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Elementary German I

# An Exploration on the History of CERN

In the aftermath of the Second World War another crisis arose, though not one of the violent nature of the recent international conflict. This crisis was one of intellectual nature. European nations, having exhausted funds on the war effort, could ill afford the cost of funding new scientific endeavors, especially those as fiscally demanding as those in the field of particle physics. The high cost of particle physics research stems from the massive machinery required to conduct experiments, particularly particle accelerators. To a number of intellectual visionaries it became apparent that a European laboratory for atomic physics would be necessary in order to not only share the financial burden, but also unite scientists across the continent. Among these scientific pioneers were the likes of Raoul Dautry, Pierre Auger, and Lew Kowarski in France, Edoardo Amaldi in Italy, and Niels Bohr in Denmark. The creation of such a laboratory was first officially suggested at the European Cultural Conference in Lausanne on December 9, 1949 by French physicist Louis de Broglie. Further support came from the fifth UNESCO General Conference in Florence in June 1950 where Isidor Rabi, an American physicist and Nobel laureate, presented a resolution which authorized UNESCO to "assist and encourage the formation of regional research laboratories in order to increase international scientific collaboration…". The first resolution concerning the establishment of a European Council for Nuclear Research was adopted at an intergovernmental meeting of UNESCO in Paris in December 1951. After two months, eleven countries had signed an agreement to establish a provisional a council and the Conseil Européen pour la Recherche Nucléaire or CERN was born. Due to Switzerland's neutrality in World War II, Geneva was chosen to be the headquarters of this newborn organization.

To understand the highly advanced research that takes place in Geneva one must first familiarize themselves with the Standard Model of Particle Physics. This theory was developed in the 1970s and serves to explain how the building blocks of matter interact. Before delving into the Standard Model, it should be noted that some of this information was unknown or not researched in much depth before CERN was established. Not only did this model serve as the basis of CERN's early experiments, but also of its present day experiments as the model has been updated and augmented as more discoveries are made. The first part of the model states that all particles occur in two different types called quarks and leptons. Both types of particles are found in six different variations categorized into three pairs known as "generations". The lightest, most stable particles make up the first generation and the heavier, less stable particles make up the second and third generations. Be that as it may, these heavier particles have a tendency to quickly decay, forming more stable particles. The quarks were dubbed up/down (first generation pairing), charm/strange (second generation pairing), and top/bottom (third generation pairing). Likewise, the leptons were also given names: electron/electron neutrino (first generation pairing), muon/muon neutrino (second generation pairing), and tau/tau neutrino (third generation pairing). The neutrinos, as their names suggest, are neutral and possess low masses while the others are charged and have sizable masses. The second part of the Standard Model states that there are four fundamental forces that govern the universe. These forces, in descending order based on strength, are the strong force, electromagnetic force, weak force, and gravitational force. Each of these forces operates not only with a different level of strength, but also of range. Electromagnetic force and gravitational force both have infinite range whereas the strong and weak forces are only effective within very short ranges and therefore affect subatomic particles. These forces act through the exchange of force carrier particles also known as bosons. Each force has a corresponding boson: the gluon for the strong force, the W and Z bosons for the weak force, the photon for the electromagnetic force, and the graviton (which is still theoretical) for the gravitational force. However, it should be noted that the gravitational force is hardly included in the Standard Model due to the fact that the quantum theory describing the micro world and the general theory of relativity describing the macro world are difficult to fit into a single framework and, as of yet, no one has made the two mathematically compatible in the context of the Standard Model. This does not pose a major problem within the Standard Model due to the miniscule scale of particles which means that the effect of gravity in the context of particle physics is almost negligible. The third and final part of the Standard Model is the Higgs boson, which is the carrier particle for the Higgs field which is essential to our understanding of the origin of mass of subatomic particles. Mankind ventured further into the unknown through the experiments held in Geneva during the process scientists underwent in order to create this model in order to better understand the nature of the universe.

The first major breakthrough reported from the researchers in CERN took place on July 19, 1973 when physicists presented direct evidence of the weak neutral current. This was done using the Gargamelle bubble chamber, a chamber 4.8 meters in length, 2 meters in diameter, and weighing in at over 1000 tonnes, which held 12 cubic meters of heavy liquid freon. Before the importance of this discovery can be understood, first one must understand what a weak neutral current is and what significance it holds in the context of the Standard Model. A weak neutral current is a process that required the existence of a neutral particle to carry the weak force. This particle, the Z boson, is carried by these currents which allows for the exchange of the weak force. The currents are neutral because, unlike the W exchange particle, the Z boson has no charge. The Z boson and the neutral currents were predicted in the 60s by electroweak theory which stated that the weak and electromagnetic forces are different versions of the same force. The discovery of these currents involved a search for the interaction of a neutrino with an electron in the liquid and the scattering of a neutrino from a hadron, which is simply a proton or neutron. The team eventually confirmed 166 hadronic events and one electron event. The results yielded from this experiment were influential in the discovery of the W and Z bosons which was significant in that it would help researchers better under how the weak force is transferred. This weak force is best known for its role in radioactive beta decay in which a proton is turned into a neutron or vice versa leading to fusion reactions such as those that occur within the sun.

The discovery of the W and Z bosons would have to wait for the construction of a particle accelerator powerful enough to produce them. This came in the form of the Super Proton Synchrotron (SPS), the second largest machine in CERN's accelerator complex measuring in at nearly 7 kilometers in circumference. It is a particle accelerator meaning it uses electromagnetic fields to propel charged particles at high speeds, containing them in focused beams. A synchrotron, more specifically, is a cyclic particle accelerator in which the accelerating particle beam travels around a fixed closed-loop path. The magnetic field which bends the particle beam into its closed path increases with time during the accelerating process, becoming synchronized to the increasing kinetic energy of the particles. Using the SPS, scientists Carlo Rubbia and Simon van der Meer, who were both awarded the Nobel Prize in Physics for their achievements during these experiments,  conducted what are known as the UA1 and UA2 experiments, during which unambiguous signals of W bosons were detected in January of 1983. UA1 and UA2, which stands for Underground Area 1 and 2 respectively, were moveable particle detectors built around the SPS when it was used as a proton-antiproton collider. The process carried charged particles through detectors  and ionized molecules in the argon-ethane gas mixture inside, releasing electrons. The electrons then drifted along an electric field shaped by 17,000 field wires and collected by 6,125 sense wires. The geometric arrangement of wires allowed physicists to reconstruct collision events in three dimensions.

Following the UA experiments, CERN commissioned what became known as the Large Electron-Positron Collider in 1989. It was and still is the largest electron-positron collider ever built boasting a circumference of 27 kilometers. With an initial energy of 91 gigaelectronvolts the LEP collided electrons with positrons, which are essentially anti-electrons, in order to produce Z bosons, though it was later upgraded in order to produce pairs of W bosons. The LEP was used for years, topping off at 209 gigaelectronvolts, which allowed researchers to observe the creation and decay of both W and Z bosons which was essential in testing the Standard Model and gaining a better understanding of the electroweak interaction.

Further research into the realm of antimatter occurred during the PS210 experiment which led to the discovery of antihydrogen atoms. These atoms are the antimatter counterpart of hydrogen possessing a positron and an antiproton whereas regular hydrogen possesses an electron and a proton. These atoms were produced using the Low Energy Antiproton Ring (LEAR), a particle accelerator used to decelerate and store antiprotons thus facilitating the creation of antihydrogen atoms in order to study the properties of antimatter. During the experiment nine antihydrogen atoms were produced in flight at speeds nearing that of light. They were detected via unique electrical signals made from detectors which destroyed the atoms via matter-antimatter annihilation, the process by which matter and antimatter destroy each other, releasing energy in the form of particles such as photons. These atoms were and continue to be studied in hopes of understanding the Baryon asymmetry. When the universe was created in the wake of the big bang matter and antimatter were created in equal amounts- or so it was thought. However, scientists have observed an apparent imbalance between the amount of matter and antimatter in the universe, with the universe favoring the former. By studying the properties and nature of antimatter atoms this disparity may one day be understood.

CERN’s next major experiment, the NA48 experiment, would then take the researchers in Geneva into the field of kaon physics. This is the field of physics focused on kaons which are any of four mesons, which are hadronic subatomic particles composed of a quark and an antiquark bound together by strong force interactions. This experiment was part of a series of experiments created with a goal of searching for what is known as CP violation. This is a violation of CP symmetry where the C stands for charge conjugation and the P stands for parity. Charge conjugation is the process by which a particle is transformed into an antiparticle and parity, also known as space inversion, is the process by which a particle or particle system’s space coordinates are reflected through the origin. Scientists assumed that processes involving the fundamental forces exhibited symmetry in regards to charge conjugation and parity. However, it was discovered through this series of experiments that this symmetry is sometimes violated during weak force decay as CERN announced in 1999. This discovery allows scientists to properly distinguish matter from antimatter which has led to the theory that the Baryon asymmetry may have resulted from the occurrence of CP violation during the first seconds following the big bang.

In the early 2000s, researchers at CERN working under the ALPHA collaboration made impressive strides in antihydrogen isolation. During these experiments single antihydrogen atoms were confined in a magnetic trap which was possible because, while electrically neutral, antihydrogen interacts with a magnetic field allowing it to be stabilized. In 2010, 38 antihydrogen atoms were trapped for up to a sixth of a second. In the following year, 309 antihydrogen atoms were trapped for up to 1,000 seconds. These isolations were carried out by the Antiproton Decelerator (AD) which produces low-energy antiprotons thus creating antiatoms. This further augmented scientists' ability to study and compare matter and antimatter particles.

Arguably the most significant discovery of CERN's history is that of the Higgs boson which is an elementary particle in the Standard Model. It is produced by quantum excitation (an increase in energy) of the theorized Higgs field which would revolutionize our understanding of the universe. One might reasonably think of mass as an intrinsic trait of matter. However, scientists have realized that this may not be the case. The Higgs mechanism, proposed by English physicist Peter Higgs, attempted to explain why particles have mass. Basically, the Higgs field is a universal medium by which massless particles are seemingly separated into different masses in a process known as symmetry breaking. When particles pass through this field they are given mass, an action which required a carrier molecule. By finding the Higgs boson particle scientists have obtained strong evidence of the existence and therefore the validity of the Higgs field. The particle's existence was confirmed in 2012 using CERN's Large Hadron Collider, the world's largest particle accelerator built by repurposing the tunnels of the acclaimed LEP. The collider was first started up on September 10, 2008 and has seven different experiments based along its tunnels. The accelerator collides two high-energy particle beams travelling near the speed of light guided around the accelerator ring by a magnetic field maintained by superconducting electromagnets. For their hand in discovering the Higgs boson the leading scientists Higgs and Englert were awarded the Nobel Prize in Physics. In the aftermath of this inspirational leap in the field of particle physics the LHC leads the current generation of researchers at CERN in their ongoing mission to unravel the intricacies of the universe.

Since its inception CERN has striven to study and explain the fundamental structure of the particles that make up the world around us. By accelerating and colliding these particles scientists have found it possible to discern their structures, how they interact, and the laws that govern them. The goal of this organization is not to have a practical impact on the daily lives of humans, but to obtain a better understanding of the fundamental structures that form our universe, the forces that act upon them, and the laws that hold it all together. In striving to reach greater scientific heights it has upheld the longstanding European tradition of not only scientific achievement, but also that of unity and cooperation. Currently, there are 23 member states and a vast number of associate member states, states/organizations with observer status, and a plethora of those with cooperation agreements. Thus CERN is not only a European laboratory for particle physics anymore, but one on a worldwide scale.

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