The Institute of High Energy Physics, Chinese Academy of Sciences

WANG YIFANG
INSTITUTE OF HIGH ENERGY PHYSICS, CHINESE ACADEMY OF SCIENCES

Fig. 1: IHEP's Main Building. (Image by IHEP)

The Institute of High Energy Physics (IHEP), a research institute of the Chinese Academy of Sciences, is China's biggest laboratory for basic sciences. We are working to understand the Universe better at the most fundamental level – from the smallest subatomic particles to the large-scale structure of the cosmos – and we also want to use the knowledge and technology that comes from our research for the good of humanity. In addition to theoretical and experimental research into particle and astroparticle physics, we conduct a broad range of research in related fields such as accelerator technologies and nuclear analysis techniques. The institute also provides X-ray and neutron beam facilities for researchers in other fields of study.

Over 1400 full-time staff members work at IHEP, and there are over 500 postdocs and graduate students at the institute. Particle physics is an extremely collaborative and international field, and we have partnerships and experimental collaborations with hundreds of universities and research institutions, both across China and throughout the world.

IHEP conducts research in three main areas of science: particle physics and astrophysics; accelerator physics and technologies; and neutron, synchrotron and nuclear radiation technologies and applications. Research is focused around six themes in fundamental and applied physics, spread across different research divisions and laboratories. IHEP is running and also is in the process of building a number of large-scale science facilities, and some of these facilities are open to scientists from other disciplines.

ACCELERATOR TECHNOLOGY AND SCIENCE

IHEP has expertise in both electron and proton accelerators. The Accelerator Division successfully developed, built and operated the Beijing Electron-Positron Collider (BEPC) and its upgrade BEPCII, which is still running. Research and development for the China Spallation Neutron Source (CSNS), a high-power, high-intensity proton accelerator, is currently ongoing. IHEP is also involved in the R&D of an accelerator-driven sub-critical system (ADS), another high-power, high-intensity proton machine, which has important potential applications, including nuclear waste transmutation. Looking to the future, design studies have begun for the Circular Electron Positron Collider (CEPC), a 100 km ring proposed to run at Higgs mass energy, upgradable to a proton-proton collider at 100 TeV, which would be the highest energy ever reached by a particle accelerator.

Fig. 2: The double storage rings of the upgraded Beijing Electron Positron Collider.

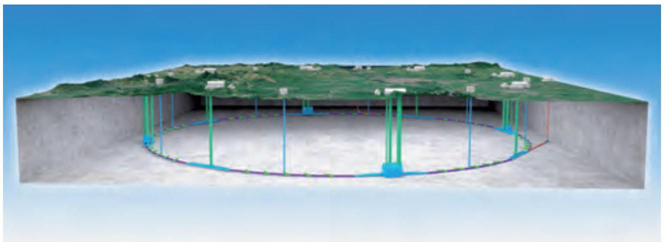

Fig. 3: The conceptual design for CEPC.

IHEP also invests in R&D for the technologies needed for particle accelerators, such as microwave technology, vacuum technology, magnets, power supplies, cryogenics for superconductivity, and beam diagnostics and control. In particular, IHEP conducts studies on superconducting technology, high-quality injectors and undulators, and is now building the largest SRF laboratory in China. Together with the BEPCII cryostat system, this constitutes a comprehensive platform for superconducting technology research.

PARTICLE PHYSICS

Particle physics at IHEP includes both theoretical and experimental research. There are two types of particle physics experiments – those that use particle accelerators, and those that don't. Accelerator-based experiments collide subatomic particles at very high energies, and study new particles produced in the collisions. Non-accelerator-based experiments study particles from other sources, such as the Sun, cosmic rays, and nuclear reactors.

IHEP's accelerator-based research is currently centered on the Beijing Spectrometer III (BESIII) experiment, which is a large detector installed at the BEPCII accelerator in Beijing. In the spring of 2013, the BESIII Collaboration reported the appearance of an electrically-charged particle, called the '$Z_c(3900)$', that was found to decay to a charged pion and a neutral J/Ψ. Because of its decay to the J/Ψ, the $Z_c(3900)$ particle must contain at least a charm quark and an anti-charm quark, a combination which has no electric charge. But since the $Z_c(3900)$ particle has one unit of electric charge, it must also contain additional quarks. Hence, the $Z_c(3900)$ particle must be (at least) a four-quark object.

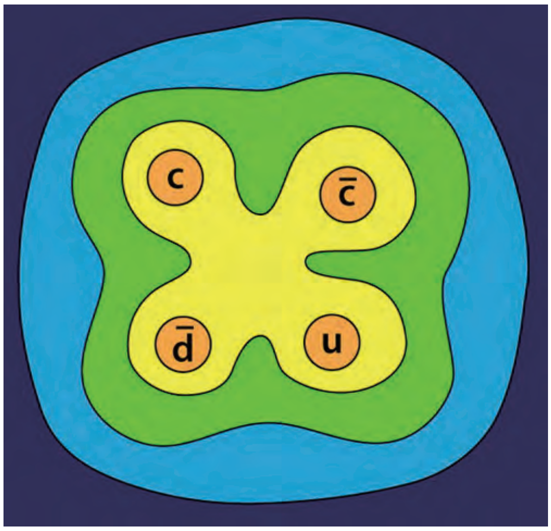

Fig. 4: Four-quark $Z_c(3900)$.

IHEP is also a collaborator in many international high energy physics experiments, such as ATLAS and the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider at CERN, and Belle II at SuperKEKB in Japan.

IHEP also has several strong, non-accelerator-based particle physics programs, particularly in neutrino physics. The Daya Bay Reactor Neutrino Experiment, based at the Daya Bay Nuclear Power Plant in Guangdong province, has been running since 2011. This experimental collaboration announced its first breakthrough result in 2012, which was the discovery of the third type of neutrino oscillation and the measurement of the neutrino mixing angle θ13. A much bigger neutrino experiment, the Jiangmen Underground Neutrino Observatory (JUNO) is currently under construction at a site near the city of Jiangmen in Guangdong province.

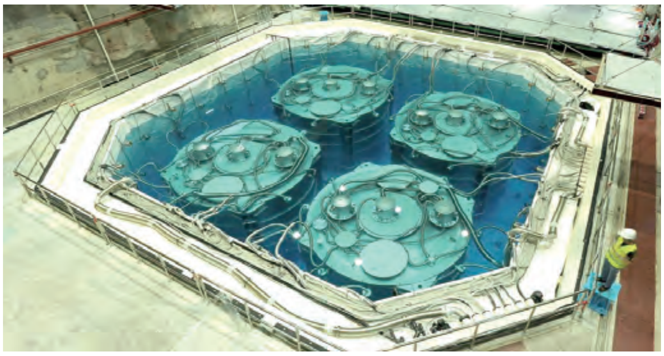

Fig. 5: Four of the eight antineutrino detectors at the Daya Bay Neutrino Experiment, successfully installed and taking data. (Image by IHEP)

Fig. 6: The JUNO experiment in Jiangmen, Guangdong. (Image by YREC)

ASTROPARTICLE PHYSICS

IHEP is the biggest research base for astroparticle physics in China, focusing on cosmic rays, astrophysics, and spaceborne experiments.

For cosmic ray experiments, the Yangbajing Cosmic Ray Observatory in Tibet is one of the four largest international ultra-high energy γ astronomy and cosmic ray research arrays in the world. It hosts two experimental collaborations, the Sino-Japanese ASγ and Solar Neutron Experiment Collaboration, and the Sino-Italian ARGO-YBJ Collaboration. Evidence for the anisotropy of cosmic rays and for cosmic rays orbiting around the center of the galaxy was discovered by the Sino-Japanese ASγ experiment.

A much larger facility, the Large High Altitude Air Shower Observatory (LHAASO) has recently begun construction in Daocheng, Sichuan province (altitude 4410 m), with an expected commissioning date of the first phase in 2018. LHAASO will be used primarily for cosmic ray physics and gamma ray astronomy.

Spaceborne experiments and projects in which IHEP is or has been involved include the Alpha Magnetic Spectrometer (AMS) experiment, a gamma-ray burst detector aboard the Shenzhou II spacecraft, the lunar exploration missions of Chang'e, and the Hard X-ray Modulation Telescope (HXMT).

The Hard X-ray Modulation Telescope (HXMT), which aims to survey the Milky Way to observe celestial X-ray sources, lifted off into space on June 15, 2017. HXMT is China's first homegrown X-ray telescope and scientists hope to use this telescope to probe mysteries such as the evolution of black holes and the strong magnetic fields of neutron stars. HXMT is able to work over a wide energy range from 1 to 250 keV, and to make many observations which previously required several satellites.

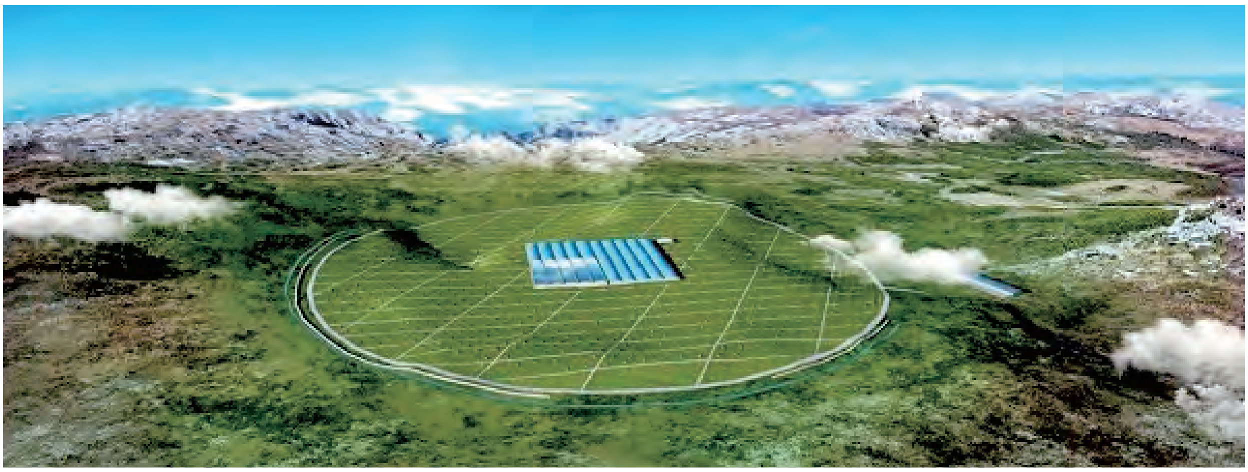

Fig. 7: Layout of LHAASO Project. (Image by IHEP)

Fig. 8: The Hard X-ray Modulation Telescope (HXMT), successfully launched on June 15, 2017. (Image by HXMT Team)

Fig. 9: The IHEP computing environment. (Image by IHEP)

IHEP also conducts research in astroparticle physics theory and phenomenology. Scientists at the institute proposed super-Eddington accreting black holes as a new type of cosmic distance probe. With luminosity commonly brighter than a supernova by one or two orders of magnitude, these sources can serve as excellent distance candles to explore the critical era of the accelerating expansion of the Universe and to unveil the nature and evolution of dark energy, thereby opening up a new window for observational cosmology.

MULTI-DISCIPLINARY RESEARCH

IHEP promotes cross-disciplinary research utilizing synchrotron radiation facilities and spallation neutron sources, thus supporting both frontier science research and industrial applications.

As part of the Beijing Electron Positron Collider (BEPC), the Beijing Synchrotron Radiation Facility (BSRF) has 5 insertion devices and 14 beamlines with experimental stations. Its research fields cover physics, chemistry, biology, environmental science and medicine. About 300-400 experiments are carried out each year by nearly 100 national research institutions. Interesting studies in fields including protein crystallography, nano-materials, X-ray phase contrast imaging, and experimental techniques have also been carried out.

COMPUTING

IHEP has been an early adopter of new computing technologies, ever since hosting the first Internet node in China, BEPC2.IHEP.CERN.CH, on a VAX785 at IHEP in 1988. Our computing research continues to develop at the forefront of networking, high performance computing, grid and cloud computing, and high performance storage.

IHEP's computing environment provides a data-intensive computing platform with high performance computing and data storage of 10 PB, with 160 Gbps backbone bandwidth for the institute's intranet and 20 Gbps bandwidth for external internet. A 10 Gbps IPv4 network and a 10 Gbps IPv6 network connect IHEP to the global network, with dedicated 10 Gbps high bandwidth network links to Europe and North America. The high performance network provides support for large volume data transfers and international collaborations.

The network link also guarantees the operation of the grid computing system at IHEP. IHEP provides a Tier-2 site in the Worldwide LHC Computing Grid (WLCG), and more than 2 PB of data have been transferred and processed per year for the ATLAS and CMS experiments. It also acts as a Regional Operations Center (ROC) for the CMS experiment, the first in Asia, allowing around-the-clock monitoring and operations. As well as the LHC experiments, IHEP also provides grid computing services to domestic experiments such as BESIII and JUNO, and other applications such as bioinformatics and geodynamics.

TECHNOLOGY TRANSFER

Constructing large-scale science facilities and working across the boundaries between different fields naturally

Fig. 10: The micro SPECT/CT scanner. (Image by IHEP)

leads to the development of many new technologies. IHEP actively encourages the development of spin-off technologies that can be of benefit to society. These technologies have included PEMi and SPEMI scanners for breast imaging, micro SPECT/CT scanners and micro PET/CT scanners, electron accelerators for industrial radiation processing, medical accelerators, accelerator-based ray sources, three-dimensional microscope CT scanners, high energy industrial CT scanners, superconducting magnetic separation devices, and gamma ray imaging devices.

In the past 20 years of international collaboration, IHEP has produced over 3000 different kinds of magnets, nearly 2,000 microwave components, and 200 accelerating tubes and energy doublers. Participating in the construction of many international high energy physics facilities, IHEP has established cooperative partnerships with the USA, Canada, Japan, Korea, Brazil and many European countries, and has become an important international accelerator facility and components supplier.

IHEP is committed to excellence, and for more information on IHEP's programs, events and researchers, please visit http://english.ihep.cas.cn/.

Wang Yifang is the current director of the Institute of High Energy Physics of the Chinese Academy of Sciences. He obtained his BSc at Nanjing University in 1984 and his PhD at the University of Florence in 1991. He subsequently worked at MIT and Stanford University before returning to China in 2001. He is an author of more than than 300 scientific papers covering his work on the L3, AMS, Palo Verde, KamLAND, BESIII, Daya Bay and JUNO experiments on neutrino physics; $e^+ e^-$ collision physics; cosmic rays and astrophysics; detector design and constructio n; and methods for data analysis. He led the design and construction of the BESIII detector at the Beijing Electron-Positron Collider, and the Daya Bay Reactor Neutrino Experiment, which precisely measured the neutrino mixing angle θ_{13}. He is now the spokesperson of the JUNO neutrino experiment and he proposed the idea of the Circular Electron-Positron Collider (CEPC) followed by a Super proton-proton Collider (SppC) as a possible future endeavor for particle physics. He has been awarded the W. K. H. Panofsky Prize in 2013, the 20th Nikkei Asia Prize in 2015, the Breakthrough Prize in Fundamental Physics in 2016 and the Bruno Pontecorvo Prize in 2016.