klystrons and magnets in storage. The damage to the klystrons, wiggler magnets that were being held in storage during construction, and the beam pipe bellows were those with the largest machine performance concerns. The SuperKEKB Team verified that the wiggler magnets and the klystrons sustained no performance damage. The team has prudently and effectively begun a radiographic examination of all of the beam pipe bellows that will allow the detection of any damage without disassembly. Leaks and other vacuum system damage to the linac were immediately repaired as the environmental conditions within the tunnel severely degraded (moisture) after the earthquake. The civil construction of the tunnel (floor, walls, and ceiling) also sustained damage and as would be anticipated, the ring became significantly misaligned. Supplemental funds have been received to address the damage resulting from the earthquake and high power klystron tests as well as the HER bellows radiographic examination are underway.

The T=0 milestone has not been changed, so the construction schedule has been somewhat compressed due to delays caused by the earthquake. The SuperKEKB team has carefully considered and prioritized the scope required for T=0. Notably, the beam current, bunch charge at the injector and βy^* have been scaled back for optimization during the commissioning operations. The commissioning is scheduled in two phases with the agreement between SuperKEKB accelerator and Belle-II detector; Phase-I is the collider commissioning for achieving luminosity of 1×10^{34} $cm^{-2}s^{-1}$ with Belle-II solenoid, and Phase-II is the commissioning with Belle-II detector and machine tuning continuing to increase luminosity. It is recommended that a back-up commissioning plan be developed for performing the initial commissioning without IR components.

While progress and management of the construction project is strong, the compression of the project schedule resulting from the earthquake and slippage of some technical areas has greatly increased the need for careful integration and "traffic planning." Facility repairs, additional alignments, magnet installation and larger aperture cooling piping replacement all require almost simultaneous access to the tunnel with the current schedule. Planning of activities in various parts of the tunnel must be done in exquisite detail to avoid delays and inefficiencies (from multiple groups being in the same area at the same time), and loss or repetition of progress from subsequent groups degrading or undoing work previously done. A trivial example of what can happen if this integrated planning is not detailed enough follows: At the home institution of one of the reviewers, a magnet was carefully installed and precision aligned to the few micron level only to discover a few days later the large dusty footprint of a technician stringing cable was found on top of the magnet. Needless to say the magnet needed to be realigned.

Staff shortages remain. While staff has been added over last year, the levels are still considerably short of the 77 FTEs needed for the complete construction phase. According to data presented at the review, total staff (permanent and non-permanent available staff) was 61 FTEs in December 2010, 66 FTEs in April 2011, and 67 FTEs projected in April 2012.

Unfortunately, unless the acquisition of staff is accelerated the shortfall will be compounded, as work is not completed on schedule for lack of resources. This in turn will increase the need for more staff that will cause more work to fall behind schedule.

Recommendations:

In the face of chronic staff shortfalls, a prioritized staffing approach that applies position slots to those areas of the highest impact is needed. Additionally, active development of multiple creative alternative solutions to meeting staffing shortfalls should be established.

5) Belle II Construction and Commissioning

Continuing from the KEKB success of integrated luminosity of 1 ab^{-1}, SuperKEKB aims to integrate a total of 50 ab^{-1}. This will yield the possibility of a much-improved accuracy in determining the CP violation parameters, in searching for new physics beyond the Standard Model and possibly new particles, and to provide data to resolve mode-by-mode statistics.

To deal with the luminosity increase by a factor of 50, Belle is undergoing a substantial upgrade of all its subsystems. The inner beryllium beam pipe radius is reduced from 1.5 cm to 1 cm. The first pixel vertex detector layer (there are two layers of pixel detectors and four layers of Silicon strip detectors) is 1.4 cm. The beryllium pipe is double layered with paraffin cooling. An injection veto algorithm has yet to be designed. To minimize the loss of events, an improvement of the pixel detector integration time from 20 μs to 5 μs was proposed, but is unlikely to be implemented. Other options are being pursued.

An effort has been made to estimate the expected increase of beam background. It is expected that the main issue will be radiative Bhabha events. It was noted that there is only a factor of two in the safety margin between the background from lost particles and the radiation lifetimes of some sensitive detector components. The detector solenoid axis will bisect the crossing angle of the two beamlines. The BEAST-II assembly to be used during commissioning stage of SuperKEKB is also under design.

A request was made by the Belle collaboration to raise the SuperKEKB center-of-mass energy from 11.5 GeV to 12 GeV to study the charged bottomium resonance 5S states. Since the LER (positrons) energy is limited by the BT magnets, the easiest way to raise the center-of-mass energy seems to be to raise the HER (electrons) energy by ramping up after injection. There might be a small reduction of the peak luminosity as well as a loss of top-up mode of operation.

6) Dynamic aperture and IR modeling

Interaction region (IR) modeling and its impact on the dynamic aperture and the Touschek lifetime is one of the most critical ingredients in the SuperKEKB. Much progress has been made since the last review. Introducing an iron yoke into the superconducting quadrupoles significantly minimizes the magnetic interference between two beamlines near the interaction point. This change also reduced the number of multipole correctors, and resulted in a simplification of the magnet design and localized the solenoid compensation.

The solenoid field was eliminated from the beamline by introducing an iron shield. As a result, the rotational symmetry was broken, and a more detailed three-dimensional solenoid model was incorporated into the IR modeling. Most importantly, the optics modeling itself was significantly improved by using a localized coordinate system centered on the design beam axis. Fringe multipole fields from the interconnect wiring at the SC quadrupole end were also included. This more realistic model actually led to some degradation in the dynamic aperture. However, after several adjustments to the magnets and optimizing the correction system, the degradation was completely removed.

The Committee is pleased that this achievement was largely possible because of the close cooperation between the magnet designers and beam dynamics specialists.

The Touschek lifetime is a suitable figure-of-merit for characterization of lattices optimized with respect to nonlinear effects. However, it is important to take account of the beam-beam effect in computing the realistic Touschek lifetime in a high-luminosity collider, including the beam size modification caused by dynamic beta/emittance change.

Despite many improvements in the dynamic aperture and IR modeling, the resulting Touschek lifetime remains low, approximately 600 second. Moreover, the lifetime calculation was based on an ideal lattice without machine errors and beam-beam effects. Any degradation could result in an overall reduction of the beam lifetime, and therefore compromise the machine performance. The Committee would like to see a sizable increase in the margin of the Touschek lifetime.

Recommendations:

Finalize the optimized dynamic aperture with the computed 3D solenoid field and improved IR modeling, in order to provide timely input for the magnet designers to finalize the IR lattice design.

Simulation the impact of realistically assessed field errors and alignment errors in the final-focus magnets on the dynamic aperture, and develop a strategy for improving it by empirical tuning of the multipole correctors incorporated in the IR magnet design.

7) Error Tolerance and Optics Correction

The experience gained in the KEKB optics correction was applied to simulate the correction of the SuperKEKB lattice; similar COD-based techniques were tried out with the aim of minimizing the x-y coupling and beta-beat.

It was assumed that the x-y coupling was caused by rotational errors of the quadrupoles and misalignment of the sextupoles. Ignoring all the BPM errors, the vertical emittance of the ring can be reduced by a factor of 46, down to 1.5 pm, using the correction scheme. Assuming 100 random error distribution with various BPM resolutions, the results indicate that the BPM resolution should be better than 2 um and the BPM rotation error less than 0.3 mrad in order to correct the emittance down to around 2 pm after several iterations. This also restores the dynamic aperture.

The optics correction of beta beating was analyzed with respect to the BPM resolution. If the BPM resolution is better than 2 um, the beta beating will be reduced to less than 5% horizontally and 10% vertically, as estimated from 100 random error sets of BPMs. The study of the optics correction will continue under various conditions and follow closely the progress of the lattice optimization. The standard correction procedures and schemes can then be established. It is also essential to use the most up to date measurement data for the magnets, BPMs and power supplies to optimize the correction strategy.

The inclusion of realistic details, especially in the IR region, will be very important. To complete the study, more optimization should be carried out to include more errors and corrections. The optimal settings of the twelve families of skew-sextupole chromatic coupling correctors need to be found.

Recommendations:

The magnet group has manufactured a prototype of the rotatable sextupole. The detailed field measurement and mechanical precision need to be checked and the proposed correction scheme should be evaluated using the measurement data of this rotatable sextupole. This scheme will require much more study: how to use these correctors, how to minimize effects on the beam aperture.

The Committee recommends carrying out a detailed simulation of the correction of the IR lattice distortions caused by realistically assessed field and alignment errors in the final-focus magnets.

8) **IR Magnets**

Work continues on all aspects of the complex systems of the Interaction Region (IR) and in particular the magnets. The IR magnet design continues and optimization progresses. Since the 16th KEKB Accelerator Review Committee meeting, iron yokes have been introduced into a number of the quadrupoles and the number of leak-field correction coils has been reduced. 3D designs of QC1 and QC2 have been completed, and their impact on beam optics is being evaluated. The compensation solenoid is being redesigned and iterated against the beam optics impact. Brookhaven National Laboratory (BNL) has been added as a collaborator and will fabricate the corrector and leak-field cancellation coils.

In the area of research and development, the QC1P R&D design verification model magnet has been constructed and cold tested since the 16th KEKB Accelerator Review Committee meeting. Vibration modeling and studies have also continued. The fabrication of a harmonic coil for magnetic field measurements has been completed, and magnetic tests of the R&D magnet will begin shortly. These tests will increase confidence in the design and calculations of the magnetic design.

The two dimensional design and modeling of the magnets has been completed, and the operating points all appear to have an adequate operating margin below the critical currents. Calculations of the 3-dimensional solenoid fields have begun. The compensation solenoids appear adequate, with the exception of the region where the BPM on the ESR side of the IR precludes the use of a compensating solenoid.

BNL's fabrication schedule of the corrector and leakage compensation coils is consistent with those of the magnets being constructed directly under the supervision of the SuperKEKB group.

Additional prototypes (QC1P and QC1E) are scheduled for 2012, and the complete construction of the IR superconducting magnets is scheduled for the first part of 2015.

The schedule for the completion of the magnets by early 2015 is very aggressive and has no schedule contingency. This leads to a natural tendency to move as quickly as possible from design development activities into fabrication. The consequent risk is that construction may begin prematurely on a magnet with the potential of producing a magnet that may not meet performance requirements. This tendency should be appropriately resisted. As was recommended from the previous review, a clear set of detailed milestones and decision points should be established, with criteria based on performance requirements. This is needed for the remaining development and fabrication of the IR SC magnets and cryostats so that progress can be carefully tracked. In addition, a backup contingency plan should be developed in case the IR development and fabrication strays from the milestone and decision point plan.

The SuperKEKB team is commended for the vibration studies and mockup testing that is scheduled, and encourages all efforts are employed to ensure that these are carried to completion and are a fully adequate set.

Overall, the IR area (both magnets and vacuum system) remains the area of highest risk for both technical and schedule. Nevertheless, the SuperKEKB is proceeding well in this area.

> Recommendations:
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> The committee recommends establishinging a clear set of milestones and criteria-based decision points for the development and fabrication of the IR SC magnets, corrector and compensation coils, and cryostats so that progress can be carefully tracked and contingent plans enacted in a timely manner if required.

9) Beam Background

Beam background is expected to become much more serious than in KEKB due to the higher beam current, higher luminosity, and smaller IR pipe size, among other factors. The sources of background considered are Touschek scattering, beam-gas Coulomb scattering, radiative Bhabha, synchrotron radiation, and the two-photon process. The beam-beam effect has not yet been included. A collimation system distributed around the ring and especially near the IP has been worked out based on simulation results. A collimator upstream of IP is shown to be very effective in removing the synchrotron radiation background. Touschek background is shown to be reduced to <0.2 GHz. Radiative Bhabha is found to be the leading background contribution.

Although most radiative Bhabha loss occurs at more than ten meters from the IP, there is still 7 GHz background for HER and 6 GHz for LER within four meters of the IP. The Bhabha gammas also generate neutrons. Additional metal shields are to be added to stop the gammas and the neutrons. This shielding scheme remains to be designed. The two-photon process contribution is estimated to be negligible.

A more complete simulation effort has been initiated and more results are to come. What will be included are: 3D solenoid field, beam-beam, and the whole detector geometry.

The Committee encourages the preparation of the simulation tools as planned, and to include beam-beam effects soon. Given the many difficult demands on the IR, as much as possible of the background reduction should be addressed in the ring. In addition, the Committee feels that there are a few questions to be addressed before the collimation system can be considered optimized:

- It is not clear why the beam-gas bremsstrahlung is not an issue as in many other colliders.
- To collimate beam-gas background, a vertical collimator (the only vertical collimator in the design) is added at ~60 m from the IP. It was estimated that this single planned collimator uses up the entire budget for the transverse mode coupling instability. This will need to be reviewed or re-optimized.
- The loss factor of collimator ridge geometry calculation gives unexpected results, leading to a particular choice of ridge design. This needs to be reconfirmed with other experts and/or other codes.
- In some cases, particle loss occurs in multiple turns. In those cases, it might be better to insert collimators away from the IP to minimize secondary background. In this study, multi-turn simulations will be needed.
- Another way to have an overall collimation design is not to differentiate according to the background sources, but according to beam dynamics, i.e. horizontal betatron, vertical betatron, and synchrotron collimations at dedicated, special-purpose locations.

It is planned that commissioning with Beast II will enable studies of background and collision tuning, with staged phases of increasing beam currents. The Committee feels this a good approach

10) IR Vacuum Chamber and Assembly

A new vacuum chamber layout has been presented taking into account the new insertion magnets and the additional ion and getter pumps. The cross sections of the chambers have been adapted to the new aperture requirement. The chambers have tapered sections for low impedance and to shield against synchrotron radiation. It is proposed to provide small ridges along the wall to reduce the reflection of synchrotron radiation. The central pipe consists of a double wall Beryllium tube brazed to Titanium end manifolds. To avoid corrosion of this delicate pipe with brazed joints, cooling with paraffin is required, as was presented to the last committee meeting. The tapered connections adjacent to the cryostats will be made out of Tantalum to provide shielding. These chambers will have ducts for water cooling and gold coating on the inside surface. The proposed design relies critically on reliable, UHV-compatible joining techniques between these different materials: brazing, hot isostatic pressing and manufacturing of Tantalum chambers. The joining techniques require validation of each of these steps.

For the connection of the IP chamber to the cryostat, it is proposed to use radiation hard elastomer seals. In this way, the insulation vacuum and beam vacuum are independent, which is very important requirement.

The revised vacuum layout has been improved with the addition of ion pumps and getter pumps located outside of the cryostat at a distance of roughly ±4m from the IP. Since photon induced desorption dominates the gas load, a dynamic pressure of 10^{-5} Pa can be expected at the IP. However, this pressure assumes an optimistic photon desorption coefficient of 10^{-6} molecules/photon.

To achieve such a low eta value it is proposed to use a gold coating. Measurements for a copper sample obtained in a test at the Photon Factory were shown to the committee. A subsequent test with a gold sample is planned.

A mock-up is proposed to evaluate in detail the assembly and installation procedures of the IP chamber and the SVD. The committee considers this as a vital step, which must precede the final design and the manufacturing of the IP components including magnets and supports.

Recommendation:

Validate design choices, the assembly and installation procedures.
Confirm parameters for the pressure estimates.

11) Collision Feedback

Based on KEKB data, the vibration magnitude of the final quadrupoles and the resulting beam orbit motion could be a few times the vertical beam size in SuperKEKB.

The problem is addressed by four measures: using the coherency of the ground motion, modified magnet supports, additional damping of oscillations, and finally orbit feedback.

A modal analysis has been performed with the ANSYS code. Vertical oscillation frequencies appear around 26, 36, and 53 Hz.

When evaluating the effect on the beam-beam separation, the vibration coherence of both beams must be taken into account. The measured coherence of the ground motion between the IR quadrupoles for the magnets of both beams reduces the relative motion of the two beams by a factor 10-20. The cancellation uses the fact that the fractional tunes for the two rings are about the same. It was remarked that at KEKB, vibrations on the left and right side of the collision point had been absolutely uncorrelated.

For SuperKEKB the quadrupole oscillations will have smaller amplitude and be at a higher frequency thanks to improved supports. The dominant remaining oscillation frequency is due to the 3 Hz component of the ground motion. A 50% reduction of motion at this frequency will be achieved by adding damping material. The lever arm effect has been included in the calculations.

Evidence from KEKB supports the assumption that ground motion is the dominant source of quadrupole and beam motion and that vibration from 4.5-K helium cooling, water-cooling, vacuum pumps (no mechanical motion) can be neglected. Namely, a model based on ground motion and mechanical resonances makes predictions that are consistent with the measurements at KEKB. No other sources of vibration were considered.

The horizontal orbit feedback cannot use the beam-beam deflection method, since the beam-beam parameter is low and there are two sources of the horizontal beam-beam kick. Instead a dithering system like at PEP-II is foreseen. The expected high ZDLM rate will allow good precision and fast response.

K. Ohmi has simulated the dependence of the luminosity on the horizontal beam-beam separation. The luminosity drops rapidly for a separation larger than 5-10 micron (roughly the horizontal rms beam size). The horizontal collision feedback system need not be very fast, since the most important perturbation is expected to be rather slow, around 3 Hz.

A proportional-integral-derivative controller proposed for the feedback will not have any gain above the first resonance of the system. Therefore, while it might be able to reduce the disturbance at 3 Hz, as planned, it will either be inactive or may even amplify motion for the higher-frequency resonances at 26, 36 Hz, 53 Hz, etc.

Helium pressure oscillations at 4.5 K could excite quadrupole vibrations around 10 Hz

Other possible concerns are vibrations of the magnet cold mass inside the cryostat and differential oscillation modes of the support and cryostat (if any) that would move the electron and positron quadrupole in opposite direction. A question is whether the oscillation damping might also lead to a decoupling from the ground at relevant frequencies, which could degrade the coherence of the magnet motion.

High current beam operation and the associated heating effects could lead to movements of accelerator beam-pipe components, changes in BPM readings, and to additional beam motion.

How does the speed of the horizontal collision feedback compare with the speed of the global orbit feedback? Is there a possible cross talk?

> Recommendation:
>
> Continuous attention should be paid to minimizing IR magnet vibration. Any additional sources of mechanical excitation in the IR region, e.g. from the experiment, should be avoided as much as possible, and their magnitudes carefully checked.
>
> Actual quadrupole vibrations inside the cryostat should be measured on the first IR magnet prototypes, e.g. by geophones or laser system, and compared with model predictions.
>
> The committee repeats its previous recommendation to look at more sophisticated feedback techniques, e.g. using state space formalism.

12) Magnet and Magnet Power Supply System

The KEKB Group continues to do a considerable amount of consistently high quality work in the area of the ring magnets and magnet power supplies. As would be expected after the March 3, 2011 earthquake, a major fraction of the activities in this area was assessing and mitigating damage and ensuring that the stability of the tunnel complex is assured. The alignment and stability of the magnets and the rings depend completely on this assurance.

The earthquake created considerable damage in the tunnel area with large movements and changes in alignment being observed, particularly on either side of expansion joints. This is not surprising as the expansion joints completely decouple the adjacent concrete structures so that they will move independently of each other in the event of an earthquake. This created very large misalignments where the beams and magnets crossed these expansion joints. The locations of all the expansion joints are easily seen when looking at the post-earthquake alignment measurements.

Several types of earthquake-related damage occurred within the tunnel complex, including: cracking of platforms and concrete structures, liquefaction in places, surface soil disruption cracks, floor movement, cracks (both structural and superficial), and large shifts in magnet and equipment stands. The KEKB Magnet group is instrumenting the tunnel with a comprehensive GPS network as well as monitoring potential shifts between expansion joints and performing extensive soil surveys. All of this is to establish and understand if residual stresses have been created by the earthquake that will be released (slowly most likely) over time and degrade alignment.

Fortunately, although some of the wiggler magnets sustained damage, it has been determined through magnetic measurements that all of the damage was superficial and had no impact on magnetic performance. Unfortunately, the same cannot be said of the KEKB LER dipoles. Many of these dipoles were damaged to the point of being unusable, but it is estimated that 10-15 of these magnets are still serviceable, which is a sufficient number for SuperKEKB. This will be verified by magnetic measurements later this year.

A creative approach to supplying additional corrector coil windings to the magnets without disassembly has been developed, but it includes a significant number of electrical connections (three per turn), so that care much be exercised to ensure the final installation is correct and robust.

The environmental conditions could no longer be controlled in the tunnel after the earthquake, and the temperature is approximately five degrees below the nominal operating temperature at the time of this review. If the environment of the tunnel remains uncontrolled, the temperature will continue to drop until it reaches the ambient temperature of the ground surrounding the tunnel. So long as the temperature remains uncontrolled, precision alignment of the magnets upon installation is futile. The approach to installation and alignment should either be amended to incorporate the need for a complete final precision alignment once the environmental controls and temperature stability of the tunnel are reestablished, or the environmental and temperature control of the tunnel should be reestablished prior to significant magnet installation. Note however that until the long-term stability of the tunnel complex is documented, neither the environmental temperature controls, nor precision alignment is advisable.

As is planned, careful active monitoring of shifts across expansion joints must continue for the foreseeable future (throughout all the construction, commissioning and operation of SuperKEKB). Without such active careful monitoring delicate structures such as the RF bellows will remain at risk.

Little time was spent describing the progress on the accuracy of the mechanically rotating sextupoles. There was an almost parenthetical mention that maintaining the magnetic center during a rotation was an issue, but no discussion of was made during the review. The committee anticipates seeing a full discussion of these important developmental magnets at the next review.

The magnet power supply systems seems to be well in hand and understood. A creative approach to providing 24-bit (0.06 PPM) digital control was presented, but the committee remains cautious. Although 1 least significant bit (LSB) resolution was shown, long term stability with feedback was demonstrated to only 1.4 PPM / 8hrs, a factor of 23.5 times larger than the resolution.

Recommendations:

Once the long term stability of the tunnel complex has been documented, either reestablish environmental temperature control of the tunnel complex to allow precision alignment to proceed along with magnet reinstallation, or amend the approach on magnet installation so that only rough alignment without permanent anchoring is done until temperature control and stability are reestablished when a final complete precision alignment may be performed.

13) Beam diagnostics, Feedback systems

The KEK team has great skills in beam instrumentation and the application of various techniques to the several orbit measurement and feedback projects. Very solid progress has been achieved in the design and development of beam diagnostics and feedback systems for SuperKEKB with effective use of existed KEKB diagnostics and feedback systems as well applying the technical expertise. We appreciate the work in defining the Bunch-by-Bunch current monitor and presenting it at this Review.

With the low cut off frequency in LER beam vacuum chamber, 509 MHz-based systems are being developed. The development of boards and detectors is in very good shape, including 1) Digitex 17K94A 509 MHz detector, 2) turn-by-turn monitor, 3) IR feedback detector with uTCA board and feedback processor, 4) bunch position detector and feedback digital filter (iGp12), and 5) bunch current monitor. The TBF and LBF are considered for LER and HER of SuperKEKB, but LBF is only an option for HER. The DAFNE type longitudinal kicker is being adopted, and the related experiments are being made under the collaboration with SLAC and INFN-LNF. The optics issues have been examined, including tunes, phase advance feedback monitor and kicker, phase advance between collision point and feedback detector, phase advance from injection point.

There has been significant technical work on the 509 MHz heterodyned BPM processing system for the LER, with a plan to produce final modules in the next year. The plan for the HER uses the existing 1 GHz modules from KEKB (the VXI modules developed by HP). In the 2010 review, we wondered if long-term support for the HP BPM modules might become problematic, and if it was worth investigating a variant of the new 509 MHz LER module, (basically a different LO to mix the signal into the processing channel). We respect the need to balance manpower among projects, but again wonder if this path has been investigated (or rejected for good reasons), or if the issue of how to support the original KEKB HP BPM modules is essentially deferred to a later date. The time to do this is before the mass production run.

The year has shown technical progress for the gated turn-by-turn monitor, and the final technical choices are being made in conjunction with the optics group as well as a plan for the number and location of the BPM monitors. The slides mention the evaluation of yet a third BPM electronics package, based on the commercial Libera system. We suggest that choosing among the possible options would be easier if there was some more specific functional requirement (isolation, or dynamic range, etc.), so that a decision could be made if the gated implementation is adequate as designed or if alternatives must be developed or purchased.

The plan to control coupled-bunch instabilities in transverse and longitudinal planes is well defined, and the KEK team has very important expertise and experience. The issue of feedback control for tunes very near the ½ integer was explored last year. The possible solutions include use of two independent BPM pickups, roughly 90 degrees apart in betatron phase, followed by two feedback processor systems, each with independent kickers. This approach certainly has flexibility, and offers increased gain, though it doubles the installed hardware.

We repeat our advice from the last review to plan now for high-current heating of the beam line components, and to develop beam line interlocks and monitors for the kickers, amplifiers, kicker loads, connections, etc. in the transverse and longitudinal systems.

The design of the IP orbit feedback processor was presented including a detector with CIC signal processing in the signal chain. A special "uTCA orbit feedback processor" architecture was shown. We understand the intent is to use Matlab/Simulink tools to develop a control filter to run on this platform. This is an excellent general-purpose approach.

However, we repeat some of our concerns from last year, particularly the important need to tie the modeling of the magnet motion, dynamics of the magnet system and the actuator responses, etc. into some sort of feedback model.

> Recommendation:
>
> Define a technical specification for the necessary performance of the gated monitor system, so that a clear decision can be made comparing the proposed gating technique and the commercial medium band detector.
>
> The orbit feedback instrumentation effort should be coupled with the modeling effort that has been presented under the heading "Collision Feedback". The design and scale of the feedback controller, and algorithm, should be very tightly coupled to knowledge of the system dynamics. It is a very complex system and the necessary task will advance the state of the art in accelerator control.

14) Photon Monitors

Three different kinds of photon monitors are foreseen: a synchrotron radiation monitor for the longitudinal bunch length (using a streak camera) and horizontal beam size (using an interferometer); an X-ray monitor for the vertical beam size; and a large angle beamstrahlung monitor for beam-size matching and IP tuning.

The photon monitors for the damping ring were covered in a separate presentation.

The heat deformation of SR mirror was already a big problem at KEKB. For SuperKEKB a new mirror is being developed which addresses this problem; a quasi monocrystalline diamond mirror is being produced together with a Japanese Company, Seki Technotron, where 3-4 monocrystals are joined together. The new design should have a much improved surface smoothness as well as excellent heat conduction and low thermal expansion coefficient. The SRM interferometer to be used for the horizontal beam size measurements cannot do single shot measurements. Applying it to the vertical beam size will yield only marginal resolution.

The X-ray monitor uses a coded aperture imaging technique that has been successfully tested at CesrTA. The scatter measured at CesrTA agrees well with simulations, demonstrating that the result is statistics limited. There is a plan to improve the associated detector and further reduce the error in the measured beam size by raising the photon detection efficiency at higher x-ray energies. Both Si+Au and Diamond+Au masks have been fabricated and are being tested at CesrTA. A 64-channel digitizer and readout system for the XRM will be tested at ATF2. The ultimate goal is to resolve the beam size for head and tail separately, which might allow a direct monitoring of the head-tail and e-cloud instabilities; the minimum goal is to resolve the beam size of all the bunches shot by shot.

A third photon monitor is planned for the beamstrahlung from the collision point. Beamstrahlung monitors were very successful at SLC, and were used for several years to detect which of the two colliding beams was responsible for performance degradation. The (different) more advanced LABM planned for SuperKEKB is based on the papers of Bonvicini. A first very short test had been done in the last days of CESR operation, with only one side of the IP operating. The polarization of the beamstrahlung radiation at specific azimuthal points varies depending on the beam-size mismatch, offset or rotation of one beam against the other. The LABM comprises 4 narrow acceptance telescopes using light extracted with small beryllium extraction mirror, counting photons in two polarizations and four bands. An optics channel prototype has been built, but changes to the recently added IR shielding may be needed. Production of the optics box with light collectors has started, and a possible beam test at Frascati in 2013 is being considered.

The committee is pleased to see that the SRM and XRM are on track to be ready at the time of the SuperKEKB start up with beam, the LABM will be ready soon after as required by the commissioning plan.

One remaining question is at which luminosity levels the LABM starts to become useful.

Another question is the difference between the beamstrahlung, which has been examined and the coherent bremsstrahlung that has been predicted for other storage-ring colliders. Assuming that the effective horizontal beam size is $\sigma_z\ \theta_c/2$ the SuperKEKB parameters would appear to be close to the coherent bremsstrahlung regime.

15) Development of New LLRF System

The committee finds good progress on the development of the new digital LLRF system, consisting of μTCA-based FPGA boards and PLC. The new LLRF system prototype has been developed and evaluated with measurable improvement. Prototype boards are in hand and being tested using a dummy cavity. Initial results show that the amplitude and phase stability meets the requirements but the long-term thermal drift is out of specification. The system stability should be confirmed by external "outside the loop" measurements on the test system. The thermal drift is mainly coming from the front-end band-pass filter and is being addressed by compensating locally with thermally sensitive components. It is expected that a revised board will be tested soon. The timing distribution for the new system will be via phase stabilized optical fibers. This is expected to give excellent timing stability over long distances. The existing timing distribution system will be preserved as a back up.

Recommendations:

Demonstrate acceptable thermal stability with the revised boards.

Confirm the system performance with "out of the loop" measurements.

16) Improvement of Superconducting Cavities

The existing SCRF systems were relatively unharmed by the earthquake. The high power klystrons retained vacuum but they have not yet been tested. Ancillary components suffered some damage and misalignment but recovery has been effective and timely. If fully recovered the present inventory of cavities and RF systems is adequate for T=0 commissioning. As was known before the earthquake, some reconditioning of cavities and redistribution between the rings will be necessary to reach full current. Analysis shows that the HOM load power in the SRF cavities is significantly higher at the higher current and shorter bunches in the new machine. According to simulations the current HOM damper might overheat to 190 C. A new HOM damper was fabricated and tested with an improved cooling scheme and reduced thickness of the ferrite plate (4mm to 3 mm). Unfortunately, it failed at the higher power level. While the existing stock of cavities and loads is thought to be adequate for T=0, the committee recommends continuing the development of a robust high power load as a backup, possibly using silicon carbide. Ideally this should be developed and tested in time to allow a possible retrofit to the existing cavities before high current beam operation is needed.

A horizontal high-pressure-rinsing (HHPR) system has been developed and demonstrated very successfully on a single cell cavity, without a cryomodule. The target of this test is to restore the performance of the SRF module after many years of operation or accidental contamination without taking apart the whole cryomodule. While this approach has some risk, it would be highly attractive to avoid the time necessary to fully rework the cryomodules. The committee recommends trying this on a spare cryostat as soon as possible while recognizing the risk that the module could be degraded or lost.

Recommendations:

Demonstrate improvement of the cavity performance with the horizontal high-pressure rinsing system.

Prepare and test the higher power HOM load as soon as possible.

17) Cavity for Damping Ring

The damping ring RF system has progressed well since the last review. Work has been done on the shielded, welded interconnect between the cavities to show that it should have a low impedance with no trapped modes. The cavity HOM loads have been redesigned with a single row of SiC tiles. The match is improved and the HOMs are better damped. Power handling should be more than adequate for the low beam current in the damping ring. The same HOM tiles are applied to the beam pipe loads between the cavities; however they are now mounted in the beam pipe rather than in the “wings” of the fluted pipe. While the loss parameter of this structure may be higher than before, it is expected to be small compared to the CSR wake. A prototype damping ring cavity is expected to be power tested in the next few months. It is expected to meet all requirements since it is closely based on the ARES cavity. While the committee’s recommendations from the last review were not followed, good progress has nevertheless been made and the system is likely to be successful.

Recommendations:

Complete the damping ring cavity system test up to the full power of 180 kW with representative HOM loads attached.

Verify that the loss parameter of the beam pipe SiC loads is acceptably small.

18) Production status of Vacuum components

The committee is pleased to hear that series production of main components for the vacuum system is in full swing this year. The first chambers produced by INP have been delivered recently. Other components have entered the mass production phase in several Japanese companies or are ready to be ordered this year. Generally, all components for the HER and LER are well on schedule. NEG strips and heaters will be delivered this year and can be assembled in the vacuum chambers.

As the products are delivered to KEK, the upcoming work will concern testing and installation of the vacuum elements in the tunnel. A detailed program for vacuum testing and baking of the vacuum chambers will be required to guarantee the quality assurance for the components prior to assembly and installation in the tunnel.

Progress with the design of the movable mask was reported, but no final solution for the mask has been found. The choice of the most appropriate material still remains under study. The ideal material should withstand a large temperature increase without loss of mechanical properties or melting.

Installation of vacuum components, chambers and bellows in the magnets should be carefully prepared to avoid interference with the work on magnets and upgrading of the water cooling system.

The importance of a close follow up of production in industry should be recognised. The associated additional cost will be a good investment.

The final assembly of vacuum components with pumps, electric feed-throughs and the insertion of the NEG strips into the chambers will require a heavy work program to be organised on site.

A Quality Assurance program must be implemented for leak checking, bakeout, TiN coating and backfilling of the chambers with clean, dry nitrogen. Cleanliness must be guaranteed from the time of initial conditioning until installation in magnets and the machine start up. In particular, contamination of the TiN surface with water could destroy its performance.

It has become a good practice to establish individual 'travellers' for each vacuum element so that its history is recorded.

Congratulations from the committee for the remarkable progress since the last meeting.

19) Baking and TiN coating equipment

The large number of vacuum chambers which go into the HER and LER rings will require an extensive conditioning program. All vacuum chambers will be baked and will undergo a final vacuum validation stage. In addition, the chambers for the LER will receive a TiN coating to mitigate the electron cloud. To cope with the large number of chambers (some 180 for the HER and 1000 for the LER), it is proposed to use hot air ovens instead of the conventional baking method with heating jackets. The required baking temperature of 150 C can be achieved in a short time. For the TiN coating process, a special facility is planned, which can accommodate several chambers at a time. Vertical installation as well as a horizontal coating facility will be provided. The planning presented to the committee shows that the installation schedule can be met.

Since the baking and TiN coating will be an integral part of the vacuum conditioning, it is proposed that the final vacuum, including the residual gas composition, should be recorded on the traveller of each chamber.

20) RF Gun and Low Emittance Transport

The RF gun is very challenging. The goal of 5 nC at 10 um is beyond what has been previously demonstrated. Two new designs are being pursued, a disk and washer structure and a new Quasi-Travelling Wave (QTW). Both look promising, while keeping surface fields below 100MV/m. The QTW offers the potential of higher accelerating gradient after the first cell, and stronger RF focusing leading to smaller beam size while preserving good emittance. Both options used a shaped cathode and re-entrant geometry in the first cell to yield good initial emittance. It is proposed to use a demountable LaB_6 cathode in the QTW. While this material is commonly used for thermionic guns, it also looks promising as a photocathode. The committee recommends demonstrating these new technologies in a well-instrumented beam test as soon as possible. Ideally, both options should be thoroughly tested before a down select is necessary. Simulations show that the low emittance out of the gun can be transported and accelerated in the linac. CSR in the first arc was mentioned but not quantified. Hopefully it is not a big effect as the energy is already high. An X-band deflecting cavity system is being built in collaboration with SLAC to be used for slice emittance measurements. The lasers for these guns are also challenging and must work consistently with very high reliability in top-off mode. The committee notes good progress on all these topics.

Following the recommendations of the previous Committee, many emittance preservation measures are being pursued: improvement of the linac alignment system using the laser tracker is underway with the aim to achieve a sub-millimeter accuracy; stripline BPMs with upgraded electronics have already achieved 20 μm precision in H/V beam position measurement (<10 um being the target); and in cooperation with SLAC, a 15 MV transverse RF deflection system will be used for transverse emittance measurement, and will be capable of reducing the transverse projected emittance by compensating for the bunch tilt caused by transverse wakes. The Committee is satisfied with the presented schedule of system upgrade.

> Recommendation:
>
> Aggressively pursue a demonstration of the QTW gun with LaB_6 cathode and the full power laser.

21) Positron Source

SuperKEKB requires a 50-fold increase in luminosity through higher current and lower emittance, requiring an upgrade to the positron source. The existing electron beam of 3.5 GeV with 2 x 10 nC is used to produce positrons with two bunches of 4 nC each. For efficient positron capture, a Flux Concentrator (FLC) and Large Aperture S-band (LAS) sections are adopted. A damping ring (DR) is required for emittance reduction before injecting into the LER.

For SuperKEKB, the e+ target is moved to a location further upstream to have enough margin for damping ring injection. The e+ source upgrade contains many ingredients: target, matching device, capture accelerating structure, capture DC solenoid, beam line, quadrupole focusing system, damping ring, and transport lines with bunch and energy compression.

Two types of flux concentrators (FCs) have been developed; one in collaboration with BINP and the other with SLAC and IHEP Beijing. The BINP device suffered from a breakdown problem above 7 T field level in 2011. The earthquake interrupted work on this device, and the damaged flux concentrator was sent to BINP for repair. The flux concentrator of the SLAC type will be used for T=0 and for the earlier linac commissioning (which will start already next autumn). Special hardened copper will be used for this FC in order to shift the mechanical resonance frequency away from 50 Hz. A possible performance improvement by shape modification of the FC is being explored through simulation studies. More time is needed for R&D on the later FC upgrade. A SC solenoid is another candidate means to boost the positron yield in the longer-term future.

For SuperKEKB the target needs to be optimized for the flux concentrator and, therefore its design will be different from the KEKB target. An amorphous tungsten target will be used at T=0.

The electron beam for the HER is on-axis, and the electron beam to the positron target passes through an offset bypass hole.

The SuperKEKB capture section will use a mixture of L-band and large-aperture S-band (LAS) structures. This combination represents a good compromise. By re-using existing S-band components it reduces the initial cost compared with a pure L-band system and provides comparable or even better performance. A large aperture S-band structure is chosen for its acceptance. The frequency difference between S band and L band structures sweeps out satellite bunches, which would otherwise be critical for the damping ring radiation shielding

The first L-band klystron tube and the first L-band structure were delivered in March 2010, and an L-band operation test stand will start in April 2012. A built-in collinear power load using Kanthal (deposited by atmospheric plasma spraying) as an RF absorber avoids the need for an output coupler and provides space for compact solenoids.

Beam optics design and tracking simulations have made a lot of progress. The fields of both the capture section flux concentrator and the solenoid peak at 6 T. Gaps for waveguides lead to oscillations in the longitudinal magnetic field that dilute the positron transverse emittance. Compensation of the field dips in the waveguide regions by adding huge solenoids is being considered.

Detailed particle simulations of the positron transport have been performed from the capture section through the linac sectors 1-2, LTR, DR, RTL, linac sectors 3-5 and BT line. A deceleration phase mode is preferred in the capture section, since this reduces the high-energy tail. An e- stopper is installed to catch low-energy electrons coming from the target.

A challenge is developing e+/e- compatible optics in linac sectors 3-5. Most DC quadrupoles in this part will be replaced by pulsed magnets for better matching of the three types of particle beams (including electrons for the Photon Factory).

Promising tracking results have also been obtained for the ECS and BCS systems in the LTR and RTL, respectively.

The positron-injector schedule is tight, with linac positron commissioning starting early in the fall of 2013.

The design charge from the positron complex is 4 nC per bunch. The ideal design without errors promises 6 nC, but degradation due to the waveguide gaps etc. leads to a reduction in the available positron charge by almost a factor of two. At T=0, only 1 nC per bunch is required, and the damping ring will not be needed due to the relaxed beta* in the collider rings.

New shielding in the linac is required due to the relocation of the target. Initially the newly added shielding will be more compact, facilitating the exchange of components when required. This compact shielding will later be replaced by a heavier shielding structure.

Recommendations:

CSR effects in the bunch compressor should be examined.

A protection scheme for the target should be developed at least conceptually.

22) CSR in Damping Ring

Since the last review, significant progress has been made in understanding the effects of coherent synchrotron radiation (CSR) in the damping ring.

The discrepancy between the codes for calculating the CSR wakefield developed by Gennady Stupakov and Katsunobu Oide was successfully resolved. Both codes deal with realistic vacuum chamber geometry and numerically compute the CSR wake generated by bending magnets, including the transient effects. Currently, Oide's code was used to calculate the one-turn integrated wake for the damping ring.

The peak value of the CSR wake is about a factor of 100 larger than the combined wake from all other common sources. A detailed study of seven different shapes of vacuum chambers was carried out using multi-particle simulations. Clearly, the chambers with narrower vertical gaps have a smaller wake. The well-known shielding effects of the metal chamber can explain this result. The simulation also showed that, given the same vertical gap, the antechamber made little difference. Since the antechamber is necessary to control the electron cloud, a vacuum chamber with a narrower gap and with an antechamber is a natural choice for the design.

The simulation clearly displayed the difficulty in achieving numerical convergence in the refinement of the mesh used in the particle-in-cell method. The poor convergence may result in some numerical artifacts, especially for a current that is significantly higher than the threshold of the microwave instability. In other words, the result at 8 nC has much higher uncertainty than the one at 4 nC.

Since two bunches with the 4 nC charge per bunch in the damping ring is sufficient to maintain the design current through top-up injection with an injection efficiency of 60% for 300 second LER total lifetime, basing the decision of the chamber geometry on the 4 nC charge should be a primary consideration.

However, given the nature of the narrow resonances in the CSR impedance, two bunches may affect each other and result in a lower threshold of the microwave instability. This multi-bunch effect should be included in the simulation.

Recommendations:

> Since there are some uncertainties seen in the simulation, the Committee recommends that the results of this study be compared with a simulation using a Vlasov-Fokker-Planck code using the same wakefield.
>
> Consider using parallel computing for improving the accuracy and achieving the numerical convergence for wake calculation and particle simulation.

23) Synchrotron Injection

Synchrotron injection was presented as an alternative solution to the conventional betatron injection scheme in the HER. The scheme seems feasible with a dispersion of -1.6 meter at the injection point and a very thin effective septum width of 3.5 mm (compared to 5 mm in KEKB). A preliminary design of the septum was presented. Further study of the implications of the thinner width is necessary, along with a realistic and achievable set of injection and stored beam parameters.

24) Beam Abort System

The beam abort system forms a critical part of the machine protection system for SuperKEKB. There are several technical and practical risks that the SuperKEKB team is addressing. The beam abort system consists of nine principal components on both the LER and HER:

1. Horizontal Kicker
2. Vertical Kicker
3. Pulsed Quadrupole
4. Lambertson Septum
5. Power Supplies
6. Pulse Compression
7. Beam Dump
8. Extraction Window

The approach is to kick the entire stored beam out of the rings within one orbit revolution, with a rise time sufficiently fast to avoid perturbing the back of the bunch train when the abort is triggered. This requirement is necessary in order to avoid damaging the machine or disrupting the RF system. The requirement of a rapid rise time results in a practical limit of one power supply for each ring. There is a need to spread the beam as much as possible in order to reduce the energy density deposition.

The tests and research development on the extraction window have indicated that, contrary to the initial lowest order modeling, the temperature rise (equated with potential damage to the window) should be independent of thickness. This has been shown not to be the case experimentally, but the BAS team has a plausible explanation for the dependence on the thickness. There is an indication in what the group has examined that there may be an optimum thickness for the Titanium-alloy window that is a trade-off between two different damage mechanisms.

The team is encouraged to examine the possibility of using two sextuple magnets instead of pulsed magnets to enlarge the horizontal beam size at the extraction window.

A pulsed magnet with a rise time of <200 ns presents several technical challenges of which the group appears to be well aware and is addressing. A water-cooled ceramic chamber coated with 6um thickness of Ti has been developed; the pulsed magnet has been prototyped; and the magnetic fields were measured with and without the chamber. The measured rise time of less than 200ns is an encouraging result that shows the potential of the optimization of the inner Ti coating thickness of the ceramic chamber. As their present prototype system has no demonstrated margin (the effective magnetic field rise time = 200 ns), the group is actively looking to optimize the thickness of the Titanium coating of the ceramic beam pipe and other aspects of the integrated system.

In all of the areas, there appears to be a good balance between analytical and empirical development of all of the components of the beam abort system. Although the group has a good hypothesis for the mechanisms responsible for the window damage, there is a strong desire on the part of the group to fully understand and characterize the mechanism.

The group is also considering alternative approaches, such as the use of two sextupoles in place of the pulsed magnets in order to increase the spreading of the aborted beam.

A practical issue and risk is the loss of the supplier for the ferrite cores necessary for the beam abort system.

Recommendations:

Study of a “striped” coating on the ceramic chamber or a slot type kicker is encouraged to generate this pulsed magnet field with fast rise time less than 200ns.

25) Control and Timing System

The control system is based on EPICS and is in an extremely mature state. The KEKB team has profited from the EPICS collaboration and is now in the process of augmenting EPICS by putting IOCs in every piece of hardware, effectively simplifying the connects. In addition, the scripting languages that have been used at KEKB are now being increased to give added flexibility. The committee fully endorses this approach.

The team is now working on adding fast, global, synchronous controls via an event driver and receivers. This will greatly facilitate the complex timing that will be needed to control three different beams through the injector chain.

Other upgrades are going on throughout the system, and the Committee is confident that the approaches taken will lead to an excellent system. The only additional feature that seems to be missing is the addition of ring buffers to the BPMs and other signals to facilitate diagnosis of a complex problem by looking at the machine status immediately prior to the problem. It is suggested that this functionality be added to the control system.

Appendix A

KEKB Accelerator Review Members

Andrew Hutton, Chair	JLab
Yunhai Cai	SLAC (replacing John Seeman)
Alexander Chao	SLAC
Oswald Gröbner	CERN (retired)
John Fox	SLAC (attended via EVO)
Stuart Henderson	FNAL (unable to attend)
Gwo-Huei Luo	NSRRC
Won Namkung	POSTECH
Evgeny Perevedentsev	BINP
David Rice	Cornell University (unable to attend)
Bob Rimmer	JLab
Kem Robinson	LBNL
John T. Seeman	SLAC (unable to attend)
Zhao Zhentang	SINAP
Frank Zimmermann	CERN
Katsunobu Oide	KEK, Ex Officio Member
Kazunori Akai	KEK, Secretary, Accelerator
Atsushi Enomoto	KEK, Secretary, Accelerator
Haruyo Koiso	KEK, Secretary, Accelerator

Appendix B

Agenda of the 17th KEKB Accelerator Review Committee

17th KEKB accelerator review

Monday 20 February 2012		
09:00 - 09:40	Recovery of Linac after the Earthquake	Atsushi Enomoto
09:40 - 09:55	Overview of Design Issues	Haruyo Koiso
09:55 - 10:35	Overview of Construction Status	Kazunori Akai
10:55 - 11:25	Belle II Construction and Commissioning	Karim Trabersi
11:25 - 11:55	Dynamic aperture and IR modeling	Akio Morita
11:55 - 12:25	Error Tolerance and Optics Correction	Hiroshi Sugimoto
14:00 - 14:45	IR Magnets	Norihito Ohuchi
14:45 - 15:25	Beam Background	Hiroyuki Nakayama
15:45 - 16:15	IR Vacuum Chamber and Assembly	Ken-ichi Kanazawa
16:15 - 16:45	Collision Feedback	Yoshihiro Funakoshi
16:45 - 17:30	Magnet	H. Iinuma, T. Oki
Tuesday 21 February 2012		
08:30 - 09:00	KEK Roadmap	Fumihiko Takasaki
09:00 - 09:25	Beam diagnostics, Feedback systems	Makoto Tobiyama
09:25 - 09:50	Photon Monitors	John Flanagan
09:50 - 10:05	Development of New LLRF System	Tetsuya Kobayashi
10:25 - 10:40	Improvement of Superconducting Cavities	Yoshiyuki Morita
10:40 - 11:00	Cavity for Damping Ring	Tetsuo Abe
11:00 - 11:25	Production Status of Vacuum Components	Yusuke Suetsugu
11:25 - 11:50	Baking equipment and coating equipment	Kyo Shibata
13:00 - 13:40	RF Gun and Low Emittance Transport	Mitsuhiro Yoshida
13:40 - 14:20	Positron Source	Takuya Kamitani
14:20 - 14:45	CSR in Damping Ring	Hitomi Ikeda
15:05 - 15:20	Synchrotron Injection	Takashi Mori
15:20 - 15:45	Beam Abort System	Toshihiro Mimashi
15:45 - 16:15	Control and Timing System	Kazuro Furukawa