Although Everett didn't see Sauerland's presentation, he suggests that the remarks could equally well be translated as two separate, direct sentences, such as: "The nut is under the banana leaf. Or so Oope says", or "Oope doesn't know. Where is the nut?"

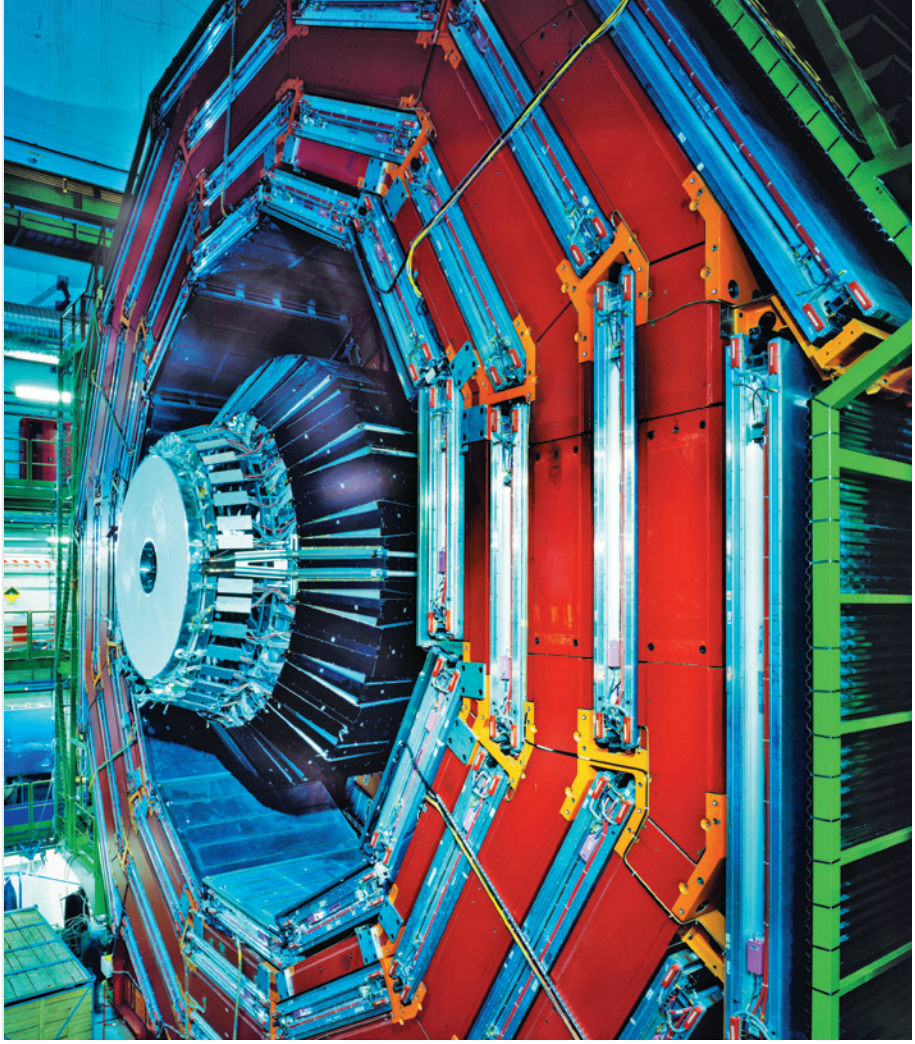
The difference is subtle, but it cuts to the heart of Everett's case against Chomsky's theory. Embedded clauses can be instances of recursion, an iterative process that Chomsky says is essential to all language because it enables ever more complex sentences to be built up out of individual words or sounds. Everett also says that Pirahã lacks colour and number terms and has no perfect tense, which is used in English for events that have been completed. Although many linguists say that Chomsky's theory of a universal grammar would hold even if Everett is right about those features, Everett believes that such a profound interplay between culture and language conflicts with Chomsky's theory of language as innate.

The situation underscores the potential difficulty in settling important claims about minority languages. The United Nations Educational, Scientific and Cultural Organization lists 2,473 languages as endangered, meaning either that they are spoken by only small communities of people or that the elderly people who speak them have not passed them on to subsequent generations. Many such languages have been studied by just a single linguist, so that other researchers must rely on that person's translations.

"For a lot of languages we have extremely poor documentation," says Lyle Campbell, a linguist at the University of Hawaii at Manoa who is leading ELCat, an online project supported by the US National Science Foundation that aims to catalogue endangered languages. Expected to launch later this month, ELCat will serve as a centralized repository for original data such as recordings, video, text, transcripts and translations. Campbell says that such documentation makes it possible for linguists to test each others' statements.

Thomas Roeper, a linguist at the University of Massachusetts in Amherst, says that linguists will inevitably have to work with data from a limited number of sources. "There are many languages that only one, two or three people have studied, with Western prejudices. It would be a great mistake if we didn't include their experiences in our knowledge," he says.

Everett and his colleagues are now testing his arguments using data on Pirahã collected by his missionary predecessor, Steve Sheldon. Everett is also working on making his own records available. "I have data recorded, and am translating more and more," he says. ■



The Compact Muon Solenoid experiment detects hundreds of millions of particle collisions every second.

ENRICO SACCHETTI

PARTICLE PHYSICS

LHC prepares for data pile-up

Physicists scramble to see through fog of collisions.

BY GEOFF BRUMFIEL

The world's largest particle accelerator is roaring along at an unprecedented pace, delivering torrents of data to its physicist handlers. But the hundreds of millions of collisions happening inside the machine every second are now growing into a thick fog that, paradoxically, threatens to obscure a fabled quarry: the Higgs boson.

The problem is known as pile-up, and it promises to be one of the greatest challenges this year for scientists working on the Large Hadron Collider (LHC) at CERN, Europe's main high-energy physics laboratory near Geneva, Switzerland.

Huge amounts of computing power, cunning software and technical tricks are helping scientists to stay ahead of the problem. But researchers may still need to scale back the collisions to find the long-sought Higgs, the manifestation of a field that is believed to confer mass on other particles.

If it exists, the Higgs will appear fleetingly inside the machine before decaying into lighter particles. Last year, the two biggest detectors at the LHC saw hints of a Higgs with a mass of about 125 gigaelectronvolts (energy and mass are interchangeable in particle physics). This year, researchers want to collect more data to see whether that signal grows into a certainty, or withers back to nothing.

Since it began its latest science run last month, the LHC has been squeezing trillions of protons into ever-smaller bunches, and smashing those bunches

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together tens of millions of times per second. The resultant data are measured in inverse femtobarns (fb^{-1}), a unit roughly equivalent to 100 trillion collisions. In the past month alone, the LHC recorded 1 fb^{-1} worth of collisions. By the end of the year it aims have captured at least 15 fb^{-1} (see 'Smashing!').

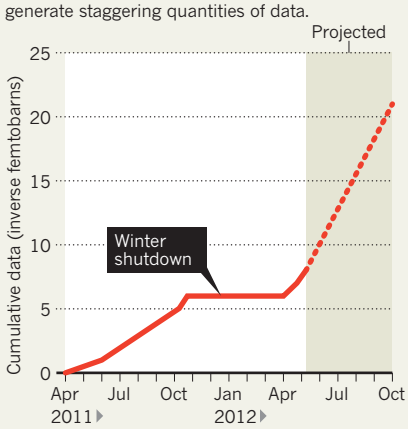
To gather these data, researchers are pushing the collider in two ways: by accelerating the particles to ever-greater energies and by increasing the number of collisions. Higher energies allow heavier particles to pop into being, but it is the number of collisions that will determine whether physicists have enough data to declare a discovery. In the weeks ahead, scientists will pack more protons inside the machine and focus the particles as tightly as possible onto the collision points at the centre of the LHC's two biggest detectors. Already, "we've done humongously better than we thought we could", says Mike Lamont, the head of accelerator operations at CERN.

Every time two tightly packed bunches of protons cross, they generate not one collision, but on average 27, Lamont says. But within a few weeks, that number is expected to rise into the mid-30s, peaking at around 40 collisions per crossing. The two main detectors at the LHC were designed to handle only around two dozen collisions at once. But they have managed to cope so far.

Each detector is made up of layers of smaller detectors that record the tracks of debris coming from their centre. When a collision occurs, computers above the machine decide whether the data are interesting and, if so, reconstruct the collision from the tracks. But when dozens of collisions occur at once, the computers must disentangle them.

SMASHING!

As the LHC ramps up its proton collisions it will generate staggering quantities of data.



SOURCE: CERN

Last year, researchers working with the ATLAS detector formed a task force to tackle the pile-up problem, rewriting computer code so that the detector could cope with the extra collisions. Team member Andreas Salzburger says that the group has been working hard to weed out the 'ghost' particles that appear when the paths of several particles align, creating the illusion of a particle that is not actually there. Eliminating these ghosts as early as possible reduces the amount of computing power needed to crunch useful data, he says.

At the Compact Muon Solenoid (CMS), ATLAS's rival detector, physicists have trained their algorithms to triage data on the fly, analysing particle tracks in order of complexity. "Did you ever play the game 'pick-up sticks?'," asks Joe Incandela, the spokesman for the CMS. "You pick up the easiest ones first, and it makes it simpler to deal with the other ones." The team is also working on ways to get rid of signals from 'loopers', low-energy particles that spiral along the detector's magnetic field lines, generating data that are irrelevant to the Higgs hunt.

Such tricks are likely to be less effective as the number of collisions rise. At the outer edges of the machine, the detector segments are larger and have coarser resolution, so it might not be possible to disentangle some of the tracks. That could reduce a detector's ability to pick up one signature of the Higgs: a decay to a pair of W bosons, which causes a cascade of particles that need to be caught by these outer segments.

For now, the mountains of extra data should offset what is lost to pile-up. Researchers expect to miss no more than 15% of events from the most likely Higgs decay pathway, which produces two γ-rays. And if ATLAS and the CMS can't handle the extra particles surging through the machine, Lamont says, the accelerator physicists are ready to dial it back. But "if they can take it, we will give it to them", he says. ■

PHYSICS

A boost for quantum reality

Theorists claim they can prove that wavefunctions are real states.

BY EUGENIE SAMUEL REICH

The philosophical status of the wavefunction — the entity that determines the probability of different outcomes of measurements on quantum-mechanical particles — would seem to be an unlikely subject for emotional debate. Yet online discussion of a paper claiming to show mathematically that the wavefunction is real has ranged from ardently star-struck to downright vitriolic since the article was first released as a preprint in November 2011.

The paper, thought by some to be one of the most important in quantum foundations in decades, was finally published last week in *Nature Physics* (M. F. Pusey, J. Barrett & T. Rudolph *Nature Phys.* http://dx.doi.org/10.1038/nphys2309; 2012), enabling the authors, who had been concerned about violating the journal's embargo, to speak about it publicly for the first time. They say that the mathematics leaves no doubt that the wavefunction is not just a statistical tool, but rather, a real, objective state of a quantum system. "People have become emotionally attached to positions that they defend with vague arguments," says Jonathan Barrett, one of the authors and a physicist at Royal Holloway, University of London. "It's better to have a theorem."

The authors have some heavyweights in their corner: their view was once shared by Austrian physicist and quantum-mechanics pioneer Erwin Schrödinger, who proposed in his famous thought experiment that a quantum-mechanical cat could be dead and alive at the same time. But other physicists have favoured an opposing view, one held by Albert Einstein: that the wavefunction reflects the partial knowledge an experimenter has about a system. In this interpretation, the cat is either dead or alive, but the experimenter does not know which. This 'epistemic' interpretation, many physicists and philosophers argue, better explains the phenomenon of wavefunction collapse, in which a quantum state is fundamentally changed by measuring it.

Barrett and his colleagues are following the approach of physicist John Bell, who in 1964 proved that quantum mechanics has another counterintuitive implication: that measurements on one particle can influence the state of another, distant particle, faster than the speed of light should allow. Bell's was a 'no-go' theorem: its strategy was to show that theories that do not allow faster-than-light ▶

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