**IDRC MEETING**

**IHEP**

**14-16 April 2025**

# **Introduction**

The IDRC met at IHEP on April 14–16 to review the draft version of the Reference Technical Design Report (Ref-TDR) for the CEPC detector. The committee congratulates the CEPC team for their outstanding work and recognizes the remarkable progress made since the IDRC’s first meeting in October 2024.

During the meeting, the CEPC team presented detailed responses to all comments and recommendations submitted by the committee following the initial meeting. The IDRC commends the team for their thorough and thoughtful replies.

The committee engaged with the CEPC team to review progress in mechanical and electronics integration, the design of the machine-detector interface, and the magnet system. In parallel sessions, panel experts evaluated updates on specific detector components, including tracking detectors, calorimetry, the muon system, as well as TDAQ and software and computing.

The committee carefully assessed the current status of the R&D program and discussed what additional work is needed to ensure the reference detector will be a robust tool capable of fully exploiting the CEPC’s physics potential if the project is approved. While the presentations were excellent, the Ref-TDR requires further editing before it can be released publicly. The IDRC issues the following general recommendations:

* **Appoint an overall editor** to enhance the document’s coherence, eliminate duplications, and ensure consistency across chapters.
* **Restructure chapters** to focus clearly on the baseline design for each detector component, including specific details showing that the required physics performance can be achieved. Clearly outline the R&D and prototyping still needed to demonstrate the feasibility of the selected baseline technologies.
* **Describe backup solutions** in detail, showing that they are available and could meet performance requirements if needed. The proposed use of HTS cables for the superconducting magnet, for instance, will require significant additional R&D.
* **Significantly shorten discussions** of alternative technologies.
* **Eliminate descriptions** of the basic working principles of well-established technologies.

The CEPC team has selected very innovative technologies for the Ref-TDR. Demonstrating sufficient technological maturity will require an intensive program of prototyping and beam testing. The committee strongly encourages the CEPC team to now focus on this critical phase.

Finally, we recommend beginning detailed evaluations of detector performance, including the impact of expected beam backgrounds, at least for key physics channels. The IDRC believes these are essential next steps on the path to realizing this exciting project.

# **Superconducting Solenoid**

### **Findings**

The CEPC Ref-TDR superconducting solenoid design has made significant progress. The solenoid provides a central magnetic field of 3T (for tt̄, Higgs, and W runs) and 2–3T (for Z runs), with an inner bore diameter of 7.07 m and a cryostat/yoke half-length of 4.53 m. It is enclosed within an iron yoke that also houses the muon detector. The variation of the solenoid magnetic field in the central tracker (TPC) region is currently calculated to be approximately 10%.

The solenoid coil design is based on four layers of Al-stabilized superconductor, supported by an aluminum-alloy outer support cylinder and cooled using a two-phase helium thermal-siphon system. This general design concept is well established, drawing on the reliable design experience of the CERN-LHC CMS detector.

A key technology development effort focuses on Al-stabilized superconductors, with two approaches to mechanical reinforcement:

* **Option A:** Double-layered, two-step co-extrusion process.
* **Option B:** Single extrusion with micro-alloying for reinforcement, followed by a cold-work process.

Further R&D is planned for 2025.

The maximum von Mises stress on the Al-stabilizer during magnet excitation is evaluated at 96 MPa, which is close to the current yield strength of the Al-stabilizer material (105 MPa). Further mechanical evaluation is necessary to ensure an adequate safety margin, including the mechanical integrity of the NbTi/Cu superconductor itself.

Remaining technical challenges primarily concern the production of large-scale, high-strength Al-stabilized superconductors, as well as ensuring the reliability of the numerous aluminum-pipe welds required in the thermal-siphon cooling system.

### **Comments**

* Field uniformity in the TPC region is a fundamental boundary condition for detector performance. The current 10% field variation must be carefully assessed to ensure it is acceptable for the required TPC performance. It is important to note that the ALICE detector has a different configuration, and that the ALICE magnet is much larger resulting in significantly better field quality compared to CEPC.
* **T**he committee recognizes the remarkable progress achieved in developing Al-stabilized superconductors, achieving a yield strength of 105 MPa at 4.2 K using micro-alloying (Ni + Be). However, further R&D is required to demonstrate the full mechanical performance of the conductor and the successful fabrication of full-scale Al-stabilized superconductor segments.
* It is critical to demonstrate that the full conductor (NbTi/Cu + Al-stabilizer) can withstand mechanical stress up to 135 MPa. This threshold is about 50% higher than the maximum von Mises stress (~90 MPa) expected during operation at 3T. If achieving this mechanical strength proves difficult, increasing the thickness of the support cylinder could be considered, although this would be undesirable. As a last resort, if necessary, a reduction in the operating field strength may need to be discussed.
* Developing a scaled model coil, including full cooling and excitation tests, will be an important step. Without such a demonstrator, confidence in the readiness of the solenoid technology for CEPC will be limited.
* Two cooling channel designs are under consideration:
  + Vertical Al-pipe channels, as used in CMS.
  + Sloped or tilted serpentine channels, which may reduce the number of welds and save cryostat space.

The latter option could be advantageous for construction reliability.

### **Recommendations**

* Carefully verify that the magnetic field uniformity of the CEPC Ref-TDR solenoid meets the TPC performance requirements without introducing unacceptable distortions to particle drift paths. If necessary, explore revised designs, such as adding extra windings in the forward and backward regions, similar to solutions studied for ILD.
* Maintain the highest priority for the R&D of the Al-stabilized superconductor, aiming to demonstrate full-scale conductor fabrication, production of sufficient lengths, and mechanical performance that meets the required safety margins.
* Develop a detailed plan for the construction and testing of a superconducting model coil, including demonstrations of cooling and excitation. Achieving this milestone is essential for progressing toward full-scale magnet construction.
* Finalize the cooling system design based on the thermal-siphon concept, with particular attention to the reliability and quality assurance of aluminium-pipe welding procedures during construction.