Letter of Interest for Snowmass 2021

CEPC Accelerator Study Group

The discovery of the Higgs boson at CERN's Large Hadron Collider (LHC) in July 2012 raised new opportunities for a large-scale accelerator. The Higgs boson is a crucial cornerstone of the Standard Model (SM). It is at the center of some of its biggest mysteries, such as the large hierarchy between the weak scale and the Planck scale, the nature of the electroweak phase transition, and many other related questions. Precise measurements of the properties of the Higgs boson serve as excellent tests of the underlying fundamental physics principles of the SM, and they are instrumental in explorations beyond the SM. Due to the low mass of the Higgs, it is possible to produce it in the relatively clean environment of a circular electron–positron collider with high luminosity, new technologies, low cost, and reduced power consumption. In September 2012, Chinese scientists proposed a 240 GeV *Circular Electron Positron Collider* (CEPC), serving two large detectors for Higgs studies and other topics. The ~100 km tunnel for such a machine could also host a *Super Proton Proton Collider* (SPPC) to reach energies beyond the LHC.

The CEPC is a large international scientific project initiated and to be hosted by China. It was presented for the first time to the international community at the ICFA Workshop *"Accelerators for a Higgs Factory: Linear vs. Circular"* (HF2012) in November 2012 at Fermilab. A Preliminary Conceptual Design Report (Pre-CDR, *the White Report*)[1] was published in March 2015, followed by a Progress Report *(the Yellow Report*)[2] in April 2017, in which the CEPC accelerator baseline choice was made. The Conceptual Design Report (CEPC Accelerator CDR, *the Blue Report*) [3] has been completed in July 2018 by hundreds of scientists and engineers after an international review from June 28-30, 2018 and was formally released on Sept 2, 2018. In May 2019, CEPC accelerator document was submitted to European High Energy Physics Strategy workshop for worldwide discussions [4].

The CEPC is a circular *e+e-* collider located in a 100-km circumference tunnel beneath the ground. The accelerator complex consists of a linear accelerator (Linac), a damping ring (DR), the Booster, the Collider and several transfer lines. In the tunnel, space is reserved for a future *pp* collider, SPPC. The center-of-mass energy of the CEPC is set at 240 GeV, and at that collision energy the CEPC will serve as a Higgs factory, generating more than one million Higgs particles. The design also allows for operation at 91 GeV as a Z factory, and at 160 GeV as a W factory. The number of Z particles produced will be close to one trillion, and W+W-pairs close to 20 million. The heart of the CEPC is a double-ring collider (except at the SCRF region, where electron and positron beams use a common beam pipe). Electron and positron beams circulate in opposite directions in separate beam pipes but with the common SCRF system. They collide at two

interaction points (IPs), where large detectors as described in detail in the CDR (Volume II) are located. The CEPC Booster is located in the same tunnel but above the Colliding rings. It is a synchrotron with a 10 GeV injection energy and extraction energy equal to the beam collision energy. The repetition cycle is 10 seconds. Top-up injection will be used to maintain constant luminosity. The 10 GeV Linac, injector to the Booster, built at ground level, accelerates both electrons and positrons. A 1.1 GeV damping ring reduces the positron beam emittance before the positrons are injected to the booster. The transport lines made of permanent magnets connect the Linac to the Booster. The tunnel size is large enough to accommodate the future SPPC without removing the CEPC collider rings. This opens up the exciting possibilities of *e-p* and *e*-ion physics in addition to *e*+*e*- physics (CEPC) and pp and ion-ion physics (SPPC). In addition to particle physics, the *e*+*e*- collider can also operate simultaneously as a powerful synchrotron radiation (SR) light source.

According to the CEPC CDR design, the circulating CEPC beams radiate 30 MW synchrotron radiation power per beam, and the total facility power consumption is kept below 300 MW. The luminosities at the Higgs and Z-pole energies are $2\text{-}5\times10^{34}$ $cm^{-2}s^{-1}$ and $30\text{-}100\times10^{34}$ $cm^{-2}s^{-1}$ per interaction point, respectively. The energy upgrade potential to tt-bar energy of 180GeV has also been considered.

Prior to the construction there will be a five-year R&D period (2018-2022). During this period, prototypes of key technical components will be built and infrastructure established for industrialization for manufacturing the large number of required components. Six sites have been considered and they all satisfy the technical requirements. The construction of CEPC is expected to start in 2023 and will be completed in 2030. After the commissioning, a tentative operation plan will be 7-year running for Higgs physics, followed by a 2-year operation in Z mode and 1-year operation in W mode.

The cost of CEPC, which was estimated at 5 Billion USD, contains mainly three parts, accelerator, two detectors, and civil constructions including the tunnel.

The SppC (Super proton-proton Collider) as an integral part of the CEPC-SppC project, aims at the energy-frontier discoveries, which will be a long-term development or more than twenty years from now after CEPC. As SppC is a long-term project with many technical challenges, it is necessary to pursue studies to work on critical physics and technological key issues. One of the key issues is the iron-based high-field superconducting magnets of at least 12 T to allow proton–proton collisions at a center-of-mass energy of 75 TeV and a luminosity level of 1035 $cm^{-2}s^{-1}$.

As for the timeline of SppC, from now up to 2035 is CDR and R&D period, and from 2035 to 2040 is the Technical Design Report period, from 2040-2045 is SppC construction period, and SppC will be put to operation started from 2045.

The CEPC-SppC is an important part of the world plan for high-energy physics research. It will support a comprehensive research program by scientists throughout the world.

References:

[1] CEPC-SppC Pre-CDR, http://cepc.ihep.ac.cn/preCDR/volume.html, 2015.

[2] CEPC-SppC Progress Report, http://cepc.ihep.ac.cn/Progress%20Report.pdf, 2017.

[3] The CEPC Conceptual Design Report, Vol I: Accelerator, arXiv: 1809.00285, http://cepc.ihep.ac.cn/CDR_v6_201808.pdf, 2018.

[4] CEPC Accelerator submitted to European Strategy in 2019: ArXiv: 1901.03169