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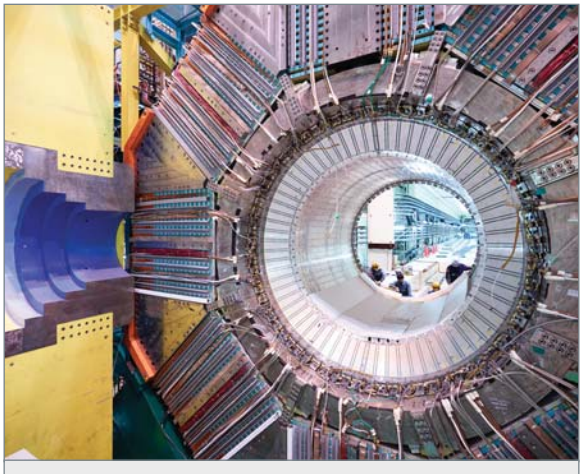
Getting the green light to restart accelerators and other large scientific facilities in Japan took up to three years following the earthquake, tsunami, and nuclear meltdown in eastern Japan on 11 March 2011. (See PHYSICS TODAY, November 2011, page 20, and November 2013, page 20.) Now tight budgets, bloated electricity prices, and a sprinkling of mishaps threaten to cripple science at the country's world-class facilities.

Before the triple disaster, about 30% of Japan's power came from 54 nuclear plants. Since then, as plants have come up for routine maintenance, they've been turned off, and none has been turned back on, although a few have been approved to do so. For a while the country had a shortage of electricity. Now, other sources, mainly fossil fuels, have been arranged, but the costs have skyrocketed: Officials at KEK, Japan's accelerator research institute, and at RIKEN and other science facilities report that the price of electricity has gone up by 30% or more. Electricity is a big chunk of their total operating costs, so they have been forced to reduce running times.

Masanori Yamauchi, the new KEK director, notes that SuperKEKB, the B factory set to start up this year, will consume twice as much power as its predecessor. And the price per kilowatt-hour has nearly doubled. "It has a serious impact to the running schedule of the new accelerator," he says. Studying quantum mechanical phenomena requires collecting large statistics, he adds. "The power bill problem in Japan is very unfortunate for our physics program."

Under Japanese law certain programs are largely shielded from the rising electricity costs. Those spared are SPring-8, the synchrotron light source; materials and life sciences neutron studies at the Japan Proton Accelerator Research Complex (J-PARC); and peta-scale computing in Kobe. Industry makes heavy use of them—about 20% in the case of SPring-8, for instance—whereas the affected facilities are used mainly by academic researchers.



KEK

The Belle II detector and the upgraded accelerator SuperKEKB make up Japan's new B factory for studying flavor physics and *CP* violation. Following some delays, the accelerator is set to start up next January, and full data-taking will begin in 2018.

No data, no competition

T2K is a long-baseline neutrino experiment. To look for flavor oscillations, the Super-Kamiokande detector in central Japan waits for neutrinos shot from J-PARC in the eastern part of the country. J-PARC also provides protons for a hadron program that focuses on studying hypernuclei and making precision tests of the standard model. Both programs suffered from the accelerator's shutdowns in 2011 after the earthquake and in 2013 due to a radiation leak, after which the facility was closed for a year for cleanup. Those closures were compounded by the reduced operations resulting from the tight budget and the high cost of electricity.

The emphases now at T2K are studying *CP* violation in the lepton sector, narrowing in on the mixing angle θ_{23}, and helping pin down the mass hierarchy of neutrinos. "We are in friendly competition with NOνA," a Fermilab experiment, says T2K international co-spokesperson Chang Kee Jung of Stony Brook University. Last year, T2K ran for about four months total. For 2015 Jung predicts less than six months. "But if we don't take data, we can't compete," he says. If better schedules become possible in the coming years, the reduced running time "does not immediately write off the experiment," says Naohito Saito, who this month assumed the J-PARC directorship. J-PARC and the other labs are trying to get more money for operations, Saito says. "We are also trying to maximize our operational efficiency, which is a product of availability of the accelerator, detector, and delivery time of the beam. While the end product may not be ideal, we are trying to make the best of what is available and possible."

The Radioactive Isotope Beam Factory (RIBF) at RIKEN's Nishina Center for Accelerator-Based Science has "the same budget as before [the earthquake], but can run only 20–30% of the usual time" because of increased electricity prices, says center director Hideto En'yo. The reductions vary by site, he says, but they are similar at facilities across the country. He says the budget from RIKEN would keep RIBF open for about one and a half months a year. "You have to beg." So far, he's managed to keep RIBF open about five months a year.

Last August, the RIBF international advisory committee's top recommendation was to find money to keep the facility running eight months a year. "Only this will allow RIBF to fully exploit the unique time window open for the upcoming years to establish and maintain its world leading position in this research area [radioactive ion beams]," wrote the committee, which was chaired by Robert Tribble of Brookhaven National Laboratory. Among the RIBF advances that the committee singled out are "the discovery of many new isotopes, evidence for the modification of shell structure far from stability, great strides in mapping out the rapid neutron capture process

line, and the definitive determination of element 113."

Muhsin Harakeh of the University of Groningen in the Netherlands was until recently the chair of RIBF's program advisory committee, which ranks scientists' proposals. He notes that because run time is scarce, the rate of approval for experiments on RIBF has sunk to 20%. It should be around 50%, he says. "At this rate of giving beam time, the backlog [in approved projects] is two-and-a-half to three years."

For fiscal year 2015, which began on 1 April, RIKEN's budget was reduced by 3%, or ¥1.6 billion ($13.2 million). "That's viewed as a major cut in Japan, where science funding used to be very stable," notes Hitoshi Murayama, director of the Kavli Institute for the Physics and Mathematics of the Universe in Tokyo and a faculty member at the University of California, Berkeley. "I'm concerned that this is a new general trend due to a tremendous amount of national debt."

User frustration

University budgets are also being squeezed, and their facilities are suffering. The Research Center for Electron Photon Science (ELPH), a user facility at Tohoku University, for example, reopened in late 2013 after recovering from the 2011 earthquake. About 40% of the cost of running ELPH's 1.3-GeV electron synchrotron and three linear accelerators is for electricity, and with the high prices, the facility was open just six months last year. "The 30% increase [in the cost of electricity] was very serious," says ELPH director Hajime Shimizu. "We cannot do anything without the beams. We need a new idea to solve the problem in the current Japanese budget system."

The Research Center for Nuclear Physics at Osaka University "is a beautiful facility for stable beams," says Harakeh, who does research there. "And they have a high-resolution spectrometer. For helium-3 charge-exchange experiments, which are important for determining Gamow–Teller matrix elements for nuclear structure, astrophysics, and neutrinoless double-beta decay, this is the best facility in the world." But competition is fierce for shrinking time on the facility. "It's very frustrating, especially for our PhD students," Harakeh says. "You try to do other experiments at other places," he says. "They are less pressing physics-wise, but still original."

Reintroducing nuclear power would help bring electricity prices down in the short term, says En'yo. But taking into account nuclear waste, the longer-term costs are unclear. "The nuclear power cycle is not completed yet, so the cost is not clear," he says. "If we start existing power plants tomorrow, it's almost costless, because we have the fuel and the infrastructure. But in the long term? That's a totally different question."

For now, En'yo says, "everywhere, people are begging the government. It's not systematic." Saito says the country's Ministry of Education, Culture, Sports, Science and Technology (MEXT) "is making a lot of effort to help us, but so far is not fully successful." Although direct cause and effect are hard to pinpoint, Japan's joining the Thirty Meter Telescope in 2013 and its preparations to host the 2020 Olympics are among many pressures on the MEXT budget.

"We try to increase the operational budget from MEXT," says Saito. "If it continues like this, we can't provide data for students. That is not desirable."

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