Machine Detector Interface at the Circular Electron Positron Collider

The machine-detector interface (MDI) issues are one of the most complicate and challenging topics at the Circular Electron Positron Collider (CEPC) and other future high energy colliders. Comprehensive understandings of the MDI issues are decisive for achieving the optimal overall performance of the accelerator and detector. The CEPC machine will operate at different beam energies, from 45.5 GeV up to 120 GeV, with an instantaneous luminosity increasing from 3×10^{34} $\mathrm{cm}^{-2}\mathrm{s}^{-1}$ for the highest energy to 3.2×10^{35} $\mathrm{cm}^{-2}\mathrm{s}^{-1}$ or even higher for the lowest energy.

The electron and positron beams are focused by the compact high gradient quadrupole magnets to increase the luminosity. The two final focusing quadrupoles are positioned inside the CEPC detector and will have to cope with the background field of the detector solenoid. The one closer to the interaction point is designed as a double-aperture superconducting magnet with Cos-Theta quadrupole coils, which will be constructed with NbTi Rutherford cables with or without iron yoke. An anti-solenoid magnet with strong field has to be introduced to cancel out the effects of the detector solenoid on the incoming beams.The central field could reach as high as 7.2 Tesla and the magnet will have to be constructed with NbTi-Cu or better with the emerging high temperature superconducting (HTS) conductors.

A flexible interaction region design will be plausible to allow for the aforementioned large beam energy range. However, the design has to provide high luminosity that is desirable for physics studies, but keep the radiation backgrounds tolerable to the detectors. This requires careful balance of the requirements from the accelerator and detector sides. In particular, incoming beams bent upstream of the interaction region will induce synchrotron radiation that may enter the detector. Synchrotron radiation and other sources of beam-induced backgrounds, e.g. pair production and beam-gas interaction, will impair the detector performance. They should be suppressed and/or mitigated by placing masks, collimators and shielding at proper locations.

The beam pipe design will foresee several constraints. In the central region ($z = \pm 20$ cm), it should be placed as close as possible to the interaction point ($r = 1.4$ cm or smaller) and with minimal material budget to allow the precise determination of the track impact parameters. But it should still stay far away enough not to interfere with the beam backgrounds. Double layers of Beryllium beam pipes with fluid coolants between have been proposed to deal with the High Order Mode (HOM) heat generated in the central region. In the forward region, the beam pipe will be built with Al and/or Cu to conduct away the deposited heat in the interaction region. The beam pipe shape will be designed to prevent synchrotron radiation shining the detector and minimize the HOM heat load.

The forward region will be instrumented with a luminometer (LumiCal), aiming to measure the integrated luminosity with a precision of 10^{-3} and 10^{-4} at the center-of-mass energies of $\sqrt{s} = 240$ GeV and $\sqrt{s} = 91$ GeV, respectively. The precision requirements on the integrated luminosity measurement are motivated by the CEPC physics program, intended to test the validity scale of the Standard Model through precision measurements in the Higgs and the electroweak sectors. The LumiCal will be a precision device to measure the Bhabha elastic e^+e^- scattering events, who cross section has been theoretically calculated with high precision. To achieve the ultimate precision on the luminosity measurement, it will be vital to position properly the LumiCal with high precision and make careful choices of both the detector technology and electronics.

Questions

There are several challenging MDI topics, which are critical for the optimal performance of the machine and experiments. They include:

Interaction Region Design The overall interaction region layout requires careful balance of the requirements form the accelerate and detectors. Deep understandings of the boundary conditions on each component in the interaction region will be vital for the optimal design.

Radiation Backgrounds It is crucial to understand the different sources of radiation backgrounds and develop accurate models and reliable programs to simulate their generation, transportation and interaction with the accelerator and detector elements. Mitigation measures and necessary protection of the accelerator and detector should also be carefully investigated.

Superconducting Magnets Compact superconducting magnets, including the final focusing quadrupoles and anti-solenoid, will be challenging to design and construct. In particular, for the high field anti-solenoid, it is necessary to explore the HTS conductors that will not only ease the operation and maintenance, but also reduce the overall magnet weight and hence simplify the mechanical design of the supporting structure.

Luminosity Measurement It is non-trivial to design a compact and precise LumiCal in the crowded interaction region. The alignment precision close to 1 μm seems inevitable to achieve the ultimate precision of 10^{-4} as required by the operation at the Z-pole.

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