Riley Motor Club visit to CERN

Tony Maddison recounts the many visits members of the club have made to CERN. (European Organisation for Nuclear Research)

CERN occupies an area which spans Swiss and French territory. The main entrance is at Meyrin near Geneva in Switzerland. It is the site of the *Large Hadron Collider*, which by a considerable margin, is the largest and most powerful particle accelerator in the world. International collaboration built and now operates the LHC which is located in a circular tunnel 27kilometers (17miles) in circumference and on average 100 meters below the surface, depending on local topography.

Research projects at the LHC address some fundamental questions, including;

• Matter and antimatter would have been created in equal amounts at the Big Bang 13.8 billion years ago. Why is antimatter not now detectable in the universe?
• What were the mechanisms by which the plasma created at the Big Bang led to the formation of the known universe? Lead ion collisions have reproduced this quark/gluon plasma on a minute scale.

• What is the dark matter which would explain star motion in distant galaxies?

• What is the nature of the force, or dark energy, thought to be responsible for the accelerating rate of expansion of the universe?

• Though the Standard Model of particle physics is widely supported by experimental evidence, no gravitational theory is yet incorporated. The search continues for supersymmetry particles which would be more massive partners of those known to exist.

To investigate these subjects using the LHC, protons, or heavy ions, are generated and accelerated outside the ring before being injected into two small diameter tubes, evacuated to ultra high vacuum @ 10-13 atm., in opposite directions.

Further beam acceleration and control is achieved using RF cavities and very intense magnetic fields surrounding the two beams, increasing speeds to 99.9999992% of the speed of light in a vacuum, c. (c=~ 300,000 km, or 186,000 miles per second). At this speed beam energy is boosted very considerably by the relativistic mass increases generated. Proton groups containing 1.2x1011 particles complete over 11,000 revolutions of the 17 mile ring per second. When required, the beams are steered to intersect within detectors at collision energies of up to 14 TeV (14 x1012 electron volts), achieving a billion collisions per second. Lead nuclei reach collision energies of 1150 TeV. (1eV is the energy acquired by an electron accelerated under a potential difference of 1 volt.)

The intense magnetic fields required are generated by 9,600 superconducting electromagnets.

The many multi-pole designs include these larger units:

Used to control beam position, 1,232 Dipole types, each 15 meters long, weighing 35 tonnes and conducting > 11,000 amps.,

Used to control beam cross section, 392 Quadrupole types, each 5-7 meters long.

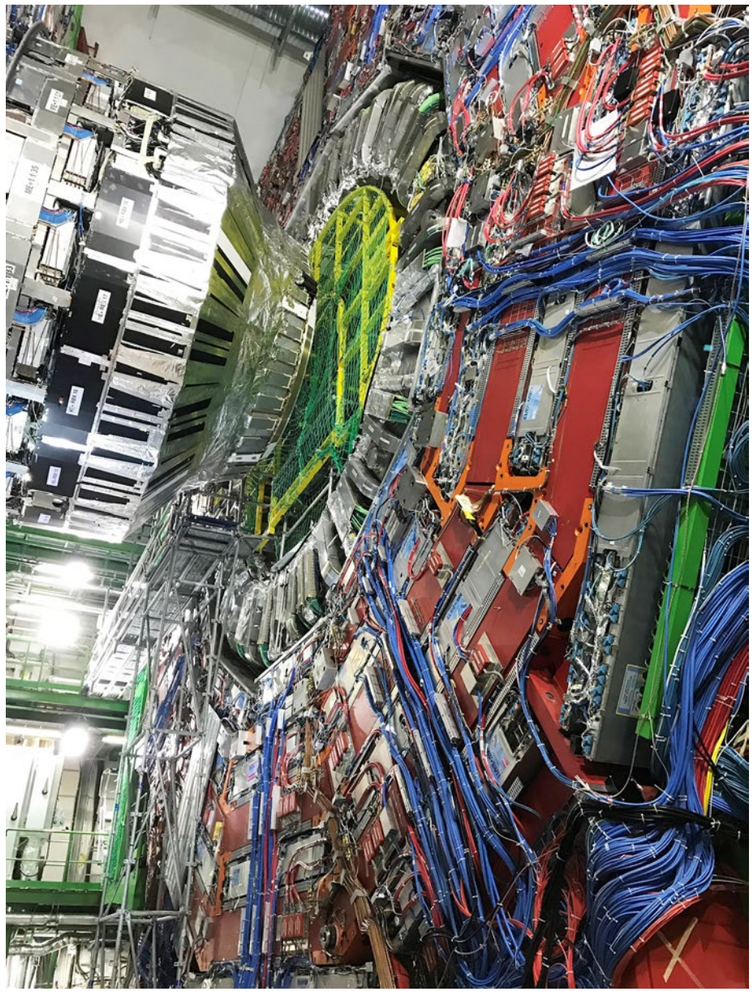
The superconducting niobium/titanium windings are cooled to -2710 C (1.90 above absolute zero) using a 120 tonne supply of liquid helium.

The collision energies available make possible the creation of mass in accordance with Einstein`s equation E=mc2. A recent example was the creation of the Higgs boson, named after Peter Higgs, the English physicist who in 1964 conceived the existence of a field responsible for particle mass. The associated boson was created in 2012 when proton beams were collided at 126 GeV.

It was found by the ATLAS and CMS detectors. Since that discovery further research on the Higgs boson continues.

We visited the CMS (Compact Muon Solenoid) in 2019. It weighs 12,500 tonnes, almost double that of the Eiffel Tower.

“The intense magnetic fields required are generated by 9,600 superconducting electromagnets.”



CERN Visit sites

Between 2019 and 2026 a number of visits to CERN have been undertaken by small groups which have always included Riley Club members.

During the 2019 shutdown open weekend we visited a number of experiments, including two detectors, LHCb and CMS. I had originally booked the ATLAS detector but 70,000 other visitors had the same idea so we went to LHCb instead.

Since then my contact at CERN, Adriaan, has expertly hosted our

visits, thanks to his long career involving both cutting- edge physics experiments and the spectacular engineering unique to this establishment. The small group sizes has also proved highly advantageous in terms of discussion opportunity and access to small areas inaccessible to larger groups.

Over the years we have enjoyed visiting many surface sites and underground experiments, including the Antimatter Factory, Large Magnet Factory, Synchrocyclotron, Data Centre, Low Energy Ion Ring, Alpha Magnetic Spectrometer, and the *Science Gateway*. CERN does not charge for visits, and we use an airport hotel which is conveniently equidistant between CERN and Geneva.

The sites visited recently by RMC members are briefly described below.

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We visited the Science Gateway which was recently built opposite the main entrance. It contains a considerable number of exhibits, many interactive, which reflect the research interests at CERN, describing the experiments and equipment deployed at surface and underground sites. We also took the opportunity to see the office used by Tim Berners-Lee, the British scientist who had invented the World Wide Web in 1989.

The next facility we visited was the *Data Centre*, where we viewed from above 10,000 servers

running continuously. Scientific data from detectors are filtered, and the small fraction of interest that remains is stored on magnetic tape for analysis by collaborating scientists worldwide.

The data stored has now reached 1 exabyte (106 terabytes, enough to play a video DVD for 50,000 years).

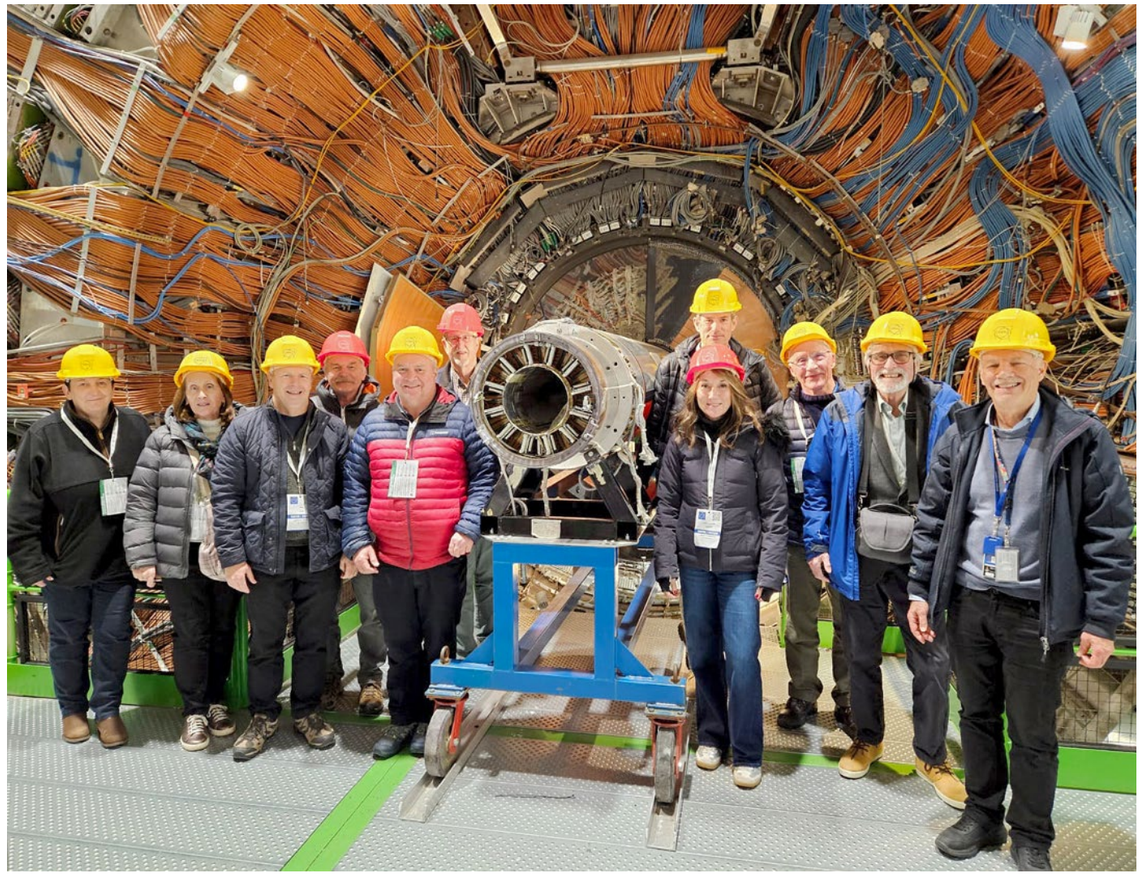
Afterwards we visited the *Antimatter Factory*.

In 1928 British physicist Paul Dirac, interpreting a solution to his equation, postulated the existence of antimatter particles of identical mass to normal matter but with opposite charge.

The existence of antimatter has since been confirmed and extensively investigated. On contact, matter and antimatter annihilate, releasing a burst of energy. For example, a negatively charged electron and the positively charged positron annihilate producing a 1.1 MeV gamma ray.

At the *Antimatter Factory* a metal target is bombarded with a proton beam to produce various particles which include antiprotons. The antiprotons are focussed and slowed down through a series of deceleration stages, leading ultimately to the creation of antihydrogen atoms.

This ability to create and isolate antimatter particles, nuclei and atoms has facilitated many studies investigating antimatter properties, including the influence of gravity.



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We crossed the border into France to visit the *Alpha Magnetic Spectrometer* Control Centre at Prevessin. This precision instrument, the first to be deployed in space, was built at CERN, then attached externally to the orbiting International Space Station.

In addition to receiving particles from the Sun, radiation emanating from Jupiter`s magnetosphere is also detected. Outside the solar system Galactic cosmic rays have been detected which contain protons, electrons and antiparticles at extremely high energies up to 106 MeV.

Unlike these dangerous cosmic rays which do not penetrate the atmosphere, the ubiquitous neutrino, has no charge and negligible rest mass. They are emitted in nuclear reactions and are very difficult to detect. Several different forms are known, in addition to corresponding antiparticles.

They pass through the earth virtually unimpeded, passing through each of us at a rate of about 100 million per second.

It was very fortuitous that Adriaan had planned a visit to the LHCb facility, since Victor had been here in 2019 and our party included his daughters Samantha and Virginia.

LHCb specialises in quark b experiments. When studying atomic and nuclear physics over half a century ago, I was aware of early quark research that had been undertaken using laboratory scale bubble chambers. LHCb however, the smallest of the four main detectors at 5,600 tonnes, represents a phenomenal advance in experimental physics and has made great contributions in this field. Quarks are now known to be fundamental particles of which there are 6 types (plus the 6 corresponding antimatter forms). They vary in mass and fractional charge, and in different combinations are the constituents of protons and neutrons which are therefore now classified as composite particles.

At CERN exotic quark combinations have been created, the pentaquark for example.

The quark is extremely small at ~ 10-16 mm across, compared to protons at ~10-12 mm and the hydrogen atom at ~10-7 mm., the latter dimension defined by the single electron orbital.

Given the separation of nucleus and electron most of the atomic volume is empty space. Making assumptions on weight distribution, I calculate that without this space the current global human population of about 9 billion would fit into the volume of a half pint glass. This is of course an estimate but it does suggest an order of magnitude. Though spectacular, such a density is trivial when compared with that observed in neutron stars. Under extreme gravitational forces a teaspoonful of neutron star material weighs ~ 1 billion tonnes.

These mere words have failed to adequately describe CERN visiting experiences. My advice is to consider experiencing it yourself.

CERN will start the third Long Shutdown, LS3, in June 2026. Because much upgrade work will be undertaken, visits will initially be very restricted. There will be no open weekend this year, but in 2027 an open weekend is a possibility.

I anticipate arranging other visits for Club members later this year and in 2027. I will issue updates via newsletters and Emma Merryweather. Meantime please feel free to send expressions of interest to me at applied.research@outlook.com ■

The late Victor Riley at CERN in 2019.

“Unlike these dangerous cosmic rays which do not penetrate the atmosphere, the ubiquitous neutrino, has no charge and negligible rest mass.”

With reference to errors printed in the March 2026 Riley Record, please attach to the CERN report the following table, which shows the correct mathematical expressions used in the original text.

Riley Record Version	**Original Superscript Text**
p19:	
-	
10-13atm.	10^{-13}atm.
1.2x1011	$1.2x10^{11}$
14x 2012 electron volts	$14x10^{12}$ electron volts
-2710 C (1.90 above absolute zero)	-271° C (1.9° above absolute zero)
.	
E=mc2	$E=mc^2$
p20:	
1 exabyte (106 terabytes)	1 exabyte (10^6 terabytes)
p21:	
energies up to 106 MeV	energies up to 10^6 MeV
quark at ~ 10-16mm	quark at ~ 10^{-16} mm
proton at ~ 10-12mm	proton at ~ 10^{-12}mm
hydrogen atom ~10-7mm	hydrogen atom at ~ 10^{-7} mm

Tony Maddison