The Sixteenth KEKB Accelerator Review Committee Report

February 7, 2011

Introduction

The Sixteenth KEKB Accelerator Review Committee meeting was held on February 7-9, 2011. The following members of the Committee retired, Warren Funk, Trevor Linnecar, Flemming Pedersen, and Wang Shuhong. They have all made significant contributions to KEKB and we would like to thank them for their support. In preparation for the SuperKEKB construction activities, the Committee has been strengthened by the addition of several new members: John Fox from SLAC, Stuart Henderson from FNAL (who was unable to attend this meeting), Gwo-Huei Luo from NSRRC, Kem Robinson from LBNL, Bob Rimmer from JLab, Zhao Zhentang from SINAP, and Frank Zimmermann from CERN. 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, all of which dealt with the design of SuperKEKB. This year the KEKB group had made a lot of progress in defining the details of the new machine. The Committee evaluated the present status of the preparation 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/**.

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A) Executive Summary

KEKB stopped operating on June 30, 2010 after reaching its goal of integrating 1 ab^{-1}, an incredible achievement of which all of the KEKB team can be justly proud. On October 27, 2010 the Japanese government formally approved the SuperKEKB Project, and on June 22, 2010 an initial budget of 1B yen (about $100M) for a "Very Advanced Research Support Program" was assigned for FY2010-FY2012. The Committee congratulates the Director on this achievement in a difficult financial environment.

The Committee is delighted that the SuperKEKB has been approved, but cannot help but be concerned that the budget and the schedule are both extremely tight for a project that aims to exceed by a factor 50 the world-record luminosity achieved at KEKB. In addition, there is a serious shortage of staff, which is expected to deteriorate due to retirements. In this scenario, the only variable left is the scope, which will have to be carefully tailored to the budget and the capabilities of the staff. Rigorous prioritization will be required to ensure that collisions can occur in FY14.

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

Repeated from last year

1) KEK management should do everything possible to ensure that the resources needed for SuperKEKB are made available (staffing, computing). The most important issue is the established shortfall in staff during the construction period (~30 FTE) and in the operating era. In this context, the Committee recommends exploring collaborations with universities, industry and other laboratories worldwide.

New Recommendations

2) Determine the necessary minimum scope required to successfully achieve the project completion milestone (T=0) and prioritize all other scope and manage to this prioritized list.

3) Develop a prioritized staffing approach that applies position slots to those areas of highest impact and actively develop alternative approaches to meeting the staffing shortfalls.

4) Examine the self-consistency of the entire Injector chain and aggressively pursue the timely completion of the components: RF Gun, positron converter, damping ring, emittance preservation, and injection into SuperKEKB, while maintaining the ability to simultaneously inject into the PF and AR.

5) Determine through integrated simulations the adequacy of the equilibrium emittances in the presence of beam-beam interaction, low-beta insertion, and intrabeam scattering.

6) Increase the effort on simulation, analysis, and improvement of the optics measurement and correction processes. Priority should be placed on identifying the measurement and correction hardware that must be installed at T=0.

7) Develop a clear set of milestones for the production of the IR SC magnets and cryostats so that progress can be carefully tracked. Re-examine the IR Vacuum design to find sufficient space and accessibility for vital machine elements.

8) Additional studies of beam vibrations from local IR magnets and global ring quadrupoles, including mitigations, should be done to bring the expected vertical beam motion within acceptable tolerances. A careful analysis of the fast IP orbit feedback performance with realistic parameters should also be carried out.

C) Findings and Comments

3) KEK Roadmap

The Director showed the evolution of the long-term goals of KEK since 2007, which started from the expectation that KEKB would shut down in 2010 and that J-PARC would be operational about the same time and a power upgrade would be needed. 2010 was targeted as a transition year in which the future should be defined for KEK. For KEKB, this has resulted in approval for an upgrade to KEKB on December 24, 2010 – the SuperKEKB Project. The Committee congratulates the Director on this accomplishment, which comes at a difficult economic time for Japan. The J-PARC Power Upgrade will also occur at the same time, which puts considerable strain on KEK resources. The Director stated clearly that the cost of SuperKEKB was limited to 315 okuyen (about $315 M at a nominal exchange rate of $1 = 100 yen). The Upgrade should be completed in 2014, which also puts considerable pressure on the KEKB team.

Removal of equipment from the KEKB tunnel and from the Belle detector is in full swing, launching the SuperKEKB and Belle2 projects.

The Committee is delighted that the SuperKEKB has been approved, but cannot help but be concerned that the budget and the schedule are both extremely tight for a project that aims to exceed by a factor 50 the world-record luminosity achieved at KEKB.

4) Belle II Experiment

The KEK Accelerator Review Committee congratulates the Belle Collaboration, in partnership with the KEKB Accelerator team, for a very successful run over more than a decade. Belle and KEKB concluded data taking in June 2010, reaching a total integrated luminosity of over 1 ab^{-1}. Belle is currently in the process of being partially dismantled so that needed upgrades can begin. At the moment, the detector dismantlement is going well in preparation of being reconstructed as Belle-II.

The construction target for the Belle-II team is to be ready in 2014 to take data at the upgraded SuperKEKB starting with a luminosity of about 1×10^{35} and then after a few years reaching the design luminosity level of 8×10^{35}. The breadth of particle physics that can be done with Belle-II at SuperKEKB is impressive with the main emphasis to look for signals of New Physics and should in many ways compliment the physics done at the LHCb, CMS and ATLAS. The design and fabrication of the sub-systems of Belle-II are well advanced and seem to be on track for the 2014 finish. The beam energies and IP boost have been studied in collaboration with the SuperKEKB accelerator team and agreed on.

The machine detector interface between Belle-II and SuperKEKB is especially important since the characteristics of a large beam crossing angle, higher currents, and very small IP beta functions make this interface more demanding than any prior e+e- collider. Studies should continue to make this interface as understand as possible.

The angle of the detector axis relative to the two accelerator beam lines has a tentative value that allows design work to proceed. A final formal agreement between the two groups on this angle should be made allowing the various project designs to be finalized.

The plan for Belle-II to remain off the beam line until the SuperKEKB accelerator has been commissioned sufficiently is reasonable. This allows the backgrounds and potential radiation damage to the detector with time from the beams to be reduced to an acceptably low value. A detector package ("BEAST") will be developed and installed in the interaction region to measure the backgrounds and provide feedback to the accelerator commissioning. This seems to be an excellent idea.

The injection time masks for event triggering will be added to prevent very large event sizes to swamp the Belle-II data stream. The study of these masks will need to continue to further optimize the early stages of machine operation to minimize the loss of data collection efficiency. The present expected dead time loss of between 6 to 20% in the various detector sub-systems is still quite high and represents a significant data loss.

R1) The Committee recommends that the Belle-II collaboration finalize an agreement with the SuperKEKB accelerator team defining the appropriate rotation angle of the detector relative to the accelerator.

5) SuperKEKB Design Overview

The original KEK reached its design peak luminosity within 4 years, and further doubled the luminosity in the following ears, delivering a total integrated luminosity of 1/ab. SuperKEKB design target is a factor 40 higher peak luminosity that should also be reached after 4 years of operation, in parallel with a staged RF upgrade, and 50 ab^{-1} should be achieved in 2021.

The much higher luminosity is achieved by reducing the vertical beta function by a factor of 20 to about 0.3 mm; by increasing the beam currents by about a factor of two to 3.6 and 2.6 A, respectively; and, lastly, by decreasing the horizontal emittance by about a factor of 5, and the horizontal beta function by a factor 10-40.

In the nano-beam scheme the overlap region of the two beams is very limited, much shorter than the bunch length, and a large crossing angle allows reducing the vertical IP beta function. The scheme also relies on a small horizontal beam size, which is achieved by a small emittance and a small horizontal IP beta function. The much decreased beam sizes in both transverse planes more than compensate for the larger geometric loss factor. The proposed combination of parameters follows from the assumed beam-beam tune shift of 0.09, which is taken to be the same as that achieved in KEKB.

The beam energy is changed from 8 & 3.5 GeV for KEKB to 7 & 4 GeV for Super-KEKB. This choice of beam energy improves Touschek scattering and IBS for the LER, and reduces emittance & SR power in the HER. The BELLE II physicists note that this change in asymmetry will have a cost of ~25% in CPV physics, but will provide a 6% gain in full reconstruction through larger acceptance.

There is no option for polarization, which looks like a reasonable design choice. The present cells of HER and LER are maintained. The arc lattice maintains the successful lattice structure based on 2.5 pi cells with great flexibility. The only major change is that the dipole magnets in the LER will be replaced by longer ones. The LER wiggler period is shortened, and (LER) wigglers will be installed in the HER.

The IR accommodates eight new SC final quadrupoles. Additional multipole correction coils will compensate the nonlinear leakage fields.

The new arc vacuum chamber will have an antechamber to extract the synchrotron radiation and suppress electron-cloud build up.

The emittance coupling ratio ex/ey needs to be 2-3 times smaller than for KEKB (where it was about 0.8% for the LER and 0.7% for the HER).

The bunch-length values of 6 and 5 mm are based on simulations taking into account IBS, impedance and CSR. Longer bunches would need to be compensated by higher beam current in proportion to the square root of the bunch length. Shorter bunches are probably not desired and may require an increase in the momentum compaction factor. The lattice appears to be sufficiently tunable.

The proposed design still permits some flexibility. For example the beam current can be traded against emittances and beta*.

Achieving all the parameter of the Super-KEKB design at the same time looks challenging, while each parameter alone looks feasible. The transverse design emittances are comparable with those of modern lights sources. The LER emittances are similar to those of NSLS-II and Diamond at similar beam energies. The HER emittances are comparable to the APS at similar energy. However, the light sources do not have a low beta insertion with Q'~1000 units of vertical chromaticity and no beam-beam collision with 0.09 tune shift and large Piwinski angle. They also have significantly less beam current.

Attempts should be made to develop a comprehensive simulation tool that ideally would allow modeling of the equilibrium emittance of both rings including all of the following: collisions, intrabeam scattering (IBS), residual electron-cloud or ion tune shifts, impedance effects, low-beta insertion, and continuous to-up injection. As a simpler sub-problem the interplay of IBS and beam-beam could be explored.

A related issue is the need and feasibility of IP optics tuning in such an environment. Is higher-order optics tuning needed in collision at high current? What are the signals? Can the required accuracy be achieved?

A different beam-beam tune shift would change the luminosity in proportion. The design beam-beam tune could have a large uncertainty, since Super-KEKB will operate in a new regime with an extremely large Piwinski angle of about 20, compared with less than 1 at KEKB. It is not evident that the beam-beam limit should be independent of the Piwinski angle, and/or be unaffected by the large intra-beam scattering. The beam-beam simulations for SuperKEKB, without IBS, do not reach the design tune shift of 0.09, but stop at 0.08, which would translate to 10% lower luminosity. At DAFNE, admittedly with much weaker radiation damping, in operation at a moderately large Piwinski angle of 1.9 a beam-beam tune shift of 0.042 was achieved with crab waist turned on, and about half this value without crab-waist sextupoles, as summarized in the table below.

Table: Piwinski angle and beam-beam tune shift limit in various e+/e- colliders with crossing angle.

	f_{piw}	x_y
KEKB (achieved)	~0.75	~0.1
DAFNE upgrade w/o crab waist (achieved)	1.9	~0.02-0.025

DAFNE upgrade w crab waist (achieved)	1.9	0.042
SuperKEKB (design)	~20 !	0.09 ?

Though the injected beam is prepared with a very low emittance in view of the poor dynamic aperture of the main rings, the vertical LER emittance is blown up after injection by a factor 16 and 5.5% of the beam is lost, through the beam-beam interaction at varying off-waist locations, and the maximum value is rather insensitive to the injected emittance. It should be studied whether the LER injection scheme can be modified to reduce the blow up (e.g. by injecting in the synchrotron phase space as for the HER) or, if not, whether the requirements on the injected beam emittance can be relaxed. The situation for the HER injection should also be investigated in simulations.

The state-of-art of simulated collider performance suggests that the predicted parameters might be approached with near-perfect correction of machine errors. The aggressive beam parameters of SuperKEKB will demand unprecedented accuracy and completeness in the measurement and correction of these errors.

Note: The emittance numbers differed slightly between presentations. E.g. the design HER horizontal emittance was 5.3 nm in the overview talk and "4.7 nm (with IBS)" in the lattice presentation.

6) Construction Plan

The KEKB group has embarked 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. On 30 June 2010 the KEKB machine was shutdown and the upgrade was begun including the start of dismantling KEKB that started officially 28 October 2010. In December 2010 the SuperKEKB budget was approved in the Cabinet of Japan as part of the JFY2011 budget and will be finalized with the official approval of the Japanese Diet. The total construction budget is set at ¥31.4 billion with an operations budget beginning in JFY2014.

The commissioning of the Main Ring and the Damping Ring is planned to begin in the latter half of JFY2014. The Damping Ring and the Main Ring are to be commissioned concurrently. The construction schedule is very aggressive and has considerable concurrent research and development and engineering as well. The approach toward large scientific projects within Japan is flexible enough to allow for such concurrent engineering and R&D and so considerable savings in the time in the actual completion of a project can be realized.

The KEKB group has carried out a very good and comprehensive work out for making an effective and executable construction plan, including the machine commissioning plans. In the presentation on construction plan, complete project budget resources and plan were given, a clear construction strategy was described, and major machine systems and component designs and construction status were evaluated and reported. The construction schedule for each machine system is made in a practical way with good consistency and effective coordination between systems and subsystems.

Nevertheless, given the project goal to have the first collisions in JFY2014 and unprecedented machine parameters needed for SuperKEKB ultimate performance, the construction schedule appears extremely tight. Additionally, there is a shortage of more than 20% in the project team staff. This project faces considerable technical challenges and complexity. Time constraints further complicate both the ease and detailed execution of the SuperKEKB construction project as presented to the MAC.

The total construction budget has been fixed before much of the design had progressed to a level sufficient to allow for control estimates. The total staff of the KEKB staff (and the entire KEK laboratory) is fixed, and presently is 20 full time equivalents (FTEs) less than what is estimated as being needed for the timely completion of the SuperKEKB project. With such fixed constraints on budget, schedule and maximum number of internal resources, scope is the only project dependent variable that retains any flexibility for proper project management (project dependent variables are cost, schedule and scope).

The KEKB Group has wisely selected an incremental commissioning strategy and interim goals working towards the ultimate SuperKEKB performance. This allows for phased scope flexibility. KEKB Group management must carefully prioritize scope to ensure that the initial execution goals upon project completion (defined as T=0 by the KEKB Group) are met. Successful execution of the SuperKEKB construction project requires rigorous scope and development prioritization, risk and issue management, and configuration and interface control.

The schedule as presented does not have a clear critical path (that series of activities within the project that if delayed will immediately delay the completion of the project). The Interaction Region (IR) magnet and cryostat design and fabrication and the sextupole magnet design and fabrication were felt to be those activities that lie on the critical path by the project leads.

The KEKB group management of the SuperKEKB construction project appears to be strongly oriented towards a collaborative-tiered team with a small select team of three strong leaders covering the management of the project itself. The situation is somewhat complicated by the fact that the Belle II upgrade project is separate and does not report through this project chain. The SuperKEKB project organization clearly works as it has demonstrated the ability to make timely and definitive decisions.

There are tools that this lead SuperKEKB management team should consider implementing to maximize the likelihood of a successful project. These tools include the following:

<u>Configuration scope control / scope prioritization:</u> The constraints on budget, schedule and resources dictate that scope must have some degree of flexibility or the project simply will not be successful. The all aspects and items of scope within the project must be carefully analyzed and prioritized as to its importance in meeting the completion milestone (T=0) and then in the full commissioning to the ultimate performance. Scope that is not necessary for the T=0 completion milestone should take a lower priority to scope which is essential. Scope that is desirable, but not essential, even for the ultimate performance should take an even lower priority. This scope prioritization is necessary as it allow the project leads to focus resources on those areas that contribute directly to successful completion. For example, if an additional staff position is made available to the SuperKEKB Project and a choice is to be made between adding this position between two groups one with an immediate scope responsibility for the T=0 and the other with scope responsibility that will ultimately facilitate the long term operation of SuperKEKB the priority should go to the former. In some project management circles, this scope prioritization is referred to as *scope contingency* as that scope which is not of the highest priority will be accomplished *contingent* upon there being sufficient resources, funds, and time to successfully accomplish it within the project.

<u>Centralized Risk, Issues, Trades, and Action Item Registers:</u> The SuperKEKB construction project is both rapidly evolving and has considerable constraints. The lead management team presently needs to have a clear and unified understanding of the risks (opportunities), issues, trades, and action items that are active at any given point in time of the project in order to focus attention resources and budgets on those activities that maximize the probability of a successful project outcome. By way of definition, a risk (opportunity) is an event or condition that if it occurs will have a negative (positive) effect on the project. A risk is generally characterized by the probability of it occurring and the impact that it has on the project once it has occurred. An issue is a risk that has occurred. Trades are specific mitigations towards design risks where multiple design solutions or configurations are being considered to meet technical objectives. A register is a type of list including not only the item, but also the person(s) responsible for addressing it, its mitigation, the deadlines associated with it, and anticipated impacts to the project. A register is now most frequently

an electronic file (database) that is made widely available to the project team (but controlled by the project leads) so that the entire project team focuses on addressing the leading risks.

On smaller projects, these registers may be somewhat informal. For a project the size and complexity of SuperKEKB the sheer number and importance of these items warrants a more formal register. The time spent initially setting up these registers, identifying risks and mitigating strategies means that in times of crisis time will not be lost getting consensus on the most important aspects of the project to address. They will have been agreed upon ahead of time.

Detailed Project Schedule: The schedule constraints on the SuperKEKB construction project are severe. Multiple activities must be done in parallel, must be integrated and require inputs from multiple sources. The project leads need to have a clear understanding of what is necessary and in what order to achieve a successful project completion T=0 milestone. The project should establish a *dense* set of intermediate milestones on all activities so that the project leads may correctly assess progress towards the successful completion of the project. Likewise, the dependencies of multiple parallel activities must be understood so that when integrating activities occur time is not lost and the scheduled completion delayed. The *critical path* and *near-critical path* chain of activities need to be understood as well to focus resources and effort on those activities which increase the probability of achieving the project completion T=0 milestone on or ahead of schedule. A *dense* set of milestones is defined as having enough milestones occurring in a short enough period of time that when compared to the project duration as a whole to allow the early detection of developing delays.

Integration / Interface Management: The SuperKEKB construction project has multiple groups some of which are not even within the KEKB Group. These external groups are necessary for the successful completion of the project. Likewise, the Belle-II Detector upgrade project is separate from the SuperKEKB construction project, but the ultimate scientific success of the SuperKEKB/Belle-II experiments requires that both projects work closely together on interfaces and other aspects. Evidence of this interface management exists, but the SuperKEKB project leads should examine the integration and interface management to assure themselves that it is adequate.

Staffing Plan Priorities: The fixed limit on staff positions within KEKB places severe constraints on the ability of the project leads to successfully complete the project. Once the scope prioritization, risk-issues-trades register, and detailed project schedule are complete, the project leads should establish a staffing prioritization and mitigating strategies including collaborative teaming external to KEKB to address resource shortfall that jeopardize the project. The situation is better than at the time of the 15th MAC, but the staff shortage needed to construct SuperKEKB is presently the most challenging issue for completing the construction plan as scheduled. The KEKB group should consider all feasible potential means of addressing the shortfall such as recruiting new staff, temporarily getting staff from other KEK areas, and effective international collaborations for help.

Recommendations:

1) Determine the necessary minimum scope required to successfully achieve the project completion milestone (T=0) and prioritize all other scope and manage to this prioritized list.
2) Develop, populate, analyze and manage to an active risk, issues, trades, and action item register for the SuperKEKB construction project.
3) Develop a detailed SuperKEKB construction project schedule with a densely populated set of intermediate milestones to allow assessment of progress and a critical and near critical paths.
4) Assess the project for adequate integration and interface management.
5) Develop a prioritized staffing approach that applies position slots to those areas of highest impact and actively develop alternative approaches to meeting the staffing shortfalls.

6) Consider phasing the commissioning of damping ring and main rings as feasible to reduce the potential difficulties as high current commissioning of the SuperKEKB proceeds.

7) Lattice Design

Lattice parameters are optimized for luminosity, leading to a consistent set of design parameters for a luminosity of 8×10^{35} $cm^{-2}s^{-1}$. Due to the nano-beam scheme, the beta functions at the IP are substantially reduced from those of the KEKB, leading e.g. to a vertical interaction-region chromaticity of about 1000 units in Q'. The required emittance coupling ratio is also much reduced. The arc-cell lattices, however, utilize the 2.5-pi cells similar to the KEKB design, and have the same cell lengths. Some degree of control of HER emittance can be obtained by adjusting the wigglers that are reinstalled from the KEKB HER. LER will install new wigglers with half the period of the KEKB wigglers. Cell lattice optimization in the HER assumes the same cell structure as KEKB. Crab cavities have been removed. The present LER and HER lattices generate the target horizontal emittance, as well as, in simulations, a very low emittance coupling ratio around 0.3%:

	ε_X (without IBS)	ε_X (with IBS)	ε_Y	σ_Z (w IBS & impedance)
LER 4 GeV with wiggler	2.0 nm	3.2 nm	8.6 pm	6 mm
HER 8 GeV with 100% wiggler	4.4 nm	4.5 nm	11.8 pm	5 mm

It is suggested that a further parameter optimization may be beneficial in the next stage. At present, the momentum compaction is determined primarily by optimization of the emittance. It is suggested that bunch length be included as part of this optimization exercise. Another parameter to be considered could be the number of bunches, which impacts, among other things, the bunch intensity and therefore on the Touschek lifetime.

The arc lattice is designed to consist of 2.5-pi cells following the KEKB design, which gives the advantage to reuse the KEKB magnets and vacuum chambers, thus saving on budget and schedule. The Committee concurs with this choice; however, it also wishes to note that this important and far-reaching decision based on cost and schedule considerations means relinquishing the latest cell lattice designs adopted by the light source community, which potentially yield much lower emittances.

Chromatic correction is realized in either ring by means of 4 local chromatic correction (LCC) sections around the interaction region (IR) as well as by two pairs of non-interleaved sextupoles in each of the 52 arc cells. With this system, the dynamic aperture is mainly determined by the IR magnet nonlinearities and errors. Dynamic-aperture calculations include the effect of synchrotron oscillation, but no synchrotron-radiation damping and excitation. This seems reasonable. The present lattice achieves the design-goal, Touschek lifetime of about 10 minutes for both rings. The dynamic aperture can accommodate the injected beam, although just barely so in the case of the HER. The Committee suggests looking for additional means to increase the HER dynamic aperture.

At the moment a downhill simplex method is used to optimize the settings of four families of octupole correctors, 56 sextupole families, and 12 or more families of skew sextupole magnets, so as to maximize the Touschek lifetime as target function. One could attempt to determine at least some of these many parameters analytically, e.g. compensating the relevant resonance driving terms for resonances around the working point, and comparing the performance obtained in this way with the one from the "black box" simplex method.

The decision whether or not to rotate the BELLE axis has not yet been definitely taken. However, ring optics with rotated axis that minimize the sum of the vertical emittances of the two rings have been developed as the first priority. Here the crossing angle of 83 mrad is tentatively considered to be evenly split between LER and HER orbits in order to minimize synchrotron radiation due to the solenoid edge fields. An alternative optics without rotation may also be designed if time and resources permit.

Studies so far indicate that the crab waist scheme does not work too well due to the interference (non-commutativity) between the crab waist optics and the IR optics. The expected benefit may be marginal in any case, and, on the other hand, it would require maintaining the absolute horizontal beam position at the IP. Crab waist is therefore considered as a future option for SuperKEKB. Possible locations outside the IR have been identified in case crab-waist sextupoles will be needed in the future. The Committee concurs with this plan of considering it as a future option.

The IR optics requires very dedicated attention. The IR final focus magnets consist of 5 iron-free SC magnets and 3 SC magnets with iron yoke, including corrector coil packages for suppressing higher-order multipole fields and leakage fields for the opposite beam. The QC1 and 2 magnets are also equipped with octupole coils that suppress the nonlinear Maxwellian fringe field. The distribution of the compensating solenoid field, overlapping QC1 & QC2, has been optimized with regard to coupling and vertical emittance. The IR has an extremely challenging optics due to (a) complicated 3D geometry and orbits, (b) complicated 3D magnetic fields, tilted solenoids, multipoles, leakage fields, fringe fields, and multipole correctors, and (c) an extremely sensitive optics with large beta functions. Modeling of this region will require great care and paying attention to detail. The Committee suggests that close attention be paid to an unprecedented level of realistic modeling of the IR optics, and as much flexibility as possible in the design be maintained for making later adjustments and corrections.

In the IR geometry there also is a minor interference between LER and HER beam lines that may need to be resolved with some priority.

8) Error Tolerance and Optics Correction

The KEKB staff has made significant progress in the simulation and analysis of expected measurement and correction capabilities for SuperKEKB. Correction of beam optics errors will be a critical factor in obtaining the required performance of SuperKEKB. Coupling in KEKB was 0.8%. In SuperKEKB, coupling must be less than 0.25%. With beam vertical emittances 15 to 20 times smaller than those in KEKB operation, optics parameters must be measured with a precision three to five times that achieved in KEKB.

The well-known COD based method for measurement of optics errors is unlikely by itself to give the resolution needed to correct to design performance. Resonant excitation with phase and amplitude sensitive methods, as well as other new innovative methods, will be essential to achieve performance goals. Gain and rotation errors in beam position monitors must be included where relevant for corrections.

The SuperKEKB team has done extensive simulations of corrections to accelerator optics, taking into account several error sources. The Committee comments follow each in italics.

Coupling from quad rotation and sextupole displacement has been simulated, concluding that tolerances without correction have been found (i.e., perturbations from magnet motion/vibration) of 0.1 mrad quad tilt and 100 um for normal sextupoles and 10 micron for non-interleaved pairs of sextupoles.

> *How much will these tolerances be reduced when combined errors are considered? Drift in closed orbit (precision of fast orbit correction) should be considered along with sextupole offsets.*

X-Y coupling measurements have been simulated with the coupling sources above. Resolution and nonlinear effects vs excitation amplitude has been simulated considering 50 um BPM jitter. These simulations show some noise-induced degradation for the r2 measurement and a general slope to the results, presumably from nonlinearities in the optics.

> *Since r2 is a critical parameter for coupling correction, any reduction in BPM jitter would be beneficial.*

The effects of BPM rotation errors on coupling measurements were found to be minimal for the critical r2 parameter.

> *Once r2 has been corrected, r1, r4 parameters can be used to determine rolls of BPM's.*

Dispersion measurement uses COD changes with RF frequency. Dispersion can also be measured at locations with single-pass BPMs by modulation of RF frequency.

> *The "RF kick" method can be much faster, and can be performed with much lower amplitude of beam motion, limiting distortions from lattice nonlinearities.*

A coupling correction scheme was demonstrated based on measuring the local r1-r4 coupling coefficients using turn-by-turn coupled phase-space correlations and correcting these coupling coefficients around the rings in an rms manner. Actual quadrupole rotation data, including some outlying data points, from KEKB provided the input. Together with correction of vertical dispersion, the vertical emittance is effectively minimized in simulations.

The effect on dynamic aperture of correcting errors resulting from 100 micron sextupole displacements plus 0.1 mrad quadrupole rotations was modeled along with BPM jitter of 50 micron and BPM tilts (σ) of 1 mrad. The resulting emittance coupling was consistently reduced to below 0.3%, most examples less than 0.2%. The Touschek lifetime calculated from the resulting dynamic aperture varied over a wide range, however, from 700 to 200 seconds.

In order to accomplish correction of coupling, sextupoles will be equipped with additional windings to create a skew-quad like field. These magnets will provide ample correction points for coupling. However the field harmonic components, principally octupole, measurably reduce the dynamic aperture, and the Touschek lifetime by about 10%. The combined conditions of injection and beam-beam effects should be modeled with these harmonic components to check for adverse effects.

Measurement and correction of vertical dispersion will be crucial to minimizing vertical emittance. Tolerances on measurement errors should be determined as necessary, guided by results of a comprehensive simulation to be able to achieve the required vertical emittance. Machine error sources may then be reliably found and corrected during operations.

Corrections at the interaction point are critical for reaching the high luminosity and to provide good dynamic apertures. IR SC quads QC1 and QC2 have 4 families of octupole coils to correct for fringe fields. Leakage multipole fields of the iron-free SC quads in one ring affect the beam in the other ring. Leakage field corrections coils have been designed for the IR. Dynamic aperture aims to reach 600 s of Toushek lifetime. More optimization is continuing, and more errors and corrections should be added to complete the study. Inclusion of realistic details, especially in the IR region, will be very important.

The12 families of skew sextupole chromatic coupling correctors need to be studied. Suggestion is to rotate physically some of the sextupoles by up to 30 degrees to provide the needed skew sextupoles. This scheme will require much more study: how to use these correctors, how to minimize effects on the beam aperture, and how can these rotations be realized engineering-wise. This proposed scheme should proceed only after these issues are sufficiently understood.

Recommendation: Increase effort on simulation, analysis, and improvement of the optics measurement and correction processes.

9) Beam Dynamics Issues for Nano-Beam Scheme

As recommended in the last Review, efforts on understanding beam dynamics with the Nano-Beam scheme have continued, and a steady progress is seen.

A weak-strong simulation was used to understand whether a crab waist collision gives a serious advantage for the SuperKEKB parameter set. The moderate beam-beam parameter of 0.09 adopted in the project gives no advantage to the crab waist optics complications, because the percentage gain in luminosity from the crab waist collision grows with the beam-beam parameter in such a way that crab waist only becomes attractive for beam-beam parameter values well above 0.1. The previous conclusion is reconfirmed: in SuperKEKB an IR optics solution with the crab sextupoles is not available because of the strong dynamic aperture degradation. Nevertheless, possible sites for the crab waist sextupoles outside of the IR are available if need in the future.

Beam-beam simulations revealed the dangerous $2\eta_x - 2\eta_s$ resonance, other synchro-betatron resonances in the working tune range are also present but less important. Strong-strong simulation also showed coherent beam-beam oscillations of head-tail type near this resonance. An effort has been invested in simulation of the tolerances to the vertical and horizontal collision offsets, the waist offset, coupling parameters and their momentum dependence. A comprehensive table of tolerances is produced. Of interest is the observation that the crab waist collision option alleviates some of these tolerances by a factor of 2 or 3, although these are not considered to be very important advantages.

From the KEKB experience with the crab collision it was concluded that errors in several IP optics parameters may lead to a dramatic degradation of the luminosity, which is not seen when scanning only one of those parameters. The Committee recommends performing beam-beam simulation of the IP parameter tolerances in a multi-parameter space to see if the luminosity is similarly sharply peaked in this space for the SuperKEKB.

Electron cloud instability causes blowup of the vertical beam size due to the head-tail mechanism, as has been theoretically predicted and now experimentally demonstrated at KEKB and CesrTA. This understanding makes the theoretical estimation of the threshold more reliable. For the SuperKEKB beam parameters, the electron cloud oscillation frequency is so high (~3 full oscillations over the positron bunch length) that the instability threshold estimation based on the coasting beam theory is applicable to the single positron bunch. This threshold is confirmed by simulation of the electron cloud instability and puts the limit of 2×10^{11} m^{-3} on the electron cloud density. The coupled-bunch instability caused by the electron cloud can be damped with the density of only 1×10^{11} m^{-3}. This number is assigned as a target of SuperKEKB LER; the relatively lower target density is partly to deal with cases when the electron cloud might occur at locations with high beta functions.

Movable masks in physics position have a vertical gap of only 2 mm and potentially cause a conventional head-tail instability, although the threshold is calculated to be above the bunch current needed in the SuperKEKB. However, the static vertical "banana" distortion due to these impedances seams to be serious, the evaluation of both the impedances and the static distortions are to be refined.

The Committee insists that completion of the impedance budget is a high-priority task of the SuperKEKB project.

The Committee recommends continuing an in-depth analysis of the beam-beam effects with the realistic conditions relevant to future operation of SuperKEKB.

The coherent synchrotron radiation wakefield is found to be 2 orders of magnitude stronger than other impedances. The coherent synchrotron radiation wake is potentially especially serious for the damping ring. Given the importance of coherent synchrotron radiation, it is suggested that calculations with different coherent synchrotron radiation codes be compared in more detail to obtain an agreed tolerance. Ways to reduce the coherent synchrotron radiation in the damping ring should be explored, e.g. longer bunch length by adjusting the lattice or RF manipulation.

10) Injector Upgrade Overview

The injector linac has been very successful in simultaneous injections to four different rings by pulse-to-pulse of 50 Hz. The beam transfer lattice was the same in all cases, and the top-up mode was adopted for KEKB and PF rings. In the SuperKEKB case, it requires higher-current and lower-emittance beams to improve the luminosity by a factor of 40.

For the HER injection, a 7-GeV electron beam is required with two 5nC bunches per pulse and an emittance of 20μm. At present, there is no reliable electron source working at such high current and low emittance. The injector group is proposing to initially employ a 1nC photo-cathode RF gun, and to improve cathode materials and the laser system by 2014. If this final goal cannot be achieved, another damping ring may also be consider for electrons as a back-up solution.

For the LER injection, a 4 GeV positron beam is also required with two 4nC bunches per pulse and emittance of 6μm. The existing electron source of 10nC is used to produce positrons at 3.5-GeV. The electron beam bypass is modified at the positron target. A Flux Concentrator (FLC) with L-band structures is also being developed for effecient positron capture. The FLC as an Adiabatic Matching Device (AMD) is under development in collaboration with BINP. The damping ring at 1.1 GeV will reduce the emittance down to 42.5nm (H) / 3.15nm (V). Further acceleration to 4.0 GeV would require additional C-band structures in addition to regular accelerating sections. Since the required emittance for LER injection is less than 4.0 nm, one must be careful to prevent the emittance growth.

It was observed that the emittance grows from Sector C to 5. To suppress this growth requires investigating the growth mechanism including precision alignments. This would require more emittance measurement devices to identify and eliminate the source of the growth. Independent optics on a pulse-to-pulse basis would also be possible in the future if more resources were available. The Committee encourages the injector linac group to overcome all the challenging tasks of delivering high-quality beams simultaneously.

9) Emittance Preservation in Linac

Emittance preservation can be a very good cooperation item with SLAC due to their long-term experience with the linear collider. SLAC has lots of experience in preserving the emittance in the linac by reducing the environment factors and from wake-fields, as well as correcting the effects by using a feedback system.

The issue of emittance blow-up came up and preliminary measurements were taken in 2009. Several experiments were carried out in 2010 to indentify the sources that caused blow-up at three points along the injector. However, the linac injector still needs to support the operation of PF. Beam-based alignment and conventional methods will be adapted to re-align the linac this year.

The first RF-gun will be installed to measure the beam emittance. An RF gun and a DC gun are proposed for the baseline design to create electrons and positrons respectively.

Components can be aligned with laser alignment or in a conventional way. The team is planning to improve the alignment to sub-mm. Alignment error down to 200 um can be achieved. It should be done as the first priority. It would be beneficial to have correlation analysis among the linac alignment, the ambient temperature and the cooling water to establish the long-term stable operation of the Linac and minimize the influence from alignment.

Comments from Japanese experts

1. Electron source

    - Determine the baseline plan, on which available resource should be focused.

    Agree with the comments from Japanese colleagues. The team should have a baseline plan and R&D project. Once the R&D program become mature, the electron source can be replaced with innovation. However, it will be essential to set time and budget limitation for the R&D target. Otherwise, fall back to the baseline plan without sacrificing any specification.

    Cooperation with LCLS project and looking into the performance of photon cathode gun might help in developing new source.

2. Emittance growth

    - correct alignment errors by practical methods

    Agree with the comments. Analyze the alignment error in detail and find the correction method. It is a zero order problem.

    - understand the growth mechanism by machine studies and simulation.

    We understand that there is a need for continuous operation for the PF. However, only a comparison between experimental data and simulation will make the problem clear and help find a solution to cure it.

10) Damping Ring

Since the last meeting, the requirements on the damping ring (DR) have been relaxed thanks to improvements in the LER design. Namely the LER injection aperture has increased by 0.2 micron (40%), and the emittance of the beam injected into the LER should be smaller than

14.5 nm instead of 4 nm. The damping ring is designed for a bunch intensity of 4 nC, which would suffice to maintain a constant SuperKEKB LER design beam current though top-up injection with an injection efficiency of 33% for 600 second LER Touschek lifetime.

Significant changes to the damping ring design have been made for the purpose of CSR mitigation. The ring optics is a FODO lattice that includes reverse bends. The latter increases the ring filling-factor and allows for shorter bending time at lower dipole field. Most importantly, to combat the CSR instability, the momentum compaction factor has been increased by more than a factor 7, and the RF voltage by a factor of 5. The RF voltage now required is 1.4 MV at 509 MHz. This voltage appears reasonable when compared with other similar rings. For example the ATF damping ring with an almost identical ring circumference has an RF voltage of 1.0 MV at 714 MHz.

An antechamber plus photon stops housed in the antechamber, as well as a grooved surface in the bending-magnet chambers will suppress electron-cloud formation, ensure a good vacuum, and facilitate the extraction of the SR heat load.

The DR transverse impedance is small. The longitudinal wake field is important. It is dominated by the CSR wake field, whose peak is a factor 100 higher than those of the vacuum chamber components. Since the last meeting a significant amount of work has been devoted to the correct modeling and understanding of the CSR wake field and its effect on the beam, and to develop mitigation measures such as the new DR optics.

Codes by Gennady Stupakov and by Katsunobu Oide (the latter representing an extension of the Yokoya-Agoh algorithm) predict significantly different CSR wake fields for the present DR. The CSR wake also depends on details of the chamber geometry, presumably including the presence of the antechamber. Multiparticle tracking with the CSR wake from Oide suggests that a bunch intensity of 2.5×10^{10} should be feasible, but not the "ultimate" intensity of 5×10^{10}.

Summing the CSR wakes from different vacuum chambers leads to a questionable result. To get a better estimate, a full calculation of the entire ring has been performed for a normal round chamber and a situation with the antechamber. The result looks either like a single resonator wake or the superposition of a few such single-mode wakes.

Analytical formulae from Heifets-Stupakov (S-H) and Bane et al have allowed for additional checks of the CSR instability threshold. Applying the S-H theory to UVSOR-II and NSLS-VUV, the observed CSR bursting instability thresholds in these two rings appear to be in fairly good agreement with the S-H prediction for a free-space CSR. With parallel plate shielding the Super-KEKB DR intensity threshold of 2.4×10^{10} (w/o shielding) becomes 6.4×10^{10}.

It is noteworthy that the CSR wake field leads to an increase not only in the bunch length but also in the momentum spread, starting at very low bunch currents, which seems to differ from the effect of conventional wake fields. The increase at low current could be related to coupling of radial modes, while a "kink" with steep slope could indicate the "threshold" of azimuthal mode coupling.

The Committee observes that it is not clear which consideration determines the size of the ring. The ring accommodates 4 bunches with 100 ns bunch spacing. However, the ATF as well as the proposed 3-km ILC damping rings can store beam with much smaller bunch spacings, of order 3 ns, and still extract individual bunches, at comparable beam energy. Perhaps the size of the ring is set by the emittance goal or by the mitigation of the CSR instability.

With the main DR parameters decided and tunnel construction underway, the Committee recommends focusing on open issues include low emittance preservation at high bunch charge, the HER injection scheme, and beam losses in the damping ring at injection.

An experimental test of the CSR instability thresholds predicted by different theories and simulation codes could be made at the ATF damping ring by lowering its beam energy to below 1 GeV in order to determine the reliability of the various theories and forecasts.

The bending magnet filling-factor in the DR design is less than 50%, already including the contribution from the reverse bends. The Committee observes that, in principle, with a two times smaller ring one might achieve a shorter damping time at the same bending field and would then need to store fewer, e.g. only two instead of four bunches in the ring. A smaller ring might also be cheaper. It is also noted that the CSR instability threshold should increase with a larger momentum compaction factor and/or with a smaller bending radius.

The Committee notes that the damping ring offers opportunities to focus effort on a timely achievement of the initial SuperKEKB operation while completing the facilities necessary to achieve ultimate performance parameters in the years following initial collisions. The full three-cavity RF system is an obvious candidate for delay.

11) Beam Transport

The beam loss in the Damping Ring (DR) and emittance growth are investigated along with the injection to the HER. The injection parameters are as follows.

LER: 4.0 GeV, emittance of 12.5 (H) / 0.9 (V)-nm, bunch charge of 4 (8) nC

HER: 7.0 GeV, emittance of 1.46 nm, bunch charge of 5 nC

The SuperKEKB performance goals impose strict limits on beam loss and emittance growth in transport of the beams from the linac to the storage ring. The positron and electron beams each pose unique challenges in meeting these limits. Efficiently capturing the cloud of positrons emitted from the target and then damping the positron beam emittance in a separate ring requires analysis and design quite different from generating and transporting a very low emittance electron beam through the linac and transfer lines.

Two design strategies have been investigated to capture the positrons from the target, accelerate, and inject into the damping ring. In both options the first 6 accelerating sections will be replaced with larger aperture structures. The large aperture S band (2856 MHz) linac has the advantages of a higher accelerating gradient and use of the present RF sources, while the larger transverse size and wavelength of the L band (1298 MHz) provides slightly more efficient capture (6.587 nC vs. 6.301 nC at the damping ring according to simulation results). A more important benefit is derived from the frequency ratio between S and L band systems chosen, resulting in delayed particles from the target falling off crest and being lost in the following S band system. Losing these particles reduces beam loss in the damping ring from 0.403% to 0.053%. The option of using the large aperture S band sections with a deflecting cavity to kick out the delayed bunches was examined. The fields in the deflecting cavity would have to be quite large in the case of close spaced S band bunches. Since new large aperture accelerating structures are required in both cases, the L band RF sources will likely require less effort, if more cost, than the deflecting cavity system.

The L-band structures combined with an energy compression system are able to reduce the beam losses in the damping ring where only 0.1% loss is allowed by the safety regulation. The 5% energy spread of the positrons at the 1 GeV point in the linac are well in excess of the 1.5% energy acceptance of the damping ring. A bunch compression system employs dispersive sections and collimators to assure compatibility with the damping ring acceptance.

From the damping ring to the LER the positron beams are transmitted without loss by adjusting RF-phases. For example, the acceptance to the LER is 707 nm, while the beam emittance at the injection point is 11.7 nm.

The emittance growth was investigated for misalignments of accelerating sections and quadrupole magnets including transverse wake effects. It shows significant growth effects in the simulations. The synchrotron radiation effects are significant for the electrons, increasing horizontal emittance from 1.86 (wake fields) to 5.57 nm. This is a concern for injection into the HER, motivating a study of synchrotron (energy phase space) injection. A combination of two could prove to be advantageous and has been suggested for further exploration.

The Committee also encourages more detailed studies on the emittance growth for various injection schemes in the simultaneous injections.

12) Beam Diagnostics

Overall, this is an excellent team with considerable expertise in these diagnostics areas.

This presentation covers beam diagnostics for HER, LER and Damping ring.

Bunch by bunch current monitors

What is the plan for bunch current/fill pattern monitor? This was not presented in the talk but based on conversations with the team; the plan is to develop a dedicated bunch-by-bunch monitor in VXI form (similar to the existing KEKB monitor). The iGp platform in feedback has this information, but the implemented Ethernet port cannot support the refresh rate of 50Hz required to control injection, so a VXI module is planned.

Recommendation: Define the bunch-by-bunch current monitor project with required resolution, measurement bandwidth and interface requirements.

Beam Position Monitors

Narrowband BPM processing – the existing VXI based narrowband BPM processing will be retained for the HER, but a new design, operating at 508 MHz, is proposed for LER (due to the vacuum chamber propagating mode cut-off). As the original HP/Agilent VXI modules have minimal manufacturer support and the long-term maintenance of these modules needs planning, we suggest consider including a x2 frequency version in the design of the new 508 MHz instrument, which would require very modest changes to the heterodyned instrument (in the filters and LO functions). Considering options for a future replacement of the existing HER modules in the 508 MHz system design phase may make the transition simpler in the future, and the actual manufacture of the HER modules could be delayed to a later funding cycle, but the operational and maintenance advantages of a common design would be achieved.

Orbit feedback and turn by-turn BPM systems

New BPM receiver processors are presented for single turn measurement, orbit feedback and bunch-by-bunch instability feedback. This is a significant amount of RF and instrument engineering to complete, but the team has demonstrated many prototype functions and should be on track to successfully develop the receivers. Prioritizing the functions by immediate vs. later need seems very important.

The bandwidth of the orbit feedback, the sampling rate, and the filter design of the orbit feedback BPM processor may need some special attention. As presented, the proposed digital filter is a very high order CIC filter, so that the phase shift across the bandwidth of feedback needs careful specification to avoid instability of the orbit feedback loop. As the phase response is not shown in the figures, it is not clear this is the best approach considering the use of the filter inside a feedback loop. Additional comments regarding the orbit feedback task are in the orbit feedback review.

Recommendation: We suggest that this important orbit feedback loop be designed as an integrated system with the specification of the digital filter in the BPM processor as part of the overall design of the orbit feedback control filter and loop.

Gated BPM Measurement –

Several schemes were presented detailing a gating function needed to separate signals from a pilot bunch for tune and orbit measurement. While not detailed in the presentation, this pilot bunch needs to be processed without transverse feedback control if the natural tune is to be measured (the iGp processing has this feature). The tune monitor information for the pilot bunch might also be obtained within the transverse feedback processing though a design of a separate PLL approach was shown.

Optics correction methods need a transverse excitation for measurement and correction of lattice functions. Any transverse excitation method (for tunes, etc.) needs coordination with transverse feedback processing and pilot bunch.

Bunch-by-Bunch Feedback Systems

Bunch by bunch feedback is a strength of the KEKB team. The experience gained from KEKB will be very important in the plans to implement transverse feedback at higher currents, and (new to KEKB) longitudinal feedback for the LER.

Transverse and longitudinal growth/damping rates are estimated. It isn't clear if worst-case operating margins should be estimated to give the feedback damping rate; it would help if the margins are used in estimates were specified. Some extra margin may be helpful as you lose gain due to timing errors, drift of LO phase, especially in longitudinal system.

Beam induced power in the pickups and kickers must be managed at high currents. Considerable experience at KEKB and PEP-II suggests that the monitoring of high-power tunnel components is important, as is the careful planning for absorptive filters, etc. to protect the power amplifiers. The group should consider if any sort of interlock or protection system is helpful for operation of the vacuum and expensive amplifier components at high currents.

Synchrotron Light Monitor and SR-based diagnostic tools

Measurement of both beam sizes is very useful for optimizing high-luminosity performance. The horizontal beam size in SuperKEKB is measurable with a conventional SR light imaging technique, and the planned upgrade of the Synchrotron Light Monitor is based on the previous experience e.g. a new diamond mirror will reduce thermal deformations which complicated the beam size measurements. A clear plan was presented for the visible light imaging system and there are no concerns.

For the vertical size measurements, a new X-ray monitor is being developed. As compared with a pinhole or Fresnel zone plate techniques, the coded-aperture x-ray imaging provided the best resolution in experimental tests at CesrTA. The turn-by-turn bunch-by-bunch vertical size data can be obtained without a monochromator, which severely cuts the photon flux. Impressive R&D to date including encouraging results from CESR tests in which a resolution of ~10 microns is already obtained. At energies higher than CesrTA hopes for further improvement of resolution are based on a newly developed multi-pixel semiconductor detector. A KEKB system still needs development of new detector technology, readout technology to push resolution as desired. Are the available resources and time scale adequate to push this development?

For the IP, an innovative beamstrahlung light monitor is under discussion. With an option of the light polarization analysis, its potential includes monitoring the collision offset and indication of the e+e- beam sizes mismatch, at least in the vertical direction. However, its applicability for the horizontal offset and size-mismatch measurement is questionable for the Nano-beam collision with a large Piwinski angle.

What resources are needed to develop this idea into a functioning diagnostic? Is this an essential instrument for the T0 commissioning plan? The Committee encourages collaboration of the KEKB team with sister laboratories in development and testing of advanced diagnostic tools.

Loss Monitor and DCCT

These functions are largely similar to the KEKB functions as implemented, and are not of concern to the review Committee. The loss monitor is probably important as a T0 instrument, as well as the DDCT.

Damping Ring

Diagnostics for the damping ring require BPM systems, yet another receiver channel is proposed, this one a log ratio detector. The processing includes digital signal processing, which would incorporate single turn BPM functions, tune measurement, etc. It is proposed this receiver might be the basis of the main ring turn-by-turn system.

The damping ring requires a synchrotron light system, bunch-by-bunch transverse feedback (no specifications provided as to instability issues), DCCT, Beam Loss monitor, and bunch current monitor. Clear specifications and requirements for these functions were not presented. The talks on the damping ring cavity suggest that HOM driven transverse instabilities are damped via synchrotron radiation, so if resistive wall or other mechanisms require a transverse feedback, it would be helpful to clearly show what impedances and growth rates need to be addressed.

Recommendation: develop specifications for these damping ring diagnostics, and especially prioritize functionality needed at T0. Every effort should be made to re-use the exact functions developed for the main ring. Even if reduced performance is possible in the damping ring, the savings in design time and development time, savings in support and spares costs would seem to overwhelm any issues regarding cost of the damping ring diagnostic hardware.

Construction Plan –

One overall observation, the schedule as presented has many parallel R&D activities in 2011 and 2012. Is there sufficient manpower to realistically staff all these concurrent projects? Clarifying the absolute minimum diagnostics required at “T0” is planned for the middle of 2012. If this minimal startup set could be defined in 2011, resource allocation might not be so tight in the critical early phase.

Recommendation: a more detailed realistic staffing and skills plan consistent with the proposed R&D and fabrication schedule may help focus critical skills. We urge the coordination of the R&D with collaborator laboratories and collaborator commercial firms to best accomplish these design tasks. We also suggest that the instrument platforms (be they Ethernet-linked EPICS IOC, dedicated VXI, etc.) be standardized to the greatest extent possible across these multiple instruments to reduce the number of operational and diagnostic software projects needed to commission and operate the beam diagnostics.

13) IR Overview & Magnets

The design of the Interaction Region (IR) for SuperKEKB contains many subsystems including magnets, mechanical supports, vacuum system, lattice optics, diagnostics and feedbacks. The interrelationship of all these systems is very important to make the IR and the resulting collisions between the two beams successful. This system has many exacting tolerances due to the very small vertical and horizontal beta functions, high beam currents, very large crossing angle, and the close proximity to the Belle-II detector. The parameters of the IR of SuperKEKB have been determined and seem appropriate. The vertical beta functions at the collision point were reduced recently by about a factor of two to compensate for the decision to minimize the lattice changes of the HER. The magnet and vacuum chamber apertures were adjusted to increase the Touschek lifetime of the beams in the rings.

The designs of the superconducting (SC) quadrupoles have progressed well over that past few years and converged about six months ago. The magnet designs seem reasonable and have sufficient technical safety margins to work reliably. These SC magnets add stray fields on the adjacent beam lines. SC correction magnets are being designed using field simulations to compensate the stray higher order multipole fields on the adjacent beam lines with the dipole and quadrupole fields remaining the same. The correction coil designs have reduced the stray fields to acceptable level as judged by dynamic aperture calculations of the lattice.

In the IR the beta functions change rapidly even internal to a given IR quadrupole. The simulations for field correction should take into account these beta variations. Cold measurements of the main and stray fields are planned after the magnets are produced and assembled in the cryostat.

There is one cryostat on each side of the interaction region each housing all the SC magnets there. These cryostats are similar to these of KEKB but have been modified to include the new magnets and the larger crossing angle. The cryostat supports will likely be made of special materials to minimize quadrupole vibration from ground motion.

The SC quadrupoles and cryostats will be made in industry. Final designs will be finished in about six months allowing industry to proceed with production. The establishment of design and production milestones will help with project management.

One of the important operational issues is to keep the two beams in collision vertically in the IR, where each size is on the order of 50 nm (Gaussian sigma). Vibration of the quadrupole magnets in the rings will cause the beams to move primarily vertically in the IR, so they do not collide head on. The luminosity can be quickly reduced with offsets larger than about 0.1 sigma. The most sensitive magnets affecting collision alignment are the IR quadrupole doublets. These magnets and their supports must be kept stable to about 10 microns. Recent studies indicate that the vibration is of the order of 50 microns. Studies to reduce this motion are ongoing. New absorbing support material is being tested to reduce the magnitude of the vibration. In addition, studies of the vibration of the sum of all the quadrupoles in each ring should continue to determine what general damping is needed to meet the tolerance for keeping the beams in collision. One potential method to reduce vibration is to add active inertial damping to the IR quadrupoles using a motion sensor and a small piezoelectric driven movable mass.

Recommendation 1) The Committee recommends making a clear set of milestones for the production of the IR SC magnets and cryostats so that progress can be carefully tracked.

Recommendation 2) Additional studies of beam vibrations from local IR magnets and global ring quadrupoles, including mitigations, should be done to bring the expected vertical beam motion within acceptable tolerances.

14) IR Vacuum Chamber and Assembly

The updated version of the IR vacuum chamber has been presented to the Committee. The Committee appreciates the large effort made since the last meeting, which constitutes a considerable progress in the design of the IP vacuum system. The layout shows the warm bore magnets with their proposed beam pipes. The central section consists of a double walled Be pipe cooled by a paraffin cooling circuit to remove up to 270W heat load dissipated by the beam with a 10°C temperature rise. With the assumption of a rather conservative value for photon desorption yield of 10-5 molecules /photon, a pressure of 10^{-6} Pa has been estimated.

The pumping system relies entirely on the internal NEG coating on the inner wall of the beam pipe. With the new warm bore design the beam pipes are no longer in contact with the magnet cold bore and can be heated to about 180°C for the NEG conditioning. Within the central region of approximately ± 3m no ion pumps have been foreseen. As a consequence of this design, the layout is extremely compact with very little space to accommodate all necessary vacuum components. The assembly procedure is conditioned by the accessibility of the vacuum flanges between the central beam pipe and the beam pipes and the QSC chambers. To make these connections at all possible, a minimised flange with a reduced number of bolts is proposed. A vacuum leak in this central location would imply a long intervention. The NEG coated vacuum chambers in the cryostats will serve in addition as radiation shield for the detector and it has been suggested to use Ta as the chamber material.

The Committee expresses its concern about the presented design, which leaves insufficient space and accessibility for vital machine elements. Since these design choices can have a big impact on the operational reliability, it is proposed to re-visit the over-all design.

The Committee draws the attention to the fact that in the absence of ion pumps in the central region of the IP vacuum system, the pressure profile may be dominated by inert gas species like hydrocarbons (CH4) and Ar, which are not pumped by the getter.

It is proposed to re-evaluate the vacuum to confirm that in the absence of a pumping speed for inert gases the design pressure can be met.

The concern about insufficient pumping capacity, i.e. the interval of NEG heating cycles depends critically on the total gas load. To minimize the gas load, ideally 100% of the surface should be coated with NEG. Therefore, it is proposed to reconsider the proposed Au layer on the inner surface of the central Be pipe.

NEG coatings have been deposited on several beam pipes in LHC experiments.

The main purpose of the getter film is low outgassing and low secondary electron emission after conditioning at ~180°C. Both effects remain after the surface is saturated with gas. Only about a monolayer will be strongly adsorbed on the activated getter surface and by comparison with a conventional technical metal surface this amount is very small. So the desired beneficial effects of the getter coating may be considered permanent. The persons in the LHC vacuum group may be contacted directly to get the latest, complete information.

The pumping effect of the getter is not considered to be relevant and there is no plan to recondition in-situ as long as the experiment is not demounted. Instead, in case of a routine intervention/opening of an experiment (Atlas) the central beam pipe is back filled to atmospheric pressure with ultraclean inert gas (Ar/Ne), which can be pumped out quickly and does not compromise the performance of the getter film.

The heating is achieved by specially developed thin heater foils (<~mm). The heaters are removed before the experiment is closed. The LHC Vacuum Group has developed with industry Kapton-foil heaters with the aim that they could remain in place. An on-going program is aimed at lowering the required activation temperature.

The effect of a temperature increase on a fresh or partially saturated getter film has certainly been studied in detail and should be available in the literature. A well understood temperature effect is diffusion and re-diffusion of solved H_2 in the getter film depending on the concentration profile. For other molecular species it will depend on the detailed adsorption process, e.g. dissociation and diffusion of C and O in the bulk. A higher temperature should enhance these processes but the concentration profile will determine the direction either into the bulk or to the surface.

A word of caution to the pumping with an internal coating on the beam pipe: it will be preferable to design the system such that the pumping surfaces are not directly exposed to synchrotron radiation, electrons and ions. In particular a cryo-pumping surface should not be exposed to synchrotron radiation, electron or ion bombardment since this will give re-desorption of the pumped molecules. For this reason one uses screens against thermal radiation in commercial cryopumps and in the LHC we had to install beam screens in the cold arc.

15) Beam Background

The Committee is pleased to see a strong joint effort of the accelerator team and the BELLE detector group; to optimize the interaction region and the machine detector interface, as had been recommended at the last meeting.

Touschek scattering in both LER and HER is one of the largest expected background sources. The simulations of KEKB background from LER Touschek scattering are in good agreement with the past observations at KEKB. The benchmarking of simulations against KEKB measurements is important and gives some confidence in the predictions.

However, the very small vertical beta functions in the IR and the larger crossing angle will make the backgrounds potentially higher in Belle-II compared to Belle and will also render the extrapolation of the present backgrounds to the new situation more difficult.

The IR losses from LER Touschek scattering are significant, amounting to 16% of all Touschek scattered positrons and to a heat load of 28 W within 6 m from the IP. These values should be compared with 1% and 60 mW for the present KEKB. The Committee endorses the attempts to install an additional collimator closer to the IP, to better shield the IR against Touschek scattered particles with large betatron amplitude, and to widen the beam pipe at the IR bottleneck.

The KEKB background arising from HER Touschek scattering was too low to be reliably measured. In consequence there exists a significant uncertainty in the corresponding background extrapolation to SuperKEKB. The effect of HER Touschek lifetime on SuperKEKB backgrounds should be studied in simulations.

The background due to the beam-beam interaction should be simulated. This includes both stored beam and injected beam.

After optimizing masks, IR chamber apertures, and beam pipe dimensions, about 200 photons per bunch passage with an energy above 5 keV hit the IR beam chamber within 10 cm of the IP. This number could increase in the presence of beam-beam tails and errors.

The IP losses for the injected beams should be studied under different injection errors for the 50 Hz injection rate for each beam. This study should include the enlargement of the injected beam by the beam-beam effect.

The Committee concurs that the most accurate IR magnet and vacuum-chamber geometry and the predicted magnetic fields be implemented in GEANT-4 simulations as soon as possible, so that a complete estimation of backgrounds can be made.

The Committee recommends completing the design of the vacuum chamber including pumping and cooling in the IR, so that better beam-gas background simulations can be made.

16) Orbit Feedback at IP

The need to keep the nanobeams colliding requires two active feedback systems, one vertical, and one horizontal. For each, a sensor of the collision error, and a strategy of control actuators are needed.

Essential work has been done to estimate disturbances to the colliding beam, mostly due to mechanical motion of the IP focus magnets. Are there any other mechanisms that must be understood, such as driven betatron motion from power supply or other noise?

A vertical error signal via beam-beam deflection is presented, and a rough system design using a PID algorithm to adjust fast correction magnets is estimated. The system dynamics are estimated via a tracking simulation study, and an analytic feedback loop model is presented as was requested by the last review Committee.

An acceptable collision offset is <10% of the beam sizes at IP. Estimation of magnet vibration amplitudes in SuperKEKB results in a vertical (and horizontal) collision offset of the order of sigma_y. Among all the components, the final focus quadrupoles give a dominant contribution. Their vibrational displacements go 1:1 into the IP orbit jitter. The measured vibration spectrum spans from a few Hertz and rolls off at a few hundred Hertz. A fast IP orbit feedback is needed to maintain the proper collision conditions.

As recommended by the last Review, serious R&D work has started developing and testing a concept and component design for the fast IP feedback. The required BPM resolution is found to be 4 times better (1micron) than in the existing KEKB collision feedback system. As detailed in the Diagnostics section a new BPM design is under way. A bandwidth of 1 kHz is presently specified, and the circuitry and kicker parameters are being studied. A preliminary result obtained by particle tracking showed the feasibility of the desired IP orbit stability; however this study raises many questions, particularly the selection of numerous feedback loop parameters, estimates of numerous system dynamic parameters. A solid feedback design based on the control theory analysis is in order.

What method is used to estimate the closed loop response, and choose among many control options? A step response slope method was illustrated to pick PID gains, but this doesn't seem to capture the complexity of the choices. How are the responses of the individual elements modeled? What numbers are really known, what are guesses?

What is the bandwidth of the Bessel filter used in analytic model of feedback loop filter? There does not seem to be any modeling of the CIC digital filter proposed in the diagnostics talks.

The example step response is oscillatory in slide 37, what is the phase margin? (A Nyquist plot shows stability but what are margins?). The closed loop disturbance plot of rejection shows amplification of disturbances in the 70 - 100 Hz range. This suggests that any noise in this band will be injected into the system, driving the beam to higher amplitudes at these frequencies than with the feedback off.

Overall comments – this is a good effort to study the problem but use of the tracking code is not best tool to develop the feedback. The Committee appreciates the effort to do analytical model, this is a solid start.

Is it helpful to have an amplification of signals near 70 Hz as shown? (What power spectrum comes in from the BPM? Can we alias higher frequency signals or noise into this band?)

Impressive, interesting and important problem, and we acknowledge the attention to date. This effort might benefit from consultation with a person with more of a control theory background to understand tradeoffs and critical specifications; more efficiently converge on possible solutions and requirements.

Recommendation – use simulink, other tools, and control concepts to study impact of various BPM filters, etc. The study should consider the use of optimal control methods to design the controller with methods besides PID, and compare useful response. The effort can evaluate and design several possible control loops, estimate the value of including compensation for the responses due to the magnet, power supply, and eddy current effects, predict and understand the control margins. Besides the step response, the study can use open loop magnitude/phase, closed loop gain and phase margins, etc. to help guide the design (root locus methods may also help design the control loops).

One of the unsolved problems is to find an adequate horizontal collision offset measurement to be used as an IP orbit feedback input. Whereas the vertical offset input is available from BPM response to the vertical beam-beam kick, the horizontal beam-beam kick is inevitably very weak in the Nano-Beam collision scheme where the horizontal beam-beam parameter is much smaller than the vertical one.

The concept still needs development of the horizontal error signal and control scheme; it is suggested to use luminosity dither. What bandwidth is possible via this error signal? What bandwidth and resolution is estimated for a practical luminosity monitor, and what processing is possible to determine a horizontal error signal, calculate a correction signal? This control loop and dynamics needs to be estimated, just as the vertical.

The Committee recommends a careful analysis of the fast IP orbit feedback performance with realistic parameters. The residual random orbit vibrations in the 10—1000 Hz range are not adiabatic in terms of the radiation damping time (~40 ms) and can cause dilution of the vertical emittance of colliding beams.

17) Magnet

The KEKB Group has done considerable work in the area a magnet systems spanning from; the dismantling and preparing for refurbishment and reuse of magnets from KEKB for SuperKEKB to the development of 400 new magnets that will shortly be ordered from industry for delivery at the end of March 2012; to the ongoing development of specialty magnets such as a rotating sextupole. It is this last element that is a major concern – the rotating sextupoles. The resources and funding of the SuperKEKB project are very limited. We recommend that the rotating sextupole be considered as a longer term item and be put into R&D program.

As a result of the design of new vacuum chamber ante-chamber, required extra damping by wigglers and requirement of reducing the emittance of LER, the dipole magnets, wigglers and some of the quadrupoles need to be redesigned to fit with the new vacuum chamber. The Magnet Group has removed the LER bending magnets, steering magnets, vacuum chamber and part of wiggler magnets from the tunnel. Most of the magnets, ~70% in number, in LER will be reused to reduce construction costs. Cooling water is being drained from the magnet coils as they are stored and prepared for reuse.

These newly designed dipoles, wigglers and some quadrupoles for the arc in LER are presently in an open bidding process with complete delivery by the end of March 2012. The specifications for these new magnets are similar to those magnets in operation.

The Magnet Group will measure the field quality of these new magnets. The field mapping system is under development. There are no prototypes of these magnets planned. It will be necessary to carefully measure the multipole components of the first article shipments for these magnets. These field-mapping results should ensure that high-order multipole components will have no impact in reducing the dynamic aperture.

The alignment network developed in the KEKB era is not sufficient. The Magnet Group is planning to add more permanent survey monuments to establish a new, more robust survey network allowing better control of the installation and future realignments. In one section of the ring tunnel ground settlement is observed to be ~2 mm/yr on average during the last 10 years. More recently (~3 years) this floor settling has reduced to ~1 mm/year. Orbit tuning with infrequent occasional re-alignment should solve this ground settlement issue. The data shows that there has been no realignment done in the last 10 years. However, for SuperKEKB with its very low emittance, a well-established alignment network and monitoring program will likely be required. The Magnet Group presented a series of interesting data documenting the structural and physical response of the tunnel and ring to the 1300T Belle II detector being moved out from the interaction.

The ripple control for the old QP power supplies will be upgraded to have better stability control for long-term operation. It maybe worthwhile to understand the variation of temperature-controlled oven used with the prototype power supply as opposed to the actual long-term stability of the power supplies.

18) Vacuum

The updated design of the vacuum system has been presented based on the new set of parameters for SuperKEKB. The most important changes result from the lower synchrotron radiation power. The construction of the LER vacuum chamber can now use extruded aluminum chambers instead of the original Cu chambers. Both rings will use the antechamber design to absorb synchrotron radiation and to accommodate linear NEG pumping. This design change results in a cost saving and uses the large in-house experience at KEK with all-aluminum vacuum systems. The HER will use copper chambers as presented previously to accommodate the higher synchrotron radiation power levels. To mitigate electron cloud instability in the LER, the aluminum profiles for the dipoles will be extruded with grooves on top and bottom of the duct. As presented at the last Review, various other means to limit the electron cloud build-up have been evaluated and are now available. These methods will be used to limit the average electron density to about 10^{10} e-/m^3 below the estimated threshold for the head-tail instability. The new wiggler sections will require copper chambers and will be fitted with a new design of electrostatic clearing electrodes.

Among the other main components, the bellows chambers with RF shields are well advanced in their design. The ion pumps of KEKB can be reused but new NEG ribbons will be required.

The Committee is presented with a detailed table of the different vacuum chambers, which are now well defined. A preliminary planning has been provided for this major part of vacuum system including a preliminary time schedule outlining the vacuum preparation for the TiN coating and bakeout.

The Committee congratulates the team for the impressive progress it has made. It gives confidence that this important system for SuperKEKB is well on schedule. With the main part of the vacuum system under 'control' the Committee recommends that an equally focused effort should go into the detailed design of the special items.

The project for the different versions of the movable masks has been going through several iterations as presented in recent MAC meetings. With the parameters for the low emittance beams, the design criteria have become even more demanding in terms of thermal strength, beam impedance and operational reliability. It may become necessary to split the project and to concentrate on a first version, which is based as much as possible on existing designs and thus accepting a lower initial performance at the start-up. This approach would gain time to search for radically new ideas. Over all this may not even be more expensive since these critical elements may not have an unlimited operational life anyway.

19) <u>RF</u>

The RF system parameters have changed significantly since the last review. In particular the HER voltage has returned to a level similar to the original KEK-B. The additional beam power at the higher current of the new machine will be supplied primarily by upgraded versions of the normal-conducting ARES cavities. By relocating some cavities from the HER to the LER and splitting RF stations from two cavities per klystron to one per klystron the overall power balance can be achieved without any new cavities being needed. The two crab cavity stations will be removed and in the final configuration two new RF stations may be added to the HER in their place. The "reversed phase mode" of the SCRF was successfully demonstrated in KEKB, however due to the high voltage now required in the HER it is now not required. The ARES cavity RF couplers will be upgraded to higher power and an improved coupler design has been developed and tested to 800 kW. The SCRF cavities can be used as they are for initial conditioning, but the external tuner drive systems will be refurbished. At full design current the beam pipe absorbers will approach their maximum design value due to the increased HOM power. Back-up solutions of higher power loads or lower impedance cavity system (using the same cavities but different beam pipe loads and tapers) are under development. The HOM loads for the ARES cavities have been verified to be adequate at the higher current with 30-50% margin. A back-up solution using SiC rockets instead of the tile absorbers on the grooved beam pipe has been developed. The full build-out of high power RF stations is not needed on day one and can be completed over time as the current is increased. Coupled bunch instability growth rates in the new configuration are within reach of the feedback systems even at the higher currents. The RF transients due to the abort gap will be more severe unless the gap duration is reduced. This requires faster kickers that are being developed.

If refurbishment of the SCRF cavities is required the capability for horizontal electropolishing has been reestablished on site at KEK. The original system at Nomura plating has been decommissioned.

A modern digital LLRF system is being developed for the upgraded RF stations. The existing analog systems will continue to be used but will be phased out over time as budget allows. The RF group does not anticipate any problems with the two systems running side by side. The new system will be better able to handle the large detuning of the single-cavity stations and will have many other practical advantages. The design and functions in the new LLRF system was not reported in detail, even on a block diagram level. The Committee would like to have a set of specifications for this essential function, including what signals are monitored, the controlled parameters, the expected closed loop bandwidth and regulation, etc.

The Committee finds that the plans for the main ring RF systems are in good shape. Both the ARES and SCRF systems are mature and well proven with good reliability. Needed upgrades have been tested and there are no outstanding technical concerns.

20) Cavity for Damping Ring

The requirements of the damping ring RF system have increased significantly since the last review as a result of concerns about CSR-induced beam instability. The installed voltage has grown to 2MV, requiring three RF cavities with up to 0.7 MV each. While simulations suggest that CSR may be a concern the plan is to install two RF cavities on day one (1.4 MV) with the option to upgrade if CSR effects prove to be significant. The Committee endorses this approach. The damping ring cavity design is based on the ARES accelerating cell, without the coupling or storage cavities but with the full compliment of HOM dampers. The space is tight for 3 such accelerating cavities requiring some redesign of the HOM loads and beam ducts between cavities. The proposed solution has no bellows between cavities and welded-up joints with captive RF spring-fingers rather than bolted joints. The Committee has reservations about this concept from the point of view of reliability and future maintenance. Since the cavities are all new the Committee recommends consideration of alternative configurations that could simplify the layout. In particular if one pair of the vertical waveguides on each cavity were to be rotated to the horizontal plane the grooved beam-pipe absorbers could be eliminated. This would allow simple circular beam pipe between the cavities allowing the possibility of bellows and flanged joints. Tuner, power coupler and HOM load components could all be the same as the storage ring cavities, although the actual power requirements are significantly lower.

The damping ring cavity presentation suggested that transverse HOM driven instabilities are damped by synchrotron radiation, yet the diagnostics talks listed a transverse feedback system for the damping ring. The Committee wonders what estimates exist for resistive wall impedance growth rates, and the specification of the instability feedback requirements for the damping ring

Recommendation: re-evaluate the proposed damping ring RF cavity configuration, in particular the concept of not using flanges between cavities needs to be re-evaluated considering only two cavities will be used in the beginning of operation but later upgrades and maintenance may be required.

21) Control

This was a very complete summary of the existing controls history of KEKB, LINAC and the recent efforts to develop a lab-wide common controls framework. The approach is very realistic, planning to use existing systems and features, and add new technology as needed. The many collaborations with partner labs, and use of standards is very significant and a positive aspect of the approach.

The overall operation of multiple "virtual accelerators" with independent control loops is solid and impressive. The issue of how to integrate the timing requirements for the PFAR with the 508 MHz RF of KEKB, Damping rings is probably worth understanding now, even if it is not an operational need in the very near term. There may be a future facility that would require such a synchronization of extraction from the damping ring, and it seems well worth the effort to understanding how this might be implemented.

The planning to develop the microTCA and other interconnect and communication standards should be coordinated with collaborator labs. The work at KEK is certainly something to share with other labs (other labs could benefit from this effort, and possibly contribute functions and modules, and codes to the overall suite of control functions).

Appendix A

KEKB Accelerator Review Members

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

Appendix B

Agenda of the 16th KEKB Accelerator Review Committee

February 7-9, 2010
In the meeting room on the first floor of Building No.4, KEK Tsukuba, Japan

Date / Time	*Subject*	*Presenter*
Feb. 7 (Mon)		
8:30 - 9:00	Executive Session	
9:00 - 9:15	KEK Roadmap	A. Suzuki
9:15 - 9:45	Belle II Experiment	Y. Ushiroda
9:45 - 10:15	SuperKEKB Design Overview	H. Koiso
10:15 - 10:45	Construction Plan	K. Akai
10:45 - 11:05	Coffee Break	
11:05 - 11:45	Lattice Design	A. Morita
11:45 - 12:25	Error Tolerance and Optics Correction	Y. Ohnishi
12:25 - 13:30	Lunch	
13:30 - 14:00	Beam Dynamics Issues for Nano-Beam Scheme	K. Ohmi
14:00 - 14:45	Injector Upgrade Overview	T. Higo
14:45 - 15:15	Emittance Preservation in Linac	M. Yoshida
15:15 - 15:35	Coffee Break	A. Morita
15:35 - 16:15	Damping Ring	M. Kikuchi
16:15 - 16:35	Beam Transport	N. Iida
16:35 - 17:20	Beam Diagnostics	H. Fukuma
Feb. 8 (Tue)		
8:30 - 9:00	Executive Session	
9:00 - 9:40	IR Overview & Magnets	N. Ohuchi
9:40 - 10:10	IR Vacuum Chamber and Assembly	K. Kanazawa
10:10 - 10:30	Coffee Break	

10:30 - 11:00	Beam Background	H. Nakayama
11:00 - 11:20	Orbit Feedback at IP	Y. Funakoshi
11:20 - 12:05	Magnet	M. Masuzawa
12:20 - 13:30	Lunch	
13:30 - 14:15	Vacuum	Y. Suetsugu
14:15 - 14:45	RF	T. Kageyama
14:45 - 15:00	Cavity for Damping Ring	T. Abe
15:00 - 15:30	Control	
15:30 -	Executive Session / Report Writing	
Feb. 9 (Wed)		
8:30 - 11:00	Executive Session	
11:00 - 12:00	Close-out	
12:00	Adjourn	