Supercharging Japan's atom smasher

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From
Physics World
July 2012

ISSN: 0953-8585

IOP
Institute of Physics Publishing
Bristol and Philadelphia

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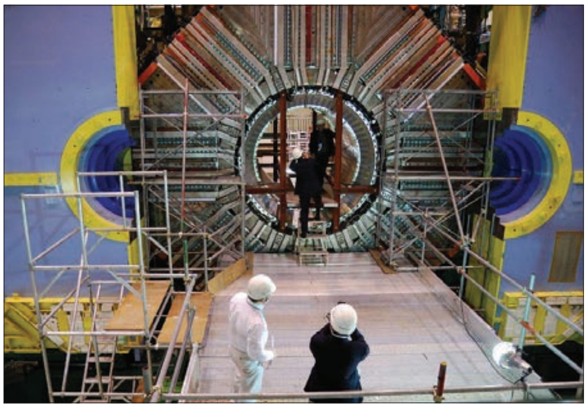
The KEKB collider in Japan is halfway through a major revamp that may help to explain why there is more matter than antimatter in the universe, as **Michael Banks** reports

Lying around 50 km north-east of Tokyo, Tsukuba is only a short 45 min train ride from Japan's bustling capital. Climbing out of Tsukuba's cavernous underground central station it is not immediately obvious why this city is such a hotbed of Japanese science. In fact, Tsukuba was specifically founded in the 1960s as an international science city to attract the best minds to live and work there. Today there are around 3000 foreign students and researchers from as many as 90 countries living in the city and its success in attracting top research is marked by the presence of the headquarters of the Japanese space agency, JAXA, and the National Institute for Materials Science. Indeed, more than 250 hi-tech companies, including Hamamatsu, Hitatchi and Intel, have R&D operations based at research parks around the city.

But Tsukuba is also a special place for high-energy physics, being home to Japan's premier particle-physics lab – the High Energy Accelerator Research Organization (known as KEK). KEK's main facility is the 3 km-circumference KEKB electron–positron collider, which consists of two circular accelerators – one carrying electrons and the other positrons. These particles are smashed together at the BELLE detector, allowing physicists to study their remnants.

Known as a "B factory", KEKB has created more than a billion B mesons and their antimatter counterparts anti-B mesons since it was switched on in 1999. The facility has led to major progress in our understanding of charge–parity (CP) violation – the slight asymmetry between the decay of such particles – and revealed several exotic new particles. The lab is now halfway through an ambitious upgrade to give KEKB a much higher collision rate as well as to improve the BELLE detector. Known as SuperKEKB, the upgraded accelerator is designed to pump out far more B mesons (around 50 billion pairs), as well as other particles such as D mesons and tau leptons that could shed further light on why the universe contains far more matter than antimatter.



KEK

Powering up Japan's High Energy Accelerator Research Organization is revamping its KEKB "B factory" to produce around 50 times more collisions.

We are currently making good progress and should be on target to hit the 2014 commissioning date

KEKB has already stamped its mark on particle physics. In 1972, while at Nagoya University, Makoto Kobayashi and Toshihide Maskawa formulated a 3 × 3 matrix that describes how the strange quark and down quark inside a kaon can switch to and fro into their antiparticles and, in doing so, occasionally break CP symmetry (*Progr. Theor. Phys.* **49** 652). Moreover, the mixing in the matrix implied the existence of new quarks – the charm, bottom and top. It was for this theory that in 2008 Kobayashi and Maskawa were awarded the Nobel Prize for Physics, which they shared with fellow Japanese physicist Yoichiro Nambu, after their theory was proved at KEKB as well as at the PEP-II collider based at what is now the SLAC National Accelerator Laboratory.

However, CP violation as predicted by Kobayashi and Maskawa's theory is still around 10 orders of magnitude too small to account for the asymmetry between matter and antimatter in the universe. There must, therefore, be so-far-undiscovered particles and processes that account for this discrepancy and that is what SuperKEKB will be hoping to figure out.

Looking for more

More than 400 scientists from 15 different countries are involved in the SuperKEKB upgrade plan. Costing around €300m, construction began on SuperKEKB in April 2011, one month after the Japanese government gave the go-ahead. A major part of the upgrade will involve replacing all the titanium-nitride-coated beampipes. The new beampipes will contain "antechambers" that are structured in such a way that the synchrotron radiation from the accelerated electrons enters these chambers. According to SuperKEKB project manager Masanori Yamauchi, the problem with the previous set-up was that synchrotron radiation from the electrons interfered with the beam as it travelled, limiting the luminosity of the machine.

SuperKEKB's electron beam will have an energy of 7 GeV, with the positron beam being 4 GeV. To increase the number of collision events, physicists intend to ramp up the current of the electron ring from 1.2 A to 2.6 A and the positron ring from 1.6 A to 3.6 A. The rate will also be boosted by reducing the size of the electron and positron beams from the width of a human hair to the thickness of a few atomic layers, giving a luminosity of $8 \times 10^{35}\,\mathrm{cm^{-2}\,s^{-1}}$ – some 50 times what was possible at KEKB. "We are currently making good progress and should be on target to hit the 2014 commissioning date," says Yamauchi.

Also being upgraded is the BELLE detector (now called BELLE-II) to handle the huge increase in the collision rate and survive the radiation damage caused by the flux. Key to this design is the inner vertex detector, which will have four layers of conventional silicon strips as well as two layers made out of a relatively new material called depleted P-channel field effect transistor (DEPFET). This material, it is hoped, will make the detector much better at pinpointing where particles decay. Outside the vertex detector is another detector, made from 2.5 m-long quartz plates, that separates muons from kaons. It works by detecting the Cerenkov radiation – flashes of light that occur when a charged particle travels faster than the speed of light in its medium – emitted by the particles.

"There are many new technologies that are involved in the new detector," says Peter Križan from Ljubljana University and the J Stefan Institute in Slovenia, who is spokesperson for BELLE-II. "In all, this is going to give us a much better resolution instrument – one that will not only complement CERN's Large Hadron Collider, but also be able to find new particles and study their effect much better than was possible before."