PARTICLE PHYSICS

Plans for LHC's super successor

CERN envisages the most powerful collider ever built.

BY DAVIDE CASTELVECCHI

CERN has unveiled its bold dream of building a new accelerator with a path nearly 4 times that of its 27-kilometre-circumference Large Hadron Collider (LHC) — currently the world's largest collider — and up to 6 times more powerful. CERN, Europe's particle-physics laboratory near Geneva, Switzerland, outlined the plan in a technical report released on 15 January (see https://fcc-cdr.web.cern.ch).

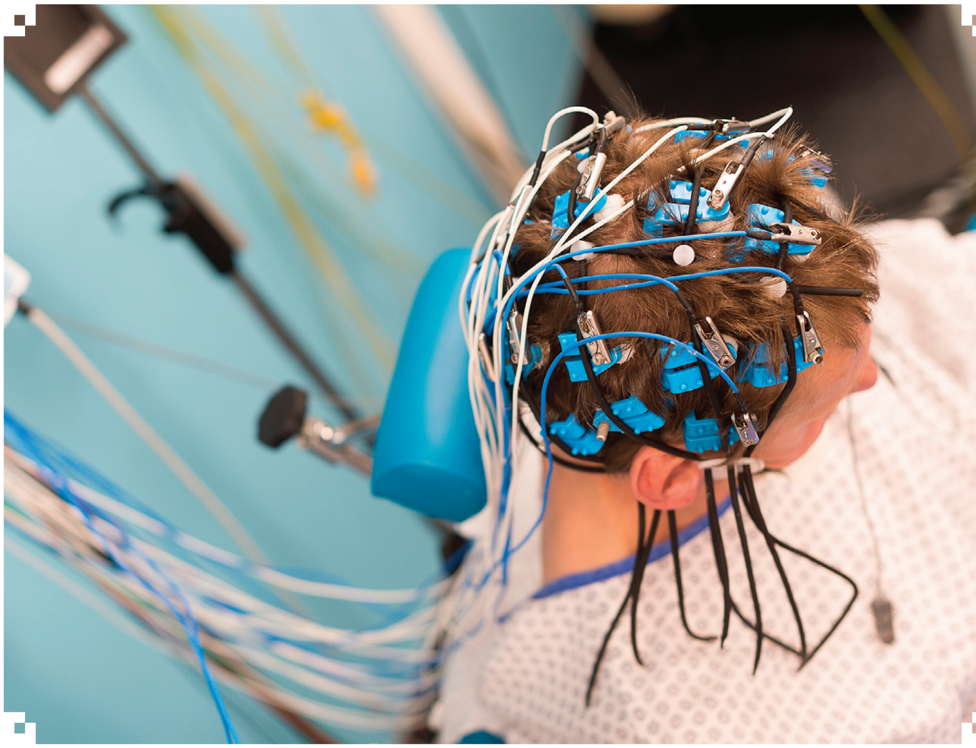
The document offers several preliminary designs for a Future Circular Collider (FCC) — one of which would be the most powerful particle smasher ever built — with different types ranging in cost from around €9 billion (US$10.2 billion) to €21 billion. It is the lab's opening bid in a priority-setting process called the European Strategy for Particle Physics Update, which will take place over the next two years and will affect the field's future well into the second half of the century.

"It's a huge leap — like planning a trip not to Mars, but to Uranus," says Gian Francesco Giudice, who heads CERN's theory department and represents the laboratory in the Physics Preparatory Group of the strategy-update process.

Since the LHC's historic discovery of the Higgs boson in 2012, the collider has not found any new particles. This points to a need to push collider energies as high as possible, Giudice says. "Today, exploring the highest possible energies with bold projects is our best hope to crack some of the mysteries of nature at the most fundamental level."

The potential for a machine such as the FCC is "very exciting", says Halina Abramowicz, a physicist at Tel Aviv University in Israel who heads the European strategy-update process. She adds that the FCC's potential will be discussed in depth as part of that exercise, and compared with other proposed projects. The CERN Council, which includes scientists and delegates from the governments of CERN's member countries, will then make the final decision on whether to fund the project.

But not everyone is convinced that the super-collider is a good investment. "There is no reason to think that there should be new physics in the energy regime that such a collider would reach," says Sabine Hossenfelder, a theoretical physicist at the Frankfurt Institute for Advanced Studies in Germany. "That's the nightmare that everyone has on their mind, but doesn't want to speak about." ■ SEE EDITORIAL P.398



People with epilepsy had the activity of single neurons tracked during surgery.

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NEUROSCIENCE

Brain study probes primate 'software'

Pioneering research tracked single neurons to reveal differences in human and monkey brain activity.

BY ALISON ABBOTT

Neuroscientists have for the first time discovered differences between the 'software' of human and monkey brains, using a technique that tracks single neurons.

They found that human brains trade off 'robustness' — a measure of how synchronized neuron signals are — for greater efficiency in information processing. The researchers suggest that the results might help to explain humans' unique intelligence, as well as their susceptibility to psychiatric disorders. The findings were published in *Cell* on 17 January (R. Pryluk *et al. Cell* http://doi.org/gfthv2; 2019).

Scientists say that this kind of unusual study could help them to translate research in animal models of psychiatric diseases to the clinic.

The research exploited a rare set of data on the activity of single neurons collected deep in the brains of people with epilepsy who were undergoing neurosurgery to identify the origin of their condition. The technique is so difficult that only a handful of clinics around the world can participate in this type of research. The study also used similar, existing data from three monkeys and collected neuron information from two more.

Over the decades, neuroscientists have discovered many subtle and significant differences in the anatomy — the hardware — of the brains of humans and other primates. But the latest study looked instead at differences in brain signals.

"There is a clear difference in behaviour and psychology between humans and non-human primates," says Mark Harnett, who studies how the biophysics of neurons affect neural computation at the Massachusetts Institute of Technology in Cambridge. "Now we see this difference in the brain's biology — it's a tremendously valuable study."

The study was a collaboration between Rony Paz at the Weizmann Institute of Science in Rehovot, Israel, who studies the dynamics of neural circuitry involved in learning in macaques, and neurosurgeon Itzhak Fried of the University of California, Los Angeles.

Paz's research focuses on two different brain areas. One is the amygdala, an evolutionarily primitive area that underlies basic survival skills, such as running away from an advancing tiger. The other is the more evolved cingulate cortex, which processes more sophisticated cognitive behaviours such as learning.

Paz wanted to find out how neurons in these regions in monkeys might differ from their equivalents in humans. He turned to Fried, who pioneered the use of single-neuron recording techniques in people with epilepsy who do not respond to drug treatment.

These patients can undergo a treatment that involves implanting a series of fine electrodes in their brains to record electrical activity, and thereby pinpoint the origin of seizures. The patients remain in hospital until a seizure occurs; surgeons then remove the electrodes and the damaged brain tissue that is the source of the epileptic activity. While waiting for seizures to occur, patients often participate in experiments that explore brain function.

PRIMATE PATTERNS

Paz and Fried identified single-neuron data from the amygdala and cingulate cortex in a large data set collected from people who happened to have had electrodes implanted close to these brain areas as part of their treatment, and had participated in a memory study (H. Gelbard-Sagiv *et al. Science* **322**, 96–101; 2008). They compared the people's neurons with those of Paz's monkeys in terms of two properties: robustness and efficiency.

The data were collected from nearly 750 neurons from the five monkeys and seven humans. They comprise a long series of firing spikes or silences from single neurons recorded over several hours. The scientists searched the data for the two properties: they defined robustness as the level of synchrony, or near synchrony, in both the firing of neurons and the frequent repetition of similar patterns of spikes, and efficiency as having more combinations of patterns in the activity.

"It's a tremendously valuable study."

They found that in both species, the signals in the amygdala were more robust than those in the cingulate cortex. But those in the cingulate cortex were more efficient. Both regions in humans were less robust and more efficient than those in monkeys — so humans have sacrificed some robustness for increased efficiency.

That makes sense, says Paz. The more robust a signal, the less ambiguous, or error-prone, it is. "If I see a tiger, I want all of my amygdala neurons to shout, 'Run away fast!'" But in higher species, such as primates, the brain evolved more flexible areas — the cortex — to allow for more considered responses to the animals' environments, says Paz.

PSYCHIATRIC SIDE EFFECTS

Humans' smarter, but more error-prone, cortices might explain their vulnerability to psychiatric disorders, says Paz.

That resonates with other theories in neuropsychology, which propose that synchronization of neuronal activity in the brain might be correlated with psychosis or depression, says cognitive neuroscientist Robert Knight at the University of California, Berkeley. "This line of research is very important, because most neuroscience studies are carried out in animals, with the assumption that the core pattern of neuronal activity holds across species — for humans, too," he says.

The researchers' robustness–efficiency trade-off hypothesis is an important one that needs to be explored in further studies, says neuroscientist Christopher Petkov of Newcastle University, UK. Direct comparisons between monkey and human data sets are challenging because it is hard to know whether the two species were in comparable states of mind when the data were collected, he notes. ■