THEORY OF ELEMENTARY PARTICLES pdf

1: elementary particles

In particle physics, an elementary particle or fundamental particle is a subatomic particle with no substructure, thus not composed of other particles. Particles currently thought to be elementary include the fundamental fermions (quarks, leptons, antiquarks, and antileptons), which generally are "matter particles" and "antimatter particles", as well as the fundamental bosons (gauge bosons and.

Home Elementary Particle Theory The ultimate goal of elementary particle physics is to understand the basic constituents of matter and their interactions in terms of an economical set of principles. This hope for unified understanding of natural laws, cherished by our early pioneers such as Newton, Maxwell, and Einstein, appears to have come very close to fulfillment during the past two decades with the discovery of unified gauge theories of fundamental interactions. Theoretical particle physics attempts to develop the models, theoretical framework, and mathematical tools to understand current experiments and make predictions for future experiments. An elementary particle theorists typically studies and does research in one or a few of the following categories: General Theorists have an interest in exploring the deeper physical meaning of the theory itself, typically exploiting various mathematical techniques to gain insight into its physical nature. This type of particle physicist is often found producing general theorems or equations that others may use to simplify their calculations. A Model Builder attempts to construct an extension at higher energies or smaller distances of the Standard Model of Particle Physics in such a way as to either fix a problem inherent in this theory or one of its extensions , or to explain some phenomenon that the experimentalists have detected. This work is often motivated by the hierarchy problem and is constrained by existing experimental data. It may involve work on supersymmetry, alternatives to the Higgs mechanism, extra spatial dimensions, Preon theory, combinations of these, or other ideas. A Phenomenologist is usually occupied with explaining some experimental phenomenon by doing an actual calculation of an experimental process using a particular model. The end result is an actual number that can be compared with current experimental data or relayed to experimentalists so that they may design an experiment to test the validity of the predicted value. String theorists attempt to construct a unified description of quantum mechanics and general relativity by building a theory based on small strings, and branes rather than particles. The fundamental building blocks of nature in the view of String Theory are extended objects having at least one length dimension , instead of, like in traditional particle physicists, point particles objects of zero size. String Theory is still young and consequently not enough is known about it: On the other hand, if the theory is successful, it may be considered a "Theory of Everything". There are also other areas of work in theoretical particle physics ranging from particle cosmology to loop quantum gravity. Particle physicists internationally agree on the most important goals of particle physics research in the near and intermediate future. The overarching goal, which is pursued in several distinct ways, is to find and understand what physics may lie beyond the Standard Model. There are several powerful experimental reasons to expect new physics, including dark matter and neutrino mass. There are also theoretical hints that this new physics should be found at accessible energy scales. Most importantly, though, there may be unexpected and unpredicted surprises which will give us the most opportunity to learn about nature. Qaisar Shafi Selected Publications: Barr, New type of seesaw mechanism for neutrino masses, Phys. Barr, The search for a permanent electric dipole moment, Phys. Today 56 6 , 33

THEORY OF ELEMENTARY PARTICLES pdf

2: Elementary Particle Theory - University of Delaware Dept. of Physics & Astronomy

Elementary particles of the Standard Model spin 1/2 matter particles, in three generations electric charge leptons (l) e e Ë• Ë• 0 1 quarks (q).

Elementary particles Electrons and quarks contain no discernible structure; they cannot be reduced or separated into smaller components. The term subatomic particle refers both to the true elementary particles, such as quarks and electrons, and to the larger particles that quarks form. Although both are elementary particles, electrons and quarks differ in several respects. Whereas quarks together form nucleons within the atomic nucleus, the electrons generally circulate toward the periphery of atoms. Indeed, electrons are regarded as distinct from quarks and are classified in a separate group of elementary particles called leptons. There are several types of lepton, just as there are several types of quark see below Quarks and antiquarks. Only two types of quark are needed to form protons and neutrons, however, and these, together with the electron and one other elementary particle, are all the building blocks that are necessary to build the everyday world. The last particle required is an electrically neutral particle called the neutrino. Neutrinos do not exist within atoms in the sense that electrons do, but they play a crucial role in certain types of radioactive decay. In a basic process of one type of radioactivity , known as beta decay , a neutron changes into a proton. In making this change, the neutron acquires one unit of positive charge. To keep the overall charge in the beta-decay process constant and thereby conform to the fundamental physical law of charge conservation , the neutron must emit a negatively charged electron. In addition, the neutron also emits a neutrino strictly speaking, an antineutrino , which has little or no mass and no electric charge. Beta decays are important in the transitions that occur when unstable atomic nuclei change to become more stable, and for this reason neutrinos are a necessary component in establishing the nature of matter. Thus, it seems at first sight that only four kinds of elementary particlesâ€”two quarks and two leptonsâ€”should exist. In the s, however, long before the concept of quarks was established, it became clear that matter is more complicated. Spin The concept of quantization led during the s to the development of quantum mechanics , which appeared to provide physicists with the correct method of calculating the structure of the atom. In his model Niels Bohr had postulated that the electrons in the atom move only in orbits in which the angular momentum angular velocity multiplied by mass has certain fixed values. Each of these allowed values is characterized by a quantum number that can have only integer values. In the full quantum mechanical treatment of the structure of the atom , developed in the s, three quantum numbers relating to angular momentum arise because there are three independent variable parameters in the equation describing the motion of atomic electrons. Goudsmit and Uhlenbeck proposed that this quantum number refers to an internal angular momentum , or spin , that the electrons possess. This implies that the electrons, in effect, behave like spinning electric charges. Each therefore creates a magnetic field and has its own magnetic moment. The internal magnet of an atomic electron orients itself in one of two directions with respect to the magnetic field created by the rest of the atom. It is either parallel or antiparallel; hence, there are two quantized statesâ€”and two possible values of the associated spin quantum number. The concept of spin is now recognized as an intrinsic property of all subatomic particles. Indeed, spin is one of the key criteria used to classify particles into two main groups: These two classes of particles have different symmetry properties that affect their behaviour. Dirac provided a sound theoretical background for the concept of electron spin. The basic equation describing the allowed energies for an electron would admit two solutions, one positive and one negative. The positive solution apparently described normal electrons. The negative solution was more of a mystery; it seemed to describe electrons with positive rather than negative charge. The mystery was resolved in , when Carl Anderson , an American physicist, discovered the particle called the positron. Positrons are very much like electrons: Matter cannot be built from both particles and antiparticles, however. When a particle meets its appropriate antiparticle , the two disappear in an act of mutual destruction known as annihilation. Atoms can exist only because there is an excess of electrons , protons , and neutrons in the everyday world, with no corresponding positrons, antiprotons, and antineutrons. Among the particles created are pairs of electrons and positrons. The positrons survive for a tiny fraction of a second until they come close enough to electrons to annihilate. The total mass of each electron-positron pair is then converted to energy in the form of gamma-ray photons. Using particle accelerators , physicists can mimic the action of cosmic rays and create collisions at high energy. Shortly afterward, a different team working on the same accelerator discovered the antineutron. Electrons and positrons produced simultaneously from individual gamma rays curl in opposite directions in the magnetic field of a bubble chamber. In the above example the gamma ray has lost some energy to an atomic electron, which leaves the long track, curling left. The gamma rays do not leave tracks in the chamber, as they have no electric charge. Indeed, it is an antineutrino , rather than a neutrino, that emerges when a neutron changes by beta decay into a proton. This reflects an empirical law regarding the production and decay of quarks and leptons: Thus, the appearance of a lepton â€"the electronâ€"in the decay of a neutron must be balanced by the simultaneous appearance of an antilepton, in this case the antineutrino. In addition to such familiar particles as the proton, neutron, and electron, studies have slowly revealed the existence of more than other subatomic particles. Moreover, they immediately decay to the more-familiar particles after brief lifetimes of only fractions of a second. The variety and behaviour of these extra particles initially bewildered scientists but have since come to be understood in terms of the quarks and leptons. In fact, only six quarks, six leptons, and their corresponding antiparticles are necessary to explain the variety and behaviour of all the subatomic particles, including those that form normal atomic matter.

3: Subatomic particle - Elementary particles | www.enganchecubano.com

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The physicist who discovered it, Murray Gell-Mann , loves words as much as he loves physics. Thus came the word quark for his most famous discovery. This highly scientific term is clever and jokey and gruff all at once, much like the man who coined it. The native New Yorker skipped three grades in elementary school and entered college early. Gell-Mann later worked with Enrico Fermi at the University of Chicago, and he debated passionately with renowned physicist Richard Feynman during his many years at Caltech. It was at Caltech that Gell-Mann helped to lay the foundations for our understanding of the components that make up matter. He drafted a blueprint of subatomic physics that he called the Eightfold Way. At the time, physicists understood that atoms are constructed from protons and neutrons, but they had also found many other mysterious particles. The Eightfold Way made sense of this baffling menagerie, finding within it places for particles never even imagined. The work was so important that it netted Gell-Mann a Nobel Prize in In Gell-Mann pursued his dream of working in other fields by cofounding the Santa Fe Institute , a think tank where scientists are encouraged to cross disciplines. Located high on a hill in the New Mexico desert, surrounded by cottonwood trees and outcroppings of rose quartz, the institute is a place where an ornithologist can trade data over lunch with a political scientist while excitedly scrawling statistical equations on a window with a Sharpie for lack of paper and pen. With its geometric design, brightly colored walls, abundant hiking trails in the vicinity, and generous supply of candy in the kitchen, the Santa Fe Institute seems a bit like a playground for scientists. Lots of people thought I was crazy. Quarks are permanently trapped inside other particles like neutrons and protons. How should a nonphysicist visualize quarks? As tiny spheres trapped inside atoms? Well, in classical physics you could think of a quark as a point. Sometimes it behaves like a point, but it can be smeared out a little. Sometimes it behaves like a wave. When people picture particles smashing together in a particle collider, what should they be imagining? It depends on the circumstances. At very high energies, two particles that smash together do not bounce off each other but create a vast number of particles. You would have all sorts of little chips flying off in all directionsâ€"that would be a little more like it. So it would be like smashing an apple and an orange together and getting bananas? Little bits of all kinds of things. Getting a whole bunch of little chips of apple and orange, but also chips of banana and antibanana, grapes How many types of elementary particles are there? We have a thing called the standard model, which is based on about 60 particles, but there may be many more. These are just the ones that have a low energy, so we can detect them. The s and s could be considered a heyday of particle physics, when many subatomic particlesâ€"and not just elementary ones, it turns outâ€"were being discovered. Could you talk a little bit about the events leading up to your discovery of the quark? That was very dramatic for me. I had been working for years on the properties of particles that participated in the strong interaction. This is the interaction responsible for holding the nucleus of the atom together. The family of strongly interacting particles includes the neutrons and protons; those are the most familiar ones. But now tens, dozens, hundreds of other particles were being discovered in experiments in which protons collided with each other in particle accelerators. There were lots and lots of energy states in which we saw relativesâ€"cousinsâ€"of the neutrons and protons. They are produced in a particle collision in an accelerator, and they decay after a short time. After a tiny fraction of a second, they fall apart into other things. One particle that I predicted, the omega-minus , can decay into a neutral pion and xi-minus, and then the pion decays into photons, and the xi-minus decays into a negative pion and a lambda. And then the lambda decays into a negative pion and a proton. The interior of the sun has a very high temperature, but even that very high temperature is not enough to make all of these things. Do all these exotic particles exist anywhere outside of physics experiments? They existed right after the Big Bang, when temperatures were incredibly high. And they occur in cosmic-ray events. Looking at the table of known particles and the experimental data, it was clear that the neutron and proton could be made up of three particles with fractional charges, which I called quarks. The neutron and proton were no longer to be considered elementary. It was not a difficult thing to deduce. What was difficult was believing it, because nobody had ever heard of making the neutron and proton composite. Nobody had ever heard of these fractional charges. Nobody had ever heard of particles being confined permanently inside observable things and not directly attainable. As time goes on, physicists seem to find more and more particles. Could there be an infinite number of them? All of us theorists believe in simplicity. Simplicity has always been a reliable guide to theory in fundamental physics. But the simplicity may not lie in the number of named particles. It may be that the theory, expressed simply, gives rise to huge numbers of particle types. The particles might go on forever, but you detect only the ones that are light enough to play a role in your experiments. Now researchers are pinning a lot of hope on finding yet another set of predicted particles in experiments at the Large Hadron Collider. Do you think this will bring some clarity? Well, there is another possibility, that they find some phenomenon that is utterly unexpected. He had had a very substantial library, a huge library. And when the bad times struckâ€"the Depressionâ€"he had to get rid of them when we moved to a tiny apartment. He had to have the furniture taken away. He paid somebody five dollars to take away his library. But he had a few books left, 50 books or something like that. One of them was a book that gave etymologies of English words borrowed from Greek and Latin. So I learned all these Greek and Latin roots and how they went to make up English words. That started me on etymology, and I have loved etymology ever since. I was always OK in math. Actually I loved math, loved studying it, loved using it. I was particularly in love with archaeology and linguistics. And I could discuss anything with my brotherâ€"archaeology, etymology, anything at all. He never did anything with it, but he was very, very intelligent and very knowledgeable about all sorts of things. He was passionate about birds and other living things. Not so much the scientific principles of ornithology, but just seeing the birds and identifying them and knowing where they were, and what kind of nest they had, and what songs they sang. Going with him on a bird trip was the best thingâ€"the best thingâ€"I did in those years. My brother taught me to read from a cracker box when I was 3. When you were going into college, you were interested in studying archaeology, natural history, or linguistics, but your father wanted you to make money as an engineer. If I designed something it would fall down. When I was admitted to Yale, I took an aptitude test, and when the counselor gave me the results of the exam, he said: General relativity, quantum mechanics, you will love it. I never took his advice on anything else. He told me how beautiful physics would be if I stuck with it, and that notion of beauty impressed me. My father studied those things. He was a great admirer of Einstein. He would lock himself in his room and study general relativity. He never really understood it. My opinion is that you have to despise something like that to get good at it. My father thought it must be very hard, and it will take years to understand it, and only a few people understand it, and so on. But I had a wonderful teacher at Yale, Henry Margenau, who took the opposite attitude. He thought relativity was for everybody. Just learn the math. Whom do you put on the highest pedestal? Feynman [who won a Nobel for his work in particle physics] was pretty good, although not as good as he thought he was. He was too self-absorbed and spent a huge amount of energy generating anecdotes about himself. Fermi [who developed the first nuclear reactor] was good, but again with limitationsâ€"every now and then he was wrong. Back then, did you understand how special the people around you were?

4: Particle Classification

All particles and their interactions observed to date can be described almost entirely by a quantum field theory called the Standard Model. The Standard Model, as currently formulated, has 61 elementary particles.

See also theoretical physics. There are several major interrelated efforts being made in theoretical particle physics today. One important branch attempts to better understand the Standard Model and its tests. Those efforts are made challenging by the difficulty of calculating quantities in quantum chromodynamics. Some theorists working in this area refer to themselves as phenomenologists and they may use the tools of quantum field theory and effective field theory. Others make use of lattice field theory and call themselves lattice theorists. Another major effort is in model building where model builders develop ideas for what physics may lie beyond the Standard Model at higher energies or smaller distances. This work is often motivated by the hierarchy problem and is constrained by existing experimental data. It may involve work on supersymmetry , alternatives to the Higgs mechanism , extra spatial dimensions such as the Randall-Sundrum models , Preon theory, combinations of these, or other ideas. A third major effort in theoretical particle physics is string theory. String theorists attempt to construct a unified description of quantum mechanics and general relativity by building a theory based on small strings, and branes rather than particles. There are also other areas of work in theoretical particle physics ranging from particle cosmology to loop quantum gravity. This division of efforts in particle physics is reflected in the names of categories on the arXiv , a preprint archive: Practical applications[edit] In principle, all physics and practical applications developed therefrom can be derived from the study of fundamental particles. In practice, even if "particle physics" is taken to mean only "high-energy atom smashers", many technologies have been developed during these pioneering investigations that later find wide uses in society. Particle accelerators are used to produce medical isotopes for research and treatment for example, isotopes used in PET imaging , or used directly in external beam radiotherapy. The development of superconductors has been pushed forward by their use in particle physics. Additional applications are found in medicine, national security, industry, computing, science, and workforce development, illustrating a long and growing list of beneficial practical applications with contributions from particle physics. There are several powerful experimental reasons to expect new physics, including dark matter and neutrino mass. There are also theoretical hints that this new physics should be found at accessible energy scales. Much of the effort to find this new physics are focused on new collider experiments. The Large Hadron Collider LHC was completed in to help continue the search for the Higgs boson , supersymmetric particles , and other new physics. An intermediate goal is the construction of the International Linear Collider ILC , which will complement the LHC by allowing more precise measurements of the properties of newly found particles. In August , a decision for the technology of the ILC was taken but the site has still to be agreed upon. In addition, there are important non-collider experiments that also attempt to find and understand physics beyond the Standard Model. One important non-collider effort is the determination of the neutrino masses, since these masses may arise from neutrinos mixing with very heavy particles. In addition, cosmological observations provide many useful constraints on the dark matter, although it may be impossible to determine the exact nature of the dark matter without the colliders. Finally, lower bounds on the very long lifetime of the proton put constraints on Grand Unified Theories at energy scales much higher than collider experiments will be able to probe any time soon. In May , the Particle Physics Project Prioritization Panel released its report on particle physics funding priorities for the United States over the next decade. This report emphasized continued U. High energy physics compared to low energy physics[edit] The term high energy physics requires elaboration. Intuitively, it might seem incorrect to associate "high energy" with the physics of very small, low mass objects, like subatomic particles. Yet, the macroscopic realm is "low energy physics",[citation needed] while that of quantum particles is "high energy physics". The interactions studied in other fields of physics and science have comparatively very low energy. For example, the photon energy of visible light is about 1. Similarly, the bond-dissociation energy of a carbonâ€”carbon bond is about 3. Other chemical reactions typically involve similar amounts of energy. Radioactive decay gamma rays are considered as part of nuclear physics , rather than high energy physics. Due to these very high energies at the single particle level, particle physics is, in fact, high-energy physics.

THEORY OF ELEMENTARY PARTICLES pdf

5: Particle physics - Wikipedia

Get this from a library! Proceedings of seminar on unified theories of elementary particles.. [D Lurie; N Mukunda; ROCHESTER UNIV N Y.;] -- Contents: Vector mesons as bound states, Electron as an energy gap in a cutoff free approximation, Some problems in the theory of the symmetries of strong interactions, Some problems in the theory of.

He obtained his B. In he became a member of the Institute for Advanced Study, during he was instructor at the University of Chicago, from to he was Assistant Professor, in he was appointed Associate Professor for research on dispersion relations. In this period he developed the strangeness theory and the eightfold way theory. In he was appointed Professor, his research then turned more to the theory of weak interactions. He is a Fellow of this society and a member of the National Academy of Sciences. Murray Gell-Mann was in married to J. Margaret Dow; they have a daughter, Elizabeth, and a son, Nicholas. It was later edited and republished in Nobel Lectures. To cite this document, always state the source as shown above. In he received the Nobel Prize in Physics for his work on the theory of elementary particles. He is the author of The Quark and the Jaguar, published in , in which his ideas on simplicity and complexity are presented to a general readership. That idea has since been fully confirmed by experiment. Professor Gell-Mann was a director of the J. From to , he was a Citizen Regent of the Smithsonian Institution. He was on the U. Earlier, he was given the Ernest O. Carty Medal of the National Academy of Sciences. He has received honorary degrees from many universities, including Yale, Columbia, the University of Chicago, Cambridge, and Oxford. In the University of Florida awarded him an honorary degree in Environmental Studies. Much of his recent research at the Santa Fe Institute has focused on the theory of complex adaptive systems, which brings many of those topics together. Another focus of his work relates to simplicity, complexity, regularity, and randomness. To cite this section.

6: Elementary particle - Wikipedia

The basic premise to string theory is that subatomic entities, such as quarks and forces, are actually tiny loops, strings and membranes that behave as particles at high energies. One of the problems in particle physics is the bewildering number of elementary particles (muons and pions and mesons etc).

The possibility that these equations may have a non-potential solution is ruled out and not considered. In this paper an exact non-potential solution of the continuity equation is described. The electric field of an elementary charged particle consists of two components: Charged particles have both components, while a neutron has only the NC. The proton and neutron NC ensures similarity of their properties. The PC is spherically symmetric and NC is axisymmetric. Therefore, to describe an elementary particle, one should take into account both its spatial coordinates and the NC orientation. The particle interaction is determined by their NC mutual orientation. Neglecting the latter leads to indefiniteness of the interaction result. In a homogeneous electric field, the force acting on the NC is zero. Therefore, a charged particle possessing the NC will behave like a potential one. In an inhomogeneous field, the situation is principally different. Due to the NC there occurs an interaction between a neutron and a proton. The non-potential field results in the existence of two types of neutrons: A neutron repels from a proton ensuring scattering of neutrons on protons. An antineutron is attracted to a proton leading to its annihilation. The NC produces the magnetic dipole moment of an elementary particle. Introduction In theoretical physics, not only the solution of differential equations is important, but the number of solutions as well. In quantum mechanics, as an example, boundary problems normally have several solutions and all these solutions are used to describe the behavior of an object. Discarding any of the solutions excludes one or another effect from consideration, and the description becomes inadequate and contrary to the fact. If a boundary problem has several solutions and only one of them is chosen, we should justify why we do so. For practically important boundary problems, the question of solution uniqueness as such is often not posed. It is thought that any obtained solution is automatically unique in accordance with the Cauchy-Kovalevsky theorem [1] ; however, the theorem considers uniqueness for a problem only at a certain point and not over the entire domain. Proofs of uniqueness are provided for particular differential equations, e. However, conditions of the uniqueness theorem, e. In this work, using the field of a concentrated charge electron, proton, neutron as an example, it is shown that the well-known equation of mathematical physics has the second, earlier unknown solution. Taking into account this solution radically alters the interpretation of some physical processes. Surely, uniqueness of the solutions of differential equations is studied by mathematicians [1] [2] , but their interest and this is quite natural is in mathematical rather than physical problems. The solution uniqueness of the electron problem has not been studied so far.

7: Elementary Particle - Physics at Minnesota

Introduction to Elementary Particle Theory details the fundamental concepts and basic principles of the theory of elementary particles. The title emphasizes on the phenomenological foundations of relativistic theory and to the strong interactions from the S-matrix standpoint.

Theory of Everything Elementary Particles: One of the primary goals in modern physics is to answer the question "What is the Universe made of? Modern physics speaks of fundamental building blocks of Nature, where fundamental takes on a reductionist meaning of simple and structureless. Many of the particles we have discussed so far appear simple in their properties. All electrons have the exact same characteristics mass, charge, etc. The search for the origin of matter means the understanding of elementary particles. And with the advent of holism, the understanding of elementary particles requires an understanding of not only their characteristics, but how they interact and relate to other particles and forces of Nature, the field of physics called particle physics. The study of particles is also a story of advanced technology begins with the search for the primary constituent. More than subatomic particles have been discovered so far, all detected in sophisticated particle accelerators. However, most are not fundamental, most are composed of other, simpler particles. For example, Rutherford showed that the atom was composed of a nucleus and orbiting electrons. Later physicists showed that the nucleus was composed of neutrons and protons. More recent work has shown that protons and neutrons are composed of quarks. The two most fundamental types of particles are quarks and leptons. The quarks and leptons are divided into 6 flavors corresponding to three generations of matter. Leptons have charges in units of 1 or 0. Normal, everyday matter is of the first generation, so we can concentrate our investigation to up and down quarks, the electron neutrino often just called the neutrino and electrons. Note that for every quark or lepton there is a corresponding antiparticle. For example, there is an up antiquark, an anti-electron called a positron and an anti-neutrino. Bosons do not have antiparticles since they are force carriers see fundamental forces. Matter is effected by forces or interactions the terms are interchangeable. There are four fundamental forces in the Universe: Light photons is explained by the interaction of electric and magnetic fields. The strong force binds quarks into protons, neutrons and mesons, and holds the nucleus of the atom together despite the repulsive electromagnetic force between protons. The weak force controls the radioactive decay of atomic nuclei and the reactions between leptons electrons and neutrinos. Current physics called quantum field theory explains the exchange of energy in interactions by the use of force carriers, called bosons. The long range forces have zero mass force carriers, the graviton and the photon. These operate on scales larger than the solar system. These operate on scales the size of atomic nuclei. So, although the strong force has the greatest strength, it also has the shortest range. Quarks combine to form the basic building blocks of matter, baryons and mesons. Baryons are made of three quarks to form the protons and neutrons of atomic nuclei and also anti-protons and anti-neutrons. Mesons, made of quark pairs, are usually found in cosmic rays. Thus, our current understanding of the structure of the atom is shown below, the atom contains a nucleus surrounded by a cloud of negatively charged electrons. The nucleus is composed of neutral neutrons and positively charged protons. The opposite charge of the electron and proton binds the atom together with electromagnetic forces. The nucleus is bound together by the nuclear strong force that overcomes the electromagnetic repulsion of like-charged protons Color Charge: Quarks in baryons and mesons are bound together by the strong force in the form of the exchange of gluons. Much like how the electromagnetic force strength is determined by the amount of electric charge, the strong force strength is determined by a new quantity called color charge. Quarks come in three colors, red, blue and green they are not actually colored, we just describe their color charge in these terms. So, unlike electromagnetic charges which come in two flavors positive and negative or north and south poles , color charge in quarks comes in three types. And, just to be more confusing, color charge also has its anti-particle nature. So there is anti-red, anti-blue and anti-green. Gluons serve the function of carrying color when they interact with quarks. Baryons and mesons must have a mix of colors such that the result is white. For example, red, blue and green make white. Also red and anti-red make white. There can exist no free quarks, i. All quarks must be bound to another quark or antiquark by the exchange of gluons. This is called quark confinement. The exchange of gluons produces a color force field, referring to the assignment of color charge to quarks, similar to electric charge. The color force field is unusual in that separating the quarks makes the force field stronger unlike electromagnetic or gravity forces which weaken with distance. Energy is needed to overcome the color force field. Two new quarks form and bind to the old quarks to make two new mesons. Thus, none of the quarks were at anytime in isolation. Quarks always travel in pairs or triplets. The subfield of physics that explains the interaction of charged particles and light is called quantum electrodynamics. Quantum electrodynamics QED extends quantum theory to fields of force, starting with electromagnetic fields. Notice the elimination of action at a distance, the interaction is due to direct contact of the photons. This new force, called electroweak, occurs at extremely high temperatures such as those found in the early Universe and reproduced in particle accelerators. Unification means that the weak and electromagnetic forces become symmetric at this point, they behave as if they were one force. Electroweak unification gave rise to the belief that the weak, electromagnetic and strong forces can be unified into what is called the Standard Model of matter. The strong force overcomes the electromagnetic or gravitational forces only on very short range. Outside the nucleus the effect of the strong force is non-existent. Action at a Distance: Newtonian physics assumes a direct connection between cause and effect. Electric and magnetic forces pose a dilemma for this interpretation since there is no direct contact between the two charges, rather there is an action at a distance. To resolve this dilemma it was postulated that there is an exchange of force carriers between charged particles. These force carriers were later identified with particles of light photons. These particles served to transfer momentum by contact between charged particles, much like colliding cars and trucks. However, this attempt to resolve the action at a distance paradox uses a particle nature to light, when observation of interference patterns clearly shows that light has a wave-like nature. Are quarks and leptons the fundamental building blocks? We are still looking to fill some holes in what is know as the Standard Model. The Standard Model is a way of making sense of the multiplicity of elementary particles and forces within a single scheme. The Standard Model is the combination of two schemes; the electroweak force unification of electromagnetism and weak force plus quantum chromodynamics. Although the Standard Model has brought a considerable amount of order to elementary particles and has led to important predictions, the model is not without some serious difficulties. For example, the Standard Model contains a large number of arbitrary constants. Good choice of the constants leads to exact matches with experimental results. However, a good fundamental theory should be one where the constants are self-evident. The Standard Model does not include the unification of all forces and, therefore, is incomplete. Even a GUTS is incomplete because it would not include spacetime and therefore gravity. For cosmology, this will be the single force that controlled the Universe at the time of formation. The current approach to the search for a TOE is to attempt to uncover some fundamental symmetry, perhaps a symmetry of symmetries. There should be predictions from a TOE, such as the existence of the Higgs particle , the origin of mass in the Universe. One example of a attempt to formula a TOE is supergravity , a quantum theory that unities particle types through the use of ten dimensional spacetime see diagram below. Spacetime 4D construct was successful at explaining gravity. What if the subatomic world is also a geometric phenomenon. Many more dimensions of time and space could lie buried at the quantum level, outside our normal experience, only having an impact on the microscopic world of elementary particles. It is entirely possible that beneath the quantum domain is a world of pure chaos, without any fixed laws or symmetries. One thing is obvious, that the more our efforts reach into the realm of fundamental laws, the more removed from experience are the results. Another recent attempt to form a TOE is through M for membrane or string theory. String theory is actually a high order theory where other models, such as supergravity and quantum gravity, appear as approximations. The basic premise to string theory is that subatomic entities, such as quarks and forces, are actually tiny loops, strings and membranes that behave as particles at high energies. One of the problems in particle physics is the bewildering number of elementary particles muons and pions and mesons etc. String theory answers this problem by proposing that small loops, about billion billion times smaller than the proton, are vibrating below the subatomic level and each mode of vibration represents a distinct resonance which corresponds to a particular particle. Thus, if we could magnify a quantum particle we would see a tiny vibrating string or loop. The fantastic aspect to string theory, that makes it such an attractive candidate for a TOE, is that it not only explains the nature of quantum particles but it also explains spacetime as well. Strings can break into smaller strings or combine to form larger strings. This complicated set of motions must obey self-consistent rules and the the constraint caused by these rules results in the same relations described by relativity theory.

8: The Man Who Found Quarks and Made Sense of the Universe | www.enganchecubano.com

An elementary particle theorists typically studies and does research in one or a few of the following categories: General Theorists: General Theorists have an interest in exploring the deeper physical meaning of the theory itself, typically exploiting various mathematical techniques to gain insight into its physical nature.

Quark Isolated quarks and antiquarks have never been detected, a fact explained by confinement. Every quark carries one of three color charges of the strong interaction ; antiquarks similarly carry anticolor. Color-charged particles interact via gluon exchange in the same way that charged particles interact via photon exchange. However, gluons are themselves color-charged, resulting in an amplification of the strong force as color-charged particles are separated. Unlike the electromagnetic force , which diminishes as charged particles separate, color-charged particles feel increasing force. However, color-charged particles may combine to form color neutral composite particles called hadrons. A quark may pair up with an antiquark: The color and anticolor cancel out, forming a color neutral meson. Alternatively, three quarks can exist together, one quark being "red", another "blue", another "green". These three colored quarks together form a color-neutral baryon. Symmetrically, three antiquarks with the colors "antired", "antiblue" and "antigreen" can form a color-neutral antibaryon. Quarks also carry fractional electric charges , but, since they are confined within hadrons whose charges are all integral, fractional charges have never been isolated. Evidence for the existence of quarks comes from deep inelastic scattering: If the charge is uniform, the electric field around the proton should be uniform and the electron should scatter elastically. Low-energy electrons do scatter in this way, but, above a particular energy, the protons deflect some electrons through large angles. The recoiling electron has much less energy and a jet of particles is emitted. This inelastic scattering suggests that the charge in the proton is not uniform but split among smaller charged particles: Boson In the Standard Model, vector spin -1 bosons gluons , photons , and the W and Z bosons mediate forces, whereas the Higgs boson spin-0 is responsible for the intrinsic mass of particles. Bosons differ from fermions in the fact that multiple bosons can occupy the same quantum state Pauli exclusion principle. Also, bosons can be either elementary, like photons, or a combination, like mesons. The spin of bosons are integers instead of half integers. Gluon Gluons mediate the strong interaction , which join quarks and thereby form hadrons , which are either baryons three quarks or mesons one quark and one antiquark. Protons and neutrons are baryons, joined by gluons to form the atomic nucleus. Like quarks, gluons exhibit color and anticolorâ€”unrelated to the concept of visual colorâ€”sometimes in combinations, altogether eight variations of gluons. W and Z bosons and Photon There are three weak gauge bosons: The W bosons are known for their mediation in nuclear decay. The Z0 does not convert charge but rather changes momentum and is the only mechanism for elastically scattering neutrinos. The weak gauge bosons were discovered due to momentum change in electrons from neutrino-Z exchange. The massless photon mediates the electromagnetic interaction. These four gauge bosons form the electroweak interaction among elementary particles. Higgs boson Although the weak and electromagnetic forces appear quite different to us at everyday energies, the two forces are theorized to unify as a single electroweak force at high energies. The differences at low energies is a consequence of the high masses of the W and Z bosons, which in turn are a consequence of the Higgs mechanism. Through the process of spontaneous symmetry breaking , the Higgs selects a special direction in electroweak space that causes three electroweak particles to become very heavy the weak bosons and one to remain massless the photon. Peter Higgs who first posited the existence of the Higgs boson was present at the announcement. In particle physics, this is the level of significance required to officially label experimental observations as a discovery. Research into the properties of the newly discovered particle continues. Graviton The graviton is a hypothetical elementary spin-2 particle proposed to mediate gravitation. While it remains undiscovered due to the difficulty inherent in its detection , it is sometimes included in tables of elementary particles. Theories beyond the Standard Model attempt to resolve these shortcomings. Such a force would be spontaneously broken into the three forces by a Higgs-like mechanism. The most dramatic prediction of grand unification is the existence of X and Y bosons , which cause proton decay. Supersymmetry Supersymmetry extends the Standard Model by adding another class of symmetries to the Lagrangian. These symmetries exchange fermionic particles with bosonic ones. Such a symmetry predicts the existence of supersymmetric particles , abbreviated as sparticles , which include the sleptons , squarks , neutralinos , and charginos. Due to the breaking of supersymmetry , the sparticles are much heavier than their ordinary counterparts; they are so heavy that existing particle colliders would not be powerful enough to produce them. String theory String theory is a model of physics where all "particles" that make up matter are composed of strings measuring at the Planck length that exist in an dimensional according to M-theory , the leading version or dimensional according to F-theory [17] universe. These strings vibrate at different frequencies that determine mass, electric charge, color charge, and spin. A string can be open a line or closed in a loop a one-dimensional sphere, like a circle. As a string moves through space it sweeps out something called a world sheet. String theory predicts 1- to branes a 1- brane being a string and a brane being a dimensional object that prevent tears in the "fabric" of space using the uncertainty principle e. String theory proposes that our universe is merely a 4-brane, inside which exist the 3 space dimensions and the 1 time dimension that we observe. Some predictions of the string theory include existence of extremely massive counterparts of ordinary particles due to vibrational excitations of the fundamental string and existence of a massless spin-2 particle behaving like the graviton. Technicolor physics Technicolor theories try to modify the Standard Model in a minimal way by introducing a new QCD-like interaction. This means one adds a new theory of so-called Techniquarks, interacting via so called Technigluons. The main idea is that the Higgs-Boson is not an elementary particle but a bound state of these objects. Preon According to preon theory there are one or more orders of particles more fundamental than those or most of those found in the Standard Model. The most fundamental of these are normally called preons, which is derived from "pre-quarks". In essence, preon theory tries to do for the Standard Model what the Standard Model did for the particle zoo that came before it. Most models assume that almost everything in the Standard Model can be explained in terms of three to half a dozen more fundamental particles and the rules that govern their interactions. Interest in preons has waned since the simplest models were experimentally ruled out in the s.

9: Murray Gell-Mann - Biographical - www.enganchecubano.com

ELEMENTARY PARTICLES IN PHYSICS 3 see that these four types of fundamental particle are replicated in two heavier families, (Âµâˆ', Î½Âµ, c, s) and (Ï„âˆ', Î½Ï„, t, b).The reason for the existence of these.

In addition, there are gluons, photons, and W and Z bosons, the force carrier particles that are responsible for strong, electromagnetic, and weak interactions respectively. These force carriers are also fundamental particles. All we know is that quarks and leptons are smaller than meters in radius. As far as we can tell, they have no internal structure or even any size. It is possible that future evidence will, once again, show our understanding to be incomplete and demonstrate that there is substructure within the particles that we now view as fundamental. The Discovery of Elementary Particles The first subatomic particle to be discovered was the electron, identified in by J. After the nucleus of the atom was discovered in by Ernest Rutherford, the nucleus of ordinary hydrogen was recognized to be a single proton. In the neutron was discovered. An atom was seen to consist of a central nucleus containing protons and neutrons, surrounded by orbiting electrons. However, other elementary particles not found in ordinary atoms immediately began to appear. In the relativistic quantum theory of P. Dirac predicted the existence of a positively charged electron, or positron, which is the antiparticle of the electron. It was first detected in Difficulties in explaining beta decay led to the prediction of the neutrino in , and by the existence of the neutrino was firmly established in theory, although it was not actually detected until Another particle was also added to the list, the photon, which had been first suggested by Einstein in as part of his quantum theory of the photoelectric effect. The next particles discovered were related to attempts to explain the strong interactions, or strong nuclear force, binding nucleons together in an atomic nucleus. In Hideki Yukawa suggested that a meson, a charged particle with a mass intermediate between those of the electron and the proton, might be exchanged between nucleons. The meson emitted by one nucleon would be absorbed by another nucleon. This would produce a strong force between the nucleons, analogous to the force produced by the exchange of photons between charged particles interacting through the electromagnetic force. It is now known that the strong force is mediated by the gluon. The following year a particle of approximately the required mass, about times that of the electron, was discovered and named the mu-meson, or muon. However, its behavior did not conform to that of the theoretical particle. In the particle predicted by Yukawa was finally discovered and named the pi-meson, or pion. Both the muon and the pion were first observed in cosmic rays. Further studies of cosmic rays turned up more particles. By the s these elementary particles were also being observed in the laboratory as a result of particle collisions in particle accelerators. By the early s over 30 "fundamental particles" had been found. A rigorous way of classifying them was needed. Were there any symmetries or patterns? Murray Gell-Mann believed that a framework for such patterns could be found in the mathematical structure of groups. A symmetry group called SU 3 offered patterns he was looking for. In Gell-Mann published a short article showing that the patterns could be produced if the known particles were viewed as combinations of 3 fundamental subunits with fractional charge, the up, down, and strange quarks and their antiquarks. There were however problems with the Pauli Exclusion Principle. The quark theory was not really accepted until deep inelastic scattering experiments revealed structure inside the protons in the later s. The charm quark was discovered in , the bottom quark in , and the top quark in The tau particle was detected in a series of experiments between and and the discovery of the tau neutrino was announced in It was the last of the particles in the Standard Model of elementary particles to be detected. One of the current frontiers in the study of elementary particles concerns the interface between that discipline and cosmology. The known quarks and leptons, for instance, are typically grouped in three families, where each family contains two quarks and two leptons. Investigators have wondered whether additional families of elementary particles might be found. Recent work in cosmology pertaining to the evolution of the universe has suggested that there could be no more families than four, and the cosmological theory has been substantiated by experimental work at the Stanford Linear Accelerator and at CERN, which indicates that there are no families of elementary particles other than the three that are known today. For example, detailed studies of Z0 decays at CERN revealed that there can be no more than three different kinds of neutrino. If there was a fourth, or a fifth, further decay routes would be open to the Z0 which would affect its measured lifetime. Conservation Laws Leptons carry an additive quantum number called the lepton number L. The electron number carried by electrons and electron neutrinos seems to an additive quantum number which is conserved in interactions. Electrons and electron neutrinos have electron number 1 and positrons and electron anti-neutrinos carry electron number They only have electromagnetic and weak interactions. The tau and its neutrino carry an additive quantum number as well, which seems to be conserved in interactions. We say that the lepton family number LF also seems to be conserved. However if neutrinos have mass and can change flavor, for example, if muon neutrinos can change into electron neutrinos and vice versa, then only L is conserved. Are there more such additive quantum numbers? Yes, there is a group of particles called baryons, and a corresponding conserved quantum number called baryon number B. The lightest baryon is the proton, and it is the only stable baryon. It is fairly easy to spot a baryon in a table of elementary particles. Suppose you are looking at a particle which might be a baryon. If it is not the proton and it is a baryon, it must decay. Baryon conservation then requires a baryon among the decay products, although you may not know which of the decay products is the baryon. Let all of the decay products themselves decay. Keep going until all the particles are stable. Among all the resulting particles there must be one net baryon. Since the proton is the only stable baryon, that baryon must be a proton. Hence, a particle is a baryon if and only if there is one net proton among its ultimate decay products. Baryons are made up of 3 quarks. Everything else in the table besides the baryons and leptons is called a meson. Mesons are made up of a quark and an anti-quark. The number of mesons is not conserved, so there is no "meson number. The K-meson decays in the following way. This prompted the introduction of a new quantum number, strangeness, by Gell-Mann and Pais. Protons, neutron an pions have no strangeness. In decay processes involving the strong interaction strangeness is conserved. In decay processes involving the weak interaction, such as K-decay or hyperon decay, strangeness is not conserved. This was the first case that some quantum numbers were conserved in strong interactions and electromagnetic interactions, but not in weak interactions. Decay processes governed by the strong interaction can be distinguished easily from decay processes governed by the weak interaction. Characteristic reaction times for the former are on the order of s while for the latter they are on the order of s. We have to check whether the decay violates any of the conservation laws. Energy conservation is not violated, the proton has enough mass to decay into the pair of pions. Momentum can be conserved if the two pions move in opposite directions after the decay. The orbital angular momentum quantum number can only be an integer, so there is no way that angular momentum can be conserved. The proposed decay cannot occur. The decay also violates conservation of Baryon number. A Xi-minus particle decays in the following way: The lambda-zero and the pi-minus particles are both unstable. The following processes occur in a cascade, until only relatively stable products remain. If the latter, is it a baryon or a meson? It must be a hadron. The baryon number of the proton is 1 and the baryon number of all the other particles is zero. The net baryon number therefore is 1 and the Xi-minus is a baryon. All lepton numbers add up to zero after the decay, and they are zero before the decay, since the Xi-minus is a baryon. The decay process conserves the three lepton numbers. It does not contain a bottom quark. What combination of quarks is it made of? The Xi-minus particle is a baryon, it is made up of three quarks. Since the b-quark is excluded, we must add a d-quark. The quark combination for the Xi-minus is dss.

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