The Present and Future of China's Particle Physics Research

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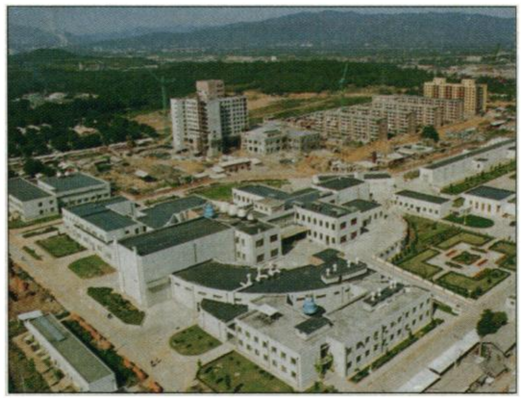
The material world we observe is so varied and changeable, yet the most elementary components of it are very simple: Whether living matter or not, from tiny dust grains to the largest bodies of the universe, each is made of fundamental particles. Particle physics is the science that studies these most elementary units of the universe and the principles governing interactions among them. Research in this area has been developed to the point that scientists have been able to summarize the structure of the world and the principles of interactions into the "Standard Model."



The Beijing Electron-Positron Collider. BEPC is shaped like a giant badminton racket, where the storage ring, 240.4 m in circumference, is the circular building. The affiliated synchrotron radiation facilities stand outside of the ring. The long building on the right is the injector, a linear accelerator 202 m long that can accelerate electron or positron beams to 1.1 to 1.4 GeV. BES is located in the Big Hall of the storage ring, at center left.

Our present understanding is that elementary particles comprise six quarks in three generations (the so-called up, down, charm, strange, top, and bottom quarks) and six leptons in three generations (electron, electron neutrino, muon, muon neutrino, tau, and tau neutrino). Today, the objects of particle physics are as tiny as 10^{-19} m and have lifetimes as short as 10^{-23} s. This requires extremely large and complicated experimental facilities—high-energy accelerators and particle detectors and the concerted efforts of scientists of many countries.

Chinese scientists have been involved in this research from the beginning. As early as the 1930s, Chinese physicists such as C. Y. Chao, K. C. Wang, and W. Y. Chang had already begun to work abroad in the frontier of physics. In the 1950s, when particle physics was established, some of these physicists returned to their homeland and trained many students, who then became the backbone of Chinese research in this field. As a result, there has been a research team working in particle physics in China all along. Since the late 1970s, Chinese physicists have actively participated in wider international collaborations and carried out significant work both in theoretical and experimental particle physics.

With the rapid development of the Chinese economy and the efforts of scientists of several generations, our modern facilities, the Beijing Electron-Positron Collider (BEPC) and the Beijing Spectrometer (BES), were finally completed in 1988. The energy of BEPC is in the range of 3.0 to 5.6 GeV, and its peak luminosity, while working in the energy region of tau lepton and charm physics, is 6×10^{30} cm^{-2} s^{-1}. BEPC is able to accelerate positrons and electrons separately to 1.5 to 2.8 GeV, and they meet in the center of BES to produce a collision energy of 3.0 to 5.6 GeV. The nature and principles of fundamental physics can be learned by studying the particles produced in the positron-electron annihilation. In addition to particle physics, applied research on synchrotron radiation as well as nuclear physics are part of BEPC's program.

Some significant results (*1*, *2*) have been obtained in the 3 years that BEPC has been in operation. In particular, our efforts at studying the J/ψ particle, which provides information about the charmed quarks, has been especially fruitful. About 10 million J/ψ events have been accumulated, which is equivalent to the total number of J/ψ events accumulated since the discovery of this particle in 1974, providing rich data for research in this field. By analyzing part of the data, we have confirmed the existence of $\Xi(2220)$ and determined the widths and some decay branch ratios of J/ψ, the spin parity of f2(1270) and f0(1710), and properties of f0(975), among other findings.

BEPC/BES, which is one of the best facilities operating in the 3 to 6 GeV range of center-of-mass energy, has performed well. In the spring of 1992, the BES Collaboration [composed of more than 100 Chinese physicists, including M. H. Ye, Z. Q. Yu, J. Li, and myself of the Institute of High Energy Physics (IHEP), and about 40 American physicists, including W. H. Toki of Colorado State University] successfully measured the mass of tau lepton with a precision value of $1776.9^{+0.4}_{-0.5} \pm 0.2$ MeV (*3*). The mass of the tau lepton is very important in testing the lepton universality of the weak interactions [that is, the three generations of lepton (electron, muon, and tau) have the same couplings in their weak interactions]. In the last decade, there have been four experimental groups that have measured tau mass, but their results had large uncertainties [1783 ± 4 (*4*), 1787 ± 10 (*5*), 1807 ± 20 (*6*), and 1787^{+10}_{-18} (*7*)]. The value obtained by the BES Collaboration has improved the precision by a factor of 7. This newly measured value by BES will dominate the world average value as a basic reference value for physics.

Until now, the Standard Model has seemed to be very successful. But there are still many significant problems that remain to be studied. For example, where does mass come from? Why can we not observe free quarks? To answer these questions, particle physics research on the one hand has to continue to go to higher energy and smaller size to search for top quark, the Higgs particle, and the state of the Big Bang at its first 10^{-15} s. All of these require huge investments and major technological breakthroughs. On the other hand, we also need measurements with higher precision, and we need to build particle factories with more efficient performance to study the nature of various particles thoroughly and look into the inner interactions between them to test and develop the Standard Model deeply.

BEPC/BES has become an important base for the research of tau and charm physics. Chinese scientists will continue to upgrade the performance of the collider and will strive to increase its luminosity by a factor of 3 to 5 within 2 to 3 years. It is the desire of Chinese scientists to provide more data for the study of J/ψ decay, ψ', D, D_s mesons, charmed baryons, and tau leptons, to achieve more significant results and to make more contributions to the development of particle physics research.

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