China carves out larger role in underground science

As it is doing in so many areas of science, China is racing onto the world stage of underground astroparticle physics.

Two searches for dark matter got started in China in 2010, when an underground laboratory opened there. Both experimental teams have published their first results. Now the China Jinping Underground Laboratory (CJPL) is being enlarged more than 30-fold, the experiments are being upgraded, and new experiments are being planned. Scientists in China who study dark matter, neutrinos, and other topics for which shielding from cosmic rays is necessary hope the move is a step toward the world's deepest lab becoming an international facility.

The lab was built when a hydropower company dug tunnels into Jinping mountain in southwestern China (see PHYSICS TODAY, September 2010, page 25). The company has dug new tunnels, and the CJPL is piggybacking again. The experimental space, which lies under about 2400 meters of rock, will go from about 4000 cubic meters to 130 000 cubic meters. The cost of the lab expansion is $50 million, with China's Ministry of Education covering $30 million and Tsingua University, the lead partner in the China Dark Matter Experiment (CDEX), picking up the rest. Qian Yue, CDEX coordinator and director of the CJPL's physical division, says the new lab space, with four experimental halls, will be ready in late 2016.

Step by step

The CDEX experiment has not identified any dark-matter events. That is important, says Yue, because it contradicts earlier reports from CoGeNT in the Soudan Underground Laboratory in Minnesota, which uses "an identical detector technique." The University of Chicago's Juan Collar, the lead scientist on CoGeNT, is skeptical of the CDEX team's analysis methods, but says "things like this sort themselves out in the long run."

Along with the lab, CDEX is also expanding. For now, says Yue, the project has funding to increase its detector from 1 kg to 10 kg of germanium, and the plan is to keep growing. A 100-kg detector will cost tens of millions of dollars, he says. And at that size, it will be used both to search for dark matter and to look for neutrinoless double beta decay. "Our target is a ton-scale germanium detector," he says. "But we need to go step by step."

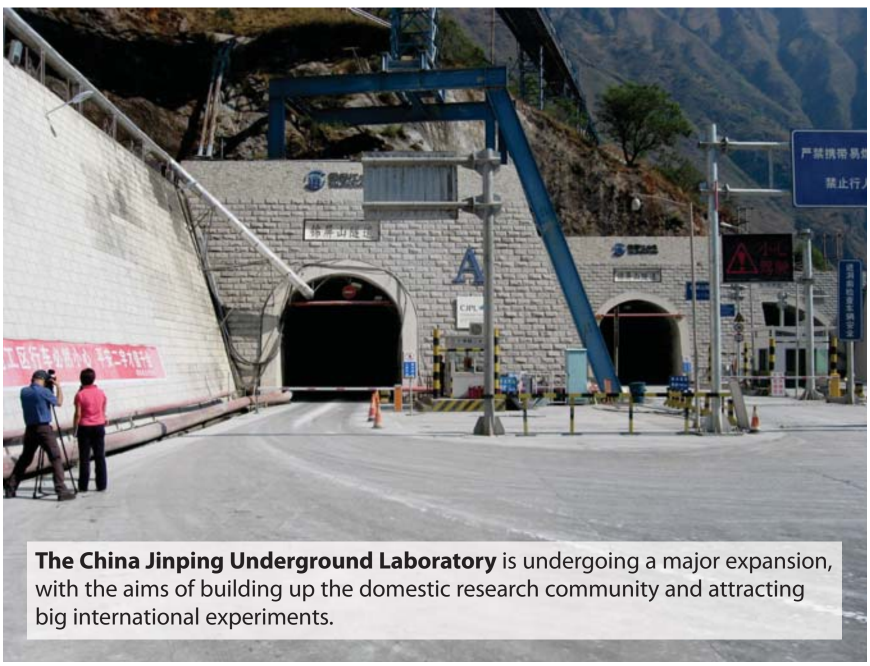
PandaX is the other experiment that has been running in the CJPL. "Our detector is powerful and capable," says spokesman Xiangdong Ji, who splits his time between Shanghai Jiao Tong University and the University of Maryland at College Park. "Our 17 days of data excluded all existing positive signals for dark matter." An incident dark-matter particle could cause a xenon atom in the PandaX detector to recoil, producing both light and charge signals. In its first phase, with 120 kg of xenon, the experiment has been particularly sensitive to low-mass dark matter, below 10 GeV. The next phase, with 500 kg of xenon, is set to start running early this year, and the focus will be on heavy-mass dark-matter particles. The larger quantity of xenon will increase PandaX's sensitivity by a factor of four and make the experiment twice as sensitive as the Large Underground Xenon experiment at the Sanford Underground Research Facility (SURF) in South Dakota, says Ji. The $3 million price tag for the upgrade brings the experiment's total cost to around $10 million, he says. "The ultimate goal is to build a 20- to 30-ton-scale xenon detector together with the international community."

A third facility that is getting ready to move into the CJPL is the $15 million Jinping Underground Laboratory for Nuclear Astrophysics, or JUNA. Like the Laboratory for Underground Nuclear Astrophysics in Italy's Gran Sasso Laboratory, it will study nuclear reactions important in stellar hydrogen burning. A similar facility, the Compact Accelerator System for Performing Astrophysical Research Underground, slated to come online next fall at SURF, will focus on higher-energy stellar helium burning. Beyond JUNA and the upgrades to CDEX and PandaX, there is talk of the CJPL hosting other large-scale projects such as multiton liquid xenon and argon detectors and a solar neutrino experiment.

"A willingness to go big"

Scientists from other countries are involved in the CJPL experiments, but it would be a big step for the laboratory to become a truly international facility, with partners involved in decision making and funding. Although China is increasingly participating in the world science arena, so far few major international facilities are on its soil; one is the Daya Bay Reactor Neutrino Experiment (see PHYSICS TODAY, October 2011, page 30).

"There are plans within the deep underground astroparticle physics community to develop several large-scale facilities to address the important outstanding questions in our field using different techniques," says Nigel Smith, director of Snolab, located more than 2 km below ground in an active nickel



SILKE ZOLLINGER/MAX PLANCK INSTITUTE FOR PHYSICS

The China Jinping Underground Laboratory is undergoing a major expansion, with the aims of building up the domestic research community and attracting big international experiments.

mine in Sudbury, Ontario, Canada, and a member of the CJPL international advisory committee. "We need to have the capability to host the experiments. I think everyone is pleased about the expansion of the facility in China."

"As you build larger, more sensitive experiments, the ability to shield gets harder, and it's important to go deeper," says Smith. Within two generations of experiments, depth may become critical, he says. "If everything goes well, that could be in about 10 years." Says Ji, "It's important to show that we can do a world-class experiment here at Jinping. That will establish credibility and boost interest in [international] collaboration." More than anything, though, he says, for collaboration to happen, "you need scientists who have a strong wish to work together."

The depth and the drive-in access of the CJPL are the most important scientific considerations, says Allen Caldwell of the Max Planck Institute for Physics in Munich, Germany. "But China is pushing to get to the forefront of research in many fields, and to build up their community of researchers, it's important for them to have their own lab." Moreover, Caldwell, a member of the lab's international advisory committee, notes that "China has shown a willingness to go big in investment, so if they provide resources for some of the big experiments being discussed for the future, it could mean they do things first. They are ambitious, and their community is growing."

In October Caldwell made the two-day trek from Munich to the CJPL. The trip involved three flights plus a bus ride. It's not easy to reach, he says, "but my feeling is that people will follow the science."

Toni Feder

DOE takes another step toward exascale computing

New supercomputers will allow more detailed simulations for nuclear weapons research and a range of scientific applications.

The US Department of Energy has awarded a $325 million contract to IBM to build two high-performance computers that are likely to be the world's most powerful when they are completed in 2017. Both machines will have a peak processing speed of at least 150 petaflops—five to seven times faster than the current top US computers. (A petaflop is 10^{15} floating point calculations per second.) They will be installed at national laboratories, one at Oak Ridge and one at Lawrence Livermore.

A third contract, for a supercomputer with comparable performance, is expected to be awarded within months to a different vendor. That machine will be installed at Argonne National Laboratory. In addition to the IBM award, DOE has announced a $100 million contract to five US companies to develop technologies that will be needed for affordable and energy-efficient machines as DOE moves toward its goal of exascale (1000 petaflops) computing within the next decade.

The Oak Ridge system, named Summit, will be five times as powerful as the lab's Titan machine, currently the second fastest in the world with a peak performance of 27 petaflops. The ratings are based on the Linpack performance benchmark, which measures how quickly the machines solve a dense set of linear equations. China's Tianhe-2, at 55 petaflops, is the world's fastest computer. "Once again the world's fastest computer will be in the United States and once again it will be at Oak Ridge," said Senator Lamar Alexander (R-TN) at a 14 November press conference.

The Livermore computer, dubbed Sierra, will offer seven times the performance of that lab's Sequoia, the world's third most powerful, rated at 20 petaflops. Although Sierra will be used mainly for classified nuclear weapons simulations, it will also carry out some unclassified research, says Livermore director William Goldstein. Los Alamos National Laboratory, the other nuclear weapons design lab, will begin installing its new high-performance Cray computer, Trinity, this year.

More realistic simulations

The new Oak Ridge and Argonne supercomputers will be open to all users, including industry, says Barbara Helland, director of facilities utilization in the DOE Office of Science's advanced scientific computing research division. Titan and Argonne's Mira, the current leading computers, are oversubscribed by a factor of three to four, and Helland expects that will also be the case with the new Oak Ridge and Argonne systems. The number of users has steadily increased over the past five years as industry looks to replace expensive experiments and prototyping with less costly simulations, Helland says.

Summit will offer the ability to run simulations with greater detail, says Helland. "If you want to do groundwater or carbon sequestration, you are talking about going through a material that is very heterogeneous, and you can put more realism into what that rock does. More power makes [the simulation] more realistic," she says. "In many cases you try to make it more realistic by picking the right parameters. We can do some uncertainty quantification to adjust the parameters during the calculations on the new machine" and improve confidence in the simulation.

Research performed on Titan has included simulations of the reactions inside fusion tokamaks and the design of advanced nuclear reactors. One climate model used 22 000 years of geological data from after the last glaciation to gain understanding of the role of carbon in

LAWRENCE LIVERMORE NATIONAL LABORATORY

The Sequoia supercomputer at Lawrence Livermore National Laboratory, rated the third most powerful in the world, will be succeeded in 2017 by a machine seven times as fast.