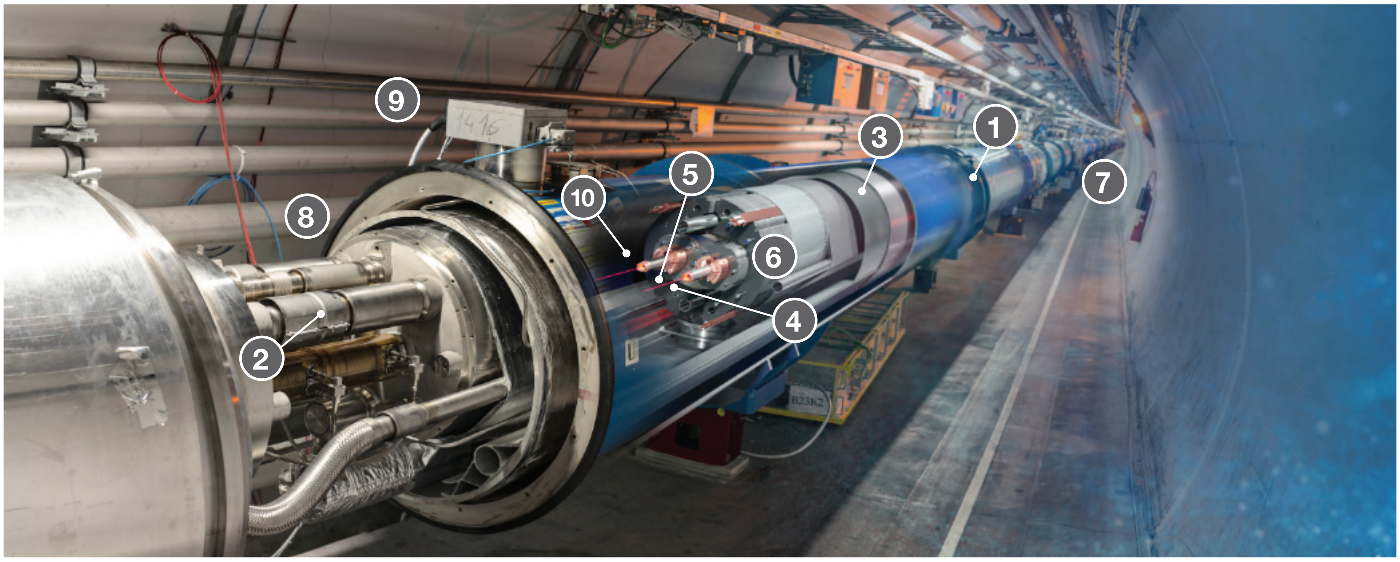
LHC Season 2: A stronger machine

In early 2013, after three years of running, the Large Hadron Collider (LHC) shut down for planned maintenance. Hundreds of engineers and technicians spent two years repairing and strengthening the accelerator in preparation for running at higher energy. Now the world's largest and most powerful particle collider is ready to start up again. So what's new?



1) NEW MAGNETS
Of the LHC's 1232 superconducting dipole magnets, which steer particle beams around the accelerator, 18 have been replaced owing to wear and tear.

2) STRONGER CONNECTIONS
More than 10,000 electrical interconnections between dipole magnets in the LHC have been fitted with splices – pieces of metal that act as an alternative path for the 11,000 amp current, saving the interconnection if there is a fault.

3) SAFER MAGNETS
The LHC's superconducting magnets have an improved quench protection system. Superconducting magnets conduct electricity without losing energy to resistance, and so can achieve higher magnetic fields. In a quench, a magnet reverts back to a resistive state, releasing a large amount of energy. The quench-protection system in the LHC serves to dissipate this energy in a more controlled manner if it finds any abnormal voltage developing across a magnet.

4) HIGHER ENERGY BEAMS
The energy of collisions in the LHC in 2015 will be 13 TeV (or 6.5 TeV per beam) compared to 8 TeV (4 TeV per beam) in 2012. Higher energy allows physicists to extend the search for new particles and to check previously untestable theories.

5) NARROWER BEAMS
Because transverse beam size – the width of the beam – decreases with increasing energy, beams in the LHC will be more tightly focused, which means more interactions and collisions for the experiments to study.

6) SMALLER BUT CLOSER PROTON PACKETS
There will be fewer protons per packet – or "bunch": 1.2 x 10^{11} compared to 1.7 x 10^{11} in 2012. When dozens of collisions occur at once, it becomes harder for a detector's computers to disentangle which particle comes from which collision. With fewer protons in each collision, this problem of "pileup" will be less severe. However, the bunches of protons will be separated in time by 25 nanoseconds compared to 50 nanoseconds. The LHC will thus deliver more particles per unit time as well as more collisions to the experiments.

7) HIGHER VOLTAGE
Radiofrequency cavities, which give particles little kicks of energy as they pass, will operate at higher voltages to give the beams higher energies.

8) SUPERIOR CRYOGENICS
The dipole magnets on the LHC must be kept at low temperature to be in their superconducting state. The cryogenics system has been fully consolidated, with complete maintenance of the cold compressors, as well as an upgrade of the control systems and renovation of the cooling plant.

9) RADIATION-RESISTANT ELECTRONICS
A full maintenance and upgrade of the electrical systems on the LHC included more than 400,000 electrical tests, and the addition of newer, more radiation-tolerant systems.

10) MORE SECURE VACUUM
The inside of the beam pipe is kept under vacuum so that the beam does not crash into molecules in its path. But charged beams can rip electrons from the inside surfaces of the pipe, forming an "electron cloud" that interferes with the beam. To dampen this effect the inside of the beam pipe has been coated with non-evaporable getter (NEG), a material that takes up the electrons. In places, solenoids have been wrapped around the beam pipe to keep electrons from deviating from the sides.

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