SUMMARY OF WORKING GROUP 3*

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Abstract

This is a brief summary of the talks and issues that came up in Working Group 3 (IR and MDI). There were many excellent presentations and several issues were raised regarding the CEPC design and the FCC-ee design.

INTRODUCTION

The working group looked at issues for backgrounds in the detector from synchrotron radiation and from beam particles. In addition, the needs of the detector were also addressed and several discussions were entertained that revolved around these various issues. The CEPC interaction region design is quite challenging and there were many points of interest raised that will require further study. The interaction region of the FCC-ee design is equally challenging and has its own set of unique issues.

PRESENTATIONS

There were a total of 6 sessions and 14 presentations. We also had 3 joint sessions with working groups 2 and 4. We list the presentations here.

1. CEPC IR Optics, Y. Wang (IHEP)
2. Status of FCC-ee Interaction Region Design, R. Martin (CERN) **FRT2B2**
3. Crab Waist Interaction Region, A. Bogomyagkov (BINP) **FRT2B3**
4. SuperKEKB Background Simulations, H. Nakayama (KEK) **FRT3A1**
5. Beam-beam limit vs. number of IPs and Energy II: scaling law, M. Xiao (IHEP) **FRT3A2**
6. Beam-beam limit vs. number of IPs and Energy I: beam-beam simulation, K. Ohmi (KEK) **FRT4A1**
7. Long-Range beam-beam interaction with the CESR bunch train operation, D. Rice (Cornell U.) **FRT4A2**
8. Choice of L* I and SR in the HF IR, M. Sullivan (SLAC) **SAT1B1**
9. Choice of L* II: IR optics and dynamic aperture, E. Levichev (BINP) **SAT1A2**
10. Choice of L* III: requirement from the detector, G. Li
11. Lost particles in the IR and Touschek effects, M. Boscolo (INFN-LNF) **SAT1B2**
12. Infrared synchrotron methods and systems for monitoring and controlling particle beams in real time, M. Maltseva (TENZOR) **SAT1B4**
13. Detector beam background simulations for CEPC, H. Zhu (IHEP) **SAT2A2**
14. Synchrotron radiation absorption and vacuum issues in the IR, J. Seeman (SLAC) **SAT1B3**

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HIGHLIGHTS

- The CEPC IR optics has been improved. The L* value has been lowered from 2.5 m to 1.5 m and the strength of the bend magnets in the chromaticity correction blocks on either side of the IP have been lowered. The Synchrotron Radiation (SR) power from the previous bends had been exceptionally large and now the values, though large, are looking manageable.
- The FCC-ee interaction region design is being studied. The design includes an 11 mrad crossing angle with two complete storage rings for the electrons and positrons. The overall design is quite ambitious with an energy range that goes from the E_{cm}: Z0 to the ttbar threshold from 92 GeV to 355 GeV
- A crab waist design was presented for the FCC-ee IR which looks quite promising.
- There was a very comprehensive presentation from the SuperKEKB background group. They have gone to great effort to model every detail of the detector hardware and the beam line components both inside and outside of the detector in order to get as accurate a simulation as possible. They have used this detailed simulation to study the effects of adding shielding in almost all possible remaining space inside the detector.
- There were two very interesting studies presented about beam-beam limits. One study collected all the available information about beam-beam limits from present and past machines and compared these numbers against some standard scaling laws and typical simulations. The other presentation showed a study of the CEPC IR design and concluded that a β_y^* design of 2 mm gave more luminosity than the current β_y^* of 1.5 mm.
- There was presentation on bunch trains and using pretzel orbits that revealed many of the difficulties of maintaining a good orbit and luminosity with such a design. This is the plan for the CEPC design. The issues of the pretzel design were difficult to handle even with a very flexible machine.
- There were three presentations on choices of L* values. The first presentation concentrated on the issues of SR coming from the final focus quadrupoles. Due to the very high strength of these quads, there is a very significant amount of SR

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power generated by just the 4 final focus magnets. The background SR from these magnets mostly comes from the beam particles that populate the tails of the transverse beam distribution. This tail distribution and the number of beam sigmas used to track these particles are important design considerations. The second presentation concentrated on the effects of nonlinear fields in the IR. In the talk, three different sources of nonlinearities were investigated; *i.e.* the kinematic term mainly from the drift space from the IP to the final focus quadrupoles, the fringe fields mainly from the final focus quadrupoles and the paired sextupole magnets used in the local chromaticity correction blocks. To estimate the nonlinear features of the final focus system, the nonlinear detuning coefficients α (particularly the vertical value α_{yy}), which have a tune dependence on the action variables, were taken as a figure of merit for the nonlinearities. The values of α_{yy} for the kinematic term, the fringe fields and the sextupoles for the chromaticity correction are proportional to L*, L^{*3} and L^{*2}, respectively. It was shown that the nonlinearities from the paired sextupoles dominates in the case of the IR of the FCC. This nonlinearity is created by the finite length effect of the magnets and can be mitigated by additional (low-strength) sextupole correctors. The larger nonlinearities that correspond to the longer values of L* usually result in a reduction of the beam dynamic aperture. A tracking study has been done to check the dynamic aperture for the IR of the FCC with several values of L*, *i.e.* 0.7m, 1m, 2m and 3m. A preliminary result showed that an IR with an L* of 2m would give a sufficient dynamic aperture. The third presentation came from the detector group for the CEPC and there was expressed interest in a small radius central beam pipe. This desire will have to be balanced by the expected SR background level from the final focus quadrupoles. As for L*, it was shown that shorter L* brings several challenges for the detector. In the talk, mainly three challenges were discussed. The first possible problem is that the momentum resolution may get worse due to the leakage magnetic filed from the final focus quadrupoles (QD0). This problem may be overcome by optimizing the VXD/FTD and by a precise mapping of the fields. The second problem is that the jet flavour tag loses some efficiency and jet resolution may get worse due to the smaller coverage of the detector. However, the statistics is expected to compensate this. The third problem is that on accuracy of the luminosity measurement with a short distance from IP to the luminosity monitor for a precise measurement of the Bhabha event rate. This issue would be really a big challenge.

- There was a presentation on detector backgrounds from all manner of lost beam particles, Beam-gas interactions, Coulomb scattering, Inter-beam scattering, Touschek scattering, and beam-beam scattering especially beamstrahlung (bending of the beam particles due to the magnetic field of the other beam bunch during a collision). All of these backgrounds need to be calculated and simulated with collimators in various places. The LEP machine had ~100 collimators for four interaction regions to help control backgrounds from these sources.
- We had an interesting presentation on a detector that monitored infrared SR from the beam in real time to obtain information on the beam for diagnostic purposes.
- There was a presentation on initial studies of detector backgrounds for the CEPC design. The preliminary results looked encouraging but further work and more detailed simulations needed to follow.
- The last presentation was on SR power and vacuum chambers for the IR design of the PEP-II B-factory. The most important thing to remember was that all vacuum beam pipe components need to be cooled.

SUMMARY

Below is a checklist of topics that came up during the Working Group 3 sessions that should be addressed by any accelerator design. There were many discussions during the workshop and we are sure we have forgotten some of the issues so here is, at best, a partial list of issues.

- The IR design is one of the more complicated sections of the accelerator with several overlapping and conflicting requirements.
- The value of L* is very important. A smaller number tends to help the accelerator design achieve the desired luminosity. It also lowers the chromaticity generated by the final focus quadrupoles. A larger value makes the IR easier to design and build as the quadrupoles are farther from the IP and this leaves more room for the detector.
- The SR power generated by local magnets near the IP must be managed and the backgrounds generated by SR must be carefully handled. The SR background studies include direct hits from SR sources but must also include one and possibly two bounces of SR photons from various local surfaces. In most cases, a suppression factor of on the order of 10^6 (and sometimes higher) must be achieved in order to attain an acceptable level of background in the detector.
- The definition of the Beam-Stay-Clear (BSC) for the IR as well as for the rest of the accelerator is an important design consideration. It is also important that the IR area have a BSC definition that is larger than all other areas of the accelerator. Otherwise, all beam particles that are on the way of being lost from all around the ring will be lost in the IR area.
- With the BSC, is the definition of the non-gaussian beam tail distributions. These tail distributions will become the source of SR backgrounds in the IR area

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and the particle density of these tails also will define the beam lifetime.

- The vacuum around the IR is very important. In most cases, it is desirable to have a much lower local vacuum pressure than the rest of the ring(s) in order to minimize local beam particle losses near the IP where one is unable to collimate because they occur too close to the IP.
- Beamstrahlung was an issue raised several times and this will need to be studied thoroughly. The effect on the beam core is one issue but, in addition, how it affects beam lifetime and whether or not there are background issues from the particles that are pushed into the beam tail distribution also needs to be looked at.
- Lost beam particles and even some of the SR in the IR area have enough energy to produce secondary backgrounds and in particular neutrons. Neutrons are very difficult to shield against and as a background in the detector can be very dangerous as they increase the total radiation doses for detector components.
- The issue of Higher-Order-Mode power (HOM power) came up several times. This will be an important consideration as vacuum chambers become more defined and beam pipe details are firmed up. HOM power is an issue for the entire ring but there are special considerations for the IR area. The detector components usually require special beam pipes that can be generating sources of HOM power that must be properly handled. This is especially true for short bunch length designs (like the CEPC) but it is an issue whenever the bunch charge is high, the beam current is high or the bunch length is short. Any one of these three conditions tend to increase luminosity and hence will be pushed to the limit. Planning in advance for HOM power handling and control will make an accelerator design much more robust.
- Vibration control of the final focus quadrupoles in particular is very important. The very small beam spots at the IP make controlling magnet vibrations an essential part of optimizing the luminosity and in maintaining the performance of the accelerator.
- It is also important to design a fast signal for luminosity performance. This signal will be crucial for machine optimization and allow operators to recognize running issues quickly when they happen as well as permit machine tuning for luminosity.

CONCLUSION

The workshop overall was very interesting and informative. Working Group 3 had a very good list of speakers with quite interesting topics. A great many issues were discussed and brought to light. It was a very useful and helpful gathering of people to discuss the issues of a large e+e- collider.

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