DENG HUA/XINHUA/ALAMY

A staff member works at the construction site of the underground neutrino observatory in Jiangmen, China.

Beaming with pride

From its first high-energy synchrotron to the world's biggest underground lab, China is going large, and it wants recognition. **By James Mitchell Crow**

The Jiangmen Underground Neutrino Observatory (JUNO) near Guangdong in southern China is undoubtedly big science. Centred on a colossal sphere filled with 20,000 tonnes of liquid and housed in a subterranean laboratory some 700 metres deep, it is designed to answer fundamental questions in particle physics. It is the largest and most sensitive instrument of its kind ever built.

On a similar bold scale is the China Jinping Underground Laboratory, in the country's southwestern Sichuan Province. The dark matter-hunting experiment has recently been expanded to become the world's largest and deepest underground lab, at 2,400 metres below the Jinping Mountains. Earthlab, a high-performance virtual laboratory in Beijing that simulates Earth's climate system, and the Large High Altitude Air Shower Observatory (LHAASO), in Sichuan, which uses an array of detectors spread across a Tibetan plateau to scan for high-energy cosmic- and γ-rays, are two more big-infrastructure science facilities that have been launched in China over the past two years. There are other facilities under construction, including the High Energy Photon Source, in Beijing, which is China's first high-energy synchrotron radiation facility, to be opened in 2025.

A focus on big science is the next phase in China's rapid ascendancy in the global research hierarchy, says Denis Simon, a distinguished fellow at the Institute of China-America Studies, a non-profit organization in Washington DC. After overtaking the United States in natural-science output in the Nature Index in 2022, China is now almost 5,000 Share ahead. The prestige that comes from building and operating massive facilities, which are designed to produce large amounts of data and insights that can feed into multiple fields and industries, could further cement the country's status as a science superpower, says Simon.

Spin-off opportunities that come from big science are a major draw for China. Technologies spun out of the European Organization for Nuclear Research's (CERN) vast particle accelerators, for example, have revolutionized medical imaging and sparked the development of the World Wide Web. And miniaturized camera technology that is now widely used in smartphones, webcams and other products can be traced back to NASA interplanetary-mission work. "China is still looking for a major breakthrough that can highlight just how fast it's moving," says Simon. But there's another factor that's pushing China to amass big-science infrastructure, he adds: "China wants to win a Nobel prize."

Given the size of its research community, China's Nobel count is very low. The only recent win for research undertaken in China — the Nobel Prize in Physiology or Medicine 2015, for the discovery of the malaria drug artemisinin — celebrated research conducted mainly in the 1970s. Winning more Nobels to affirm China's lead in global science is something that is openly discussed by its leaders, says Simon. "It's partly about national pride — a kind of continuous morale builder to show that China is no longer a follower and can be a leader."

Historically, most of the world's big-science projects have been hosted by the United States, Europe and Japan, which started building facilities several decades before China launched its first major piece of science infrastructure, the Beijing Electron Positron Collider (BEPC), in 1984. But it hasn't taken long for China to catch up. "In 1980, when China decided to begin collaboration with the West, relationships were very asymmetrical, with China far behind," says Simon. Now, the country enjoys a much more even footing, "and may even be a leader in some research fields or sub-fields", he adds.

In particle physics, for example, after a series of upgrades, BEPC became the first instrument in the world to detect a confirmed 'tetraquark', an exotic form of subatomic matter (M. Ablikim *et al. Phys. Rev. Lett.* **110**, 252001; 2013). In astrophysics, LHAASO captured the highest-energy γ-ray burst ever detected, an event so bright that it challenges classical theories of physics (The LHAASO Collaboration *Sci. Adv.* **9**, eadj2778; 2023). "I think [China's president] Xi Jinping sees an era in which China is a more proactive and influential player, shaping the rules of the game," says Simon.

How this shift will affect the global research ecosystem is yet to be seen. There is ongoing discussion, including within China, that the country has played an important role in international science by operating just behind the frontier, excelling at high-quality follow-up work, rather than pioneering new trends itself, says Anna Lisa Ahlers, who heads a research group studying China in the global science system at the Max Planck Institute for the History of Science in Berlin. "If they build scientific infrastructure that other countries don't have, this may change," she says. In a policy meeting earlier this year, Xi called for more "disruptive innovation" in science and technology, and boosted the country's science budget by 10%, despite the slow growth of the overall economy.

High-pressure science

Much of whether China's new, big-science infrastructure delivers the intended gains hangs on the Chinese Academy of Sciences (CAS) in Beijing, the largest scientific research organization in the world, which is responsible for building and operating most of China's big-science facilities. As the country's foremost research-funding recipient, CAS is expected to deliver the game-changing discoveries that China's leadership craves. "The academy has been arguing that if China wants to become a big science and technology power, it needs to up its game in basic research, including big-science infrastructure," says Simon. "Their wish came true, and they're under a lot of pressure to deliver. Among Chinese leaders, there is a constant admonishment to the system as a whole that you've got to do a better job."

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Researchers pour liquid nitrogen at the China Jinping Underground Laboratory.

One major challenge for CAS in building such large and specialized infrastructure is that China's skilled workforce is being stretched thin, as multiple projects commence at the same time. Within high-energy photon science, for example, which is an important area of research for China, facilities are poaching workers from each other, as projects funded by regional governments compete with those in development by CAS and other research institutes in Beijing and Shanghai. "I'm not sure it is wise to have so many infrastructure projects [running] at the same time," says Marcus Conlé, an area-studies researcher at the German Electron Synchrotron, a fundamental-science institute in Hamburg, Germany. Conlé visited China last year as a part of a delegation exploring potential research collaboration.

The facility-first approach of many of China's big-science projects is another pain-point, Conlé says. "In Europe, the process would be that researchers would propose an experiment that is beyond the limits of existing research infrastructure, and then put forward the case for a new instrument to be built." In China, there is more of a drive to build instruments to claim world-first status — particularly where infrastructure is funded by local governments — "and then the scientists try to work out what to do with it", says Conlé. The situation reflects China's relative inexperience in building and operating such instruments, he adds, although that situation is changing rapidly in major centres for research such as Shanghai.

Learning from other countries through collaboration is strategically very important for China's big-science future, even as political relations with the West remain tense, says Caroline Wagner, a public-policy researcher who studies international science collaboration at Ohio State University, in Columbus. Wagner points out that most of the big-science infrastructure that China has invested in has been designed in consultation with scientists at world-leading facilities overseas. "Researchers know that disengagement is the pathway to lower quality work, as we can see from Russia's experience, for example," she says.

There have been concerns in some Western countries that a collaborative research relationship with China equates to a one-way technology transfer. As a result, "it has become much harder for Chinese universities to convince international scientists" to work in China, says Ahlers. But the country's big-science projects have a more powerful draw. "To be a global science power player, you need to attract international researchers, and that's exactly what these big-science infrastructure projects are doing," says Ahlers. "Many researchers really want to go to these unique big-science infrastructure facilities because it's a source of new data that they wouldn't get elsewhere."

Global benefits could also flow from China's investment in big science, says Conlé. "Cooperating with Chinese partners is getting more difficult, but also more interesting," he says. "In the past, it would usually involve cooperation at facilities in Europe — but now it could also be cooperation at their facilities."

Simon also sees mainly upsides for global science in China's big-science push. "We need to go in with both eyes open," he says. "But the West would be foolish to walk away from China just when the term 'mutual benefit' has some potential meaning — when the flows can be not only from us to them, but now also from them."

James Mitchell Crow is a freelance writer, based in Melbourne, Australia.