The 2019 CEPC International Accelerator Review Committee

Review Report

December 6, 2019

Overview

The review meeting overlapped with the 2019 International Workshop on High Energy Circular Electron Positron Collider (CEPC). The International Accelerator Review Committee (IARC) reviewed the talks in the accelerator and machine-detector interface (MDI) sessions of the workshop. Talks not specific to CEPC have been omitted.

The IARC was pleased to see the progress on the work performed up to now toward the TDR. The quality of the work performed, how most important issues were addressed, even if not already solved, and how there is still design work on-going to increase the luminosity performances at Higgs and Z were highly appreciated. Some suggestions for improving the format of the review are summarised in the final section.

The IARC is pleased to see efforts for several improvements over the CDR. The IARC would like to thank Jie Gao, Dou Wang, Zhaoru Zhang, and the CEPC team for their help and hospitality during the meeting.

Answers to the charges

1) Are the project parameters clear and reasonable?

Several improvements on the design parameters over the CDR have been presented including:

- higher luminosity at H (5.2×10^{34} vs 2.9×10^{34})
- "High-Lumi" for Z (102×10^{34} vs 32×10^{34})
- assure compatibility for top-pair production at the appropriate energy (~365 GeV)
- higher energy injection into the booster with a longer linac
- capability to handle 50 MW/beam synchrotron radiation (SR) power
- compatibility with SppC collider layout.

All of them expand the capability of the project with a moderate increase of the cost. The IARC would therefore like to endorse all of these improvements. These improvements may not be necessarily installed at Day-1, but the extendability and compatibility should be secured.

It is suggested that the new parameters should be defined as a "new baseline", to make all systems consistent with them. Proper documentation database and approval procedure for new baselines must be established, to achieve coherence through the entire project.

All related parameters including RF and the injector should be re-optimised to match the new baseline. Separate types of RF cavities should be optimised for each energy using bypass lines.

2) Does the progress match the goal of the TDR:

The IARC recognizes the strong rise of activities by new staff, industry, and international collaboration. However, to answer this question, the "goal" must be clearly stated consistently.

Not every technical detail and drawing will be necessary at the completion of the TDR. The project should clarify the exact timetable by when each detail will be necessary, including prototyping.

3) Are the R&D items correctly identified?

The IARC would like to endorse the following R&D items:

- CEPC 650 MHz 800 kW high efficiency klystron (80%) (No commercial products)
- High-precision booster dipole magnet (critical for booster operation), which depends on the adoption of >20 GeV linac, see recommendation 2-10
- CEPC 650 MHz superconducting (SC) accelerator system, including SC cavities and cryomodules
- Collider dual-aperture dipole magnets and dual-aperture quadrupoles with the real lengths
- Vacuum chamber system including coating, SR handling, etc.
- Interaction region (IR) SC magnets including cryostats and mechanical structures
- MDI and its mechanical system
- Collimators & collimation scenario
- Linac components incl. e+ source and damping ring (DR)
- Injection/extraction schemes with necessary components
- 18 kW@4.5K cryoplant (by company)

The details of each item will be addressed in the rest of this report.

4) Evaluation or suggestions on team and international collaborations

One thing the IARC suggests is that each presentation or document must indicate the names of each team working in that area, sources of expertise consulted, tools which are used, etc.

International and domestic collaborations are highly recommended in several critical areas, eg., MDI, SC-RF, polarization, beam dynamics (beam-beam, dynamic aperture, etc.), C-band linac, RF sources, information technology, etc.

Current on-going bilateral international collaborations with BINP and KEK are very fruitful. They can be possible models for future collaborations.

Major international collaboration such as the ILC and the HiLumi LHC can be a model of extended international collaborations.

5) Is there any missing or weak point during the TDR study

Better communications between accelerator and detector communities will be more & more important to finalize the TDR. For instance, the 2T/3T choice of the detector solenoid is taking too long. Another example that needs better communication is the length of the solenoid iron yoke. The project management should set up a high-level working group between accelerator and detector representatives to define a workable scenario for the MDI area to allow work to continue on the accelerator design.

Other missing points will be noted in the rest of the report.

Report on Presentations

1. CEPC accelerator (Jie Gao)

Findings & comments

The IARC appreciates the efforts of the CEPC accelerator team after the CDR for further improvements and optimizations in various parts of the project, as already written in *Answer to the Charge #1* in this report.

Recommendations

See *Answer to the charges*, above in this report, esp. #1 - 3.

2. CEPC beam dynamic key issues (Chenghui Yu) & **CEPC collider ring lattice design** (Yiwei WANG)

Findings & comments

Work on the collider lattice continues, with a lot of effort by a limited number of people. A new “Higgs high luminosity” lattice was presented. To double the luminosity, reducing β_y* and horizontal emittance, while keeping under control the synchrotron losses, a higher dipole filling factor for the lattice was chosen, with a shorter arc cell, longer dipoles and 10% more quadrupoles. At the same time, to decrease the contribution to the radiated power by the interaction point (IP) quadrupoles, the QD0 and QF1 were lengthened (the QD0 was split in two) and have lower gradients, while keeping L* the same. This should improve the dynamic aperture. As a result, both the upstream and downstream critical energies have been decreased (upstream 45 to 25 keV, downstream 97 to 37 keV).

Dynamic aperture (DA) studies, without magnet errors, for the old/new lattices were presented and compared. The need for crab-waist sextupole correction at 100% is to be verified: FCC-ee's best is 80%, for SuperB (see simulations by D. Shatilov for SuperB in 2006) the best value was between 40% and 60%. This should improve DA, lifetime and beam-beam tails.

The off-energy aperture is only 1.5% while 1.7% is recommended: one conceivable solution is adding a weak decapole inside the IR in a dispersive region. Also, in SuperB a sextupole in the dispersion-free region close to the IP chromaticity correcting pairs helps with the off-momentum particles.

The lifetime for high N_{part} is an issue. The present limit is $N_{part} = 11x10^{10}$, while the new design is $N_{part} =17x10^{10}$: solutions should be studied. DA calculations with magnet errors were not shown for the new lattice. The behaviour of the emittance as a function of beam current in the new lattice with higher charge/bunch should also be checked.

The effects of beam-beam and fluctuations on the DA are an issue, in particular fluctuations seem to have an important role in reducing the vertical DA. The same effect, even if milder, was found in FCC-ee. Strong-strong BB simulations need to be performed on the new lattice, checking coherent BB and flip-flop instabilities, since tunes and beam parameters strongly depend on that. With BB, the vertical beam size blows up to 12 σ_y. What happens at Z running (»$30x10^{34}$) should be investigated. The present DA is about 15 σ_y. Dmitry Shatilov recommended a DA of 50 σ_y for FCC-ee. Only 145 turns of tracking was shown, which corresponds approximately to 2 damping times at the Higgs. At the Z, the damping time should be around 1000-2000 turns.

The studied increase of the β_x at the injection point, as well as a decrease of the booster emittance will hopefully help in dealing with the small DA at injection even for the off-axis case.

A pre-booster from 10 to 45 GeV is being considered in order to avoid the necessity for very low field booster dipoles. The presented extension of the Linac energy to 20 GeV, 200m longer than the baseline, looks to be a wiser choice rather than building a new pre-booster ring, as also suggested. This will relax the requirements for the booster magnets.

A higher-order-mode (HOM) absorbing section (in the Y-chamber) is not mentioned. If it is needed, is 1.1 m from the IP to the cryostat enough to accommodate all equipment?

A concern is the alignment and support of QD0 inside the detector: the effect of vibrations has to be checked, and whether IP feedback is needed to maintain orbit and luminosity.

An orbital fast-feedback system to adjust the beams collision should be foreseen in the MDI section.

For online measurement of the magnet position inside the FF cryostat during cooling and detector-field switching, two recommendations can be made (1) stretched wire through the whole IR from one side of the detector to another to measure the magnetic field on the beam axis (as done at SuperKEKB), (2) laser-tracker system through the windows in the cryostat (there is an example at Argonne Lab with alignment of a superconducting undulator inside the cryostat).

Recommendations:

2-1. Performances of the new lattice should be checked at all CEPC operating energies.

2-2. More work is needed on the Dynamic Aperture: the DA with magnet errors for the different energies/lattices should be checked; the correction of 2nd order chromaticity and 2nd order dispersion for increasing off-energy DA should be optimised; the DA with a lower crab sextupole setting (40%-60%) should be calculated; the DA with beam/luminosity parameters corresponding to Z operation (both low and high luminosity options) should be simulated. Longer final quadrupoles to reduce the effects from radiation fluctuation should be considered.

2-3. The behaviour of emittance as a function of beam current in the new lattice with higher charge/bunch should be checked.

2-4. The sensitivity of IP quadrupoles misalignment should be relaxed to 100 μm (instead of 30 μm), a much more realistic value according to SuperKEKB experience. The orbit/vertical dispersion/beta-beating corrections with this higher sensitivity should be studied more carefully.

2-5. The lifetime for higher bunch current for high-luminosity Higgs operation is an issue.

2-6. The working point should be moved further from the synchro-betatron resonance line.

2-7. Coherent beam-beam and flip-flop instabilities should be checked with strong-strong simulations, since tunes and beam parameters strongly depend on that.

2-8. Beam-beam and orbit fast-alignment feedback systems should be considered.

2-9. Magnet alignment inside the cryostat should be considered. Closer contact with the mechanical group to address the IP mechanics is recommended.

2-10. Extending the Linac energy (20 GeV, presented, just 200 m longer than baseline) will solve the low-field booster-magnets issue. The cost of this option should be evaluated.

3. CEPC booster and damping ring (Dou Wang)

Finding & Comments

The injector chain of CEPC was described, consisting of a 10 GeV linac providing electrons and positrons into a booster for the top-up injections into the collider rings. Parameters are available for operation at the Higgs, W and Z mass energies. Both on-axis and off-axis injection into the main rings are possible at the Higgs energy. An acceptable dynamic aperture was found when simulating the booster with conservative errors on magnet alignment/strength/multipole and beam-position monitors (BPMs), both at injection and Higgs energies. The effect of the earth's magnetic field was studied, which leads to unstable behavior unless the beam pipe is systematically shielded. A global closed-orbit distortion correction is expected to solve this issue and will be tried. A significant cost reduction of 30-50% on magnet and power supplies is considered by reducing the beam pipe from 55 to 44 mm. A new lattice to reduce the emittance, which can relax coupling correction requirements and facilitate on-axis injections at the Higgs mass energy, was also studied with satisfactory results. Progress designing feedback necessary for both the transverse and longitudinal motion to mitigate the multi-bunch instability at the injection energy was reviewed. The damping ring (DR) design was reviewed, including impedance, coherent synchrotron radiation (CSR) and intrabeam scattering (IBS) effects. The parameters of the energy compression and bunch compression were also presented, along with simulation results of the emittance evolution in ideal conditions.

Recommendations

3-1. A larger separation of the horizontal and vertical tunes in the booster could be tried to mitigate stability issues in the presence of the earth's magnetic field.

3-2. All possible impedance sources should be considered in the damping ring.

3-3. Simulation study of the energy/bunch compressors (EC/BC) with errors should be carried out.

3-4. Start-to-end simulation with complete set of errors in linac, DR, booster, EC/BC and main ring to check overall efficiency should be carried out.

3-5. Instrumentation and beam-tuning scheme to control beam parameters in top-up injections, including to reduce effects from beam tail/halo particle loss on detector backgrounds and the final focus (FF) quadrupole quenching should be devised.

3-6. Flexibility to use the DR also for electrons to reduce beam jitter arising from the gun and the low-energy part of the linac should be retained.

4. Imperfection and correction for CEPC (Yuanyuan WEI)

Findings and comments

Excellent results in emittances and beta beatings with misalignments and corrections have been obtained with 100, 50, 30 μm/μrad for arc magnets, IR quads, and final focus quads, respectively, as well as 0.01%/0.02% dipole/quadrupole field errors. The resulting dynamic aperture more or less satisfies the requirements on the injection and lifetime.

It was not clear in the presentation slides whether the misalignment of sextupoles combined with dipoles is taken into account. Also the correction scheme starts by turning off sextupoles for bootstrapping, but this is not possible for such combined sextupoles.

Recommendations

4-1. Explore further enlargement of the alignment tolerances for the IR/FF quads by making use of corrector windings on those quadrupoles.

4-2. Consider the use of trim windings of sextupoles to work as normal and skew quadrupoles and dipoles to eliminate additional correctors in the arc.

4-3. Estimate the vertical emittance with errors by tracking to include effects due to synchro-beta resonance and SR in each magnet.

4-4. Estimate the tolerances for those dipoles combined with sextupoles, as well as the bootstrapping process of the correction including these sextupoles.

5. Study and optimization of the CEPC dynamic aperture with the help of Accelerator Toolbox code (Kseniia Kariukina)

Findings and comments

The possibility of CEPC dynamic aperture optimization with the help of the Accelerator Toolbox (AT) was discussed. AT is an open collection of accelerator design and optimization tools and algorithms realised in the MatLab platform. It is rather popular among synchrotron light-source designers and possesses the powerful optimization genetic module NSGA-II.

In the talk, the example of the NICA heavy-ion collider was used. The main source of the NICA nonlinearity comes from the octupole-like quadrupole fringe-fields caused mainly by the final-focus quadrupoles. With the help of properly inserted octupole magnets, AT improved the NICA transverse DA by 40-50% by proper control of the betatron tunes as a function of the betatron oscillation amplitudes. The same method can be applied to the CEPC lattice.

Recommendation

5-1. Continue study of the CEPC nonlinear beam dynamics using the Accelerator Toolbox software and try to increase the CEPC dynamic aperture by controlling the tune-amplitude dependence by additional octupole magnets.

6. CEPC Z-pole polarization (Zhe DUAN)

Findings & Comments

A valuable investigation of possibilities to obtain small levels of transverse beam polarization has been pursued. This would enable precise energy calibrations at the energies of the Z- and W-boson pairs through the resonance depolarization technique, as well as longitudinally polarized colliding beams, to benefit the Z and W physics programs. To obtain small levels of transverse polarization, self-polarization through the Sokolov-Ternov effect is enough when wigglers are used to boost the build-up rate. A key issue that has been identified is the understanding of the errors affecting the resonant-depolarization technique. For > 50% colliding-beam polarization, the self-polarization time is too long compared to typical beam lifetimes at high luminosity. However, with continuous injection, suitable levels can still be obtained if the beams are produced polarized at the source. The main tasks being addressed are the design of spin rotators, production of polarized beams at injection, mitigation of depolarizing effects and investigation of whether or not there are detrimental effects from very high luminosity. While producing a polarized e- beam is a mature technology, for the e+ beam a combined damping + polarizing ring is considered, involving however a challenging 15 Tesla SC magnet.

Several questions on the presentation:

- Why is a longitudinally polarized e+ beam not considered essential along with the longitudinally polarized e- beam?
- Are there biases between the energies of non-colliding pilot bunches and regular colliding bunches, e.g. through (1) the beam-beam deflections in the presence of residual offsets at the IP and resulting path-length differences through the RF cavities, and (2) the beam-beam effects affecting the colliding bunches ?
- Are there significant depolarizing effects from the beam-beam interaction to take into account for the evaluation of the polarization level ?

- Could the damping + polarizing ring also be feasible with a lower than 15 Tesla dipole?

Recommendations

6-1. Quantify any trade-off between longitudinal polarization level and the potential reduction of the luminosity for the Z and W physics programs.

6-2. Quantify the precision goal for energy calibrations through the resonant-depolarization technique (relevant in context of understanding errors affecting this technique).

7. CEPC collective instabilities in collider, booster and damping rings

(Yu dong LIU)

Findings & comments

Careful studies of collective effects and impedance budget were presented for all rings. The impedance budget for all components was estimated.

Resistive wall impedance with partial coating with non-evaporative getter (NEG), electrostatic-separator impedance and optimization, collimator impedance, transverse-mode coupling instability (TMCI) and microwave instability (MI) with bunch lengthening, e-cloud instability and the secondary electron yield (SEY) measurements, were studied for the collider rings.

When considering the bunch lengthening in the collider, due to the impedance or beamstrahlung, the transverse effective impedance decreases, due to its dependence on the bunch distribution, and the TMCI threshold increases. The Microwave Instability may reduce the luminosity due to the deformed beam distribution and the increase of the beam energy spread. The design bunch intensity is just above the MI threshold, and turbulent distributions are observed above the threshold. The solutions are to decrease the impedance and optimise the beam parameters (α_c, σ_l, σ_E). The impact of this on the luminosity performances should be evaluated.

A “partial” NEG coating (1 μm) in the beam pipe will help with the RWI with no impact on the machine impedance. For Z operation, a shorter bunch spacing is needed (25 ns) and e-cloud instability will be a serious issue. An apparatus has been set up and SEY measurements for different coatings have been performed.

The threshold for resistive wall instability in the booster was evaluated. Al was chosen as the material for the vacuum chamber of the Booster.

The beam-current threshold in the damping ring was evaluated; the e-cloud will not be a problem.

The number of collimators is shown at around 2-4. Taking into account the necessary freedom required for tuning, the number of the collimators is extremely insufficient. According to experience in other colliders such as LEP, KEKB, PEP-II, SuperKEKB, 10-20 of them may be needed per IP.

Recommendations

7-1. Evaluate the impact of a change of beam parameters (α_c, σ_l, σ_E) on the luminosity performances.

7-2. Make the partial NEG coating of the positron beam pipe in vertical and not only in horizontal, as this will also help with e-cloud.

7-3. Estimate the tune shift due to the image current in the case of an elliptical chamber.

7-4. Install a sufficient number of collimators in several betatron phases relative to each IP.

7-5. The SEY for 25 ns bunch spacing is larger than the limit, which is set at 1.3. Consider additional e-cloud mitigation methods.

8. CEPC linac dynamics with S+C bands (Cai Meng)

Findings & Comments

A preliminary analysis of the availability of the linac was obtained using the RAAS Monte Carlo availability analysis program. Based on 15% redundancy for the accelerator components, the linac availability was shown to increase from 85 to 96%. Increasing the linac energy is considered to enable raising the injection energy into the booster, which would be important to avoid very low magnetic fields, and to mitigate potential instabilities at very low energies. C-band and S-band RF solutions are considered for a 20 GeV linac. An option for a plasma-wakefield acceleration based 45 GeV linac was also presented. Lattice design and beam-dynamics studies with errors show that the 20 GeV S/C-band

20 GeV linacs meet the requirements. Such a linac would be feasible, however the associated cost was not discussed.

Questions on the presentation:

- Cost/benefit relation of obtained availability with respect to required redundancy fraction. Are some accelerator components more important than others ?
- In the C-band solution for the alternative linac, why is the C-band RF used only beyond 4 GeV, and not for instance right after the DR?

Recommendations

8-1. Benchmarking / comparison of RAAS availability analysis program with other similar programs (e.g. AvailSim 1.0 and 2.0).

8-2. More detailed evaluation of the bunch compression down to 0.5 mm may be needed for the C-band 20 GeV linac solution.

9. CEPC plasma injector status (Wei Lu)

Findings & Comments

Plasma-wakefield acceleration (PWFA) is an area of great growth and substantial progress in current accelerator physics. The proposed solution for a PWFA injector is still at the conceptual stage and requires a significant amount of R&D before even a conceptual design can be ready. The proponent estimation of five years until a detailed design can be produced is ambitious but not impossible. A substantial number of tests is proposed, many of which can be done at low energy in facilities in China, notably at Tsing-hua and the Shanghai XFEL facility under construction.

While major advances have been made recently in electron PWFA, including by the proponents at Tsing-hua, progress with positron acceleration is much more limited. Positrons are only readily available at the FACET facility at SLAC, currently closed for upgrade to FACET II but due to reopen in the next few months. Positron acceleration is much more difficult due to the asymmetry caused by the much heavier positive ions compared to the plasma electrons. The proponents described a programme of development to investigate positron acceleration, including experimental investigations at FACET-II. The proponents will investigate three main techniques for positron acceleration, all of which require the plasma to be shaped by different forms of diffractive masks illuminated by a high-power laser. These techniques are still under investigation in the community and further significant R&D is required before they can be considered mature.

While basic feasibility and availability are clearly the main issues for such a PWFA/LWFA based injector, how to ensure minimal beam quality into the collider ring will be another hurdle. Control of injected emittance and tails are quite important to avoid backgrounds and SC magnet quenching in the continuous injection scheme.

The major challenge here is to design a completely reliable production system. If the injector is not close to 100% reliable, CEPC will fail. Although there is now an enormous amount of activity in the field of PWFA, to date the only system to produce accelerated beams via laser-driven plasma wakefield acceleration (LWFA) in a "production" way is the LUX beamline at DESY, where recently the facility produced beams for roughly 24 hours with almost no down-time. To take a MUCH more ambitious system and extend its reliable operation from one day to years, for a TDR for CEPC to be produced by 2022 seems impossible. However, a TDR addendum that may be implemented as an upgrade a few years later may be possible.

Recommendations

9-1. Continue intensive R&D to converge on techniques for electron acceleration, but particularly positron acceleration, as close to 2022 as practicable.

9-2. Once an outline scheme is decided on, concentrate on proving the principle of the delivery of beams in a highly reliable way with ~100% uptime.

10. CEPC light sources applications (Huang YONGSHENG)

Findings & Comments

The possibility to have very high energy photons with very high flux opens the way to many new industrial and material science applications of synchrotron radiation in the collider. In particular the insertion of undulators and wigglers could provide a flux larger than 10^{13} – 10^{16} photons/sec, a huge factor beyond the current state of 3rd generation light sources. However, the focusing of such hard X-ray beams needs new technologies, and the high stored current could be a problem for the beamline instrumentation.

The insertion of wigglers or undulators in the CEPC lattice can be a challenge for the dynamic aperture. The difficulty of designing beamlines for a deep underground tunnel should be carefully considered. Since the collider operation will be in top-up mode to fulfill integrated luminosity requests, the parasitic operation of SL beamlines can also be an issue.

Using the gamma rays from the CEPC collider is an interesting idea. However, it is always very difficult to change the lattice or install insertion devices after the optimization of the lattice for the collider. The SR station will need many kinds of timing signals.

Recommendations

10-1. The case for these experiments should be clearly justified and stated since the impact on the machine design and operation are not negligible.

10-2. Keep tight contact with the lattice design team as well as the control/timing division.

11. CEPC SCRF systems (Jiyuan Chai), CEPC SC cavities and SC Lab status (Peng SHA)

Findings & Comments

A large number of new options compared to the CDR are now being considered for the SCRF system. The main reason for examining new options is to double the luminosity for the Z option by increasing the beam current.

A list of TDR tasks for the system was given as:

- Simulation and experiment on HOM power generation and propagation through multi-cavity string and HOM couplers, absorbers and practical HOM damping scheme. Cryomodule design for HL Z.
- Optimize HOM damping of most dangerous mode to the CBI growth time that longitudinal bunch-by-bunch feedback system can deal with. Details of cavity shape, asymmetry, beam pipe diameter, HOM coupler shape and orientation, etc..
- Develop time-domain simulation code for beam-cavity interaction using Elegant initially.
- Finalise Booster RF ramping and stability.

The main limitation for the CDR system is the HOM power coupler. There are several ways to approach this problem. One being examined is to have single-cell cavities in the collider ring which can then cope with the power requirements at the Z. However, if they are also to serve the requirements for Higgs running, very large gradients are required to deliver the necessary acceleration. The aim specified is 45 MV/m with a Q of $4 * 10^{10}$. This would be the highest specification for a machine yet required and very few cavities exist that meet it.

An outline plan for the R&D requirements for the TDR and required resources including FTEs in the period 2020 – 2023 was given. An ERL scheme was examined but not considered useful as it is likely to be expensive and taking cooling costs into account may not reduce the power requirements.

Prototypes of the 2-cell cavities have been produced, both fine and large grain. Both work well. One cavity (BCP, buffered chemical polishing treated, without Nitrogen-doping) reached 3.2E10 @ 22 MV/m, close to the required specification. Generally the cavity testing is limited by field emission, not quenching. Electropolishing was successfully demonstrated on 1.3 GHz single-cell cavity, with over 40 MV/m and Q ~ 10^{10}. Nitrogen doping also successfully tested on 1.3 GHz, single-cell cavities, giving improvements in Q by factor >~ 2 but with gradient limited to around 20 MV/m. The HOM couplers and cryomodules have been manufactured and tested successfully at low power.

Industrialisation of 1.3 GHz 9-cell cavity production is being pursued with two companies. This is being carried out within the context of the production for the SHINE Shanghai XFEL project, for which IHEP is responsible for a fraction of the cavity production. As yet, chemical surface treatment is not possible inside the SRF lab, which is an essential element in the success of developments for Euro-XFEL etc. High-pressure-vessel code needs to be developed. Database specification for production control is being developed. So far 7 9-cell 1.3 GHz cavities have been produced for SHINE R&D and vertically tested. They will be delivered to Shanghai for module test assembly.

The New SRF Laboratory at Huairou is under construction and should be commissioned by mid-2020. Its capacity will be 200 ~400 cavities (couplers) tests, 20 cryomodules assembly and horizontal tests per year. There is also a new IHEP electro polishing (EP) Facility at Ningxia, developed in collaboration with KEK. Longer-term R&D including issues such as Niobium-Tin and High-Tc surface coatings are being explored.

In summary, excellent progress in both R&D and the development of facilities such as EP etc. for large-scale production in collaboration with industry is noted. Many successful tests have been carried out. The IHEP team is to be congratulated.

Recommendations

11-1. It is important to make a clear distinction between long-term R&D, such as high-Tc coating of cavities, peripheral development, such a Centrifugal Barrel Polishing, and high-priority items to produce industrial-scale production required for CEPC construction. Given limited resources, particularly of staff, priority must be given to the latter.

11-2. Optimisation to produce the required performance for the higher luminosity Z running is essential. Using single-cell cavities in the collider ring also for the Higgs running gives cavity performance requirements not yet regularly achieved anywhere in the world. A scheme with bypasses is more realistic.

12. CEPC cryogenic system (Shaopeng LI)

Findings and comments

The salient features of the CEPC cryogenic system are a 2K refrigerator using superfluid He and a high heat load. The cryogenic group at IHEP has manufactured 58 1.3GHz 9-cell cryomodules for Euro-XFEL in cooperation with domestic companies that proves the required practical experience of the group. A test platform of the SC cavity (PAPS), consisting of three vertical test stations, two horizontal test stations and one beam test station is being constructed from 2017 in the Huairou district and will be completed next year. A dedicated Test Platform of 2K JT heat exchanger is in operation.

The concept of the cryo-plant and R&D activities look adequate to the goal; however the system performance will be determined by the technical details. For instance, one of the problems during Euro-XFEL cryo-plant operation was related to the bearings of the cold compressor motors.

Estimation of the technical requirements and a preliminary design for the cryogenics for the SppC SC magnets will be required once the basic scheme is established.

Recommendations

12-1. Presume a cascaded pressure regulation in combination with the automatic heat load compensation, which can improve the pressure stability significantly.

12-2. Continue R&D works on the 18 kW@4.5K cryo-plant, 2K JT heat exchanger and the cold compressor.

12-3. Provide international co-operation with scientific centers having experience in the design and operation of novel cryo-plants, such as DESY (2 years experience in the operation Euro-XFEL cryo-plant) and JINR (design and construction of 8 kW@4.5K cryo-plant).

13. CEPC 650 MHz Klystron (Zusheng Zhou)

Findings & Comments

The goals and parameters for the klystron development are: 650MHz/800kW CW with more than 80% efficiency, 1st prototype tube being prepared in parallel with plant and infrastructure preparation.

The work is being performed within a recently established “High-efficiency klystron collaboration consortium”, including IHEP & IE (Institute of Electronic) of CAS, and Kunshan Guoli Science and Tech.

The timeline presented was a follows:

- 2016 – 2018: Design conventional & high efficiency klystron
- 2017 – 2018:Fabricate conventional klystron & test
- 2018 - 2019 :Fabricate 1st high efficiency klystron & test
- 2019 - 2020 :Fabricate 2nd high efficiency klystron & test
- 2020 - 2021 :Fabricate 3rd high efficiency klystron & test

This work has two key positive aspects and is encouraged. Recent progress in design and simulation of high-efficiency klystrons is being pursued and benchmarked with prototypes. A new “consortium” is being organised to produce high-efficiency klystrons - there are only a handful vendors world-wide - which can benefit the field overall.

Recommendations

13-1. Continue the development of the high-efficiency klystron together with the newly formed consortium.

14. CEPC injection/extraction, transport connection lines (Xiaohao CUI)

Findings & comments

The optics of transport lines and some basic considerations of injection and extraction were presented. The Injection time structure and some other parameters changed to match the requirement of hardware. More optimization is needed with the collaboration of magnet designers. Machine errors will be added as the next step.

Recommendations

14-1. Explore the compatibility with possible changes beyond the CDR, esp. for High-Lumi Z option. Another possible extension is the use of the damping ring in addition for electrons. These options may not be installed at "Day-1", but the extendability should be preserved.

15. CEPC injection/extract hardware R&D (Jinhui Chen)

Findings & comments

There are 9 injection and extraction sub-systems in the CEPC accelerator complex:

1. DR injection and Extraction system (e+)
2. Booster low energy injection system (e+,e-)
3. Booster Extraction system1 (e+,e-) - Off-axis injection in W, Z mode
4. Collider off-axis injection system (e+,e-). - Off-axis injection in W, Z mode
5. Booster Extraction system2 (e+,e-) - On-axis injection only in Higgs mode
6. Booster high energy injection system (e+,e-) - On-axis injection only in Higgs mode
7. Collider swap out injection system (e+,e-) - On-axis injection only in Higgs mode
8. Collider swap out extraction system (e+,e-) - On-axis injection only in Higgs mode
9. Collider beam dump system(e+,e-)

A Lambertson magnet is the first choice for the extraction septa, since there is a height difference between the machines. Lambertson is considered more reliable than other types of septa with typical septum wall width of 2mm to 10mm.

The choice of kicker is determined by the injection scheme, the waveform of pulse and the required kick strength. The waveform of the kicker pulse is determined by the injection scheme, filling pattern and revolution period.

Since the CDR, a preliminary injection-layout design has been carried out and a solution proposed. Input parameters are not final due to post-CDR evolution, such as High-Lumi Z. Hardware suggestions have been made and hence an R&D programme can be envisaged.

Recommendations

15.1 Review solutions chosen with small set of experts in preparation of a significant hardware R&D programme.

16. CEPC control system (Gang LI)

Findings and comments

The Experimental Physics and Industrial Control System (EPICS) control system has been selected. The slides also show the control group has already accumulated the number of control points. Though the EPICS system works from the small trial systems to large accelerators, it is suggested that the possible data rate, traffic in the network especially on the broadcast signal should be confirmed to be small enough compared to the capacity of the end-nodes. It also suggested to split the network into several pathways to reduce unnecessary broadcasting.

Though the controls of the detectors and accelerator may need to follow different rules, with the former handled by international collaborations needing both good remote monitoring and control of some components, while the latter should presumably allow only local control, for safety reasons, it will be important for the overall architecture to provide enough flexibility for efficient information exchange between the detectors and accelerator, in order to guarantee at the same time safe and efficient running of both.

Recommendations

16-1. Confirm the possible traffic rate is well below the capacity of the end nodes.

16-2. Define a common architecture for the control systems of the accelerator and detectors with enough flexibility for efficient information exchange between accelerator and detectors, to allow smooth joint operation, while enforcing safe beam operation through only local on-site accelerator control.

16-3. Provide appropriate hardware signal and timing connections between the detectors and the accelerator.

17. CEPC injector linac R&D (Jinru ZHANG)

Findings and comments

The key components of the linac baseline have been developed including:

- Electron gun
- Sub-harmonic bunchers (SHBs)
- Buncher
- S-band accelerating structure
- Pulse compressor
- Positron source
- Big hole accelerating structure
- DR 650MHz RF cavity
- Low level RF system (LLRF)
- Phase reference line

The accelerating structure is under high-power test. The flux concentrator is also finished and tested.

The IARC appreciates these efforts.

Recommendations

17-1. Explore extension of the linac up to ~20 GeV with C-band.

17-2. The linac after the damping ring to the 4 GeV merging point can be C-band.

17-3. Consider 2 bunches per RF pulse, especially for the Hi-Lumi Z.

17-4. Special components such as energy/bunch compressors as well as several diagnostic tools such as wire scanners, optical transition/diffraction radiation (OTR/ODR) screens, deflecting kickers should be prepared.

18. CEPC collider ring magnets (Mei YANG)

Findings and comments

Over 80% of the collider-ring circumference is covered by conventional magnets working in DC mode. The CEPC collider-ring dual-aperture magnets are based on aluminum wires for the excitation coils – air cooled in dipoles and water cooled in quadrupoles. The prototype of the dipole magnet of 1 meter length demonstrated acceptable parameters. The prototype of the quadrupole magnet is under preparation for the magnetic measurements.

Recommendations

18-1. Consider water-cooled aluminum conductor for long dipole magnets.

18-2. Estimate thermal regime of the magnets at the current required for top-pair production mode.

18-3. Carry out R&D work for the collider dual-aperture dipole magnets with the real lengths, dual-aperture quadrupoles and sextupole magnets.

19. CEPC booster magnets (Wen KANG)

Findings and comments

The low magnetic field in the dipoles at the beam injection from the 10 GeV linac is a critical issue for the booster magnet design. This design cannot be made by field simulation alone; experimental work with different types of magnets is necessary. The Chinese magnet team's experimental activity is impressive. Three different designs were studied, including H-shape iron yoke magnets, canted cosine theta (CCT) and cosine theta (CT) iron-free magnets. Two sub-scale prototypes (diluted yoke H-shape dipole and CT dipole without iron core) were produced recently. Both magnets have advantages and drawbacks and the prototype study is not yet finished.

The prototypes were measured under the "clean" conditions of magnetic lab, however the real booster magnets will be installed inside the tunnel which will also contain magnets of the main ring, current buses, cables and wires. This entire environment should also be considered.

Recommendations

19-1. Continue study of the prototypes. Imitate the CEPC tunnel environment in the magnetic measurement lab and assure that parasitic magnetic field from other sources (storage ring magnets, cables, etc.) does not influence the booster magnet field at injection.

20. CEPC Vacuum system (Haiyi DONG)

Findings & comments

A Cu chamber with NEG coating (1um thickness, horizontal only) will be used for the positron ring. For the electron ring, Al alloy will be used. ConFlat®(CF) flange will be used for the chamber connection. Some 6m vacuum chambers (aluminum and copper) have been fabricated. The elliptical cross section of the vacuum chamber causes a beam-current-dependent tune shift. It is recommended that the magnitude of the tune shift should be estimated and whether or not the anticipated current-dependent tune shift will be acceptable.

In the current design there are no photon absorbers to protect the flange from heating up due to SR. It is recommended to validate the current design assumptions on the heat load and possible deformation by simulations.

As the energy of the SR is very high, there is concern that there will be radiation damage to the accelerator components. Although a thick lead wall will be prepared outside the vacuum chamber, using light materials such as aluminum alloy for the vacuum chamber still looks rather worrisome.

In the current design the NEG coating inside the Cu vacuum chamber is only in the horizontal plane. it is recommended to coat also in the vertical direction (whole chamber) to suppress the SEY in the vertical plane, where electrons will be trapped in the vertical direction in the bending magnet. The re-activation method using a thin-film heater was explained during the Q&A section of the presentation. It is suggested to evaluate the heat capacity including heat insulators and magnets to determine whether the heater can be utilised.

Recommendations

20-1. Estimate the magnitude of the tune shift associated with the elliptical beam pipe.

20-2. Estimate the heat load and possible deformation using simulations.

20-3. Consider NEG coating all surfaces of the beam pipe.

20-4. Evaluate the heat capacity including heat insulators and magnets.

21. CEPC Power source and electromagnet separators (Bin CHEN)

Findings & comments

The IARC appreciates the progress that has been made on the combined unit of electrostatic separator and dipole magnet:

- A separator unit consists of a pair of pure Titanium electrodes — each 4 m long and 180 mm wide —mounted in an ultra high vacuum (UHV) tank of about 380 mm inner diameter.

- The H-type magnet achieved the uniformity of the field integrals within 2e-4, within a central magnetic field of 66.7 Gauss.

- Two methods have been implemented in the design of the separator to reduce the loss parameter: ground electrodes & tapered ends, but the loss factor is still high. The structure of separator needs to be optimized and an absorber may be necessary.

- Field clamps, along with the mirror plates and flaring open the electrode ends progressively to minimize the distortions in the fringe field region.

Prototypes for Booster power supply and Correctors with Multi-unit combination structure are under design. The Digital Power Supply Control Module (DPSCM)-II will be embedded into the prototype.

Recommendations

21-1. Estimate the formation of electron-cloud between the separator electrodes.

22. CEPC mechanical systems (Haijing WANG)

Findings & comments

Progress has been made on various areas of the CEPC mechanical systems:

- A 40 meters long tunnel mockup has been preliminary designed to check interfaces between the equipment locations, installation, alignment and transportation.

- Transport vehicles or magnet transportation and coarse positioning have had preliminary designs.

- “Mini CEPC” are under design for popularization of CEPC, which length in 100 meters.

- The preliminary thermal and impedance analyses of movable collimators have been done, based on which the optimization of the inner profile is on-going.
- For the MDI region, the design of the remote vacuum connection methods has been reviewed, and the support system for the SC magnets is under design.

Recommendations

22-1. Each system is highly connected with the entire design of the collider: tight interaction is necessary with beam dynamics, optics, impedance, magnets, vacuum, and MDI groups.

22-2. Evaluate the vibration eigenfrequency of components, for the IP quads and solenoids as well as arc-magnet supports.

22-3. The required number of collimators can be as large as 10 per IP.

22-4. Consider a common girder for quads and sextupoles to reduce the relative misalignment between them.

23. CEPC instrumentation (Yanfeng SUI)

Findings & comments

The in-house developed BPM electronics have been developed and tested in the BEPC-II.

It is planned to use button-type electrodes with a diameter of 8 mm. As the diameter is fairly large compared to the size of the vacuum chamber, there is a danger of high output power from the button; this must be carefully evaluated.

On the transverse bunch feedback system, it is planned to use the vector-sum scheme to make a 90-degree phase shift to the kicker. It is, however, not recommended to use such an analog method due to the complexity of the tuning. Rather a one-BPM to one-kicker scheme should be used. A short stripline kicker (50 - 57.7 cm) has been shown. To get enough shunt impedance in the required feedback bandwidth of 20 MHz, the length and the bandwidth of the kicker and the final amplifiers should be optimized with a much longer stripline.

Depending on the damping-time requirement, it might be necessary to install several bxb feedback systems in a ring to increase the effective damping rate. It is also recommended to evaluate the rise and fall response of the final feedback amplifiers as some of the high-power amplifiers have very nasty, long-ringing response.

A bunch-current monitor with 12-bit resolution has been shown. With the evolution of the JESD204B(C) high-speed multi-channel serial interface, a very high speed (>GSPS) ADC with more than 12-bit resolution is now available. Though such an ADC has the difficulty of high latency and not easy tuning of the high-speed digital interface with the external clock, the continuation of these developments is highly encouraged.

Recommendations:

23-1. Evaluate the beam-induced output power from the relatively large button of the BPM.

23-2. Use the one-BPM to one-kicker scheme for the transverse bunch-by-bunch feedback.

23-3. Evaluate the rise and fall response of the final feedback amplifiers, taking characteristics of each amplifier.

23-4. Optimize the length of the stripline kicker and the bandwidth of the final power amplifiers for the transverse bunch feedback systems.

23-5. Consider narrow-band feedback, in addition to bunch-by-bunch ones, for specific instabilities such as resistive wall coupled bunch, etc.

24. MDI: Radiation Backgrounds at CEPC (Haoyu Shi)

Findings & comments

The bremsstrahlung spectrum in the simulations might be cut off at a slightly too low energy (it was flat from 96% of beam energy but should still rise and is important up to 98.5%); this could be an artefact of the presentation.

The beam-gas is only simulated for a short length near the IP but the off-momentum particles can survive for more than one turn. Integrating over the full circumference may produce much larger numbers. The same applies to the scattering off thermal photons.

Recommendations

24-1. Similar estimations must be done for Z, which has higher beam currents and higher luminosity by more than an order of magnitude.

24-2. Some beam-induced backgrounds such as radiative Bhabhas have impacts on accelerator components including the final superconducting magnets. Strong coordination with the accelerator group will be necessary for this point.

25. SppC status (Jingyu Tang)

Findings and comments

Work on the SppC concept is continued with a lot of effort by a limited number of people and funding. In the report, the concept of proton injection chain was presented, main attention was attracted to the collider lattice design and study of the particle dynamics in it. The most challenging problems at this stage are the beam-collimation and beam- dump systems because of the unprecedented stored energy in the beams. The most crucial technical problems are the high-field SC magnets and compatibility of all the SppC systems with the CEPC design.

Recommendations:

25-1. Prepare a detailed list of SppC systems, which are different from CepC systems and can require additional sufficient civil works. For instance: injection complex, magnetic system power supply, cryogenic system, beam dump and so on.

25-2. Concentrate main efforts on preliminary design of these systems in order to formulate additional requirements to the site selection, design of the accelerator tunnels and galleries.

25-3. Consider a normal-conducting proton linac as the front end of the proton injection chain.

25-4. Continue the R&D efforts on high-field SC magnets supported in a wider national and international cooperation

26. CEPC and SppC compatibility (Yiwei WANG)

Findings & Comments

Efforts have been started on the layout of the collider rings of SppC with a minimum deviation from the CEPC. The bypass around the CEPC interaction region has been an issue, requiring stronger dipoles in some cases to fit the orbit along the CEPC beam line.

The resulting circumference of SppC has been different from CEPC's, making e-p collisions difficult.

The layout of the injector chain for SppC has not been precisely integrated. It will be very site-dependent, and must be incorporated before the site selection.

Recommendations

26-1. Explore the possibility to make the circumferences of SppC and CEPC equal for far-future extensions such as SpeC and other options.

26-2. The SppC injector complex need to be considered during the site selection and planning.

26-3. Continue these studies by also including infrastructure and equipment compatibilities, clearances and space allocations for movement of equipment, installation activities and personnel passages, including escape routes.

27. SppC magnets R&D (Qingjin XU)

Findings & Comments

The IARC was encouraged by the significant progress in the development of iron-based high-Tc superconducting (IBHTS) magnets, including measurements of the critical current of a first IBHTS solenoid coil in a 24 T background field.

Recommendation

27-1. Pursue increased international collaboration in the high-field magnets for the future high-energy frontier.

28. CEPC radiation protection (Zhongjian MA)

Findings & Comments

Shielding for the synchrotron radiation in the arc section has been cross-checked and more actual structure will be developed for further simulation. A basic analysis procedure for dump and transfer line has been established. Heat analysis for the dump absorber and dimensions for dump cavern will be verified and fixed. Radiological impact to the environment is the main issue in the next step.

Recommendation

28-1. Estimate the impact of the High-Lumi Z option, both for the SR and the beam dump.

28-2. Consider multiple beam dumps per ring, to shorten the time lag for a beam abort.

29. MDI: Status of the CEPC LumiCal Design (Suen Hou)

Findings & Comments

The plans for precision absolute luminosity measurements were presented. Accuracies of 10^{-4} and 10^{-3} are specified for the Z and Higgs boson physics, respectively. Major challenges are the precise knowledge of the inner geometric acceptance of the active detection volume, given the step angular dependence of the Bhabha differential cross section, a good understanding of the selection efficiency of Bhabha events, taking into account initial/final-state radiation (ISR/FSR) effects as well as biases from beam-beam electromagnetic deflections and beamstrahlung, and efficient rejection of background processes. Recently, a new beam-pipe geometry with projective geometry has been implemented, with smoother transitions to avoid heating from higher-order modes. The detector is centered on the median of the two beam lines, which implies fixed horizontal displacements of the Bhabha-scattered particles around the actual outgoing beam trajectories. GEANT4 simulations have been started using this new geometry, with for the moment only preliminary results.

Recommendations

29-1. The design of the luminosity measurement needs further development, with a complete simulation to evaluate the expected precision. The impact of realistic alignment tolerances needs to be studied, and a strategy considered for minimizing the resulting uncertainties.

29-2. Biases from electromagnetic deflections from the strong space charge of the colliding bunches, the shifts of the effective center of mass from beamstrahlung needs to be considered, and a mitigation strategy should be defined.

29-3. It would be important to consider more carefully the advantages and disadvantages of centering the two detectors around the median of the two beam lines, or around each outgoing beam-line direction, from the point of view of minimizing the uncertainties in the selection efficiency, by creating, in the second case, a more symmetrical geometry with respect to the Bhabha cross section.

30. MDI: Mechanical design of beam pipe & pixel supporting structure (Quan Ji)

Findings & Comments

The beam pipe will support both the vertex detector in the central part and luminosity monitors at both ends. Minimal amount of material is important, while ensuring sufficient rigidity and accommodating cooling to remove heat from the vertex detector electronics and resulting from the passage of the beams. A structural analysis was performed, showing significant mechanical deformation, especially when the system with both luminosity monitors is cantilevered with the support only on one side. Adding a carbon-fiber cylinder to strengthen the structure was shown to reduce the deformations significantly. Thermal calculations including the various heating effects and cooling are currently starting. The design is not finished and will still need to be discussed

Recommendations

30-1. Not only higher-order modes and synchrotron radiation, but also resistive losses in the beam pipe need to be considered among the heating effects.

30-2. Vibration analysis should be performed in addition to the static mechanical deformation studies, in particular to assess possible resonances in the mechanical structure.

30-3. Thermal gradients and resulting mechanical deformations from differential expansion should be considered given the size, specific shapes and different materials of the components composing the structure.

30-4. The mounting and installation procedure needs to be defined, including an estimate of the required effort and time.

31. CEPC civil engineering (Qinhuangdao: Yu Xiao, Huzhou: Ke Huang, Changsha: Li Zhiji) & CEPC Auxiliary Facilities (Jinshu HUANG)

Findings & Comments

Three site investigations were discussed in detail: Qinhuangdao, Zhe Jiang Hu Zhou, Changsa. All three have carried out impressively detailed work in terms of the topology, geological factors and infrastructure of the sites and all three have preliminary layouts of the accelerator and infrastructure that avoid conflicts with historical sites, ecology etc. Some sites reported detailed comparisons of tunnel construction methods – e.g. drill & blast in Changsa is 2 billion yuan cheaper than tunnel boring machine (TBM) and takes 50 months compared to 52 months for TBM. All three sites showed plans for a “Science City” associated with the accelerator. All three sites mentioned strong support from local government.

There is a detailed plan for the provision of auxiliary systems, with a planned power of 270 MW. Enough reserve and free space is planned to allow for upgrades at least for the electron machine. A plan for the connections from the main substation to subsidiary subsystems is available and is a mixture of overhead and underground lines. Cooling/air conditioning inside the tunnel is specified with an aim to keep the temperature in the tunnel below 35 degrees.

Recommendations

31-1. Summarise all sites currently being investigated and whether more are likely to be added in future. Clarify the process by which the final site will be selected eventually. The criteria on the selection, from technical and environmental, as well as convenience for a large international participation should be shown.

31-2. Clarify the schedule for beneficial occupancy of the experimental halls in the current construction plan.

31-3. Specify the legal steps necessary to acquire land, planning permissions etc and the schedule required in order to begin construction on the planned dates. The IARC thinks that the technical and environmental issues should be clarified for each site to promote a large-scale international collaboration smoothly.

31-4. Clarify the specification of supplied power, cooling etc. and that it is sufficient for likely upgrades for CEPC, and for SppC.

31-5. Ensure that SppC footprint does not cause conflict with proposed site for CEPC and minimise interference with urban areas, historical sites, ecological constraints etc.

32. CEPC installation and alignment (Xiaolong Wang)

Findings & Comments

Detailed schedule of the control network construction, control network measurement, support setting and installation, components fiducialization, ring and linac installation, and final smoothing have been shown. Though all of them are well considered based on a realistic basis for the workers, there still remains anxiety that the schedule is too aggressive. Especially on the installation and the alignment of collider and booster, the parallel work shown (first day installation, second day alignment) might be too difficult given the traffic in the tunnel. The BPM positions are scheduled to be measured. In case BPM blocks are fixed relative to quadrupole magnets with good precision, though the rotation of the BPM blocks also needs to be measured, position measurement will not have high priority because the offset could be easily measured by beam-based alignment (BBA). Though it was not mentioned in the presentation, the connection from the accelerator to the colliding detector is important. It is recommended to start considering how to connect the accelerator to the detector with enough precision.

Recommendations

32-1. Consider safer work in the tunnel during installation and alignment and prepare enough contingency.

32-2. Evaluate which BPM measurements are required from the alignment group.

32-3. Start to consider how to connect and align the accelerator to the detector.

32-4. Consider a common girder for quadrupoles and sextupoles to reduce the relative aignment error between them.

33. Integration design in the CEPC Interaction Region (Haijing WANG)

Findings & Comments

The integration of the IP beam pipe with cryostats, detector and diagnostics is a huge mechanical and vacuum problem. SuperKEKB has faced the same challenge. A lot of effort is being done to design the integration taking into account all aspects. The critical points seem to be the Remote Vacuum Connection (RVC) and the deformation of the IP cryostat support.

Four solutions are being considered for the remote vacuum connection: the RVC used at SuperKEKB, an inflatable seal, a remote chain seal and long tools. Each of them has disadvantages; no clear decision has yet been made. In particular the RVC is a big and complex structure. However, it seems that shifting the Lumical position closer to the IP (in front of QD0) could make space for the RVC and also be better for the luminosity measurement since there will be less material before Lumical.

The deformation of the cryostats at the IP due to the gravity (190 μm) and to temperature changes (48 μm) is a real challenge, especially if compared to the simulated sensitivity error of 30 μm required by lattice group on the IP quadrupole positions. It seems this number is highly unrealistic. An IP orbit feedback able to cope with these movements has to be operating. No estimation of vibration effects (vibration resonance frequency is to be evaluated) was performed yet.

The RF fingers at the bellows can easily get deformed during assembly. Particular care has to be given to this problem, which was already faced by SuperKEKB.

The integration design was performed for a detector magnet yoke of 9.2 m, if this is going to be changed to 12 m, as requested by the detector group for magnet stability, this work needs to be updated, in which case the deformation problem will probably get worse.

Recommendations:

33-1. Profit as much as possible from the SuperKEKB experience. Work in close connection with the group at KEK which faced and solved the same challenges. A 100 μm misalignment error seems a much more realistic value to consider.

33-2. The choice of an RVC similar to SuperKEKB will probably be optimal in view of their experience.

33-3. The deformation of the IP cryostats should be addressed with care and a solution found to alleviate it as much as possible. Vibrations should be also considered.

33-4. Synergy between the detector, the beam dynamics and the mechanical engineering groups is mandatory in order to face these problems.

34. MDI: Focusing Quadrupole Design for CEPC (Yingshun Zhu)

Findings & Comments

A preliminary design of the cosine-theta final-focus quadrupole with 136 T/m gradient was presented. There is a separate quadrupole for each beam. Field cross-talk between the quads is compensated either by additional correction coils or by an iron core around both quadrupoles.

The gradient is higher than that for FCC-ee (100 T/m); this fact can increase the SR background in the detector.

The multipole field content after the 3D field simulation seems reasonable but it should be checked by direct beam tracking with the QD0 field imperfections. For instance, a 10 Gs dipole field along the quadrupole (2 m) produces a displacement of the 30 GeV beam of around 40 μm at the IP, which is much higher than the IP beam size (Sigma_x = 6 μm, Sigma_y = 0.04 μm).

It is also desirable to simulate the quadrupole field together with the anti-solenoid because its fringe field may influence the field distribution at the quadrupole entrance.

Correction coils (horizontal/vertical, skew quadrupole, multipole) should be located inside the cryostat. The best place for them is at the position of the FF quadrupoles (because the relevant betas are maximum there) but there is a question if these additional coils can be incorporated in the quadrupoles or not.

The mechanical design and alignment procedure inside the cryostat, ensuring proper quadrupole spatial positions after cooling down and detector field switching on, should be foreseen.

Recommendations

34-1. Estimate detector SR background from the strong field of the quadrupole.

34-2. Provide beam-tracking and beam-dynamics study with the field imperfections obtained from the QD0 field simulation.

34-3. Simulate the QD0 3D field together with anti-solenoid.

34-4. Consider how to insert correction coils in or close to the final focus quadrupoles.

34-5. Keep close contact with the beam dynamics team as these quadrupoles limit the dynamic aperture through synchrotron radiation, misalignment, etc.

Suggestions for future format of the Review meeting

While the overlapping scheme with the workshop may save time, the IARC feels that it is not adequate for an intensive review. Q&A for each presentation in the workshop were not sufficient for reviewing. The IARC requests a different format in future, more adequate for a review. A possible way is to dedicate the Monday of the week containing the Workshop and IAC meetings for presentations based on topics agreed with the committee in advance. There needs to be a session for the MDI, joint with the detector committee. Also we need a full day of dedicated time for the committee discussions after the presentations, possibly in parallel with a part of the workshop.

The IARC would like to access documentation (incl. preliminary slides) before the review, at least by the Friday of the previous week.

The 2019 CEPC International Accelerator Review Committee Meeting

IHEP, Beijing, China

Monday, November 18, 2019

13:30 - 14:00	Organization and assignments (A418) 30'
16:00 - 16:30	Visit Accelerator R&D Laboratory 30'
18:30 - 21:00	Private Dinner 2h30'

Wednesday, November 20, 2019

10:30 - 15:00	discussions, additional Q&A, and report-writing (A419) 4h30'
12:00 - 12:30	Lunch Box

Presentations: The 2019 International Workshop on the High Energy Circular Electron Positron Collider
https://indico.ihep.ac.cn/event/9960/other-view?view=standard#20191118.detailed

Committee members:

Philippe Bambade (LAL)

Maria Enrica Biagini (INFN)

Brian Foster (DESY/Oxford)

In-Soo Koo (PAL, absent this time)

Eugene Levichev (BINP)

Katsunobu Oide (CERN/KEK, chair)

Anatoly Sidorin (JINR)

Steinar Stapnes (CERN)

Makoto Tobiyama (KEK)

Zhentang Zhao (SINAP, absent this time)