The safety of the LHC

The Large Hadron Collider (LHC) can achieve an energy that no other particle accelerators have reached before, but Nature routinely produces higher energies in cosmic-ray collisions. Concerns about the safety of whatever may be created in such high-energy particle collisions have been addressed for many years. In the light of new experimental data and theoretical understanding, the LHC Safety Assessment Group (LSAG) has updated a review of the analysis made in 2003 by the LHC Safety Study Group, a group of independent scientists.

LSAG reaffirms and extends the conclusions of the 2003 report that LHC collisions present no danger and that there are no reasons for concern. Whatever the LHC will do, Nature has already done many times over during the lifetime of the Earth and other astronomical bodies. The LSAG report has been reviewed and endorsed by CERN's Scientific Policy Committee, a group of external scientists that advises CERN's governing body, its Council.

The following summarizes the main arguments given in the LSAG report. Anyone interested in more details is encouraged to consult it directly, and the technical scientific papers to which it refers.

Cosmic rays

The LHC, like other particle accelerators, recreates the natural phenomena of cosmic rays under controlled laboratory conditions, enabling them to be studied in more detail. Cosmic rays are particles produced in outer space, some of which are accelerated to energies far exceeding those of the LHC. The energy and the rate at which they reach the Earth's atmosphere have been measured in experiments for some 70 years. Over the past billions of years, Nature has already generated on Earth as many collisions as about a million LHC experiments – and the planet still exists. Astronomers observe an enormous number of larger astronomical bodies throughout the Universe, all of which are also struck by cosmic rays. The Universe as a whole conducts more than 10 million million LHC-like experiments per second. The possibility of any dangerous consequences contradicts what astronomers see - stars and galaxies still exist.

Microscopic black holes

Nature forms black holes when certain stars, much larger than our Sun, collapse on themselves at the end of their lives. They concentrate a very large amount of matter in a very small space. Speculations about microscopic black holes at the LHC refer to particles produced in the collisions of pairs of protons, each of which has an energy comparable to that of a mosquito in flight. Astronomical black holes are much heavier than anything that could be produced at the LHC.

According to the well-established properties of gravity, described by Einstein's relativity, it is impossible for microscopic black holes to be produced at the LHC. There are, however, some speculative theories that predict the production of such particles at the LHC. All these theories predict that these particles would disintegrate immediately. Black holes, therefore, would have no time to start accreting matter and to cause macroscopic effects.

Although stable microscopic black holes are not expected in theory, study of the consequences of their production by cosmic rays shows that they would be harmless. Collisions at the LHC differ from cosmic-ray collisions with astronomical bodies like the

Earth in that new particles produced in LHC collisions tend to move more slowly than those produced by cosmic rays. Stable black holes could be either electrically charged or neutral. If they had electric charge, they would interact with ordinary matter and be stopped while traversing the Earth, whether produced by cosmic rays or the LHC. The fact that the Earth is still here rules out the possibility that cosmic rays or the LHC could produce dangerous charged microscopic black holes. If stable microscopic black holes had no electric charge, their interactions with the Earth would be very weak. Those produced by cosmic rays would pass harmlessly through the Earth into space, whereas those produced by the LHC could remain on Earth. However, there are much larger and denser astronomical bodies than the Earth in the Universe. Black holes produced in cosmic-ray collisions with bodies such as neutron stars and white dwarf stars would be brought to rest. The continued existence of such dense bodies, as well as the Earth, rules out the possibility of the LHC producing any dangerous black holes.

Strangelets

Strangelet is the term given to a hypothetical microscopic lump of 'strange matter' containing almost equal numbers of particles called up, down and strange quarks. According to most theoretical work, strangelets should change to ordinary matter within a thousand-millionth of a second. But could strangelets coalesce with ordinary matter and change it to strange matter? This question was first raised before the start up of the Relativistic Heavy Ion Collider, RHIC, in 2000 in the United States. A study at the time showed that there was no cause for concern, and RHIC has now run for eight years, searching for strangelets without detecting any. At times, the LHC will run with beams of heavy nuclei, just as RHIC does. The LHC's beams will have more energy than RHIC, but this makes it even less likely that strangelets could form. It is difficult for strange matter to stick together in the high temperatures produced by such colliders, rather as ice does not form in hot water. In addition, quarks will be more dilute at the LHC than at RHIC, making it more difficult to assemble strange matter. Strangelet production at the LHC is therefore less likely than at RHIC, and experience there has already validated the arguments that strangelets cannot be produced.

Vacuum bubbles

There have been speculations that the Universe is not in its most stable configuration, and that perturbations caused by the LHC could tip it into a more stable state, called a vacuum bubble, in which we could not exist. If the LHC could do this, then so could cosmic-ray collisions. Since such vacuum bubbles have not been produced anywhere in the visible Universe, they will not be made by the LHC.

Magnetic monopoles

Magnetic monopoles are hypothetical particles with a single magnetic charge, either a north pole or a south pole. Some speculative theories suggest that, if they do exist, magnetic monopoles could cause protons to decay. These theories also say that such monopoles would be too heavy to be produced at the LHC. Nevertheless, if the magnetic monopoles were light enough to appear at the LHC, cosmic rays striking the Earth's atmosphere would already be making them, and the Earth would very effectively stop and trap them. The continued existence of the Earth and other astronomical bodies therefore rules out dangerous proton-eating magnetic monopoles light enough to be produced at the LHC.