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News & Views

Chinese physicists set to unveil conceptual designs for the globe's most advanced circular collider

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The leaders of China's high energy physics sector will soon unveil initial designs for the world's most technologically advanced circular collider, set to stage near-speed-of-light particle collisions aimed at recreating the conditions of the universe in the instant following the Big Bang.

By accelerating beams of leptons or hadrons to nearly 300,000 km/s before colliding them inside the ringed accelerator, these physicists aim to illuminate understanding of elementary particles and fundamental forces whose interactions guide the inner workings of the universe.

Construction of the super collider—at least twice the size of the circular accelerator operated by Conseil Européen pour la Recherche Nucléaire (CERN) on the French–Swiss border—would position China at the global forefront in terms of experimental particle physics.

This next-generation China-based ringed collider could generate new pieces in the puzzle of the basic structure of the universe and in the process help physicists answer the deepest questions asked across the ages about the cosmos by some of humanity's greatest thinkers.

Assembling a global confederation of scientists around this ringed particle smasher would, like the CERN complex, represent one of the greatest collective endeavors focused on science and peace in human history, according to Jie Gao, one of the leaders of China's proposed accelerator project at the Institute of High Energy Physics (IHEP), part of the prestigious Chinese Academy of Sciences.

"There is a peace factor to this project" that would benefit the entire world, explained Professor Gao.

"This is a machine for the world and by the world", added Jie Gao, who conducted accelerator research at Laboratoire de l'Accélérateur Linéaire in the French city of Orsay, for more than 15 years.

To underscore the global orientation of China's proposed circular collider, he added, IHEP has created the new Center for Future High Energy Physics, headed by Nima Arkani-Hamed, one of the top theoretical physicists in the USA.

Professor Arkani-Hamed, a scholar at Princeton's Institute for Advanced Study, has begun inviting prominent scientists around the world to join him in giving talks at the new center, based at the IHEP campus in western Beijing, on topics ranging from the design of a 100 tera-electron volts (TeV) collider to exploring the Higgs boson via increasingly powerful accelerators to inflationary cosmology.

The unveiling of the supergiant accelerator complex would signal China's evolution into the global epicenter for experiments in high energy physics, said Professor Arkani-Hamed, who won the Fundamental Physics Prize in 2012. He received that award, one of the world's top honors in physics, "for original approaches to outstanding problems in particle physics, including the proposal of large extra dimensions, new theories for the Higgs boson, novel realizations of supersymmetry and theories for dark matter", according to the prize jurors.

Xiangdong Ji, a professor in theoretical physics at the University of Maryland who has closely examined draft schemes for the Chinese collider project, predicted that with the leading-edge accelerator, China could "dominate high energy physics for 20 or 30 years".

Professor Ji, who also heads Shanghai Jiao Tong University's Institute of Nuclear and Particle Physics, Astronomy and Cosmology, was appointed to a special panel created by the Chinese Academy of Sciences to conduct an intricate review of the super collider proposal. "We gave strong support for the collider project", he said.

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Theoretical and accelerator physicists who have begun coalescing around the Center for Future High Energy Physics, explained Professor Gao, could form the seeds of an international lab situated along the edges of the proposed collider. Leaders of the future physics center, along with visitors from labs around the world, have collaborated on a preliminary conceptual design report to be submitted to the Chinese government by the end of 2014, he said.

Shapers of the conceptual design envision building the massive collider outpost in two successive stages, explained Jie Gao.

During the first phase, a 54-km Circular Electron Positron Collider (CEPC) would initially focus on exploring the Brout–Englert–Higgs Mechanism via its associated particle to deepen understanding of the origin of the mass of subatomic particles.

This CEPC accelerator, featuring a beam energy range of up to 120 giga-electron volts (GeV), will smash together electrons and their anti-matter counterparts in collisions that will be examined for traces of the Higgs particle, which was discovered at CERN's Large Hadron Collider in July of 2012 (please see Fig. 1).

If the drafters of the electron collider proposal obtain positive feedback on the conceptual design from the Chinese leadership, Jie Gao explained that intensive research and development of the circular accelerator would be conducted for the next 5 years. The collider's engineering design could likewise be finalized by 2020, while construction could be completed by 2028 "under the most optimistic scenario", he said.

Professor Gao, who outlined details of the super collider plans at the International Conference on High Energy Physics in Valencia, Spain, in July of 2014, said that this lepton-smashing accelerator could be followed with a super proton proton collider (SPPC) inside the same underground complex.

"It is aimed to station two machines—both the electron and proton colliders—inside the same tunnel", he explained.

Chinese scientists deployed along the frontiers of fundamental physics research, along with a circle of their Western counterparts, have already begun charting out an initial conceptual design for this second-stage SPPC; if approved, research and development during the 2020s would be followed by engineering design and construction over the next dozen years.

Their preliminary conceptual design outline for the SPPC proton collider, with an energy range of 50–100 TeV, will likewise be submitted to China's pro-science government—which is sprinkled with graduates of prestigious science and engineering universities—by the close of 2014.

The league of leading Chinese physicists propelling the super collider project forward includes scholars from IHEP, Tsinghua University, Peking University and Shanghai Jiao Tong University, along with other organizations. If the China-hosted ringed particle smasher becomes an internationally funded endeavor, the collider could be designed to measure 80–100 km in circumference, or up to four times the size of the CERN complex.

CERN and its Large Hadron Collider, currently the largest particle physics laboratory on the planet, are co-funded, operated and governed by an expanding array of member states. The CERN confederation was founded by 12 nations committed to organizing a pro-peace, future- and science-oriented grouping to rebuild Europe in the aftermath of World War II.

The China-based super collider is envisioned as "an international science center and city", said Professor Gao.

This colossal collider outpost could evolve into a futuristic cosmopolis, attracting physicists, World Wide Web entrepreneurs, museum operators and technologists

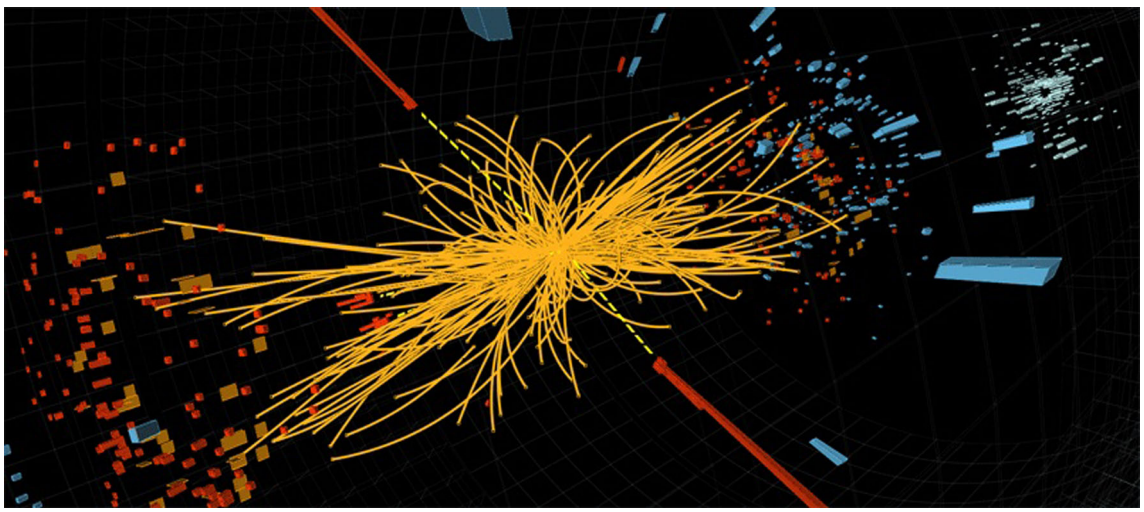

Fig. 1 A proton–proton collision event in a CERN experiment that produces two high-energy photons (red towers). This could mark the decay of a Higgs boson. Image courtesy of CERN

into a center focused on scientific creativity and perpetual advances, predicted Professor Arkani-Hamed.

The China-based super collider and circular cosmopolis, said Jie Gao, could be patterned after the CERN complex on the outskirts of Geneva. "Geneva and its new collider city", he said, "is one of the most creative sectors on the planet".

Chinese scientists began cooperating with CERN more than three decades ago, in areas ranging from accelerator technology to a continuing series of particle physics experiments. China signed an International Cooperation Agreement with CERN in 1991 to step up joint endeavors in high energy physics, and Chinese scientists have joined colleagues across the globe in aiding accelerator design, detector construction and experimental data analysis at the European Organization for Nuclear Research.

CERN, in turn, has dispatched an array of theoretical and experimental physicists to host seminars and workshops at the new Center for Future High Energy Physics in the Chinese capital.

In establishing this outpost, Professor Gao explained, "The idea is to create an international center with a spirit that is open to the world".

And just as an intercontinental mix of scientists is taking shape at the new center, the crafters of the twin collider plans aim to foster global participation in the design and construction of the machines, he added.

"Starting with the Circular Electron Positron Collider", Professor Gao said, "we will welcome Americans and other international scientists across the whole world to participate".

Gerard 't Hooft, who won the Nobel Prize in Physics in 1999, predicted that creating the globe's most advanced collider in China could attract thousands of the world's foremost physicists and engineers to take up posts around the accelerator rings.

A theoretical physicist at Utrecht University in the Netherlands, Professor 't Hooft has been a central figure in the development of the Standard Model of Particle Physics, whose theories on the fundamental building blocks and forces of nature have been tested over the last half century at increasingly powerful colliders in the USA and Europe. The Royal Swedish Academy of Sciences selected him for the Nobel Prize for developing "a well functioning 'theoretical machinery' which can be used for, among other things, predicting the properties of new particles".

The next stage in the revolution of understanding these primary particles and forces, and their interactions, Professor't Hooft forecast, could partially unfold in China with the construction of the electron accelerator and then the more powerful proton collider.

These advanced accelerators will provide a new gateway to exploring the mysteries remaining within and beyond the Standard Model, he said, and scientists involved in designing and building the super collider collectively "will share the glamour" of new discoveries.

With the building of the China-based colliders, the Nobel laureate predicted, "Chinese scientists will participate more than ever before in our most challenging attempts to make scientific progress".

Meanwhile, Jie Gao forecast that China's orb-shaped collider could act like a newly formed star, pulling rings of leading accelerator, theoretical and experimental physicists into its orbit.

Many physicists, he suggested, are global nomads, perpetually seeking the planet's most powerful colliders to test their theories or stage their experiments.

"Science is global, and scientists move from place to place", he said.

"In the past", he explained, "in addition to working at the low energy Beijing Electron Positron Collider (BEPC and BEPCII), Chinese scientists moved from Japan to the United States to Europe" as they sought out accelerators and collaborators to explore the primary particles and forces of nature at new energy frontiers.

Now, with China's economic and scientific ascendance, he said, "The high energy physics culture could gravitate here".

Nima Arkani-Hamed forecast that the force of attraction of China's super collider will grow as construction begins on the ringed laboratory complex. The circle of scholars who have already begun touching down at the Center for Future High Energy Physics, he said, could evolve into a rapidly expanding gyre of physicists involved in the next-generation collider.

"This center", he said, "is a microcosm of the future".

As the China-based collider complex nears completion, he said, "those studying particle physics around the world will begin taking Chinese classes, just as experimentalists who go to CERN now study French".

"All of the young people in our field all over the world are so excited by the prospect of these machines", he said.

Constructing these twin colliders will ensure that China "will be the absolute best in this field", Professor Arkani-Hamed said. The machines, he forecast, "will lead to the globalization of the Chinese scientific community".

"This will foster East–West cooperation and internationalization on an unprecedented scale", he predicted. "It will make China the center of the world in this sphere of science".

Jie Gao, at the Institute of High Energy Physics, said: "The super collider is also a new way to develop society". The collider complex could likewise help absorb part of China's expanding sea of young scientists.

At the same time, the Chinese- and French-educated scientist warned that: "There's a big danger that if a new super collider isn't built, the size of the high energy physics community around the world will shrink".

As a result, he added, "The great human endeavor to explore the fundamental principles of the universe will greatly slow down".